SCRIT Electron Scattering Facility

- current status and future perspectives -

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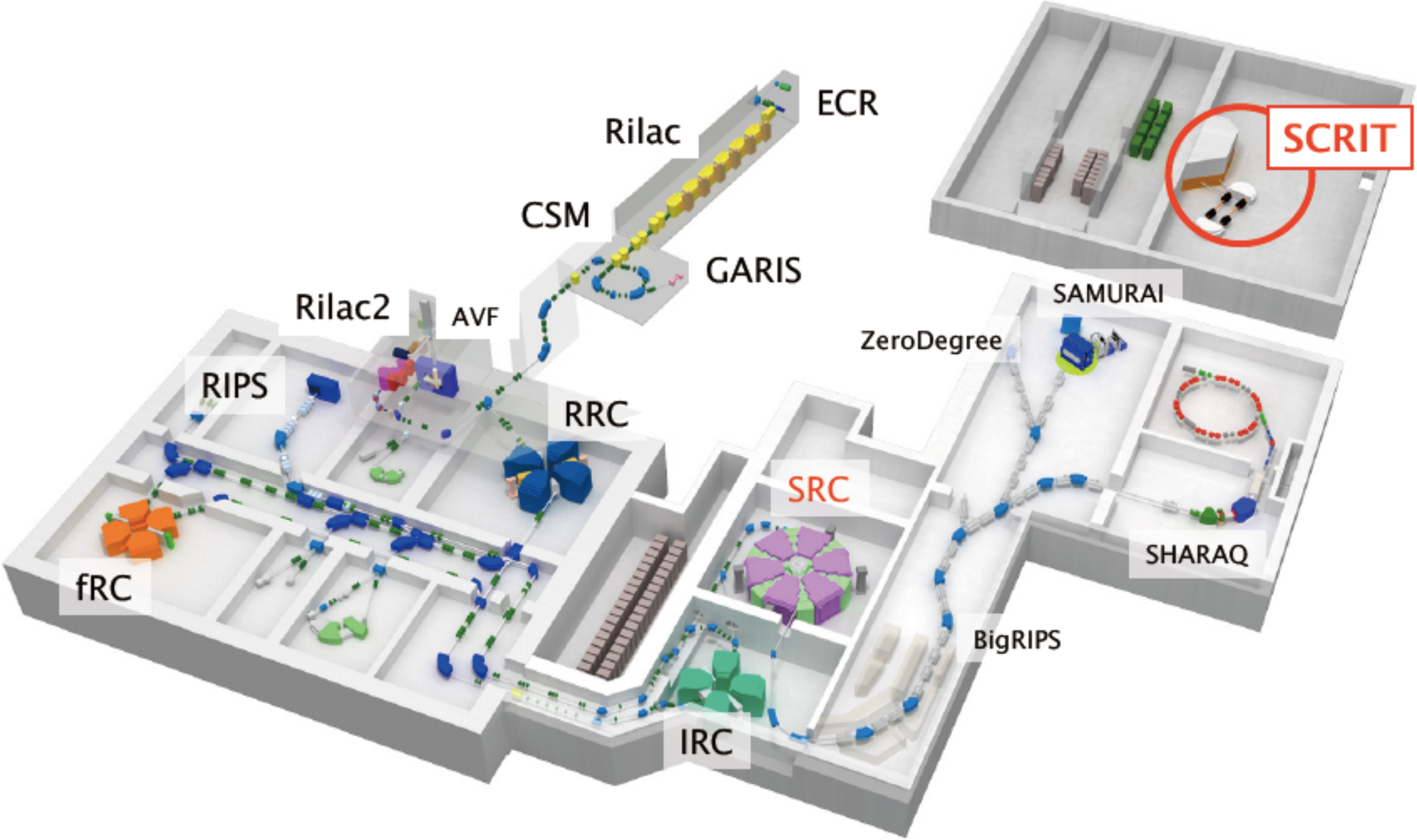
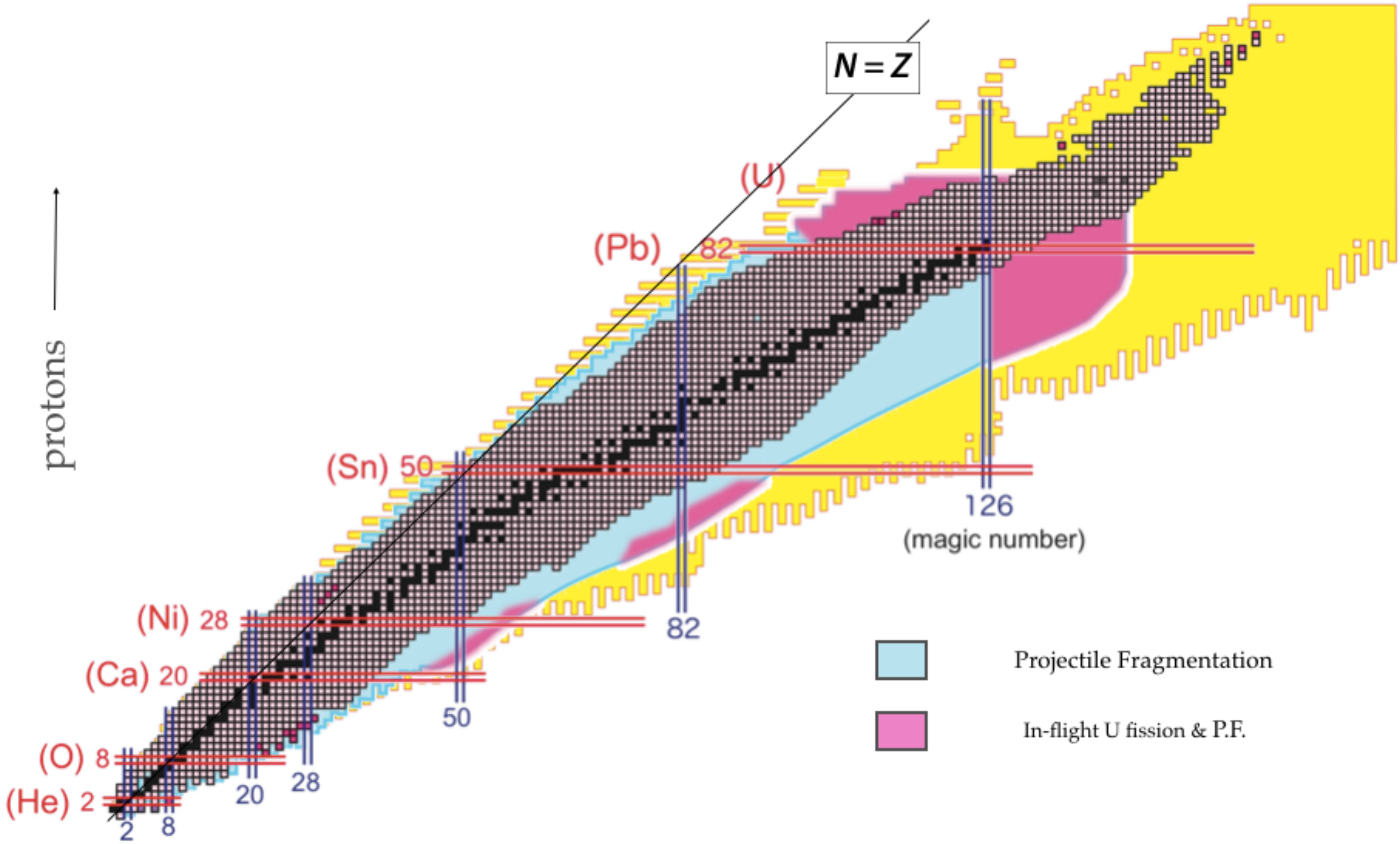
SCRIT electron scattering facility @ RIBF

World's first electron facility dedicated for exotic nuclei

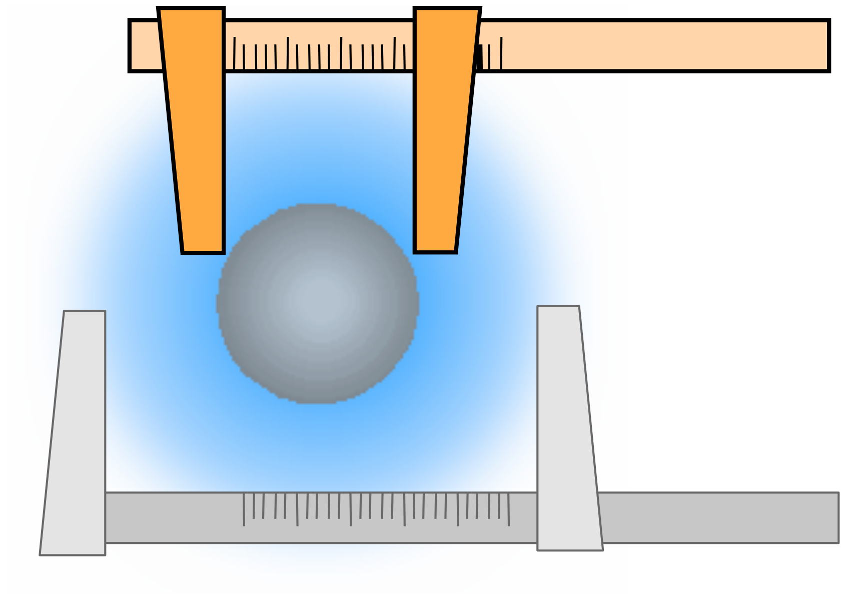


RIKEN RI Beam Factory (Japan)

Exotic nuclei accessible RIKEN RI Beam Factory



size and shape of neutro- and proton-rich nuclei



$$< r_c^2 >= \int r^2 \rho_c(r)\ d\vec{r}$$

$$\rho_c(\vec{r}) = \sum_p \psi^*(\vec{r})\psi(\vec{r})$$

	size	shape
proton	isotope shift	electron scattering
matter	reaction cross section	proton scattering

⇦ EM probe

⇦ Hadronic probe

(reaction mechanism ??)

SCRIT electron scattering facility

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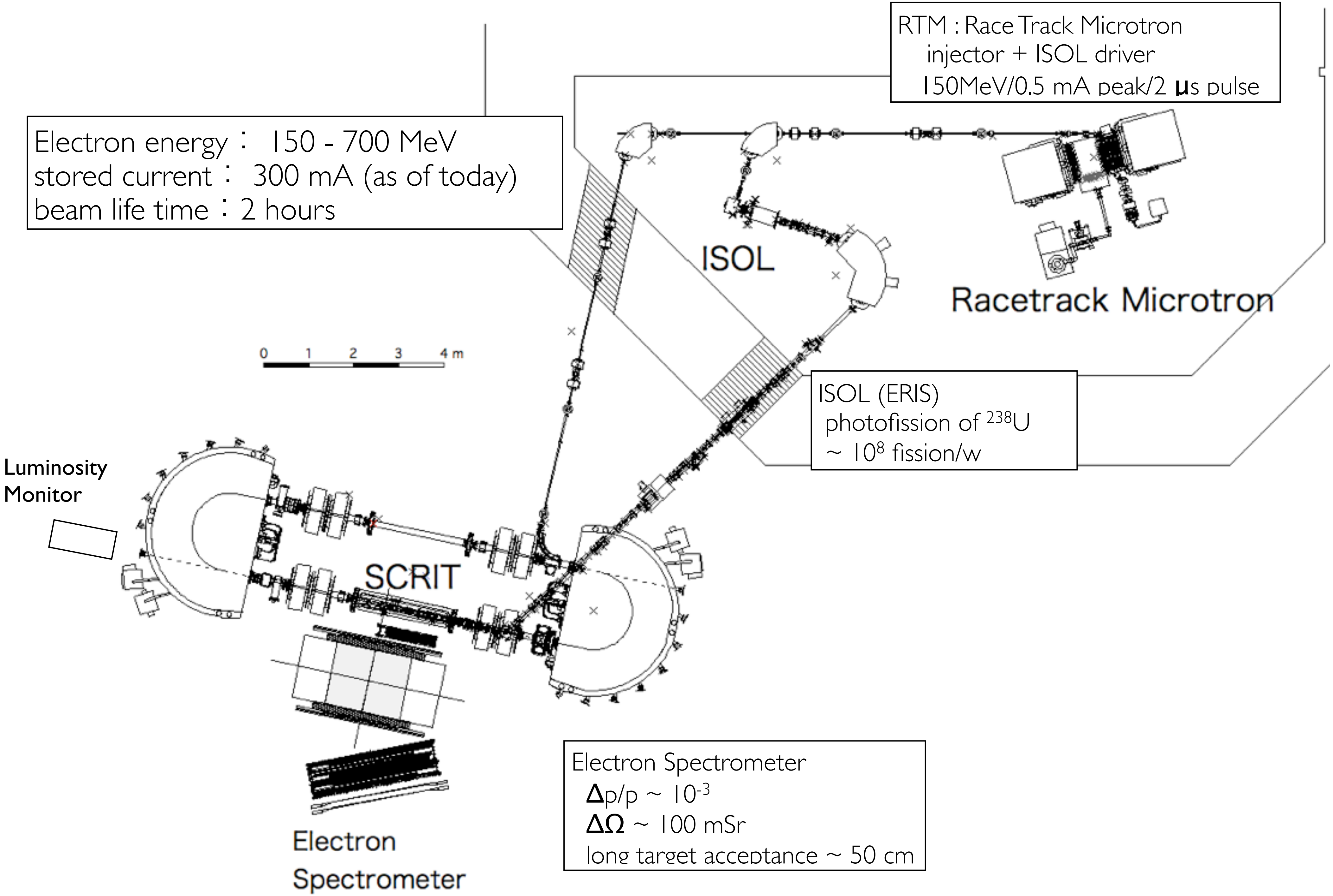
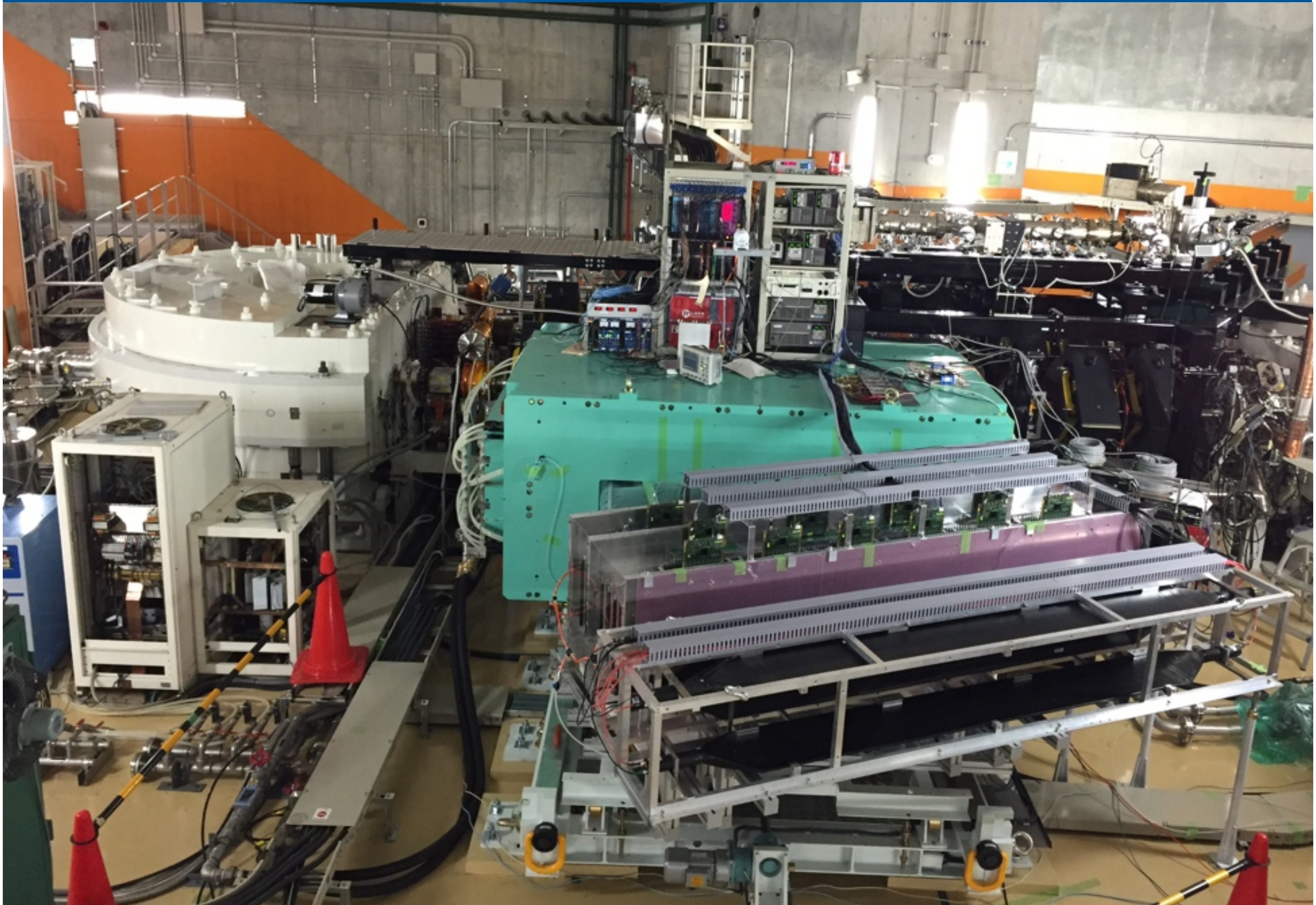


