The performance of the SCRIT detectors for electron-RI scattering experiment

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Physics motivation

- The SCRIT device is an unique tool to measure a precise internal structure (i.e. the charge density distribution) of unstable short-lived nuclei which have never been measured before.

- The charge density distribution is derived from the form factor which can be obtained by the Mott cross section and the measured **angular cross-section** of elastic electron scattering.

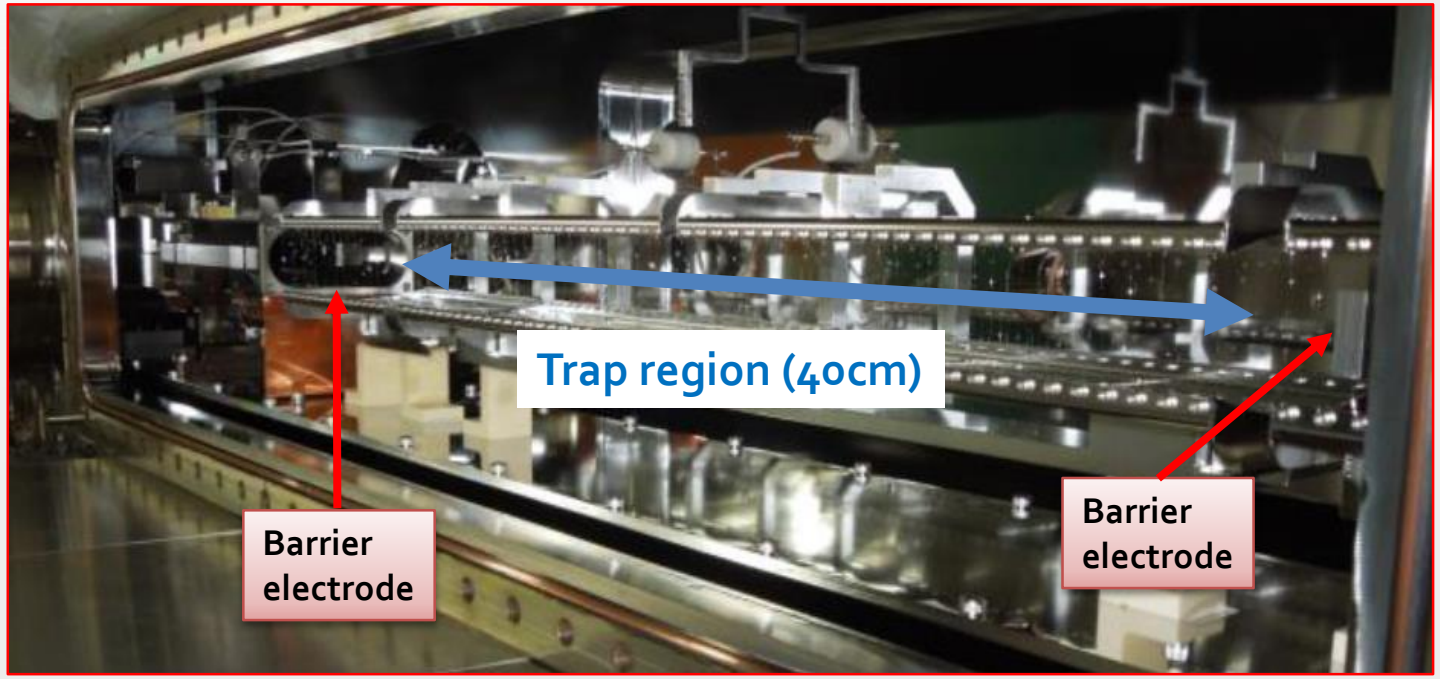
$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{Mott} |F(q)|^2$$

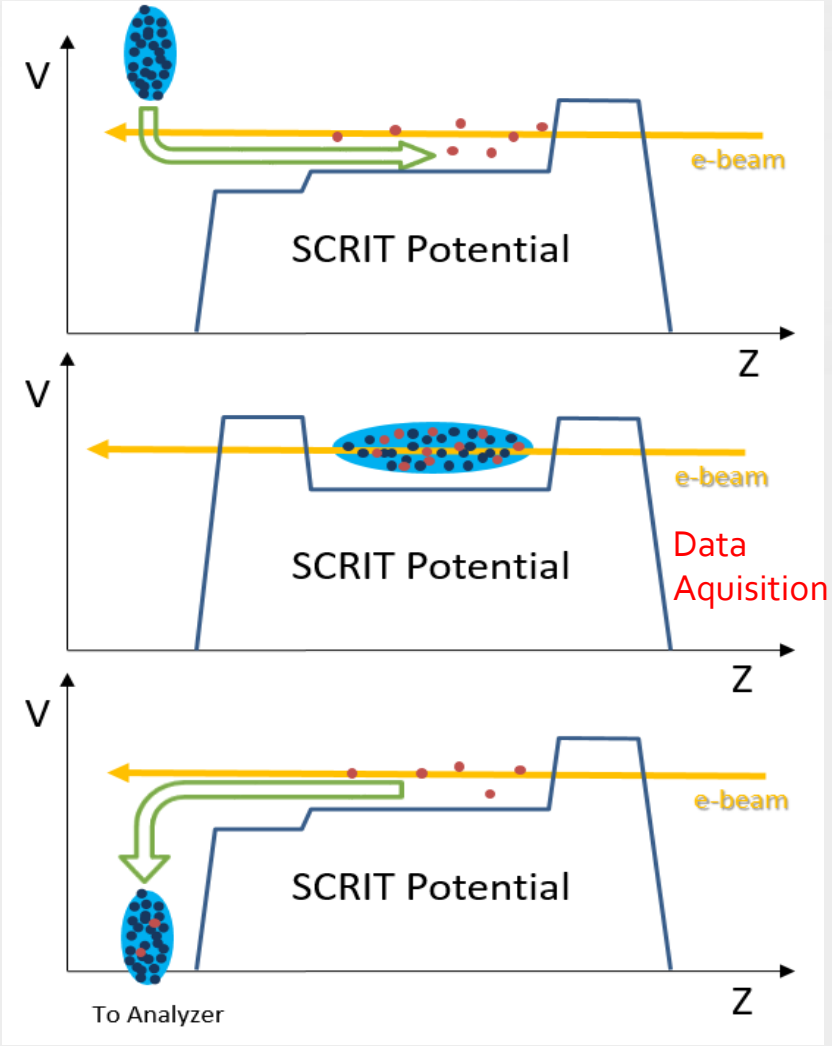
- To obtain the angular cross-section, the **angular distribution** and the **absolute luminosity** of electron elastic scattering have to be measured.

$$\frac{d\sigma}{d\Omega} = \frac{1}{L}\frac{dN}{d\Omega}$$

SCRIT (Self-Confining RI Target)

- Short-lived RIs are injected in SCRIT device and horizontally confined by mirror potentials. Traversing electron bunches focus the confined ions transversely (Beam trapping phenomena).

