

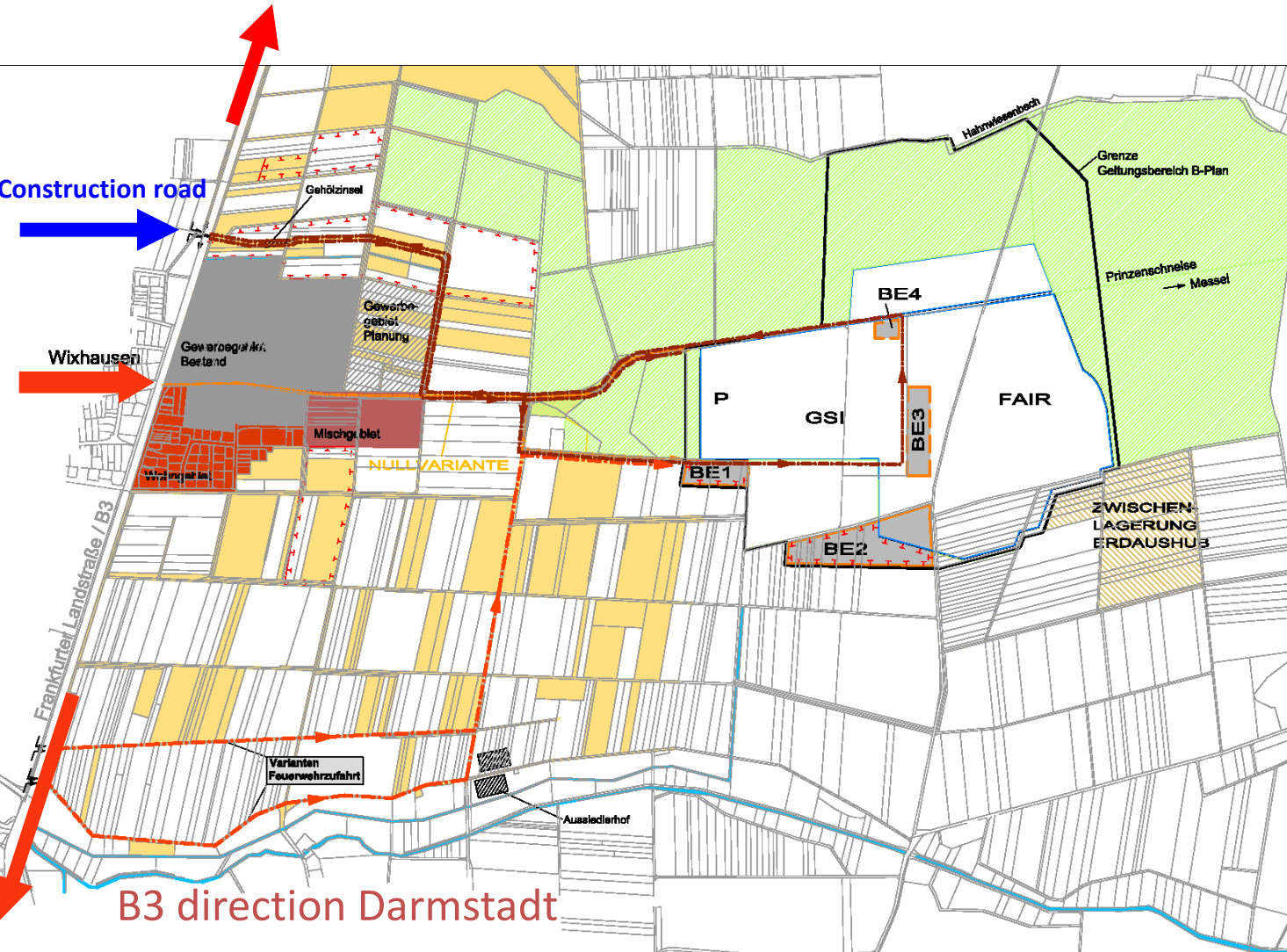
# **India's participation in the Facility for Antiproton and Ion Research (FAIR)**

*(an upcoming accelerator centre at Darmstadt, Germany)*

*Subhasis Chattopadhyay  
VECC-Kolkata*

# Location of FAIR









B3 Direction Frankfurt



B3 direction Darmstadt



**Legende:**

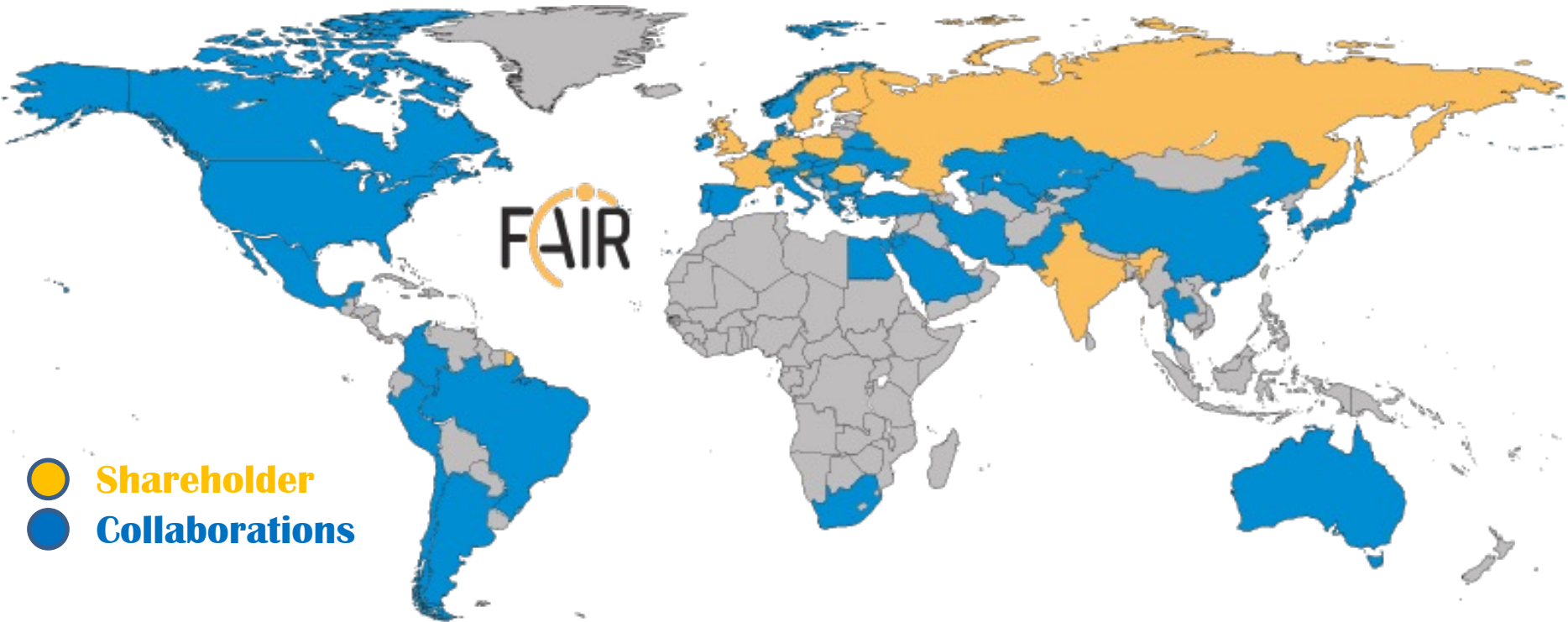
-  Aufrostungsfläche (Ersetz)
-  BE Baustellen-Einrichtungsfächen
-  Städtische Grundstücke
-  Wald
-  Zwischenlagerung Erdaushub
-  Baustellenschließung über Messeler-Park-Str.
-  Zusätzliche Baustellenschließungsstrasse
-  Feuerwehrezufahrt

|   |                          |   |  |
|---|--------------------------|---|--|
| UMWELTPLANUNG BULLERMANNSCHNEBLE GmbH<br>www.umweltschneble.de                    |                          |   |  |
| Erweiterung GSI, Projekt FAIR<br>Konzept Verkehrliche Baustellenschließung        |                          |   |  |
| <b>Übersichtslageplan</b>   |                          |   | Zeichnungsnummer:<br><b>063101</b><br>Maßstab:<br><b>1:5.000</b> |
| KUNDENSTELLE<br>Bürger  | PROJEKTNUMMER<br>0625410 | ERSTELLT<br>Feb. 2009   | BEARBEITUNGSSTADIUM<br>21.02.2011                                |
| GSI<br>GESELLSCHAFT FÜR SCHWERMETALLFORSCHUNG<br>PLANCKSTRASSE 1, 64291 DARMSTADT |                          | UMWELTPLANUNG BULLERMANNSCHNEBLE GmbH<br>HAVELSTRASSE 7A, D-64286 DARMSTADT<br>TELEFON 06181 87768-0 TELEFAX 06181 87768-30 |  |

## Periodic table Elements discovered at GSI-Darmstadt , Germany

|     |                                       |   |                                  |
|-----|---------------------------------------|---|----------------------------------|
| 107 | Bohrium (Bh)                          | Niels Bohr,   | (1981) December 1997             |
| 108 | Hassium (Hs)                          | German State of Hesse,                                    | March 14, 1984<br>December 1997  |
| 109 | Meitnerium (Mt)<br>of nuclear fission | Lise Meitner, Austrian physicist, theoretical description | August 29, 1982<br>December 1997 |
| 110 | Darmstadtium (Ds)                     | Darmstadt, location of GSI<br>November 9, 1994 ,          | August 2003                      |
| 111 | Roentgenium (Rg)                      | Wilhelm Conrad Röntgen,<br>December 8, 1994               | November 2004                    |
| 112 | Copernicium (Cn)                      | Nikolaus Kopernikus,<br>February 9, 1996                  | February 2010                    |

# FAIR – International Cooperation



- Shareholder
- Collaborations

- **Realization and operation in international cooperation**
- **Ten international partners own the company**
- **More than 53 countries participate in the experiments**
- **Participation of 3.000 scientists from all continents**

# FAIR accelerator and Indian participation

## High Intensity beams:

1000 x

For primary HI beam

10 000 x

For radioactive ion beams

10 0 x

For antiproton beams

## Primary beams:

$10^{12}$  /s  $^{238}\text{U}^{28+}$  1-2 AGeV

$4 \cdot 10^{13}$ /s Protons 90 GeV

$10^{10}$ /s U 35 AGeV (Ni 45 AGeV)

## Secondary beams:

rare isotopes 1-2 AGeV

antiprotons up to 30 GeV

- Highest Beam Intensities
- Brilliant Beam Quality
- Higher Beam Energies
- Highest Beam Power
- 4 parallel operations

Existing GSI

p - LINAC

Synchrotrons  
SIS100 SIS300

Compressed Baryonic  
Matter (CBM)

High-Energy Storage Ring  
HESR

Superconducting  
large-acceptance  
Fragment Separator  
Super-FRS

Collector Ring  
CR

Recycled Exp. Storage Ring  
RESR

New Experimental Storage Ring  
NESR

Indian contribution: 3% in construction of FAIR

## Member Countries:

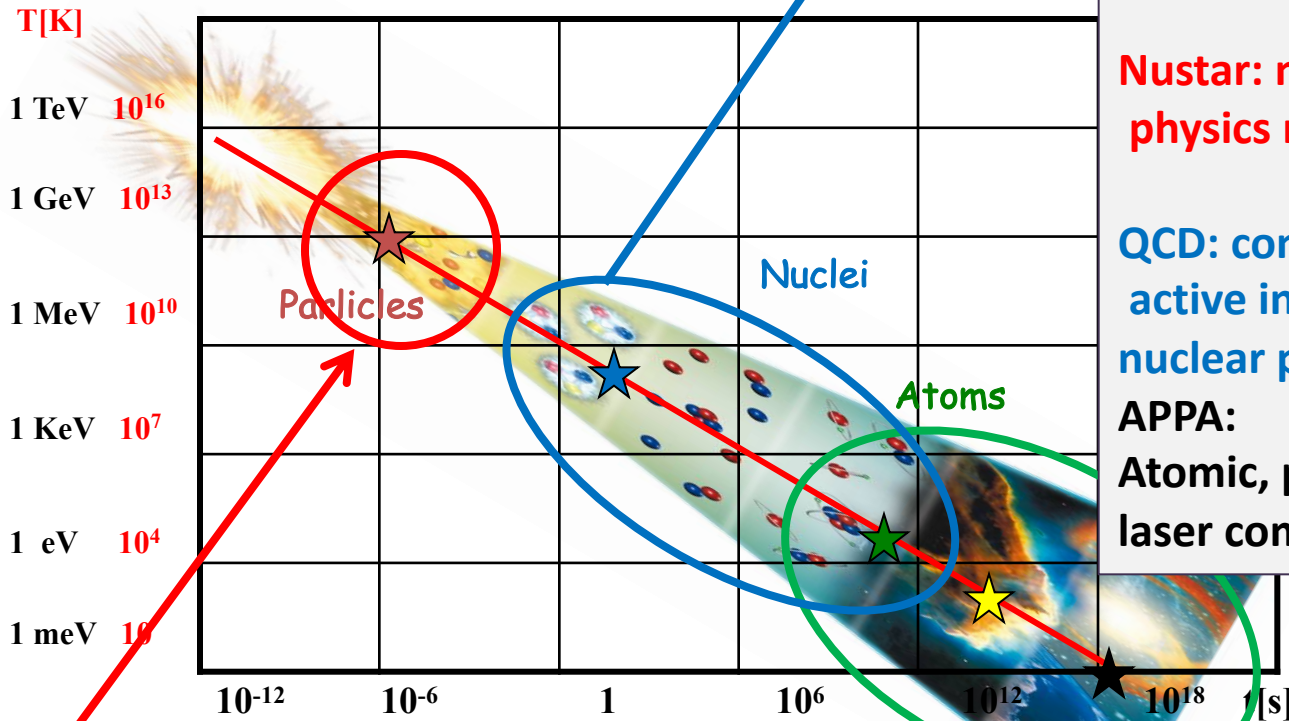
Germany  
Russia  
India  
France  
Poland  
Romania  
Finland  
Slovenia  
Spain  
Sweden  
UK

