NAL Proposal No. 277

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PROPOSAL TO STUDY π^+ and K^+ INTERACTIONS AT 300 GEV IN THE NAL 30-INCH HYDROGEN BUBBLE CHAMBER

January, 1974

We propose to study $\pi^+ p$ interactions at 300 GeV in the hydrogen filled NAL 30-inch bubble chamber, using a tagged beam with low proton contamination, produced on a secondary target by an intermediate negative beam. The supplementary visual spectrometer of Experiment 2B would also be used if available. K^+ will probably be a useful fraction of the beam, and would also be studied. 100K pictures are requested.

Purdue High Energy Physics Group

We propose to analyze 100K pictures taken with a proton depleted 300 GeV π^+ beam into the NAL 30-inch hydrogen bubble chamber. By now the rich range of data thus obtainable is well known, and the interest of extending our knowledge of π^+p interactions to still higher energy is obvious. K^+ will be present at the level of at least a few percent or more and will be well worth studying. With a 45 cm fiducial volume length and a rather well controlled 7 tracks per picture using the Walker kicker, we expect 25,000 π^+p interactions, and 1,000 K^+p interactions per 5% K^+ fraction in the beam. The Lach-Pruss differential Cerenkov counter should be able to just separate π from K at 300 GeV, working at 3 milliradians with the protons just below threshold. (See Appendix A)

The positive beam is obtained by letting primary protons strike a target, removing the positive outgoing component by magnetic deflection, and letting the negatives (mostly π^-) strike a second target. The flux of high momentum positive particles emerging at zero degrees from the second target will contain few protons, mostly π^+, and may well be rather enriched in K^+. We assume a primary proton energy of 400 GeV. A π^+ momentum of 75% of the incident proton momentum is quite feasible (See Appendix B) and with higher proton flux the primary proton energy can be approached even closer. Studies of such a configuration with both targets in Enclosure 100 are imminent, using 300 GeV protons. A report of the outcome will be appended to this proposal in the near future.

This exposure is a natural outgrowth of our 100 GeV π^+p exposure in Hybrid Experiment 2B, using the bubble chamber and supplementary downstream wide gap optical spark chambers. If the spark chamber system is available, we would hope also to use it to obtain considerable improvement in momentum resolution of fast forward tracks, as well as to have valuable gamma detection in the forward cone (one inch of lead precedes the final module of the spark chamber system). (See Appendix C)

We have already measured and reconstructed some bubble chamber and spark chamber pictures from the 100 GeV π^+p exposure, and have tuned up the analysis system for Hybrid data. The number of events involved in this proposed 300 GeV exposure is not large compared with the Purdue measuring rate of over 200,000 events per year in our conventional shop, not counting our POLLY measuring machine which is now being tuned up.

APPENDIX A

300 GeV Use of the 34 meter Cerenkov Counter in the N3 Beam Line

We have described this Cerenkov counter, which was built by S. Pruss and J. Lach, in an unpublished report.[1] It is a focussing differential Cerenkov counter 110 feet long, located between enclosures 105 and 106. Cerenkov light from each particle is focussed into a ring near the first photomultiplier, where also a pierced mirror with a 1.0 inch diameter circular hole is located. Light rings greater than 5 milliradians fall on the mirror surface and are reflected to a second photomultiplier. Smaller rings register on the first photomultiplier. The light rings are spread out by about 0.5 mr due to beam divergence (10^{-4} radians), off axis spherical aberration of the main mirror, dispersion in the Helium, possible temperature variations in the Helium, multiple scattering, and β variation due to the finite momentum bite of the beam (see Figures 1 and 2).

At 300 GeV, proton threshold is at 2 PSI of Helium (see Figure 3), and the ring of light from K^+ is at 2.5 milliradians and π^+ light is at 3 mr. This mode will require a secondary pierced mirror with a 0.6 inch diameter circular hole, as opposed to the mirror currently in use. Interchangeable secondary mirrors of various hole size were envisioned for this Cerenkov counter from the outset, and are needed to work optimally at various beam energies.

The edges of the π and K rings will just touch at 300 GeV, or possibly overlap slightly. Pressure curves at lower momentum tend to validate the theoretical calculations of ring spreading. If the K component is considerably less than the π component, as we expect, we can set the K ring relatively near to the inside edge of the 0.6 inch hole. This will move the edge of the π ring out away from the edge of the hole, minimizing π feed-through into the K signal. K feed-through into the π signal will be of second order, and tolerable. Furthermore, we will tag as junk and reject from our usable beam flux any particles which register on both photomultipliers. This will cause some loss of useful π and K beam, but will result in purer tagging. Protons will be indicated by no signal, in coincidence with a local beam telescope.

[1]"Review of the 34 Meter Pruss-Lach Differential Cerenkov Counter for the 30" Bubble Chamber Hadron Beam at NAL." V. E. Barnes, A. Erwin, and J. Lamsa, October 26, 1971. Internal Report to members of Experiment 2B Collaboration.

Occasionally, a δ ray accompanying a proton will cause a π or K tag, or will give both π and K signals and be rejected. Since the protons will be a small fraction of the beam, this feed-through will be of second order.

