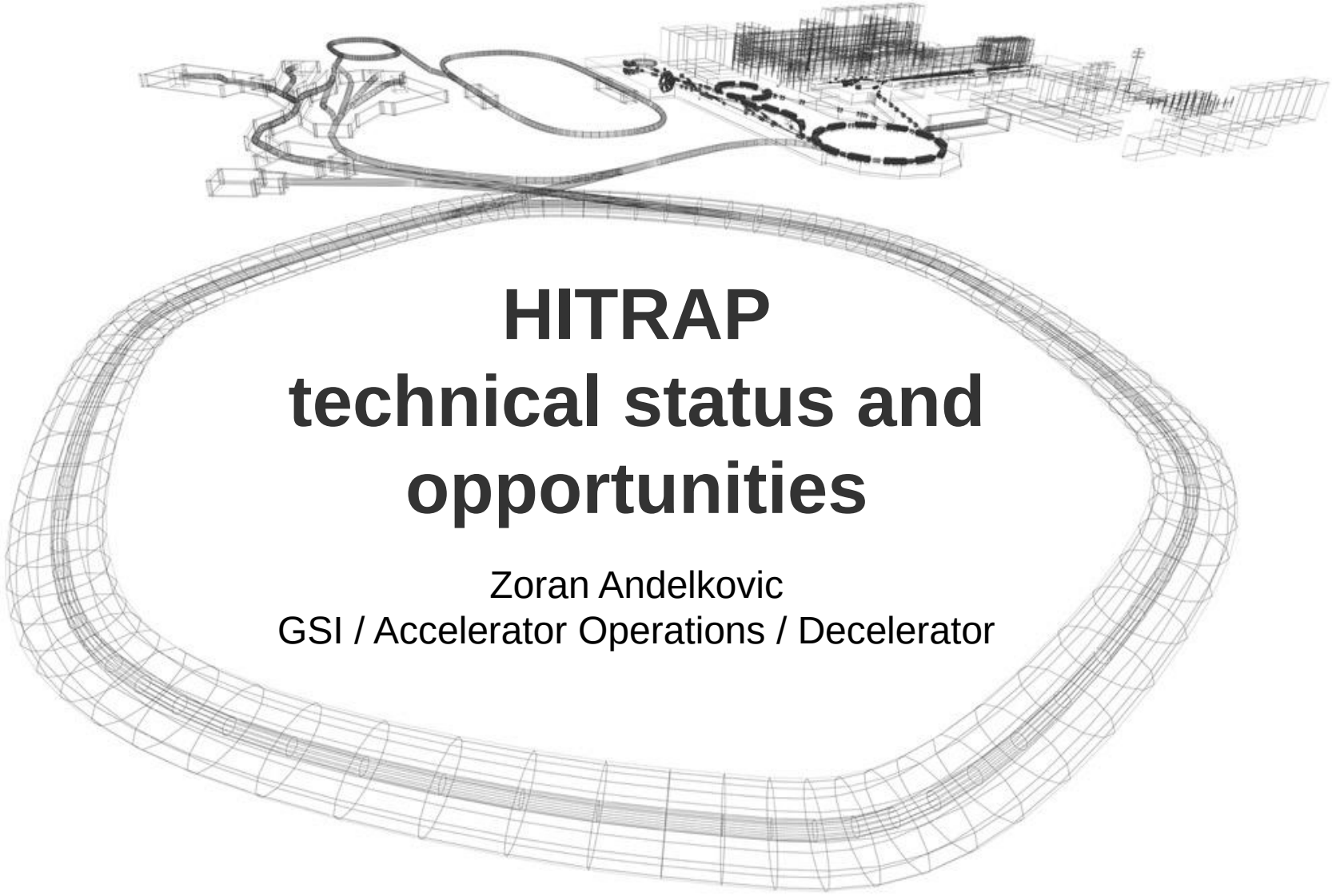
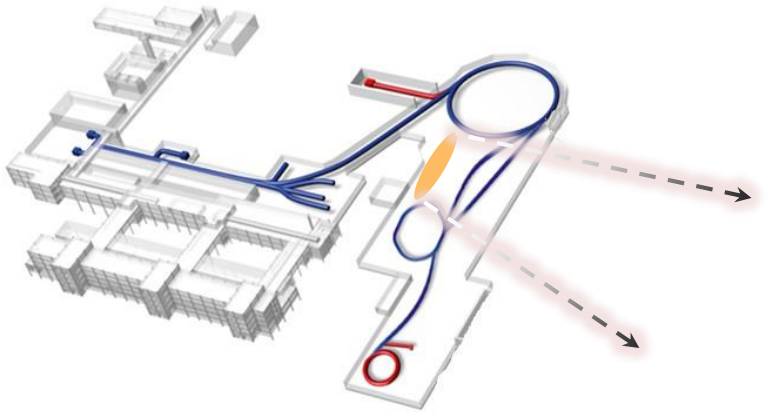
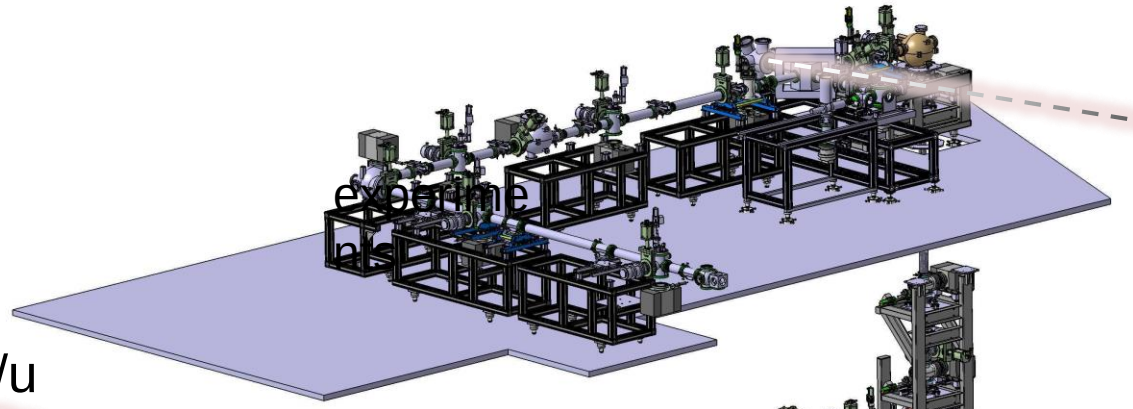


