

Active Target TPC 시작품 만들기

안정근

2019년 5월 14일

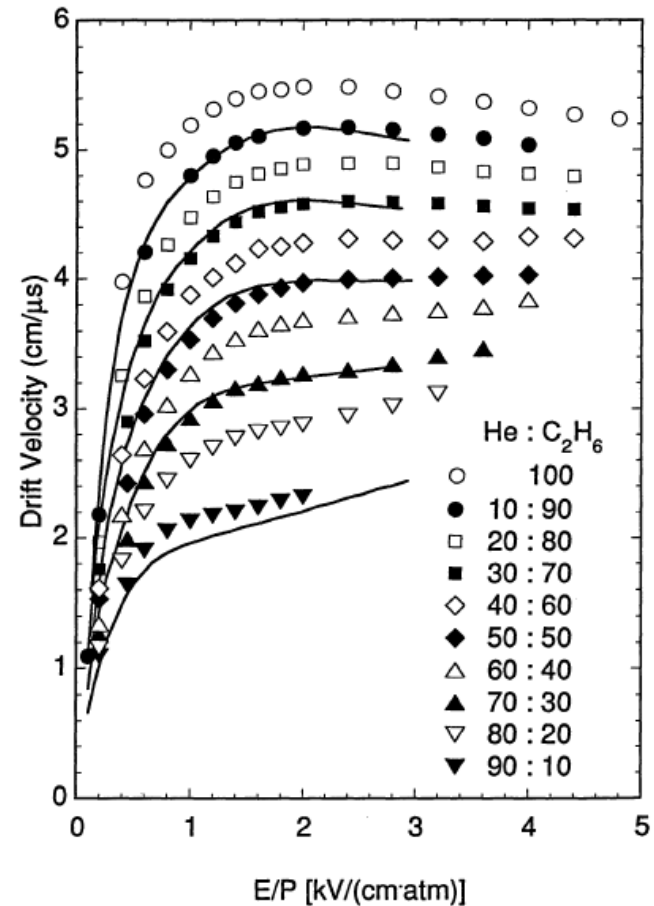
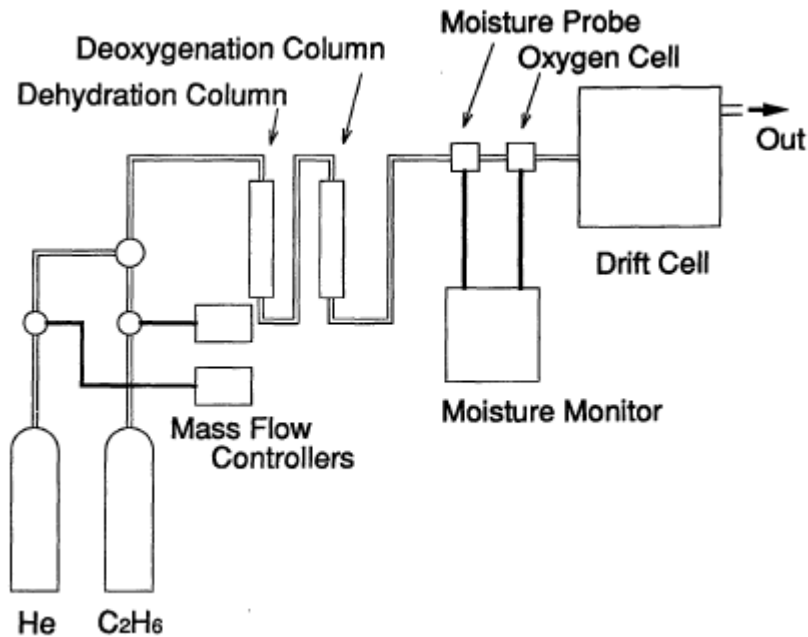
ATTPC 만들기 두 번째 모임

AT TPC **시작품** 만들기

- 디자인 (간단한 계산) → 구매 → 시작품의 시작품 제작
→ 테스트 → 반성/디자인수정 → 구매 → 시작품 제작
(6개월) → 시작품 테스트 (1년)
- **가스 시스템**
- **HV 시스템 (Field Cage)**
- **Readout Chamber**
- **Readout Electronics (GET system)**
- **Geant4 시뮬레이션**

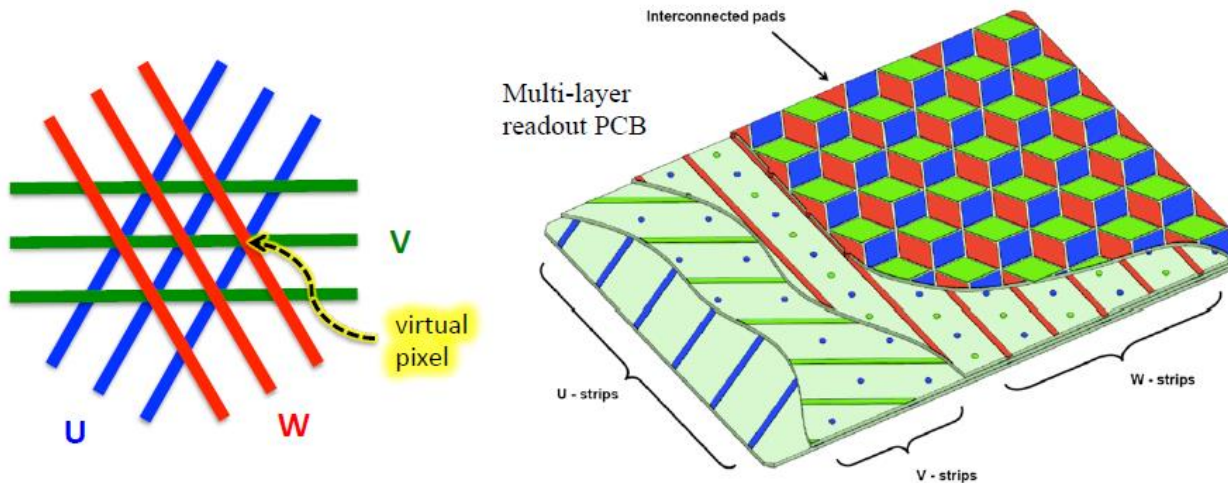
Gas System

- He + CO₂ (i-C₄H₁₀) gas mixture : Gas mixer, Circulation, Monitoring system, Vacuum pump and gauge.



