Indian participation in the construction of the Facility for Antiproton and Ion Research (FAIR)

Saikat Biswas

Bose Institute, Kolkata

10th Asian Triangle Heavy-Ion Conference - ATHIC 2025

January 13 – 16, 2025, IISER, Berhampur

Department of Science and Technology
Ministry of Science and Technology
Government of India

Indo-German Cooperation in High Energy Heavy-Ion Physics

It all started in 1990-91

Large detectors built at CERN

In collaboration with

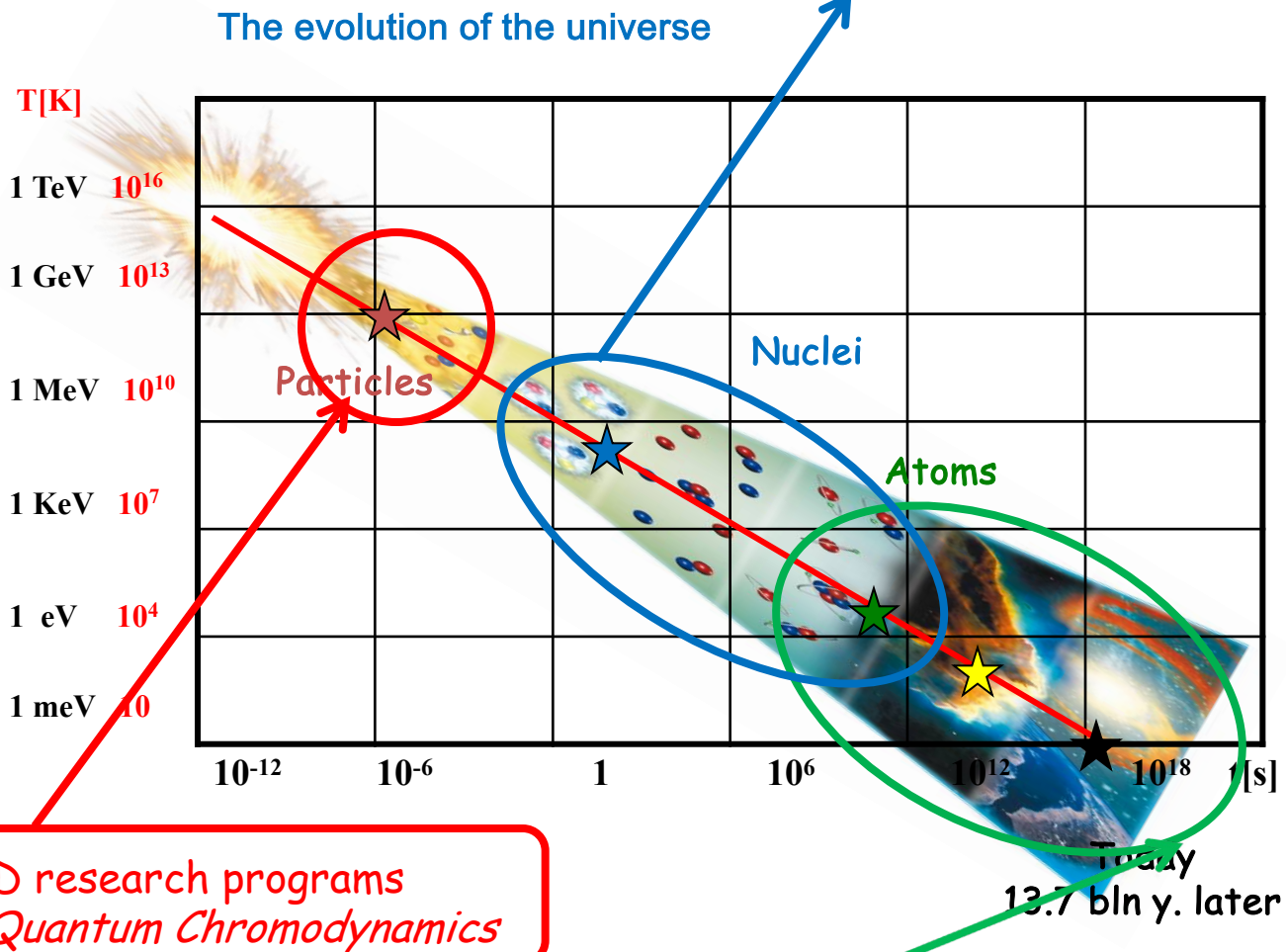
GSI, Germany

NuPECC summarized Nuclear Physics questions:

- How do the structure of hadrons and their interactions emerge from QCD?
- What is the structure of nuclear matter?
- What are the phases of nuclear matter?
- What is the role of nuclei in shaping the evolution of the Universe?
- What lies beyond the Standard Model?

Physics at FAIR

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

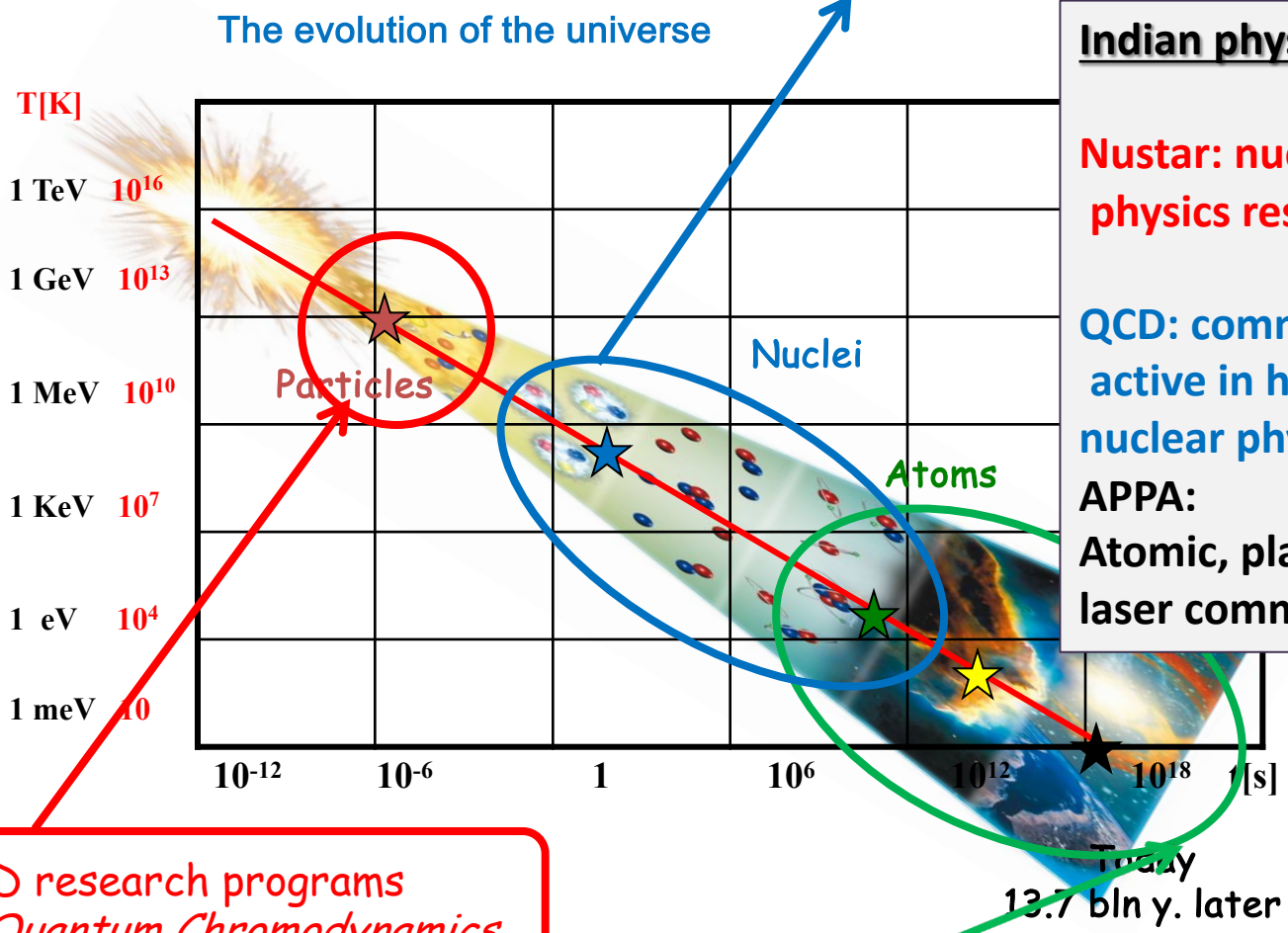


FAIR – QCD research programs
(*Quantum Chromodynamics*

_FAIR – APPA research programs
(*Atomic ,Plasma Physics and Applications)*

Physics at FAIR

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



Indian physics 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)*

Four Pillars of FAIR

- APPA Physics (Atomic, Plasma Physics and Applications)
- CBM – Compressed Baryonic Matter
- NUSTAR Physics (Nuclear Structure, Astrophysics and Reactions)
- PANDA – Antiproton Annihilation at Darmstadt

