Electron-RI scattering at SCRIT and ARIEL

ARIEL Science Workshop 2026, Vancouver, Canada, April. 22, 2026

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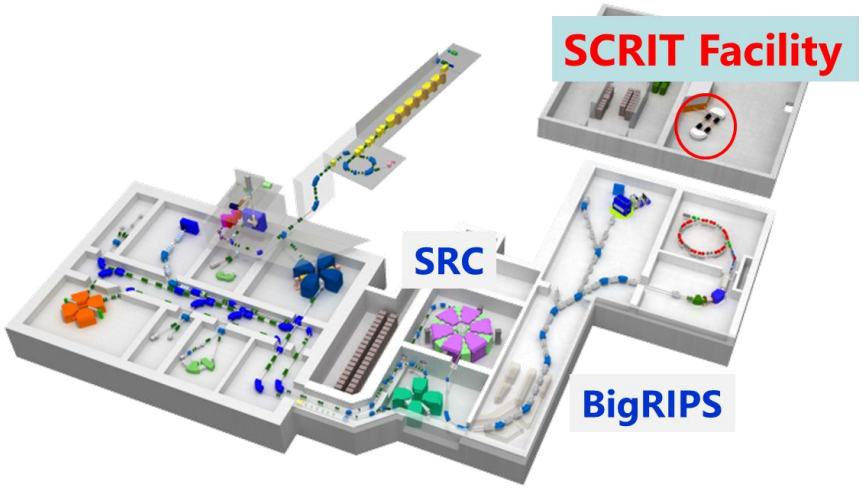
RIKEN RI Beam Factory



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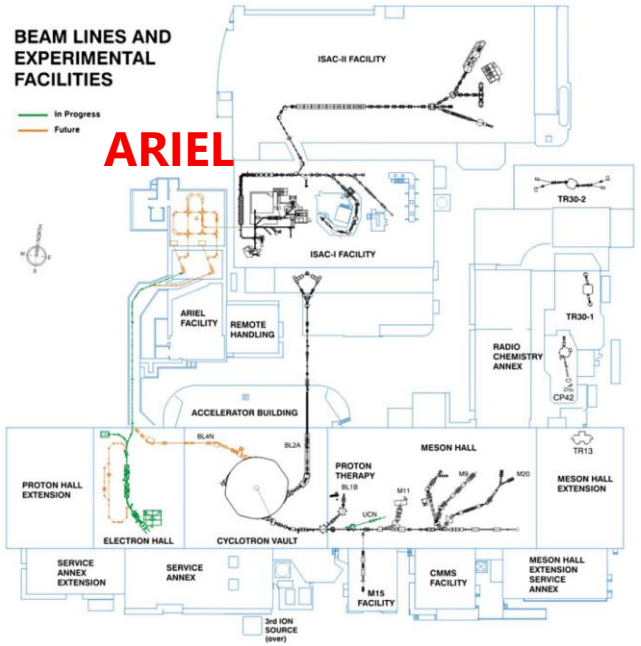


J. Dilling et al., Hyperfine Interact (2014) 225:253-262

1. Introduction
2. e-RI scattering at SCRIT
3. e-RI scattering at ARIEL
4. Summary

1. Introduction

Electron scattering

Powerful tool to study the internal structure of nuclei

Well known interaction (Coulomb interaction)

Structure-less probe

No serious modification of nucleus

How realize e-RI scattering?

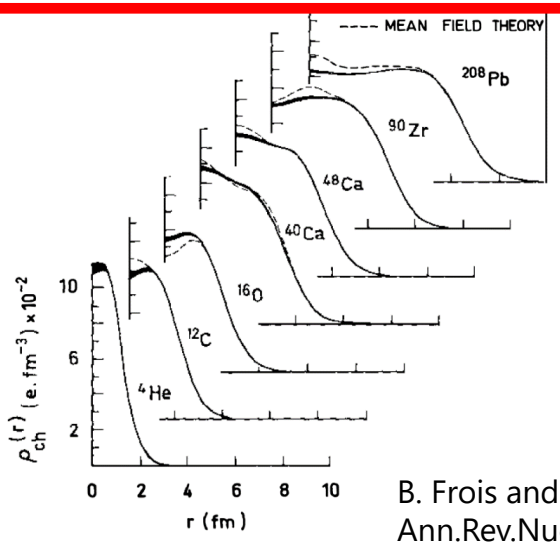
Elastic electron

= Mott scattering × Form factor

→ Charge density distribution

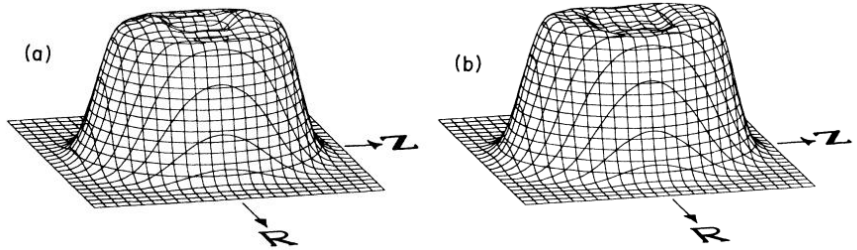
Inelastic electron scattering

= Various excitation modes etc....



