PROPOSAL TO STUDY HIGH MOMENTUM TRANSFER Λ^o, $\overline{\Lambda}^o$ AND HADRON JETS

submitted by

K. Abe, S. Erhan, W. Lockman, M. Medinnis
P. Schlein and J. Zweizig
University of California, Los Angeles

Abstract

We propose an experiment to study the detailed structure of high momentum transfer (P_t) multiparticle systems ("jets") at the highest energies and P_t accessible at Fermilab. The apparatus is optimized to perform an inclusive measurement of Λ^o and $\overline{\Lambda}^o$ production and polarization at high P_t. The proposed spectrometer configuration covers a rapidity range of 3.0 and utilizes a 40-ton calorimeter presently being tested in P-West. Two existing multi-celled UCLA Cerenkov counters will be modified and improved. Magnetic measurement will be performed by a new 2 KGauss-meter magnet and an array of fast drift chambers. Operation in the existing low-halo experimental area of the proton-west beam line with an interaction rate of 10^7/spill yields one 8 Gev P_t jet per spill.

Scientific Spokesman:
Peter Schlein
Department of Physics
University of California
Los Angeles, CA 90024

FTS No. 965-3507
Comm. No. (213) 825-3507

13 pp.

I. Introduction

High momentum transfer (P_t) scattering is of great interest as a means of obtaining information about the constituent structure of matter. Considerable progress in this area has been made in the last few years both at Fermilab and at the CERN-ISR. Coplanar jets of hadrons, similar to those observed in lepton-hadron and e^+-e^- collisions, are known to emerge at large angles in the center-of-mass in hadronic interactions. A given high P_t is found to reside in a single particle less than 1% of the time , and there is evidence that the constituents seem to possess a type of Fermi motion within the incident particles.

Still, there are many outstanding questions, of which we list a few:

(a) What is the detailed internal structure of a hadron jet ? What are the $P_{\parallel}$ and P_t distributions of all particles with respect to the jet axis ? How does this depend on particle type ? What are the leading particle effects ? What is the nature of resonance structure within the jet ?

(b) What are the detailed correlations with the particles possessing the P_t in the other hemisphere ?

(c) Will high P_t jets (8 Gev or higher) display an obvious jet structure without the need to do sphericity analyses, as expected at PEP, for example ?

(d) What is the strange particle content of jets ? Strangeness is an obvious tag of a sea-quark. Moreover, $s\bar{s}$ must be produced in pairs. Where does the other strange particle go ? Are they in the same or opposite hemispheres ?

(e) Λ^o are observed to be polarized at Fermilab; the polarization is observed to increase with P_t. Will Λ^o at 5 or 6 Gev P_t be polarized ? What about the $\bar{\Lambda}^o$? Can we learn about the spin dependence of constituent interactions by studying the correlations in $\Lambda^o\bar{\Lambda}^o$ production ?

(f) How do all the above depend on beam particle ?

(g) What is the source of the striking A-dependence of high P_t cross sections observed by Cronin et al.? How do jet properties depend on nuclear A ? Are there heavy nuclear fragments emerging with high P_t when A is large ?

We propose a high rate inclusive hadron jet study, with a particular emphasise on strange particle production, at the highest energies and momentum transfers accessible at Fermilab. Our own experiences in E-260 and in the P-519 tests we are presently carrying out have led us to an optimized design of a spectrometer shown in Figure 1, which is both appropriate and within our physical and financial capability. A later proposal, possibly with additional collaborators, will suggest duplicating the spectrometer on the east side of the beam line. For now, we concentrate on the west spectrometer and on an inclusive measurement of high P_t Λ^o and $\bar{\Lambda}^o$ production. The proposed apparatus has the following ingredients:

(a) trigger calorimeter which has:
   (i) large acceptance in the center-of-mass to see complete jet with plenty of acceptance to spare.
   (ii) good resolution to avoid being swamped by the much more abundant production of systems with P_t lower than desired.
   (iii) sufficient longitudinal and transverse segmentation to distinguish showers from multiple tracks in the calorimeter and to optimize resolution in off-line analysis. (see below)

(b) weak magnetic field (2 Kgauss-meter) in front of and close to calorimeter to complement and calibrate calorimetry.

(c) proximity of magnet and calorimeter in (b) minimized distortion of jet by magnetic field and allows for long (5 m) field-free decay path before chambers for Λ^o, $\bar{\Lambda}^o$, K^o, Ξ^-, Ω^-, etc.

(d) fast, high resolution wire chamber system before and after magnet for track reconstruction has drift time of 120 nsec, allowing us to run with interaction rates of 10^7/spill, or more.

(e) multi-celled Cerenkov counter system with two thresholds. Cerenkov cells match calorimeter cells.

