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DEVELOPMENT REPORT

PHOTODISINTEGRATION STUDIES OF He^{3*}

(preliminary results)

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We have measured, and present preliminary results for the differential cross-section for two-body photodisintegration of Helium-3,

$$\gamma + He^3 \rightarrow p + d \quad ,$$

for incident photon energies from 200 to 500 MeV. Data were taken at center-of-mass angles from 30^o to 150^o in 30^o steps, as well as at 75^o. These energies and angles were chosen so as to investigate the contribution of the $\Delta(1236)$ resonance in the S-channel. The presence of the Δ would appear centered at a photon energy of about 300 MeV. The width of a "bump" in the cross-section due to the Δ is broadened by the relative momentum of the Δ and the other two nucleons in the intermediate state. This broadening should be large because isospin conservation requires the two non-resonant nucleons to be in an I=1 state, the simplest of which is an unbound ^1S_o configuration. In contrast, the photodisintegration of the deuteron shows a clear resonance bump at photon energy near 270 MeV[1)].

The experiment was performed at the Caltech 1.5 GeV electron synchrotron. A bremsstrahlung photon beam, collimated to 3 milliradians, was incident on a condensation-type liquid He^3 target maintained at a temperature of 2^o K. The photon beam was continuously monitored by a thick-plate ion chamber, which was calibrated daily against two Wilson quantameters. The detection apparatus consisted of two arms, each containing wire spark chambers and scintillation counters. The forward arm also included a magnet with the wire chambers arrayed before and after it for accurate momentum measurement. Whichever particle in the final state, proton or deuteron, was produced at forward angles in the center of mass was detected in this arm. For production at 90°, data were taken with either the proton or deuteron in the forward arm as a consistency check. The event signature was the coincidence of a charged particle in each of the scintillation counter telescopes of the two arms. The coordinates of sparks in the wire chambers were recorded on magnetic tape for each event via a magnetostrictive readout system connected to an on-line PDP-5 computer. Also recorded on tape were the pulse heights of the signals in the scintillation counters and the time of flight of the particle in the forward arm. Approximately 300,000 events were collected.

The data are being analyzed with the aid of a digital computer. The reconstruction of particle tracks is entirely completed. We estimate the efficiency of the track reconstruction program to be better than 99%. For each event, we have reconstructed the angles of two charged particles in the final state, and the momentum of the forward moving one. For further analysis, we assume we know the mass of the forward moving particle and also the direction of the incoming photon (but not its energy). Good $\gamma + He^3 \rightarrow p + d$ events are extracted from the total sample by means of cuts on the following parameters: 1) pulse heights in the scintillation counters; 2) time of flight of the forward moving particle; 3) coplanarity of (or azimuthal angle between) the two particle tracks; and 4) the reconstructed mass of the backward moving particle. Figure 1 shows plots of time of flight against coplanarity and time of flight against the reconstructed mass excess for a run with the deuteron in the forward arm. The signal at times of flight greater than 80 (arbitrary units) stands out clearly from the background of events with protons in the forward arm.

The above procedure left us with approximately 30,000 events, in which we estimate presently a 5-10% contamination due to background processes. This background is primarily due to three-body breakup of He^3 -- $\gamma + He^3 \rightarrow p + p + n$, and pion production in addition to the two or three baryons in the final states.

To calculate the cross-sections, the numbers of good events at each setting are weighted with the geometrical detection efficiency and the spark chamber efficiency, the number of incident photons per unit energy interval, etc. The geometrical efficiency is calculated by means of a Monte Carlo computer program which has accumulated statistics to the 1% level. The spark chamber efficiency for "good" events is extrapolated from the full sample of events which satisfy our pulse height requirements; they define an efficiency since pulse heights are recorded for all events whether or not some chamber fired. This procedure is performed for every setting of the experiment. As a measure of the uncertainty caused by this extrapolation, we use the statistical error associated with the efficiency generated as above. This efficiency is verified by a calculation based on the observed efficiency of each chamber individually. The latter approach is not, however, statistically as accurate as the one used.

