Study of ^{9}Li-alpha cluster states in ^{13}B using the Resonant Scattering Method

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Outline

- Introduction: clusters in light nuclei.
- The experimental technique: Inverse kinematics thick target method
- The ^{9}Li+^{4}He at TRIUMF
- Conclusions

Conventional cluster structure

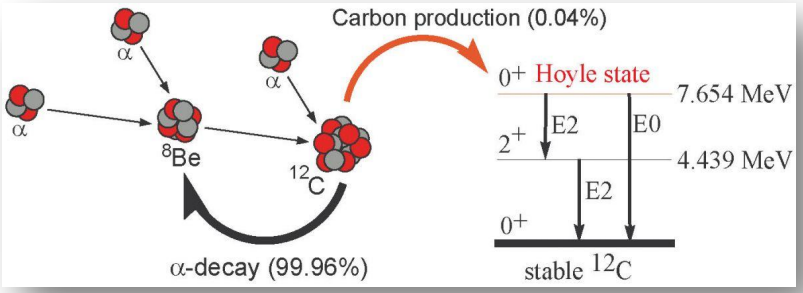
Cluster structure is a well established feature of many light N≈Z nuclei both in their ground and excited states.

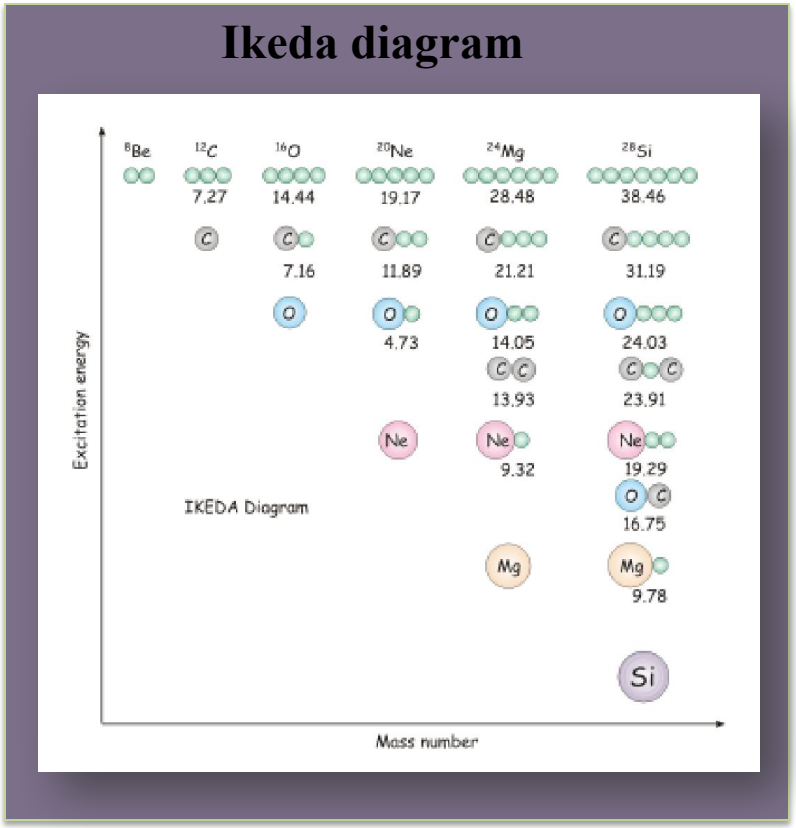
Weak coupling picture:

1. Clusters are formed by tightly bound nucleons (cluster is stiff, i.e. not easy to excite);
2. Weakly coupled inter-cluster motion is considered.

Threshold rule: i.e. these states appear close to the threshold for breaking-up into the cluster constituents.

