Experimental evidence for cluster structure in ^{11}B

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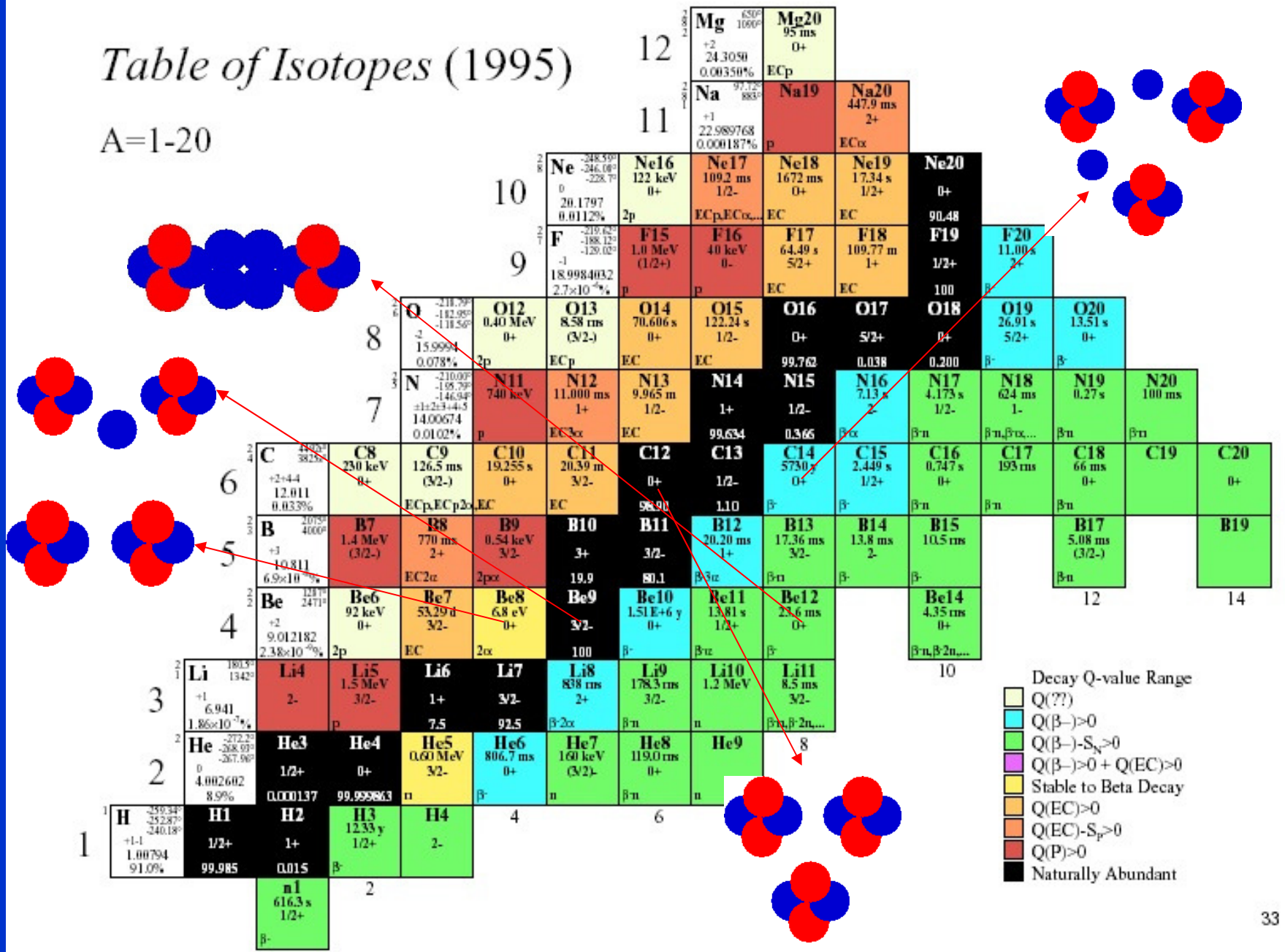
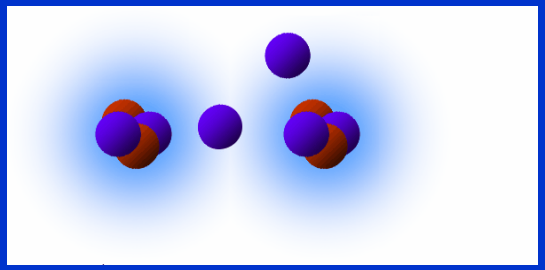


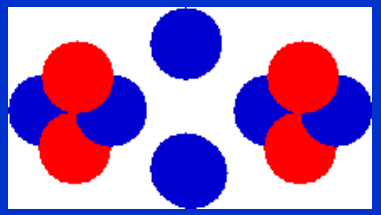
Table of Isotopes (1995)
A=1-20
Decay Q-value Range
Q(??)
Q(β−)>0
Q(β−)-S_N>0
Q(β−)>0 + Q(EC)>0
Stable to Beta Decay
Q(EC)>0
Q(EC)-S_P>0
Q(P)>0
Naturally Abundant

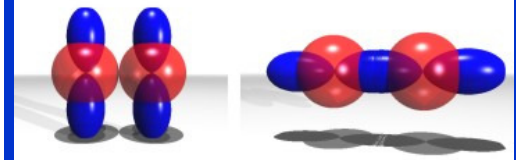


^{10}Be

^{6}He+^{6}Li→^{6}He+α+d , ^{6}He+^{7}Li→^{6}He+α+t
resonant ^{6}He+α elastic scattering

Rotational band:
0^+(6.18 MeV), 2^+(7.54 MeV), 4^+(10.15 MeV)
ħ/2I = 200 keV ; axes ratio 2.5 : 1
very large α–cluster spectroscopic factors
α-2n-α molecular structure





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Nuclear Physics A 753 (2005) 263–287

NUCLEAR PHYSICS A

Sequential decay reactions induced by a 18 MeV ^{6}He beam on ^{6}Li and ^{7}Li

M. Milin [a], M. Zadro [a], S. Cherubini [b,1], T. Davinson [c], A. Di Pietro [c,1], P. Figuera [d], Đ. Miljanić [a], A. Musumarra [b,1], A. Ninane [b], A.N. Ostrowski [c,2], M.G. Pellegriti [d], A.C. Shotter [c,3], N. Soić [a], C. Spitaleri [d]

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Available online 22 March 2005

PRL 96, 042501 (2006) PHYSICAL REVIEW LETTERS week ending 3 FEBRUARY 2006

α:2n:α Molecular Band in ^{10}Be

M. Freer,[1] E. Casarejos,[2] L. Achouri,[3] C. Angulo,[2] N.I. Ashwood,[1] N. Curtis,[1] P. Demaret,[2] C. Harlin,[4] B. Laurent,[3] M. Milin,[5] N.A. Orr,[3] D. Price,[1] R. Raabe,[6] N. Soić,[5] and V.A. Ziman[1]

