ErUM-FSP T05

“Aufbau von APPA bei FAIR”

Status and Perspectives

Stefan Schippers

Sprecher des ErUM-FSP T05

Justus-Liebig-Universität Gießen

HFHF Campus Gießen

APPA: Matter under Extreme Conditions

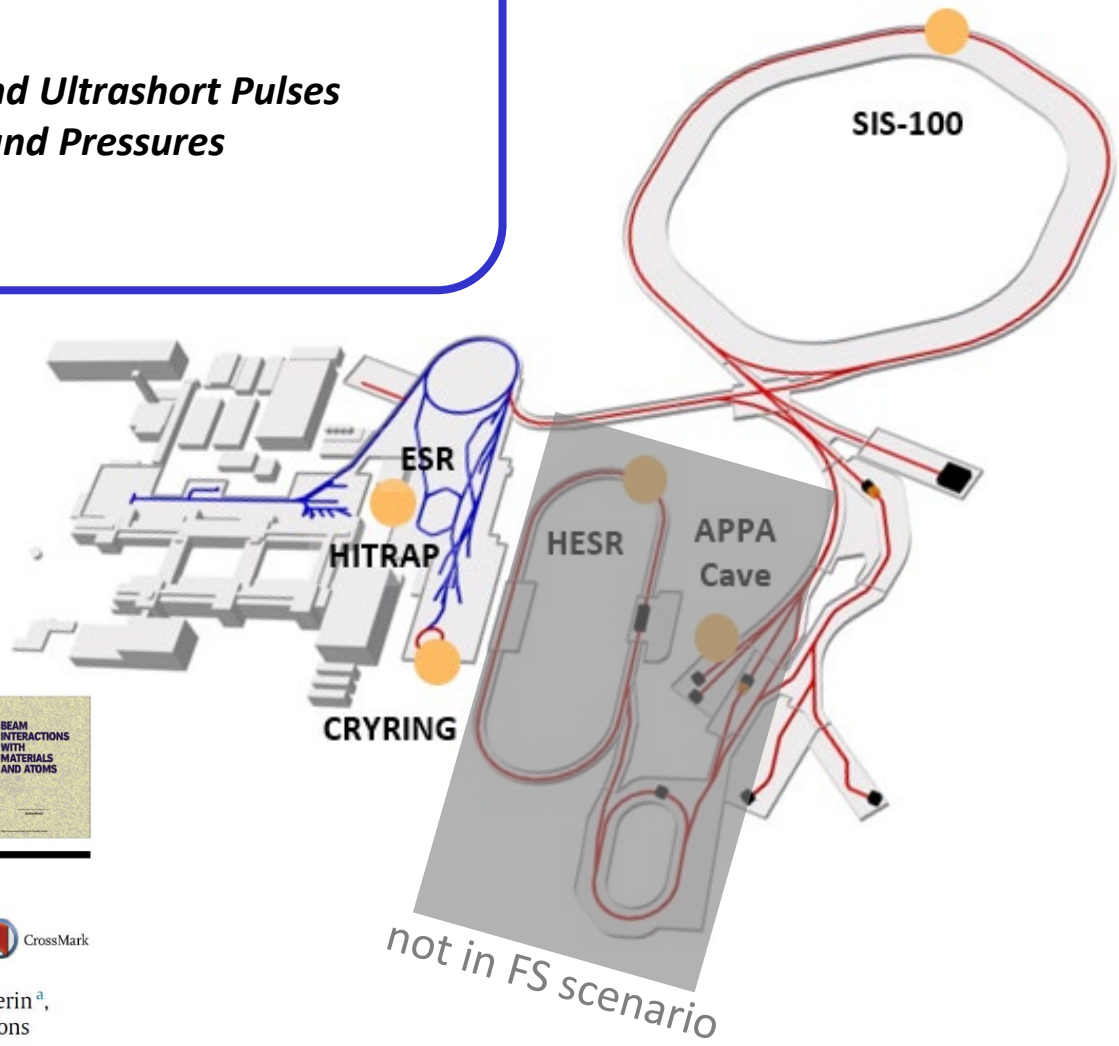
FACILITY CAPABILITY

Highest Charge States
Relativistic Energies
High Intensities
High Charge at Low Velocity

⇔

SCIENTIFIC CAPABILITY

Extreme Static Fields
Extreme Dynamical Fields and Ultrashort Pulses
Very High Energy Densities and Pressures
Large Energy Deposition



Plasma Physics
200 members from 11 countries

Atomic and Fundamental Physics
419 members from 35 countries

APPA White Paper

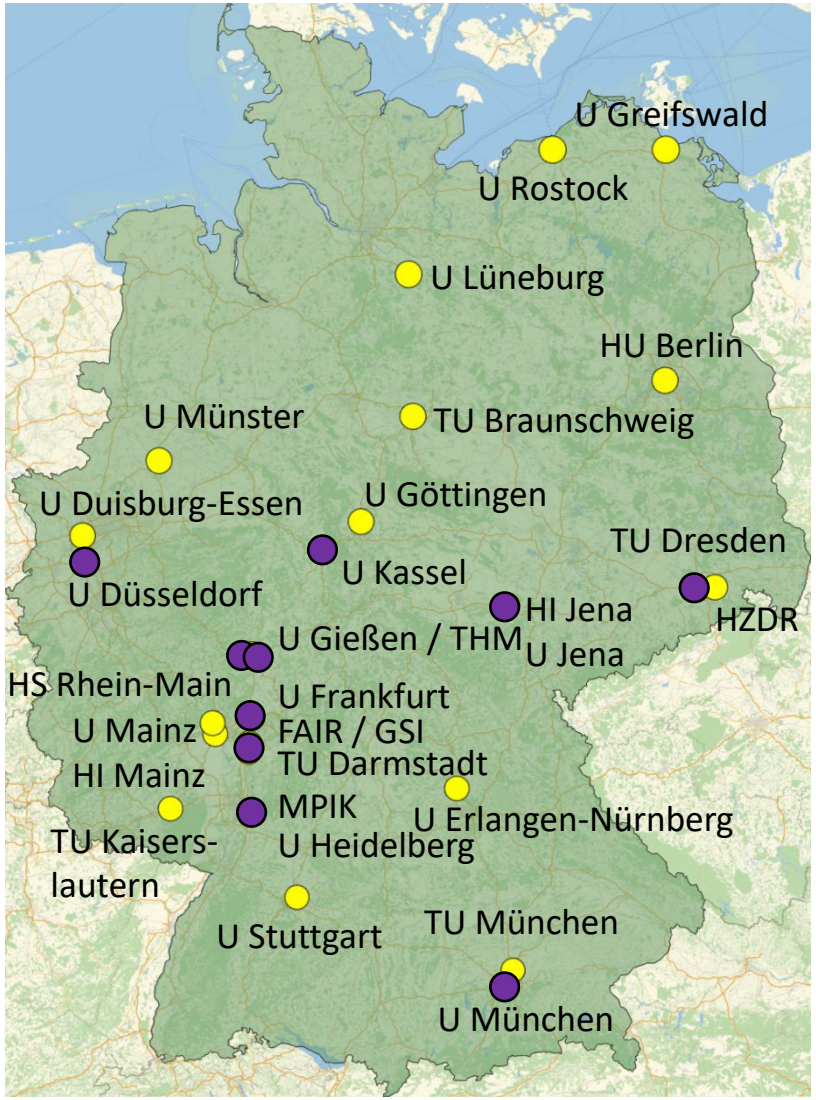
NIMB 365 (2015) 680

Contents lists available at ScienceDirect
Nuclear Instruments and Methods in Physics Research B
journal homepage: www.elsevier.com/locate/nimb

APPA at FAIR: From fundamental to applied research

Th. Stöhlker [a,b,c,*], V. Bagnoud [a,b], K. Blaum [d], A. Blazevic [a], A. Bräuning-Demian [a,e], M. Durante [a], F. Herfurth [a], M. Lestinsky [a], Y. Litvinov [a], S. Neff [a,f], R. Pleskac [a], R. Schuch [g], S. Schippers [h], D. Severin [a], A. Tauschwitz [a], C. Trautmann [a,f], D. Varentsov [a], E. Widmann [i], on behalf of the APPA Collaborations

BMFTR Funding of German University Groups



not all universities applied for funding

ErUM-FSP T05 – „Aufbau von APPA bei FAIR“

With funding from the:

Federal Ministry of Research, Technology and Space

SPARC & HED@FAIR (2024-2027)

11 projects funded (31 asked for)

