SDC-93-414

SDC
SOLENOIDAL DETECTOR NOTES

SDC FORWARD MUON WORKSHOP
JANUARY 18-29, 1993

SSCL

Volume I

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AGENDA FOR THE SDC FORWARD MUON WORKSHOP, SSCL, JAN. 18-29, 1993

Please send additions, corrections, and comments to sscvx1::willis
1/18/93 modify Tuesday's schedule to allow travel time to/from CF
add talks by Lawler, Daoudi on Wednesday

Monday, Jan 18, 1993 Cafetorium COORDINATION

9:00	SDC and SSCL participants	Internal coordination and planning This is an opportunity for us to discuss our plans and requirements for the next two weeks, and also for the whole 3-month period of the Russian group's visit. We will also discuss how to interact with other concerned parties around the Laboratory.

Tuesday, Jan 19, 1993 Cafetorium NEUTRONS; ABSORBER DESIGN

9:00	A. Skuja	Introduction
9:15	S. Willis	Summary of Santa Fe workshop
10:00	T. Gabriel	Available Simulation Programs
10:15	S. Kunori	Neutrons and Trigger Simulation
10:45	Christian Zeitnitz	CALOR-GEANT Interface
11:15	R. Little	IR Questions
5	Lunch	
1:00	R. LITTLE	IR QUESTIONS JOHN REES' CONF RM, MEZZANINE
1:30	Johannes Ranft (Room E849, Central Facility)	"Hadron Production at Supercolliders"
3:00	S. KUNORI	NEUTRONS + TRIGGER SIMULATION
3:15	Valery Kubarovsky	Estimations of rates in scintillators, drift tubes and trigger rate in FMS based on neutron currents from note 92-361.
3:15	Steve Ball	Neutron Background Rates
4:15	Andrea Palounek	Overview of Methods and Calculations
4:45	[redacted]	Recent Results on SDC and GEM Fluences

Wednesday, Jan 20, 1993 Directorate 2 ACCELERATOR INTERFACE; INTERNAL SDC COORDINATION

9:00	T. Pal	Effects of Neutrons on other SDC Subsystems
9:30	Mourad Daoudi	Simulations using CALOR
10:00	Nikolai Mokhov	Control of Beam Loss and Related Effects in the Collider IRs
11:00	Jim Lawler	Activation Levels
30	Igor Azhgirey	Calculations of backgrounds for the SDC Forward Muon Spectrometer.
12:00	Lunch	
1:00	Andrey Uzunian	Experimental investigation and calculations of attenuation of low energy neutron and photon

		fluxes in different shield materials using Cf-252 source.
1:30	Gennady Zholobov	1. The background sources: their intensity, emitted charged particle types and energy spectra. 2. Charged particle fluxes and energy spectra at sensitive detectors (drift tube chambers, scintillator and Cerenkov counters).
2:00	Renat Fahrutdinov	Experimental studies of scintillation counters sensitivity to neutron and gammas. Effects of various shielding.
2:20	Alexander Surkov	Integration Design of the Forward Muon System. Design of the FMS absorbers.
3:20	J. Piles	Forward Calorimeter placement, absorber requirements for FW1/FW2 region
4:20	Kubarovsky/Skuja/ Willis	Discussion: The problems Goals Getting started

Thursday, Jan 21 through Wednesday, Jan 27

	Willis	Getting Started on Simulation Work

Friday, Jan 22

7:00 pm	Willis	Muon Simulation Video Conference

Monday, Jan 25 FORWARD MUON SYSTEM DESIGN DETAILS

9:00	Yuri Antipov	Status of IHEP activities in studies and design of FMS tracking system.
9:30	Renat Fahrutdinov	Drift tube with wire field shaping.
9:50	Valery Kubarovsky	Cerenkov Counter for Forward Muon System of SDC.
10:10	Leonid Baliev	Recent achievements in design of FMS tracking system
11:30	M. Murbach	Summary of FMS Measuring System work at Maryland

[assembly workshop Tuesday and Wednesday - Charlie Grinnell, SSCVX1::GRINNELL, is maintaining the schedule for this]

Thursday, Jan 28, 1993 FIRST RESULTS

9:00	Willis	Summary
9:30	TBA	Individual presentations

Friday, Jan 29, 1993 THE NEXT STEP

9:00	all	Discussion and assignments for the next meeting

Andris Skuja
Jan 19, 1993

Radiation

Activation - Disposal of equipment in 30 years
Environment now → DOE requirements
EPA requirements

Backgrounds - Will equipment work
Muon System
Other detectors in SDC

Access - Can equipment be repaired
Inner detector
Forward calorimeter

We have seen Los Alamos calculations that predict $10^{12} - 10^{13}$ neutrons/cm^2/yr on outside of TDR detector

1 yr = 10^{15} beam crossings at 10^{33} luminosity

1 photon / 1 neutron

Monte Carlo Programs

LAHET - Los Alamos (Prael)
CALOR - Oak Ridge (Gabriel)
FLUKA - CERN/Milan (Ferrari) ('92 version)
MARS 12 - Protvino/SSCL (Mokhov)
+ GEANT interfaces

There are overlaps in codes both at low energy end and high energy end

There seems to be general agreement that J. Ranft's DTUJET should be used as particle generator for primary interactions when calculating backgrounds
Cross checks between programs required

Other Programs (ORNL)
Discrete ordinate code Richard Lillie
ASOP = shielding optimization code

For Muon System

Need to Know response of muon drift tubes to neutrons
photons

Guess: neutrons $\varepsilon_n = 10^{-3}$
photons $\varepsilon_\gamma = 10^{-2}$

Calculation: Brent Moore (CALOR)
Others ?

Measurement: UW Van der Graaph
('93)
ORNL electron/neutron source

Sources (p-p interaction)

(i) Inside Edge of Endcap Calorimeter

(ii) Front Face of Forward Calorimeter

(iii) Flared Beam Pipe

(iv) Beam pipe after FCAL
Should be flared

(v) Colimator in front of Low-β Quad

(vi) Quads themselves

Sources (beam-X interactions)

(i) Beam-gas everywhere
Plug tunnel

(ii) Scrapers in dog-legs

(iii) Beam - Low β-Quad scraping

(iv) Muon Halo - toroids in tunnel

Shielding -

I propose that participants calculate attenuation of neutrons and photon production as a function of energy for different materials

$$I \approx I_0 e^{-x/\lambda}$$

for Iron $\lambda = 21$ cm for $E_n > 20$ MeV

What is λ_{Fe} for lower energies

T. Gabriel proposes that Carbon be added to Fe to improve its rejection of low energy neutrons

Energy range ½ eV → 500 GeV

Materials

- aluminum
- concrete
- polyethylene
- boroflex (30% boron + poly)
- Li - poly (7% poly → <u>no</u> γ's)

Important

What exits the shielding?

Many lower energy neutrons?

Photons?

What do we need to achieve?

For Muons

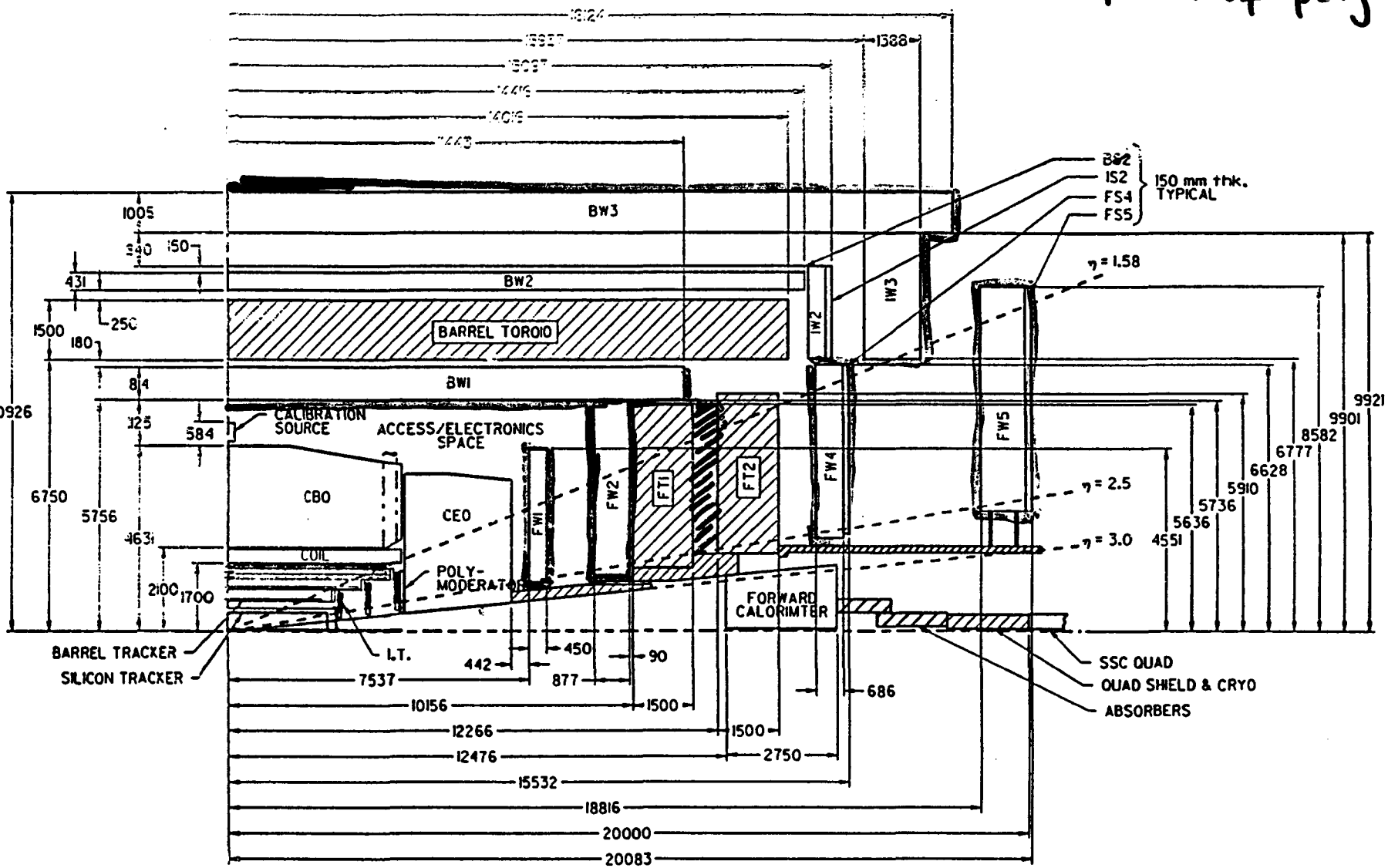
Shielding $\equiv \sim 10^{-3}$

Shield sources $\sim 10^{-2}$

Shield chambers $\sim 10^{-2}$?

According to GEM shielding chambers with 10cm poly can get this additional factor of 10^{-2}

Shield Chambers
10 cm of p-g



SDC DETECTOR
TECHNICAL PROPOSAL DIMENSIONS
SSC DRAWING # sdd000081.c00
08-SEP-1992

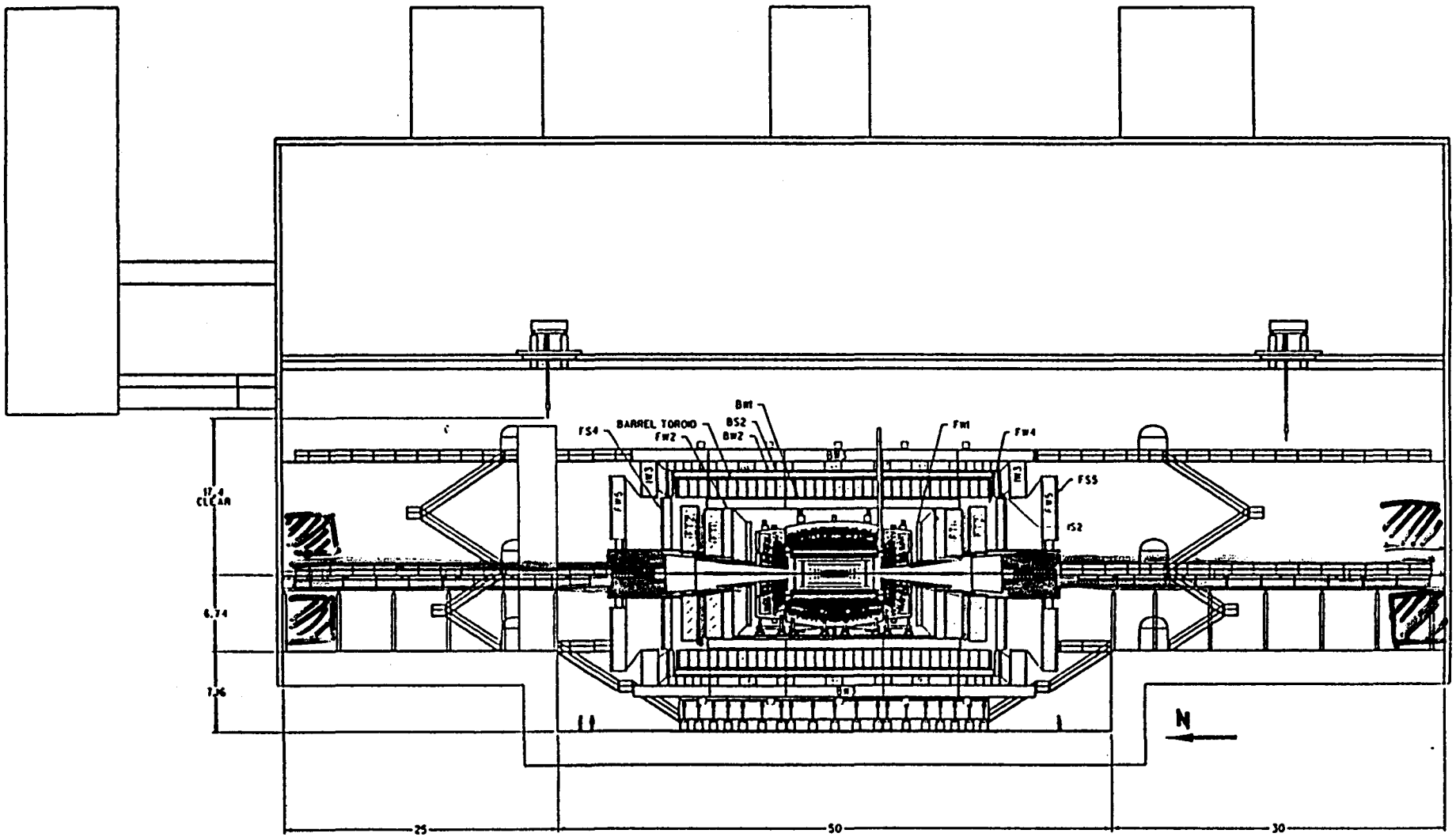
0 1 2 3 4 5M

NOTE: DIMENSIONS ARE IN MILLIMETERS

SDC-000010.F

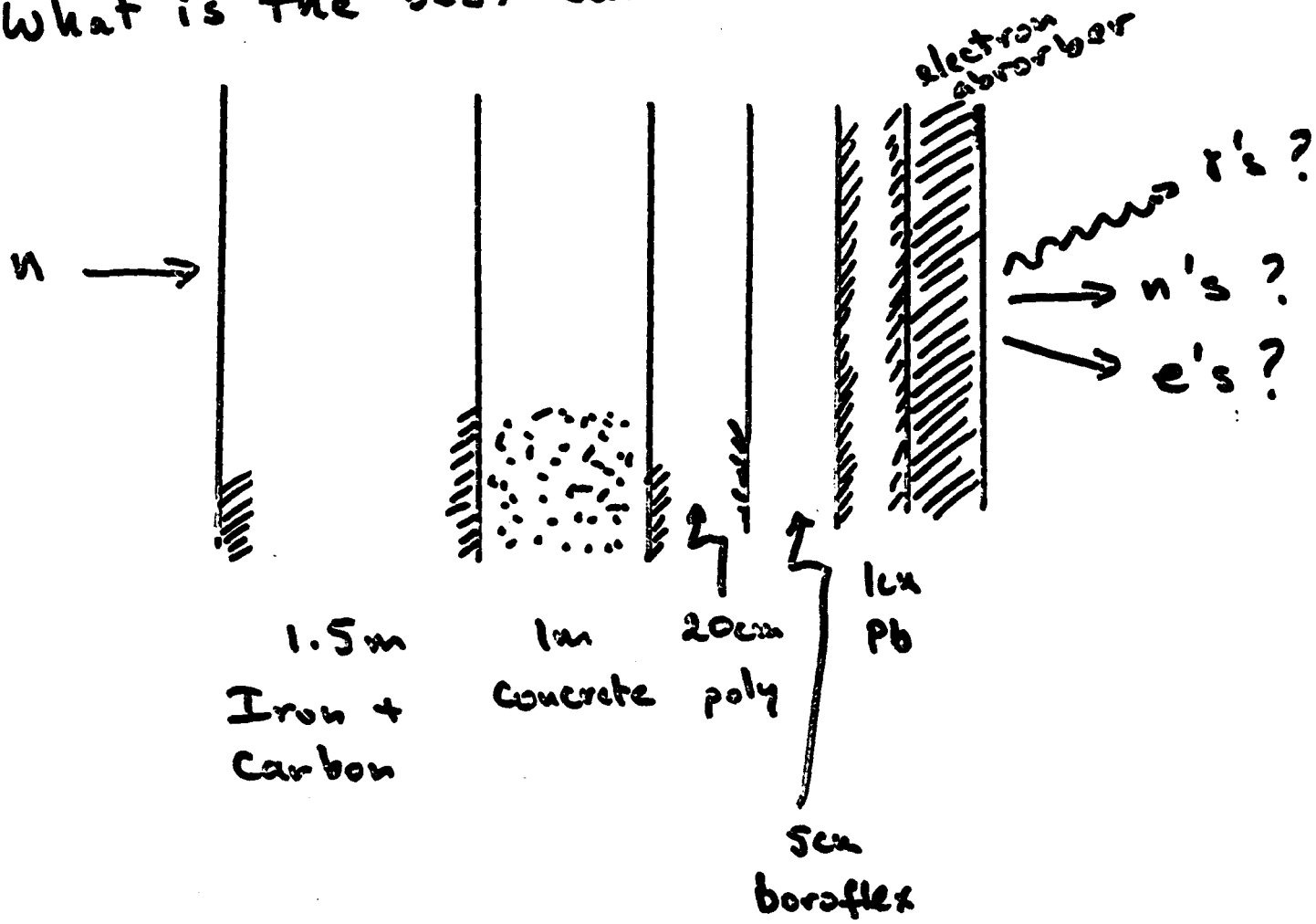
Shield sources
Fill gaps

IR-8 DETECTOR HALL



SDD DRAWING *acd00284.001

What is the best sandwich ??



Learn about simple shielding situations first - before doing it all.

If 10^{-3} is easy, lets get the best shielding and obtain 10^{-4}

Baseline

QUAD 1 = 25 m

① Suggestion: { 1.5 m iron, 1 m concrete } around everything past FCAL

Close FT1 / FT2 gap

Increase gap between FW1 and FW2

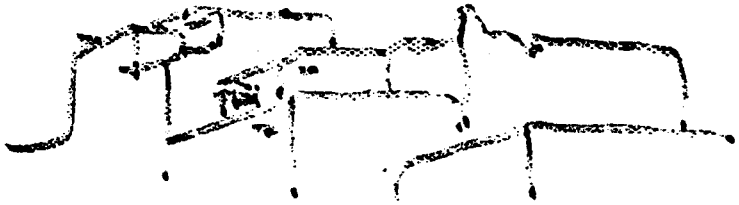
{ 40 cm of iron, 10 cm poly } to shield FW1 and FW2

{ 3 QUADS + Concrete walls }

② Enclose chambers in 10 cm of Li/Poly (no γ's ?!)

③ Optimize shielding in ① for best sandwich.

SIMULATING ACCELERATOR RADIATION ENVIRONMENTS, SANTA FE, JAN. 11-15

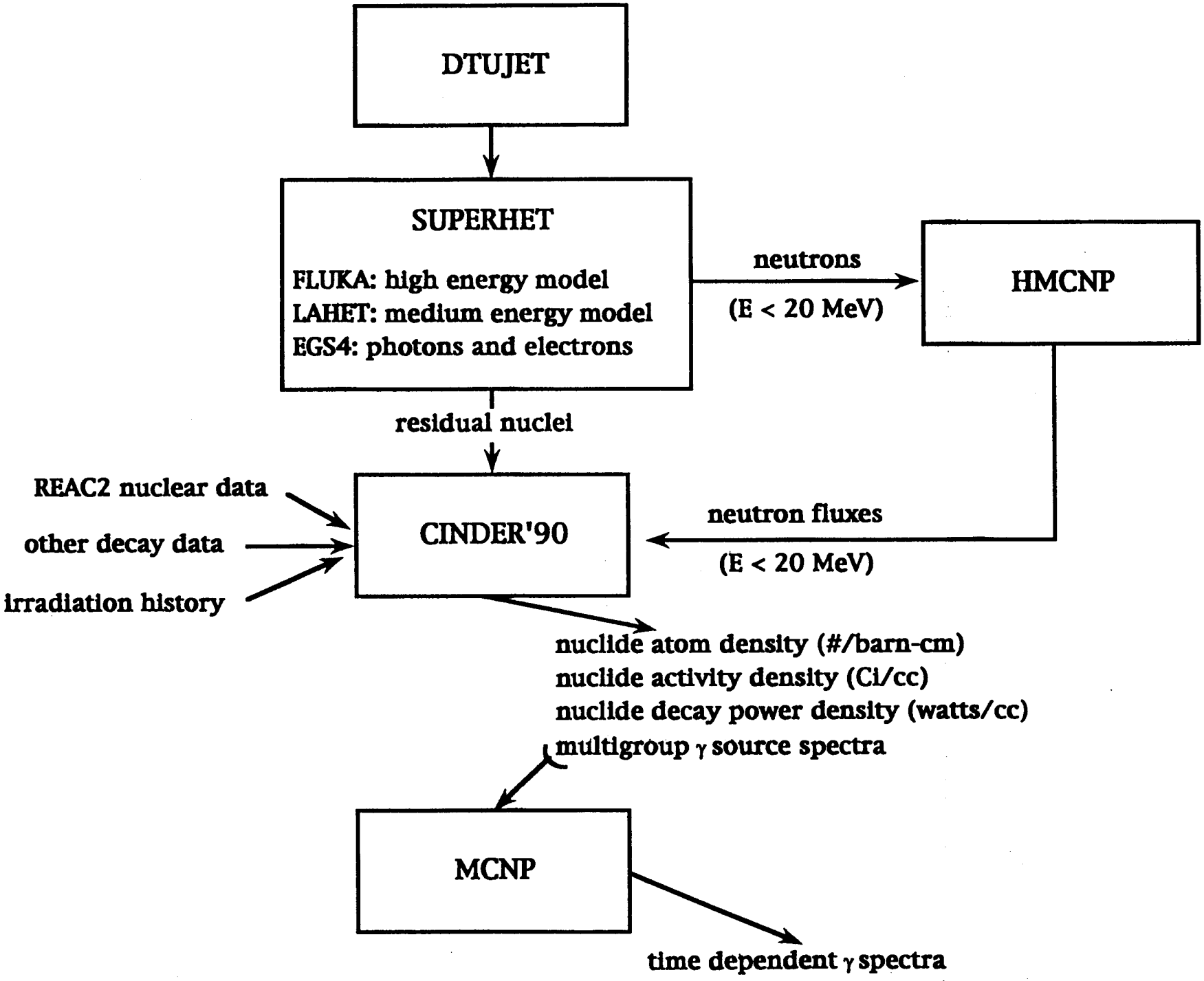


CONFERENCE REVIEW

S. WILLIS
1/19/93

OVERVIEW OF THE WORKSHOP

- SPECIFIC NEEDS
  - SSC
  - SPALLATION NEUTRON STUDIES
  - ACCELERATOR PRODUCTION OF TRITIUM
  - ACCELERATOR TRANSMUTATION OF WASTE
  - CANCER THERAPY
- CODES
  - CALOR/HETC
  - LAHET/MCNP/CINDER'90
  - FLUKA/DTUJET/DTUNUC
  - MARS12
  - FKK-GNASH
  - DISCRETE ORDINATES
- SHIELDING
- EXPERIMENTS
- BENCHMARKING/CALCULATIONS
- EXPERIENCE/PROPOSALS


DTUJET
SUPERHET
FLUKA: high energy model
LAHET: medium energy model
EGS4: photons and electrons
neutrons
(E < 20 MeV)
HMCNP
residual nuclei
REAC2 nuclear data
other decay data
irradiation history
CINDER'90
neutron fluxes
(E < 20 MeV)
nuclide atom density (#/barn-cm)
nuclide activity density (Ci/cc)
nuclide decay power density (watts/cc)
multigroup γ source spectra
MCNP
time dependent γ spectra

DTUJET

Conclusions

two component DPM with supercritical Pomeron

good fits with KMRS [B0] ($1./x$) MRS[D0]

structure functions: KMRS [B-5] ($1./x^{1.5}$) MRS[D-]

σ_{tot}
σ_{el}
σ_{Diffr}

Rapidity distribution ....

Predictions at LHC and SSC.

depend sensitively on hard structure function at small x

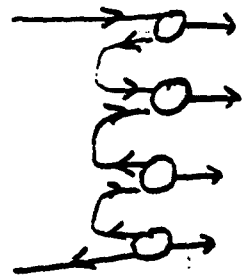
best fit: • corresponds to Block Halzen Margolis
• support supercritical Pomeron

reliable predictions for LHC, SSC only after structure function measurement at HERA

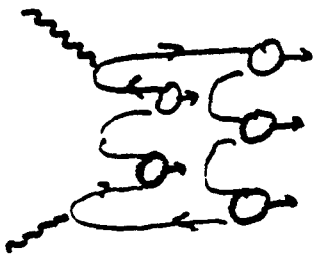
Production of Charm in DTUJET

Soft chain:

① Charm from inside chain decay:



② Charm from sea-chain ends



charm quark probability in BAMJET:

$$P_{q\bar{q}} = C\int_{m_q}^{E_{jet}} 2E\exp(-\beta\cdot E)\,dE$$

for $E_{jet} > m_q$, $\sum P_{q\bar{q}} = 1$

old BAMJET (Strangeness production): $\beta_{s\bar{s}} = 8$

new: $\beta_{c\bar{c}} = \beta_{s\bar{s}} + 1.3 - \log_{10}\left(\frac{E_{CM}}{1\,GeV}\right)$

Semihard chains

③ Semihard chain ends:

use: Anisovich + Metsch

$$P_Q = \frac{m_q^2}{m_Q^2}\,\frac{1}{\ln^2\left(\frac{m_Q^2}{\Lambda^2}\right)}$$

charm $m_c = 1.4\ GeV/c^2$

$\Lambda = 0.2\ GeV/c^2$

$m_q = 0.35\ GeV/c^2$

$\longrightarrow P_c = 0.00506$

See also: De Rujula et al. CERN-TH-6452
(Neutrino fluxes from Charm decay in DPM)

Summary

- The two component Dual Parton Model includes consistently triple Pomeron graphs (diffraction) into the multiparticle production model

- In the model multiparticle production is highly constrained by:
  - measured cross sections: $\sigma_{tot}, \sigma_{inel}, \sigma_{el}, \sigma_{diff.} \ldots$
  - the unitarization scheme
  - QCD perturbation theory, which fixes the minijet component.

- The model is consistent with data in the collider energy range:
  - Rise of the rapidity plateau
  - rise of average $p_\perp$ and the $p_\perp$ tail
  - Violation of KNO scaling
  - $\langle p_\perp \rangle$ – Multiplicity correlation
  - Forward - backward correlation
  - short range correlation
  - Minijets
  - Correlation of jets with the underlying events

- Missing :- theoretical guide lines to constrain string fragmentation
  - Unified description of the soft and hard component.

Conclusions: Hadron production

- Predictions beyond SSC energy very unsafe
  even without new physics
  Measure structure functions at HERA before
  big differences in model predictions

- Pomeron — critical or supercritical ?
  dominance of minijets or soft chains?

- $\frac{1}{x^{1.5}}$ structure functions:
  break at $\sqrt{s} = 1$ TeV ... 10 TeV (10^{15}–10^{17} eV)
  change of slope: σ_{tot}
  Rapidity plateau
  $\langle p_\perp \rangle$

- Model in good agreement with most data
  on hadron production up to 1.8 TeV

- $\sigma_{Diffraction}$ Measurements badly needed.

Santa Fe Jan. 1992

J. Ranft

DTUNUC

Dual Parton Model with full formation zone intranuclear cascade for hadron-hadron, hadron-nucleus and nucleus-nucleus collisions

(E_{lab} up to 20 TeV)

- Glauber cascade
- two-chain Dual Parton Model
  (DPMJET: full multi-chain, two component DPM)
  $E_{CM} < 10$ TeV/N
- full formation zone cascade
- Strange Mesons and Baryons

Leipzig:
H. J. Möhring
I. Kawrakov
J. R

Orsay:
A. Capella
J. Tran Thanh Van

Santiago:
C. Merino
C. Pajares

Milano:
A. Ferrari

DTUNUC will go as event generator into FLUKA

EVENTD replacing:

EVENTV = NUCEVT (E > 5 GeV)
NUCRIN (E < 5 GeV)
empirical cascade particles

WHAT CAN WE LEARN?

1. DEFINING THE PROBLEM.

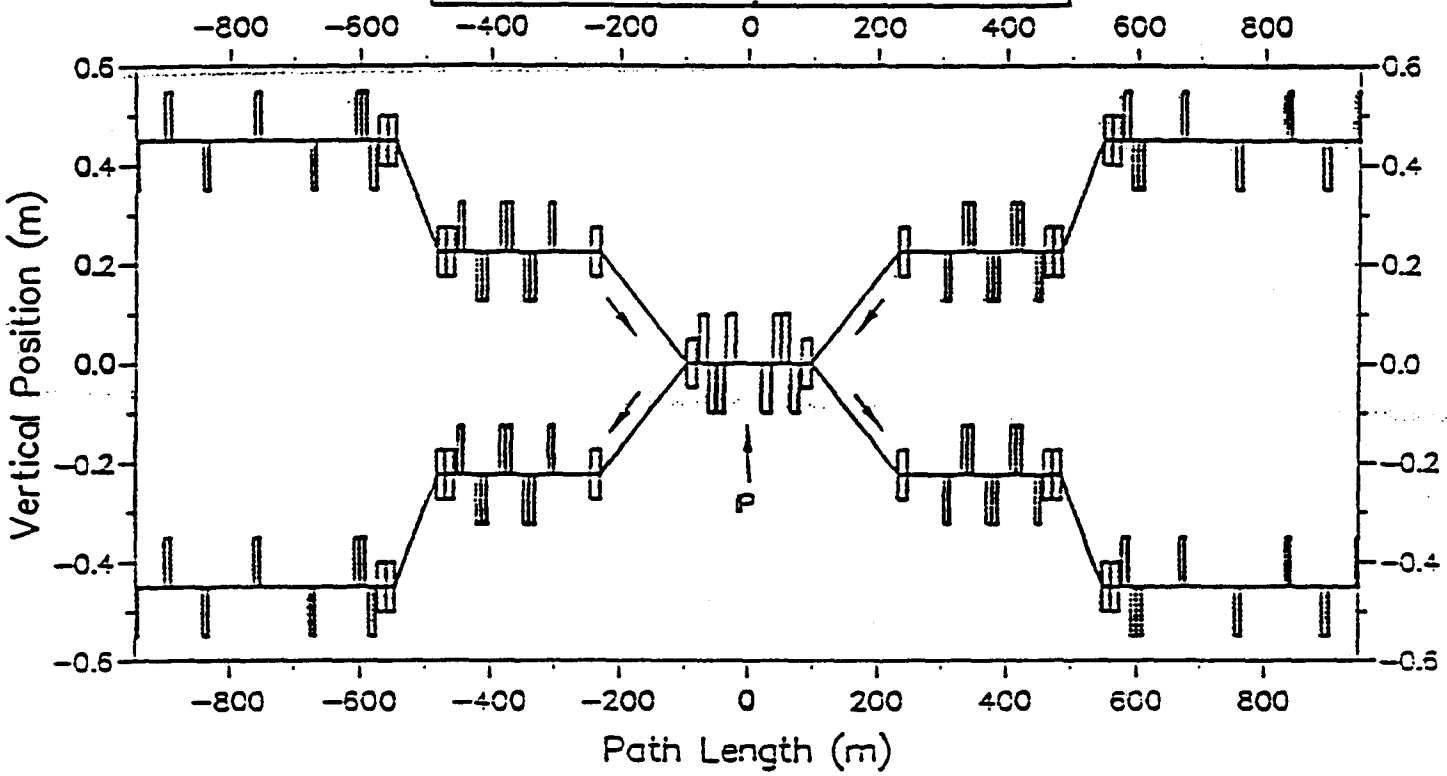
20 TeV PROTONS ⇒ LOTS OF NEUTRONS
(MOST OF THE ENERGY ENDS UP AS LOW-ENERGY NEUTRONS)
CAUSING PROBLEMS WITH
RATES
RADIATION DAMAGE
ACTIVATION
ALSO: HIGH-ENERGY MUONS FROM DOGLEGS

2. UNDERSTANDING THE PROBLEM

AVAILABLE CODES; NEED SIMULATION ALL THE WAY DOWN TO THERMAL NEUTRON ENERGIES (INCLUDING (n,γ) REACTIONS AND RECOIL OF NUCLEUS) → BE AWARE OF WHAT CODES DO + DON'T DO
ALSO: NEUTRONS ≲10keV RATTLE AROUND FOR 0.1 SEC OR MORE; CAN'T STOP FOLLOWING THEM TOO SOON!
DETECTOR RESPONSE
TUBES (BEING SIMULATED BY BRENT MOORE)
SCINTILLATOR / PHOTOTUBES (BNL GROUP SAW SIGNALS INDUCED IN PHOTOTUBES THEMSELVES, PERHAPS DUE TO BORON IN FACE)
RPC's
MEASUREMENTS USING RADIOACTIVE SOURCES (AND OTHERS!) NEED TO BE CAREFUL ABOUT SEPARATING NEUTRONS AND PHOTONS

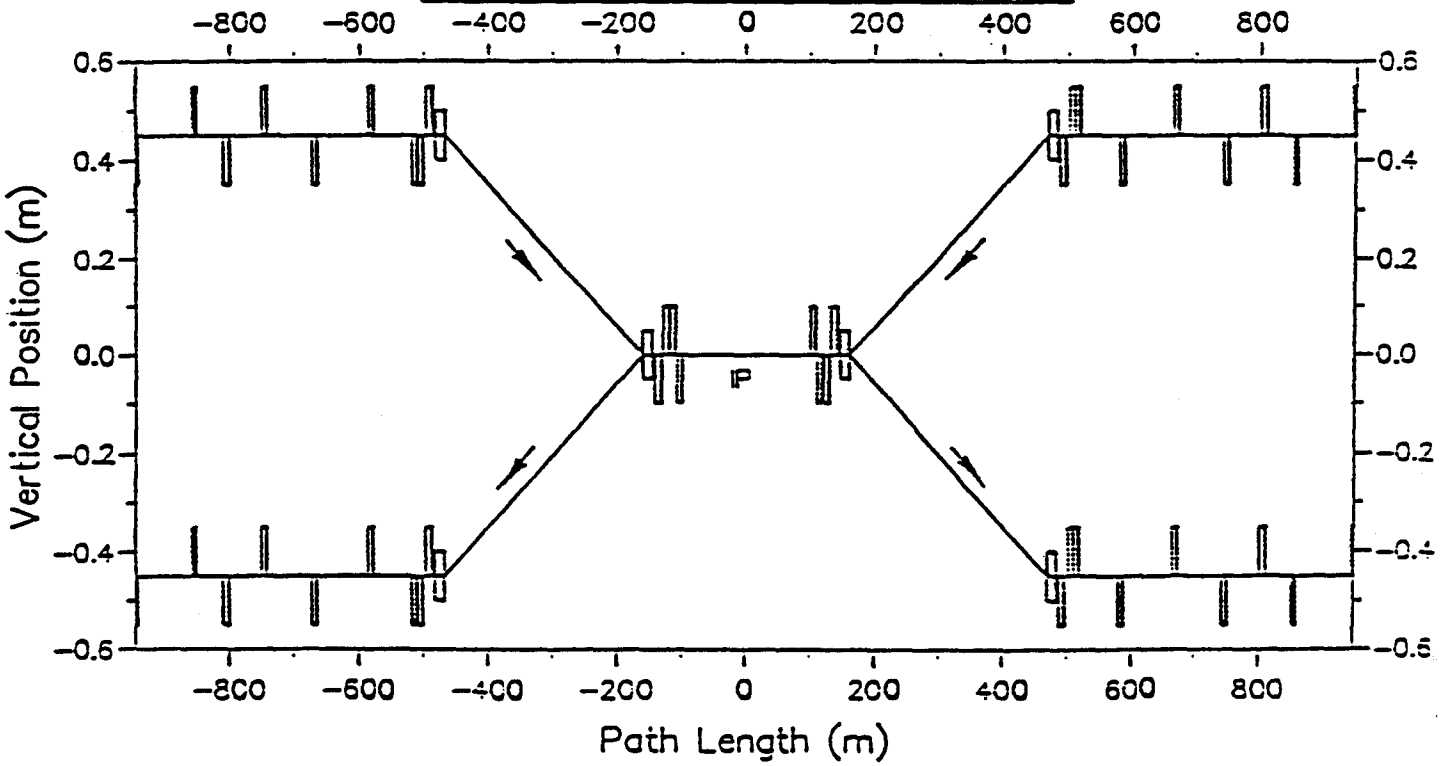
Low Beta Interaction Region.

Detector Free Space 2 x 20 m.



Medium Beta Interaction Region. Alternative Design.

Detector Free Space 2 x 100 m.



