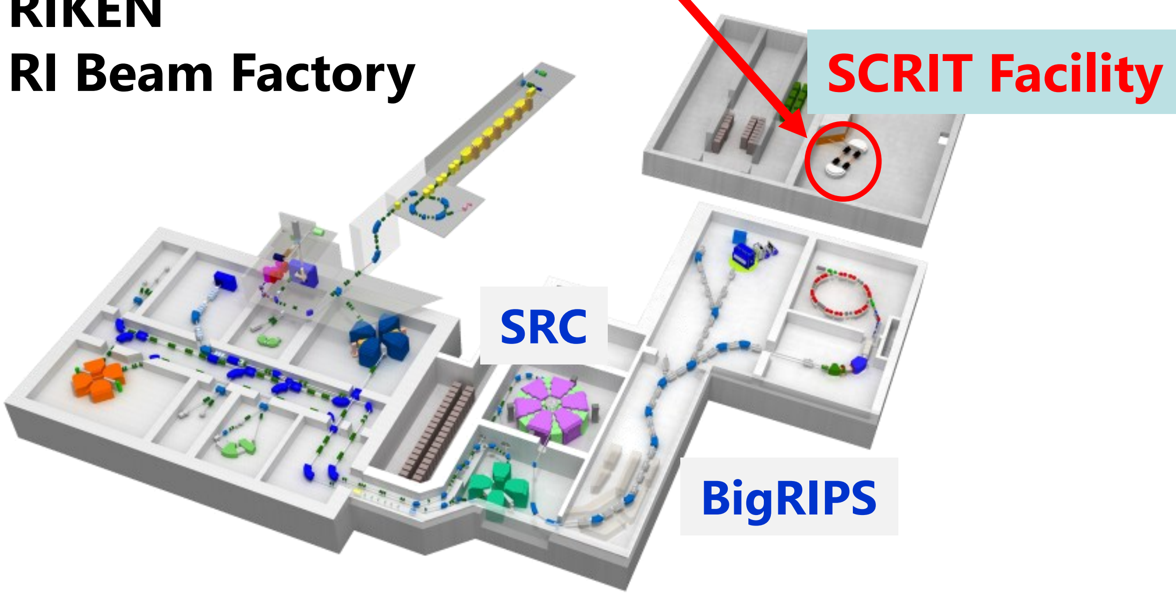
Present status and perspective of the ISOL system, ERIS, at the SCRIT electron scattering facility

LEES2024, October 28, 2024, Sendai

RIKEN Nishina Center
T. Ohnishi
and
SCRIT collaboration

ERIS: Electron beam-driven RI separator for SCRIT

RIKEN
RI Beam Factory



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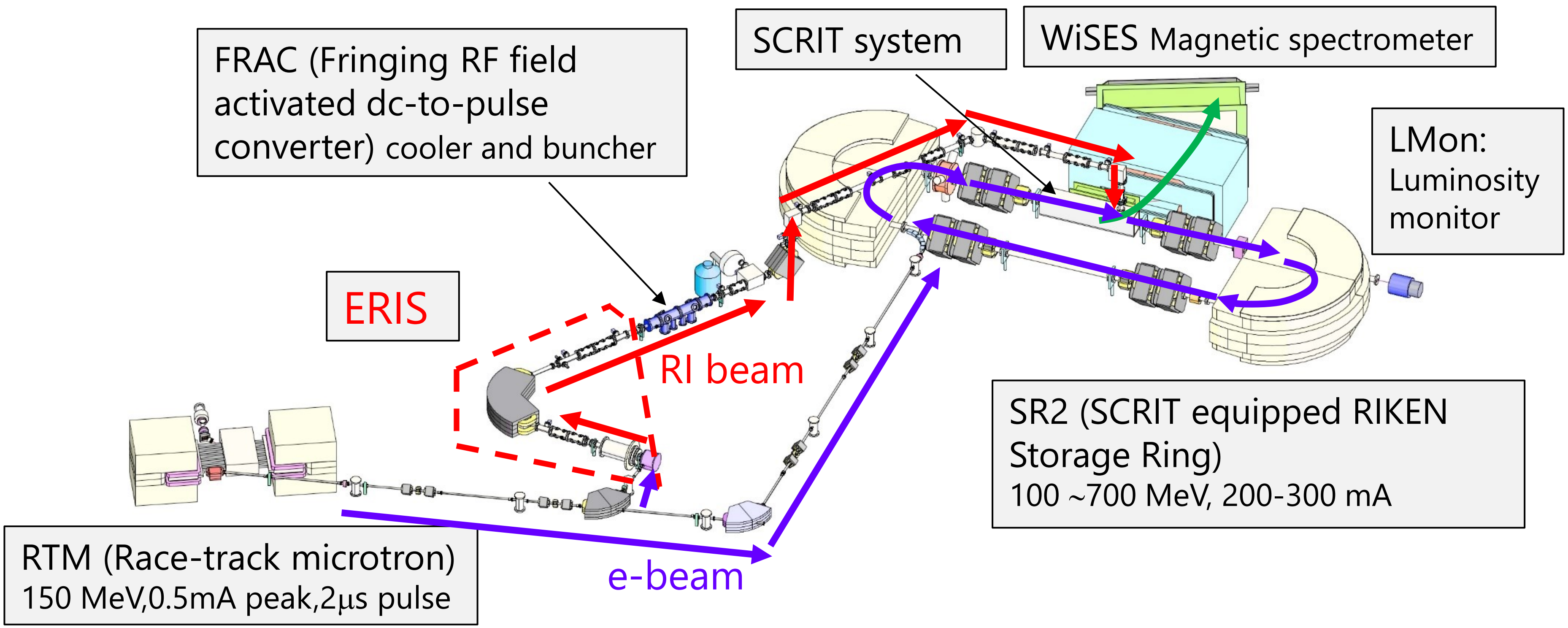
2. ERIS setup
3. Results
4. Future plan

1. Introduction

SCRIT electron scattering facility

M. Wakasugi et al., NIMB 317 (2013) 668.
T. Ohnishi et al., NIMB 541 (2023) 380.



Requirements for RI beams in SCRIT

Low-energy (～keV)

High quality (small emittance)

High intensity (～10^8 ions/pulse)

➡ ISOL system: ERIS

Character of ERIS

1. Photofission of uranium

Photofission (Ex ～ 15 MeV)

Thicker target can be applied.