Indian participation in FAIR Experiments

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
Aligrah Muslim University, Aligrah
Karnatak University, Dharwa
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
NISER, Jatni
IIT Kharagpur
Gowhati Univ.
Bose-Institute, Kolkata
North Bengal Univ, WB

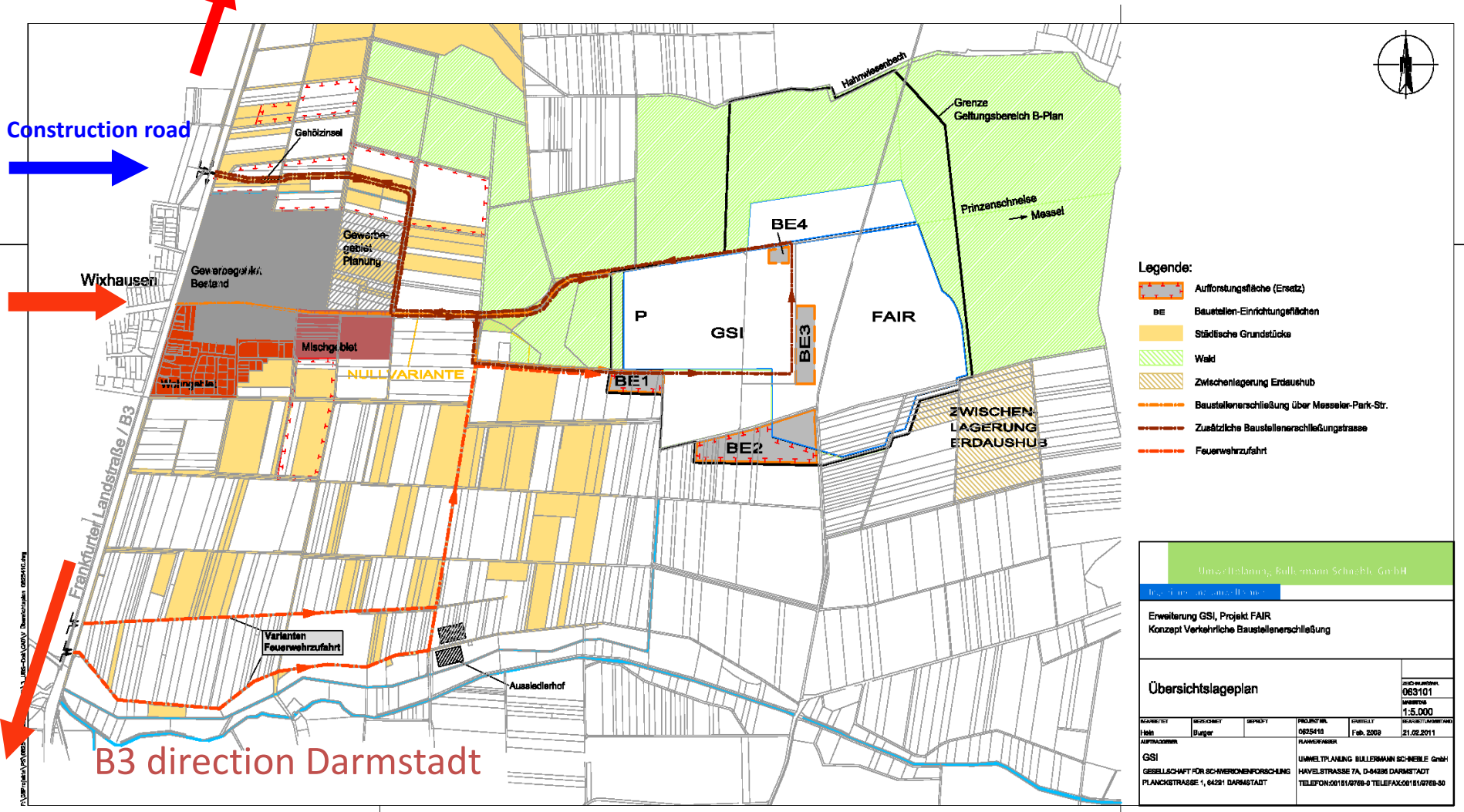
India-PANDA collaboration (EOIs)

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

+ APPA collaboration

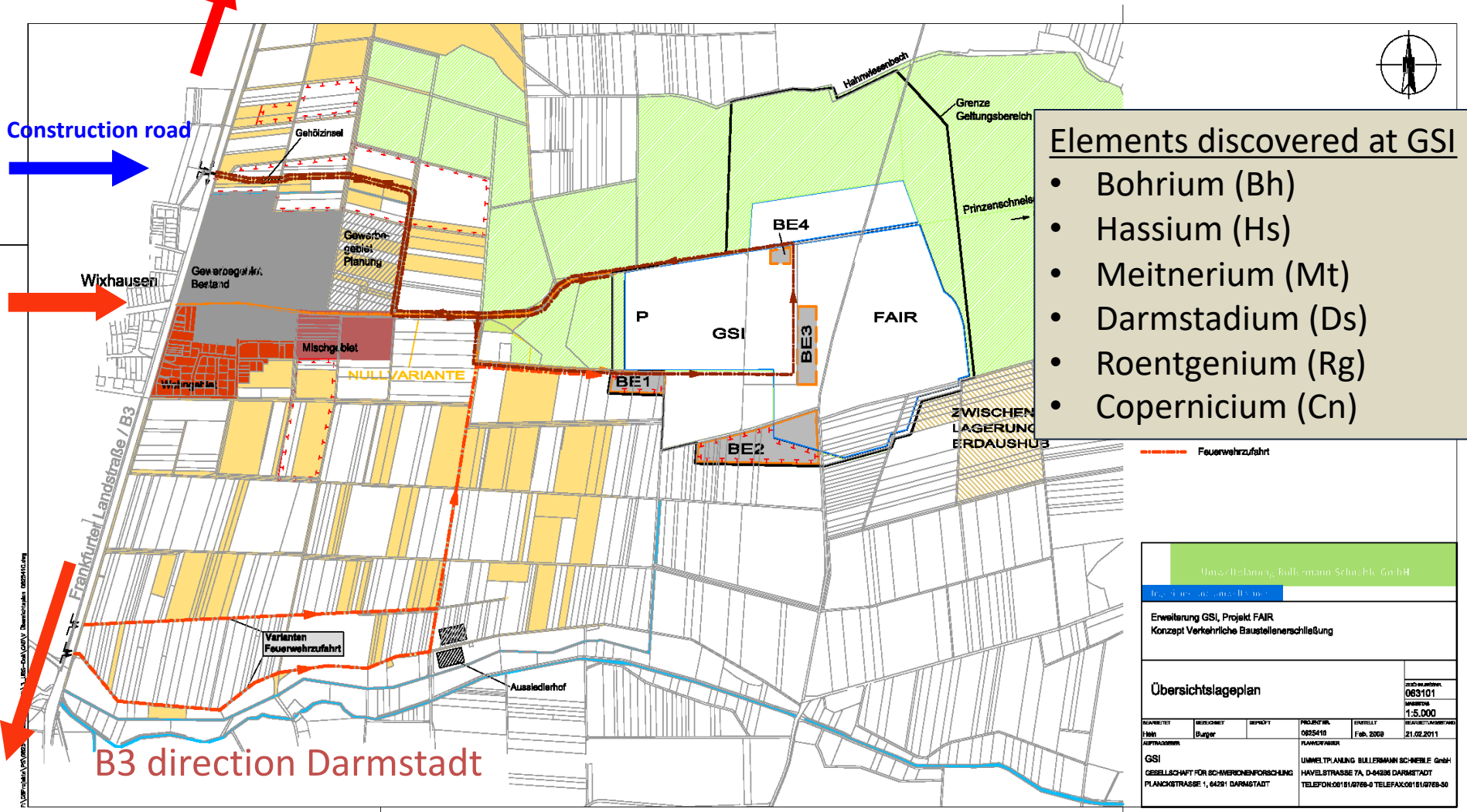
Motivation of our participation is to take part in advanced scientific and technological activities

B3 Direction Frankfurt



B3 direction Darmstadt

B3 Direction Frankfurt



B3 direction Darmstadt

Elements discovered at GSI

- Bohrium (Bh)
- Hassium (Hs)
- Meitnerium (Mt)
- Darmstadium (Ds)
- Roentgenium (Rg)
- Copernicium (Cn)

Umweltplanung Bullermann Schneible GmbH

Erweiterung GSI, Projekt FAIR
Konzept Verkehrliche Baustellenerschließung

Übersichtslageplan

063101

1:5.000

BEARBEITET	BEREICHNET	GEPRÜFT	PROJEKT-NR.	ERSTELLT	BEARBEITUNGSSTAND
Hein	Burger		0625416	Feb. 2008	21.02.2011

AUFTRAGGEBER
GSI
GESELLSCHAFT FÜR SCHWERIONENFORSCHUNG
PLANCKSTRASSE 1, 64291 DARMSTADT

PLANVERFASSER
UMWELTPLANUNG BULLERMANN SCHNEIBLE GmbH
HAVELSTRASSE 7A, D-64295 DARMSTADT
TELEFON:06151/9769-0 TELEFAX:06151/9769-50