ISOL (ERIS)
photofission of ^{238}U
~ 10^8 fission/w

Electron Spectrometer
$\Delta p/p \sim 10^{-3}$
$\Delta\Omega \sim 100$ mSr
long target acceptance ~ 50 cm

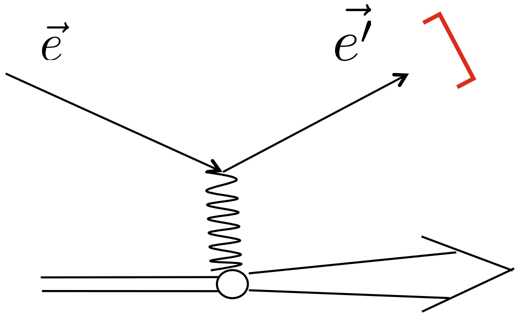
SCRIT Electron Scattering Facility



Electron scattering

Electron Scattering

Electron scattering provides direct and unambiguous structure information of atomic nuclei



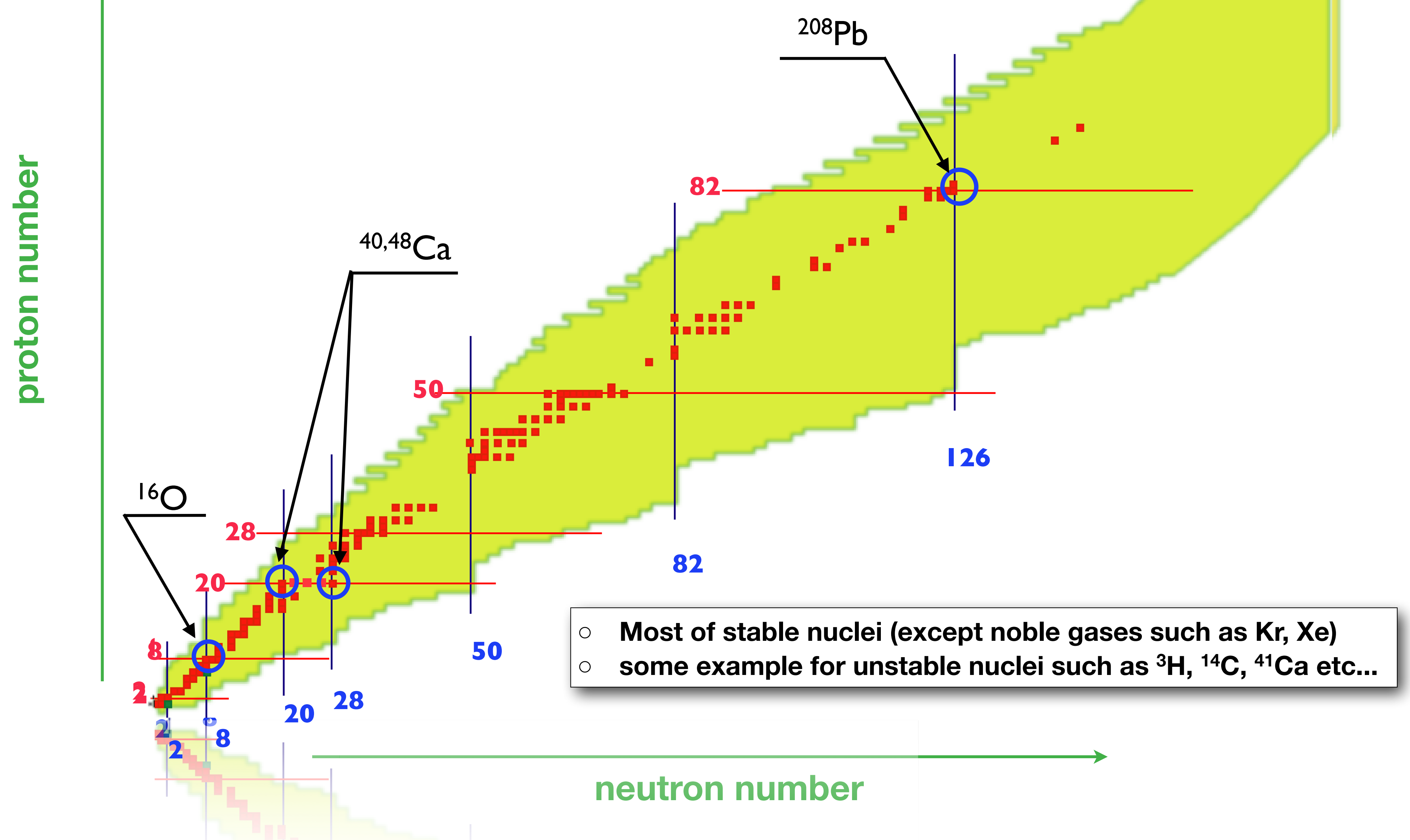
$$\omega = e - e'$$
$$\vec{q} = \vec{e} - \vec{e'}$$

1. *point particle*
2. *electromagnetic interaction*
   - *i) coupling : charge and current => el.mag. structure*
   - *ii) "weak" -> probing whole volume*
     perturbation theory
   - *iii) exp. data => structure information*
3. *variable q for fixed ω*

Nuclei studied by electron scattering

H.deVries, C. deJager and C. deVries
Atomic Data and Nuclear Data Tables 36 (987)495

- *strictly limited to stable nuclei*
- *never applied for exotic nuclei (short-lived)*



low production rate
short half lives ⇨ no “thick” target

expected low luminosity ⇨ elastic scattering (largest σ)

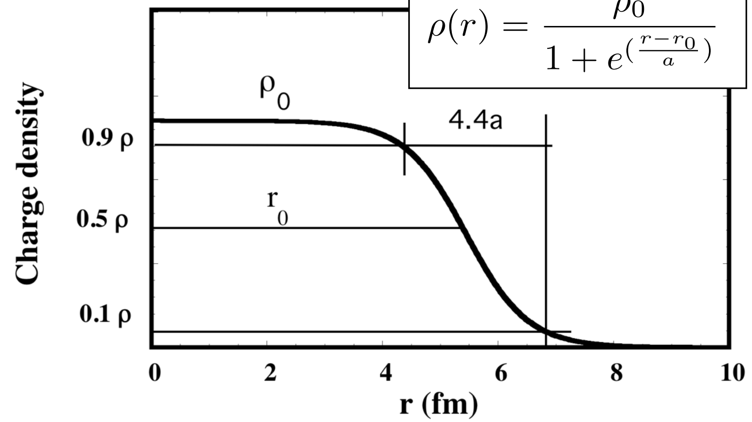
Elastic Scattering for spinless nuclei

PWIA

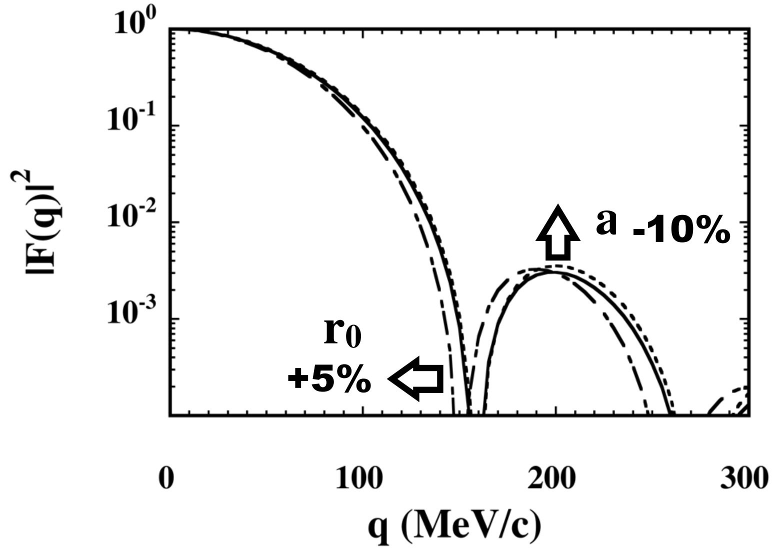
$$\frac{d\sigma}{d\Omega} = \frac{d\sigma_{\rm Mott}}{d\Omega}|F_c(q)|^2,$$

$$\frac{d\sigma_{\rm Mott}}{d\Omega} = \frac{z^2\alpha^2}{4e^2}\frac{\cos^2\theta}{\sin^4\theta}.$$

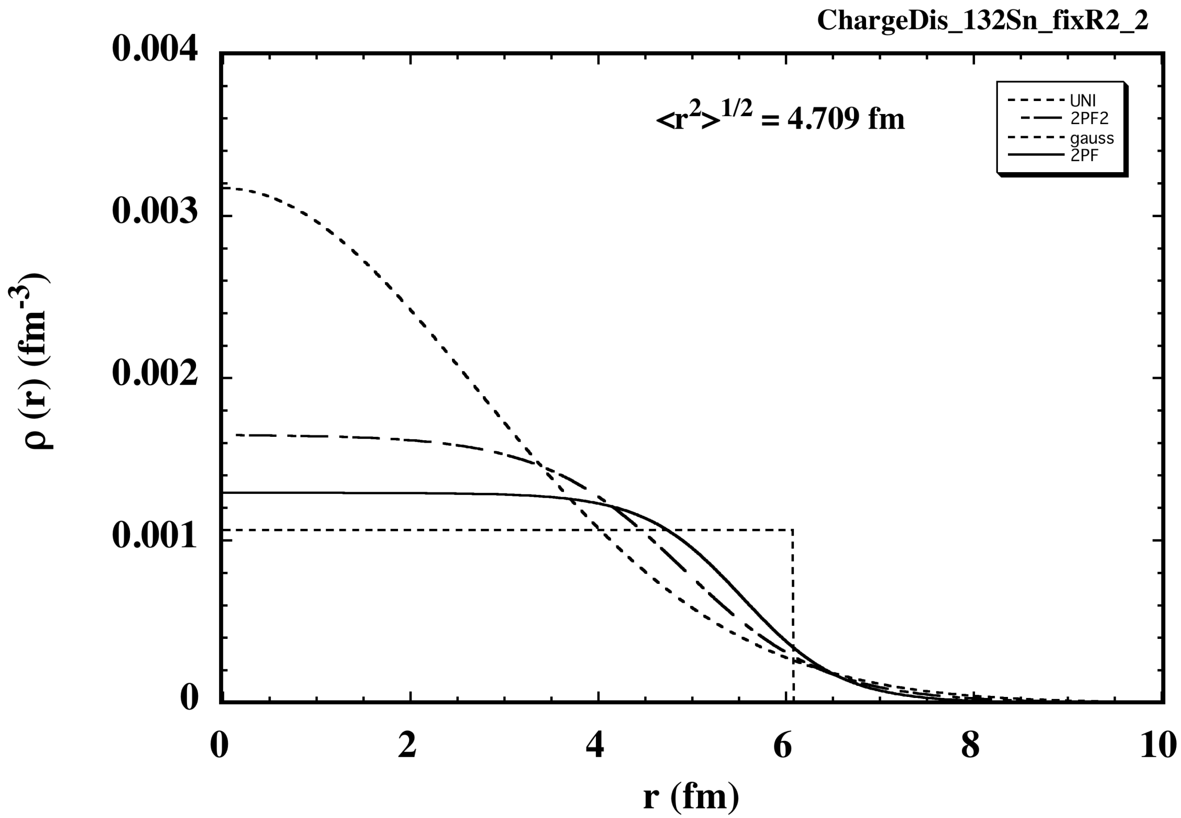
$$F_c(q) = \int \rho_c(\vec{r})e^{i\vec{q}\vec{r}}d\vec{r}$$