APPENDIX B

π^+/K^+ Beam From High Energy Protons via Double Conversion

A substantial flux of π^- is available at 80 to 90% of the bombarding proton energy. We use the Hagedorn-Ranft model curves from NAL report TM-285. For the production of fast forward π^+ from incident π^- we use Ferbel's curves (see Fig. 4) based mainly on production of fast forward A_1 mesons[1]. An early estimate by D. Cords of the proton flux necessary to obtain 144 GeV π^+ from 200 GeV protons apears at the end of this appendix. These numbers scale well to 288 GeV pi plus from 400 GeV protons, and lead to an estimate of $2x10^{12}$ protons needed for 12 pi plus at the bubble chamber, in agreement with the calculation below.

We are about to participate in a test proposed by W. Neale[2] with the two targets separated by one main ring magnet, approximately 20 feet. The second target is one inch square and one foot long Aluminum. The solid angle is thus about 17 μster, very close to that estimated by Cords. Also, his estimate of $\delta p/p = \pm$ 5% for the intermediate pi minus beam seems reasonable here. Using Fig. 6 of TM-285, we find for 410 GeV pi minus from 500 GeV protons that $8x10^6$ protons yield one pi minus into 1 μster and 0.1% momentum bite. This implies $1x10^4$ protons per pion into the Neale configuration. Scaling to 400 GeV protons, the intermediate pion momentum is 328 GeV/c.

Using Fig. 4, with the momentum scaled by a factor 328/300, we find that 10^5 interacting pi minus will yield 0.3 pi plus of 300 GeV into a 1 μster beam with 1 GeV momentum bite. The actual acceptance of the bubble chamber hadron beam is 1/4 μster and the momentum bite is typically 0.1% but can be increased towards 1% if necessary. Using the smaller momentum bite, and requiring 12 pi plus into the final beam, and allowing a factor of 1/3 for incomplete interaction at the two targets, then about $1.6x10^8$ pi minus are required. Hence, about $1.6x10^{12}$ protons are required. Some further optimization may be possible by moving the intermediate pi minus momentum closer to the final pi plus momentum. We hope to try this during the experimental test.

To produce 400 GeV pi plus from 500 GeV protons this way, an intermediate pi minus energy of 440 GeV gives the same point on Ferbel's curve when it is scaled by 440/300/ Again about $1.6x10^8$ pi minus are needed, allowing for beam acceptance and targeting inefficiencies. Fig. 6 of TM-285 implies that $4. x10^4$ protons are needed to yield one pi minus into the Neale configuration. Thus 7×10^{12} protons are required to give 12 pi plus at the bubble chamber. These estimates could easily be off by a factor of three or more either way. We do have the option of increasing the final momentum bite if necessary.

1. "Production of π^+ Mesons Using π^- Beams at NAL", T. Ferbel, URPA - 330

2. F. R. Huson, private communication.

11/18/71
D. Cords

π^+ Beam from 200 GeV/c Protons via Double-Conversion

at 1st target ($p \to \pi^-$): $\Delta\Omega = 16\ \mu sr$

$\frac{\Delta p}{p} = \pm 5\%$

at 2nd target ($\pi^- \to \pi^+$): $\Delta\Omega = \frac{1}{4}\ \mu sr$

$\frac{\Delta p}{p} = .1\%$

at B.C.: 12 π^+/pict. $\hat{=}$ 1 interaction/picture

P_{π^-}	P_{π^+} at $N_{\pi^+}(A_1) = \frac{1}{2}$ max	I proton	P_{π^+} at $N_{\pi^+}(A_1) =$ max	I proton
180	162	4×10^{13}	144	2×10^{13}
160	144	2×10^{12}	128	10^{12}
140	126	5×10^{11}	112	2.5×10^{11}
120	108	3×10^{11}	96	1.5×10^{11}
[GeV/c]	[GeV/c]		[GeV/c]	

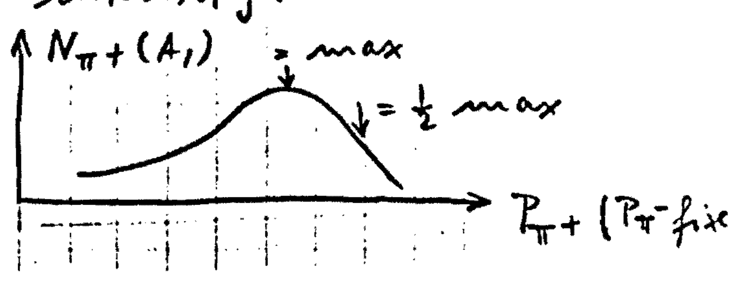
Conversion from p to π^- intensity:

Lach and Pruss using Hagedorn-Ranft model

Conversion from π^- to π^+ intensity:

Ferbel:

A_1-production



APPENDIX C

Downstream Hybrid Spark Chamber Spectrometer

The wide gap optical spark chamber system of Experiment 2B consists of four modules, each with a double eight inch gap, and measuring 30 inches by 40 inches horizontally by vertically transverse to the beam. They are located between four and eight meters downstream from the center of the bubble chamber. The fringing field of the bubble chamber helps the momentum resolution, which is typically $\delta p/p = \pm 10\%$ for a 300 GeV beam track (see Fig. 5). This is obtained by hooking up spark chamber measurements to bubble chamber measurements of the same track. This has been done to ~ 2 mm accuracy in space by Smith et al (see Fig. 6). The hybrid momentum measurements are generally at least 10 times more accurate than measurements made by using the bubble chamber alone (see Fig. 7). Most tracks above 20 GeV enter the spark chambers. Below this momentum the bubble chamber is adequate for momentum measurements, if run at full magnetic field.