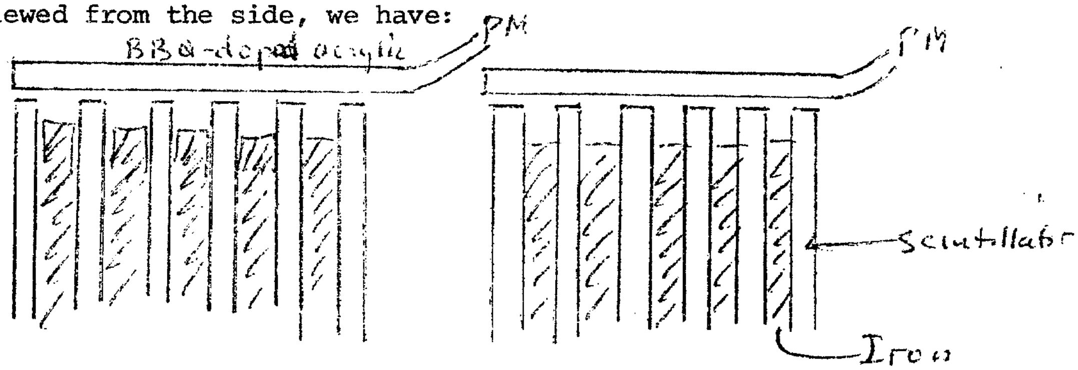
The calorimeter exists and is presently being tested in P-west. The UCLA Cerenkov counters, presently on loan in the M6W beam, will be modified and improved to satisfy present requirements. One segmented Cerenkov counter (20 cells) is in the magnet. A larger multi-celled counter through which the beam pipe passes, occupies the field-free region between target and spectrometer, and will later service both west and east spectrometers.

II. Experimental Apparatus.

(A) Calorimeter: The calorimeter as presently installed in P-West is shown in Figure 2(a). It has 3 m^2 frontal area and in depth consists of 56 steel plates each 3/4 in. thick. Not yet installed are 20 lead plates 1/4 in. thick in the front of the calorimeter. The total weight is 40 tons.

40% of the lateral dimension is presently instrumented with scintillator (224 strips, 8 in. x 60 in.).Fig. 2(b) shows the scintillator as seen from the rear bottom before installation of the phototube-lightguide assemblies. The transverse dimension is divided into four 8 inch wide cells.

A given scintillator cell is read out longitudinally in four 14 plate sections with the use of a BBQ-doped wavelength-shifter panel suggested by Barish (SLAC TN-76-7). Viewed from the side, we have:



Each group of 14 scintillators is read out from both top and bottom. A photograph of the top phototube assembly is shown in Figure 2(c). There are a total of 32 phototubes in the section presently instrumented.

The resolution properties of the apparatus have been thoroughly studied in the P-West secondary test beam. We have studied the lateral and longitudinal containment problems and, in particular, the optimization of the resolution in an off-line analysis program which scales the individual phototube pulse height distributions to minimize σ/mean of the total hadron pulse height distribution. We find a resolution of σ/mean = 13% at E = 20 Gev, compared to 23%, 20% and 15% for E260, U395 and U236 as quoted by G. Fox (Argonne APS meeting preprint) at this energy. Our results correspond to;

$$\frac{\sigma}{\text{mean}} = \frac{0.58}{\sqrt{E}\,(\text{Gev})}$$

for energies less than about 30 Gev. Shown in Figure 3 is this resolution compared with the spectrometer resolution described below.

Figure 4 shows the acceptance of the calorimeter in the center-of-mass $P_{\parallel} - P_t$ plane. It is seen to be substantially larger than either E-260 or E-557.

(B) Magnet and Resolution:

The 1 KGauss magnet shown in the layout drawing of Figure 1 has an aperture of 2 x 1.5 m^2 to match the calorimeter dimensions, and a field length of 2 meters ($\int B\,dl = 2$ KGm). The estimated cost of the steel and coils for this magnet, including coil winding, is $20-25K. The magnet would be assembled in the P-West pit. The resolution attainable with 2 KGm and 1 meter lever arm measurements before and after the magnet using drift chambers with $\delta x \sim 0.15$ mm is shown in Figure 3.

(C) Chambers: High resolution drift chambers are necessary to properly utilize the 2 KGm analyzing power. We have already constructed and tested on-line two 1m x 1m and one 2m x 1m prototype drift chambers and are presently installing them in P-West for the P-519 tests. The large chamber has 1/4 inch drift cells, while the small chambers utilize delay lines for two-dimensional readout and have 1 in. drift cells.

(D) Cerenkov Counters: The two large UCLA multi-celled Cerenkov counters (22-cell and 16-cell, respectively), presently on loan to E110 in the M6W beam will be modified and improved to satisfy the requirements of this proposal. $\check{C}_2$ in Figure 1 will have 20 cells that match the calorimeter cells and will be used on-line, as described below, for triggering on Λ^o and $\overline{\Lambda}^o$. $\check{C}_1$ will provide a second threshold to aid in identifying tracks that come directly from the target.

