Development of Active Target TPC for COREA

2025. 07. 07
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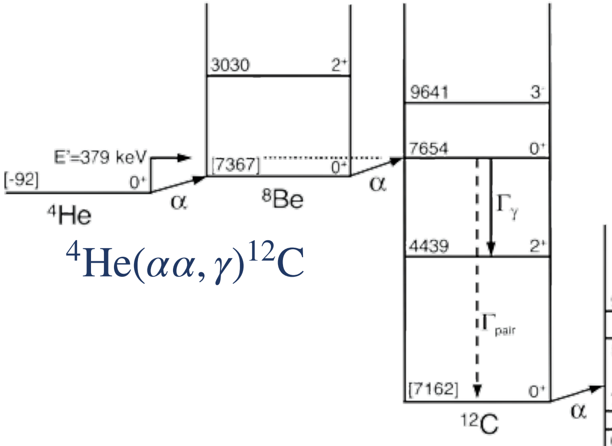
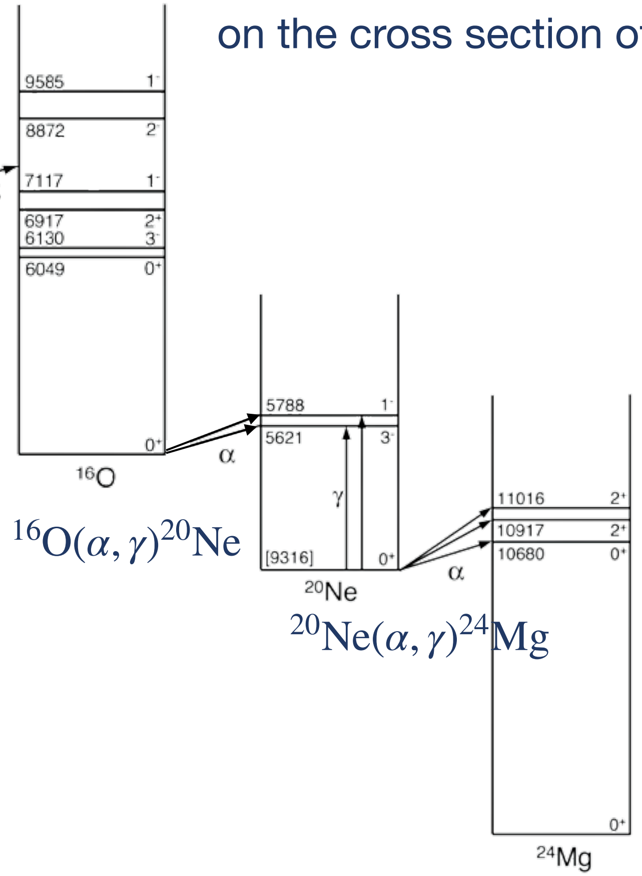
Stellar Nucleosynthesis Reactions

Alpha capture process (α,γ)

Production factors of elements vary significantly depending on the cross section of the reactions.



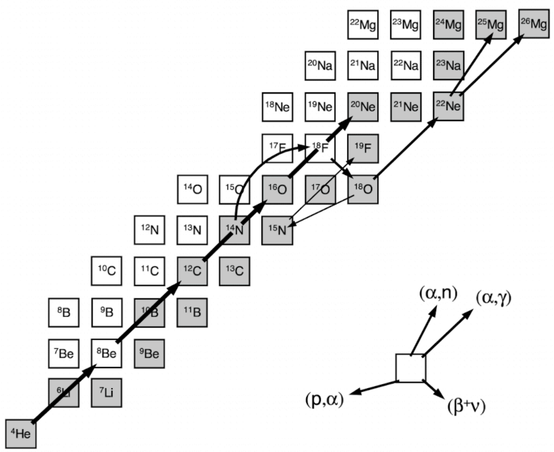
$^{4}\text{He}(\alpha\alpha,\gamma)^{12}\text{C}$

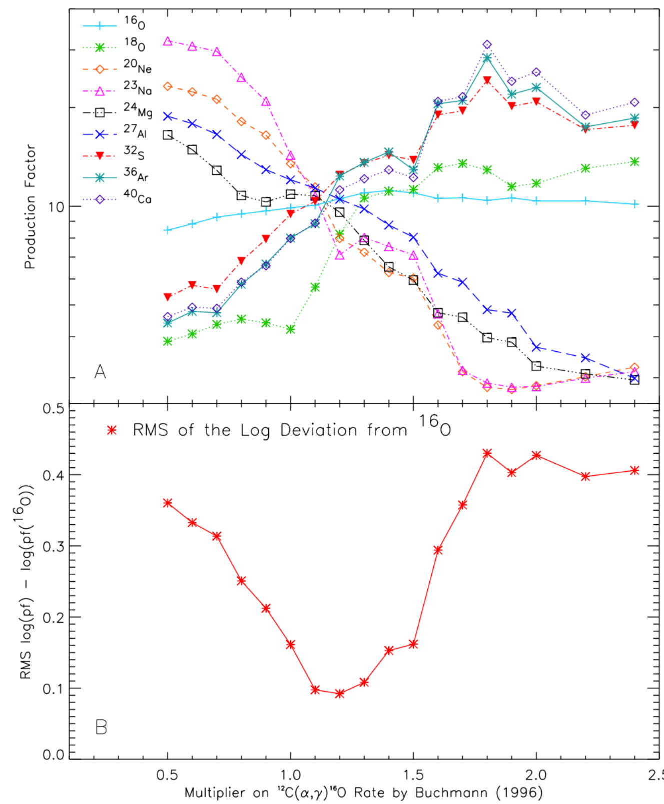


$^{12}\text{C}(\alpha,\gamma)^{16}\text{O}$

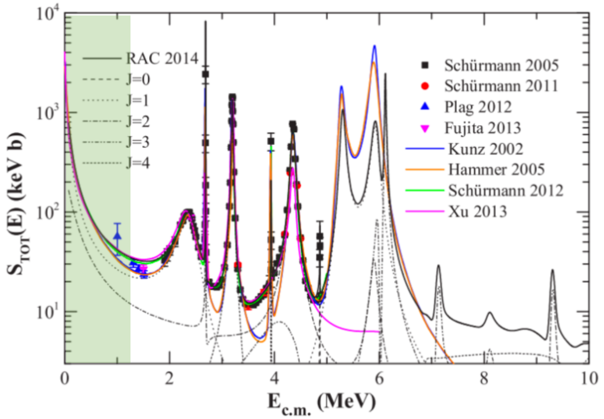
$^{16}\text{O}(\alpha,\gamma)^{20}\text{Ne}$

