COREA Detector and Perspectives for the Measurement of $^{12}C(\alpha,\gamma)^{16}O$ Reactions at BIBA

HELIUM25

Jul 21 – 25, 2025
Helmholtz-Zentrum Dresden-Rossendorf (HZDR)

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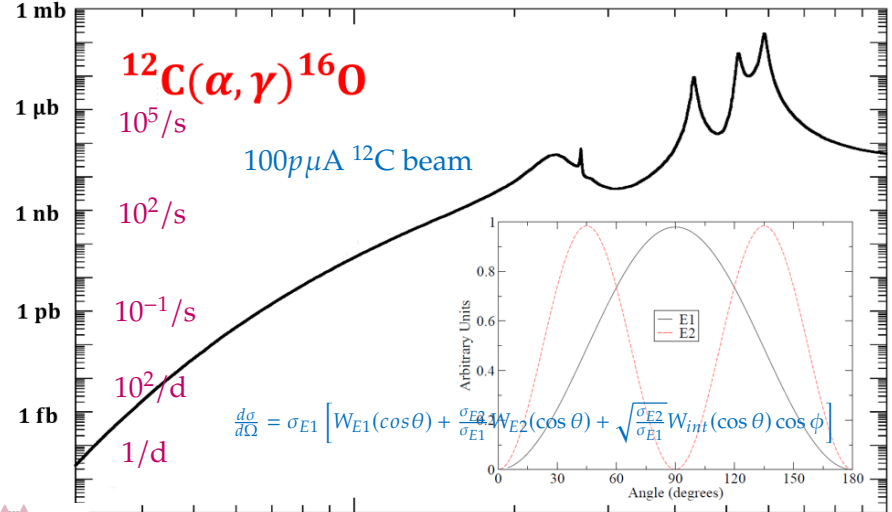
COREA

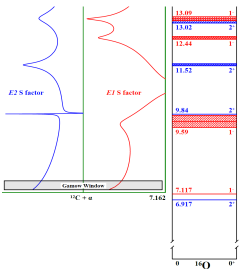
$^{12}C(\alpha,\gamma)^{16}O$ Reaction with COREA Detector

Superconducting magnet

Carbon **O**xygen **R**eaction **E**xperiment with **A**ctive-target TPC

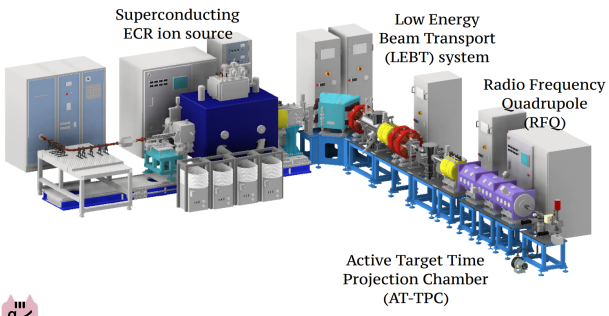
$^{12}C(\alpha,\gamma)^{16}O$ Cross-Sections and Event Rates

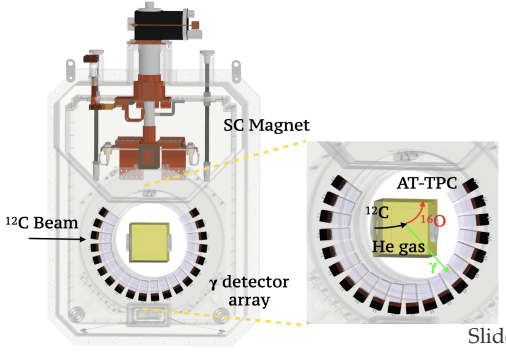




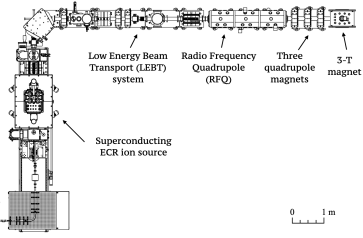
$^{12}C(\alpha,\gamma)^{16}O$ Measurement with COREA Detector

- 500-keV/u 100 pμA $^{12}C^{q+}$ ion beam.
- Large acceptance windowless ^{4}He gas TPC
- $LaBr_3$ detector array for the $E1/E2$ capture ratio measurement
- Coincidence measurement of recoil ^{16}O and γ
- Measurement of p/q with the 3 T magnet (dE/dx in TPC)