Readout Chamber

- Triple-GEM + anode pad : 국산 GEM 구입, PCB 인쇄
- Circular pad layers? Pads with $2 \times 4 \text{ mm}^2$?
- Strips in three directions? $XY \rightarrow XUV$



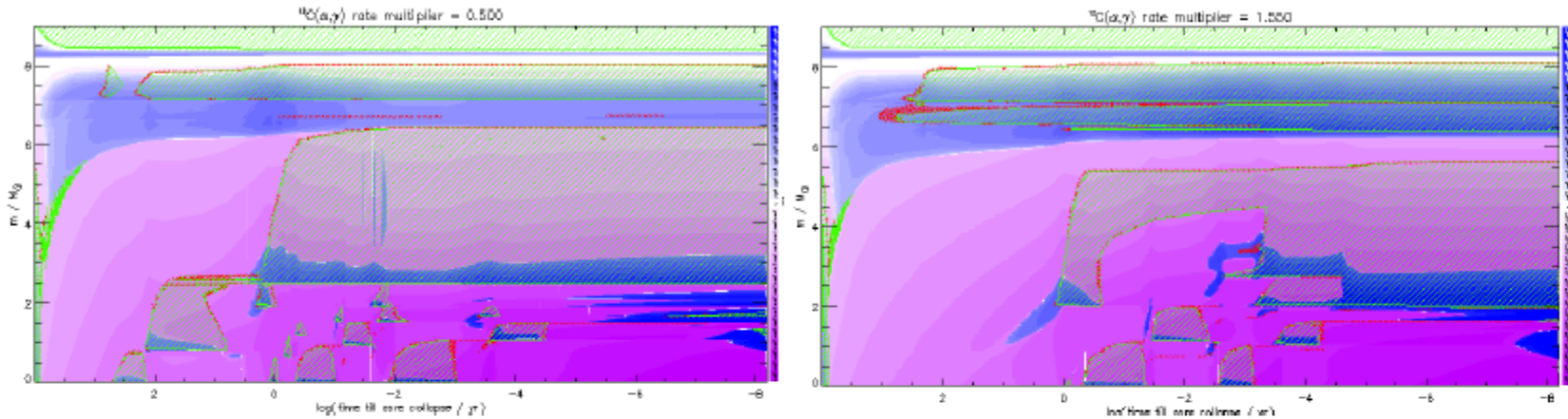
- ${}^4\text{He}^{2+}$ range in ${}^4\text{He}$ gas ($0.178 \times 10^{-3} \text{ g/cm}^3$ at $20 \text{ }^\circ\text{C}$)
- $5.07 \times 10^{-4} \text{ g/cm}^2$ @ 1 MeV (2.85 cm)
- $3.37 \times 10^{-3} \text{ g/cm}^2$ @ 5 MeV (19 cm)
- $1.05 \times 10^{-2} \text{ g/cm}^2$ @ 10 MeV (59 cm)

Prototype TPC at ELI-NP

- Extreme Light Infrastructure (EU Consortium, Romania)
- Electron Linac 300, 720 MeV
- Compton scattered photon beam in 0.2-19.5 MeV with $8.3 \times 10^8/s$.
- Astrophysical S-factor near the Gamow peak (300 keV) in red giant : $^{12}\text{C}(\alpha,\gamma)^{16}\text{O}$
- $^{12}\text{C} + \alpha \rightarrow \gamma + ^{16}\text{O}$
- $\alpha + ^{12}\text{C} \rightarrow \gamma + ^{16}\text{O}$ (X)
- $\gamma + ^{16}\text{O} \rightarrow ^{12}\text{C} + \alpha$

Evolution of Nuclear Burning Phases

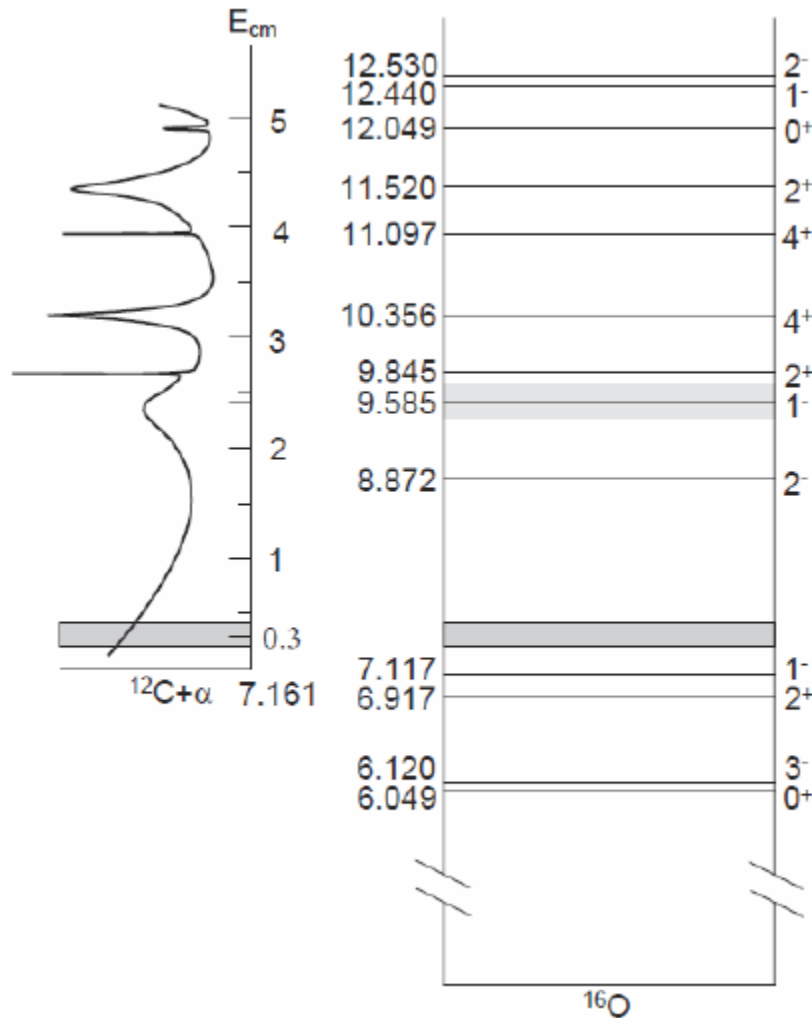
○ Stellar structure in terms of $^{12}\text{C}(\alpha, \gamma)$ rate for a $25M_{\odot}$ star.



