

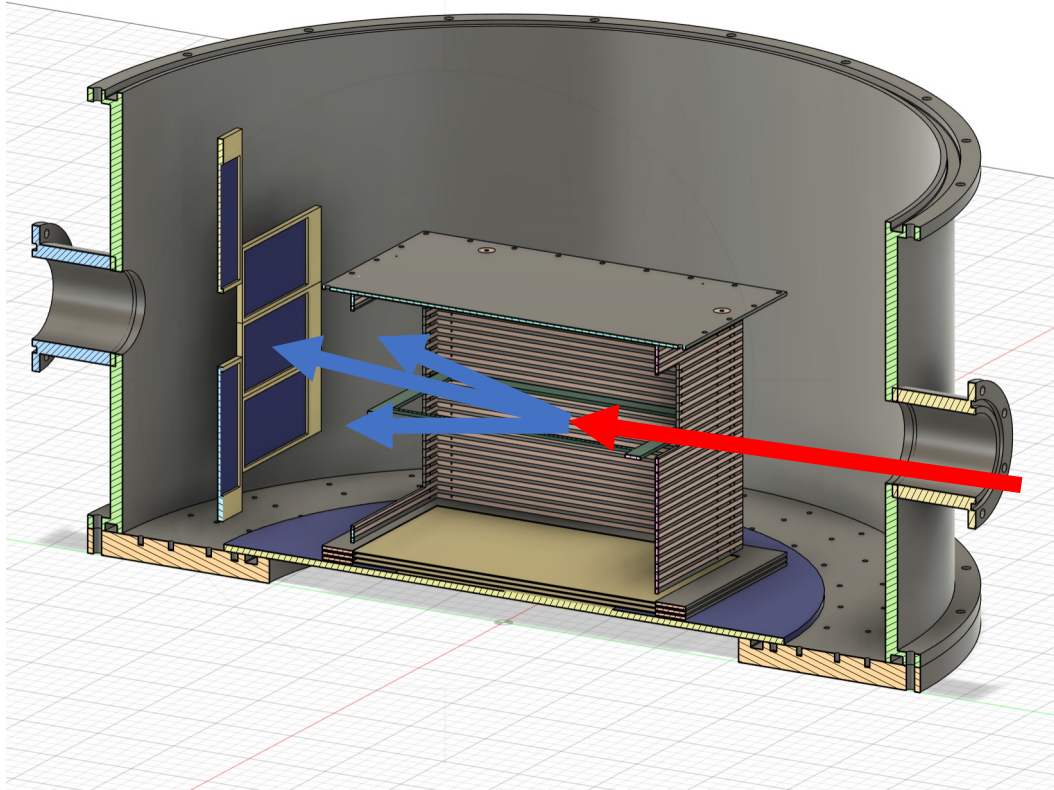
Study of alpha cluster with TPC-Drum

The 4th Korea-China workshop

08/July/2025

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TPC-Drum



- **TPC-Drum:**

- 8 Si detectors

- 768 channels

- Triple GEM stacking

- Gating-Grid in beam-line

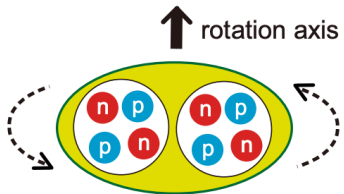
- He4 + CO2 mixture gas (650Torr)

