

Recommissioning of the CRYRING@ESR Electron Cooler

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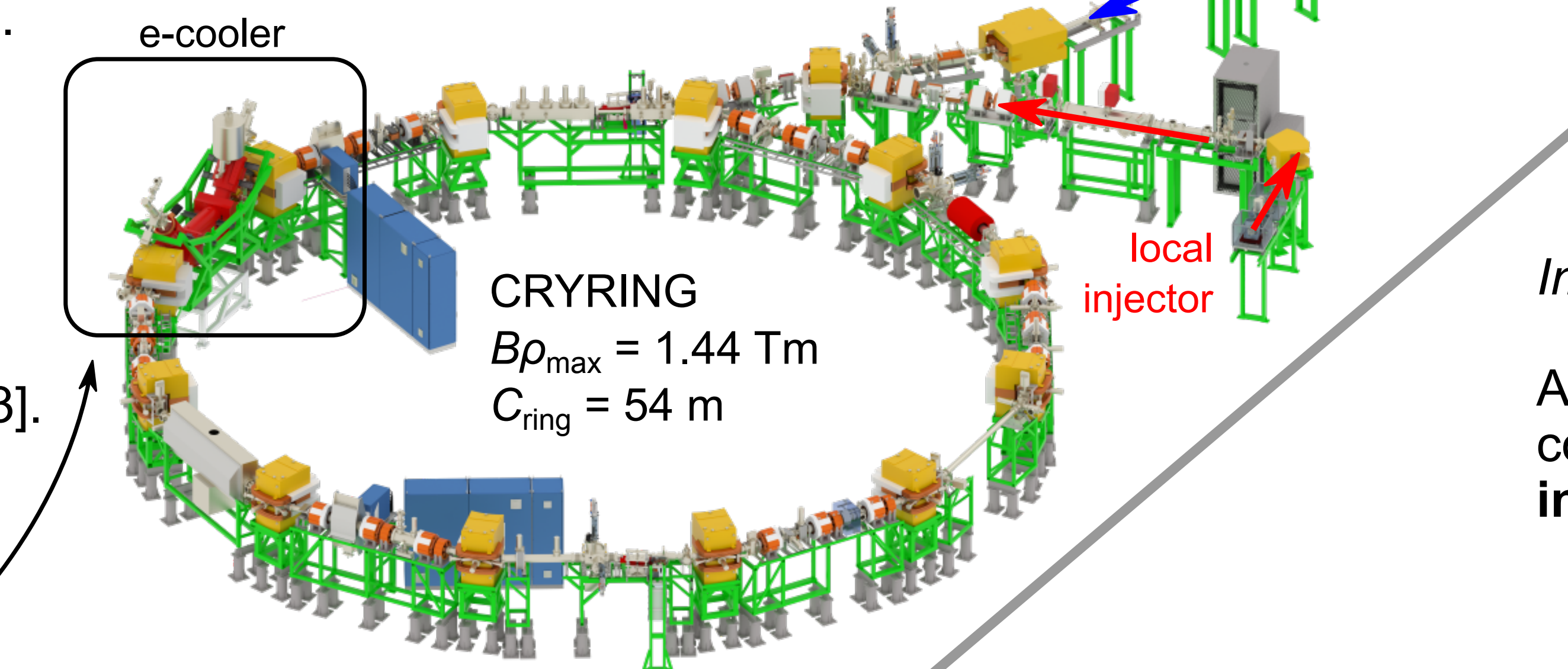
