

European Nuclear Physics Conference 2025

Caen 2025-09-26

The FAIR/GSI facility - Status and future perspectives

Thomas Nilsson
Scientific Managing Director GSI/FAIR

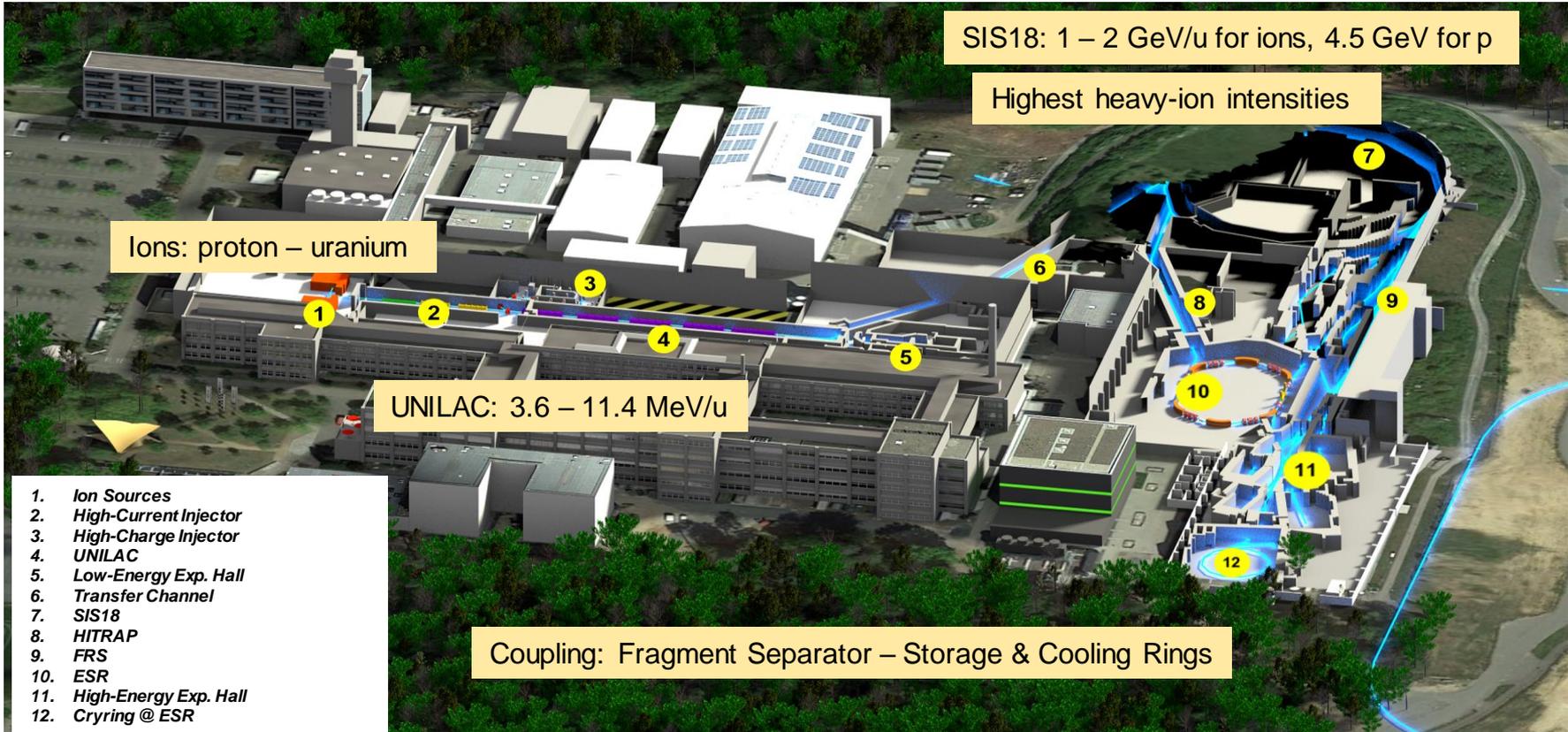


GSI – Facts and Numbers

- **GSI Helmholtzzentrum für Schwerionenforschung**
- Founded in 1969
- Campus Darmstadt
 - Employees (2023): 1,550 (thereof 1,150 scientific personnel)
 - Users of the GSI facilities: more than 1,500 per year
- **Mission:**
 - Fundamental and applied research with heavy ions.
 - Development, construction and operation of heavy-ion accelerators and experimental facilities.
 - Research in hadron, nuclear, atomic, plasma physics, materials research, biophysics and heavy-ion therapy
 - Forefront developments and innovations in accelerator, laser, detector and IT technologies
- **Two outposts:** Helmholtz Institute Jena and Mainz since 2009



GSI: Unique Accelerator Complex for Heavy Ions



... with cutting-edge instrumentation

CALIFA@R³B



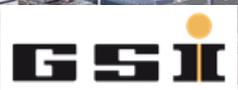
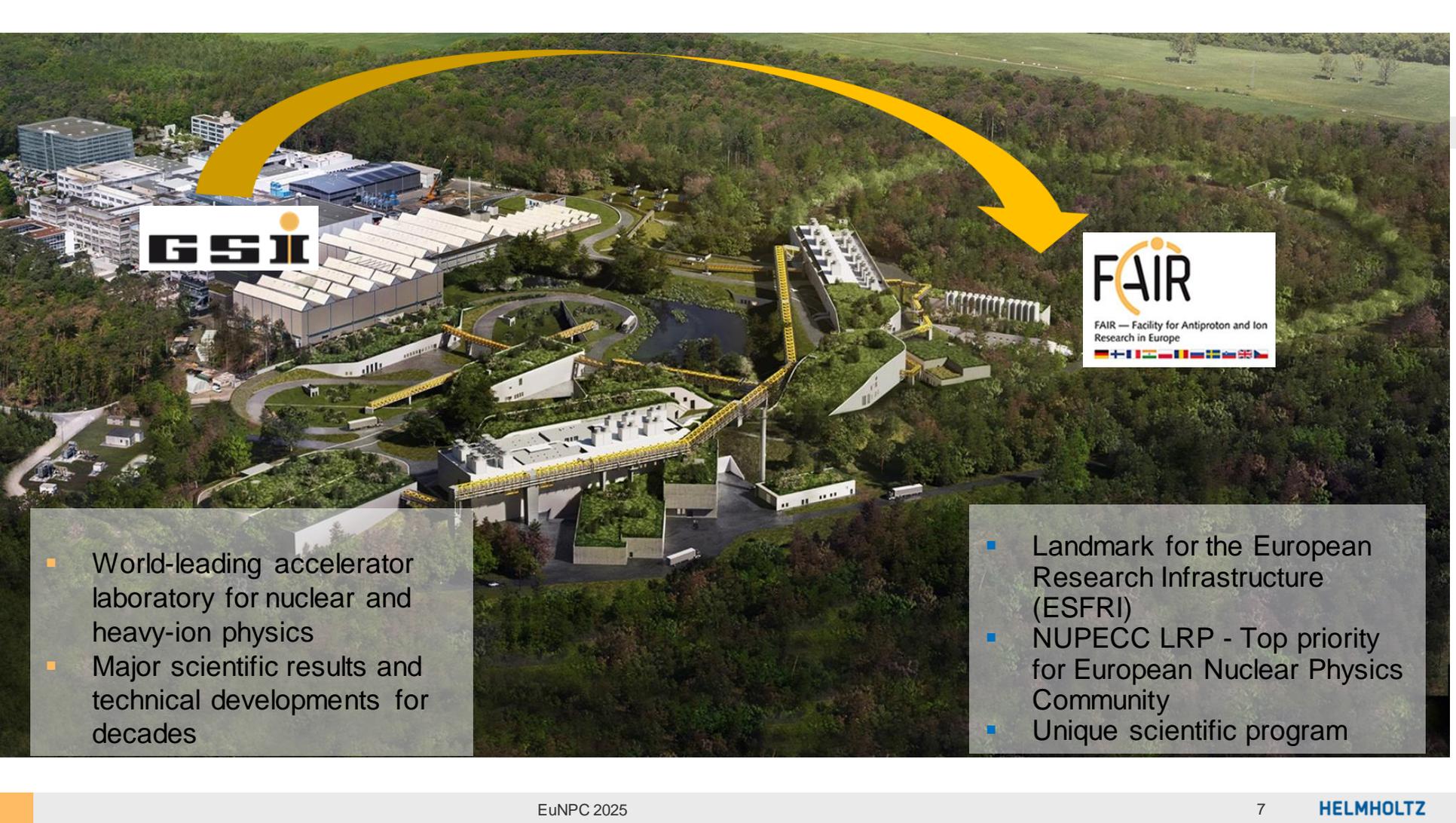
HADES