2. Low-energy and high intensity RI beam separator

1 kW e-beam + U 30g → 10^{11} fissions/sec (^{132}Sn 10^{9}/sec)

First electron-beam ISOL facility in Japan

First full-scale ISOL facility in RIKEN

3. Sharing of electron beam driver

Shared use with the injection to storage ring ➔ Cost effective

4. Independent RI beam separator

Complementary to BigRIPS

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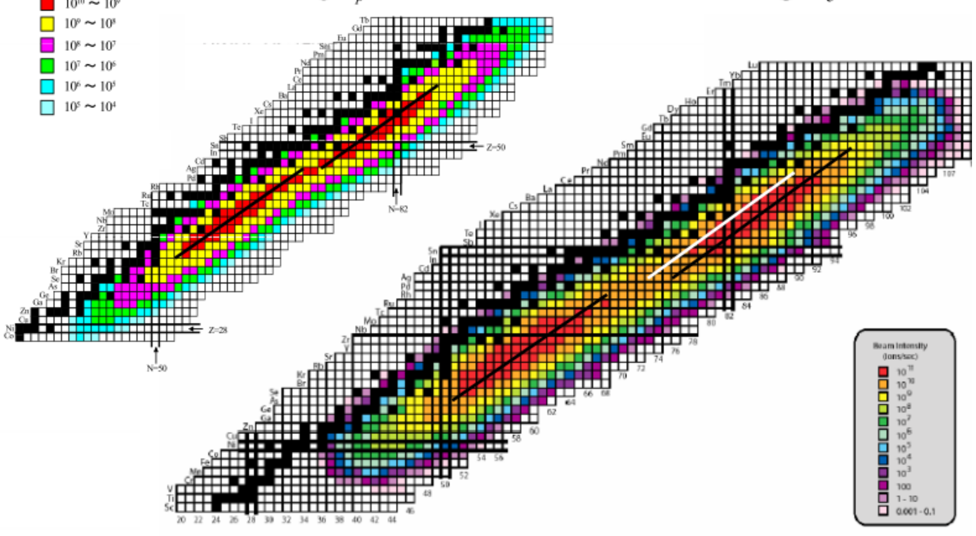
Photo fission vs Proton induced fission

Proton induced

$<A> Xe \approx 136.5 @ E_p \approx 30 MeV$

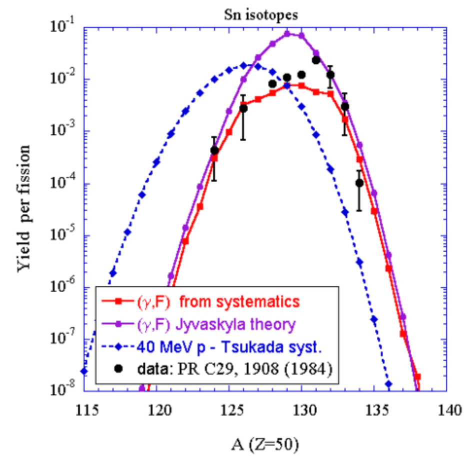
Photo fission

$<A> Xe \approx 139 @ E_e \approx 25 MeV$



Taken from eRIBs'07 Workshop Reported by Jim Beene

A sample comparison with data: Sn isotopes



taken from eRIB's07 workshop
Reported by Jim Beene

Photofission has advantage to produce more neutron rich (2～3 neutron) unstable nuclei.

Character of ERIS

1. Photofission of uranium

Photofission (Ex ～ 15 MeV) ➔ Thicker target can be applied.

More neutron rich unstable nuclei than proton beam

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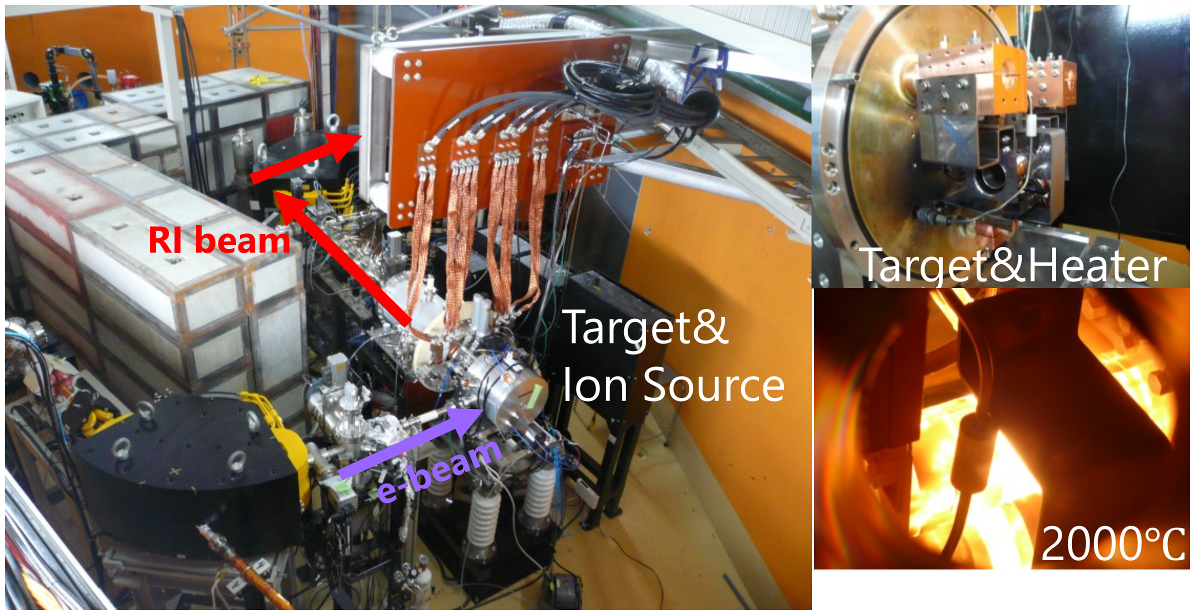
2. ERIS setup

Production target + Ion source + Transport line

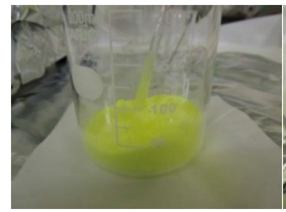
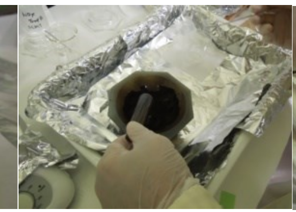
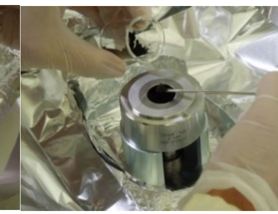


2009 Construction start
2011 Commissioning & Uranium target production
2013 First RI beam produced by uranium photo-fission
2016 Grid operation for pre-stacking
2017 Surface ionization type ion source
2022 e-RI scattering experiment using online-produced RI

Production target

Self-made Uranium carbide disk

Uranyl nitrate solution mixed with graphite powder (20μm)