4.7 M€ (14 M€ asked for)

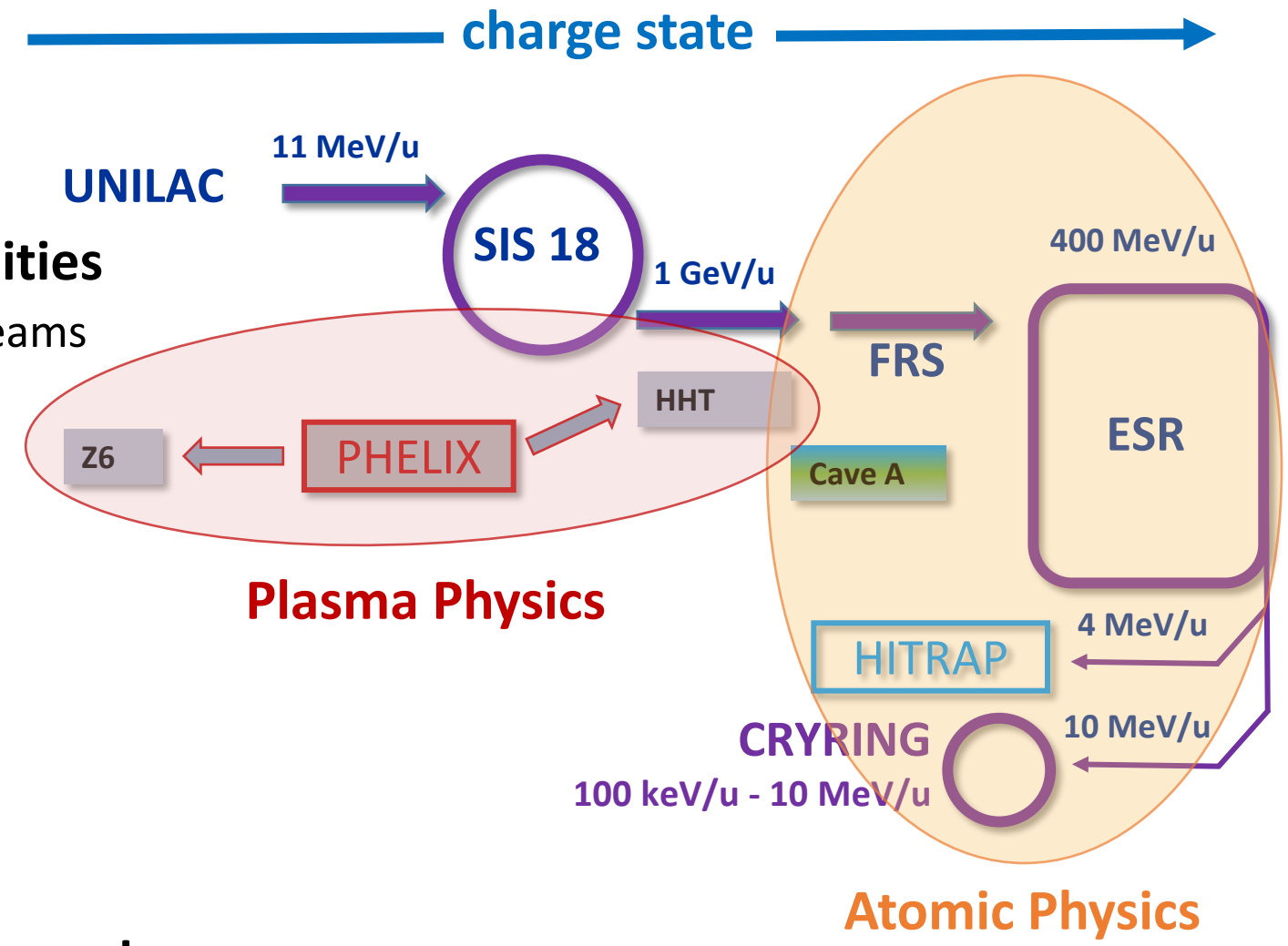
Heavily oversubscribed!

APPA Facilities in Operation (HED@FAIR and SPARC)

- **Worldwide unique experimental capabilities**
  - Plasma physics with combined laser and ion beams
  - Atomic physics in rings and traps

- **APPA fully involved in FAIR Phase 0**
  - **ESR, CRYRING, HITRAP** are part of FAIR MSV
  - **PRIOR** (proton microscope) and Heavy-Ion Heating setup (**HIHEX**) commissioned at HHT

- **APPA continuously further develops its instrumentation towards FS and beyond**



block diagram of relevant facilities

Scientific Highlights 2025

PHYSICAL REVIEW LETTERS **135,** 113001 (2025)

Testing Strong-Field QED to Second Order in the Highly Correlated Atomic System Berylliumlike Pb^{78+} by Electron-Ion Collision Spectroscopy

S. Schippers,[1,2] C. Brandau,[1,3] S. Fuchs,[1,2] M. Lestinsky,[3] S. X. Wang,[1,2] C. Y. Zhang,[4] N. R. Badnell,[4] A. Borovik, Jr.,[1,5] M. Fogle,[6] V. Hannen,[7] Z. Harman,[8] P.-M. Hillenbrand,[1,3] E. B. Menz,[3,5] Y. Zhang,[8,9] Z. Andelkovic,[3] F. Herfurth,[3] R. Heß,[3] A. Kalinin,[3] C. Kozhuharov,[3] C. Krantz,[3] S. Litvinov,[3] B. Lorentz,[3] U. Spillmann,[3] M. Steck,[3] G. Vorobyev,[3] D. Banaś,[10] S. Fritzsche,[3,5,11] E. Lindroth,[12] X. Ma,[13] A. Müller,[1] R. Schuch,[12] A. Surzhykov,[14,15] M. Trassinelli,[16] K. Ueberholz,[7] C. Weinheimer,[7] and Th. Stöhlker[3,5,17]

PHYSICAL REVIEW LETTERS **134,** 153001 (2025)

Quantum Electrodynamics in Strong Electromagnetic Fields: Substate Resolved Kα Transition Energies in Heliumlike Uranium

Ph. Pfäfflein,[1,2,3,*] G. Weber,[1,2] S. Allgeier,[4] Z. Andelkovic,[1] S. Bernitt,[1,2] A. I. Bondarev,[1,2] A. Borovik, Jr.,[5,6] L. Duval,[7] A. Fleischmann,[4] O. Forstner,[1,2,3] M. Friedrich,[4] J. Glorius,[1] A. Gumberidze,[1] Ch. Hahn,[1,2] F. Herfurth,[1] D. Hengstler,[4] M. O. Herdrich,[1,2,3] P.-M. Hillenbrand,[1,5,6] A. Kalinin,[1] M. Kiffer,[1,2,3] F. M. Kröger,[1,2,3] M. Kubullek,[3] P. Kuntz,[4] M. Lestinsky,[1] Yu. A. Litvinov,[1] B. Löher,[1] E. B. Menz,[1,2,3] T. Over,[2,3] N. Petridis,[1] S. Ringleb,[2,3] R. S. Sidhu,[1,8] U. Spillmann,[1] S. Trotsenko,[1] A. Warczak,[9] B. Zhu,[10] Ch. Enss,[4] and Th. Stöhlker[1,2,3]

precision spectroscopy of slow highly charged ions testing QED in strong fields

Experimental Setups at the CRYRING@ESR Electron Cooler

experimental equipment highly integrated into accelerator hardware

C. Brandau et al., Chin. Phys. C **49**, 064001 (2025)

CRYRING electron cooler providing ultra-cold electrons

superconducting magnet

A. Koutsostathis et al., HPNS Adv. Nucl. Phys. **31** (2025) 86

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

precise control of electron energy

particle detector

Universität Münster

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

With funding from the:

Federal Ministry of Research, Technology and Space

Highlight: Testing 2nd Order QED in a Highly Correlated Atomic System – Electron-Ion Collision Spectroscopy at CRYRING@ESR