HITRAP technical status and opportunities

Zoran Andelkovic
GSI / Accelerator Operations / Decelerator

HITRAP facility & experimental area





EBIT & experiments

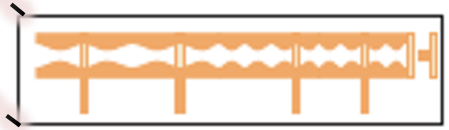
4 → 0.5 MeV/u

Interdigital H-type linac (IH)

Ion Trap

from ESR
4 MeV/u

0.5 → 0.006 MeV/u



Four-rod radiofrequency quadrupole (RFQ)

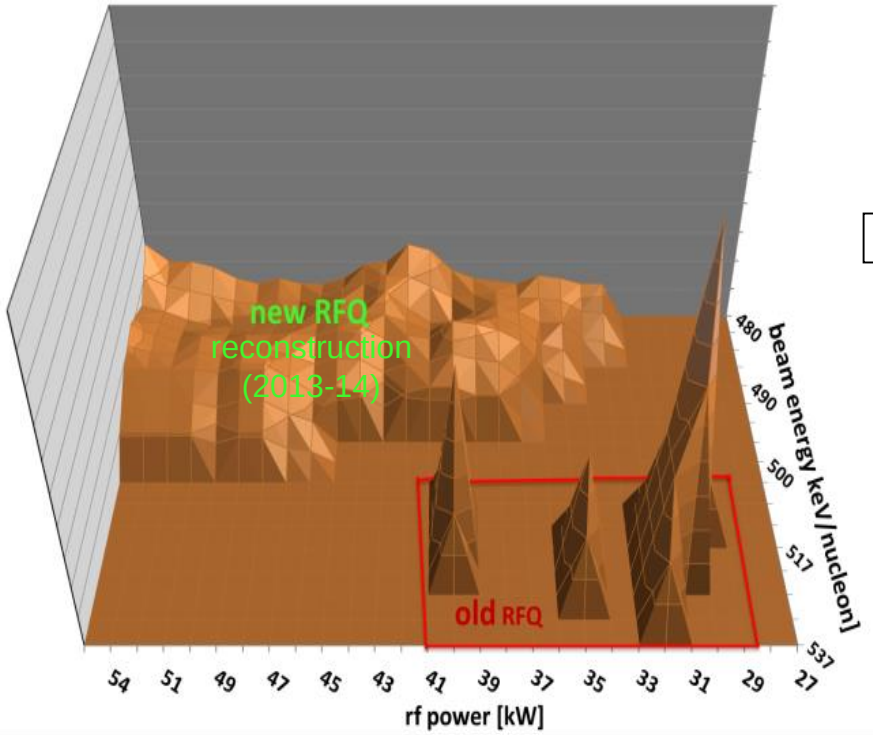
DD Buncher
108 MHz & 216 MHz

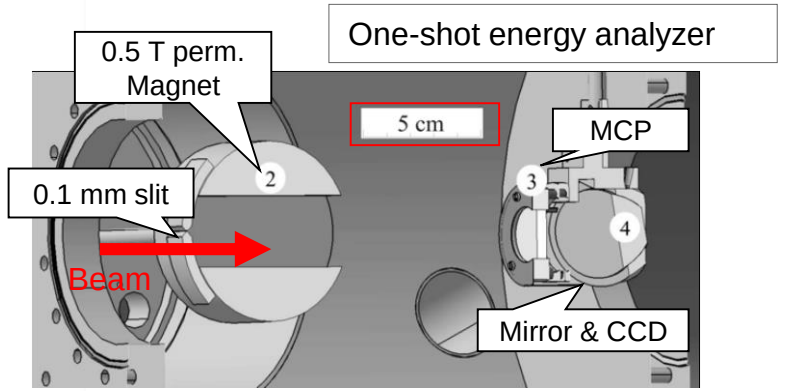
Commissioning experience

Why is a linear decelerator NOT simply a reversed accelerator?