- We aim to study the alpha cluster with hoyle state using TPC-Drum

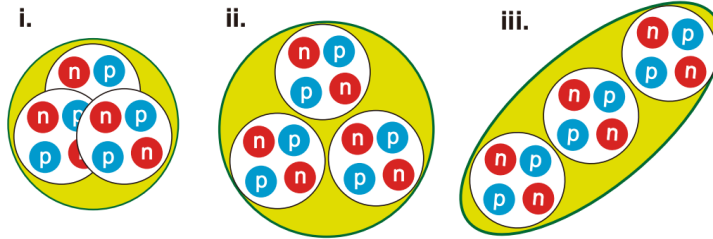
Alpha cluster in ^{12}C

- Alpha cluster structure in nucleus

b. Cluster model for Be-8 nucleus

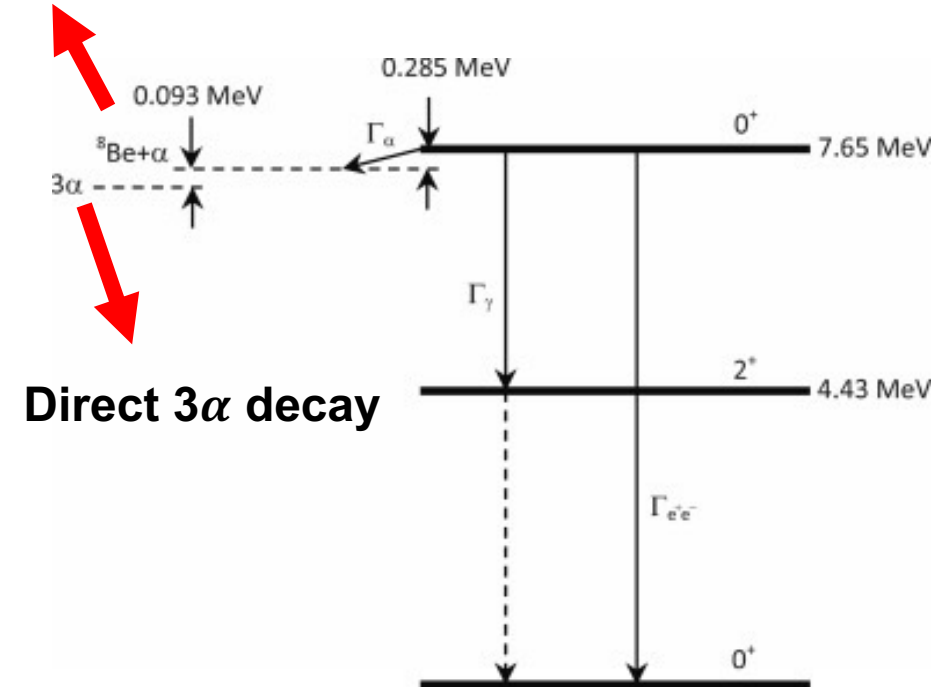


c. Cluster model for C-12 nucleus



sequential 3α decay

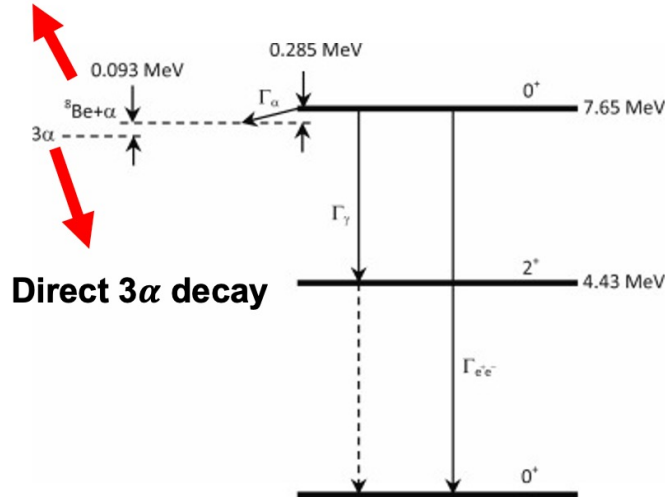
- ^{12}C excite states



- The ^{12}C nucleus enables the existence of the Hoyle state in an α -cluster configuration

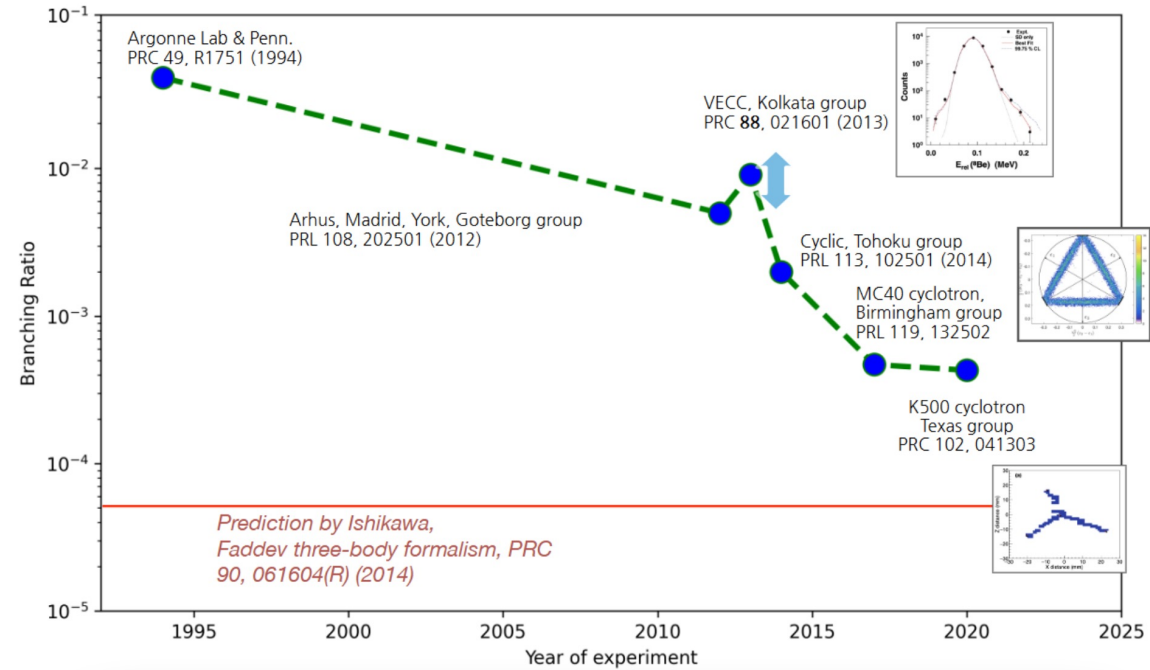
Alpha cluster in ^{12}C

sequential 3α decay



Direct 3α decay

Upper limit of the Branching Ratio of direct decay

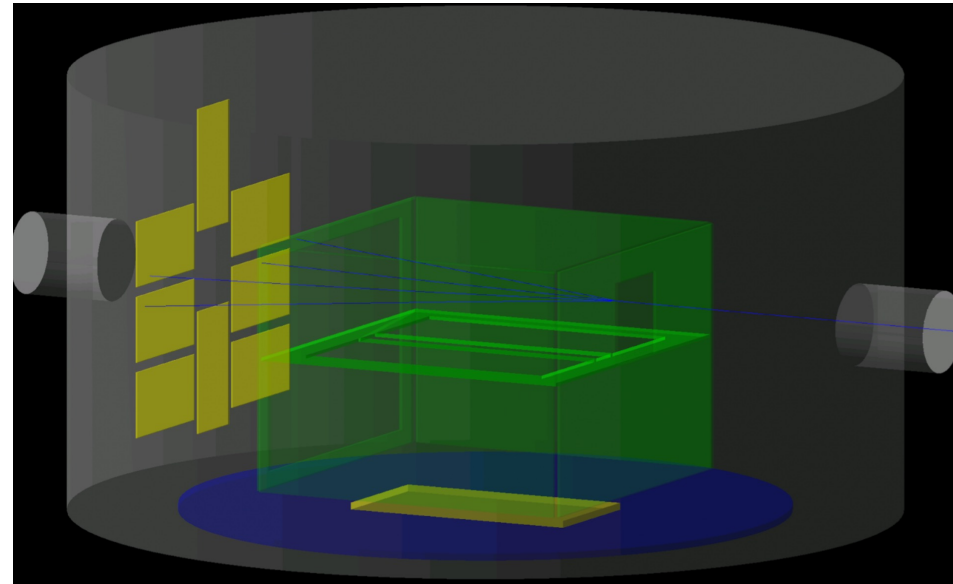
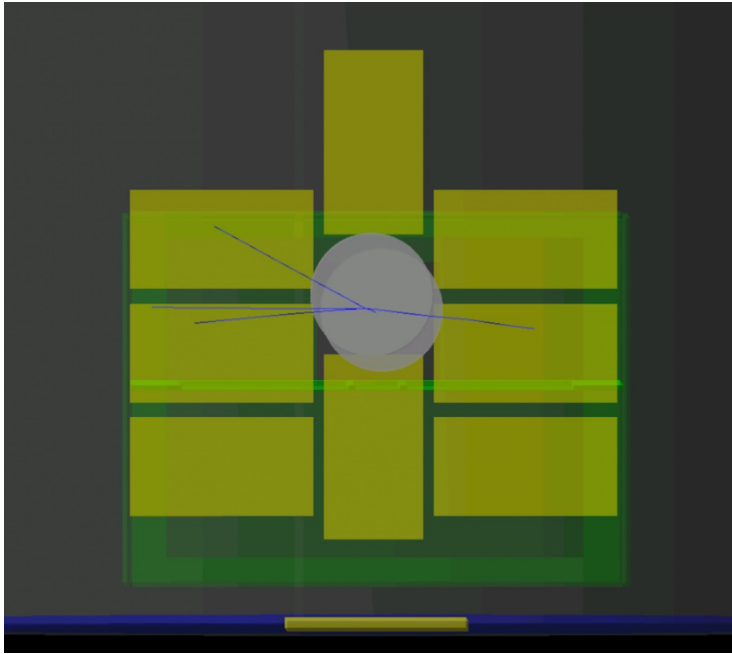


