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Carrie Smith
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SIMPLE FAST FORTRAN CALCULATIONAL ROUTINES for HADRON, MUON and ELECTRON Yields for SSCL Test Beams

@ OU — PHYSICS
405-325-3961 (X309)

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SSCL and OU

@ SSCL
F395 — BLDG 4
X 3038

June 1990
Corrected and Revised, July 1991

AUG.

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See (REBECCA HAFLEY)
or VALERIE KELLEY ←
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etc

The report SSC-230. "**Calibration Beams at the SSC**", by A.Autin. *et al.* August 1989. and earlier studies were reviewed by the author. It became apparent that the test beam design is in such a state of flux. that many calculations of particle yields. muon backgrounds. and instrumentation layouts would have to be made before **any** such beams can actually be finalized. A set of **simple fast fortran** routines to make some of these calculations appeared to be desirable. Indeed, the exercise of writing these routines proved fruitful in delineating what (possibly not correct) assumptions were involved in these prior calculations, and which parameters would have to be carefully checked before a final design (especially those for muon dEdx and Range).

The particle **yield** calculations were taken from a comprehensive formulation found in a recent translation of a Russian textbook in the SSCL library (see Appendix A). This formulation joins the standard (1.-x)**n and exp(-b*Pt**2) parameterizations with some corrective factors, such that a better job of fitting all of the experimental data over a large part of the **x**, **Pt** and **E** ranges jointly appears to have been done. The fortran routine RUSSIAN.for is shown in Fig. 1.

Particle yield programs YIELD.for, YPLUS.for and YTHETA.for exist on the SSCVX1 computer disk **USER2:[GRK]** for use by the SSCL community. Appendix B gives the listings and output for some YTHETA calculations. These gave the **negative pion** yields shown in Fig. 2. The YPLUS program has the proton yield formulas. YIELD does the calculations for various **x** values at some requested **Pt**, whereas YTHETA presents the yields for various **x** at constant laboratory angle **theta**. The yields are given "per interacting proton" and "per incident proton" at the target, and "per incident proton" at the detector, allowing for particle decay-in-flight over the specified beam length.

Additional routines taylorM.for, taylorF.for and chojvat.for were written to check variations in the yields as given by different parameterizations and variances in measured data sets. Comparisons were made with **taylorM,F** for pions and kaons: antiproton comparisons with these and **chojvat** have not been done ('chojvat' should be OK. although it has not been tested). These are shown in Fig. 3. and show that the yields are within a **factor of 2** either way in the regions of phase space (x.Pt) where the data and fits are good. At low **x** values (and presumably at very high x and Pt values) the yields may be incorrect by an order of magnitude. The total inclusive crossections yield **multiplicities** of hadrons that are in reasonable agreement with experiment (see "comparison" references in Appendix C).

Muon distributions are very sensitive to **multiple scattering** and **energy loss** parameters of the Austin chalk (density) and the rapidly increasing dEdx of very energetic muons (greater than 100 GeV). Any **2 TeV** future beams must look very carefully at this. The energy loss parameters and range formulae are based on Eastman and Loken (1987): see Appendix D for the references. dEdx curves. and the program **power-dEdx** that I used to parameterize them.

The program **muSCatZ.for** calculates the transverse muon distributions for a beam of protons incident on a wall of Austin chalk. assuming a one meter absorption distance (or

alternatively, if the secondary beam is buried after some meters of flight path, **per meter**). The hadronic cascade muons have been ignored. (This is OK as long as one does not look at distances closer to the target area than 10 percent or so of the most energetic muons range, as the average multiplicity in this regime is at least 10.) The program calculates the sum of the pion and kaon particle yields (both positive and negative) and lets them all decay as pions to muons. The spread out of the decay products over the 0.57 to 1.0 times the **x and Pt** region for each particle is done by the subroutine **spread.for**. The multiple scattering and the determination of the transverse radial distribution of these muons is done by the subroutine **inside.for**. A typical output for **2 TeV** protons is given in Table 1. Some of these values are plotted upon the Fig. 7A,B CASIM results of SSC-230 in Fig. 4 and 5. Reasonable agreement is obtained, but the beam design, muon energy loss and multiple scattering parameters must be carefully investigated before any CASIM or muSCatZ results are to be trusted.

The program listings and full output from **muSCatZ** for 200 GeV and 2000 GeV runs are given in Appendix E.

Electron yields can be obtained by doing the **"spread.for"** spread-out twice (only doing it over a range [0.0 to 1.0] times the (x,Pt) of the parent pions the first time, and the secondary gammas the second time). Of course a conversion efficiency for the gamma-to-photon foil must be specified, which factor would multiply the output from such a program. THIS PROGRAM HAS NOT YET BEEN DONE. The electron yield estimates that were shown in Fig. 2 above were done (by a very crude back-of-the-envelope) calculation of this nature.

APPENDIX F

TO FIX

[μ STRAGGLING
μ YIELDS]

```
      subroutine russian(itype,xpr,pperp,atwt,Ezero,dsdp3)
c     parameters for particle yields...1=pi+, 2=pi- from New Russian Xlation
c     "Passage of H.E. Particles thru Matter, AN Kalinovski,etal,AIP,eqn3.26
      dimension c1(5),c2(5),c3(5),c4(5),c5(5),c6(5),fm(5),omeg(5),
     x fmusq(5),bzero(5),gam(5)
CCCC
C      1=pi+, 2=pi-, 3=K+, 4=K- and 5=p- (ie pbar)    ( =i = itype)
CCCC
c     units are GeV for fm,omeg,gam (and GeV**-1 for bzero)...)
      data c1/0.25, 0.20, 0.075, 0.078, 0.080/
      data c2/3.1, 4.0, 2.5, 6.1, 8.6/
      data c3/0.88, 1.18, 1.60, 2.46, 2.30/
      data c4/3.0, 3.0, 3.0, 3.5, 4.2/
      data c5/2., 2., 2., 2., 2./
      data c6/11.3, 9.8, 10.7, 8.8, 10.5/
      data fm/2*0.1396, 2*0.4937, 0.9382/
      data omeg/1.8778, 2.016, 2.054, 2.370, 2.815/
      data fmusq/0.88, 0.86, 1.2, 1.2, 1.1/
      data bzero/0.10, 0.11, 0.12, 0.12, 0.12/
      data gam/4.0, 3.5, 4.0, 4.0, 5.0/
c
c     formulae 3.26...given as function of "p-perp and x-prime"...to be input
c     where x-prime=(E*/E*max)...ie 0. thru +1.
      i=itype
      srtofS=sqrt(2.0*0.9382*Ezero)
      bperp=bzero(i)*pperp
      if(pperp.gt.gam(i)) bperp=bzero(i)*gam(i)
      psq=pperp**2
      xperp=2.*pperp/srtofS
      phi=exp(-c4(i)*psq)+c5(i)*exp(-c6(i)*xperp)/((psq+fmusq(i)**2)**4)
      xxx=c1(i)*(atwt**bperp)*((1.-xpr)**c2(i))*exp(-c3(i)*xpr)*phi
c..........AND SCALE BY Be absorption crossection (199 mb)
      ccsect=((atwt-0.40)/(9.01-0.40))**0.69
      ccsect=ccsect*199.
      xxx=ccsect*xxx
      dsdp3=xxx
      return
      end
```

Fig. 1 — "RUSSIAN.for"

```
      program yplus
CCCCCCC*****   yplus...pi+ and proton AND ratio....6-18-90 grk
CCCCC.....uses eqn. 3.27 for protons
c       dimensions in 'inches'..program converts to meters
        data fmperin/0.0254/
CCCCCCCCCCCCCC.......................PI+  /  PROTON........
c       parameters for particle yields.1=pi+, 2=prot from New Russian Xlation
c       "Passage of H.E. Particles thru Matter, AN Kalinovski,etal,AIP,eqn3.26
        dimension c1(9),c2(9),c3(9),c4(9),c5(9),c6(9),fm(9),omeg(9),
     x  fmusq(9),bzero(9),gam(9)
        dimension dsdp(100,9),xpr(100),fnum(100,9),gnum(100,9),ratio(100)
c       units are GeV for fm,omeg,gam (and GeV**-1 for bzero)...)
        data c1/0.25, 0.018, 7*0./
        data c2/3.1, 126., 7*0./
        data c3/0.88, 1.14, 7*0./
        data c4/3.0, 0., 7*0./
        data c5/2., 0., 7*0./
        data c6/11.3, 0., 7*0./
        data fm/0.1396, 0.9383, 7*0./
        data omeg/1.8778, 0.9383, 7*0./
        data fmusq/0.88, 1.3, 7*0./
        data bzero/0.10, 0.13, 7*0./
        data gam/4.0, 5.0, 7*0./
c.............and 3.27 for protons
c       formulae 3.26...given as function of "p-perp and x-prime"...to be input
c       where x-prime=(E*/E*max)...ie -1. thru 0. to +1.
        write(6,10)
   10   format(1x,'INPUT p-perp(GeV),delta-xpr,sqrt(S),atnum (4F8.3)')
        read(5,11)pperp,dxpr,srtofS,atnum
   11   format(4f8.3)
        write(6,12)pperp,dxpr,srtofS,atnum
        write(3,12)pperp,dxpr,srtofS,atnum
   12   format(1x,'ECHO p-perp,delxpr,srtofS,A=',4f8.3)
c       DO A PPERP loop also...by 0.1 starting with readin pperp
c       do 100 lll=1,11
c       do 100 lll=1,6
c       loop over pi+,proton (ie 1,2)
        do 101 i=1,2
c       do xpr values from dxpr UP, but MAX of 100, and NOT xpr=1. either
        nn=1./dxpr
        nn=nn-1
        if(nn.gt.100) nn=100
        xpr(1)=dxpr
        do 102 j=1,nn
        bperp=bzero(i)*pperp
        if(pperp.gt.gam(i)) bperp=bzero(i)*gam(i)
        psq=pperp**2
        xperp=2.*pperp/srtofS
        IF(i.eq.1) THEN
        phi=exp(-c4(i)*psq)+c5(i)*exp(-c6(i)*xperp)/((psq+fmusq(i)**2)**4)
        xxx=c1(i)*(atnum**bperp)*((1.-xpr(J))**c2(i))*exp(-c3(i)*xpr(J))*phi
              ELSE
c.....protons...........i=2
                fppp=srtofS*sqrt(1.-xpr(J))
                fxx=-1.+0.3*psq
                fpp=((1.-xpr(J))**fxx)*exp(-3.5*psq)*(1.+1./fppp)
                fxx=c3(i)*psq
                xxx=c1(i)*(fpp+c2(i)*(atnum**bperp)*xpr(J)*((1.-xpr(J))**
     x          fxx)/((psq+fmusq(i))**4.5)   )
        ENDIF
c..........AND SCALE BY Be absorption crossection (199 mb)
        ccsect=((atnum-0.40)/(9.01-0.40))**0.69
        ccsect=ccsect*199.
c 12-26-90..... xxx=ccsect*xxx
        dsdp(j,i)=xxx*ccsect
c       assuming 0.5 min of aperture at 150 feet  d(solid angle)=3 x 10**-6
```

```
ccc.....(3 micro-sterradians)..0.33 Labsorpt Be target..x=exp(-x)=.24...ie 24%
ccc.....incident protons interact...then yield per interact-proton is
ccc.....plab**2 * (dp/p) *ster-rad * inv.sigma(=dsdp(..)), where dp/p=0.2(=-10%)
ccc.....and plab=xpr*(pzero=Ezero-200 GeV,..'MEB')..., and sigma(abs).Be=199 mb.
ccc..... #/int-p = xpr**2 * 0.2 * 3x10**-6 * (Elab)**2 * dsdp(..,..) / 199mb
        fnum(j,i)=(1.2e-4)*xxx*(xpr(J)**2)*199.
c...correct for non-200. GeV...11-16-90 grk
                fnum(j,i)=fnum(j,i)*(Ezero/200.)**2
c       24 % interact in 0.33 absorption length target
        gnum(j,i)=fnum(j,i)*0.24
        if(j.ne.nn) xpr(j+1)=xpr(j)+dxpr
  102   continue
  101   continue
        do 2222 jj=1,nn
 2222   ratio(jj)=dsdp(jj,2)/dsdp(jj,1)
        write(3,221)pperp
  221   format(10x,'PPERP=',f10.2)
        write(3,222)(m,xpr(m),dsdp(m,1),dsdp(m,2),fnum(m,1),fnum(m,2),
     x  gnum(m,1),gnum(m,2),ratio(m),m=1,nn)
  222   format(1x,'m,xpr,dsdp(pi+,prot)=',i2,f6.3,2f12.3/
     x  10x,'#/int-p(pi+,p)',20x,2e10.3/10x,'#/incident-p..',20x,2e10.3/
     x  10x,'ratio(p/pi+).=',e13.4)
        pperp=pperp+0.1
  100   continue
        call exit
        end
```

FIG. 2

SSC Laboratory **Physics Research Division**

Table 4.1.1.4-1
Particle Yields for 200 GeV Beam per 10^{11} Incident Protons

Secondary Momentum (GeV/c)	π^-	e^- (estimated)	100 L	CONV 5 π
150	2×10^4	10^2	$\times 10^2$	10^1
100	6×10^5	5×10^3	20×10^3	10^3
50	2×10^6	10^4	30×10^4	$1.5 \times$
10	4×10^5	10^5	12×10^5	$0.6 \times$
5	5×10^4	6×10^4		
3	10^4	2×10^4		
1	10^2	2×10^3		

$\frac{1}{4}$ EMITTANCE (5M2)

$$\left[\begin{array}{l} \frac{\Delta p}{p} = 0.06 \ (\pm 3\%) \\ \Delta\Omega = 2.5 \ \mu sr \\ \bar{\theta} = 4.5 \ mr \end{array}\right] = \left(\frac{1}{4} * \text{"}\gamma\pi + E\right.$$

GRK
6/30/90

FIG. 2

Table 4.1.1.4-1
Particle Yields for 200 GeV Beam per 10^{11} Incident Protons

Secondary Momentum (GeV/c)	π^-	e^- (estimated)
150	2×10^4	10^2
100	6×10^5	5×10^3
50	2×10^6	10^4
10	4×10^5	10^5
5	5×10^4	6×10^4
3	10^4	2×10^4
1	10^2	2×10^3

$$\left[\begin{array}{l} \frac{\Delta p}{p} = 0.06 \ (\pm 3\%) \\ \Delta\Omega = 2.5\ \mu sr \\ \bar{\theta} = 4.5\ mr \end{array}\right] = \left(\frac{1}{4} * \text{"}Y_{\pi^+ET}\right.$$

GRK
6/30/90

6/26/90 GRK.

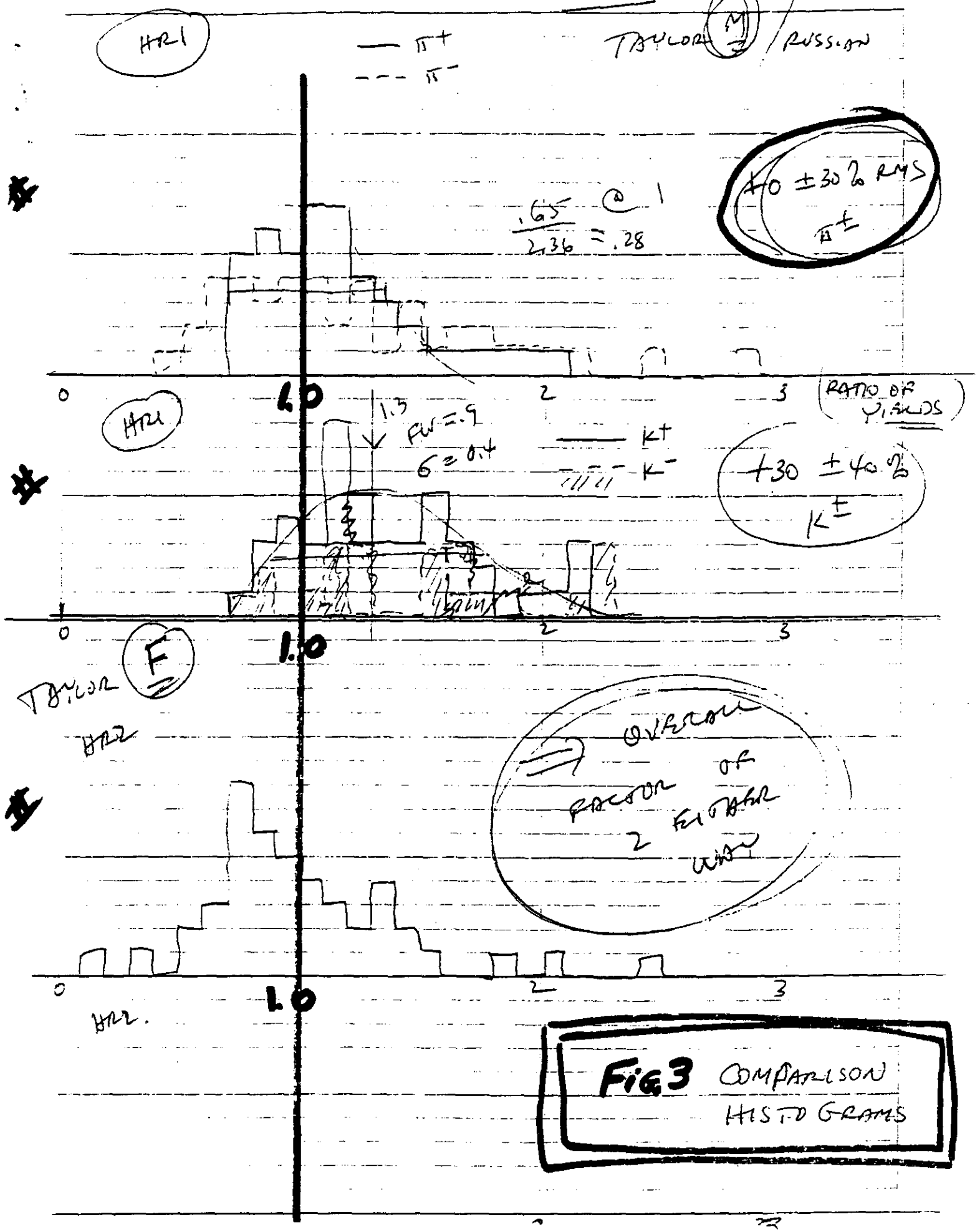


FIG 3 COMPARISON HISTOGRAMS

Page 4, muSCatZ ...INSIDE results..
A,EC,RR= 9.0 2000.0 1.0

TABLE 1.

PER METER OF DECAY PATH !!

first...UNscattered

Step#	Range(m)		PPmin	Log10(mus/m**2/10**12,Radius=1,10)..								
1	0.	0.	8.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	221.	100.	7.81	6.54	5.00	3.86	2.95	1.98	0.00	0.00	0.00	0.00
3	386.	200.	7.31	6.08	4.60	3.46	2.53	1.67	0.17	0.00	0.00	0.00
4	518.	300.	6.90	5.61	4.06	2.89	1.97	1.00	0.00	0.00	0.00	0.00
5	628.	400.	6.55	5.18	3.54	2.38	1.40	0.22	0.00	0.00	0.00	0.00
6	722.	500.	6.23	4.76	3.09	1.90	0.84	-0.73	0.00	0.00	0.00	0.00
7	804.	600.	5.93	4.35	2.64	1.42	0.27	0.00	0.00	0.00	0.00	0.00
8	877.	700.	5.63	3.98	2.24	0.97	-0.34	0.00	0.00	0.00	0.00	0.00
9	943.	800.	5.33	3.60	1.80	0.52	-1.02	0.00	0.00	0.00	0.00	0.00
10	1002.	900.	5.03	3.22	1.41	0.06	-1.81	0.00	0.00	0.00	0.00	0.00
11	1057.	1000.	4.72	2.81	0.98	-0.41	-2.89	0.00	0.00	0.00	0.00	0.00
12	1108.	1100.	4.39	2.42	0.57	-0.90	0.00	0.00	0.00	0.00	0.00	0.00
13	1155.	1200.	4.05	2.01	0.13	-1.42	0.00	0.00	0.00	0.00	0.00	0.00
14	1198.	1300.	3.68	1.57	-0.33	-1.98	0.00	0.00	0.00	0.00	0.00	0.00
15	1240.	1400.	3.27	1.09	-0.81	-2.58	0.00	0.00	0.00	0.00	0.00	0.00
16	1278.	1500.	2.82	0.56	-1.36	-3.29	0.00	0.00	0.00	0.00	0.00	0.00
17	1315.	1600.	2.28	-0.01	-1.95	-4.13	0.00	0.00	0.00	0.00	0.00	0.00
18	1349.	1700.	1.63	-0.71	-2.69	-5.14	0.00	0.00	0.00	0.00	0.00	0.00
19	1382.	1800.	0.75	-1.63	-3.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	1413.	1900.	-0.78	-3.22	-5.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00

second .. Multiply Scattered

5.36 → 2.3 X10^5

6.71 → 5.1 X10^6
4.52 → 3.3 X10^4
2.19 → 1.5 X10^2
3.49 → 3 X10^3

Step#	Range(m)		PPmin	Log10(mus/m**2/10**12,Radius=1,10).								
1	0.	0.	8.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	221.	100.	7.68	6.78	6.14	5.59	4.83	3.88	2.87	1.77	0.78	-0.50
3	386.	200.	7.14	6.21	5.81	5.32	4.82	4.30	3.63	2.95	2.17	1.10
4	518.	300.	6.71	5.77	5.36	4.96	4.52	4.02	3.49	2.88	2.19	1.47
5	628.	400.	6.35	5.41	4.99	4.60	4.21	3.73	3.17	2.58	1.97	1.27
6	722.	500.	6.02	5.06	4.68	4.29	3.90	3.36	2.91	2.26	1.64	0.93
7	804.	600.	5.71	4.76	4.35	4.01	3.55	3.09	2.54	1.93	1.33	0.56
8	877.	700.	5.40	4.45	4.05	3.72	3.22	2.82	2.18	1.66	0.88	0.26
9	943.	800.	5.12	4.10	3.79	3.35	2.97	2.42	1.91	1.22	0.56	-0.19
10	1002.	900.	4.81	3.79	3.48	3.10	2.56	2.13	1.52	0.80	0.19	-0.67
11	1057.	1000.	4.49	3.51	3.13	2.76	2.29	1.74	1.16	0.53	-0.25	-1.22
12	1108.	1100.	4.17	3.21	2.80	2.37	1.96	1.43	0.79	0.08	-0.69	-1.88
13	1155.	1200.	3.82	2.85	2.46	2.06	1.59	1.01	0.37	-0.37	-1.16	-2.60
14	1198.	1300.	3.45	2.47	2.10	1.68	1.20	0.64	-0.07	-0.76	-1.61	-3.29
15	1240.	1400.	3.05	2.07	1.70	1.25	0.75	0.16	-0.50	-1.28	-2.13	-4.06
16	1278.	1500.	2.60	1.61	1.21	0.79	0.29	-0.32	-1.04	-1.83	-2.73	-4.78
17	1315.	1600.	2.07	1.08	0.69	0.25	-0.29	-0.90	-1.57	-2.45	-3.47	-5.92
18	1349.	1700.	1.42	0.41	0.05	-0.45	-0.94	-1.62	-2.33	-3.16	-4.41	-6.35
19	1382.	1800.	0.54	-0.47	-0.82	-1.31	-1.84	-2.50	-3.30	-4.09	-5.61	-7.43
20	1413.	1900.	-1.00	-1.97	-2.41	-2.84	-3.43	-4.08	-4.85	-5.76	-7.47	-9.23

↑ 0.5 ↑ 2.5 ↑ 4.5 ↑ 6.5 ↑ 8.5 meters

(8+1) (15') (21.5') (28')

5.36 → 2.3 X10^5

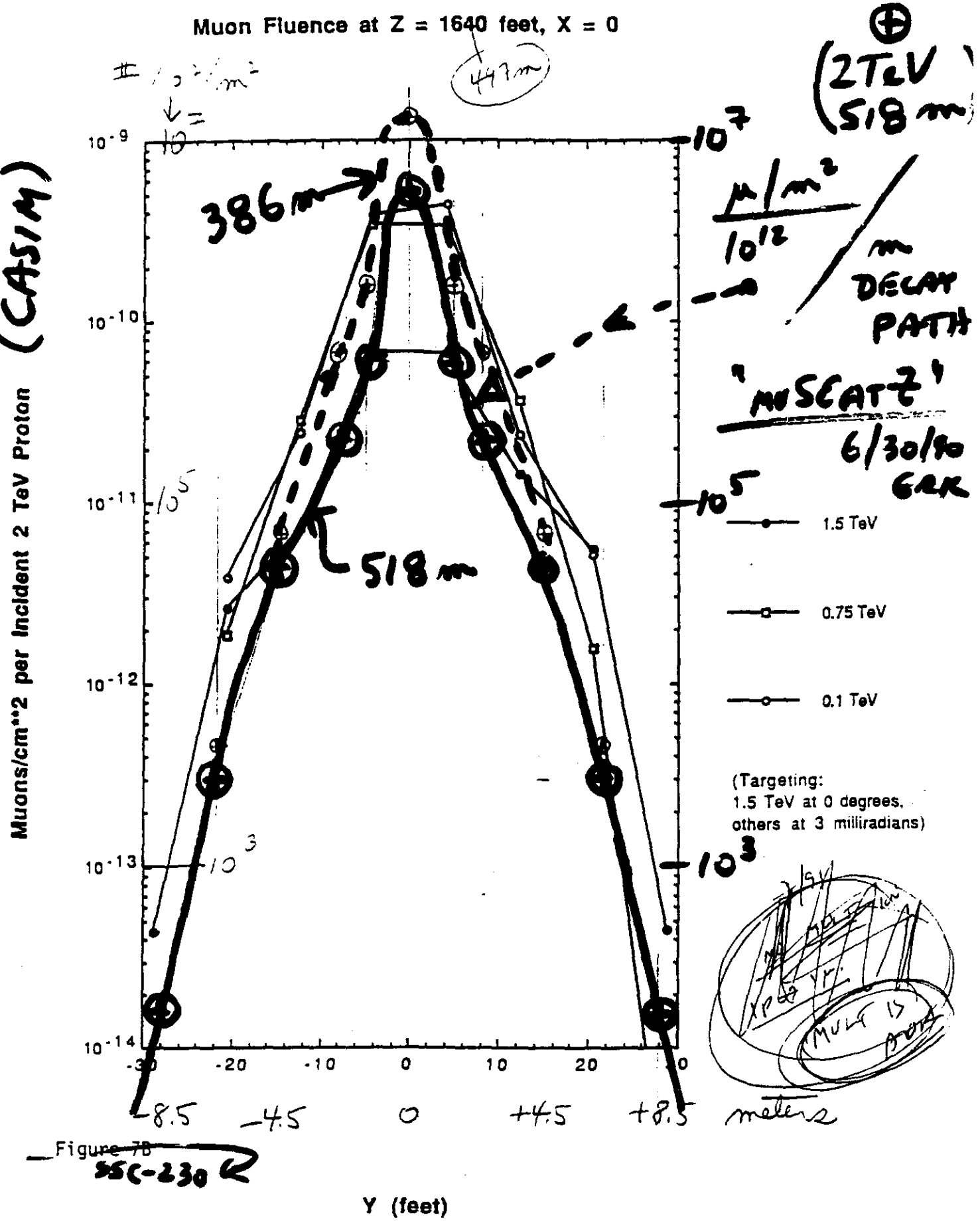
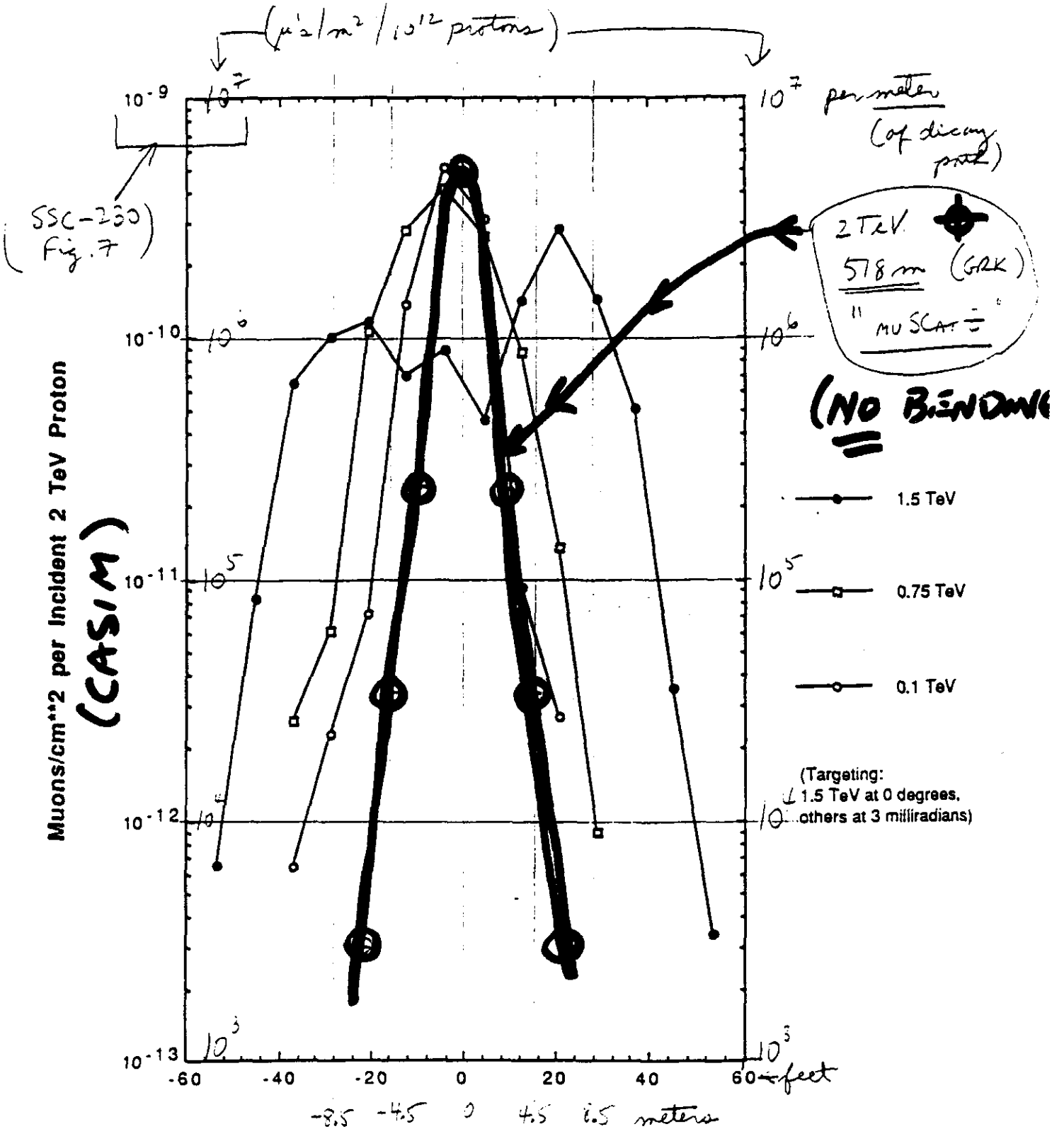


Figure 7B
SSC-230

FIG. 4

500 m, 2 TeV.

Muon Fluence at Z = 1640 feet, Y = 0



~~Figure 7A~~ SSC-230 X (feet) (THE "BENDING" PLANE ?)

FIG. 5

Appendix A

Russian Reference

Translation Series

SSC LIBRARY
JUN 11 1990
ORDER NO: 7012-01173
US GOV'T PROPERTY

INCLUSIVE $\frac{d\sigma}{E\,dp}$

Passage of High-Energy Particles through Matter

A. N. Kalinovskii
N. V. Mokhov
Yu. P. Nikitin

here @ SSCL (according to J. Shea (3/00))

Translated by
S. J. Amoretty

AIP
American Institute of Physics New York

where $N_{A_1} = A_1\sigma_{in}(NA_2)/\sigma_{in}(A_1A_2)$ is the average number of nucleons in the nucleus A_1 which participate in the interaction. The behavior of the quantity $\gamma(x_F) > 0$ is determined from the data on NA and NN interactions. The parameter $\gamma(x_F)$ increases slowly with increasing x_F. At $x_F \simeq 0.5$ we have $\gamma(x_F) \simeq 0.2$.

(3) An equation similar to Eq. (3.23) applies in the region of fragmentation of the nucleons of the nucleus A_2. Relations (3.22) and (3.23) are valid when the energy of the nucleon of an incident nucleus A_1 is high ($E_{A_1}/A_1 \gtrsim 100$ GeV; Ref. 28). If, on the other hand, $A_1 \ll A_2$, these relations will apply even at energies on the order of several (tens) of GeV per nucleon of the nucleus.

At a moderately high energy, relations (3.22) and (3.23) generally do not apply, and either the phenomenological parametrizations of the experimental data or the intranuclear cascade model should be used.[48]

4. Phenomenological description of the inclusive spectra

The existing models for the description of the inclusive distributions of hadrons in pp collisions at $E_0 > 1$ GeV are based on simplifying specific assumptions. These models therefore describe the process in a particular limited region of the kinematic variables. The complex-momentum method, which is generalized to the inclusive processes, for example, predicts the behavior of the distribution in the scaling variable x_F separately for the fragmentation region and the pionization region, without yielding any information about the intermediate region. Since the transverse-momentum distribution is not determined in the complex-momentum method, it must be postulated by choosing a Gaussian or exponential shape and by fitting the parameters from a comparison with the experiment. Statistical and thermodynamic models also have an adequate number of adjustable parameters. Furthermore, such models give an incorrect dependence of the invariant cross section on the transverse momentum at $p_\perp \gtrsim 1$–2 GeV/c.

All these factors prevent a particular model from establishing a quantitative agreement between theory and experimental data over a broad kinematic interval without choosing free parameters. An urgent need to describe the inclusive spectra, especially in going up the energy scale, has initiated many attempts to construct relevant phenomenological equations.

The main features of the inclusive hadron distributions in the reaction $hp \to cX$ can be analyzed by using simple expressions of the type

$$Ed^3\sigma/d^3p = C_0(p_\perp)(1 - x_F)^n; \quad n \neq n(p_\perp, p_0) . \tag{3.24}$$

The values of the parameter n for various reactions at primary hadron momenta $p_0 \sim 100$–200 GeV/c in the laboratory frame at $p_\perp < 1.2$ GeV/c and $0.2 < x_F < 1$ are presented[73] in Table 3.3.

FANSKI 14-JUN-1990 10:13:05.05

elds from malensek

particles at 100 GeV/c with 200 GeV on target are:

Electron/P = 5.7 E-7

esigned, the bends run at 16 kg and the quads aabout
:. I have therefore not run any yields at 150 GeV/c.
retty good, we could just add enough bends to make
is at their 100 Gev values. If you want me to run
let me know.

The startup is going pretty well. MP and NM are tuned up and are getting expected yields. NE has taken beam through the pinhole all the way down to Lab G. NW is down to Enc. 102; NT/NK has beam on the primary target in NE8.

Regards,

Anthony

8/1/1991

(AT SMR) 200 GeV p 100 GeV π^-/e^-

"GRAL" case ($x'=0.5$) $\frac{\pi^-}{p} = 1.6\times10^{-5}$ $\frac{e^-}{p} = 8\times10^{-7}$

@ $\theta = 5$ mr / $\frac{\Delta p}{p} = \pm 10\%$ / $\Delta\Omega = 3\times10^{-5}$ sr

Table 3.3. Values of the parameter n in Eq. (3.24) for various reactions.

Reaction	$\pi^+ + K^+$	$\pi^- + K^-$	$K^+ + \pi^+$	$K^- + \pi^-$	$\pi^+ + p$	$\pi^- + \bar{p}$
n	1.28	1.40	2.28	2.50	1.78	2.13
Reaction	$\pi^+ + \bar{p}$	$\pi^- + p$	$K^+ + p$	$K^- + \bar{p}$	$p + \pi^+$	$\bar{p} + \pi^-$
n	2.98	2.58	1.72	1.56	3.43	3.10
Reaction	$p + K^+$	$p + \pi^-$	$\bar{p} + \pi^+$	$\pi^+ + \pi^-$	$\pi^- + \pi^+$	$\pi^+ + K^-$
n	2.87	4.53	3.71	3.12	2.94	2.30
Reaction	$\pi^- + K^+$	$K^+ + \pi^-$	$K^- + \pi^+$	$K^- + p$	$p + K^-$	$p + \bar{p}$
n	1.98	2.98	2.51	4.13	4.68	8.09

Table 3.4. Average values of the inelasticity coefficient $\langle K_\gamma \rangle$.

Reaction	E_0, GeV	CH_2	Al	Fe	Pb
$\gamma + \pi^0 N$	200–2000	0.17 ± 0.01 0.17	0.19 ± 0.02 0.19	0.19 ± 0.02 0.21	0.21 ± 0.02 0.21
$\pi^- + \pi^0 N$	200–2000	0.33 ± 0.02 0.31	0.38 ± 0.04 0.31	0.37 ± 0.05 0.31	0.39 ± 0.04 0.30
$\gamma + \pi^0 N$	10^3–1×10^4	— —	— —	— —	0.17 ± 0.01 0.19

The average inelasticity coefficient $\langle K \rangle$ is a useful concept in the analy- of an interaction. The calculated (lower numbers) and experimentally ob- ned (upper numbers) asymptotic values $\langle K_\gamma \rangle = \langle K_{\pi^0} \rangle$, taken from Ref. 74, given in Table 3.4. At $E \sim 20$ GeV in the pN reaction $\langle K_\gamma \rangle \simeq 0.15$, $\rangle \simeq 0.46$, $\langle K_- \rangle \simeq 0.13$, and $\langle K_0 \rangle \simeq 0.41$ (Ref. 74).

