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PROPOSAL TO MEASURE LARGE ANGLE π-p ELASTIC SCATTERING

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1. Introduction

With a straight forward modification of our E-290 equipment in the M6 beam line, we will be able to make a significant measurement of large angle scattering of pions, kaons and antiprotons on hydrogen at 200 GeV/c. Previous large angle data from Fermilab[1] (E-7) extend only to $-t \simeq 2$ for pions. We will be able to measure cross sections several decades below those of E-7, making this an appropriate second generation experiment. We expect to reach cross sections of $\sim 10^{-34}$ cm^2/(GeV/c)^2, which should correspond to $|t|$ values of greater than 5 (GeV/c)^2.

2. Layout

In Fig. 1 we show our proposed layout. The major change from E-290 is to move the large aperture magnet and detectors from backward to forward angles.

We propose to take data on three incident particle types simultaneously, using the existing Cerenkov counters in the M6 beam to tag the incoming particles. For additional particle identification, we will tag the scattered particles with two threshold Cerenkov counters.

3. Event Rate

Our event rate is calculated using the following assumptions:

(i) We use our current 1 meter hydrogen target (appropriately modified for this geometry).

(ii) A beam intensity of $\sim 3 \times 10^6$ pions/accelerator cycle; we hope to use more π^- than this, but possibly less π^+ due to the protons in the incident beam.

(iii) We propose to run 350 hours at each polarity.

(iv) The experiment uses proportional chambers, and a "tight" triggering scheme, which should give little readout dead time.

A target length of 1 meter gives the number of target protons $N_p = 4.2 \times 10^{24}$ cm^{-2}.

With 3×10^6 pion/pulse, 12 second repetition rate and 350 hours, total number of pions = $N_\pi = 3.2 \times 10^{11}$.

The number of counts N_B in a bin Δt $(\mathrm{GeV}/c)^2$ wide, with azimuthal acceptance $\Delta\phi/2\pi$, for a cross section $\frac{d\sigma}{dt}$ cm$^2/(\mathrm{GeV}/c)^2$ is

$$N_B = N_\pi N_p \frac{d\sigma}{dt} \Delta t \frac{\Delta\phi}{2\pi}$$

For $\Delta t = 1$ $(\mathrm{GeV}/c)^2$ and our typical $\Delta\phi/2\pi$ of 0.05, we expect 7 events for a cross section of 10^{-34} cm$^2/(\mathrm{GeV}/c)^2$.

4. Background

(i) We will have momentum analysis on both outgoing particles, with $\Delta p/p$ varying from under $\pm 1\%$ at $t = -2.5$ to $\pm 4\%$ at $t = -6$ in the recoil arm; E-7 momentum analyzed only the forward particle. This gives us another constraint in the analysis. In addition it reduces the number of particles hitting the recoil arm trigger counters and causing false triggers.

(ii) Our trigger is very selective. In the forward arm, coincidences are made between a counter in hodoscope α and a corresponding counter in hodoscope β, cutting down the momentum acceptance for triggers in this arm. An appropriate matrix of coincidences is made between the forward (α, β) hodoscopes and the recoil hodoscope to trigger preferentially on elastic events.

Predicting inelastic background in such two-arm spectrometer elastic scattering experiments is notoriously difficult. Processes that could cause such background, such as $\pi p \rightarrow \pi p \pi^{0}$, must be at an extreme of their phase space if they are to simulate elastic scattering within the experimental resolution. Estimating such extremely low probability configurations is difficult. Experience at the AGS[2,3,4] has shown that the restrictive trigger system described above does help to lower background.

A better way of estimating backgrounds for this experiment is by comparison with similar experiments. E-177 (J. Orear) is measuring pp elastic scattering to larger values of t and smaller cross sections than we are proposing. In our range,

πp and pp elastic scattering cross sections should be approximately the same, based on preliminary results from E-177 and assuming 200 GeV πp data continue to be similar to 23 GeV data. There is no reason to believe that inelastic scattering should be very different in the two interactions. The experimental arrangement of E-177 is similar to ours, with two magnetic spectrometers. They have somewhat higher bending power, but a looser trigger and no chambers in front of their magnets. Even out to $-t$ of 10 $(\mathrm{GeV}/c)^2$, with $d\sigma/dt$ 10^{-36} $\mathrm{cm}^2/(\mathrm{GeV}/c)^2$ nowhere is their background more than ~5% of the elastic signal.[5] Based on this, we believe that we should not have background problems over the range of our experiment.

