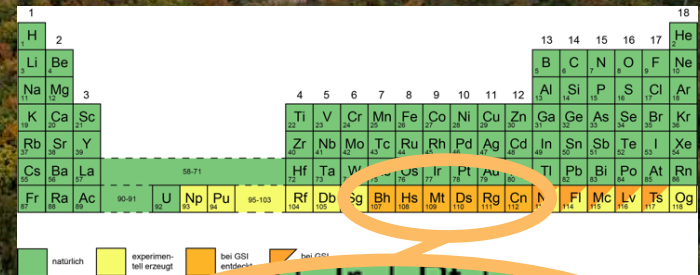


# FAIR

European Cryogenic Days, GSI, March 28-29

P.Giubellino

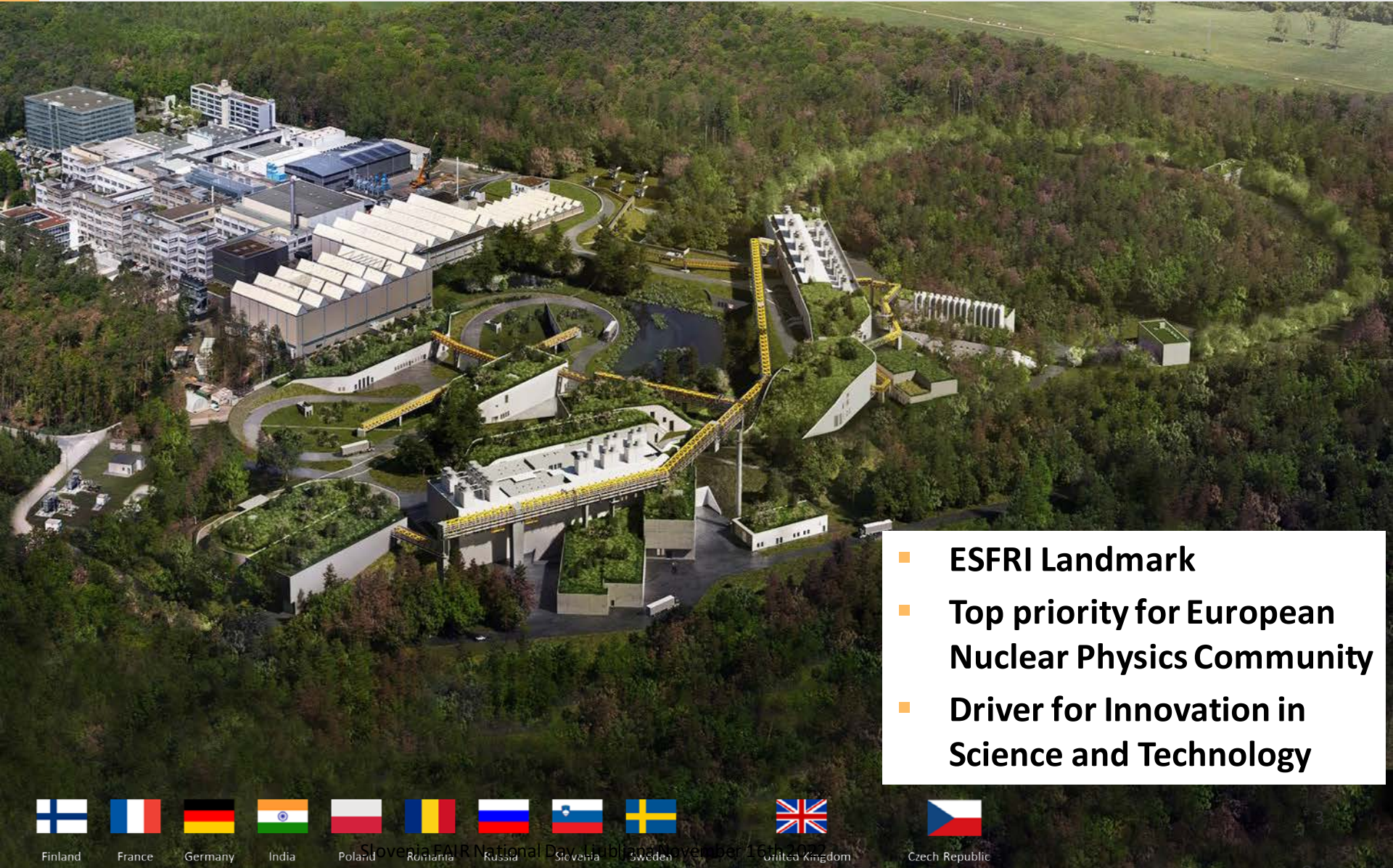




- 
- |         |         |            |              |             |             |          |           |           |             |            |           |
|---------|---------|------------|--------------|-------------|-------------|----------|-----------|-----------|-------------|------------|-----------|
| Os      | Ir      | Pt         | Au           | Hg          |             |          |           |           |             |            |           |
| 76      | 77      | 78         | 79           | 80          |             |          |           |           |             |            |           |
| Bh      | Hs      | Mt         | Ds           | Rg          | Cn          | Nh       | Fl        | Mc        | Lv          | Ts         | Og        |
| 107     | 108     | 109        | 110          | 111         | 112         | 113      | 114       | 115       | 116         | 117        | 118       |
| Bohrium | Hassium | Meitnerium | Darmstadtium | Roentgenium | Copernicium | Nihonium | Flerovium | Moscovium | Livermorium | Tennessine | Oganesson |



# FAIR: Facility for Antiproton and Ion Research



- **ESFRI Landmark**
- **Top priority for European Nuclear Physics Community**
- **Driver for Innovation in Science and Technology**