- Direct 3α may related to Bose-Einstein Condensation
- Although numerous experiments have been conducted to detect the direct 3α decay, only upper limits have been established.

TPC-Drum simulation

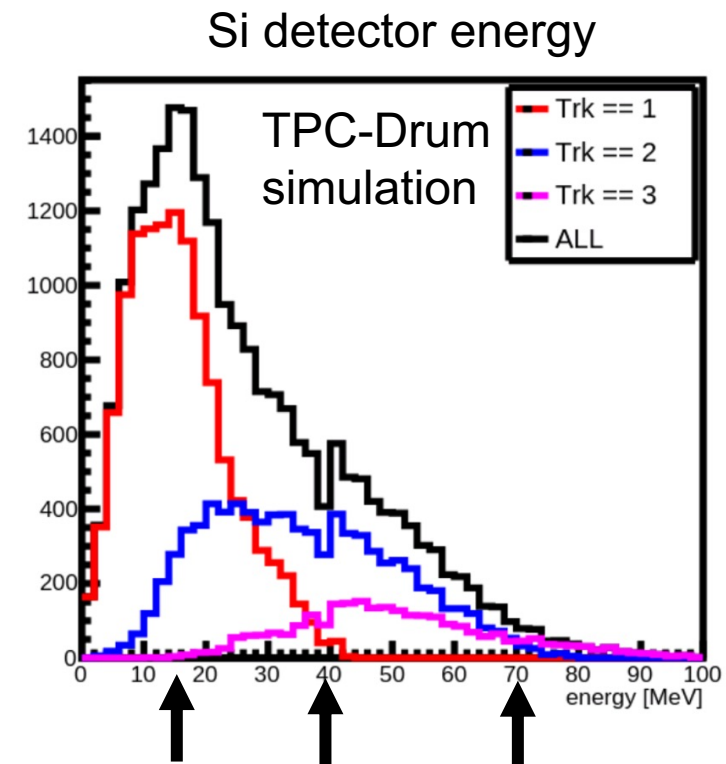
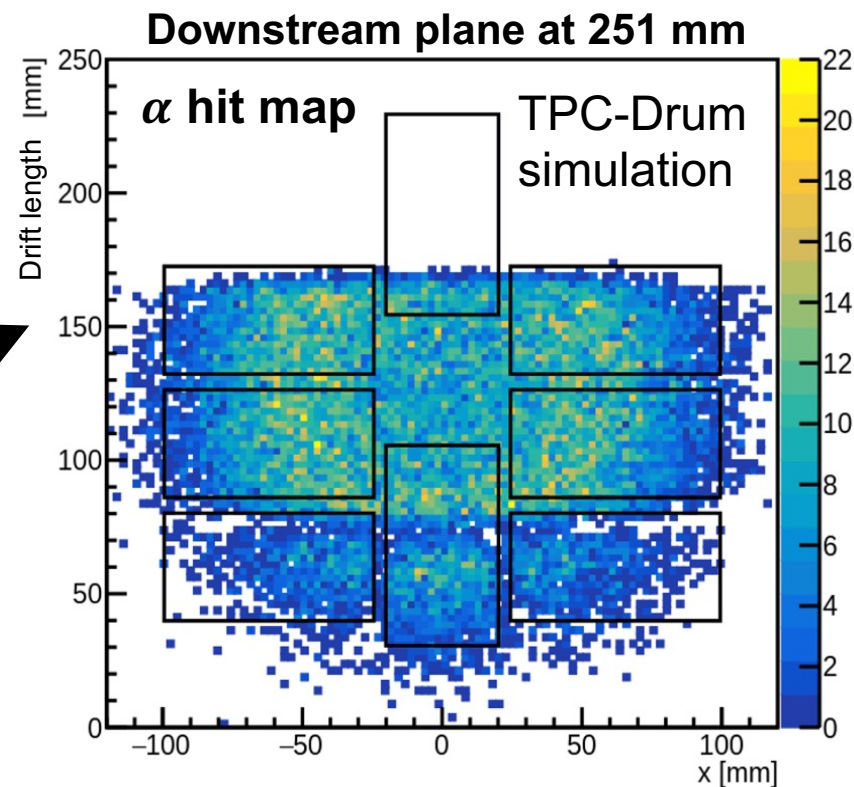
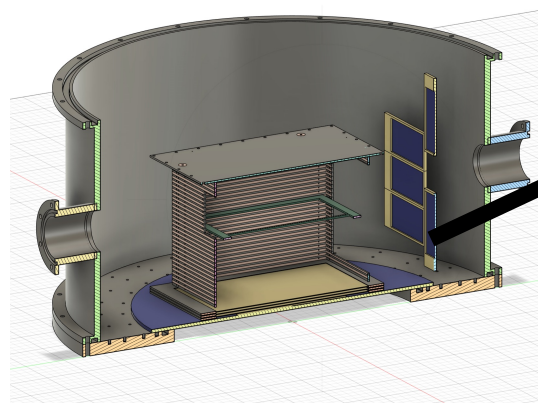
Beam : ^{20}Ne @ 10 MeV/u

