FAIR: the next generation accelerator, a technology marvel

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FAIR: Facility for Antiproton and Ion Research

(a facility for discovery science !)

Influence of Accelerator Science on Physics Research

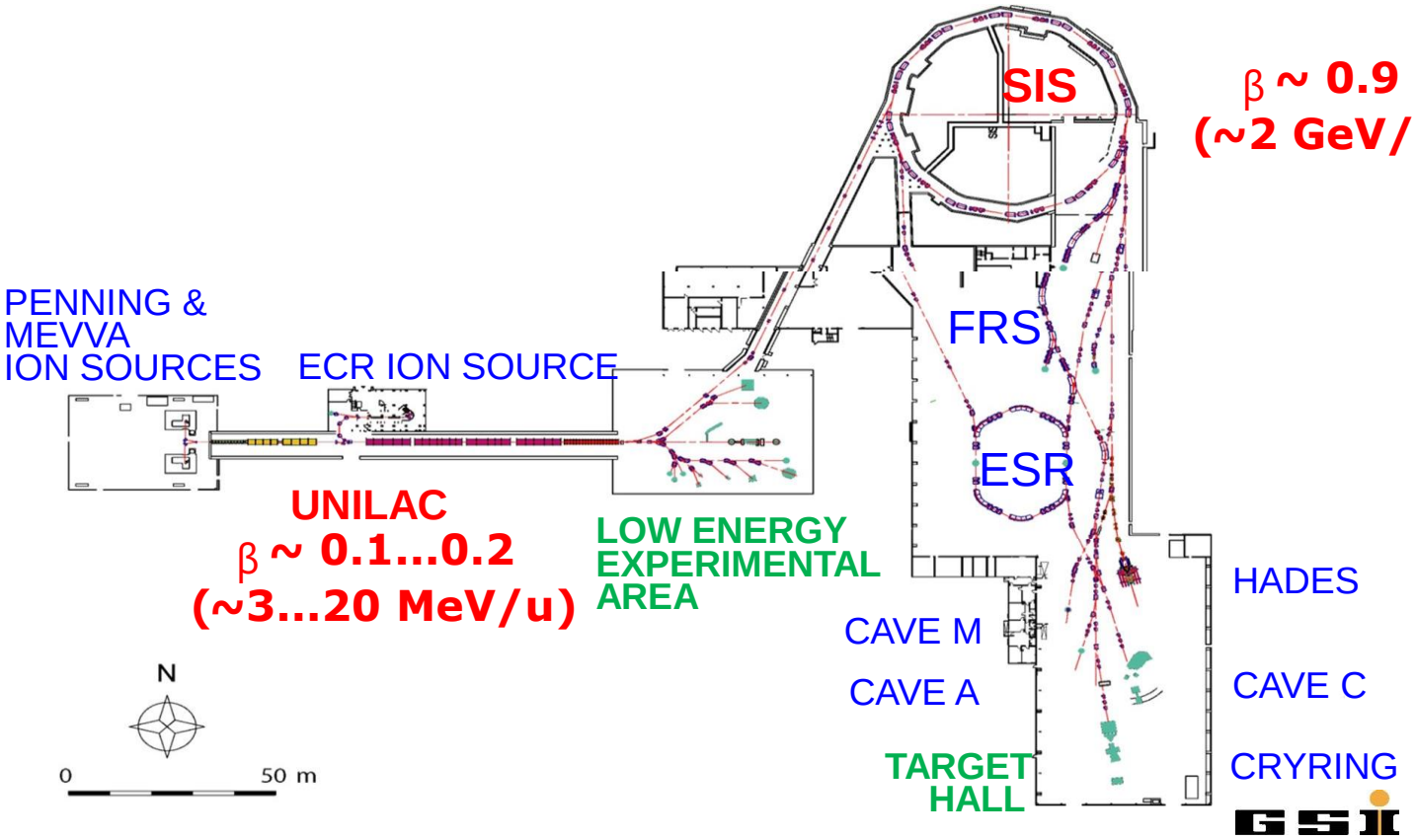
Enzo Haussecker and Alexander Chao
SLAC National Accelerator Laboratory, Menlo Park, California, USA

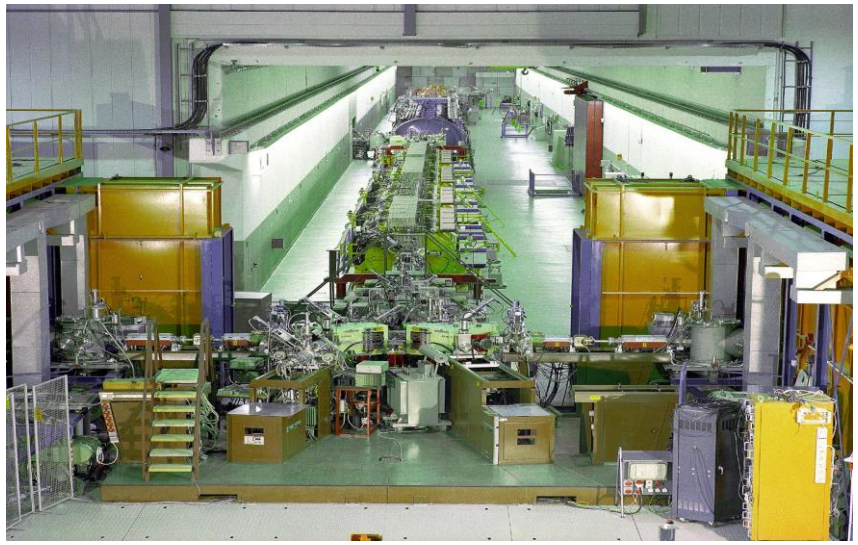
- Physics in Perspective, June 2011

- **accelerator science has played an integral role in influencing 28% of physicists working between 1939 and 2009 by either inspiring or facilitating their research**

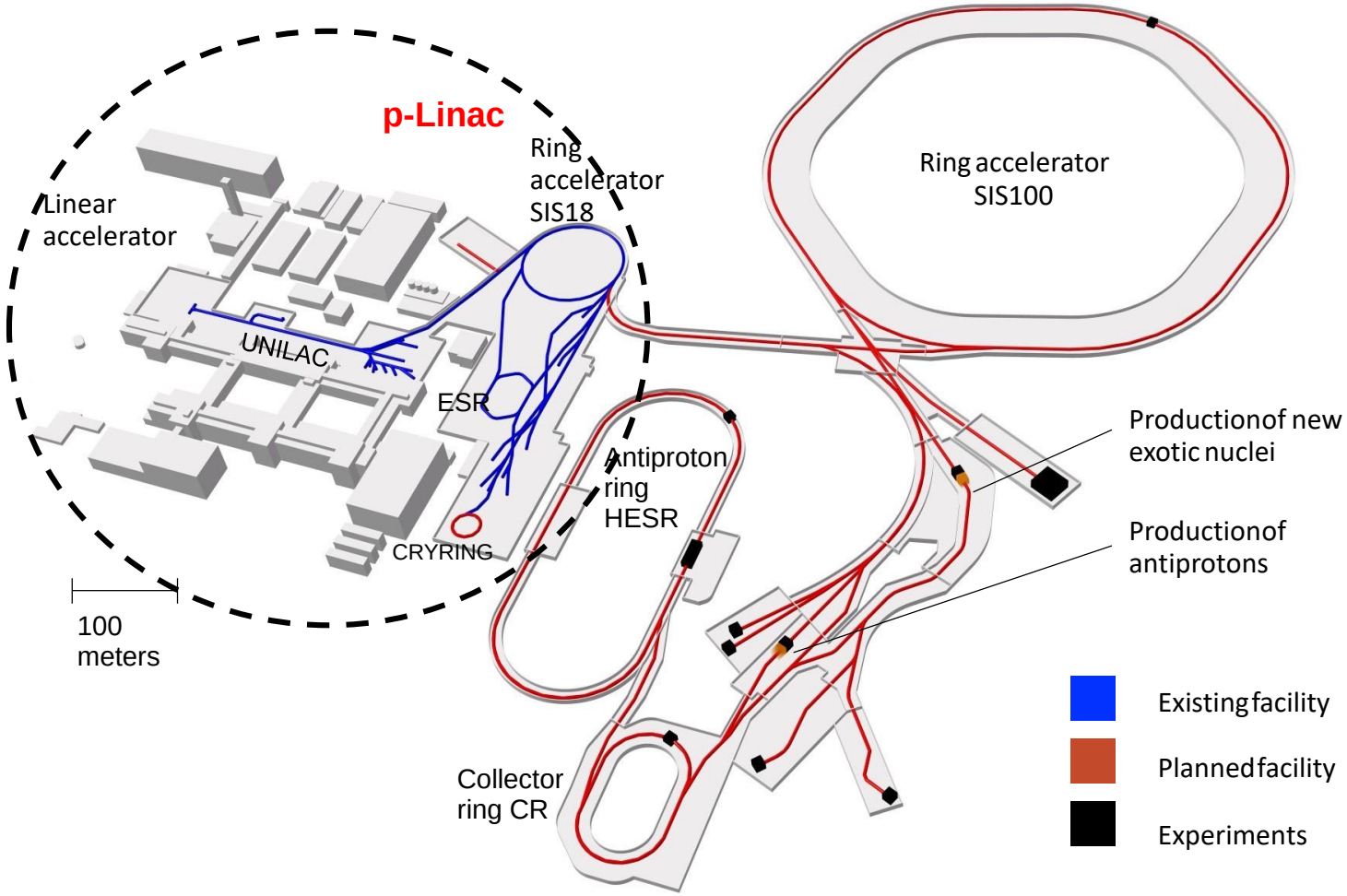
- **on an average accelerator science contributed to a Nobel Prize for Physics every 2.9 years *(24 Nobel Prizes in 70 years due to accelerators)***

