Future Perspectives of the SCRIT Facility

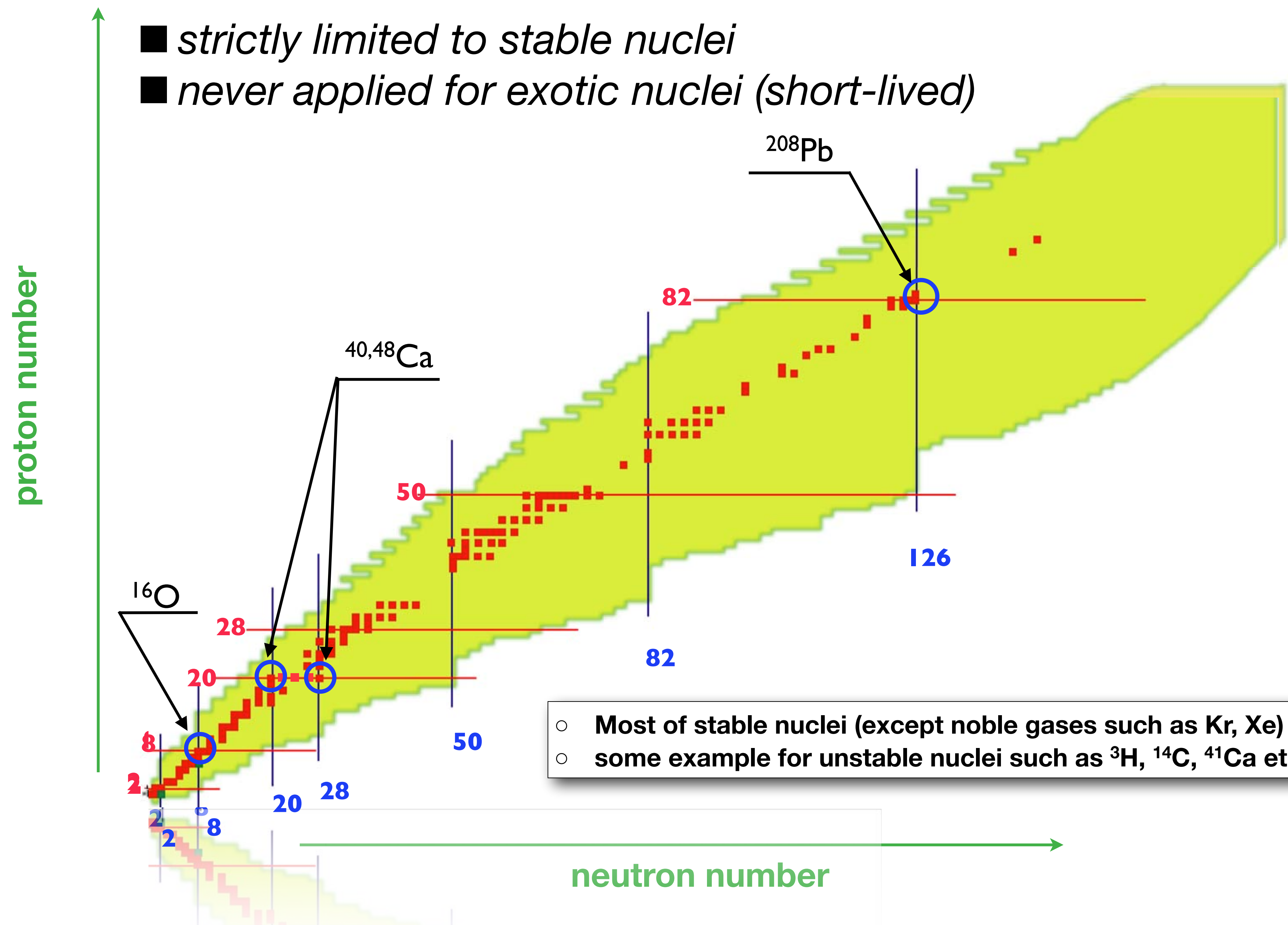
Toshimi Suda

Research Center for Electron Photon Science (ELPH)
TOHOKU University
Sendai

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)*



- Most of stable nuclei (except noble gases such as Kr, Xe)
- some example for unstable nuclei such as ^{3}H, ^{14}C, ^{41}Ca etc...

“Hofstadter’s experiments for exotic nuclei”

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

expected low luminosity ⇨ elastic scattering (largest σ)

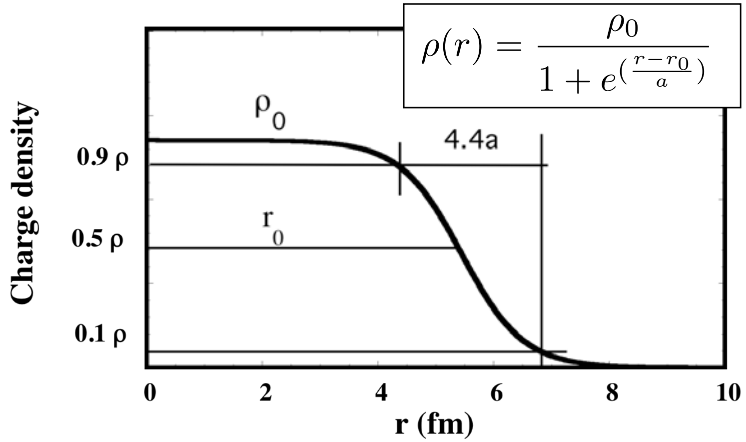
Elastic Scattering for spinless nuclei

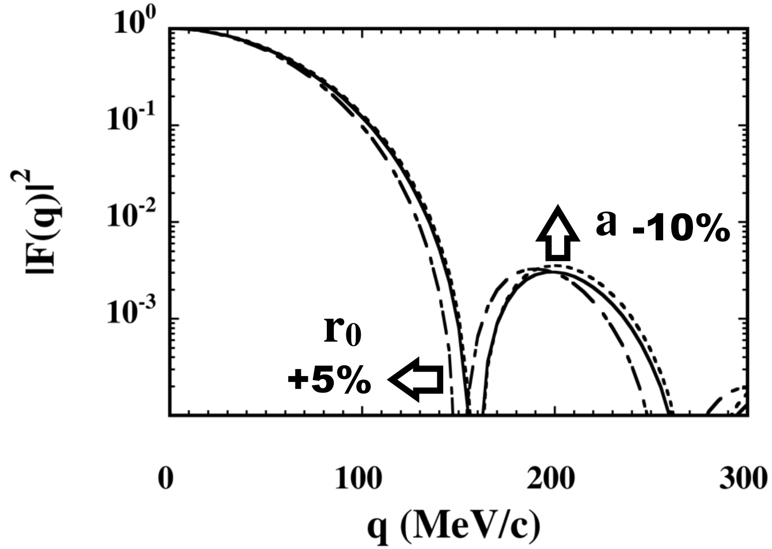
PWIA

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

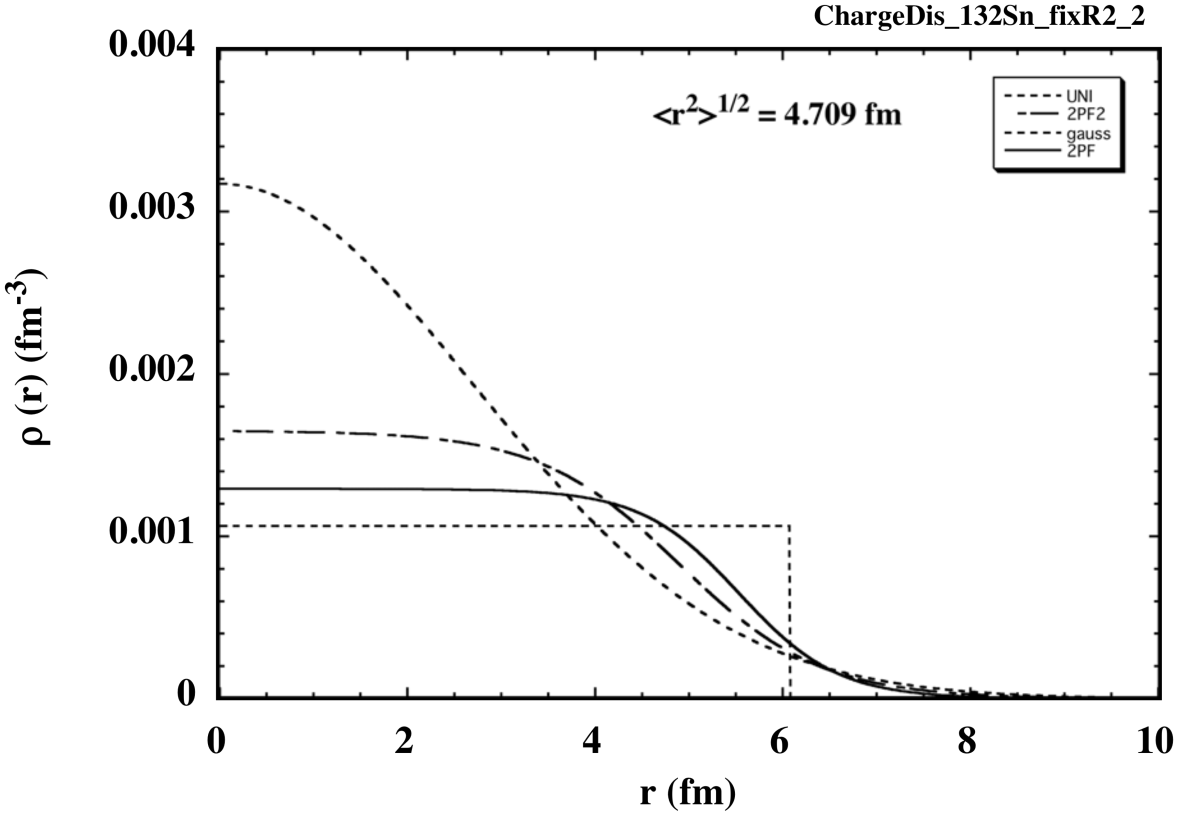
$$\frac{d\sigma_{Mott}}{d\Omega} = \frac{z^2\alpha^2 cos^2(\frac{\theta}{2})}{4e^2 sin^4(\frac{\theta}{2})}$$

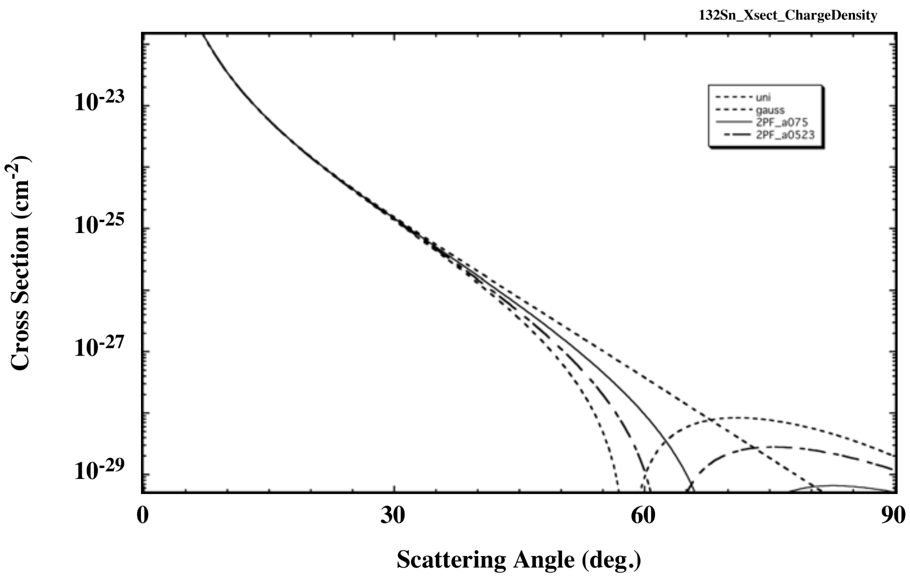
$$F_c(q) = \int \rho_c(\vec{r}) e^{i\vec{q}\vec{r}} d\vec{r}$$

