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ACCELERATOR DEPARTMENT
Informal Report

INTERSECTING STORAGE ACCELERATOR NOTES

Revised Design of Large Angle Proton-Proton
Elastic Scattering for ISABELLE

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July 26, 1972

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REVISED DESIGN OF LARGE ANGLE PROTON-PROTON
ELASTIC SCATTERING FOR ISABELLE

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Theoretical Motivation

What is the energy dependence of large angle elastic scattering? At lower energies (up to 30-GeV protons), $d\sigma/dt$ for fixed momentum transfer can be fit by a $\frac{1}{s^2}$ dependence. Many theorists have speculated that $d\sigma/dt$ cannot drop faster than the fourth power of the e-p form factor. This happens to correspond to the measured $d\sigma/dt$ for p-p at 30 GeV/c. Hence the prediction is that above 30 GeV $d\sigma/dt$ is independent of energy. For example, at $-t = 7 \text{ GeV}^2$, $d\sigma/dt \approx 10^{-33} \text{ cm}^2/\text{GeV}^2$ for 30-GeV protons. An s^{-2} dependence would give a cross section 3000 times smaller. The predicted cross section is shown in Fig. 1. Another question concerns dips in the angular distribution. Is the dip at $t = 1.4 \text{ GeV}^2$ still there, and will new dips appear at "infinite" energy?

Experimental Layout

The highest luminosity insertion (Ib with $\mathcal{L} = 1.4 \times 10^{34} \text{ cm}^{-2}/\text{sec}$) is used to maximize reaction rate and allow the scattered protons to clear the primary beams more easily. The preferred crossing options uses the four dipoles in the order (-+-). The crossing configurations is:



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Solid angle is limited by the momentum transfer region corresponding to measurable cross sections. $d\sigma/d\omega$ for $p_{\perp} > 6$ GeV/c will be too small to give detectable rates. The geometry shown here covers $4 < -t < 25$ GeV². In this kinematical region the scattering angles are large enough for the scattered protons to clear the first set of quadrupoles. Magnetic analysis (or sweeping of lower energy secondaries) is achieved by the first dipoles close to the interacting region. Additional magnetic analysis and separation is achieved by using conventional septum magnets (could be 18 C 72's) just after the first dipoles. The first dipoles give the same 20 mr of bending as specified in Fig. IV - 3 of BNL 16716 or p. 10 of CRISP 72-5. The septum magnets have an aperture of 15 cm by 15 cm and give a bending of 9 mr.

Both scattered protons are detected by proportional chambers. The measured θ and ϕ of one proton determines the θ and ϕ of the other proton. Such a high resolution ($\Delta \theta \sim \pm 0.1$ mr) two-constraint fit should eliminate all background. For example, the 1236N* has a most probable pion decay angle of ~ 7 mr from the N* direction. Taking into account beam divergence, our angular resolution is ~ 20 times better in the horizontal plane and 10 times in the vertical plane; i.e., N* background under the elastic peak would be $\sim \frac{1}{200}$ if the N* cross section were the same (assuming no momentum analysis). In the case of a N* proton decay product, the most probable decay angle is ~ 1.2 mr and the angular resolution only gains a factor of 5. However the average proton momentum would be $\sim 15\%$ low. A $\pm 1\%$ momentum resolution would gain a factor of 30 in reducing this source of background. Considering the combined effect of momentum, angle, and charge discrimination, the N* contribution to the elastic peak would be $\sim 1\%$ of the total $PP \rightarrow PN^{*+}$ in the same momentum transfer region. If there is a N* background, it will show up as a measurable "pedestal" upon which the elastic peak sits. AGS and PS results show that N* two

body cross sections drop below the PP elastic at large t . Two additional constraints are the momentum resolutions of $\pm 1\%$ determined by the 29 mr of bend and the size of the interaction region. Hence there is an overall 4 constraint fit. The two momentum constraints can be incorporated into the trigger by placing hadron calorimeters behind the last proportional chambers. These calorimeters would have an aperture of 2 ft by 2 ft and should give $\sim 4\%$ energy resolution.

