Title
SUMMARY OF THE RESEARCH PROGRESS MEETING OF FEBRUARY 23, 1950

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Summary of the Research Progress Meeting of February 23, 1950

Henry P. Kramer

Radiation Laboratory, Department of Physics
University of California, Berkeley, California

March 16, 1950

Showers from Synchrotron γ-Rays. E. Hayward.

The use of the synchrotron in the investigation of showers offers decided advantages over techniques involving cosmic rays since the synchrotron makes available a γ-ray spectrum of known energy distribution at high intensity.

Existing shower theory makes an attempt to predict the shape of the shower curve, the function which relates the number of electrons to the thickness of material, the energy distribution of the electrons with thickness as a parameter, the angular dispersion of the shower, and the electron multiplication. Kenney and Blocher et al. have made measurements of these quantities for showers produced by γ-rays from the synchrotron by using crystal detectors. The present investigation is concerned with the measurement of these quantities by means of a cloud chamber.

A cloud chamber in a field of 18,000 gauss which allows the measurement of 3-150 Mev electrons, was equipped with a lead materializer 0.48 in. in thickness. This thickness was chosen because it corresponds to the peak intensity on the shower curve determined by Kenney, Blocher et al. The uncertainty in the energy determination was about 5 percent, and the error in the determination of angles due to multiple scattering is about six percent. The variation of intensity with energy is shown in Fig. 1 superimposed on a curve calculated from theory by W. Aron. At low energies the experimental results are made unreliable by the fact that multiply scattered electrons at these energies produce tracks that lie very close to the lead plate and do not therefore yield completely clear results.

Fig. 2 shows the angular distribution as a function of energy. These curves are based on a total count of 760 electron tracks.

Electron multiplication will be investigated in the future by varying the thickness of materializer used.

Synchrotron Experiments with Nuclear Plates.

1. Hydrogen Target Experiment. L. Cook.

The experiment whose arrangement is sketched in Fig. 3 is designed to measure the cross section of hydrogen for the production of positive mesons at various energies and an angular range of 90° ± 30°. The liquid hydrogen line target, enclosed in a vacuum and cooled by liquid hydrogen, is exposed to a collimated beam of γ-rays. Nuclear plates arranged on the circumference of a circle with the line target as a perpendicular axis are capable of recording all mesons that are emitted at 90°, 30° to the beam direction and have passed through an absorbing foil.

700 mesons have been counted. Among these, only one negative π-meson has been observed. Of the 700 tracks, 300 have been plotted and of these 170 were found to be due to π-mesons. Finally, 112 π-mesons have been detected whose tracks are so oriented as to indicate that the mesons came from the target. Fig. 4 shows the plot of the differential cross section $d^2N_o/dE_\pi d\Omega$ where N_o is the number of mesons counted, E_π is their energy and $d\Omega$ is an element of solid angle.

2. Carbon Target Experiment. J. Peterson.

Fig. 5 shows the experimental arrangement for the detection of mesons produced at 45°, 90°, and 135° in a carbon sphere by the synchrotron γ-ray beam. Nuclear plates are embedded at different depths in a copper cylinder which is concentric with the beam. The plates are arranged in three sets so that the vectors from the carbon sphere to the plates in a set subtend the same angle with the direction of the beam.

The data are insufficient at present to allow an estimate of the ratio of the number of positive heavy mesons and the number of negative heavy mesons as a function of energy. For all energies:

Fig. 6 gives an indication of the variation of differential cross section as a function of meson energy for the three angles 45°, 90°, and 135°. It is of interest that in the range of energies 20-70 Mev more mesons appeared in the backward than in the forward direction.

For the ratio of production cross sections per nucleon for hydrogen and for carbon, Cook and Peterson found the value 3.2 with nuclear plates whereas Steinberger and Bishop determined the value 3.5 with crystal counters.

3. Photostars. R. Miller.

Nuclear plates were placed behind absorbers of various thicknesses directly into the uncollimated synchrotron beam. Exposures were made with the maximum energy of photons in the beam at 335 Mev, the maximum energy available from the machine, 290 Mev, 240 Mev, and 190 Mev. The sketch of Fig. 7 indicates the relative number of stars at different energies as a function of the number of prongs.

Theoretical Interpretations of Photomeson Production. K. Brueckner.

The interaction of a photon with a nucleon to produce a heavy meson submits to analysis of a simpler sort than that of a particle with a nucleon since in essence it may be regarded as the interaction only of an electro-magnetic field with electric and magnetic dipoles. For, a nucleon may be thought to be surrounded by a distribution of meson current which is oriented into an electric dipole by the action of the electro-magnetic field of the photon. Thus, a neutron is dissociated into a proton surrounded by a negative mesonic current with a certain probability that an electric dipole is set up in the manner indicated in Fig. 8. The energy of the photon may then be sufficient to cause a complete dissociation of the neutron into a negative π-meson and a proton.

In the production of photomesons as sketched above there is a strong asymmetry in the angular distribution of the ejected mesons about 90° with the direction of motion of the photon since a characteristic term in all the calculations is $1/(1-(v/c)\cos\theta)$, where θ is the angle of the ejected meson with the direction of motion of the photon and v is its velocity. It is only when v is comparable to c, the velocity of light, that this term is appreciably greater than 1 and that asymmetry arises.