Ex. Hoyle state in ^{12}C



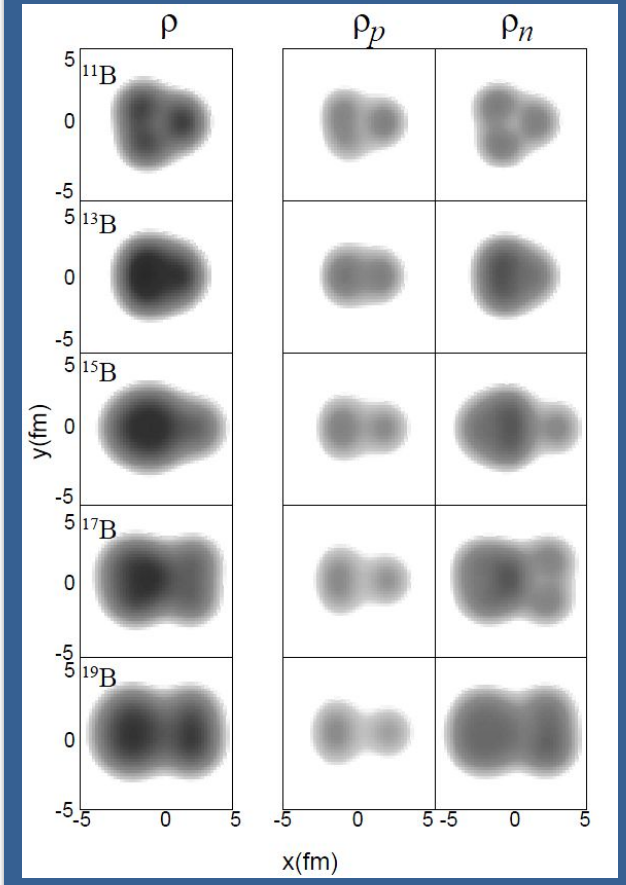


K. Ikeda et al. Supp.Progr.Theo.Phys. 68(1980)1

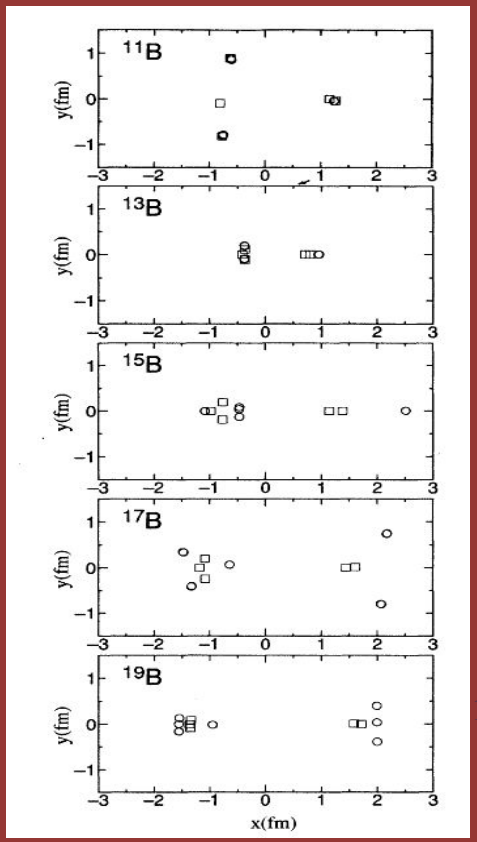
Exotic clustering: B isotopes

In n-rich nuclei the condition that the cluster must be a stiff particle (e.g α particle) is dropped .
Antisymmetrized Molecular Dynamics calculations (AMD) predicts the existence of cluster configuration of Li-He type in B isotope.

B isotopes density distribution



Center wave function spatial distribution



→ ^{7}Li – α structure

H. Yamaguchi et al.PRC 83, 034306 (2011)

→ N=8 shell closure

Well developed di-nuclear structure

^{11}Li-^{8}He

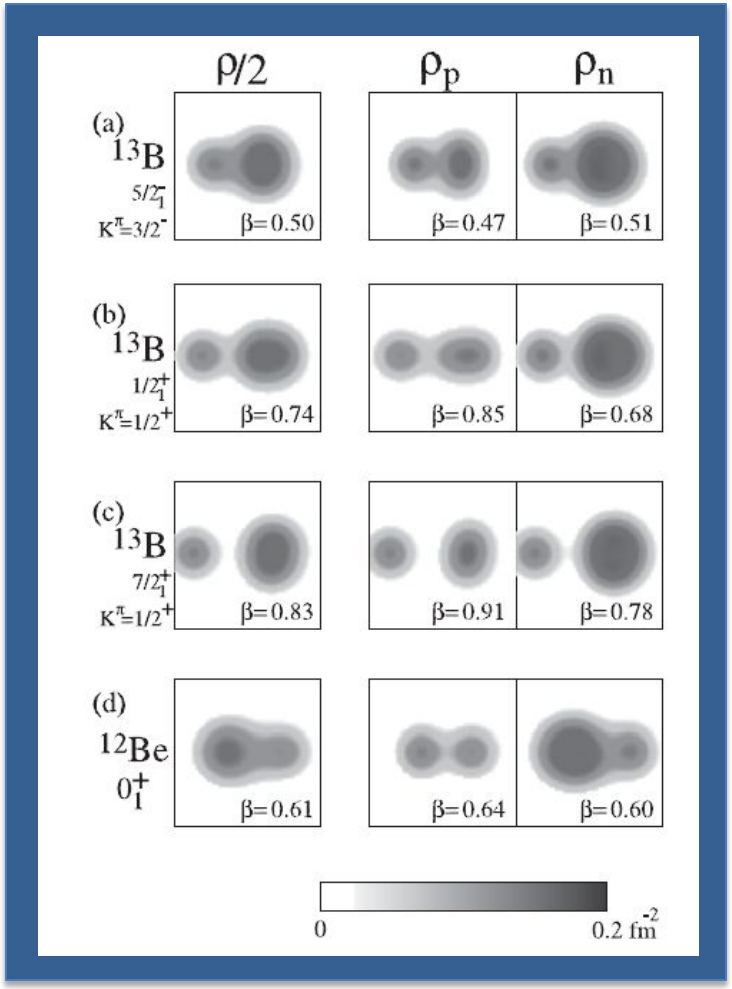
Y. Kanada-En'yo and H. Horiuchi Prog. Theor. Phys. Supp.142(2001)205 and Kanada En'yo et al PRC 52 (1995) 647

