Physics program with **SCRIT**
-- motivation of the project and results of commissioning --

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SCRIT collaboration

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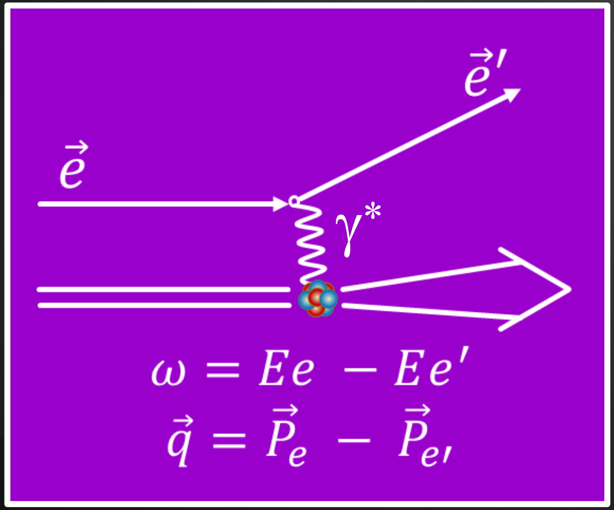
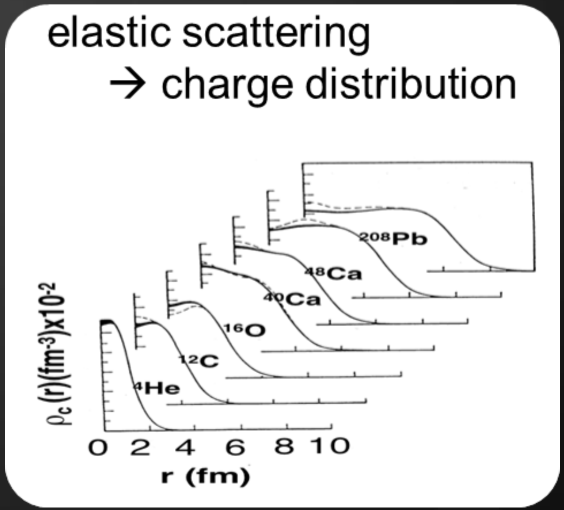
Introduction

Electron scattering

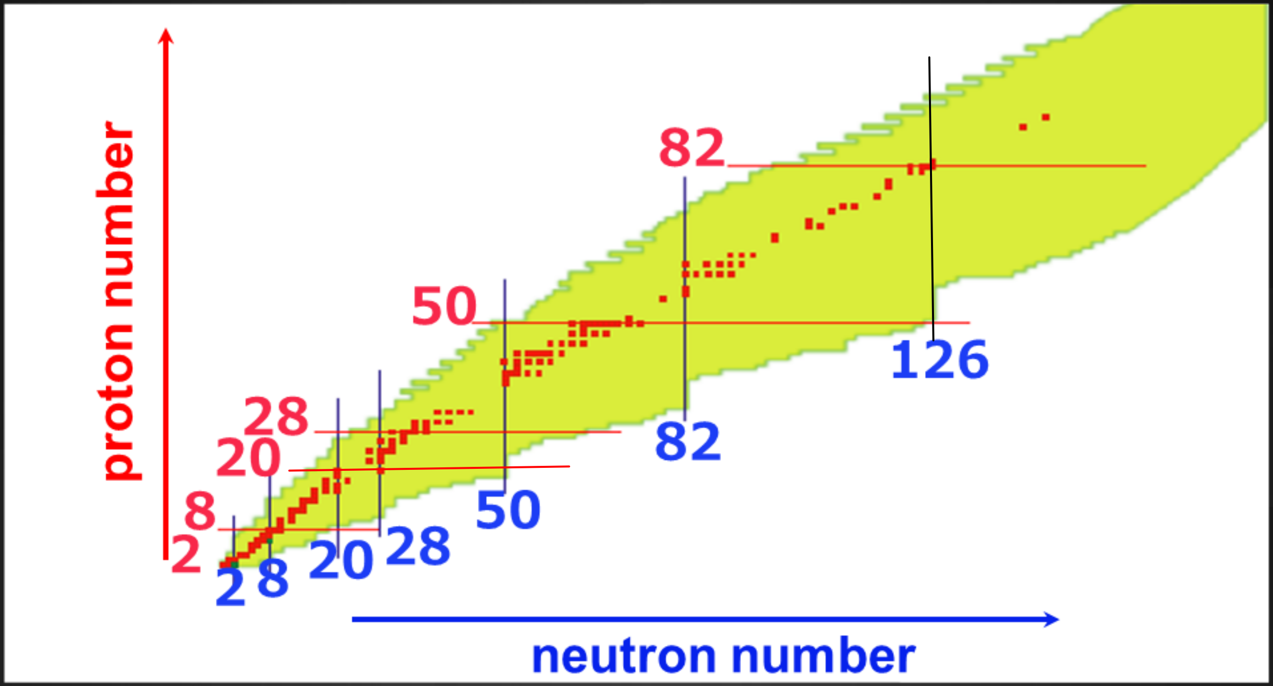
Direct and **unambiguous** structure information of atomic nuclei

- structureless particle
- well known electromagnetic interaction
  - charge and current coupling → EM structure
  - weak coupling → probing whole volume without serious modification
    valid for perturbation theory





Nuclei studied by electron scattering



Electron scattering is so powerful to investigate the nuclear structure information. But …

- Strictly limited to stable nuclei
- Almost no data of unstable nuclei

(a few exceptions: ^{3}H, ^{14}C,,,)

Elastic electron scattering

- Relatively large cross section
- Doorway to various electron scattering experiments