$^{20}\text{Ne}(\alpha,\gamma)^{24}\text{Mg}$

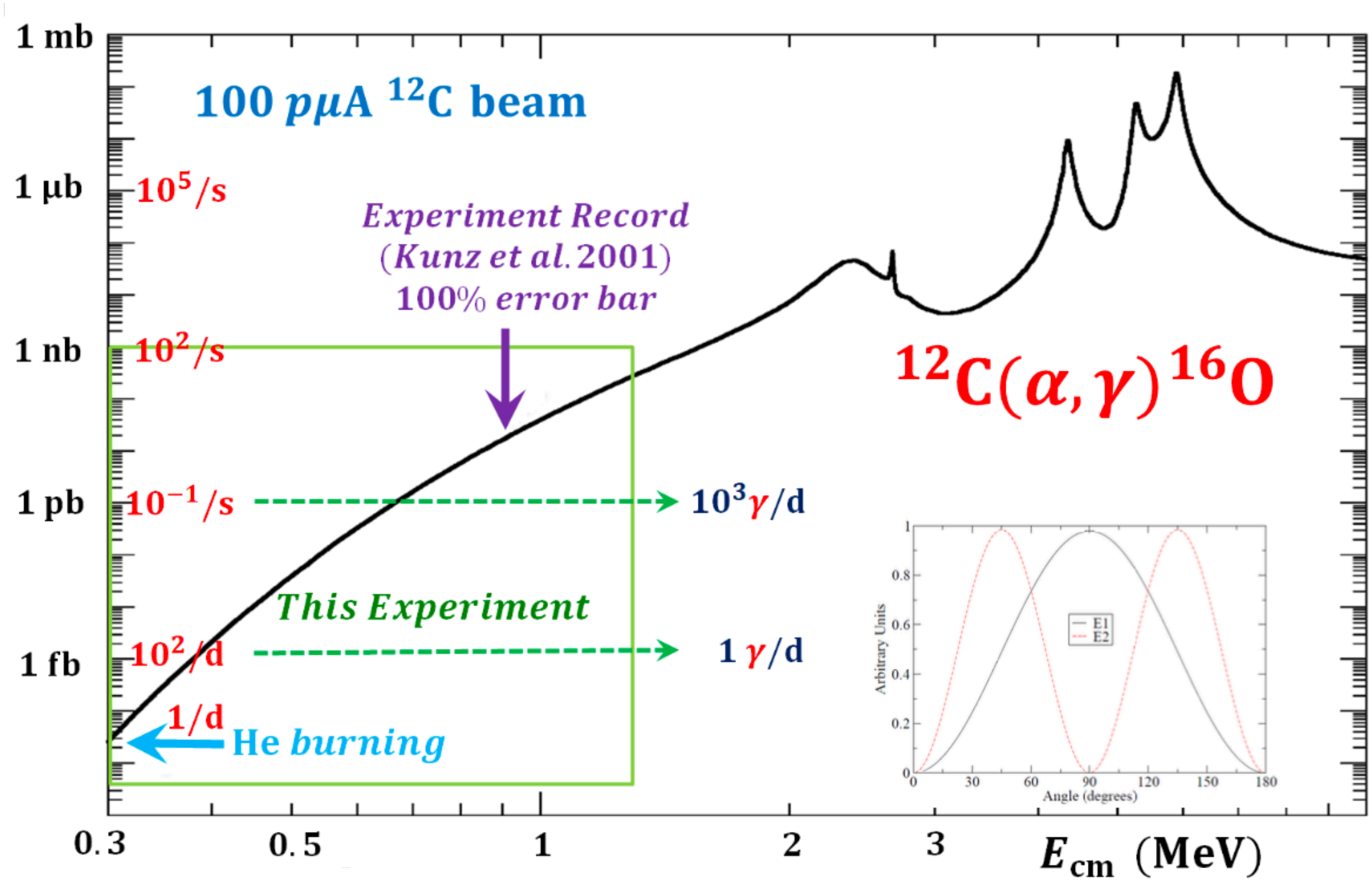




▪ COREA experiment



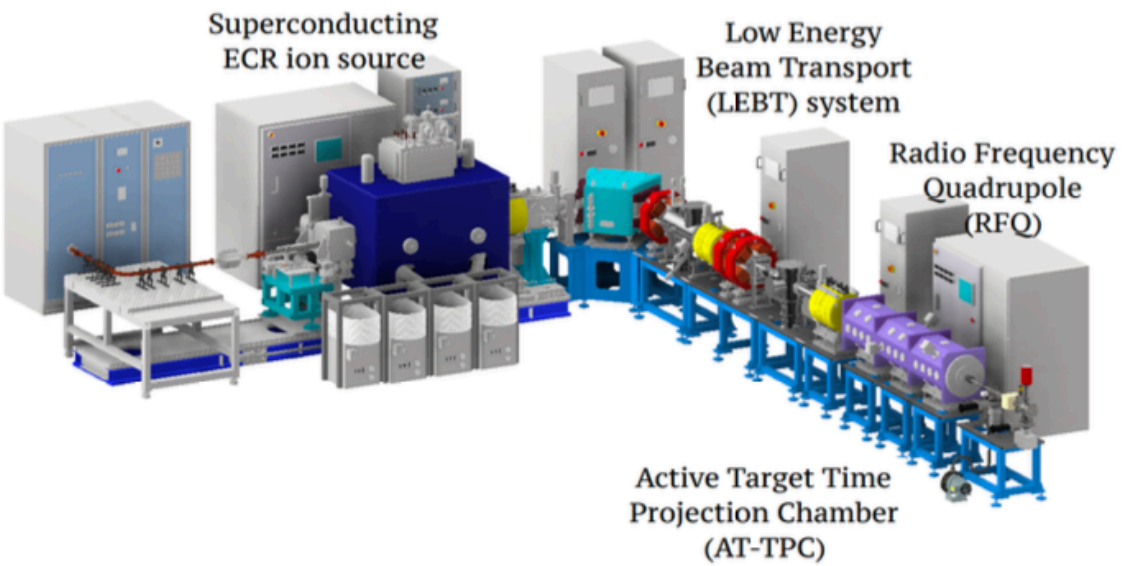
↑ significant lack of experimental data below 1 MeV



Measurement of cross section of $^{12}C(\alpha,\gamma)^{16}O$ near the Gamow window

COREA experiment

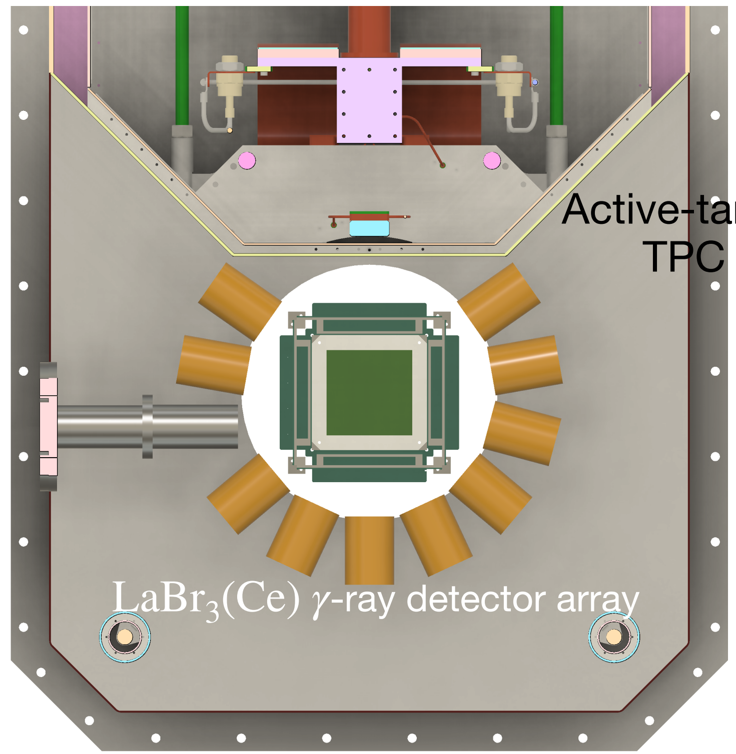
- 500 keV/u 100 pμA $^{12}C^{q+}$ ion beam
- active target TPC w/ ^{4}He gas
- Measurement of p/q with the 3 T magnet
- $LaBr_3$ detector array for the E1/E2 capture ratio measurement
- Coincidence measurement of recoil ^{16}O and γ

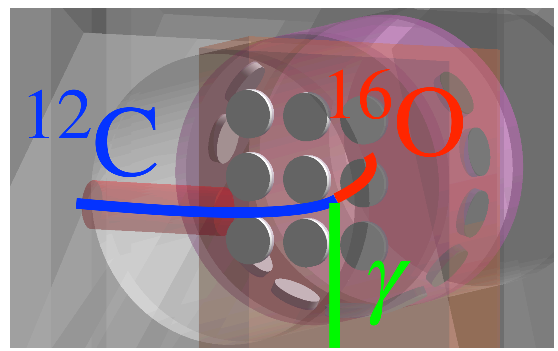


KBSI Busan Ion Beam Accelerator BIBA

S.H. Kim & J.K. Ahn, "Development of a GEM-based time projection chamber prototype for low-energy rare-isotope beam experiments", NIM A 962, (2020)

