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Gamma Rays from a 14.4 mev Level in Be^9

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The 5 Kev upper limit on the width of the 14.39 Mev level in Be^9 observed in the reaction $Li^7(He^3\ p)\ Be^9$ suggested that it might be possible to detect the γ-ray decay of this state, particularly as the 180° inelastic electron scattering work of Edge and Peterson at Stanford had indicated the presence of a level in Be^9 at about 14.7 Mev with a γ-ray width of approximately 20 ev.

A 4" x 4" cylindrical Na I crystal was used with 3" of lead shielding on all sides plus a lead collimator. Targets of isotopically separated Li^7 were evaporated to a thickness of 10^{17} atoms/cm^2 on a tantulum backing. The background from the target backing and beam defining stops was relatively small, however that from (He^3, n) reactions in the target was not. This required beam currents to be kept below 150 nA in order not to saturate the counting system with neutron capture γ-rays.

Slide 1 shows on a logarithmic scale some typical γ-ray spectra covering the energy range from 10 to 20 Mev for several bombarding energies. At 5 Mev, which is off the slide to the left the counting rate was about 50 times higher than around 14 Mev. This very high counting rate at low energies accounts for the rather poor resolution of the spectra shown here.

For bombarding energies above 4.6 Mev there is a yield of 12 and 14.5 Mev γ-rays; since the threshold for forming Be^9 in a level at 14.39 Mev is at 4.56 Mev we attribute these γ-rays to the decay of the 14.39 Mev state to the ground state and first excited state in Be^9 at 2.43 Mev. The γ-ray yield is not a monotonic function of bombarding energy, for the yield at 6.5 Mev is higher than at 5.5 or 7.5

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Mev as indicated by the ink line. Between 9 and 10 Mev there is an additional contribution from γ-rays of around 17 Mev.

By assuming a background with a shape like that of the 4.6 Mev spectrum and using standard spectrum shapes obtained from other reactions it was possible to separate the γ-ray spectra into components. Then from the geometry and counter efficiencies calculated on the Burroughs 220 computer it was possible to obtain the relative yields for each γ-ray.

The absolute cross sections for the γ-ray yields was then obtained from knowledge of the target thickness obtained in the following way. A solid state counter at 90° to the beam in the γ-ray target chamber was provided with a 48 mg/cm^2 absorber of aluminum so that it only counted ground state protons of about 16 Mev from the reaction $Li^7(He^3, p) Be^9$. This yield is proportional to the target thickness and the constant of proportionality was separately determined by using the same solid state counter in the target chamber of the 60 cm double focussing magnetic spectrometer during measurements of the target thickness by energy shift of the elastic He^3 edge scattered from the Ni backing. This then permits us to give absolute cross sections for the γ-ray yields and further to give the ratio of γ-ray yield to the number of protons forming the 14.39 Mev state.

Angular distributions of the γ-rays were measured from 30° to 140° and to within 25% the yield of 12 and 14.5 Mev γ-rays is isotropic. The rather large error is due to the fact that the background changes rapidly with angle; in fact at 0° it wasn't possible to make a satisfactory separation of the spectra.

Slide 2 shows the total cross section for the γ-ray yields as a function of bombarding energy. Also marked in are rough measurements of the cross section for protons forming the 14.39 Mev state in Be^9. Below 7.8 Mev the γ-ray yield follows the proton yield and corresponds to the decay of the 14.39 Mev state.

However above this there is a surplus of γ-rays. Measurements on the reaction Li^7 (He^3, n) B^9 to be reported in a following paper indicate that above a threshold of 7.63 Mev B^9 is formed in a state at 14.7 Mev, presumably the mirror to the 14.39 Mev level in Be^9. Therefore above 7.63 Mev there are γ-rays from both Be^9 and B^9 differing in energy by only about 300 Kev.