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

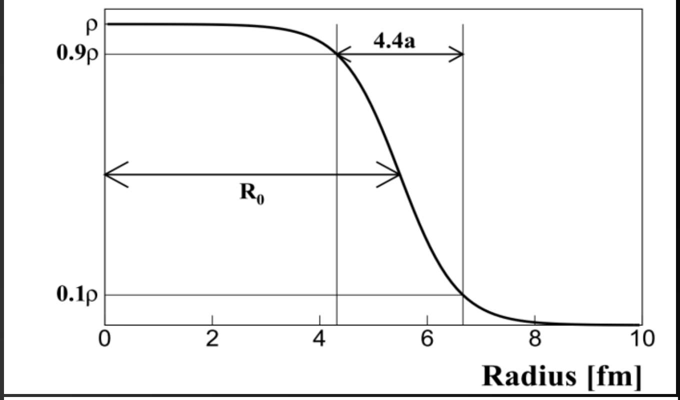
Cross section of Mott scattering

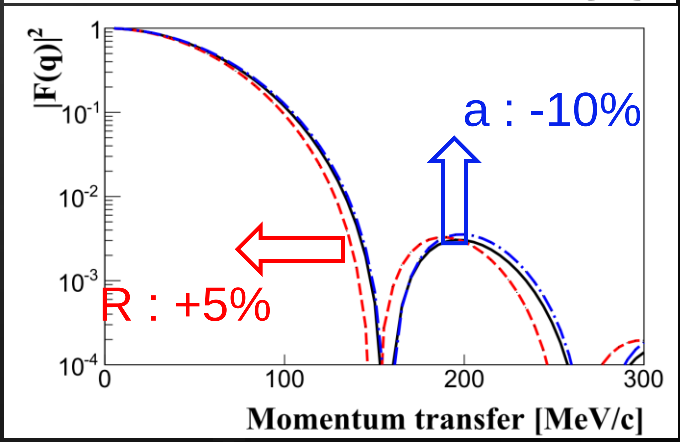
Form factor

$$Fc(q) = \int \rho_C(\vec{r}) e^{i\vec{q}\vec{r}} d\vec{r}$$

Charge density distribution

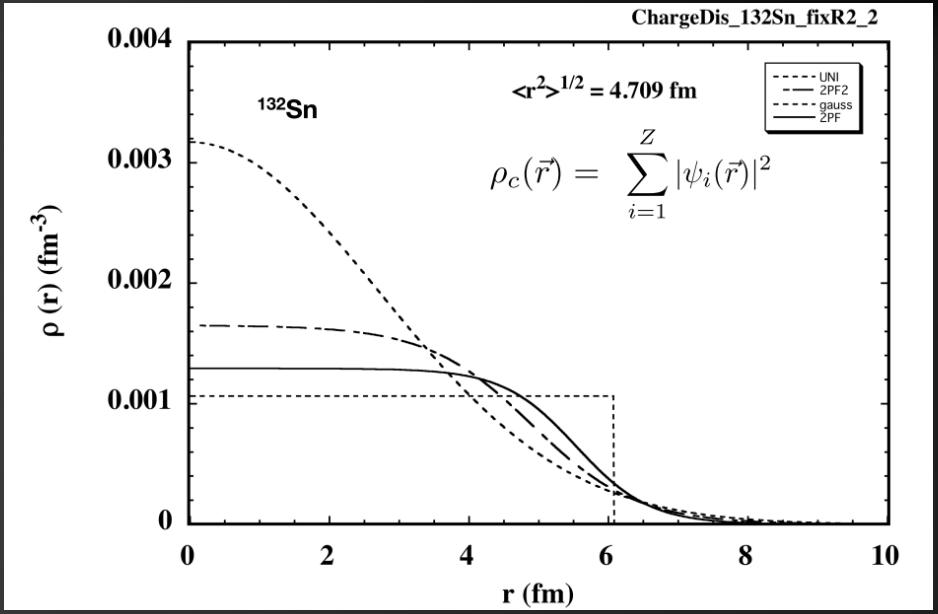
$$\rho_C = \rho/(1 + e^{(r-R)/a})$$





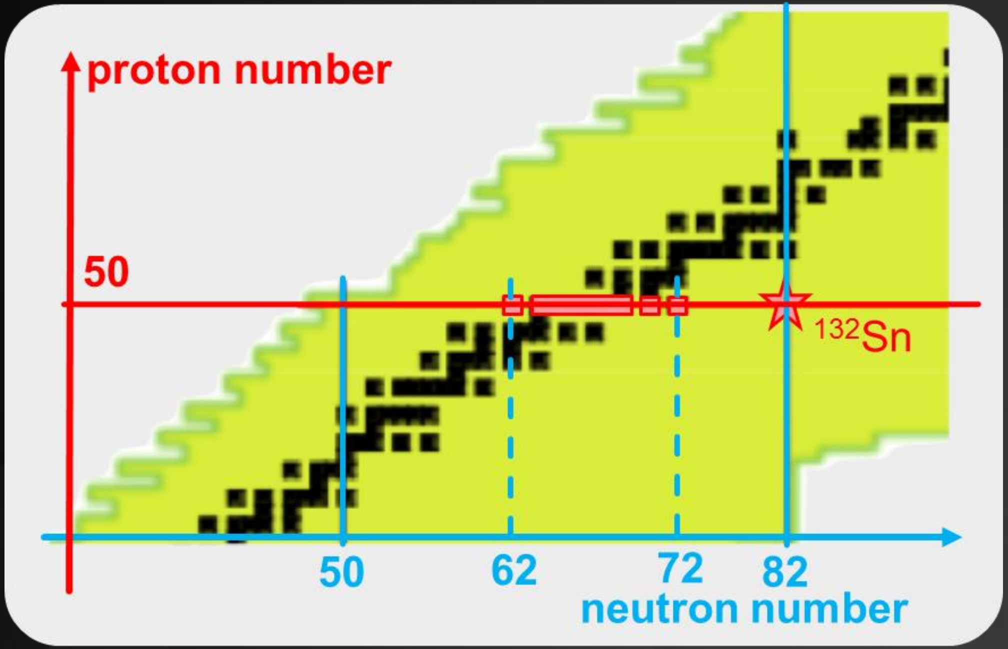
Nuclear radii with EM probe

- X-ray from muonic atom (2P-1S)
  - <r^2> with assumption of the shape
  - Stable nuclei
- Isotope shift of optical transition
  - δ<r^2>
  - Relative change among isotopes
  - Stable and unstable nuclei
- Electron scattering
  - Charge density distribution
  - Stable nuclei so far



Only electron scattering can determine the nuclear shape.

The first goal of the project



Isotope chain of Sn

$^{112-124}$Sn : stable

$^{126-132}$Sn : unstable

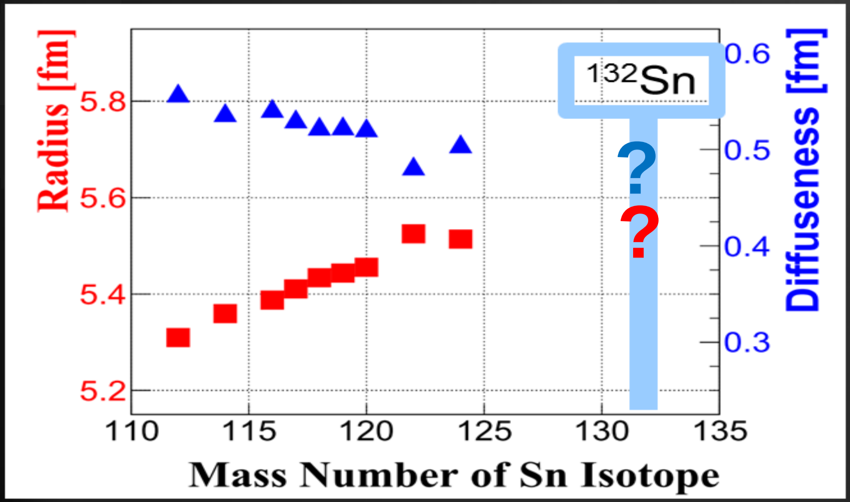
^{126}Sn : 10^5 year

^{128}Sn : 59 msec

^{130}Sn : 3.7 msec

^{132}Sn : 39 sec

^{134}Sn : 1.2 sec



^{132}Sn

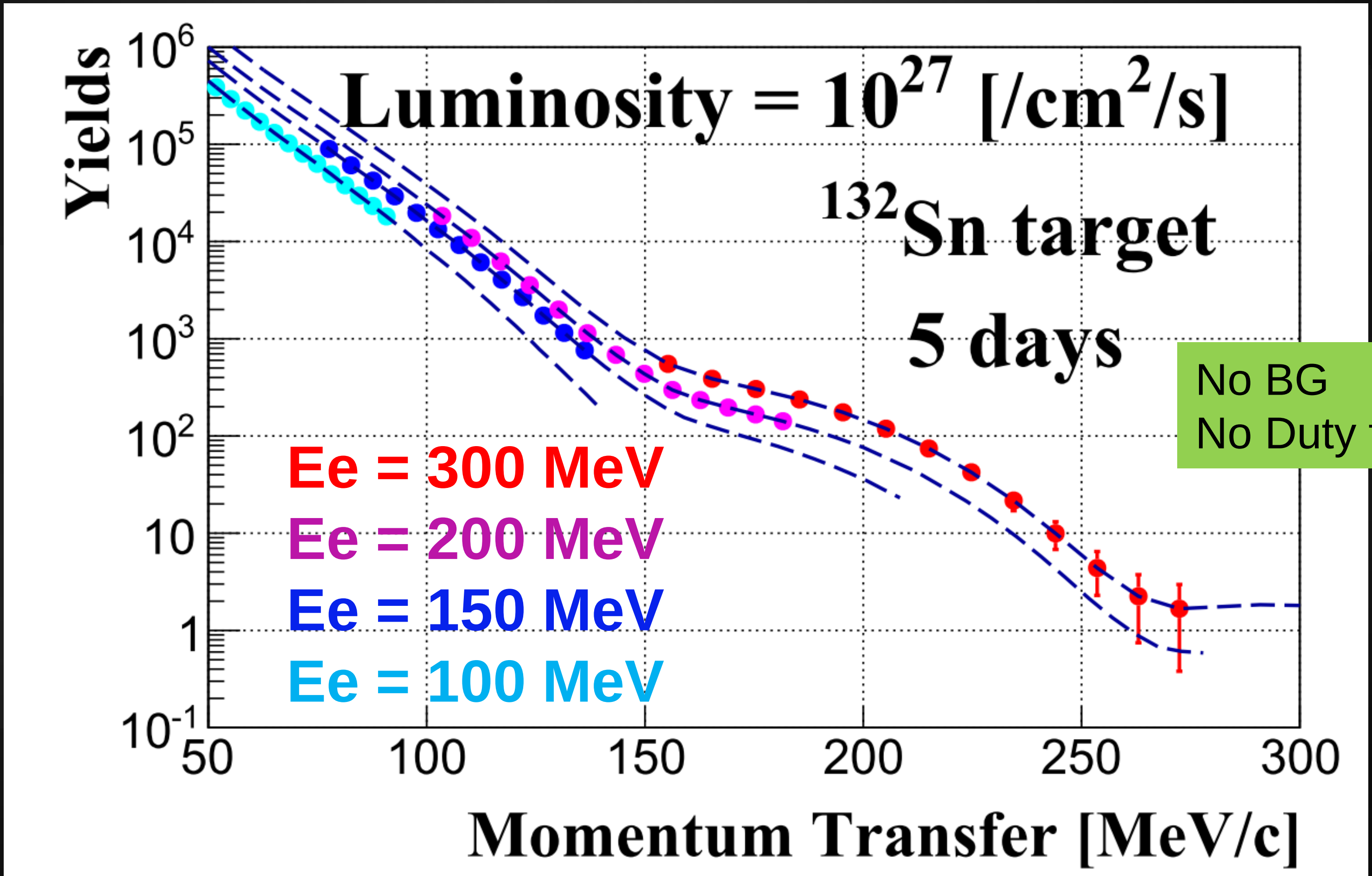
- unstable
- double magic (50+82)
- important roles for nuclear structure study

Luminosity required for elastic electron scattering

Assumptions:

Spectrometer acceptance (dΩ~80 msr, dθ:30-55 deg)

