



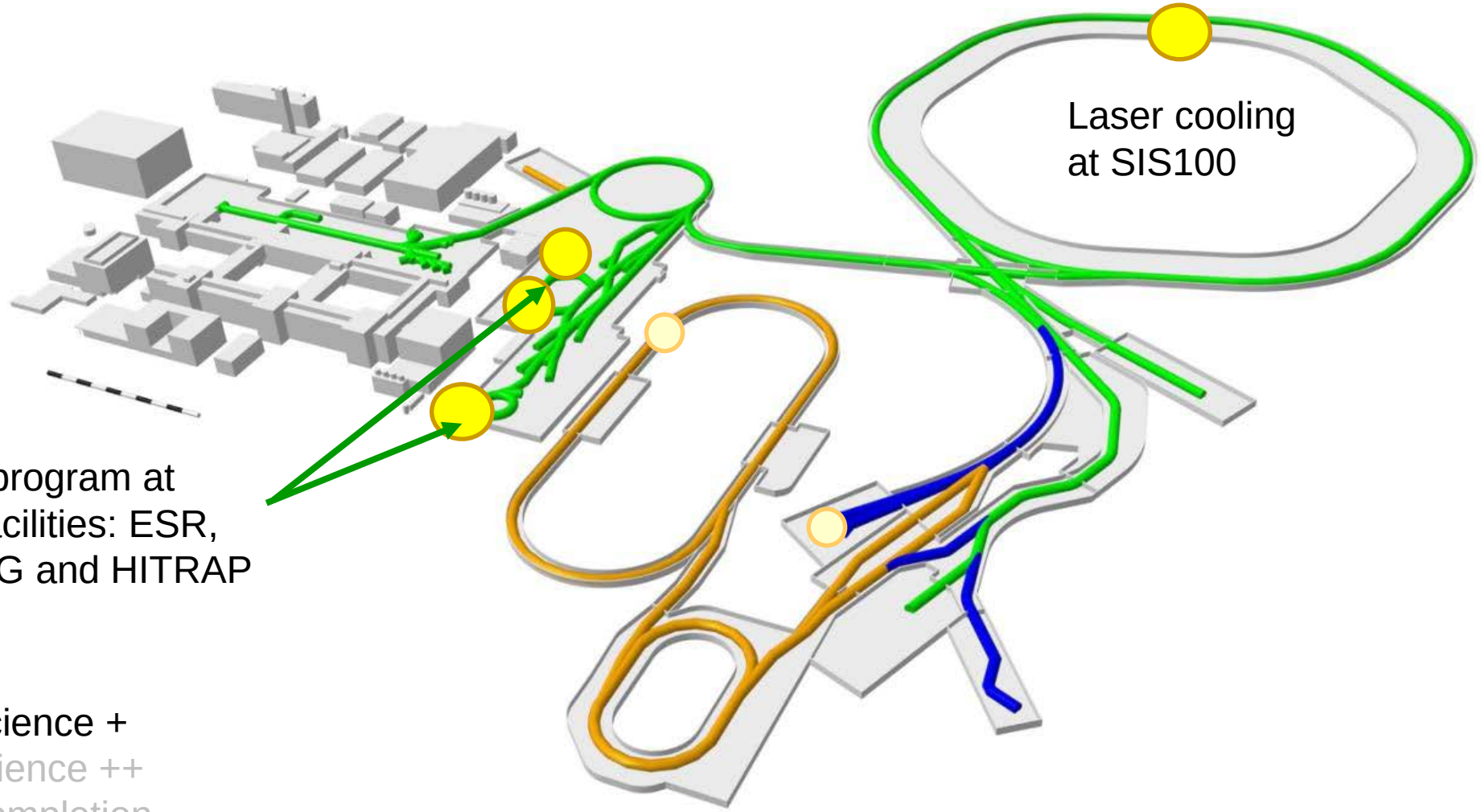
# SPARC progress report

Alexandre Gumberidze

for the SPARC collaboration

RRB 13, May 16th & 17h 2024

# SPARC at FAIR FS




SPARC program at exiting facilities: ESR, CRYRING and HITRAP

First Science +

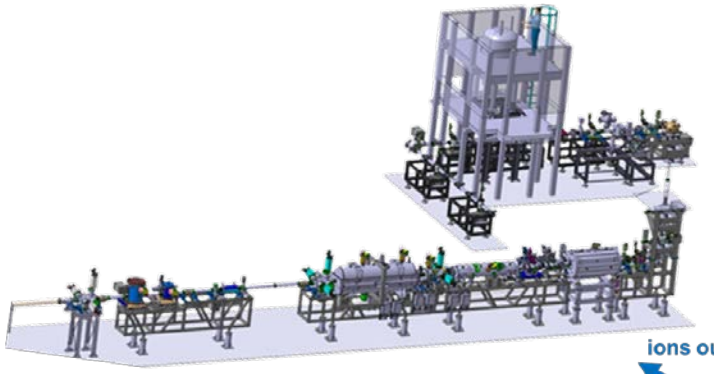
First science ++

MSV completion

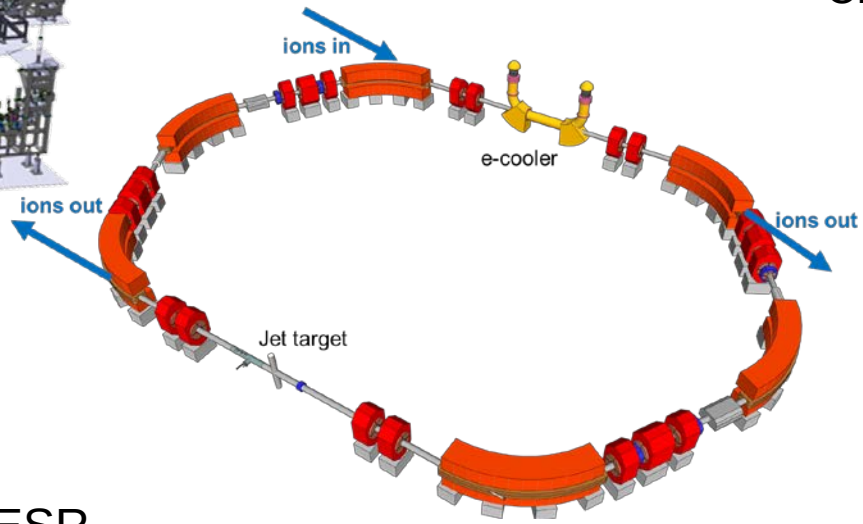
SPARC@FAIR FS

# Status SPARC: overview

## Crucial maintenance and upgrades

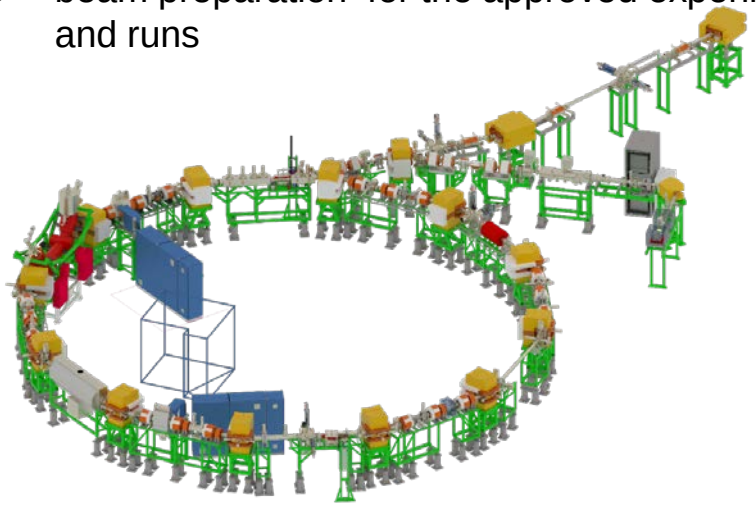


HITRAP:
- recommissioning and
- experiment setups




ESR
- retrofitting e-cooler
- repair stochastic cooling kicker system
- beam diagnostic repairs
- vacuum system upgrades
- internal target control modernization
- beam time preparation and runs

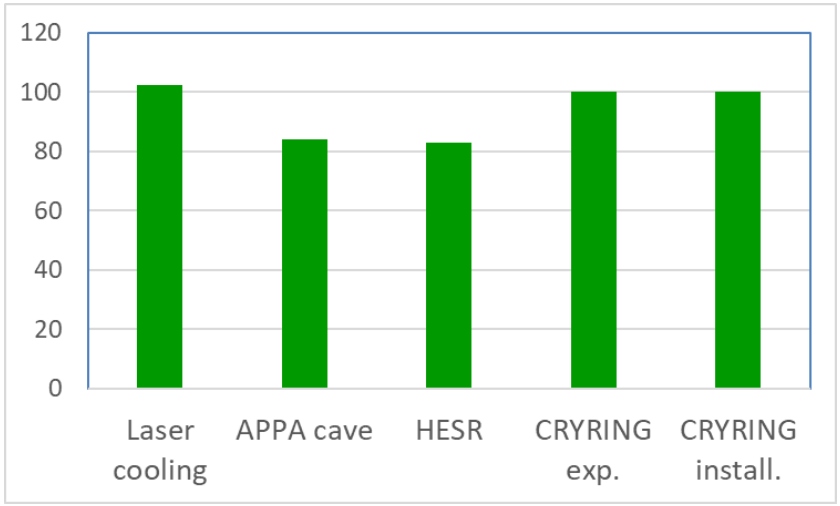
CRYRING Priorities for 2023-2024:
- partial refurbishing of the e-cooler; vacuum improvement
- local ion source reconstruction
- installation, completion, maintenance for the E-target, CARME and the Internal Jet Target
- beam preparation for the approved experiments and runs

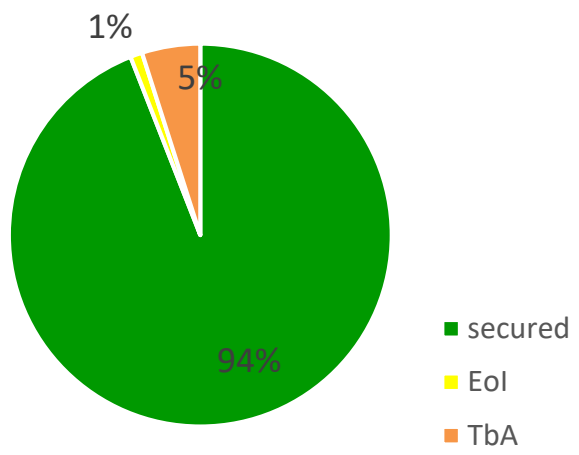


# Funding SPARC experiments Day-one

| RRB13 Day-one experiment funding APPA-SPARC | | | | | | |
|---|---|---|---|---|---|---|
| Experiment | PSP | Total cost [k€, 2005] | Funding [k€, 2005] | | | Secured [%] |
| | | | Secured | EoI | TbA | |
| SPARC Laser Experiments | 1.3.1.1 | 466 | 476.53 | 0.00 | 0.00 | 102.26 |
| SPARC at APPA-cave | 1.3.1.2 | 931 | 780.86 | 0.00 | 150.00 | 83.87 |