(E) Beam and Target: Because we are presently testing there, thoughts have naturally been directed towards P-West for locating this experiment. On the other hand, the imminent removal of two pairs of quadrupoles from the P-west pre-target area may make it impossible for us to perform this experiment in that area. We are currently testing the effect of turning off these quads on our beam optics and are also measuring the halo condition for a wide range of beam intensities through the hall. The results of these tests should be available by the time of the PAC meeting. In the event that life in the present P-West pit becomes too difficult, we would consider other possibilities, such as the P-West high intensity laboratory. This has the advantage that we could make a direct comparison of pp and $\overline{p}p$ hadron jet production in the same beam line and with the same apparatus. Moreover, our high P_t Λ^o and $\overline{\Lambda}^o$ measurement might provide a more sensitive search for C violation that that of E-302, if the Λ^o are polarized.

In P-West, our target initially would be different types of vertical wires positioned inside the vacuum pipe. This has the effect of creating a nearly point source, which will be very helpful in applying the coplanarity condition for the Λ^o's and obtaining a clean sample. Such a wire would typically interact 10^{-3} of the primary beam. We will look into the possibility of using a hydrogen target and also of obtaining a higher energy negative secondary beam in that area, so that we could also study $\pi^- p$ interactions.

III. Trigger Rates:

(A) Jet Trigger Rate: The hadron jet trigger rates at high P_t are estimated from the 400 Gev single particle high P_t results of Cronin et al. and our result from E260 that the collective high P_t (i.e. jet) cross section is about 100 x larger that the single particle high P_t cross sections at the same P_t. The jet trigger is obtained by adding together the pulse heights in all phototubes (weighted by angle) before discrimination.

In Figure 5, is shown the expected jet trigger rate per Gev P_t for 400 Gev protons on tungsten. These rates are estimated assuming a total interaction rate of 5×10^6/spill. We expect to detect one 8 Gev/c P_t jet per spill.

(B) Λ^o, $\overline{\Lambda}^o$ Inclusive Trigger Rate: We estimate the high P_t rates for inclusive Λ^o and $\overline{\Lambda}^o$ from the ISR measurement of the CCRS collaboration (Busser et al.) that $\Lambda^o/p \sim \overline{\Lambda}^o/\overline{p} \sim 1/4$ at 90^o. This value is combined with the high P_t cross sections of Cronin et al. for p and $\overline{p}$ to yield the rates shown in Figure 6.

To achieve this recorded rate, the calorimeter will provide a trigger in which a high P_t signal is required in a single calorimeter module. These rates are typically a factor of about 100 below the jet rates given in Figure 5. If necessary, the Cerenkov counter $\check{C}_2$ can be used in a veto mode. With a Helium filling, proton threshold is well above 100 Gev (π threshold $\sim$ 17 Gev); a no-light condition will be required in front of a calorimeter cell with a high P_t trigger

IV. COSTS:

UCLA	to complete west arm I
1. Calorimeter (existing) additional costs to complete instumentation	$45,000.
2. Drift Chambers (prototypes exist) cost not including time digitizers (see below)	$40,000.
3. Cerenkov Counters (existing) additional costs to modify and improve	$40,000.
Requested from FNAL	
4. Magnet Iron and Coils UCLA contributes Engineering Costs	$25,000.

In addition, we would require PREP electronics from Fermilab, including 1700 channels of time digitization for the drift chambers.

V. Run Request and Time Scale:

We request a total of 1000 hours for this experiment; 300 for testing and debugging and 700 for data taking. Since the calorimeter and prototype chambers are already installed in P-West, we can adiabatically run-in our system as we add components. New chambers will be added as they are completed. The entire chamber system could be running 6 months from approval.

Work on the Cerenkov counter conversions could begin as soon as the present E110 run is completed. We would install the counters during the summer

The magnet is a straight-forward simple design. the engineering design work could be completed shortly after the PAC meeting.

VI. Computing:

Our group's Data General ECLIPSE computer (1/3 the computing power of a CDC6600) will be completely dedicated to the analysis of this experiment. When we are running at Fermilab, we would like the usual amount of time for testing and debugging.

