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Evidence for Multibody Breakup of the Boron

Isotopes by 25 MeV Alphas

CONF-46-13

The data presented here was taken in the course of a series of pilot experiments which were designed to seek out evidence of alpha particle clusters in the light nuclei. Results for Be^9 and C^{12} targets have been reported: on the basis of the good fit of three- and four-body phase space distributions to the continuous distributions of alpha particles under the inelastic peaks, the presence of alphas in these nuclei was deduced.

These fits are, at best, only tentative evidence for internal alpha clusters and were possible in Be^9 and C^{12} only because the low level densities permitted the background distribution to be identified.

The FIRST SLIDE shows the experimental arrangement: all particles coming from the target at an angle near 45^o are collimated and momentum analyzed into a thin windowed, gas-filled proportional counter. The counter could not be placed at a focal point conjugate to the target and thus the resolution, while adequate to resolve the excited levels on the beryllium and carbon nuclei, was insufficient to separate most of the inelastic levels in the boron isotopes.

DISCLAIMER

It was previously shown that the counter pulse height, H, from particle mass M, entering the counter at a particular field setting was proportional to M^2. This must be modified to

$$H \propto \left(\frac{Z_{rms}}{Z_o}\right)^2 M^2$$

in the event that a heavy particle, entering the counter at charge state Z_o, is sufficiently slowed by the counter window to go into a different root-mean-square charge state Z_{rms} while in the counter gas.

The B^{10} target was about 0.50 mg/cm^2 thick, plated on 1.1 mg/cm^2 Al. After subtraction of the aluminum background, target thickness correction and transformation the barycentric alpha spectrum was obtained. It is shown in the SECOND SLIDE. Various known levels above the ground state appear. The phase space distributions for $B^{10}(\alpha, 2\alpha)Li^6$ and $B^{10}(\alpha, 3\alpha)L$ are plotted beneath. (The heavy line connecting the measured points is solely to aid the eye.) The steadily rising background is almost fitted by the fourbody distribution although there are almost certainly unreported levels on top; there is no striking evidence for the three body reaction except that the high continuous background above the 6 MeV inelastic levels may be in part composed of B^{10} (α, 2α) Li^6. Upon examining the laboratory momentum spectrum of particles of masses above the alpha particles (THIRD SLIDE) peaks are seen corresponding to $(B^{10})^{+3}$, $(B^{10})^{+4}$ and $(B^{10})^{+5}$, representing the charge equillibrium of boron isotopes of about 10 MeV, which are recoils from elastic scattering in the target. Their proportions are in good agreement with recent work by L.C. Northcliffe.

If the counter spectrum at 11.00 mV magnet shunt voltage setting is examined, the $(B^{10})^{+4}$ ions are observed to have a root-mean-square charge of slightly over 3 in the counter, and a pulse height spread of between three and four times the alpha pulse peak. An intermediate group can be readily identified as Li^6, at a pulse height roughly twice that of the alphas. These may originate from either the three-body reaction or from decay of boron states excited above 4.8 MeV by inelastic scattering. Deuterons appear at one-quarter the alpha pulse height, and may also arise from either the direct or excitation and decay.

The next (FOURTH SLIDE) barycentric spectrum of alphas was derived from about 0.3 mg/cm^2 B^{11} evaporated on 1.1