| SPARC at HESR | 1.3.1.3 | 2726.96 | 2264.46 | 104.50 | 358.00 | 83.04 |
| SPARC at CRYRING | 1.3.1.5 | 2379.00 | 2376.55 | 0.00 | 0.00 | 99.90 |
| CRYRING Installation | 1.3.4.2 | 3801.36 | 3801.36 | 0.00 | 0.00 | 100.00 |
| **Grand Total** | | **10304.32** | **9699.76** | **104.50** | **508.00** | **94.13** |

- additional 210 k€ are considered as secured trough the German universities.
- three subprojects (all three are ES-FS) are 100% funded for the start phase (day-one setups).

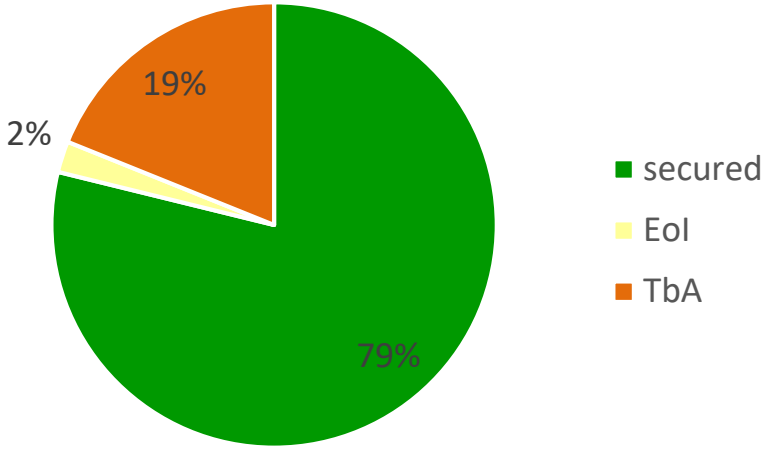



- The APPA cave and the HESR (FS++ and MSVc) are currently frozen subprojects. No funding for further components is available.
- Some of the FS++ and MSVc components which are constructed can be adapted and used in FAIR Phase-zero at the GSI campus

# Funding SPARC experiments MSV

| RRB13 Status experiment funding APPA-SPARC | | | | | |
|---|---|---|---|---|---|
| Experiment/Project | Prices, k Euro | | | | |
| | 2005 prices | | | 2024 prices | |
| | Secured amount * | EoI | To be assigned | EoI | TbA |
| SPARC Laser Experiments at SIS100 | 476.53 | 0 | 671.62 | 0.00 | 1126.58 |
| SPARC at APPA cave | 780.86 | 0 | 360 | 0.00 | 603.86 |
| SPARC at HESR | 2414.50 | 191.5 | 1040 | 321.22 | 1744.50 |
| SPARC at CRYRING | 3476.55 | 122.45 | 554 | 205.40 | 929.28 |
| CRYRING | 3801.36 | 0 | 0 | 0.00 | 0.00 |
| | | | | | |
| **Grand Total** | **10949.80** | **313.95** | **2625.62** | 526.62 | 4404.21 |