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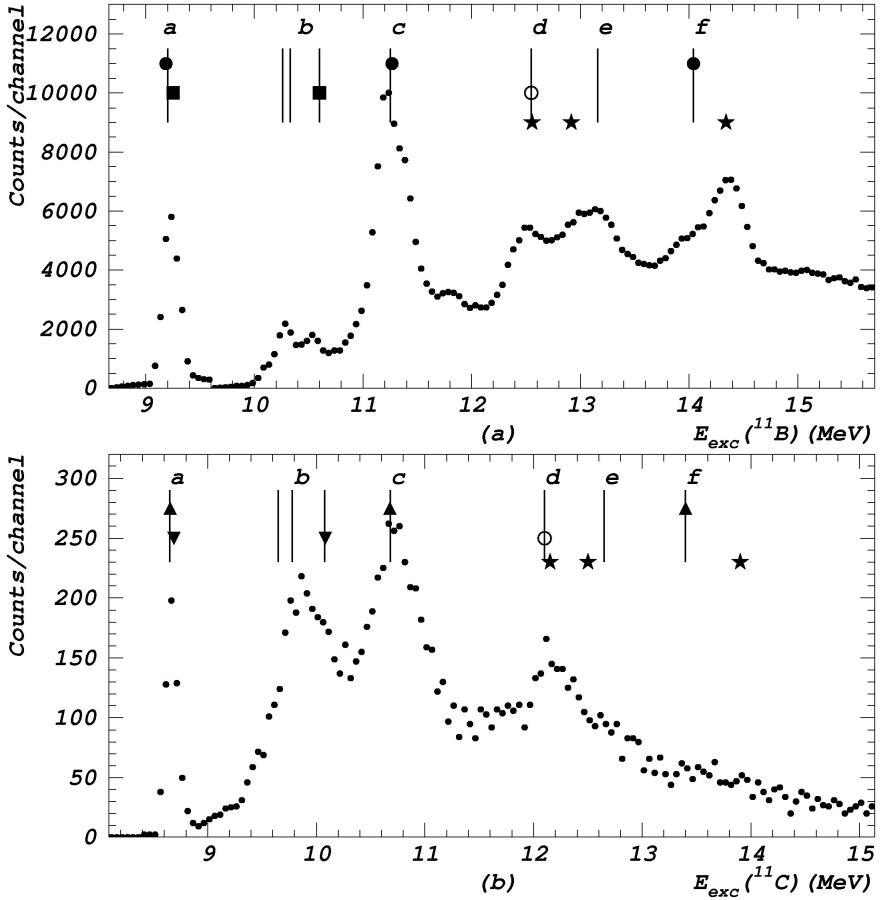
$^{11}C, ^{11}B$

- $^{16}O(^{9}Be,^{11}C^{*}\rightarrow ^{7}Be+\alpha)^{14}C$, $^{7}Li(^{9}Be,^{11}B^{*}\rightarrow ^{7}Li+\alpha)^{5}He$
- resonant particle spectroscopy technique
- 2p pickup to ^{9}Be and d pickup to ^{9}Be



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Nuclear Physics A 742 (2004) 271–290

NUCLEAR PHYSICS A

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α-decay of excited states in ^{11}C and ^{11}B

N. Soić [a,b,*], M. Freer [a], L. Donadille [a,1], N.M. Clarke [a], P.J. Leask [a], W.N. Catford [c], K.L. Jones [c,2], D. Mahboub [c], B.R. Fulton [d], B.J. Greenhalgh [d], D.L. Watson [d], D.C. Weisser [e]

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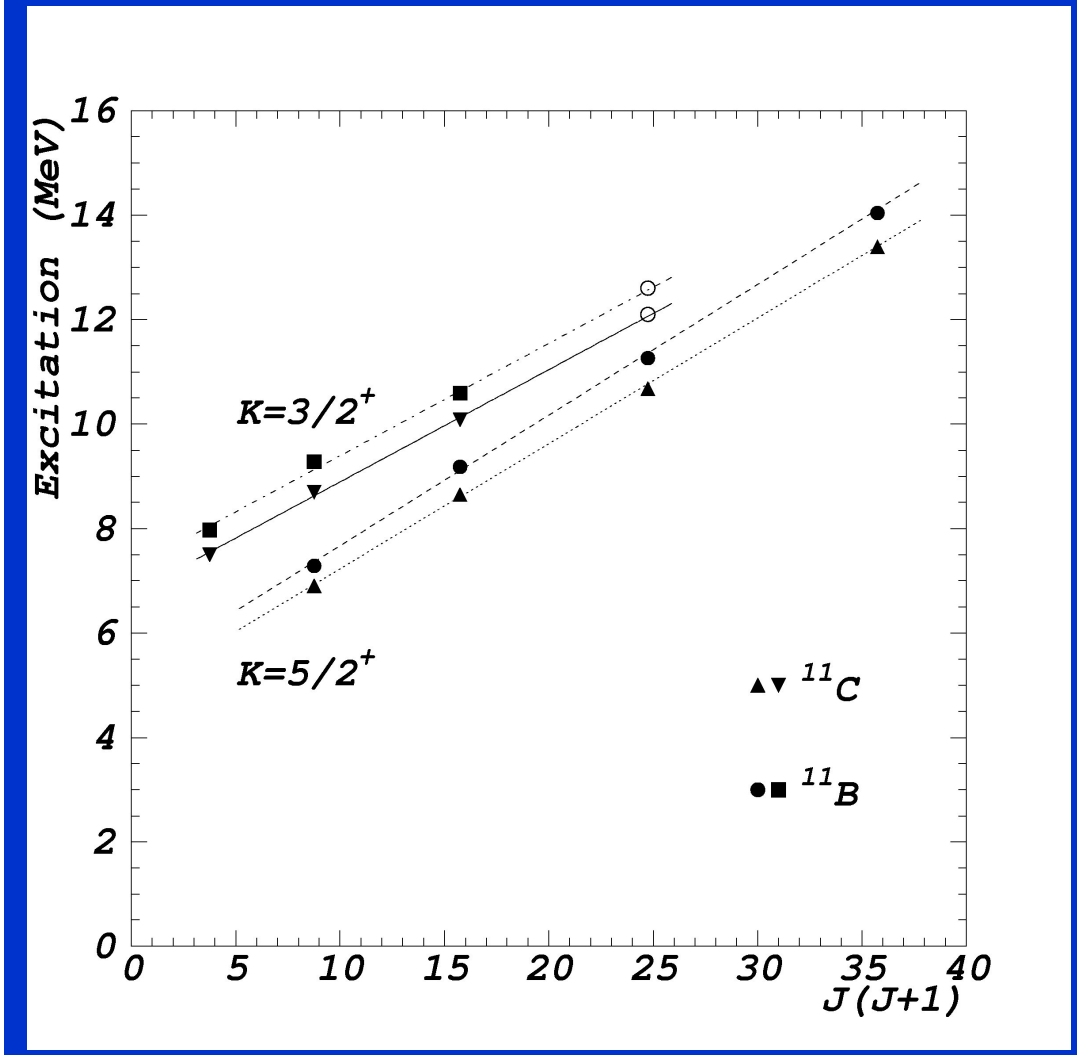
Available online 14 July 2004

these strongly excited states observed in α-decay of both nuclei should have similar cluster structure



- Rotational bands:

^{11}B:

K=5/2$^+$: 7.286, 9.185, 11.265, 14.04 MeV

rotational parameter ħ/2I=250 keV

K=3/2$^+$: 7.978, 9.274, 10.597, (12.5) MeV

rotational parameter ħ/2I=215 keV

^{11}C:

K=5/2$^+$: 6.905, 8.655, 10.679, 13.4 MeV

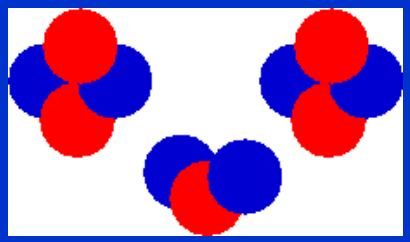
rotational parameter ħ/2I=240 keV

K=3/2$^+$: 7.500, 8.699, 10.083, (12.1) MeV

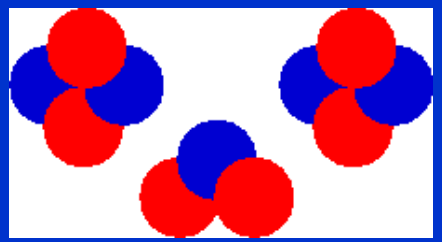
rotational parameter ħ/2I=215 keV

very deformed structure

^{11}B: α+t+α



^{11}C: α+^{3}He+α



^{10,11,12}B

PHYSICAL REVIEW C 72, 044320 (2005)

α+Li and H+Be decay of ^{10,11,12}B

N. Curtis,[1,*] N. I. Ashwood,[1] W. N. Catford,[1] N. M. Clarke,[1] M. Freer,[1] D. Mahboub,[2] C. J. Metelko,[1,†] S. D. Pain,[2,‡] N. Soić,[1,§] and D. C. Weisser[3]