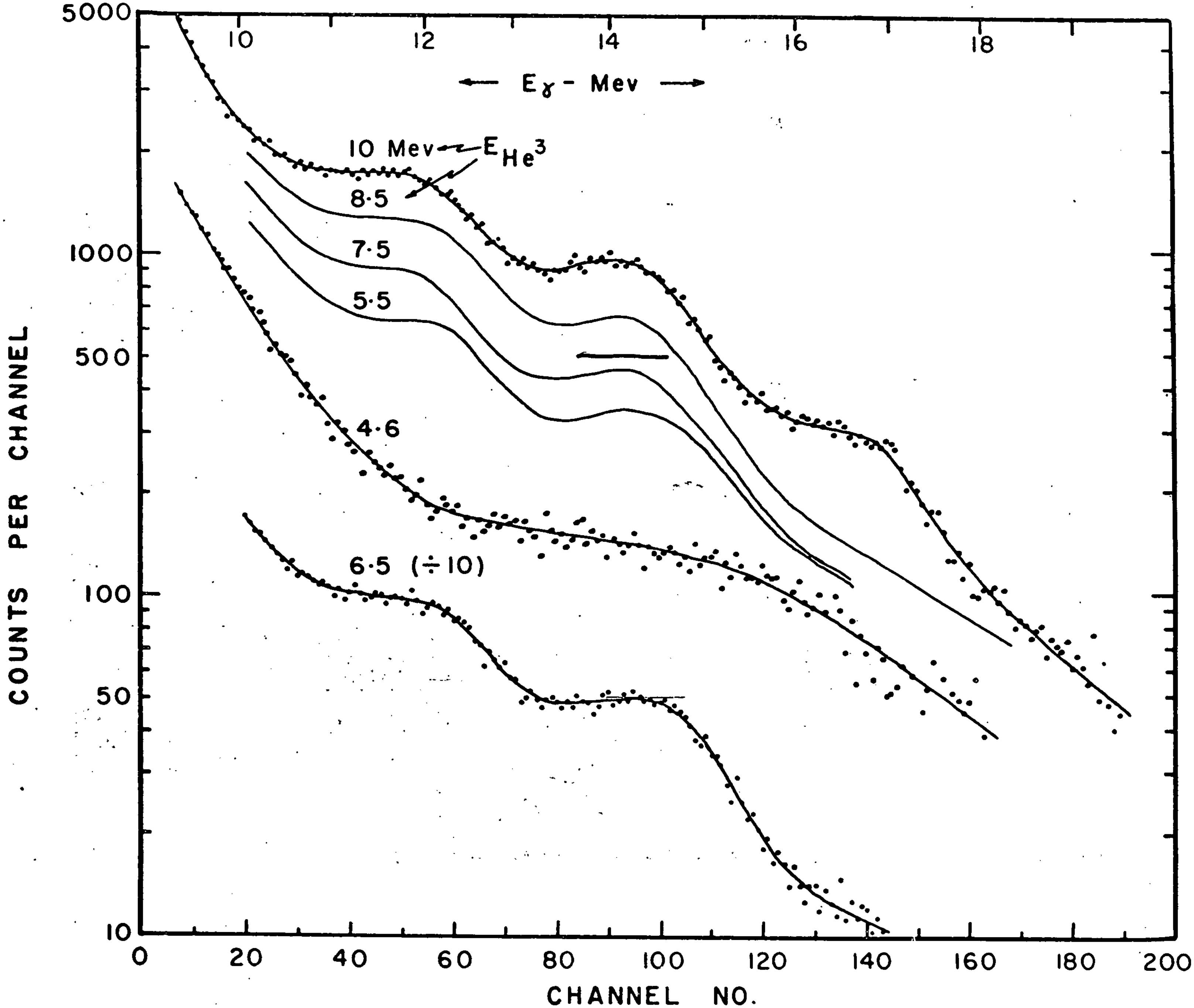
Taking the results below 7.5 Mev which refer to Be^9 only the cross section ratio

