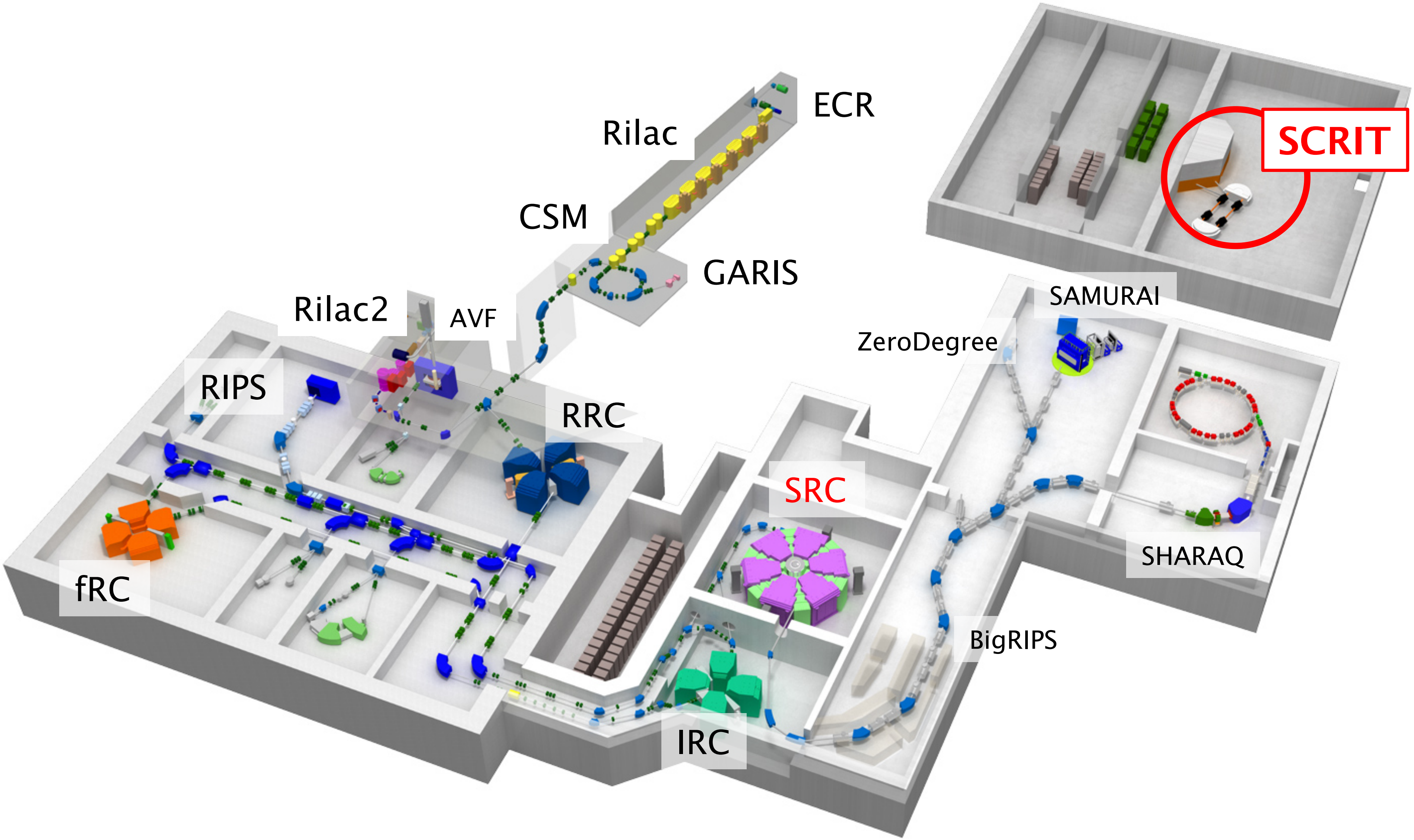
Current Status of the SCRIT Electron Scattering Facility

M. Wakasugi and SCRIT collaborations

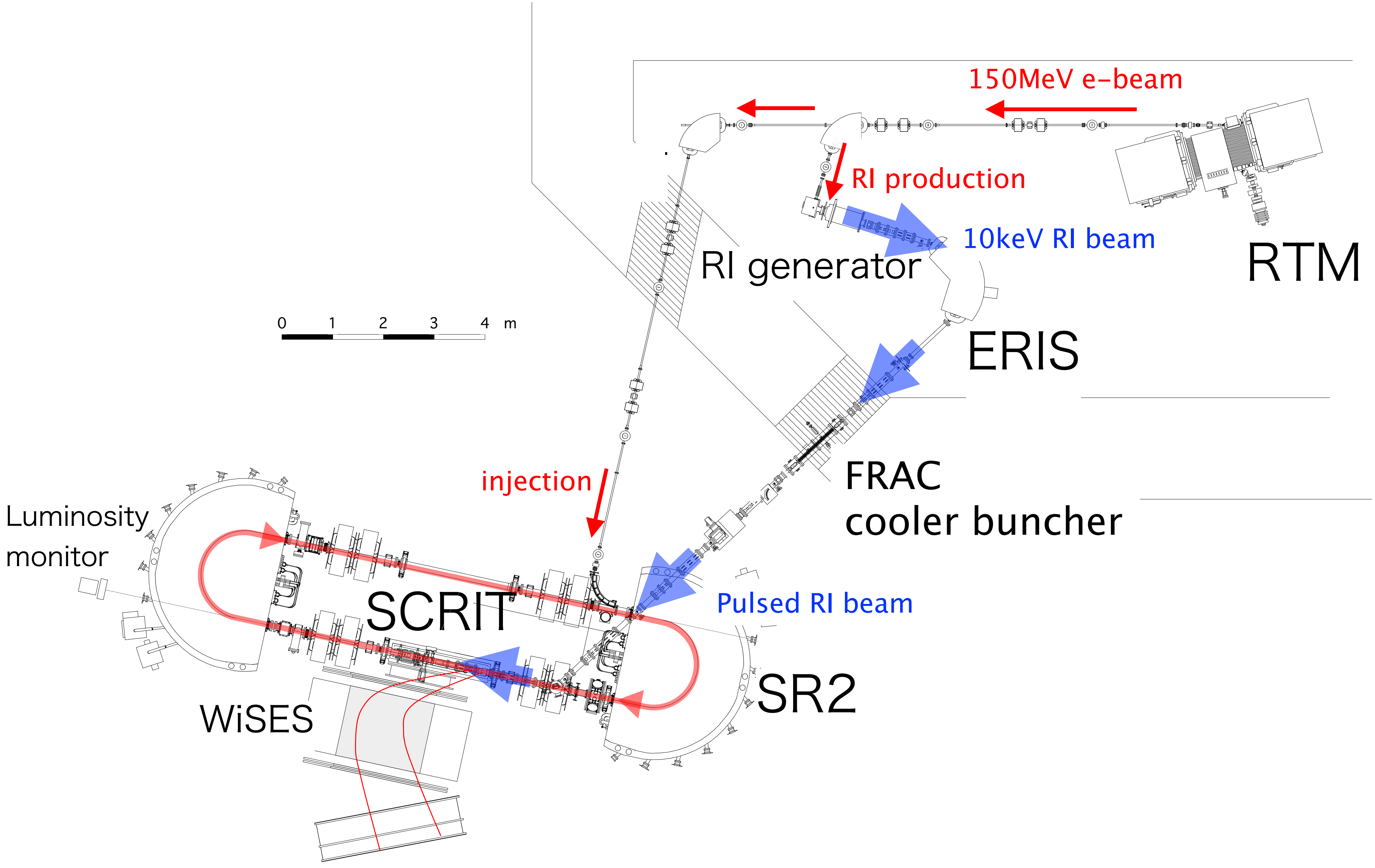
ECT* Work Shop
Proving Exotic Structure of Short-lived Nuclei by Electron Scattering
(16-20 July. 2018)

Contents :

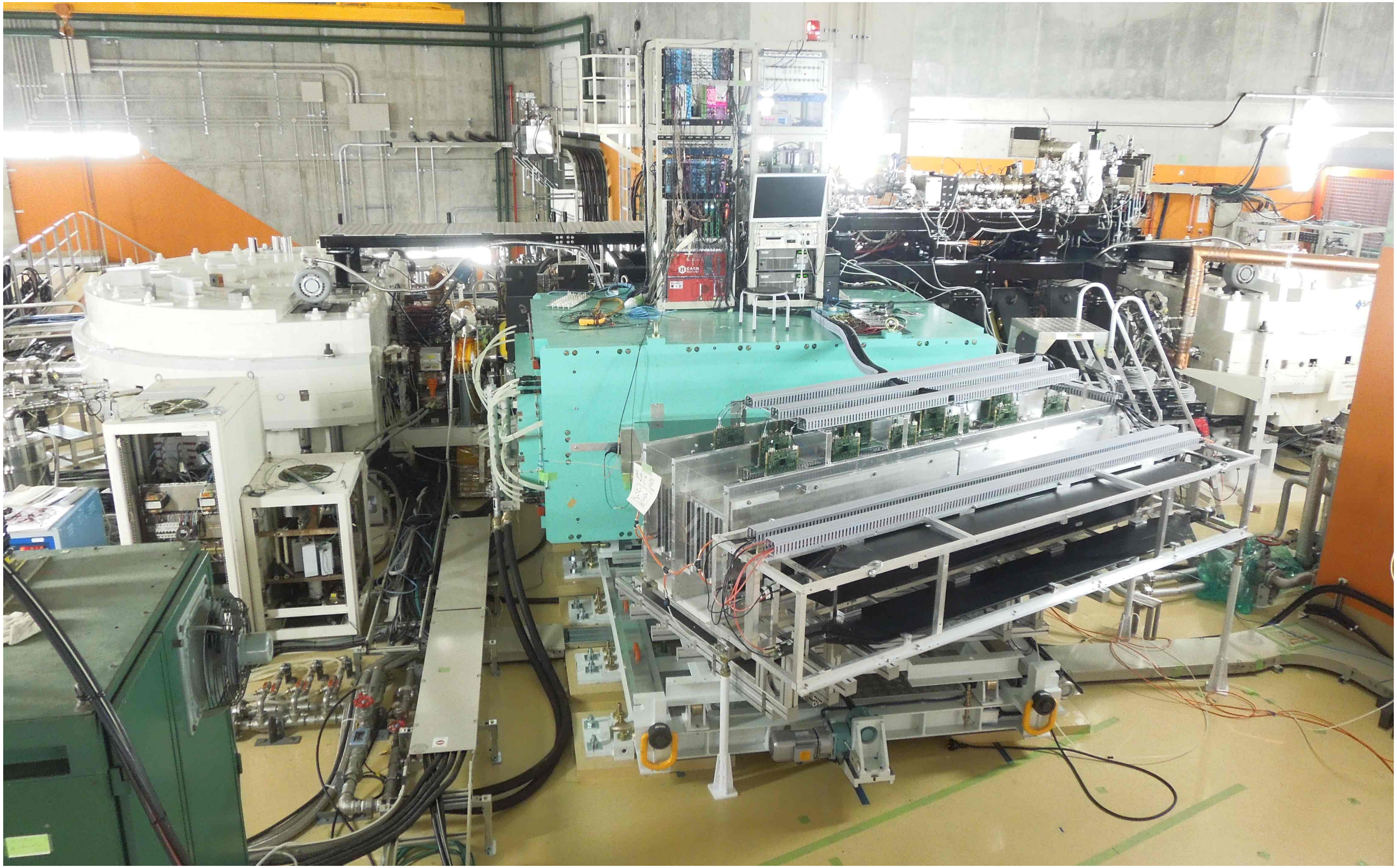
The SCRIT Facility in the RIKEN RI Beam Factory



