A novel trap for electron scattering off short-lived exotic nuclei

Groundbreaking experiments now in sight :

the structure studies of short-lived nuclei by electron scattering

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NIM A532 (2004) 216
PRL 100 (2008) 164801.

RIKEN RI Beam Factory

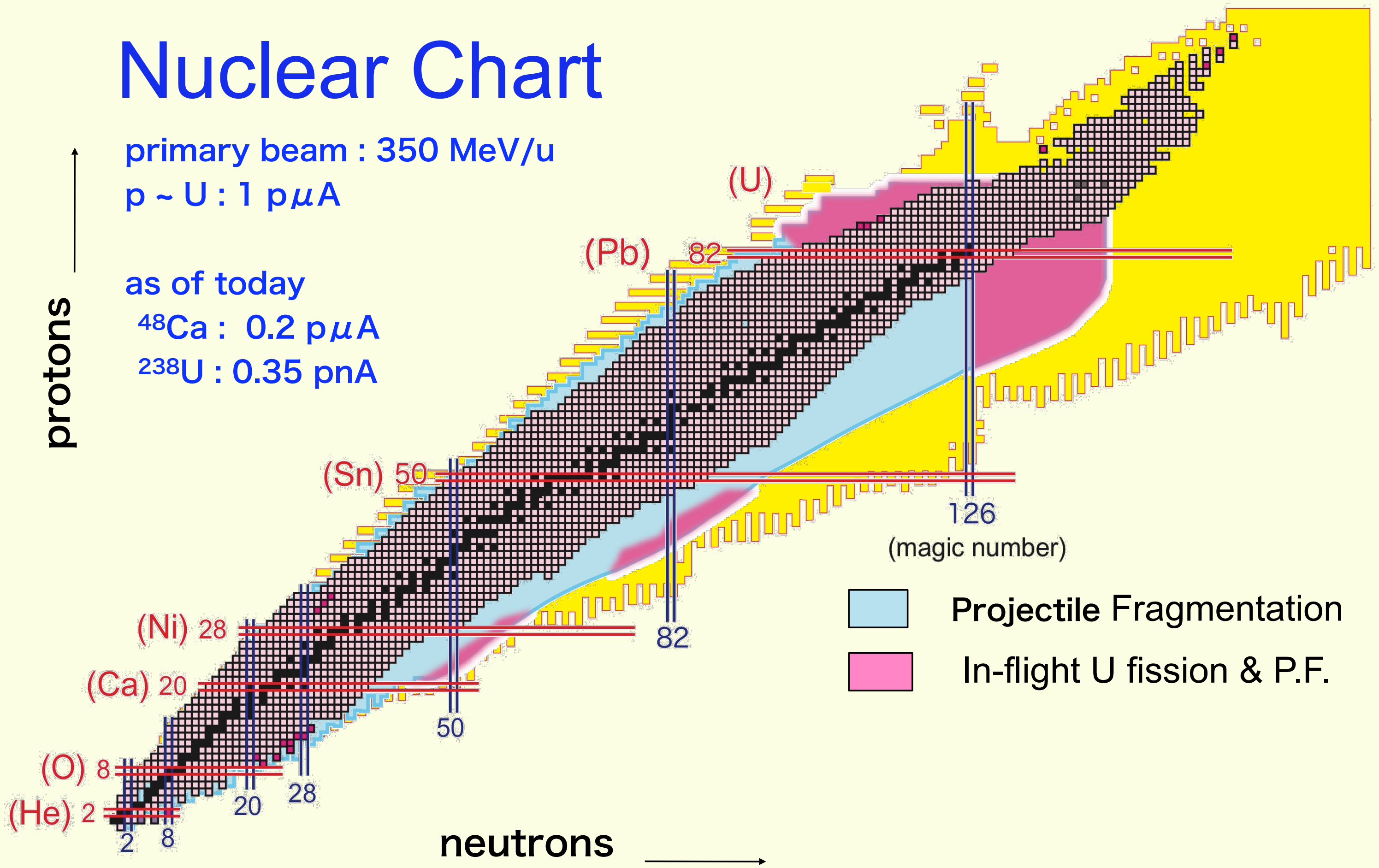
(RI : Radioactive Isotope)

in operation since 2007

Nuclear Chart

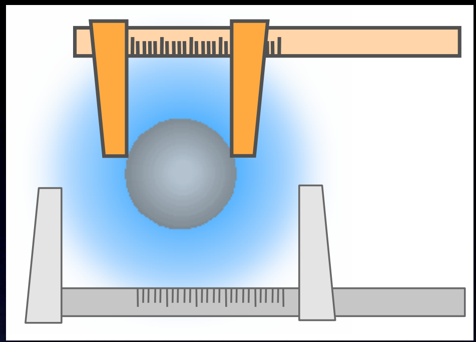
primary beam : 350 MeV/u
p ~ U : 1 pμA

as of today
^{48}Ca : 0.2 pμA
^{238}U : 0.35 pnA



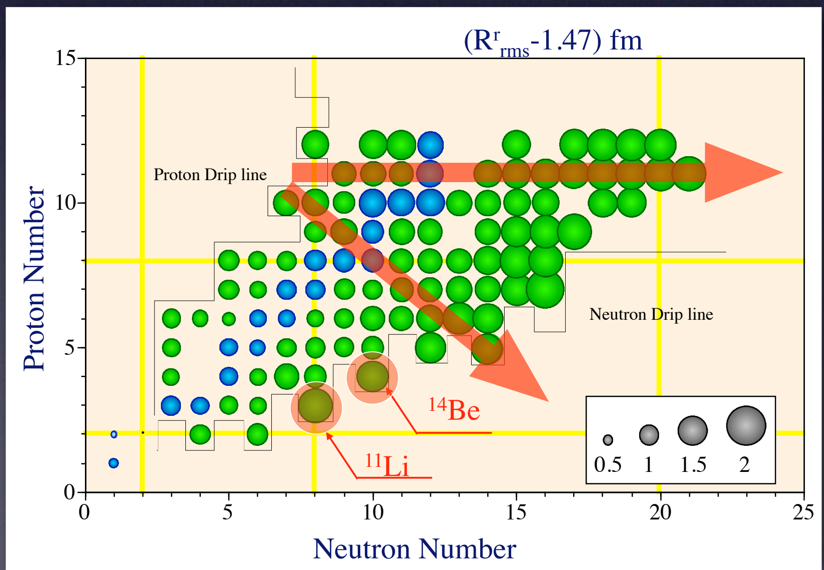
Size and Shape of short-lived nuclei

one of main programs at RIBF

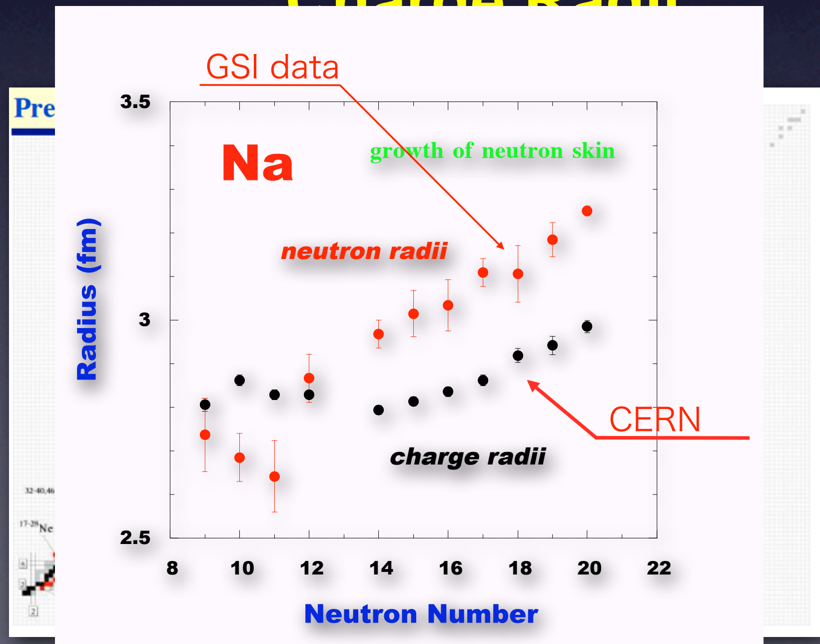


	size	shape
proton	isotope shift	electron scattering
neutron	reaction cross section	proton scattering

