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PHYSICS AT E0 FOR THE 1991-92 COLLIDER RUN, a proposal

Spokesperson:

Jay Orear

Cornell University

Introduction

Some of the experimenters of E710 along with some others would like to do some new physics at E0 using a new generation of detector at the E0 pot positions. The E710 data analysis is now far enough along to show that it has achieved the goals stated in its proposal. Significant rises in σ_t, B, and especially σ_{el} have been measured independent of luminosity.[1,2,3,4] As stated in its proposal, the E710 detector design was such that it could not measure ρ at the full energy of $\sqrt{s}$= 1.8 TeV. (This is further demonstrated in Section I of Appendix I.) However, E710 had runs at $\sqrt{s}$ = 546 and 1000 GeV which will soon give determinations of ρ more accurate than that of UA4.

If one accepts the UA4 value of ρ, it appears to be rising much faster than σ_t. Both UA4 and E710 have confirmed that σ_{el} is rising significantly faster than σ_t. E710 has found that the slope parameter B no longer decreases with increasing angle, at least up to $-t\sim 0.5$ GeV^2. The only way to resolve these mysteries is to measure ρ at the full energy and $d\sigma/dt$ at larger angles. Our goals are threefold: (1)to do some new physics which was not obtainable in the last run, (2) to develop and fully test a new-generation small angle detector

for the LHC and SSC, and (3) to give an accurate and reliable calibration of the Tevatron luminosity.

Goals

1. An accurate measurement of ρ at $\sqrt{s}$ = 1.8 TeV.

2. A luminosity independent accurate measurement of σ_t at $\sqrt{s}$ = 1.8 TeV. (Our new detector will have adequate resolution and acceptance to measure $d\sigma/dt$ in the "pure" coulomb region. See Appendix I.)

3. Large angle $d\sigma/dt$ in the region $0.4 < -t < 3$ GeV^2 (using collisions at B0).

4. Single diffractive (using collisions at D0 and D0 detector).

5. To develop a detector and the technology for doing the same physics at the SSC and LHC. (The best test of a new detector is to do some new physics with it.)

6. To improve the present Tevatron collider luminosity calibrations by an order of magnitude.

Equipment

Everything would be the same as in E710 except that the drift chambers in the pots would be replaced by scintillating fiber detectors using CCD readout. In the design of E710 we estimated on the basis of ISR results and predicted emittance that our detector could not get closer than ~5 mm from the beam and that a resolution ~1 mm would be adequate; in fact we stated in the proposal that we could not get into the coulomb region at the full energy. But, in the running of E710, after proper scraping, we found a factor ~5 improvement in emittance and we learned that high resolution detectors would work

closer than 2 mm from the beam. We measured that the emittance spread at the detector after scraping was 0.3 mm or less rather than 1.2 mm. The observed time constant for emittance growth was significantly more than 1 hour. These new conditions along with a newly designed detector will make possible the measurement of ρ at $\sqrt{s}$ = 1.8 TeV. (See Section II of Appendix I.) So we now have underway the design and construction of a scintillating fiber detector with 0.2 mm diameter fibers.

Some of the early concepts of this new detector were developed at the 1988 Berkeley SSC Summer Workshop with the help of Riccardo DeSalvo.[5] See Figure in Appendix II. At present we have a group of about 3 physicists working on this at CERN under the direct supervision of DeSalvo. Most of the components such as SCIFI bundles, fiber optic "cables" and windows, image intensifier stages, ccd's, ccd readout software and hardware will be produced by private firms such as Kyowa Gas, Hamamatsu, Datacube, DEP, Phillips, and Thompson. We have access to CERN facilities such as an aluminum sputtering rig, the ccd readout and encoding system, test beams, vacuum testing rig, etc. CERN also regards this effort as part of their development program of a small angle detector system for the LHC.

The new detectors are designed to "hang" in the vacuum from the end plates of the existing roman pots. The E710 cables, electronics, computers, and trailers are still in place and would be reused. Some of the exisiting ring counters would be reused.

Resources and Manpower

The SCIFI detectors are now being designed and constructed and will be tested in test beams and hard vacuum at CERN by Rosy

Mondardini and Cinzia Davia under the supervision of Riccardo DeSalvo, Tiziano Camporesi and Jay Orear. Our initial group of collaborators are from CERN, Cornell University, Fermilab, and the University of Bologna. The present spokesperson is Jay Orear of the Cornell University users group.