Finland



France



Germany



India



Poland



Romania



Russia



Slovenia



Sweden



United Kingdom

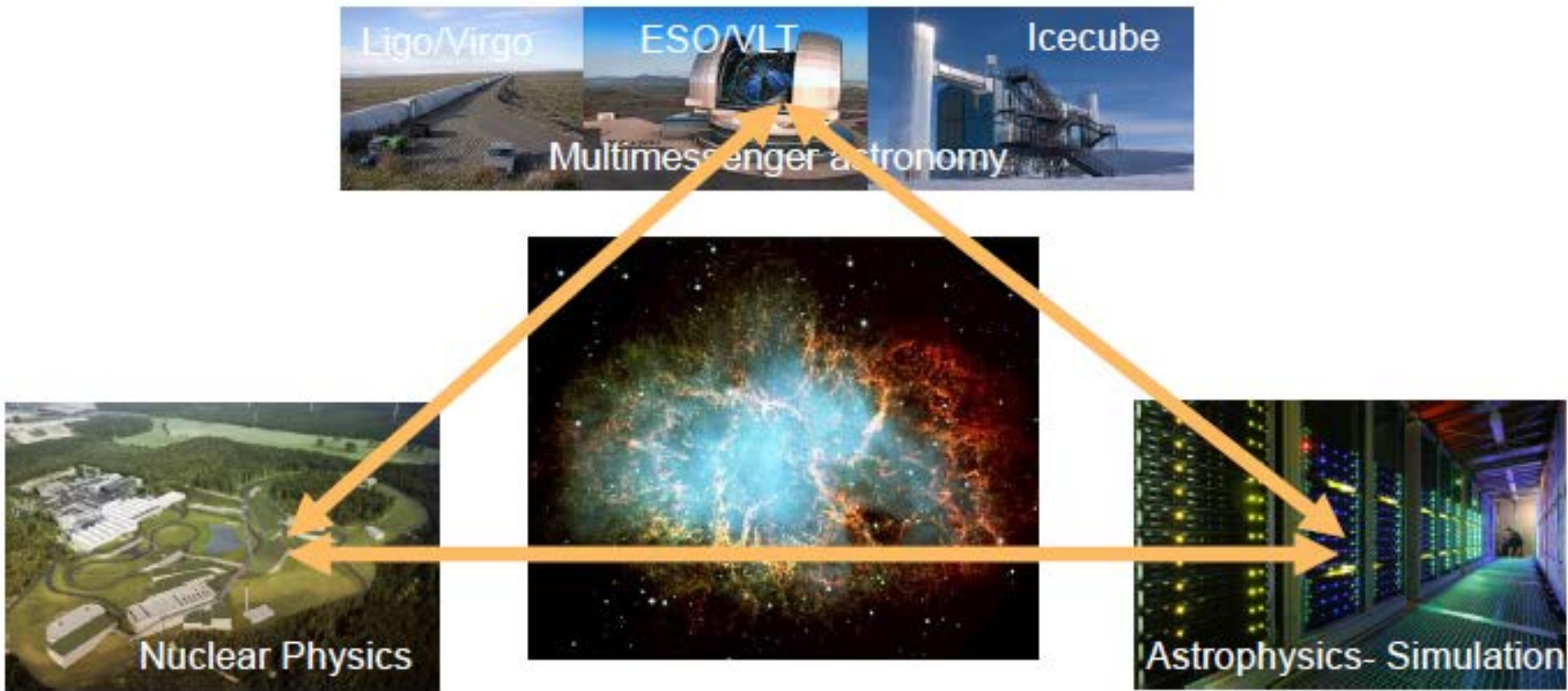


Czech Republic

Slovenia FAIR National Day, Ljubljana, November 16th



# An important moment for our understanding of the universe



**Our objective:**

**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. Lell et al.; T. Tenim et al.; F. Seward et al.; VLAA/RAO/AU/NSE; 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 ...**

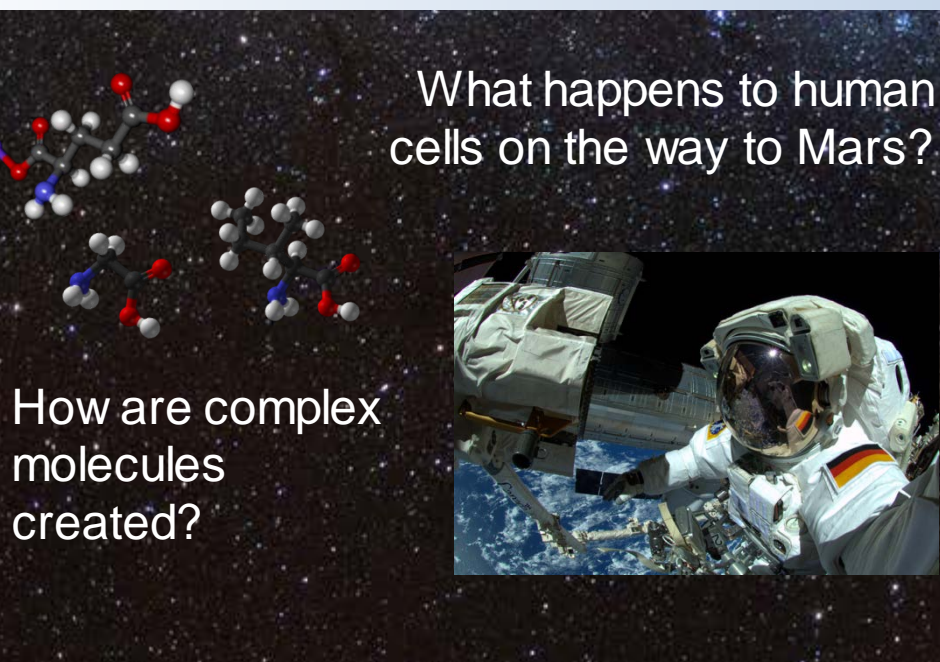


Where are heavy elements created?



What is in the interior of a neutron star?

What happens to human cells on the way to Mars?

This block contains two images. On the left, there are several 3D ball-and-stick molecular models of complex organic molecules, including what appears to be a sugar molecule and a protein-like structure. On the right, there is a photograph of an astronaut in a white spacesuit with a German flag patch, floating in space next to a large satellite or space station module.

How are complex molecules created?

How do materials behave under high pressure?

This block contains three images of celestial bodies. On the left is a large, blue, gaseous planet (Jupiter). In the center is a smaller, blue and white planet (Earth). On the right is a large, orange and white striped planet (Jupiter). The background is a dark space filled with stars.

