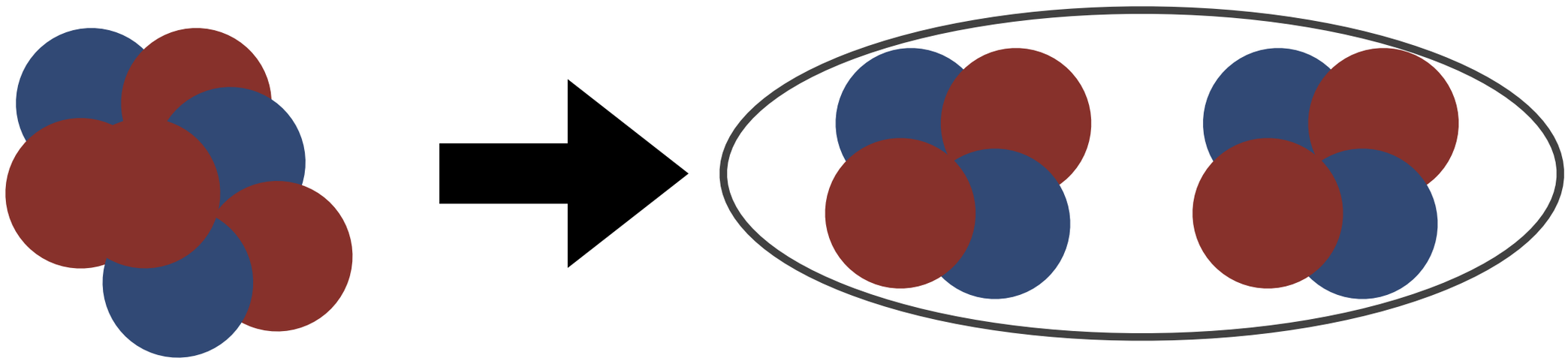
Sriteja Upadhyayula - May 17, 2018
Cyclotron Institute - Texas A&M University

Cluster Physics - ^{6}He(α, α) @ TAMU

Search for the 6^{+} state of ^{10}Be

Motivation

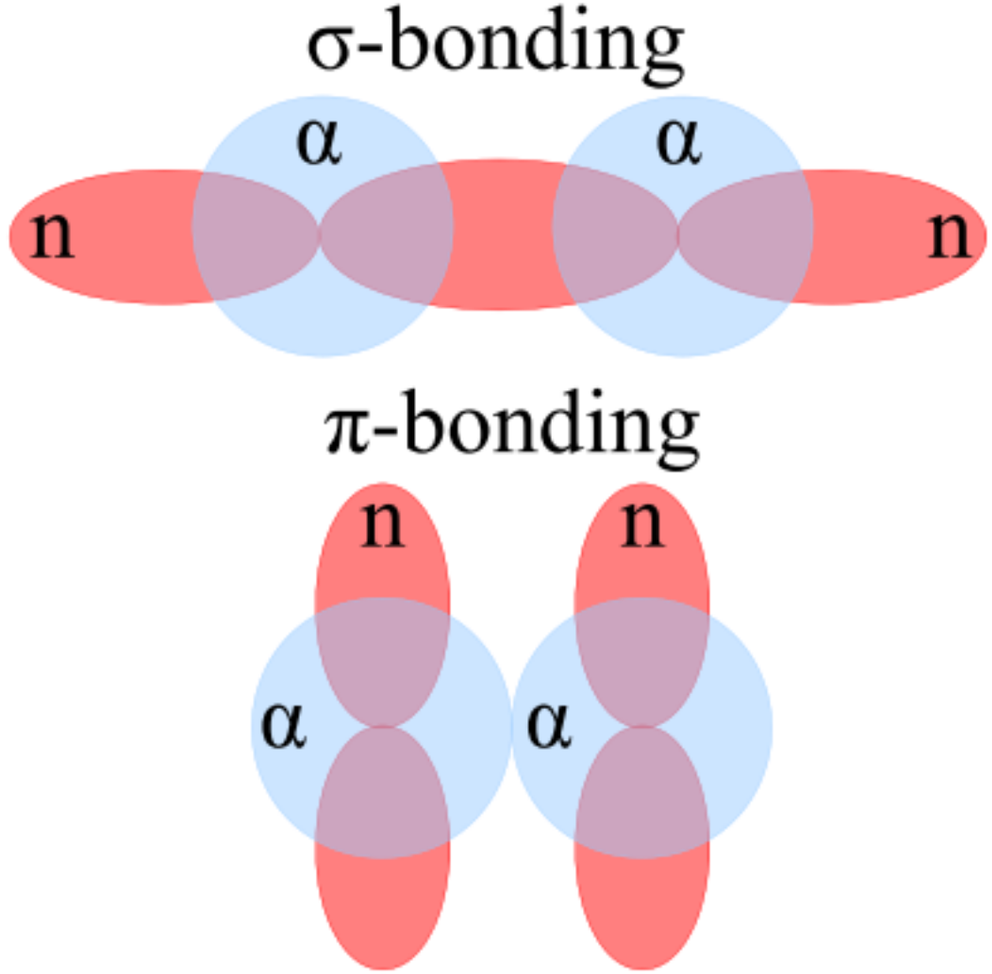


- Clustering phenomena play an dominant role in structure of light nuclei.
- ^{8}Be shows pronounced two-cluster configuration in its ground state.
- The molecular-like α:2n:α configurations for some excited states in ^{10}Be have been suggested

A. Dote, et al., Phys. Rev. C 56, 1877 (1997)
N. Itagaki and S. Okabe, Phys. Rev. C 61, 044306 (2000)
M. Ito, K. Kato and K. Ikeda, Phys. Lett. B 636, 293 (2006)

Motivation

- Deformed orbitals manifests in the rotational band which has a very large moment of inertia, compared to the rotational band built on the ground state structure.



σ- and π-bonding of neutrons to α particles for ^{10}Be. The ground state has a $(\pi)^2$ configuration, and the 0^+_2 is more deformed because of a $(\sigma)^2$ configuration

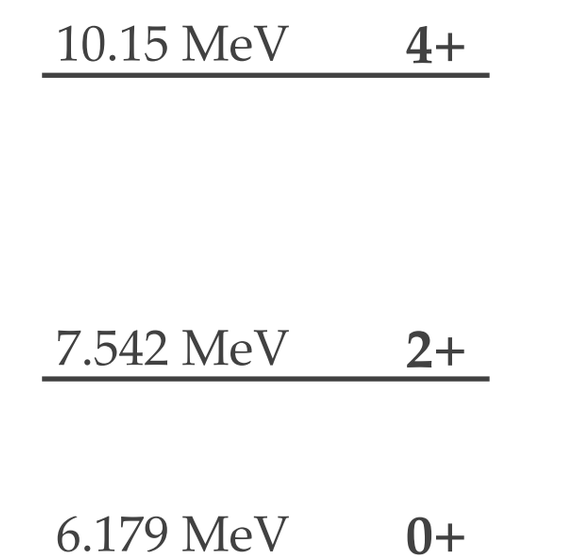
[Kuchera, A (2013) Clustering Phenomena in the a=10 T=1 Isobaric Multiplet]

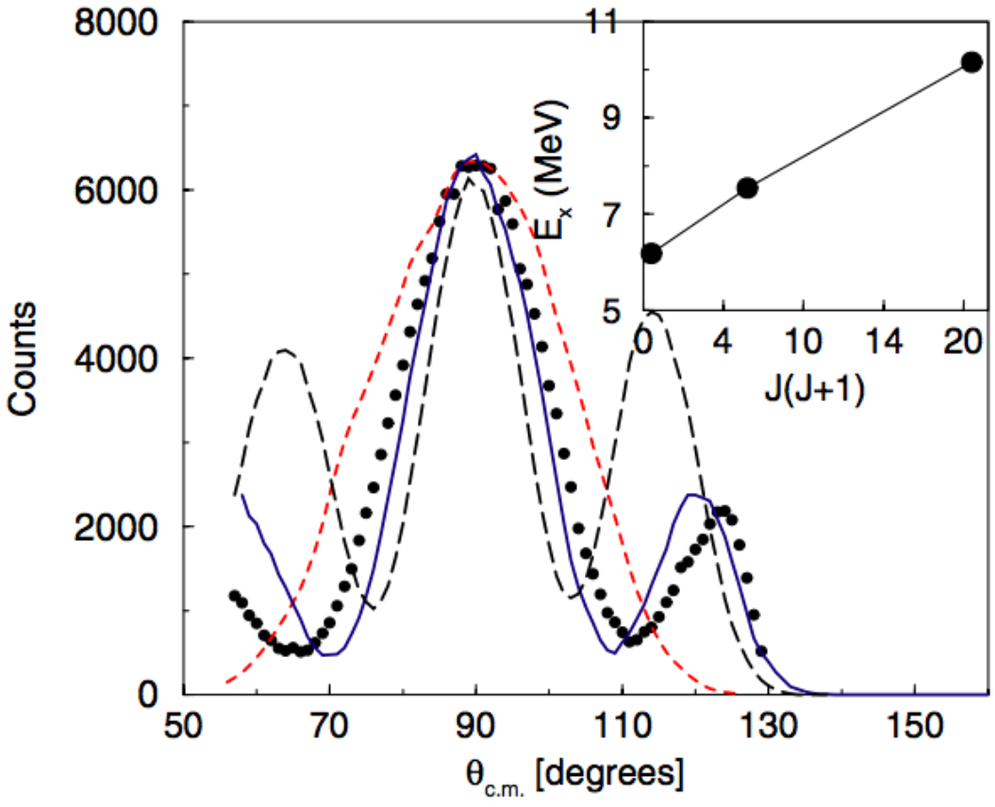
Motivation

- Many experiments have been done in the past that showed the existence of the 0+, 2+ and 4+ members of the rotational band.