# Physics at FAIR

# Physics at FAIR

FAIR - NUSTAR research programs  
(*Nuclear Structure, Astrophysics and Reactions*)

The evolution of the universe



## Indian connection

**Nustar: nuclear physics research**

**QCD: community active in high energy nuclear physics**

**APPA: Atomic, plasma and laser community is large**

FAIR - QCD research programs  
(*Quantum Chromodynamics*)

FAIR - APPA research programs  
(*Atomic, Plasma Physics and Applications*)

# Indian participation (Experiments)

(41 groups)

## India-NUSTAR collaboration

Bhabha Atomic Research Centre, Mumbai  
Saha Institute of Nuclear Physics, Kolkata  
Tata Institute of Fundamental Research, Mumbai  
Variable Energy Cyclotron Center, Kolkata  
Inter University Accelerator Center, New Delhi  
Indian Institute of Technology, Bombay  
Indian Institute of Technology, Kharagpur  
Indian Institute of Technology, Roorkee  
University of Delhi, New Delhi  
University of Calcutta, Kolkata  
Punjab University, Chandigarh  
Aligarh Muslim University, Aligarh  
Karnatak University, Dharwad  
Guwahati University

Continuation of activities at VECC,  
IUAC and TIFR accelerator centres

## India-CBM collaboration

Aligarh Muslim Univ.  
Panjab Univ.  
Rajasthan Univ.  
Univ. of Jammu  
Univ. of Kashmir  
Univ. of Calcutta  
B.H. Univ. Varanasi  
VECC Kolkata  
SINP Kolkata  
IOP Bhubaneswar  
IIT Kharagpur  
Gowhati Univ.  
Bose-Institute, Kolkata  
North Bengal Univ, WB

## India-PANDA collaboration

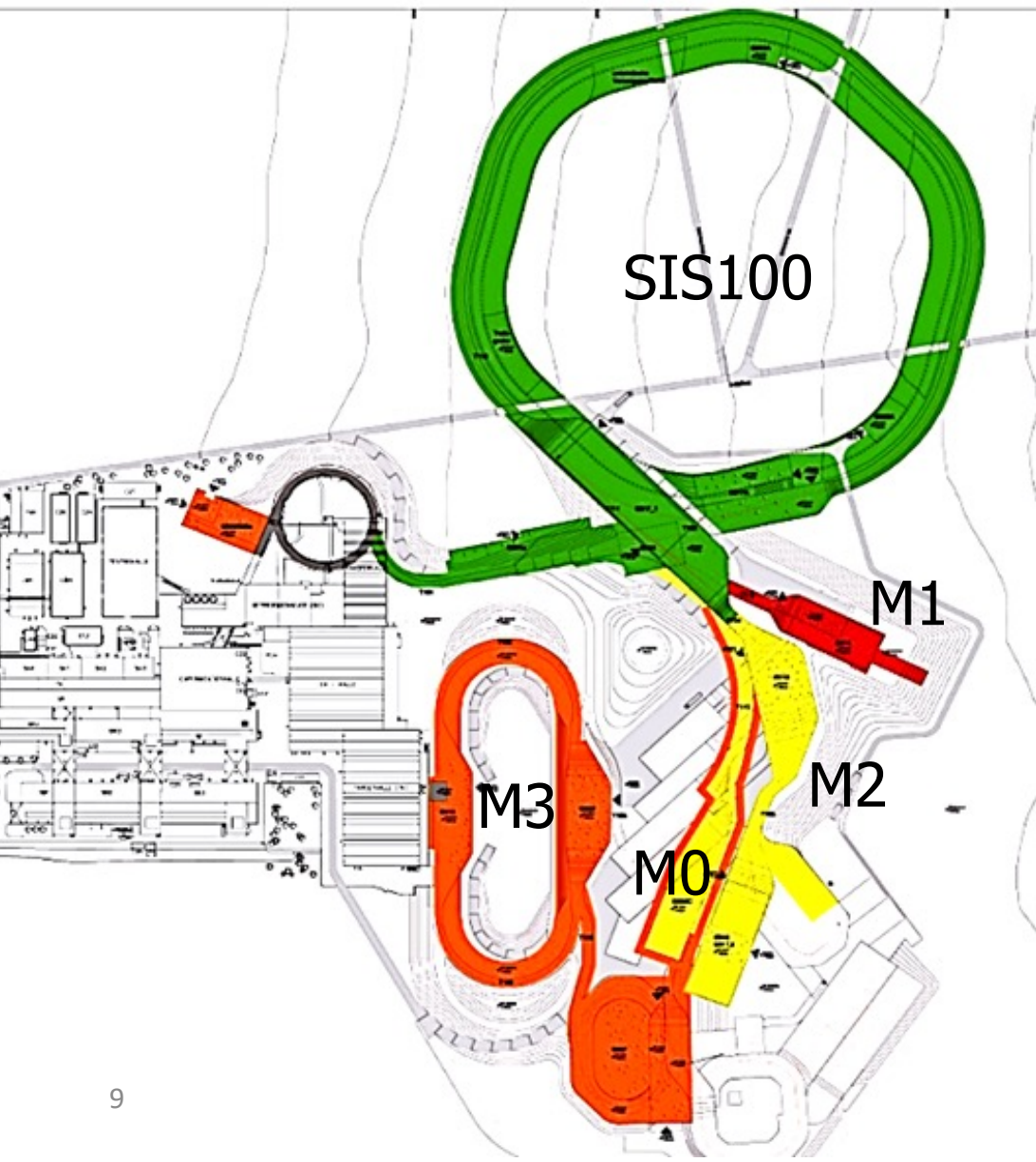
BARC-Mumbai (NPD)  
IIT Mumbai  
SINP- Kolkata  
VECC- Kolkata  
IIT Indore  
IIT- Gowhati  
Pune university  
AMU Aligarh  
South Gujarat Univ.  
NIT Jalandhar  
MSU Vadodara  
Magadh University  
TIFR- Mumbai

+ Industrial participation

**Motivation of our participation is to take part in advanced scientific and technological activities**



# The FAIR Modularized Start Version



## Experiments

M0: APPA

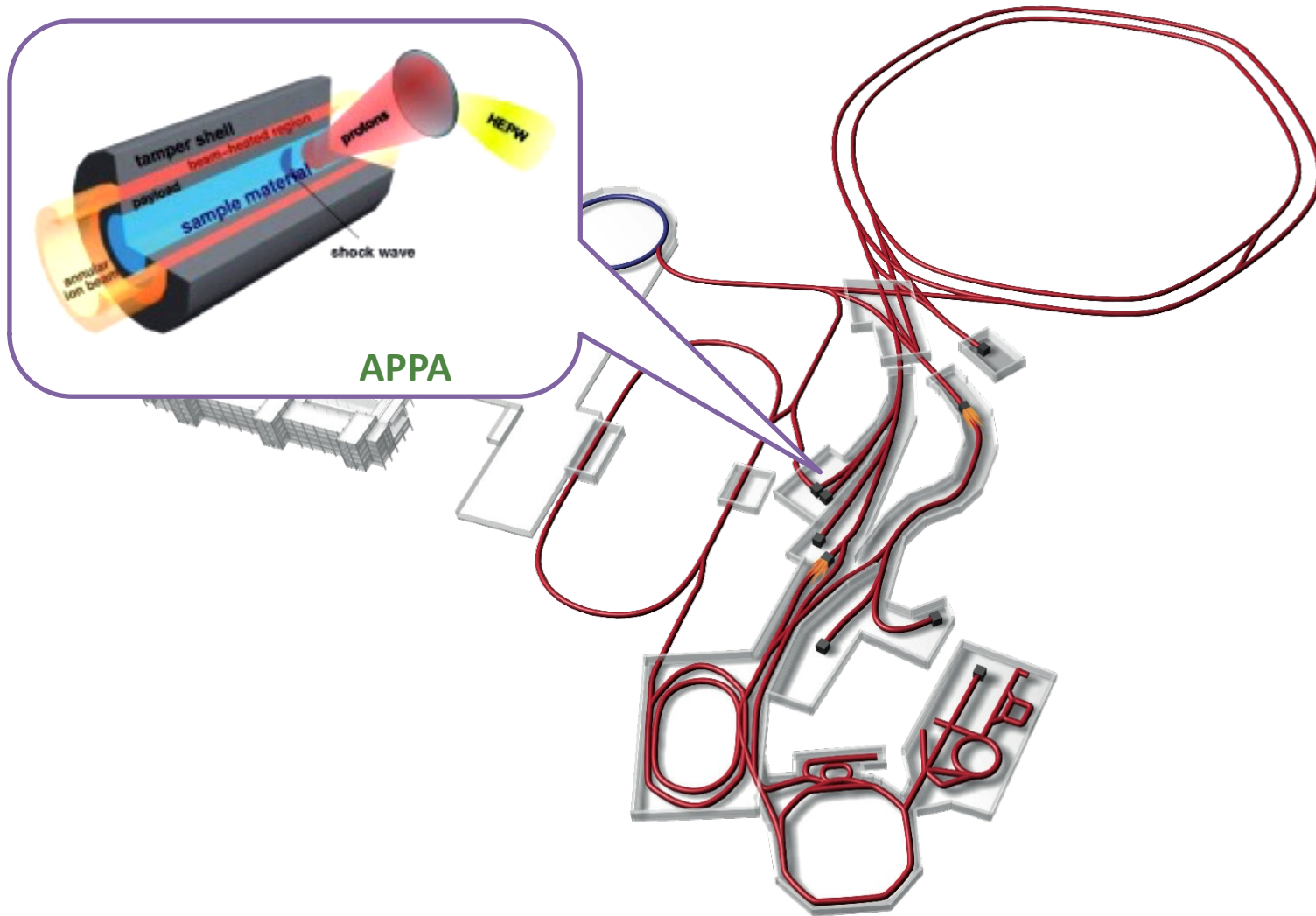
(Atomic Physics Plasma  
and Applications)

M1: CBM (Compressed  
Baryonic Matter)