GSI accelerators





Layout of the FAIR accelerator facility



FAIR Buildings: About 25 meter long segment of shell construction for the accelerator and the supply tunnel which run next to each other

FAIR: the next generation accelerator

- **A sophisticated complex of accelerators comprising of linacs, synchrotrons, cooler ring, high energy storage rings, several beam transfer lines**

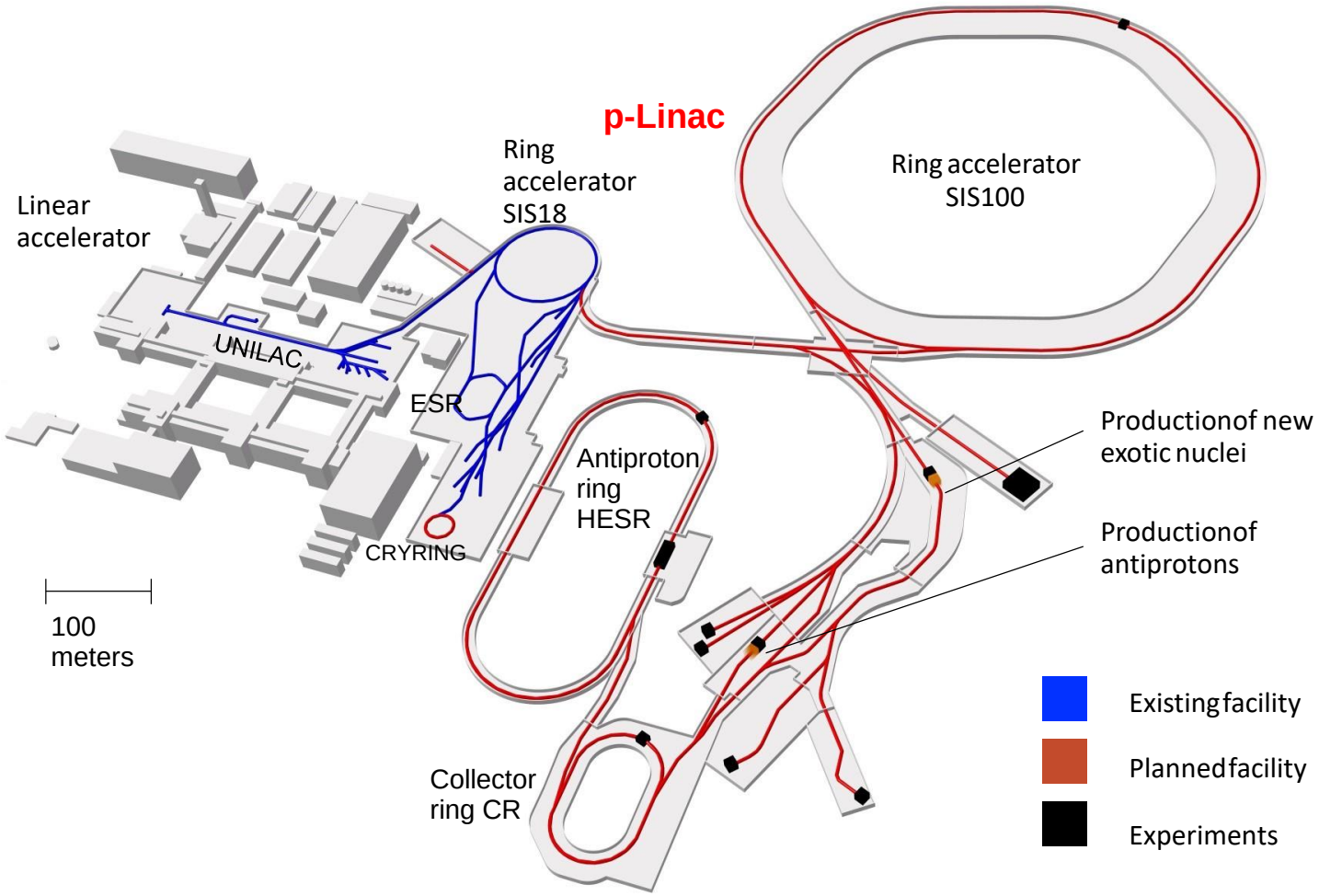
- **Primary and secondary beams of virtually all elements across the periodic table will be available**

- **Large energy range : e.g. U beams up to 1.5 Gev/u in low charge state scenario and 11 GeV/u in high charge state scenario**

- **Very high intensity for both primary as well as secondary beams (~ 1000 times the present facilities)**

- **Up to 4 experiments can go on in parallel with different beams and different energies**

Layout of the FAIR accelerator facility



Synchrotrons and storage rings with their intrinsic cycle time for acceleration, accumulation, storage and cooling offer the opportunity to carry out 4 dedicated experiments in parallel without loosing intensity/ luminosity for any of them : A unique feature of FAIR

FAIR: a technology marvel !

- **Superconducting magnets of the main accelerator SIS100 have a unique and challenging design. They have very fast ramp rate (4T/s) to accelerate unusually intense heavy ion beams➔ unique lattice design (charge separator lattice)**

- **Special designs for production targets and collimators for intense beams**

- **Ultrahigh vacuum (< $5x10^{-12}$ mbar) has to be maintained in spite of intense beams being accelerated➔ actively cooled magnet chambers, cryo-catchers for local suppression of gas desorption**

- **Most powerful, in-flight fragment separator (Super-FRS) has big superconducting magnets with large acceptance to capture variety of exotic nuclei. Fast separation of the fragmented nuclei (<50 ns)➔ very short-lived nuclei can be studied**

FAIR: a technology marvel ! (cont.)

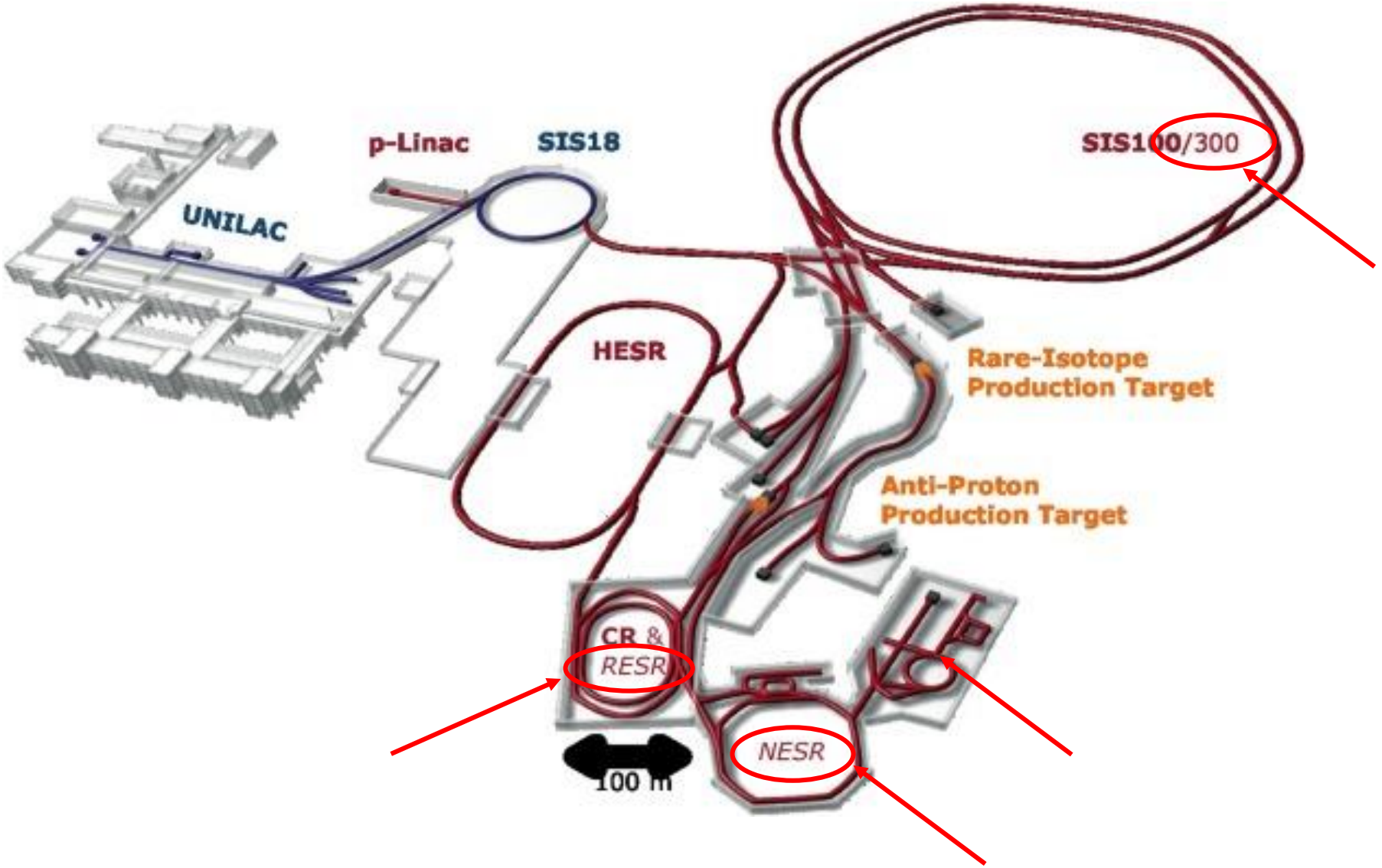
- **Unusually high intensity of beams leads to high radiation damage problems. Both electrical as well as thermal properties tend to change. New materials are required.**

