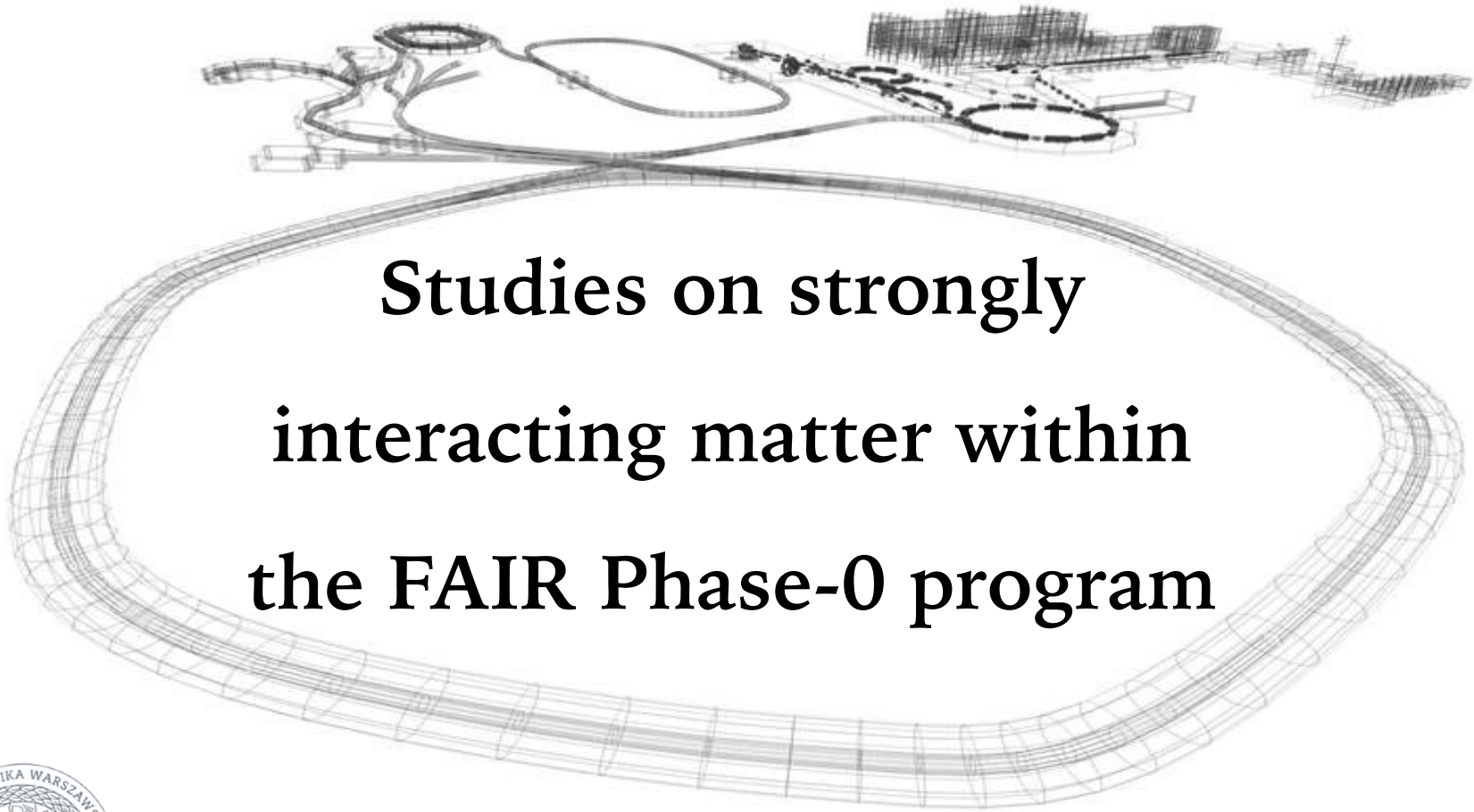


Studies on strongly interacting matter within the FAIR Phase-0 program

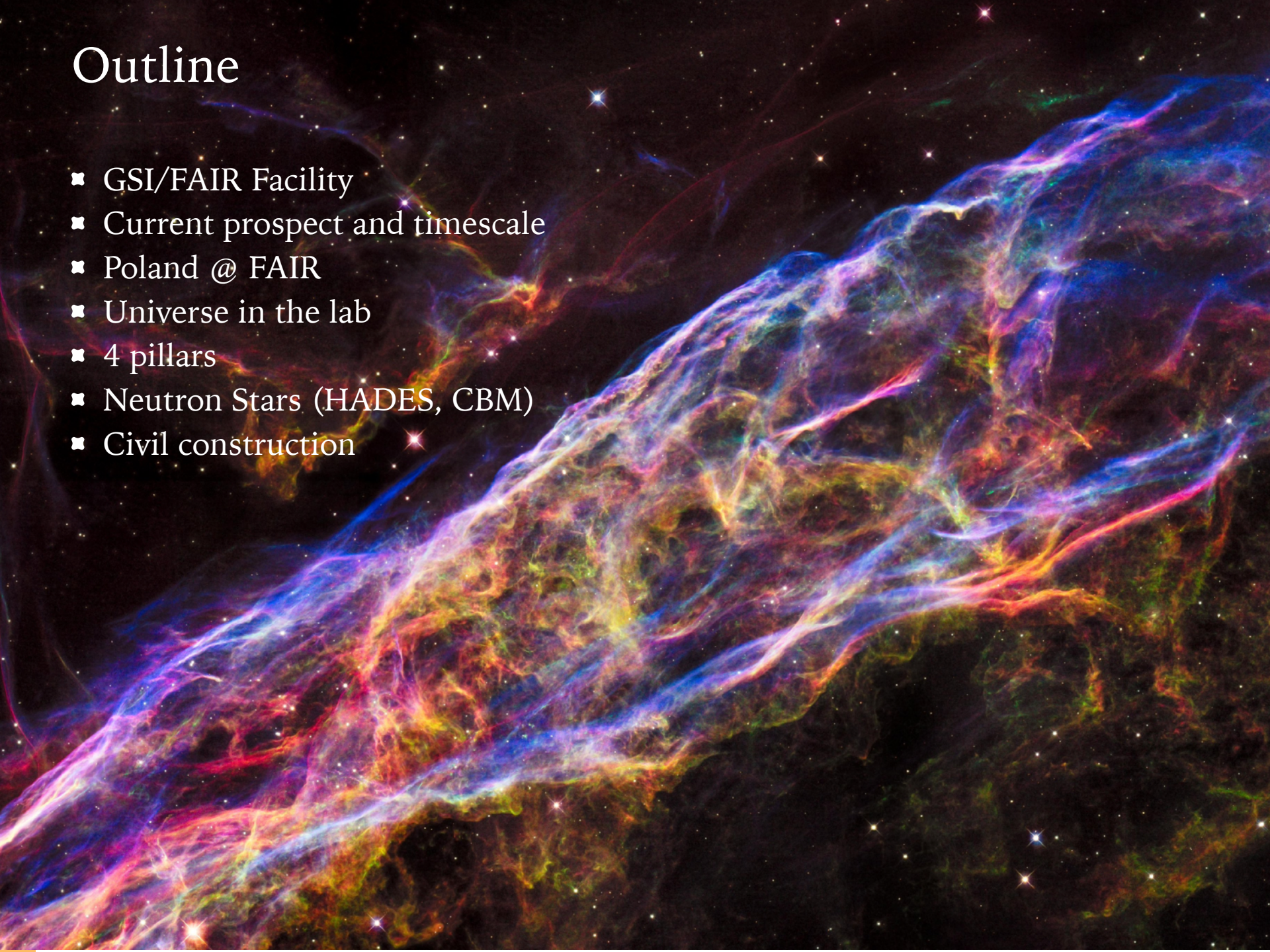
Hanna Zbroszczyk (WUT)