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

Deformation

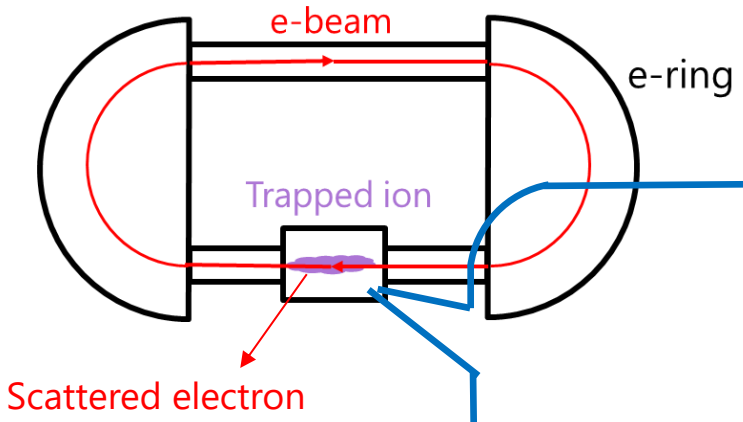


F. W. Hersman et al., Phys. Rev. C33 (1986) 1905.

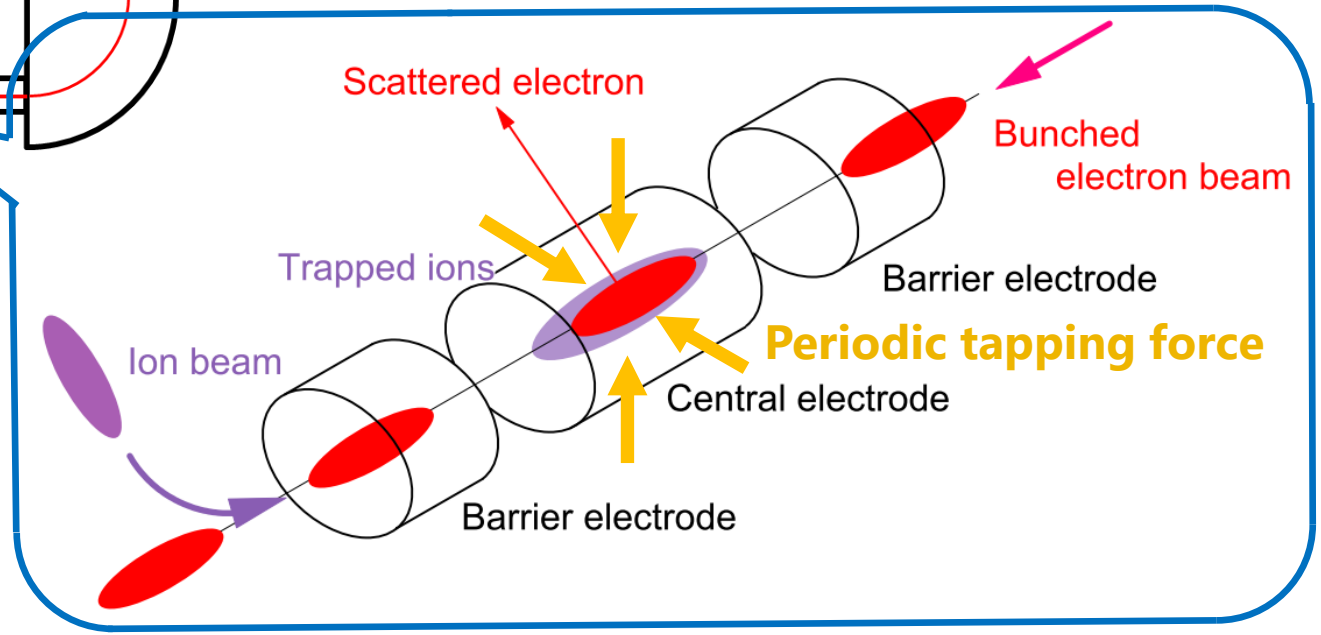
SCRIT(Self Confining RI Ion Target) method

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

Novel target forming method to realize e-RI scattering



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



Typical values

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

e-beam

current～200 mA

size ～mm^2

10^8 ions/pulse

→ 10^9 cm^{-2}

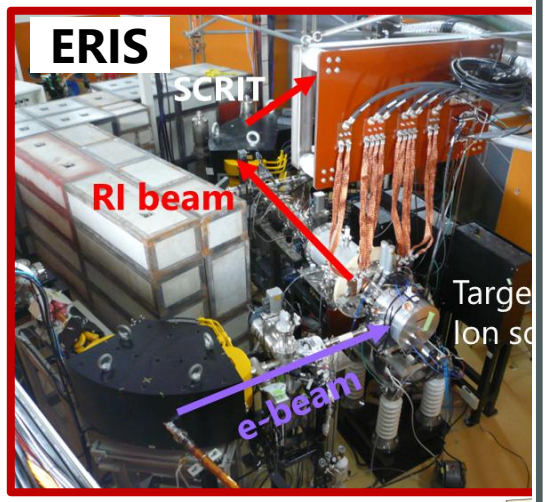
Automatic electron scattering with trapped ions

