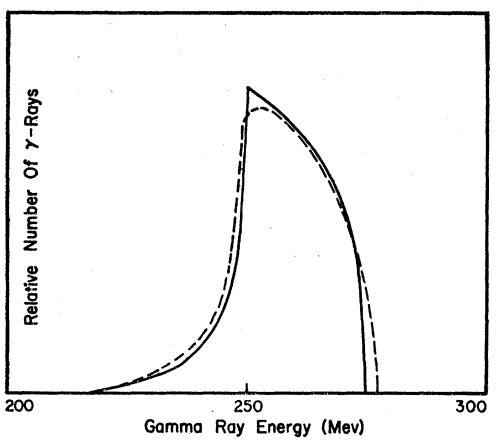


FIG. 1. Difference spectrum resulting from subtraction of 275- and 250-Mev spectra. Dotted curve shows approximate spectrum due to the experimentally used spectra.

one can obtain the yield due to "monochromatic" gamma-rays. Figure 1 shows a typical difference spectrum resulting from the subtraction of two bremsstrahlen spectra of different maximum energy. Because the beam was slightly spread out in time to reduce background, there was a slight spread in the maximum energy of the beam. This introduces more spread to the difference spectrum. It was assumed that all the meson production from the 225-Mev maximum gamma-rays was due to the band of gamma rays between 200 and 225 Mev. A run at lower energy yielded no mesons within the statistics. Figure 2 shows the cross sections for

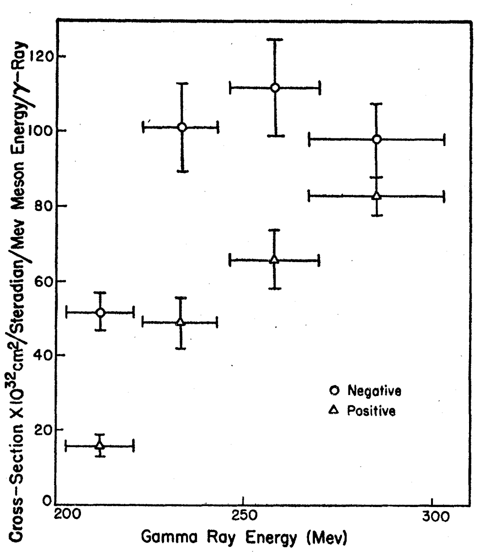


FIG. 2. Cross sections for production of 54-Mev $\pi^-$ and $\pi^+$ mesons from beryllium *vs* $\gamma$-ray energy.

the production of 54-Mev charged mesons *vs* gamma-ray energy. The errors indicated are those due to counting statistics. Other systematic errors may have occurred due to errors in determination of the maximum energies.

The results of the experiment are consistent with the following interpretation: the difference in positive and negative production is due mainly to the "extra loosely bound" neutron of $Be^9$. Figure 3 shows the production due to the extra neutron. It was assumed that neutrons in the core are 1.0 times as efficient as protons in the core (from the plus-minus ratio of carbon). The solid curve is the approximate shape expected if the neutron were free and had a

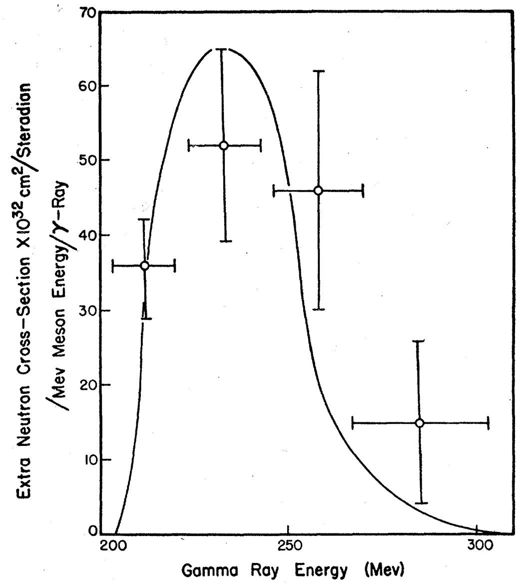


FIG. 3. Extra-neutron of beryllium cross section *vs* $\gamma$-ray energy.

cross section equal to the free proton cross section. The width of the free particle curve is mainly due to the resolving power of the magnet and the asymmetry on the high energy side to the long low energy tail of the difference spectra. For a bound neutron, one would expect the width to be increased because of the momentum distribution. Hence the extra neutron acts approximately as if it were free, in agreement with other experiments[3] and with what one would expect from shell structure theory and the small binding energy of the extra neutron.

