Indian Accelerator Programme

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Plan of the Talk:

1. **Accelerators in India** (BARC, RRCAT, VECC, IUAC)
2. **New proposals**
3. **Activities under IIFC**

Project-X Collaboration Meeting, Fermilab, October 25, 2011

Accelerators in India

Heavy Ion

- 6 MV Folded Tandem Ion Accelerator (BARC, Mumbai)
- 14 MV Pelletron (Mumbai)
- Superconducting Linac booster at Mumbai (Pb plated cavities)-Mumbai
- 16 MV Pelletron (IUAC, New Delhi)
- Superconducting Linac Booster at IUAC (Niobium cavities)-IUAC
- K=130 Room temp cyclotron (VECC, Kolkata)
- K= 500 Superconducting Cyclotron at Kolkata (VECC, Kolkata-under commissioning)
- 3 MV Tandetron at Hyderabad
- 1.7 MV high current Tandem Accelerator at IUAC
- 8 MeV Cyclotron at Chandigarh

Electron

- 450 MeV INDUS-I (SRS at RRCAT, Indore)
- 2.5 GeV INDUS-II (SRS at RRCAT, Indore)
- 10 MeV, 10 kW Linac at Mumbai for industrial application (BARC, Mumbai)
- 20 MeV Microtron (Mangalore)
- 10 MeV Electron Linac at RRCAT
- 7 MeV Electron accelerator (BARC, Mumbai)
- 2 MeV Electron Linac (ILU-6) at Mumbai
- 750 keV Electron DC accelerator at RRCAT

Proton (projects) and R&D

- ✓ 1 GeV, 30 mA Linac (Injector: 20 MeV LEHIPA)- BARC
- ✓ 1 GeV SNS [100 MeV H^- Linac+ RCS]- proposal by RRCAT, Indore

Fermilab

Present Accelerators

14 MV BARC-TIFR Pelletron at Mumbai

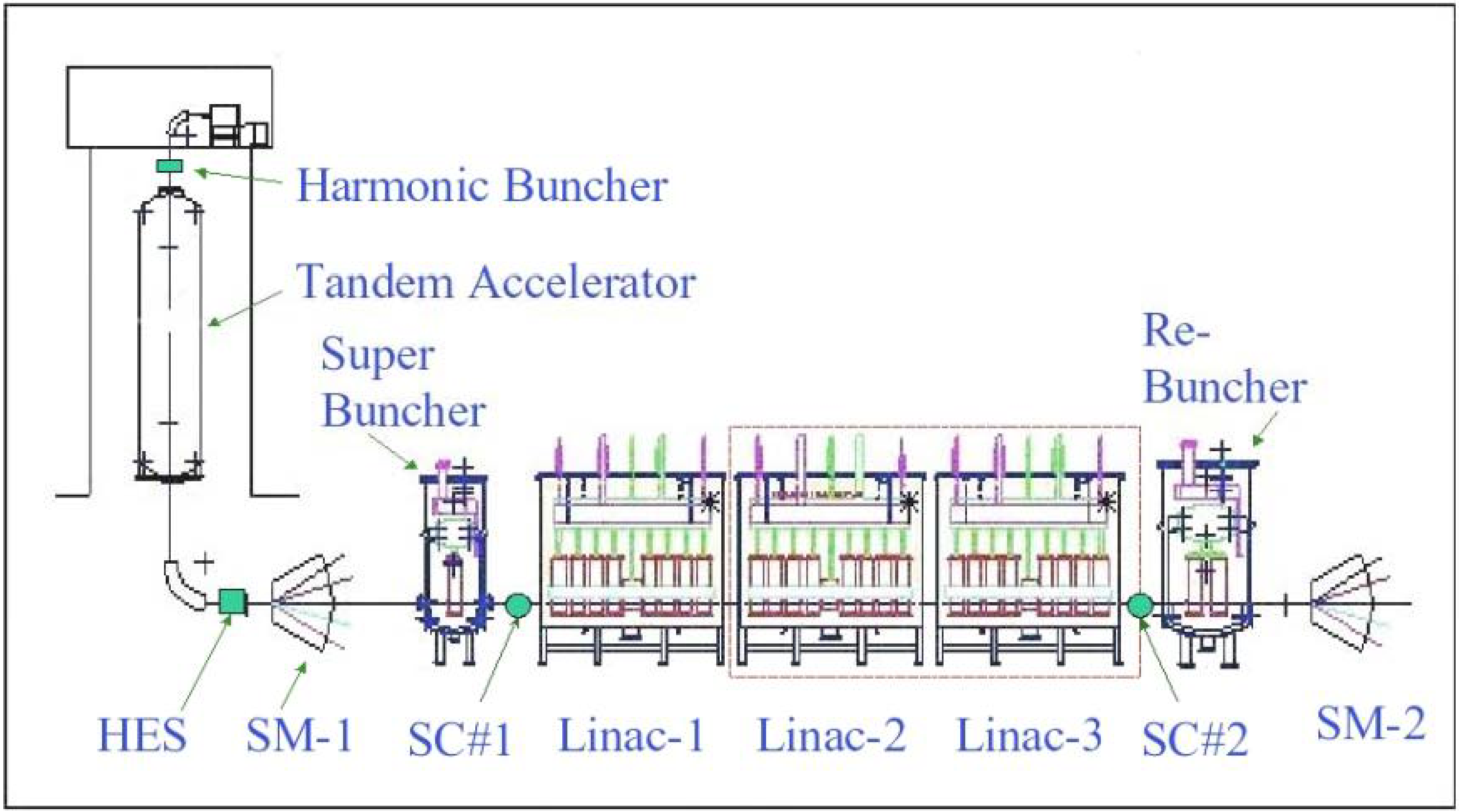
a)

b)

a) 14 UD Pelletron Facility at Mumbai   b) High voltage column section

Superconducting LINAC Booster

28 Pb plated QWR in 7 Cryomodules , Energy Gain 14 MeV /q



Harmonic Buncher
Tandem Accelerator
Super Buncher
Re-Buncher
HES
SM-1
SC#1
Linac-1
Linac-2
Linac-3
SC#2
SM-2

QWRs for IUAC Linac

QWRs: Required 27, built 30

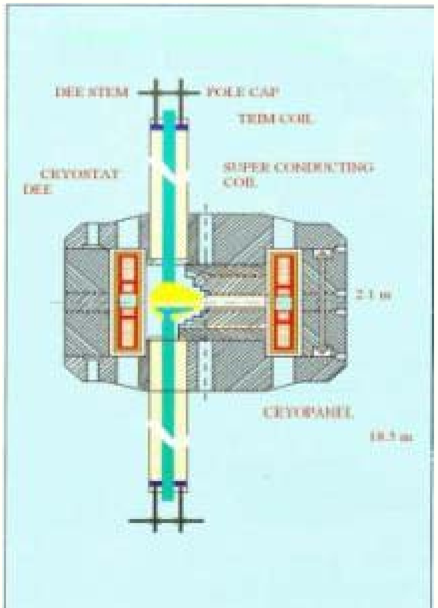
Automation of the linac operation is undertaken with 2 modules. Beam delivered with two modules.