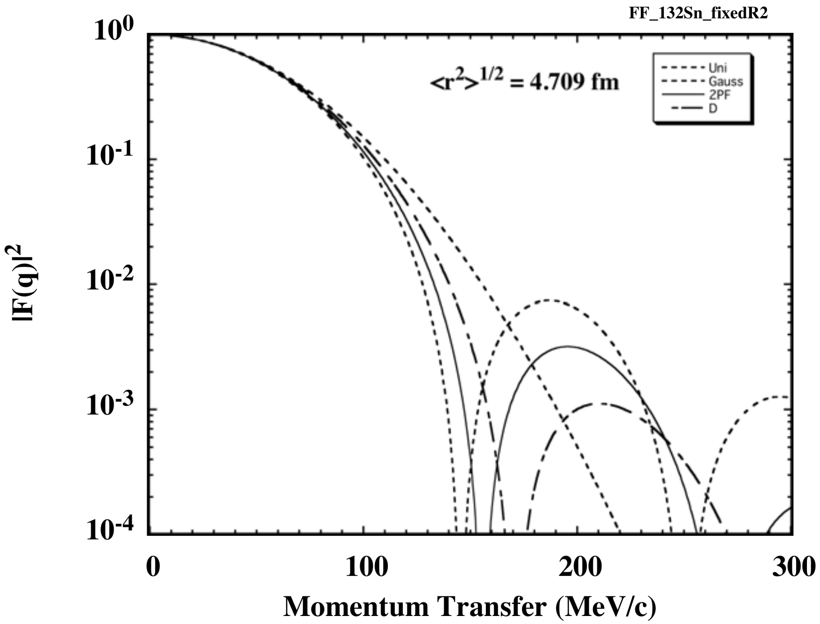




Beyond charge radii (isotope shifts)