A one inch thick lead plate covering the active area of the spark chamber is hung just before the fourth module. Gamma showers can clearly be seen to diverge from the vicinity of the converter plate.

The system has recently been adapted to multi pulsing, and has worked well in conjunction with the 30 inch bubble chamber at four pulses per flat top, at 290 ms intervals. In addition, the event trigger now consists of the logical sum of a sensitive beam deflection trigger using five narrow matched pairs of finger counters, plus a dE/dx telescope just downstream of the bubble chamber which is sensitive to events which send at least two charged particles into the solid angle of the spark chambers.

Since the memory time of the spark chambers is a few microseconds, one of the modules is held in reserve at the first interaction trigger and used if a second interaction is detected later in the beam spill. The incidence of three or more interactions in one spill is low. The detection efficiency of the event trigger counters is high, even for two prong events.

FIGURE 1

Distribution of photons at 2d mirror as a function of ring radius, resulting from (a) beam divergence + (b.) off axis spherical aberration.

f of main mirror = 100"

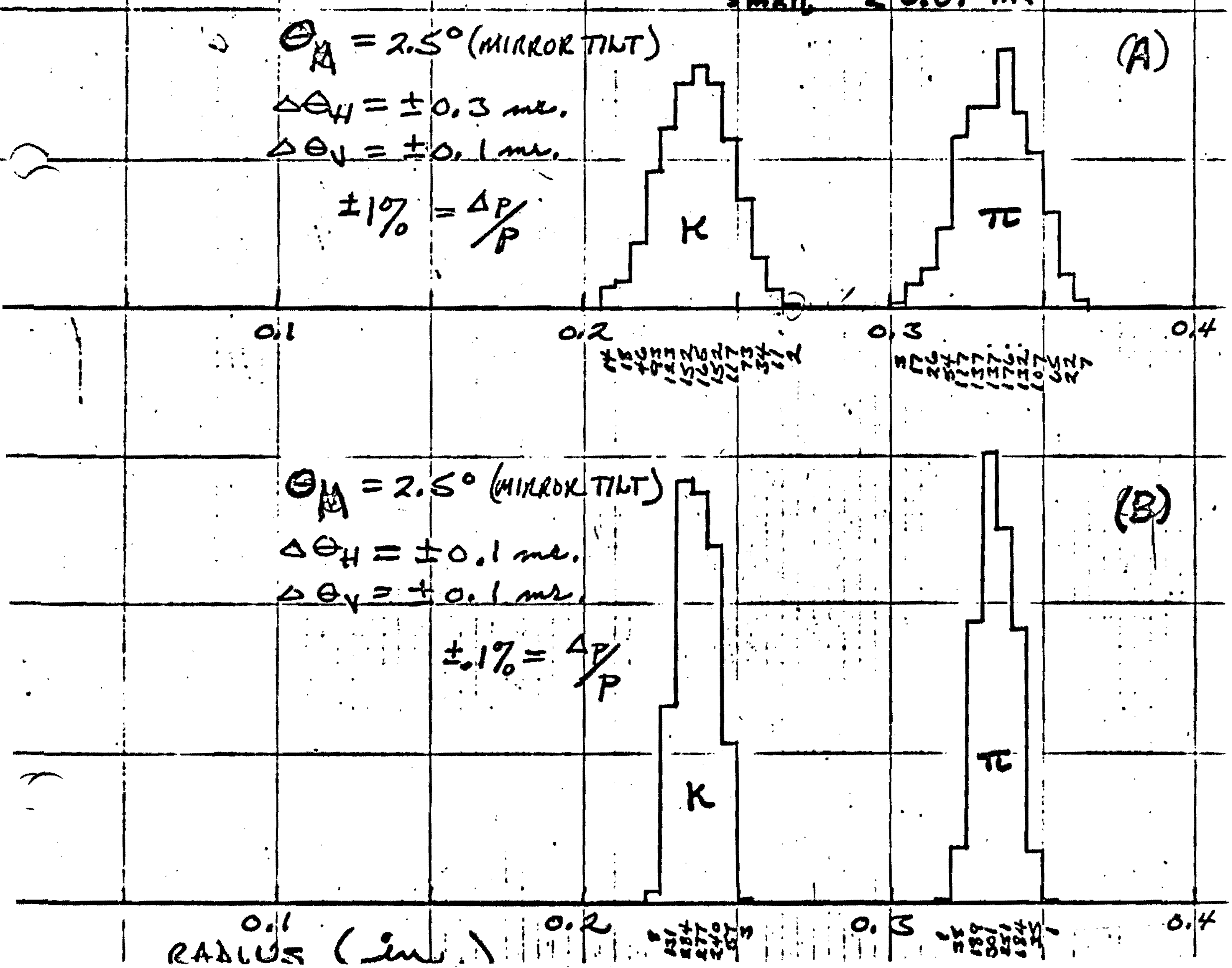
1 mr $\theta_{\gamma} \longleftrightarrow 0.1"$ ring radius

CASE A : $\frac{\delta p}{p}$ = 1.0%

CASE B = 0.1%

MULTIPLE SCATTERING IN He will be << beam divergence.