The expressions for effective invariant cross sections of the inclusive re- tions

$$pA \to (\pi^\pm, K^\pm, \bar{p}, \Sigma^\pm) + X_A; \quad pA \to (p, n) + X_A \tag{3.25}$$

the proton and nuclear targets were proposed in Ref. 75. These equations ve no more free parameters than the specific models and, most important, y have all the qualitative properties at small transverse momenta $\lesssim 1.5$ GeV/c) and large transverse momenta ($p_\perp \gtrsim 1.5$ GeV/c), describing spectra in the entire region, $-1 < x_F < 1$.

As the kinematic variables one can use $x' = E^*/E^*_{max}$ and $p_\perp$, where E^* d E^*_{max} are the total energy of the inclusive particle in the c.m. frame and its aximum possible value. The variables x' and $p_\perp$ are useful near the phase undary and in the central region (see Sec. 1.3). In addition, these variables ould reveal an early scaling.

Taking into account the qualitative predictions of the Regge and parton odels, the following expression was obtained in Ref. 75 for the particle spec- of the first reaction in (3.25):

Table 3.5. Values of the parameters in Eqs. (3.26) and (3.27).

Particle	m, GeV	ω, GeV	μ^2	b_0	Γ, GeV	C_1	C_2	C_3	C_4	C_5	C_6
p	0.938 28	0.938 28	1.3	0.13	5.0	0.018	126	1.14	—	—	
n	0.939 57	1.077 85	1.3	0.14	5.0	0.018	126	1.14	—	—	
π^+	0.139 57	1.877 75	0.88	0.10	4.0	0.25	3.1	0.88	3.0	2	[illegible]
π^-	0.139 57	2.016 13	0.86	0.11	3.5	0.20	4.0	1.18	3.0	2	[illegible]
K^+	0.493 71	2.053 88	1.2	0.12	4.0	0.075	2.5	1.60	3.0	2	[illegible]
K^-	0.493 71	2.370 27	1.2	0.12	4.0	0.078	6.1	2.46	3.5	2	[illegible]
$\bar{p}$	0.938 28	2.814 84	1.1	0.12	5.0	0.080	8.6	2.30	4.2	2	[illegible]
Σ^+	1.189 37	1.435 98	1.1	0.12	4.0	0.015	0.3	1.3	4.0	1	
Σ^-	1.197 35	1.575 55	1.1	0.12	4.0	0.014	0.4	1.6	3.8	1	

$$\frac{E}{\sigma_A}\frac{d\sigma_A}{d^3p} = C_1 A^{b(p_\perp)}(1-x')^{C_2}\exp(-C_3 x')\Phi(p_\perp);$$

$$\Phi(p_\perp) = \exp(-C_4 p_\perp^2) + C_5 \frac{\exp(-C_6 p_\perp)}{(p_\perp^2 + \mu^2)^4},$$

where

$$b(p_\perp) = \begin{cases} b_0 p_\perp, p_\perp < \Gamma; \\ b_0 \Gamma, p_\perp > \Gamma, x_\perp \simeq 2p_\perp/\sqrt{S}, \end{cases}$$

and the parameters b_0, Γ, μ^2, and C_i, found by the method of least sq from the experimental data, are presented in Table 3.5. Also given i table are the masses m of the corresponding particles and the min masses ω of the X_A system from (3.25) for the nucleon target.

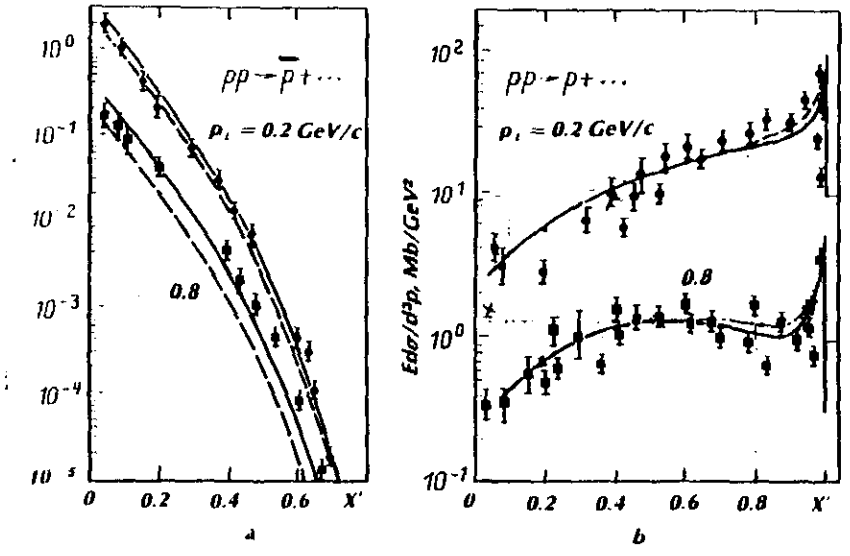
The differential cross section of the second reaction in (3.25) w scribed in Ref. 75 by using the predictions of the Regge model for $|x_F|$ the two-cluster diffraction model for $|x_F| < 0.7$, and the predictions parton model for large $p_\perp$. The three-Reggeon vertices PPP, PPR, RR RRR (see Sec. 3.1), which were parametrized in the form $G_{PPP(R)}(t$ $\times \exp(at)$, were taken into account. Here P is a pomeron with the traj $\alpha_P(t) = 1 + 0.15t$, and R is the effective nonvacuum pole with the traj $\alpha_R(t) = 0.5 + 0.75t$ and $a = \text{const}$. Finally,

$$\frac{E}{\sigma_A}\frac{d^3\sigma_A}{d^3p} = C_1\left[F_{PP} + C_2 A^{b(p_\perp)} x'(1-x')^{C_3 p_\perp^2}(p_\perp^2 + \mu^2)^{-4.5}\right];$$

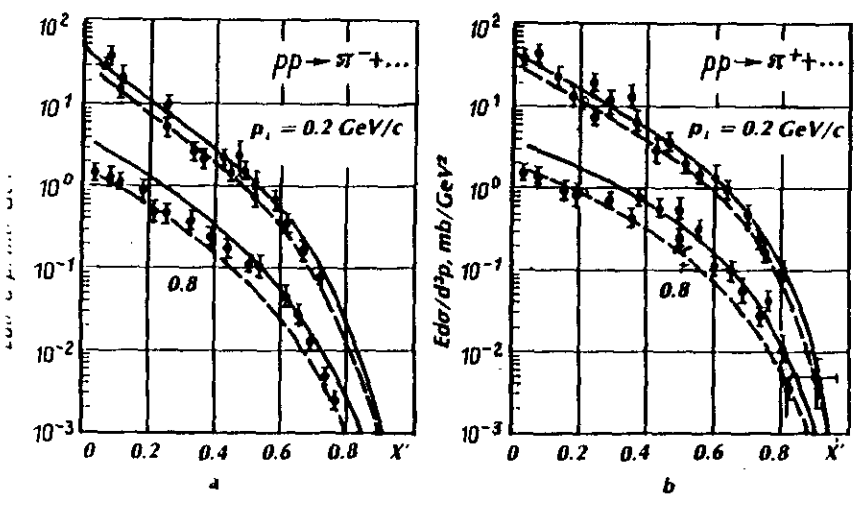
$$F_{PP} = [1 + S^{-1/2}(1-x')^{-1/2}](1-x')^{-1+0.3p_\perp^2}\exp(-3.5p_\perp^2),$$

where the function $b(p_\perp)$ is the same as that in Eq. (3.26) and the par values are given in Table 3.5. For the reaction $pA \to nX_A$ we have F_{PP}

Figures 3.15–3.21 compare the results of calculations based on Eqs and (3.27) with the experimental data of Ref. 75. These figures reveal agreement over a broad range of target nuclei (p, Be, Ti, and W) of t mary momenta $6 < p_0 < 1500$ GeV/c, transverse momenta $0.2 < p_\perp < 8$ and longitudinal momenta $0 < |p_\parallel^*| < p^*_{max}$. This result is evidence that t



ure 3.15. Invariant cross sections $Ed^3\sigma/d^3p$ for (a) the inclusive reaction $pp \to \bar{p} + \cdots$ [curves, lculation based on Eq. (3.26): —, $p_0 = 24$ GeV/c, —·, $p_0 = 1500$ GeV/c; the experimental data for from 6 to 1500 GeV/c were taken from Ref. 75: ●, $p_\perp = 0.2$ GeV/c; ■, $p_\perp = 0.8$ GeV/c, $E^*E^*_{max}$; (b) the reaction $pp \to p + \cdots$ [curves, calculation based on Eq. (3.27)].



gure 3.16. Invariant cross sections for (a) the reaction $pp \to \pi^- + \cdots$ and (b) the reaction $p \to \pi^+ + \cdots$. (The notation is the same as in Fig. 3.15.)

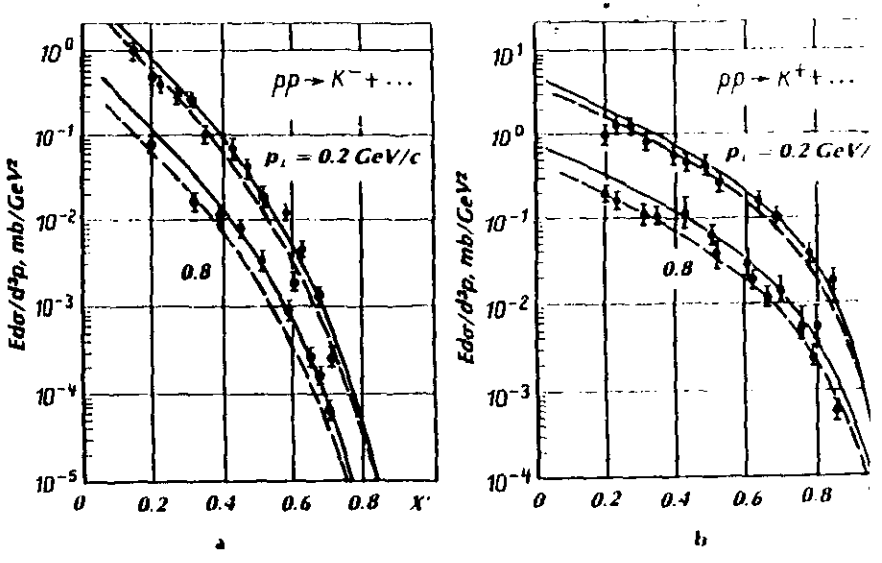
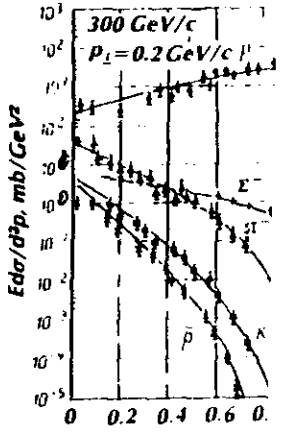


Figure 3.17. Invariant cross sections for (a) the reaction $pp \to K^- + \cdots$ and (b) the react $pp \to K^+ + \cdots$. (The notation is the same as in Fig. 3.1

Figure 3.18. Invariant cross section for the production of inclusive hadrons in pp collisions at $p_\perp = 0.2$ GeV/c (curves, calculation from Ref. 75 for $p_0 = 300$ GeV/c; experimental points from Ref. 75 for $6 < p_0 < 1500$ GeV/c; Σ^-, experimental data (Ref. 75) on pBe interaction for $p_0 = 29$ GeV/c and $p_\perp = 0$; $x' = E^*E^*_{max}$).



gested equations are highly precise, which makes them a useful tool for analysis of the inclusive distributions.

A slightly less accurate description of the spectra at small $p_\perp$ and o particular features of the A dependence are, however, the tradeoff for universal applicability of Eqs. (3.26) and (3.27). The small transverse menta play an important role in the calculation of electromagnetic casc In addition, information on the reactions of the type (3.25) must be avai for all incident particles (over a broad range of the primary momenta p_0 GeV/c) which participate in the development of the electromagnetic cas

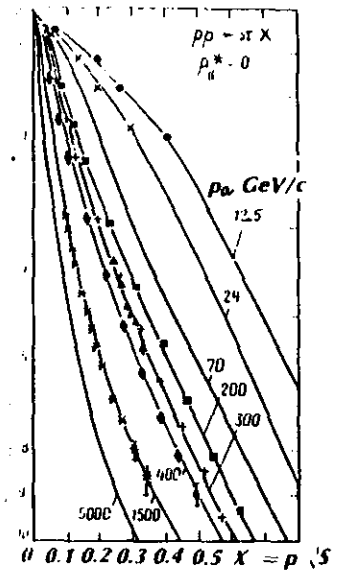


Figure 3.19. Invariant cross section for the production of π^0 mesons in pp collision (the calculated curves and experimental points were taken from Ref. 75).

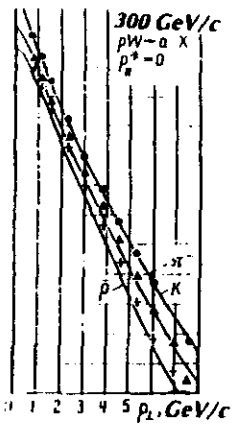


Figure 3.20. Invariant cross section for the production of hadrons in pW interaction at $p = 300$ GeV/c (the calculated curves and experimental points were taken from Ref. 75).

lysis of various semiempirical equations published in the literature[76–83] ·s that the following description of inclusive hadron distributions in hA ·ractions can now be used in the theoretical predictions of electromagnetic ·ides.

·egion $E_0 > 5$ GeV

·ssume that the incident particle is a nucleon. In the interval $0.8 \lesssim x_F \lesssim 1$ ·ading-nucleon spectra can then be described by the PPP and PPR contri- ·ns of the three-Reggeon formalism. The average multiplicity of these

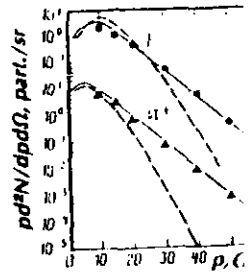


Figure 3.21. Momentum distribution of protons and pions at an angle $\theta = 77$ mrad in the laboratory frame in pT, interaction at $p_0 = 300$ GeV/c. The solid curve was calculated from Eqs. (3.26) and (3.27), the dashed curve was plotted on the basis of the thermodynamic model, and the experimental data points were taken from Ref. 79.

Table 3.6. Values of the parameters C_i in Eq. (3.28).

A	C_1	C_2	C_3	C_4	C_5	C_6
< 40	2.87	− 2.99	3.2	3.91	5.82	2.94
> 40	2.80	− 1.78	0.3	5.38	5.80	2.80

nucleons is described by the empirical formula $\langle n \rangle \simeq 0.135(A+2)^{0.355}$. distributions of the other fast nucleons are found by means of the fo las[76,80] ($x = x_F$)

$$\frac{d^2N}{dx\,dp_\perp^2} = C_1 \frac{p^*_{max}}{4\sqrt{S}}(1 + C_2|x| + C_3x^2) \times [\exp(-C_4 p_\perp^2) + C_5 \exp(-C_6 p_\perp)] ,$$

where $x = x_F = p_\parallel^*/p^*_{max}$, and the modified parameters C_i which make a sistent description of the spectra possible, are given in Table 3.6.

The following equations can be used to describe the production of se ary π and K mesons[77–79]:

$$\left.\begin{aligned} &\frac{d^2N}{dx\,dp_\perp^2} = C_1 \frac{\pi}{x'}(1 - x_R)^{C_2} F \exp(-C_5 x_R)\Phi(p_\perp^2); \\ &F = 1 - \exp(-Tr^{*2}/C_3 - p_\perp^2/C_4); \\ &\Phi(p_\perp^2) = (1 - C_6)\exp(-C_7 p_\perp^2) + C_6 \exp(-C_8 p_\perp^2), \end{aligned}\right\}$$

where $x_R = p^*/p^*_{max}$, $x' = E^*/E^*_{max}$, and the parameters C_i are given in 3.7. The quantities in the c.m. frame of the reaction are denoted by an isk.

We assume now that the incident particle is a $\pi^\pm$ meson. At x_F nucleon spectra are described by Eq. (3.28) and at $x_F > 0$ they are descri an equation which describes the experimental data in an approximate

$$\frac{d^2N}{dx\,dp_\perp^2} = B_1 \exp(-B_2 x)[\exp(-B_3 p_\perp^2) + B_4 \exp(-B_5 p_\perp)] .$$

Here $B_1 = 1.8$, $B_2 = 5.2$, $B_3 = 3.78$, $B_4 = 0.47$, and $B_5 = 3.6$.

3.7. Values of the parameters C_i in Eq. (3.29).

leus	Particle	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
	π^+	2.47	1.80	3.0	0.010	2.78	0.30	12.0	2.70
	π^-	1.74	2.60	1.0	0.009	2.94	0.30	12.0	2.70
	K^+	0.17	1.30	3.0	0.010	2.78	0.46	4.2	2.65
	K^-	0.12	3.60	1.0	0.009	2.94	0.48	5.0	2.70
	π^+	2.32	1.89	2.6	0.010	3.03	0.30	12.5	2.65
	π^-	1.62	2.52	0.7	0.008	3.13	0.32	11.0	2.70
	K^+	0.11	1.28	2.6	0.010	3.03	0.51	4.3	2.65
	K^-	0.09	3.80	0.7	0.008	3.13	0.52	5.5	2.70
	π^+	2.27	1.93	2.0	0.008	3.23	0.32	12.0	2.65
	π^-	1.61	2.58	0.3	0.005	3.33	0.35	10.5	2.70
	K^+	0.12	1.31	2.0	0.008	3.23	0.52	4.4	2.70
	K^-	0.09	3.84	0.3	0.005	3.33	0.52	5.7	2.75
	π^+	2.25	1.89	1.8	0.006	3.57	0.35	11.2	2.65
	π^-	1.59	2.53	0.2	0.002	3.70	0.37	10.0	2.70
	K^+	0.13	1.35	1.8	0.006	3.57	0.54	4.6	2.75
	K^-	0.10	3.90	0.2	0.002	3.70	0.55	6.0	2.80
	π^+	1.95	1.82	1.5	0.005	4.00	0.37	11.0	2.65
	π^-	1.52	2.44	0.1	0.001	4.17	0.40	10.0	2.70
	K^+	0.14	1.40	1.5	0.005	4.00	0.55	4.9	2.85
	K^-	0.10	3.96	0.1	0.001	4.17	0.56	6.5	2.90

3.8. Values of the parameters C_i in Eq. (3.31).

ction	x	C_0	C_1	C_2	C_3	C_4
π^+	<0	1.7	0.33	7	0.0001	5.7
	>0	1.7	0.22	5	0.115	5.7
π^-	<0	1.7	0.31	13	0.0001	5.7
	>0	1.7	0.2	5	0.115	5.7
π^+	<0	5.4	$0.14-0.14/10\sqrt{s}$	13	0.0001	5.7
π^-	>0	5.4	$0.14-0.14/10\sqrt{s}$	5.5	0.0001	5.7

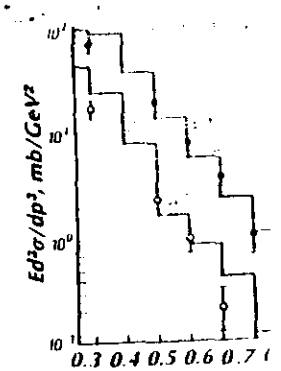
A better description of the A dependence of the spectra can be obtained ing Eqs. (3.28)–(3.31) for the hydrogen target in combination with the l-based predictions (3.16)–(3.18) and Fig. 3.13.

The inclusive distributions of secondary π mesons are described approxi- ly by an equation obtained in Ref. 80:

$$\frac{d^2N}{dx\,dp_\perp^2} = \frac{C_0}{2x'}\left[C_1\exp(-C_2x_F^2) + C_3\right]C_4^2\exp(-C_4p_\perp)\,. \qquad (3.31)$$

parameters C_i are given in Table 3.8.

Figure 3.22. Invariant cross section for the reaction $pAl \to \pi^+ X$ at $E_0 = 100$ GeV and $p_\perp = 0.3$ GeV/c. Histograms, result of simulation using Eq. (3.29); points, experimental data taken from Ref. 84 (the calculated and experimental data for π^- mesons were reduced by a factor of 2).



The distribution of slow cascade nucleons produced in hA interaction high energies in the laboratory frame can be described by equations obtai in Ref. 76:

$$\frac{d^2N}{dE\,d\Omega} = \left[\frac{n_{1i}\exp(-E/\alpha_{1i})}{\alpha_{1i}[1-\exp(-E_0/\alpha_{1i})]} + \frac{n_{2i}\exp(-E/\alpha_{2i})}{\alpha_{2i}[1-\exp(-E_0/\alpha_{2i})]}\right]g(E,\theta);$$

$$g(E,\theta) = \begin{cases} N_0\exp(-\theta^2/\lambda_0), & \theta < \pi/2; \\ N_0\exp(-\pi^2/\lambda_0), & \theta \geq \pi/2, \end{cases} \qquad (3$$

where the parameters have the following values at $E_0 > 5$ GeV: $n_{1p} = 0.21$ $n_{2p} = 0.0245\sqrt{A}$, $n_{1n} = 0.27\sqrt{A}$, $n_{2n} = 0.032\sqrt{A}$, $\alpha_{1p} = 0.027C$, $\alpha_{2p} = 0.$ $\alpha_{1n} = 0.023C$, $\alpha_{2n} = 0.15C$, $C = 1 - 0.001A$, $\lambda_0 = (0.12 + 0.00036A)/E$, an is a normalization factor such that $2\pi\int_0^\pi g(E,\theta)\sin\theta\,d\theta = 1$.

Figures 3.22–3.24 show some results of the inclusive distributions of tons and $\pi^\pm$ mesons in pA and πA collisions at energies $E_0 = 100$–3000 (simulated by the Monte Carlo method (see Chap. 6). The Monte Carlo sim tion was based on Eqs. (3.28)–(3.32).

The region $E_0 < 5$ GeV

If the primary kinetic energy of the hadrons lies in the interval $0.1 <$ GeV, we can use the equations from Ref. 83, which are particularly usef analytic solutions of the intermediate-energy nucleon transport equa The differential spectra of secondary nucleons in the laboratory frame c represented as a sum of the quasifree and cascade components:

$$d^2N_{ij}/dE\,d\Omega = d^2N_{ij}^q/dE\,d\Omega + d^2N_{ij}^c/dE\,d\Omega\,,$$

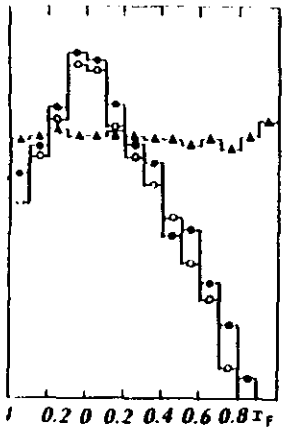


Figure 3.23. Result of simulation of the inclusive hadron distributions in the reaction $pp \to cX$ at $E_0 = 3000$ GeV (the transverse momentum is in the range $0 < p_\perp < 0.2$ GeV/c; ▲, p; ●, π^+; ○, π^-).

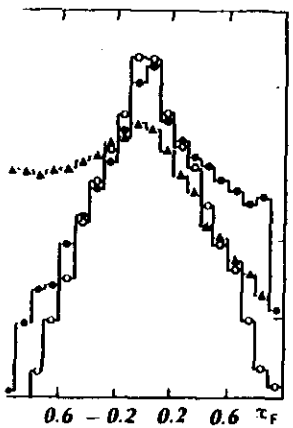


Figure 3.24. The $p_\perp$-integrated inclusive distribution of protons (▲), π^+ mesons (●), and π^- mesons (○) in the reaction $\pi^+ p \to cX$ at $E_0 = 3000$ GeV.

$$\left.\begin{aligned}
&\frac{d^2N^q_{ij}}{dEd\Omega}(E_0,E,\mu_s) = n_{ij}(E_0')\,\frac{\xi(E_0')+1}{2\pi E_0'}\left(\frac{E}{E_0'}\right)^{\xi(E_0')}\\
&\times\,\delta\left(\mu_s - \sqrt{\frac{E}{E_0}}\right);\\
&\frac{d^2N^c_{ij}}{dEd\Omega}(E_0,E,\mu_s) = \frac{\alpha}{4\pi}\left[\left(\frac{E}{E_0}\right)^{-\tau} - \left(\frac{E}{E_0}\right)^{\omega-\tau}\right](1+3\eta\mu_s);
\end{aligned}\right\} \qquad (3.34)$$

os θ is the cosine of the scattering angle in the laboratory frame. Here α, τ, ω, and η are the parameters found by approximating the results of ation of the nucleon–nucleus interactions on the basis of the intranu- ascade model.[83] Table 3.9 gives the values of the parameters n_{nn} and ξ tain nuclei. For other reactions n_{ij} are determined as follows:

Table 3.9. Values of the parameters in Eq. (3.34).

	O		Al		Cu		Pb	
E_0, GeV	n_{nn}	ξ	n_{nn}	ξ	n_{nn}	ξ	n_{nn}	ξ
0.05	0.68	0.01	0.61	0.04	0.53	0.01	0.40	0.01
0.1	0.78	0.02	0.69	0.02	0.56	0.02	0.42	0.02
0.2	0.78	0.20	0.79	0.02	0.63	0.02	0.46	0.02
0.3	0.80	0.20	0.72	0.20	0.56	0.20	0.44	0.05
0.4	0.66	0.40	0.59	0.40	0.52	0.20	0.31	0.40
0.5	0.47	1.00	0.41	1.00	0.34	0.80	0.23	0.80
0.6	0.33	1.60	0.30	1.60	0.24	1.40	0.16	1.40

$$\left.\begin{aligned}
n_{pn} &= [(A-Z)/(2A-Z)]n_{nn};\\
n_{np} &= [Z/(2A-Z)]n_{nn};\\
n_{pp} &= [(A+Z)/(2A-Z)]n_{nn},
\end{aligned}\right\} \qquad (3.$$

where A and Z are the atomic mass and atomic number, respectively.

The parameters of the second equation in (3.34) are virtually indep dent of Z for $13 \lesssim Z \lesssim 82$ and incident-nucleon energies in the inter $0.1 \lesssim E_0 \lesssim 1$ GeV. These parameters are $\alpha = 0.3$ MeV^{1}, $\omega = 0.01$, $\tau \simeq 0.2$, a $\eta = 0.5$.

The inclusive hadron spectra in various reactions in the primary-had kinetic energy range $0.02 \lesssim E_0 \lesssim 5$ GeV can be described in greater detail using the equation[81]

$$\frac{d^2N_{ij}}{dEd\Omega}(A, E_0, E, \theta) = F_q + F_L + F_c, \quad A > 1, \qquad (3$$

where the terms on the right side describe the angular and energy distri tions of hadrons produced as a result of quasielastic scattering of the lead and cascade hadrons, respectively.

$$F_q = \frac{\eta^q_{ij}N_q(E_0, A)}{2\pi^{3/2}\delta_q(E_0, \theta)}\,f_q(\theta)\exp\left[-\frac{(E - E_q(E_0, \theta))^2}{\delta_q^2(E_0, \theta)}\right]; \qquad (3$$

$$F_L = \frac{\eta^L_{ij}N_L(E_0, A)}{2\pi}\,f_L(E, \theta)\,\frac{dN_L}{dE}(E_0, E); \qquad ($$

$$F_c = \frac{\eta^c_{ij}}{2\pi}\,f^c_{ij}(E, \theta)\,\frac{dN_c}{dE}(E_0, E, A). \qquad ($$

Here we present the parameters and functions contained in these ex sions, making use, as in Ref. 81, of the kinetic energies E_0 and E (MeV angles θ (rad) in the laboratory frame.

r Eq. (3.37):

$$\eta^q_{ij} = \begin{cases} 0.8, & \text{if } i = j (i, j = p, n); \\ 0.2, & \text{if } i \neq j; \end{cases}$$

$$\lambda_q(E_0, A) = 1.17[1 - 0.8\exp(-g_1(E_0))]\{1 - \exp[-(E_0/350)^{1.5}]\}$$
$$\times \exp(-0.08\sqrt{A-1});$$
$$f_q(\theta) = a_q(E_0)\exp[-0.5a_q(E_0)\theta^2];$$
$$E_q(E_0,\theta) = E_0\cos^2\theta/[1 + E_0\sin^2\theta/(2m_N)] - 0.25;$$
$$g_1(E_0) = 4\times 10^{10}E_0^{-4} + 33.9E_0^{-0.65};$$
$$\delta_q(E_0,\theta) = 25(1 + 0.008E_0\theta);$$
$$a_q(E_0) = 4[0.5 + 0.01E_0^2/(2000 + E_0)](1 + E_0/2m_N),$$

m_N is the rest mass of the nucleon (MeV).

r Eq. (3.38):

$$\eta^L_{ij} = \begin{cases} \frac{2}{3} \text{ if } i = j; \\ \frac{1}{3} \text{ if the charge state of the secondary hadron differs from the charge state of the primary hadron by unity;} \\ 0 \text{ in the other cases;} \end{cases}$$

$$N_L(E_0, A) = 28.1\exp[-g_1(E_0)](A + 69)^{-1};$$
$$f_L(E,\theta) = g_2(u,k_4)\exp[-u(\theta + k_4\theta^2)];$$
$$\frac{dN_L}{dE}(E_0, E) = (1 - E/E_0)/E_0, \quad i = j; \quad 2/3E_0, \quad i \neq j;$$
$$g_2(u,k_4) = (1 + u^2)[1 + 5.2k_4(2 + u^2)^{-1}]/[1 + \exp(-u\pi)];$$
$$u = E/\tau^2; \quad \tau_2 = 200E_0/(E_0 + 2600);$$
$$k_4 = 1.21E_0[(2000 + E_0)\sqrt{1 + \ln A}]^{-1};$$

r Eq. (3.39):

$$q_c(E,\theta) = q_c(E_0)\exp\left\{-\left[\frac{2000}{\tau_3 k_7}(\sqrt{1 + k_7 E\theta\times 10^{-3}} - 1) + k_4 u_3\theta^2\right]\right\};$$
$$\frac{dN_c}{dE}(E_0, E, A) = \frac{a_c(E_0,A)}{E + \delta_2}\left(1 - \frac{E}{\varepsilon_{ij\max}}\right)^{\gamma}\frac{E_0}{\varepsilon_{ij\max}};$$
$$a_c(E_0, A) = \frac{\varepsilon_c k_6}{E_0\{(\gamma + 1)^{-1} - \delta_2[E_0^{-1}\ln(1 + E_0/\delta_2(\gamma + 1))]\}};$$

$\varepsilon_q - \varepsilon_L$ is the kinetic energy carried off by the cascade particles; ε_q are the kinetic energies carried off by the quasielastic-scattering nucleons and the leading particles, respectively; $\varepsilon_{ij\max}$ is the maximum allowable kinetic energy of the particles of type j; $\varepsilon = E_0 - E^*(E_0, A) - [N_N(E_0, A) - 1]E_c(A) - m_\pi N_\pi(E_0, A) - E_z(E_0, A)$; E^*, E_c, and E_z are the average energies of excitation of the nucleus, of the detachment of a nucleon from the nucleus, and of the disintegration of the nucleus, respectively;

$$\gamma(E_0, A) = 3(0.001E_0)^{0.06}[1 - \exp(-k_2E_0)]; \quad k_2 = 5\times 10^{-4}(1 + A^{1/3});$$
$$k_6 = [1 + \delta_2(\gamma + 1)/3E_0(\delta_2/E_0 + 1.75)]^{-1};$$
$$\delta_2 = 250A^{-1/2}[1 + 2.5E_0(1000 + E_0)^{-1}\exp(-0.02A)];$$
$$N_N(E_0, A) = (1 + \sqrt{A})\exp\{-\xi(A)\exp[-\lambda(A)u]\};$$
$$u = \ln(E_0/3.68); \quad \xi(A) = 0.087A^{2/3} + 4.15; \quad \lambda(A) = 0.72(1 + \ln A)^{-0.4};$$
$$N_\pi(E_0, A) = N_{\pi M}\exp(0.075\sqrt{A-1})g(E_0, A);$$
$$N_{\pi M} = 0.5335(E_0^2 + 2m_NE_0)^{0.125} - 2;$$
$$g(E_0, A) = \exp[-0.25\times 10^6E_0^{-2} - 0.7(A-1)^{1/4}/(1 + 10^{-3}E_0)];$$
$$q_c(E) = \frac{(1 + u_3^2)[1 + 5.2k_4u_3(2 + u_3^2)^{-1}]}{1 + \exp(-u_3\pi)};$$
$$u_3 = E/\tau_3; \quad \tau_3 = 200E_0(E_0 + 560)^{-1};$$
$$k_4 = \begin{cases} 1.21E_0(2000 + E_0)^{-1}(1 + \ln A)^{-0.5}, & j = n,p; \\ 0.3(E_0 - 1000)(E_0 + 1000)^{-1}, & j = \pi; \end{cases}$$
$$k_7 = 0.01\sqrt{E_0\times 10^{-3}}(1 + 0.25\ln A).$$

The fraction η^c_{ij} of the cascade particles [for the particular case of th primary neutrons in Eq. (3.39)] is determined from the relations

$$N_n/N_p = [1 + \exp(-E_0/2000)](A + 1 - Z)Z^{-1};$$
$$N_{\pi^-} = \left(\frac{1}{3}N_{\pi M} + \frac{3 - a_n}{b_n}\right)\frac{N_\pi(E_0, A)}{N_{\pi M}};$$
$$N_{\pi^0} = \left(\frac{1}{3}N_{\pi M} + \frac{2a_n - 1}{b_n}\right)\frac{N_\pi(E_0, A)}{N_{\pi M}};$$
$$N_{\pi^+} = \left(\frac{1}{3}N_{\pi M} - \frac{2 + a_n}{b_n}\right)\frac{N_\pi(E_0, A)}{N_{\pi M}}; \quad b_n = 6(1 + a_n);$$
$$a_n = Z(A - Z)^{-1}[1 - 0.5\exp(-10^{-9}E_0^3)].$$

The distribution of evaporative particles produced as a result of the dec of the excited states of the nuclei is isotropic in the angles. Taking into count the Coulomb potential barrier as a function of the temperature T_0 of t excited nucleus, the energy spectra of nucleons can be approximately scribed by

$$dN_j/dE = N_j(\tilde{E}/T^2)\exp(-\tilde{E}/T), \qquad (3.$$

where N_j is the yield of the evaporative particles of type j,

$$\bar{E} = \begin{cases} E, & j = n; \\ E - V_0/(1 + 0.15T), & j = p, \end{cases}$$

$T = 0.4T_0$, $T_0 = (10E^*/A)^{1/2}$, $V_0 = 1.115A^{-1/3}$, and E^* is the excitation energy of the residual nucleus (see Sec. 6.3).

The total and differential cross sections (mb) of the high-energy elastic and quasi-elastic scattering can be described adequately[85] by the equations for $A > 9$ and $E_0 \gtrsim 5$ GeV:

$$\left.\begin{aligned} \sigma_{el}(A) &= 6.38A^{1.04}; \\ \sigma_{el}(A)/\sigma_{abs}(A) &= 0.13A^{0.37}; \end{aligned}\right\} \tag{3.41}$$

$$\begin{aligned} \frac{d\sigma_{el}}{d\Omega} &= 12.5A^{1.63}\exp(-14.5A^{0.66}|t|) \\ &+ 17.5A^{0.33}\exp(-10|t|), \quad A < 62; \end{aligned} \tag{3.42}$$

$$\begin{aligned} \frac{d\sigma_{el}}{d\Omega} &= 50A^{1.33}\exp(-60A^{0.33}|t|) \\ &+ 20A^{0.40}\exp(-10|t|), \quad A > 62. \end{aligned} \tag{3.43}$$

Here $t = -2p^2(1 - \cos\theta) \simeq -p^2\theta^2$, and p is the particle momentum (GeV/c).