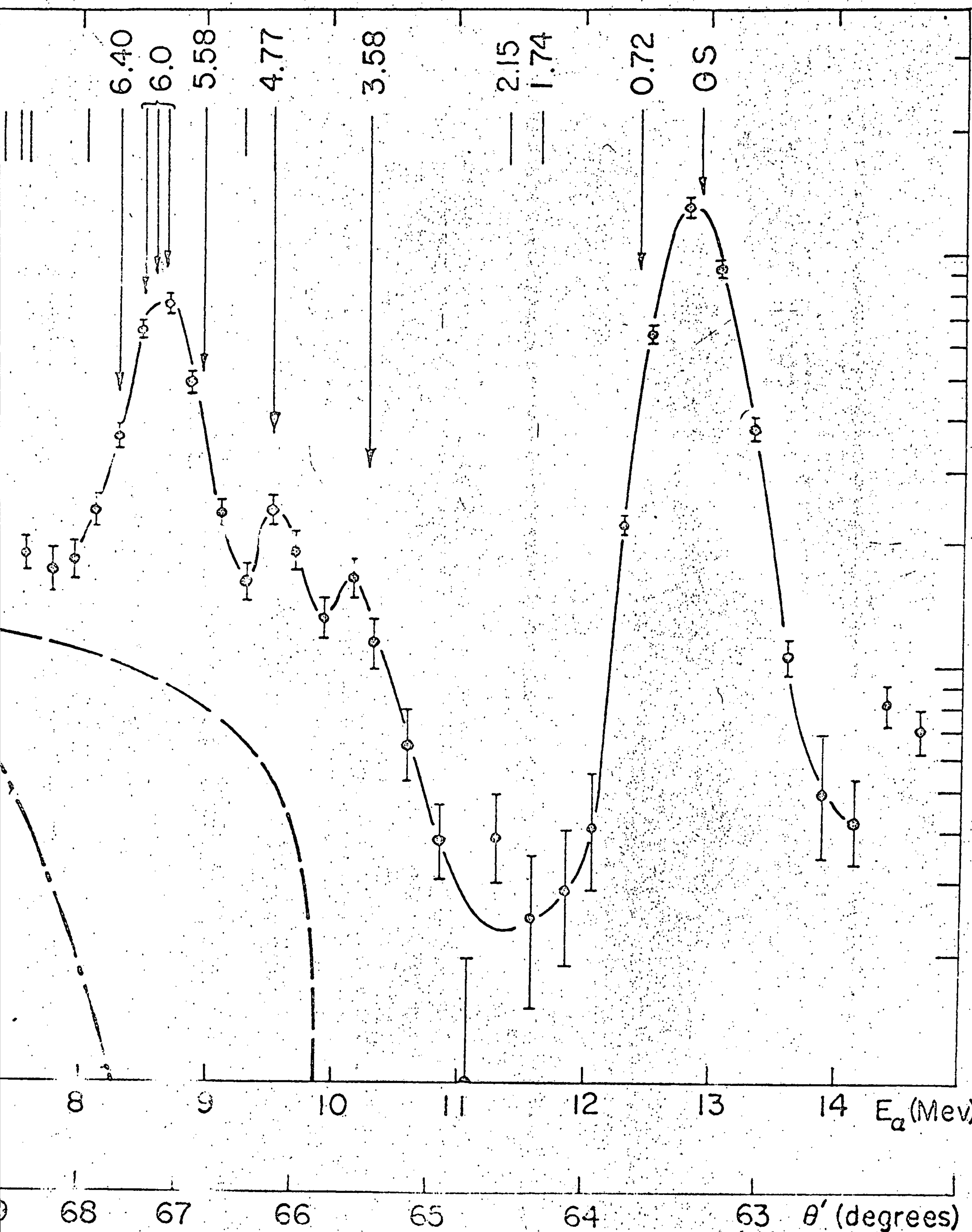
mg/cm^{2}Al. In this case, the high "plateau" under the inelastic levels above MeV suggests that B^{11} (α , 2α) Li^7 may contribute to the background, while the four-body reaction B^{11} (α , 3α) t does not appear. Many of the known inelastic levels of B^{11} are excited, while the two highest broad peaks may arise from excitation and decay reactions.

The laboratory momentum spectrum of particles of mass greater than four shows the same sort of pattern as the comparable spectrum for B^{10} (FIFTH SLIDE); The number of B^{11} ions of charge +3 state is increased at the expense of the charge +5 state as would be expected since the laboratory energy of the B^{11} elastic recoil is about 9 MeV. The pulse spectrum taken at 11.00 mV shows that the B^{11} has an rms charge of less than 3 inside the counter, while an intermediate group can be readily identified as Li^7 with almost the maximum possible Z_{rms} (+2.7). There is no peak of tritons evident although some may be present. Some of the Li^7 are believed to originate from reaction-decay modes. Referring to the high mass laboratory momentum spectrum again, a peak appears at about 12.50 mV, which is definitelyn not a charge state of B^{11}. A pulse spectrum taken at this point showed only the intermediate group, previously identified as Li^7. The peak must result from a two-body reaction and is well fitted by $B^{11}(\alpha, Be^8)Li^7$ and by no other possible reaction. (It does not originate from the aluminum target backing: there was virtually no structure in the high mass counts from the Al^{27} at any field setting.) The presence of this unusual reaction tends to suggest a structure for B^{11} which is partially described by a two-cluster model: $Li^7 + \alpha$.