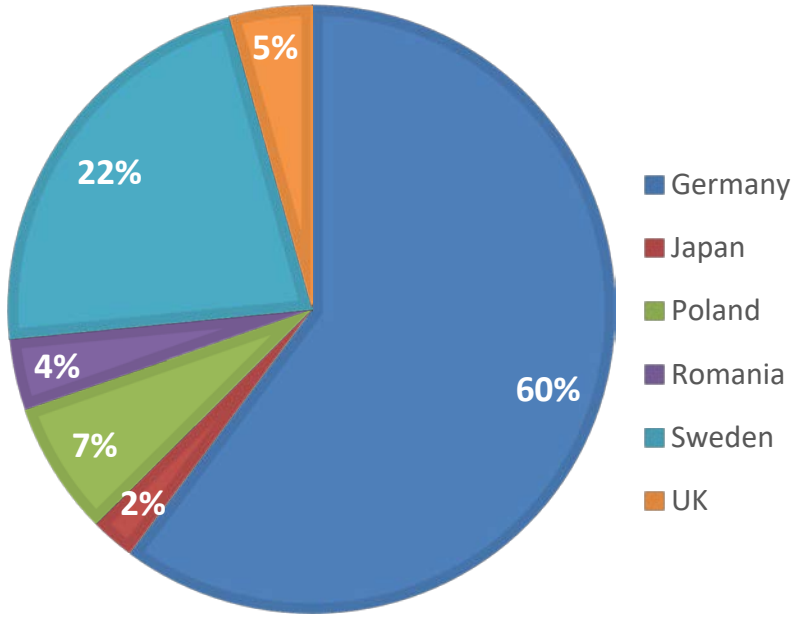



Full MSV cost: 13,9 M€

Total secured: 11,15 M€

# Country Funding for SPARC experiments

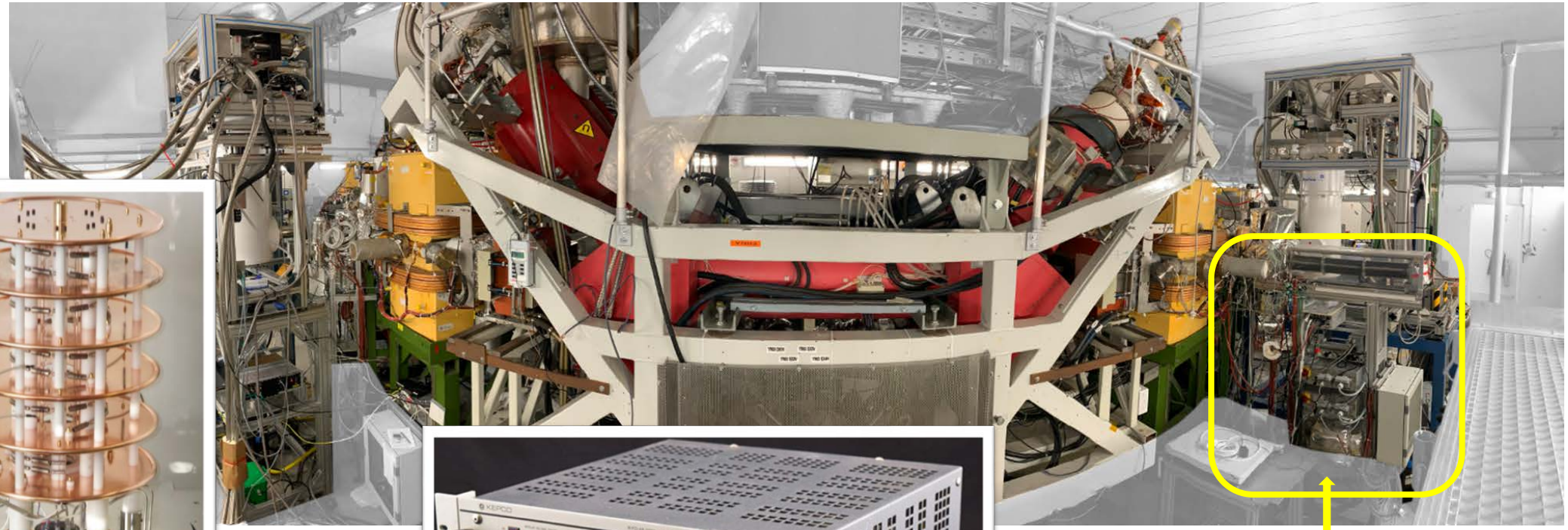
| Funding by country: Secured / EoI [k€, 2005 prices] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPARC | Germany | | Japan | | Poland | | Romania | | Sweden | | UK | |
| | 6470 | 314 | 263.22 | | 800 | | 425 | | 2500 | | 492 | |




Secured budget: 11159 k€

# Electron-Ion Collision Spectroscopy at the CRYRING@ESR E-Cooler

Highly integrated (FAIR) experimental equipment into the ring hardware





precision HV-divider
($10^{-6}$ accuracy)

precise control of electron energy

Particle detector system

Universität Münster

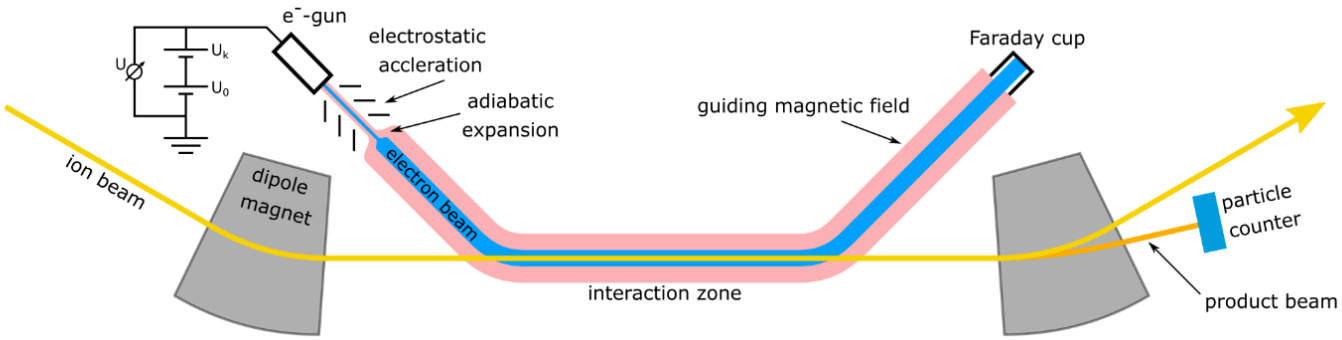
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

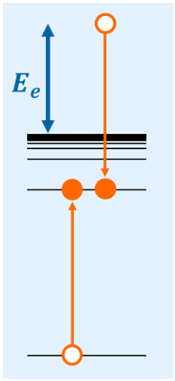
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