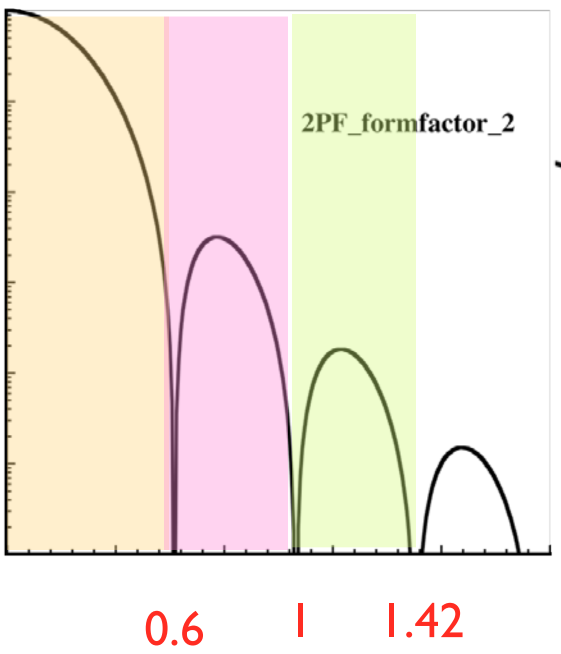


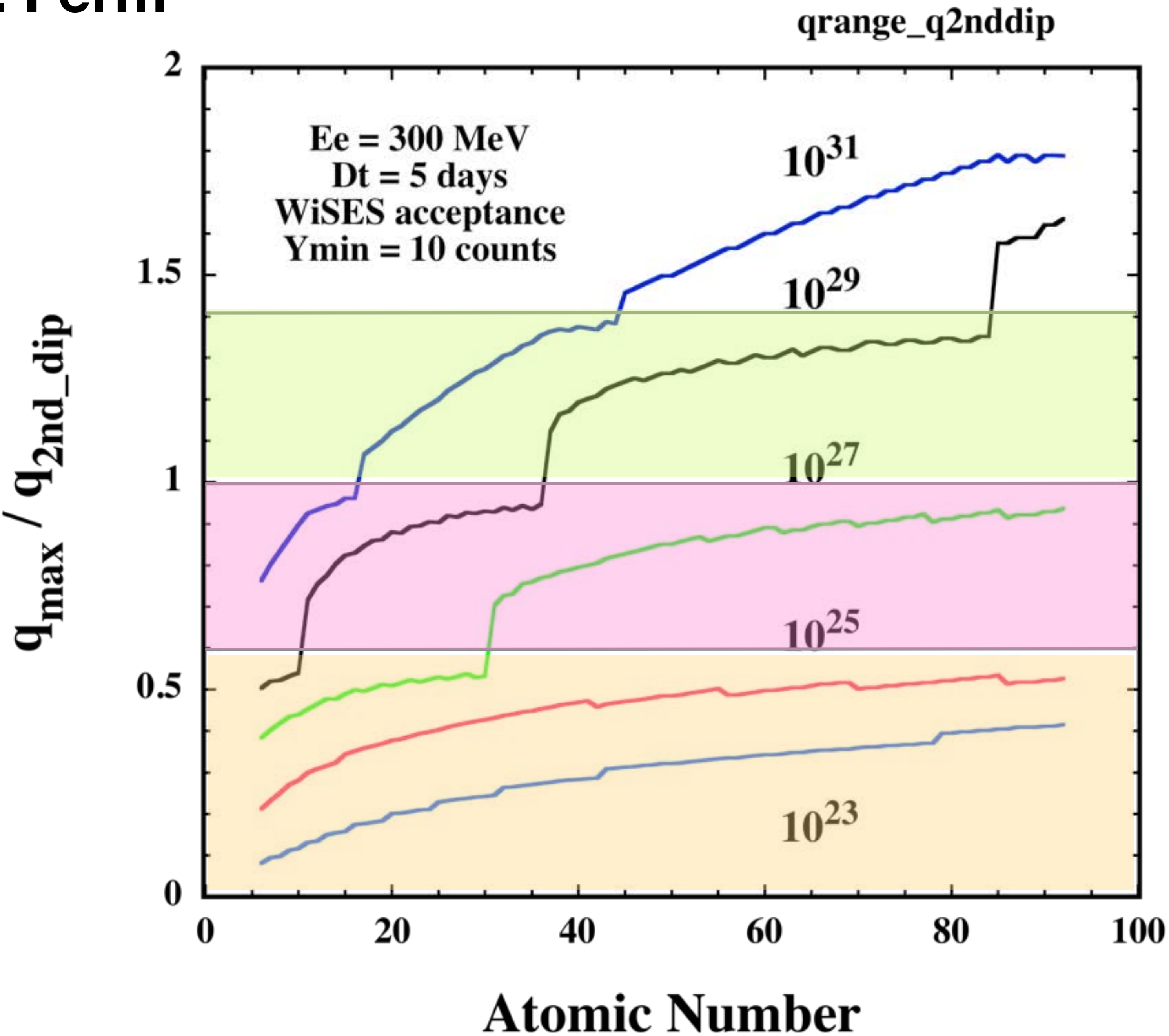
Accessible q-range for *L* and *Z*

ρ(r) : two-parm. Ferm

$$\sigma \propto Z^2$$

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





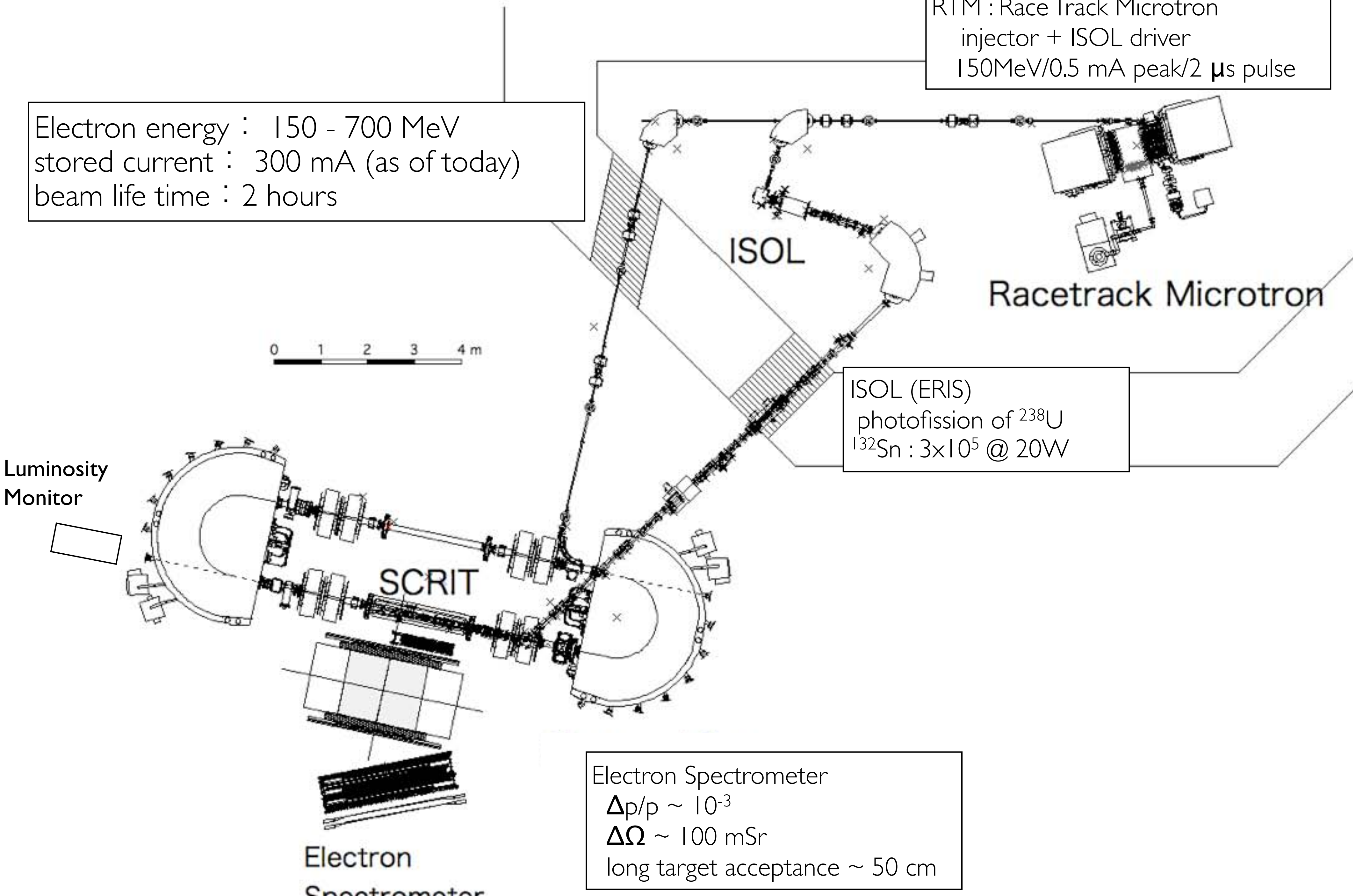
The SCRIT electron scattering facility

world's first electron scattering facility for short-lived nuclei

SCRIT electron scattering facility @ RIKEN

RTM : Race Track Microtron
injector + ISOL driver
150MeV/0.5 mA peak/2 μs pulse

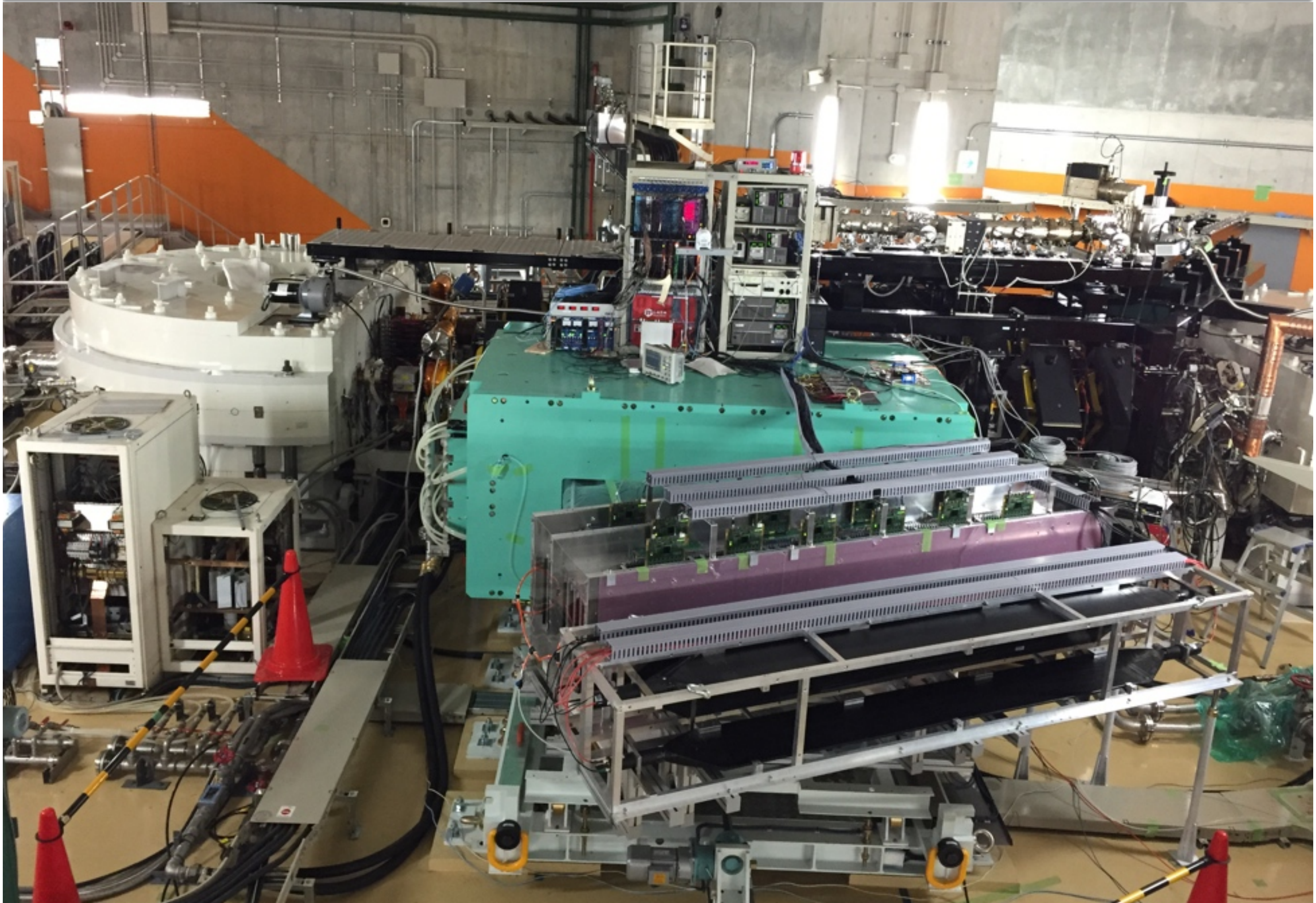
Electron energy ： 150 - 700 MeV
stored current ： 300 mA (as of today)
beam life time ：2 hours



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

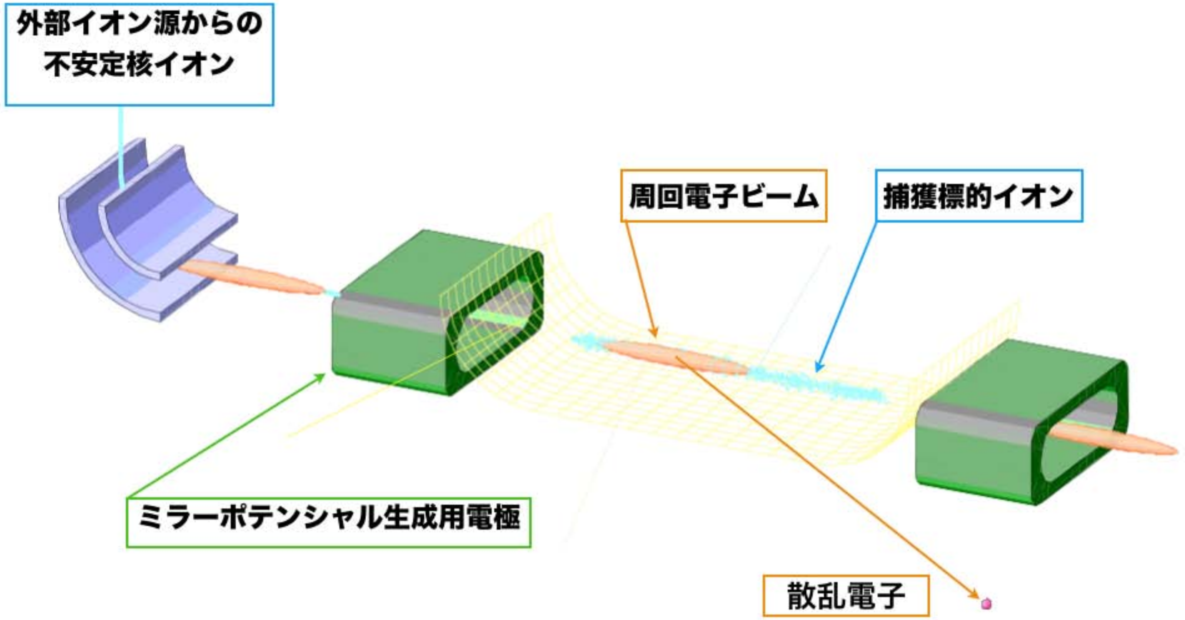
Electron Spectrometer
$\Delta p/p \sim 10^{-3}$
$\Delta\Omega \sim 100$ mSr
long target acceptance ~ 50 cm

SCRIT facility as of today



電子ビーム（断面 ~ 1 mm²) に~10^7ヶの標的不安定核イオンを捕獲

標的厚： ~10^7 /mm² => 10^9 /cm²



	Ee	N_{beam}	ρ・t	L
Hofstadter's era (1950s)	150 MeV	~ 1nA (~10^9 /s)	~10^{19} /cm²	~10^{28} /cm²/s
JLAB	6 GeV	~100μA (~10^{14} /s)	~10^{23} /cm2	~10^{37} /cm²/s
SCRIT	**150 - 300 MeV**	**~200 mA (~10^{18} /s)**	**~ 10^9 /cm²**	**~10^{27} /cm²/s**

SCRIT 法により、必要な標的数が 10^{-10} 倍にできた！！

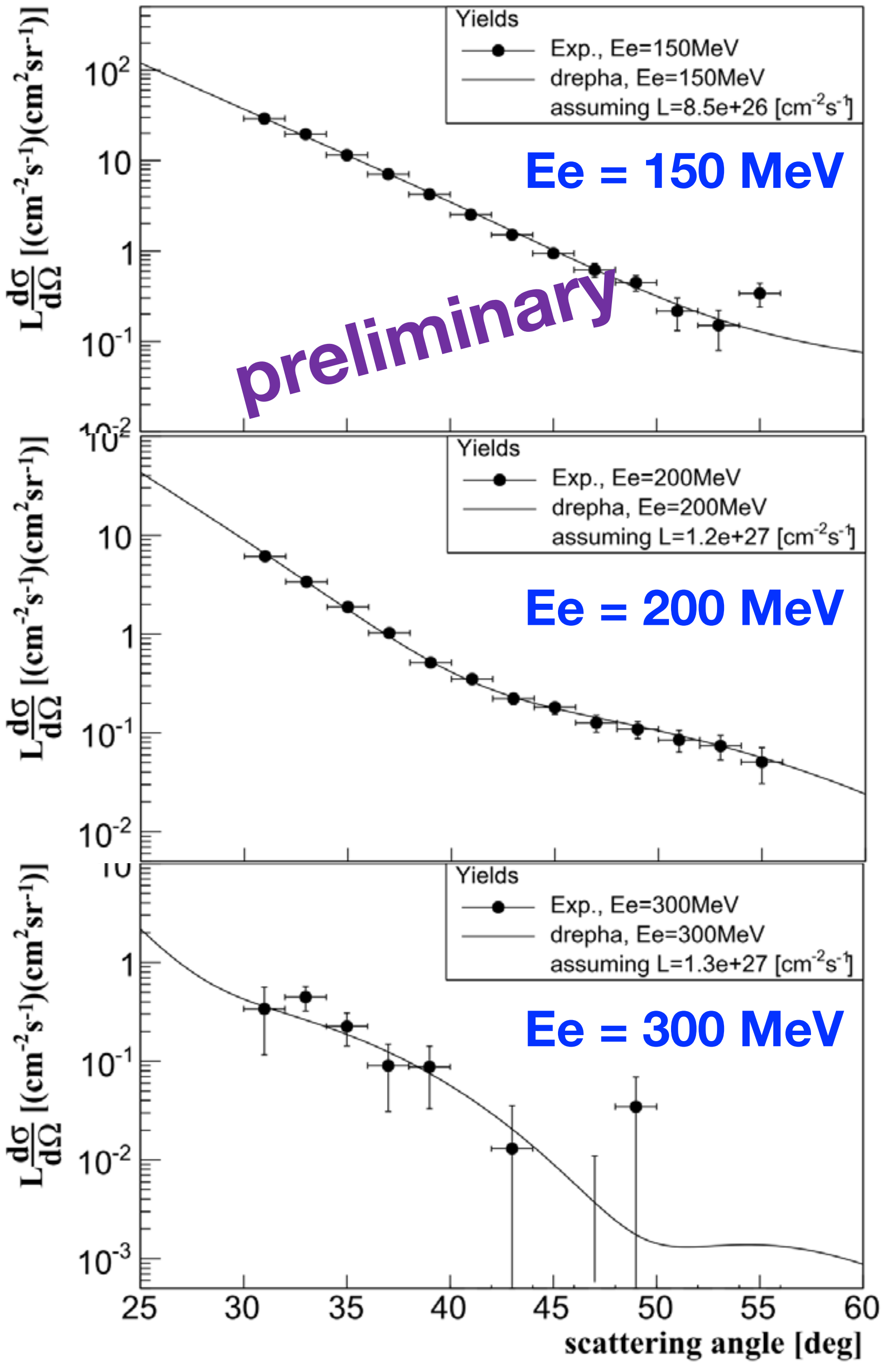
^{132}Xe(e,e')

First electron scattering data for (stable) Xenon nuclei.

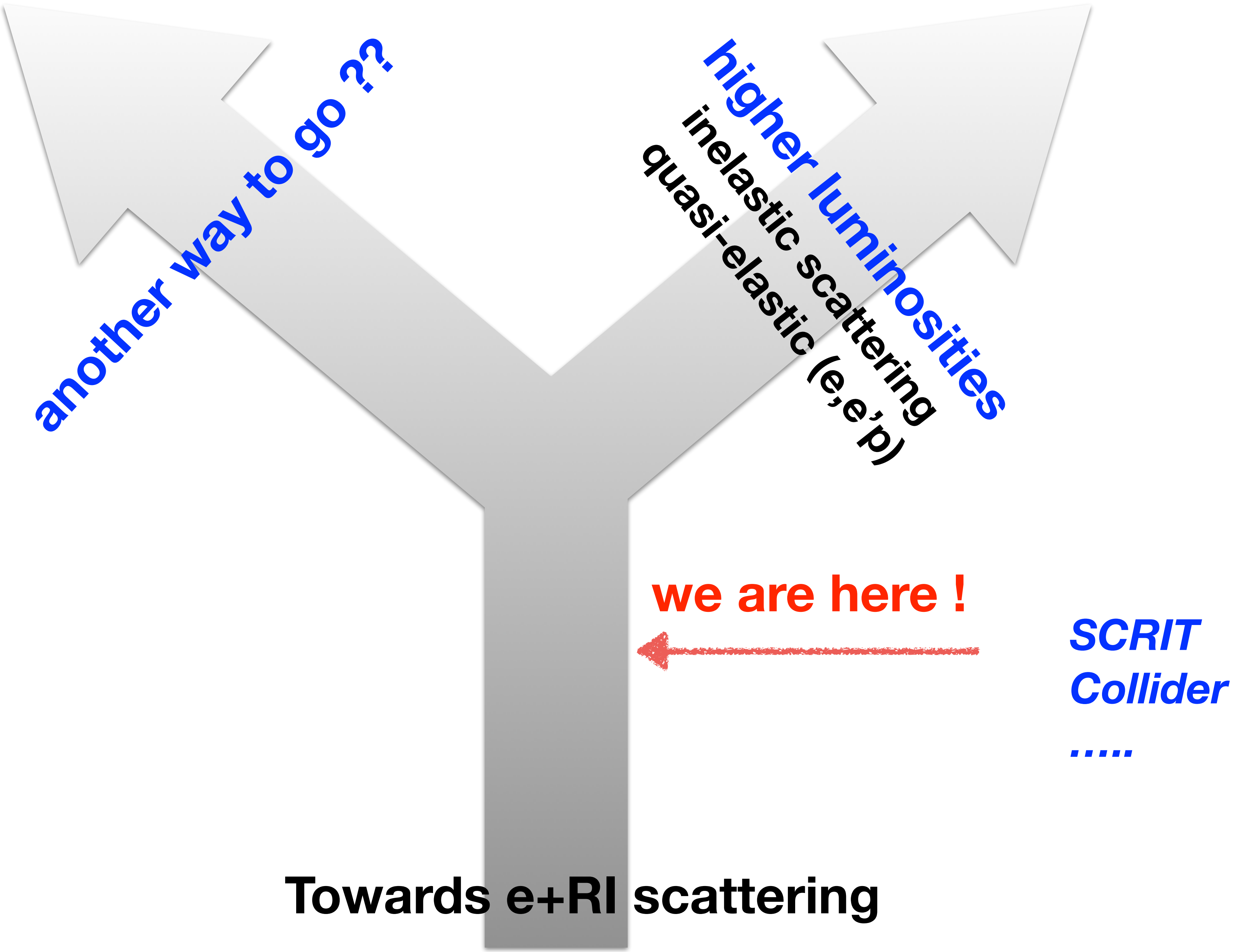
~10^7 ions on the electron beam

(Liq. Xenon for Dark matter search ?)