Cross section calculated by DREPHA code

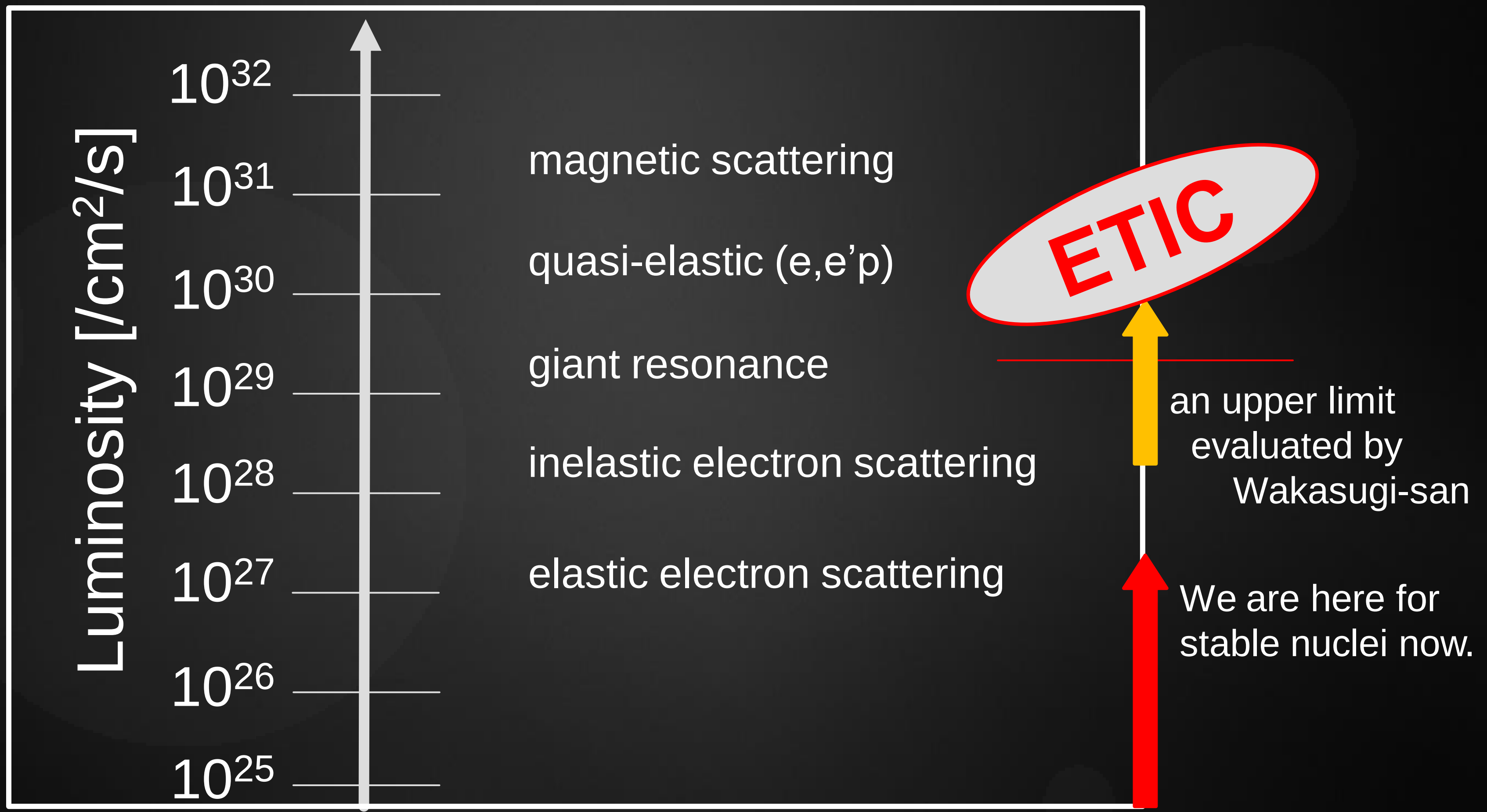


No BG

No Duty factor

Luminosity required for …

- elastic : charge density distribution
- inelastic : transition density
- quasi-elastic : momentum density dist., S-factor, …

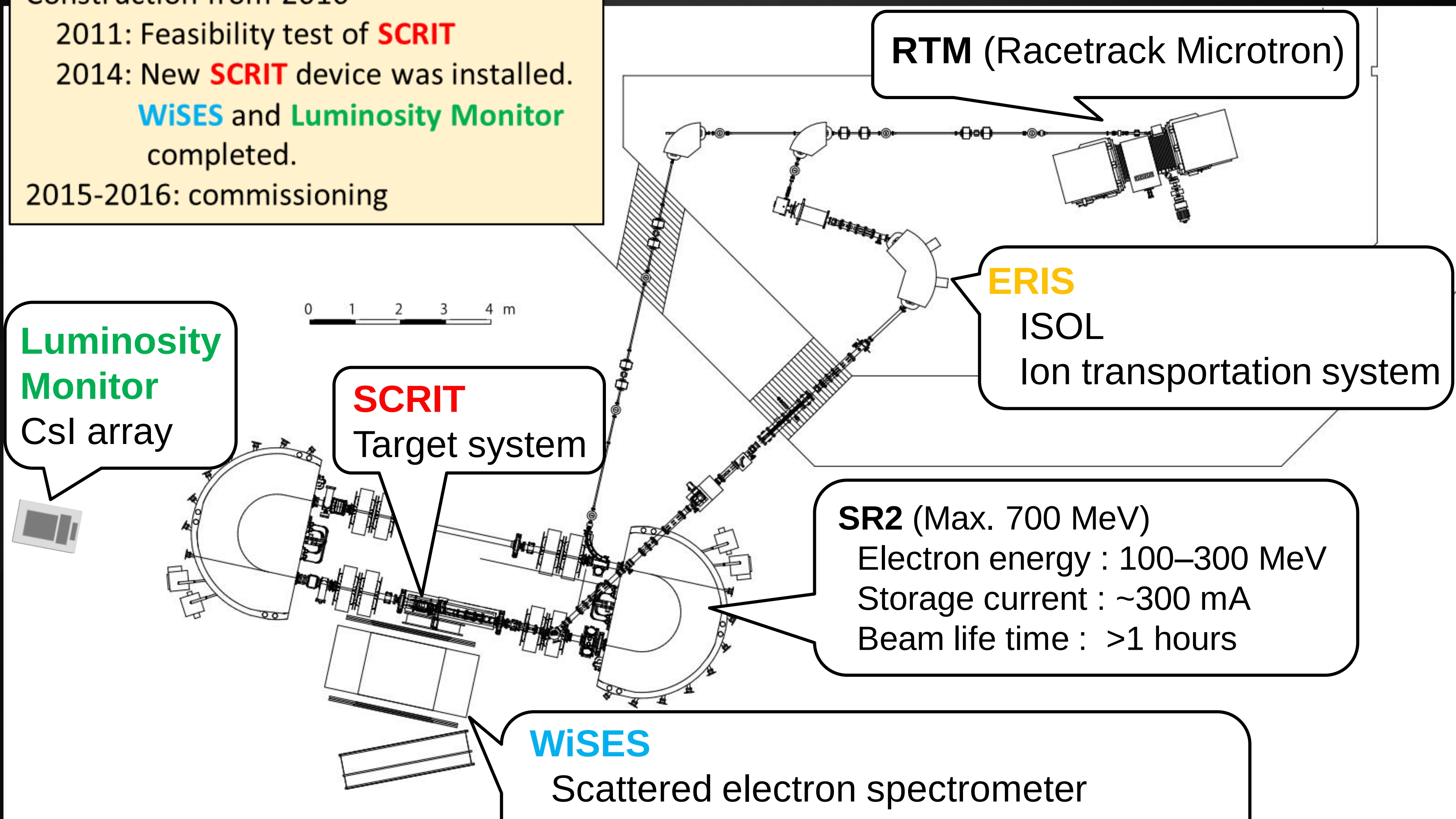


Present Status of the facility and experimental study

SCRIT electron scattering facility

Construction from 2010 –
- 2011: Feasibility test of SCRIT
- 2014: New SCRIT device was installed. WiSES and Luminosity Monitor completed.

2015-2016: commissioning



Commissioning experiments

2015-2016

- The purposes are
  - A) to achieve stable operations and **higher luminosity** by tuning the accelerator and ion transportation system,
  - B) to study the **spectrometer acceptance** by measuring the angular distributions of stable nuclear targets,
  - C) to establish the **absolute luminosity** measurement.
- Targets
  - Metal wire : Tungsten mounted at the center of the target region
    - Point source
    - Simple optics and acceptance
  - Gas ion : ^{132}**Xe** separated by the **ERIS**
    - Stable nucleus
    - Natural abundance is 26.9 %
    - No impurity of other isotopes due to good mass resolution of the **ERIS**