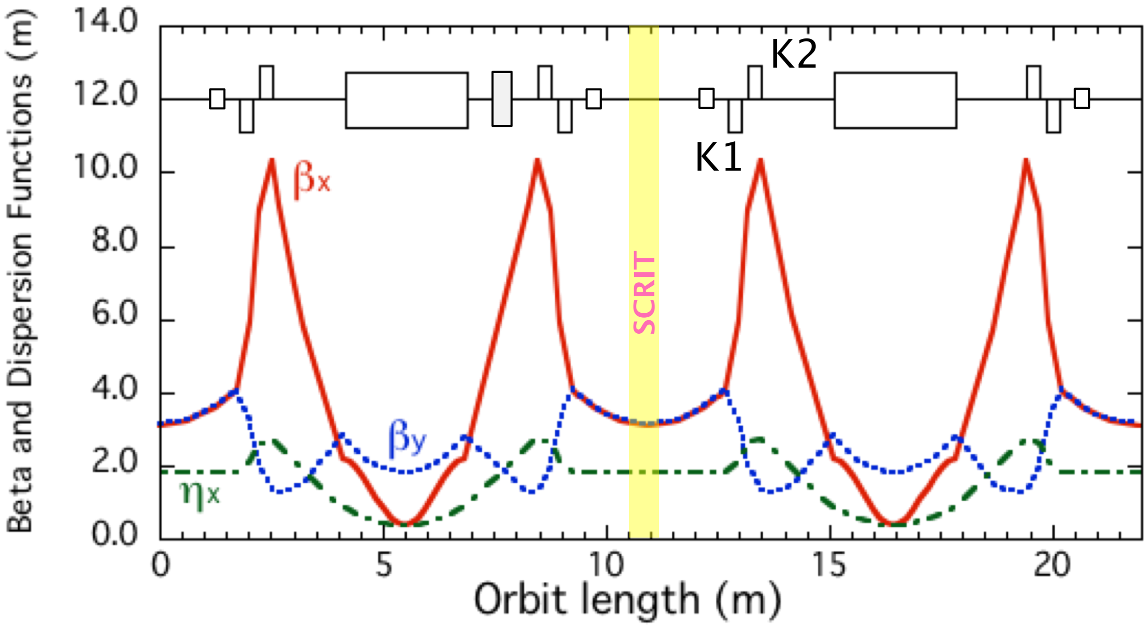
The SCRIT Electron Scattering Facility



The SCRIT Electron Scattering Facility

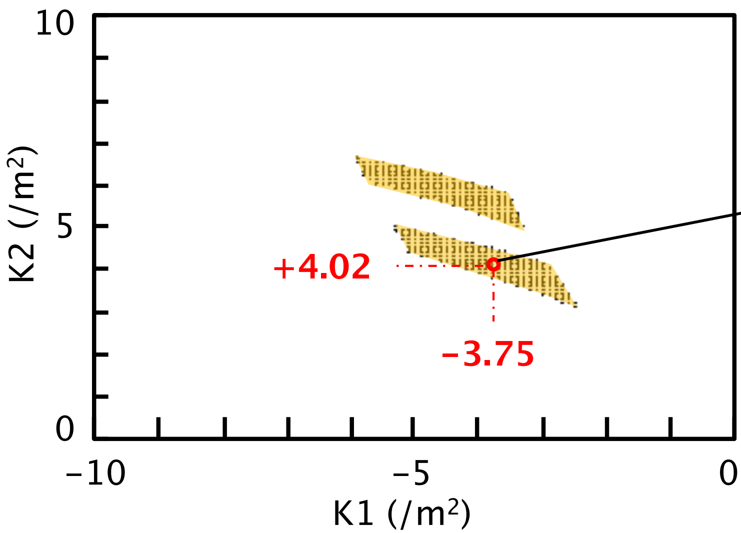


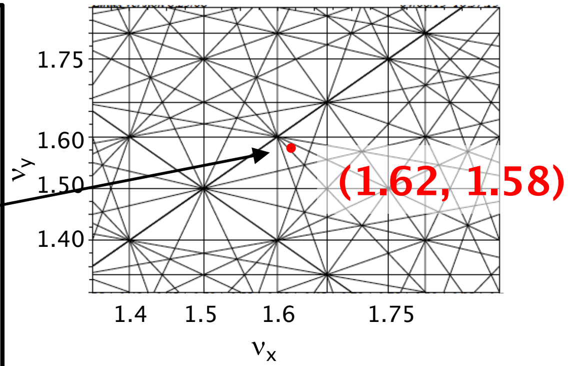
Electron Storage Ring (SR2)



C =21.95 m
E_e =100~700 MeV
I_e ≦300 mA
RF =191.244 MHz
h =14

Operation points

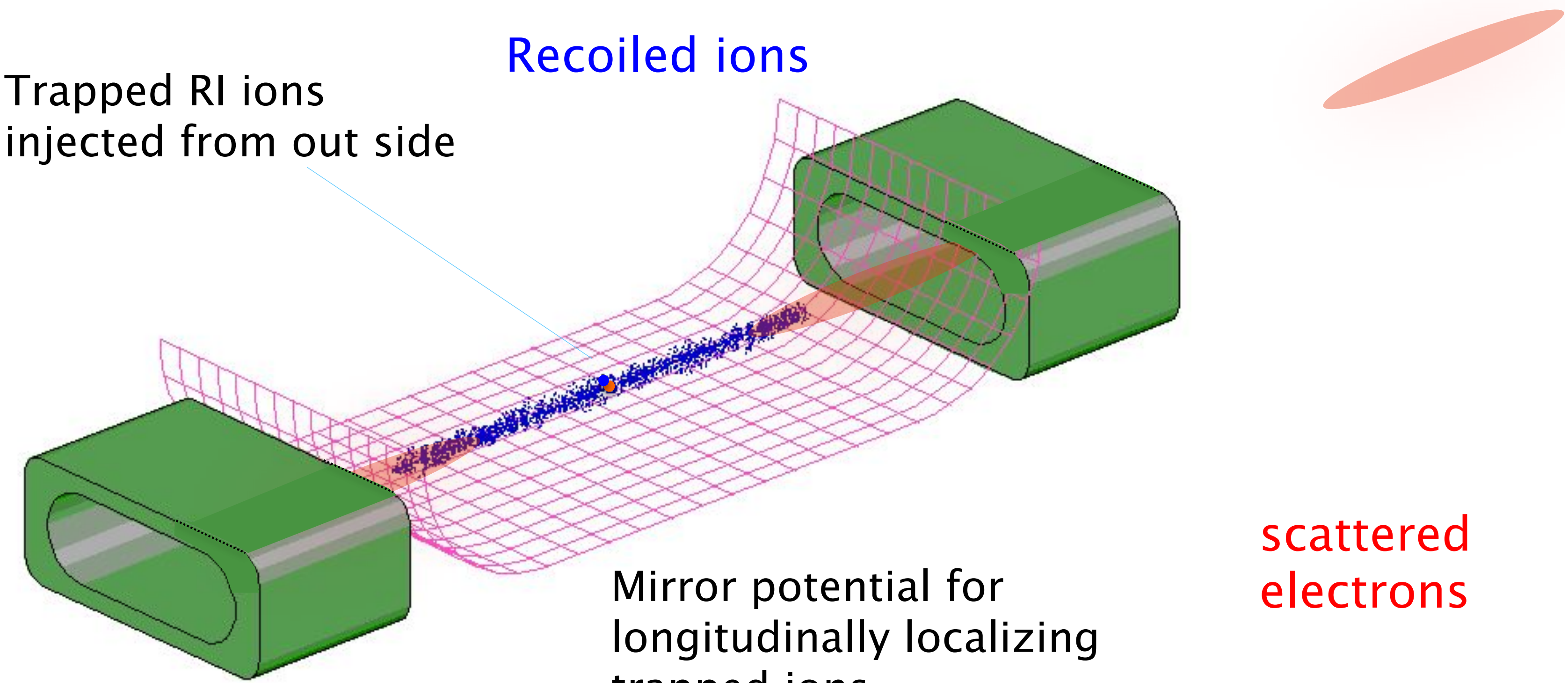




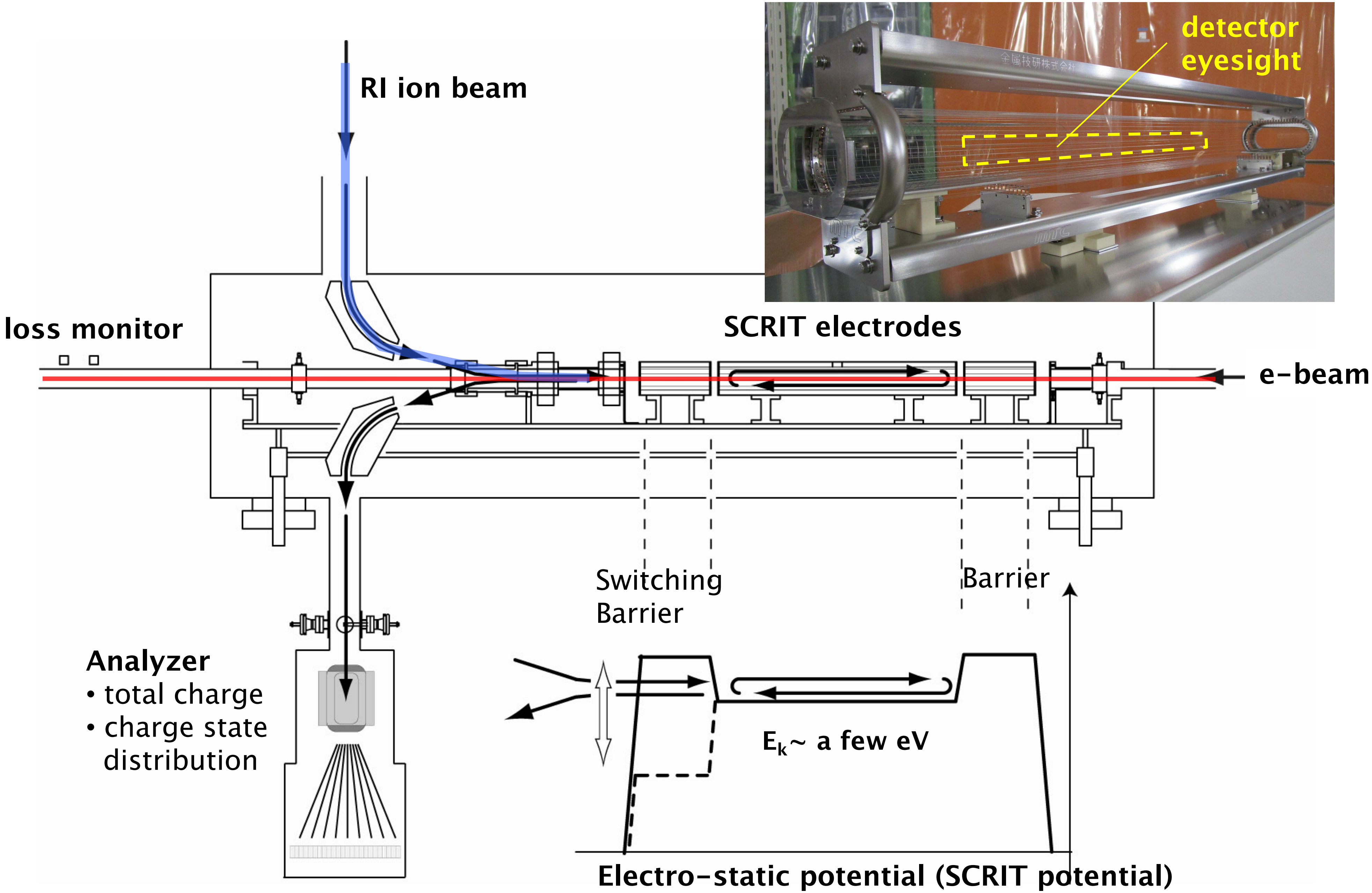
SCRIT (Self-Confining RI Ion Target)

SCRIT is internal-target-forming technique in an electron storage ring.

Target ions are confined in the beam orbit by periodic focusing force.

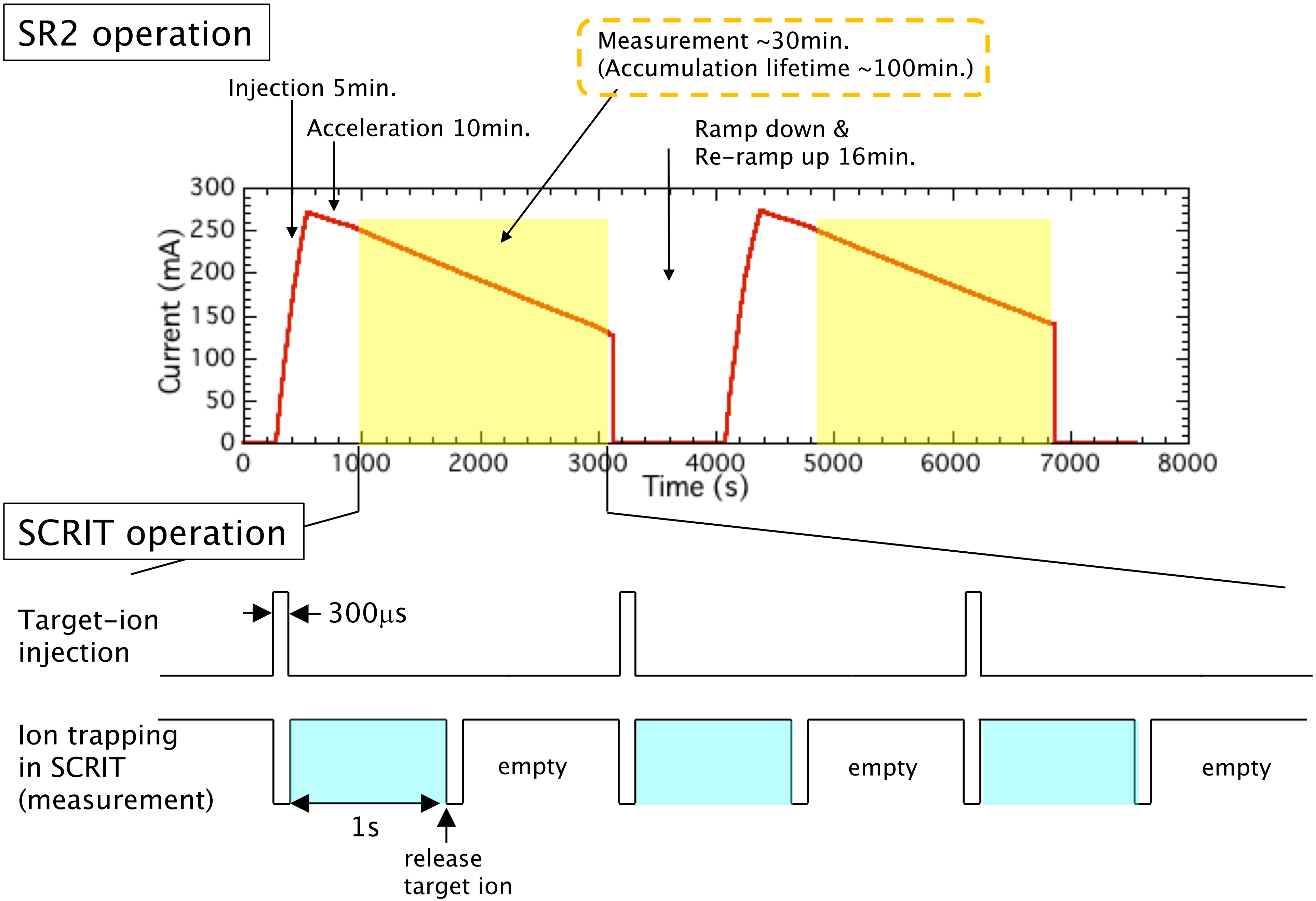


The SCRIT device



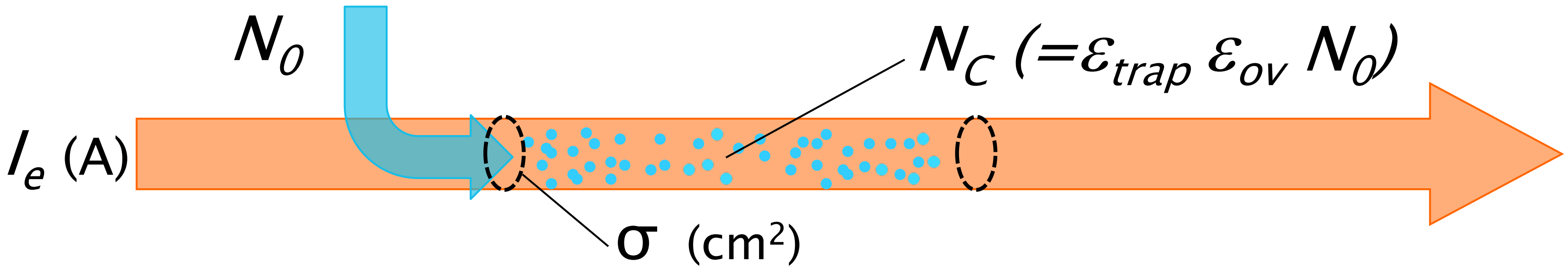
Time sequence of the SCRIT system operation