The author wishes to thank Thomas Palfrey, Thomas Jenkins, and Professor R. R. Wilson.

* Supported by the U. S. Office of Naval Research.
† General Electric Fellow.
[1] R. M. Littauer and D. Walker, Phys. Rev. **86**, 846 (1952).
[2] J. DeWire and A. Perry (private communication).
[3] J. C. Keck and R. Littauer have studied the photomeson production from the extra neutron by requiring a correlated proton in coincidence with the meson (private communication).

---

## Differential Cross Section for Elastic *p-p* Scattering at 435 Mev*

W. E. MOTT, R. B. SUTTON, J. G. FOX, AND J. A. KANE
*Carnegie Institute of Technology, Pittsburgh, Pennsylvania*
(Received March 23, 1953)

THE differential scattering cross section for elastic collisions of high energy protons with protons as a function of the angle of scattering in the center-of-mass system has been measured using the external beam of the Carnegie Institute of Technology synchrocyclotron.

Figure 1 gives a general picture of the cyclotron, deflecting magnet, collimators, the path of the particles in the external beam, and the scattering arrangement, including target, counters, and ionization chamber.

The protons which emerge from the cyclotron without the aid of deflecting mechanisms have an intensity 10 meters from the machine of the order of $2\times10^5$ cm$^{-2}$ sec$^{-1}$. The beam was monitored by integrating the current of an argon-filled ionization chamber similar to the one described by Chamberlain, Segrè, and Wiegand.[1] A knowledge of the energy loss per proton per cm of argon[2] and the energy necessary to produce one ion pair in this gas[3] made an absolute calibration of the monitoring device possible. A nuclear emulsion technique is now being investigated as an alternate, and perhaps more accurate, method of calibrating the chamber. Absorption and time of flight measurements have indicated that the proton energy is approximately 435 Mev.

The scattered and recoil protons were detected simultaneously in scintillation counters (*trans*-stilbene crystals viewed by 5819 photomultipliers). The associated coincidence circuit had a resolving time of $2\times 10^{-9}$ sec.

Foils of polyethylene varying in weight from 643 to 110 mg/cm² were used as targets. The cross sections were obtained by taking polyethylene-carbon differences, where each polyethylene target was matched with a carbon target of equal stopping power. The effect from hydrogen has been calculated using the formula

$$H=(CH_2-b)-z(C-b),$$

where $CH_2$, C, and $b$ are the number of coincidence counts obtained when using a polyethylene target, a carbon target, and no target; and $z$ is the ratio of the carbon surface density of the polyethylene target to the surface density of the carbon target. In

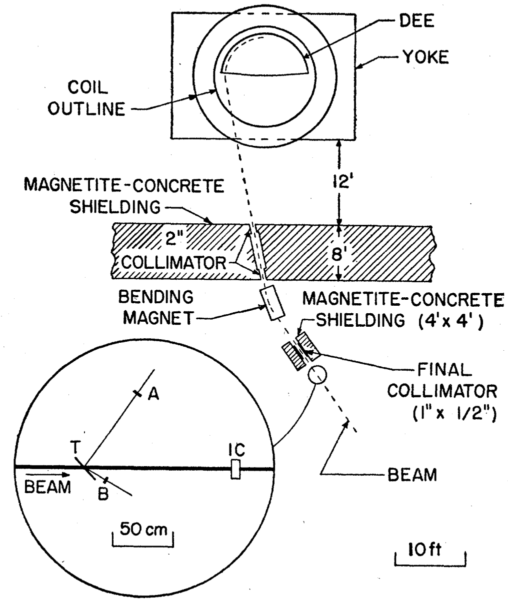


FIG. 1. Diagram of the cyclotron, bending magnet, collimators and scattering area. The inset shows the target, $T$; defining counter, $A$; monitoring counter, $B$; argon ionization chamber, $IC$.

each case the counts were recorded for a given integrated beam. This method of subtracting the carbon has been checked by comparing cross sections taken under different conditions of beam intensity and target thickness. In all cases the cross sections have agreed to within the counting statistics.

Previously[4] the ratios of the cross sections were reported for the scattering angles of 90°, 65.3°, and 36.4° in the center-of-mass system. Measurements have now been improved and extended to include the angle at 25.2°. The results indicate a definite deviation from isotropy in contrast to the investigations[1,5–7] in the energy range 100–345 Mev which suggested an isotropic cross section over the same angular region.