↓ Oxidization around 500 °C
180 MPa compression with no binder
Φ 20 mm, t = 1 mm

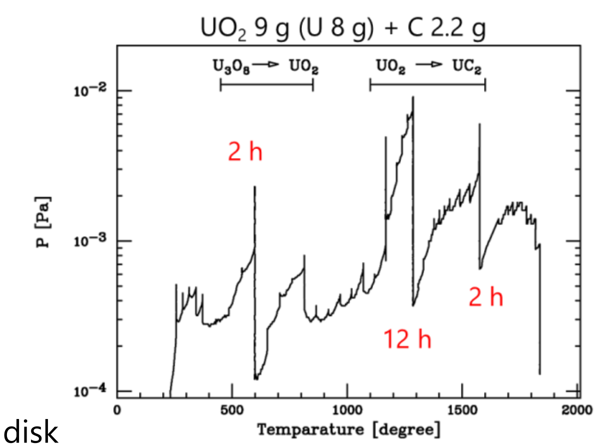
Uranium-oxide disk

↓ Carbothermal reduction

$U_3O_8 + C \rightarrow 3UO_2 + CO_2$ at 600-800℃

$UO_2 + 4C \rightarrow UC_2 + 2CO$ at 1100-1600℃

Ref. Gmelin handbook Supp. Vol. C12



Uranium carbide disk

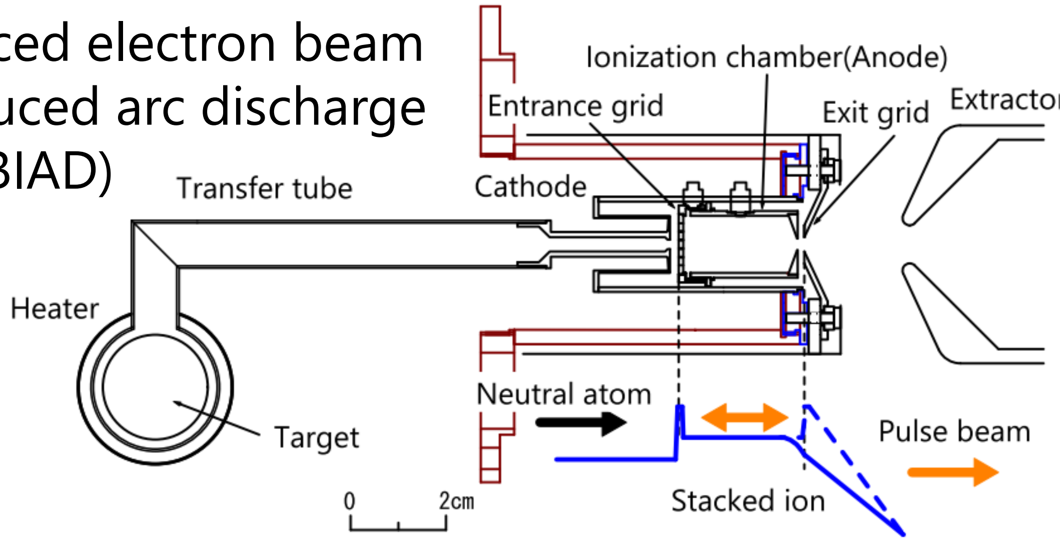
Φ 18 mm, t 0.8 mm
43 disks U-28 g
→ U density 3.2 g/cm3)

Uranium carbide disk

Left side: Ta converter
Right side: C spacer

Ion source at ERIS

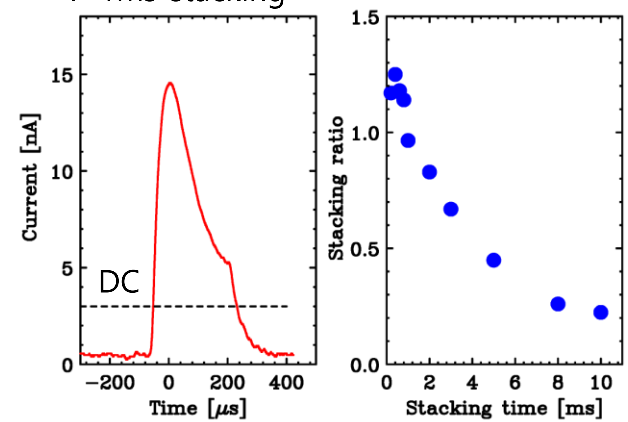
Forced electron beam induced arc discharge (FEBIAD)