# G-22-00047 – PI: M. Lestinsky

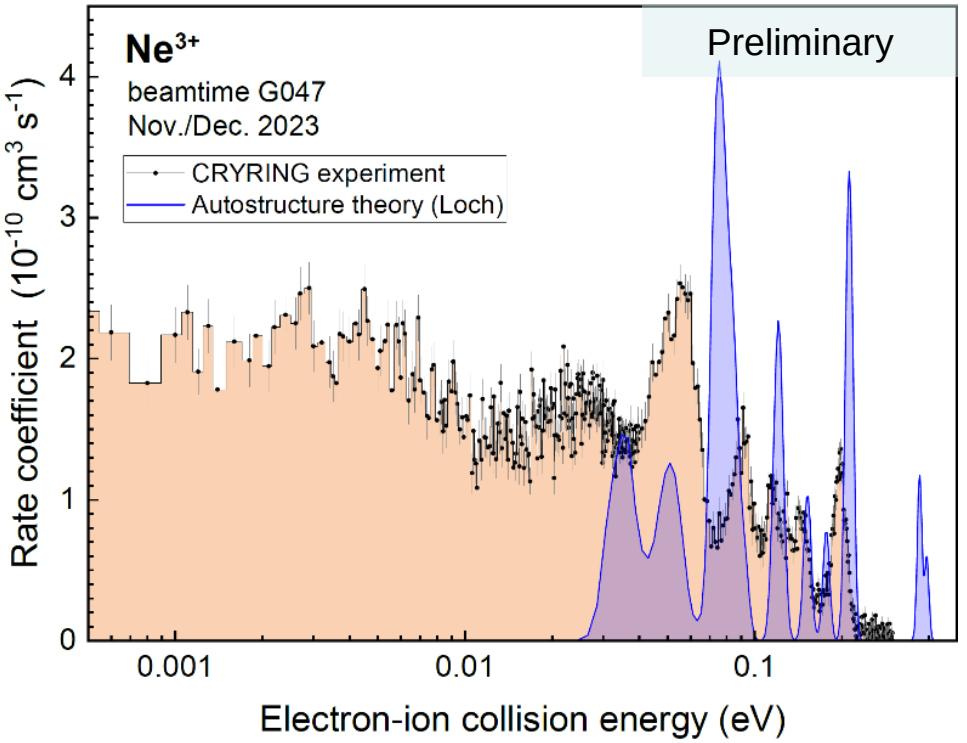
## Absolute rate coefficients from dielectronic recombination for the astrophysically relevant ions $Ne^{3+}$ and $S^{3+}$




dielectronic recombination (DR) via resonance states

First part of the proposal scheduled in Nov/Dec 2023
25 Shifts - $Ne^{3+}$ ion beam - 1e7 ions stored and cooled




Low-energy theoretical data underpredicts rate coefficient; relevant for low-T charge state distributions, such as e.g. in planetary nebulae, HII regions, AGN…

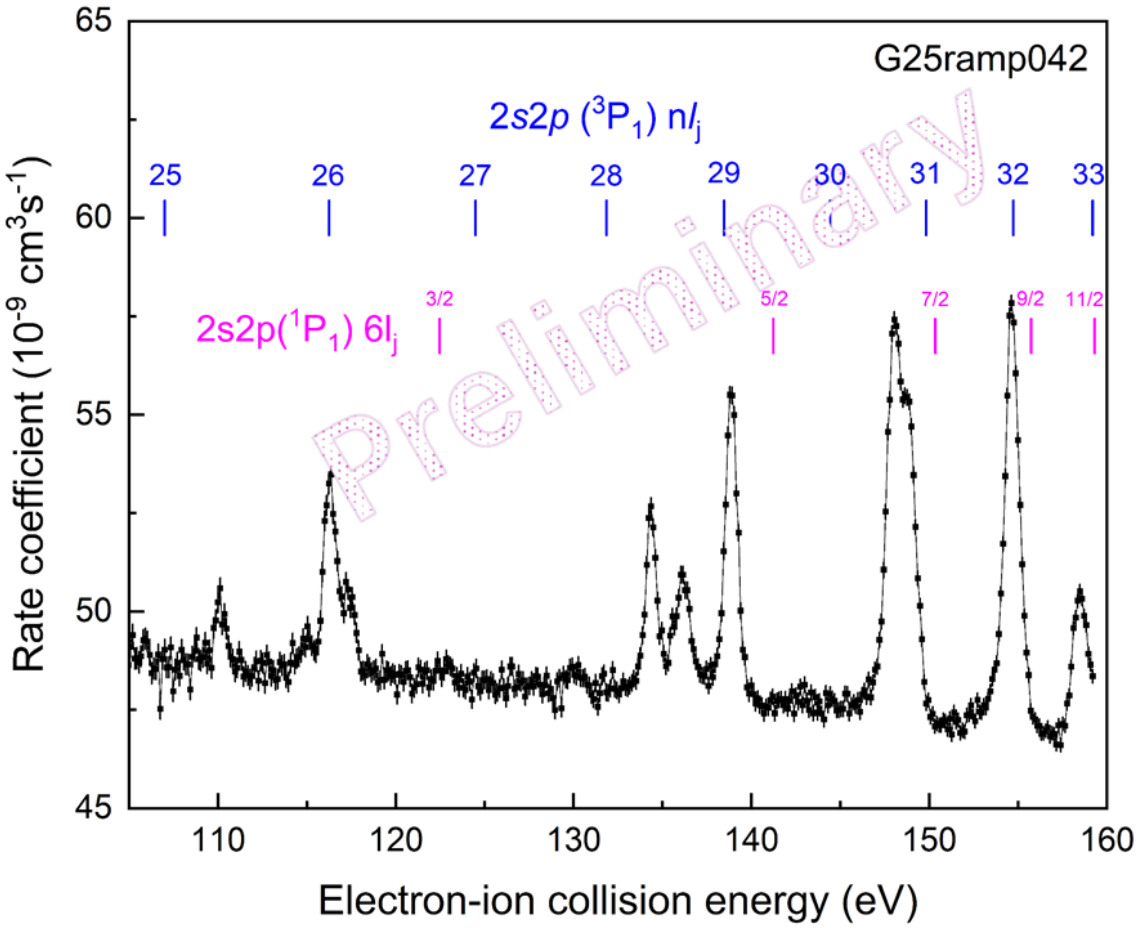
*Elena Hanu , Esther Menz, et al.*

# G-22-00022 – PI: S. Schippers

## High-Resolution Electron-Ion Collision Spectroscopy of Beryllium-like Heavy Ions in CRYRING@ESR

Proposal scheduled in March 2024
31 Shifts – $Au^{75+}$ ion beam from ESR
2e7 ions stored and cooled