Beam Requirements

The 900 GeV running for σ_t and ρ will require special scraping and running with the separators off. The previous running conditions would be very adequate. The ccd's are limited to a master trigger rate ~ 60 Hz which is comparable to our tape writing speed. Our goal is to obtain several hundred thousand elastic events. This will only take a few hours of running. It would be useful for other experiments to at least turn on their luminosity monitors during our several hour "dedicated" run, since we would be measuring E0 luminosity in an accurate way independent of the usual uncertainties. A comfortable luminosity for this dedicated run is $\sim 10^{28}$ $cm^{-2}s^{-1}$ at E0.

The large-angle elastic and single-diffractive data collection will be purely parasitic and will not affect the running at B0 and D0. The scheme for parasitic running was studied at the Breckenridge workshop. The relevant part of the Breckenridge report is quoted in Appendix II. Norman Amos of the D0 group would act as liason between the D0 group and our group. Stan Pruss and Norman Gelfand will provide accelerator liason.

Footnotes:

1. Amos, et al, Phys. Rev. Letters 61, 525 (1988).

2. Amos, et al, Phys. Rev. Letters 63, 2784 (1989).

3. Amos, et al, *A luminosity independent measurement of the $\bar{p}p$ total cross section at $\sqrt{s}$= 1.8 TeV*, submitted to Physics Letters.

4. Amos, et al, *Measurement of large angle $\bar{p}p$ elastic scattering at $\sqrt{s}$= 1.8 TeV*, submitted to Physics Letters.

5. Goulianos, et al, *Low p_t physics at the SSC*, p. 828, "Experiments, detectors and experimental areas for the supercollider", World Scientific Publishing Co. 1988, ISBN 9971-5-473-1.

Appendix I

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J. Orear

CAN WE GET ρ FROM EXISTING DATA AT 900 GEV?
and
CAN WE GET ρ FROM NEW DETECTORS AT 900 GEV?

Section I: The Present Detectors

In the low-t running at 900 GeV we did get our pots close enough to the beam to see elastic scatters in the region where the coulomb amplitude equals the nuclear amplitude. Unfortunately the solid angle at low-t was small because t is increasing fast with x as well as y and the x region is limited at small y. In this memo I shall do a statistical analysis showing that we can get only an upper limit on ρ. We might be able to get a luminosity independent σ_t based on coulomb normalization, but it would be no better than what we have already obtained. In Section II I shall show that a scintillating fiber (SCIFI) detector should be able to get good determinations of ρ and σ_t. In Sect. I I shall make the following rather optimistic assumptions: there is no error to the background subtraction and we can get data with adequate t-resolution in the low-t bins with little loss correction. Shekhar points out that this assumption is overly optimistic because on some wires our scale factor is 1 mm/bit. It is never better than 0.5mm/bit. I also assume we know the beam center in x for each wire. But it might be off by ~1 bit or ~ 1mm. In some regions of my bins 1, 2, and 3 the separation in x is only ~0.4 mm which is smaller than our least count. But I feel that if we cannot determine ρ with these optimistic assumptions, then we certainly cannot measure ρ if the true situation is even worse; i.e., there is no way we can do better with the existing data.[1] In my calculation I use true $\rho = 0.1$, $(L_{eff})_y = 80$ m and $(L_{eff})_x = 40$ m. The bins I use are shown in Fig. 1 and tabulated in Table I. I use true $\sigma_t = 80$ mb. The differential cross section is

$$\left(\frac{d\sigma}{dt}\right)_j = .0513\ \left\{\sigma_t^2(1+\rho^2) + \frac{.1424\rho\ \sigma_t}{t_j} + \frac{5.07\times10^{-3}}{t_j^2}\right\}\ \mathrm{mb/GeV^2} \equiv F_j(\rho,\sigma_t)$$

where σ_t is in mb and t is in GeV^2. In order to simplify the calculation, I have used $\exp(-Bt) = 1$ in this low t region. (This is OK as long as we have an independent sufficiently accurate

determination of B which is the case.) The expected number of events in the jth bin is