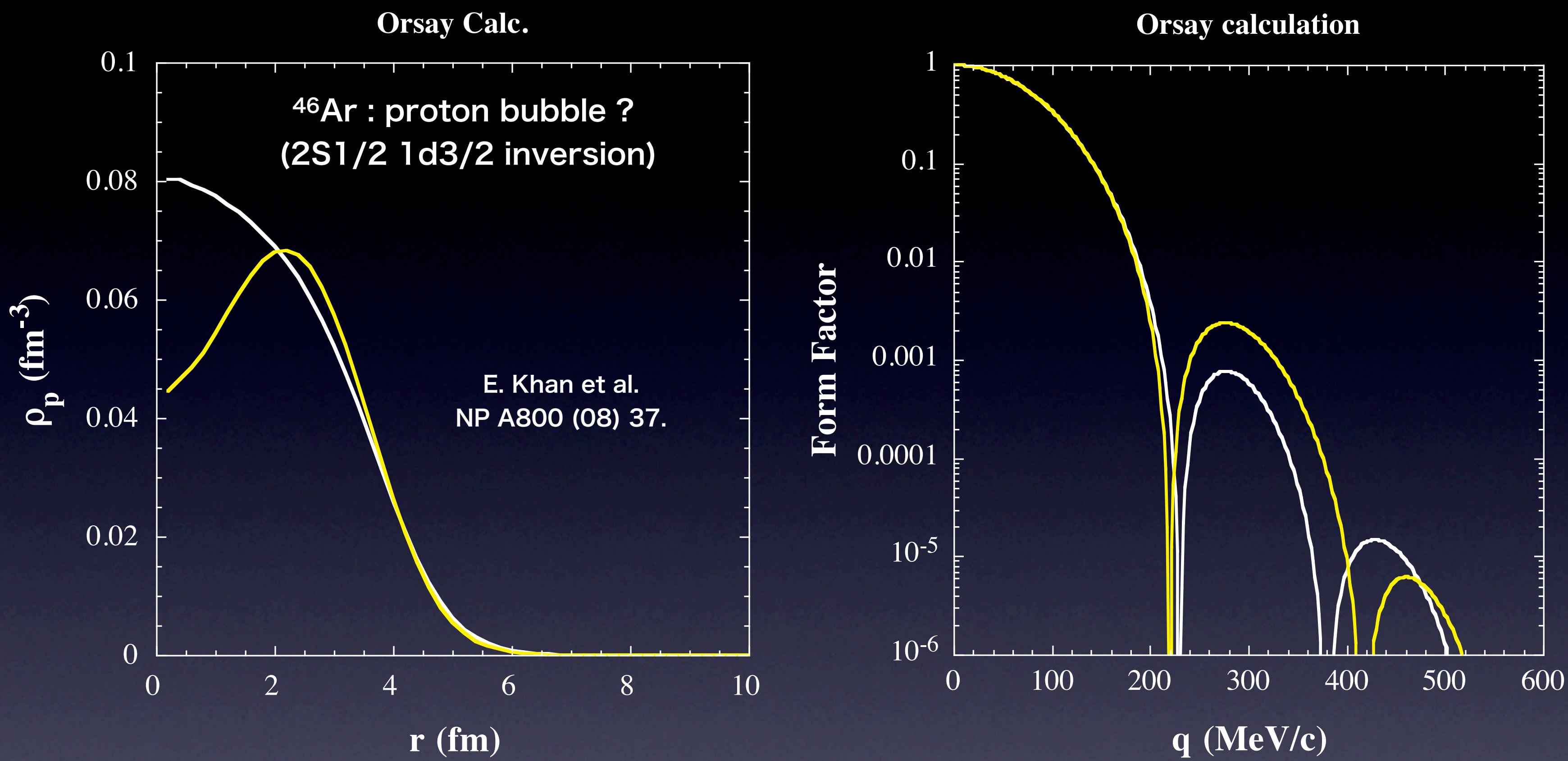
Nuclear Radii



Charge Radii



Size is NOT enough



To go beyond $\langle r^2 \rangle^{1/2}$

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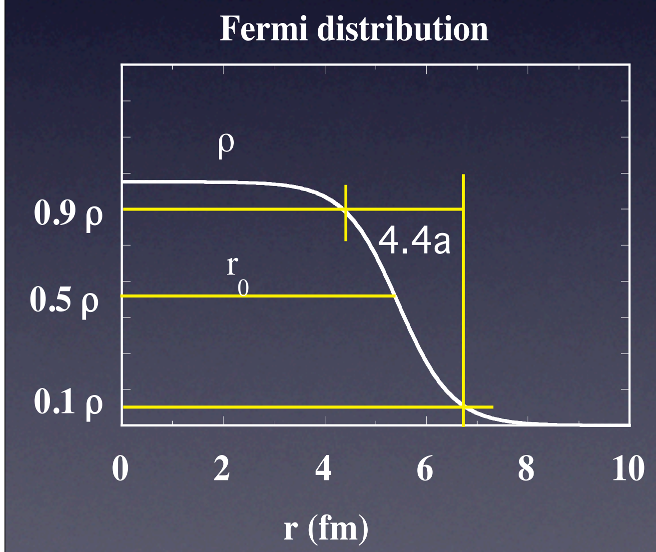
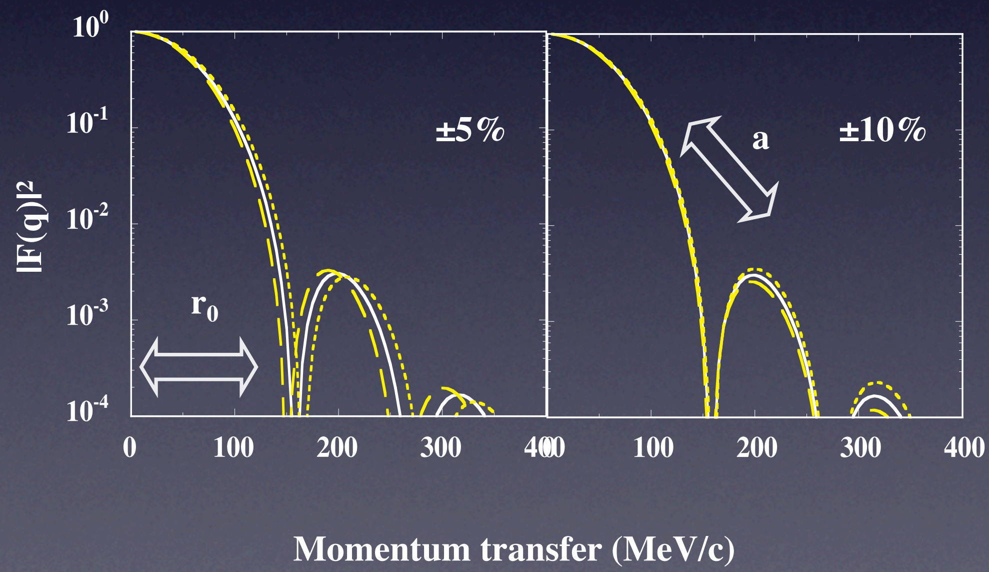
scattering experiments