2. e-RI scattering at SCRIT facility

^{137}Cs(e,e'): World

online-produced RI

al., Phys. Rev. Lett. 131, 092502 (2023)

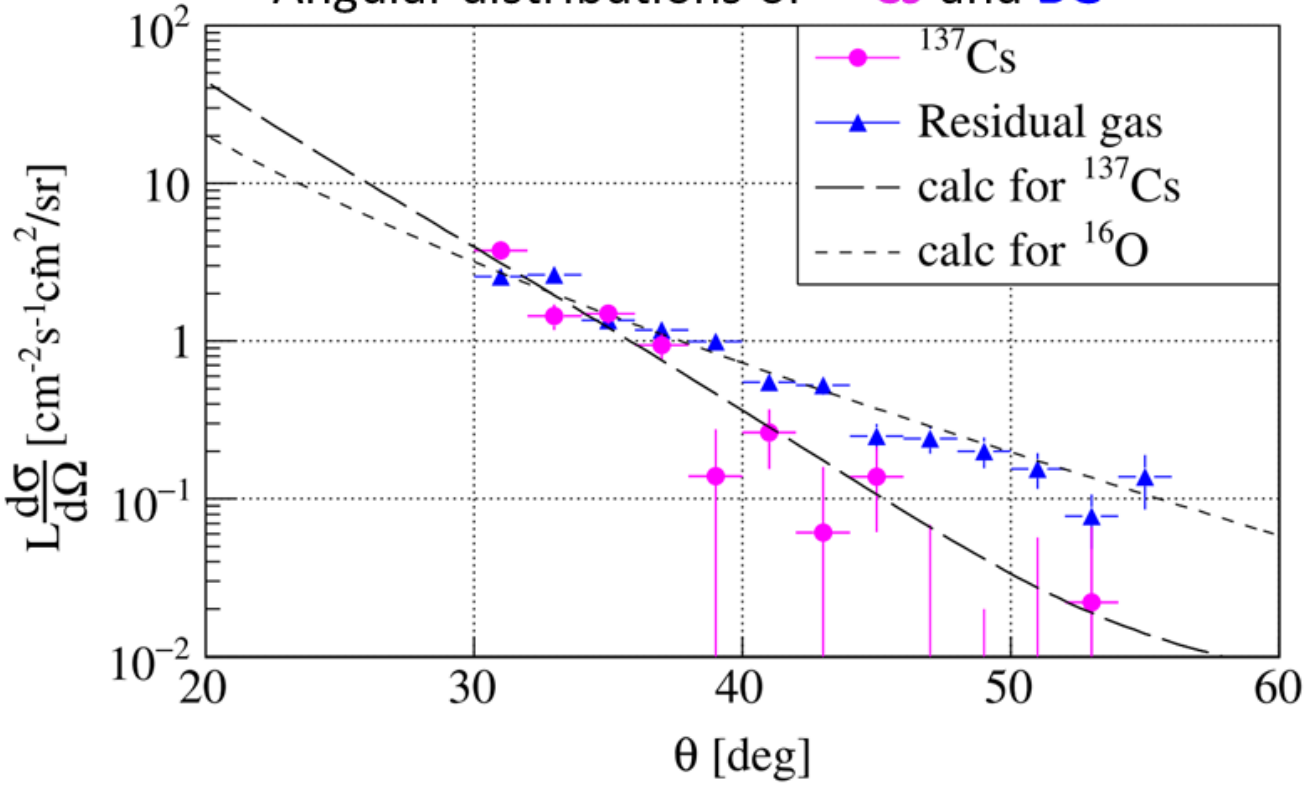


RTM: e-driv

WiSES

WiSES condition
$\Delta\Omega$: 80 mSr
θ : 30 – 60 deg
$\delta p/p$: 1 – 4x10^{-3}