~~$\delta\beta$ effects will be very small~~ < 0.01 mr



$\theta_{MAX}(K) = 3.0$ mr

Dispersion Aberration due to He $\delta\eta/\eta = 7.28\%$ from 1800Å to 6000Å

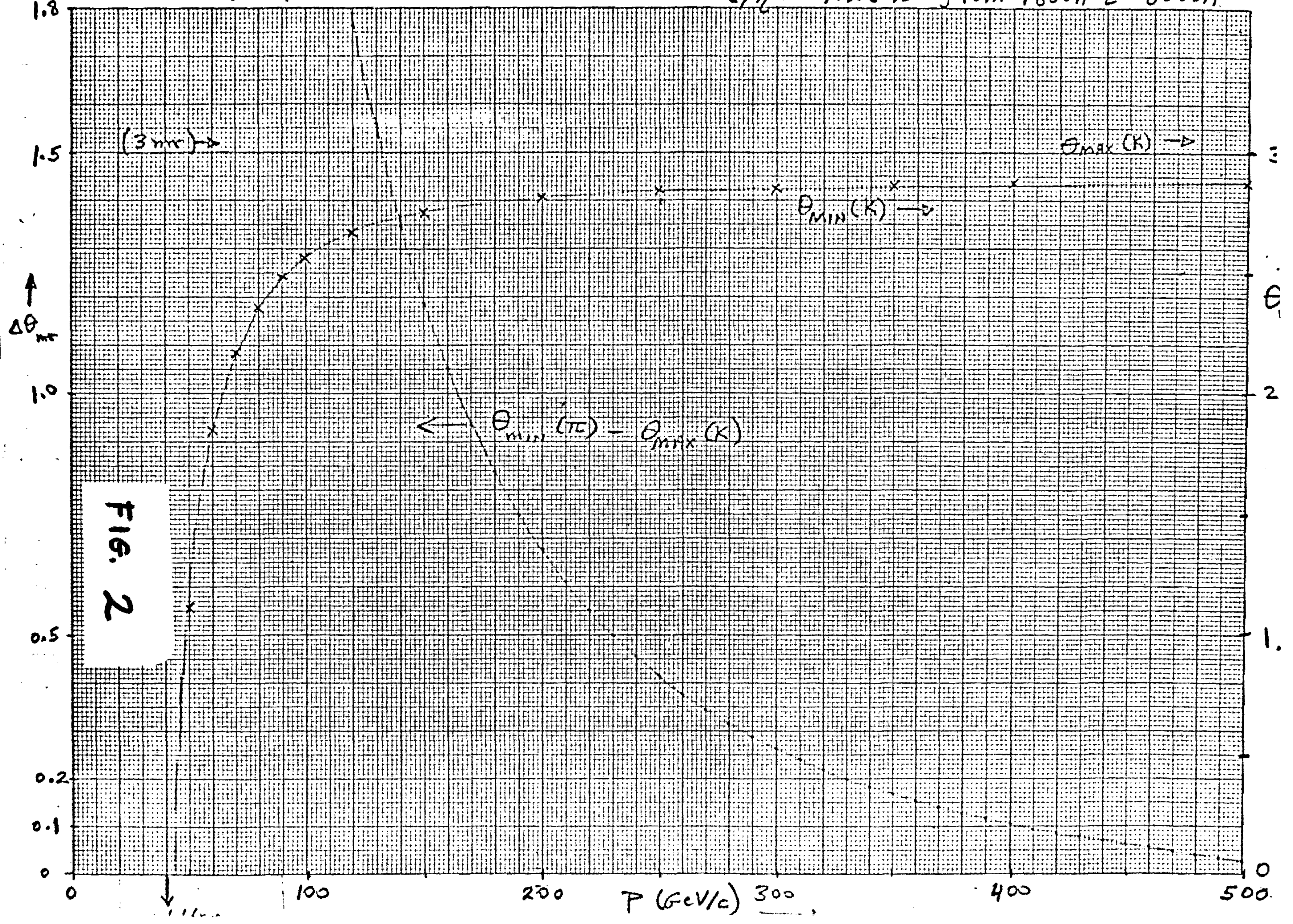
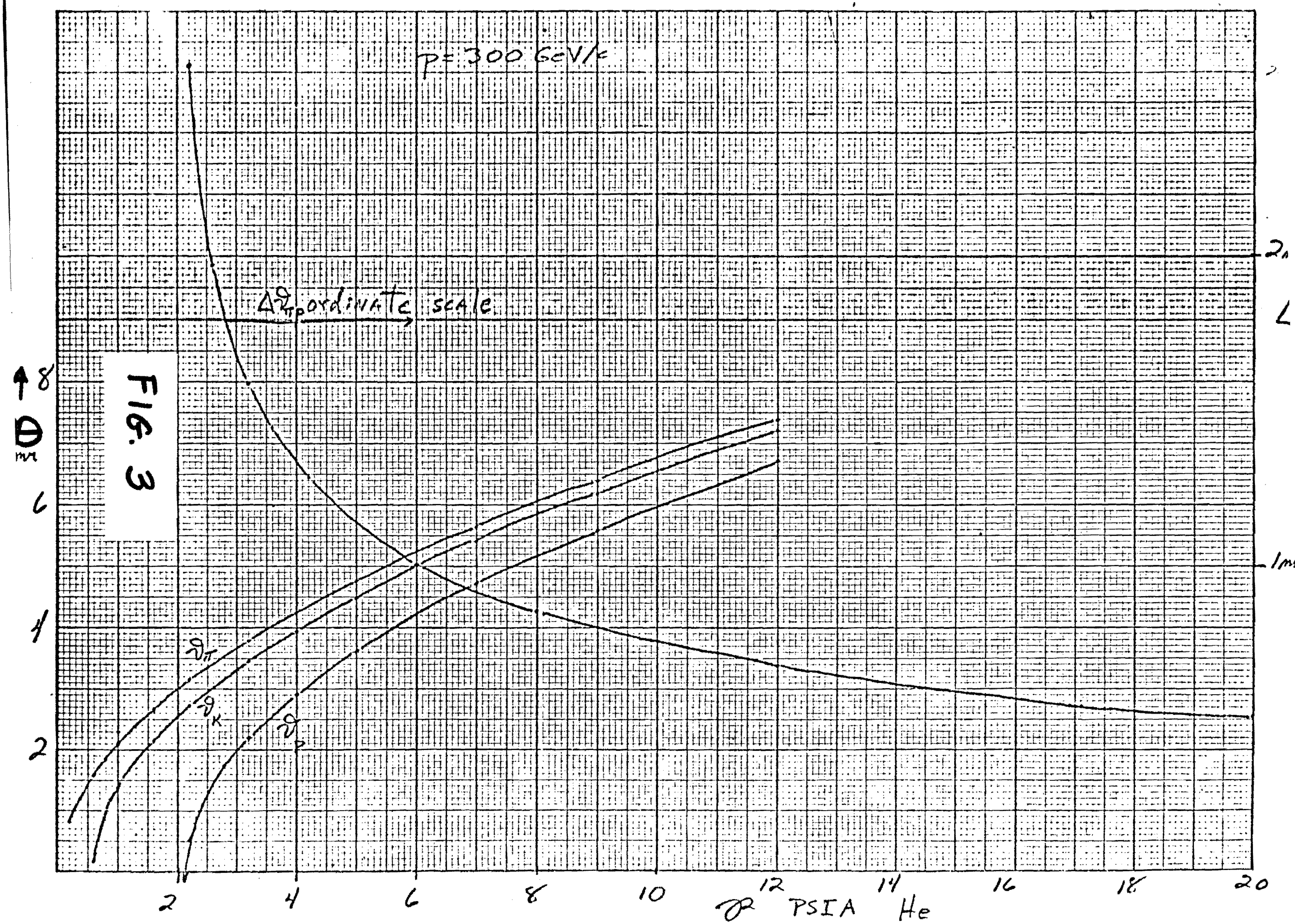
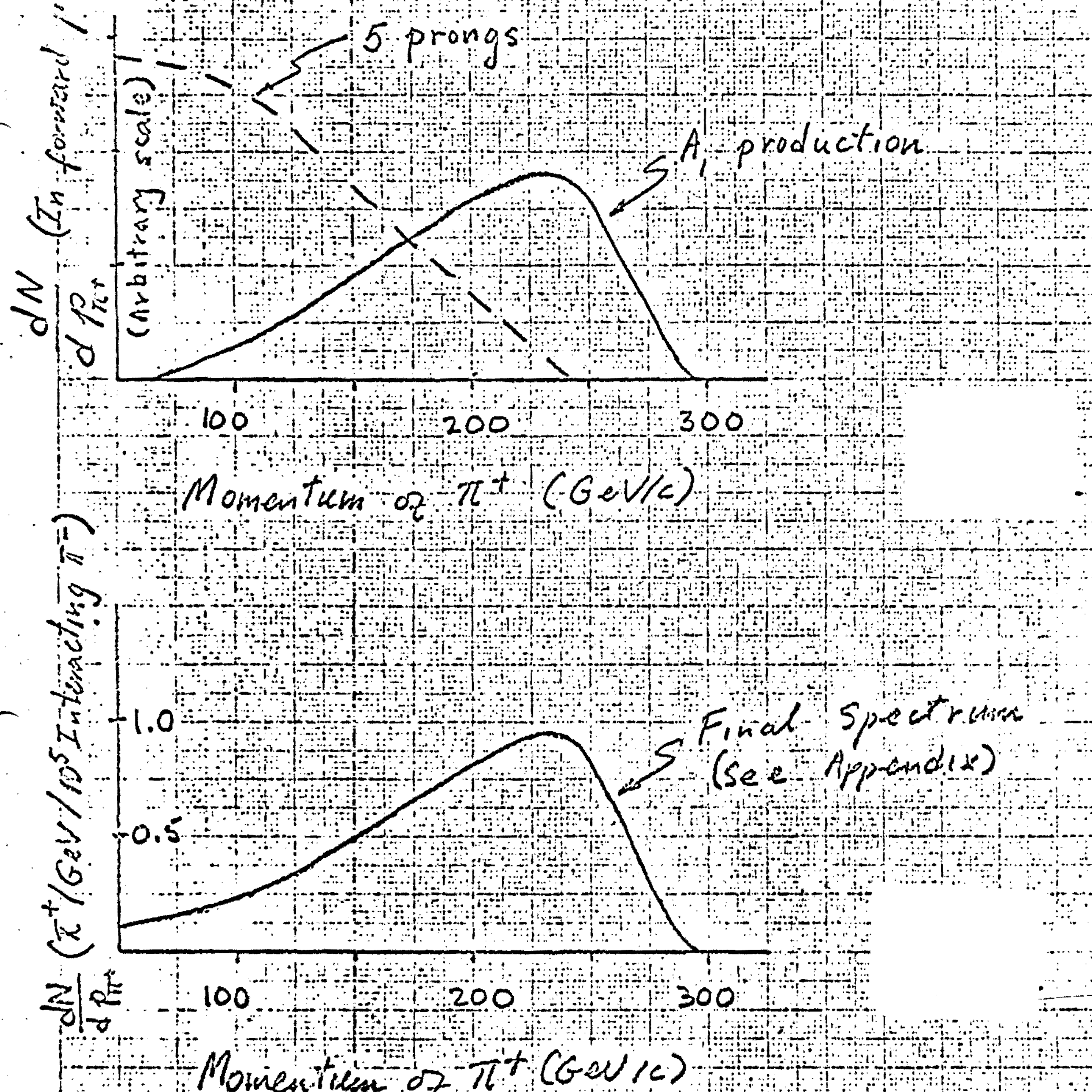