Total duty factor ~0.25



Luminosity and its limit in the SCRIT system

Achievable luminosity



$$L \sim \frac{I_e/e \;\; N_C}{\sigma} \;/(\mathrm{cm}^2\mathrm{s})$$

Current performance (typical)

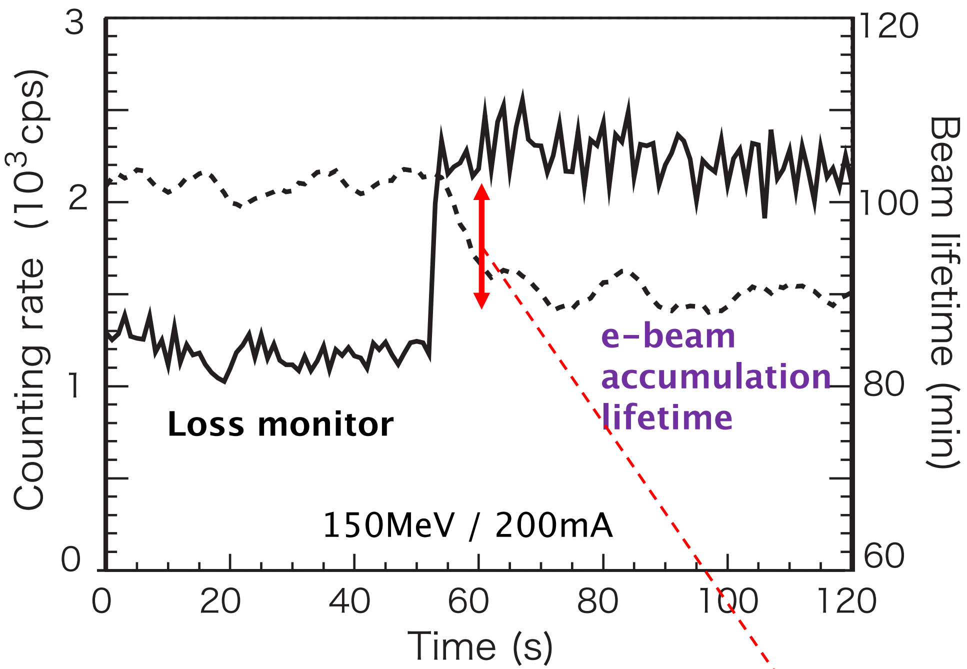
I_e ~ 220 mA ($1.3\mathrm{x}10^{18}$ /s)
σ ~ 3.5 mm^2
N_C ~ $2.6\mathrm{x}10^7$

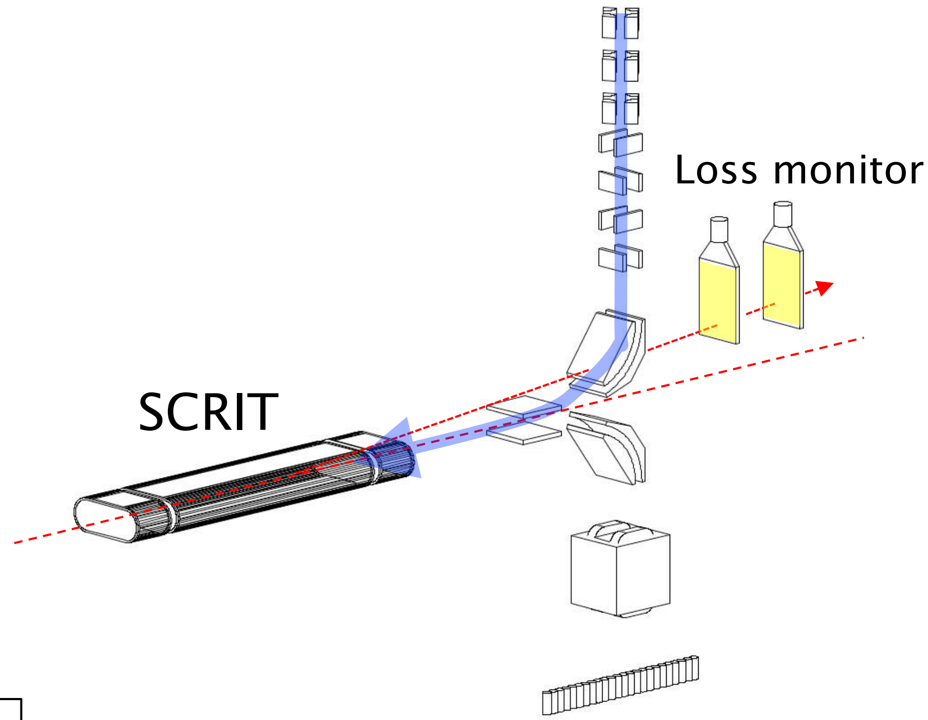
⇨ L ~ 10^{27} /(cm^{2}s)

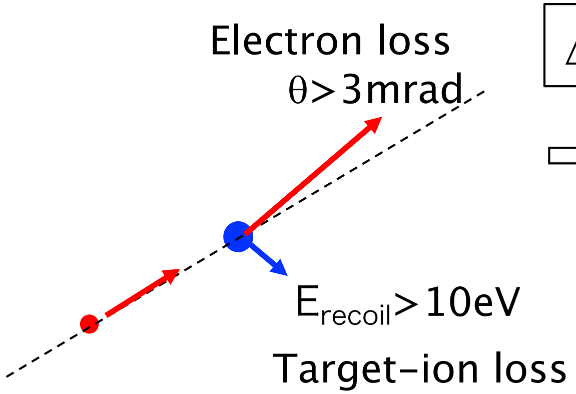
(Target thickness (N_C/σ) ~ $7.4\mathrm{x}10^8$/cm^2)

e-beam loss due to collision with target ions

Higher luminosity induces e-beam loss and target-ion loss







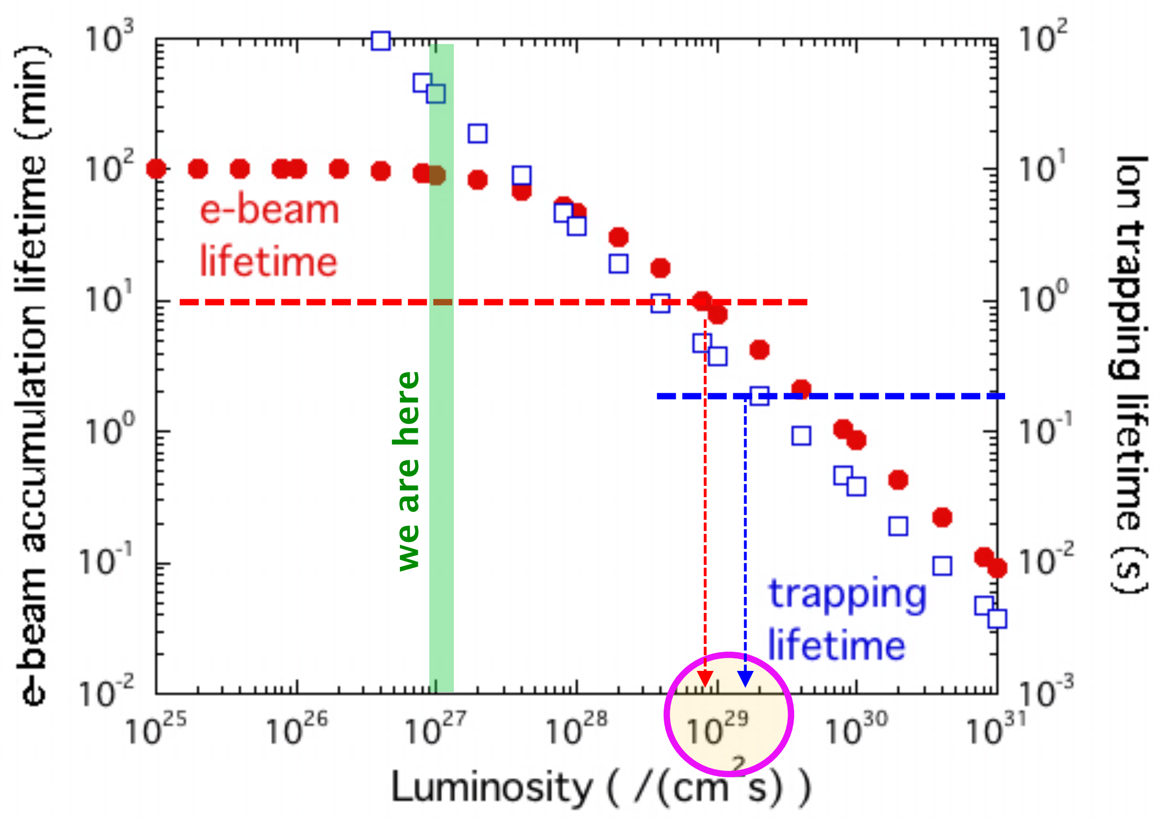
$\Delta\tau$ = -12 min.

⇨ Luminosity $1\times10^{27}/(cm^2 s)$

Electron loss rate due to target ions $2\times10^{6}/s$

Target-ion loss rate due to recoil $3\times10^{6}/s$

Luminosity limit estimated from the e-beam loss and target ion loss



Assuming minma:

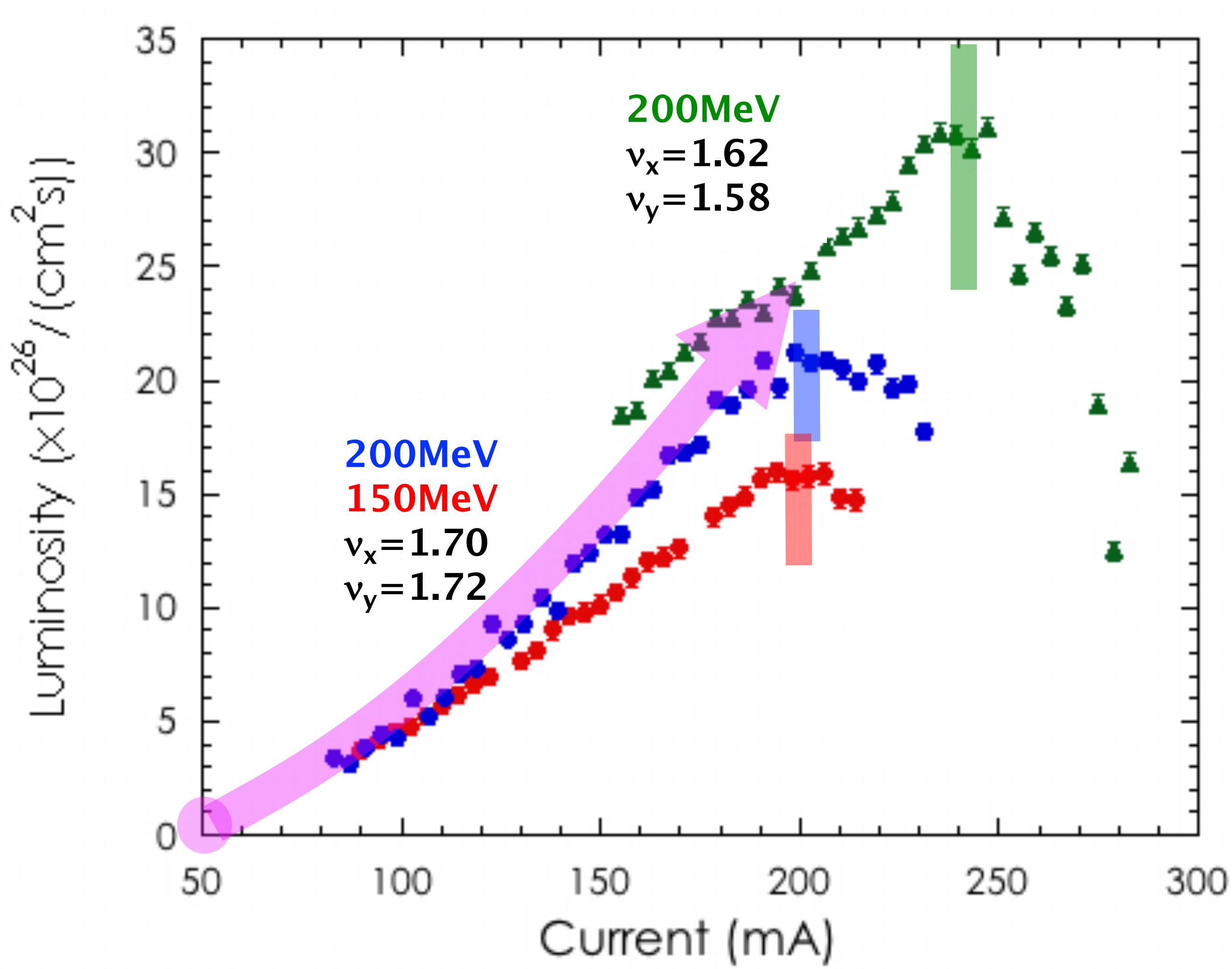
e-beam accumulation lifetime limit = **10 min.**

ion trapping lifetime limit = **200 ms**

Upper limit of luminosity:

$\boxed{\sim 10^{29}\ /(\mathrm{cm}^2\mathrm{s})}$

Achieved luminosity as a function of current



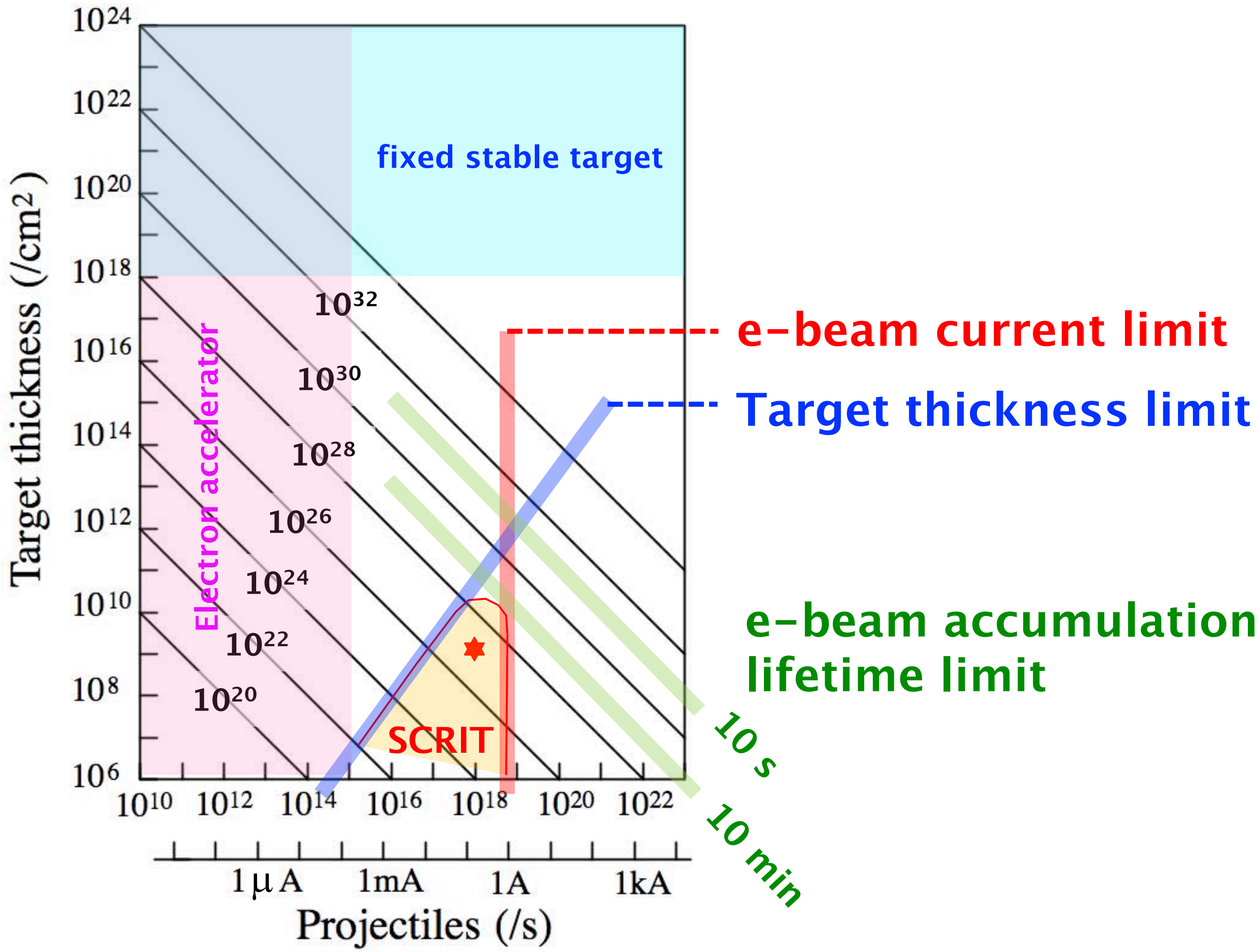
Injection N_0 = 3×10^8.

Trapping time 240ms.

- Ion trapping is started from 50mA
- Luminosity is increase with current
- Maximum Luminosity ~2×10^{27} /(cm2s)
- Instability was happen in large current region.
- Luminosity at 200MeV is lager than that at 150MeV, because of smaller beam size.

Short summary of luminosity at SCRIT

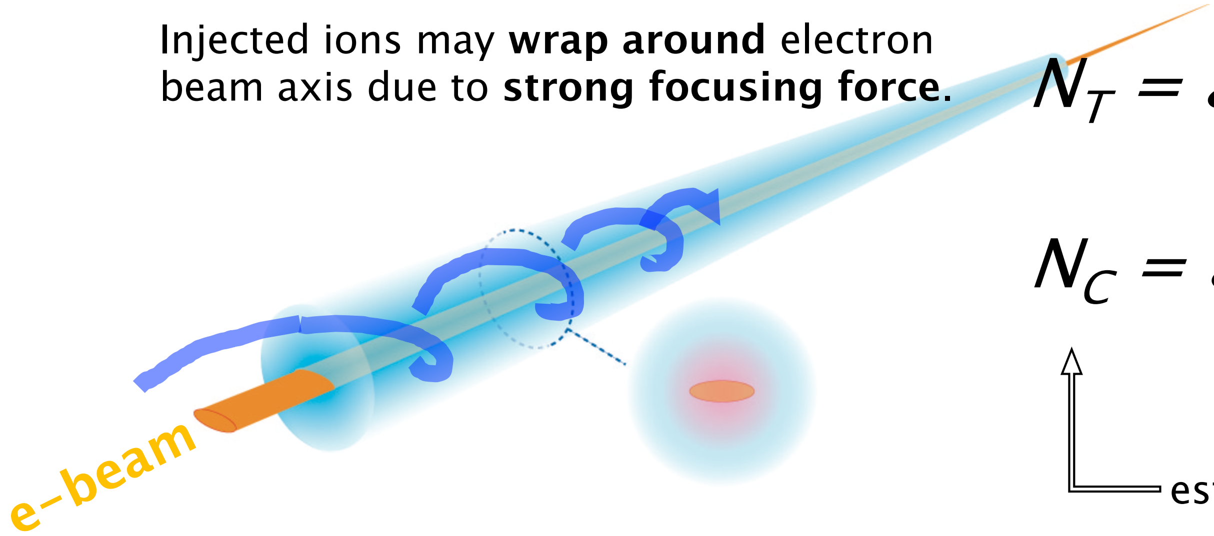
(with perfectly stable e-beam)



Properties of the target-ion trapping

Trapping efficiency ε_{trap} and overlap efficiency ε_{ov}

Injected ions may **wrap around** electron beam axis due to **strong focusing force**.



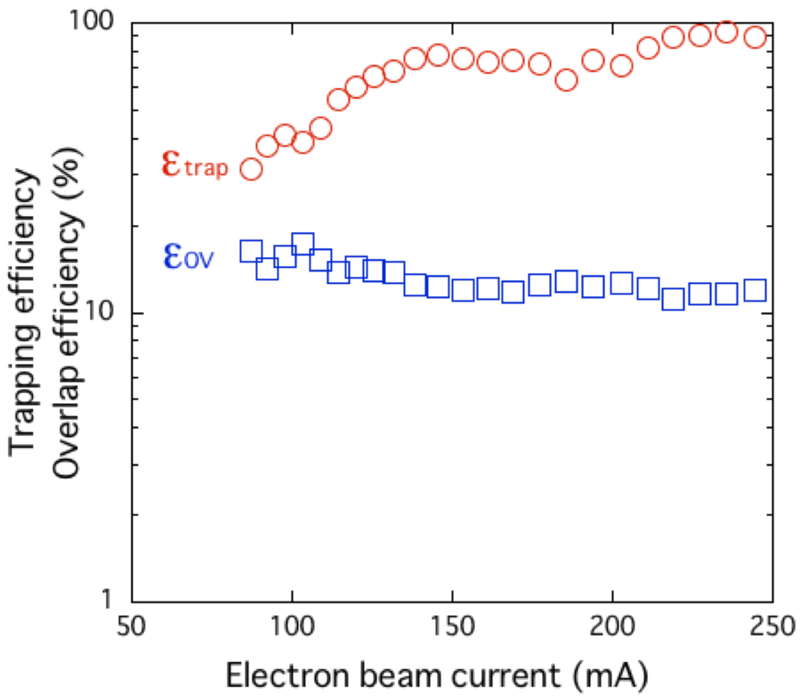
$$N_T = \varepsilon_{trap} \underline{N_0}$$

measurable

$$N_C = \varepsilon_{ov} \underline{N_T} = \varepsilon_{OV}\, \varepsilon_{trap}\, N_0$$

