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STUDY OF MULTIPARTICLE PRODUCTION IN A ~~SMALL~~ 30" BUBBLE CHAMBER

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Study of Multiparticle Production in a Small Bubble Chamber

I. Abstract

We propose to study 60,000 inelastic interactions in a small ($\lesssim$ 80-inch) hydrogen chamber. We request four exposures of 15,000 interactions each, using both π^- and p as beam particles, at the two beam momenta 100 and 200 GeV/c. This requires 100,000 to 200,000 pictures, depending on the size of the chamber used.

We couple this proposal to our strong recommendation that a small bubble chamber be available as soon as the machine provides experimental beams.

Experimenters

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II. Physics Justification

We believe this experiment is an important first step in trying to understand the dynamics of the obviously complicated multiparticle final states which make up the majority of the total hadronic cross section. About 85% of the inelastic cross section has ≥ 4 charged prongs at 200 GeV/c (See Fig. 1).

The predictions of various models (multiperipheral, multi-Regge, Limiting Fragmentation, Parton, etc.) can best be tested by varying both the beam energy and the beam particle. We believe it is important to do this in a single experiment in order to minimize the effects of systematic errors.

(A) The advantages of a bubble chamber

We reiterate these simply to emphasize that the properties of a bubble chamber are particularly well suited to the physics we are proposing to do.

(1) The bubble can record many tracks with 4π solid angle and 100% efficiency, independent of the number of tracks.

(2) It is easy to count tracks in a bubble chamber with 1 mrad angular resolution. It can even record two fast tracks practically on top of each other by showing a double ionization density.

(3) It records the sign of the charge for all tracks with momentum ≤ 10 GeV/c, and charge conservation can be used to infer the total charge of faster tracks. These first three properties are difficult to achieve with non-continuous devices such as wire chambers and the difficulty increases rapidly with increasing multiplicity.

(4) One obtains accurate measurements of angles and momenta for tracks with momentum $\lesssim$ 10 GeV/c, and good angular measurements for faster tracks.

(5) Ionization gives good mass discrimination for momenta < 1.0 GeV/c.

(6) The bubble chamber gives good visual information on short tracks, stopping tracks, and decaying tracks. This is particularly important in looking for slow protons and strange particles.

These last two properties are achieved better in small bubble chambers than in huge ones.

About half the tracks that get produced in these multibody events will have lab momenta of less than 5 GeV/c. The bubble chamber has no serious competitor for studying such groups of tracks, especially given the large production cross sections with which we are dealing.

(B) Specific physics questions

(1) General properties of multiparticle events. We first point out that detailed kinematical information will be available for all backward hemisphere tracks in the c.m. Fig. 2 shows the c.m. contours of constant lab momentum surfaces for 200 GeV/c beam momentum. The line P_π = 5 GeV/c covers essentially the whole backward hemisphere, if one recalls the typical exponential decrease of the cross sections with $P_\perp$. All particles below the line P_π = 5 will have lab momenta and an-

gles accurately measured. Particles with momentum between 5 and 10 GeV/c will be less accurately measured, depending on the size of the chamber. Particles to the right of the line $P_\pi = 10$ will have only their lab angles measured. However, since the great majority of the tracks are pions, their c.m. angles are very accurately given from their lab angles simply by putting $\beta_\pi = 1$ in the equation

$$\tan \theta^* = \frac{\sin \theta}{\gamma(\cos \theta - \beta/\beta_\pi)}$$

We also note that protons below the line $P_p = 1.0$ can be identified by bubble density. This region should contain most of the so-called "leading" protons. There will probably be 5-10 mb worth of events in which there is a single proton in this region along with a fast low-mass state in the forward hemisphere. We can get a rough measure of $d\sigma/dMdt$ for these events (t is measured very accurately from the momentum of the slow proton in the lab but M not very well) and correlate this with the momentum and angles of the fast tracks.