Forefront IT Developments



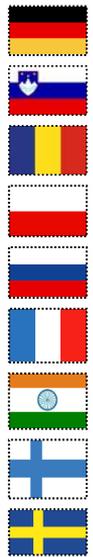
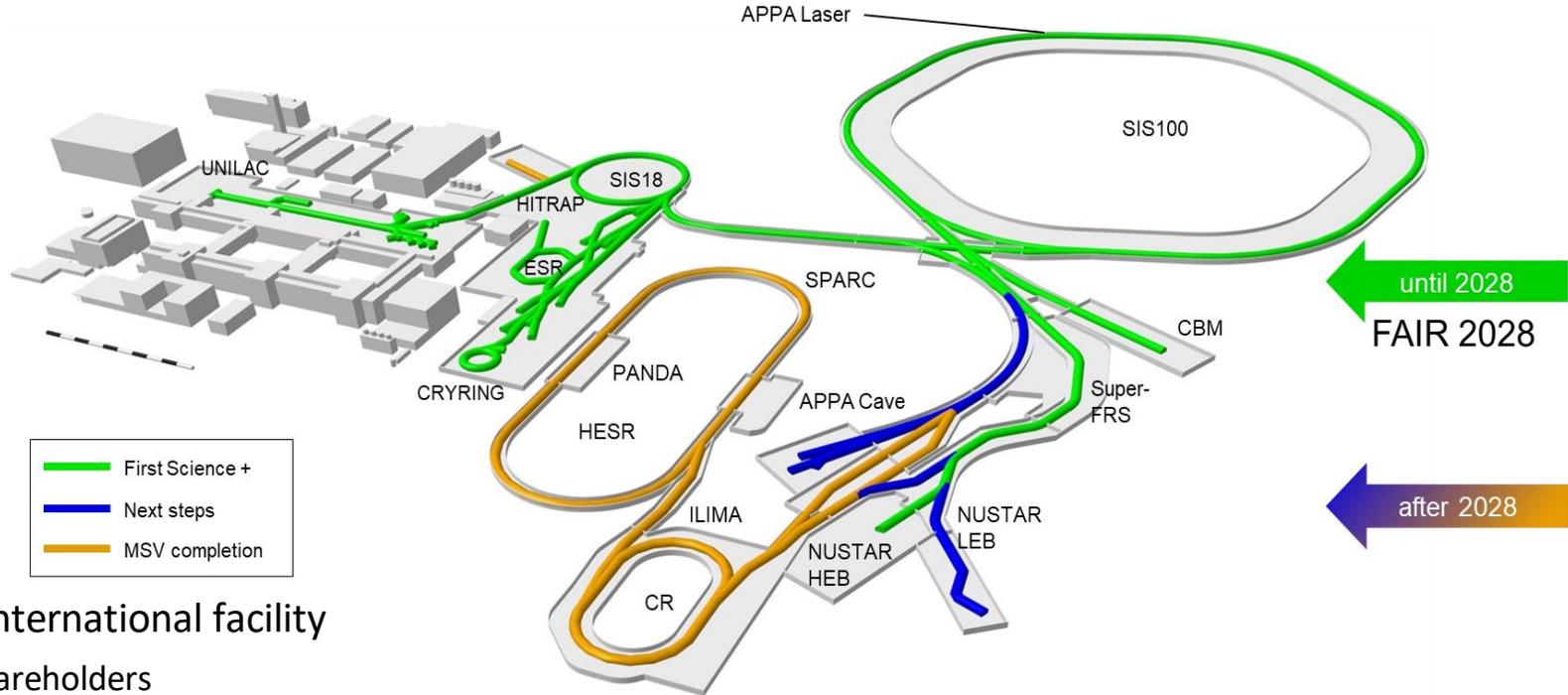
- Green IT & Big Data
- Energy-efficient high-performance computing
- AI innovation lab of the Hessian Center for Artificial Intelligence (hessian.AI)
- 600 nodes/54.000 cores/400 GPUs (2023)



- World-leading accelerator laboratory for nuclear and heavy-ion physics
- Major scientific results and technical developments for decades

- Landmark for the European Research Infrastructure (ESFRI)
- NUPECC LRP - Top priority for European Nuclear Physics Community
- Unique scientific program

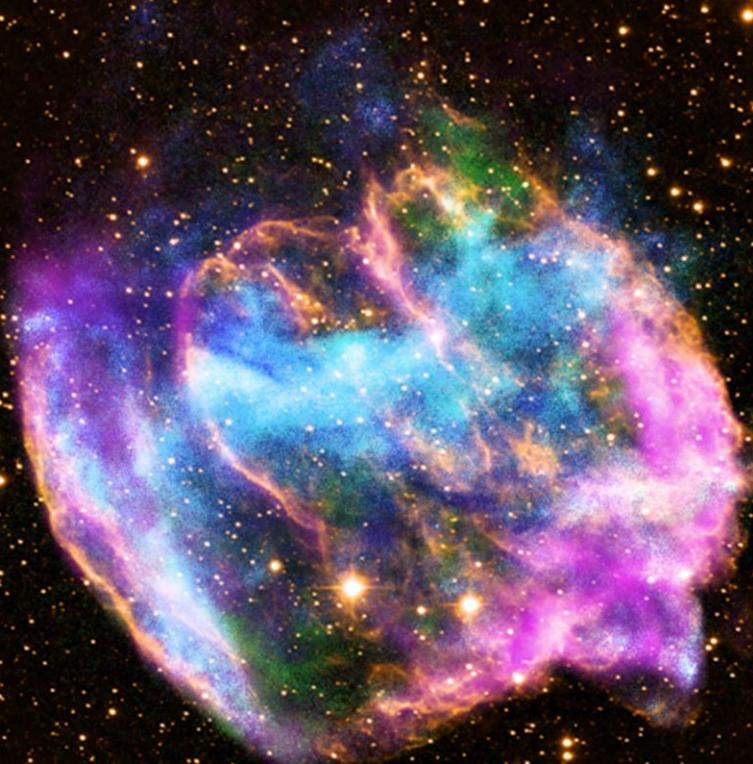
FAIR – Facility for Antiproton and Ion Research