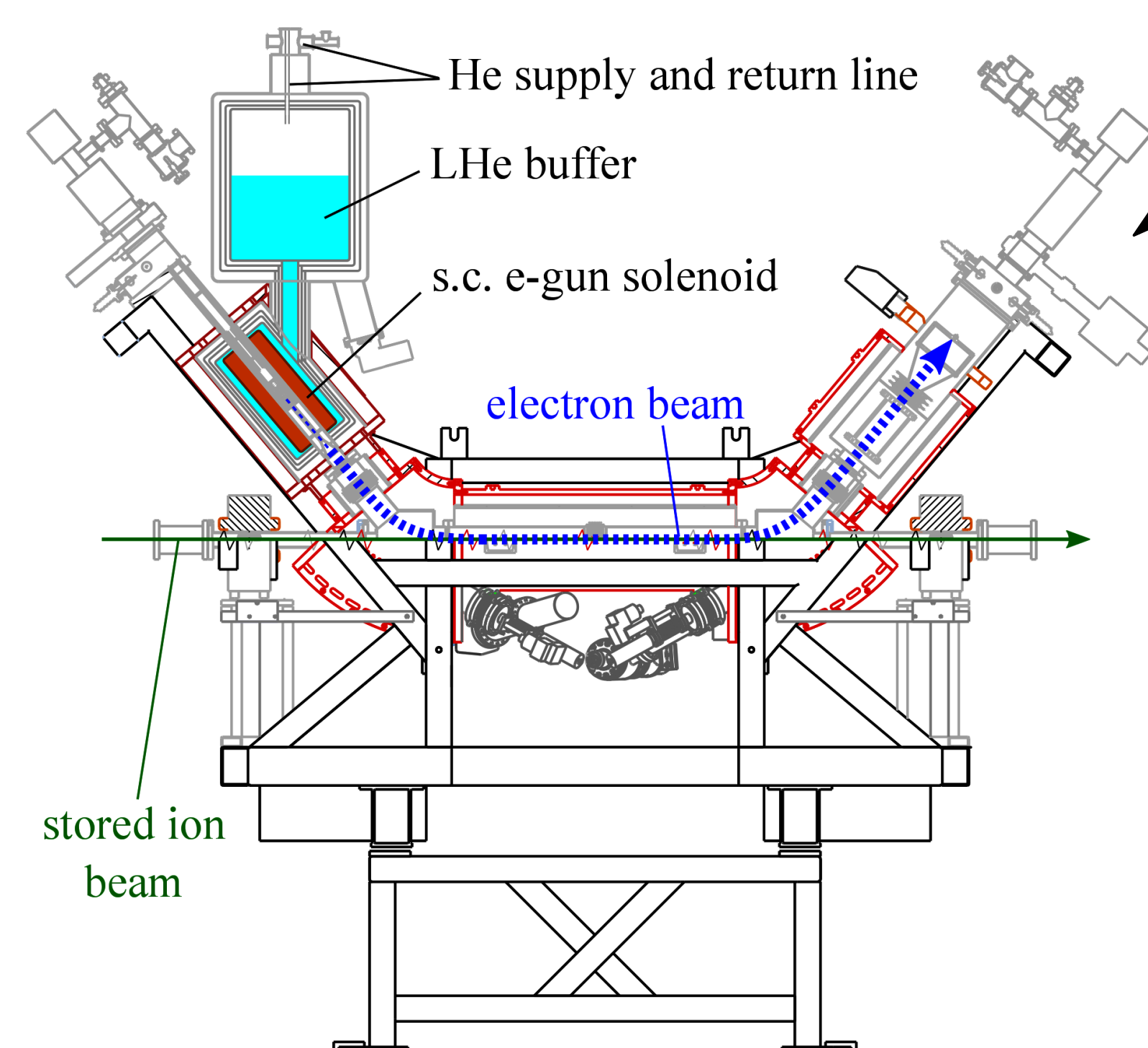
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CRYRING@ESR