$\bar{N}_j = L\left[\frac{d\sigma}{dt}\right]_j A_j$ where $L = 4.5\times10^{30}\ \mathrm{cm}^{-2}$ is the integrated luminosity and $A = \Delta t_j\ \Delta\Phi_j/2\pi$. (This value of L gives 40,000 elastics in the region $.01 < t < .09\ \mathrm{GeV}^2$ as in our data.) These events are given statistical fluctuations of $\sqrt{N_j}$ and the least squares sum S is evaluated as a function of L, ρ and σ_t:

$$S = \sum_j \left[\frac{L\ F_j A_j - \bar{N}_j}{\sqrt{N_j}}\right]^2 \qquad \text{(Eq. 1)}$$

The solution for the ρ, σ_t, and L which minimize S corresponds closely to the starting values giving $S^* = 9.5$. Then I found the 3D "ellipsoid" corresponding to $S(L,\rho,\sigma) = S^*+1$. As might be expected, the errors in L and σ_t are highly correlated. The correlations are properly taken into account if one finds the extreme excursions the surface makes along the ρ-axis.[2] They are $0.05 < \rho < 0.19$. The one standard deviation determination on σ_t was $74 < \sigma_t < 87$ mb or $\sigma_t = 80.5 \pm 6.5$. This is without using any information on the accelerator measurement of L. If we have such information using our calibrated monitor, then a term $(L-L^*)^2/\Delta L^2$ should be added to Eq. 1 where L^* is the measured value of L with error ΔL. But in this analysis I did not include such a term -- I wanted to see what coulomb amplitude normalization would do for us all by itself. By coincidence it also gave us a 8% error.

So I conclude that if the true $\rho=0.1$, we can only say that $\rho<0.2$ and that we cannot use coulomb normalization by itself to improve our measurement of σ_t. The situation is probably worse than this because of error in background subtraction and because of Footnote 1. It is still worth analysing our 900 GeV low-t data in order to make these checks, but as I have just shown, we will not get any new results out of it except for a crude upper limit on ρ.

Section II: New Detectors

In order to measure ρ at 900 GeV and to get an accurate, reliable

measurement of σ_t using coulomb normalization, we need detectors with resolution better than 300μ in both x and y. (300μ is the measured "emittance limit" at our detector position after scraping.) In the last run we have discovered how to get detectors within 2.2 mm of the beam, but then there is some bothersome halo-halo background. With the present drift chamber detectors, halo particles with y< 3 mm and x within 2 mm of beam center all end up in the same bin. But if we had an x-resolution ten times better, we could perhaps reduce this background by an order of magnitude. A detector using a bundle of 200μ diameter scintillating fibers should be able to meet these conditions. This memo will not deal with construction and performance details. In this memo we assume the background free bins shown in Fig. 2 and Table II. We shall repeat the above least squares analysis assuming a total of 100K elastics in these bins (this corresponds to an integrated luminosity of $L=4.5\times10^{31}$ cm^{-2}). My least squares solutions to the simulated data in Table II is $\rho = 0.090\pm0.022$ and $\sigma_t = 79.9\pm1.1$ mb starting with " true" values $\rho=0.1$ and $\sigma_t = 80$ mb. The total cross section is obtained only from coulomb normalization.

Note in Fig. 2 that bin 1 and part of bin 2 gets closer than 2 mm from the beam. I am guessing that we can get our detector edge 1.75 mm from the beam. However, we know from the last run that we can at least get to ≈2 mm from the beam. I have repeated the analysis for this more pessimistic assumption; i.e., bin 1 and half of bin 2 are eliminated. Then my solution is $\rho = 0.093\pm .035$ and $\sigma_t = 79.9\pm2.1$ mb. Even in this pessimistic case we get a ρ-value more accurate than UA4 and a luminosity independent measure of σ_t of about 2%.

<u>Footnotes:</u>

1. Shekhar also points out that the charge division smearing in x is so bad that to be safe one should do an x-independent analysis. I have not yet done this, but it will give larger errors on ρ and σ_t than what I have obtained.

2. J. Orear, "Notes on Statisics for Physicists", page 46, Cornell

preprint CLNS 82-511. (I do have a proof.)