FIG. 2



p = 300 GeV/c
Δϑπp ordinate scale
ϑπ
ϑK
ϑp
Θ mr
8
6
4
2
2m
1m
2
4
6
8
10
12
14
16
18
20
PSIA He

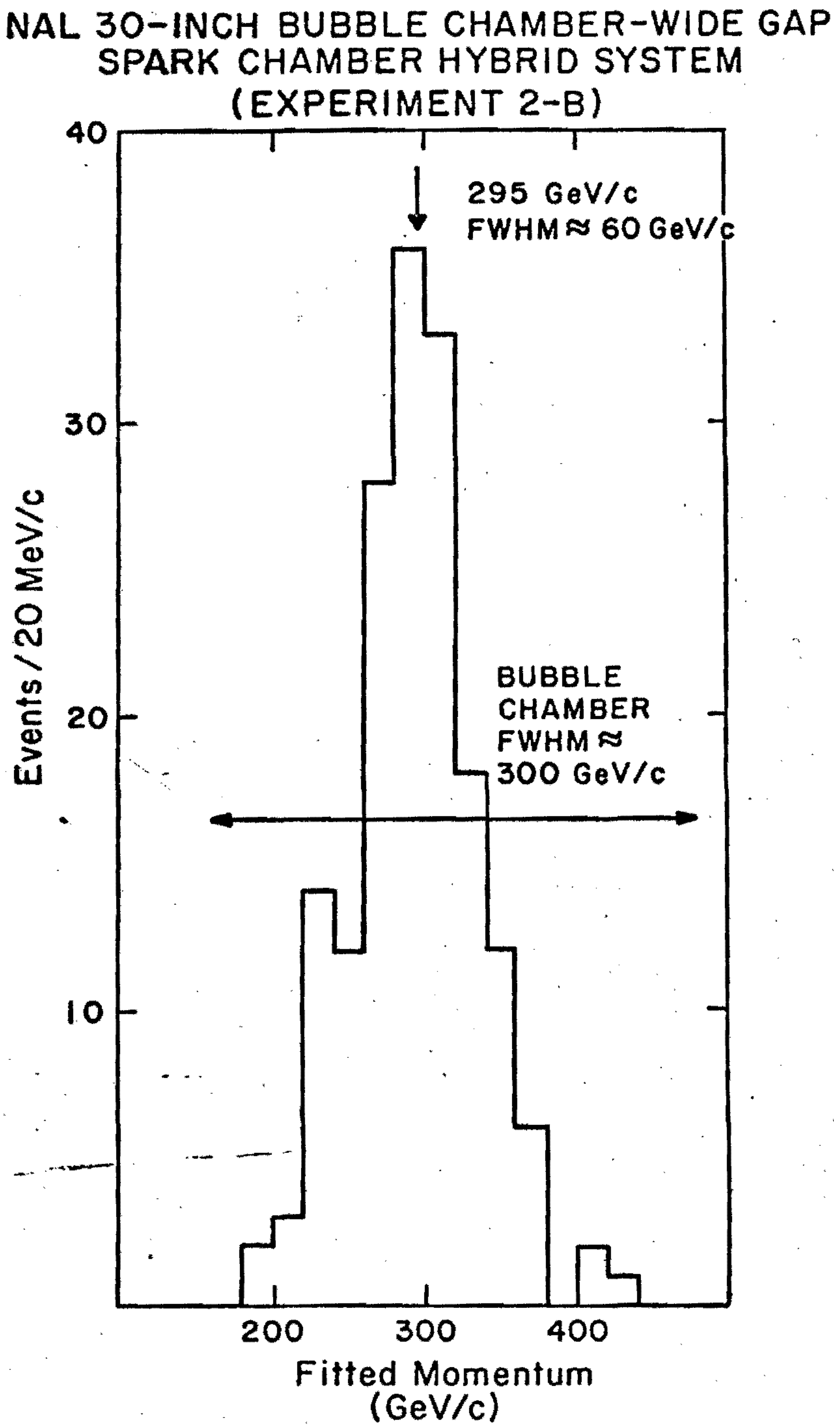
FIG. 3



(Incident π^- Momentum of 300 GeV/c)

FIGURE 4

from Ferbel's report URPA-330 (His figures 1 & 2)