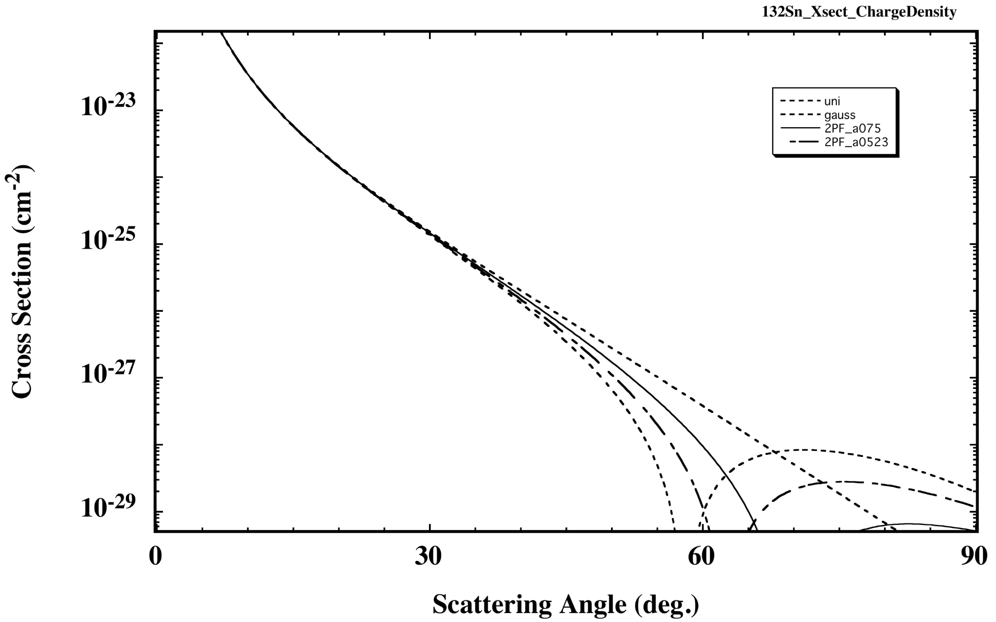


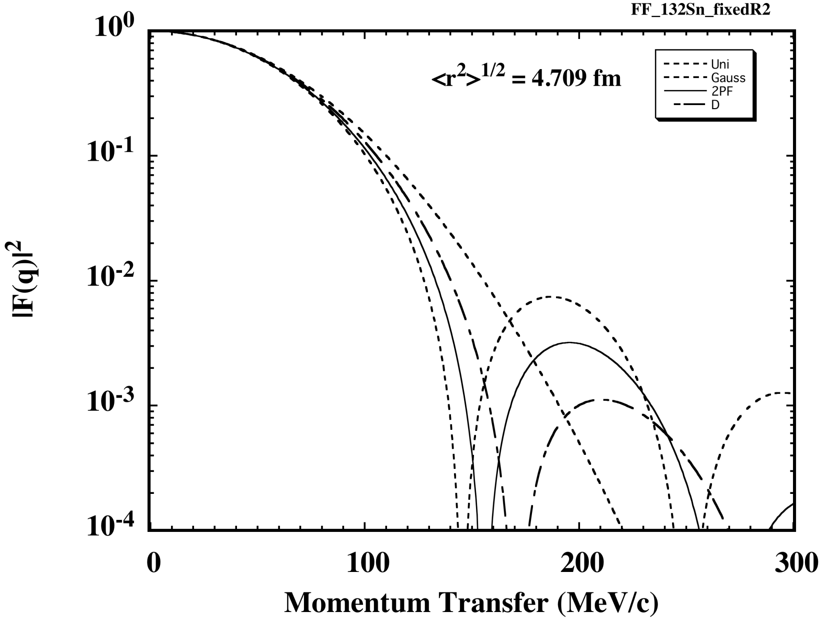
$$\rho(r) = \frac{\rho_0}{1+e^{(\frac{r-r_0}{a})}}$$



Beyond charge radii (isotope shifts)





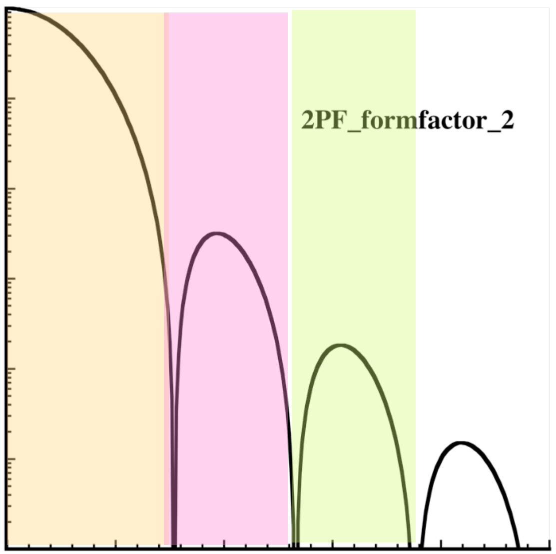


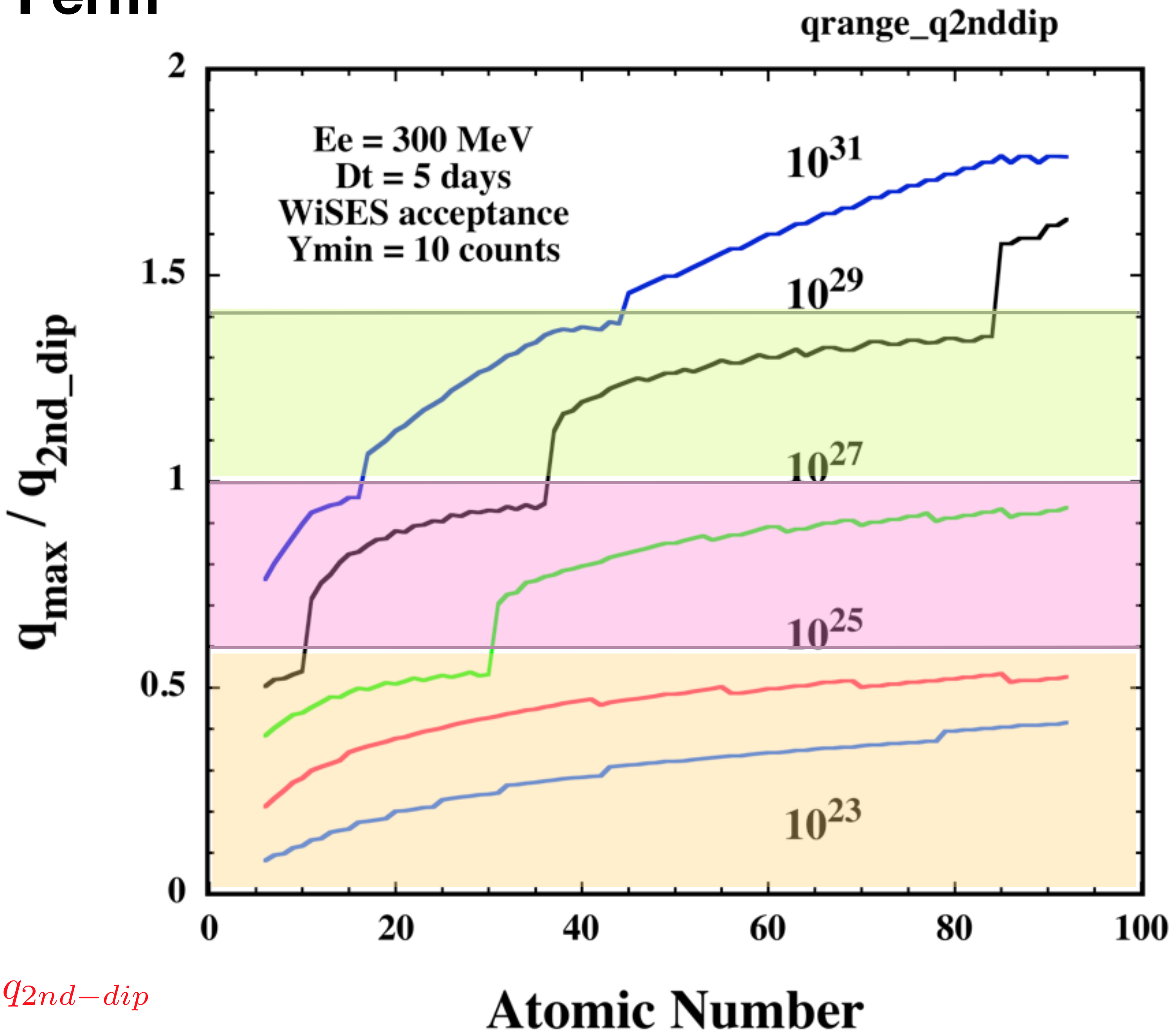
Accessible q-range for *L* and *Z*

ρ(r) : two-parm. Ferm

$$\sigma \propto Z^2$$

$$\sigma \propto 1/q^4$$





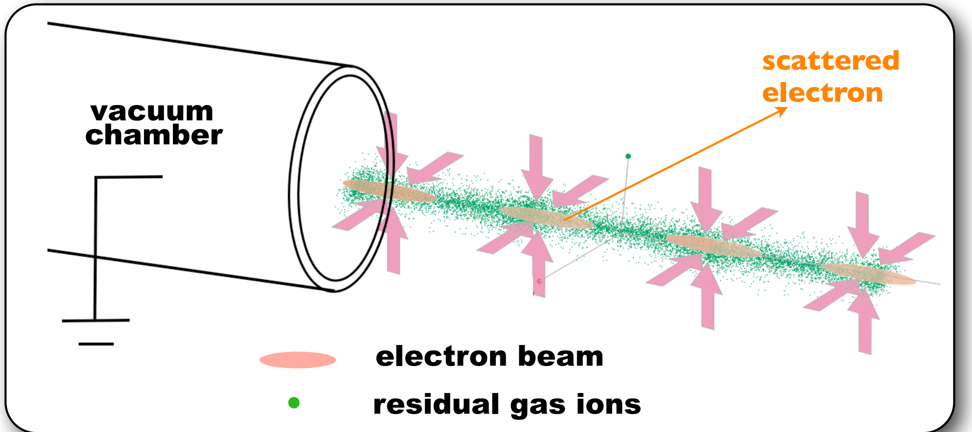
SCRIT electron scattering facility

what is SCRIT (Self-Confining RI Target) ??

Idea

Problematic ion trapping phenomena
@
electron storage ring

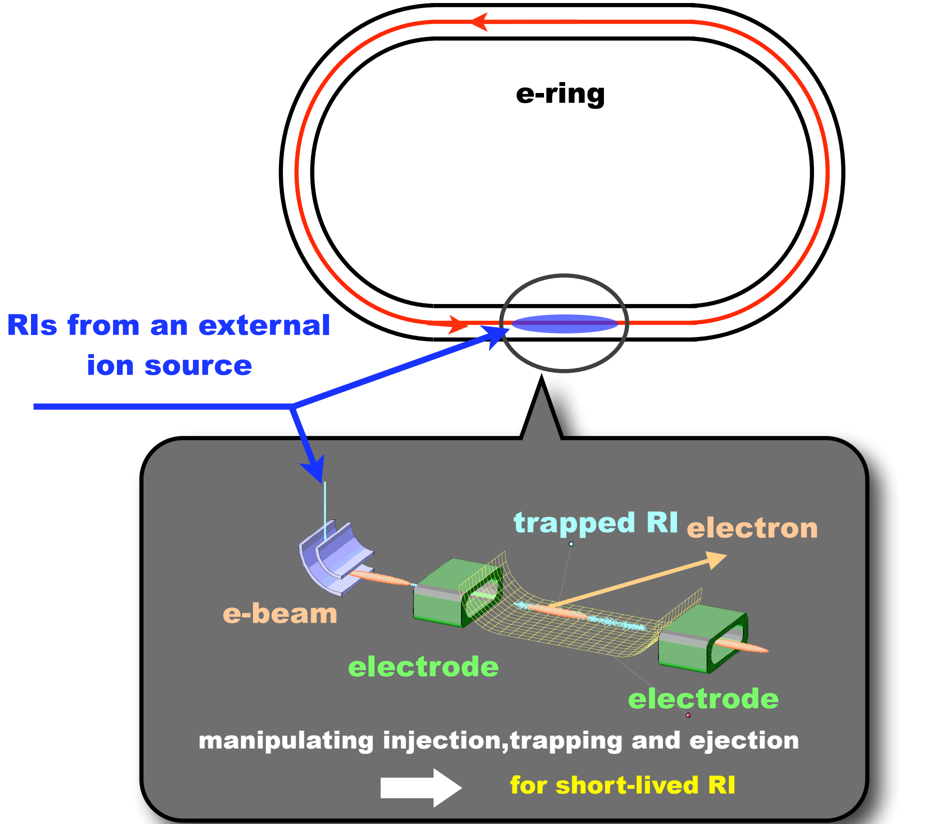
ionized residual gases are trapped
by the circulating electron beam



ill problem of e-storage ring

new ion trap for e-RI scattering

trapping RIs on electron beam
(automatic e-scattering off trapped RIs)



Nucl. Instrum. Methods A532 (2004) 216.
Phys. Rev. Lett. 100 (2008) 164801.
Pays. Rev. Lett. 102 (2009) 102501.