Table I: Bins for existing detector in low-t runs.

bin no.	t_j (GeV²)	A_j (GeV²)	$\bar{N}_j$
1	1.36×10^{-3}	$.889\times10^{-4}$	220
2	1.79	1.12	209
3	2.25	3.57	659
4	3.82	4.59	726
5	5.3	5.18	1010
6	7.2	7.4	1114
7	9.1	8.79	1386
8	11.4	10.1	1500
9	18.7	51.3	7832
10	37.4	80.2	11915

Table II: Bins for proposed detector.

bin no.	t_j	A_j	$\bar{N}_j$
1	$.445\times10^{-3}$	$.317\times10^{-4}$	2584
2	.641	.665	3103
3	.957	1.08	3345
4	1.34	1.48	3405
5	1.78	1.72	3514
6	2.55	5.62	9870
7	3.82	6.55	10854
8	5.3	8.02	12587
9	7.2	9.13	14282
10	9.1	10.4	15840
11	11.4	11.6	17814

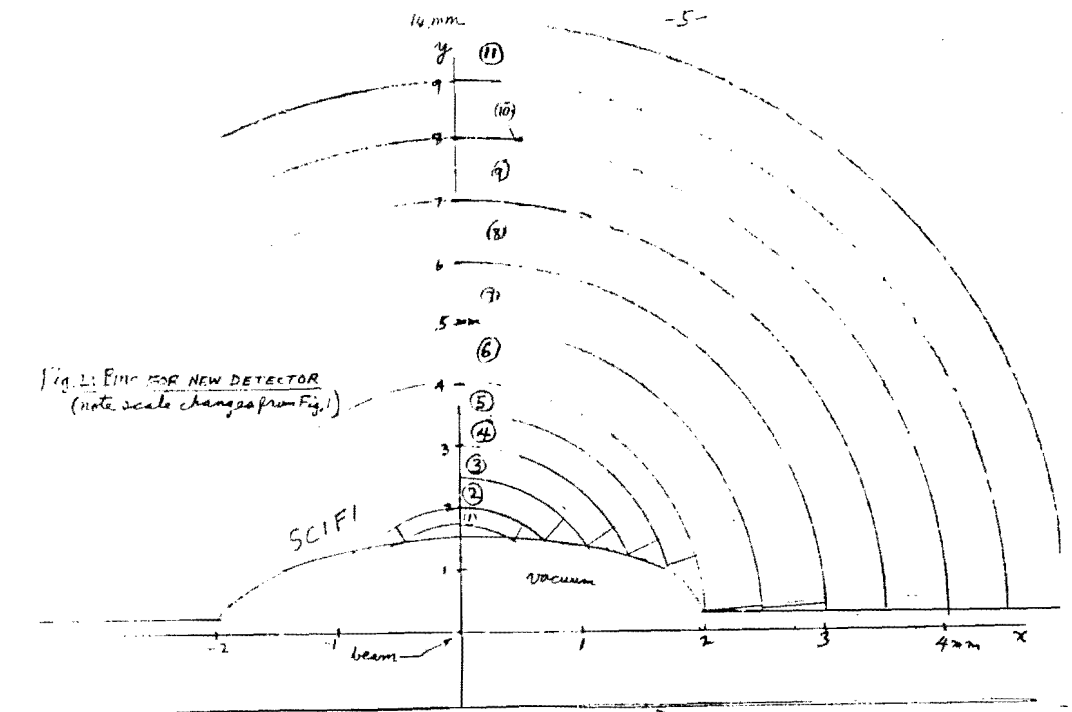


Fig. 2: Bins for new detector (note scale changes from Fig. 1)