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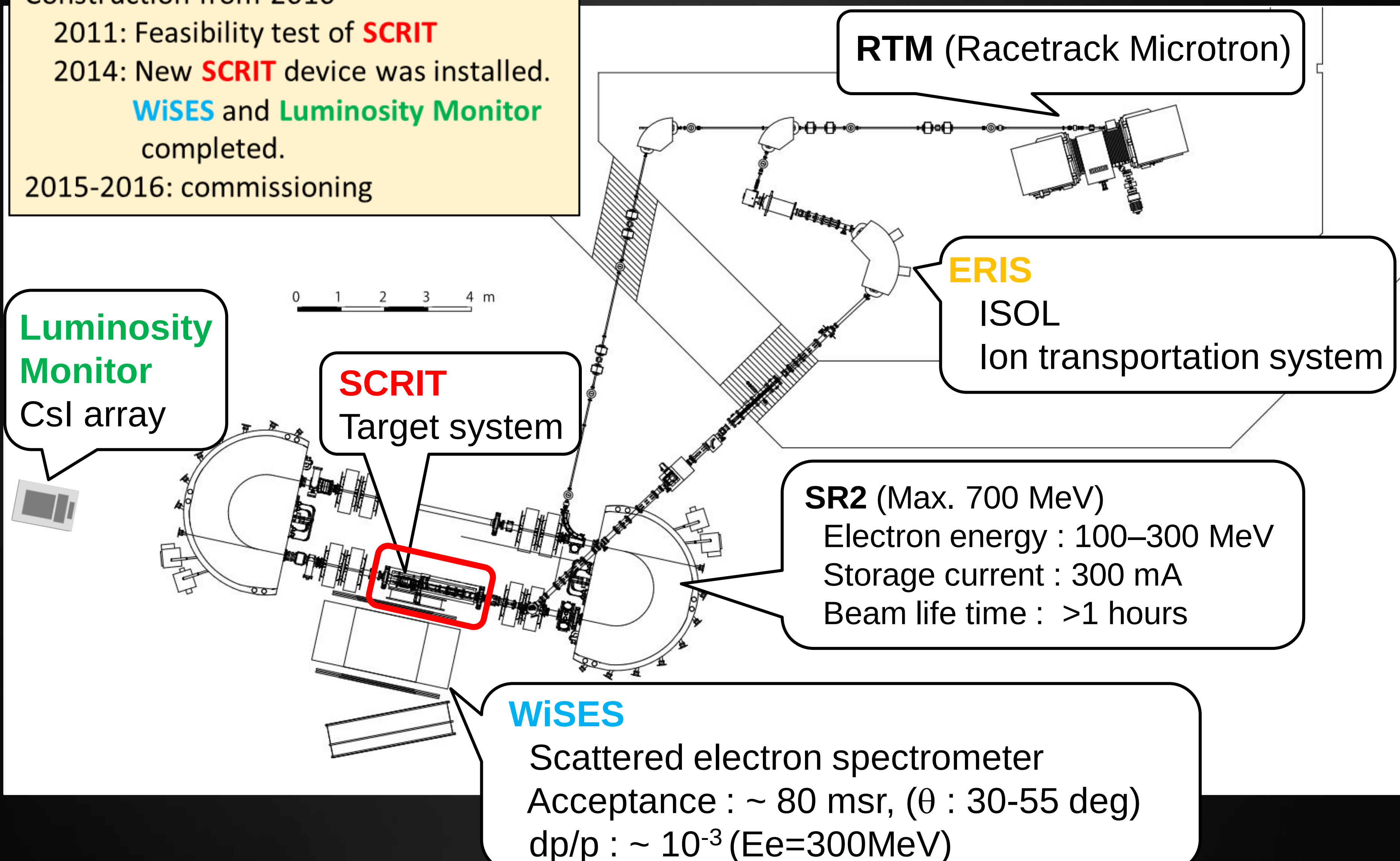
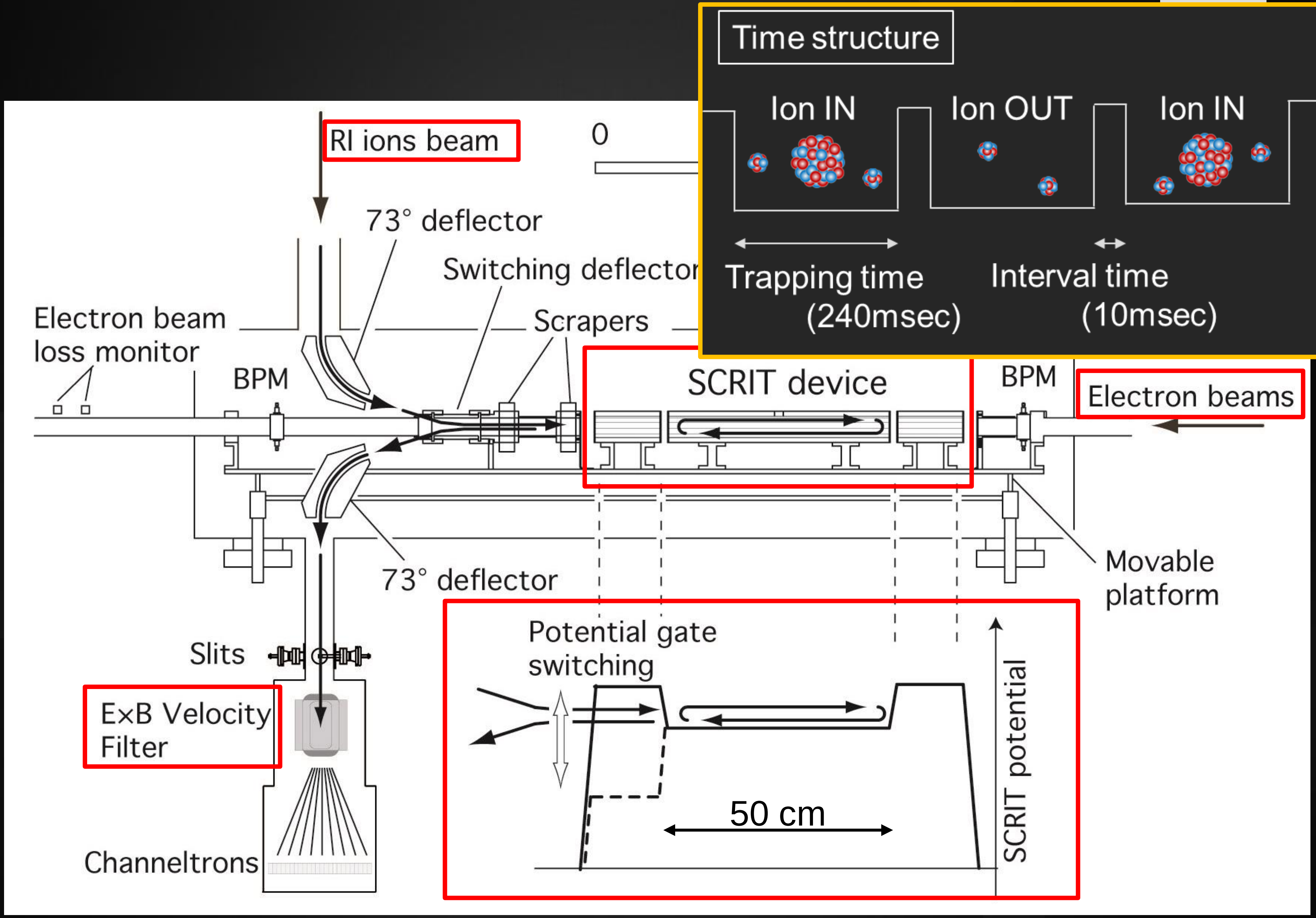


Schematic of SCRIT system



SCRIT electron scattering facility

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2011: Feasibility test of SCRIT
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WiSES and Luminosity Monitor completed.
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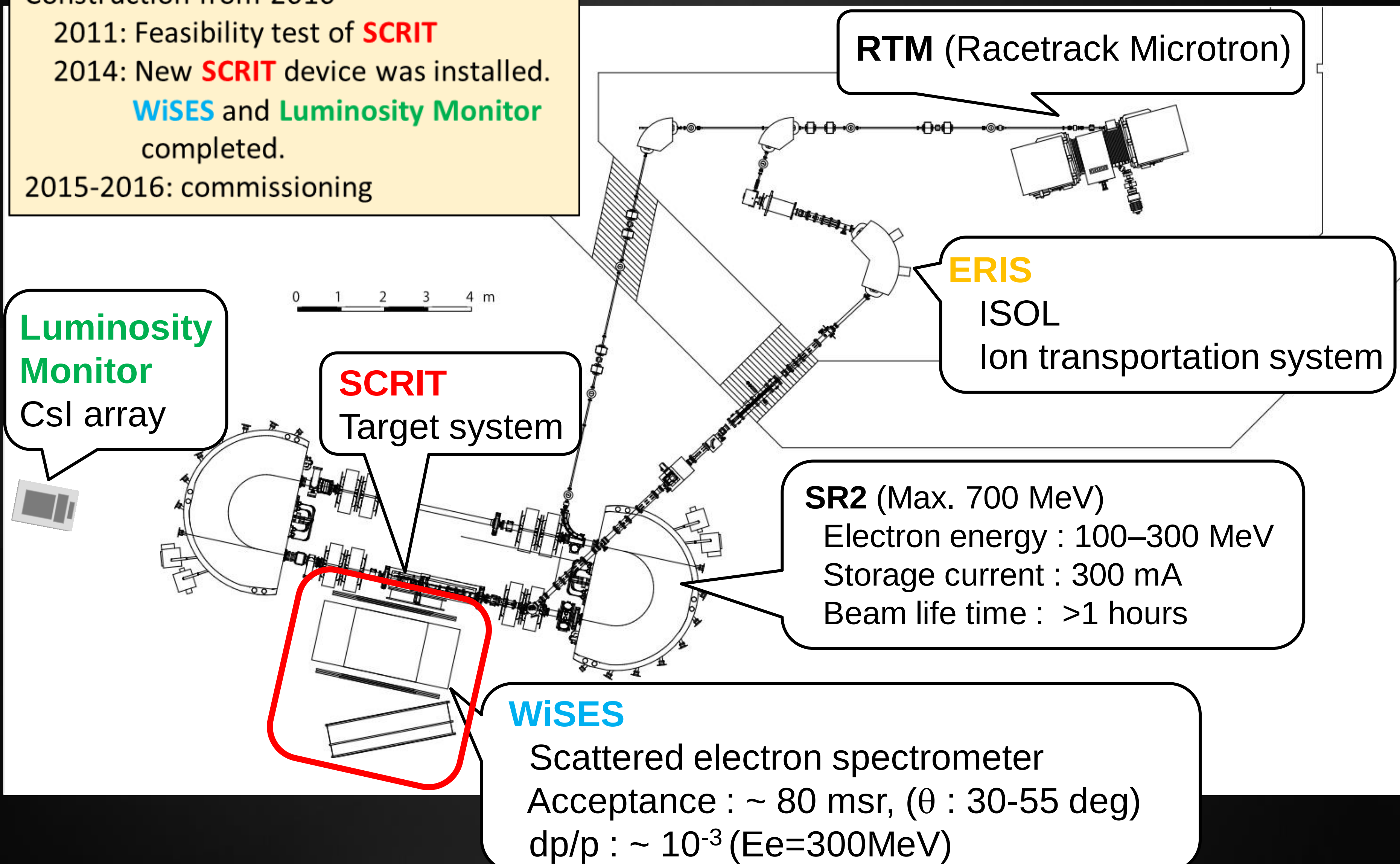
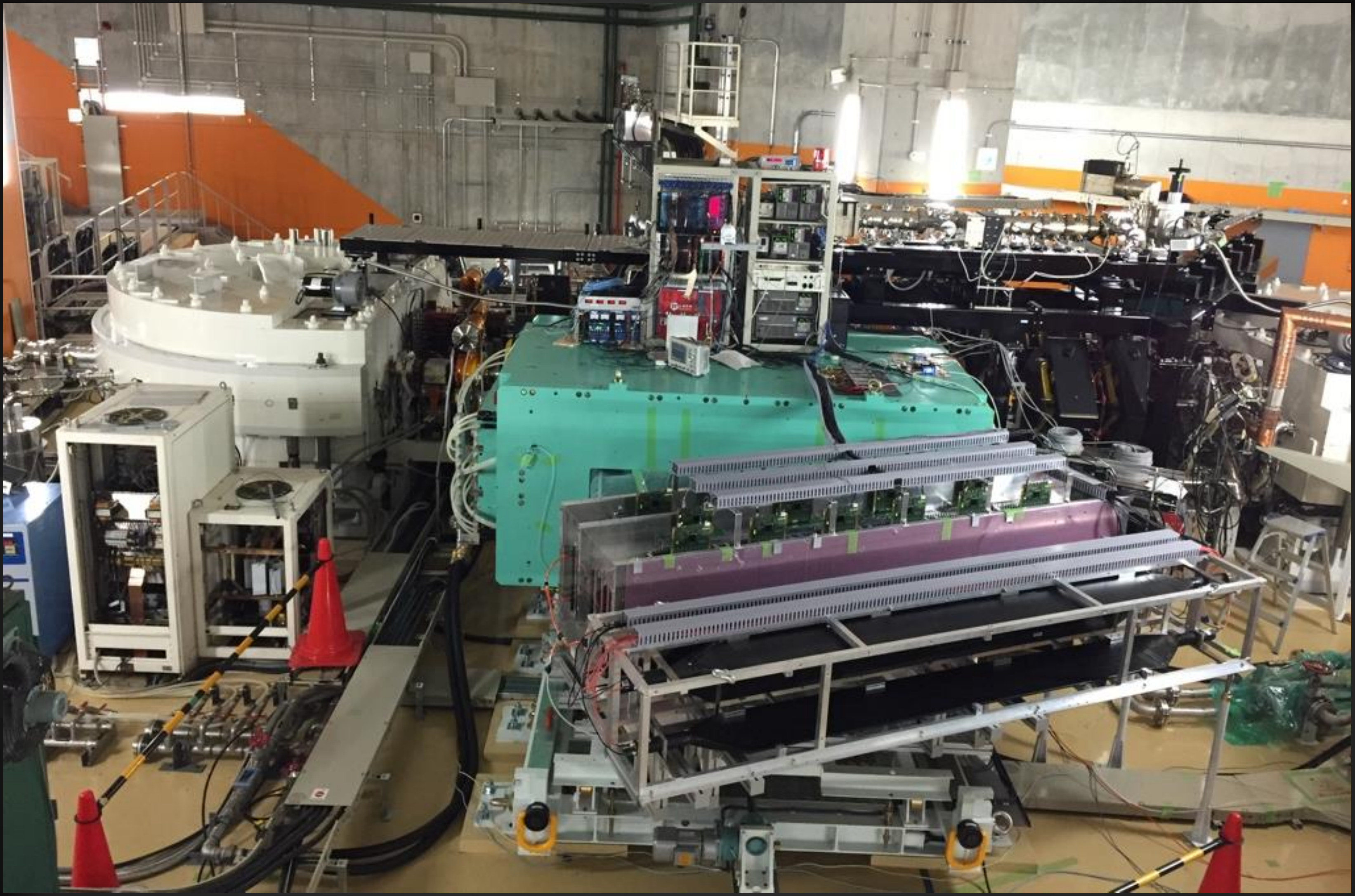


