

Missing-mass spectroscopy of $^{10}\text{C}(\alpha, \alpha')$ with the MAIKo active target

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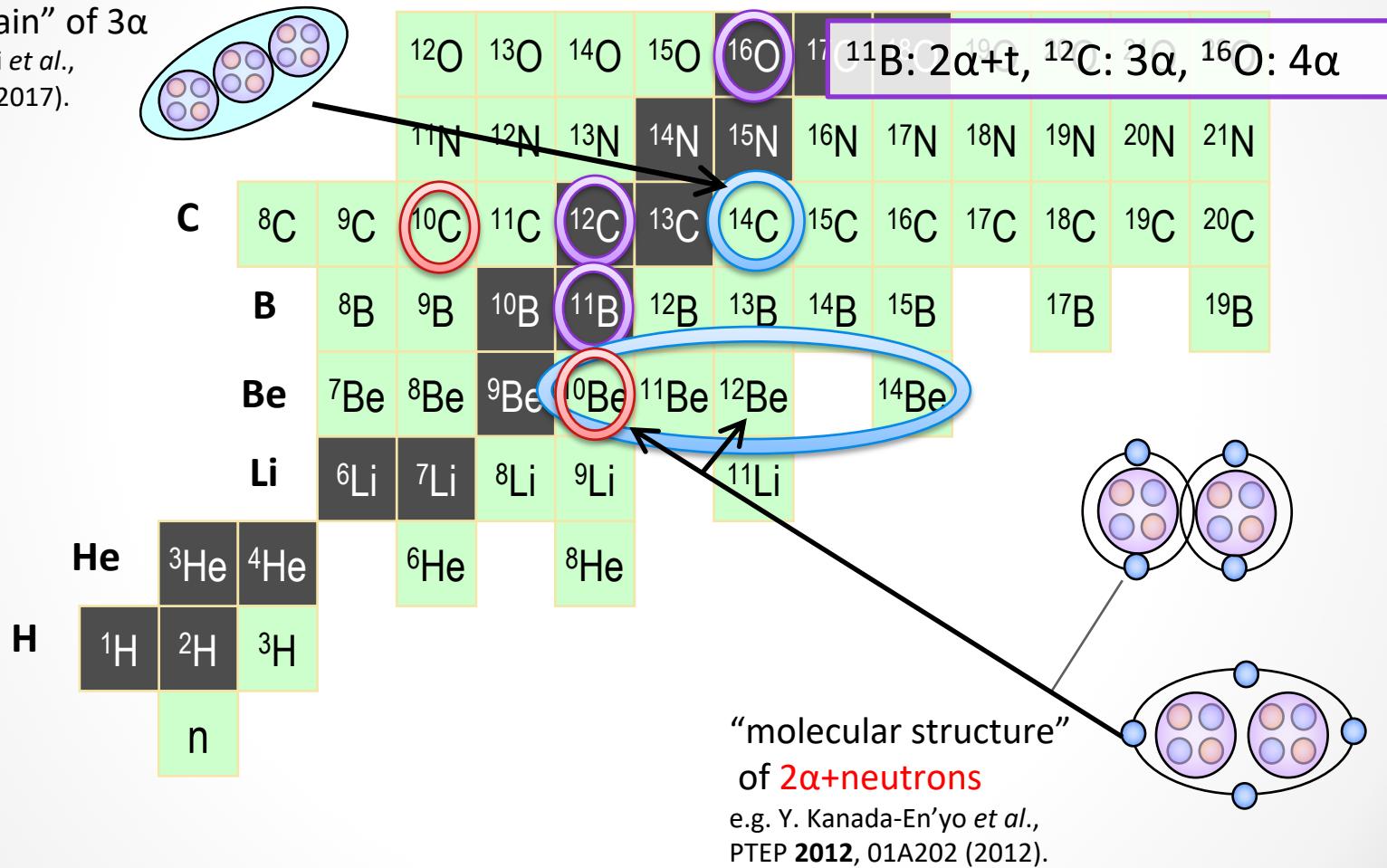
Cluster structures in unstable nuclei

α clustering is an important aspect of atomic nuclei.

