Performance evaluation of the prototype beam drift chamber for LAMPS at RAON

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on behalf of the LAMPS Collaboration

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May 25-30, 2025
DCC, Daejeon, Korea

LAMPS (Large Acceptance Multi-Purpose Spectrometer)

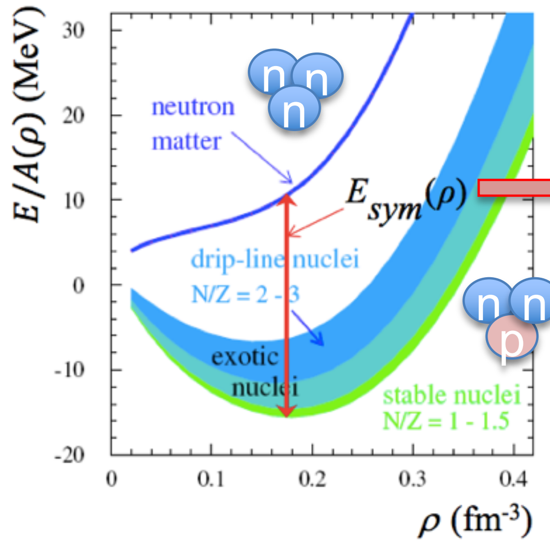
- **Main goal of LAMPS**
  - Determination the trend of the symmetry energy beyond normal nuclear density

$\rho_0 \simeq 0.16\ /\mathrm{fm}^3$

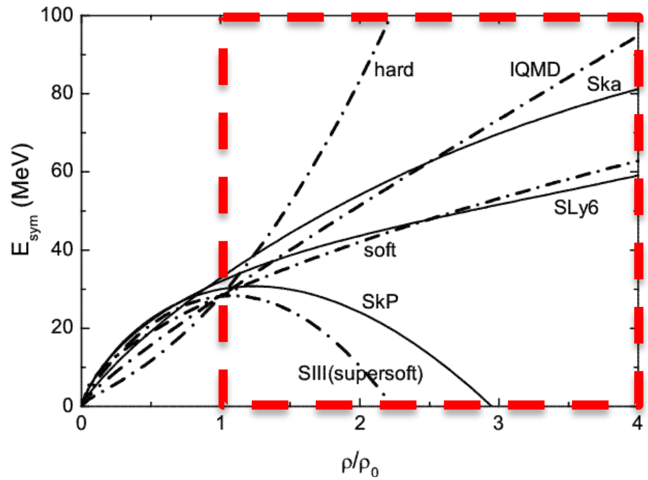
$$\frac{E}{A} = \varepsilon(\rho, \delta) = E(\rho, \delta = 0) + \boxed{E_{sym}(\rho)\delta^2} + O(\delta^4)$$

$\rho = \rho_n + \rho_p$ Baryon density

$\delta = \frac{\rho_n - \rho_p}{\rho} = \frac{N - Z}{A}$ Isospin asymmetric parameter



Phys. Rev. C 57, 3099 (1998)
Phys. Rev. C 64, 034314 (2001)



Phys. Lett. B683, 140 (2010)

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  - Determination the trend of the symmetry energy beyond normal nuclear density

$\rho_0 \simeq 0.16\ /\mathrm{fm}^3$

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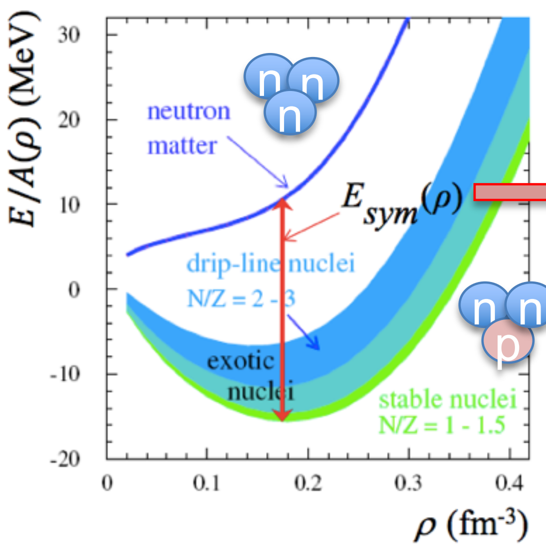
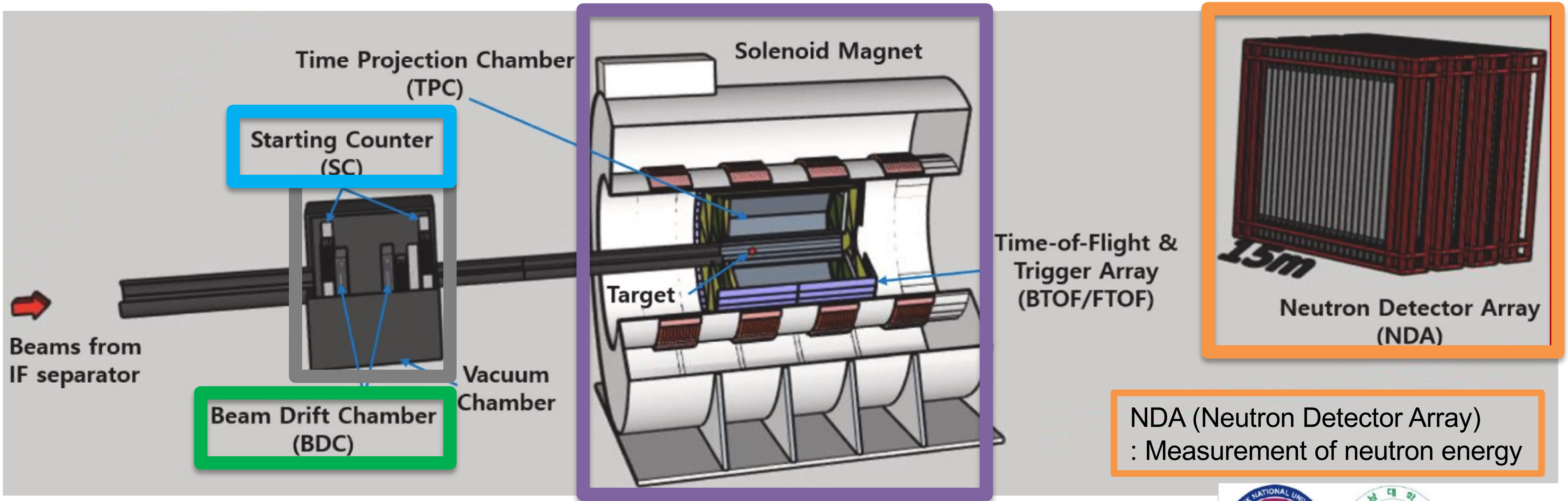


Phys. Rev. C 57, 3099 (1998)
Phys. Rev. C 64, 034314 (2001)

- **Measured variables**
  - Yield ratios of isotopes, collective flow
  - sensitive to nuclear symmetry energy
- **Collision scenarios**
  - Commissioning with stable isotopes
    - ^{40}Ca + ^{40}Ca (N/Z=1)
  - More exotic Ca isotopes
    - ^{50,54}Ca + ^{40}Ca (N/Z>1)
  - Heavier nuclei because of various isotopes available
    - ^{58,60,64,68,70,72}Ni + ^{58,60,64}Ni
    - ^{106,112,116,118,124,130,132}Sn + ^{112,116,118,124}Sn

LAMPS outline

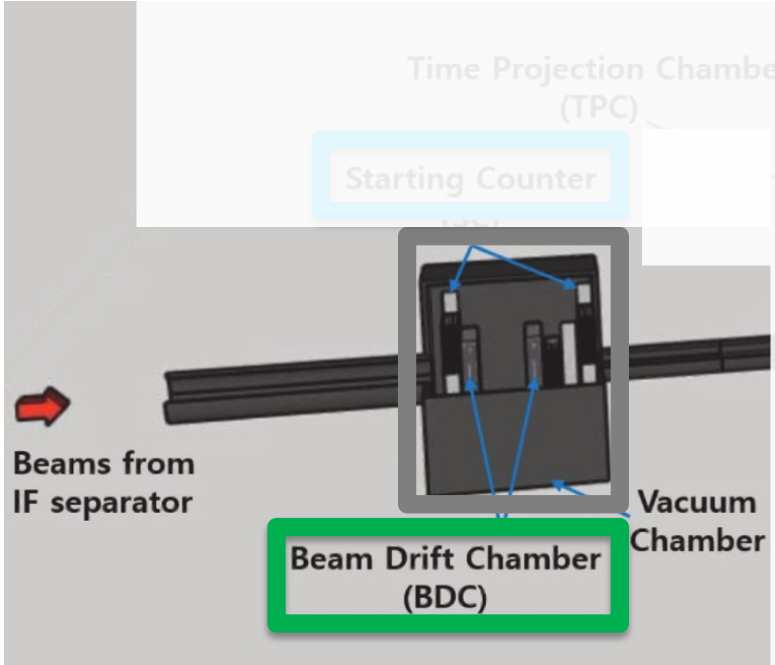


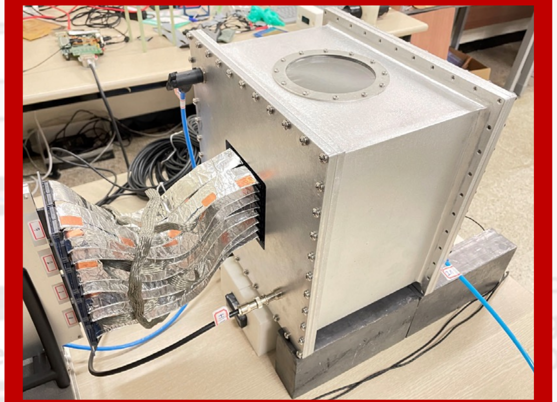
NDA (Neutron Detector Array)
: Measurement of neutron energy