Piezotuner for cryostats 2 & 3 are being planned

3 cryostat also tested upto LN2 temperature.

Accelrating Field reached in QWR, 5-6 MV/m

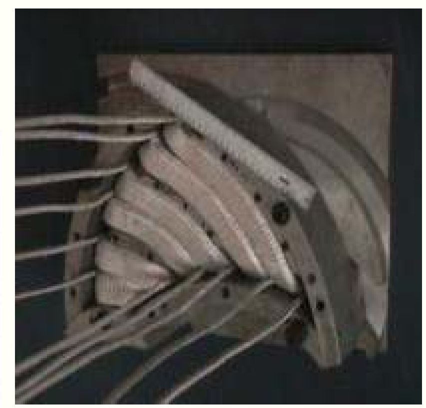
K=500 Superconducting Cyclotron at Kolkata



K=500

Superconducting Cyclotron

Magnet assembly at the fabrication site

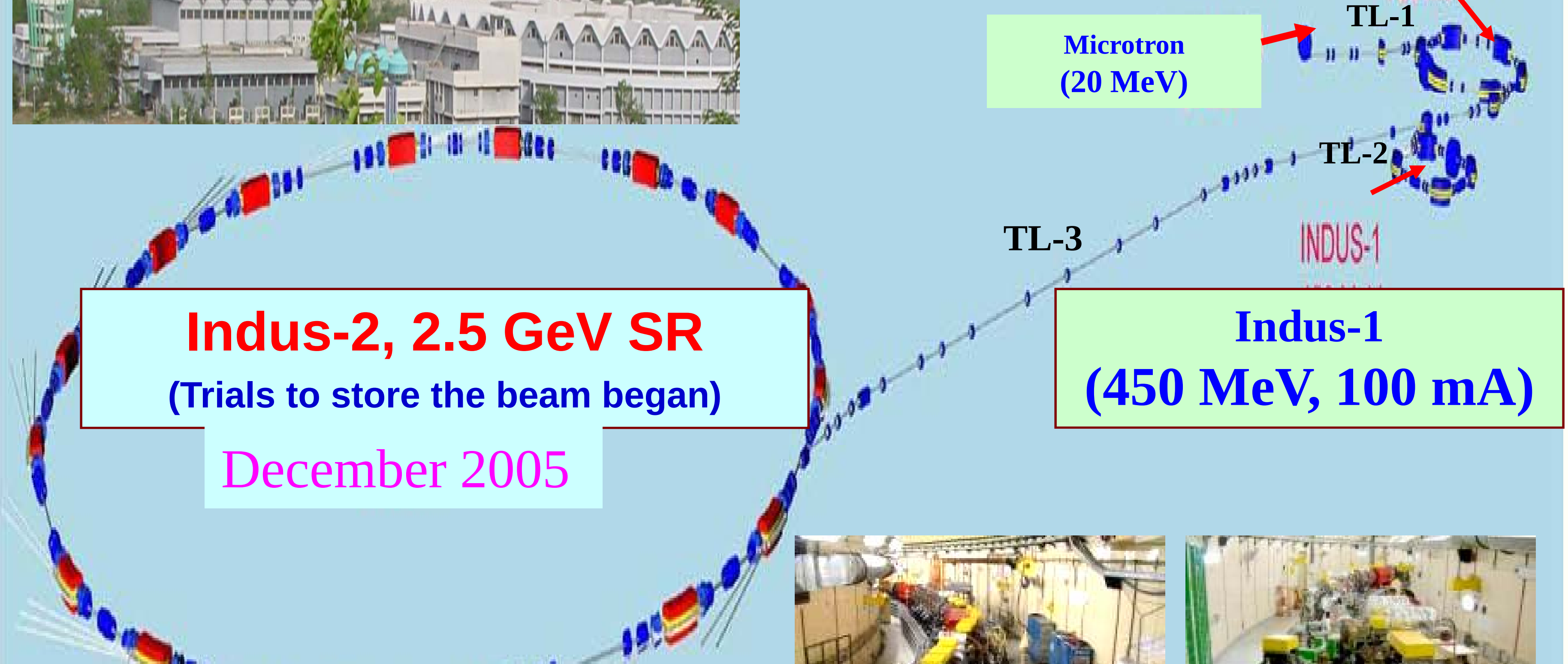


Trim coils wound on pole tip before potting

Vertical cross-sectional view

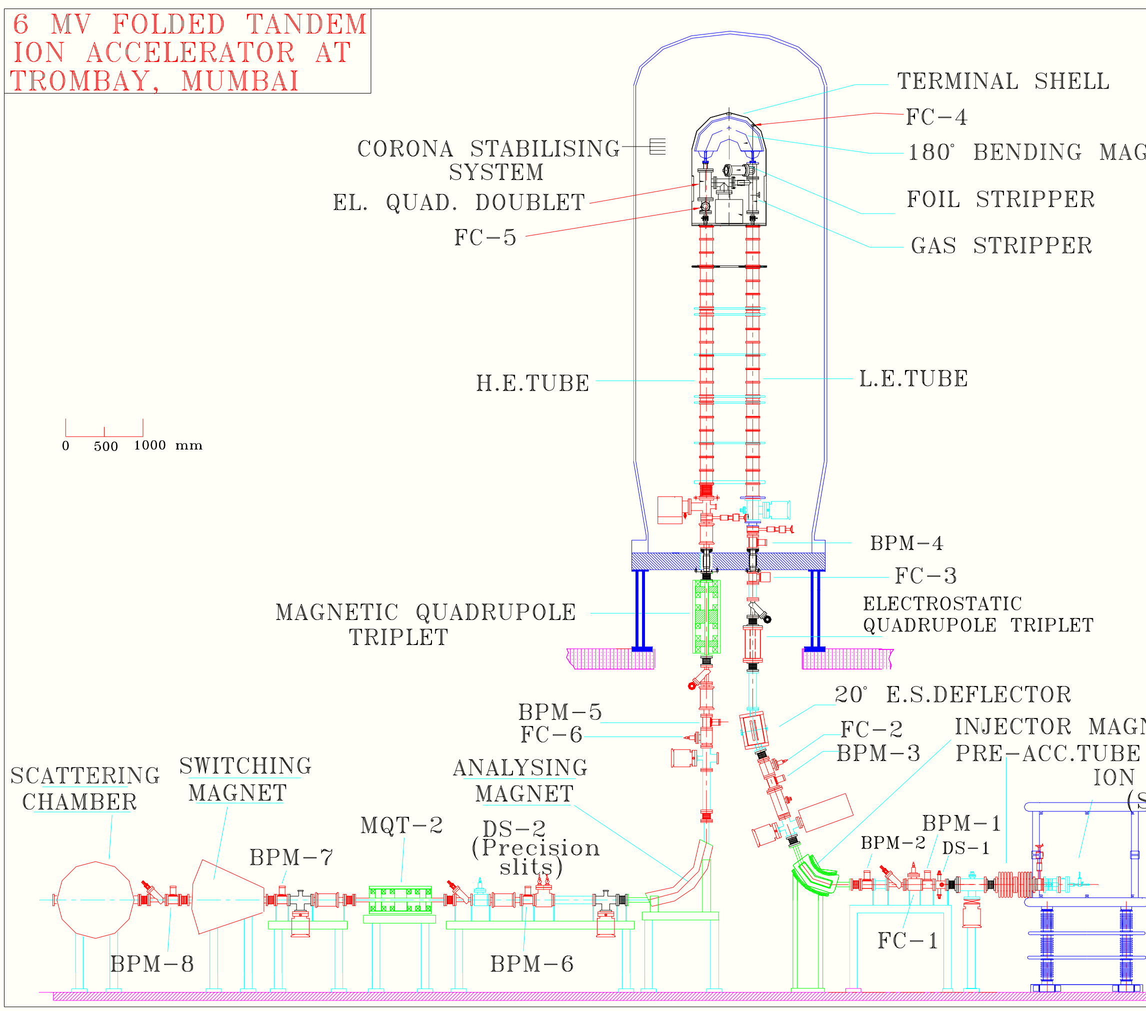
Pole tip assembly

SCHEMATIC OF INDUS COMPLEX at RRCAT, Indore



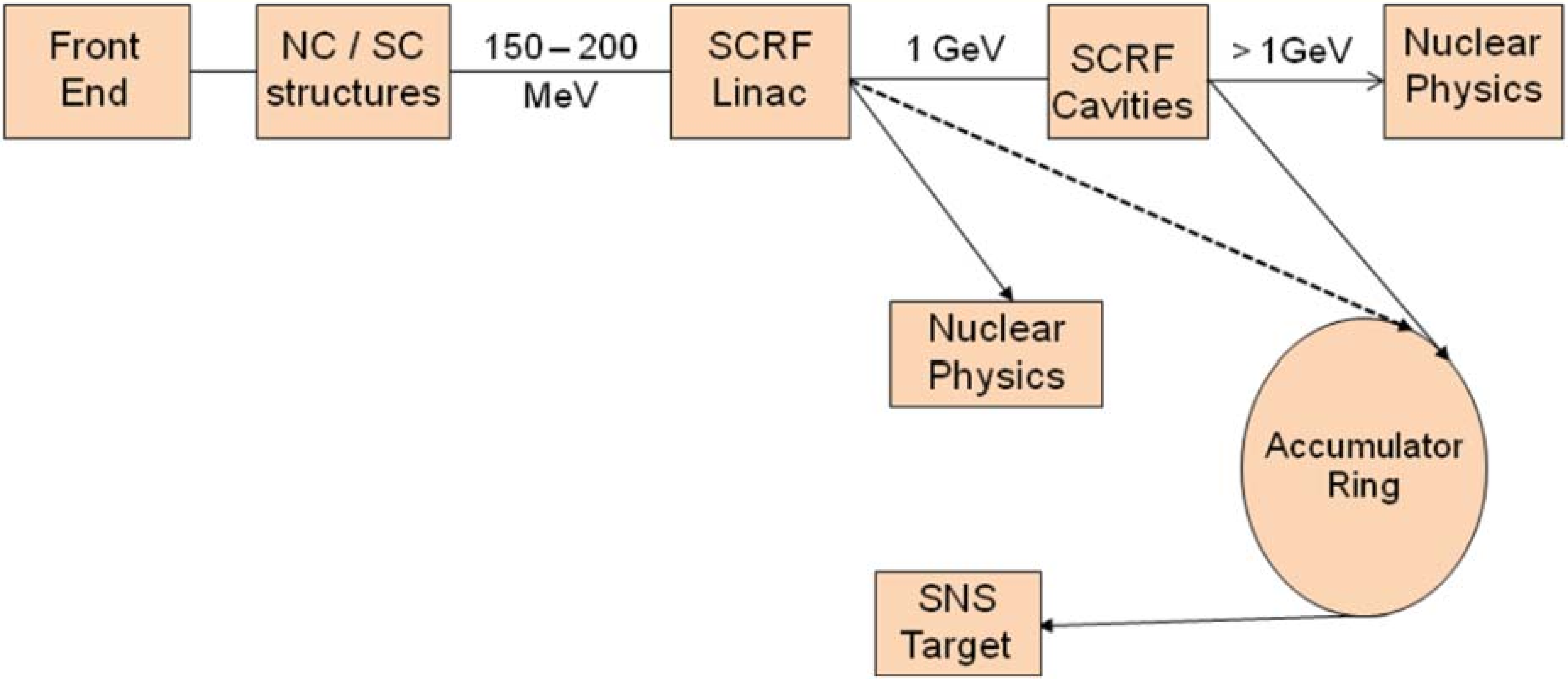
Both Indus-1 & Indus-2 are being run for users.

