NAL PROPOSAL NO. 284

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SURVEY OF PARTICLE PRODUCTION IN PROTON COLLISIONS AT NAL

(An Updated Version of NAL Proposal 63)

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D. Ritchie, D. Theriot, and J. K. Walker
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February 1974

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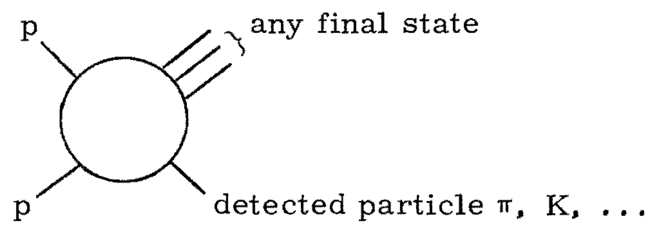
ABSTRACT

A spectrometer which can analyze up to 2.4 GeV/c particles is proposed for a high-energy survey at NAL of the reactions:

$$
\begin{aligned}
p + p \rightarrow\ & p + \text{anything} \\
& \bar{p} + \text{anything} \\
& \pi^{\pm} + \text{anything} \\
& K^{\pm} + \text{anything} \\
& \mu^{\pm} + \text{anything} \\
& e^{\pm} + \text{anything}
\end{aligned}
$$

A. General Discussion

We are interested in the reactions



Due to the forward-backward symmetry in the cms of the pp collision the detection of a particle produced backwards in the cms (low laboratory energy) or forwards in the cms (high laboratory energy) is equivalent. The importance of this fact at NAL was pointed out several years ago by D. Jovanovic. The experimental study of the yield of high energy particles at very small angles involve severe problems of particle identification and great precision in alignment. These problems become increasingly severe in the range 200 to 500 GeV. We propose, instead, to study the yield of particles in the backward hemisphere in the center of mass system. In this case, the angular alignment is trivial and particle identification for momenta less than 2.4 GeV/c is relatively easy.

Figure 1 is a plot of the kinematic relation between forward and backward production of pions and kaons in 200 GeV pp collisions. It is clear that detection of backward mesons limits the accessible range of forward pions to $\geq$ 40 GeV/c and for kaons $\geq$ 120 GeV/c. Extending the range for pions to less than 40 GeV/c will be done by detecting low energy forward going pions. The limit of a pion having zero longitudinal momentum in the center of mass corresponds to a forward going 1.4 GeV/c pion in 200 GeV pp collisions. The corresponding figure for 500 GeV pp collisions is 2.4 GeV/c forward pions which sets the upper limit of momentum analysis for the spectrometer. In a similar way, the range for kaons can be extended.

Figure 2 is a plot showing the relation between forward and backward production angles for several pion momenta.

B. Spectrometer

Figure 3 shows a schematic of the spectrometer layout. At the hydrogen target the vertical size of the proton beam is about 1 mm. Particles emitted from the target are focused in both planes by the two half quadrupoles to produce a parallel beam at the exit of the magnets. The trajectory of a particle is measured by 1.5" x 1.5" planes of multiwire proportional chambers with a spatial accuracy of $\simeq \pm 0.5$ mm. The momentum resolution of the spectrometer is about 1% and there is a total momentum acceptance of seven percent $\Delta p/p$. The solid angle of acceptance is 2×10^{-4} sr.

Particles are detected with thin scintillation counters and identified with four Cerenkov counters, time of flight, specific ionization loss, range and pulse height in an electromagnetic shower detector.

C. Brief Discussion of Reactions

1) $pp \rightarrow \pi^{\pm}$ + anything.

If we define $\theta_c = \frac{0.3}{p\ (\mathrm{GeV/c})}$ as the characteristic angle for the production of high energy secondaries of momentum p (GeV/c) then we will obtain information on the yield of these secondaries in the angular range $\theta_1 \rightarrow \theta_2$ where $\theta_1 << \theta_c << \theta_2$. The counting rates are very high. The existence and momentum distribution of low energy pions in the center of mass system (sometimes called pionization process) is of some current theoretical interest. This process should be able to be studied.

