NAL PROPOSAL No. 121 - A

Correspondent: R. L. Lander
Department of Physics
Univ. of Calif., Davis
Davis, California 95616

FTS/Off-net: 916 - 449-2000
752-1011

A PROPOSAL TO SEARCH FOR VERY HEAVY STRANGE PARTICLES USING A SMALL HYDROGEN BUBBLE CHAMBER

W. Ko, R. Lander, P. Yager, J. Erwin
J. H. Friedman, D. Faulkner, D. Pellett
University of California, Davis

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Addendum to Proposal No. 121

Lawrence Radiation Laboratory

and

University of California, Davis

Abstract

We propose to take 50,000 photos at each of four incident proton momenta, 100, 200, 300 and 400 GeV/c. These exposures will provide better data on the inclusive reactions than envisioned in the original proposal and will take no longer to measure because of the availability of the spiral reader. The search for heavy Λ^c's, quarks and monopoles will also be improved.

Names of Experimenters:

Ph.D.'s	Students
J. H. Friedman	J. Erwin
W. Ko	D. Faulkner
R. Lander	
D. Pellett	
P. Yager	

Date: May 10, 1971

Name of Correspondent: R. L. Lander

INTRODUCTION

Proposal 121 originally estimated that first results would be obtained within 3 to 6 months after the exposure date. That time estimate has now been reduced to a few weeks by our having arranged to use the LRL spiral reader facility for measurements. This speedup will not in any way reduce the charged particle multiplicity information or the momentum distribution information described in the original proposal. However, since the analysis time is so short now, it seems feasible to expand the proposal to include more than one incident energy. We will then be able to determine multiplicities and momenta spectra as a function of beam momentum in one experiment, with one consistent set of analysis procedures for all incident momenta.

Therefore, we propose to take 50,000 photos each at 100, 200, 300 and 400 GeV incident proton energies.

PHYSICS

The kind of information that one could expect to obtain from small bubble chamber exposures to NAL proton beams has been clear for some time now, namely charged particle multiplicity distributions, the average multiplicity as a function of $\ell n(S)$, and the lower end of the laboratory momentum spectra, which for pp collisions are by symmetry equivalent to the high momenta. In fact, as we describe below, because of the limited transverse momentum distribution, one obtains all but a very small fraction of the single particle differential cross sections in the center of mass for pp collisions.

The original proposal pointed out that backward particles in the center of mass would be slow in the laboratory and therefore would be measurable. We now show below in more detail the explicit kinematics. Figure R5-2 is taken from the Berkeley High Energy Physics Study, Summer 1961. (UCRL-10022). The shaded portions of Figure R5-2 represents the pions and protons emitted backward in the center of mass and having less than 1 GeV/c of transverse momentum. It is seen that at 90 GeV/c incident momentum all of those backward secondaries have less than 9 GeV/c in the laboratory and can therefore adequately be measured. The 1 GeV/c transverse momentum restriction is not serious at all, since nearly all of the particles will have much less than this. We have made similar calculations for 100, 200, 300 and 400 GeV/c incident momenta and find that for laboratory momenta below ∿9 GeV/c we can obtain the following data:

(1) $\frac{d^2\sigma}{dP_L d(P_T^2)}$ for $p+p \to V^o$ + anything, where $V^o \equiv K^o$ or Λ^o, as well as any <u>new</u> heavy Λ^o's. For the $\Lambda^o(1115)$, the entire backward center of mass longitudinal momentum range can be searched, with the (weak) restriction that $P_T \leq 1.0$ GeV/c at 100 GeV/c, for example.

(2) $\frac{d^2\sigma}{dP_L (P_T^2)}$ for $p+p \to \pi^-$ + anything over the entire center of mass distribution with $P_T <$ [illegible] .86, .70, .60 GeV/c for an incident momentum of 100, 200, 300, 400 GeV/c, respectively.