Switching to unstable ^{138}Xe this summer



Kyo Tsukada


another way to go ??
higher luminosities
inelastic scattering
quasi-elastic (e,e'p)
we are here !
SCRIT
Collider
.....
Towards e+RI scattering

Photonuclear reaction of exotic nuclei
at
the SCRIT electron scattering facility

Nuclear response function in the (ω, q) plane

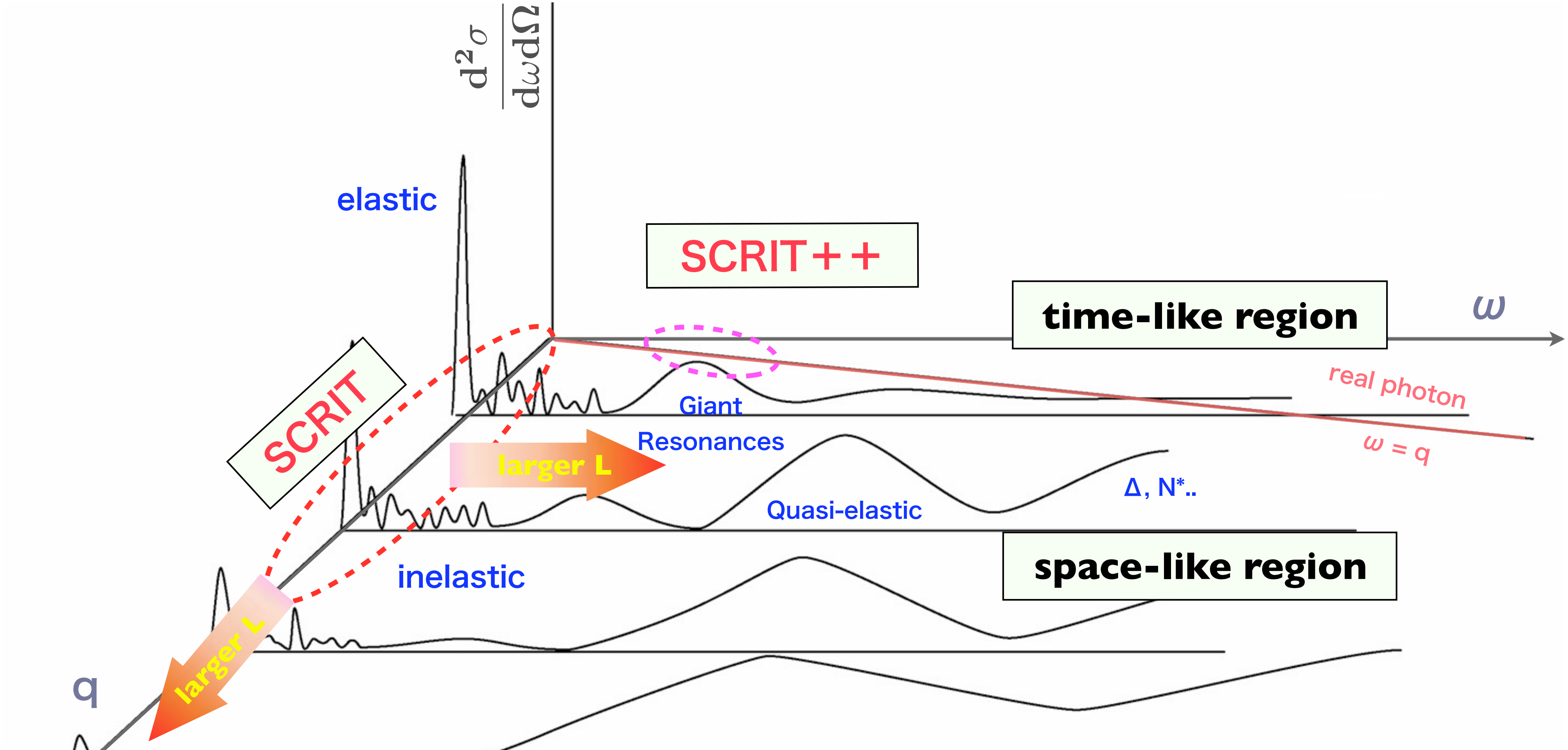
ω~ q (photon point)

ω ~ 0 MeV : isotope shift, β-NMR with stopped RI
ω ~ a few MeV : B(E2) (Coulomb excitation)

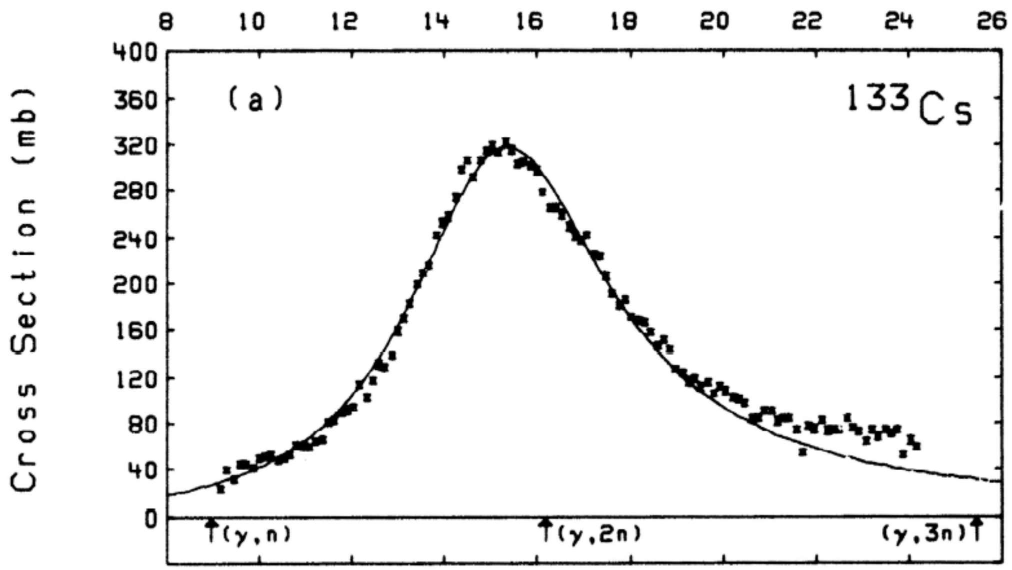
ω ~ a few 10 MeV : GDR @ SCRIT++ (Total Photoabsorption)

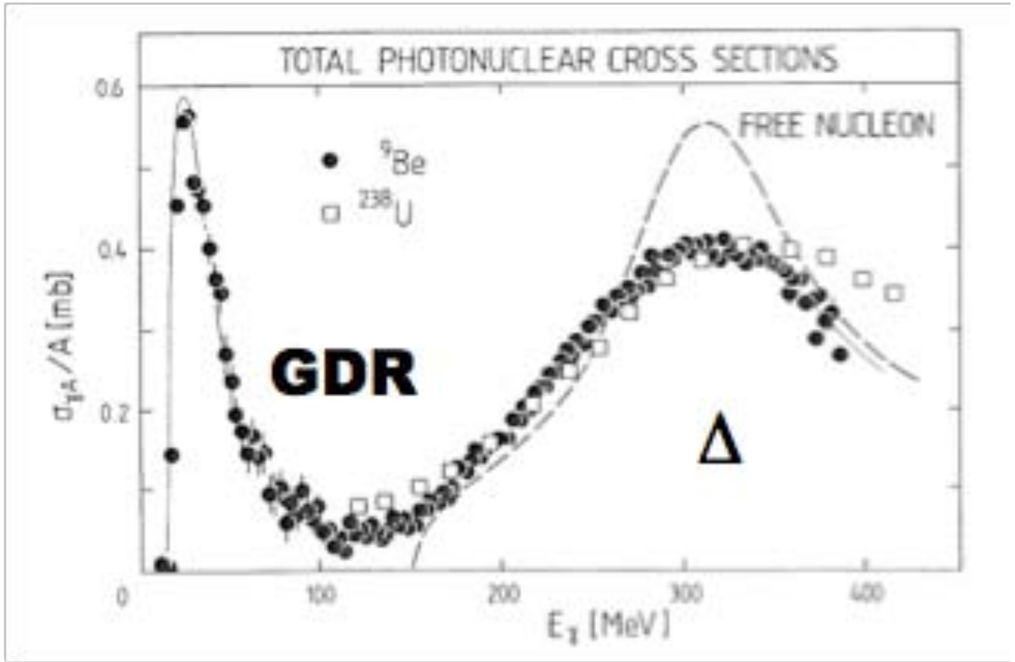
ω < q (electron scattering)

ω ~ 0 MeV : charge density distribution
ω > 0 MeV : transition density, Giant Resonance, QE (e,e'p) ...



Total Photoabsorption Cross Section





1) Response functions (operators : well-known)

2) E1 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

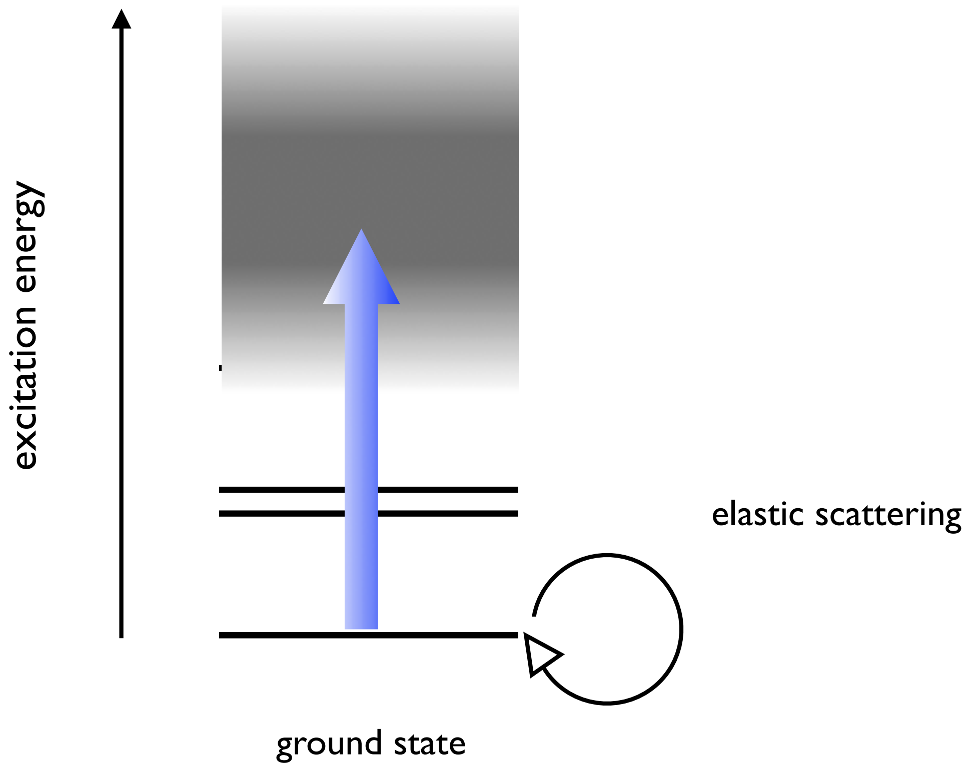
$$\int_0^\infty \frac{\sigma(E_\gamma)}{E_\gamma}dE_\gamma = \frac{4\pi^2 e^2}{3\hbar}\frac{NZ}{A-1} < r^2 >$$