2) $pp \rightarrow K^{\pm}$ + anything.

Similar remarks to 1) can be applied here. Of course we will not be able to study kaons which have very low center of mass momenta.

By fitting the data to a reasonable particle production model (say that due to Hagedorn and Ranft) we will be able to extrapolate across the range of momenta in which particles do not get out of the target. This applies to all of the reactions studied.

3) $pp \rightarrow p$ + anything.

Perhaps, the dominant feature here is the diffractive elastic scattering. However, the deep inelastic proton spectrum will be used in various ways for secondary beams. This process has been extensively studied at CERN and BNL. In both cases the high energy outgoing proton was detected. Figure 4 shows the kinematics relationship between the slow recoil proton momentum and angle against the mass of the "anything" for 200 GeV pp collisions. We should be able to obtain useful proton spectra and interesting physics information from these mass distributions.

4) $pp \rightarrow \bar{p} + \text{anything}$

Predictions on antiproton yields at very high energy are particularly unreliable. These measurements will greatly assist in the design of secondary beams.

5) $pp \rightarrow \mu^{\pm} + \text{anything}$

$\rightarrow e^{\pm} + \text{anything}.$

It is likely that the detection of these particles is dominated by the decay, of π and K mesons. On the other hand it may be interesting to look at the yield of high transverse momentum ($\lesssim$ 2.4 GeV/c) leptons as a function of incident proton energy. Any threshold effect might signal the production of the intermediate boson followed by leptonic decay.

D. <u>Schedule</u>

The spectrometer is currently being installed in the P-West laboratory. The entire system including detectors, cabling, electronics, and computer should be ready to begin testing by late spring or early summer. At that time it is hoped that modifications to the proton beam line will have been completed. Data taking should be able to begin later in the summer of 1974.