The four meson theories that have been proposed, the scalar, vector, pseudovector and pseudoscalar theories, attempt to predict the coupling between nucleons and their meson clouds, and hence, the magnitude of the electric and magnetic dipoles. Calculations have been made of angular distribution of mesons ejected at two distinct energies, 40 and 80 Mev, by photons from the continuous 1/E spectrum from the synchrotron. The results of the calculations are displayed in Figs. 9, 10, 11, and 12.

The scalar and vector theory must be rejected since experimental evidence shows no peak in the forward direction as predicted by these theories. The principal objection to the vector theory is that it predicts a larger cross section for mesons ejected at high energies than for those ejected at low energies. This is contrary to experimental evidence. The angular distribution and the variation of cross section with energy that are predicted by the pseudoscalar theory are in approximate agreement with observation. This is characteristic not alone of the pseudoscalar theory but of any theory that binds mesons closely to the nucleon and considers the magnetic dipole interaction.

A further test of the theories is offered by the calculations whose results are exhibited in Fig. 13. The ratio of positive to negative mesons calculated on the basis of the pseudoscalar theory is not in accord with observation.

The conclusion that can be drawn from the work is that all meson theories that have been proposed are unsatisfactory in predicting experimental results and that a satisfactory theory must have in common with the pseudoscalar theory the assumption of close binding between nucleons and mesons and the consideration of the magnetic dipole.

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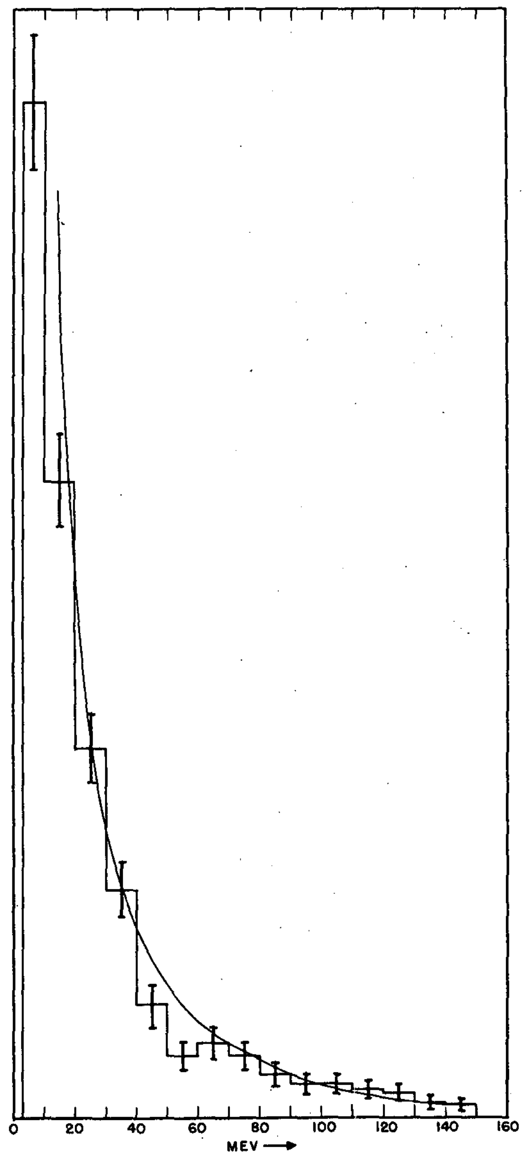
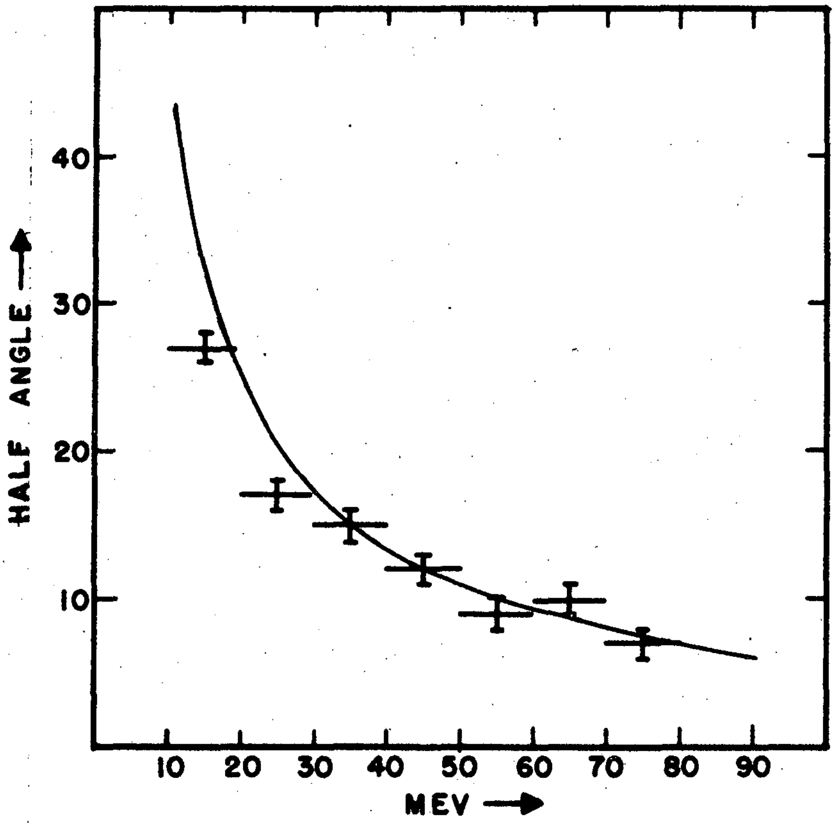