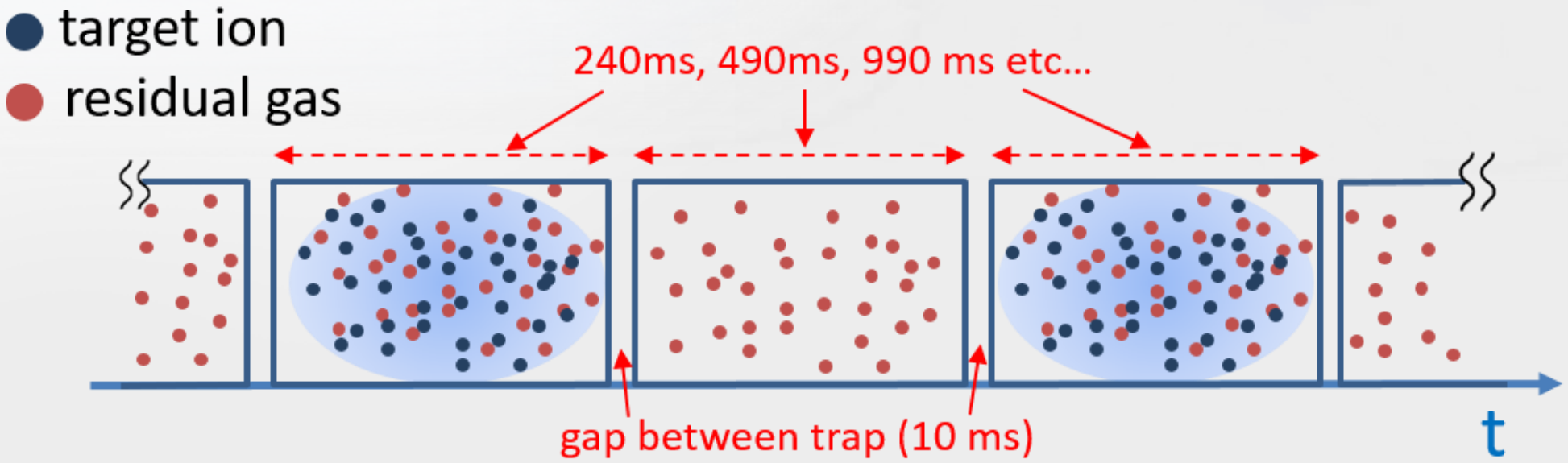




Presentation by T. Ohnishi (this session)

How to measure the target ions

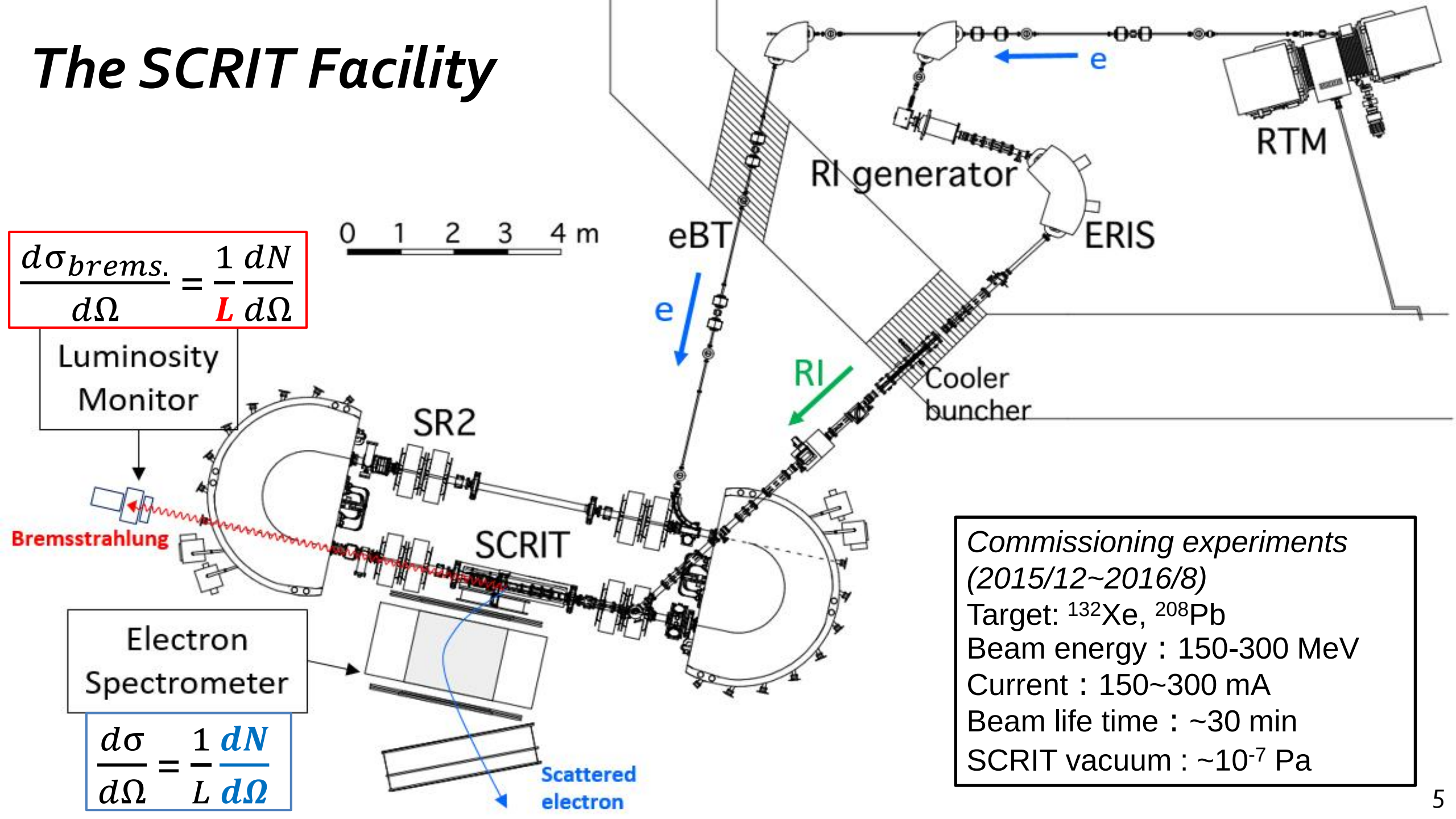
To evaluate the background from residual gas, the SCRIT detectors measure for both periods with and without target ion trapped (**Ion IN**, **Ion OUT**)



The net amount of the target ion trapping can be evaluated as **Ion IN-OUT**.

- (Premise) The amount of trapping of residual gas doesn't change between **Ion IN** and **Ion OUT** period.

The SCRIT Facility



$$\frac{d\sigma_{brems.}}{d\Omega} = \frac{1}{\boldsymbol{L}}\frac{dN}{d\Omega}$$