In conclusion, since the phase space d^3p/E is invariant, we can write out the relationship between the invariant cross sections of inclusive processes for different choices of the independent variables:

$$E\frac{d\sigma}{d^3p} = \frac{x'}{\pi}\frac{d\sigma}{dx\,dp_\perp^2} = \frac{E}{p^2}\frac{d\sigma}{dp\,d\Omega} = \frac{1}{p}\frac{d\sigma}{dE\,d\Omega}.$$

Appendix B

YIELD Programs..Listings and Outputs

YTHETA(2).for and CSECT.for

```
      program csectx
      dimension csect(25),zee(25),at(25)
      data csect/ 33., 61., 102., 157., 199.,
     x 231., 265., 292., 347., 421., 440., 566., 637.,
     x 703., 782., 858., 1210., 1290., 1650., 1708., 1770., 1980.,
     x 3*9999./
      data zee/1.,1.,2.,3.,4., 6.,7.,8.,10.,13.,14.,18.,22.,
     x 26.,29.,32.,50.,54.,74.,78.,82.,92.,   3*99./
      data at/1.01,2.01,4.00,6.94,9.01,   12.01,14.01,16.00,20.18,
     x 26.98,28.09,39.95,47.88,    55.85,63.55,72.59,118.69,131.29,
     x 183.85,195.08,207.19,238.03,    3*99999./
c....check a**2/3 vs csect
      do 10 i=1,22
      xxx=0.69
      bb=-.4
c NORMALIZE at Be (Z=4, A=9).....std target material..
      aa=((at(i)+bb)/(at(5)+bb))**xxx
      r=(csect(i)/csect(5))/aa
      write(16,9) i,xxx,bb,zee(i),at(i),aa,csect(i),r
    9 format(1x,'i,x,bb,z,A,A**x,cs,ratio=',i3,3f6.2,2f7.2,f9.2,f7.2)
   10 continue
      call exit
      end
```

See DATA (next page)

i,x,bb,z,A,A**x,cs,ratio=	1	0.69	-0.40	1.00	1.01	0.16	33.00	1.03
i,x,bb,z,A,A**x,cs,ratio=	2	0.69	-0.40	1.00	2.01	0.31	61.00	0.97
i,x,bb,z,A,A**x,cs,ratio=	3	0.69	-0.40	2.00	4.00	0.55	102.00	0.94
i,x,bb,z,A,A**x,cs,ratio=	4	0.69	-0.40	3.00	6.94	0.83	157.00	0.95
i,x,bb,z,A,A**x,cs,ratio=	5	0.69	-0.40	4.00	9.01	1.00	199.00	1.00
i,x,bb,z,A,A**x,cs,ratio=	6	0.69	-0.40	6.00	12.01	1.23	231.00	0.94
i,x,bb,z,A,A**x,cs,ratio=	7	0.69	-0.40	7.00	14.01	1.37	265.00	0.97
i,x,bb,z,A,A**x,cs,ratio=	8	0.69	-0.40	8.00	16.00	1.51	292.00	0.97
i,x,bb,z,A,A**x,cs,ratio=	9	0.69	-0.40	10.00	20.18	1.78	347.00	0.98
i,x,bb,z,A,A**x,cs,ratio=	10	0.69	-0.40	13.00	26.98	2.18	421.00	0.97
i,x,bb,z,A,A**x,cs,ratio=	11	0.69	-0.40	14.00	28.09	2.24	440.00	0.99
i,x,bb,z,A,A**x,cs,ratio=	12	0.69	-0.40	18.00	39.95	2.86	566.00	0.99
i,x,bb,z,A,A**x,cs,ratio=	13	0.69	-0.40	22.00	47.88	3.25	637.00	0.99
i,x,bb,z,A,A**x,cs,ratio=	14	0.69	-0.40	26.00	55.85	3.62	703.00	0.98
i,x,bb,z,A,A**x,cs,ratio=	15	0.69	-0.40	29.00	63.55	3.95	782.00	0.99
i,x,bb,z,A,A**x,cs,ratio=	16	0.69	-0.40	32.00	72.59	4.34	858.00	0.99
i,x,bb,z,A,A**x,cs,ratio=	17	0.69	-0.40	50.00	118.69	6.10	1210.00	1.00
i,x,bb,z,A,A**x,cs,ratio=	18	0.69	-0.40	54.00	131.29	6.54	1290.00	0.99
i,x,bb,z,A,A**x,cs,ratio=	19	0.69	-0.40	74.00	183.85	8.25	1650.00	1.00
i,x,bb,z,A,A**x,cs,ratio=	20	0.69	-0.40	78.00	195.08	8.60	1708.00	1.00
i,x,bb,z,A,A**x,cs,ratio=	21	0.69	-0.40	82.00	207.19	8.97	1770.00	0.99
i,x,bb,z,A,A**x,cs,ratio=	22	0.69	-0.40	92.00	238.03	9.87	1980.00	1.01

$\longrightarrow$ ie $\left(\sigma(A) = \sigma(Be) * \left(\frac{A - 0.40}{9.01 - 0.40} \right)^{0.69} \right)$

$\sigma_A(Be) = 199$ mb (PDG).

```
      program ytheta
CCCC  6-19-90....ADD IN DECAY probability (according to nominal mean energy)
c     dimensions in 'inches'..program converts to meters
      data fmperin/0.0254/
c     parameters for particle yields...1=pi+, 2=pi- from New Russian Xlation
c     "Passage of H.E. Particles thru Matter, AN Kalinovski,etal,AIP,eqn3.26
      dimension c1(9),c2(9),c3(9),c4(9),c5(9),c6(9),fm(9),omeg(9),
     x fmusq(9),bzero(9),gam(9)
      dimension dsdp(100,9),xpr(100),bp(100),fnum(100,9),gnum(100,9)
      dimension decay(100,9),time(9)
c.....proper decay times...as cee*tau IN meters (from PDG 1988)
      data time/2*7.803, 3.709, 6*9.99e+5/
c     units are GeV for fm,omeg,gam (and GeV**-1 for bzero)...)
      data c1/0.25, 0.20, 0.078, 0.080, 5*0./
      data c2/3.1, 4.0, 6.1, 8.6, 5*0./
      data c3/0.88, 1.18, 2.46, 2.30, 5*0./
      data c4/3.0, 3.0, 3.5, 4.2, 5*0./
      data c5/2., 2., 2., 2., 5*0./
      data c6/11.3, 9.8, 8.8, 10.5, 5*0./
      data fm/2*0.1396, 0.4937, 0.9382, 5*0./
      data omeg/1.8778, 2.016, 2.370, 2.815, 5*0./
      data fmusq/0.88, 0.86, 1.2, 1.1, 5*0./
      data bzero/0.10, 0.11, 0.12, 0.12, 5*0./
      data gam/4.0, 3.5, 4.0, 5.0, 5*0./
c
c     formulae 3.26...given as function of "p-perp and x-prime"...to be input
c     where x-prime=(E*/E*max)...ie -1. thru 0. to +1.
      write(3,9)
    9 format(/1x,'**..YTHETA.FOR..DP/P=0.2,DOMEGA= 3 microSR,0.33 tgt')
      write(6,10)
   10 format(1x,
     x 'INPUT theta,delth,del-xpr,Ezero,atnum,leng(ft.)(6F8.3)')
      read(5,11)theta,delth,dxpr,Ezero,atnum,fleng
   11 format(6f8.3)
      srtofS=sqrt(2.0*0.9382*Ezero)
      write(6,12)theta,delth,dxpr,Ezero,srtofS,atnum,fleng
      write(3,12)theta,delth,dxpr,Ezero,srtofS,atnum,fleng
   12 format(1x,'ECHO theta(mr),delth,delxpr,Ezero,srtofS,A='/
     x 10x,6f8.3/10x,'Beam length(ft.)=',f8.1)
c CONVERT fleng to METERs now...
      fleng=fmperin*12.0*fleng
c   LOOP over thetas here...
      do 100 LMN=1,5
      write(3,1111)theta*0.001
 1111 format(/20x,'theta(rad)='f7.4,2x,'************************')
c     loop over pi+,pi- (ie 1,2)   ....and 3=K-, 4=p-
      do 101 i=1,4
c     do xpr values from dxpr UP, but MAX of 100, and NOT xpr=1. either
      nn=1./dxpr
      nn=nn-1
      if(nn.gt.100) nn=100
      xpr(1)=dxpr
      do 102 j=1,nn
c     calculate **pperp** from theta(mr) and xpr(J)...
      pperp=xpr(J)*theta*Ezero*0.001
      bp(J)=pperp
c.............................done...
      bperp=bzero(i)*pperp
      if(pperp.gt.gam(i)) bperp=bzero(i)*gam(i)
      psq=pperp**2
      xperp=2.*pperp/srtofS
      phi=exp(-c4(i)*psq)+c5(i)*exp(-c6(i)*xperp)/((psq+fmusq(i)**2)**4)
      xxx=c1(i)*(atnum**bperp)*((1.-xpr(J))**c2(i))*exp(-c3(i)*xpr(J))*phi
c..........AND SCALE BY Be absorption crossection (199 mb)
      ccsect=((atnum-0.40)/(9.01-0.40))**0.69
      ccsect=ccsect*199.
```

```
      xxx=ccsect*xxx
      dsdp(j,i)=xxx
ccc.....assuming 9 sqin of aperture at 150 feet..d(solid.angle)=3 x 10**-6
ccc.....(3 micro-sterradians)..0.33 Labsorpt Be target..x*exp(-x)=.24...ie 24%
ccc.....incident protons interact...then yield per interact-proton is
ccc.....plab**2 * (dp/p) *ster-rad * inv.sigma(=dsdp(..)), where dp/p=0.2(+-10%)
ccc.....and plab=xpr*(pzero=Ezero-200 GeV,..'MEB')..., and sigma(abs).Be=199 mb.
ccc..... #/int-p = xpr**2 * 0.2 * 3x10**-6 * (Elab)**2 * dsdp(..,..) / 199mb
      fnum(j,i)=(1.2e-4)*xxx*(xpr(J)**2)
c     24 % interact in 0.33 absorption length target
      gnum(j,i)=fnum(j,i)*0.24
c and decays......
      plong=xpr(J)*Ezero
      eta=plong/fm(i)
      decay(J,i)=gnum(j,i)*exp(-fleng/(eta*time(i)))
      if(j.ne.nn) xpr(j+1)=xpr(j)+dxpr
  102 continue
  101 continue
      write(3,222)(m,xpr(m),bp(m),(dsdp(m,K),K=1,4),(fnum(m,K),K=1,4),
     x (gnum(m,K),K=1,4),(decay(m,K),K=1,4),m=1,nn)
  222 format(1x,'m,x,Pt,dsdp(+,-,K-,p-)=',i2,f6.3,f5.2,f8.3,
     x 3f10.3/
     x 10x,'#/int-p(+,-,..)',14x,4e10.3/10x,'#/incident-p..',15x,
     x 4e10.3/
     x 10x,'# at detector/inc.p',10x,4e10.3)
      theta=theta+delth
  100 continue
      call exit
      end
```

correction for E scaling
* (Ezero/200.) **2
done!

```
**..YTHETA.FOR..DP/P=0.2,DOMEGA= 3 microSR,0.33 tgt
ECHO theta(mr),delth,delxpr,Ezero,srtofS,A=
          2.500   1.000   0.050 200.000  19.372   9.000
        Beam length(ft.)=   720.0

                  theta(rad)= 0.0025  ************************
n,x,Pt,dsdp(+,-,K-,p-)= 1 0.050 0.03 260.391   230.198    14.657    17.479
        #/int-p(+,-,..)                0.781E-04 0.691E-04 0.440E-05 0.524E-05
        #/incident-p..                 0.187E-04 0.166E-04 0.106E-05 0.126E-05
        # at detector/inc.p            0.127E-04 0.112E-04 0.569E-07 0.126E-05
m,x,Pt,dsdp(+,-,K-,p-)= 2 0.100 0.05 204.897   170.429     9.258     9.657
        #/int-p(+,-,..)                0.246E-03 0.205E-03 0.111E-04 0.116E-04
        #/incident-p..                 0.590E-04 0.491E-04 0.267E-05 0.278E-05
        # at detector/inc.p            0.485E-04 0.403E-04 0.619E-06 0.278E-05
m,x,Pt,dsdp(+,-,K-,p-)= 3 0.150 0.08 158.767   123.862     5.716     5.172
        #/int-p(+,-,..)                0.429E-03 0.334E-03 0.154E-04 0.140E-04
        #/incident-p..                 0.103E-03 0.803E-04 0.370E-05 0.335E-05
        # at detector/inc.p            0.903E-04 0.704E-04 0.140E-05 0.335E-05
m,x,Pt,dsdp(+,-,K-,p-)= 4 0.200 0.10 121.016    88.242     3.441     2.676
        #/int-p(+,-,..)                0.581E-03 0.424E-03 0.165E-04 0.128E-04
        #/incident-p..                 0.139E-03 0.102E-03 0.396E-05 0.308E-05
        # at detector/inc.p            0.126E-03 0.922E-04 0.191E-05 0.308E-05
m,x,Pt,dsdp(+,-,K-,p-)= 5 0.250 0.13  90.624    61.523     2.015     1.333
        #/int-p(+,-,..)                0.680E-03 0.461E-03 0.151E-04 0.100E-04
        #/incident-p..                 0.163E-03 0.111E-03 0.363E-05 0.240E-05
        # at detector/inc.p            0.151E-03 0.102E-03 0.202E-05 0.240E-05
m,x,Pt,dsdp(+,-,K-,p-)= 6 0.300 0.15  66.572    41.896     1.143     0.636
        #/int-p(+,-,..)                0.719E-03 0.452E-03 0.123E-04 0.687E-05
        #/incident-p..                 0.173E-03 0.109E-03 0.296E-05 0.165E-05
        # at detector/inc.p            0.162E-03 0.102E-03 0.182E-05 0.165E-05
m,x,Pt,dsdp(+,-,K-,p-)= 7 0.350 0.18  47.884    27.797     0.626     0.289
        #/int-p(+,-,..)                0.704E-03 0.409E-03 0.921E-05 0.425E-05
        #/incident-p..                 0.169E-03 0.981E-04 0.221E-05 0.102E-05
        # at detector/inc.p            0.160E-03 0.927E-04 0.146E-05 0.102E-05
m,x,Pt,dsdp(+,-,K-,p-)= 8 0.400 0.20  33.644    17.914     0.330     0.124
        #/int-p(+,-,..)                0.646E-03 0.344E-03 0.633E-05 0.239E-05
        #/incident-p..                 0.155E-03 0.825E-04 0.152E-05 0.573E-06
        # at detector/inc.p            0.148E-03 0.786E-04 0.105E-05 0.573E-06
m,x,Pt,dsdp(+,-,K-,p-)= 9 0.450 0.23  23.023    11.170     0.166     0.050
        #/int-p(+,-,..)                0.559E-03 0.271E-03 0.403E-05 0.122E-05
        #/incident-p..                 0.134E-03 0.651E-04 0.966E-06 0.292E-06
        # at detector/inc.p            0.129E-03 0.624E-04 0.698E-06 0.292E-06
m,x,Pt,dsdp(+,-,K-,p-)=10 0.500 0.25  15.284     6.705     0.079     0.019
        #/int-p(+,-,..)                0.459E-03 0.201E-03 0.236E-05 0.562E-06
        #/incident-p..                 0.110E-03 0.483E-04 0.567E-06 0.135E-06
        # at detector/inc.p            0.106E-03 0.464E-04 0.424E-06 0.135E-06
m,x,Pt,dsdp(+,-,K-,p-)=11 0.550 0.28   9.793     3.848     0.035     0.006
        #/int-p(+,-,..)                0.355E-03 0.140E-03 0.127E-05 0.232E-06
        #/incident-p..                 0.853E-04 0.335E-04 0.306E-06 0.557E-07
        # at detector/inc.p            0.823E-04 0.323E-04 0.235E-06 0.557E-07
m,x,Pt,dsdp(+,-,K-,p-)=12 0.600 0.30   6.013     2.092     0.014     0.002
        #/int-p(+,-,..)                0.260E-03 0.904E-04 0.624E-06 0.843E-07
        #/incident-p..                 0.623E-04 0.217E-04 0.150E-06 0.202E-07
        # at detector/inc.p            0.603E-04 0.210E-04 0.117E-06 0.202E-07
m,x,Pt,dsdp(+,-,K-,p-)=13 0.650 0.33   3.502     1.064     0.005     0.001
        #/int-p(+,-,..)                0.178E-03 0.539E-04 0.273E-06 0.263E-07
        #/incident-p..                 0.426E-04 0.129E-04 0.655E-07 0.630E-08
        # at detector/inc.p            0.413E-04 0.126E-04 0.523E-07 0.630E-08
m,x,Pt,dsdp(+,-,K-,p-)=14 0.700 0.35   1.907     0.496     0.002     0.000
        #/int-p(+,-,..)                0.112E-03 0.292E-04 0.103E-06 0.674E-08
        #/incident-p..                 0.269E-04 0.700E-05 0.248E-07 0.162E-08
        # at detector/inc.p            0.262E-04 0.681E-05 0.202E-07 0.162E-08
m,x,Pt,dsdp(+,-,K-,p-)=15 0.750 0.38   0.948     0.206     0.000     0.000
        #/int-p(+,-,..)                0.640E-04 0.139E-04 0.326E-07 0.134E-08
        #/incident-p..                 0.154E-04 0.334E-05 0.782E-08 0.321E-09
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          # at detector/inc.p              0.150E-04 0.325E-05 0.643E-08 0.321E-09
m,x,Pt,dsdp(+,-,K-,p-)=16 0.800 0.40       0.414     0.072     0.000     0.000
          #/int-p(+,-,..)                  0.318E-04 0.556E-05 0.789E-08 0.185E-09
          #/incident-p..                   0.763E-05 0.134E-05 0.189E-08 0.443E-10
          # at detector/inc.p              0.744E-05 0.130E-05 0.158E-08 0.443E-10
m,x,Pt,dsdp(+,-,K-,p-)=17 0.850 0.43       0.148     0.020     0.000     0.000
          #/int-p(+,-,..)                  0.128E-04 0.170E-05 0.128E-08 0.144E-10
          #/incident-p..                   0.307E-05 0.408E-06 0.306E-09 0.347E-11
          # at detector/inc.p              0.300E-05 0.399E-06 0.258E-09 0.347E-11
m,x,Pt,dsdp(+,-,K-,p-)=18 0.900 0.45       0.036     0.003     0.000     0.000
          #/int-p(+,-,..)                  0.354E-05 0.321E-06 0.994E-10 0.406E-12
          #/incident-p..                   0.849E-06 0.771E-07 0.239E-10 0.974E-13
          # at detector/inc.p              0.831E-06 0.754E-07 0.203E-10 0.974E-13
m,x,Pt,dsdp(+,-,K-,p-)=19 0.950 0.48       0.004     0.000     0.000     0.000
          #/int-p(+,-,..)                  0.398E-06 0.190E-07 0.133E-11 0.951E-15
          #/incident-p..                   0.954E-07 0.457E-08 0.318E-12 0.228E-15
          # at detector/inc.p              0.935E-07 0.447E-08 0.273E-12 0.228E-15

                    theta(rad)= 0.0035  ************************
m,x,Pt,dsdp(+,-,K-,p-)= 1 0.050 0.04 257.665   228.046    14.625    17.395
          #/int-p(+,-,..)                  0.773E-04 0.684E-04 0.439E-05 0.522E-05
          #/incident-p..                   0.186E-04 0.164E-04 0.105E-05 0.125E-05
          # at detector/inc.p              0.125E-04 0.111E-04 0.567E-07 0.125E-05
m,x,Pt,dsdp(+,-,K-,p-)= 2 0.100 0.07 199.510   166.266     9.183     9.524
          #/int-p(+,-,..)                  0.239E-03 0.200E-03 0.110E-04 0.114E-04
          #/incident-p..                   0.575E-04 0.479E-04 0.264E-05 0.274E-05
          # at detector/inc.p              0.472E-04 0.393E-04 0.614E-06 0.274E-05
m,x,Pt,dsdp(+,-,K-,p-)= 3 0.150 0.11 151.301   118.314     5.614     5.032
          #/int-p(+,-,..)                  0.409E-03 0.319E-03 0.152E-04 0.136E-04
          #/incident-p..                   0.980E-04 0.767E-04 0.364E-05 0.326E-05
          # at detector/inc.p              0.860E-04 0.673E-04 0.137E-05 0.326E-05
m,x,Pt,dsdp(+,-,K-,p-)= 4 0.200 0.14 112.291    82.080     3.334     2.558
          #/int-p(+,-,..)                  0.539E-03 0.394E-03 0.160E-04 0.123E-04
          #/incident-p..                   0.129E-03 0.946E-04 0.384E-05 0.295E-05
          # at detector/inc.p              0.117E-03 0.857E-04 0.185E-05 0.295E-05
m,x,Pt,dsdp(+,-,K-,p-)= 5 0.250 0.18  81.483    55.441     1.918     1.246
          #/int-p(+,-,..)                  0.611E-03 0.416E-03 0.144E-04 0.934E-05
          #/incident-p..                   0.147E-03 0.998E-04 0.345E-05 0.224E-05
          # at detector/inc.p              0.136E-03 0.923E-04 0.192E-05 0.224E-05
m,x,Pt,dsdp(+,-,K-,p-)= 6 0.300 0.21  57.745    36.403     1.066     0.579
          #/int-p(+,-,..)                  0.624E-03 0.393E-03 0.115E-04 0.625E-05
          #/incident-p..                   0.150E-03 0.944E-04 0.276E-05 0.150E-05
          # at detector/inc.p              0.140E-03 0.884E-04 0.170E-05 0.150E-05
m,x,Pt,dsdp(+,-,K-,p-)= 7 0.350 0.25  39.907    23.189     0.569     0.255
          #/int-p(+,-,..)                  0.587E-03 0.341E-03 0.837E-05 0.375E-05
          #/incident-p..                   0.141E-03 0.818E-04 0.201E-05 0.900E-06
          # at detector/inc.p              0.133E-03 0.773E-04 0.132E-05 0.900E-06
m,x,Pt,dsdp(+,-,K-,p-)= 8 0.400 0.28  26.844    14.294     0.291     0.106
          #/int-p(+,-,..)                  0.515E-03 0.274E-03 0.559E-05 0.203E-05
          #/incident-p..                   0.124E-03 0.659E-04 0.134E-05 0.488E-06
          # at detector/inc.p              0.118E-03 0.627E-04 0.931E-06 0.488E-06
m,x,Pt,dsdp(+,-,K-,p-)= 9 0.450 0.32  17.531     8.497     0.142     0.041
          #/int-p(+,-,..)                  0.426E-03 0.206E-03 0.344E-05 0.998E-06
          #/incident-p..                   0.102E-03 0.496E-04 0.825E-06 0.239E-06
          # at detector/inc.p              0.979E-04 0.474E-04 0.597E-06 0.239E-06
m,x,Pt,dsdp(+,-,K-,p-)=10 0.500 0.35  11.077     4.848     0.065     0.015
          #/int-p(+,-,..)                  0.332E-03 0.145E-03 0.195E-05 0.441E-06
          #/incident-p..                   0.798E-04 0.349E-04 0.467E-06 0.106E-06
          # at detector/inc.p              0.767E-04 0.336E-04 0.349E-06 0.106E-06
m,x,Pt,dsdp(+,-,K-,p-)=11 0.550 0.39   6.739     2.639     0.028     0.005
          #/int-p(+,-,..)                  0.245E-03 0.958E-04 0.101E-05 0.174E-06
          #/incident-p..                   0.587E-04 0.230E-04 0.242E-06 0.416E-07
          # at detector/inc.p              0.567E-04 0.222E-04 0.186E-06 0.416E-07
m,x,Pt,dsdp(+,-,K-,p-)=12 0.600 0.42   3.921     1.358     0.011     0.001
          #/int-p(+,-,..)                  0.169E-03 0.587E-04 0.473E-06 0.599E-07
          #/incident-p..                   0.407E-04 0.141E-04 0.113E-06 0.144E-07
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          # at detector/inc.p              0.393E-04 0.136E-04 0.889E-07 0.144E-07
m,x,Pt,dsdp(+,-,K-,p-)=13 0.650 0.46       2.161     0.652     0.004     0.000
          #/int-p(+,-,..)                  0.110E-03 0.331E-04 0.197E-06 0.177E-07
          #/incident-p..                   0.263E-04 0.794E-05 0.473E-07 0.424E-08
          # at detector/inc.p              0.255E-04 0.770E-05 0.378E-07 0.424E-08
m,x,Pt,dsdp(+,-,K-,p-)=14 0.700 0.49       1.111     0.287     0.001     0.000
          #/int-p(+,-,..)                  0.653E-04 0.169E-04 0.710E-07 0.428E-08
          #/incident-p..                   0.157E-04 0.405E-05 0.170E-07 0.103E-08
          # at detector/inc.p              0.152E-04 0.394E-05 0.138E-07 0.103E-08
m,x,Pt,dsdp(+,-,K-,p-)=15 0.750 0.53       0.521     0.112     0.000     0.000
          #/int-p(+,-,..)                  0.352E-04 0.759E-05 0.212E-07 0.798E-09
          #/incident-p..                   0.845E-05 0.182E-05 0.508E-08 0.191E-09
          # at detector/inc.p              0.823E-05 0.177E-05 0.418E-08 0.191E-09
m,x,Pt,dsdp(+,-,K-,p-)=16 0.800 0.56       0.215     0.037     0.000     0.000
          #/int-p(+,-,..)                  0.165E-04 0.286E-05 0.484E-08 0.103E-09
          #/incident-p..                   0.395E-05 0.686E-06 0.116E-08 0.247E-10
          # at detector/inc.p              0.386E-05 0.669E-06 0.969E-09 0.247E-10
m,x,Pt,dsdp(+,-,K-,p-)=17 0.850 0.60       0.072     0.009     0.000     0.000
          #/int-p(+,-,..)                  0.624E-05 0.822E-06 0.736E-09 0.753E-11
          #/incident-p..                   0.150E-05 0.197E-06 0.177E-09 0.181E-11
          # at detector/inc.p              0.146E-05 0.193E-06 0.149E-09 0.181E-11
m,x,Pt,dsdp(+,-,K-,p-)=18 0.900 0.63       0.017     0.002     0.000     0.000
          #/int-p(+,-,..)                  0.162E-05 0.146E-06 0.538E-10 0.197E-12
          #/incident-p..                   0.390E-06 0.350E-07 0.129E-10 0.473E-13
          # at detector/inc.p              0.381E-06 0.343E-07 0.110E-10 0.473E-13
m,x,Pt,dsdp(+,-,K-,p-)=19 0.950 0.67       0.002     0.000     0.000     0.000
          #/int-p(+,-,..)                  0.172E-06 0.812E-08 0.671E-12 0.428E-15
          #/incident-p..                   0.412E-07 0.195E-08 0.161E-12 0.103E-15
          # at detector/inc.p              0.403E-07 0.191E-08 0.138E-12 0.103E-15

                    theta(rad)= 0.0045  *************************
m,x,Pt,dsdp(+,-,K-,p-)= 1 0.050 0.05 254.728   225.689    14.584    17.300
          #/int-p(+,-,..)                  0.764E-04 0.677E-04 0.438E-05 0.519E-05
          #/incident-p..                   0.183E-04 0.162E-04 0.105E-05 0.125E-05
          # at detector/inc.p              0.124E-04 0.110E-04 0.566E-07 0.125E-05
m,x,Pt,dsdp(+,-,K-,p-)= 2 0.100 0.09 193.554   161.574     9.085     9.365
          #/int-p(+,-,..)                  0.232E-03 0.194E-03 0.109E-04 0.112E-04
          #/incident-p..                   0.557E-04 0.465E-04 0.262E-05 0.270E-05
          # at detector/inc.p              0.458E-04 0.382E-04 0.607E-06 0.270E-05
m,x,Pt,dsdp(+,-,K-,p-)= 3 0.150 0.14 143.042   112.061     5.482     4.864
          #/int-p(+,-,..)                  0.386E-03 0.303E-03 0.148E-04 0.131E-04
          #/incident-p..                   0.927E-04 0.726E-04 0.355E-05 0.315E-05
          # at detector/inc.p              0.813E-04 0.637E-04 0.134E-05 0.315E-05
m,x,Pt,dsdp(+,-,K-,p-)= 4 0.200 0.18 102.791    75.254     3.197     2.416
          #/int-p(+,-,..)                  0.493E-03 0.361E-03 0.153E-04 0.116E-04
          #/incident-p..                   0.118E-03 0.867E-04 0.368E-05 0.278E-05
          # at detector/inc.p              0.107E-03 0.786E-04 0.177E-05 0.278E-05
m,x,Pt,dsdp(+,-,K-,p-)= 5 0.250 0.23  71.806    48.904     1.797     1.143
          #/int-p(+,-,..)                  0.539E-03 0.367E-03 0.135E-04 0.858E-05
          #/incident-p..                   0.129E-03 0.880E-04 0.323E-05 0.206E-05
          # at detector/inc.p              0.119E-03 0.814E-04 0.180E-05 0.206E-05
m,x,Pt,dsdp(+,-,K-,p-)= 6 0.300 0.27  48.744    30.730     0.970     0.513
          #/int-p(+,-,..)                  0.526E-03 0.332E-03 0.105E-04 0.554E-05
          #/incident-p..                   0.126E-03 0.797E-04 0.252E-05 0.133E-05
          # at detector/inc.p              0.118E-03 0.746E-04 0.155E-05 0.133E-05
m,x,Pt,dsdp(+,-,K-,p-)= 7 0.350 0.32  32.132    18.651     0.501     0.217
          #/int-p(+,-,..)                  0.472E-03 0.274E-03 0.737E-05 0.320E-05
          #/incident-p..                   0.113E-03 0.658E-04 0.177E-05 0.767E-06
          # at detector/inc.p              0.107E-03 0.622E-04 0.117E-05 0.767E-06
m,x,Pt,dsdp(+,-,K-,p-)= 8 0.400 0.36  20.545    10.914     0.247     0.086
          #/int-p(+,-,..)                  0.394E-03 0.210E-03 0.474E-05 0.166E-05
          #/incident-p..                   0.947E-04 0.503E-04 0.114E-05 0.397E-06
          # at detector/inc.p              0.901E-04 0.479E-04 0.789E-06 0.397E-06
m,x,Pt,dsdp(+,-,K-,p-)= 9 0.450 0.41  12.718     6.142     0.115     0.032
          #/int-p(+,-,..)                  0.309E-03 0.149E-03 0.279E-05 0.772E-06
          #/incident-p..                   0.742E-04 0.358E-04 0.670E-06 0.185E-06
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          # at detector/inc.p              0.710E-04 0.343E-04 0.484E-06 0.185E-06
m,x,Pt,dsdp(+,-,K-,p-)=10 0.500 0.45       7.600     3.310     0.050     0.011
          #/int-p(+,-,..)                  0.228E-03 0.993E-04 0.151E-05 0.323E-06
          #/incident-p..                   0.547E-04 0.238E-04 0.362E-06 0.774E-07
          # at detector/inc.p              0.526E-04 0.229E-04 0.270E-06 0.774E-07
m,x,Pt,dsdp(+,-,K-,p-)=11 0.550 0.50       4.365     1.699     0.020     0.003
          #/int-p(+,-,..)                  0.158E-03 0.617E-04 0.740E-06 0.120E-06
          #/incident-p..                   0.380E-04 0.148E-04 0.178E-06 0.287E-07
          # at detector/inc.p              0.367E-04 0.143E-04 0.136E-06 0.287E-07
m,x,Pt,dsdp(+,-,K-,p-)=12 0.600 0.54       2.394     0.824     0.008     0.001
          #/int-p(+,-,..)                  0.103E-03 0.356E-04 0.328E-06 0.387E-07
          #/incident-p..                   0.248E-04 0.854E-05 0.786E-07 0.928E-08
          # at detector/inc.p              0.240E-04 0.826E-05 0.617E-07 0.928E-08
m,x,Pt,dsdp(+,-,K-,p-)=13 0.650 0.59       1.242     0.372     0.003     0.000
          #/int-p(+,-,..)                  0.630E-04 0.189E-04 0.128E-06 0.106E-07
          #/incident-p..                   0.151E-04 0.453E-05 0.308E-07 0.255E-08
          # at detector/inc.p              0.147E-04 0.439E-05 0.246E-07 0.255E-08
m,x,Pt,dsdp(+,-,K-,p-)=14 0.700 0.63       0.600     0.154     0.001     0.000
          #/int-p(+,-,..)                  0.353E-04 0.906E-05 0.433E-07 0.239E-08
          #/incident-p..                   0.847E-05 0.217E-05 0.104E-07 0.574E-09
          # at detector/inc.p              0.824E-05 0.211E-05 0.844E-08 0.574E-09
m,x,Pt,dsdp(+,-,K-,p-)=15 0.750 0.68       0.264     0.057     0.000     0.000
          #/int-p(+,-,..)                  0.179E-04 0.382E-05 0.121E-07 0.414E-09
          #/incident-p..                   0.428E-05 0.917E-06 0.289E-08 0.993E-10
          # at detector/inc.p              0.417E-05 0.893E-06 0.238E-08 0.993E-10
m,x,Pt,dsdp(+,-,K-,p-)=16 0.800 0.72       0.102     0.018     0.000     0.000
          #/int-p(+,-,..)                  0.784E-05 0.135E-05 0.256E-08 0.494E-10
          #/incident-p..                   0.188E-05 0.324E-06 0.615E-09 0.119E-10
          # at detector/inc.p              0.184E-05 0.316E-06 0.512E-09 0.119E-10
m,x,Pt,dsdp(+,-,K-,p-)=17 0.850 0.77       0.032     0.004     0.000     0.000
          #/int-p(+,-,..)                  0.278E-05 0.364E-06 0.361E-09 0.333E-11
          #/incident-p..                   0.667E-06 0.873E-07 0.866E-10 0.798E-12
          # at detector/inc.p              0.652E-06 0.853E-07 0.729E-10 0.798E-12
m,x,Pt,dsdp(+,-,K-,p-)=18 0.900 0.81       0.007     0.001     0.000     0.000
          #/int-p(+,-,..)                  0.676E-06 0.605E-07 0.243E-10 0.802E-13
          #/incident-p..                   0.162E-06 0.145E-07 0.584E-11 0.192E-13
          # at detector/inc.p              0.159E-06 0.142E-07 0.497E-11 0.192E-13
m,x,Pt,dsdp(+,-,K-,p-)=19 0.950 0.86       0.001     0.000     0.000     0.000
          #/int-p(+,-,..)                  0.666E-07 0.315E-08 0.280E-12 0.161E-15
          #/incident-p..                   0.160E-07 0.755E-09 0.671E-13 0.385E-16
          # at detector/inc.p              0.156E-07 0.740E-09 0.576E-13 0.385E-16

                    theta(rad)= 0.0055  ************************
m,x,Pt,dsdp(+,-,K-,p-)= 1 0.050 0.06 251.590   223.135    14.534    17.192
          #/int-p(+,-,..)                  0.755E-04 0.669E-04 0.436E-05 0.516E-05
          #/incident-p..                   0.181E-04 0.161E-04 0.105E-05 0.124E-05
          # at detector/inc.p              0.122E-04 0.108E-04 0.564E-07 0.124E-05
m,x,Pt,dsdp(+,-,K-,p-)= 2 0.100 0.11 187.102   156.415     8.965     9.181
          #/int-p(+,-,..)                  0.225E-03 0.188E-03 0.108E-04 0.110E-04
          #/incident-p..                   0.539E-04 0.450E-04 0.258E-05 0.264E-05
          # at detector/inc.p              0.443E-04 0.370E-04 0.599E-06 0.264E-05
m,x,Pt,dsdp(+,-,K-,p-)= 3 0.150 0.17 134.199   105.274     5.322     4.670
          #/int-p(+,-,..)                  0.362E-03 0.284E-03 0.144E-04 0.126E-04
          #/incident-p..                   0.870E-04 0.682E-04 0.345E-05 0.303E-05
          # at detector/inc.p              0.763E-04 0.598E-04 0.130E-05 0.303E-05
m,x,Pt,dsdp(+,-,K-,p-)= 4 0.200 0.22  92.901    68.065     3.034     2.256
          #/int-p(+,-,..)                  0.446E-03 0.327E-03 0.146E-04 0.108E-04
          #/incident-p..                   0.107E-03 0.784E-04 0.350E-05 0.260E-05
          # at detector/inc.p              0.970E-04 0.711E-04 0.168E-05 0.260E-05
m,x,Pt,dsdp(+,-,K-,p-)= 5 0.250 0.28  62.129    42.305     1.657     1.031
          #/int-p(+,-,..)                  0.466E-03 0.317E-03 0.124E-04 0.773E-05
          #/incident-p..                   0.112E-03 0.761E-04 0.298E-05 0.186E-05
          # at detector/inc.p              0.103E-03 0.704E-04 0.166E-05 0.186E-05
m,x,Pt,dsdp(+,-,K-,p-)= 6 0.300 0.33  40.172    25.291     0.864     0.444
          #/int-p(+,-,..)                  0.434E-03 0.273E-03 0.933E-05 0.479E-05
          #/incident-p..                   0.104E-03 0.656E-04 0.224E-05 0.115E-05
```

```
          # at detector/inc.p            0.975E-04 0.614E-04 0.138E-05 0.115E-05
m,x,Pt,dsdp(+,-,K-,p-)= 7 0.350 0.39  25.125    14.545     0.428     0.179
          #/int-p(+,-,..)               0.369E-03 0.214E-03 0.629E-05 0.263E-05
          #/incident-p..                0.886E-04 0.513E-04 0.151E-05 0.631E-06
          # at detector/inc.p            0.838E-04 0.485E-04 0.995E-06 0.631E-06
m,x,Pt,dsdp(+,-,K-,p-)= 8 0.400 0.44  15.197     8.042     0.201     0.067
          #/int-p(+,-,..)               0.292E-03 0.154E-03 0.386E-05 0.129E-05
          #/incident-p..                0.700E-04 0.371E-04 0.926E-06 0.310E-06
          # at detector/inc.p            0.667E-04 0.353E-04 0.643E-06 0.310E-06
m,x,Pt,dsdp(+,-,K-,p-)= 9 0.450 0.50   8.879     4.266     0.089     0.023
          #/int-p(+,-,..)               0.216E-03 0.104E-03 0.216E-05 0.566E-06
          #/incident-p..                0.518E-04 0.249E-04 0.517E-06 0.136E-06
          # at detector/inc.p            0.496E-04 0.238E-04 0.374E-06 0.136E-06
m,x,Pt,dsdp(+,-,K-,p-)=10 0.500 0.55   4.999     2.165     0.037     0.007
          #/int-p(+,-,..)               0.150E-03 0.649E-04 0.110E-05 0.221E-06
          #/incident-p..                0.360E-04 0.156E-04 0.263E-06 0.531E-07
          # at detector/inc.p            0.346E-04 0.150E-04 0.197E-06 0.531E-07
m,x,Pt,dsdp(+,-,K-,p-)=11 0.550 0.61   2.700     1.045     0.014     0.002
          #/int-p(+,-,..)               0.980E-04 0.379E-04 0.505E-06 0.763E-07
          #/incident-p..                0.235E-04 0.910E-05 0.121E-06 0.183E-07
          # at detector/inc.p            0.227E-04 0.878E-05 0.930E-07 0.183E-07
m,x,Pt,dsdp(+,-,K-,p-)=12 0.600 0.66   1.391     0.476     0.005     0.001
          #/int-p(+,-,..)               0.601E-04 0.205E-04 0.209E-06 0.229E-07
          #/incident-p..                0.144E-04 0.493E-05 0.501E-07 0.549E-08
          # at detector/inc.p            0.140E-04 0.477E-05 0.393E-07 0.549E-08
m,x,Pt,dsdp(+,-,K-,p-)=13 0.650 0.72   0.676     0.202     0.001     0.000
          #/int-p(+,-,..)               0.343E-04 0.102E-04 0.759E-07 0.581E-08
          #/incident-p..                0.823E-05 0.245E-05 0.182E-07 0.139E-08
          # at detector/inc.p            0.798E-05 0.238E-05 0.146E-07 0.139E-08
m,x,Pt,dsdp(+,-,K-,p-)=14 0.700 0.77   0.306     0.078     0.000     0.000
          #/int-p(+,-,..)               0.180E-04 0.459E-05 0.237E-07 0.120E-08
          #/incident-p..                0.432E-05 0.110E-05 0.569E-08 0.289E-09
          # at detector/inc.p            0.420E-05 0.107E-05 0.462E-08 0.289E-09
m,x,Pt,dsdp(+,-,K-,p-)=15 0.750 0.83   0.126     0.027     0.000     0.000
          #/int-p(+,-,..)               0.849E-05 0.181E-05 0.608E-08 0.192E-09
          #/incident-p..                0.204E-05 0.435E-06 0.146E-08 0.460E-10
          # at detector/inc.p            0.198E-05 0.424E-06 0.120E-08 0.460E-10
m,x,Pt,dsdp(+,-,K-,p-)=16 0.800 0.88   0.045     0.008     0.000     0.000
          #/int-p(+,-,..)               0.347E-05 0.598E-06 0.119E-08 0.211E-10
          #/incident-p..                0.833E-06 0.143E-06 0.285E-09 0.506E-11
          # at detector/inc.p            0.813E-06 0.140E-06 0.238E-09 0.506E-11
m,x,Pt,dsdp(+,-,K-,p-)=17 0.850 0.94   0.013     0.002     0.000     0.000
          #/int-p(+,-,..)               0.114E-05 0.150E-06 0.154E-09 0.131E-11
          #/incident-p..                0.275E-06 0.360E-07 0.369E-10 0.315E-12
          # at detector/inc.p            0.268E-06 0.352E-07 0.311E-10 0.315E-12
m,x,Pt,dsdp(+,-,K-,p-)=18 0.900 0.99   0.003     0.000     0.000     0.000
          #/int-p(+,-,..)               0.258E-06 0.232E-07 0.953E-11 0.293E-13
          #/incident-p..                0.619E-07 0.558E-08 0.229E-11 0.703E-14
          # at detector/inc.p            0.606E-07 0.546E-08 0.194E-11 0.703E-14
m,x,Pt,dsdp(+,-,K-,p-)=19 0.950 1.05   0.000     0.000     0.000     0.000
          #/int-p(+,-,..)               0.235E-07 0.112E-08 0.101E-12 0.547E-16
          #/incident-p..                0.564E-08 0.270E-09 0.242E-13 0.131E-16
          # at detector/inc.p            0.553E-08 0.264E-09 0.207E-13 0.131E-16

                theta(rad)= 0.0065  ************************
m,x,Pt,dsdp(+,-,K-,p-)= 1 0.050 0.07 248.260   220.393    14.475    17.073
          #/int-p(+,-,..)               0.745E-04 0.661E-04 0.434E-05 0.512E-05
          #/incident-p..                0.179E-04 0.159E-04 0.104E-05 0.123E-05
          # at detector/inc.p            0.121E-04 0.107E-04 0.561E-07 0.123E-05
m,x,Pt,dsdp(+,-,K-,p-)= 2 0.100 0.13 180.229   150.853     8.824     8.975
          #/int-p(+,-,..)               0.216E-03 0.181E-03 0.106E-04 0.108E-04
          #/incident-p..                0.519E-04 0.434E-04 0.254E-05 0.258E-05
          # at detector/inc.p            0.427E-04 0.357E-04 0.590E-06 0.258E-05
m,x,Pt,dsdp(+,-,K-,p-)= 3 0.150 0.20 124.979    98.126     5.138     4.455
          #/int-p(+,-,..)               0.337E-03 0.265E-03 0.139E-04 0.120E-04
          #/incident-p..                0.810E-04 0.636E-04 0.333E-05 0.289E-05
```

```
        # at detector/inc.p                0.711E-04 0.558E-04 0.126E-05 0.289E-05
m,x,Pt,dsdp(+,-,K-,p-)= 4 0.200 0.26  82.974    60.793      2.851     2.082
        #/int-p(+,-,..)                  0.398E-03 0.292E-03 0.137E-04 0.999E-05
        #/incident-p..                   0.956E-04 0.700E-04 0.328E-05 0.240E-05
        # at detector/inc.p              0.866E-04 0.635E-04 0.158E-05 0.240E-05
m,x,Pt,dsdp(+,-,K-,p-)= 5 0.250 0.33  52.879    35.965      1.504     0.913
        #/int-p(+,-,..)                  0.397E-03 0.270E-03 0.113E-04 0.685E-05
        #/incident-p..                   0.952E-04 0.647E-04 0.271E-05 0.164E-05
        # at detector/inc.p              0.880E-04 0.598E-04 0.151E-05 0.164E-05
m,x,Pt,dsdp(+,-,K-,p-)= 6 0.300 0.39  32.429    20.367      0.752     0.374
        #/int-p(+,-,..)                  0.350E-03 0.220E-03 0.812E-05 0.404E-05
        #/incident-p..                   0.841E-04 0.528E-04 0.195E-05 0.969E-06
        # at detector/inc.p              0.787E-04 0.494E-04 0.120E-05 0.969E-06
m,x,Pt,dsdp(+,-,K-,p-)= 7 0.350 0.46  19.172    11.058      0.355     0.142
        #/int-p(+,-,..)                  0.282E-03 0.163E-03 0.521E-05 0.209E-05
        #/incident-p..                   0.676E-04 0.390E-04 0.125E-05 0.503E-06
        # at detector/inc.p              0.639E-04 0.369E-04 0.825E-06 0.503E-06
m,x,Pt,dsdp(+,-,K-,p-)= 8 0.400 0.52  10.934     5.760      0.157     0.050
        #/int-p(+,-,..)                  0.210E-03 0.111E-03 0.302E-05 0.963E-06
        #/incident-p..                   0.504E-04 0.265E-04 0.725E-06 0.231E-06
        # at detector/inc.p              0.480E-04 0.253E-04 0.503E-06 0.231E-06
m,x,Pt,dsdp(+,-,K-,p-)= 9 0.450 0.59   6.012     2.874      0.065     0.016
        #/int-p(+,-,..)                  0.146E-03 0.698E-04 0.159E-05 0.394E-06
        #/incident-p..                   0.351E-04 0.168E-04 0.381E-06 0.945E-07
        # at detector/inc.p              0.336E-04 0.160E-04 0.275E-06 0.945E-07
m,x,Pt,dsdp(+,-,K-,p-)=10 0.500 0.65   3.179     1.370      0.025     0.005
        #/int-p(+,-,..)                  0.954E-04 0.411E-04 0.753E-06 0.143E-06
        #/incident-p..                   0.229E-04 0.986E-05 0.181E-06 0.343E-07
        # at detector/inc.p              0.220E-04 0.948E-05 0.135E-06 0.343E-07
m,x,Pt,dsdp(+,-,K-,p-)=11 0.550 0.72   1.610     0.620      0.009     0.001
        #/int-p(+,-,..)                  0.584E-04 0.225E-04 0.322E-06 0.455E-07
        #/incident-p..                   0.140E-04 0.540E-05 0.773E-07 0.109E-07
        # at detector/inc.p              0.135E-04 0.521E-05 0.593E-07 0.109E-07
m,x,Pt,dsdp(+,-,K-,p-)=12 0.600 0.78   0.775     0.264      0.003     0.000
        #/int-p(+,-,..)                  0.335E-04 0.114E-04 0.123E-06 0.125E-07
        #/incident-p..                   0.804E-05 0.274E-05 0.295E-07 0.301E-08
        # at detector/inc.p              0.778E-05 0.265E-05 0.231E-07 0.301E-08
m,x,Pt,dsdp(+,-,K-,p-)=13 0.650 0.85   0.351     0.105      0.001     0.000
        #/int-p(+,-,..)                  0.178E-04 0.531E-05 0.412E-07 0.293E-08
        #/incident-p..                   0.428E-05 0.127E-05 0.988E-08 0.704E-09
        # at detector/inc.p              0.415E-05 0.124E-05 0.789E-08 0.704E-09
m,x,Pt,dsdp(+,-,K-,p-)=14 0.700 0.91   0.148     0.038      0.000     0.000
        #/int-p(+,-,..)                  0.869E-05 0.222E-05 0.118E-07 0.561E-09
        #/incident-p..                   0.209E-05 0.534E-06 0.283E-08 0.135E-09
        # at detector/inc.p              0.203E-05 0.519E-06 0.230E-08 0.135E-09
m,x,Pt,dsdp(+,-,K-,p-)=15 0.750 0.98   0.056     0.012      0.000     0.000
        #/int-p(+,-,..)                  0.380E-05 0.817E-06 0.278E-08 0.827E-10
        #/incident-p..                   0.913E-06 0.196E-06 0.667E-09 0.199E-10
        # at detector/inc.p              0.889E-06 0.191E-06 0.549E-09 0.199E-10
m,x,Pt,dsdp(+,-,K-,p-)=16 0.800 1.04   0.019     0.003      0.000     0.000
        #/int-p(+,-,..)                  0.144E-05 0.250E-06 0.500E-09 0.849E-11
        #/incident-p..                   0.345E-06 0.601E-07 0.120E-09 0.204E-11
        # at detector/inc.p              0.337E-06 0.587E-07 0.100E-09 0.204E-11
m,x,Pt,dsdp(+,-,K-,p-)=17 0.850 1.11   0.005     0.001      0.000     0.000
        #/int-p(+,-,..)                  0.439E-06 0.585E-07 0.598E-10 0.498E-12
        #/incident-p..                   0.105E-06 0.140E-07 0.144E-10 0.120E-12
        # at detector/inc.p              0.103E-06 0.137E-07 0.121E-10 0.120E-12
m,x,Pt,dsdp(+,-,K-,p-)=18 0.900 1.17   0.001     0.000      0.000     0.000
        #/int-p(+,-,..)                  0.914E-07 0.841E-08 0.346E-11 0.106E-13
        #/incident-p..                   0.219E-07 0.202E-08 0.829E-12 0.255E-14
        # at detector/inc.p              0.215E-07 0.198E-08 0.705E-12 0.255E-14
m,x,Pt,dsdp(+,-,K-,p-)=19 0.950 1.24   0.000     0.000      0.000     0.000
        #/int-p(+,-,..)                  0.772E-08 0.379E-09 0.344E-13 0.191E-16
        #/incident-p..                   0.185E-08 0.911E-10 0.826E-14 0.459E-17
        # at detector/inc.p              0.182E-08 0.892E-10 0.709E-14 0.459E-17
```

```
      program ytheta2
CCCC  6-19-90....ADD IN DECAY probability (according to nominal mean energy)
c     dimensions in 'inches'..program converts to meters
      data fmperin/0.0254/
c     parameters for particle yields...1=pi+, 2=pi- from New Russian Xlation
c     "Passage of H.E. Particles thru Matter, AN Kalinovski,etal,AIP,eqn3.26
      dimension c1(9),c2(9),c3(9),c4(9),c5(9),c6(9),fm(9),omeg(9),
     x fmusq(9),bzero(9),gam(9)
      dimension dsdp(100,9),xpr(100),bp(100),fnum(100,9),gnum(100,9)
      dimension decay(100,9),time(9)
c.....proper decay times...as cee*tau IN meters (from PDG 1988)
      data time/2*7.803, 3.709, 6*9.99e+5/
c     units are GeV for fm,omeg,gam (and GeV**-1 for bzero)...)
      data c1/0.25, 0.20, 0.078, 0.080, 5*0./
      data c2/3.1, 4.0, 6.1, 8.6, 5*0./
      data c3/0.88, 1.18, 2.46, 2.30, 5*0./
      data c4/3.0, 3.0, 3.5, 4.2, 5*0./
      data c5/2., 2., 2., 2., 5*0./
      data c6/11.3, 9.8, 8.8, 10.5, 5*0./
      data fm/2*0.1396, 0.4937, 0.9382, 5*0./
      data omeg/1.8778, 2.016, 2.370, 2.815, 5*0./
      data fmusq/0.88, 0.86, 1.2, 1.1, 5*0./
      data bzero/0.10, 0.11, 0.12, 0.12, 5*0./
      data gam/4.0, 3.5, 4.0, 5.0, 5*0./
c
c     formulae 3.26...given as function of "p-perp and x-prime"...to be input
c     where x-prime=(E*/E*max)...ie -1. thru 0. to +1.
      write(3,9)
    9 format(/1x,'..YTHETA2.FOR..DP/P=0.2,DOMEGA= 3 microSR,0.33 tgt')
      write(6,10)
   10 format(1x,
     x 'INPUT theta,delth,del-xpr,Ezero,atnum,leng(ft.)(6F8.3)')
      read(5,11)theta,delth,dxpr,Ezero,atnum,fleng
   11 format(6f8.3)
      srtofS=sqrt(2.0*0.9382*Ezero)
      write(6,12)theta,delth,dxpr,Ezero,srtofS,atnum,fleng
      write(3,12)theta,delth,dxpr,Ezero,srtofS,atnum,fleng
   12 format(1x,'ECHO theta(mr),delth,delxpr,Ezero,srtofS,A='/
     x 10x,6f8.3/10x,'Beam length(ft.)=',f8.1)
c CONVERT fleng to METERs now...
      fleng=fmperin*12.0*fleng
c   LOOP over thetas here...
      do 100 LMN=1,5
      write(3,1111)theta*0.001
 1111 format(/20x,'theta(rad)='f7.4,2x,'*************************')
c     loop over pi+,pi- (ie 1,2)   ....and 3=K-, 4=p-
      do 101 i=1,4
c     do xpr values from dxpr UP, but MAX of 100, and NOT xpr=1. either
      nn=3
      xpr(1)=.005
      do 102 j=1,nn
c     calculate **pperp** from theta(mr) and xpr(J)...
      pperp=xpr(J)*theta*Ezero*0.001
      bp(J)=pperp
c.............................done...
      bperp=bzero(i)*pperp
      if(pperp.gt.gam(i)) bperp=bzero(i)*gam(i)
      psq=pperp**2
      xperp=2.*pperp/srtofS
      phi=exp(-c4(i)*psq)+c5(i)*exp(-c6(i)*xperp)/((psq+fmusq(i)**2)**4)
      xxx=c1(i)*(atnum**bperp)*((1.-xpr(J))**c2(i))*exp(-c3(i)*xpr(J))*phi
c..........AND SCALE BY Be absorption crossection (199 mb)
      ccsect=((atnum-0.40)/(9.01-0.40))**0.69
      ccsect=ccsect*199.
      xxx=ccsect*xxx
      dsdp(j,i)=xxx
```

```
ccc.....assuming 9 sqin of aperture at 150 feet..d(solid.angle)=3 x 10**-6
ccc.....(3 micro-sterradians)..0.33 Labsorpt Be target..x*exp(-x)=.24...ie 24%
ccc.....incident protons interact...then yield per interact-proton is
ccc.....plab**2 * (dp/p) *ster-rad * inv.sigma(=dsdp(..)), where dp/p=0.2(+-10%)
ccc.....and plab=xpr*(pzero=Ezero-200 GeV,..'MEB')..,  and sigma(abs).Be=199 mb.
ccc..... #/int-p = xpr**2 * 0.2 * 3x10**-6 * (Elab)**2 * dsdp(..,..) / 199mb
        fnum(j,i)=(1.2e-4)*xxx*(xpr(J)**2)
c       24 % interact in 0.33 absorption length target
        gnum(j,i)=fnum(j,i)*0.24
c and decays......
        plong=xpr(J)*Ezero
        eta=plong/fm(i)
        decay(J,i)=gnum(j,i)*exp(-fleng/(eta*time(i)))
        if(j.ne.nn) xpr(j+1)=xpr(j)+dxpr
  102   continue
  101   continue
        write(3,222)(m,xpr(m),bp(m),(dsdp(m,K),K=1,4),(fnum(m,K),K=1,4),
     x  (gnum(m,K),K=1,4),(decay(m,K),K=1,4),m=1,nn)
  222   format(1x,'m,x,Pt,dsdp(+,-,K-,p-)=',i2,f6.3,f5.2,f8.3,
     x  3f10.3/
     x  10x,'#/int-p(+,-,..)',14x,4e10.3/10x,'#/incident-p..',15x,
     x  4e10.3/
     x  10x,'# at detector/inc.p',10x,4e10.3)
        theta=theta+delth
  100   continue
        call exit
        end
```