XVI Polish Workshop on Relativistic Heavy-Ion Collisions

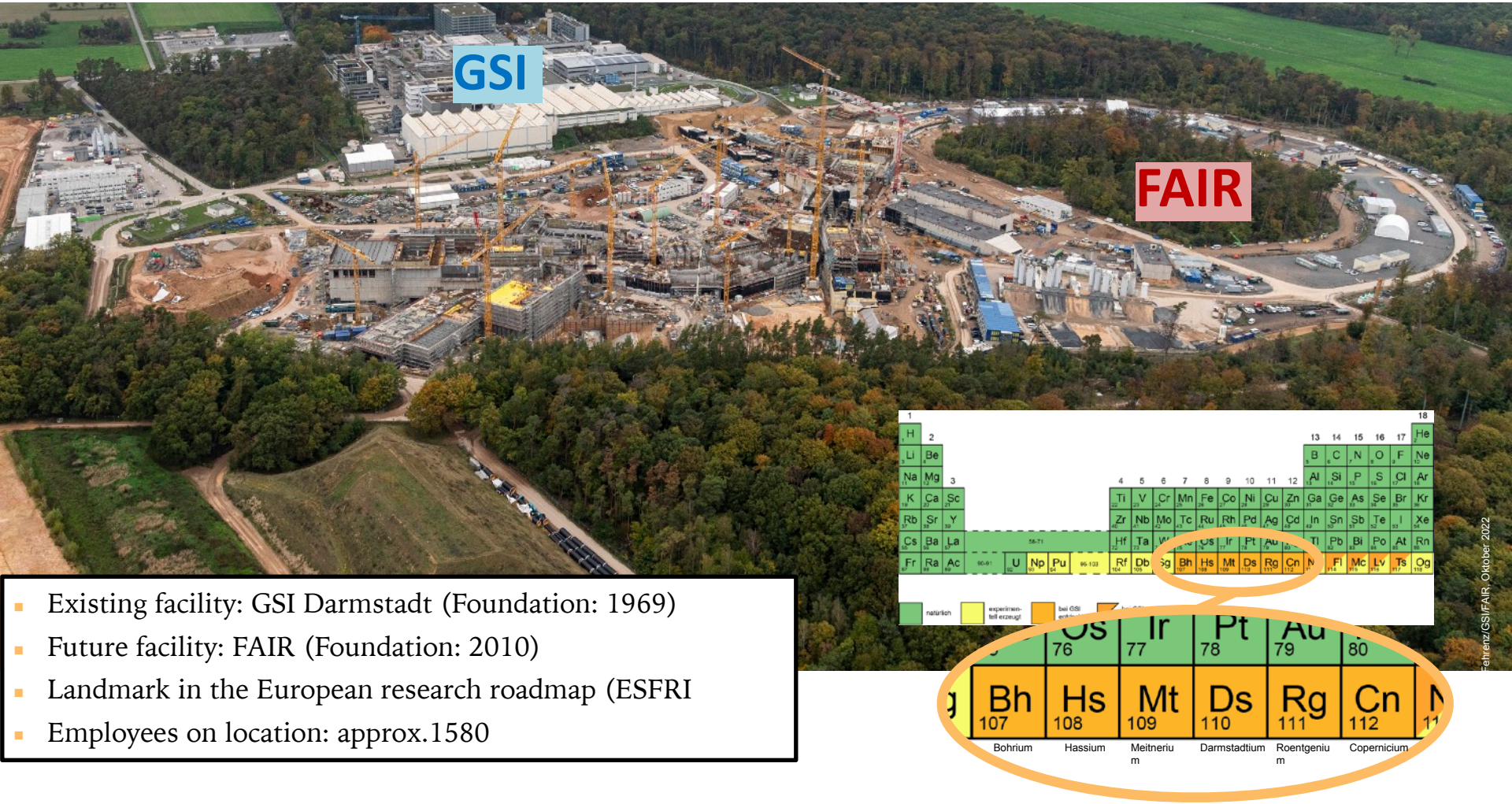
December 3rd, 2023

Outline

- GSI/FAIR Facility
- Current prospect and timescale
- Poland @ FAIR
- Universe in the lab
- 4 pillars
- Neutron Stars (HADES, CBM)
- Civil construction

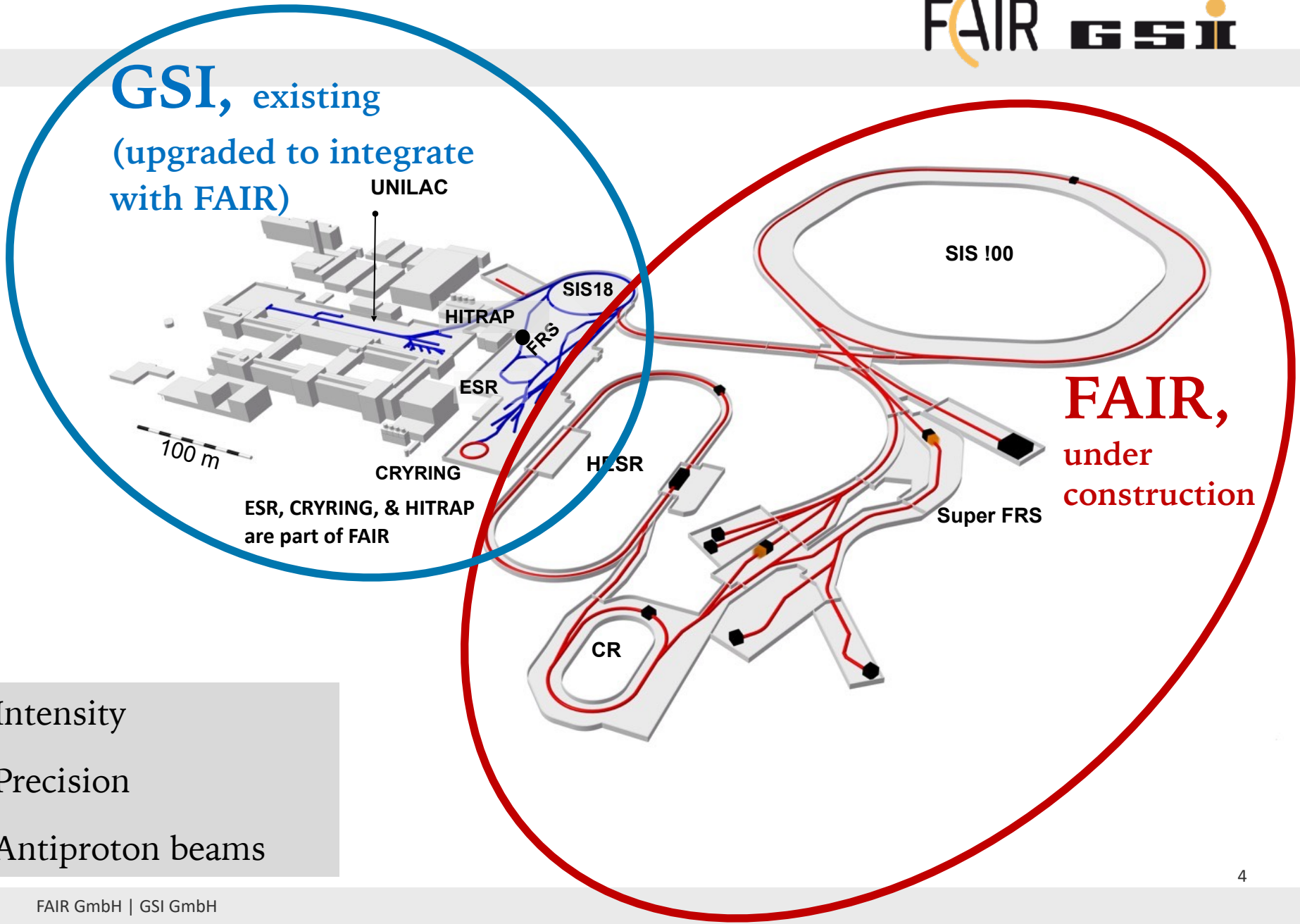


GSI GmbH – Helmholtzzentrum für Schwerionenforschung
FAIR GmbH – Facility for Antiproton and Ion Research