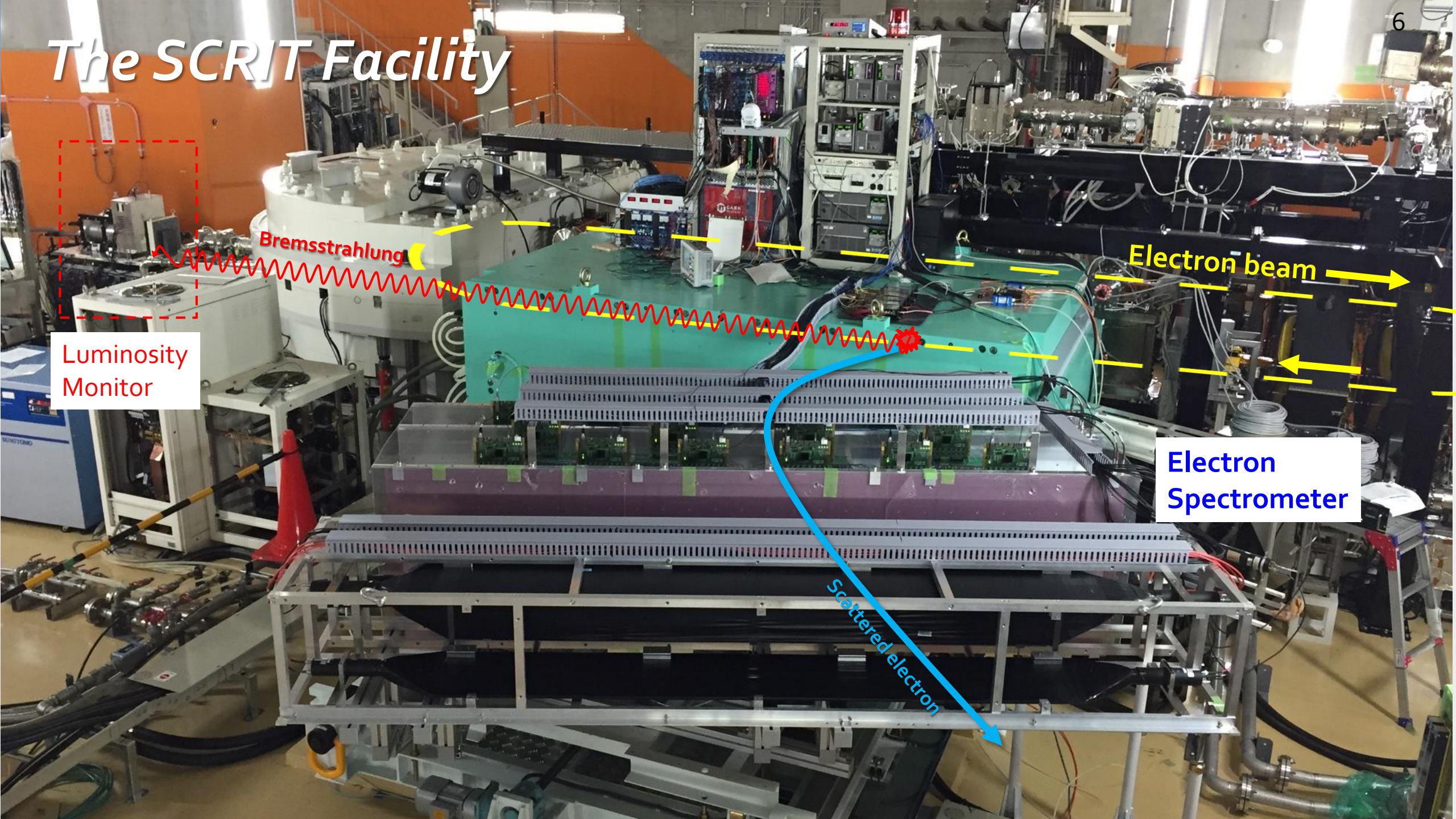
Luminosity Monitor

Electron Spectrometer

$$\frac{d\sigma}{d\Omega} = \frac{1}{L}\frac{\boldsymbol{dN}}{\boldsymbol{d\Omega}}$$

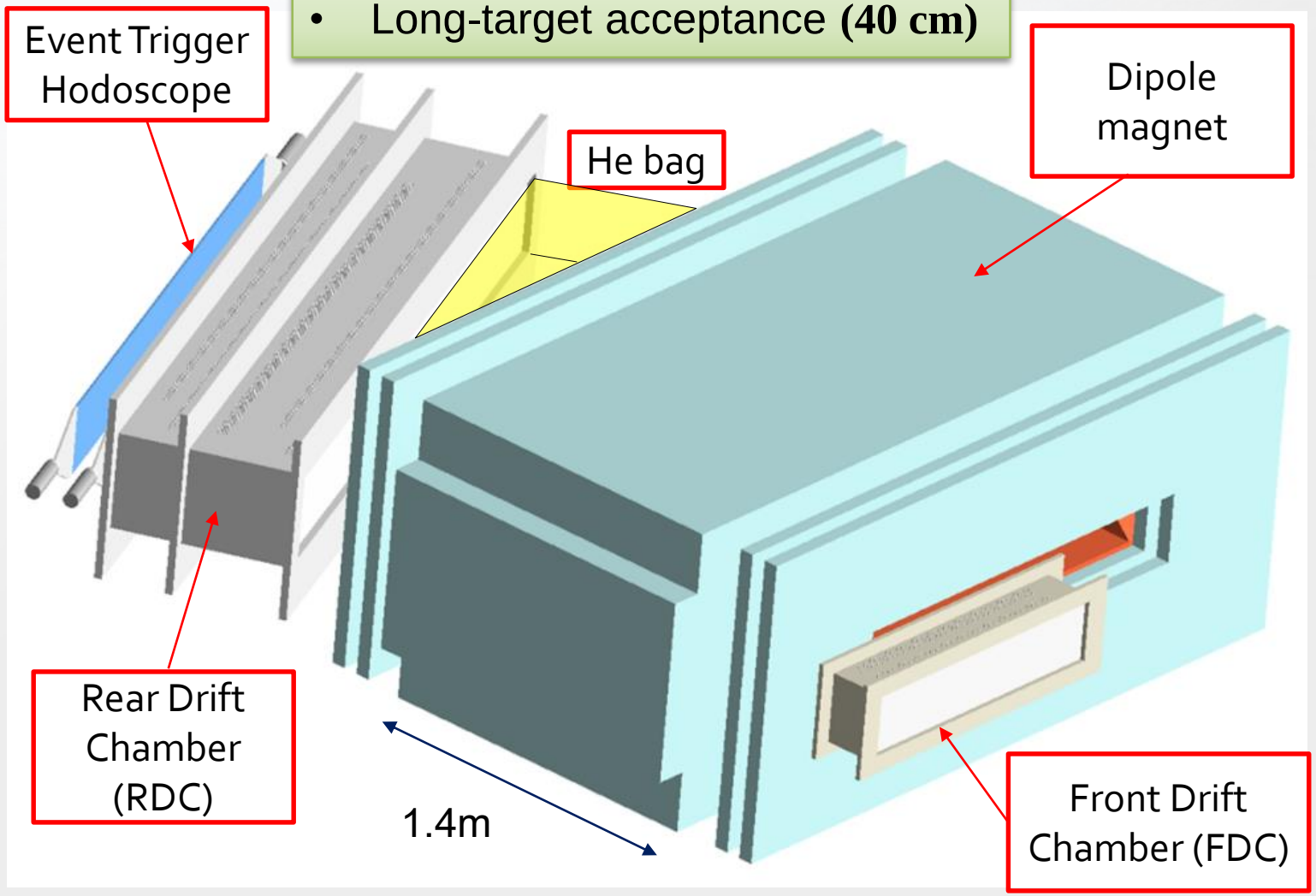
Commissioning experiments (2015/12~2016/8)
Target: ^{132}Xe, ^{208}Pb
Beam energy：150-300 MeV
Current：150~300 mA
Beam life time：~30 min
SCRIT vacuum : ~10^{-7} Pa

The SCRIT Facility



SCRIT electron spectrometer (WiSES)

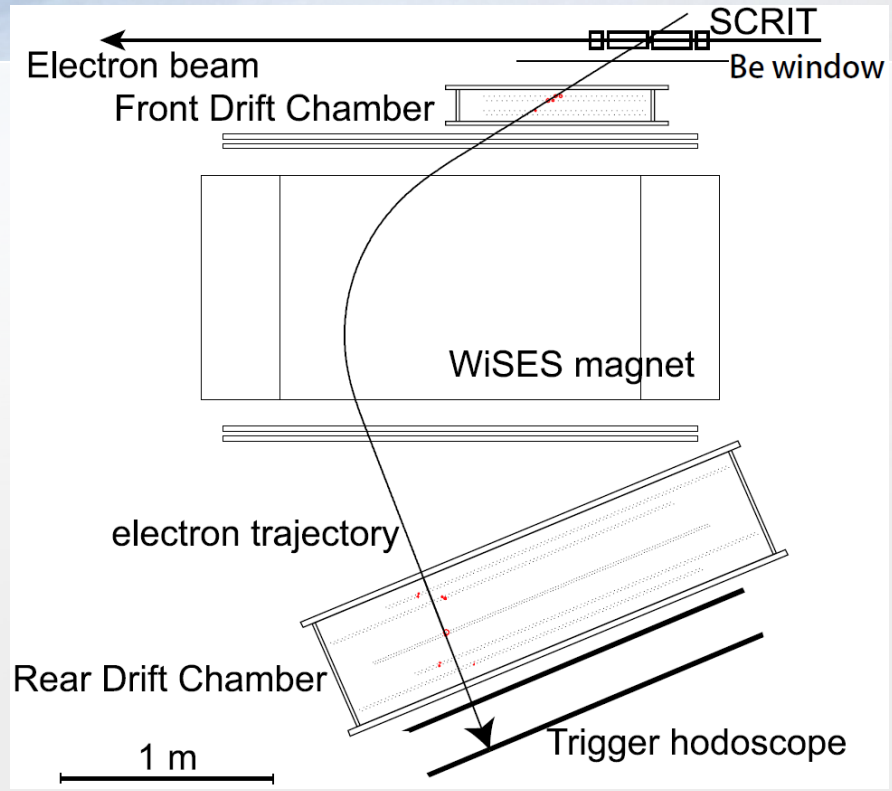
- High resolution ($\Delta p/p \sim 10^{-3}$)
- Large Acceptance (~100 msr)
- Long-target acceptance (40 cm)