The analysis which remains to be done is the investigation of possible systematic errors. We shall make a subtraction to eliminate the remaining background in the sample of "good" events. Empty target runs were taken and the resulting corrections are small, but they have not been applied to the preliminary results given here. Corrections for the variation of target density with temperature have yet to be made; this effect is of the order of 2%, as long as no gross malfunction in the cryogenics system occurred.

The preliminary cross-sections as a function of center of mass angle of the proton for various energies are presented in Figure 2. The curves are the results of the fits described below. The data have been binned in 50 MeV intervals for display; they were, of course, collected from a continuum of energies due to the nature of the bremsstrahlung spectrum. Figure 3 presents the total cross-section as a function of energy, based on the fits to the differential cross-sections described below.

The only previous study of the photodisintegration of Helium-3 in the present energy range is that of Picozza, Schaerf, and Scrimaglio[2]. They measured the differential cross-section at 90^{o} in the center of mass from 200 to 500 MeV incident photon energies. Their results are about a factor of 2.5 larger than ours. We note that lower energy data, taken below 150 MeV[3], extrapolate smoothly into our results presented here.

To parametrize our results in a simple fashion we consider only the first three multipole transitions

$$E1 \rightarrow {}^2P_{1/2} \ , \ {}^2P_{3/2}$$

$$E2 \rightarrow {}^2D_{3/2} \ , \ {}^2D_{5/2}$$

$$M1 \rightarrow {}^4S_{3/2} \qquad ,$$

where S, P, and D label the p-d relative orbital angular momentum, the superscript labels the p-d spin multiplet, and the subscript labels the total angular momentum. The magnetic dipole transition, $M1 \rightarrow {}^4S_{3/2}$, could contain the $\Delta(1236)$ in an intermediate state. These transitions lead to an angular distribution of the form

$$A + B\cos\theta + \sin^2\theta\,(C + D\cos\theta + E\cos^2\theta) \qquad ,$$

where θ is the center of mass angle. Parameter A is the only one which contains the effect of the magnetic dipole transition. The results of fitting the above angular distribution to the data are shown in Figure 2.

The number of parameters combined with the preliminary status of the data allow only general conclusions to be drawn at this time. Similar fits to lower energy Helium-3 photodisintegration indicate the magnetic dipole transition to be almost entirely absent[4]. Our fits indicate the contribution of this transition rises with energy to a plateau of roughly 1/3 of the cross-section above 300 MeV.

REFERENCES

1. J. Buon, V. Gracco, J. LeFrancois, P. Lehmann, B. Merkel, and Ph. Roy, Physics Letters 26B, 595 (1968).
2. P. Picozza, C. Schaerf, and R. Scrimaglio, Nuovo Cimento 55A, 206 (1968).
3. See N.J. Carron, Physical Review 168, 1095 (1968).
4. G.M. Bailey, G.M. Griffiths, and T.W. Donnelly, Nuclear Physics A94, 502 (1967).