- *the emittance grows*
- *narrow acceptance*
- *fast beams stay in*
- *low repetition rate*

$$\iint \mathrm{d}x\mathrm{d}x' = \pi\epsilon \approx x \cdot x' \approx x \cdot \frac{p_x}{p_z}$$





16 On-Line Tests (3-7 days, 45 sec / shot)
= 1 (one) hour of operation @ 50 Hz

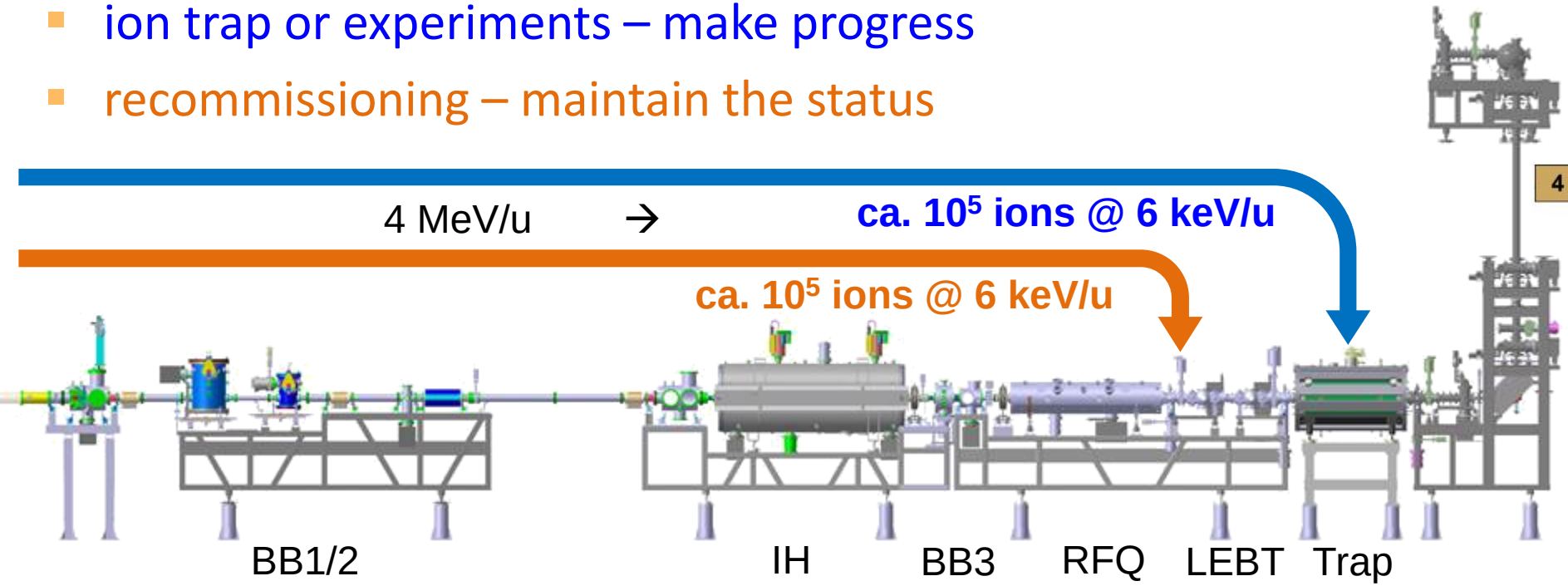
45 sec delivery rate:

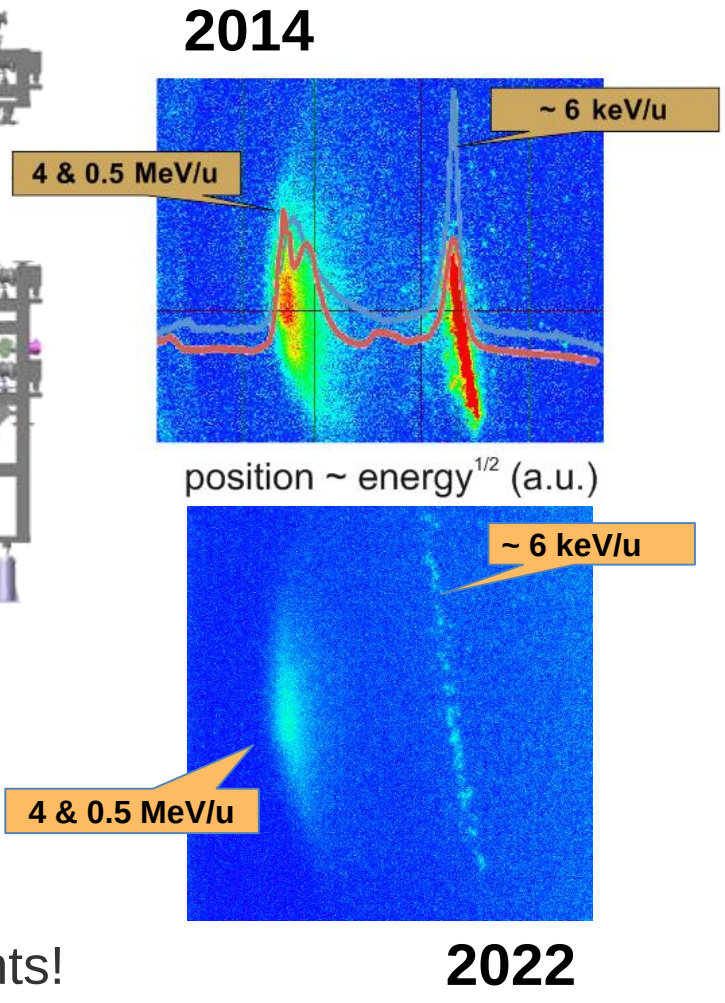
→ set one dipole = 20 min
→ set two dipoles = 20*20 min = 6h
→ 360° RFQ rough scan = 3h
→ 360° RFQ full scan = one shift

if everything OK:
» ca. 5 days for beam setup
» ca. 5 days for experiment
=> minimum two online beams per year for progress

Status 2014 + recommissioning 2022

- ion trap or experiments – make progress
- recommissioning – maintain the status





- new FAIR CS & diagnostics taken into operation
- recommissioned HF, deceleration to 6 keV/u
- train new personnel, expand CS
- … but reached neither the LEBT nor the trap → necessary for experiments!

Slow HCI: a challenge & an opportunity

Decelerated “beam”	
Energy	6 keV/u
Dispersion	30% (±1keV/u)
Emittance	180 π mm mrad

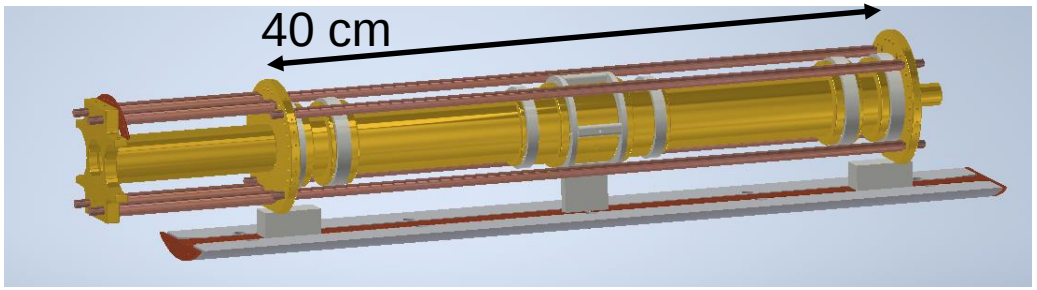
» similar to e$^-$ cooling in a storage ring at extremely low E

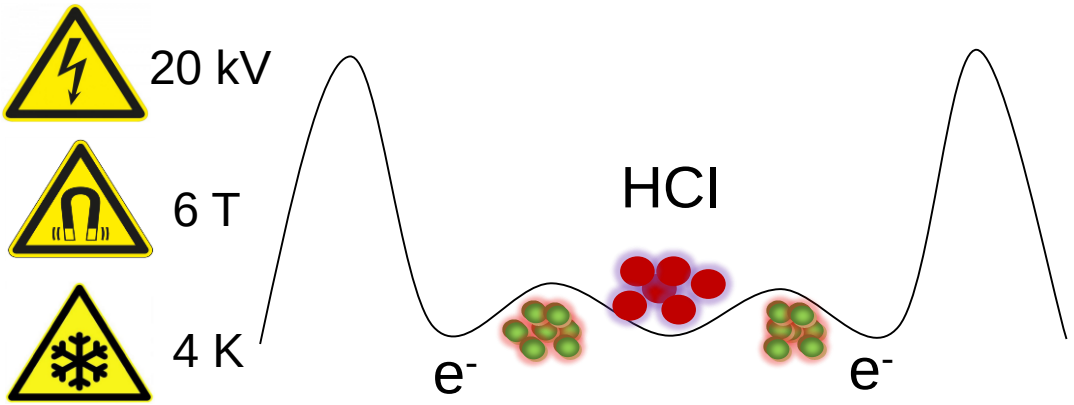
» an experiment in itself, with constant research demand