Stage reached	Time scale	$T_{\text{core}}(10^9\text{K})$	Density(g/cm^3)
H burning	$7 \times 10^6\text{y}$	0.06	5
He burning	$5 \times 10^5\text{y}$	0.23	7×10^2
C/O burning	600y/6 months	0.93-2.3	$2 \times 10^5 - 1 \times 10^7$
Si melting	1d	4.1	3×10^7
Explosive burning	0.1-1s	1.2-7	varies

³Boyes, Heger and Woosley, 2sn.org/stellarevolution/

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

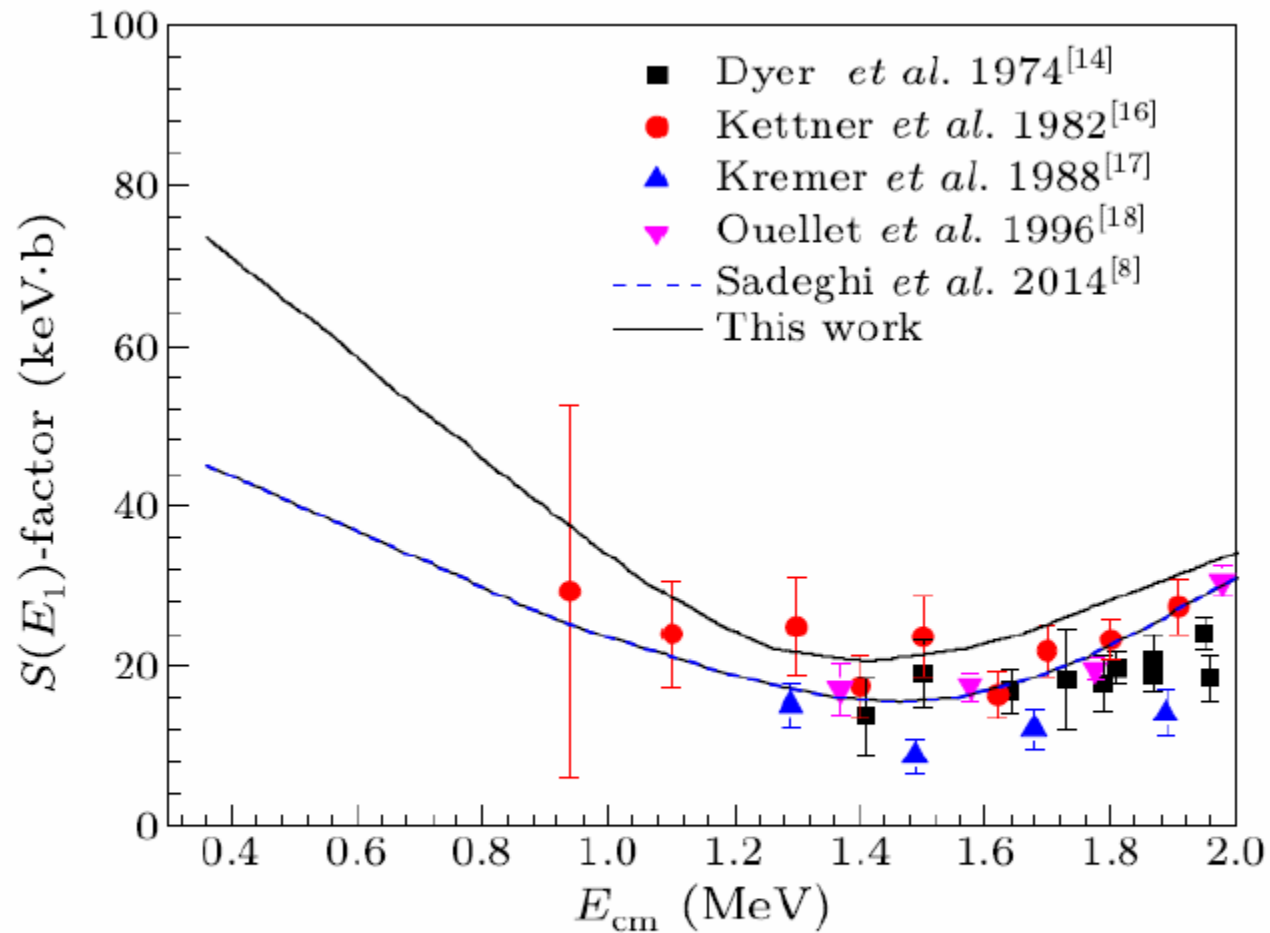


- $^{12}\text{C}/^{16}\text{O}$ ratio after helium burning process affects evolution of heavy stars - supernova or white dwarf.