20x20 TEV PP-COLLISIONS IN LOW-BETA IR

DTUJET92 + MARS12:

Component	Length (m)	Energy (%)	γ / total
Detector	0 - 18	1.6	0.3
Collimator	18 - 20	4.2	
QL1- QL2_1	20.5 - 50	18.0	0.5
QL2_2 - QL3	50 - 78.3	13.7	
BV1$^-$ - BV1$^+$	78.3 - 244	15.0	
Leak(Protons)	> 244	24.0	
Leak(Neutral)	> 78.3	23.5	0.6

SOURCE TERM IN INTERACTION REGIONS

- <u>20×20 TeV pp collisions</u> at 10^8 Hz (10^{33} $cm^{-2}s^{-1}$)

  Three components: $x_F < 0.8$ secondaries

  $x_F > 0.8$ charge particles (protons)

  $x_F > 0.8$ neutrals

- <u>Beam Halo</u> - Low-beta quads are a bottleneck for halo particles, so even with scrapers and collimators in the system on, they will experience increased beam loss, being a source of background to detector

  At $\beta^* = 0.5$ m $\beta_{peak} = 9180$ m. For 50 mm bore quadrupoles with 42mm beam pipe, LBQ aperture is +/- 30 σ. So, at maximum one can expect ~ 10^7 Hz beam loss rate at these locations

- <u>Accidental Beam Loss</u> $(1.3 - 4) \times 10^{14}$ ppp

NEUTRON BACKGROUND

Neutron Fluence at L=20m and R=2m per the SSC year

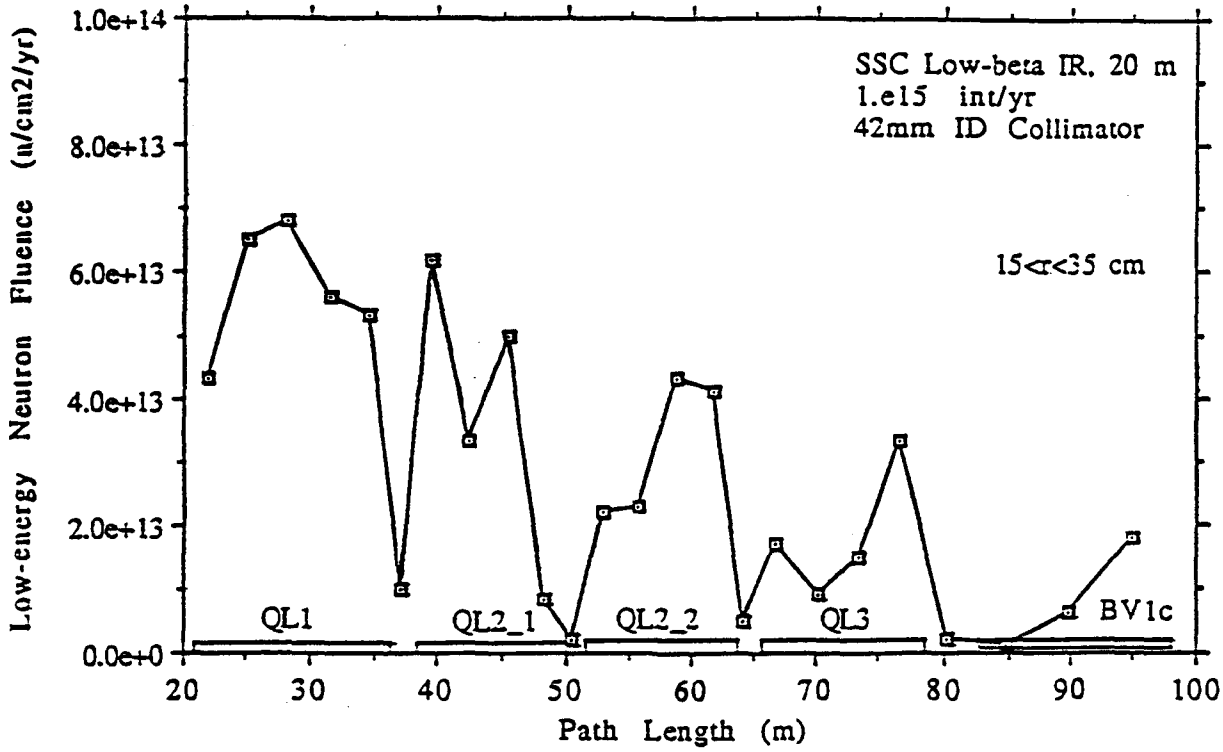
- pp-collisions (10^{33} @ 20 m): 2×10^{12} cm^{-2}

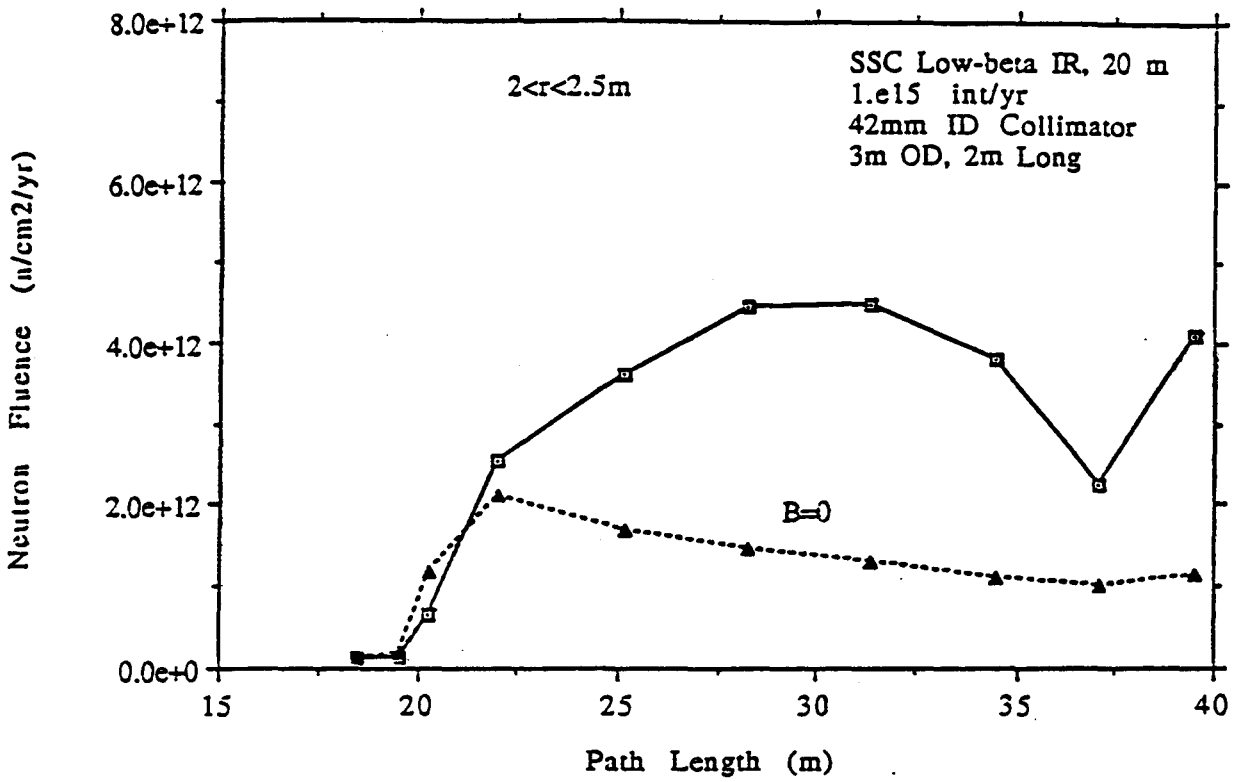
  (can be significantly reduced @ 35 m)

- Local Beam Loss (Normal Operation): 1×10^{9} cm^{-2}

- Beam-Gas (cold+10^{-8} torr in warm): 5×10^{10} cm^{-2}

  around beam pipe: 3.5×10^{12} cm^{-2}


SSC Low-beta IR, 20 m
1.e15 int/yr
42mm ID Collimator
15<r<35 cm
Low-energy Neutron Fluence (n/cm2/yr)
1.0e+14
8.0e+13
6.0e+13
4.0e+13
2.0e+13
0.0e+0
20
30
40
50
60
70
80
90
100
Path Length (m)
QL1
QL2_1
QL2_2
QL3
BV1c


8.0e+12
6.0e+12
4.0e+12
2.0e+12
0.0e+0
Neutron Fluence (n/cm2/yr)
2<r<2.5m
SSC Low-beta IR, 20 m
1.e15 int/yr
42mm ID Collimator
3m OD, 2m Long
B=0
15
20
25
30
35
40
Path Length (m)

3. HOW TO ADDRESS THE PROBLEM

SHIELDING

MANY TYPES OF SHIELDING MATERIAL TEND TO MODERATE NEUTRONS RATHER THAN ABSORB THEM (POLYETHYLENE, WATER, ETC)

MATERIALS WHICH ABSORB (ESPECIALLY THERMAL) NEUTRONS TEND TO DO SO VIA (n, γ) REACTIONS, RESULTING IN ~MeV PHOTONS

DETECTOR MODIFICATIONS

COMPONENTS COULD BE MOVED

IMPACT ON SCINTILLATOR/RPC DECISION?

ČERENKOV COUNTERS?

ACCELERATOR MODIFICATIONS

SHAPE/MATERIAL OF BEAM PIPE

POSITION OF QUADRUPOLE MAGNETS

LOCATION OF "DOGLEGS" (MAJOR REDESIGN TO CHANGE THIS)

4. ASSESSING PROGRESS – QUICK TOOLS

FOR DETECTOR RATE QUESTIONS, ACTIVATION PART OF CALCULATIONS CAN CERTAINLY BE SKIPPED

NEED LOW-ENERGY NUCLEAR REACTIONS

BE CAREFUL ABOUT ASSUMPTIONS! IMPURITIES WITH HIGH CROSS SECTIONS FOR THERMAL NEUTRONS CAN BE IMPORTANT, FOR EXAMPLE

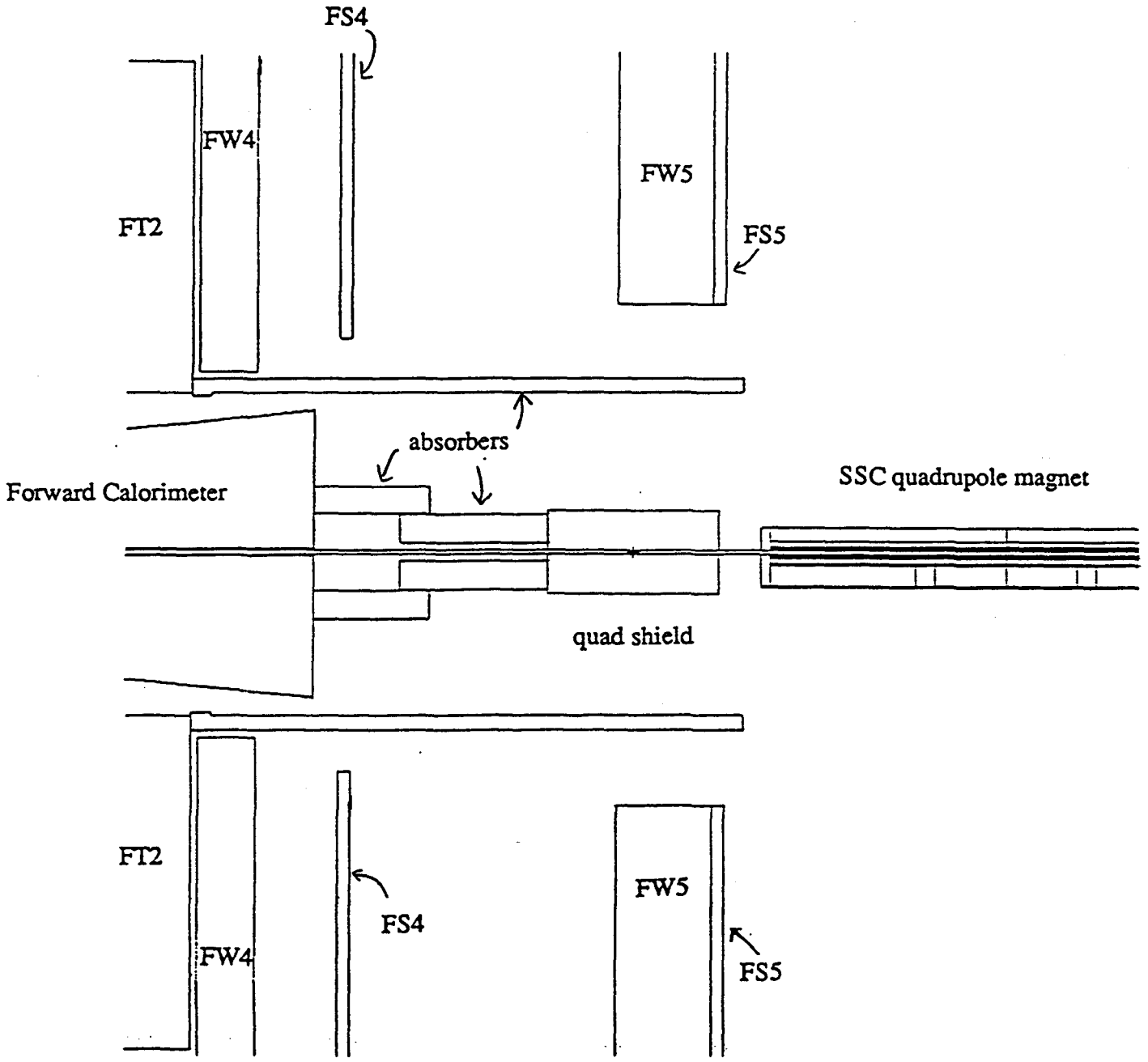


Figure 2: A close-up of the region around z=19m. This shows the end of the quadrupole magnet, the magnet collimators, part of the forward calorimeter, and edges of several muon chambers.

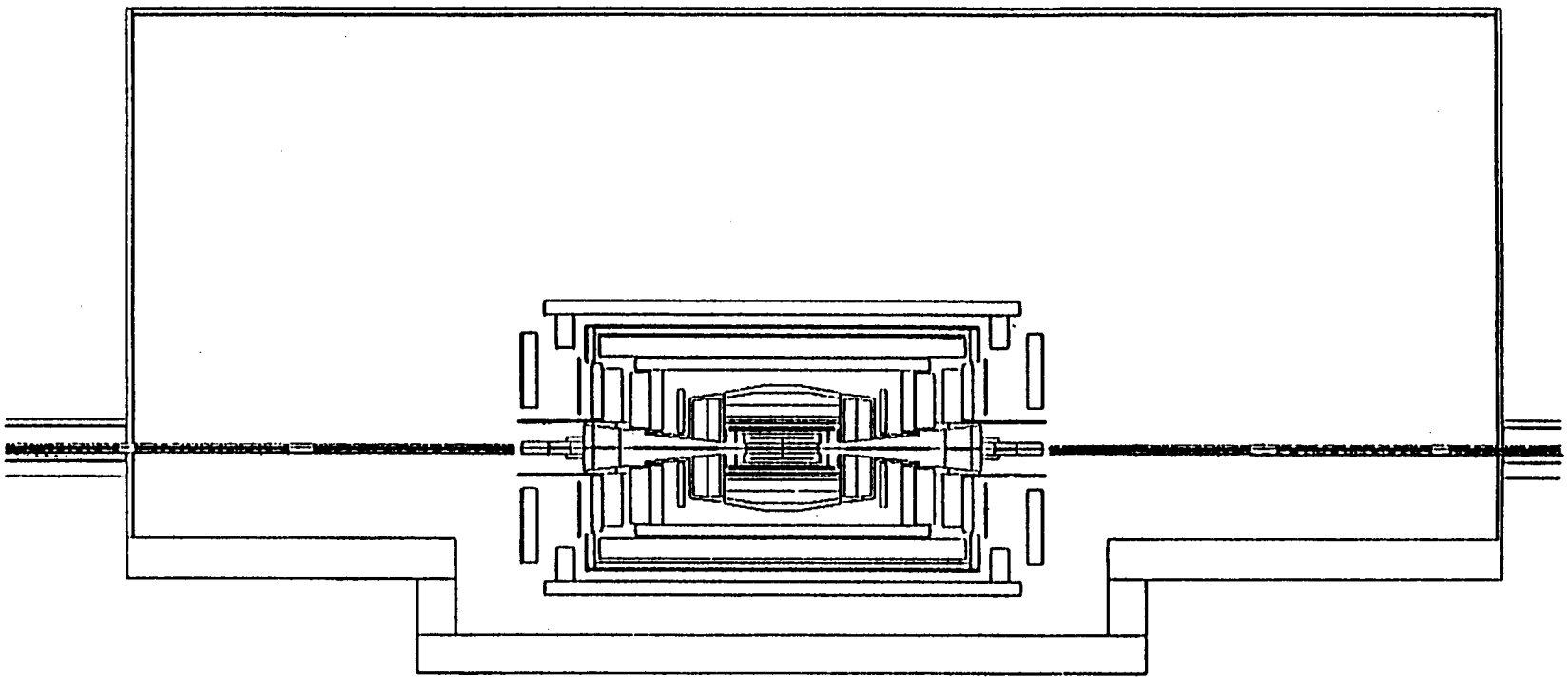
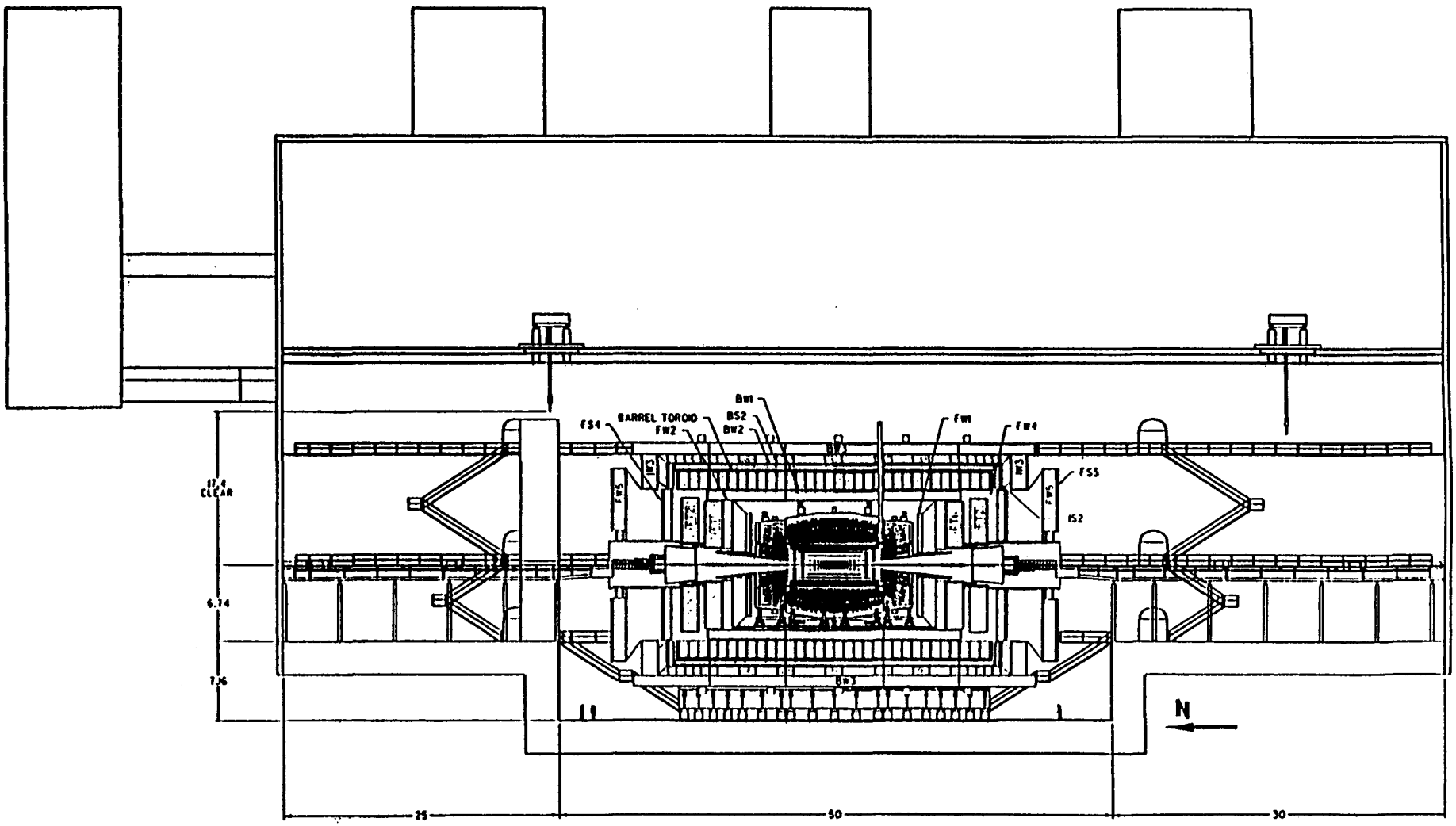


Figure 1: A view of the SDC detector and its hall as modeled for this study.

IR-8 DETECTOR HALL



SDD DRAWING #scd00284.001
10-SEP-1992

Overview of the Codes and Cross Sections Libraries for Shielding the MUON Chambers from Neutrons and Gamma Rays

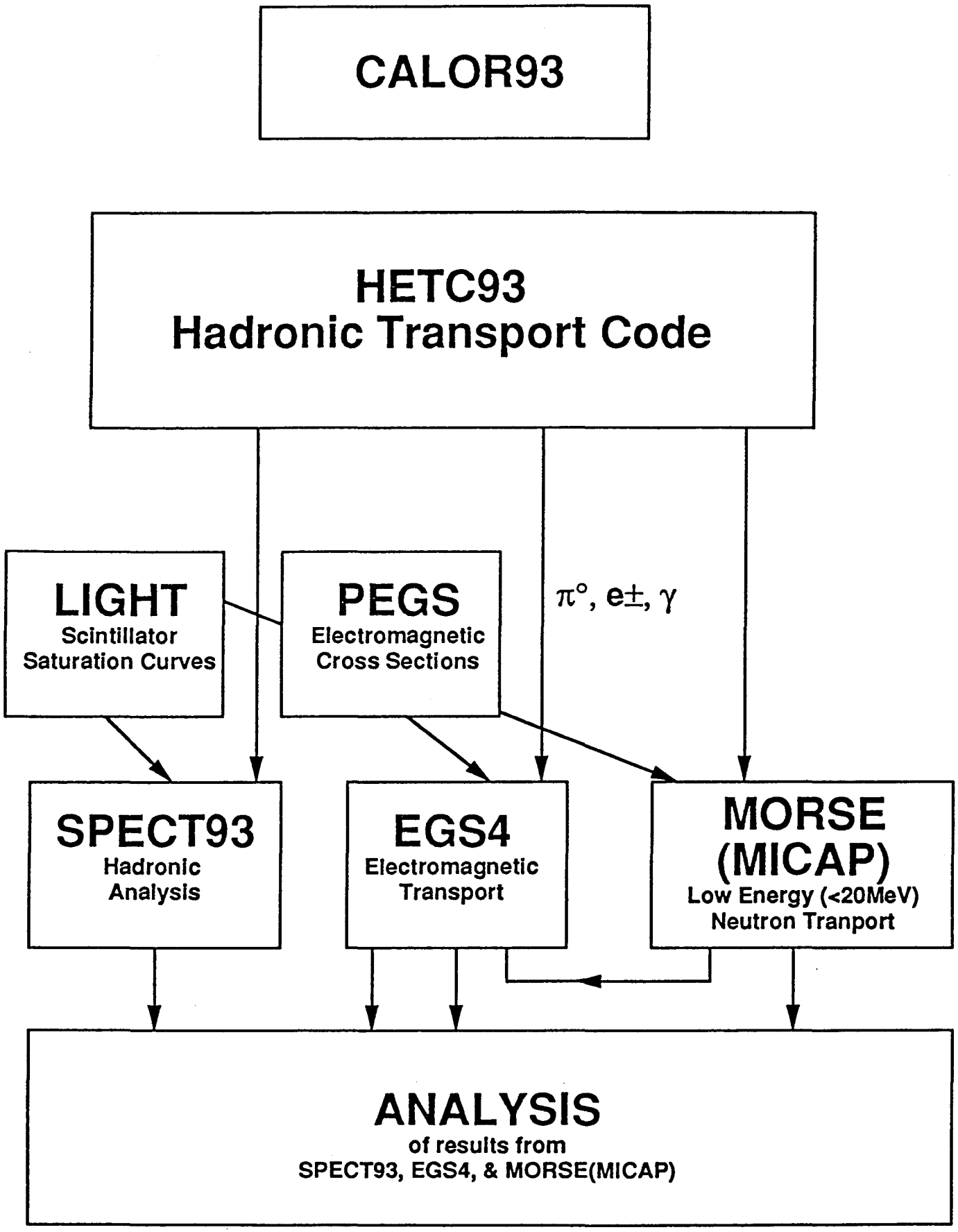
Tony Gabriel
ORNL

During the past 30 years, scientists at ORNL have developed and adapted radiation transport codes for describing in general electromagnetic and hadronic cascades in matter.

This effort has culminated in the CALOR93 code system which is a coupling package linking state-of-the-art codes such as HETC93, SPECT93, LIGHT, EGS4, PEGS4, MORSE, and MICAP.

This code system over the past several years has been used specifically for the analyzing and designing of calorimeter systems for the SSC detector collaborations and for the determination of radiation levels around the accelerator and experimental areas at the SSC for the safety personnel.

During this presentation I would like to briefly describe CALOR and other transport codes and cross section Libraries that can be used to design the optimum μ detector shields


CALOR93
HETC93
Hadronic Transport Code
LIGHT
Scintillator
Saturation Curves
PEGS
Electromagnetic
Cross Sections
π°, e±, γ
SPECT93
Hadronic
Analysis
EGS4
Electromagnetic
Transport
MORSE
(MICAP)
Low Energy (<20MeV)
Neutron Tranport
ANALYSIS
of results from
SPECT93, EGS4, & MORSE(MICAP)

This code system has contributed significantly to the understanding of the physics of calorimeters.

Some of this understanding includes:

- the importance of hydrogen content in the active media,
- the significant role the "electromagnetic sampling inefficiencies" plays in compensation,
- the importance of saturation effects in the active media, and
- the problems liquid argon has with respect to compensations.

This code system predicted (since experimentally verified) that a Pb/plastic calorimeter could be build that was compensating.

Discrete Ordinates Codes (Not Monte Carlo) for the solution of the Boltzmann transport equation

ANISN	1-	Dimensional codes for obtaining n and γ fluxes $(\vec{r}, \vec{\Omega}, E)$
DOT	2-	
TORT	3-	

High Energy Multigroup Cross Section Library

HILO - n (≤ 400 MeV) and γ (≤ 20 MeV)

One-Dimensional Discretes Ordinates Shield Optimization

ASOP - ANISN Shield Optimization Program

Objective - Minimize the weight of a layered shield by moving N boundaries and obtain a desired dose D at a given distance from a radiation source.

Assumptions:

$$\ln D \approx \sum_{i=1}^{N} a_i r_i + C \quad \text{and} \quad \Gamma_i \approx e_i r_i + f_i \quad \textit{for } i = 1,N \;\; ; \;\; \Gamma_i = \left(\frac{\Delta D}{\Delta W}\right)_i$$

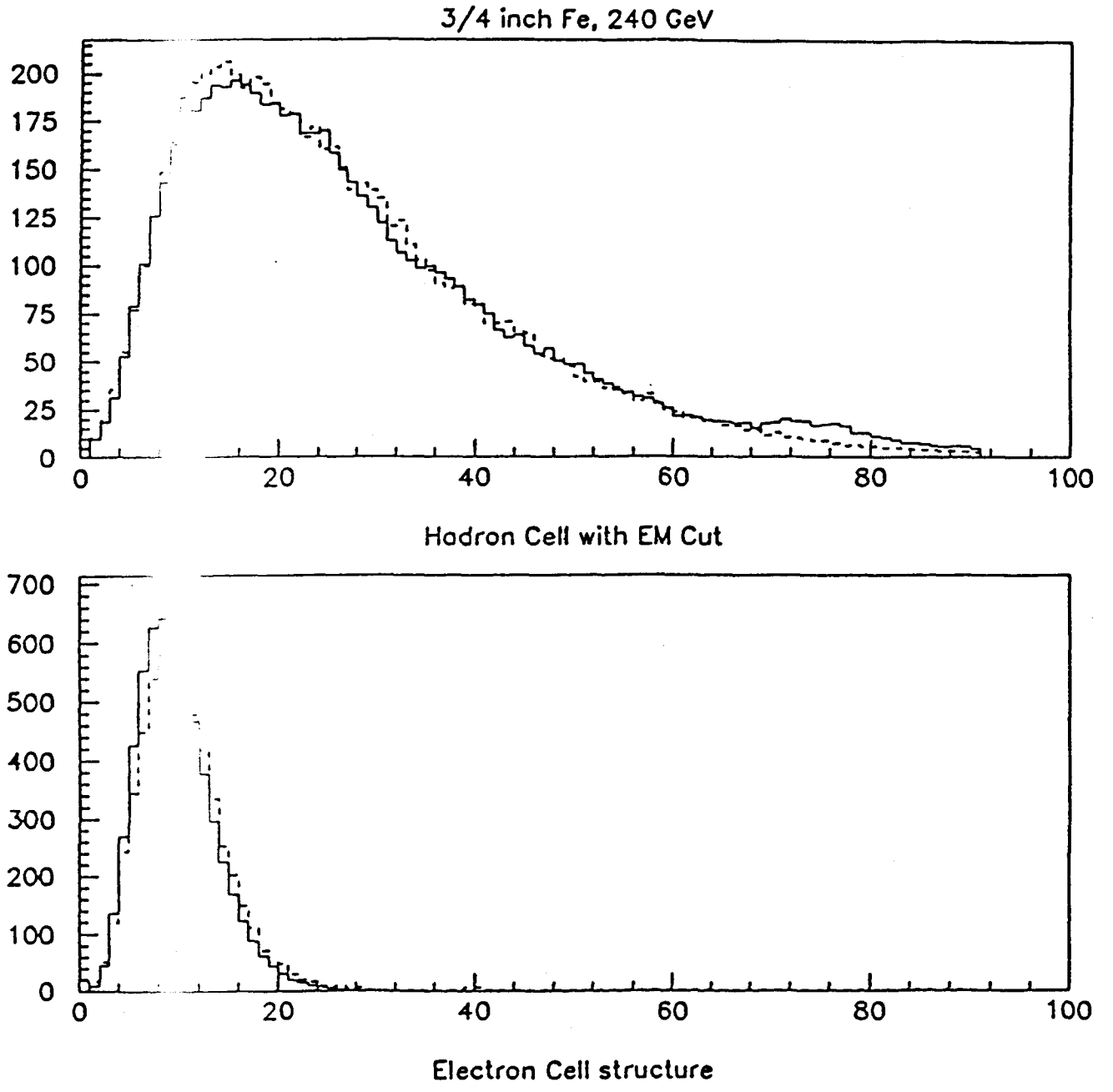
The parameters, i.e., the a_i's, e_i's, f_i's and C, can be obtained by performing a "base case" calculation plus 2 N additional calculations. In each of the 2 N calculations, each of the r_i's is either increased or descreased. With the parameters determined and D set equal to the desired dose, the above equations represent a set of N+1 coupled equations with the r_i's and Γ unknown. Γ represents the value of the $(\Delta D/\Delta W)_i$'s when

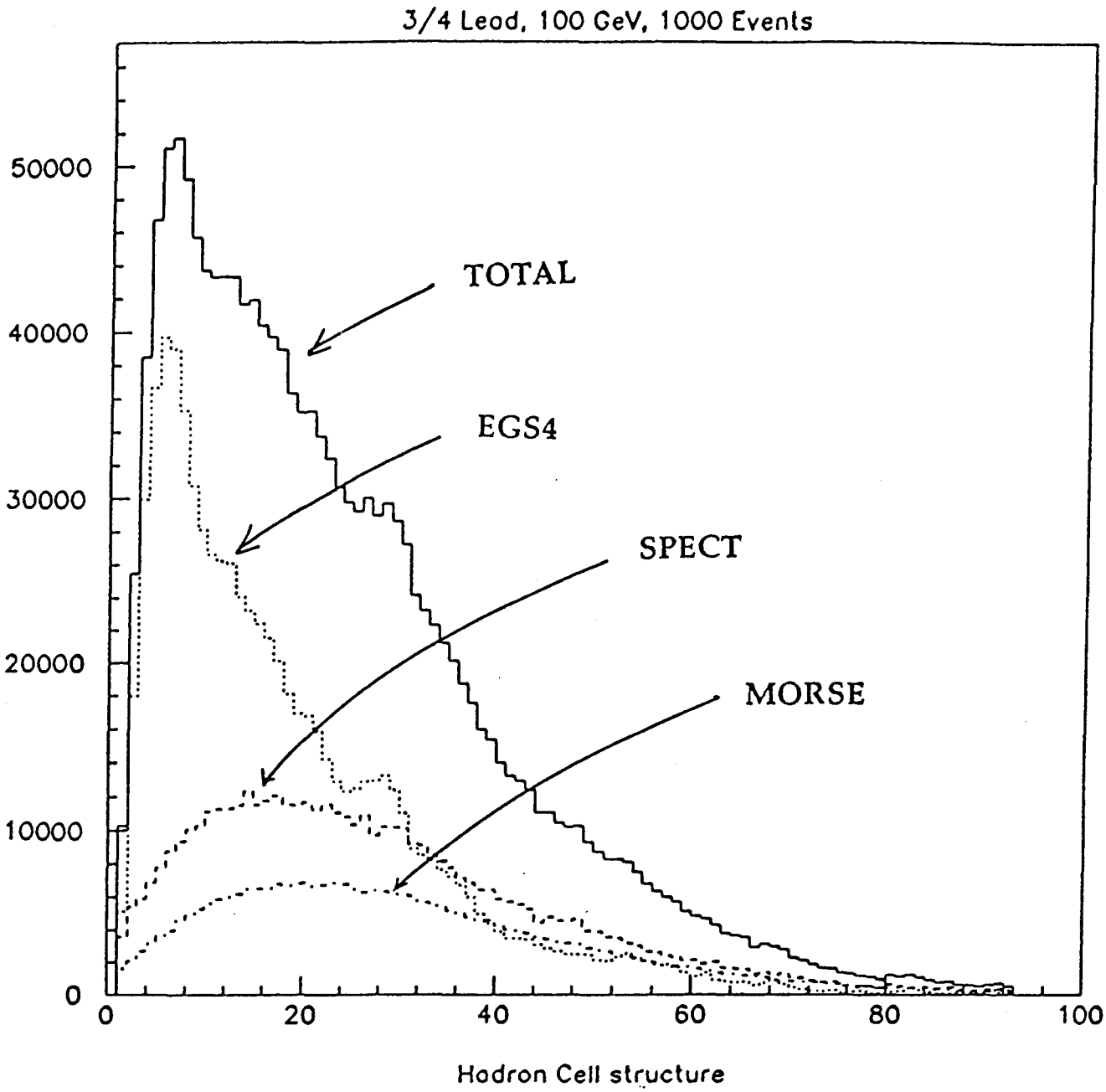
$$\left[\max_i \left(\frac{\Delta D}{\Delta W}\right)_i \Big/ \min_i \left(\frac{\Delta D}{\Delta W}\right)_i\right] - 1 \leq \epsilon$$

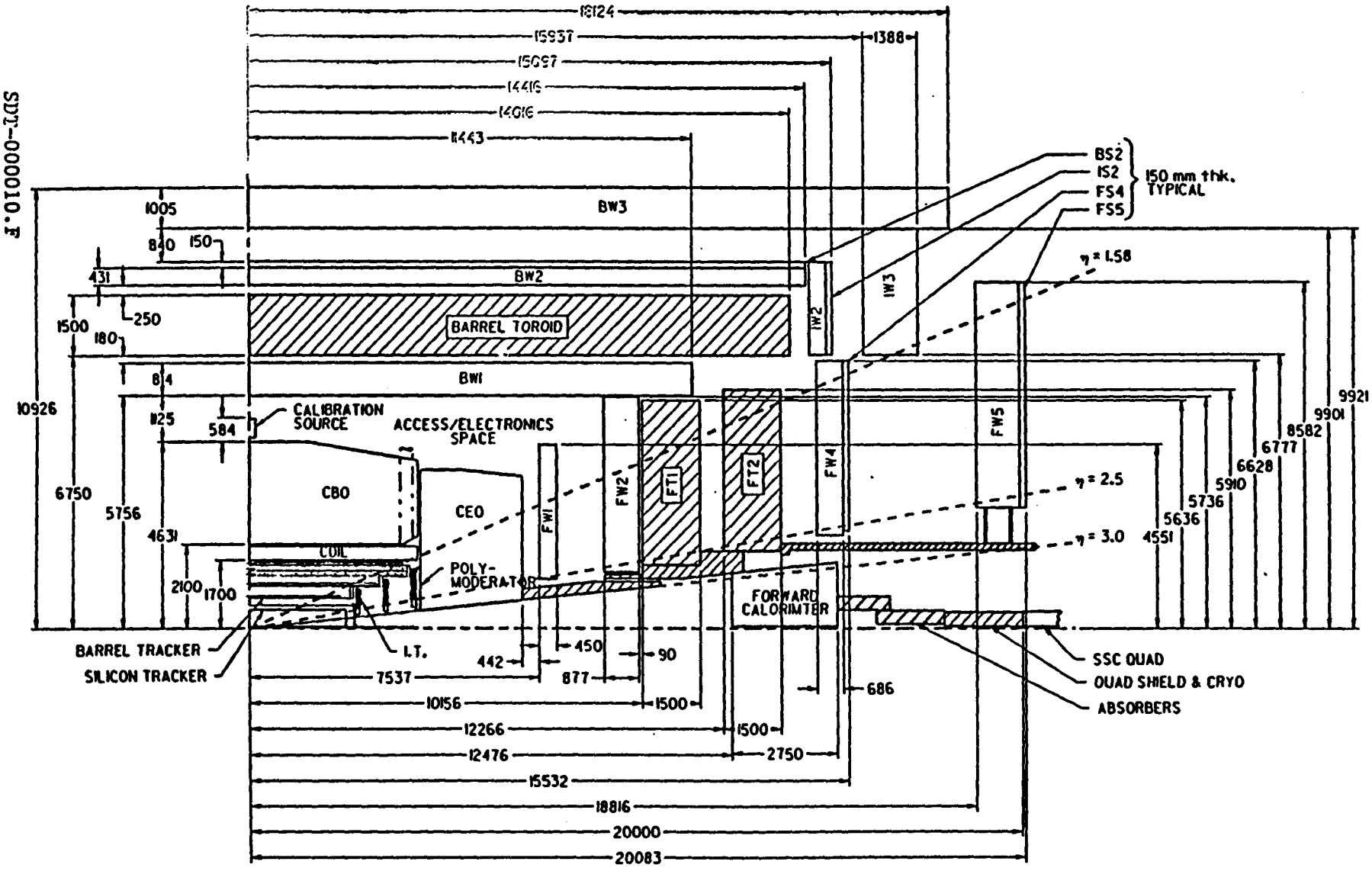
Solve for r_i's, perform 2 N + 1 calculations for new configuration, repeat until above value of Γ is met.

