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II-4-35. Neutron Production in Lead by Cosmic Ray Protons

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The average number of evaporation neutrons produced by the interaction of protons in lead has been determined for protons of momenta 0.3 to 150 Gev/c.

A magnetic spectrograph[1] was used at sea level to select protons of known momenta up to a maximum detectable value of 150 Gev/c. The protons interacted in a standard neutron monitor placed beneath the spectrograph and the evaporation neutrons produced were detected by opening a gate in the neutron monitor recording channel from 20 to 250 μsec after the passage of any single particle through the spectrograph.

The criteria adopted to distinguish accidental neutron coincidences and neutron production by positive muons from proton interactions were as follows. Those events in which a single charged particle emerged from the monitor with a deflection of less than two standard deviation of the expected multiple scattering distribution were rejected as being most probably due to accidental coincidences and those events in which the deflection lay between two and seven standard deviations were rejected as being possibly due to muon interactions. The events accepted as proton interactions were those in which a) no particles emerged from the monitor b) in which one particle emerged with a deflection greater than seven standard deviations of the expected scattering distribution and c) in which two or more particles emerged.

Fig. 1 shows on a semi-logarithmic scale the relative frequencies with which the various multiplicities were observed for proton interactions in four momentum intervals. The experimental points have been fitted by straight lines, which is consistent with the assumption that at all momenta the neutrons are produced according to an exponential multiplicity spectrum. An exponential production spectrum has also been reported recently[2] for evaporation protons produced by 20 Gev/c protons interacting with emulsion nuclei. The average number of produced neutrons is shown in Fig. 2 as a function of proton energy together with the variation expected up to 2 Gev from the Monte Carlo calculations of Metropolis[3] and Dostrovsky[4].

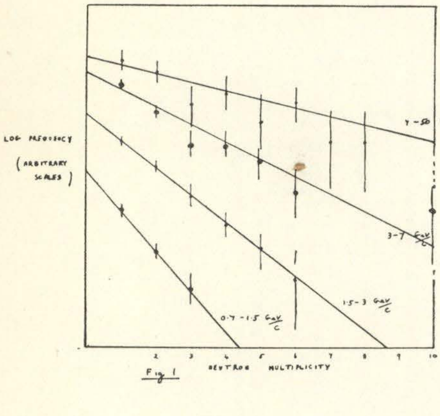

Fig. 1.

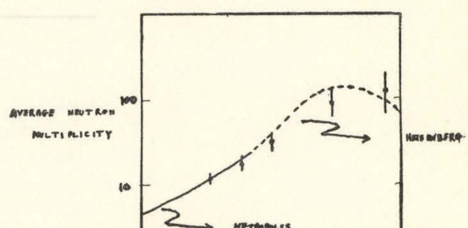

Fig. 2.

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The agreement between theory and experiment up to 2 Gev (also found by Bercovitch up to 1 Gev[5]) suggest that pion production and subsequent pion interactions within the nucleus are mainly responsible for the large number of evaporation particles in high energy nucleon-nucleus collisions. The form of the experimental curve at energies in excess of 2 Gev would be expected from a pion production theory in which low energy pions were most frequently produced. The dashed curve of Fig. 2 gives an estimate of the variation to be expected according to Heisenberg's theory[6] for the target thickness used in the present experiment (13.2 cms).

References

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2) G. Cvijanovich, et al.: Nuovo Cimento, **20** (1961) 1012.
3) N. Metropolis, et al.: Phys. Rev., **110** (1958) 188.
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Discussion

Stoker, P.H.: How much is the contribution to neutron production by π-mesons with respect to the protons for the different energy regions?

Marsden, P.L.: There is no experimental evidence to suggest that the neutron production by π-mesons and protons is different and therefore the relative neutron production by these particles depends upon their relative fluxes. These are, at energy E, in the ratio.

E	1 Gev	10 Gev.	100 Gev.
π/proton	0.05	0.10	$\sim$0.10