Towards Hofstadter's experiments for exotic nuclei

a novel trap of rarely-produced short-lived nuclei
for electron scattering

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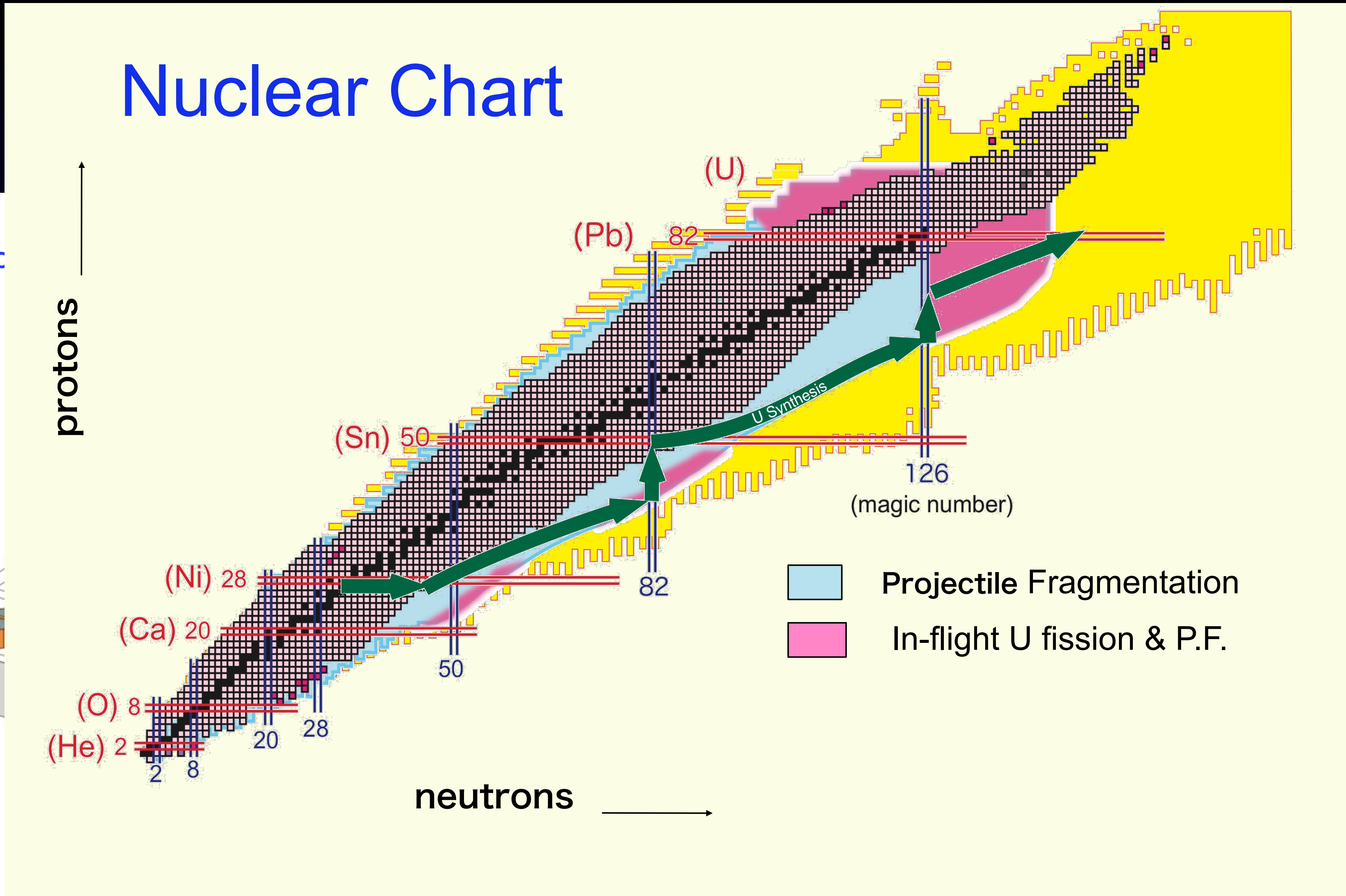
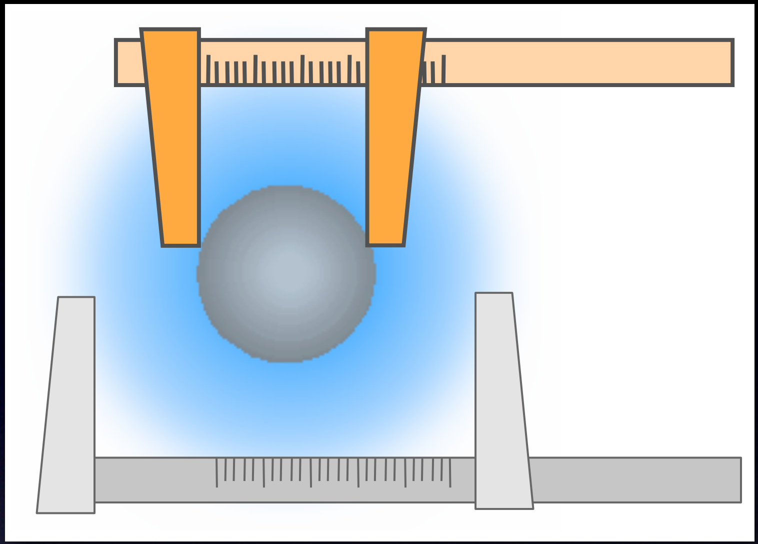
PRL 101 (2009) 102501.

RIKEN RI Beam Factory (RIBF)

primary beam : p - U (350 AMeV, β~0.7)
goal intensity : 1 puA (~6×10^{12} particle/s)