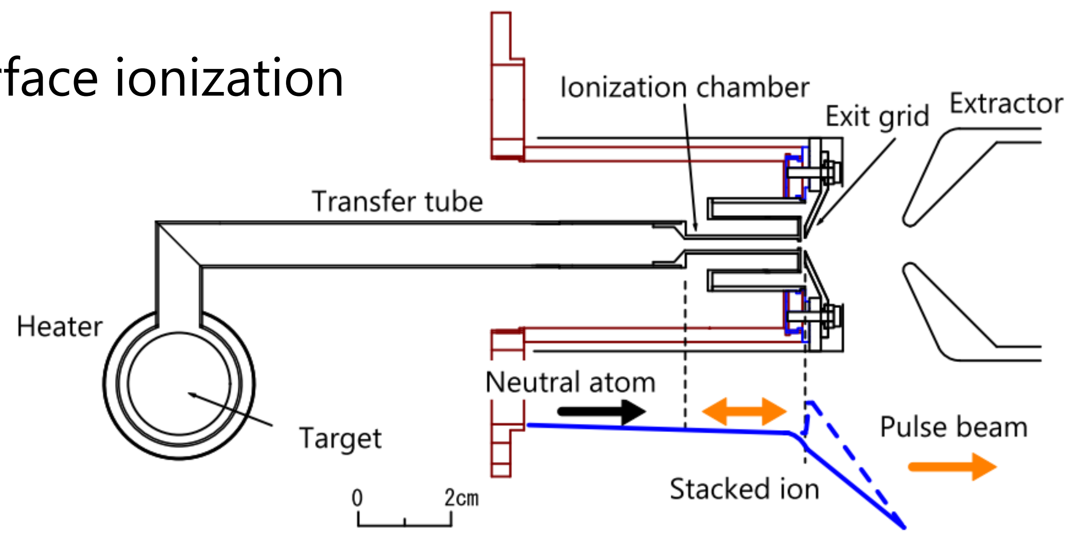
grid system

Conversion to pulse beam

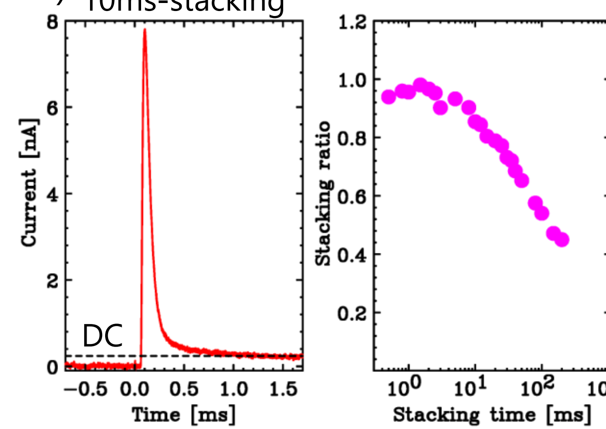
^{132}Xe) 1ms-stacking



Surface ionization

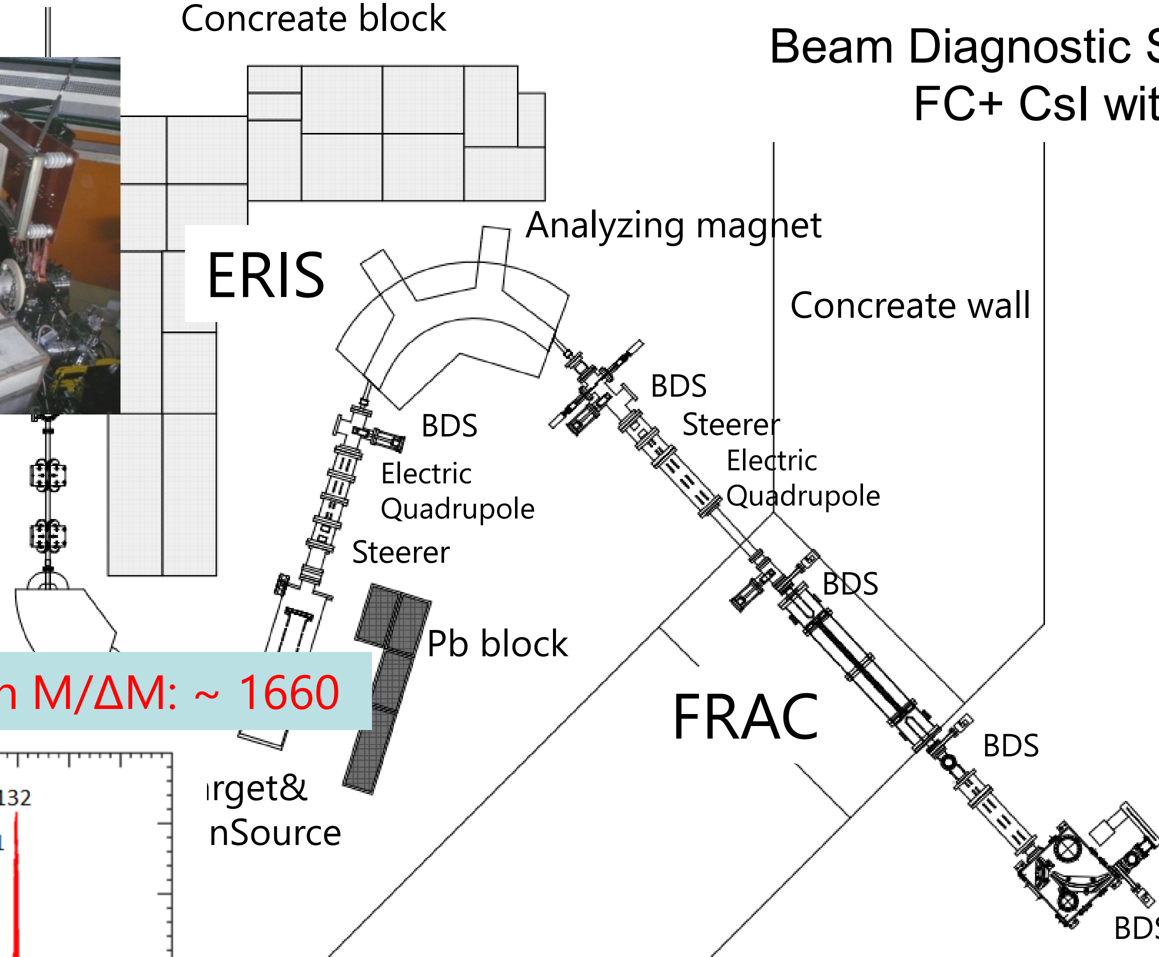


^{133}Cs) 10ms-stacking

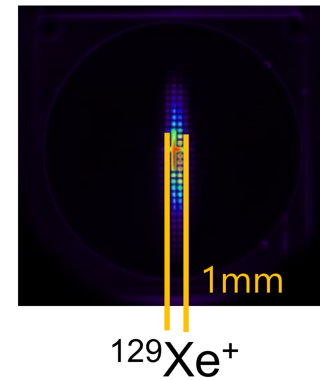


Stacking ratio = Q(pulse)/Q(DC×Stacking time)

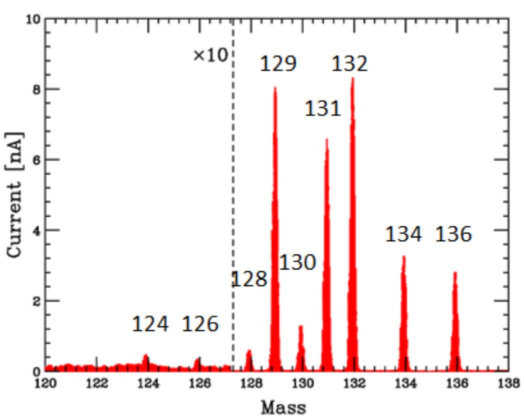
Transport line

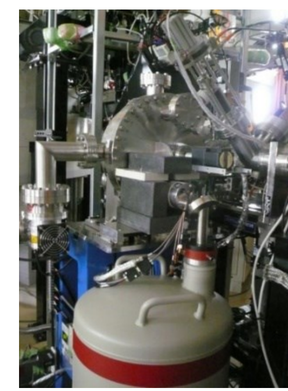


Beam Diagnostic System (BDS)
FC+ CsI with CCD



Mass resolution M/ΔM: ~ 1660

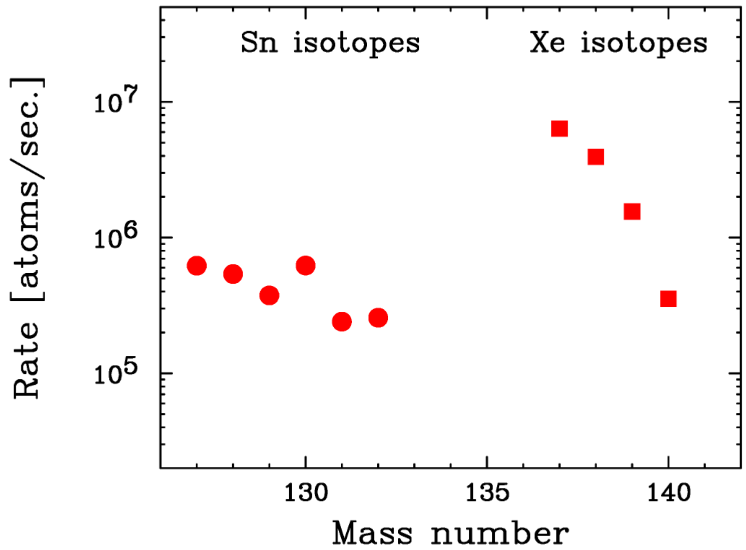




PID system
Rotating target disk
Ge detector

3. Results

RI production with FEBIAD



FEBIAD ion source
U 15g
10W electron beam

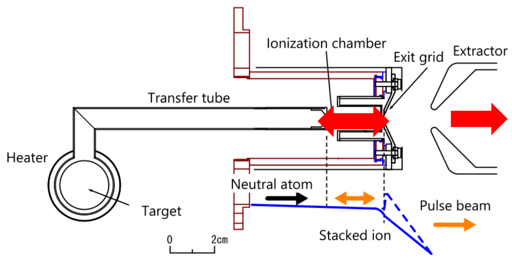
Overall efficiency = Release × Ionization × Transport