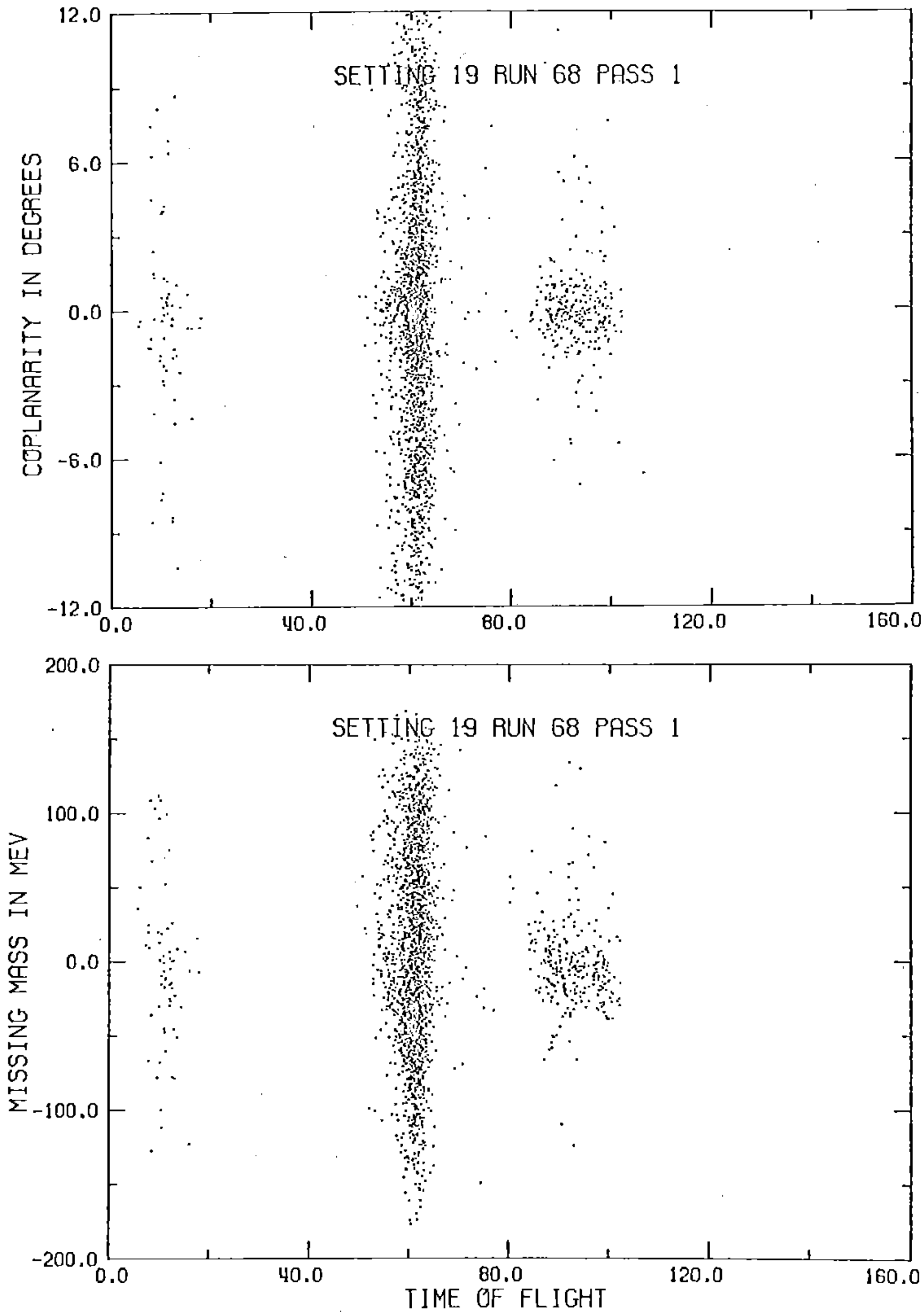