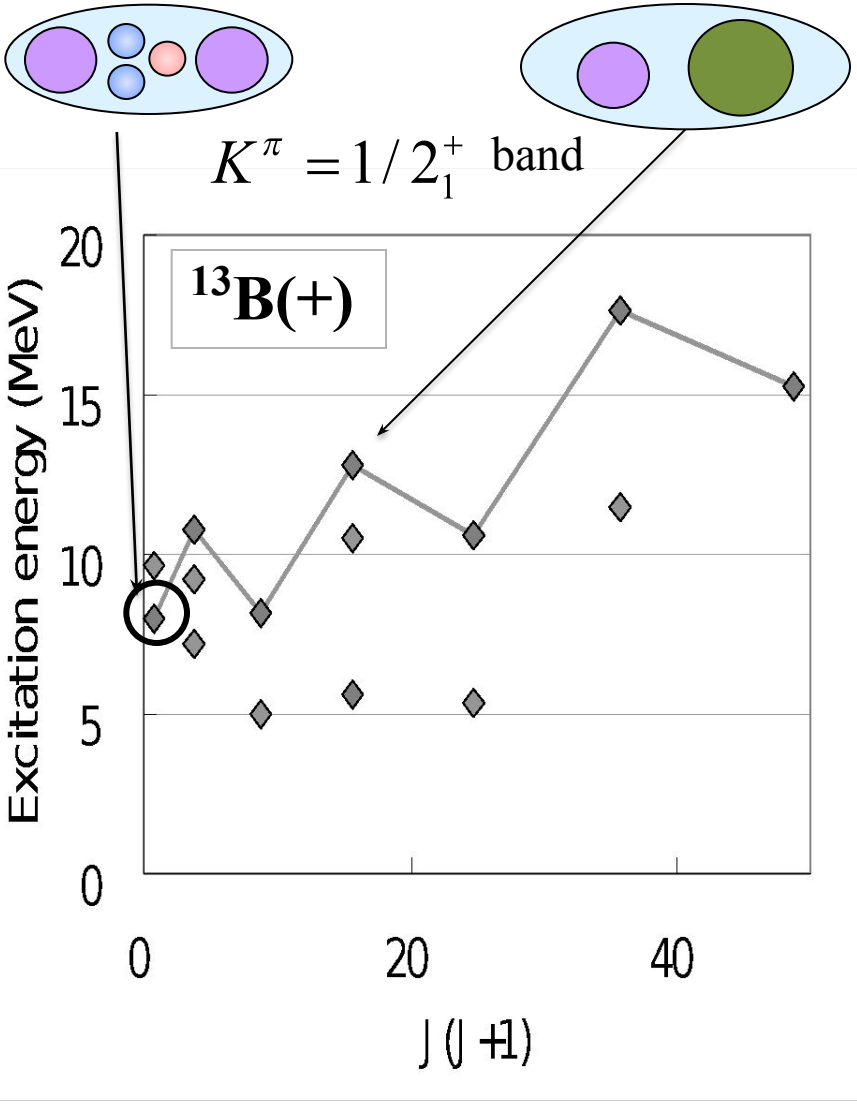
Excited states of ^{13}B studied with AMD

AMD calculations

Y. Kanada En'yo et al. Prog.Theor.Phys.120(2008)917

No known states ^{13}B E_x>11 MeV

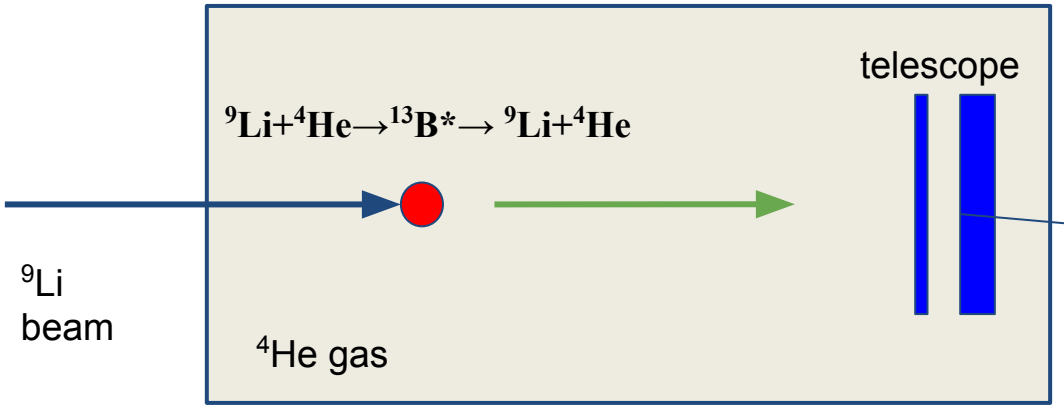




Thick Target Inverse Kinematics scattering method

K.P.Artemov et al. Sov.J.Nucl.Phys. 52(1990)408

K. Kallman et al., Nucl. Instr. And Meth. in Phys. Res. A338, (1994) 413



4He gas:

1. target
2. degrader of the beam

recoil energy and detection angle

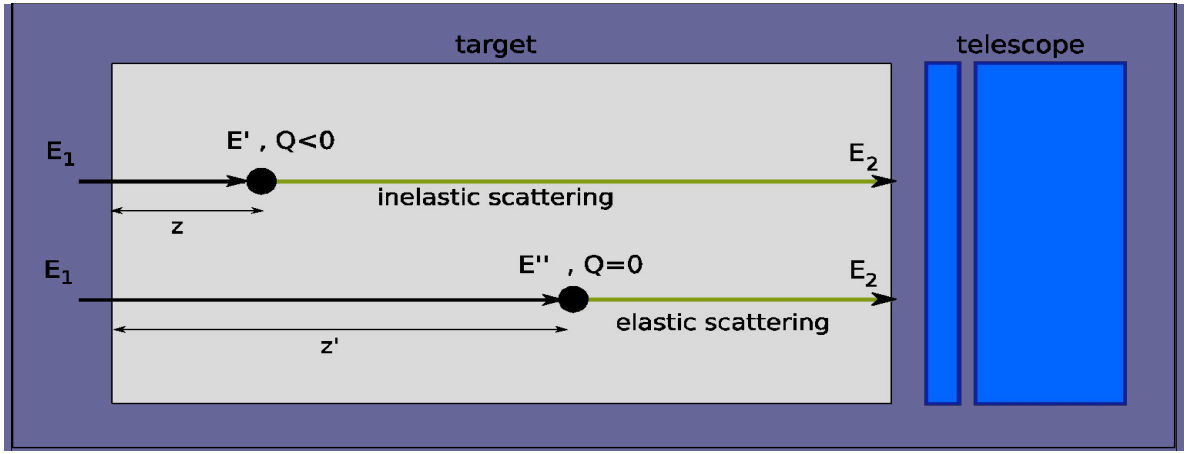
the emission angle and the impact position → energy of the scattering event

