

Recommissioning of the **CRYRING@ESR** Electron Cooler

COOL 2021

Claude Krantz, GSI

5 November 2021

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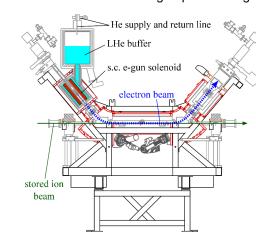
¹ GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt; ² I. Physikalisches Institut, Uni. Giessen, 35392 Giessen; ³ Institut für Kernphysik, Uni. Münster, 48149 Münster

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].



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.

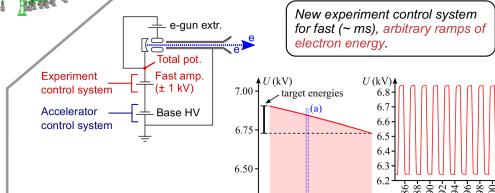
Planned upgrades:
* Vacuum system
* New HV supplies
* e-beam diagnostics
* New s.c. solenoid

Cooler operation as internal electron target

Important part of experimental program:

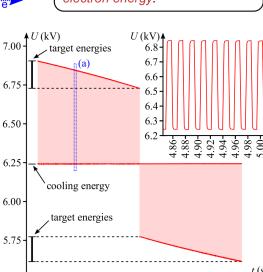
Atomic physics experiments on electron-ion collisions. Require usage of cooler as **internal electron target** of variable energy.

New experiment control system for fast (~ ms), arbitrary ramps of electron energy.



Monitoring of terminal potential at < 10 ppm by custom-made precision voltage dividers.

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



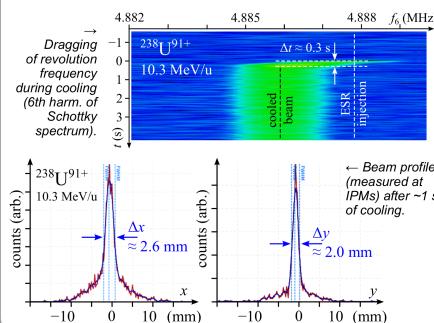
Electron cooling: first results

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.

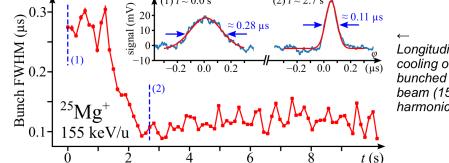
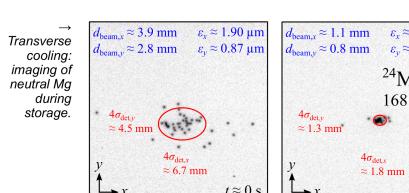


Weakly-charged ions: $^{24}\text{Mg}^+$ / $^{25}\text{Mg}^+$

Injected from local ECR source at 35 keV (1.46 keV/u and 1.40 keV/u, respectively). Ramped in CRYRING to maximum B_{0p} ; 168 keV/u ($^{24}\text{Mg}^+$) and 155 keV/u ($^{25}\text{Mg}^+$).

Cooler parameters

Acc. voltage: ~ 100 V
Current: 1.7 mA
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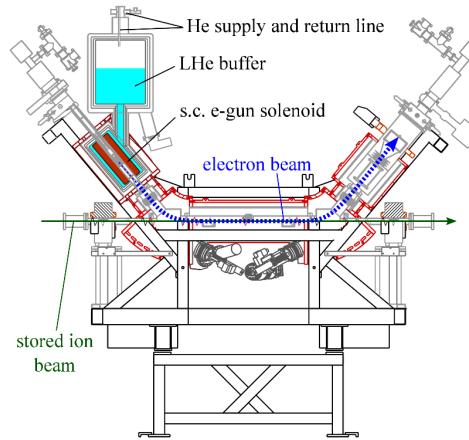
- [1] Abrahamsson *et al.*, NIM B 79 (1993) 296
- [2] Lestinsky *et al.*, Eur. Phys. J. ST 225 (2016) 797
- [3] Danared *et al.*, NIM A 441 (2000) 123
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CRYRING@ESR