"linear chain" of 3α

H. Yamaguchi *et al.*,

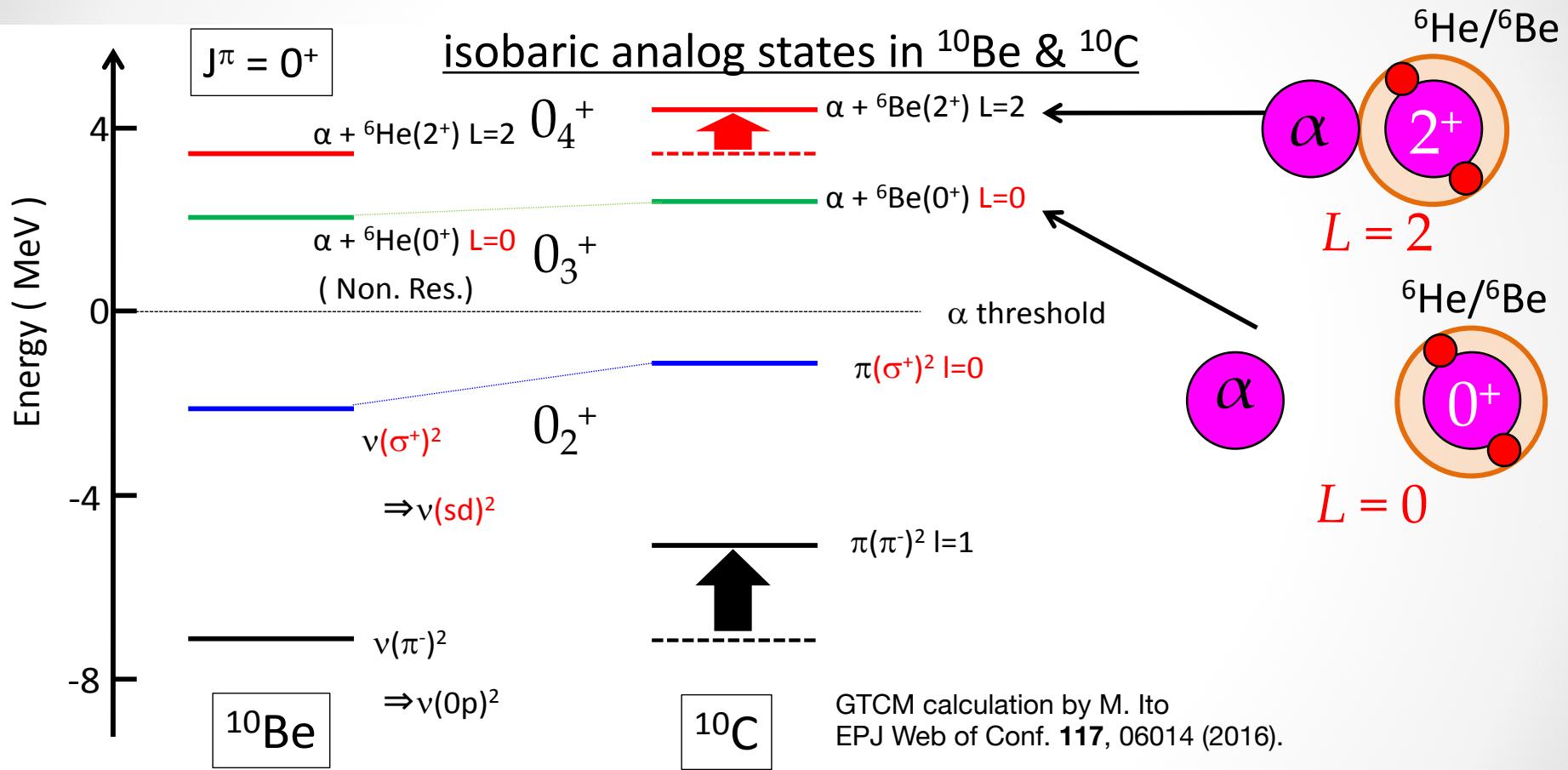
PLB **776**, 11 (2017).



We propose a search for α cluster structures in ^{10}C (mirror of ^{10}Be).

The mirror system of ^{10}C - ^{10}Be

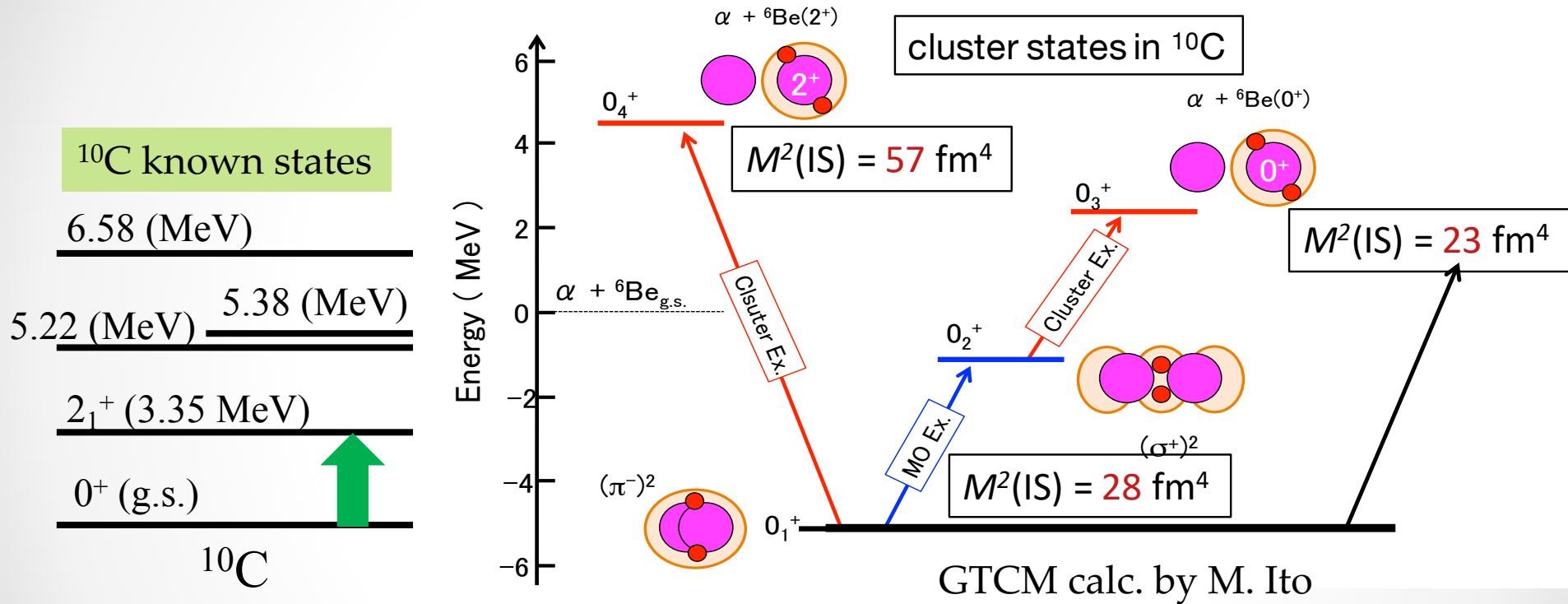
The mirror system will give a new approach to α clusters.