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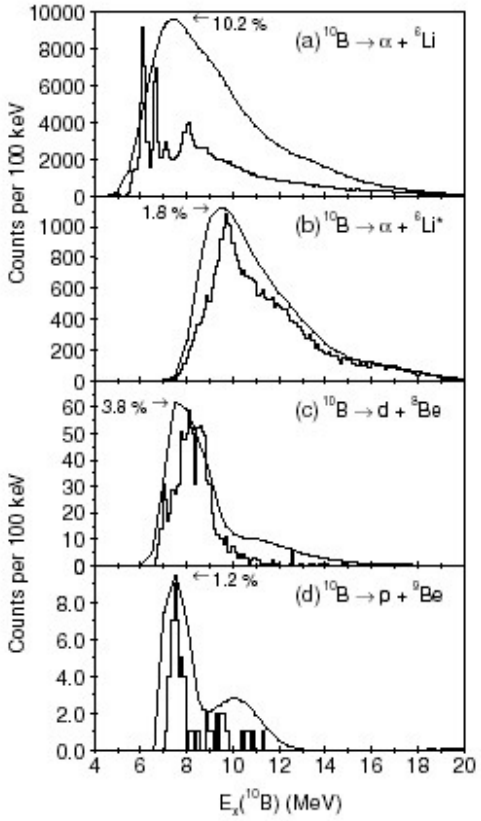
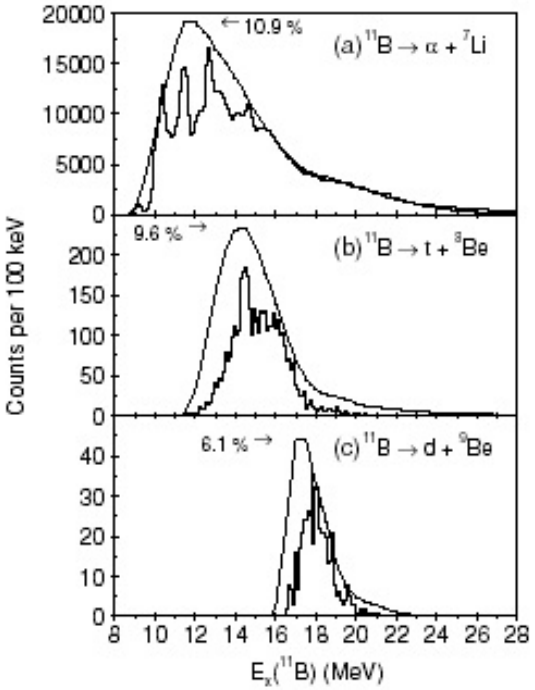
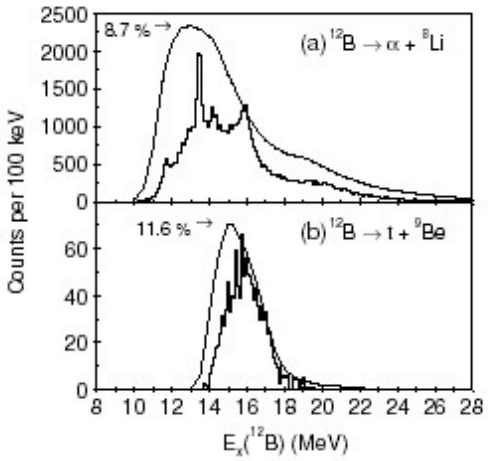
^{12}C(^{7}Li,^{10}B*)^{9}Be
^{16}O(^{7}Li,^{10}B*)^{13}C
^{7}Li(^{7}Li,^{11}B*)t
^{7}Li(^{7}Li,^{12}B*)d
α-decay channel dominates: α+Li cluster structure







^{12}B

EUROPHYSICS LETTERS 15 August 2003

Europhys. Lett., 63 (4), pp. 524–530 (2003)

^{8}Li + α decay of ^{12}B and its possible astrophysical implications

N. Soić[1], S. Cherubini[2], M. Lattuada[2], Đ. Miljanić[1], S. Romano[2], C. Spitaleri[2] and M. Zadro[1]

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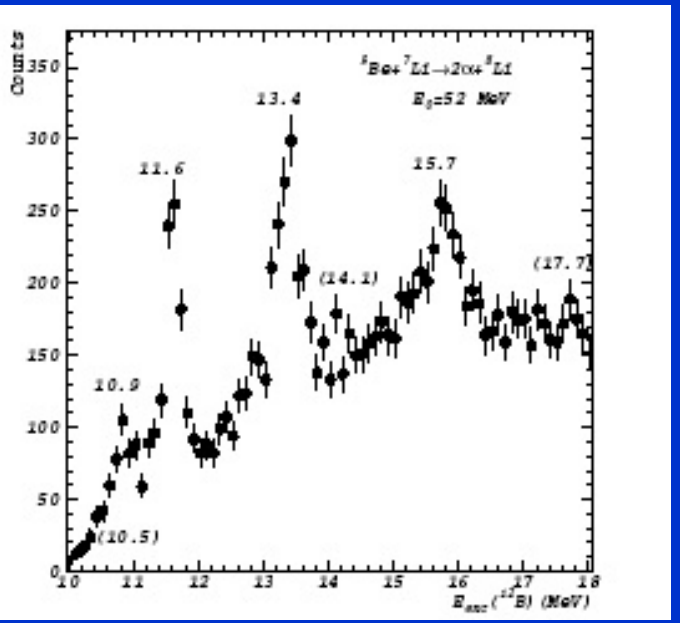
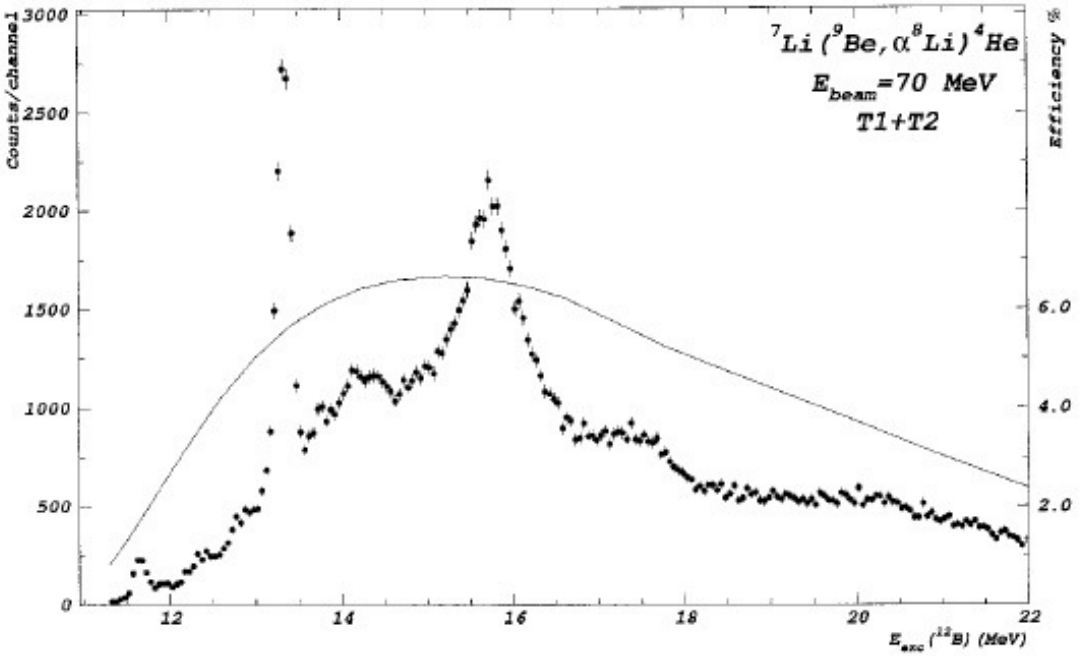
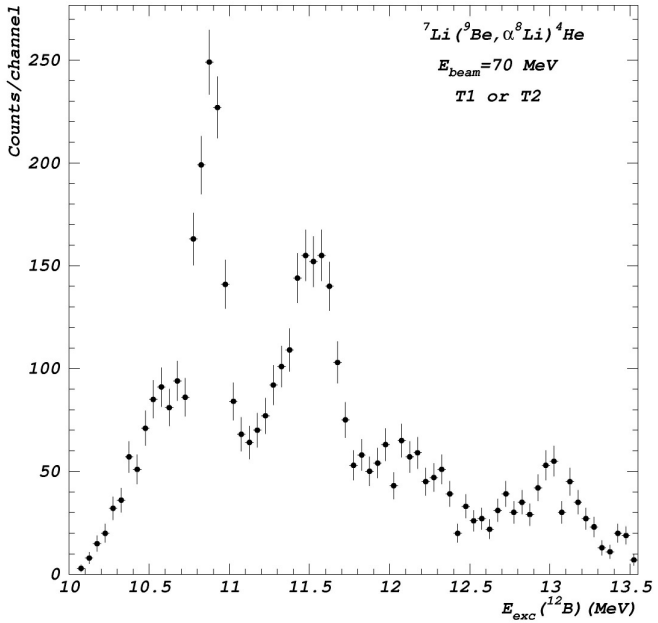
[2] *INFN-Laboratori Nazionali del Sud and Università di Catania - Catania, Italy*