Beam diagnostic detectors
in vacuum Chamber
- SC (Starting Counter) : Trigger
- BDC (Beam Drift Chamber) :
  Beam Tracking

Charge particle detection system
- ToF (Time-of-Flight) :
  ToF Measurement, Trigger
- TPC (Time Projection Chamber):
  Tracking

LAMPS outline





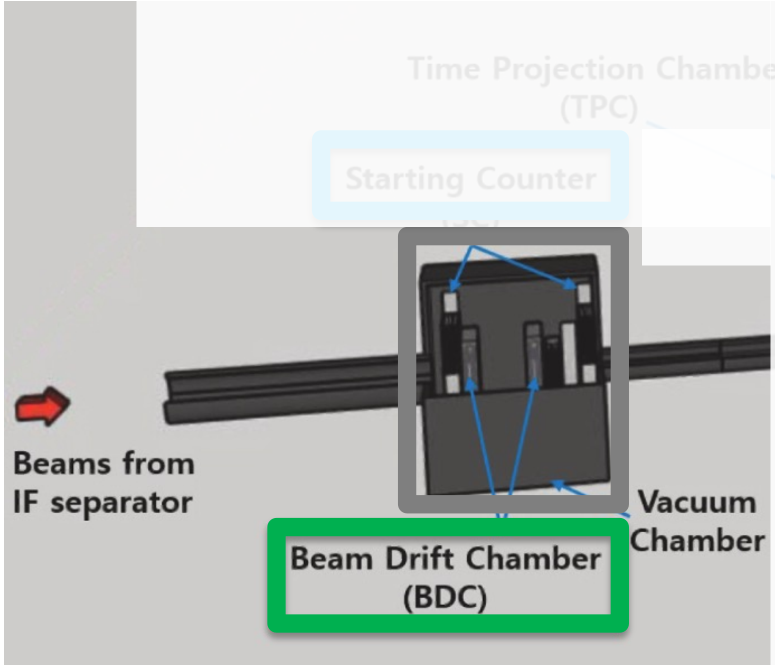
For low energy experiment
- **AT-TPC (Active Target Time Projection Chamber)**

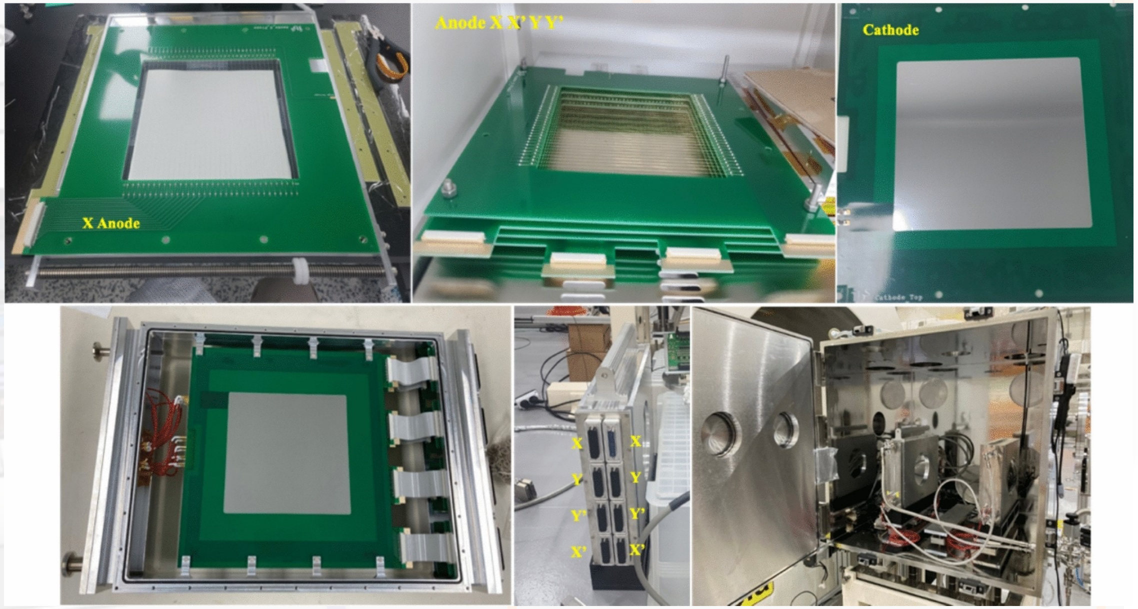
Seonggeun Hwang's talk
(May 29th. 16:45)

Beam diagnostic detectors
in vacuum Chamber
- **BDC (Beam Drift Chamber) : Beam Tracking**
    - *JINST 19 (2024) P12008*

For real LAMPS : **JKPS (2024) DOI: 10.1007/s40042-024-01229-x**

LAMPS BDC





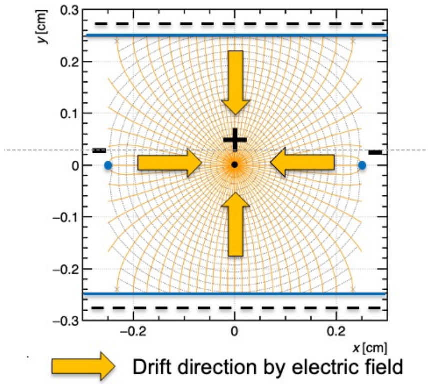
J. Korean Phys. Soc. (2024)
DOI: 10.1007/s40042-024-01229-x

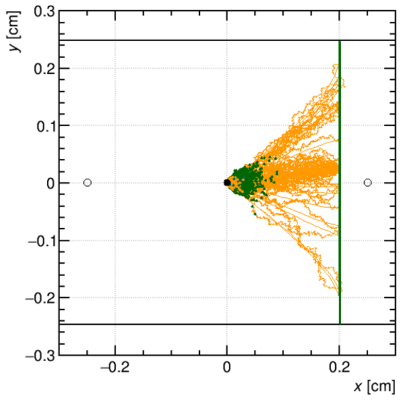
BDC (Beam Drift Chamber)

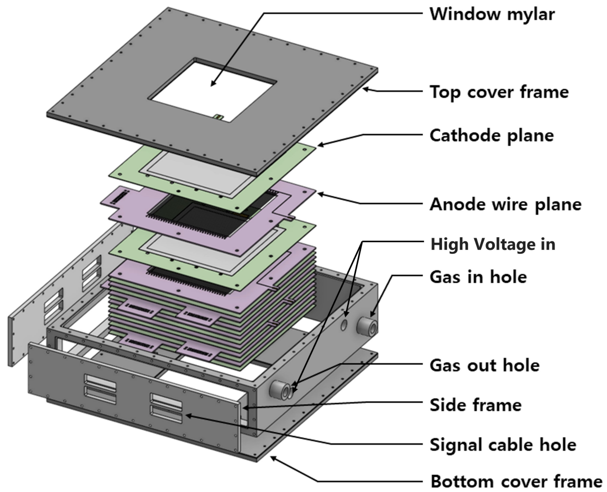
- Beam path tracking from the beamline to the target
- Required specification
  - **Position resolution : < 100 μm**
  - **Low material budget** to avoid the energy loss