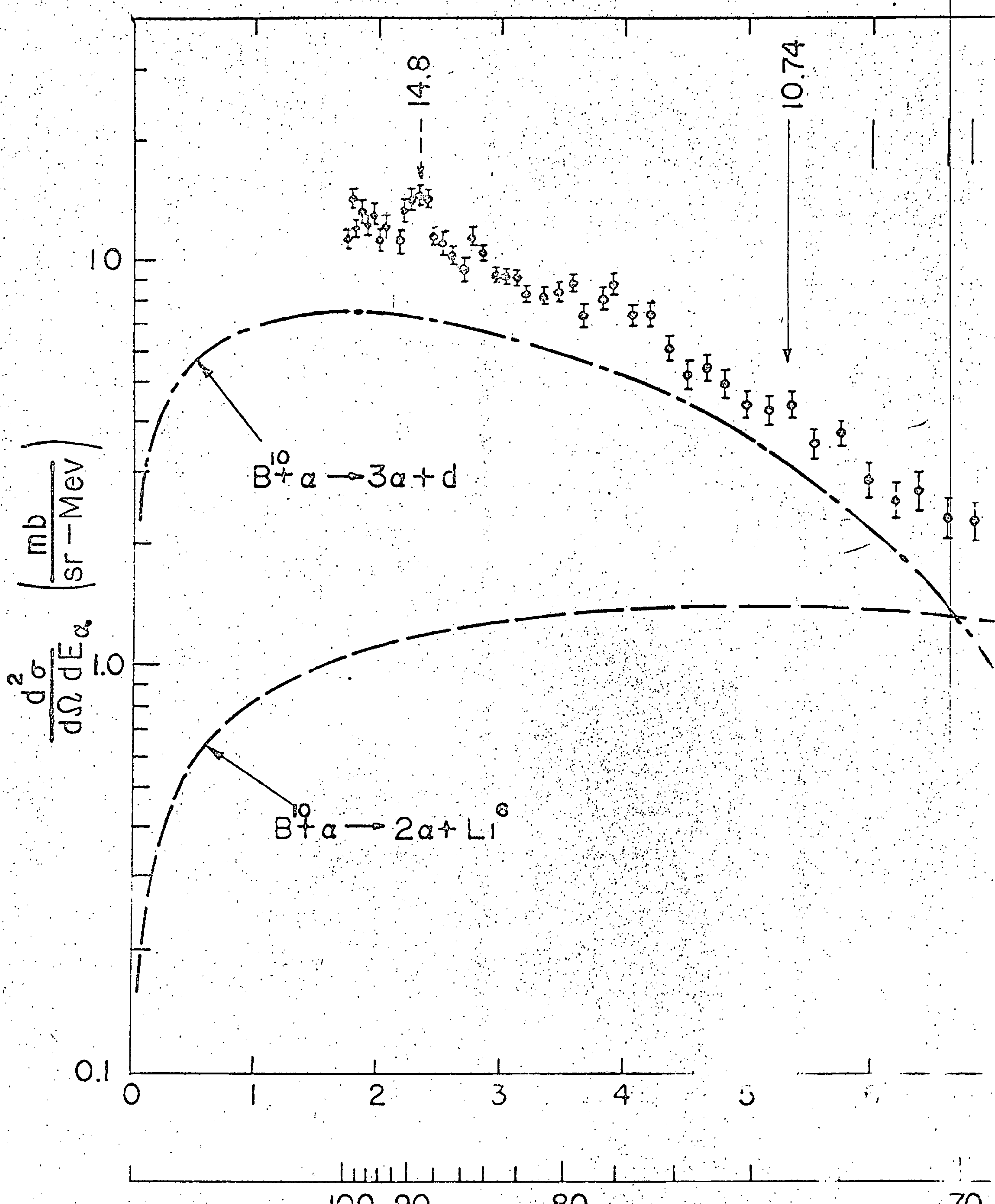
In conclusion, it is remarkable that the 25 MeV α-induced spectra from all stable target nuclei of masses 9 thru 12 show a low energy continuum which can be approximately fitted by either a simple three-or-four-body phase space distribution. More definitive experiments are indicated to determine the degree of strong α-clustering in these (and other) light nuclei.

