TABLE I. The total interaction cross sections in carbon, paraffin, and lead for pions of median energy 920 Mev.

Material	$C^{\pm}$	C^{+}	C^{-}	$CH_2^{\pm}$	$Pb^{\pm}$
Σ in g cm^{-2}	21.2	21.2	21.2	23.8	71
λ in g cm^{-2}	74±7	74±8	74±9	77±8	208±38
σ in mb	270±25	270±30	270±34		1660±300
$\sigma/A^{2/3}\pi r_0^2$ [a]	0.76±0.07	0.76±0.09	0.76±0.10		0.70±0.13
Relative corrected numbers of events classified according to their appearance only					
Stop plus scattering >20°	51	49	52	53.5	78
Interactions	14.5	13.5	14.5	20.5	11
Scattering 0°–20°	34.5	37.5	33.5	26	11

[a] $r_0 = 1.47 \times 10^{-13}$ cm.

For the scattering greater than 10° (proj; lab), $\sigma(\pm) = 10 \pm 10$ mb. The correction for pions and recoil protons scattered at projected angles <10° may amount to a factor 2 if one assumes $\sigma(\theta) \propto \cos^2(\theta)$ (in the c.m. system). Even though the error is uncomfortably large, comparison with the value of 100 mb (average for + and −) observed at 135 Mev[5] still appears significant, indicating that the elastic scattering decreases at large energies.

The number of events attributed to production of mesons, again not of good statistical accuracy, seems to indicate that this process[6] occurs for pion-proton collisions of high energy; the measured cross section is 13.5±6 mb. Also, such a process would best explain the observed occurrence in carbon and lead of visible interactions within a restricted solid angle. A detailed account will be given later.

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An Unusual Meson-Induced Star*

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AN event which is interpreted as a heavy meson-induced star has been observed in an Ilford G5 400-micron thick plate which had been exposed for ten hours above 90,000 feet by means of a "skyhook" balloon. About three pounds of water in metal containers were directly below the stack of plates. The plates were searched for τ- and κ-meson events. A total of 51 $\pi-\mu$ decays, 39 negative π-stars, and 211 mesons which stopped in the emulsion without associated tracks other than electrons, the bulk of which are μ-mesons, have been observed along with the unusual meson star. A projection drawing of the unusual meson star is shown in Fig. 1. The grain density along track 1 is the same, within statistical limits, as along minimum ionizing tracks in the plate. The track has been followed into the adjacent plate. However, the track is nearly perpendicular to the plane of the emulsion; therefore careful scattering measurements were not made. The particle which produced the track was scattered at a point through an angle of about 2 degrees in the adjacent plate. Track 2 is 490 microns long and goes into the glass backing of the plate. From the multiple scattering along track 2, the energy of the particle was found to be about 15 Mev. Since the grain density along the track is about 2 times higher than the grain density along minimum tracks, the track was most probably produced by a π-meson. If it is assumed that the track was produced by a proton, the grain density along the track would indicate that the proton had an energy of about 200 Mev which is in disagreement with the scattering measurements. Track 3 is about 200 microns long and ends in the emulsion and was produced by a proton or a deuteron.

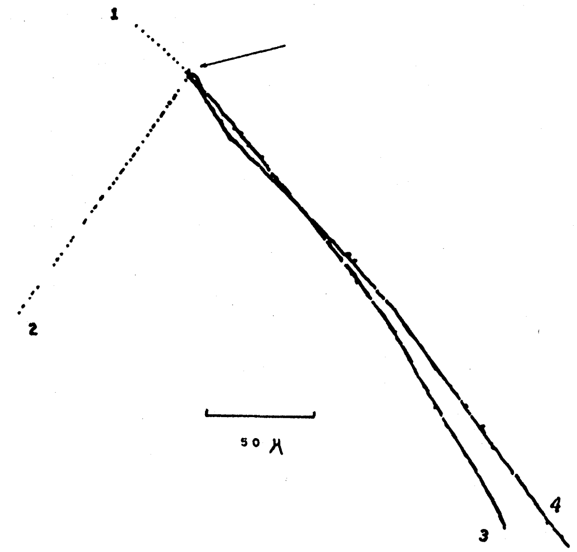

FIG. 1. A projection-drawing of an event which is interpreted as a star due to the nuclear capture of a negative τ- or κ-meson. The large amount of scattering along track 4 near the star strongly indicates that the particle was going toward the star with a low velocity. A recoil or low energy electron track is indicated by the arrow.