- **Specialized beam diagnostic sensors and supporting electronics to deal with highly intense beams**

- **Special detectors and fast electronics required due to intense incident beams in experiments with FAIR.**

- **Provision for future upgrades: SIS300 in the SIS100 tunnel, storage rings New Experimental Storage Ring (NESR), Recycled Experiments Storage Ring (RESR)**

Future extension of FAIR accelerator facilities



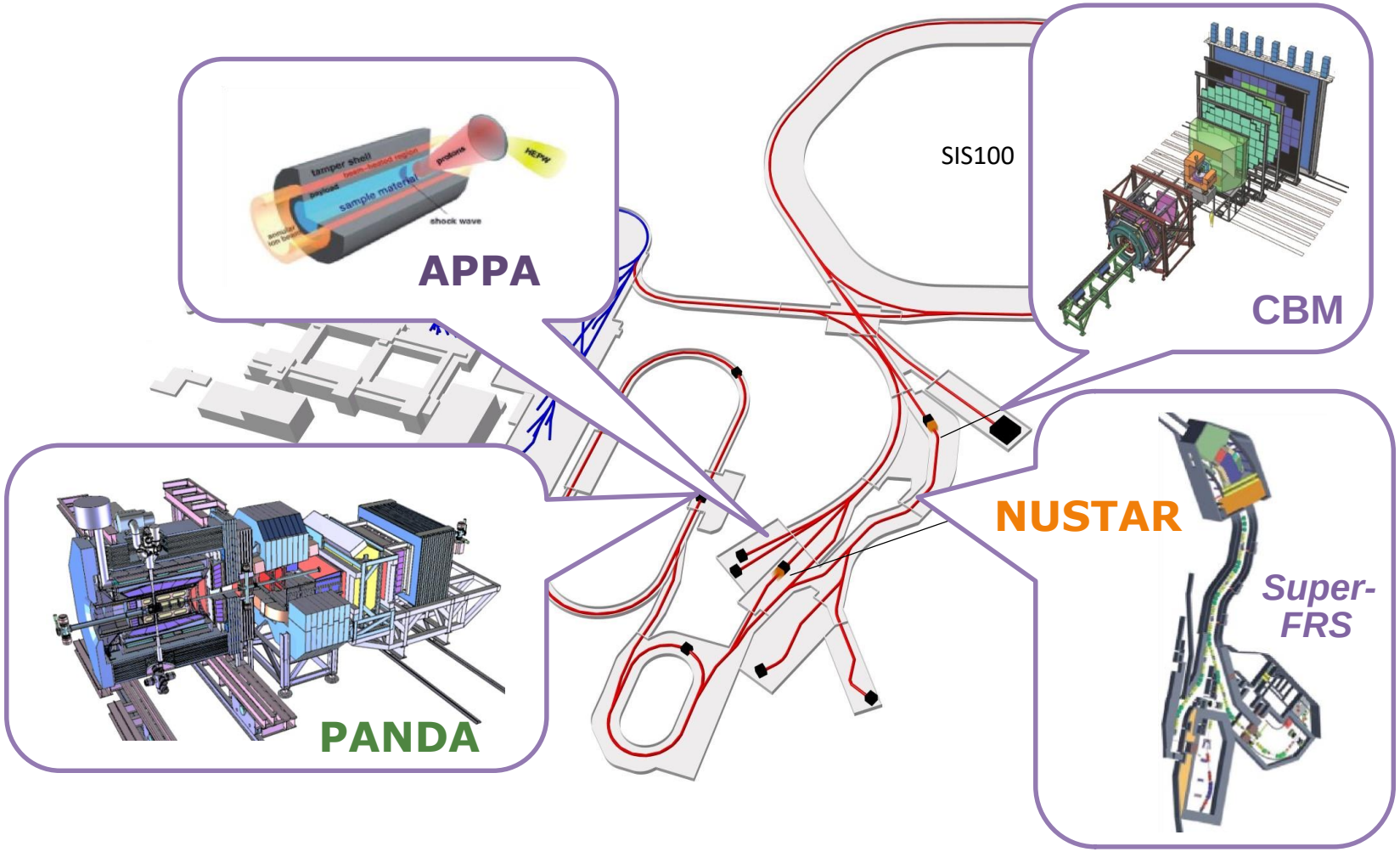
Why are we participating at FAIR ?

Two primary reasons:

- **India has a rich tradition of doing nuclear physics research – theoretical as well as experimental. We have a strong and growing community that is active at our research laboratories and academic institutions. Several accelerator facilities have been set up for this purpose in the country. Participation at FAIR will ensure availability of a truly frontline facility to our researchers for the next several decades.**

- **Participation and contribution to the construction of FAIR would directly benefit our ambitious accelerator projects of the near future for frontline research and applications. Also, ensure advantage to our industry.**

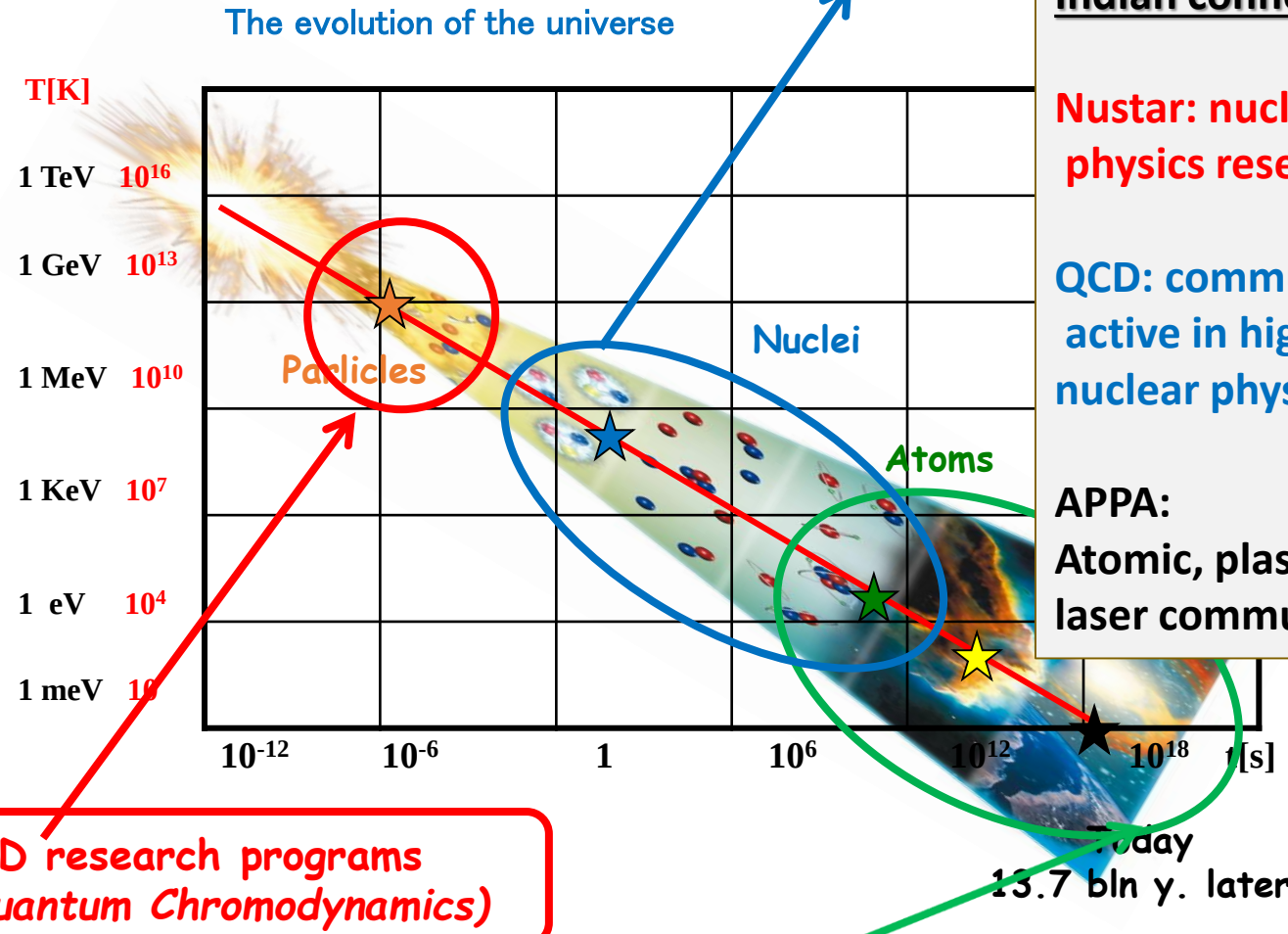
FAIR: experimental pillars



FAIR Research

Indian proposes participation in 7 Experiments out of total 14

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



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*)

A Super-FRS multiplet (superconducting) being test at CERN

Major Accelerator Laboratories in India

Raja Rammana Centre for Advanced Technology (RRCAT), Indore : Home for 2 SRS; Running SCRF Program Nodal DAE institute for CERN Collaboration