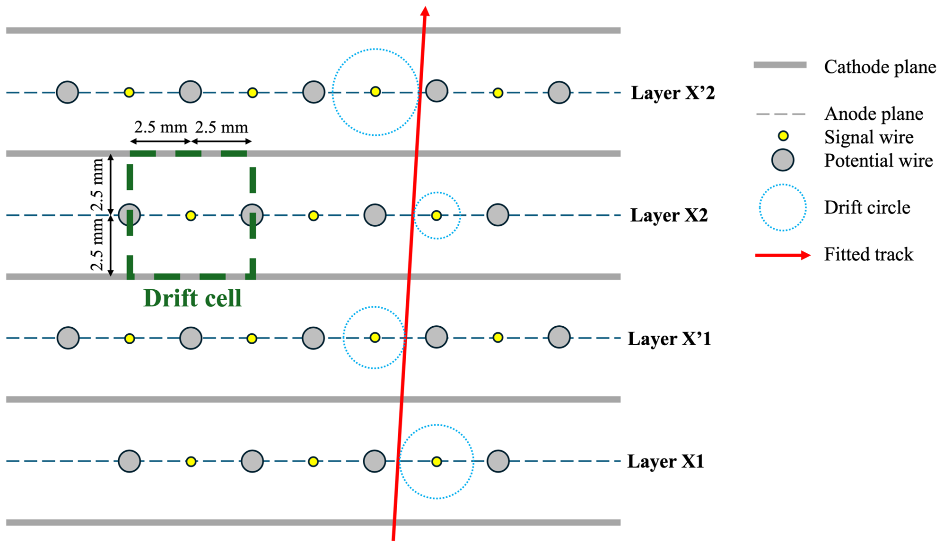
Consists of two chambers with 8 layers per each chamber

Prototype BDC





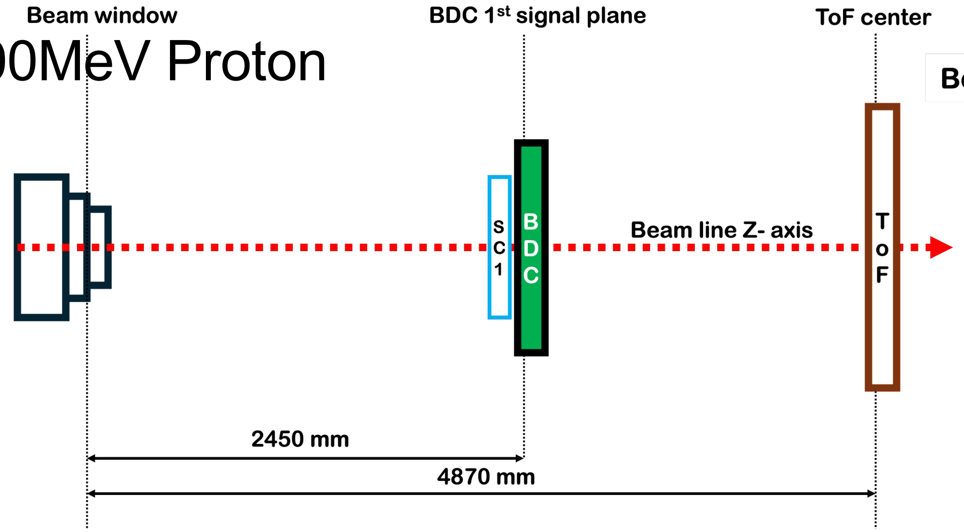




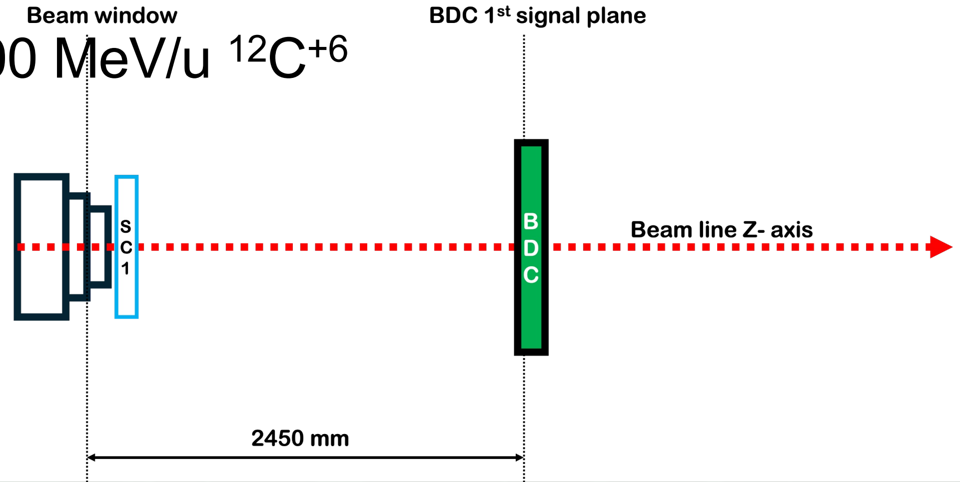
Parameter	Value
Sense wire	20 μm, Au-W
Potential wire	80 μm, Au-W
Anode configuration	*XX'XX'YY'YY'* (total 8 layers)
Cathode	6 μm, Aluminized mylar, 9 layers
Cell size	5 mm (drift length 2.5 mm)
Active area	160 X 160 mm^2
Number of channels	256 (32 wires/plane X 8 planes)
Operation gas	P-10 (Ar (90%) + CH4 (10%)) at 1 atm

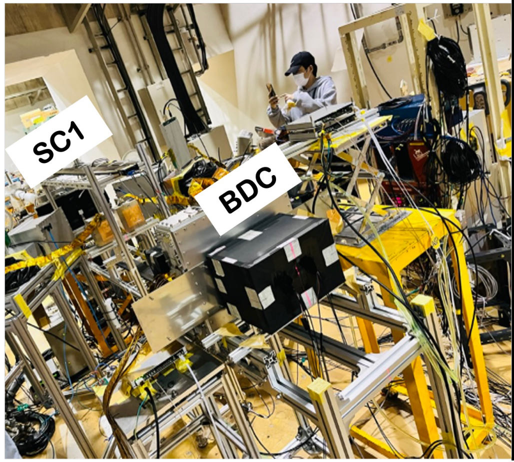
Experimental setup for BDC at HIMAC

100MeV Proton



200 MeV/u $^{12}C^{+6}$

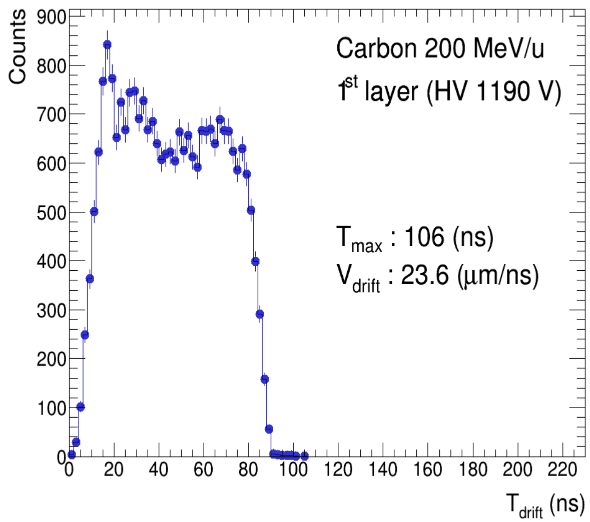


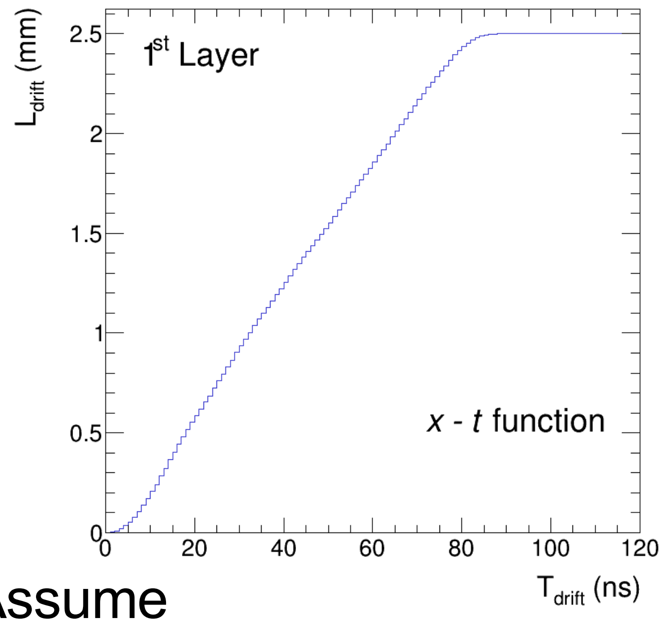


Trigger
Coincidence signal between SC1 and ToF
Only use SC1 in front of beam window, considering collaboration with other experimental tests