Slide #1 Fig 1 of prior paper.

Slide #2

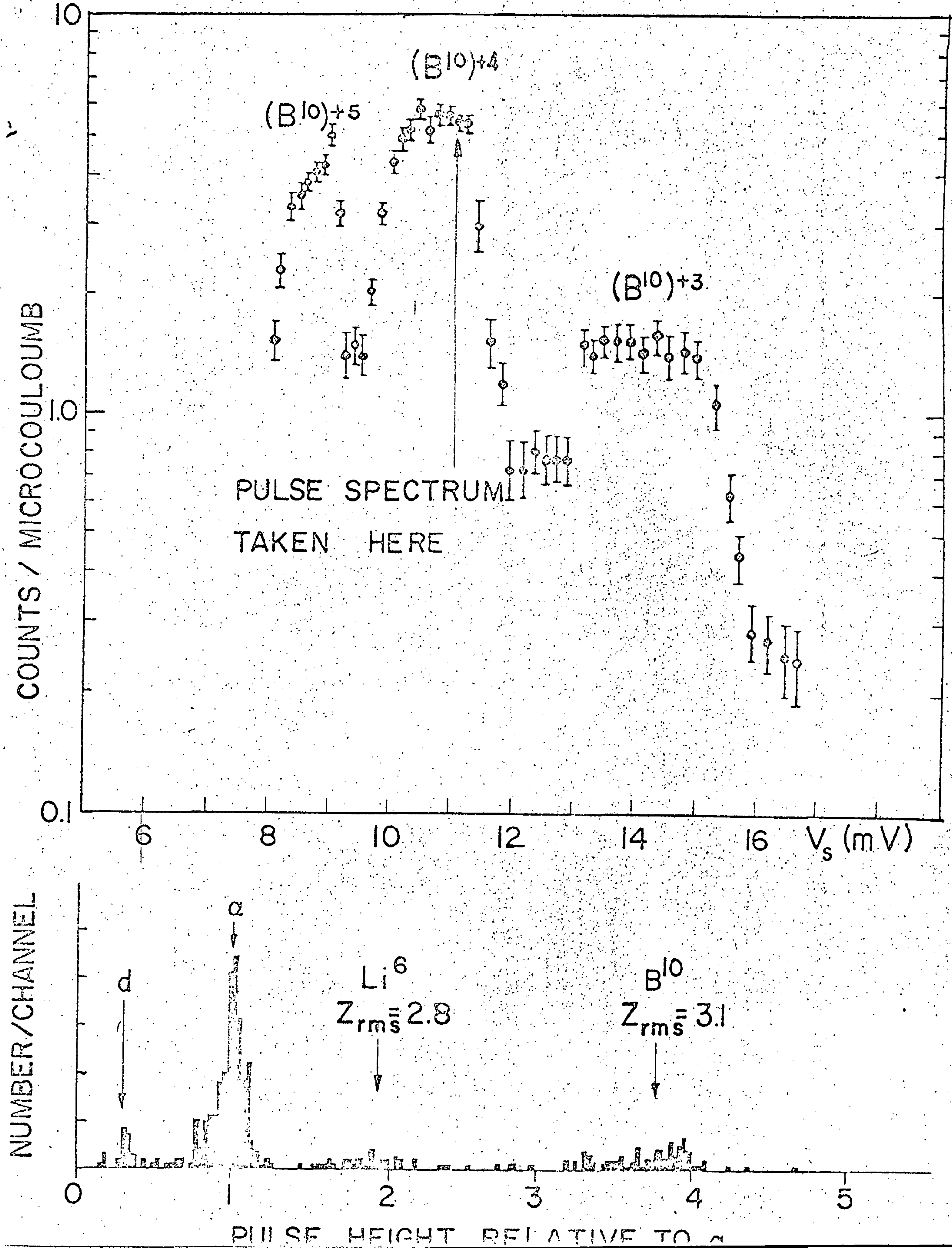


6.40
6.0
5.58
4.77
3.58
2.15
1.74
0.72
GS
8
9
10
11
12
13
14
E_α (Mev)
68
67
66
65
64
63
θ′ (degrees)