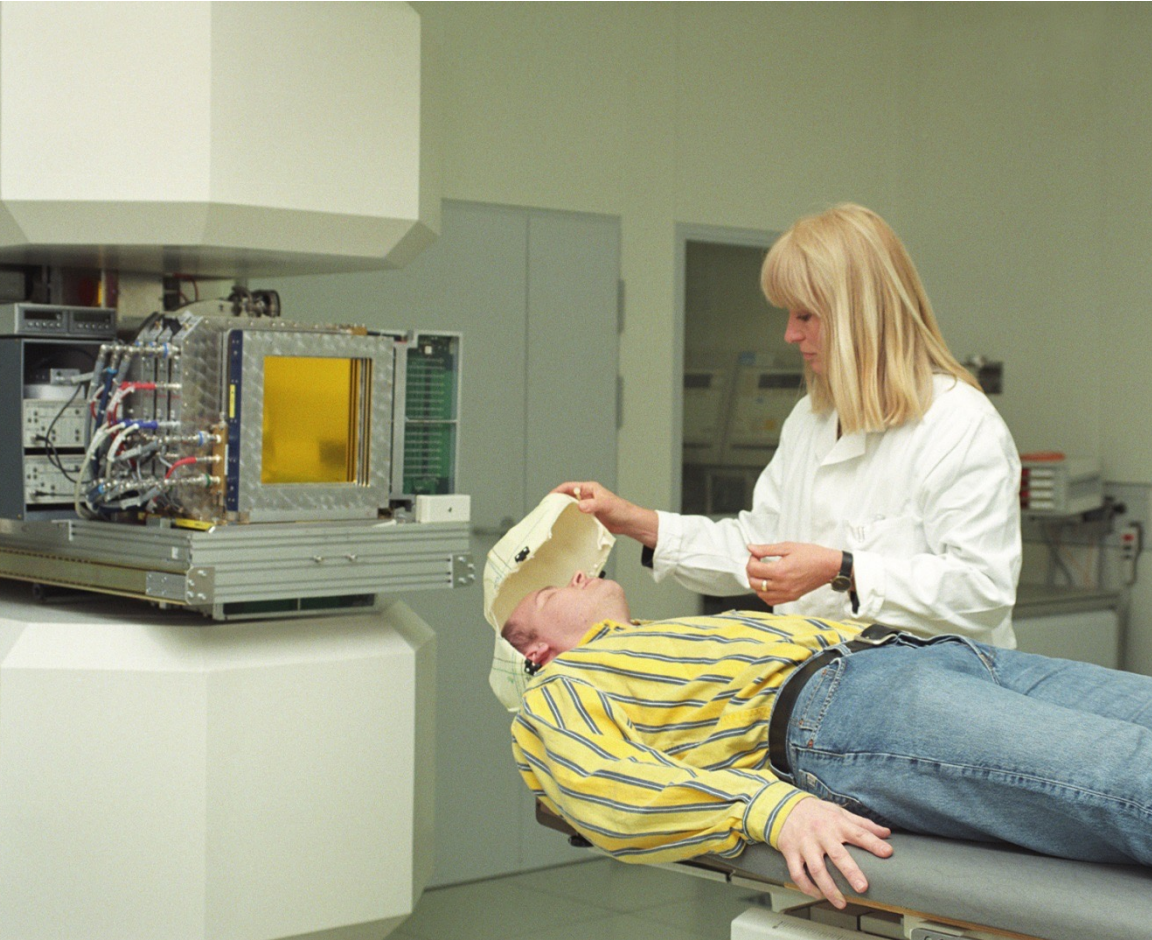
M2: NUSTAR (Nuclear  
Structure, Astrophysics  
and Reactions)

M3: PANDA  
(hadron physics)

# FAIR Experiments

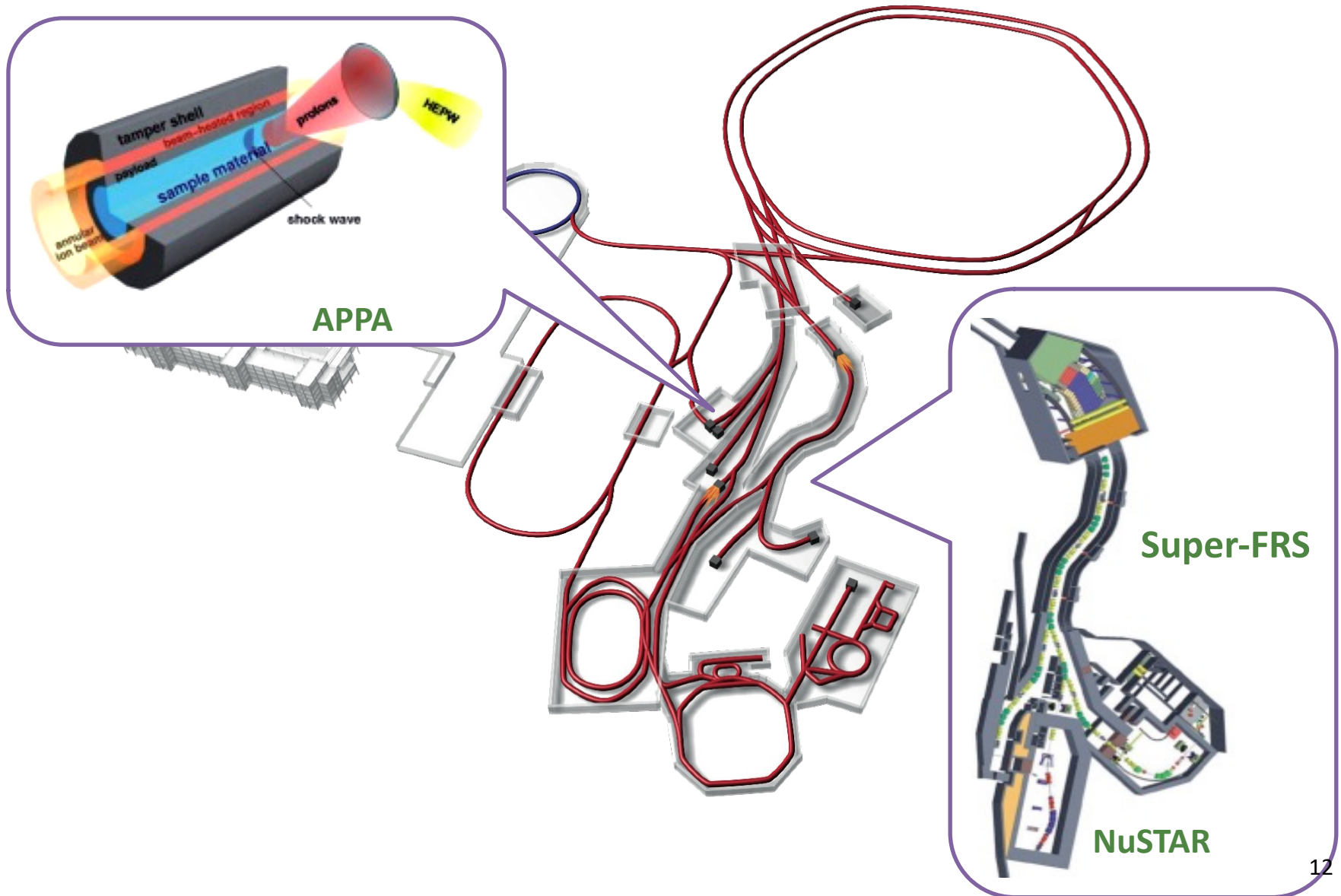


# Health and medical therapy



**Breakthroughs in medical research**

# FAIR Experiments



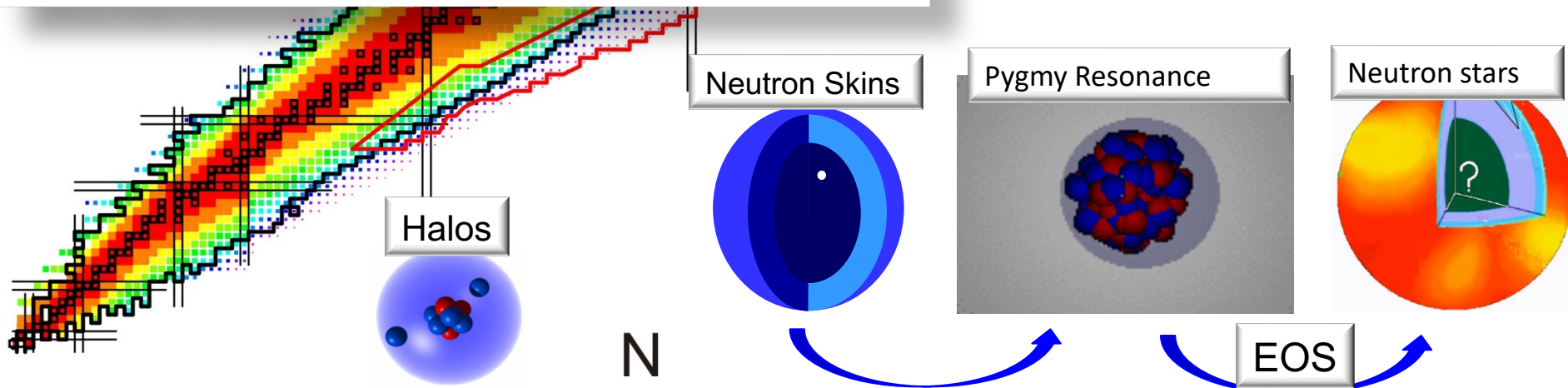
# NuSTAR: Nuclear Structure, Astrophysics, Reactions

## Quest for the limits of existence

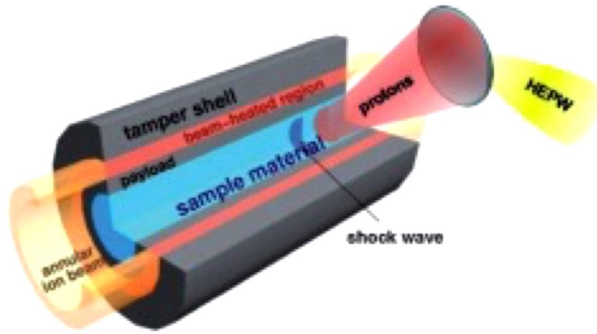
- Halos, Few Body Correlations
- Changing shell structure far away from stability
- Skins, new collective modes, nuclear matter, neutron stars
- Origin of the elements

$10^{10}$  /s  
 $10^8$  /s  
 $10^6$  /s  
 $10^3$  /s  
 $10^0$  /s  
 $10^{-3}$  /s  
 $10^{-6}$  /s

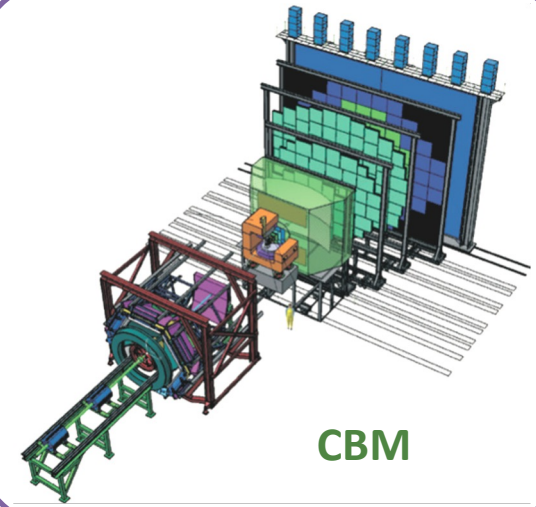
→ Combine accurate **nuclear physics** with precision **astronomy** to constrain **astrophysical scenarios**