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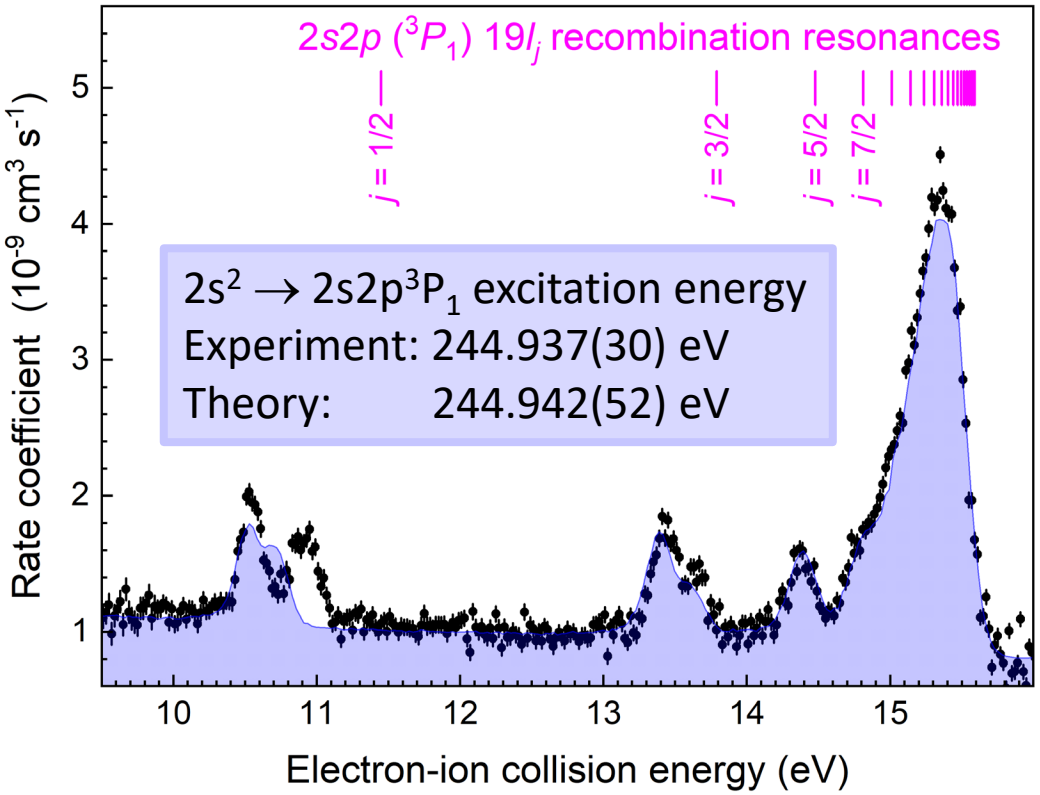
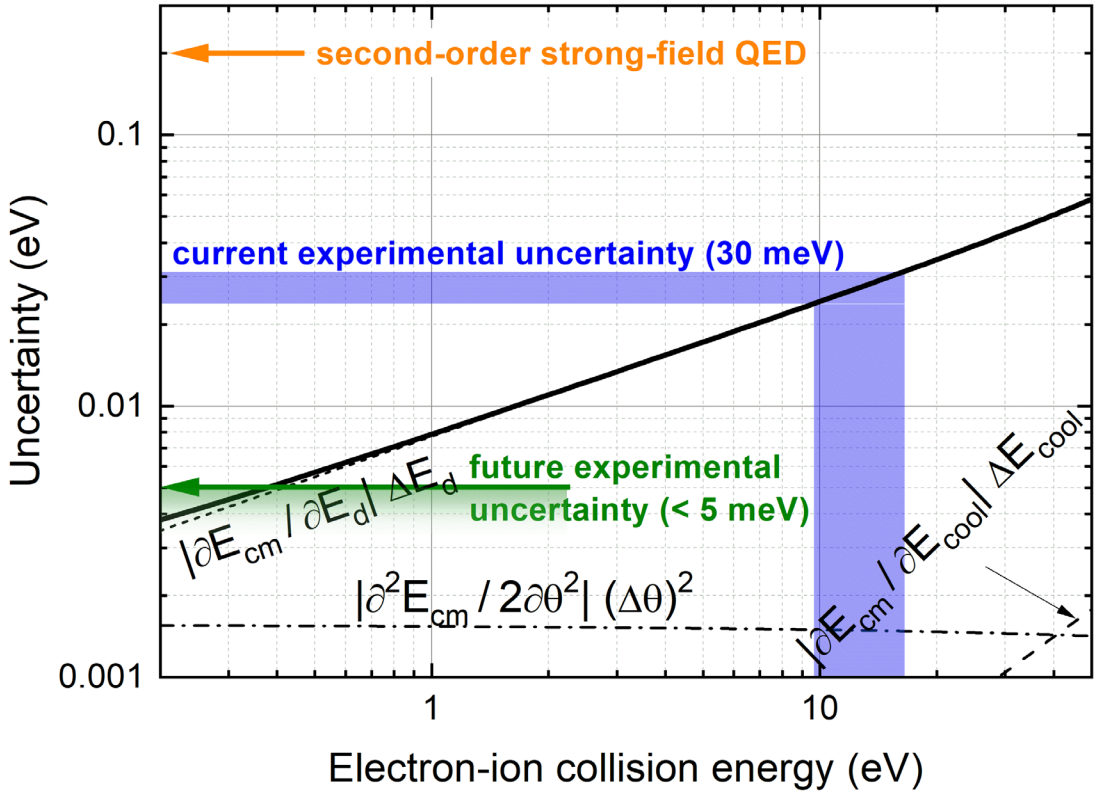
FAIR

Decelerated Be-like Pb^{78+} ions from the ESR



Record low experimental uncertainty thanks to the ultra-cold electron beam



Merged-beams kinematics: Extremely low collision energies are accessible with highest precision

S. Schippers et al., PRL **135**, 113001 (2025)

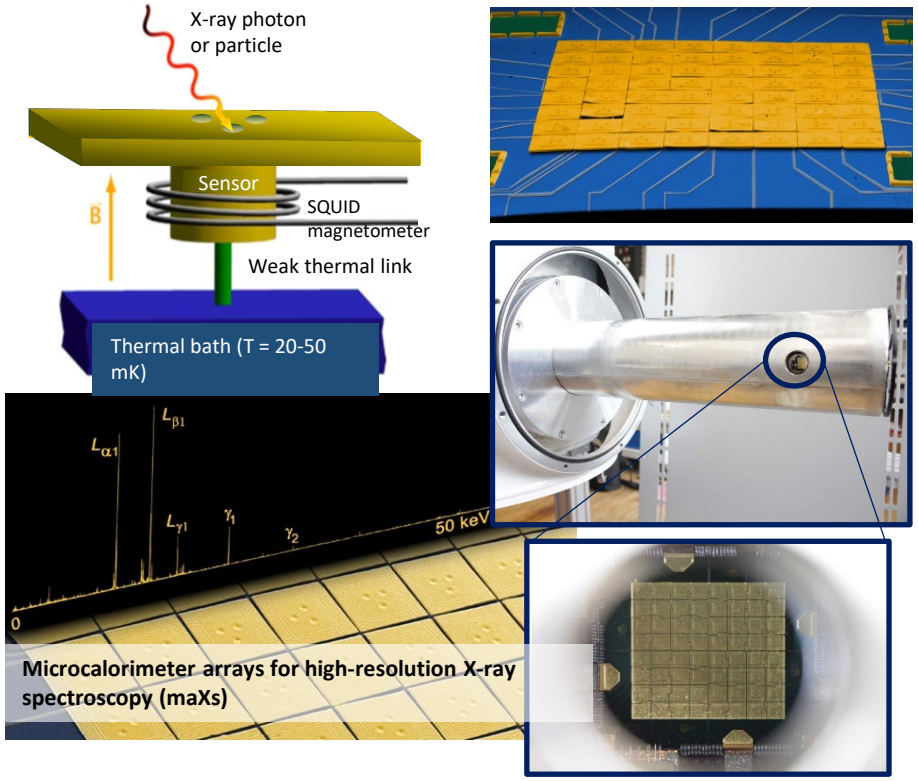
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN · FRIEDRICH-SCHILLER-UNIVERSITÄT JENA · HI Jena Helmholtz-Institut Jena · Universität Münster · TECHNISCHE UNIVERSITÄT DARMSTADT

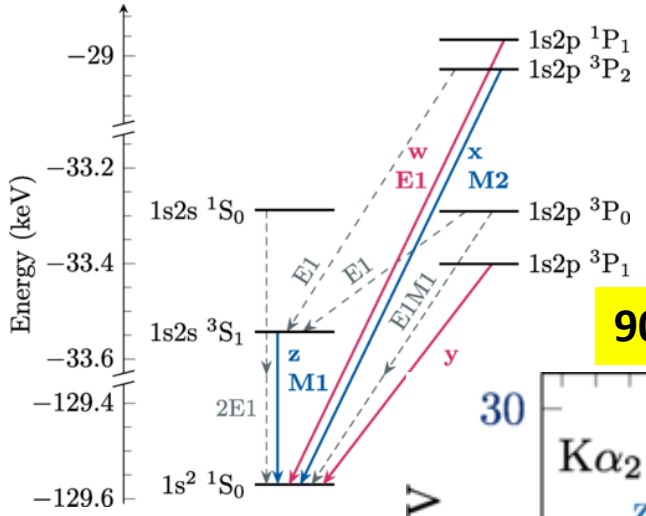
S. Fritzsche et al., EPJD **79**, 22 (2025)

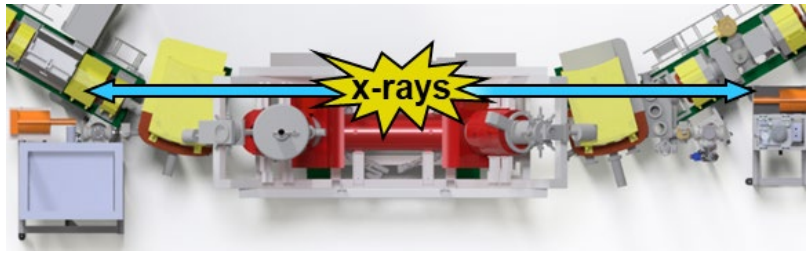
Jena Atomic Calculator (JAC)

Highlight: High-Resolution Spectra of X-Ray Transitions in the Heaviest Heliumlike Ion (U^{90+}) from CRYRING@ESR