(received 10 March 2003; accepted in final form 17 June 2003)

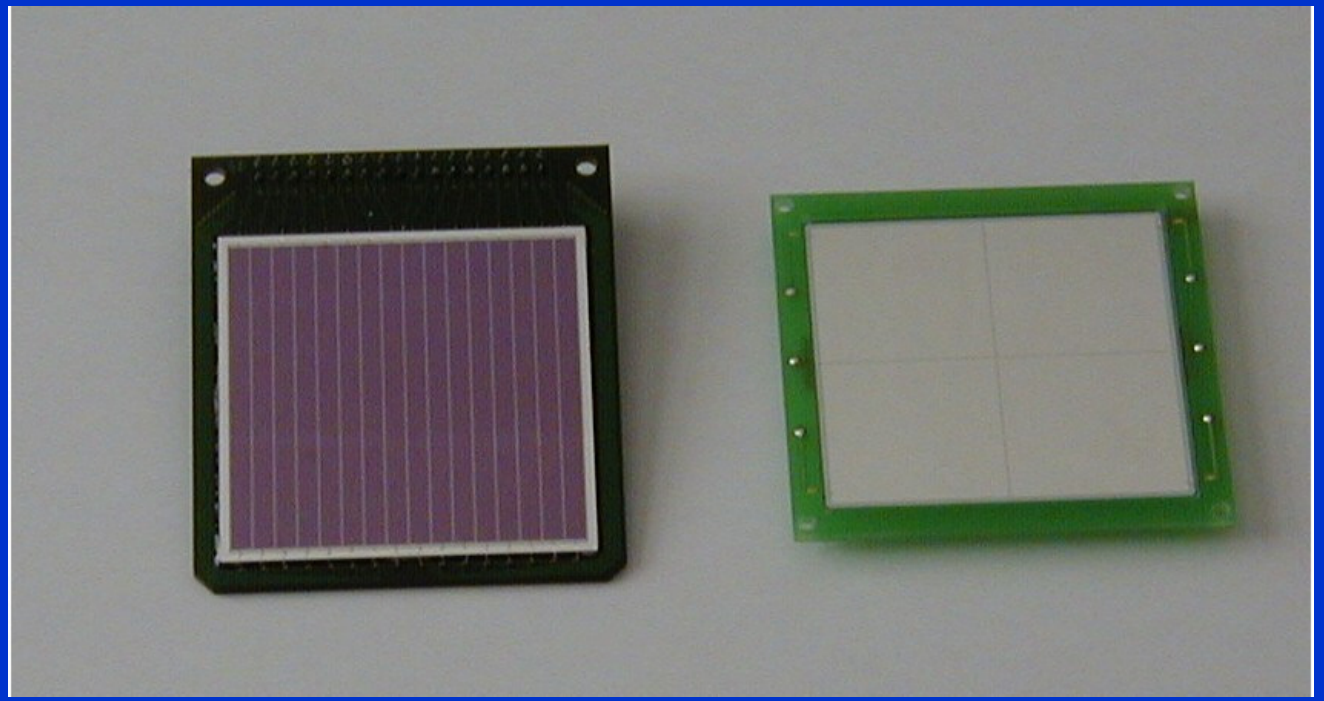




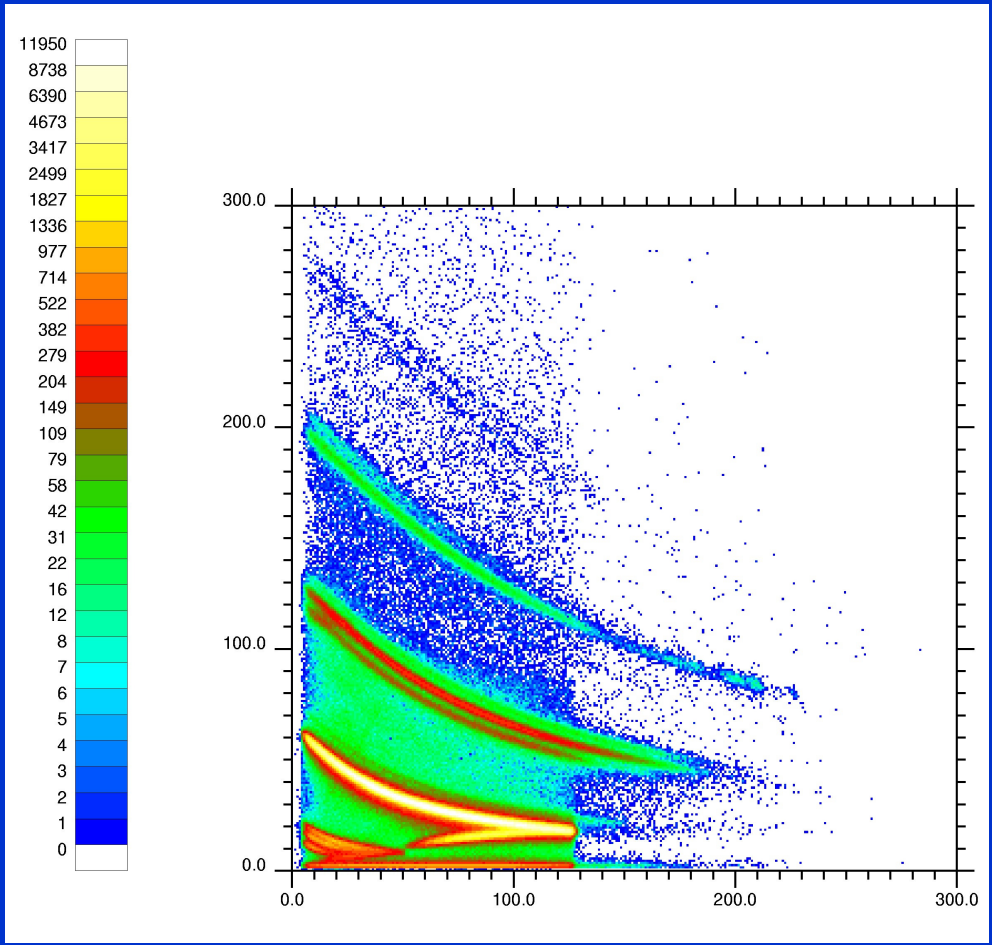


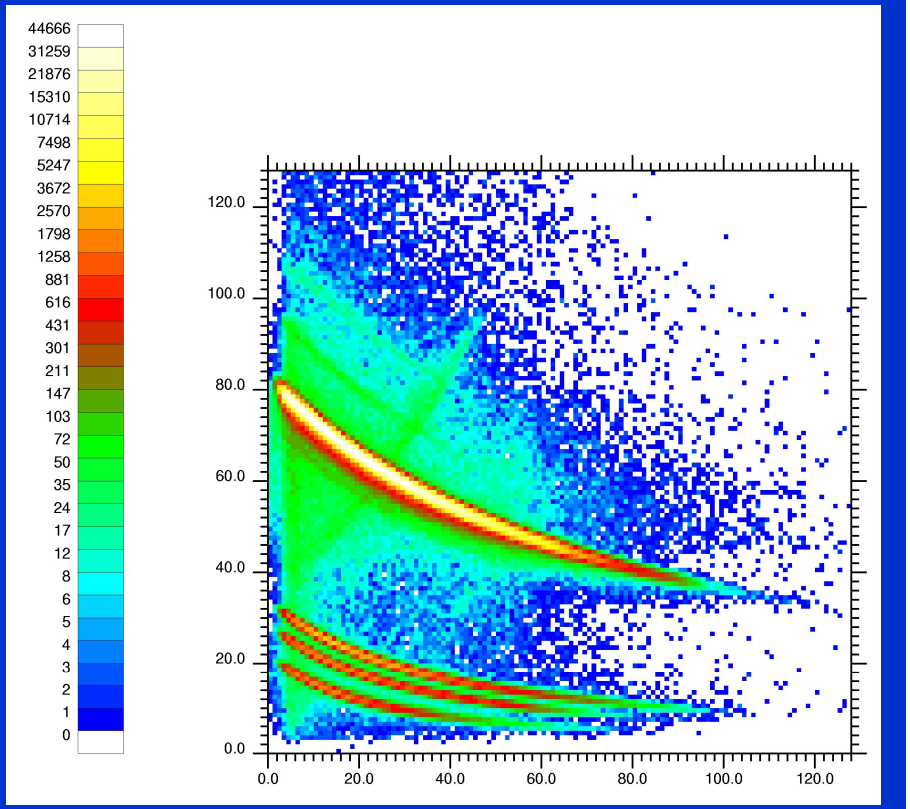
Experimental details

- Measurements performed at the Australian National University's 14UD Tandem Van de Graaff accelerator, Canberra, Australia
- Beam: 70 and 55 MeV ^{9}Be intensity ≈3 enA
- Target: Li_2O_3 foil, 100 μg/cm^2
- Detector array: four telescopes for charged particles in a cross-like arrangement
