Measurement of the γ Decay Probability of the Hoyle State

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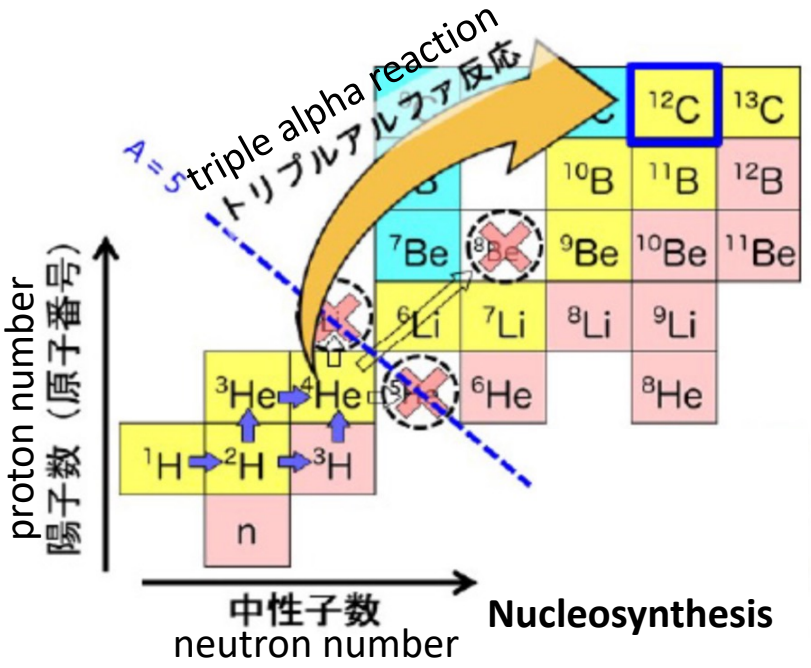
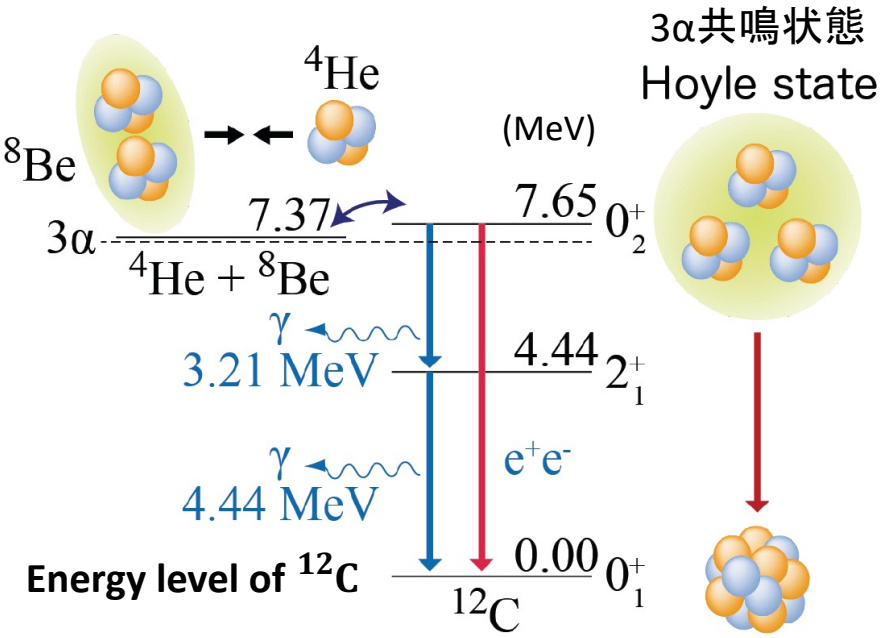
Research background

- ✓ triple alpha reaction
  - An α particle is captured by a 2α resonance in $^{8}\mathrm{Be}$
  - Decays to the g.s. of $^{12}\mathrm{C}$ and emits γ-rays with a slight probability
  - $T \sim 10^{8}$ K , the 3α reaction via the **Hoyle state** is dominant.