elastic electron scattering

spin 0

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





Matter distribution by proton scattering

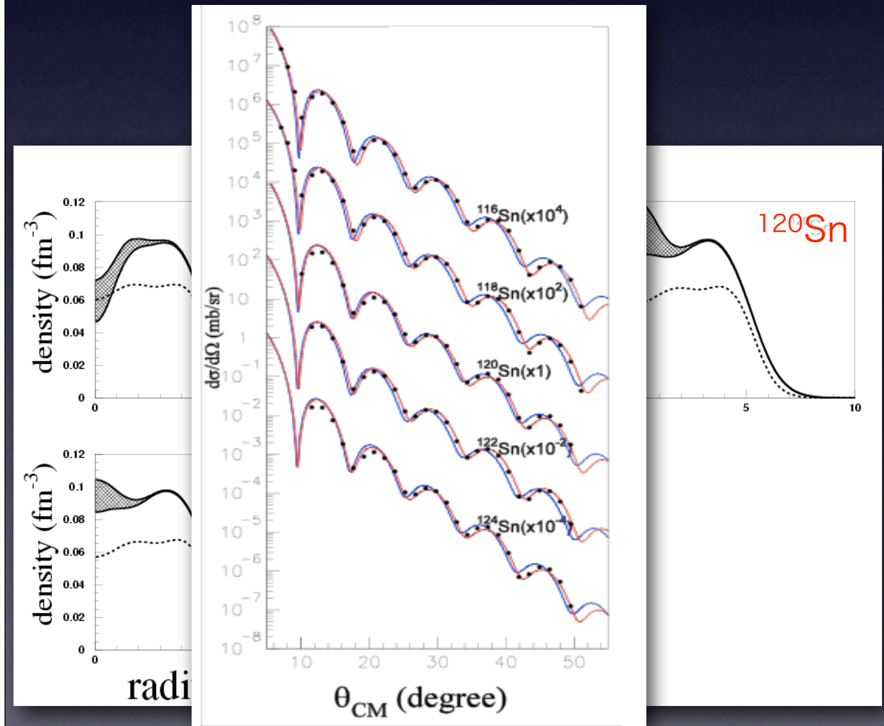
^{116,118,120,122,124}Sn(p,p') at RCNP, Osaka, JAPAN

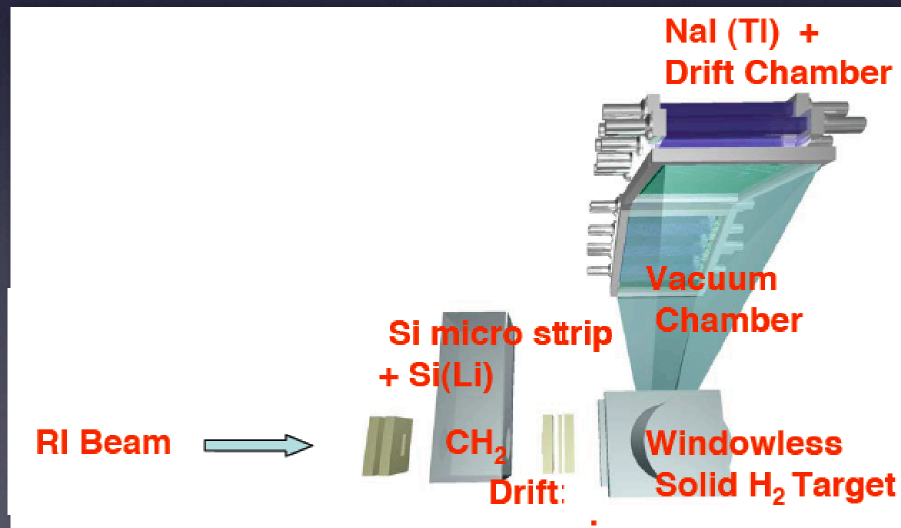
- Ep = 300-400 MeV
- Relativistic Impulse Approximation
- Parameters fixed for ^{58}Ni data
- "Extract" the neutron distribution

proton scattering at RI Beam Factory

RI beam ~ 250 MeV/u
solid hydrogen target
recoil proton spectrometer
NRI > 10^3 /s

demonstrating experiments done at HIMAC
Experiments at RIBF starts soon





H. Sakaguchi et al.

Required luminosity for electron elastic scattering

key : luminosity

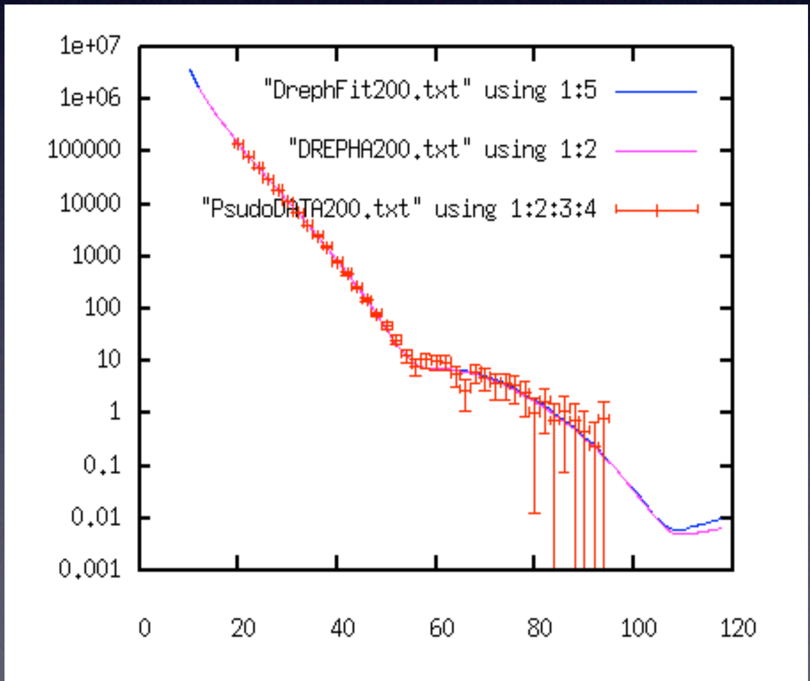
ex. elastic scattering for Ni, Sn isotopes