- Energy shift will be observed in 0_4^+ states ($\alpha + {}^6\text{He}/{}^6\text{Be}$ with $L=2$).
 \rightarrow *Thomas-Ehrman shift (TES)* of “cluster structures”
- The T-E shift **unveil the inner structures of the clusters**.

Measurement on ^{10}C

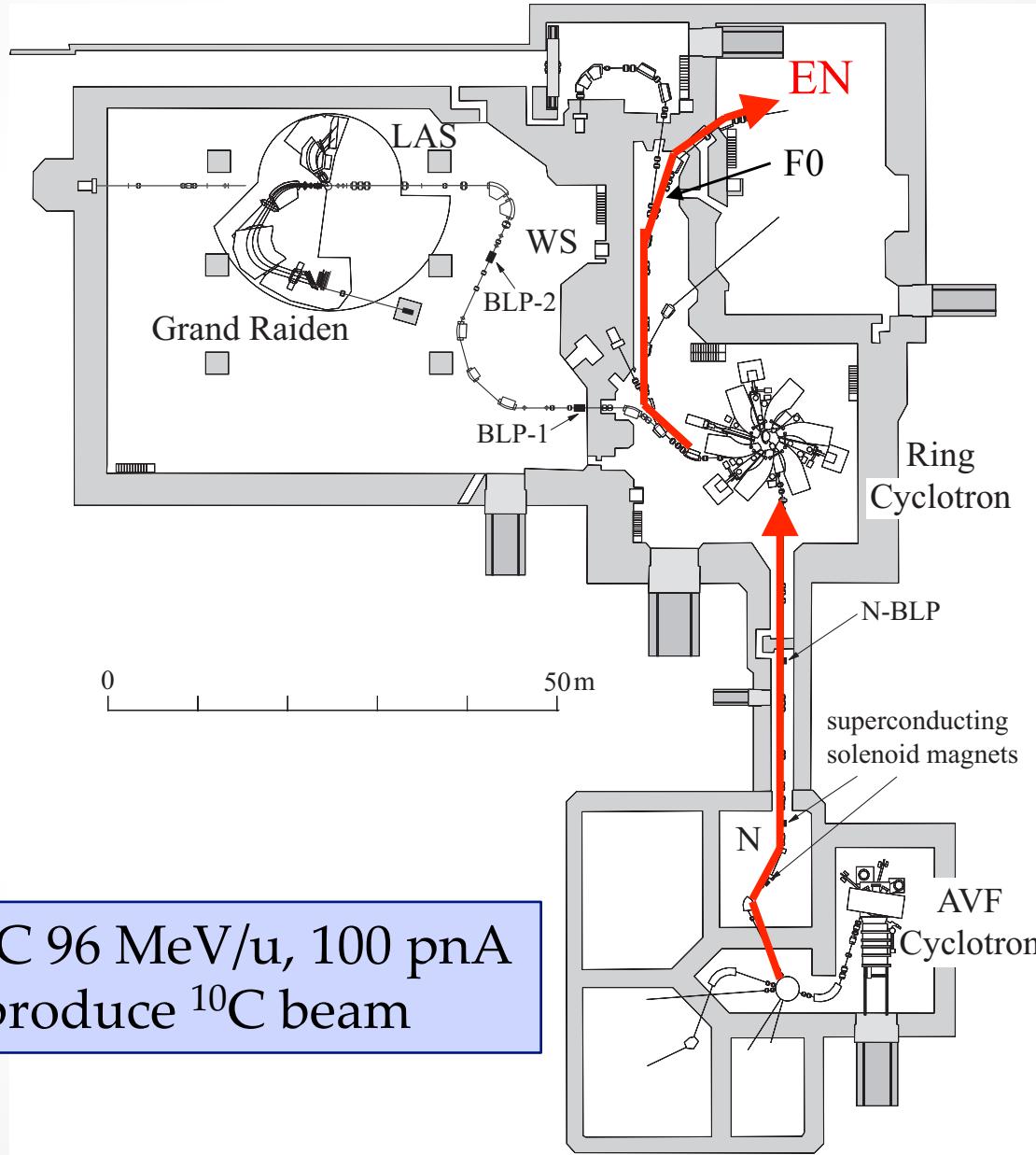
Measurement on ^{10}C was performed in 2017.