Event generator : direct 3α decay events with NPTOOL



- TPC-Drum simulation has been constructed as well

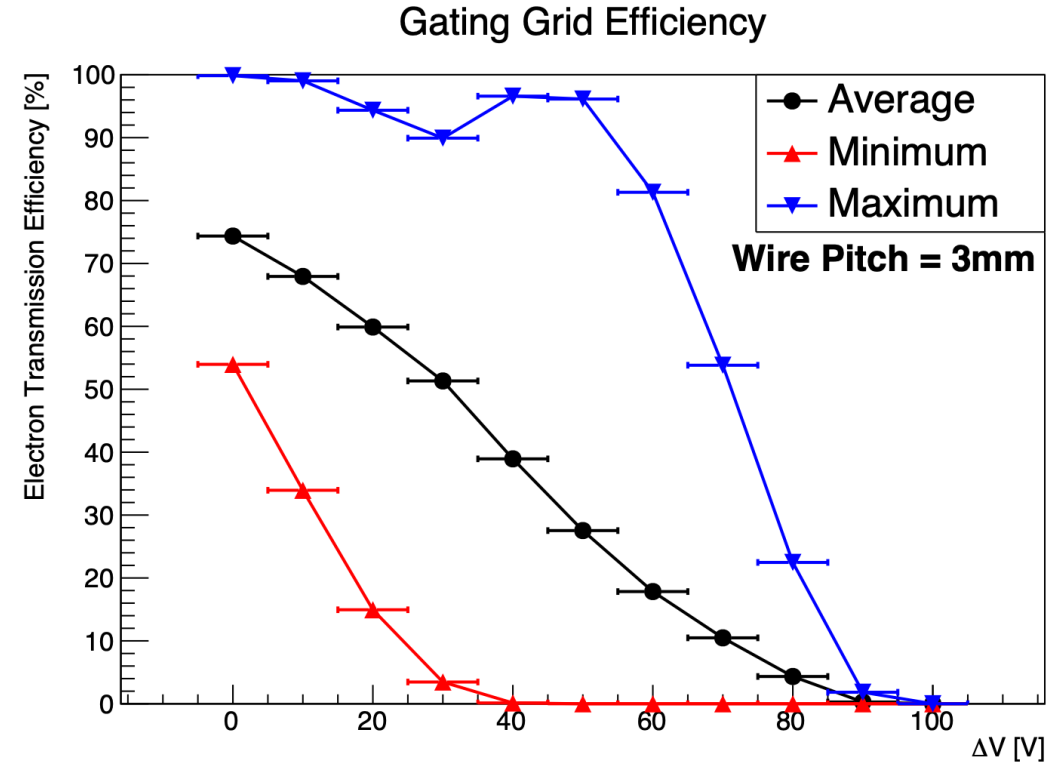
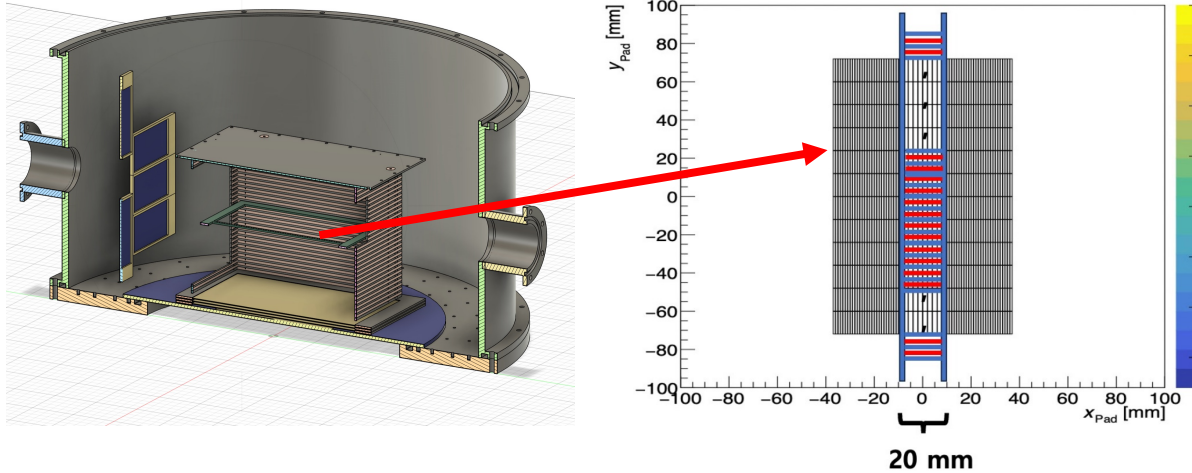
Trigger study



Energy boundaries for trigger

- We determined Si detectors position using α hit map
- More detailed trigger condition will be studied