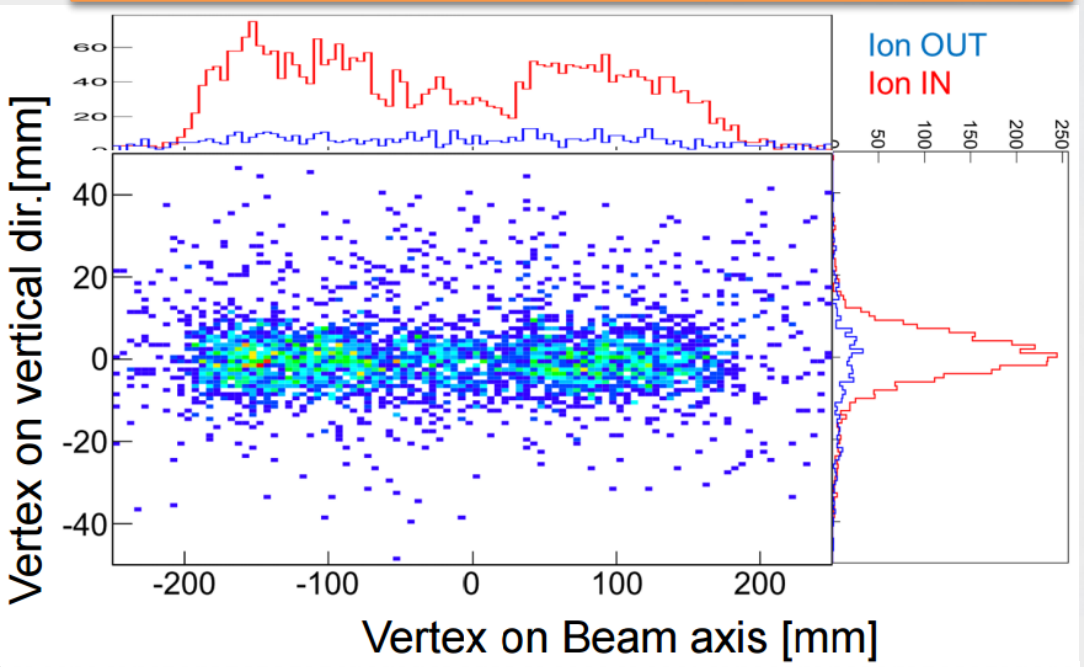


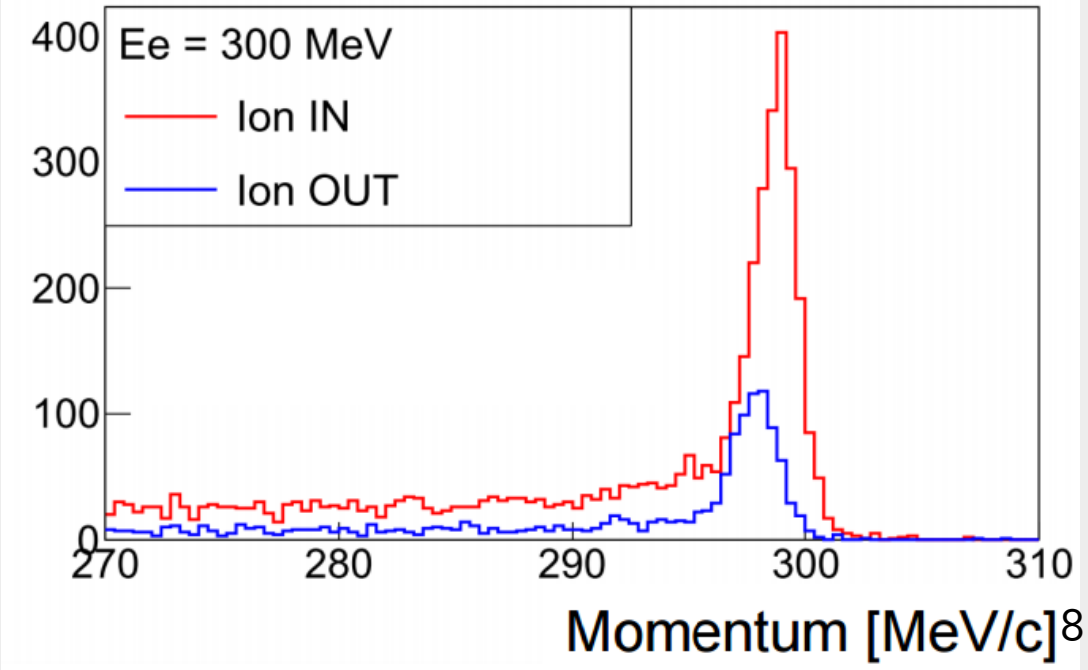
- **FDC (Front Drift Chamber)**
  - XX'XX' (Cell size: 18 mm)
  - Gas : He+C_2H_6 (80:20)
  - Resolution : 150um
- **RDC (Rear Drift Chamber)**
  - UU'VV'XX'UU'VV' (Cell size: 10 mm)
  - Gas : He+C_2H_6 (80:20)
  - Resolution : 130um
- **Dipole Magnet**
  - weight 55 tons
  - B_{max} = 0.8 T
  - Less than 1% magnetic filed leak outside the field clamp
- **Trigger Hodoscope**
  - two scintillation counters

Results from ^{132}Xe trap

Presentation by K. Tsukada (12 Sep 15:40 Hall L)