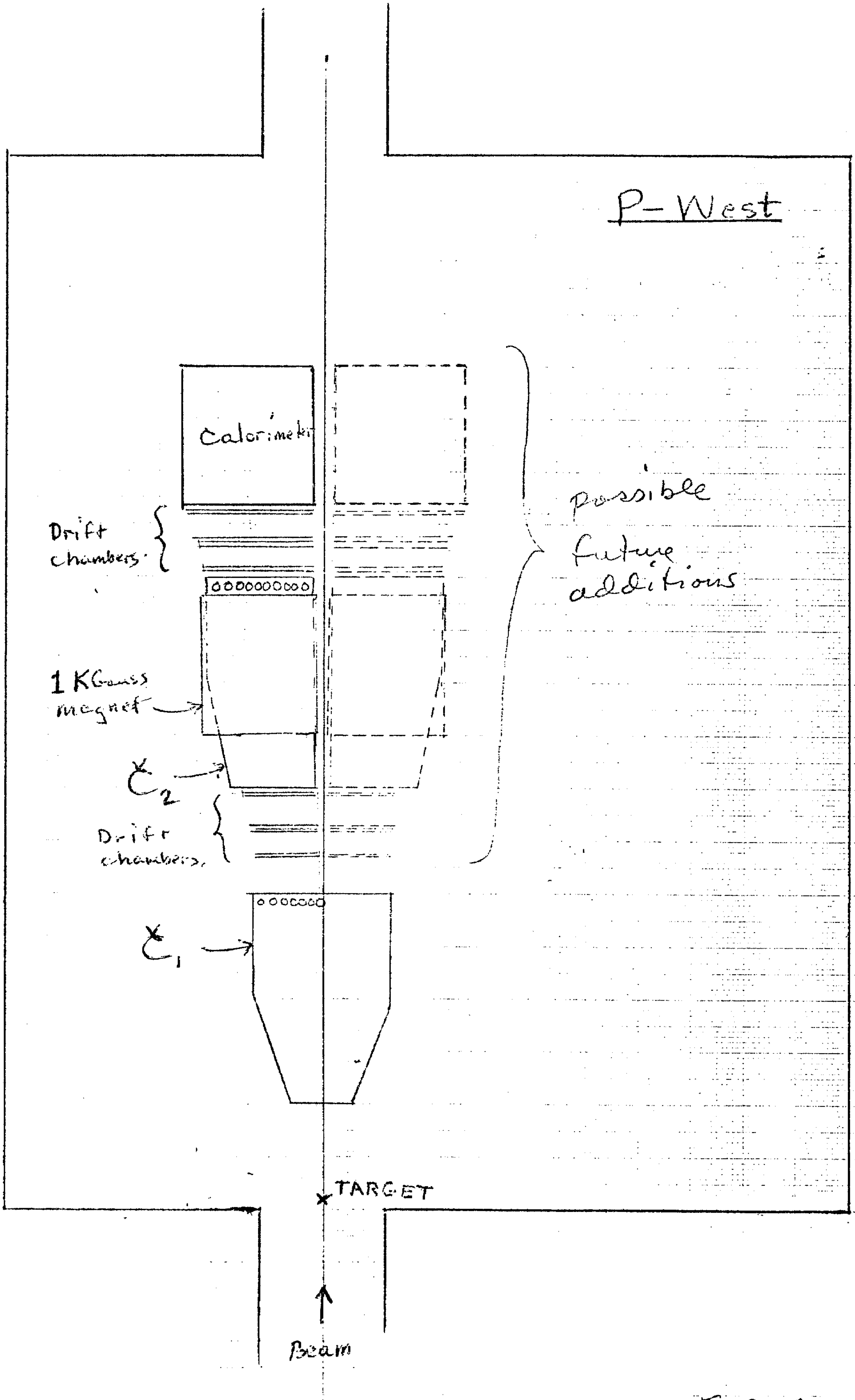
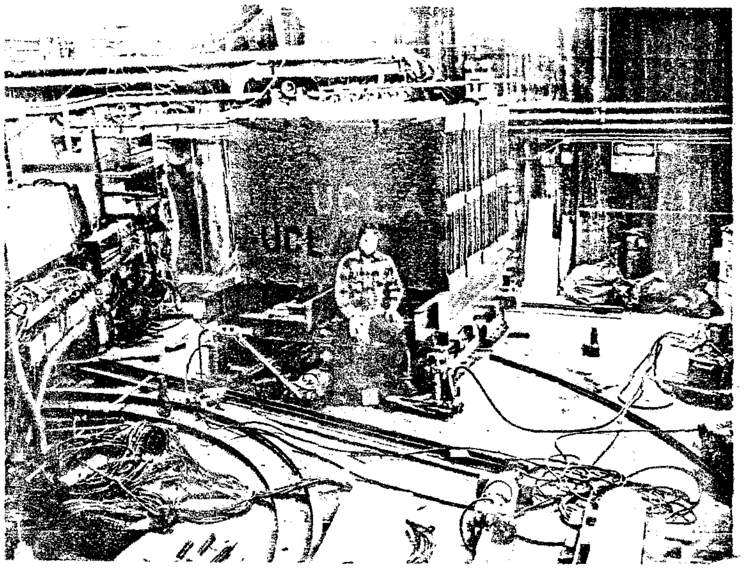
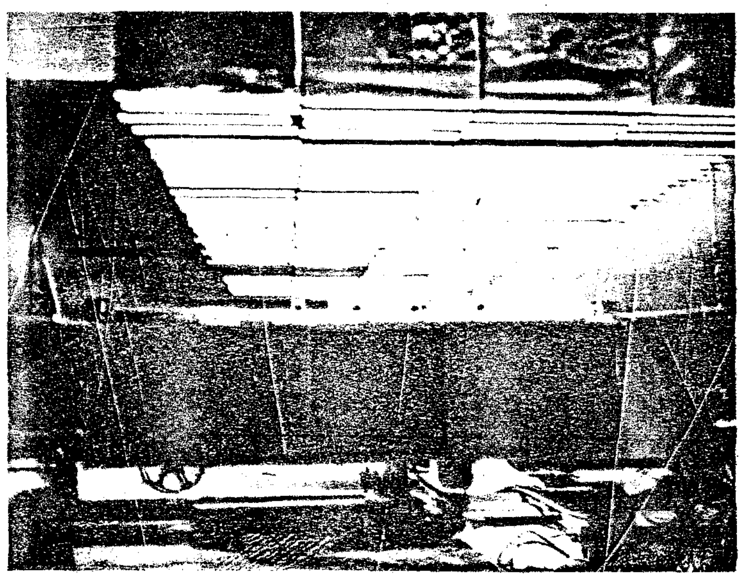