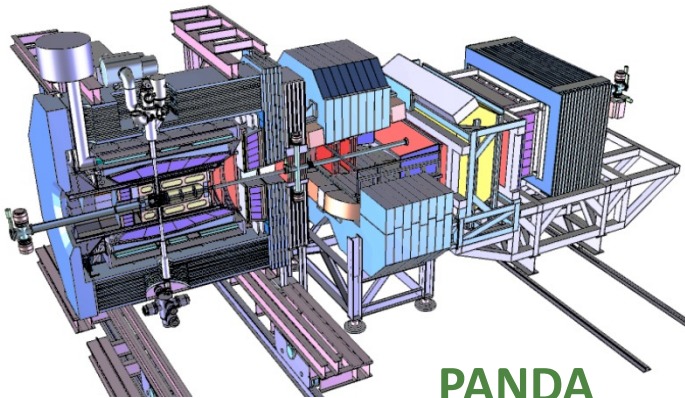
# FAIR Experiments



APPA



CBM



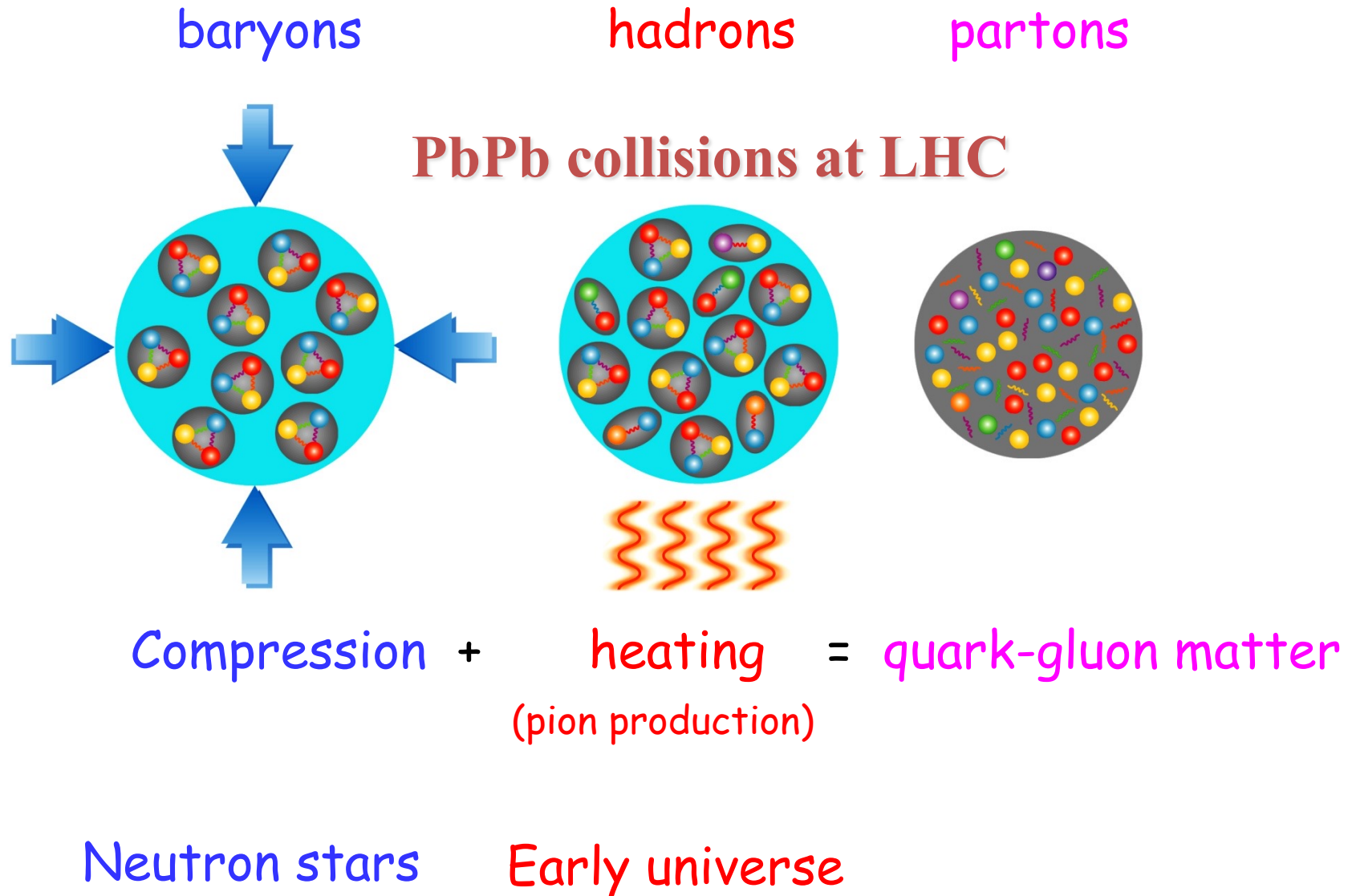
PANDA



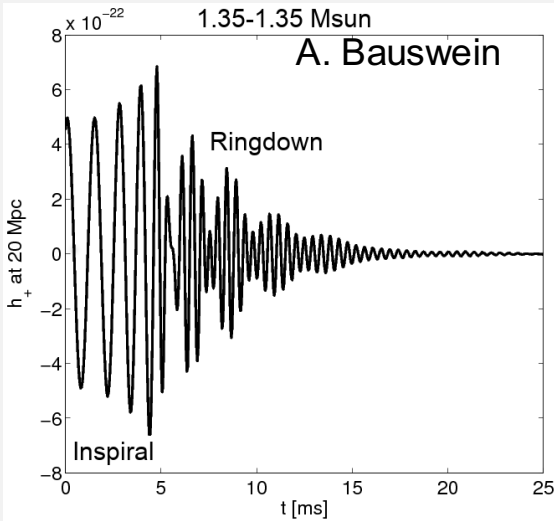
Super-FRS

NuSTAR

# States of strongly interacting matter



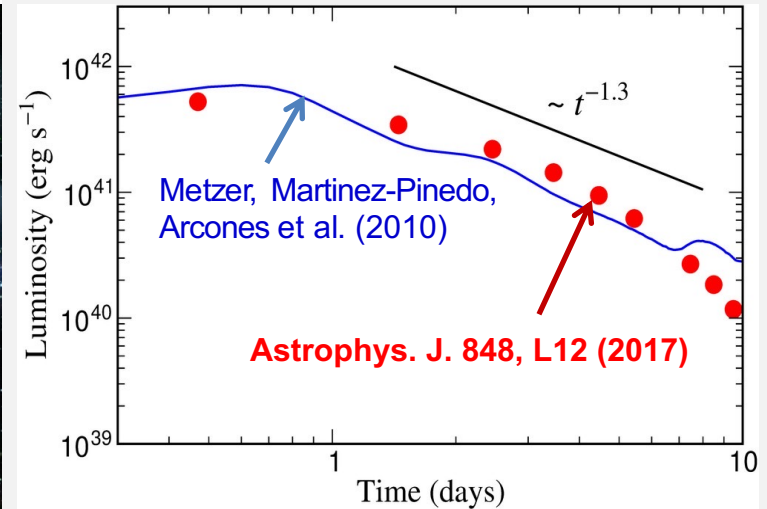
# Astrophysical site of heavy element production (r process) in the universe: Neutron star merger !



Gravitational  
Wave Signal



Copyright: Dana Berry, SkyWorks Digital, Inc



Electromagnetic  
"Kilonova" Signal

- Electromagnetic "Kilonova" signal due to "r process" in neutron star merger theoretically predicted by GSI scientists in 2010.
- Confirmation by recent astronomical observations after gravitational wave detection from GW170817 (August 2017).
- Source of heavy elements including gold, platinum and uranium.

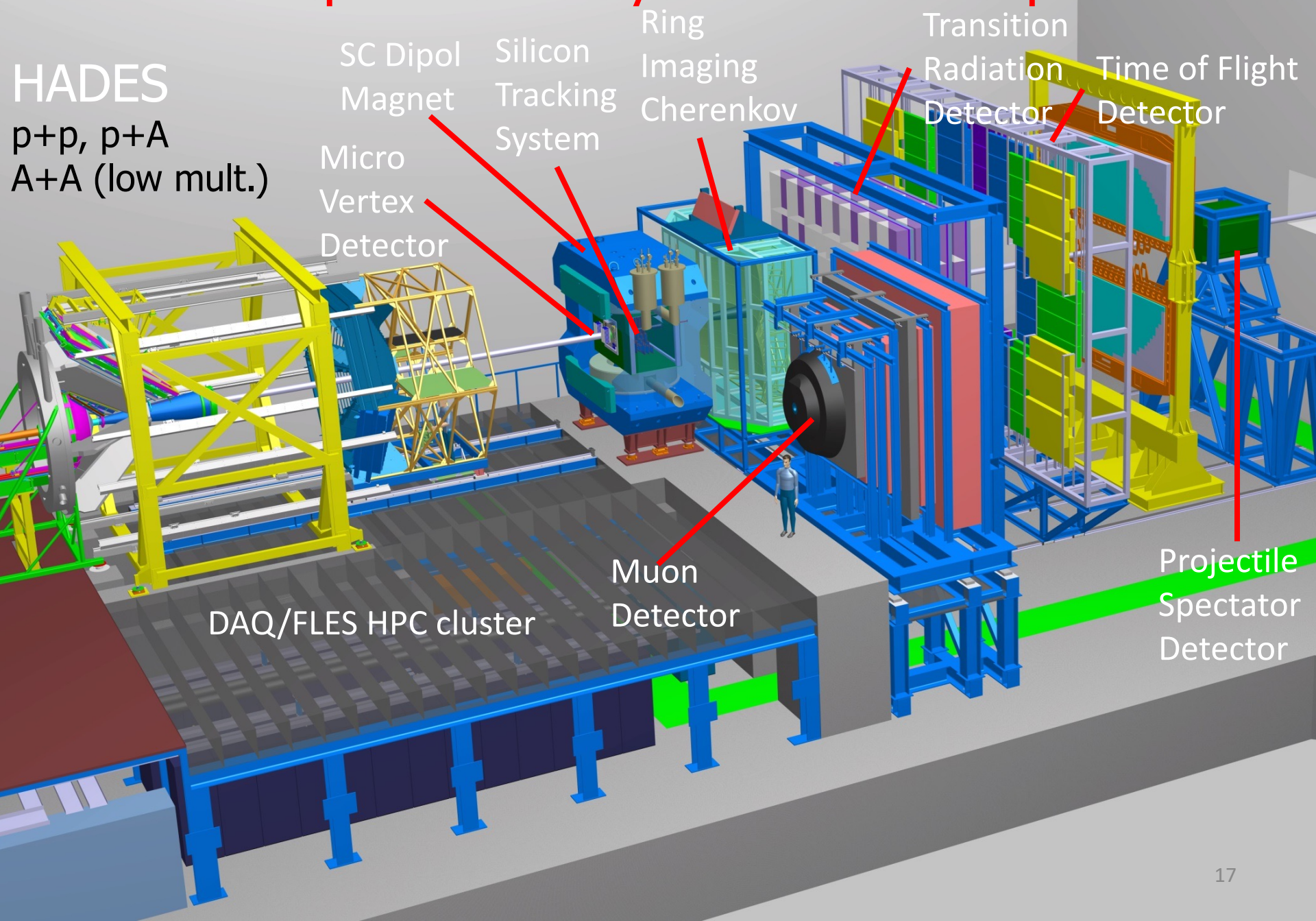
Renewed interest



# The Compressed Baryonic Matter Experiment

HADES

p+p, p+A  
A+A (low mult.)



SC Dipol  
Magnet

Silicon  
Tracking  
System

Ring  
Imaging  
Cherenkov

Transition  
Radiation  
Detector

Time of Flight  
Detector

Micro  
Vertex  
Detector

Muon  
Detector

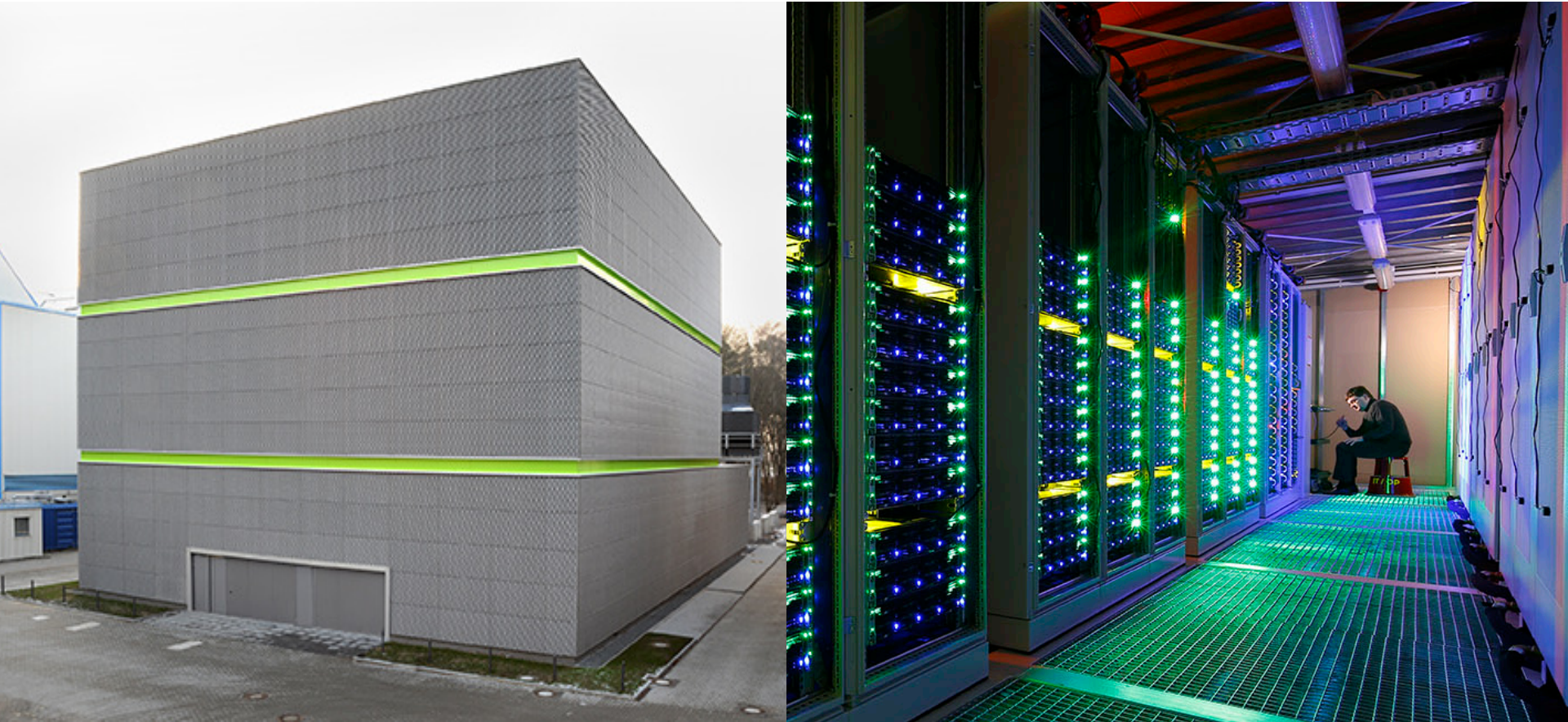
Projectile  
Spectator  
Detector

DAQ/FLES HPC cluster

# CBM experimental challenges

- $10^5 - 10^7$  Au+Au reactions/sec
- determination of (displaced) vertices ( $\sigma \approx 50 \mu\text{m}$ )
- identification of leptons and hadrons
- fast and radiation hard detectors
- free-streaming readout electronics
- high speed data acquisition and high performance computer farm for online event selection
- 4-D event reconstruction

# Forefront Technologies (Green IT)



- **Technological advancements in high-performance & scientific computing, Big Data, Green IT**

# Indian participation

(a) Accelerator equipment

(b) Experiment equipment

**7<sup>th</sup> February'07: signing of ministerial agreement on FAIR**



## JOINT DECLARATION

### CONCERNING THE PARTICIPATION IN CONSTRUCTION AND OPERATION OF THE INTERNATIONAL FACILITY FOR ANTI-PROTON AND ION RESEARCH (FAIR)

The Ministry of Science & Technology, Government of the Republic of India, and the Ministry of Education and Research, Government of the Federal Republic of Germany express their common intent to participate in the construction and operation of the International Facility for Antiproton and Ion Research (FAIR) to be built in Darmstadt, Germany.