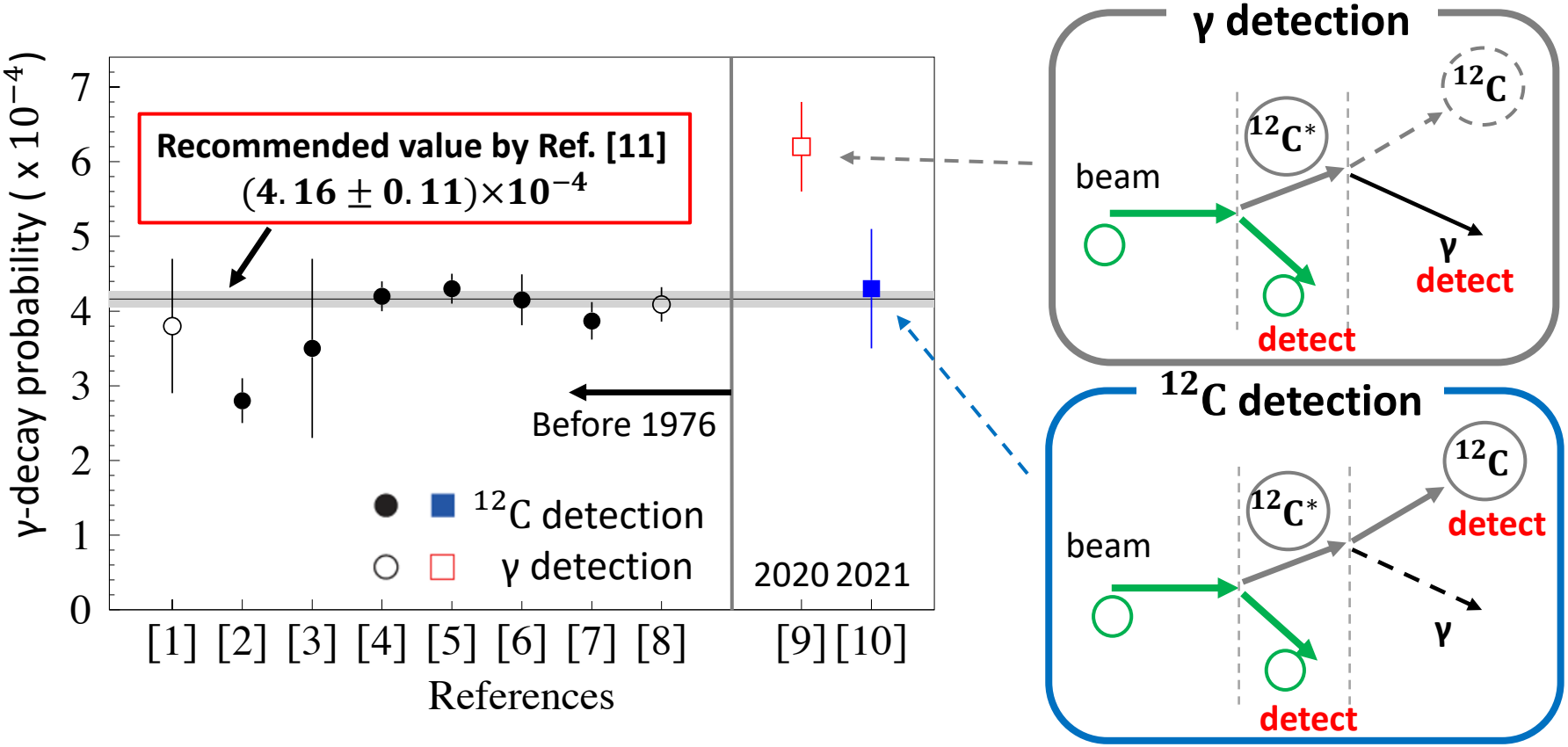


The γ-decay probabilities of the **Hoyle state** are very important parameters to determine the 3α rate in the nucleosynthesis.

Previous research

[9] T. kibedi, Phys. Rev. Lett. **125**, 182701 (2020).
[10] M. Tsumura, Phys. Lett. B **817**, 136283 (2021).

✓ A puzzle has arisen on the γ-decay probability of the Hoyle state.