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



... with direct applications



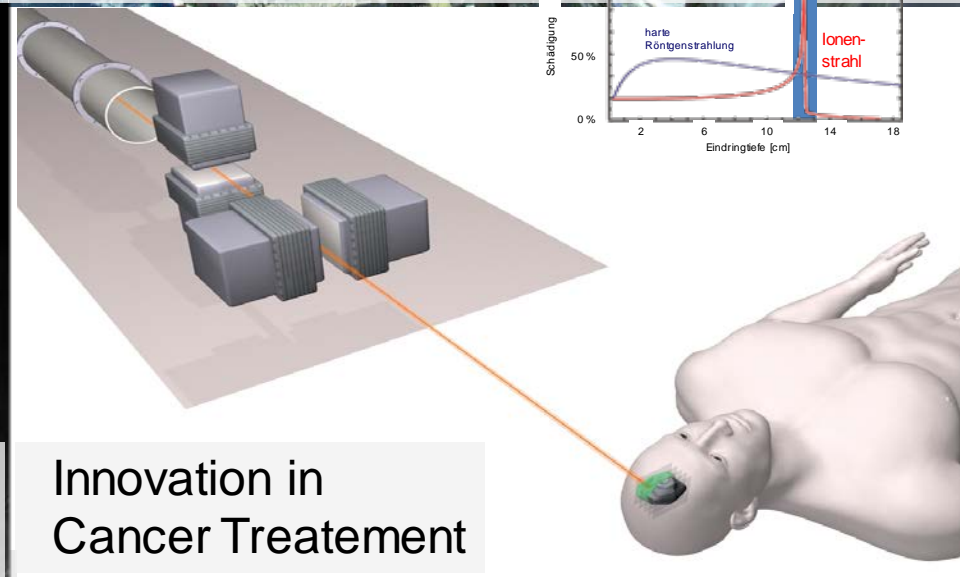
High-performance and scientific computing,  
big data, green IT