*(Ezero/200.)**2

```
..YTHETA2.FOR..DP/P=0.2,DOMEGA= 3 microSR,0.33 tgt
ECHO theta(mr),delth,delxpr,Ezero,srtofS,A=
            2.500   1.000   0.010 200.000  19.372   9.000
         Beam length(ft.)=   720.0

                    theta(rad)= 0.0025  ************************
m,x,Pt,dsdp(+,-,K-,p-)= 1 0.005 0.00 319.096   297.270    21.768    29.095
         #/int-p(+,-,..)                0.957E-06 0.892E-06 0.653E-07 0.873E-07
         #/incident-p..                 0.230E-06 0.214E-06 0.157E-07 0.209E-07
         # at detector/inc.p            0.453E-08 0.422E-08 0.323E-20 0.209E-07
m,x,Pt,dsdp(+,-,K-,p-)= 2 0.015 0.01 305.300   281.179    19.964    26.029
         #/int-p(+,-,..)                0.824E-05 0.759E-05 0.539E-06 0.703E-06
         #/incident-p..                 0.198E-05 0.182E-05 0.129E-06 0.169E-06
         # at detector/inc.p            0.534E-06 0.492E-06 0.764E-11 0.169E-06
m,x,Pt,dsdp(+,-,K-,p-)= 3 0.025 0.01 291.938   265.783    18.296    23.262
         #/int-p(+,-,..)                0.219E-04 0.199E-04 0.137E-05 0.174E-05
         #/incident-p..                 0.525E-05 0.478E-05 0.329E-06 0.419E-06
         # at detector/inc.p            0.240E-05 0.218E-05 0.956E-09 0.419E-06

                    theta(rad)= 0.0035  ************************
m,x,Pt,dsdp(+,-,K-,p-)= 1 0.005 0.00 318.841   297.071    21.767    29.087
         #/int-p(+,-,..)                0.957E-06 0.891E-06 0.653E-07 0.873E-07
         #/incident-p..                 0.230E-06 0.214E-06 0.157E-07 0.209E-07
         # at detector/inc.p            0.453E-08 0.422E-08 0.323E-20 0.209E-07
m,x,Pt,dsdp(+,-,K-,p-)= 2 0.015 0.01 304.518   280.565    19.959    26.004
         #/int-p(+,-,..)                0.822E-05 0.758E-05 0.539E-06 0.702E-06
         #/incident-p..                 0.197E-05 0.182E-05 0.129E-06 0.169E-06
         # at detector/inc.p            0.533E-06 0.491E-06 0.764E-11 0.168E-06
m,x,Pt,dsdp(+,-,K-,p-)= 3 0.025 0.02 290.611   264.736    18.285    23.219
         #/int-p(+,-,..)                0.218E-04 0.199E-04 0.137E-05 0.174E-05
         #/incident-p..                 0.523E-05 0.477E-05 0.329E-06 0.418E-06
         # at detector/inc.p            0.239E-05 0.217E-05 0.955E-09 0.418E-06

                    theta(rad)= 0.0045  ************************
m,x,Pt,dsdp(+,-,K-,p-)= 1 0.005 0.00 318.584   296.869    21.766    29.079
         #/int-p(+,-,..)                0.956E-06 0.891E-06 0.653E-07 0.872E-07
         #/incident-p..                 0.229E-06 0.214E-06 0.157E-07 0.209E-07
         # at detector/inc.p            0.452E-08 0.421E-08 0.323E-20 0.209E-07
m,x,Pt,dsdp(+,-,K-,p-)= 2 0.015 0.01 303.713   279.926    19.953    25.977
         #/int-p(+,-,..)                0.820E-05 0.756E-05 0.539E-06 0.701E-06
         #/incident-p..                 0.197E-05 0.181E-05 0.129E-06 0.168E-06
         # at detector/inc.p            0.532E-06 0.490E-06 0.763E-11 0.168E-06
m,x,Pt,dsdp(+,-,K-,p-)= 3 0.025 0.02 289.222   263.627    18.271    23.172
         #/int-p(+,-,..)                0.217E-04 0.198E-04 0.137E-05 0.174E-05
         #/incident-p..                 0.521E-05 0.475E-05 0.329E-06 0.417E-06
         # at detector/inc.p            0.237E-05 0.216E-05 0.954E-09 0.417E-06

                    theta(rad)= 0.0055  ************************
m,x,Pt,dsdp(+,-,K-,p-)= 1 0.005 0.01 318.324   296.665    21.765    29.070
         #/int-p(+,-,..)                0.955E-06 0.890E-06 0.653E-07 0.872E-07
         #/incident-p..                 0.229E-06 0.214E-06 0.157E-07 0.209E-07
         # at detector/inc.p            0.452E-08 0.421E-08 0.323E-20 0.209E-07
m,x,Pt,dsdp(+,-,K-,p-)= 2 0.015 0.02 302.884   279.264    19.946    25.948
         #/int-p(+,-,..)                0.818E-05 0.754E-05 0.539E-06 0.701E-06
         #/incident-p..                 0.196E-05 0.181E-05 0.129E-06 0.168E-06
         # at detector/inc.p            0.530E-06 0.489E-06 0.763E-11 0.168E-06
m,x,Pt,dsdp(+,-,K-,p-)= 3 0.025 0.03 287.771   262.457    18.254    23.121
         #/int-p(+,-,..)                0.216E-04 0.197E-04 0.137E-05 0.173E-05
         #/incident-p..                 0.518E-05 0.472E-05 0.329E-06 0.416E-06
         # at detector/inc.p            0.236E-05 0.215E-05 0.954E-09 0.416E-06

                    theta(rad)= 0.0065  ************************
m,x,Pt,dsdp(+,-,K-,p-)= 1 0.005 0.01 318.061   296.458    21.763    29.061
         #/int-p(+,-,..)                0.954E-06 0.889E-06 0.653E-07 0.872E-07
         #/incident-p..                 0.229E-06 0.213E-06 0.157E-07 0.209E-07
```

```
        # at detector/inc.p            0.452E-08 0.421E-08 0.323E-20 0.209E-07
m,x,Pt,dsdp(+,-,K-,p-)= 2 0.015 0.02 302.031   278.579    19.938    25.918
        #/int-p(+,-,..)              0.815E-05 0.752E-05 0.538E-06 0.700E-06
        #/incident-p..               0.196E-05 0.181E-05 0.129E-06 0.168E-06
        # at detector/inc.p            0.529E-06 0.488E-06 0.763E-11 0.168E-06
m,x,Pt,dsdp(+,-,K-,p-)= 3 0.025 0.03 286.261   261.228    18.234    23.066
        #/int-p(+,-,..)              0.215E-04 0.196E-04 0.137E-05 0.173E-05
        #/incident-p..               0.515E-05 0.470E-05 0.328E-06 0.415E-06
        # at detector/inc.p            0.235E-05 0.214E-05 0.953E-09 0.415E-06
```

Appendix C

Yield Comparison References

PHYSICAL REVIEW D VOLUME 17, NUMBER 5 1 MARCH 1978

Inclusive charged-hadron production in 100–400-GeV p-p collisions

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SUBR TAYLOR M

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(Received 3 October 1977)

Measurements have been made on the single-particle inclusive reactions $p+p\to\pi^{\pm}$, $K^{\pm}$, p, or $\bar{p}$ + anything at 100, 200, and 400 GeV incident proton energies at Fermilab. The data cover a wide range in the radial scaling variable x_R ($0.05 \le x_R \le 1.0$) in the low-$p_\perp$ region ($0.25 \le p_\perp \le 1.5$ GeV/c). The x_R and $p_\perp$ distributions are presented. The π^+/π^-, K^+/K^-, and $\pi^{\pm}/K^{\pm}$ ratios are shown and are compared with data at higher $p_\perp$. The experimental techniques and the data analysis procedures are described in detail.

INTRODUCTION

Single-particle inclusive reactions in high-energy hadron-hadron collisions are of major experimental and theoretical interest. This interest is derived from the hope that at high $p_\perp$, the quark-parton model, which has been so successful in high-energy lepton-hadron scattering, may be applied to pure hadron scattering. In terms of the quark-parton model, inclusive hadron production at large $p_\perp$ may be used to probe the constituent structure of the colliding hadrons and of the detected hadron.

The understanding of single-particle inclusive cross sections has been slow, primarily because the observed $p_\perp$ dependence does not agree with dimensional arguments of the quark-parton model at currently available energies. Various mechanisms, based for example on quark-quark elastic scattering[1] or on constituent interchange,[2] have been proposed to explain the experimental results. These models are generally limited to the large-$p_\perp$ region where the hard scattering of the initial projectiles is supposed to reveal a simple underlying structure.

A complete understanding of inclusive reactions must cover the entire kinematic region and hence must include the low-$p_\perp$ region as well as the high-$p_\perp$ region. In the low-$p_\perp$ region we expect hadrons to be produced by low-$p_\perp$ quarks fragmenting from the initial colliding hadrons. This hadron-production mechanism is a long-range process. High-$p_\perp$ hadron production, on the other hand, must be a short-range process. Therefore, it is of interest to compare the $p_\perp$ and x_R dependences for various secondary particles in these two kinematic regions. Of particular interest is to compare the particle ratios π^+/π^-, K^+/K^-, $\pi^{\pm}/K^{\pm}$ in these two kinematic regions since this would allow interesting small differences of the cross sections to be seen.[3]

The invariant cross section for single-particle inclusive production $E(d\sigma/dp^3)(p+p\to h+X)$ may be written as a function of three variables $p_\perp$, $x_R = E^*/E^*_{max}$, and the c.m. energy squared, s. We have previously used the radial scaling variable x_R in the analysis of an experiment performed at Fermilab on single-π^0 inclusive production[4] as well as in an analysis of an extensive compilation of inclusive hadron data.[5] The invariant cross sections in terms of x_R show a simple scaling behavior over a wide kinematic range. This scaling range appears to be wider when x_R is used than when Feynman $x = 2p^*_\parallel/\sqrt{s}$ is used. It is therefore worthwhile to measure the invariant cross section by systematically holding two of these three variables constant while varying the third. It is hoped that in this way, certain simplicities will be evident and detailed questions such as radial scaling, the $p_\perp$ and x_R dependencies may be measured without model-dependent assumptions.

The data presented here were taken in the low-$p_\perp$ region, $0.25 \le p_\perp \le 1.5$ GeV/c, for incident proton energies of 100, 200, and 400 GeV for the reactions $p+p\to h+X$ where $h=\pi^{\pm}$, $K^{\pm}$, p, or $\bar{p}$. The invariant cross sections for fixed $p_\perp$ and s were measured versus x_R in the range $0.05 \le x_R \le 1.0$ corresponding to roughly 126° to 177° in the c.m. frame.

EXPERIMENTAL SETUP

The experiment was conducted in the P-West pit area of the Proton Laboratory of Fermi National Accelerator Laboratory. A well collimated primary proton beam was allowed to traverse a 13-cm liquid-hydrogen target. The produced particles were detected by a set of scintillation and Čerenkov counters in a 2.4-GeV/c spectrometer made from two half quadrupole magnets. A system of proportional wire chambers was used

PHYSICAL REVIEW D VOLUME 14, NUMBER 5 1 SEPTEMBER 1976

Analysis of radial scaling in single-particle inclusive reactions

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SUPR TAYLOR F

(Received 12 December 1975)

An analysis of an extensive sample of the world's data has been performed to test the hypothesis of radial scaling. We have studied the inclusive reactions $p+p\to(\pi^{\pm,0}$ or $K^{\pm}$ or p or $\bar{p})+$anything to determine the behavior of the invariant cross section as a function of $p_\perp$, $x_R = E^*/E^*_{max}$, the radial scaling variable, and s. The data cover a range in $p_\perp$ from 0.25 to ~ 6.0 GeV/c and a range in $\sqrt{s}$ from 3.0 to 63 GeV. For small x_R and all available $p_\perp$ the single-particle inclusive cross sections for the reactions studied scale to a good approximation for all $\sqrt{s}$, even down to the kinematic threshold. For large x_R, the single-particle inclusive cross sections for increasing $\sqrt{s}$ show a rapid approach to the scaling limit from above. In these cases the scaling limit is always approached by $\sqrt{s}\simeq 10$ GeV. Thus, data for all particles to a good approximation exhibit radial scaling at all available $p_\perp$ and x_R over the CERN ISR energy range. A comparison of radial scaling with Feynman scaling is given. It is shown that in the Feynman case the cross sections for small $x_\parallel$ ($x_\parallel = p^*_\parallel/p^*_{max}$) approach their scaling limit from below, and that the approach to the scaling limit is slower than is exhibited for the case of small x_R. The systematic differences among the inclusive cross sections of various particles are discussed in the range of $\sqrt{s}$ where radial scaling has been shown to be valid. In particular, the $p_\perp$ and x_R distributions of $E\,d\sigma/dp^3$ are examined.

I. INTRODUCTION

In a separate paper we presented data on inclusive π^0 production from pp collisions at the Fermi National Accelerator Laboratory.[1] Here we present an analysis and interpretation of these π^0 data. In addition, we examine other single-particle inclusive cross sections in order to search for systematics in their behavior.

To study the single-particle inclusive experiments, a set of variables should be chosen such that the single-particle inclusive cross section displays the simplest behavior with respect to energy, $p_\perp$, the center-of-momentum (c.m.) frame angle, etc. It is natural to choose a parameterization of the inclusive cross section which is meaningful in the exclusive limit.[2] We therefore define the scaling variable

$$x_R = \left(\frac{E^*}{E^*_{max}}\right), \tag{1}$$

where E^* = the energy of the detected particle in the center-of-momentum frame, and E^*_{max} = the maximum energy kinematically available to the detected particle in the c.m. frame. The range of x_R is $0 < x_R \leq 1$ for all $p_\perp$, and the case $x_R = 1$ corresponds to the exclusive limit. Since this variable is independent of the center-of-momentum angle and depends on only the radial distance from the kinematic boundary, we have called it the "radial" scaling variable.

Using this variable x_R, the proton-proton single-particle inclusive cross section can be expressed as a function of three variables, s, $p_\perp$, and x_R,

$$E\frac{d\sigma}{dp^3} = f(s, p_\perp, x_R), \tag{2}$$

where s is the square of the total c.m. energy. In this work we study whether the invariant cross section at sufficiently high energy scales, that is, becomes independent of s. It is shown that this scaling is reached at a lower s than obtained with the use of the Feynman variable $x_\parallel$.

In an analysis of a single-π^0 inclusive experiment in p-p collisions,[3] it has been shown that for sufficiently high $\sqrt{s}$ ($\sqrt{s}\gtrsim 10$ GeV) there is radial scaling

$$E\frac{d\sigma}{dp^3} \simeq f(p_\perp, x_R). \tag{3}$$

This scaling is observed for 0.3 GeV/$c \leq p_\perp \leq 3.0$ GeV/c, 10 GeV $\leq \sqrt{s} \leq 27$ GeV, and for center-of-mass angle $20° \leq \theta^* \leq 150°$. It is therefore interesting to test this new form of scaling over as wide a kinematic range as possible for other particles produced in p-p collisions. We shall discuss the reactions

$$p+p\to(\pi^{\pm,0} \text{ or } K^{\pm} \text{ or } p \text{ or } \bar{p})+\text{anything}.$$

In Sec. II, the variable x_R is discussed and it is compared with the Feynman scaling variable $x_\parallel$. Section III is a discussion of the method of data analysis. A comparison of radial scaling with Feynman scaling is given in Sec. IV. Section V

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CALCULATION OF ANTIPROTON YIELDS FOR THE FERMILAB ANTIPROTON SOURCE

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Received 27 July 1982

The available experimental data for antiproton production are described by an analytical formula, including target nucleus dependence. This formula, in conjunction with a Monte Carlo program that includes the effect of hadronic showers, is used to optimize the design of the Fermilab Antiproton Source. Comparison is made with measurements of yields at the CERN Antiproton Accumulator.

1. Introduction

Due to developments in beam cooling techniques it is now possible to accumulate antiprotons ($\bar{p}$) in sufficient numbers within phase space areas compatible with utilization in accelerators. The possibility of increasing the phase space density of antiprotons is a direct result of the development of electron cooling techniques by Budker [1] and the invention of stochastic cooling by Van der Meer [2]. Intense bunches of $\bar{p}$ can be made to collide with proton bunches in colliding beam machines with large gains in center-of-mass energy over collisions with stationary targets. Several laboratories have proposed such facilities [3]. At the CERN SPS accelerator experiments which study 270 GeV $\bar{p}p$ collisions have recently started [4].

This report summarizes a set of calculations on antiproton production in complex targets for aiding in the design of the Fermilab Tevatron I Antiproton Source. The emphasis is on the optimization of the accumulation rate of antiprotons to maximize the expected peak and average luminosity of the $\bar{p}p$ collisions in the Tevatron accelerator. Although several other calculations [5] exist a comparison is presently not attempted.

The calculations rely on the Monte Carlo (MC) program CASIM [6]. This program generates three dimensional nuclear cascades. Antiproton production by all members of the cascade is included, along with the subsequent transport of the $\bar{p}$ through the target and collection devices. An empirical fit to available data of $\bar{p}$ production is introduced into the program expressly for this study. This fit is described below, along with a brief sketch of its implementation into CASIM.

The CERN Antiproton Accumulator has now been in operation for some time. It provides the opportunity of comparing expected $\bar{p}$ yields from the present calculations with actual measurements for that specific geometry. Such comparisons are made below.

This report is divided in six sections. Section 2 contains the model for $\bar{p}$ production. Section 3 discusses its adaptation to the MC code CASIM. The results for the Fermilab parameters are given in section 4 and the comparison with CERN data in section 5. Section 6 contrasts the differences between Fermilab and CERN designs.

2. Antiproton production cross section

The calculation of $\bar{p}$ yields relies on the production cross section not only for beam protons (primaries) but also for particles participating in the shower development (secondaries). In the present calculation the secondaries considered are p, n, π^+, π^-, and $\bar{p}$. Production of $\bar{n}$ which may subsequently transform to $\bar{p}$ via charge exchange (including inelastic charge exchange, i.e., transformation of a leading particle) is not considered explicitly. To first order this process and its (likewise neglected) inverse are expected to compensate each other.

For nucleons and pions incident on protons as well as on nuclear targets the available data are described by an empirical formula which factors into three parts:

1) a fit to data [7] in the (high energy) scaling region,
2) a factor describing the approach to scaling at lower incident energies, and
3) nuclear mass dependence.

The scaling variables chosen are the transverse momentum, p_t, and the radial scaling variable, $x_R (\equiv E/E_{max}$, the $\bar{p}$ energy in the center of mass expressed as a fraction of its largest kinematically allowed value). It has been shown [8] that x_R has better scaling properties, especially at lower incident energies, than the more conventional Feynman x.