P-West
Calorimeter
Drift chambers.
1 KGauss magnet
$\check{C}_2$
Drift chambers.
$\check{C}_1$
possible future additions
TARGET
Beam

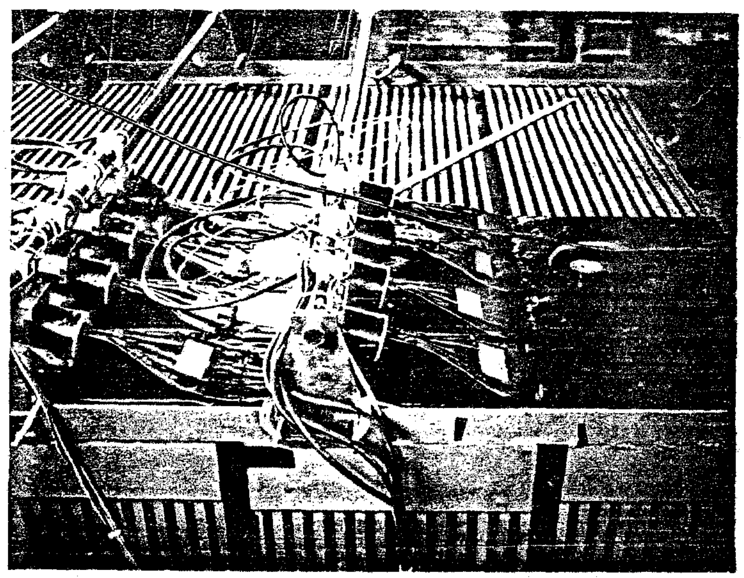
FIG. 1



(a)



(b)



(c)