Bhabha Atomic Research Centre (BARC), Mumbai: Folded Tandem Ion Accelerator, Building an injector for HIPA

Tata Institute of Fundamental Research (TIFR), Mumbai: 14 UD Pelletron+SC Booster

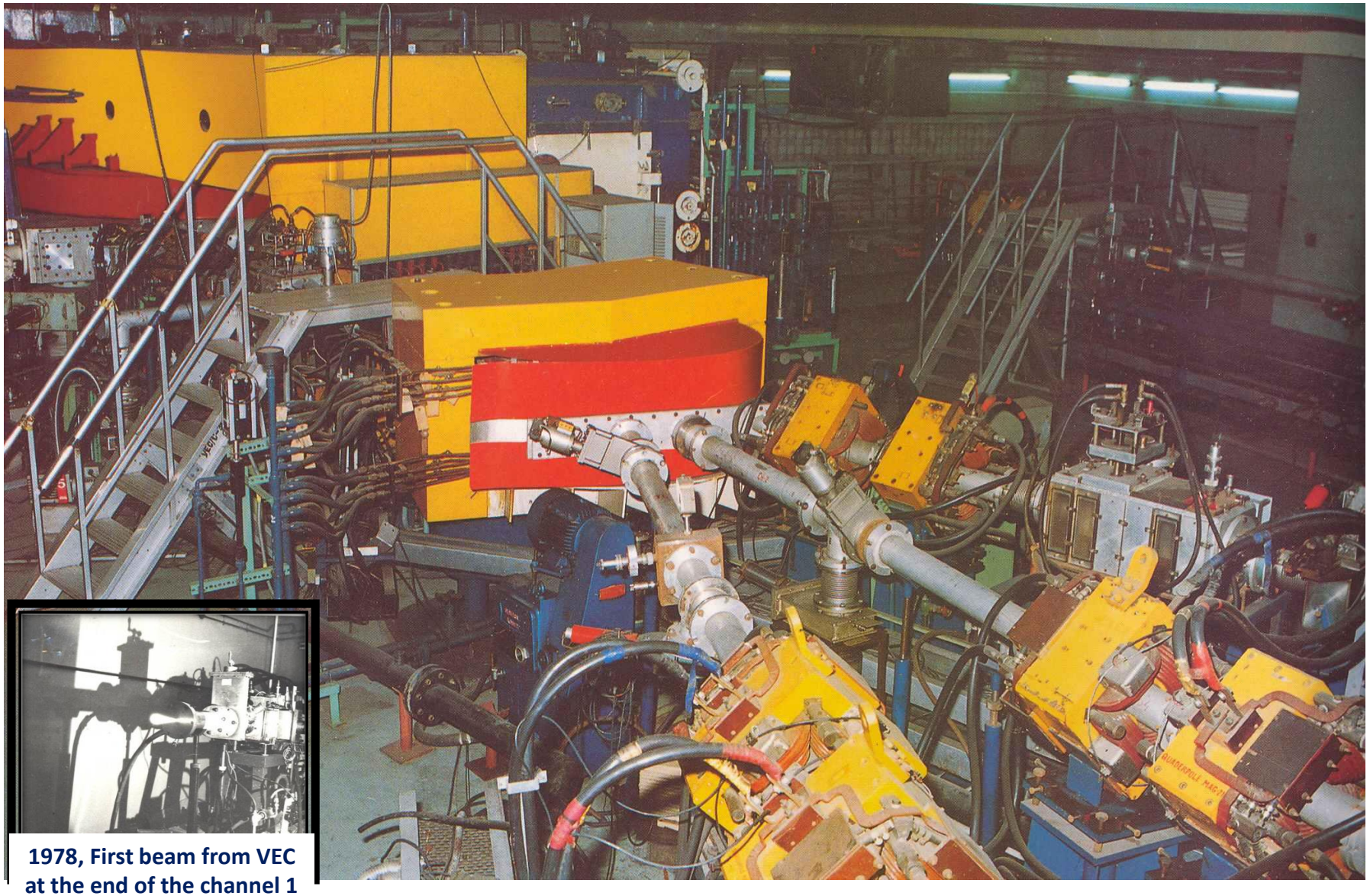
Inter University Accelerator Centre (IUAC), Delhi : 15 UD Pelletron & SC Booster - Nuclear Physics & Material Science.

Variable Energy Cyclotron Centre (VECC), Kolkata: Hosts Variable Energy Cyclotron; SC Cyclotron has been set up; Building RIB Facility

Note: There are several small accelerators in universities and R&D laboratories including IOP, Bhubaneswar, IGCAR, Kalpakkam, Panjab University, IIT Kanpur, Mangalore University , 3 MV tandem at GGV, Bilaspur, Kurukshetra University, Allahabad University etc.

Slide: S. Banerjee, BARC

224cm Variable Energy Cyclotron at Kolkata



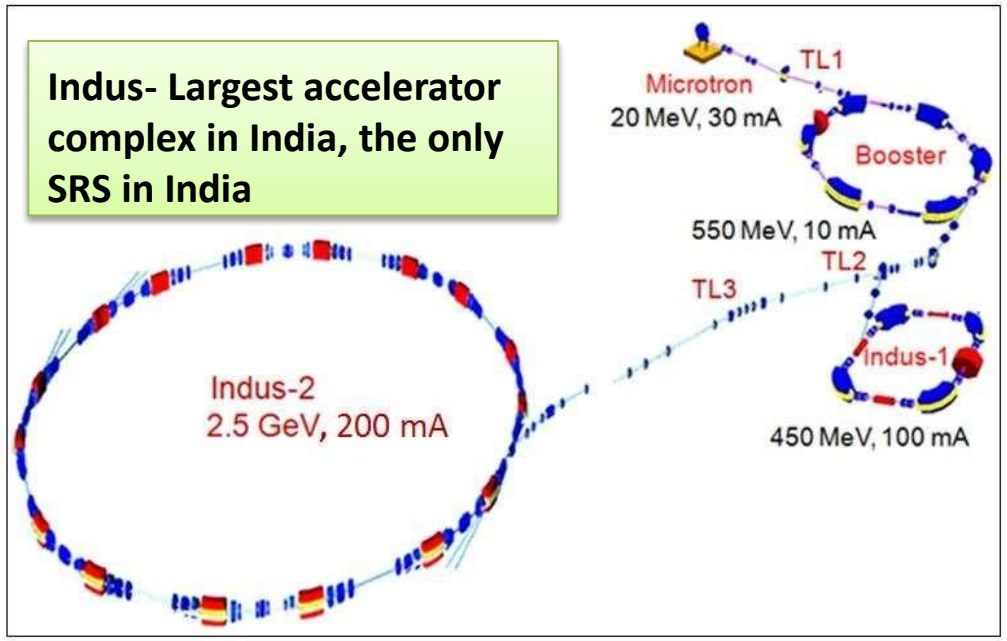
1978, First beam from VEC at the end of the channel 1