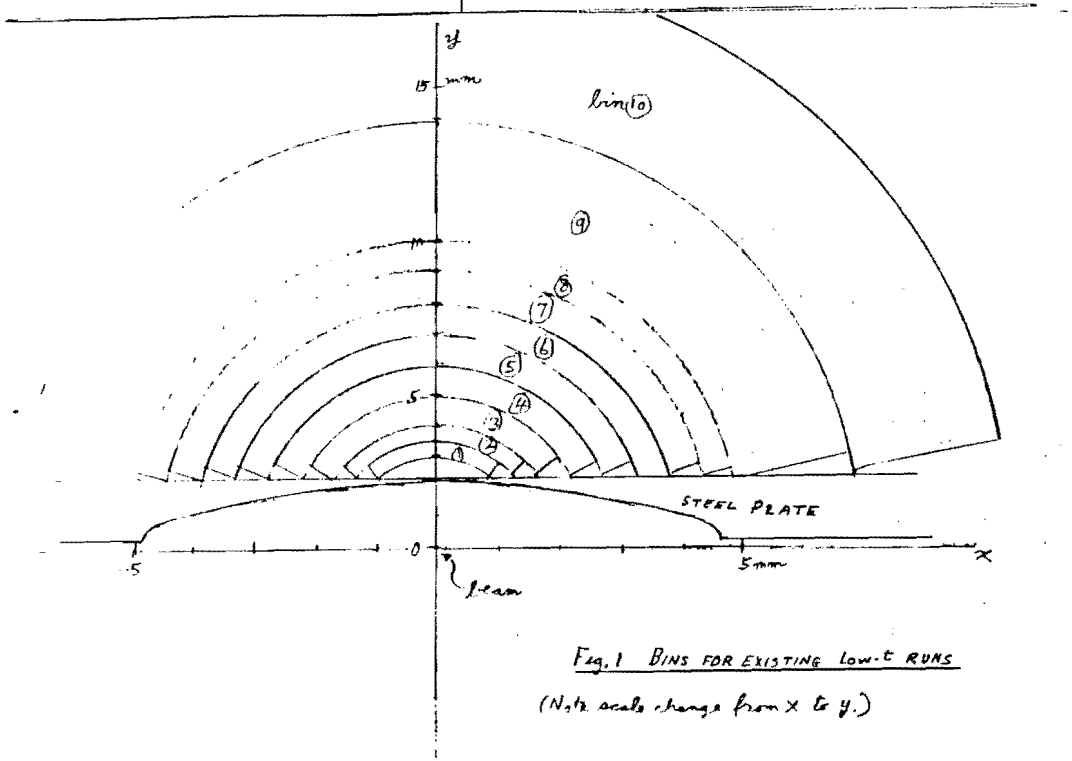


Fig. 1 Bins for existing low-t runs

(Note scale change from x to y.)

Appendix II

Submitted to Proceedings of Breckenridge 1989 Summer Workshop:
Jay Orear
Sept. 28, 1989

ELASTIC AND SINGLE DIFFRACTIVE SCATTERING

Sections 1 and 2 deal with small and large angle elastic scattering using detectors at E0. An accurate luminosity-independent determination of σ_t and ρ would be made. Section 3 treats single diffractive scattering using detectors at D0 and E0.

1. Small angle elastic (σ_t and ρ-value)

If the elastically scattered proton and antiproton can be detected at very small angles (in the coulomb region), the luminosity and total cross section can be determined to within 1 or 2%. The ρ-value is determined by the amount of coulomb interference. E710 in the last run was not quite able to reach the coulomb region because of detector wall thickness and resolution. An improved detector with zero wall thickness and order of magnitude improvement in resolution is now in the design and prototype construction stage. As shown in Fig. 1 , it would use a scintillating fiber bundle attached to the existing Roman Pots in the E0 region. The fibers would be oriented parallel to the beam. A short run under high beta with special beam scraping would be needed. The conditions used by E710 in the last run would be adequate. Not only would the new detectors give accurate values for σ_t and ρ, but they would give an accurate and independent calibration of luminosity. About one day of running using the fixed target lattice would be needed. At the same time B0 and D0 could run under interesting high beta conditions.

2. Large angle elastic scattering

The SCIFI detectors of Fig. 1 could be used in a parasitic mode under normal low beta running conditions when the beams are separated

at E0. For large angle elastic scattering at B0 or D0 both the scattered proton and antiproton will be seen in some of the E0 detectors. There are two inner detectors (at ends of the long straight section) and two outer detectors "buried" in the lattice. From B0 to the left-outer detector the vertical L-effective is 6.59 m. Assuming the detector can get within 4 mm of the beam (in E710 the old detectors could operate as close as 2.2 mm from the beam), the minimum scattering angle would be 4 mm/6.59 m = 0.6 mrad or t_{min}= 0.3 GeV^2. The antiproton would encounter the right-outer detector with L_y= -6.57 m. If the fiber bundle is 15 mm thick, t_{max}= 6.8 GeV^2.