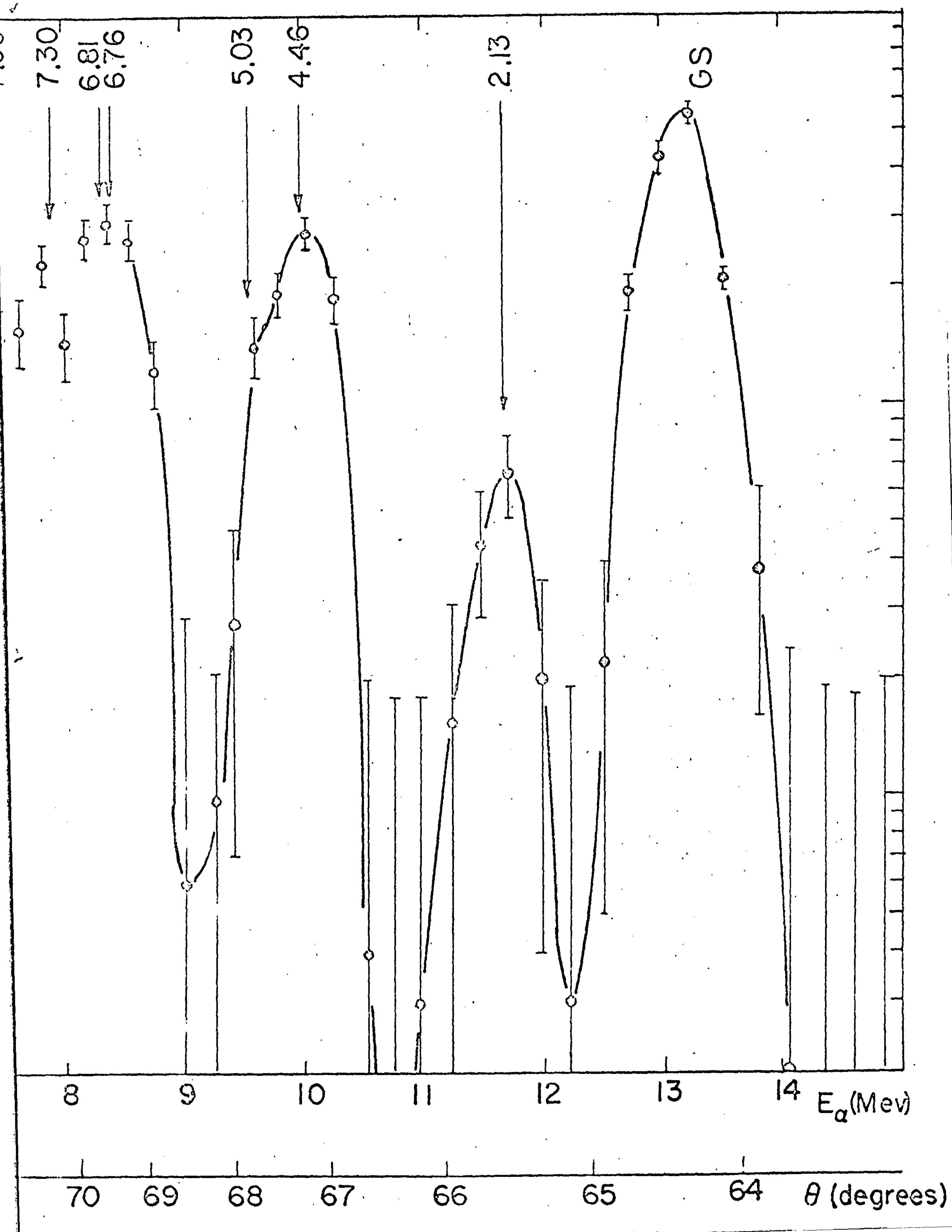
14.8
10.74
10
1.0
0.1
$\frac{d^2\sigma}{d\Omega\, dE_\alpha}$ $\left(\frac{mb}{sr-Mev}\right)$
$B^{10} + \alpha \to 3\alpha + d$
$B^{10} + \alpha \to 2\alpha + Li^6$
0
1
2
3
4
5
100
90
80
70