FAIR international facility

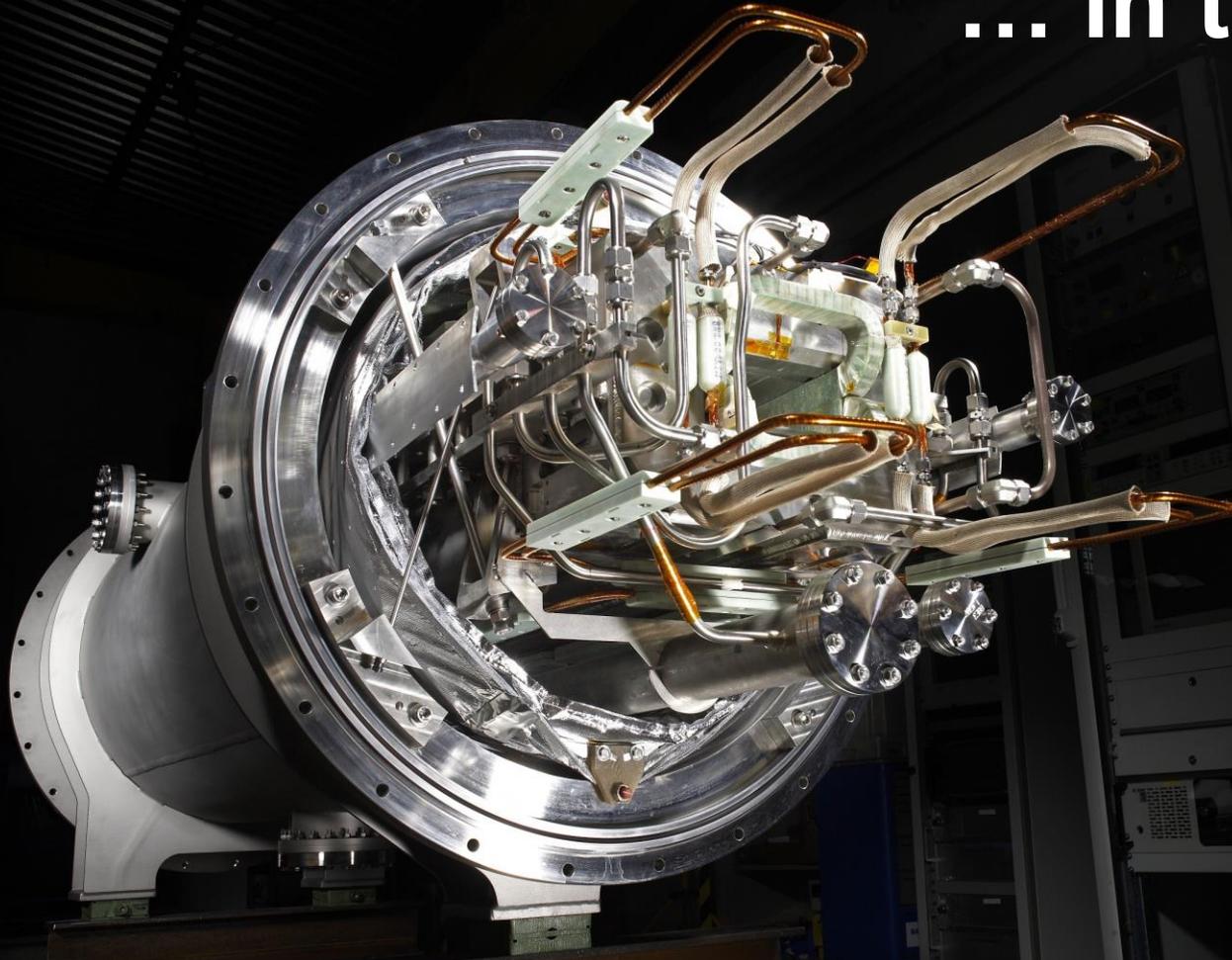
- 9 shareholders
- + 1 associated partner
- + 1 aspirant partner

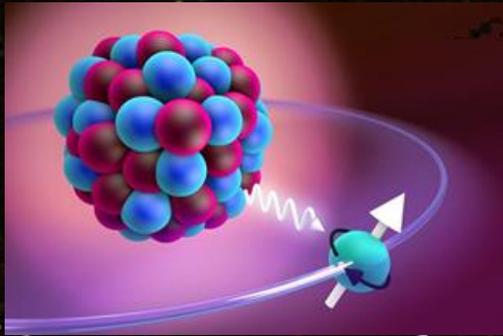


A vibrant, multi-colored nebula, likely the Helix Nebula, is the central focus of the image. It displays a rich palette of colors including purple, blue, cyan, green, and yellow, set against a dark, star-filled background. The nebula's structure is complex, with various filaments and shells of gas and dust.

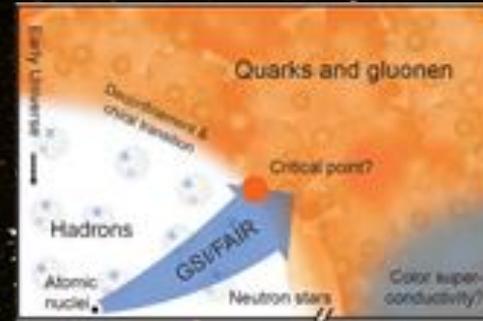
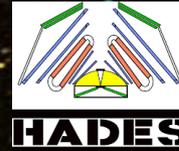
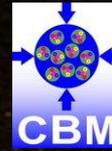
**We explore
the universe...**

... in the lab.

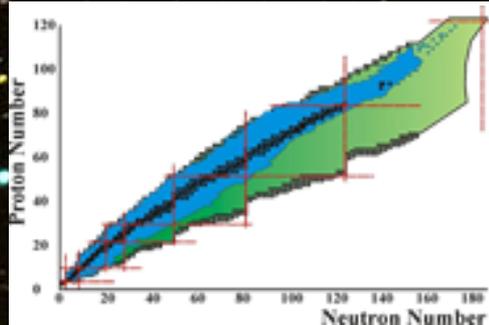




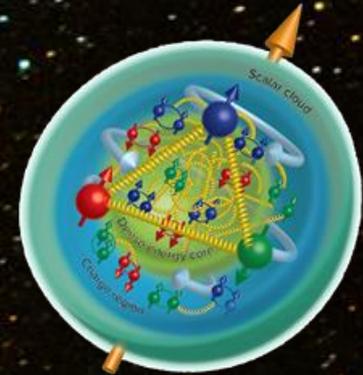
- Precision tests of QED
- Cosmic ray simulator for irradiation studies
- Materials under high pressure



- QCD matter at high baryon densities
- Phase transition and critical point
- Particles in dense medium



- Nucleosynthesis of heavy elements
- Structure of exotic nuclei (e.g. hypernuclei)
- Neutron matter equation of state



- Gluonic excitations: Hybrids, glueballs
- Precision spectroscopy of charmonium states
- Time-like form factors, nucleon structure

Common strategic goals and management

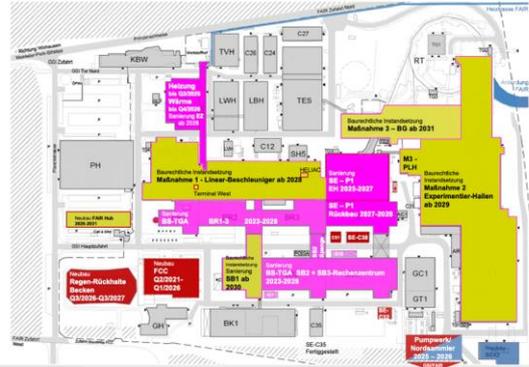
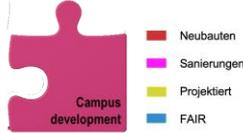


- Con and
- GSI
- P



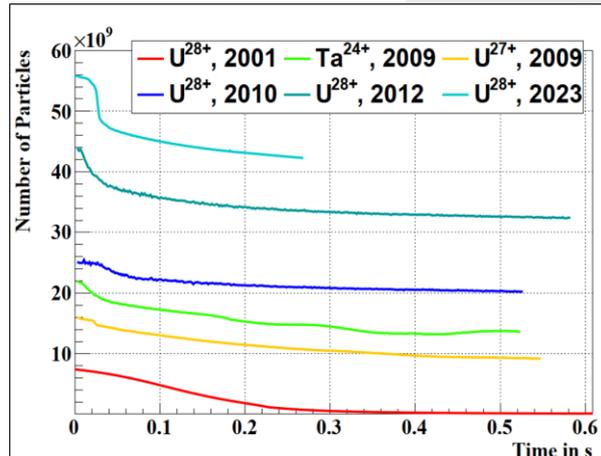
Jörg Blaurock Thomas Nilsson Katharina Stummeyer
Technical Managing Director Scientific Managing Director Administrative Managing Director

Campus Development, e.g. FAIR Control Center (FCC)



- Variety of building activities
- FAIR Control center completion mid 2026
- Taking over of main control room Q4 2025

- SIS18 Booster mode as required for FAIR operation was tested in 2023.