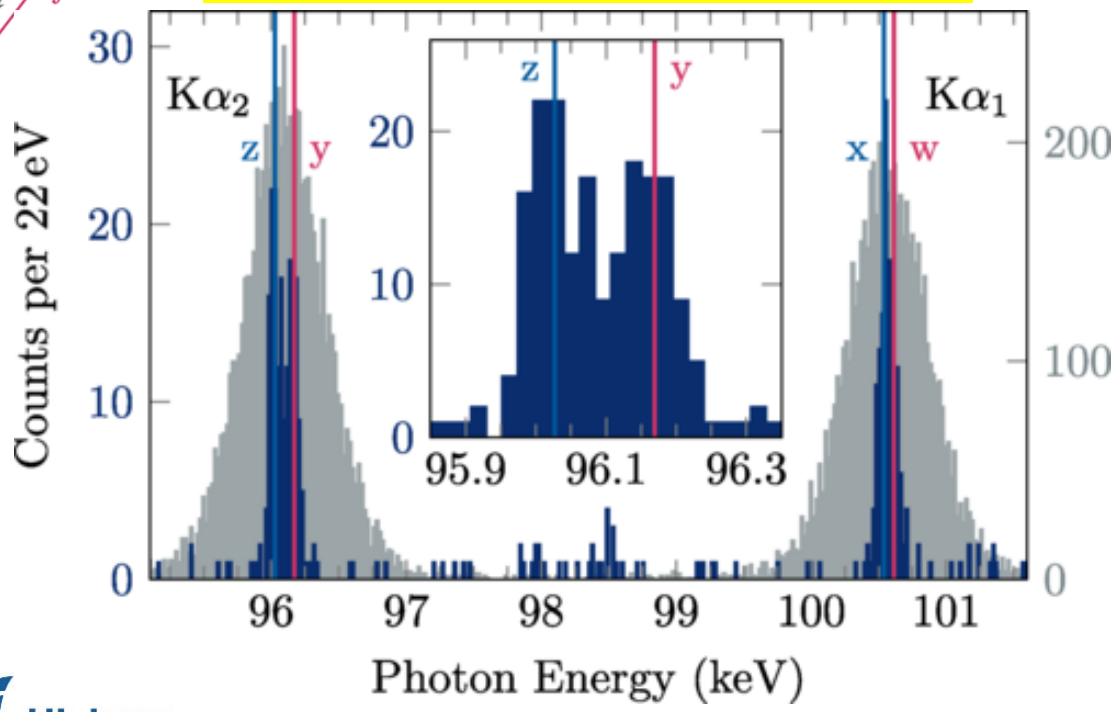
Metallic magnetic microcalorimeter







90-eV spectral resolution @100 keV!



Combination of high spectral resolution and broad bandwidth offers unique possibilities.

With funding from the:

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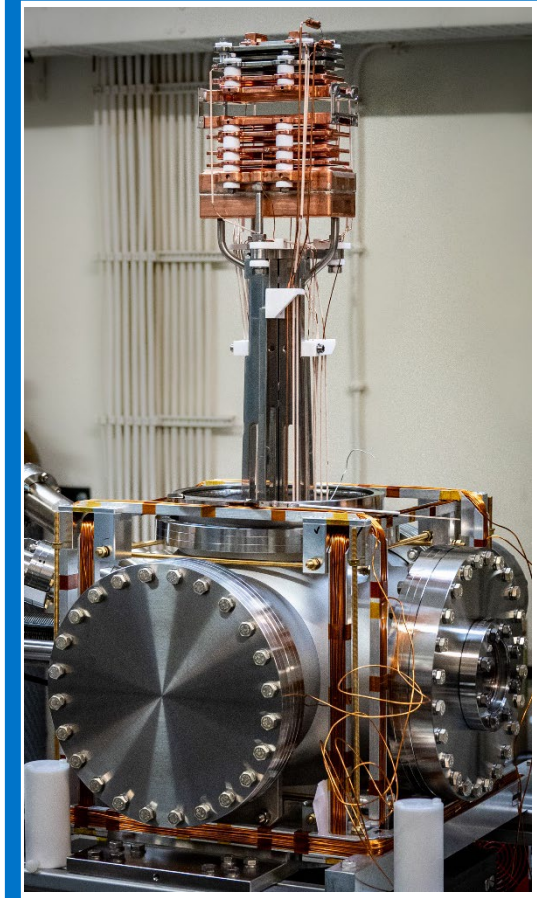
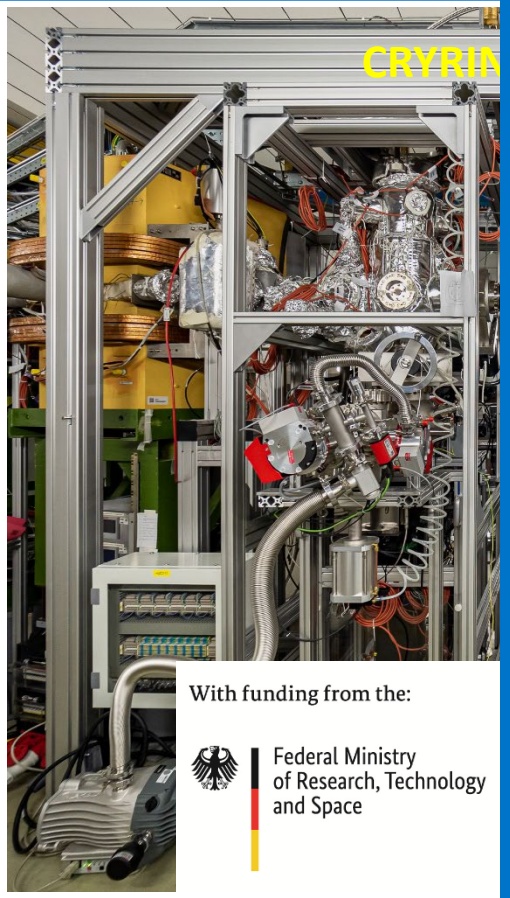
FRIEDRICH-SCHILLER-UNIVERSITÄT JENA