Applications

- Space reactor shielding
- ANS
- Detector performance
- etc


3/4 inch Fe, 240 GeV
200
175
150
125
100
75
50
25
0
0
20
40
60
80
100
Hadron Cell with EM Cut
700
600
500
400
300
200
100
0
0
20
40
60
80
100
Electron Cell structure


3/4 Lead, 100 GeV, 1000 Events
50000
40000
30000
20000
10000
0
0
20
40
60
80
100
TOTAL
EGS4
SPECT
MORSE
Hadron Cell structure



SDC DETECTOR
TECHNICAL PROPOSAL DIMENSIONS
SSC DRAWING # sdd000081.c00
08-SEP-1992

0 1 2 3 5M
NOTE: DIMENSIONS MILLIMETERS

SDC-000010.F

Determination of the Optimum n and γ Shields for the μ Chambers

1) Determine spatial, energy, and angular dependent n and γ currents into shields (LANL + others)

2) Utilize the codes ASOP + MORSE and the σ library HILO to determine minimum shield for minimum n and γ currents into μ chambers (ORNL + others)

3) Determine sensitivity of μ chamber to n and γ
   a) Calculationally (Az, Ms, TN, ORNL + others)
   b) Experimentally (ORELA)

4) Couple sensitivity of μ detectors to n and γ currents to obtain expected events rates...

Summary

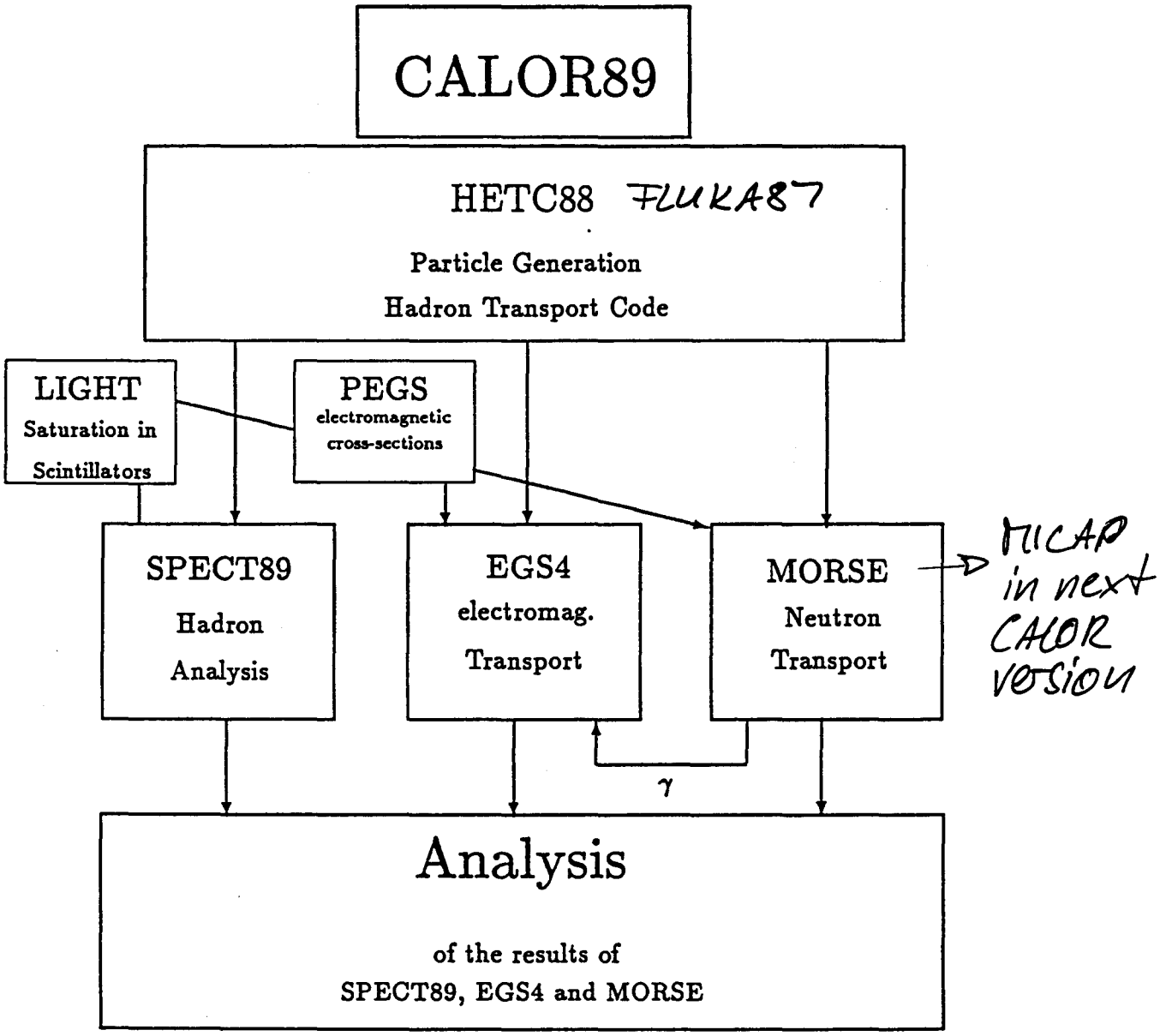
- The codes and experimental facilities exist to carry out the shielding analysis
- funding and manpower are needed
- Let's move!!

C. Zeitnitz
T.A. Gabriel

The GEANT-CALOR interface

-GCALOR-

- CALOR 89
- CALOR in GCALOR
- How to use the interface?
- Comparison of neutron Leakage between CALOR89 and GCALOR
- Simulation of a Cf^{252} neutron source on a Limited streamer tube with GCALOR
- Conclusion


CALOR89
HETC88 FLUKA87
Particle Generation
Hadron Transport Code
LIGHT
Saturation in
Scintillators
PEGS
electromagnetic
cross-sections
SPECT89
Hadron
Analysis
EGS4
electromag.
Transport
MORSE
Neutron
Transport
MICAP
in next
CALOR
version
γ
Analysis
of the results of
SPECT89, EGS4 and MORSE

CALOR 89

- HETC - High Energy Transport Code
  - NMTC - Nucleon Meson Transport Code
    nucleons E > 2.5 GeV
    charged mesons E > 2.5 GeV

    based on intranuclear-cascade-evaporation model

  - Scaling model
    [illegible]

    smooth transition to FLUKA

- modified FLUKA 87
  nucleons E > [illegible] GeV
  charged mesons E > [illegible] GeV
  other particles [illegible]

- MORSE - Multigroup Oak Ridge Stochastic Experiments
  neutrons E < [illegible] GeV
  [illegible]

- EGS 4
  [illegible]

GCALOR

- HETC
  - modified in order to use GEANT material descriptions
  - no weights
  - generation of deexcitation gammas added

- FLUKA version 92 released with GEANT

- Scaling Model
  - Linear transition from HETC to FLUKA between ~3 GeV and 10 GeV
  - particle weights transfered into multiplicity

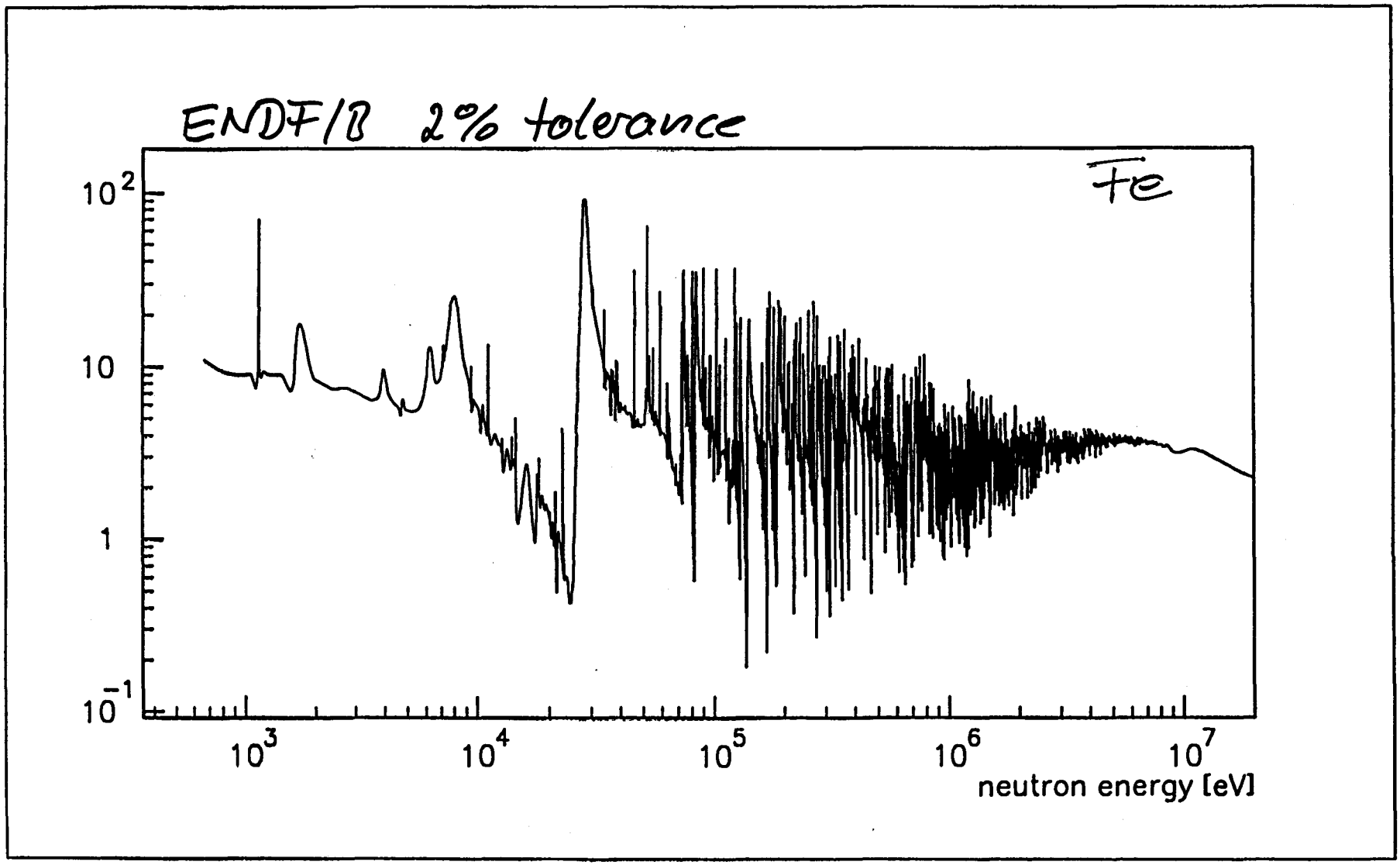
- MICAP neutron code ($E_{kin} < 20$ MeV)
  - similar to MORSE
  - uses ENDF/B data files

MICAP Neutron Code

Monte carlo Ionization Chamber Analysis Package

- similar to MORSE
- advantages:
  - uses preprocessed ENDF/B cross-section data
  - no limited number of energy bins like MORSE → uses all informations from cross-section file
  - energy range : 10^{-5} eV – 20 MeV
  - secondary particle distributions (energy + multiplicity) from ENDF/B data
- changes :
  - no more particle weights are used all particles are explicitly generated (e.g. fission neutrons, deexcitation photons)
  - particle storage
  - material description taken from GEANT

te


ENDF/B 2% tolerance
Fe
10^2
10
1
10^{-1}
10^3
10^4
10^5
10^6
10^7
neutron energy [eV]

- Reaction types

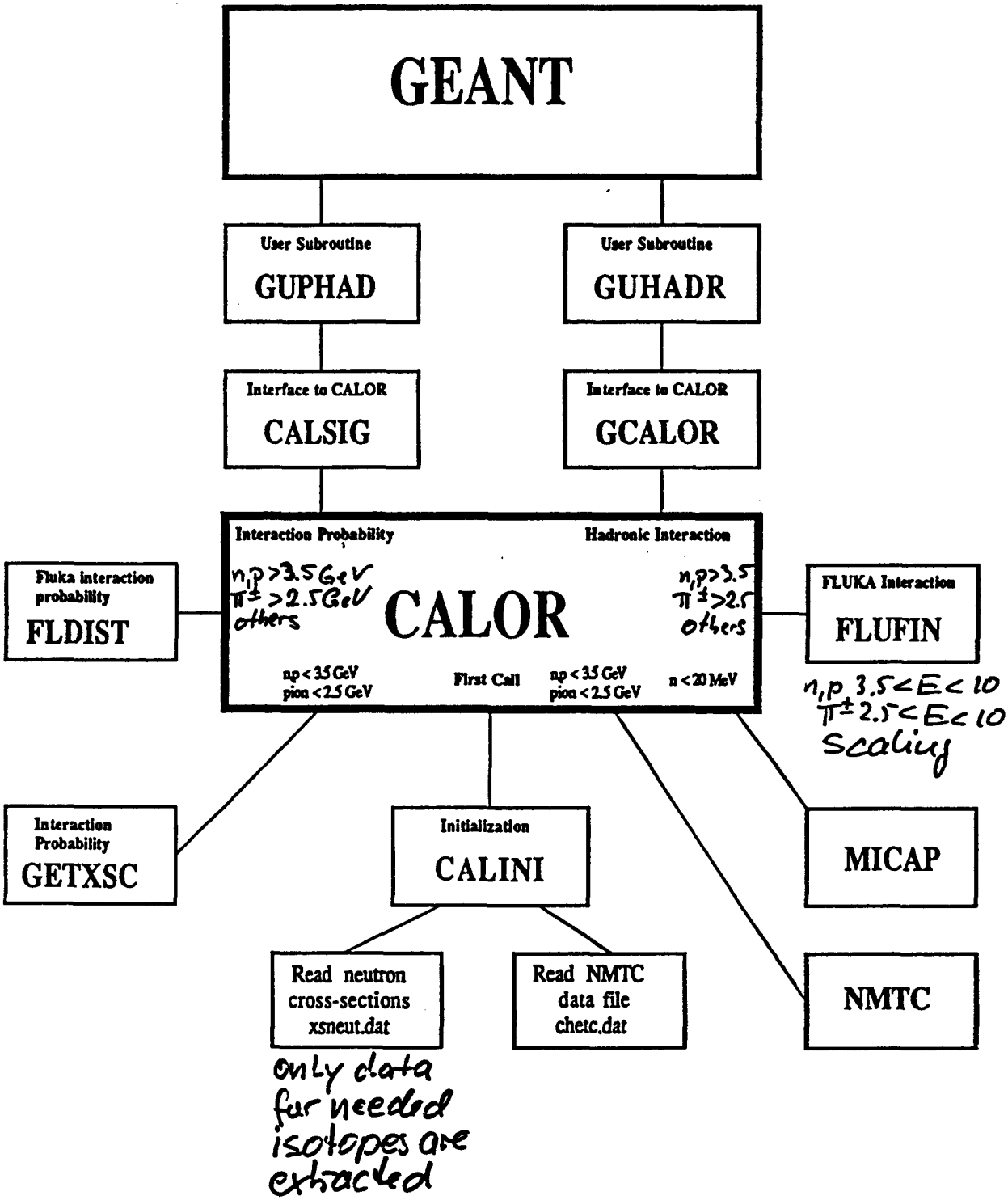
Type of Reaction	final state particles
elastic scatt.	n
(nA,n'A)	n
(nA,2n'A')	2n
(nA,n'αA')	n, α
(nA,2n'αA')	2n, α
(nA,n'pA')	n,p
(nA,n'3αA')	n, 3α
(nA,γA')	γ
(nA,pA')	p
(nA,DA')	D
(nA,TA')	T
(nA,^3HeA')	^3He
absorption	capture γ
(nA,αA')	α
(nA,2αA')	2α
(nA,3αA')	3α
(nA,2pA')	2p
(nA,pαA')	p,α
(nA,T2αA')	T, 2α
(nA,D2αA')	D, 2α
fission	n, p , α

- deexcitation gammas generated, if nucleus after reaction in excitated state

• Isotopes in cross-section file

Isotope		charge number Z	kBytes
Hydrogen	H	1	6
Hydrogen	H_2O bound	1	6
Lithium	^{6}Li	3	29
Lithium	^{7}Li	3	31
Boron	^{10}B	5	47
Boron	^{11}B	5	11
Carbon	C	6	58
Nitrogen	N	7	126
Oxygen	O	8	122
Fluorine	F	9	96
Sodium	Na	11	492
Magnesium	Mg	12	73
Aluminum	Al	13	202
Silicon	Si	14	365
Chlorine	Cl	17	104
Argon	Ar	18	17
Calcium	Ca	20	156
Chromium	Cr	24	289
Iron	Fe	26	591
Nickel	Ni	28	237
Copper	Cu	29	129
Molybdenum	Mo	42	104
Cadmium	Cd	48	68
Barium	Ba	56	21
Tantalum	Ta	73	225
Tungsten	W	74	386
Lead	Pb	82	123
Uranium	^{235}U	92	173
Uranium	^{238}U	92	649

$\sum_{29}$ 4.8 MByte


GEANT
User Subroutine
GUPHAD
User Subroutine
GUHADR
Interface to CALOR
CALSIG
Interface to CALOR
GCALOR
Interaction Probability
Hadronic Interaction
n,p>3.5GeV
π±>2.5GeV
others
CALOR
n,p>3.5
π±>2.5
others
np < 3.5 GeV
pion < 2.5 GeV
First Call
np < 3.5 GeV
pion < 2.5 GeV
n < 20 MeV
Fluka interaction probability
FLDIST
FLUKA Interaction
FLUFIN
n,p 3.5<E<10
π±2.5<E<10
Scaling
Interaction Probability
GETXSC
Initialization
CALINI
MICAP
Read neutron cross-sections xsneut.dat
Read NMTC data file chetc.dat
NMTC
only data for needed isotopes are extracted

Comparison CALOR89 – GCALOR

Particle	Energy	CALOR89	CALOR in GEANT
$\gamma, e^{\pm}, \pi^{0}$	all	EGS4	GEANT em code
$\pi^{\pm}$	$1\,MeV < E < 2.5\,GeV$	NMTC	NMTC
$\pi^{\pm}$	$2.5\,GeV < E < 10\,GeV$	Scaling	Scaling
$\pi^{\pm}$	$> 10\,GeV$	FLUKA87	FLUKA92?
p	$1\,MeV < E < 3.5\,GeV$	NMTC	NMTC
p	$3.5\,GeV < E < 10\,GeV$	Scaling	Scaling
p	$> 10\,GeV$	FLUKA87	FLUKA92
n	$20\,MeV < E < 3.5\,GeV$	NMTC	NMTC
n	$3.5\,GeV < E < 10\,GeV$	Scaling	Scaling
n	$> 10\,GeV$	FLUKA87	FLUKA92
n	$10^{-5}\,eV < E < 20\,MeV$	MORSE	MICAP
other	all	FLUKA87	FLUKA92

```
*****************************************************
*                                                   *
*    GEANT - CALOR Interface  Version  0.91/08      *
*    ----------------------------------------       *
*    24 November 1992 C.Zeitnitz, T.A.Gabriel       *
*                                                   *
*     NMTC is used for hadronic interactions of     *
*        protons,neutrons and charged pions         *
*   up to 3.5 GeV (proton,neutron), 2.5 GeV(pion)   *
*                                                   *
*    A Scaling Model is used for the energy range   *
*                  up to 10 GeV.                    *
*                                                   *
*      MICAP is calculating the interaction of      *
*       Neutrons with an energy below 20 MeV        *
*                                                   *
*   For interactions of hadrons not implemented in  *
*        CALOR or with an energy above 10 GeV       *
*                  FLUKA is called                  *
*                                                   *
*  The transport of electrons, positrons and gammas *
*                  is done by GEANT                 *
*                                                   *
*****************************************************
```

Message in GEANT OUTPUT

File CALOR.OUT

GEANT-CALOR INTERFACE V 0.91/07 Output File

MICAP Material Parameters

Medium	GEANT	A	Z	Density (Atoms/cm^3*E-24)	No. words
1	9	26.98	13	0.6027E-01	51943
2	10	55.84	26	0.8486E-01	151368
3	13	207.21	82	0.3299E-01	31675
4	14	238.05	92	0.4794E-01	166271
5	15	14.00	7	0.4967E-04	32479
6	99	1.01	1	0.5251E-01	2097
6	99	12.00	6	0.4774E-01	14722

Neutron x-section file generated Wed Sep 23 13:41:01 1992
MICAP neutron cross-section file. TOL=2.0% ANG=2.0% C.Zeitnitz

MICAP : 456621 words used in GCBANK for neutron x-section tables

Density : Element $\frac{\rho[g/cm^3]}{A[g]} \cdot 0.6022$

in Molecule $\frac{\rho}{A_{mol}} \cdot 0.6022 \cdot N_i$ -

How to use GCALOR on PDSF-cluster

- changes to GEANT source:

Subroutine GUPHAD

```
C  Call GHEISH
   Call GCALOR
   RETURN
```

Subroutine GUHADR

```
C  Call GPGHEI
   Call CALSIG
   RETURN
```

- GCALOR Library:

/home/dssg3/gem/zeitnitz/gcalor/Lib

HP: ./hp/Libgcalor.a
Sun: ./sun/Libgcalor.a
SGI: ./sgi/Libgcalor.a

- Data files:
Files are expected in cwd

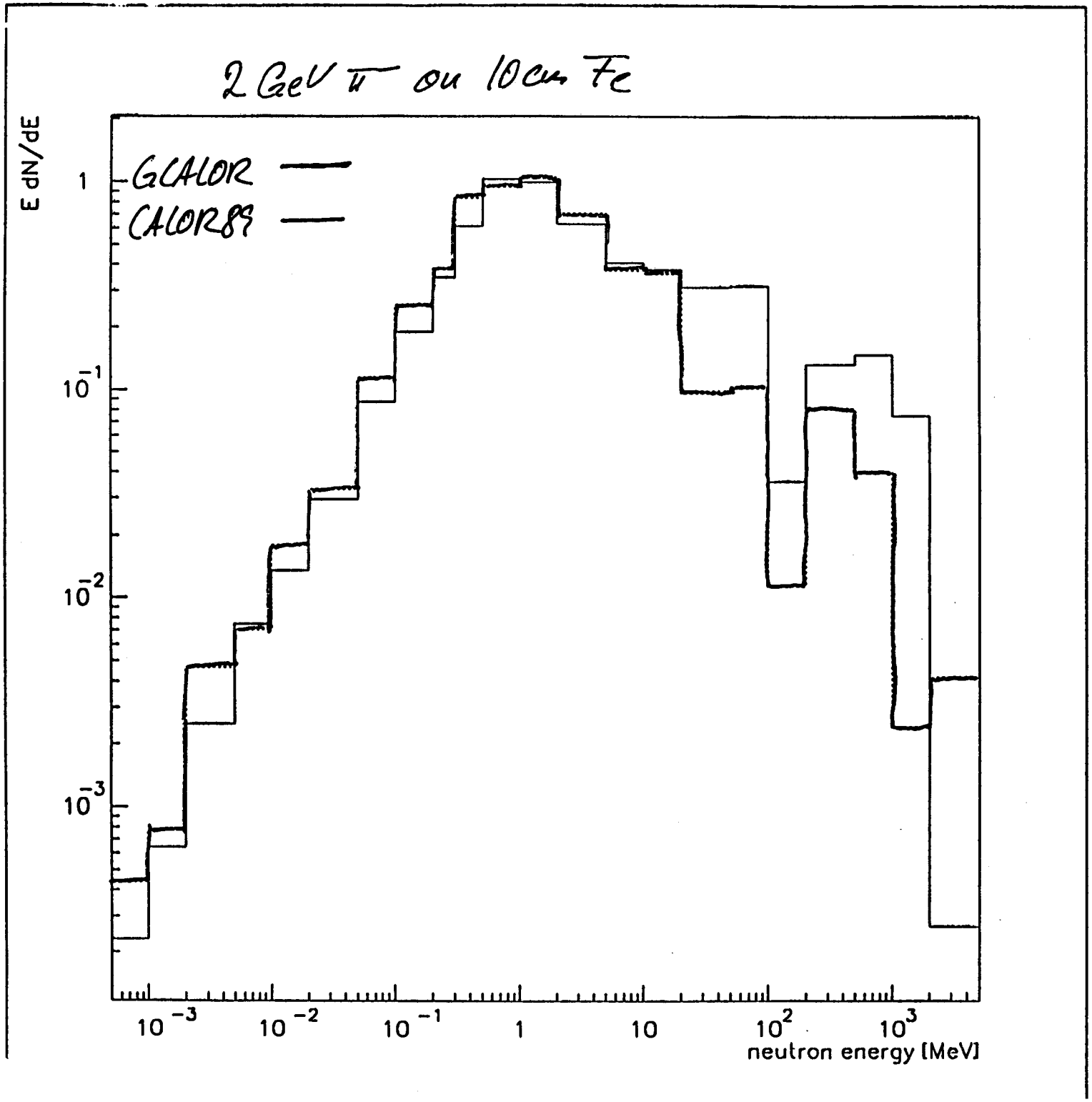
```
ln -s /home/dssg3/gem/zeitnitz/gcalor/data/chetc.dat
                                          chetc.dat

ln -s " /xsneut.dat  xsneut.dat
```

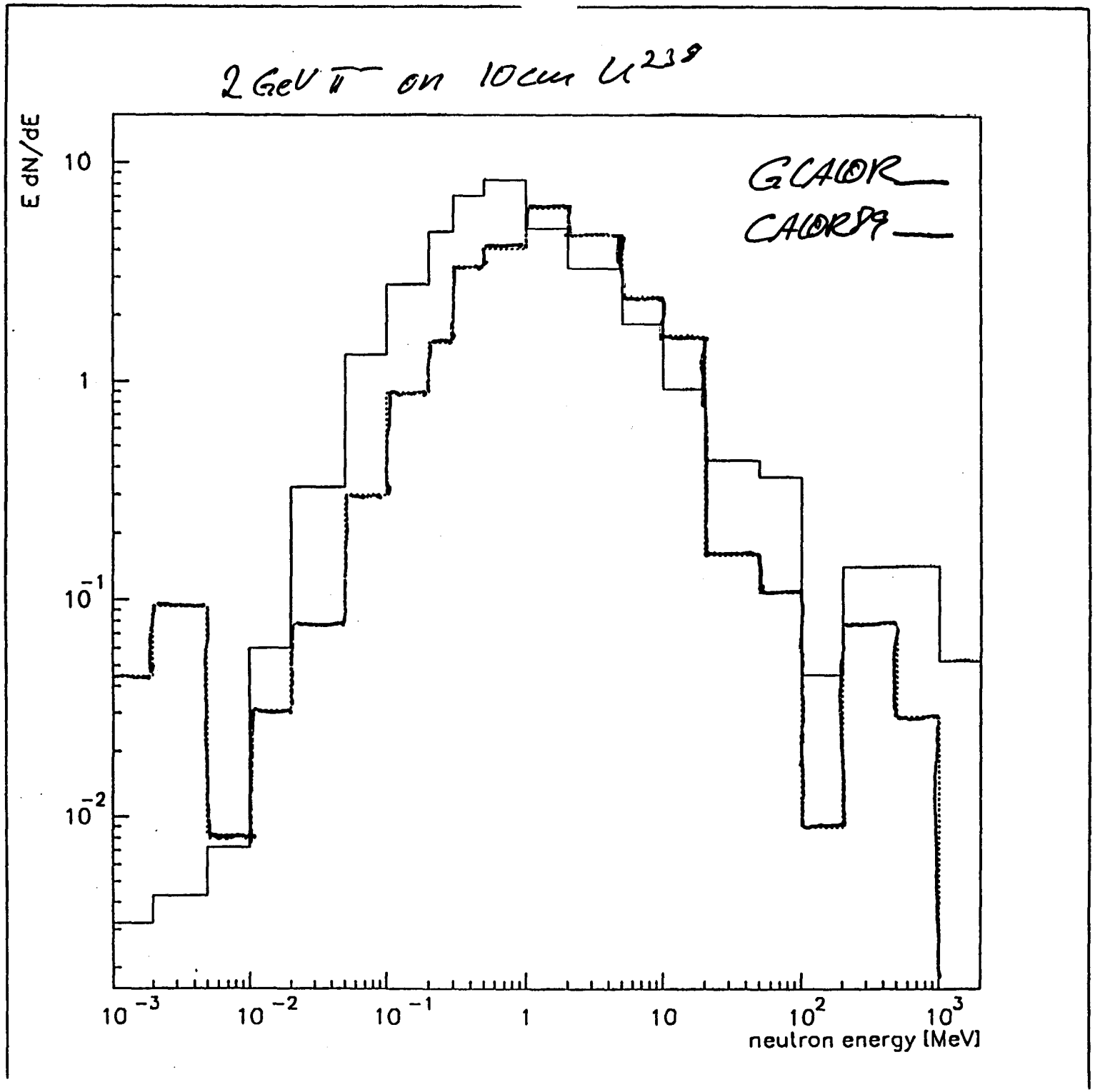
- Cuts:
CUTNEU > 10^{-13}
TOFCUT ~ 500 nsec

Comparison of neutron leakage

- Fe (U^{238}) slab 500 x 500 cm^2
  thickness 10 cm, 100 cm
- Incident particle : π^- 2, 10 GeV
  n 14 MeV
- Cuts: time cut = 500 usec
  CUTNEU = 0.1 eV
- Neutron Multiplicity

Setup	E	n/incident particle GCALOR	CALOR89
10cm Fe	2 GeV π^-	4.3	3.9
	10 GeV π^-	5.4	8.1
100cm Fe	10 GeV π^-	14.6	9.5
10cm U	2 GeV π^-	25.4	18.4
	10 GeV π^-	51.9	45.4
20cm Fe	14 MeV n	0.54	0.51


2 GeV π⁻ on 10cm Fe
GCALOR
CALOR89
E dN/dE
1
10⁻¹
10⁻²
10⁻³
10⁻³
10⁻²
10⁻¹
1
10
10²
10³
neutron energy [MeV]


2 GeV π⁻ on 10cm U²³⁸
GCALOR
CALOR89
E dN/dE
10
1
10⁻¹
10⁻²
10⁻³
10⁻²
10⁻¹
1
10
10²
10³
neutron energy [MeV]

Cf^{252} source on $Ar-C_4H_{10}$ gas chamber

- Measurements show, that ~0.4% of the neutrons give hit in Limited streamer tube (90% isobutane) GEN TN-92-122

- Simulation:
  - Setup: $2 \times 2\ cm^2$ cross-section
    22 cm long
    1mm thick AL wall

  - Neutron spectrum taken from GEN report
  - Cutoffs: CUTNEU = 10^{-4} eV
    TOFCUT = 1 sec

  - Direct photons not taken into account

  - Simulation redone with flat energy spectrum $E_n < 20$ MeV

  - 10^5 neutrons simulated

- Results (including recoil nucleus energy)

% C_4H_{10}	Cf^{252}-spectrum		Flat-spectrum	
	>0.0	>1keV	>0.0	>1ke
90	0.418%	0.339%	0.168%	0.167%
40	0.2%	0.155%	0.087%	0.084%
1	0.033%	0.025%	0.036%	0.034%

Contribution from recoil nucleus: 0.08%–0.03%

Conclusion

- The GEANT-CALOR interface does work, but some problems have to be studied
- Available on PDSF-cluster
- Code can be copied from:

ANONYMOUS@UAZHEP.PHYSICS.ARIZONA.EDU
Password: GUEST
Directory : GCALOR

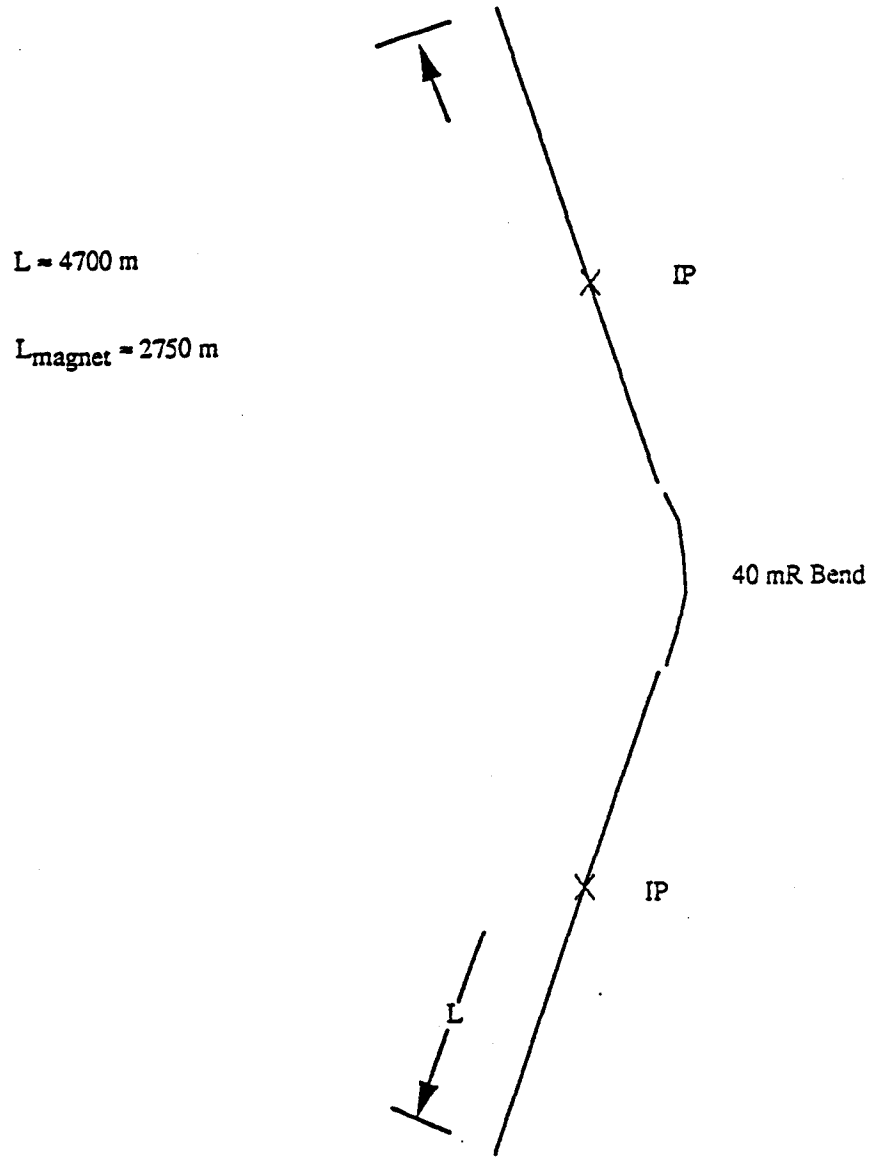
GCALOR.CAR
GCALOR_VAX.FOR
GCALOR_UNIX.FOR
XSNEUT.DAT
CHETC.DAT

S.D.C. WORKSHOP

1/19/93

ROY LITTLE (PMO)

ACCELERATOR
- ASPECTS
- PERSPECTIVE
- INTRODUCTION
- OVERVIEW
- ⋮
- OPINIONS



The East Low β* Interaction Regions

The Preferred Design
August 14, 1992

$$L = \frac{N_B^2 \gamma_r c}{4\pi\varepsilon_N \beta^* S_B}$$

$N_B = 0.75 \times 10^{10}$ protons/bunch
$\gamma_r = 2.13 \times 10^4$ at 20 TeV
$c = 3 \times 10^8$ m/s
$S_B = 5$m
$\varepsilon_N = 10^{-6}$ m x rad

For $\beta^* = 0.5$m, $L = 1.1 \times 10^{33}$ cm^{-2}s^{-1}
For $\beta^* = 40$m, $L = 2.8 \times 10^{31}$ cm^{-2}s^{-1}

For "preferred design" the optics can span the range

$0.5\text{m} < \beta^* < 40\text{m}$ w 5cm bore quads
$20.5\text{m} < L^* < 90\text{m}$

Without changing the basic design of major components such as superconducting magnets. (Not all points in β^*, L^* simultaneously available)

L^* (m)	β squeeze range (m)
20.5	$7 \rightarrow 0.5$
34.6	$11 \rightarrow 0.7$
56.9	$23 \rightarrow 1.1$
90	$40 \rightarrow 2$

- TRANSVERSE BEAM SIZE AT IP:

$$\sigma^2 = \varepsilon\beta^* \,,\ \varepsilon = \varepsilon_N/\beta_r\gamma_r$$

$1\sigma = 5 \times 10^{-6}$ m at $\beta^* = 0.5$m, 20TeV
$1\sigma = 43 \times 10^{-6}$ m at $\beta^* = 40$m, 20TeV
Need > 10σ transverse for beam lifetime

- BEAM DIVERGENCE AT IP:

$$(\sigma')^2 = \frac{\varepsilon_N}{\gamma_r\beta^*}$$

$1\sigma' \cong 10\,\mu$rad at $\beta^* = 0.5$m, 20 TeV
$1\sigma' \cong 1.1\,\mu$rad at $\beta^* = 40$m, 20 TeV

- LONGITUDINAL BEAM SIZE:

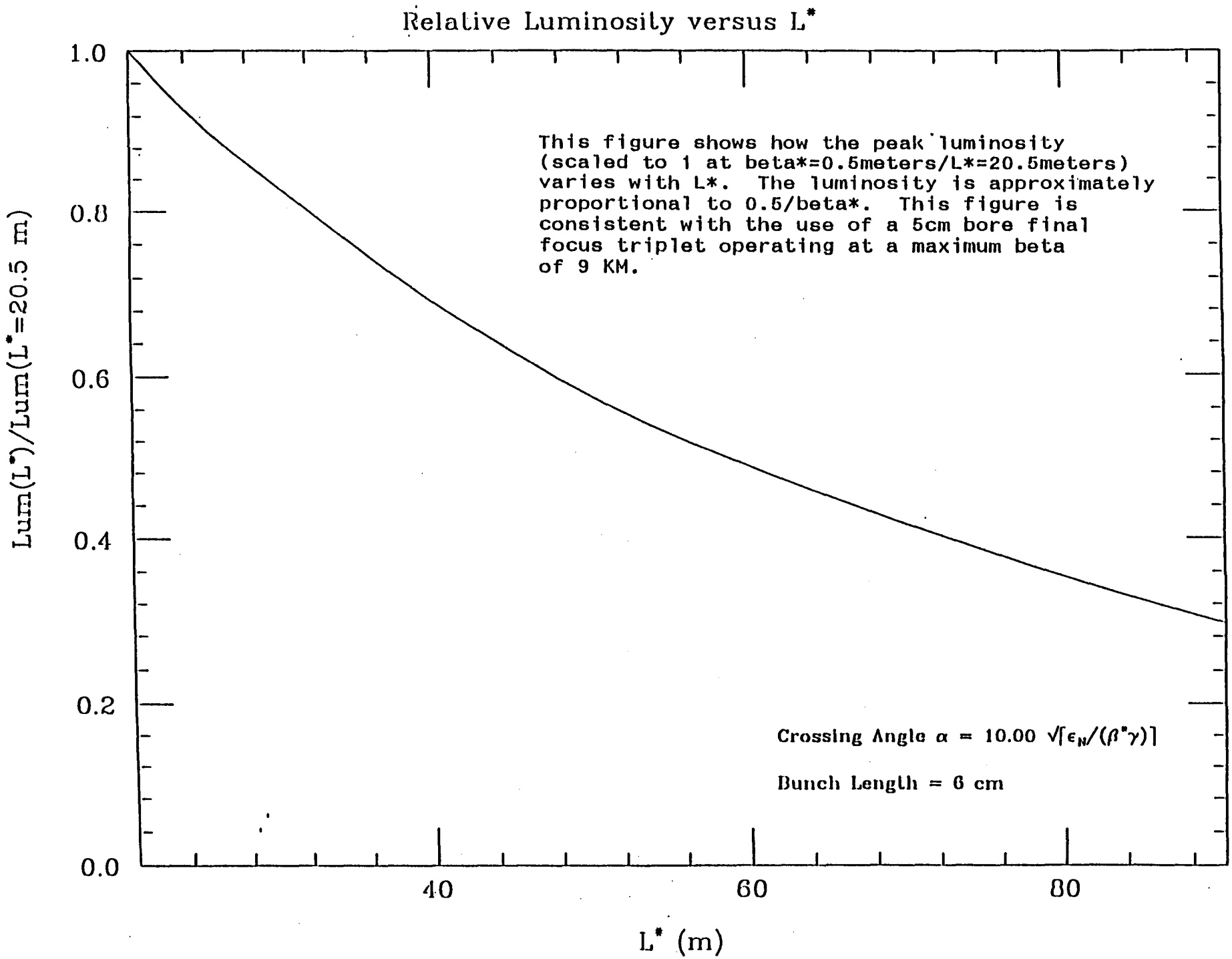
$$1\sigma \cong 6 \times 10^{-2}\ \text{m}$$

- CROSSING ANGLE (TOTAL)

$$\theta = A\sqrt{\frac{\varepsilon_N}{\gamma_r\beta^*}}$$

$\Theta \cong 10 \times$ beam divergence

$\Theta \cong$ ~~100~~ 140 μrad at $\beta^* = 0.5$m, 20 TeV


Relative Luminosity versus L*
This figure shows how the peak luminosity (scaled to 1 at beta*=0.5meters/L*=20.5meters) varies with L*. The luminosity is approximately proportional to 0.5/beta*. This figure is consistent with the use of a 5cm bore final focus triplet operating at a maximum beta of 9 KM.
Crossing Angle α = 10.00 √[εN/(β*γ)]
Bunch Length = 6 cm
Lum(L*)/Lum(L*=20.5 m)
1.0
0.8
0.6
0.4
0.2
0.0
40
60
80
L* (m)

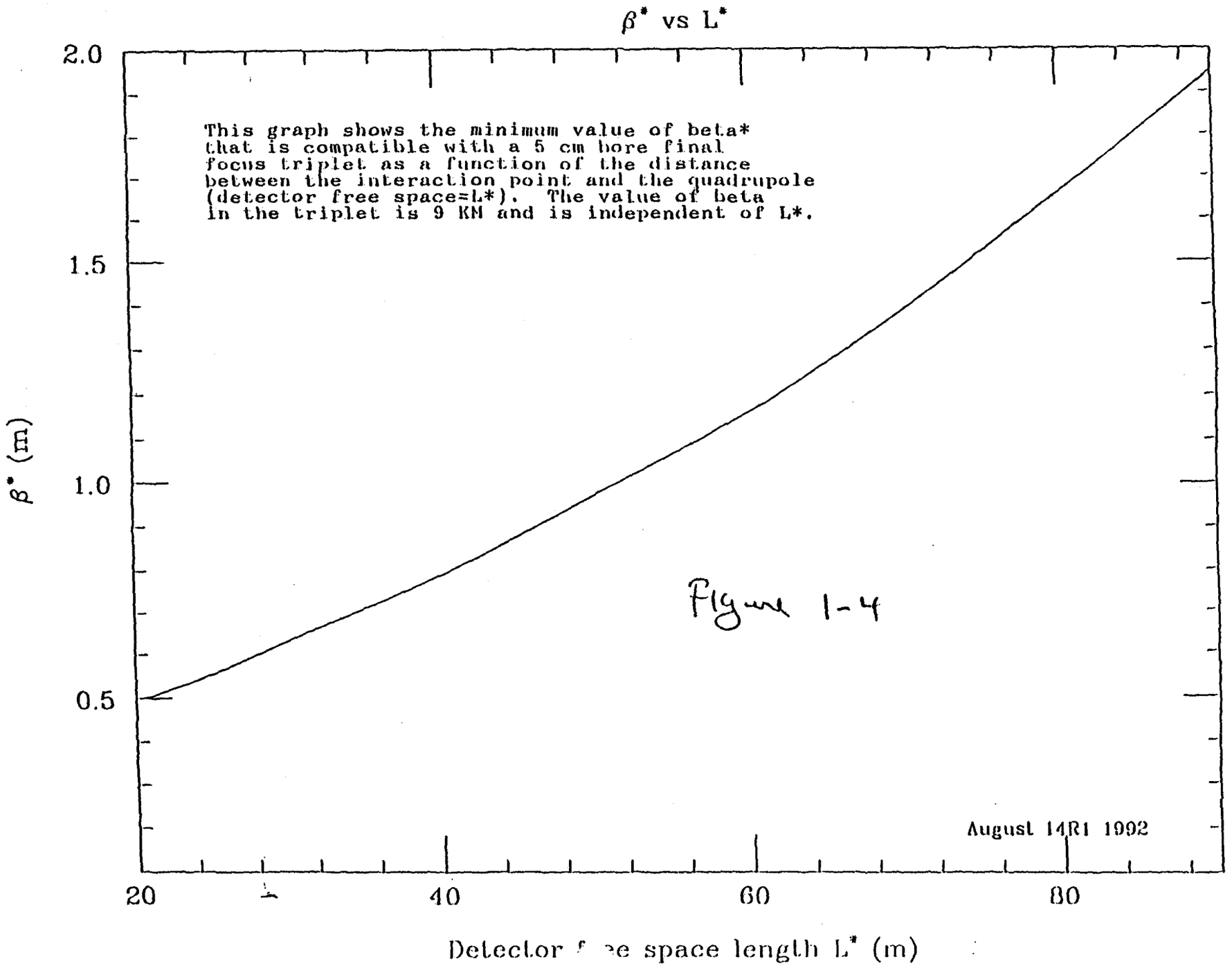
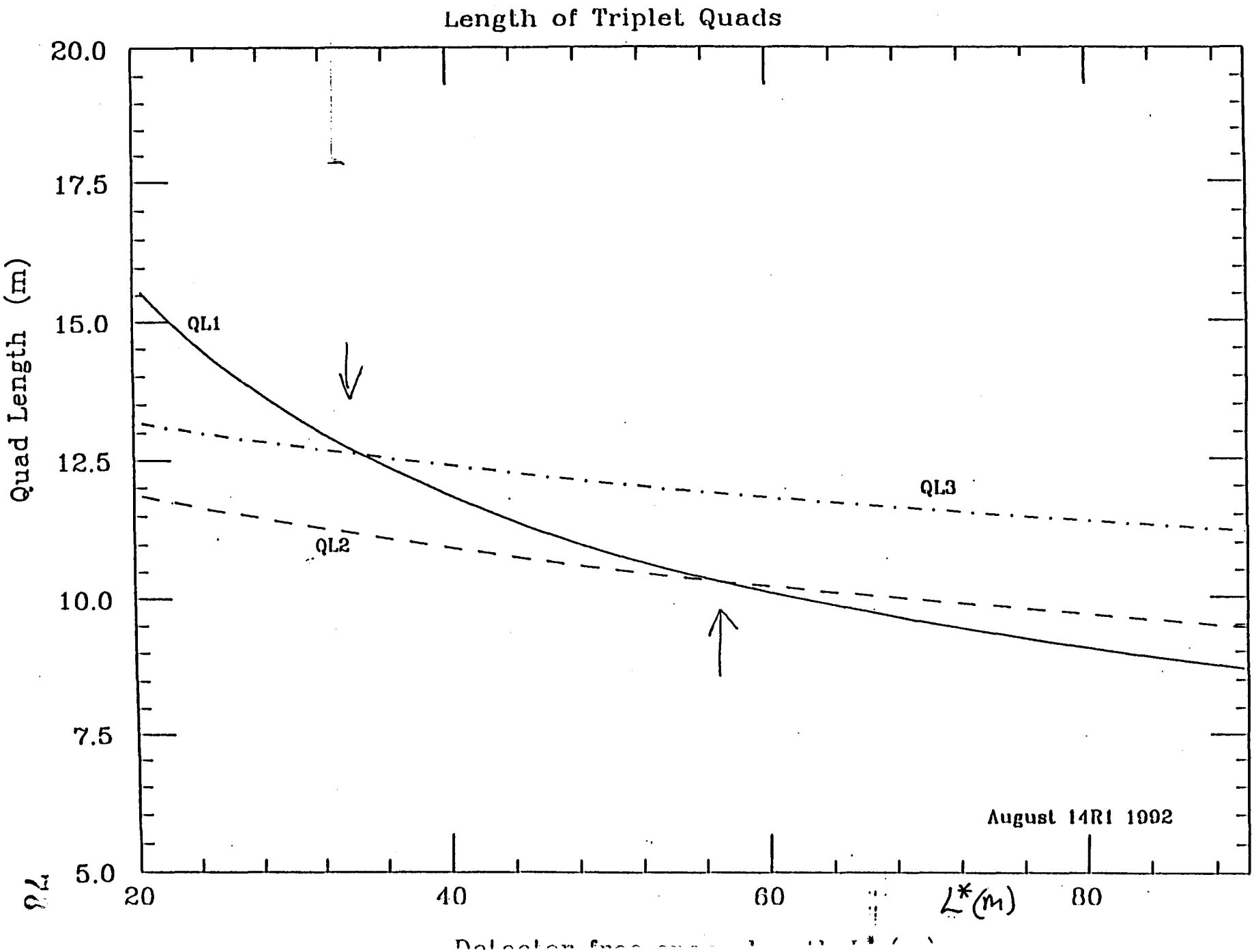
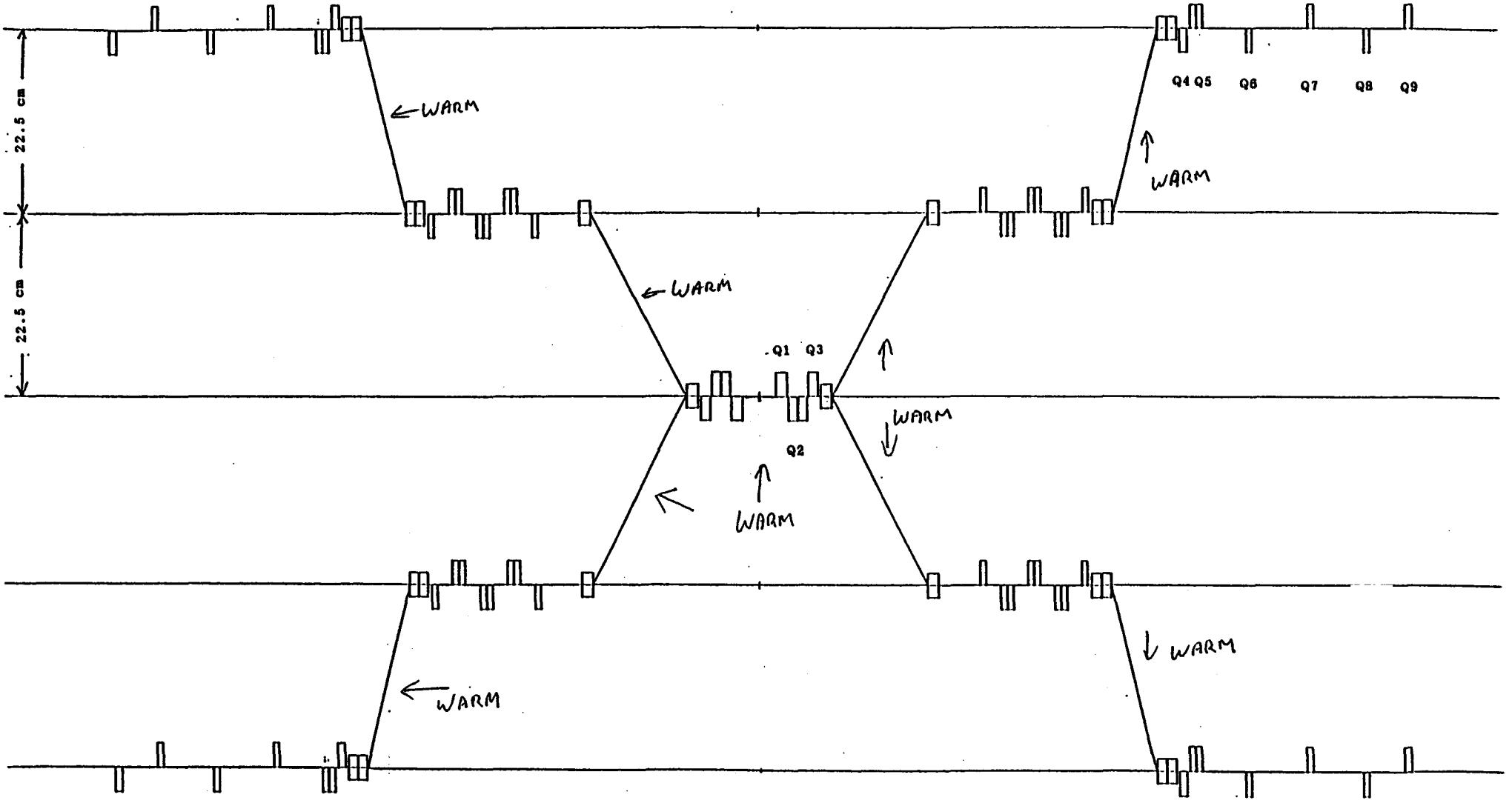

β* vs L*
This graph shows the minimum value of beta*
that is compatible with a 5 cm bore final
focus triplet as a function of the distance
between the interaction point and the quadrupole
(detector free space=L*). The value of beta
in the triplet is 9 KM and is independent of L*.
2.0
1.5
1.0
0.5
β* (m)
20
40
60
80
Detector free space length L* (m)
August 14R1 1992

Figure 1-4

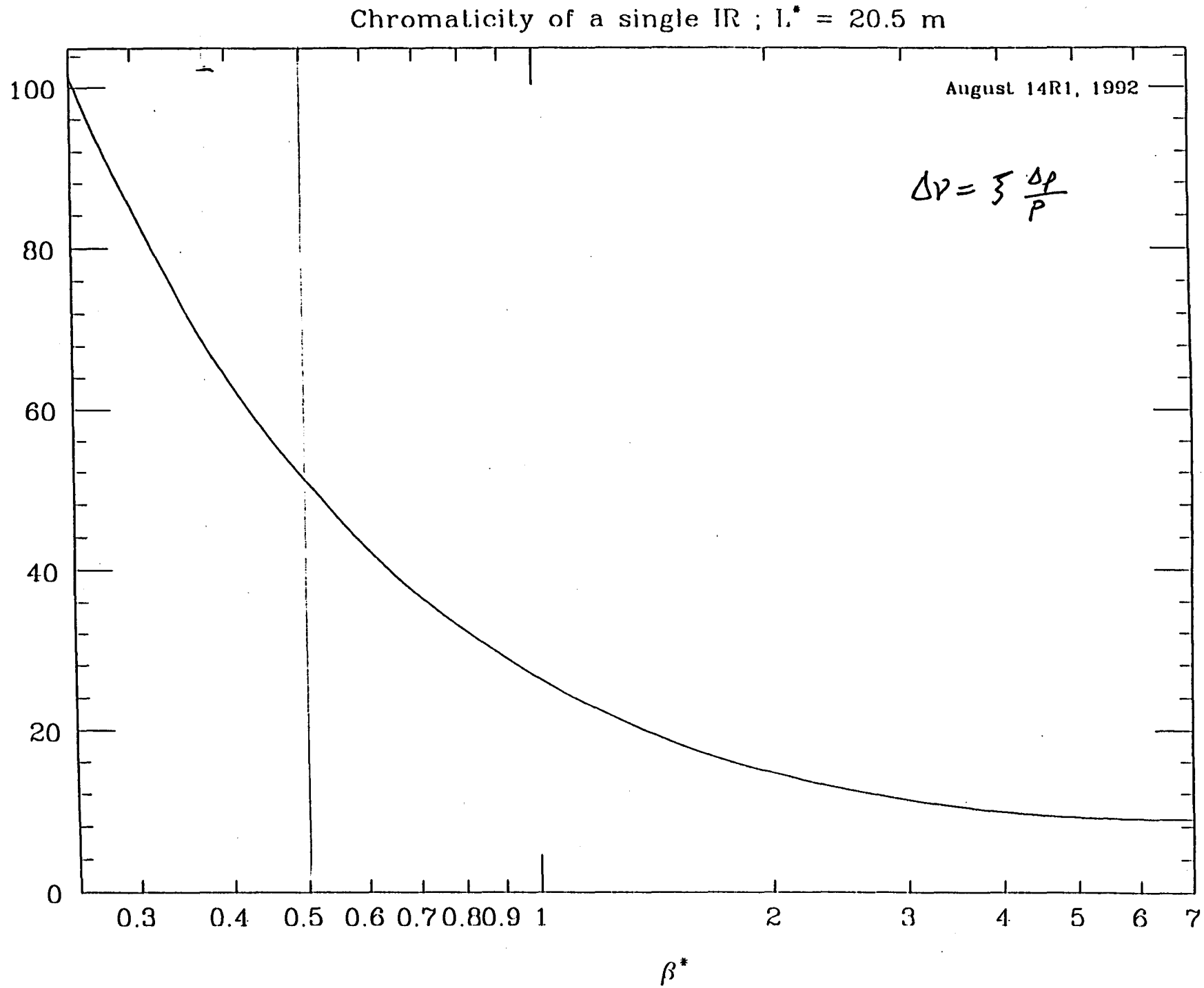

Length of Triplet Quads
Quad Length (m)
20.0
17.5
15.0
12.5
10.0
7.5
5.0
20
40
60
80
L*(m)
QL1
QL2
QL3
August 14R1 1992

The Preferred Design, August 14 Rev 1



NOT TO BE USED FOR INSTALLATION

Meters from IP 0 100 200 300 400 500 600 700 800 900


Chromaticity of a single IR ; L* = 20.5 m
August 14R1, 1992
$\Delta\nu = \xi \frac{\Delta p}{p}$
100
80
60
40
20
0
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2
3
4
5
6
7
β^*

$100 < \sigma_T \lesssim 140\,mb$, $L = 10^{33}\,cm^{-2}s^{-1}$, RATE $\leq 1.4 \times 10^8$

AT 20 TEV $\Rightarrow \begin{cases} 900\,W \\ 640\,W \end{cases}$ FROM I.P.

IMPLIES 320 — 450 W IN EACH DIRECTION

COMPONENT	LENGTH (m)	ENERGY %
DETECTOR	0-18	1.6
COLLIMATOR	18-20	4.2
QL1 – QL2.1	20.5 – 49.9	18.0
QL2.2 – QL3	50 – 78.3	13.7
LEAK NEUTRAL	>78.3	23.5
LEAK CHARGE	>78.3	39.0

See N MOKHOV

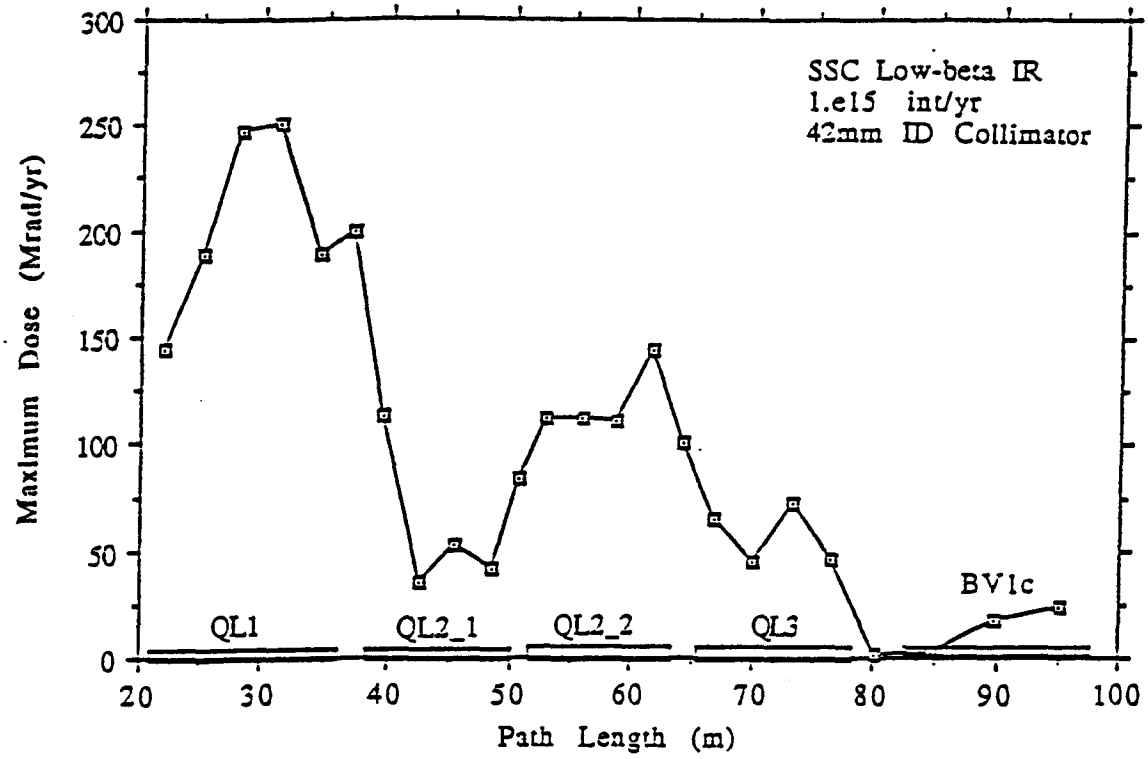


Figure 9-3 The yearly dose at the point of maximum irradiation. The operating year is 10^{33} luminosity for 10^{7} seconds. Interaction Region magnets must be designed to have a minimum life of three years under these operating conditions.

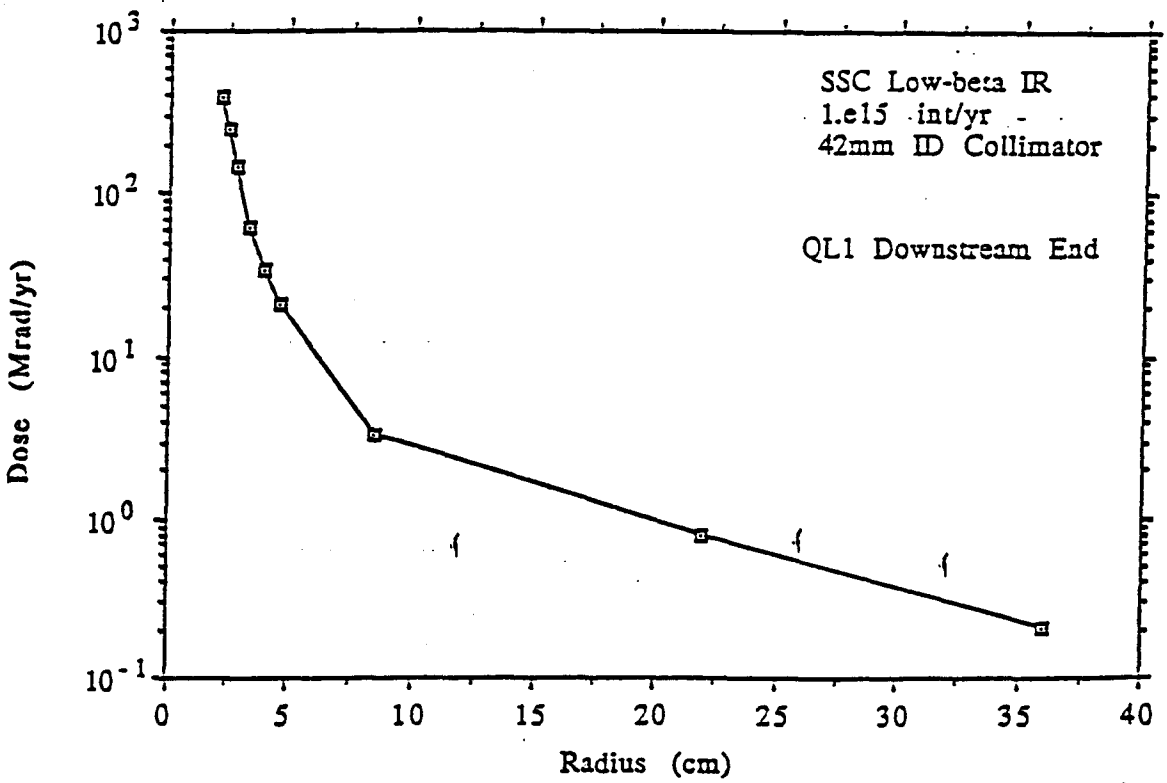
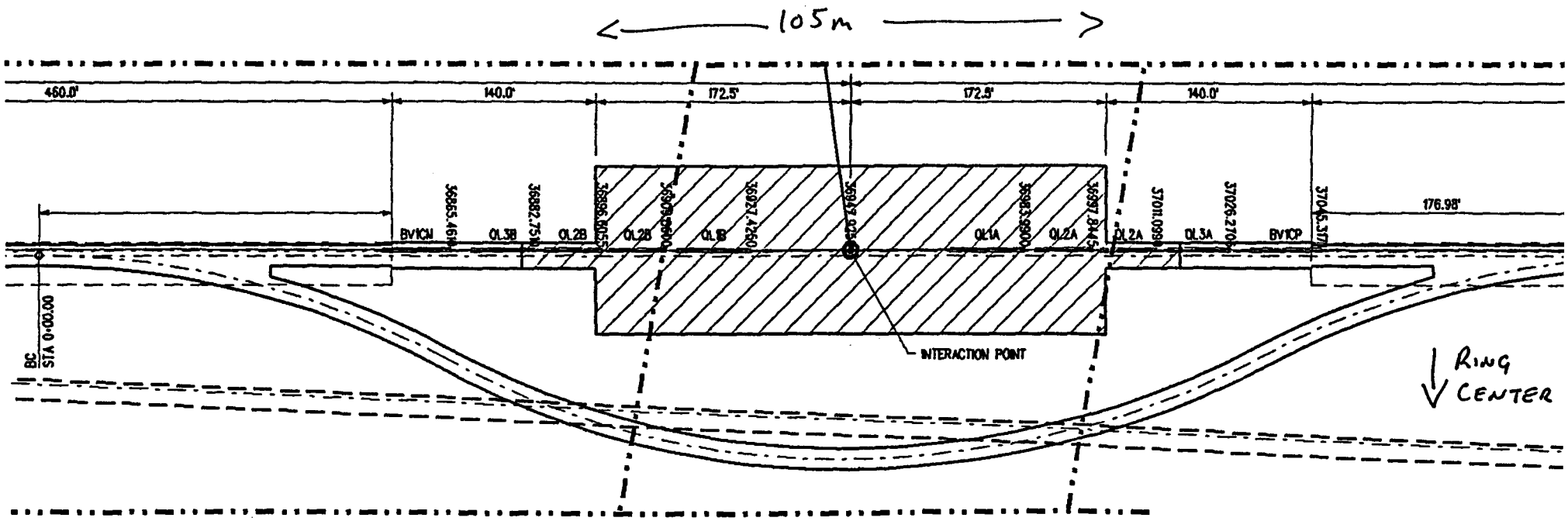
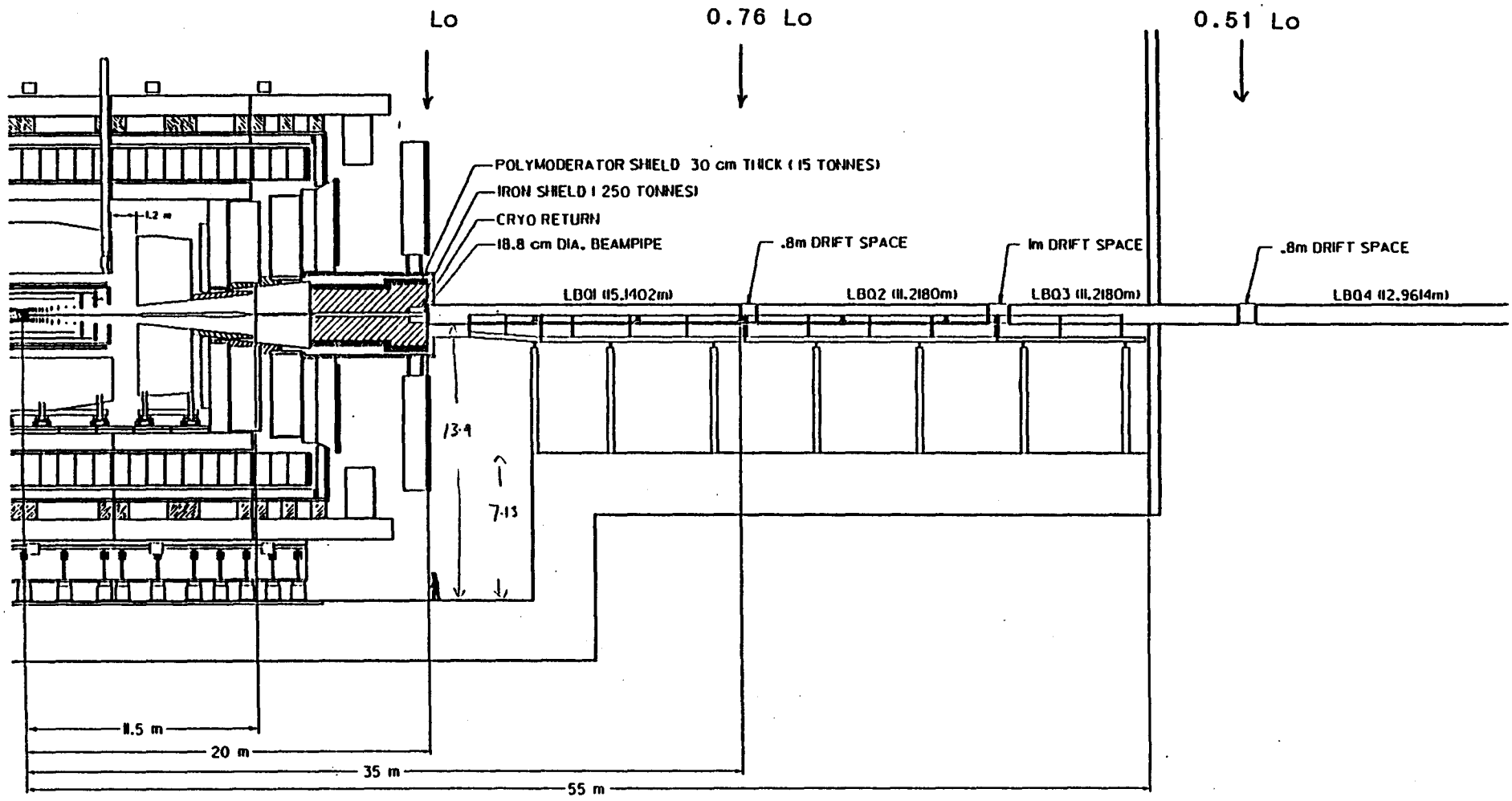


Figure 9-4 This figure shows the radial distribution of the yearly dose at the point of maximum irradiation.

"PRESENT" PROPOSAL 1/18/93

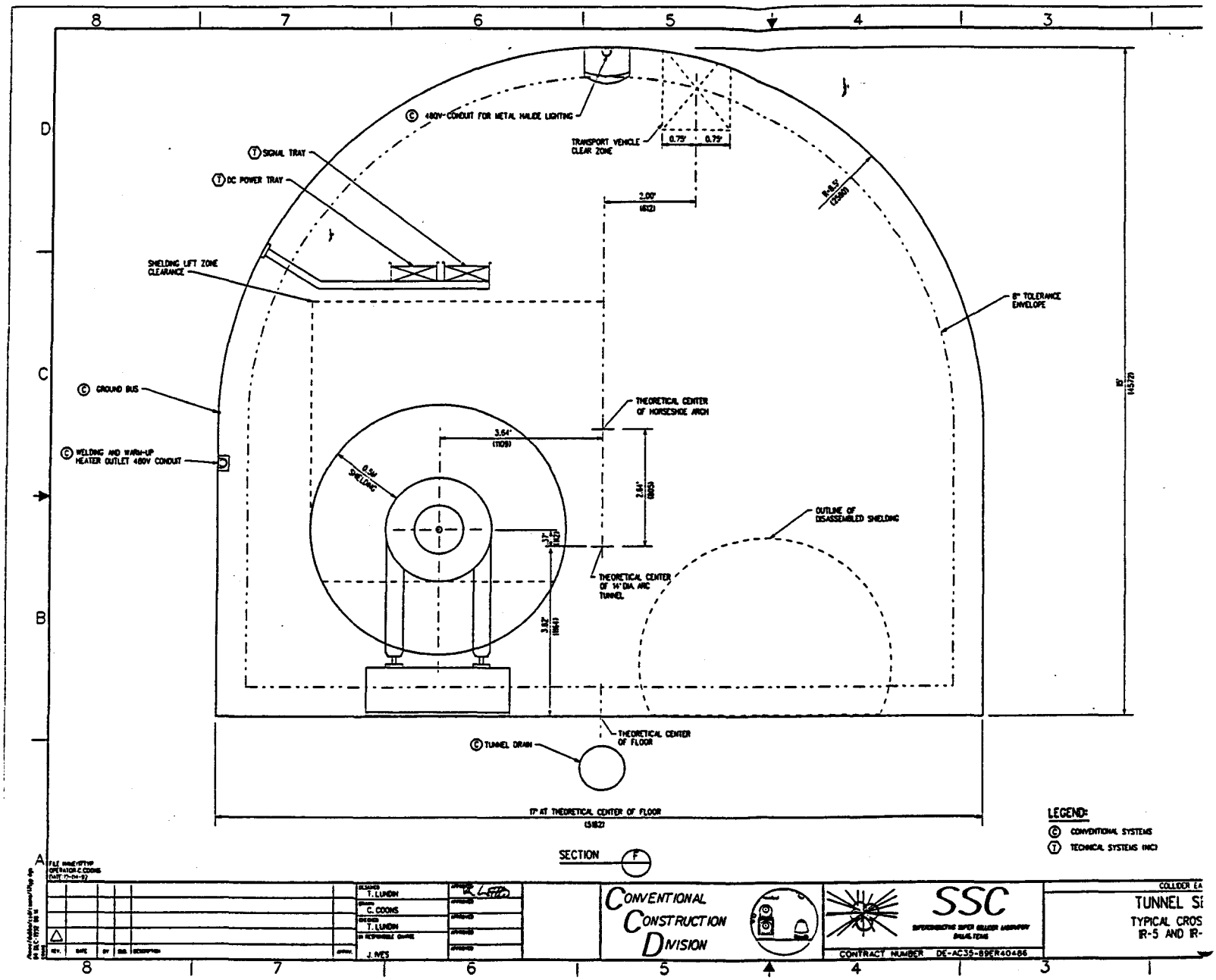
UTILITY BYPASS FURTHER AWAY FROM EXP. HALL THAN ORIGINALLY EXPECTED





SDC detector

Luminosity projections are based on maintaining a 9 Km maximum beta function in the 5cm triplet quadrupoles.