$$I_{^{12}\text{C}} = 100 \text{ p}\mu\text{A}$$

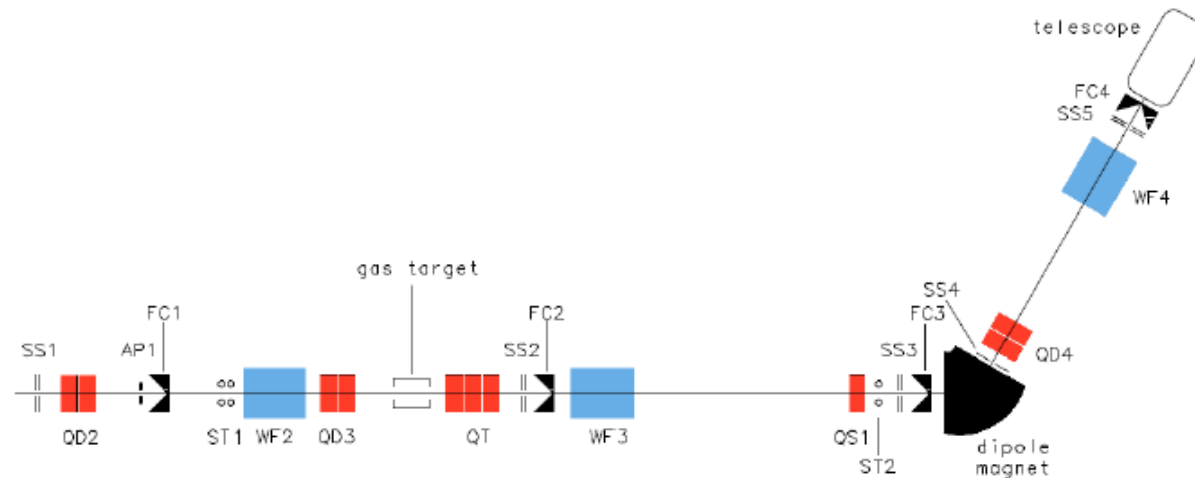
E_{cm} (MeV)	σ (pb)	Rate (fusions/d)
2.0	7500	4×10^5
1.0	36	2000
0.5	0.03	2
0.3	0.0001	0.4

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



⁴K.U. Kettner *et al.*, *Z. Phys. A*, 308, 73 (1982); P. Dyer and C.A. Barnes, *Nucl. Phys. A* 233, 495 (1974)

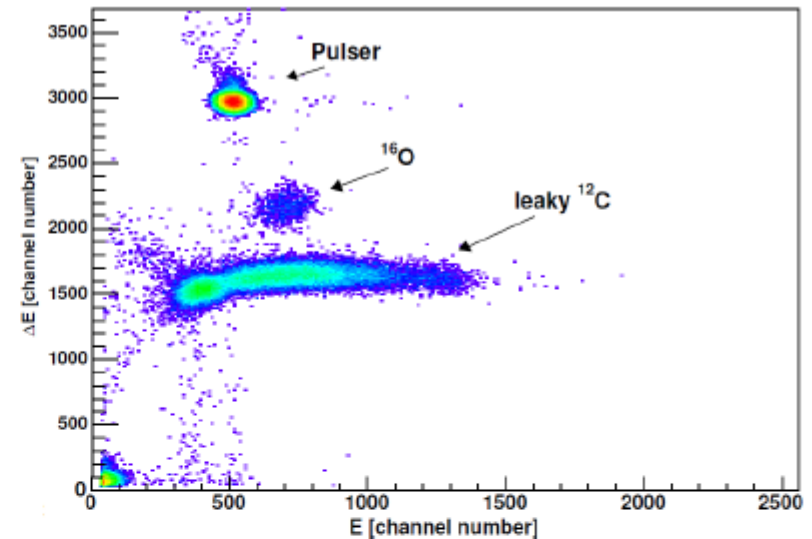
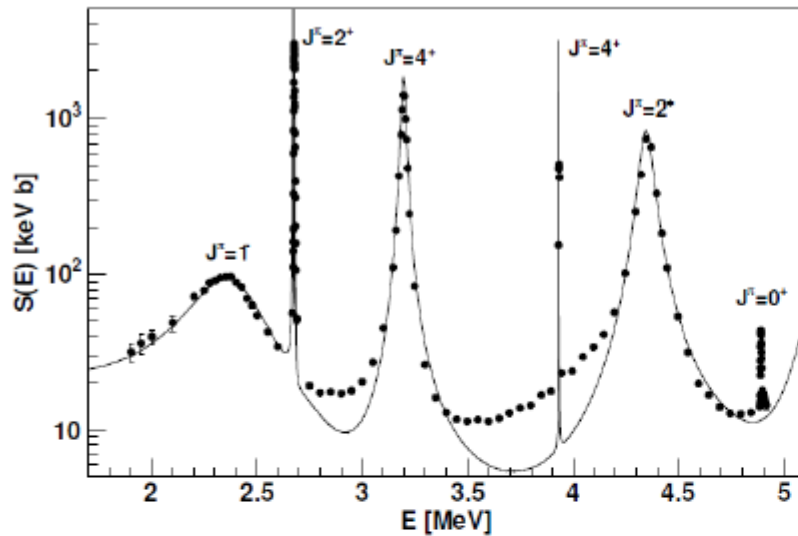
$^{12}\text{C}(\alpha,\gamma)^{16}\text{O}$ Reaction



- 4 MV Dynamitron in Bochum (European Recoil separator for Nuclear Astrophysics ERNA)
- ^{12}C ion beam up to $10\text{ p}\mu\text{A}$ and a windowless ^4He gas target.
- $\Delta E - E$ telescope to measure a recoil ^{16}O ion.

⁸D. Schürmann, *et al.*, Eur. Phys. J. A **26**, 301 (2005)

