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EXPERIMENTS ON PROTON-PROTON INTERACTIONS

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In another report I described the advantages of using a thin target station to study p-p interactions. In this report, I shall give a more detailed account of the experimental procedure involved in these experiments. At the present time, there appear to be three interesting kinds of experiments to be done at high transverse momentum:

1. Proton-proton elastic scattering at high $p_\perp^2$.
2. Proton-proton inelastic scattering at high $p_\perp^2$ ($p + p \rightarrow p + \text{anything}$).
3. Particle production in high-energy proton-proton collisions.

$$p + p \rightarrow \pi^\pm + \text{anything},$$

$$p + p \rightarrow K^\pm + \text{anything},$$

$$p + p \rightarrow \bar{p} + \text{anything}.$$

First we shall describe an experiment to measure p-p elastic scattering at high $p_\perp^2$. Since the cross section is small (10^{-31}-10^{-39} cm^2/sr) it is necessary to use the high intensity EPB itself. To minimize corrections due to nuclear interactions of the scattered protons in the target it is necessary to have a short (~1%) target. The target would be of liquid hydrogen about 3 in. long. The incident proton beam flux would be measured by the monitor scintillation telescopes, which are calibrated by radiochemical analysis or possibly a current loop. The experimental layout is shown in Fig. 1.

The two scattered protons are detected by a double arm spectrometer. I believe strongly that this will give better rejection of inelastic background and more reliable results than a single-arm spectrometer. Each of these spectrometers uses the steering magnet idea with a septum in close to the H_2 target. Then different $p_\perp^2$ are studied by varying the currents in the steering magnets and bending magnets without going into the EPB tunnel. Each proton is detected by a telescope of scintillation counters. A coincidence between both telescopes is called an event. The event rate per hour is given by

$$N(\text{events/hour}) = I_o(\rho N_o t)\frac{d\sigma}{d\Omega} \quad \Delta\Omega.$$

We choose the following parameters

I_o = $(3 \times 10^{13}$ protons/pulse$)(1000$ pulses/hour$) = 3 \times 10^{16}$ protons/hr

ρ = 0.07, $N_o = 6\times10^{23}$, $t \approx 10$ cm,

Thus, $\rho N_o t \approx 4\times10^{23}$

$\Delta\Omega_{c.m.} \approx 5 \times 10^{-4}$ to insure good background rejection.

Thus we get

$$N\frac{(\text{events})}{\text{hour}} = 3\times10^{16}(4\times10^{23})\left(\frac{d\sigma}{d\Omega}\right)_{c.m.}(5\times10^{-4})$$

$$= 6\times10^{36}\left(\frac{d\sigma}{d\Omega}\right)_{c.m.}$$

If we choose a minimum event rate of 1/10 of an event per hour, we get a minimum cross section of about

$$\left[\left(\frac{d\sigma}{d\Omega}\right)_{c.m.}\right]_{min} \approx 10^{-38}\ cm^2/sr.$$

This will allow one to go out to

$$\beta^2 p_\perp^2 = 15 \rightarrow 20\ (GeV/c)^2,$$

depending on whether the cross section breaks for a third time or not.

Next, we discuss together pp inelastic scattering at high $p_\perp^2$ and particle production in p-p collisions. These both use an identical spectrometer, with the Cerenkov counters set to detect either protons or π's, K^-'s and $\bar{p}$'s.

The identical EPB again strikes a hydrogen target and is normalized as for elastic scattering. Now a single produced particle is detected with a single-arm spectrometer. Again the steering magnet idea is used to allow changes in center-of-mass variables without moving the spectrometer. The layout of the experiment is similar to that shown in Fig. 1. The particles are detected by a telescope of scintillation counters and identified by Cerenkov counters (either DISC or threshold). The event rate is given by

$$\text{Events/hour} = I_o\,(\rho\, N_o t)\,\frac{d^2\sigma}{d\Omega\, dp}\,\Delta\Omega\Delta p.$$

All parameters are identical to elastic except that $\Delta\Omega\Delta p \approx 5\times10^{-5}$ GeV/c-sr. Thus, we can probably measure down to

$$\left[\left(\frac{d^2\sigma}{d\Omega\, dp}\right)_{c.m.}\right]_{min} \approx 10^{-37}\ \frac{cm^2}{GeV/c\ sr}.$$

It is clear that these inelastic cross sections will have a simpler form in the center-of-mass frame than the lab, so that we shall probably choose to vary center-of-mass variables, perhaps as shown in Fig. 2. For pp inelastic I believe that $p_{c.m.}$ and $\theta_{c.m.}$ are useful orthogonal variables; while for particle production, I believe that $p_\ell^{c.m.}$ and $p_\perp$ will turn out to be more useful orthogonal variables.