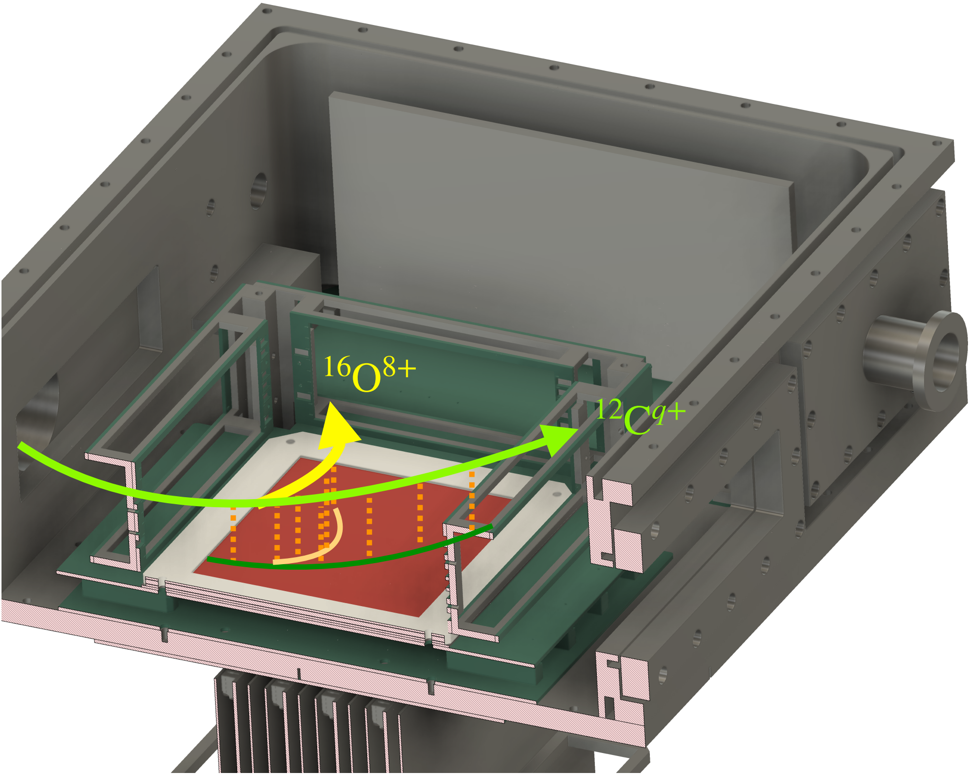
3 T SC Magnet

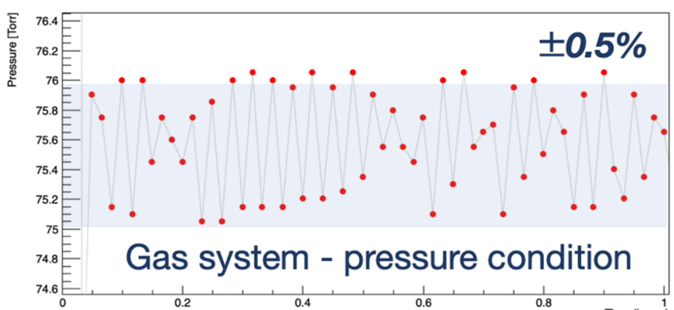


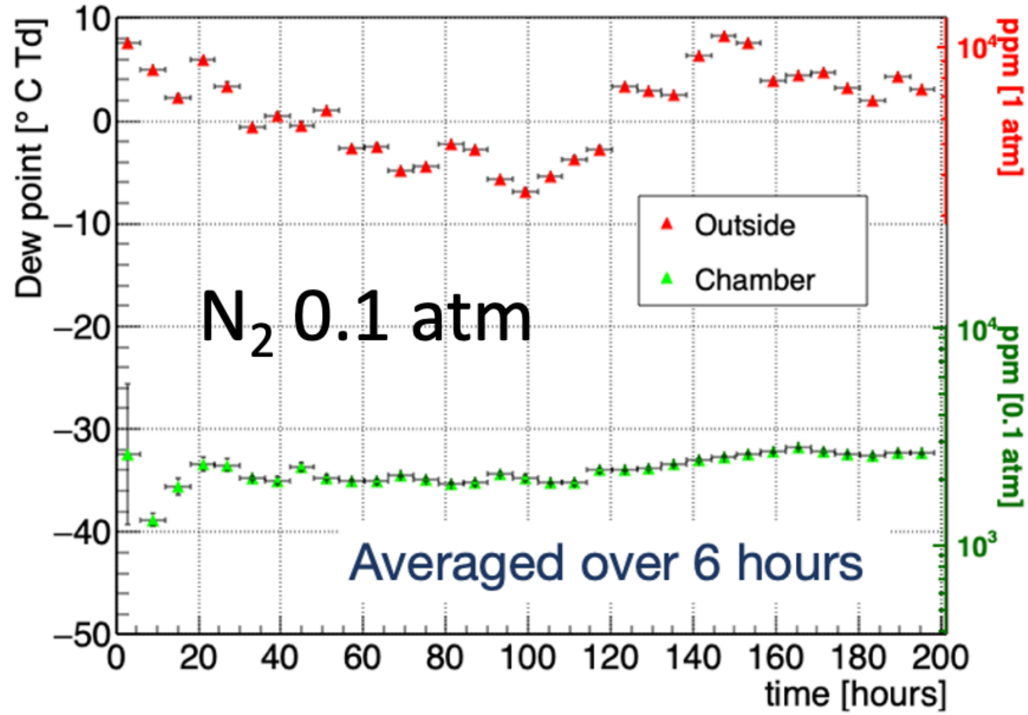


▪ Active Target TPC

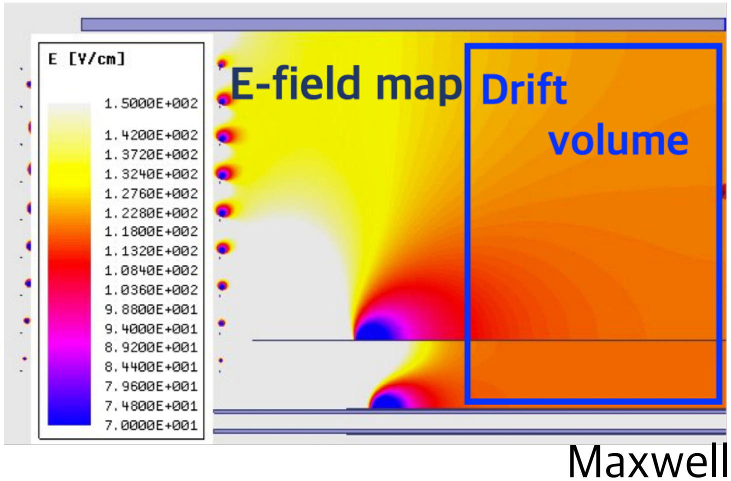
- Operation at 0.05 atm - 0.5 atm He : iC_4H_{10} = 9:1
- Wire-type Field cage
- Amplification w/ Triple GEM

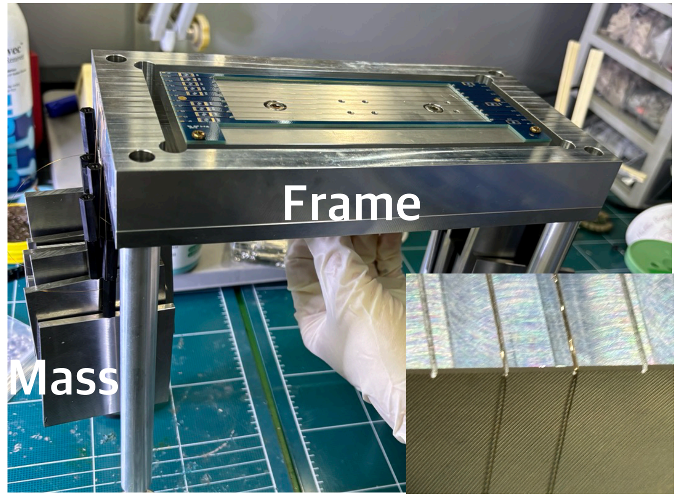


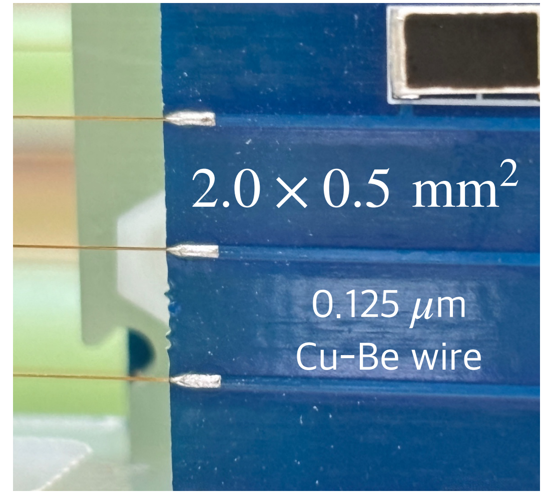


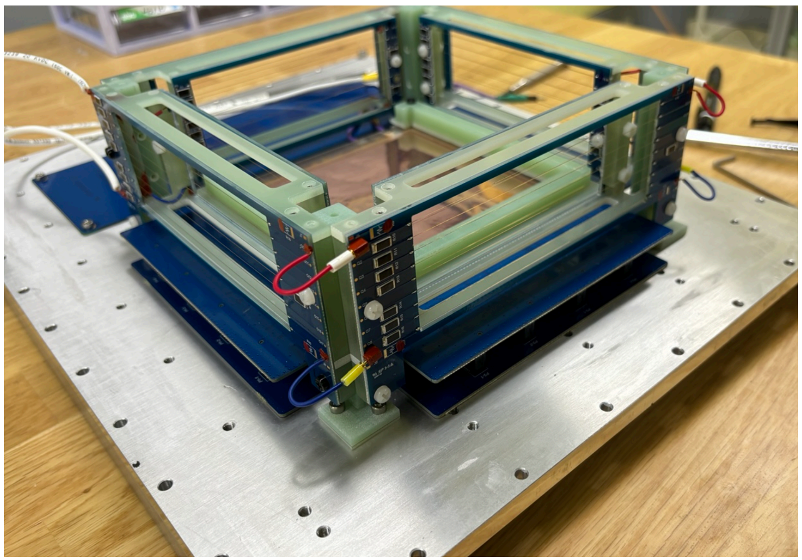


Active Target TPC - Field Cage



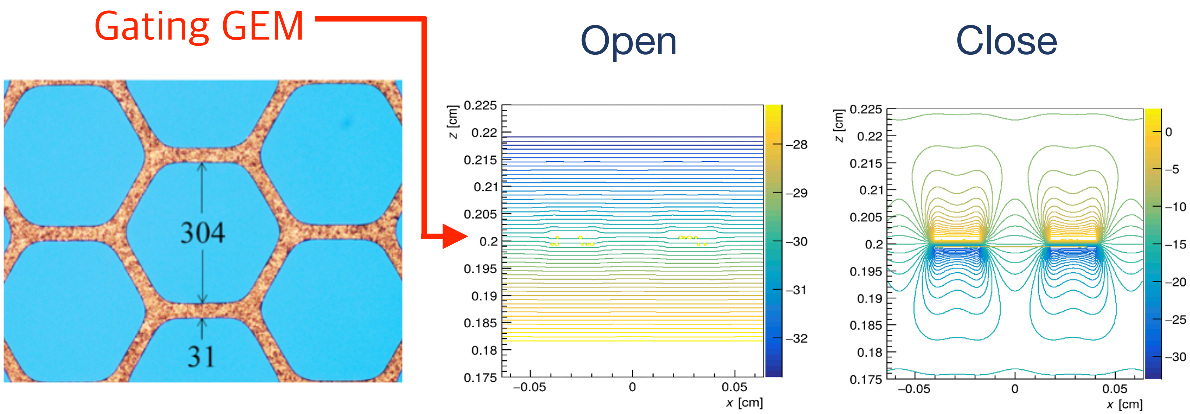


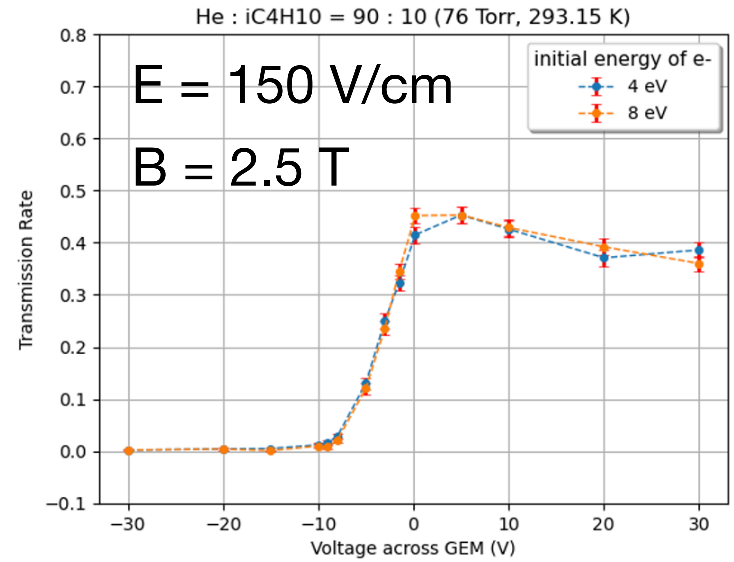




- Double-sided field cages, spaced 2 cm apart, were employed to establish a uniform E-field.
- A dedicated frame and mass ensure consistent wiring and high reliability.