Estimate of Rates:

Consider the largest angle bin $-t = 20 \pm 5 \text{ Gev}^2$. In this bin

$$\frac{\Delta\phi}{2\pi} \approx .12 \text{ and } \Delta\omega \approx 8 \times 10^{-5} \text{ sr.}$$

The $G^4(t)$ prediction gives $\frac{d\sigma}{dt} = 10^{-37} \text{ cm}^2/\text{Gev}^2$. The ISABELLE lab cross section is $\frac{d\sigma}{d\omega} = \frac{p^2}{\pi} \frac{d\sigma}{dt} = 1.3 \times 10^{-33} \text{ cm}^2$. Note that there is a kinematical advantage to higher ISABELLE energies. The event rate is

$$N = \int \frac{d\sigma}{d\omega} \Delta\omega = (1.4 \times 10^{34}) (1.3 \times 10^{-33}) (8 \times 10^{-5}) = 15 \times 10^{-4}/\text{sec} \\ = 5.5 \text{ events/hr for } -t = 20 \text{ Gev}^2. \text{ One could go at least an order of magnitude lower in cross section.}$$

Estimate of Background:

All tracks will be assumed to be 200 Gev/c. If they do not trace back through the dipoles into the interacting region of $\sim 1 \text{ mm}$ diameter x 100 cm length they will be rejected. Lower momentum tracks can contribute to singles rate in the proportional wire chambers. We can use scaling of the inclusive production cross sections to estimate the singles rate in the proportional chambers (and the trigger scintillators). Recent CERN results of Allaby, et al show that $\frac{E d^2\sigma}{p^2 d\omega dp} \approx 2 \times 10^{-26} \text{ cm}^2/\text{sr GeV}^2$ in the region $.5 < x < 1$ for low p_{\perp} . They and others also show that for high p_{\perp} this should be multiplied by $e^{-6.3 p_{\perp}}$. The lowest p_{\perp} which can

reach our proportional chambers is $p_{\perp} \approx 1.3 \text{ GeV}/c$. For this $e^{-6.3 p_{\perp}} \approx \frac{1}{4 \times 10^3}$ or $\frac{d^2\sigma}{d\omega dp} \approx \frac{2 P \times 10^{-26}}{4 \times 10^3} \approx 10^{-27}$

The singles rate is

$$N = \int \frac{d^2\sigma}{d\omega dp} \Delta\omega \Delta p = (1.4 \times 10^{34}) (10^{-27}) (25 \times 10^{-5}) (50) = 1.7 \times 10^5/\text{sec}$$

This is a very safe singles rate for proportional chambers and scintillators. The hadron calorimeters reduce the singles rate in each arm to $\sim 2.5 \times 10^4/\text{sec}$. Assuming a coincidence time gate of 5 ns, the trigger rate due to accidentals would be $\sim 0.3/\text{sec}$ which is much less than the true event rate near the low t limit of 4 GeV^2 .

I wish to thank Alan Carroll, John Peoples and Klaus Pretzl for helpful discussions.

Fig. 1

Experimental results for PP elastic scattering showing energy dependence of $\frac{dG}{dt}$ from 3 to 24 GeV/c. The "limiting curve" $G^4(t)$ is also shown.

Fig. 2

Experimental layout using Insertion Ib parameters, M_1 is the normal dipole used to separate the two beams. M_2 is a septum magnet which gives additional bending to the scattered protons only. PC are proportional wire chambers.