The International Facility for Antiproton and Ion Research (FAIR) is going to be constructed and operated as an international facility in Darmstadt, Germany. It will provide the International science community with a worldwide unique and technically innovative accelerator system to perform forefront research in the sciences concerned with the basic structure of matter, and in intersections with other fields. The facility will deliver an extensive range of primary and secondary particle beams from protons and their antimatter partners, antiprotons, to ion beams of all chemical elements up to the heaviest, uranium, with in many respects unique properties and intensities.

#### 1. Purpose of this Joint Declaration

Germany and India have – together with other interested countries – signed a Memorandum of Understanding for the preparatory phase of FAIR, as testimony of their intention to become a member of this international facility and to participate in the construction and operation of FAIR. The purpose of this Joint Declaration is to specify the intended scope of their contribution.

#### 2. Frame of Participation

The basis of the participation in FAIR are the regulations laid down in the FAIR Convention and the Annexes thereof, in particular the Articles of Association, and the FAIR Baseline Technical Design Report issued in 2006.

It is understood that exchange of human resources between India and Germany centred around the FAIR programme will be most important. In this context, India intends to establish a network of Indo-FAIR Centres in India.

#### 3. Scope of Participation

The Federal Republic of Germany intends to contribute up to a maximum of 75 per cent of the construction cost of FAIR. The Republic of India intends to contribute at least 3 per cent of the construction cost. From the contribution by the Republic of India, a major part shall be in kind. Both sides intend to contribute in an appropriate way to the operating cost of FAIR.

#### 4. Implementation of Participation

The participation of both Parties in FAIR will become effective only upon signature of the FAIR Convention, together with the other Contracting Parties.

This Joint Declaration is signed in two copies, in English and German, respectively.

Done at New Delhi on February 7th, 2007

The Minister for Science & Technology  
and Earth Sciences

Government of India



Kapil Sibal

The Federal Minister of Education  
and Research

Federal Republic of Germany



Dr. Annette Schavan

# Joint Declaration

# FAIR GmbH formed on 4<sup>th</sup> October 2010



## Founder countries:

Germany

Russia

India

France

Poland

Romania

Finland

Slovenia

Sweden

# Indian in-kind accelerator items to the FAIR project

## In-kind Accelerator items identified from India

I. Ultra-stable Power Converters for FAIR magnets: ECIL – provider: 678 units , Design: DAE labs  
*339 shipped and accepted*

II. Ultra-high Vacuum Chambers for beam diagnostics –VT-Blore, provider: 71 Units  
*58 shipped and accepted*

III. Beam Stopper to stop high intensity beams with proper cooling: 3 Units  
*Design- CMERI-CSIR, Durgapur*  
*PO issued to an Indian company*

IV. Co-axial power cables (194 Km, 4 types):  
*PO issued to an Indian company*

V. IT-cables (16 types) : *PO issued to an Indian company*

VI. Steel roof-shielding (~700 tonne): *PO issued to an Indian company*

VIII: Design of superconducting magnets for FAIR, completed: VECC team





Tri-party agreement with ECIL for power converter: 2011



# Ultra-stable Power converters



At ECIL-Hyd



At FAIR, Germany



# Ultra-high vacuum chambers

Vacuum Technique , Blore

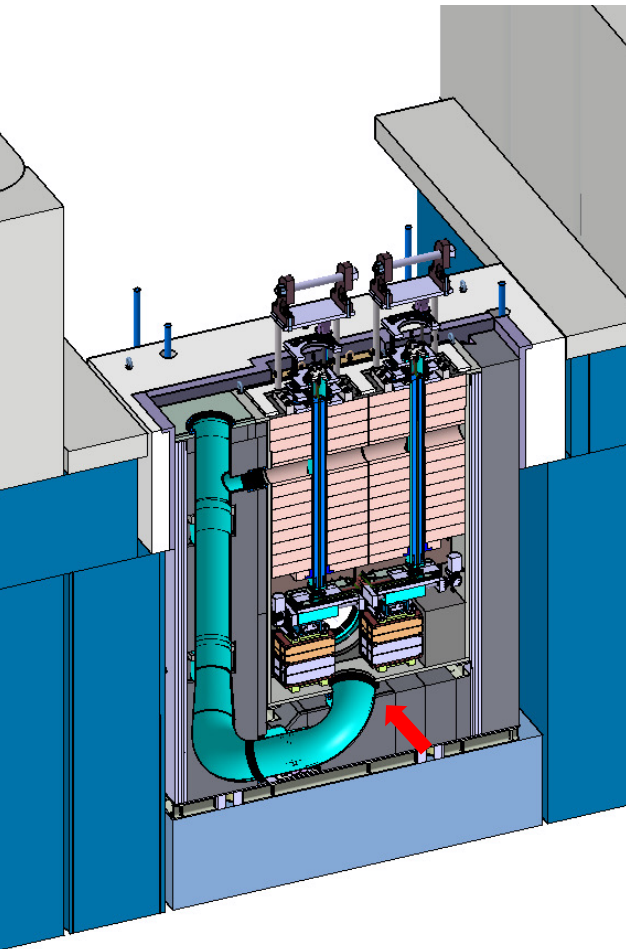


At FAIR, Germany

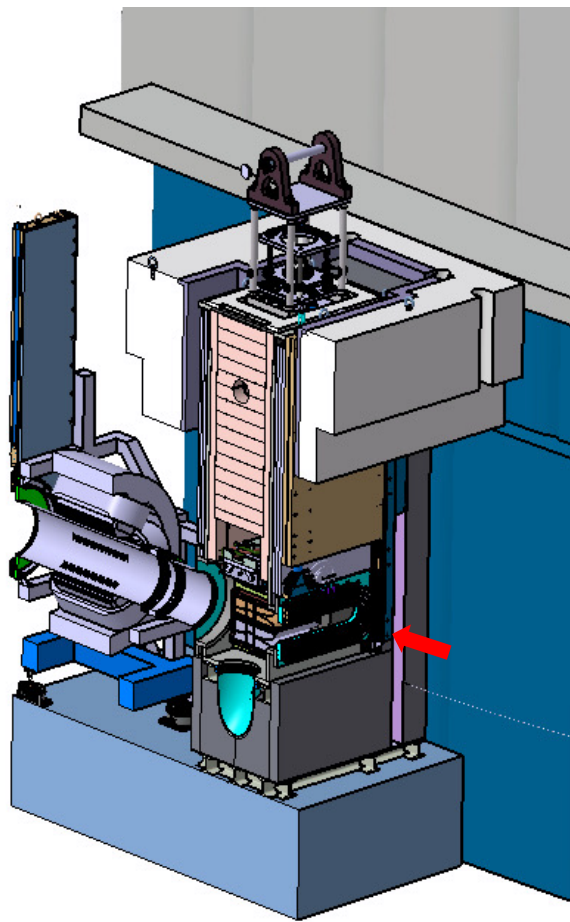




Agreement signed with CMERI-Durgapur for beam stopper



Transverse section view



Longitudinal section view

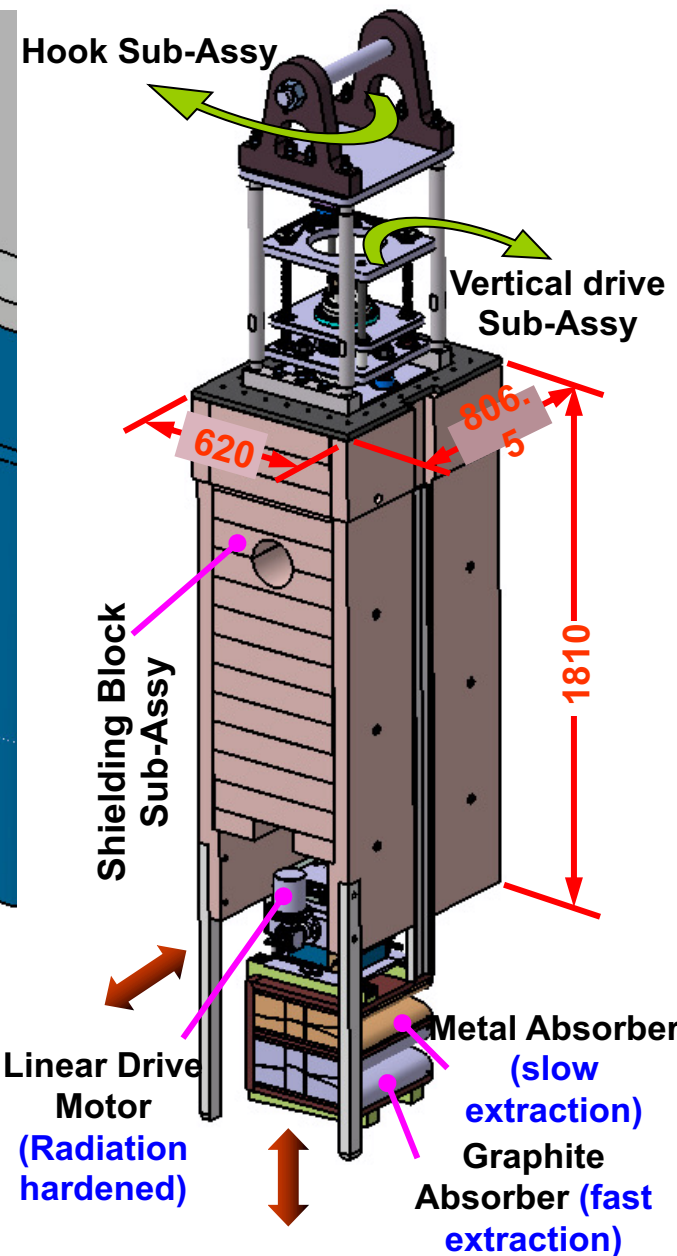
**BC1, BC2, BC3 Cavity Dimensions**

**Structural Frame**

- Dimensions (LxBxH): 2838mm x 860mm x 3350mm
- **BC1, BC2 and BC3 frames are identical**