: 150 MeV
150-200 mA

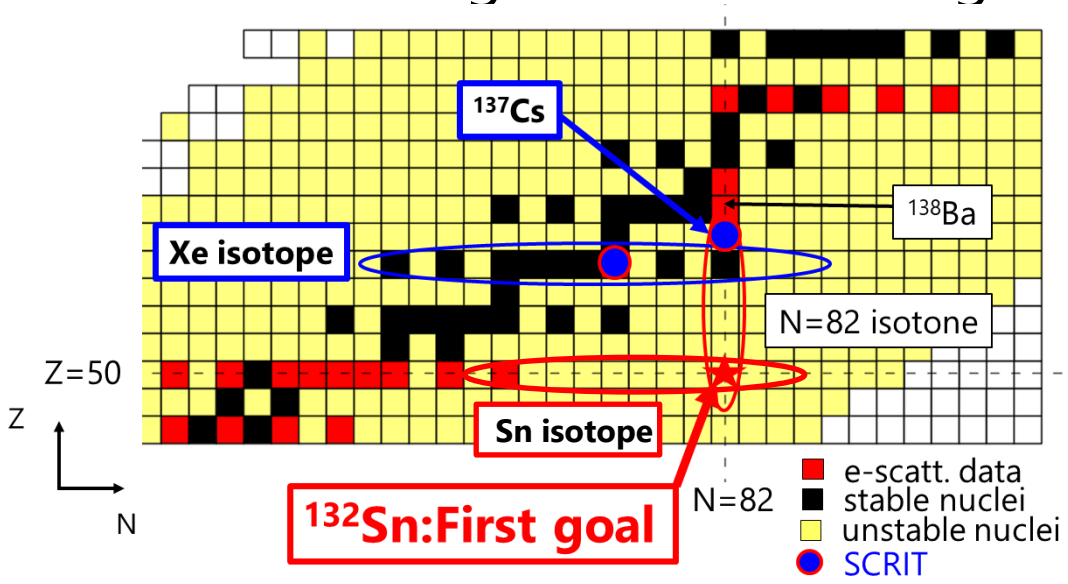


Luminosities: 0.9×10^{26} cm^{-2}s^{-1} for ^{137}Cs
1.5×10^{27} cm^{-2}s^{-1} for BG

Total measurement time: 3 days

Next program and future plan at SCRIT facility

Electron scattering around ^{132}Sn region



Upgrade plans

- ☐ Improvement of e-beam stability
- ☐ Optimization of SCRIT system
- ☐ Development of isobar separator
- ☐ Upgrade of e-beam driver (→2kW)

> 10^{27}/cm^2/s luminosity
> with short-lived unstable nuclei

Future plan

Limit of luminosity

Luminosity [/cm^2/s]

10^{27} | 10^{29} | 10^{31}

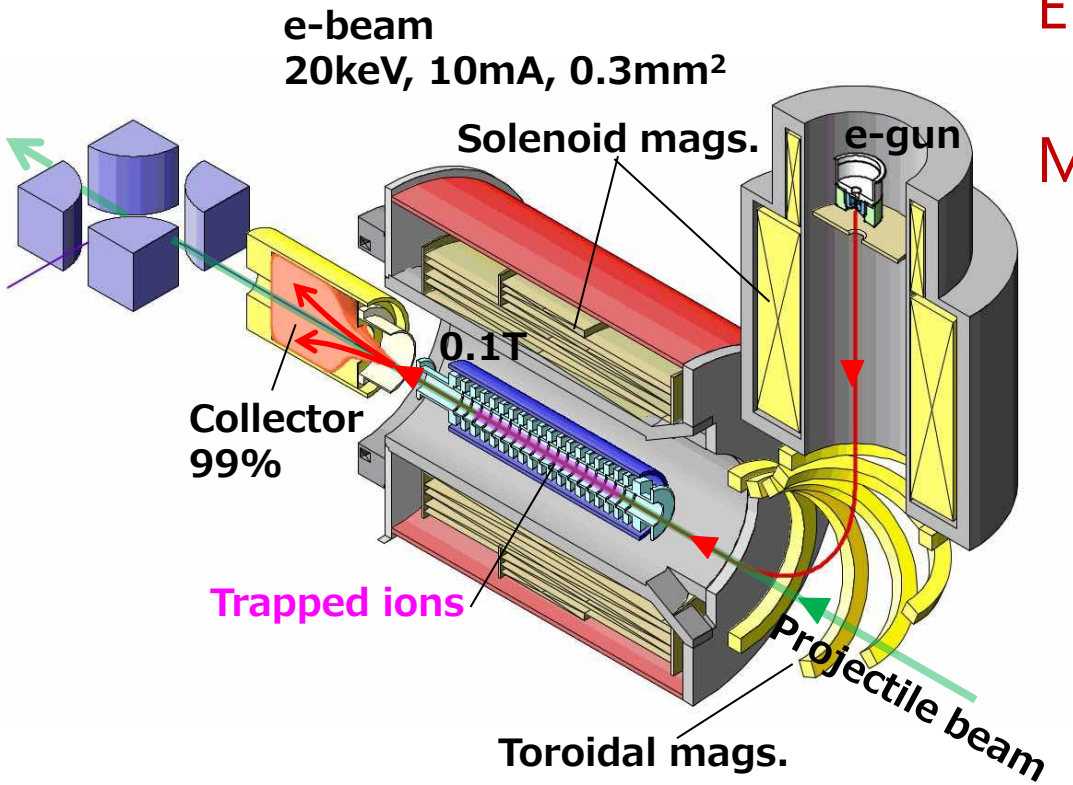
Elastic scattering
(charge density distribution)
→ Systematic study