Slide #3

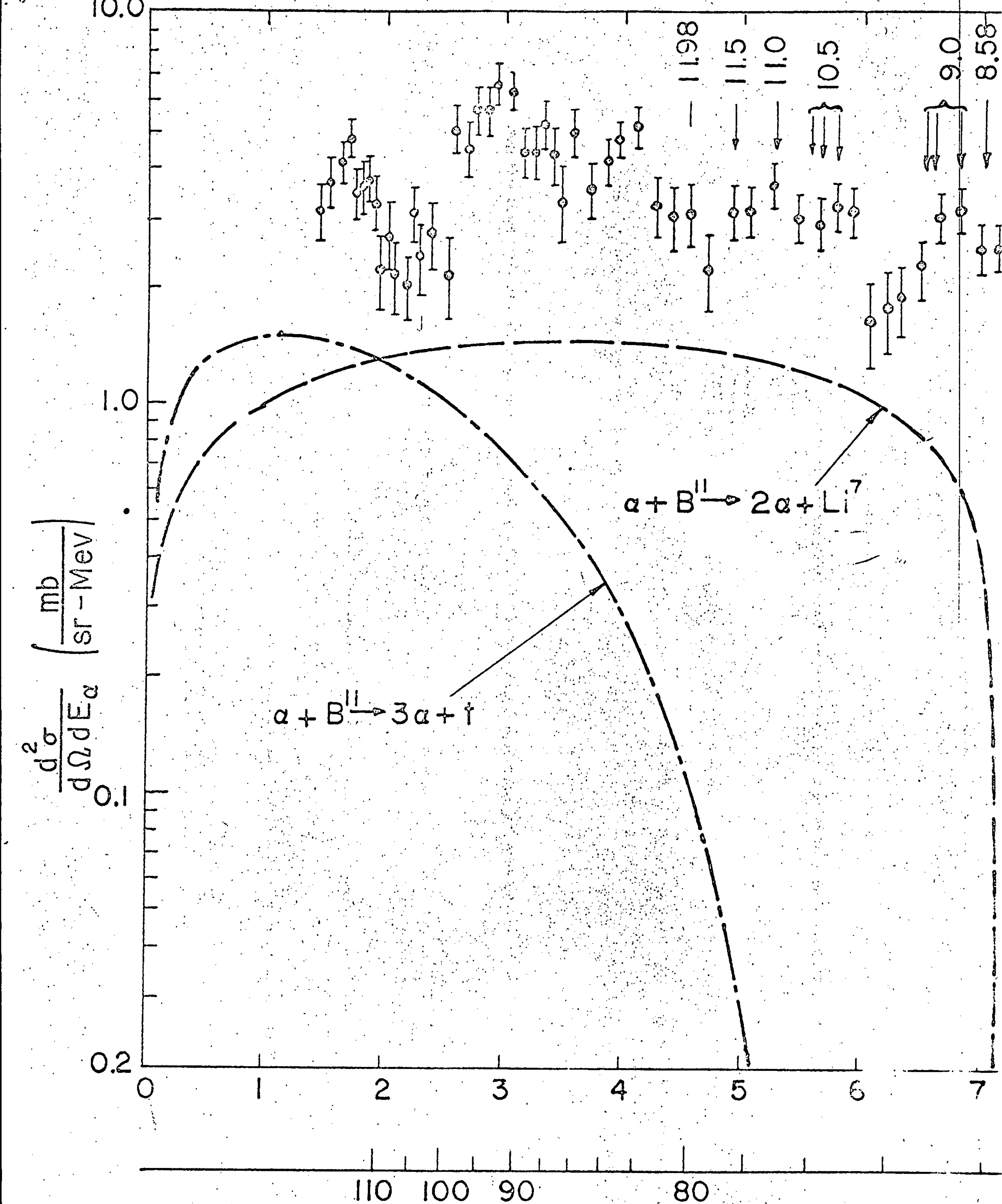


10
1.0
0.1
COUNTS / MICROCOULOUMB
$(B^{10})^{+5}$
$(B^{10})^{+4}$
$(B^{10})^{+3}$
PULSE SPECTRUM
TAKEN HERE
6
8
10
12
14
16
V_s (mV)
NUMBER/CHANNEL
d
α
Li^6
Z_{rms}= 2.8
B^{10}
Z_{rms}= 3.1
0
1
2
3
4
5
PULSE HEIGHT RELATIVE TO α