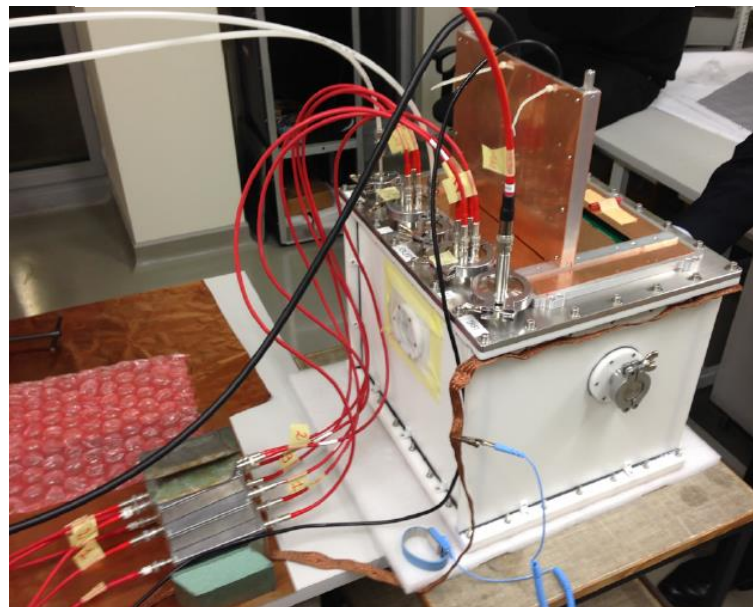
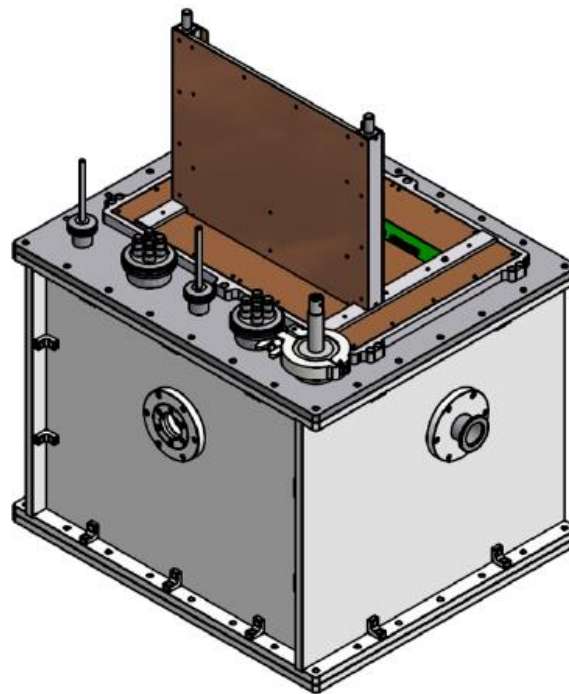
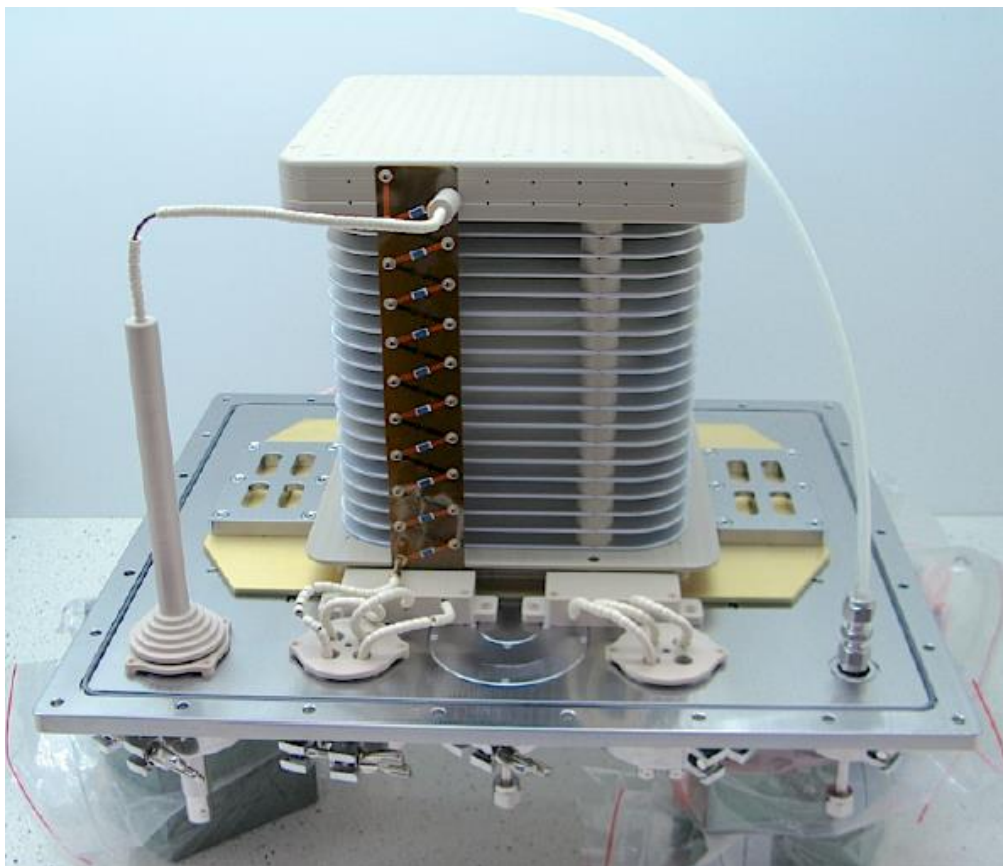
$^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$ Reaction