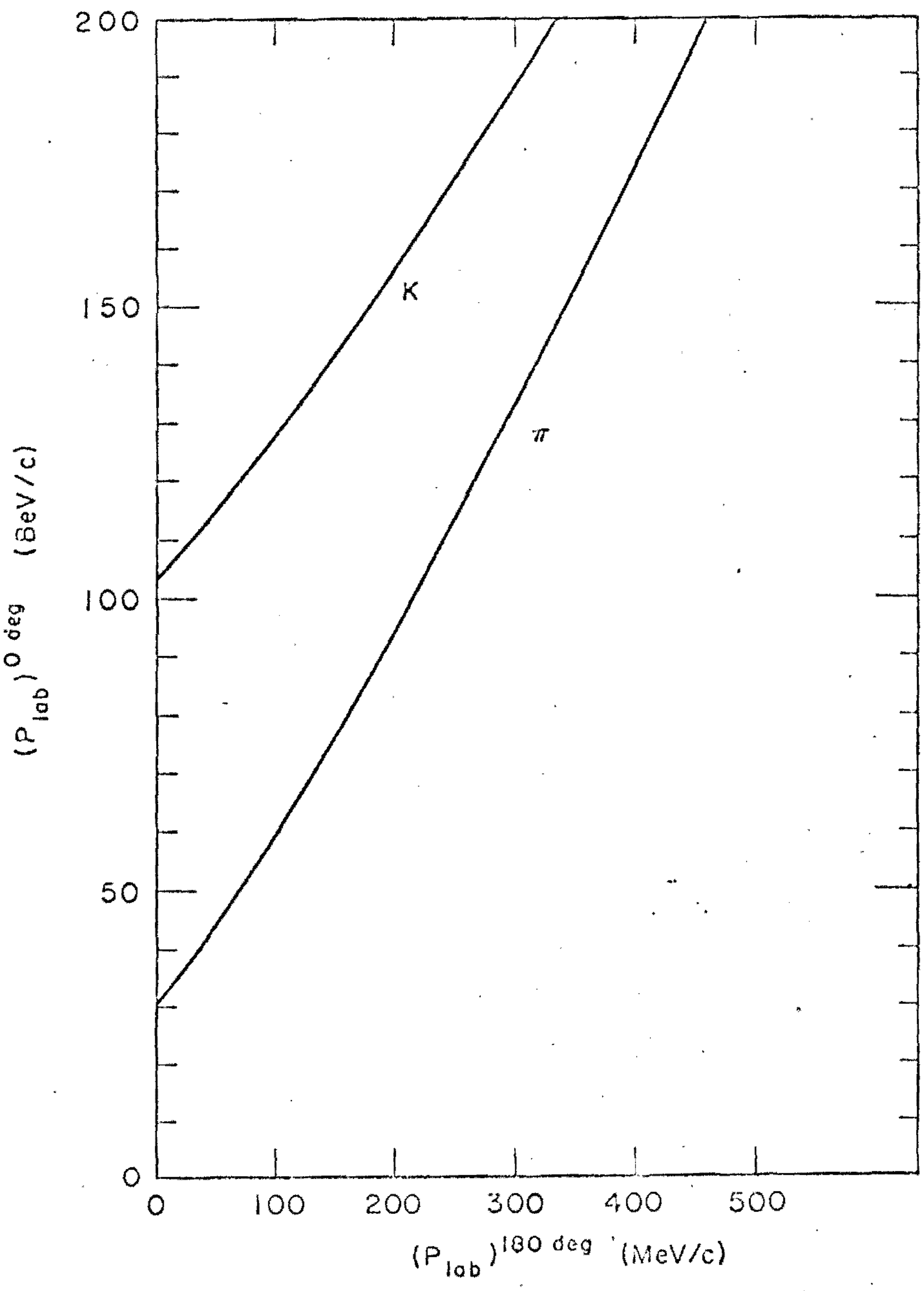


Fig. 1. Relation between particle momenta at 180 deg and particle momenta at 0 deg for pions and kaons produced in 200-BeV p-p collisions.