6 MV Folded Tandem Ion Accelerator



Major High Intensity Proton Accelerator Projects

Schematic of SNS at RRCAT



Linac output energy:	**1 GeV**
Type of particle:	**H^- ion**
Average linac pulse current:	**20 mA**
Pulse repetition rate:	**50 Hz**
Pulse duration:	**1 ms**
Duty factor:	**5%**

Roadmap for Accelerator Development for ADS

Modified

Normal Conducting

Phase III

High current injector 20 MeV, 30 mA

Proton IS
50 keV

RFQ
3 MeV

DTL
20 MeV

Phase 1

DTL/
CCDTL

Phase II

Super-
conducting

100 MeV

SC Linac

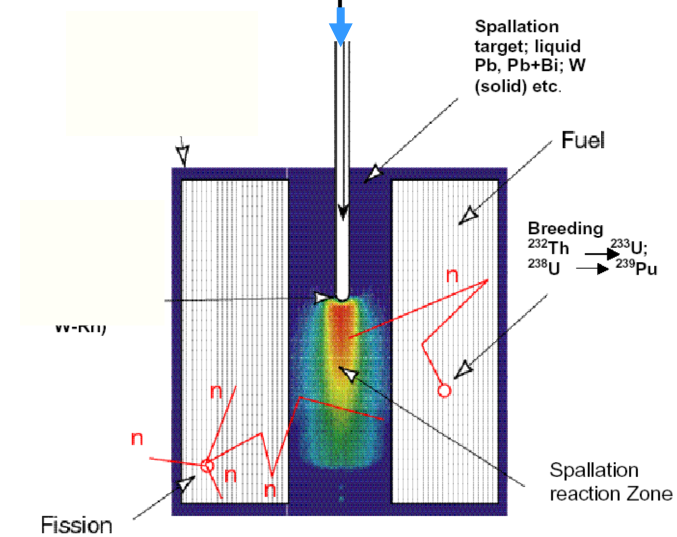
1 GeV

Proton beam from high power accelerator

Super-conducting

Spoke cavities or/ and HWR

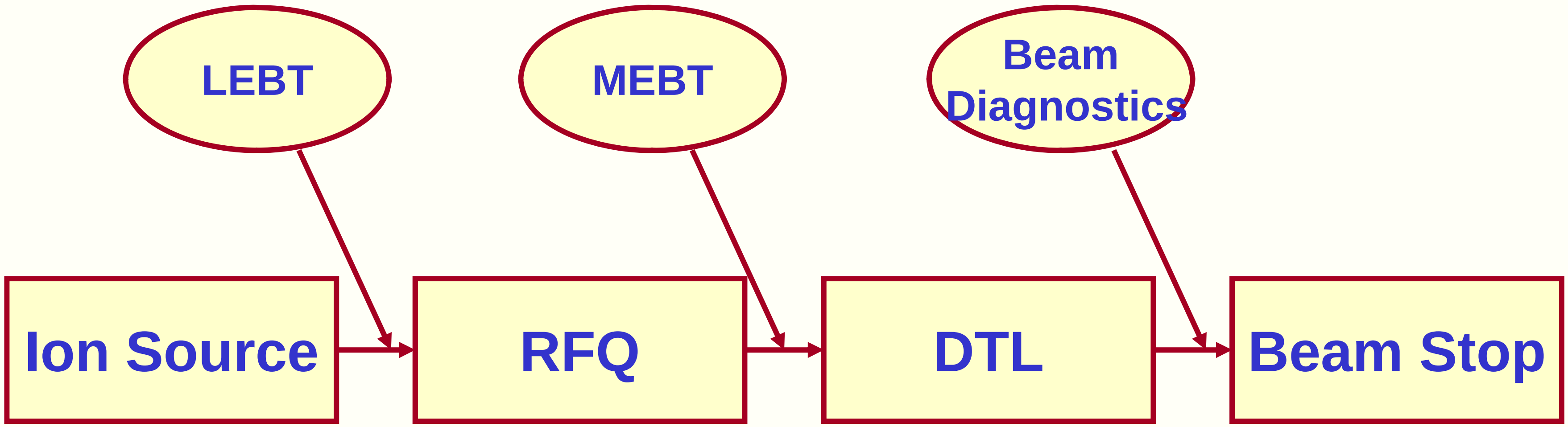
325 and 650 MHz under IIFC



Phase I

Building of a Low Energy High Intensity Accelerator
LEHIPA (20 MeV, 30 mA)

Layout of 20 MeV Linac Section (LEHIPA)



ECR Ion source
50 keV, 35mA.

RFQ 4 Vane type
3MeV, 30 mA

20 MeV, 30 mA
Alvarez type DTL

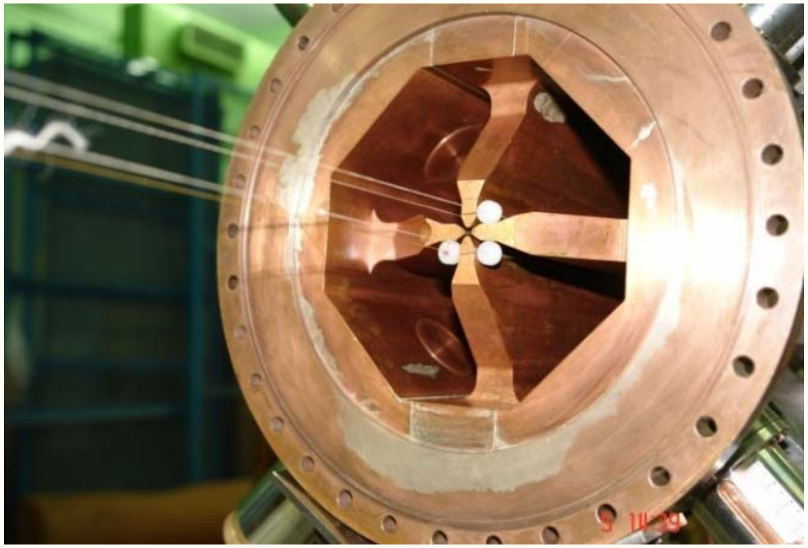
LEBT : Low Energy Beam Transport System

RFQ : Radio Frequency Quadrupole

MEBT : Medium Energy Beam Transport System

DTL : Drift Tube Linac

RFQ, & DTL and PMQ Prototypes



Anatomy of drift tube
(exploded view)

Prototype Drift Tube with permanent magnet quadrupole focussing and coolant channels

DAE & US Accelerator Laboratories MOUs

Memorandum of Understanding
between
US Universities & Accelerator Laboratories
and
Indian Universities & Accelerator Laboratories
concerning
Collaboration on R&D for Various Accelerator Physics and High Energy Physics Projects

January 9, 2006

1. Introduction

1.1 General Description

This Memorandum of Understanding (MOU) establishes a collaboration framework between various US and Indian Accelerator Laboratories and

