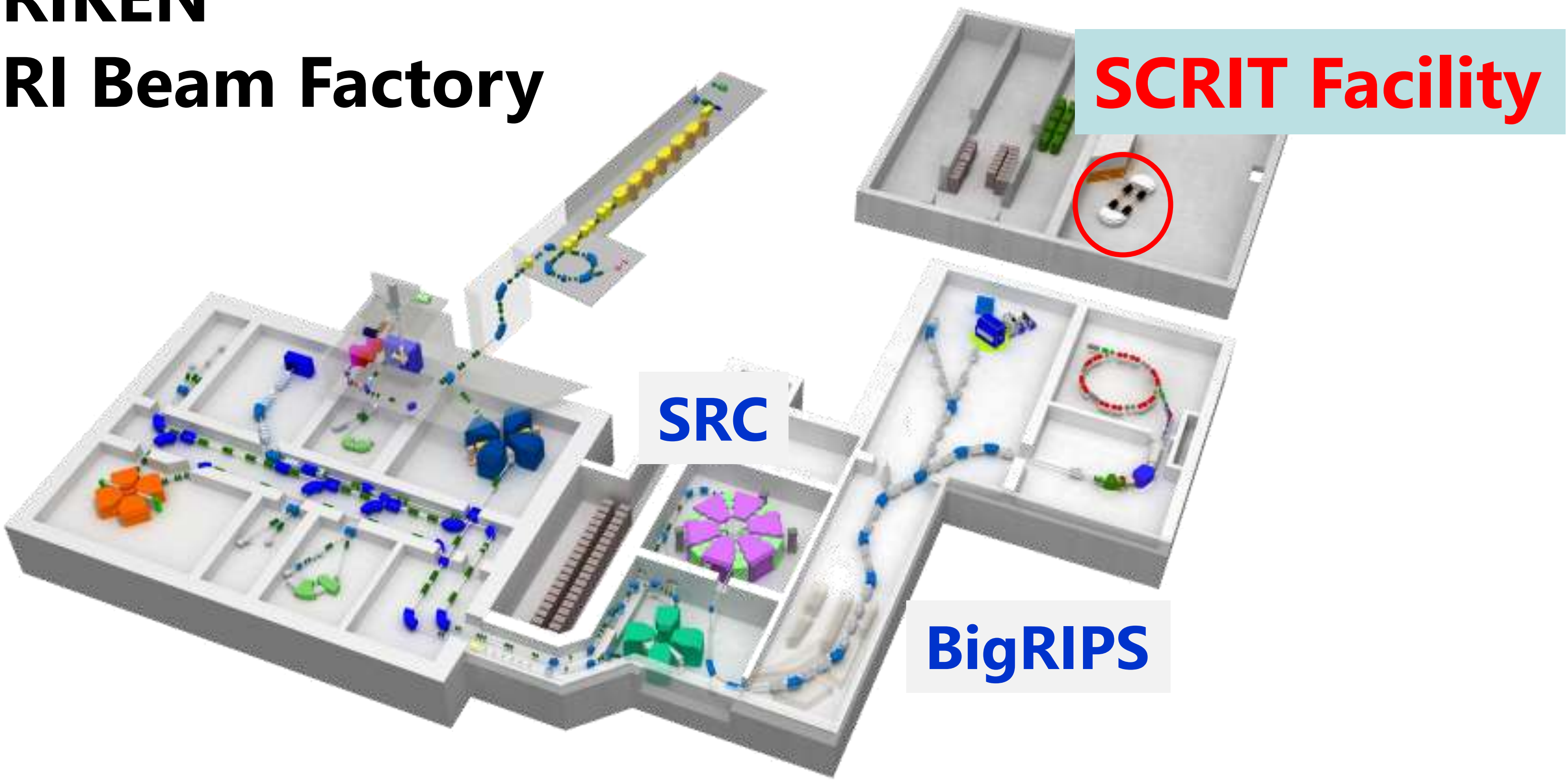
The SCRIT electron scattering facility at RIKEN RI Beam Factory

EMIS XIX, RAON, Daejeon, Korea, Oct. 3, 2022

RIKEN Nishina Center
Tetsuya Ohnishi
and
SCRIT collaboration

RIKEN
RI Beam Factory



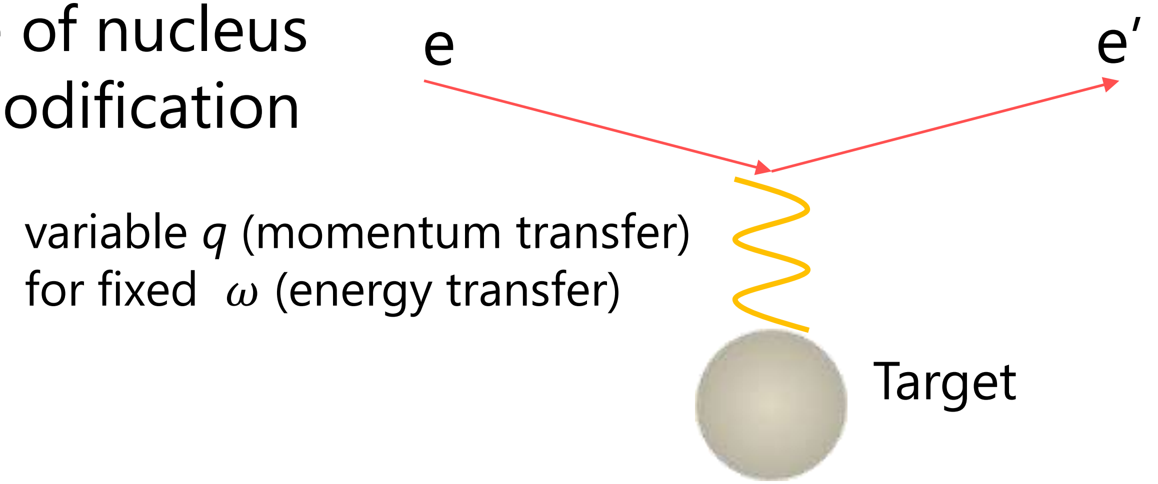
1. Introduction
2. SCRIT facility
3. Recent results
4. Future plans
5. Summary

1. Introduction

Electron scattering

Powerful tool to study the internal structure of nuclei

Coulomb interaction	Well known and model independent
Structure-less particle	Point-like probe
Weak interaction	Probing whole volume of nucleus without any serious modification



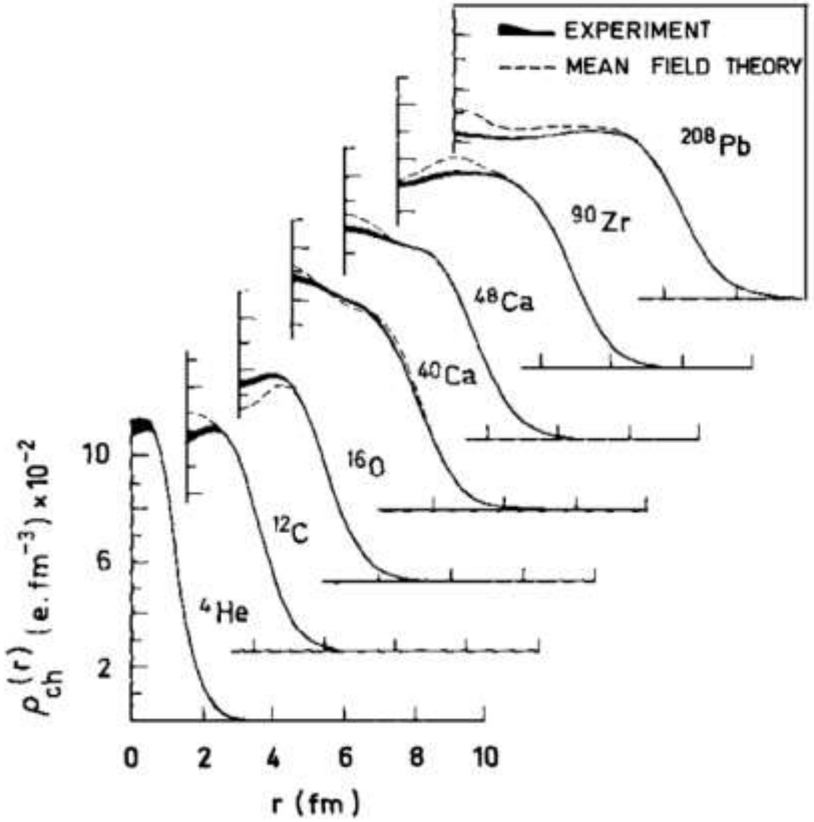
“Direct and unambiguous structure information”.

Electron scattering on nuclei

Elastic electron scattering

= Mott scattering × Form factor

➔ Charge density distribution

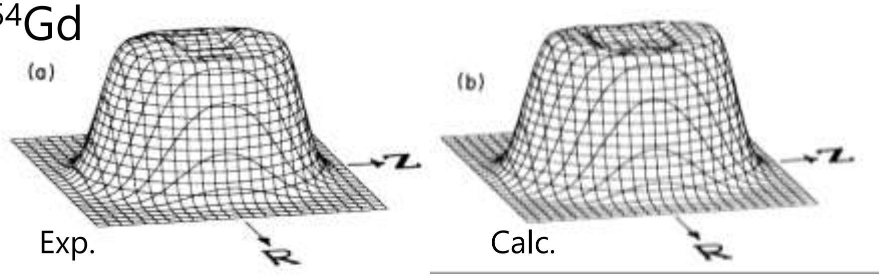


B. Frois and C. N. Papanicolas, Ann.Rev.Nucl.Part.Sci. 37 (1987) 133.

Various subjects

Deformation

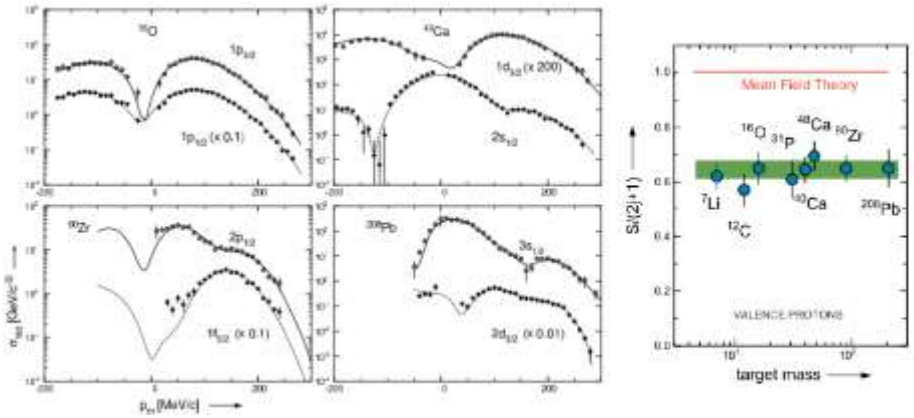
^{154}Gd



F. W. Hersman et al., Phys. Rev. C33 (1986) 1905.

quasi-elastic scattering (e,e′p)

⟶ Spectroscopic factor



H. Dickhoff, C. Barbieri, Prog. Part. Nucl. Phys. 52 (2004) 377.

Electron scattering with unstable nuclei

Unstable nuclei: Exotic structure (halo, skin, new magic number..)