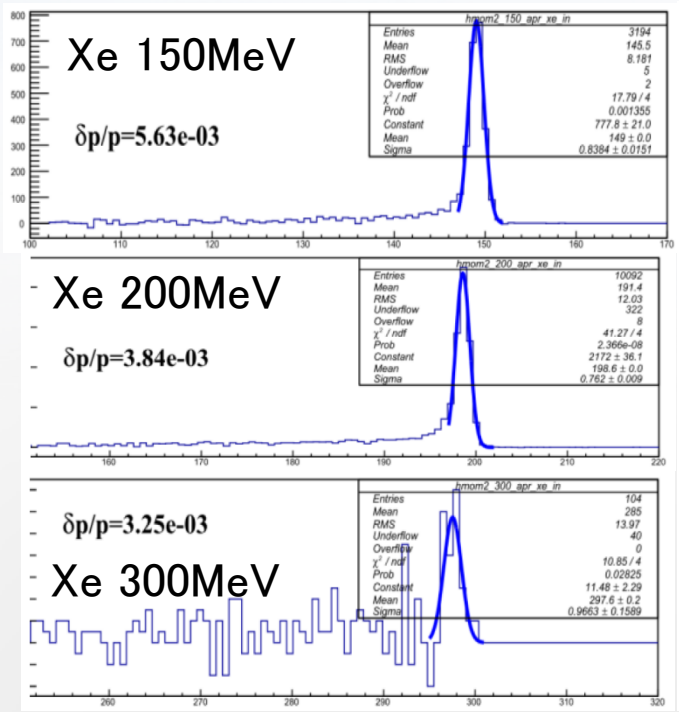


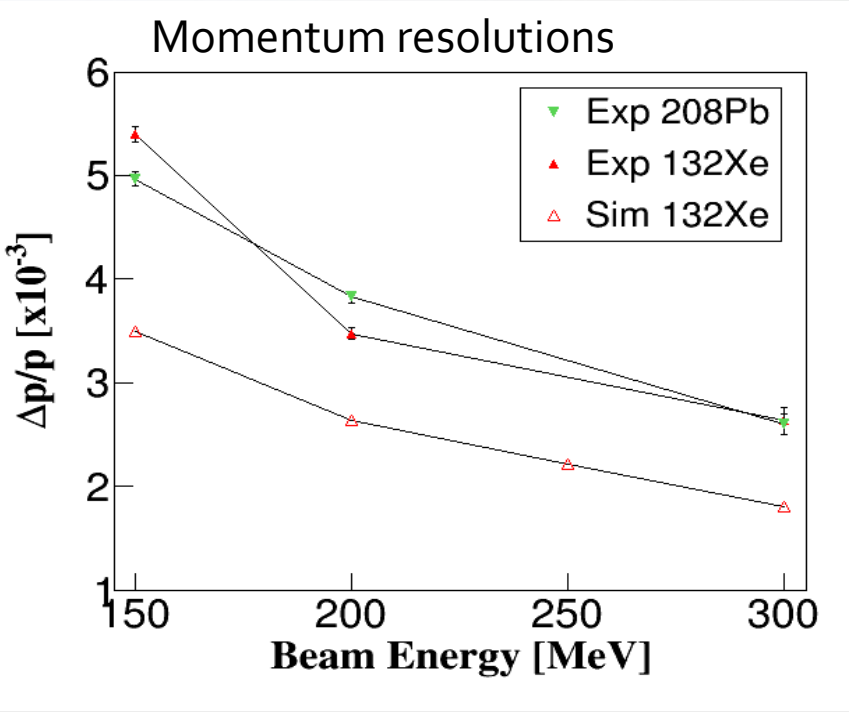


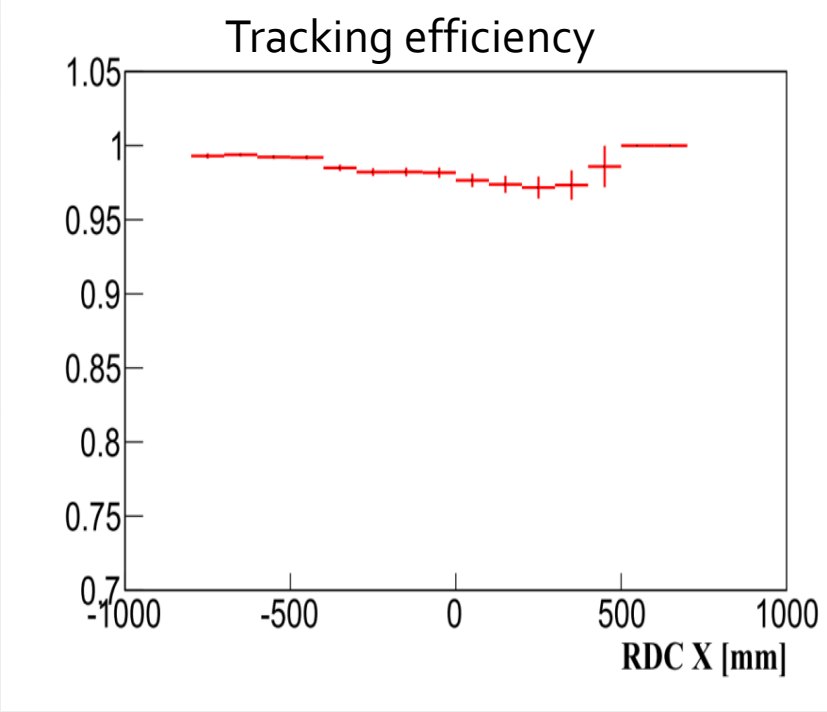


- The trajectory of scattered electron is reconstructed (by Runge-Kutta) and extrapolated to the SCRIT beam line to get the vertex position.
- Distributions of the target ion (^{132}Xe, ^{208}Pb) can be measured from **Ion IN-OUT**

Momentum resolution and tracking efficiency

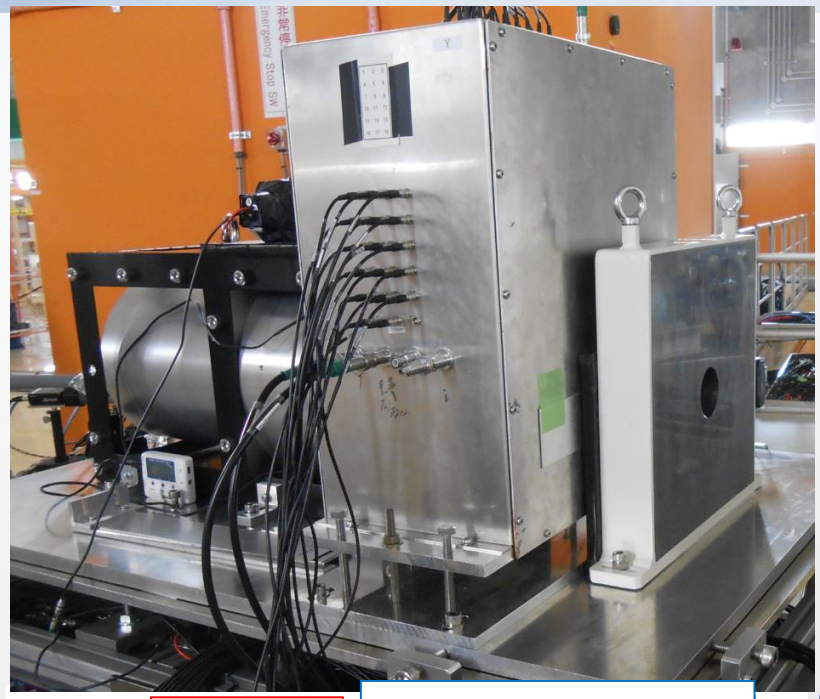


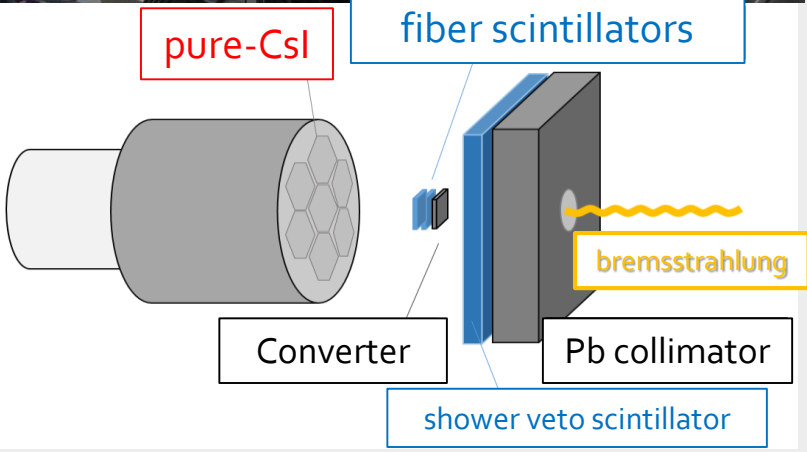




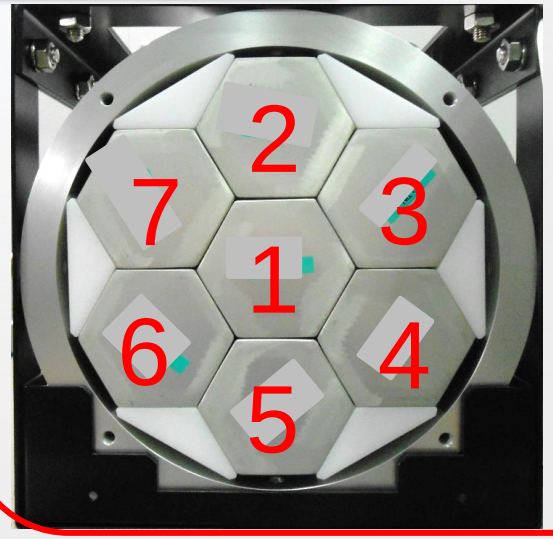
- The WiSES momentum resolution is ~3 x 10^{-3} at E_e = 300MeV.
  - Worse than the estimate from the simulation. Need further investigations.
- The angular uncertainty of the tracking efficiency is less than ±2%.