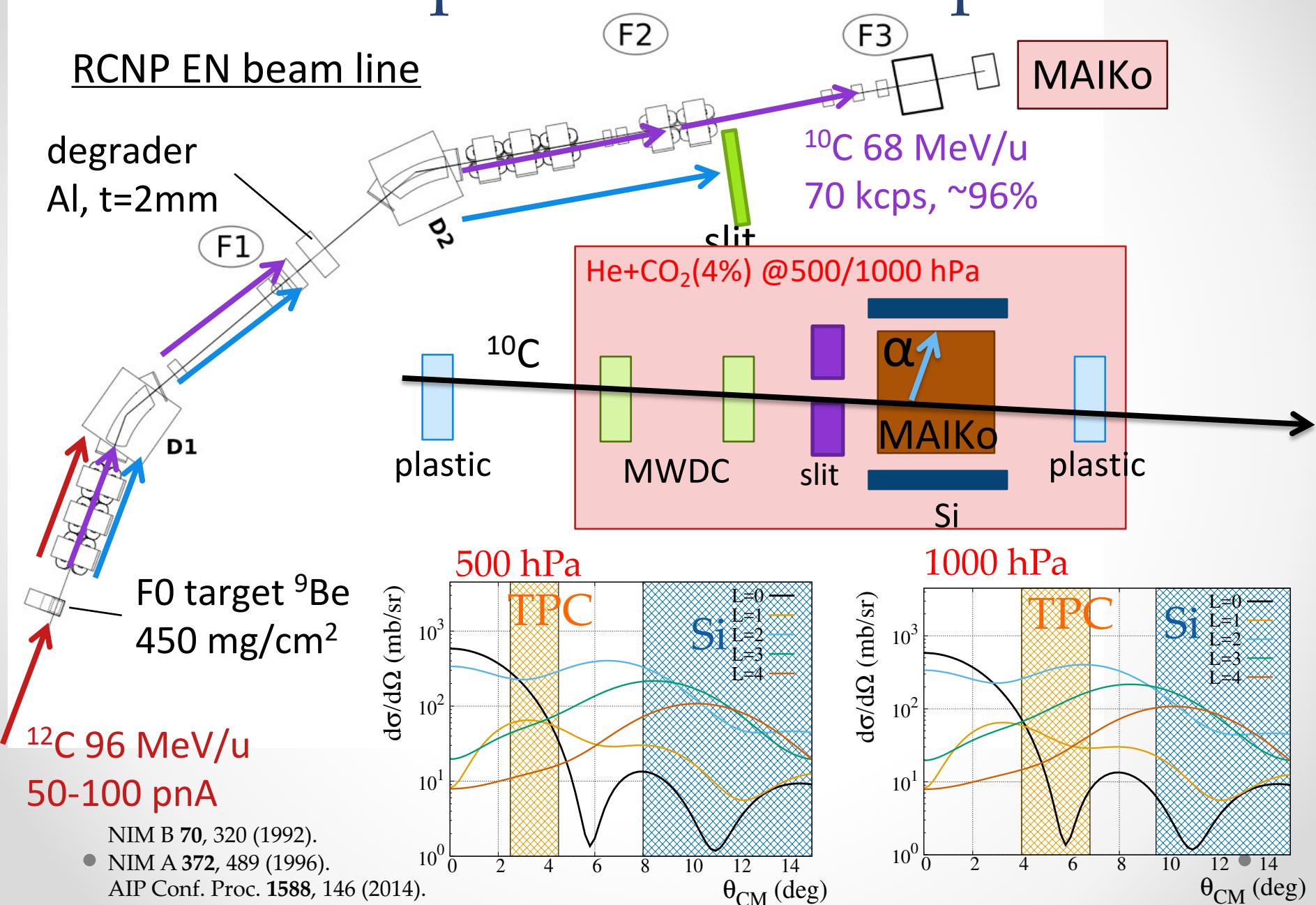
Purposes of the experiment

- ✓ Search for α cluster states above particle decay threshold.
- ✓ α inelastic scattering on ^{10}C at 68 MeV/u