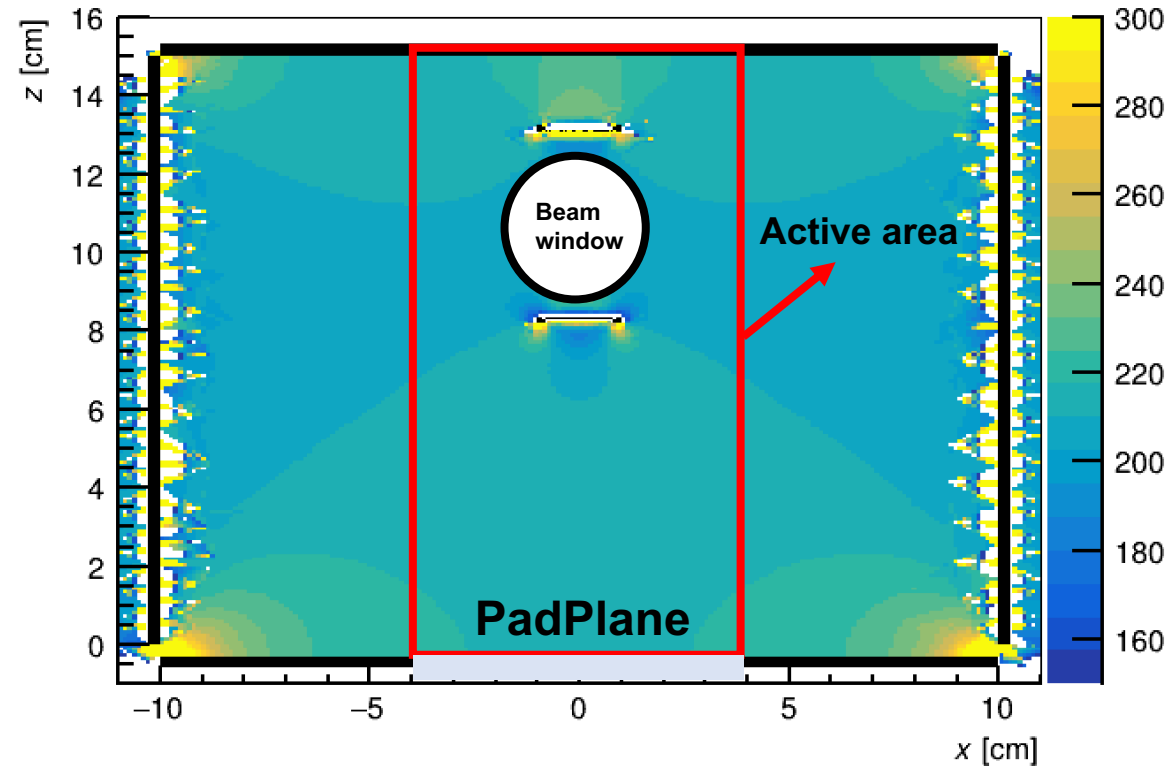
Gating Grid response



- Gating grid can reduce the space charge effect along beam line
- We have optimized Gating grid voltage to electron transmission efficiency ~10%

E-field distortion

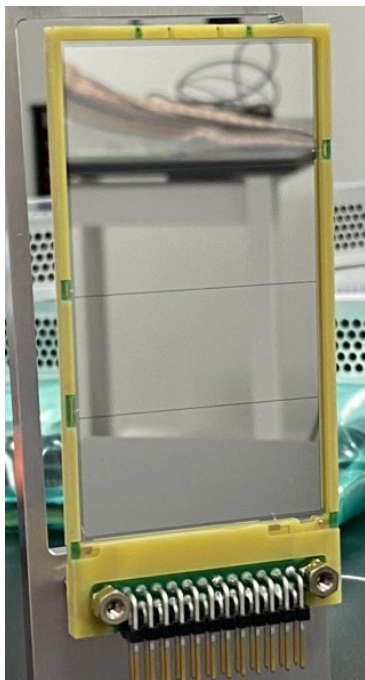
E-field map in Field-Cage



- E-Field distortion in active area approximately 5%
- Distortion effect will be implemented in simulation