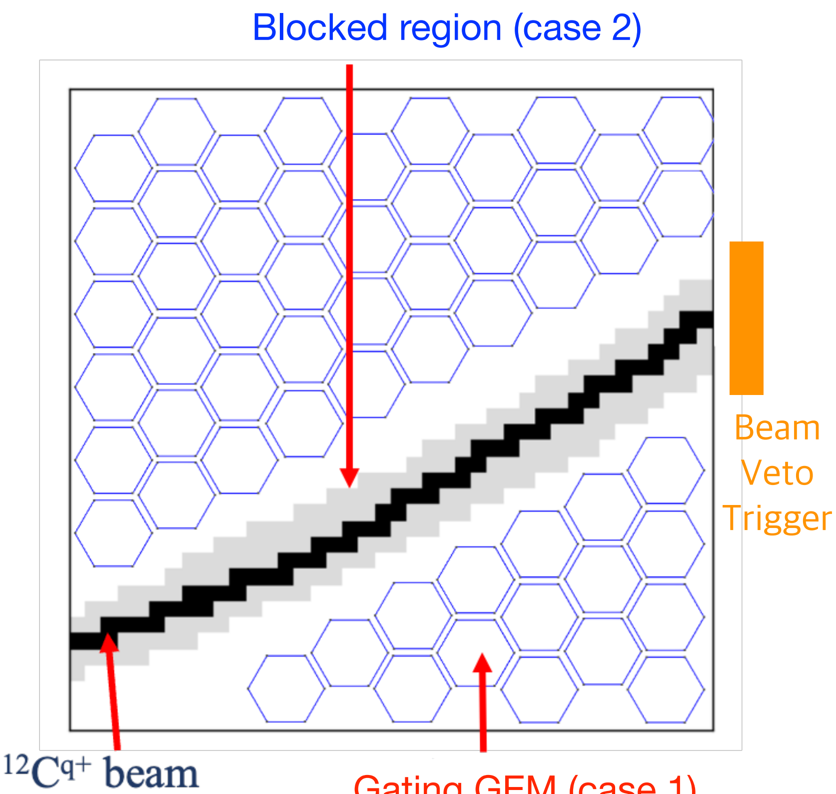
■ Active Target TPC - Gating system

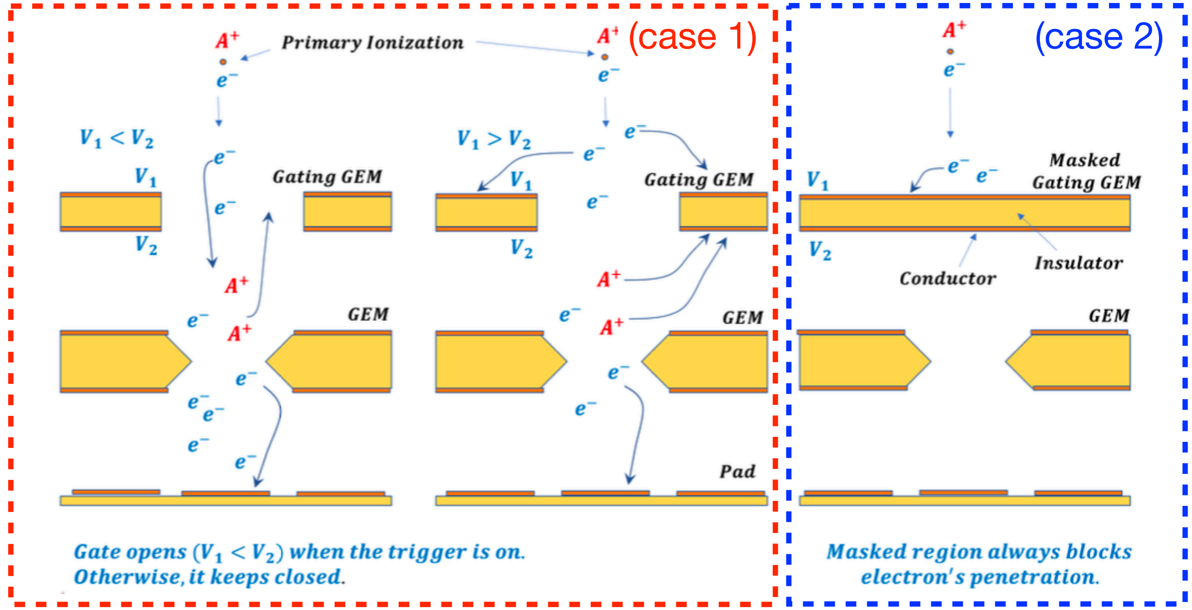


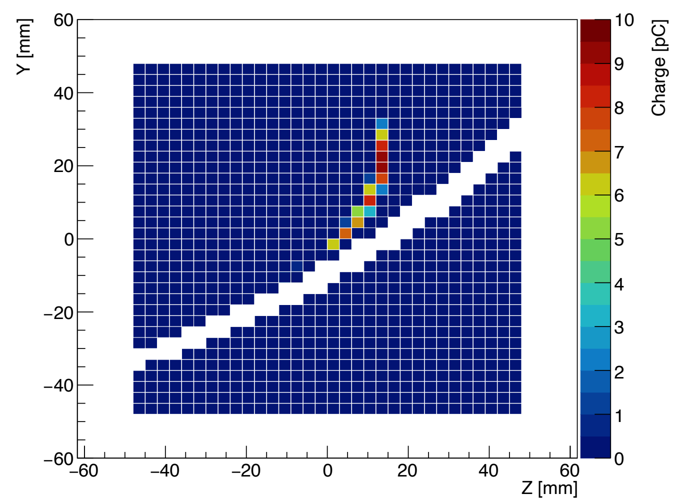


Gating GEM HV driver and LaBr3 Readout with MPPC - Dahyun Choi (7/8 Tue. 16:15)