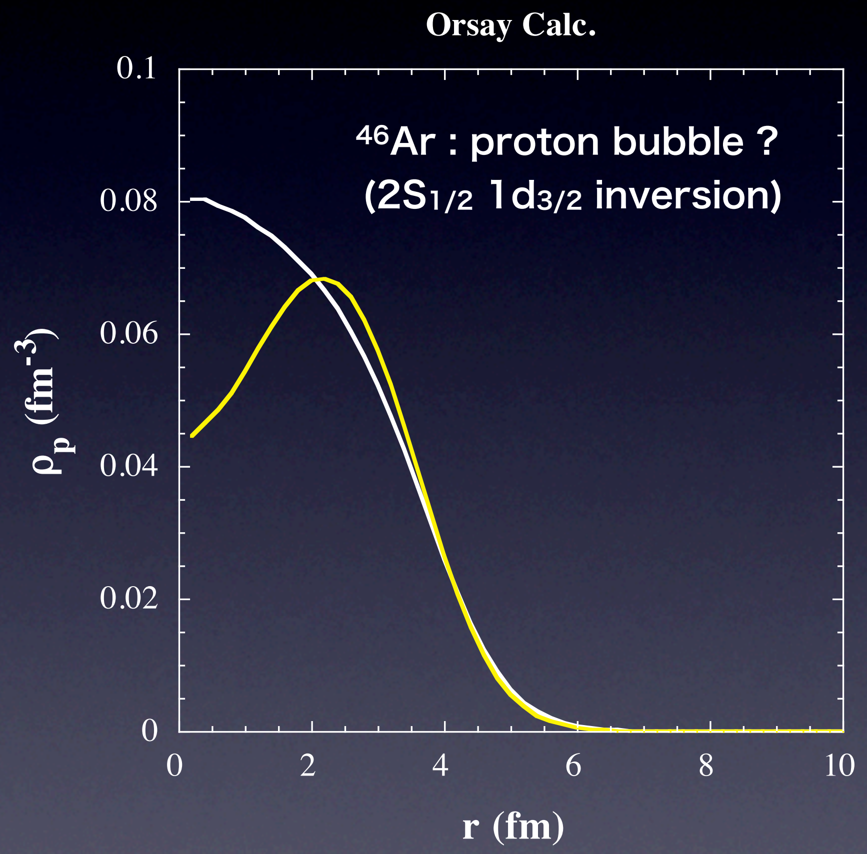
Size and shapes of exotic nuclei

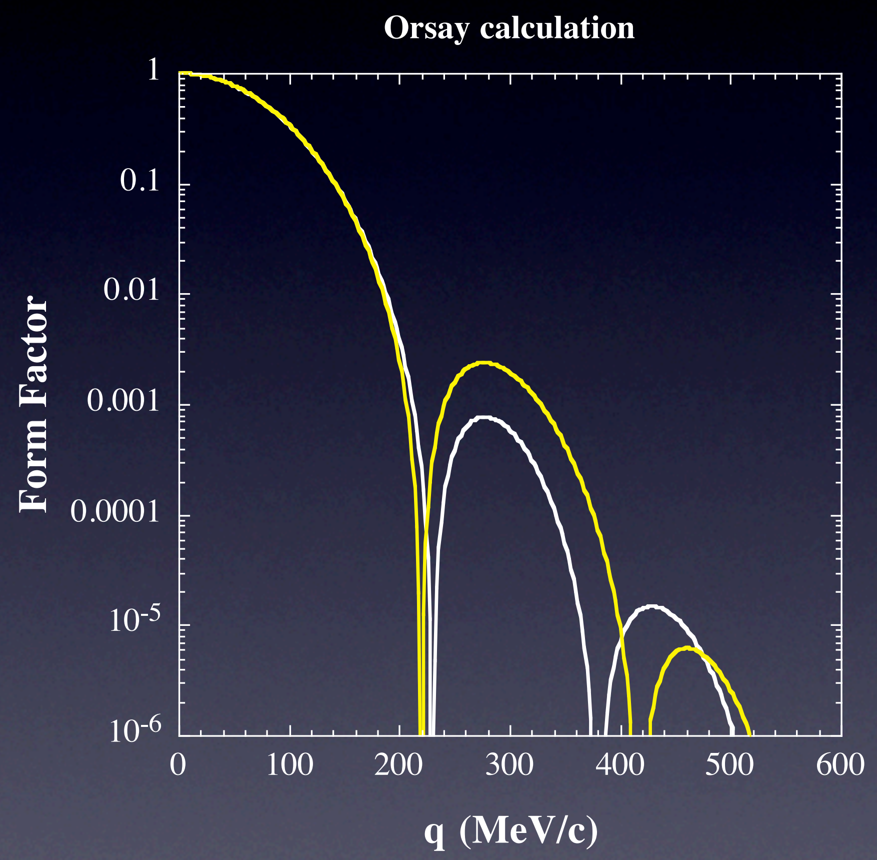


	size	shape
proton	isotope shift	electron scattering
neutron	reaction cross section	proton scattering

An example of charge distribution for exotic nuclei

E. Khan et al. : NP A800 (08) 37.





electron scattering for short-lived nuclei

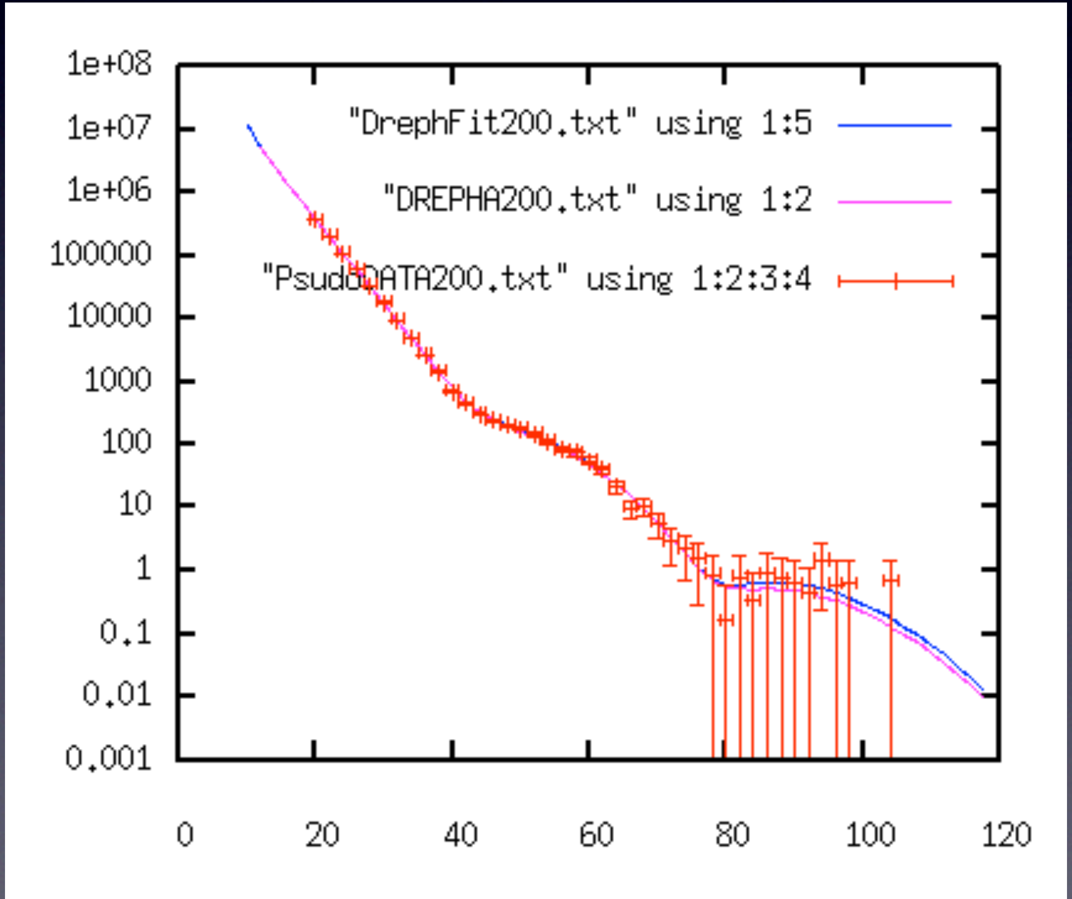
key : luminosity

$L = 10^{26}$ /cm^2/s

Ee = 200 MeV 1 week

$\Delta\theta$ = 1 deg. $\Delta\phi$ = 90 deg.