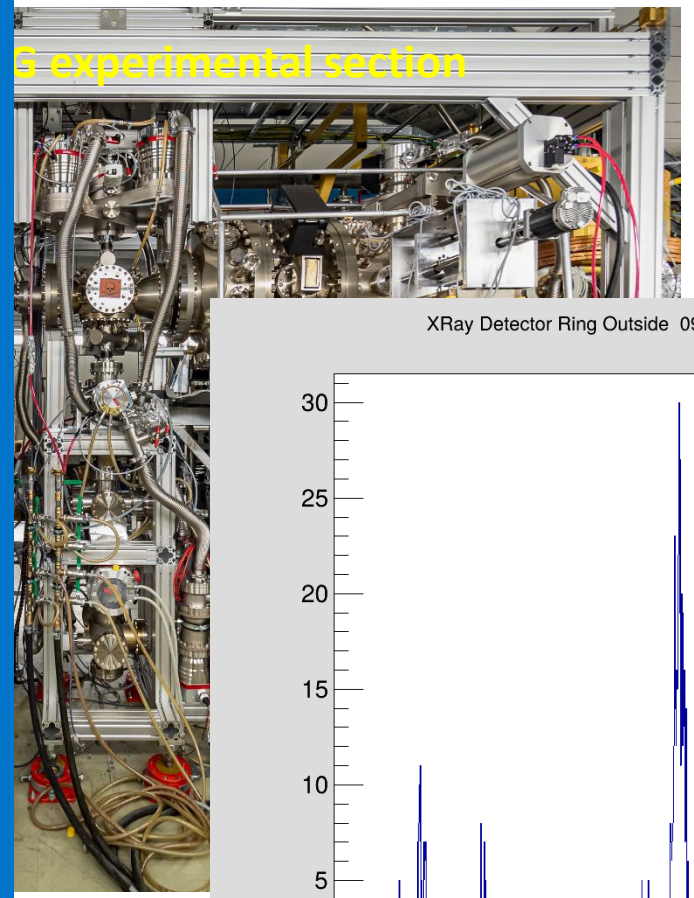
HI Jena Helmholtz-Institut Jena

P. Pfäfflein et al., PRL **134**, 153001 (2025)

Commissioning of the CRYRING Electron Target







Electron Target

and associated ion and photon detectors

gas jet

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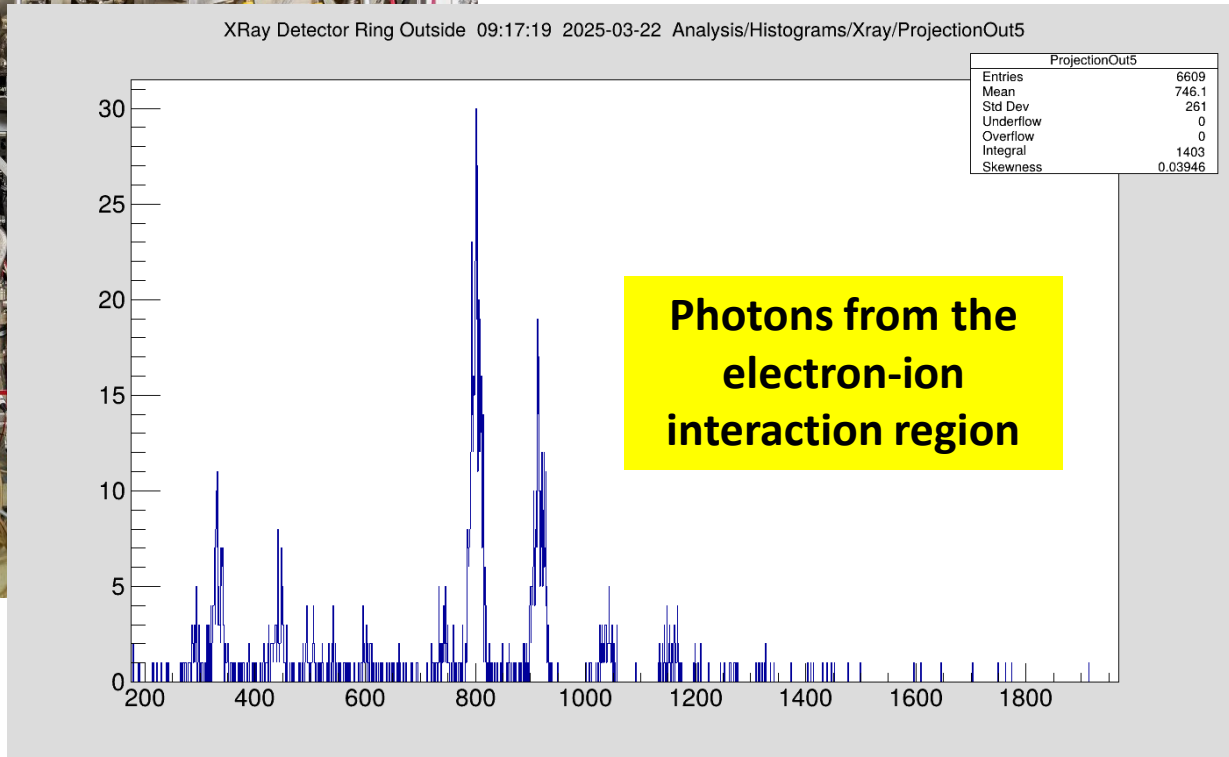
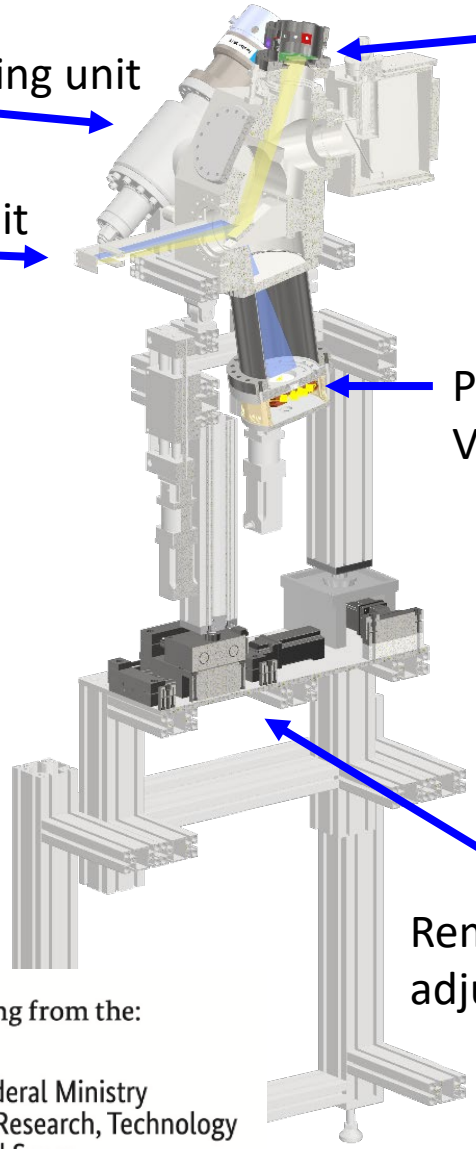
UNIKASSEL VERSITÄT

Commissioning beamtime G-22-00072 with a Au^{75+} ion beam in March 2025

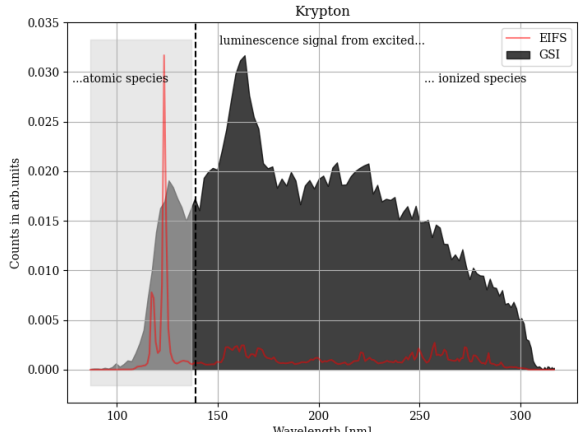


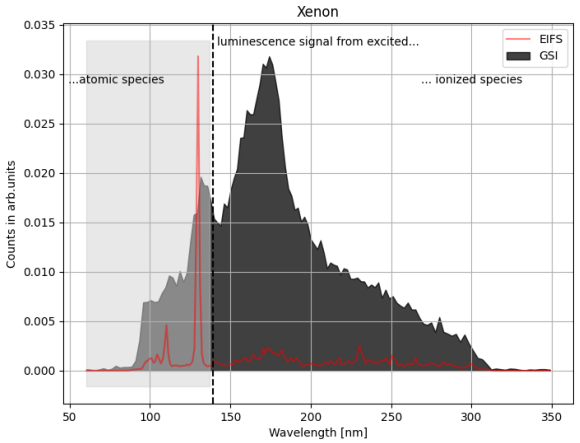
data analysis in progress …

Photon detection between 40 – 350 nm



Beamtime G-22-00199: Target electron correlations in 5 MeV/u Ne^{7+} collisions with Krypton and Xenon





Results:

1. Luminescence flux from ionized species detectable
2. Low resolution due to non-optimum position of the grating with respect to the interaction volume

To Dos:

1. Spectrometer position change such that interaction volume is in focus.
2. Improve slit unit
3. Modify remotely controlled adjustment stage

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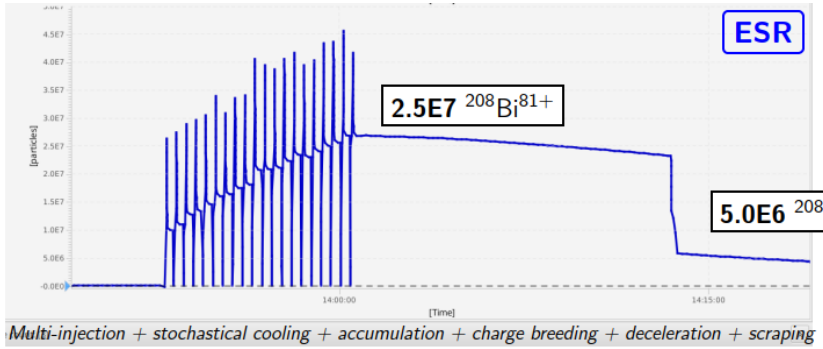
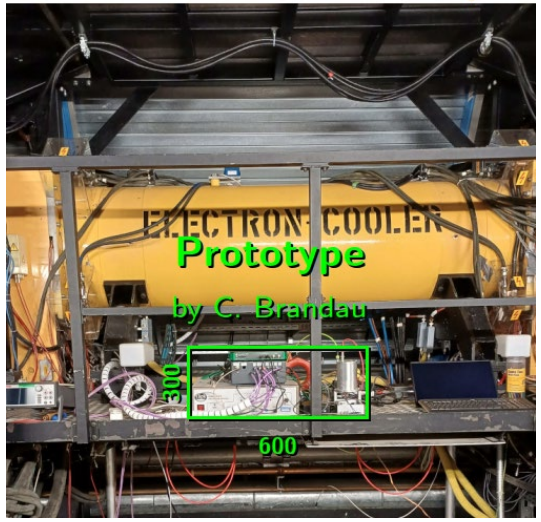
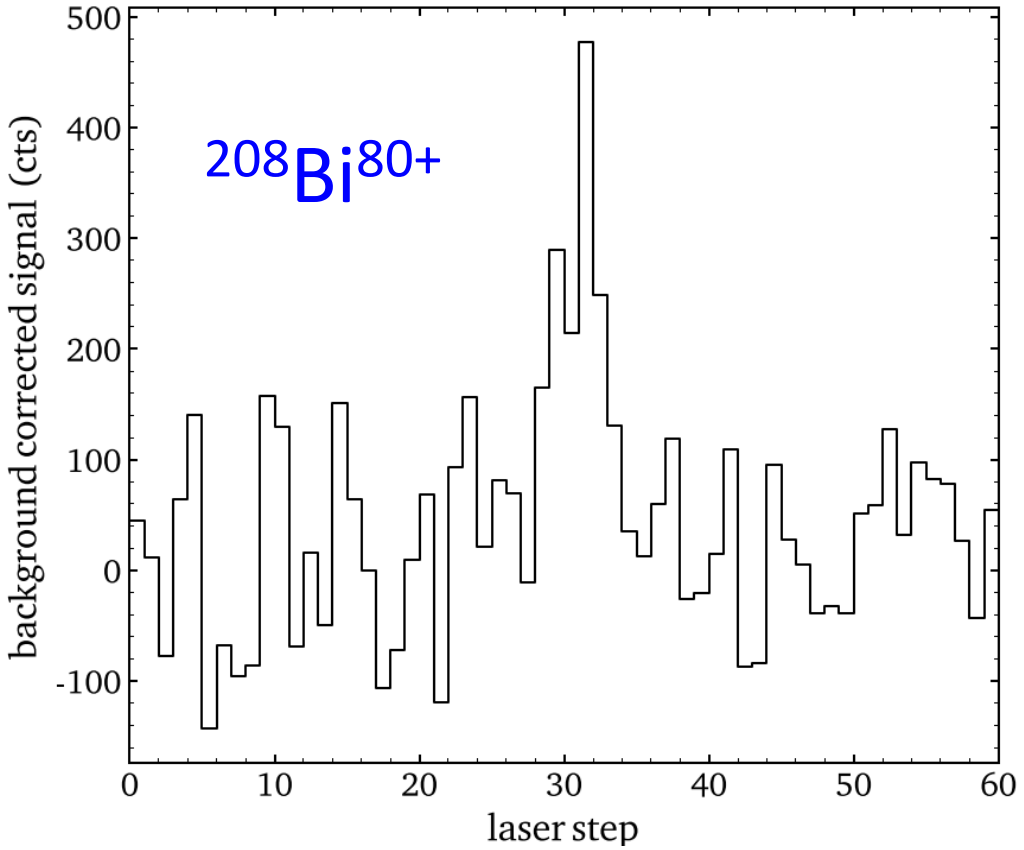
First Demonstration of Dielectronic-Recombination Assisted Laser Spectroscopy (DRALS)