Prominent features of (FAIR) accelerator

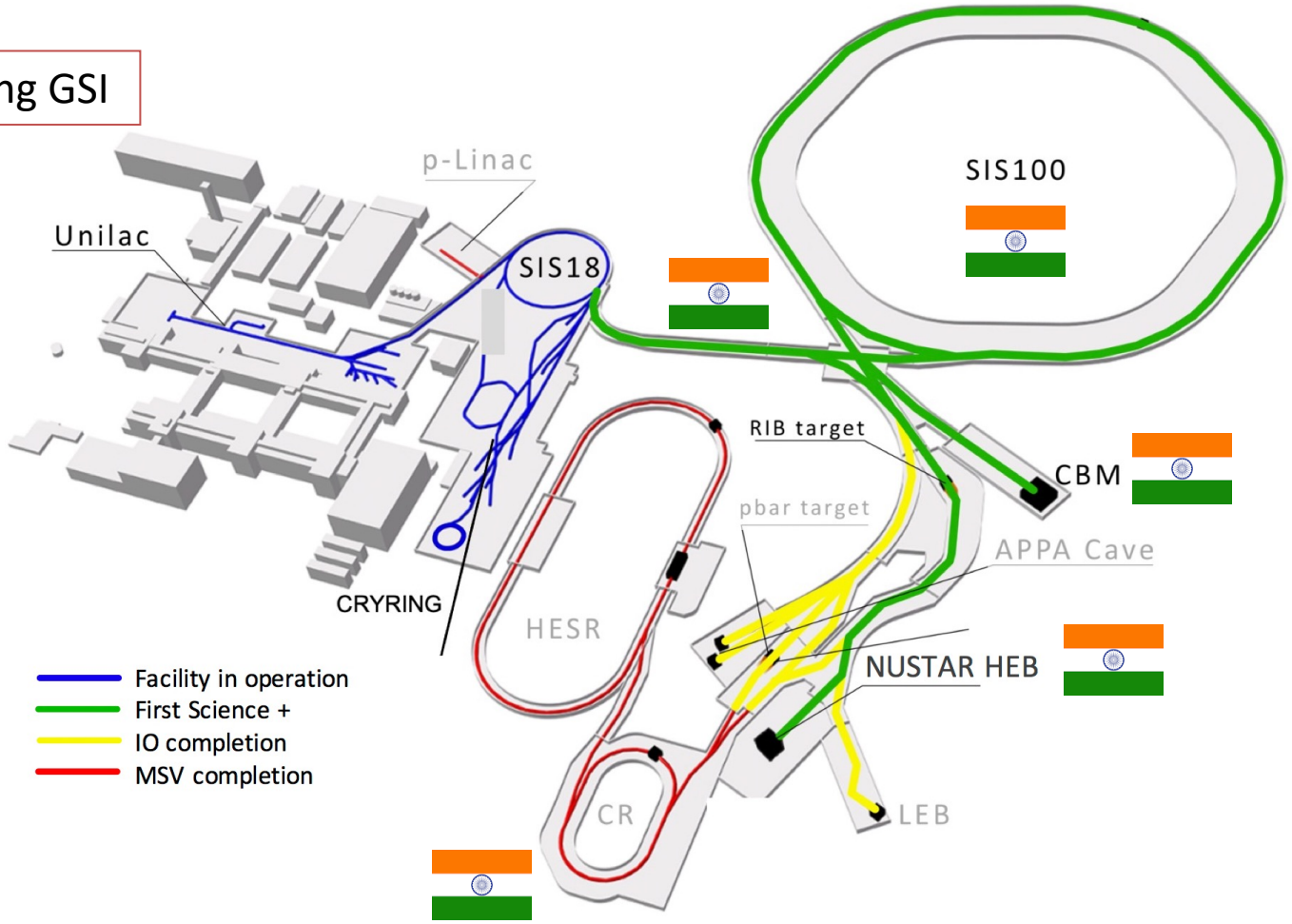
High Intensity beams:
1000 x
For primary HI beam
10 000 x
For radioactive ion beams
10 0 x
For antiproton beams

Primary beams:
10^{12} /s $^{238}U^{28+}$ 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

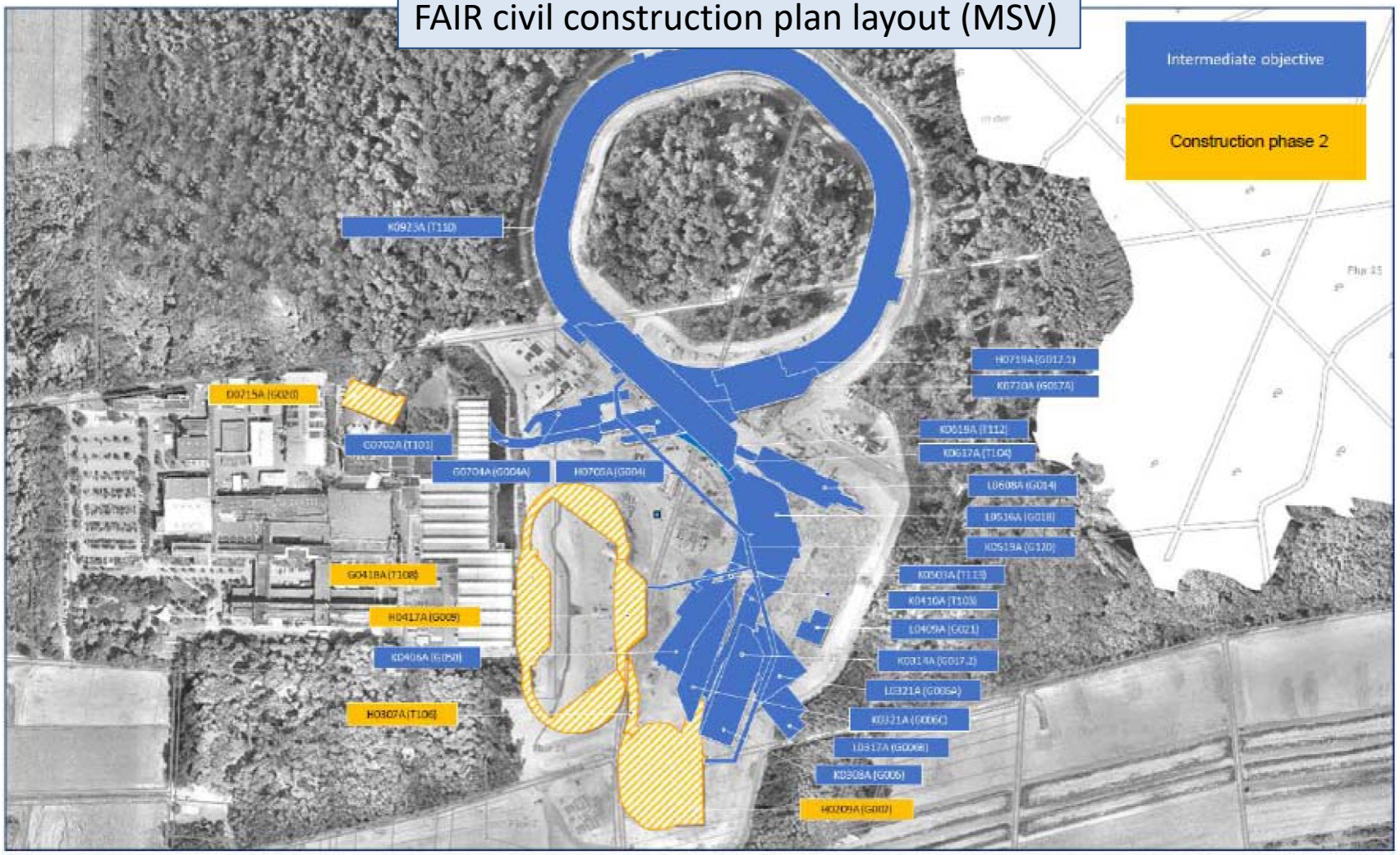


Member Countries:
Germany
Russia
India
France
Poland
Romania
Finland
Slovenia
Spain
Sweden
UK

Steps for the construction of new facilities

- Early Science (ES): FAIR pre-cursor programme at the Super-Fragment-Separator (S-FRS) and NUSTAR High-Energy Branch (HEB) served by beams from SIS18.
- First Science (FS): first science at the Super-Fragment-Separator (S-FRS) and NUSTAR High-Energy Branch (HEB) served by beams from SIS100.
- First Science + (FS+): in addition to FS the CBM branch served by beams from SIS100.
- First Science ++ (FS++): in addition to FS+:
  - the branch into the APPA cave, and
  - the NUSTAR Low-Energy Branch (LEB)

FAIR civil construction plan layout (MSV)