(3) $\frac{d^2\sigma}{dP_L d(P_T^2)}$ for $\begin{Bmatrix} p+p \to \pi^+ + \text{anything} \\ p+p \to p^+ + \text{anything} \end{Bmatrix}$ separately, except for the lower one-third of the $|P_L|$ spectrum in the center of mass. The lower one-third, however, may not be so interesting in the case of protons as it is in the case of π^- mesons, because the protons (at present energies) are known to favor larger values of $|P_L|$ in the center of mass. The separation of the proton and π^+ secondaries is done automatically by the spiral reader pulse height information. This separation is known to be reliable below ∿1 GeV/c in the laboratory momenta. It is, of course, this 1 GeV/c limitation that limits us to the upper two thirds of the $|P_L^*|$ spectrum. Figure 3 shows explicitly the regions of separation in the center of mass.

(4) $\frac{d^2\sigma}{dP_L d(P_T^2)}$ for $p+p \to$ the above reactions (1), (2), (3) can be obtained for each prong multiplicity separately. This kind of data provides tests of multiperipheral model calculations as well as bearing on the question of frames of forward-backward symmetry (quark-quark center of mass systems).

(5) Correlations among the particles of the above inclusive reactions, will also be obtained. Many possibilities exist here and we do not list them all. (See Ken Wilson,

"Some Experiments on Multiple Production", CLNS-131, November 1970.)

(6) Apart from any measurement of momentum at all, the frequency distribution of the charged particle multiplicity, n_{ch} at each incident momentum can be obtained. The distribution in n_{ch} can then be compared to, for example, a Poisson distribution. Also the average multiplicity as a function of incident momentum (or S) can be obtained and compared to a $\ell n(S)$ distribution.

(7) One can also, of course, hope to see quarks or monopoles, although this experiment is not the best one to put upper limits on their production cross sections. One-ninth minimum/ionizing tracks (or pairs of such tracks!) coming from a vertex can be identified for most of the tracks. (The transverse momentum is limited, so most tracks will not dip much.) Monopoles could be identified by their unusual trajectories (the magnetic field of the bubble chamber would act like a force field for them) as well as by their ionization.

Clearly there is much good physics to be obtained from the proposed exposure. We have only outlined some of the more obvious studies. The next question is how long the analysis would take, and what biases might exist.

ANALYSIS PROCEDURES

The time period for data reduction will be minimized by (1) using the LRL spiral reader for measuring and (2) splitting the film between two simultaneous scans. One scan will be a fast scan to locate the frame numbers and zone locations of events. The other scan will be designed to count the number of tracks in each event and to find events with peculiar characteristics (e.g., less than miminum ionizing tracks).

We show below that by these procedures we can, within 30 days of startup, have 900 events of known charged particle multiplicity at each of the four incident beam momenta, have 4,700 inelastic events measured at each of the four beam momenta, and have reached a 1.6 μb limit for the production of very heavy V^o particles.

These results are adequate to provide a rather good measure of the average charge multiplicity as a function of S, a rather good measure of the charged particle frequency distribution, and a fair test of limiting fragmentation and scaling behavior, and could detect "pionization" peaks or "fireball" dips in dN/dP_L.

These estimates are based on a spiral reader rate of 75 events/hour, 12 hours per day. This rate is a quite conservative one. There is no doubt that it can be maintained even after deducting losses for "crutch point" helping and minor breakdowns. It may be possible to have the reader for more than 12 hours, but we can at this time guarantee only twelve. (Details of the spiral reader measurements are discussed later on.)

To feed the spiral reader, the fast scan will locate the frames in which events exist and will provide the vertex location. Such information speeds the spiral reader operation. Only the frame number and a two-character zone number need be recorded. We expect therefore a rate of 200 frames per hour. We have achieved a sustained rate of 150 frames per hour on more difficult film (K^+ deuterium, limited topologies), so we are confident of the 200 figure. One scan table operating 8 hours per day can thus match the spiral reader.