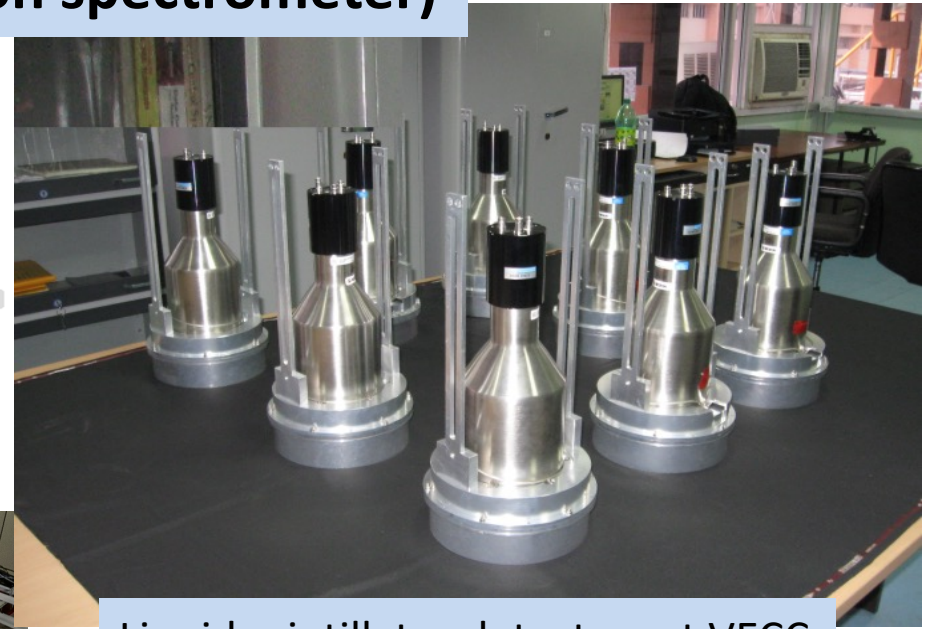
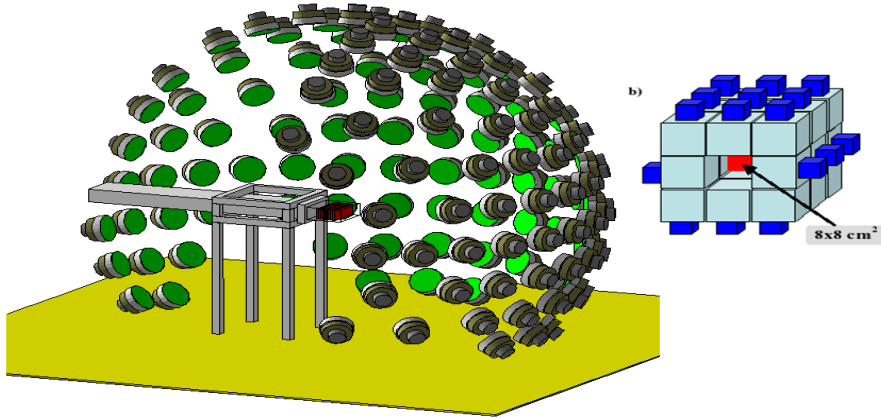
**Vacuum Cavity**

- Dimensions (LxBxH): 1600mm x 600mm x 2520mm

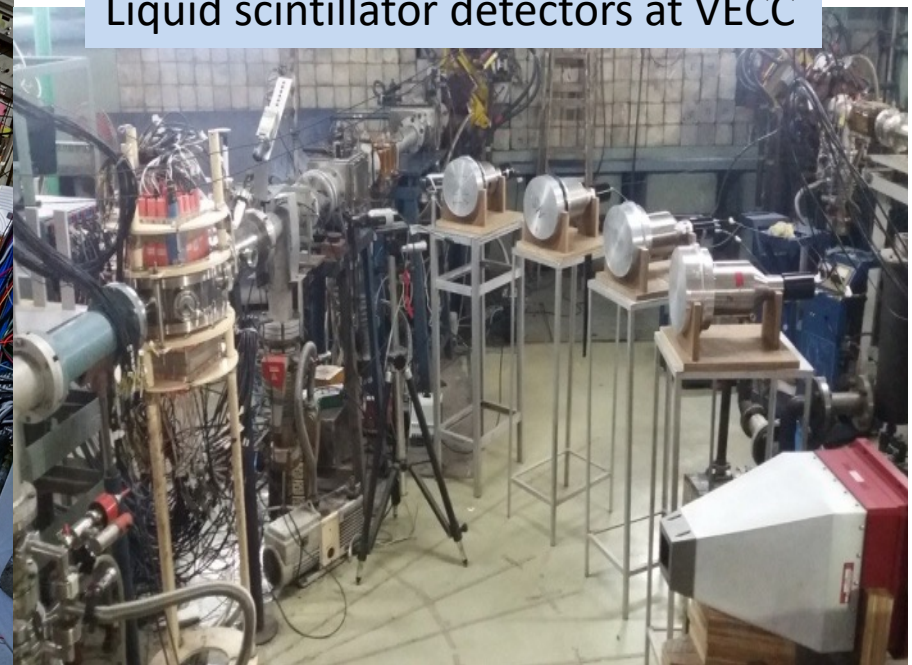
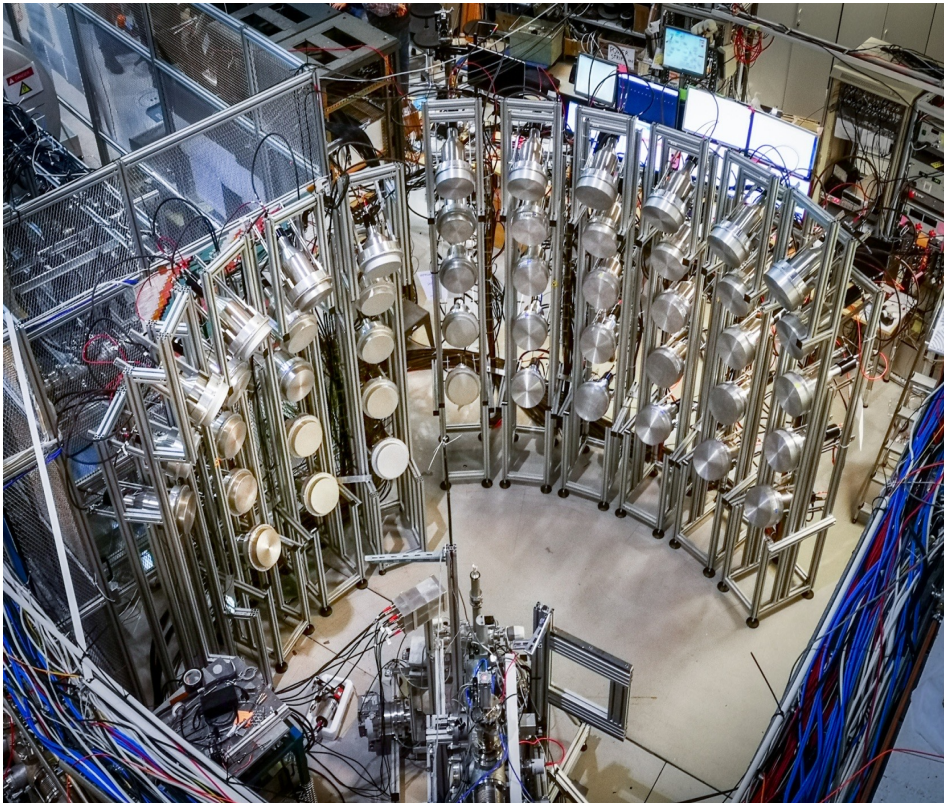


**BC3 Top Plug Assy (≈7.0t)**

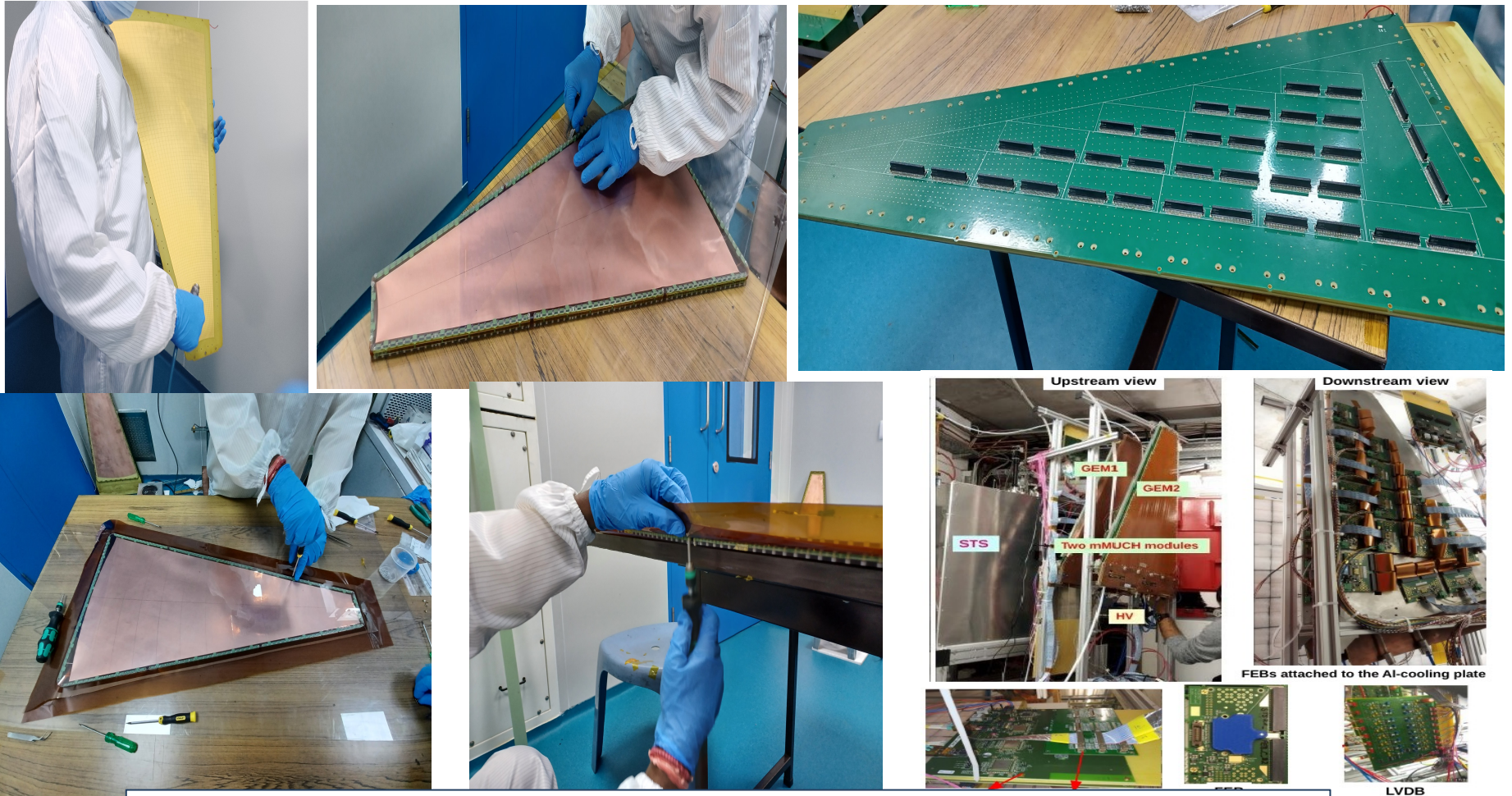
# MONSTER Array (neutron spectrometer)



Liquid scintillator detectors at VECC



# GEM MODULE ASSEMBLY and testing at mCBM

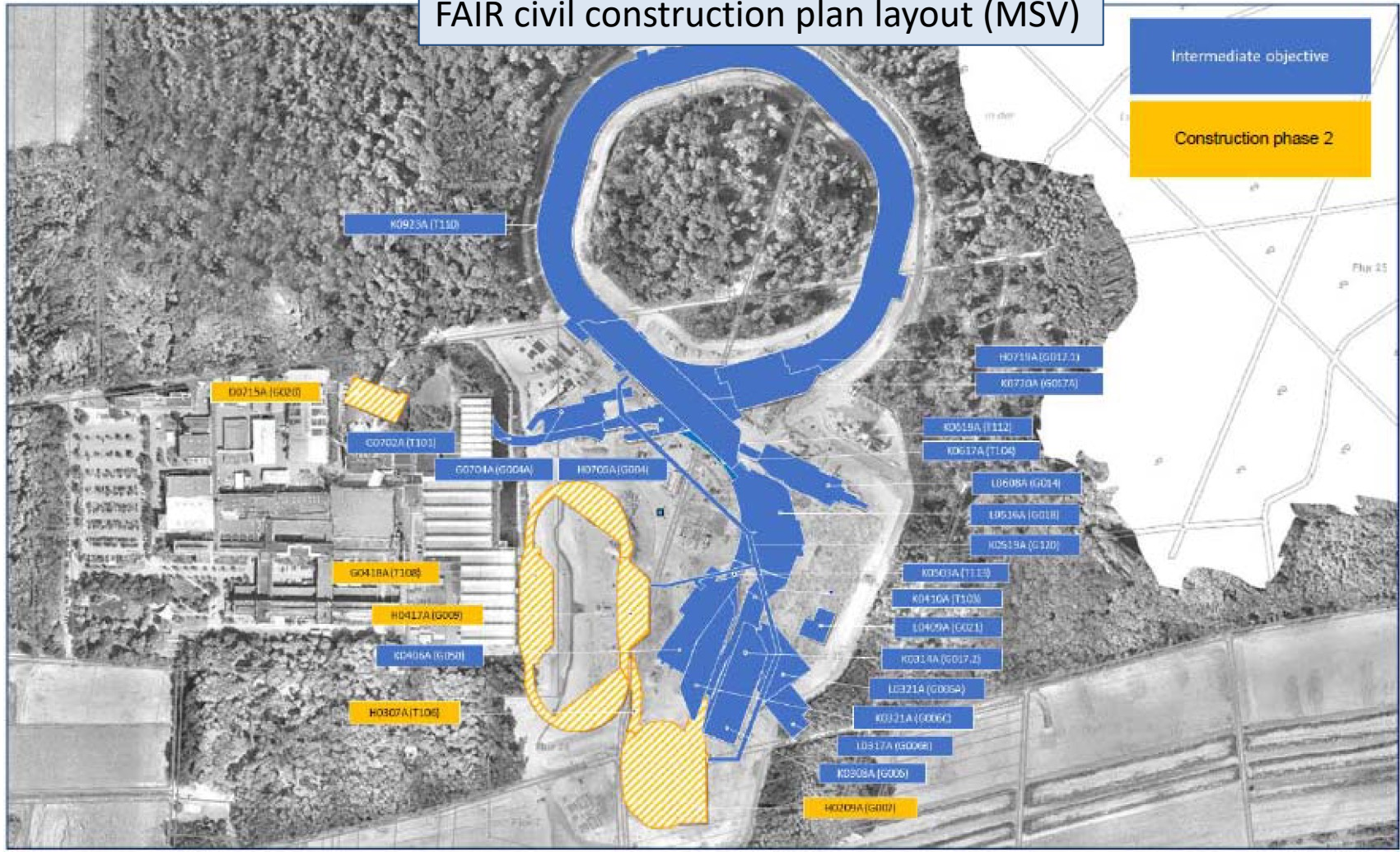


Tested at mCBM (Au+Au, Au+Ni, U+Au collisions) upto 350 KHz/cm<sup>2</sup> hit rate  
without any saturation in efficiency  
**Ready for production**