480V CONDUIT FOR METAL HALIDE LIGHTING
TRANSPORT VEHICLE CLEAR ZONE
0.75'
0.75'
SIGNAL TRAY
DC POWER TRAY
2.00'
(612)
SHIELDING LIFT ZONE CLEARANCE
8" TOLERANCE ENVELOPE
GROUND BUS
THEORETICAL CENTER OF HORSESHOE ARCH
3.64'
(1109)
WELDING AND WARM-UP HEATER OUTLET 480V CONDUIT
0.5M SHIELDING
2.64'
(805)
OUTLINE OF DISASSEMBLED SHIELDING
THEORETICAL CENTER OF 14' DIA. ARC TUNNEL
3.82'
(1164)
15'
(4572)
THEORETICAL CENTER OF FLOOR
TUNNEL DRAIN
17' AT THEORETICAL CENTER OF FLOOR
(5182)
SECTION F
LEGEND:
CONVENTIONAL SYSTEMS
TECHNICAL SYSTEMS (NC)
T. LUNDIN
C. COONS
T. LUNDIN
J. IVES
CONVENTIONAL CONSTRUCTION DIVISION
SSC
CONTRACT NUMBER DE-AC35-89ER40486
TUNNEL S
TYPICAL CROS
IR-5 AND IR-

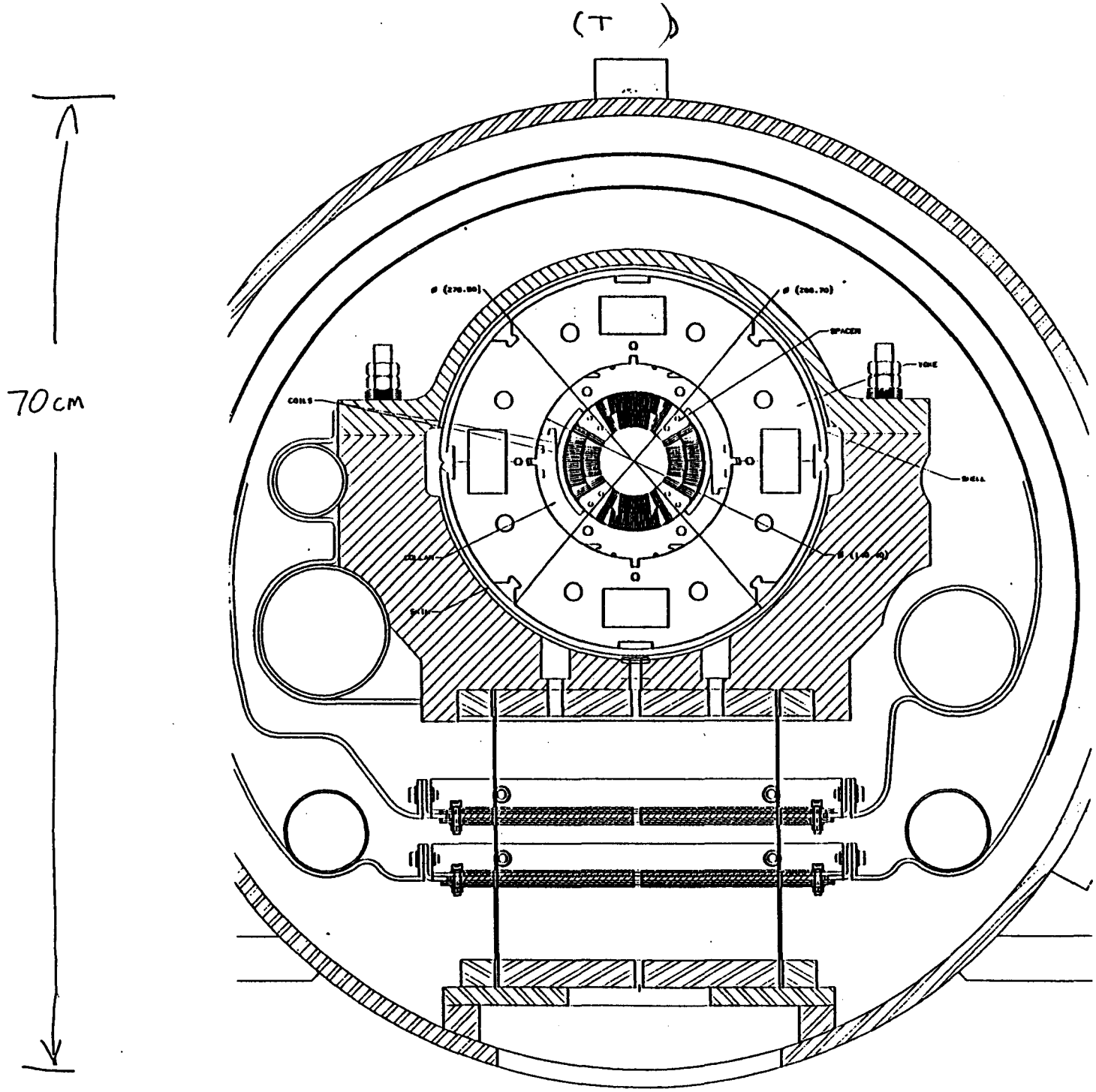
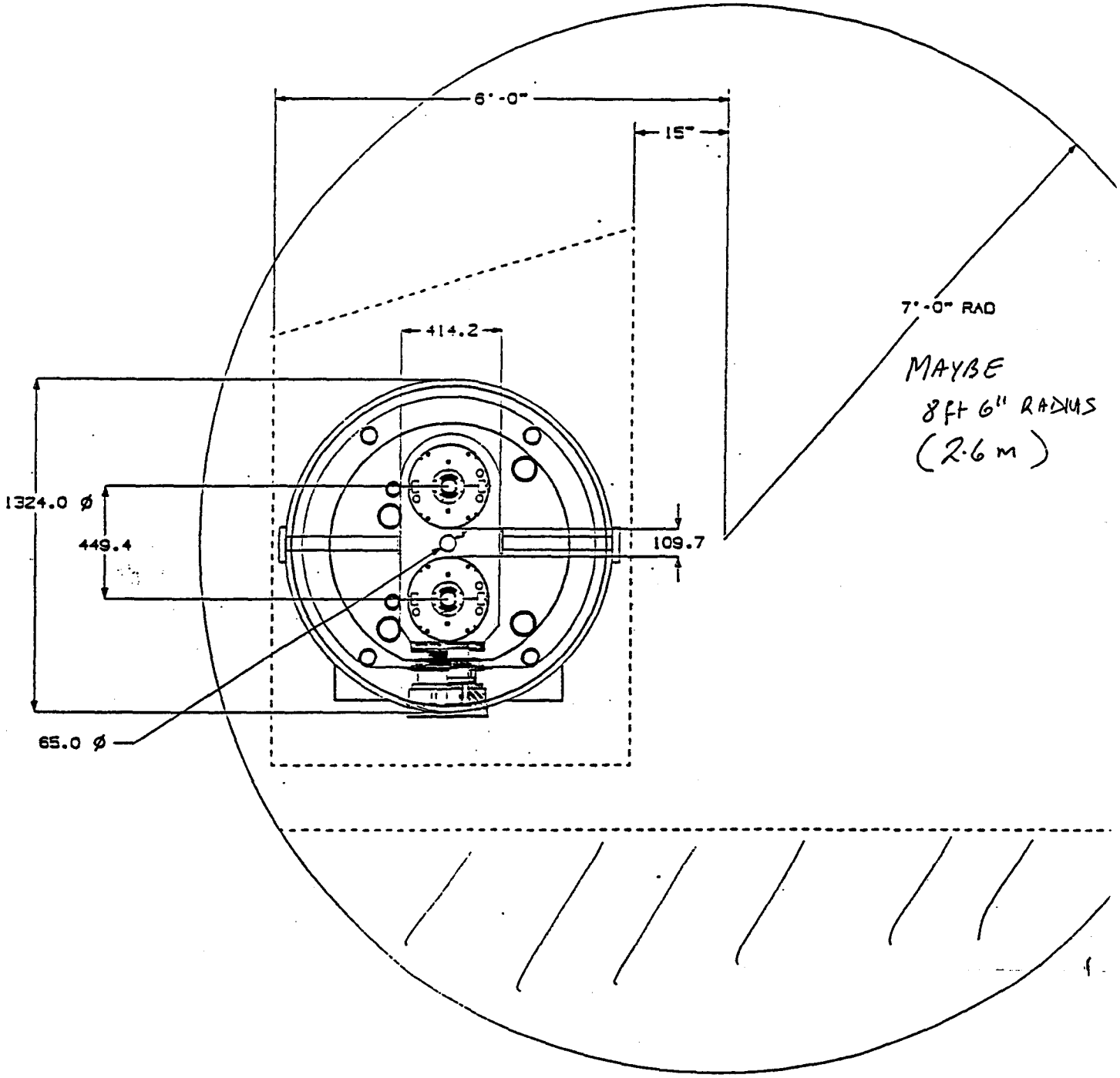


Figure 1 The prototype 5cm final focus quadrupole in its cryostat.

mm

	QCE-101 MAGNET		
Magnet Component	Radial Dimension	Thickness	Material
Beam Tube Inner Radius	21.055		SS 304 LN
Beam Tube Outer Radius	22.305		SS 304 LN
Beam Tube Insulation		0.25	Kapton
Inner Cable Insulation		0.1354	Fiberglass/Kapton
Inner Cable Inner Radius	24.85	(11.98)	TiNb/Cu Cable
Inner Cable Outer Radius	36.83		TiNb/Cu Cable
Inner Cable Insulation		0.1354	Fiberglass/Kapton
Inter-Coil Spacer Support		0.38	G-11 CR
Inter-Coil Spacer Kapton		0.17	Kapton/Adhesive
Outer Cable Insulation		0.1354	Fiberglass/Kapton
Outer Cable Inner Radius	37.38	(11.98)	TiNb/Cu Cable
Outer Cable Outer Radius	49.36		TiNb/Cu Cable
Outer Cable & Ground Insulation		0.7604	Fiberglass/Kapton
Shoe		0.4	C26000 Cartridge Brass
Spacer		30.89	C26000 Cartridge Brass
Collar Inner Radius		54.93	Nitronic 40
Collar Outer Radius		70.2	Nitronic 40
Yoke Inner Radius		70.2	Low Carbon Magnet Steel
Yoke Outer Radius		133.35	Low Carbon Magnet Steel
Shell		4.77	SS 304 LN
Cast Cradle Top Strap		11.43	Cast Stainless - M35-000008
DU Bearing Pad		3.17	DU Flat Strip Group 5
20k Shield		1.6	6061 T6 Alum. Sheet
80k Shield		1.6	6061 T6 Alum. Sheet
80k MLI Blanket Inner & Outer		16	DAM/RSP
Vacuum Vessel		12.7	ASTM A516 Grade 70

TABLE I Materials and dimensions of the prototype 5 cm final focus quadrupole.



Vertical bending dipoles located in the "2-in-1" segment of the low beta interaction regions.

Nominal operating cycle

Inject into collider (2 TeV)	~ 70 min
Accelerate to 20 TeV	~ 20 min
Beta squeeze	~ 2 min
Beam scraping etc	~ 30 min
Run, w halo removal (?)	~ 21 hrs
Decelerate, dump	~ 30 min
	~ 24 hours

VACUUM REQUIREMENTS (TENTATIVE)

- NEUTRAL BEAM PRODUCED BY INTERACTION OF CIRCULATING PROTONS WITH RESIDUAL GAS < 100 mW TO LIMIT RISK OF QUENCHING DOWNSTREAM MAGNET

- NOT CAUSE UNACCEPTABLE BACKGROUNDS OF MUONS IN DETECTORS. < 25 kHz (?)

IMPLY $\lesssim$ 200 INTERACTIONS / μ SEC

IMPLIES ~ 10^{-9} TORR HYDROGEN EQUIVALENT IN WARM SECTIONS

OFFICIAL SPEC. VALUES PRESENTLY FOR ARCS

COLD < 3×10^{8} H_2/cm^3 NUCLEAR SCATTERING EQUIVALENT

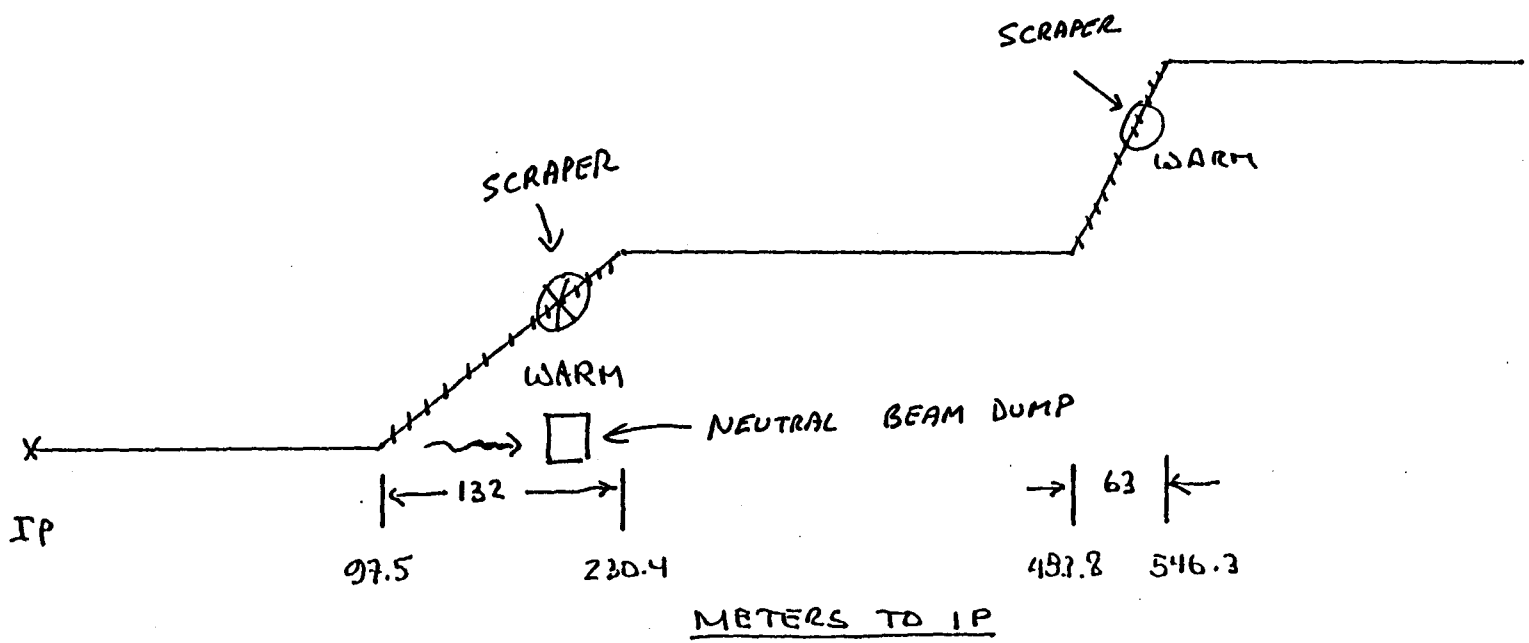
WARM $\lesssim 10^{-8}$ TORR H_2 EQUIV. AT 300°K

GAS COMPOSITION ?

BACKGROUNDS

- LOW ENERGY NEUTRONS FROM VARIOUS SOURCES. IMPLIES (TO ME) SEVERAL M OF SHIELDING BETWEEN COLLIMATOR AND DETECTOR

- HIGH-ENERGY MUONS FROM COLLIMATORS UPSTREAM OF DETECTOR IMPLIES CALCULATIONS SOON TO DETERMINE ~~SCR~~ SIZE OF PROBLEM. (SCRAPE $10^6 - 10^7$ PROTONS/SEC ?)


SCRAPER
WARM
SCRAPER
WARM
NEUTRAL BEAM DUMP
IP
132
63
97.5
230.4
493.8
546.3
METERS TO IP

BORE ID = 42 MM

- PRODUCE REVISED BASELINE GEOMETRY FOR SDC, GEM BY 2/93. INCLUDE LOCATION OF QUADRUPOLES, SHIELD WALL, VACUUM PIPE SHAPE, ETC

- CALCULATE BACKGROUND FLUXES BY 4/93 (VARIOUS DEADLINES AROUND THIS TIME; GEM, SDC AND POSSIBLY C.I.R. DESIGN REVIEW)

- BASED ON THE ABOVE, ITERATE GEOMETRY AND CALCULATIONS BY 9/93. AFTER THIS TIME, VARIOUS GROUPS SHOULD BE ABLE TO CONCENTRATE MUCH MORE ON THEIR INDIVIDUAL DETAILS

- FOR ABOVE, MINIMUM OF 2 ANALYSIS TECHNIQUES. MARS 12 FOR ACCELERATOR, MISC. CODES EMPLOYING DTUJET 92 FOR DETECTORS, PLUS MANY BASIC EXPERIENCE CHECKS

- LONG-TERM: FLUKA HAS MOST PROMISE, DEVELOP IT FOR SOME TASKS, BECOME "STANDARD CODE". THIS DOES NOT MEAN ONLY CODE.
  ~ 9/93 FORMALISE SOME "RADIATION FLUX BOUNDARIES TO PERMIT VARIOUS GROUPS TO WORK INDEPENDENTLY BUT COORDINATED

10/92

Assumptions

1. SDC is similar to GEM for this purpose.

2. Quads are at 20.5m.

3. Have to remove everything to a distance of 55m from the IP (i.e. to the detector wall). This means that QL1, QL2, QL2 have to be removed, but not QL3.

4. If this replacement has to be done at both ends of the detector, two crews working in parallel can do it without interference.

5. Assume no "extra" time is needed as a result of high levels of induced radioactivity. This may be the most uncertain assumption since "remote-handling" activities take longer than "hands-on" activities.

6. Exclude any alignment of the detector with-respect-to the beam line, since this can only be done after everything is resettled, and I do not have any good answers. This is also a significant uncertainty, at least for me.

7. Personnel will be working all shifts.

8. The cryogenic valving and therefore time to warm-up and cool-down is similar to that of the arcs.

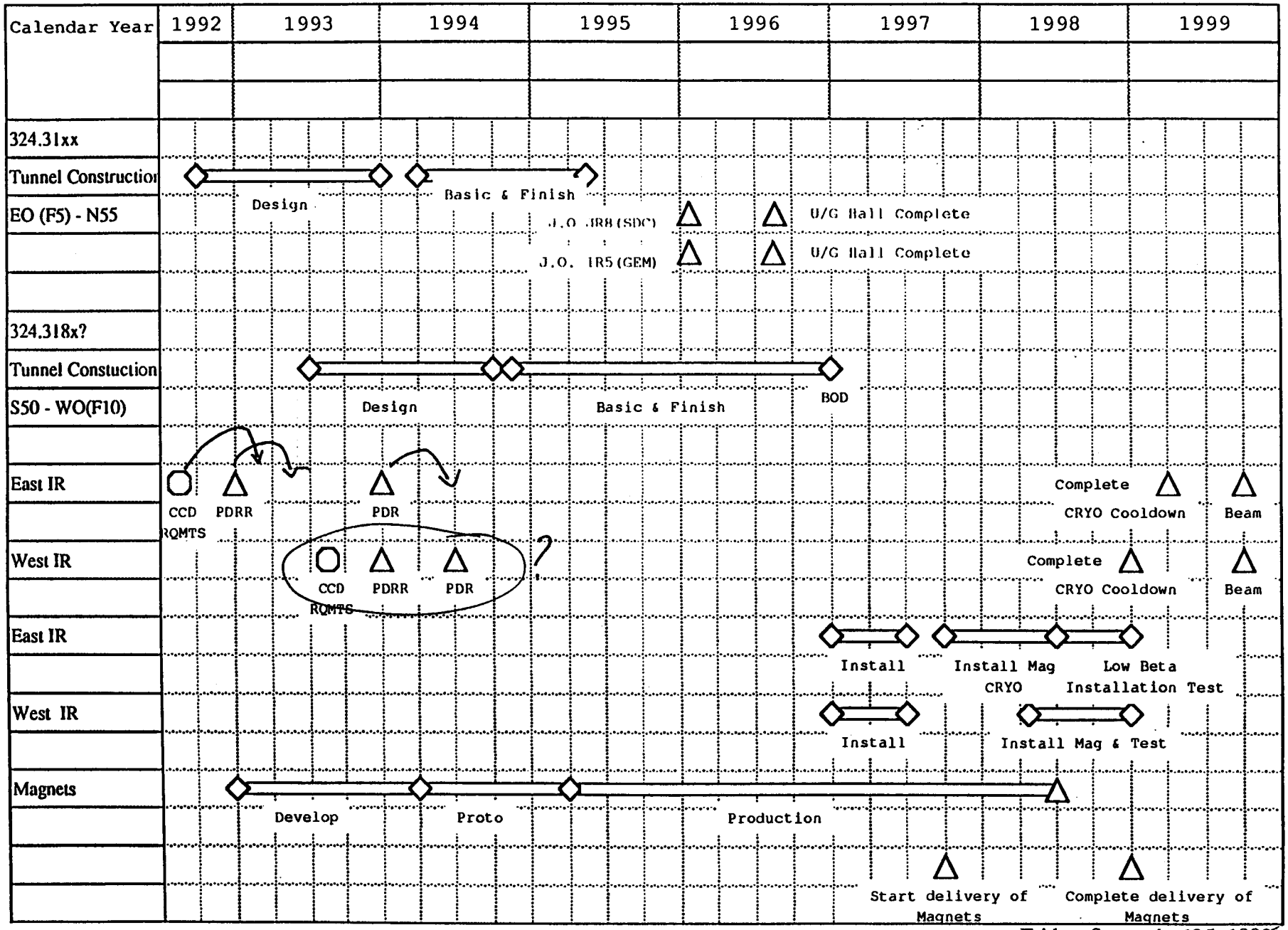
	Activity	Days
a	Check alignment before moving	1
b	Warm-up ring section	3
c	Remove shielding (if any)	1
d	Disconnect magnet and remove (3)	1.5
e	Disconnect supports and remove (3)	1
f	Change detector	0
g	Install supports	1
h	Place new magnets and other components	1.5
i	Align new magnets and other components	1
j	Connect electrically and mechanically	1.5
k	Pump-down and leak check	2
l	Cool-down	3
m	Check-out	1
n	Replace shielding (if any)	1
		19.5

If QL1 was located at L* = 35m, then only QL1 and possibly the first QL2 would removed. As a result the shortest time would be in the region of 14 days.

Conclusion

Given the assumptions, I suspect this is optimistic if the baseline arc replacement time of 10.5 days is valid. At this time I would say that the work can be done in less than 30 days (i.e. 50% contingency; 20 days + 10 days) for 3 quads or 20 days for only 1 quad.

DRAFT



Roy Little 8/20/92

Friday, ~~September~~ 25, ~~1992~~ 1/19/9.

93

Survey and Alignment Tolerances

This section gives specifications on the large scale geometry of the interaction regions and on the relationships between fiducials on the external surfaces of beam line objects and that geometry after the installation and alignment process has been completed. Tolerances on the relationship between external fiducials and internal beam line components will be found in the appropriate sections on magnets and beam diagnostic devices. Any tolerance given as "not to exceed" may be interpreted as a three sigma tolerance.

Large scale geometry:

The two interaction regions in a cluster are separated by a 0.04051 radian region of bending called the hinge. The survey tolerance for this bend is:

Hinge angle = 0.040517 +/- 0.000025 radian (1 sigma)

Since the Collider dipoles within this region will bend the beam by 0.04051 radian, correction dipoles will be provided to compensate for errors in the survey.

A similar angular error applies to the transitions between the IR straight sections and the adjacent regions of the Collider.

Component alignment:

Within a cluster, the initial alignment will establish an approximately straight path that will lie within the envelope shown in Figure 23-1. After smoothing, the fiducials on individual magnets will be aligned to be within 0.35mm RMS vertically and horizontally with respect to the framing quadrupoles.

The alignment of the external fiducials of secondary components relative to nearby main magnet fiducials will be accomplished with a tolerance of 0.15mm.

All component fiducials will be aligned with a roll error about the beam line which will not exceed 0.0002 radian.

After a detector is installed, it will much more difficult to survey across the interaction region hall. Some of the triplet final focus quadrupoles may be removed from time to time to provide access to the detector. The tolerance on the coaxial alignment of the interaction region quads on opposite sides of the hall after the detector is in place is:

Horizontal displacement = 1.00 mm (1 sigma)
Vertical displacement = 0.25 mm (1 sigma)

The vertical displacement error is smaller because a liquid level system is intended for vertical alignment while optical alignment is used for horizontal alignment.

Alignment information provided to the experimental detector groups will allow the detectors to be positioned with respect to a line between the low beta quadrupoles with an error which will not exceed +/- 2 mm.

Neutrons and

Forward Drift Chamber Trigger

S. Kunori

19 - Jan - 1993

Functions

1. Particle identification for muons

2. Momentum measurement

3. Triggers
   L1(4usec), L2(20-30usec), L3(sec)

Components

- toroidal magnets
  1.8tesla x 3meters
  bend angle(mr)= 1620xtan(theta)/ pt(Gev/c)
  1280tons/one-end

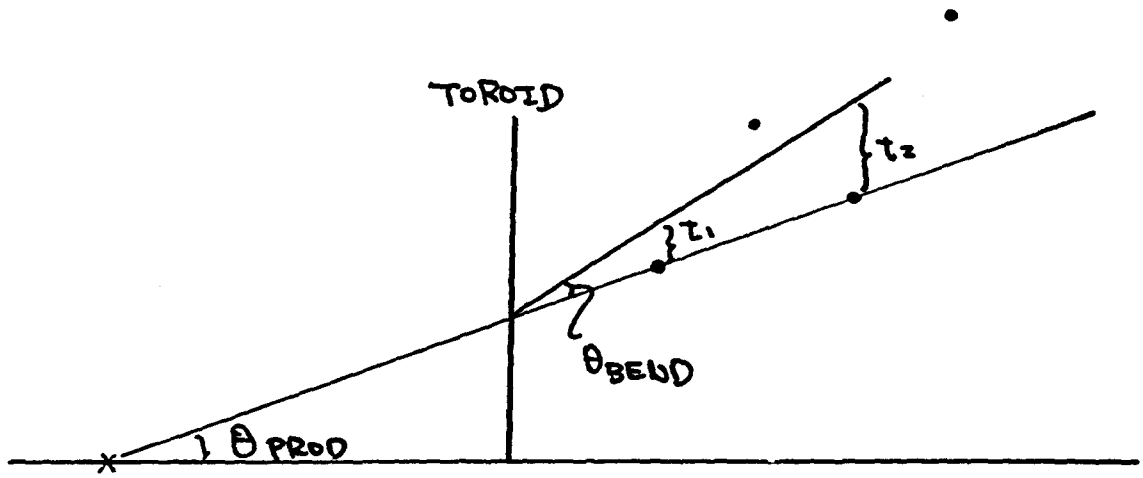
- drift chambers
  4.5cm, 6.0cm drift tubes (diameters)
  total 32240 tubes

- scintillation counters
  7-29cm wide, 1.1-2.6m long, 1cm thick
  total 2256 counters

- cerenkov counters (optional)
  38x46cm mirrors, mirrors
  4 mirrors/PM tube

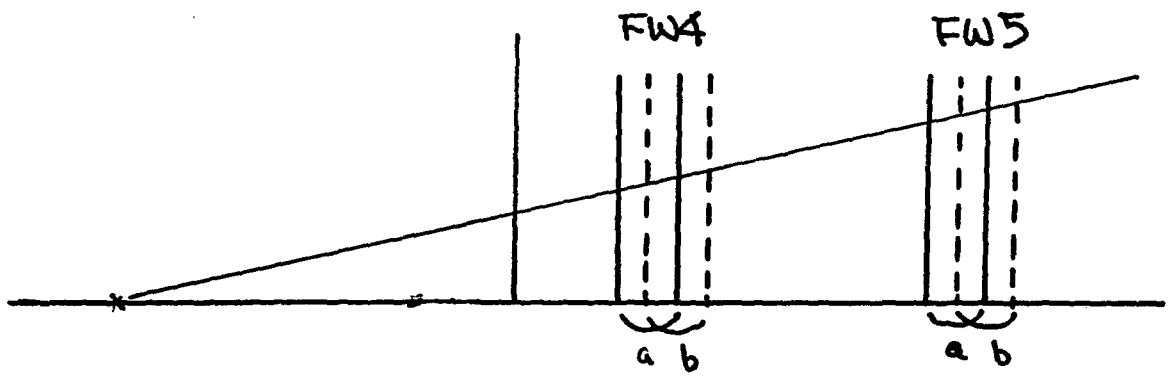
+ shielding, beam pipe, calorimeter edge
  low beta quad magnet ....

Drift Chamber Trigger



$$\boxed{\left|\frac{1}{P_T}\right| \propto |\theta_{BEND}| \propto |t_2 - t_1|}$$

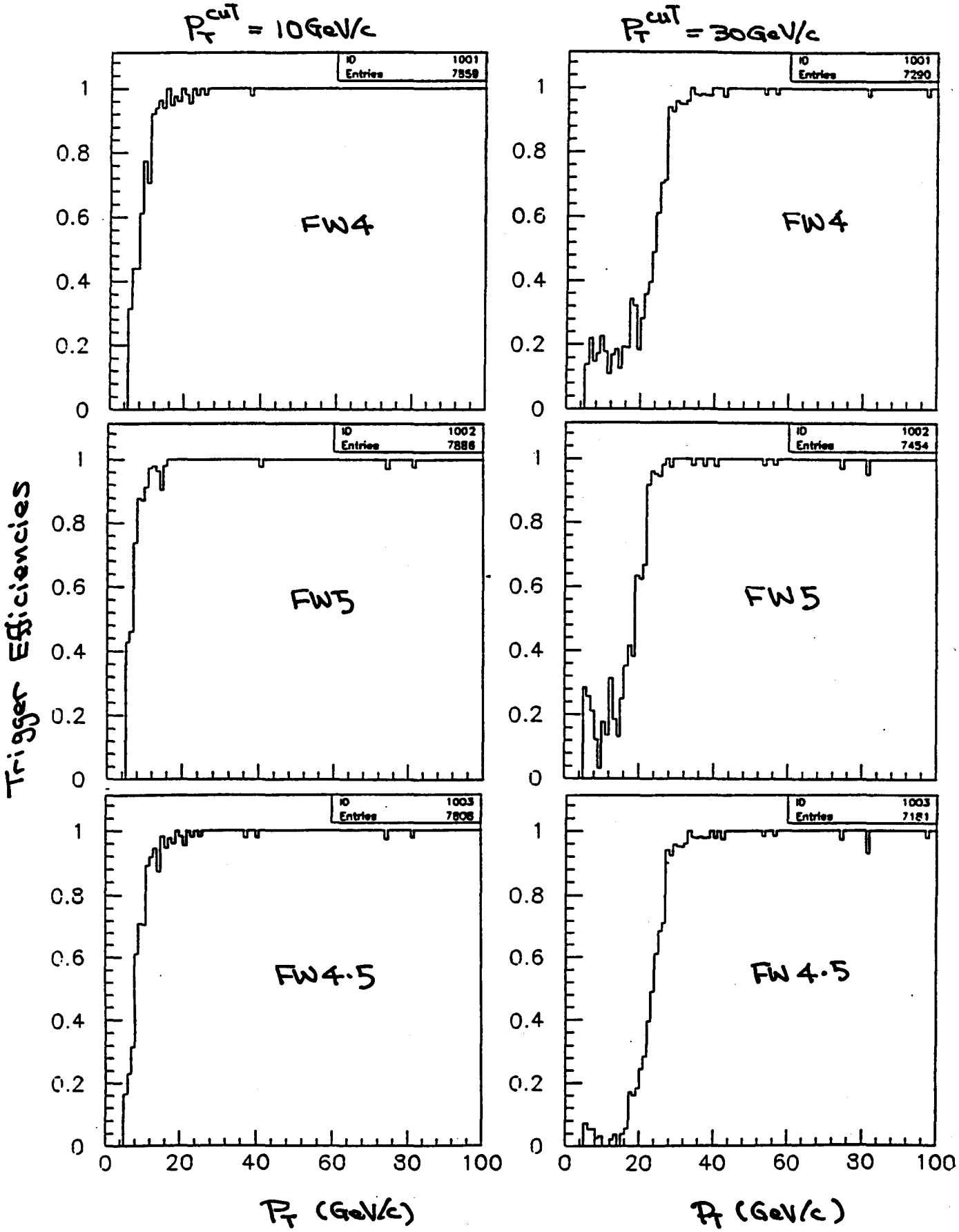
$$\theta_{BEND} = \frac{1.62}{P_T} \tan\theta_{PROD}$$



Trigger = (FW4a + FW4b) • (FW5a + FW5b)

or

(FW4a • FW4b) + (FW5a • FW5b)


P_T^{cut} = 10GeV/c
P_T^{cut} = 30GeV/c
ID 1001 Entries 7858
ID 1001 Entries 7290
ID 1002 Entries 7886
ID 1002 Entries 7454
ID 1003 Entries 7806
ID 1003 Entries 7181
FW4
FW5
FW4·5
Trigger Efficiencies
P_T (GeV/c)
0
0.2
0.4
0.6
0.8
1
20
40
60
80
100

Trigger due to random hits

- hits due to slow neutron ≡ random hits

$(FW4a + FW4b) \cdot (FW5a + FW5b)$

# of pairs

$$\text{Probability} = \{(\varepsilon \times \varepsilon \times 100) + (\varepsilon \times \varepsilon \times 100)\}$$
$$\times \{(\varepsilon \times \varepsilon \times 100) + (\varepsilon \times \varepsilon \times 100)\} \quad \times 16 \text{ sectors}$$
$$= \varepsilon^4 \times 64 \times 10^4$$

random hit : ε

			$\frac{N_{2WT}}{N_{TRIG}}$
$\varepsilon = 0.1$	$\longrightarrow$	Prob = 64	1
$\varepsilon = 0.01$	$\longrightarrow$	Prob = 64×10^{-4} $\rightarrow$ 0.6 MHz	156

Neutron Flux (through inner chamber)

	$S(cm^2)$	N	neutrons /tube/500 nsec	
FW1	464	0.6	14	if we need occupancy 0.01 with Nsignal/Nneutron = 0.01, ⇒ required extra reduction factor.
FW2	567	1.6	45	
FW4	1140	0.9	51	
FW5	1548	4.0	310	

Δt time window ~ 500 nsec outer

160 nsec inner

extra factor $\left(\frac{160}{500}\right) = \frac{1}{3.1}$

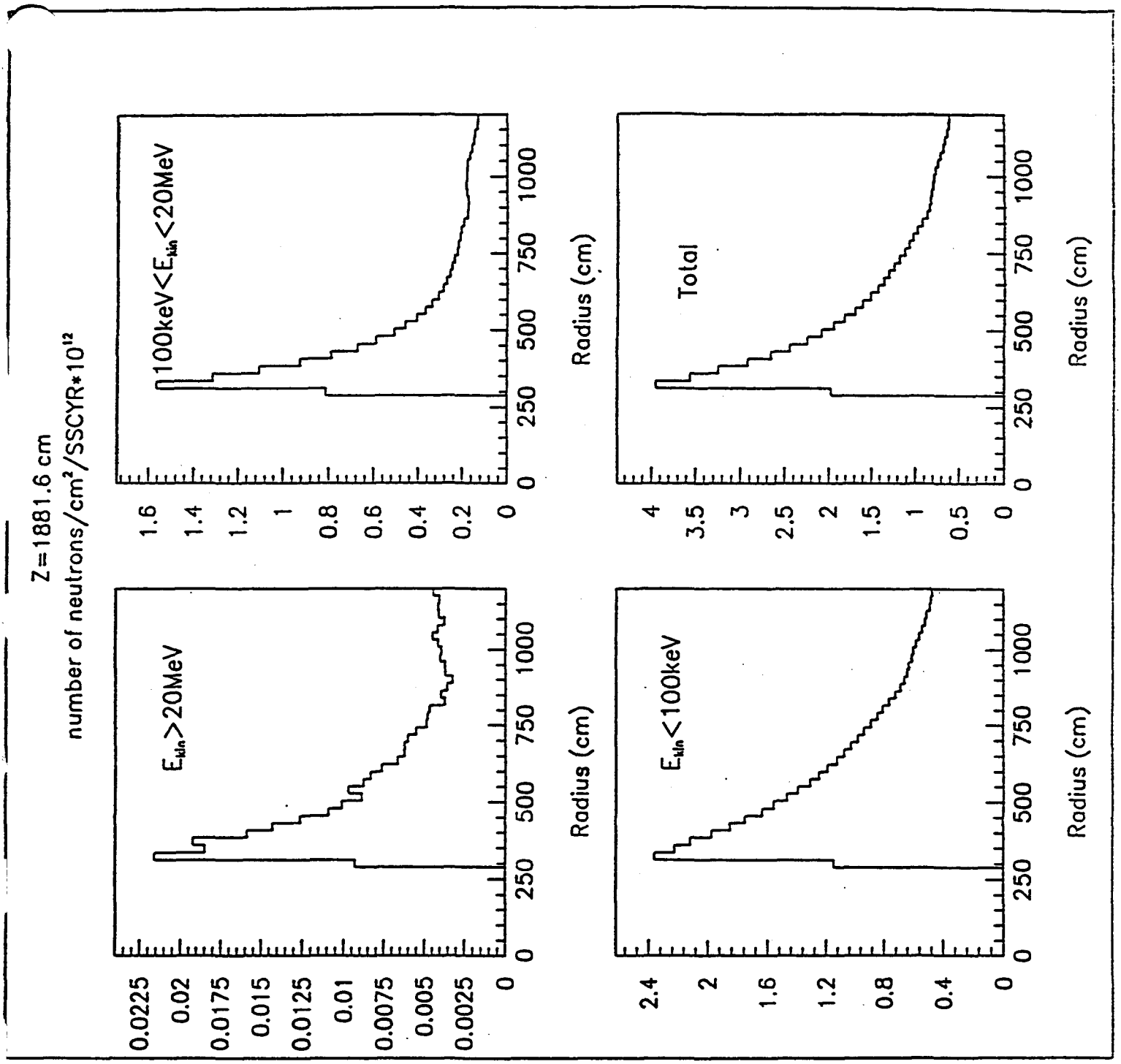


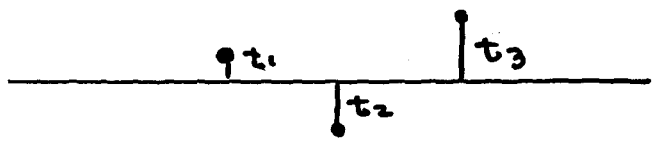
Figure 10: Neutron currents at the fifth and final plane of forward muon chambers (FW5), at z=1881.6 cm. This plane sees a large neutron current reflected back from the collimator (higher energy neutrons) and from the concrete hall walls (lower energy and thermal neutrons).

Improvements ?

① better shielding.

② improve trigger.

- coincidence with FS (or FC)
- FS4 - FS5 link
  - road restriction
  - $\Delta(\Delta t) = |\Delta t_4 - \Delta t_5|$ (≡ slope correlation)
- absolute timing — 3/4



$t_1 + t_2 = \text{constant}$

- higher P_T threshold
- multi muon trigger

How bad is the halo muons?

January 19, 1993

SDC Muon Group

Estimations of Rates in Scintillator Counters and Drift Tubes and Trigger Rate in the FMS due to Neutron Currents.

Valery Kubarovsky

Institute for High Energy Physics
Protvino, Russia

Low energy neutrons come from the interaction of the secondary particles in the construction elements such as beam-pipe, calorimeters , collimators and low beta quads.

The first estimation of neutron currents were published in the SDC note [92-361].

Neutron fluence produced in hadronic showers was measured at FNAL [T-821].

It was concluded that

- ☞ Energy spectra of neutrons sharply cut off at few MeV and peak at a few hundred keV approximately independently of incident beam momentum and absorber thickness.

- ☞ Total Fluence increases approximately with the incident momentum

- ☞ The fluence decreases by a factor of 2.5 to 4 for each additional 5 lambda

Neutron Background at SSC

Neutron background is very important at SSC and LHC. It is connected with the fact that

Neutron Flux ~ Luminosity x Energy

$$\frac{\text{Flux(SSC)}}{\text{Flux(FNAL)}} = \frac{10^{33} \times 40 \text{ TeV}}{2\ 10^{30} \times 2 \text{ TeV}} = 10{,}000$$

1 MeV neutron has 30% probability to elastically scatter in 1 cm plastic scintillator loosing 0.5 Mev of energy in average.