- T1: θ_c=17.3° Φ_c=0° ; T2: θ_c=17.8° Φ_c=180° ; Θ= ≈7° - ≈28°
- T3: θ_c=28.6° Φ_c=90° ; T4: θ_c=29.7° Φ_c=270° ; Θ= ≈20° - ≈38°
- Telescopes: 70μm 5x5cm^2 silicon detector segmented into 4 squares, 500μm 5x5cm^2 silicon strip detector divided into 16 position-sensitive strips, 2.5 cm thick CsI detector

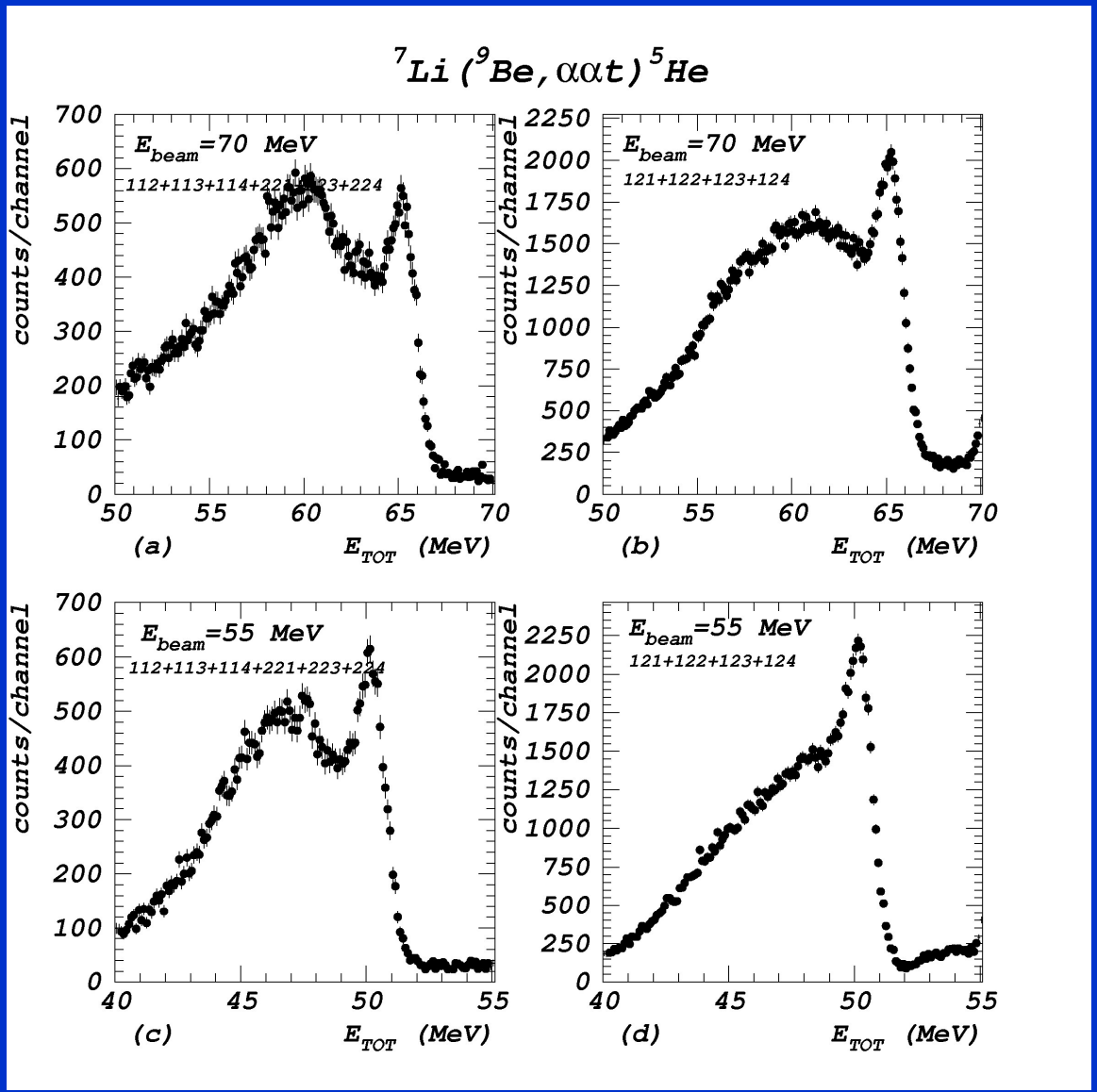


Charge and mass resolution from hydrogen to beryllium isotopes





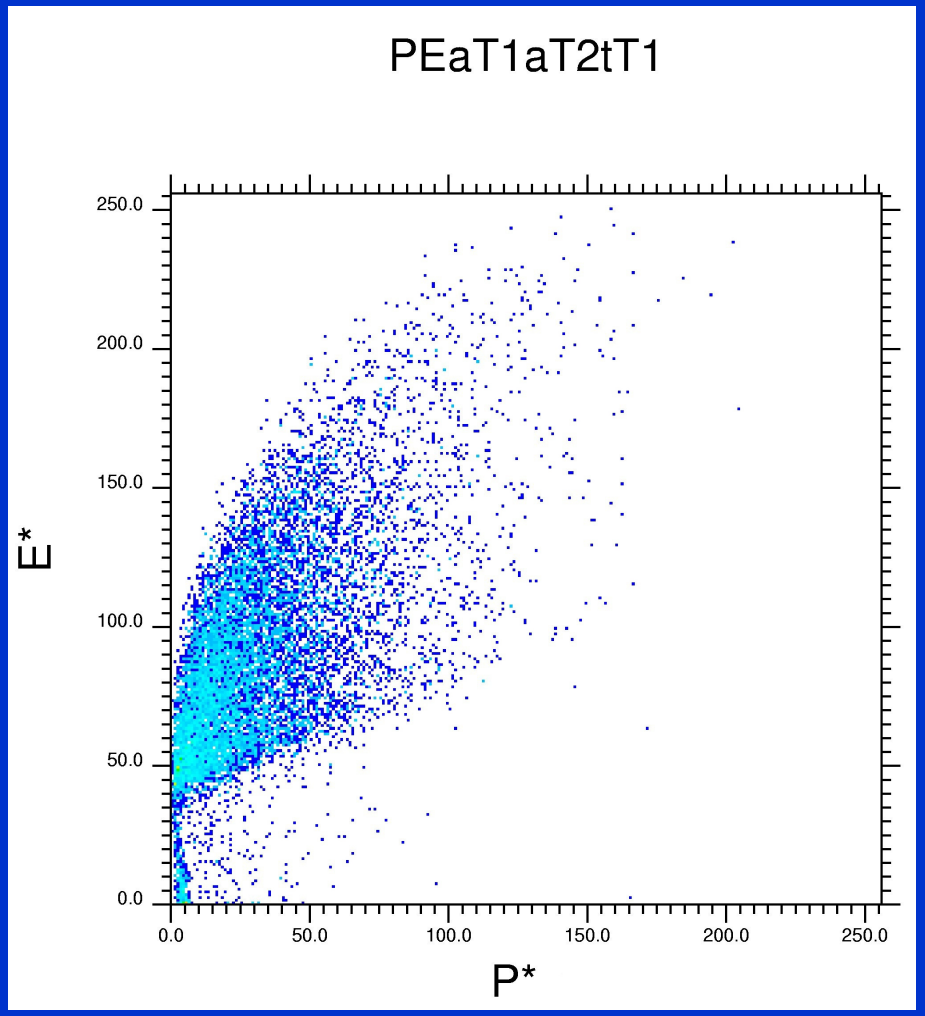
$^{7}Li(^{9}Be,^{11}B^{*}\rightarrow\alpha+\alpha+t)^{5}He$