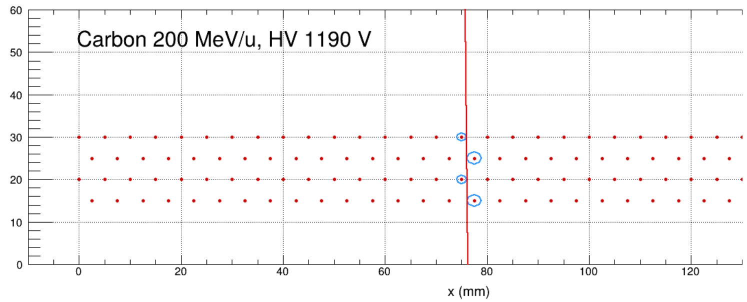
Analysis procedure

Extract time distribution → Get the x-t function → Reconstruct of the track by fitting





Assume homogeneous beam

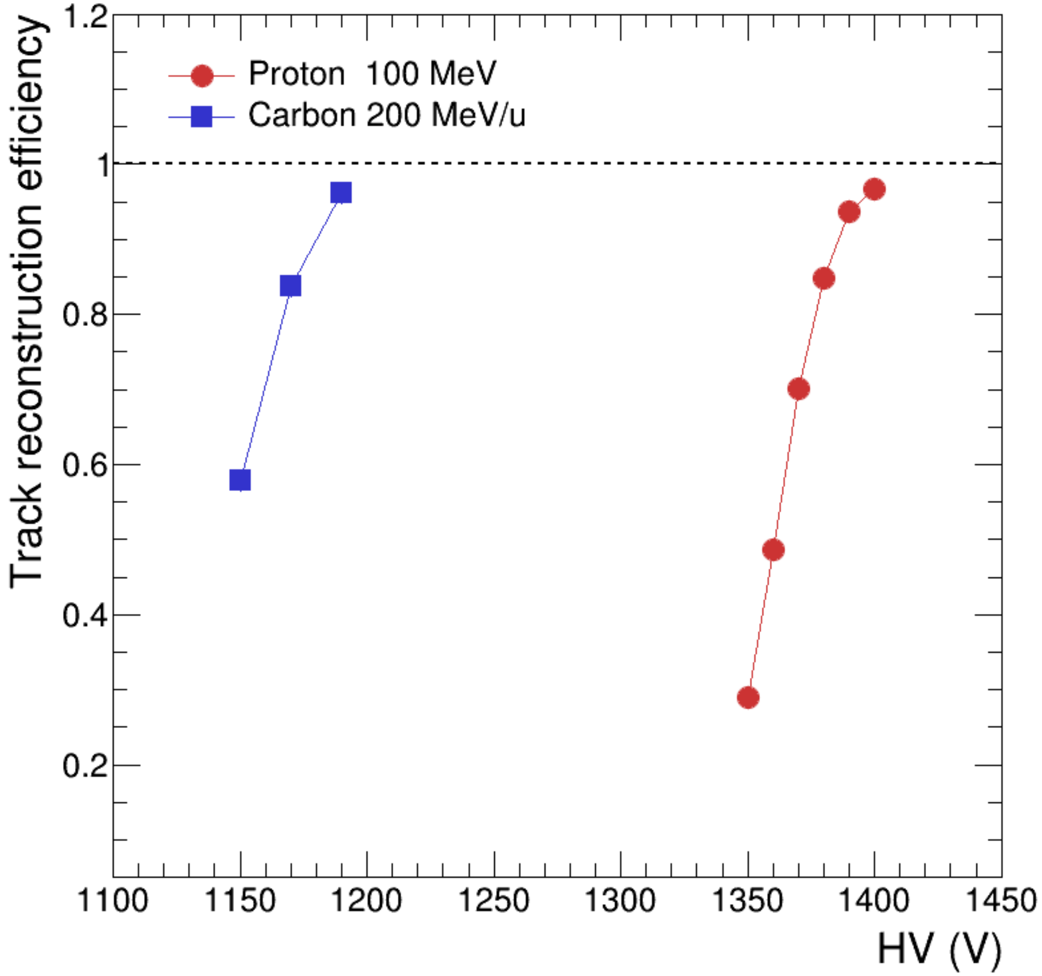


Fit the track with 4 hits
(one hit for each layer)

From the residual, extract the position resolution

Residual = distance between track and drift circle on the layer

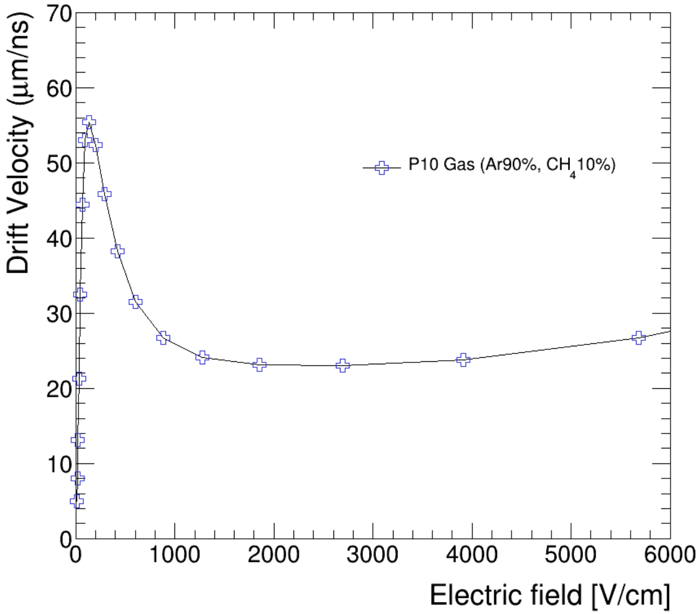
Track reconstruction efficiency

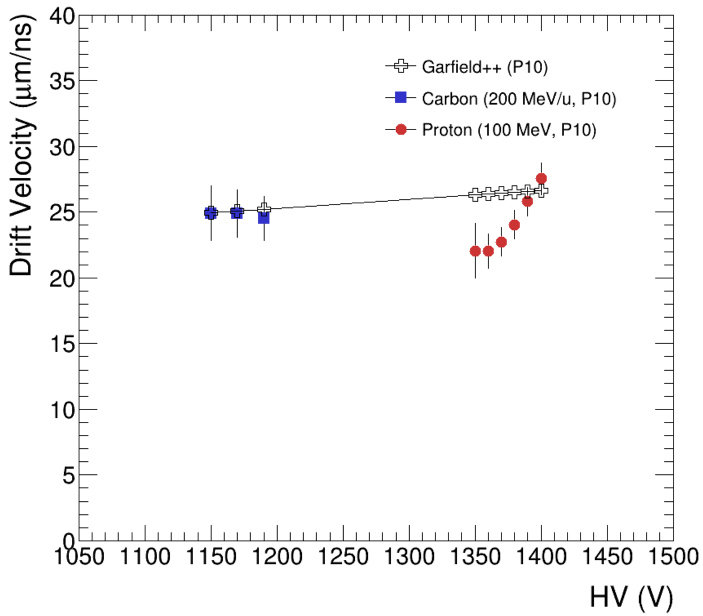


- Track reconstruction efficiency = Number of events containing at least one track candidate / total number of triggered events
- The reconstruction efficiency reached a value higher than 95% at the highest HV
- Suggest that it is close to the plateau of the working region of the detector

Drift velocity

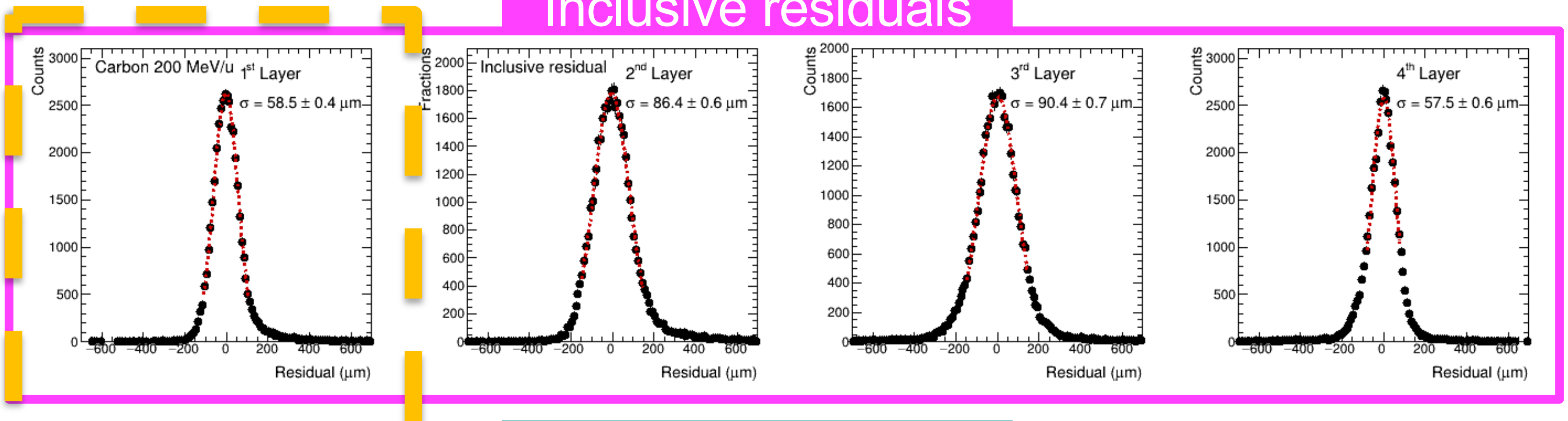
- **Drift velocity is estimated by the Garfield++ simulation and compared with it from data**
- **For carbon, good agreement is shown within uncertainties**
- **For proton, experimental results become closer to simulation results**