The empirical formula for the invariant $\bar{p}$ production cross section (divided by the target absorption cross

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INCLUSIVE REACTIONS

* 5554

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CONTENTS

INTRODUCTION AND NOMENCLATURE 451
Inclusive Measurements 452
Kinematic Variables 456
LIMITING BEHAVIOR AND INCLUSIVE PRODUCTION SPECTRA 458
Expectations at Asymptotic Energies 458
Mueller's Theorem and its Applications 462
Region of Proton Fragmentation 465
Central Region 471
Two-Pion Production 471
Dependence on p_T 473
SYSTEMATICS OF CHARGED AND NEUTRAL PARTICLE PRODUCTION 476
Semi-Inclusive Scaling 478
Moments of the Multiplicity Distribution 482
Particle Composition 485
DIFFRACTIVE-PRODUCTION PHENOMENON 487
Kinematic Regions of Interest and Triple-Regge Analysis 488
Comparison with Data 490
CORRELATIONS IN PRODUCTION 497
Charge and Prong Correlations 497
Longitudinal Rapidity Correlations 501
Transverse Momentum Correlations 509
CONCLUSION 511

INTRODUCTION AND NOMENCLATURE

Although the term "inclusive" reactions is relatively new,[3] those experimental studies which relate to this general area of high energy physics are as old as the field itself. The newly revived interest in inclusive reactions has been

[1] Dr. Ferbel is an Alfred P. Sloan Fellow.

[2] Research supported by the US Atomic Energy Commission.

[3] The phraseology is attributed to Feynman, who used it freely at the time of the 1969 Stony Brook Conference on High Energy Collisions.

Appendix D

Eastman and Loken.(1987).reference **Muon's dEdx**
(including program **powerdEdx** and output)
Revised July 1991

Proceedings of the Workshop on

EXPERIMENTS, DETECTORS, AND EXPERIMENTAL AREAS FOR THE SUPERCOLLIDER

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MUON ENERGY LOSS AT HIGH ENERGY AND IMPLICATIONS FOR DETECTOR DESIGN

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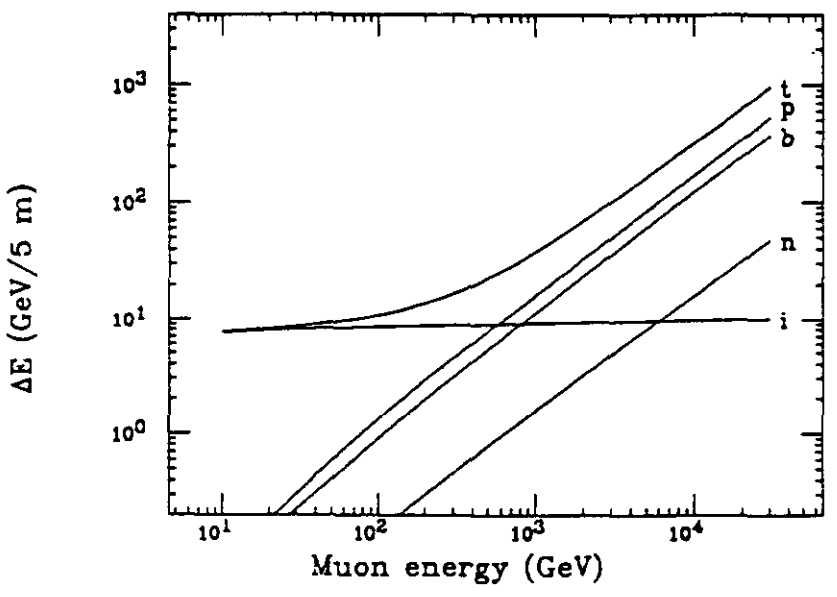
Abstract

We study the effects of energy loss and associated electromagnetic showers on muon tracking and momentum measurement in muon detectors operating in the energy range 100 GeV–5 TeV. A detailed Monte Carlo simulation tracks muons and shower particles through a detector structure and evaluates the charged-particle environment in chambers. We find that catastrophic energy loss events accompanied by energetic showers can pose serious problems to designers of muon spectrometers.

Figure 1: Contributions of several processes to the average energy loss of a muon in 5 m of iron as a function of muon energy. The processes are (p) direct e^+e^- pair production, (b) bremsstrahlung, (n) photonuclear interactions, and (i) ionization; t marks the total loss.



7/1991

```
      program powerdEdx
      E=12.5
      do 10 i=1,10
      dEdx=8.0+8.0*(E/250.)**1.0
      dEdx2=8.0
      i2toi=2**i
      write(6,9)i,i2toi,E,dEdx,dEdx2
    9 format(1x,'i,2**i,E(GeV),dEdx(Fe)(GeV/5.0m)1&2=',i3,i5,3f10.1)
      write(16,9)i,i2toi,E,dEdx,dEdx2
      E=2.0*E
   10 continue
c....and integrate to get range....R(E)= (b/a)* ln[1 + E/b ] ,
c................where dEdx(GeV/m) = a * [ 1 + E(GeV)/b ]
c.....a=8/5=1.6 GeV/m Fe...and 0.4 GeV/m chalk....ie 250/0.4=625
c...      SO  R(E) = 625 * log ( 1 + E/250 )...where log=natural log..
      EE=10.
      factor=sqrt(10.)
      do 20 i=1,9
      if(i.eq.8)EE=200.
      if(i.eq.9)EE=2000.
c....from muscat....stuff..........AUSTIN chalk.....0.38 better 0.4
      GeVperM=1.73*2.2*100./1000.
      RR=(250./GeVperM)*log(1.+EE/250.)
      RR2=EE/GeVperM
      write(6,19)i,EE,RR,RR2
      write(16,19)i,EE,RR,RR2
   19 format(1x,'i,EE(GeV),RR(chalk)meters1&2',i4,9x,3f10.1)
      EE=EE*factor
   20 continue
      call exit
      end
```

TO CHECK!

1) SCALING WITH (A, Z) (USED FOR HERE)

2) DENSITY OF CHALK

3) PARAMETERS a, b VS. EXPT.?
(POSSIBLY FNAL, FALL 1991 TO 600+ GeV

i,2**i,E(GeV),dEdx(Fe)(GeV/5.0m)1&2=	1	2	12.5	8.4	8.0
i,2**i,E(GeV),dEdx(Fe)(GeV/5.0m)1&2=	2	4	25.0	8.8	8.0
i,2**i,E(GeV),dEdx(Fe)(GeV/5.0m)1&2=	3	8	50.0	9.6	8.0
i,2**i,E(GeV),dEdx(Fe)(GeV/5.0m)1&2=	4	16	100.0	11.2	8.0
i,2**i,E(GeV),dEdx(Fe)(GeV/5.0m)1&2=	5	32	200.0	14.4	8.0
i,2**i,E(GeV),dEdx(Fe)(GeV/5.0m)1&2=	6	64	400.0	20.8	8.0
i,2**i,E(GeV),dEdx(Fe)(GeV/5.0m)1&2=	7	128	800.0	33.6	8.0
i,2**i,E(GeV),dEdx(Fe)(GeV/5.0m)1&2=	8	256	1600.0	59.2	8.0
i,2**i,E(GeV),dEdx(Fe)(GeV/5.0m)1&2=	9	512	3200.0	110.4	8.0
i,2**i,E(GeV),dEdx(Fe)(GeV/5.0m)1&2=	10	1024	6400.0	212.8	8.0
i,EE(GeV),RR(chalk)meters1&2	1		10.0	25.8	26.3
i,EE(GeV),RR(chalk)meters1&2	2		31.6	78.2	83.1
i,EE(GeV),RR(chalk)meters1&2	3		100.0	221.0	262.7
i,EE(GeV),RR(chalk)meters1&2	4		316.2	537.0	830.9
i,EE(GeV),RR(chalk)meters1&2	5		1000.0	1057.2	2627.4
i,EE(GeV),RR(chalk)meters1&2	6		3162.3	1716.8	8308.7
i,EE(GeV),RR(chalk)meters1&2	7		10000.0	2439.3	26274.3
i,EE(GeV),RR(chalk)meters1&2	8		200.0	386.1	525.5
i,EE(GeV),RR(chalk)meters1&2	9		2000.0	1443.3	5254.9

dE/dx (GeV/5m Fe) (Fig. 1) DATA + LOKEN

$\frac{dE}{dx} = a$

7/1991

E(GeV)

RANGE ($\frac{dE}{dx}$ VARIABLE)

"R IF ONLY IONIZ.

$$\frac{dE}{dx}\left(GeV/m\right) = a * \left[1 + \frac{E(GeV)}{b(GeV)}\right]$$

$$\left[a \equiv GeV/m\right]$$

and

$$R_i(E_0) = \frac{250}{a_i} * \log_{(e)}\left[1 + \frac{E_0(GeV)}{250.}\right]$$

$$\left\{\begin{aligned} a_{\underline{CHALK}} &= 1.73 * 2.2 * 100./1000. \\ &= 0.38 \ GeV/m. \\ b &= 250 \ GeV \end{aligned}\right\}$$

Appendix E

Program **muMScatZ.for** for Muon Distributions
including SpreadMU.for and Inside.for)
Spread2 error corrected to SpreadMU, July 1991

```
ccc
ccc.......................file MUPASS3.for.............................
ccc
        program muMScatZ
CCCCCC            GRK 6-30-90...Sat..noonish...........(do in INSIDE..)
CCCCCCCC.............and FINALLY... Multiple Scattering of Muons in Chalk
CCCCCCCCCCCCC                                +
CCCCCCCCCCCCC.......and ALSO put in (one Meter) decay (about 2*Labsorpt)
CCCCCCCCCCCCC                                +
CCCCCCCCCCCCC   NON-linear RANGE-out...use Range(i)= correct..Loken 1987
CCCCCCCCCCCCC...........(muons radiate highly above 200 GeV..6-30-90 grk)
CCCCCCCCCCCCC..ipass=3 (solenoidally field bbending outward).implies.MUPASS3
CCCCCCCCCCCCC..spreadGE to spreadMU for old (wrong) spread2..grk 7-22-91
CCCCCCCCCCCCC
c       dimension fnmu(ixpr,jrovz,kzee).....indexed on  pmu,radius/z,z
c.......................................=Ezero*xprmu(GeV),meters/m,meters
        dimension fnmu(20,20,20)
c..................store 'russian' yields in...yy(lxpr,mpT) summed over type..
        dimension yy(20,20),zz(20,20)
c....where zz(,) is for spread out pions INTO muons..which get Xformed to fnmu.
c..................we will treat all as pions (K/pi ratio small, and compress-
c..................ing Kaon muons into upper half is conservative....)
CCCCCCC...upper-limit...conservative estimation is what I am doing here.
c
c.....FnFr is output of  INSIDE  the muons/m**2 beyond range FR
c                   (0th to 19th, ie last-1)        &  inside radius RR
        dimension FnFr(20,10),Range(20),Fring(20),FFFlog(20)
CCCCCCCCCCCCCCCCmake an array which gives  (ring,step) for seeing radial dist.
ccccc  LOGarithm-ically....so can use fixed format (Fx.y)...
        dimension FrFz(10,20),PPmin(20)
c....zero out zz array to avoid any trouble
        do 5 ii=1,20
        do 5 jj=1,20
    5   zz(ii,jj)=0.
c
c       first get yy-array filled
        total=0.
        Ezero=200.
        RR=1.
        write(6,666)
  666   format(1x,'ENTER value of Ezero(GeV) and RR(m)=')
        read(5,667)Ezero,RR
  667   format(2f10.5)
        write(6,668)Ezero,RR
  668   format(1x,'Ezero input and RR=',2f10.1)
        atwt=9.01
        dxpr=0.05
        xpr=-dxpr/2.
        do 10 lxpr=1,20
        PPmin(lxpr)=(lxpr-1)*Ezero/20.
        xpr=xpr+dxpr
        dpperp=0.2
        pperp=-dpperp/2.
        do 11 mpT=1,20
        pperp=pperp+dpperp
        yyy=0.
c..............................sum over particle 1,2,3,4...ie pi+,pi-,K+,K-
        do 12 it=1,4
CCCC...test 3 nonzero values..1 ON and 2 OFF diagonal..
cccc    if(lxpr.ne.8.or.mpt.ne.8) go to 9912
cccc    go to 8812
c 9912  if(lxpr.ne.4.or.mpt.ne.7) go to 9812
cccc    go to 8812
c 9812  if(lxpr.ne.6.or.mpt.ne.3) go to 12
cccCCCCCCCC...end this
c 8812  continue
```

```
      call russian(it,xpr,pperp,atwt,Ezero,russ)
      yyy=yyy+russ
   12 continue
c....russ=E*(ds/dp3)...implies del.s = russ * dp3/E =
c                .. (russ)*2.*pi*(pT/xpr)*dxpr*dpT.........grk 6-27-90
      yyy=yyy*6.2832*(pperp/xpr)*dxpr*dpperp
      total=total+yyy
      yy(lxpr,mpT)=yyy
   11 continue
   10 continue
      write(55,43)total,atwt,Ezero,RR
   43 format(//1x,'Page1'/
     x 1x,'PROGRAM.. muSCatZ ..(muons/m**2/10**12 p) per meter'/
     x 1x'.......of decay path...INCLUDES radiative dEdx & Mult. Scat.'/
     x /1x,'russian TOTAL sigma(mb)=',f7.1,
     x 'for A,E0,RR=',3f7.1//)
      write(55,44)yy
   44 format(1x,10f8.4)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
c
c....now "muon" these "pions"...
c....take K's as Pions...decay to muons is pmu from 0.57 to 1.0 *ppi
c........ie xpr for mus is flat spectrum from .57 to 1 xprpi...
c...pT kick of 30 MeV/c ingnored realtive to 100 mev binning....
c.....this implies that pTmu= .57 to 1 times pTpi...also
c...
cccc....spread(all pi's decay) TO...SPREADmu..(1 meter of decay path for pi's)
CCCCCCCCCCC...spreadMU....
      write(55,443)atwt,Ezero,RR
  443 format(1H1//
     x 1x,'Page 2,  muSCatZ  .. using SPREADmu (mb), all pions decay'/
     x 1x,'  [next page (3) for 1 meter path length]...A,E0,RR=',3f7.1)
      call SPREADmu(20,20,dxpr,dpperp,Ezero,yy,zz)
      write (55,444)atwt,Ezero,RR,zz
  444 format(1H1//
     x 1x,' Page 3, muSCatZ..this "per meter"(mb).&...A,E0,RR=',
cccc    x      3f7.1///(1x,10f8.5))
     X 3f7.1///(1x,10e8.1))
c....now do the SIMPLE thing of counting muons inside radius RR, range gt FR
CCCC...do series of ANNULI........also
c...need cross-section...also...all p interact...sig_incl/sig_absorpt=mult.
      ccsect=199.*((atwt-0.40)/(9.01-0.40))**0.69
      write(55,442)atwt,Ezero,RR
  442 format(1H1//1x,'  Page 4,  muSCatZ  ...INSIDE results..'/
     x 1x,'  A,E0,RR=',3f7.1)
      write(55,3345)
 3345 format(//20x,'PER METER OF DECAY PATH'
     x          //21x,' first...UNscattered')
cccccc
cccccc
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC  two passes...no/yes MScat
ccc.....................................& third..solenoidal bend outward
ccc......9-10-90 grk...add pass 3...ie SOLENOIDAL field always bending outward
ccc......Bfield and Path = 2.0 T and 1.0 m  (1.0m approx. 2*La(chalk))...treat
ccc..........as Path over 2. of bend with sigma of Path width...Simplest/and
ccc.............................OVER-ESTIMATED......
ccc......
            do 975 ipass=1,3
      do 999 jring=1,10
      RRRR=RR*jring
      call inside(20,20,dxpr,dpperp,Ezero,atwt,zz,RRRR,
     x Range,FnFr,jring,ipass)
c....FnFr = vector with SUCH number (muons/m**2) indexed on increasing FR's
c....FR's at boundaries of GeV of the ..yy and zz..grids..ie Ezero*dxpr*number
      area1=3.1416*((jring-1)*RR)**2
      area2=3.1416*(jring*RR)**2
```

MUPASS 3 ...

TO ADD 8/31/91
" RINGS
SPHEROLINGS
BREAK Pi dσ/dω

```
        conv=1.e+12
c....convert to Hertz of muons/m**2...per 10**12 protons/sec..per ring
        do 998 jR=1,20
        if(jring.gt.1) then
                Fring(jR)=FnFr(jR,jring)-FnFr(jR,jring-1)
        else
                Fring(jR)=FnFr(jR,1)
        endif
        Fring(jR)=(Fring(jR)/ccsect)*conv/(area2-area1)
        FFFlog(jR)=0.
        FFFFFF=Fring(jR)
        if (FFFFFF.gt.0.) FFFlog(jR)=alog10(FFFFFF)
CCCCC store the data in new array by (ring,range)...logarithmically..
        FrFz(jring,jR)=FFFlog(jR)
  998   continue
CC-log10        write(55,555)(jring,ii,Range(ii),Fring(ii),FFFlog(ii),ii=1,20)
  555   format(//1x,'ring,step,Range,(Mus/m**2)&log10 gt 0th,1st,...'/
     x  (1x,2i4,f10.4,e12.4,f10.3))
  999   continue
        if(ipass.eq.2) write(55,4567)
 4567   format(//20x,' second .. Multiply Scattered')
        if(ipass.eq.3) write(55,4576)
 4576   format(//20x,' third PASS..SOLENOID-ally bent outward')
        write(55,567)((ii,Range(ii),PPmin(ii),(FrFz(jj,ii),jj=1,10)),
     x  ii=1,20)
  567   format(///1x,
     x  'Step#, Range(m), PPmin, Log10(mus/m**2/10**12,Radius=1,10)..'/
     x  (1x,i3,2f6.0,10f6.2))
  975   continue
        call exit
        end
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
        subroutine inside(MM,NN,dxpr,dpT,Ezero,atwt,zz,RR,
     x  Range,FnFr,jring,ipass)
        dimension zz(20,20),FnFr(20,10),Range(20)
c   AUSTIN chalk...CaCO3 (?)...calcite etc density= 2.7-2.9 g/cc (2.8 avg.)
c  chalk less dense??..Ray S. sez 2.2 (he thinks)..use 2.2 and dEdx(Zbar=10)
c.....ie dEdx = (Ne) = 1.73 MeV/g..
        data dEdx,dens/1.73,2.2/
        GeVperM=dEdx*dens*100./1000.
CCCCCCCC
CCCCCCCCCCCCC...muon radiation increase dEdx...we will use for MUDEDXZ
CCCCCCC...( see program...POWERDEDX....R(chalk)=250/dedxmin*loge(1+Ei/250)
        delP=dxpr*Ezero
        PP=0.
        do 987 ip=1,20
        Range(ip)=(250./GeVperM)*log(1.+PP/250.)
        PP=PP+delP
  987   continue
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C       delR=dxpr*Ezero/GeVperM
C       Ra=0.
        do 10 iR=1,20
CCCC    do 10 iR=1,20************************* TESTING one iR
C               iR=17
C               Ra=420.389
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC  and its Ra
C       Range(iR)=Ra......it is done above as Range(PP)...
        Ra=Range(iR)
        FnFr(iR,jring)=0.
ccc..must sum from iR to 20 for thos whose pT gives flux inside radius RR
        pl=-Ezero*dxpr/2.+Ezero*dxpr*iR
        do 11 jR=iR,20
        pt=dpT/2.
        dth=pt/pl
        do 12 kpt=1,20
```

```
        theta=pt/pl
        thmin=theta-dth
        thmax=theta+dth
        rad1=thmin*Ra
        rad2=thmax*Ra
cccc........ipass to 3...solenoidal bending overestimated........
c       if(ipass.eq.2) go to 966
        if(ipass.ge.2) go to 966
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCC...delete this for gaussian FRACT below
        if(rad1.gt.RR)then
                fract=0.
                go to 9
        else
                if(rad2.le.RR)then
                        fract=1.0
                else
                        fract=(RR**2-rad1**2)/(rad2**2-rad1**2)
                endif
        endif
    9   continue
CCCCCC  write(55,456)iR,jr,kpt,fract,zz(jr,kpt)
c 456   format(1x,'testing pieces..iR,jr,kpt,fract,zz(jr,kpt)='/
c    x  (1x,3i5,2f10.5))
c....now sum it up
c
c           M. S. HERE, here....somewhat..different summing TECHNIQUE....
c                       rather than fract piece of BOX inside radiusRR..
c             it is LOWside TAIL of a GAUSSIAN that's inside RR...gives FRACT
        go to 963
  966   thetRR=1.57
        if (Ra.gt.0.)thetRR=RR/Ra
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC   here for ipass = 2 AND 3!!!!!
cccc grk 9-10-90
        call gFRACT(theta,thmin,thmax,thetRR,pl,Ra,FRACT    , IPASS   )
  963   FnFr(iR,jring)=FnFr(iR,jring)+fract*zz(jr,kpt)
c
c       end FRACT from Gaussian....
        pt=pt+dpT
   12   continue
        pl=pl+Ezero*dxpr
   11   continue
ccccc   Ra=Ra+delR......not needed here...Range(PP) done a priori
   10   continue
        return
        end
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC*************************************
C*****************************************CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
        subroutine gFRACT(theta,thmin,thmax,thetRR,Pl,Ra,FRACT    ,ipass)
c...gaussianize BOX(thmax,thmin)...sig**2= W**2/12, W=(thmax-thmin)
c...and fold in quadrature
c               with ...thetMS=(0.014/Pl)*sqrt(L/Lr)*[1.+(1/9)*log10(L/Lr)]
c....use table of integral values -4sig to position (out to max +4sig)
        dimension sig(41),value(41)
        data sig/-4.0,-3.8,-3.6,-3.4,-3.2,-3.0,-2.8,-2.6,-2.4,-2.2,
     x  -2.0,-1.8,-1.6,-1.4,-1.2,-1.0,-0.8,-0.6,-0.4,-0.2, 0.0,
     x   0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0,
     x   2.2, 2.4, 2.6, 2.8, 3.0, 3.2, 3.4, 3.6, 3.8, 4.0/
        data value/3.e-5, 7.e-5, 1.6e-4, 3.3e-4, 6.8e-4, 1.35e-3,
     x  2.55e-3, 4.66e-3, 8.20e-3, 0.0139, 0.0228, 0.0359 ,0.0548,
     x  0.0808, 0.115, 0.159, 0.212, 0.274, 0.345, 0.421, 0.500,
     x  0.579, 0.655, 0.726, 0.788, 0.841, 0.885, 0.919, 0.9452,
     x  0.9641, 0.9773, 0.9861, 0.9918, 0.99534, 0.99745, 0.99865,
     x  0.99932, 0.99967, 0.99984, 0.99993, 0.99997/
c....the radiation length Lrad for chalk about 0.1 meter (Z**2 wting of
c...Lrads..gives about 22 g/cm**2...and since density is 2.2..VOILA)
```

```
CCCCC........and ipass = 2 AND 3...grk 9-10-90...3=solenoidal bent overly..
CCCCC
      data fLrad/0.1/
ccc.......start with Bfield =2.0 Tesla and Path = 1.0 (2*La) meter chalk
ccc.....go to non-magnetic iron..ie Cu/brass/zinc....2*La=0.3 m.
      data Bfield,Path,itest/2.0,0.3,0/
cccc...readin over default if desired...
      if(ipass.ne.3) go to 13
      if(itest.ne.0) go to 13
      itest=1
      write(6,11)
 11   format(1x,'Enter Bfield(T), Path(m)..use 2.0,0.3=std.')
      read(5,12)Bfield,Path
 12   format(2f8.3)
      write(55,112)Bfield,Path
112   format(1H1/15x,'Bfield(Tesla), Path(m.)=',2f8.2)
 13   continue
CCCCCCCCCCCCCCCCCCCCCCCCCCC
      thetaX=theta
      thetMS=0.
      if(Ra.le.0.) go to 543
      thetMS=(0.0141/Pl)*sqrt(Ra/fLrad)*(1.+0.1111*log10(Ra/fLrad))
c...for first testing...test gaussianized box with square BOX..ms to zero
543   Wsq=(thmax-thmin)**2/12.+thetMS**2
      sigW=sqrt(Wsq)
cc...add solenoidal bending for iss=3
ccc.. p(Mev/c)=0.3*B*rho (Kg-cm) or = 300*B(Tesla)*rho(meters)
ccc...times theta gives Pt=Pl*delth=0.3*Bfield*Path(T-m)  GeV/c now...
      delth=0.3*Bfield*Path/Pl
      if(ipass.eq.3) thetaX=thetaX+0.5*delth
      if(ipass.eq.3) Wsq=Wsq+delth**2/12.
ccc....change theta here to thetaX...for ipass=3 mods...grk..9-10-90
      fNsig=(thetRR-thetaX)/sigW
      ifNsig=fNsig/0.2+20.5
      if(ifNsig.lt.1) then
              fFRACT=value(1)
      else
              if(ifNsig.ge.41) then
                      fFRACT=1.0
              else
                      fFRACT=0.5*(value(ifNsig)+value(ifNsig+1))
              endif
      endif
CCCCCCCC....done................CCCCCCCCCCCCCC
              FRACT=fFRACT
      return
      end
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      subroutine SPREADmu(MMxpr,NNpT,dxpr,dpT,Ezero,yy,zzD)                   //
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
cc7-22-91..FIX..subroutine spreadGE(MMxpr,NNpT,dxpr,dpT,Ezero,yy,zz) to mu..
CCCCCCCCC...gamma/e+-.. spread out both cases is  ON-A-LINE (0,0) to (xpr,pT)
CCC......but for MU's along line from 0.57 to 1.0 instead in xpr,pT...
C..............THIS is because pT* of decays are negligible to pTproduced
c........(of order 70 MeV for gammas vs pTbins of 200, and nil for g-to-e)
c.....and 30 MeV/c for pi to mu's (K's treated as mu's..they are 10%-ish..OK).
c.....WILL BE WORSE approx. when bin sizes reduced and grid size increased..
c..........but still a reasonable approx....grk 9-28-90....
c....yy is input array, zzD output (D=DECAY factor)...
ccc...call spreadMU once to do single pion decay
CC..fix..7-17-91         dimension yy(20,20),zz(20,20),zxpr(100),zzpT(100)
ccc...100x100 and pTmax=4. GeV/c is AOK...grk 7-22-91
cc..debug dimension yy(100,100),zz(100,100),zxpr(100),zzpT(100),zzD(100,100)
      dimension yy(20,20),zz(20,20),zxpr(20),zzpT(20),zzd(20,20)
      dimension DECAY(100)
```

```
      data CtauPi/7.803/
c     MM,NN are EXTENT of arrays used in main...
      SUMmu=0.
      SUMdec=0.
      xpr=-dxpr/2.
      do 210 m=1,MMxpr
      xpr=xpr+dxpr
CCCCCC [ 1 -exp(L(eta*c*t) ] = L/(eta*CTauPi)..eta =Ezero*xpr(pi)/0.1396
              ddecay=(xpr*Ezero)/0.1396
              DECAY(m)=1./(ddecay*CTauPi)
CCCCCC now have decay FACTOR...to multiply finally zz upon exiting call..
      zxpr(m)=xpr
  210 continue
              xpr=-dxpr/2.
              do 10 m=1,MMxpr
                      mpion=m
              xpr=xpr+dxpr
      pT=-dpT/2.
      do 11 n=1,NNpT
      pT=pT+dpT
      zzpT(n)=pT
      aa=yy(m,n)
      if(n.gt.m) go to 3333
      xprmin=0.57*xpr
      bb=0.43*xpr/dxpr
      ibb=bb
cc   ibb total boxes on the diagonal line...ibb-1 are full and get
cc    1/bb-th of aa, lowest gets balance.....
      mm=m-ibb+1
      aabb=aa/bb
c and now zpT goes linearly with zxpr.....
      alpha=zzpT(n)/zxpr(m)
      do 97 mmm=mm,m
      zpT=alpha*zxpr(mmm)
      izpT=zpT/dpT+1.
      zz(mmm,izpT)=zz(mmm,izpT)+aabb
      zzD(mmm,izpT)=zzD(mmm,izpT)+aabb*DECAY(mpion)
   97 continue
c...find (and fill) partial bin
      ixpr=xprmin/dxpr+1.
      zpl=alpha*xprmin
      izpl=zpl/dpT+1.
      zz(ixpr,izpl)=zz(ixpr,izpl)+aabb*(bb-ibb)
      zzD(ixpr,izpl)=zzD(ixpr,izpl)+aabb*(bb-ibb)*DECAY(mpion)
cccccccccccccccccccccccccccccccccccccc*****************this MUST be tested
      go to 3344
ccccccccccccccccccccopposite case..
 3333 pTmin=0.57*pT
      bb=0.43*pT/dpT
      ibb=bb
      nn=n-ibb+1
      aabb=aa/bb
c now zxpr goes linearly with zpT
      alpha=xpr/pT
      do 397 nnn=nn,n
      zzxpr=alpha*zzpT(nnn)
      izxpr=zzxpr/dxpr+1.
      zz(izxpr,nnn)=zz(izxpr,nnn)+aabb
      zzD(izxpr,nnn)=zzD(izxpr,nnn)+aabb*DECAY(mpion)
  397 continue
c....find (and fill in) partial bin
      ipT=pTmin/dpT+1.
      xpl=alpha*pTmin
      ixpl=xpl/dxpr+1.
      zz(ixpl,ipT)=zz(ixpl,ipT)+aabb*(bb-ibb)
```

```
 3344   continue
cccccc......done....
   98   continue
c...and is FINI
CCCCCCCCCCCCCCCCCCCCCC
   11   continue
   10   continue
CCCCCCCCCCCCCCCCCCCCCC...to restor....see above fixes..
        do 21 m=1,MMxpr
        do 21 n=1,NNpT
        SUMmu=SUMmu+zz(m,n)
        SUMdec=SUMdec+zzD(m,n)
   21   continue
        write(55,22)SUMmu,SUMdec
   22   format(//1x,'.....SUMmu(mb),SUMdec(mb)=',f10.1,f10.4)
c...write zz(mu) all pions decay..out HERE..
        write(55,44)((zz(m,n),m=1,MMxpr),n=1,NNpT)
   44   format(/(1x,10e8.1))
        return
        end
        subroutine russian(itype,xpr,pperp,atwt,Ezero,dsdp3)
c       parameters for particle yields...1=pi+, 2=pi- from New Russian Xlation
c       "Passage of H.E. Particles thru Matter, AN Kalinovski,etal,AIP,eqn3.26
        dimension c1(5),c2(5),c3(5),c4(5),c5(5),c6(5),fm(5),omeg(5),
     x  fmusq(5),bzero(5),gam(5)
CCCC
C        1=pi+, 2=pi-, 3=K+, 4=K- and 5=p- (ie pbar)    ( =i = itype)
CCCC
c       units are GeV for fm,omeg,gam (and GeV**-1 for bzero)...)
        data c1/0.25, 0.20, 0.075, 0.078, 0.080/
        data c2/3.1, 4.0, 2.5, 6.1, 8.6/
        data c3/0.88, 1.18, 1.60, 2.46, 2.30/
        data c4/3.0, 3.0, 3.0, 3.5, 4.2/
        data c5/2., 2., 2., 2., 2./
        data c6/11.3, 9.8, 10.7, 8.8, 10.5/
        data fm/2*0.1396, 2*0.4937, 0.9382/
        data omeg/1.8778, 2.016, 2.054, 2.370, 2.815/
        data fmusq/0.88, 0.86, 1.2, 1.2, 1.1/
        data bzero/0.10, 0.11, 0.12, 0.12, 0.12/
        data gam/4.0, 3.5, 4.0, 4.0, 5.0/
c
c       formulae 3.26...given as function of "p-perp and x-prime"...to be input
c       where x-prime=(E*/E*max)...ie 0. thru +1.
        i=itype
        srtofS=sqrt(2.0*0.9382*Ezero)
        bperp=bzero(i)*pperp
        if(pperp.gt.gam(i)) bperp=bzero(i)*gam(i)
        psq=pperp**2
        xperp=2.*pperp/srtofS
        phi=exp(-c4(i)*psq)+c5(i)*exp(-c6(i)*xperp)/((psq+fmusq(i)**2)**4)
        xxx=c1(i)*(atwt**bperp)*((1.-xpr)**c2(i))*exp(-c3(i)*xpr)*phi
c..........AND SCALE BY Be absorption crossection (199 mb)
        ccsect=((atwt-0.40)/(9.01-0.40))**0.69
        ccsect=ccsect*199.
        xxx=ccsect*xxx
        dsdp3=xxx
        return
        end
```

PROGRAM.. muSCatZ ..(muons/m**2/10**12 p) per meter
.....of decay path...INCLUDES radiative dEdx & Mult. Scat.

russian TOTAL sigma(mb)= 1234.7for A,E0,RR= 9.0 200.0 1.0

134.9918	35.3300	16.5074	9.0959	5.3990	3.3297	2.0935	1.3259	0.8384	0.5252
0.3236	0.1944	0.1128	0.0623	0.0322	0.0151	0.0061	0.0019	0.0004	0.0000
250.5505	65.4861	30.5640	16.8270	9.9815	6.1530	3.8676	2.4493	1.5489	0.9706
0.5982	0.3597	0.2088	0.1155	0.0597	0.0280	0.0113	0.0036	0.0007	0.0000
201.5472	52.6052	24.5261	13.4925	7.9997	4.9302	3.0991	1.9631	1.2421	0.7789
0.4806	0.2893	0.1682	0.0933	0.0484	0.0228	0.0093	0.0029	0.0006	0.0000
116.4698	30.3722	14.1512	7.7818	4.6129	2.8430	1.7875	1.1328	0.7172	0.4501
0.2780	0.1676	0.0976	0.0542	0.0282	0.0133	0.0054	0.0017	0.0003	0.0000
54.8989	14.3125	6.6675	3.6663	2.1734	1.3397	0.8425	0.5341	0.3383	0.2124
0.1313	0.0792	0.0462	0.0257	0.0134	0.0063	0.0026	0.0008	0.0002	0.0000
22.2096	5.7892	2.6965	1.4825	0.8787	0.5416	0.3405	0.2159	0.1367	0.0859
0.0531	0.0320	0.0187	0.0104	0.0054	0.0026	0.0011	0.0003	0.0001	0.0000
8.1658	2.1263	0.9894	0.5434	0.3218	0.1982	0.1245	0.0789	0.0499	0.0313
0.0193	0.0117	0.0068	0.0038	0.0020	0.0009	0.0004	0.0001	0.0000	0.0000
2.9795	0.7738	0.3592	0.1969	0.1163	0.0715	0.0448	0.0284	0.0179	0.0112
0.0069	0.0042	0.0024	0.0013	0.0007	0.0003	0.0001	0.0000	0.0000	0.0000
1.1762	0.3044	0.1408	0.0769	0.0453	0.0278	0.0174	0.0110	0.0069	0.0043
0.0027	0.0016	0.0009	0.0005	0.0003	0.0001	0.0001	0.0000	0.0000	0.0000
0.5163	0.1331	0.0614	0.0334	0.0197	0.0120	0.0075	0.0047	0.0030	0.0019
0.0011	0.0007	0.0004	0.0002	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000
0.2454	0.0631	0.0290	0.0158	0.0093	0.0057	0.0035	0.0022	0.0014	0.0009
0.0005	0.0003	0.0002	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
0.1226	0.0315	0.0144	0.0078	0.0046	0.0028	0.0017	0.0011	0.0007	0.0004
0.0003	0.0002	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0635	0.0162	0.0074	0.0040	0.0024	0.0014	0.0009	0.0006	0.0004	0.0002
0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0338	0.0086	0.0039	0.0021	0.0012	0.0008	0.0005	0.0003	0.0002	0.0001
0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0185	0.0047	0.0022	0.0012	0.0007	0.0004	0.0003	0.0002	0.0001	0.0001
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0104	0.0026	0.0012	0.0006	0.0004	0.0002	0.0001	0.0001	0.0001	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0059	0.0015	0.0007	0.0004	0.0002	0.0001	0.0001	0.0001	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0035	0.0009	0.0004	0.0002	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0020	0.0005	0.0002	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0012	0.0003	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

printed	24-jul-1991 11:23
filename	for055.dat;161
directory	_1duc0:[grk]
user	grk
job	for055
site	superconducting super collider

Page 2, muSCatZ .. using SPREADmu (mb), all pions decay
[next page (3) for 1 meter path length]...A,E0,RR= 9.0 200.0 1.0