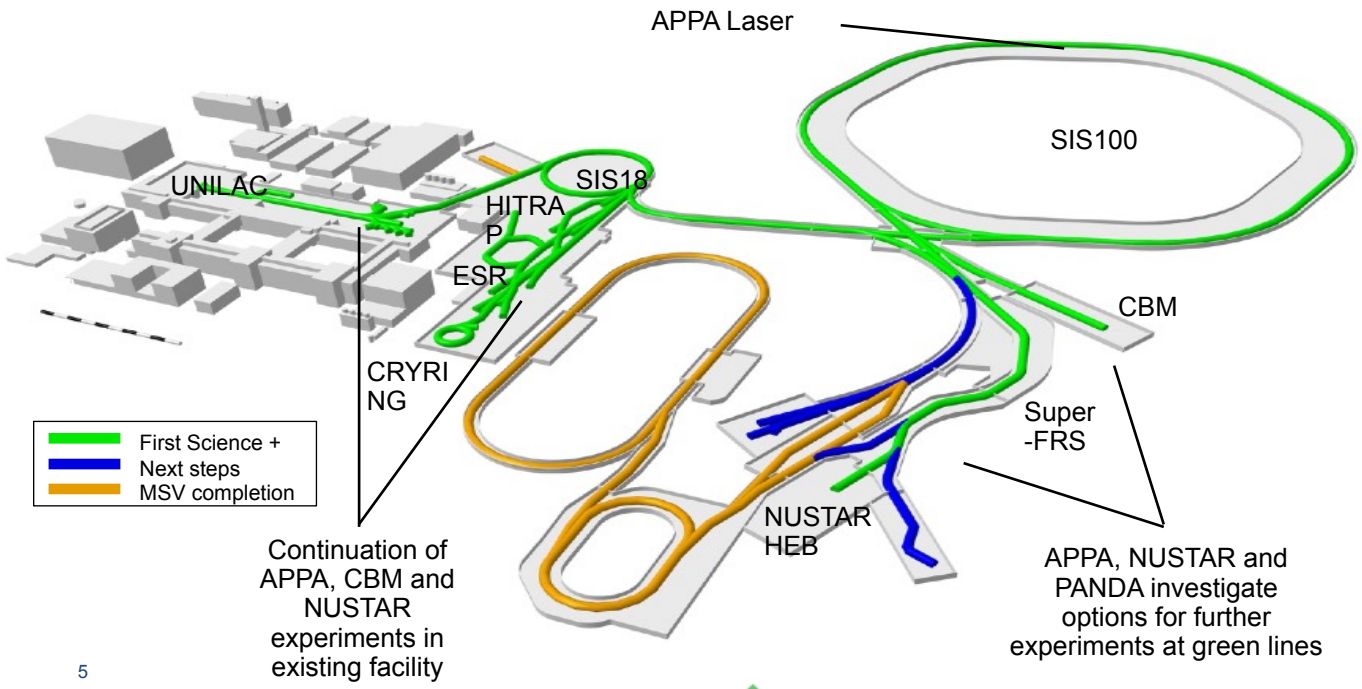
- Existing facility: GSI Darmstadt (Foundation: 1969)
- Future facility: FAIR (Foundation: 2010)
- Landmark in the European research roadmap (ESFRI
- Employees on location: approx.1580

GSI and FAIR – The Facility



- Intensity
- Precision
- Antiproton beams

Current prospects and timeline



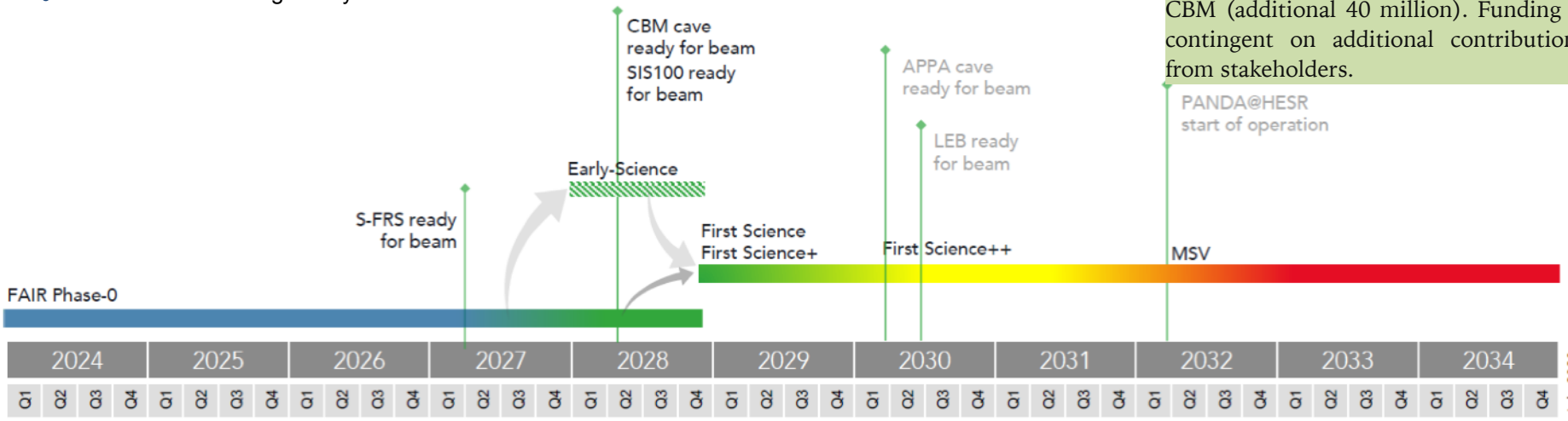
until 2028

FAIR Phase-0

after 2028

Staged implementation recommended by the Heuer/Tribble Commission's report (2022) with the First Science stage endorsed by the FAIR Council as "the most appropriate starting scenario to achieve world-leading science."

A budget of 2.8 billion Euros is available (including a new contribution of 0.58 billion from Germany), enabling the implementation of First Science without CBM (additional 40 million). Funding is contingent on additional contributions from stakeholders.

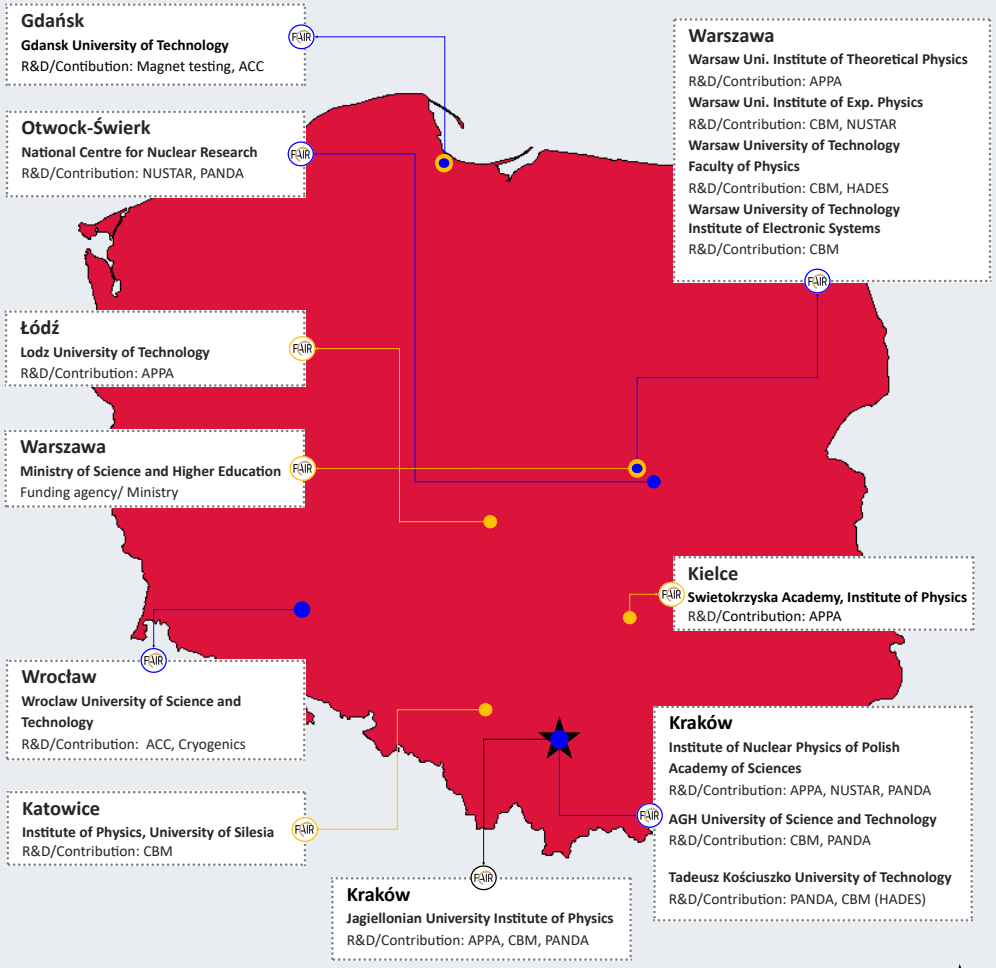


Poland @ FAIR

- FAIR governed by international convention
  - 9 shareholders:
  - + 1 associated partner:
  - + 1 aspirant partner:
  - Over 3000 Scientists and Engineers from all over the world
- Scientists from More than 200 institutions from 53 countries (orange + blue)