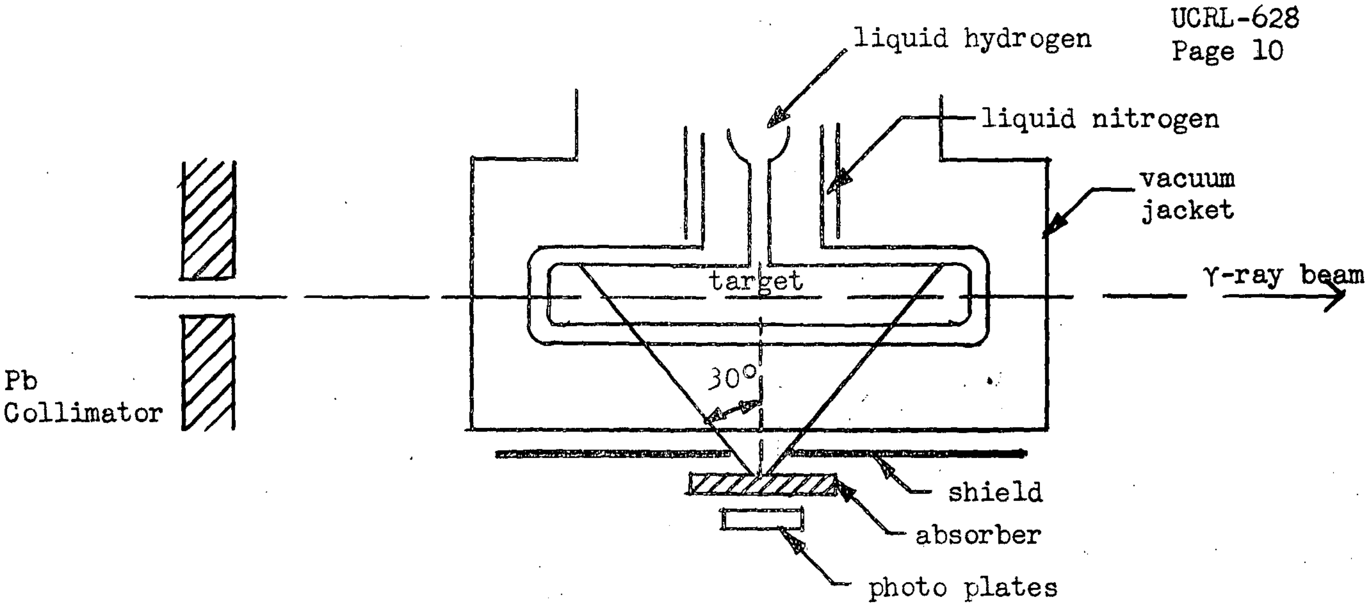
Mu 74

FIG. 1

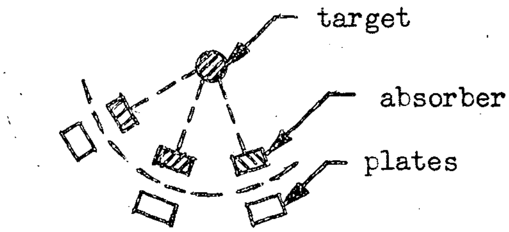


Mu 73

FIG. 2

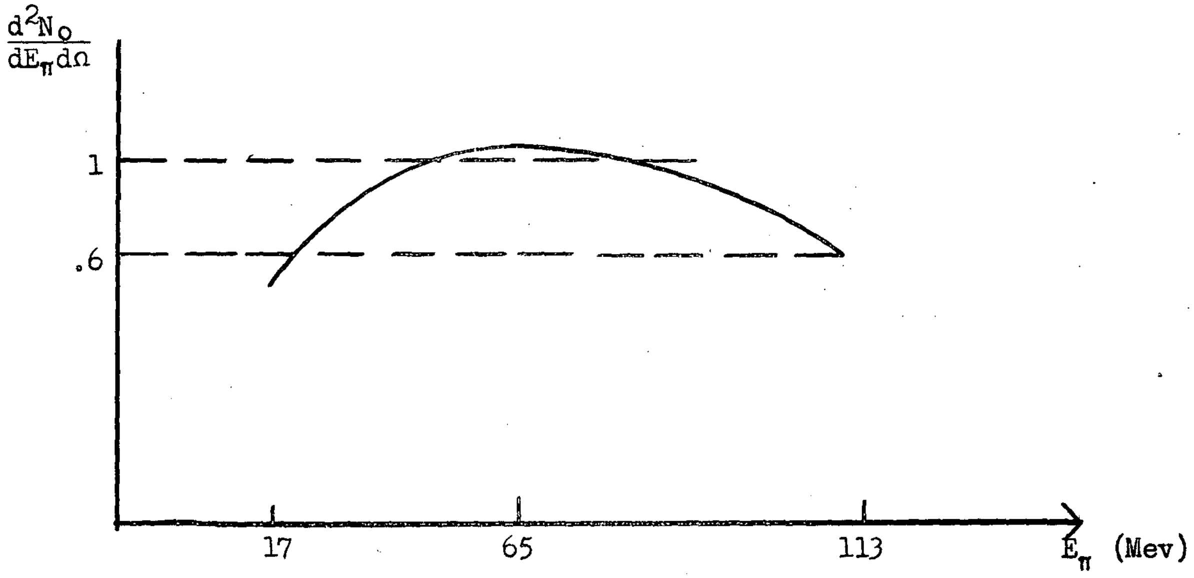