.....SUMmu(mb),SUMdec(mb)= 1234.7 3.2112

0.5E+03	0.1E+02	0.2E+02	0.9E+01	0.5E+01	0.3E+01	0.2E+01	0.9E+00	0.5E+00	0.3E+00
0.2E+00	0.8E-01	0.4E-01	0.2E-01	0.9E-02	0.3E-02	0.1E-02	0.3E-03	0.5E-04	0.1E-05
0.7E+02	0.1E+02	0.3E+02	0.1E+02	0.8E+01	0.5E+01	0.3E+01	0.2E+01	0.1E+01	0.6E+00
0.3E+00	0.2E+00	0.8E-01	0.4E-01	0.2E-01	0.6E-02	0.2E-02	0.6E-03	0.9E-04	0.3E-05
0.2E+03	0.5E+02	0.2E+02	0.9E+01	0.8E+01	0.4E+01	0.2E+01	0.1E+01	0.8E+00	0.4E+00
0.2E+00	0.1E+00	0.6E-01	0.3E-01	0.1E-01	0.5E-02	0.2E-02	0.5E-03	0.7E-04	0.2E-05
0.8E+02	0.2E+02	0.1E+02	0.5E+01	0.3E+01	0.2E+01	0.1E+01	0.7E+00	0.4E+00	0.2E+00
0.1E+00	0.6E-01	0.4E-01	0.2E-01	0.8E-02	0.3E-02	0.1E-02	0.3E-03	0.4E-04	0.1E-05
0.4E+02	0.1E+02	0.5E+01	0.2E+01	0.1E+01	0.8E+00	0.4E+00	0.2E+00	0.2E+00	0.1E+00
0.5E-01	0.3E-01	0.1E-01	0.7E-02	0.3E-02	0.1E-02	0.5E-03	0.1E-03	0.2E-04	0.7E-06
0.1E+02	0.4E+01	0.2E+01	0.8E+00	0.5E+00	0.3E+00	0.2E+00	0.9E-01	0.5E-01	0.3E-01
0.2E-01	0.1E-01	0.6E-02	0.3E-02	0.1E-02	0.6E-03	0.2E-03	0.5E-04	0.9E-05	0.3E-06
0.4E+01	0.1E+01	0.5E+00	0.3E+00	0.2E+00	0.9E-01	0.6E-01	0.3E-01	0.2E-01	0.1E-01
0.6E-02	0.3E-02	0.2E-02	0.1E-02	0.5E-03	0.2E-03	0.7E-04	0.2E-04	0.3E-05	0.1E-06
0.1E+01	0.4E+00	0.2E+00	0.1E+00	0.5E-01	0.3E-01	0.2E-01	0.1E-01	0.6E-02	0.4E-02
0.2E-02	0.1E-02	0.6E-03	0.3E-03	0.2E-03	0.8E-04	0.3E-04	0.7E-05	0.1E-05	0.4E-07
0.5E+00	0.1E+00	0.7E-01	0.3E-01	0.2E-01	0.1E-01	0.7E-02	0.4E-02	0.3E-02	0.1E-02
0.8E-03	0.5E-03	0.2E-03	0.1E-03	0.5E-04	0.2E-04	0.1E-04	0.3E-05	0.4E-06	0.1E-07
0.2E+00	0.6E-01	0.3E-01	0.1E-01	0.9E-02	0.4E-02	0.3E-02	0.2E-02	0.1E-02	0.6E-03
0.3E-03	0.2E-03	0.1E-03	0.5E-04	0.2E-04	0.1E-04	0.4E-05	0.1E-05	0.2E-06	0.6E-08
0.1E+00	0.3E-01	0.1E-01	0.6E-02	0.3E-02	0.3E-02	0.1E-02	0.8E-03	0.4E-03	0.3E-03
0.2E-03	0.9E-04	0.5E-04	0.3E-04	0.1E-04	0.5E-05	0.2E-05	0.5E-06	0.8E-07	0.3E-08
0.5E-01	0.1E-01	0.6E-02	0.3E-02	0.2E-02	0.1E-02	0.5E-03	0.3E-03	0.2E-03	0.1E-03
0.7E-04	0.4E-04	0.2E-04	0.1E-04	0.5E-05	0.2E-05	0.8E-06	0.2E-06	0.4E-07	0.1E-08
0.2E-01	0.6E-02	0.3E-02	0.2E-02	0.8E-03	0.5E-03	0.4E-03	0.2E-03	0.1E-03	0.7E-04
0.4E-04	0.2E-04	0.1E-04	0.6E-05	0.3E-05	0.1E-05	0.4E-06	0.1E-06	0.2E-07	0.8E-09
0.1E-01	0.3E-02	0.1E-02	0.8E-03	0.4E-03	0.2E-03	0.2E-03	0.8E-04	0.5E-04	0.3E-04
0.2E-04	0.1E-04	0.6E-05	0.3E-05	0.1E-05	0.6E-06	0.2E-06	0.6E-07	0.1E-07	0.4E-09
0.6E-02	0.2E-02	0.7E-03	0.4E-03	0.2E-03	0.1E-03	0.7E-04	0.6E-04	0.3E-04	0.2E-04
0.1E-04	0.5E-05	0.3E-05	0.2E-05	0.8E-06	0.3E-06	0.1E-06	0.3E-07	0.6E-08	0.2E-09
0.3E-02	0.8E-03	0.4E-03	0.2E-03	0.1E-03	0.6E-04	0.4E-04	0.3E-04	0.1E-04	0.8E-05
0.5E-05	0.3E-05	0.2E-05	0.8E-06	0.4E-06	0.2E-06	0.7E-07	0.2E-07	0.3E-08	0.1E-09
0.2E-02	0.4E-03	0.2E-03	0.1E-03	0.6E-04	0.3E-04	0.2E-04	0.1E-04	0.1E-04	0.4E-05
0.3E-05	0.2E-05	0.9E-06	0.5E-06	0.2E-06	0.1E-06	0.4E-07	0.1E-07	0.2E-08	0.7E-10
0.9E-03	0.2E-03	0.1E-03	0.5E-04	0.3E-04	0.2E-04	0.1E-04	0.7E-05	0.5E-05	0.2E-05
0.1E-05	0.8E-06	0.5E-06	0.3E-06	0.1E-06	0.5E-07	0.2E-07	0.6E-08	0.1E-08	0.4E-10
0.4E-03	0.1E-03	0.5E-04	0.2E-04	0.1E-04	0.8E-05	0.5E-05	0.3E-05	0.2E-05	0.2E-05
0.7E-06	0.4E-06	0.2E-06	0.1E-06	0.6E-07	0.3E-07	0.1E-07	0.3E-08	0.6E-09	0.2E-10
0.1E-03	0.4E-04	0.2E-04	0.9E-05	0.5E-05	0.3E-05	0.2E-05	0.1E-05	0.7E-06	0.5E-06
0.3E-06	0.2E-06	0.1E-06	0.5E-07	0.3E-07	0.1E-07	0.5E-08	0.2E-08	0.4E-09	0.1E-10

0.1E+01	0.7E-02	0.1E-01	0.4E-02	0.2E-02	0.8E-03	0.4E-03	0.2E-03	0.9E-04	0.5E-04
0.2E-04	0.1E-04	0.5E-05	0.2E-05	0.1E-05	0.4E-06	0.1E-06	0.3E-07	0.4E-08	0.1E-09
0.2E+00	0.8E-02	0.2E-01	0.6E-02	0.3E-02	0.2E-02	0.8E-03	0.4E-03	0.2E-03	0.9E-04
0.5E-04	0.2E-04	0.1E-04	0.5E-05	0.2E-05	0.7E-06	0.2E-06	0.6E-07	0.8E-08	0.2E-09
0.8E+00	0.6E-01	0.2E-01	0.5E-02	0.3E-02	0.1E-02	0.5E-03	0.2E-03	0.1E-03	0.7E-04
0.4E-04	0.2E-04	0.8E-05	0.4E-05	0.2E-05	0.6E-06	0.2E-06	0.5E-07	0.7E-08	0.2E-09
0.3E+00	0.2E-01	0.7E-02	0.3E-02	0.1E-02	0.5E-03	0.3E-03	0.2E-03	0.7E-04	0.4E-04
0.2E-04	0.9E-05	0.5E-05	0.2E-05	0.9E-06	0.4E-06	0.1E-06	0.3E-07	0.4E-08	0.1E-09
0.1E+00	0.1E-01	0.4E-02	0.1E-02	0.5E-03	0.2E-03	0.1E-03	0.5E-04	0.4E-04	0.2E-04
0.8E-05	0.4E-05	0.2E-05	0.9E-06	0.4E-06	0.2E-06	0.5E-07	0.1E-07	0.2E-08	0.7E-10
0.5E-01	0.4E-02	0.1E-02	0.4E-03	0.2E-03	0.9E-04	0.4E-04	0.2E-04	0.1E-04	0.5E-05
0.4E-05	0.2E-05	0.8E-06	0.4E-06	0.2E-06	0.6E-07	0.2E-07	0.5E-08	0.8E-09	0.3E-10
0.2E-01	0.1E-02	0.3E-03	0.2E-03	0.6E-04	0.3E-04	0.1E-04	0.7E-05	0.4E-05	0.2E-05
0.9E-06	0.5E-06	0.3E-06	0.1E-06	0.6E-07	0.2E-07	0.8E-08	0.2E-08	0.3E-09	0.1E-10
0.5E-02	0.5E-03	0.1E-03	0.5E-04	0.2E-04	0.9E-05	0.5E-05	0.3E-05	0.1E-05	0.7E-06
0.4E-06	0.2E-06	0.8E-07	0.4E-07	0.2E-07	0.9E-08	0.3E-08	0.7E-09	0.1E-09	0.3E-11
0.2E-02	0.2E-03	0.5E-04	0.2E-04	0.9E-05	0.3E-05	0.2E-05	0.9E-06	0.5E-06	0.3E-06
0.1E-06	0.7E-07	0.3E-07	0.2E-07	0.7E-08	0.3E-08	0.1E-08	0.3E-09	0.4E-10	0.1E-11
0.8E-03	0.7E-04	0.2E-04	0.7E-05	0.3E-05	0.1E-05	0.7E-06	0.4E-06	0.2E-06	0.1E-06
0.6E-07	0.3E-07	0.1E-07	0.7E-08	0.3E-08	0.1E-08	0.4E-09	0.1E-09	0.2E-10	0.6E-12
0.4E-03	0.3E-04	0.8E-05	0.3E-05	0.1E-05	0.8E-06	0.3E-06	0.2E-06	0.9E-07	0.5E-07
0.3E-07	0.1E-07	0.7E-08	0.3E-08	0.1E-08	0.5E-09	0.2E-09	0.5E-10	0.8E-11	0.3E-12
0.2E-03	0.2E-04	0.4E-05	0.1E-05	0.6E-06	0.4E-06	0.1E-06	0.8E-07	0.4E-07	0.2E-07
0.1E-07	0.7E-08	0.3E-08	0.2E-08	0.7E-09	0.3E-09	0.9E-10	0.2E-10	0.4E-11	0.1E-12
0.9E-04	0.7E-05	0.2E-05	0.8E-06	0.3E-06	0.1E-06	0.9E-07	0.4E-07	0.2E-07	0.1E-07
0.6E-08	0.3E-08	0.2E-08	0.8E-09	0.3E-09	0.1E-09	0.5E-10	0.1E-10	0.2E-11	0.7E-13
0.4E-04	0.4E-05	0.1E-05	0.4E-06	0.2E-06	0.8E-07	0.5E-07	0.2E-07	0.1E-07	0.6E-08
0.3E-08	0.2E-08	0.8E-09	0.4E-09	0.2E-09	0.7E-10	0.2E-10	0.7E-11	0.1E-11	0.4E-13
0.2E-04	0.2E-05	0.5E-06	0.2E-06	0.8E-07	0.4E-07	0.2E-07	0.1E-07	0.5E-08	0.3E-08
0.2E-08	0.8E-09	0.4E-09	0.2E-09	0.1E-09	0.4E-10	0.1E-10	0.4E-11	0.6E-12	0.2E-13
0.1E-04	0.1E-05	0.3E-06	0.1E-06	0.4E-07	0.2E-07	0.1E-07	0.7E-08	0.3E-08	0.1E-08
0.8E-09	0.5E-09	0.2E-09	0.1E-09	0.5E-10	0.2E-10	0.7E-11	0.2E-11	0.3E-12	0.1E-13
0.6E-05	0.5E-06	0.1E-06	0.5E-07	0.2E-07	0.1E-07	0.6E-08	0.3E-08	0.2E-08	0.8E-09
0.4E-09	0.2E-09	0.1E-09	0.6E-10	0.3E-10	0.1E-10	0.4E-11	0.1E-11	0.2E-12	0.7E-14
0.3E-05	0.3E-06	0.7E-07	0.3E-07	0.1E-07	0.6E-08	0.3E-08	0.2E-08	0.1E-08	0.4E-09
0.2E-09	0.1E-09	0.6E-10	0.3E-10	0.1E-10	0.6E-11	0.2E-11	0.6E-12	0.1E-12	0.4E-14
0.1E-05	0.1E-06	0.3E-07	0.1E-07	0.6E-08	0.3E-08	0.1E-08	0.8E-09	0.4E-09	0.3E-09
0.1E-09	0.6E-10	0.3E-10	0.2E-10	0.8E-11	0.3E-11	0.1E-11	0.4E-12	0.6E-13	0.2E-14
0.5E-06	0.4E-07	0.1E-07	0.4E-08	0.2E-08	0.1E-08	0.5E-09	0.3E-09	0.2E-09	0.9E-10
0.5E-10	0.3E-10	0.1E-10	0.7E-11	0.3E-11	0.2E-11	0.6E-12	0.2E-12	0.3E-13	0.1E-14

Page 4, muSCatZ ...INSIDE results..
A,E0,RR= 9.0 200.0 1.0

PER METER OF DECAY PATH

first...UNscattered

Step#, Range(m), PPmin, Log10(mus/m**2/10**12,Radius=1,10)..

1	0.	0.	9.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	26.	10.	8.44	7.42	5.95	4.56	3.50	2.56	1.56	0.00	0.00	0.00
3	51.	20.	8.10	7.10	5.79	4.49	3.44	2.60	1.80	0.94	-0.15	0.00
4	74.	30.	7.65	6.70	5.50	4.22	3.18	2.36	1.58	0.83	-0.15	0.00
5	97.	40.	7.31	6.43	5.24	3.92	2.95	2.07	1.28	0.60	-0.28	0.00
6	120.	50.	6.99	6.13	4.94	3.65	2.63	1.83	1.03	0.25	-0.58	0.00
7	141.	60.	6.68	5.84	4.63	3.37	2.32	1.54	0.76	-0.03	-0.88	0.00
8	162.	70.	6.36	5.54	4.33	3.09	2.07	1.20	0.53	-0.30	-1.18	0.00
9	182.	80.	6.06	5.26	4.08	2.78	1.79	0.93	0.12	-0.49	-1.66	0.00
10	202.	90.	5.75	4.96	3.79	2.49	1.51	0.64	-0.15	-0.88	-1.78	0.00
11	221.	100.	5.43	4.65	3.50	2.18	1.21	0.33	-0.43	-1.19	-2.56	0.00
12	240.	110.	5.10	4.34	3.18	1.86	0.89	0.00	-0.74	-1.55	-2.56	0.00
13	258.	120.	4.74	4.01	2.83	1.52	0.55	-0.31	-1.07	-1.89	-3.16	0.00
14	275.	130.	4.37	3.64	2.45	1.15	0.18	-0.66	-1.44	-2.24	-3.47	0.00
15	292.	140.	3.96	3.23	2.04	0.81	-0.24	-1.06	-1.84	-2.60	-4.07	0.00
16	309.	150.	3.50	2.78	1.58	0.36	-0.70	-1.50	-2.27	-3.05	0.00	0.00
17	325.	160.	2.97	2.25	1.05	-0.15	-1.22	-2.03	-2.78	-3.55	0.00	0.00
18	341.	170.	2.32	1.59	0.41	-0.81	-1.85	-2.68	-3.40	-4.21	0.00	0.00
19	356.	180.	1.44	0.72	-0.46	-1.71	-2.70	-3.55	-4.26	-5.03	0.00	0.00
20	371.	190.	-0.10	-0.81	-1.97	-3.25	-4.21	-5.05	-5.76	-6.54	0.00	0.00

second .. Multiply Scattered

Step#, Range(m), PPmin, Log10(mus/m**2/10**12,Radius=1,10)..

1	0.	0.	9.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	26.	10.	8.39	7.52	6.42	5.04	3.80	2.80	1.84	0.68	0.00	0.00
3	51.	20.	8.02	7.18	6.43	5.48	4.35	3.26	2.31	1.49	0.45	-0.20
4	74.	30.	7.56	6.73	6.15	5.37	4.42	3.56	2.48	1.53	0.82	-0.03
5	97.	40.	7.20	6.43	5.88	5.22	4.50	3.61	2.66	1.67	0.78	0.10
6	120.	50.	6.88	6.09	5.61	5.03	4.35	3.57	2.70	1.74	0.82	-0.03
7	141.	60.	6.56	5.75	5.33	4.79	4.20	3.49	2.71	1.83	0.86	-0.03
8	162.	70.	6.24	5.44	5.02	4.56	4.01	3.37	2.63	1.81	0.89	-0.07
9	182.	80.	5.94	5.12	4.71	4.32	3.77	3.20	2.48	1.73	0.88	-0.09
10	202.	90.	5.64	4.79	4.40	4.04	3.55	2.94	2.34	1.61	0.82	-0.08
11	221.	100.	5.32	4.45	4.12	3.75	3.23	2.79	2.11	1.46	0.69	-0.22
12	240.	110.	4.99	4.09	3.82	3.37	3.03	2.49	1.90	1.24	0.53	-0.33
13	258.	120.	4.64	3.73	3.47	3.06	2.75	2.10	1.72	0.93	0.35	-0.57
14	275.	130.	4.26	3.35	3.10	2.70	2.36	1.84	1.31	0.82	0.00	-0.62
15	292.	140.	3.85	2.94	2.70	2.28	1.91	1.59	0.90	0.45	-0.20	-1.00
16	309.	150.	3.39	2.47	2.23	1.84	1.47	1.13	0.57	-0.01	-0.55	-1.30
17	325.	160.	2.86	1.93	1.67	1.35	0.96	0.58	0.17	-0.51	-1.05	-1.69
18	341.	170.	2.21	1.26	1.02	0.70	0.31	-0.06	-0.50	-1.01	-1.67	-2.27
19	356.	180.	1.33	0.37	0.15	-0.18	-0.55	-0.94	-1.35	-1.81	-2.47	-3.11
20	371.	190.	-0.20	-1.16	-1.42	-1.69	-2.01	-2.46	-2.87	-3.35	-3.93	-4.57

Bfield(Tesla), Path(m.)= 2.00 0.30

third PASS..SOLENOID-ally bent outward

Step#, Range(m), PPmin, Log10(mus/m**2/10**12,Radius=1,10)..

1	0.	0.	9.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	26.	10.	8.35	7.57	6.60	5.22	3.95	2.94	1.98	0.90	0.00	0.00
3	51.	20.	7.97	7.24	6.53	5.62	4.57	3.43	2.44	1.63	0.75	-0.20
4	74.	30.	7.50	6.77	6.23	5.51	4.58	3.75	2.68	1.69	0.89	0.20
5	97.	40.	7.16	6.46	5.93	5.35	4.61	3.77	2.86	1.84	0.93	0.20
6	120.	50.	6.84	6.09	5.67	5.12	4.50	3.76	2.92	1.99	1.04	0.12
7	141.	60.	6.51	5.79	5.37	4.87	4.32	3.61	2.84	1.98	1.06	0.10
8	162.	70.	6.20	5.44	5.07	4.63	4.10	3.47	2.75	1.95	1.05	0.11
9	182.	80.	5.90	5.13	4.76	4.38	3.85	3.28	2.63	1.89	1.05	0.12
10	202.	90.	5.59	4.80	4.47	4.06	3.61	3.09	2.42	1.74	0.98	0.00
11	221.	100.	5.28	4.47	4.15	3.76	3.39	2.79	2.26	1.55	0.82	0.00
12	240.	110.	4.95	4.12	3.81	3.49	3.05	2.53	2.02	1.34	0.65	-0.17
13	258.	120.	4.59	3.79	3.43	3.19	2.66	2.36	1.67	1.17	0.35	-0.28
14	275.	130.	4.24	3.37	3.05	2.81	2.36	1.99	1.36	0.81	0.27	-0.62
15	292.	140.	3.85	2.91	2.64	2.40	1.98	1.52	1.17	0.42	-0.11	-0.77
16	309.	150.	3.39	2.45	2.18	1.93	1.56	1.10	0.70	0.13	-0.55	-1.14
17	325.	160.	2.85	1.91	1.63	1.39	1.07	0.61	0.16	-0.29	-1.00	-1.64
18	341.	170.	2.20	1.26	0.98	0.73	0.40	0.02	-0.47	-0.93	-1.49	-2.20
19	356.	180.	1.32	0.39	0.09	-0.17	-0.42	-0.86	-1.31	-1.80	-2.31	-2.99
20	371.	190.	-0.22	-1.14	-1.44	-1.70	-1.98	-2.34	-2.77	-3.31	-3.84	-4.45

PROGRAM.. muSCatZ ..(muons/m**2/10**12 p) per meter
.....of decay path...INCLUDES radiative dEdx & Mult. Scat.

russian TOTAL sigma(mb)= 1584.7for A,E0,RR= 9.0 2000.0 1.0

143.3876	37.5395	17.5447	9.6699	5.7410	3.5413	2.2269	1.4106	0.8921	0.5589
0.3444	0.2069	0.1200	0.0663	0.0342	0.0160	0.0065	0.0020	0.0004	0.0000
296.9518	77.6911	36.2919	19.9955	11.8688	7.3204	4.6035	2.9165	1.8449	1.1564
0.7128	0.4286	0.2488	0.1376	0.0711	0.0334	0.0135	0.0042	0.0008	0.0000
260.8983	68.2053	31.8432	17.5384	10.4088	6.4202	4.0383	2.5594	1.6199	1.0161
0.6269	0.3774	0.2194	0.1215	0.0630	0.0296	0.0120	0.0038	0.0007	0.0000
162.3022	42.4061	19.7908	10.8982	6.4677	3.9898	2.5103	1.5916	1.0080	0.6327
0.3907	0.2355	0.1371	0.0761	0.0395	0.0186	0.0076	0.0024	0.0005	0.0000
83.2140	21.7364	10.1427	5.5849	3.3145	2.0449	1.2869	0.8162	0.5171	0.3247
0.2007	0.1210	0.0705	0.0392	0.0204	0.0096	0.0039	0.0012	0.0002	0.0000
38.1504	9.9617	4.6470	2.5582	1.5180	0.9364	0.5892	0.3737	0.2368	0.1487
0.0919	0.0554	0.0323	0.0180	0.0093	0.0044	0.0018	0.0006	0.0001	0.0000
16.8844	4.4043	2.0527	1.1292	0.6696	0.4128	0.2596	0.1646	0.1042	0.0655
0.0404	0.0244	0.0142	0.0079	0.0041	0.0019	0.0008	0.0003	0.0000	0.0000
7.7589	2.0204	0.9402	0.5165	0.3059	0.1884	0.1184	0.0750	0.0475	0.0298
0.0184	0.0111	0.0065	0.0036	0.0019	0.0009	0.0004	0.0001	0.0000	0.0000
3.8410	0.9982	0.4637	0.2544	0.1505	0.0926	0.0581	0.0368	0.0233	0.0146
0.0090	0.0054	0.0032	0.0018	0.0009	0.0004	0.0002	0.0001	0.0000	0.0000
2.0370	0.5284	0.2451	0.1343	0.0794	0.0488	0.0306	0.0194	0.0123	0.0077
0.0047	0.0029	0.0017	0.0009	0.0005	0.0002	0.0001	0.0000	0.0000	0.0000
1.1357	0.2942	0.1363	0.0746	0.0440	0.0271	0.0170	0.0107	0.0068	0.0043
0.0026	0.0016	0.0009	0.0005	0.0003	0.0001	0.0001	0.0000	0.0000	0.0000
0.6574	0.1700	0.0787	0.0430	0.0254	0.0156	0.0098	0.0062	0.0039	0.0024
0.0015	0.0009	0.0005	0.0003	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000
0.3927	0.1014	0.0469	0.0256	0.0151	0.0093	0.0058	0.0037	0.0023	0.0015
0.0009	0.0005	0.0003	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
0.2413	0.0623	0.0287	0.0157	0.0092	0.0057	0.0036	0.0022	0.0014	0.0009
0.0005	0.0003	0.0002	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
0.1521	0.0392	0.0181	0.0099	0.0058	0.0036	0.0022	0.0014	0.0009	0.0006
0.0003	0.0002	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0981	0.0253	0.0117	0.0063	0.0037	0.0023	0.0014	0.0009	0.0006	0.0004
0.0002	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0647	0.0166	0.0077	0.0042	0.0025	0.0015	0.0009	0.0006	0.0004	0.0002
0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0435	0.0112	0.0051	0.0028	0.0016	0.0010	0.0006	0.0004	0.0003	0.0002
0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0293	0.0075	0.0035	0.0019	0.0011	0.0007	0.0004	0.0003	0.0002	0.0001
0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0200	0.0051	0.0024	0.0013	0.0008	0.0005	0.0003	0.0002	0.0001	0.0001
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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user	grk
job	for055
site	superconducting super collider

Page 2, muSCatZ .. using SPREADmu (mb), all pions decay
[next page (3) for 1 meter path length]...A,E0,RR= 9.0 2000.0 1.0

.....SUMmu(mb),SUMdec(mb)= 1584.7 0.4119

0.6E+03	0.1E+02	0.2E+02	0.1E+02	0.5E+01	0.3E+01	0.2E+01	0.9E+00	0.5E+00	0.3E+00
0.2E+00	0.9E-01	0.4E-01	0.2E-01	0.9E-02	0.4E-02	0.1E-02	0.3E-03	0.5E-04	0.1E-05
0.9E+02	0.2E+02	0.4E+02	0.2E+02	0.1E+02	0.7E+01	0.4E+01	0.2E+01	0.1E+01	0.7E+00
0.4E+00	0.2E+00	0.9E-01	0.4E-01	0.2E-01	0.8E-02	0.3E-02	0.7E-03	0.1E-03	0.3E-05
0.3E+03	0.7E+02	0.3E+02	0.1E+02	0.1E+02	0.6E+01	0.3E+01	0.1E+01	0.1E+01	0.6E+00
0.3E+00	0.2E+00	0.8E-01	0.4E-01	0.2E-01	0.7E-02	0.2E-02	0.6E-03	0.9E-04	0.3E-05
0.1E+03	0.3E+02	0.1E+02	0.8E+01	0.4E+01	0.2E+01	0.2E+01	0.1E+01	0.5E+00	0.3E+00
0.2E+00	0.9E-01	0.5E-01	0.2E-01	0.1E-01	0.4E-02	0.1E-02	0.4E-03	0.6E-04	0.2E-05
0.6E+02	0.2E+02	0.8E+01	0.4E+01	0.2E+01	0.1E+01	0.7E+00	0.4E+00	0.3E+00	0.2E+00
0.8E-01	0.4E-01	0.2E-01	0.1E-01	0.5E-02	0.2E-02	0.8E-03	0.2E-03	0.3E-04	0.1E-05
0.2E+02	0.7E+01	0.3E+01	0.1E+01	0.9E+00	0.5E+00	0.3E+00	0.2E+00	0.9E-01	0.5E-01
0.4E-01	0.2E-01	0.1E-01	0.5E-02	0.2E-02	0.1E-02	0.3E-03	0.9E-04	0.1E-04	0.5E-06
0.1E+02	0.3E+01	0.1E+01	0.7E+00	0.3E+00	0.2E+00	0.1E+00	0.7E-01	0.4E-01	0.2E-01
0.1E-01	0.7E-02	0.5E-02	0.3E-02	0.1E-02	0.4E-03	0.1E-03	0.4E-04	0.6E-05	0.2E-06
0.4E+01	0.1E+01	0.5E+00	0.3E+00	0.1E+00	0.9E-01	0.5E-01	0.3E-01	0.2E-01	0.1E-01
0.6E-02	0.3E-02	0.2E-02	0.8E-03	0.5E-03	0.2E-03	0.7E-04	0.2E-04	0.3E-05	0.1E-06
0.2E+01	0.5E+00	0.2E+00	0.1E+00	0.8E-01	0.4E-01	0.3E-01	0.2E-01	0.9E-02	0.5E-02
0.3E-02	0.2E-02	0.9E-03	0.4E-03	0.2E-03	0.8E-04	0.4E-04	0.1E-04	0.1E-05	0.5E-07
0.1E+01	0.3E+00	0.1E+00	0.6E-01	0.4E-01	0.2E-01	0.1E-01	0.8E-02	0.4E-02	0.3E-02
0.2E-02	0.9E-03	0.5E-03	0.2E-03	0.1E-03	0.4E-04	0.2E-04	0.4E-05	0.8E-06	0.3E-07
0.6E+00	0.2E+00	0.7E-01	0.3E-01	0.2E-01	0.1E-01	0.6E-02	0.4E-02	0.2E-02	0.1E-02
0.9E-03	0.5E-03	0.3E-03	0.1E-03	0.6E-04	0.2E-04	0.9E-05	0.2E-05	0.4E-06	0.1E-07
0.3E+00	0.8E-01	0.4E-01	0.2E-01	0.1E-01	0.7E-02	0.3E-02	0.2E-02	0.1E-02	0.8E-03
0.5E-03	0.3E-03	0.1E-03	0.7E-04	0.3E-04	0.1E-04	0.5E-05	0.1E-05	0.2E-06	0.9E-08
0.2E+00	0.5E-01	0.2E-01	0.1E-01	0.6E-02	0.3E-02	0.3E-02	0.1E-02	0.7E-03	0.5E-03
0.3E-03	0.2E-03	0.9E-04	0.4E-04	0.2E-04	0.9E-05	0.3E-05	0.9E-06	0.1E-06	0.5E-08
0.1E+00	0.3E-01	0.1E-01	0.7E-02	0.3E-02	0.2E-02	0.2E-02	0.7E-03	0.4E-03	0.3E-03
0.2E-03	0.9E-04	0.5E-04	0.3E-04	0.1E-04	0.5E-05	0.2E-05	0.5E-06	0.9E-07	0.3E-08
0.6E-01	0.2E-01	0.7E-02	0.4E-02	0.2E-02	0.1E-02	0.7E-03	0.6E-03	0.3E-03	0.2E-03
0.1E-03	0.5E-04	0.3E-04	0.2E-04	0.8E-05	0.3E-05	0.1E-05	0.3E-06	0.6E-07	0.2E-08
0.4E-01	0.9E-02	0.4E-02	0.2E-02	0.1E-02	0.7E-03	0.4E-03	0.3E-03	0.2E-03	0.1E-03
0.6E-04	0.4E-04	0.2E-04	0.1E-04	0.5E-05	0.2E-05	0.8E-06	0.2E-06	0.4E-07	0.1E-08
0.2E-01	0.5E-02	0.3E-02	0.1E-02	0.8E-03	0.4E-03	0.3E-03	0.2E-03	0.1E-03	0.6E-04
0.4E-04	0.2E-04	0.1E-04	0.6E-05	0.3E-05	0.1E-05	0.5E-06	0.1E-06	0.2E-07	0.9E-09
0.1E-01	0.3E-02	0.1E-02	0.8E-03	0.5E-03	0.3E-03	0.2E-03	0.1E-03	0.8E-04	0.3E-04
0.2E-04	0.1E-04	0.7E-05	0.4E-05	0.2E-05	0.8E-06	0.3E-06	0.1E-06	0.2E-07	0.6E-09
0.6E-02	0.2E-02	0.7E-03	0.4E-03	0.2E-03	0.1E-03	0.9E-04	0.6E-04	0.3E-04	0.3E-04
0.1E-04	0.7E-05	0.4E-05	0.2E-05	0.1E-05	0.5E-06	0.2E-06	0.6E-07	0.1E-07	0.4E-09
0.2E-02	0.6E-03	0.3E-03	0.2E-03	0.9E-04	0.6E-04	0.3E-04	0.2E-04	0.1E-04	0.9E-05
0.5E-05	0.3E-05	0.2E-05	0.1E-05	0.6E-06	0.3E-06	0.1E-06	0.4E-07	0.7E-08	0.3E-09

0.2E+00	0.8E-03	0.2E-02	0.4E-03	0.2E-03	0.8E-04	0.4E-04	0.2E-04	0.1E-04	0.5E-05
0.3E-05	0.1E-05	0.6E-06	0.3E-06	0.1E-06	0.4E-07	0.1E-07	0.3E-08	0.5E-09	0.1E-10
0.3E-01	0.1E-02	0.3E-02	0.8E-03	0.4E-03	0.2E-03	0.1E-03	0.5E-04	0.2E-04	0.1E-04
0.6E-05	0.3E-05	0.1E-05	0.5E-06	0.2E-06	0.9E-07	0.3E-07	0.7E-08	0.1E-08	0.3E-10
0.1E+00	0.8E-02	0.2E-02	0.6E-03	0.4E-03	0.2E-03	0.7E-04	0.3E-04	0.2E-04	0.1E-04
0.5E-05	0.2E-05	0.1E-05	0.5E-06	0.2E-06	0.8E-07	0.2E-07	0.6E-08	0.9E-09	0.3E-10
0.4E-01	0.3E-02	0.1E-02	0.4E-03	0.2E-03	0.7E-04	0.5E-04	0.2E-04	0.1E-04	0.5E-05
0.3E-05	0.1E-05	0.7E-06	0.3E-06	0.1E-06	0.5E-07	0.2E-07	0.4E-08	0.6E-09	0.2E-10
0.2E-01	0.2E-02	0.6E-03	0.2E-03	0.8E-04	0.4E-04	0.2E-04	0.8E-05	0.6E-05	0.3E-05
0.1E-05	0.6E-06	0.3E-06	0.1E-06	0.6E-07	0.2E-07	0.8E-08	0.2E-08	0.3E-09	0.9E-11
0.9E-02	0.8E-03	0.2E-03	0.7E-04	0.3E-04	0.2E-04	0.8E-05	0.4E-05	0.2E-05	0.9E-06
0.7E-06	0.3E-06	0.1E-06	0.6E-07	0.3E-07	0.1E-07	0.4E-08	0.9E-09	0.1E-09	0.4E-11
0.4E-02	0.3E-03	0.8E-04	0.4E-04	0.1E-04	0.6E-05	0.3E-05	0.2E-05	0.9E-06	0.4E-06
0.2E-06	0.1E-06	0.7E-07	0.3E-07	0.1E-07	0.5E-08	0.2E-08	0.4E-09	0.6E-10	0.2E-11
0.2E-02	0.1E-03	0.3E-04	0.1E-04	0.5E-05	0.3E-05	0.1E-05	0.7E-06	0.4E-06	0.2E-06
0.1E-06	0.5E-07	0.2E-07	0.1E-07	0.6E-08	0.2E-08	0.7E-09	0.2E-09	0.3E-10	0.9E-12
0.7E-03	0.6E-04	0.2E-04	0.6E-05	0.3E-05	0.1E-05	0.7E-06	0.3E-06	0.2E-06	0.9E-07
0.5E-07	0.3E-07	0.1E-07	0.5E-08	0.2E-08	0.9E-09	0.4E-09	0.1E-09	0.1E-10	0.4E-12
0.4E-03	0.3E-04	0.9E-05	0.3E-05	0.2E-05	0.6E-06	0.3E-06	0.2E-06	0.9E-07	0.5E-07
0.3E-07	0.1E-07	0.7E-08	0.3E-08	0.1E-08	0.5E-09	0.2E-09	0.5E-10	0.7E-11	0.2E-12
0.2E-03	0.2E-04	0.4E-05	0.2E-05	0.7E-06	0.4E-06	0.2E-06	0.9E-07	0.5E-07	0.3E-07
0.1E-07	0.7E-08	0.3E-08	0.2E-08	0.7E-09	0.3E-09	0.1E-09	0.3E-10	0.4E-11	0.1E-12
0.1E-03	0.1E-04	0.2E-05	0.8E-06	0.4E-06	0.2E-06	0.9E-07	0.5E-07	0.3E-07	0.1E-07
0.8E-08	0.4E-08	0.2E-08	0.9E-09	0.4E-09	0.2E-09	0.6E-10	0.1E-10	0.2E-11	0.8E-13
0.6E-04	0.5E-05	0.1E-05	0.6E-06	0.2E-06	0.1E-06	0.7E-07	0.3E-07	0.1E-07	0.9E-08
0.4E-08	0.2E-08	0.1E-08	0.6E-09	0.2E-09	0.1E-09	0.3E-10	0.9E-11	0.1E-11	0.5E-13
0.4E-04	0.3E-05	0.8E-06	0.3E-06	0.1E-06	0.7E-07	0.4E-07	0.2E-07	0.9E-08	0.5E-08
0.3E-08	0.1E-08	0.7E-09	0.3E-09	0.1E-09	0.6E-10	0.2E-10	0.5E-11	0.9E-12	0.3E-13
0.2E-04	0.2E-05	0.5E-06	0.2E-06	0.8E-07	0.4E-07	0.2E-07	0.1E-07	0.5E-08	0.3E-08
0.2E-08	0.8E-09	0.4E-09	0.2E-09	0.9E-10	0.4E-10	0.1E-10	0.3E-11	0.6E-12	0.2E-13
0.1E-04	0.1E-05	0.3E-06	0.1E-06	0.4E-07	0.2E-07	0.1E-07	0.8E-08	0.3E-08	0.2E-08
0.9E-09	0.5E-09	0.3E-09	0.1E-09	0.6E-10	0.2E-10	0.8E-11	0.2E-11	0.4E-12	0.1E-13
0.8E-05	0.6E-06	0.2E-06	0.6E-07	0.3E-07	0.1E-07	0.7E-08	0.4E-08	0.3E-08	0.1E-08
0.6E-09	0.3E-09	0.2E-09	0.8E-10	0.4E-10	0.2E-10	0.5E-11	0.1E-11	0.2E-12	0.8E-14
0.4E-05	0.4E-06	0.1E-06	0.4E-07	0.2E-07	0.8E-08	0.4E-08	0.2E-08	0.2E-08	0.6E-09
0.3E-09	0.2E-09	0.1E-09	0.5E-10	0.2E-10	0.9E-11	0.3E-11	0.1E-11	0.2E-12	0.6E-14
0.2E-05	0.2E-06	0.5E-07	0.2E-07	0.9E-08	0.5E-08	0.2E-08	0.1E-08	0.7E-09	0.5E-09
0.2E-09	0.1E-09	0.6E-10	0.3E-10	0.1E-10	0.6E-11	0.2E-11	0.6E-12	0.1E-12	0.4E-14
0.9E-06	0.7E-07	0.2E-07	0.8E-08	0.4E-08	0.2E-08	0.9E-09	0.5E-09	0.3E-09	0.2E-09
0.9E-10	0.5E-10	0.3E-10	0.1E-10	0.7E-11	0.3E-11	0.1E-11	0.4E-12	0.7E-13	0.3E-14

Page 4, muSCatZ ...INSIDE results..
A,E0,RR= 9.0 2000.0 1.0 m.