I believe that these inelastic experiments will become increasingly more interesting as people come to realize that at 200 GeV at least 39 of the 40 millibarns of the pp total cross section either is a high multiplicity inelastic event or is caused by one in the case of elastic diffraction scattering. Thus, it would be quite inappropriate in the study of strong interactions to avoid studying the processes which make up 39 of the 40 millibarns. Consequently, I believe that there will be a continuous stream of users hoping to study inelastic pp interactions at 200 GeV/c.

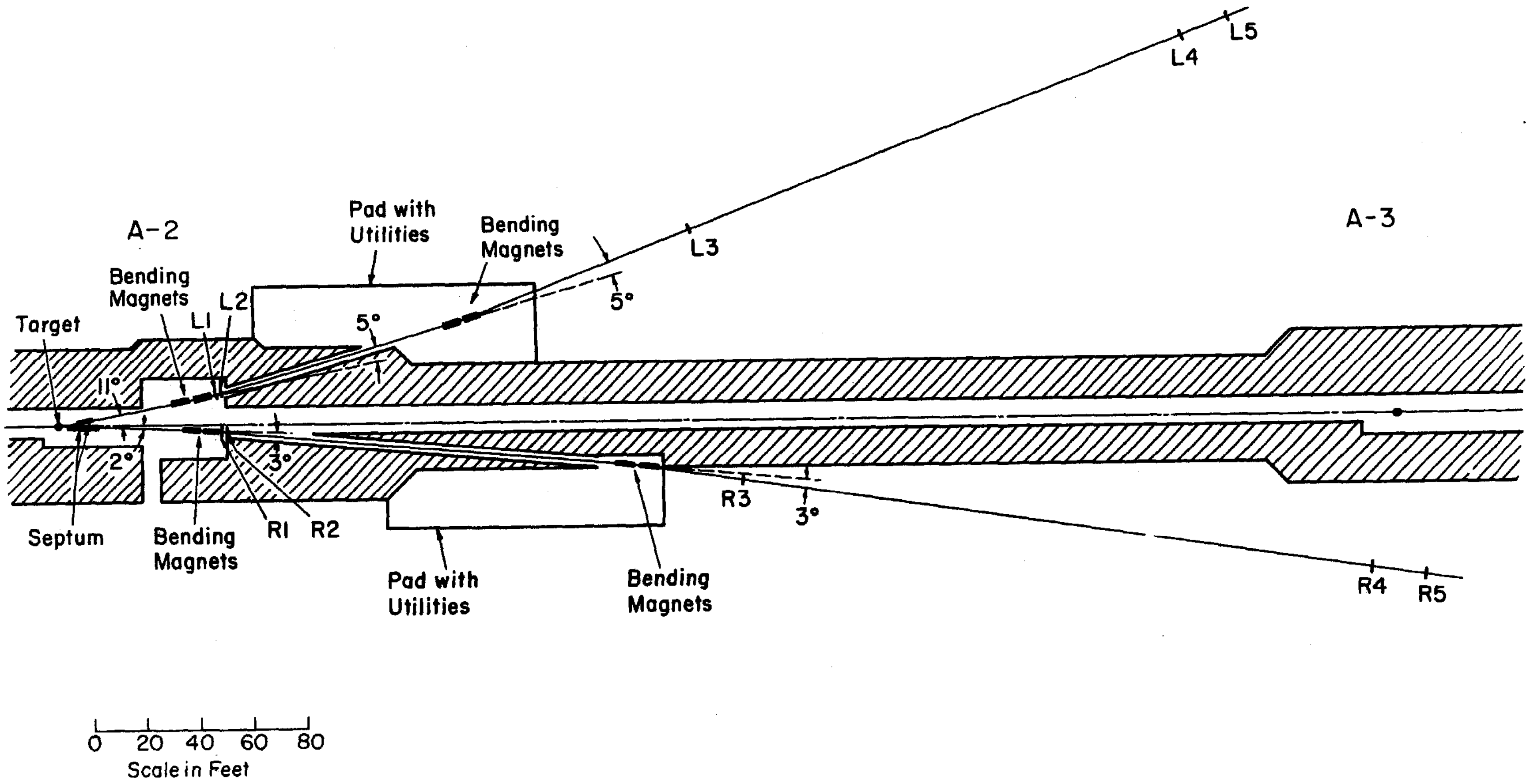

Fig. 1. Experiment on p-p elastic scattering at thin target station A-2.