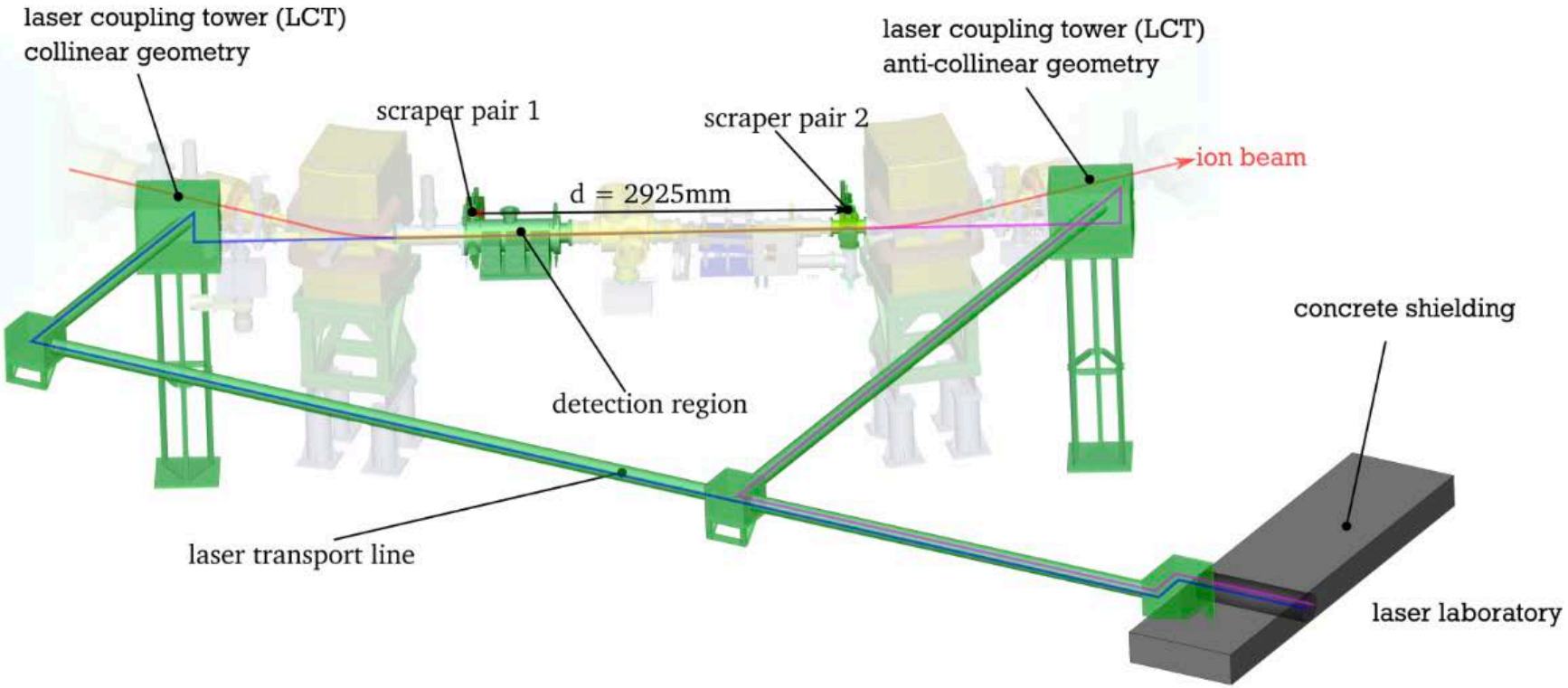
Cooler voltage ramping in the energy window from 104 eV to 160 eV. Many resonances are visible. Preliminary evaluation suggest that here a mix of 3P1 and 1P1 series  was measured

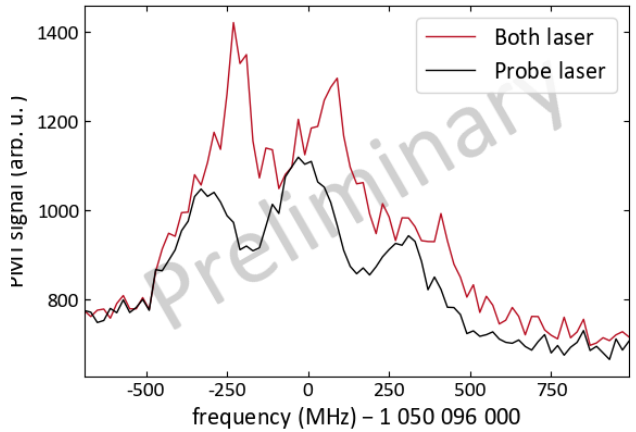



*Mirko Looshorn et al.*

# Ion beam and level population dynamics in $Mg^+$ laser spectroscopy at CRYRING@ESR

Proposal scheduled in Nov/Dec 2023: $^{24,25}Mg^+$ ion beam stored at 155 keV/u addressed simultaneously two UV-laser beams in co- and counter propagating direction, in section YR07 of the ring.




Addressing two hyperfine transitions of $^{25}Mg^+$ in coasting beam mode with two lasers results in a resolved hyperfine structure. This is the best condition to look for optical pumping.

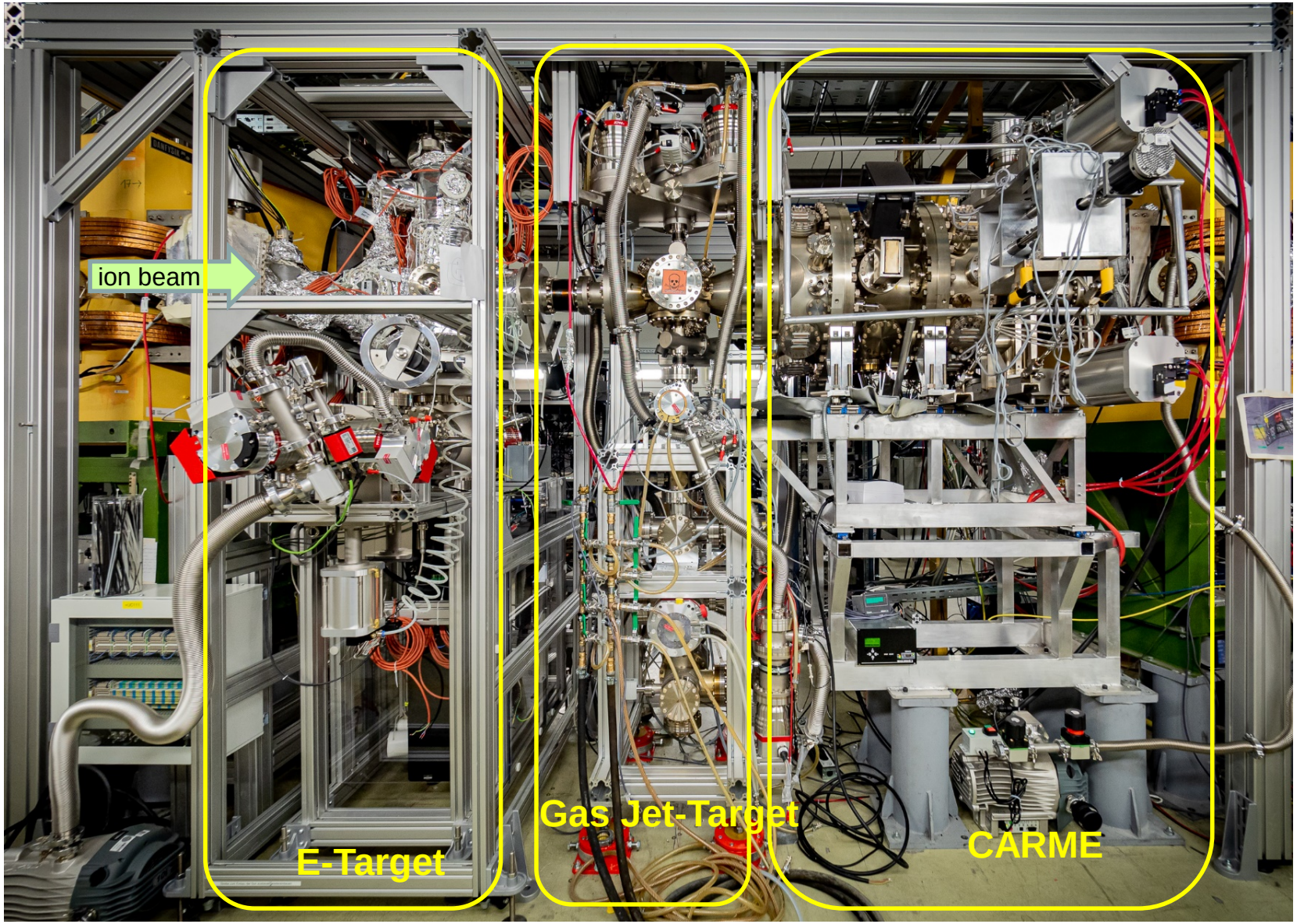
*R.Sánchez, K. Mohr, W. Nörtershäuser et al.*