- **ADVANTAGE**
  - Wide energy range of measurements with a single beam energy.
  - It is possible to measure at 0° (^{9}Li at 180° in centre of mass frame): the best condition to study resonances in the elastic scattering.
- **DISADVANTAGE**
  - Precise knowledge of stopping power needed.
  - Limits on the width of the states that can be measured, because of low resolution.

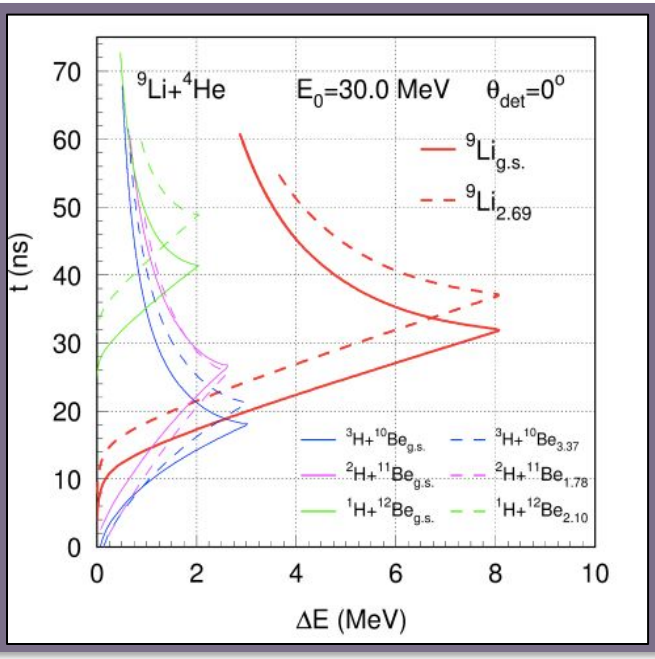
Importance of Time measurement

➢ Background ⇒ radioactive decay of the beam, inelastic scattering and reaction events.
From α or Hydrogen spectra no possibilities to discriminate different reaction processes.

Time measurement



Calculations of
Time *vs* ΔE for a ΔE thickness=50μm
Elastic, inelastic and some reaction process are considered



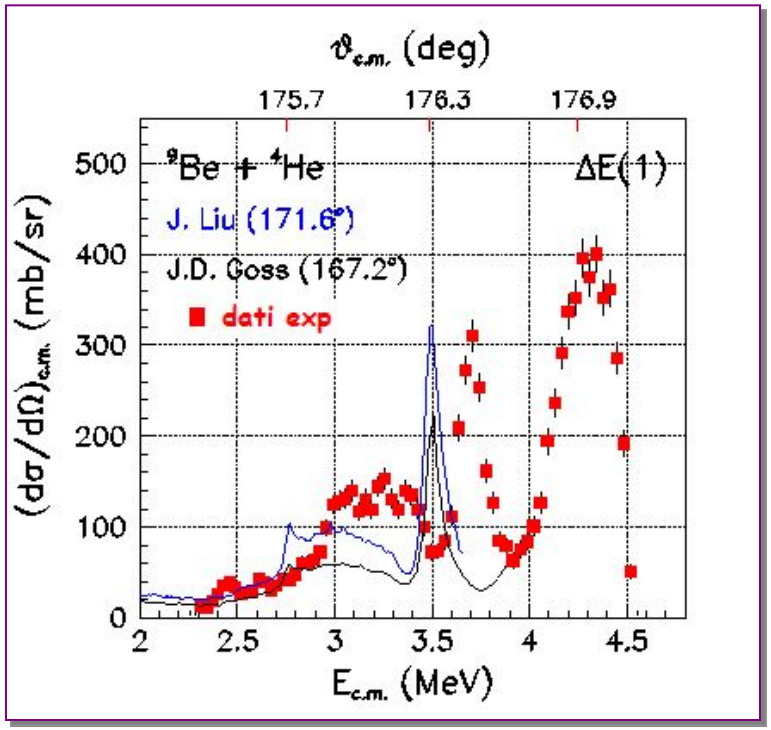
Problems with stopping power calculations.