TABLE I. Differential scattering cross section $\sigma(\theta)$ in center-of-mass coordinate system in $10^{-27}$ cm²/sterad. Errors indicated are standard deviations from counting statistics only.

| $\theta$ | $\sigma(\theta)$ | $\sigma(\theta)/\sigma(\theta=90°)$ |
|---|---|---|
| 25.2° | 4.49±0.25 | 1.32 |
| 36.4° | 4.16±0.14 | 1.23 |
| 65.3° | 3.59±0.10 | 1.06 |
| 90° | 3.39±0.10 | 1 |

Table I gives the differential scattering cross section $\sigma(\theta)$ at the center-of-mass angle $\theta$, and the ratios of $\sigma(\theta)/\sigma(\theta=90°)$.

The errors quoted in Table I are standard deviations due to counting statistics only. To obtain the uncertainty in the cross section an error due to other factors, estimated to be 8 percent for the point at $\theta=25.2°$ and 6 percent for the other points, should be superimposed on the errors in the table. A 6 percent error is assigned to the values of $\sigma(\theta)/\sigma(\theta=90°)$.

Complete details of the experiment and additional results will follow with the completion of small angle measurements.

* Supported in part by the U. S. Atomic Energy Commission.

[1] Chamberlain, Segrè, and Wiegand, Phys. Rev. **83**, 923 (1951).
[2] Aron, Hoffman, and Williams, U. S. Atomic Energy Commission Report AECU-663 (unpublished).
[3] C. J. Bakker and E. Segrè, Phys. Rev. **81**, 489 (1951).
[4] W. E. Mott and R. B. Sutton, Bull. Am. Phys. Soc. **28**, No. 10 (1953).
[5] C. L. Oxley and R. D. Schamberger, Phys. Rev. **85**, 416 (1952); O. A. Towler, Phys. Rev. **84**, 1262 (1951).
[6] Birge, Kruse, and Ramsey, Phys. Rev. **83**, 274 (1951).
[7] Cassels, Pickavance, and Stafford, Proc. Roy. Soc. (London) **214**, 262 (1952).

## Constancy of Cosmic-Ray Flux over the Past 30 000 Years*†

J. LAURENCE KULP AND HERBERT L. VOLCHOK
*Lamont Geological Observatory, Columbia University, Palisades, New York*
(Received March 27, 1953)

THE carbon-14 method of age determination[1] which has been used to date archeological and geological samples[1–3] is based on two major assumptions. (1) The integrated cosmic-ray flux is constant. (2) The $C^{14}$ atoms produced in the upper atmosphere by the $N^{14}(n,p)C^{14}$ reaction are rapidly mixed into the carbon reservoir of the atmosphere, biosphere, and hydrosphere. The time scale for these assumptions is on the order of centuries since the average life of $C^{14}$ atoms is approximately 8000 years, and the present maximum $C^{14}$ dating accuracy is ±100 years.

The second assumption has been verified by the observation that the concentration of $C^{14}$ in living organisms at widely different latitudes and in the carbon dioxide of the air at various locations and altitudes is essentially constant. The first assumption has been verified for the period of written history by showing that the carbon-14 ages on archeological specimens are correct. Since this agreement was established for the last 4000 years, and since the

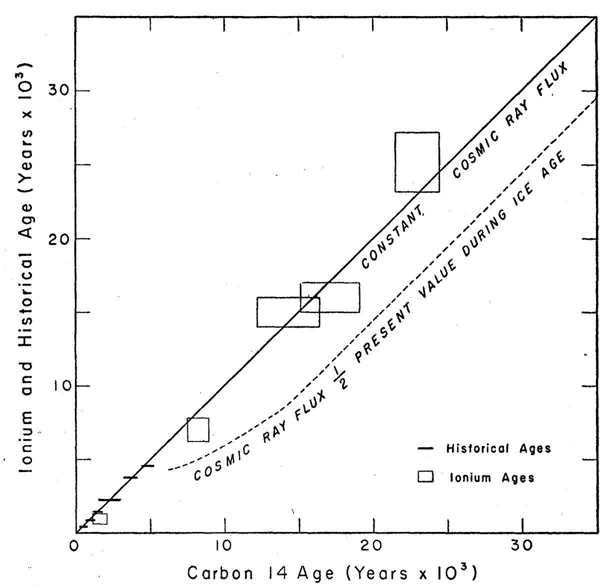


FIG. 1. Correlation of carbon-14 age of various samples with age determined by written history or the ionium method.