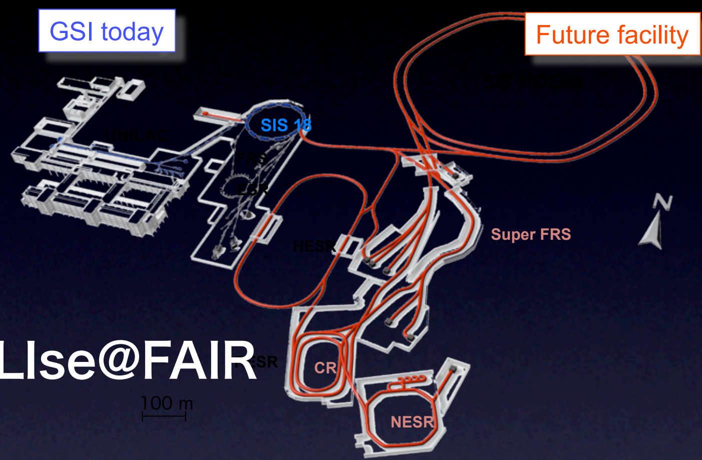
Sn isotopes



How to realize electron scattering experiments off short-lived Radioactive Isotopes (RI) ?

e-RI collider

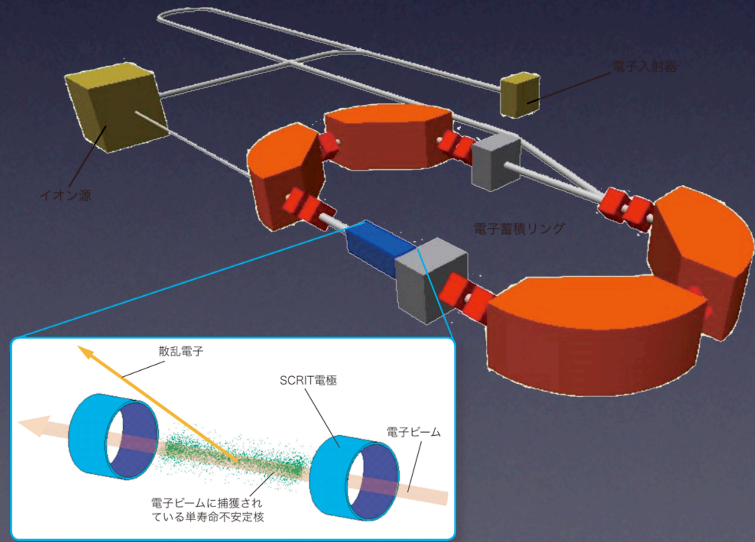
a large accelerator complex
including a cooler ring and a collider



ELIse@FAIR

RI at rest

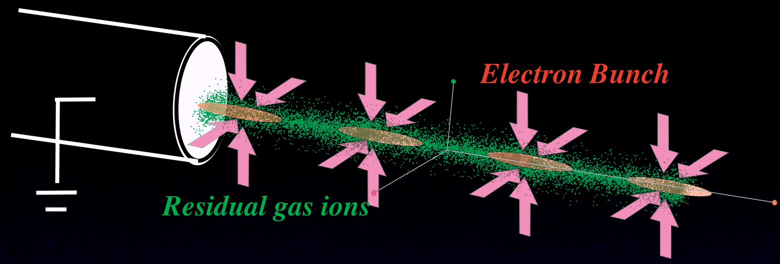
electron ring only



SCRIT@RI Beam Factory

SCRIT (Self-Confining RI Target)

"Ion trapping" phenomena observed at electron rings

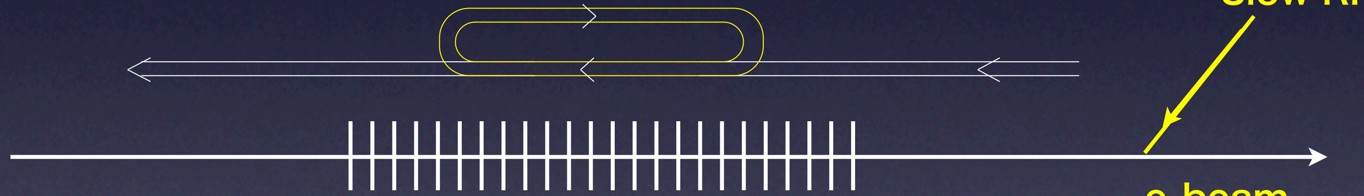


V ~ -20V @ 100 mA

ionized residual gases by electrons are trapped by electron beam itself.

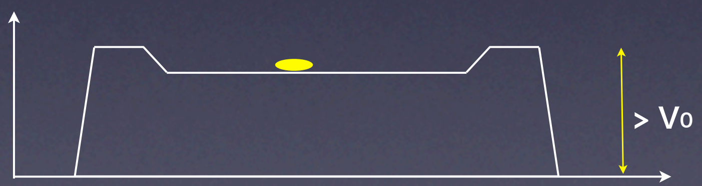
the trapped ions kick out electrons ---> shorter beam lifetime

electron scattering !!