Courtsey: VECC

Superconducting Cyclotron at VECC

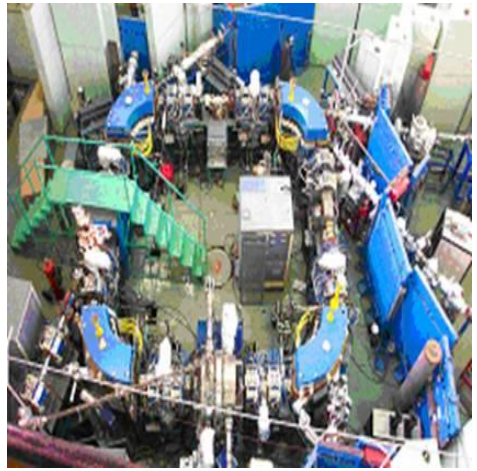
Courtsey: VECC

Raja Ramanna Centre for Advanced Technology (RRCAT), Indore



Indus-2 beam hall

Booster synchrotron



Indus-1 ring

Indus-2 ring

Courtsey: P.D. Gupta, RRCAT

Inter-University Accelerator Centre, New Delhi

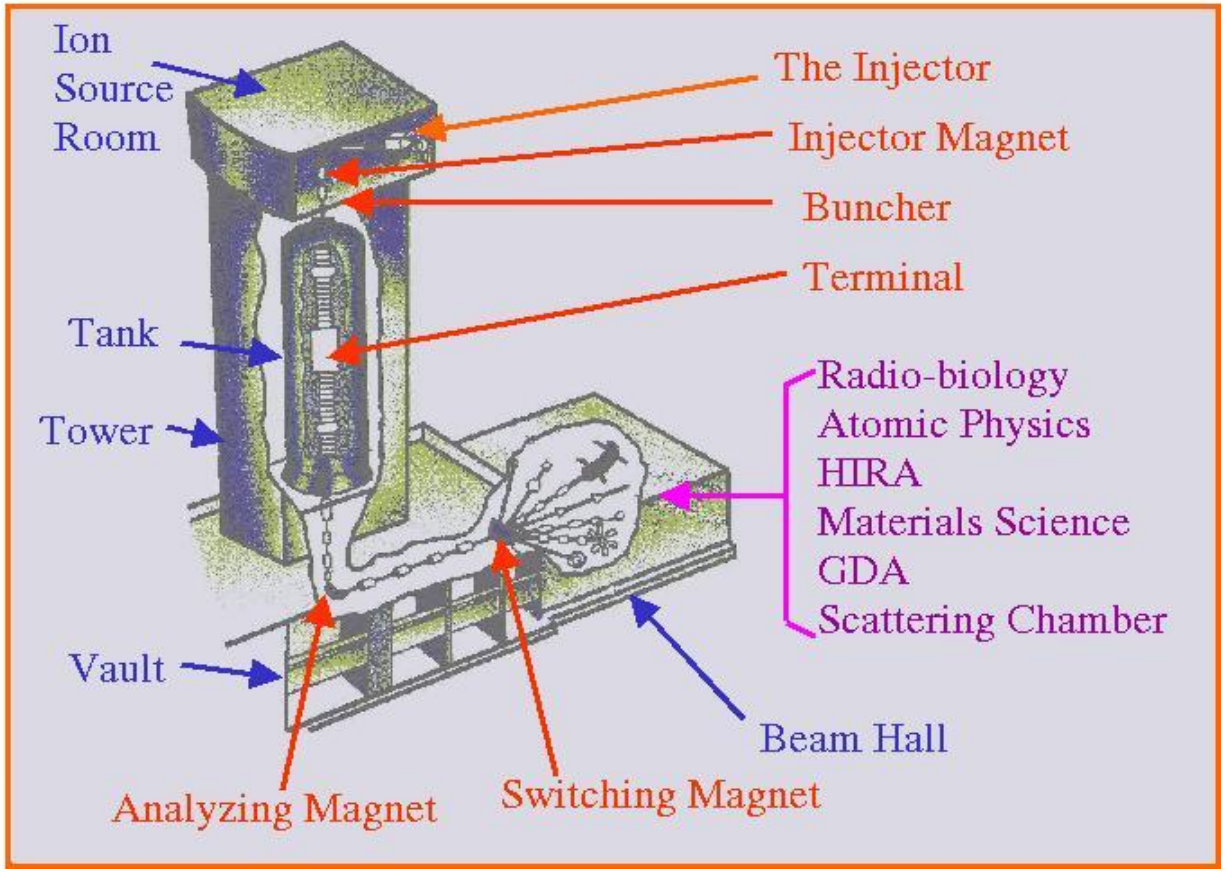
The Pelletron Accelerator

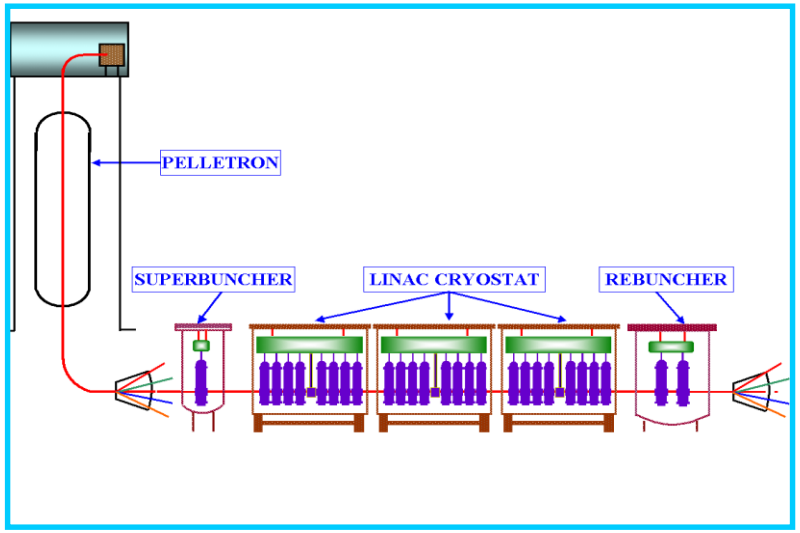
Tank ht: 26.5 m
Diameter: 5.5 m
Pressure: 86 PSI of SF6 gas

Ions accelerated:
H to Au beams

Ion Currents:
Typically
5 - 50 pnA

Energy : 30 - 250 MeV



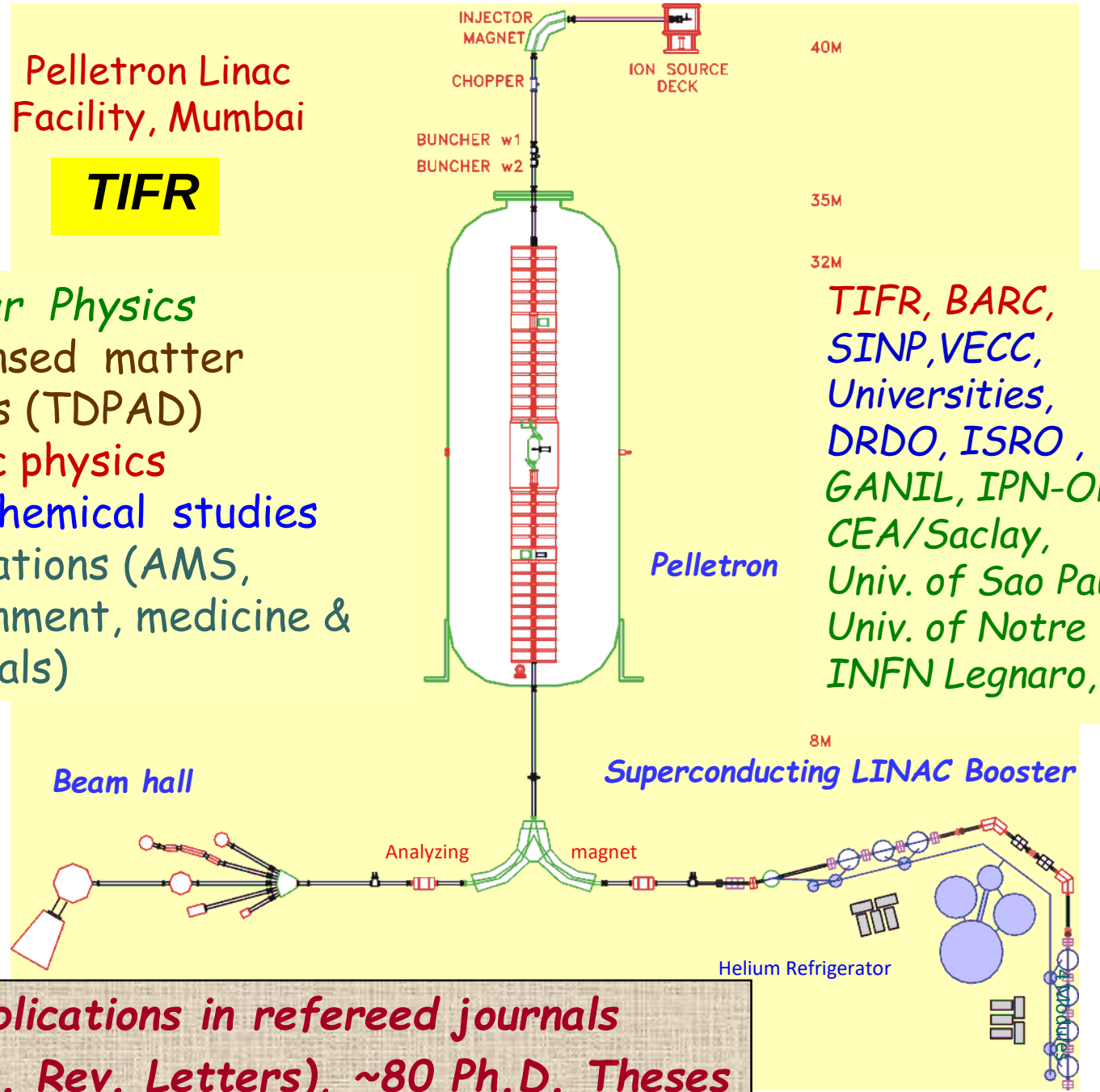


Courtsey: IUAC

Pelletron Linac Facility, Mumbai

TIFR

- *Nuclear Physics*
- Condensed matter physics (TDPAD)
- Atomic physics
- Radiochemical studies
- Applications (AMS, environment, medicine & materials)