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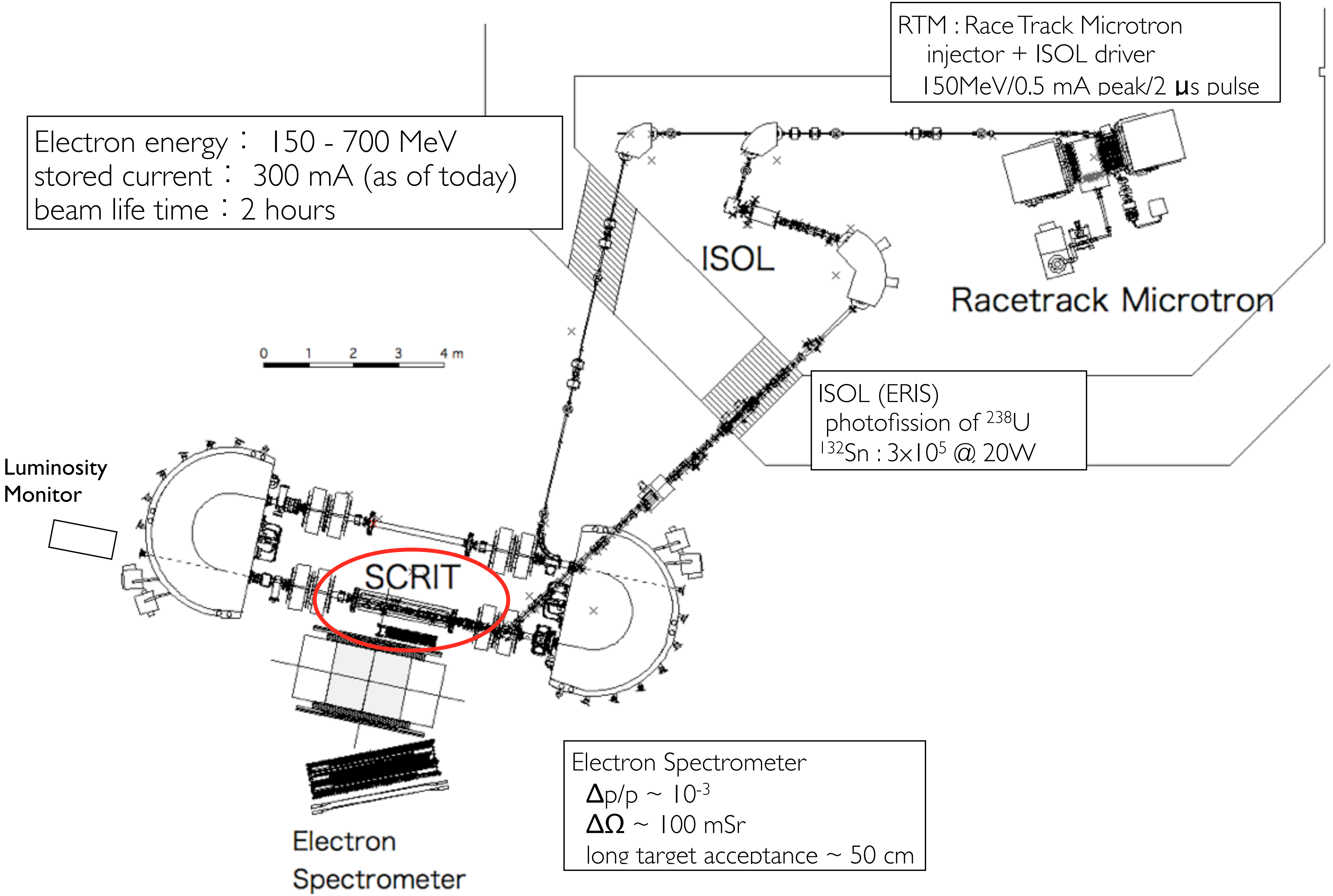
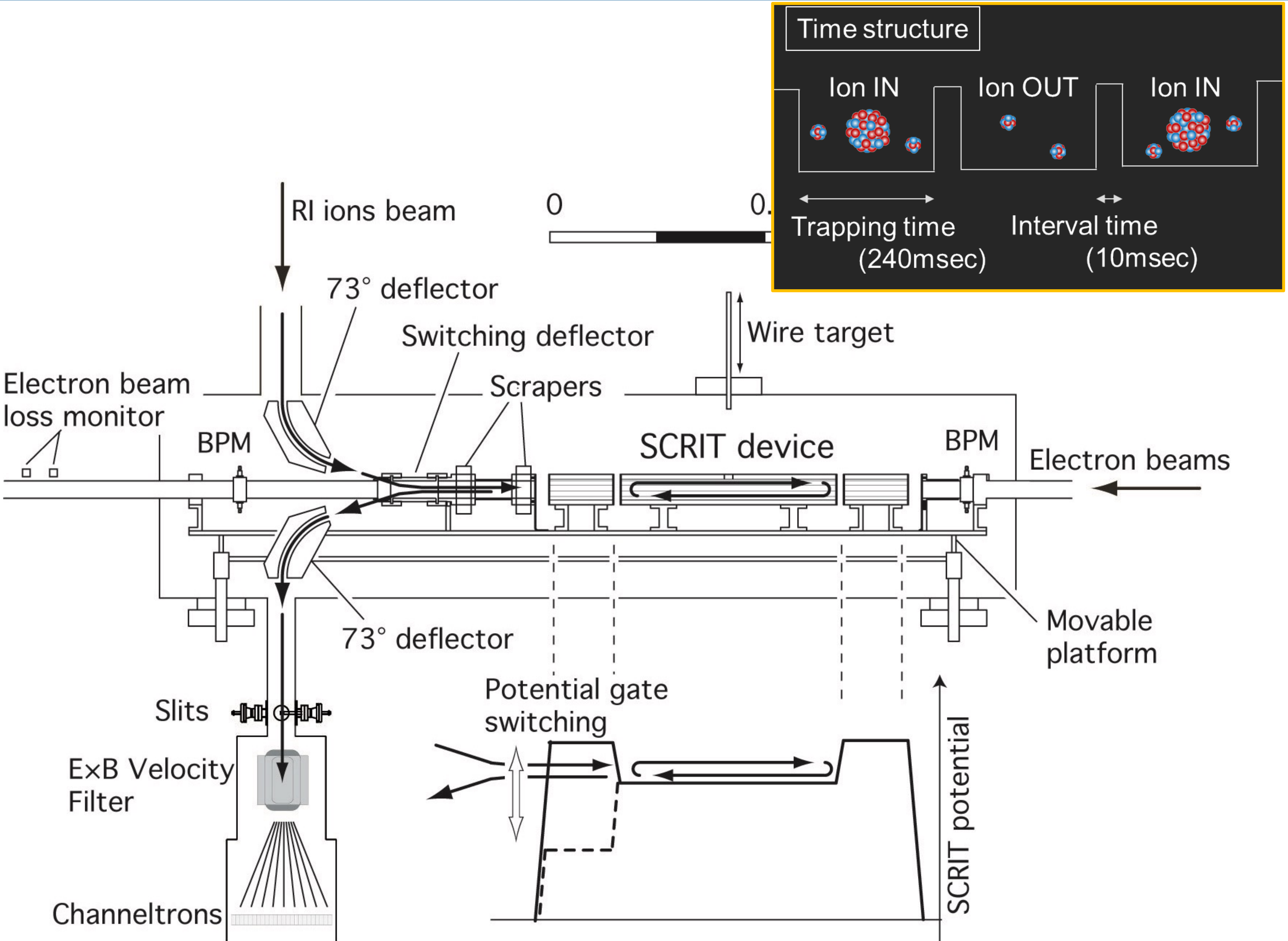
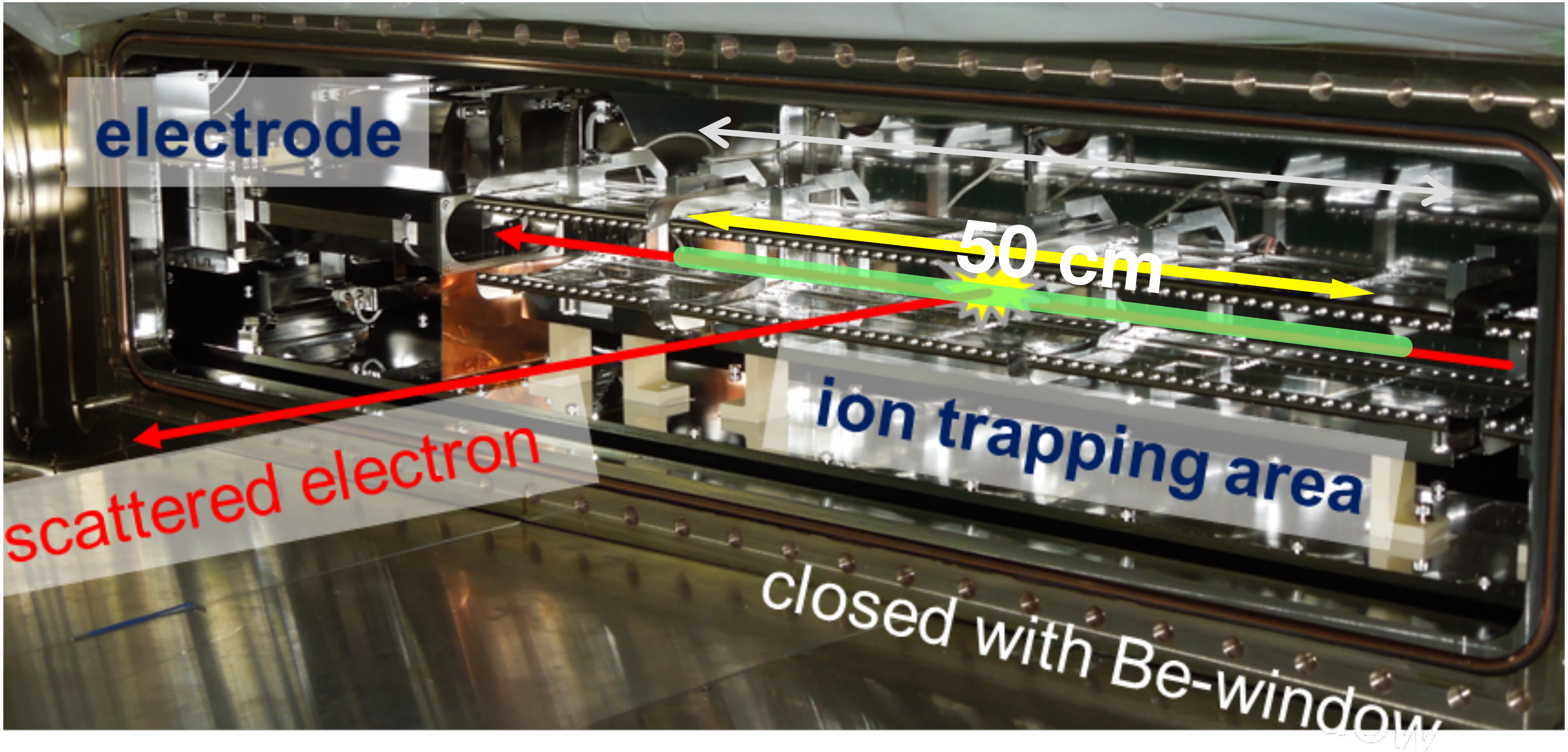
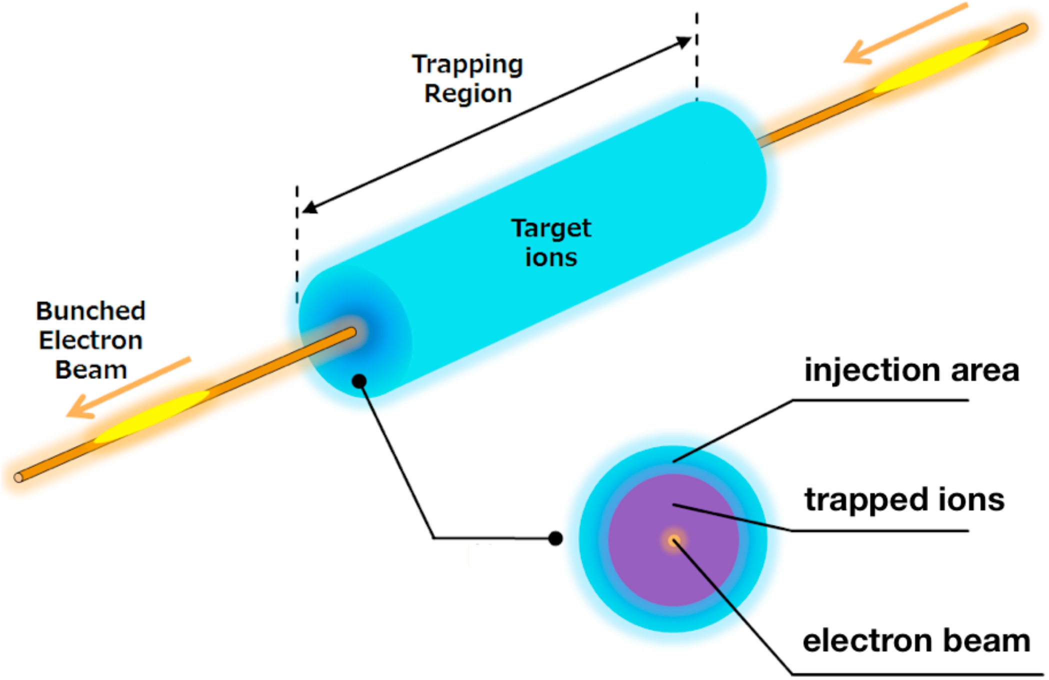


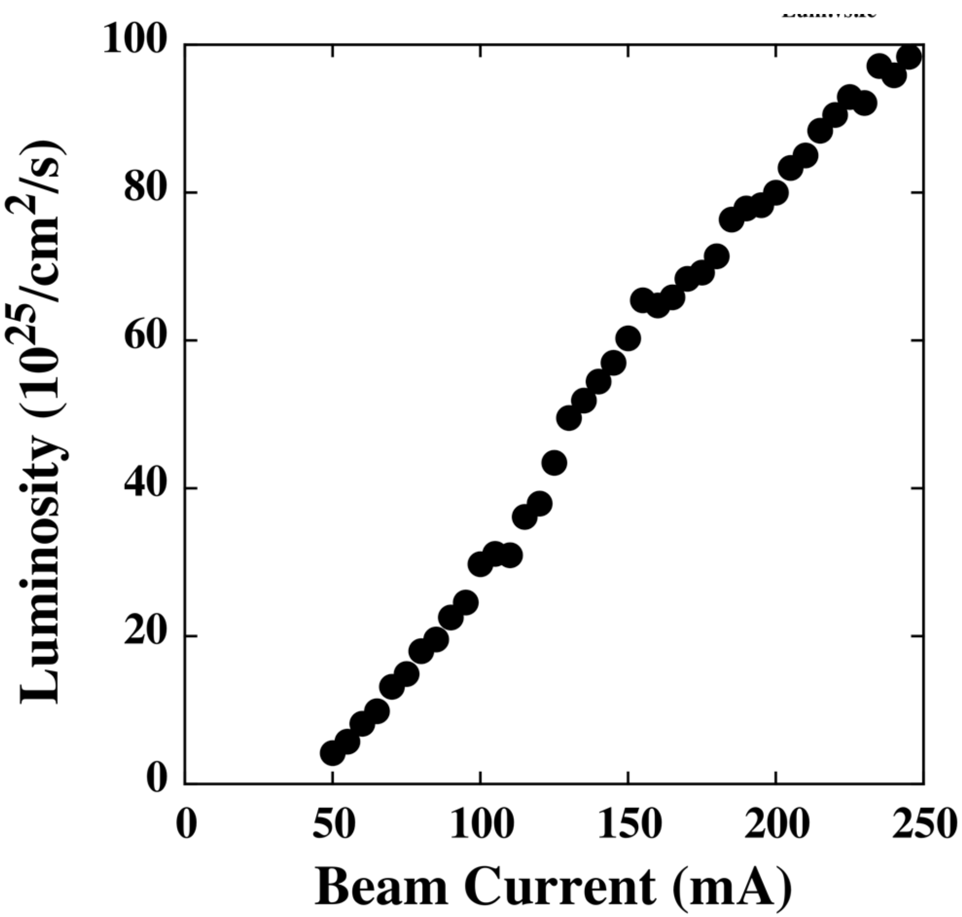
the SCRIT system




electrode
50 cm
ion trapping area
scattered electron
closed with Be-window

Ion trapping and luminosities



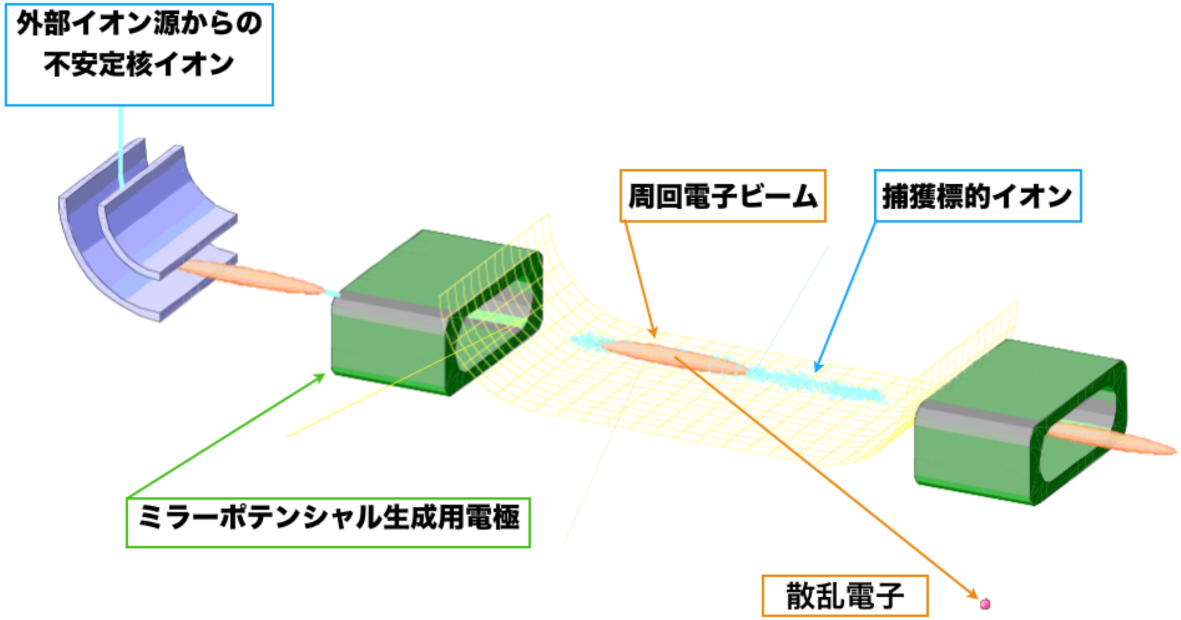


trapping efficiency ~ 100 %
overlapping efficiency ~ 17 %

Luminosities

~10^7 ions are trapped on e-beam (~ 1 mm^2)

