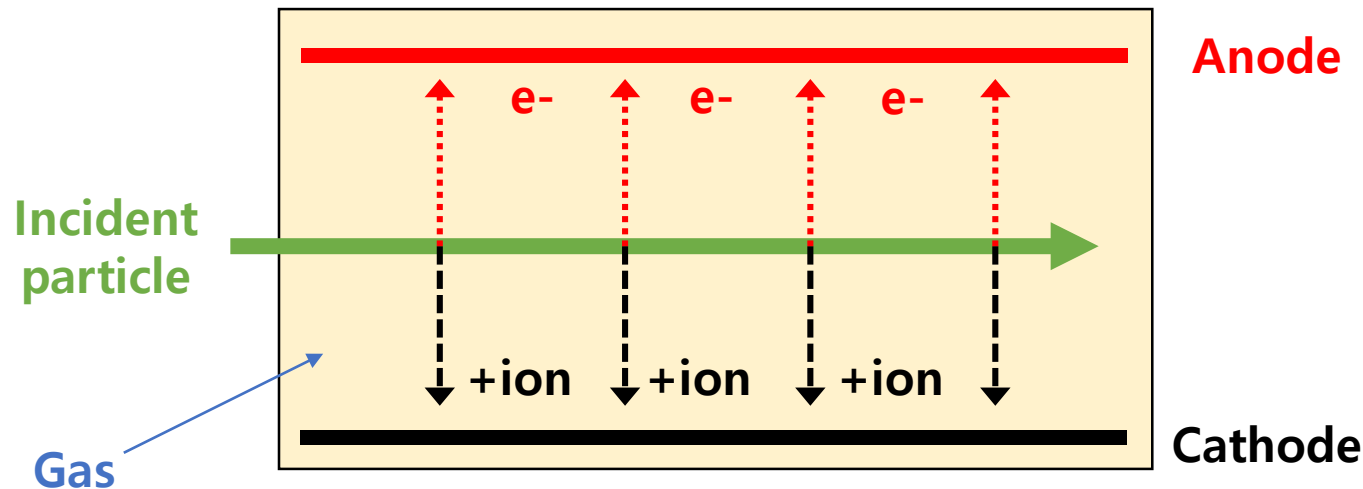


Current Status and Development of the Ionization Chamber

Soomi Cha
(Center for Exotic Nuclear Studies)

on behalf of IC project team



**Incident particle
ionizes gas molecules**



**Electron-Positive ion
pairs created**



**Charged particles
collected in electrodes**

- The amount of created pairs $\propto$ Energy deposit (ΔE) in the detector
- ΔE measurement $\rightarrow$ used for particle identification

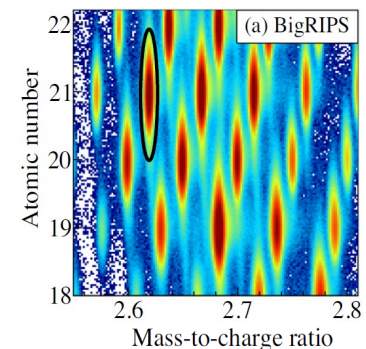
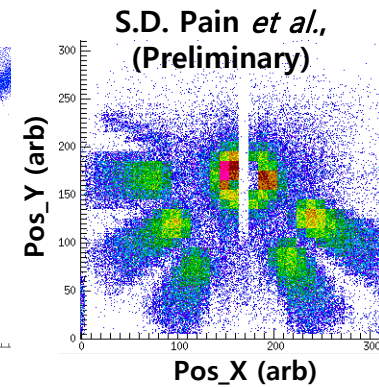
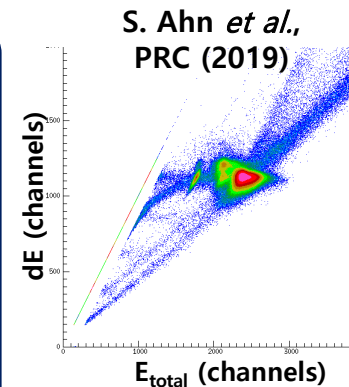
$$-\left\langle \frac{dE}{dx} \right\rangle = \boxed{Z^2} \frac{Z_m \rho_m}{A_m m_u} \frac{4\pi (\hbar c \alpha)^2}{m_e c^2} \frac{1}{\beta^2} \left[\ln \left(\frac{2m_e c^2 \beta^2 \gamma^2}{I} \right) - \beta^2 \right]$$

Bethe-Bloch formula

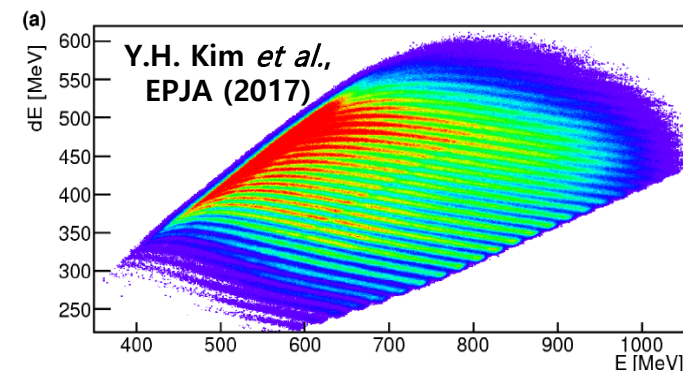
Advantage and Usage

- Strong in radiation damage
- Relatively easy to manufacture and performance test
- Reasonable energy resolution

- Energy and position measurement
- Particle identification
- Detecting heavy recoils
- Beam current normalization