4.2 Approvals
The following concur in the terms of this Memorandum of Understanding:

Piermaria Oddone, Director, FNAL	Vinod C. Sahni, Director, CAT
Date 1/9/06	Date March 8, 2006
Jonathan Dorfan, Director, SLAC	Bikash Sinha, Director, VECC
Date 1/23/06	Date March 9, 2006
Christoph Leemann, Director, TJNAF	Amit Roy, Director, IUAC
Date 1/18/06	Date March 9, 2006
Maury Tigner, Director, Newman Lab	S. Bhattacharya, Director, TIFR
Date	Date April 17, 2006
	S. Banerjee, Director, BARC
Date	Date March 14, 2006
	Deepak Pental, Vice Chancellor, DU
Date	Date April 10, 2006

ADDENDUM
to the
Memorandum of Understanding
between
US Universities & Accelerator Laboratories
and
Indian Universities & Accelerator Laboratories
concerning
Collaboration on R&D for Accelerator Physics and High Energy Physics Projects

Addendum I: "Fermilab, RRCAT, BARC, IUAC and VECC Collaboration on ILC Main Linac SRF Accelerator Technology R&D"

October 2, 2007

1. Introduction

The work detailed in this document falls within the scope of the Memorandum of Understanding (MOU) between US and Indian Institutions dated January 9, 2006. It

7 Management and Approval:

The work under this MOU will be jointly managed by Dr. Shekhar Mishra, Fermilab and Dr. Vinod C. Sahni, India. They represent the institutions in the respective countries and serve as a single point of contact.

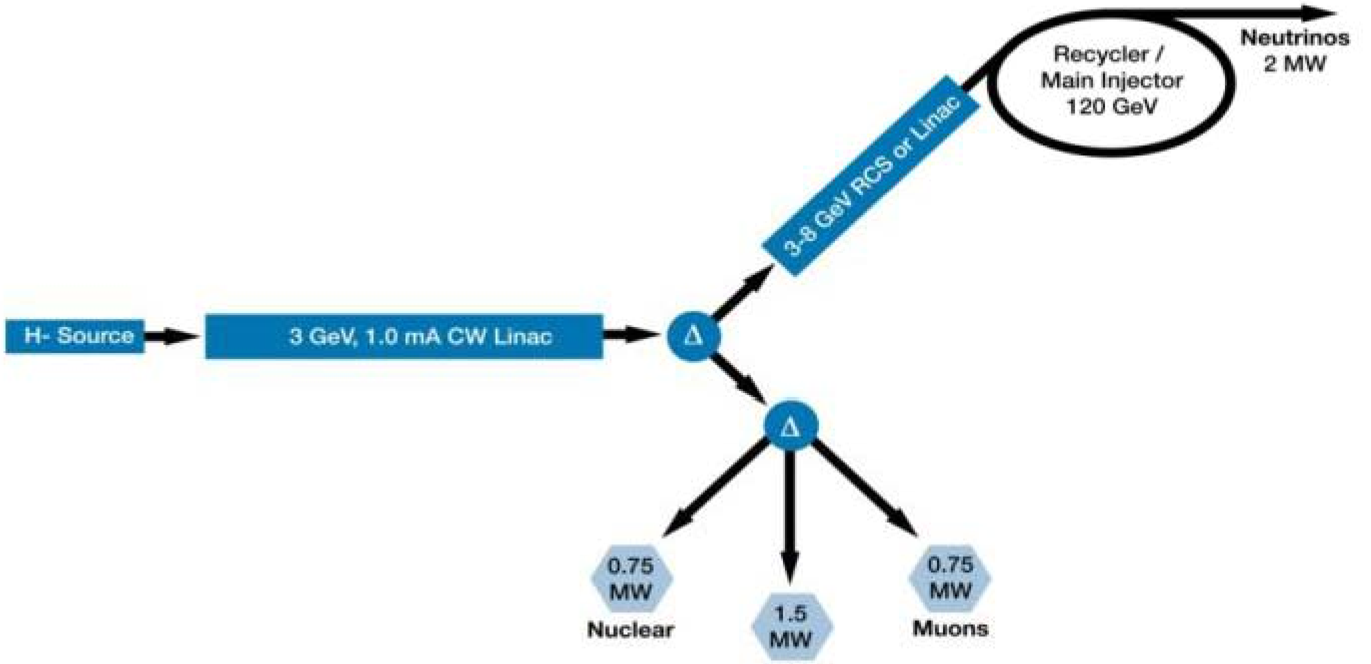
The following concur on the terms of this Memorandum of Understanding:

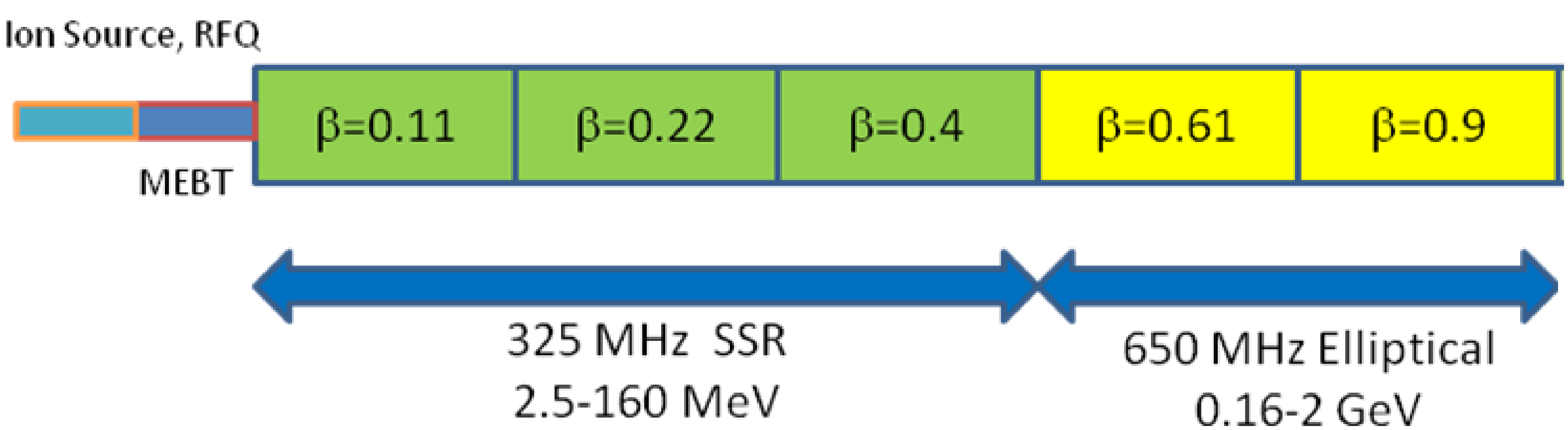
Dr Vinod C. Sahni, Director, RRCAT	Dr. Piermaria Oddone Director, FNAL
Oct 2, 2007 Date	10/2/07 Date
	Dr. Shekhar Mishra Deputy ILC Program Director, FNAL
	10/2/07 Date