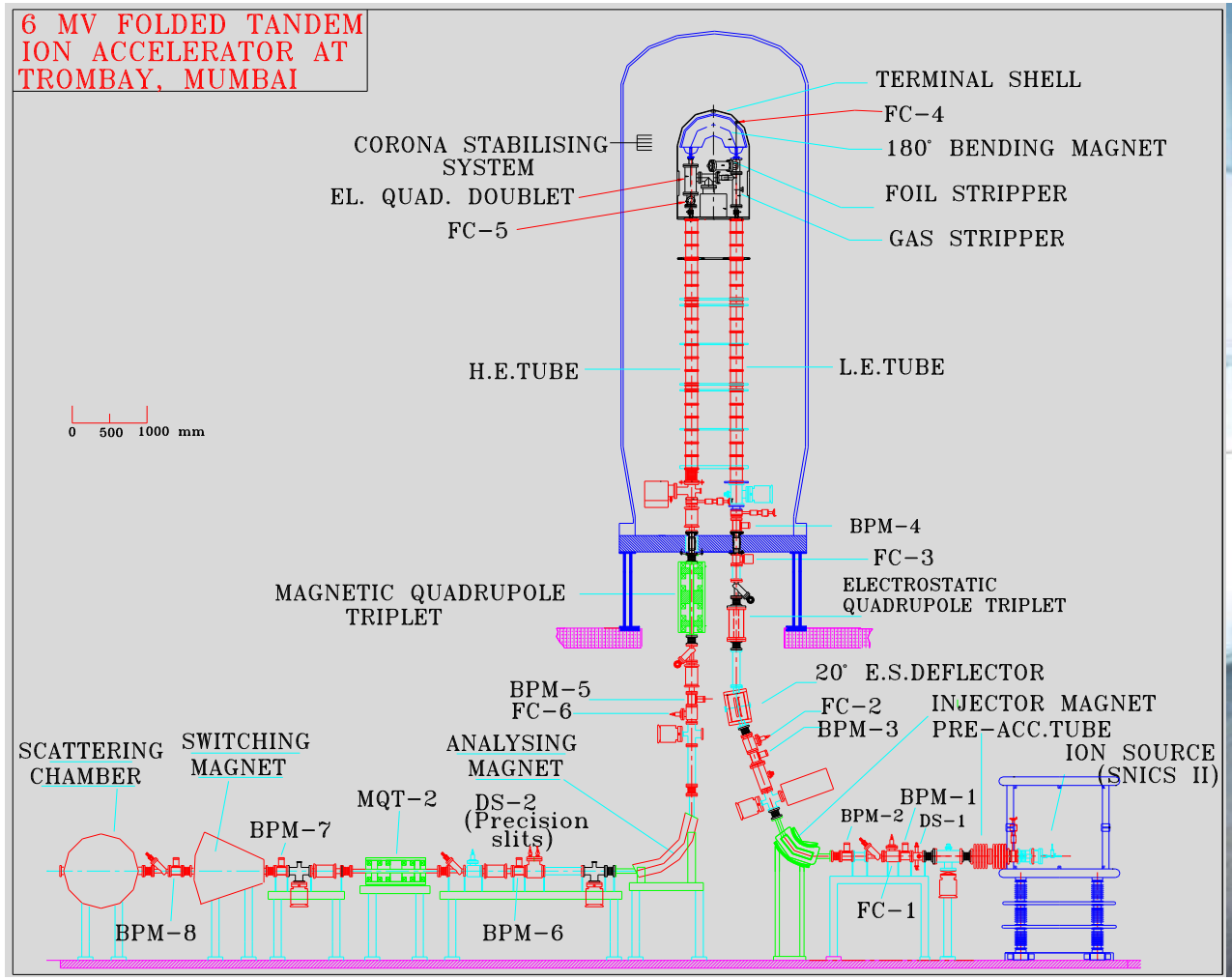


TIFR, BARC, SINP,VECC, Universities, DRDO, ISRO , GANIL, IPN-Orsay, CEA/Saclay, Univ. of Sao Paulo, Univ. of Notre Dame, INFN Legnaro, …

>500 publications in refereed journals (16 Phys. Rev. Letters), ~80 Ph.D. Theses

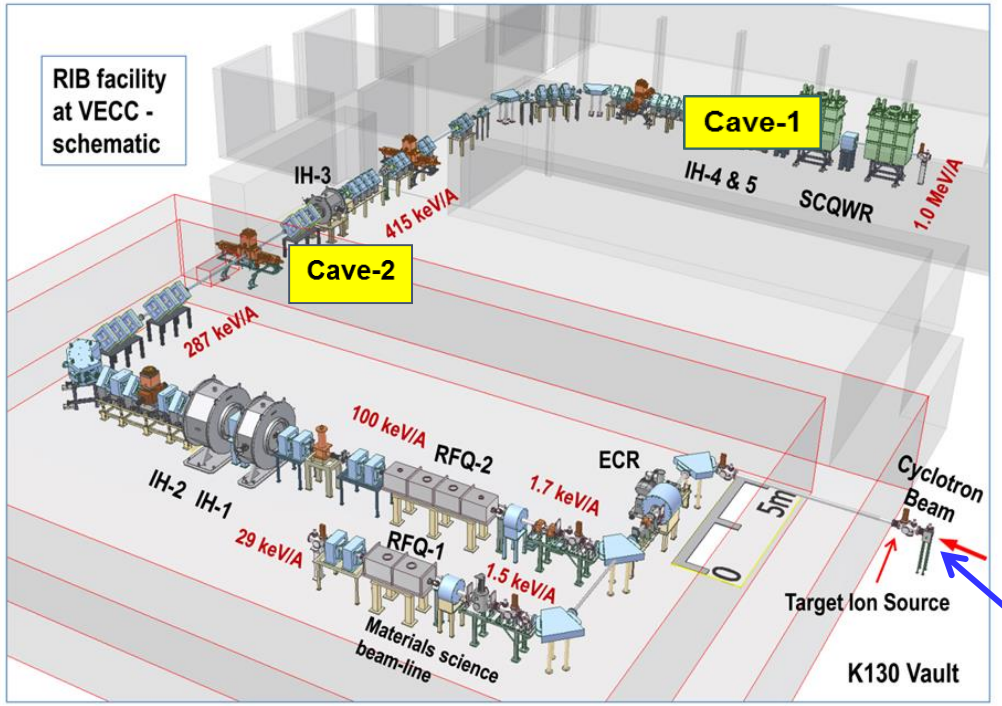
Courtesy: Vandana Nanal

6 MV Folded Tandem Ion Accelerator at BARC

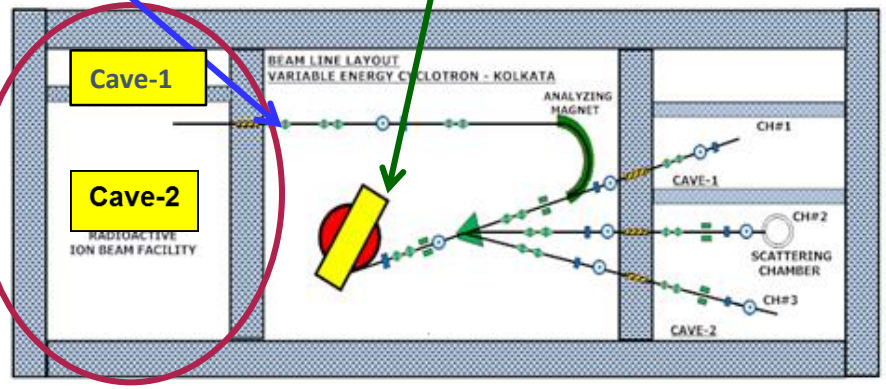


Courtsey: Pitamber Singh, BARC

Radioactive Ion Beam (RIB) development at VECC : the R&D phase



ANURIB



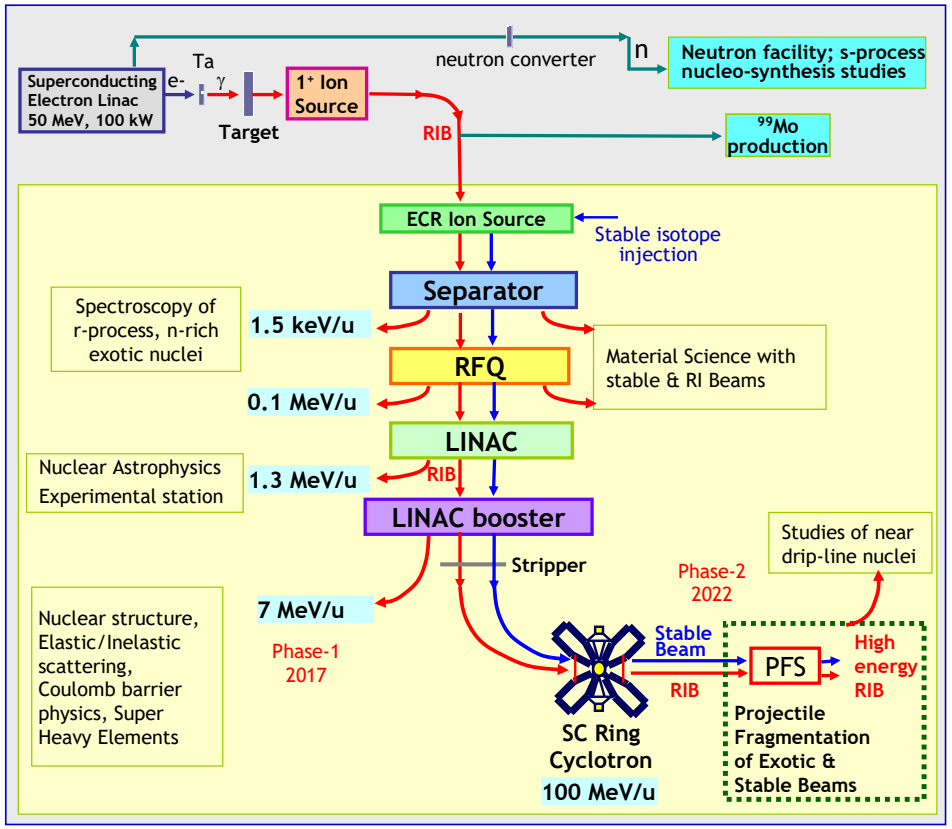
Courtsey: Alok Chakrabarti, VECC

(VECC)