WiSES

(Window-frame Spectrometer for Electron Scattering)



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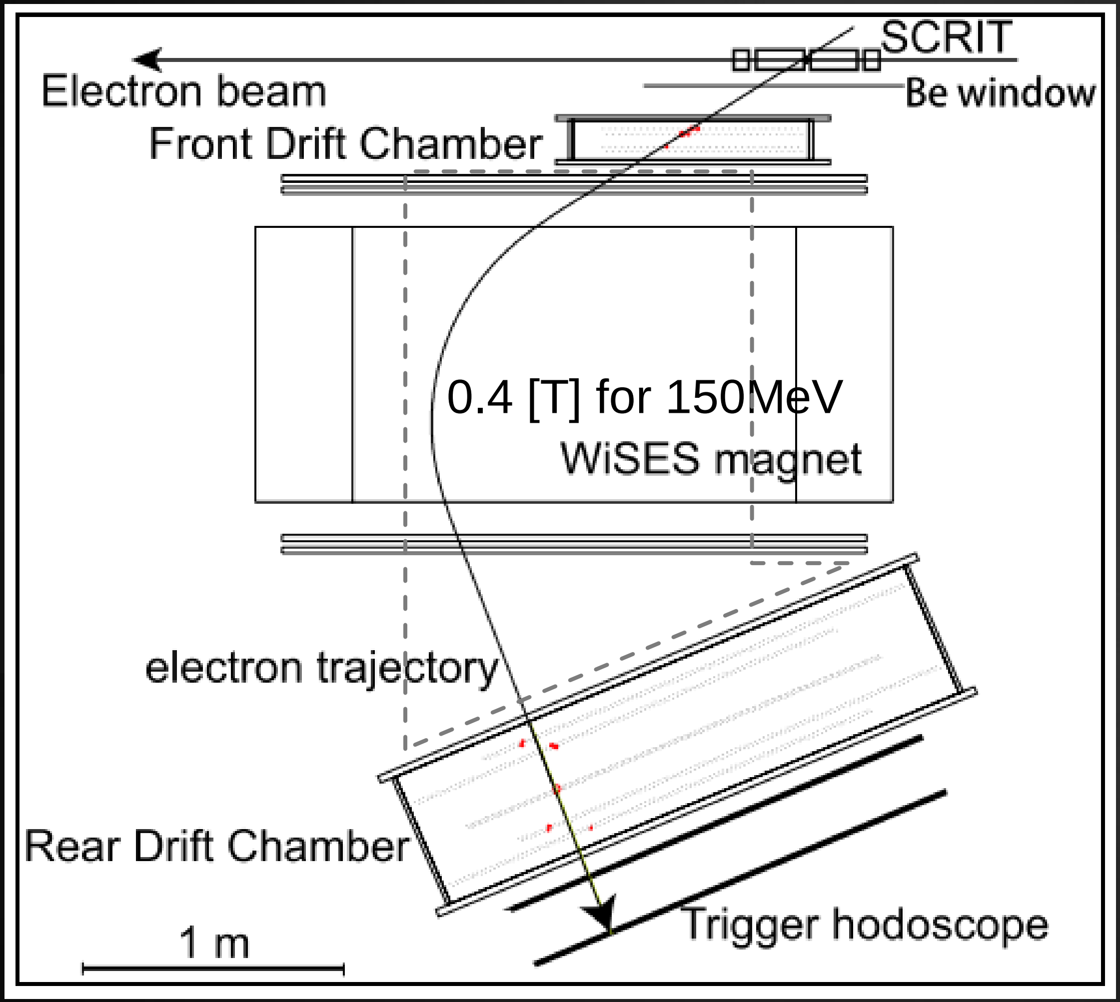


FDC (Front drift chamber)

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

Trigger hodoscope

two scintillation counter

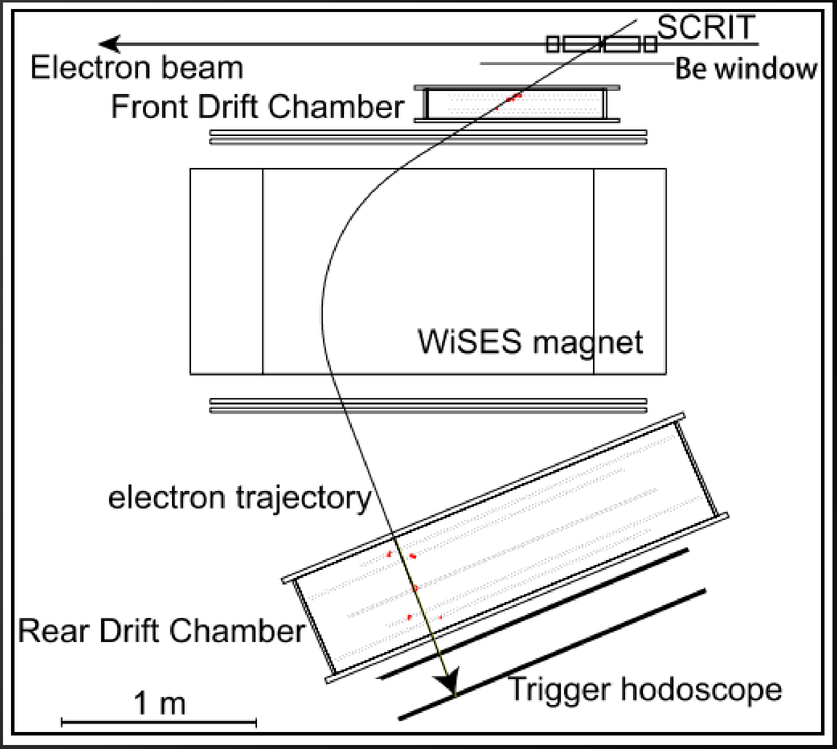
Helium bag

Vinyl, 30μm thick

Volume : 2000 l

Momentum resolution

- A Drift chamber between the target and the magnet.
  - in order to cover the long target, ~50 cm
- Materials on the trajectory of scattered electron
  - Be window : 5.7×10^{-3} X_0
  - FDC+HeBag+RDC : 1.3×10^{-3} X_0



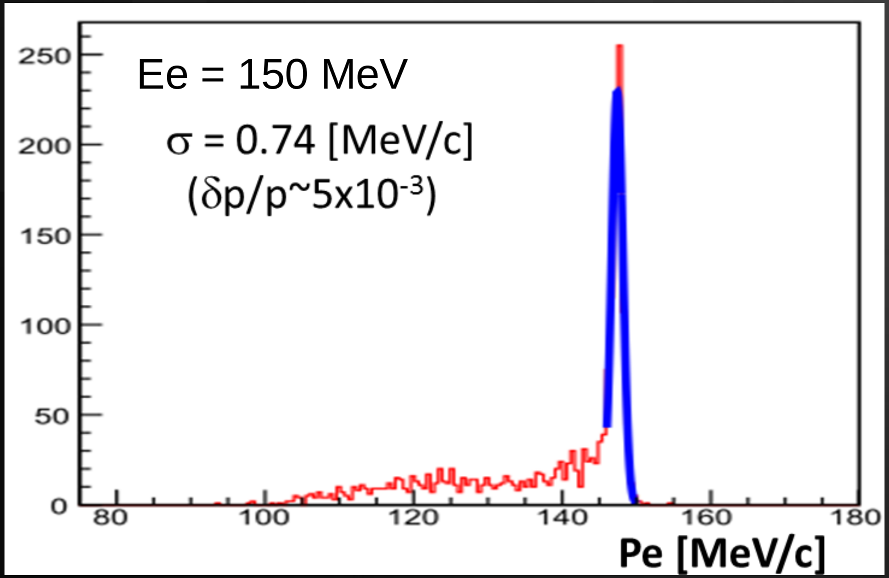
- The momentum resolutions ($\delta p/p$) are
  - ~1.5×10^{-3} for Ee=300 MeV
  - ~2×10^{-3} for Ee=200 MeV
  - ~3×10^{-3} for Ee=150 MeV