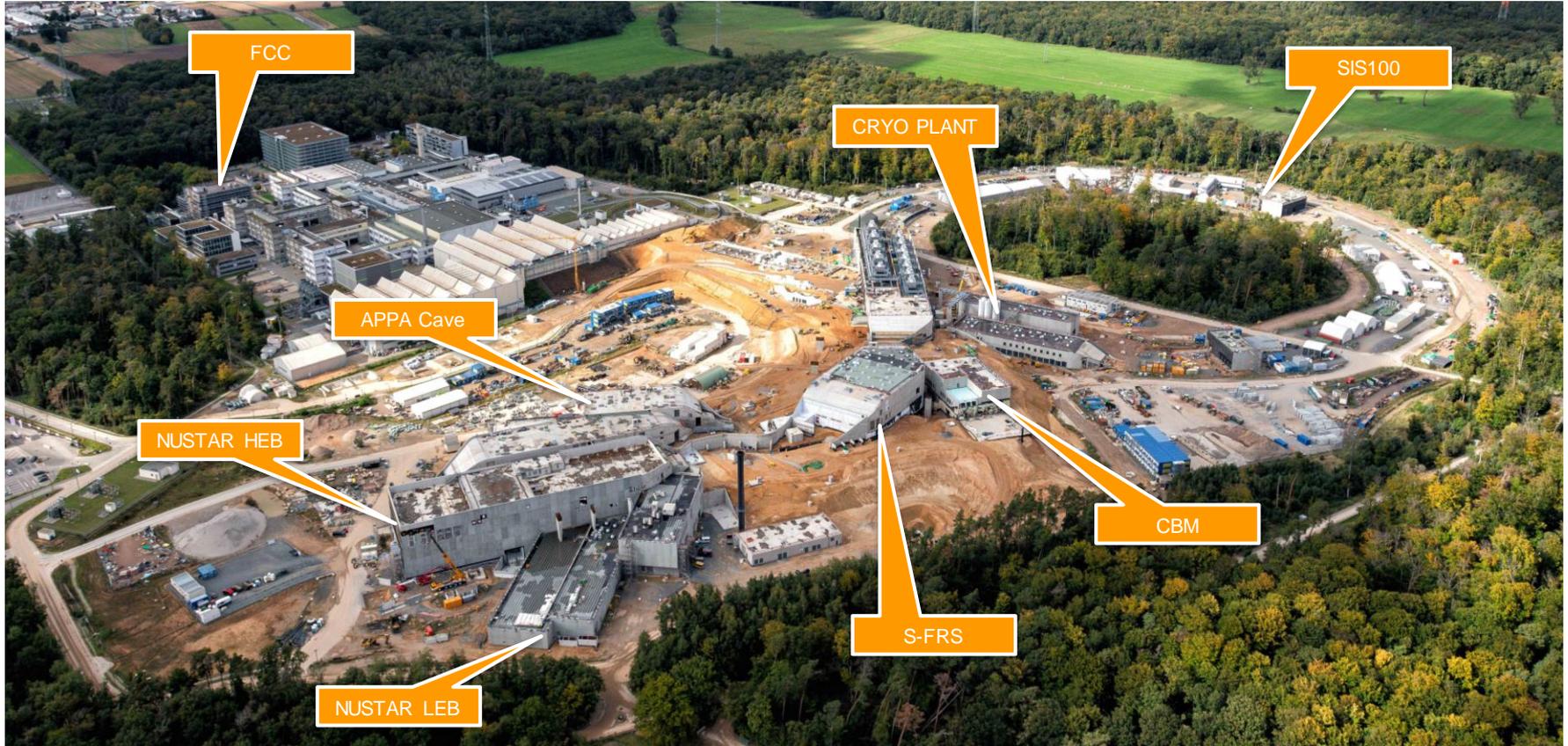
FAIR Project Progress – Civil Construction

- Construction site view

Construction and
commissioning
of FAIR

FAIR

GSII



FAIR Project Progress – Civil Construction

View of south area with all buildings completed and soil modelling in progress



FAIR Project Progress – Civil Construction

View of north area (SIS100) with all buildings completed

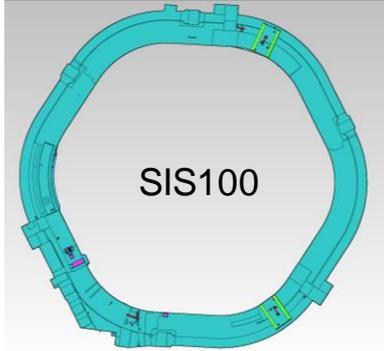


FAIR Project Progress – Civil Construction

- Central Transfer building



SIS100



SIS100
power
supplies



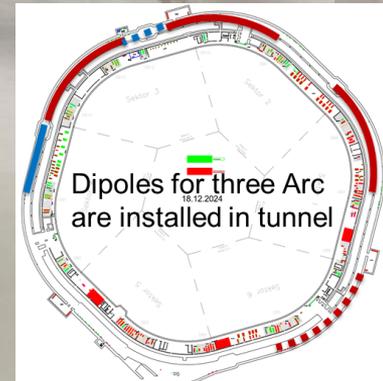
- **Core accelerator of FAIR**, which acts as a feeder for experimental stations (and storage rings)
- Circumference 1,100 m; rigidity: 100 Tm
 - maximum proton energy ~ 29 GeV
 - maximum Uranium U^{92+} ~ 10 GeV/u
- Optimized for intense beams of heavy ions
- Provides slow and fast extraction
- Superconducting fast-ramping dipole magnets



cryo plant

FAIR Project Progress – Accelerator

- Accelerator Installation - SIS100



FAIR Highlights – Super FRS

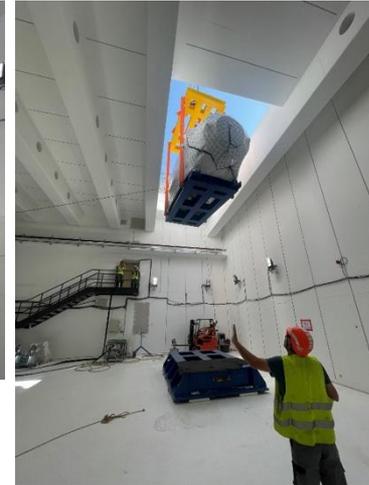
Pre-Assembly SC Magnets



Using a mobile crane to unload a 60-tonne multiplet from a lorry and carefully guiding it into the L0317A hall (Low Energy Cave)



Positioning the multiplet in the L0317A hall using air cushions and a forklift for smooth and accurate placement



Manoeuvring the multiplet through the shaft of the L0317A hall with precision



Aligning the multiplets in rows to begin pre-assembly tasks, with the capacity to arrange up to three lines, each consisting of four to five components, in the L0317A hall

FAIR Project Progress – Accelerator - Accelerator Installation - SFRS

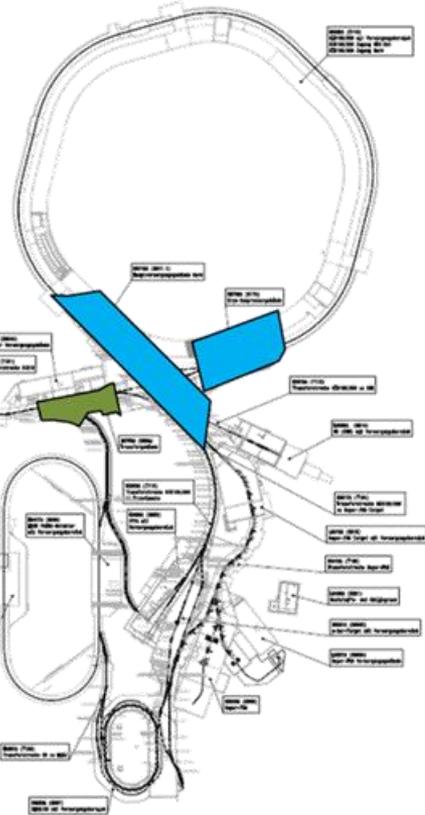
SFRS flask delivered



Super-FRS Branch Box



SFRS – Transport of T-Branch and
Multiplets to PreTarget Area



- **Q3 2025: Start of commissioning of cryo-plant and cooling water system**
- **Q4 2025: Initial steps for HEBT commissioning**
- **Q4 2025: Takeover of main control room in FAIR Control Centre (FCC)**
- Gradual ramp-up of all activities