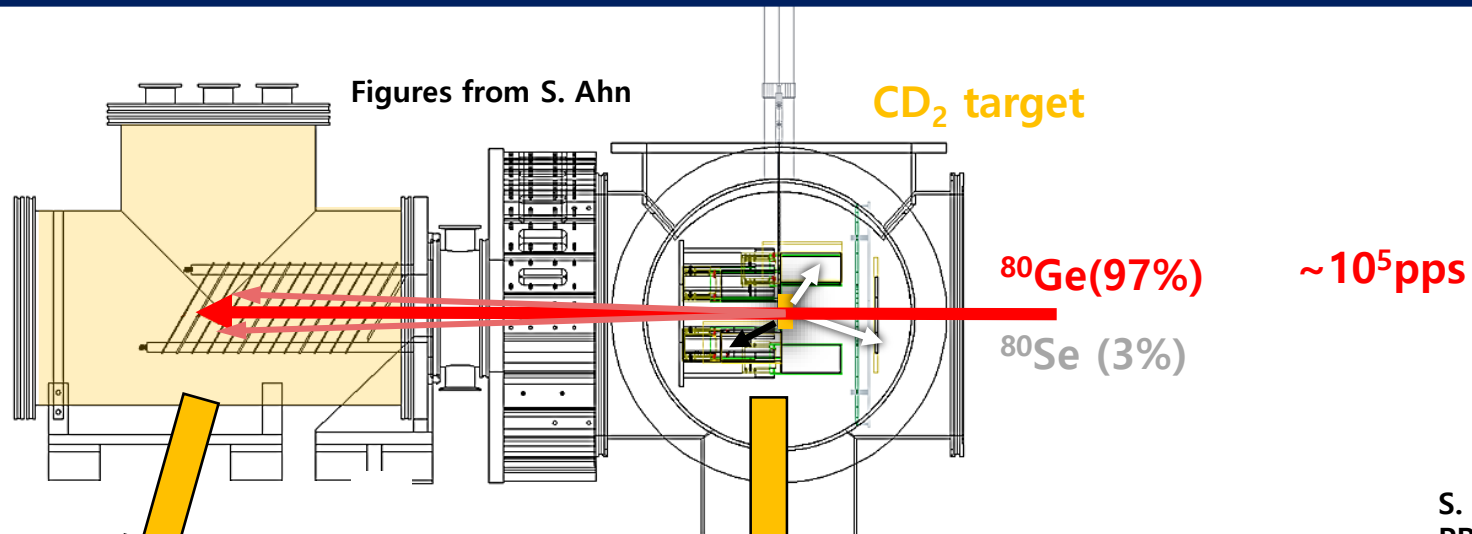


F. Brown *et al.*, PRL (2021)

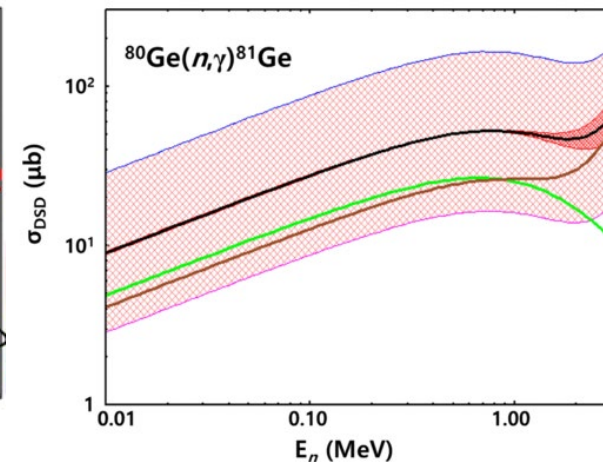
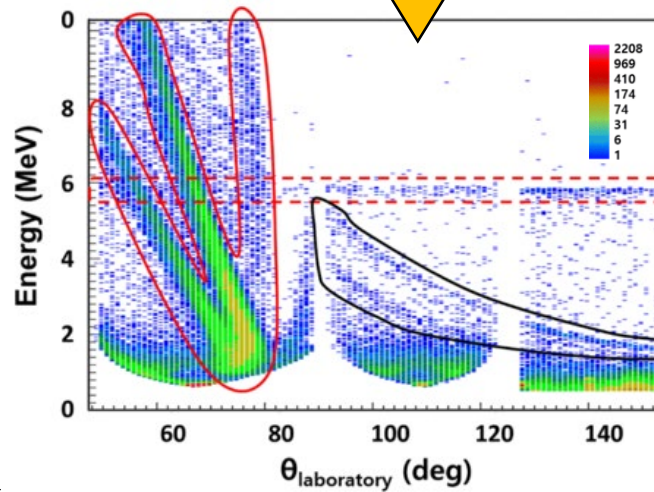
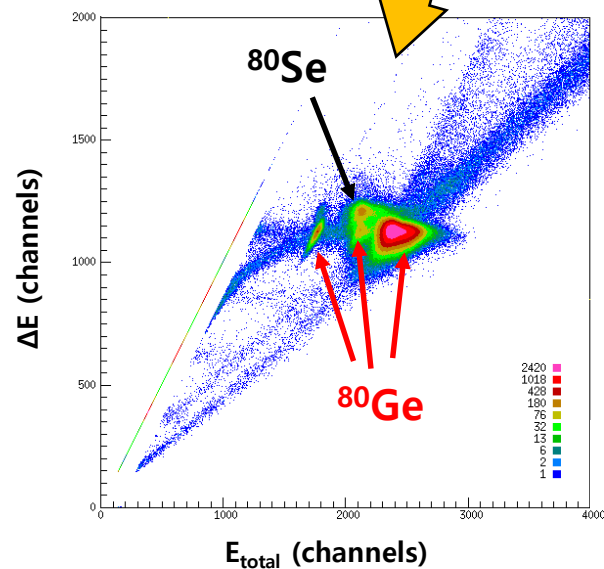


Example of Ionization Chamber in Experiment

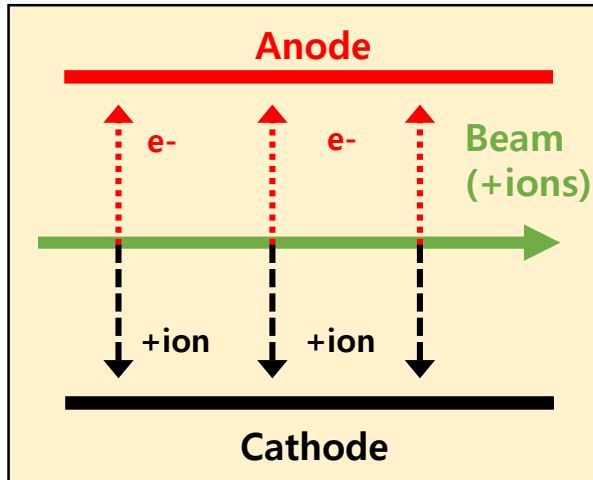
$^{80}\text{Ge}(d,p)^{81}\text{Ge}$ neutron transfer reaction measurement at ORNL