No electron scattering experiment on short-lived unstable nuclei at present

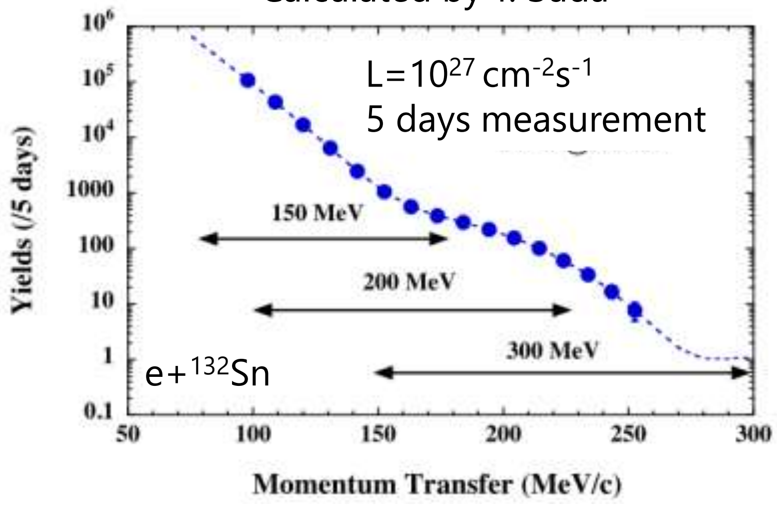
→ Main difficulty: **Luminosity**

L = Beam [atoms/s] × Target [atoms/cm^2]

Elastic scattering (largest σ)

Required luminosity 10^{27} cm^{-2}s^{-1}

Calculated by T. Suda



"Application to unstable nuclei has been long awaited."

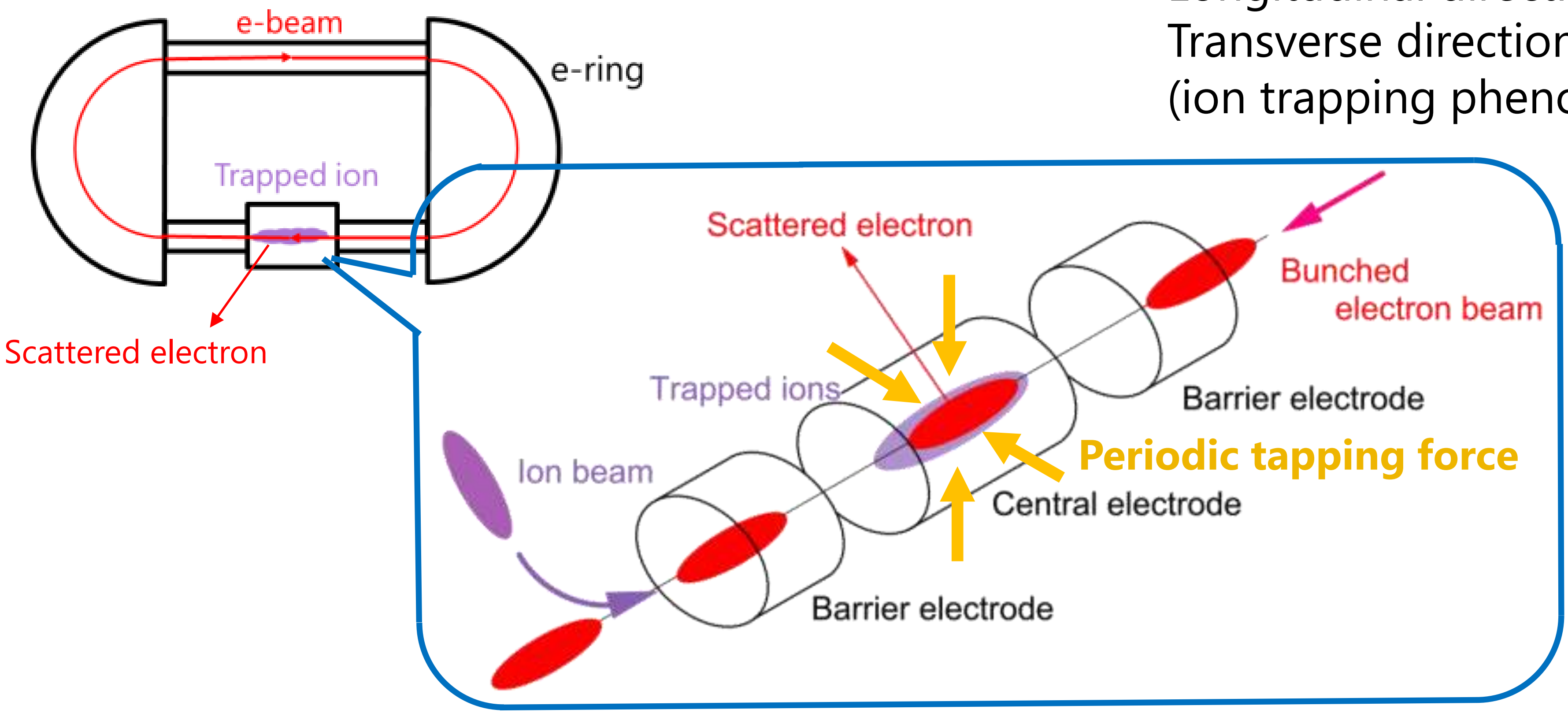
Electron storage ring + new target forming technique

SCRIT

SCRIT(Self Confining RI Ion Target) method

M. Wakasugi et al., Phys. Rev. Lett. 100 (2008) 164801.

Longitudinal direction: Electric static potential
Transverse direction: Trapping force by e-beam
(ion trapping phenomena)