5. <u>Comparison with Previous Data</u>

Figure 2 shows existing data at 23[2] and 200[1] GeV/c for $\pi^- p$ elastic scattering; our expected sensitivity at 200 GeV/c ($\sim 10^{-34}$ $\mathrm{cm}^2/(\mathrm{GeV}/c)^2$) is a decade below the data shown. If the differential cross section at 200 GeV/c is similar to that at 23 GeV/c, we should be able to measure considerably beyond $-t$ $\simeq$ 5 for $\pi^- p$. For kaons and antiprotons, we would expect to measure to $-t \simeq 2.5$, appreciably further than present data.

6. <u>Physics</u>

There exist many models for high energy, large angle proton-proton elastic scattering, stimulated by the existence of data from the ISR. Examples are constituent scattering models,[6] eikonal models,[7] quark-glue hadron models,[8] pomeron models,[9] and many others, all of which fit the data to a limited extent. In addition there are several parametrizations of the data.[10,11]

There has been much less theoretical work on large angle meson-proton elastic scattering, possibly because of the absence of comparable data. However, many of the models for proton-proton scattering could be modified for the meson-proton [redacted] case; it is to be hoped that meson-proton experimental data will be useful in differentiating between the models. Among specific predictions are that large angle meson-proton scattering will be less energy dependent than proton-proton scattering,[12] and that new dips will appear in the angular distribution.[13]

Aside from comparisons with detailed theoretical models, there are a number of empirical questions that can be answered by the data.

(i) Do new diffraction-type phenomena appear at high energies? In pp elastic scattering, the $-t = 1.4$ dip is not present at 100 GeV/c, but appears in 200 GeV/c data.[1] Does similar behavior occur in the meson-proton case?

(ii) The $\pi^- p$ data at 23 GeV/c has an (unexplained) abrupt change of slope at $-t = 3$; is this still present at 200 GeV/c? (We observe also in large angle pp scattering at ISR energies that the slope at $-t \simeq 5$ is appreciably less than at smaller $|t|$ values).

(iii) All measured K and π meson-proton cross sections appear to be equal around $-t = 1$ with no momentum dependence between 14 and 200 GeV/c[1,3] - see Fig. 3. This says that all meson-proton collisions behave similarly at small impact parameters, whereas they do not do so at large impact parameters (near t $\simeq$ 0). Is this equality fortuitous, or does it continue to be true at even larger values of -t?

7. Equipment Required from Fermilab
(in addition to that currently used by E-290)

(i) The 72D18 magnet needs to be moved to its new position; extra power cable and possible power supply rearrangement will be needed to give the required current.

(ii) Some small modifications to PWC's and their stands will be required to fit the geometry of this experiment.

(iii) We will need an additional threshold Cerenkov counter; this will be essentially a duplicate of our existing counter (~$25K), except for a 50' instead of a 30' vessel.

(iv) A modest amount of additional PREP equipment will be needed in order to take data on the three incident particle types simultaneously.

(v) We will need some modification of the E-290 hydrogen target vacuum vessel because of the geometry of this experiment.

8. Running Time

We will need 700 hours of running time to make measurements for both beam polarities to the accuracy noted earlier; we will be able to take this data shortly after completion of E-290. In addition, 100 hours of additional set-up time would be required.