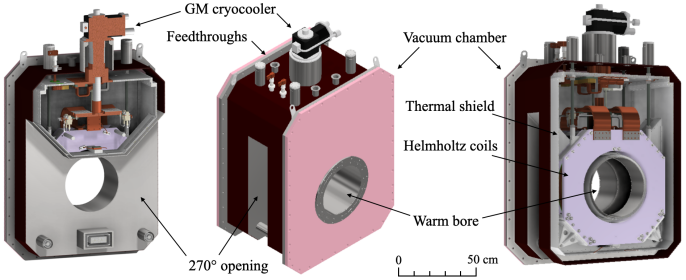


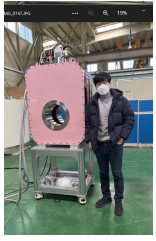
KBSI Busan Ion Beam Accelerator (BIBA)

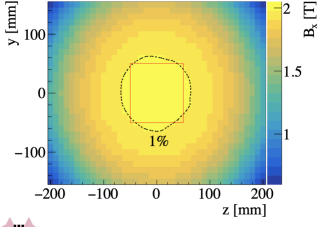


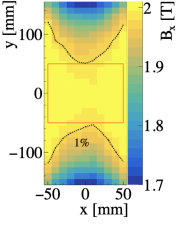
- 28-GHz ECRIS + 500-keV/u RFQ at 81.25 MHz / 100 kW
- BIBA currently delivers low-energy ion beams with the 28-GHz ECRIS.
- A full operation is anticipated in late 2025.

3-T Conduction-cooled Superconducting Magnet







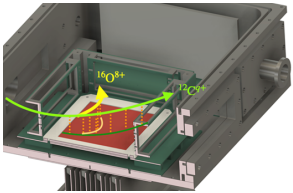


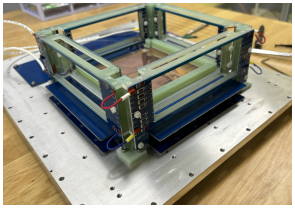
- Superconducting Helmholtz magnet (B_{max} = 3 T, RT Bore = 300 mm, 270° opening) operated successfully in 70 hours at 3 T. [a]

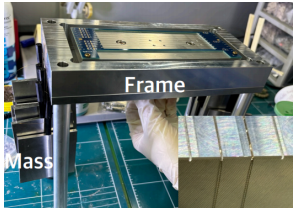
[a] S.H. Kim and J.K. Ahn, NIMA1049, 168062(2023).

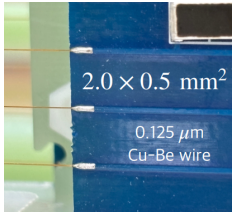
Active Target TPC (aTPC)

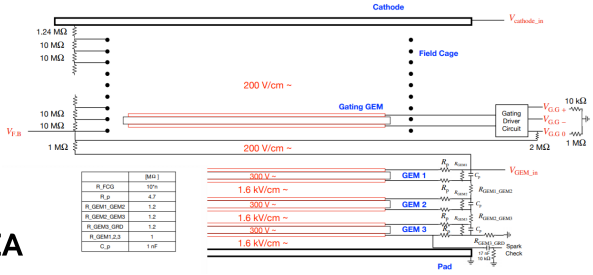
- The aTPC prototype reads 1000 channels using four AsAd boards of GET electronics, and operate with a gas mixture of a 0.05–0.5 atm He/CO_2, or He/iC_4H_{10}. It has a wire-type field cage and amplifies signals with triple GEMs.