It is also evident from Fig. 2 that backward hemisphere K_1°, Λ°, $\Sigma^\pm$ and γ conversions can also be identified. The ambiguity of π^+ and p for tracks that have $P > 1.0$ does not pose a serious problem since the cross section for making π^+ with this lab momentum is about a factor of ten larger than that of a proton.

Given this complete kinematic information for

the backward hemisphere, a great deal can be learned about dynamics and various theories can be tested. We list here some possible questions that can be answered, realizing that they may not be the most relevant questions at the time the experiment is done. It's hard to beat a bubble chamber, however, when it comes to adaptibility to questions.

(a) Do the distributions of single slow particles emitted from a proton target depend on the type of beam particle?

(b) Do they depend on beam momentum P_o?

(c) How does the cross section $d\sigma/dmdt$ or $d\sigma/dP_\perp dP_\parallel$ for specific groups of particles of invariant mass m depend on m, P_o, beam particle?

(d) How are the answers to the above questions correlated to the number and angular distribution of the fast tracks in the lab?

(e) Do transverse momenta tend to lie in a plane, as suggested by Bjorken?

(f) What is the full c.m. angular distribution? How are the charges distributed?

(g) What roles do strange particles and low lying meson and baryon resonances play?

(2) Diffraction dissociation. Are events describable by a diffraction dissociation process? Can they be divided according to beam dissociation and target dissociation? What are the probabilities that one or the other or both occur?

(3) <u>The question of pionization</u>. The term pionization refers to the production of slow pions in the c.m., possibly following some sort of statistical or phase space distribution. Whether or not this occurs is unresolved at the present time. Measurements below 30 GeV/c generally show a maximum density near $P^* = 0$. An example of this is shown in Fig. 3. The interpretation of such a peak is not at all clear at present energies, however, dut to the fact that peripherally produced low-mass N^* states also tend to give pions predominantly in this region. Most present models predict that the pions not too close to $P^* = 0$ will be "stretched out" in the $\pm P^*_{\parallel}$ directions by an amount proportional to $\sqrt{P_0}$ as the beam momentum increases. Whether or not any pionization pions are left behind is an interesting question.

Generally speaking, one wants to investigate the detailed shape of a curve such as that shown in Fig. 3 as a function of beam momentum and beam particle. It is also important to check multiparticle correlations near $P^* = 0$, e.g., are slow c.m. pions produced in pairs with opposite charges, etc.?

Fig. 4 shows lab momentum space contours of surfaces of constant P^* for pions. We see from this that being able to measure lab momenta < 10 GeV/c covers the entire region inside the sphere $P^* = .5$ GeV/c, where most of the pionization is expected to occur. For $.5 < P^* < 1.0$ the entire backward

hemisphere is covered. At 100 GeV/c the $P_{\parallel}$ axis gets compressed by a factor $\approx 1/\sqrt{2}$, making the situation somewhat better. The bubble chamber is clearly well adapted to the study of pions from the region near $P^* = 0$.

(4) Charge exchange reactions. The cross sections for specific charge exchange channels such as $\pi^- p \rightarrow \pi^\circ n$, $pp \rightarrow \Delta^{++} n$ are clearly falling off very rapidly with beam momentum at present energies. Such channels will undoubtedly be too small to study in an untriggered bubble chamber at NAL energies. The behavior of summed topological charge exchange processes is less clear, however. We have in mind here such reactions as $\pi^- p \rightarrow$ (all neutrals), $\pi^- p \rightarrow X^\circ_{slow} + Y^\circ_{fast}$ or $pp \rightarrow \Delta^{++}$ + (anything). The bubble chamber is well suited to measuring, or at least setting upper limits on such cross sections. Similar questions of strangeness-exchange reactions can also be investigated. E.g., if a slow (lab) Λ° is produced, is it always accompanied by a slow K^+?