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

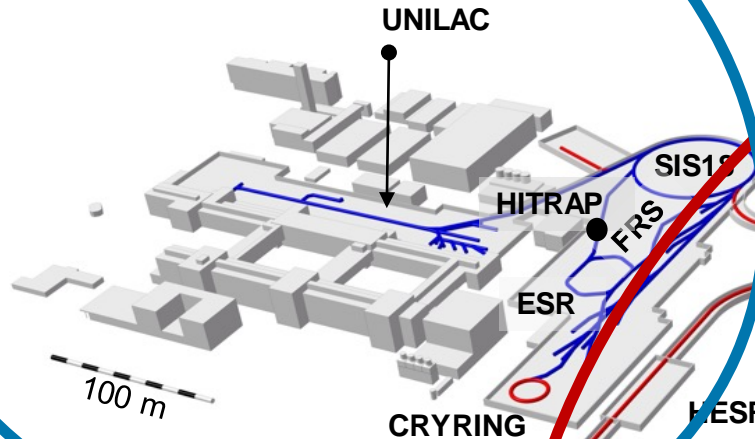


Development of nuclear clock:  
Promising candidate thorium-229

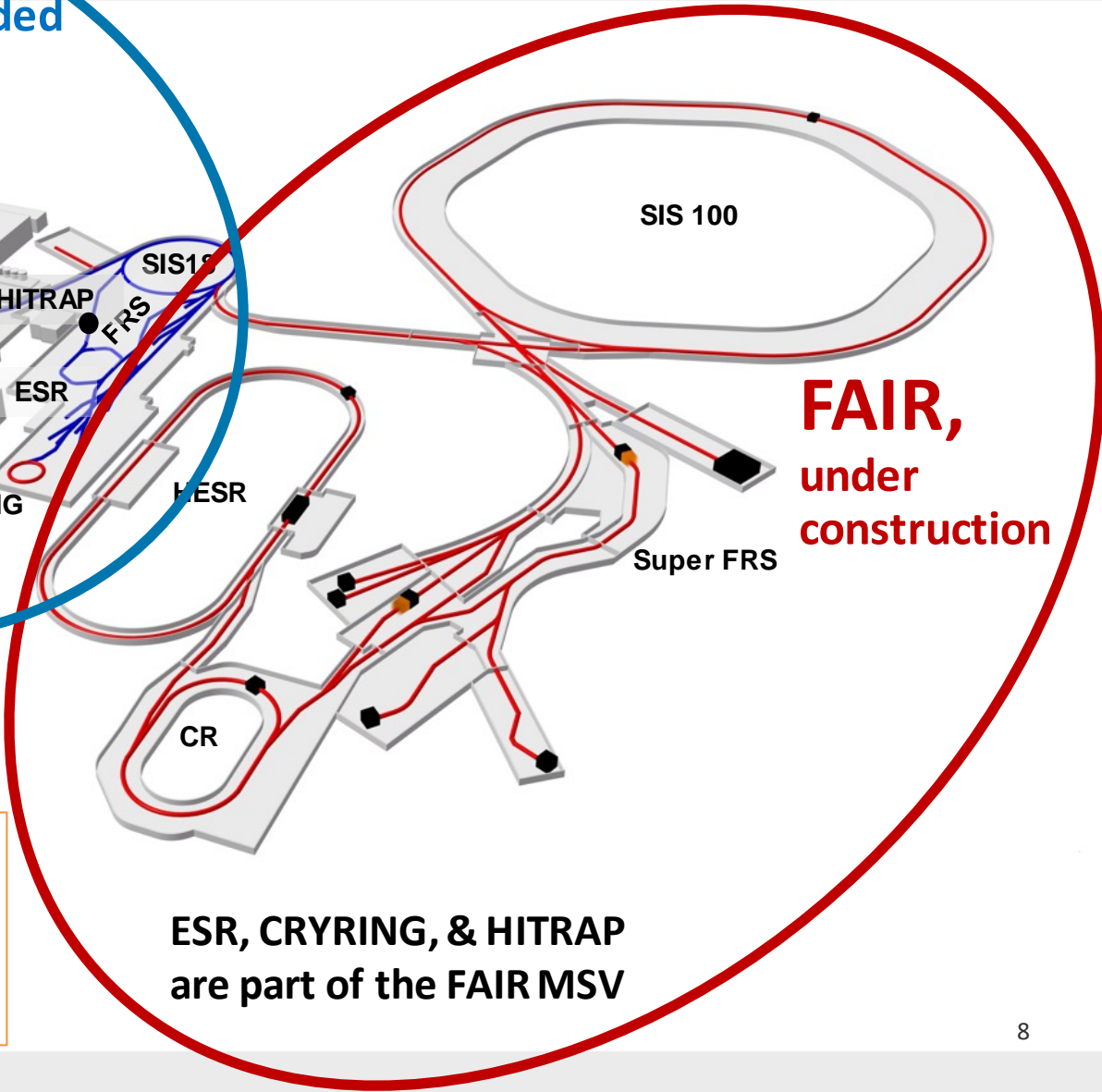


Innovation in  
Cancer Treatment

**GSI, existing (upgraded to integrate with FAIR)**



**FAIR, under construction**



**ESR, CRYRING, & HITRAP are part of the FAIR MSV**

## FAIR key features

- intensity for wide range of ions
- storage rings
- antiproton beams



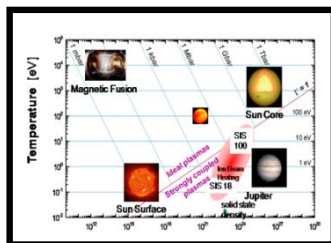
# Many superconducting magnets in FAIR!



- For SIS100, superconductivity provides:
  - Huge pumping power for the beam pipe due to the actively cooled vacuum chambers, the cryo absorption and the cryo ion catchers. This is essential for the operation with low charge state heavy ions.
  - Actually we are developing cryogenic inserts to make use of cryopumping also in sis18.
  - Furthermore, the higher current density in the coils of sc magnets enables more compact magnets.