REFERENCES

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FIGURE 1A. TARGET AREA

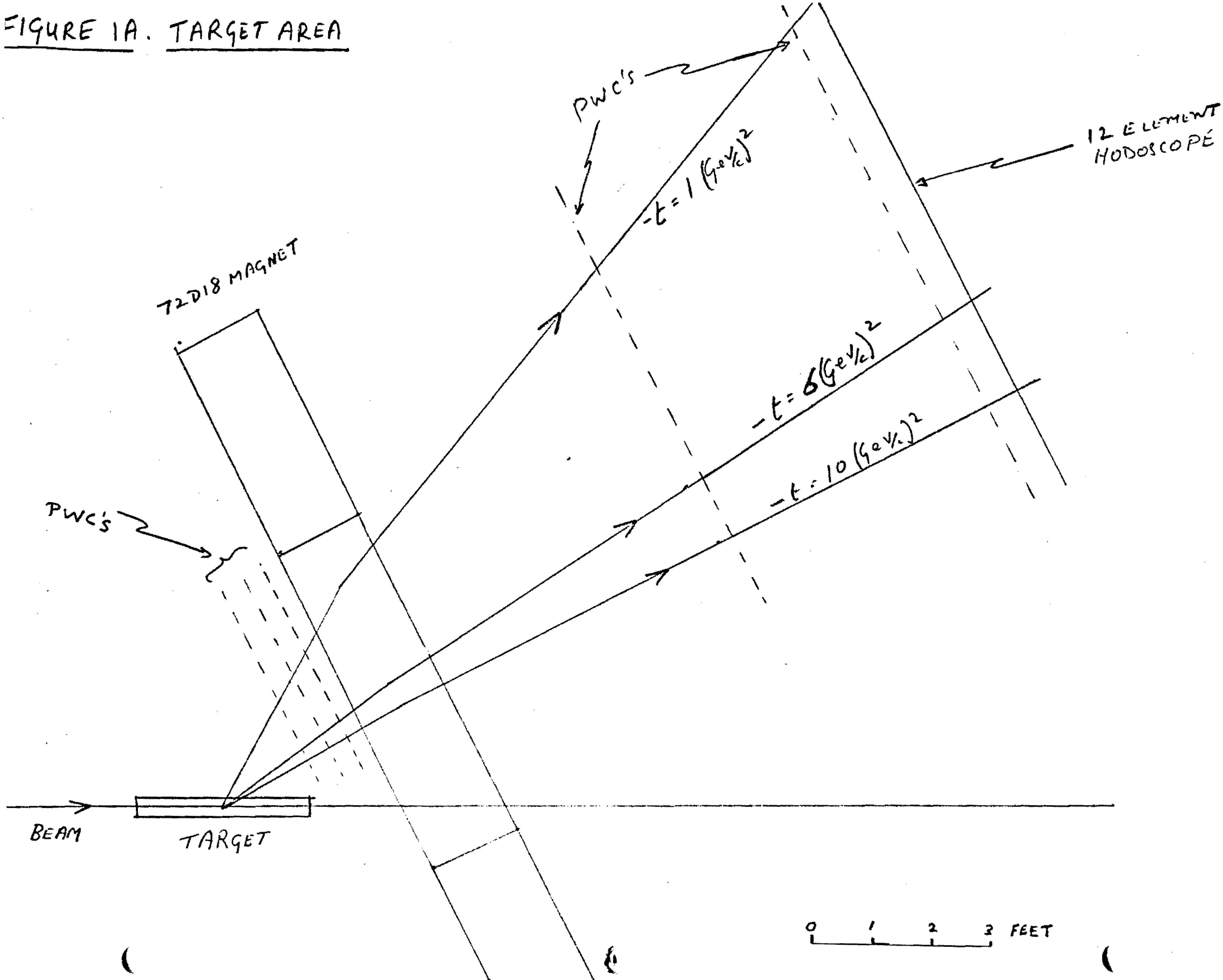