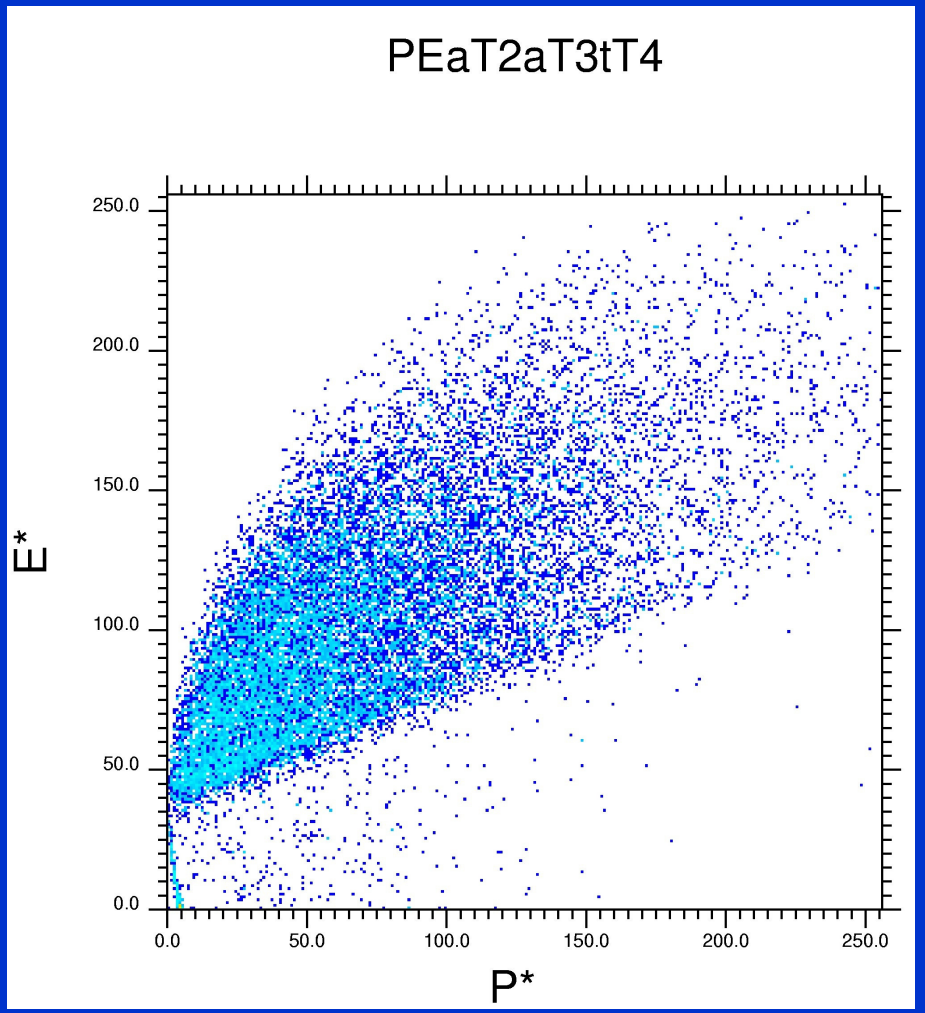


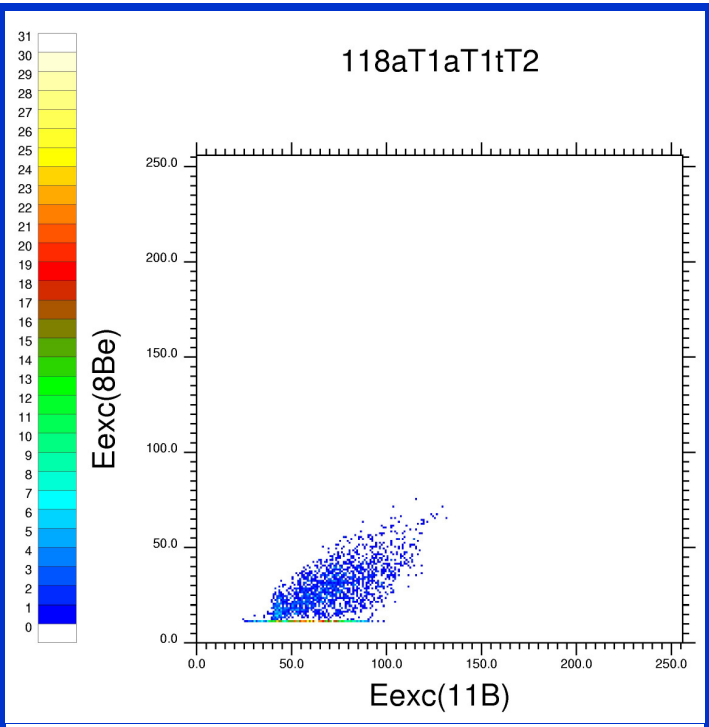
- Q = -4.9 MeV
- similar spectra for other telescope combinations
- peak width: 1.0-1.5 MeV
- width of the ^{5}He gs 600 keV

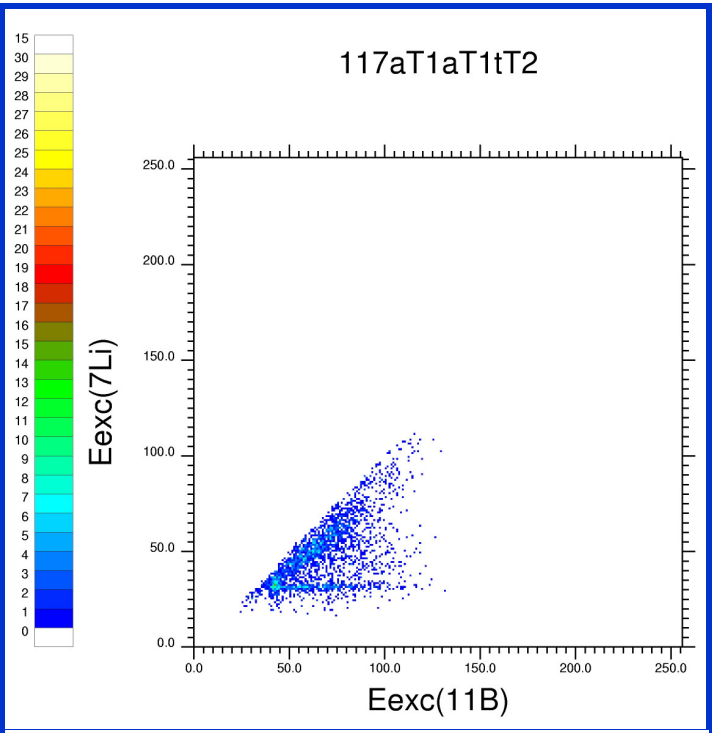
- reaction identification: 3 detected particles of 4 in the exit reaction channel