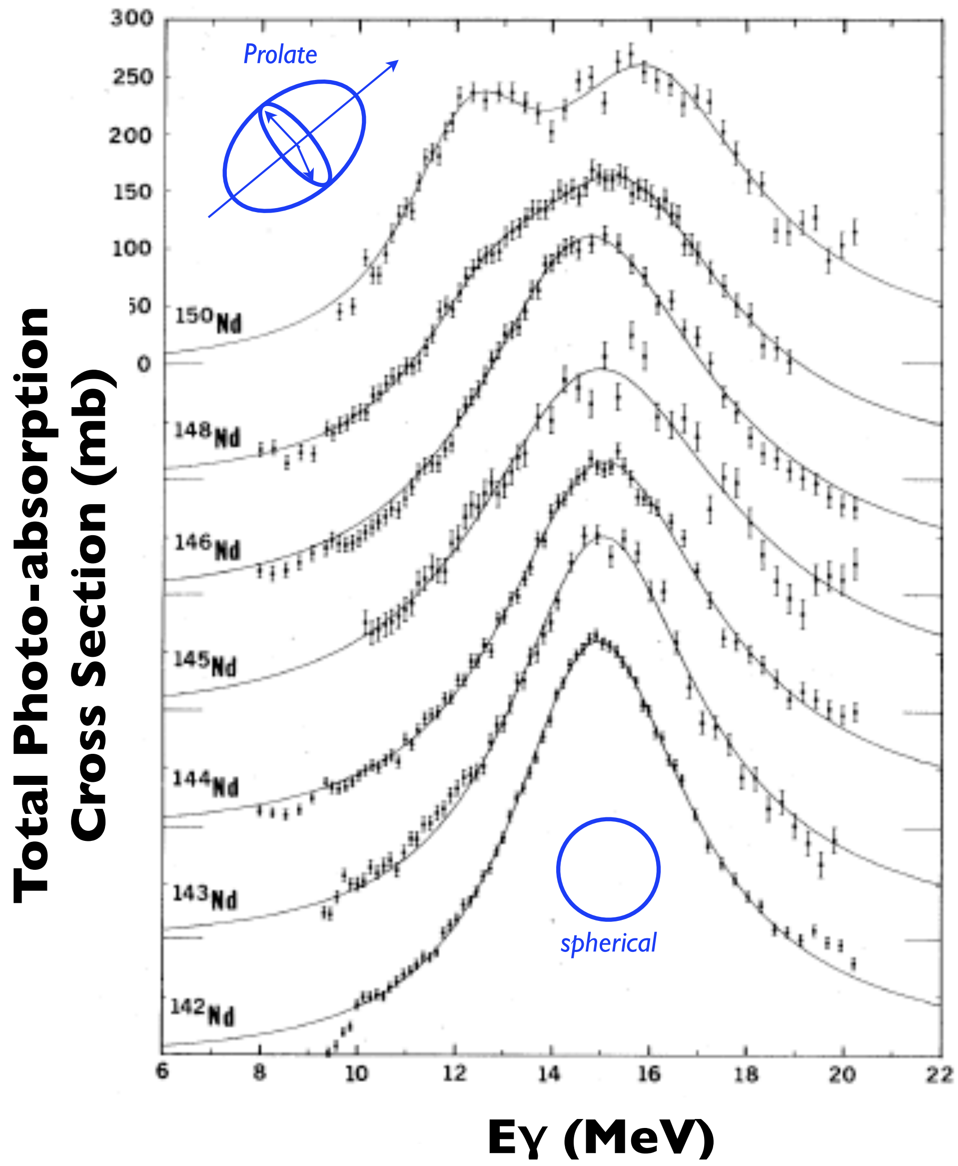
Migdal sum rule

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

P : polarizability

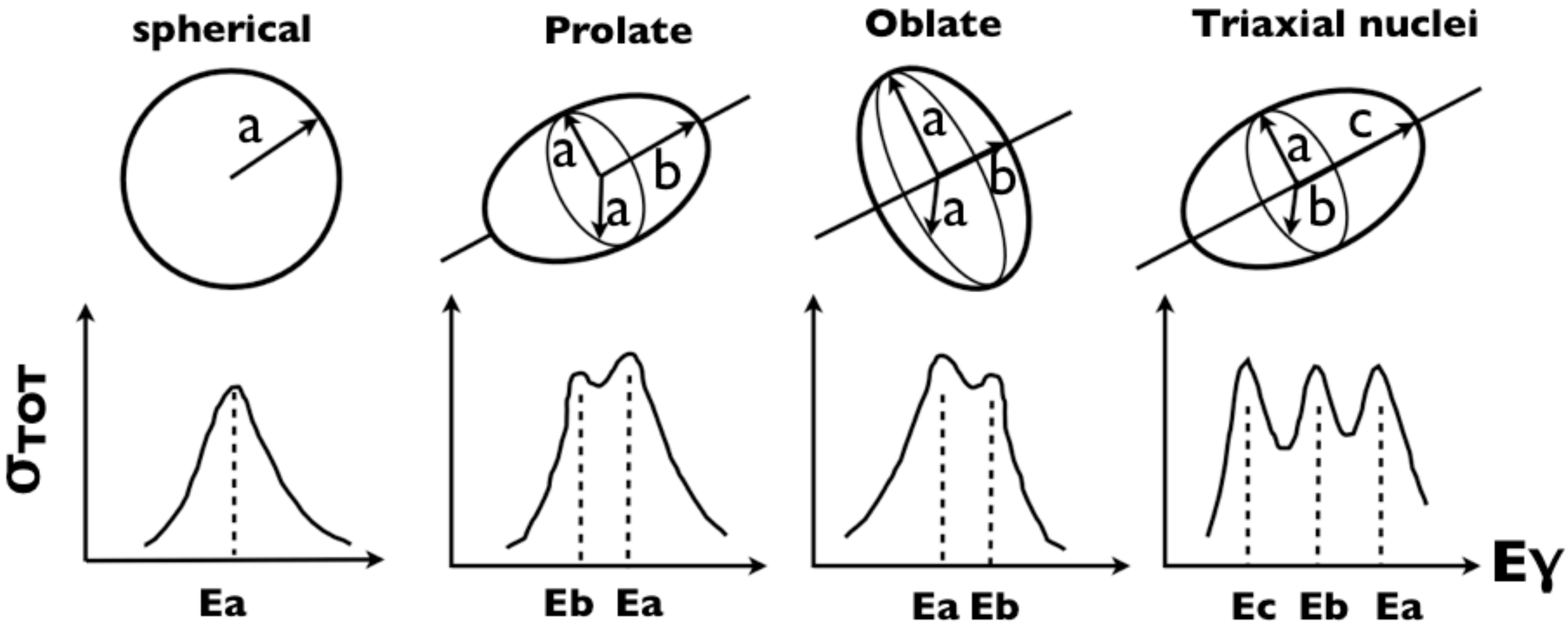
σ_{TOT} in GDR region





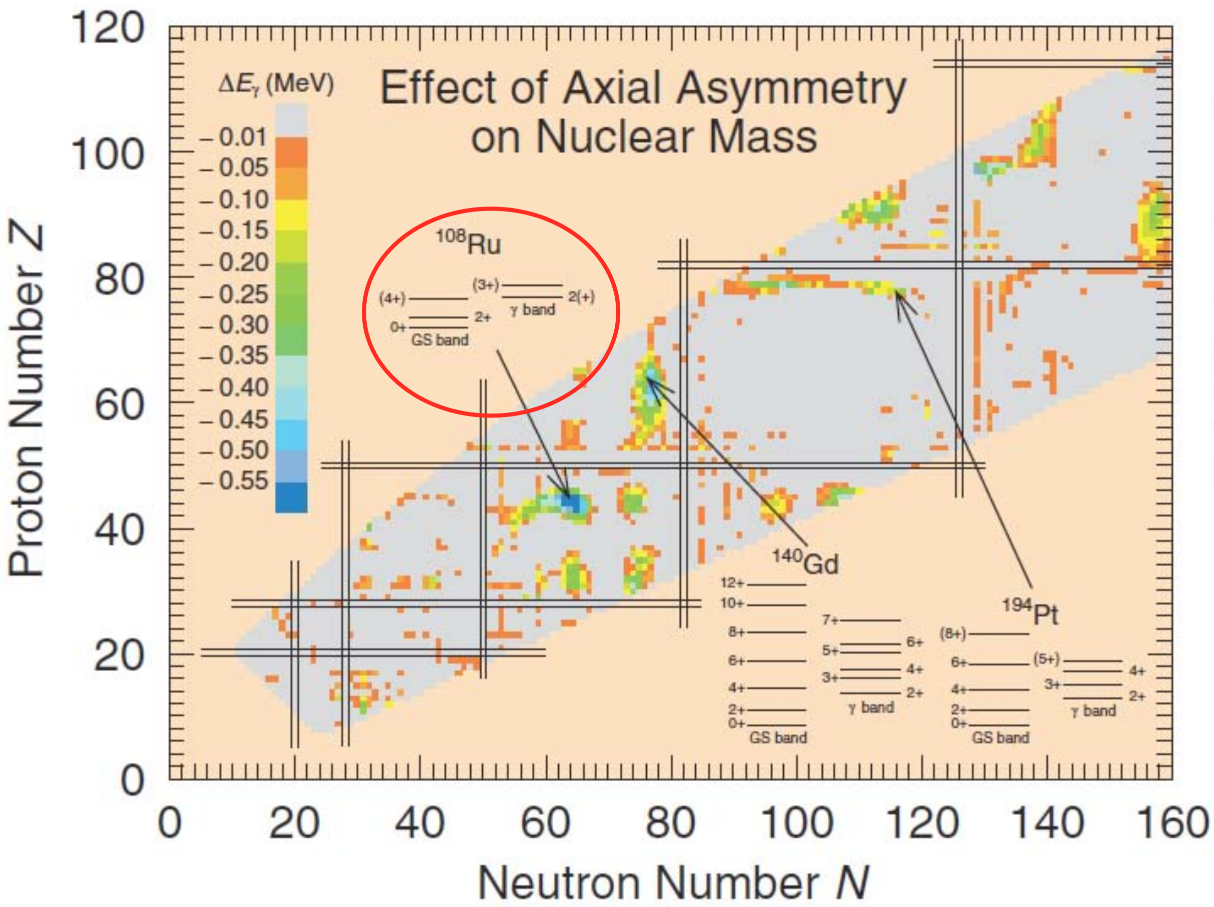
B. L. Berman and S. C. Fultz, Rev. of Mod. Phys. 47 (1975) 713