Production of $^{208}Bi^{81+}$ (He-like, radioactive) → Accumulation → Charge Breeding $^{208}Bi^{80+}$ → q/m-Separation → Laser Excitation → DR → Ion Detection

Beamtime G-22-00038





With funding from the:

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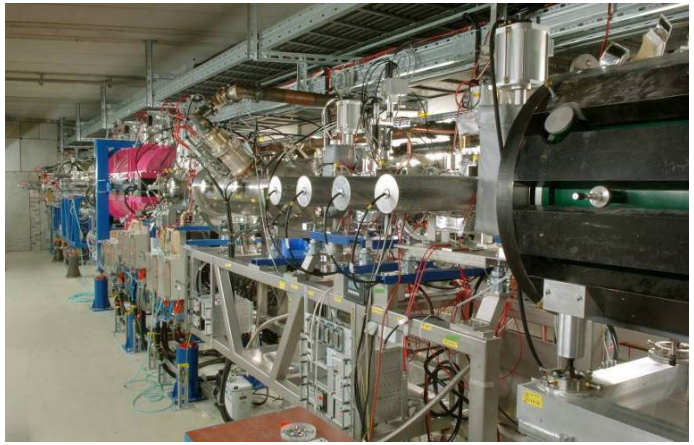
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

Universität Münster

HITRAP: First Experiment with Decelerated High-Z Ions

Beamtime G-22-00057 : Nanostructuring of monolayer graphene using slow heavy ions at high charge states



TU WIEN
A. Niggas, S. Spannagl, F. Aumayr, R.A. Wilhelm
G-22-00057, M-22-00146
C. Frank, C. Böttger, L. Breuer, M. Schleberger
UNIVERSITÄT DUISBURG ESSEN

@HITRAP

6keV/u Au^{79+}

E_{kin} ~1.2MeV

E_{pot} ~440keV

7 samples

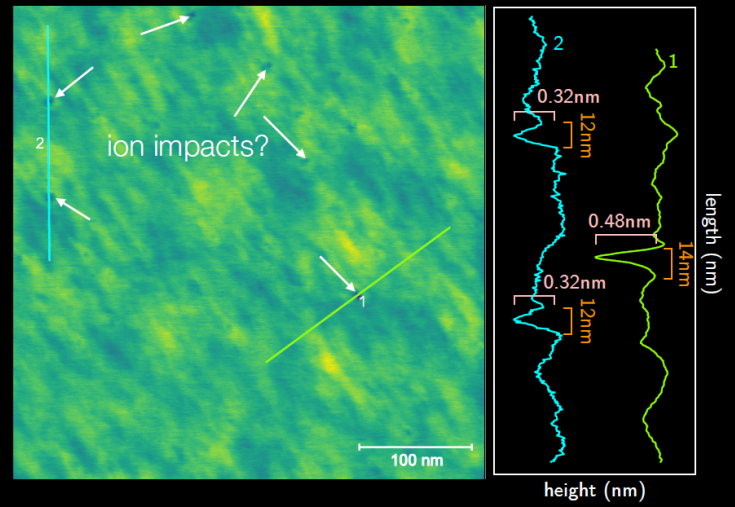
1-, 2-, 3-layer graphene (on SiC)
bulk CaF_2
MoS_2 on Au
MoS_2 on SiO_2
WS_2 on SiO_2

Microscopy

nanostructures on surfaces?

characterisation of samples shared between TU Wien and Uni Duisburg

(Very) Preliminary Data



Atomic Force Microscopy: MoS_2 on SiO_2

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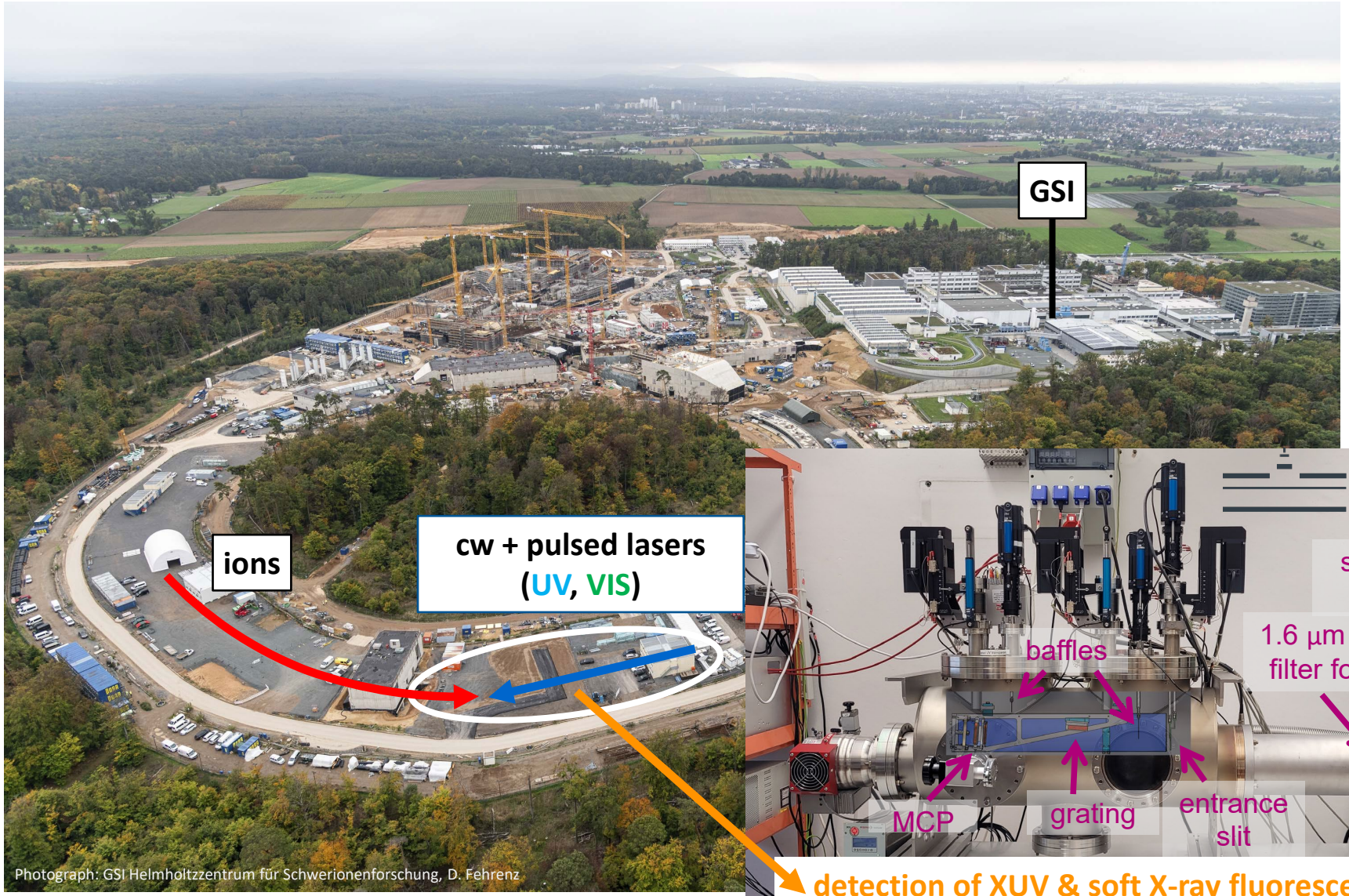
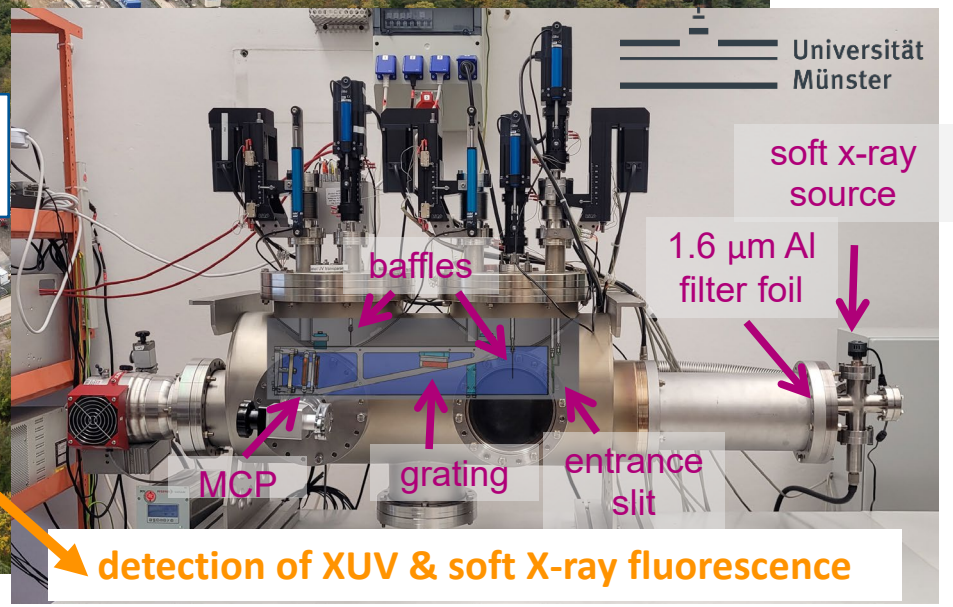
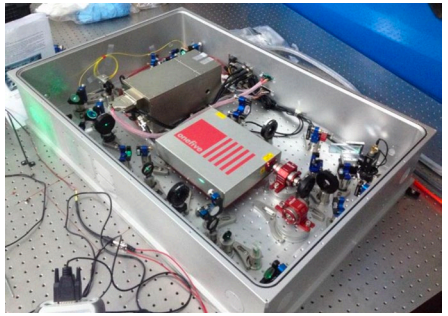
Laser Cooling Facility at SIS-100