- On the other side compact magnets lead to lower overall pulse power required for SIS100.
- Actually the pulse power of SiS100 is lower than SIS18 although SIS100 is 5 times larger.
- For super FRS and storage rings it is at most energy dissipation/consumption in large aperture magnets. Which means finally operation cost.

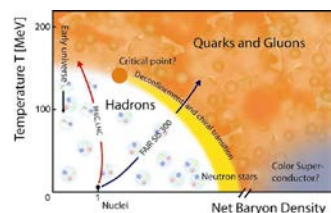


# The FAIR science: four pillars



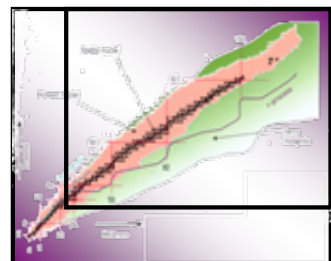
atomic physics, biophysics,  
plasma physics, material research

**APPA**



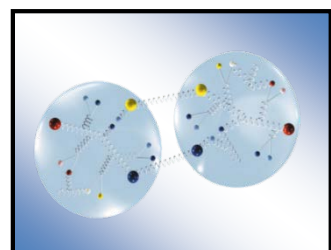
nuclear- and quark-matter

**CBM**



nuclear structure and  
nuclear astrophysics

**NuSTAR**



hadron structure and dynamics












**PANDA**

FAIR



# FAIR: a World-wide project



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



# Civil Construction



- Civil Construction continues to make rapid progress



October, 2022

Drone videos available via [www.gsi.de](http://www.gsi.de)

