

FAIR Satus

1st Workshop on Polarized Beam and Target -Physics and Applications (PBT2024), Huizhou, February 26-28

Paolo Giubellino

A special moment for Nuclear Physics





- But also "Nuclear Physics in Everyday Life"... space, energy, medicine...
- https://www.nupecc.org/pub/np_life_web.pdf

GSI: a historic lab, over 50 years old









Discovery of new elements:

- In total, six new chemical elements added to the periodic table
- Investigation of the physical and chemical properties of superheavy elements

Tumor therapy with carbon ions:

- Precise, gentle and susscessful: more than 90% cure rate
- Treatment of 440 patients at GSI
- Transfer to clinical application, among others in Heidelberg and Marburg
- At GSI: Research and further development

FAIR: Facility for Antiproton and Ion Research





FAIR: A World Lab





- 9 international FAIR Shareholders
- 1 Associated Partner (United Kingdom)
- 1 Aspirant Partner Czech Republic (Since 2018)
- Participation of **3.000 scientists from all continents**

Creating extreme conditions existing in the universe with heavy ion accelerators

To find answers to fundamental questions about the Universe : The universe in the lab ...



FAIR

GSI





How do materials behave under high pressure?



How are complex molecules created?



... with direct applications



High-performance and scientific computing, big data, green IT

Space radiation protection, unique facility fo simulation, collaboration with ESA



Development of nuclear clock: Promising candidate thorium-229 Novel applications for tumor and non-tumor diseases

The FAIR science: four pillars





atomic physics, biophysics, plasma physics, material research

APPA

nuclear- and quark-matter

CBM



nuclear structure and nuclear astrophysics

NuSTAR



hadron structure and dynamics



FAIR Construction





FAIR Highlights- Civil Construction Construction Area North





FAIR Highlights- Civil Construction Construction Area South





FAIR Highlights - Civil Construction Construction Area South





FAIR Highlights - Civil Construction

First 2 air coolers installed on the building H0719A





Civil Construction





Movie via <u>fair-center.eu</u> or https://www.youtube.com/watch?v=AfeGI4JkQIE

Accelerators: delivery of components continues steadily









FAIR construction highlights



<u>Q4-2023</u>

Start of cable pulling work



FAIR construction highlights



September 2023

String Test SIS100 – pressure test successfully passed and cold test in progress.





September 2023

Linde Cryo facility assembly work is finished. Start of Commissioning in 2025.

FAIR construction highlights



Januar 2024

Start Montage

First SIS100 Power Supply Units (PSU) installed in the

SIS100 Tunnel



Status of FAIR Accelerators



Start of installation at four locations in 2024



Experiment Construction





FAIR 2028



2023



FAIR STORAGE RINGS



2023



Ongoing: Early science program FAIR Phase-0





Science while commissioning FAIR

- 2021 and 2022 runs completed as planned
- The program will continue in the coming years
- Up to 2025 we continue with FAIR Phase-0, from 2026 onwards we enter the mixedmode with the commissioning of the new beamlines

Beamtime proposals 2022

- 124 proposals submitted (to all 4 PACs: G-PAC, Mat-PAC, Bio-PAC and PPAC)
- 1729 participants of proposals
- From institutes in 45 countries (15% internal users)
- Committee evaluation took
 place in September 2022
- Beamtime granted in October 2022





FAIR/GSI strategic operation scenario towards FS+





NUSTAR: DESPEC set-ups prepared for Phase-0 and ready for ES/FS





DESPEC High-resolution set-up with novel DEGAS Ge detectors



DESPEC High-efficiency set-up with the DTAS Total Absorption Spectrometer



NUSTAR: R3B set-ups prepared for Phase-0 ready for ES/FSFAR II III

er NNPC NUS **R**³B experimental setup for complete kinematics measurements Beam of ²³⁸U at 560A MeV NeuLand Si-tracker MUSIC start Ш LH. Fragments Protons 14⁰ CALIFA CALorimeter for In-Flight detection of y-rays MNPC Nall and high energy charged pArticles Magnetic field: 4 T • CALIFA and Si-tracker: Proton momenta and γ -rays Energy res. protons(gamma) 1%(5% at 1 MeV), Position res. 70µm MUSIC, ToF wall and MWPC detectors: Fission fragments ΔZ~0.37, ToF~40ps, Position res. 200µm (FWHM) NeuLand: Neutron multiplicities (max. 10 neutrons)

Experiment Installations and Testing at CRYRING





✓ Installation in ring of the forward part.
 ✓ Ready for first experiments.



- ✓ The upper part is installed in the ring and ready backing and vacuum test.
- System installed and ready for experiments.

Gas-Jet target



- ✓ Two successful experiment beam on N₂ and He.
- ✓ Target areal densities of u at target width of ∆x = 1 m

CBM in Phase-0: mCBM

- During the last campaign, mCBM was successfully tested with the highest collision rates available in FAIR Phase-0
- Customised chain of electronics to process and transfer the data of all subsystems to the final data processing proven its capability

with the highest







mCBM: Data analysis in progress





data-driven detector alignment







FAIR: Unique Opportunities . . . & Challenges



Upgrade with new PRIOR magnets

Example: PRIOR II, Proton Microscope

complete

Proton radiography

- Commissioning in February 2021
- Achieved resolutions
 - spatial 20 µm
 - in time 10 ns







Chemical properties of element 114, Flerovium



- Flerovium: heaviest element with experimentally studied chemical properties
- Eight registered atoms in three beamtimes of total 2.5 months duration



Ground-breaking experiment opening way for nuclear astrophysics experiments at FAIR with ESR

- E127: Proton-capture rates for nuclear astrophysics:
 First reaction study on stored radiobeam at low energies
- Study of radioactive ¹¹⁸Te (6 days half-life)
 - production, storage, accumulation and deceleration in FRS-ESR
 - proton-capture measurements realized at 7 MeV/u and 6 MeV/u
- New background-free detection method demonstrated



Jan Glorius et al. 🖬 🎫 🏛 🧧

Research highlight FLASH radiotherapy

- FLASH Radiotherapy, is a novel approach of RT using ultra-high dose rate aiming to get unchanged tumor control protection (TCP) and decreased normal tissue complication probability (NTCP).
- GSI has demonstrated for the first time that the FLASH effect can be obtained with accelerated carbon ions (18 Gy in one spill of 150 ms) paving the way to clinical translation in particle therapy
- The paper made the cover of the prestiogious Nature Reviews Clinical Oncology



December 2022 volume 19 no. 12 www.nature.com/nrclinonc

nature reviews clinical oncology



Materials Research 3d, highly interconnected nanowire networks FAR E =





Spares



Why FAIR? (... just SOME of the questions)



FAIR GmbH | GSI GmbH

FAIR ES

Neutron star mergers and their role for the production of heavy elements





Electromagnetic afterglow - "Kilonova-lightcurve" - reveals that heavy elements, e.g. Au and Pt, were produced (r-process as predicted by GSI theorists.

Neutron Stars and Mergers vs HI collisions





Neutron stars

Temperature T < 10 MeV

Density $\rho < 10 \rho_0$ Lifetime T ~ infinity



Neutron star merger

Temperature T < 50 MeV

Density $\rho < 2 - 6 \rho_0$

Reaction time (GW170817) T ~ 10 ms

Heavy ion collisions at SIS100



Compressed Baryonic Matter

Temperature T < 120 MeV

Density ρ < 8ρ₀

Reaction time $t \sim 10^{-23} s$