Excitation function $^{9}Be+^{4}He$ at $E_{c.m.}$<4.5MeV

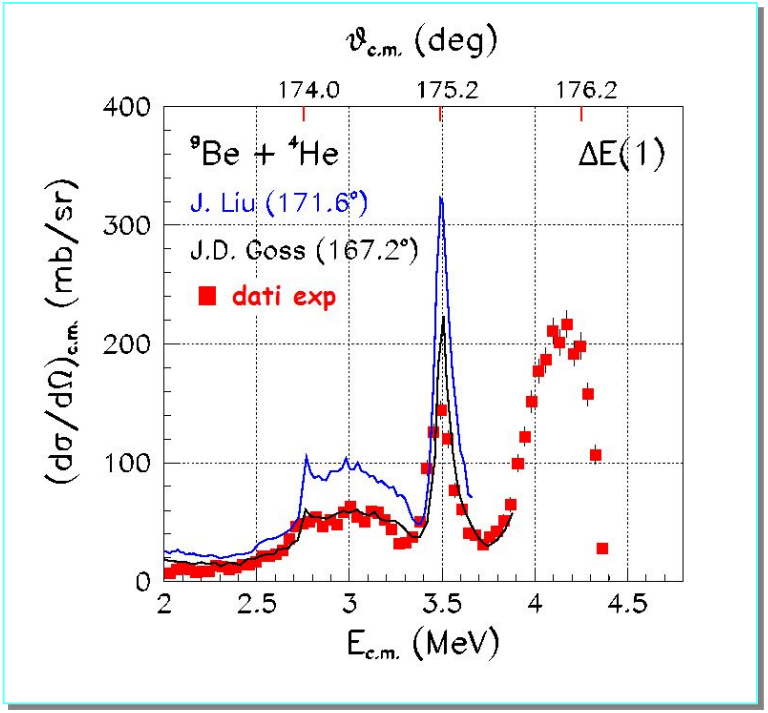
<Excitation function $^{9}Be + \alpha$ with resonance scattering method. M. Zadro et al, NIM B259 (2007).

— Excitation function $\alpha+^{9}Be$ measured with thin target method varying beam energy at small streps J. Liu [NIM B 108,(1996) 247] , J.D. Goss [PRC 7,(1973) 247]

dE/dx from SRIM



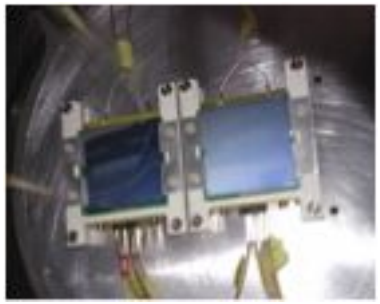
dE/dx measured

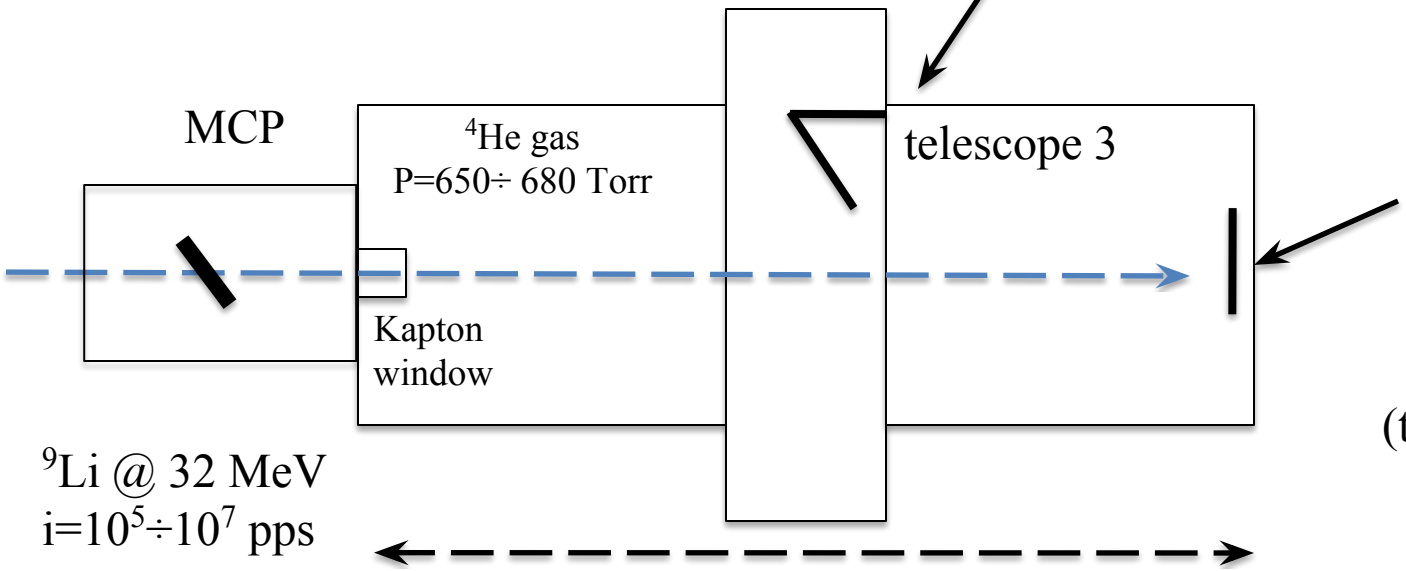


Cluster states in ^{13}B: ^{9}Li+α at TRIUMF

Detectors:

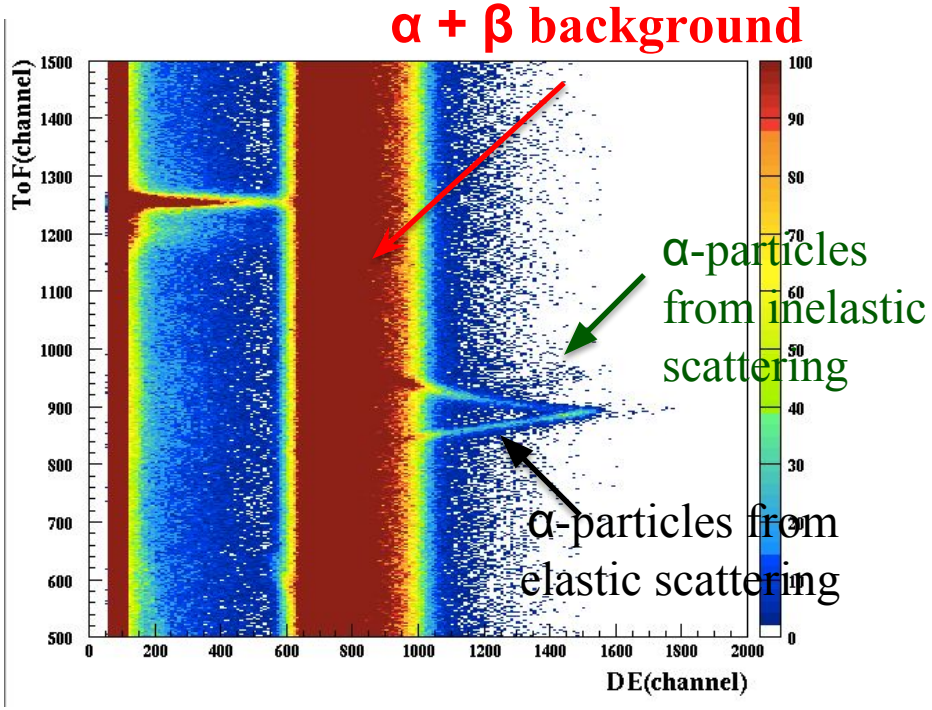
MCP : ToF measurement
and beam-particle counting
3 Si-telescopes :
4 quadrant ΔE detectors: 50 μm
E- single pad: 1000 μm

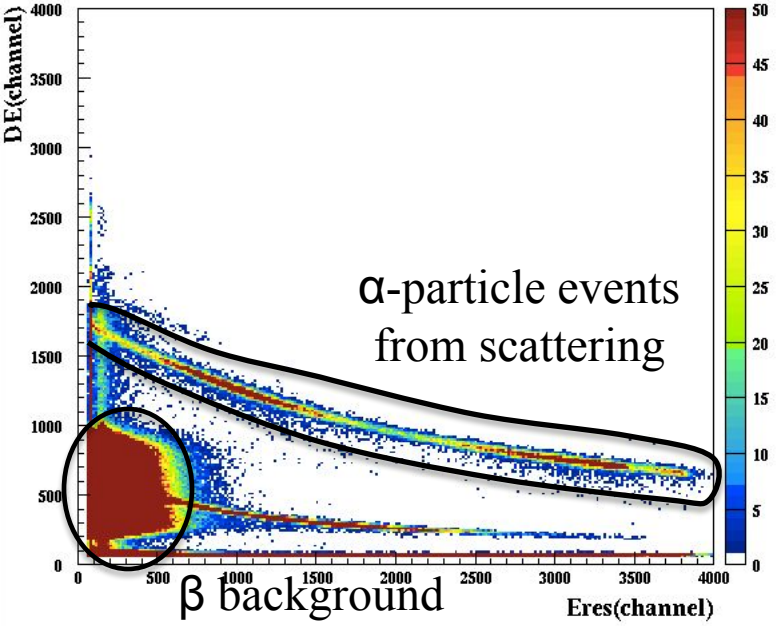




0^{0} detectors
(telescopes 1 & 2)