photo-nuclear responses of exotic nuclei

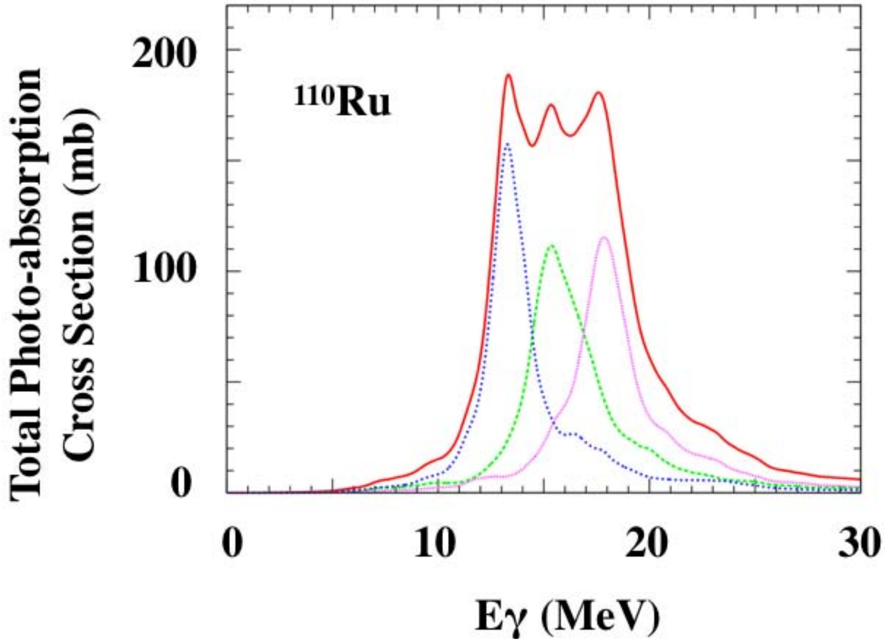


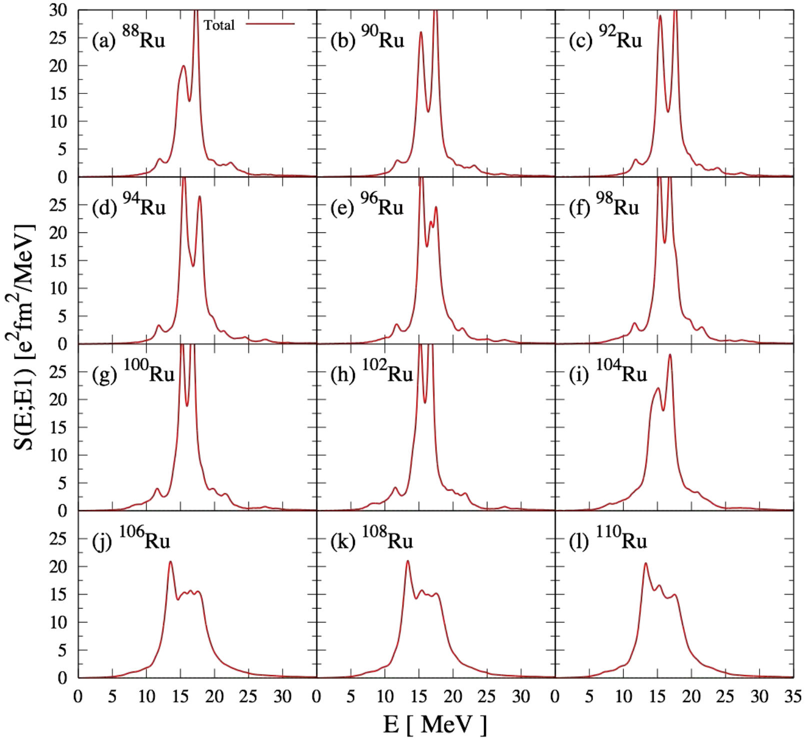
R. Bergere :Lecture Note in Physics, 61 (1971) 84

Triaxial nucleus and their $\sigma_{TOT}(E\gamma)$



P. Moller et al.,PRL97,162502 (2006)





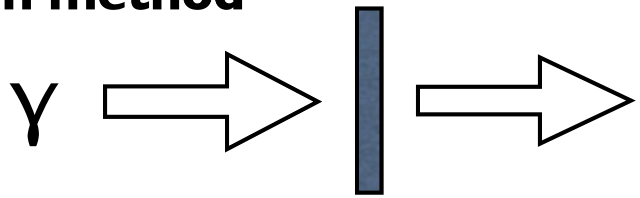
S. Ebata : private communication

^{108}Ru 273 sec

^{110}Ru 15 sec

Total Photoabsorption Cross Section

1. Attenuation method

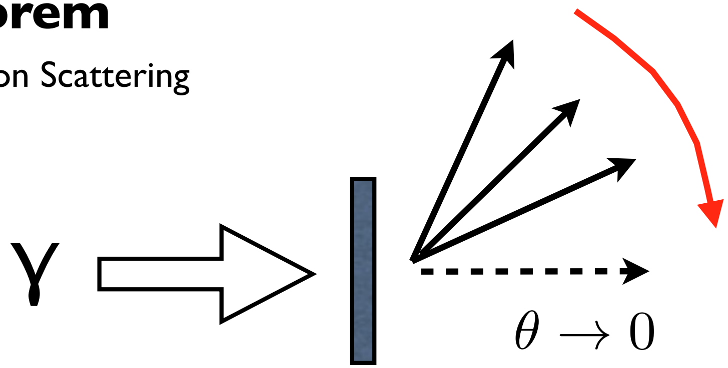


$$N(E_\gamma) = N_0(E_\gamma)e^{-n\sigma_{tot}(E_\gamma)}$$

$$\sigma_{tot}(E_\gamma) = \sigma_{tot}^{nucl}(E_\gamma) + \sigma_{tot}^{atomic}(E_\gamma)$$

2. Optical theorem

(elastic) Compton Scattering



$$\frac{d\sigma}{d\Omega}(E_\gamma, \theta) = |R(E_\gamma, \theta)|^2$$

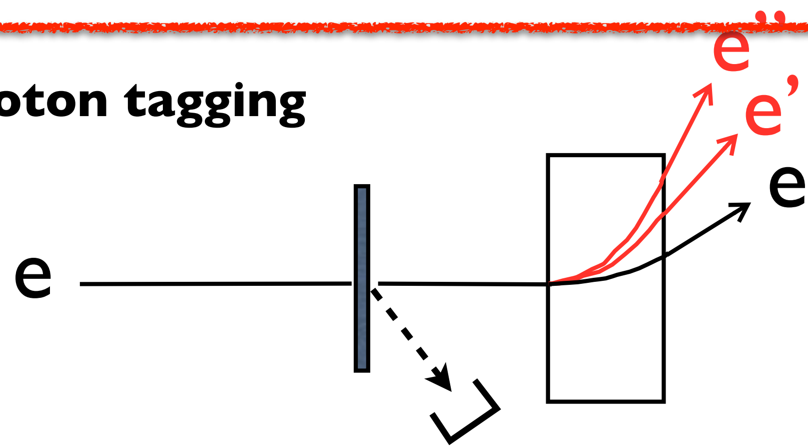
$$\sigma_{tot}(E_\gamma) = 4\pi\frac{\lambda}{2\pi} \cdot ImR(E_\gamma, 0)$$

3. detecting all final states

few nucleon system, heavy nucleis (γ,xn)

$$\sigma_{tot}(E_\gamma) = \sigma_{tot}^{A}(E_\gamma) + \sigma_{tot}^{B}(E_\gamma) + \sigma_{tot}^{c}(E_\gamma) + \ldots$$

4. virtual photon tagging

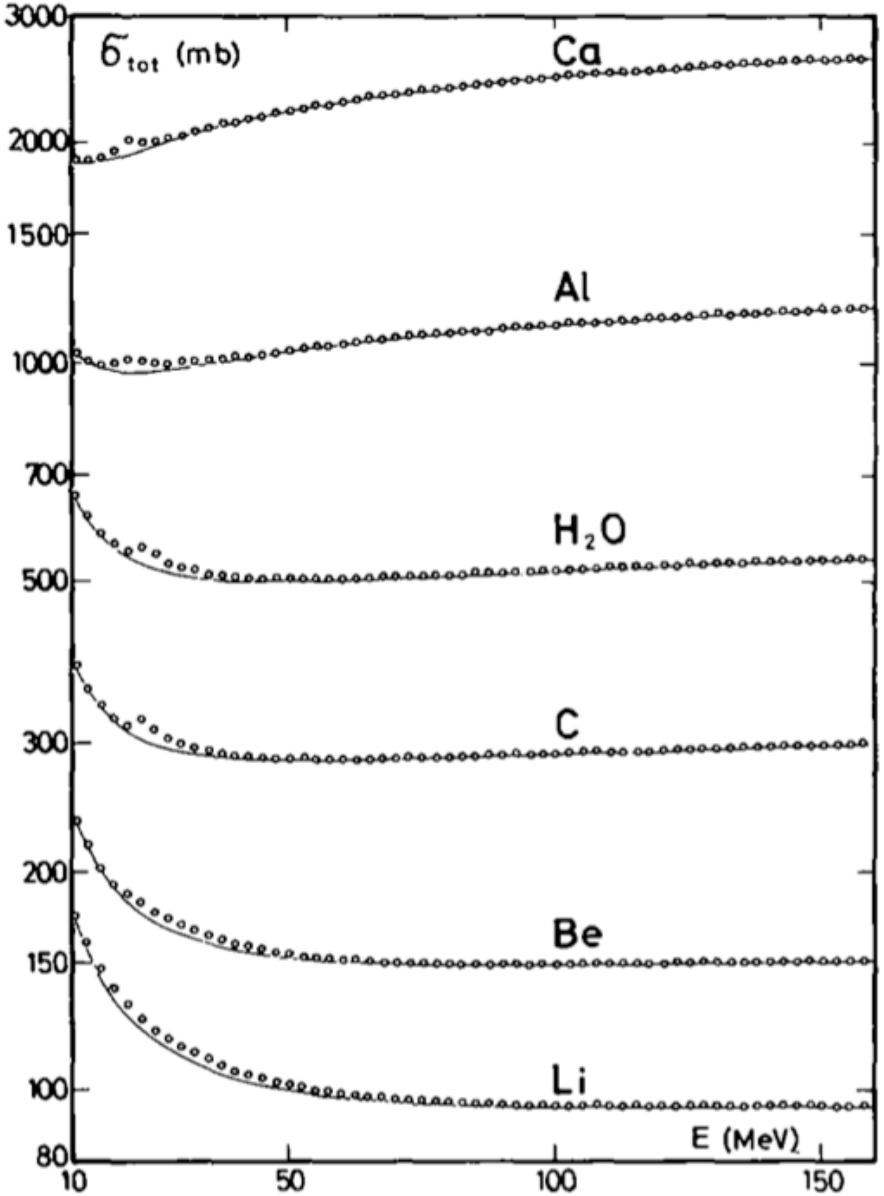


electro-excitation
+ virtual photon theory

photo-reaction cross section

σ_{TOT} by attenuation method

under huge EM backgrounds (Compton scattering, pair production)



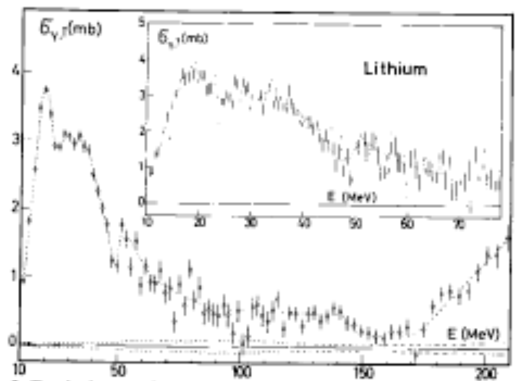


Fig. 2. Total photonuclear cross section for natural Li. The error bars indicate one standard deviation of counting statistics from the main spectrometer. The dashed lines along the abscissa indicate the uncertainty due to counting statistics in the normalizing spectrometer. Oscillations of the base line within this area are possible, the period of these oscillations, however, must not be smaller than 10% in photon energy. The dashed and dotted lines through the cross section values have been drawn to guide the eye.

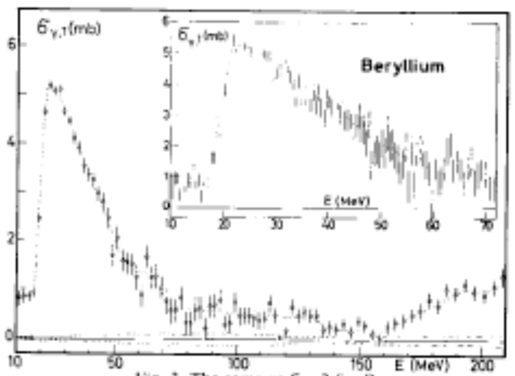


Fig. 3. The same as fig. 2 for Be.