measurable

estimated from luminosity

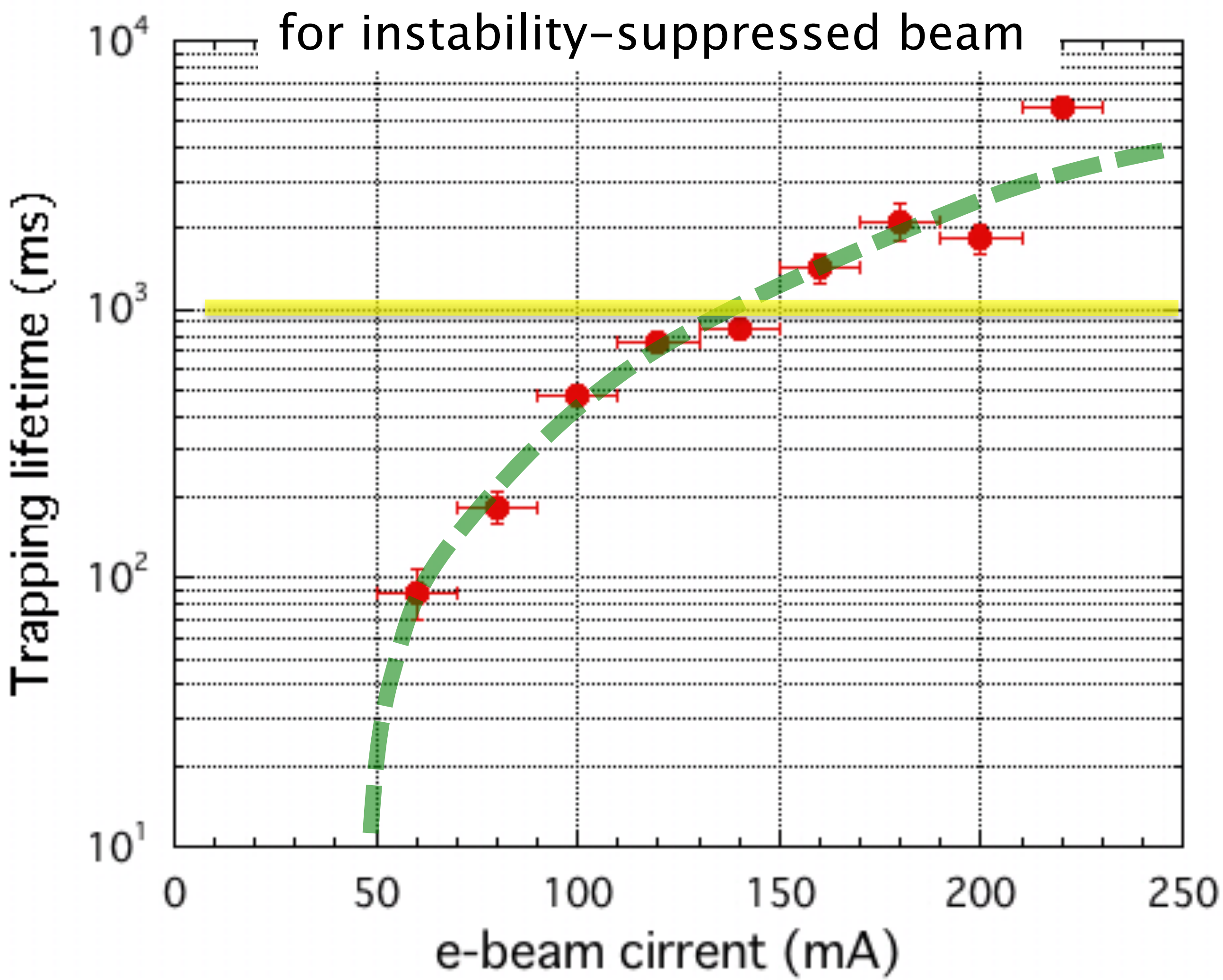


$\varepsilon_{trap} > 90$ %

$\varepsilon_{OV} \sim 13$ %

∼10 % of injected target ions participate collision

Current dependence of trapping lifetime



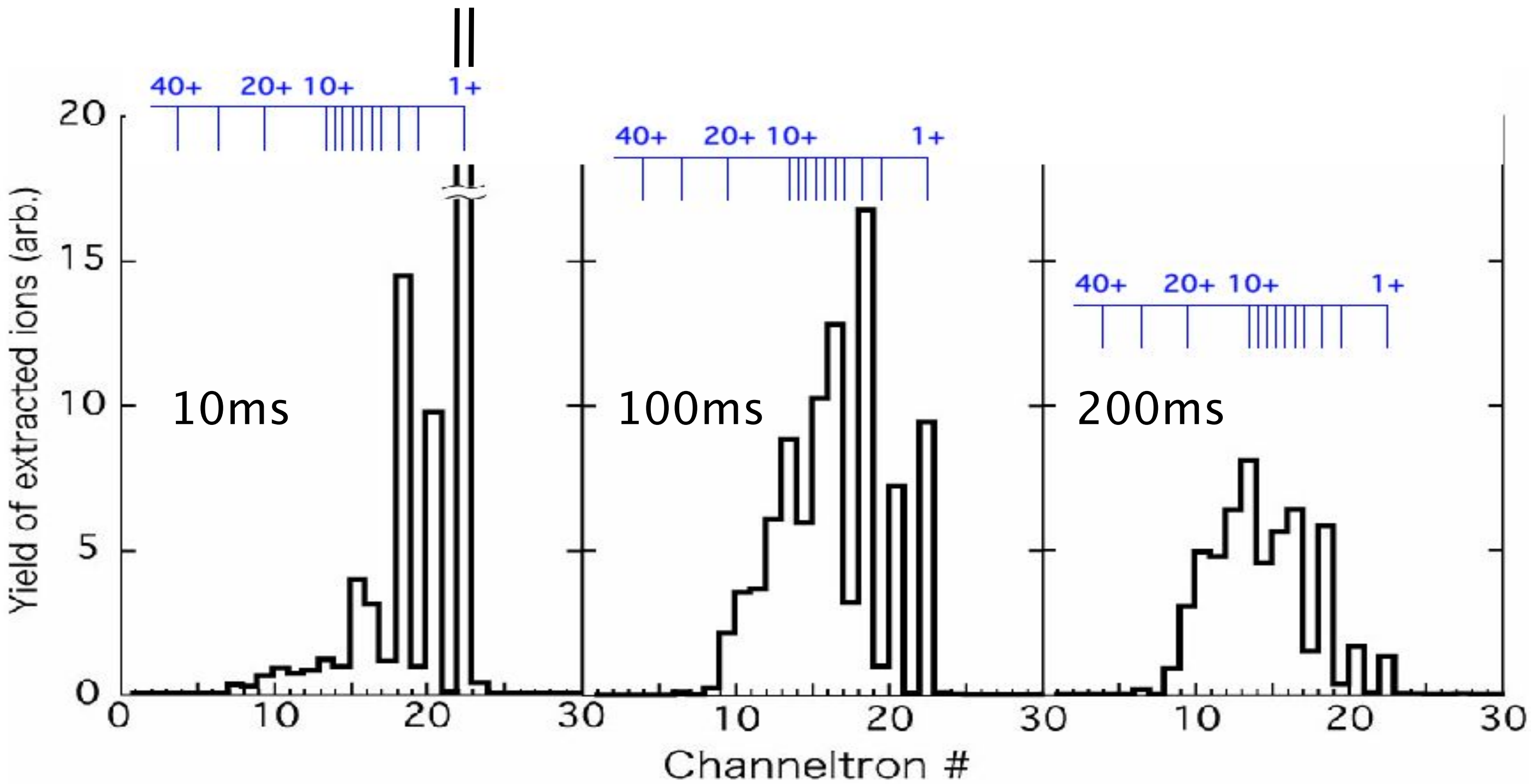
Necessary lifetime is
~1s for practical use

Prerequisite for e-beam

I_e > 150mA

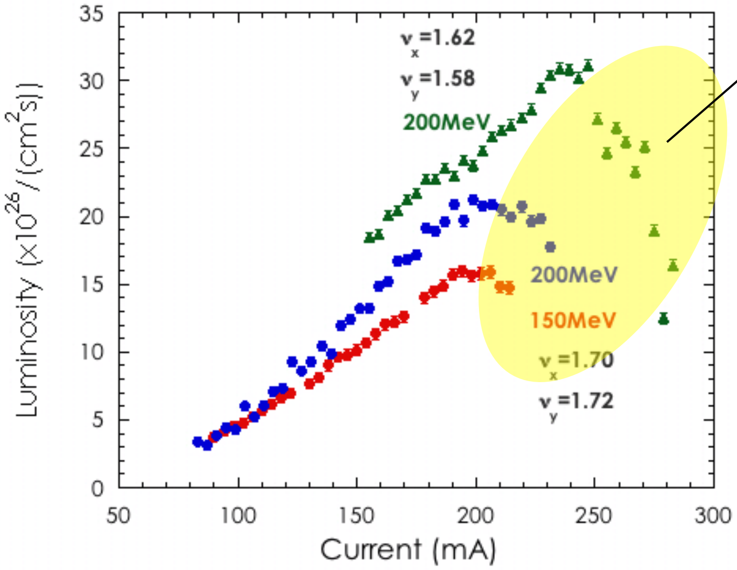
without instability

Temporal evolution of charge states of target ions



- Maximum charge state is ~20^{+}, and higher charge states (>20+) do not exist in the SCRIT.
  - → Dropout of higher charge state ions
- Rapid increase of a total charge (target ions + residual gas ions)
  - → Space charge effect (Neutralization limit : ***~10^{9} charges***)

Electron beam instability



What happen in this region

Microwave instability
Coupled bunch instability
HOM excited in cavity
Intra-beam scattering
etc.

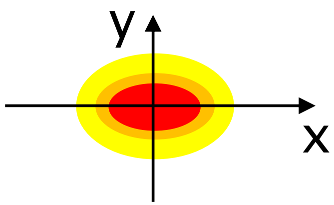
coupled to

Synchrotron oscillation

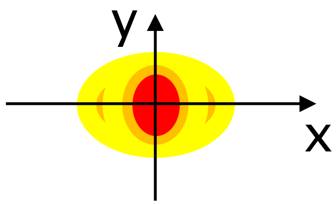
Betatron oscillation

Induced multi-pole coherent motion

Dipole oscillation



Quadrupole oscillation



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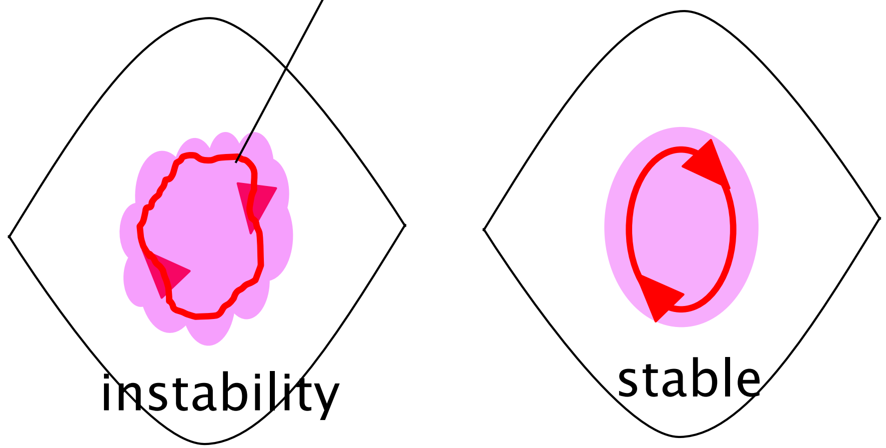
higher multi-modes



Beam motion in longitudinal phase space

Influences of e-beam oscillation and space charge on trapping lifetime

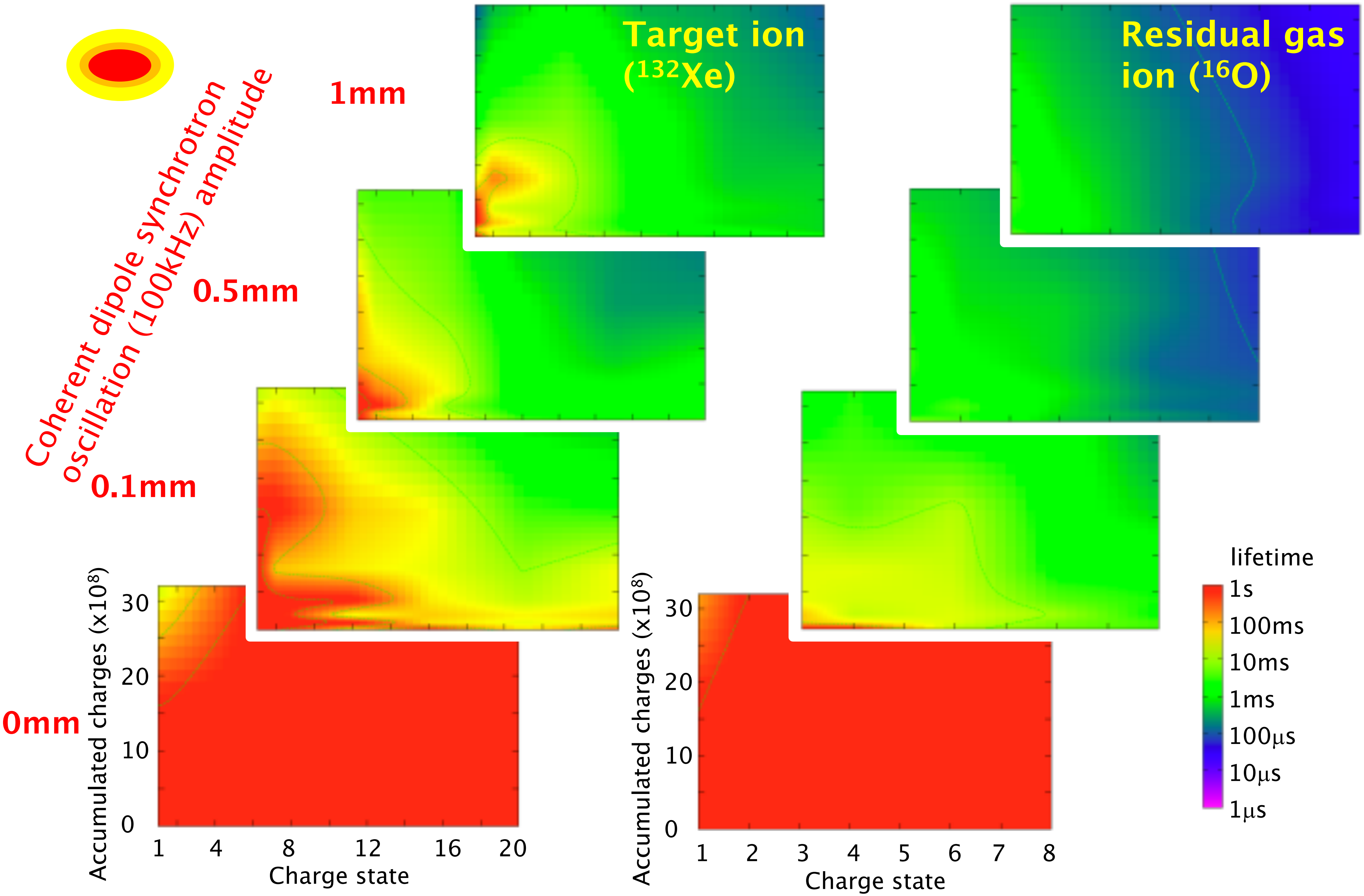
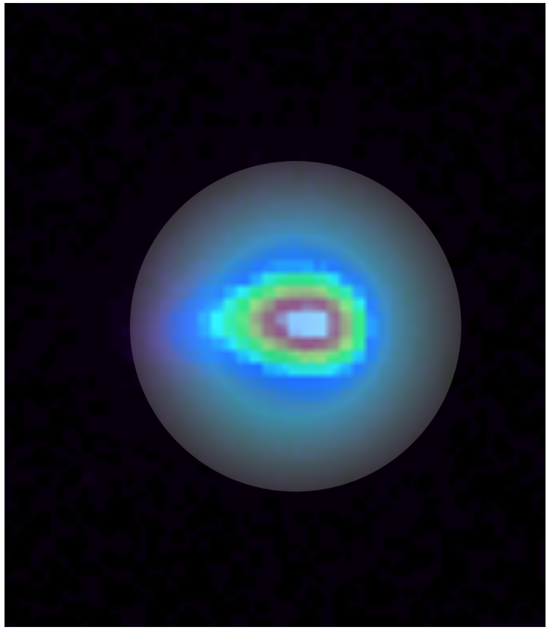
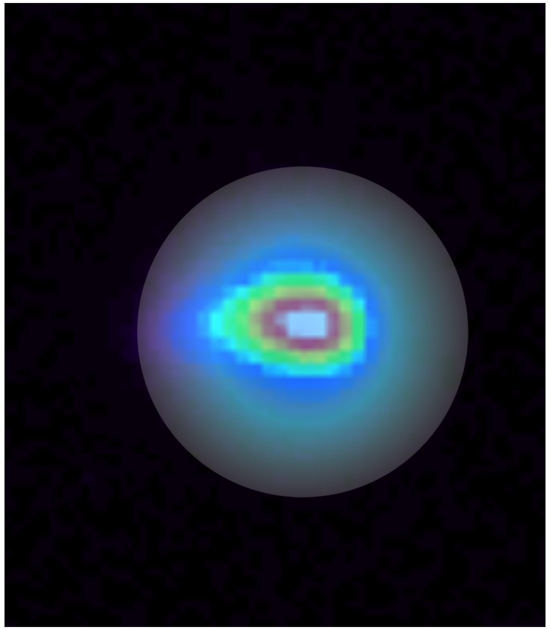
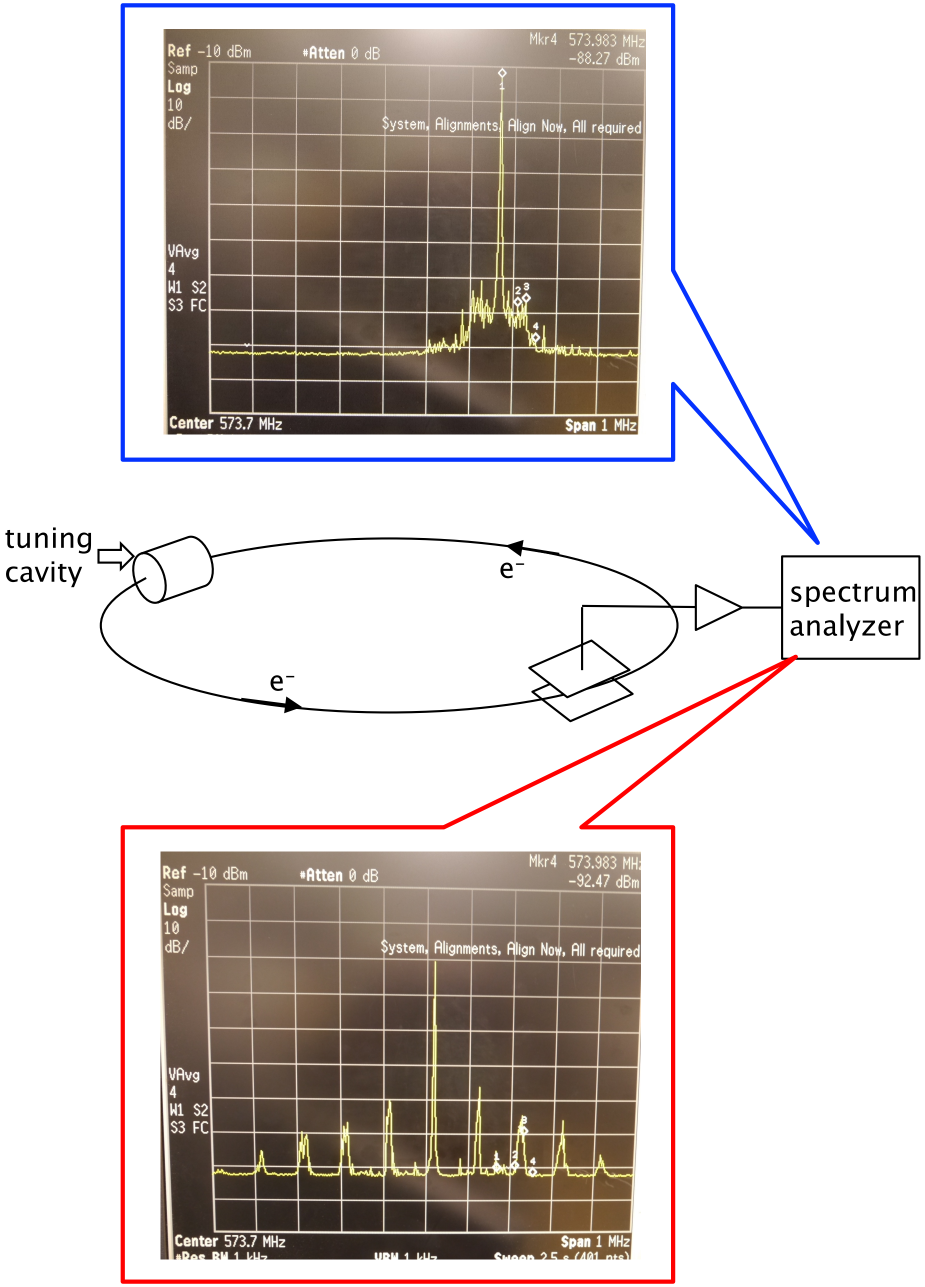