Luminosity 10^{27} $cm^{-2}s^{-1}$

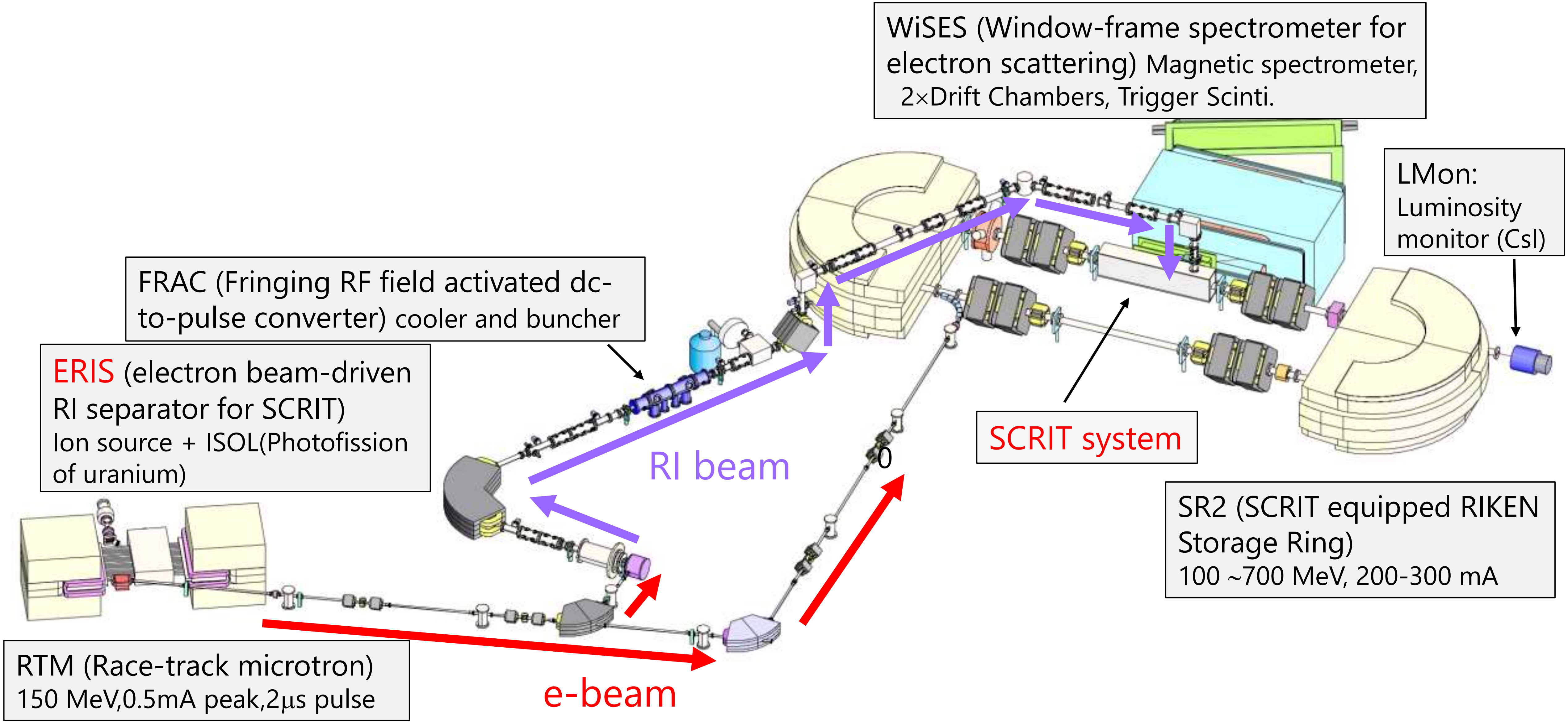
e-beam
current～200 mA
size ～mm^2

10^8 ions

Automatic electron scattering with trapped ions

2. SCRIT electron scattering facility

M. Wakasugi et al., NIMB 317 (2013) 668.

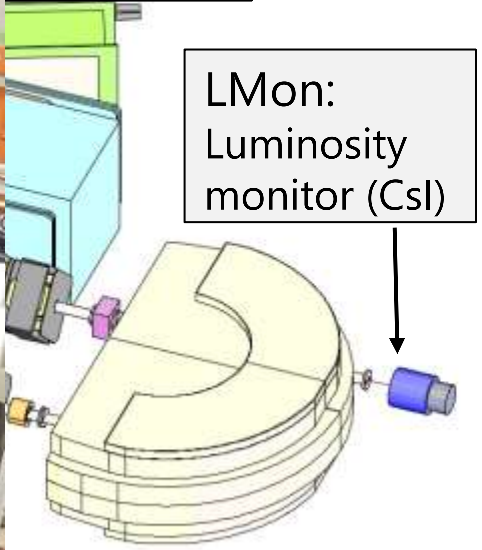


2. SCRIT electron scattering facility

M. Wakasugi et al., NIMB 317 (2013) 668.

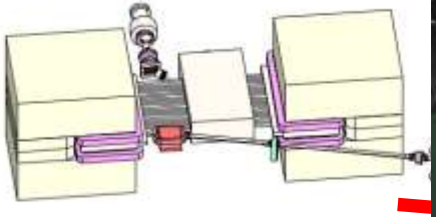
ometer for
pectrometer,

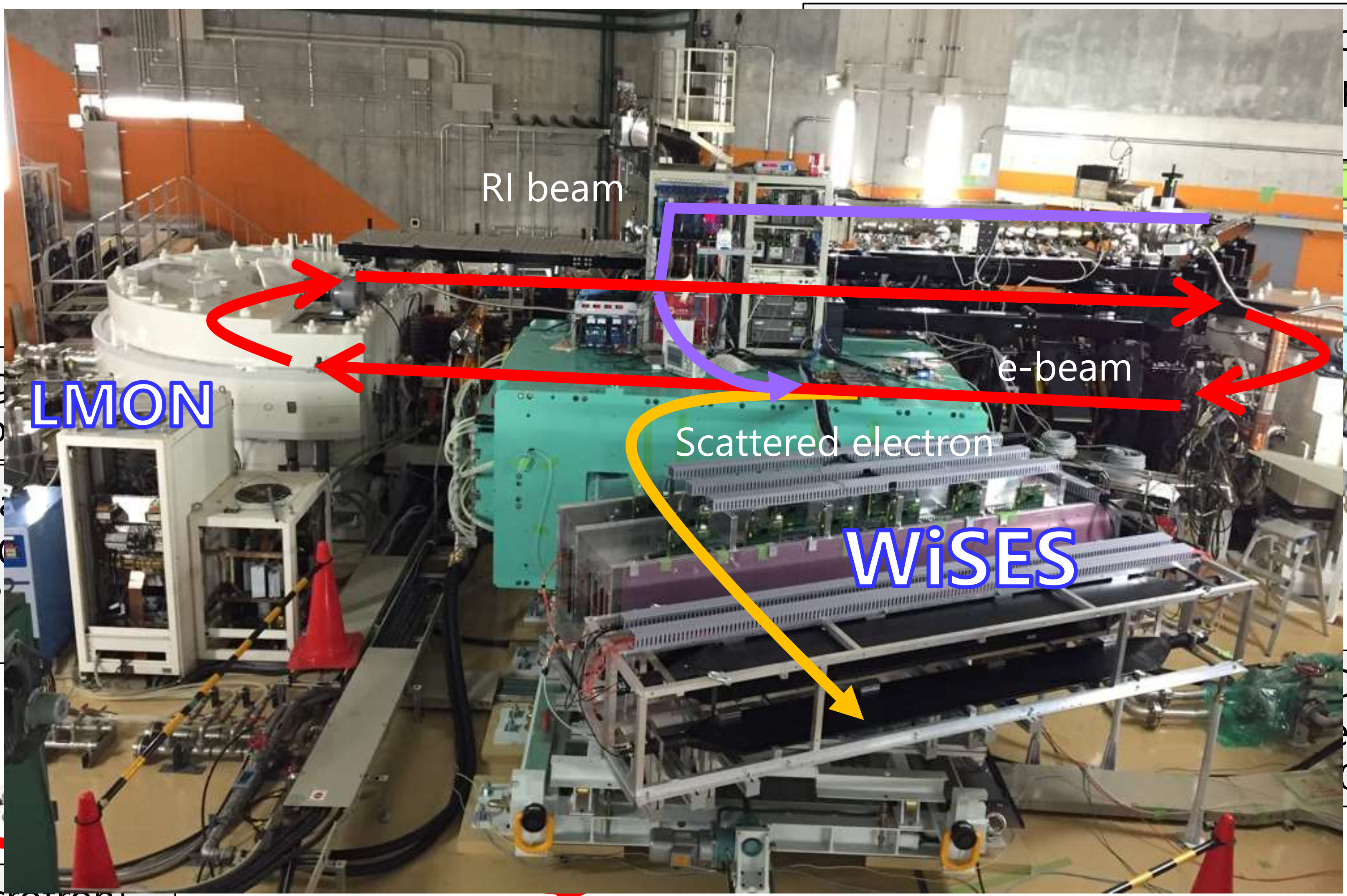
LMon:
Luminosity
monitor (CsI)



FRAC (Fring
to-pulse co

ERIS (electron bea
RI separator for SC
Ion source + ISOL(P
of uranium)





RIT equipped RIKEN
Ring)
0 MeV, 200-300 mA

RTM (Race-track microtron)
150 MeV,0.5mA peak,2μs pulse

e-beam

2. SCRIT electron scattering facility

M. Wakasugi et al., NIMB 317 (2013) 668.

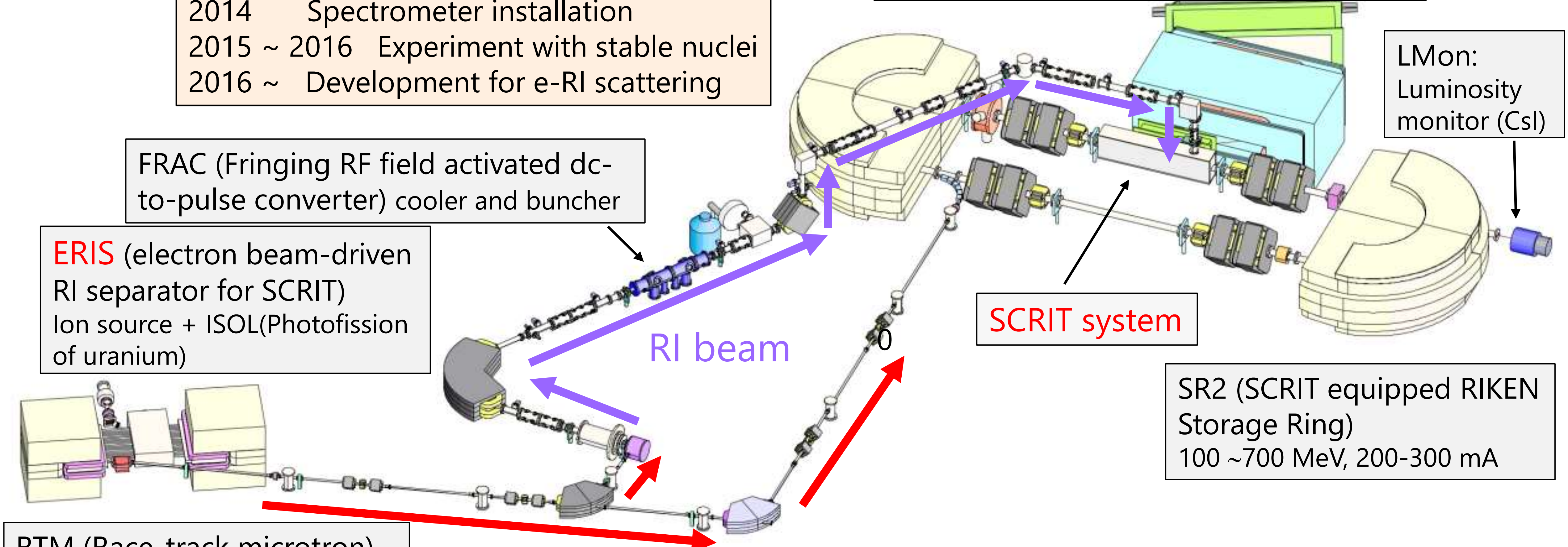
2009	Construction start
2011	Facility commissioning
2013	RI production start
2014	Spectrometer installation
2015 ~ 2016	Experiment with stable nuclei
2016 ~	Development for e-RI scattering

WiSES (Window-frame spectrometer for electron scattering) Magnetic spectrometer, 2×Drift Chambers, Trigger Scinti.

LMon: Luminosity monitor (CsI)

FRAC (Fringing RF field activated dc-to-pulse converter) cooler and buncher

ERIS (electron beam-driven RI separator for SCRIT) Ion source + ISOL(Photofission of uranium)



SR2 (SCRIT equipped RIKEN Storage Ring) 100 ~700 MeV, 200-300 mA

RTM (Race-track microtron) 150 MeV,0.5mA peak,2μs pulse

2. SCRIT electron scattering facility

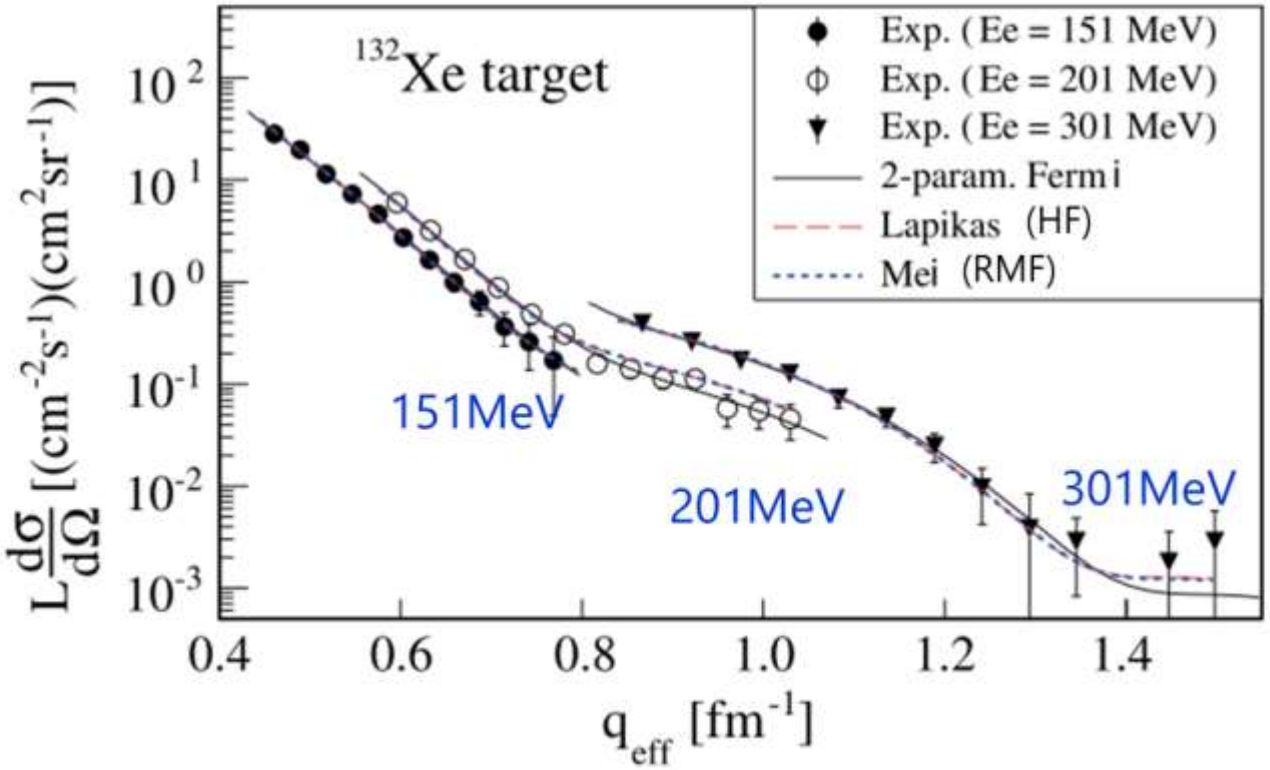
M. Wakasugi et al., NIMB 317 (2013) 668.