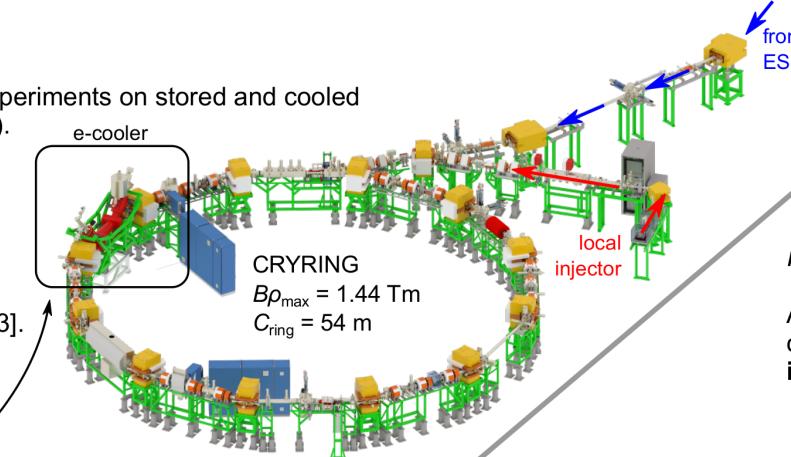
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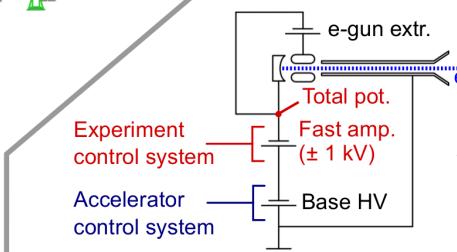
e-energy: $\lesssim 8 \text{ keV}$
($\lesssim 14.6 \text{ MeV/u}$)
Current: $< 110 \text{ mA}$
Expansion: $1 \dots 100$
Beam ϕ : $4 \dots 40 \text{ mm}$
Length: 1.1 m
($\sim 2\% C_{\text{ring}}$)



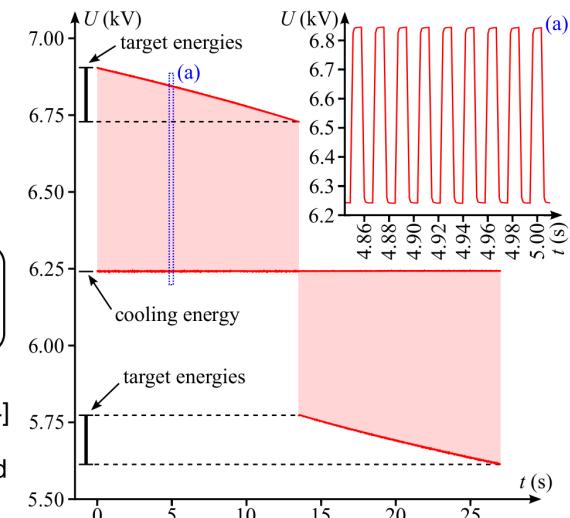
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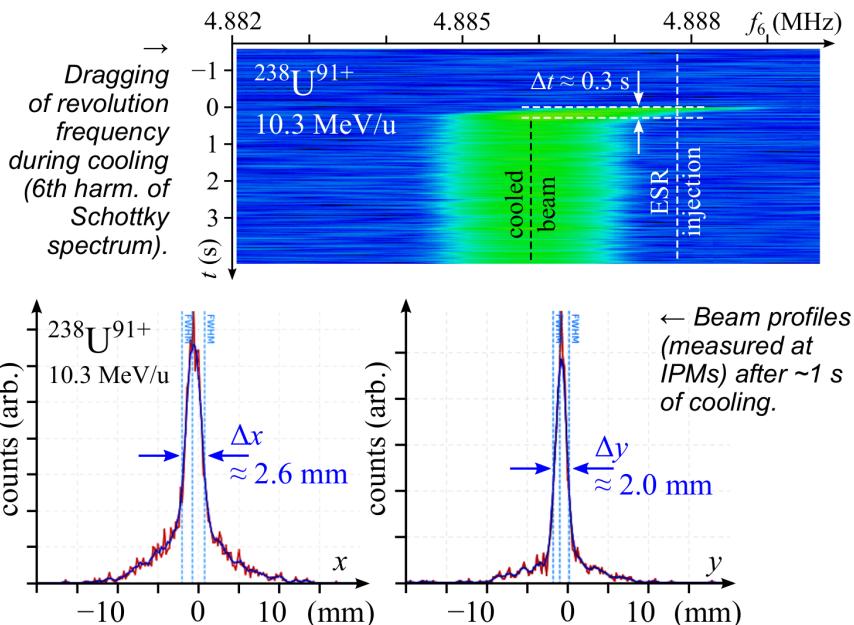
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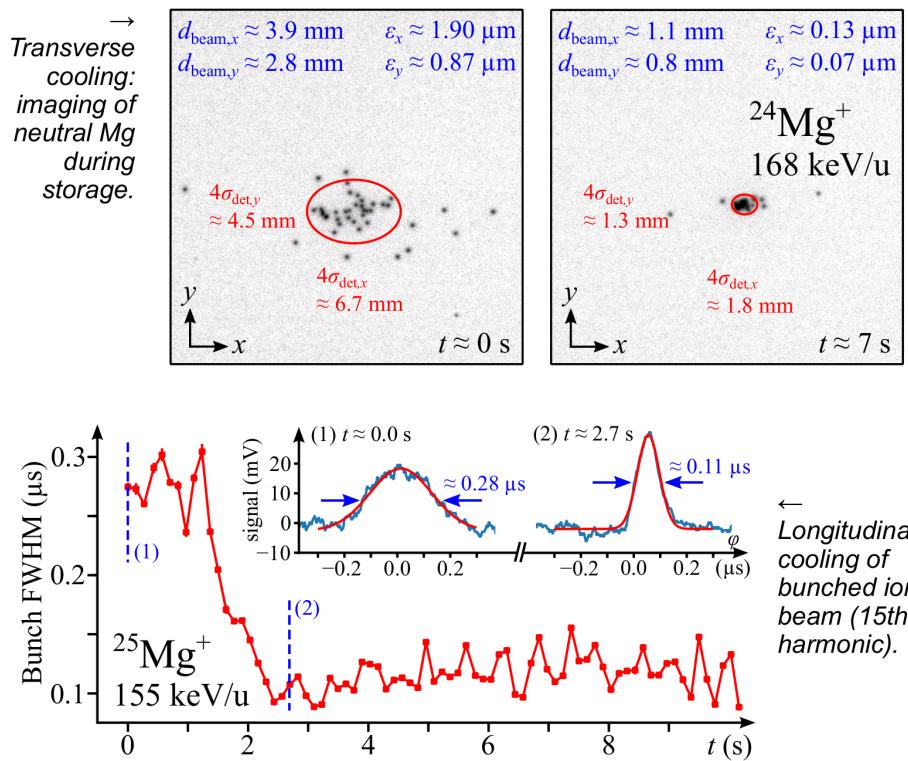
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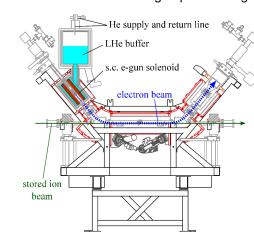
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CRYRING
 $B_{0\text{max}} = 1.44 \text{ Tm}$
 $C_{\text{ring}} = 54 \text{ m}$