transverse : ion trapping

longitudinal : mirror potential



precise position control -> higher luminosity

fast ion manipulation -> short-lived nuclei

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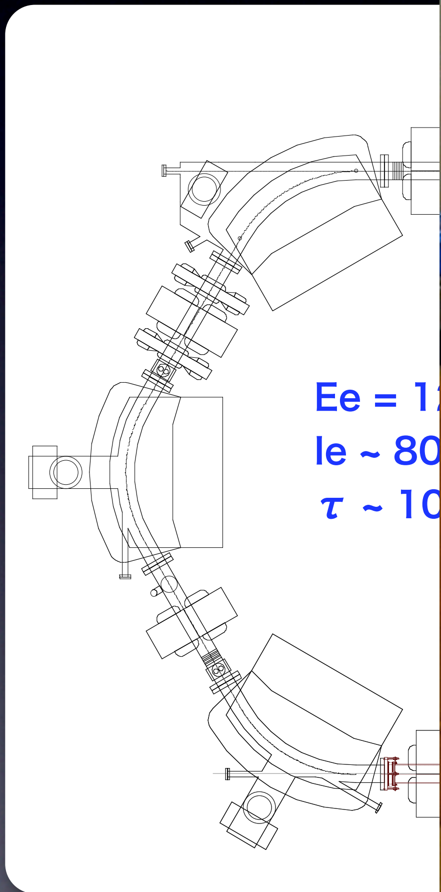
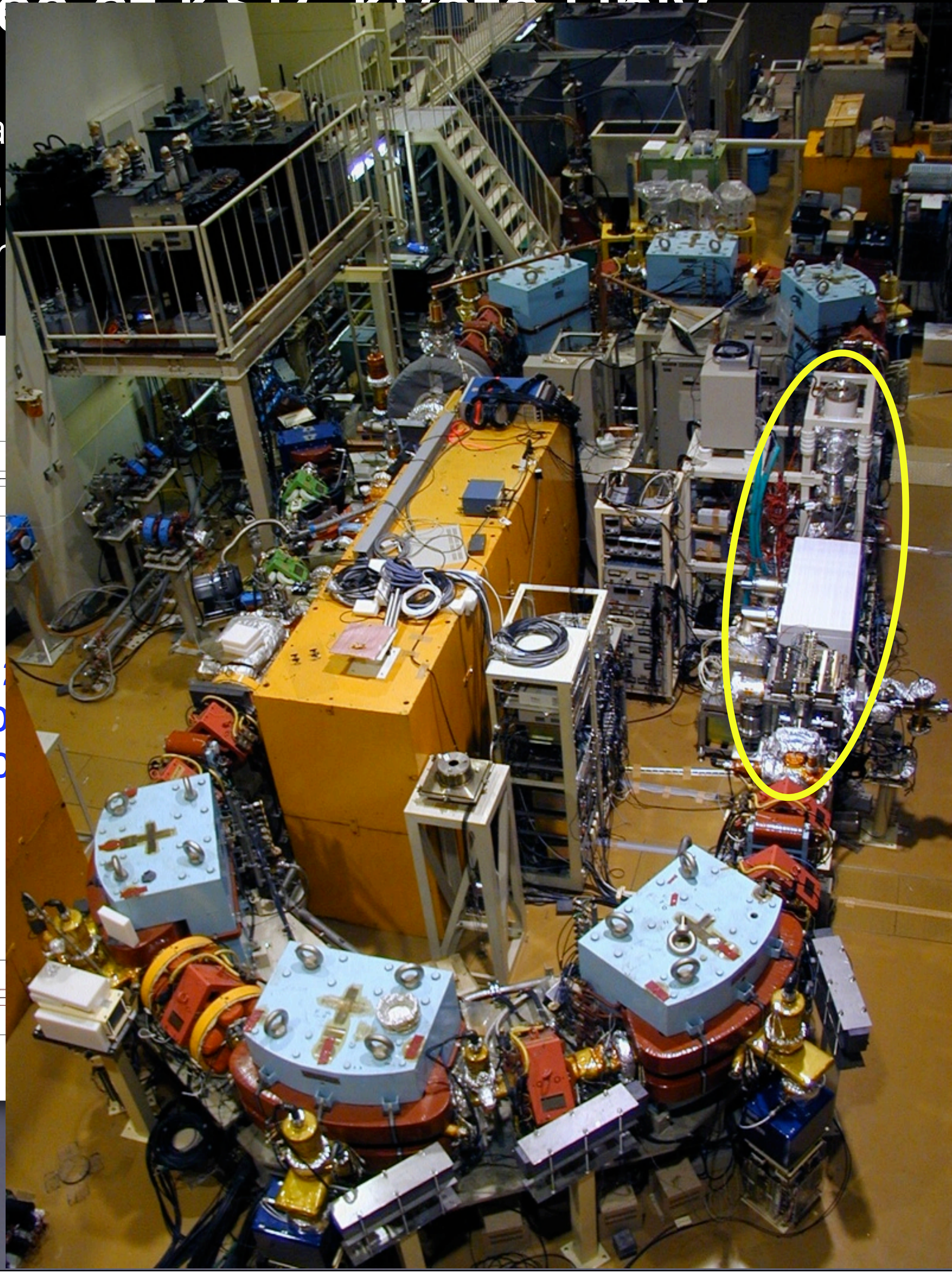
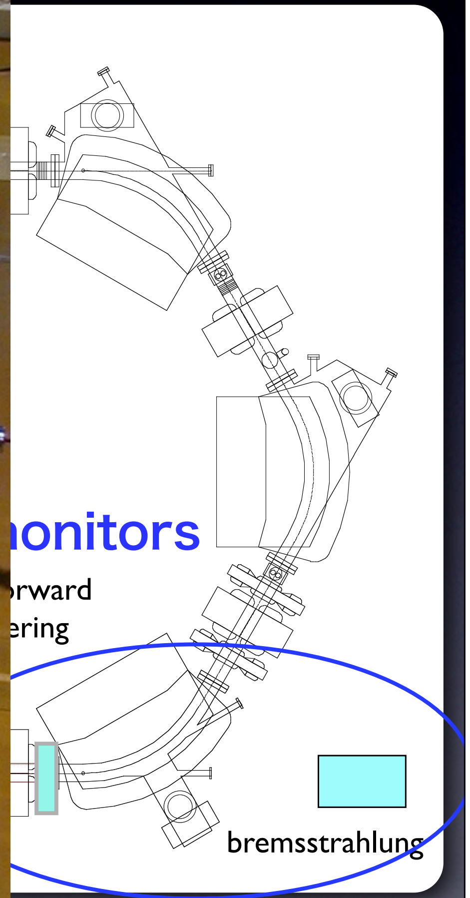
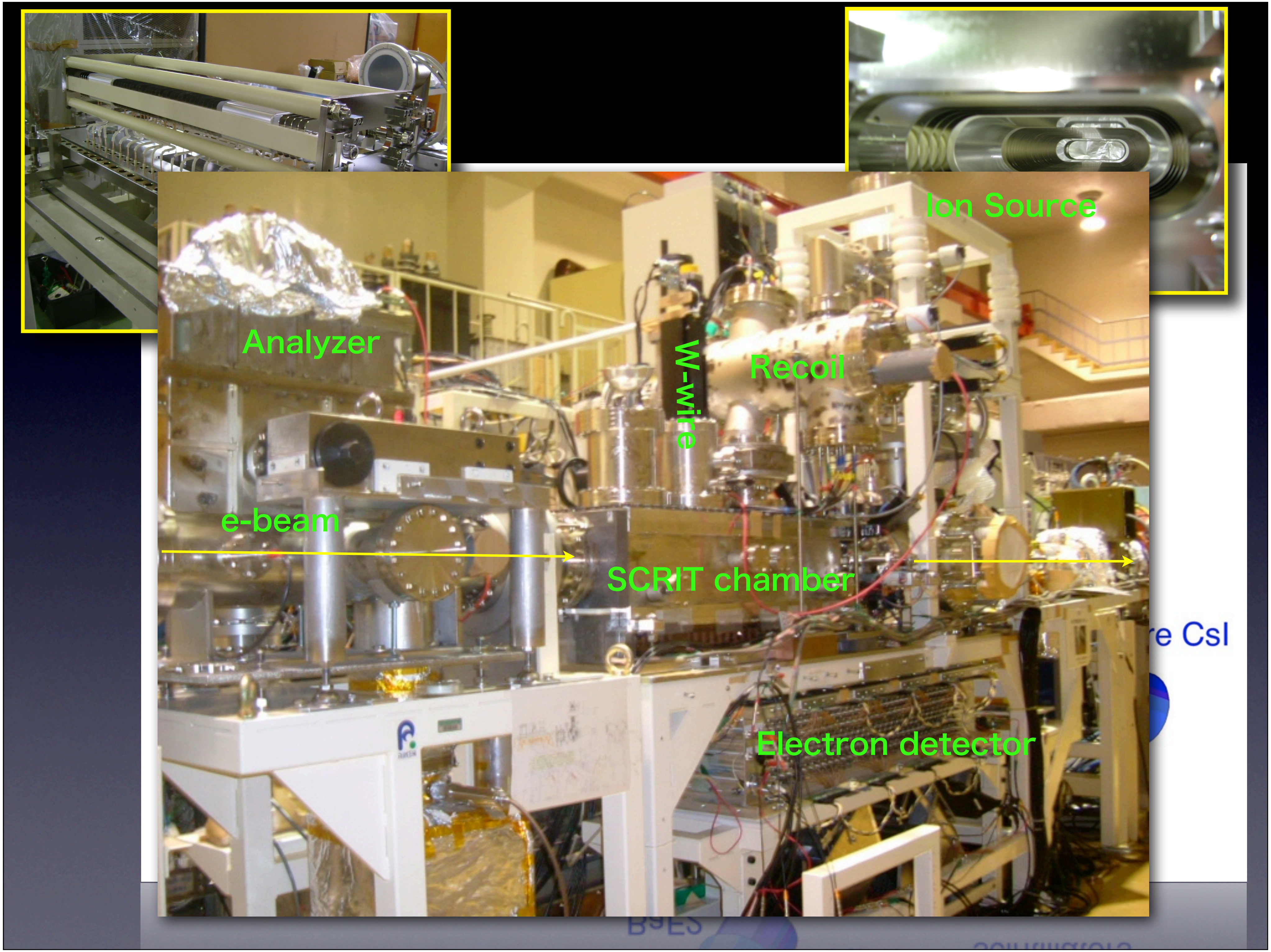
R&D studi