2009 Construction start
2011 Facility commissioning

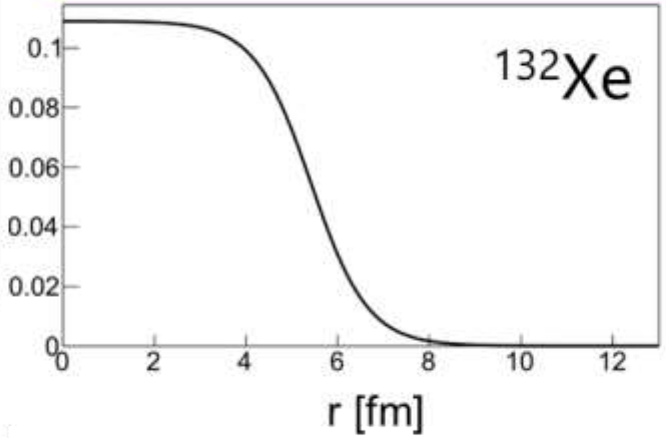
WiSES (Window-frame spectrometer for
electron scattering) Magnetic spectrometer

K. Tsukada et al., Phys. Rev. Lett. 118 (2017) 262501.

Calc: DREPHA(Phase shift)

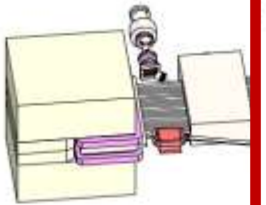


$$\rho_C = \rho/(1 + e^{4.4(r-C)/t})$$
$$C = 5.42^{+0.11}_{-0.08}$$
$$t = 2.71^{+0.29}_{-0.38}$$
$$\langle r \rangle^{1/2} = 4.79^{+0.12}_{-0.10}$$

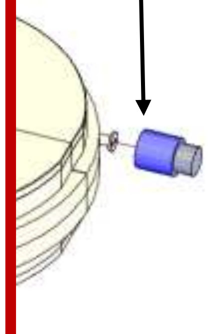


FR...
to-...

ERIS (ele...
RI separa...
Ion source...
of uranium...



...on:
...minosity
...nitor (CsI)



...d RIKEN
...0 mA

RTM (Race-track microtron)
150 MeV,0.5mA peak,2μs pulse

e-beam

2. SCRIT electron scattering facility

M. Wakasugi et al., NIMB 317 (2013) 668.

2009	Construction start
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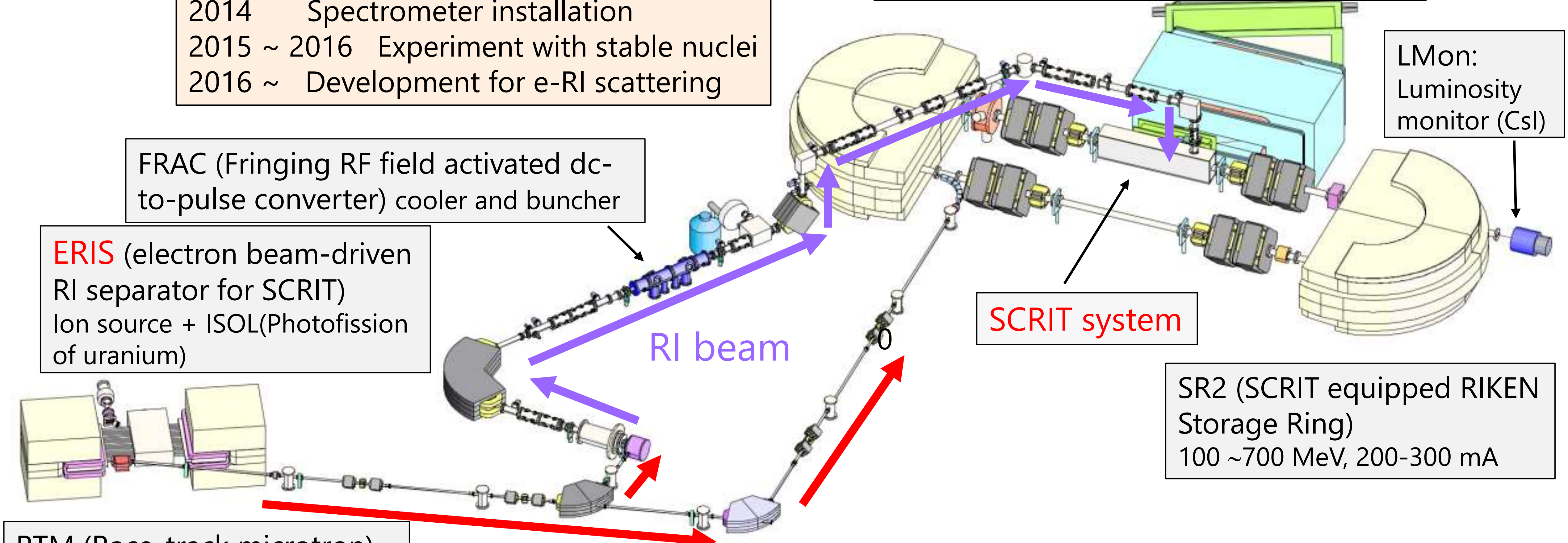
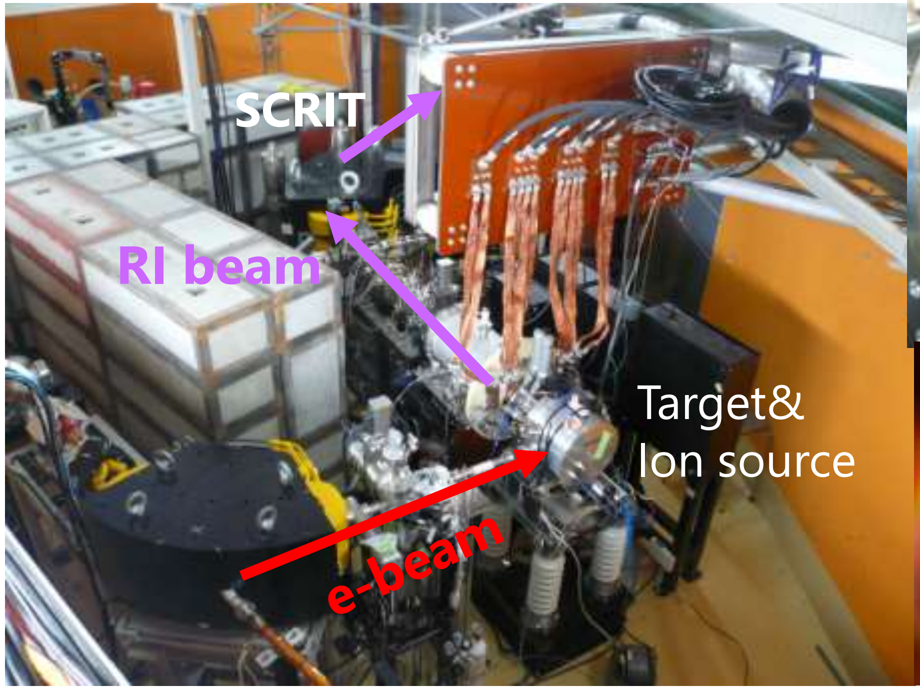


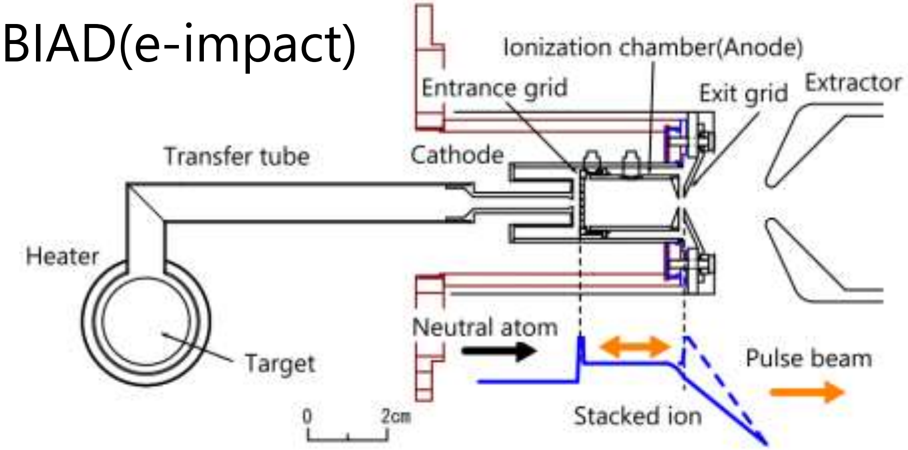
ERIS (Electron beam-driven RI separator for SCRIT)

Production method: Photo-fission of uranium

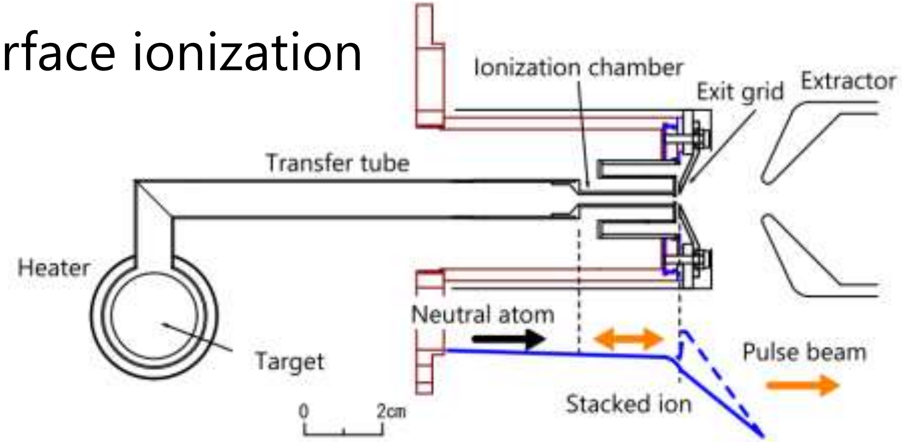


Ion source

FEBIAD(e-impact)