Movie of the construction site as of Nov 2022

[https://edms.cern.ch/file/2796608/LATEST/FAIR\\*720p\\*.mp4](https://edms.cern.ch/file/2796608/LATEST/FAIR*720p*.mp4)

or via [www.gsi.de](http://www.gsi.de)



# Accelerators: components continues steadily

delivery of



- Storage area: approx. 9.900 m<sup>2</sup>
- 4.195 objects (Components, assemblies, boxes, etc.)
- 50% of SIS100 components stored
- 90% of HESR components stored





# Experiment Construction Highlights

**APPA**

Setup in target chamber

XRTS

XRD

pyro (point)

pyro (img.)

ions

HED@FAIR diagnostics

4 & 0.5 MeV/u

~ 6 keV/u

HITRAP commissioning

The image shows the APPA experiment setup in a target chamber, with various components labeled: XRTS, XRD, pyro (point), and pyro (img.). A green laser beam is visible. To the right, two plots are shown: a 2D color plot of position vs energy<sup>12</sup> (a.u.) and a 1D line plot of position vs energy<sup>12</sup> (a.u.) with a peak at ~ 6 keV/u. The text 'HITRAP commissioning' is written vertically on the right.

**CBM**

mCBM performance

DATA

SIM.

The image shows the CBM experiment setup, a large circular structure with multiple detectors. To the right, a plot shows the mCBM performance, comparing DATA (black line) and SIM. (red line) for the variable 'Sts0\_Sts1\_diffX-OutRefTrackMatch'. The plot shows a sharp peak at zero. A photograph of the construction site is also visible on the right.

**NUSTAR**

R3B: LH2 target, CALIFA, GLAD

The image shows the NUSTAR experiment setup, featuring a large, complex structure with many cables and components. A photograph of the R3B: LH2 target, CALIFA, and GLAD is also shown. The NUSTAR logo is visible in the bottom left corner.

**PANDA**

Forward tracker

cable tray

FEE card

straw detectors

gas valve holder

base frame

movable table

linear bearings

rails

side bracket

side bracket ribs

connecting rod

The image shows the PANDA experiment setup, featuring a large, complex structure with many cables and components. A diagram of the forward tracker is shown on the right, with labels for various parts: cable tray, FEE card, straw detectors, gas valve holder, base frame, movable table, linear bearings, rails, side bracket, side bracket ribs, and connecting rod.

