Large-Angle Scattering of 18.7-Mev Alpha Particles by C^{12}†

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The differential cross section of C^{12} for elastic scattering of 18.7-Mev alpha particles has been measured from 165° to 179° (c.m.). The rapid rise found by Corelli, Bleuler, and Tendam (from 3 mb/sr at 159.6° to 670 mb/sr at 173.3°) was confirmed and shown to continue to the largest angle investigated. The cross section at 180° is 1.2±0.1 b/sr.

CORELLI *et al.*[1] reported an oscillatory pattern for the angular distribution of ~18-Mev alpha particles elastically scattered by C^{12}, with a steep rise at large angles. At 18.2 Mev, the center-of-mass cross section rises from 3.0 mb/sr at 159.6° ($\theta_{lab}=150°$) to 670 mb/sr at 173.3° ($\theta_{lab}=170°$). Since the maxima of the differential cross section (cf. Fig. 2) were found to occur at nearly constant intervals (at angles of about 35°, 57°, 79°, 101°, 124°, 149°) it seemed of interest to check whether a further maximum exists below 180°. The present investigation extends the range of scattering angles to 178.5° in the laboratory (179° c. m.).

EXPERIMENT

The 19-Mev alpha-particle beam from the Purdue cyclotron is focused by a pair of quadrupole lenses and a 20-in. analyzing magnet into the collimator of a special nuclear-emulsion camera (Fig. 1). Alpha particles scattered back from a polyethylene target are recorded on two 3×1 in. Ilford C-2 plates lying in grooves milled in the camera wall at 10° angles to the left and right of the incident beam. The emulsion plates are held tightly in place during bombardment by screws applied against aluminum backing plates which fit in the grooves with less than 0.005-in. spacing. Fiducial marks are produced on the emulsions by shining light through four small holes in each backing plate.

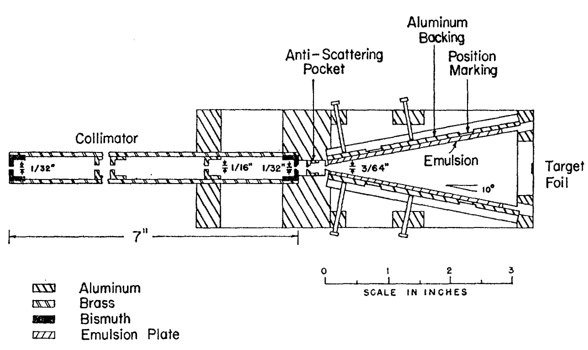

FIG. 1. Cross-sectional view of emulsion camera.

The maximum deviation of the incident alpha particles from the collimator axis is limited to 0.128° by the two defining apertures of $\frac{1}{32}$-in. diameter, spaced 7 in. They are machined from bismuth to reduce the production of gamma rays by the intercepted beam. The three intermediate irises, with a $\frac{1}{16}$-in. diameter, are made from aluminum. Immediately after the collimator the beam passes through an antiscattering pocket inserted for the purpose of reducing the background of alpha particles scattered from the collimator onto the emulsion.

The target foil is made to be wider than the divergence of the beam so that absolute cross sections can be measured. The target thickness was measured, by weighing a known area, to be 0.818 mg/cm² with an estimated (standard) error of 2%. The energy loss of the incident alpha particles in the target is about 290 kev.[2] The target is thin enough for a clean track-length separation of the elastically and inelastically ($Q=-4.43$ Mev) back-scattered alpha particles.

TABLE I. Exposures.

No.	Incident energy (Mev)	Energy at target center (Mev)	Incident alpha particles
1	18.80	18.65	8×10^{11}
2	18.86	no target	16×10^{11}
3	18.85	18.70	8×10^{11}

For an infinitely thin incident beam, the locus for constant scattering angle on the emulsion is a conic section with apex on the center line of the plate, opening toward the collimator. Instead of following these conic sections in scanning, small rectangular areas near the apex were scanned and the spread in scattering angles due to this finite detector area as well as to the finite collimator aperture was calculated.[3]

RESULTS

Three pairs of plates were exposed for the final measurements, as listed in Table I. The second exposure, without target, was used to measure for each scanning

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[1] J. C. Corelli, E. Bleuler, and D. J. Tendam, Phys. Rev. 116, 1184 (1959).

