tially 1375 fission disintegrations/minute, is decaying with a 2.1±0.4 year half-life. A summary of the nuclear properties of some isotopes of berkelium and californium are given in Table II. The decrease in spontaneous fission half-life of the heavy even-A californium isotopes agrees with recent predictions.[3]

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* Nuclear properties of some of these isotopes were measured in other work at Argonne National Laboratory, University of California Radiation Laboratory, and at Los Alamos Scientific Laboratory, not yet published [see also Thompson, Ghiorso, Harvey, and Chopping, Phys. Rev. **93**, 908 (1954)].

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Inelastic Scattering of 190-Mev Electrons in Beryllium*†‡

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In investigating the elastic scattering of high-energy electrons from various nuclei[1] we reported preliminary evidence of structure in the "elastic" profiles observed at 70° and 90° in beryllium at 125 Mev. We have re-examined this problem with a newly rewound analyzing magnet which permits studies up to 200 Mev. With incident electrons of 190 Mev in a band 1.0-Mev wide we have confirmed this structure and the details have now been more clearly revealed. Figure 1 shows the elastically scattered peak A and two additional inelastically scattered peaks B and C at 70° for a 100-mil beryllium target set at 45° with respect to the incident beam. The abscissa is given in terms of the settings of the potentiometer reading the current through the analyzing magnetic spectrometer. Figure 2 shows similar data at 90°. We have also observed inelastic scattering at 60° and have observed the peaks A and B, but unfortunately did not carry the observations below B to look for peak C. Table I shows the positions of the peaks at 90°, 70°, and 60° and also shows the differences $A-B$, $A-C$. These differences may be converted into the excitation energies of the levels excited in beryllium by 190-Mev electrons when the energy calibration of the abscissa is known. An initial calibration in terms of magnetic field measured at the center of the spectrometer trajectories gave the instantaneous slope of the curve of energy *versus* potentiometer setting as 0.20 Mev per division of potentiometer reading. Averaging the intervals $A-B$ and $A-C$ provides $A-B=12.7$ divisions or 2.54 Mev and $A-C=34.8$ divisions or 6.96 Mev. These values are in good agreement with those excitation levels reported by Britten,[2] and the single low-lying level of Davis and Hafner[3] and Rhoderick.[4] Britten's values are 2.5±0.2 Mev and 6.8±0.3 Mev. Britten's third level at 11.6 Mev was not sought.

The beryllium levels previously observed have been found by inelastic scattering of protons whereas these levels have now been

TABLE I. Summary of data on elastic and inelastic peaks.

Angle \ Peak	A	B	C	$A-B$	$A-C$
60°	418.0	404.0	—	14.0	—
70°	413.6	400.0	378.4	13.6	35.2
90°	404.5	394.0	370.0	10.5	34.5
			Average	12.7±1.5	34.8±1.5

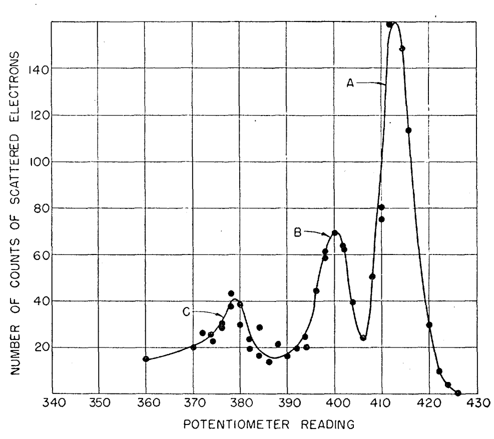

FIG. 1. Elastic peak (A) and first and second inelastic peaks (B and C) in beryllium at 70°.

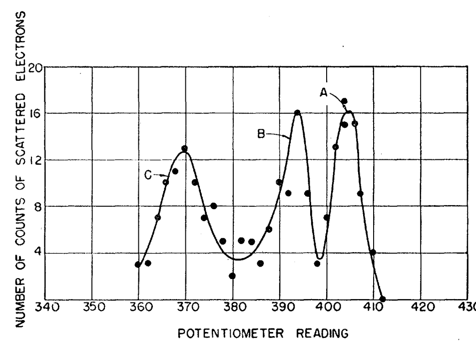

FIG. 2. Elastic peak (A) and first and second inelastic peaks (B and C) in beryllium at 90°.