$N_t \sim 10^7\ /mm^2 \Rightarrow\ 10^9\ /cm^2$



	Ee	N_{beam}	ρ・t	L
Hofstadter's era (1950s)	150 MeV	~ 1nA (~10^9 /s)	~10^{19} /cm^2	~10^{28} /cm^2/s
JLAB	6 GeV	~100μA (~10^{14} /s)	~10^{22} /cm2	~10^{36} /cm^2/s
SCRIT	**150 - 300 MeV**	**~200 mA (~10^{18} /s)**	**~ 10^9 /cm^2**	**~10^{27} /cm^2/s**

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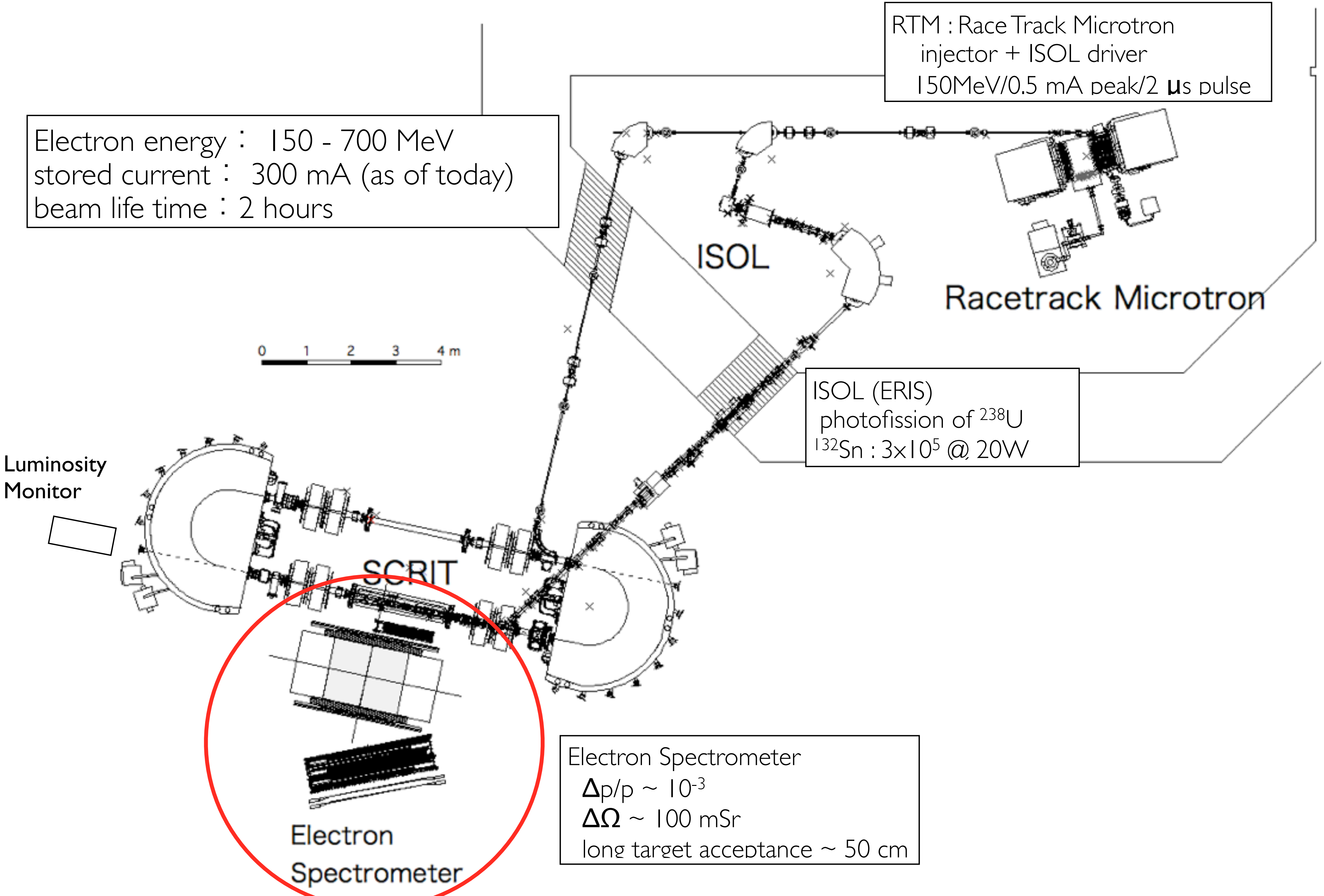

ISOL (ERIS)
photofission of ^{238}U
^{132}Sn : 3×10^5 @ 20W

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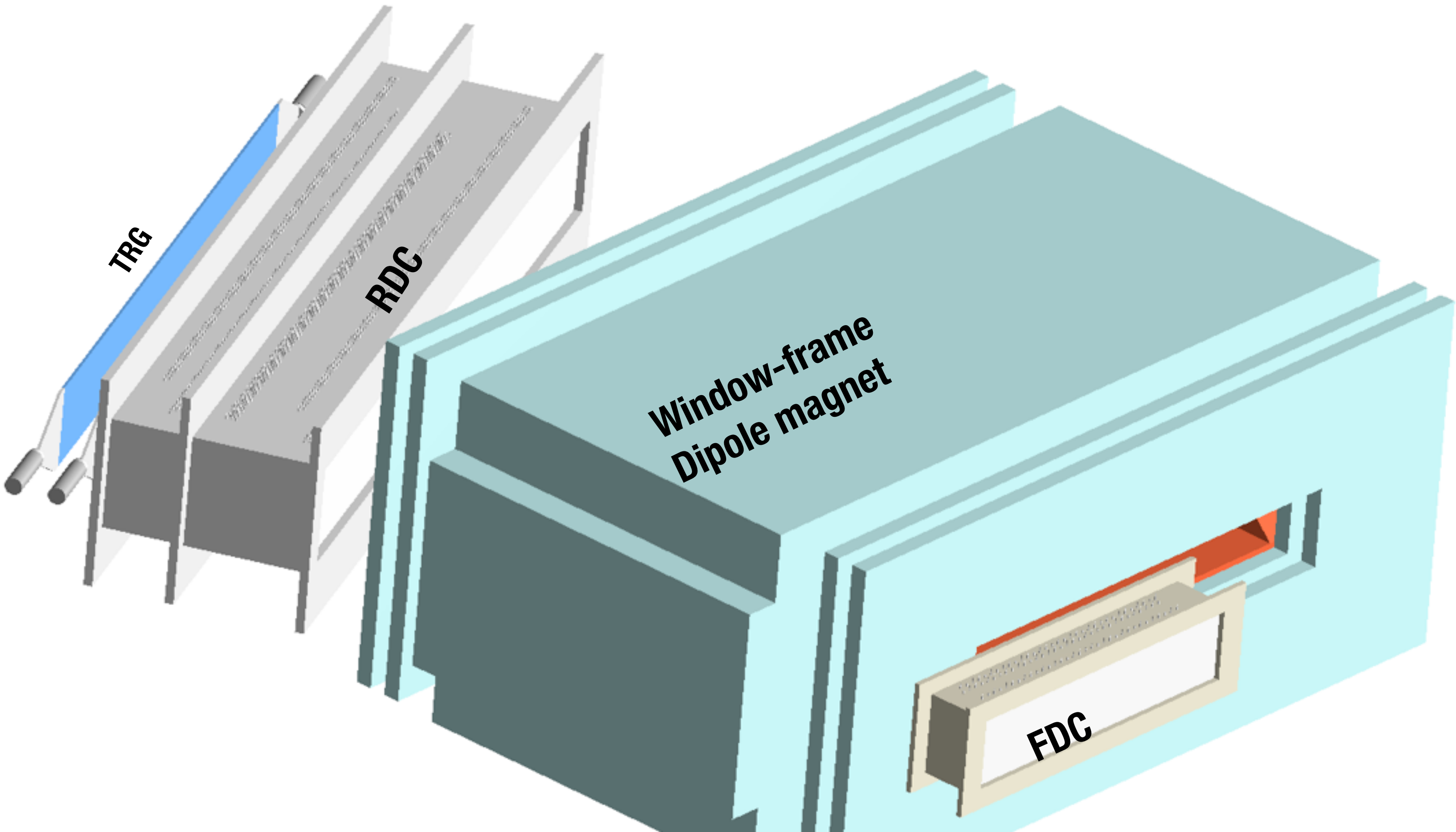
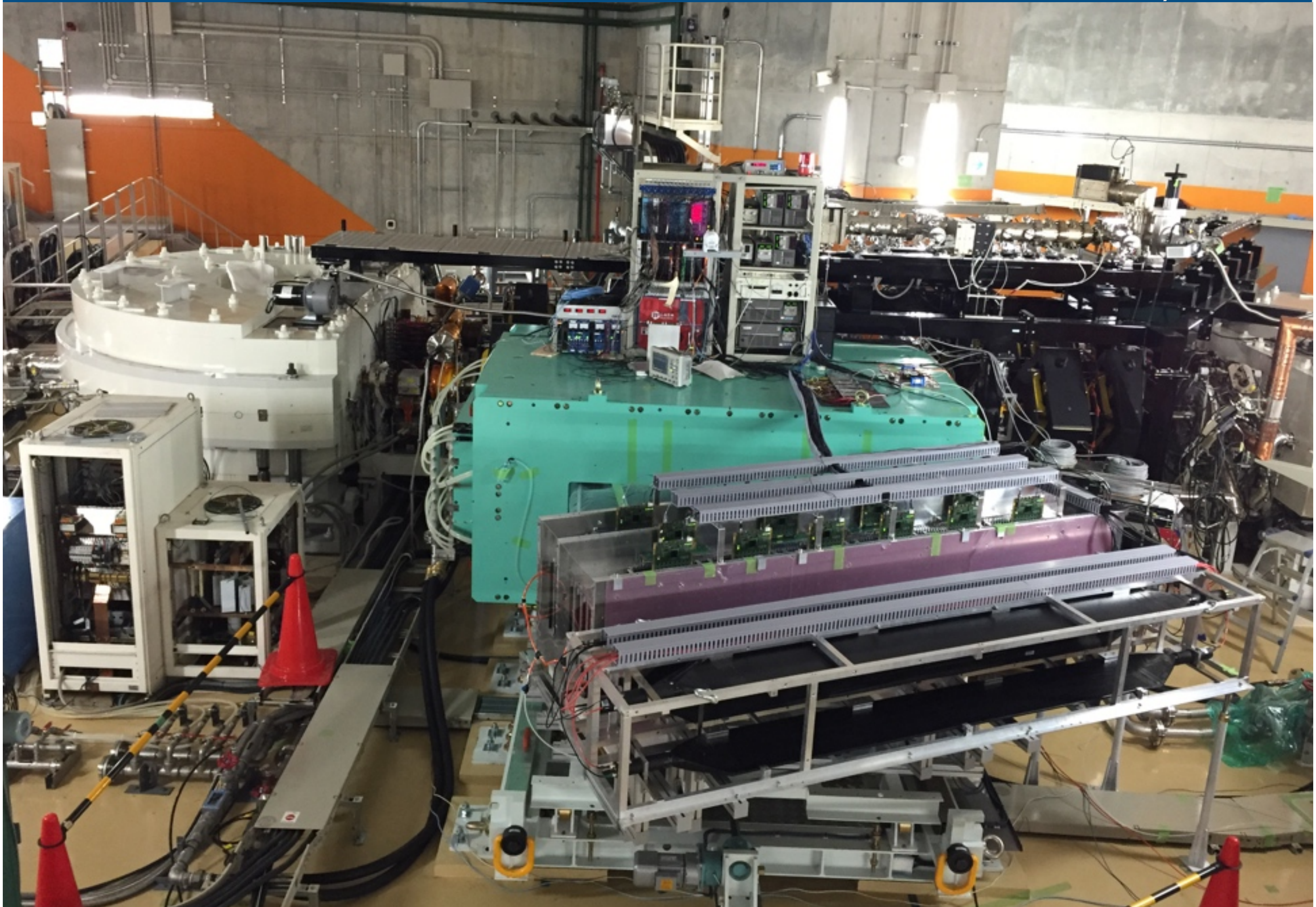
WiSES

(Window-frame Spectrometer for Electron Scattering)

- **long target acceptance (50cm)**
- **$\Delta p/p \leq 10^{-3}$ @ Ee = 300MeV**
- **$\Delta\theta$ = 30° (45±15°), $\Delta\Omega$~ 100 msr**