View to the future : SIS100



Progress on detectors and installations

I. Keshelashvili, Monday

1st User Experiment at HITRAP



APPA

@HITRAP

6keV/u Au⁷⁹⁺

$E_{\text{kin}} \sim 1.2\text{MeV}$

$E_{\text{pot}} \sim 440\text{keV}$

7 samples

1-, 2-, 3-layer graphene (on SiC)

bulk CaF₂

MoS₂ on Au

MoS₂ on SiO₂

WS₂ on SiO₂

Microscopy nanostructures on surfaces?

CaF₂, PRL 2015

characterisation of samples shared between TU Wien and Uni Duisburg

(Very) Preliminary Data

ion impacts?

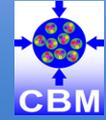
Atomic Force Microscopy:



Series production

- STS modules/ladders
- TOF MRPC counters
- RICH cameras

CBM



Effort to best use the part of FAIR which will be available by 2028

NUSTAR

fission measurement, published in Nature (2025)

Number of protons

Number of neutrons, N

lifetime measurement with AIDA

$T_{1/2} = 49.7 (47) \text{ ms}$

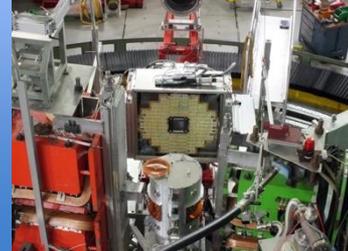
Isomer in $^{184}\text{Pt}^{78+}$

$T_{1/2} \sim 1 \text{ ms}$

Asymmetry, A



EMC Backw. Endcap at MAM



PANDA

Forward Tracker at JU Krakow



FAIR Project Progress – Experimental Caves

- Crane and platform available
- Access roads built
- Magnet foundation poured
- Magnet holding structure accepted



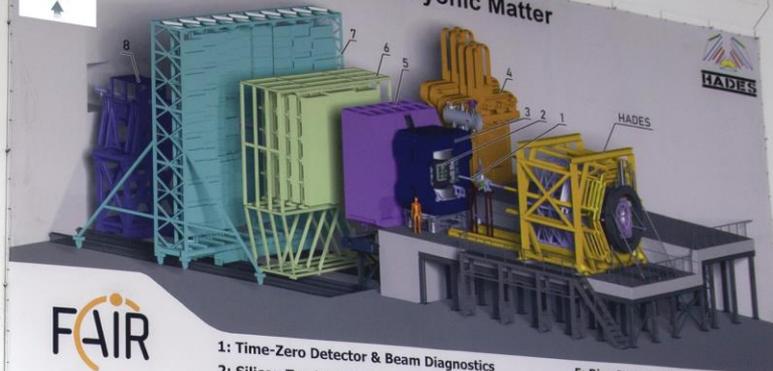
Example: CBM cave

45. CBM Collaboration Meeting

GSI, Darmstadt 16-21 February 2025



Compressed Baryonic Matter



FAIR
GSI

- 1: Time-Zero Detector & Beam Diagnostics
- 2: Silicon Tracking System / Micro Vertex Detector
- 3: Superconducting Dipole Magnet
- 4: Muon Chambers
- 5: Ring Imaging Cherenkov Detector
- 6: Transition Radiation Detector
- 7: Time of Flight Detector
- 8: Forward Spectator Detector

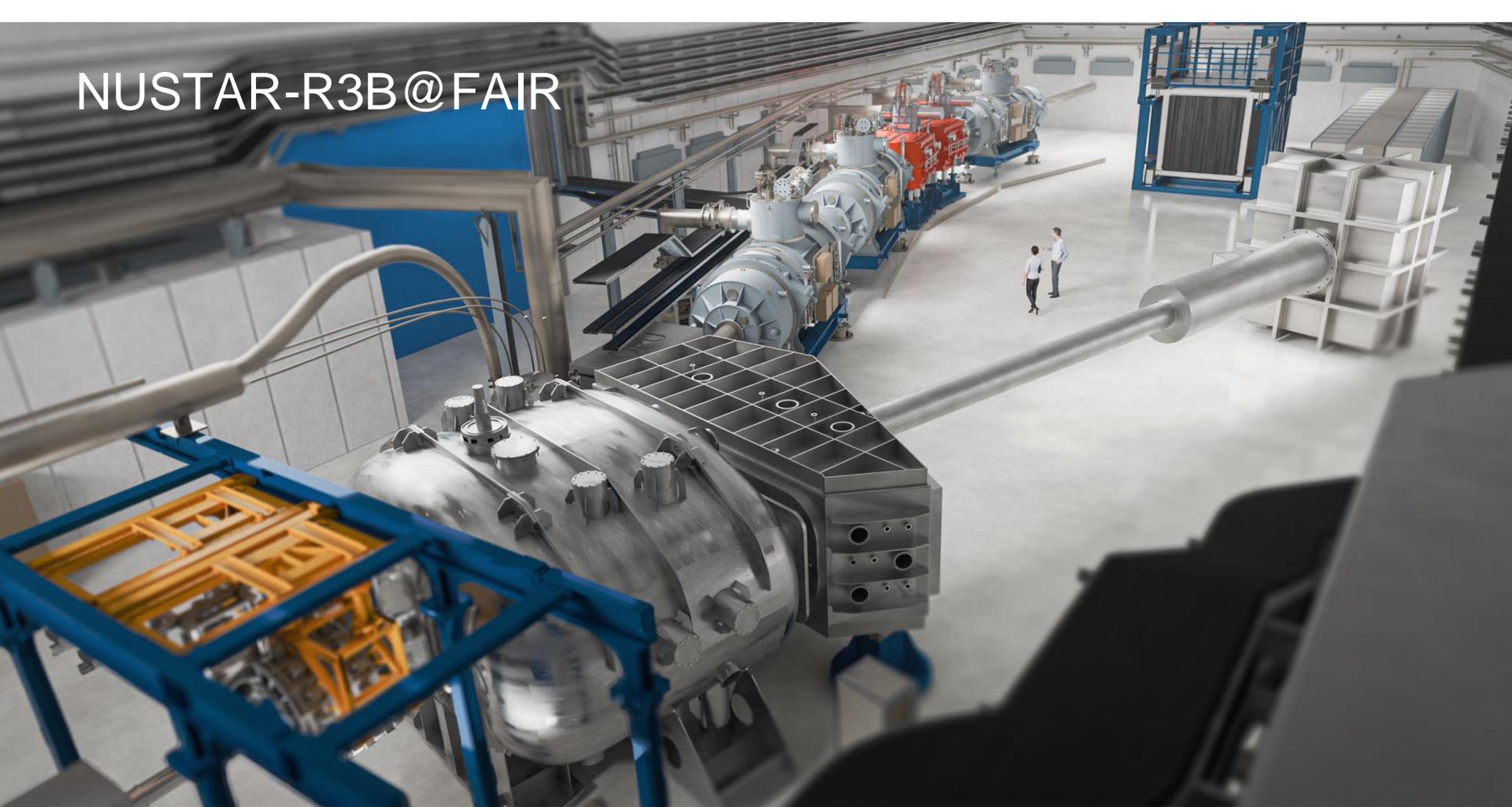


CBM final setup including HADES



D. Dobrigkeit Chinellato, Thursday Plenary 6

NUSTAR-R3B@FAIR



Experiments 2025

65
Experiments in 2025

Acceleration of **11** elements

FAIR GSI

FAIR Phase 0
research
programme

Experiment Time

127 Days
Accelerator operation

Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec

~9450 USER HOURS

Facility	Percentage
UNILAC	41,5%
SIS18	40,9%
ESR	8,2%
CRYRING	8,4%
HITRAP	1,0%

ACCELERATOR FACILITIES

FAIR GSI

People

~2000
SCIENTISTS

From ~50 countries

							>30 countries 10,2%
42,1%	6,1%	5,5%	5,3%	4,8%	4,5%	3,8%	
3,8%	3,6%	3,0%	2,5%	1,9%	1,6%	1,3%	