Dedicated low-energy ring [1] for precision experiments on stored and cooled ions [2] (Swedish in-kind contribution to FAIR). Can accept **highly-charged ions from ESR** or **weakly-charged ions from local injector**.

Electron cooler

Main feature: low-temperature ($\sim 2 \text{ meV}/k_B$) electron beam from strong-expansion e-gun [3].



e-energy: $\leq 8 \text{ keV}$
($\leq 14.6 \text{ MeV/u}$)
Current: $< 110 \text{ mA}$
Expansion: 1 ... 100
Beam $\varnothing$: 4 ... 40 mm
Length: 1.1 m
($\sim 2\% C_{\text{ring}}$)

Hardware upgrades

Cryostat of s.c. gun solenoid connected to closed-loop LHe plant.
→ Refills require no e-beam interruption or cave access.

New front-end CPUs for all power and HV supplies.
→ Integrated into FAIR accelerator control system.

Planned upgrades:
* Vacuum system
* New HV supplies
* e-beam diagnostics
* New s.c. solenoid

Monitoring of terminal potential at $< 10 \text{ ppm}$ by custom-made precision voltage dividers.

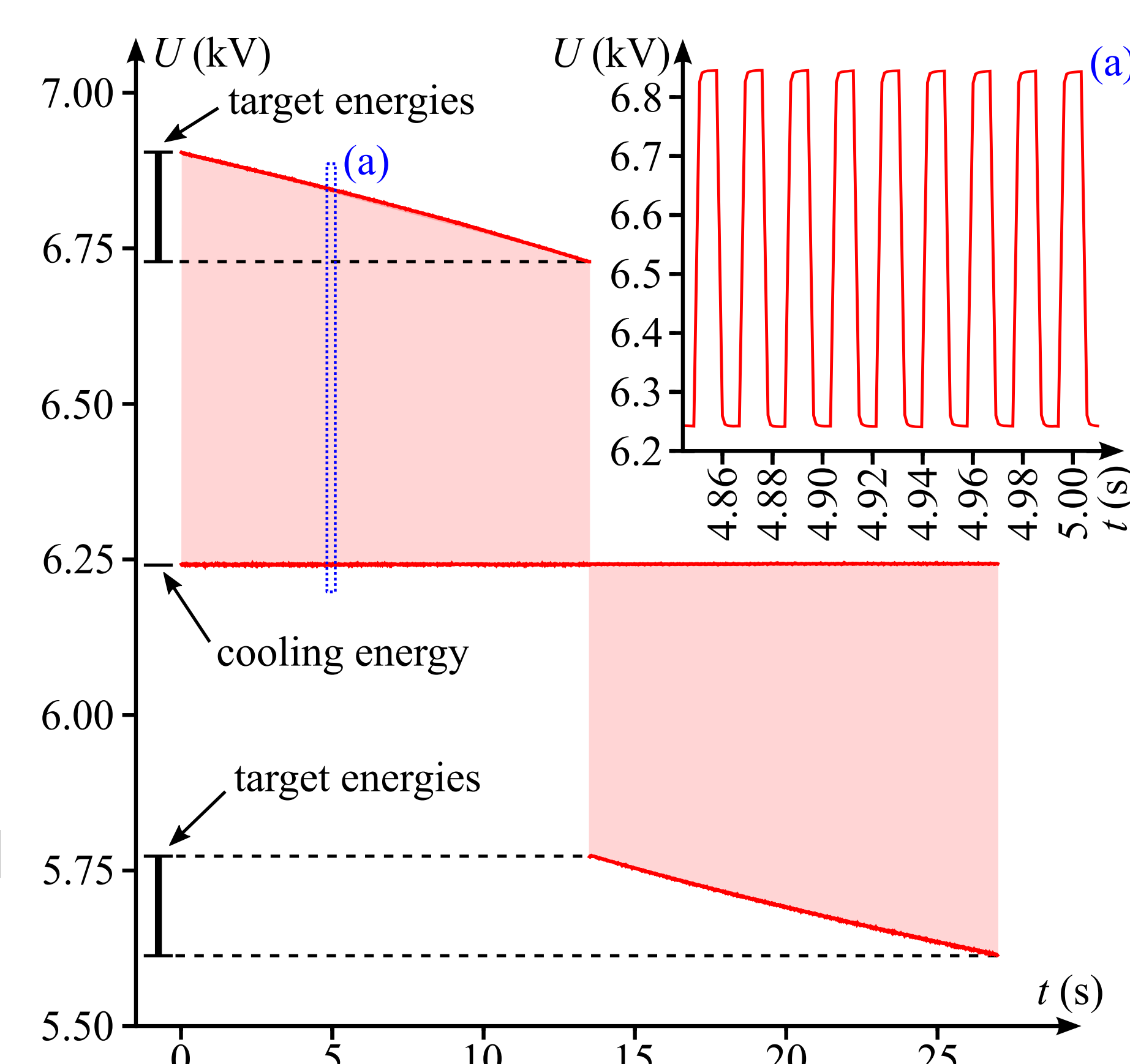
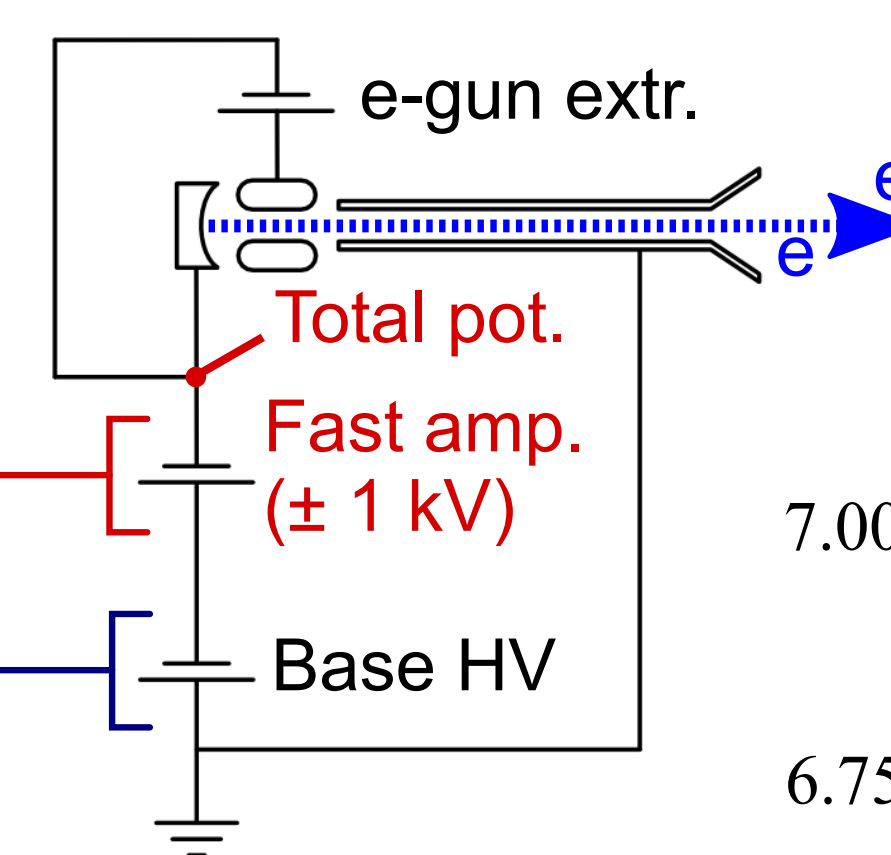
- 'G35': Highest accuracy, long-time-stability, DC mode [4]
- 'FC20': Frequency-compensated for $< 10 \text{ ms}$ ramps [5]