S. Ahn et al.
PRC (2019)

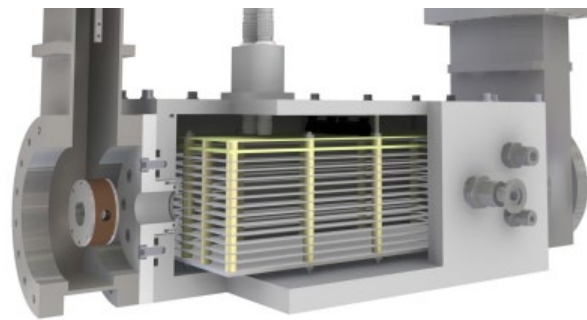
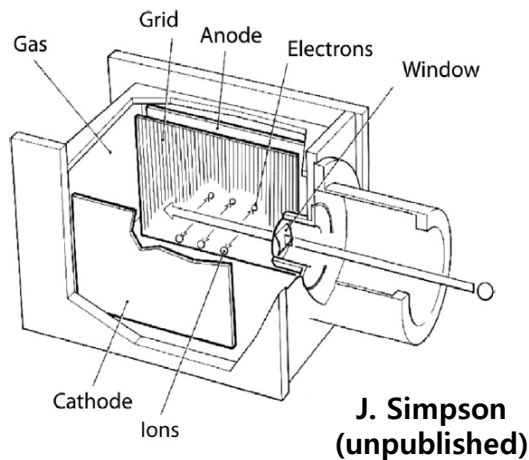


Types of Ionization Chamber : Conventional IC

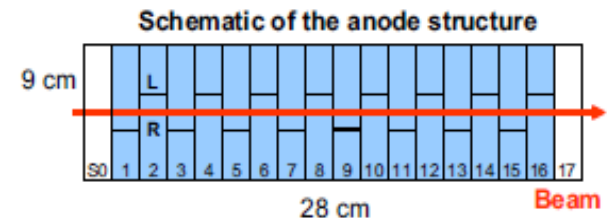
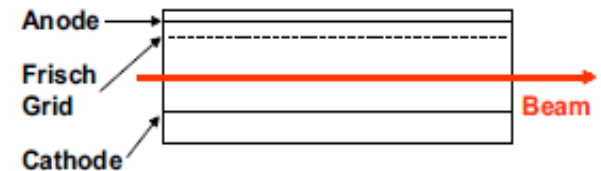


- Electrons (and positive ions) should travel relatively long distance
- Maximum counting rate is limited to $\sim 10^4$ pps
- Good energy resolution ($\because$ Frisch Grid)

Conventional

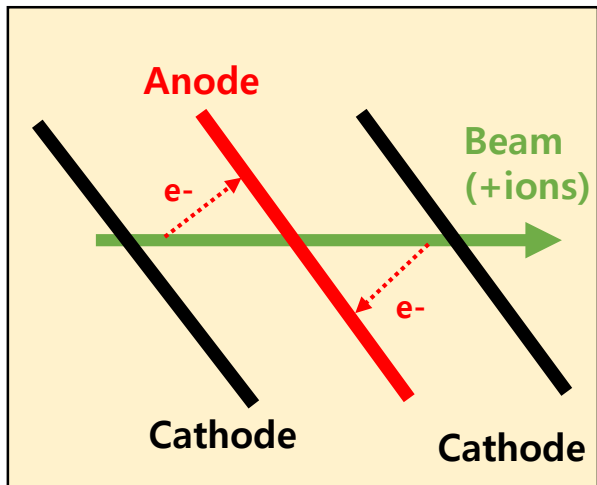


Multi-Sampling Ionization Chamber (MUSIC)
ANL



P.F.F. Carnelli *et al.*,
NIM A (2015)

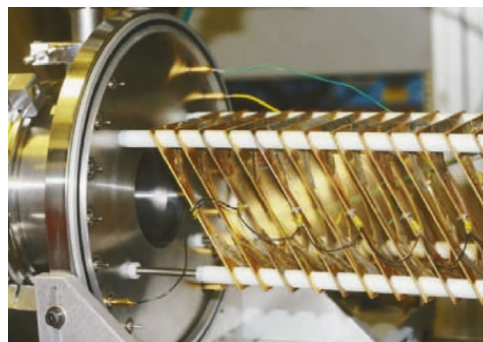
Types of Ionization Chamber : Tilted Electrode IC



**Tilted
Electrode**

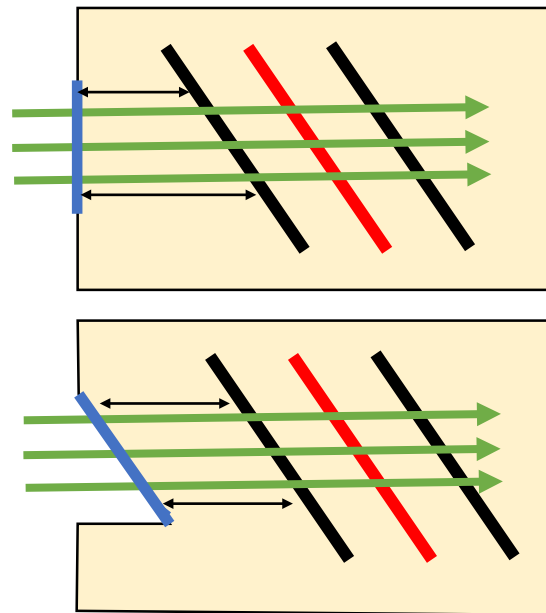


K. Kimura *et al.*,
NIM A (2005)

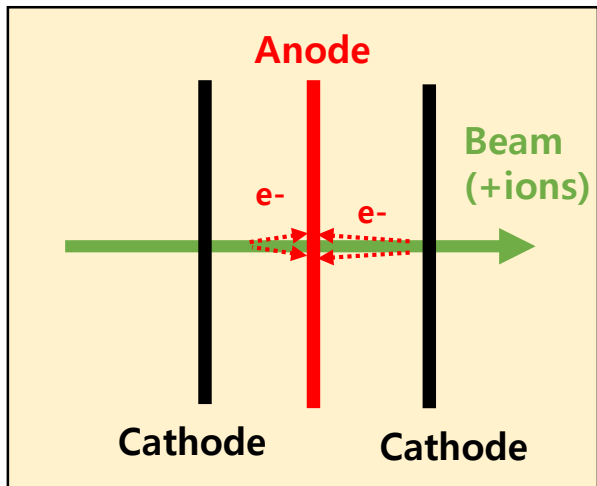


K.Y. Chae *et al.*,
NIM A (2014)