Addendum III

Addendum III: Fermilab and Indian Accelerator Laboratories Collaboration on High Intensity Proton Accelerator & SRF Infrastructure Development

Schematic of Project-X





2 Committees were formed for Indian Institutes Fermilab Collaboration (IIFC).

1. **Apex IIFC Committee (Policy matters)**
2. **IC-IIFC Committee (Technical matters)**

6 documents were signed on August 22, 2011 at OYC, Mumbai:

Fermilab and Indian Accelerator Laboratories collaboration for High Intensity Proton Accelerator on:

1. **RF Power Development (325 MHz) - Addendum V**
2. **RF Power Development (650 MHz) - Addendum VI**
3. **Instrumentation and Control - Addendum VII**
4. **Accelerator Physics Issues - Addendum VIII**
5. **Cryo-module Test Facility (CMTF)**
6. **Supplement 1 to Addendum III (to MoU) between Fermilab and Indian DAE Laboratories (BARC, RRCAT, VECC) & IUAC**

Addendum Signing at Mumbai on Aug 22, 2011

Activities under IIFC

BARC:

1. Accelerator Physics,
2. 1,3 and 7 kW Solid State Power Amplifier at 325 MHz
3. LLRF system, RF protection system, Cryogenic Temperature Monitoring System, Beam Position Monitor (BPM) System
4. Design and development of CMTF

VECC:

1. R&D of 650 MHz , beta= 0.61 elliptical cavity
2. R&D for Helium vessel & Blade Tuner for 650 MHz, beta= 0.61, 5 cell cavity
3. SS Jacketing for single spoke beta=0.20 resonator.
4. Design of Test Cryostat for 650 MHz, beta=0.61, 5 cell elliptical cavity
5. High Power RF source development (60 kW IOT based)

RRCAT

1. Vertical and Horizontal Test Stands
2. R&D for 650 MHz , beta=0.90 elliptical cavity and cryomodule
3. 30 kW Solid State Amplifiers at 650 MHz
4. Development of RF components for 650 MHz
5. Infrastructure developments for cavity fabrication, processing and testing

IUAC

1. Design and fabrication of SSR1, 325 MHz, beta = 0.22
2. EBW of superconducting cavities

Phase 1:

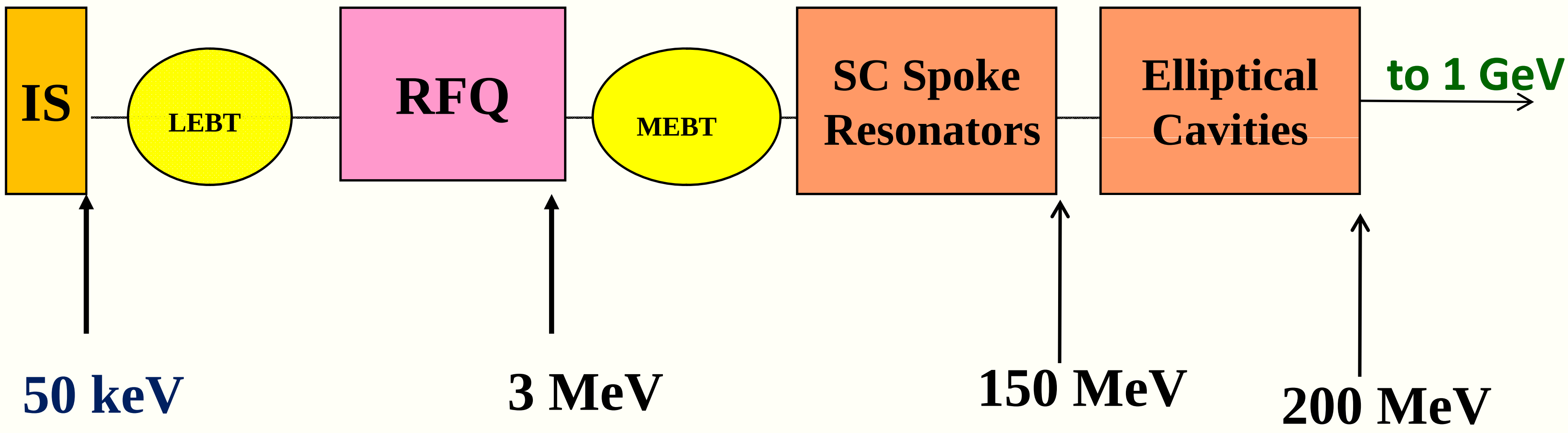
Institutions	Components to Fermilab	Quantity	Date	Indian POC
IUAC	SSR1	2	May 2011	P. N. Prakash
	SSR1	4+1	Oct 2014	P. N. Prakash
IUAC+VECC	Spoke Resonator Cryomodule Design and Prototype		Oct 2014	A. Duttagupta
RRCAT	1.3 MHz 1-cell, beta=0.9	2	May 2011	A. Puntambekar
	1.3 MHz 5-cell, beta=0.9	1	July 2011	A. Puntambekar
	650 MHz 1-cell, beta=0.9	1+1	Oct 2011	A. Puntambekar
	650 MHz 5-cell, beta=0.9	1	Oct 2012	A. Puntambekar
	650 MHz 5-cell, beta=0.9	4+1	May 2014	A. Puntambekar
RRCAT	650 MHz 5-cell, He Vessel	4+1	May 2014	J. Dewedi
RRCAT	650 MHz 5-cell, Blade Tuner	4+1	May 2014	J. Dewedi
VECC	650 MHz 1-cell, beta=0.6	1+1	Oct 2011	S. Som
	650 MHz 5-cell, beta= 0.6	1	Oct 2012	S. Som
	650 MHz 5-cell, beta= 0.6	2+1	May 2014	S. Som
VECC	650 MHz 5-cell, He Vessel	2+1	May 2014	S. Som
VECC	650 MHz 5-cell, Blade Tuner	2+1	May 2014	S. Som
RRCAT	650 MHz Cryomodule Design, beta = 0.9	1	Dec 2011	P. Khare
RRCAT	2 cavities HTS	1	Oct 2012	P. Kush
Fermilab	2 cavities VTS (to RRCAT)	1	May 2011	S. Joshi
BARC	Cryomodule Test Stand 1300 MHz Pulsed/650 MHz Design	1	June 2012	Manjit Singh
BARC	Cryomodule Test Stand 1300 MHz Pulsed/650 MHz CW	1	Oct 2014	Manjit Singh