The other scan will proceed simultaneously. There the scanner will not only find the events, but will record the number of tracks in each event. Counting the tracks will take the most time, but will not, we think, be very difficult. First, if we may believe the Echo Lake cosmic ray experiment, the average inelastic charged multiplicity at 400 GeV will be only $\sim$6.6. This average is also what one would get by $\ell n(S)$ scaling of present accelerator energies, approximately. Thus the numbers of high multiplicity events (8, 10, 12) will not be so large (14%, 9%, 5%, respectively). Further, one-half of these numbers will be tracks that go backward in the center of mass, by the symmetry of p-p interactions. For these tracks the laboratory angles will be large. For example, at 400 GeV/c the peak of the transverse momentum distribution (~300 MeV/c) has a laboratory angle greater than ~25 milliradians no matter what the backward longitudinal momentum in the center of mass. Twenty-five milliradians means a 12 mm displacement in 50 cm. Thus essentially all of the backward center of mass tracks will be well distinguished. We are now reduced to considering not 8, 10 and 12 tracks, for example, but only 4, 5, and 6. Most of these will be pions and will therefore have low longitudinal momentum in the center of mass, and consequently relatively longer laboratory angles. Thus relatively few tracks in any interaction will have extremely large laboratory momenta. Some will however. Consider one very likely source, $\Delta^{++}(1236)$ production and decay to $p+\pi^+$. Assume a 200 GeV/c Δ^{++}. The maximum transverse momentum from the decay is 230 MeV/c. Such a decay pion would be emitted at an angle of $\sim .23/25.0$ 50 = 9 mrad 4.5 mr. with respect to the Δ^{++} direction. That angle would give a 4.5 mm separation in 50 cm, or about 9 track widths. (An additional millimeter would come from the proton emission angle.) Averaging over the $1+3\cos^2\theta$ decay distribution will reduce the average separation to about 5 track widths, still appreciable. In addition, the why 25 GeV/c 25 GeV/c π^+ would bend about 20 mr in 50 cm of 32 K gauss field, giving a displacement of ~ 5 mm or 10 track widths at 50 cm from the vertex. Such displacements are more than adequate to enable the scanner to detect the tracks. Of course, in any one view (film strip) there can be projection overlap, but the other view will resolve those ambiguities. Finally we note that when two tracks do exactly overlap, their bubble density looks twice minimum (if both are minimum, as most of the forward tracks will be) and hence the scanner will be alerted to examine it closely.

These considerations, and even more that we do not set down here, lead us to believe that a rate of 50 frames per hour is reasonable for this track-count scan. Since every other frame will be blank, on the average, that rate means two minutes per event. But events with 6 or more total prongs will occur in only 25% of the frames, so there are actually about four minutes for every event of 6 prongs or greater. In 40 hours one scan table can thus produce about 900 inelastic events (assuming $\sigma_{inel} = 30$ mb). Assuming the cosmic ray results to be correct, these 900 events will have the following distribution: 128 2P, 260 4P, 260 6P, 128 8P, 80 10P, 44 12P, and smaller numbers of higher multiplicity events. These numbers are sufficient to get $\langle n_{ch} \rangle$ quite accurately and also provide a rather good measure of the distribution in n_{ch}. In four weeks, these numbers would be available at all four beam momenta.

We mention now some details of the spiral reader operation. The 75 event/hour rate means 6300 measured events in even 12-hour days. About 3/4 of these will be inelastic events, say 4700. The reader will pick up "hits" from all tracks in the picture, and it might be thought that the fast forward tracks, lying close together, would cause trouble for the reader even though the human scanner can detect them. Indeed, they might, but these are just the tracks that we do <u>not</u> need to <u>measure</u>. The large angle and/or low momentum tracks are the only ones we need to measure, and these are the tracks that the spiral reader can handle well. The other tracks will be rejected in the filtering process.

We expect no difficulty due to the ten beam tracks per picture. They would give difficulty only with fast forward secondaries, and we do not measure those. At 12 GeV/c, we have found no loss of events up to an incident beam intensity of sixteen tracks per picture. Thus we do not believe that 10 will cause trouble with the low momentum secondaries.

Bubble density information will be obtained automatically, of course, and will enable us to separate π^+ and P^+ below 1 GeV/c in the laboratory. This corresponds, for 100 GeV/c incident, to center of mass greater than ∿2.6 in the backward direction. Thus a large fraction (∿ 2/3) of the center of mass longitudinal momentum range will be susceptible to separation of π^+ and P^+.

The two vertical lines are drawn where the transverse momentum is 1 Gev/c, a momentum which we have seen from cosmic-ray data is already in the tail of the transverse-momentum distribution. Thus most of the particles will be observed in the very narrow strip going up the center of the figure.