(5) Topological cross sections. The cross sections for producing n-charged particles in p-p collisions seem to be flattening out at around 30 GeV/c, as shown in Fig. 5. This behavior should be studied at NAL energies with good statistics as a function of $P_\circ$ and beam particle. The bubble chamber is the ideal device for such an inestigation.

III. Experimental arrangement.

We propose to have a small bubble chamber located such that unseparated π^- and p beams of 100 and 200 GeV/c could be brought to it. The chamber would be operated in the standard untriggered mode for this experiment and no use of auxiliary spectrometer magnets, counters, etc. is required. The beam should come in bursts of $\sim$ 10 particles in a time interval < 1 msec. A momentum bite of $\pm 1\%$ would suffice for this experiment, although use of such a chamber in other triggered experiments might well require much better beam resolution. There is also no need for rapid cycling in this experiment.

IV. Data reduction

The film would be analyzed by human scanner-measurers who would code every event as to number of prongs, charges, etc. and probably do some on-line digitizing of fast tracks and vertices. It is hoped that we will be able to do the measuring and bubble density of slow tracks using an automatic device such as POLLY. Data reduction can be accomplished in about 9-12 months.

V. Choice of bubble chamber

The experiment we describe here can be done in a chamber as small as the 30-inch, 30 kilogauss MURA chamber presently at ANL. In such a chamber we would use a 1 ft. fiducial region for interactions near the chamber entrance, leaving > 1 ft. at the exit to count and measure angles on fast forward tracks. With 10 tracks per picture this gives us our estimate of 200,000 pictures for 60,000 inelastic events. A 10 GeV/c track has a sagitta of 1 mm (3 bubble diameters) in 1 foot of track length.

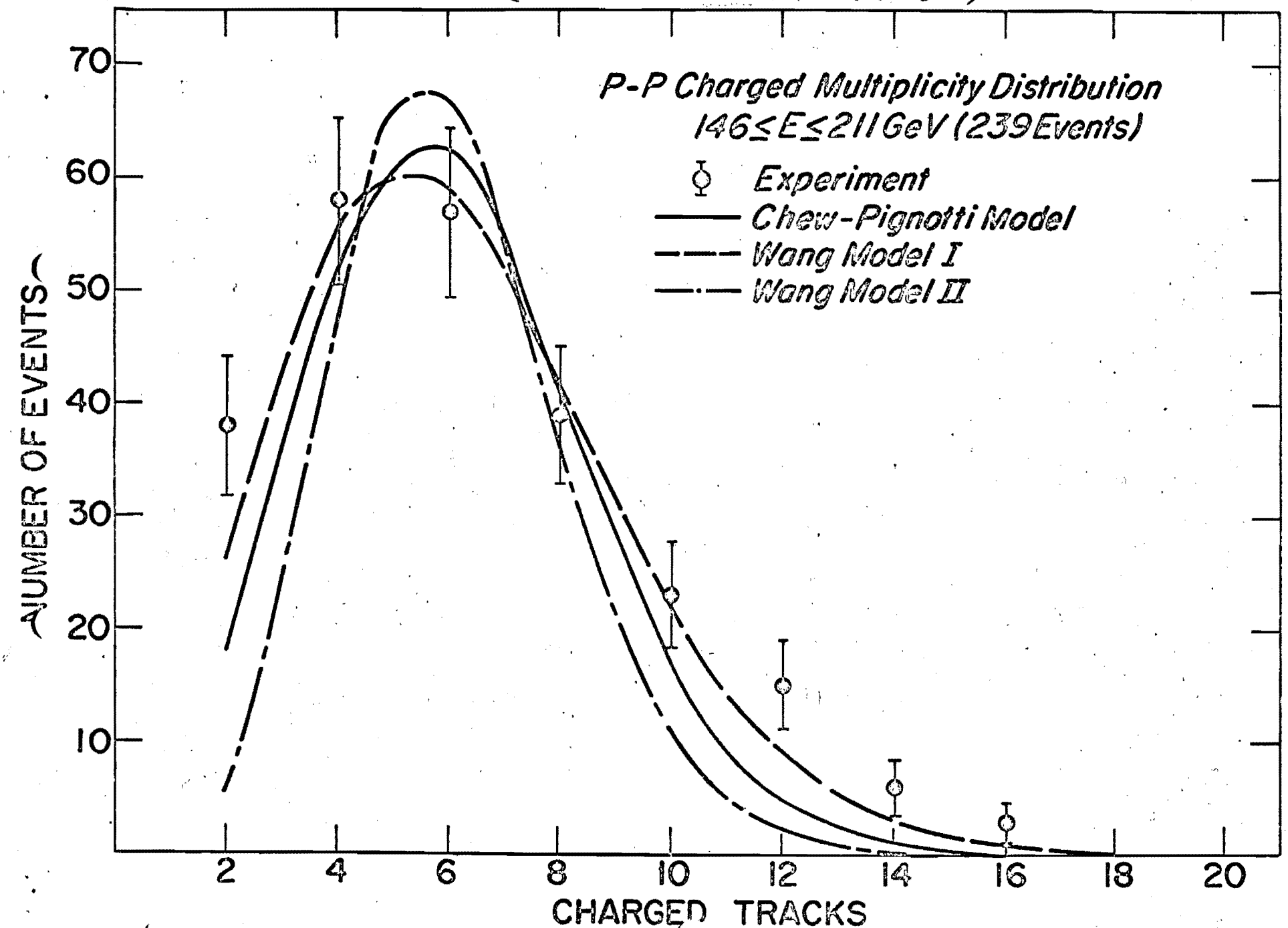
A larger chamber (e.g. BNL 80-inch) would have the advan-