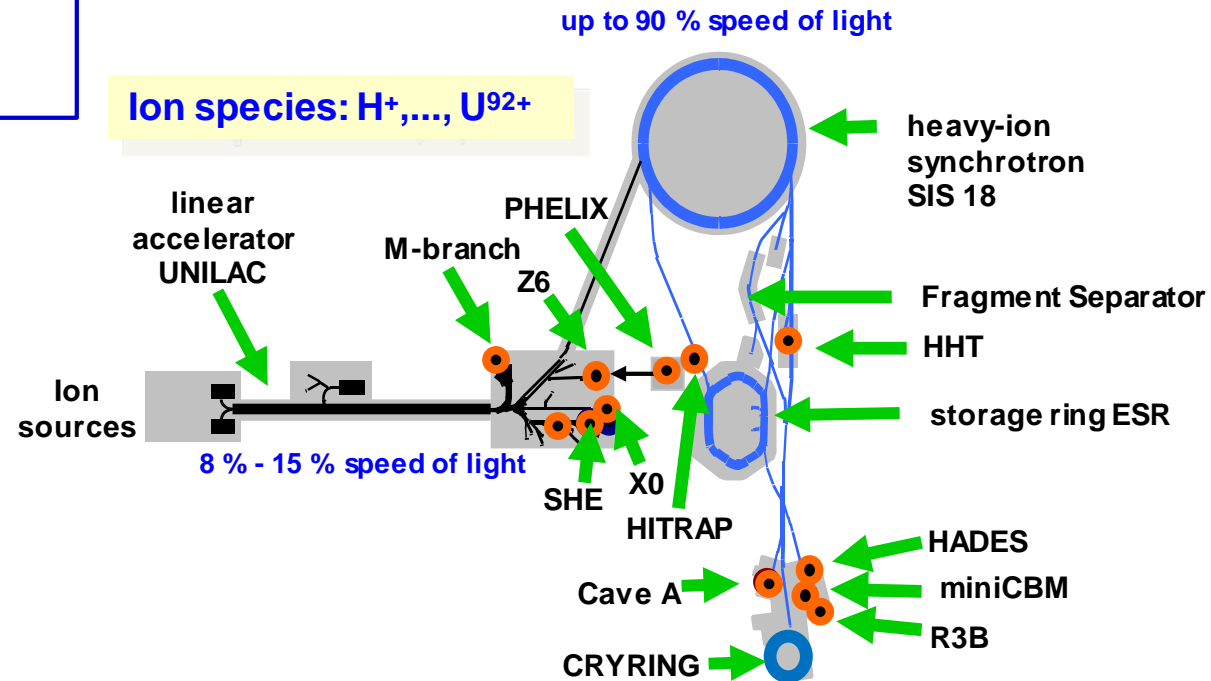


- Up to 2025 we continue with FAIR Phase-0, from 2026 onwards we enter the mixed-mode with the commissioning of the new beamlines. Annual beamtime for science will increase progressively, to reach full year operation from 2028 onwards.
- „First Science+“ includes all the facilities on the GSI campus plus the Super-FRS with the High Energy Branch, SIS100 and the CBM cave.
- Some experiments will start already in 2027 at the Super-FRS using SIS18 beams („Early Science“)
  - The amount of beam time to the new cave during Early Science will depend on the physics case, which should now be updated and detailed.
- We will try to keep a broad research program on campus, which will also serve the long-term goals of FAIR.