Status of FAIR Civil Construction

FAIR Project Progress – Civil Construction; Construction Area North

FAIR Project Progress – SIS100 ring accelerator

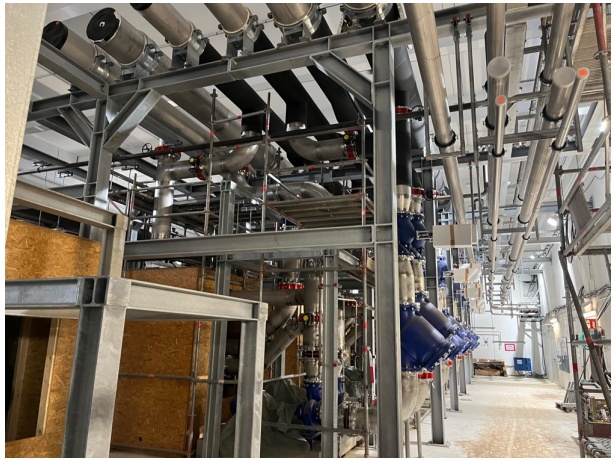
Status: 12/2023

Towards SIS100

1100 m trip under the roof

FAIR Project Progress – Technical Installations

Status: 12/2023



FAIR in 2028

Indian involvement

Beginning of India's journey at FAIR

Signing of joint ministerial declaration on Indian participation in construction and operation of Facility for Antiproton and Ion Research (FAIR)

7th February 2007
New Delhi, India

FAIR Convention signed (FAIR GmbH formed)

4th October 2010

Wisbaden, Germany

Country	
Germany (Federal Gov. and Hessen)	
Russia	
Finland	
France	
India	
Poland	
Romania	
Slovenia	
Sweden	

Bose Institute (Kolkata) is Indian shareholder

DAE-DST mega-science project

India's contributions: 3% of the total cost of FAIR construction (in-kind)

Developments in India

Indian in-kind items identified so far

Accelerator components

- SC magnets for LEB
- Power converters
- Ultra-high Vacuum chambers
- Power cables
- Beam stoppers
- IT Cable

Detectors and Electronics

- Spectrometer for nuclear physics
- Neutron detector for nuclear physics
- Ion-trap for nuclear physics
- Muon chambers for high energy expts.

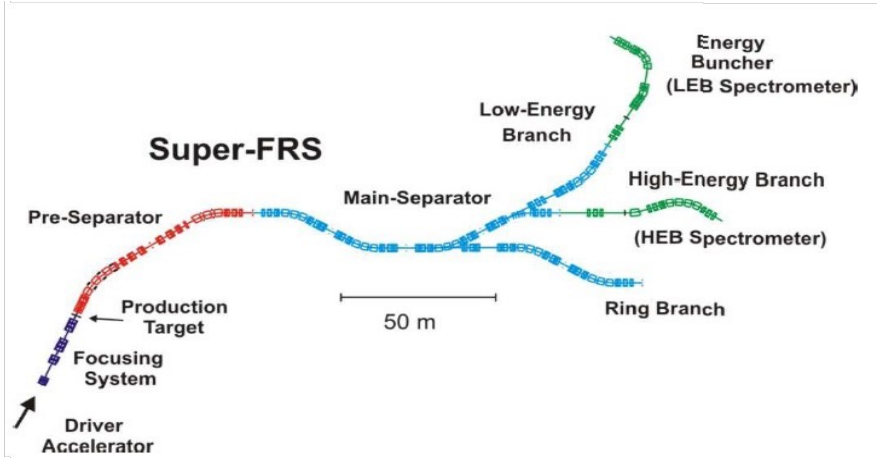
Experiments:

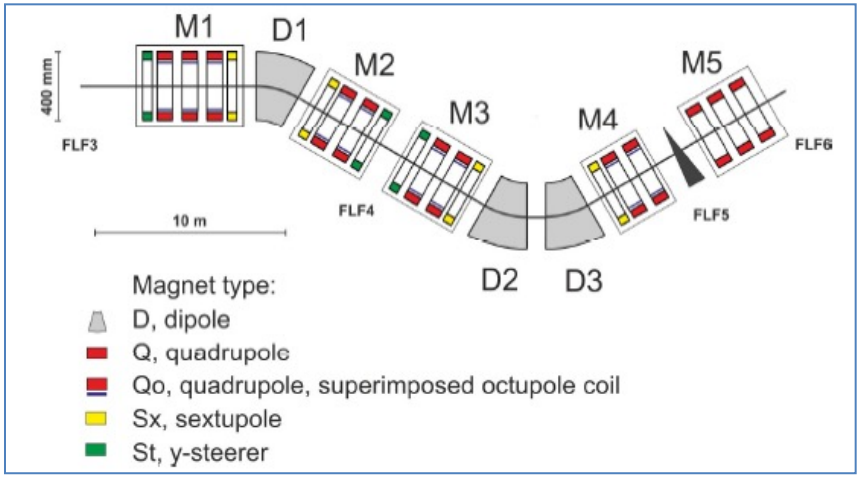
1. ***NUSTAR***
2. ***CBM***

I. Low Energy Buncher magnets

❖ Low Energy Buncher (LEB) of the Superconducting Fragment Separator (Super-FRS) - device for particle identification after secondary reactions

❖ Dipole, quadrupole and sextupole magnets forming the Energy Buncher have to accept fragment beams requiring large usable apertures with stringent magnetic field quality





I. LEB Magnets Status

- Physics design (VECC): complete
- Basic engineering design: complete
- Based on Engineering design CAD modeling: complete
- *CDR and FDR cleared by FAIR*
- Production withdrawn due to much higher cost
- **0.5 M Euro credited to India (2005 price)**
- **Offshoot**: Indian engineers have been offered to be consultant for dipoles

II. Ultra Stable Power Converters

- These are required for powering superconducting and room temperature magnets
- ppm stability in voltage and current
- Both single and dual power supplies
- **Most of the power converters for HEBT quadrupole- and steering magnets are being built by the Indian company ECIL** (Electronics Corporation of India Limited).

II. Ultra Stable Power Converters: Status

- ***Design: VECC, RRCAT, BARC, ECIL, BI***
- ***Provider: ECIL, Hyderabad***
- ***Shipped: 454***

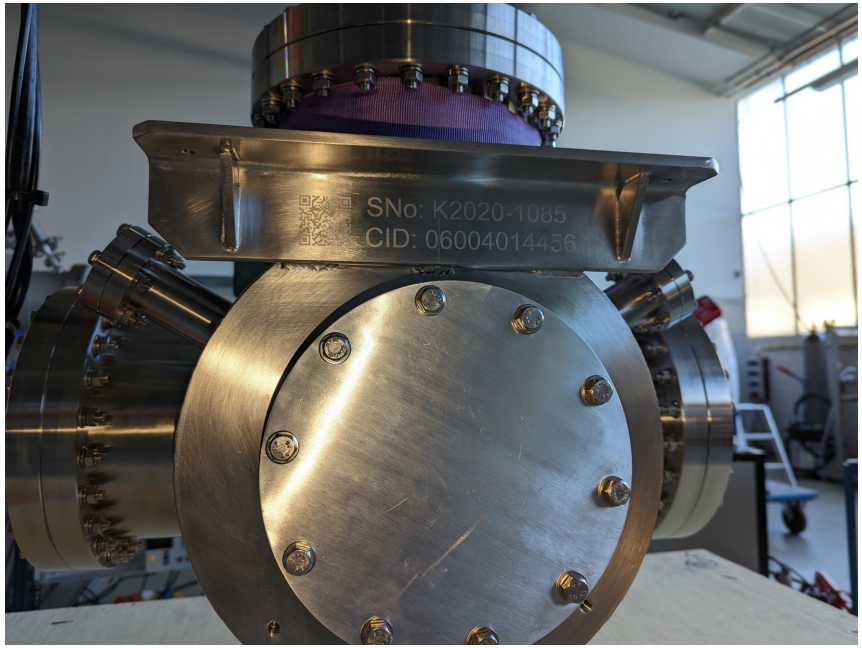
A new set of 70 nos. of Power Converters for Corrector (Steerer, Sextupole and Octapole) Magnets in Super-FRS is under discussion as in-kind.

III. Ultra-high Vacuum Chambers for beam diagnostics

- Thin-walled chambers to house the beam diagnostic equipment.
- To maintain a vacuum level of 10^{-9} millibar pressure.
- Challenging features: special quality of steel is to be used as material
- Welding and other manufacturing processes require special handling, multistep cleaning is required to ensure vacuum quality etc.
- A major challenge is to weld up to 7 cylindrical ports on a barrel, which, when completed, should maintain mechanical tolerances at the level of tens of microns. The technology demands extremes of care and quality control.

III. Ultra-high Vacuum Chambers for beam diagnostics

- ***Design: (VTPL, IUAC, VECC, BI)***
- ***Provider: Vacuum Techniques Pvt. Ltd., Bengaluru***
- ***All 58 chambers have been supplied and accepted by FAIR***



FAIR
Facility for Antiproton and Ion Research in

Certificate of Completion

The components mentioned in Council Decision IV.15.5 was delivered, successfully tested and accepted. Thus a value of 452,400.00 € (@2005 Indian Shareholder Bose Institute).