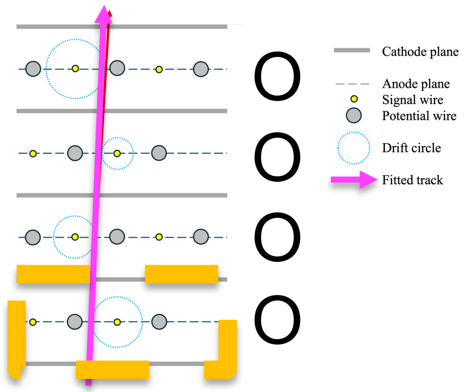




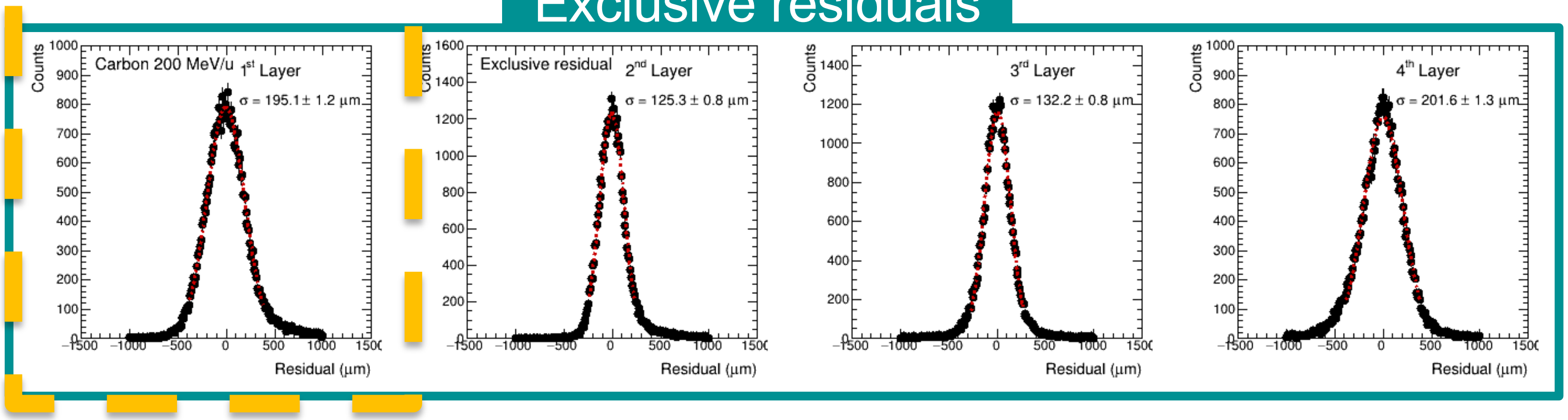
Residual distributions

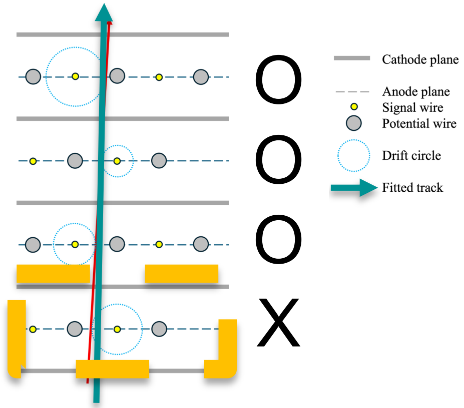
Inclusive residuals



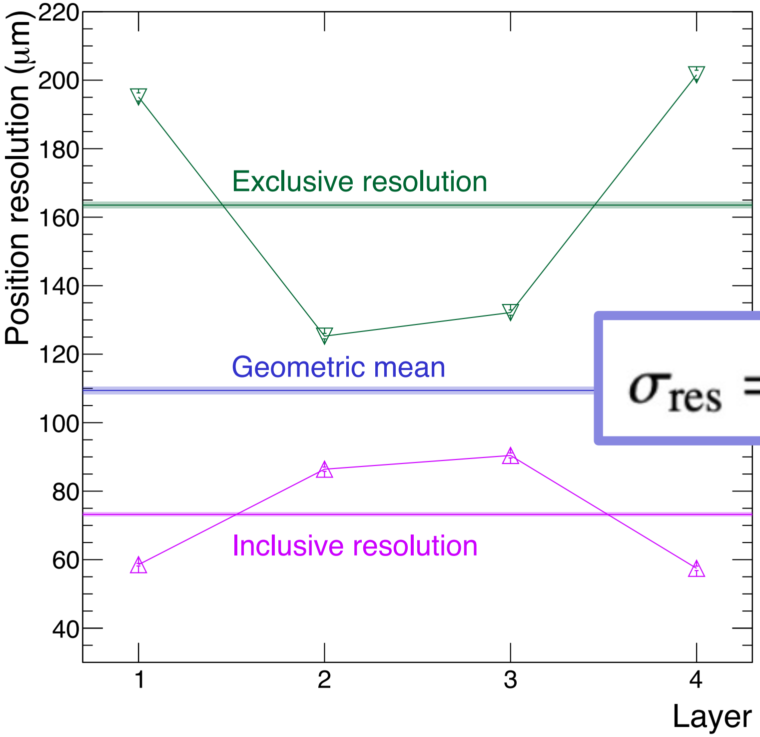


Exclusive residuals

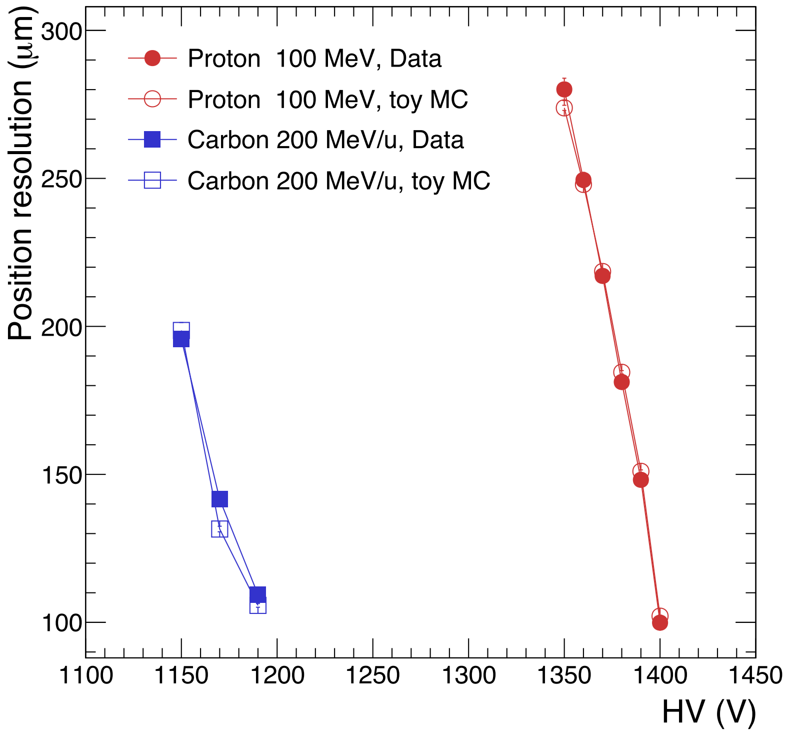




Position resolution



$$\sigma_{\mathrm{res}} = \sqrt{\sigma_{\mathrm{in}} \times \sigma_{\mathrm{ex}}}$$