S. Hamada, et al., Phys. Rev. C 49, 3192 (1994)
N. Soic, et al., Europhys. Lett. 34, 7 (1996)
M. Milin, et al., Europhys. Lett. 48, 616 (1999).
N. Curtis, et al., Phys. Rev. C 64, 044604 (2001)
M. Freer, et al., Phys. Rev. Lett. 96, 042501 (2006)
D. Suzuki, et al., Phys. Rev. C 87, 054301 (2013)

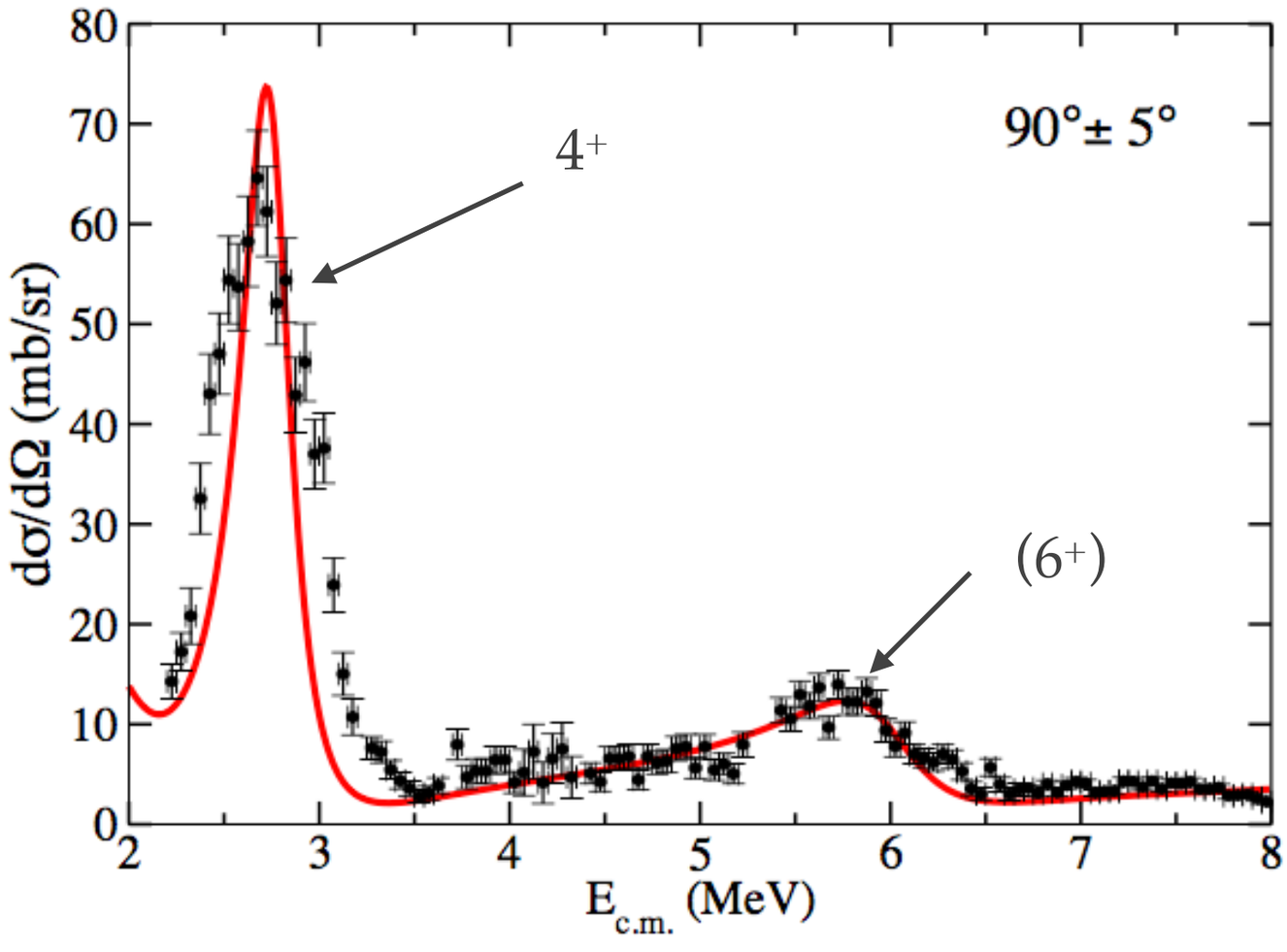
- Existence of the next, 6^+ member of this band was predicted in [**R. Wolski**, et al. (2010).] based on SU(3) algebraic model, but has not observed experimentally.





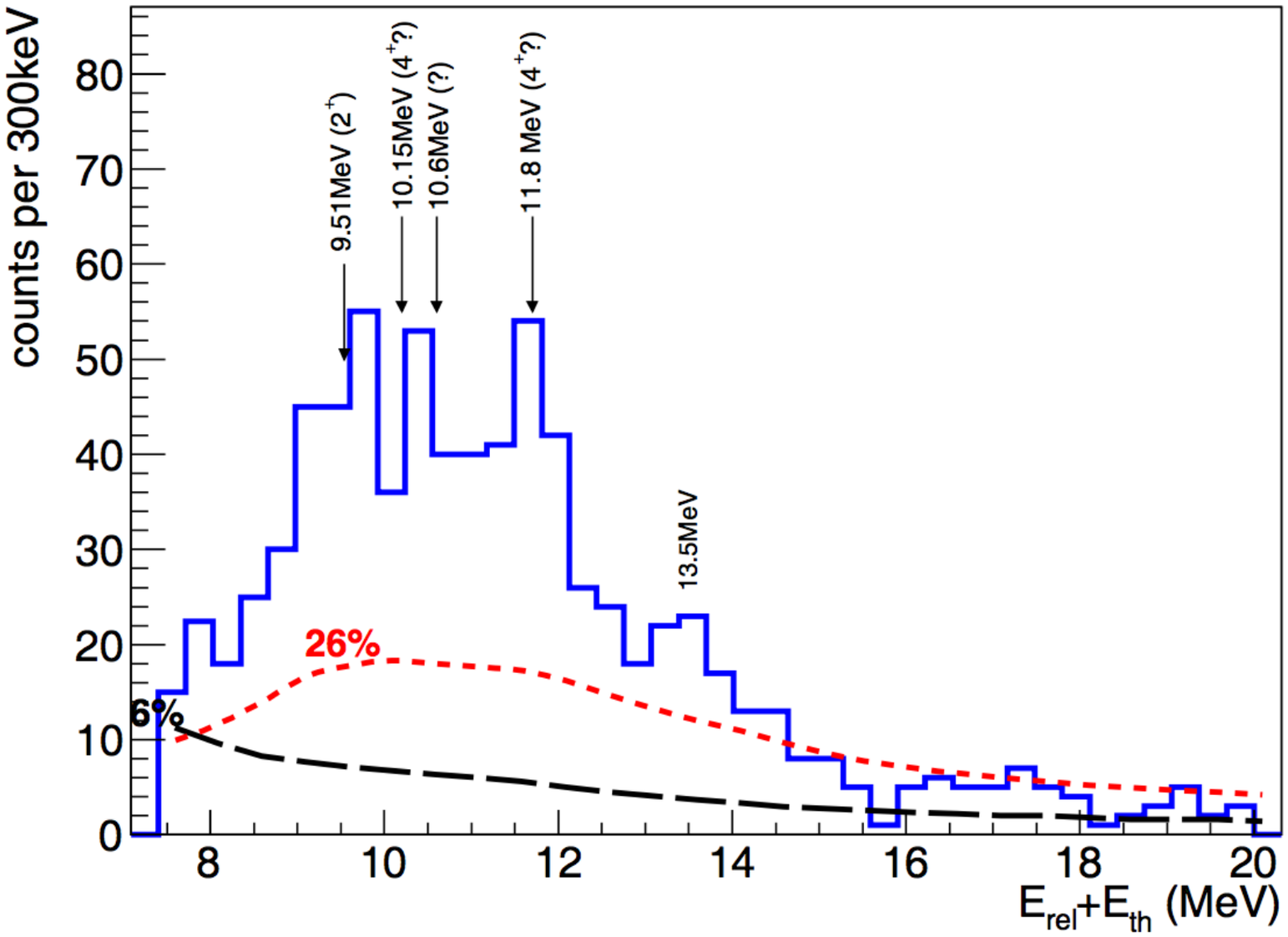
Experimental vs. calculated CM angle distributions for the 4+ state [Freer, M (2006) *PRL*]

- A measurement was also done at FSU by Rogachev *et al*.
  - Found 4^+ state.
  - Another broad peak at $E_{c.m.}$=6 MeV (13.5 MeV lab) was observed.(**^{6}He + α elastic scattering**)