Smearing

X6 silicon detector



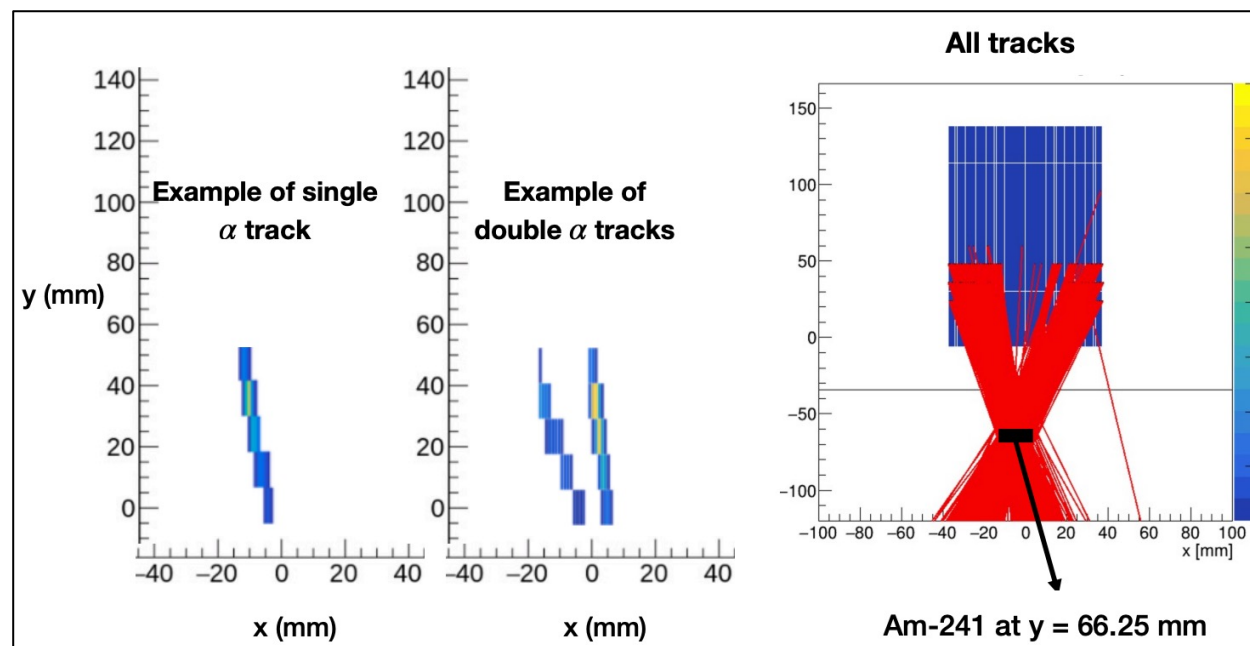
**Si detector
Resolution:**

$$\sigma_E \sim 1 \%$$

$$\sigma_{pos} \sim 1 \text{ mm}$$

X. Pereira-Lopez et al, NIM A, 541, 134-136 (2023)

TPC performance for Am241 test

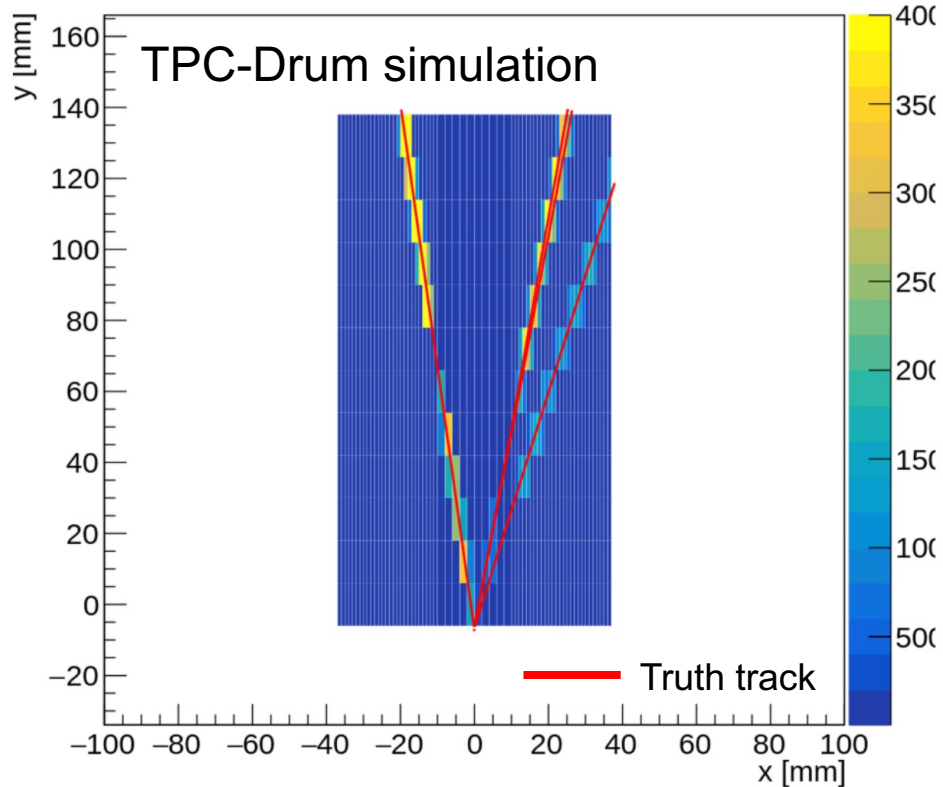


$$\sigma_{ADC} \sim 5\% , \sigma_{Time} \sim 5\%$$

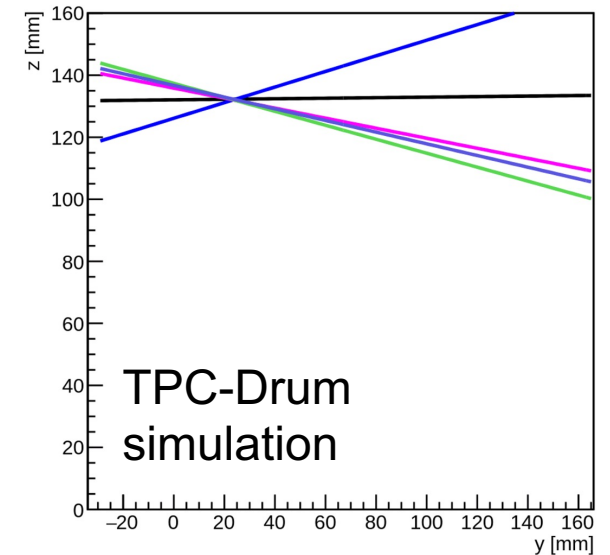
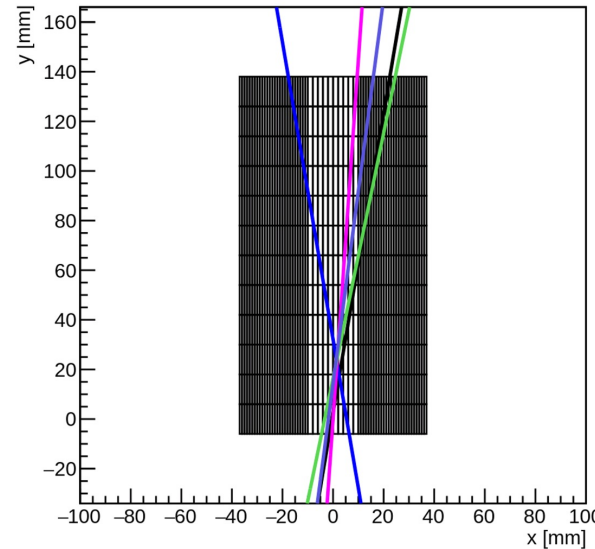
- Simulated data smeared by detectors resolution