Because there must be forward-backward symmetry in proton-proton interactions, one can learn all one needs to know about these interactions from a study of only those particles which come out in the backward region in the center-of-mass system. Lines drawn at about 8° on Fig. R5-1 separate the particles that were produced in the forward hemisphere in the c.m. system from those produced in the backward region. Figure R5-2 is a magnification of the low-momentum region of Fig. R5-1. It shows that if one confines oneself to a study of particles emitted backward in the c.m. system all particles with a transverse momentum less than 1 Gev/c (those in the shaded region) have a lab momentum of less than 10 Gev/c, a momentum which can be measured with an accuracy of 5% with present-day bubble chamber techniques. Even particles with transverse momenta of 3 Gev/c will have lab momenta less than 25 Gev/c. This means that one can obtain quite accurate momentum and angular distributions for particles from proton-proton interactions.

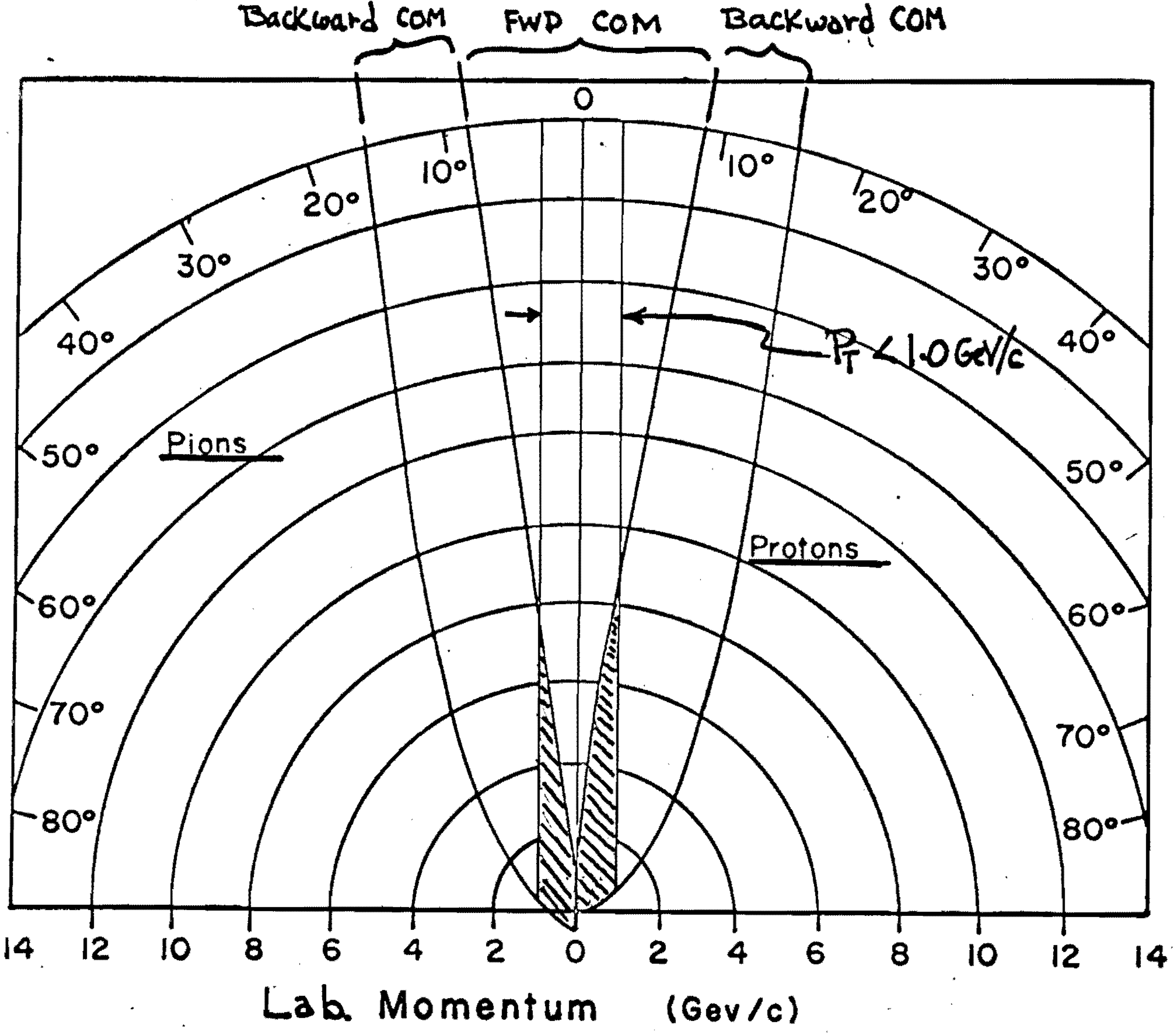

Fig. R5-2.