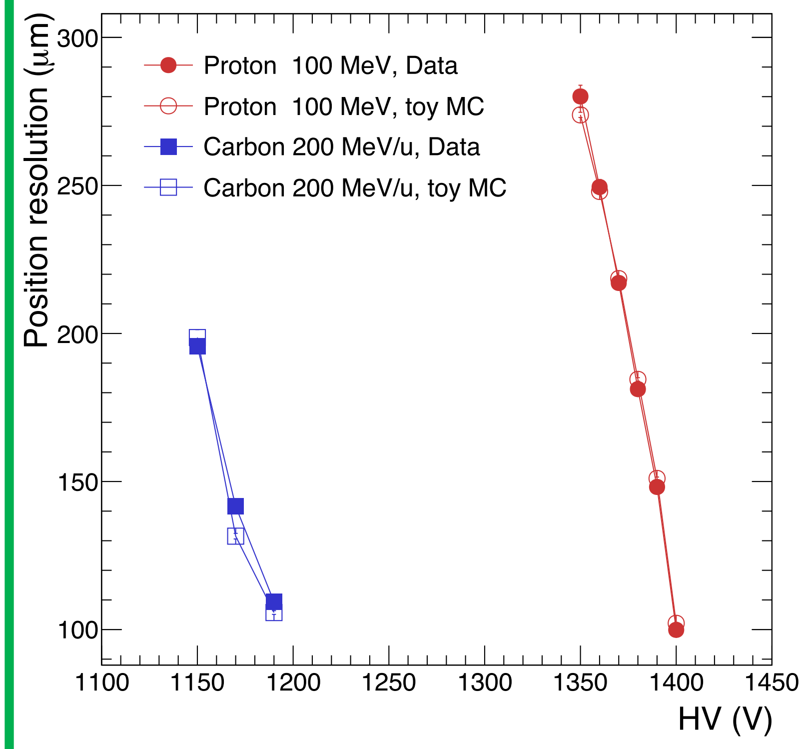


- **Average of the geometric mean is considered as the position resolution, and confirmed by the toy Monte Carlo study**

- **Best resolution at maximum HV**
  - Carbon : 109.4 ± 1.1 μm
  - Proton : 99.9 ± 1.4 μm

Summary and Future plan

- **LAMPS BDC was made for beam tracking to the target**
- **Prototype BDC was made for the performance study and tested with the proton and carbon beam from HIMAC, Japan**
- **Best resolution at maximum HV**
  - Carbon : 109.4 ± 1.1 μm
  - Proton : 99.9 ± 1.4 μm
- **Expect the good performance of the real LAMPS BDC**
- **Plan to test with full configuration for prototype BDC, and expect 2D(X-Y) results**



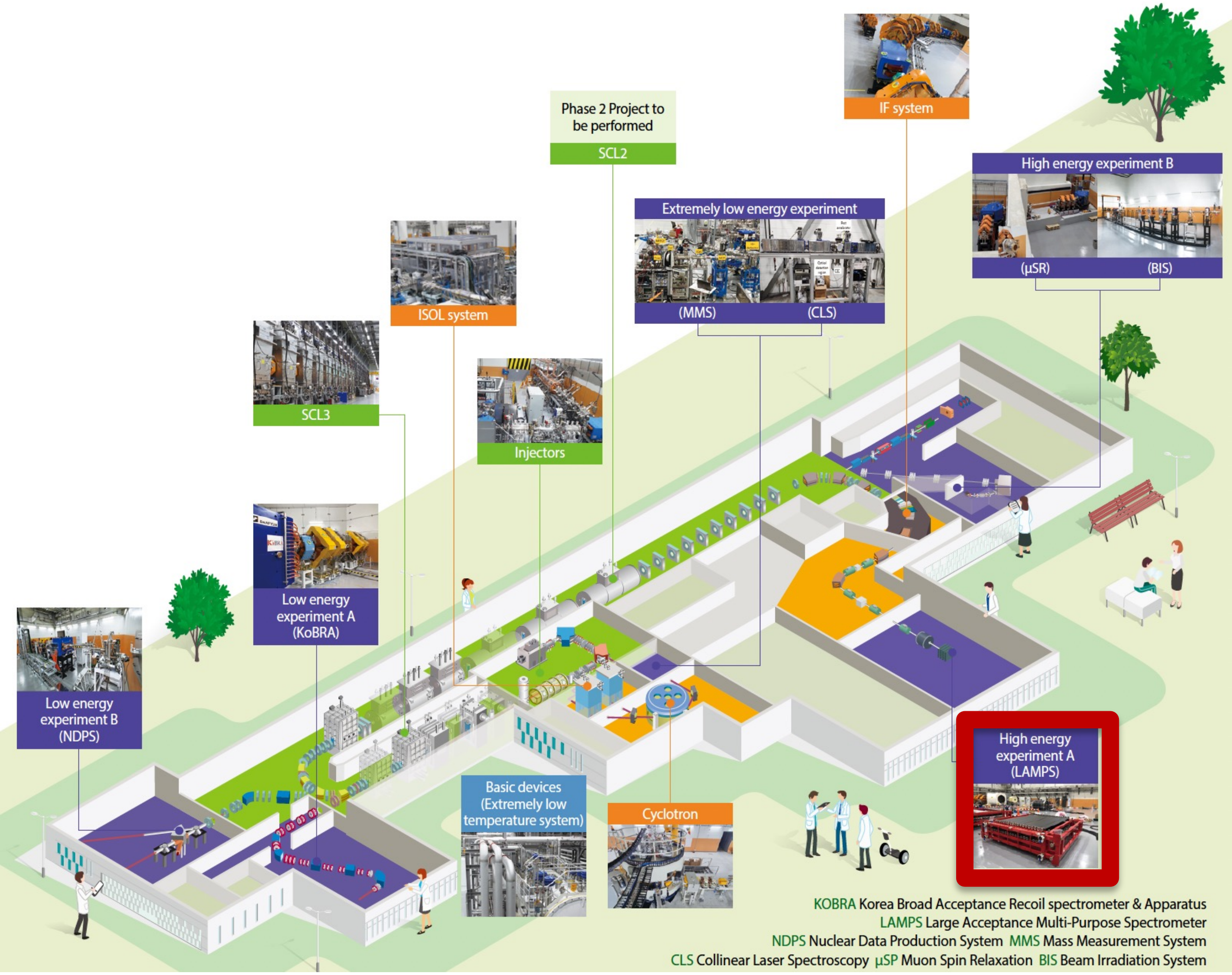
BDC : *JINST 19 (2024) P12008*

Please visit Cheong Heo's poster, also


Thank you for your attention
감사합니다

Backup

RAON (Rare isotope Accelerator complex for ONline experiments)



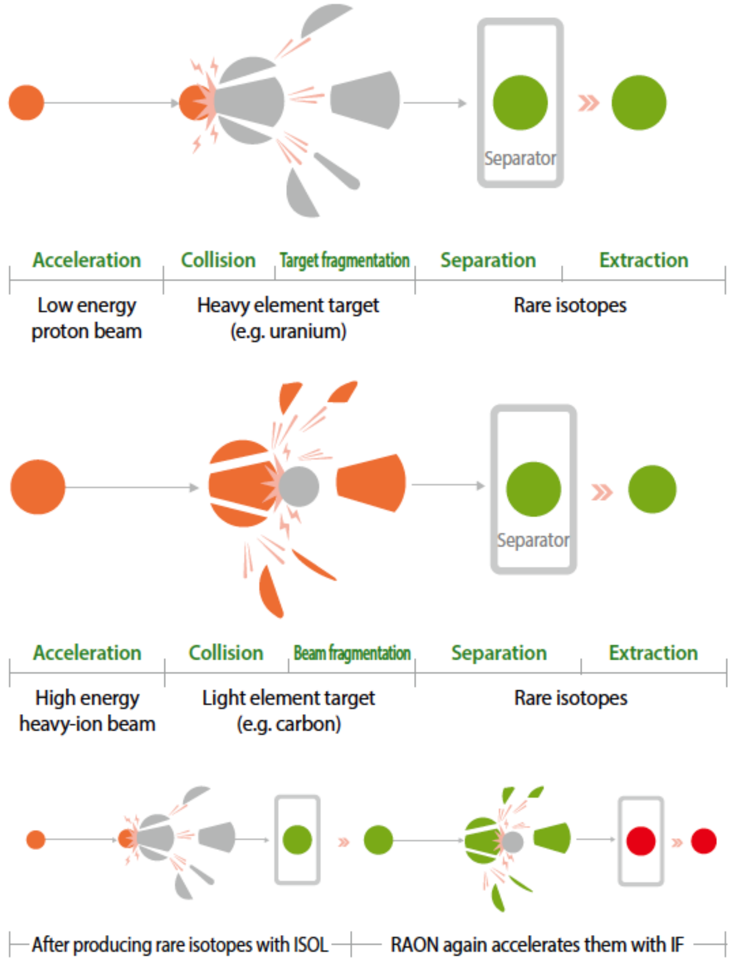
- **Designed to produce highly rare isotopes**
- **Unique generation of highly rare isotopes by the combination of ISOL and IF**
  - After producing rare isotopes with ISOL (Isotope Separation On-Line), RAON again accelerates them with IF (In-flight Fragmentation)
  - Possible to make larger number of new and rare isotopes
- **Primary beam energy**