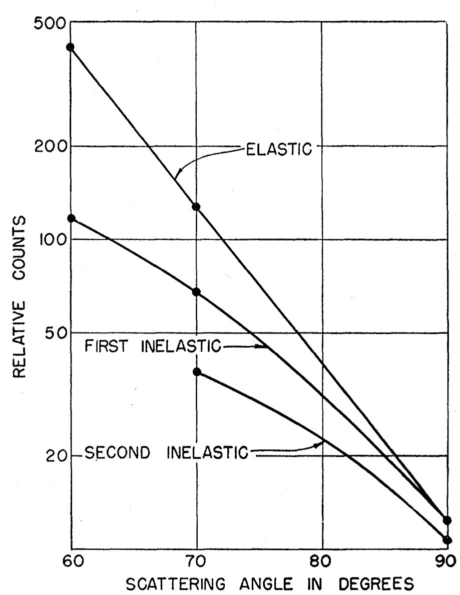

FIG. 3. Elastic and inelastic cross sections on a relative scale as a function of scattering angle.

excited by fast electrons. Presumably a specifically nuclear interaction is not involved, which suggests that there may be similarities between electron excitation of levels and Coulomb excitation by heavy particles.

Figures 1 and 2 and the data at 60° permit a rough, limited measurement of the angular distribution of the cross section for the inelastic scattered electrons. These data are plotted in Fig. 3 along with the elastic cross section. The flatter angular distributions of the inelastic electrons appear to be in agreement with a preliminary theory.[5]

Inelastic processes have also been observed in copper.

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Pion Production Ratios*

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MEASUREMENTS have recently been made[1] on the production of charged pions in the reaction Be^9+p. The π^+/π^- ratio ρ shows a striking energy dependence,[2] decreasing from $\rho\approx 6$ at $E_p=1$ Bev to $\rho=1.8$ at $E_p=2.3$ Bev. The present note interprets this behavior in terms of an "excited state" of the nucleon with isotopic spin $\frac{3}{2}$.

Pion production is envisioned as follows: two nucleons collide, forming a "compound state"; on emerging, one or both of the nucleons are in an excited state, which subsequently decays by π emission. This separation of the process into two distinct stages linked by a quasi-stable excited nucleon state is without justification; it should not, however, vitiate conclusions based on charge independence arguments and forms a convenient physical picture. For the sake of simplicity the nucleon is assumed to have only one excited state, which can decay to the ground state by emission of a single π meson. The excited state must therefore have $T'=\frac{1}{2}$ or $\frac{3}{2}$; meson production can be characterized by the indices 1 or 2, according as one or both nucleons emerge from the collision in an excited state. Because of the threshold for excitation, the production cross section satisfies $\sigma_1>\sigma_2$ for low E_p, while $\sigma_2\gtrsim\sigma_1$ for high E_p. The variation of ρ with E_p can be related to that of σ_1/σ_2, provided that $\rho_1\neq\rho_2$. This immediately excludes the case $T'=\frac{1}{2}$, for then the charge symmetries of the system are identical whether 0, 1, or 2 nucleons are excited, so that $\rho=\rho_1=\rho_2=$const.

The case $T'=\frac{3}{2}$ remains to be examined. For this purpose let $\sigma^{xy}(T^c)$ be the cross section for production of a compound state of isotopic spin T^c by the collision of incident nucleons x, y. Charge independence requires that $\sigma^{np}(1)=\frac{1}{2}\sigma^{pp}(1)=\sigma^s$, but does not relate $\sigma^a=\sigma^{np}(0)$ to σ^s; of course $\sigma^{pp}(0)=0$. Consider a p-p collision with excitation of both nucleons: the compound state has $T^c=1$, $T_z^c=1$, and the Clebsch-Gordon coefficients for decomposition into two $T'=\frac{3}{2}$ nucleons yield respective fractional weights of $\frac{2}{5}$ and $\frac{3}{5}$ for the combinations $T_z'=(\frac{1}{2},\frac{1}{2})$ and $T_z'=(\frac{3}{2},-\frac{1}{2})$. The fractional weights for decay of the excited state by π^+, π^0, π^- emission are (100), $(\frac{1}{3}\,\frac{2}{3}\,0)$, $(0\,\frac{2}{3}\,\frac{1}{3})$ according as $T_z'=\frac{3}{2}, \frac{1}{2}, -\frac{1}{2}$. Combining these factors leads to over-all fractional weights for π production of (13/15, 14/15, 3/15). These last are normalized to give a total production of two π mesons.