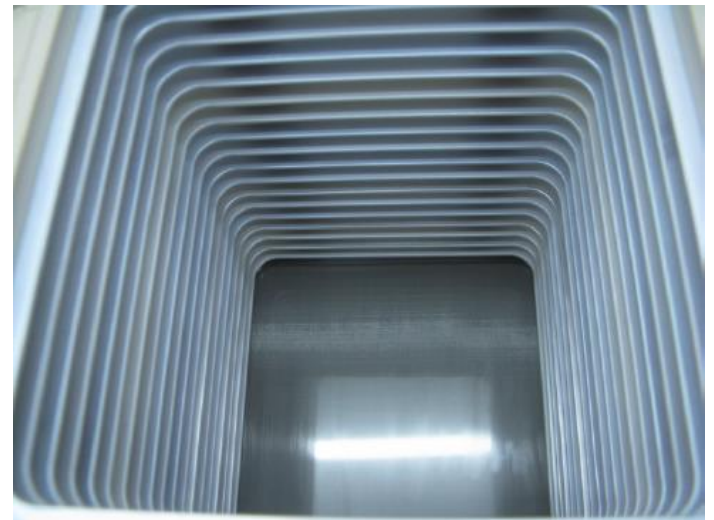
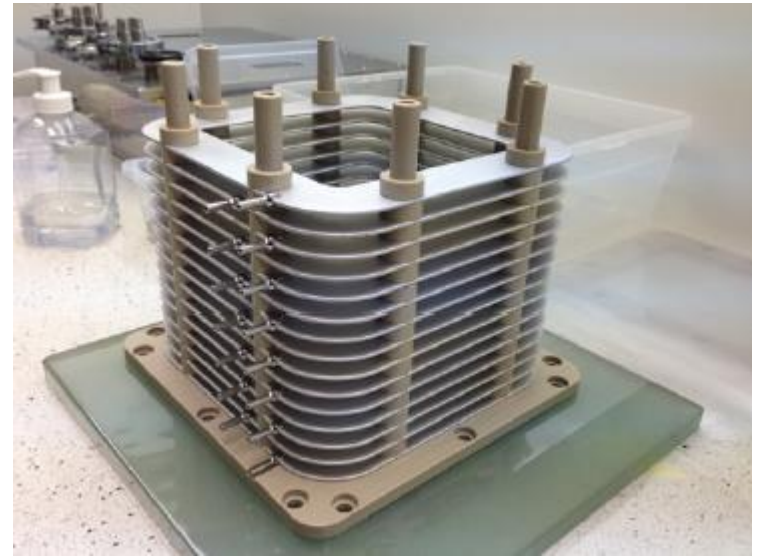
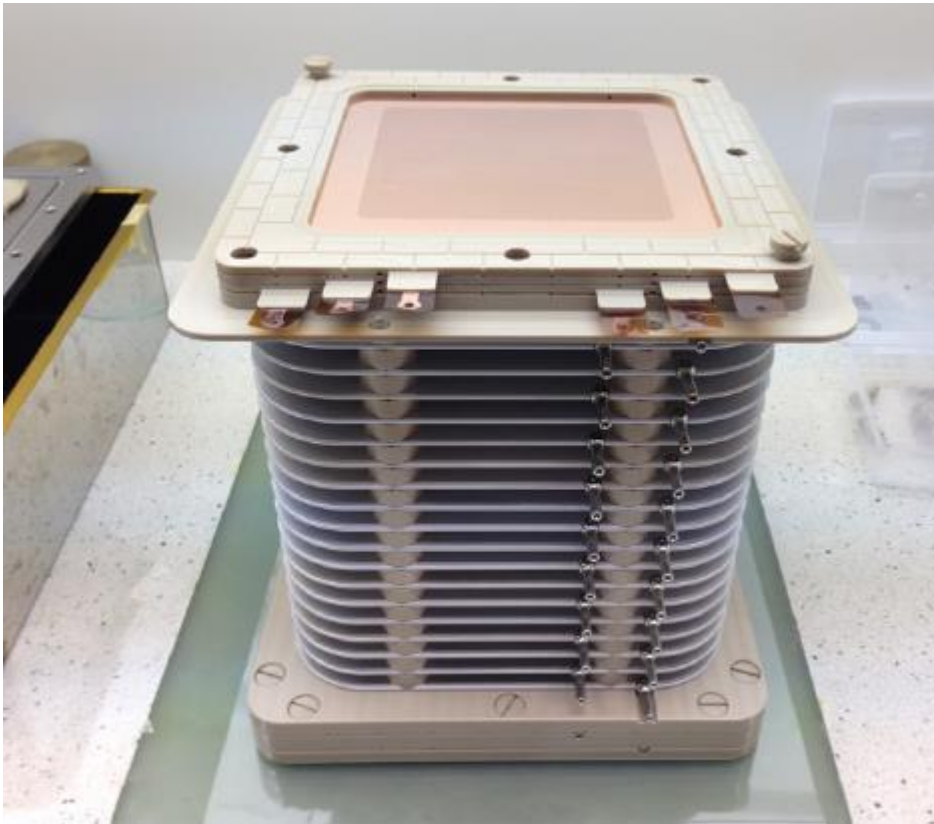
- First direct measurement of the total cross-section of $^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$ via the detection of the ^{16}O recoils.
- Identification matrix of the $\Delta E - E$ telescope at $E=2.2$ MeV for the ^4He gas target and Ar post-stripper.

Prototype TPC at ELI-NP

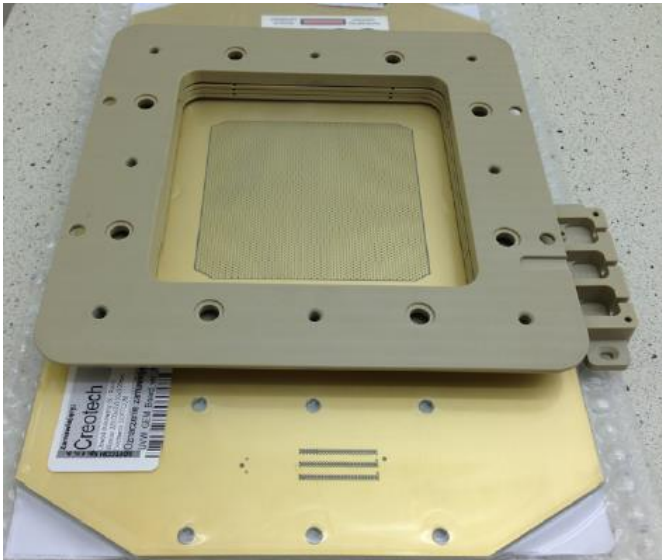
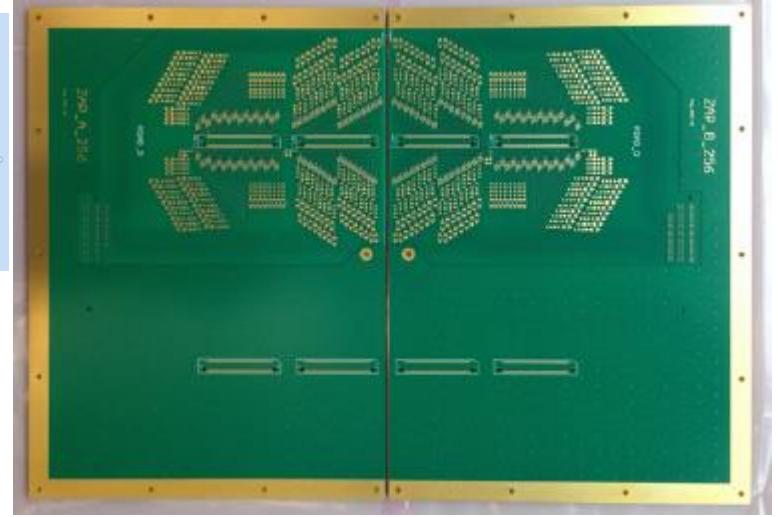
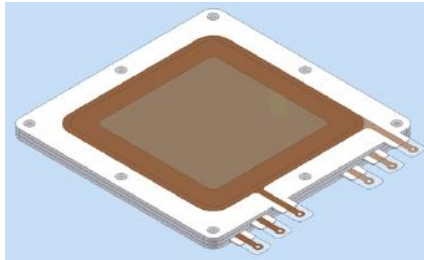
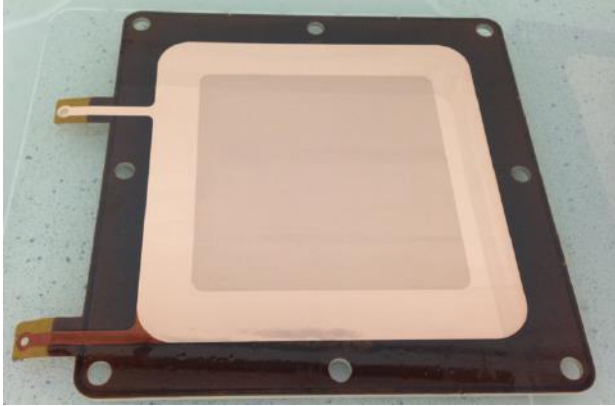
- Mini-eTPC (U. Warsaw)
- 10 x 10 x 20 cm³ @ 1 atm
- 72 U-, 92 V-, 92 W-strips = 256 channels