Exp./Calc. — Release: Target～Ionization — Transport: from ^{129}Xe gas (14～15%)

	Rate at 10W (atoms/s)	Calc at 10W (atoms/s)	Overall	Release
^{138}Xe	3.9×10^{6}	7.1×10^{7}	5.5 %	40 %
^{132}Sn	2.6×10^{5}	1.3×10^{7}	2.0 %	14 %

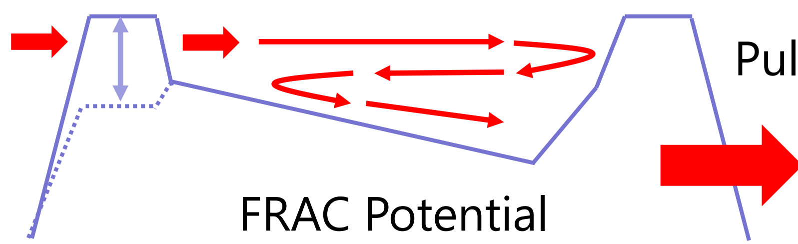
Two stage stacking inside ERIS & FRAC

Conversion from DC to pulse beam



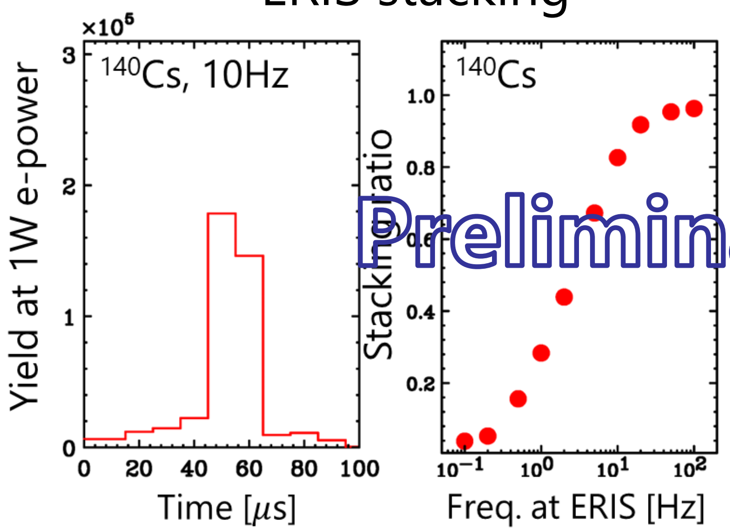
Stacking inside ERIS

Pulse beam from ERIS

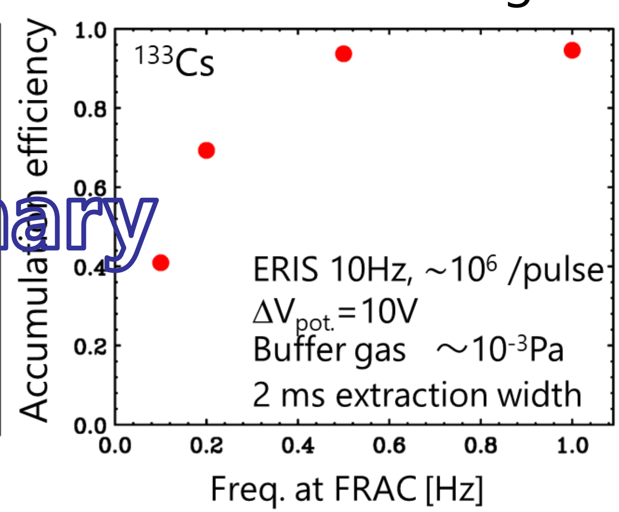


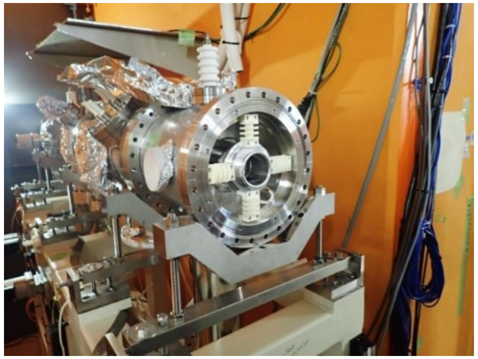
FRAC Potential

ERIS stacking



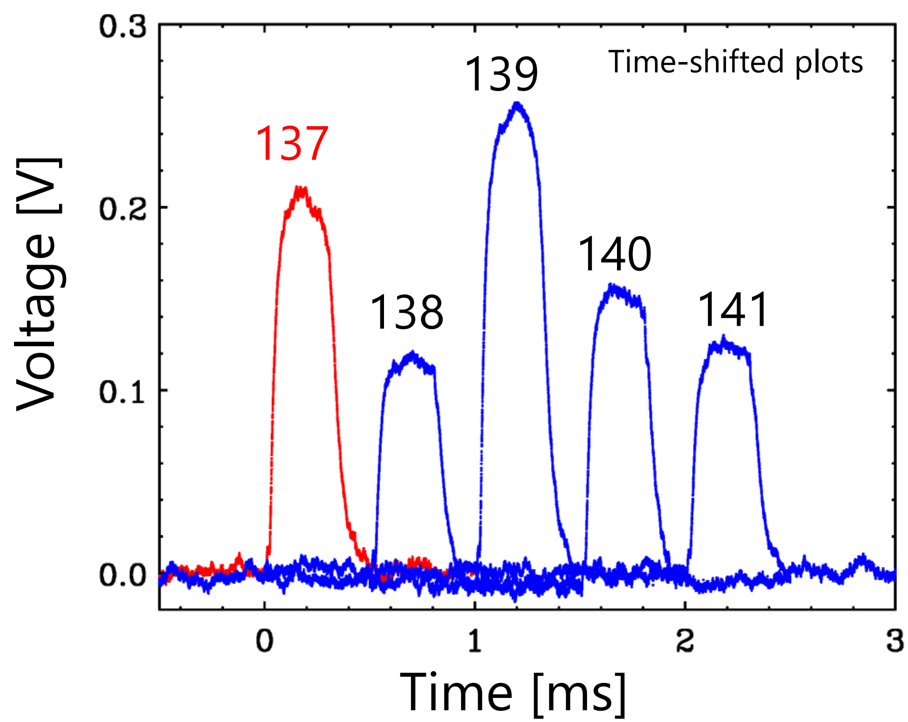