Simulation result

Event display

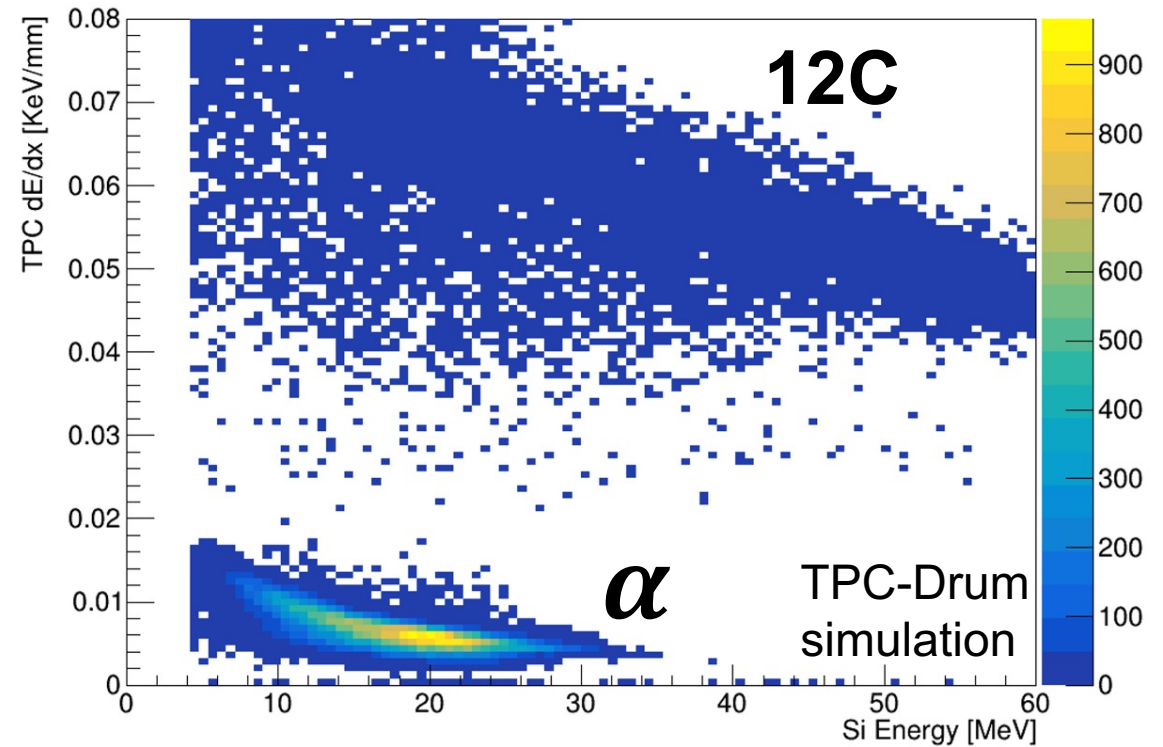
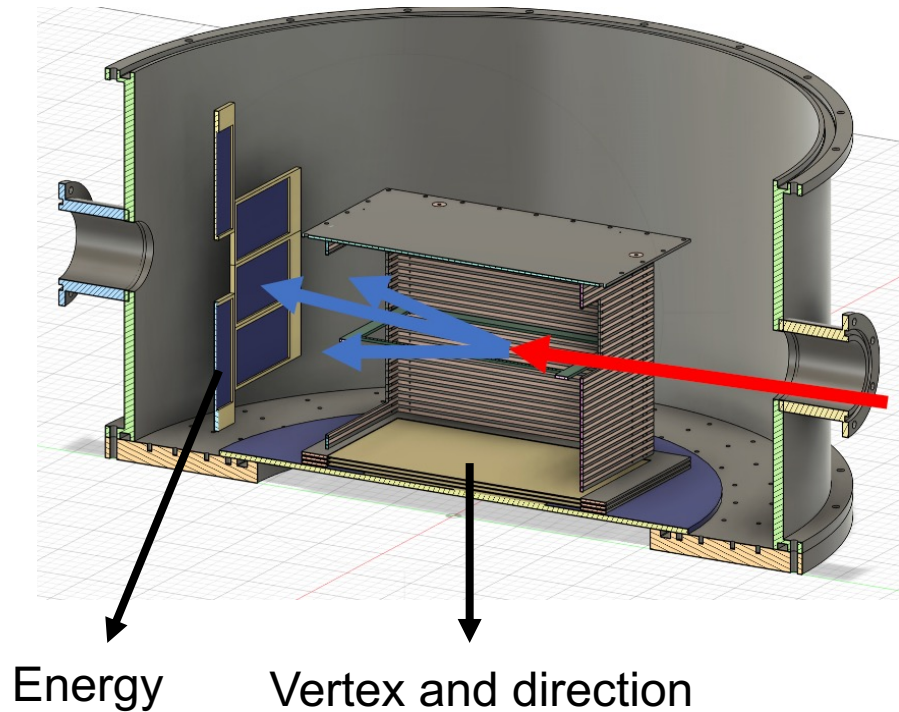


Tracking results



- Traditional tracking and vertexing method used in this study
- Simulation results shown the Gating Grid effect