$L = 10^{26}$ /cm²/s

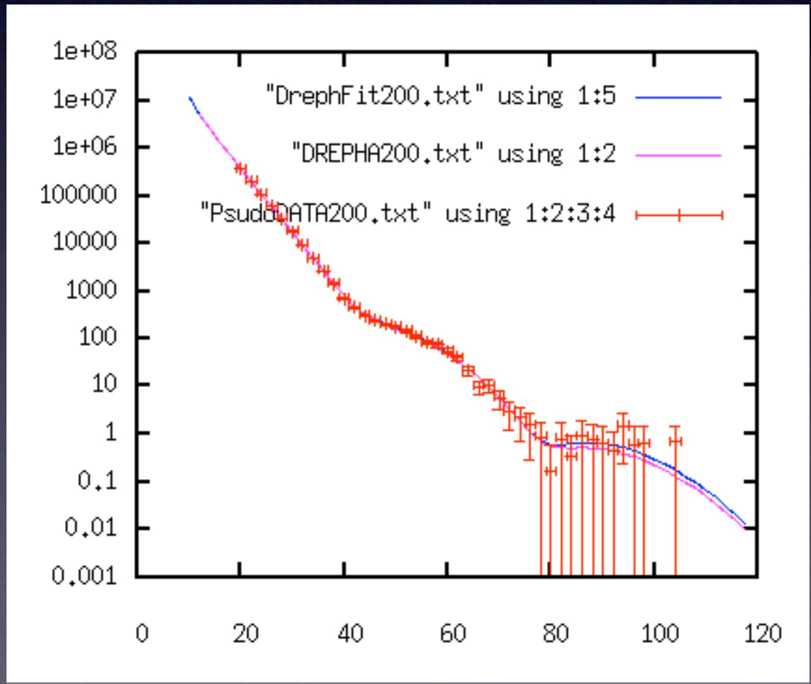
Ee = 200 MeV 1 week

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

Ni



Sn

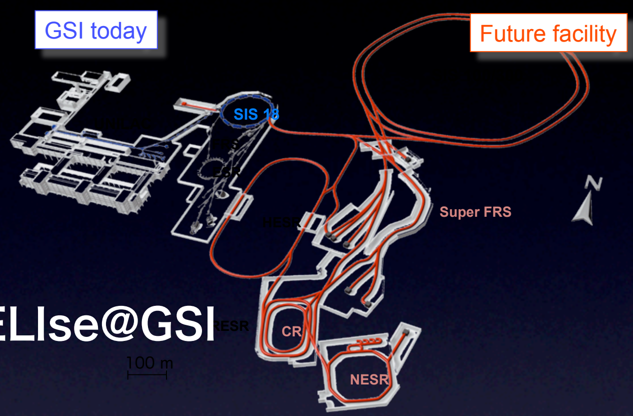


better than a few % accuracy of diff. radius and diffuseness

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

e-RI collider

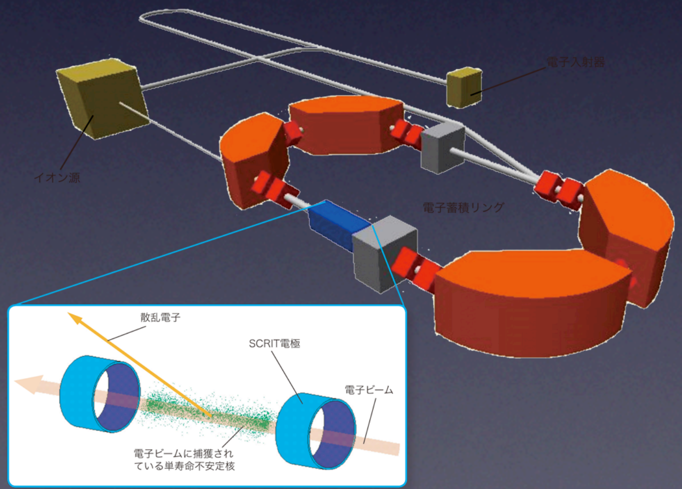
a large accelerator complex
including a cooler ring and a collider



ELIse@GSI

RI at rest

electron ring only



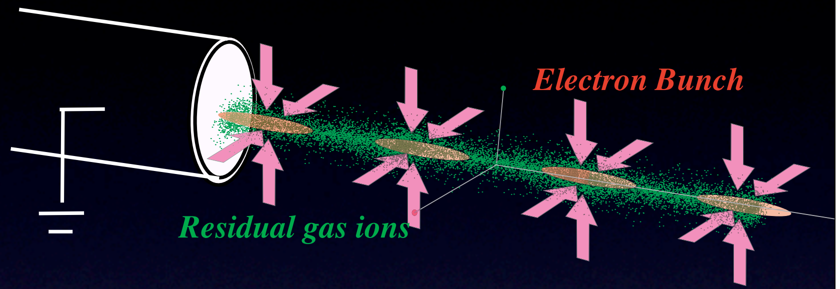
SCRIT@RI Beam Factory

What is SCRIT (Self-Confining RI Target) ?

"Ion trapping" phenomena observed at electron rings

ionized residual gases by electrons

are trapped by electron beam itself.

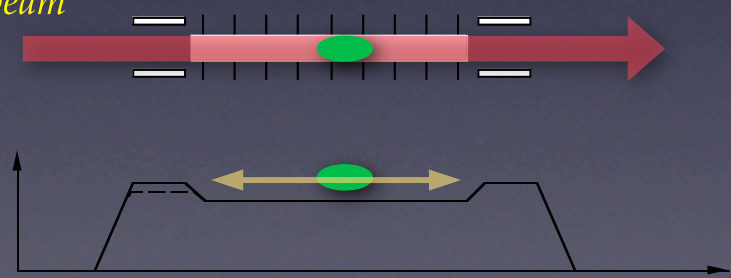


the trapped ions kick out electrons ---> shorter beam lifetime

electron scattering !!

SCRIT technique

trap the target nuclei externally injected on (high energy) electron beam.