Berkeley High Energy Physics Study
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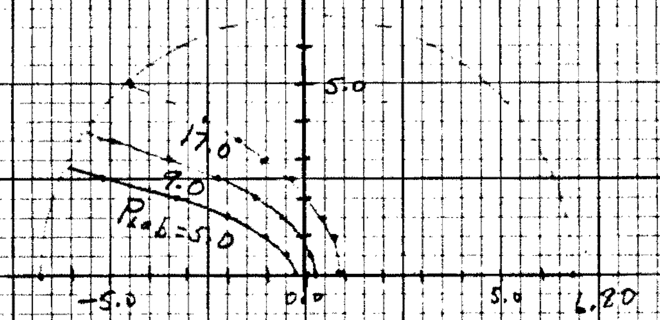
G. Lynch

P_T ↑ → P_L

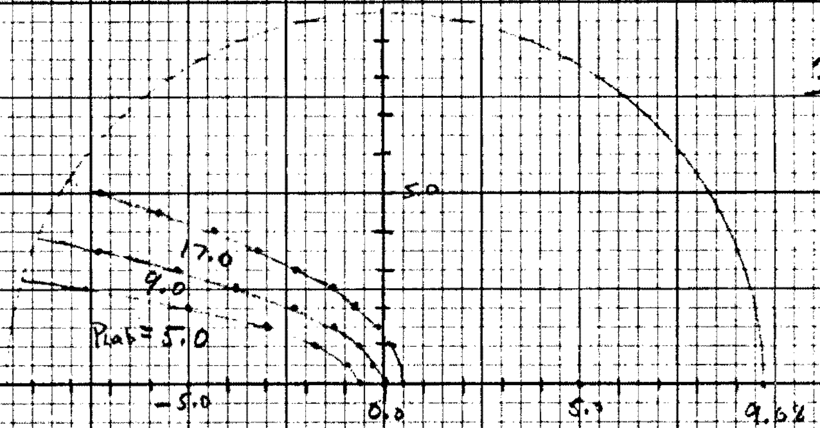
In the cm

Locii of protons with 5, 9 and 17 GeV/c lab momenta