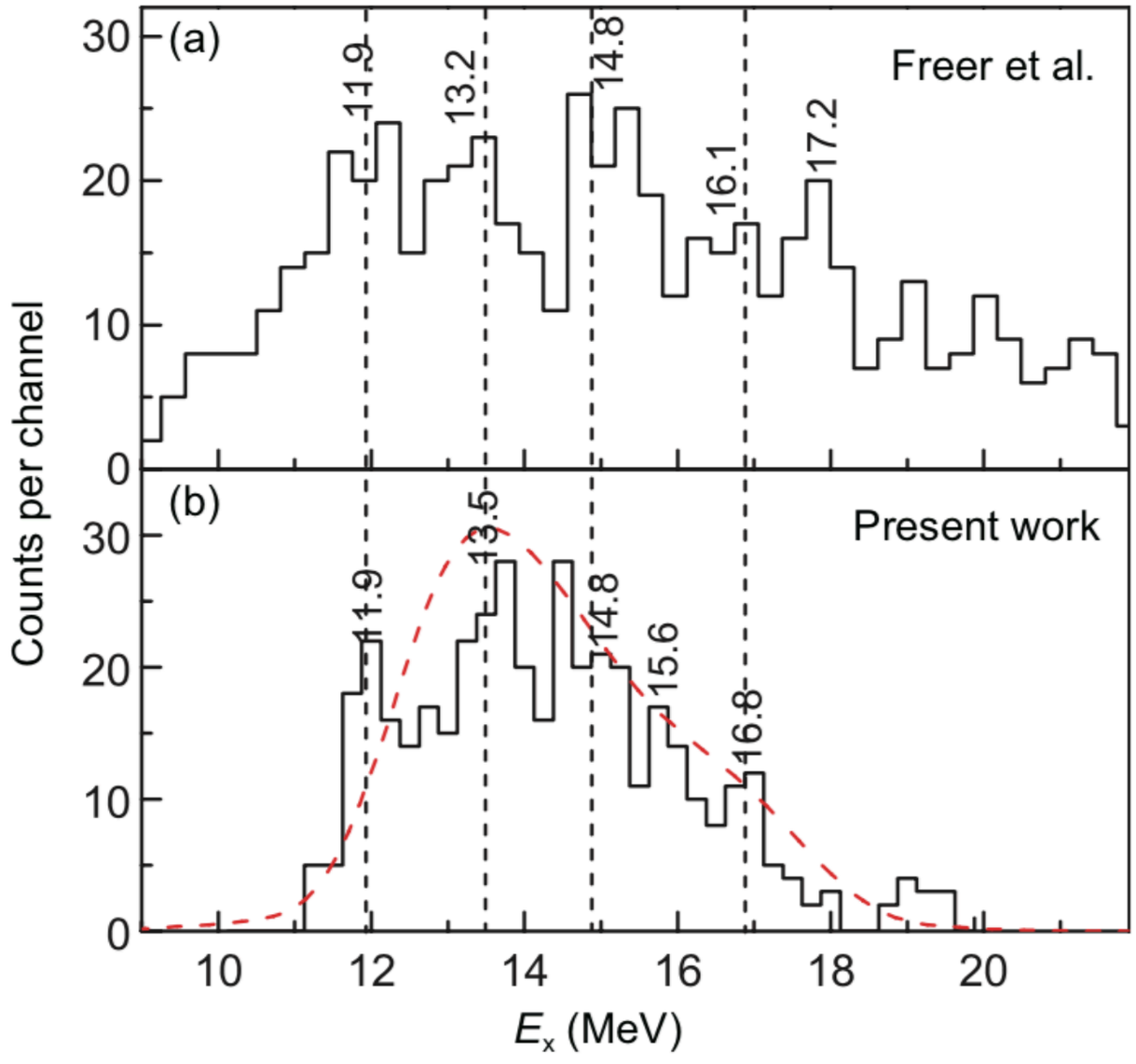
Excitation function for the ^{6}He+α elastic scattering at 90^0 in center of mass. We can see the 4^+ and 6^+?? states at 2.78 MeV and 6 MeV c.m respectively [Koshchiy *et al*. (2016) NIM]

- Results from a measurement performed by Dell' Aquila *et al*., found a peak at **13.5 MeV**
- **^{10}Be beam -> CH_2 target**



Energy spectrum for the ^{6}He + ^{4}He break-up. [Dell' Aquila *et al*. (2016) *PRC*

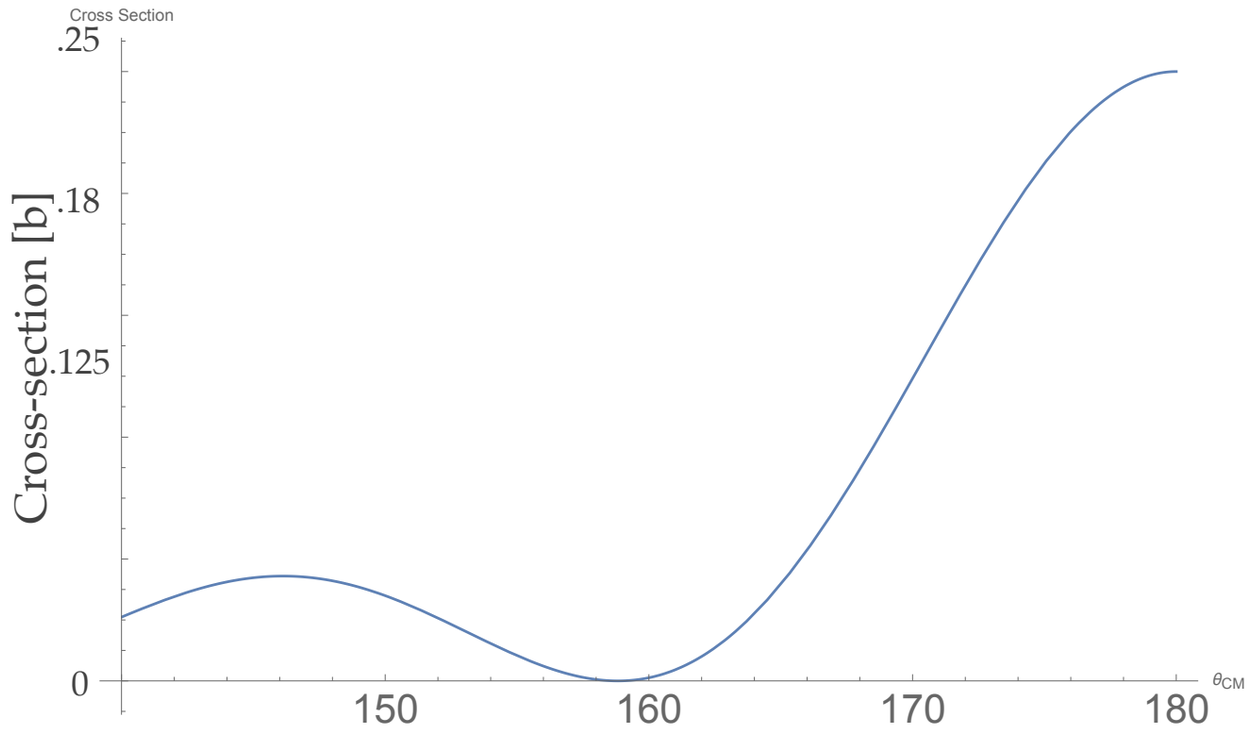
- Results from a measurement performed by Jiang *et al*., found a peak at **13.5 MeV**
- **^{9}Be(^{9}Be, ^{10}Be* → α + ^{6}He)^{8}Be**



Energy spectrum for the ^{6}He + ^{4}He break-up.
(a) Freer *et al.* (2001) *PRC*
(b) Jiang *et al*. (2017) *Science China*

Motivation

- This experiment was designed to further probe the **broad peak** at $E_{c.m.}$=6 MeV found at **FSU** at an angle close to **180⁰ c.m.** where the 6^+ state has a strong maximum.