$\bar{E}_{e_{TOT}}$ → i.e. 2 TeV !

PER METER OF DECAY PATH ← + !!

first...UNscattered

Step#,	Range(m),		PPmin,	Log10(mus/m**2/10**12,Radius=1,10)..								
1	0.	0.	8.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	221.	100.	7.59	6.46	5.00	3.86	2.95	1.97	0.00	0.00	0.00	0.00
3	386.	200.	7.26	5.99	4.53	3.42	2.50	1.66	0.17	0.00	0.00	0.00
4	518.	300.	6.83	5.55	4.08	2.87	1.99	1.03	0.00	0.00	0.00	0.00
5	628.	400.	6.52	5.16	3.57	2.40	1.44	0.31	0.00	0.00	0.00	0.00
6	722.	500.	6.22	4.76	3.13	1.99	0.93	-0.60	0.00	0.00	0.00	0.00
7	804.	600.	5.92	4.36	2.71	1.58	0.42	0.00	0.00	0.00	0.00	0.00
8	877.	700.	5.62	4.00	2.34	1.12	-0.14	0.00	0.00	0.00	0.00	0.00
9	943.	800.	5.32	3.68	1.92	0.69	-0.75	0.00	0.00	0.00	0.00	0.00
10	1002.	900.	5.02	3.31	1.57	0.26	-1.47	0.00	0.00	0.00	0.00	0.00
11	1057.	1000.	4.71	2.95	1.17	-0.17	-2.71	0.00	0.00	0.00	0.00	0.00
12	1108.	1100.	4.39	2.58	0.78	-0.59	0.00	0.00	0.00	0.00	0.00	0.00
13	1155.	1200.	4.04	2.19	0.38	-1.05	0.00	0.00	0.00	0.00	0.00	0.00
14	1198.	1300.	3.67	1.77	-0.05	-1.55	0.00	0.00	0.00	0.00	0.00	0.00
15	1240.	1400.	3.27	1.31	-0.51	-2.10	0.00	0.00	0.00	0.00	0.00	0.00
16	1278.	1500.	2.81	0.79	-1.02	-2.71	0.00	0.00	0.00	0.00	0.00	0.00
17	1315.	1600.	2.28	0.23	-1.58	-3.44	0.00	0.00	0.00	0.00	0.00	0.00
18	1349.	1700.	1.63	-0.45	-2.28	-4.33	0.00	0.00	0.00	0.00	0.00	0.00
19	1382.	1800.	0.75	-1.38	-3.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	1413.	1900.	-0.79	-2.96	-4.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00

second .. Multiply Scattered

(E.G.) $5.29 \rightarrow 10^{5.29} = 2 \times 10^5\ \mu/m^2$ @ $\bar{R}$

Step#,	Range(m),		PPmin	Log10(mus/m**2/10**12,Radius=1,10)..								
1	0.	0.	8.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	221.	100.	7.48	6.57	5.93	5.44	4.69	3.79	2.85	1.76	0.78	-0.20
3	386.	200.	7.08	6.15	5.74	5.25	4.76	4.22	3.56	2.89	2.09	1.06
4	518.	300.	6.65	5.70	5.29	4.87	4.43	3.93	3.38	2.79	2.10	1.38
5	628.	400.	6.32	5.38	4.96	4.58	4.18	3.69	3.14	2.56	1.94	1.24
6	722.	500.	6.01	5.05	4.67	4.28	3.88	3.35	2.89	2.25	1.63	0.92
7	804.	600.	5.70	4.75	4.35	4.00	3.55	3.10	2.54	1.93	1.32	0.58
8	877.	700.	5.40	4.45	4.04	3.70	3.22	2.82	2.17	1.65	0.89	0.27
9	943.	800.	5.11	4.10	3.79	3.35	2.97	2.42	1.92	1.23	0.57	-0.18
10	1002.	900.	4.81	3.79	3.49	3.10	2.56	2.14	1.53	0.82	0.21	-0.65
11	1057.	1000.	4.49	3.51	3.14	2.76	2.30	1.75	1.18	0.54	-0.23	-1.19
12	1108.	1100.	4.16	3.21	2.81	2.38	1.97	1.44	0.81	0.11	-0.67	-1.81
13	1155.	1200.	3.82	2.85	2.47	2.07	1.60	1.02	0.39	-0.34	-1.12	-2.42
14	1198.	1300.	3.45	2.47	2.11	1.68	1.21	0.66	-0.05	-0.74	-1.58	-3.07
15	1240.	1400.	3.04	2.08	1.70	1.26	0.76	0.18	-0.48	-1.25	-2.09	-3.76
16	1278.	1500.	2.59	1.61	1.22	0.80	0.30	-0.30	-1.00	-1.79	-2.69	-4.51
17	1315.	1600.	2.06	1.08	0.70	0.25	-0.27	-0.88	-1.55	-2.40	-3.40	-5.22
18	1349.	1700.	1.41	0.42	0.05	-0.44	-0.92	-1.59	-2.30	-3.13	-4.29	-5.98
19	1382.	1800.	0.53	-0.46	-0.82	-1.30	-1.83	-2.48	-3.26	-4.05	-5.41	-7.73
20	1413.	1900.	-1.00	-1.97	-2.40	-2.83	-3.41	-4.05	-4.82	-5.71	-7.23	0.00

$\bar{R}$ = RADIUS → 0.5 2.5 4.5 6.5 8.5 meters

(6') (15') (21.5') (28') (feet)

Bfield(Tesla), Path(m.)= 2.00 0.30

third PASS..SOLENOID-ally bent outward

Step#, Range(m), PPmin, Log10(mus/m**2/10**12,Radius=1,10)..

1	0.	0.	8.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	221.	100.	7.44	6.59	6.06	5.44	4.75	3.97	2.96	1.90	0.91	-0.20
3	386.	200.	7.06	6.20	5.72	5.30	4.84	4.26	3.69	2.98	2.18	1.12
4	518.	300.	6.63	5.71	5.32	4.91	4.47	4.00	3.45	2.86	2.20	1.47
5	628.	400.	6.31	5.38	5.01	4.61	4.18	3.74	3.22	2.62	1.97	1.33
6	722.	500.	6.00	5.06	4.69	4.29	3.89	3.45	2.90	2.35	1.71	1.03
7	804.	600.	5.69	4.75	4.41	3.98	3.60	3.10	2.61	2.02	1.33	0.69
8	877.	700.	5.39	4.42	4.11	3.68	3.29	2.77	2.32	1.63	1.03	0.25
9	943.	800.	5.09	4.15	3.74	3.43	2.94	2.52	1.91	1.36	0.64	-0.18
10	1002.	900.	4.79	3.85	3.48	3.06	2.68	2.13	1.62	0.96	0.17	-0.48
11	1057.	1000.	4.47	3.53	3.17	2.78	2.30	1.83	1.24	0.55	-0.22	-0.96
12	1108.	1100.	4.16	3.16	2.84	2.46	1.99	1.46	0.83	0.12	-0.58	-1.51
13	1155.	1200.	3.81	2.84	2.48	2.10	1.60	1.08	0.45	-0.24	-1.01	-2.12
14	1198.	1300.	3.44	2.49	2.10	1.71	1.24	0.67	0.03	-0.70	-1.50	-2.78
15	1240.	1400.	3.03	2.08	1.70	1.31	0.80	0.22	-0.47	-1.21	-2.04	-3.53
16	1278.	1500.	2.58	1.63	1.25	0.82	0.31	-0.25	-0.94	-1.73	-2.61	-4.51
17	1315.	1600.	2.05	1.09	0.73	0.28	-0.22	-0.81	-1.54	-2.35	-3.26	-5.08
18	1349.	1700.	1.39	0.47	0.02	-0.36	-0.91	-1.51	-2.23	-3.08	-4.08	-5.98
19	1382.	1800.	0.53	-0.45	-0.83	-1.26	-1.79	-2.45	-3.18	-4.05	-5.17	-7.43
20	1413.	1900.	-1.01	-1.98	-2.36	-2.83	-3.36	-4.00	-4.80	-5.68	-7.19	0.00

Appendix F

Program **Etheta.for** for Electron Distributions
including SpreadGE.for
Added July 1991

```
ccc
ccc.......................file ETHETA.for...............................
ccc
        program ELtheta
ccccc.....electron YIELDS using double spread out of "spreadGE*2"in ELECTRON
c......instead of using russian directly
CCCC
cccc....   assumes (photon-electron conversion probability) = 100% (ie 1.0)
cccc
c       dimensions in 'inches'..program converts to meters
        data fmperin/0.0254/
c12-27-90       dimension EE(20,20),FF(20,20)
CCC...testing july 19-91...pTmax=4.0 GeV/c gives all sigma (to 1%)...
cccccccc.....and gids to 200x200 show good running compromise is (100)**2
cccc...grk 7-22-91...
        dimension EE(100,100),FF(100,100)
        dimension dsdp(100,9),xpr(100),bp(100),fnum(100,9),gnum(100,9)
c
c **formulae 3.26...given as function of "p-perp and x-prime"...to be input
c       where x-prime=(E*/E*max)...ie -1. thru 0. to +1.
        write(3,9)
    9   format(/1x,'**..elTHETA.FOR..DP/P=0.2,DOMEGA= 3 microSR,0.33 tgt')
        write(6,10)
   10   format(1x,
     x  'INPUT theta(mr),delth(mr)(pTmax.lt.10.),Ezero(GeV),AtWt(4F8.3)')
        read(5,11)theta,delth,Ezero,atnum
   11   format(4f8.3)
        srtofS=sqrt(2.0*0.9382*Ezero)
cccccc
cccccc    for the MOMENT...ELECTRON controls dxpr=.05..and dpperp (dpT) = 0.2
ccccc
ccccc....they are RETURNED from electron    FIXing atnum/wt naming error..
        atwt=atnum
c..move this down12-27-90grk    call electron(atwt,Ezero,FF,dxpr,dpT)
c....for eltheta...pperp varies...so must interpolate 'electron's pT grid..
c
CC...the above is delSIGMA in a box (dpT by dxpr) in mb....it is NOT the
CC...invariant E*ds/d3p  NEEDED here...must transform back...
CC...
CC...          E*ds/d3p = A =( xpr/(2*pi*pT)*ds/dxdpT...
CC...     so that  delSIGbox = (2*pi*pT/xpr)* A * delXpr * delpT in Electron
CC...     IS doubly spread out to a delSprime which is then related to the
CC... INVARIANT sigma we want...ie delSpr = (2*pi*pTprime/XPRprimed)*Apr*dx*dpT
CC..      which is solved to give  INVARIANT-electon sigmas = Apr =
CC...                  (xPRpr/(2*pi*pTpr)*(delSpr/(dx*dpT)
cc...      let FF( , ) come back from electron (ie delSpr)...
CC...               and transform it to   Apr = EE( , )...
CC...    grk 9-27-90
CC...        and dpT=0.2 (12-27-90 grk fixed here now..NOT in electron)
c..........and..................................variable dxpr...
                MMpT=100
                pTmaxx=4.0
cc***...use out to 4 GeV/c to be good to 2 without trouble (see 5,10,20 runs)
                NNxpr=100
                        dxpr=1./NNxpr
                        XXX=-dxpr/2.
                        DDx=dxpr
c  define dpT here...not inside electron..
        dpT=pTmaxx/MMpT
ccc  50*0.08=4gev/c...ok to 2plus...ie 10 mr thetas at 200 gev...or 1 mr 2000
        call electron(NNxpr,MMpT,atwt,Ezero,FF,dxpr,dpT)
                totEE=0.
        do 1 ixpr=1,NNxpr
        PPP=-dpT/2.
        DDp=dpT
                XXX=XXX+DDx
```

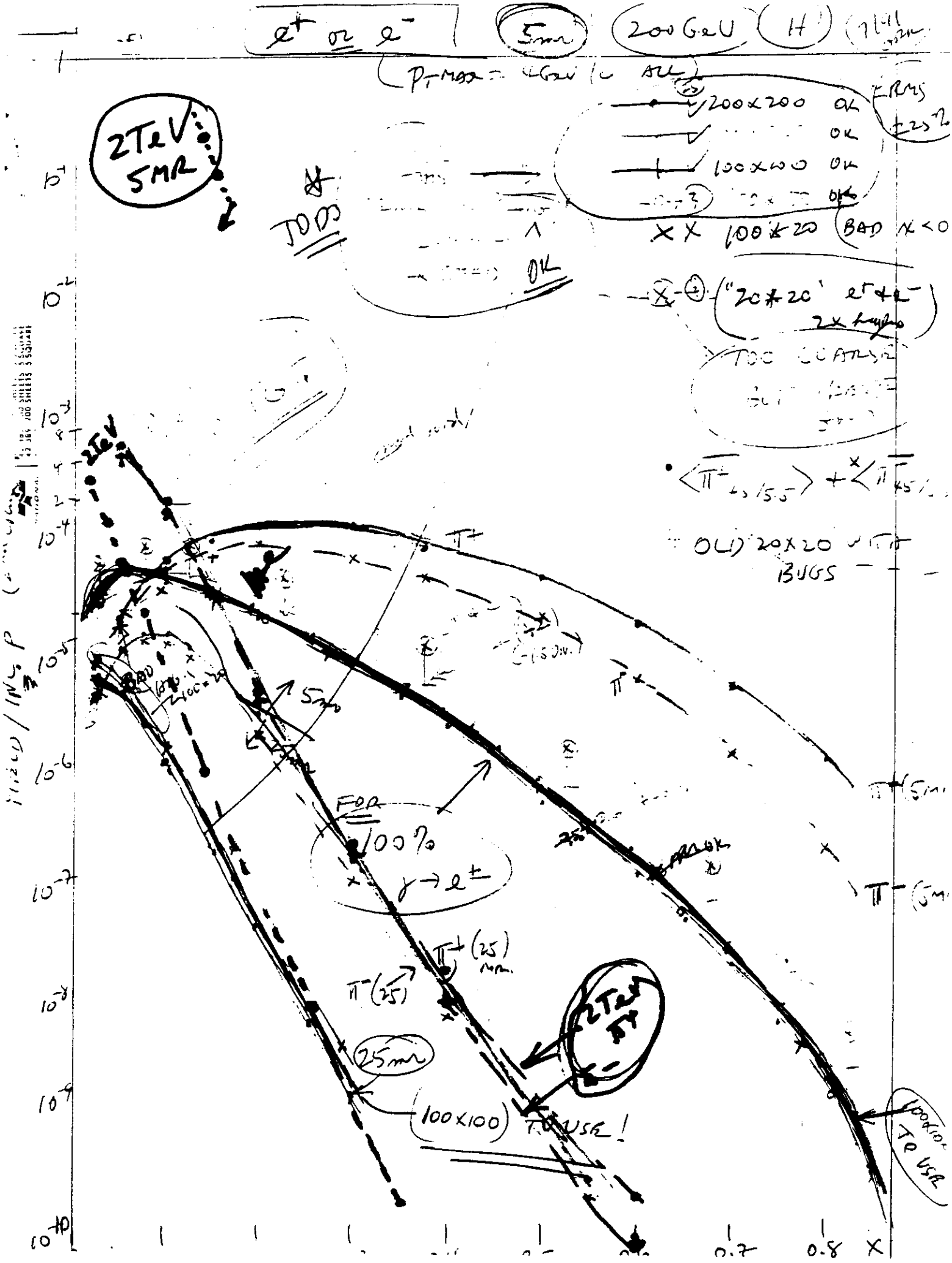
```
CCC.bug 7-17.for testing        do 2 jpT=1,50
                do 2 jpT=1,MMpT
                PPP=PPP+DDp
                Factor=XXX/(6.2832*PPP*DDx*DDp)
                EE(ixpr,jpT)=FF(ixpr,jpT)*Factor
                totEE=totEE+EE(ixpr,jpT)
CC7-17-91...WHY oh WHY was this done??  if(jpT.le.1)totEE=FF(ixpr,jpT)+totEE
    2   continue
    1   continue
ccc             write (3,4) ((FF(m,n),m=1,nnxpr),n=1,mmpt)
    4   format(///1x,' DEBUG...FF(x,p)='//(1x,5e12.2))
ccc             write (3,3) totEE,((EE(m,n),m=1,nnxpr),n=1,mmpt)
    3   format(///1x,' DEBUG, totEE=',e15.4,'  ...EE(xpr,pT)='//
     x  (1x,5e12.2))
CCCCCCCCCCCCCCCCCCCCC...transformation to INV electrons done...
c
        write(6,12)nnxpr,mmpt,ptmaxx,theta,delth,dxpr,
     x  Ezero,srtofS,atnum
        write(3,12)nnxpr,mmpt,ptmaxx,theta,delth,dxpr,
     x  Ezero,srtofS,atnum
   12   format(1x,'ECHO #x,#pT,pTmax,th(mr),dth,dxpr,Ezero,sq(S),A='/
     x  2x,2i4,7f8.3)
ccc             DO 100 lmn=1,1
        do 100 LMN=1,5
        write(3,1111)theta*0.001
 1111   format(/20x,'theta(rad)='f7.4,2x,'************************')
c       one loop (on i)to 101..since only electrons.....
        i=1
c       do xpr values from dxpr UP, but MAX of 100, and NOT xpr=1. either
        nnpr=1./dxpr
CCCCCCCCCCCCCC7-17---max out to 100 covering whole range....
        idnnpr=1
        nnst=1
        if(nnpr.ge.41)idnnpr=2
        if(nnpr.ge.41)nnst=2
CCCC..must do it by HITTING the real xpr values..max xpr's is 200..
        xpr(1)=dxpr/2.
        do 102 j=1,nnpr
c       calculate **pperp** from theta(mr) and xpr(J)...
        pperp=xpr(J)*theta*Ezero*0.001
c.......................done...now get electron yields....7-17-90 grk...
        ipT=pperp/dpT+1.
                if(ipT.gt.MMpT) ipT=MMpT
c....INTERPOLATE as fraction of bin we are in to next lower or higher as approp.
        pipT=-dpT/2.+ipT*dpT
                if(pperp.le.pipT) then
                        ipTlo=ipT-1
cccc...7-18-91...the IF(ipt.lt....bug fixed to  iptlo.....next line..***
                        if(ipTlo.lt.1)ipTlo=1
                        ipThi=ipT
                else
                        ipTlo=ipT
                        ipThi=ipT+1
                        if(ipThi.gt.MMpT)ipThi=MMpT
                endif
CCC   now interpolate.....................................
        pipTlo=-dpT/2.+ipTlo*dpT
        delta=(pperp-pipTlo)/dpT
        xxx=EE(J,ipTlo)+ delta*(EE(J,ipThi)-EE(J,ipTlo))
CCCC..debug for strange large nos.....(iptlo=0 bug above...)..
ccccc   write(6,9753)iptlo,ipthi,pperp,delta,dpt,xxx
 9753   format(1x,'iptlo,ipthi,pt,del,dpt,x=',2i3,3f6.2,e9.2)
CCCCCCCCCCCCCCCCCC*************************************************
c
c..DO NOT (subr RUSSIAN above has it) SCALE BY Be absorption crossection
c       xxx = now the invariant electron cross-section
```

```
      dsdp(j,i)=xxx
      ccsect=((atnum-0.40)/(9.01-0.40))**0.69
            ccsect=ccsect*199.
cccc...12-26---90....for per...proton...rescale by divide-ing by ccsect
            xxx=xxx/ccsect
      bp(j)=pperp
ccc.....assuming 9 sqin of aperture at 150 feet..d(solid.angle)=3 x 10**-6
ccc.....(3 micro-sterradians)..0.33 Labsorpt Be target..x*exp(-x)=.24...ie 24%
ccc.....incident protons interact...then yield per interact-proton is
ccc.....plab**2 * (dp/p) *ster-rad * inv.sigma(=dsdp(..)), where dp/p=0.2(+-10%)
ccc.....and plab=xpr*(pzero=Ezero-200 GeV,..'MEB')..., and sigma(abs).Be=199 mb.
ccc..... #/int-p = xpr**2 * 0.2 * 3x10**-6 * (Elab)**2 * dsdp(..,..) / 199mb
      fnum(j,i)=199.*(1.2e-4)*xxx*(xpr(J)**2)*(Ezero/200.)**2
CCC...in this program..each pi0 makes one gam  makes one elect.
ccc...real world 1 gives 2 gives 4= 2 e+ and 2e-
ccc..sig0 used is double true...ie sig+ + sig- = 2*sig0..gives (in computer)
ccccccccc...........equivalent of 2 generic electrons..so
c...  #e+ = # e- = 0.5* the number (fnum) just calculated..so take HALF
c...and change e+&e-  TO e+ OR e-****************
      fnum(j,i)=0.5*fnum(j,i)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC...end correct counting(still must put in
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC...photon conversion efficiency (ie 100% here)
c     24 % interact in 0.33 absorption length target
      gnum(j,i)=fnum(j,i)*0.24
      if(j.ge.nnpr) go to 102
      xpr(j+1)=xpr(j)+dxpr
  102 continue
CC  101 continue
      write(3,222)(m,xpr(m),bp(m),dsdp(m,1),fnum(m,1),gnum(m,1),m=
     x nnst,nnpr,idnnpr)
  222 format(1x,'m,x,Pt,dsdp(e+ OR e-)=',i3,f6.3,f5.2,f12.3/
     x 10x,'#(e+ OR e-)/inter-p, & /incid-p..',2e10.3)
CCCCC... corrected (above line, as above discuss.)  &  to OR for the *0.5
      theta=theta+delth
  100 continue
      call exit
      end
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC....fix to 50 x 50...grk 12-27-90
      subroutine electron(NNxpr,MMpT,atwt,Ezero,EE,dxpr,dpperp)
CCCCCC          GRK 7-17-90...Tues @ SSCL...modify mumscatz into ELECTRON
cccccc                ie double spread with....spreadGE...
CCCCCCCC
c..................store 'russian' yields in...yy(lxpr,mpT) summed over type..
ccc...100x100 to pTmax=4. GeV/c is good compromise ..grk 7-22-91
      dimension yy(100,100),zz(100,100),EE(100,100),PPmin(100)
c....where zz(,) is for spread out pions (yy) INTO gammas,  AND
c.........................and EE(,) for the 2nd spread out into EElectrons
c....YOU WILL supply PHOTON CONVERSION EFF. as a (later) multiplier on the e's
c
c......each pizero = 2 gammas, and pizeroes = average of pi+/-
c..........SO use pizero = sum of pi+ and pi-...ie. sum over itype = 1,2
c....zero out zz array to avoid any trouble
      do 5 ii=1,NNxpr
      do 5 jj=1,MMpT
    5 zz(ii,jj)=0.
c
c     first get yy-array filled
      total=0.
      write(6,668)Ezero
  668 format(1x,'Ezero input ',f10.1)
cccccccc        dxpr=.05   NOW defined in eltheta.main
      xpr=-dxpr/2.
      do 10 lxpr=1,NNxpr
CCCCCC PPmin(lxpr)=(lxpr-1)*Ezero/50.
      xpr=xpr+dxpr
cccccccc        dpperp=0.2    NOW defined in eltheta.main
```

```
        pperp=-dpperp/2.
        do 11 mpT=1,MMpT
        pperp=pperp+dpperp
        yyy=0.
c......gamma=2*pizero=(pi+)+(pi-)..ie....sum over particle 1,2...ie pi+,pi-
        do 12 it=1,2
        call russian(it,xpr,pperp,atwt,Ezero,russ)
        yyy=yyy+russ
   12   continue
c....russ=E*(ds/dp3)...implies del.s = russ * dp3/E =
c                  ..  (russ)*2.*pi*(pT/xpr)*dxpr*dpT.........grk 6-27-90
        yyy=yyy*6.2832*(pperp/xpr)*dxpr*dpperp
        total=total+yyy
        yy(lxpr,mpT)=yyy
   11   continue
   10   continue
ccc     write(55,43)total,atwt,Ezero
   43   format(//1x,'Page1'/
     x  1x,'PROGRAM.. ELECTRON ..'/
     x  1x'...PIzero Yields (decay to gammas and convert to electrons)'/
     x  /1x,'russian TOTAL (pizero) sigma(mb)=',f7.1,
     x  'for A,E0',2f7.1//)
ccc     write(55,44)((yy(m,n),m=1,nnxpr),n=1,mmpt)
   44   format(1x,10f8.4)
cccccccccccccccccccccccccccccccccccccc
c
c....now "muon" these "pions"...    (ie gamma these pizeroes..7-17-90)
c....take K's as Pions...decay to muons is pmu from 0.57 to 1.0 *ppi
c........ie xpr for mus is flat spectrum from .57 to 1 xprpi...
c...pT kick (to gamma) of 70 MeV/c ingnored relative to 200 MeV binning....
c.....this implies that pTgam= 0 to 1 times pTpiz...also
c...start double spread out of a given yy(xpr,pT)..first pT spread
c.........................................then each one, xpr spreadout
ccc
cccc.... first spread(all piz's decay) in...spreadGE.......
cccc    write(55,443)atwt,Ezero
  443   format(1H1//
     x  1x,'Page 2,  ELECTRON.....GAMMA Yields..(mb) (all piz.s decay)'/
     x  1x,2f7.1)
        call spreadGE(NNxpr,MMpT,dxpr,dpperp,Ezero,yy,zz)
c...........done double spread out...NOW need gam-elect conv.eff....
c....................
cccc    write (55,444)atwt,Ezero
  444   format(1H1//
     x  1x,' Page 3, ELECTRON..this is electron-yield.&...A,E0',
     x  2f7.1///)
cccccc 2 pi0 = pi+ + pi- goes to two electrons/and/2 positrons..ie e-/e+ each=
        call spreadGE(NNxpr,MMpT,dxpr,dpperp,Ezero,zz,EE)
        return
        end
c.....renamed back to ...spreadGE.for....11-16-90 fri...grk..after testing
c.....and purge old
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
c
c         T added to name tempor...9-28-90 grk
c ...    removed in ouspread2...11-16-90--to cf. with spreadge in testelect
        subroutine spreadGE(MMxpr,NNpT,dxpr,dpT,Ezero,yy,zz)
cccccccccccc   do double spread out..GE..gammas, then 2nd electrons
ccc......................double BY calling this routine TWICE....
cccccccccccc                spread out both cases is  ON-A-LINE (0,0) to (xpr,pT)
c..............THIS is because pT* of decays are negligible to pTproduced
c.......(of order 70 MeV for gammas vs pTbins of 200, and nil for g-to-e)
c.....WILL BE WORSE approx. when bin sizes reduced and grid size increased..
c..........but still a reasonable approx....grk 9-28-90....
c....yy is input array, zz output...call spreadGE twice to do double spread out
cc..fix..7-17-91          dimension yy(20,20),zz(20,20),zxpr(100),zzpT(100)
```

```
ccc...100x100 and pTmax=4. GeV/c is AOK...grk 7-22-91
        dimension yy(100,100),zz(100,100),zxpr(100),zzpT(100)
c   do spread out in xpr and then each into pT spread...
c       MM,NN are EXTENT of arrays used in main...
        SUMmu=0.
        xpr=-dxpr/2.
        do 210 m=1,MMxpr
        xpr=xpr+dxpr
        zxpr(m)=xpr
  210   continue
                xpr=-dxpr/2.
                do 10 m=1,MMxpr
                xpr=xpr+dxpr
ccccc   above 3 lines to be put back when next line removed...CCCCCCCCC
c                       m=MMxpr
        pT=-dpT/2.
        do 11 n=1,NNpT
        pT=pT+dpT
        zzpT(n)=pT
c  11   continue
c                       n=NNpT
CCCCCCCCCCCCCC....11...above goes out and one below comes back when...
c...now SPREAD out starts
        aa=yy(m,n)
        bb=m
        if(n.gt.m) go to 3333
        aabb=aa/bb
c and now zpT goes linearly with zxpr.....
        alpha=zzpT(n)/zxpr(m)
        do 97 mmm=1,m
        zpT=alpha*zxpr(mmm)
        izpT=zpT/dpT+1.
        zz(mmm,izpT)=zz(mmm,izpT)+aabb
   97   continue
        go to 3344
cccccccccccccccccccopposite case..
 3333   bb=n
        aabb=aa/bb
c now zxpr goes linearly with zpT
        alpha=xpr/pT
        do 397 nnn=1,n
        zzxpr=alpha*zzpT(nnn)
        izxpr=zzxpr/dxpr+1.
        zz(izxpr,nnn)=zz(izxpr,nnn)+aabb
  397   continue
 3344   continue
cccccc......done....
   98   continue
c...and is FINI
CCCCCCCCCCCCCCCCCCCCCC
   11   continue
   10   continue
CCCCCCCCCCCCCCCCCCCCCC...to restor....see above fixes..
        do 21 m=1,MMxpr
        do 21 n=1,NNpT
        SUMmu=SUMmu+zz(m,n)
   21   continue
ccc     write(3,22)SUMmu,SUMdec
   22   format(//1x,'.....SUMmu(mb),SUMdec(mb)=',f10.1,f10.4)
c...write zz(mu) all pions decay..out HERE..
ccc     write(3,44)((zz(m,n),m=1,MMxpr),n=1,NNpT)
   44   format(/(1x,5e12.2))
        return
        end
        subroutine russian(itype,xpr,pperp,atwt,Ezero,dsdp3)
c       parameters for particle yields...1=pi+, 2=pi- from New Russian Xlation
```

```
c       "Passage of H.E. Particles thru Matter, AN Kalinovski,etal,AIP,eqn3.26
        dimension c1(5),c2(5),c3(5),c4(5),c5(5),c6(5),fm(5),omeg(5),
     x  fmusq(5),bzero(5),gam(5)
CCCC
C        1=pi+, 2=pi-, 3=K+, 4=K- and 5=p- (ie pbar)    ( =i = itype)
CCCC
c       units are GeV for fm,omeg,gam (and GeV**-1 for bzero)...)
        data c1/0.25, 0.20, 0.075, 0.078, 0.080/
        data c2/3.1, 4.0, 2.5, 6.1, 8.6/
        data c3/0.88, 1.18, 1.60, 2.46, 2.30/
        data c4/3.0, 3.0, 3.0, 3.5, 4.2/
        data c5/2., 2., 2., 2., 2./
        data c6/11.3, 9.8, 10.7, 8.8, 10.5/
        data fm/2*0.1396, 2*0.4937, 0.9382/
        data omeg/1.8778, 2.016, 2.054, 2.370, 2.815/
        data fmusq/0.88, 0.86, 1.2, 1.2, 1.1/
        data bzero/0.10, 0.11, 0.12, 0.12, 0.12/
        data gam/4.0, 3.5, 4.0, 4.0, 5.0/
c
c       formulae 3.26...given as function of "p-perp and x-prime"...to be input
c       where x-prime=(E*/E*max)...ie 0. thru +1.
        i=itype
        srtofS=sqrt(2.0*0.9382*Ezero)
        bperp=bzero(i)*pperp
        if(pperp.gt.gam(i)) bperp=bzero(i)*gam(i)
        psq=pperp**2
        xperp=2.*pperp/srtofS
        phi=exp(-c4(i)*psq)+c5(i)*exp(-c6(i)*xperp)/((psq+fmusq(i)**2)**4)
        xxx=c1(i)*(atwt**bperp)*((1.-xpr)**c2(i))*exp(-c3(i)*xpr)*phi
c..........AND SCALE BY Be absorption crossection (199 mb)
        ccsect=((atwt-0.40)/(9.01-0.40))**0.69
        ccsect=ccsect*199.
        xxx=ccsect*xxx
        dsdp3=xxx
        return
        end
```


e+ or e-
5mr
200 GeV
H
2TeV 5MR
200x200 OK
100x100 OK
100x20 BAD x<0
OK
20x20 e+ + e-
2x bugs
OLD 20x20 w/ π0 BUGS
π+
π-
5mr
25mr
FOR 100% γ→e±
π+(25) mr
π-(25)
2TeV 5T
100x100 TO USE!
100x100 TO USE
0.7
0.8
x

```
**..elTHETA.FOR..DP/P=0.2,DOMEGA= 3 microSR,0.33 tgt
ECHO #x,#pT,pTmax,th(mr),dth,dxpr,Ezero,sq(S),A=
  100 100   4.000   2.500   2.500   0.010 200.000  19.372   9.000

                    theta(rad)= 0.0025  *************************
m,x,Pt,dsdp(e+ OR e-)=  2 0.015 0.01    8058.869
        #(e+ OR e-)/inter-p, & /incid-p.. 0.109E-03 0.261E-04
m,x,Pt,dsdp(e+ OR e-)=  4 0.035 0.02    3079.692
        #(e+ OR e-)/inter-p, & /incid-p.. 0.227E-03 0.544E-04
m,x,Pt,dsdp(e+ OR e-)=  6 0.055 0.03    1437.440
        #(e+ OR e-)/inter-p, & /incid-p.. 0.261E-03 0.627E-04
m,x,Pt,dsdp(e+ OR e-)=  8 0.075 0.04     797.503
        #(e+ OR e-)/inter-p, & /incid-p.. 0.269E-03 0.646E-04
m,x,Pt,dsdp(e+ OR e-)= 10 0.095 0.05     467.379
        #(e+ OR e-)/inter-p, & /incid-p.. 0.253E-03 0.608E-04
m,x,Pt,dsdp(e+ OR e-)= 12 0.115 0.06     316.659
        #(e+ OR e-)/inter-p, & /incid-p.. 0.251E-03 0.604E-04
m,x,Pt,dsdp(e+ OR e-)= 14 0.135 0.07     202.431
        #(e+ OR e-)/inter-p, & /incid-p.. 0.222E-03 0.532E-04
m,x,Pt,dsdp(e+ OR e-)= 16 0.155 0.08     142.940
        #(e+ OR e-)/inter-p, & /incid-p.. 0.206E-03 0.495E-04
m,x,Pt,dsdp(e+ OR e-)= 18 0.175 0.09     101.061
        #(e+ OR e-)/inter-p, & /incid-p.. 0.186E-03 0.446E-04
m,x,Pt,dsdp(e+ OR e-)= 20 0.195 0.10      67.919
        #(e+ OR e-)/inter-p, & /incid-p.. 0.155E-03 0.372E-04
m,x,Pt,dsdp(e+ OR e-)= 22 0.215 0.11      51.263
        #(e+ OR e-)/inter-p, & /incid-p.. 0.142E-03 0.341E-04
m,x,Pt,dsdp(e+ OR e-)= 24 0.235 0.12      37.202
        #(e+ OR e-)/inter-p, & /incid-p.. 0.123E-03 0.296E-04
m,x,Pt,dsdp(e+ OR e-)= 26 0.255 0.13      26.415
        #(e+ OR e-)/inter-p, & /incid-p.. 0.103E-03 0.248E-04
m,x,Pt,dsdp(e+ OR e-)= 28 0.275 0.14      19.165
        #(e+ OR e-)/inter-p, & /incid-p.. 0.870E-04 0.209E-04
m,x,Pt,dsdp(e+ OR e-)= 30 0.295 0.15      14.377
        #(e+ OR e-)/inter-p, & /incid-p.. 0.751E-04 0.180E-04
m,x,Pt,dsdp(e+ OR e-)= 32 0.315 0.16      10.744
        #(e+ OR e-)/inter-p, & /incid-p.. 0.640E-04 0.154E-04
m,x,Pt,dsdp(e+ OR e-)= 34 0.335 0.17       7.836
        #(e+ OR e-)/inter-p, & /incid-p.. 0.528E-04 0.127E-04
m,x,Pt,dsdp(e+ OR e-)= 36 0.355 0.18       6.038
        #(e+ OR e-)/inter-p, & /incid-p.. 0.457E-04 0.110E-04
m,x,Pt,dsdp(e+ OR e-)= 38 0.375 0.19       4.408
        #(e+ OR e-)/inter-p, & /incid-p.. 0.372E-04 0.893E-05
m,x,Pt,dsdp(e+ OR e-)= 40 0.395 0.20       3.209
        #(e+ OR e-)/inter-p, & /incid-p.. 0.301E-04 0.721E-05
m,x,Pt,dsdp(e+ OR e-)= 42 0.415 0.21       2.431
        #(e+ OR e-)/inter-p, & /incid-p.. 0.251E-04 0.603E-05
m,x,Pt,dsdp(e+ OR e-)= 44 0.435 0.22       1.856
        #(e+ OR e-)/inter-p, & /incid-p.. 0.211E-04 0.506E-05
m,x,Pt,dsdp(e+ OR e-)= 46 0.455 0.23       1.325
        #(e+ OR e-)/inter-p, & /incid-p.. 0.165E-04 0.395E-05
m,x,Pt,dsdp(e+ OR e-)= 48 0.475 0.24       0.959
        #(e+ OR e-)/inter-p, & /incid-p.. 0.130E-04 0.312E-05
m,x,Pt,dsdp(e+ OR e-)= 50 0.495 0.25       0.709
        #(e+ OR e-)/inter-p, & /incid-p.. 0.104E-04 0.251E-05
m,x,Pt,dsdp(e+ OR e-)= 52 0.515 0.26       0.529
        #(e+ OR e-)/inter-p, & /incid-p.. 0.842E-05 0.202E-05
m,x,Pt,dsdp(e+ OR e-)= 54 0.535 0.27       0.380
        #(e+ OR e-)/inter-p, & /incid-p.. 0.653E-05 0.157E-05
m,x,Pt,dsdp(e+ OR e-)= 56 0.555 0.28       0.265
        #(e+ OR e-)/inter-p, & /incid-p.. 0.490E-05 0.118E-05
m,x,Pt,dsdp(e+ OR e-)= 58 0.575 0.29       0.194
        #(e+ OR e-)/inter-p, & /incid-p.. 0.384E-05 0.923E-06
m,x,Pt,dsdp(e+ OR e-)= 60 0.595 0.30       0.140
        #(e+ OR e-)/inter-p, & /incid-p.. 0.298E-05 0.715E-06
```