	1st. phase	2nd. phase
Proton	80 MeV	600 MeV
Uranium	18 MeV	200 MeV/u
		For LAMPS

See Seung-Woo Hong's keynote talk

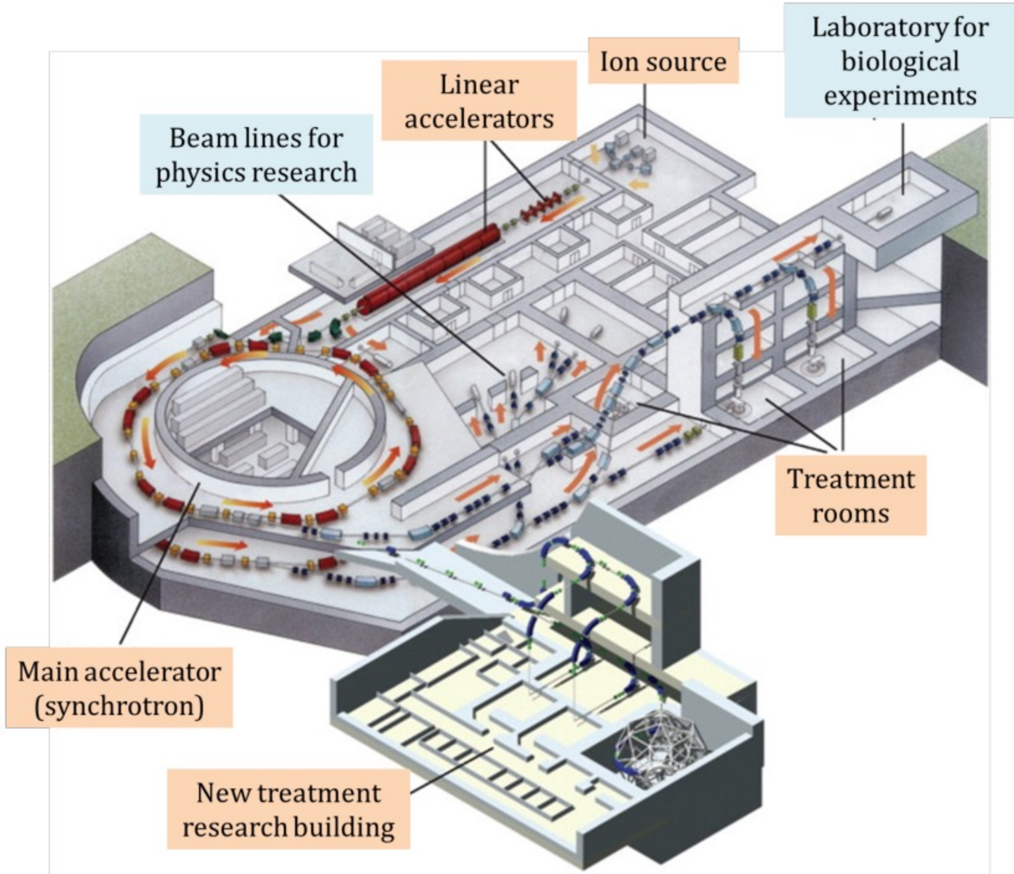
Methods of rare isotope production

- **ISOL (Isotope Separation On-Line)**
  - Acceleration of light atomic ions for collisions with heavy atomic targets
  - Production of large amounts of rare isotopes
- **IF (In-flight Fragmentation)**
  - Acceleration of heavy atomic ions for collisions with light atomic targets
  - Production of various rare isotopes
- **ISOL + IF**
  - Applying an IF method to rare isotopes which are re-accelerated after being produced by using and ISOL method
  - Production of newer and more rare isotopes than isotopes produced by an existing method



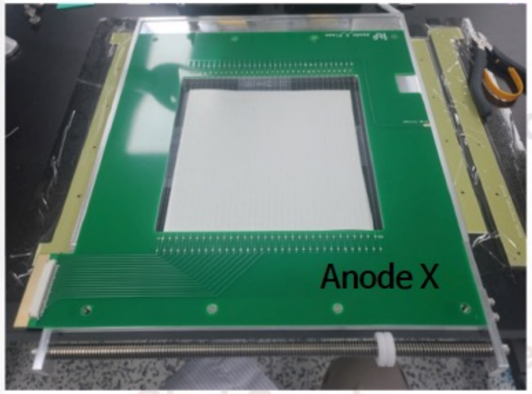
HIMAC (Heavy Ion Medical Accelerator in Chiba)

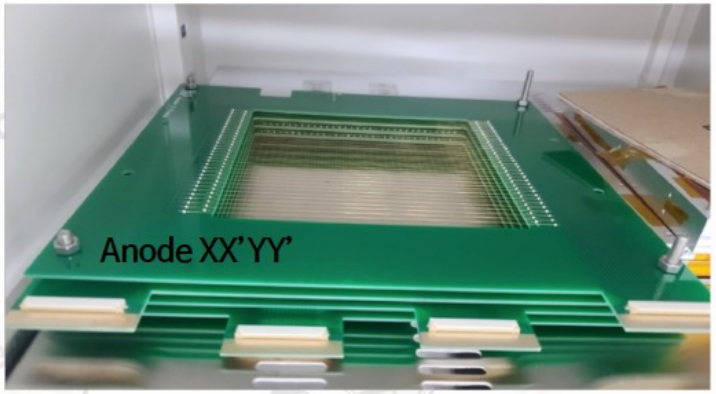
- **Located at Chiba, Japan**
- **Accelerator designed for cancer therapy**
- **Accelerate various ions to energies ranging from 100 to 800 MeV/u**
- **<u>100 MeV proton and 200 MeV/u $^{12}C^{+6}$ ion beams were utilized for the test</u>**