tage of somewhat better momentum measurements but other factors such as cost of installation, adaptibility to other experiments requiring triggering etc. must be considered.

We believe that the small bubble chamber should not be viewed as just a one-shot device for the type of experiment we describe here, but that it will serve as a permanent facility to be used in conjunction with following spectrometers, wire chambers etc. in more complicated experiments. (See, for example, our proposal entitled "Study of Low-mass Peripheral States in a Small Triggered Bubble Chamber.")

Fig. 1

From K.N. Erickson, thesis, Colo. State Univ.
(Also Published as U. of Mich., Tech. Report # UM HE 70-4)
(Available from L.W. Jones)



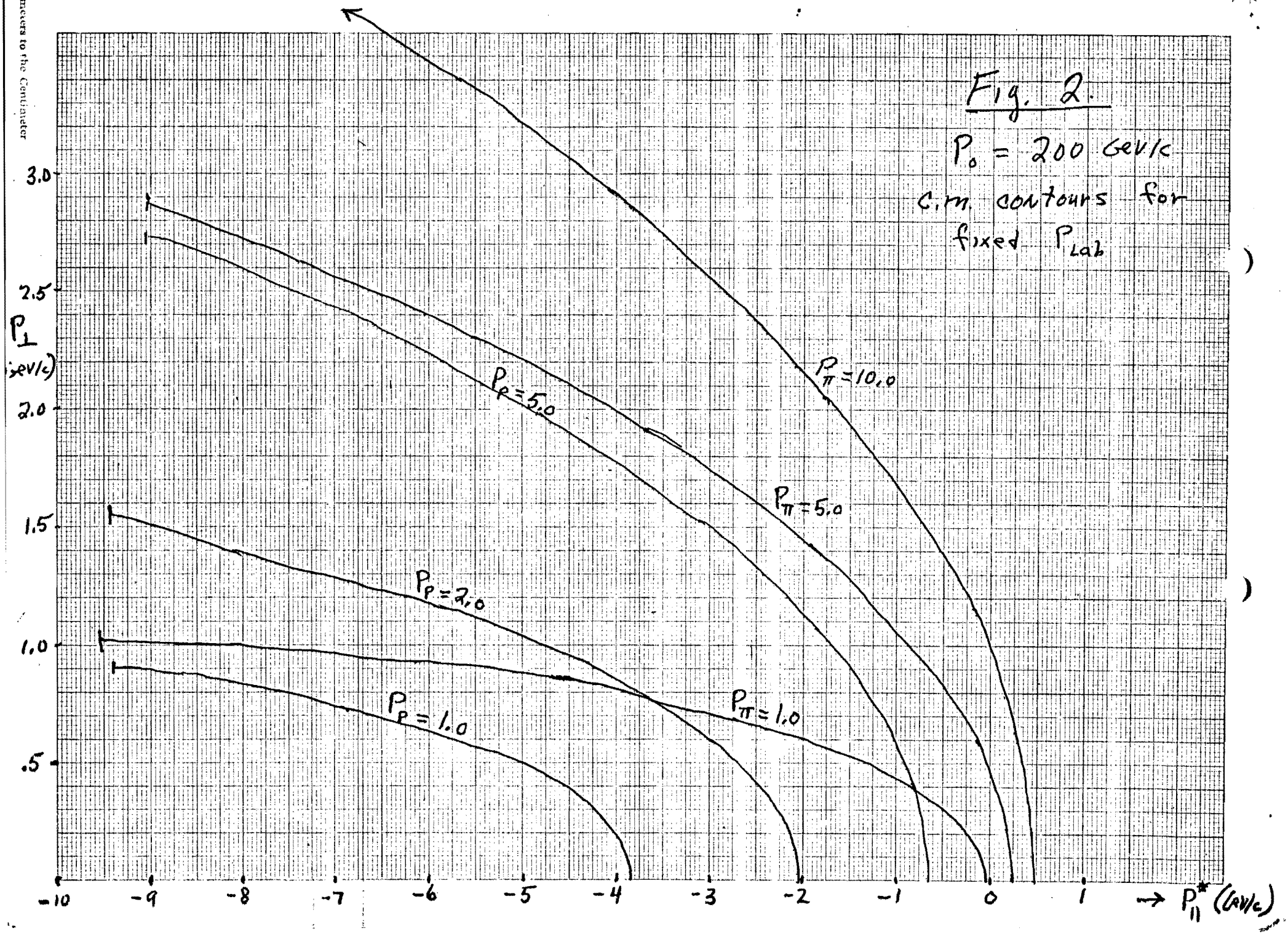


Fig. 2.
P_0 = 200 GeV/c
c.m. contours for fixed P_{Lab}
$P_\pi = 10.0$
$P_p = 5.0$
$P_\pi = 5.0$
$P_p = 2.0$
$P_\pi = 1.0$
$P_p = 1.0$
$P_\perp$ (GeV/c)
3.0
2.5
2.0
1.5
1.0
.5
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
→ $P_\parallel^*$ (GeV/c)

Fig. 3 (from A. Erwin, Proc. of Wisconsin meeting, April, 1970)