- externa
- high en
- number ... ity



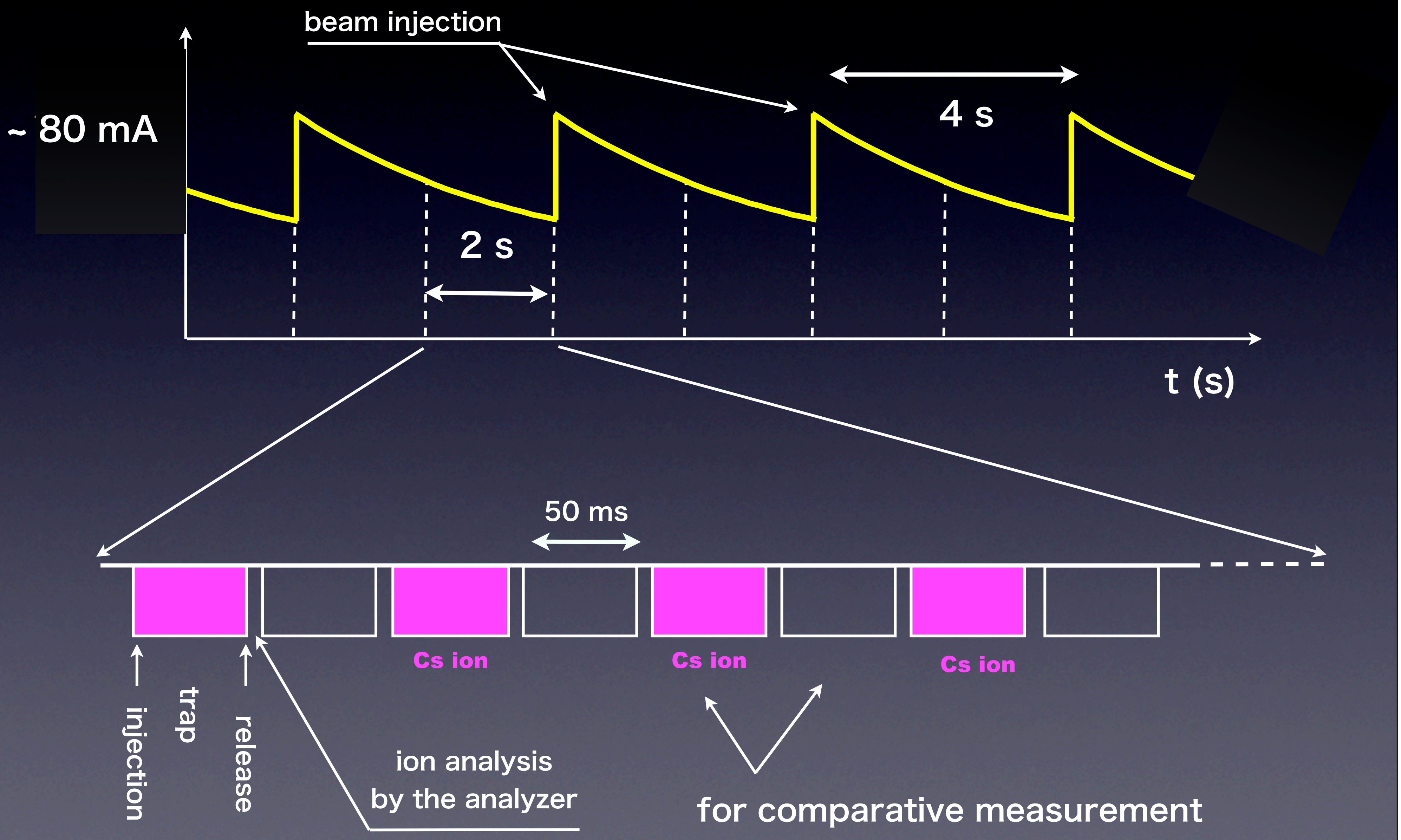




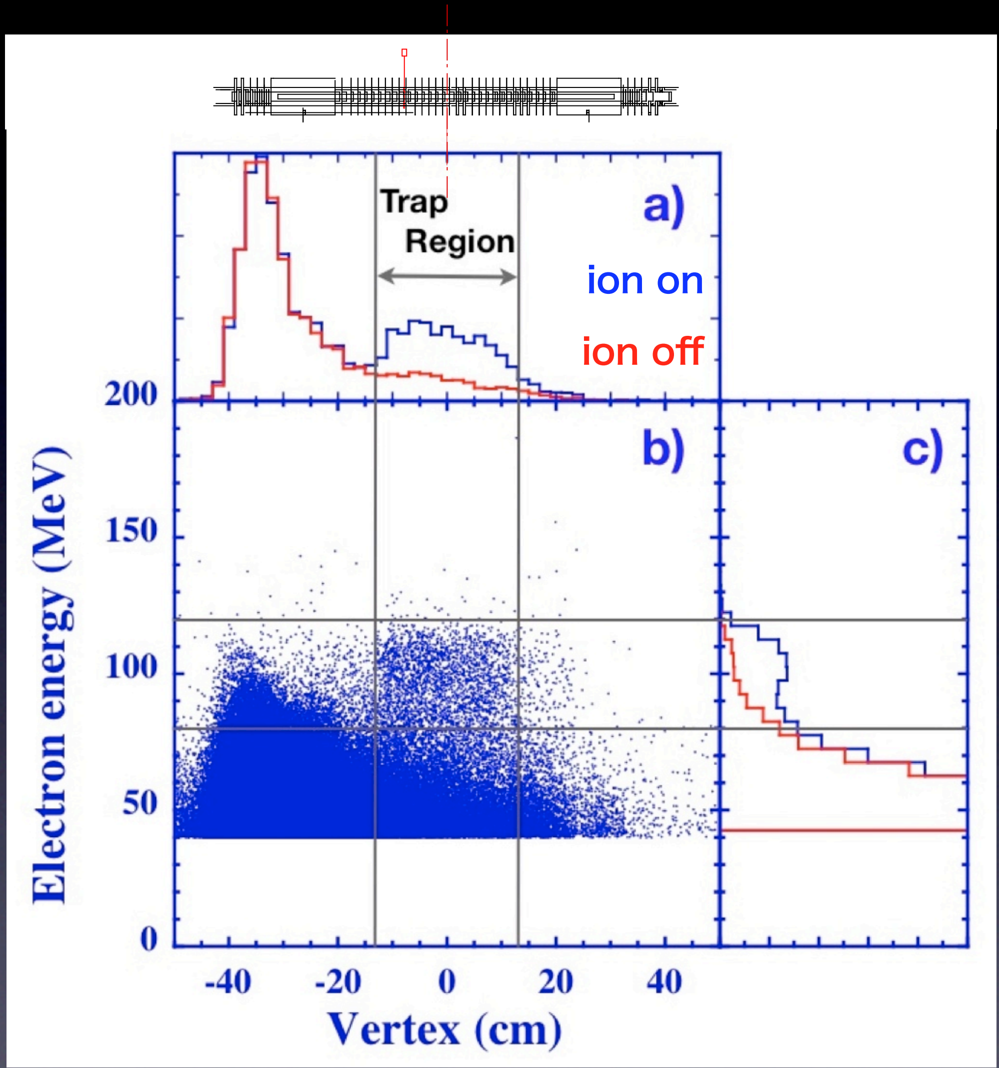

Ion Source
Analyzer
W-wire
Recoil
e-beam
SCRIT chamber
Electron detector

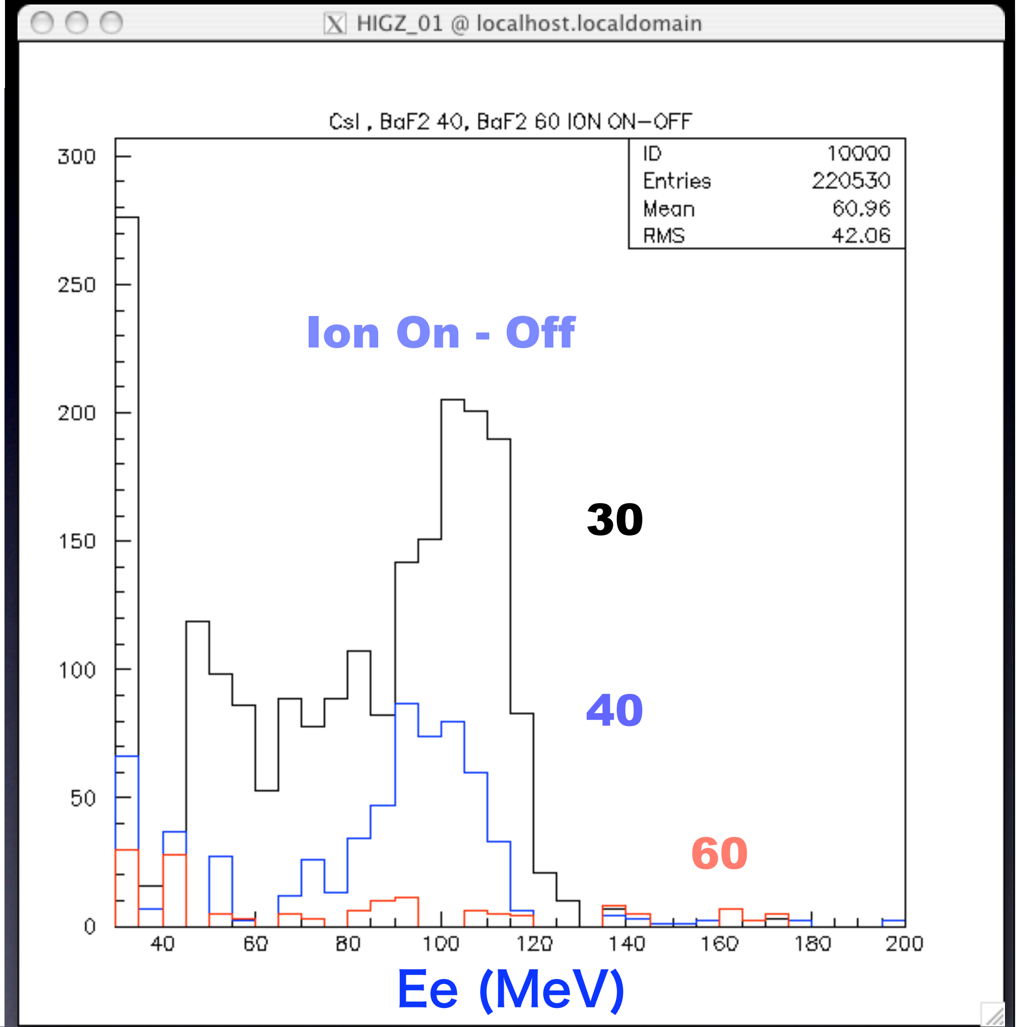
Time sequence of the measurement

beam lifetime of KSR τ~100 s @ 80 mA



electron scattered from the trapped Cs ions

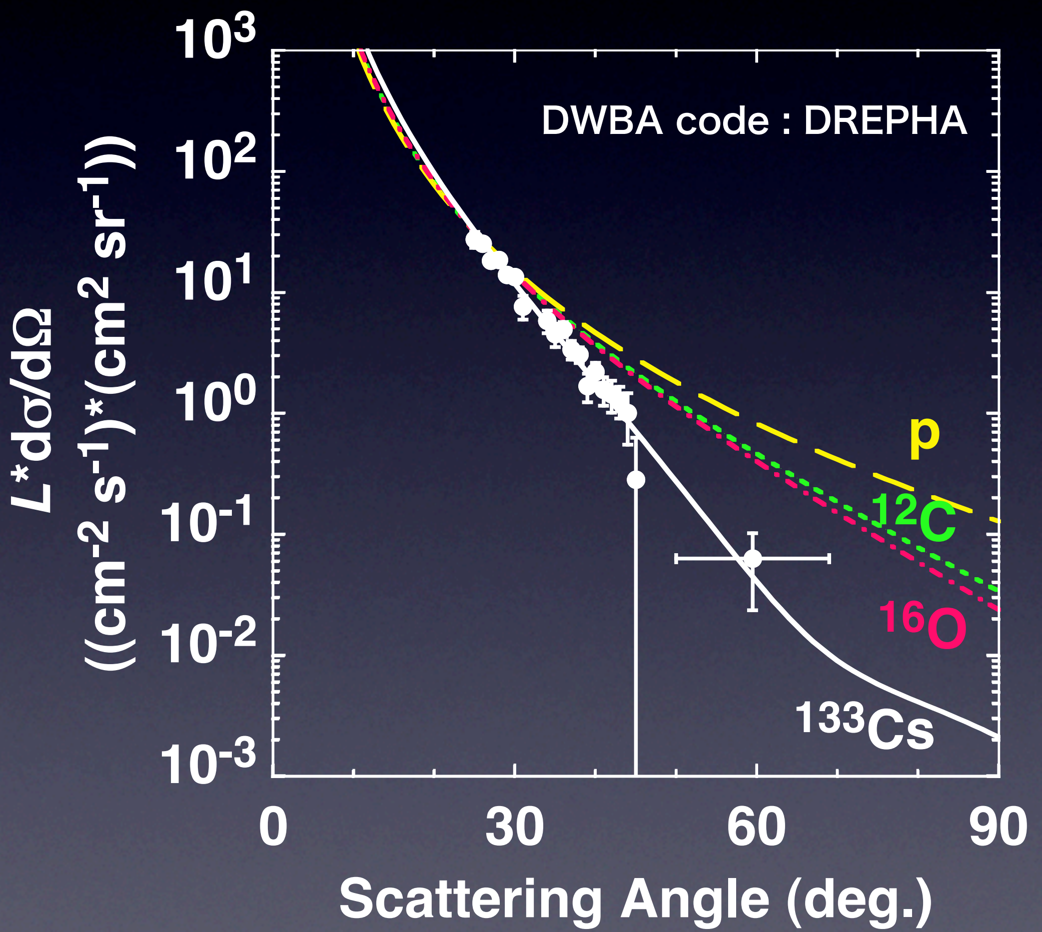




Consistent with the response of