Surface ionization



Uranium Carbide target

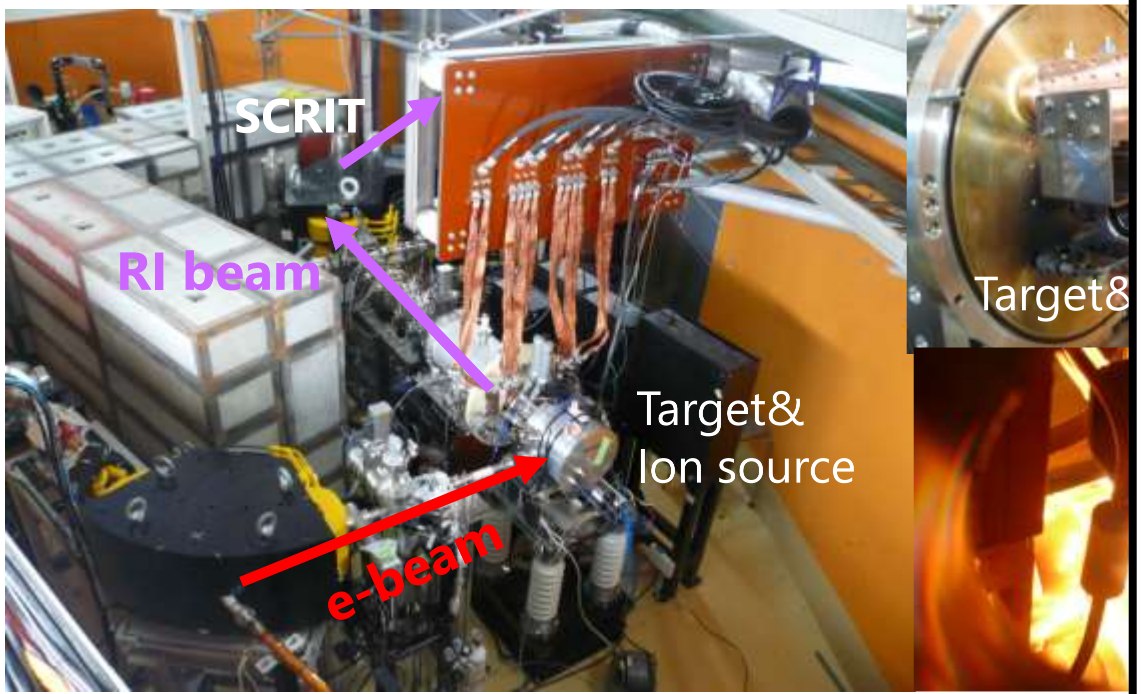
RIKEN original production method

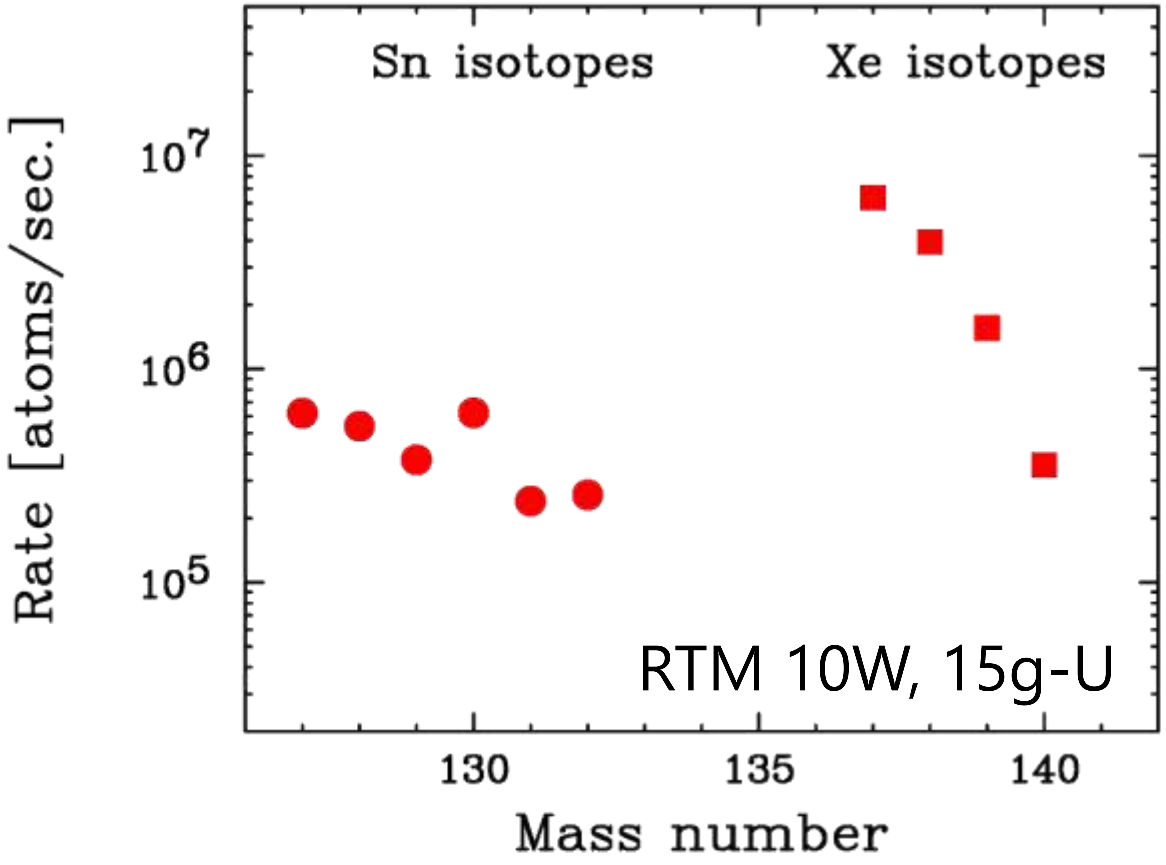
Uranyl nitrate(liquid)+C powder+w/o bond

φ 18 mm, t 0.8 mm disks

ERIS (Electron beam-driven RI separator for SCRIT)

Production method: Photo-fission of uranium





^{138}Xe: 3.9×10^6 cps, ^{132}Sn: 2.6×10^5 cps

Uranium Carbide target

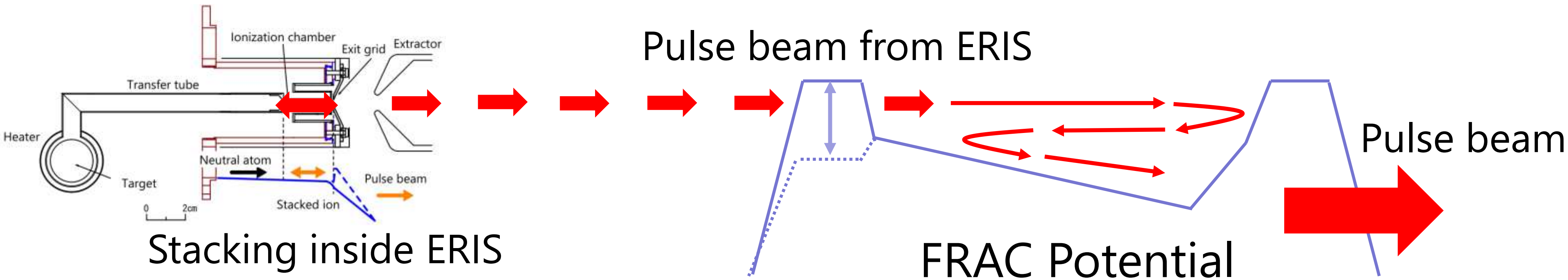
RIKEN original production method

Uranyl nitrate(liquid)+C powder+w/o bond

φ 18 mm, t 0.8 mm disks

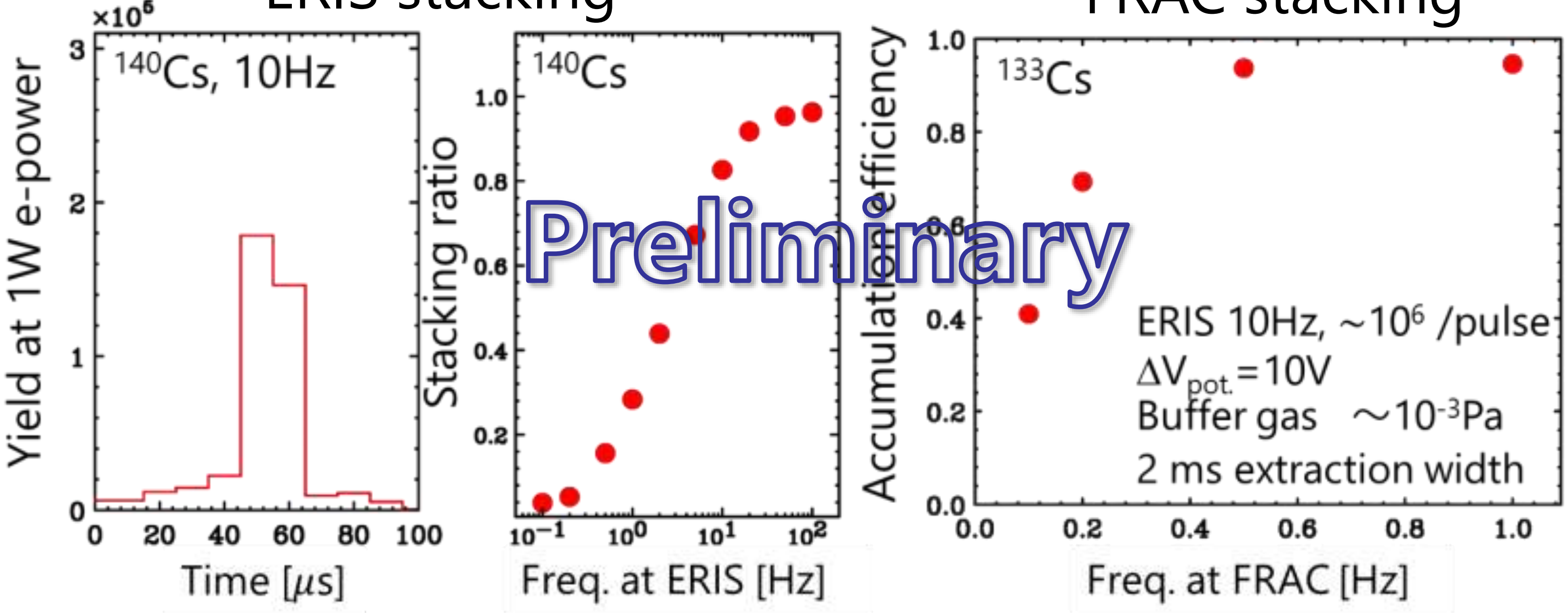
Two stage stacking inside ERIS & FRAC

Conversion from DC to pulse beam



ERIS stacking

FRAC stacking



SCRIT system

M. Wakasugi et al., NIMB 317 (2013) 668.

Number of injected ions (N_{inj})

RI ion beams

Luminosity monitor

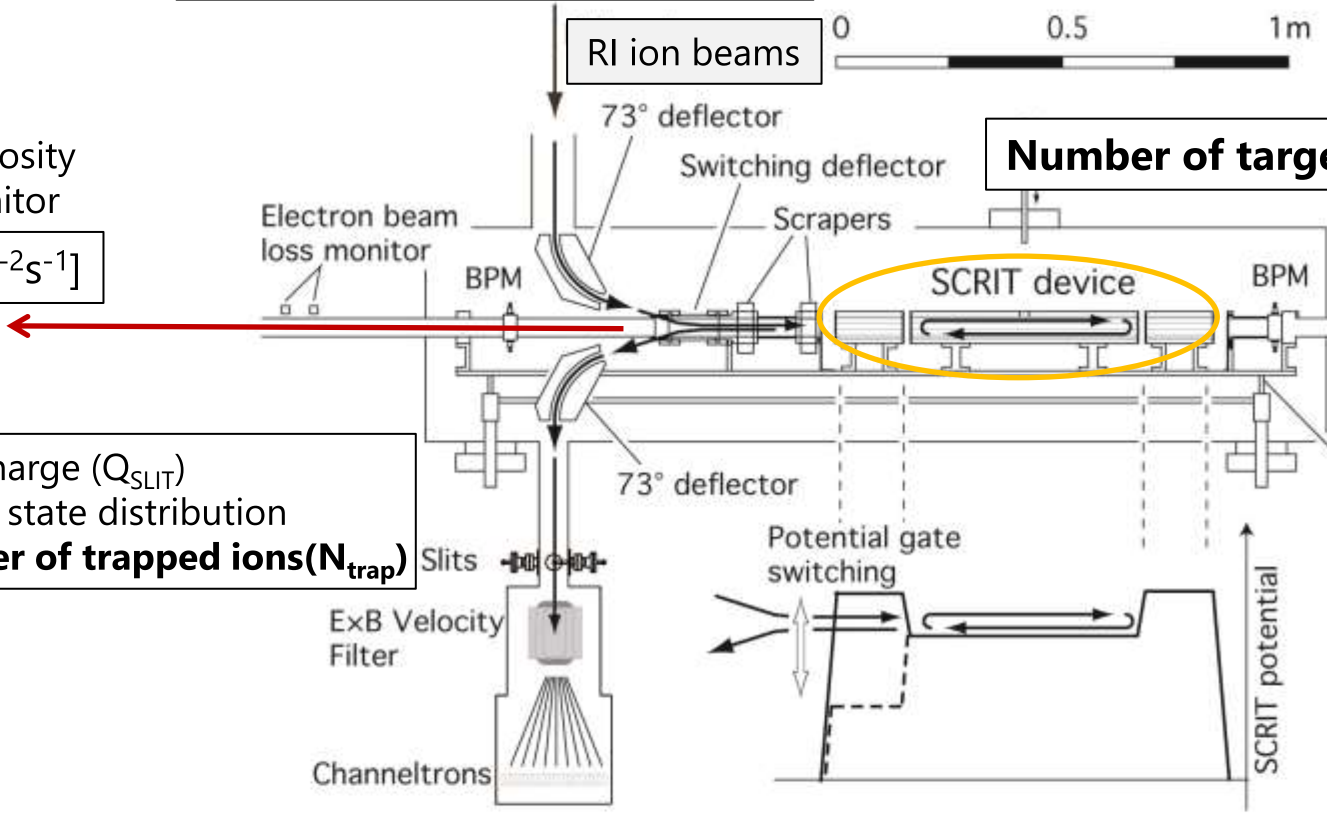
L [$cm^{-2}s^{-1}$]

