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SMALL ANGLE PROTON-PROTON SCATTERING AT 330 MEV

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In conjunction with the program on p-p and n-p cross section measurement, the p-p scattering at 330 Mev has been measured down to small angles (2.2° to 14° lab.). In this angular interval the Rutherford scattering and nuclear scattering become of the same order of magnitude and interference phenomena may be expected to occur.

The method used consisted of getting a very highly collimated beam (the electrostatically deflected 340 Mev proton beam of the UCRL 184-inch synchrocyclotron was used) and then detecting with nuclear emulsions the protons scattered from a liquid hydrogen target. A plate camera was constructed holding seven 1 in. by 3 in., 200 micron Ilford G-5 emulsions on the left and right side of the beam. (See Fig. 1). The emulsions were placed lengthwise in a horizontal row with the emulsion plane inclined at an angle of 43° with the proton beam. Exposures to an integrated flux of 5×10^{10} protons were made with target filled and with target empty. A copper absorber 2-1/2 in. thick was placed in front of the emulsions. During the target empty exposure additional absorber was added to compensate for the energy loss and attenuation in the liquid hydrogen. One of the plates at 14° lab. was not covered by absorber so that the attenuation could be determined and the absolute cross section evaluated.

In scanning the plates, the protons were counted as they entered the surface of the emulsion. Since there was 2-1/2 in. of copper absorber in front of the plates, the tracks were more than twice minimum ionizing and quite easily counted. The ratio of "target filled" to "target empty" counts varied from 7.0 to 2.5. The angular resolution at the camera varied from $\pm 0.5^\circ$ lab. to $\pm 0.9^\circ$ lab.

The absolute cross section determination gives 3.8 ± 0.25 mb/ster. for angles above 20° c.m. The principal uncertainty in this value is due to the calibration of the attenuation ($I/I_0 = 0.79 \pm .04$) in the 2-1/2 in. copper absorber ahead of the emulsions and the scanning efficiency ($\epsilon = 0.95 \pm 0.05$). This value is in good agreement with the recent Berkeley value¹ of 3.72 ± 0.15 mb/ster. Our angular distribution is shown in Fig. 2, normalized to the 3.7 mb/ster. value. In Fig. 2 is also shown the sum of the Rutherford scattering (calculated) and the nuclear scattering (considered constant at 3.7 mb/ster.). If one considers the differential cross section separated into three terms² $P_{\text{nuc.}} + P_{\text{Ruth.}} + P_{\text{int.}}$, i.e., the nuclear scattering, the Rutherford scattering, and the interference between them, then the difference between the solid curve and the experimental points should represent $P_{\text{int.}}$. There appears to be a net effect of destructive interference in the region of 6° to 14° c.m.

It is interesting to note that the interference term $P_{\text{int.}}$ is extremely sensitive to the relativistic corrections used for Rutherford scattering. The curve in Fig. 2 was drawn according to Møller's³ formula. In the small angle approximation this is identical with a modified form of Mott's formula.⁴ The latter is obtained when the wave length of relative motion λ is factored out and replaced by its relativistic value², leaving the remaining velocity dependence unchanged. If Mott's formula is evaluated without any relativistic corrections, the resulting scattering is larger by a factor $2\gamma^2/(\gamma + 1) = 1.55$, and the interference term then appears increased correspondingly. The relativistic approximation used by Van Hove⁵ gives a value larger than that given by Møller's formula by a factor $(\gamma + 1)/2 = 1.18$.

We were able to fit the experimental points fairly well by a selection of one s and three p wave phase shifts. In the symbols of Thaler and Bengtson² for instance $^1K_0 = 31^\circ$, $\alpha = 1.2$, $\beta = 0.28$ can give possible sets of phase shifts, where 1K_0 is the s wave phase shift⁶ and α and β are functions of the p wave phase shifts. However, as was pointed out by Fried⁷, without the use of additional phase shifts this type of analysis is not able to account for the recent⁸ polarization data, and a more detailed analysis will be required.

We wish to thank Professors Segrè and Chamberlain for their help and cooperation in this work, and Miss Sheila Livingston for her contribution to the scanning of the plates.

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REFERENCES

1. Chamberlain, Pettengill, Segrè, and Wiegand, Phys. Rev. 93, 1424, (1954).
2. Thaler and Bengston, Phys. Rev. 94, 679 (1954).
3. Møller, Ann. der Phys. 14, 531, (1932).
4. At small angles Mott's formula (non-relativistic) for p-p scattering, c.m. system can be expressed as

$$P_{\text{Mott}} = \left(e^4 / M_p^2 v^4 \right) \sin^{-4}(\theta/2) \text{ cm}^2/\text{ster} \quad \text{and}$$

Møller's formula reduced to $P_{\text{Mott}} (\gamma + 1/2\gamma^2)$ where e is the electron charge, M_p the proton mass, v the relative velocity, θ the c.m. angle and $\gamma = (1 - v^2/c^2)^{-1/2}$.

5. L. Van Hove Phys. Rev. 88, 1359 (1952).
6. The estimate of the singlet s phase shift was made by Dr. ^{meson} H. P. Noyes using the low energy/well parameters of Hall and Powell (Phys. Rev. 90, 912, 1953).
7. B. D. Fried, Phys. Rev. (In press).
8. Chamberlain, Donaldson, Segrè, Tripp Wiegand, Ypsilantis, Phys. Review (In press).

FIGURE CAPTIONS

- Fig. 1 Plan of the target and camera geometry.
- Fig. 2 Differential cross section for 330 Mev p-p scattering normalized to 3.7 mb/steradian in the region of pure nuclear scattering. The circles and triangles represent measurements on plates placed on the right and left side of the beam respectively. The errors indicated are the statistical standard deviations. The solid curve represents the sum of Rutherford scattering and a constant nuclear scattering of 3.7 mb/steradian.

P-P SCATTERING 330 MEV