Hydrogen Target Experiment



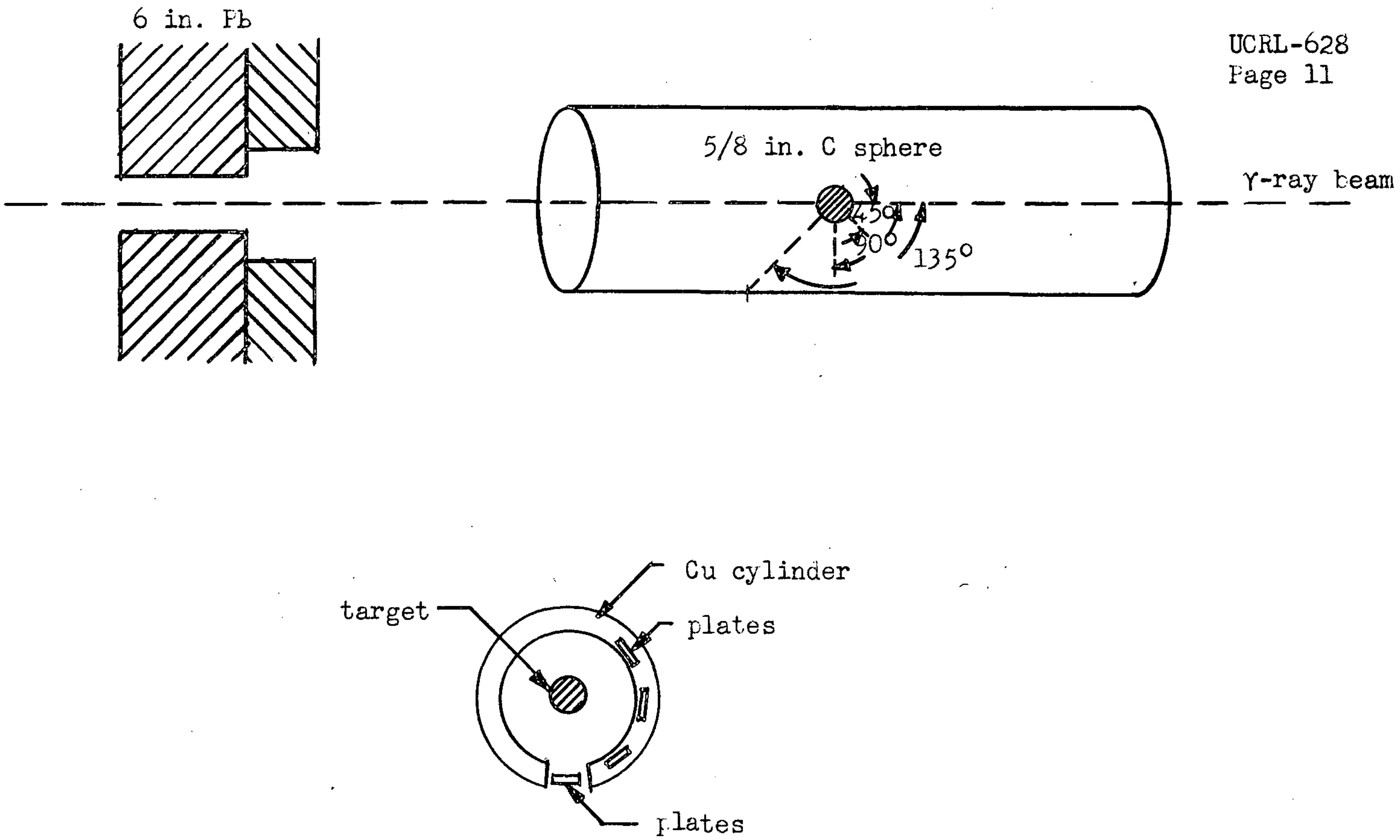
Front view: Hydrogen Target Experiment

Fig. 3



Differential Cross Section