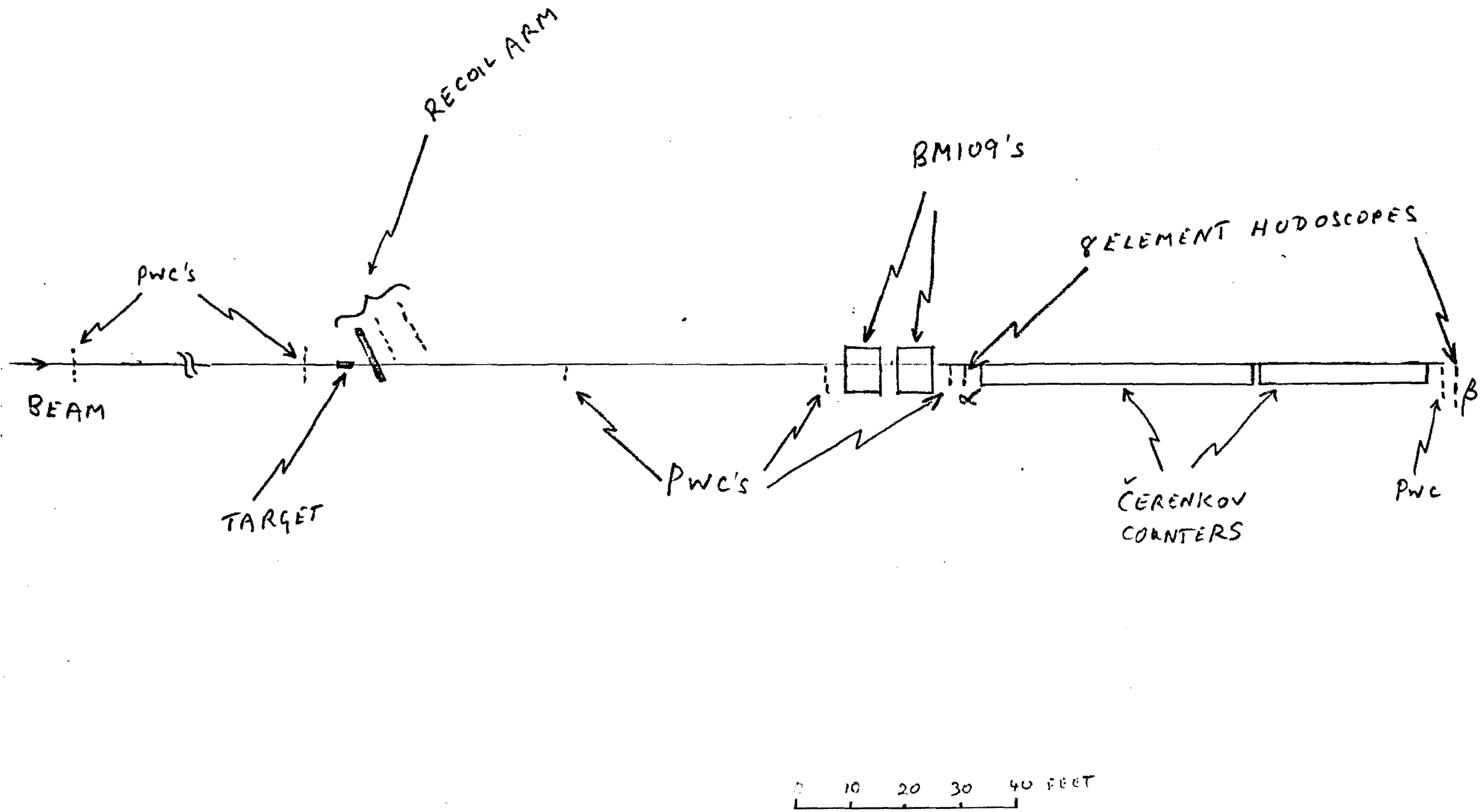
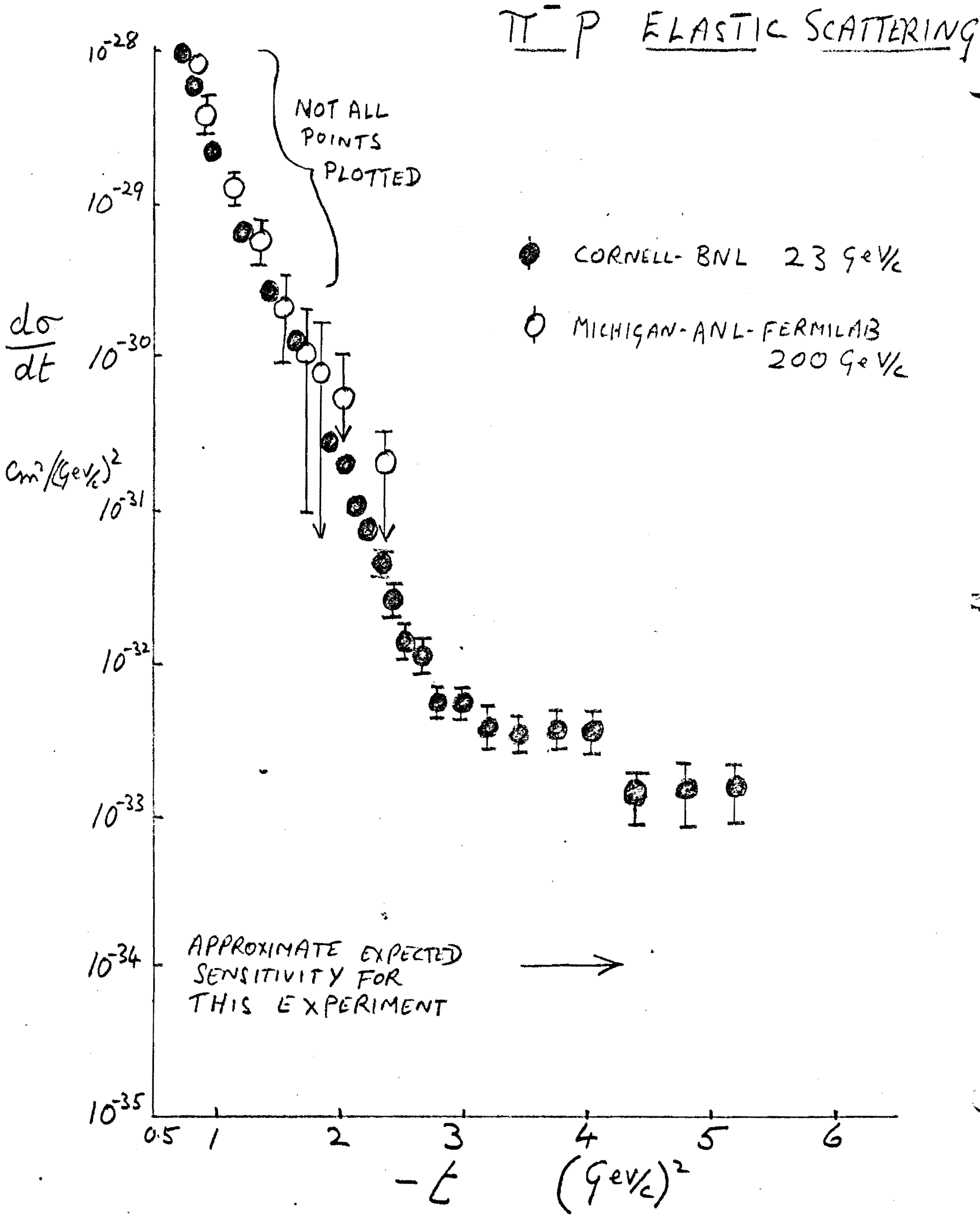