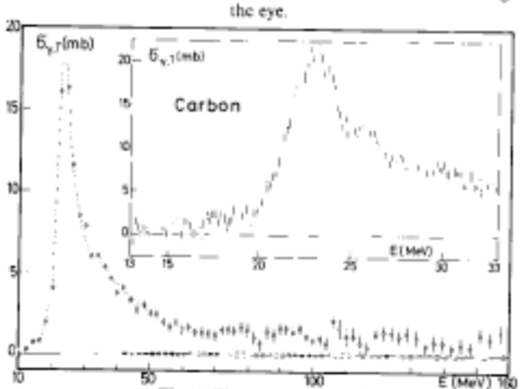


Fig. 4. The same as fig. 2 for C.

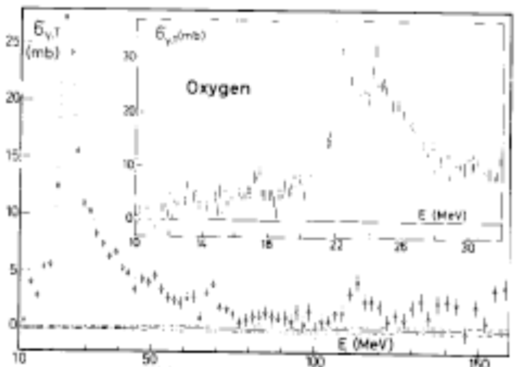


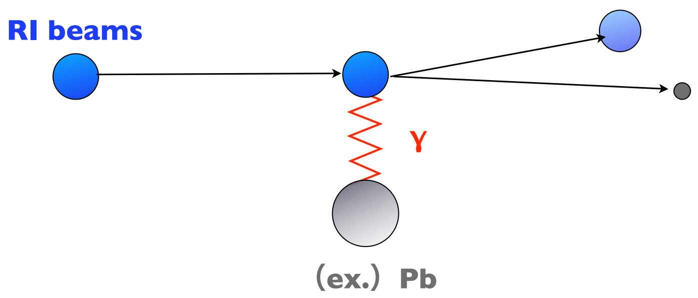
Fig. 5. The same as fig. 2 for O.

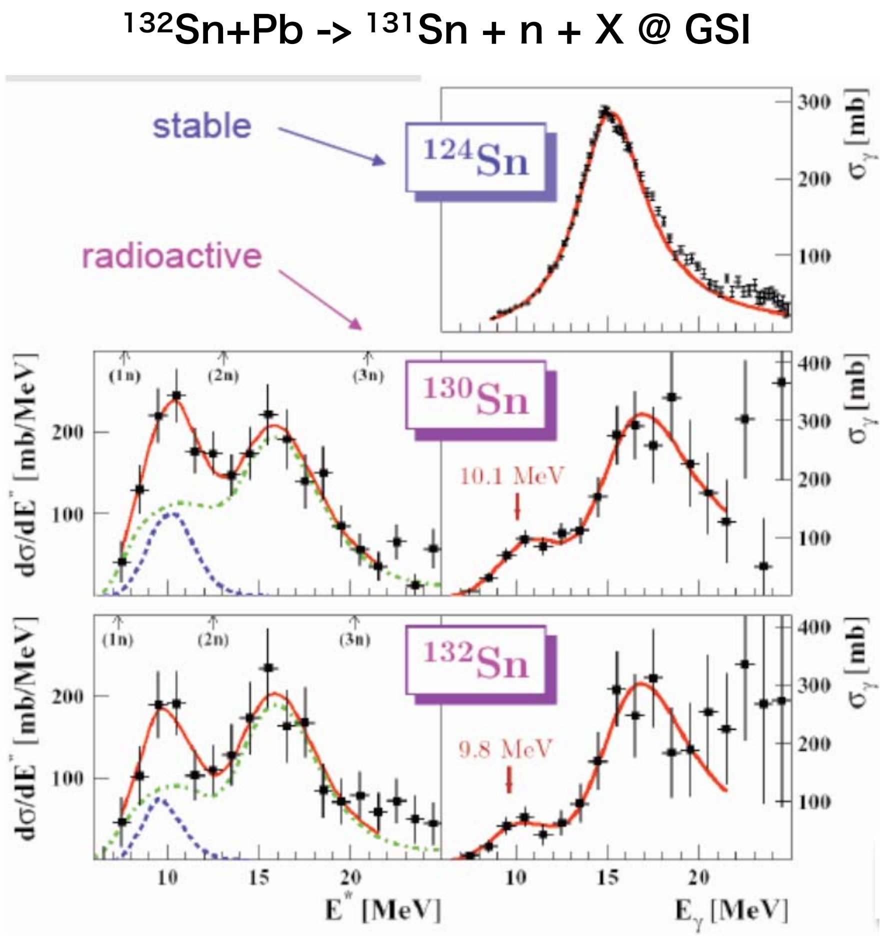
J. Ahrens et al., NIM 108 (1973) 517

photonuclear reaction for exotic nuclei

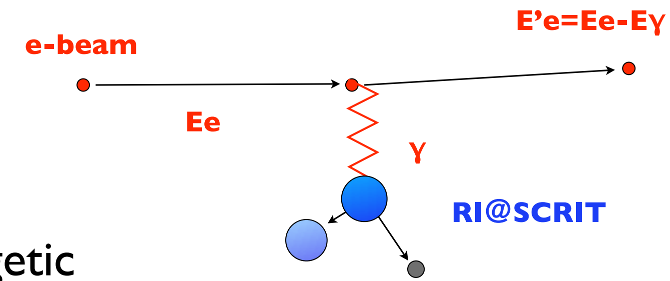
so far

only way : Coulomb excitation in heavy ion reaction
: strong int. and/or multi steps ???





SCRIT facility



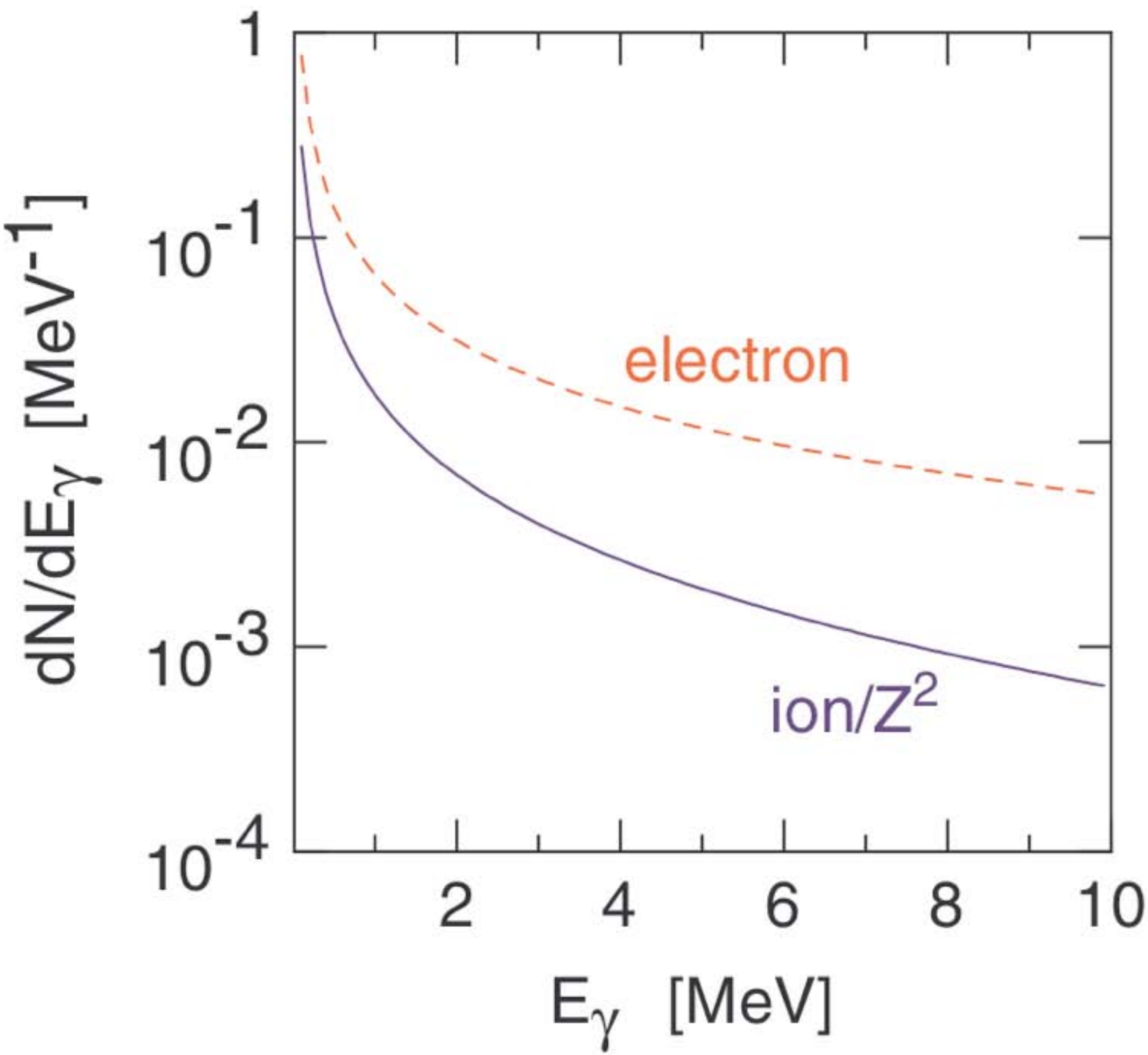
purely electromangetic
well under control
negligible multi-stop