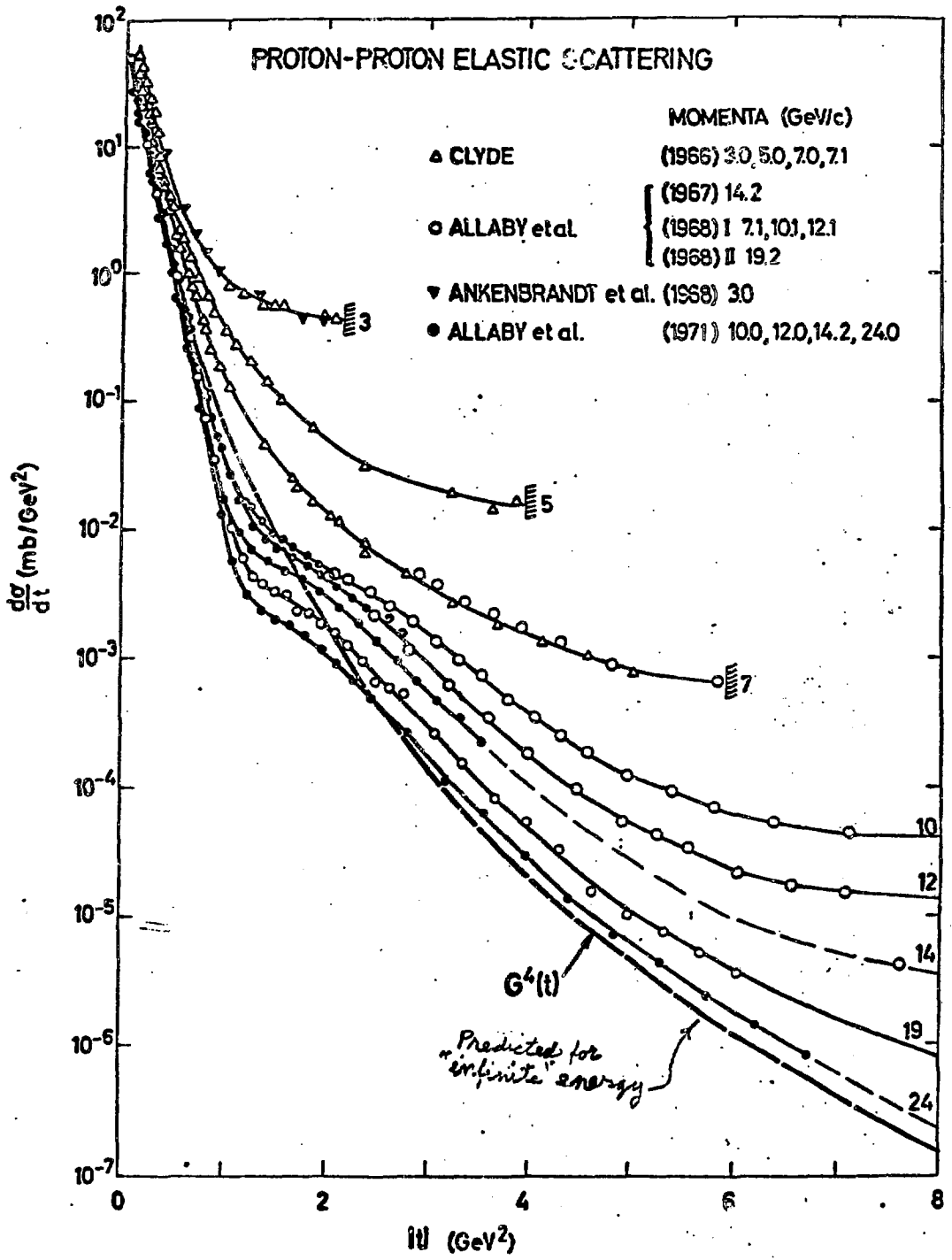


Fig. 1

200 x 200 GeV/c PP LARGE ANGLE ELASTIC