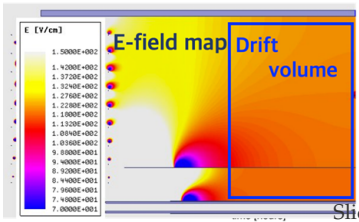




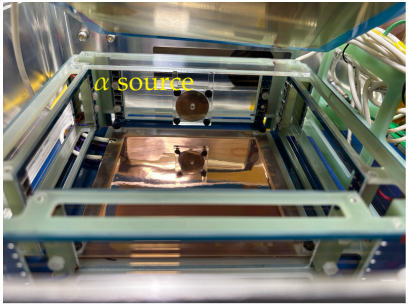


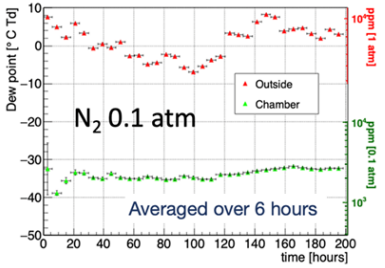


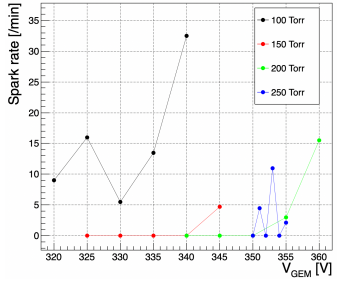




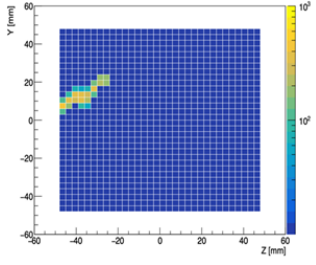
Bench Test of Active Target TPC (aTPC)

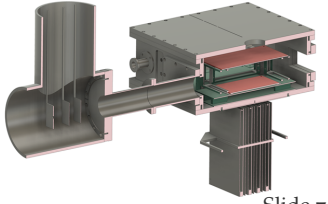




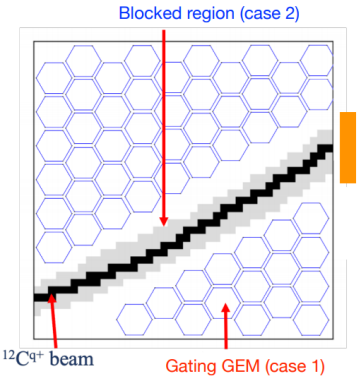


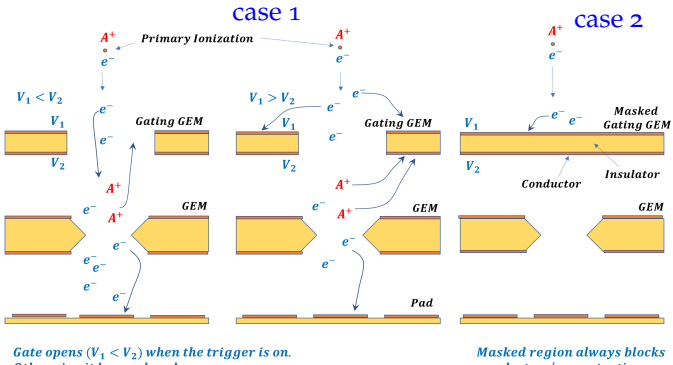
- Performance tests using an ^{241}Am source are underway for different gas mixtures (P10, He/CO_2, He/iC_4H_{10}) and pressures.

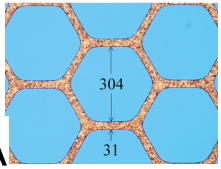


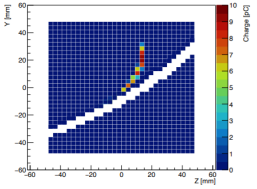


Active Target TPC (aTPC) with a Gating GEM



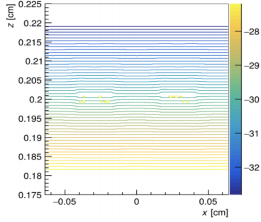


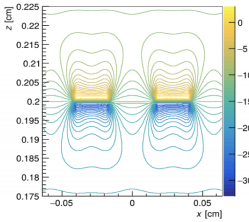


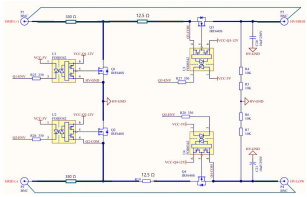


- Blocking the high-intensity beam region to mitigate space charge and ion backflow, which ensures stable operation.