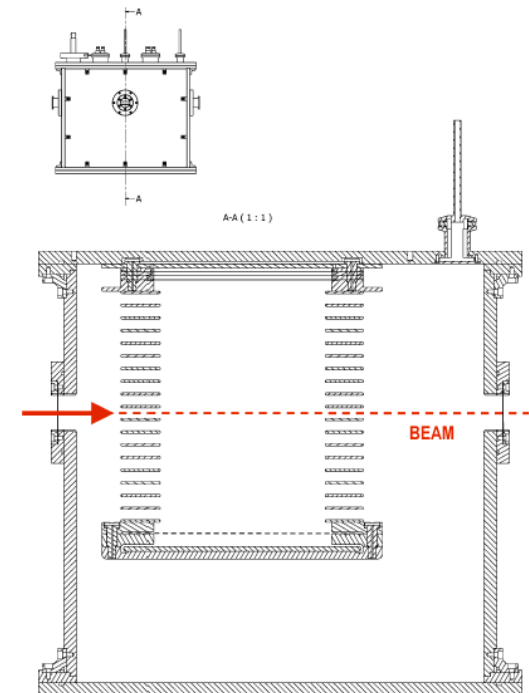
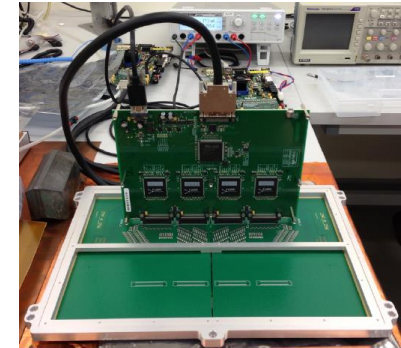
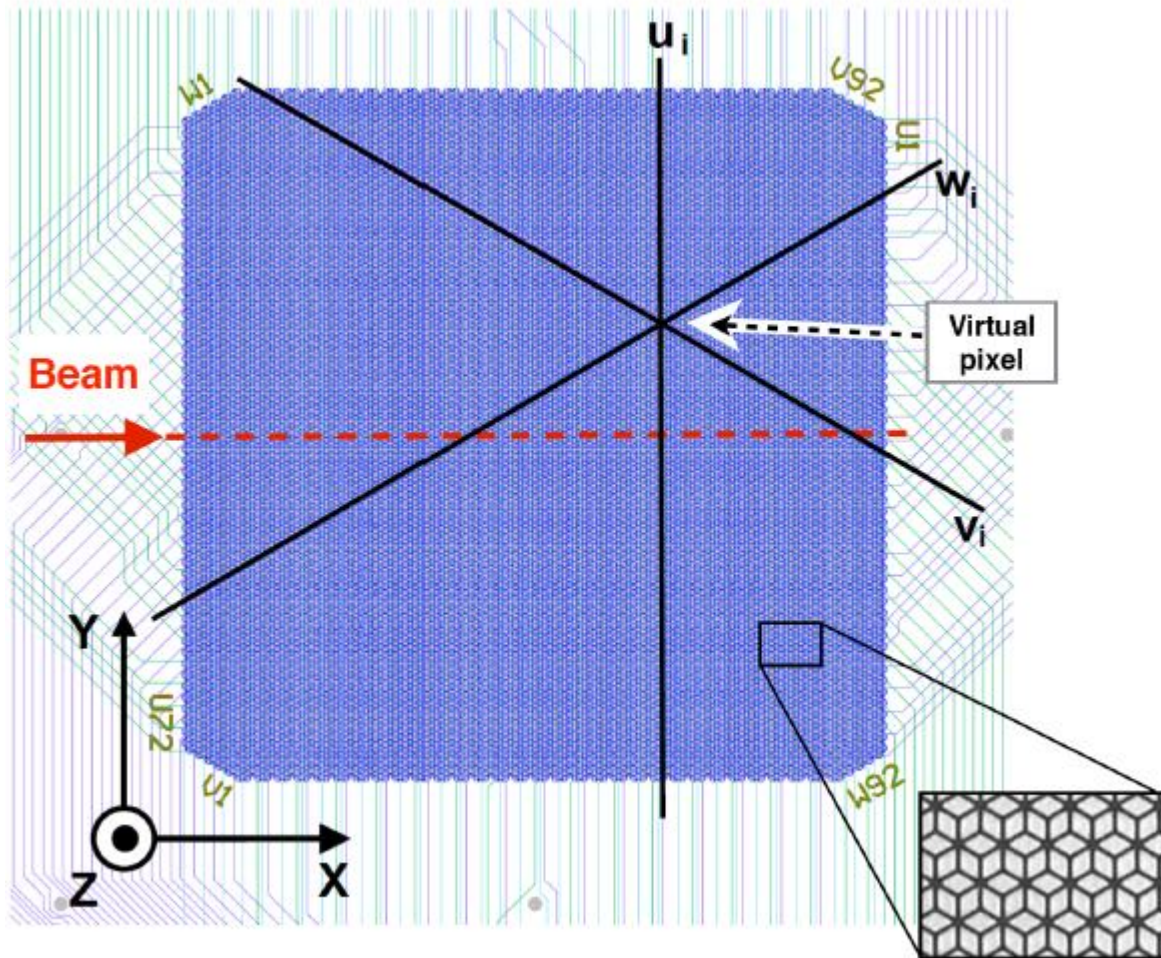
Field Cage