Facility for Antiproton and Ion Research in Europe GmbH

Polands´s Participation and Contribution to the FAIR Project



APPA Physics — **A**tomic, **P**lasma **P**hysics and **A**pplications
CBM — **C**ompressed **B**aryonic **M**atter experiment
NUSTAR — **NU**clear **ST**ructure, **A**strophysics and **R**eactions
PANDA — **A**ntiproton **A**nnihilation at **D**armstadt experiment

Poland holds a 2.3% share, is represented by Jagiellonian University, coordinating Polish in-kind contributions to FAIR, funded by the Ministry of National Education (approximately 23.7 million Euros in 2005).

Over 95% of the funds allocated to in-kind contributions to research infrastructure and experiments at FAIR. More at https://fair.uj.edu.pl/.

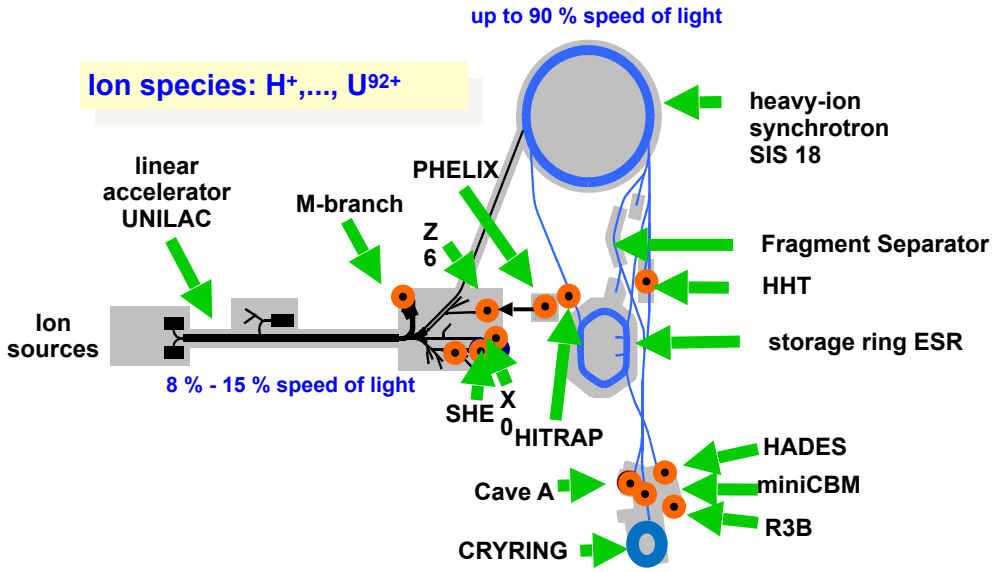
The National Consortium of Femtophysics comprises 12 Polish universities and research institutes (https://fair.uj.edu.pl/konsorcjum).

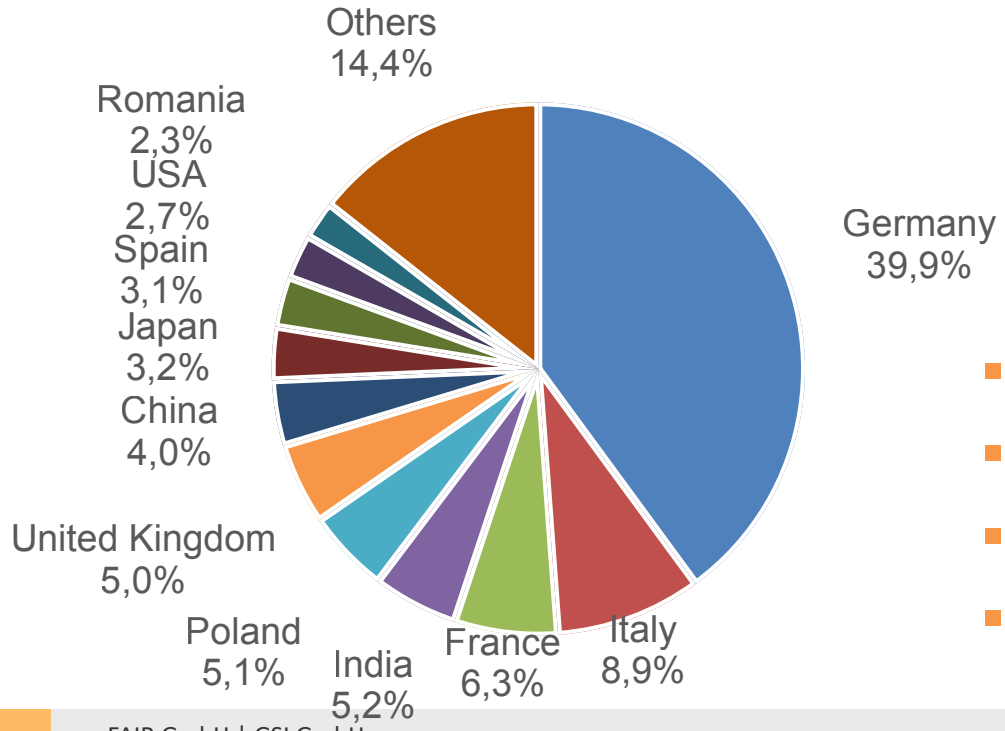
FAIR included in the roadmap of European and Polish research infrastructure.

Early science program FAIR Phase-0

- Started in 2019, annual runs of ~110 days until FAIR operation

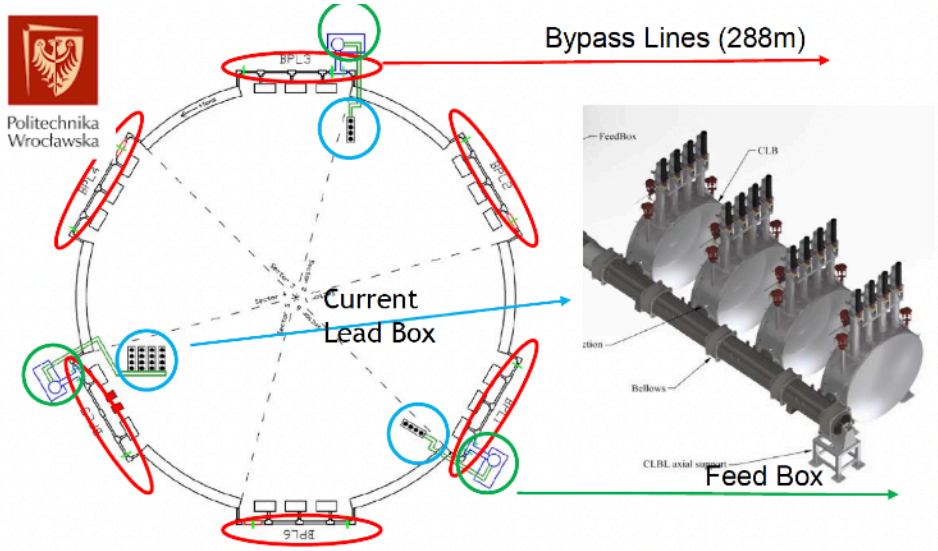
FAIR Phase 0 Research Program





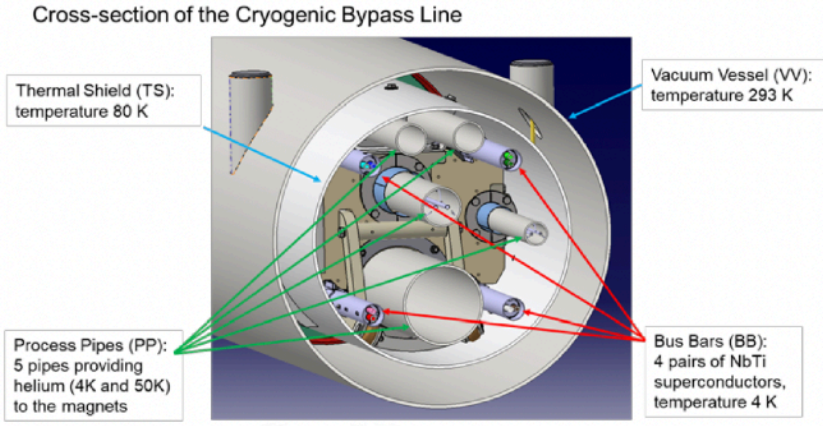
- Science while commissioning FAIR
- latest call: 124 proposals submitted
- 1729 participants of proposals
- From institutes in 45 countries