First physics run in April

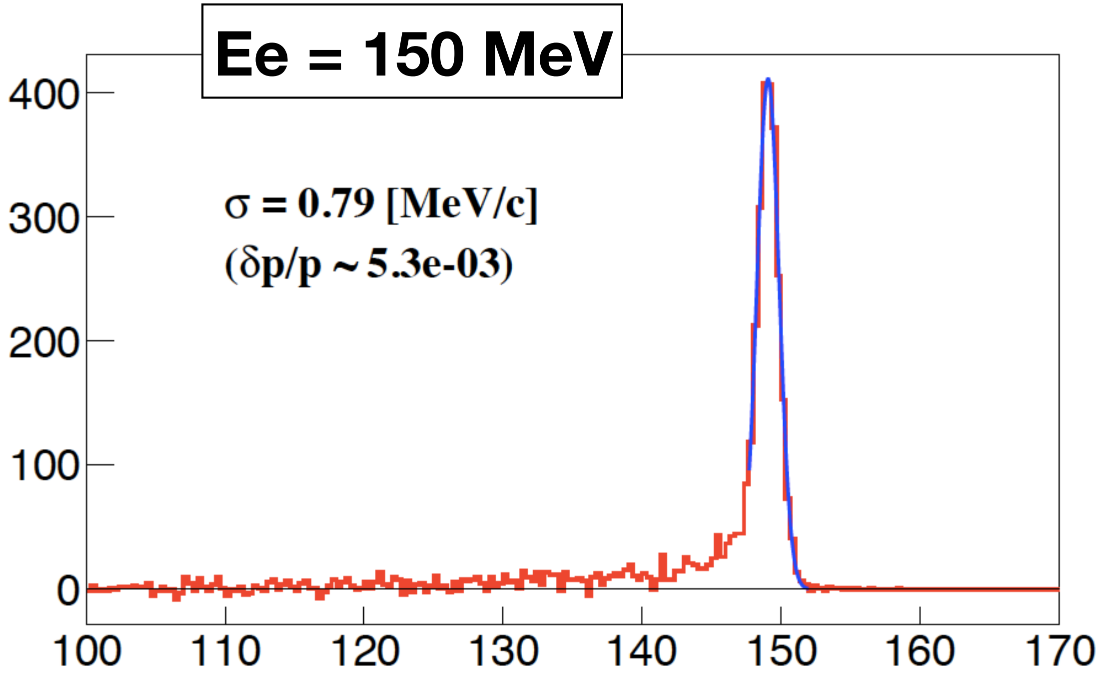
$^{132}Xe(e,e')$

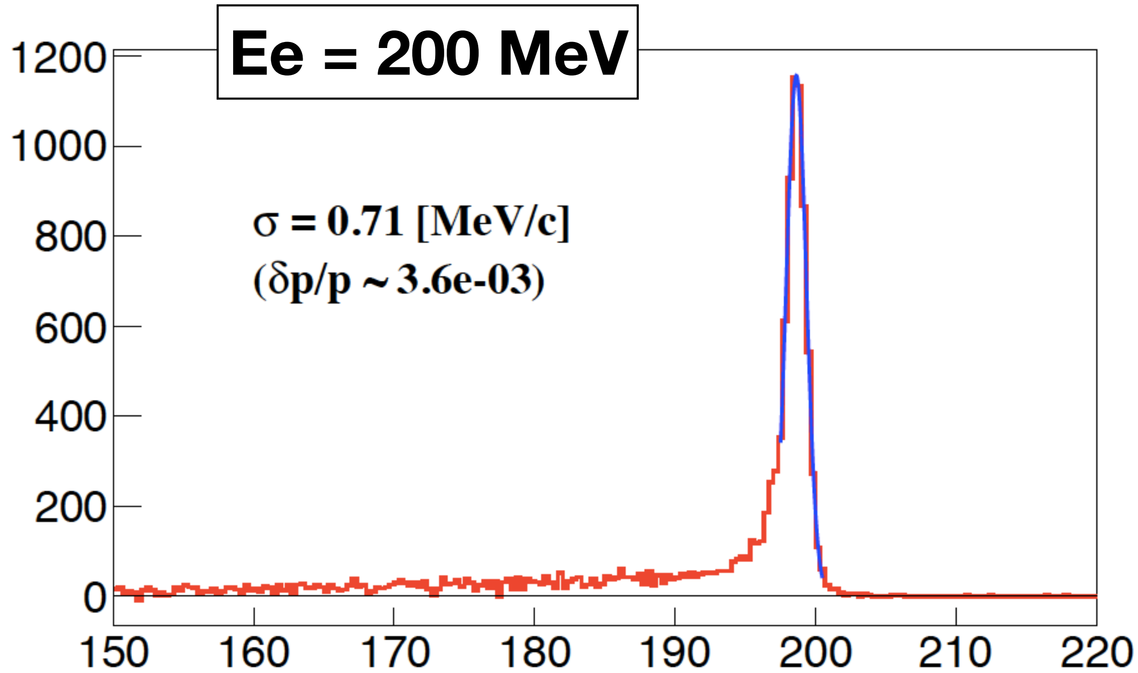
Ee = 150, 200 and 300 MeV
θ = 30 - 60 deg.
=> q = 80 - 300 MeV

$N_{trapped}$ ~ 10^7 @ Ie = 250 mA
ΔT ~ a few days

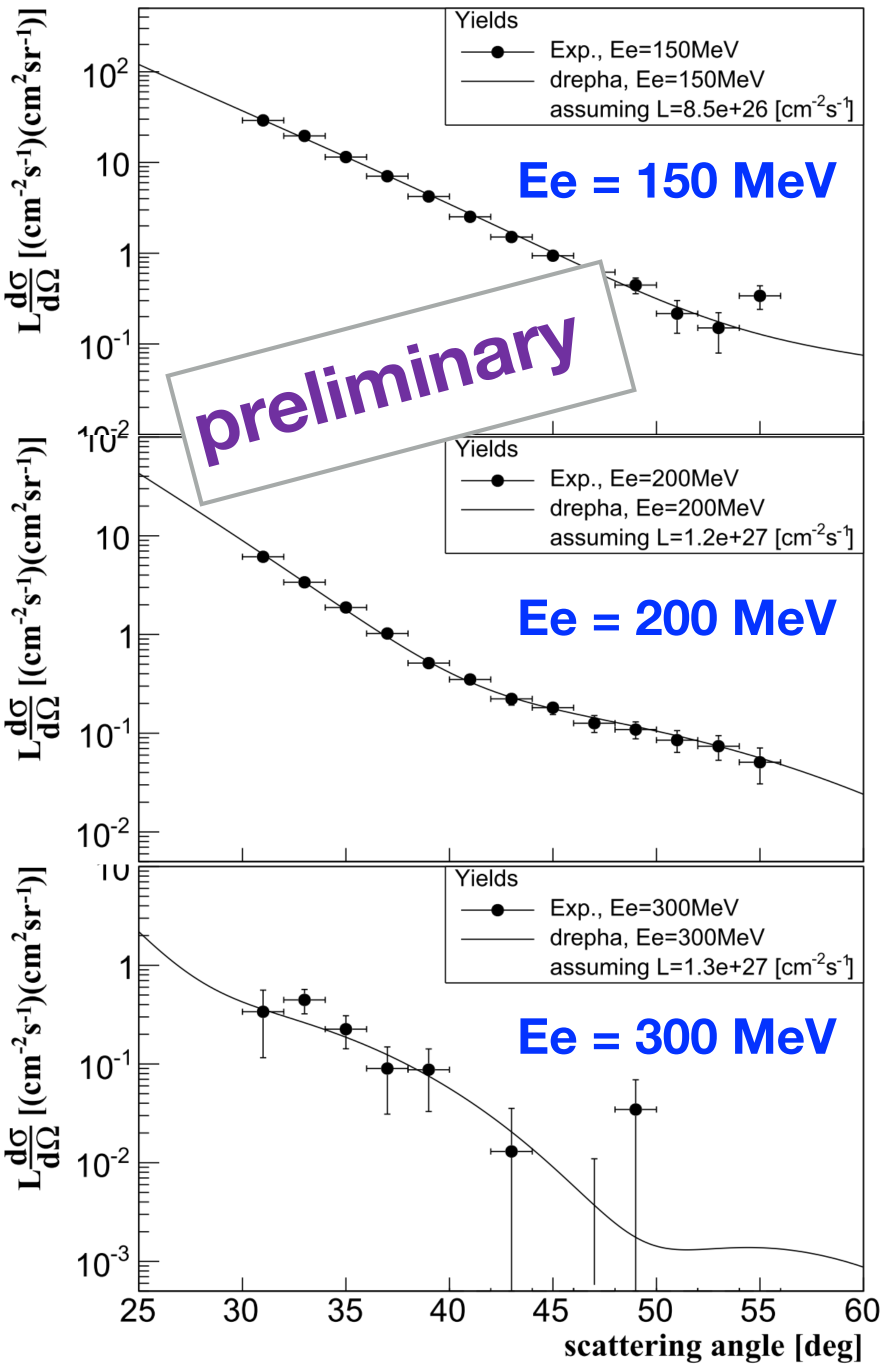
Momentum resolution
to be improved

"Online" spectra





First Physics Data from the SCRIT facility



DWBA (DREPHA) calculation assuming 2PF distribution

for fixing diffuseness to bet = 2.3 fm

$\langle r^2\rangle^{1/2} = 4.789 \,^{+0.044}_{-0.046}$

⇕

$\langle r^2\rangle^{1/2} = 4.787$ by μ-atom X-rays

1) 300 MeV measurement continued
2) (diff.) radius + diffuseness extraction

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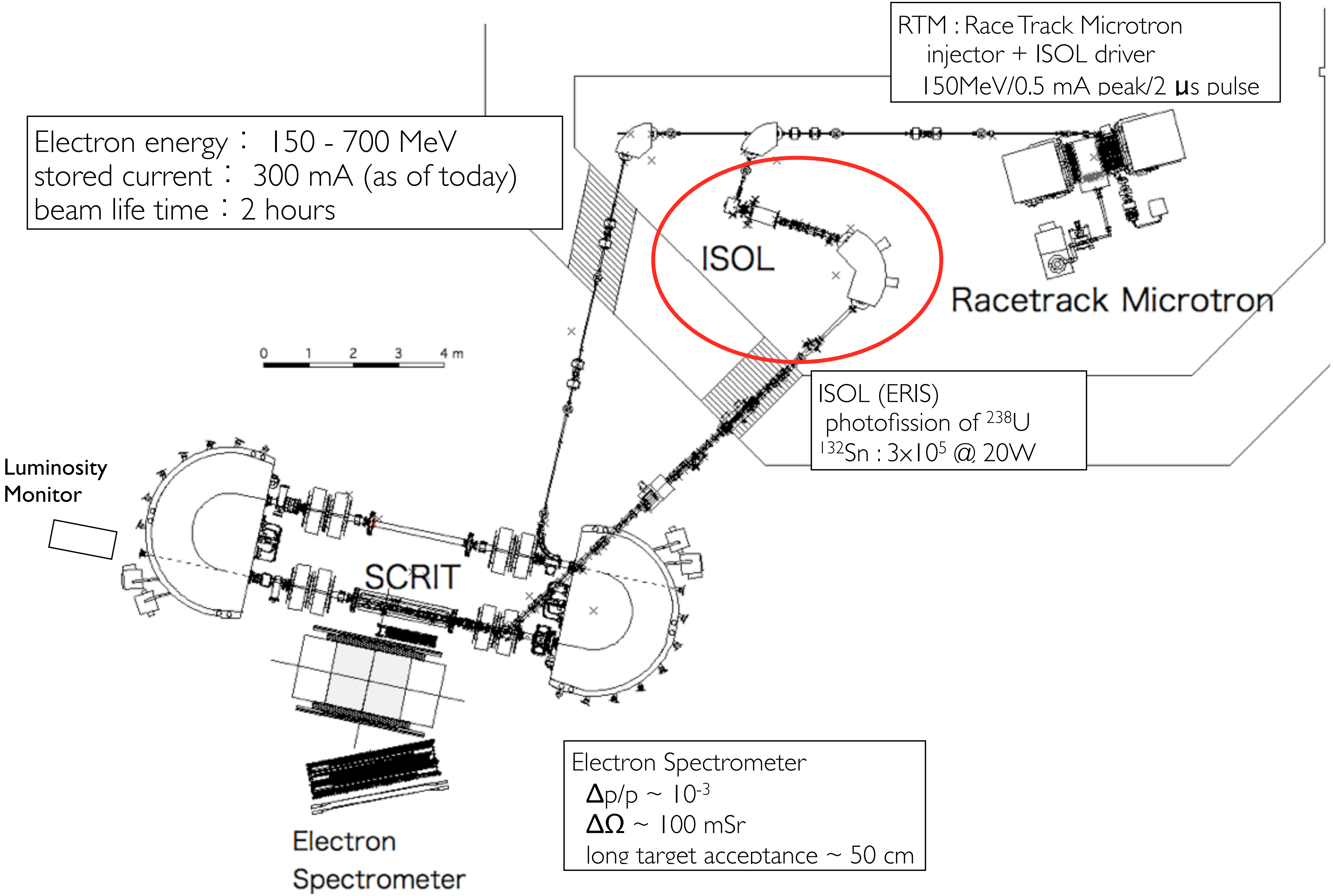

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photofission of ^{238}U
^{132}Sn : 3×10^5 @ 20W