Gating Operation



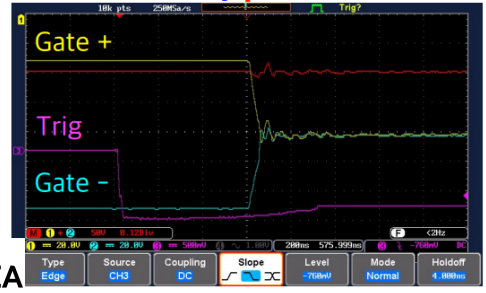




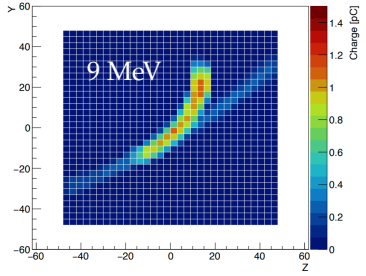
Close

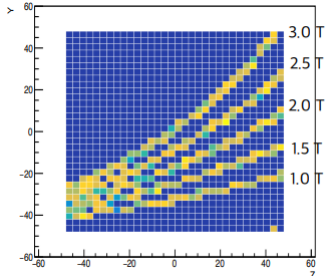
Open

Close

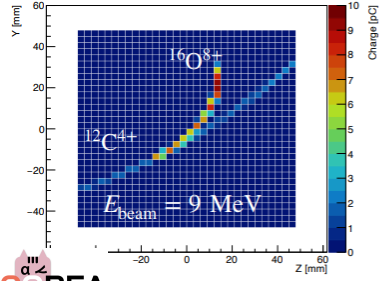


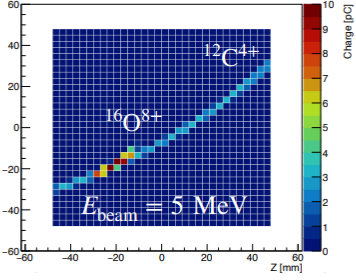
Simulation on the aTPC Performance

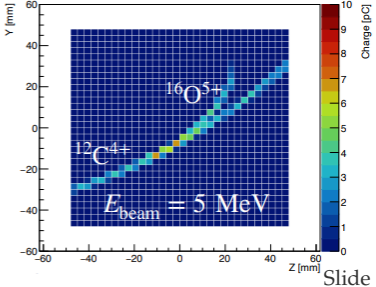




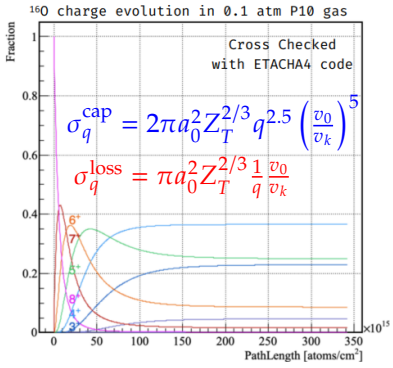
- Beam particles pass the same path when B field changes with the beam energy.
- Recoils are easily separated from beams at high energies, but not always at low energies.

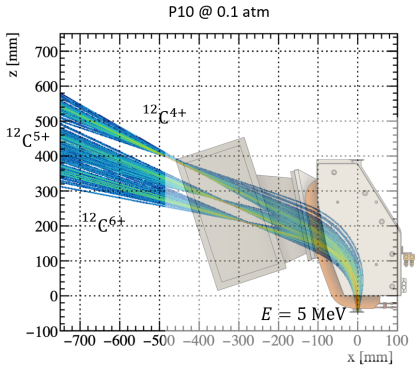


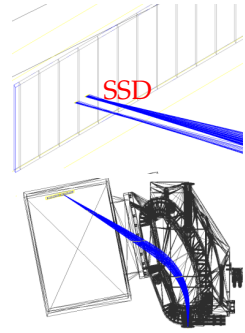


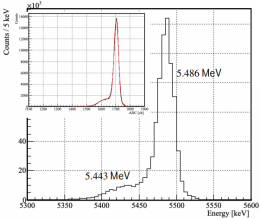


Effective Charge States of Recoil $^{16}O^{q+}$



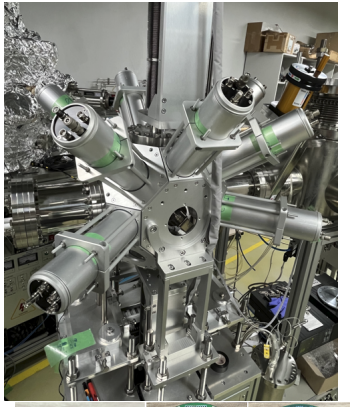


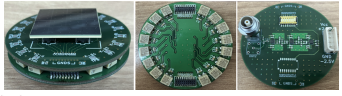


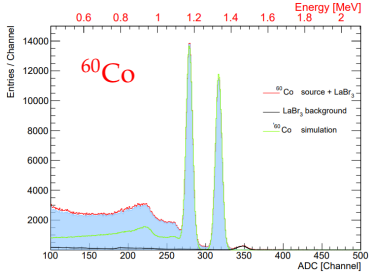


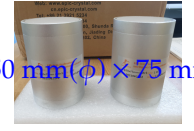
- Recoil nuclei quickly take up and/or lose atomic electrons in He gas to change their charge states.
- A focal-plane spectrometer measures Q_{eff} of $^{12}C^{q+}$ and $^{16}O^{q+}$ in He gas at different energies and gas pressures.