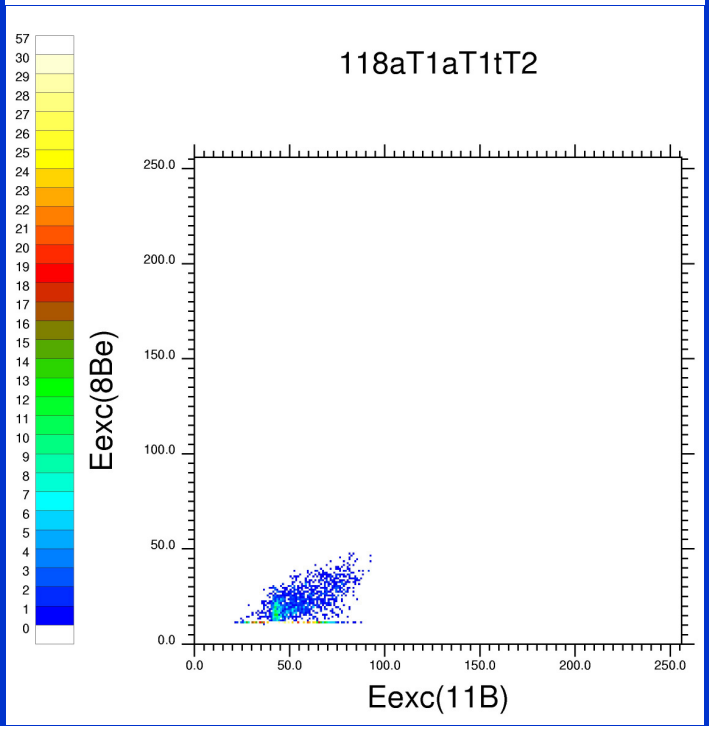
$$P^* = \frac{\vec{p}_{beam} - \vec{p}_1 - \vec{p}_2 - \vec{p}_3}{2 * amu} \qquad E^* = E_{beam} - E_1 - E_2 - E_3 \qquad E^* = \frac{P^*}{A_{recoil}} - Q$$