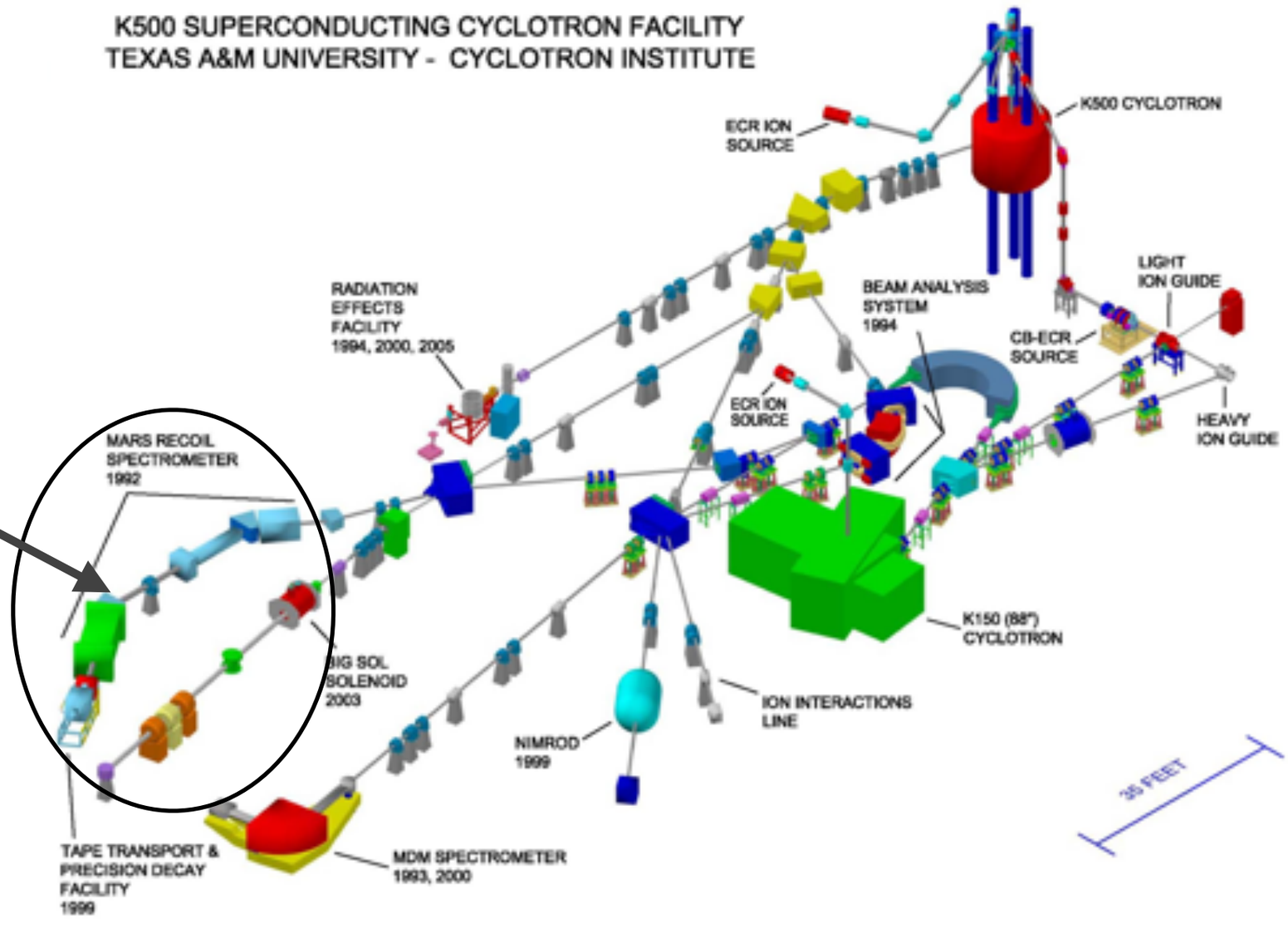


R-Matrix fit of the angular distribution for the ^{6}He+ α scattering at 6.0 MeV c.m. energy.

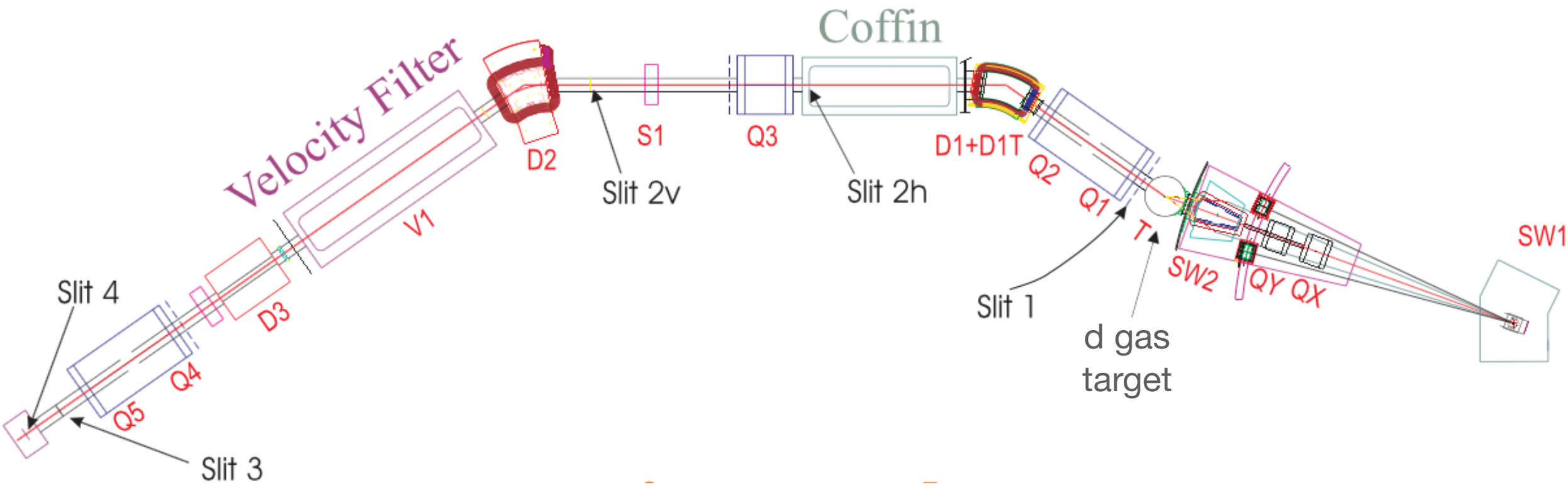
Setup

Our experiment was performed at the Cyclotron Institute at TAMU

MARS
(Momentum Achromat Recoil Spectrometer) beam line



Setup



^{6}He beam create from ^{7}Li through

d(^{7}Li, ^{6}He) ^{3}He

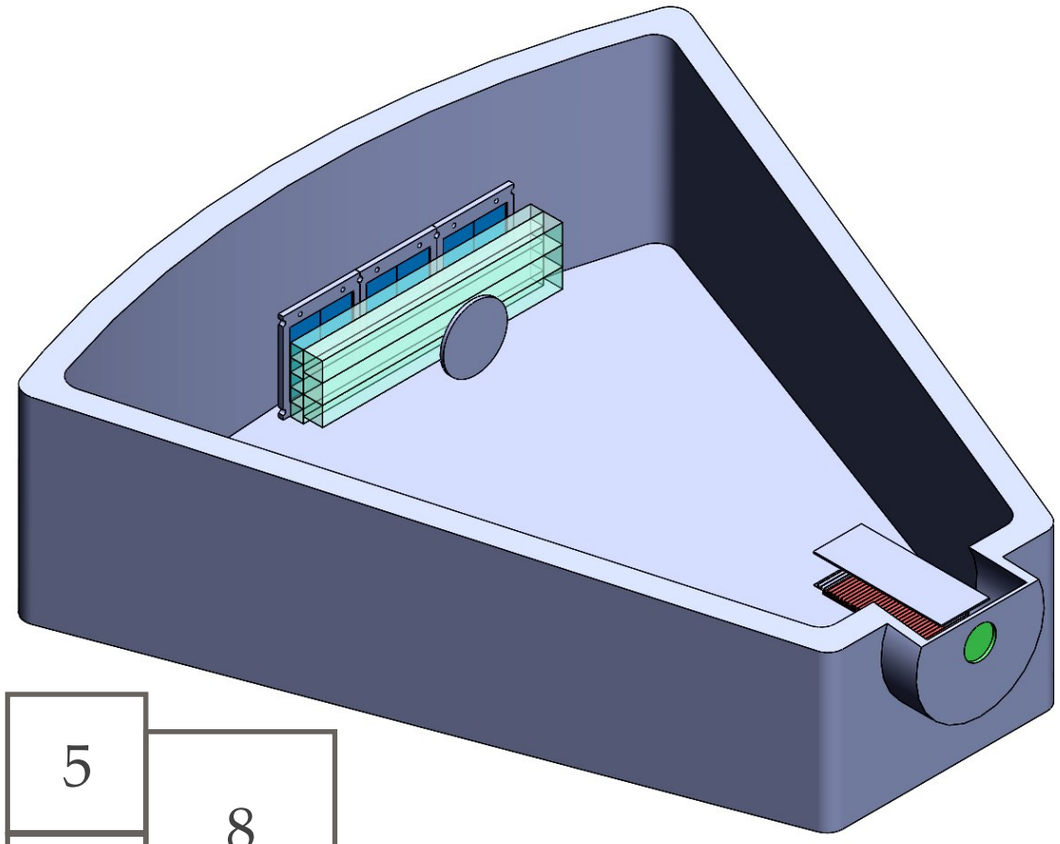
End Result: **^{6}He at 6 MeV/u**

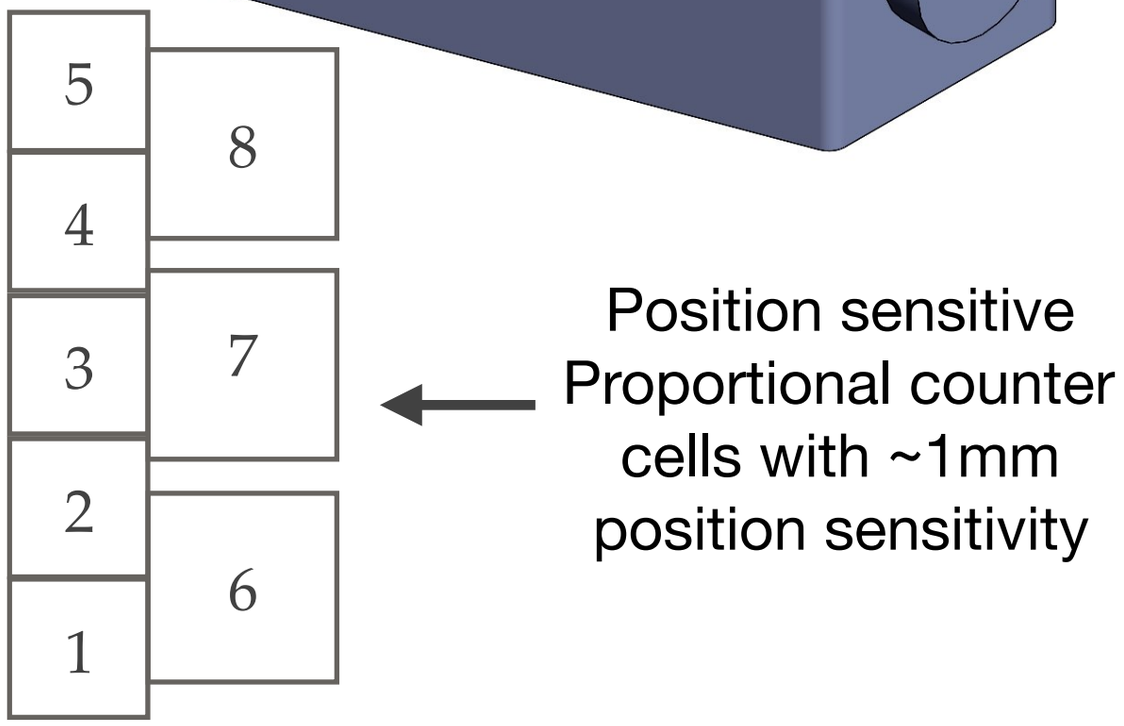
Setup

- **Beam**: ^{6}He
- **Intensity**: ~10^{4}
- **Beam Energy**: 36 MeV
- **Beam Energy in chamber**: 22 MeV
- **Target**: ^{4}He
- **Gas Mixture**: ^{4}He + CO_2 (96:4)
- **Pressure**: 1700 Torr and 1000 Torr
- **Alpha Energy Range**: 6 MeV_{cm} ->13.5 MeV (for alphas)