as a Function of Energy

Fig. 4



Carbon Target Experiment
Fig. 5

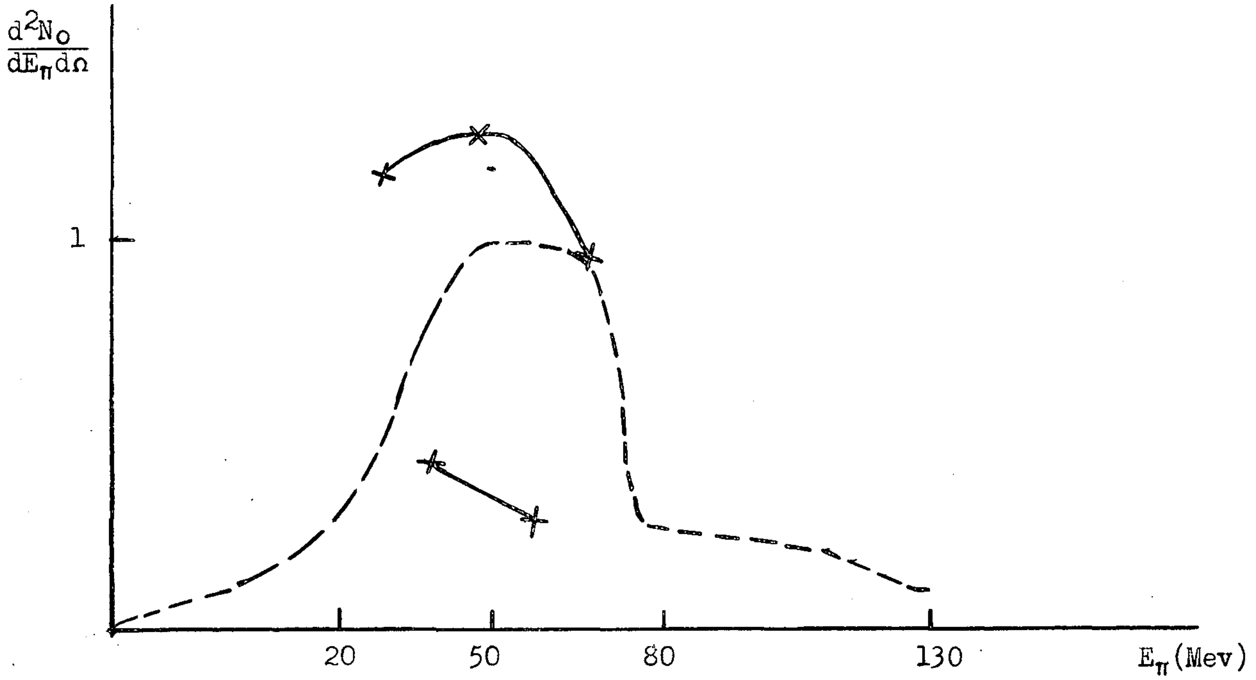
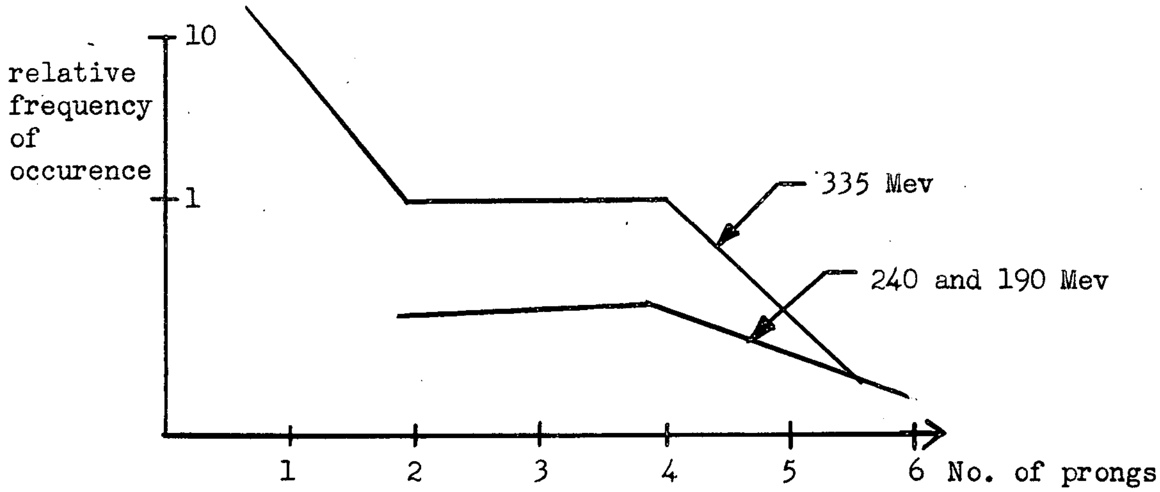