Phase II:

Institutions	Components to Fermilab	Quantity	Date	Indian POC
BARC	325 MHz RF Power (1 KW)	1	Dec 2011	M Pande
	325 MHz RF Power (3 KW)	1	Dec 2012	M. Pande
	325 MHz RF Power (7 KW)	1	Dec 2014	M. Pande
RRCAT	650 MHz RF Power (250 W)	1	Dec 2011	P. R. Hannurkar
	650 MHz RF Power (1 KW)	1	Dec 2012	P. R. Hannurkar
	650 MHz RF Power (30 KW)	1	Dec 2014	P. R. Hannurkar
BARC	Low-Level RF System	1	Dec 2014	C. K. Pithawa
	RF Protection Interlock System	1	Dec 2014	C. K. Pithawa
	Cryogenic Temperature Monitoring System	1	Dec 2014	C. K. Pithawa
	Beam Position Monitor	4	Dec 2013	C. K. Pithawa
BARC+RRCAT + VECC + IUAC	Cryomodule Test Facility at 650 MHz	1	Dec 2014	M. Singh

Frequency: 325 and 650 MHz

Scheme for 200 MeV High Intensity Proton Accelerator (a front end of the 1 GeV Linac)

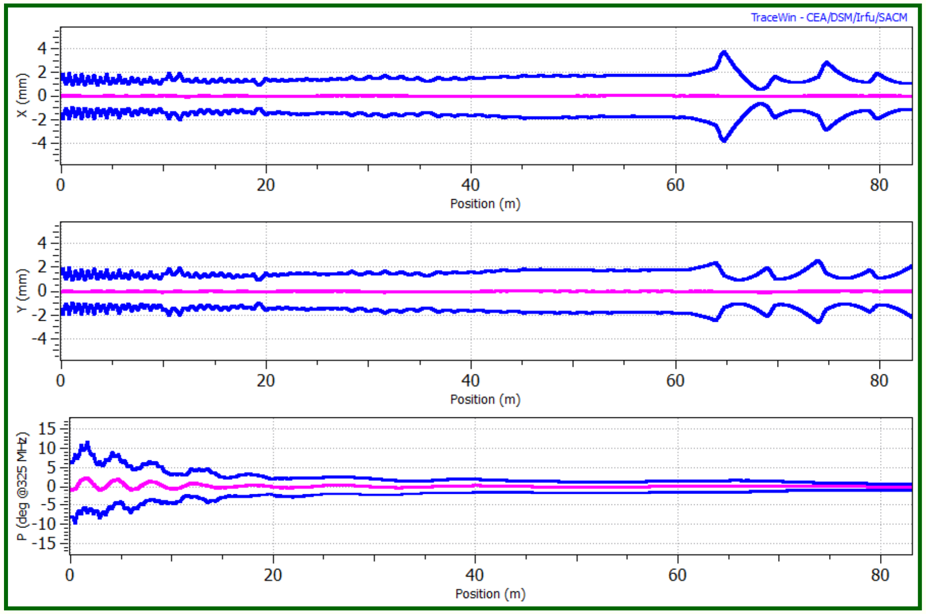


Current : 30 mA

We may go in steps but the design needs to be done for 30 mA

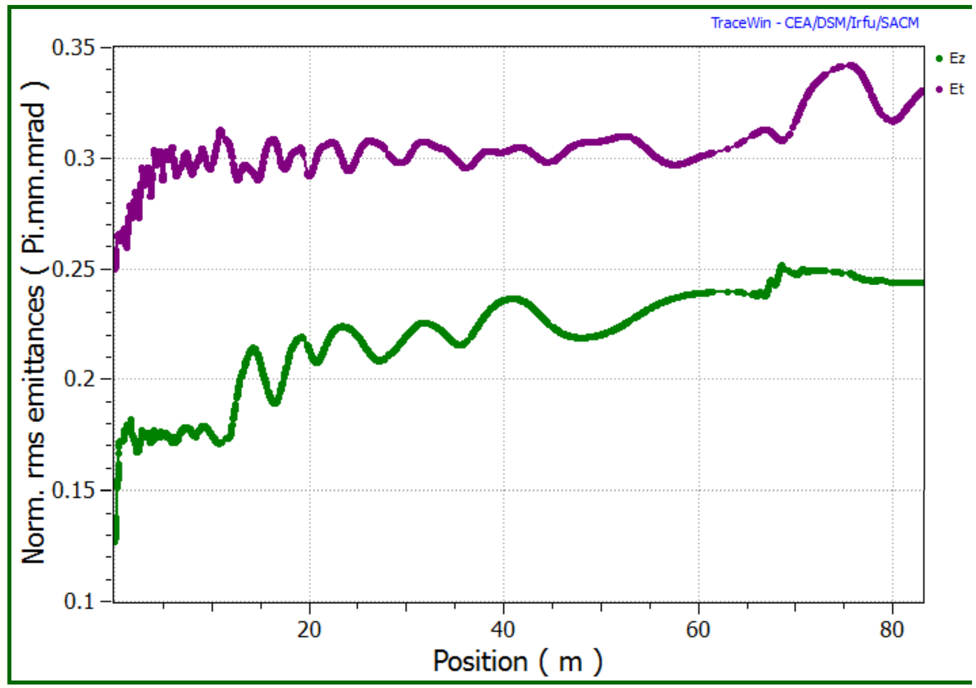
Beam dynamics simulations

In collaboration with A. Saini and Shekhar Mishra under IIFC



Beam envelopes

Evolution of Beam emittances



Fermilab

Accelerator Physics of High Intensity beams (working together under IIFC)

- **Beam Dynamics**
- **Cavity design**
- **Halo formation**
- **Space Charge Effects**
- **HOM**
- **Codes writing**

Solid-State Power Amplifier (SSPA) Development

Deliverables under the collaboration for TPD, BARC

Design and development of :