E theta output
5 Q
2.5, 5, ... 15 mr

printed 24-jul-1991 13:29
filename for003.dat;180
directory 1duc0:[grk]
user grk
job for003
site superconducting super collider

```
m,x,Pt,dsdp(e+ OR e-)= 62 0.615 0.31        0.097
         #(e+ OR e-)/inter-p, & /incid-p.. 0.221E-05 0.531E-06
m,x,Pt,dsdp(e+ OR e-)= 64 0.635 0.32        0.065
         #(e+ OR e-)/inter-p, & /incid-p.. 0.158E-05 0.379E-06
m,x,Pt,dsdp(e+ OR e-)= 66 0.655 0.33        0.045
         #(e+ OR e-)/inter-p, & /incid-p.. 0.117E-05 0.280E-06
m,x,Pt,dsdp(e+ OR e-)= 68 0.675 0.34        0.032
         #(e+ OR e-)/inter-p, & /incid-p.. 0.863E-06 0.207E-06
m,x,Pt,dsdp(e+ OR e-)= 70 0.695 0.35        0.021
         #(e+ OR e-)/inter-p, & /incid-p.. 0.599E-06 0.144E-06
m,x,Pt,dsdp(e+ OR e-)= 72 0.715 0.36        0.013
         #(e+ OR e-)/inter-p, & /incid-p.. 0.396E-06 0.950E-07
m,x,Pt,dsdp(e+ OR e-)= 74 0.735 0.37        0.008
         #(e+ OR e-)/inter-p, & /incid-p.. 0.267E-06 0.641E-07
m,x,Pt,dsdp(e+ OR e-)= 76 0.755 0.38        0.005
         #(e+ OR e-)/inter-p, & /incid-p.. 0.183E-06 0.439E-07
m,x,Pt,dsdp(e+ OR e-)= 78 0.775 0.39        0.003
         #(e+ OR e-)/inter-p, & /incid-p.. 0.113E-06 0.272E-07
m,x,Pt,dsdp(e+ OR e-)= 80 0.795 0.40        0.002
         #(e+ OR e-)/inter-p, & /incid-p.. 0.666E-07 0.160E-07
m,x,Pt,dsdp(e+ OR e-)= 82 0.815 0.41        0.001
         #(e+ OR e-)/inter-p, & /incid-p.. 0.392E-07 0.941E-08
m,x,Pt,dsdp(e+ OR e-)= 84 0.835 0.42        0.001
         #(e+ OR e-)/inter-p, & /incid-p.. 0.224E-07 0.538E-08
m,x,Pt,dsdp(e+ OR e-)= 86 0.855 0.43        0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.113E-07 0.271E-08
m,x,Pt,dsdp(e+ OR e-)= 88 0.875 0.44        0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.514E-08 0.123E-08
m,x,Pt,dsdp(e+ OR e-)= 90 0.895 0.45        0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.217E-08 0.521E-09
m,x,Pt,dsdp(e+ OR e-)= 92 0.915 0.46        0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.777E-09 0.186E-09
m,x,Pt,dsdp(e+ OR e-)= 94 0.935 0.47        0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.212E-09 0.509E-10
m,x,Pt,dsdp(e+ OR e-)= 96 0.955 0.48        0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.397E-10 0.952E-11
m,x,Pt,dsdp(e+ OR e-)= 98 0.975 0.49        0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.343E-11 0.824E-12
m,x,Pt,dsdp(e+ OR e-)=100 0.995 0.50        0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.153E-13 0.367E-14

                    theta(rad)= 0.0050  ************************
m,x,Pt,dsdp(e+ OR e-)=  2 0.015 0.01    8058.869
         #(e+ OR e-)/inter-p, & /incid-p.. 0.109E-03 0.261E-04
m,x,Pt,dsdp(e+ OR e-)=  4 0.035 0.04    2632.144
         #(e+ OR e-)/inter-p, & /incid-p.. 0.194E-03 0.465E-04
m,x,Pt,dsdp(e+ OR e-)=  6 0.055 0.06    1090.469
         #(e+ OR e-)/inter-p, & /incid-p.. 0.198E-03 0.475E-04
m,x,Pt,dsdp(e+ OR e-)=  8 0.075 0.08     600.414
         #(e+ OR e-)/inter-p, & /incid-p.. 0.203E-03 0.487E-04
m,x,Pt,dsdp(e+ OR e-)= 10 0.095 0.10     352.269
         #(e+ OR e-)/inter-p, & /incid-p.. 0.191E-03 0.458E-04
m,x,Pt,dsdp(e+ OR e-)= 12 0.115 0.12     208.695
         #(e+ OR e-)/inter-p, & /incid-p.. 0.166E-03 0.398E-04
m,x,Pt,dsdp(e+ OR e-)= 14 0.135 0.13     136.624
         #(e+ OR e-)/inter-p, & /incid-p.. 0.150E-03 0.359E-04
m,x,Pt,dsdp(e+ OR e-)= 16 0.155 0.16      89.608
         #(e+ OR e-)/inter-p, & /incid-p.. 0.129E-03 0.310E-04
m,x,Pt,dsdp(e+ OR e-)= 18 0.175 0.18      60.962
         #(e+ OR e-)/inter-p, & /incid-p.. 0.112E-03 0.269E-04
m,x,Pt,dsdp(e+ OR e-)= 20 0.195 0.20      42.089
         #(e+ OR e-)/inter-p, & /incid-p.. 0.961E-04 0.231E-04
m,x,Pt,dsdp(e+ OR e-)= 22 0.215 0.22      29.545
         #(e+ OR e-)/inter-p, & /incid-p.. 0.820E-04 0.197E-04
m,x,Pt,dsdp(e+ OR e-)= 24 0.235 0.24      20.198
         #(e+ OR e-)/inter-p, & /incid-p.. 0.670E-04 0.161E-04
```

```
m,x,Pt,dsdp(e+ OR e-)= 26 0.255 0.26       14.360
         #(e+ OR e-)/inter-p, & /incid-p.. 0.561E-04 0.135E-04
m,x,Pt,dsdp(e+ OR e-)= 28 0.275 0.28       9.887
         #(e+ OR e-)/inter-p, & /incid-p.. 0.449E-04 0.108E-04
m,x,Pt,dsdp(e+ OR e-)= 30 0.295 0.30       7.339
         #(e+ OR e-)/inter-p, & /incid-p.. 0.384E-04 0.920E-05
m,x,Pt,dsdp(e+ OR e-)= 32 0.315 0.32       5.003
         #(e+ OR e-)/inter-p, & /incid-p.. 0.298E-04 0.715E-05
m,x,Pt,dsdp(e+ OR e-)= 34 0.335 0.34       3.726
         #(e+ OR e-)/inter-p, & /incid-p.. 0.251E-04 0.603E-05
m,x,Pt,dsdp(e+ OR e-)= 36 0.355 0.35       2.562
         #(e+ OR e-)/inter-p, & /incid-p.. 0.194E-04 0.465E-05
m,x,Pt,dsdp(e+ OR e-)= 38 0.375 0.37       1.912
         #(e+ OR e-)/inter-p, & /incid-p.. 0.161E-04 0.387E-05
m,x,Pt,dsdp(e+ OR e-)= 40 0.395 0.39       1.287
         #(e+ OR e-)/inter-p, & /incid-p.. 0.121E-04 0.289E-05
m,x,Pt,dsdp(e+ OR e-)= 42 0.415 0.41       0.969
         #(e+ OR e-)/inter-p, & /incid-p.. 0.100E-04 0.240E-05
m,x,Pt,dsdp(e+ OR e-)= 44 0.435 0.43       0.646
         #(e+ OR e-)/inter-p, & /incid-p.. 0.735E-05 0.176E-05
m,x,Pt,dsdp(e+ OR e-)= 46 0.455 0.45       0.486
         #(e+ OR e-)/inter-p, & /incid-p.. 0.604E-05 0.145E-05
m,x,Pt,dsdp(e+ OR e-)= 48 0.475 0.47       0.322
         #(e+ OR e-)/inter-p, & /incid-p.. 0.437E-05 0.105E-05
m,x,Pt,dsdp(e+ OR e-)= 50 0.495 0.49       0.241
         #(e+ OR e-)/inter-p, & /incid-p.. 0.355E-05 0.851E-06
m,x,Pt,dsdp(e+ OR e-)= 52 0.515 0.51       0.158
         #(e+ OR e-)/inter-p, & /incid-p.. 0.251E-05 0.603E-06
m,x,Pt,dsdp(e+ OR e-)= 54 0.535 0.53       0.117
         #(e+ OR e-)/inter-p, & /incid-p.. 0.200E-05 0.481E-06
m,x,Pt,dsdp(e+ OR e-)= 56 0.555 0.55       0.075
         #(e+ OR e-)/inter-p, & /incid-p.. 0.138E-05 0.331E-06
m,x,Pt,dsdp(e+ OR e-)= 58 0.575 0.57       0.055
         #(e+ OR e-)/inter-p, & /incid-p.. 0.109E-05 0.261E-06
m,x,Pt,dsdp(e+ OR e-)= 60 0.595 0.59       0.034
         #(e+ OR e-)/inter-p, & /incid-p.. 0.729E-06 0.175E-06
m,x,Pt,dsdp(e+ OR e-)= 62 0.615 0.61       0.025
         #(e+ OR e-)/inter-p, & /incid-p.. 0.564E-06 0.135E-06
m,x,Pt,dsdp(e+ OR e-)= 64 0.635 0.63       0.015
         #(e+ OR e-)/inter-p, & /incid-p.. 0.368E-06 0.883E-07
m,x,Pt,dsdp(e+ OR e-)= 66 0.655 0.65       0.011
         #(e+ OR e-)/inter-p, & /incid-p.. 0.277E-06 0.664E-07
m,x,Pt,dsdp(e+ OR e-)= 68 0.675 0.67       0.006
         #(e+ OR e-)/inter-p, & /incid-p.. 0.174E-06 0.419E-07
m,x,Pt,dsdp(e+ OR e-)= 70 0.695 0.69       0.004
         #(e+ OR e-)/inter-p, & /incid-p.. 0.127E-06 0.304E-07
m,x,Pt,dsdp(e+ OR e-)= 72 0.715 0.71       0.003
         #(e+ OR e-)/inter-p, & /incid-p.. 0.768E-07 0.184E-07
m,x,Pt,dsdp(e+ OR e-)= 74 0.735 0.73       0.002
         #(e+ OR e-)/inter-p, & /incid-p.. 0.533E-07 0.128E-07
m,x,Pt,dsdp(e+ OR e-)= 76 0.755 0.75       0.001
         #(e+ OR e-)/inter-p, & /incid-p.. 0.306E-07 0.736E-08
m,x,Pt,dsdp(e+ OR e-)= 78 0.775 0.77       0.001
         #(e+ OR e-)/inter-p, & /incid-p.. 0.200E-07 0.480E-08
m,x,Pt,dsdp(e+ OR e-)= 80 0.795 0.79       0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.107E-07 0.258E-08
m,x,Pt,dsdp(e+ OR e-)= 82 0.815 0.81       0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.643E-08 0.154E-08
m,x,Pt,dsdp(e+ OR e-)= 84 0.835 0.83       0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.313E-08 0.750E-09
m,x,Pt,dsdp(e+ OR e-)= 86 0.855 0.85       0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.165E-08 0.395E-09
m,x,Pt,dsdp(e+ OR e-)= 88 0.875 0.87       0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.686E-09 0.165E-09
m,x,Pt,dsdp(e+ OR e-)= 90 0.895 0.89       0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.291E-09 0.700E-10
```

```
m,x,Pt,dsdp(e+ OR e-)= 92 0.915 0.91        0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.921E-10 0.221E-10
m,x,Pt,dsdp(e+ OR e-)= 94 0.935 0.93        0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.254E-10 0.610E-11
m,x,Pt,dsdp(e+ OR e-)= 96 0.955 0.95        0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.420E-11 0.101E-11
m,x,Pt,dsdp(e+ OR e-)= 98 0.975 0.97        0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.319E-12 0.765E-13
m,x,Pt,dsdp(e+ OR e-)=100 0.995 0.99        0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.132E-14 0.317E-15

                    theta(rad)= 0.0075  ************************
m,x,Pt,dsdp(e+ OR e-)=  2 0.015 0.02    7771.343
         #(e+ OR e-)/inter-p, & /incid-p.. 0.105E-03 0.252E-04
m,x,Pt,dsdp(e+ OR e-)=  4 0.035 0.05    2110.006
         #(e+ OR e-)/inter-p, & /incid-p.. 0.155E-03 0.373E-04
m,x,Pt,dsdp(e+ OR e-)=  6 0.055 0.08     877.184
         #(e+ OR e-)/inter-p, & /incid-p.. 0.159E-03 0.382E-04
m,x,Pt,dsdp(e+ OR e-)=  8 0.075 0.11     411.252
         #(e+ OR e-)/inter-p, & /incid-p.. 0.139E-03 0.333E-04
m,x,Pt,dsdp(e+ OR e-)= 10 0.095 0.14     215.330
         #(e+ OR e-)/inter-p, & /incid-p.. 0.117E-03 0.280E-04
m,x,Pt,dsdp(e+ OR e-)= 12 0.115 0.17     127.414
         #(e+ OR e-)/inter-p, & /incid-p.. 0.101E-03 0.243E-04
m,x,Pt,dsdp(e+ OR e-)= 14 0.135 0.20      78.078
         #(e+ OR e-)/inter-p, & /incid-p.. 0.854E-04 0.205E-04
m,x,Pt,dsdp(e+ OR e-)= 16 0.155 0.23      47.865
         #(e+ OR e-)/inter-p, & /incid-p.. 0.691E-04 0.166E-04
m,x,Pt,dsdp(e+ OR e-)= 18 0.175 0.26      32.354
         #(e+ OR e-)/inter-p, & /incid-p.. 0.595E-04 0.143E-04
m,x,Pt,dsdp(e+ OR e-)= 20 0.195 0.29      20.397
         #(e+ OR e-)/inter-p, & /incid-p.. 0.466E-04 0.112E-04
m,x,Pt,dsdp(e+ OR e-)= 22 0.215 0.32      13.301
         #(e+ OR e-)/inter-p, & /incid-p.. 0.369E-04 0.886E-05
m,x,Pt,dsdp(e+ OR e-)= 24 0.235 0.35       9.168
         #(e+ OR e-)/inter-p, & /incid-p.. 0.304E-04 0.730E-05
m,x,Pt,dsdp(e+ OR e-)= 26 0.255 0.38       6.226
         #(e+ OR e-)/inter-p, & /incid-p.. 0.243E-04 0.583E-05
m,x,Pt,dsdp(e+ OR e-)= 28 0.275 0.41       3.987
         #(e+ OR e-)/inter-p, & /incid-p.. 0.181E-04 0.435E-05
m,x,Pt,dsdp(e+ OR e-)= 30 0.295 0.44       2.682
         #(e+ OR e-)/inter-p, & /incid-p.. 0.140E-04 0.336E-05
m,x,Pt,dsdp(e+ OR e-)= 32 0.315 0.47       1.862
         #(e+ OR e-)/inter-p, & /incid-p.. 0.111E-04 0.266E-05
m,x,Pt,dsdp(e+ OR e-)= 34 0.335 0.50       1.227
         #(e+ OR e-)/inter-p, & /incid-p.. 0.827E-05 0.198E-05
m,x,Pt,dsdp(e+ OR e-)= 36 0.355 0.53       0.844
         #(e+ OR e-)/inter-p, & /incid-p.. 0.639E-05 0.153E-05
m,x,Pt,dsdp(e+ OR e-)= 38 0.375 0.56       0.557
         #(e+ OR e-)/inter-p, & /incid-p.. 0.470E-05 0.113E-05
m,x,Pt,dsdp(e+ OR e-)= 40 0.395 0.59       0.379
         #(e+ OR e-)/inter-p, & /incid-p.. 0.355E-05 0.851E-06
m,x,Pt,dsdp(e+ OR e-)= 42 0.415 0.62       0.252
         #(e+ OR e-)/inter-p, & /incid-p.. 0.260E-05 0.625E-06
m,x,Pt,dsdp(e+ OR e-)= 44 0.435 0.65       0.171
         #(e+ OR e-)/inter-p, & /incid-p.. 0.194E-05 0.466E-06
m,x,Pt,dsdp(e+ OR e-)= 46 0.455 0.68       0.111
         #(e+ OR e-)/inter-p, & /incid-p.. 0.138E-05 0.332E-06
m,x,Pt,dsdp(e+ OR e-)= 48 0.475 0.71       0.073
         #(e+ OR e-)/inter-p, & /incid-p.. 0.985E-06 0.236E-06
m,x,Pt,dsdp(e+ OR e-)= 50 0.495 0.74       0.050
         #(e+ OR e-)/inter-p, & /incid-p.. 0.729E-06 0.175E-06
m,x,Pt,dsdp(e+ OR e-)= 52 0.515 0.77       0.032
         #(e+ OR e-)/inter-p, & /incid-p.. 0.513E-06 0.123E-06
m,x,Pt,dsdp(e+ OR e-)= 54 0.535 0.80       0.021
         #(e+ OR e-)/inter-p, & /incid-p.. 0.357E-06 0.858E-07
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m,x,Pt,dsdp(e+ OR e-)= 56 0.555 0.83        0.013
          #(e+ OR e-)/inter-p, & /incid-p.. 0.246E-06 0.590E-07
m,x,Pt,dsdp(e+ OR e-)= 58 0.575 0.86        0.009
          #(e+ OR e-)/inter-p, & /incid-p.. 0.174E-06 0.417E-07
m,x,Pt,dsdp(e+ OR e-)= 60 0.595 0.89        0.006
          #(e+ OR e-)/inter-p, & /incid-p.. 0.117E-06 0.281E-07
m,x,Pt,dsdp(e+ OR e-)= 62 0.615 0.92        0.003
          #(e+ OR e-)/inter-p, & /incid-p.. 0.760E-07 0.183E-07
m,x,Pt,dsdp(e+ OR e-)= 64 0.635 0.95        0.002
          #(e+ OR e-)/inter-p, & /incid-p.. 0.511E-07 0.123E-07
m,x,Pt,dsdp(e+ OR e-)= 66 0.655 0.98        0.001
          #(e+ OR e-)/inter-p, & /incid-p.. 0.342E-07 0.821E-08
m,x,Pt,dsdp(e+ OR e-)= 68 0.675 1.01        0.001
          #(e+ OR e-)/inter-p, & /incid-p.. 0.217E-07 0.521E-08
m,x,Pt,dsdp(e+ OR e-)= 70 0.695 1.04        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.131E-07 0.314E-08
m,x,Pt,dsdp(e+ OR e-)= 72 0.715 1.07        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.819E-08 0.197E-08
m,x,Pt,dsdp(e+ OR e-)= 74 0.735 1.10        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.510E-08 0.122E-08
m,x,Pt,dsdp(e+ OR e-)= 76 0.755 1.13        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.293E-08 0.703E-09
m,x,Pt,dsdp(e+ OR e-)= 78 0.775 1.16        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.161E-08 0.386E-09
m,x,Pt,dsdp(e+ OR e-)= 80 0.795 1.19        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.892E-09 0.214E-09
m,x,Pt,dsdp(e+ OR e-)= 82 0.815 1.22        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.481E-09 0.115E-09
m,x,Pt,dsdp(e+ OR e-)= 84 0.835 1.25        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.234E-09 0.561E-10
m,x,Pt,dsdp(e+ OR e-)= 86 0.855 1.28        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.105E-09 0.252E-10
m,x,Pt,dsdp(e+ OR e-)= 88 0.875 1.31        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.449E-10 0.108E-10
m,x,Pt,dsdp(e+ OR e-)= 90 0.895 1.34        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.172E-10 0.414E-11
m,x,Pt,dsdp(e+ OR e-)= 92 0.915 1.37        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.544E-11 0.131E-11
m,x,Pt,dsdp(e+ OR e-)= 94 0.935 1.40        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.136E-11 0.326E-12
m,x,Pt,dsdp(e+ OR e-)= 96 0.955 1.43        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.233E-12 0.559E-13
m,x,Pt,dsdp(e+ OR e-)= 98 0.975 1.46        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.181E-13 0.434E-14
m,x,Pt,dsdp(e+ OR e-)=100 0.995 1.49        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.709E-16 0.170E-16

                    theta(rad)= 0.0100  ************************
m,x,Pt,dsdp(e+ OR e-)=  2 0.015 0.03    6908.767
          #(e+ OR e-)/inter-p, & /incid-p.. 0.933E-04 0.224E-04
m,x,Pt,dsdp(e+ OR e-)=  4 0.035 0.07    1662.866
          #(e+ OR e-)/inter-p, & /incid-p.. 0.122E-03 0.294E-04
m,x,Pt,dsdp(e+ OR e-)=  6 0.055 0.11     666.362
          #(e+ OR e-)/inter-p, & /incid-p.. 0.121E-03 0.291E-04
m,x,Pt,dsdp(e+ OR e-)=  8 0.075 0.15     320.170
          #(e+ OR e-)/inter-p, & /incid-p.. 0.108E-03 0.260E-04
m,x,Pt,dsdp(e+ OR e-)= 10 0.095 0.19     170.202
          #(e+ OR e-)/inter-p, & /incid-p.. 0.922E-04 0.221E-04
m,x,Pt,dsdp(e+ OR e-)= 12 0.115 0.23      96.956
          #(e+ OR e-)/inter-p, & /incid-p.. 0.770E-04 0.185E-04
m,x,Pt,dsdp(e+ OR e-)= 14 0.135 0.27      56.916
          #(e+ OR e-)/inter-p, & /incid-p.. 0.623E-04 0.149E-04
m,x,Pt,dsdp(e+ OR e-)= 16 0.155 0.31      34.054
          #(e+ OR e-)/inter-p, & /incid-p.. 0.491E-04 0.118E-04
m,x,Pt,dsdp(e+ OR e-)= 18 0.175 0.35      21.136
          #(e+ OR e-)/inter-p, & /incid-p.. 0.389E-04 0.933E-05
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```
m,x,Pt,dsdp(e+ OR e-)= 20 0.195 0.39       13.119
         #(e+ OR e-)/inter-p, & /incid-p.. 0.300E-04 0.719E-05
m,x,Pt,dsdp(e+ OR e-)= 22 0.215 0.43       8.215
         #(e+ OR e-)/inter-p, & /incid-p.. 0.228E-04 0.547E-05
m,x,Pt,dsdp(e+ OR e-)= 24 0.235 0.47       5.223
         #(e+ OR e-)/inter-p, & /incid-p.. 0.173E-04 0.416E-05
m,x,Pt,dsdp(e+ OR e-)= 26 0.255 0.51       3.305
         #(e+ OR e-)/inter-p, & /incid-p.. 0.129E-04 0.310E-05
m,x,Pt,dsdp(e+ OR e-)= 28 0.275 0.55       2.107
         #(e+ OR e-)/inter-p, & /incid-p.. 0.957E-05 0.230E-05
m,x,Pt,dsdp(e+ OR e-)= 30 0.295 0.59       1.347
         #(e+ OR e-)/inter-p, & /incid-p.. 0.704E-05 0.169E-05
m,x,Pt,dsdp(e+ OR e-)= 32 0.315 0.63       0.859
         #(e+ OR e-)/inter-p, & /incid-p.. 0.512E-05 0.123E-05
m,x,Pt,dsdp(e+ OR e-)= 34 0.335 0.67       0.549
         #(e+ OR e-)/inter-p, & /incid-p.. 0.370E-05 0.887E-06
m,x,Pt,dsdp(e+ OR e-)= 36 0.355 0.71       0.349
         #(e+ OR e-)/inter-p, & /incid-p.. 0.264E-05 0.634E-06
m,x,Pt,dsdp(e+ OR e-)= 38 0.375 0.75       0.222
         #(e+ OR e-)/inter-p, & /incid-p.. 0.188E-05 0.450E-06
m,x,Pt,dsdp(e+ OR e-)= 40 0.395 0.79       0.141
         #(e+ OR e-)/inter-p, & /incid-p.. 0.132E-05 0.316E-06
m,x,Pt,dsdp(e+ OR e-)= 42 0.415 0.83       0.089
         #(e+ OR e-)/inter-p, & /incid-p.. 0.919E-06 0.221E-06
m,x,Pt,dsdp(e+ OR e-)= 44 0.435 0.87       0.056
         #(e+ OR e-)/inter-p, & /incid-p.. 0.635E-06 0.152E-06
m,x,Pt,dsdp(e+ OR e-)= 46 0.455 0.91       0.035
         #(e+ OR e-)/inter-p, & /incid-p.. 0.435E-06 0.104E-06
m,x,Pt,dsdp(e+ OR e-)= 48 0.475 0.95       0.022
         #(e+ OR e-)/inter-p, & /incid-p.. 0.295E-06 0.708E-07
m,x,Pt,dsdp(e+ OR e-)= 50 0.495 0.99       0.013
         #(e+ OR e-)/inter-p, & /incid-p.. 0.198E-06 0.476E-07
m,x,Pt,dsdp(e+ OR e-)= 52 0.515 1.03       0.008
         #(e+ OR e-)/inter-p, & /incid-p.. 0.132E-06 0.317E-07
m,x,Pt,dsdp(e+ OR e-)= 54 0.535 1.07       0.005
         #(e+ OR e-)/inter-p, & /incid-p.. 0.871E-07 0.209E-07
m,x,Pt,dsdp(e+ OR e-)= 56 0.555 1.11       0.003
         #(e+ OR e-)/inter-p, & /incid-p.. 0.569E-07 0.137E-07
m,x,Pt,dsdp(e+ OR e-)= 58 0.575 1.15       0.002
         #(e+ OR e-)/inter-p, & /incid-p.. 0.368E-07 0.883E-08
m,x,Pt,dsdp(e+ OR e-)= 60 0.595 1.19       0.001
         #(e+ OR e-)/inter-p, & /incid-p.. 0.236E-07 0.565E-08
m,x,Pt,dsdp(e+ OR e-)= 62 0.615 1.23       0.001
         #(e+ OR e-)/inter-p, & /incid-p.. 0.149E-07 0.358E-08
m,x,Pt,dsdp(e+ OR e-)= 64 0.635 1.27       0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.932E-08 0.224E-08
m,x,Pt,dsdp(e+ OR e-)= 66 0.655 1.31       0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.576E-08 0.138E-08
m,x,Pt,dsdp(e+ OR e-)= 68 0.675 1.35       0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.351E-08 0.842E-09
m,x,Pt,dsdp(e+ OR e-)= 70 0.695 1.39       0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.210E-08 0.505E-09
m,x,Pt,dsdp(e+ OR e-)= 72 0.715 1.43       0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.124E-08 0.298E-09
m,x,Pt,dsdp(e+ OR e-)= 74 0.735 1.47       0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.716E-09 0.172E-09
m,x,Pt,dsdp(e+ OR e-)= 76 0.755 1.51       0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.404E-09 0.969E-10
m,x,Pt,dsdp(e+ OR e-)= 78 0.775 1.55       0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.221E-09 0.531E-10
m,x,Pt,dsdp(e+ OR e-)= 80 0.795 1.59       0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.117E-09 0.282E-10
m,x,Pt,dsdp(e+ OR e-)= 82 0.815 1.63       0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.597E-10 0.143E-10
m,x,Pt,dsdp(e+ OR e-)= 84 0.835 1.67       0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.289E-10 0.693E-11
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```
m,x,Pt,dsdp(e+ OR e-)= 86 0.855 1.71        0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.131E-10 0.314E-11
m,x,Pt,dsdp(e+ OR e-)= 88 0.875 1.75        0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.543E-11 0.130E-11
m,x,Pt,dsdp(e+ OR e-)= 90 0.895 1.79        0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.201E-11 0.483E-12
m,x,Pt,dsdp(e+ OR e-)= 92 0.915 1.83        0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.634E-12 0.152E-12
m,x,Pt,dsdp(e+ OR e-)= 94 0.935 1.87        0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.156E-12 0.374E-13
m,x,Pt,dsdp(e+ OR e-)= 96 0.955 1.91        0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.252E-13 0.606E-14
m,x,Pt,dsdp(e+ OR e-)= 98 0.975 1.95        0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.172E-14 0.412E-15
m,x,Pt,dsdp(e+ OR e-)=100 0.995 1.99        0.000
         #(e+ OR e-)/inter-p, & /incid-p.. 0.564E-17 0.135E-17

                    theta(rad)= 0.0125  ************************
m,x,Pt,dsdp(e+ OR e-)=  2 0.015 0.04    6046.190
         #(e+ OR e-)/inter-p, & /incid-p.. 0.817E-04 0.196E-04
m,x,Pt,dsdp(e+ OR e-)=  4 0.035 0.09    1271.976
         #(e+ OR e-)/inter-p, & /incid-p.. 0.936E-04 0.225E-04
m,x,Pt,dsdp(e+ OR e-)=  6 0.055 0.14     407.863
         #(e+ OR e-)/inter-p, & /incid-p.. 0.741E-04 0.178E-04
m,x,Pt,dsdp(e+ OR e-)=  8 0.075 0.19     183.011
         #(e+ OR e-)/inter-p, & /incid-p.. 0.618E-04 0.148E-04
m,x,Pt,dsdp(e+ OR e-)= 10 0.095 0.24      90.228
         #(e+ OR e-)/inter-p, & /incid-p.. 0.489E-04 0.117E-04
m,x,Pt,dsdp(e+ OR e-)= 12 0.115 0.29      47.646
         #(e+ OR e-)/inter-p, & /incid-p.. 0.378E-04 0.908E-05
m,x,Pt,dsdp(e+ OR e-)= 14 0.135 0.34      26.789
         #(e+ OR e-)/inter-p, & /incid-p.. 0.293E-04 0.704E-05
m,x,Pt,dsdp(e+ OR e-)= 16 0.155 0.39      15.897
         #(e+ OR e-)/inter-p, & /incid-p.. 0.229E-04 0.550E-05
m,x,Pt,dsdp(e+ OR e-)= 18 0.175 0.44       8.671
         #(e+ OR e-)/inter-p, & /incid-p.. 0.159E-04 0.383E-05
m,x,Pt,dsdp(e+ OR e-)= 20 0.195 0.49       5.058
         #(e+ OR e-)/inter-p, & /incid-p.. 0.115E-04 0.277E-05
m,x,Pt,dsdp(e+ OR e-)= 22 0.215 0.54       3.106
         #(e+ OR e-)/inter-p, & /incid-p.. 0.862E-05 0.207E-05
m,x,Pt,dsdp(e+ OR e-)= 24 0.235 0.59       1.736
         #(e+ OR e-)/inter-p, & /incid-p.. 0.576E-05 0.138E-05
m,x,Pt,dsdp(e+ OR e-)= 26 0.255 0.64       1.021
         #(e+ OR e-)/inter-p, & /incid-p.. 0.399E-05 0.957E-06
m,x,Pt,dsdp(e+ OR e-)= 28 0.275 0.69       0.629
         #(e+ OR e-)/inter-p, & /incid-p.. 0.286E-05 0.686E-06
m,x,Pt,dsdp(e+ OR e-)= 30 0.295 0.74       0.384
         #(e+ OR e-)/inter-p, & /incid-p.. 0.201E-05 0.482E-06
m,x,Pt,dsdp(e+ OR e-)= 32 0.315 0.79       0.219
         #(e+ OR e-)/inter-p, & /incid-p.. 0.130E-05 0.313E-06
m,x,Pt,dsdp(e+ OR e-)= 34 0.335 0.84       0.126
         #(e+ OR e-)/inter-p, & /incid-p.. 0.850E-06 0.204E-06
m,x,Pt,dsdp(e+ OR e-)= 36 0.355 0.89       0.075
         #(e+ OR e-)/inter-p, & /incid-p.. 0.569E-06 0.136E-06
m,x,Pt,dsdp(e+ OR e-)= 38 0.375 0.94       0.045
         #(e+ OR e-)/inter-p, & /incid-p.. 0.379E-06 0.910E-07
m,x,Pt,dsdp(e+ OR e-)= 40 0.395 0.99       0.027
         #(e+ OR e-)/inter-p, & /incid-p.. 0.250E-06 0.599E-07
m,x,Pt,dsdp(e+ OR e-)= 42 0.415 1.04       0.015
         #(e+ OR e-)/inter-p, & /incid-p.. 0.159E-06 0.381E-07
m,x,Pt,dsdp(e+ OR e-)= 44 0.435 1.09       0.009
         #(e+ OR e-)/inter-p, & /incid-p.. 0.103E-06 0.246E-07
m,x,Pt,dsdp(e+ OR e-)= 46 0.455 1.14       0.005
         #(e+ OR e-)/inter-p, & /incid-p.. 0.664E-07 0.159E-07
m,x,Pt,dsdp(e+ OR e-)= 48 0.475 1.19       0.003
         #(e+ OR e-)/inter-p, & /incid-p.. 0.426E-07 0.102E-07
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m,x,Pt,dsdp(e+ OR e-)= 50 0.495 1.24        0.002
          #(e+ OR e-)/inter-p, & /incid-p.. 0.262E-07 0.629E-08
m,x,Pt,dsdp(e+ OR e-)= 52 0.515 1.29        0.001
          #(e+ OR e-)/inter-p, & /incid-p.. 0.163E-07 0.392E-08
m,x,Pt,dsdp(e+ OR e-)= 54 0.535 1.34        0.001
          #(e+ OR e-)/inter-p, & /incid-p.. 0.105E-07 0.253E-08
m,x,Pt,dsdp(e+ OR e-)= 56 0.555 1.39        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.652E-08 0.157E-08
m,x,Pt,dsdp(e+ OR e-)= 58 0.575 1.44        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.402E-08 0.964E-09
m,x,Pt,dsdp(e+ OR e-)= 60 0.595 1.49        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.247E-08 0.592E-09
m,x,Pt,dsdp(e+ OR e-)= 62 0.615 1.54        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.157E-08 0.376E-09
m,x,Pt,dsdp(e+ OR e-)= 64 0.635 1.59        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.951E-09 0.228E-09
m,x,Pt,dsdp(e+ OR e-)= 66 0.655 1.64        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.563E-09 0.135E-09
m,x,Pt,dsdp(e+ OR e-)= 68 0.675 1.69        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.339E-09 0.814E-10
m,x,Pt,dsdp(e+ OR e-)= 70 0.695 1.74        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.208E-09 0.500E-10
m,x,Pt,dsdp(e+ OR e-)= 72 0.715 1.79        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.121E-09 0.290E-10
m,x,Pt,dsdp(e+ OR e-)= 74 0.735 1.84        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.667E-10 0.160E-10
m,x,Pt,dsdp(e+ OR e-)= 76 0.755 1.89        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.380E-10 0.912E-11
m,x,Pt,dsdp(e+ OR e-)= 78 0.775 1.94        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.215E-10 0.516E-11
m,x,Pt,dsdp(e+ OR e-)= 80 0.795 1.99        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.112E-10 0.269E-11
m,x,Pt,dsdp(e+ OR e-)= 82 0.815 2.04        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.548E-11 0.132E-11
m,x,Pt,dsdp(e+ OR e-)= 84 0.835 2.09        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.267E-11 0.641E-12
m,x,Pt,dsdp(e+ OR e-)= 86 0.855 2.14        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.124E-11 0.298E-12
m,x,Pt,dsdp(e+ OR e-)= 88 0.875 2.19        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.505E-12 0.121E-12
m,x,Pt,dsdp(e+ OR e-)= 90 0.895 2.24        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.182E-12 0.436E-13
m,x,Pt,dsdp(e+ OR e-)= 92 0.915 2.29        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.572E-13 0.137E-13
m,x,Pt,dsdp(e+ OR e-)= 94 0.935 2.34        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.142E-13 0.341E-14
m,x,Pt,dsdp(e+ OR e-)= 96 0.955 2.39        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.238E-14 0.572E-15
m,x,Pt,dsdp(e+ OR e-)= 98 0.975 2.44        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.186E-15 0.447E-16
m,x,Pt,dsdp(e+ OR e-)=100 0.995 2.49        0.000
          #(e+ OR e-)/inter-p, & /incid-p.. 0.740E-18 0.178E-18
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August 22, 1991

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Re: Request for Patent Clearance for Release of Unclassified Documents: SSCL-N-768

Dear Mr. Albrecht:

Enclosed please find the above-referenced document for patent review at your earliest convenience. I would appreciate your returning this document to me at Mail Stop 1091.

Thank you for your assistance.

Sincerely,

Mary Wasserman

Mary Wasserman
Legal Administrative Assistant

/mw

Encls.