Slide #4

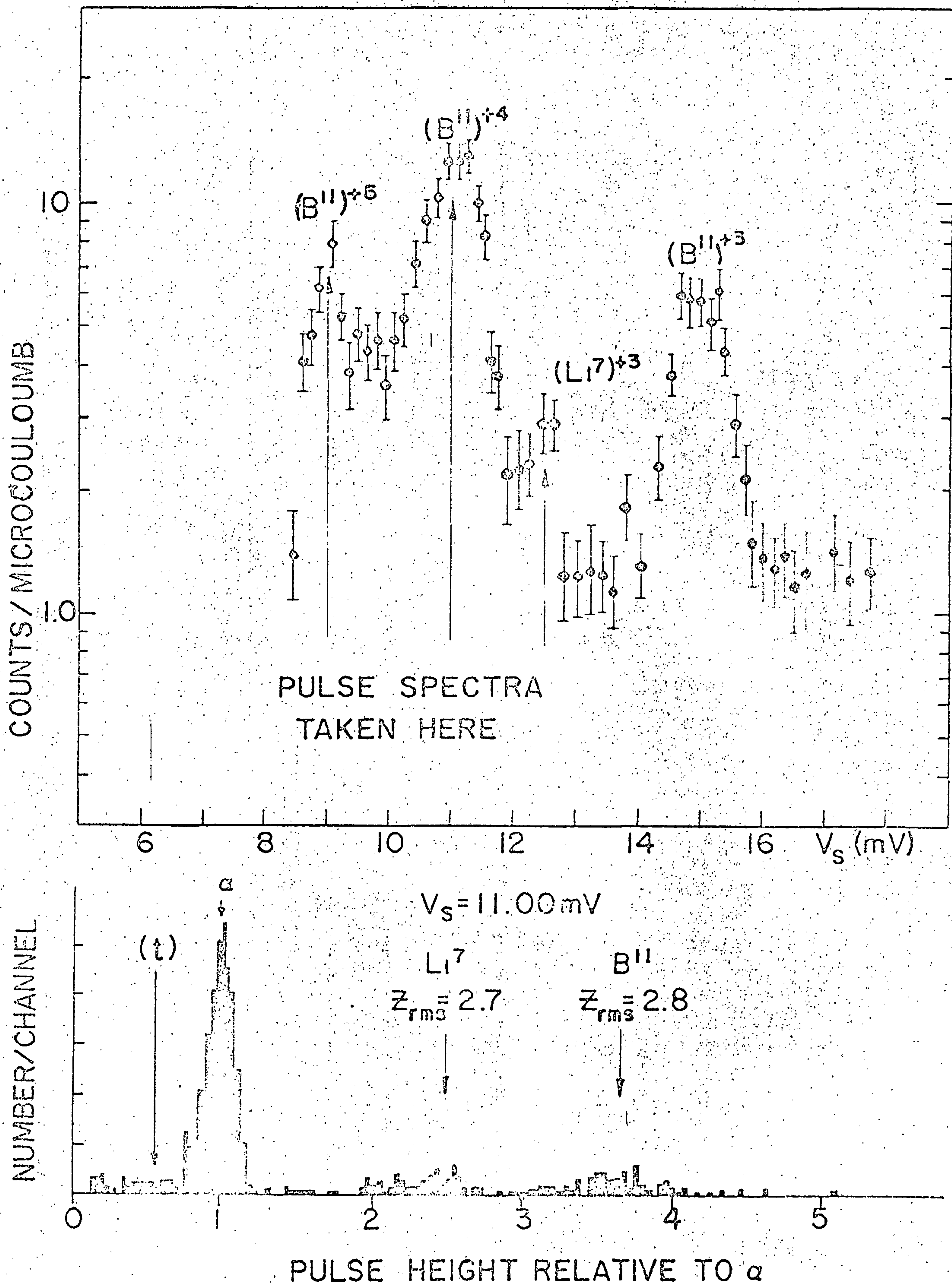


7.30
6.81
6.76
5.03
4.46
2.13
GS
8
9
10
11
12
13
14
E_α(Mev)
70
69
68
67
66
65
64
θ (degrees)



10.0
1.0
0.1
0.2
0
1
2
3
4
5
6
7
110
100
90
80
11.98
11.5
11.0
10.5
9.0
8.58
α + B11 → 2α + Li7
α + B11 → 3α + t
d2σ/dΩdEα (mb/sr-Mev)