By this reason the scintillator counters have a rather high efficiency for the neutrons in this energy spectra. The efficiency depends on energy cut off. Maximum detection efficiency with the threshold 0.2 MeV is 6% for the neutron energy of 2 MeV and falls to 4% at 10 MeV.

In the estimations that was done in this note neutron currents (from SDC note 92-361) with the energy 100keV<E<20MeV were used assuming the detection efficiency 2.5% for scintillator counters.

NUCLEAR INSTRUMENTS AND METHODS 105 (1972) 573–584; © NORTH-HOLLAND PUBLISHING CO.

ACCURATE MEASUREMENT OF THE COUNTING EFFICIENCY OF A NE-213 NEUTRON DETECTOR BETWEEN 2 AND 26 MeV*

M. DROSG†

Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico 87544, U.S.A.

Received 4 July 1972

The neutron detection efficiency of a liquid scintillator (NE-213, 12 cm diam. × 5.7 cm) was measured with various bias settings corresponding to proton energies from 1 MeV to 6 MeV. For neutron energies below about 12 MeV a simplified calculation fits the data very well and the uncertainty in the shape is less than 2%. The importance of contributions from the reaction $^{12}C(n,n')3\alpha$ above that energy is shown. An extensive survey of publications dealing with the efficiency of organic scintillators is also presented.

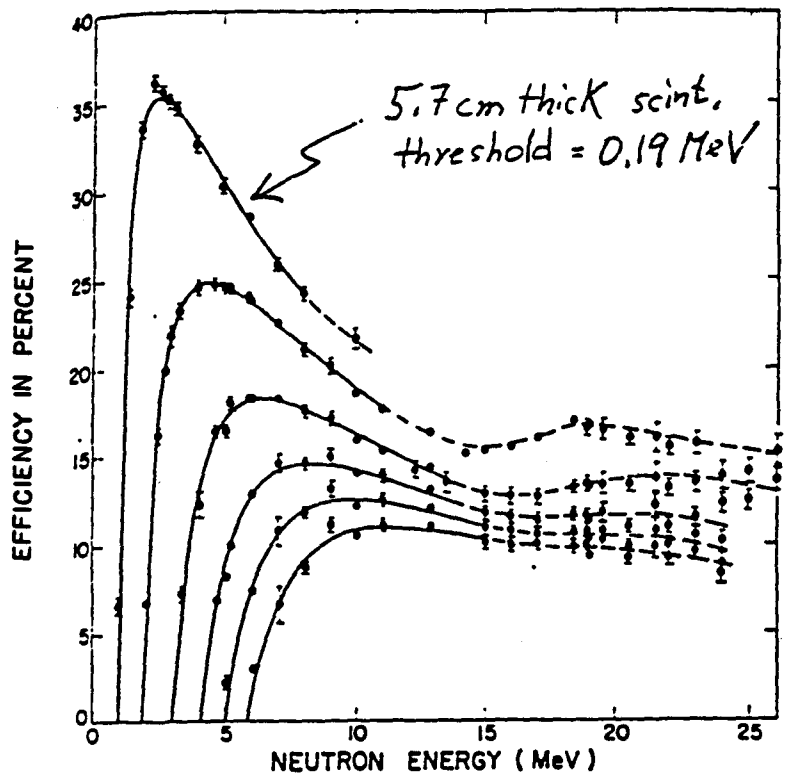


Fig. 4. Measured efficiency points for biases at 0.4, 1.0, 2.0, 3.0, 4.0 and 5.0 times Cs and calculated fits (solid lines). The dashed lines are handfitted.

SDC: 1.0 cm thick scintillator Threshold ~ 0.2 MeV

FIG 12

The detection efficiency of neutrons by SDC drift tubes is not known. It was measured the sensitivity of the limited streamer drift tubes to neutrons using Cf_{252} spontaneous fission source GEM 92-122. The detection efficiency of these tubes is 0.4%.

Estimations of the efficiency of SDC drift tubes show that it may be in the range 10**-4 or so.

Gamma convoy may rise this value up (if we will normalize to neutron flux).

The energy and flux of gammas strongly depends on the material of shielding.

The ratio gamma/neutron may be in the range 0.1-1 and efficiency of drift tubes as high as 10**-2.

In the estimations in this note the efficiency <u>0.1%</u> was used (normalized to neutron flux). This value takes into account possible convoy of gammas.

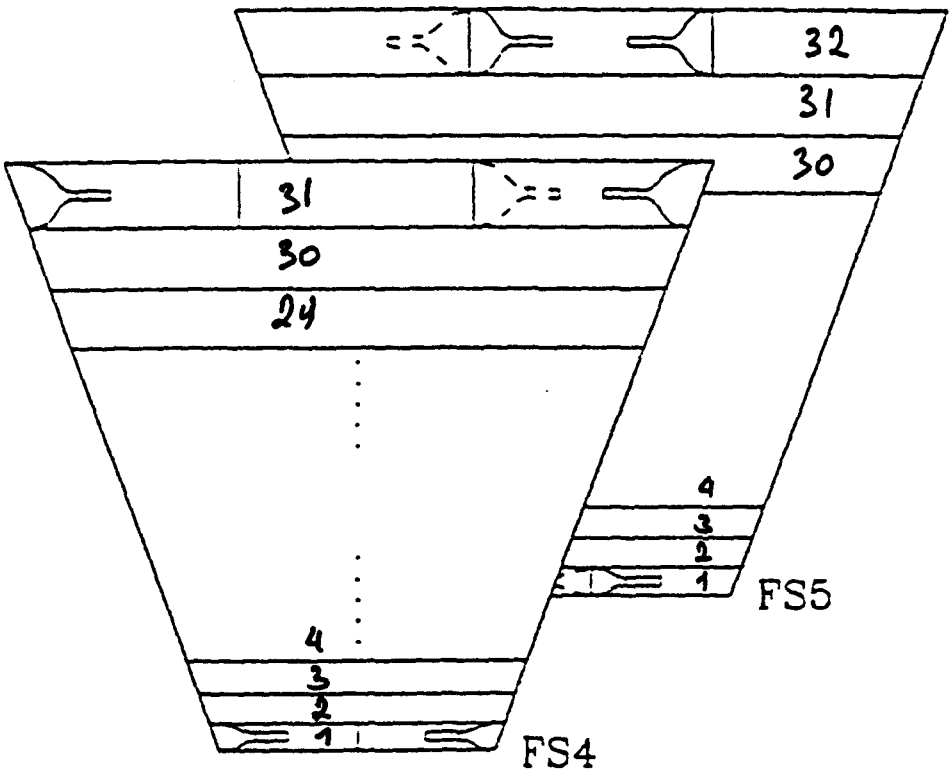


FIG. 7-15. Configuration of muon scintillation counters in the forward region.

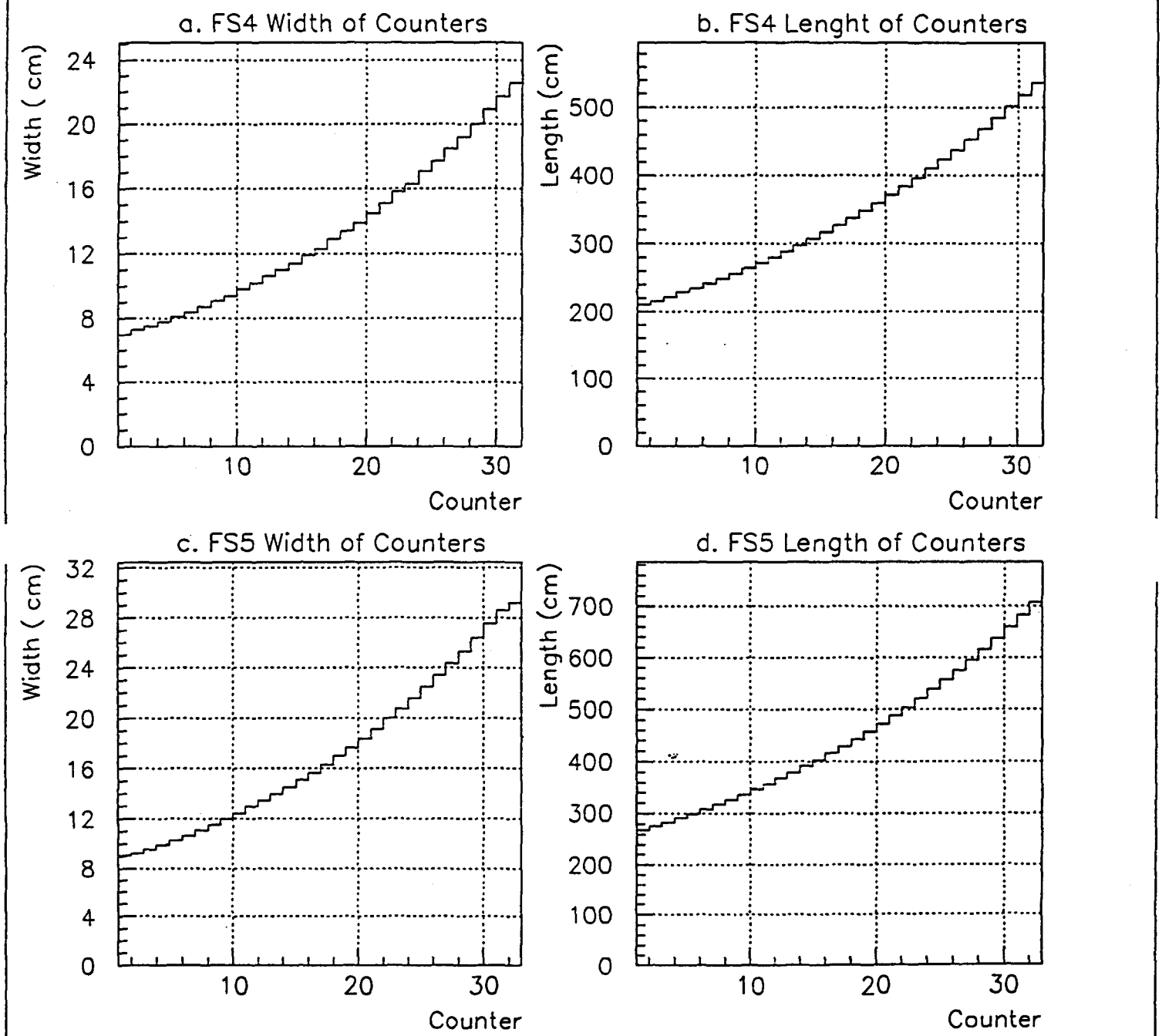

a. FS4 Width of Counters
Width (cm)
0
4
8
12
16
20
24
10
20
30
Counter
b. FS4 Lenght of Counters
Length (cm)
0
100
200
300
400
500
10
20
30
Counter
c. FS5 Width of Counters
Width (cm)
0
4
8
12
16
20
24
28
32
10
20
30
Counter
d. FS5 Length of Counters
Length (cm)
0
100
200
300
400
500
600
700
10
20
30
Counter

Figure 1

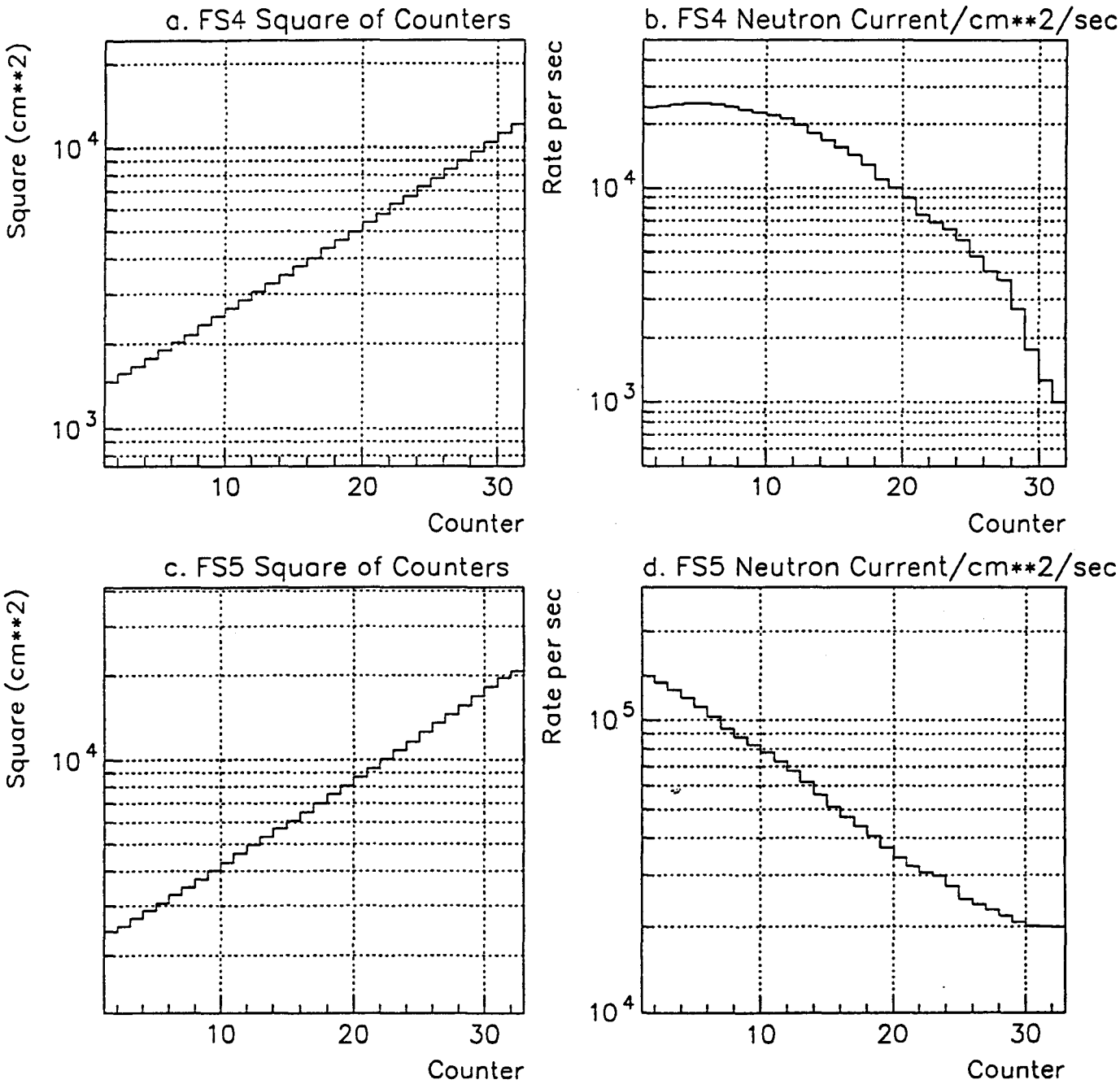

a. FS4 Square of Counters
Square (cm**2)
10^4
10^3
10
20
30
Counter
b. FS4 Neutron Current/cm**2/sec
Rate per sec
10^4
10^3
10
20
30
Counter
c. FS5 Square of Counters
Square (cm**2)
10^4
10
20
30
Counter
d. FS5 Neutron Current/cm**2/sec
Rate per sec
10^5
10^4
10
20
30
Counter

Figure 2

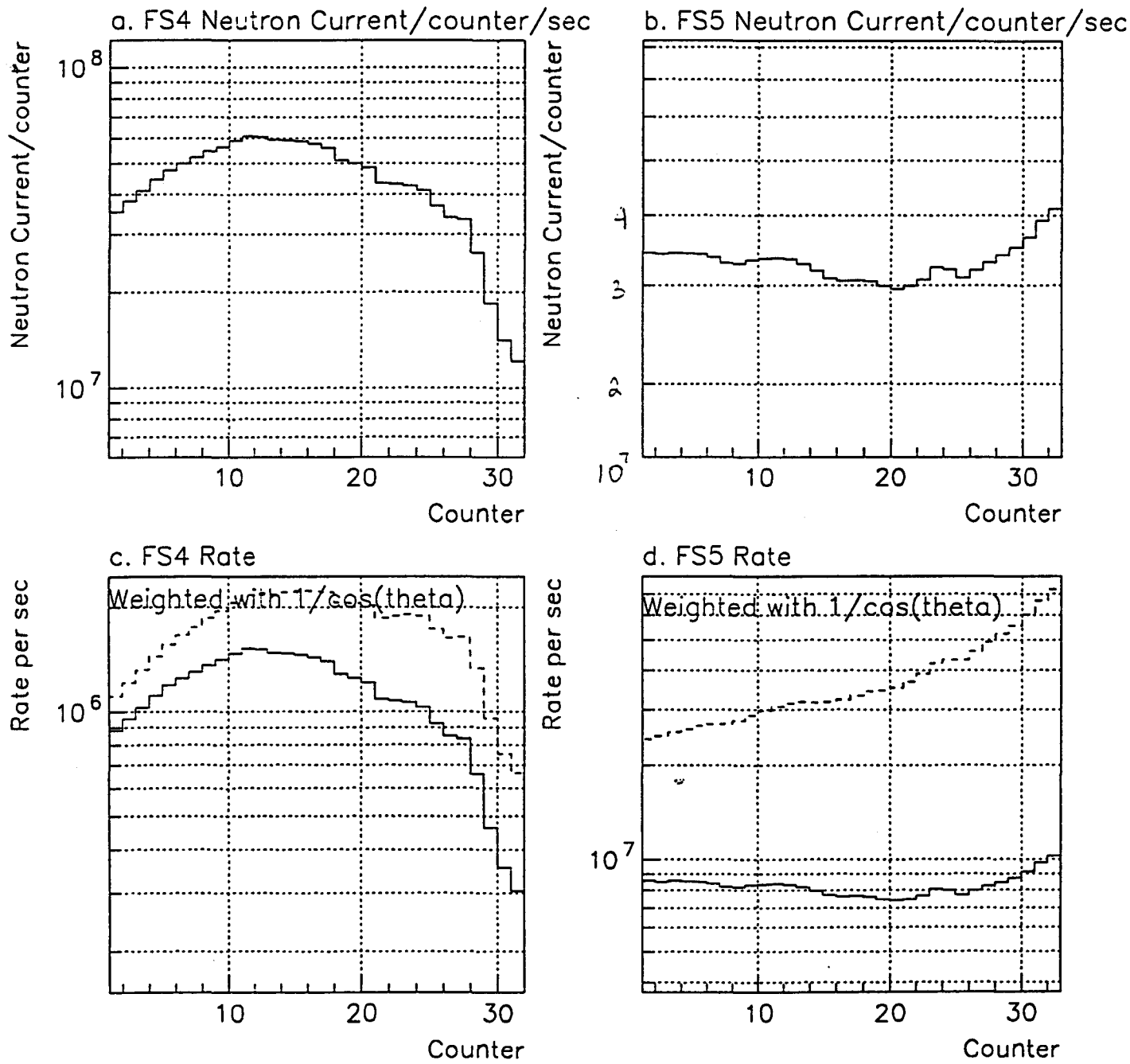

a. FS4 Neutron Current/counter/sec
Neutron Current/counter
10^8
10^7
10
20
30
Counter
b. FS5 Neutron Current/counter/sec
Neutron Current/counter
10^7
10
20
30
Counter
c. FS4 Rate
Weighted with 1/cos(theta)
Rate per sec
10^6
10
20
30
Counter
d. FS5 Rate
Weighted with 1/cos(theta)
Rate per sec
10^7
10
20
30
Counter

Figure 3

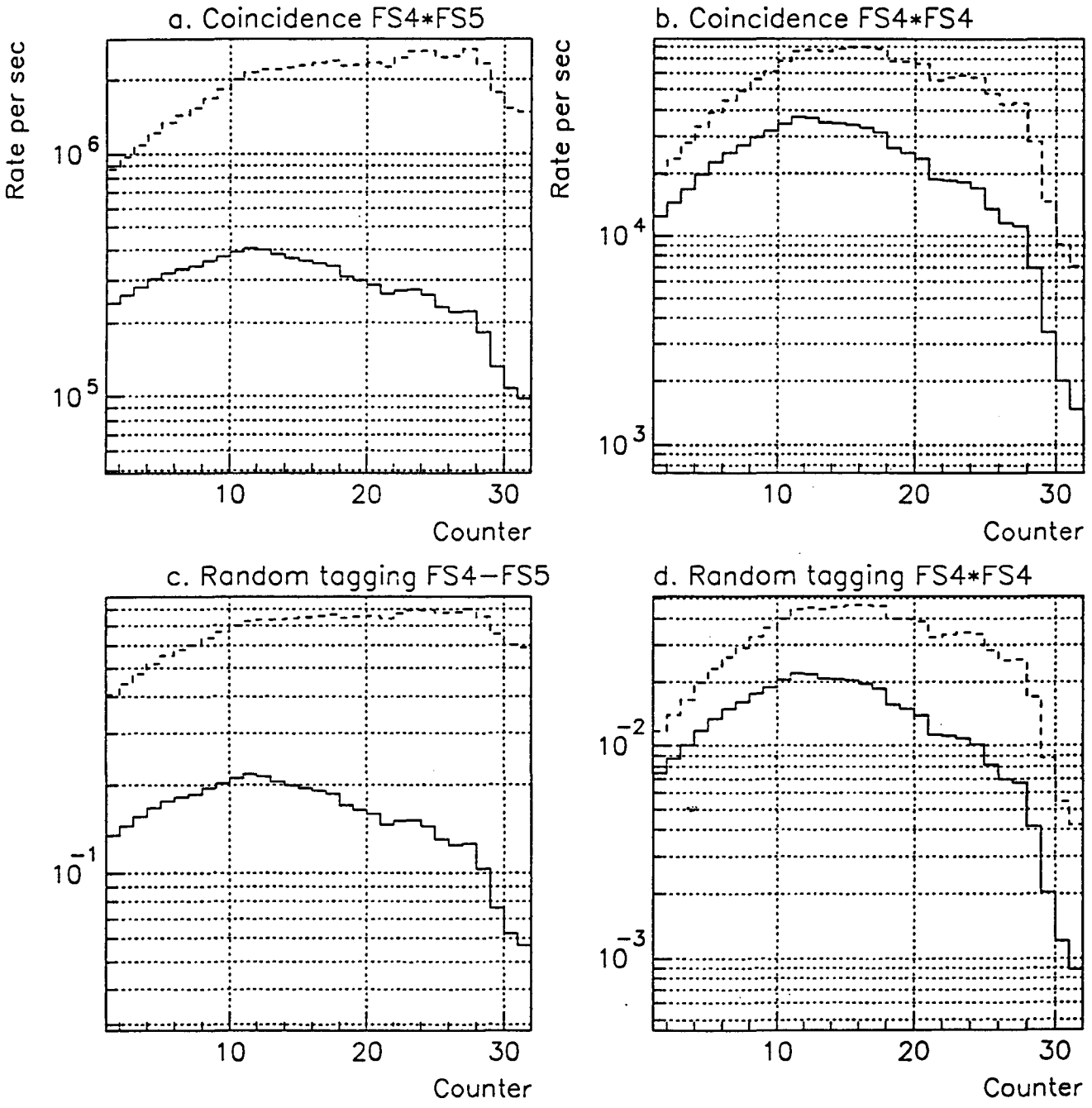

a. Coincidence FS4*FS5
Rate per sec
10^6
10^5
10
20
30
Counter
b. Coincidence FS4*FS4
Rate per sec
10^4
10^3
10
20
30
Counter
c. Random tagging FS4−FS5
10^{-1}
10
20
30
Counter
d. Random tagging FS4*FS4
10^{-2}
10^{-3}
10
20
30
Counter

Figure 4

It may be difficult to operate an efficient trigger system with only the use of standard scintillator counters, particularly at luminosity above the design value. For this reason, we are proposing, as an upgrade option, the incorporation of multi-cell nitrogen gas Cerenkov counters into the forward trigger.

The Cerenkov counter has the obvious advantages for the background rejection.

✔ **The Cerenkov counter is very fast. It is easy to achieve the time resolution better than 1 ns.**

✔ **The Cerenkov counter is completely insensitive to the neutrons and the low momentum particles expected as a main background.**

Momentum threshold for muons = 4.25 GeV/c,
for electrons and positrons = 20 MeV/c).

98% of the background particles in the Cerenkov box have gamma < threshold value !

$$\frac{\text{Background rate of the Cerenkov counter}}{\text{Background rate of the scintillator hodoscope}} \ll 1$$

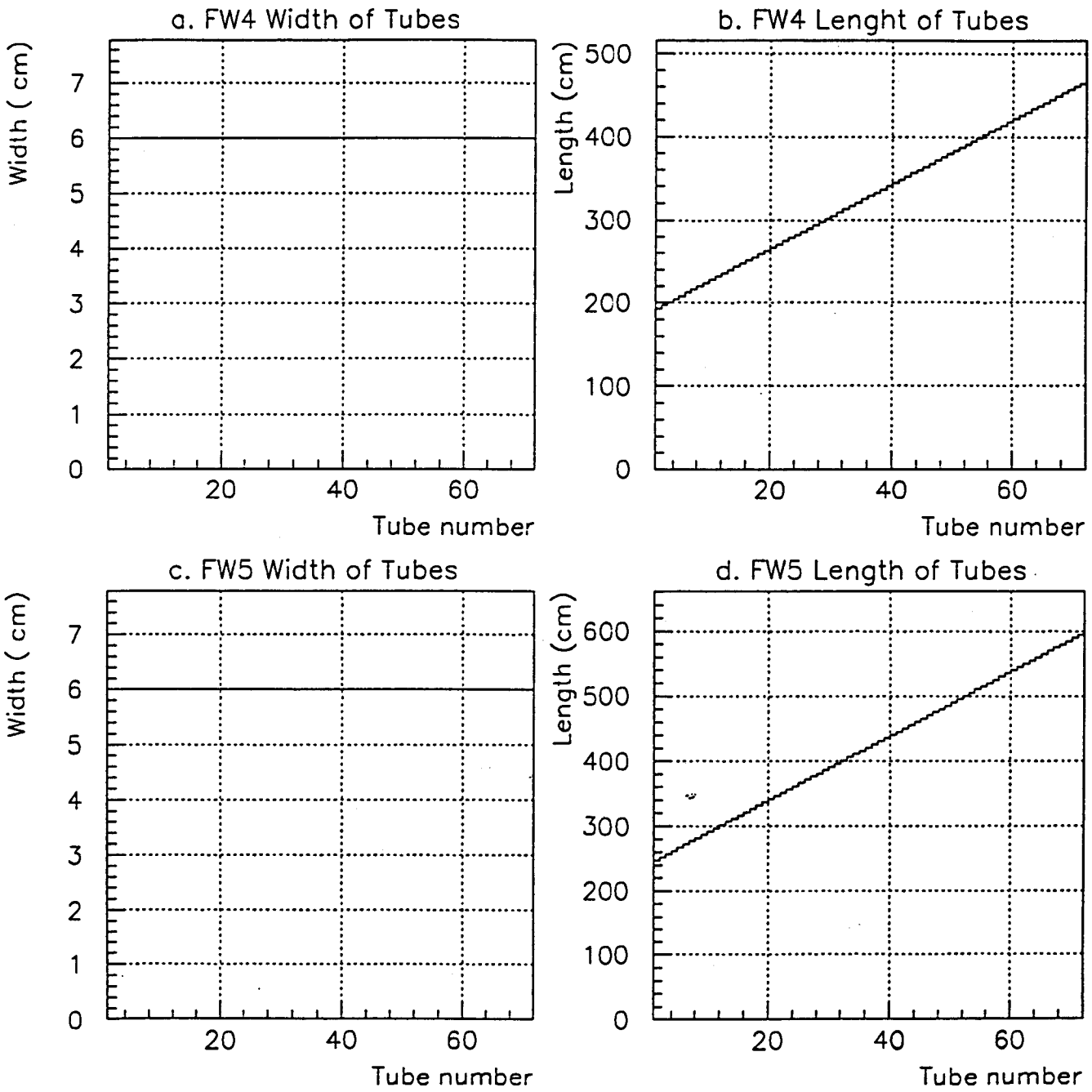

a. FW4 Width of Tubes
Width (cm)
0
1
2
3
4
5
6
7
20
40
60
Tube number
b. FW4 Lenght of Tubes
Length (cm)
0
100
200
300
400
500
20
40
60
Tube number
c. FW5 Width of Tubes
Width (cm)
0
1
2
3
4
5
6
7
20
40
60
Tube number
d. FW5 Length of Tubes
Length (cm)
0
100
200
300
400
500
600
20
40
60
Tube number

Figure 5

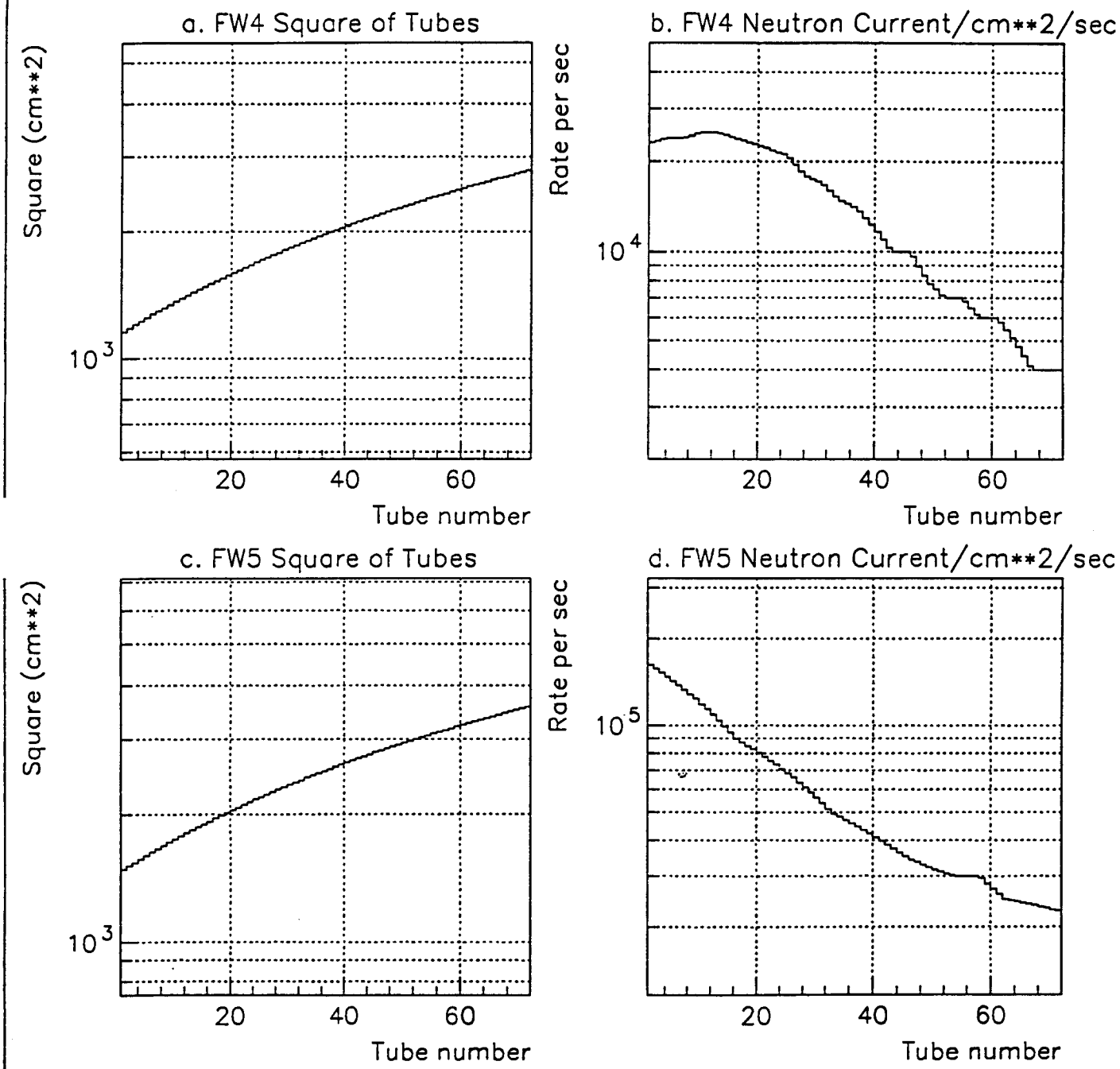

a. FW4 Square of Tubes
Square (cm**2)
10^3
20
40
60
Tube number
b. FW4 Neutron Current/cm**2/sec
Rate per sec
10^4
20
40
60
Tube number
c. FW5 Square of Tubes
Square (cm**2)
10^3
20
40
60
Tube number
d. FW5 Neutron Current/cm**2/sec
Rate per sec
10^5
20
40
60
Tube number

Figure 6

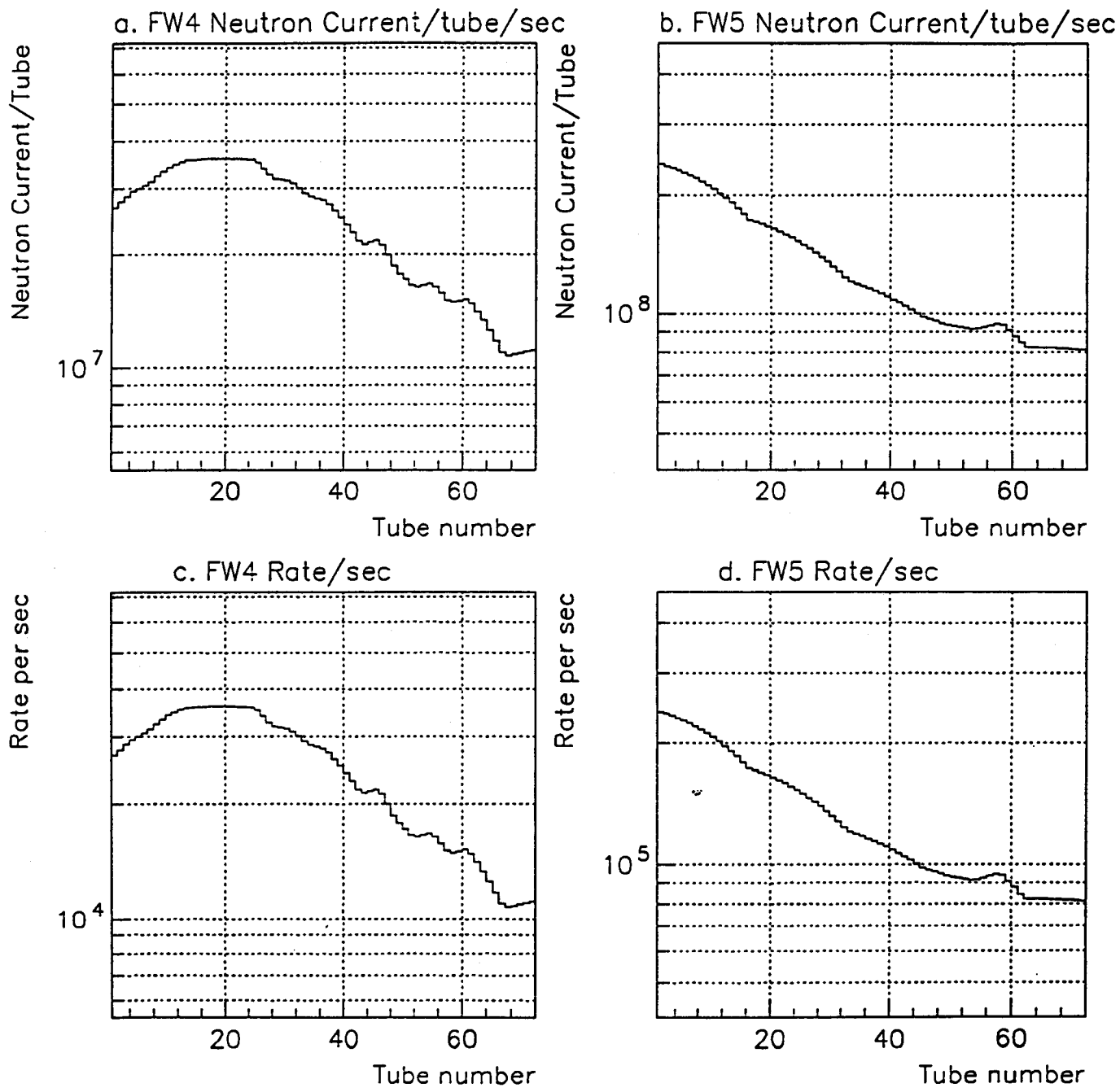

a. FW4 Neutron Current/tube/sec
Neutron Current/Tube
10^7
20
40
60
Tube number
b. FW5 Neutron Current/tube/sec
Neutron Current/Tube
10^8
20
40
60
Tube number
c. FW4 Rate/sec
Rate per sec
10^4
20
40
60
Tube number
d. FW5 Rate/sec
Rate per sec
10^5
20
40
60
Tube number