# CRYRING@ESR Section YR09

**Jet internal target:** the hardware for the H2- gas system was installed. The technical acceptance from TÜV expected for May but it still must be scheduled.

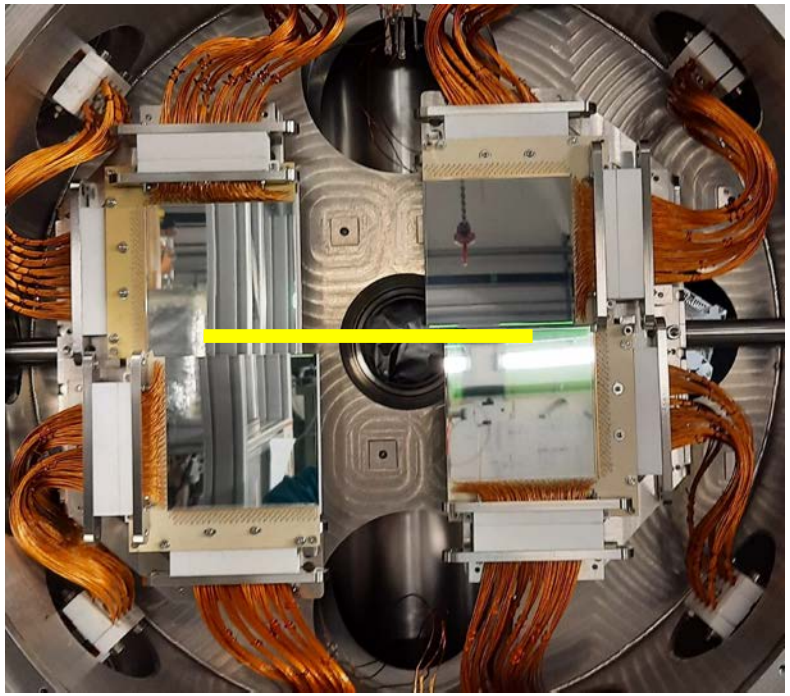
**E-Target:**
Installation has been completed.

**First commissioning run with $Ne^{7+}$ beam has been successfully conducted very recently.**

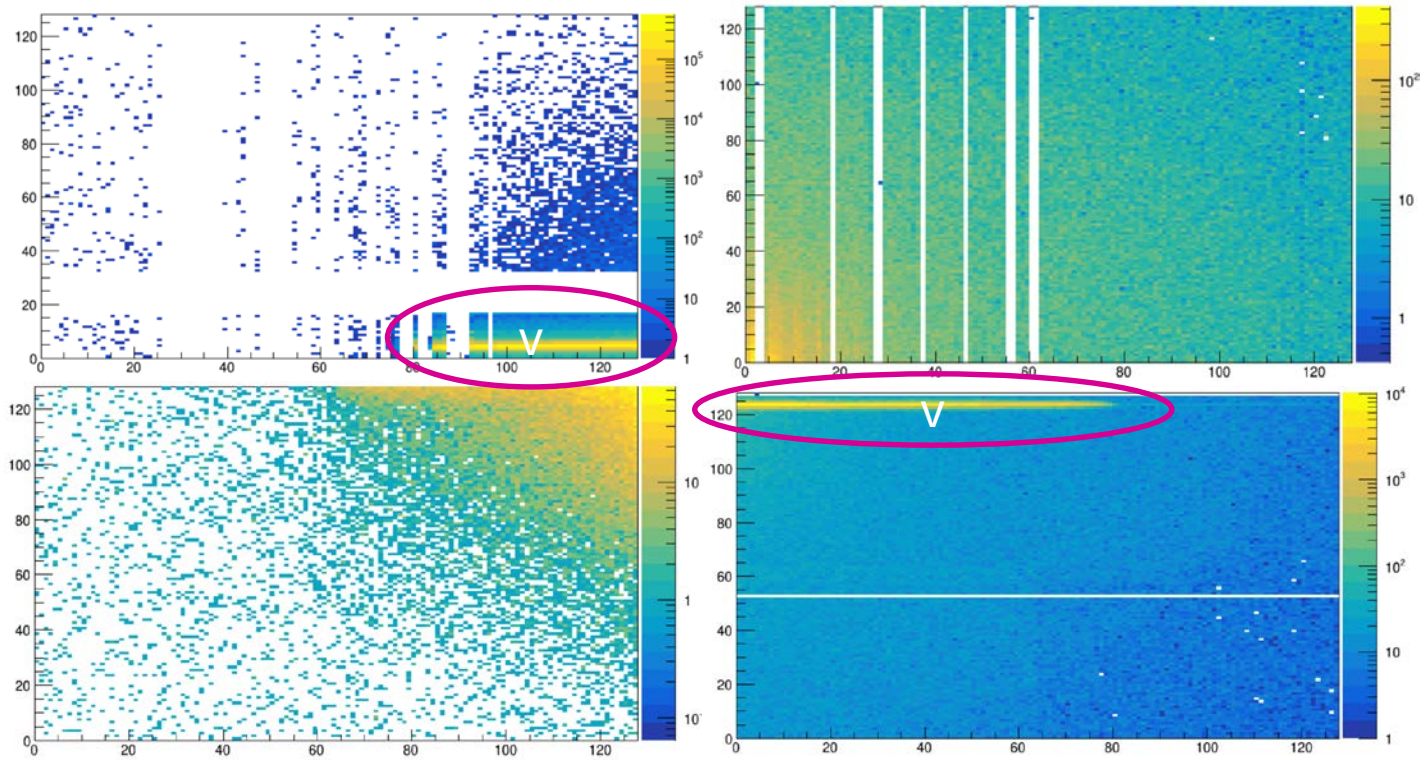


# G-22-00086 – PI: C. Bruno

**$^{16}O(\alpha,\alpha)^{16}O$ @ 20 MeV**



*DSSDs when fully in-beam with approx. location of the beam stripe*




*Events detected (z) vs. detector position (x,y). The measurement does not include the acceleration/cooling periods*