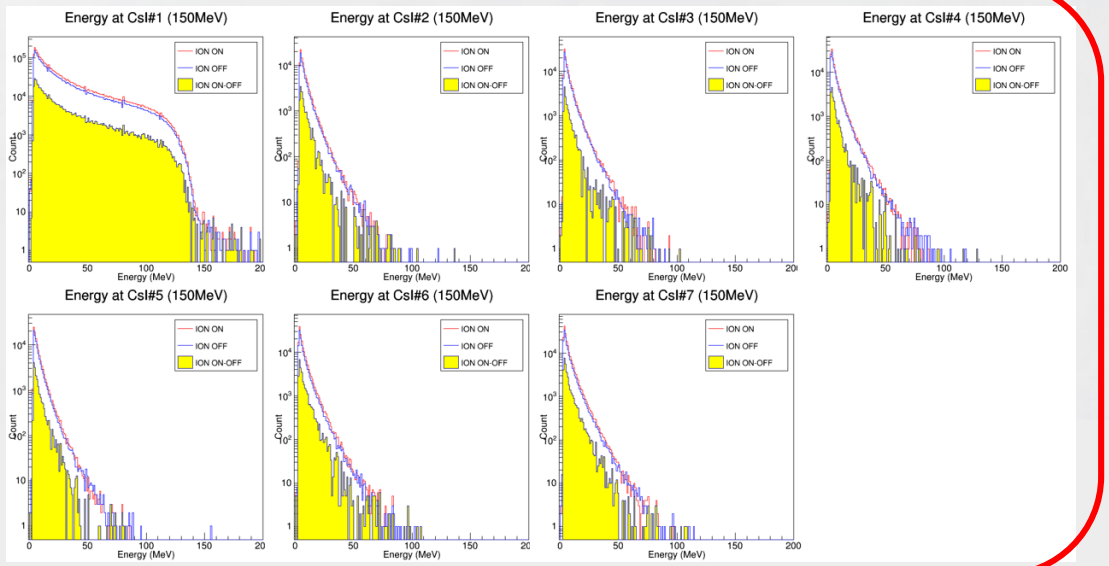
Luminosity Monitor (LMon)



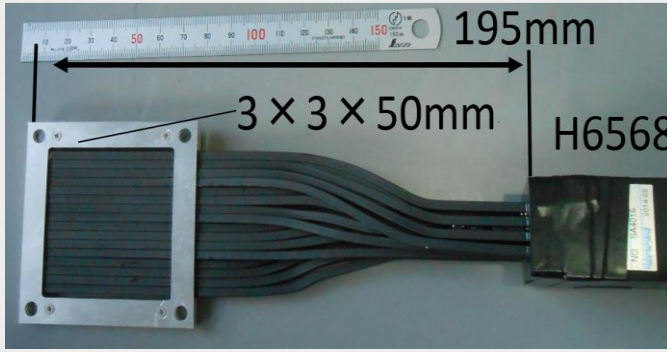


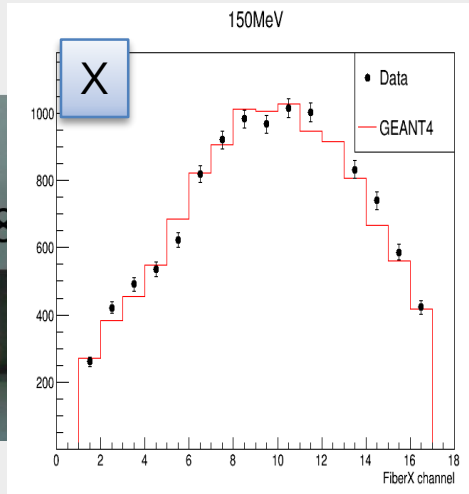
CsI calorimeter

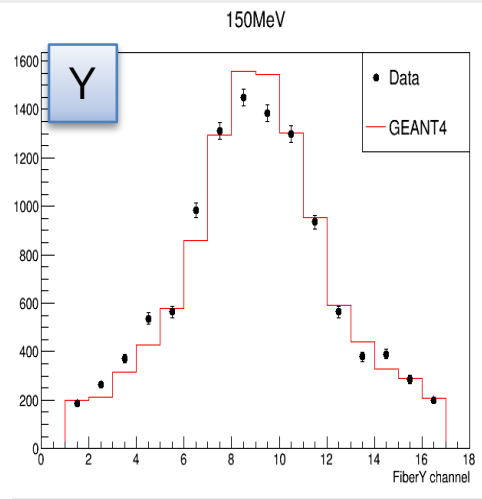




Fiber scintillator（X,Y）







How to determine the absolute luminosity?

$$L = \frac{N_{\mathrm{CsI}}}{t} \cdot \frac{1}{\sigma} \cdot \frac{1}{\varepsilon}$$

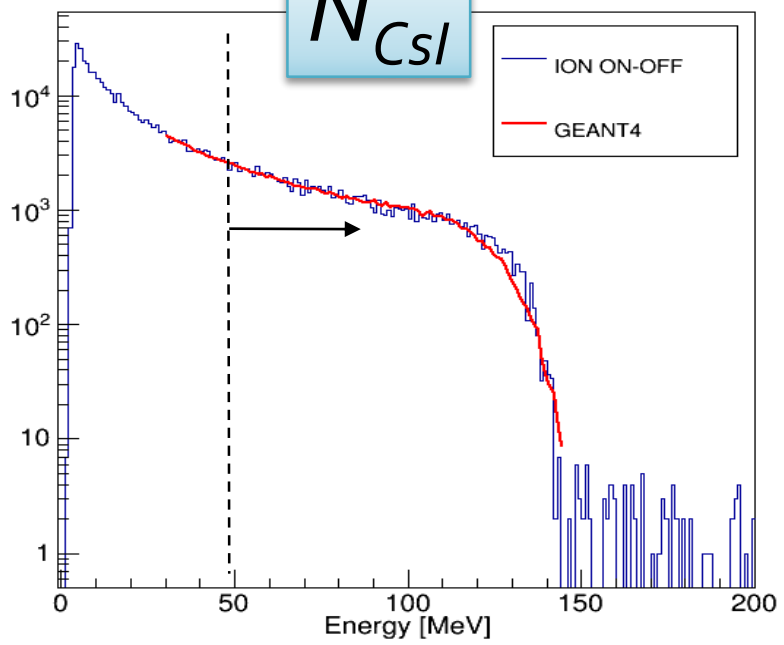
N_{CsI}/t: Measured hit rate at CsI

σ : Bremsstrahlung cross-section calculation

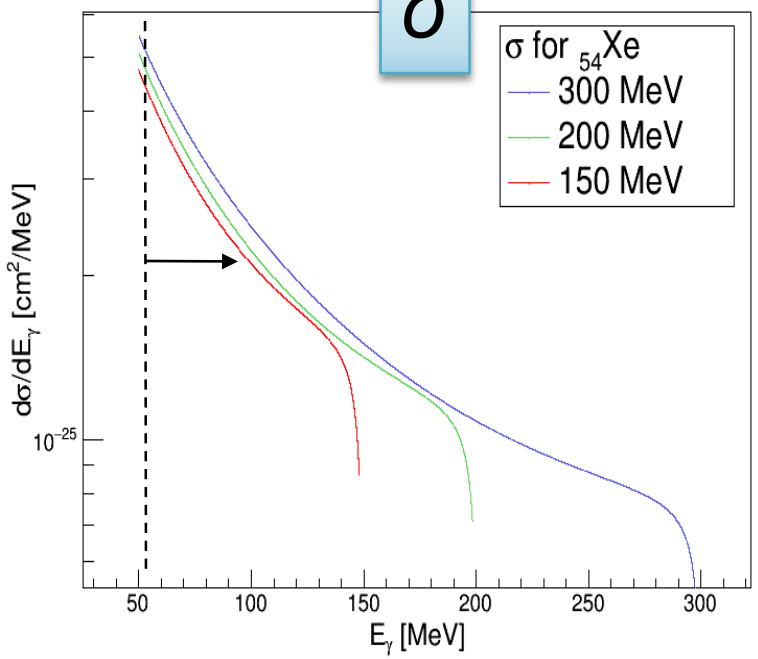
ε : Detection efficiency (estimated by GEANT4)

(All values are obtained for E > 50 MeV)