Figure 7

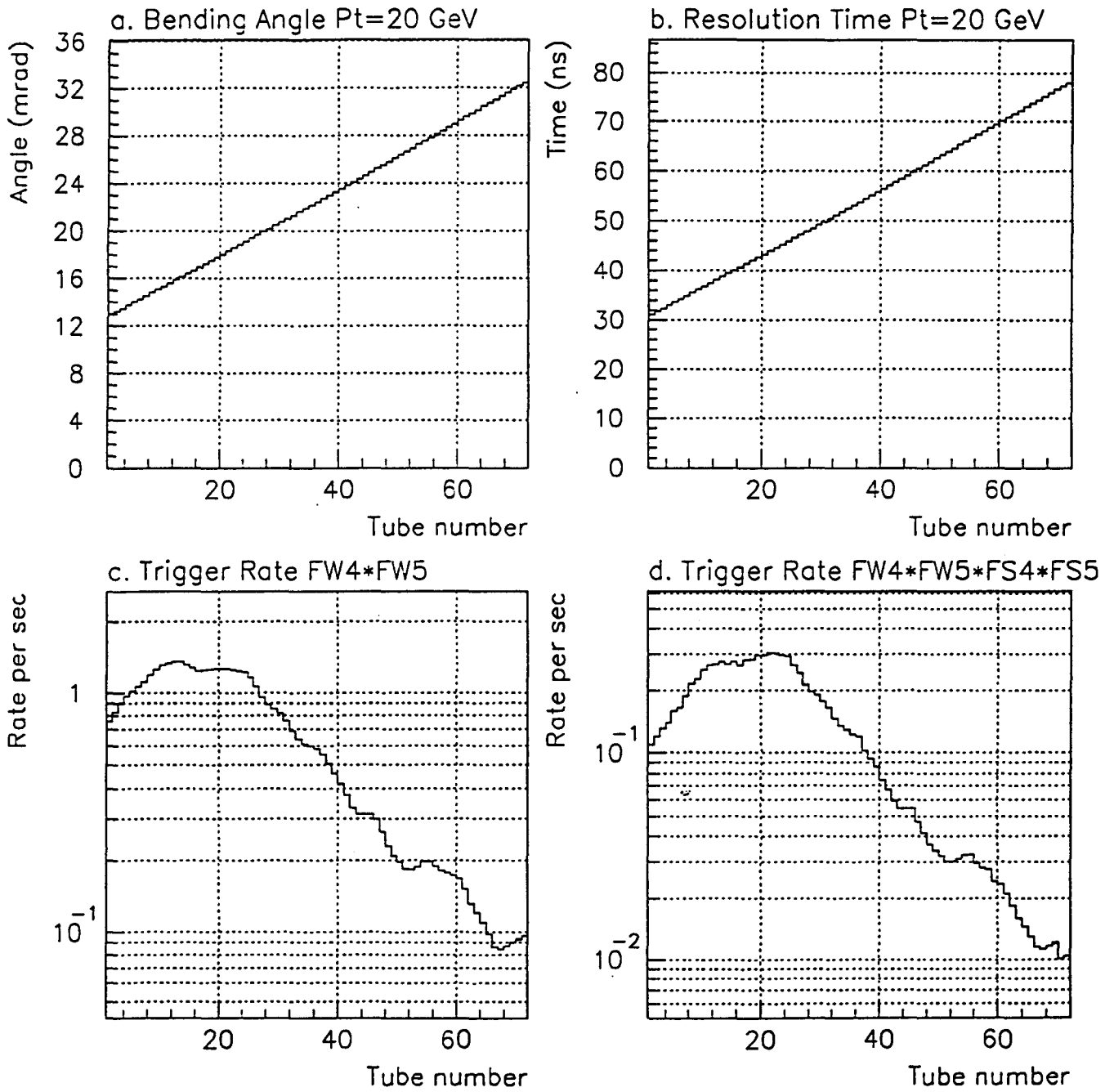

a. Bending Angle Pt=20 GeV
Angle (mrad)
36
32
28
24
20
16
12
8
4
0
20
40
60
Tube number
b. Resolution Time Pt=20 GeV
Time (ns)
80
70
60
50
40
30
20
10
0
20
40
60
Tube number
c. Trigger Rate FW4*FW5
Rate per sec
1
10^{-1}
20
40
60
Tube number
d. Trigger Rate FW4*FW5*FS4*FS5
Rate per sec
10^{-1}
10^{-2}
20
40
60
Tube number

Figure 8

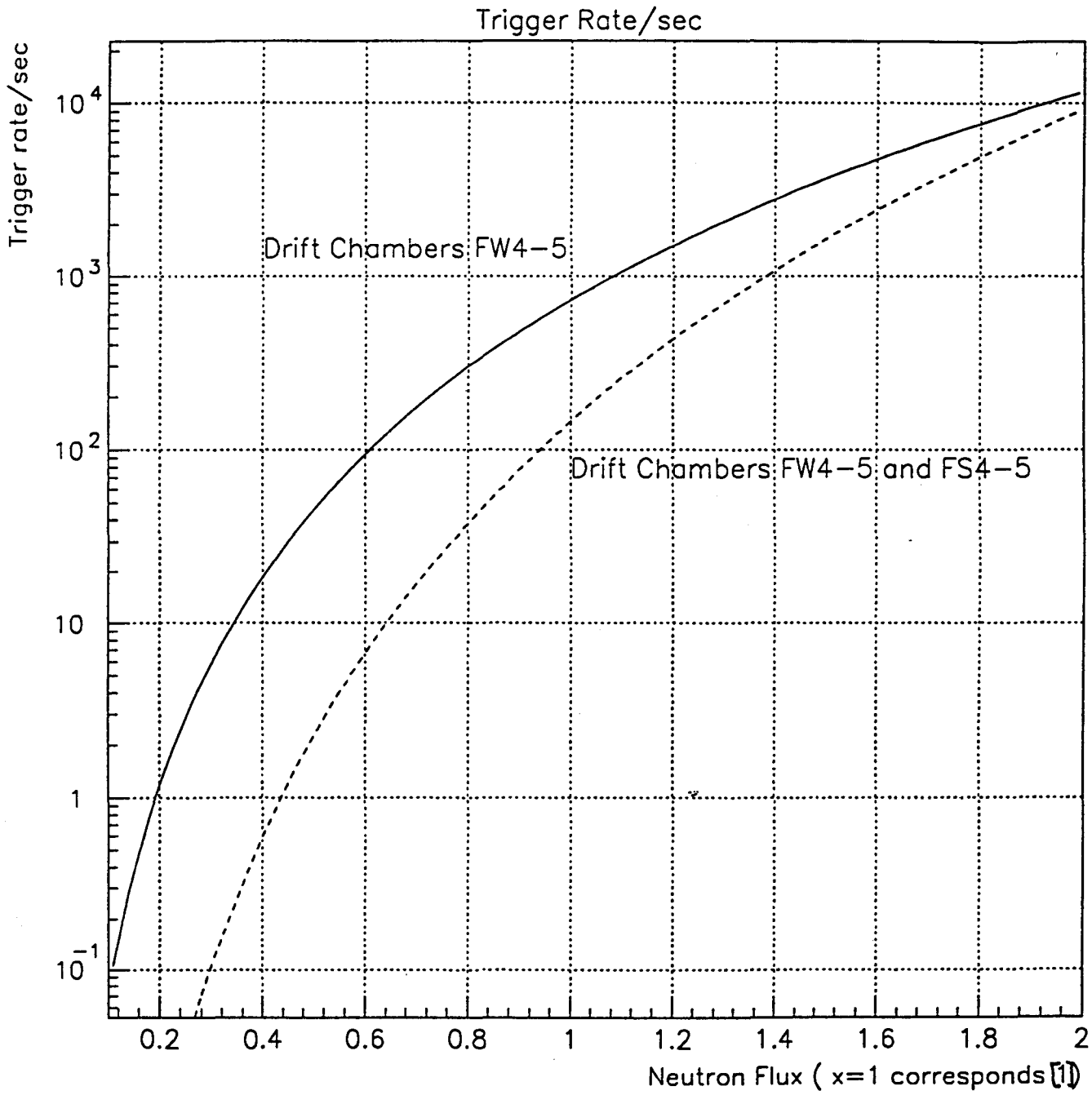

Trigger Rate/sec
Trigger rate/sec
10^4
10^3
10^2
10
1
10^{-1}
Drift Chambers FW4−5
Drift Chambers FW4−5 and FS4−5
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Neutron Flux (x=1 corresponds [1])

Figure 9

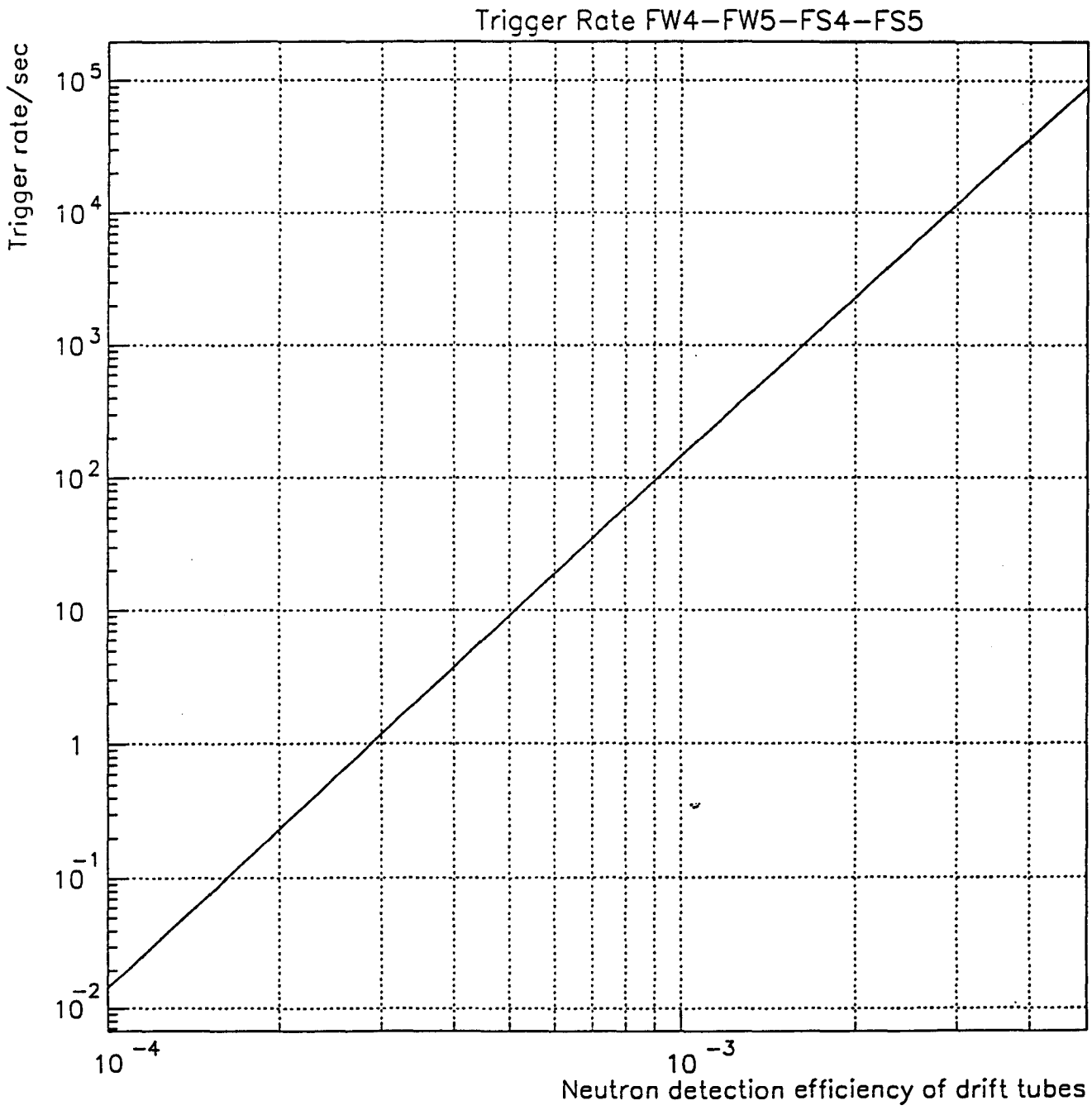

Trigger Rate FW4−FW5−FS4−FS5
Trigger rate/sec
10^5
10^4
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-4}
10^{-3}
Neutron detection efficiency of drift tubes

Figure 10

CONCLUSION

✔ Scintillator hodoscope can't operate a robust trigger in the FMS (in the base line geometry). It is very attractive to use Cerenkov counter as a trigger device in the forward direction

✔ Background rate of drift tube is the function of the efficiency and to neutrons and gammas. In the reasonable assumption on these values background rate is acceptable.

✔ The trigger rate is the sharp function on neutron fluxes (flux**6). To operate a robust trigger we have to keep trigger rate due to neutron background as low as possible.

How to minimize the neutron fluxes?

Key concept - to reduce the sources of neutrons:

- ☞ Use right shape of beam pipe before Fcal
- ☞ Use Fcal as deep as possible
- ☞ Use the proper shielding against low energy neutrons
- ☞ Remove the secondary sources after Fcal
- ☞ Use conical shape of beam pipe after Fcal

If we move low beta quads to the position. Z=35m

- ☞ Luminosity will be only 24% less
- ☞ We will remove radiation spot from FMS
- ☞ Access to the experimental set up in this area will be easier
- ☞ A lot of integration issues will be simplified

GEM has already moved S-Quad from 20.5 m to 35 m.

Possible improvements of the geometry:

- ☞ **Close FT1 and FT2 together.**

- ☞ **Move the FCAL to the interaction point to reduce the leakage of neutrons to FW4 and FW5.**

- ☞ **Use the right shielding after (and may be before FCAL).**

- ☞ **Move the quads as far from IP as possible.**

- ☞ **Use right shielding around low beta quads as much as possible.**

Steve Ball
SDC FMS Neutron Flux
1/19/93

Simulations

① Absorber 3 is Fe 30 cm

② Absorber 3 is Polyethylene (CH_2)
30 cm

Absorbers 1, 2, 4 are Fe

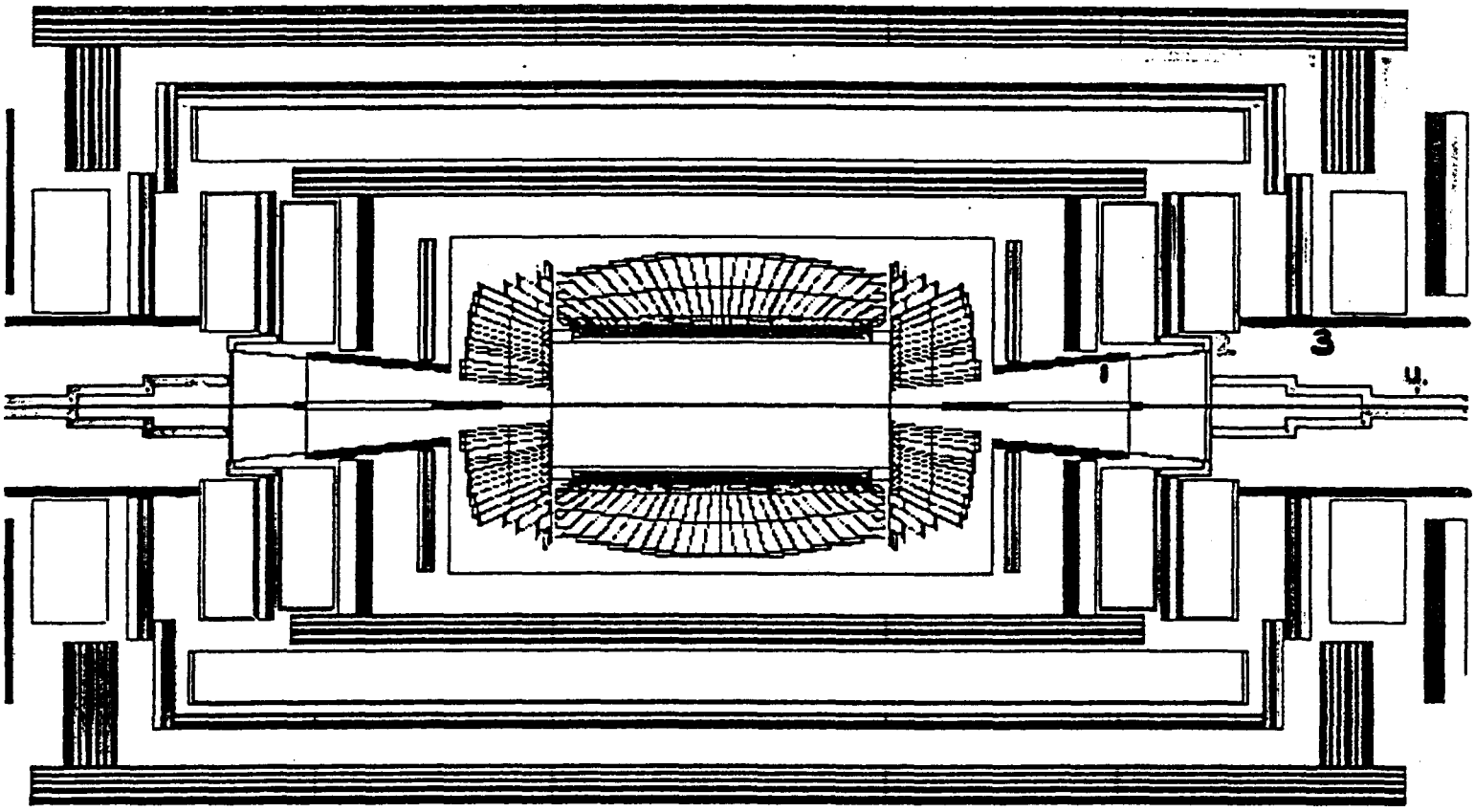
tiered Absorber 4 is 30 cm

SDCSIM program
GEANT via GHEISHA

$E_{kin} > 1$ MeV

5 events for ① and ② each

SDC



Mu geometry

August 1992

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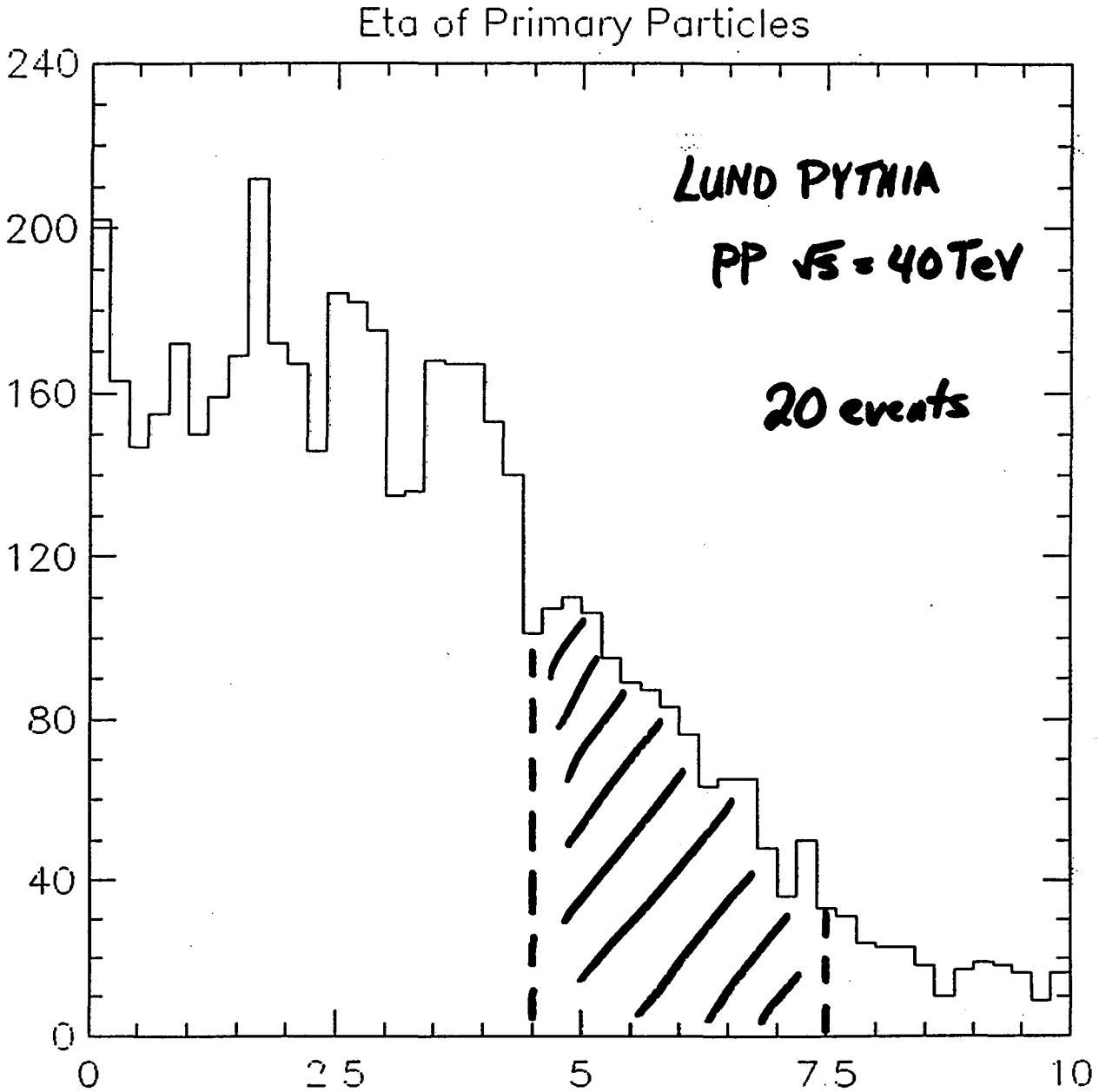

$\eta = -\ln(\tan \theta/2)$

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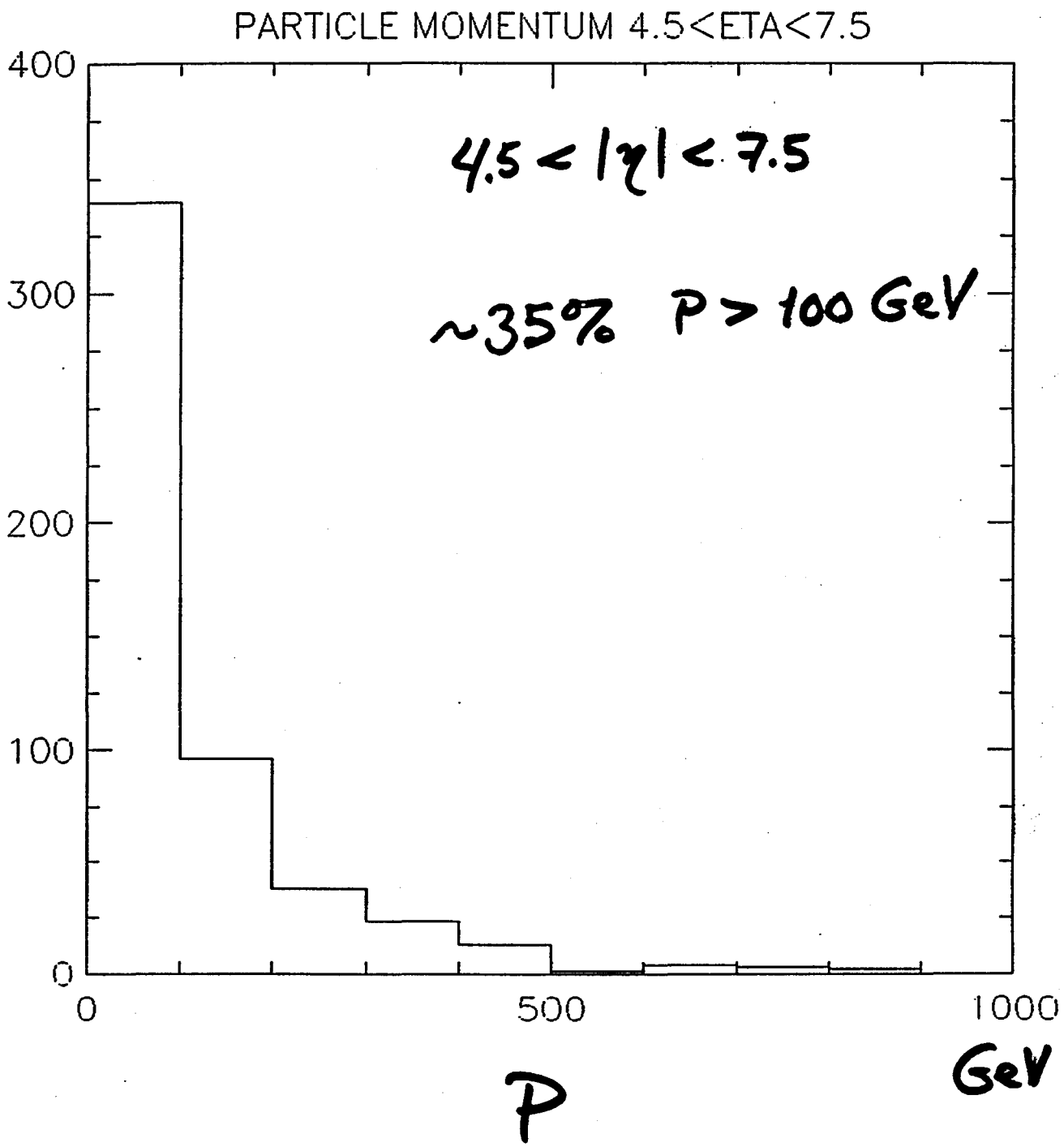

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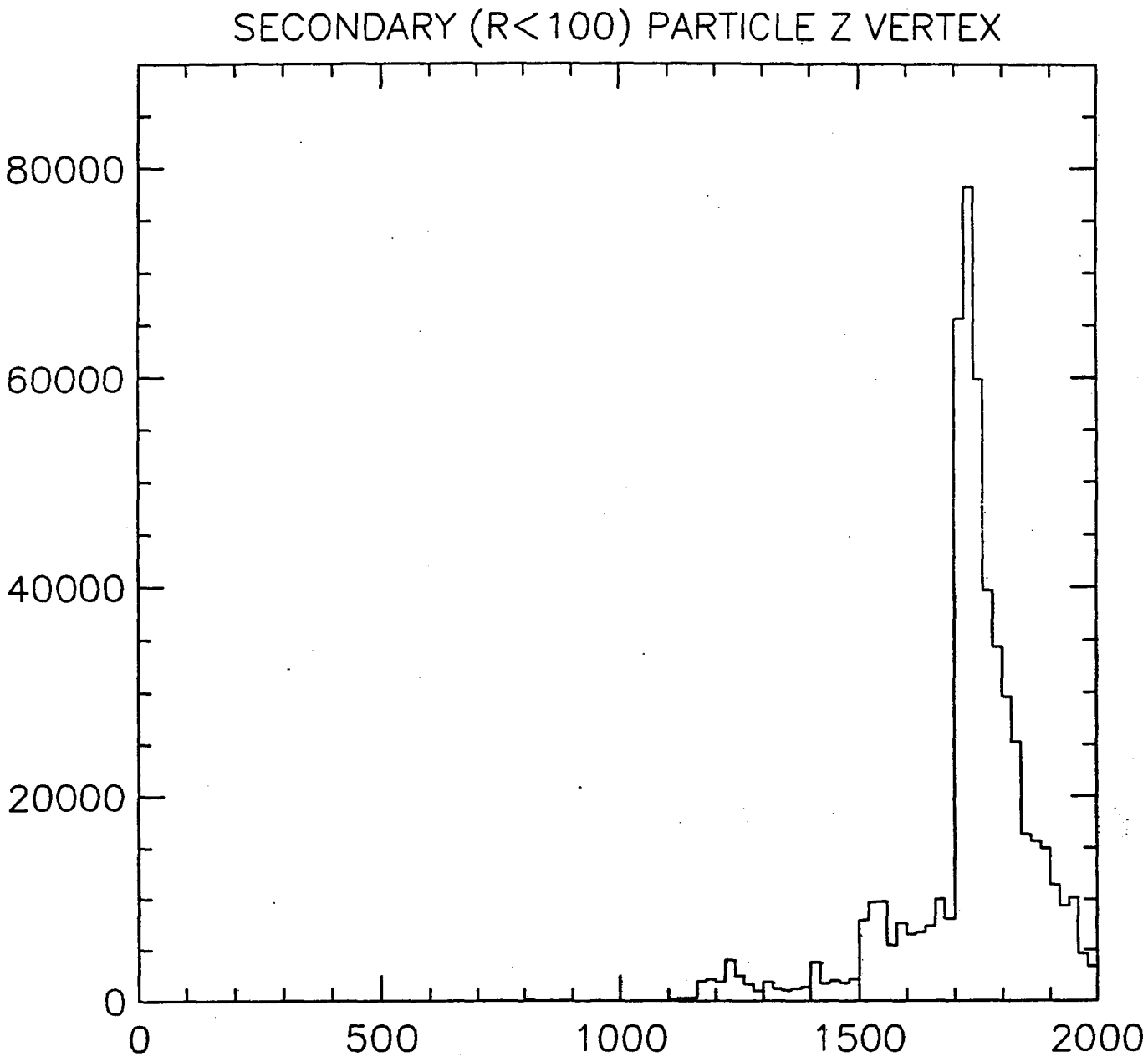

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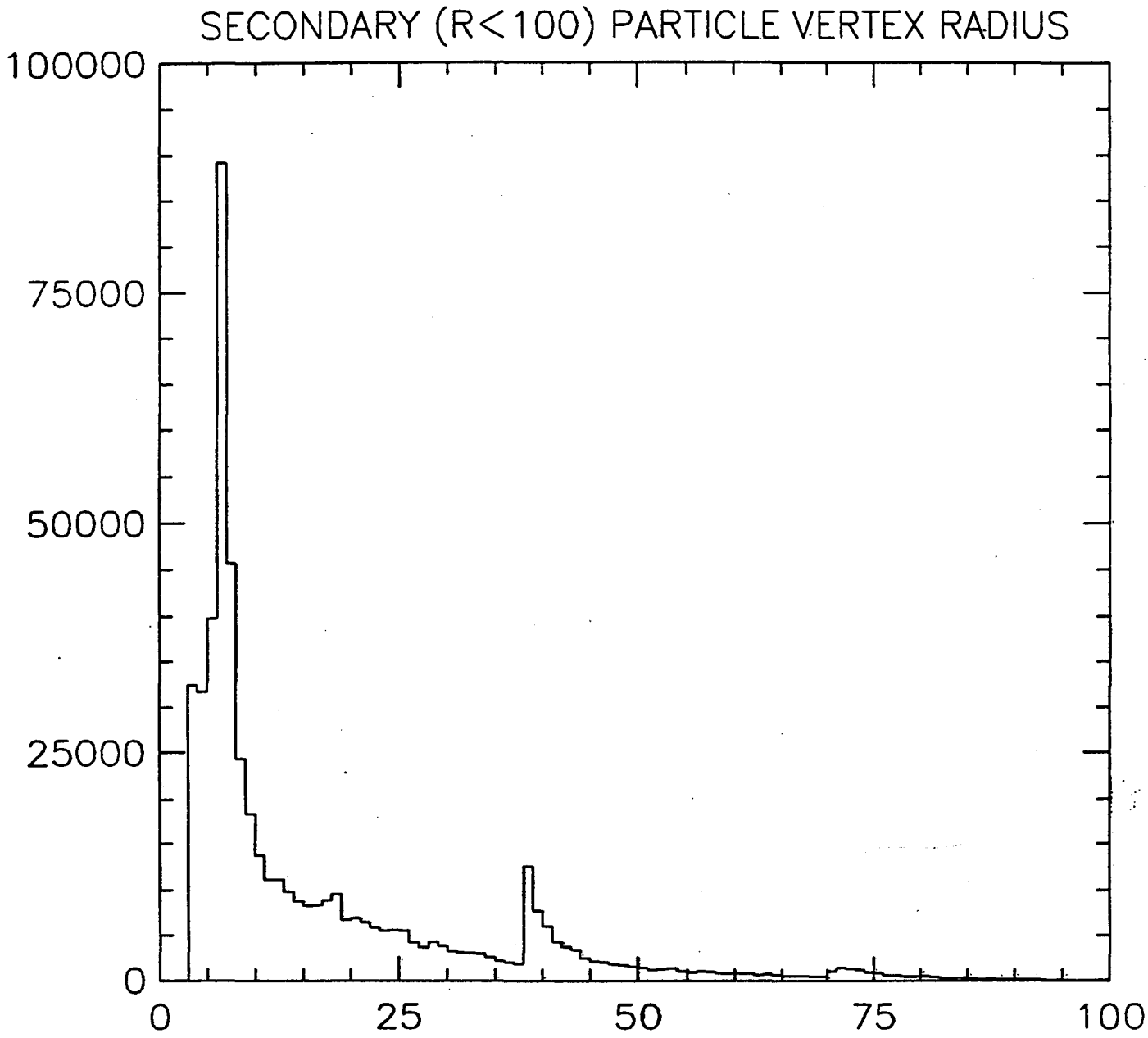

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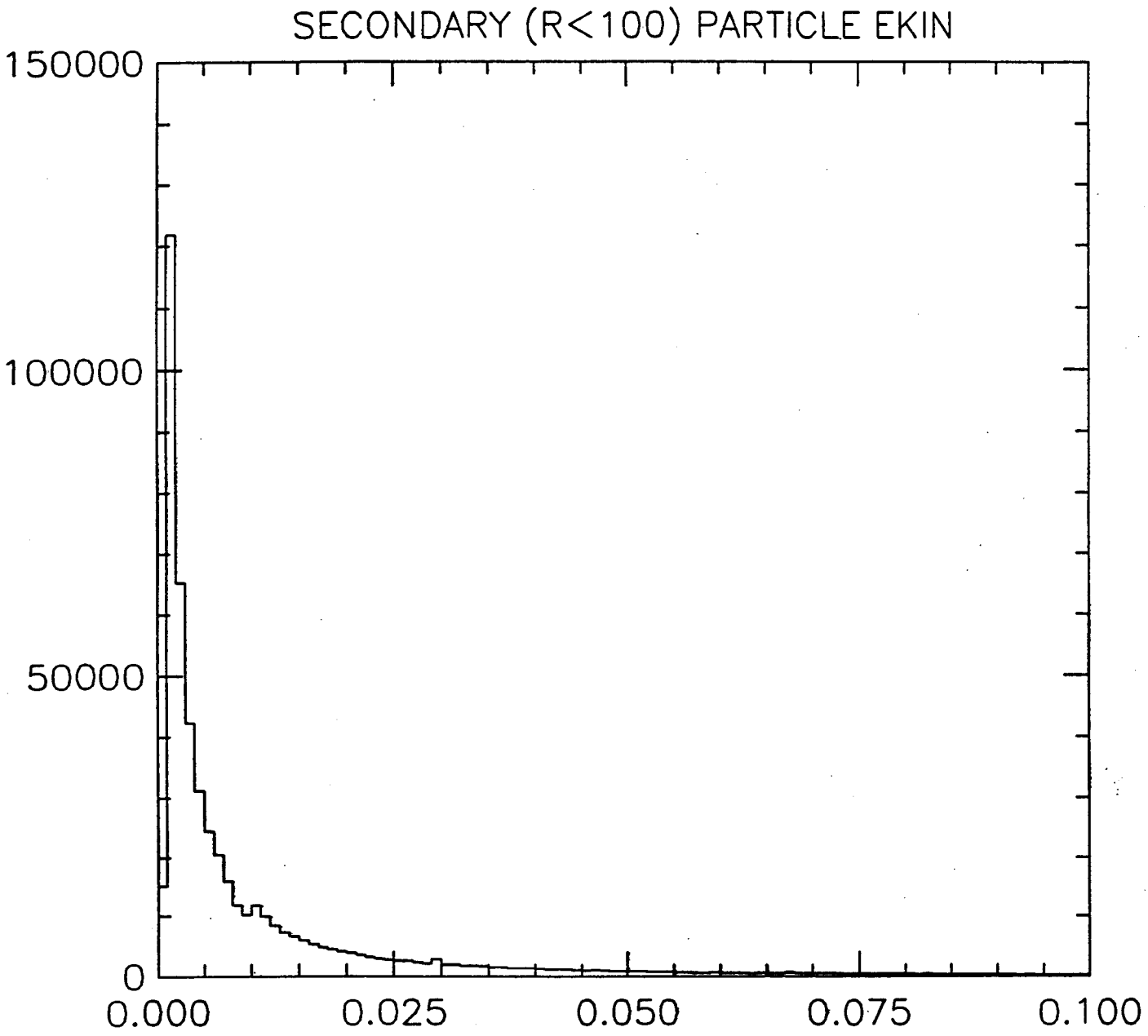
72	0	1	930114/2008	5.0181E+05	1.0806E-02	1.6208E-02



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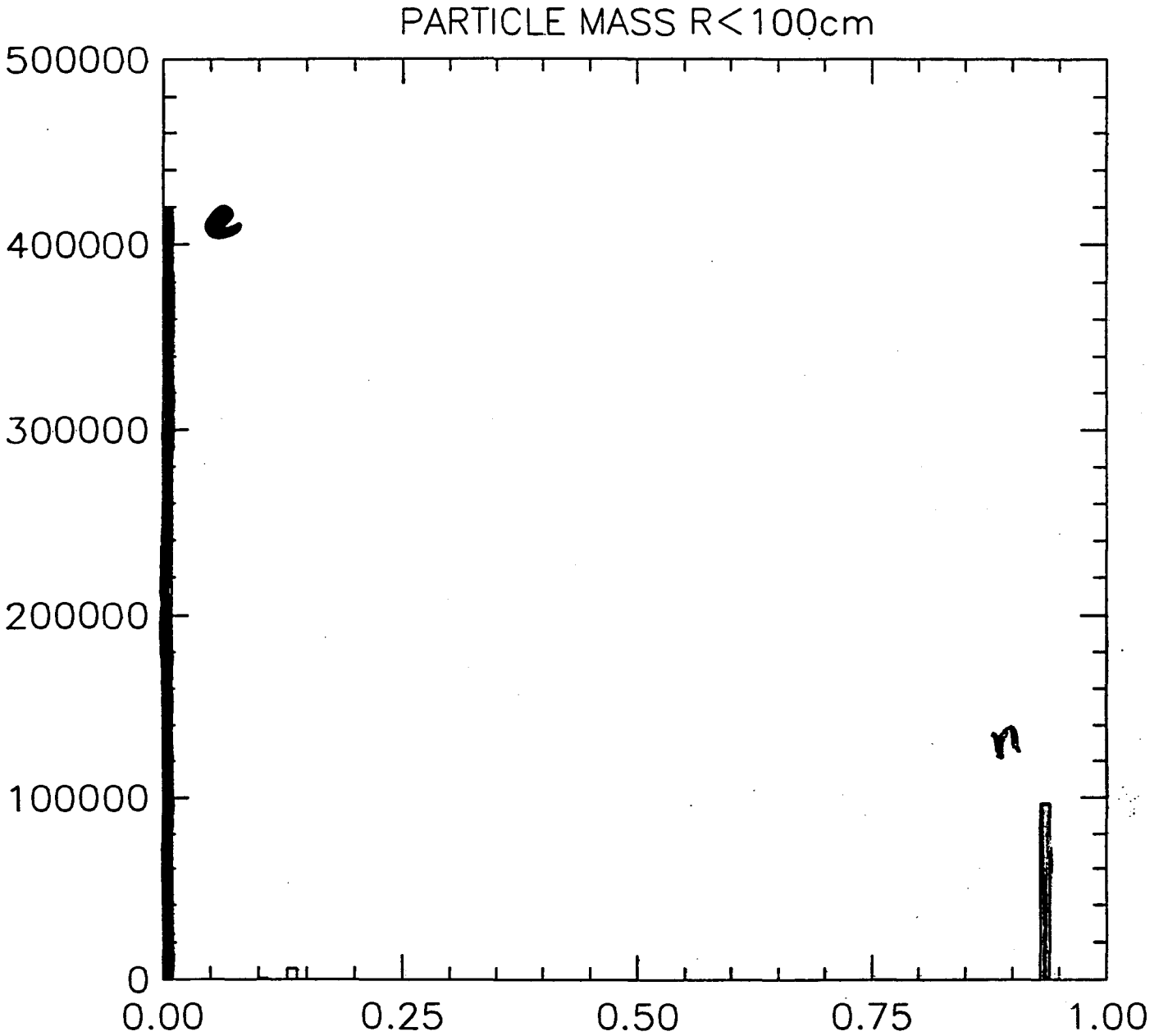
77	0	1	930114/2008	5.2255E+05	0.1784	0.3604