Image of ion trapping with/without e-beam instability







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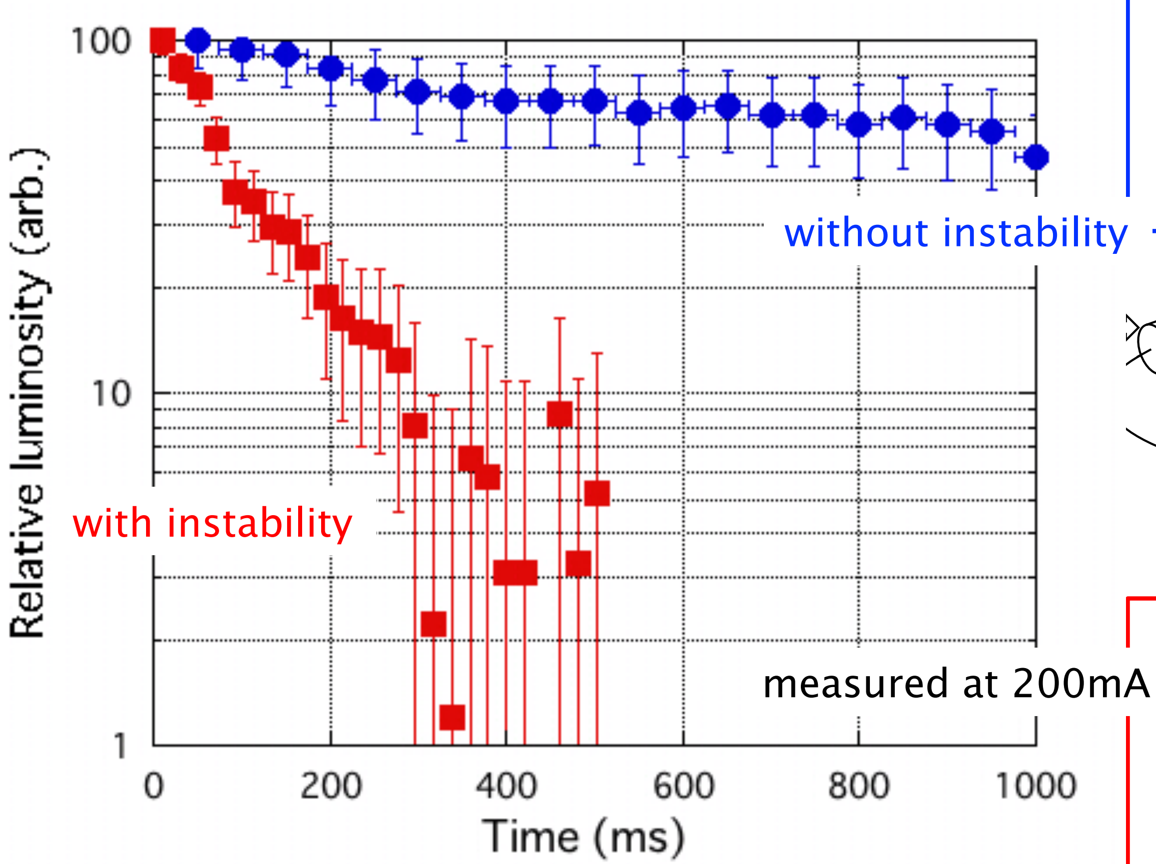
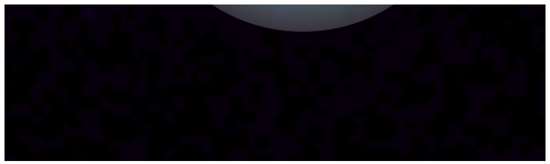
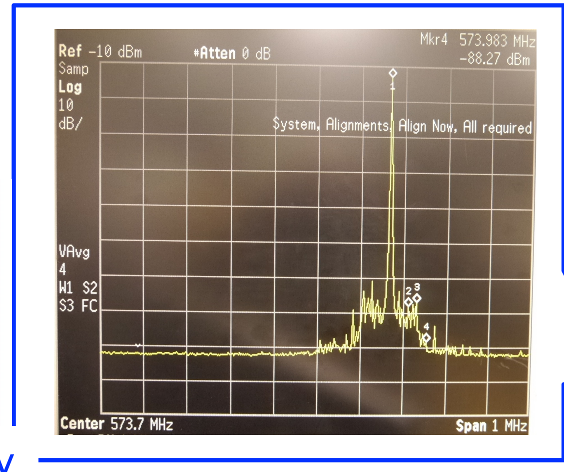
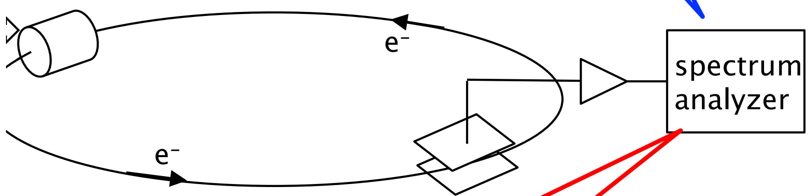
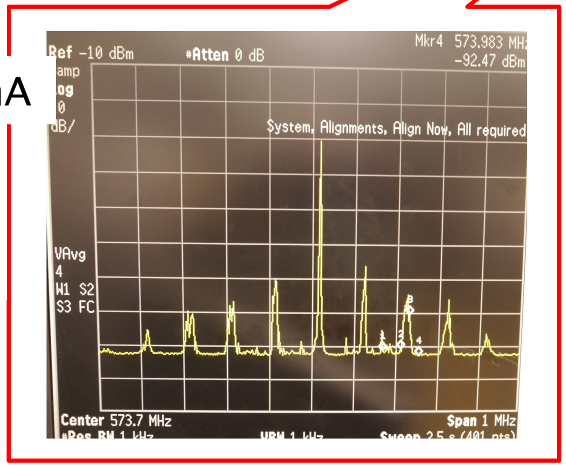




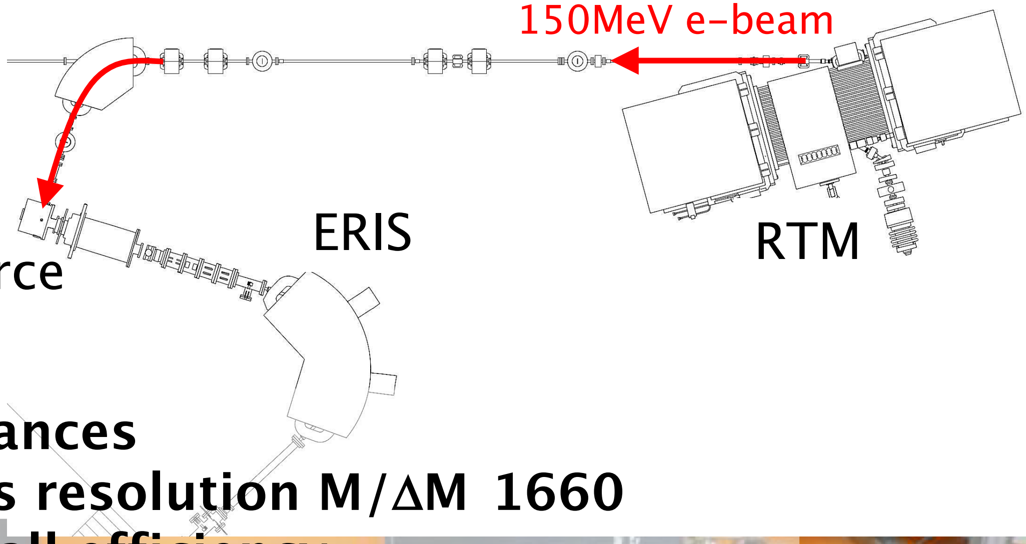






Preparation of target RI ions

ERIS (Electron-beam-driven RI separator for SCRIT)