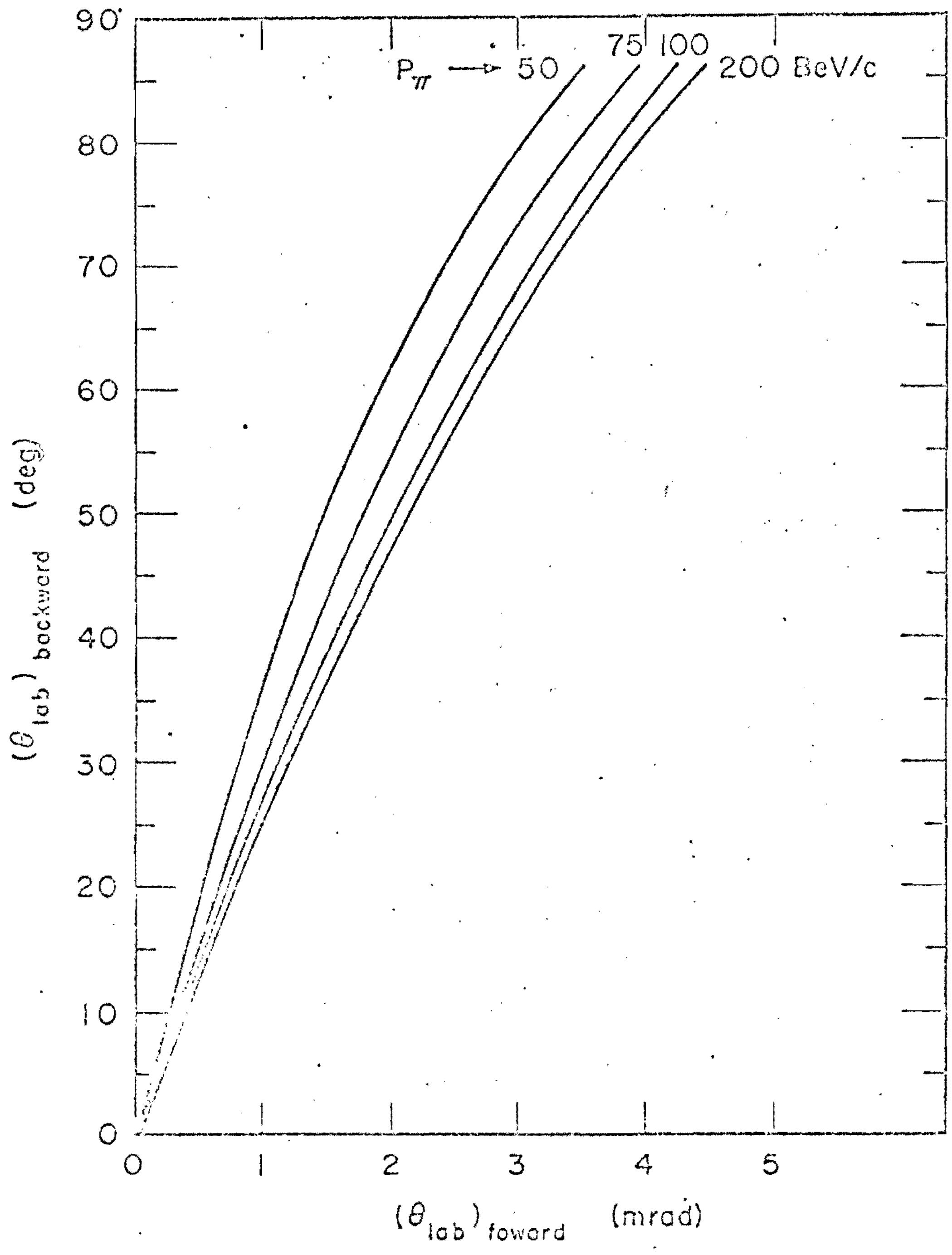
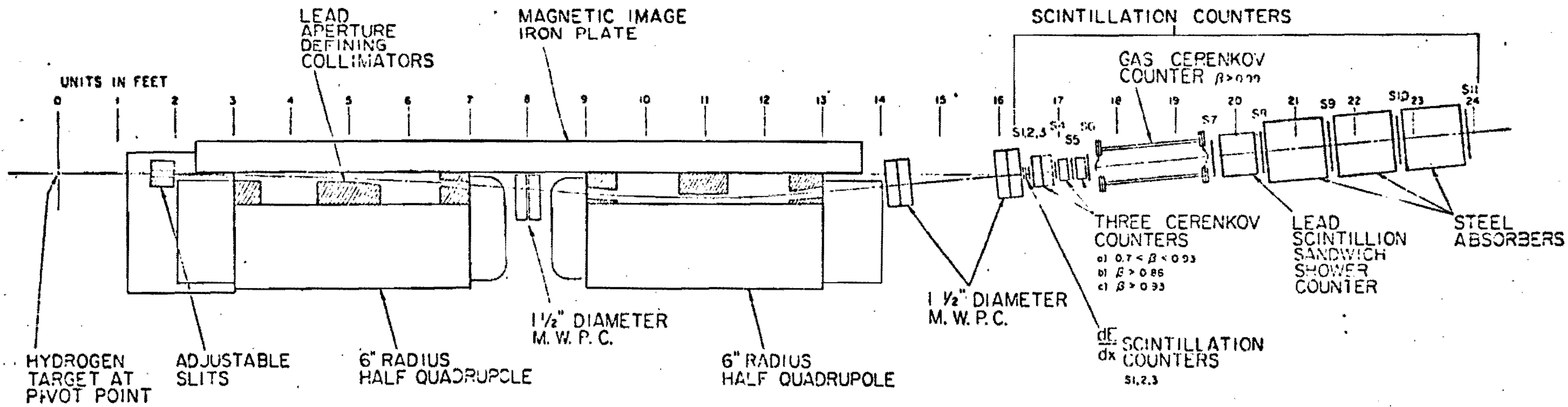


Fig. 3. Relation between forward and backward production angles for several pion momenta in symmetric p-p collisions.