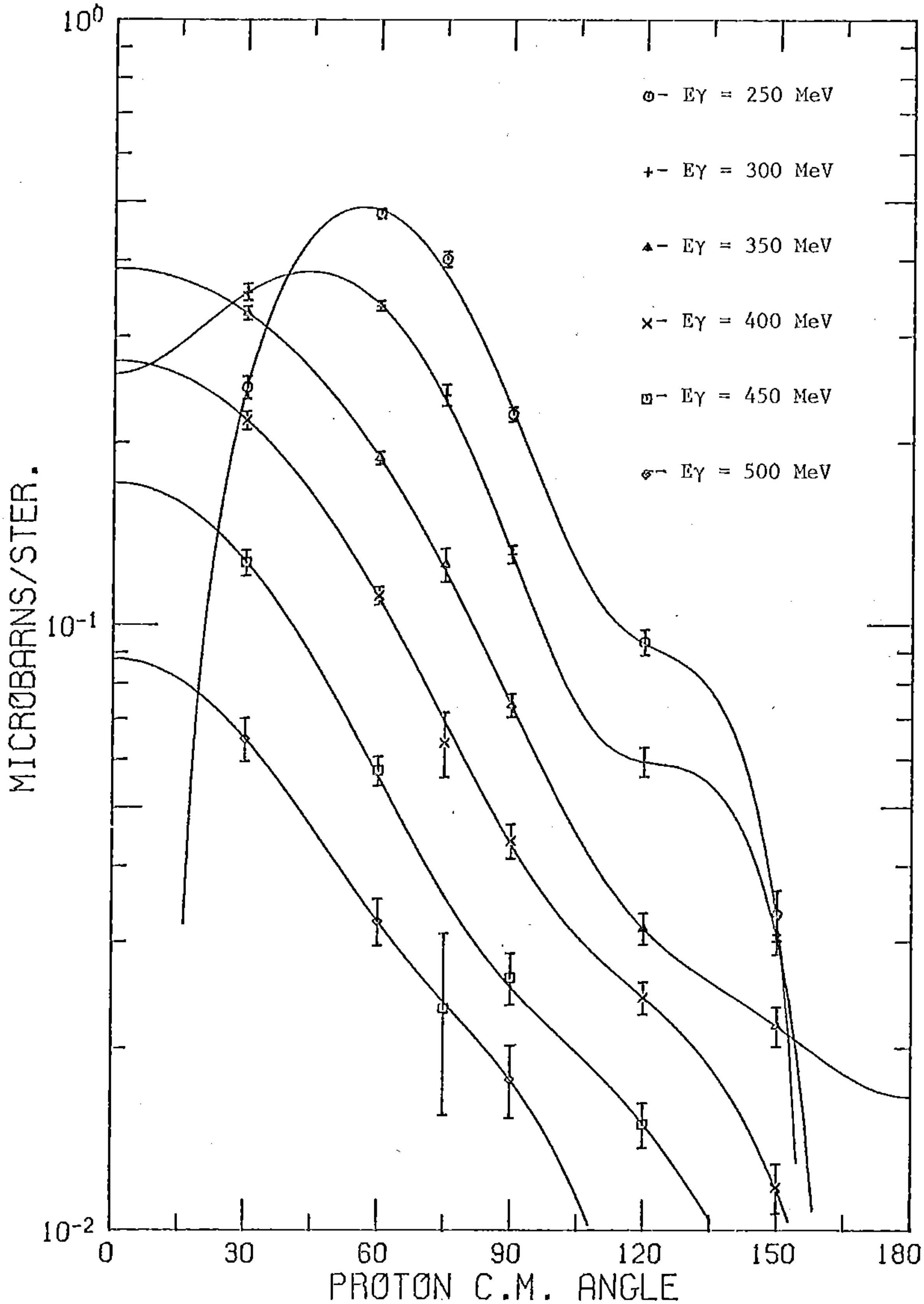

