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[18]The angular dependence in pion production will tend to average out due to the Fermi motion of the initial proton. The width of the 3-3 resonance is comparable to the available $\pi$-$N$ phase space. Our final angular dependence in pion production was found to be almost entirely due to the interference of the two Pauli terms.
[19]The known $T=1$ final-state interactions have not been taken into account. Therefore, for small $Q$, even in the absence of a $T=2$ state, Fig. 3 does not represent what would be expected experimentally.

## LARGE ANGLE $p$-$p$ ELASTIC SCATTERING AT 30 BeV†

W. F. Baker, E. W. Jenkins, and A. L. Read
Brookhaven National Laboratory, Upton, New York

and

G. Cocconi,* V. T. Cocconi,* A. D. Krisch, J. Orear, R. Rubinstein, D. B. Scarl, and B. T. Ulrich
Laboratory of Nuclear Studies, Cornell University, Ithaca, New York
(Received 13 January 1964)

In a previous Letter[1] our group presented 18 elastic $p$-$p$ differential cross sections ranging in four-momentum-transfer squared from $-t=2.28$ to 19.65 $(\text{BeV}/c)^2$. The highest momentum transfers were at beam energies of about 20 BeV and scattering angles up to 90° in the center of mass. In a subsequent run at the Brookhaven AGS we have attempted to detect the elastic scattering of 30-BeV protons in the 90° region which would then be the highest momentum transfer currently obtainable. In this new run we succeeded in measuring 11 additional cross sections, two of which involved 30-BeV protons at center-of-mass angles near 90°. The highest momentum transfer achieved was $-t=24.4$ $(\text{BeV}/c)^2$ using a beam momentum of 30.9 BeV/$c$ and center-of-mass scattering angle of 82.4°. In units of inverse fermi squared, this momentum transfer is $q^2=630$ F$^{-2}$ or an interaction distance of $\hbar/q=4.0\times10^{-15}$ cm. The center-of-mass cross section was found to be $1.1\times10^{-36}$ cm$^2$/sr.

As in the previous run,[1] both scattered protons were magnetically analyzed and detected in coincidence. However, in the case of the two most difficult measurements, it was necessary to use quadrupole doublets with 8-inch diameter apertures in each telescope in order to increase the solid angle of acceptance without increasing counter sizes. This permitted an increase in coincidence rate without a corresponding increase in background due to accidental coincidences. Even so, with a laboratory solid angle of $3.5\times10^{-4}$ sr, the coincidence rate for elastic $p$-$p$ scatterings was about 2 per hour. Both the accidental coincidence rate and the background rate from the carbon in the polyethylene were measured to be about 10% of the effect.

The 11 cross sections corrected for carbon background and other systematics such as proton absorption in the scintillators are given in Ta-

Table I. The 11 $p$-$p$ elastic cross sections measured in this experiment.

| $-t$ $(\text{BeV}/c)^2$ | $P_0$ (BeV/$c$) | $\theta_{\text{c.m.}}$ (deg) | $(d\sigma/d\omega)_{\text{c.m.}}$ (cm$^2$/sr) | $X$ | Percent error in $d\sigma/d\omega$ and $X$ |
|---|---|---|---|---|---|
| 2.25[a] | 18.9[b] | 29.9[c] | $1.61\times10^{-30}$ | $7.31\times10^{-6}$ | +25, -20 |
| 3.80 | 24.9 | 33.8 | $1.16\times10^{-31}$ | $3.96\times10^{-7}$ | +25, -20 |
| 6.00 | 31.5 | 37.7 | $3.53\times10^{-33}$ | $9.42\times10^{-9}$ | +25, -20 |
| 11.56 | 19.6 | 70.2 | $2.82\times10^{-34}$ | $1.23\times10^{-9}$ | +30, -25 |
| 12.46 | 23.8 | 65.2 | $8.41\times10^{-35}$ | $3.01\times10^{-10}$ | +30, -25 |
| 13.94 | 21.9 | 73.1 | $6.90\times10^{-35}$ | $2.69\times10^{-10}$ | +30, -25 |
| 14.50 | 18.0 | 86.0 | $3.65\times10^{-34}$ | $1.74\times10^{-9}$ | +25, -20 |
| 15.06 | 26.6 | 68.1 | $1.46\times10^{-35}$ | $4.64\times10^{-11}$ | +30, -25 |
| 18.77 | 26.2 | 77.9 | $5.18\times10^{-36}$ | $1.67\times10^{-11}$ | +35, -30 |
| 20.38 | 31.8 | 72.8 | $9.20\times10^{-37}$ | $2.41\times10^{-12}$ | +100, -50 |
| 24.39 | 30.9 | 82.4 | $1.10\times10^{-36}$ | $3.00\times10^{-12}$ | +100, -50 |

[a]All squared four-momentum transfers, $t$, have an error of ±1 %.
[b]All internal beam momenta, $P_0$, have an error of ±1 %.
[c]All center-of-mass scattering angles have an error of ±0.2°.

ble I. The errors are the combined statistical and systematic errors. Further discussion of the corrections and experimental details are contained in our previous Letter.[1]

In Fig. 1 the resulting values of $X$ are plotted vs $t$ where

$$X = \frac{d\sigma/d\omega}{(d\sigma/d\omega)_0},$$

and the optical theorem is used to obtain

$$(d\sigma/d\omega)_0 = (k\sigma_T/4\pi)^2.$$

Since $t/t_{\text{max}} = 1 - \cos\theta_{\text{c.m.}}$, the dashed curves in Fig. 1 also serve as the angular distributions at fixed energy plotted against $\cos\theta_{\text{c.m.}}$. We note that the 30-BeV angular distribution appears similar in shape to the lower energy angular distributions. In the large angle region the 30-BeV points appear to be about a factor of 100 lower than the 20-BeV points.

We are indebted to the AGS staff for their invaluable cooperation and help with various aspects of this experiment. We also wish to thank Dr. J. Hudis for analysis of our targets.

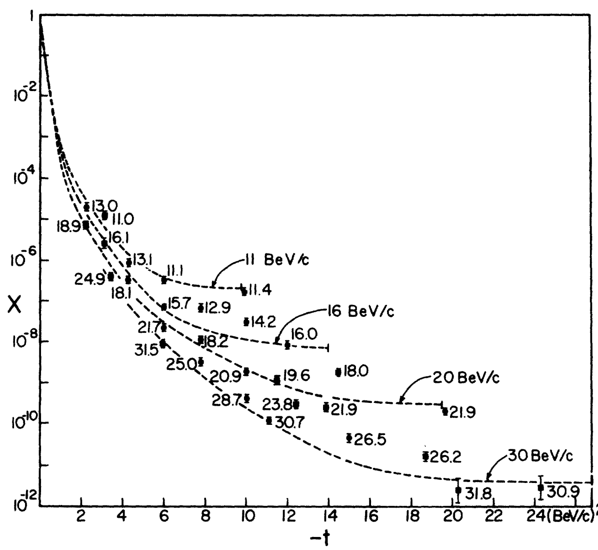


FIG. 1. Elastic differential cross section normalized to the forward scattering cross section, as a function of the squared four-momentum transfer $-t$. The 11 cross sections of this experiment are indicated by squares and the 18 cross sections of reference 1 by circles. Dashed lines describe the behavior of $X$ at fixed beam momenta of 11, 16, 20, and 30 BeV/$c$; each line ends at $t_{\text{max}}$ which corresponds to $\theta_{\text{c.m.}} = 90°$.

†Research supported by the U. S. Atomic Energy Commission and a research grant from the National Science Foundation.

*Present address: CERN, Geneva, Switzerland.

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