▪ Active Target TPC - Gating system



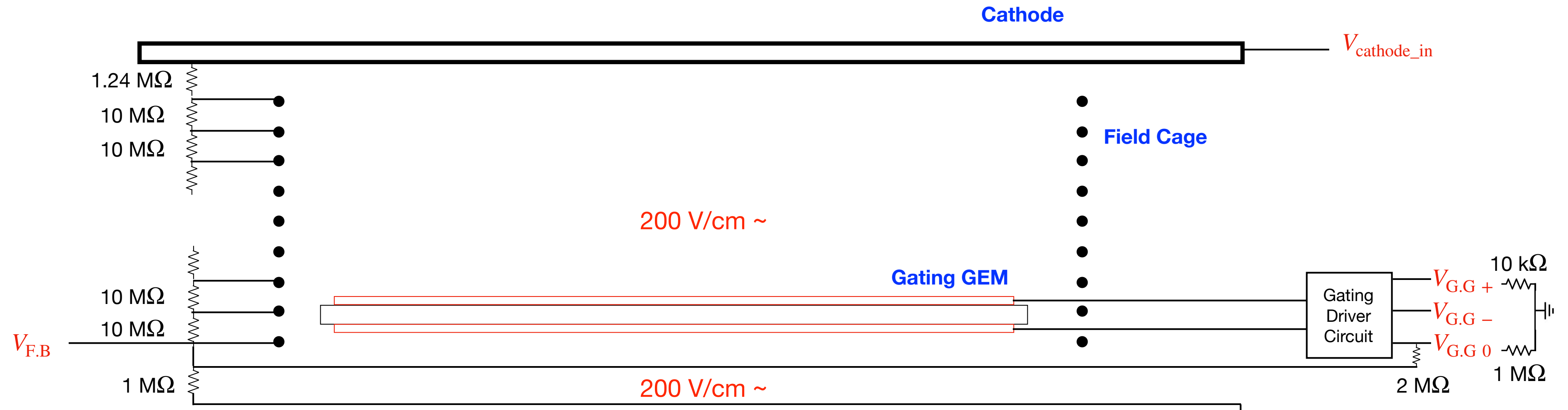


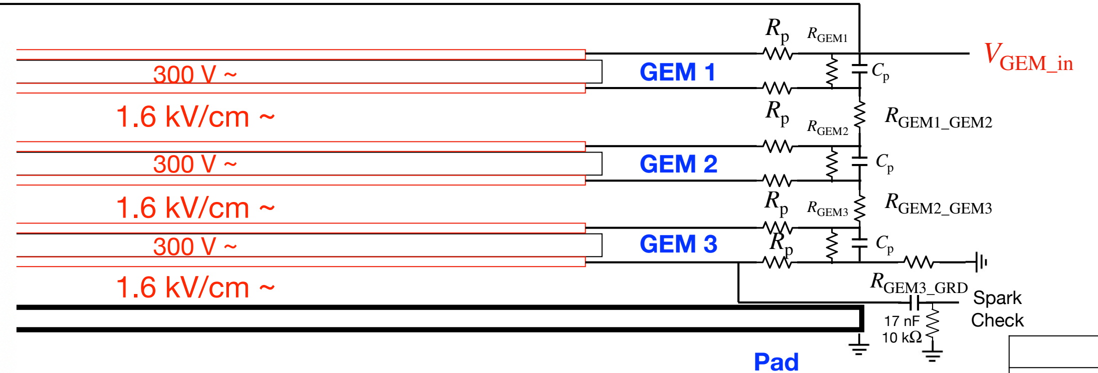


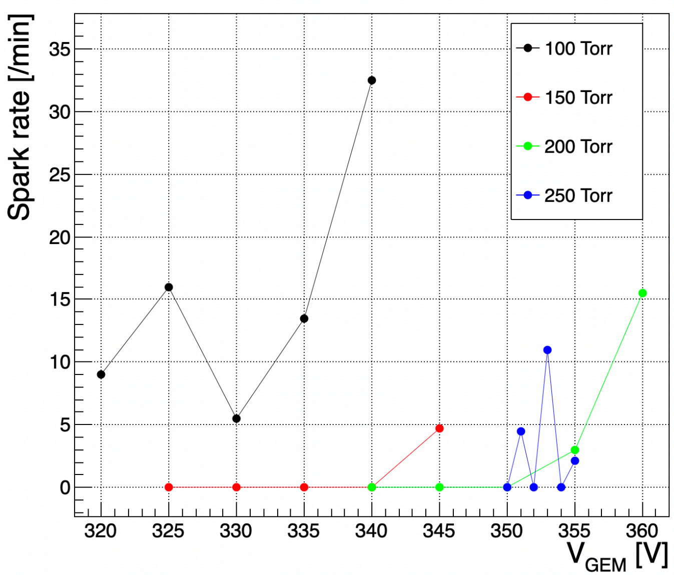
Blocking **High Intensity Beam** region

- Space charge effect, ion back flow ↓
- Stable operation

Performance test of Active Target TPC



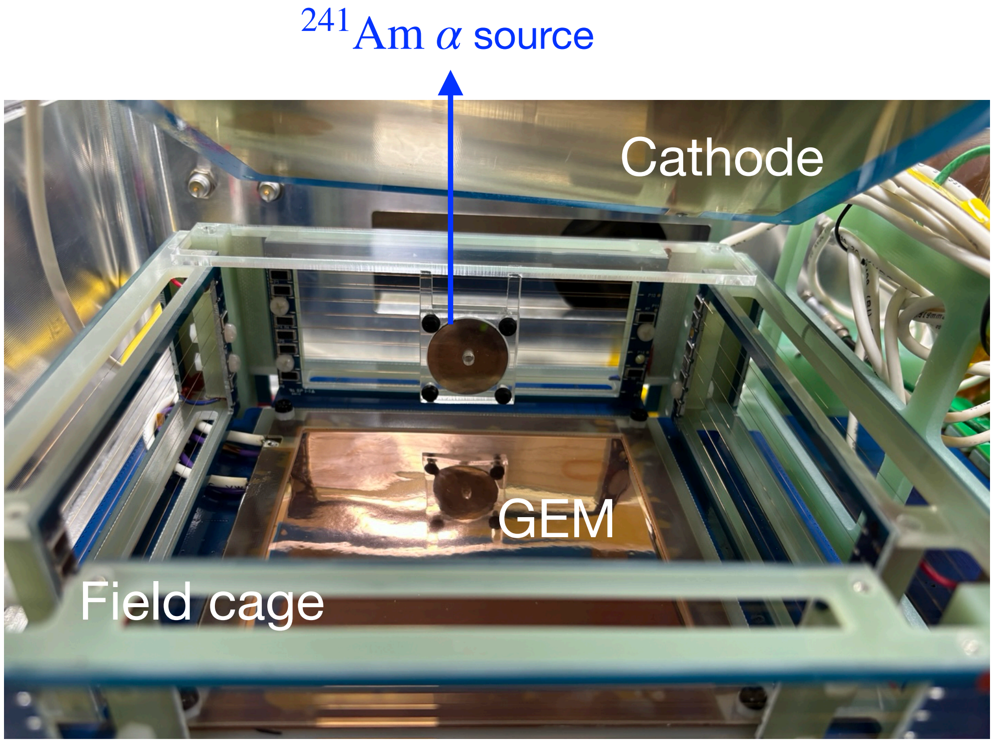


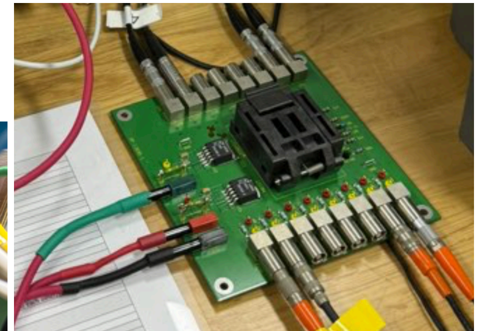


- To ensure stable operation even at 0.05 atm, component values are being adjusted.
- The entire TPC circuit is continuously tested while monitoring the spark rate.

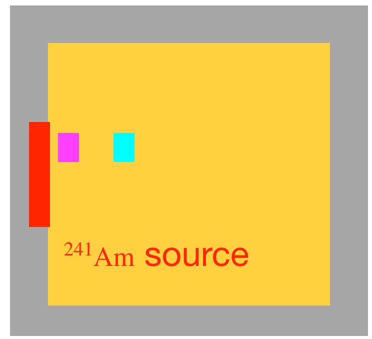
	[MΩ]
R_FCG	10*n
R_p	4.7
R_GEM1_GEM2	1.2
R_GEM2_GEM3	1.2
R_GEM3_GRD	1.2
R_GEM1,2,3	1
C_p	1 nF

▪ Performance test of Active Target TPC



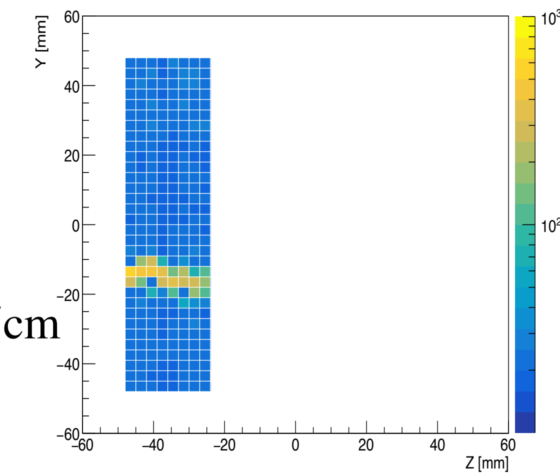


analog shaper
- 1 V/pC

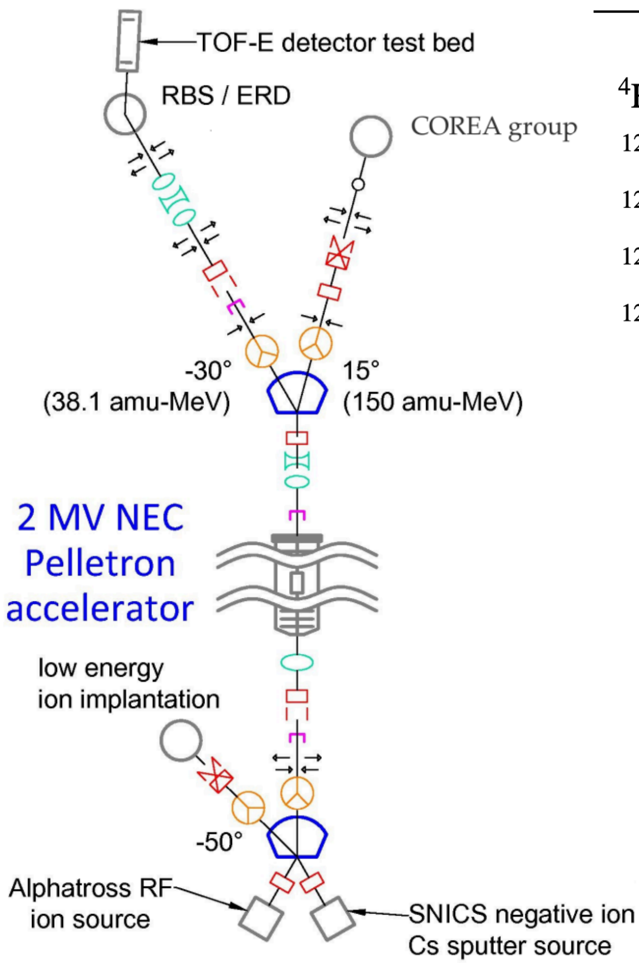


- Performance tests using an ^{241}Am source are underway for different gas mixtures and pressures.

Event Display
- Self Trigger
- $V_{\text{GEM}} = 300$ V
- $E_{\text{field}} = 200$ V/cm
- P10, 300 Torr

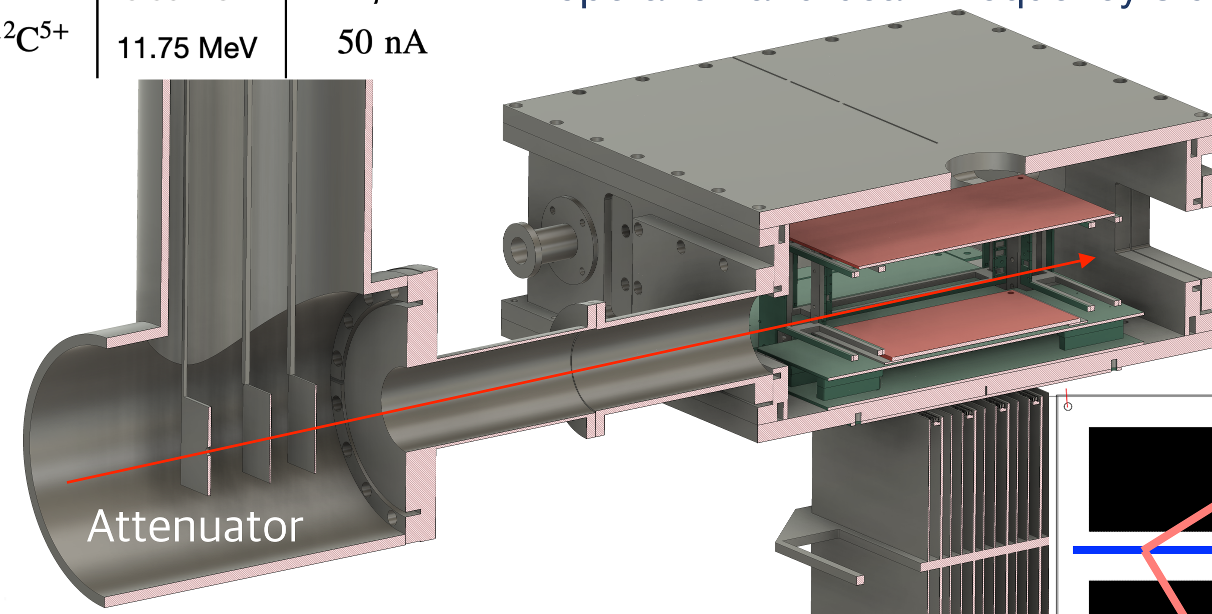


Plan - Performance test at KIST Pelletron

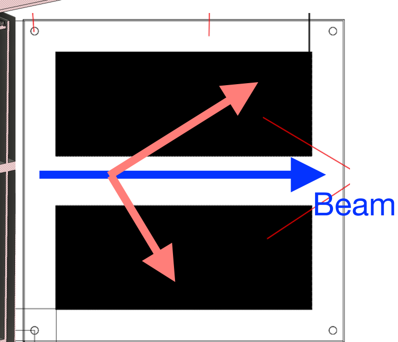


Ion	Energy	Current
p	2 MeV	$2\ \mu A$
$^{4}He^{2+}$	3.9 MeV	$1.2 - 2\ \mu A$
$^{12}C^{2+}$	5.92 MeV	$3\ \mu A$
$^{12}C^{3+}$	7.85 MeV	$10\ \mu A$
$^{12}C^{4+}$	9.80 MeV	$3\ \mu A$
$^{12}C^{5+}$	11.75 MeV	$50\ nA$

- Diffusion and gain studies for various energies and ions will be conducted w/o B-field at this stage.
- Prototype Gating GEM will be tested to refine the gating system.
- An attenuator will be added to enable stable operation and beam frequency studies.