# FAIR civil construction: plan

FAIR civil construction plan layout (MSV)



November 2021



- Civil Construction continues to make good progress

Agenda item  
7c

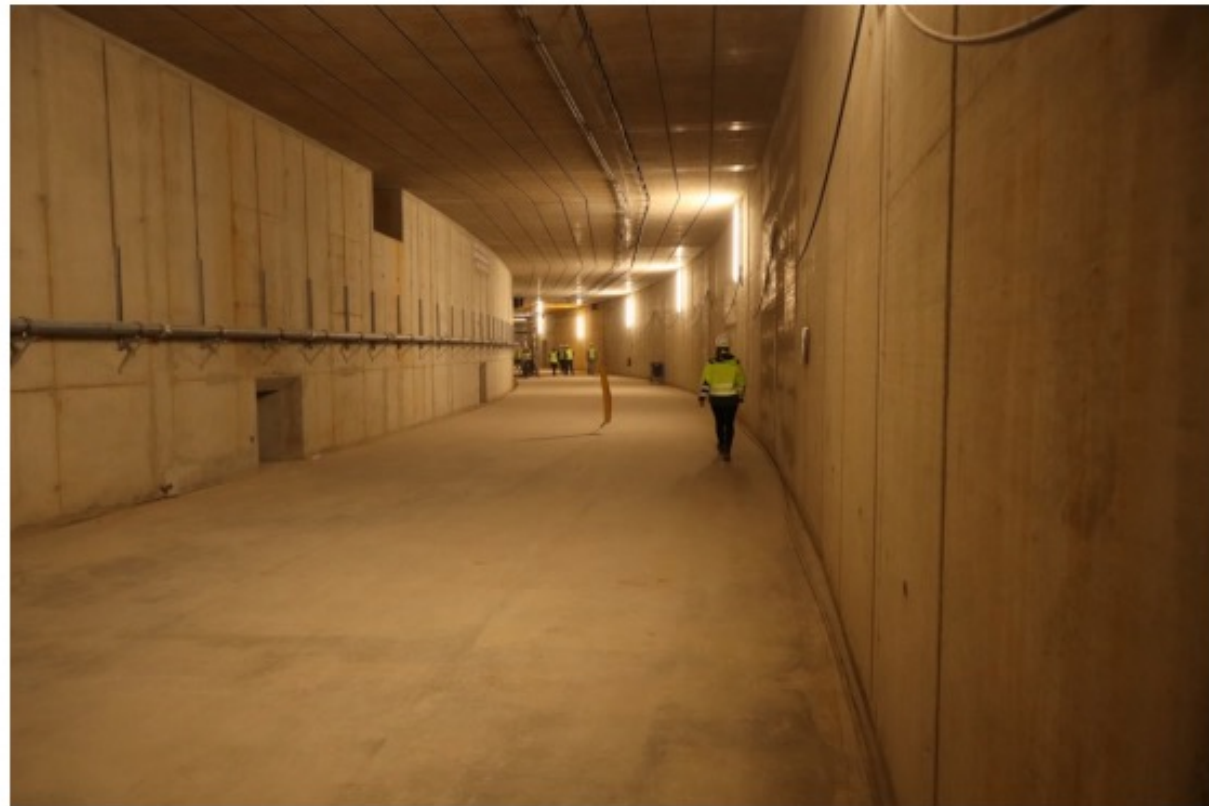


October, 2022

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



Towards SIS100

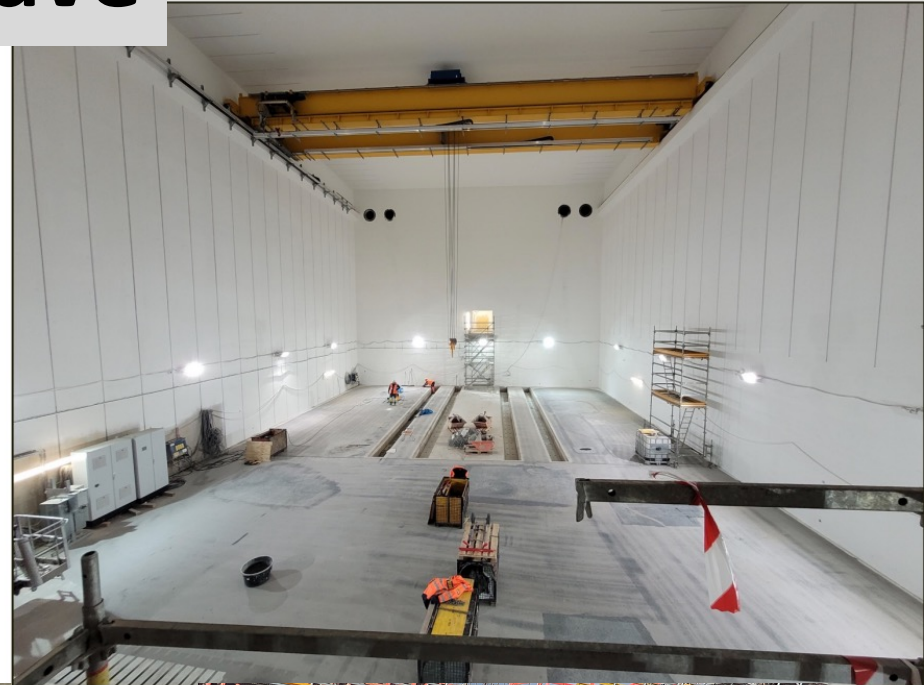


1100 m trip under the roof

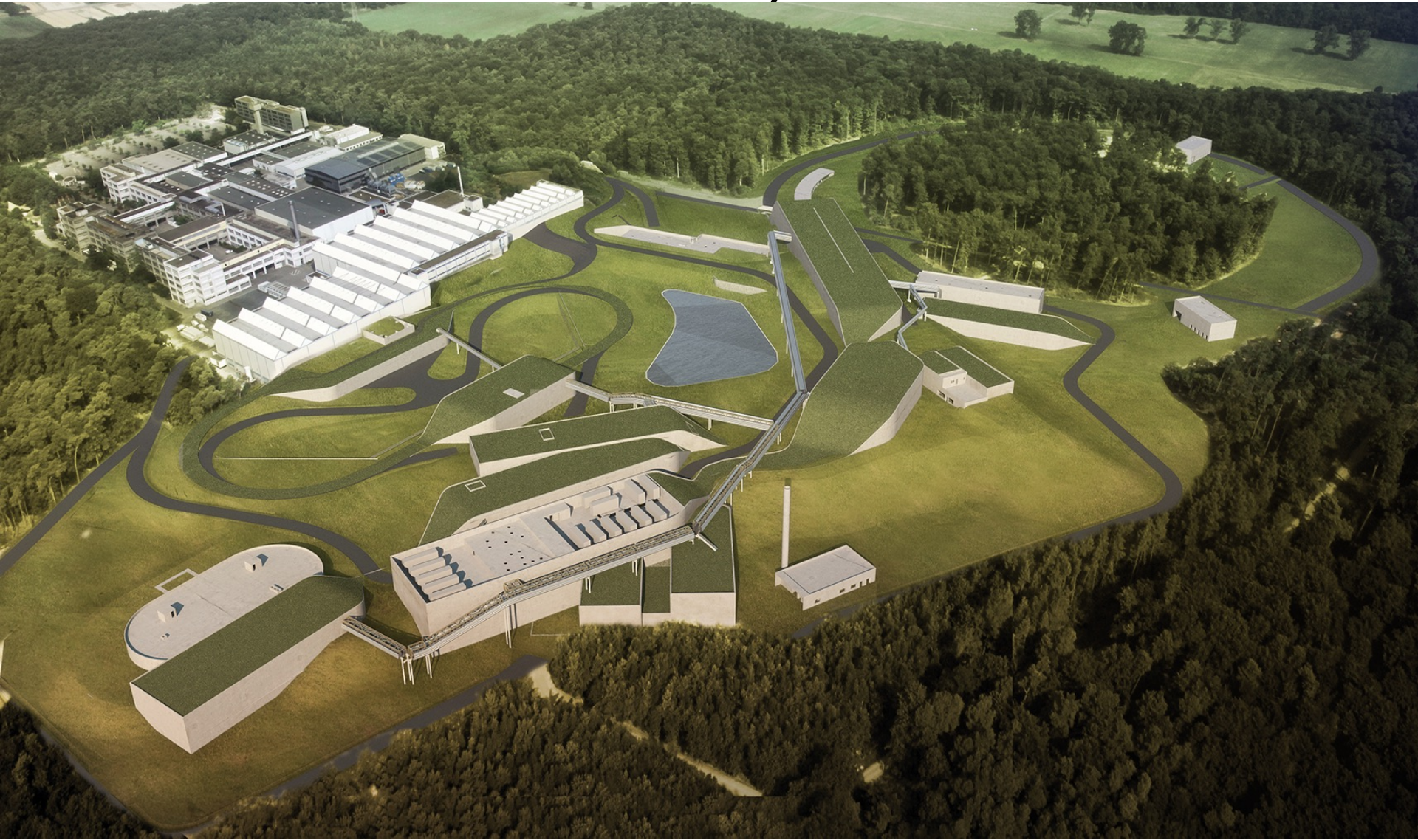
# Visiting the facility (July 2022)