Cooler operation as internal electron target

Important part of experimental program:

Atomic physics experiments on electron-ion collisions. Require usage of cooler as **internal electron target** of variable energy.

New experiment control system for fast ($\sim \text{ms}$), **arbitrary ramps of electron energy**.



Electron cooling: first results

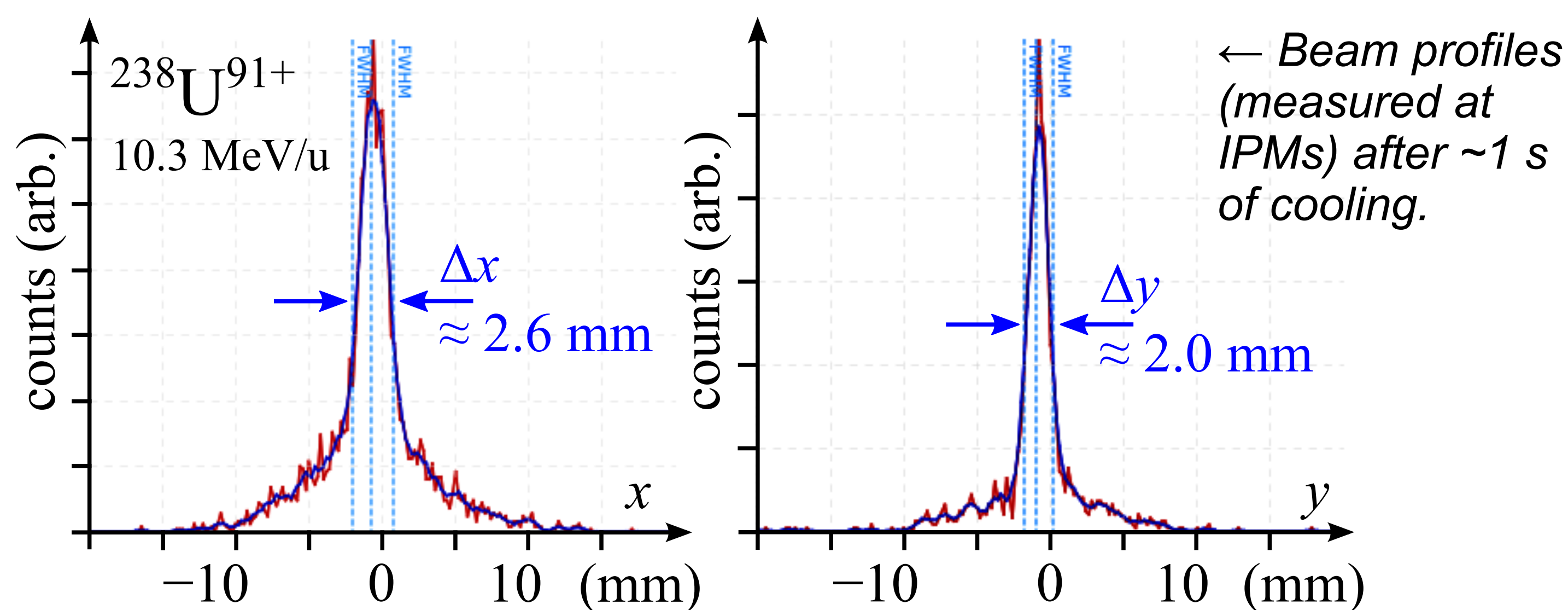
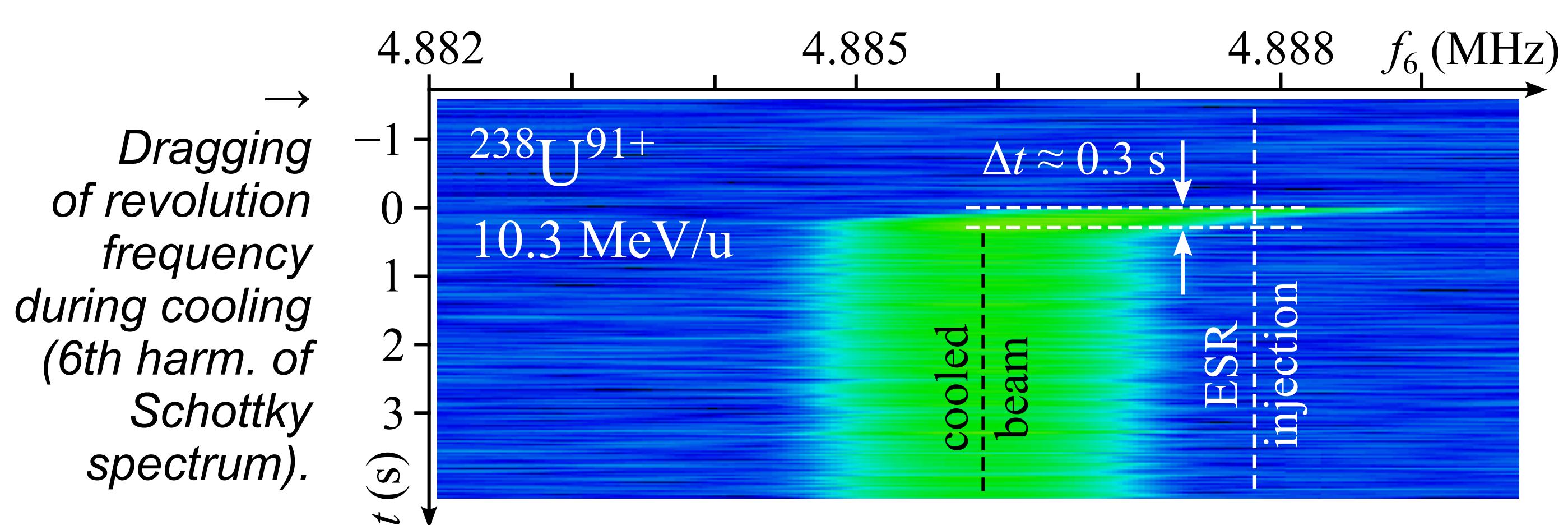
Cooler parameters