FIGURE 1B

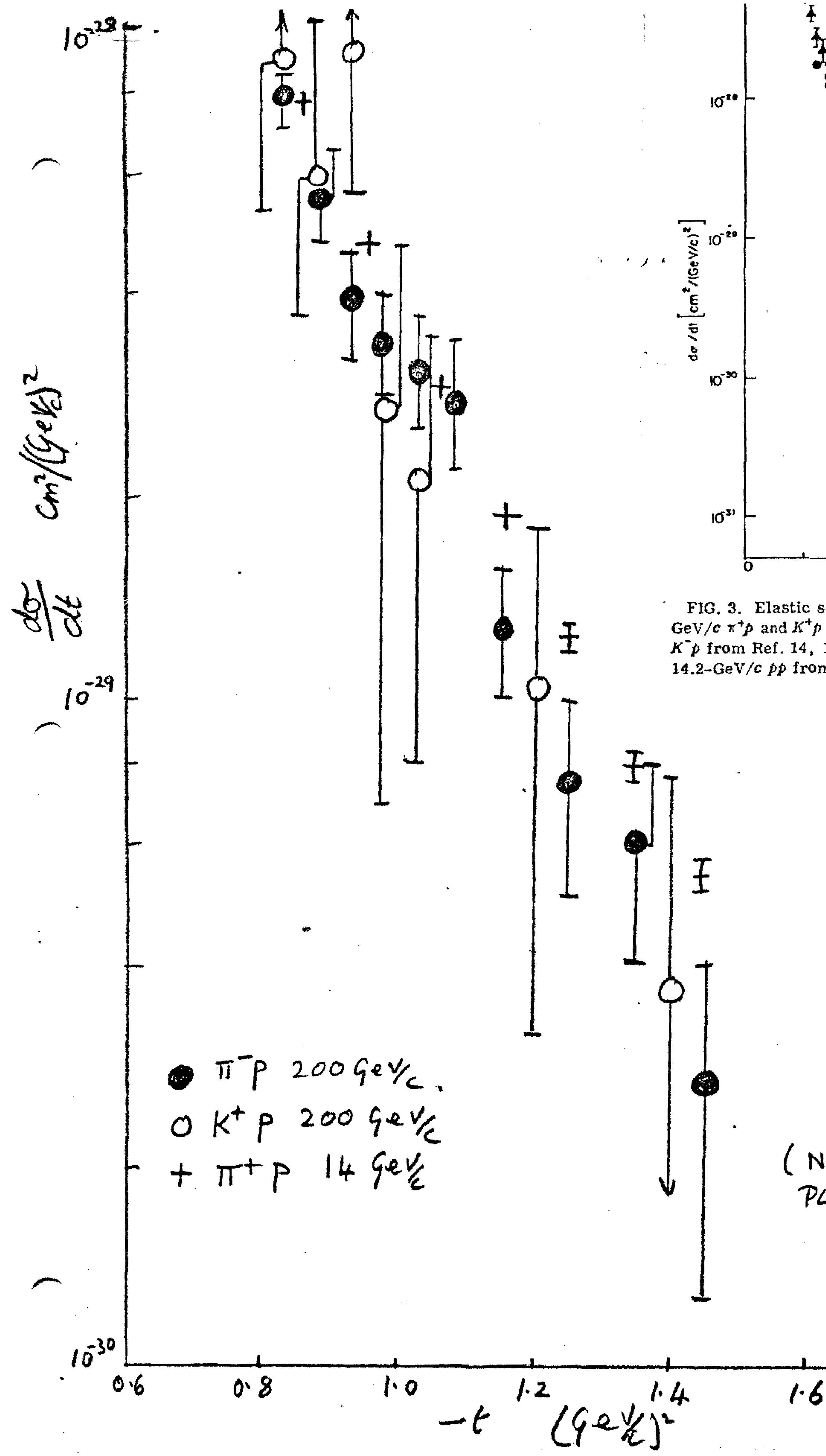


RECOIL ARM
BM109's
8 ELEMENT HODOSCOPES
PWC's
BEAM
TARGET
PWC's
α
β
ČERENKOV COUNTERS
PWC
0 10 20 30 40 FEET

FIGURE 2



π⁻P ELASTIC SCATTERING
NOT ALL POINTS PLOTTED
CORNELL-BNL 23 GeV/c
MICHIGAN-ANL-FERMILAB 200 GeV/c
dσ/dt
cm²/(GeV/c)²
10⁻²⁸
10⁻²⁹
10⁻³⁰
10⁻³¹
10⁻³²
10⁻³³
10⁻³⁴
10⁻³⁵
APPROXIMATE EXPECTED SENSITIVITY FOR THIS EXPERIMENT
0.5
1
2
3
4
5
6
-t (GeV/c)²



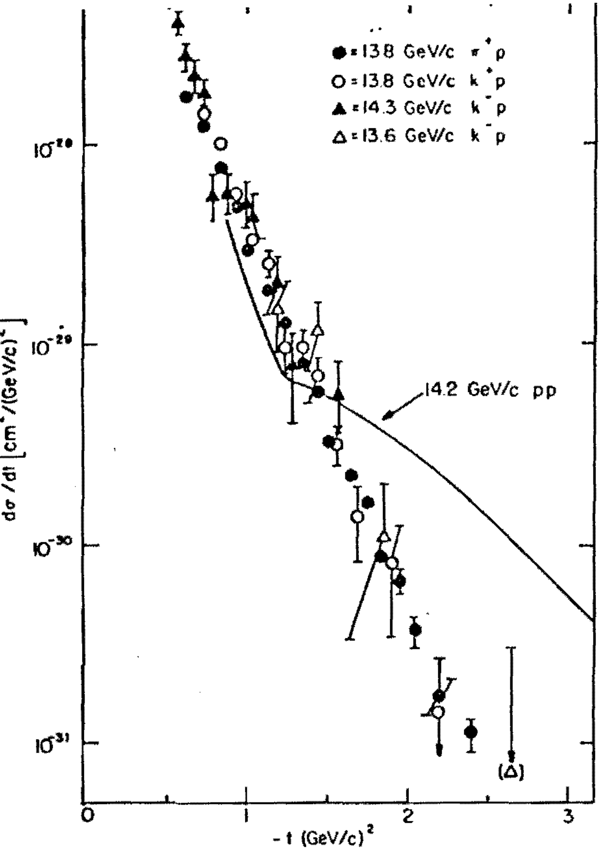


FIG. 3. Elastic scattering near 14 GeV/*c*: 13.8-GeV/*c* π^+p and K^+p from this experiment, 13.6-GeV/*c* K^-p from Ref. 14, 14.3-GeV/*c* K^-p from Ref. 15, and 14.2-GeV/*c* *pp* from Ref. 8.

FIGURE 3

(NOT ALL PARTICLES PLOTTED, FOR CLARITY)