FRAC stacking

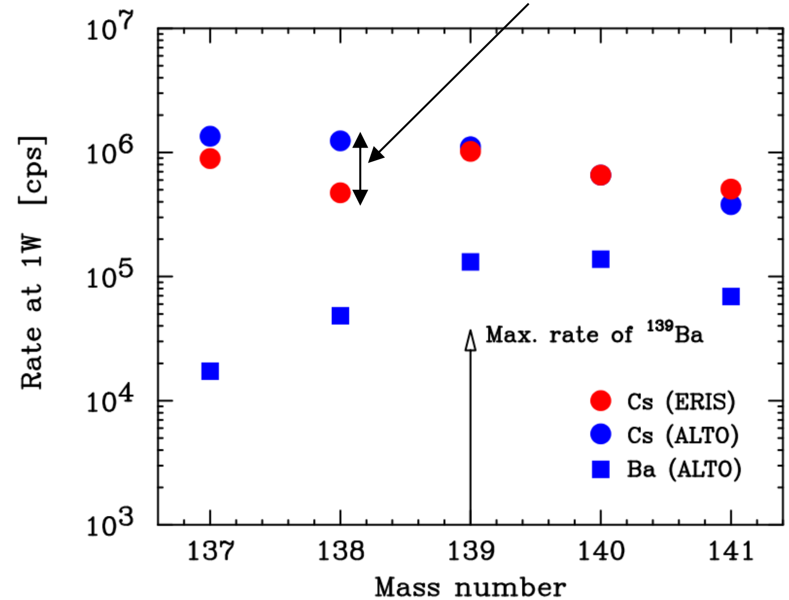




^{137}Cs beam production for e-RI scattering

ERIS 40 Hz, FRAC 1 Hz, RTM 15W, U 28g at FRAC exit





ALTO: NIMB317(2013)218.

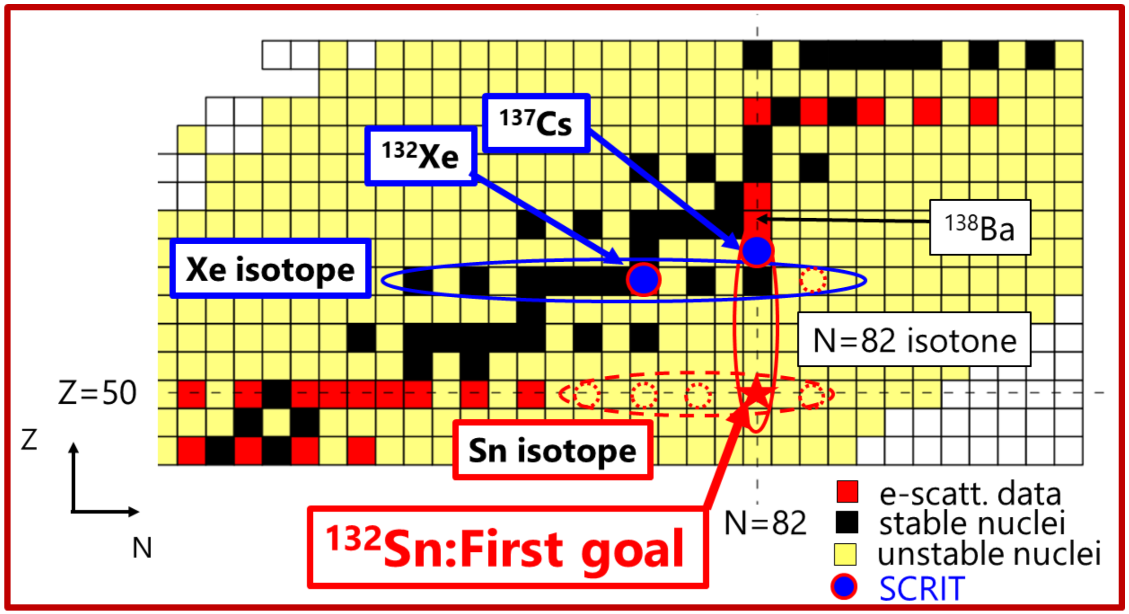
Normalized to ^{140}Cs at ERIS

^{137}Ba/^{137}Cs < 0.5%

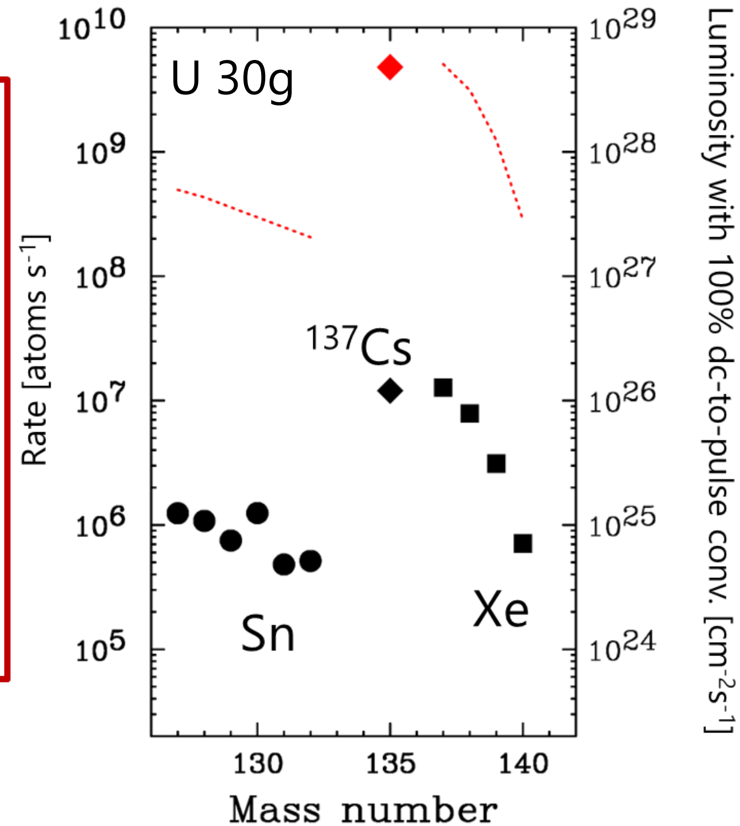
^{137}Cs pulse beam: 2×10^7 ions/pulse to SCRIT (ERIS 40Hz, FRAC 0.25 Hz)

World's first electron scattering with online-produced RI

4. Future plan



1 kW beam
ERIS Eff. × 4



"High intensity RI beam with high power electron beam"