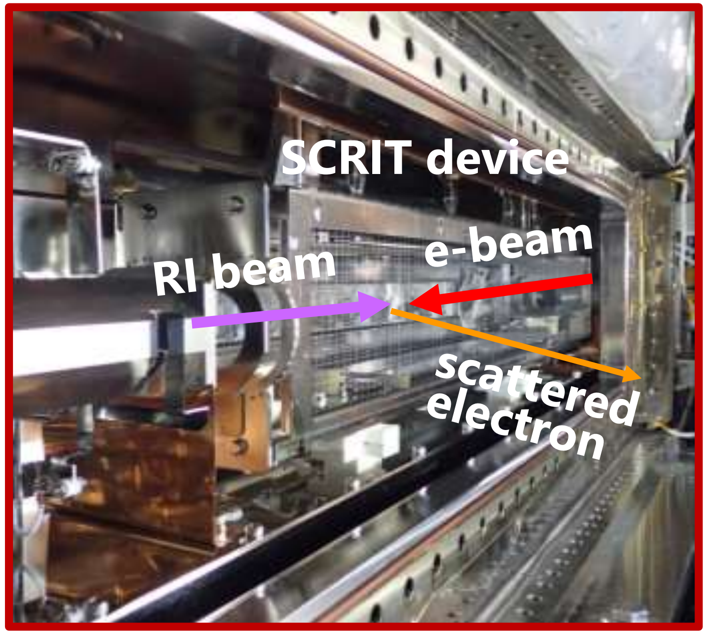
Number of target ions (N_T)

Electron beams

I_e [A], σ [cm^2]

Total charge (Q_{SLIT})
Charge state distribution
Number of trapped ions(N_{trap})





Luminosity $L \sim \dfrac{I_e/e \cdot N_T}{\sigma}$ [$\mathrm{cm^{-2}s^{-1}}$]

$N_T = \varepsilon_{overlap} N_{trap}$ $\quad Q_{SLIT} = q_{ave} N_{trap} = q_{ave} \varepsilon_{trap} N_{inj}$

Typical values at 150MeV, 200ms trap

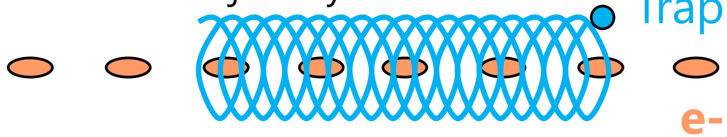
$^{138}Ba^+$ injection

- L ~ 2.3×10^{27} $cm^{-2}s^{-1}$ at 250 mA
- σ ~ 2.6 mm^2
- $N_{inj} \sim 2.5\times10^8$ /pulse
- $N_T \sim 3.8\times10^7$ /pulse
- $\varepsilon_{overlap}$ ~40% ε_{trap}~40%

Ion trap property at SCRIT

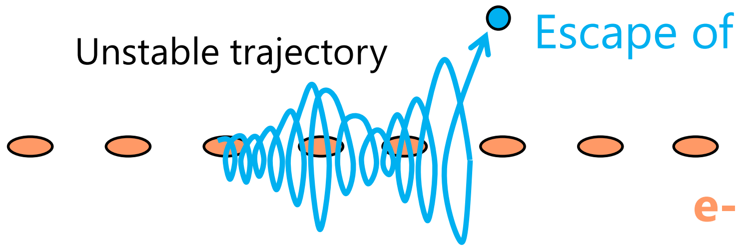
Trap potential produced by e-beam at SCRIT