Performances

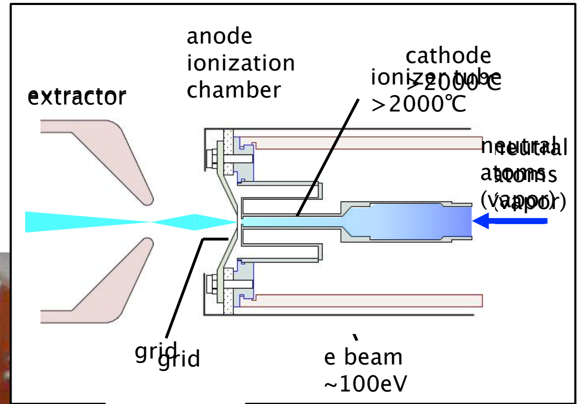
mass resolution M/ΔM 1660

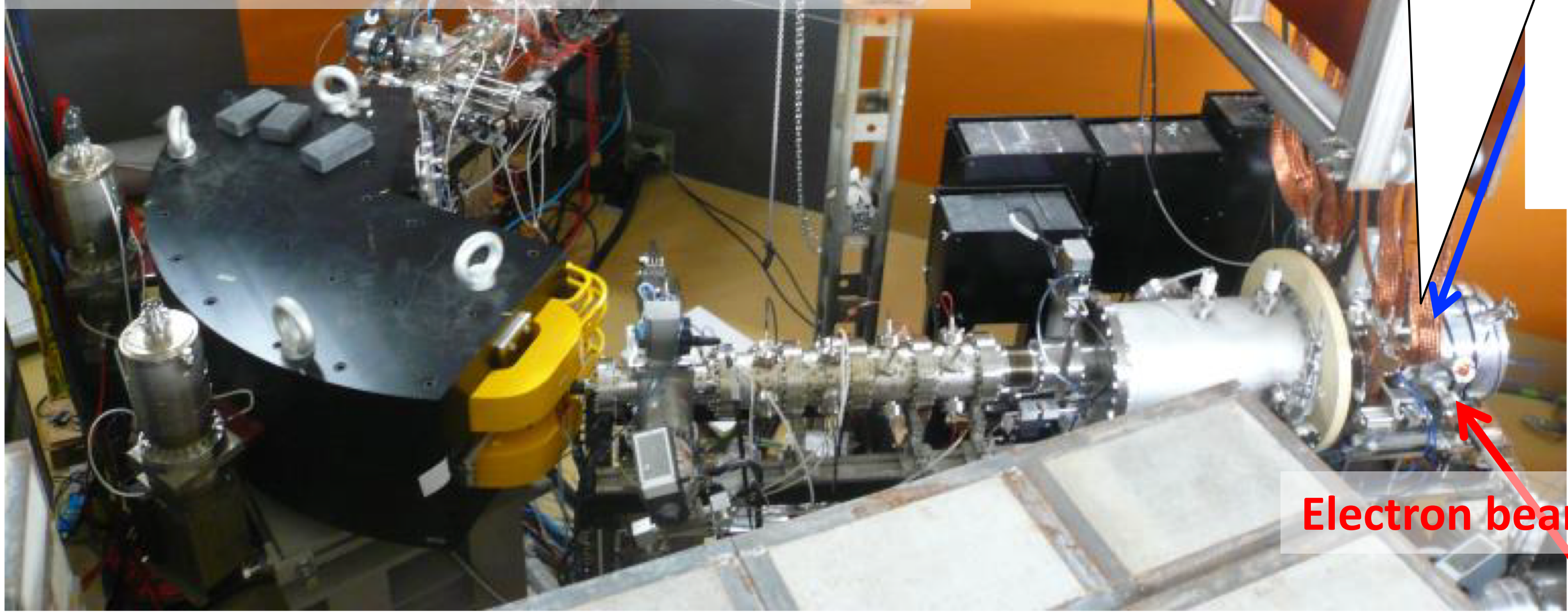
overall efficiency

21 % (record values for Xe in FEBIAD)

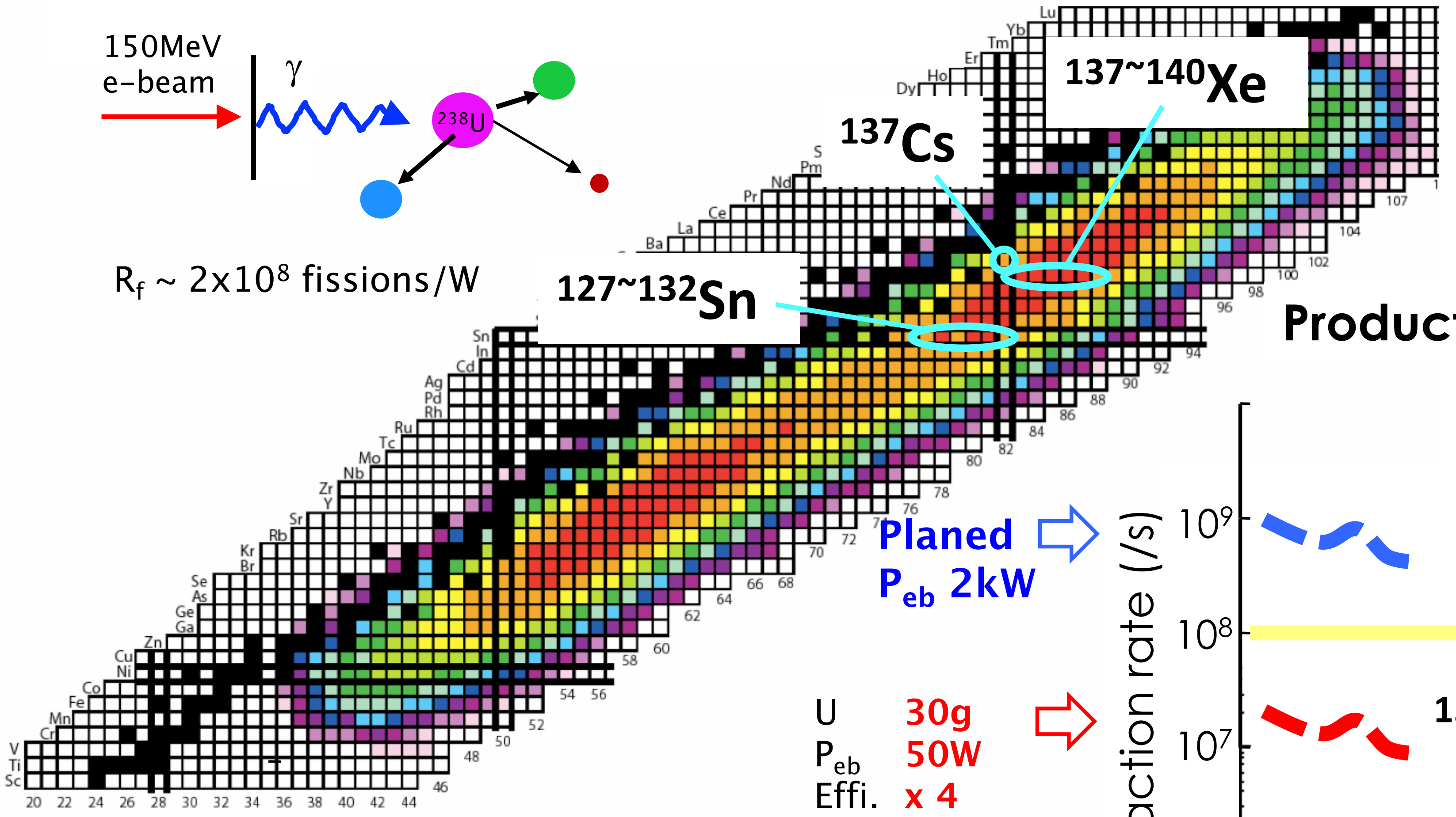
>99 % (Cs in SI)

FEBIAD or SI ion source





Unstable nuclei produced by photo-fission of ^{238}U



R_f ~ 2x10^8 fissions/W

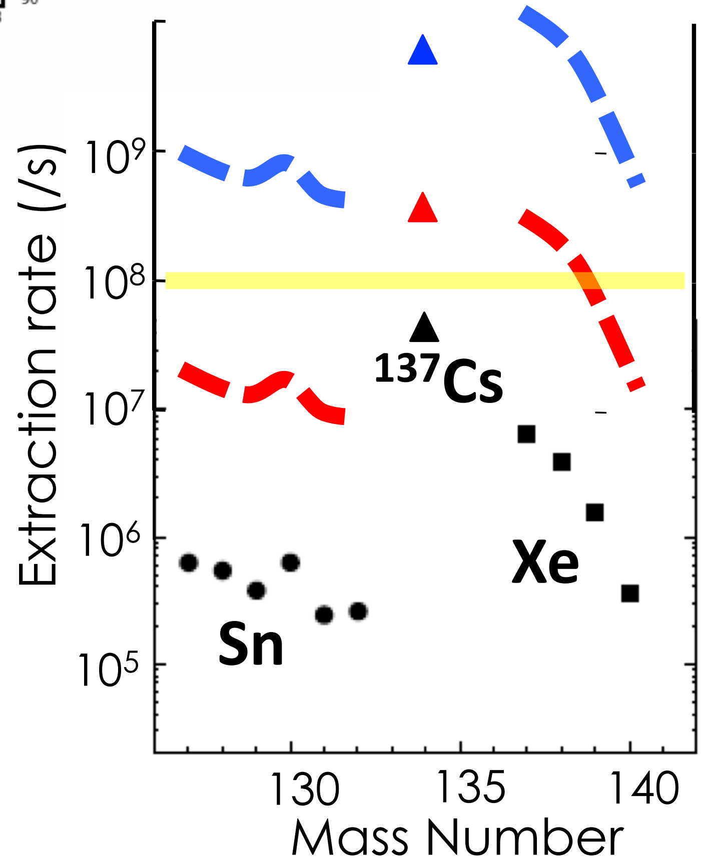
RI production for ■ > 1 % of R_f
(candidates of experiments)

Production rate

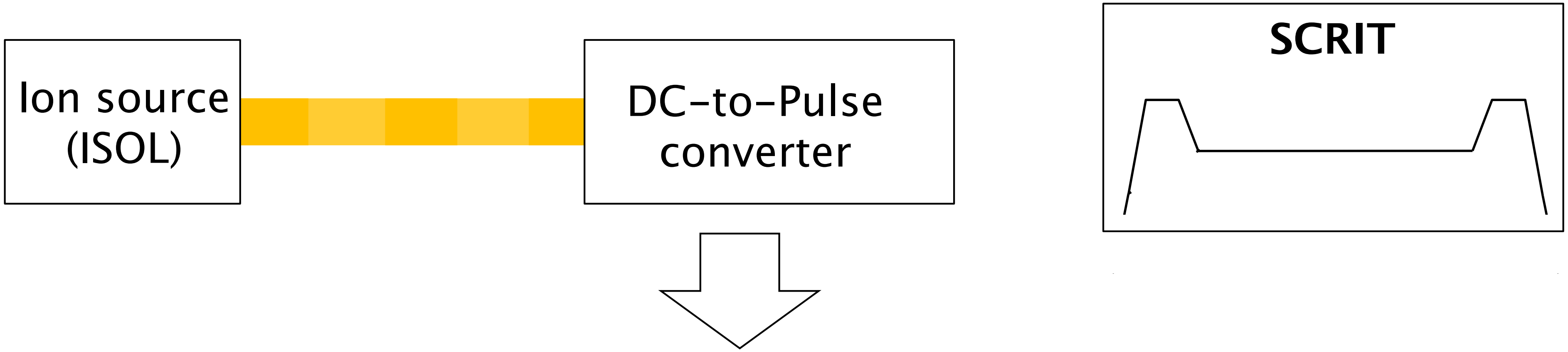
Planed
P_{eb} 2kW

U 30g
P_{eb} 50W
Effi. x 4

U 15g
P_{eb} 10W
Effi. 5.5% ^{138}Xe
2.0% ^{132}Sn

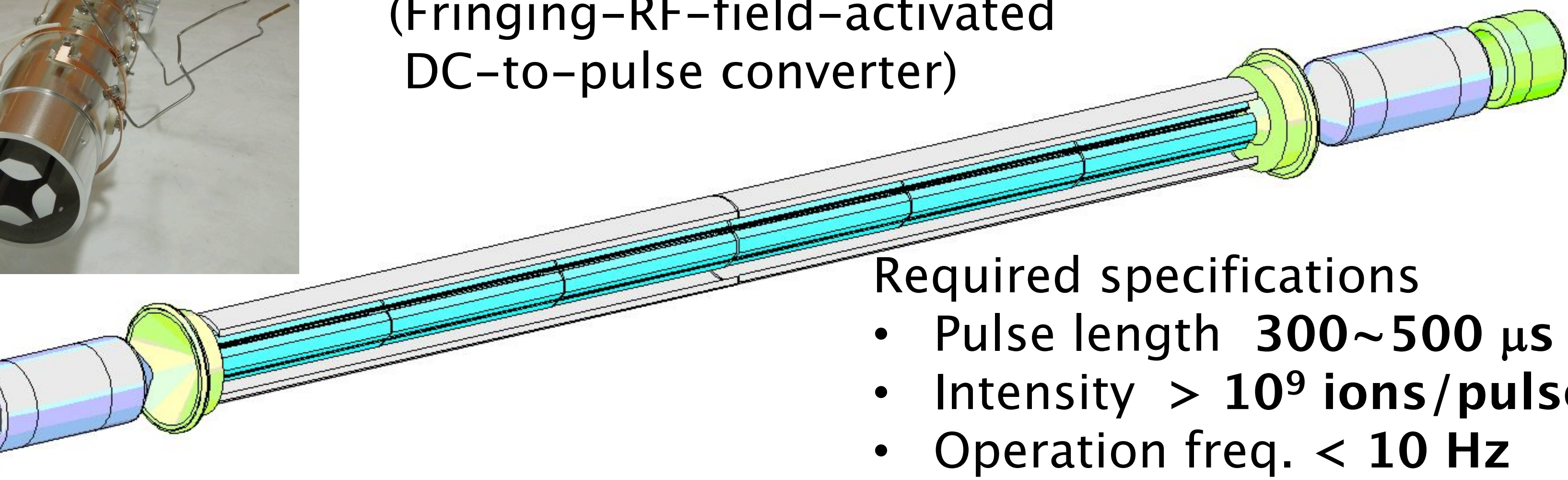


DC-to-Pulse conversion for injecting ions into SCRIT



RFQ linear trap device

FRAC
(Fringing-RF-field-activated
DC-to-pulse converter)