Fig. 6



Relative Frequency of Occurrence of Stars at Different Energies
Fig. 7

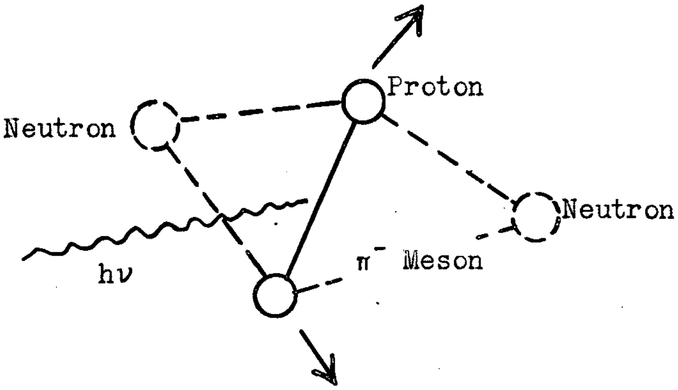


Fig. 8

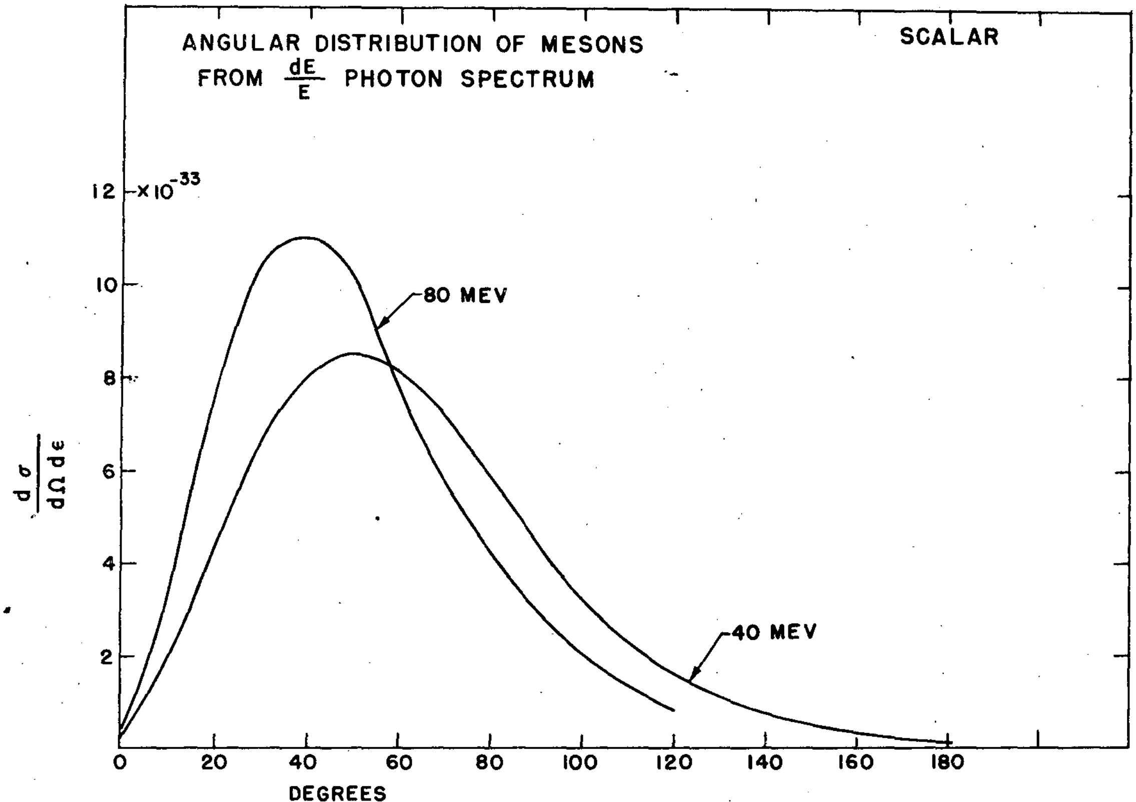


FIG. 9

Mu 70

14370

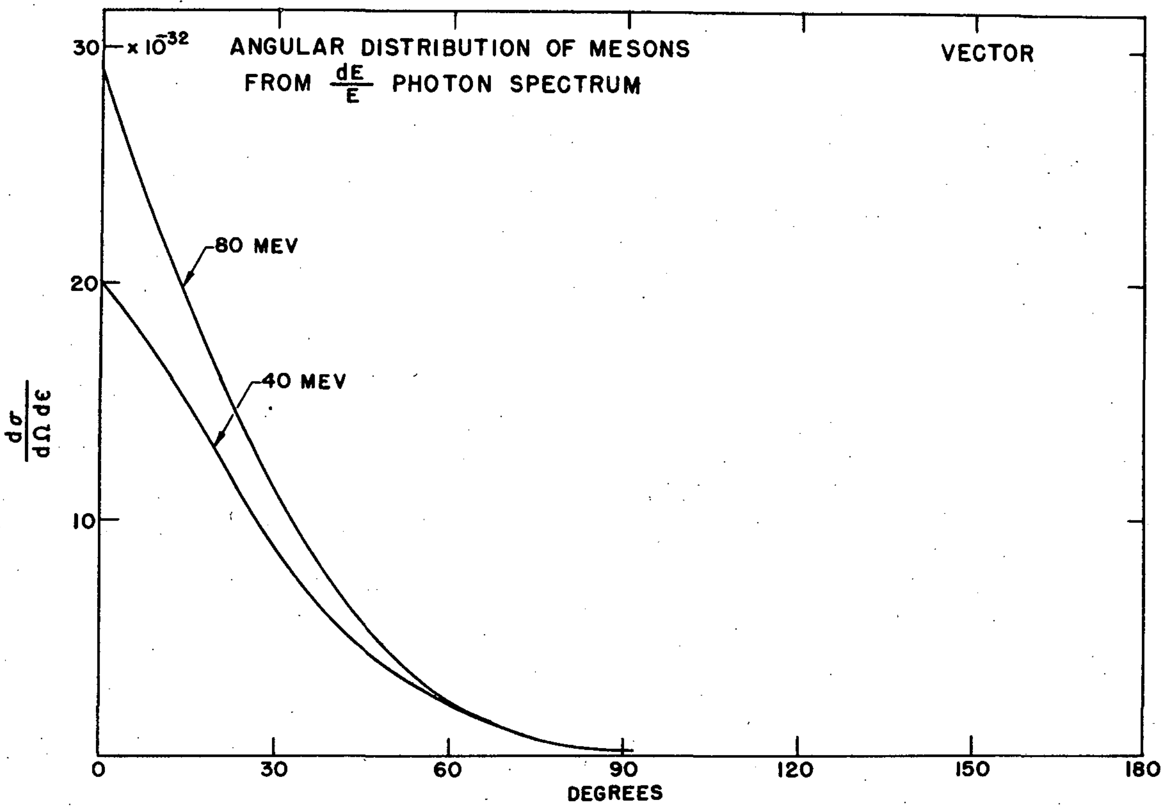


FIG. 10

