The Dependence of the 33-Mev π^+ Production Cross Section on Atomic Number

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A PRELIMINARY result has been obtained on the variation of the ($T_\pi = 33$ Mev) positive pion-production cross section with atomic number which results from the interaction of a ($T_p = 340$ Mev) proton beam with target nuclei. The chief concern is the functional behavior with atomic number of pion-production cross sections at different pion energies.

For this experiment the targets consisted of six elements (Be, C, Al, Cu, Ag, and Pb). These targets were in tubular form having the following dimensions: (a) for the light elements (Be, C, Al) $\frac{3}{4}$ in. o.d., $\frac{1}{2}$ in. i.d., and $1\frac{1}{2}$ in. long; (b) for the heavy elements (Cu, Ag, Pb) $\frac{3}{4}$ in. o.d., $\frac{1}{2}$ in. i.d., and $\frac{1}{2}$ in. long. A $\frac{1}{2}$ in. long tubular carbon target was used to determine the normalization factor necessary for the difference in target geometry between the light and heavy elements.

The targets were mounted on the axis of a 22-in. (pole-diameter) spiral orbit spectrometer. They were bombarded by a (1-in. diameter) collimated proton beam which was electrically deflected out from the 184-inch synchro-cyclotron, integrated by an argon-

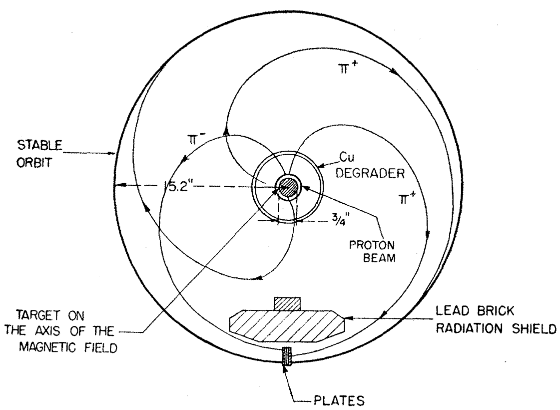

FIG. 1. Schematic diagram of experimental arrangement illustrating the charged pion trajectories in the median plane of the spiral-orbit spectrometer.

filled ion chamber, and then passed through the ($1\frac{1}{2}$-in. i.d.) axial hole of the magnet.

The principle of "the sprial-orbit spectrometer"[1] was used to focus pions of known energy which were emitted at 90° to the incoming proton beam. The pions were detected by means of C–2 Ilford (200μ) nuclear emulsions which were placed in the region of the "stable orbit" as is shown schematically in Fig. 1. Since pions of $T_\pi = 9.2$ Mev were being focussed at the "stable orbit," a 4 in. o.d. tubular copper degrader of appropriate thickness permitted the selection of pions of $T_\pi = 33 \pm 3$ Mev created in the target.

The same volume of emulsion was scanned for each of the seven exposures. The relative π^+ production cross section per target nucleus was determined and is presented in Fig. 2. The uncertainties indicated in the spectral data are statistical probable errors involved in the counting of pions. Shown also in Fig. 2 are (a) Z^1 variation normalized at the Ag point, (b) $Z^{\frac{2}{3}}$ variation normalized at the Ag point, (c) $Z^{\frac{2}{3}}$ variation normalized at the Al point.

The experimental results for the six elements indicate clearly a better fit to a $Z^{\frac{2}{3}}$ variation. This is quite similar to the results obtained by one of the authors for pions of $T_\pi = 42$ Mev.[2] Furthermore the data are in accord with those reported by Hamlin *et al.*[3]

Exposures have also been obtained (for $T_\pi = 25$ Mev and

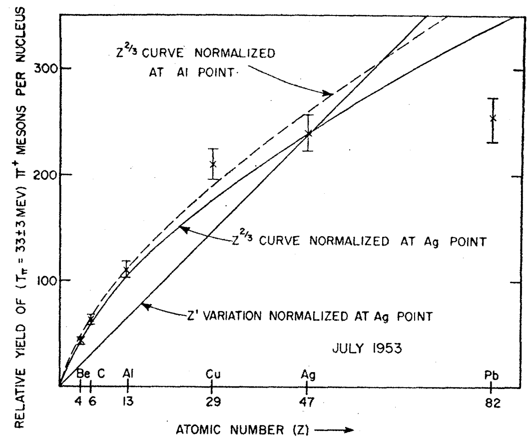

FIG. 2. Relative ($T_\pi = 33 \pm 3$ Mev) π^+ production cross sections as a function of atomic number, illustrating the variation of experimental data from a Z^1 and $Z^{2/3}$ dependence.

$T_\pi = 11$ Mev) for negative and positive pions. These results will be reported soon.

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[2] R. Sagane, Phys. Rev. **90**, 1003 (1953); University of California Radiation Laboratory Report UCRL-2161, 1953 (unpublished).
[3] Hamlin, Jakobson, Merritt, and Schultz, Phys. Rev. **84**, 957 (1951).

Polarization of Nuclear Spins in Metals*

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WHEN a metal such as lithium is placed in a static magnetic field, two set of Zeeman levels are produced associated with the nuclear spins[1,2] and the conduction electron spins,[3,4] respectively. The corresponding resonance transitions have been observed. With magnetic resonances in general it is found that when the amplitude of the alternating magnetic field is increased, the population difference between the Zeeman levels decreases, a phenomenon known as saturation. For example, we have found previously[4] that for the conduction electrons in lithium, an alternating field of some 5 gauss produces saturation. On the basis of a detailed calculation of the nucleus-electron interaction, Overhauser[5] has predicted that for metals the saturation of the conduction electrons should simultaneously *increase* the population difference between the nuclear Zeeman levels by a factor of several thousand, and has proposed this as a method of polarizing nuclear spins. Since the strength of the nuclear resonance absorption is proportional to the population difference between adjacent nuclear Zeeman levels, the nuclear resonance forms a convenient method of measuring the degree of nuclear alignment. We have verified Overhauser's theory by observing the enhancement of the nuclear resonance in metallic lithium produced by electron saturation.

The experiment was performed in a static magnetic field of 30.3 gauss provided by a small end-corrected solenoid. The sample containing 5 cm³ of lithium dispersed in oil was placed in the tank coil of a 50-watt oscillator operating at 84 Mc/sec, the Larmor frequency for the electrons in the magnetic field. Measurements