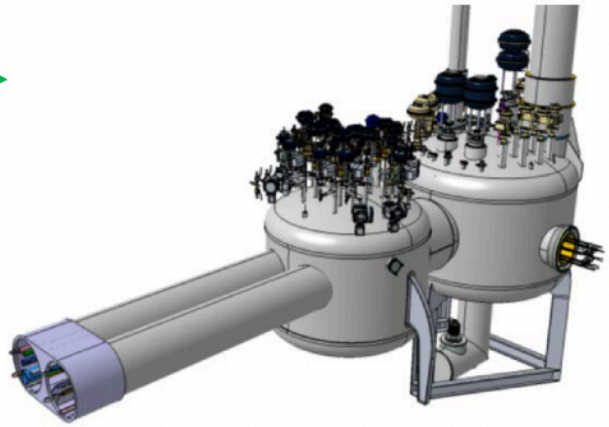
Example of Polish in-kind contributions to SIS-100



Wrocław University of Science and Technology: Design and implementation of the power (current) and cooling (He) distribution system for the SIS100 magnets. Unique competencies combining low temperatures with superconductivity (transport of helium and current in a single vacuum insulation). A crucial contribution to First Science+.

Polish in-kind contribution to SIS100 includes Bypass Lines (288m), Feed Box, and Current Lead Box.





Gdańsk University of Technology: Test system for SIS100 magnets.

Creating extreme
conditions existing in the
universe with
heavy ion accelerators

Foto: NASA, ESA, G. Dubner (IAFE, CONICET-University of Buenos Aires) et al.; A. Loll et al.; T. Temim et al.; F. Seward et al.; VLA/NRAO/AUI/NSF; Chandra/CXC; Spitzer/JPL-Caltech; XMM-Newton/ESA; and Hubble/STScI (oben), Penn State University (unten)

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

Where are heavy elements created?

NUSTAR

What is in the interior of a neutron star?

CBM

PANDA

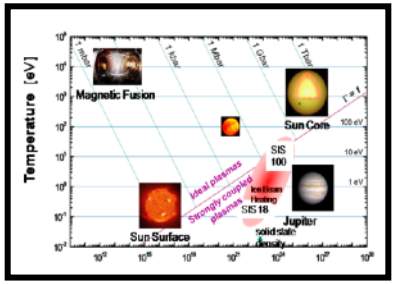
Glueballs:
What are protons and neutrons made of?
What is the structure of hadrons?

APPA

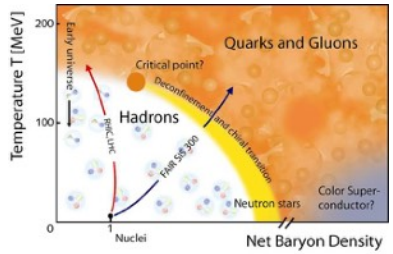
How do materials behave under high pressure?

Fotos: Uranus, Jupiter, Erde Quelle: http://de.wikipedia.org

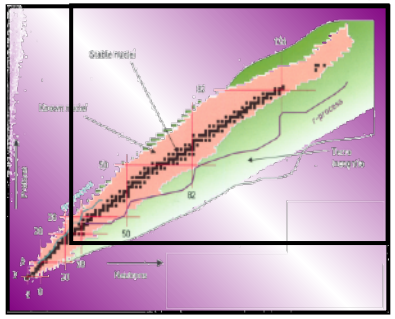
The FAIR science: four pillars



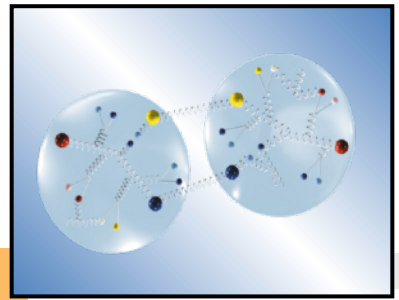
atomic physics, biophysics,
plasma physics, material research **APPA**



nuclear- and quark-matter **CBM**



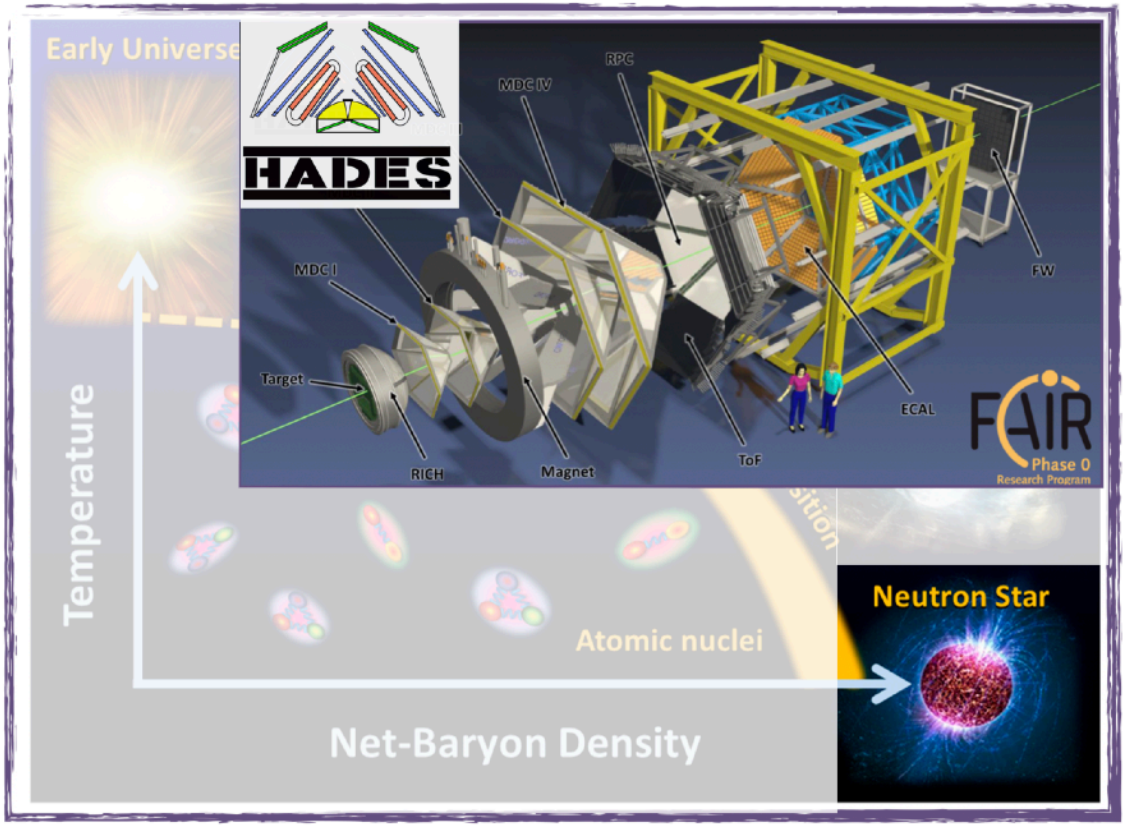
nuclear structure and
nuclear astrophysics **NuSTAR**