Inelastic scattering
→ Photo absorption

Various reaction
→ (e,p), (e,pγ) reactions

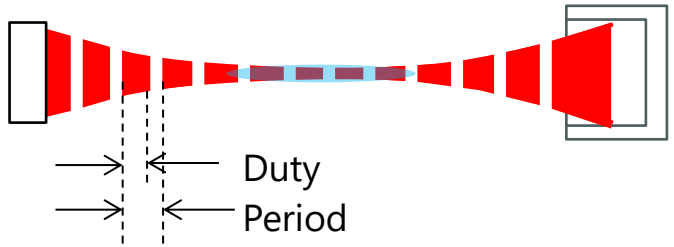
Space charge limit, Lifetime of e-beam

Next generation SCRIT target



EBIT based ion trapping: Separating roles of e-beam
(Trapping and Scattering)

Modulated electron beam: SCRIT type trapping



Instability control via periodic conditions

1) Control of max q/A
→ Suppression of residual gas ion
Increasing of number of trapped ions

2) Instability of highly charged ions = Large space distribution
→ Slowing down the charge state increasing

Goal: 10^{11}/cm² (100 × present SCRIT)

General-purpose target: Application of experimental methods used on stable nuclei

The prototype is currently under development at ICR, Kyoto University.

3. e-RI scattering at ARIEL facility

Importance of electron scattering using low-energy e-beam

Update of electron scattering data with precise measurement

Low statics data → Difficulty of the comparison with modern nuclear theory (DFT)

New data of electron scattering with unstable nuclei

New information of nuclear structure → Example: 4^{th} order moment measurement

Advantages at ARIEL

- Various high-intensity RI beam

  High-power proton and electron beams→ Fission, Spattering, and other reactions

- High intensity continuous electron beam

  30 MeV, 10 mA → 50 MeV 10 mA (future)

Electron beam (LINAC) + NextGen SCRIT target

4th-order moment measurement to study neutron distribution

H. Kurasawa and T. Suzuki, Prog. Theor. Exp. Phys. 2019, 113D01.

$$\langle r_C^4 \rangle = \int r^4 \rho_C(r)\, dr^3 = \langle r^4_{p(point)} \rangle + \frac{10}{3}\langle r^2_{p(point)} \rangle \langle r_p^2 \rangle + \frac{10}{3}\langle r^2_{n(point)} \rangle \langle r_n^2 \rangle \frac{N}{Z} + \text{relativistic corr.}$$