precise position control

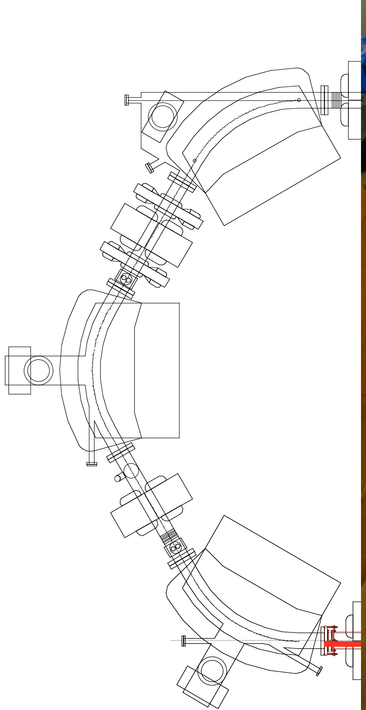
-> higher luminosity

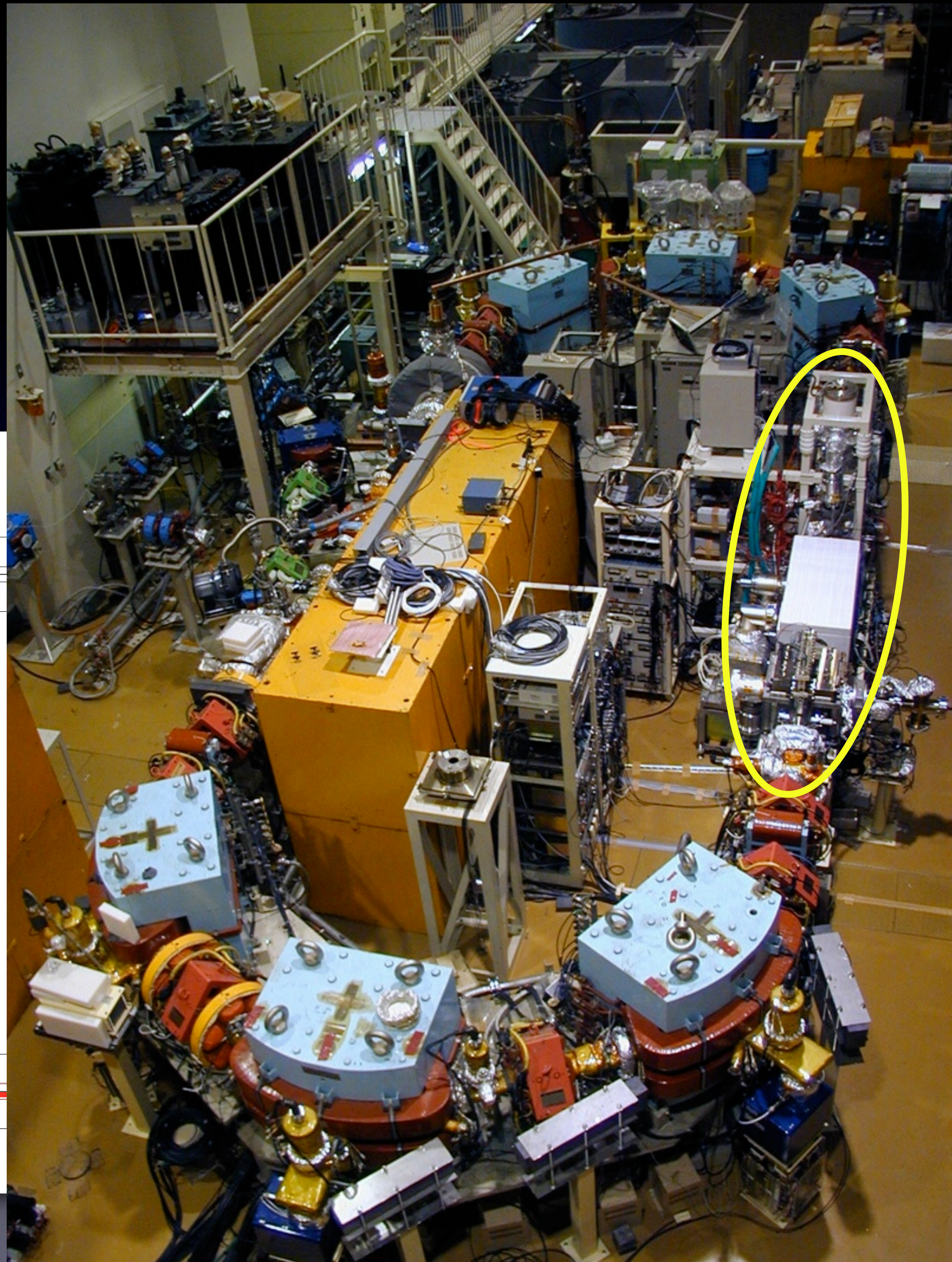
fast ion manipulation

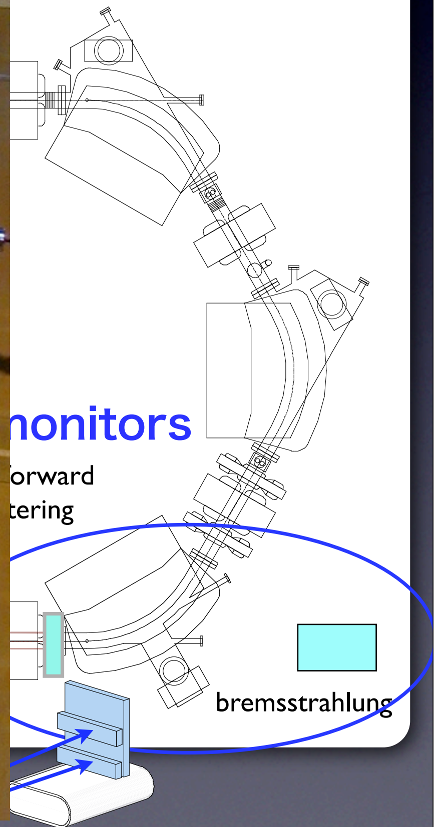
-> short-lived nuclei

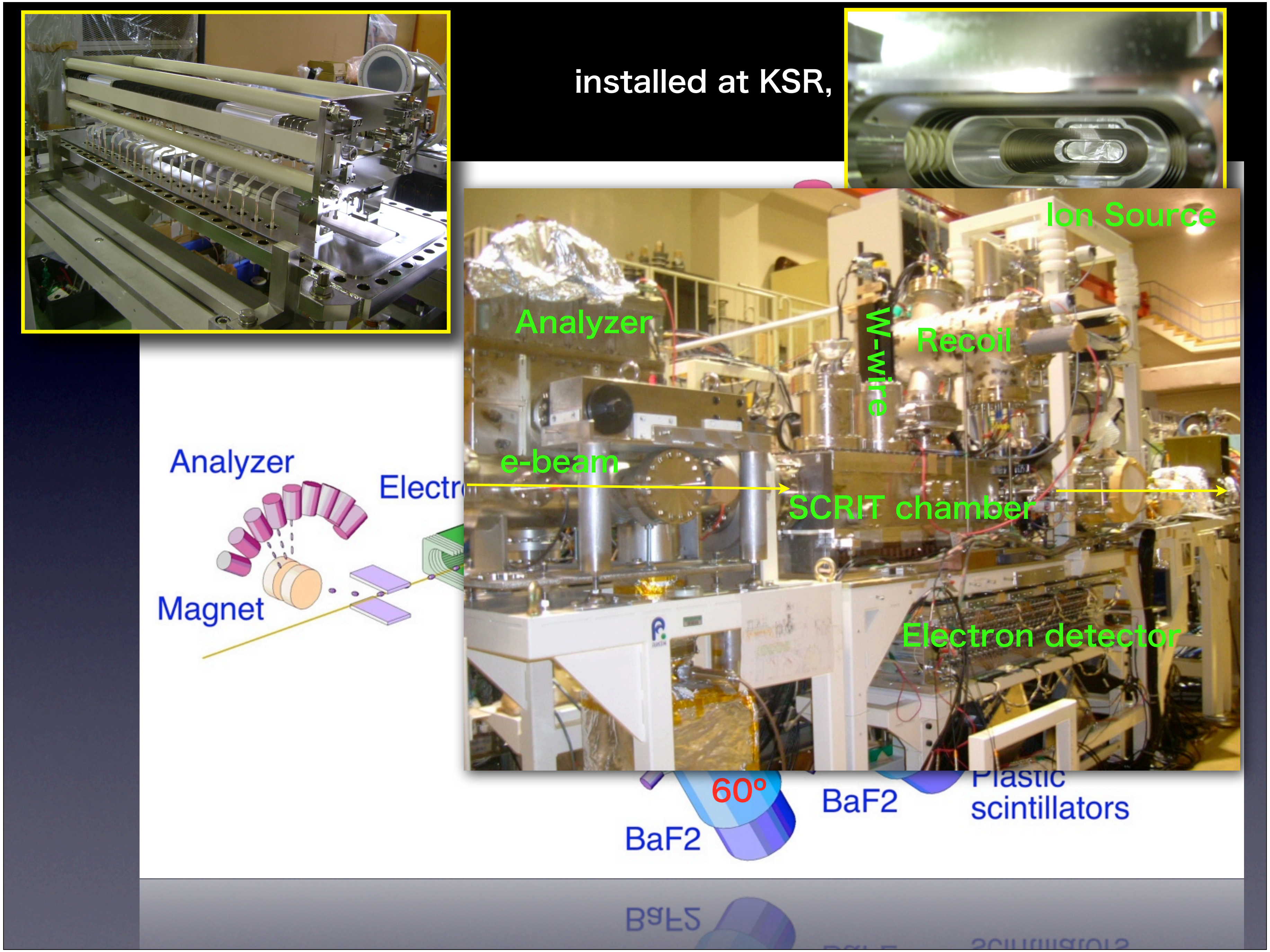