Mu 71

14371

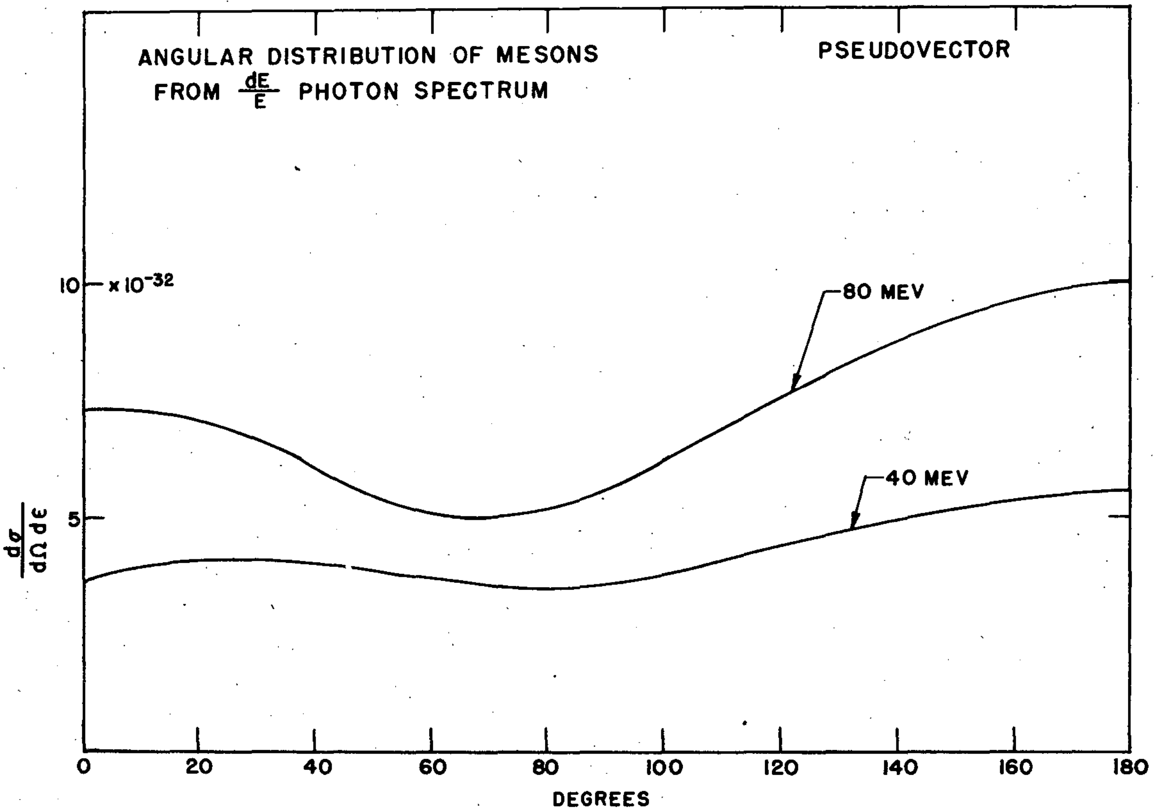

ANGULAR DISTRIBUTION OF MESONS
FROM $\frac{dE}{E}$ PHOTON SPECTRUM
PSEUDOVECTOR
80 MEV
40 MEV
10
$\times 10^{-32}$
5
$\frac{d\sigma}{d\Omega\, d\epsilon}$
0
20
40
60
80
100
120
140
160
180
DEGREES