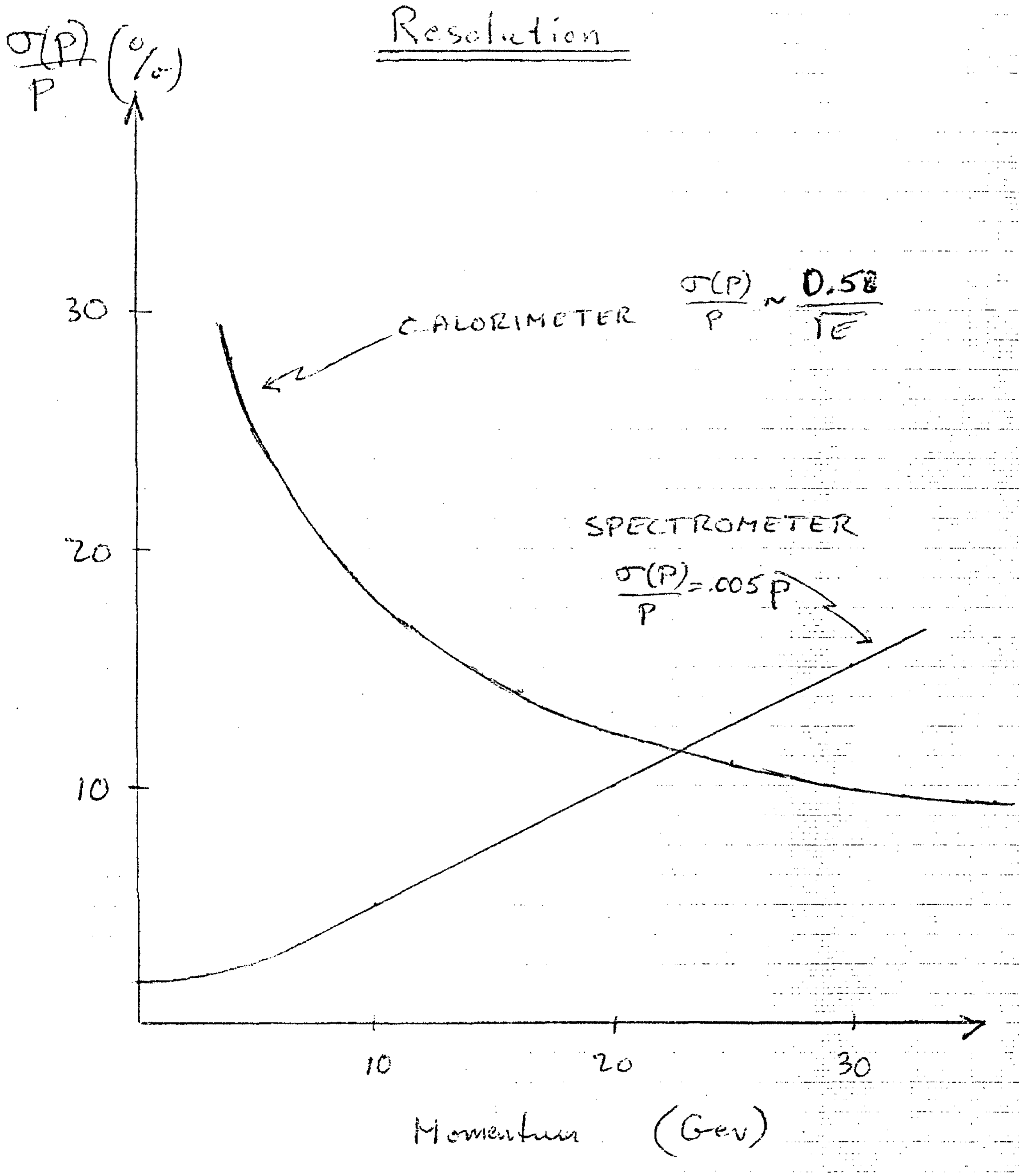
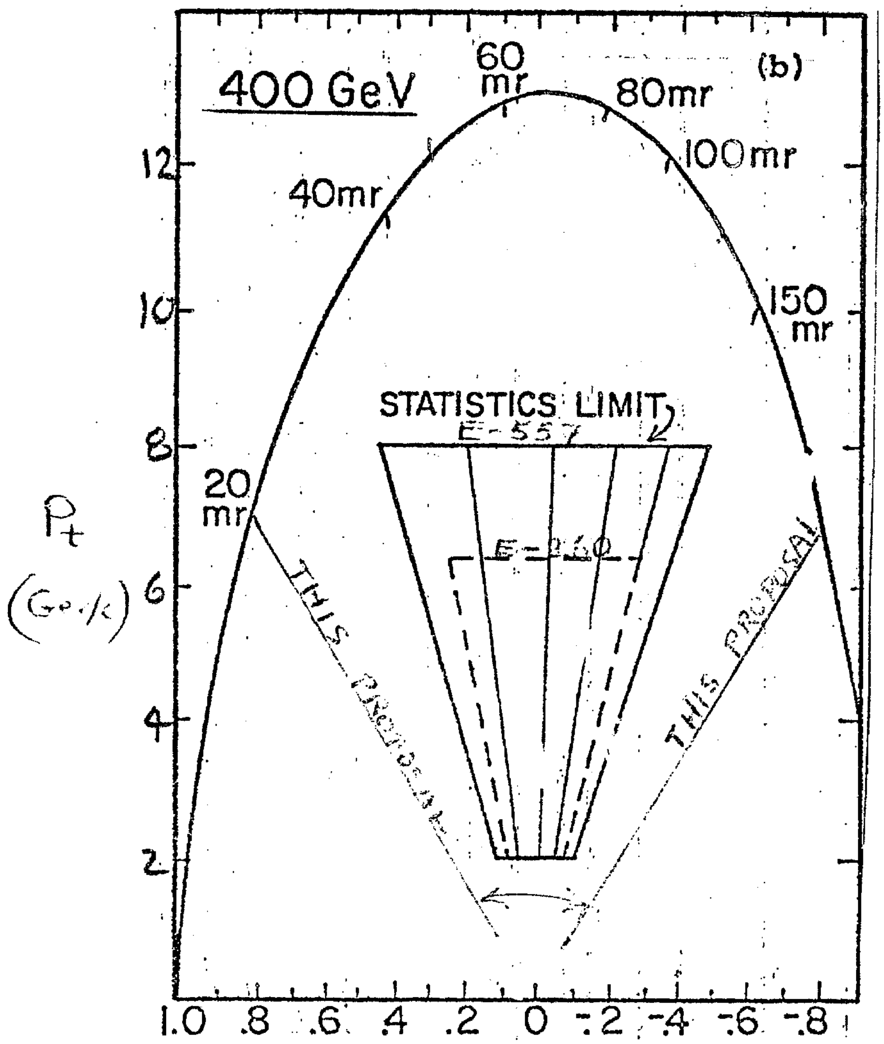