Acc. voltage: 5.63 kV
Current: 30 mA
Expansion: 33.3

Highly-charged ions: $^{238}\text{U}^{91+}$

Accelerated in UNILAC and SIS18 to 300 MeV/u for stripping.

Transfer to CRYRING at 10.3 MeV/u after deceleration in ESR.



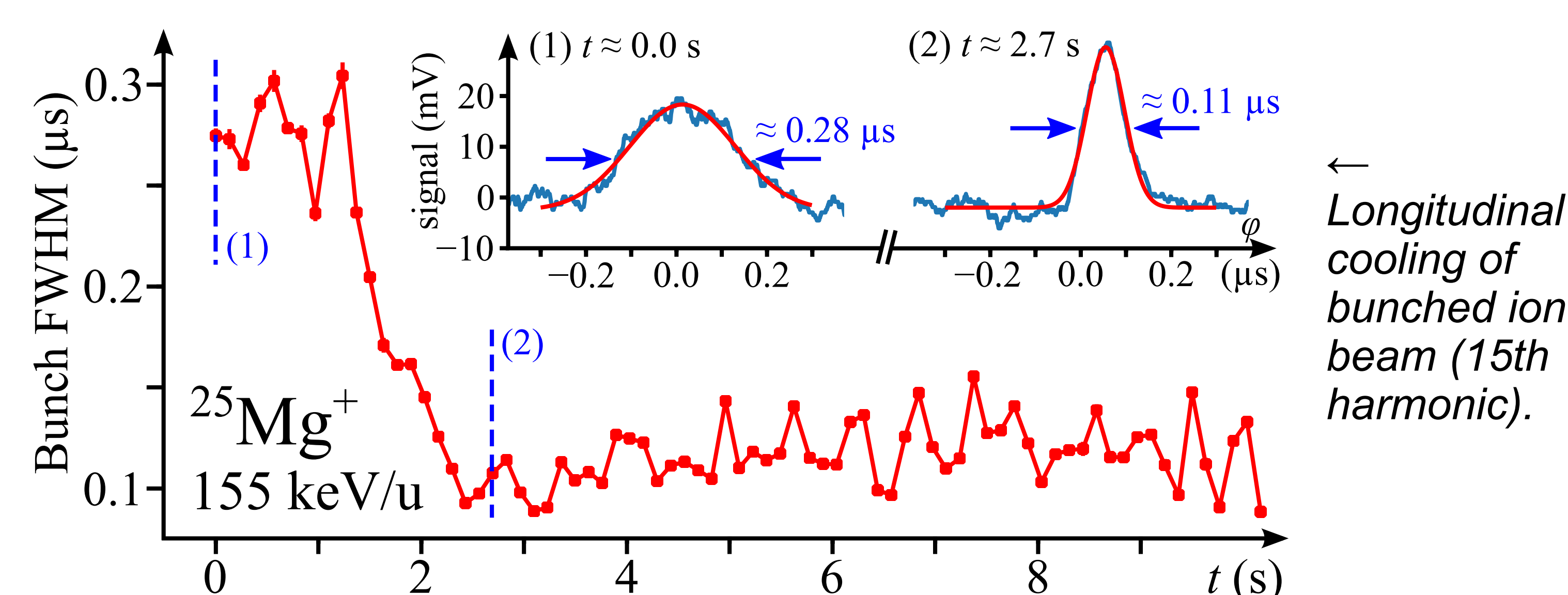
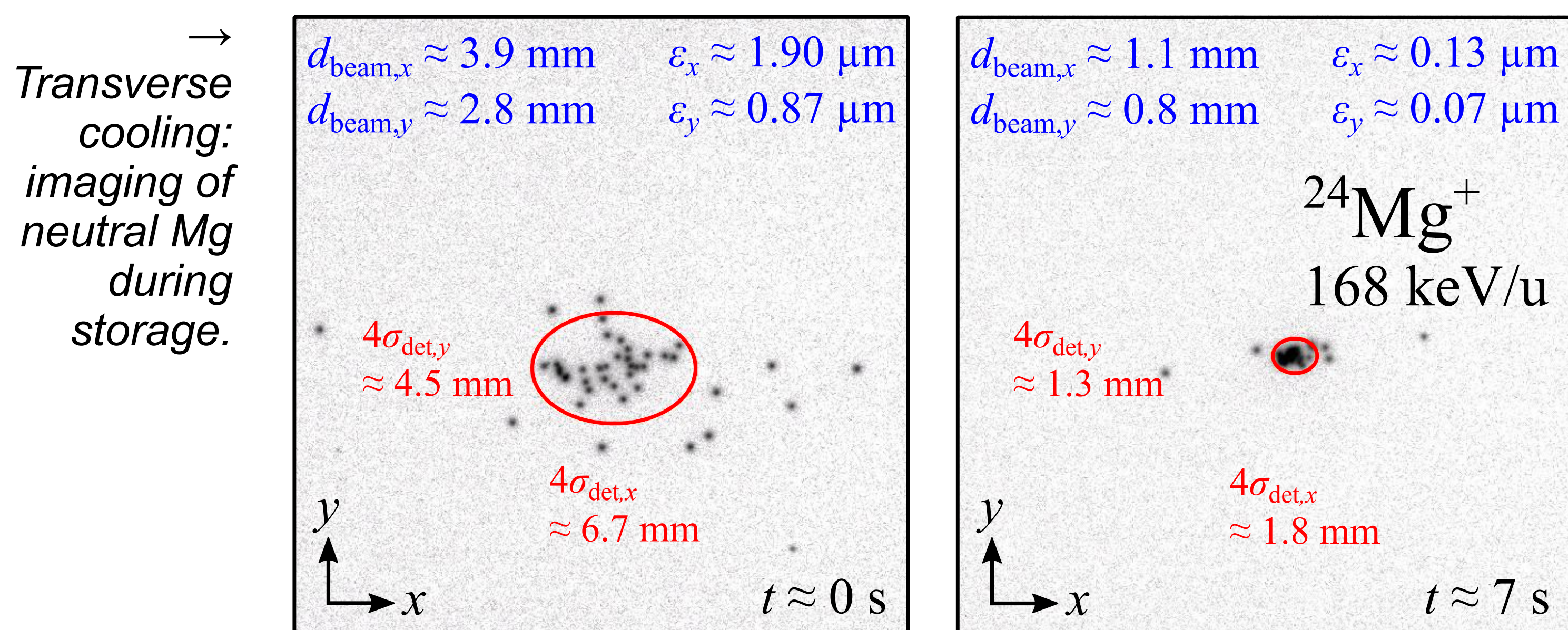
Weakly-charged ions: $^{24}\text{Mg}^+$ / $^{25}\text{Mg}^+$

Injected from local ECR source at 35 keV (1.46 keV/u and 1.40 keV/u, respectively).

Ramped in CRYRING to maximum $B\rho_0$: 168 keV/u ($^{24}\text{Mg}^+$) and 155 keV/u ($^{25}\text{Mg}^+$).

Cooler parameters

Acc. voltage: $\sim 100 \text{ V}$
Current: 1.7 mA
Expansion: 33.3



- [1] Abrahamsson *et al.*, NIM B 79 (1993) 296
[2] Lestinsky *et al.*, Eur. Phys. J. ST 225 (2016) 797
[3] Danared *et al.*, NIM A 441 (2000) 123
[4] Thümmel *et al.*, New J. Phys. 11 (2009) 103007
[5] Dirkes, Master's thesis, Univ. Münster, 2020