The multiple scattering was measured along track 4, using cells of 10 microns. The track is 330 microns long. The average scattering along a 50-micron section of the track near the star is more than 4 times larger than the average scattering along the remainder of the track. The increase in the scattering near the star strongly indicates that the particle was traveling toward the star with a low velocity. The rapid increase in the multiple scattering in the last 50 microns of track length is to be expected from a consideration of the increase in the scattering parameter, $1/p\beta$ for a particle of mass 1000 m_e. The particle which produced track 4 entered the emulsion from the glass backing and came from the direction of the material below the plates. The number of gaps along track 4 has been measured and compared with the number of gaps in the neighborhood of the star along μ-meson and proton tracks which had approximately the same range and which also made about the same angle with the plane of the emulsion. The results of the gap counting are shown in Fig. 2. The gap density is less along the portion of the track near the star. If the track is divided into two

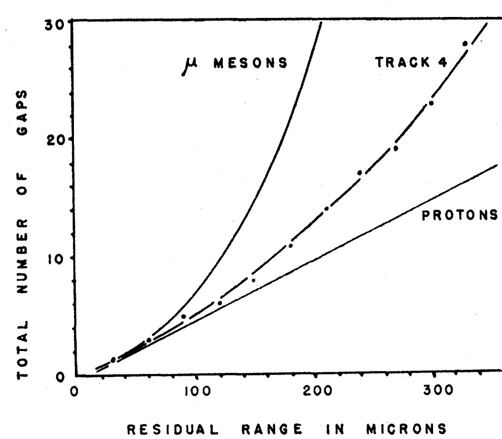

FIG. 2. The total number of gaps up to the range R is plotted against the range R, starting at the end of the track. The number of gaps along track 4 is clearly inconsistent with the assumption that the track was produced by a π-meson.

parts, the half of the track near the star has 10 gaps while the other half of the track has 18 gaps. This variation in the gap density further indicates that the particle which produced the track traveled toward the star. Aside from the characteristics of the track itself, the observable energy release in the star cannot be explained if track 4 is assumed to be due to a slow negative π-meson. The gap density, δ-rays and multiple scattering along track 4 make it quite certain that the track was produced by a slow meson whose mass was less than that of a proton and which traveled toward the star; therefore, it seems probable that the meson was a negatively charged τ- or κ-meson, of which several examples of the positively charged mesons have been observed recently.[1-6] From the grain density and the point scattering along the track, it would seem reasonable to assume that track 1 is due to a π-meson with a kinetic energy of the order of the rest energy. Assuming that track 1 was produced by such a π-meson, track 2 by a π-meson and track 3 by a proton, the vector sum of the momentum of the charged particles from the star is 160 Mev/c, which corresponds to the momentum of a neutron of about 11 Mev energy. The total kinetic energy of all the charged particles observed plus the rest energy of the two mesons is less than the rest energy of a τ-meson or κ-meson It is then concluded that the event is an example of the nuclear capture of a negative τ- or κ-meson where two mesons and one heavy particle are ejected plus one or more neutral particles and possibly a recoil or a low energy electron.

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Angular Distributions of the Be^9+D Neutrons†

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Neutrons from $Be^9(d, n)B^{10}$, B^{10*} were observed at six angles between 15° and 140°, by means of recoil proton tracks in 100-micron Ilford C-2 nuclear plates. A thin Be target (0.1 mg/cm²), supported by 1/64-inch copper backing, was bombarded by 0.94-Mev deuterons focused on a target spot 1/8-inch in diameter. The nuclear plates were mounted 5 cm from the target inside a large paraffin-lined target chamber, with the target spot in the plane of each emulsion.

Recoil proton tracks were measured under oil immersion (40× objective, N.A. 1.00), using acceptance criteria similar to those adopted by others.[1] Angular distributions obtained for five neutron groups are shown in Fig. 1. Using a standard range-energy curve[2] the ground state Q was calculated to be 4.44 Mev, and excitation energies in B^{10} for the other groups are 0.76, 1.78, 2.22, and 3.68 Mev. It is estimated that these numbers are good ±0.05 Mev, aside from possible errors in the range-energy relation. The agreement with neutron data of Ajzenberg[3] and gamma-ray data of Rasmussen *et al.*[4] is satisfactory.