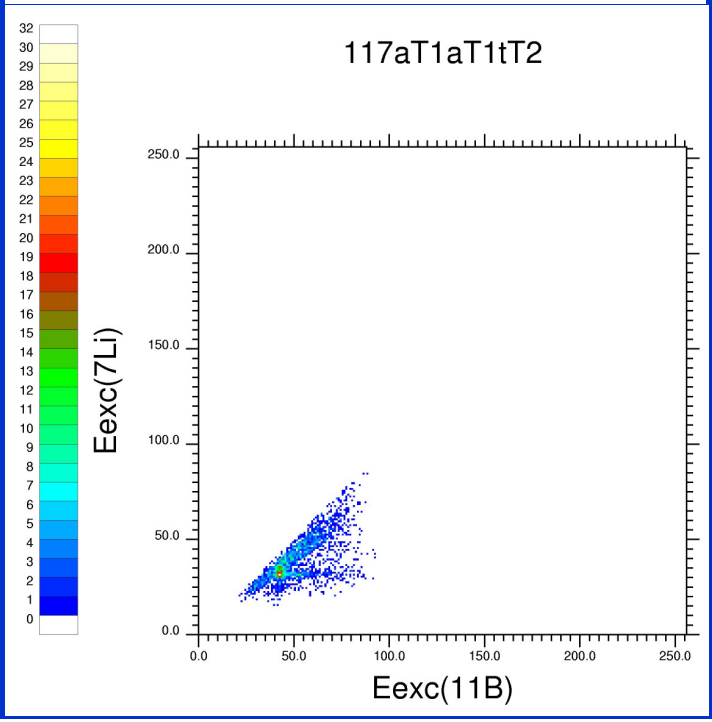




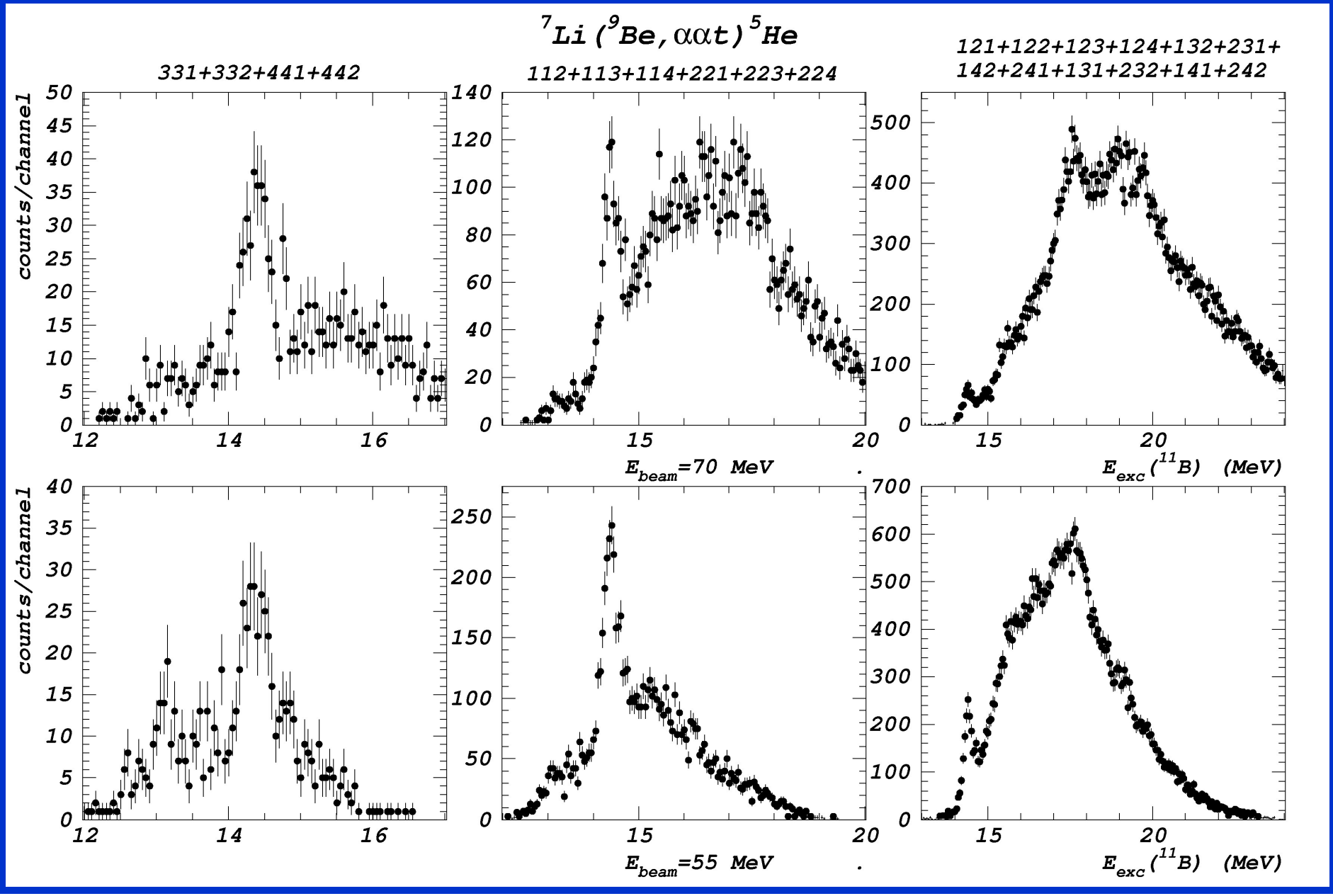

118aT1aT1tT2
Eexc(8Be)
Eexc(11B)
0.0
50.0
100.0
150.0
200.0
250.0


117aT1aT1tT2
Eexc(7Li)
Eexc(11B)
0.0
50.0
100.0
150.0
200.0
250.0


118aT1aT1tT2
Eexc(8Be)
Eexc(11B)
0.0
50.0
100.0
150.0
200.0
250.0

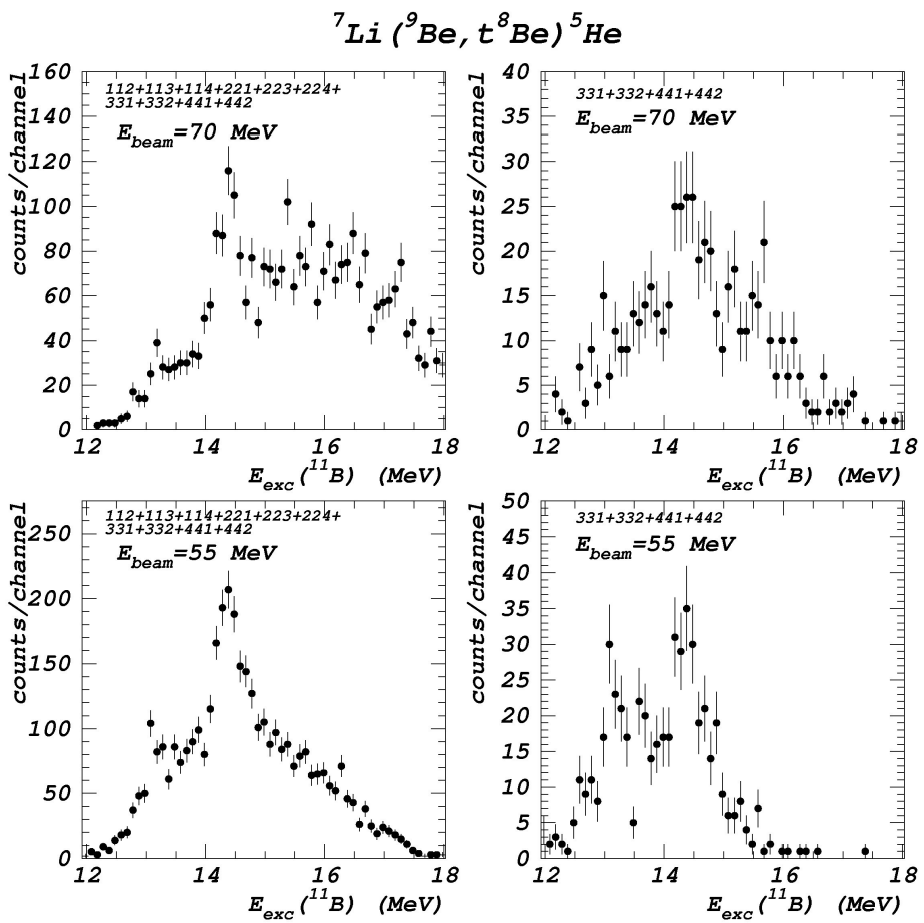

117aT1aT1tT2
Eexc(7Li)
Eexc(11B)
0.0
50.0
100.0
150.0
200.0
250.0

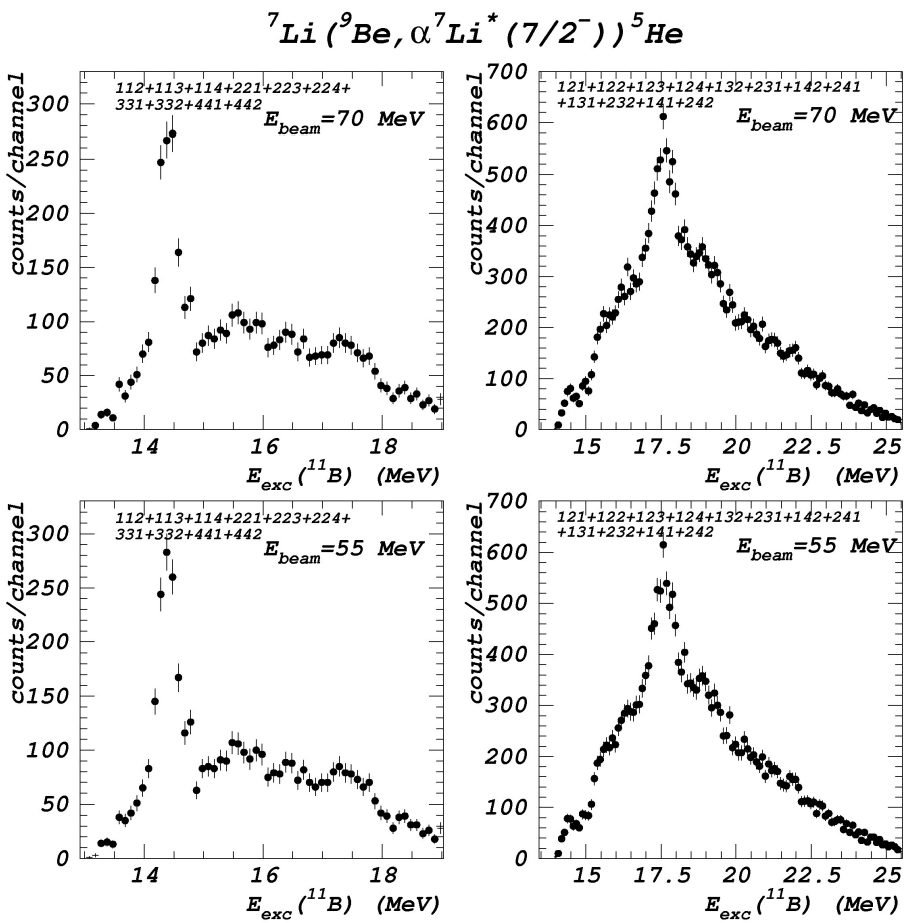
- ^{11}B excitation energy spectra reconstructed from the energy and momentum of three detected particles: peaks at 13.1, 14.4 and 17.5 MeV



$^{11}B \rightarrow t + {}^{8}Be(gs)$ decay
peaks at 13.1 and 14.4 MeV

$^{11}B \rightarrow \alpha + {}^{7}Li^{*}(4.652\ MeV, J^{\pi}=7/2^{-})$ decay
peaks at 14.4 MeV and 17.5 MeV





- Relative decay strengths of the $\alpha+^{7}Li(gs)$, $\alpha+^{7}Li^{*}(4.652\ MeV, J^{\pi}=7/2^{-})$ and $t+^{8}Be(gs)$ decays for the 14.4 MeV state in ^{11}B:
  - all angular range for $^{11}B^{*}(14.4\ MeV)$ c. m. scattering angle θ^{*}
  - $10° \leq \theta^{*} \leq 40°$ (this range is covered in all three decay channels)
  - three intervals: $10° \leq \theta^{*} \leq 20°$, $20° \leq \theta^{*} \leq 30°$, $30° \leq \theta^{*} \leq 40°$
- data corrected for detection efficiency, analysis excludes events for which kinematics allow decay via two different decay channels (all events included only once), analyzed data for both beam energies
- Result: $N(\alpha+^{7}Li(gs)) / N(\alpha+^{7}Li^{*}(4.652\ MeV, J^{\pi}=7/2^{-})) = 4.90 \pm 0.75$

  $N(\alpha+^{7}Li^{*}(4.652\ MeV, J^{\pi}=7/2^{-})) / N(t+^{8}Be(gs)) = 5.15 \pm 0.75$
- $^{11}B^{*}$ decay thresholds (MeV):

$\alpha+^{7}Li(gs)$	$t+2\alpha$	$t+^{8}Be(gs)$	$p+^{10}Be$	$n+^{10}B$	$\alpha+^{7}Li^{*}(4.652\ MeV, J^{\pi}=7/2^{-})$
8.664	11.131	11.223	11.228	11.454	13.316

- if the 14.4 MeV state decays only into these three channels: 80.5% into $\alpha+^{7}Li(gs)$, 16.3% into $\alpha+^{7}Li^{*}(4.652\ MeV, J^{\pi}=7/2^{-})$ and 3.2% into $t+^{8}Be(gs)$
- spin and parity of the 14.4 MeV state unknown
- it has been claimed that at this excitation is $J^{\pi}=5/2^{+}$, T=3/2 state and that its isospin is mixed
- additional measurements are planned for the near future