- Electron travel path : short $\rightarrow$ fast response !
- E field not parallel to the beam axis
- Electrons drift away from the original particle
- Avoid the recombination of liberated electrons and beam ions
- Maximum counting rate $\sim 7 \times 10^5$ pps

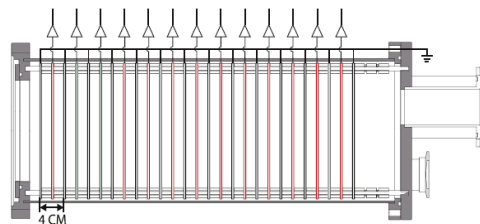


Types of Ionization Chamber : Perpendicular Electrode IC

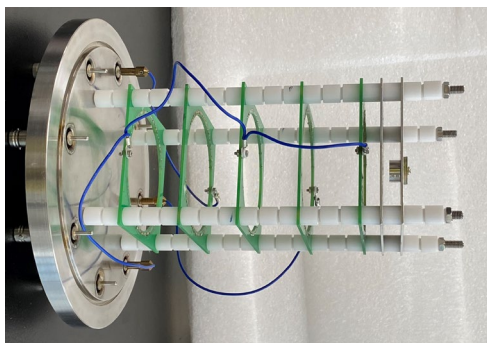
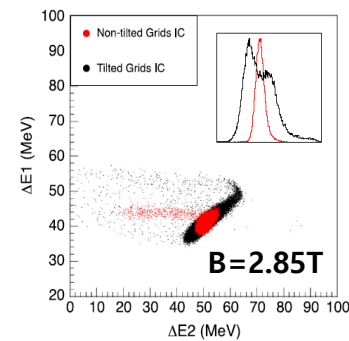
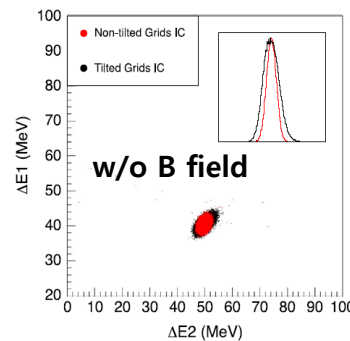


Perpendicular Electrode

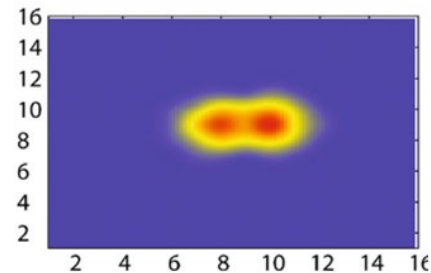
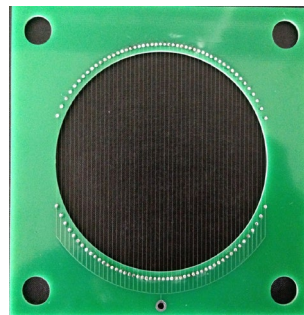
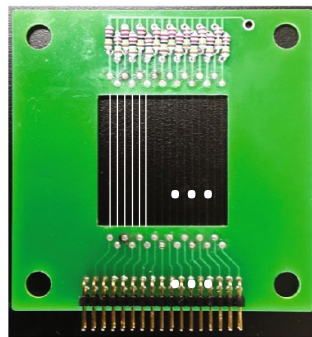
- Heavy recoils from reaction : angular dependency
- Improved the energy resolution



*J. Lai et al.,
NIM A (2018)*



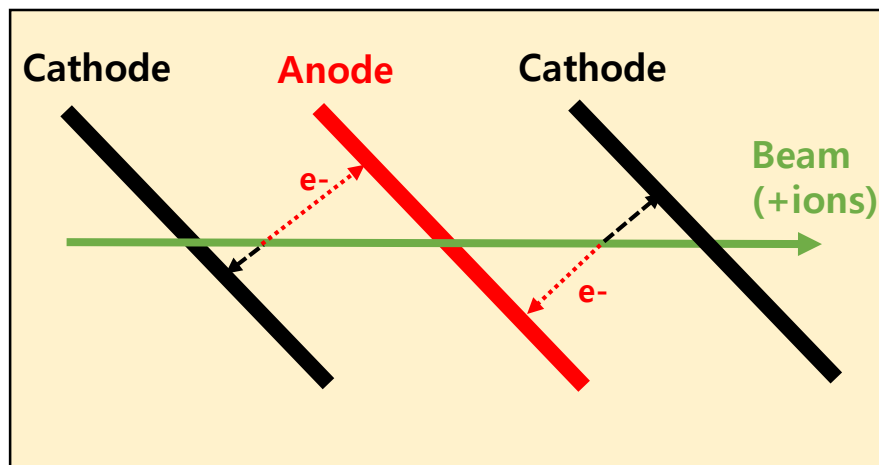
*M.S. Kwag et al.,
J. Radioanal. Nucl. Chem (2019)*