Feasibility ototype

at sity



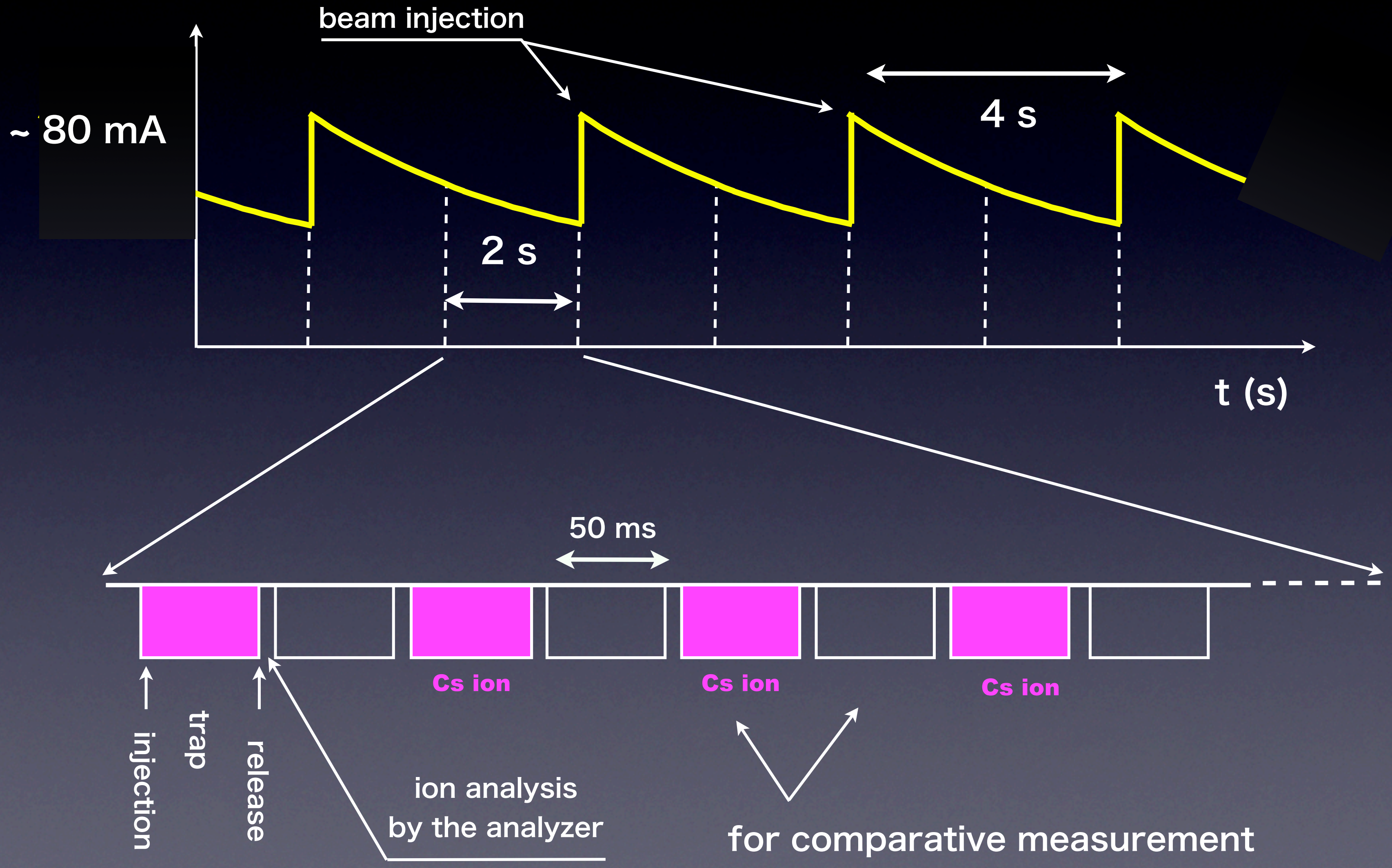




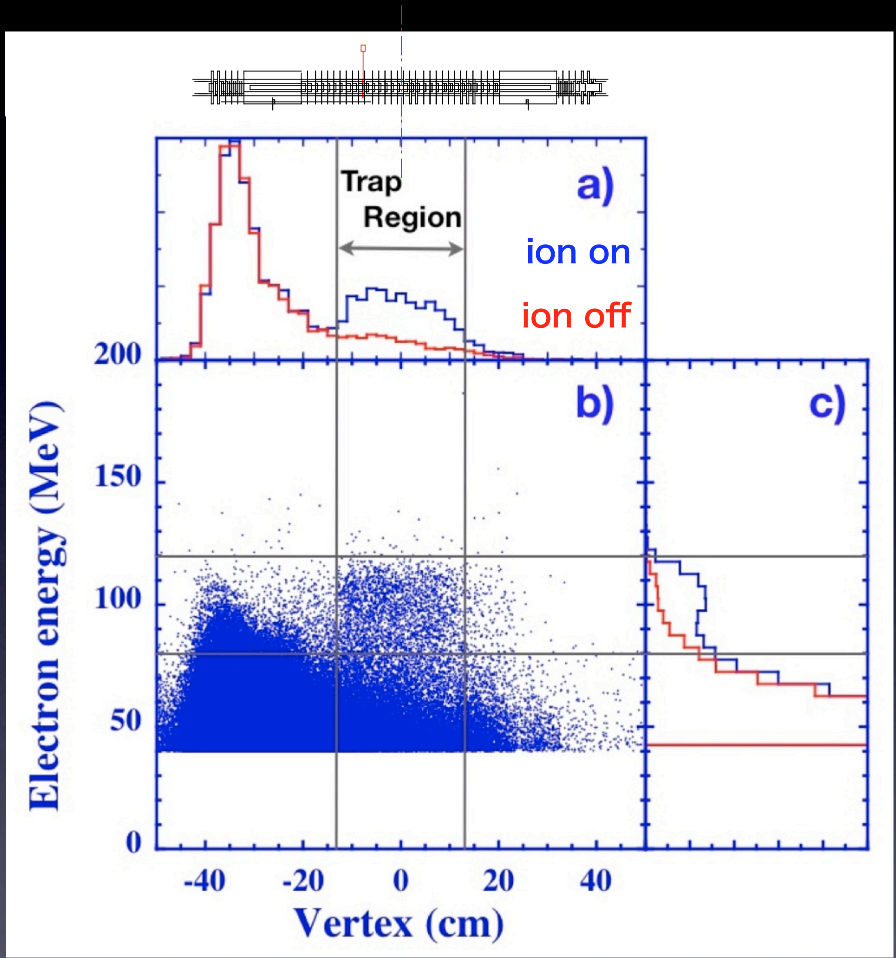

installed at KSR,
Ion Source
Analyzer
W-wire
Recoil
e-beam
SCRIT chamber
Electron detector
Analyzer
Magnet
60°
BaF2
BaF2
Plastic
scintillators