For a p-p collision with excitation of one nucleon, the compound state decomposes into $T'=\frac{3}{2}$, $T=\frac{1}{2}$ with fractional weights $\frac{1}{4}$ and $\frac{3}{4}$ for T_z', $T_z=(\frac{3}{2},-\frac{1}{2})$ and $(\frac{1}{2},\frac{1}{2})$, respectively. The resultant over-all fractional weights for π production are $(\frac{1}{2},\frac{1}{2},0)$, normalized to a total of one meson. The total cross sections for π production in a p-p collision are then

$$\begin{aligned}(\pi^+)&:\ (1/15)[26\sigma_2^s+15\sigma_1^s],\\ (\pi^0)&:\ (1/15)(28\sigma_2^s+15\sigma_1^s],\\ (\pi^-)&;\ (1/15)[6\sigma_2^s].\end{aligned}\tag{1}$$

In a similar way the cross sections for meson production in an n-p collision are

$$\begin{aligned}(\pi^+\text{ or }\pi^-)&:\ (1/15)[14\sigma_2^s+(5/2)\sigma_1^s+10\sigma_2^a],\\ (\pi^0)&:\ (1/15)[2\sigma_2^s+10\sigma_1^s+10\sigma_2^a].\end{aligned}\tag{2}$$

Combining Eqs. (1) and (2) in the ratio 4 to 5 for a Be^9 nucleus leads to

$$\begin{aligned}(\pi^+)&:\ [1.28\sigma_2^s+0.54\sigma_1^s+0.37\sigma_2^a],\\ (\pi^0)&:\ [0.90\sigma_2^s+0.82\sigma_1^s+0.37\sigma_2^a],\\ (\pi^-)&:\ [0.70\sigma_2^s+0.09\sigma_1^s+0.37\sigma_2^a].\end{aligned}\tag{3}$$

When $\sigma_1\gg\sigma_2$, $\rho\approx 6$; when $\sigma_2\gg\sigma_1$, $1\lesssim\rho\lesssim 1.8$, depending on the relative magnitudes of σ_2^a and σ_2^s.

Of course these considerations are subject to many qualifications, but in terms of the model employed they indicate that (i) wide variation in ρ implies $T'=\frac{3}{2}$ for the excited nucleon state; (ii) the observed variation of ρ suggests $\sigma_1\gg\sigma_2$ for $E_p=1$ Bev, $\sigma_2\gg\sigma_1$ for $E_p=2.3$ Bev. The variation (ii) is plausible if the $T'=\frac{3}{2}$ state is identified with the "resonance" appearing at about 0.2 Bev in π-nucleon scattering, as has been suggested from energy analysis of the produced mesons.[1] According to (ii) and Eq. (3), the relative π^0 production should also show a marked variation with energy: for low E_p, π^0 production exceeds the total charged π production; for high E_p, π^0 production is intermediate between π^+ and π^-.

The same model can be applied to calculation of various other production ratios. For example, in n-p collisions the ratio of (π^-,π^0) plus (π^-,π^+) production to single π^- production is $(5.6\sigma_2^a+4\sigma_2^a)/\sigma_1^s$. For neutrons in the 1–2 Bev range, this ratio is observed[3] to be of order 5, suggesting that $\sigma_2\sim\sigma_1$ for an average $\bar{E}_n\sim 1.5$ Bev. This is compatible with the conclusions from Be^9+p.

It is tempting to speculate on the existence of a further "excited state" of the nucleon with $T''=5/2$, which would decay to the ground state by emission of two mesons. It could not appear in π-nucleon scattering but would be associated with three- and four-meson production in a nucleon-nucleon collision. If the T'' state has a well-defined energy, the threshold for these processes may be high. We could, for example, compute ρ for a p-p collision involving $T''=5/2$ states. The cross sections concerned are σ_3^s (excitation of one nucleon to $T'=\frac{3}{2}$, the other to $T''=5/2$) and σ_4^s (excitation of both to $T''=5/2$). The meson production cross sections are

$$\begin{aligned}(\pi^+)&:\ (1/50)(78\sigma_3^s+76\sigma_4^s),\\ (\pi^0)&:\ (1/50)(39\sigma_3^s+88\sigma_4^s),\\ (\pi^-)&:\ (1/50)(33\sigma_3^s+36\sigma_4^s).\end{aligned}\tag{4}$$

Excitation of the $T''=5/2$ state gives a characteristic value $\rho\approx 2$, more or less independent of the ratio σ_3/σ_4. To (4) must of course be added to cross sections (1), which give $\rho>4$. Thus observation of $\rho<4$ would be indication of a $T''=5/2$ state.

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