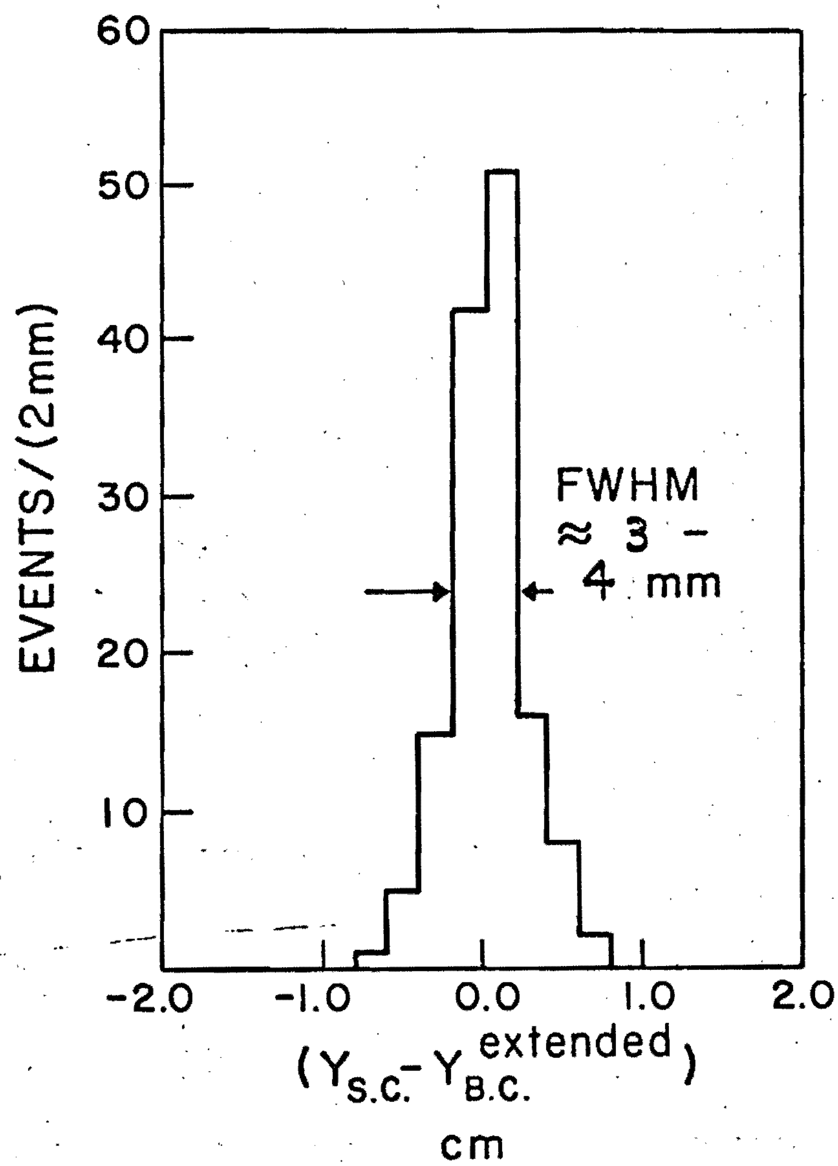


Fitted Beam Momentum using Bubble-Chamber-Spark Chamber Hook-up data

FIGURE 5

from Smith et al

NAL 30-INCH BUBBLE CHAMBER-WIDE GAP SPARK CHAMBER HYBRID SYSTEM (EXPERIMENT 2-B)