Setup

- **3 forward Silicon detectors:** Measure the total energy of the recoil alphas
- **8 position sensitive proportional counter cells**: energy loss (particle ID), position and scattering angle reconstruction.
  - Removable “**lollipop**”: Avoid permanently damaging the Silicon detectors and saturating the DAQ.
- **Scintillator** in place before the entrance of the reaction chamber.
- **Windowless ionization chamber** at the entrance of the chamber.





Setup

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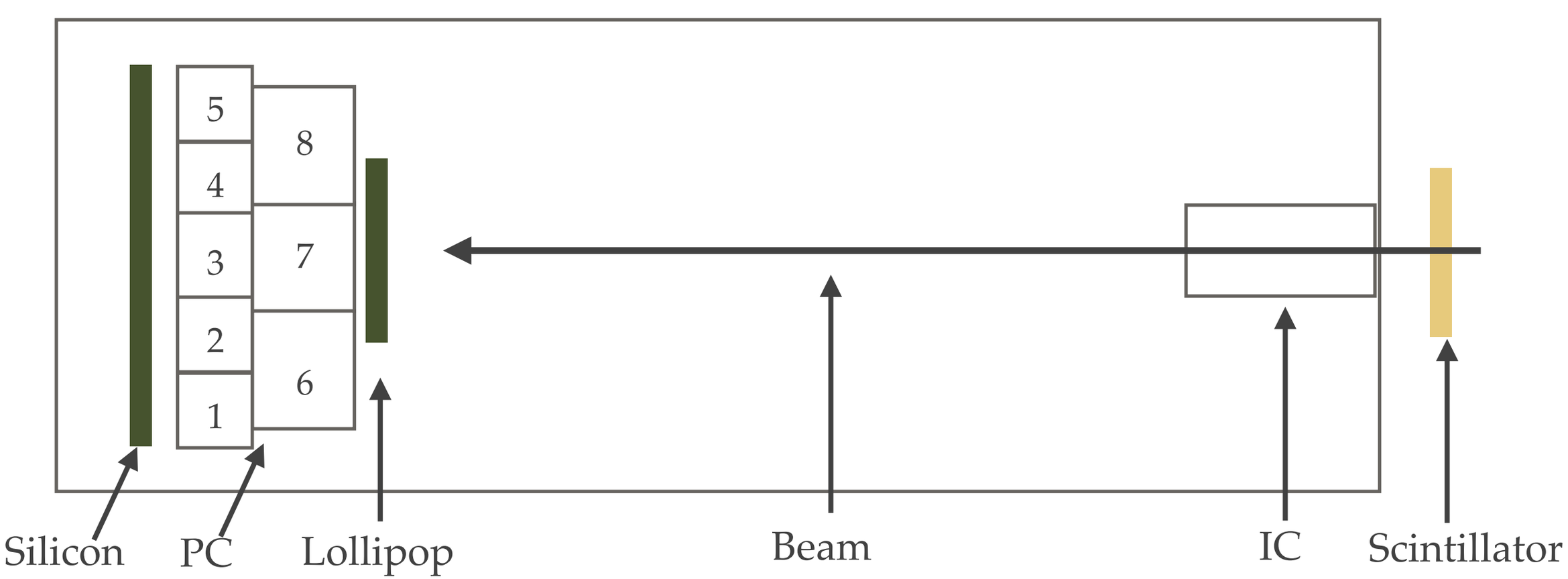