$LaBr_3(Ce)$ γ-ray Detector Array

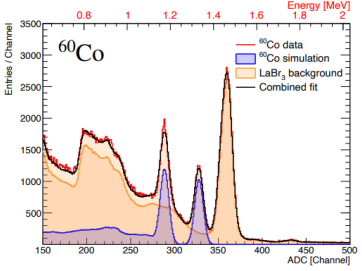


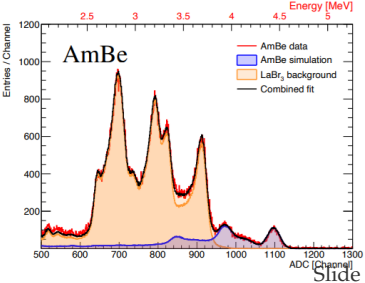






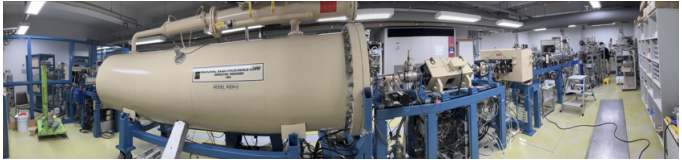
50 mm(ϕ) × 75 mm





KIST 2MV Pelletron and KU Beamline

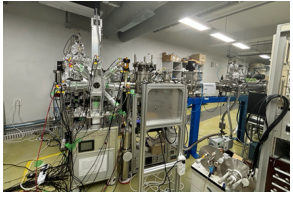
- KIST Advanced Analysis Center (Seoul)
  (6MV Tandetron/2MV Pelletron)

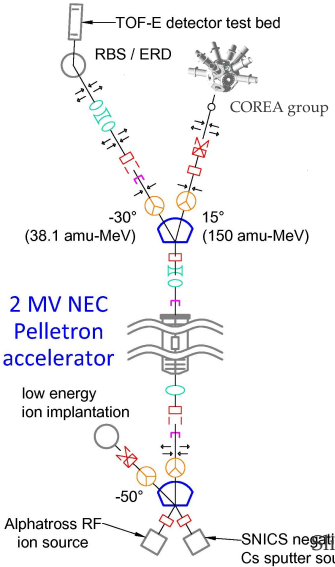


$^{4}He^{2+}$, E = 3.9 MeV, I = 1.2 – 2 μA

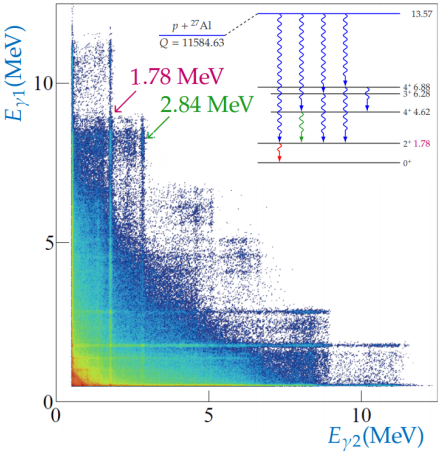
$^{12}C^{2+}$, E = 5.92 MeV, I = 3 μA / $^{12}C^{3+}$, E = 7.85 MeV, I = 10 μA

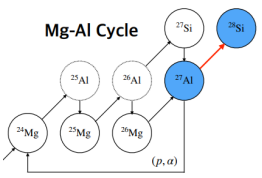
$^{12}C^{4+}$, E = 9.80 MeV, I = 3 μA / $^{12}C^{5+}$, E = 11.75 MeV, I = 50 nA

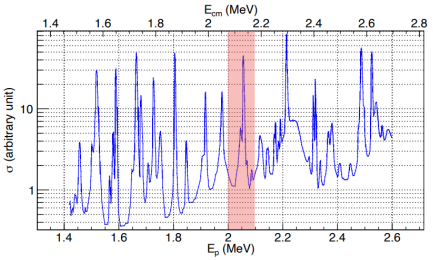


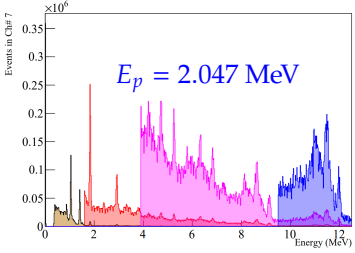


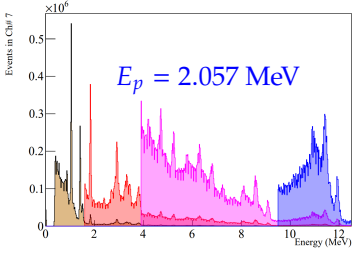
Gamma-ray Energy Spectra from ^{27}Al$(p,\gamma)^{28}$Si