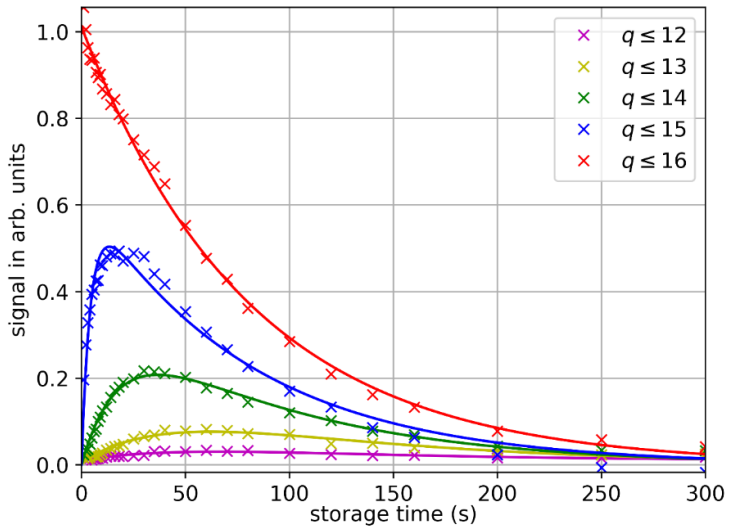
(currently 2 PhD students, TU-DA + 1 Postdoc, Uni-Frankfurt)

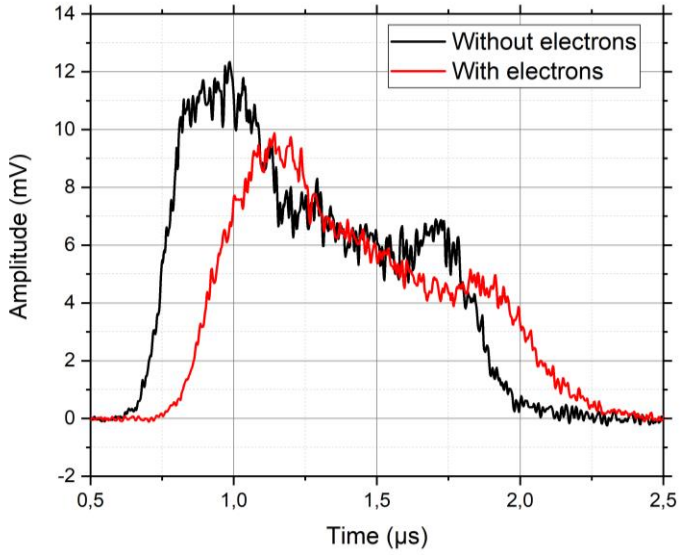
» <u>major progress in 2022-23, first worldwide:</u>

ions	electrons	cooling	online operation
✓	✓	✓	✗

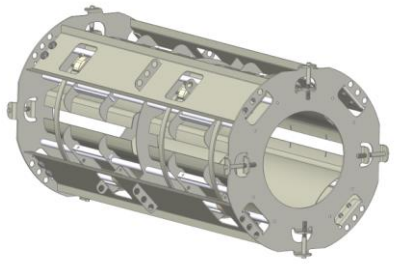


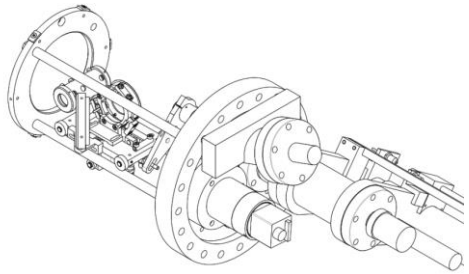






HITRAP low-energy beamline





guides cooled HCI to experiments

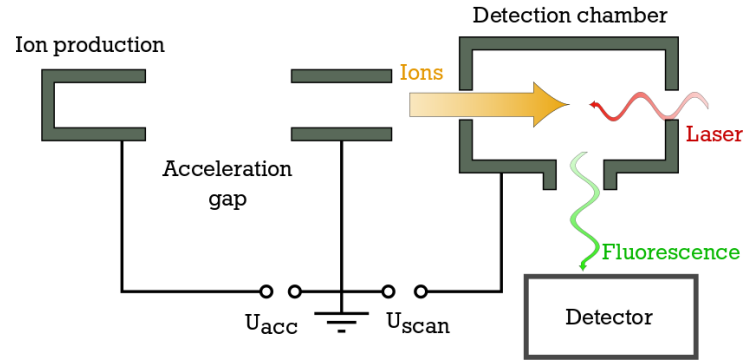
- a small, local EBIT
- 20 m of low-E beamline
- mass separation
- delivery to multiple stations
- operated by HITRAP team

Some early experiments:

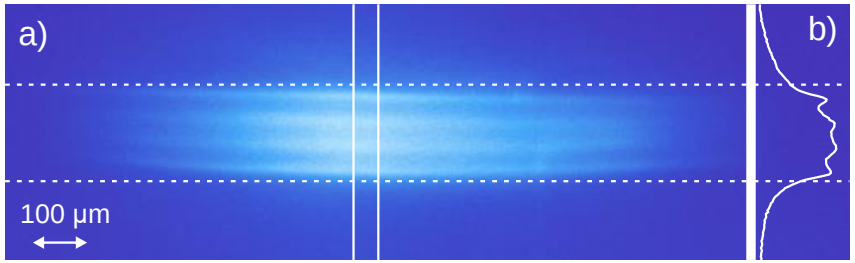
- charge-exchange cross sections

$$A^{q+} + Mg \rightarrow A^{(q-p)+} + Mg^{r+} + (r-p)e^{-}$$

- spectroscopy of B^{3+}



- trapped Coulomb crystals

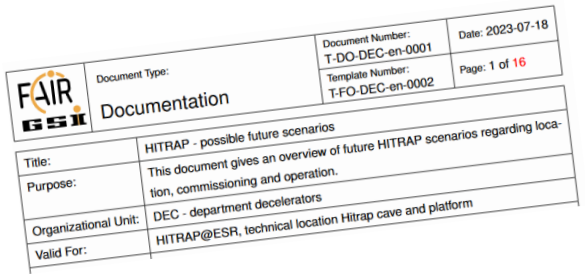


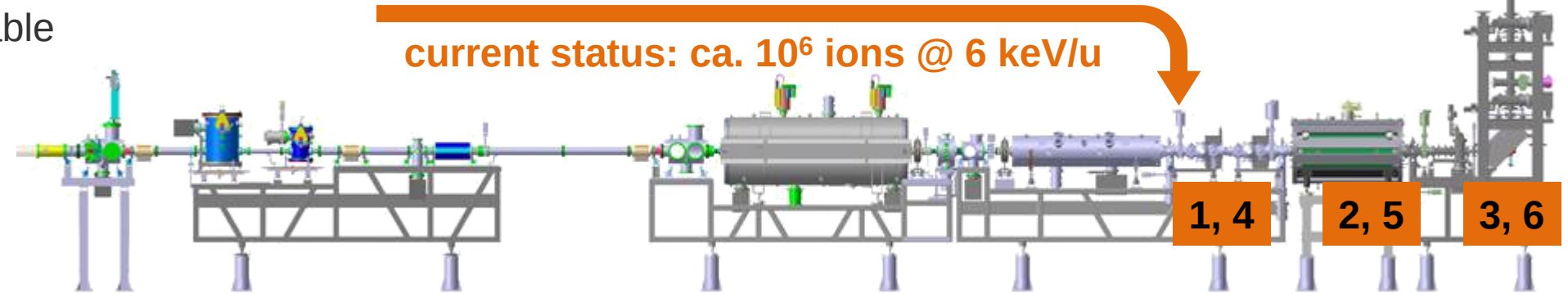
Perspectives

- achieved so far
  - deceleration to 6 keV/u
  - e-cooling of offline HCI
  - low-energy beam transport
  - control system
- to be done
  - ion transport to trap
  - e-cooling of online ions
  - ion transport to experiments
- alternative scenarios investigated
  - a study report available

a no-fail scenario / in units of beamtime:

1. transport through LEBT
2. capturing & cooling; test run E134 with Ar^{18+} } 2024
3. extraction and mass separation
4. physics run E134 with U^{91+} } 2025
5. multiplexed operation
6. single ions for HYI-Jena (optical clocks)
7. transport towards the second floor
8. physics run E130 with Bi^{82+}
9. …