As shown in Fig. 1, each angular distribution shows some evidence for a forward peak, suggestive of the stripping process. In particular, the lowest energy neutron group (E_x=3.68 Mev) can be fitted remarkably well by a curve calculated from the theory of Butler[5] for $l_p=1$. Curves for $l_p=0$ and 2 are included for comparison. The effect of the low deuteron energy in broadening and separating the peaks corresponding to different values of l_p is quite evident.

The other four distributions show an increasing yield in the backward quadrant, similar to distributions observed in the $Be^9(d, p)Be^{10}$, Be^{10*} reaction.[6] At higher bombarding energies,

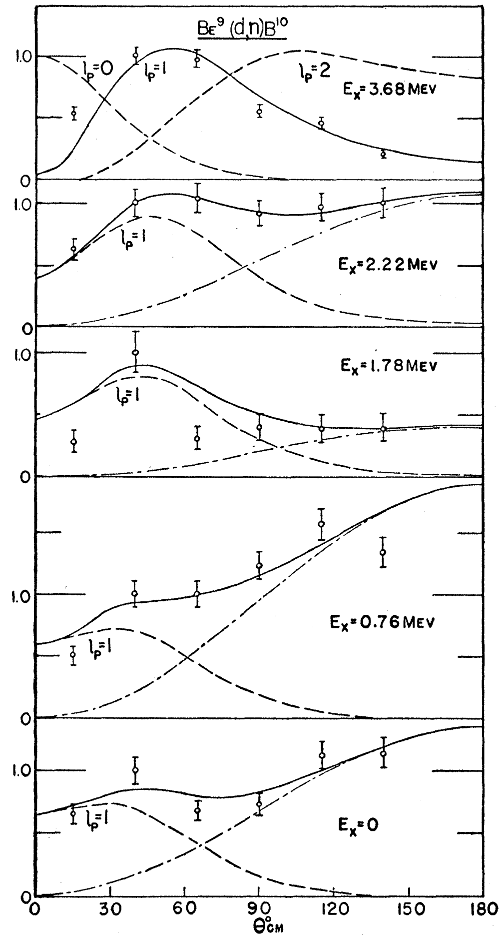

Fig. 1. Angular distributions in the center-of-mass system of neutrons from $Be^9(d, n)B^{10}$, B^{10*}. E_x = excitation energy of B^{10}. Dashed curve = stripping curve for the value of l_p shown. Dash-dot curve = $(1-\cos\theta)$. Solid curve = sum.

departures from the theoretical stripping curves have generally been attributed to compound nucleus formation. At low bombarding energies, the compound nucleus undoubtedly plays an important if not a predominant role. Accordingly, we have attempted to analyze the observed distributions into two parts: one attributed to the stripping process, the other to compound nucleus formation. In view of the uncertainties in the measurements and the fact that the theory used[5] does not take into account the Coulomb barrier, which is certainly important at low bombarding energy, we have not attempted a detailed analysis. A simple $(1-\cos\theta)$ curve added to the $l_p=1$ stripping curve gives a reasonable fit to most of the data. (It should be mentioned that statistics were extremely poor for the group at E_x=1.78 Mev.) Such a distribution is typical of strong interference between waves of opposite parity and low angular momenta in the compound nucleus process.

Diesendruck[7] has made a similar analysis of the distribution of long-range protons from $Be^9(d, p)Be^{10}$ for deuteron energies of 1 to 3 Mev. The assignment of $l=1$ in these (d, n) and (d, p) reactions is confirmed by observations[8] at higher bombarding energies where the stripping process is well substantiated. This assignment fixes the parities of the final states as even, if Be^9 is odd, and limits the angular momenta to 0, 1, 2 or 3.

Table I shows the relative "neutron weights" of the 5 states of B^{10} from our thin target data. Also shown for comparison are the "gamma-ray weights" of the excited states from the thick target intensity data of Rasmussen[4] at E_d=1.2 Mev, assuming the level