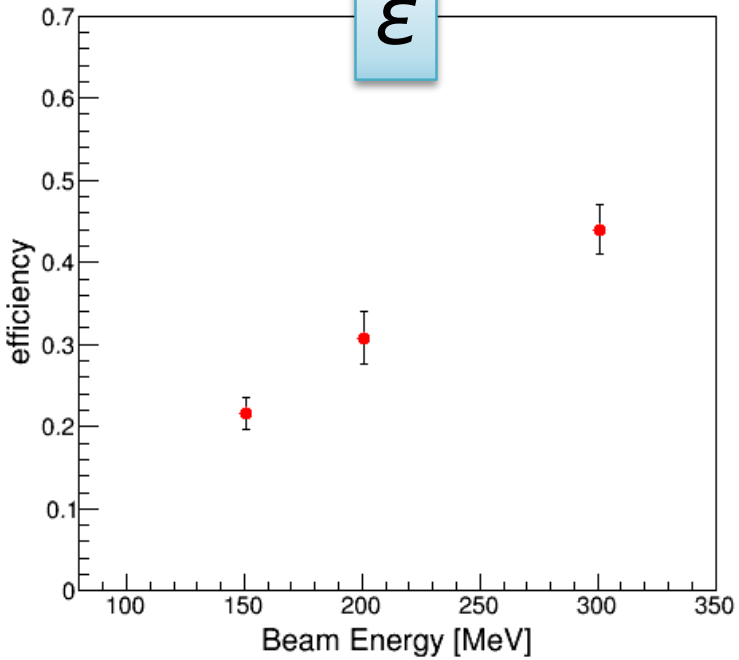
N_{CsI}



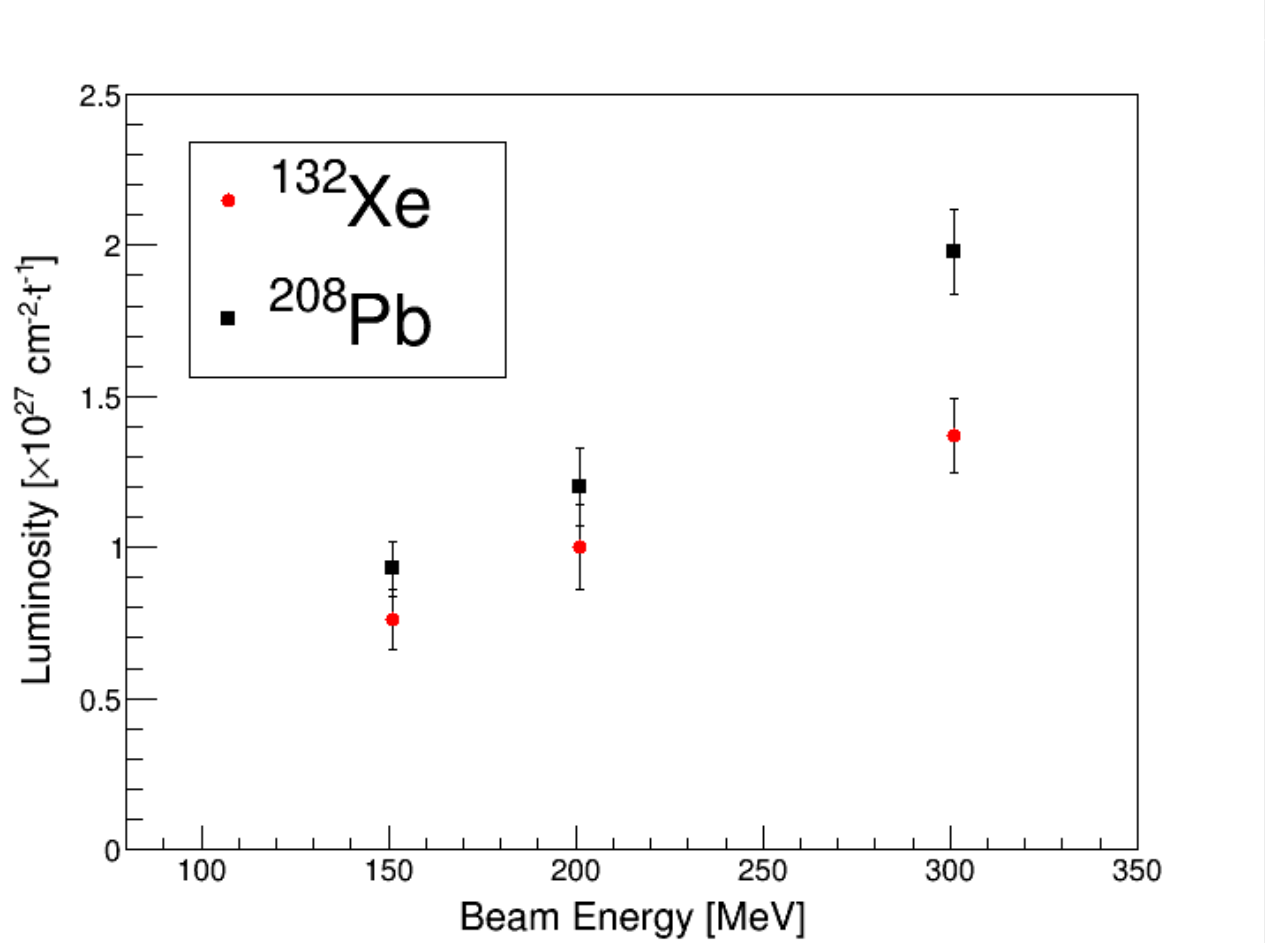
σ



ε



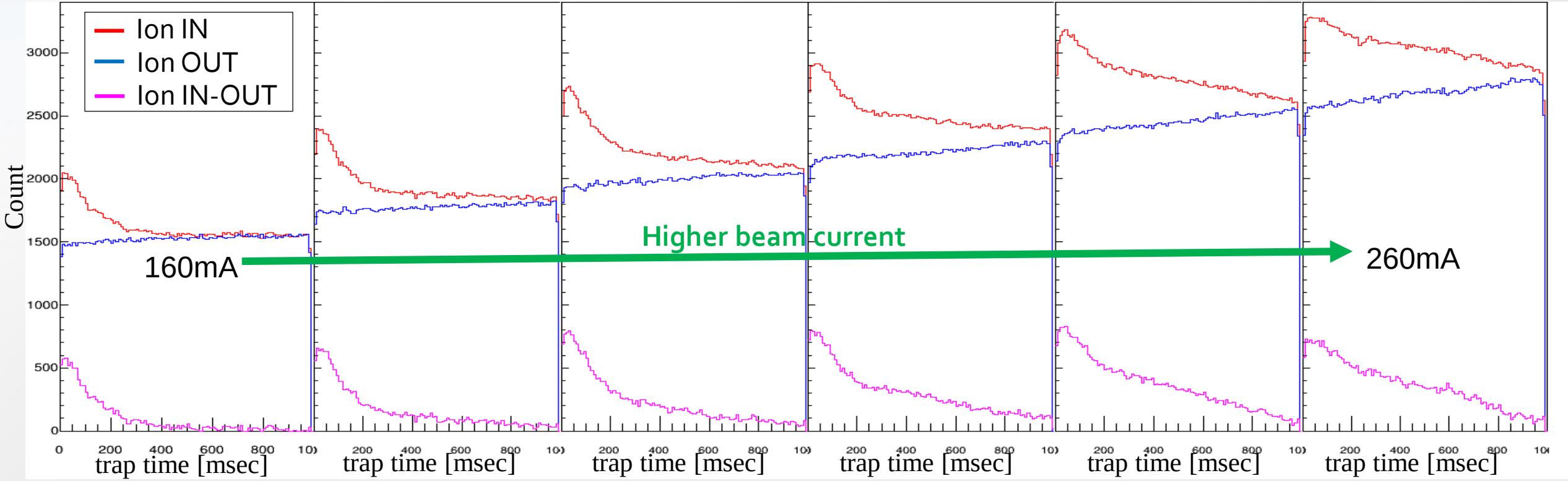
Measured luminosities



- The average luminosity reaches ~2x10^{27} for ^{208}Pb at 300MeV
- Total systematic uncertainty ~ 10% (Mostly from the uncertainty of the detection efficiency)