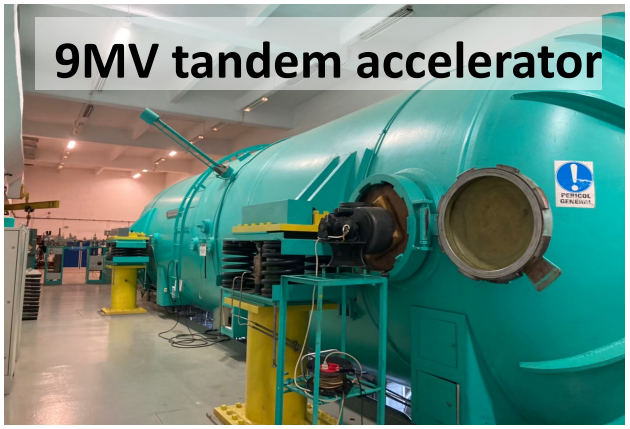


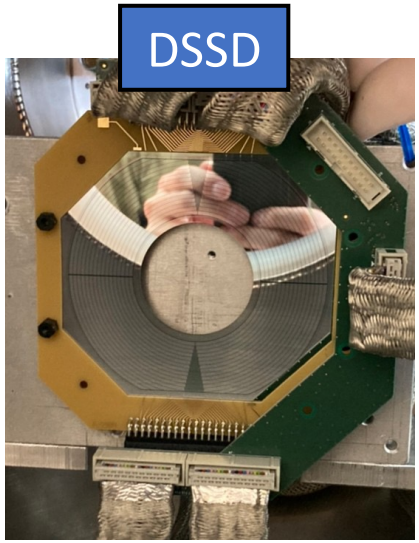
✓ <u>Different γ-decay probabilities have been reported for two different methods</u>.

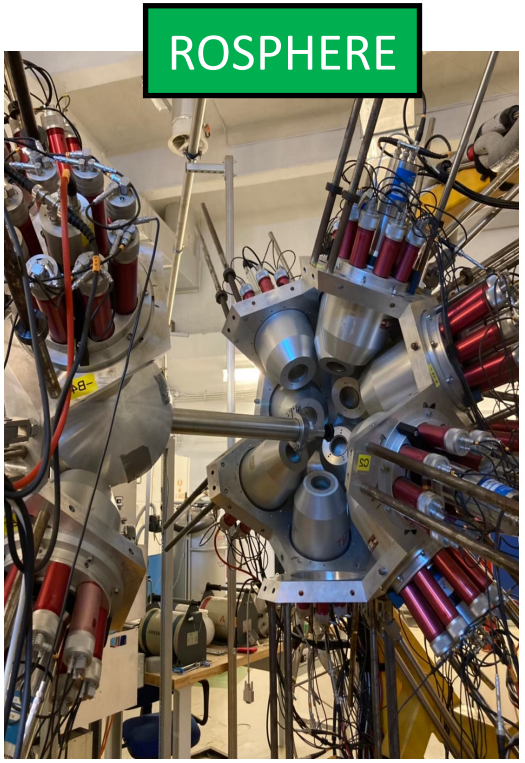
$$\Gamma_\gamma/\Gamma = \mathbf{6.1(6)\times10^{-4}}\ [9]\ ,\quad \Gamma_\gamma/\Gamma = \mathbf{4.2(8)\times10^{-4}}\ [10]$$

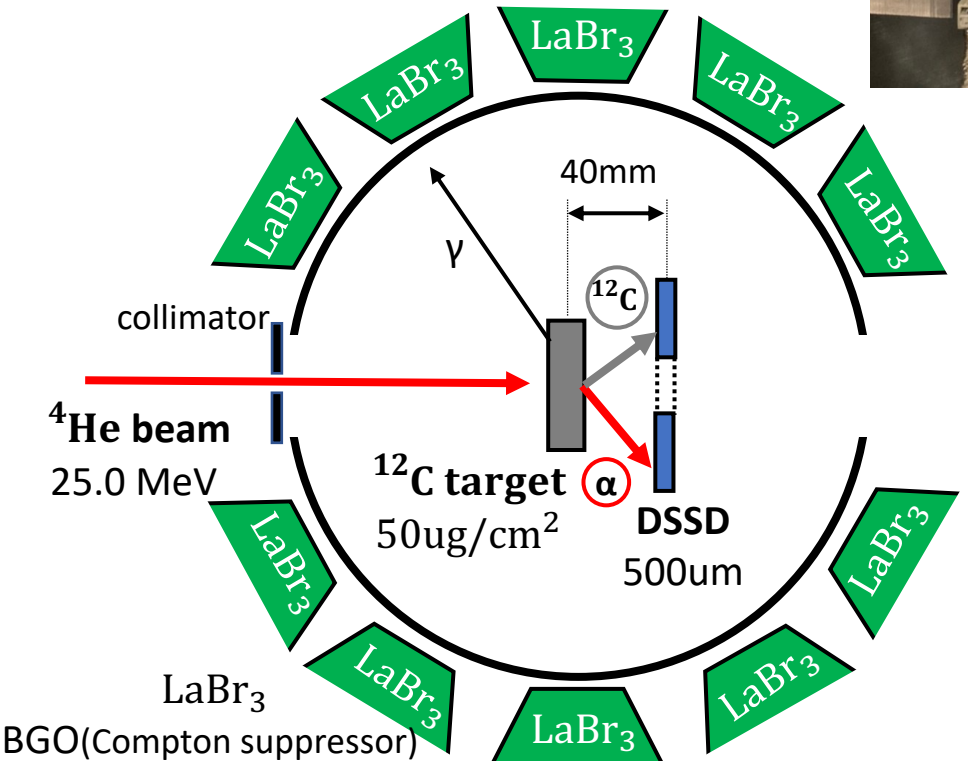
→ This inconsistent result might be due to the different measurement methods.