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

Towards the supply of high intensity RI beams

1. Upgrading of e-beam driver

Improvement items for 1～2 kW e-beam

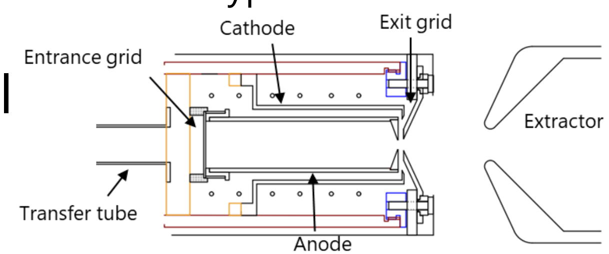
High frequency (～ 10 Hz ➔ ～ 100 Hz)
High peak current (～ 0.5 mA ➔ ～ 2.5 mA)
Long pulse width (～ 5 μs ➔ ～ 10 μs)

} Upgrading of RTM has been already started.
New klystron system
New injection line…

2. Upgrading of ERIS

Improvement of overall efficiency
Uranium carbide target ➔ Nano material
More efficient structure of ion source
Improvement of RI separation
Isobar separation → **Iimura-san's talk&Matsubara-san’s poster**

EBGP type ion source



3. High-power e-beam operation

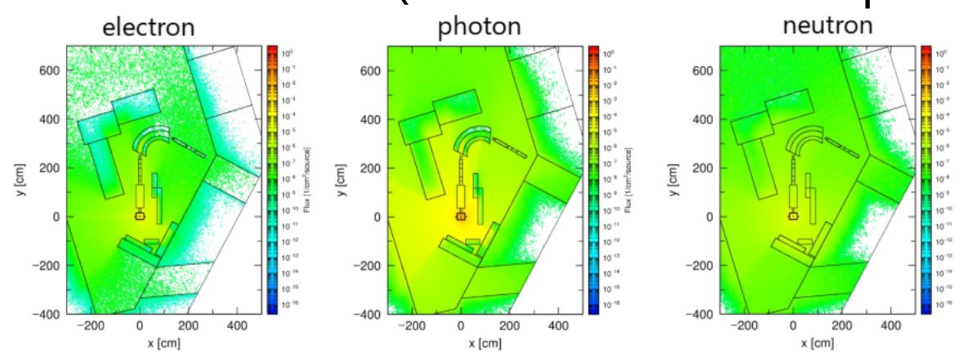
- Shielding
- Maintenance scenario
- Target operation

Shielding

Items for consideration in shielding

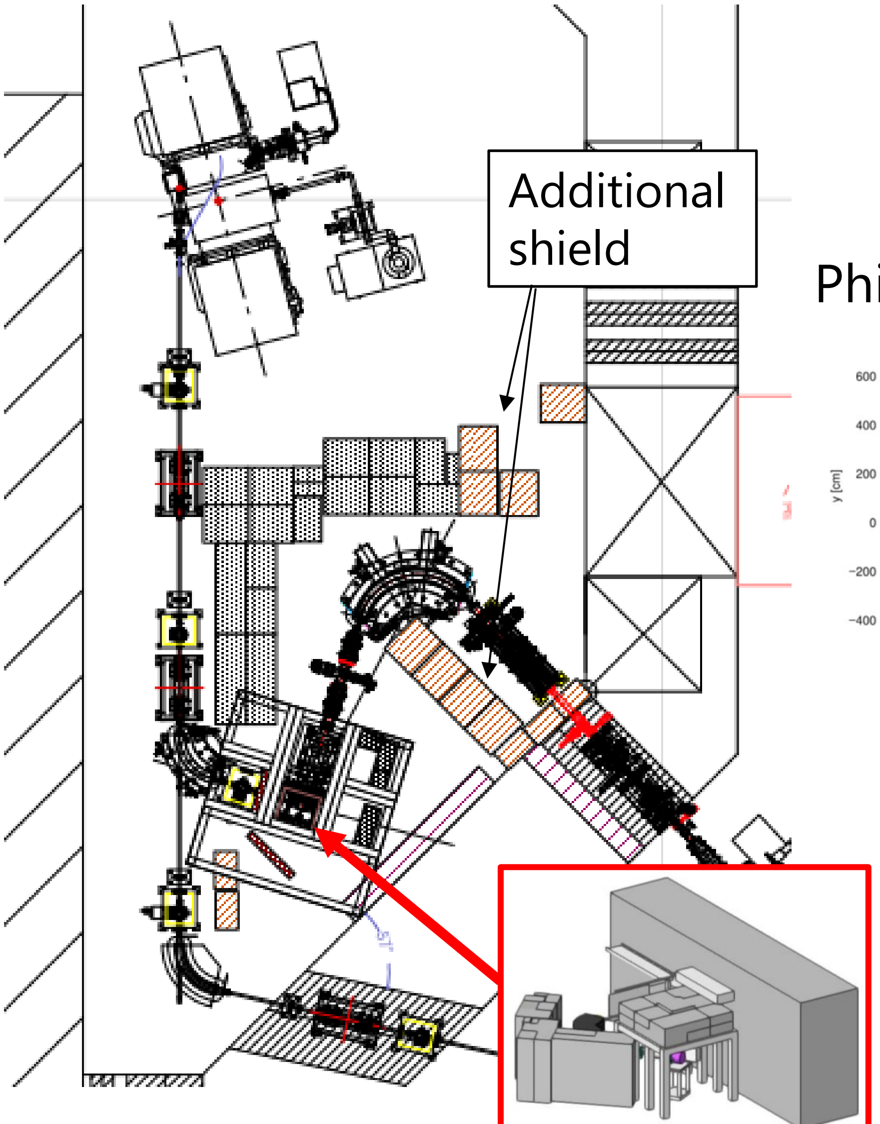
- Radiation level for outside of controlled area
- Prevent of radioactivation for electronics and devices

Phits calculation (±5mm from beam plane)