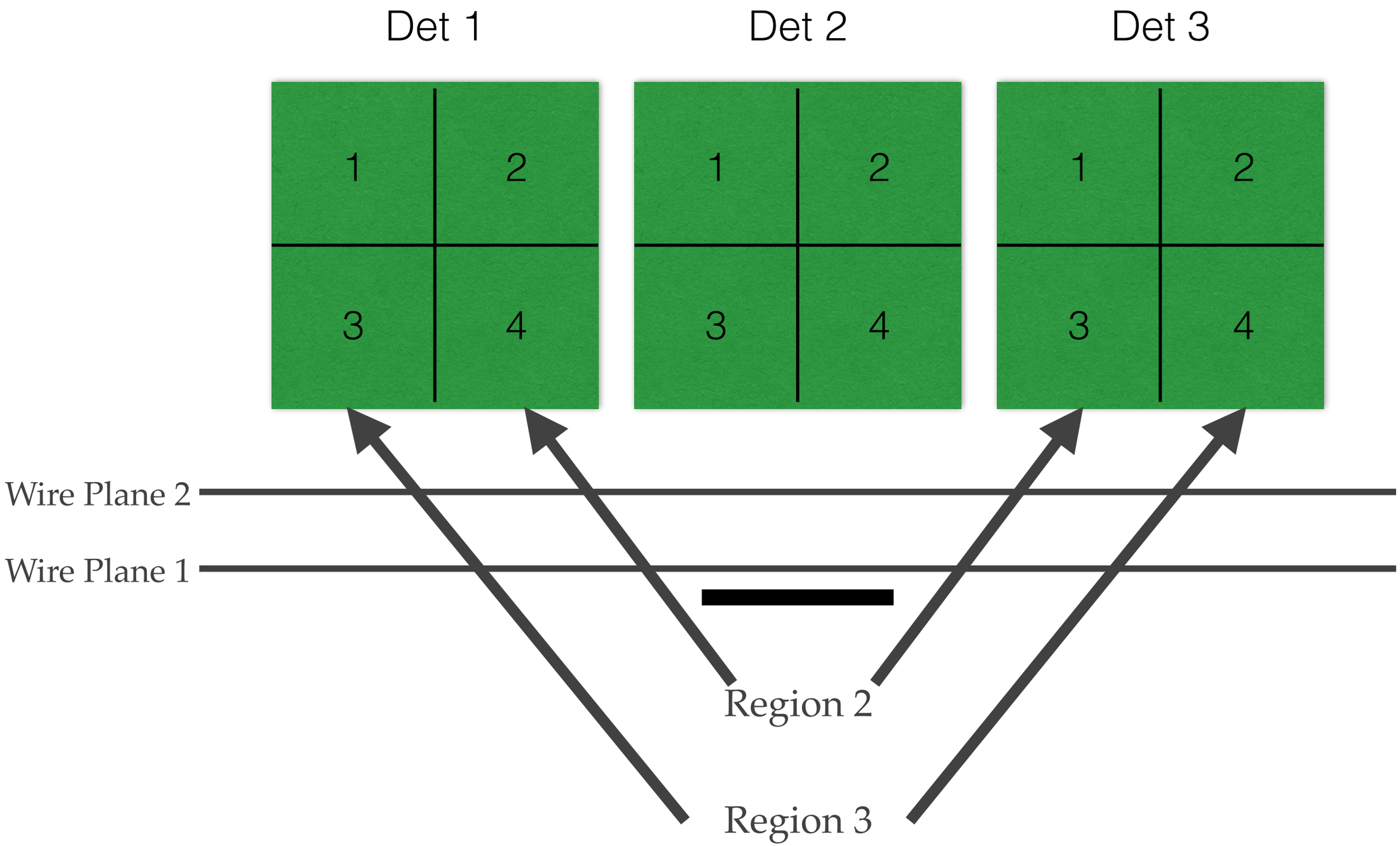
Det 1
Det 2
Det 3
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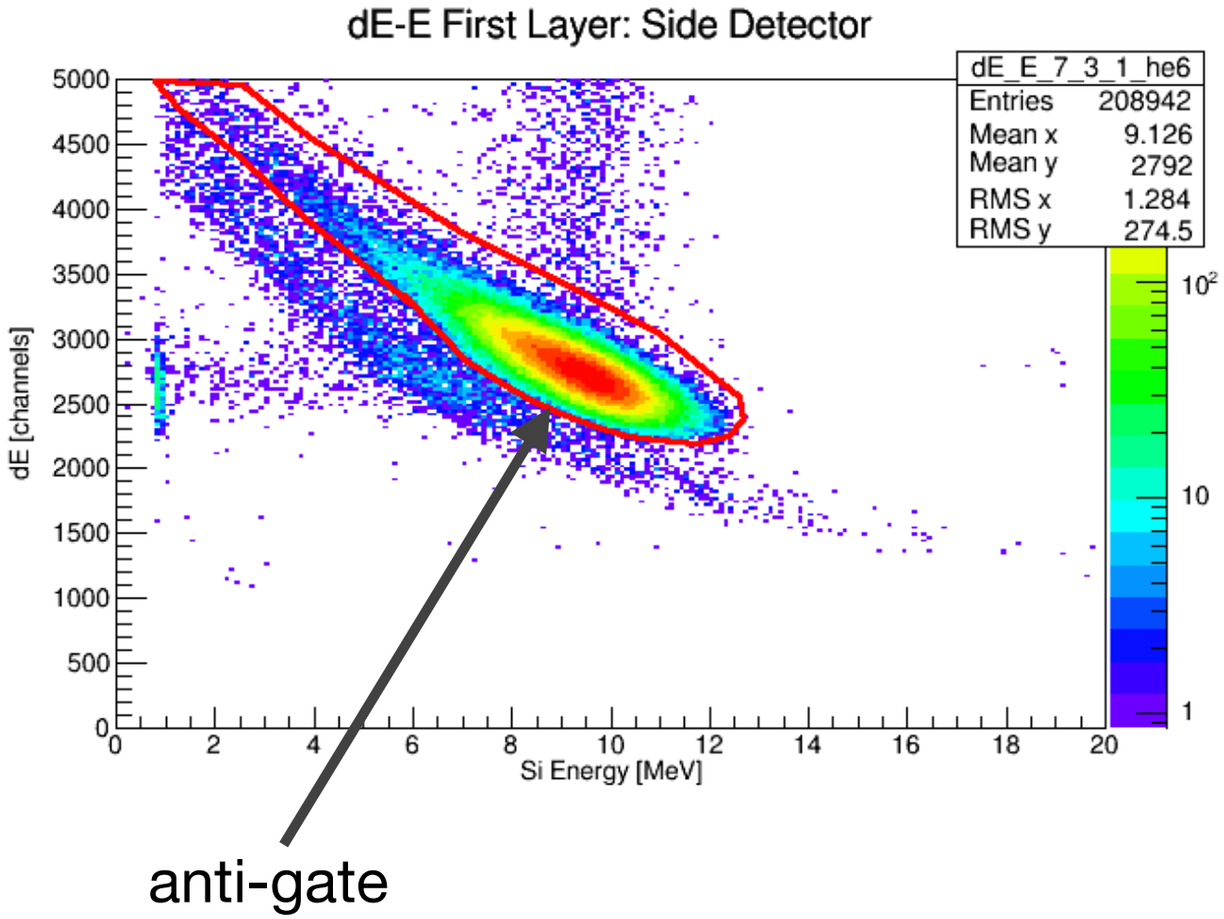
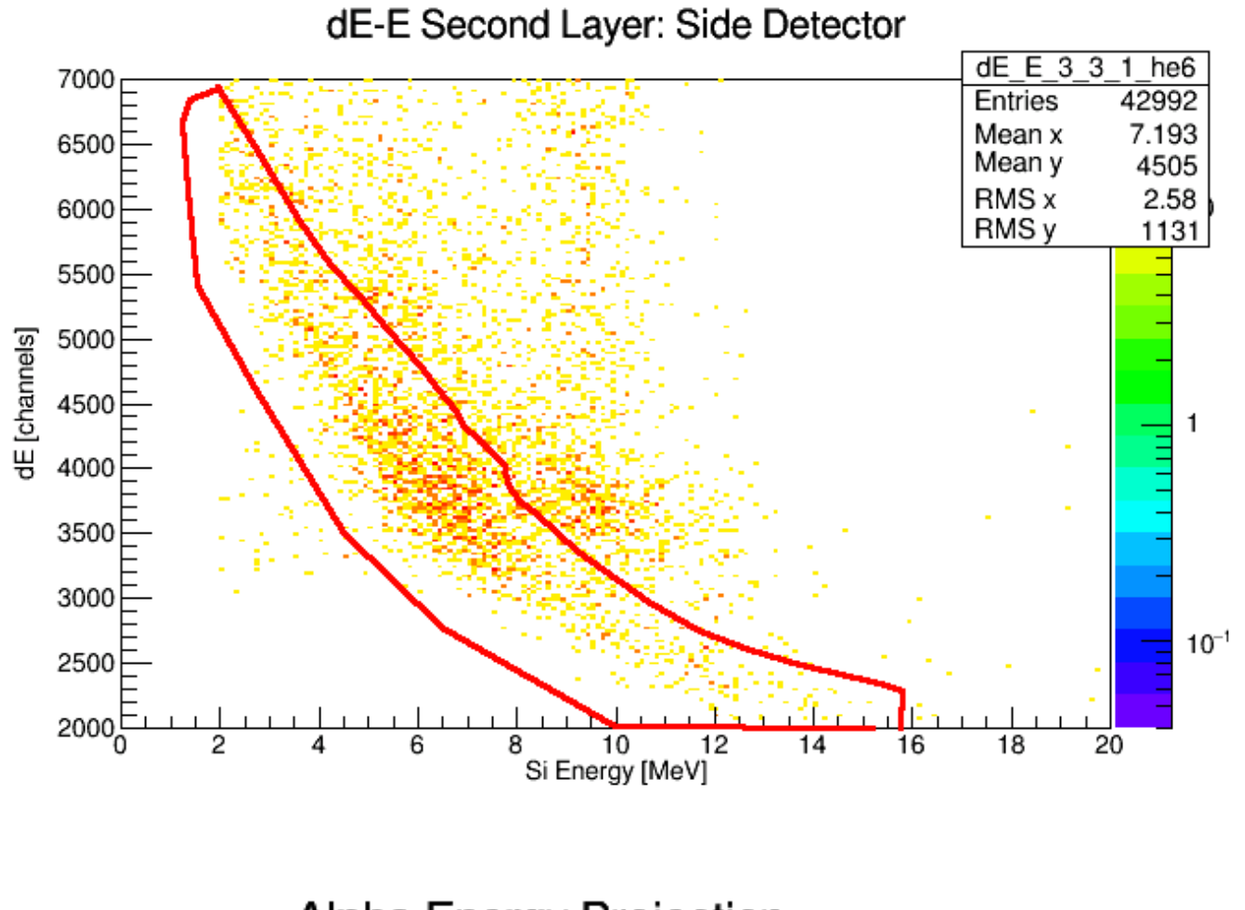
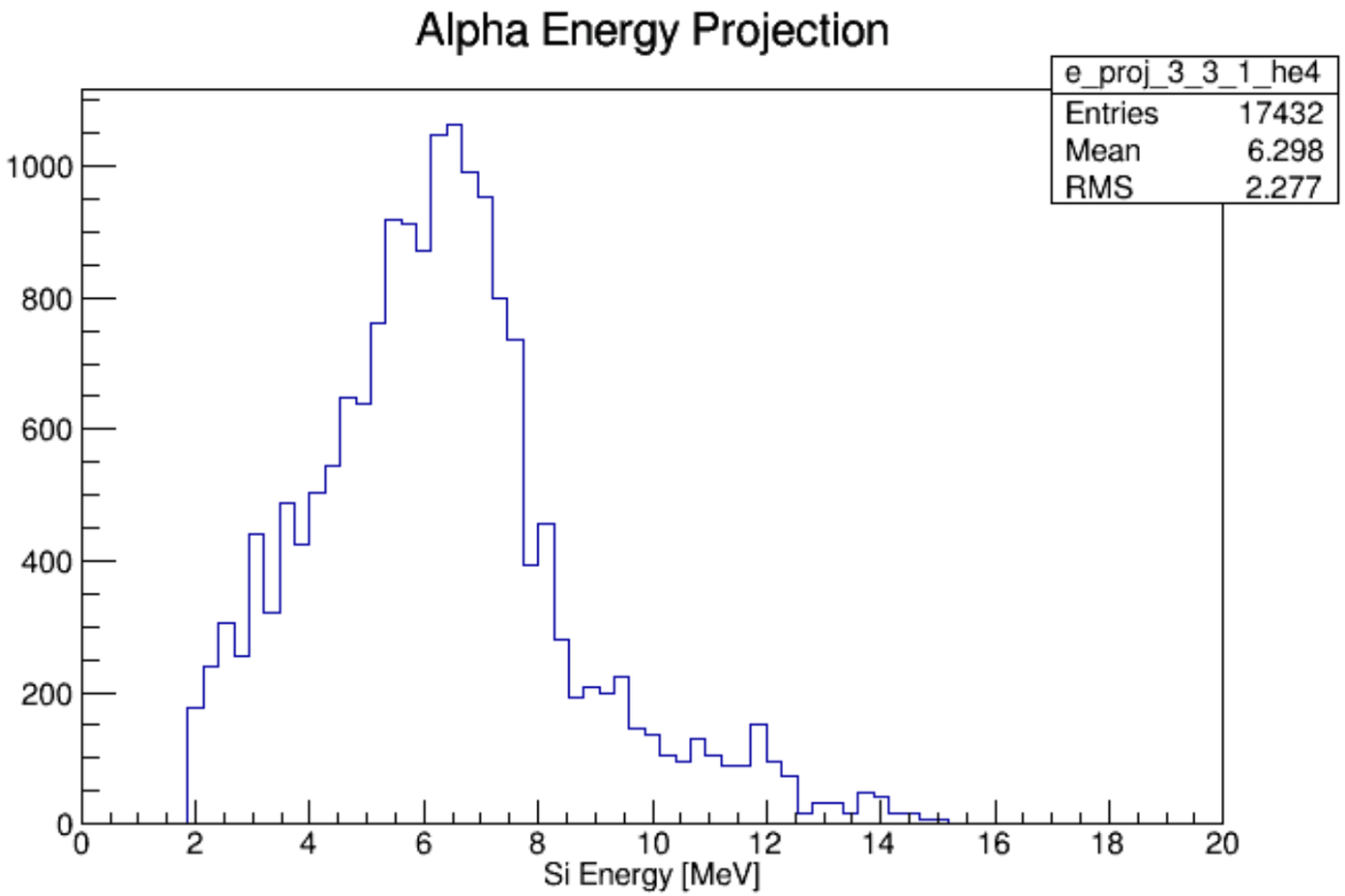
Wire Plane 2
Wire Plane 1
Region 2
Region 3