$\alpha + {}^{12}C + \gamma$ coincidence measurement









$\underline{{}^{12}C\ (\alpha, \alpha' + {}^{12}C\ + \gamma)\ @\ 25MeV\ {}^{4}He}$

- ✓ DSSD : front 16x4 strip, rear 16 strip
- ✓ ROSPHERE : $(LaBr_3 + BGO)$x24

→ Detection efficiency ε = 2.5% (@5MeV)

- ✓ Target : ${}^{nat.}C$, ${}^{13}C$, blank

Result - PID using Pulse Shape Analysis

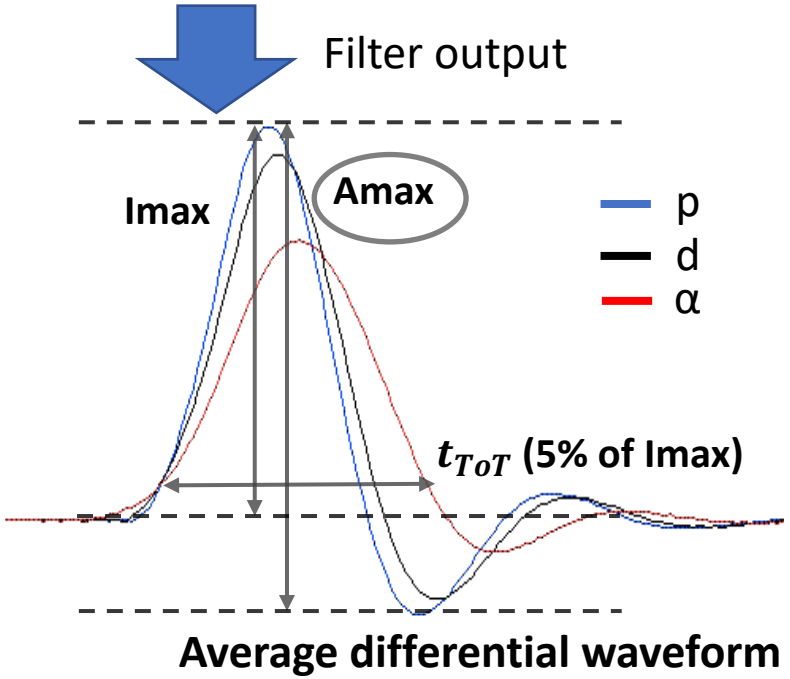