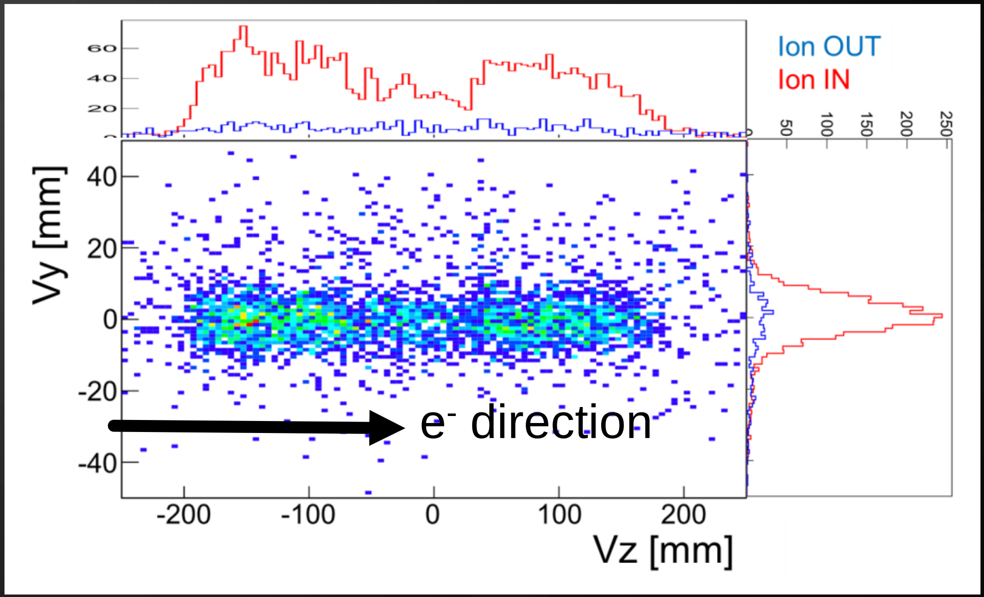
  with 150 um resolution of DCs

  if we know the mag. field very well.

Commissioning data for WiSES

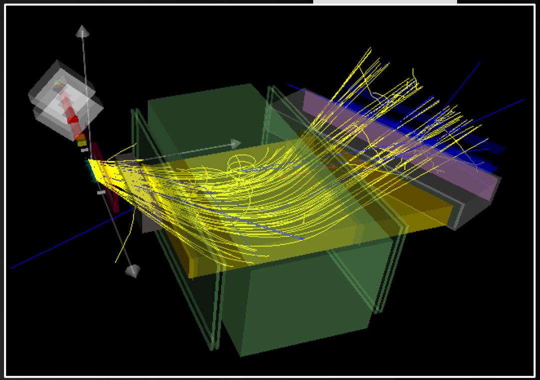
- Targer : ^{132}Xe
- Electron beam energy
  - 150 MeV : 5 days, irradiation time (IN+OUT) = 55,000 sec (Jan,Feb/2016)
  - 200 MeV : 8 days, irradiation time = 278,000 sec (Apr/2016) *until last Monday!*
  - 300 MeV : 1.5 days, irradiation time = 32,000 sec (Apr/2016)
- Electron beam current : 150 – 250 mA

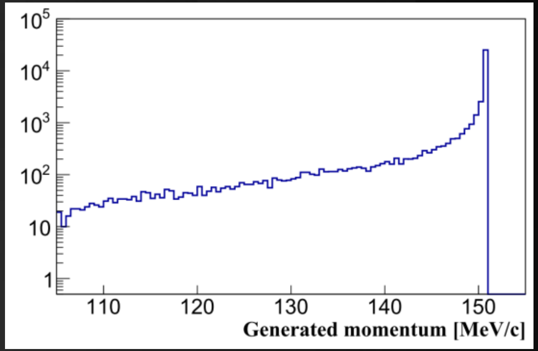


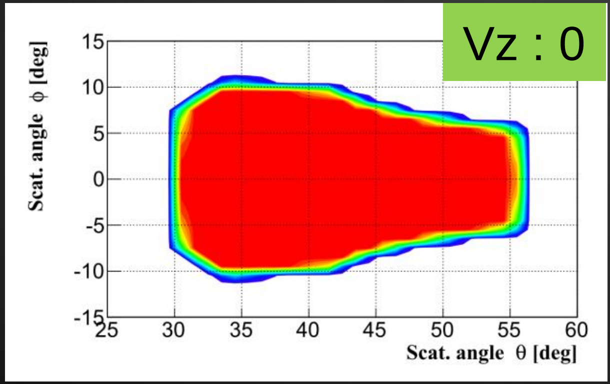


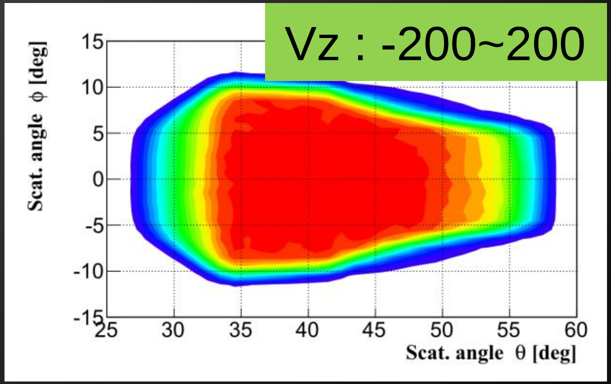
Acceptance of **WiSES**

- Geant4 simulation
  - Generation
    - Ee : 150, 200, 300 MeV
    - Vz : -200 ~ 200 mm
      - Distribution is taken into account.
    - Radiative tail
      - Considering the Schwinger contribution
        J. Friedrich, Nucl.Instr.Meth.129 (1975) 505
  - Tracking code is the same for the exp. data.







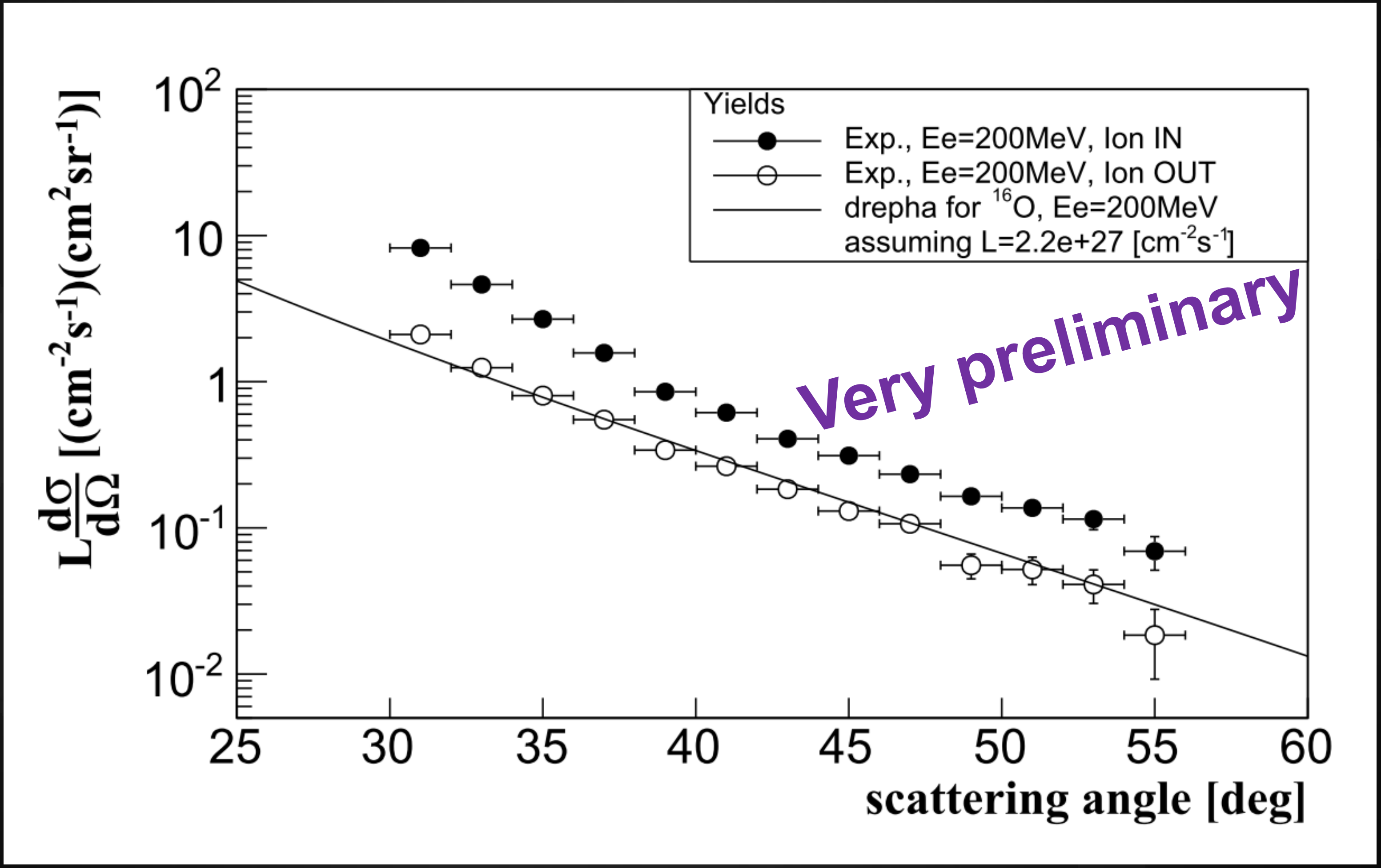


75 [msr] in total

Angular distributions

- BG : L ~ 2x10^{27} [/cm^2/s]

  (assuming oxygen calculated by DREPHA code)