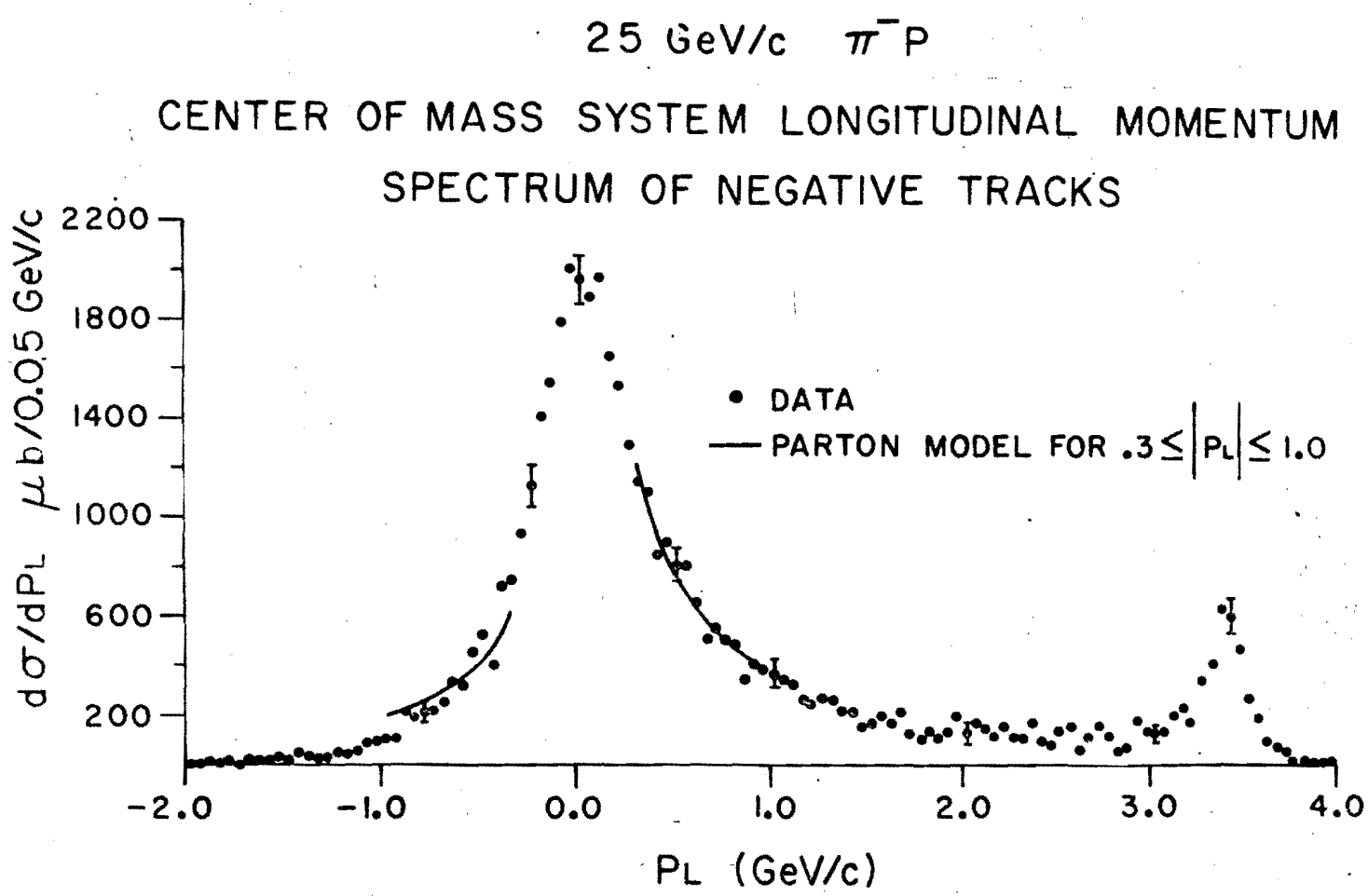


FIG. 13

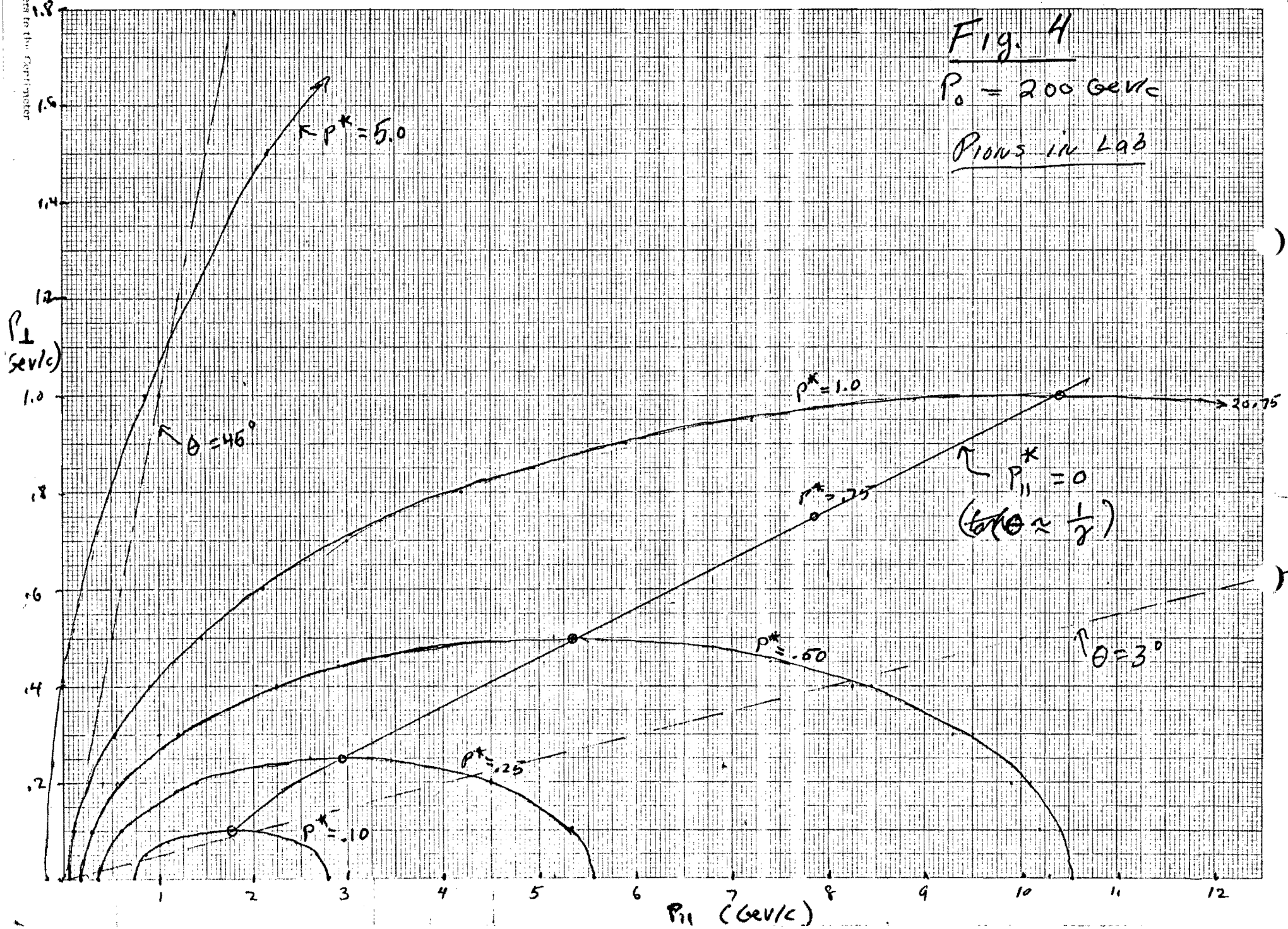


Fig. 4
$P_0 = 200$ GeV/c
Pions in Lab
$p^* = 5.0$
$\theta = 46°$
$p^* = 1.0$
$p^* = .75$
$p^* = .50$
$p^* = .25$
$p^* = .10$
$P_{\parallel}^* = 0$
$(\tan\theta \approx \frac{1}{\gamma})$
$\theta = 3°$
20.75
$P_\perp$ (GeV/c)
$P_{\parallel}$ (GeV/c)
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
1
2
3
4
5
6
7
8
9
10
11
12