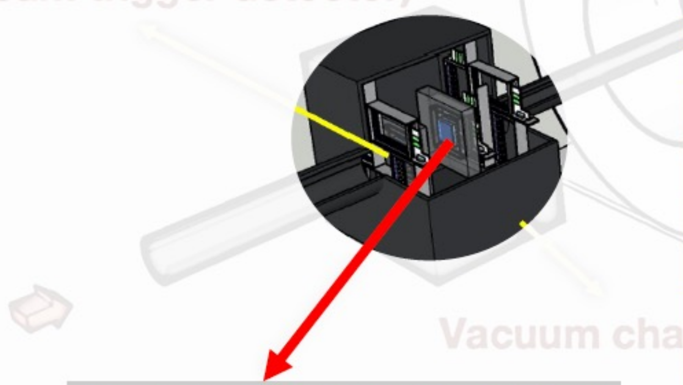


Real LAMPS BDC

From Sanghoon Lim's KPS slides





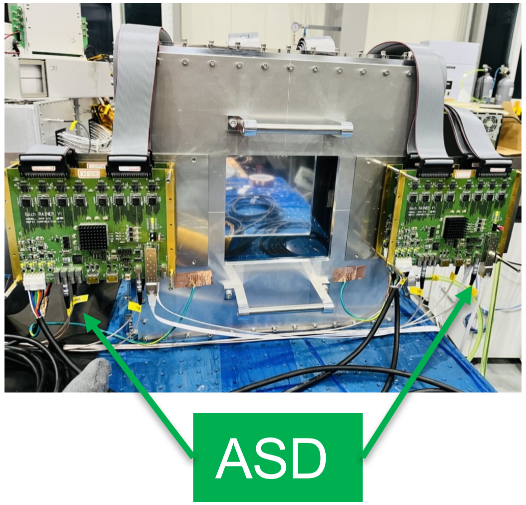


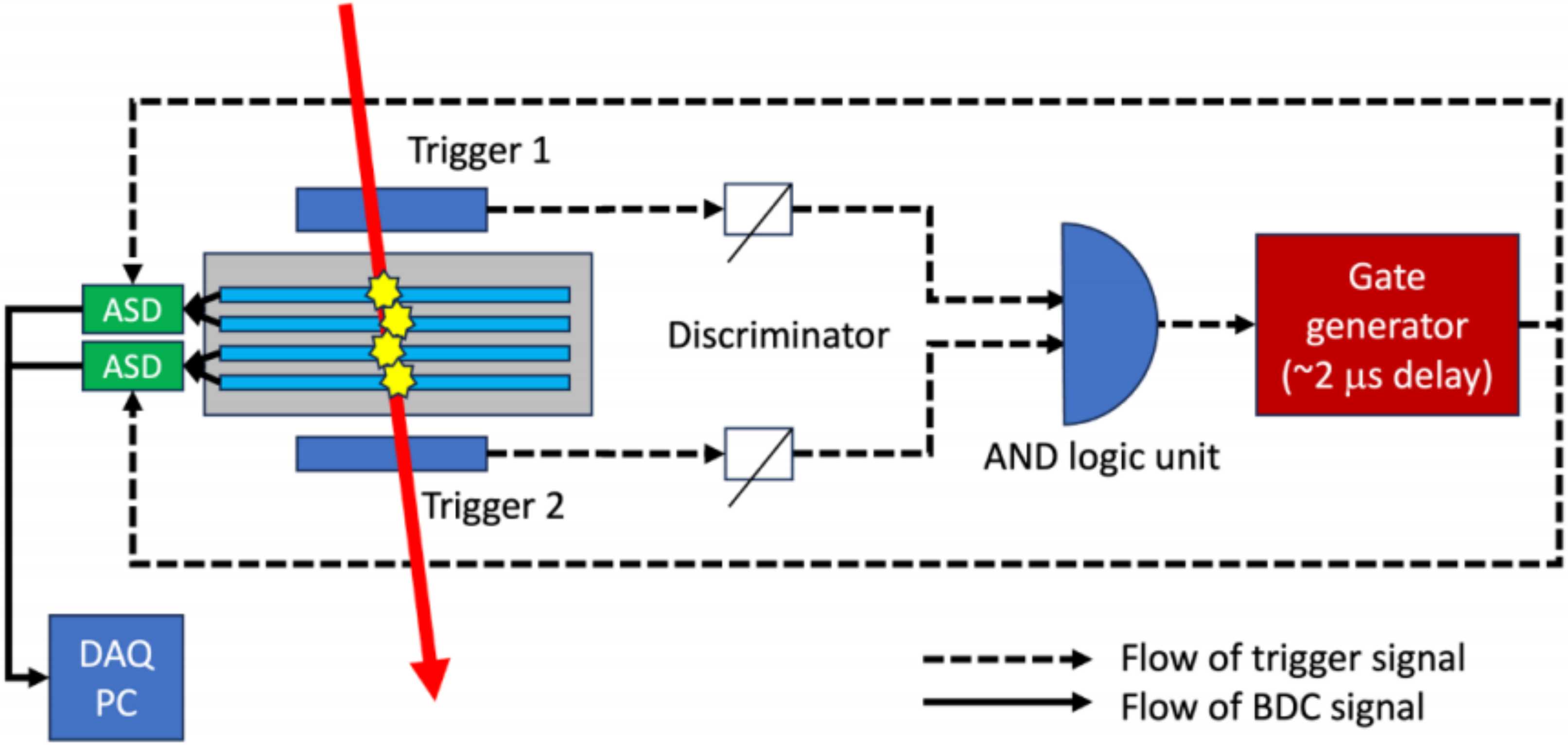
Anode Wire	ϕ 20 μm Au-W
Potential Wire	ϕ 80 μm Cu-Be or Au-W
Cathode	2 μm thick Al-Mylar, 9 layers
Cell Size	5 mm (max. drift length 2.5 mm)
Active Area	170 x 170 mm^2
Anode Configuration	XX'YY'XX'YY', 8 layers
Number of Channels	256 (32 wires/plane, 8 planes)
Operation Gas	i-C_4H_{10} below 1 atm P-10 at 1 atm
High Voltage	2 channels for Cathode, Potential Wires
Front End Electronics	ASD(RP-2125)
Body Dimension	490 (L) x 360 (H) x 100 (W) mm^3
Beam window (variable)	12 μm Al-Mylar (up to 20 kPa) 50 μm Al-Mylar (up to 50 kPa)

11

Schematic diagram of the experimental setup at HIMAC

BDC

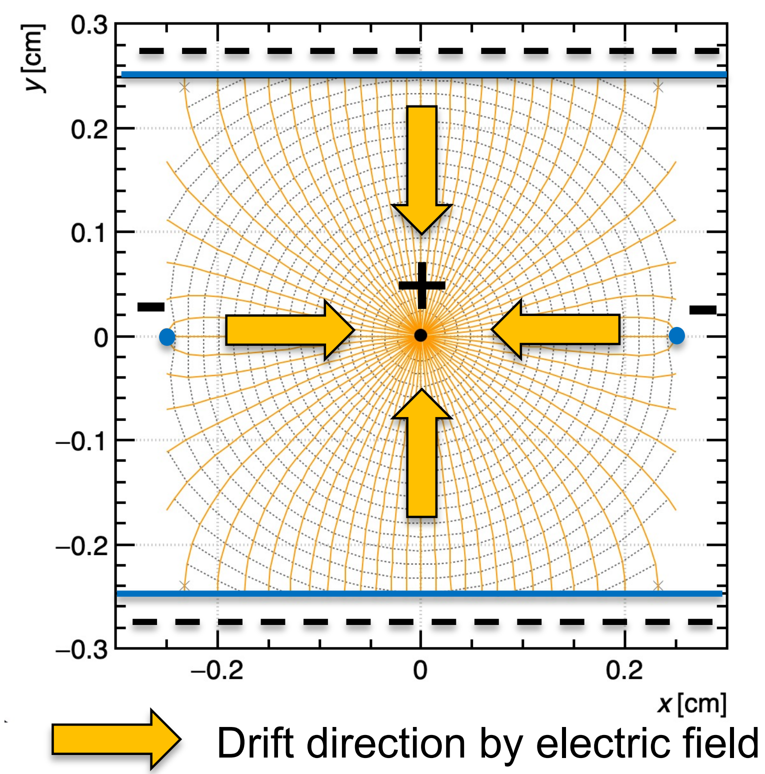


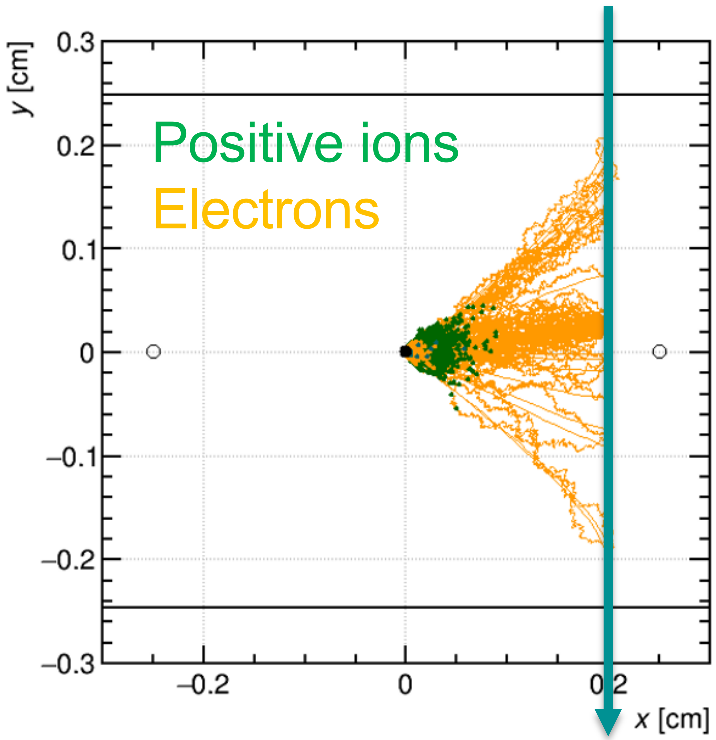


- **Prototype BDC was tested at HIMAC in Japan using the 100 MeV proton and 200 MeV/u carbon ion beam**
- **TDC time is measured by ASD (Amplification, Shaper and Discriminator) board with 1 ns timing resolution**

BDC : Drift chamber

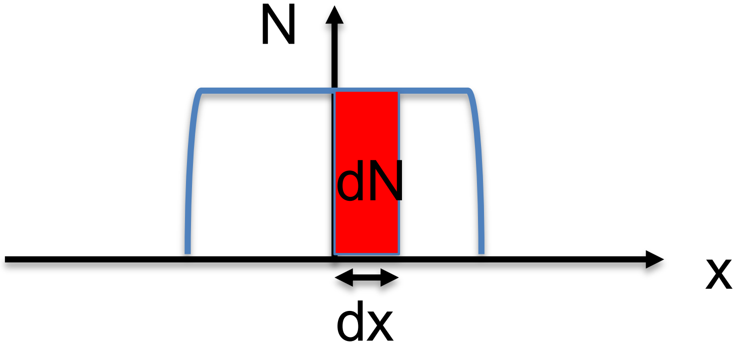
- **Minimizing beam energy loss and good position resolution**





Electric field map at 1400 V and 100 MeV proton by Garfield++ simulation

Homogeneous method



dN **=** cdx **(**$where\ c\ is\ constant$**)**

$$\frac{dN}{dt}dt = cdx \Rightarrow x(t) = \frac{\int_0^t \frac{dN}{dt}dt}{c}$$

$$c = \frac{\int_0^{t_{max}} \frac{dN}{dt}dt}{d}$$

d : $maximum\ drift\ length$ **(2.5 mm)**

Important assumption : flat region vs. x