Evaluation of radiation level

Enhancement of shielding



Ceiling shield for ion source

Concreate: 2.4x2.4x0.6m^3

Pb block: 0.8x0.8x0.1m^3

Maintenance scenario

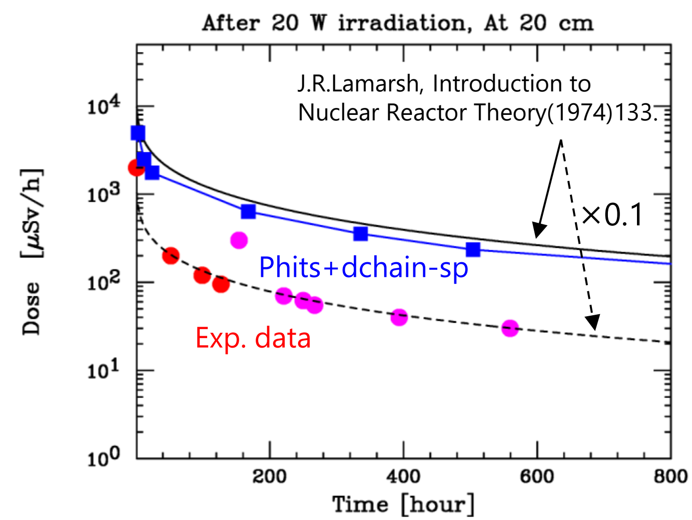
Residual radiation from target

Measured data: 20 cm from target with 20W
～50 μSv/h after 2 weeks

➔ 2.5 mSv/h after 2 weeks @ 1kW

➔ < 20 μSv/h after 2 years…

Calculation → 10 times larger
Estimation of various locations



Waiting time for work: several weeks

➔ Remote handling system

Condition: 20 min. work, 2 mSv/h at 1m

Simpler system than other facilities

- Crane system
- Specialized working tools
- Preparation of storage space

Higher power(～100 kW) facility

ISAC target module at TRIUMF

G. Minor et al., Nuclear Engineering and Technology 53 (2021) 1378

Target operation

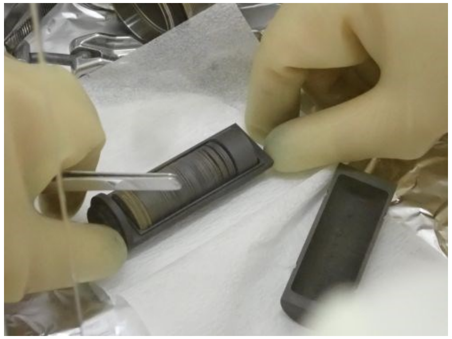
Uranium carbide → Carbon nano material

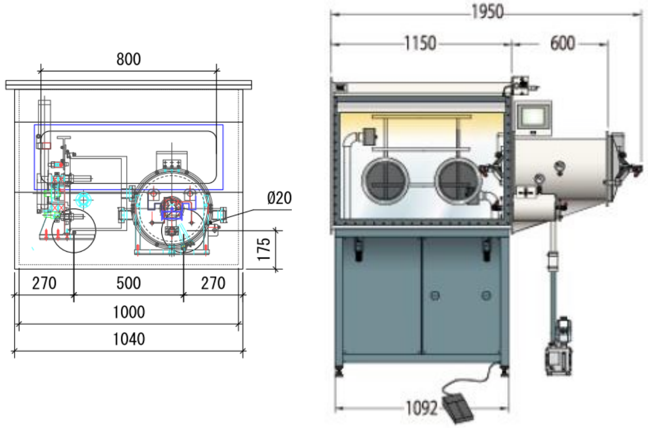
Fast release, Long lifetime A. Gottberg, NIMB 376 (2016) 8

Problem: Easily oxidization in the air

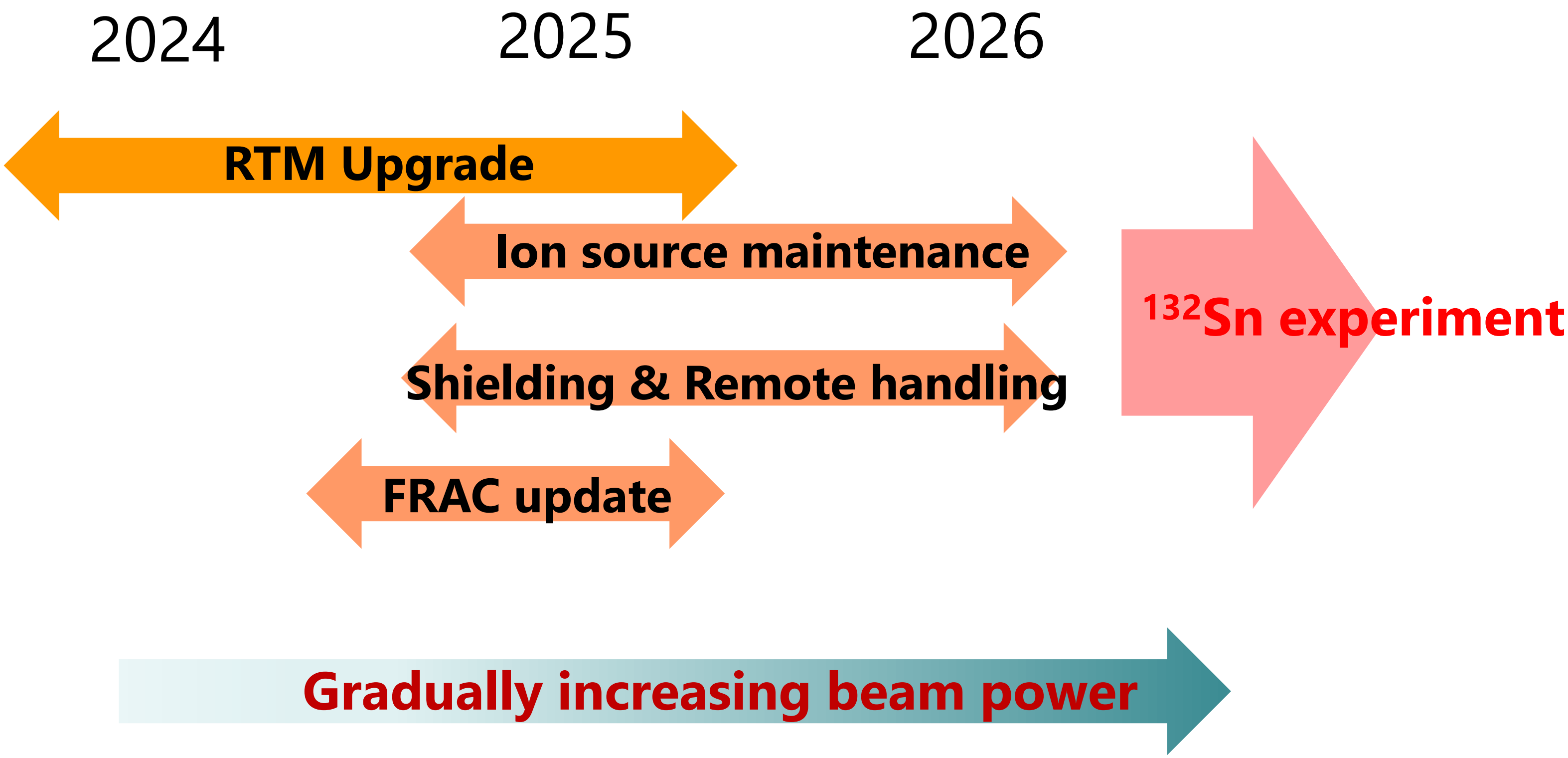
Uranium carbide with graphene
→ Oxidization began within a minute of being released in the air.

Present: Small glove box (only target) ➔ Large glove box (Ion source)





Time schedule



Measurements are conducted and responded to on a case-by-case basis.

Summary

- ERIS at the SCRIT electron scattering facility was constructed and the development has been continued.
- The world's first electron scattering with online-produced RI was successfully conducted.
- The upgrade for high intensity RI beam has been already started.

Electron scattering with ^{132}Sn will be performed soon.

For high power e-beam operation, global collaboration with other ISOL facilities is very important.

SCRIT collaboration

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

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Thank you for your attention!