We kindly ask for you support!

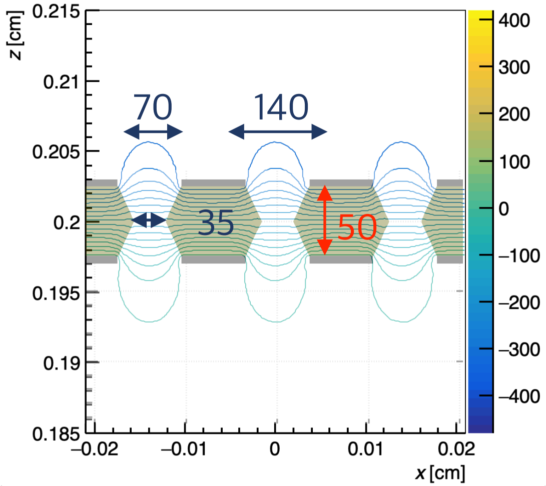


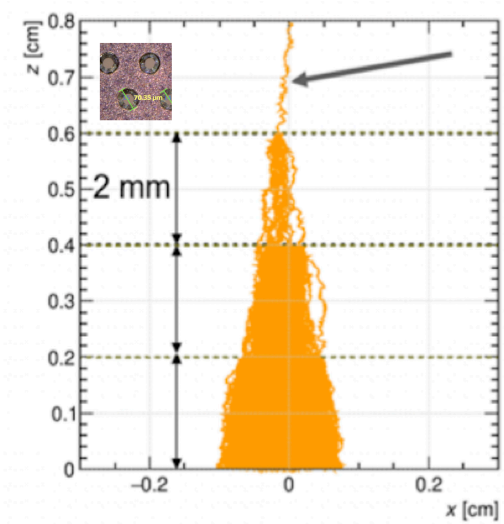
Prototype Gating GEM

▪ Active Target TPC - Simulation study

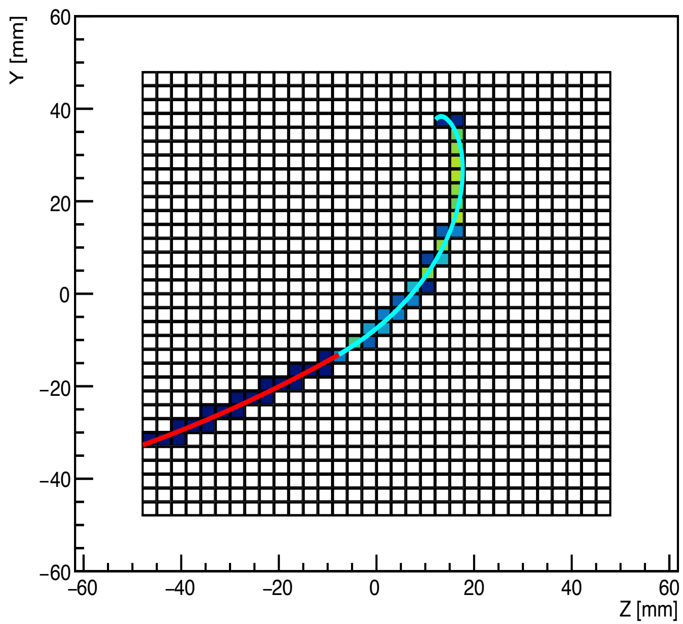
H.M. Yang, “Track Reconstruction in the Active-Target Time Projection Chamber using Deep Learning Methods”, Master’s thesis

$$\frac{dC_i}{d\rho} = \frac{en_i}{2\pi\sigma^2}\exp\left(-\frac{(\rho-\rho_i)^2}{2\sigma^2}\right), \sigma = \sqrt{D_T^2 L_i + \sigma_{\mathrm{GEM}}^2}$$