Council Decision IV.15.5:
The Council assigns the components specified in the Expressions of Interest from India, for contributing in kind to the FAIR Accelerator Facility, to the Indian Shareholder Bose Institute as in-kind contribution.
A detailed in-kind contract including all annexes and complete technical specifications, according to FAIR Council Resolution III.10.1 is to be signed.

The corresponding PSP-Codes are: 2.3.6.3.1.2.1; 2.3.6.5.1.2.1; 2.3.6.5.2.2; 2.3.6.5.3.2.1, HEBT Vacuum Chambers for the Commons subproject.

For information: The cost-book value of these items amounts to 452,400.00€. This project comprises several other PSP-codes with a total cost-book value of 14,614,290.50 €.

Scientific Managing Director	Technical Managing Director	Deputy Administrative Director
Prof. Paolo Giubellino	Jörg Blaurock	Markus Jaeger

Facility for Antiproton and Ion Research in Europe GmbH · Planckstraße 1 · 64291 Darmstadt · www.fair-center.eu

IV. Co-axial Power Cables (148 Km, 3 types)

- To connect power converters with the magnets.
- Shielded and e-beam cured.
- Operating in high radiation environment.
- Voltage class = 1.8 / 3 KV (Max. Voltage 3.6KV, as per IEC-60502-1)
- Not a standard type,
- Special cable as per user's requirement

Cross-section of Power Cable

FAT at M/s. Siechem, Pondicherry

Three prototypes built, FAT accepted, shipped to FAIR for SAT

V. IT and Diagnostic Cables (52 types, 930 Km)

- Required for signal/data transfer for diagnostic purpose.
- Not so complex otherwise but needs radiation hard insulation.
- EBXL-XLPE insulation with halogen free sheath used as per user requirement

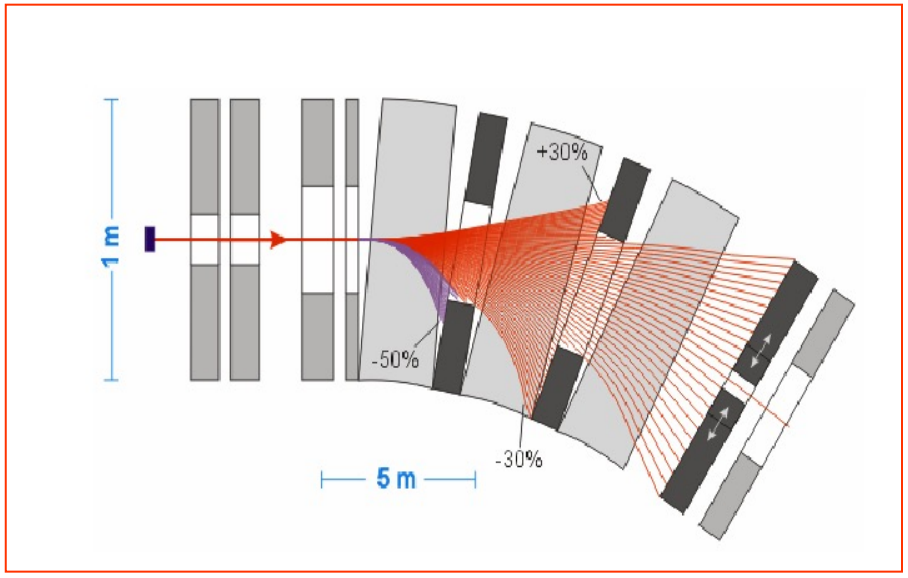
FAT at M/s. Siechem, Pondicherry

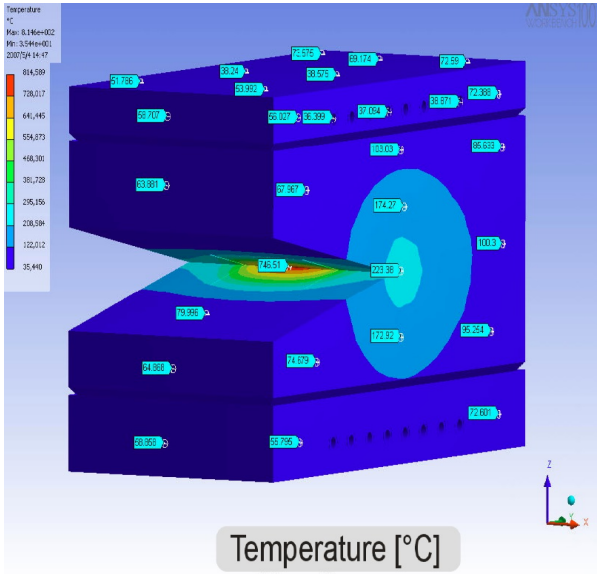
Cables ready to be shipped

- Bulk materials supplied in 3 lots
- SAT ongoing

VI. Beam Catchers (beam stoppers)

Required to safely catch the unreacted primary beams and a large share of unwanted fragments after the target in Super-FRS.

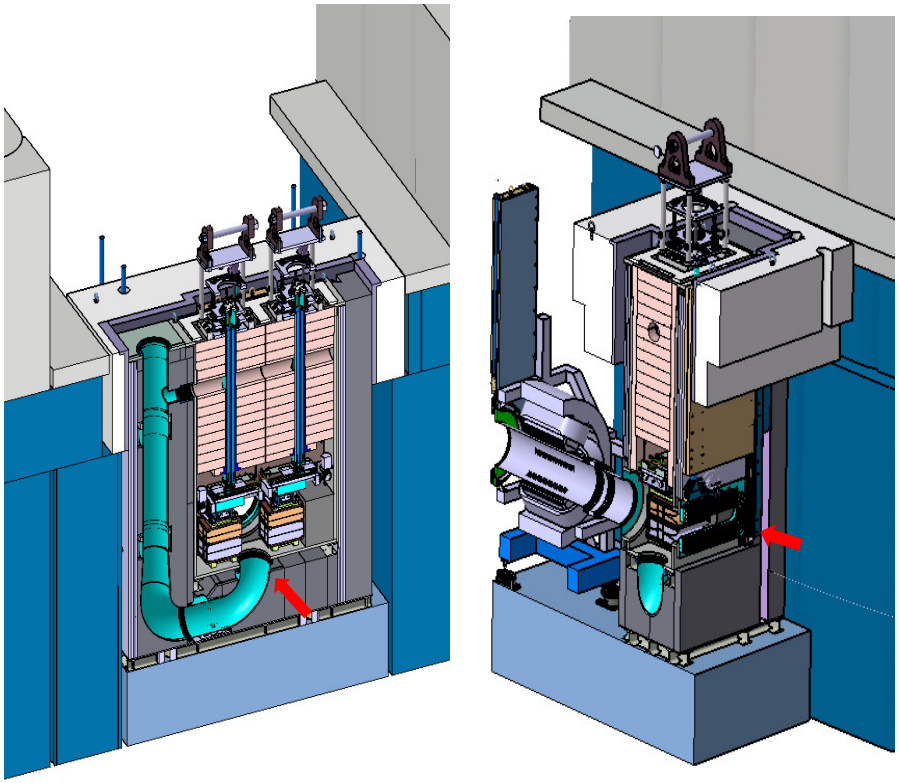




Challenges:

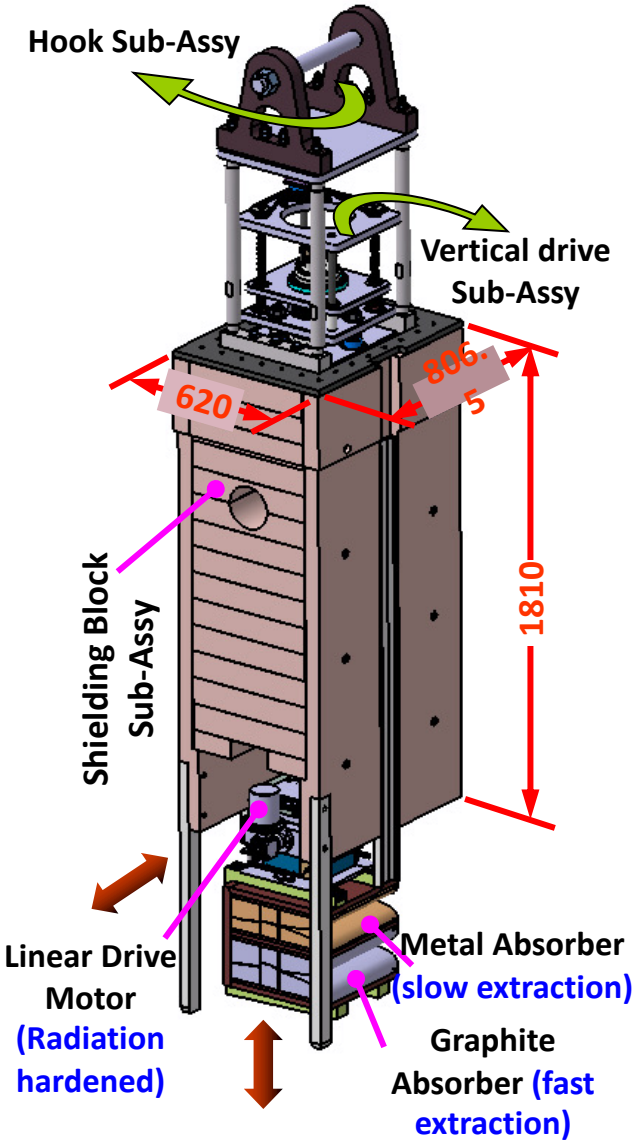
- Must be integrated directly into the separator
- Huge average power (23KW) dumps in very short time (100 nsec)
- Both fast and slow extraction method needs to be incorporated
- Absorber is needed to be built suitable for remote handling