SETTING 19 RUN 68 PASS 1
COPLANARITY IN DEGREES
12.0
6.0
0.0
-6.0
-12.0
0.0
40.0
80.0
120.0
160.0
SETTING 19 RUN 68 PASS 1
MISSING MASS IN MEV
200.0
100.0
0.0
-100.0
-200.0
0.0
40.0
80.0
120.0
160.0
TIME OF FLIGHT

Figure 1.



HE3 PHØTØDISINTEGRATIØN CRØSS SECTIØNS

Figure 2

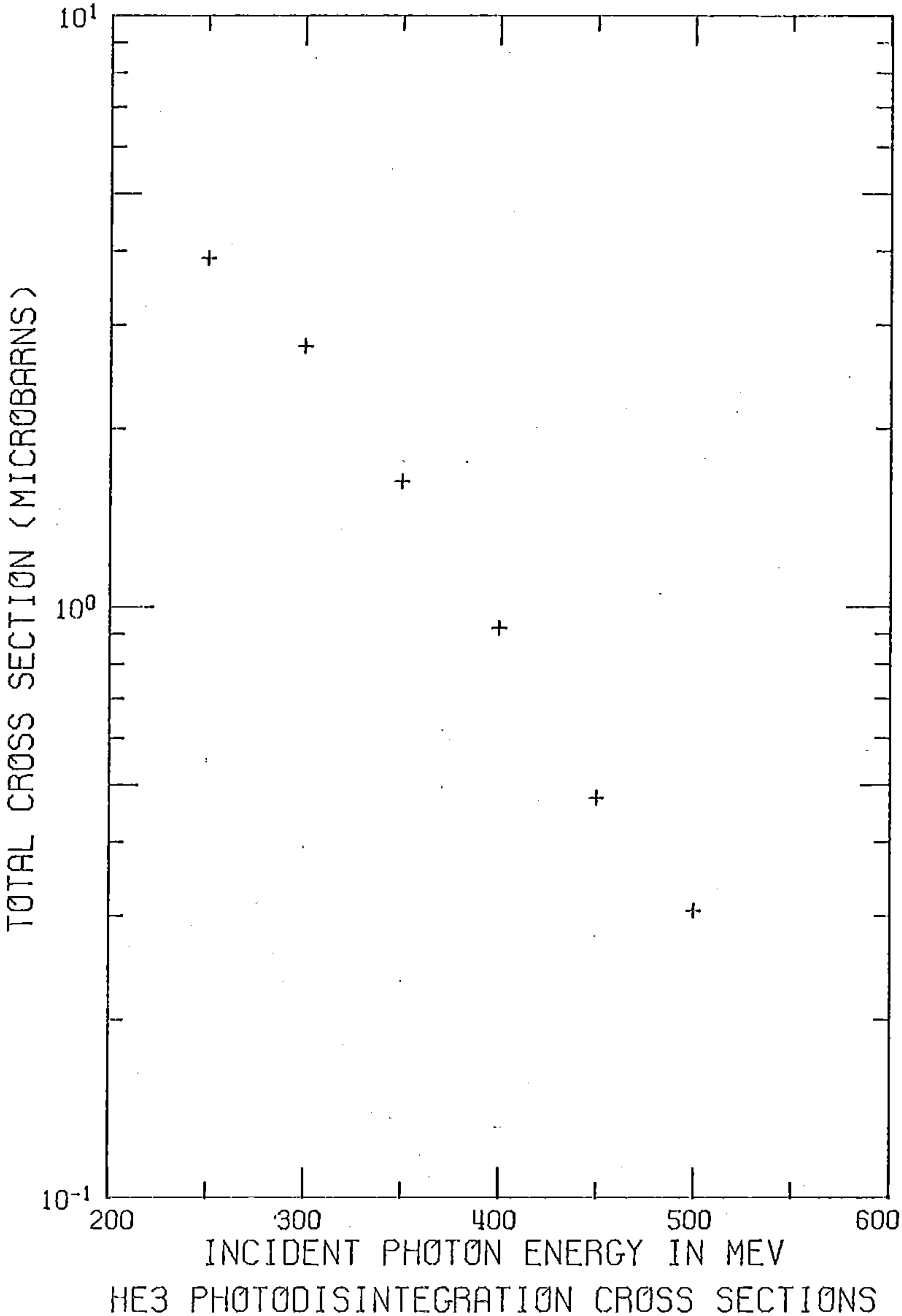

TOTAL CROSS SECTION (MICROBARNS)
10^1
10^0
10^-1
200
300
400
500
600
INCIDENT PHOTON ENERGY IN MEV
HE3 PHOTODISINTEGRATION CROSS SECTIONS

Figure 3