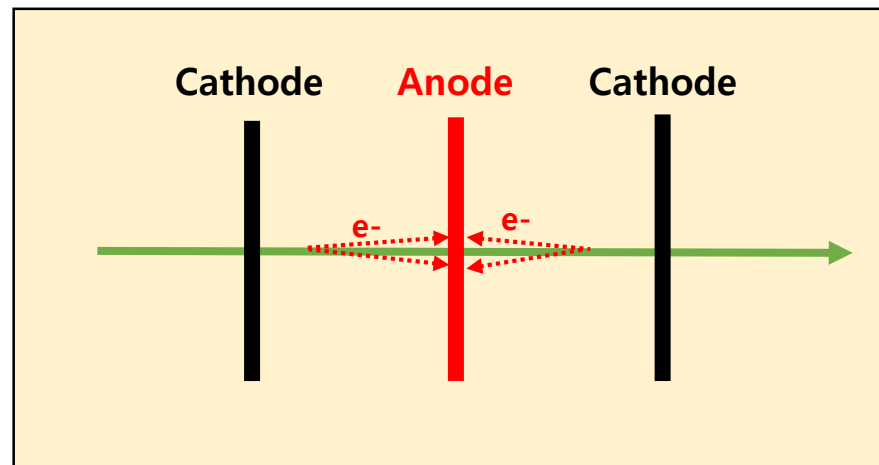
*M.S. Kwag et al.,
JKPS (2016)*

NEW Ionization Chamber projects





**Tilted
Electrode**



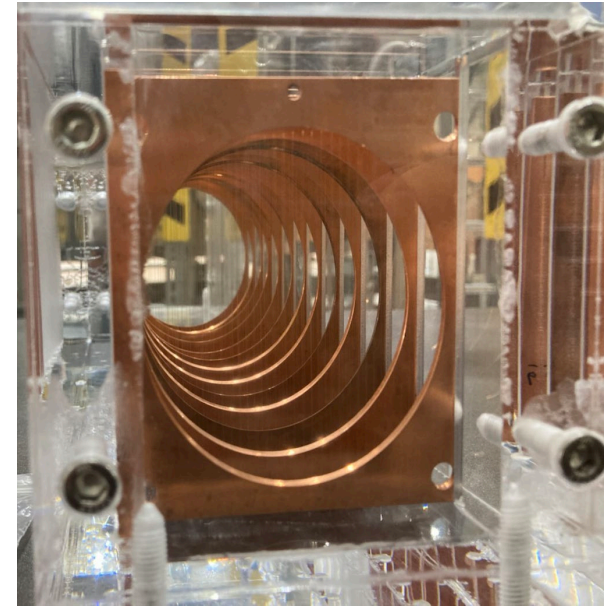
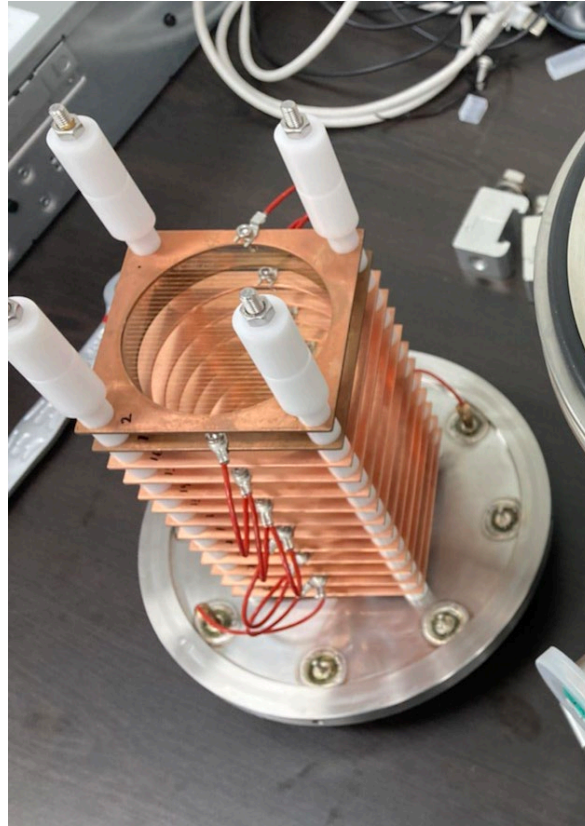
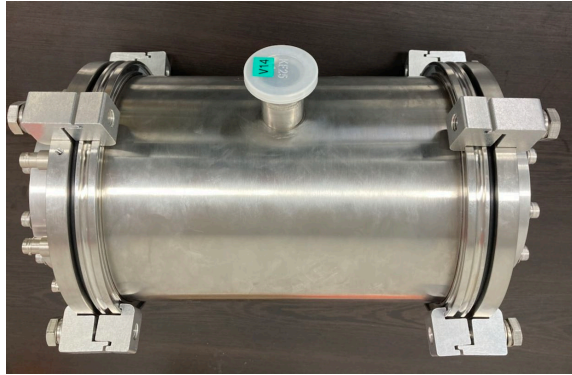
**Perpendicular
Electrode**

- Direct comparison of the performance required
- Optimization for various experimental conditions required
(Electrode configuration, gas type, ...)

Cathode 		M. Kimura et al.	M.S. Kwag et al.	
	Type	Tilted	Perpendicular	
	Counting rate	$\sim 10^6$ pps	$\sim 8 \times 10^5$ pps	
	Beam species	^{40}Ar	^{16}O , ^{12}C	
	Beam energy	90 MeV/u	~ 3 MeV/u	
	Gas	Ar-CF ₄	P-10	

- Direct comparison of the performance required
- Optimization for various experimental conditions required
(Electrode configuration, gas type, ...)

Project Plan 1



- **Made by KoBRA team, collaboration started !**
- Both configurations (tilted / perpendicular) available
- Performance test with beam required (ex. RIKEN, CRIB, Kyushu Univ, ...)