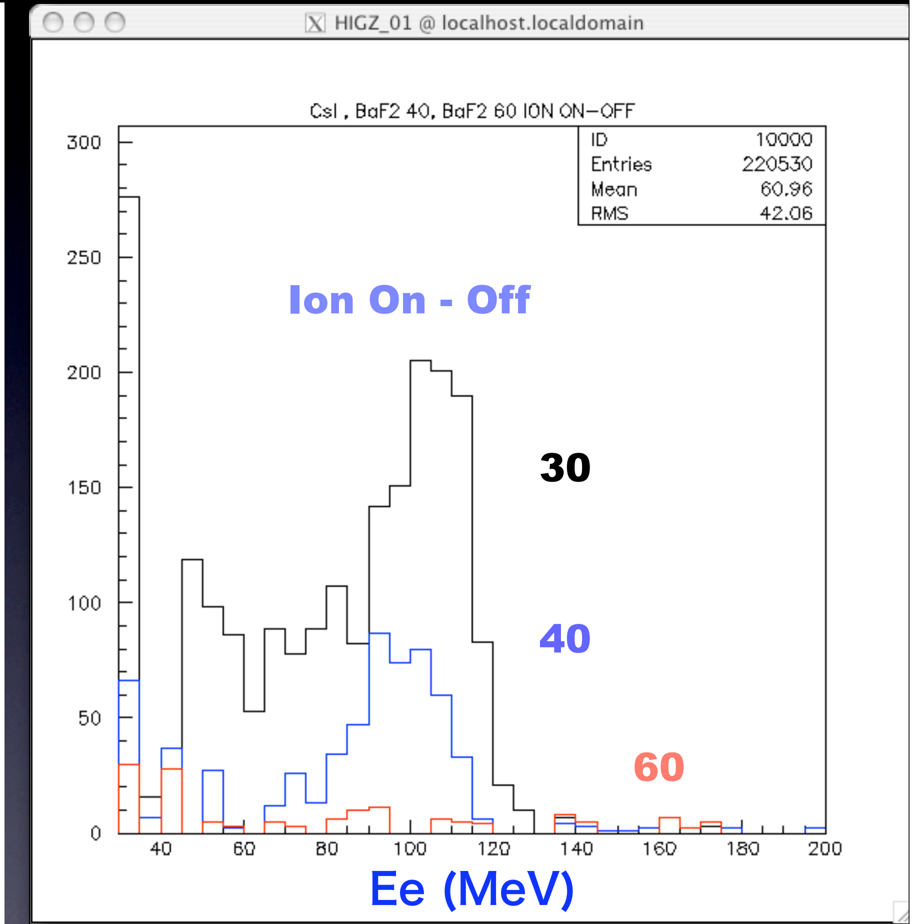
Time sequence of the measurement

beam lifetime of KSR τ~100 s @ 80 mA



electron scattered from the trapped Cs ions

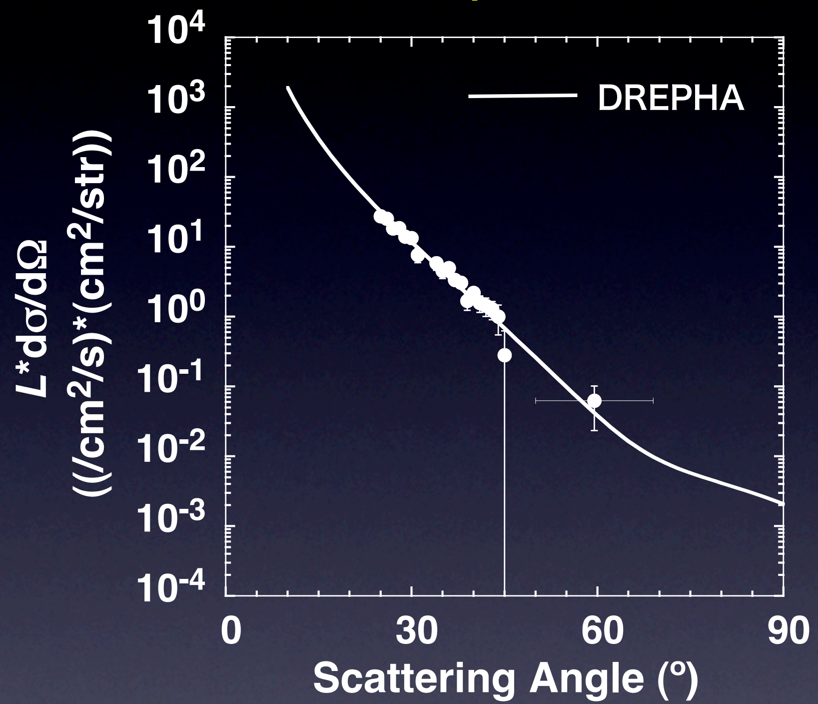


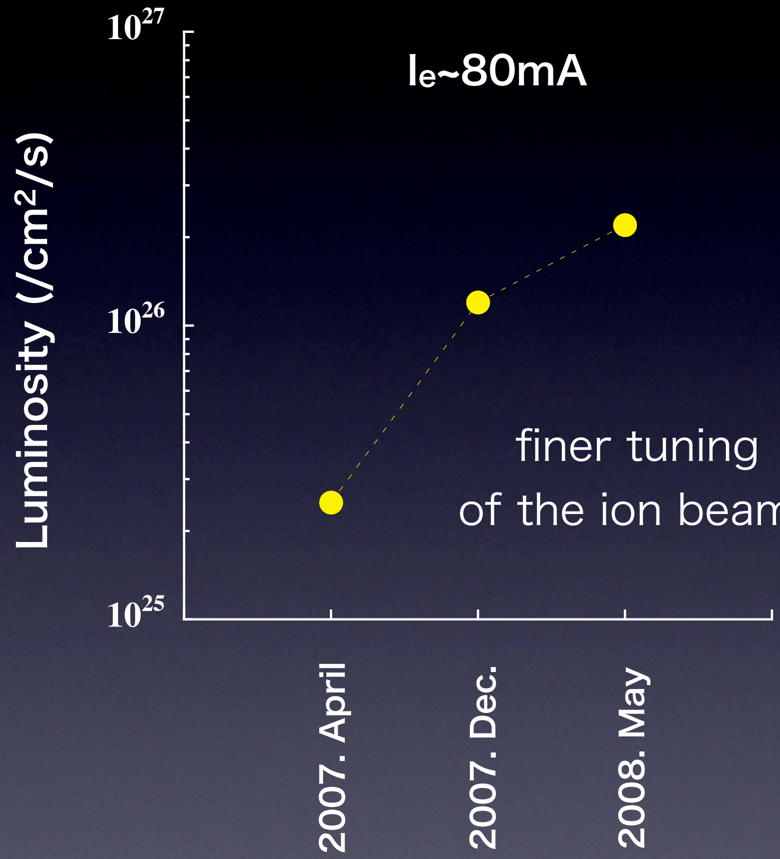


Consistent with the response
of pure CsI to 120 MeV electrons

elastic scattering and achieived luminosity

$Y = L^* d\sigma/d\Omega \, ^*\Delta\Omega^* T$





$L=1.2 \times 10^{26}$ /cm²/s

@ I_e = 80 mA ($Ne=5\times10^{17}$ /s)

target thickness = L/Ne = 2.4×10^{8} /cm²

Ions trapped on the electron beam ~10^{6}

Beyond charge elastic scattering ...