V. Beam Catchers (contd.)



Transverse section

Longitudinal section



BC3 Top Plug Assy (≈7.0t)

BC1, BC2, BC3 Cavity Dimensions

Structural Frame

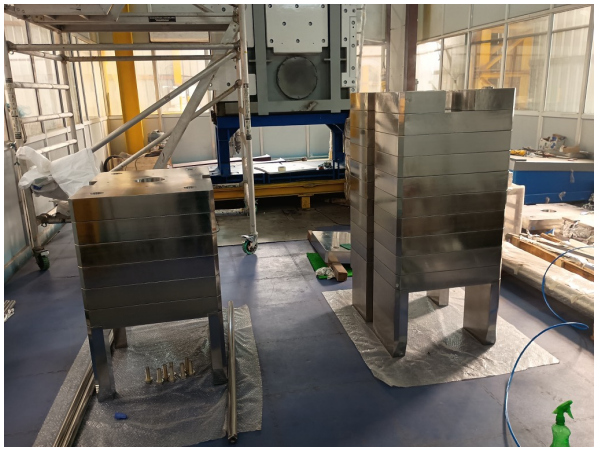
- Dimensions (LxBxH): 2838mm x 860mm x 3350mm
- **BC1, BC2 and BC3 frames are identical**

Vacuum Cavity

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

VI. Beam Catchers: Status

- ***Design:*** **CSIR-CMERI, VECC, BI**
- ***Provider:*** **M/s. Trident Auto Components Pvt. Ltd., Kanpur**





- Prototype (BC3) production is on the way, FAT ongoing

Status in-kind supplies: Summary

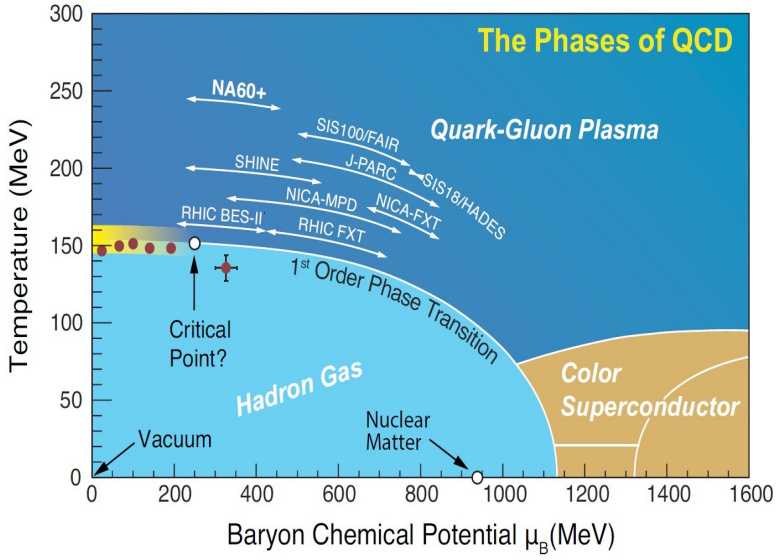
Sr.	Item	Status	Next step
I	LEB Magnets	Design completed	NIL
II	Ultra Stable Power Converters	454 delivered (70 under process which will go to Fast Track Committee)	NIL
III	Ultra high Vacuum Chambers	Delivery completed	NIL
IV	Power Cables	Prototypes developed, FAT completed	SAT of prototypes
V	IT and diagnostic cables	Bulk materials supplied	SAT
VI	Beam Catchers	Prototype (BC3) is being developed	FAT ongoing
VII	Experiments	FEEC recommendation received	Funding approval

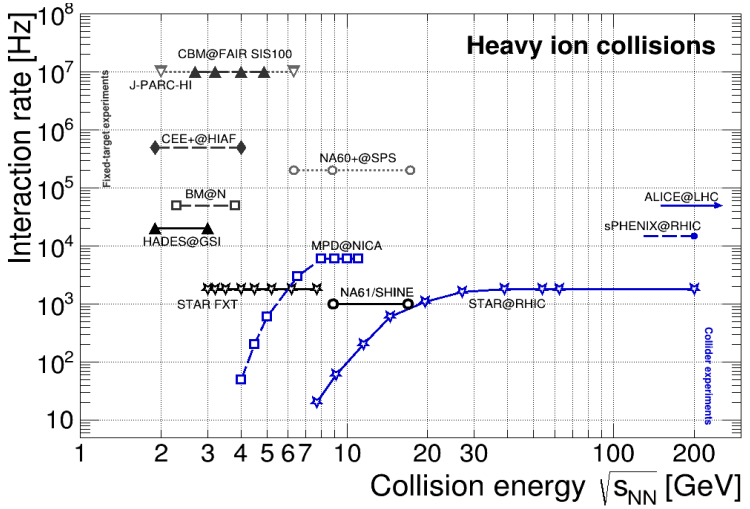
What is our interest?

Compressed Baryonic Matter (CBM)

Motivation

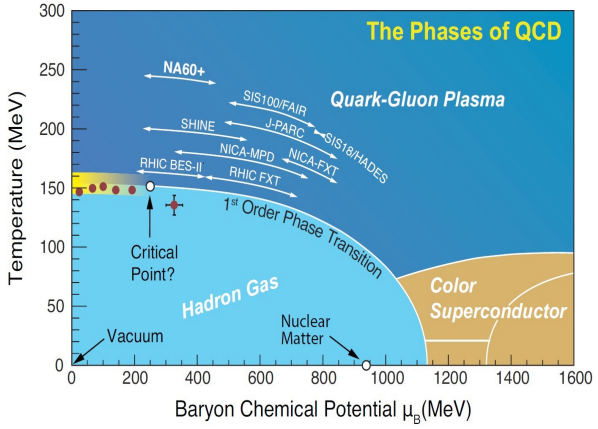
- **Systematic exploration of the QCD phase diagram**
  - Low baryon density regime (LHC, RHIC ...)
  - High baryon density regime (RHIC, CERN-SPS, CBM ...)
- **Precise measurement of the physics observables of interest**
  - High luminosity
- **Detectors with high rate handling capabilities**
  - Micro Pattern Gas Detectors (MPGD)
  - Resistive Plate Chamber (RPC) ?
- **Innovative technologies for data acquisition**

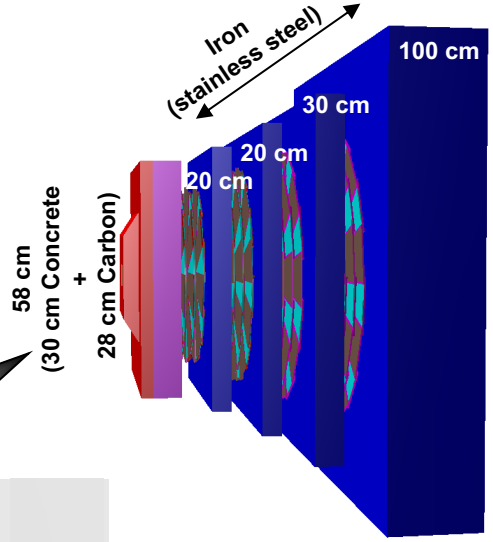




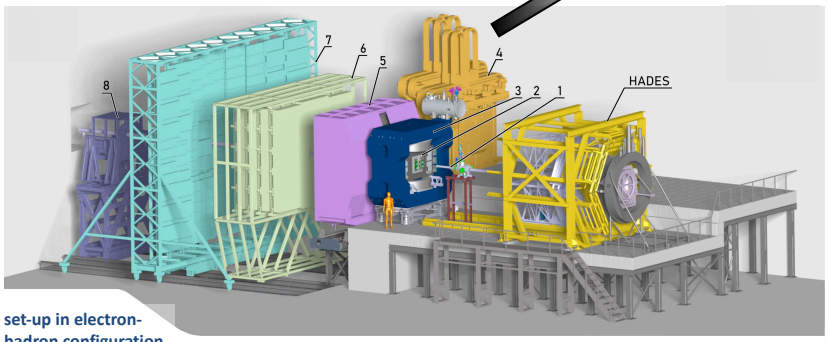
** Please attend the Talk by Supriya Das in Future experiments, Detectors session