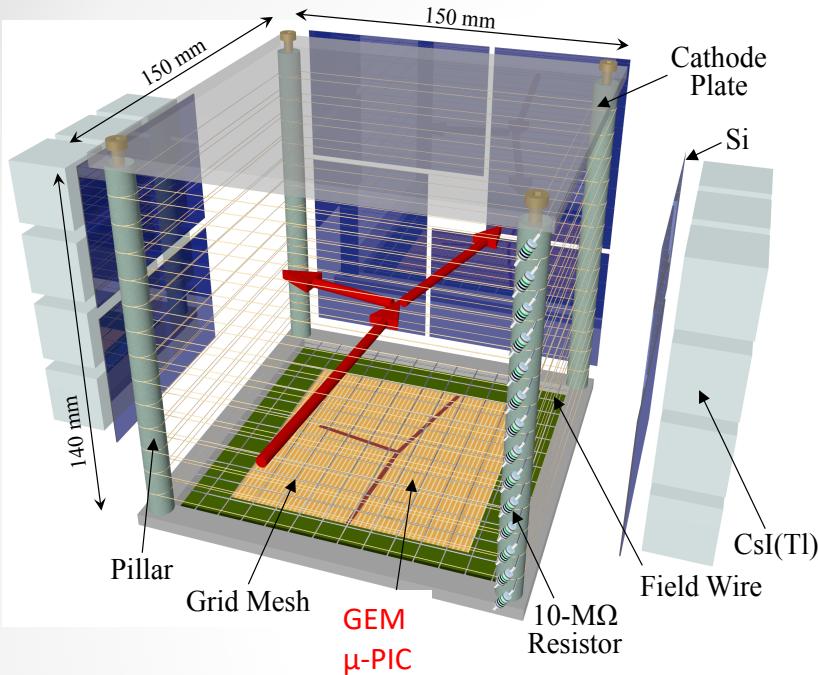
Experiment at RCNP



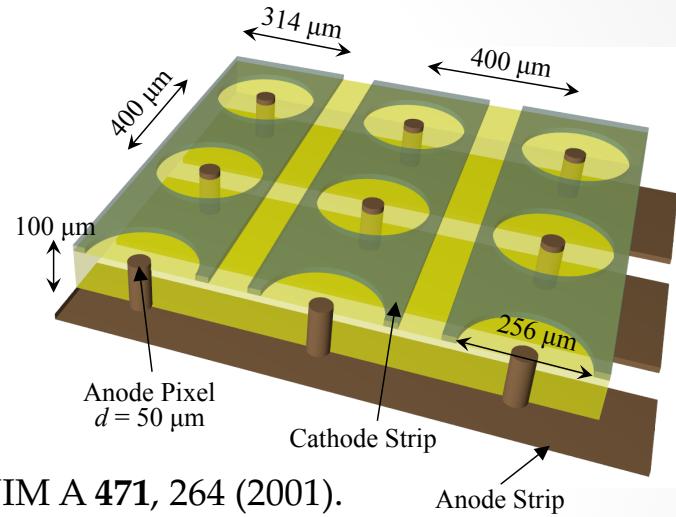
Experimental Setup



MAIKo Active Target



μ-PIC for amplification and readout

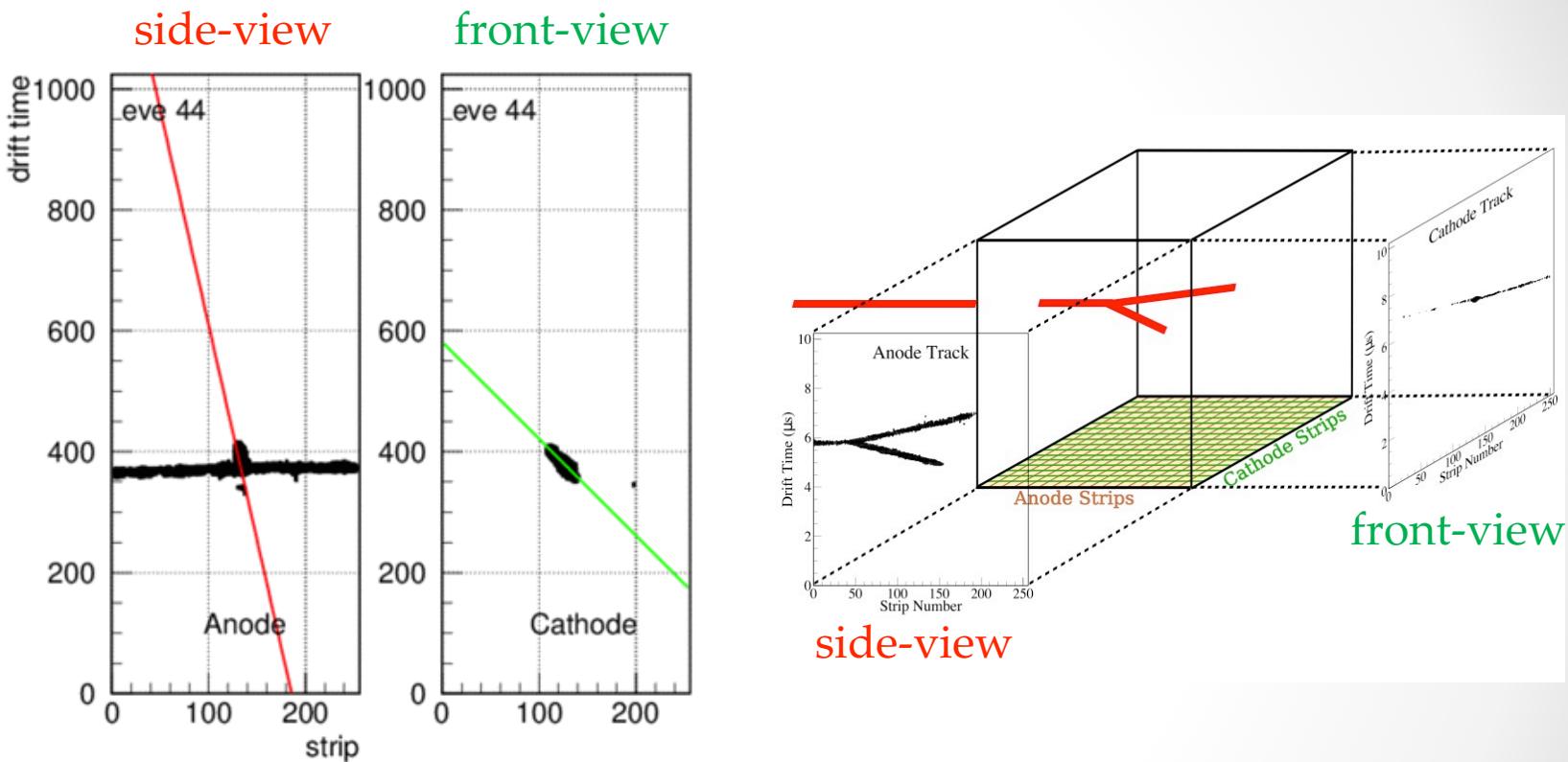


NIM A 471, 264 (2001).

NIM A 908, 215 (2018).

- ◆ TPC gas: He + CO₂(4%) at 0.5 – 2.0 atm
- ◆ μ-PIC + GEM amplification
 - μ-PIC (gain~1000): 2 dimensional strip readout (400 μm pitch).
256A+256C = 512 ch.
 - GEM (gain~30): 140 μm pitch, d=70 μm, t=100 μm (thick GEM)
- ◆ TPC track → θ_α, range in the gas / Si+CsI → E_α