Project Plan 2 – Low Energy

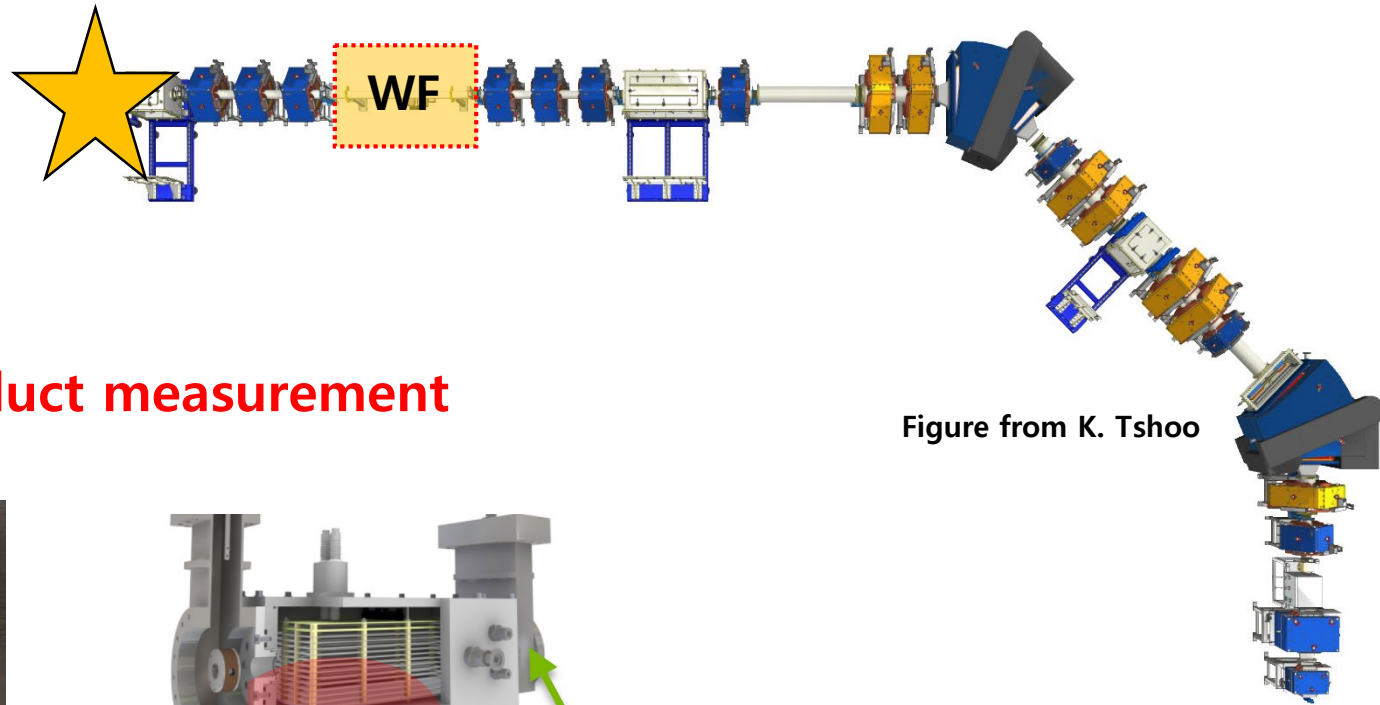
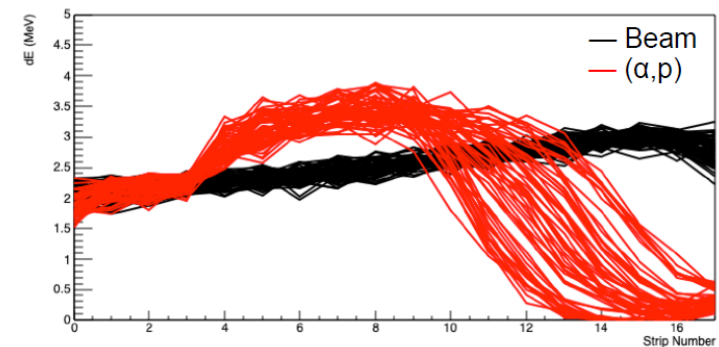
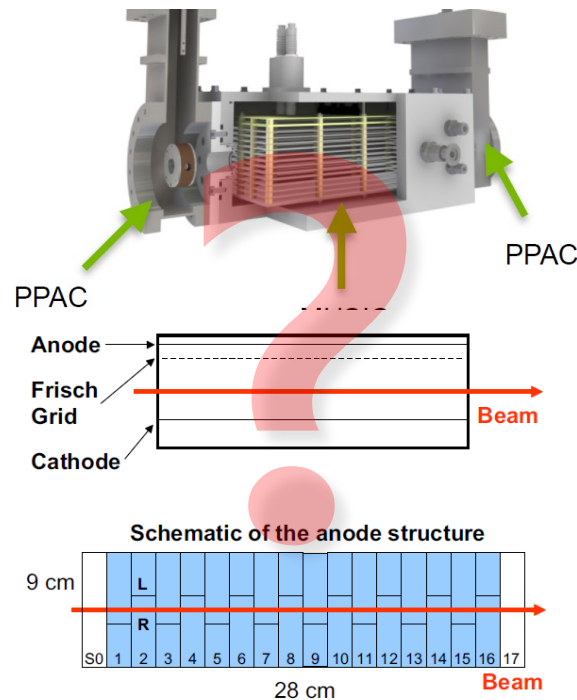
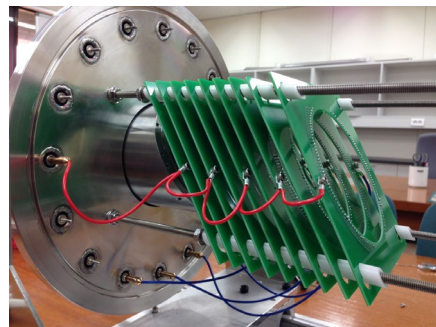