CBM detector sub-systems





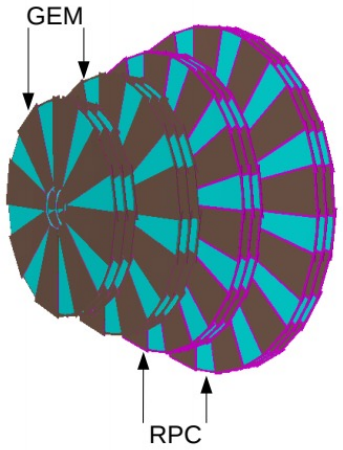
Simulated MuCh setup



set-up in electron-hadron configuration

HADES detector for separate running

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



Muon Chamber (MuCh):

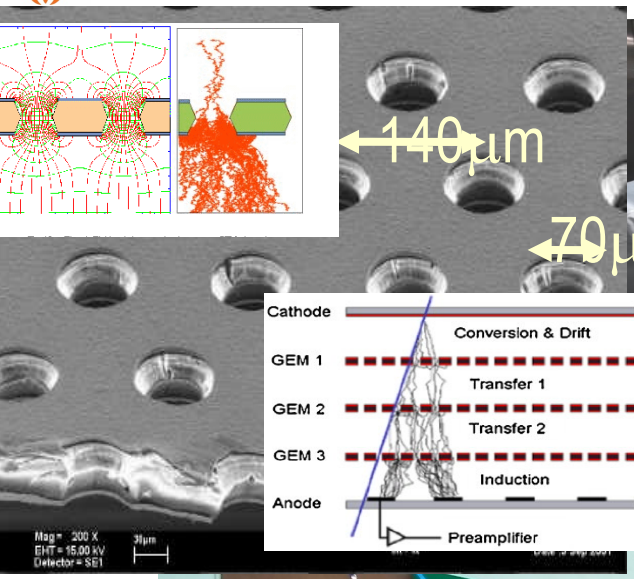
- MuCh Comprises of several detectors & segmented hadron absorbers
- Longitudinal segmentation of absorber and detectors are placed inside absorbers to facilitate tracking
- Angular coverage ~ 5.7° to 25°
- GEM will be used in the first two stations and RPC for the last two stations

Challenges:

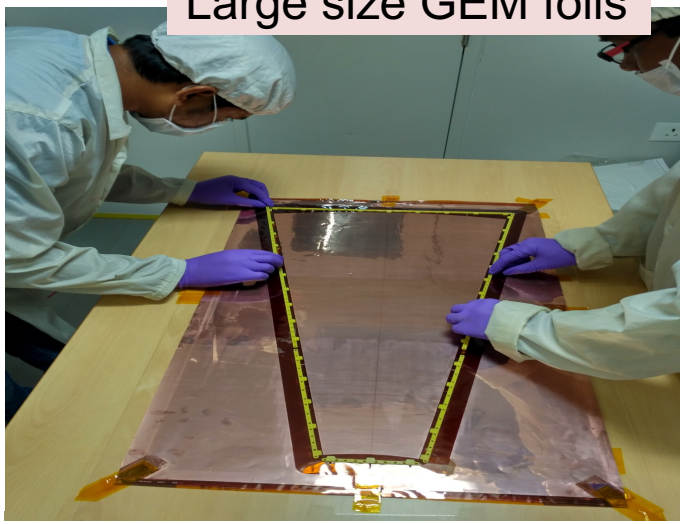
- High particle flux at the detector stations (~ MHz/cm^2 in the 1st station for central collisions)
- Self triggered electronics

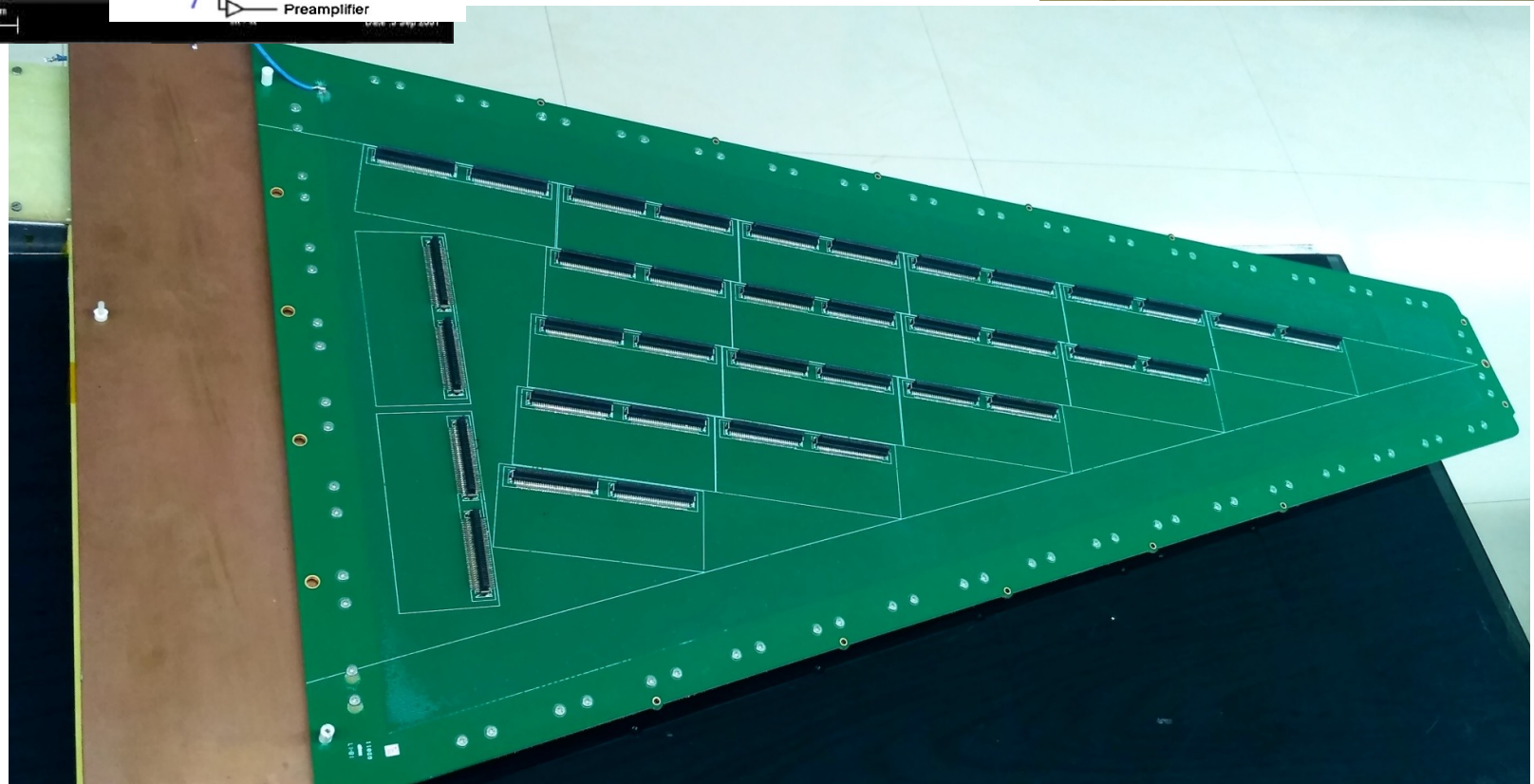
- **Detectors with high rate handling capabilities**
  - Micro Pattern Gas Detectors (MPGD)
  - Resistive Plate Chamber (RPC) ?