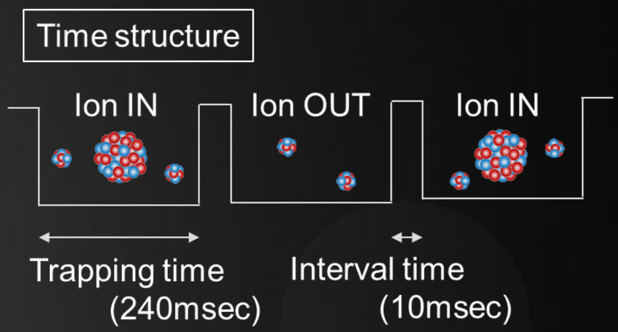
Background evaluation

- Beam current : ~200 mA → 10^{18} [e⁻/s]
- Residual gases in the SCRIT : ~5×10^{-8} Pa

  → 6×10^{8} [particles/cm^2]

  → L ~ 0.6×10^{27} [/cm^2/s]

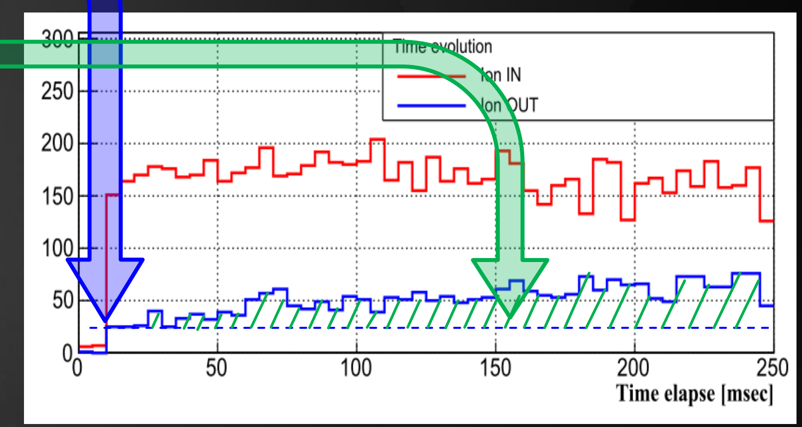
  for neutral gas



- Residual gases are ionized by the beam.
  - Amount is similar to the neutral ones.
- Other materials
  - Beam halo hits the structures of SCRIT

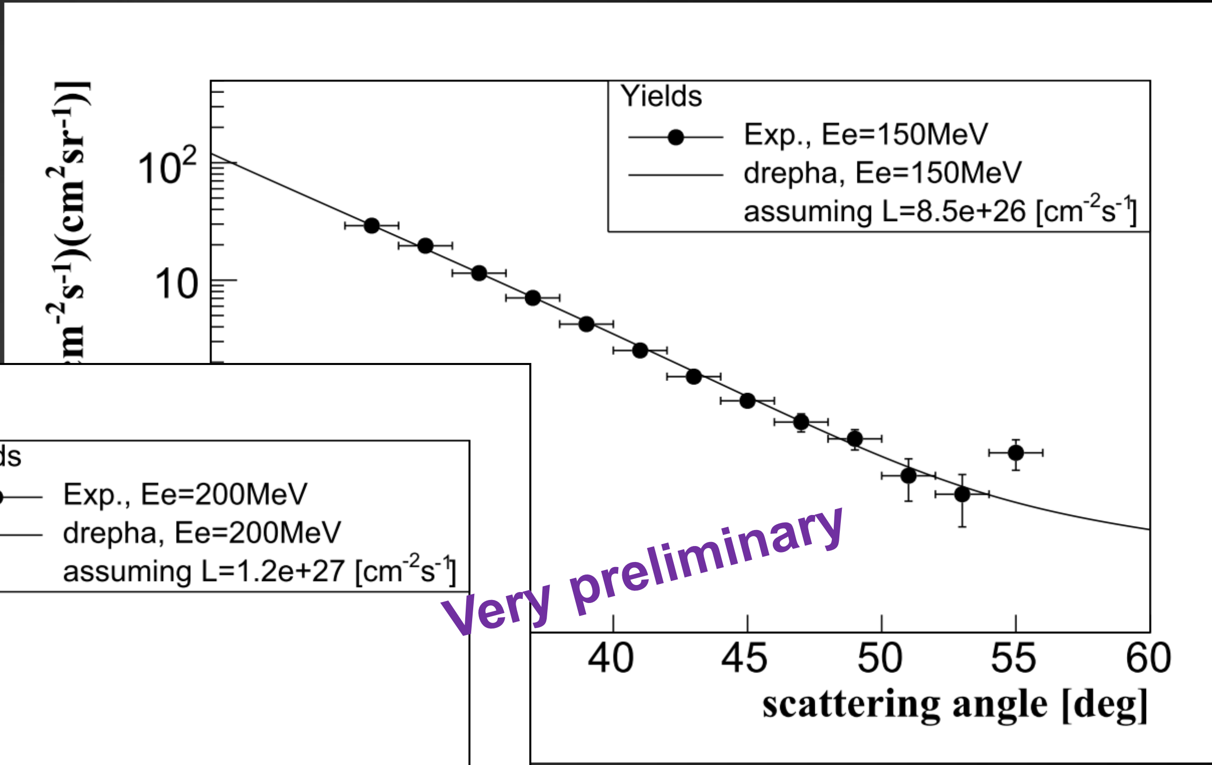
    and generate BG.

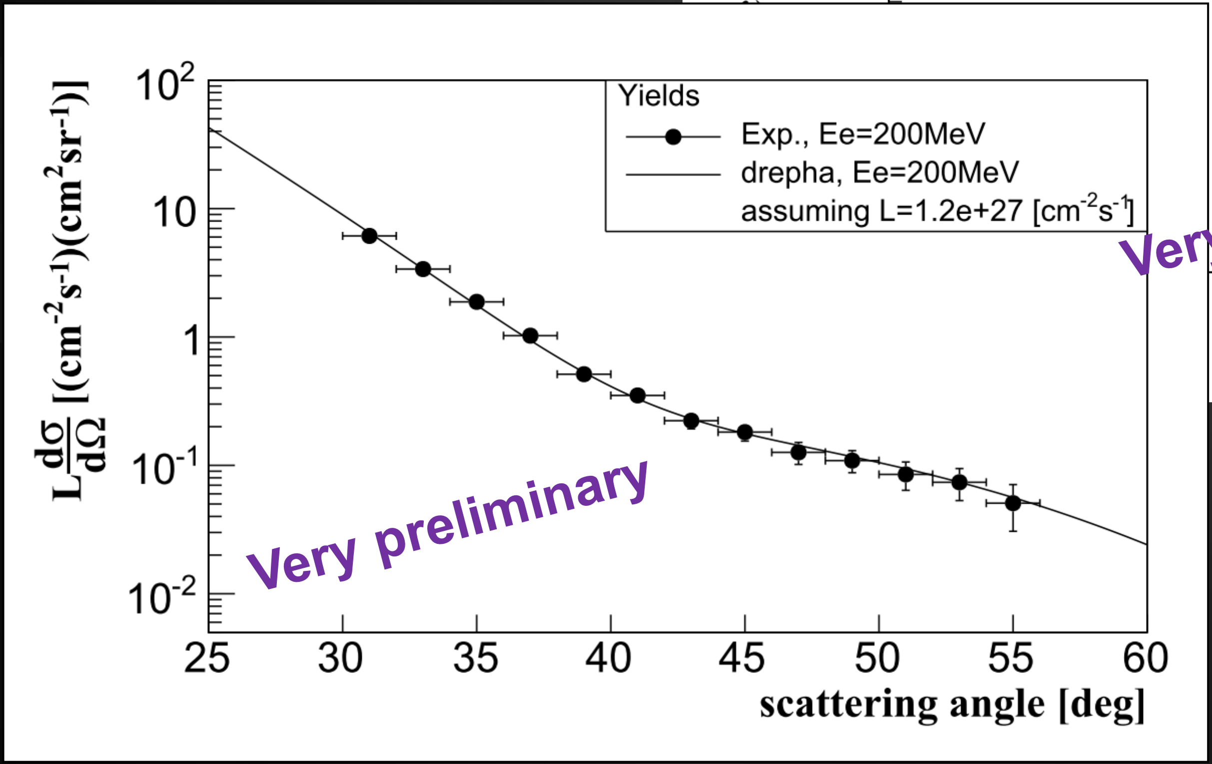
    a few % of residual gas



L~2×10^{27} [/cm^2/s] for the BG is reasonable and unavoidable.
We assume that the BG contribution can be removed by subtraction,
IonIN-IonOUT.

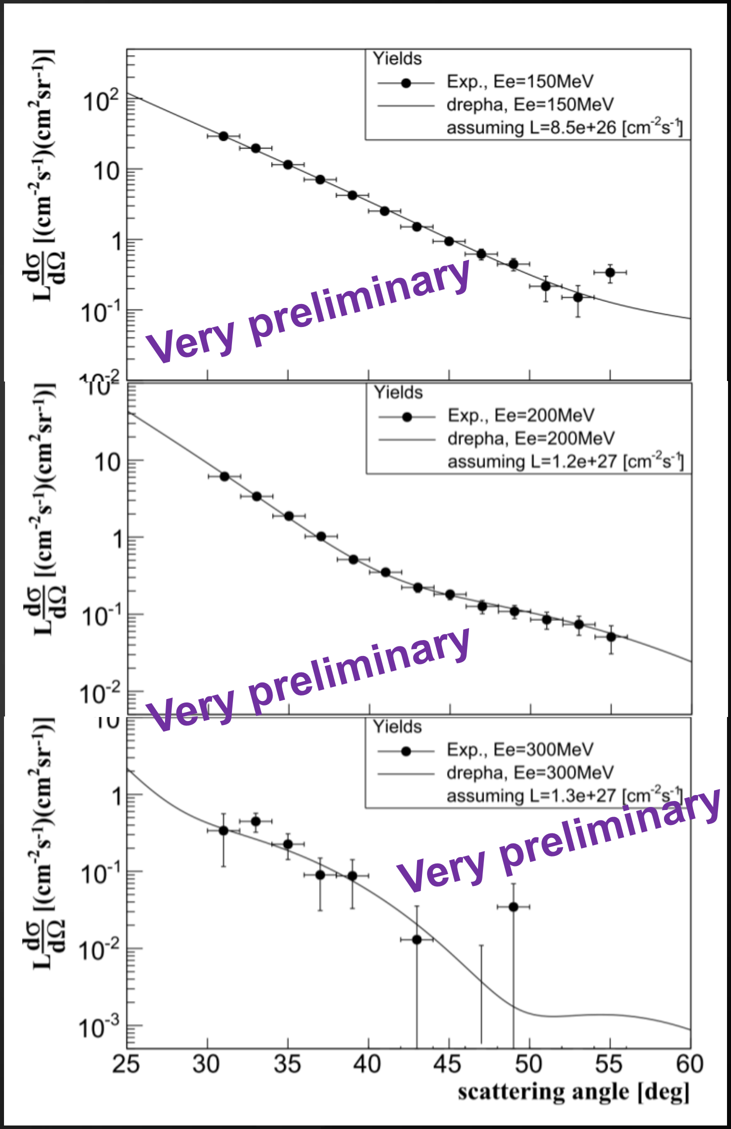
Angular distribution after BG subtraction