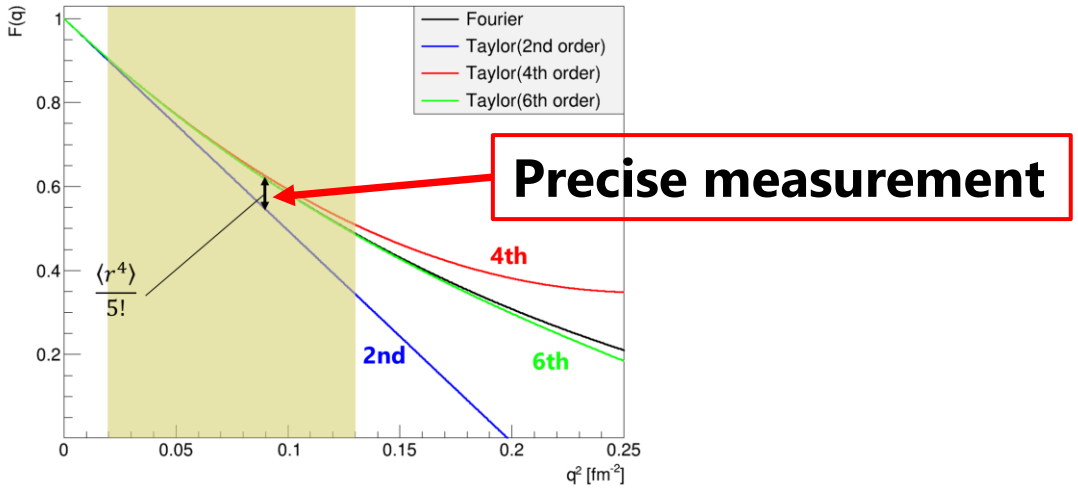
proton radius — neutron radius

Point proton radius — Point neutron radius

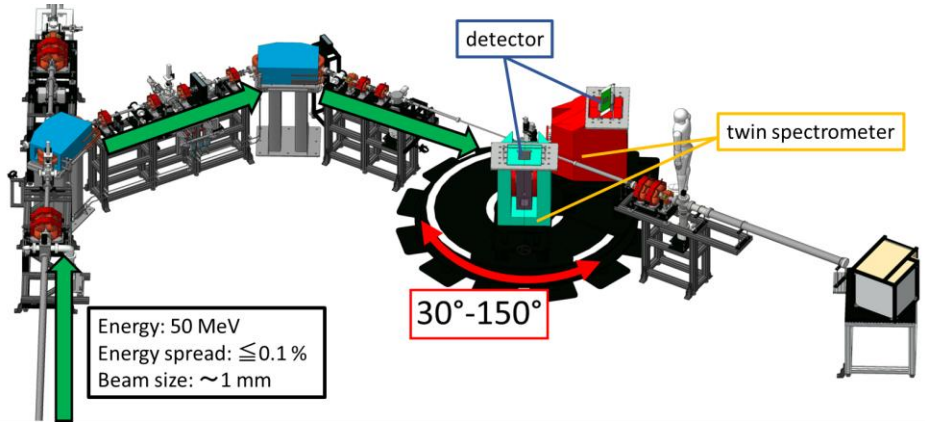
Precise measurement at low momentum transfer region

Low-q region

$$F(q) \sim 1 - \frac{\langle r_C^2 \rangle}{3!} q^2 + \frac{\langle r_C^4 \rangle}{5!} q^4 - \cancel{\frac{\langle r_C^6 \rangle}{7!} q^6 + \cdots} \quad \text{(PWIA)}$$



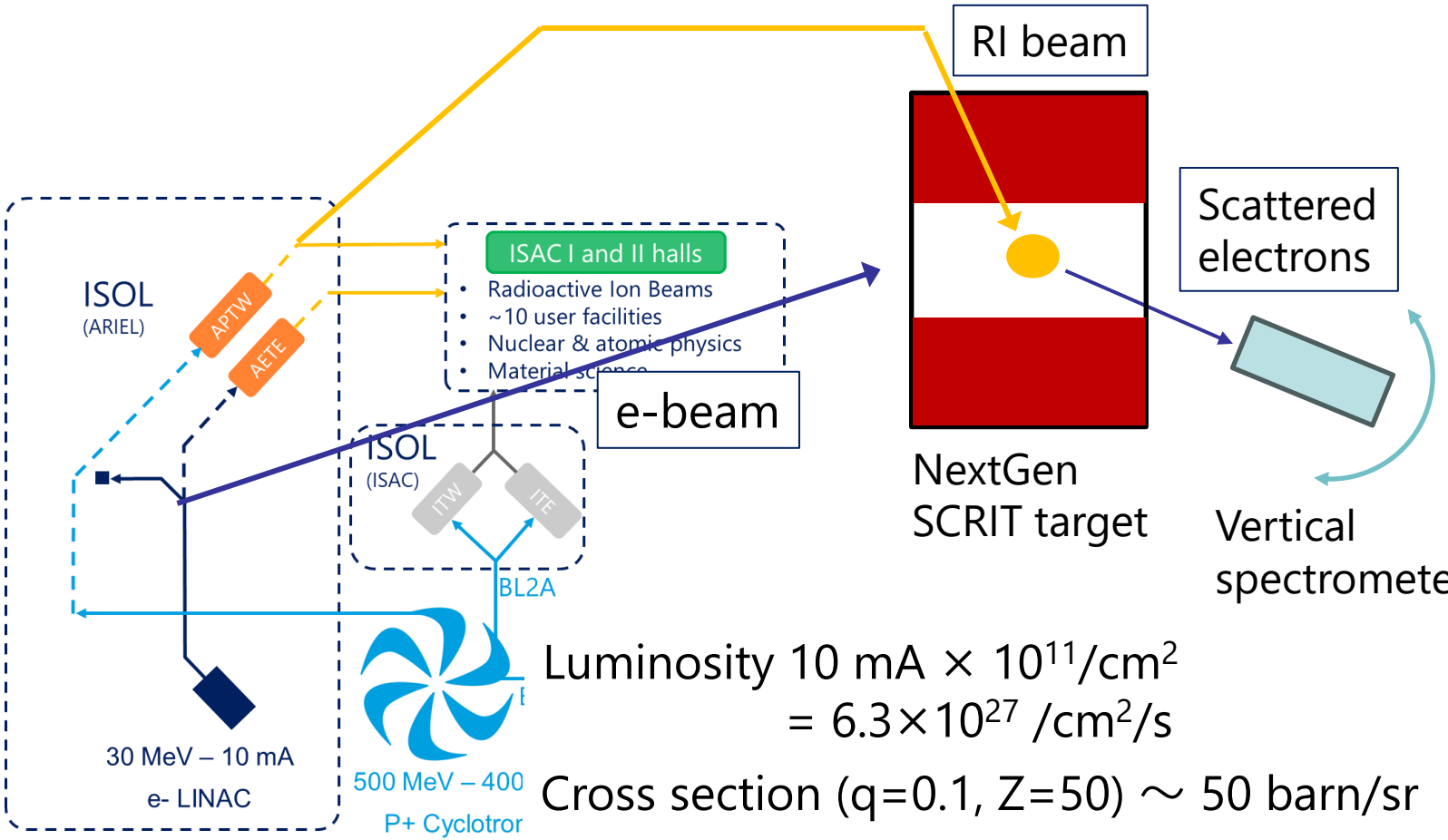
LEEP (Low Energy Electron scattering with ^{208}Pb) experiment at RARiS, Tohoku Univ.