✓ Take the waveform using digitizers

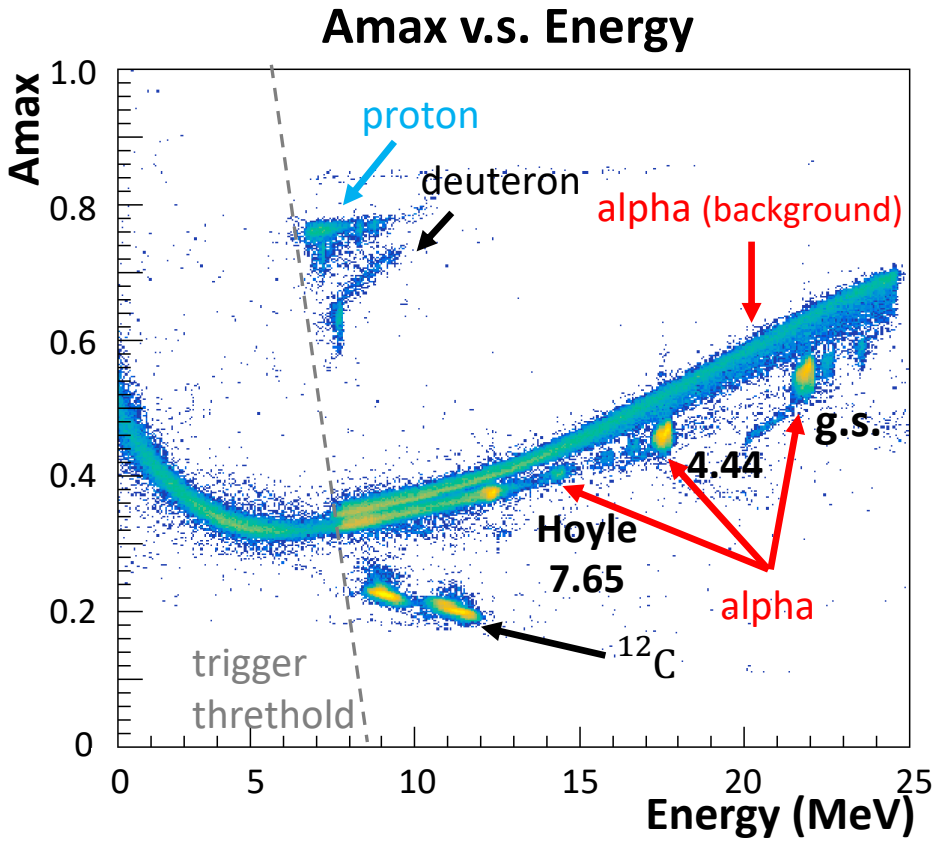
→ PID by pulse shape analysis (PSA)

Triangle Filter

$$y_i = \left(\sum_{k=1}^{L} x_{i+k}\right)/L - \left(\sum_{k=-L}^{-1} x_{i+k}\right)/L$$

L：Filter length





✓ Successfully separated α from p, d and ^{12}C

✓ Continuous background alpha particles

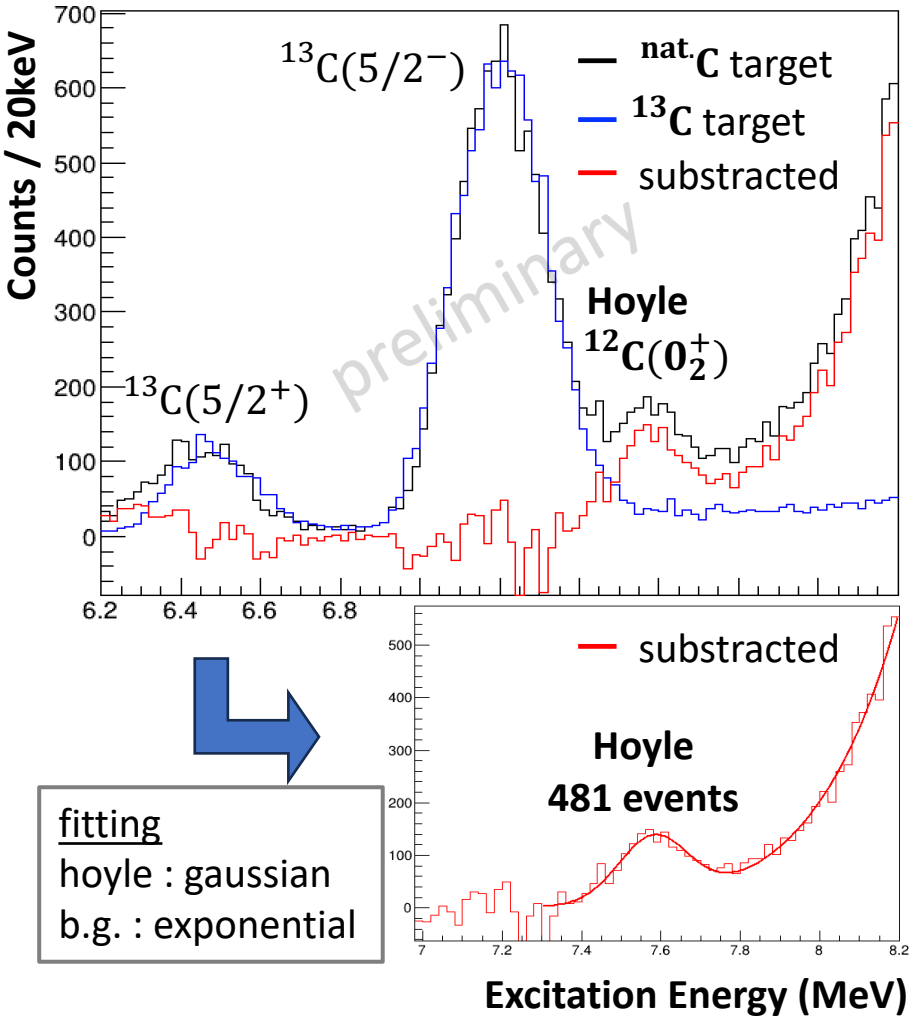
→ Beam scattered by upstream collimators