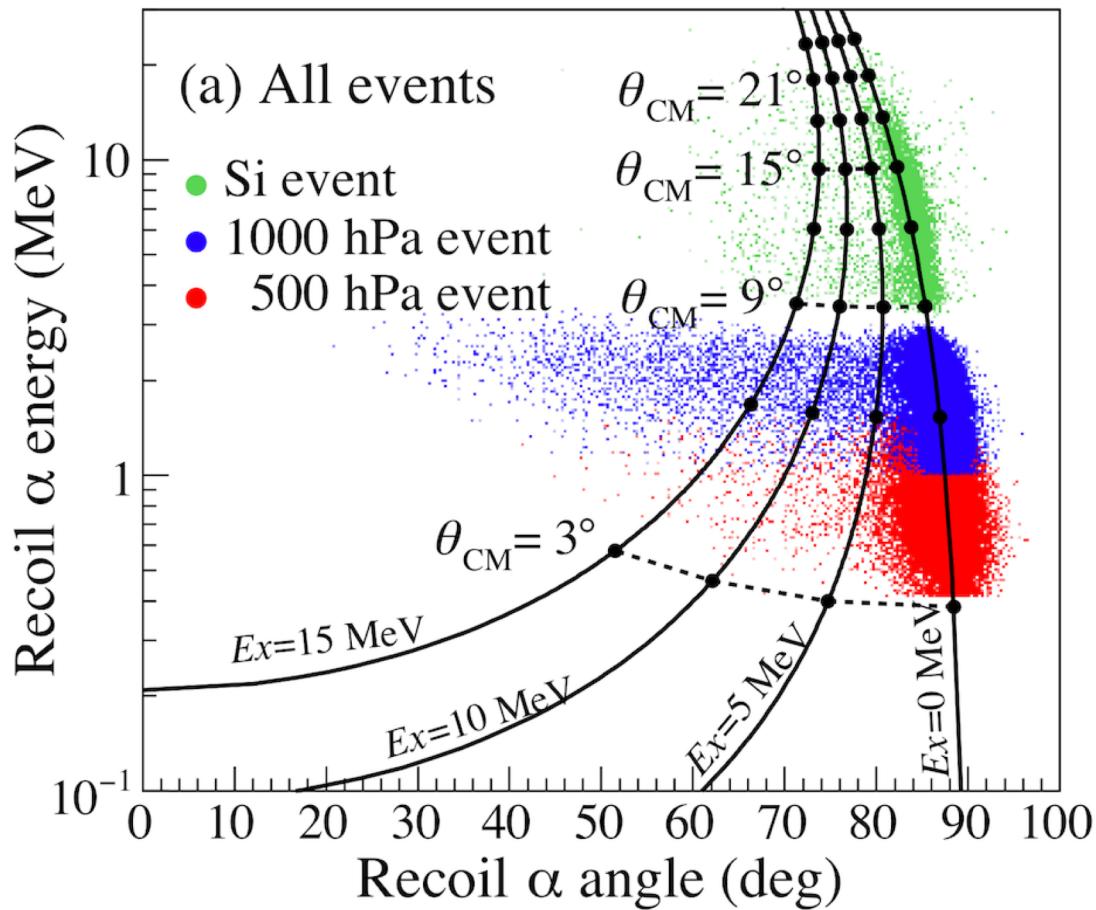
Track Examples



Reconstruct θ_{LAB} and E_α of recoil α particles
to get the ^{10}C excitation energy and θ_{CM} .

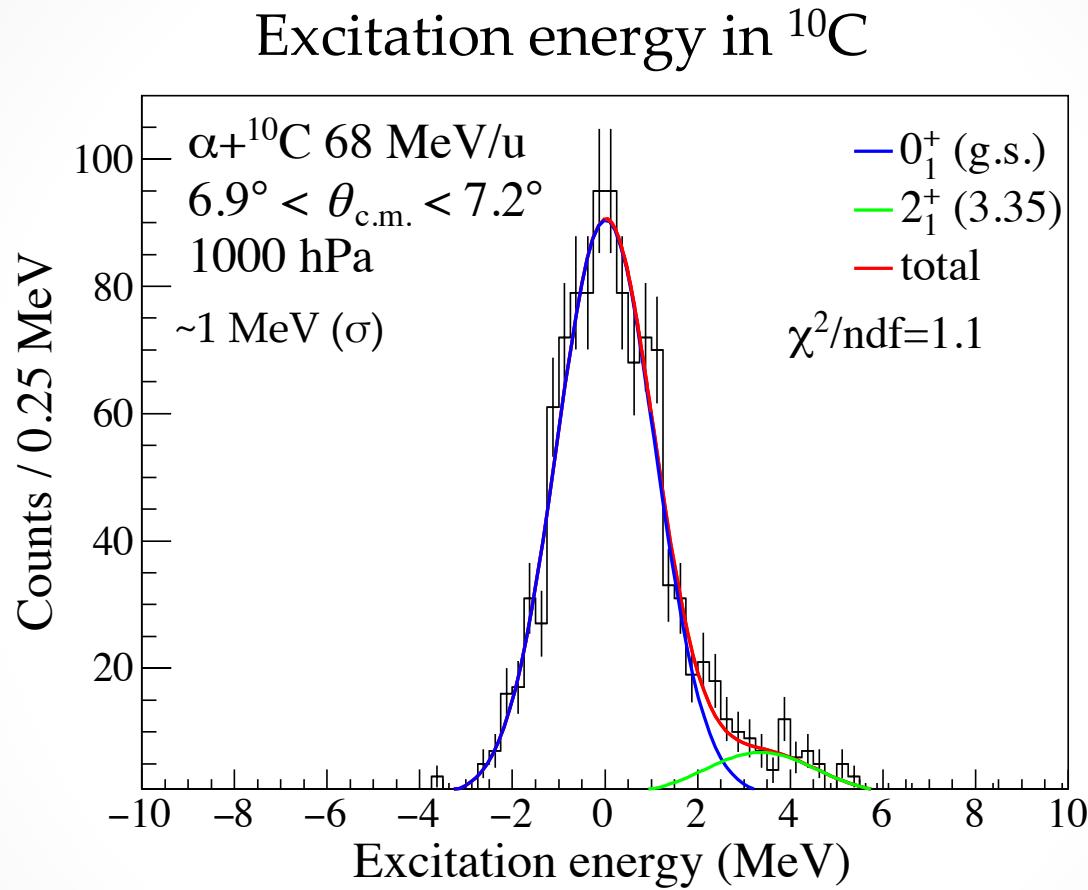
Results

Kinematic plot of recoil α



- Detection threshold down to 500 keV.
- Elastic scattering is dominant.