Slide #5



(B11)+5
(B11)+4
(B11)+3
(Li7)+3
COUNTS / MICROCOULOUMB
10
1.0
PULSE SPECTRA
TAKEN HERE
6
8
10
12
14
16
Vs (mV)
Vs = 11.00 mV
α
(t)
Li7
Zrms = 2.7
B11
Zrms = 2.8
NUMBER/CHANNEL
0
1
2
3
4
5
PULSE HEIGHT RELATIVE TO α

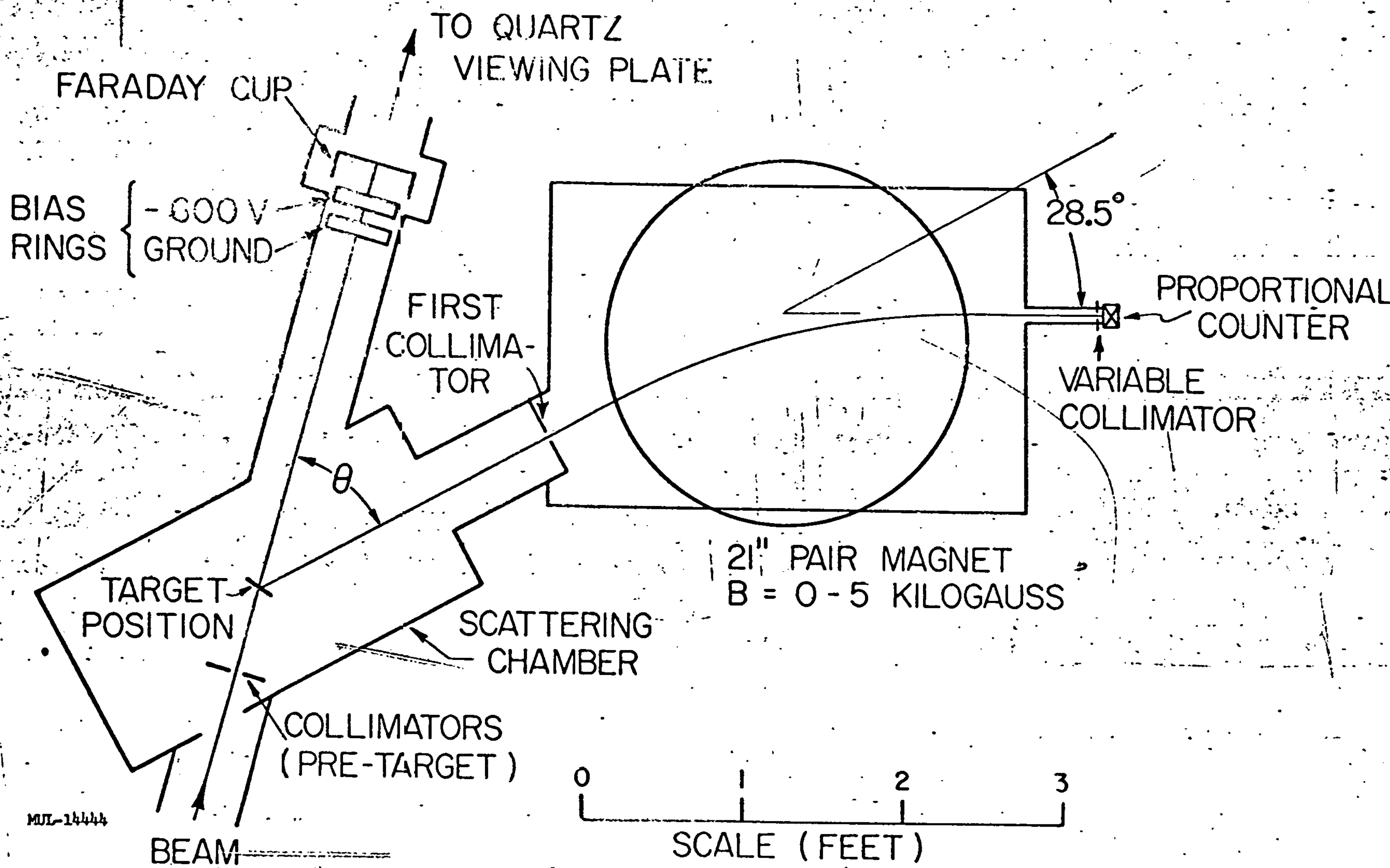


Fig. 1. Experimental apparatus.