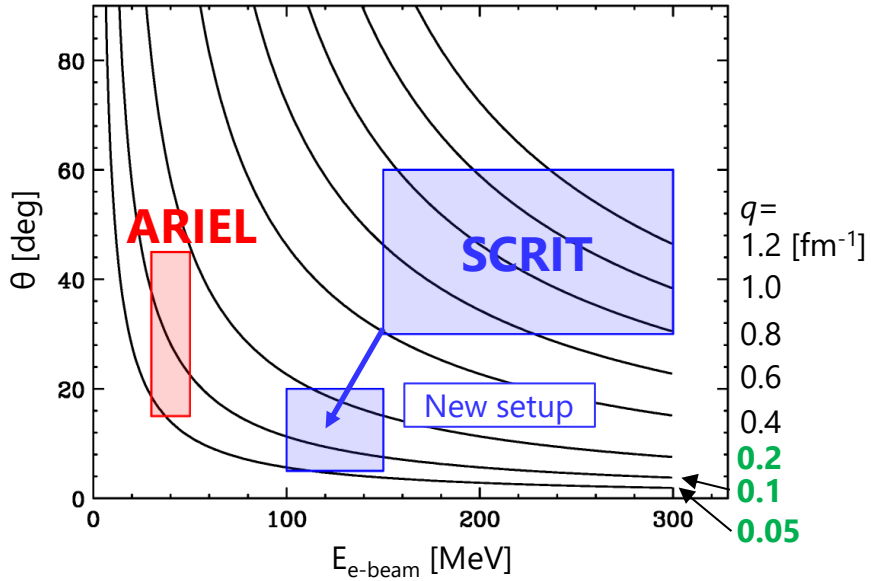
Energy ~ 50 MeV, 4.4mSr

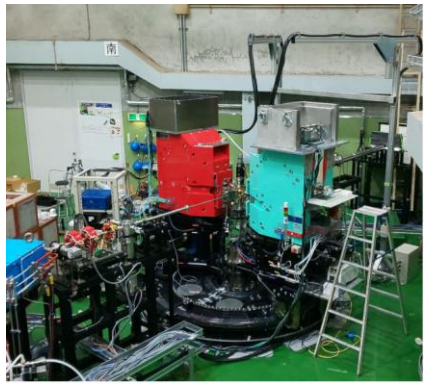
Low Energy Electron scattering with RI (LEER) experiment

- Large cross section at small q ($1/q^4$) → Suitable for RI
- More feasible setup compared with storage ring



Energy vs Scattering angle





Solid angle
(LEEP)
4.4 msr

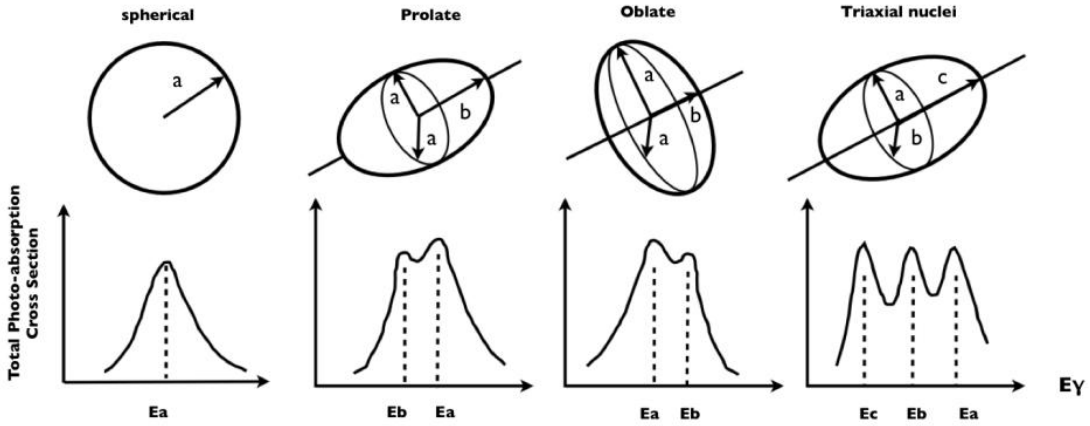
Luminosity 10 mA × 10^{11}/cm^2
= 6.3×10^{27} /cm^2/s