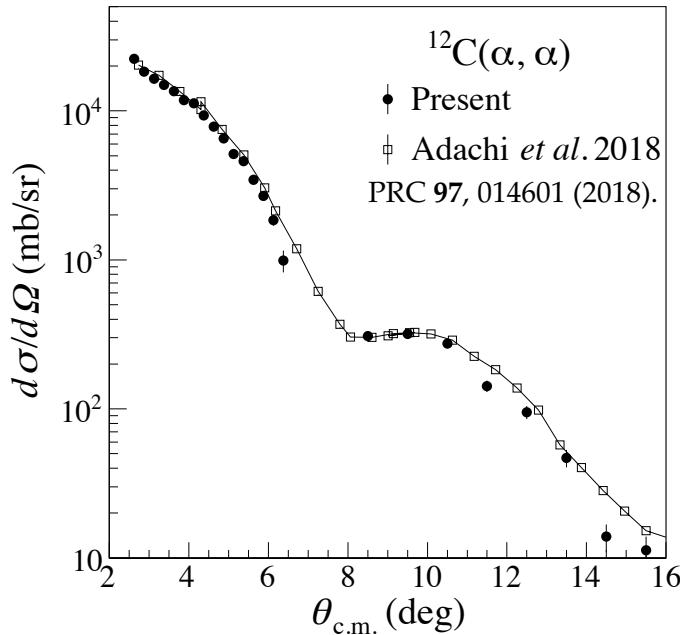
Results



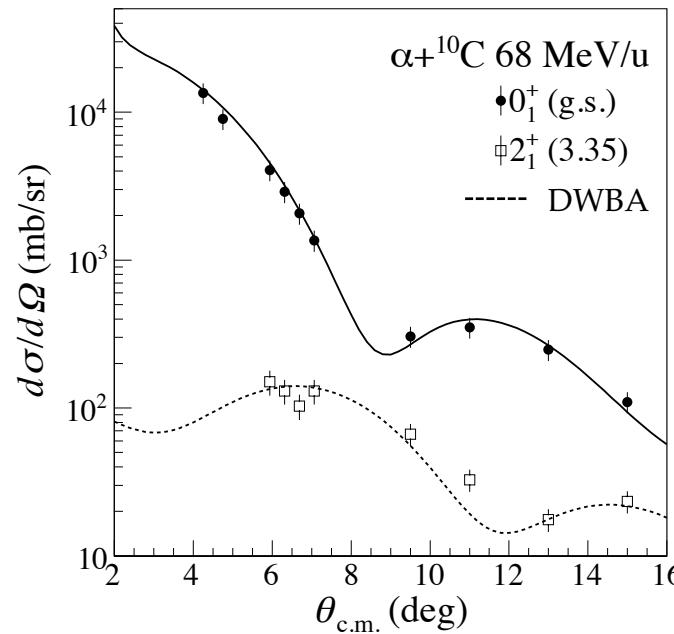
Obtained the 0_1^+ and 2_1^+ yields.

Cross Sections for Low E_χ

$^{12}\text{C} + \alpha$



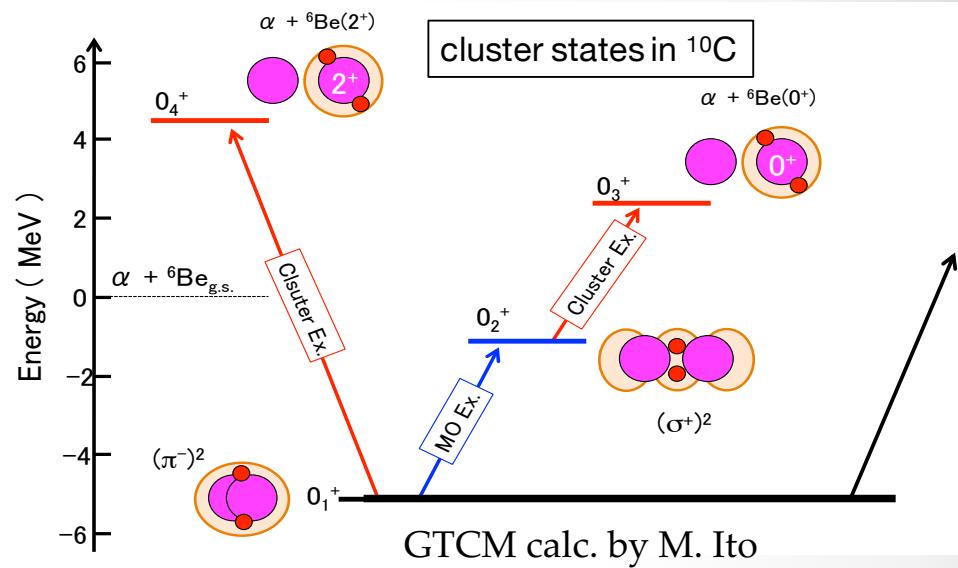
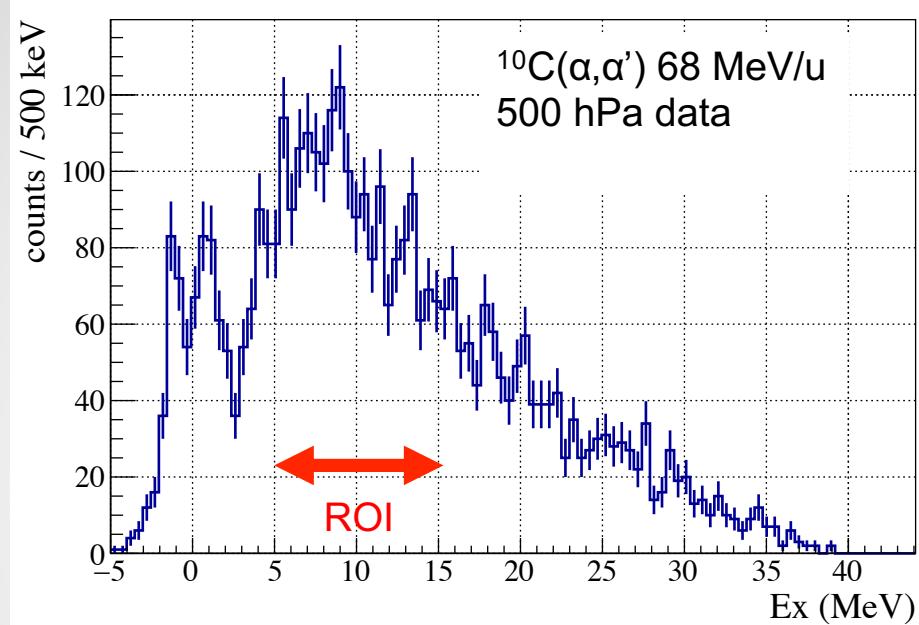
$^{10}\text{C} + \alpha$