hadron structure and dynamics **PANDA**

Neutron Stars

Exploration of unknown QCD territory: high μ_B



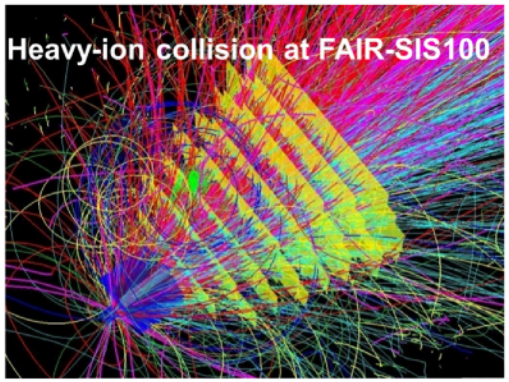
https://www.researchgate.net

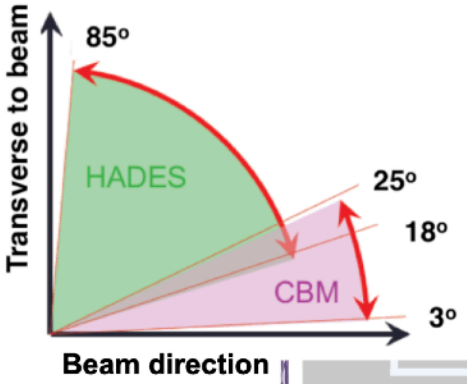
Temperature
T<10 MeV

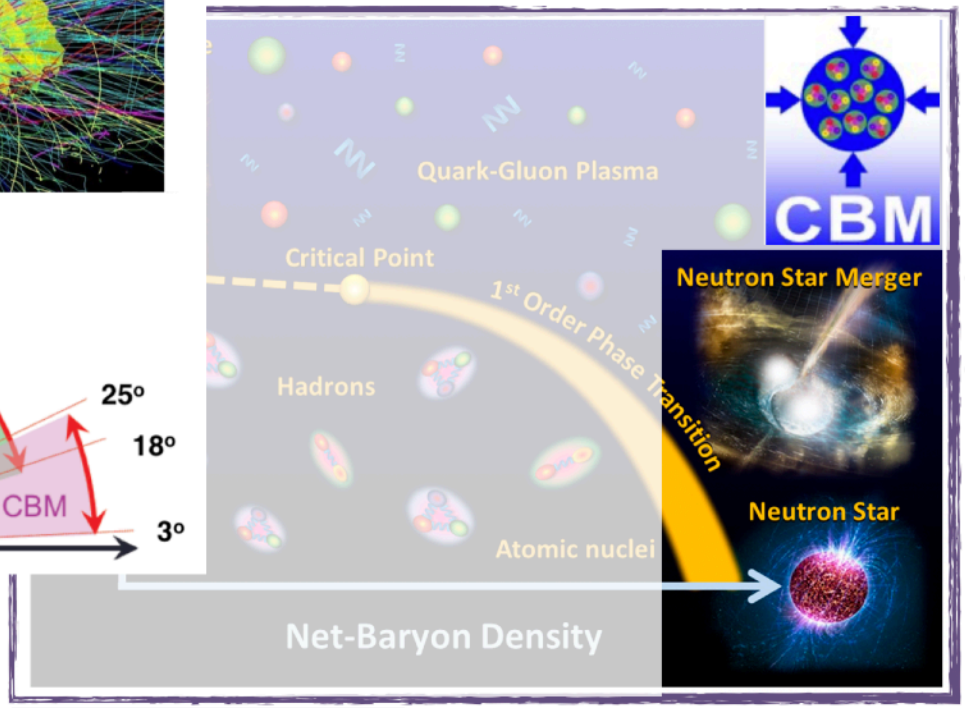
Density
$n < 3n_0$

Lifetime
t ~ long

CBM and HADES future







https://www.researchgate.net

Temperature
T<50 MeV

Density
$n < 2 - 6n_0$

Reaction time
t ~ 10 ms
(GW170817)

Temperature
T<10 MeV

Density
$n < 10n_0$

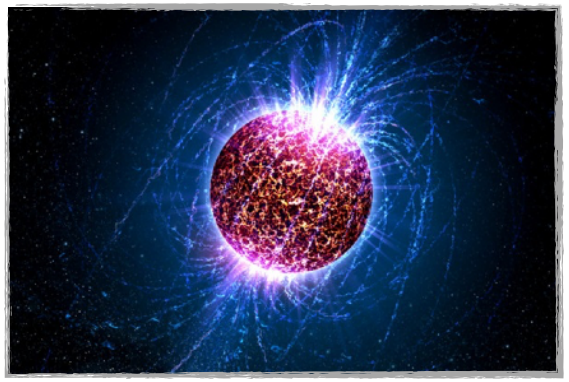
Lifetime
t ~ infinity

SIS-100: Temperature T<120 MeV | Density $n < 8n_0$ | Reaction time t ~ 10^{-23} s

NSM and HIC

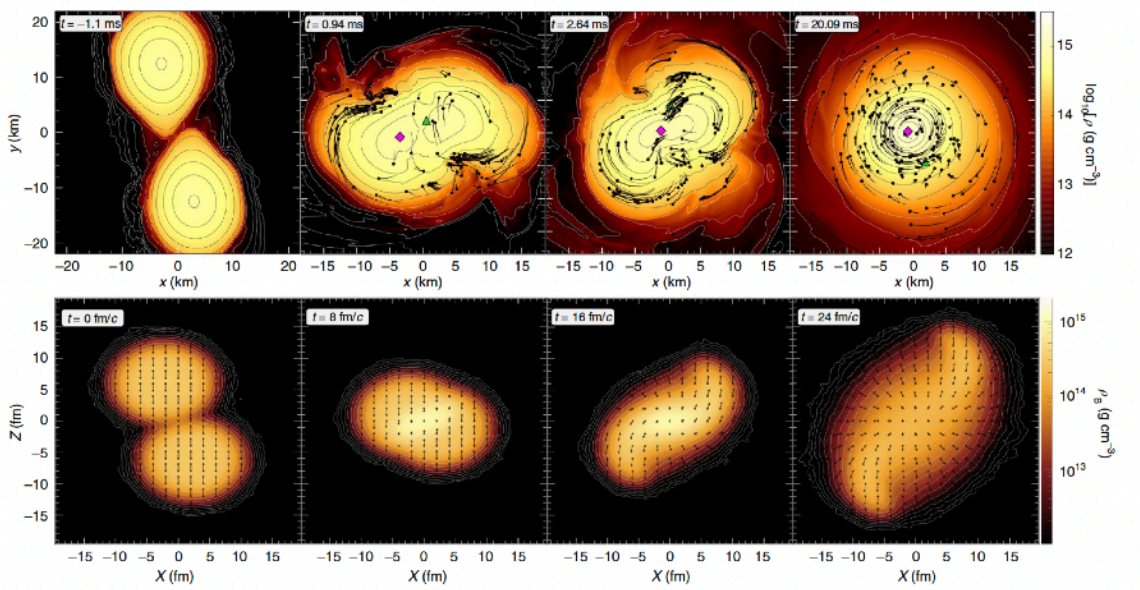
Top row: simulation of **neutron stars mergers**
2 neutron stars of 1.35 M⊙ each,
merging into a single object ($2R \sim 10$ km, $n \simeq 5n_0$, $T \leq 20$ MeV).
Overlap region: $t \simeq 20$ms, $n \simeq 2n_0$, $T \simeq 75$ MeV

- max. temperature
- max. density



Bottom row: non-central-**collision Au+Au** at $\sqrt{s_{NN}} = 2.42$ GeV
$n \simeq 3n_0$, $T \simeq 80$ MeV

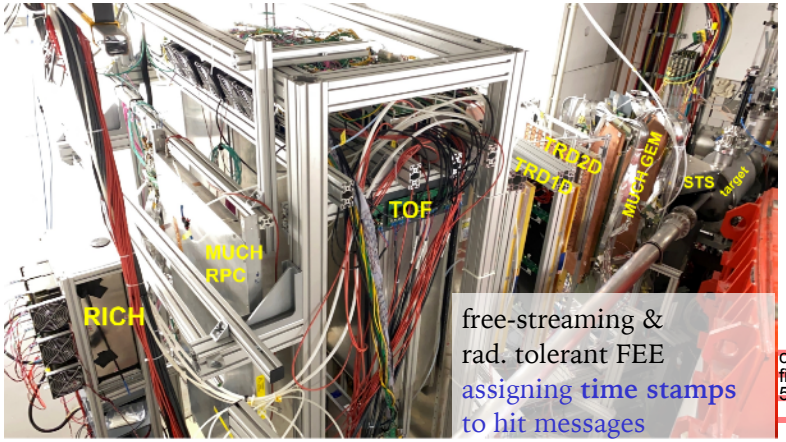
HADES, Nature Phys. 15, 1040–1045 (2019)



Similar **densities** and **temperatures** are achieved.