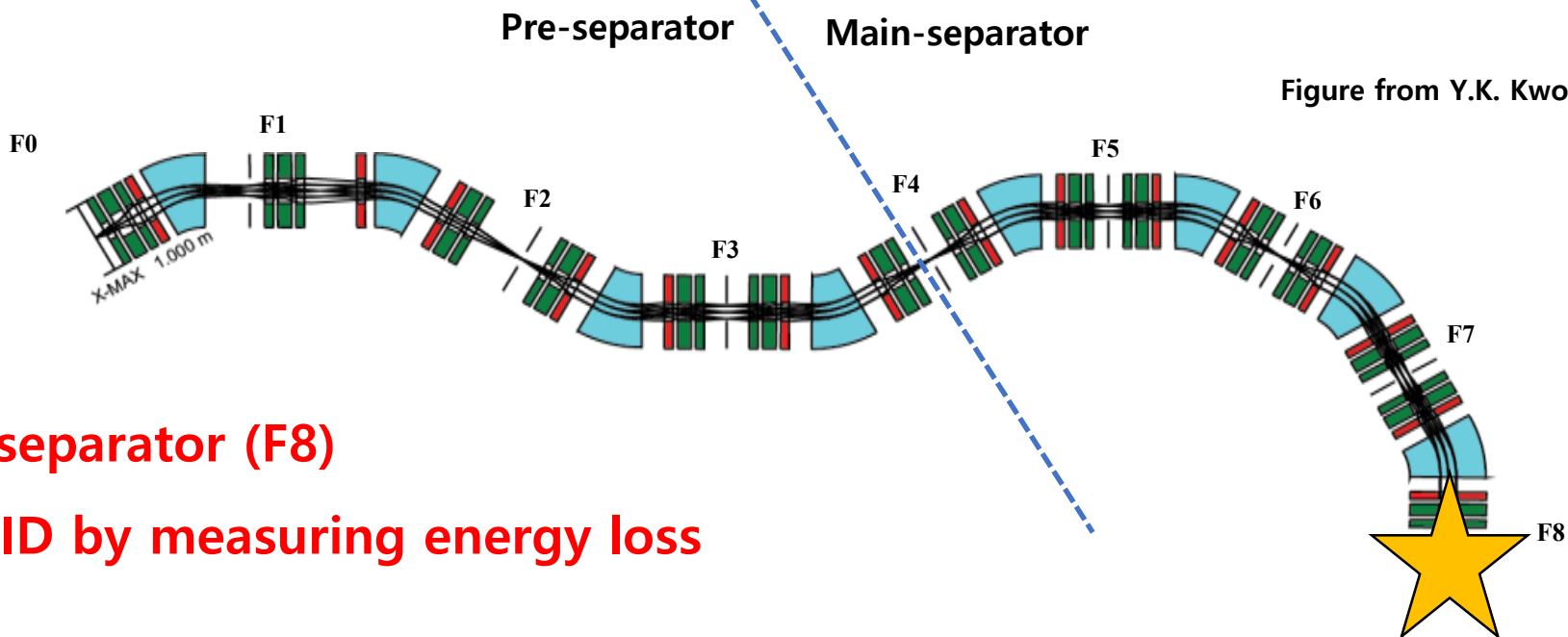
Figure from K. Tshoo

- KoBRA (F3)
- Reaction product measurement

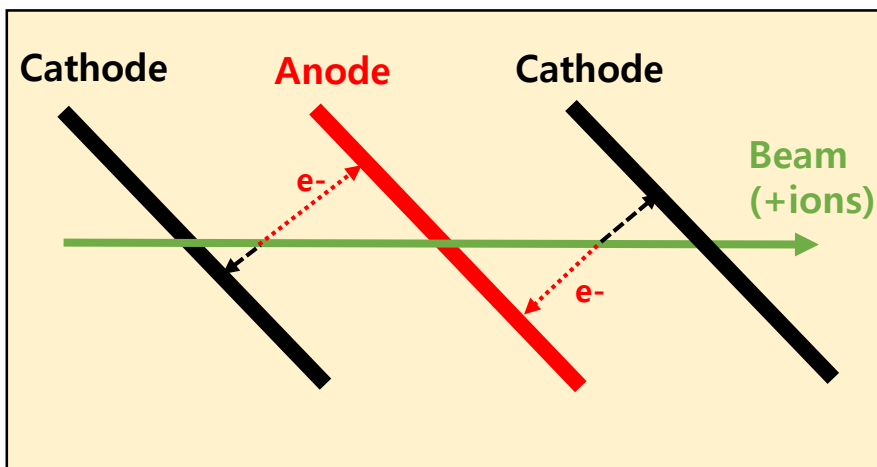


H. Jayatissa
(NIC XVI conference,
Preliminary)

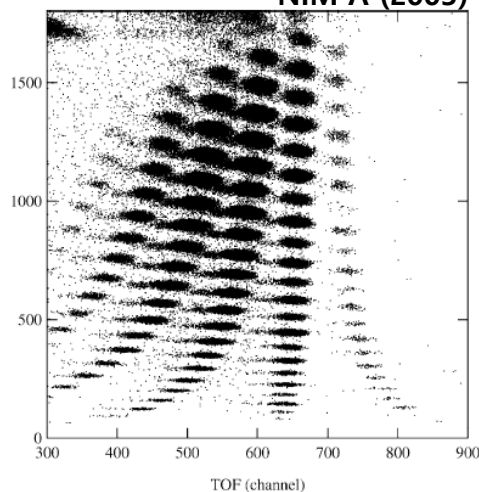
Project Plan 2 – High Energy



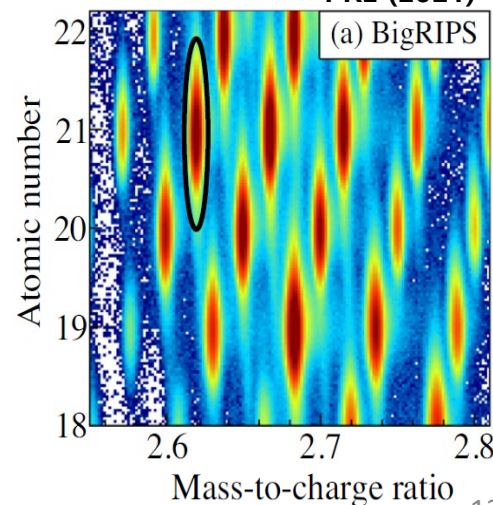
- IF separator (F8)
- PID by measuring energy loss