Cross section (q=0.1, Z=50) ∼ 50 barn/sr

→ Event rate: 1500 events/sec

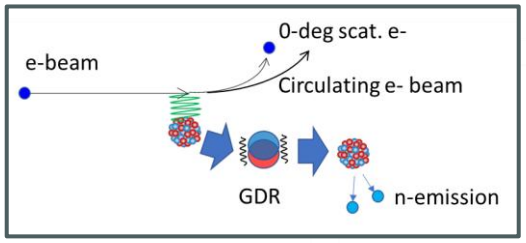
Photo-absorption total cross section

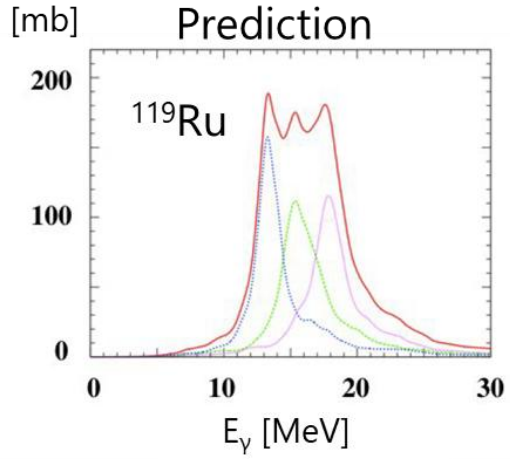
T. Suda and H. Simon, Prog. Part. Nucl. Phys. 96(2017) 1.
T. Suda, Handbook of Nuclear Physics, Springer 2023, 1591.



0-deg e-scattering + Virtual photon theory

- Measurement with purely electro-magnetic probe at high flux GDR region
- This method has been established using stable nuclei.





Number of virtual photon at Z∼50, E_γ∼15 MeV,

∼ 0.01 at E_e=27 MeV

c.f 10^{-3} at E_e=150MeV

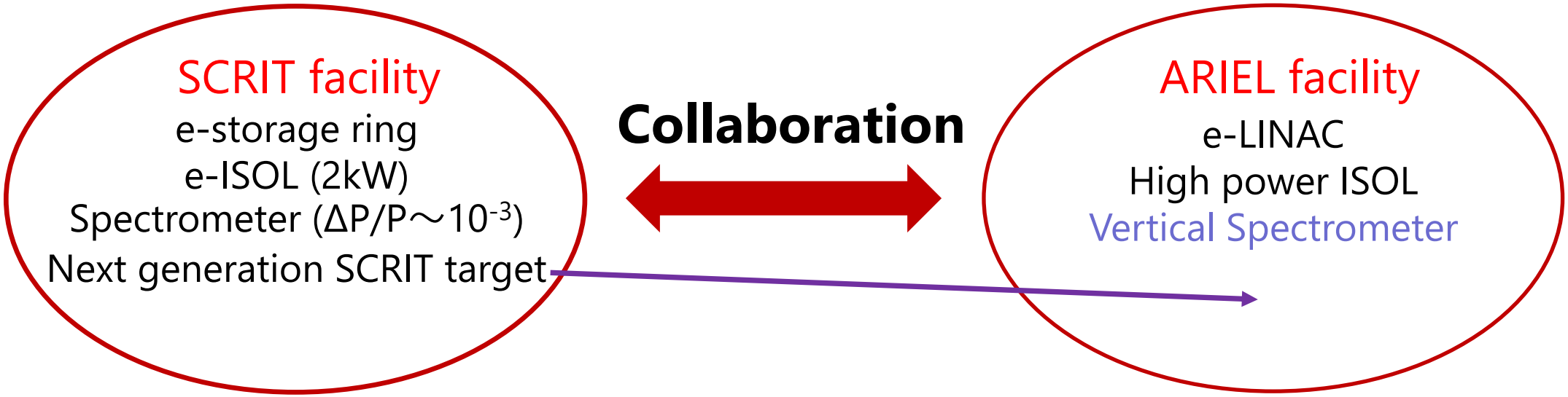
200 mb×0.01/MeV×10^{27} $cm^{-2}s^{-1}$

= 2 counts/MeV/sec

4. Summary

SCRIT facility: World's first electron-RI scattering was successfully performed.
Upgrade projects are already started.

ARIEL facility: Possibility of electron-RI scattering using NextGen SCRIT target.
Nuclear spectroscopy with various unstable nuclei is expected.



SCRIT collaboration

D. Abe[1], Y. Abe[2], T. Akimoto[3], 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],R. Kagami[4], Y. Kikuchi[5], H. Kobayashi[4], K. Kurita[3], C. Legris[1], Y. Maeda[4], Y. Maehara[4], H. Matsubara[3], R. Obara[1], R. Ogawara[2] , T. Ohnishi[2], R. Otake[4], H. Shimobeppu[3], T. Suda[1,2] , M. Tachibana[4], T. Tamae[1], R. Teraguchi[3], H. Tonguu[4], K. Tsukada[2,4], K. Ueno[3], M. Wakasugi[2,4], M. Watanabe[2], H. Wauke[1,2] , T. Yamaguchi[5], T. Yamano[3], S. Yoshida[4]

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Thank you for your attention!