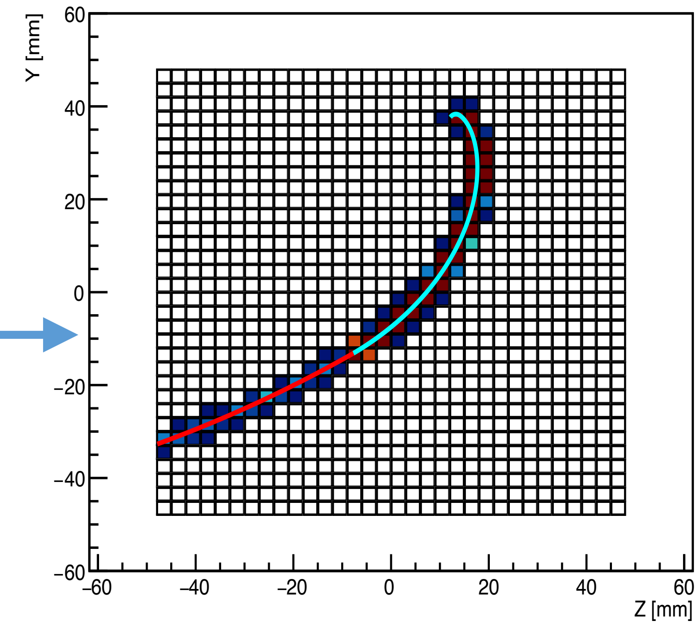




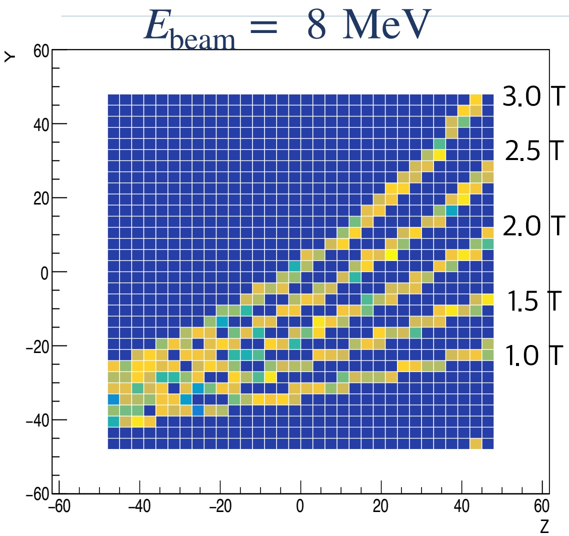
Geant4

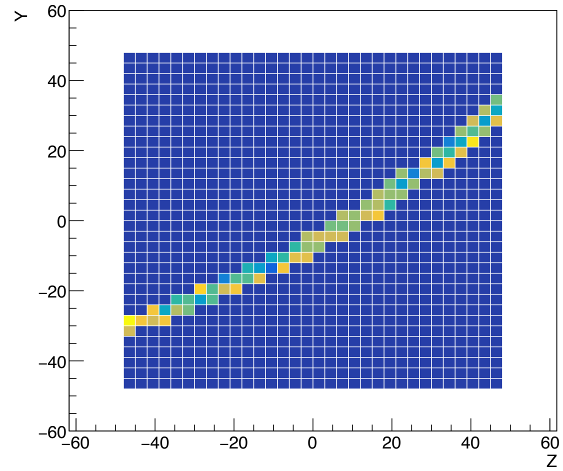


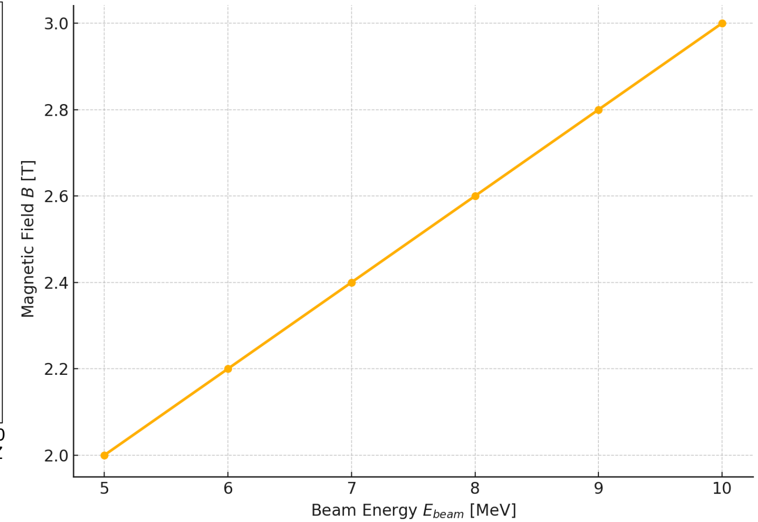
Geant4 + Garfield++



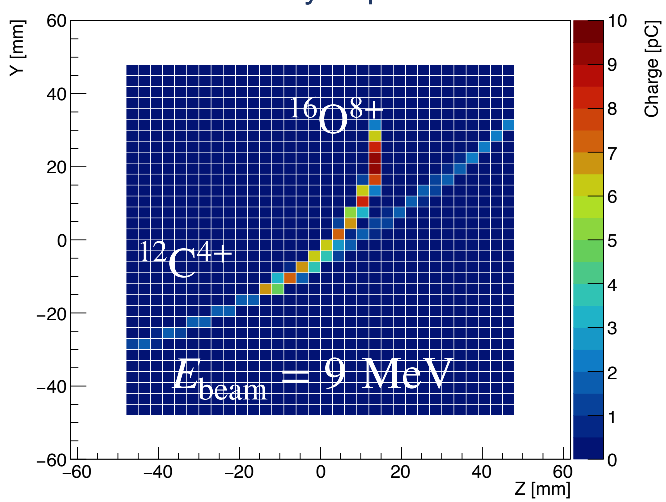
Active Target TPC - Simulation study

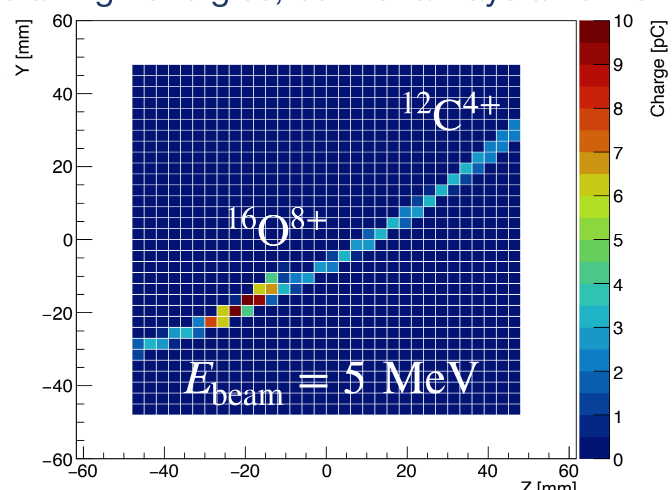


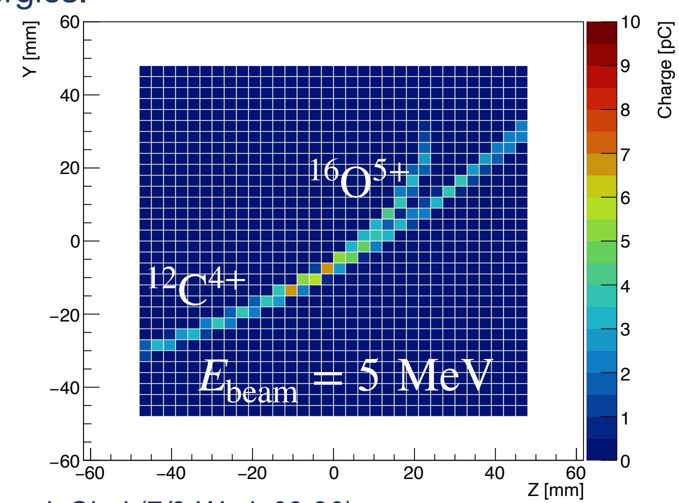




- Simulation study with various E_{beam}, B and charge states
- Recoils are easily separated from beams at high energies, but not always at low energies.

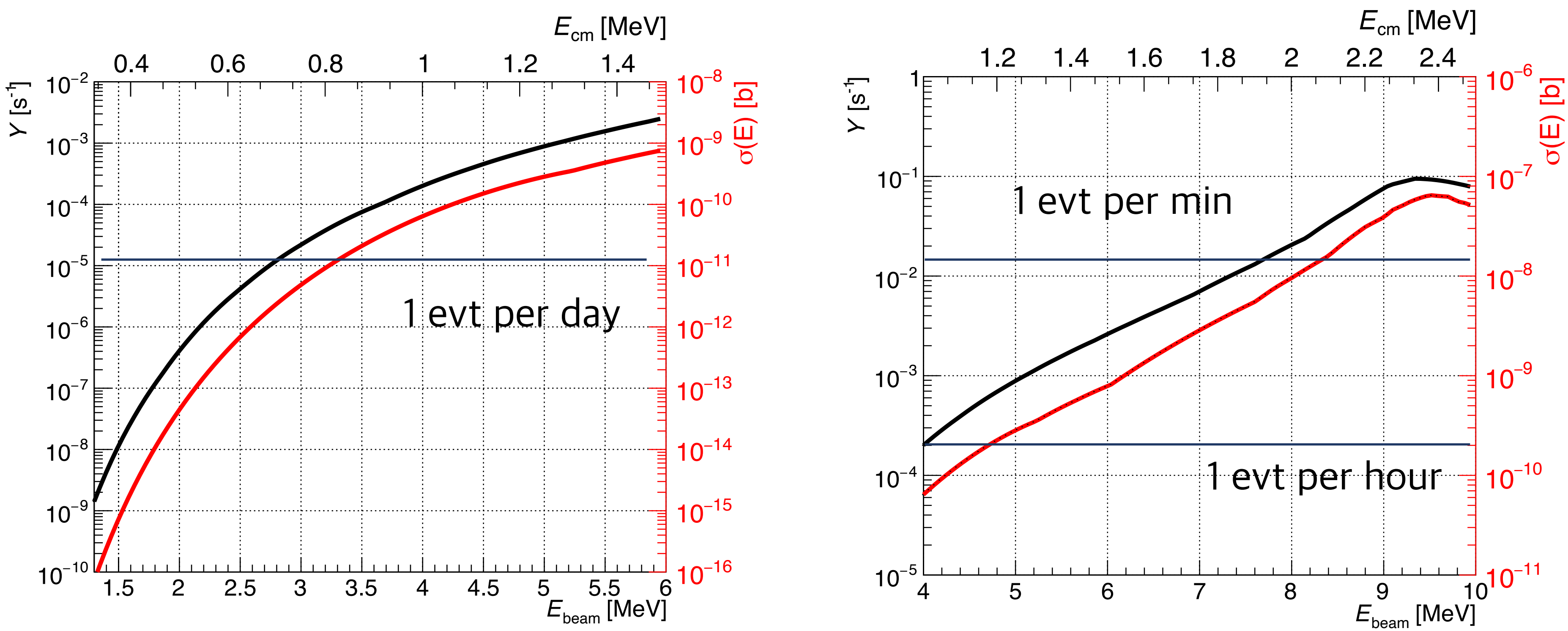






Silicon Detector with a Dipole Magnet - Sungwook Choi (7/9 Wed. 09:20)

Yield Estimation

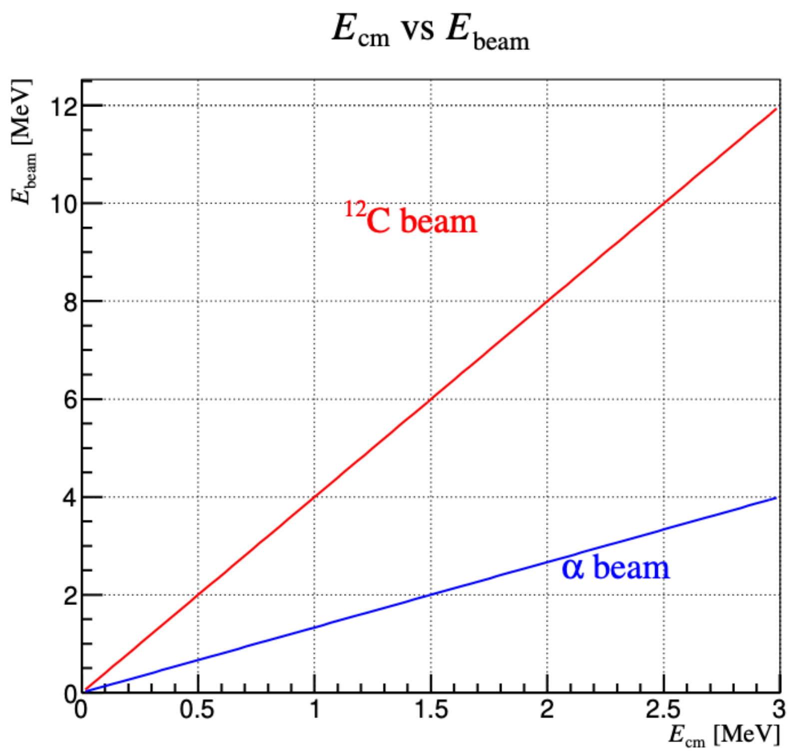


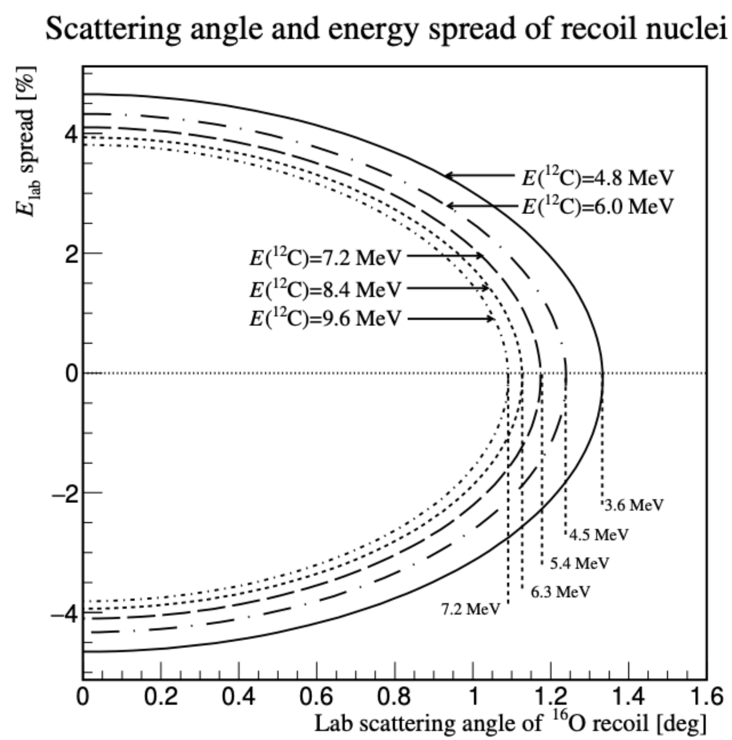
- Small detector prototype will prove the operation principle with high-intensity beams in 2025.
- The COREA experiment will run in these years from early 2026.