 $4 < -t < 25 \text{ GeV}^2$

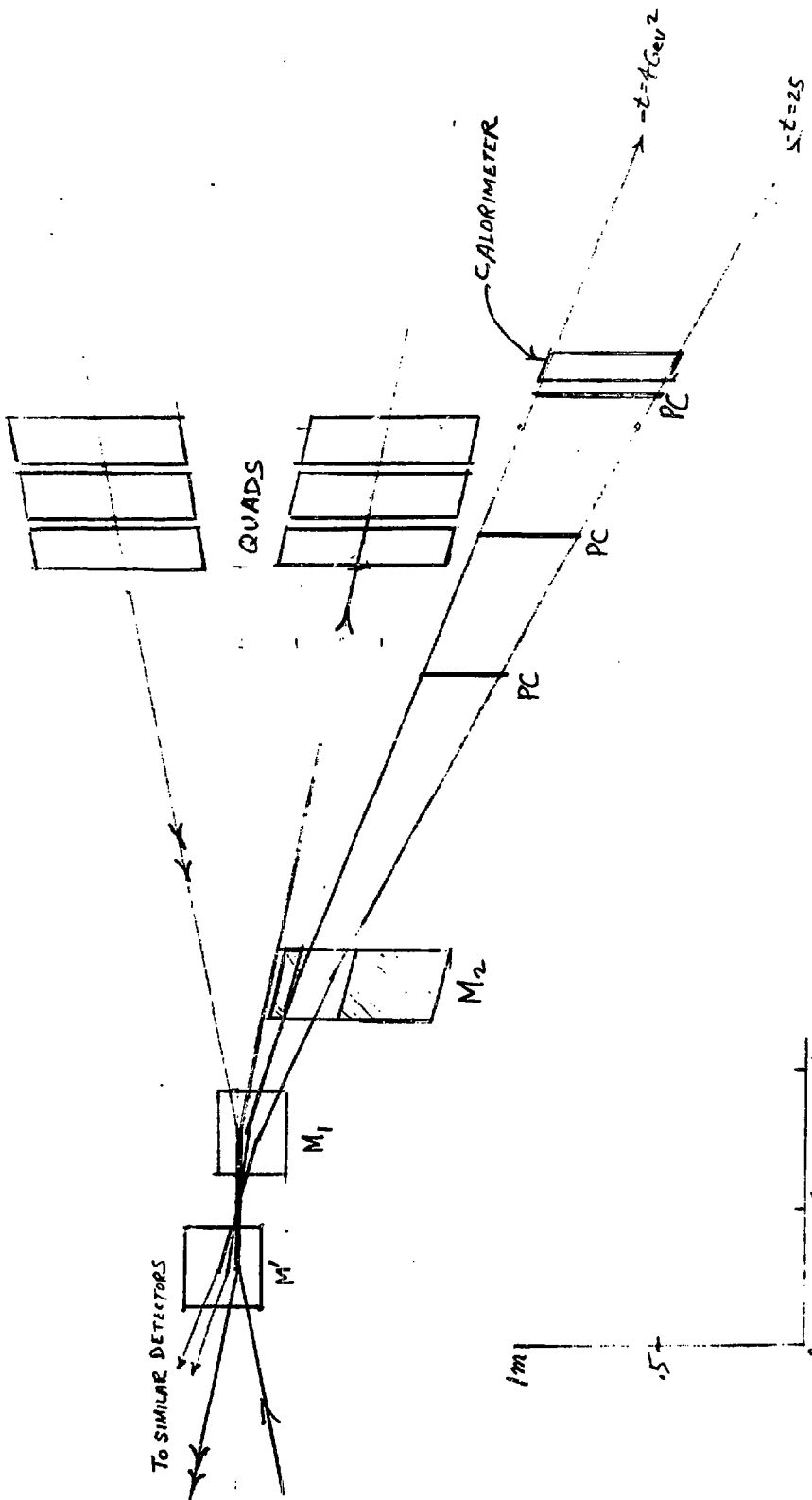


FIG. 2

SCALES