BUBBLE CHAMBER – SPARK CHAMBER HOOK-UP MEASUREMENT

FIGURE 6

from Smith et al

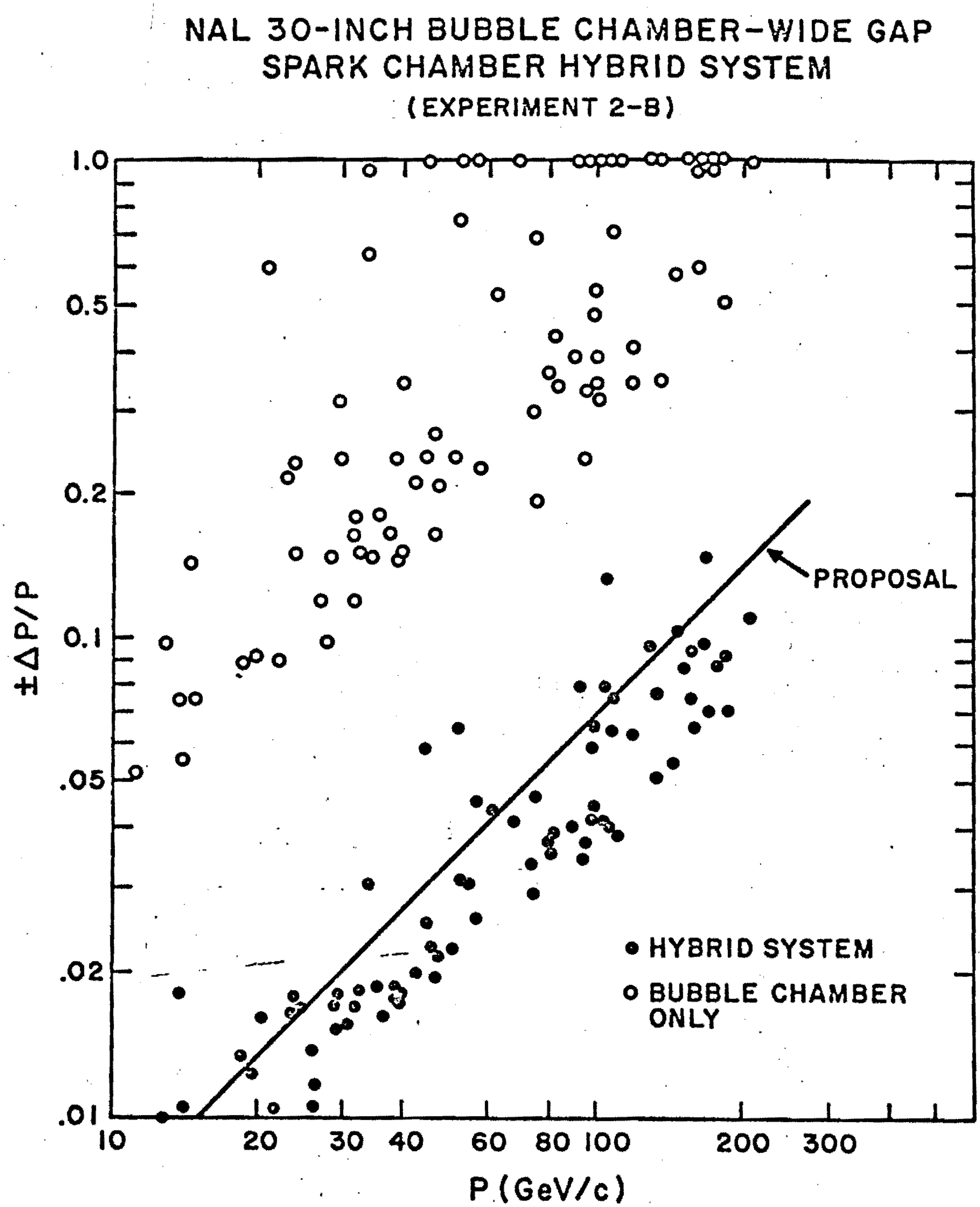


FIGURE 7

from Smith et al

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277 278
Summaries already filed in notebook

March 11, 1974

Dr. James Sanford
Program Planning
National Accelerator Laboratory
Batavia, Illinois 60510

Dear Jim:

Enclosed are one page summaries of my proposals #277 and 278, and also brief addenda to the two proposals mentioning the possible use of transition radiation detectors (in addition to the existing Cerenkov counter) to separately tag K^+ and π^+ at 400 GeV as well as at 300 GeV. Accordingly I am extending my 400 GeV π^+ proposal to include K^+ interactions as well, if this should prove feasible after the transition radiation devices are tested at NAL. I would encourage the vigorous pursuit of this new technology with a view to its early use in the 30-inch program if it works as well as expected.

As I have mentioned to you, we came exceedingly close to a test of double targeting on February 26, and were forced off by a switchyard failure and by the 200 GeV π^- hybrid experiment which was waiting for such a break to switch polarity in the 30-inch beam-line. We eagerly await the next opportunity to test this idea which is crucial to the high energy π^+/K^+ runs. Among other things, it will be most interesting to see if a K^+ fraction can be obtained which is greater than the canonical $\sim 5\%$.

Best regards,

Virgil

Virgil Barnes

VB:jl

Enclosures

ADDENDUM TO NAL PROPOSALS 277 AND 278

March, 1974 V. Barnes, et al. (Purdue)

In view of the prospects for using transition radiation for mass tagging of beams, I wish to add a study of K^+ interactions to the proposal to study 400 GeV π^+p interactions in the 30-inch HBC. Moreover, transition radiation detectors could improve the tagging at 300 GeV. However, we emphasize that the existing differential Cerenkov counter is adequate to separate K from π at 300 GeV provided one is willing to tolerate modest inefficiencies in detecting mesons. Specifically, of one runs the Cerenkov at 2 psia of Helium, protons are below threshold, light from K's forms a ring at 2.5 milliradians, and light from π forms a ring at 3.0 milliradians. (See our Proposal 277, Appendix A.) K's are then detected with 96% efficiency, and π's are detected with 99% efficiency. The undetected mesons are tagged as protons, which we are not interested in, and represent only a modest unbiased loss of beam flux (we count as beam only well tagged particles). At 400 GeV, to obtain 0.5 milliradian separation of the π and K rings, one must work at such a small angle that the detection efficiency is very low.

Coming back to transition radiation detectors, there is considerable promise in various devices which it has been proposed to test at NAL[1,2]. In particular, separation of π from K down to 200 GeV is seriously mentioned. The method improves rapidly with particle momentum. One configuration mentioned may be expected to give a positive signal from π's at high efficiency (99%) with 32:1 signal to noise ratio[1]. The cost of such devices for the 30-inch and/or 15-foot hadron beam lines does not seem prohibitive. I wish to encourage NAL to pursue research and development of transition radiation devices for use soon in the 30-inch bubble chamber program.

1. NAL Proposal #261: "Proposal to Test Transition Counters at NAL," J. Fischer, V. Radeka, C. L. Wang, (BNL) and M. Atac (NAL).

2. NAL Proposal #229: "A Proposal for Testing a Transition Radiation Detector at NAL," P. W. Alley, A. Bamberger, G. F. Dell, Jr., H. Uto, and Luke C. L. Yuan (BNL).