Thank you

Backup

■ $^{12}C(\alpha,\gamma)^{16}O$ Kinematics





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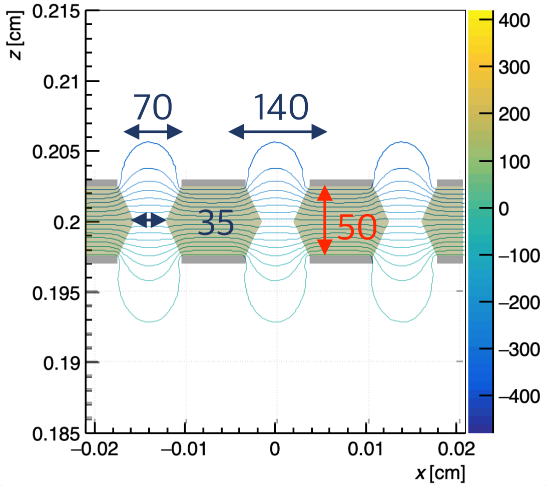

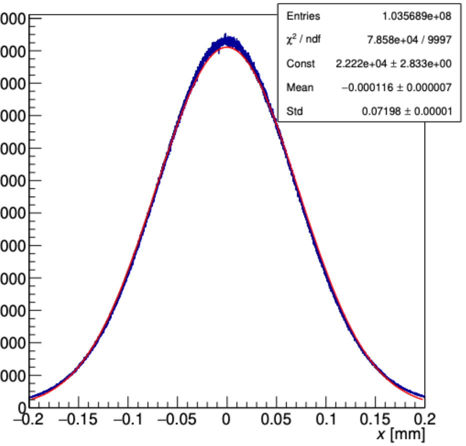

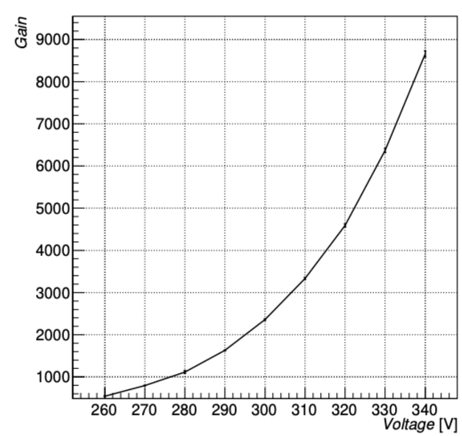

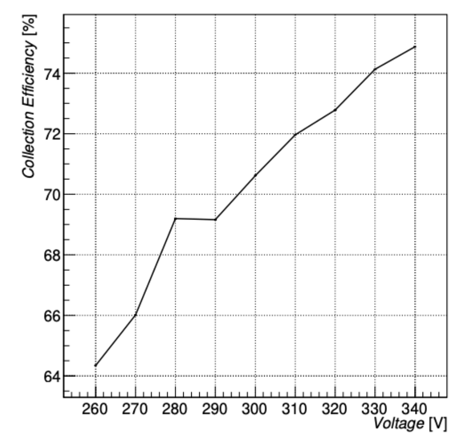

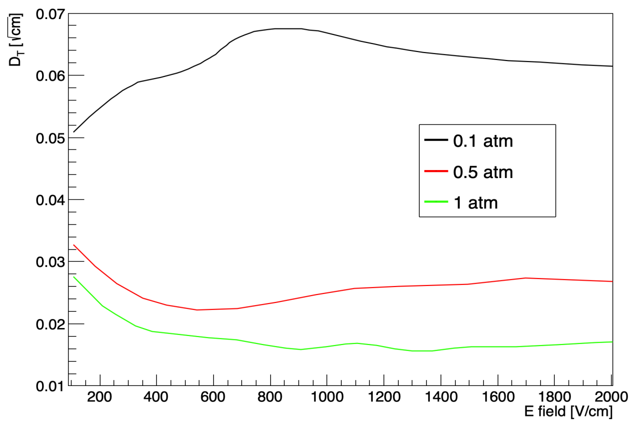

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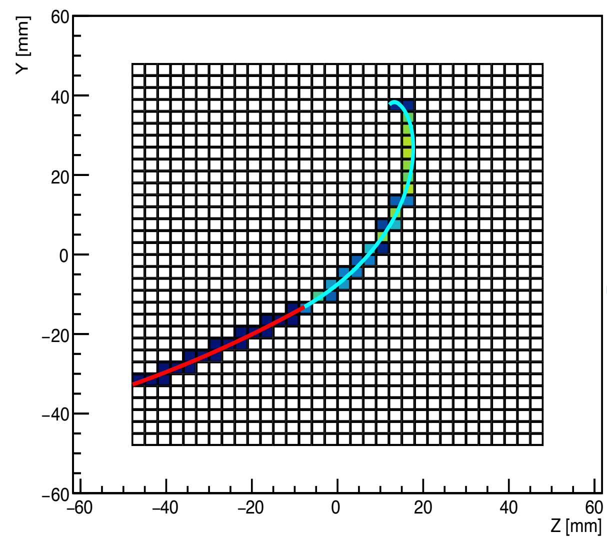
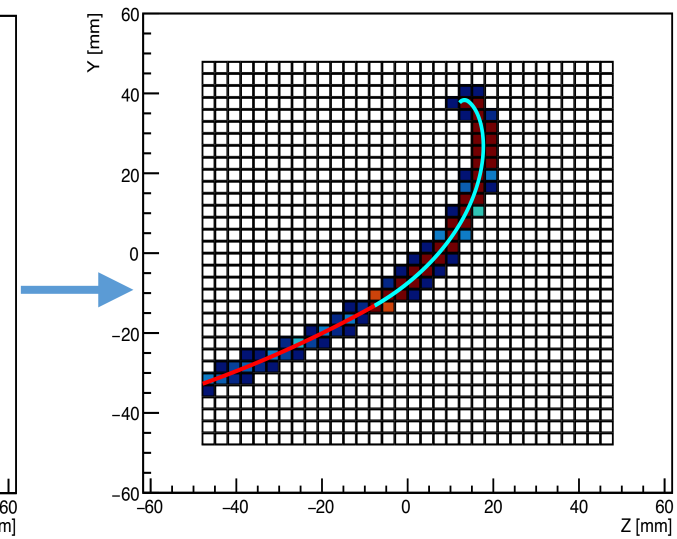
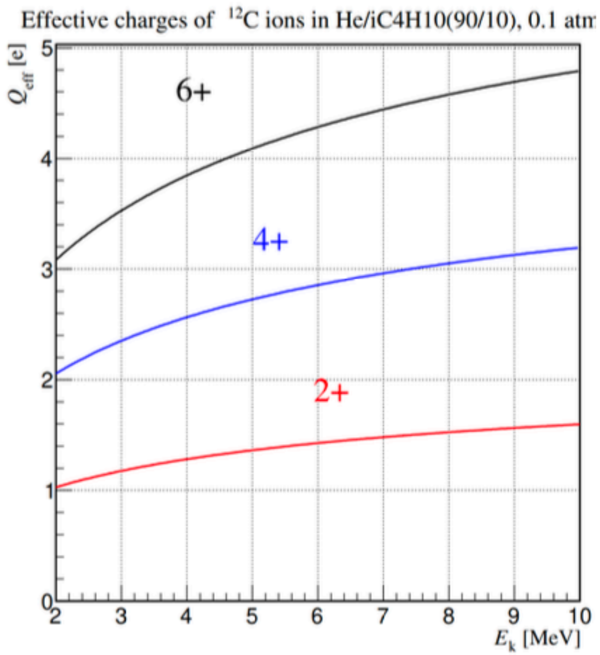
Geant4

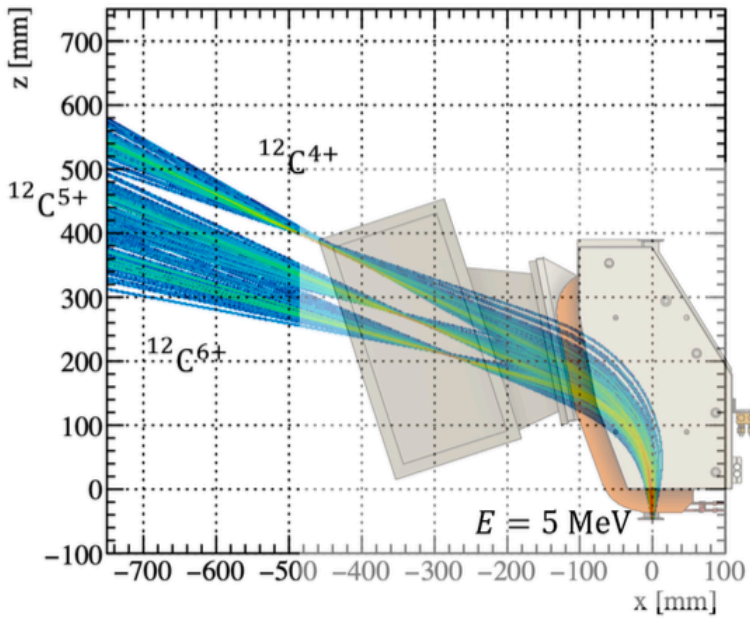


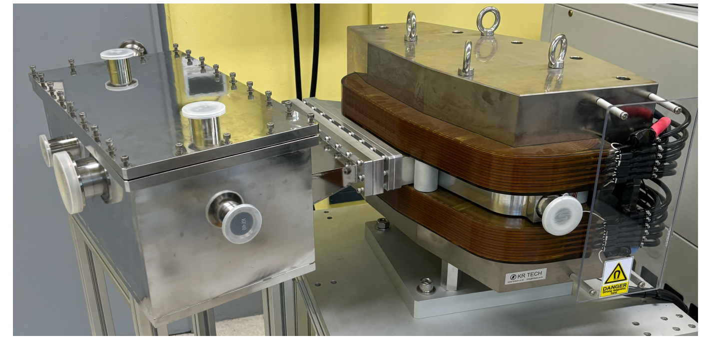
Geant4 + Garfield++



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







1.2 T magnet + Silicon detector

- Recoil nuclei quickly take up 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