1: Periodic and Pulse potential



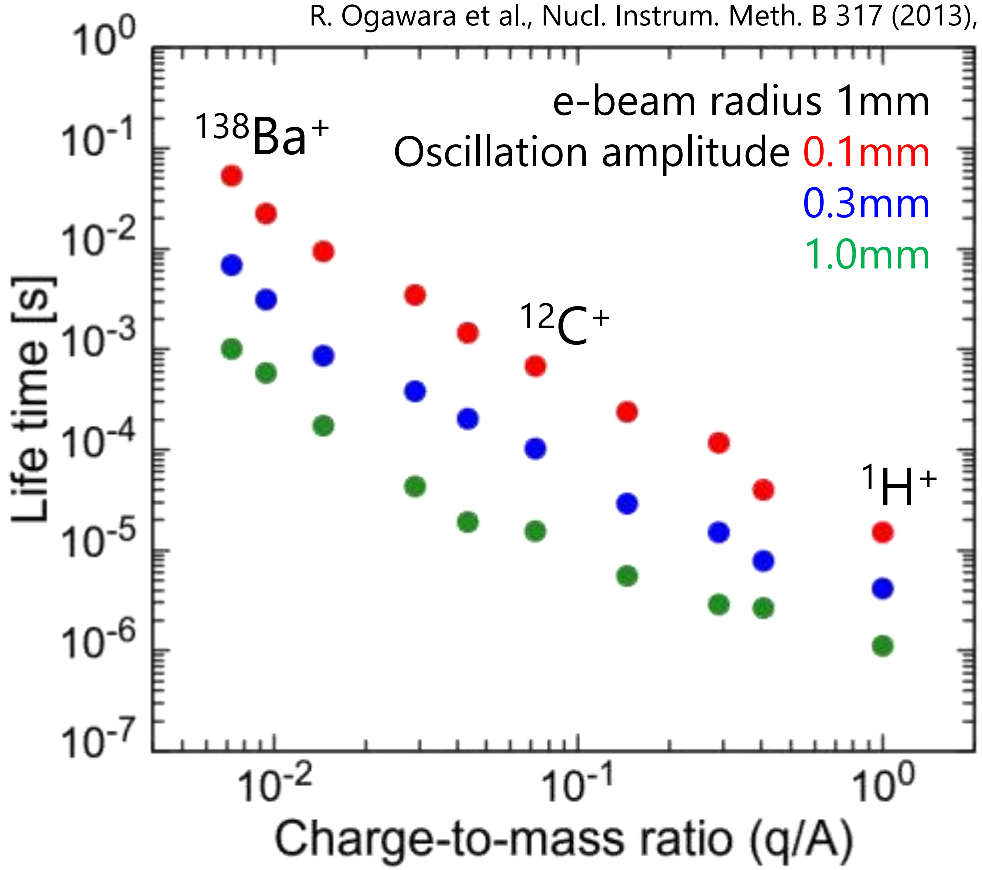
2: Collective synchrotron oscillation

e-beam in-stability



Simulation

R. Ogawara et al., Nucl. Instrum. Meth. B 317 (2013), 674-678.

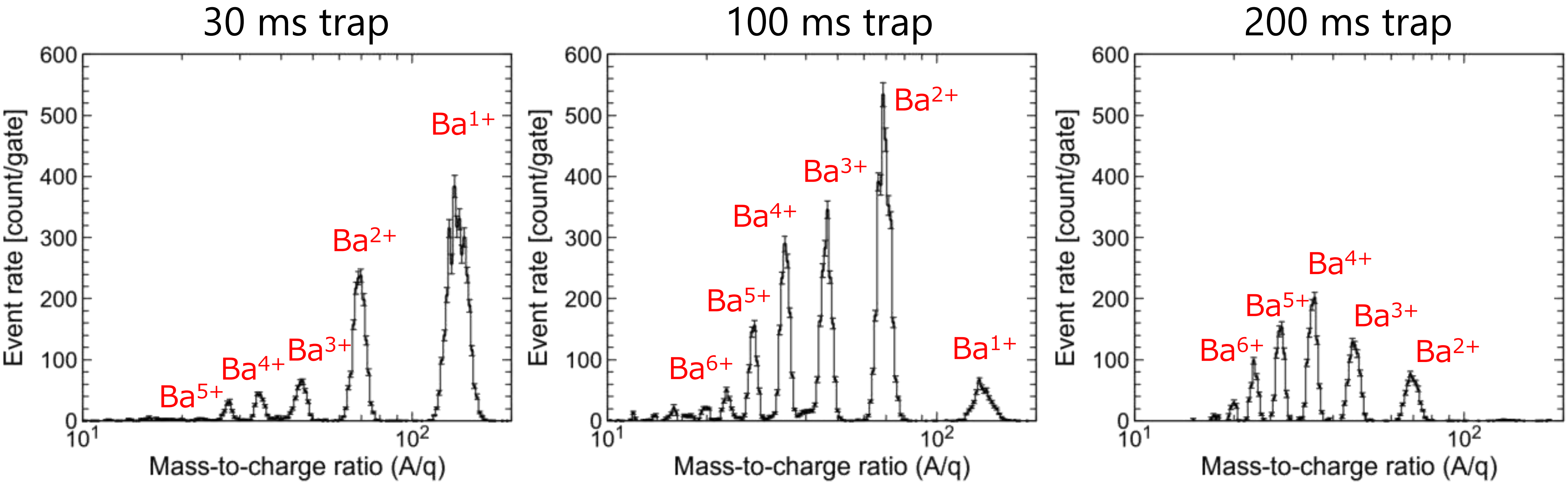


- Large e-beam oscillation amplitude
- Large q/A = High charge-state ion

➔ Short lifetime of trap

Measurement of the charge state distribution

$^{138}Ba^{+}$ injection , e-beam 150 MeV

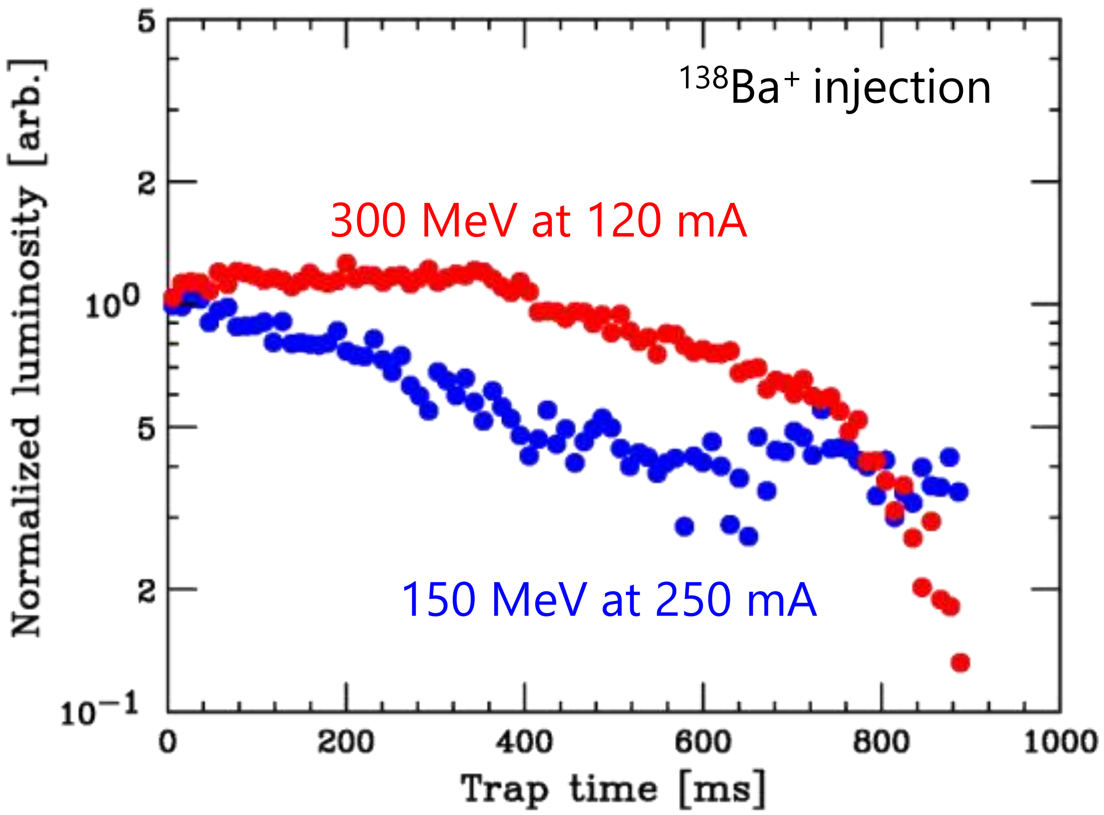


Long trap time ➔ Main components: high charge-state ions

High charge-state ions escape from the SCRIT trap.

Poster presentation by R. Ogawara

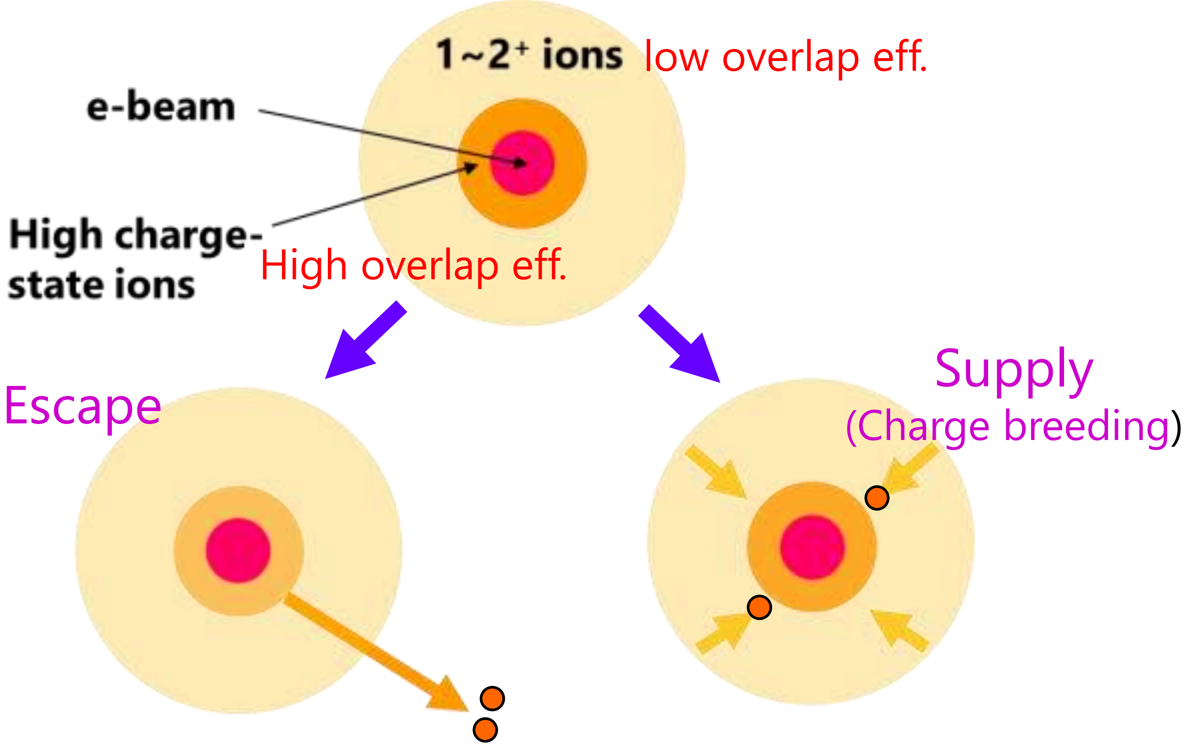
Trap time dependence of luminosity



Degree of change in luminosity $\neq$ Change of N_{trap}

Example: 150 MeV at 200 ms trap
N_{trap} : 40% of injected ions
N_T : 80% of initial value

One hypothesis

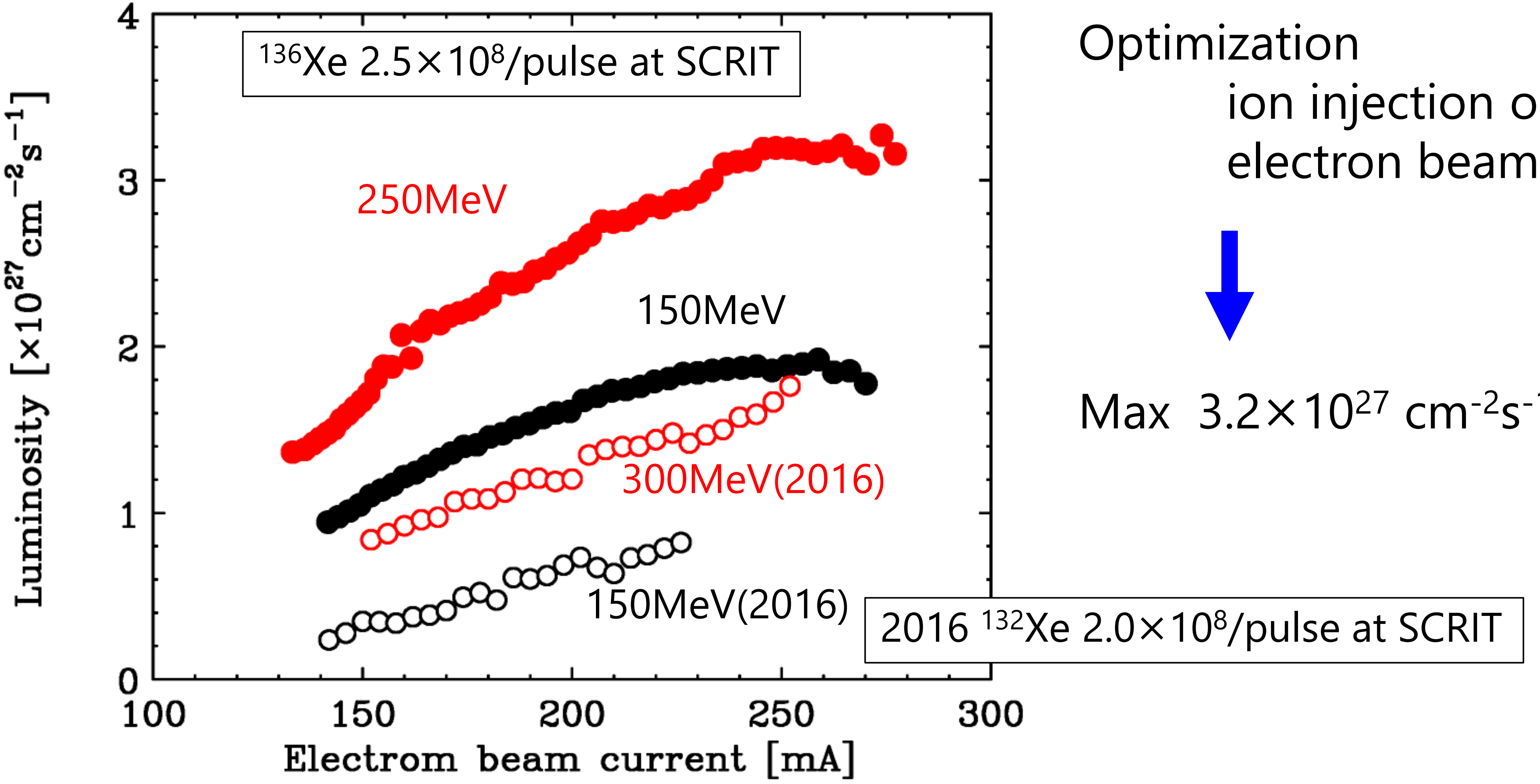


N_T&N_{trap} : Decrease

N_T : Increase

Competition between escape and supply
➔ Study of trapped ion's dynamics is in progress.