FIG. 11

Mu 72

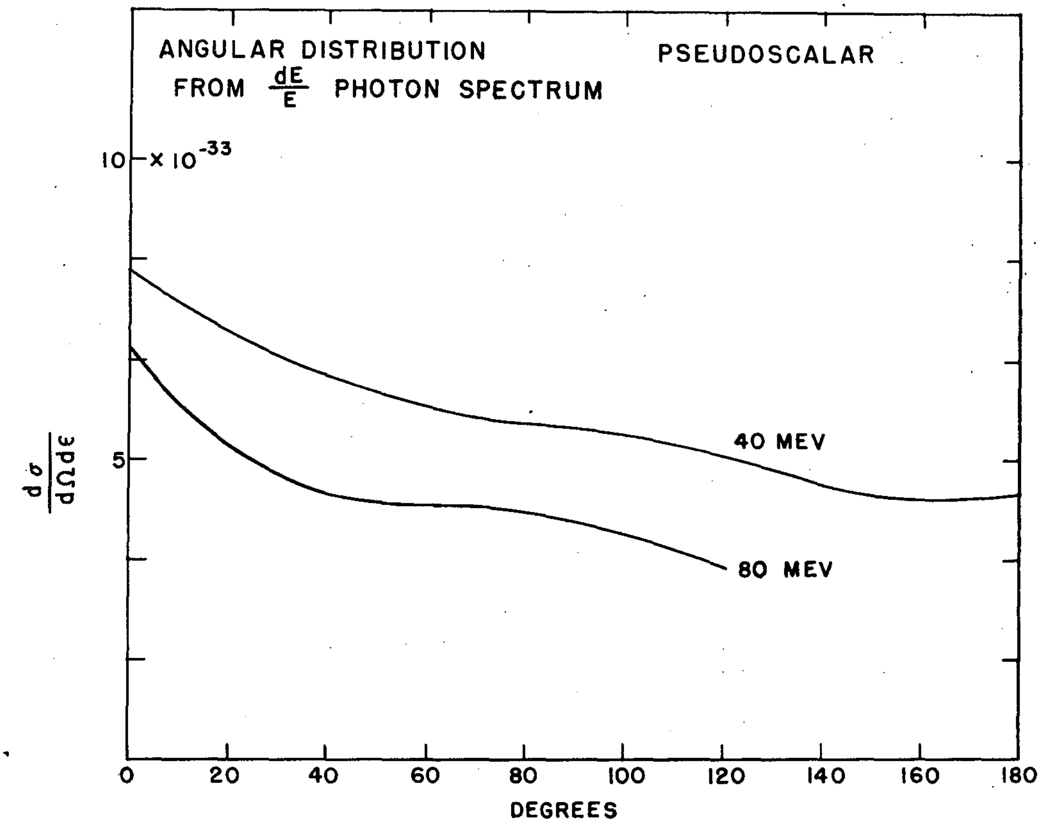


FIG. 12

Mu 69

14369

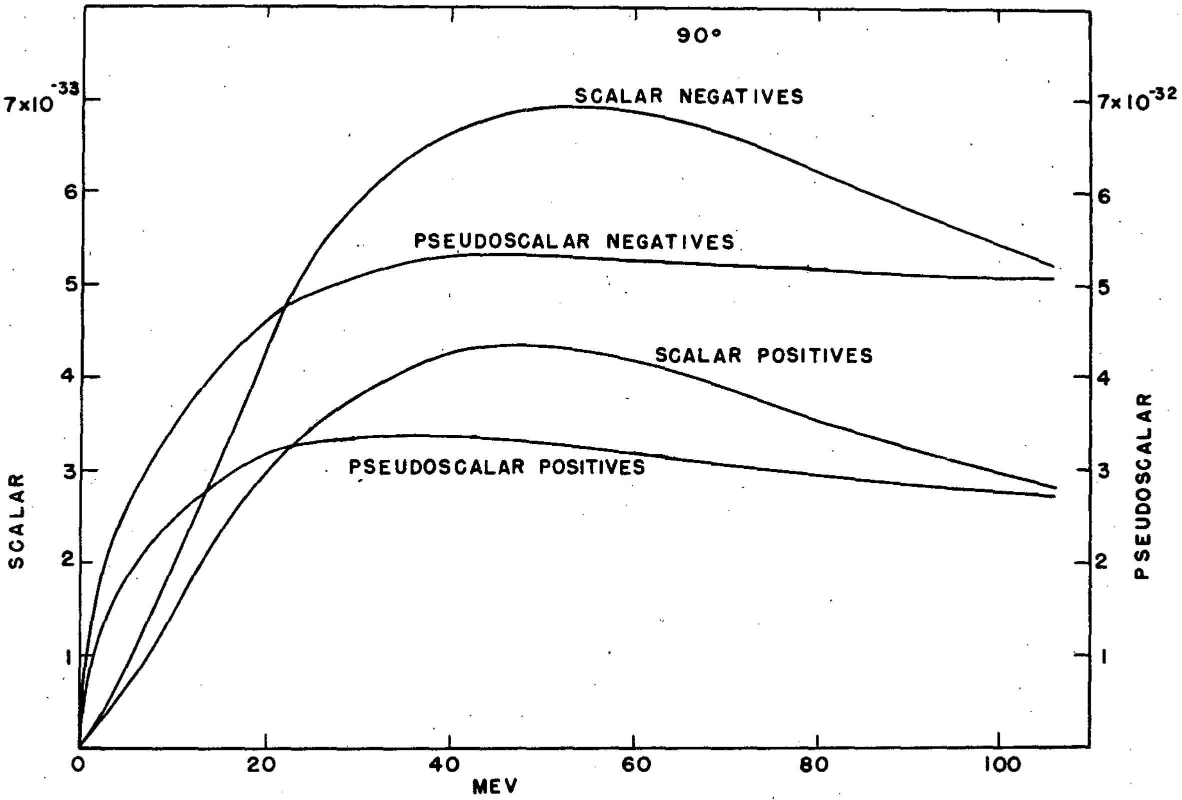


FIG. 13

Mu 68

13933-1