Triple-GEM Stack and Readout Strips



UVW Strips

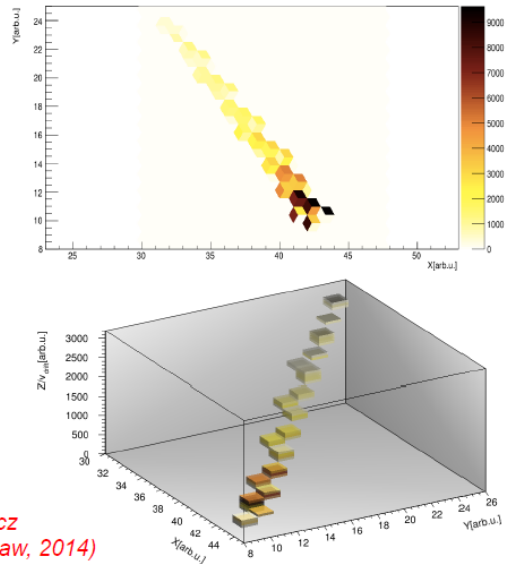
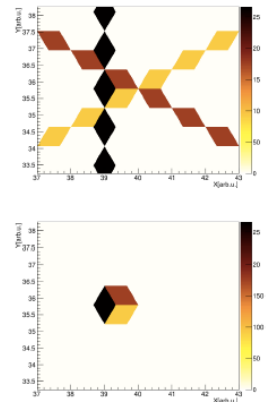
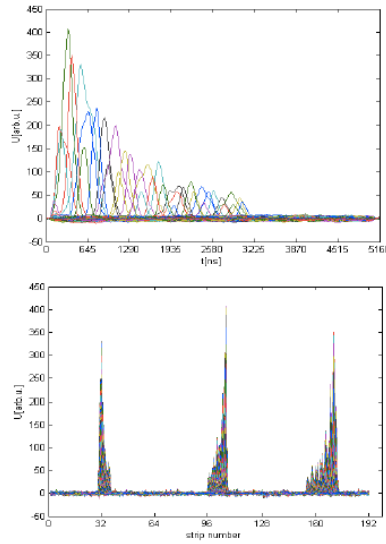


Track Reconstruction

Step 1: Raw data waveforms

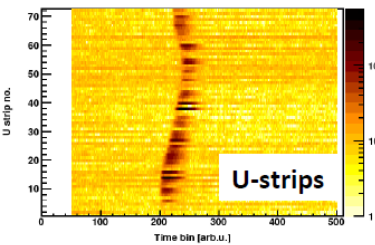
Step 2: Clustering

Step 3: 2D and 3D reconstruction

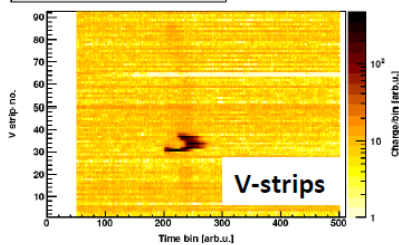


results by Jan Bihalowicz
(BSc thesis, U. of Warsaw, 2014)

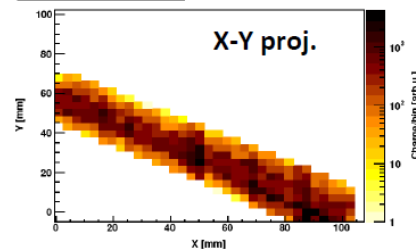
Event-236: Raw signals from U strips



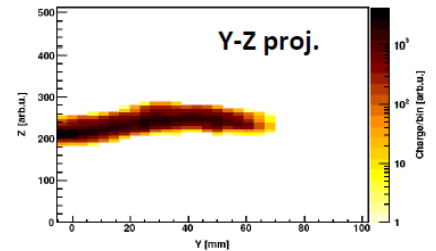
Event-236: Raw signals from V strips



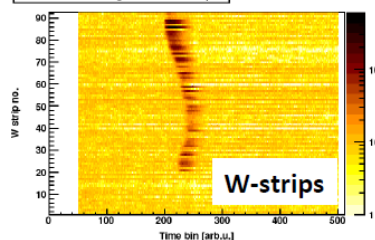
Event-236: Projection in XY



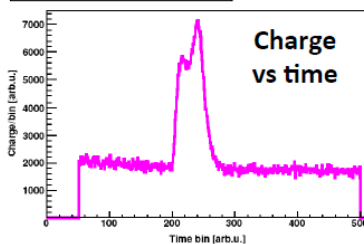
Event-236: Projection in YZ



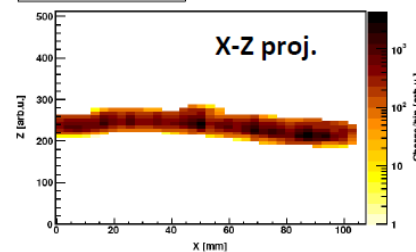
Event-236: Raw signals from W strips



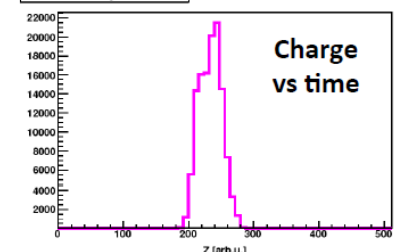
Event-236: Raw signals from all strips



Event-236: Projection in XZ



Event-236: Projection in YZ



AT TPC **시작품** 만들기 시간표

	19/04	19/05	19/06	19/07	19/08	담당
Field Cage	계획	디자인 E-Field	구매	시작품의 시작품 제작	테스트	?
Gas System	계획	디자인	구매 견적	제작	테스트	?
Readout Chamber	계획	디자인	구매 견적	제작	테스트	?
Geant4	계획	Event Gene	→	Geom	→	?
GET system	계획	테스트	→	→	→	?