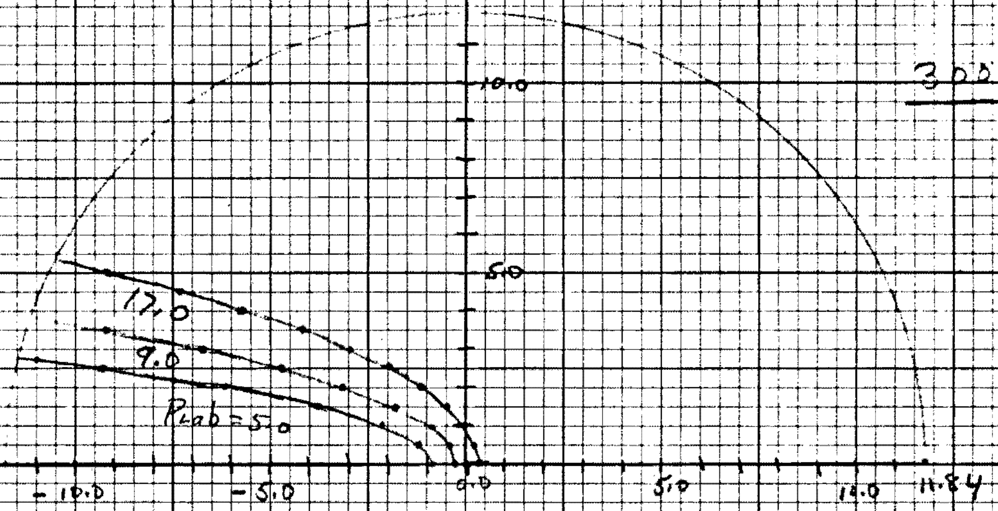
100 GeV/c



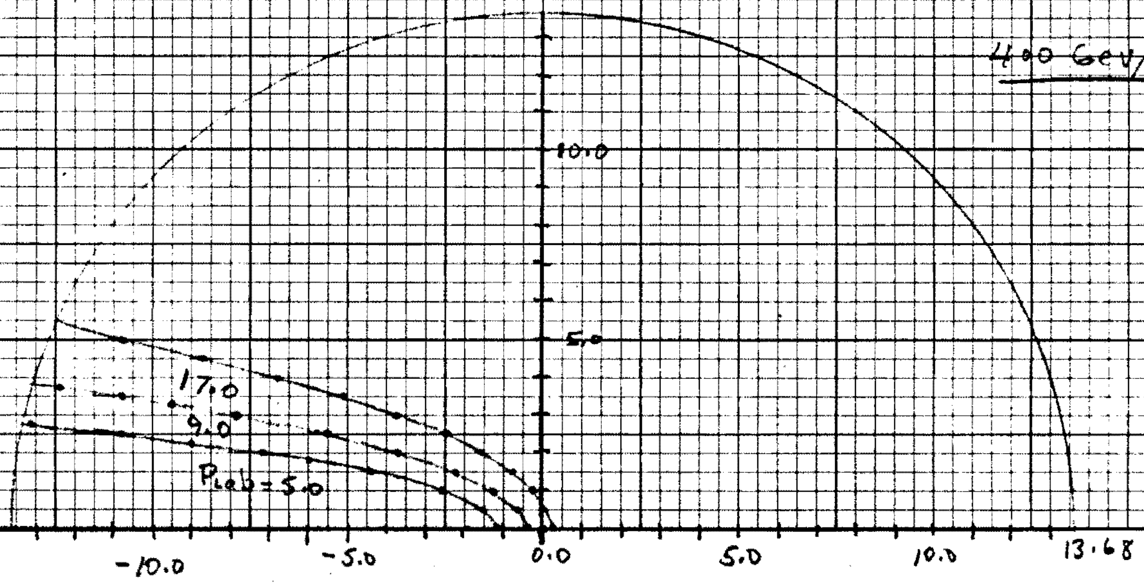
200 GeV/c



300 GeV/c



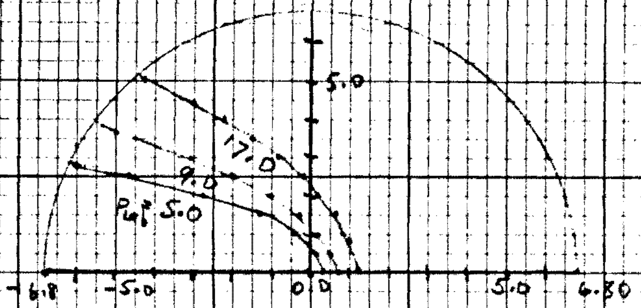
400 GeV/c



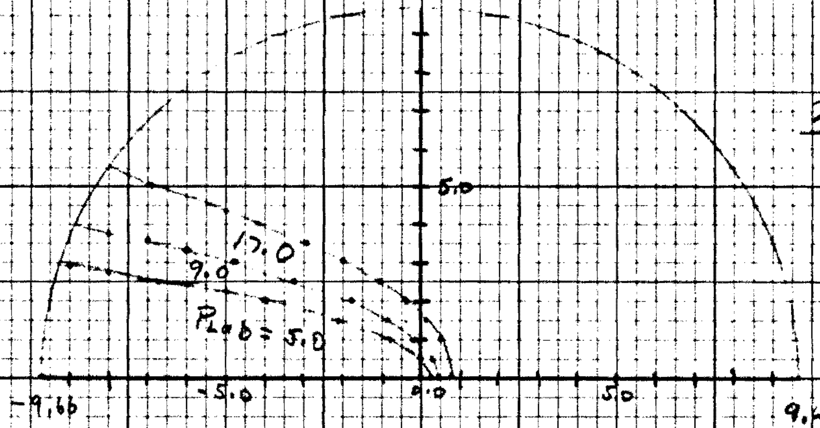