GEM Module Fabrication

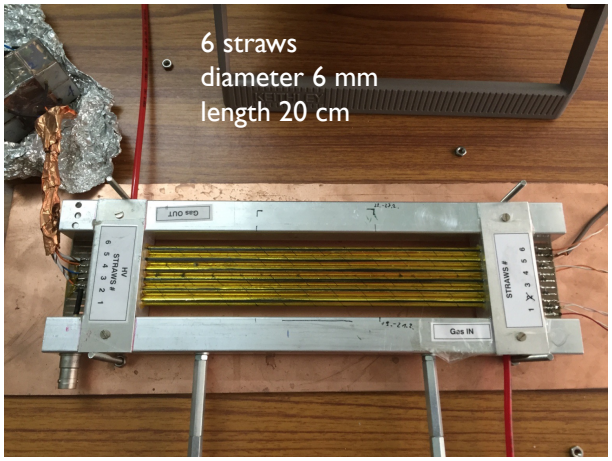


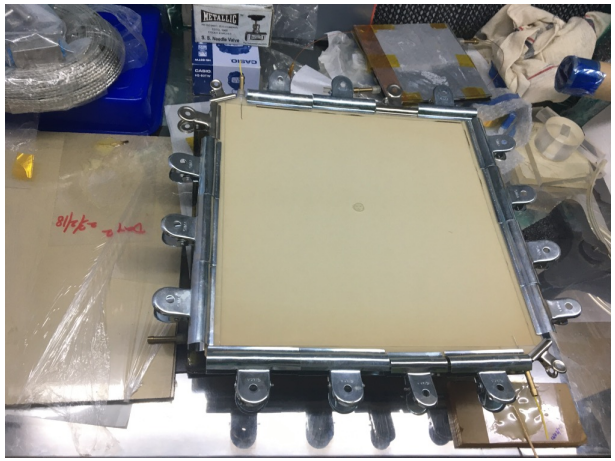
Large size GEM foils

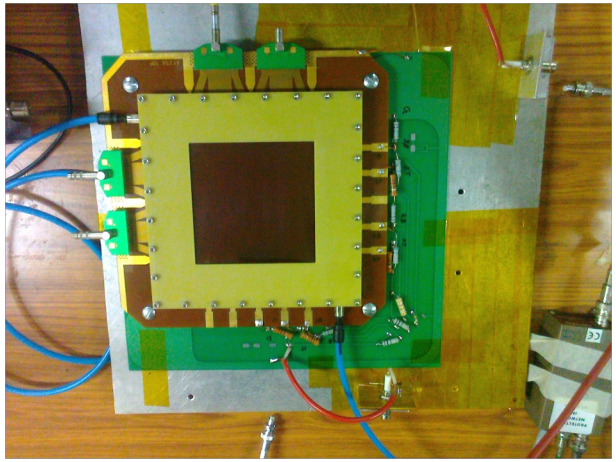




Detector lab at Bose Institute







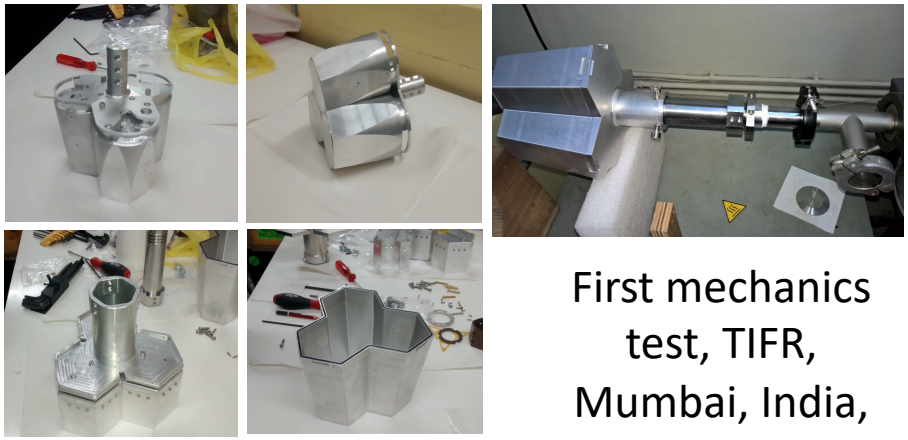
**** Please attend the Talk by Subir Mandal in Parallel A (Future experiments, Detectors)**

सत्यमेव जयते
Department of Science and Technology
Ministry of Science and Technology
Government of India

India in NuSTAR

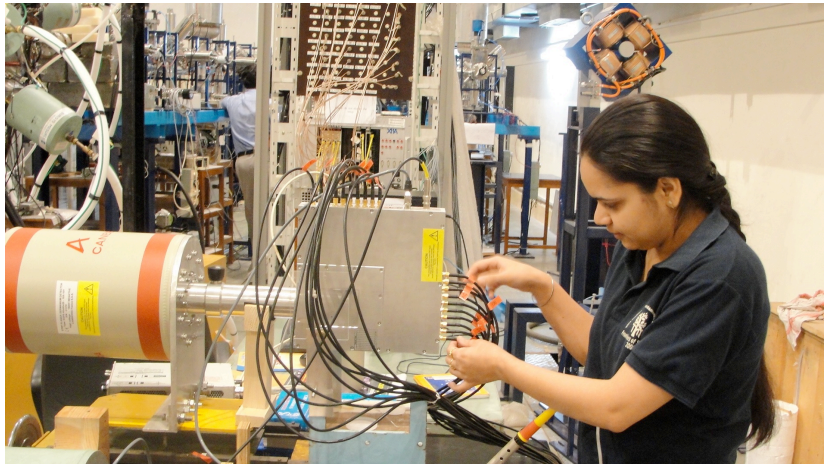
India in NuSTAR

Development and testing of DEGAS detectors @TIFR



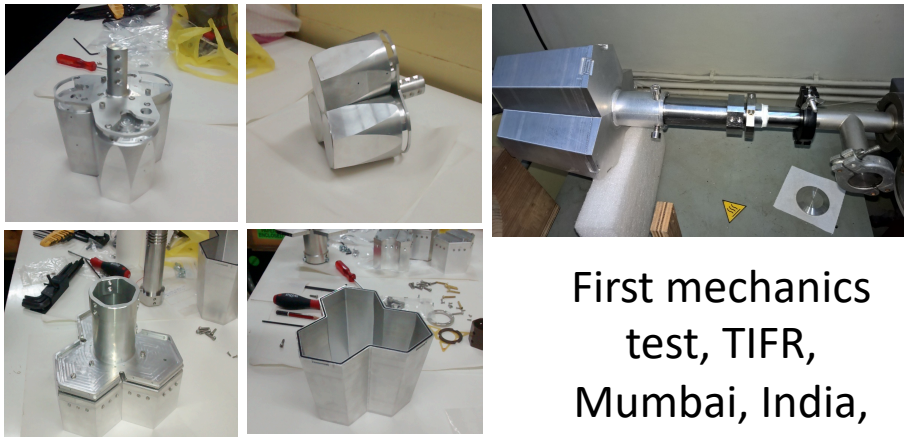
First mechanics test, TIFR, Mumbai, India, February 2016

Testing of Planar Ge detector



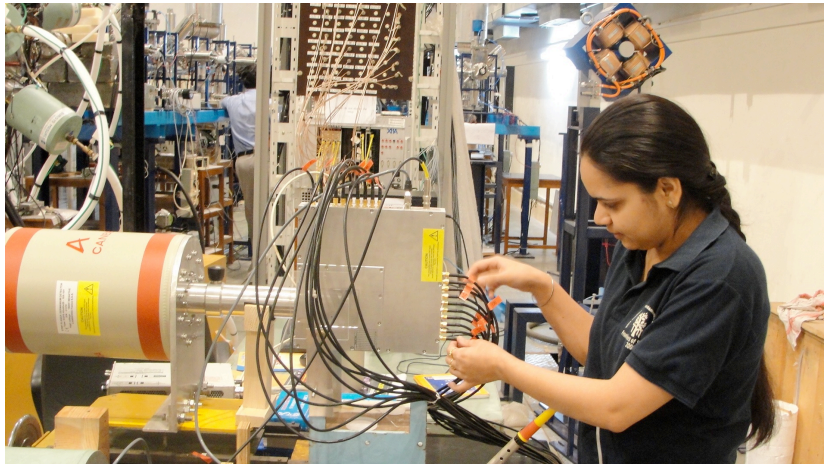
India in NuSTAR

Development and testing of DEGAS detectors @TIFR

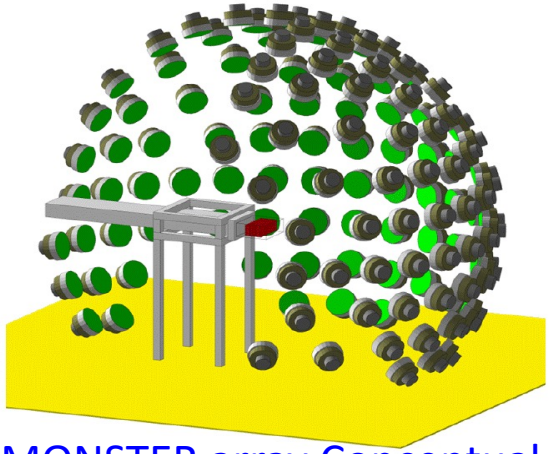


First mechanics test, TIFR, Mumbai, India, February 2016

Testing of Planar Ge detector



Development and testing of MONSTER detectors @VECC



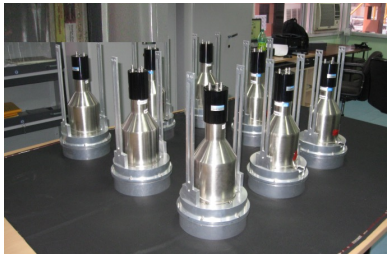
MONSTER array Conceptual design

Organic Liquid Scintillator based

High energy resolution:
4% (1.5 m TOF)

High efficiency:
60% (at 1 MeV)

Fast timing:
1 ns time resolution



Compact:
Capillary type expansion chamber

Biophysics & Tumor Therapy with Ion Beams@ FAIR

Group photo of the 1st International Biophysics Collaboration meeting at GSI on May 20-22, 2019

- An interdisciplinary collaboration of biologists, physicists, chemists, biochemists and technicians
- Multidisciplinary research on radiobiology, physics, space research and therapy.

https://www.gsi.de/en/work/research/biophysics


DORA

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- Once completed, this facility will be used by a much larger community of scientists from India not only in the area of nuclear and high energy physics but also in other areas such as biophysics and applications

Development of detectors is at the core of new discoveries

It is a journey at Bose Institute that started by Bose himself

Now, the journey has become a collective entity formed by International collaborations

The journey at Bose Institute continues

It is a FAIR of modern Science

You are welcome to join

Thank you