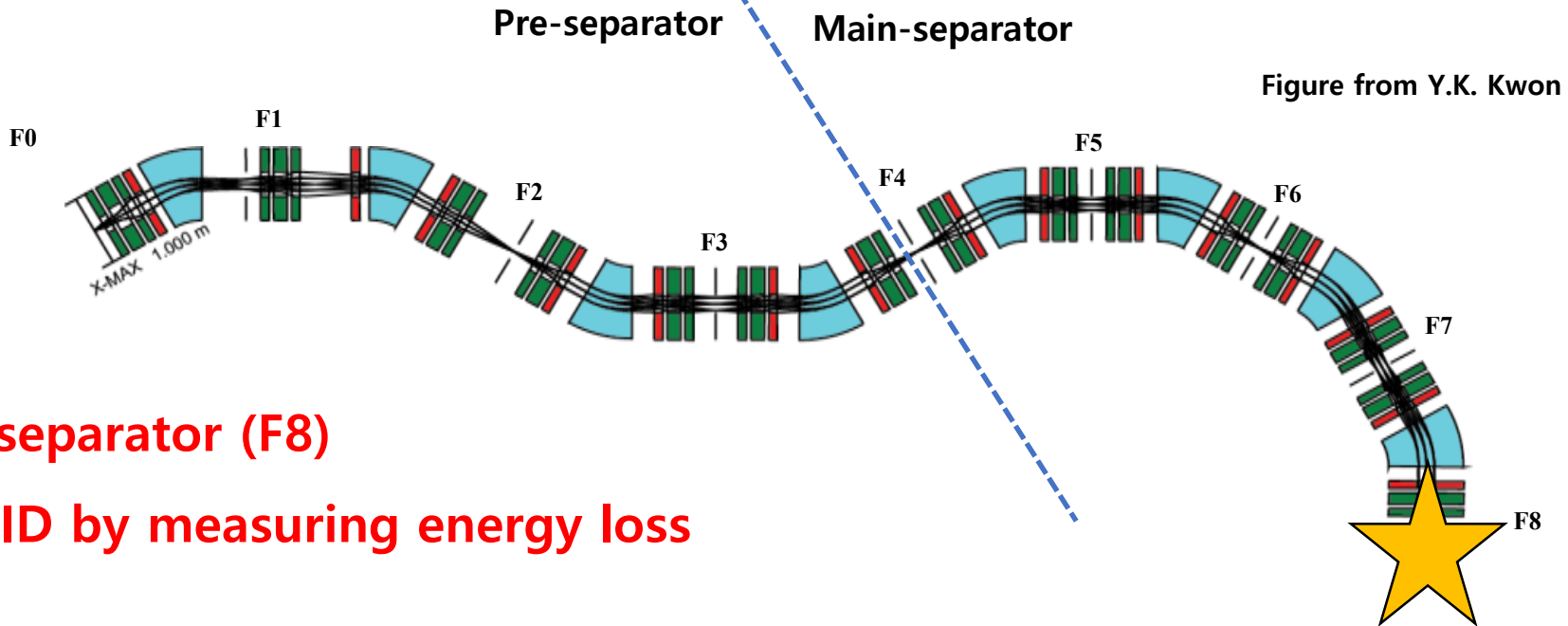
K. Kimura et al.
NIM A (2005)



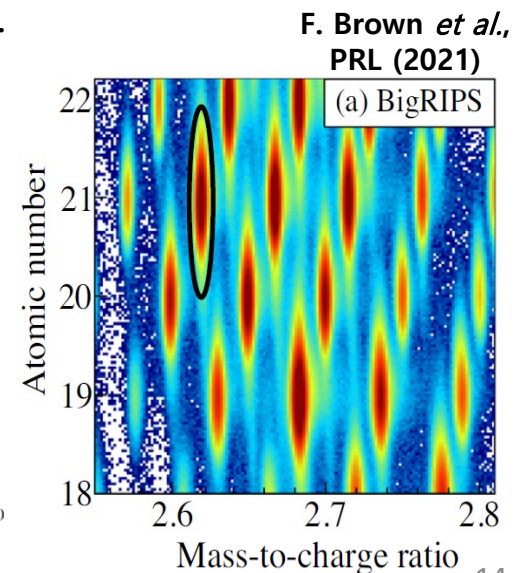
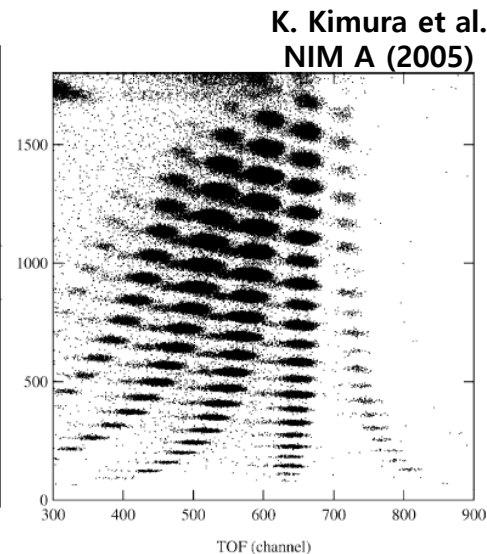
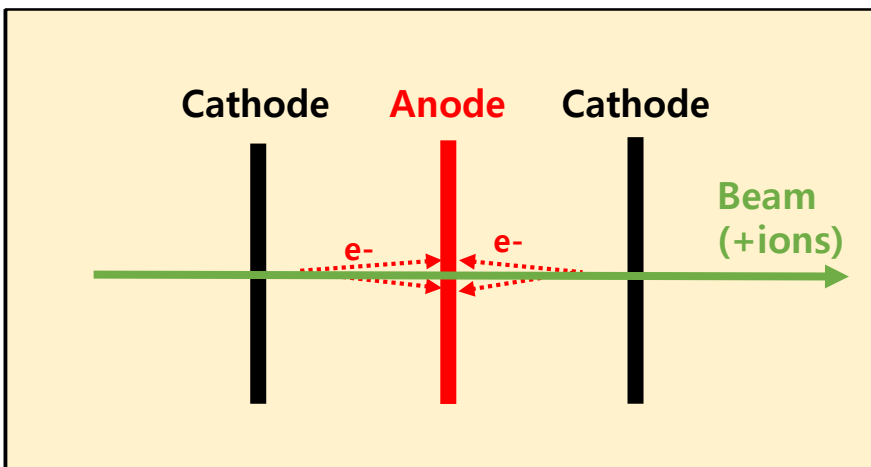
F. Brown et al.,
PRL (2021)



Project Plan 2 – High Energy



- IF separator (F8)
- PID by measuring energy loss





Thank you
for your attention

중이온가속기연구소-
저에너지 실험장치팀

희귀핵연구단