$P_T \uparrow \rightarrow P_L$

In the cm

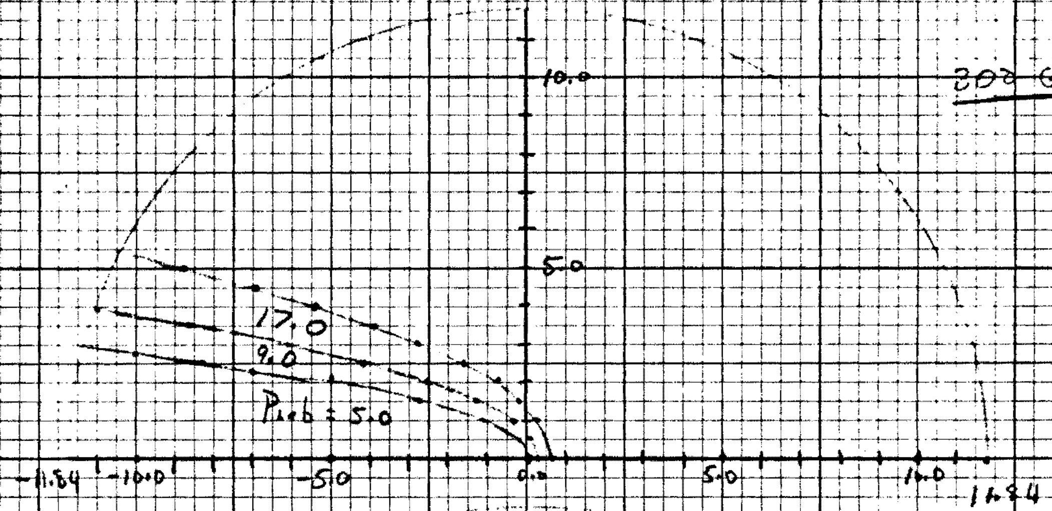
Loci of π's with 5, 9 and 17 GeV/c lab momenta



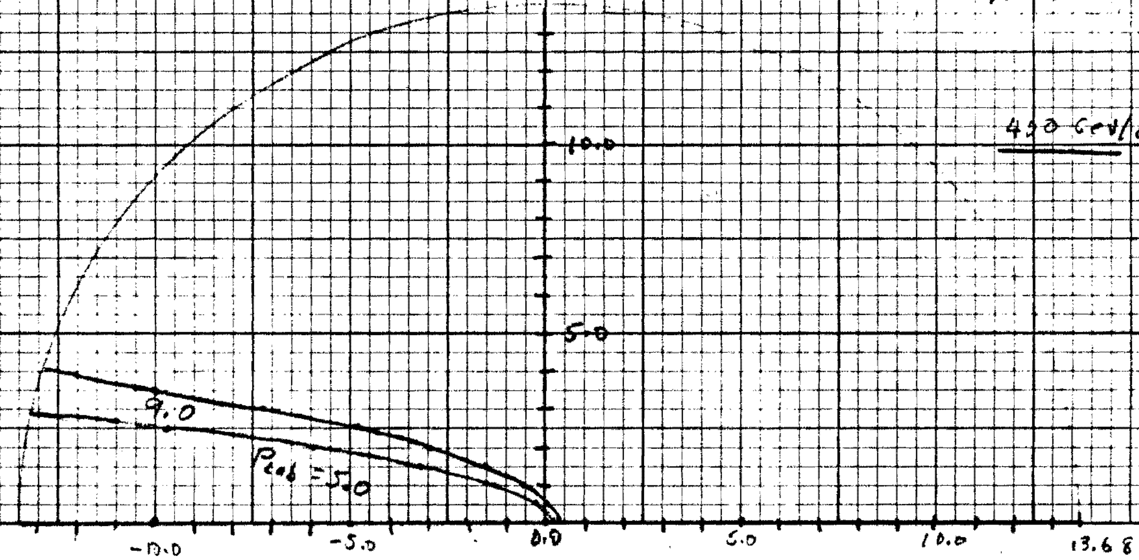
100 GeV/c incident lab momentum



200 GeV/c



300 GeV/c



450 GeV/c