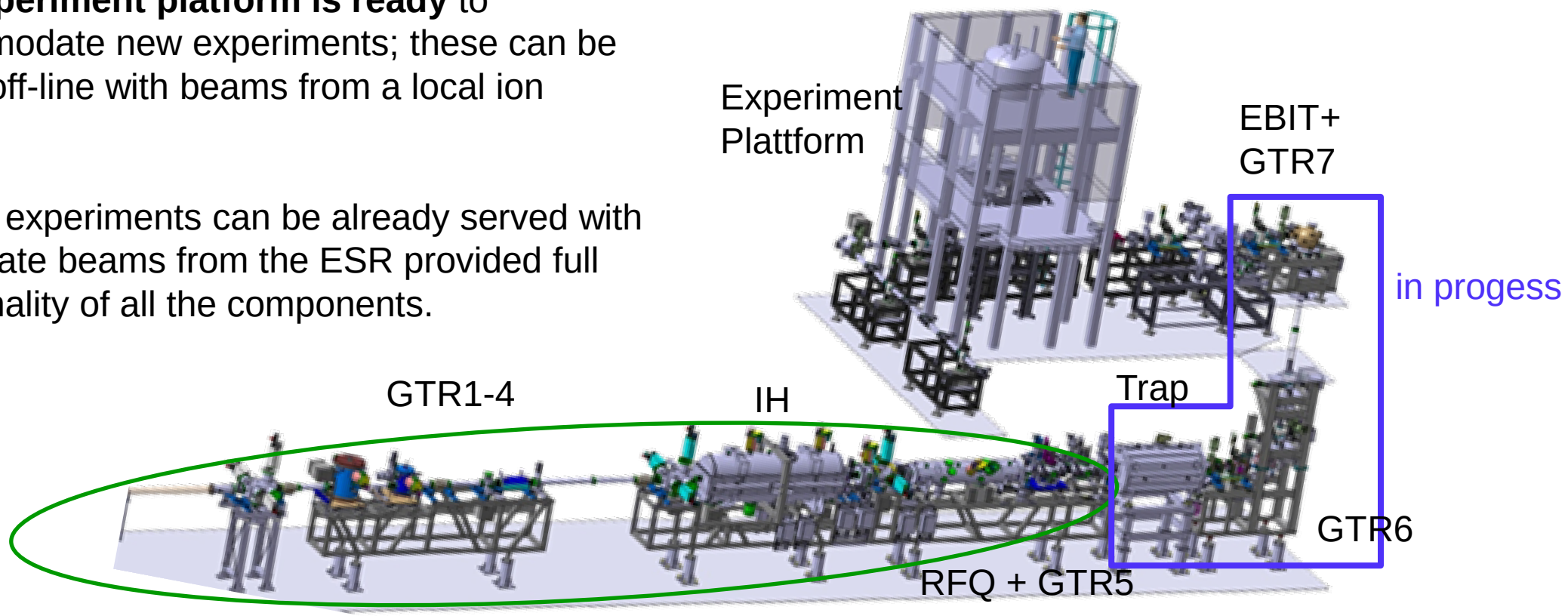
- **First ever** test of narrow nuclear resonance measurement using **cooled beams** at rings
- **Aim**: measure elastic and resonant scattering of $^{16}O$ beam on alpha (He internal target)
- The internal jet target performed excellent during the experiment: stability and intensity
- Issues with a PS of the electron cooler during the experiment – repaired thanks to heroic efforts from the CRYRING team!
- Unfortunately, we observe a beam halo/stripe/shadow present across the detectors. **18 cm long!** Origin: **unclear today**

# HITRAP re-commissioning

- The **HITRAP re-commissioning** has made substantial progress.
- Completion time strongly depends on the available beam time: amount and schedule
- **Two beam times this year (February $^{12}C^{6+}$ and $^{18}O^{8+}$ and $^{36}Ar^{18+}$ in April) have allowed to identify and solve few issues and to decelerate and bring the $^{36}Ar^{18+}$ beam into the cooler trap**

- **The experiment platform is ready** to accommodate new experiments; these can be tested off-line with beams from a local ion source.

- Certain experiments can be already served with decelerate beams from the ESR provided full functionality of all the components.




re-commissioned

# Laser laboratory at HITRAP

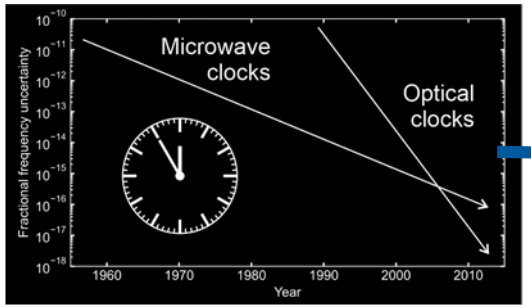
## New infrastructure: the laser laboratory for quantum logic spectroscopy and novel optical clocks

**Unique platform at HITRAP** for unprecedented optical spectroscopy of heavy highly charged ions

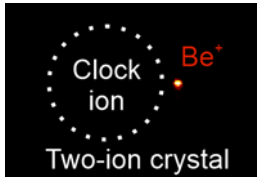
- Hyperfine-structure transitions
- Nuclear transition in thorium

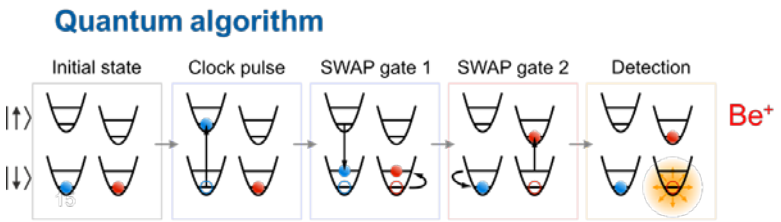
**Objectives:**

- Tests of fundamental, atomic, and nuclear physics
- Searches for physics beyond the Standard Model