- $^{12}\text{C} + \alpha \rightarrow$ Consistent with the previous result
 - ✓ MAIKo measurement is reliable.
- $^{10}\text{C} + \alpha$ elastic and inelastic
 - ✓ Elastic \rightarrow Effective α -N interaction, density distribution
 - ✓ Inelastic \rightarrow Neutron transition matrix element M_n

First paper from MAIKo!! T. F. *et al.*, PRC **100**, 054322 (2019).

High E_x spectrum



To assign the J^π , multi-pole decomposition analysis (MDA) is required.

- ✓ Divide the E_x spectrum into different θ_{CM} .
- ✓ Compare $d\sigma/d\Omega$ with the DWBA calculations.

The statistics might not be sufficient for MDA...

Upgrade of MAIKo

The MAIKo TPC will be enlarged: $10 \times 10 \times 15 \text{ cm}^3 \rightarrow 30 \times 30 \times 30 \text{ cm}^3$

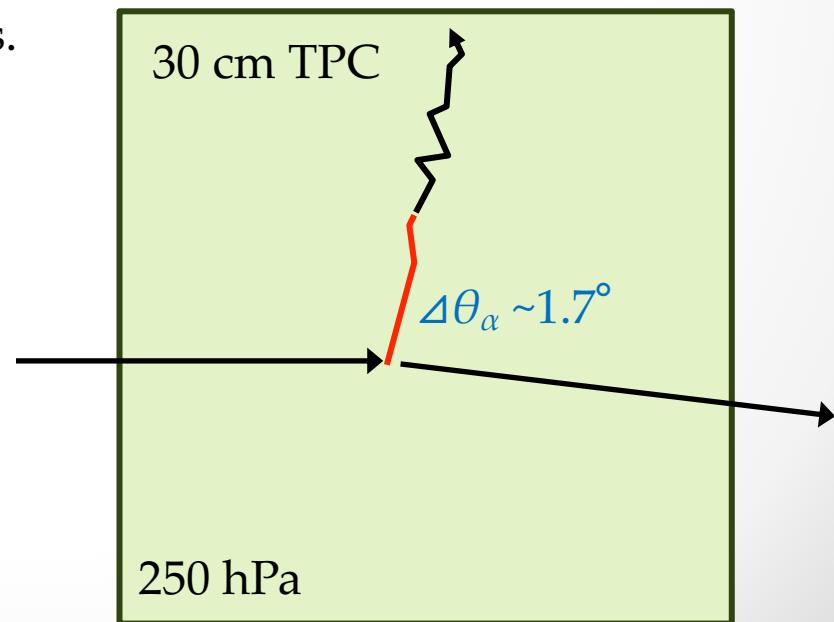
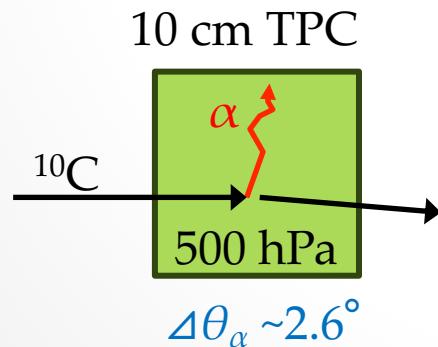
Total statistics: $\times 10$

- ✓ Target thickness: $\times 3$
- ✓ Recoil α acceptance: $\times 3$

Better Ex resolution can be achieved with lower gas pressure operation.

$\Delta Ex \sim 1 \text{ MeV}$ is dominated by angular straggling of α in the TPC gas.

- ✓ range of 1 MeV α : 50 mm



Summary

- Energy shift between mirror system reflects cluster structures.
- Measurement of $^{10}\text{C}(\alpha, \alpha')$ was performed at RCNP.
 - ✓ Missing mass spectroscopy at forward θ_{CM} with MAIKo.
 - ✓ Detection threshold down to 0.5 MeV.
- Elastic scattering and inelastic scattering to 2_1^+ state.
 - ✓ Effective interaction, density distribution
 - ✓ Transition matrix element [PRC 100, 054322 (2019)]
- High Ex spectrum → Search for α clustering. Analysis is on going.
- Active target is useful for missing mass spectroscopy.
- MAIKo is now under upgrade
 - for x10 statistics and better Ex resolution.
- Future measurement at SAMURAI
 - ✓ Missing mass with MAIKo + decay measurement