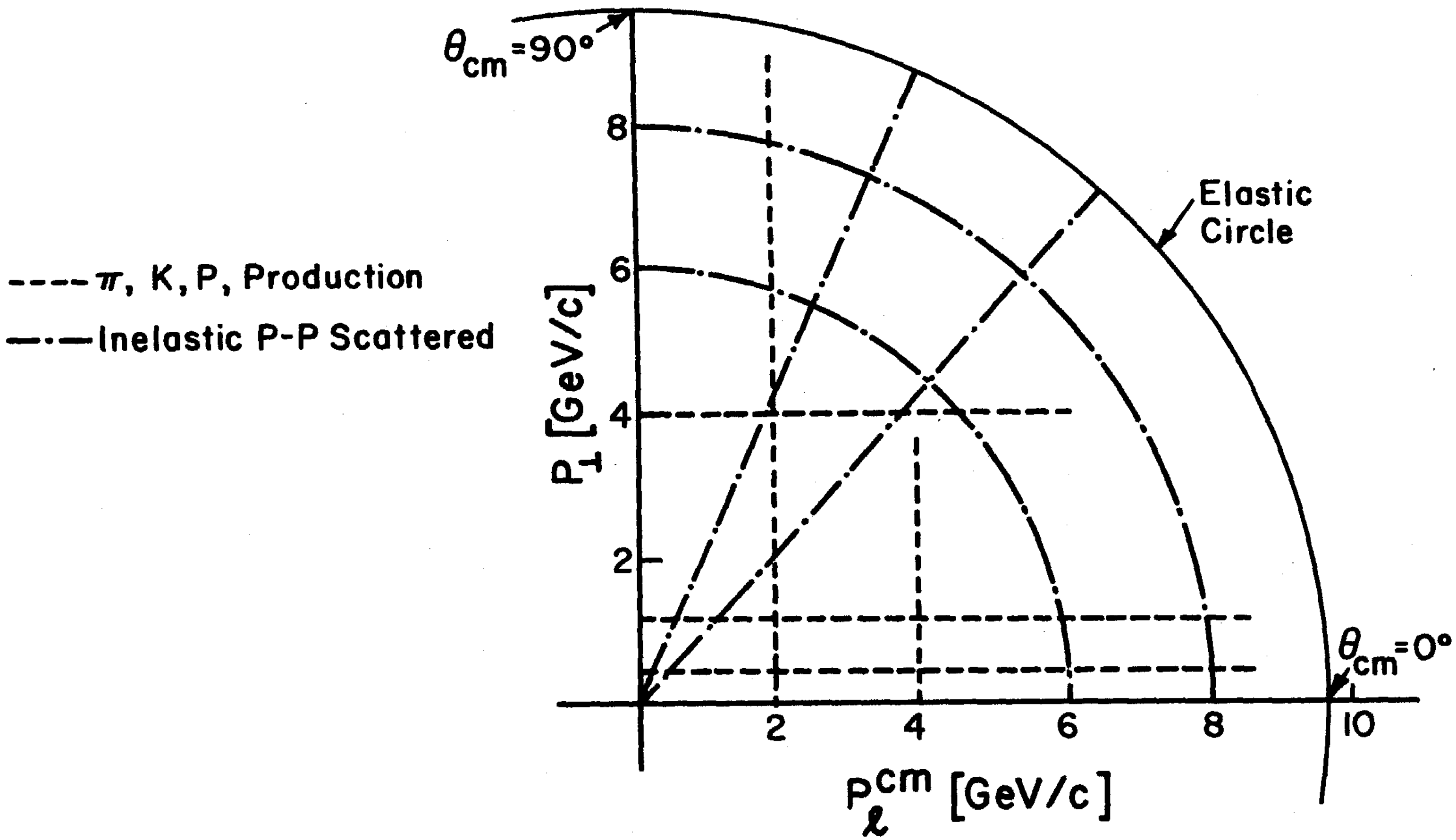

Fig. 2. Kinematic curves for elastic and inelastic p-p scattering.