# Early science program FAIR Phase-0



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

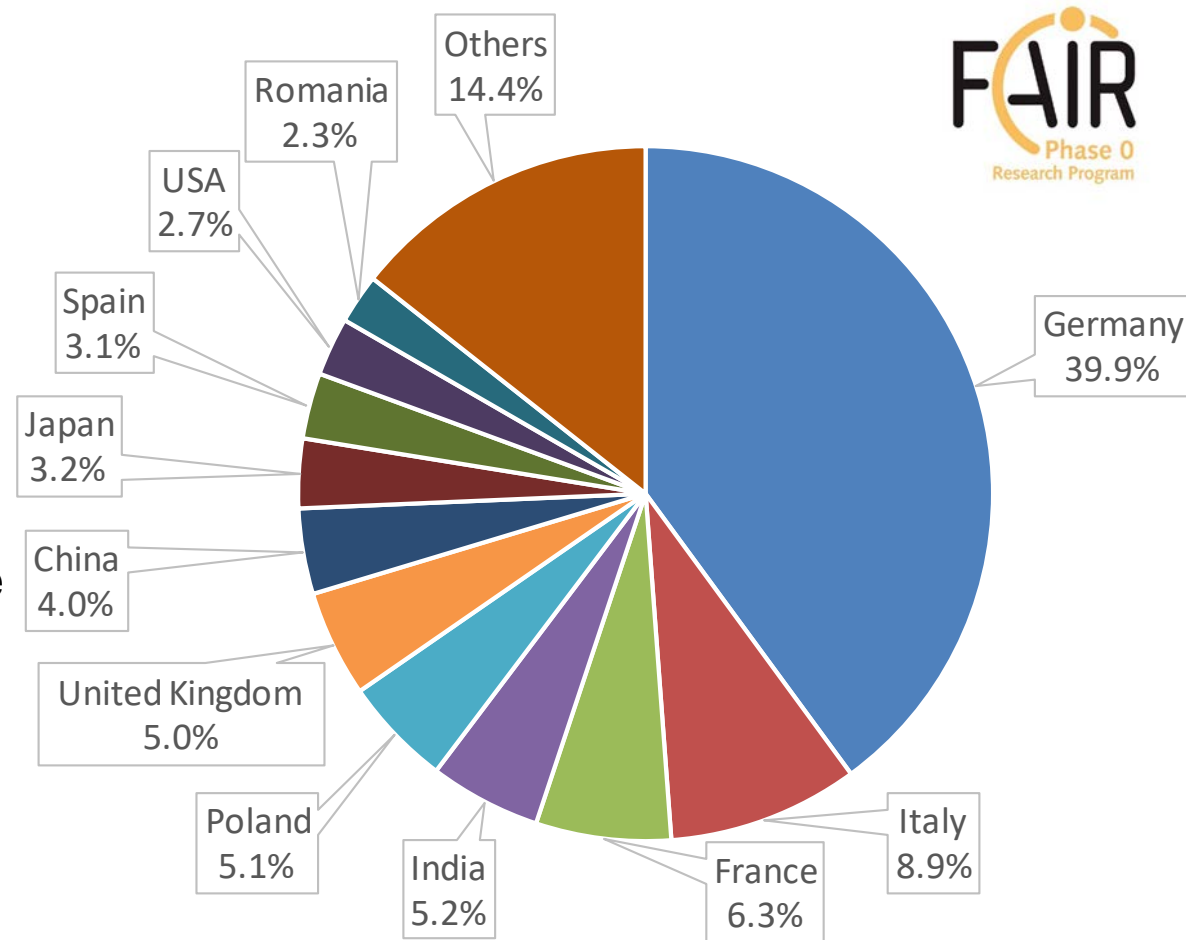


- Science while commissioning FAIR
  - 2021 and 2022 runs completed as planned
  - The program will continue in the coming years



# Beamtime Proposals 2022 for the next two periods

- 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)
- Scientists from Slovenia are involved in 18 submitted proposals





## Health of astronauts

- Experiments demonstrate, that artificial hibernation could protect astronauts from cosmic radiation
- Large international response in the media, e. g. Forbes (USA)

W. Tiganelli et al., Radiotherapy&Oncology, Vol.175, P185-190 (2022)

## FLASH cancer therapy

- Short, highly intense ion pulses for effective and gentle tumor therapy
- Title story of the most important oncology journal

M.-C. Vozenin, Nature Reviews Clinical Oncology 19, 791-803 (2022)

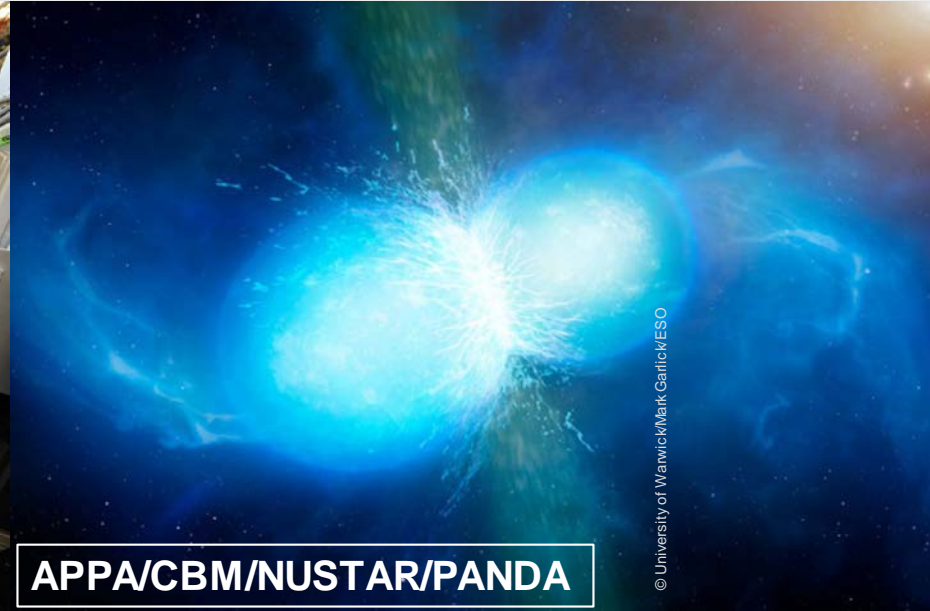




## Pushing the boundaries of the periodic table

- Determination of the properties of the heaviest chemically studied element so far, element 114, by experimenting with only eight atoms existing for fractions of a second

A.Yajushev et al., Front. Chem., (2022)



## Origin of the chemical elements

- Theoretical work regarding gravitational waves and the synthesis of elements in neutron star mergers
- Recently honored with Leibniz Award, ERC Advanced Grant, ERC Synergy Grant

K. Langanke et al., Frontiers in Physics (2021), DOI 10.1088/1361-6633/abf207  
O. Just et al., Monthly Notices of the Royal Astronomical Society, Vol. 509 (2022), P1377–1412  
A. Bauswein et al., Phys. Rev. Lett. 125, 141103



Thank you!!



Photo: C. Feiz