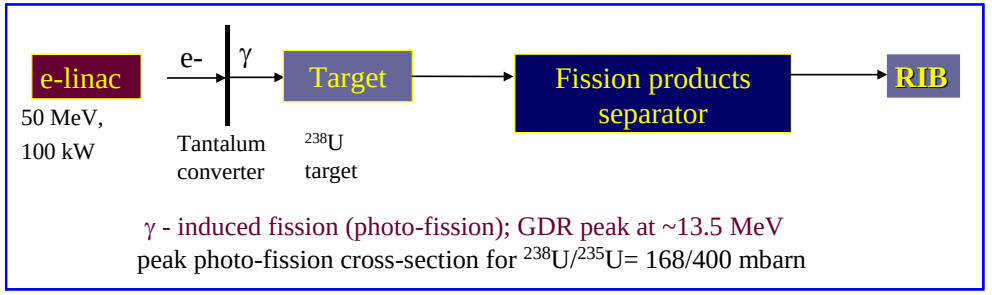
ANURIB

R&D activities are ongoing

Proposed mega-science facility ANURIB
Advanced National facility for Unstable & Rare Isotope Beams

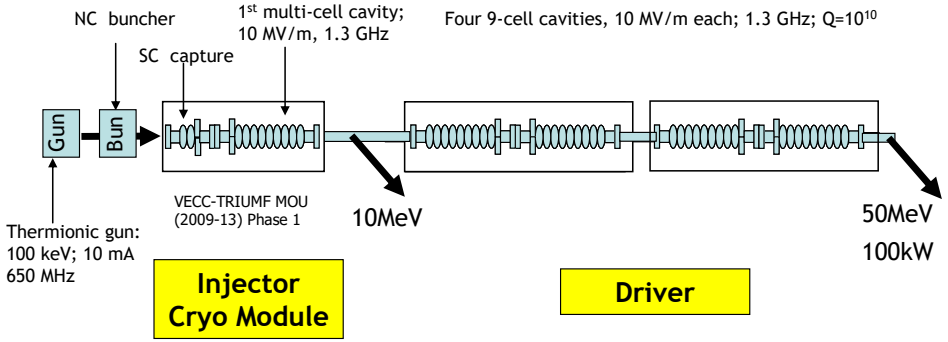


Production of neutron rich RIB using photo-fission of actinides



γ - induced fission (photo-fission); GDR peak at ~13.5 MeV
peak photo-fission cross-section for $^{238}U/^{235}U$= 168/400 mbarn

Superconducting Electron Linac photo-fission driver (VECC-Triumf collaboration)



Courtsey: Alok Chakrabarti, VECC

RRCAT & BARC

(R&D activities are ongoing)

Broad Parameters of Proton Linac System

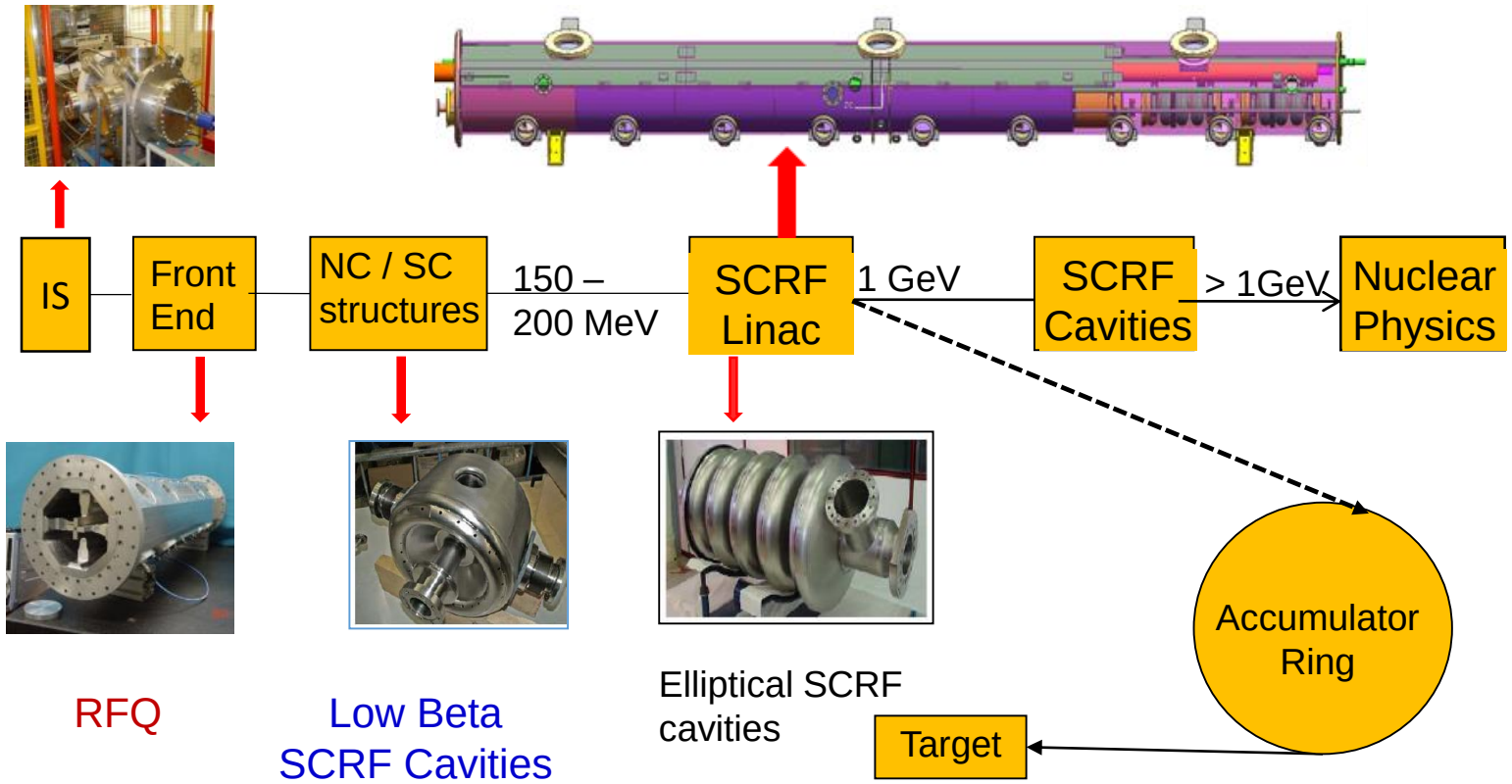
- Proton linac for Accelerator Driven System (ADS)
- Injector linac for Spallation neutron Source (SNS)

	Ions	Energy	Average current	Rep rate
ADS	Proton	1 GeV or higher	>10 mA	CW
SNS	H^-	1GeV	1 mA or higher*	20-50 Hz

* Typical pulse duration : 500 ms - 1ms, Peak current : 20 - 50 mA

Courtsey: P.D. Gupta, RRCAT

Proposed ISNS Facility (RRCAT)