FAIR GSI

Fun Facts

Accelerated material vs 1 grain of sand

0,18 mg

Distance traveled **$5,616 \cdot 10^{20}$ km**

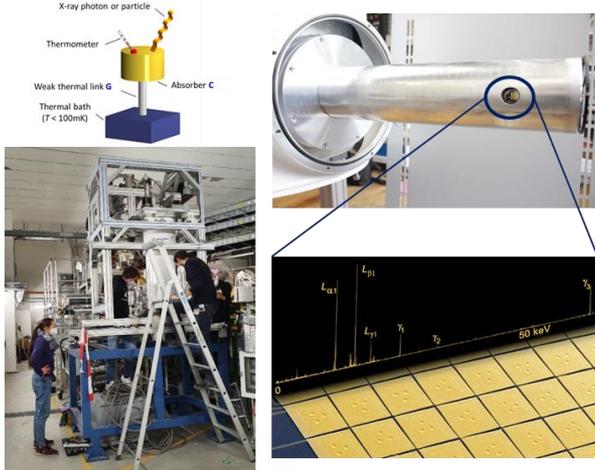
To the center of the Milky Way Galaxy and back!

FAIR GSI

Some highlights

... QED in Strong Electromagnetic Fields

Metallic Magnetic Microcalorimeter (MMC) Detectors

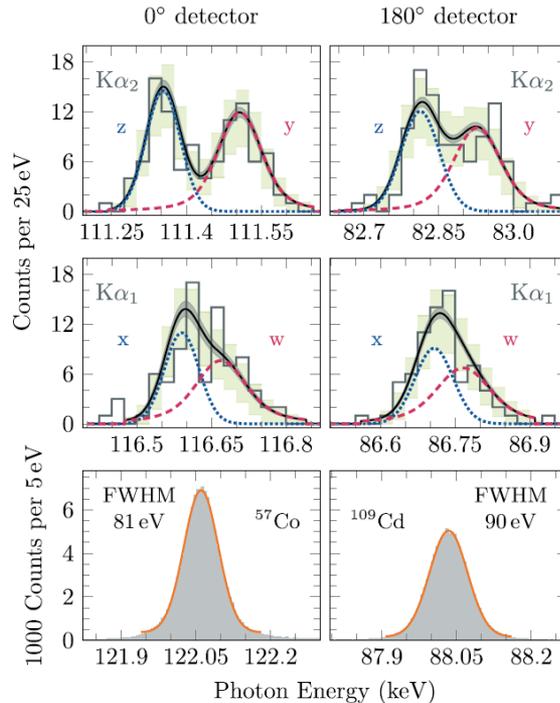


➔ Combination of high spectral resolution and broad bandwidth acceptance offers unique possibilities.



Substate Resolved $K\alpha$ Transition Energies in Helium like Uranium

HI JENA
Helmholtz Institute Jena



First well-resolved $K\alpha$ spectra recorded for a high-Z system.

Spectral resolution of $\Delta E < 100$ eV FWHM @ 100 keV was achieved

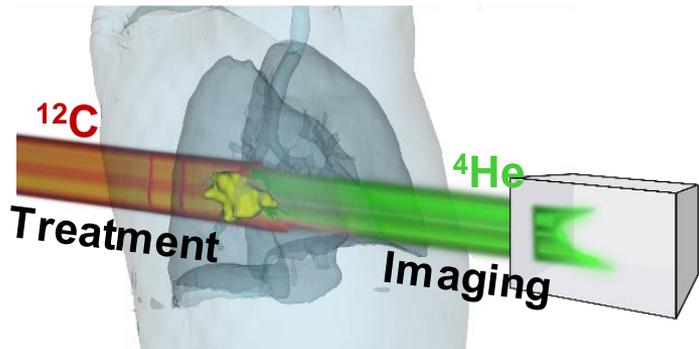
First exploitation of microcalorimeter timing capabilities with $\Delta t_{\text{FWHM}} < 400$ ns.

- ✓ insensitive to geometric misalignments
- ✓ combining 0° and 180° provides unique redundancy
- ✓ coincidences between x-rays and down-charged ions

Some highlights

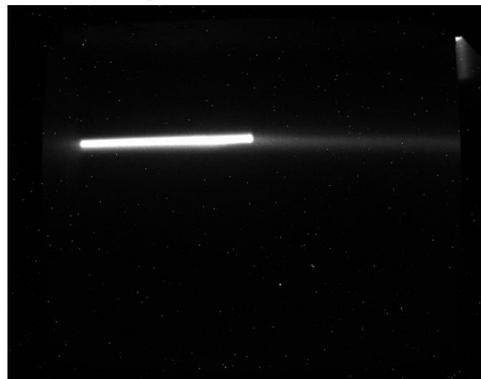
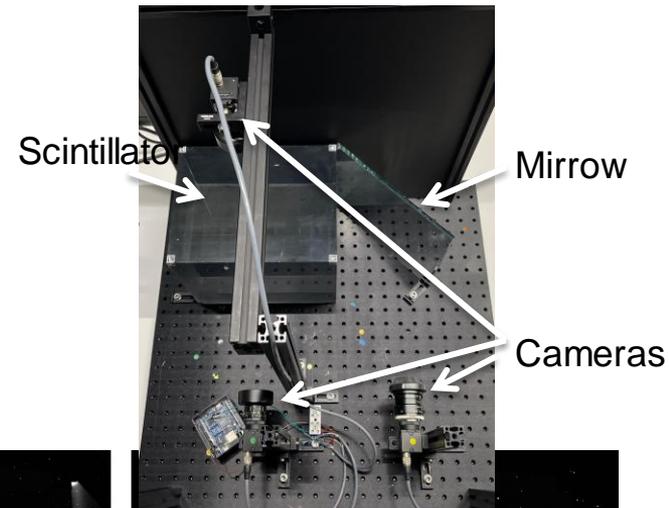
... Imaging with mixed C- and He beams

C- and He ions simultaneously accelerated



May 2025 –
First images
with a
scintillator-
camera system
(UCL)

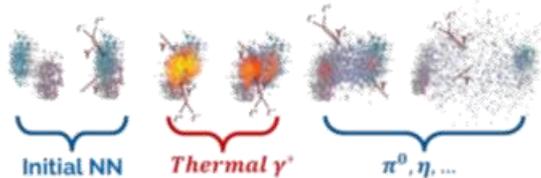
Carbon beam stopped
with rangeshifter



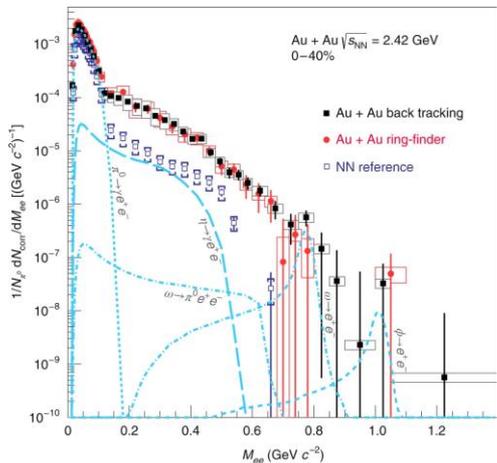
Experiment will continue
at GSI till 2029 and then could
be implemented at CNAO or
MedAustron(ERC Christian
Graeff)