Space and **time** scales are vastly different
(km - NS, fm - HIC).
The collision events differ in duration by 20 orders of magnitude.

With mCBM@SIS18 towards CBM



free-streaming &
rad. tolerant FEE
assigning **time stamps**
to hit messages

optical fibers 50m

FLES entry nodes
CRI FPGA
***μ*Slice** building
(DAQ container)

optical fibers

300 m

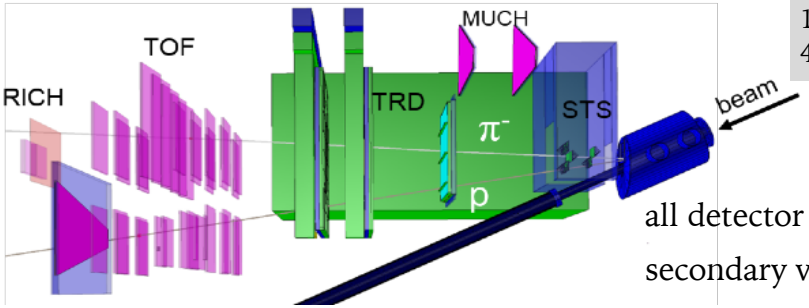
FLES processing nodes
time slice building
event reconstruction
& selection
archiving

Free-streaming CBM data transport

Pre-series productions of all CBM detector systems

High-rate studies up to 10 MHz coll. rate in nucleus-nucleus collisions

Rare signal reconstructed: Λ → p π⁻

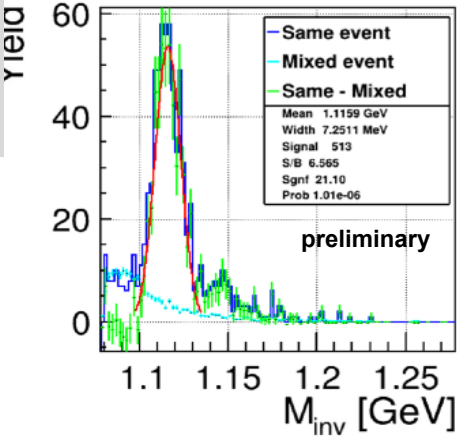


Ni+Ni 1.93 AGeV
run 2391 (May '22):
10^9 collisions, 1:57h
400 kHz av. coll. rate

all detector systems involved

secondary vertex

velocity windows for p and π⁻ candidate



Campaign 2024:

high-rate studies

online reconstruction & selection

Λ baryons in Ni+Ni at 1.0 - 1.93 AGeV

CBM/HADES program

Key observables – systematic measurements!

- **Dileptons**

→ Emissivity of dense baryonic matter: lifetime, temperature, density, in-medium properties