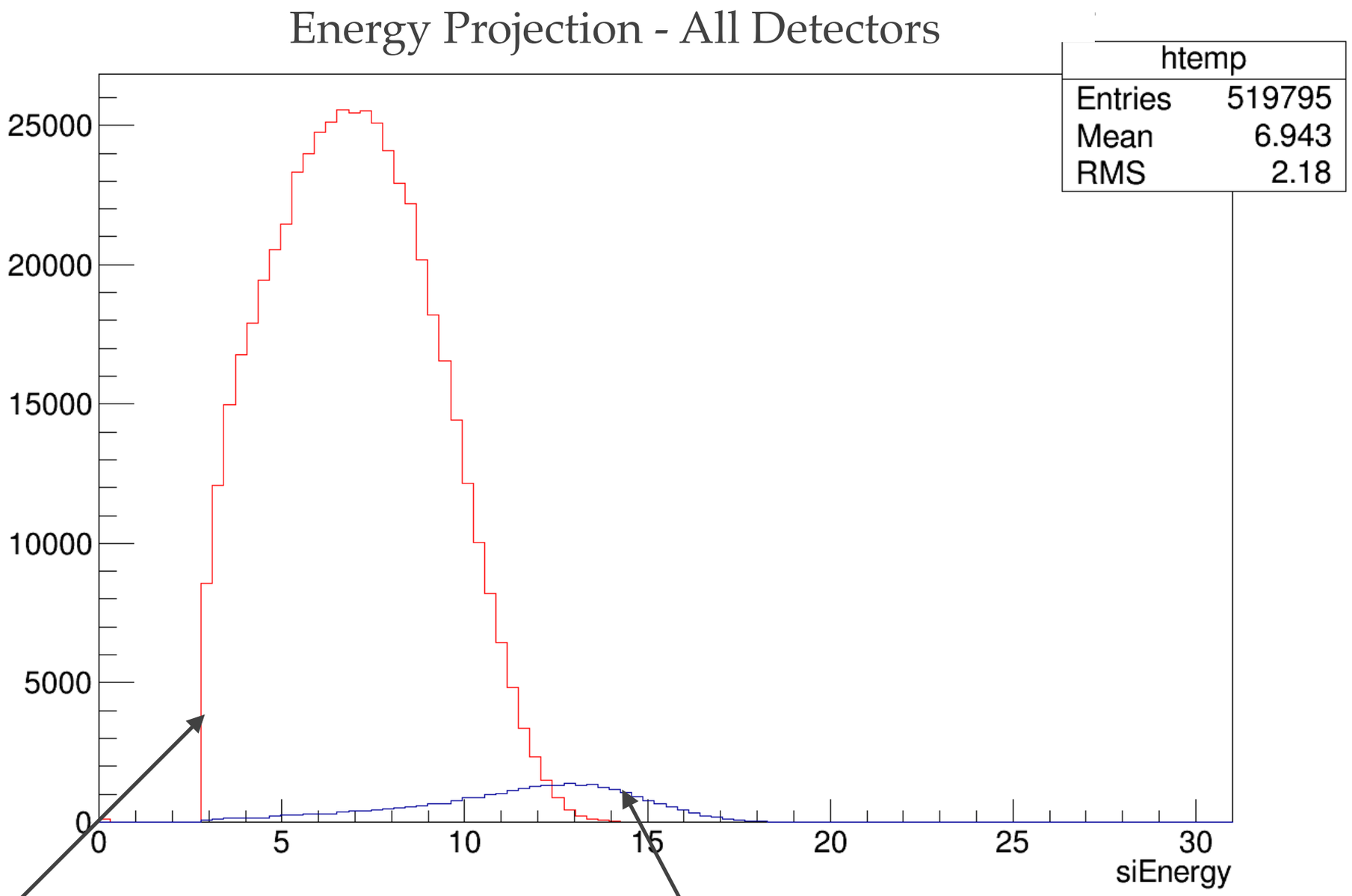
anti-gate
on ^{6}He



- The α particles were identified using the two layers of the proportional counter cells.



GEANT4 Simulation



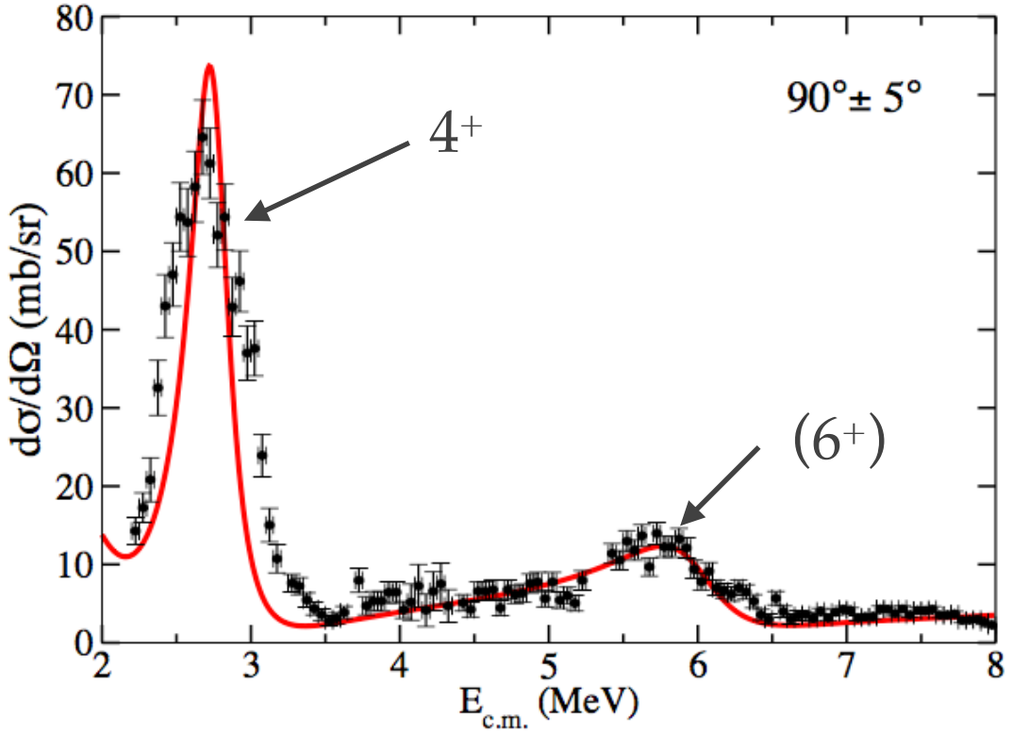
α from $^{6}He^{*}$ Break-up

2^{+} @ 1.8 MeV

α from inelastic scattering

Results

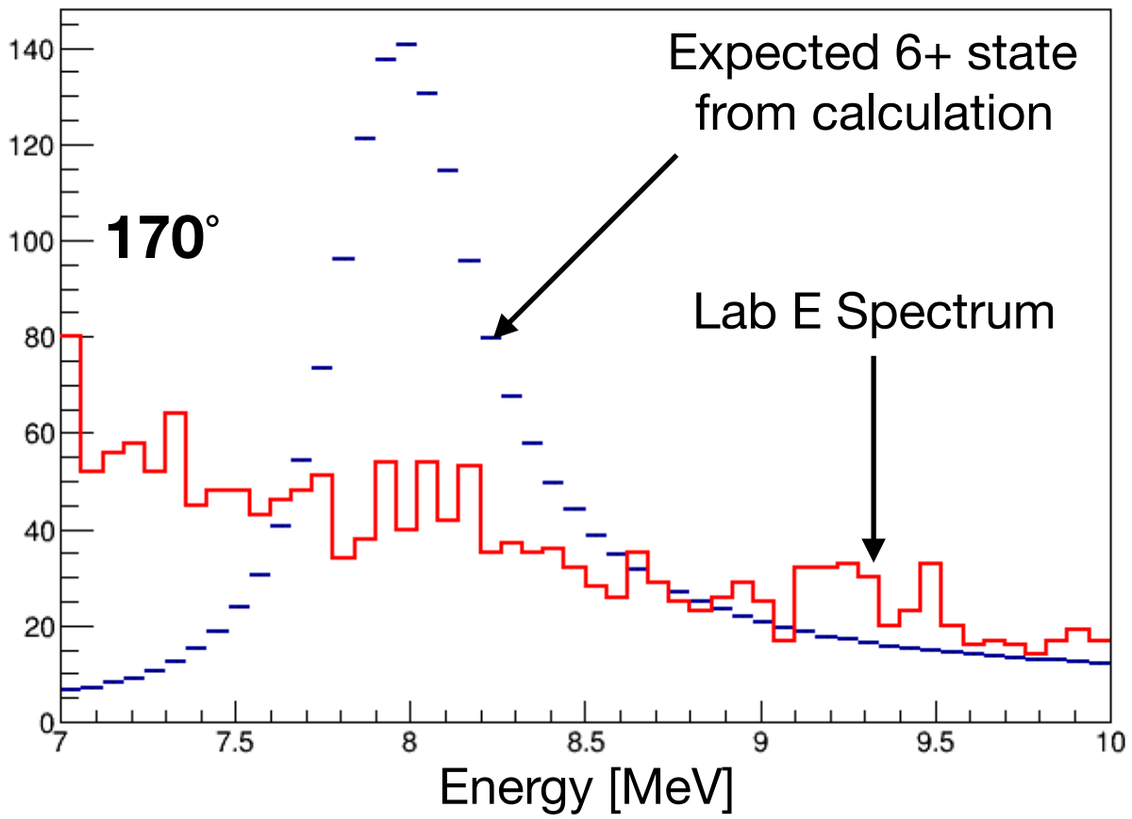
- We see a peak at lower energies (from ^{6}He break-up).
- This peak is not where we expect to see it (~8 MeV).
- At higher energies (areas of interest for 6^{+}), our spectrum is clean, and populated by elastic scattering