Detailed insight into the trapping by LMon

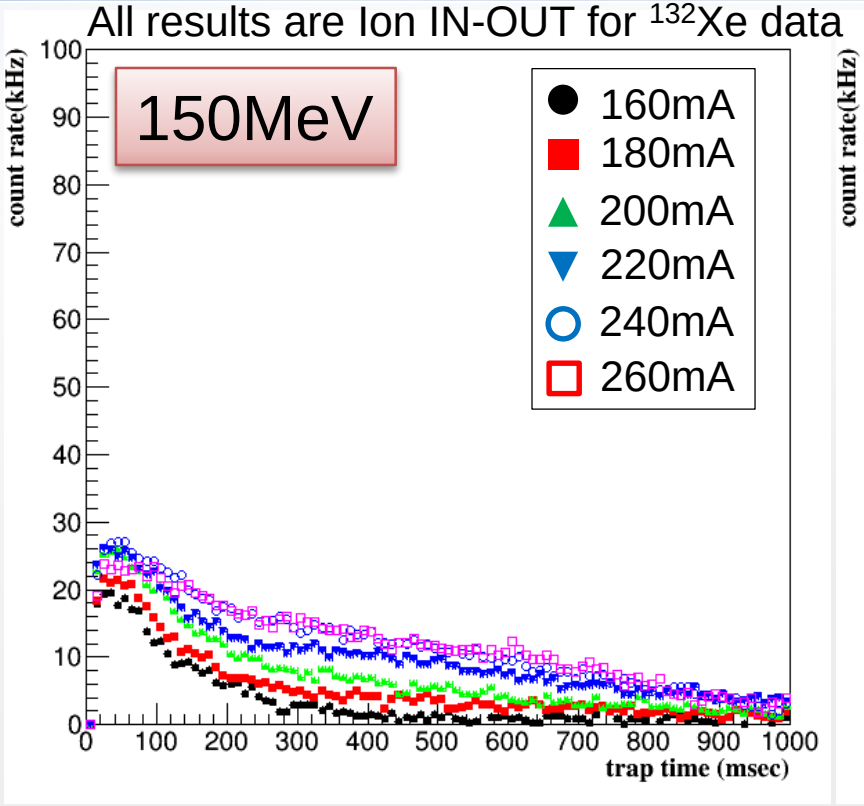
^{132}Xe 200MeV data

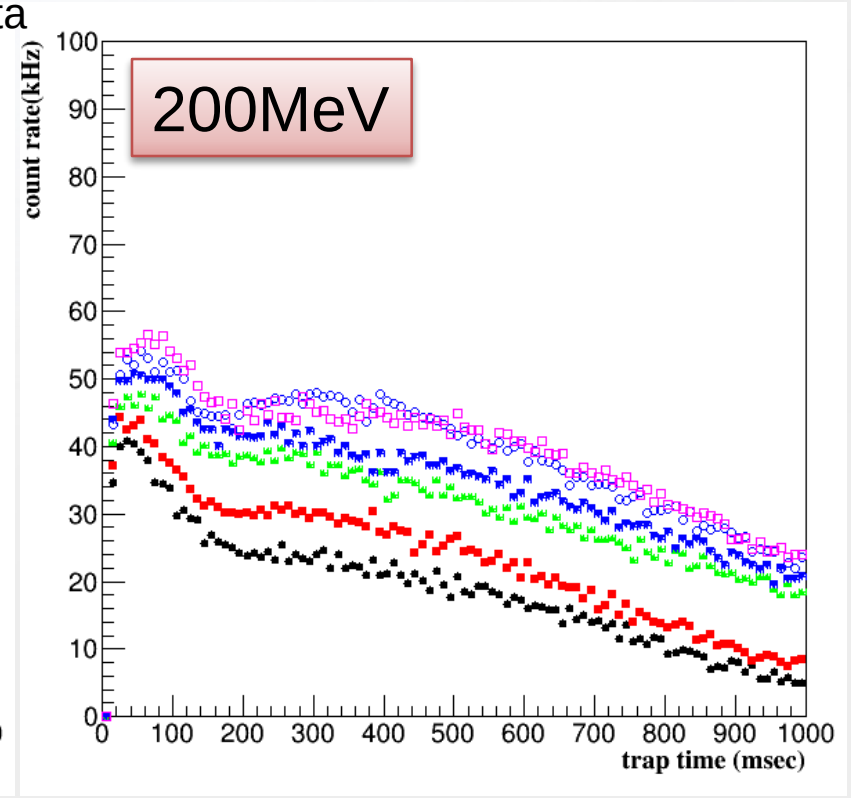


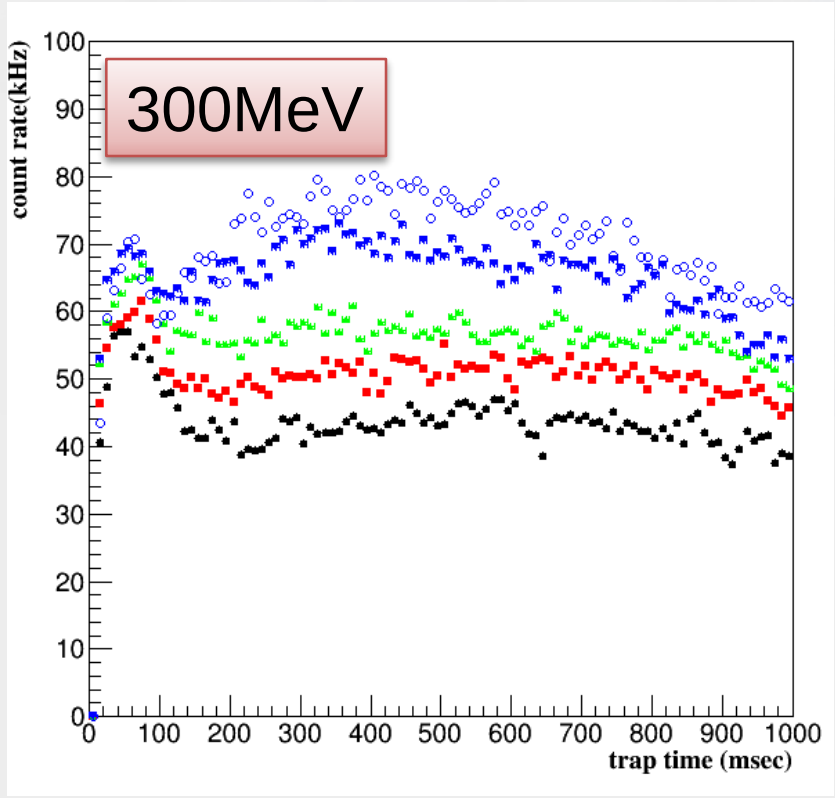
- **Ion OUT** (residual gas) trapping increases as the trap time elapses.
- Decay time of **Ion IN-OUT** (target ion) trapping becomes longer for higher beam current.

Count Rate (Ion IN–OUT) by LMon

All results are Ion IN-OUT for ^{132}Xe data







- The amount of the ion trapping increases as higher beam energy, and the current dependence becomes significant for higher beam energy.
- LMon is a powerful device to optimize beam parameters/trapping method, and to maximize the luminosity.

Summary & Challenges

- Performances of the electron spectrometer
  - $\Delta p/p \sim 3\text{-}5 \times 10^{-3}$ for the electron beam energy 150-300 MeV.
- Performance of the luminosity monitor
  - Total systematic error ~ 10%. Need to be improved by further studies.
  - A powerful device to find the beam tuning and trapping parameters.

- How do we know the backgrounds from the residual gas are same between target ion IN and OUT?
  - Ion analyzer is being installed now for the probe. (Recoil ion detector in future.)
- For ^{132}Xe experiment, S/N is ~0.3 at best with 10^{-7} Pa and10^{8} target ion injection. Need to improve the S/N for ^{132}Sn experiment.
  - the RTM upgrade, a better ion transport, a better trapping method, or a better vacuum (if possible)…