Laser systems:

short-pulse

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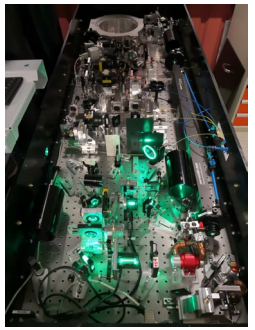

long-pulse

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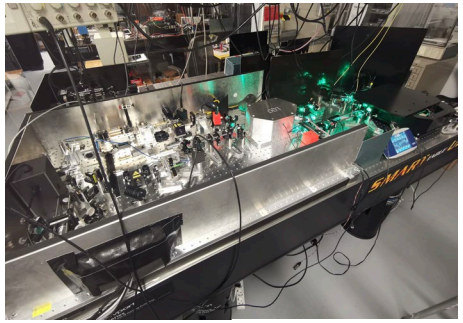
continuous



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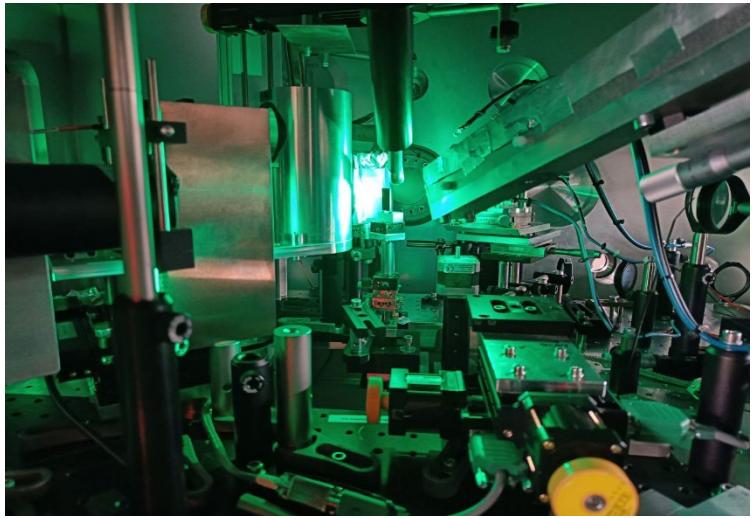
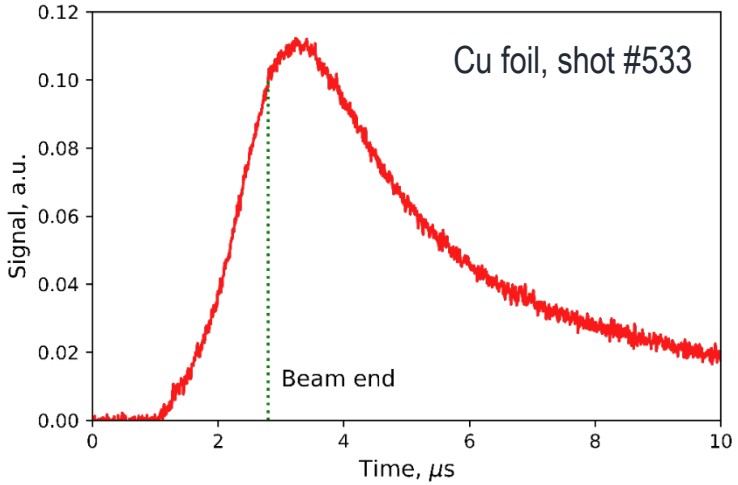
Ultraschnelle Pyrometrie



Experiment P-22-00125 (PI Prof Dr Vincent Bagnoud, GSI, June-July 2025) **at HHT**: **Successful test of pyrometer**



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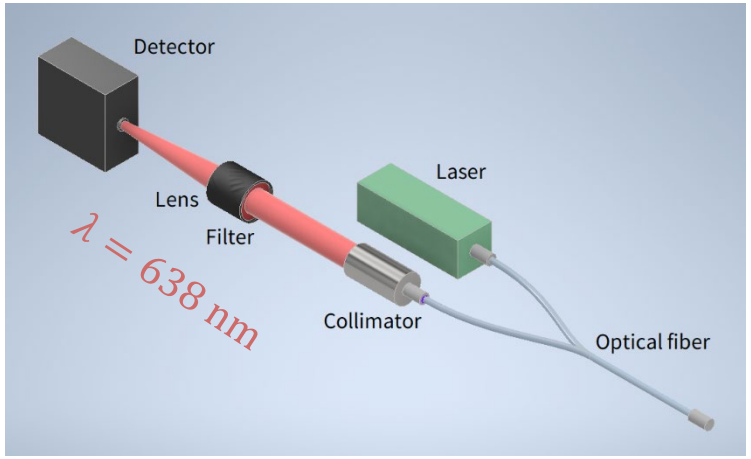
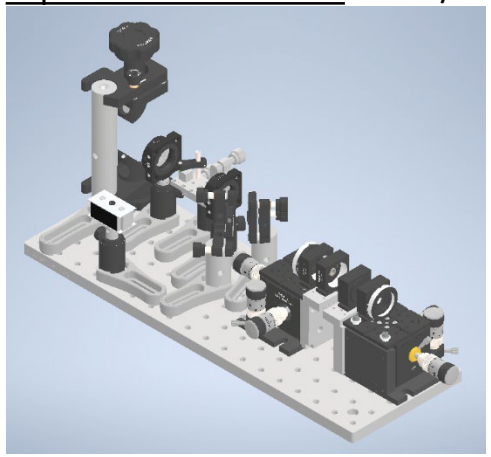
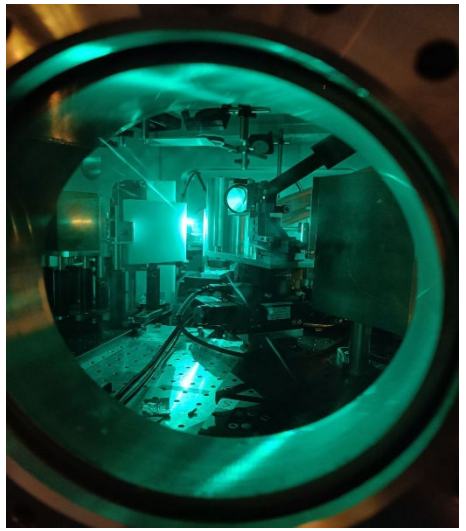
For reflectometry, some channels are used for the laser reflection signal. Additional information about the reflectivity of the surface at different wavelengths can be used to estimate the emissivity at these wavelengths and in the whole spectrum, improving the accuracy and reliability of the temperature measurements.

Test of the thermoreflectometry technique with a reflected laser signal and a bifurcated fiber.