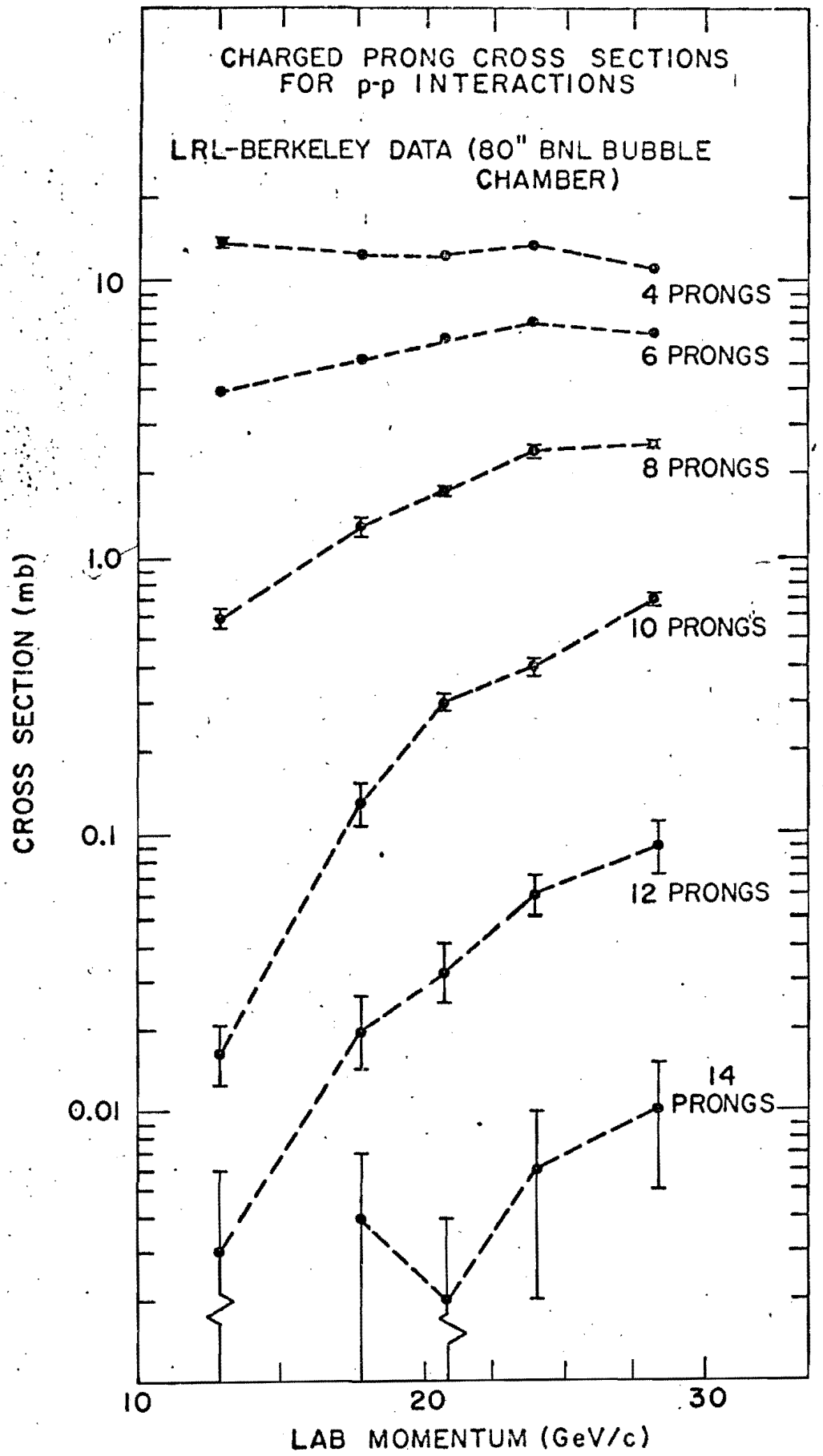



Fig. 5 (From Smith et al., PRL 23 1064 (1969))