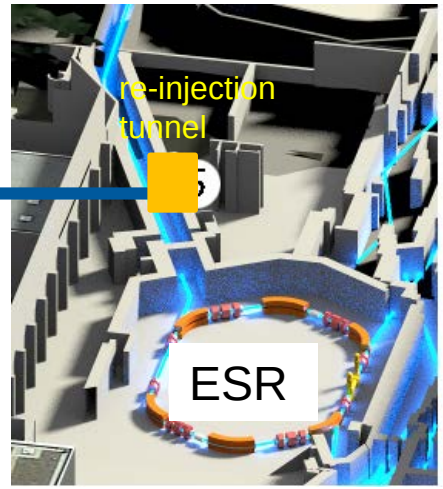



Optical clocks are the most accurate measuring instruments




the existing beam line was removed





***Helmholtz Young Investigator Group,*** *Peter Micke, since Aug 2023*

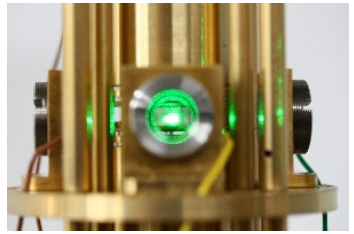
# Third Party Funding

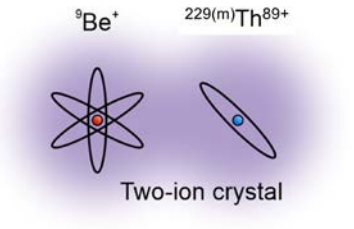
## ERC Advanced Grant for Thomas Stöhlker

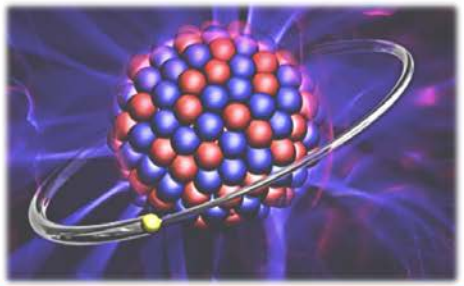
**2.5 M€ grant for 5 years, for the project HITHOR**
**“Highly Ionized Trapped 229-Thorium: A New Paradigm Towards a Nuclear Clock”**

European Research Council
Established by the European Commission

**HITHOR** at GSI's ion storage ring and trapping facilities (**ESR** and **HITRAP**): **Highly ionized 229-thorium** can be synthesized, decelerated, trapped, cooled and precisely studied.



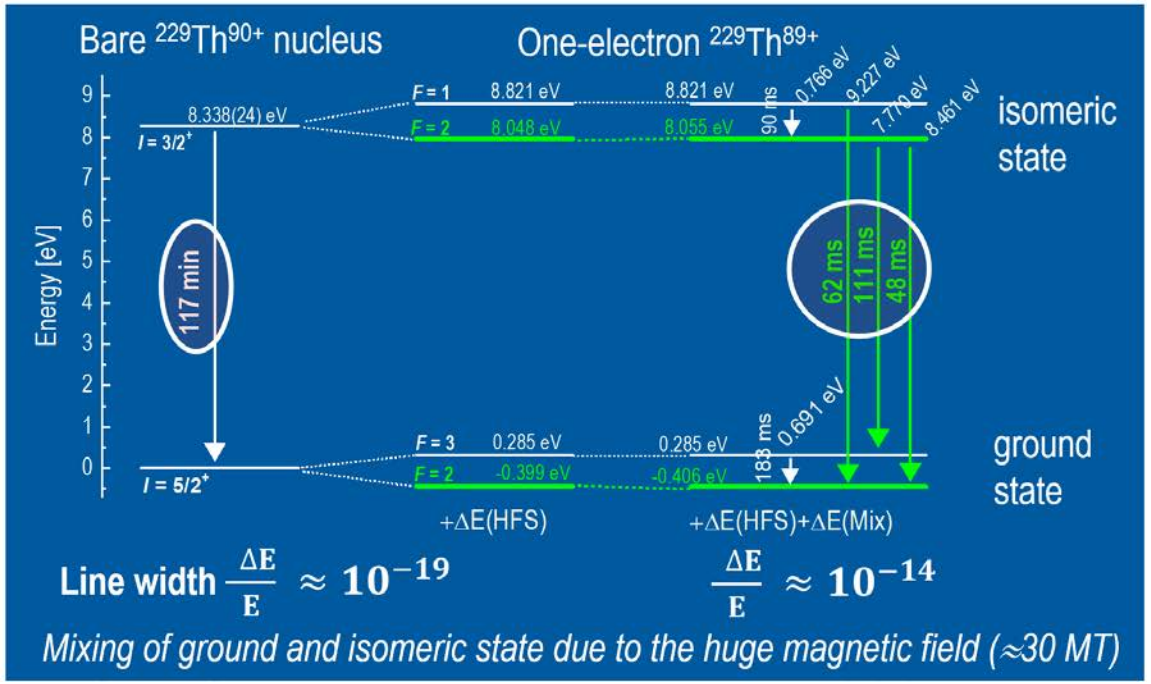


**Nuclear Hyperfine Mixing**
One unpaired electron required

**Laser excitation of $^{229(m)}Th^{89+}$**
- ~$10^{5}$-$10^{6}$ more probable *and*
- ~$10^{5}$-$10^{6}$ more decays

**From hours to milliseconds!**



# Experiment Infrastructure

**The SIRTAKI – Laboratory: S**upercooled **I**nte**R**nal **Ta**rgets for **C**ollision Experiments in **I**on Storage Rings

**Internal gas targets for the storage rings**: at FAIR at least 4 internal gas targets will operate for the experiments: at ESR, CRYRING and at HESR

- essential infrastructure for the in-ring experiments
- depending on the ring and beam species, the target must have different operation parameters

An existing laboratory, ~ 65 $m^2$ provided all the required technical infrastructure for the development of internal targets for storage rings.


In the course of last year, the existing space was cleaned up and renovated

- internal gas-jet target and cryogenic liquid droplet target development
- a hub not only for the development, but also for the optimization and maintenance of the current internal target stations that are used by SPARC and PANDA collaborations.

*N. Petridis with GSI support*

# Open issues

- To be addressed: operation, maintenance and R&D budget. In some cases no manpower and cash for keeping the already constructed SPARC components in use; loss of expertise if the work on and with the components can’t be continuously supported.

- **Host lab support**: the different, complex SPARC experiments require often setup changes which makes the support of the specialized technical teams of GSI indispensable not only during the shutdown periods.

- The long term survival of the collaboration, until the later FAIR stages are implemented and beyond, depends on the capability to secure the education of the next generation of experts and to keep them involved in FAIR.

# Concluding remarks

- The SPARC collaboration made good progress in the completion of components and, in parallel, successfully performed some experiments since November 2023.
- **Laser cooling and spectroscopy of relativistic heavy ion beams at SIS100**
  German VF funding has been secured which is of utmost importance.
- For the rest of 2024 and 2025 numerous evaluated proposals expect to be scheduled to run. For the time beyond, a new call and G-PAC evaluation are expected in 2025.
- For the coming years, until the realisation of the FS++ and MSVc stages, SPARC will concentrate on the extensive and efficient operation of the existing components and those still in construction. Regular beam time availability is requested for every year until the start of the main FAIR facilities.
- A sustained R&D program should be also pursued, both for further developments of the components in use and for the ones needed later at APPA cave and HESR. The technology progress will be on the focus of the collaboration.