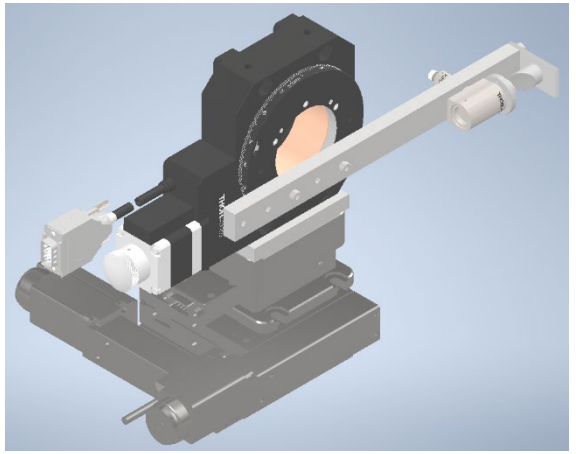


Reflectivity measurements with supercontinuum laser SCKB2/M.





Modification of the light collection system.



Novel Research Opportunities based on Sophisticated and Versatile Instrumentation

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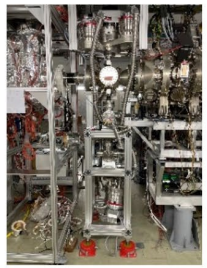
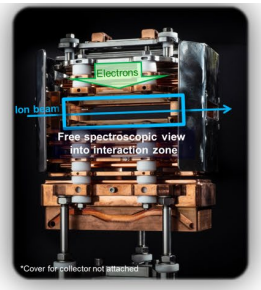
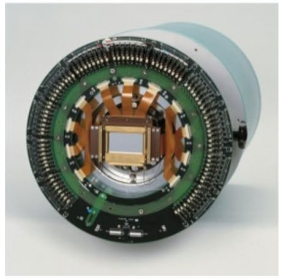
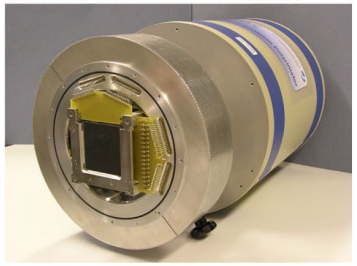


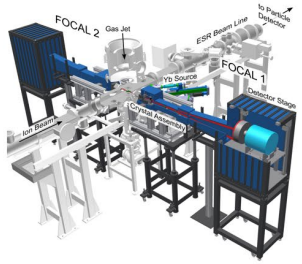


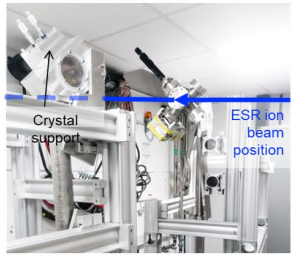
Targets



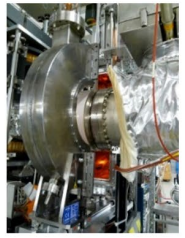


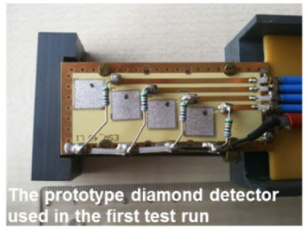
2D micro-strip Ge(i) detectors



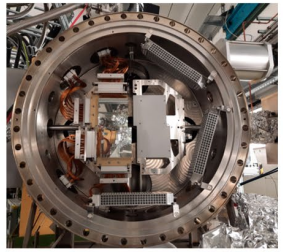


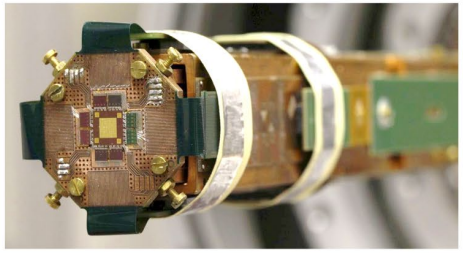
crystal spectrometers

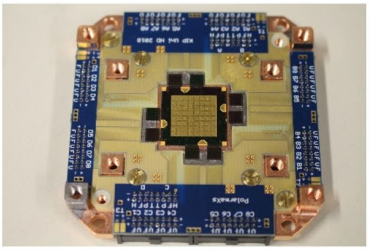




Particle detectors

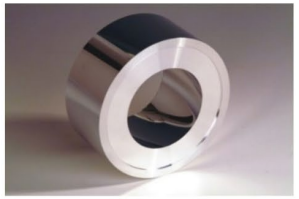


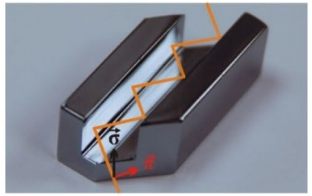




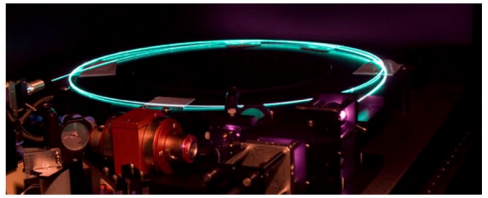
microcalorimeters

Traps





X-ray optics, channel-cut crystals

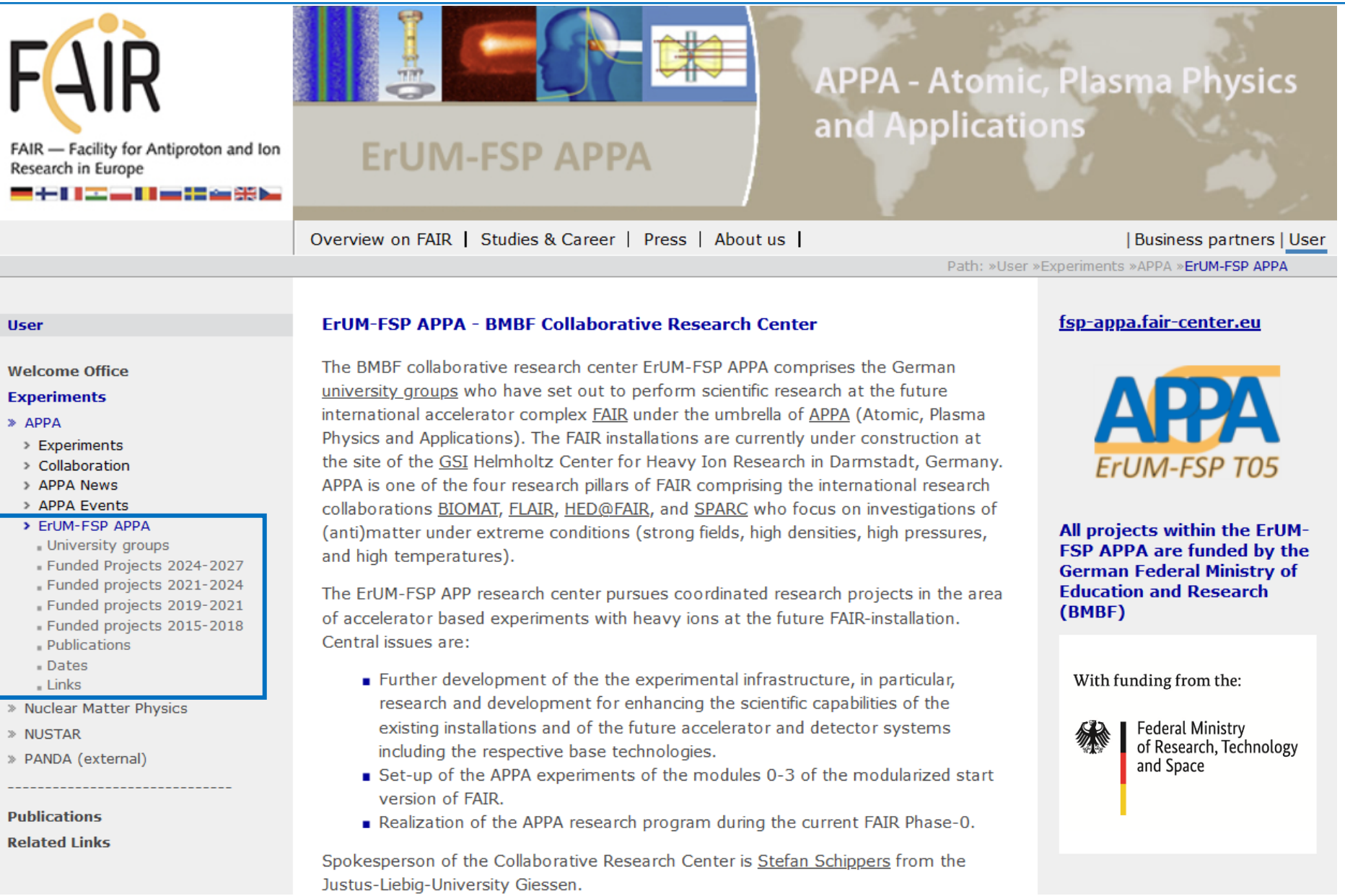


versatile Laser systems

SPARC/APPA: Besides its facilities, **instrumentation** is of utmost importance. Already the large portfolio of novel FAIR instrumentation guarantees for a rich science research program at the existing facilities HITRAP, CRYRING@ESR, and ESR.

Continuous R&D is required for keeping the instrumentation at the cutting edge.

Website https://fsp-appa.fair-center.eu



Next Annual Meeting of the ErUM-FSP APPA

Participants of 2025 meeting (Photograph: Lea Wunderlich)

22/23 January 2026 at GSI

https://indico.gsi.de/e/APPA_FSP_2026

Thank you for your attention!