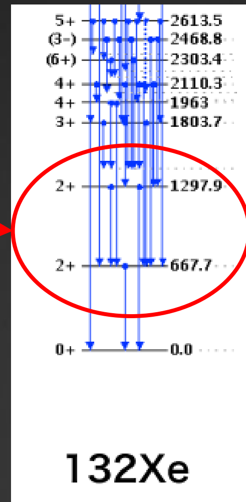
Angular distribution after BG subtraction

- Data
  - Analysis efficiency : 80±5 %
    - Improvement and evaluation ongoing …
  - Systematic errors are not considered.
- Calculation
  - DREPHA code : a DWBA calc.
  - 2 parameters fermi (2PF) distribution is assumed.
    - C= 5.646 [fm]
    - t = 2.30 [fm]
- Distributions are well reproduced.
- Luminosities are estimated by fitting.
- Luminosity reach 10^{27} [/cm^2/s] on average.

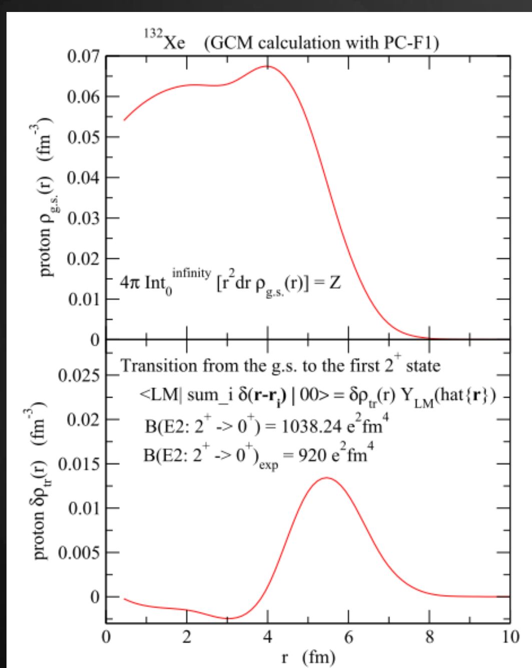


Excited states of ^{132}Xe

- Excited state
  - 2^+ : 667 keV
  - 2^+ : 1297.9 keV



The ground state and1st/2nd excited states could not be distinguished due to the momentum resolution of **WiSES**.



The ground state density and the transition density to the first 2^+ state.

The influence of the excited states in the angular distribution will be studied.

Private communication with Theor. Group, Tohoku Univ.

Charge radius of ^{132}Xe

- No electron scattering data for xenon isotopes
- μ-X ray → $\langle r^2 \rangle^{1/2}$ = 4.787 [fm] assuming 2PF and t=2.30 [fm]

G. Fricke *et al*., Atom.Nucl.Data Tables **60**, 177 (1995)

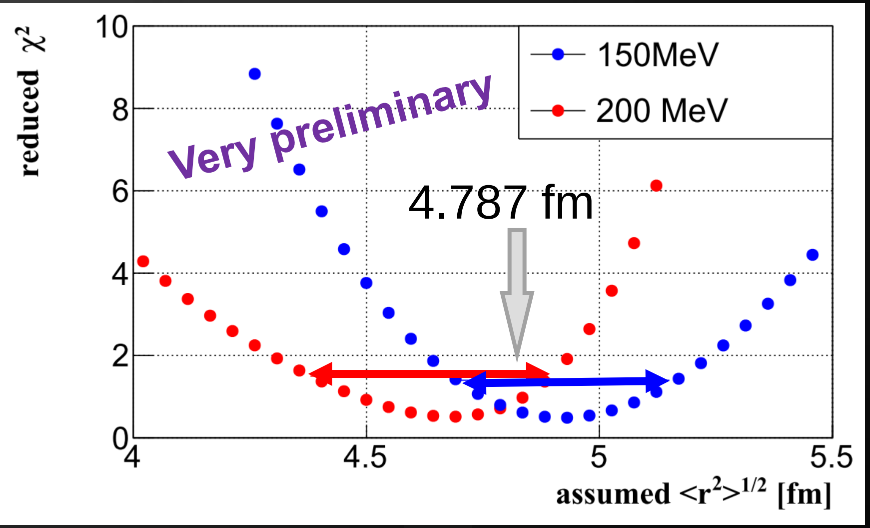
A	124	126	128	129	130	131	132	134	136
r_{rms} [fm]	4.762	4.770	4.776	4.776	4.783	4.781	4.787	4.792	4.799

Very simple analysis for consistency check

- Analysis with same procedure as μ-X ray
  - t = 2.30 [fm] fixed
  - $\langle r^2 \rangle^{1/2}$ dependence of χ^2

$\langle r^2 \rangle^{1/2}$ = 4.68+0.23-0.30

$\langle r^2 \rangle^{1/2}$ = 4.92+0.23-0.22

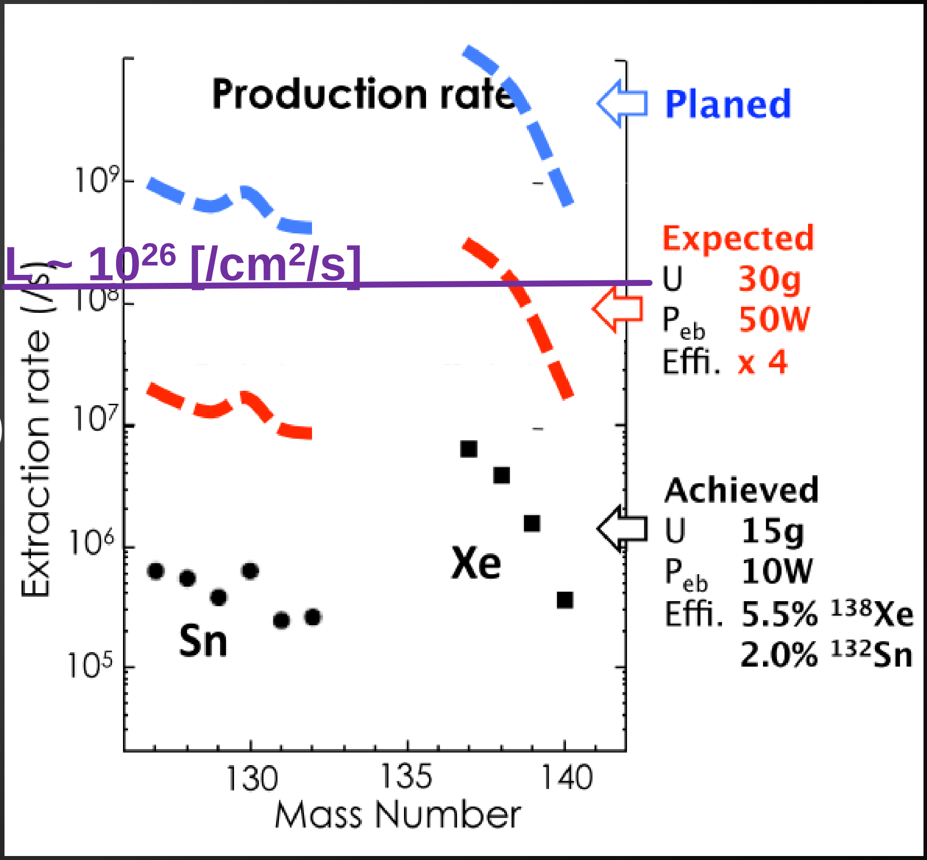


Analysis for diffuseness is ongoing by using large angle data.

unstable nuclei targets

- in one year
  - ^{138}Xe with L~10^{26} [/cm2/s]
  - ^{132}Sn with L~10^{25} [/cm2/s]
- after beam power upgrade
  - ^{132}Sn with L~10^{27} [/cm2/s]
- what is the next? (under discussion)
  - Sn(Z=50) isotopes
  - Xe(Z=54) isotopes
  - N=82 isotones
    - ^{132}Sn-^{133}Sb-^{134}Te-^{135}I-^{136}Xe
    - how important or interesting?

from Wakasugi-san's slide



Summary and outlook

- Electron scattering is so powerful for nuclear structure study.
- We have been developed the **SCRIT** electron scattering facility to realize electron scattering off unstable nuclei target.
  - The first goal of a target is ^{132}Sn.
  - Luminosity of 10^{27} $cm^{-2}s^{-1}$ or more is necessary.
- In 2015-2016, commissioning experiments have been carried out.
  - Luminosity improvement
    - For ^{132}Xe target, 10^{27} [/cm^2/s] was achieved.
    - Also for Residual gas, L is larger than 10^{27} [/cm^2/s]
  - Acceptance study
    - Angular distribution of ^{132}Xe was consistent with the past measurement of μX-ray.
- Electron scattering off unstable nucleus (^{138}Xe,^{132}Sn) will be performed near future.