$$\frac{\sigma_\gamma}{\sigma_p} = 0.026$$

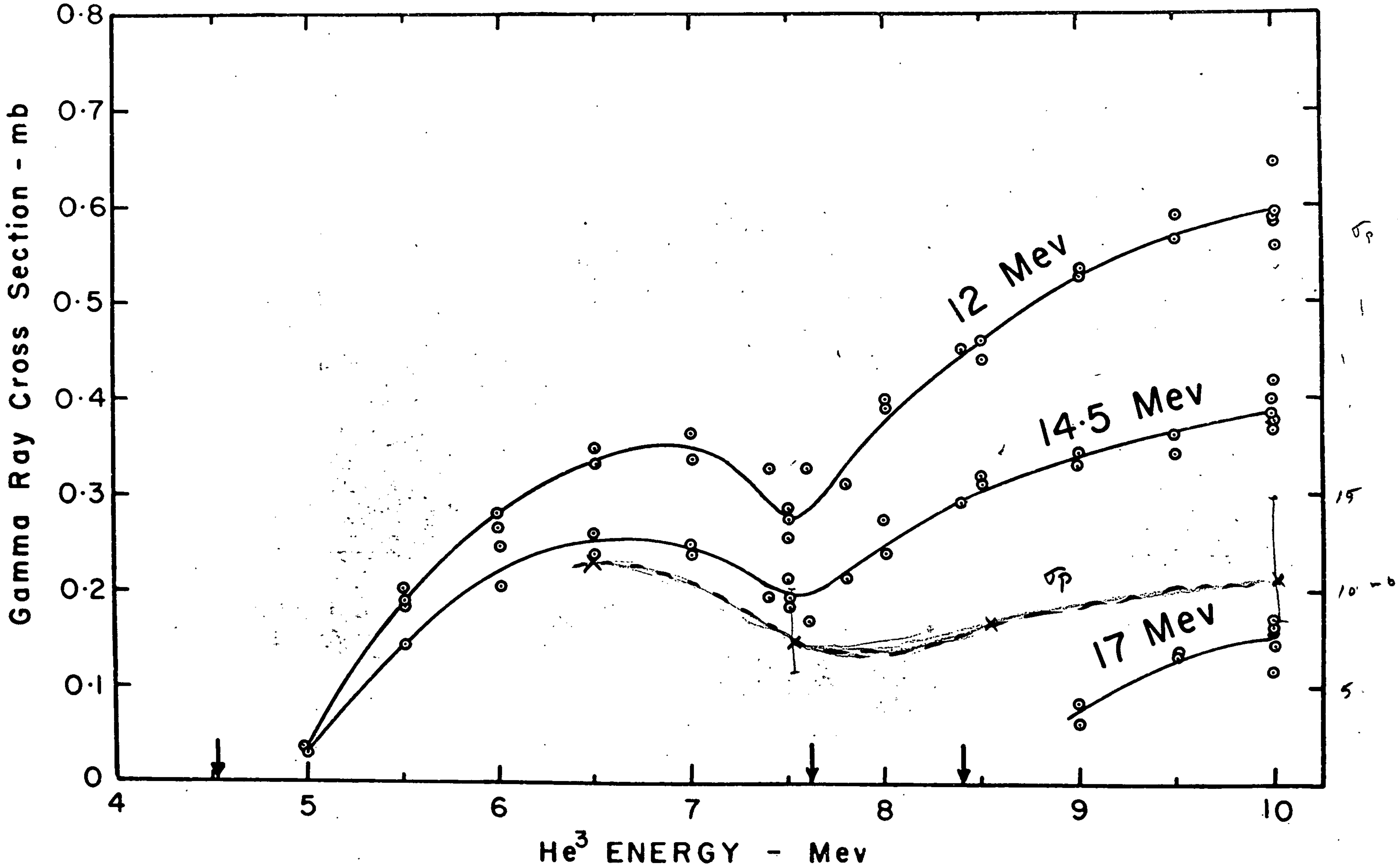
for 14 Mev ground state γ-rays. This is clearly the ratio of the ground state γ-ray width to the total width of the level. If we assume the radiation is magnetic dipole, consistent with a shell model prediction of 3/2 for the first T = 3/2 level in Be^9 and with the observed isotropic angular distribution of the γ-rays then the Weisshopf width is about 60 ev, and the Wilkinson adjusted value for average M1 transitions in p shell nuclei is 10 ev. in reasonable agreement with the approximately 18 ev given by Edge and Peterson for a level in the neighborhood of 14.5 Mev in Be^9. Taking 20 ev for the ground state width then the γ-ray to proton ratio obtained here gives a total width of 0.77 Kev or less than 1 Kev. This then indicates a high isotopic spin forbiddeness for the decay of the level to Be^8 + n or He^5 + α which are energetically allowed by 12 to 13 Mev. It is difficult to be quantitative but the simple Wigner limits for these separations are 3.5 and 1.2 Mev respectively and there are known levels in Be^9 with widths greater than 1 Mev. Consequently the isotopic spin hindrance factor for the break up of the 14.39 Mev level to $T = \frac{1}{2}$ combinations appears to be of the order of 1000.

Similar argummnts should be possible for B^9 from the γ-ray data obtained here when the absolute neutron yield to the 14.7 Mev level is known.

One other point is that there may be evidence for a second T = 3/2 state in Be^9 in the 17 Mev γ-rays. These γ-rays were first attributed to the reaction $Li^7(He^3, d, \gamma)\ Be^8$ forming Be^8 in the well known γ-ray decaying state at 17.64 Mev with a threshold at 8.40 Mev. However a rough measure of the deuteron yield to the 17.6 Mev level in Be^8 for 10 Mev He^3 indicated that there are too many γ-rays to be accounted for in this way, also the γ-ray energy appears to be less than 17.6 Mev. This suggests that Be^9 is being formed in a state around 17.28 Mev which would have a threshold at 8.70 Mev for formation by $Li^7(He^3, p)\ Be^{9*}$. This or another state in this region may be the second T = 3/2 state in Be^9 corresponding to the first excited state in Li^9 found at an excitation of 2.69 Mev in Li^9 by Middleton and Pullen.



COUNTS PER CHANNEL
CHANNEL NO.
← Eγ - Mev →
10 Mev
E He3
8·5
7·5
5·5
4·6
6·5 (÷10)
5000
1000
500
100
50
10
0
20
40
60
80
100
120
140
160
180
200
10
12
14
16
18



Gamma Ray Cross Section - mb
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
0
4
5
6
7
8
9
10
He3 ENERGY - Mev
12 Mev
14·5 Mev
17 Mev
σp
15
5