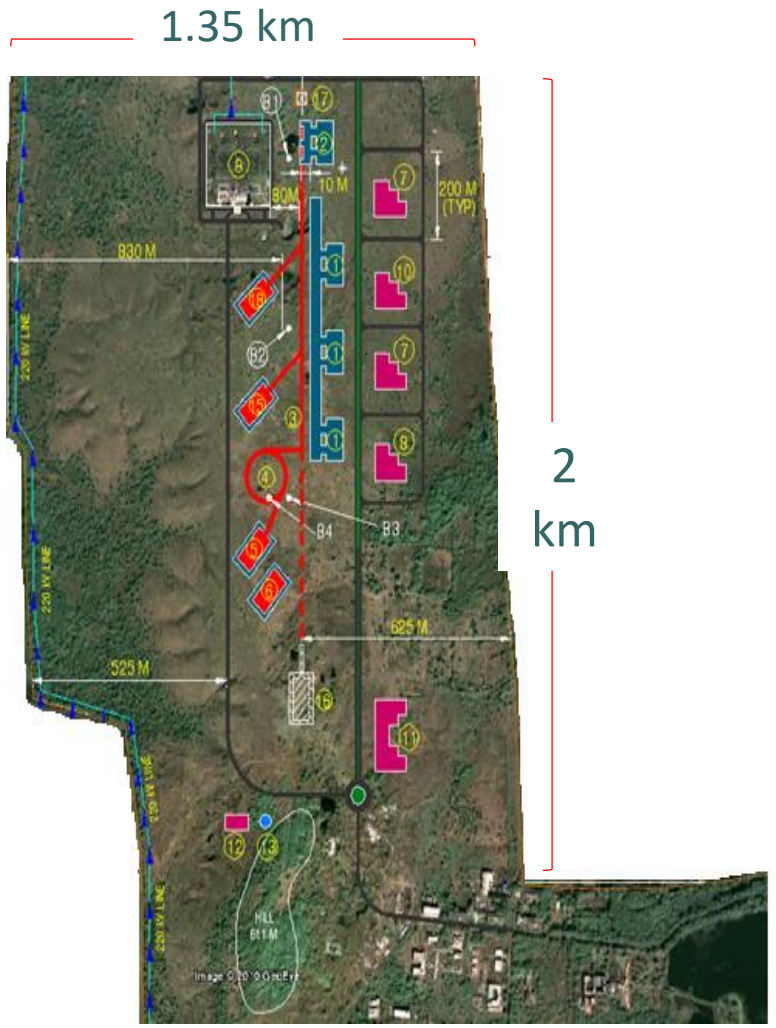


Courtsey: Satish Joshi, RRCAT

RRCAT

Preliminary Layout of Proposed ISNS Facility

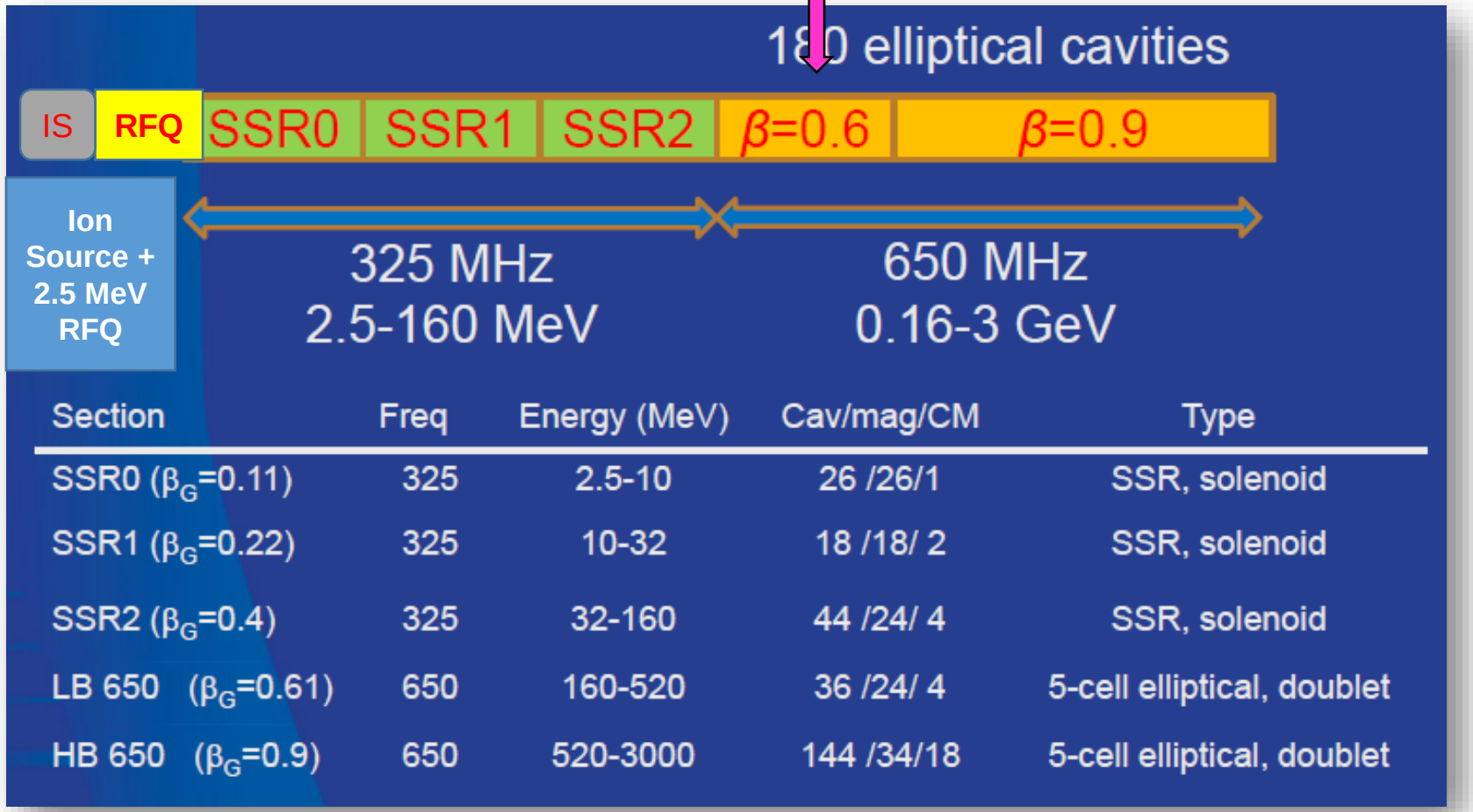
01 Klystron Gallary
02 Front End Building
03 Linac Tunnel 800M Long
04 Ring
05 Target Lab
06 Future Target Lab
07 Support Building
08 Cryogenic Plant
09 220/132/11 kV Sub Station
10 SCRF Facility
11 Lab & Office Building
12 Pump House
13 Over Head Water Tank
14 220 kV Over Head Line
15 Nuclear Exp. Facility
16 Future Nuclear Exp. Facility
17 Vertical Shaft for Tunnel Boring Machine
18 Proton Therapy Related Research Facility (~ 300 Mev)



Courtsey: P.D. Gupta, RRCAT

BARC

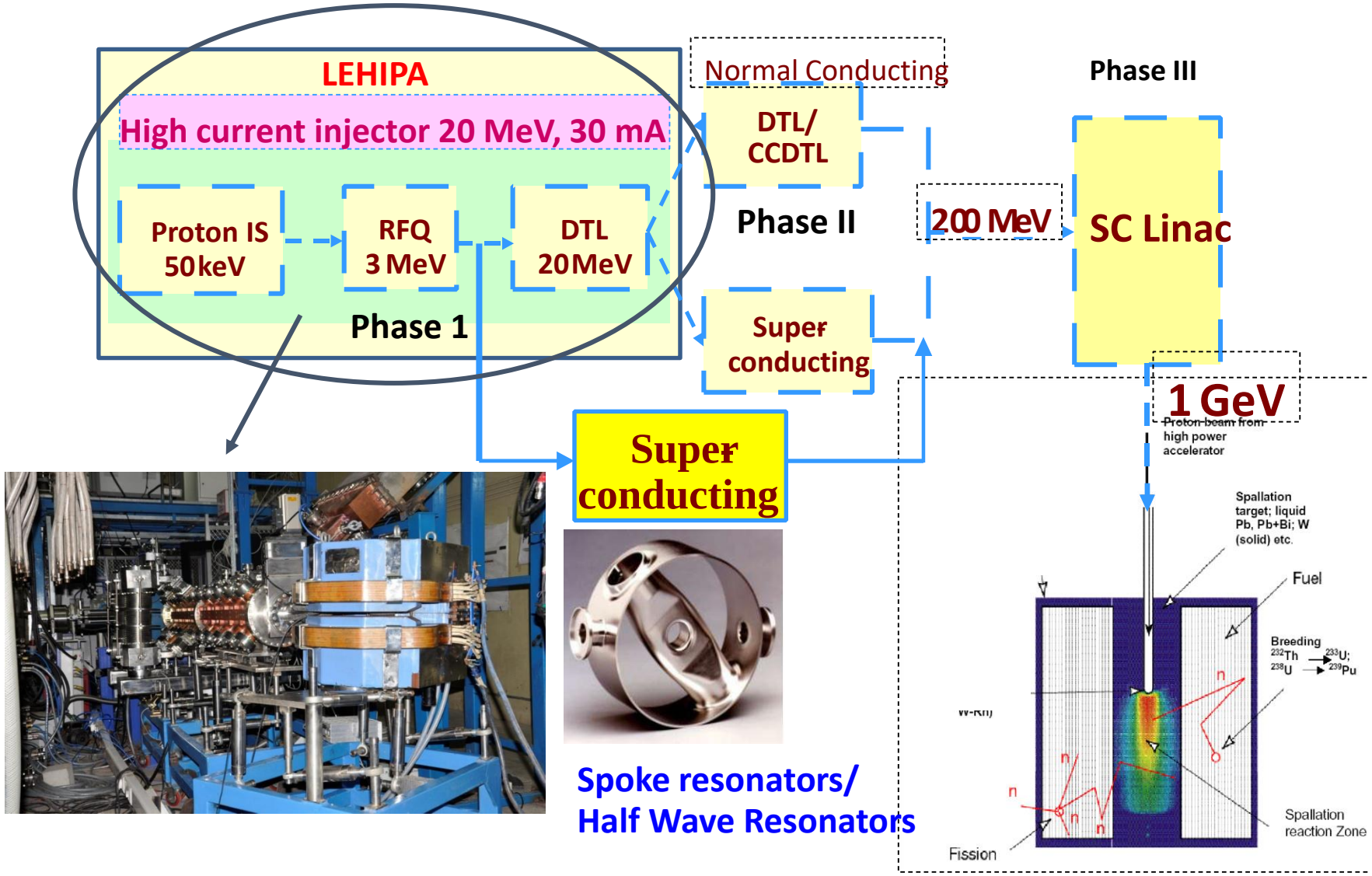
Superconducting linac (cw) :
200 – 300 MeV, ~5 mA protons



Section	Freq	Energy (MeV)	Cav/mag/CM	Type
SSR0 (β_G=0.11)	325	2.5-10	26 /26/1	SSR, solenoid
SSR1 (β_G=0.22)	325	10-32	18 /18/ 2	SSR, solenoid
SSR2 (β_G=0.4)	325	32-160	44 /24/ 4	SSR, solenoid
LB 650 (β_G=0.61)	650	160-520	36 /24/ 4	5-cell elliptical, doublet
HB 650 (β_G=0.9)	650	520-3000	144 /34/18	5-cell elliptical, doublet

Courtsey: Pitamber Singh, BARC

Roadmap for Accelerator Development for ADS in *BARC*



Spoke resonators/
Half Wave Resonators

Courtsey: Pitamber Singh, BARC

Pledged Indian in-kind contributions to FAIR

- Power converters for ~500 magnets of all sizes
- SC magnets for Low Energy Branch for nuclear physics research
- Beam catchers for pulsed beams (secondary) of heavy ions
- Vacuum chambers for diagnostics
- ~200 km long heavy duty current carrying cable
- Detectors and electronics for experiments (CBM, NuSTAR, ++)

All items are making good progress at various R&D laboratories and industries: Next talk !

Thank you all!