the crystals (pureCsI, BaF2) to 120 MeV electrons

Angular distribution of elastic events

$$\mathbf{N}(\theta) = \mathbf{L}\frac{\mathbf{d}\sigma}{\mathbf{d}\Omega} \cdot \mathbf{T} \int \mathbf{dv}\boldsymbol{\Delta\Omega}(\theta, \mathbf{v})$$



$L = 1.2 \times 10^{26}$ /cm²/s

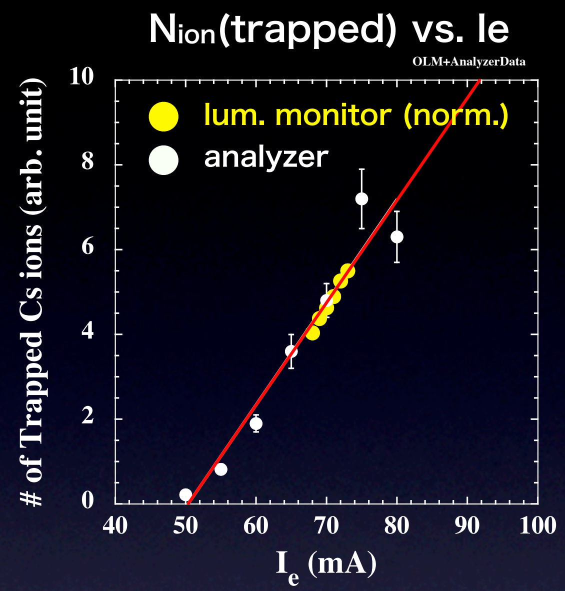
@ $I_e = 80$ mA ($Ne = 5 \times 10^{17}$ /s)

N_{ion} *(on e-beam)* ~ 10^6

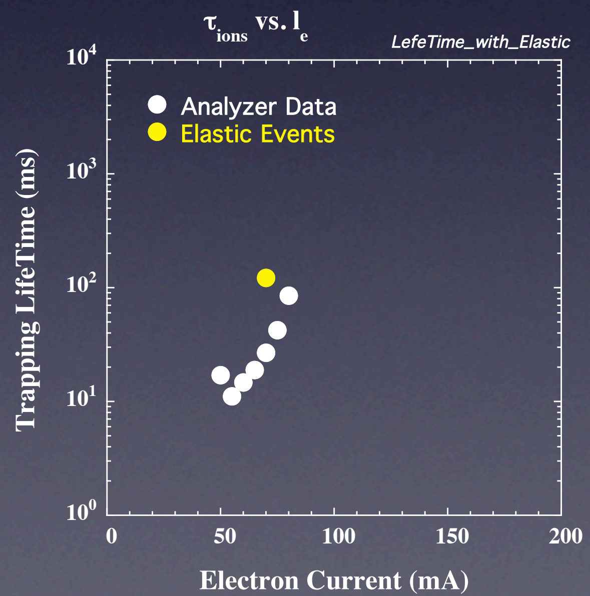
T. Suda et al., PRL 101 (2009) 102501.