Analysis

✓ α-^{12}C coincidence

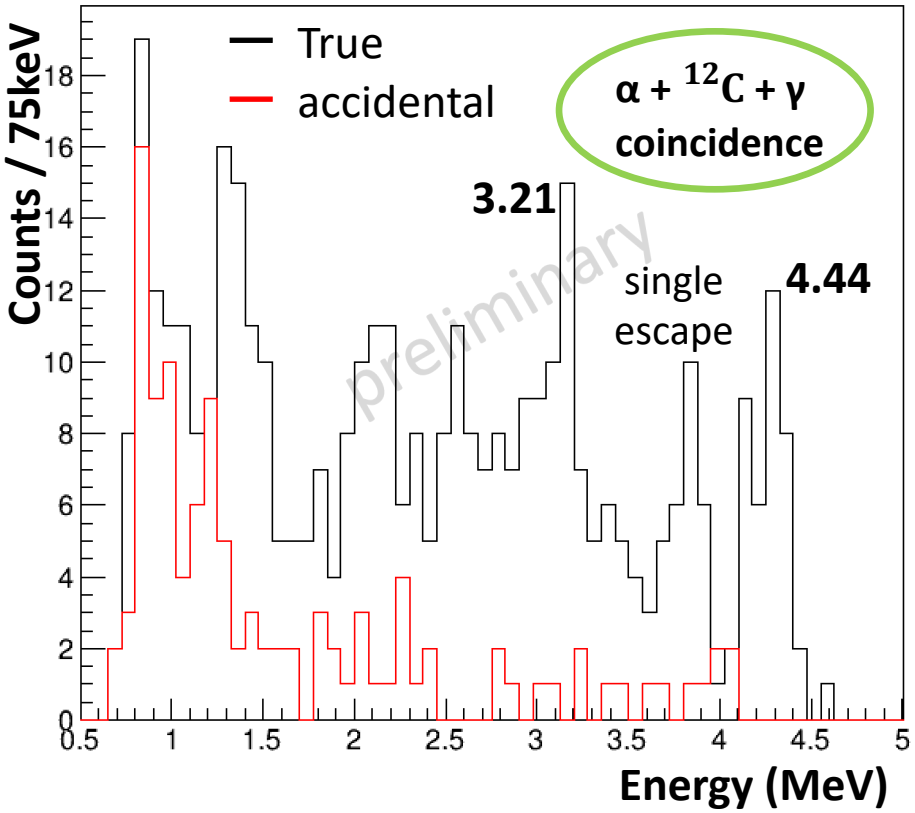
✓ γ-ray coincidence in Hoyle-like events

Candidate events of Hoyle state



fitting
hoyle : gaussian
b.g. : exponential

Energy Spectrum of γ ray



6. Summary and Future plan

- Mearsured γ-decay probability from the Hoyle state with combination of Si and ROSPHERE.

- **Obtained α + ^{12}C + γ coincidence events for the first time ever.**

- Need to estimate the detection efficiency of Si and ROSPHERE.

  ・There are some issues
  - Due to the dead layer of the Si, detection efficience deteriorated significantly.
  - Compton suppressor did not work for low energy γ rays.

Thank you for your attention