Some highlights

... Accessing dense matter with dileptons at HADES

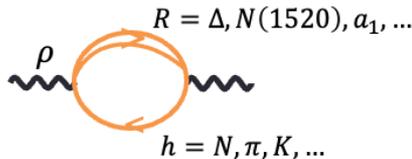


Measured signal is integral over whole evolution



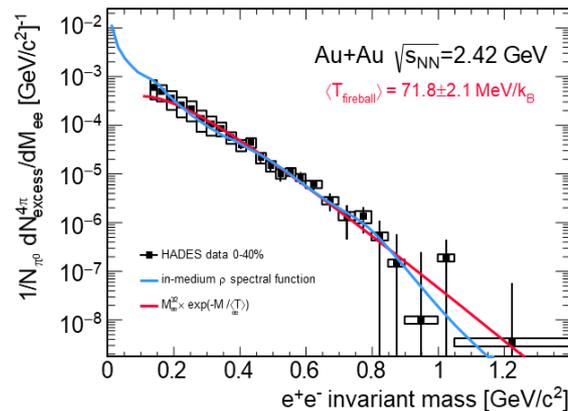
HADES, Nature Phys. 15, 1040-1045 (2019)

- radiation explained by medium modified vector mesons (VMD, „radiation of the cloud“)



Rapp, van Hees; arXiv:1411.4612v

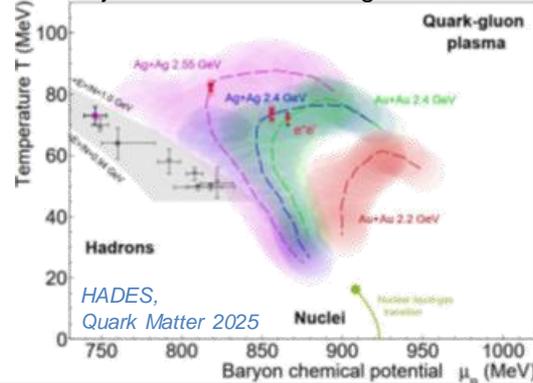
- spectral distribution reproduced by a fit assuming thermal radiation
- significantly higher temperatures at higher beam energies
- no indication of ρ -meson at lower beam energies
- spectral distribution provides information on
 - ρ - a_1 mixing (chiral symmetry restorator)
 - caloric curve



HADES, Nature Phys. 15, 1040-1045 (2019)

→ isolate thermal contribution

Trajectories from coarse grained UrQMD



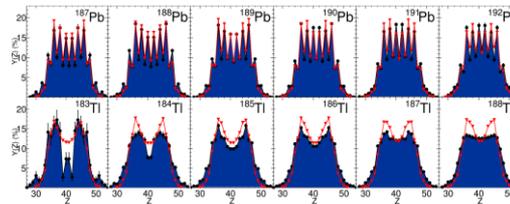
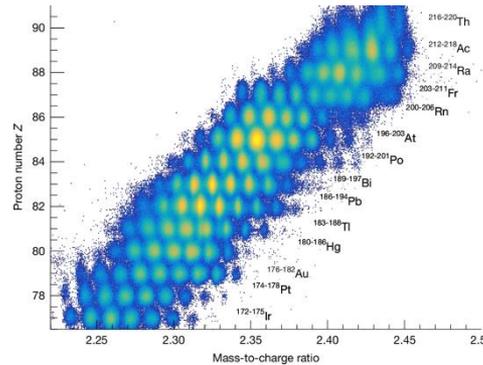
HADES, Quark Matter 2025

Some highlights

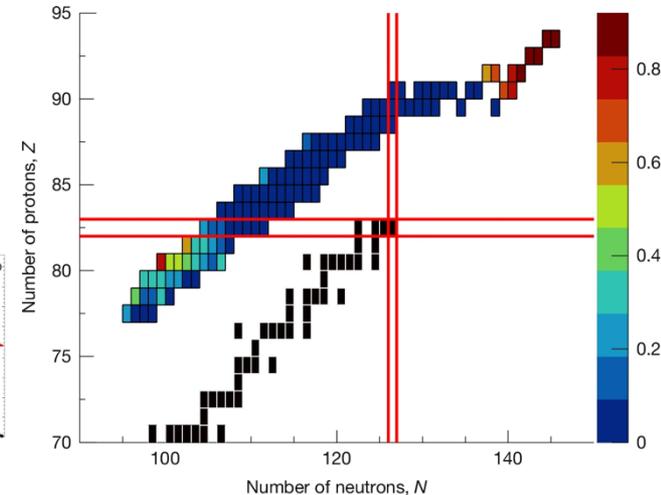
... New island of asymmetric fission

Fission of exotic nuclei

- Important in r-process nucleosynthesis: fragment distributions + fission barriers
- Experiment: Charge distributions for 100 neutron-deficient isotopes produced in Coulomb fission
- **New asymmetric fission island in the sub-lead region discovered**



Map of evolution of asymmetric fission



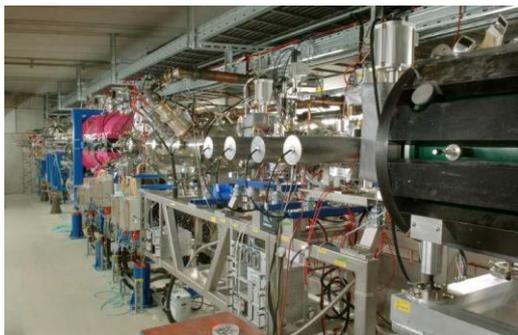
First Science at R³B

- (p,2p) induced fission enables measurement of excitation energy (-> fission barriers)
- Charge- and mass-distributions + fission barriers towards r-process nuclei

P. Morfouace, Nature doi:10.1038/s41586-025-08882-7 (2025)

HITRAP: First Experiment with Decelerated Bare Ions at High-Z

Beamtime 2025: Nanostructuring of monolayer graphene using slow heavy ions at high charge states (G-22-00057)



A. Niggas
S. Spannagl

F. Aumayr
R.A. Wilhelm

G-22-00057
M-22-00146

C. Frank
C. Böttger

L. Breuer
M. Schleberger



@HITRAP

6keV/u Au⁷⁹⁺

$E_{kin} \sim 1.2\text{MeV}$

$E_{pot} \sim 440\text{keV}$



7 samples

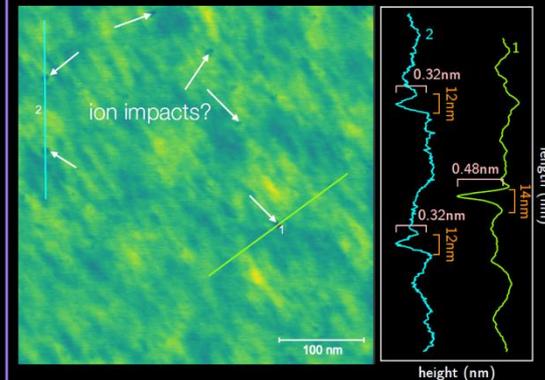
- 1-, 2-, 3-layer graphene (on SiC)
- bulk CaF₂
- MoS₂ on Au
- MoS₂ on SiO₂
- WS₂ on SiO₂

Microscopy nanostructures on surfaces?