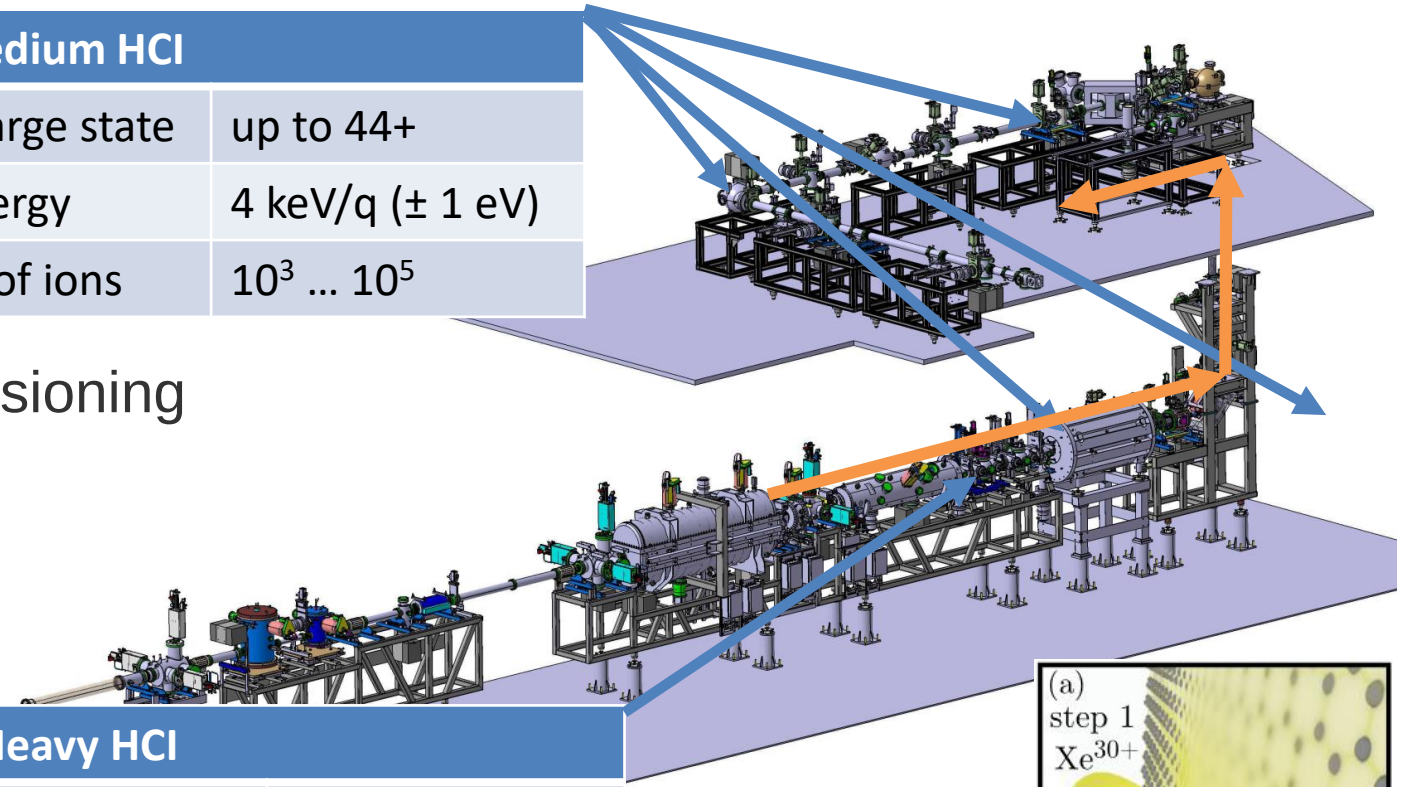




What can HITRAP deliver?

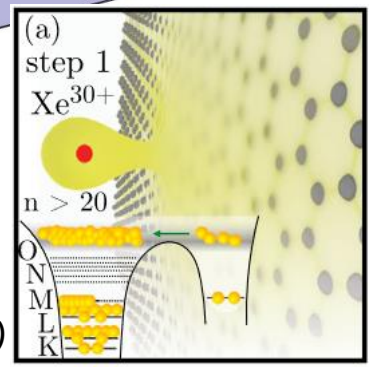
- partly operational; not finished in full scope!
  - suffcient beamtime & manpower
  - regular dry-runs
  - FAIR CS expansion
  - further work on cooling trap concept
- otherwise, locked in constant recommissioning
- what is full scope?

Medium HCI	
charge state	up to 44+
energy	4 keV/q (± 1 eV)
N. of ions	10^3 … 10^5



Heavy HCI	
charge state	any up to 92+
energy	4 keV/u ± 1 eV/u
N. of ions	1 … 10^4

Heavy HCI	
charge state	any up to 92+
energy	6 ± 1 keV/u
N. of ions	1 … 10^4



HCI interaction with surfaces, Wilhelm et al., PRL 119 (2017)

Overview of resources

	2007– 2014 to reach the current state	2014 – 2022 standby & trap reconstruction	2022 – recommissioning & development
Master	5	2	4
PhD	5	0	2
ACC	3	0.5	3
Beamtime	2-3 p.a.	0	1

in 2022

- <u>one position</u> by the GSI technical board
- <u>one postdoc</u> by the GSI research board (but limited to 2024)

- one in ‘22
- two planned for ’24
- two tentative for ‘25

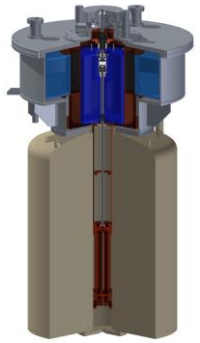
- imperative to keep the current momentum
- expected timeline, if resources available: 1-2 years
- horizon for running experiments: 10+ years

Opportunities beyond 2024

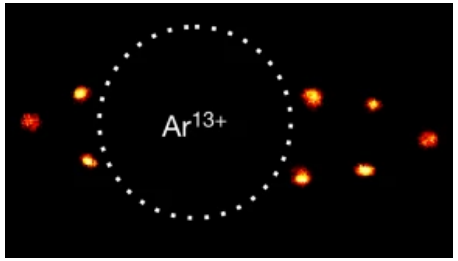
- HITRAP can be a worldwide unique source of slow, heavy HCI
- ion delivery supplemented by local EBIT(s) for offline operation
- staged approach for experiments as commissioning progresses
- a platform for technology development