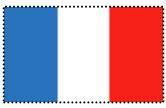
# CBM cave



# FAIR: A reality in 2028 !!



**Finland**



**France**



**Germany**



**India**



**Poland**



**Romania**



**Russia**



**Slovenia**



**Sweden**



**UK**

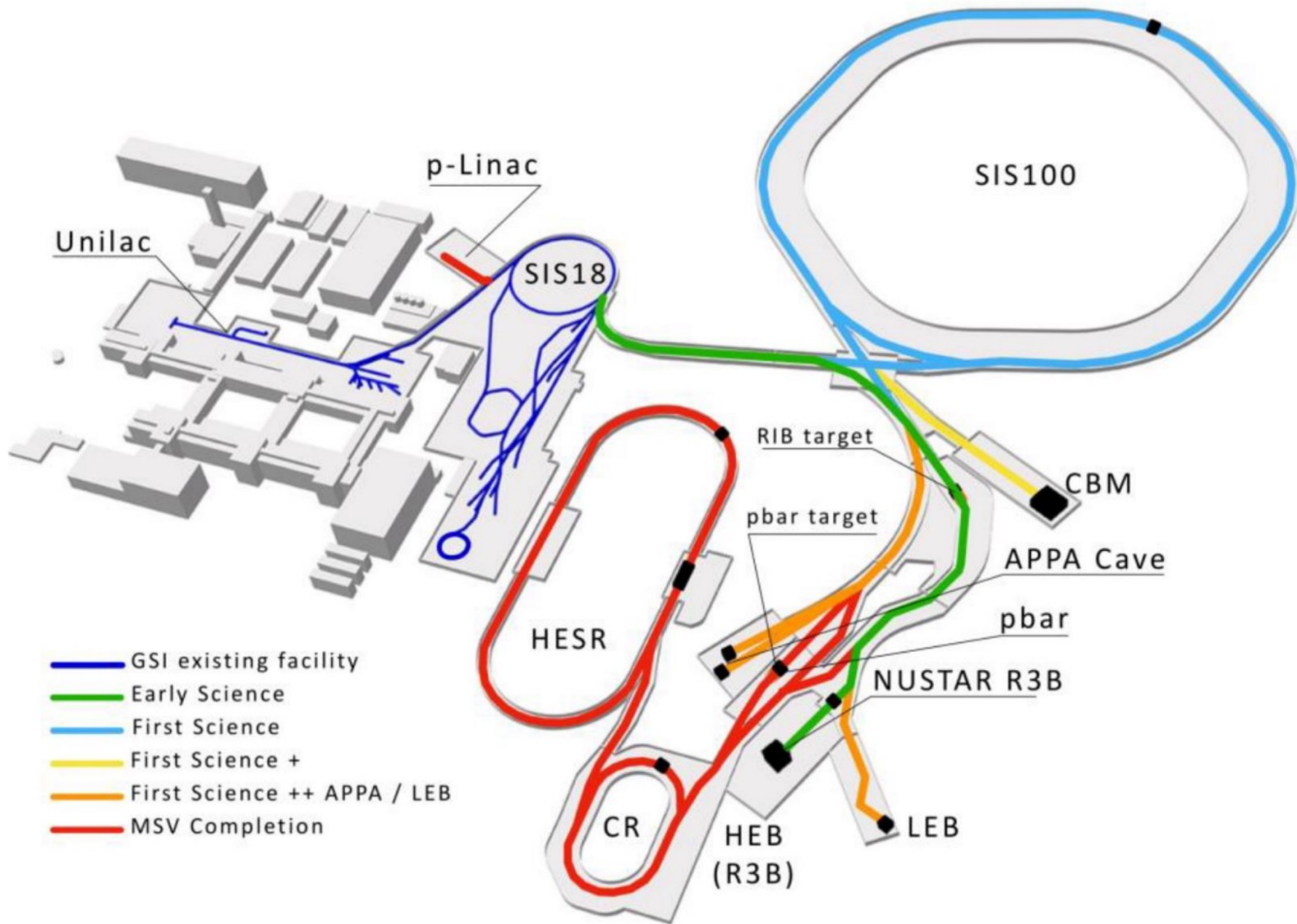
# Impact of recent world developments on FAIR

- Feb'22: Conflict between Russia and Ukraine started
- An International review committee (Chairs: Prof. R. Heuer, Prof. Tribble) formed by the FAIR council for an **early science review**
- Review results (**FAIR First science (FS)**): (a) *Super-FRS to be made ready with R3B cave, NUSTAR experiments* (b) *SIS100 to be made ready*

*FS+: CBM cave and beamline to CBM*

- FAIR cancelled all collaboration contracts to Russian institutes for in-kind items
- *Exception is made ion JINR-Dubna, discussions ongoing*
- *(Indian industry can help to build those components)*
- March'23: German govt has pledged fund for the FS scenario.
- *All Indian accelerator in-kind contributions are in the FS phase*





# Industry meet held on 10/5/2012 at Hyderabad



**24 members, 14 houses**

- 1. ECIL (Hyderabad)**
- 2. BHEL (New Delhi)**
- 3. L&T (Mumbai)**
- 4. National Instruments (Bangalore)**
- 5. Indo-German tool room (Indore)**
- 6. Hind-Hi vac (Hyderabad)**
- 7. VT-vacuum (Bangalore)**
- 8. Vacuum Techniques (Bangalore)**
- 9. Avsarala (Bangalore)**
- 10. Stesalit (Kolkata)**
- 11. Pfeiffer-Vacuum (Secunderabad)**
- 12. Rittal (Secunderabad)**
- 13. Seto Teknolog Pvt Ltd (mumbai)**
- 14. Growcontrols(Hyderabad)**



- An world laboratory coming up for studying the universe, past and present
- India is a member state with a significant contributions both science and technology
- Indian industry is requested to come forward to make it a reality
- FAIR colleagues are requested to help in this effort

# APPA: Atomic Physics, Plasma Physics, Bio Physics and Applied Sciences

## Atomic Physics

(SPARC & FLAIR)

Dynamic electric fields (upto  $10^{20}$  V/cm) produced in collisions of heavy ion beams give access to

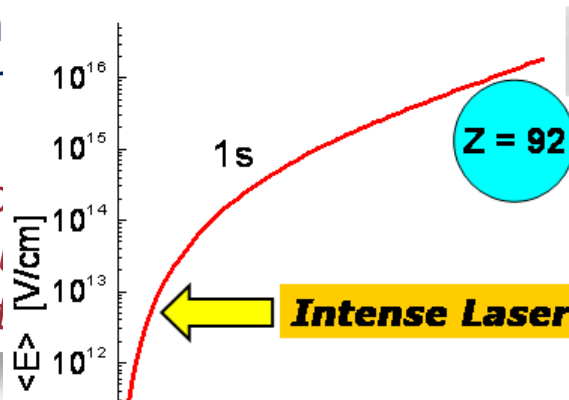
- *Spectroscopy upto the limits of atomic matter*
- *QED in non-perturbative regime*
- *Precision determination of fundamental constants*
- *Influence of atomic structure on nuclear decay properties*

## Plasma Physics

(Hedgehog & WDM)

High inten  
of extrer

- *Equatic*
- *Matter*
- *Interact*



get produce plasma  
(planets)

transport phenomena

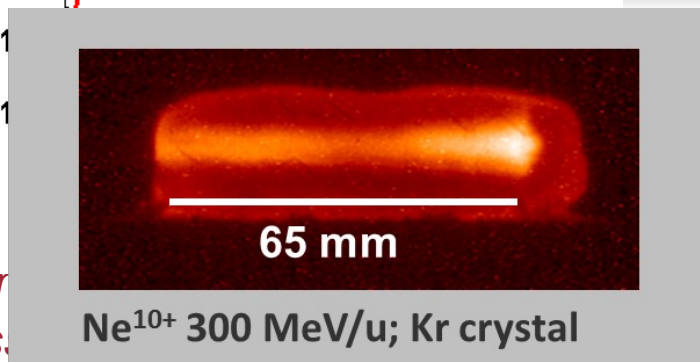
plasma

## Bio Physics &

Materials Science (BIOMAT)

High inten  
access:

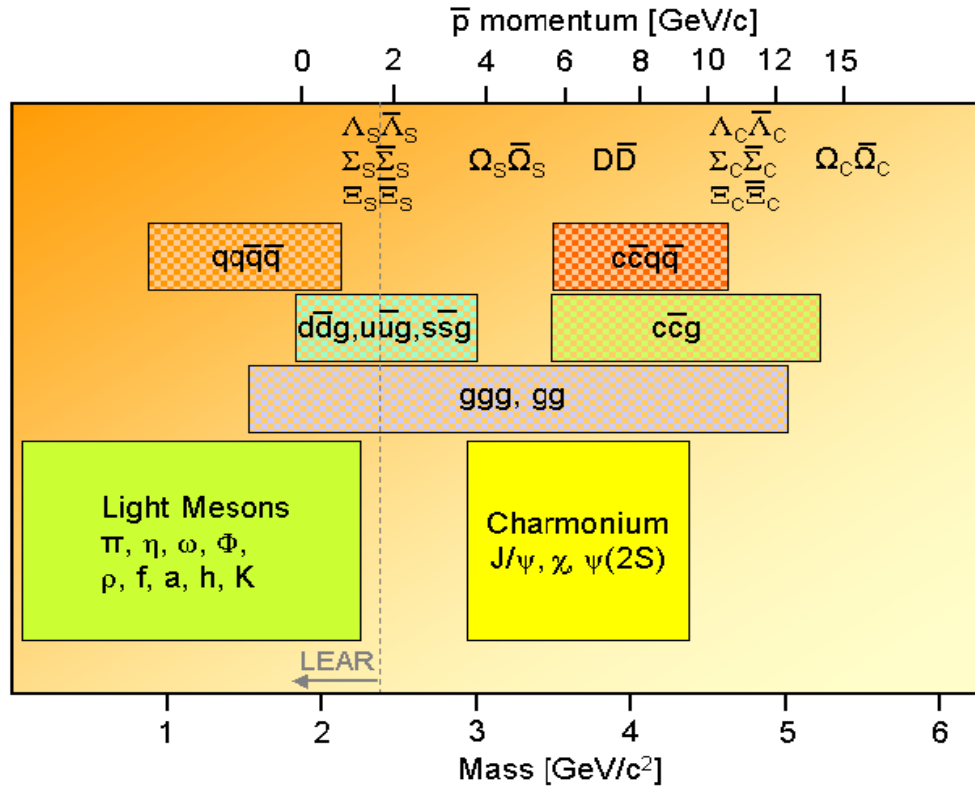
- *Cosmic*
- *Cancer*
- *Material m*
- *High-pres*



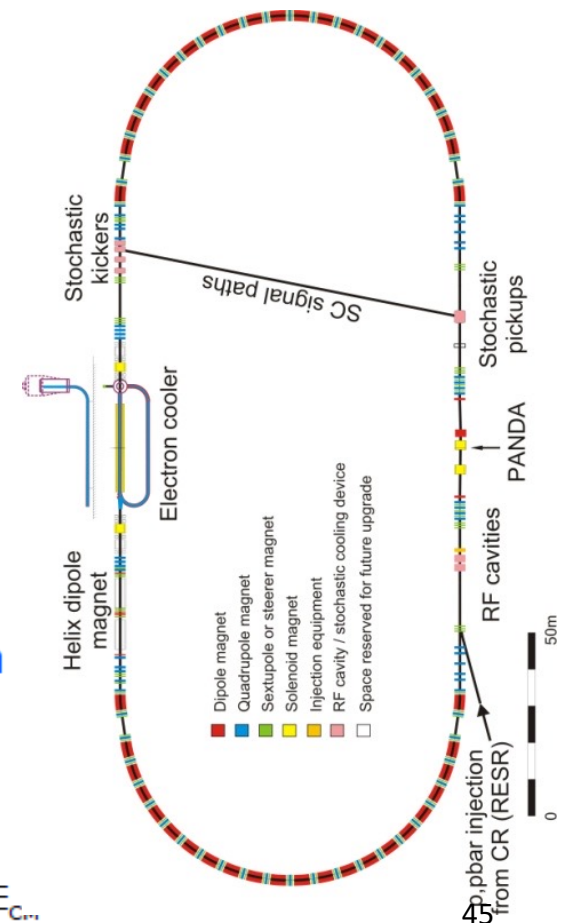
material targets to

ce

# Anti-Proton Annihilation @ DA

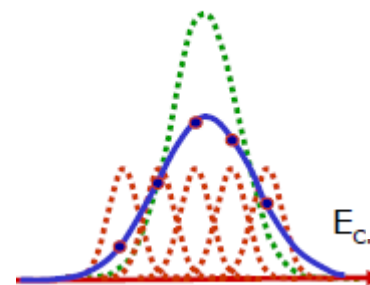


HESR:  
High-Energy  
Storage Ring

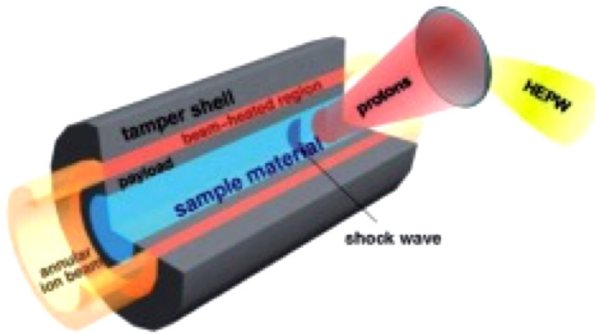


- Luminosity up to  $L \sim 2 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$
- Stochastic & electron cooling
- Resolution  $\sim 50 \text{ keV}$
- Tune  $E_{\text{CM}}$  to scan resonance
- Get precise  $m$  and  $\Gamma$

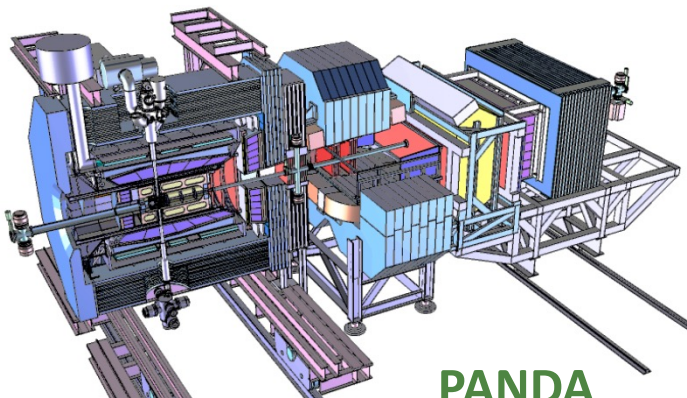
Resonance Scan



# FAIR Experiments



APPA



PANDA



Super-FRS

NuSTAR