electron scattering is the most superior probe for the structure studies

1. point particle
2. QED
3. Probing whole nucleus

Required luminosities

elastic scattering (magnetic)	~ 10^{30} /cm^2/s
Inelastic scattering : transition density	~ 10^{28} /cm^2/s
Giant resonance : collectivity	~ 10^{29} /cm^2/s
Quasi-elastic : $\|\phi\|^2$, s-factor through (e,e'p)	~ 10^{29} /cm^2/s

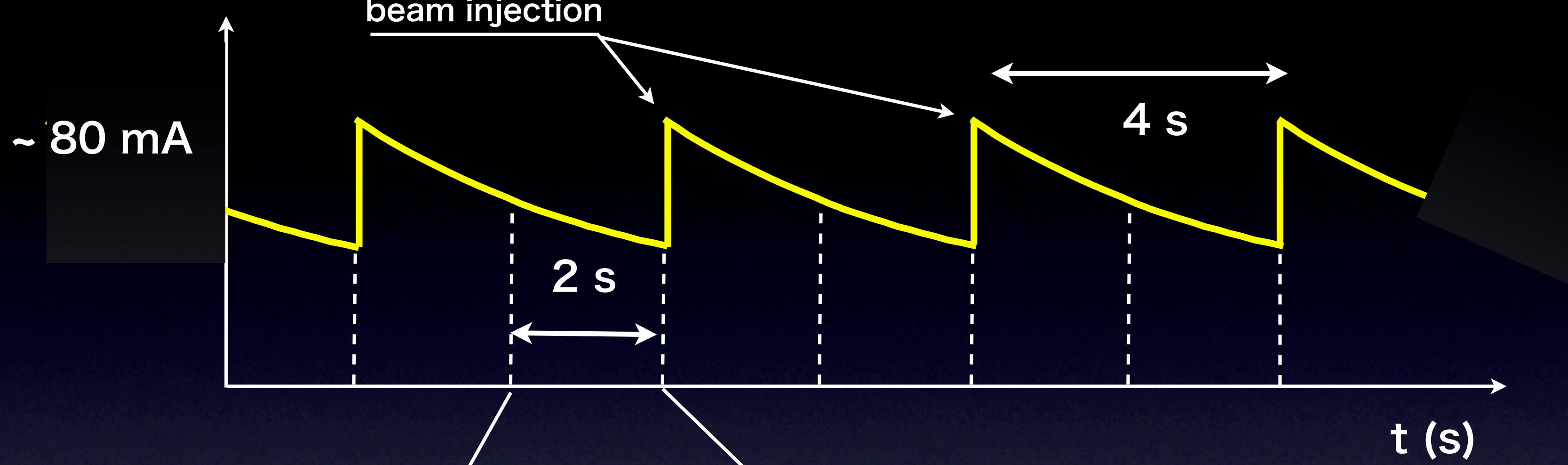
Challenges ...

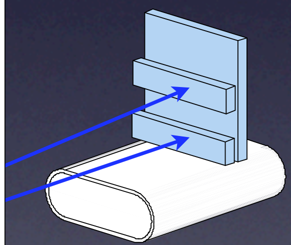
higher luminosity with less number of ions

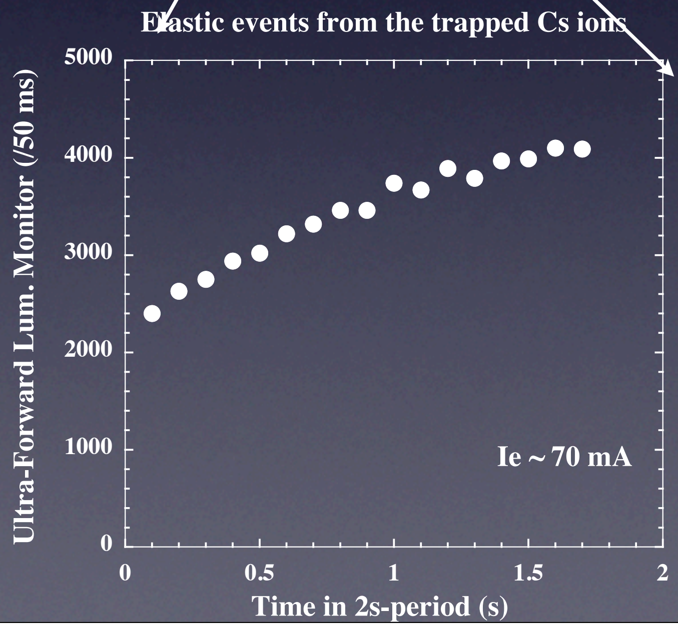
high resolution ($\leq 10^{-3}$) * large acceptance

collaboration and ideas

Higher luminosities ?







I_e goes lower, but

luminosity in increasing !

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radiative cooling underway

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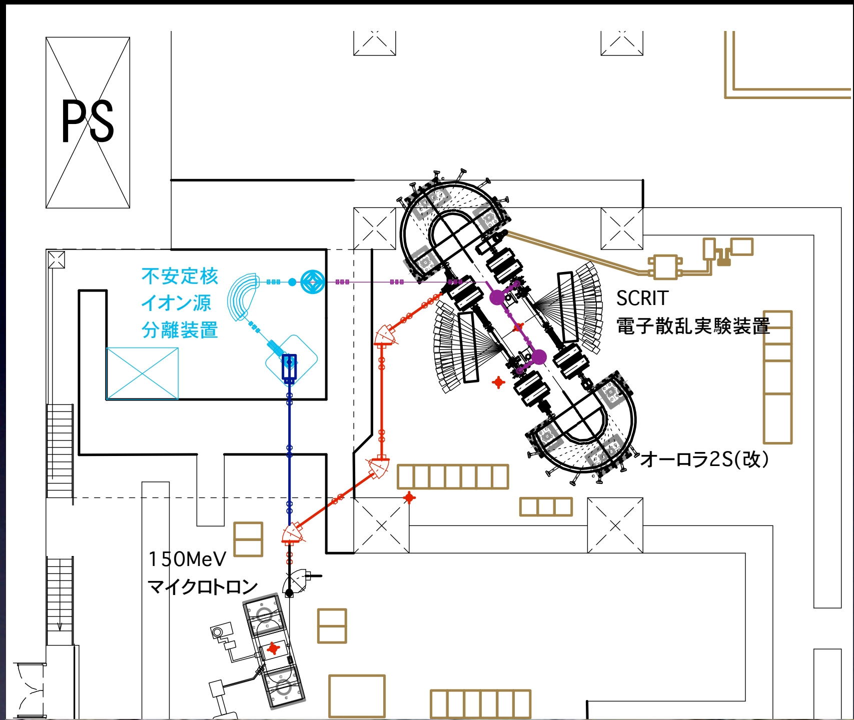
automatic increase of luminosity

electron scattering at RI Beam Factory



Aurora (electron ring)

Ee = 150 ~ 700 MeV

Ie = 100 ~ 500 mA

τe ~ 500 min @ 250 mA

in operation next year

slow RI beam

ISOL : e (γ) + U fission

Fast RI beam + gas catcher

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

present situation

Slow RI beams

fragment separator + gas chacther : ready

ISOL based on e (γ) + U fission : development

Electron beam

electron ring (AURORA) is ready in operation next year

E_e = 200 -300 MeV, $I_e \sim$ 200 mA, $\tau_e \sim$ a few 100 min @ 200 mA

ready to open the door to e-RI scattering experiments