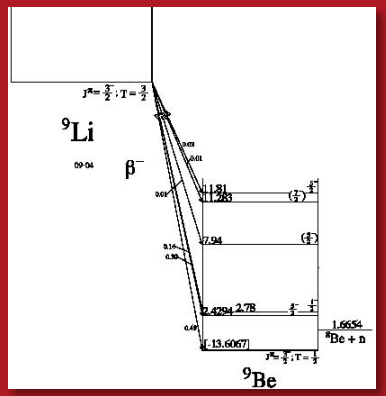
^{9}Li+^{4}He @ TRIUMF



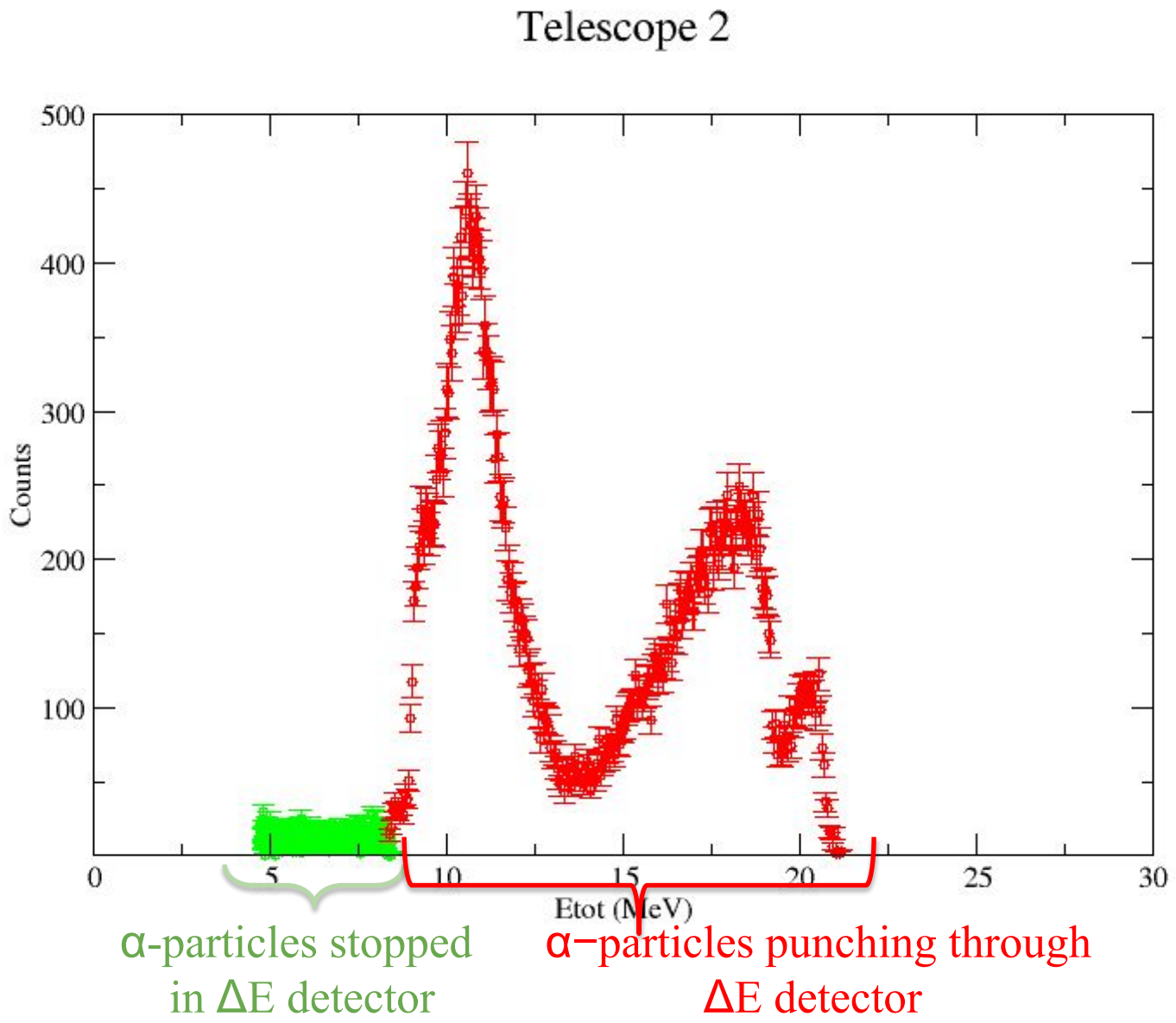


Uncorrelated α and β particles coming from ^{9}Li radioactive decay. Due to the large size of the detectors β particles release large energy in both ΔE and E detectors. α–energy not sufficient to punch-through the ΔE