ultra-forward
electron scattering

Virtual Photon flux

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

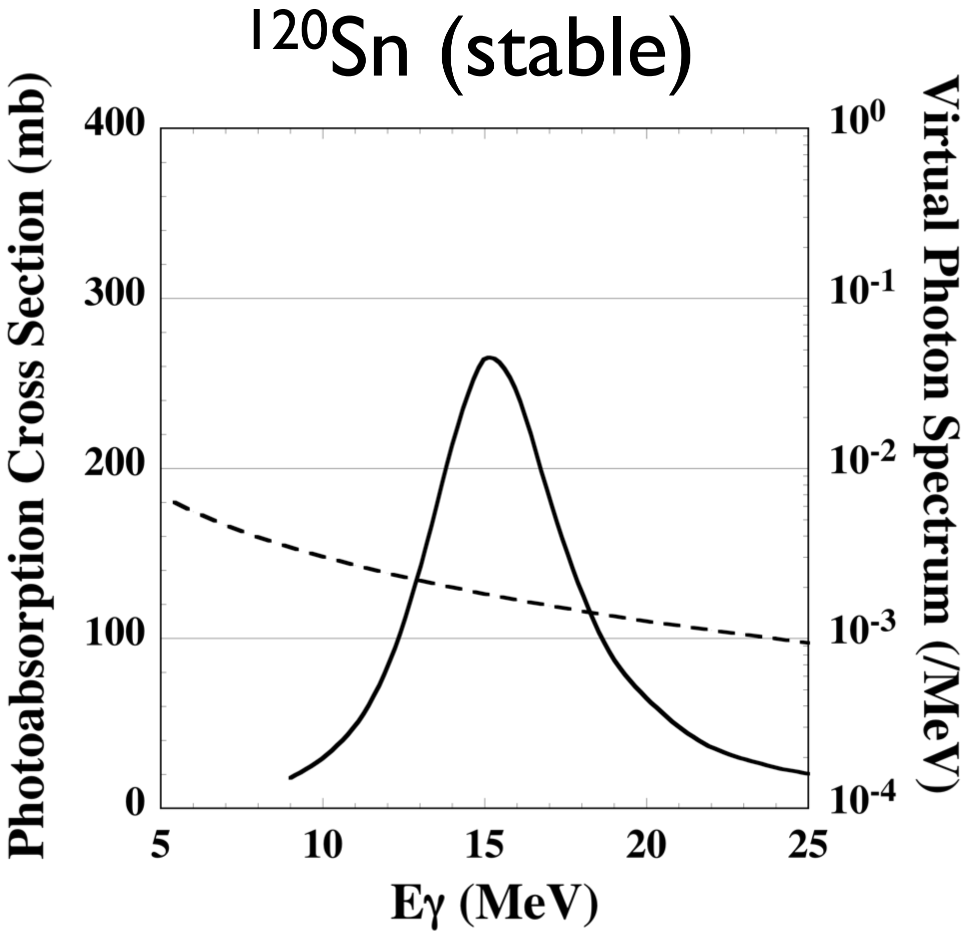
Virtual photon flux

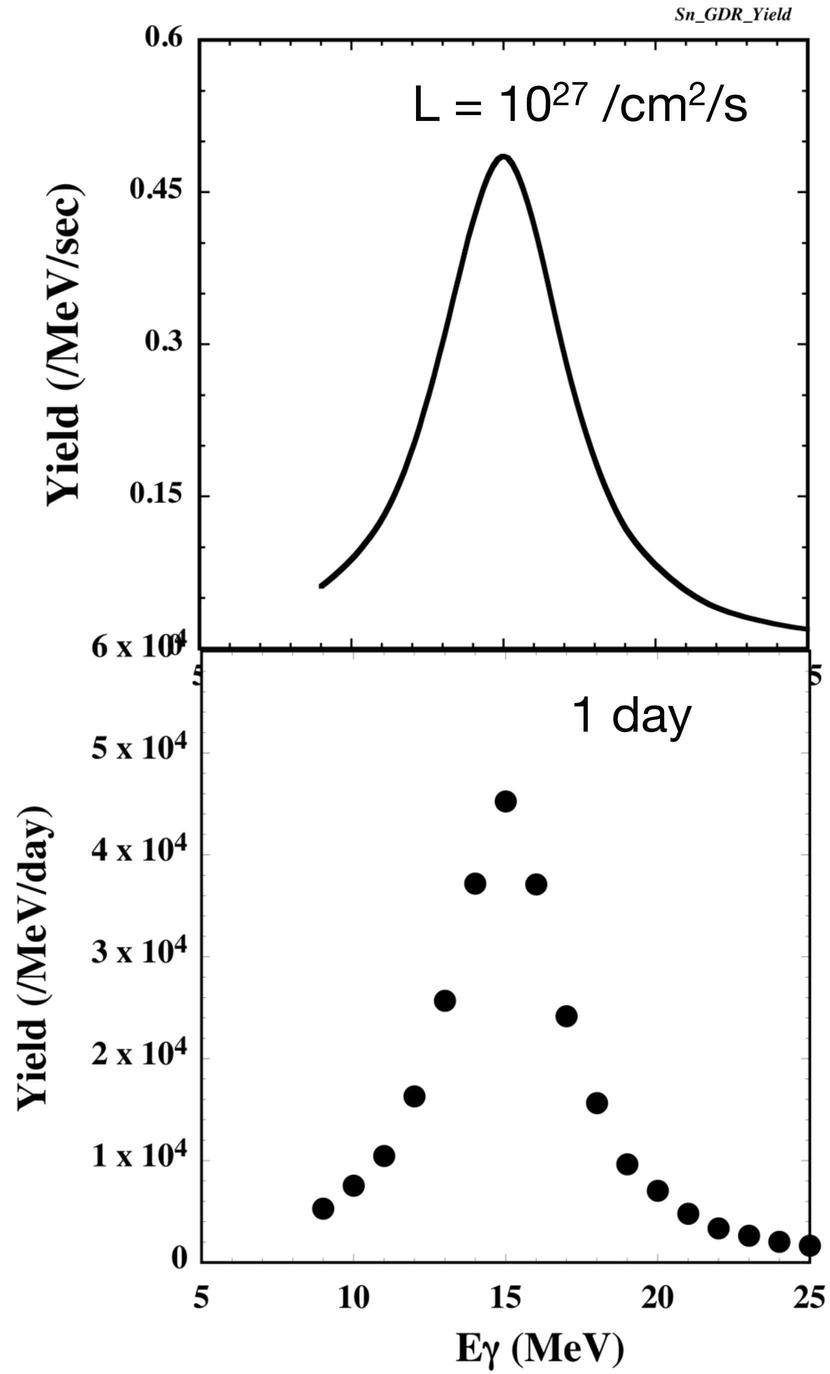


Expected reaction rate for $L = 10^{27}$ /cm²/s

virtual photon theory

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



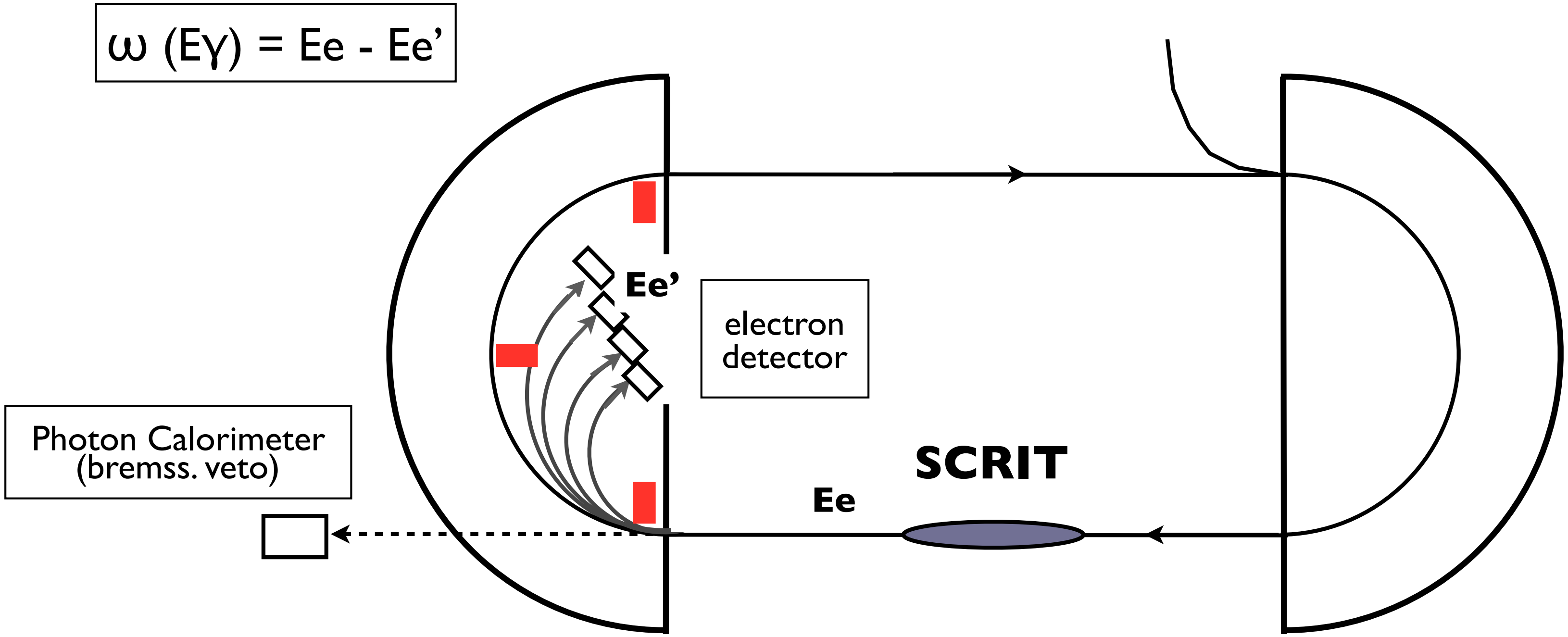


P. Durgapal and D.S. Onley
Comp. Phys. Comm. 32 (1984) 291

Possible photoabsorption exp. at the SCRIT facility

Inclusive measurement :

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



background sources

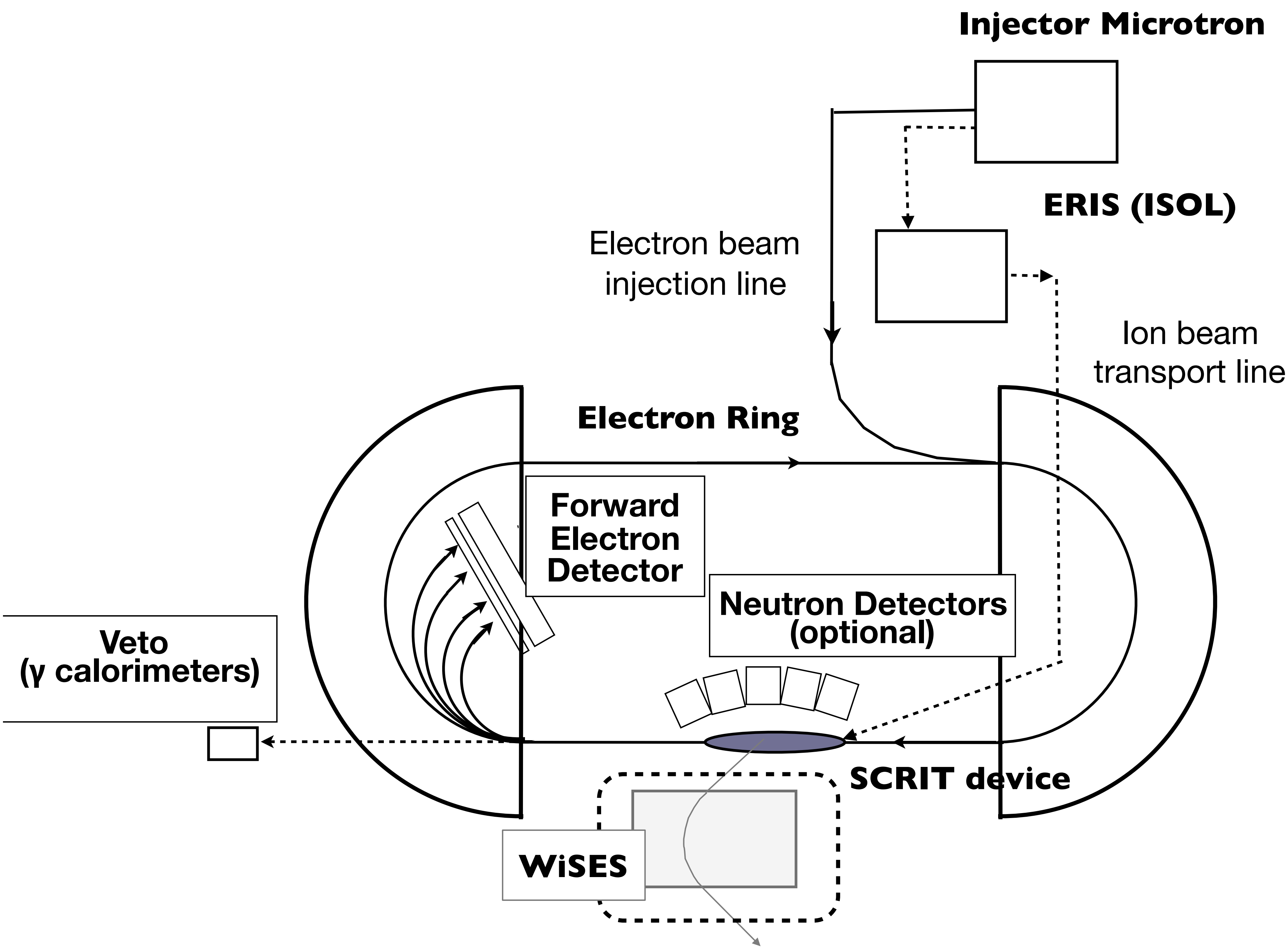
1) lost electrons from the circulating orbit

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.


Injector Microtron
ERIS (ISOL)
Electron beam
injection line
Ion beam
transport line
Electron Ring
Forward
Electron
Detector
Neutron Detectors
(optional)
Veto
(γ calorimeters)
SCRIT device
WiSES

Conclusions

1. SCRIT electron scattering facility started its operation.
2. Electron accelerator + SCRIT system : req. luminosity achieved ($L \sim 10^{27}$ /cm^2/s)
3. ISOL (γ+U) : towards higher beam power (a few W -> 20 W ---> 1 kW) : ~10^8 fission/W
4. first e+RI (^{138}Xe, ^{132}Sn) scattering starts soon @ $L > 10^{25-26}$ /cm^2/s !!

5. photonuclear response of exotic nuclei

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