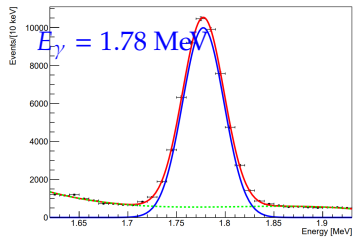


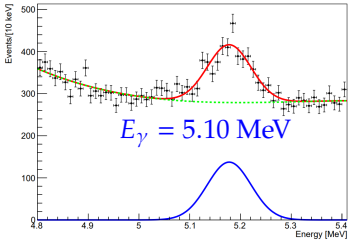


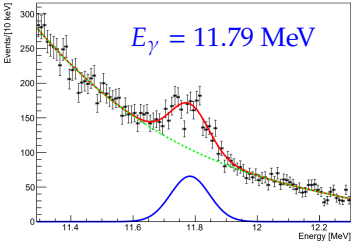


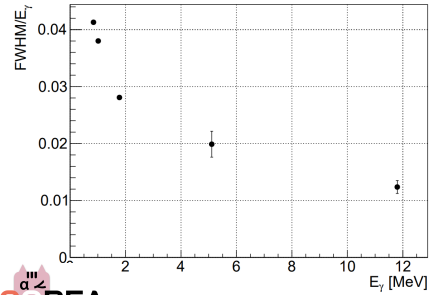
- Major γ transitions are clearly identified and used for energy and efficiency calibrations.

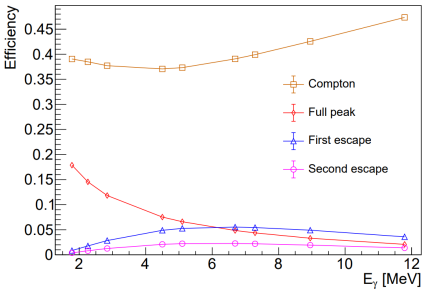
Performance of $LaBr_3(Ce)$ γ-ray Detector Array







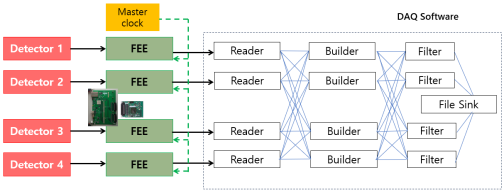


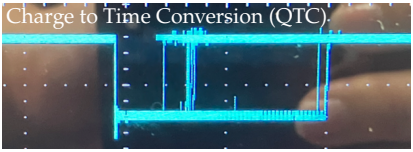


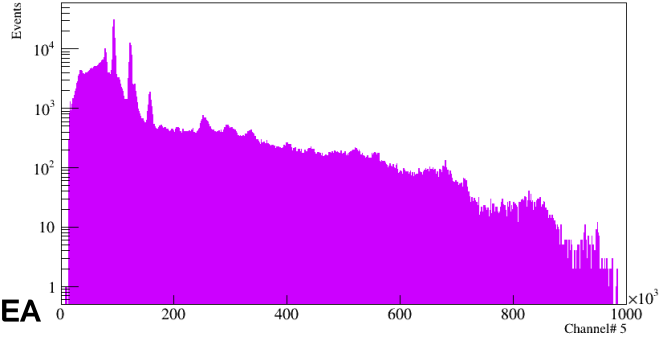
- $\frac{\text{FWHM}}{E_\gamma} \sim 1.5\%$ and $\varepsilon_{\text{full}} \sim 5\%$ near 7 MeV.

Triggerless Streaming-Mode Data Acquisition

- We successfully collected data using a triggerless streaming-mode DAQ system.







Our Challenges for the $^{12}C(\alpha,\gamma)^{16}O$ Measurement

- A small detector prototype will demonstrate the operation principle using high-intensity beams in late 2025.
- The COREA experiment is scheduled to run for three years, starting in late 2026, after the beam commissioning is completed.