Behaviors of the trapped ions in SCRIT

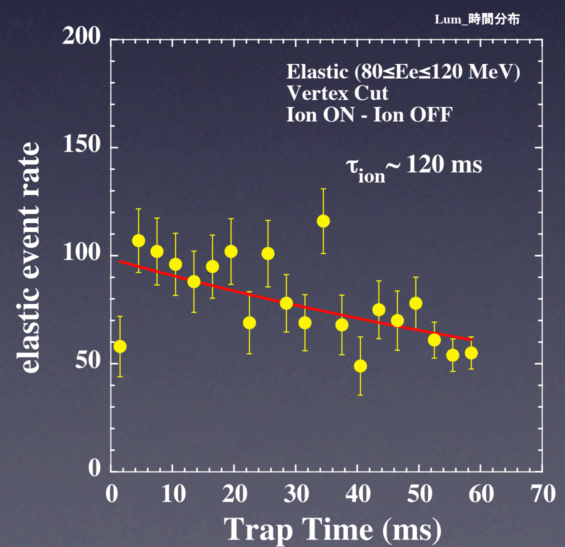
N_{ION} vs. I_e



T_{ION} vs. I_e



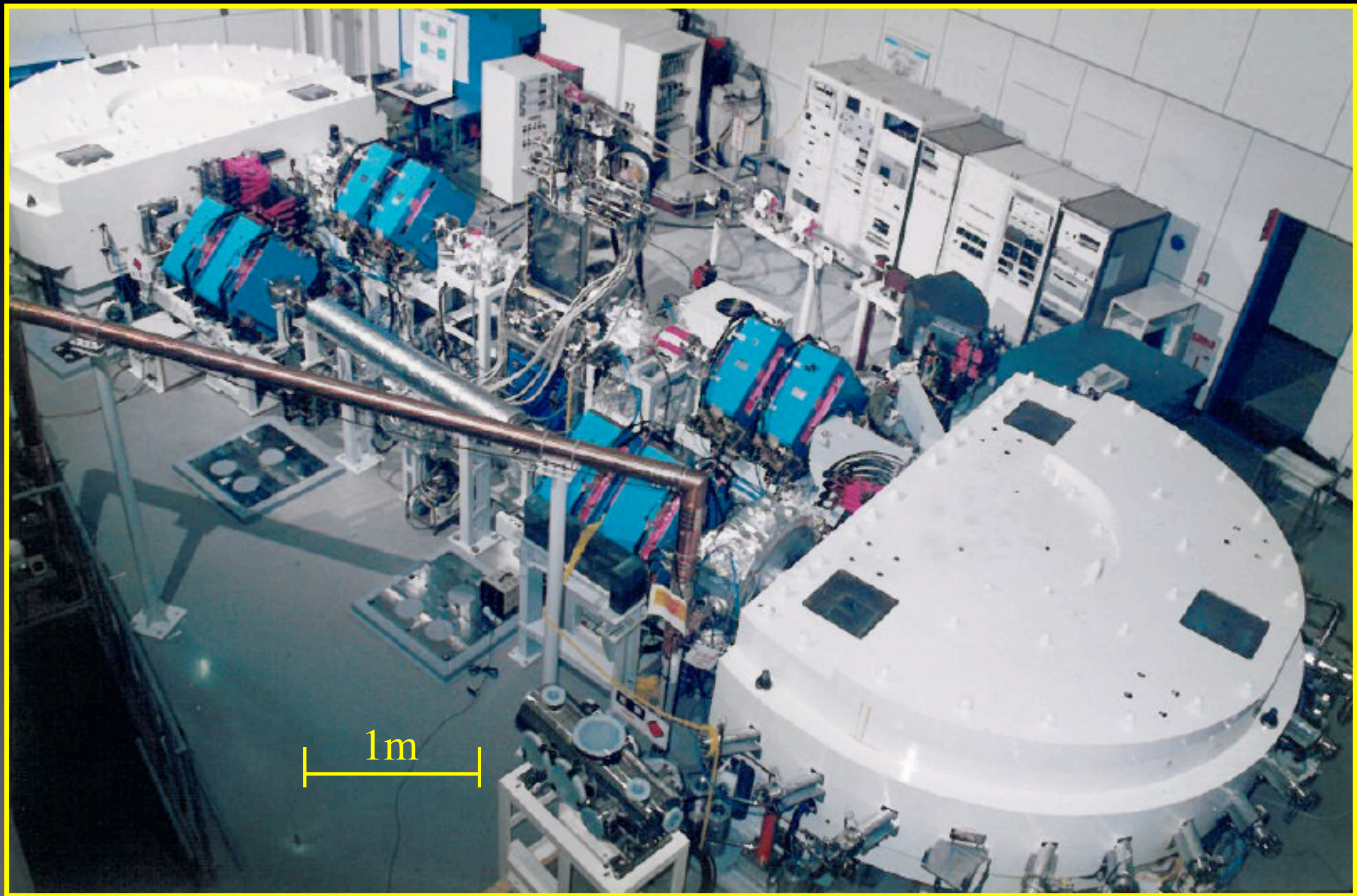
elastic event rate in 50ms



e-RI facility at RIBF

Electron ring (AURORA) : donated from Sumitomo

Currently under installation
Operation in 2010



e-RI facility at RIBF

AURORA : under installation

operation : 2010

Expected luminosity at AURORA

	KSR (120 MeV)	AURORA	AURORA/KSR
I_e (mA)	80	$\geq$ 300	4
N_{ion}	1	> 10	>10
τ_{ion} (ms)	120	much longer	
Nion for $L=10^{26}$ /cm²/s	10^6	$< 10^4$	

1) At least, ~10^2 larger luminosity will be easily achievable.
2) longer measuring time (typically 1 week <==> 5 hours KSR) ~10
3) lower-emittance ion beam, better ion manipulation ... x 10^{α}

Summary & Outlook

SCRIT scheme

1. A SCRIT prototype using (stable) ^{133}Cs ions
   completely mimicking short-livd nuclei (~50 ms trapping)
2. feasibility has been confirmed by R&D studies at KSR
   $L = 1.2 \times 10^{26}$ /cm^2/s with $N_{ion} \sim 10^6$ at 80 mA

e-RI facility at RIKEN RIBF

Slow RI beams

ISOL based on e (γ) + U fission : under construction

fragment separator + gas catcher : under discussion

Electron beam

electron ring (AURORA) is being installed. Operation in the next year.

E_e = 200 -300 MeV, $I_e \sim$ 300 mA, $\tau_e \sim$ 300 min

A door to e-RI scattering experiment is being opened.