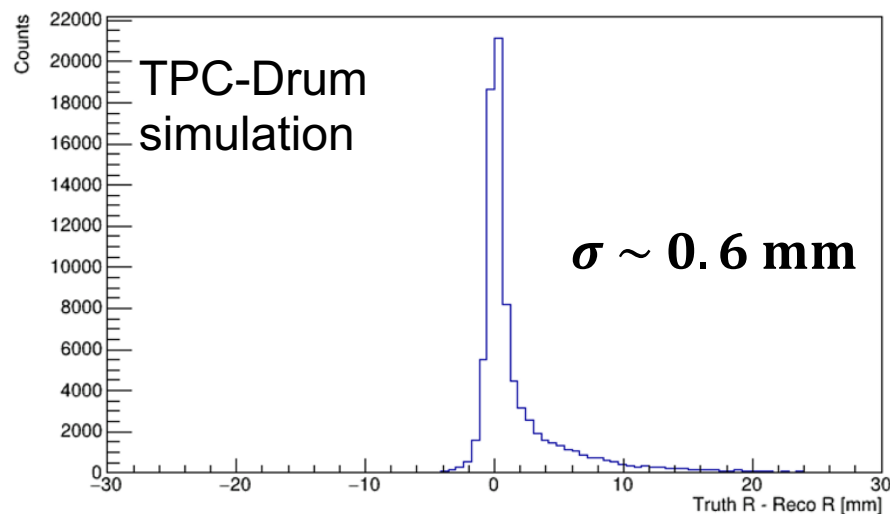
Simulation result



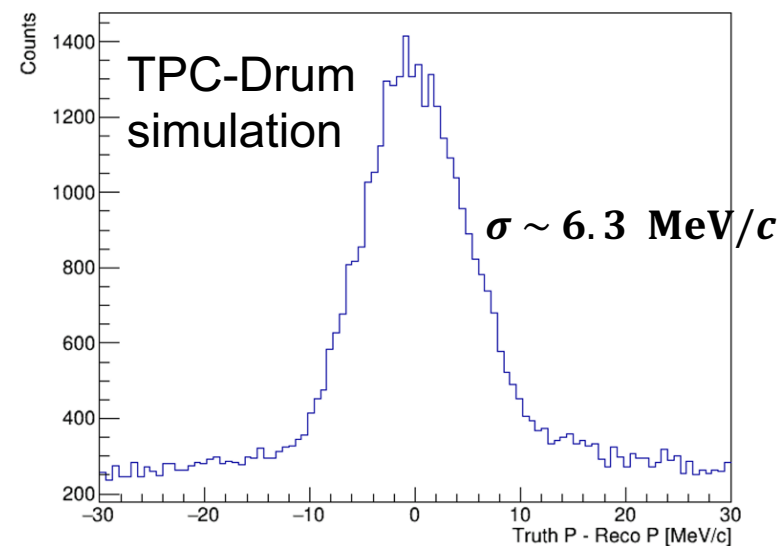
- Momentum can calculate with TPC ($\frac{\vec{p}}{|p|}$) and Si (E)
- α particles are distinguishable

Simulation result

Difference in vertex R (truth – reco)

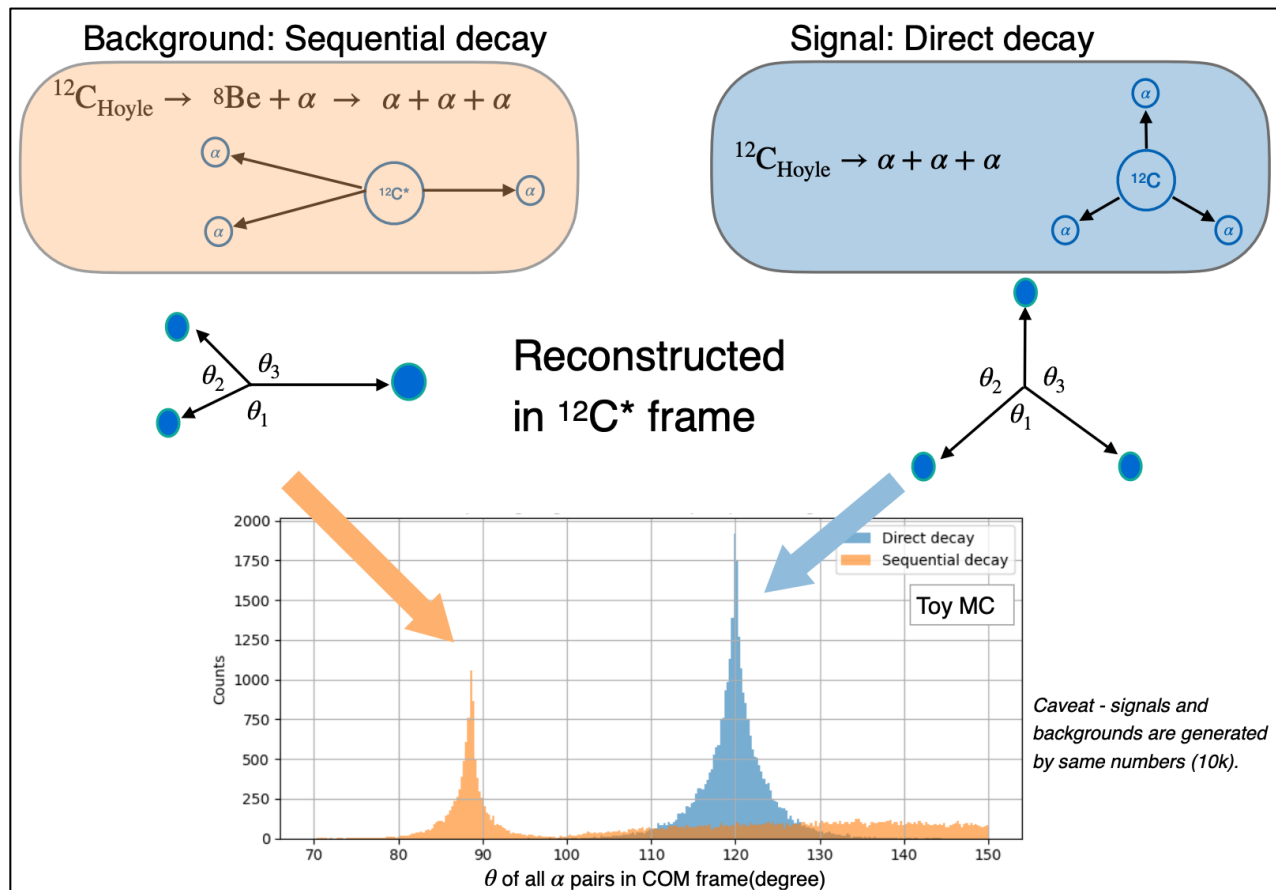


Difference in momentum (truth – reco)



- We estimate resolution of vertex and momentum are up to 0.6 mm and 6.3 MeV/c, respectively

3 α events



Toy-MC study

- Direct 3 α events can distinguish from sequential decay using angle correlations of α s in CM frame
- We will conduct the feasibility study and measuring of yield

Summary

- We will plan to measure the direct 3α decay events for Hoyle state using ^{20}Ne beams at RAON
- Reconstruction method will be improved with simulation (Hough transform)
- More detailed study for trigger and distinction of direct and sequential 3α events will be conducted