Resolution
σ(p)/p (%)
30
20
10
CALORIMETER
σ(p)/p ~ 0.58/√E
SPECTROMETER
σ(p)/p = .005 p
10
20
30
Momentum (Gev)

FIG. 3



400 GeV
(b)
60 mr
80mr
100mr
40mr
150 mr
20 mr
STATISTICS LIMIT
E-557
E-260
THIS PROPOSAL
THIS PROPOSAL
Pt (GeV/c)
12
10
8
6
4
2
1.0 .8 .6 .4 .2 0 -.2 -.4 -.6 -.8
XCM

FIG. 4

Jet Trigger Rate per Spill

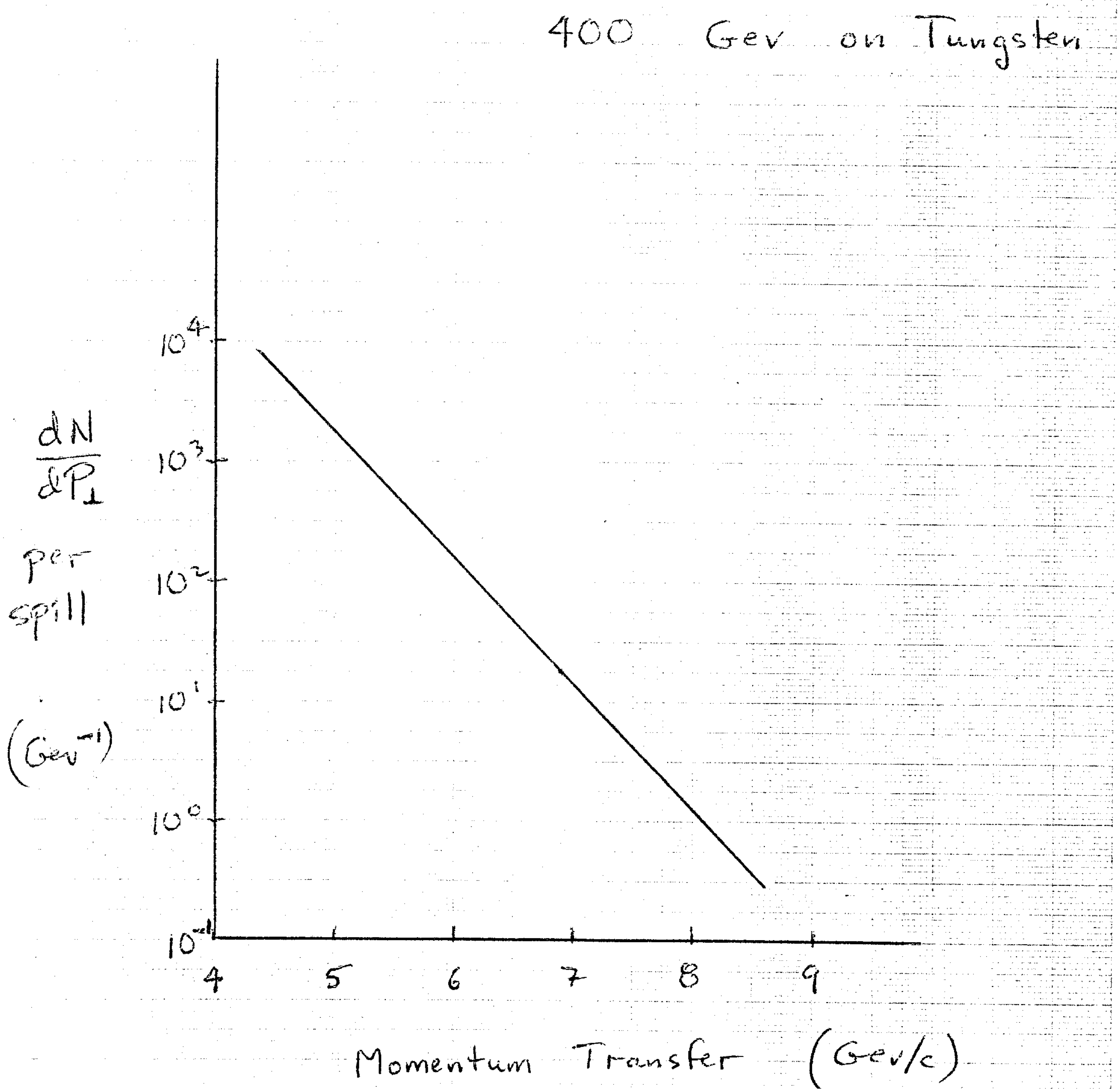