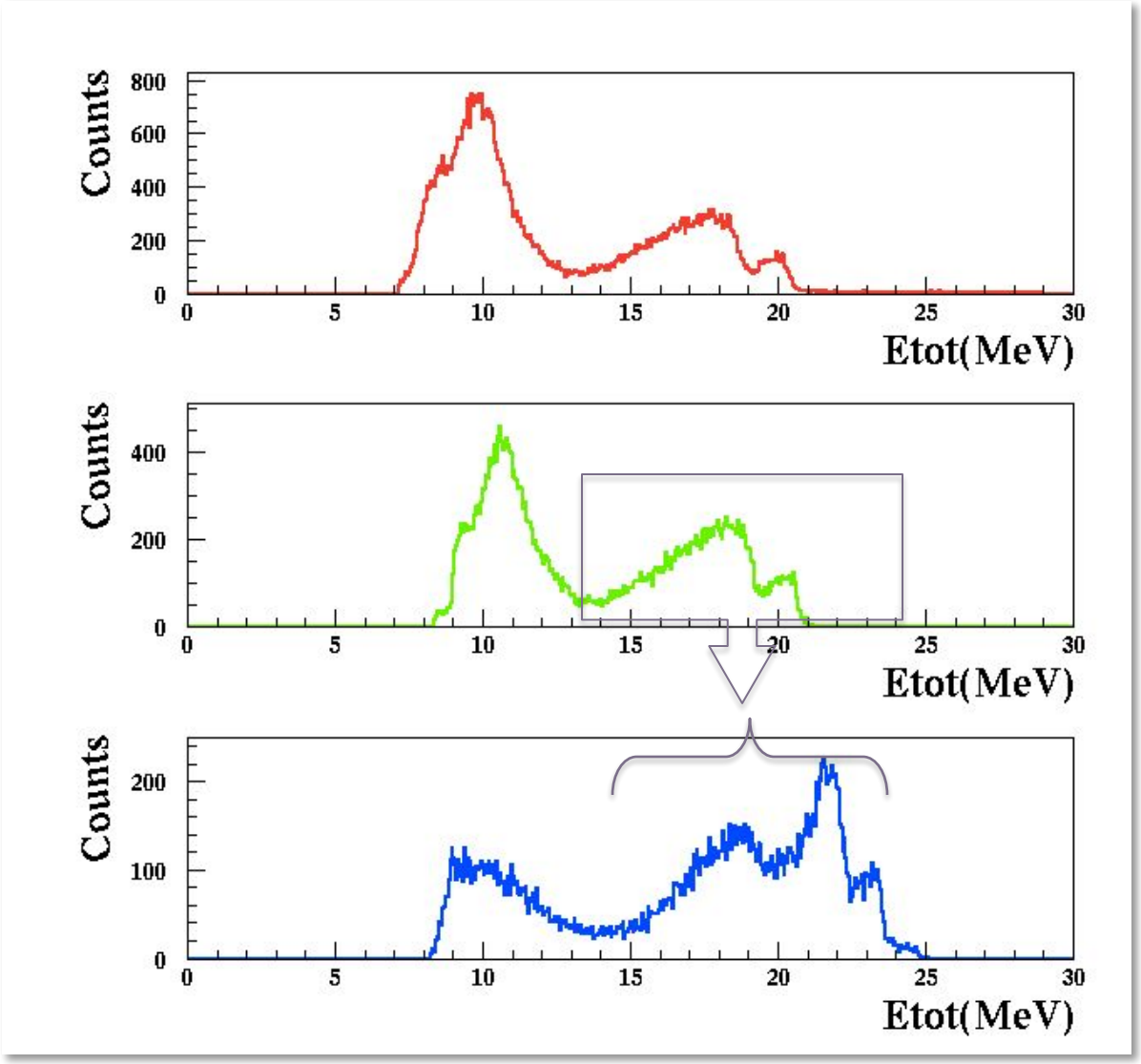
^{9}Li decay scheme



α-particle total energy spectrum



Total-energy spectra for α-particles punching through ΔE detectors (E_{tot}=ΔE+E)

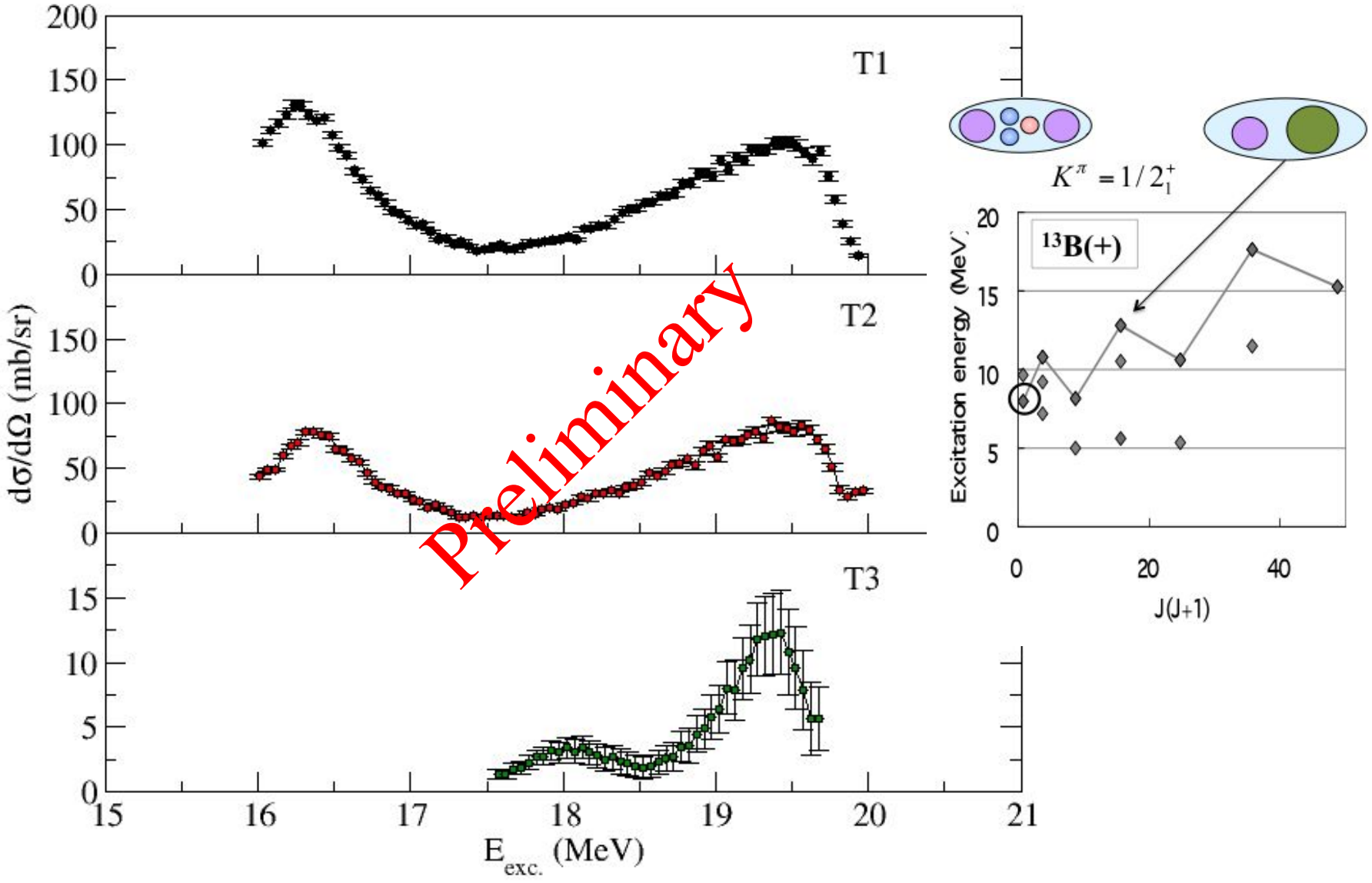


Telescope 1

Telescope 2

Telescope 3

^{13}B Excitation function



Summary

➢The existence of exotic cluster configurations is predicted by AMD calculations in n-rich B isotopes, including the closed shell nucleus ^{13}B.

➢ Resonant scattering of light nuclei powerful tool to investigate cluster structures.

➢ Use of extended targets + ToF allows discrimination of reaction processes.

➢Important precise knowledge of stopping power. Measured stopping power used in the present analysis.

➢^{9}Li+^{4}He excitation function shows presence of structures at high excitation energy. Possible ^{13}B α-cluster states? R-Matrix analysis needs to be performed.