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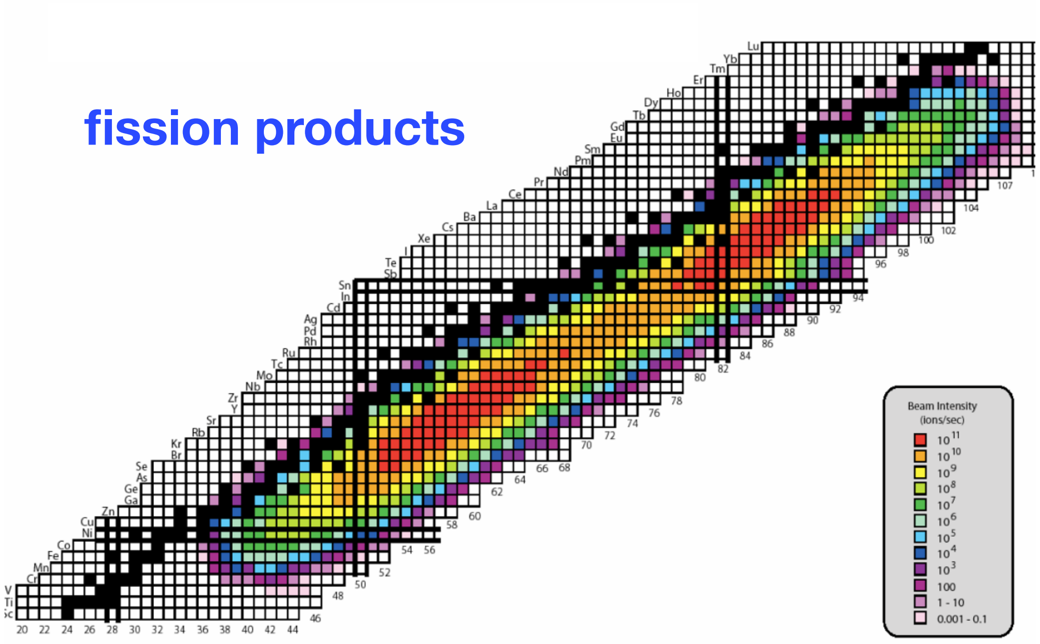
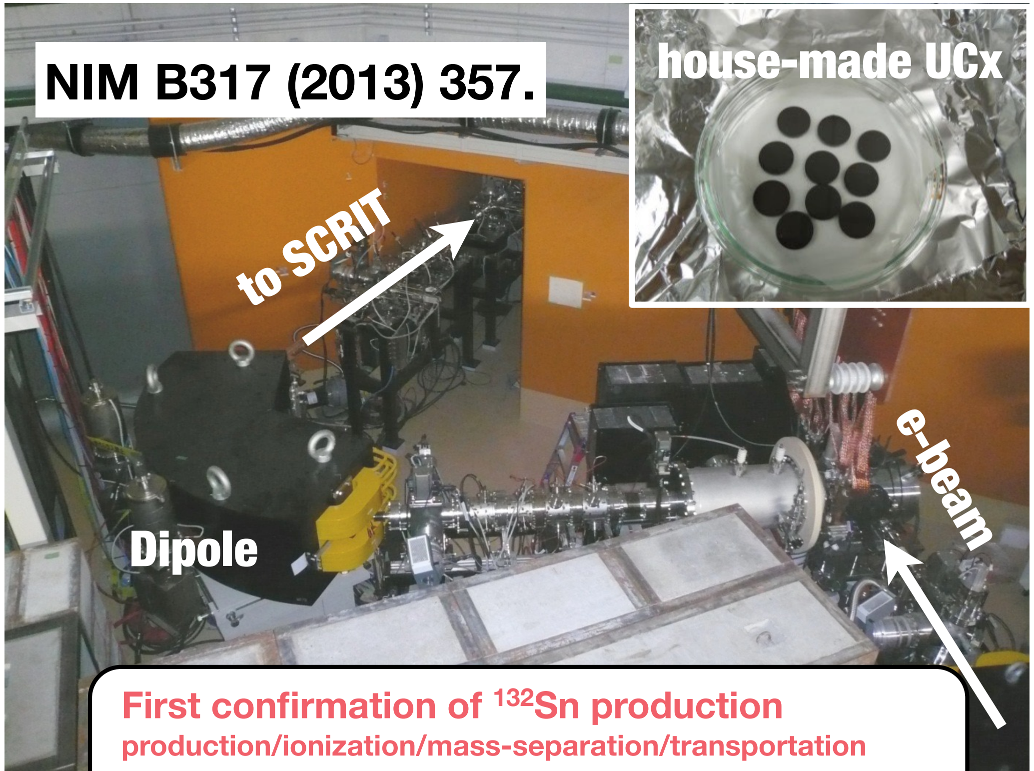
ISOL (Isotope Separator On-Line)

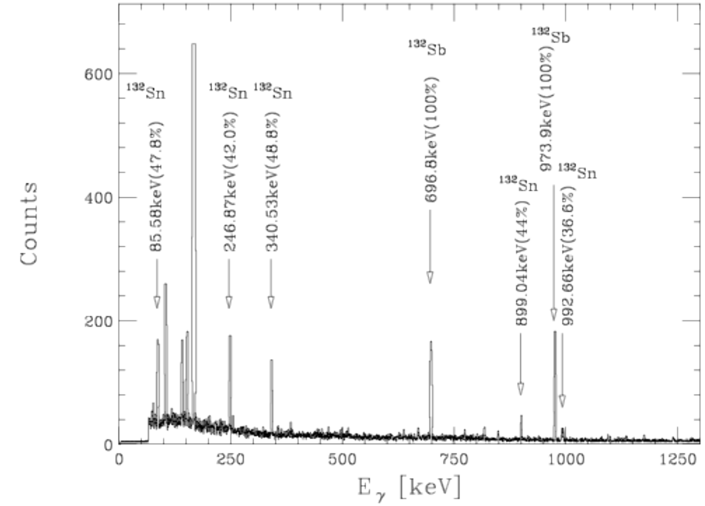
Reaction : photo- (electro-) fission of ^{238}U.
Target : house-made UCx
Driver : Race Track Microtron
(Ee=150 MeV)
Ion Source : FEBIAD type

fission products





First confirmation of ^{132}Sn production
production/ionization/mass-separation/transportation

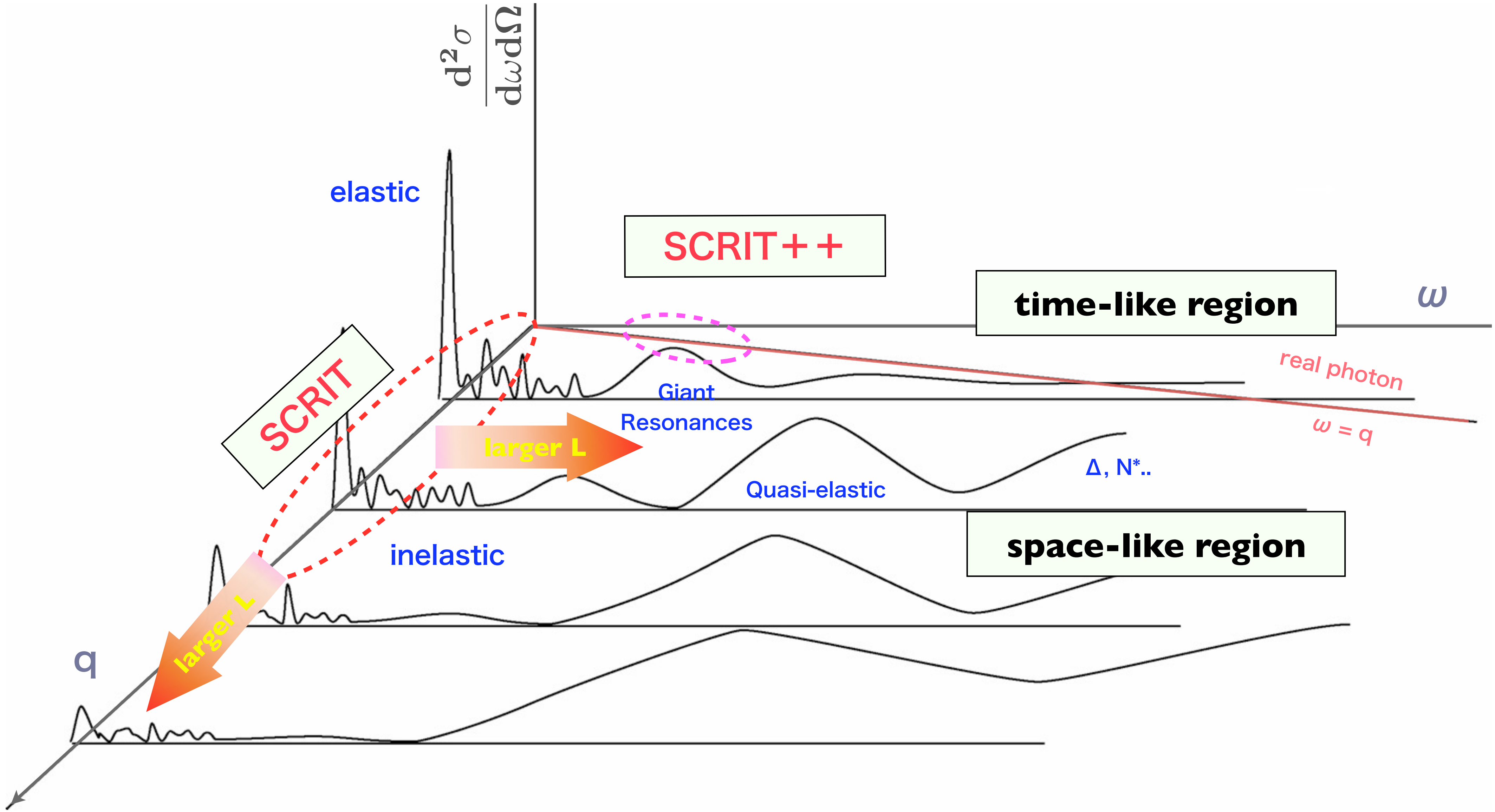


Production Rate
$N_{fission}$ ~ 10^8 /watt
$N_{^{132}Sn}$ ~ 10^6 / watt * 1% ($\varepsilon_{trans.}$)

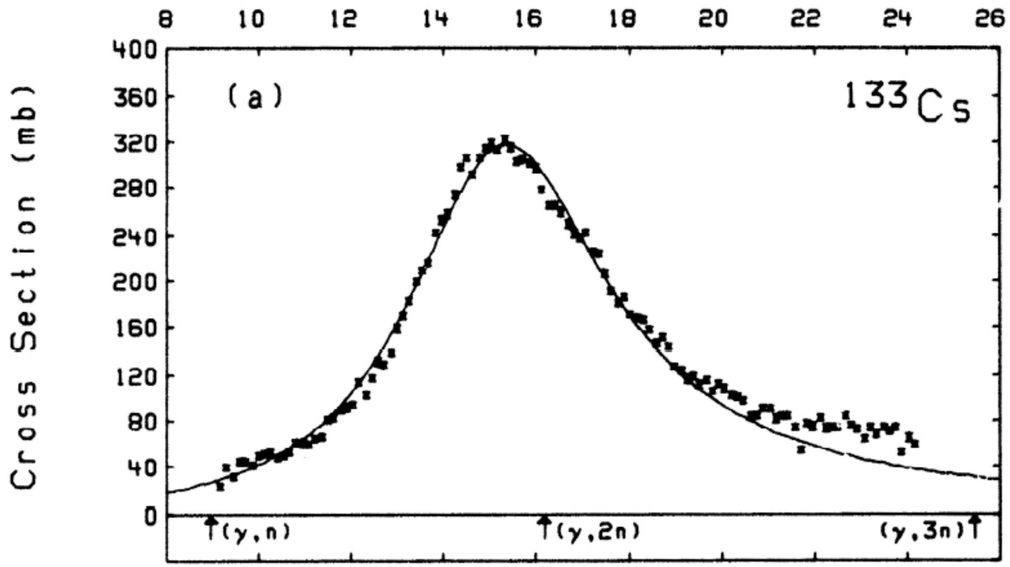
beam power : ~ 20W in operation
~ 1 kW the goal

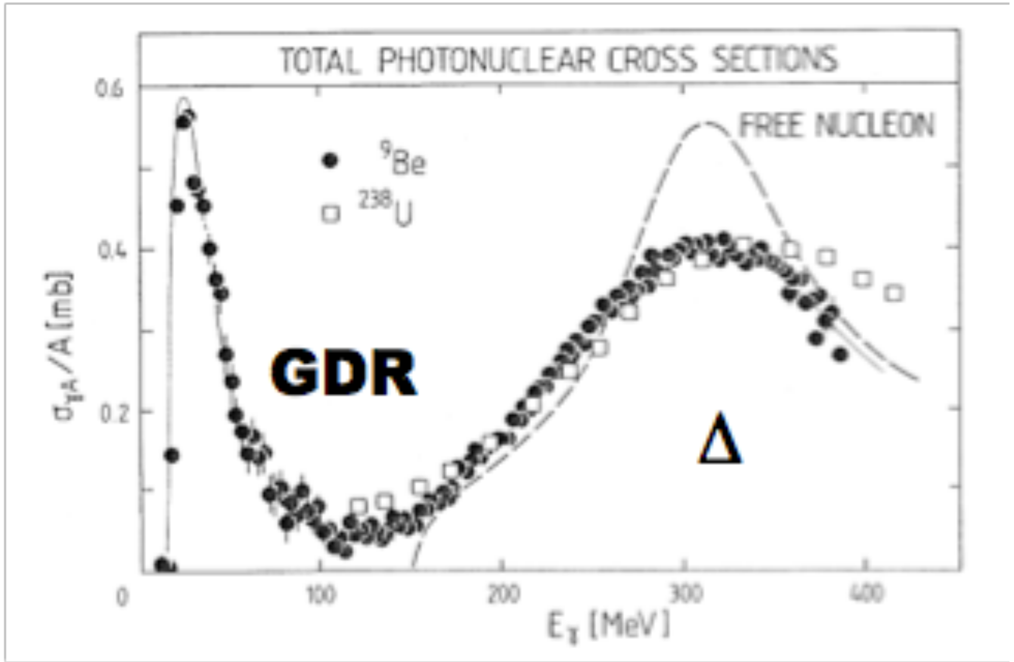
Photonuclear reaction of exotic nuclei at the SCRIT electron scattering facility

Nuclear response function in the (ω, q) plane



Total Photoabsorption Cross Section





1) Response functions (operators : well-known)

2) Sum Rules

TRK sum rule

$$\int_0^\infty \sigma(E_\gamma)dE_\gamma = \frac{2\pi^2 e^2\hbar}{M}\frac{NZ}{A}(1+\kappa) = 60\frac{NZ}{A}(1+\kappa)MeV\cdot mb$$

Bremmstrahlung sum rule

$$\int_0^\infty \frac{\sigma(E_\gamma)}{E_\gamma}dE_\gamma = \frac{4\pi^2 e^2}{3\hbar}\frac{NZ}{A-1}<r^2>$$

Migdal sum rule

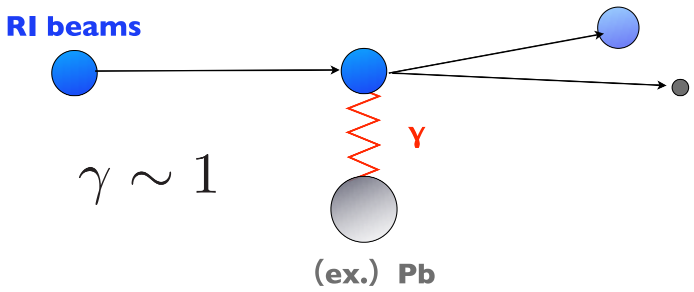
$$\int_0^\infty \frac{\sigma(E_\gamma)}{E_\gamma^2}dE_\gamma = \frac{2\pi^2}{\hbar}P$$