2.4 GeV/c SPECTROMETER

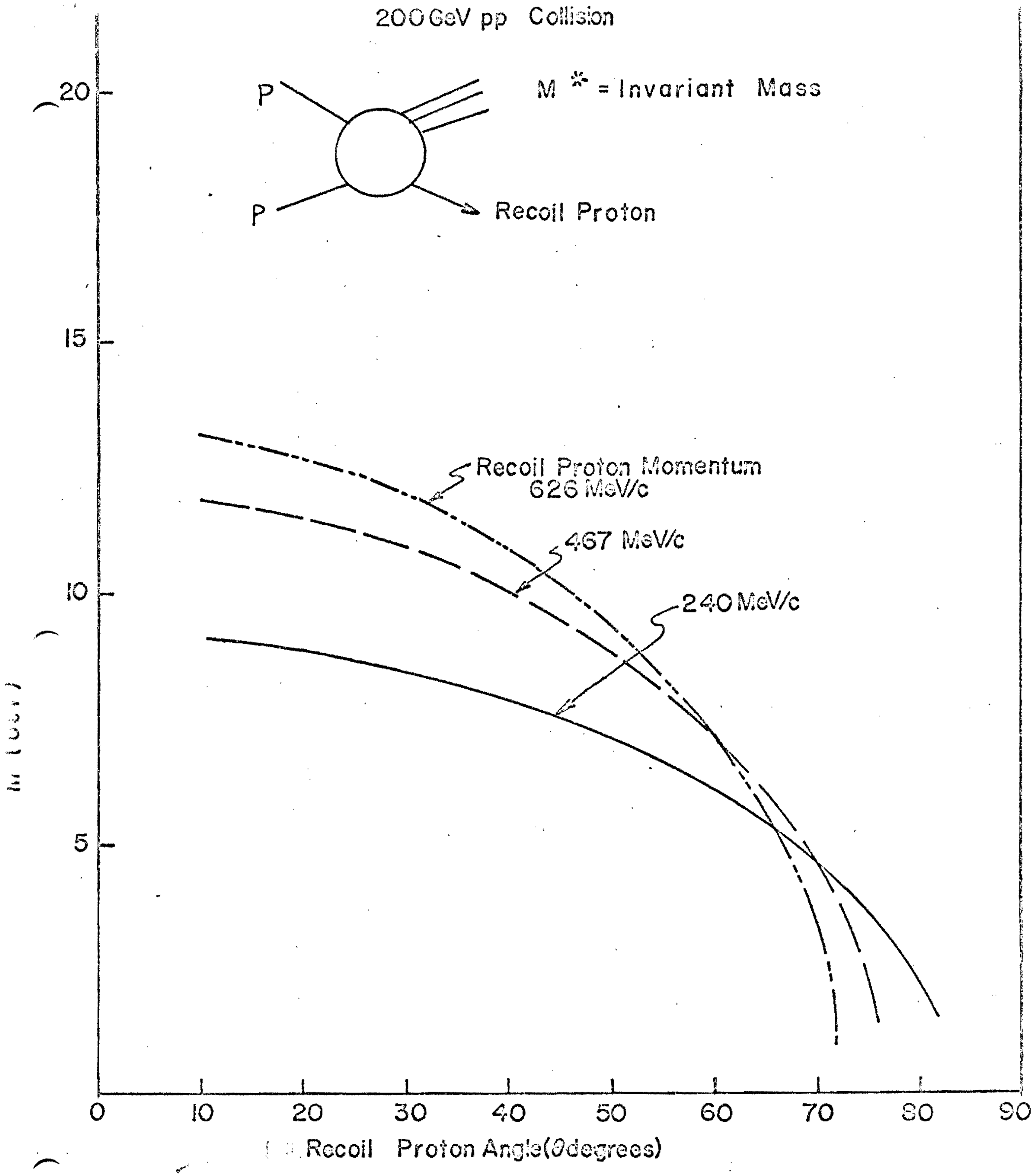

200 GeV pp Collision
M * = Invariant Mass
P
P
Recoil Proton
Recoil Proton Momentum 626 MeV/c
467 MeV/c
240 MeV/c
20
15
10
5
0
10
20
30
40
50
60
70
80
90
Recoil Proton Angle(θ degrees)

Fig. 4