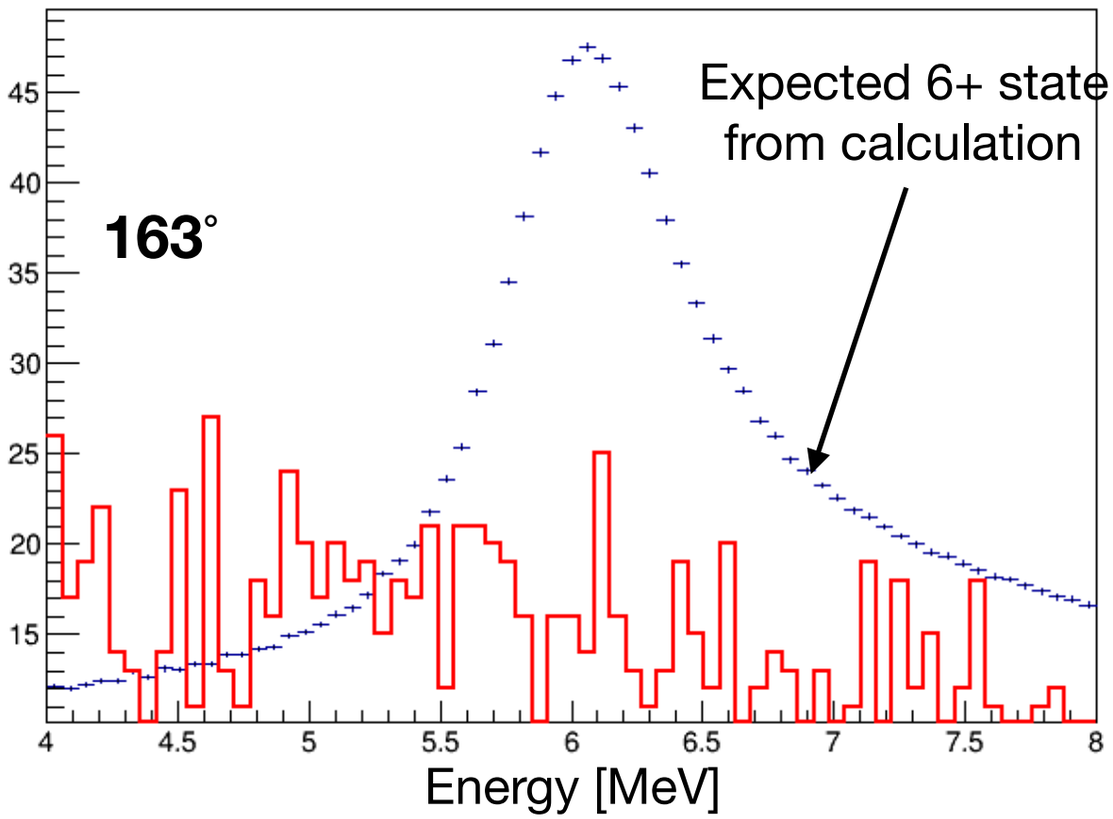
There is no indication for a resonance-like structure in our spectrum at the expected energy.

Our results cast significant doubts on the validity of the algebraic model predictions

Lab Energy Spectrum Region 2



Lab Energy Spectrum Region 3



Summary

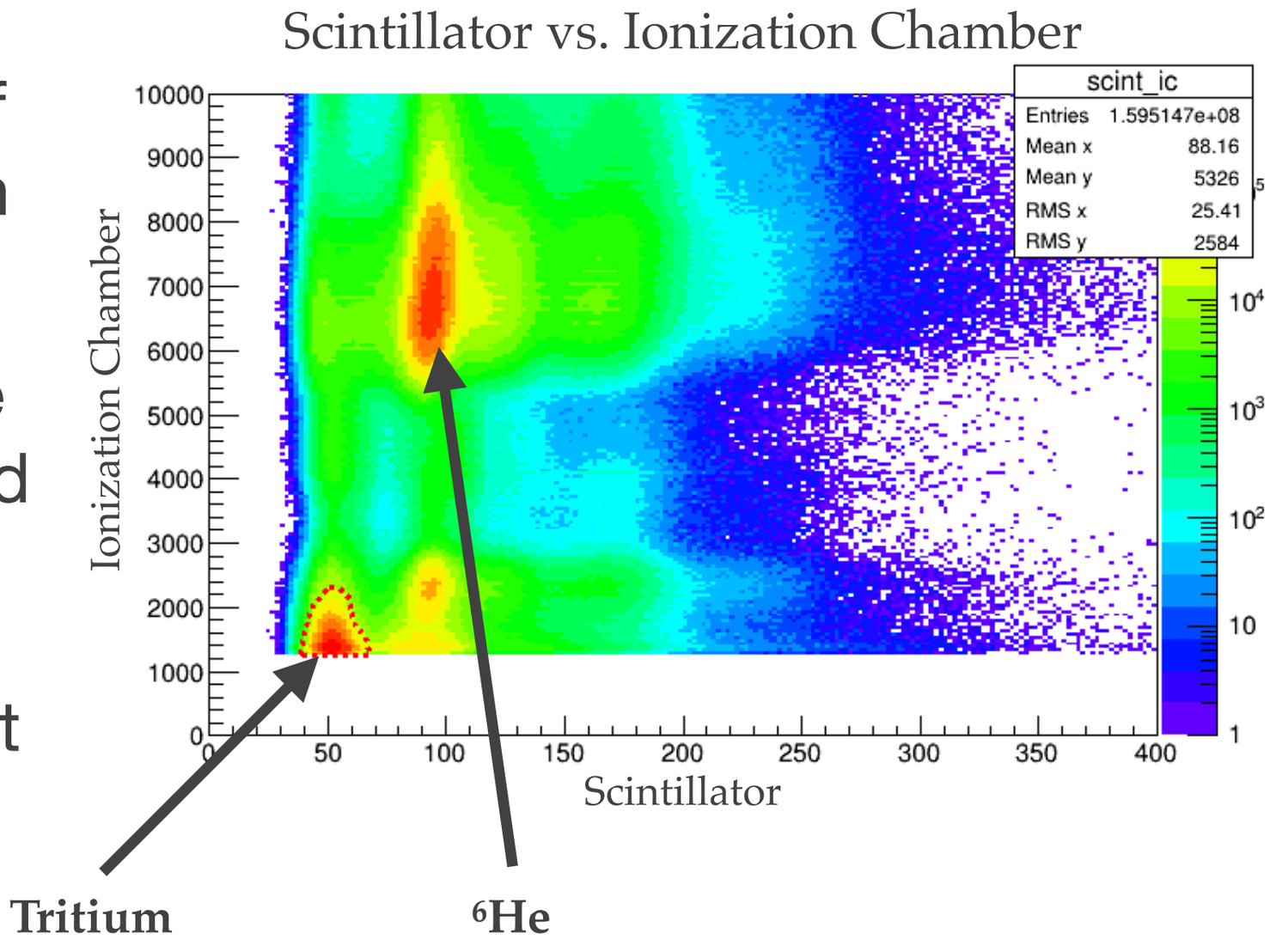
- The scattering of ^{6}He + α was measured over a few angles close to 180^{0} c.m. to probe the 6^{+} state of the highly deformed cluster band in ^{10}Be.
- If the bump observed by [Kuchera, (2013)] corresponds to 6^{+} in ^{10}Be at 13.5 MeV excitation energy, then, the blue curve (on the previous slide) would represent the expected counts at the angle relevant for this spectrum. (~170 & 163 degrees).
- **There is no high spin, highly clustered, narrow state which has a significant reduced width for $^{6}He_{(gs)}$ + α channel**

Acknowledgements

- G. Rogachev
- E. Koschiy
- E. Uberseder
- V. Z. Goldberg
- J. Hooker
- H. Jayatissa
- C. Hunt
- Cyclotron Staff

Setup

- Considerable amount of **tritium** contamination in the beam: Same A:Z
- We were able to use the **ionization chamber** and the **scintillator** to exclude the contaminants and select the ^{6}He.



Results

- We see a peak at lower energies (from ^{6}He break-up).
- This peak is not where we expect to see it (~8 MeV).

Silicon energy spectrum of alphas measured at 1700 torr.
We expected to see a strong peak at ~9-10 MeV that corresponds to the 6^{+} state.