characterisation of samples shared between TU Wien and Uni Duisburg

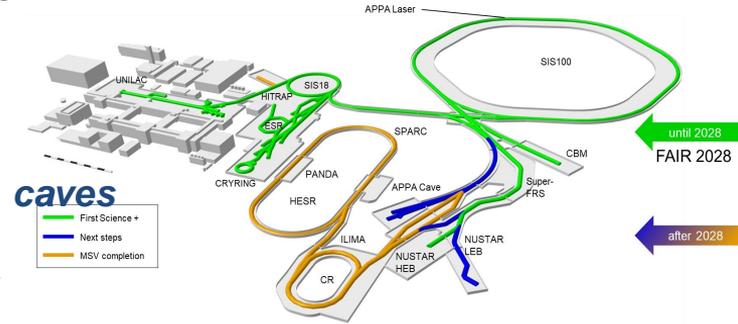
(Very) Preliminary Data



Atomic Force Microscopy: MoS₂ on SiO₂

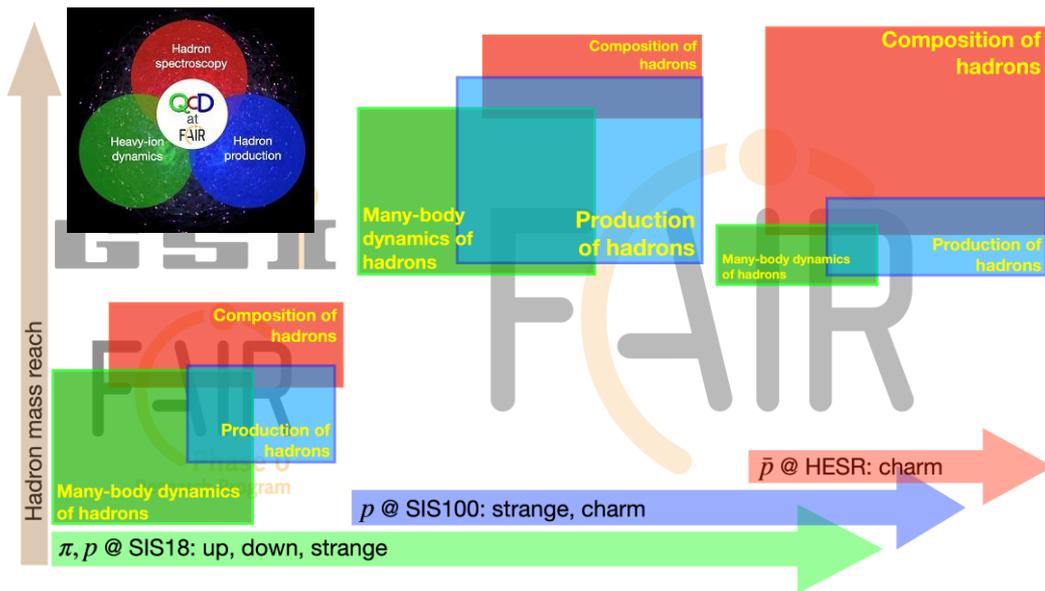
Our vision for the future: FAIR 2028

- FAIR in 2028 will feature the most valuable science program which can be hosted in the FS+ infrastructure.
- The "FAIR 2028" science program will include:
 - APPA experiments *at the low-energy rings, at SIS100*, at the *caves* *at SIS18 and UNILAC* with and at *PHELIX* and a limited set of experiments which could be hosted at all the *caves served by SIS100*
 - NUSTAR at the *Super FRS with SIS100 beams*, plus *SHE and MATS experiments at UNILAC* and *ILIMA at the low-energy rings*
 - CBM at the *new cave with SIS100 beams*, and *HADES at SIS18*
 - PANDA is developing a hadron physics program to be carried as bridge towards the program with antiprotons, when possible *using the caves and beams available at GSI/FAIR* and synergies with other experiments.



Pion- and proton-induced QCD studies at GSI/FAIR

Hadron physics with CBM, HADES, and NUSTAR



Hadron Physics at GSI and FAIR: Prospects for the Next Decade

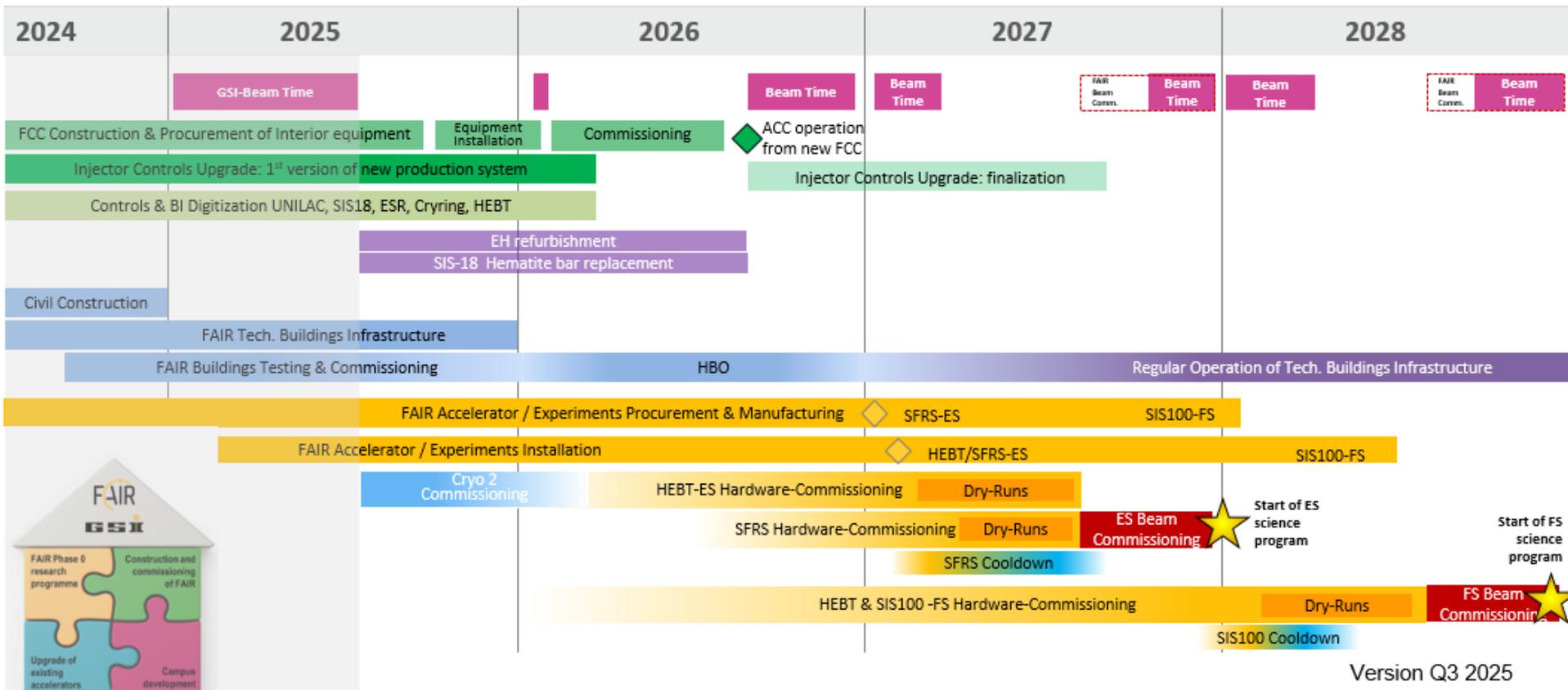
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Roadmap

- Versatile program during the various phases of FAIR
- FAIR Phase0: pions/protons at HADES@SIS18
 - FS+: protons at CBM@SIS100
 - ...towards antiprotons at HESR

FAIR & GSI Integrated Schedule



Version Q3 2025

- Several programmes set up to enhance mobility, e.g.:
 - FAIR Fellow and Associate Programme
fair-center.eu/career/fair-fellow-and-associate-program
for mid-career and senior scientists, respectively
Call with deadline: 15 Oct
 - GET_INvolved Programme for international students
fair-center.eu/career/get_involved



[Overview on FAIR](#) | [Studies & Career](#) | [Press](#) | [About us](#) |

Path: »Studies & Career

Career

Job Offers

[FAIR Fellow and Associate Program](#)

[GET_INvolved Programme](#)

[Studying Opportunities](#)

[Ausbildungsberufe \(Apprenticeship\)](#)

[Betriebspraktika \(Internship\)](#)

[Working at FAIR and GSI](#)

FAIR Fellow and Associate Program





Thank you for your attention!