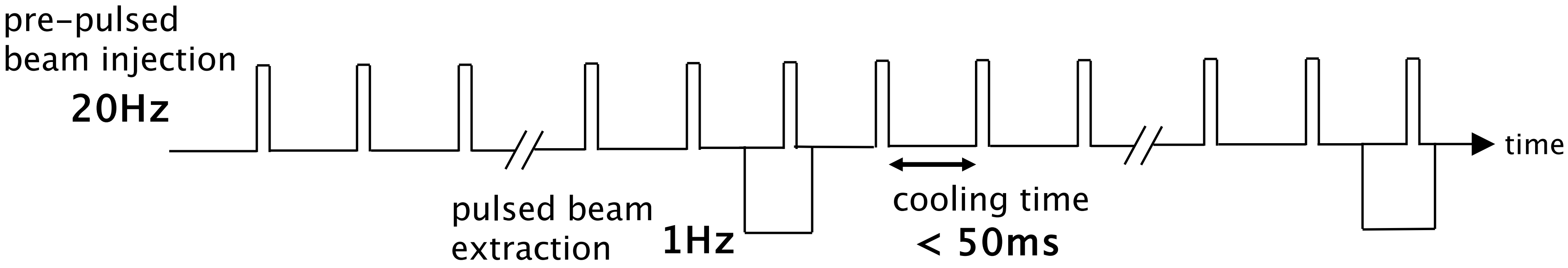


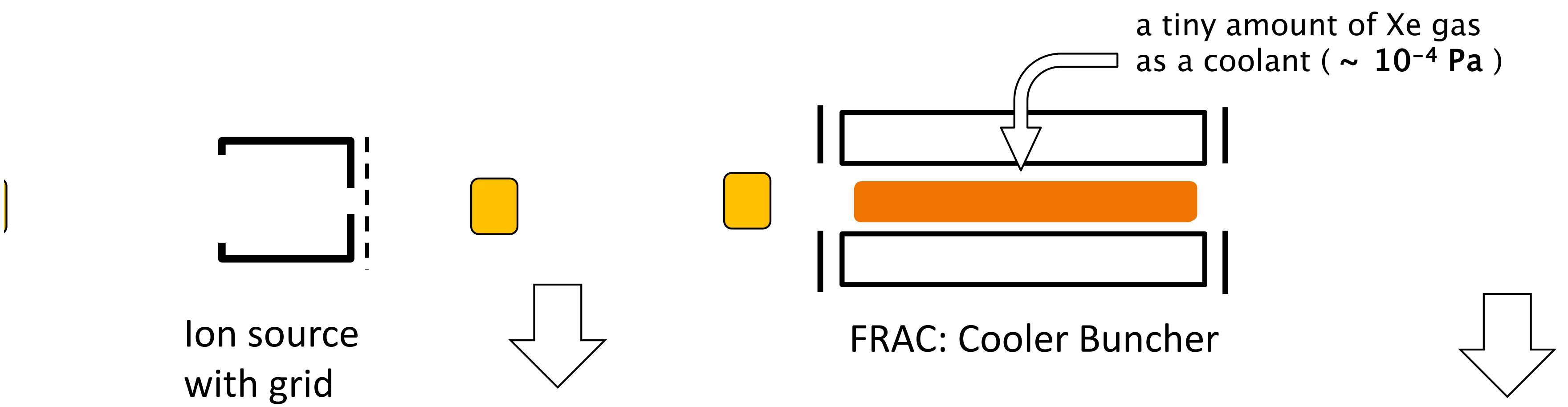
Required specifications

- Pulse length **$300 \sim 500\ \mu s$**
- Intensity **> 10^9 ions/pulse**
- Operation freq. **< 10 Hz**
- Conversion eff. **~ 100 %**

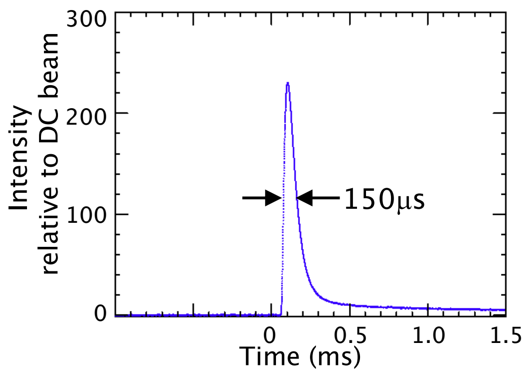
Two-step pulsing for higher conversion efficiency

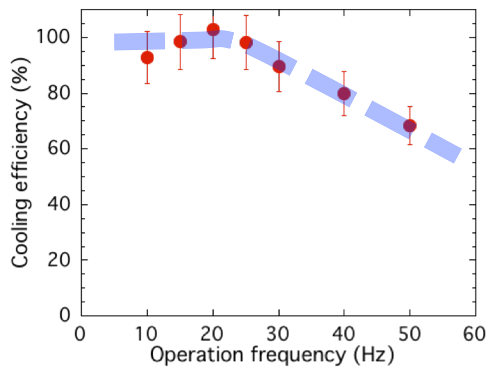
Grid pre-pulsing at IS + Stacking and Cooling in FRAC

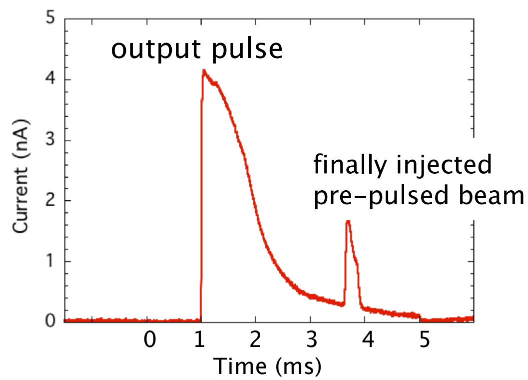




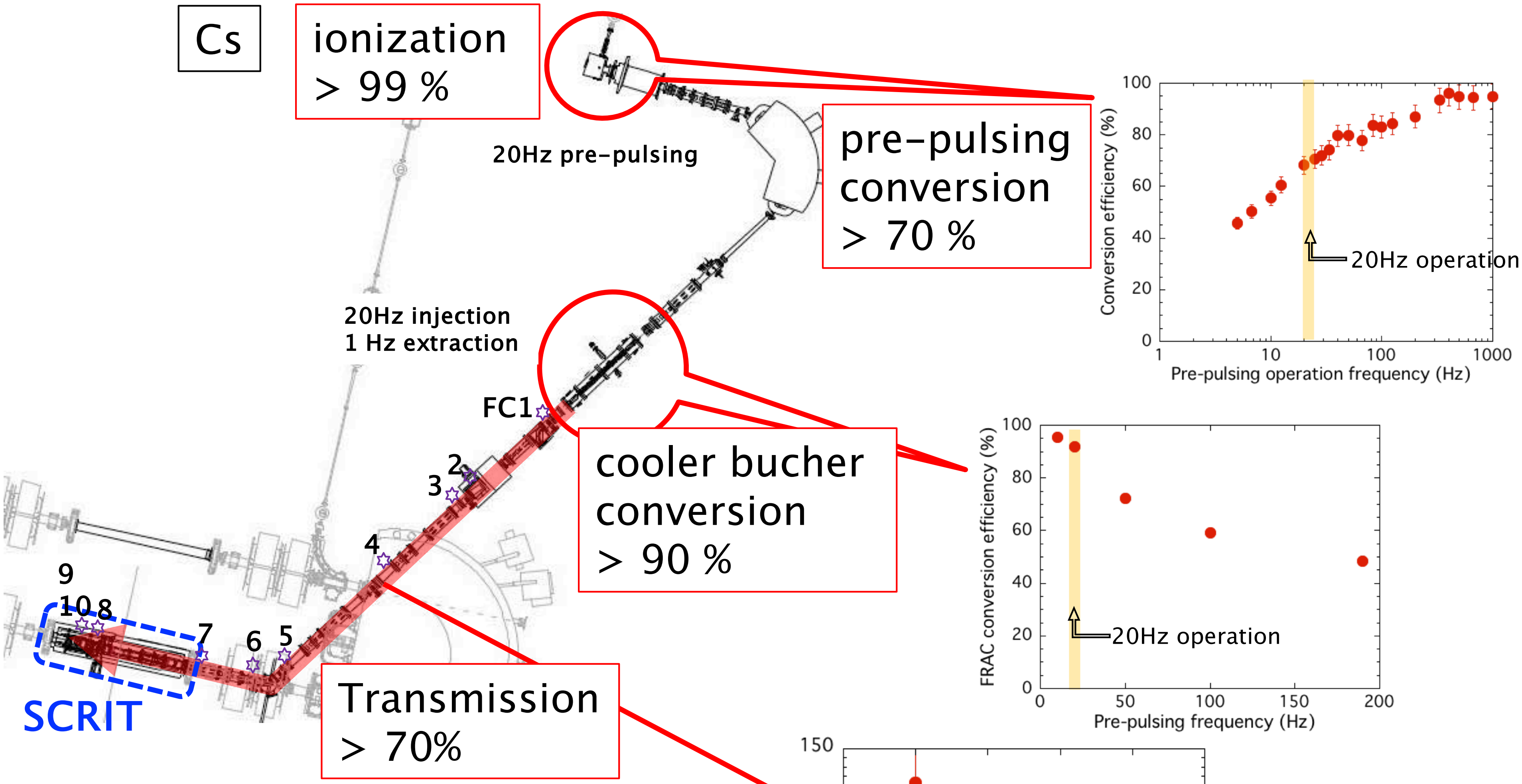
Cs

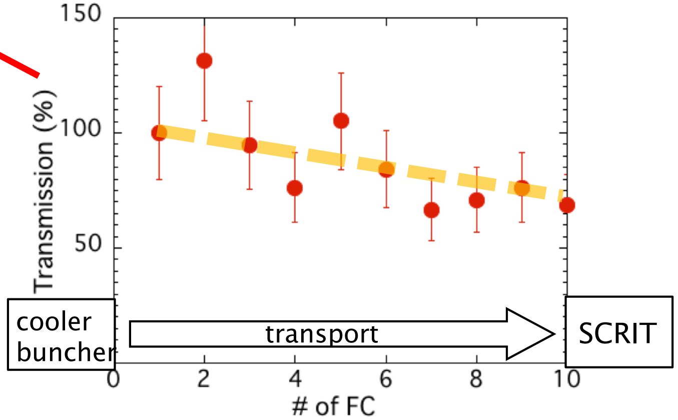






Recent improvement in overall efficiency for target ion injection

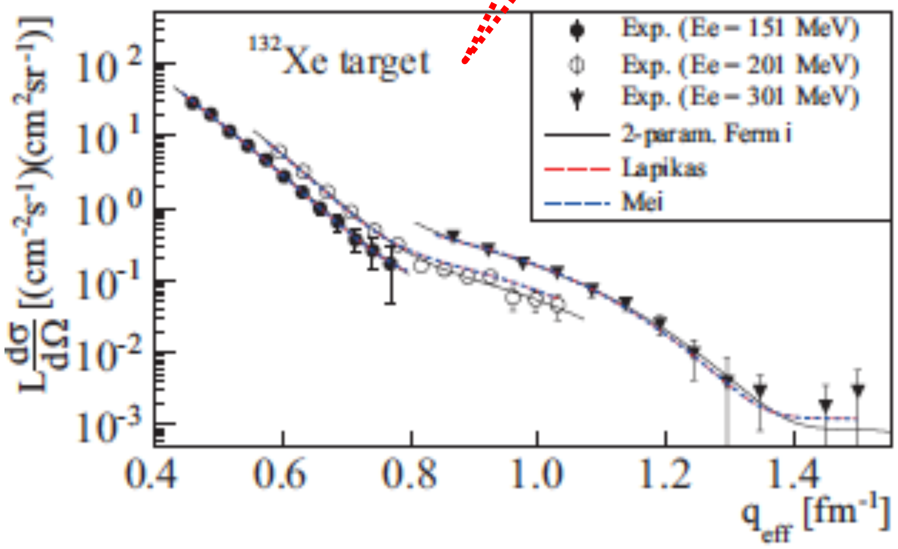




$$\frac{\text{(Injected ions into SCRIT)}}{\text{(Extracted ions from ERIS)}} \sim 50\ \%$$

Overall efficiency for target ion injection

	at ^{132}Xe experiment	recent improvements
Injection efficiency	< 1%	~ 50 %
Required ERIS intensity for L~10^{27}/(cm^{2}s)	a few nA (~2×10^{10} ions/s)	~ 30 pA (~2×10^{8} ions/s)



Tsukada et al., PRL, 118, 262501 (2017)

The first unstable ^{137}Cs experiment

RTM 10W ⇨ 50~100W

# of U fissions 2×10^{10} /s

production ^{137}Cs 4×10^{8} /s

possible to reach L~10^{27} /(cm^{2}s)

Summary

1. **The SCRIT facility has been constructed and an electron scattering has become one of ISOL experiments**

2. **Upper limit of achievable luminosity in our SCRIT system is $\sim 10^{29}$ /($cm^2 s$), and new technique is required for further luminosity.**

3. **Electron-beam-instability suppression is the most important issue to get higher and temporally stable luminosity.**

4. **Improvement of the target-ions transmission from ERIS to SCRIT has been completed, and we will be ready for the first experiment for unstable nuclei.**

Thank you for your attention