Achieved luminosity



Optimization

ion injection optics

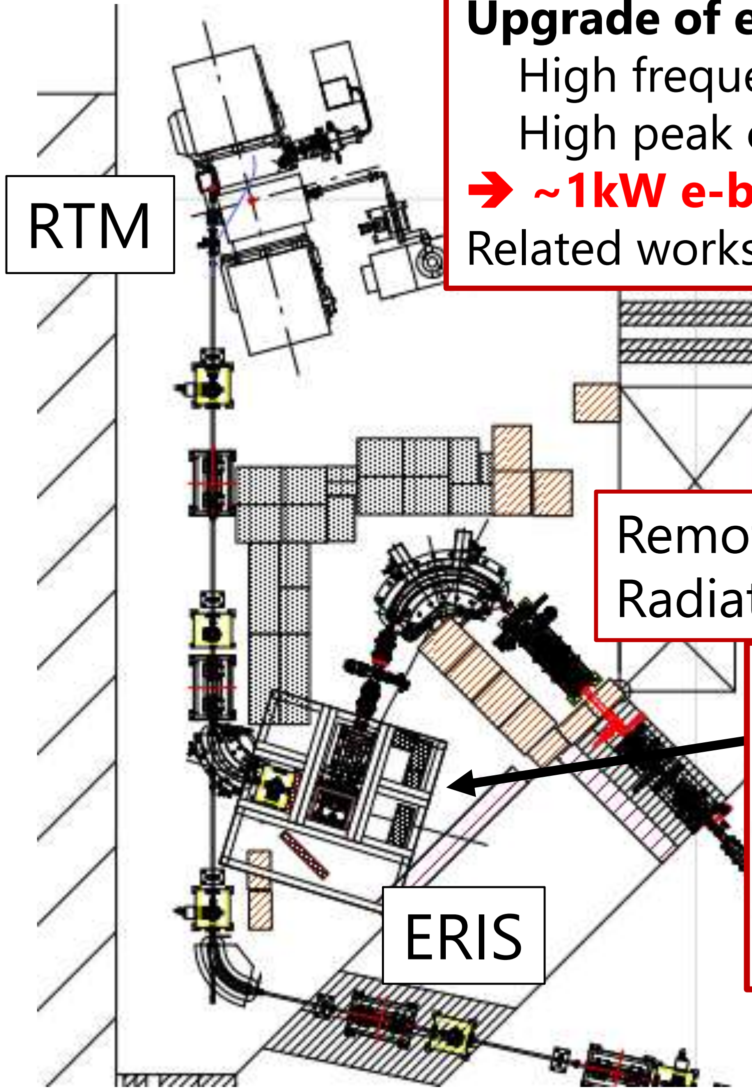
electron beam stability

Max 3.2×10^{27} cm^{-2}s^{-1} at 250 mA

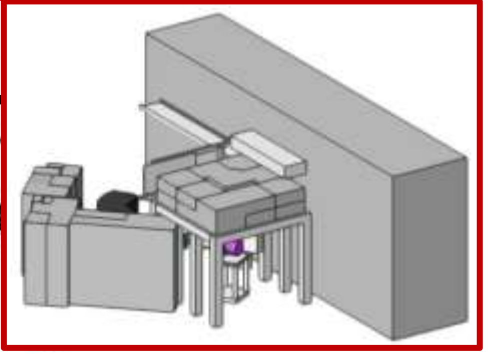
4. Future plans

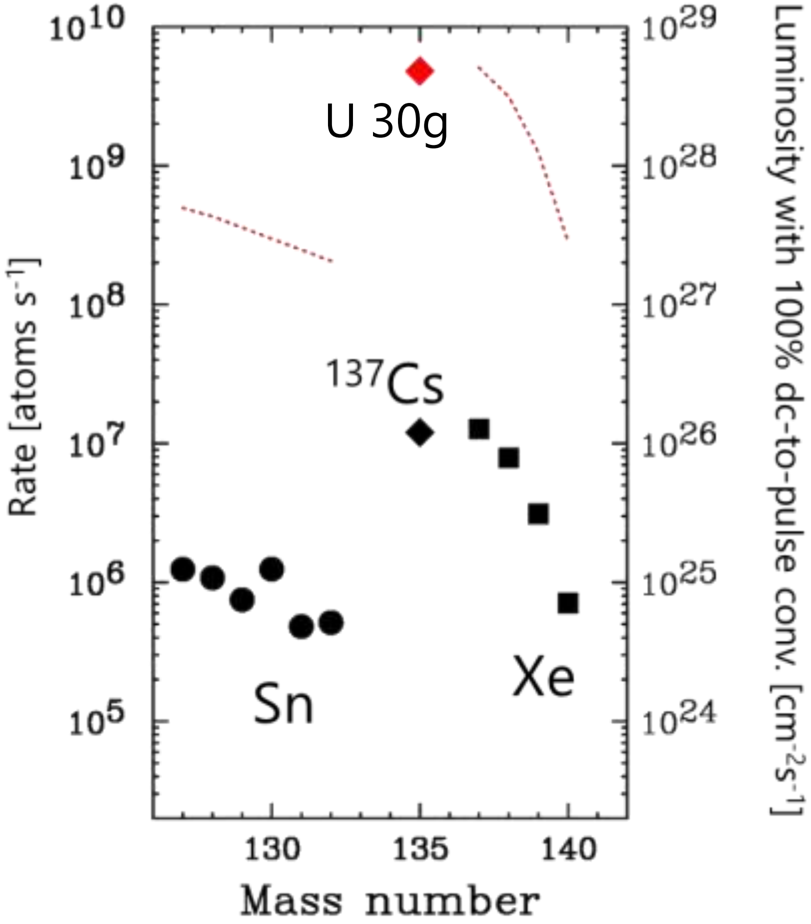
Upgrade towards short-lived nuclei

Upgrade of e-beam driver
High frequency (2Hz → 100 Hz)
High peak current
➔ ~1kW e-beam
Related works are ongoing.



Remote handling system
Radiation shield





1 kW beam
ERIS Eff. × 4

10W beam
ERIS Eff.
5.5%(^{138}Xe)
2.0%(^{132}Sn)
5.5% (^{137}Cs)

Electron scattering with ^{132}Sn will be performed in near future.

Future physics plans at SCRIT

- Elastic electron scattering with short-lived nuclei

  ^{132}Sn : first goal of our project ➔ Charge density distribution

- Systematic study around ^{132}Sn

  Xe isotope dependence

  N=82 isotone dependence

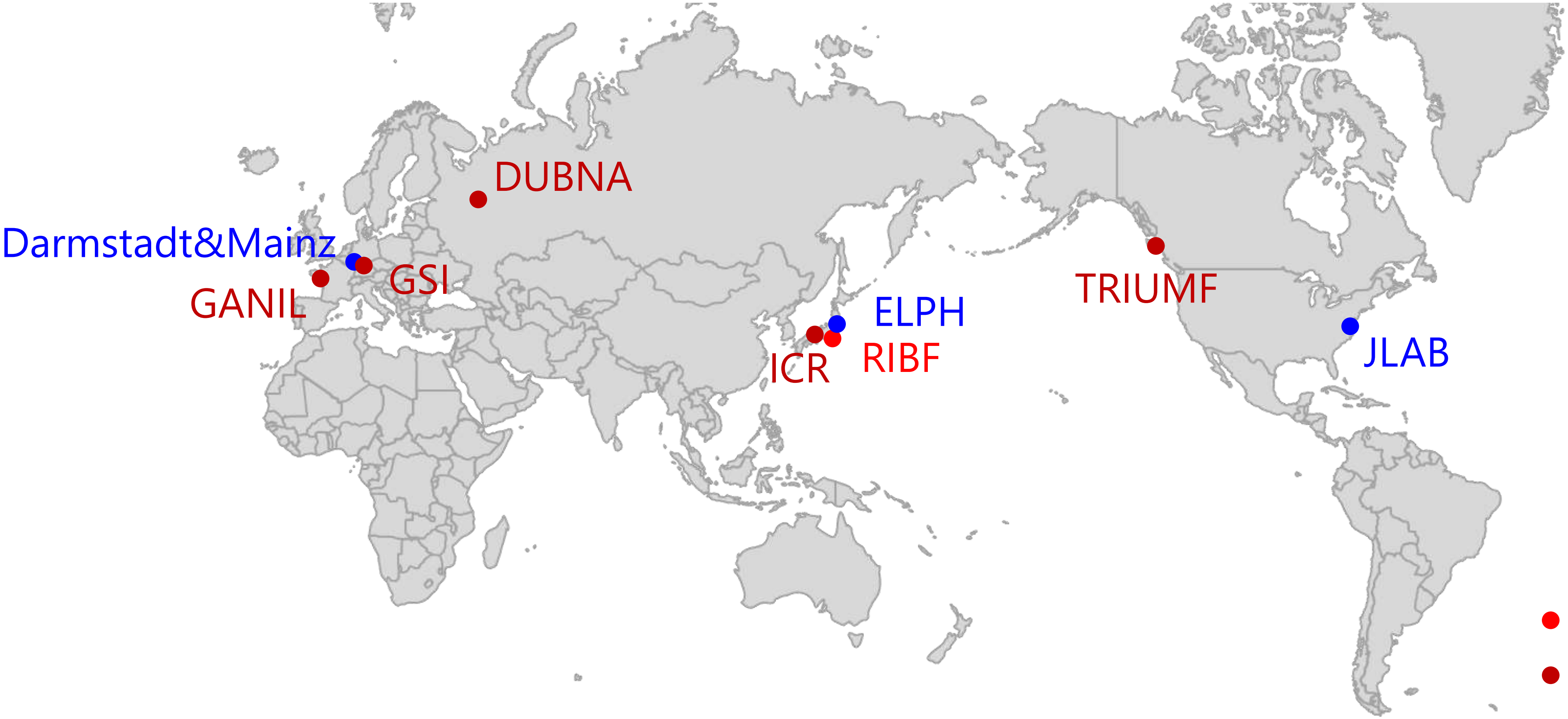
- 4th-order moment measurement to study neutron distribution

  Precise measurement at low momentum transfer region

- Photo-absorption measurement

  Zero degree scattering → Detector system inside the dipole magnet

Electron-Nuclei scattering facility



- e + RI
- e + RI (planed)
- e + stable nuclei

The SCRIT facility leads this research field.
World's wide collaboration is being established.

5. Summary

・The SCRIT electron scattering facility was constructed and many development have performed.

・World's first experiment of electron scattering with online-produced unstable nuclei was successfully performed.

・Upgrade of electron beam power is already started.

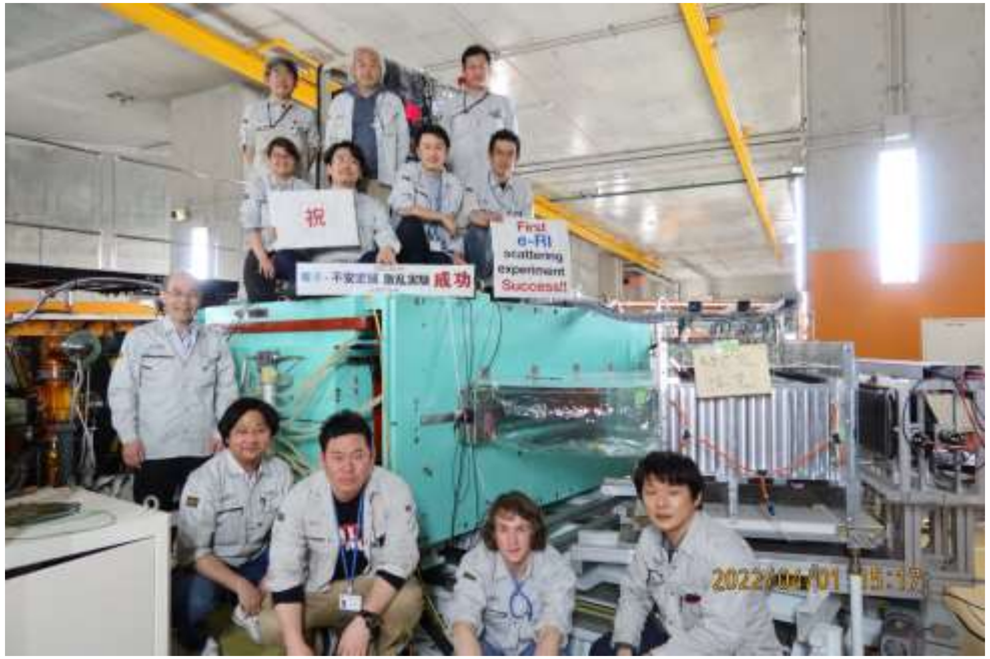
The electron scattering with ^{132}Sn will be performed in near future.

The way to new and long-awaited research method,
electron scattering with unstable nuclei, is opened now.

SCRIT collaboration

D. Abe[1], Y. Abe[2], R. Danjyo[1], A. Enokizono[3] , T. Goke[1], M. Hara[2] ,Y. Honda[1], T. Hori[2] , S. Iimura[3], S. Ichikawa[2] , Y. Ishikura[1], K. Kurita[3], C. Legris[1], Y. Maehara[4], Y. Nagano[1], R. Ogawara[2,4] , T. Ohnishi[2], R. Ohara[1], T. Suda[1,2] , K. Tsukada[2,4], M. Wakasugi[2,4], M. Watanabe[2], H. Wauke[1,2] , S. Yoshida[4]

[1]ELPH Tohoku University, [2]RIKEN, Nishina Center, [3]Rikkyo University, [4]ICR Kyoto University



Thank you for your attention!