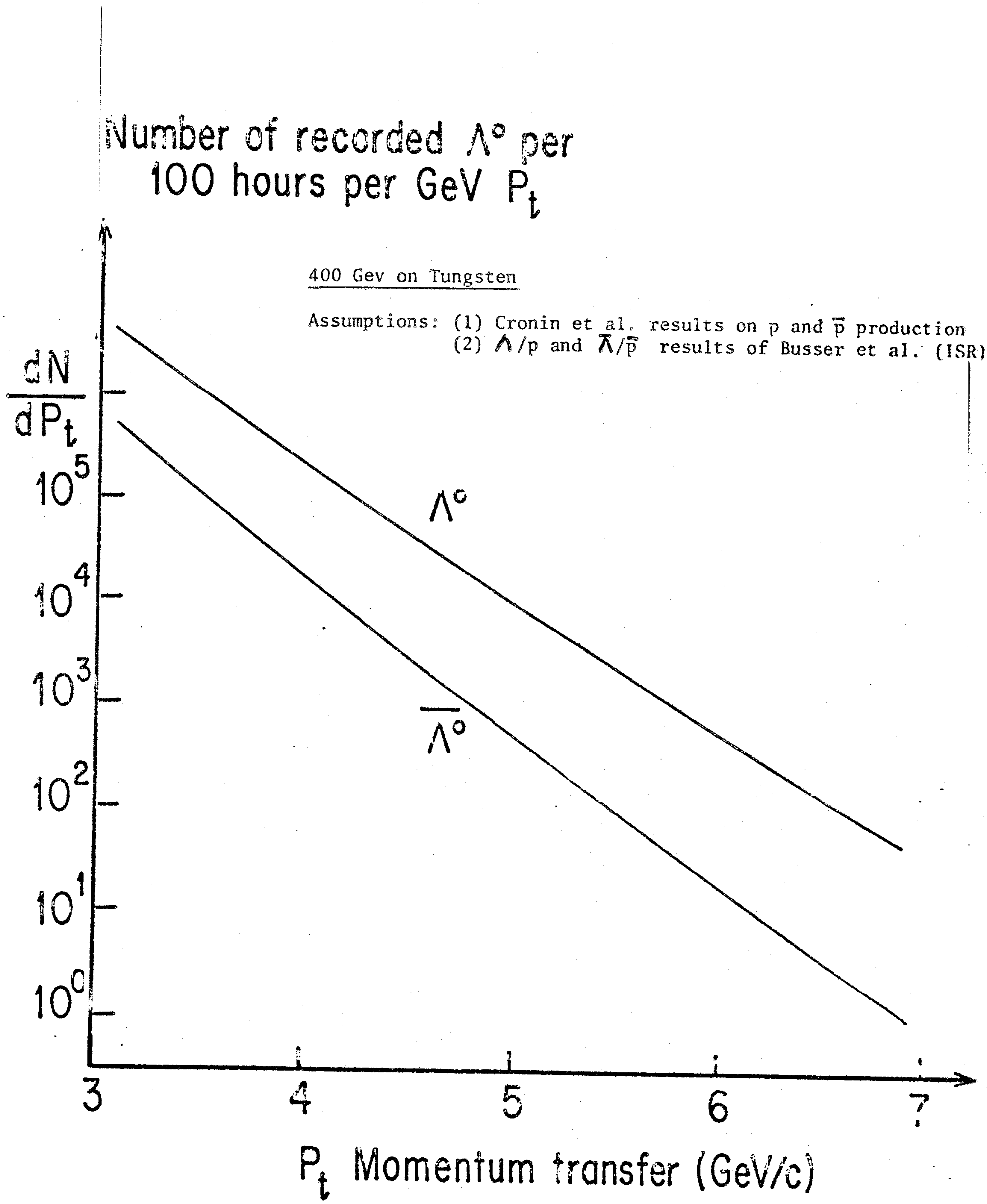


FIG. 5


Number of recorded Λ° per 100 hours per GeV P_t
400 Gev on Tungsten
Assumptions: (1) Cronin et al. results on p and $\bar{p}$ production
(2) Λ/p and $\bar{\Lambda}/\bar{p}$ results of Busser et al. (ISR)
$\frac{dN}{dP_t}$
10^5
10^4
10^3
10^2
10^1
10^0
Λ°
$\bar{\Lambda}$°
3
4
5
6
7
P_t Momentum transfer (GeV/c)