For elastics from D0 the situation is similar except that the L-effectives are about 20% shorter. The difference in arrival time would be 2/3 of the circumference. Electronic delay could be used on the trigger.

3. Single diffractive scattering

The scattered proton from single diffractive scattering at B0 or D0 can make it to the E0 detectors in an interesting region of t and M^2. ($0<-t< 4$ GeV^2 and $1.4< M < 150$ GeV .) In order to be well within the diffraction peak it would be necessary to rotate the Roman Pots from the vertical to the horizontal.

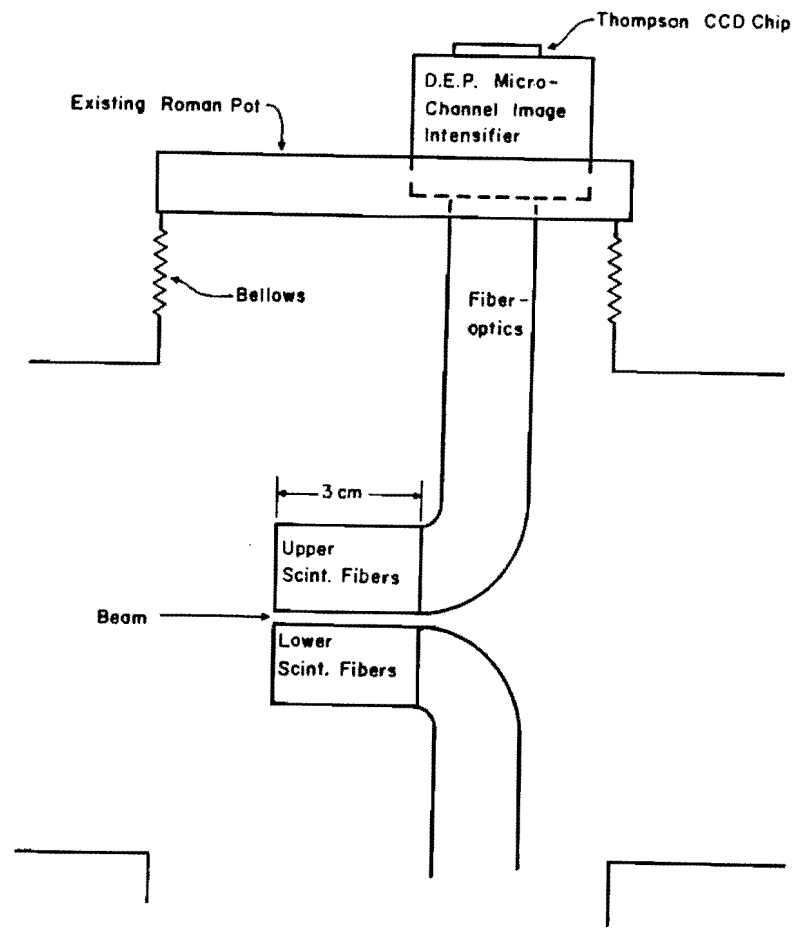
In principle both the scattering angle and momentum (or t and M) can be determined from two sets of (x,y) measurements; i.e., two detectors near E0). In order to reduce possible background a third detector would provide two more over-determinations. In the last run E710 did a two detector short run on single diffractives and found a strong, clean signal.

Even though scatterings corresponding to low M would be seen in the detectors, only values of M greater than 10 GeV could be resolved. This is because $\Delta p/p$ due to measuring resolution and beam momentum spread is $\sim 2\times10^{-5}$.

It is of great interest to see the entire event -- the M-decay as well as the scattered hadron. The "4π" detector of D0 which gets to higher rapidity might be well-suited for this. Some fraction of

their triggers will be random. Of these ~10% will send diffractively scattered protons into the E0 detectors. At E0 only those bunches selected by D0 for "random" triggers would be looked at.

Depending on the polarity of the electrostatic separators, the antiproton beam could be at smaller x than the proton beam at the E0 detectors. This would prevent the E0 pots from getting close enough to the proton beam. Since the polarity of the separator system is arbitrary, one choses the polarity which puts the antiproton beam on the far side.



Modification of Roman Pots for Tevatron