local injector

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(a)

(b)

(c)

(d)

(e)

(f)

(g)

(h)

(i)

(j)

(k)

(l)

(m)

(n)

(o)

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(v)

(w)

(x)

(y)

(z)

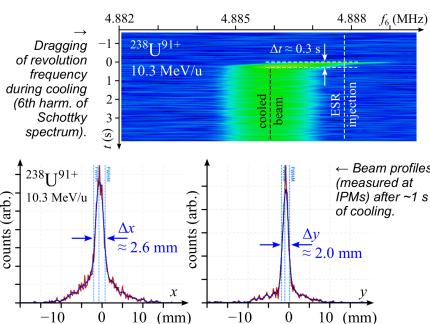
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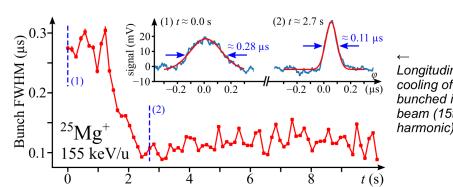
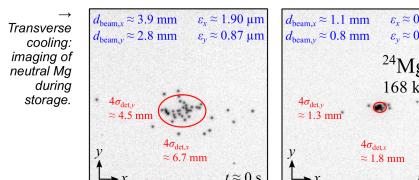
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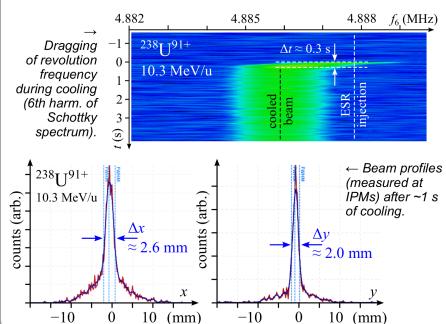
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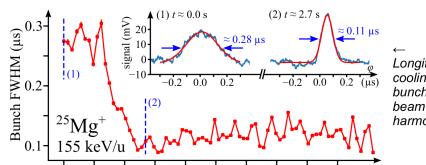
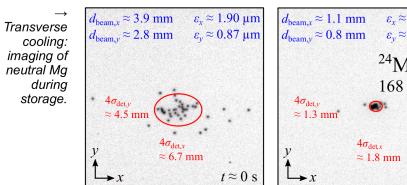
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Transverse cooling: imaging of neutral Mg during storage.



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