- **Fluctuations**

→ System transition via first-order phase transition line, CEP

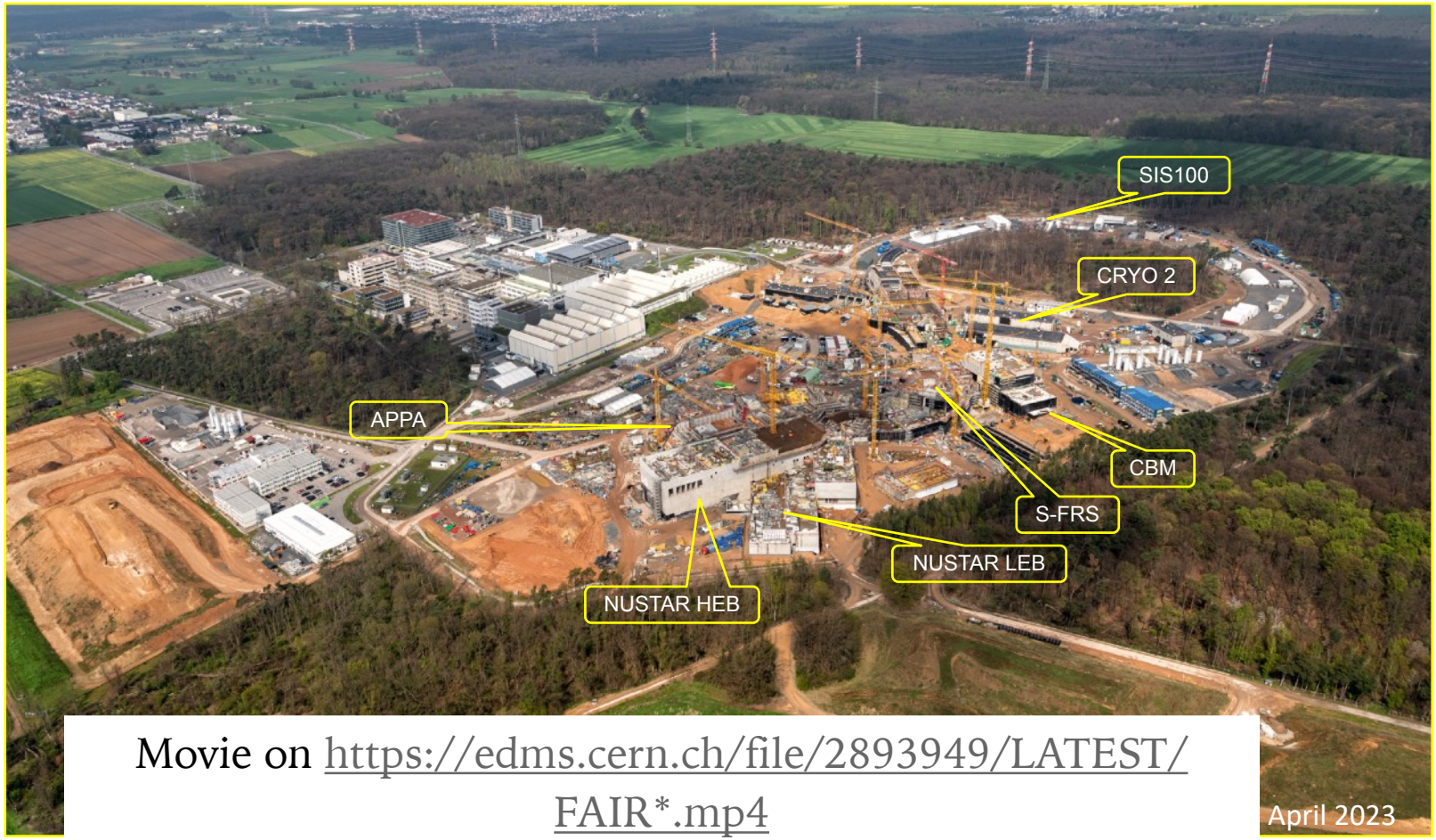
- **Hadrons/ Strangeness/ Charm**

→ System in equilibrium, Hypernuclei, Vorticity, Flow, EOS

- **Correlations**

→ Flow, Vorticity, YN & YNN interactions

Civil Construction



Movie on https://edms.cern.ch/file/2893949/LATEST/FAIR*.mp4

FAIR SIS100 accelerator tunnel

FAIR SIS 100 supply tunnel

April 2023

FAIR Area South

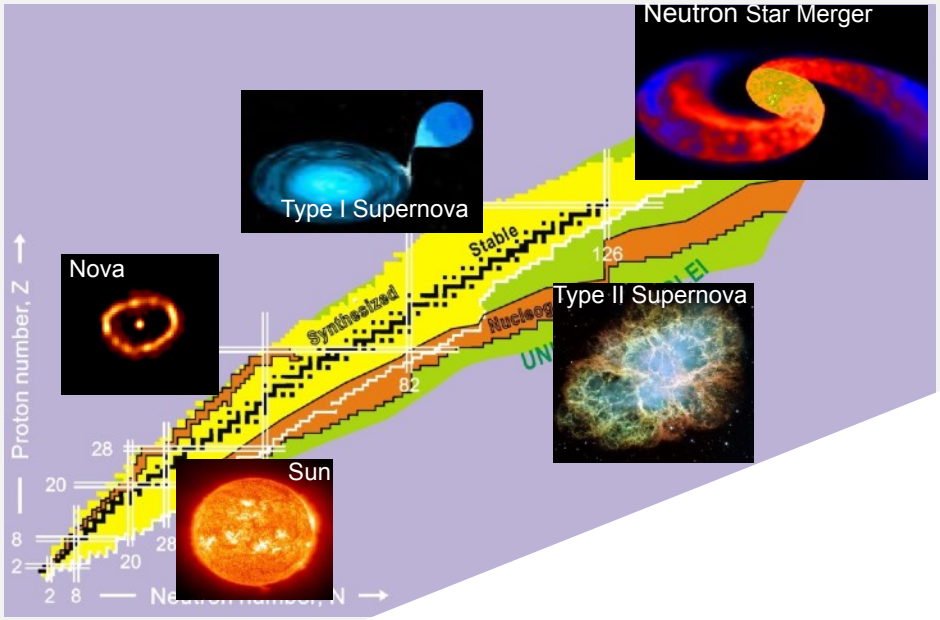
FAIR visit

July 2023

FAIR CBM Cave

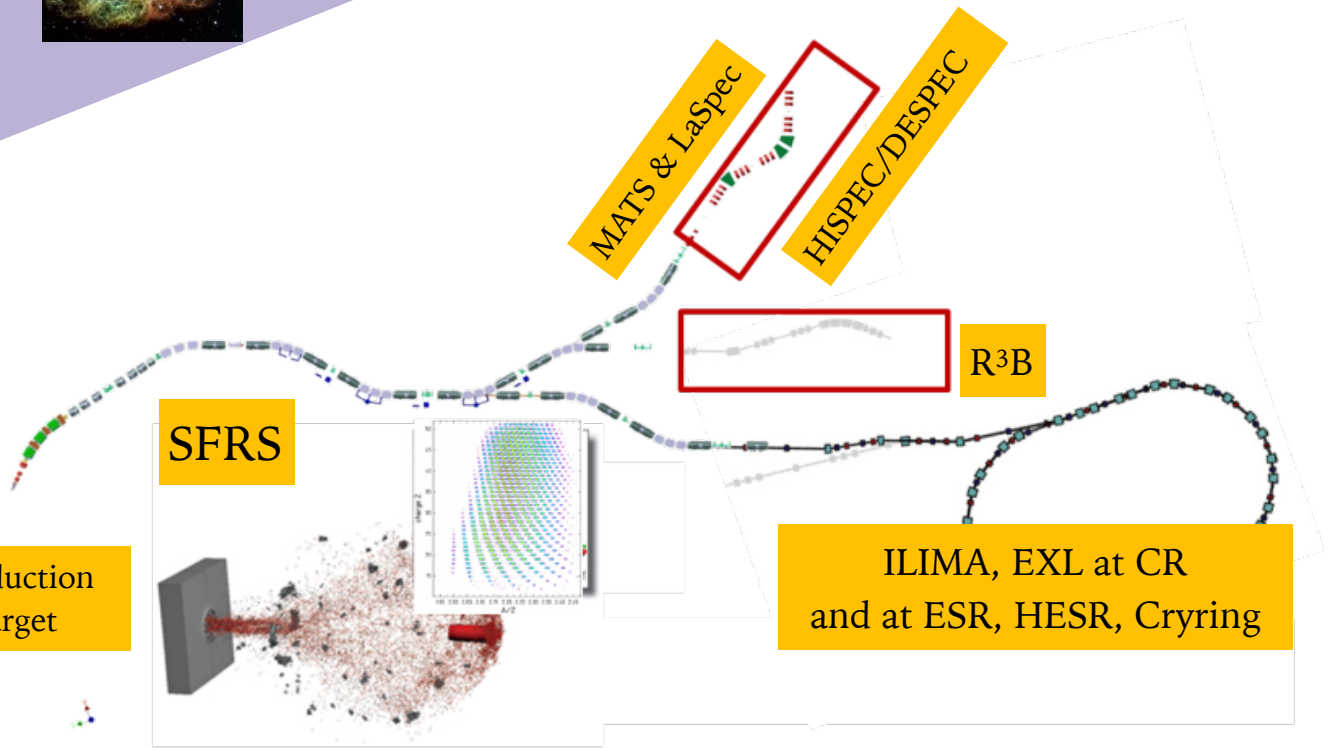
FAIR: Unique Opportunities . . . & Challenges

NUSTAR
- Origin of Elements in the Universe



„Nucleosynthesis sites“ in the universe

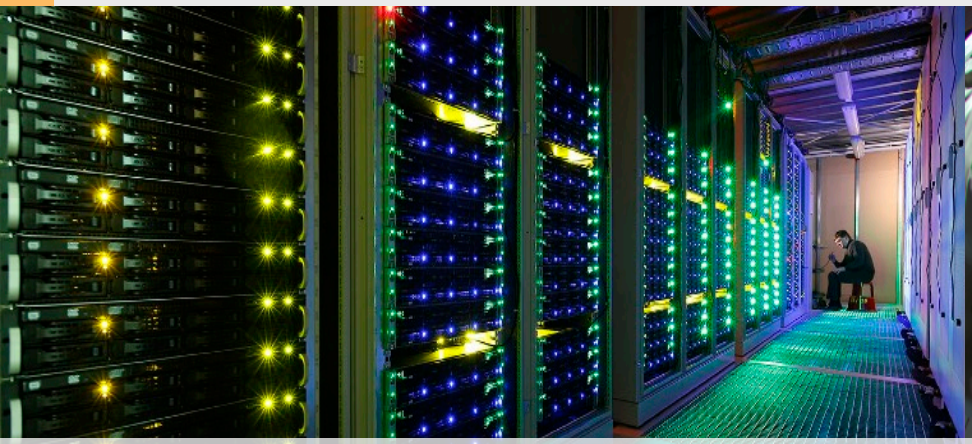
„Nucleosynthesis sites” at FAIR



Primary intensities vs. GSI: x 100

SIS 100

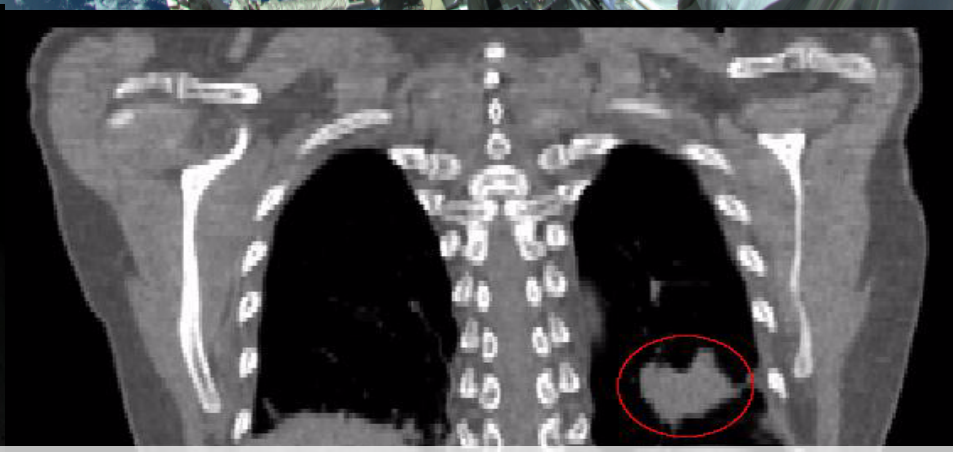
... with direct applications



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

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

Development of nuclear clock:
Promising candidate thorium-229



Novel applications for tumor and non-tumor diseases