- multiple gains for a relatively low price
- long-term prospects

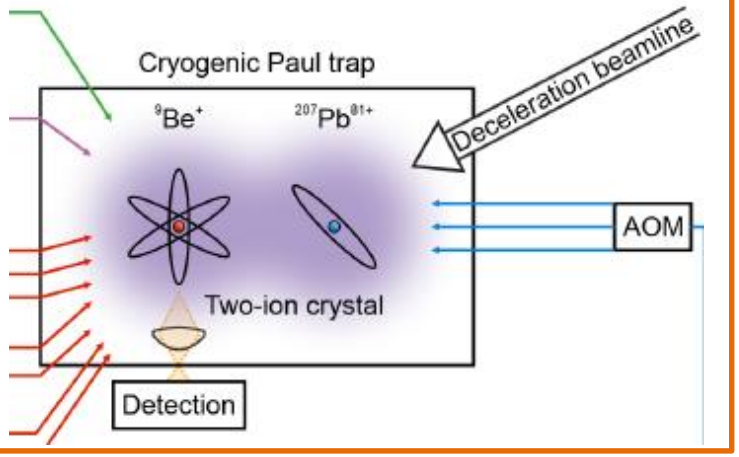
$$g = 2\frac{\omega_L}{\omega_c}$$



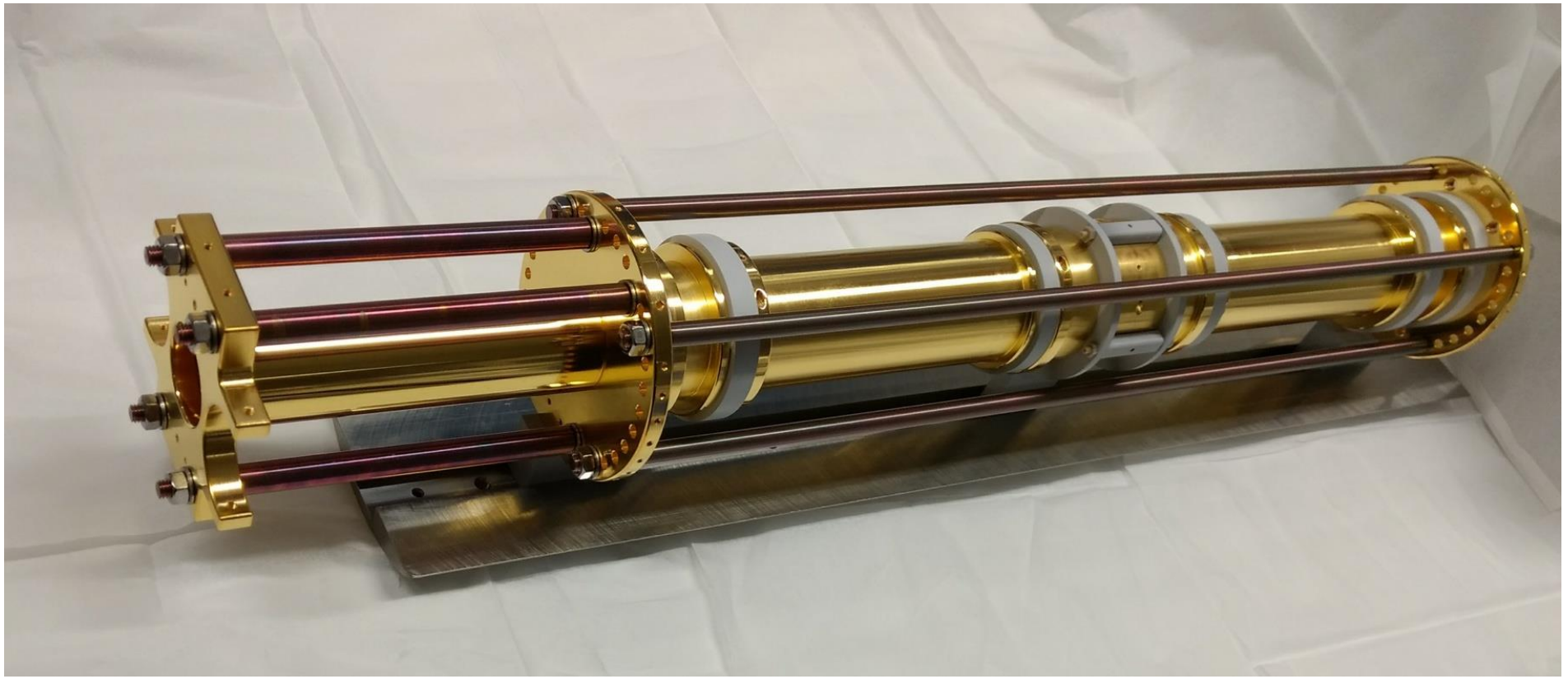
new laser laboratory – approved for a HYIG by P. Micke
BIG-2020306-03-HITRAP



Optical Clocks with HCI, e.g. Micke, Leopold, King et al., Nature 578 (2020)



Thank you for listening!



Also thanks to the DEC team and collaborators:

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