P : polarizability

photonuclear reaction for exotic nuclei

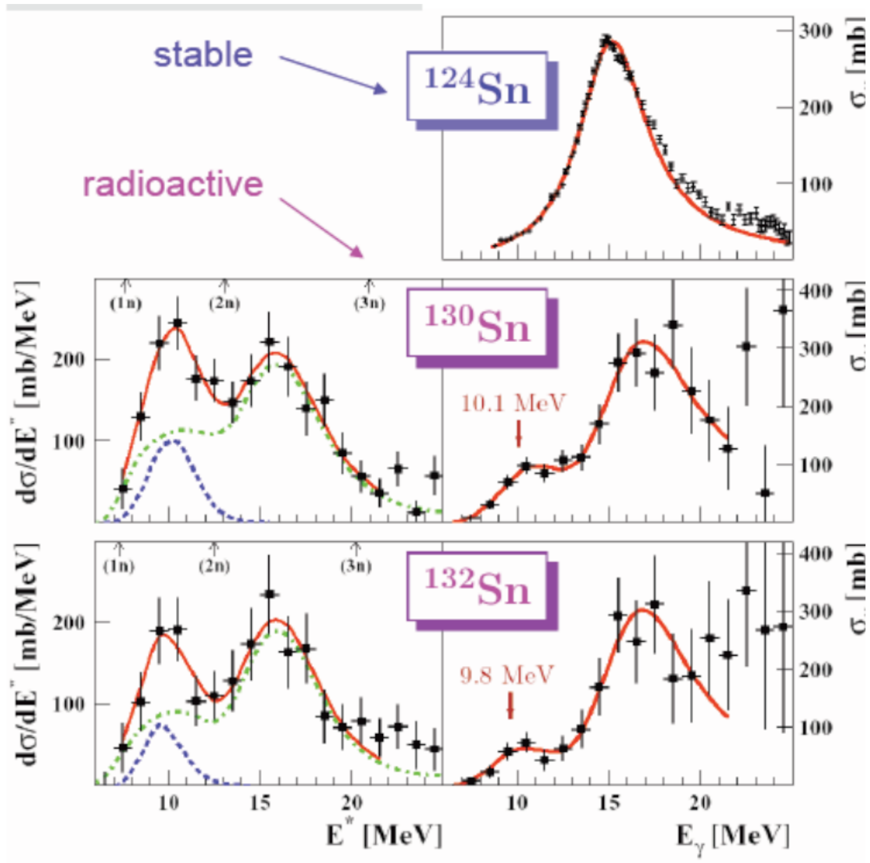
so far

only way : Coulomb excitation in heavy ion reaction

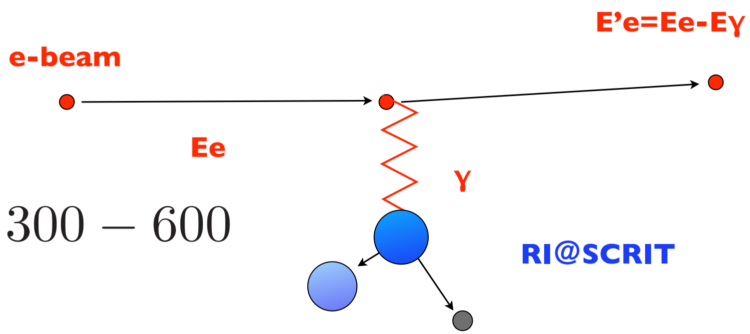


$\gamma \sim 1$

^{132}Sn+Pb -> ^{131}Sn + n + X @ GSI



SCRIT facility



$\gamma \sim 300 - 600$

purely EM probe
  well under control
  negligible multi-stop

ultra-forward
  electron scattering

Virtual Photon flux

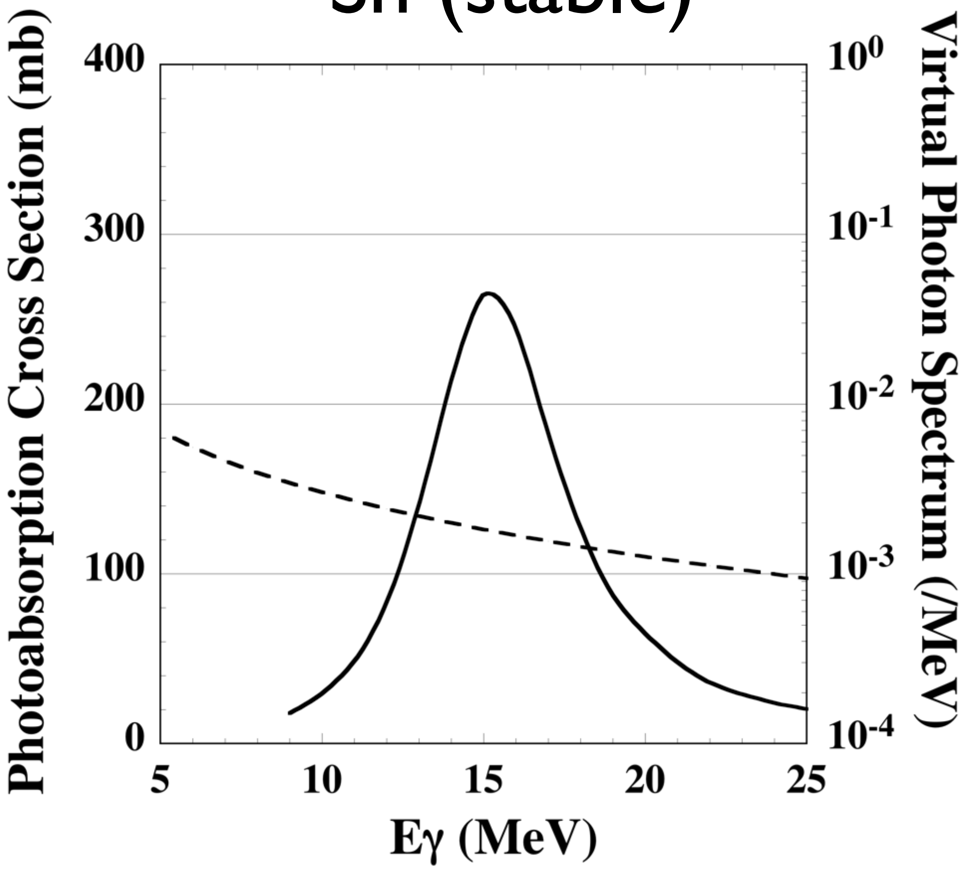
$$\frac{d^2\sigma}{dE_e d\Omega} = \sum \frac{d^2N_e^{EL}(E, E_\gamma, \theta)}{dE_\gamma d\Omega} \cdot \sigma_\gamma^{EL}(E_\gamma)$$

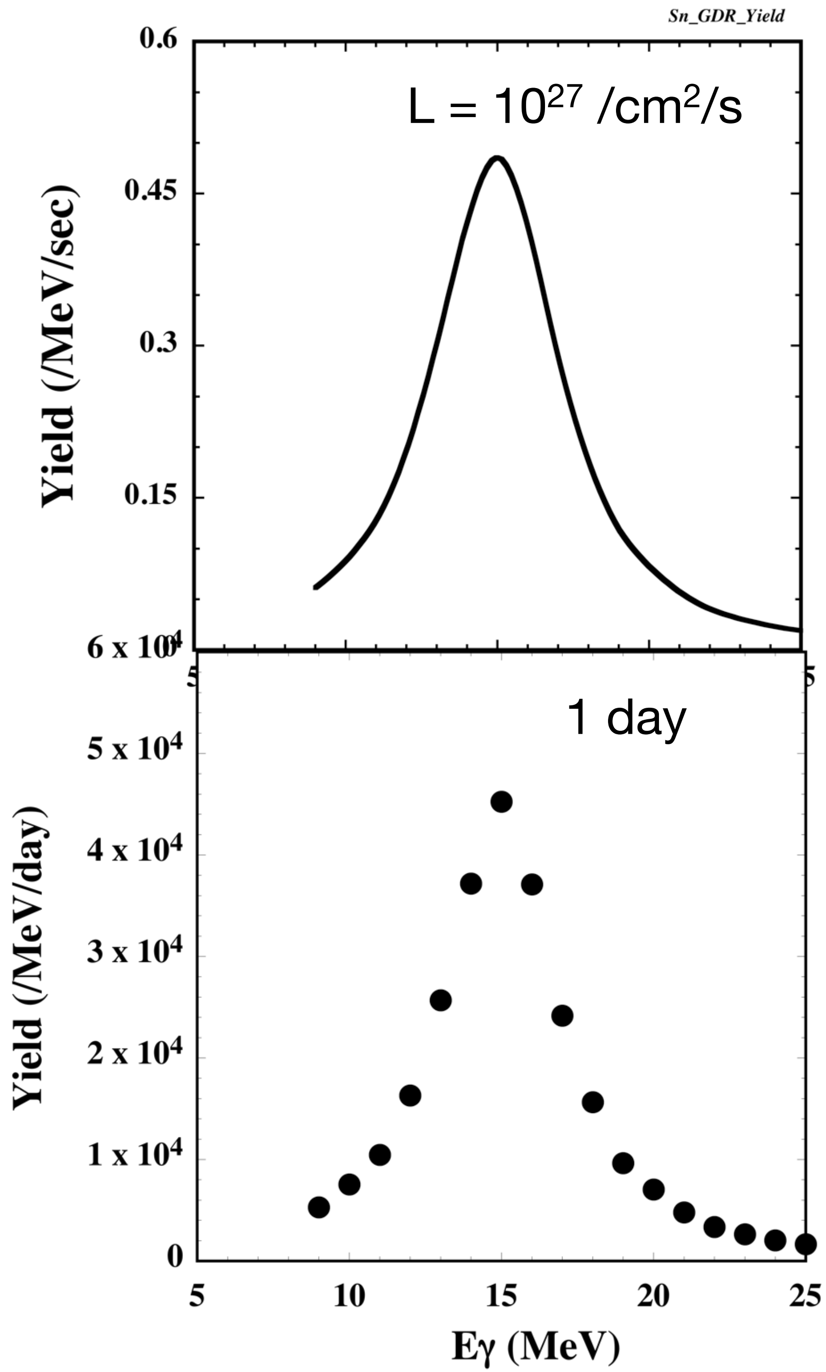
Expected reaction rate for $L = 10^{27}$ /cm²/s

virtual photon theory

$$\frac{dN}{dE_\gamma} = L \cdot \int d\Omega \frac{d^2 N_e^{E1}(E, E_\gamma, \theta)}{dE_\gamma d\Omega} \cdot \sigma_\gamma^{E1}(E_\gamma)$$

^{120}Sn (stable)

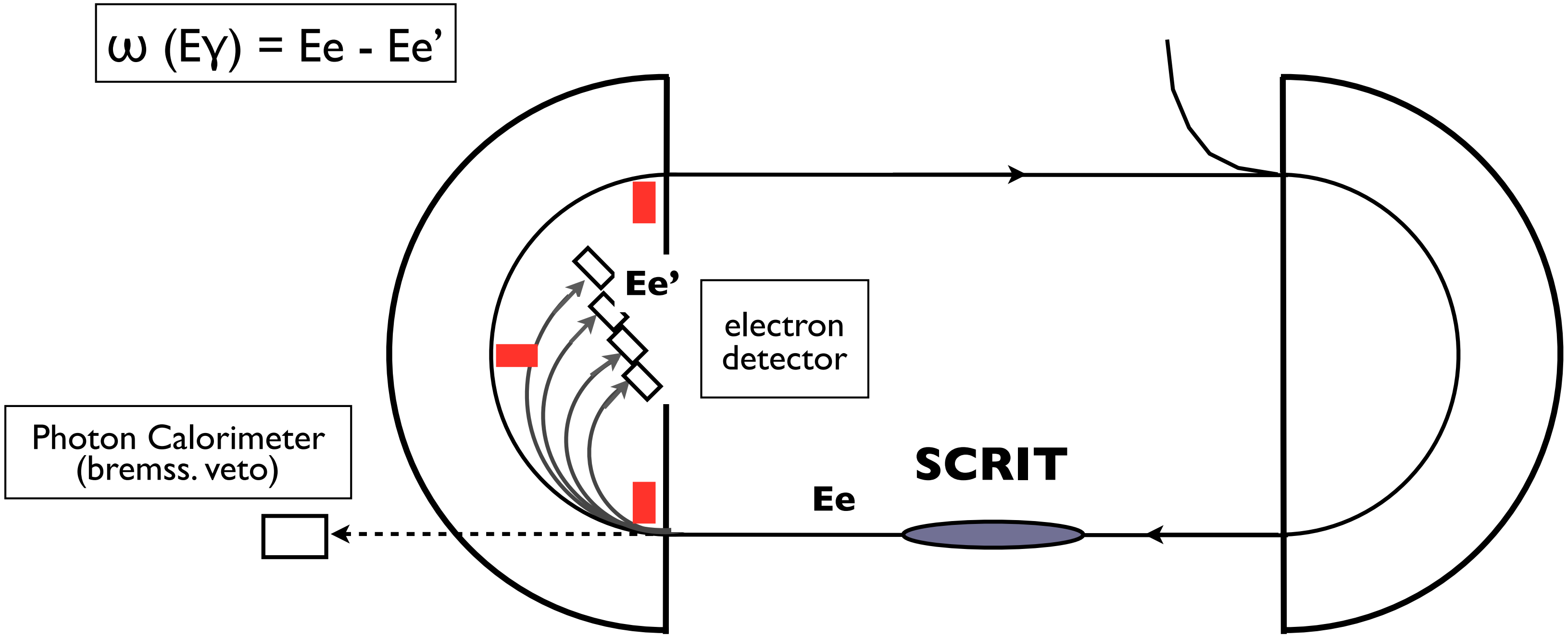




P. Durgapal and D.S. Onley
Comp. Phys. Comm. 32 (1984) 291

Possible photoabsorption exp. at the SCRIT facility

Inclusive measurement :
detecting energy-lost electron at the SCRIT target in the bending magnet



background sources

1) lost electrons from the circulating orbit

2) bremsstrahlung : $\theta_\gamma \sim m_e/E_e$ ~3 mrad for Ee=150 MeV $\sigma_{brems} \sim 10^3 \ \sigma_{\gamma A}$

Feasibility studies on those backgrounds **using plastic scintillators inserted**

1) background counting rate is quite low (small acceptance, well-shielded)

2) bremsstrahlung events are clearly identified.

Conclusions

1. SCRIT electron scattering facility started its operation.
2. stable 132Xe (e,e') measured: L ~ 10^{27} /cm^2/s with ~10^7 ions on e-beam

   dσ/dΩ @ $q \leq 1.5$ fm^{-1}

3. first e+RI (^{138}Xe, ^{132}Sn) scattering starts soon @ L > $10^{25\text{-}26}$ /cm^2/s

   ISOL (γ+U) : towards higher beam power (20 W ---> 1 kW) : ~10^8 fission/W

Future perspectives

Total photo absorption cross section of exotic nuclei covering the whole GDR region

ultra-forward inelastic electron scattering : well established in “old-days” experiments
L ~ 10^{27} /cm^2/s is high enough for measuring $\sigma_{total}(E\gamma)$ in $E\gamma \leq 30$ MeV
background study : positive