[2] W. Brandt, "Energy Loss and Range of Charged Particles in Compounds", Radiation Physics Laboratory Report, E. I. du Pont de Nemours and Company, Wilmington, Delaware, 1960 (unpublished).

[3] S. S. M. Wong, M.S. thesis, Purdue University, January, 1962 (unpublished).

area the background of tracks which fell in the same track-length interval as the target-scattered alpha particles and fulfilled the same directional conditions. This background whose nature was not investigated, amounted to about 30% of the true tracks at $\theta_{c.m.} = 179°$ and dropped rapidly to 8% at 176°, 2% at 170°, with a slight rise to 3% at 165°.

The differential cross sections obtained from these runs are shown in Figs. 2 and 3, together with the

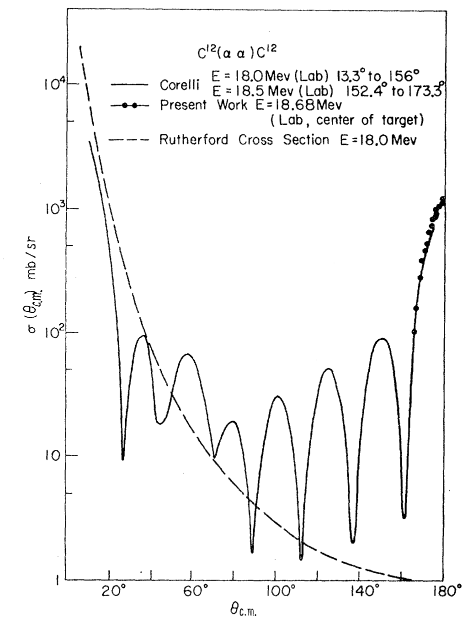

FIG. 2. Elastic scattering cross section of 18- to 18.7-Mev alpha particles from carbon.

results of Corelli *et al.*[1] Figure 2 shows the over-all angular distribution from 13° to 179°, Fig. 3 shows the details at large angles. The agreement between the two investigations is satisfactory in the region of overlap except for the last two points of the earlier work. It is possible that the high track density and the background fogging on the last plates of Corelli *et al.* introduced an error.

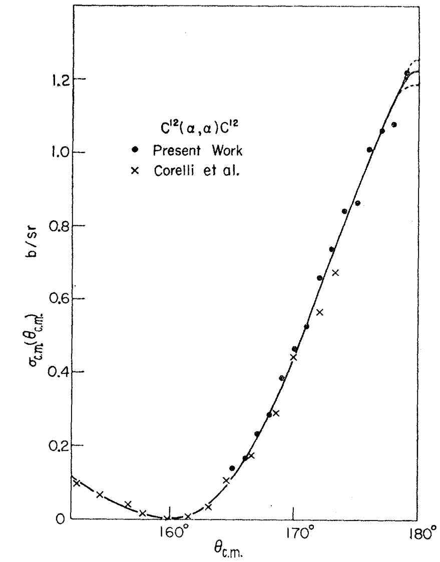

FIG. 3. Elastic scattering cross section of 18.5- to 18.7-Mev alpha particles from carbon at large angles.

In the present work, the standard counting error for each point is 3%; with the uncertainties of target thickness, beam integration, and background subtraction, the total standard error is estimated to be about 5% for angles less than 177°, up to 8% for the largest angles. The rms spread of the scattering angles accepted in the scanning area, due mainly to the finite collimator size, is 0.16° at the nominal scattering angles of 179° and 178°, then increases approximately linearly with decreasing angle, to a value of 0.5° at 165°. Because of the small curvature of the plot of Fig. 3, the corrections due to this spread are negligible.

There is no indication for a maximum in the angular distribution just below 180°. Instead, the cross section reaches a maximum value of 1.2 ± 0.1 b/sr at 180°. The differential cross section thus rises by a factor 400 from 160° to 180°. This is probably the strongest variation of a cross section observed at other than forward angles, and it would appear to be an interesting problem for a phase-shift analysis (or partial-wave synthesis with an optical-model potential).