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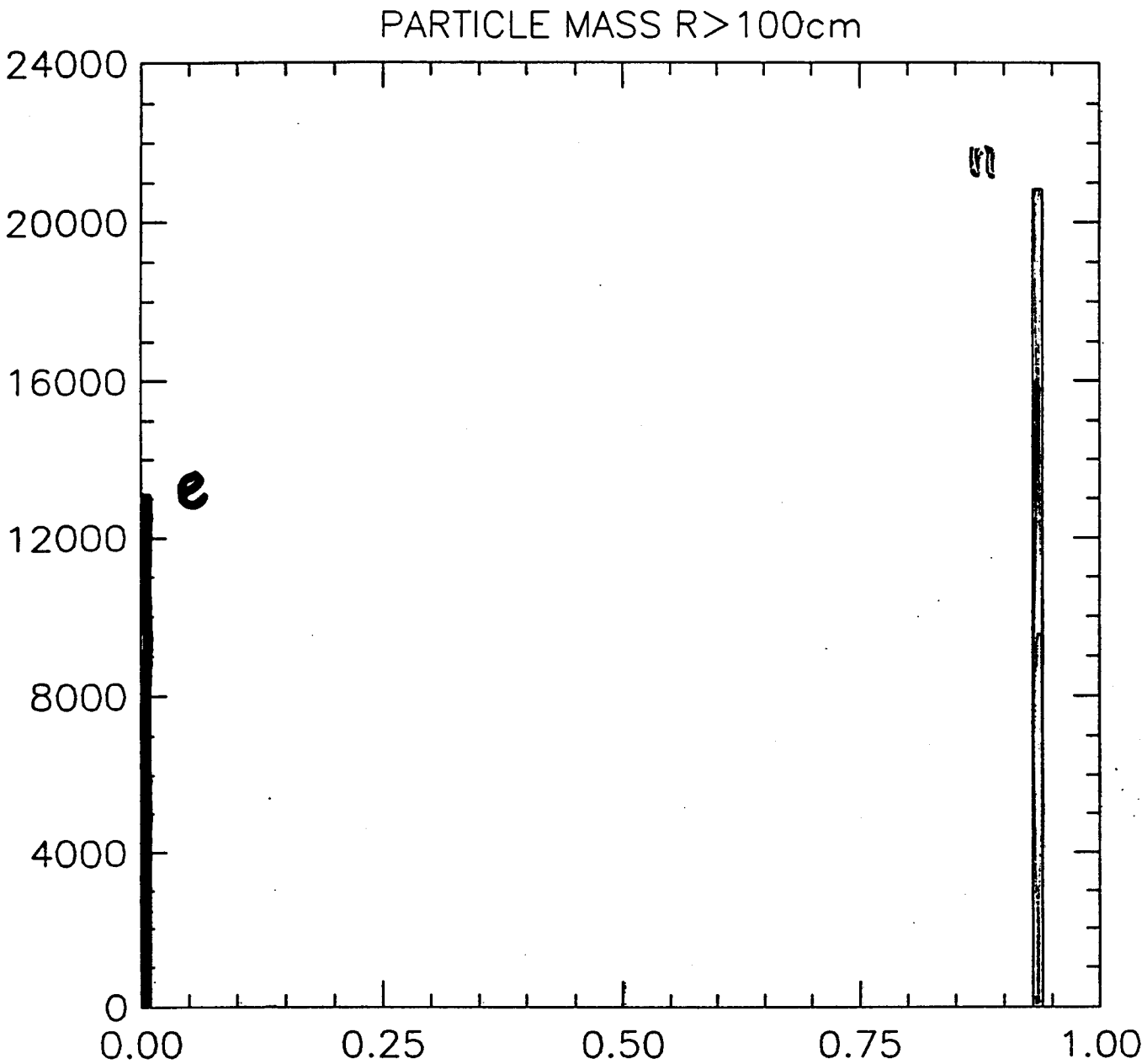
87	0	1	930114/2008	3.3990E+04	0.5753	0.4528



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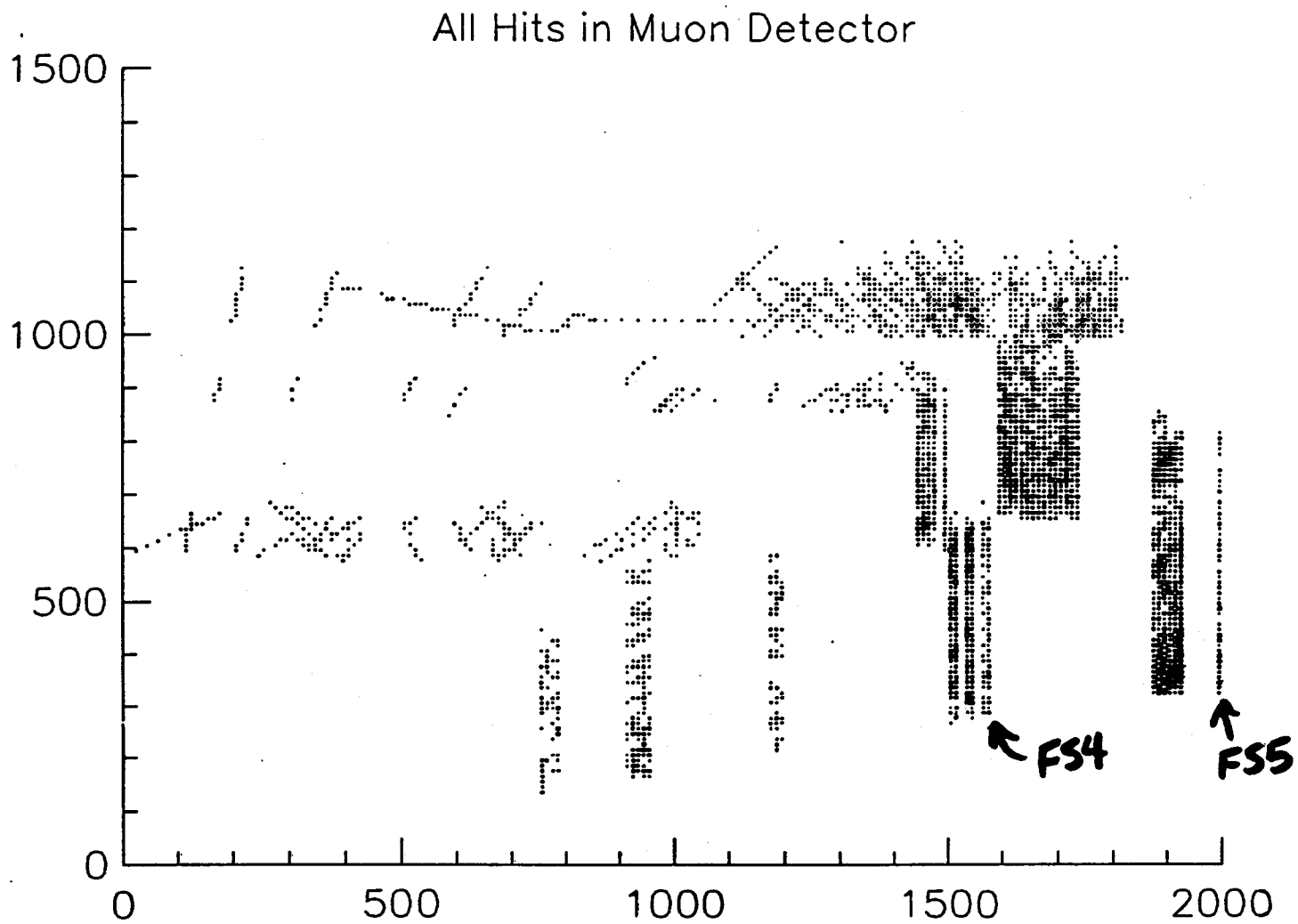
40	0	12	930115/1703	6724.	1562.	341.0
					690.7	244.8



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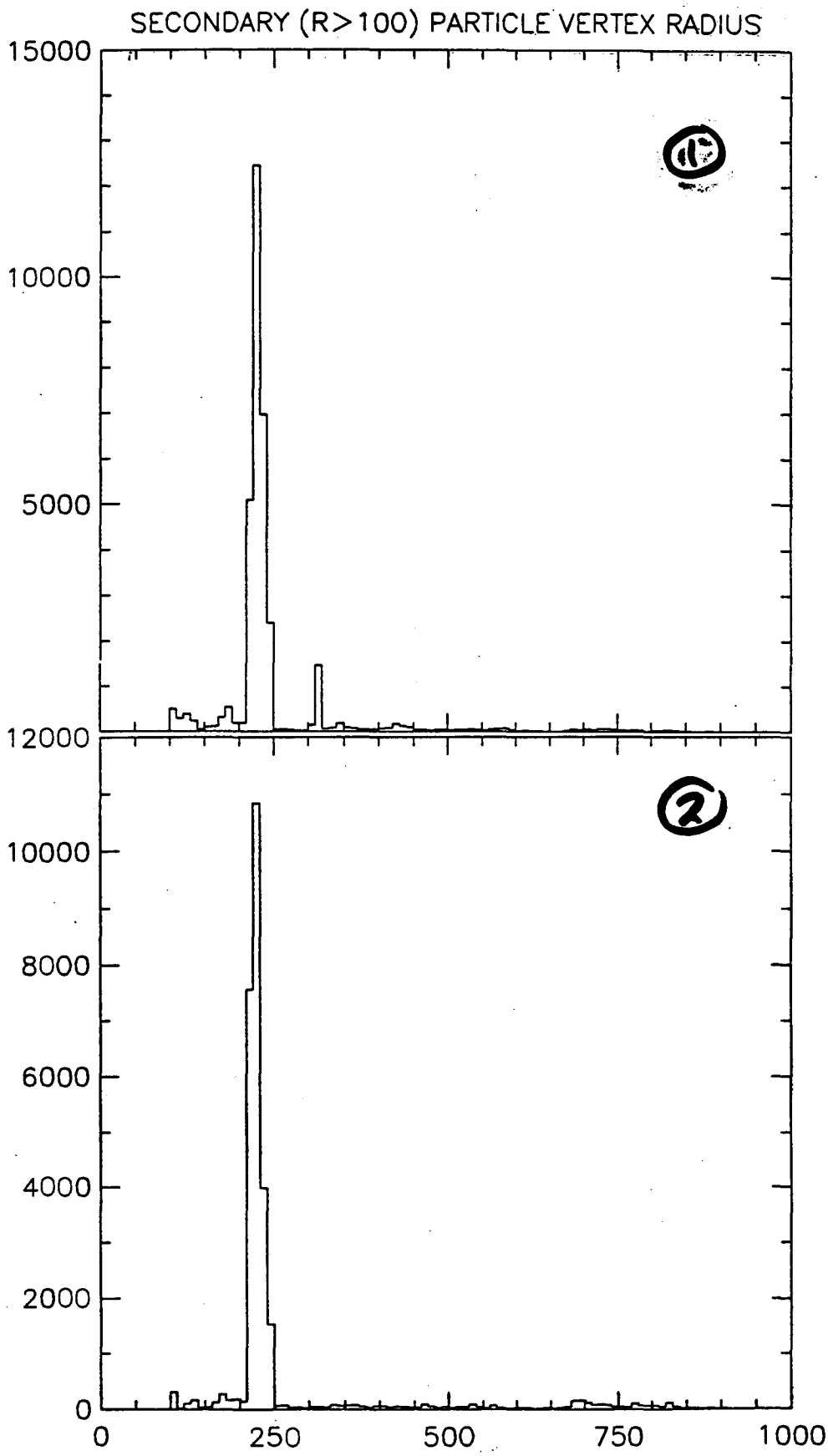
85	0	1	930114/2008	3.4272E+04	249.4	99.46



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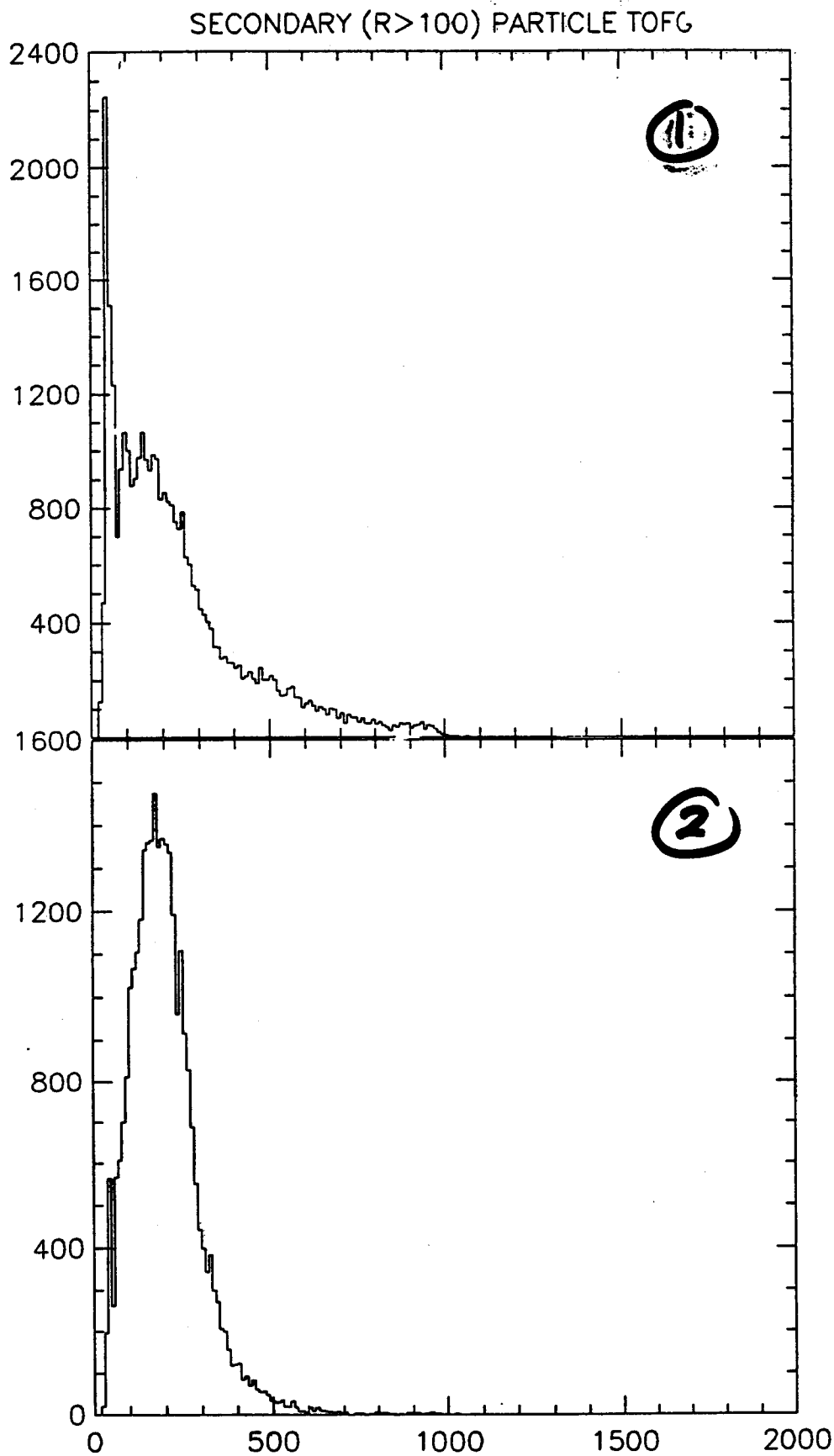
86	0	1	930114/2008	3.4406E+04	246.8	194.5



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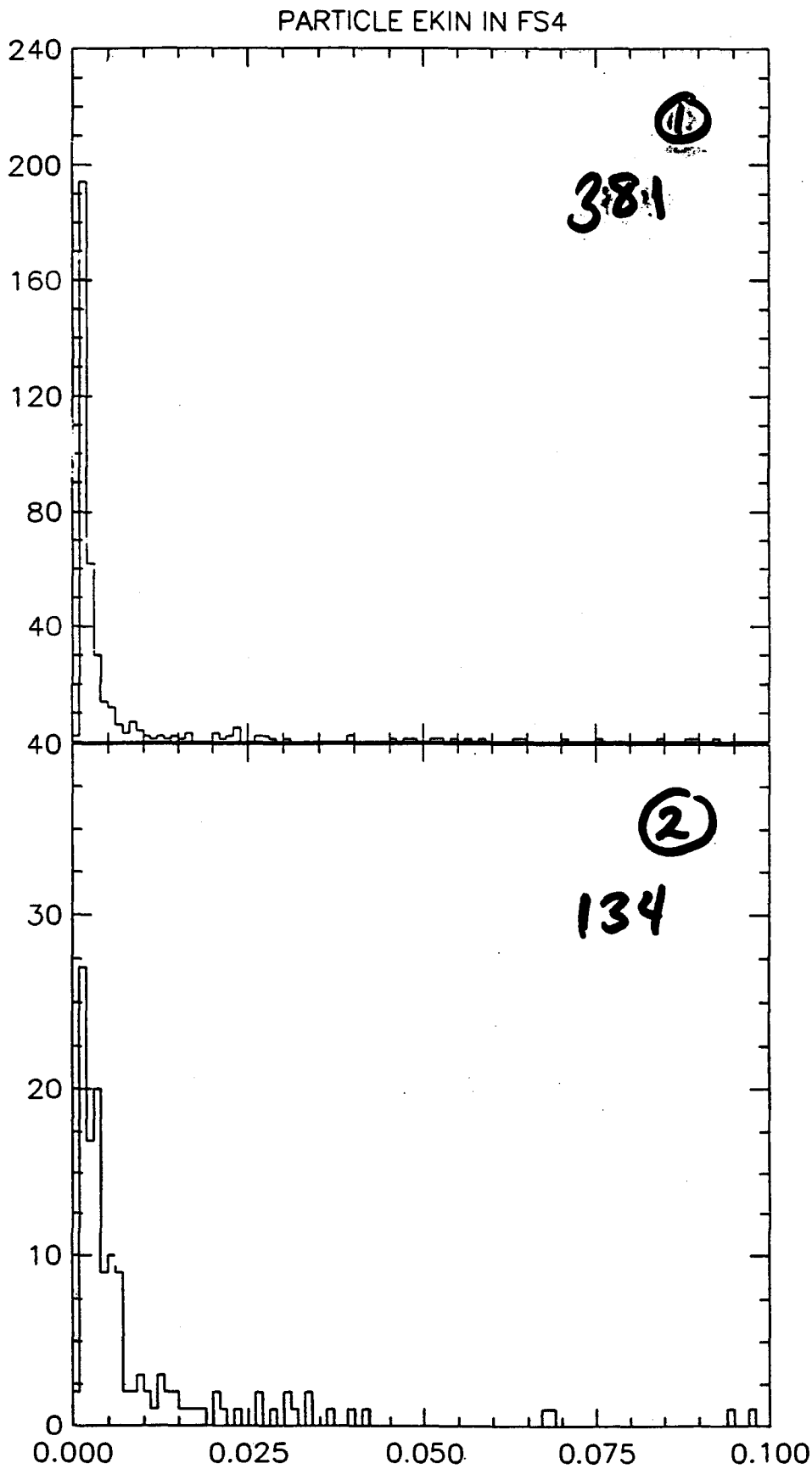
42	0	1	930114/2008	381.0	6.6680E-03	1.3924E-02



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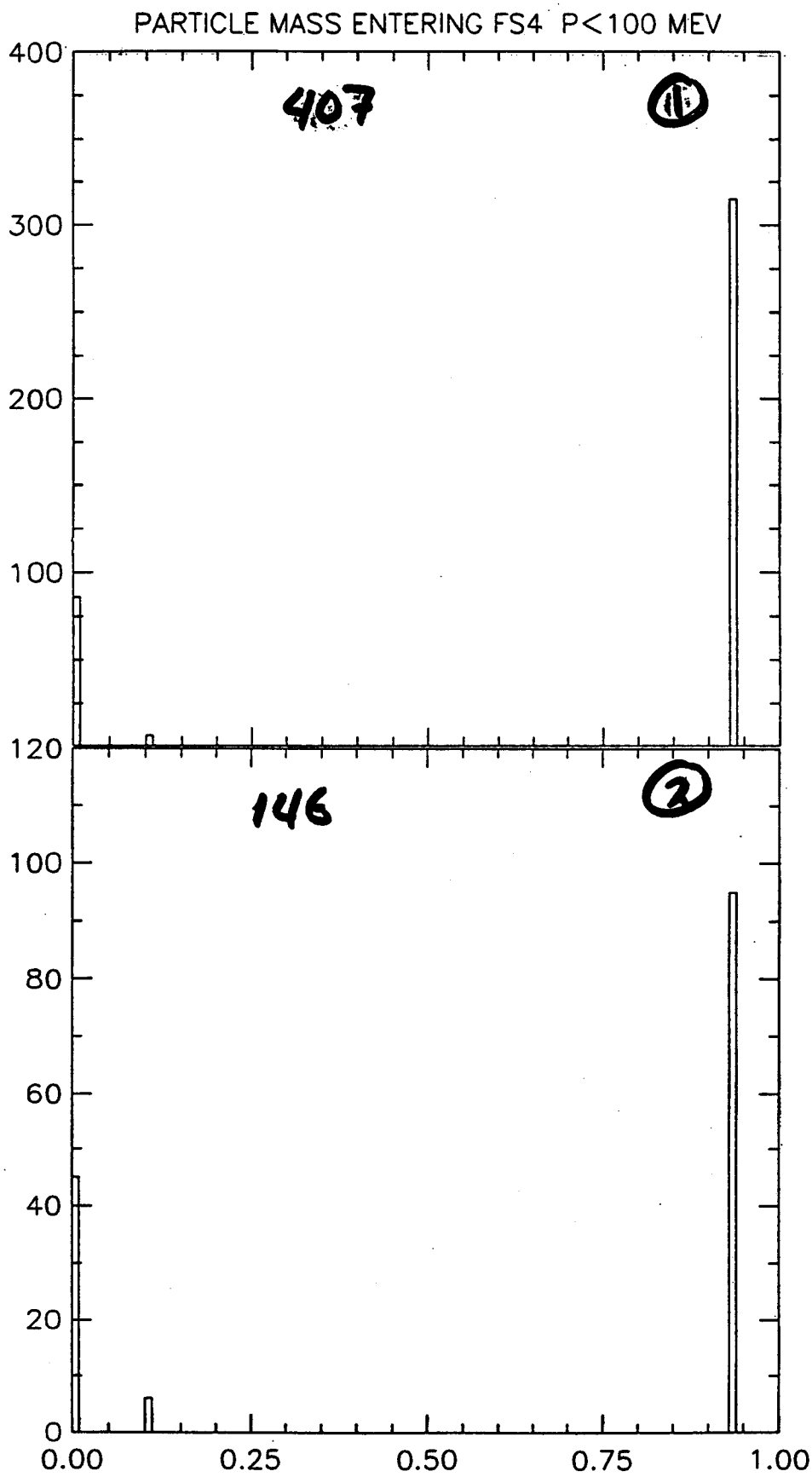
44	0	1	930114/2008	407.0	0.7263	0.3864



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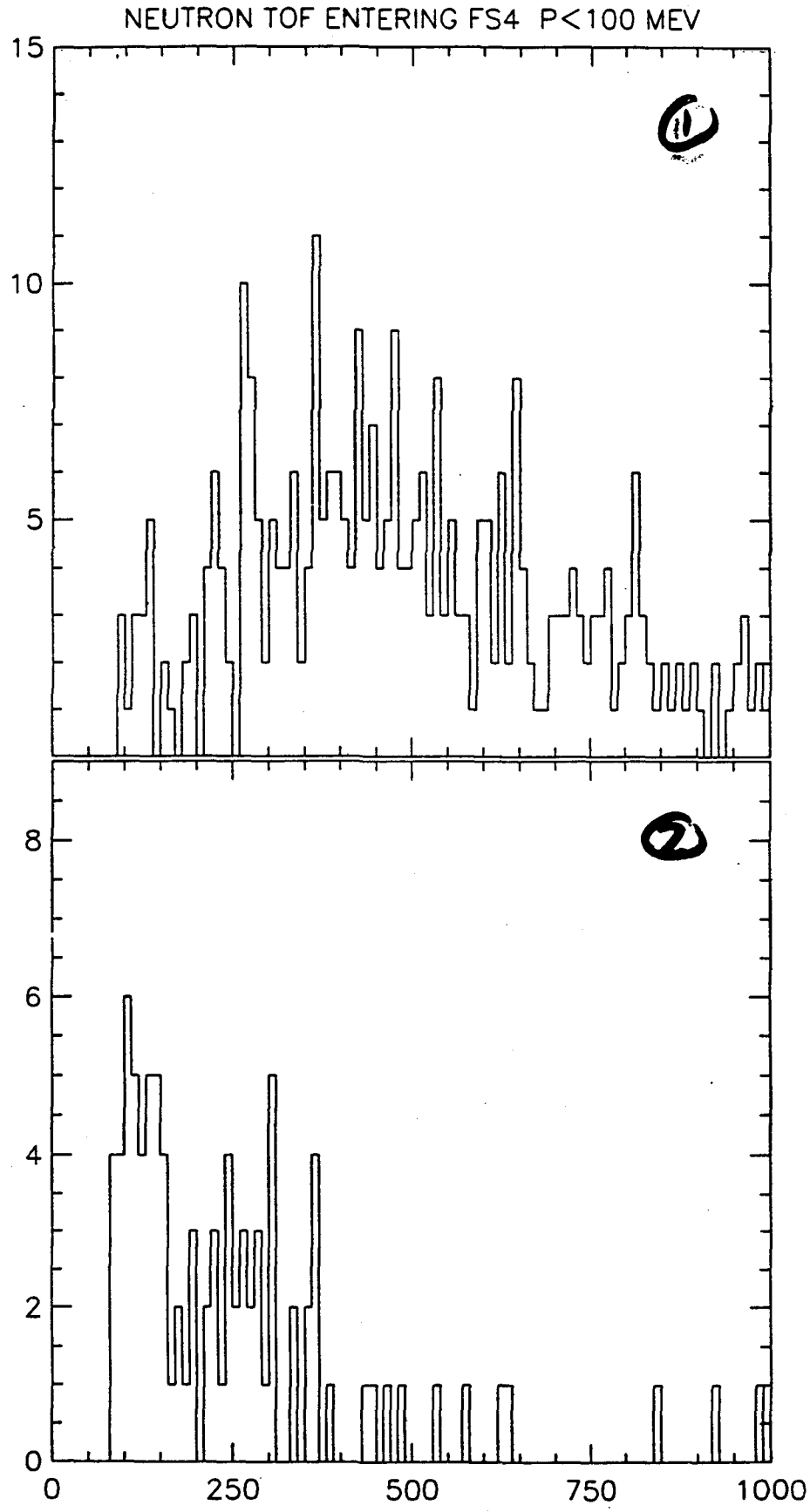
50	0	'	'0114/2008	313.0	495.1	217.1



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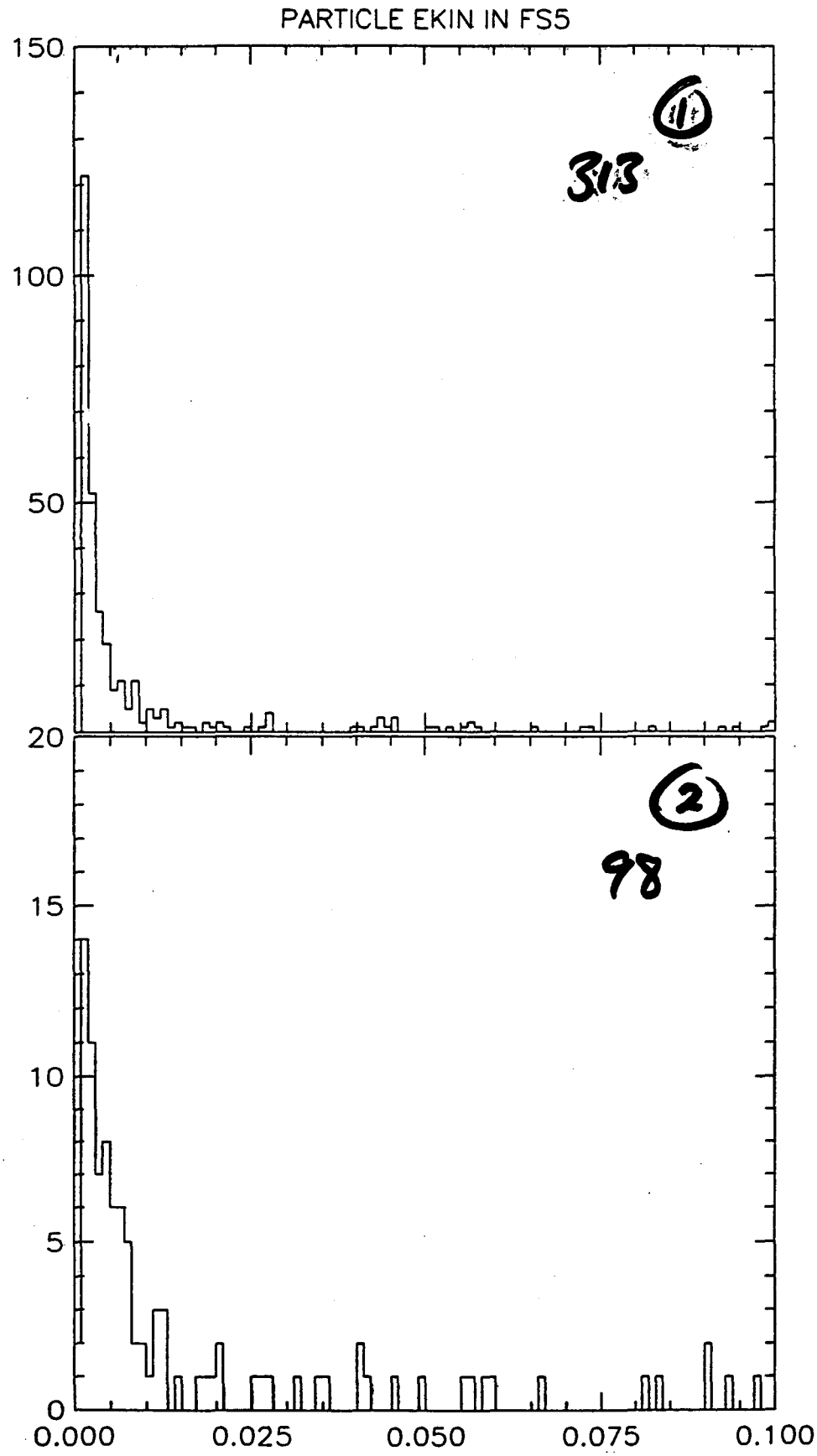
52	0	1	930114/2008	313.0	9.1326E-03	1.7439E-02



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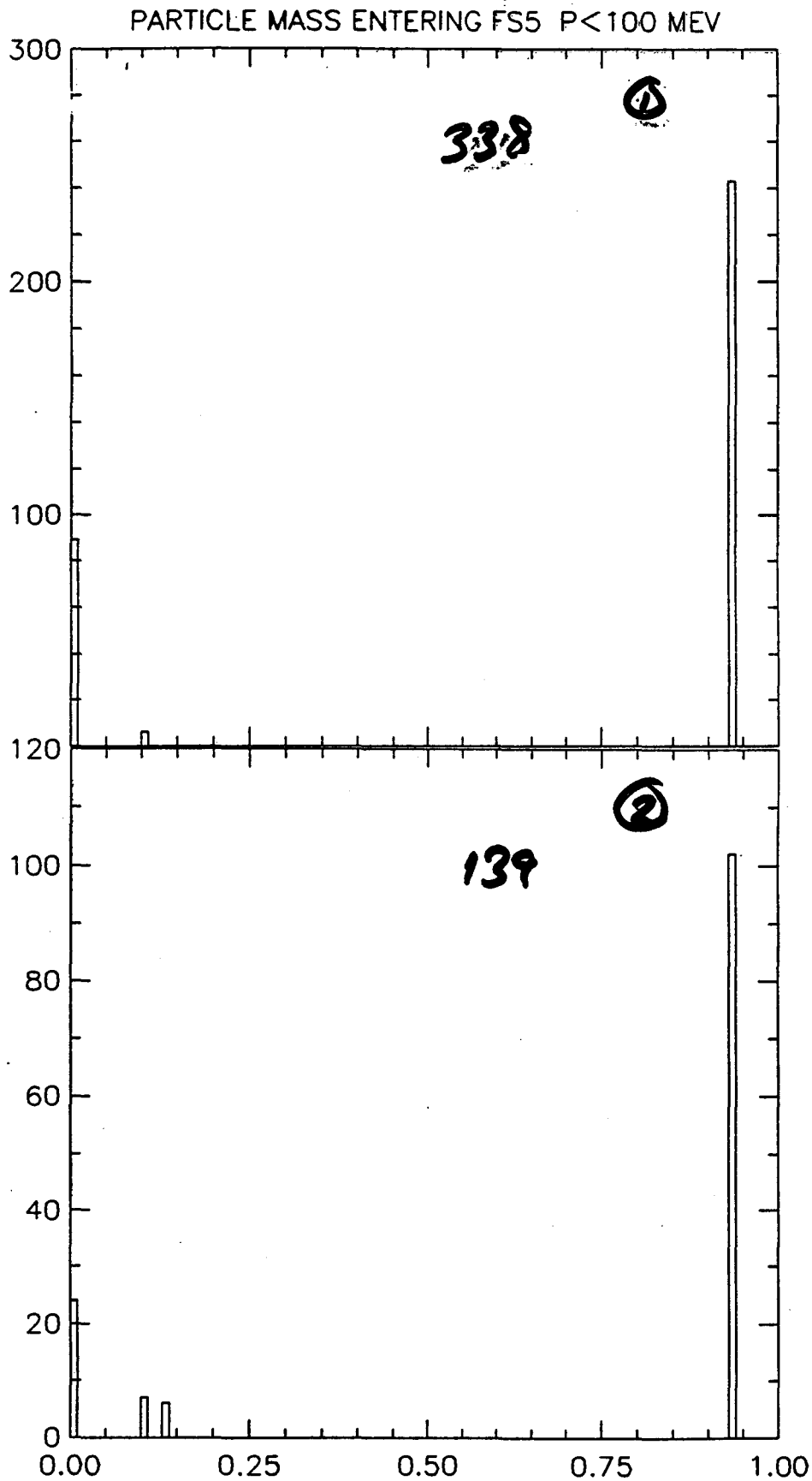

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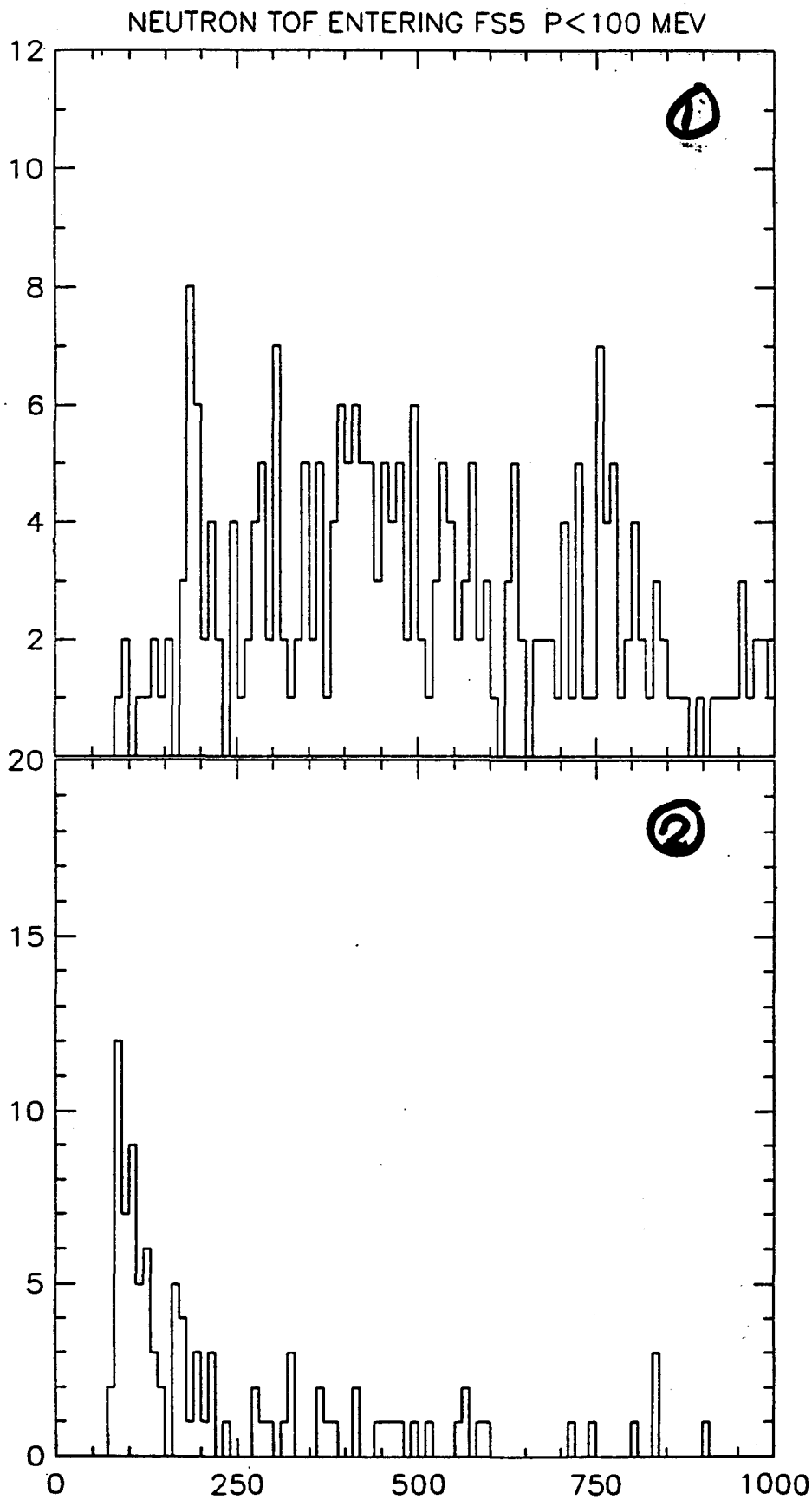
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60	0	1	930114/2008	242.0	501.1	228.9