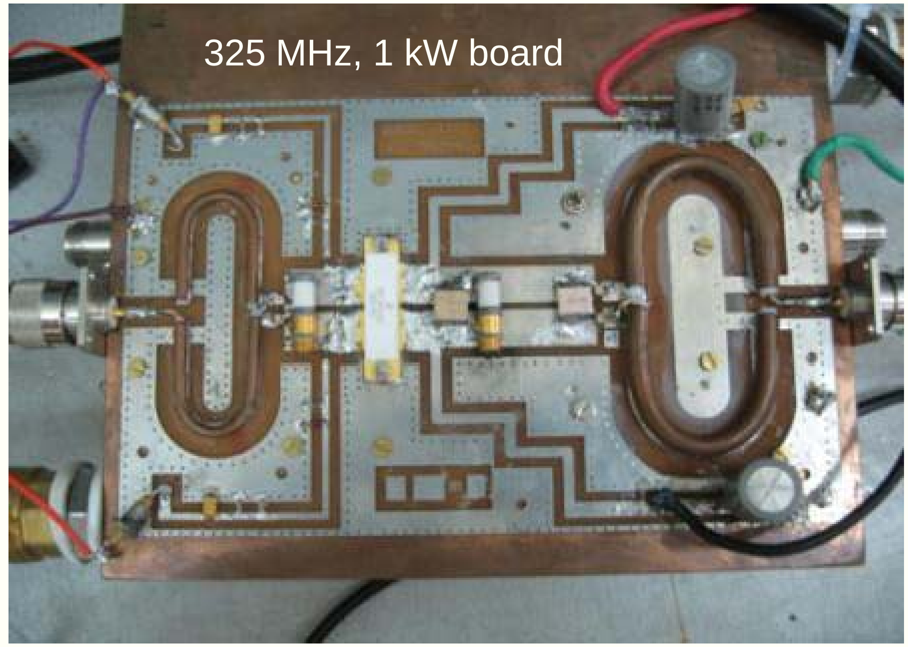
- 1 kW, 3 kW, 7 kW at 325 MHz SSPA -- 1 No each

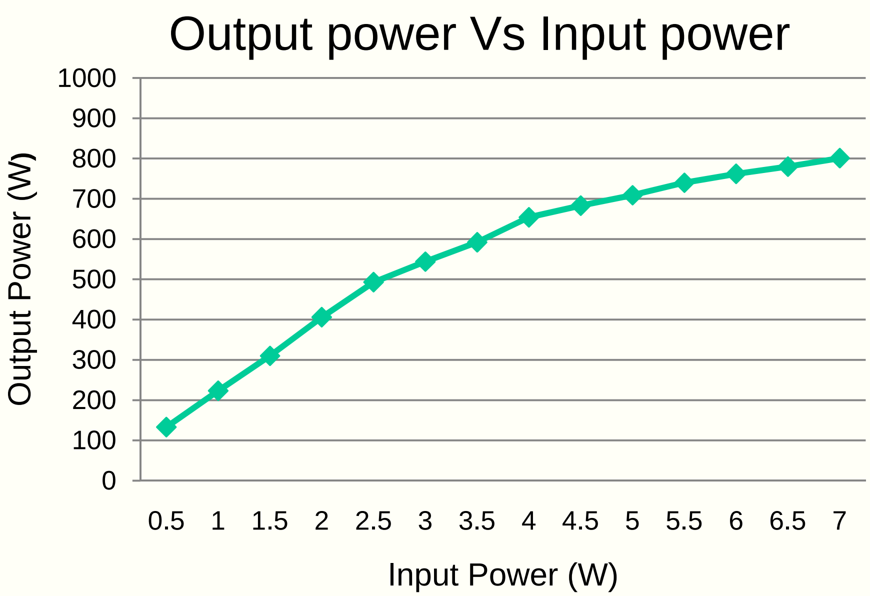
- **One prototype amplifier assembled**
- **Bolted to water cooled heat sink**
- **Test set-up arranged with**
  - **SMPS power supply, Power meters along with sensors**
  - **VNA & SPA, Signal generator , Drive amplifier**
  - **Spectrum Analyzer, Directional couplers, Test Load**

Test results

The first prototype 325 MHz Amplifier has been tested.

1. Short time test (1/2 hr) : 1 kW
2. Long term test (8 hrs) : 800 W
3. Power gain (1 dB) : 19.5 dB
4. Efficiency : 68 %





Comparison of Specifications

Specification	Fermi Lab	SSPA Developed @ RFSS, TPD,BARC	Remarks
Center frequency (MHz)	325	325	
Bandwidth (kHz)	100	>100	
Power output (kW)	1	0.8	1 kW test is under progress
Power Gain (dB)	67	>70	Inclusive of drive PA
Efficiency (%)	60	68	

Fermilab

Cryo-Module Test Facility

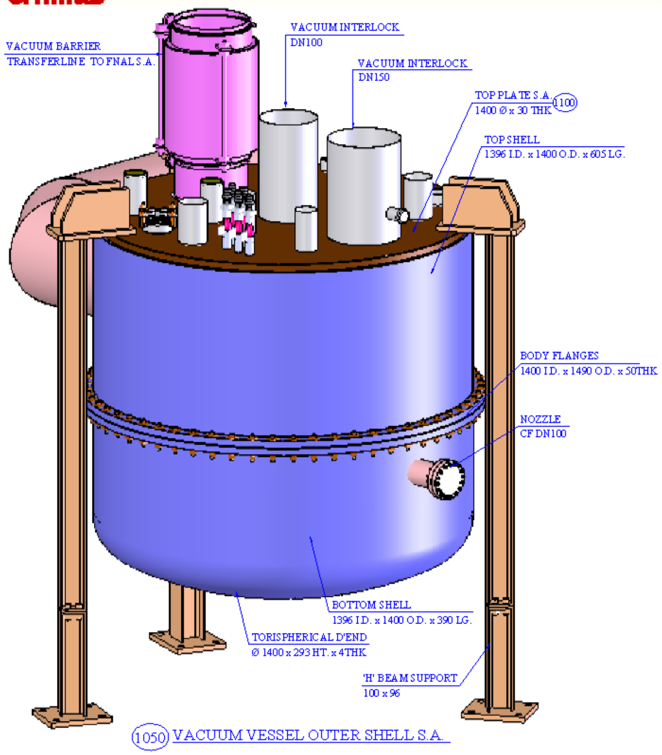
पऊवि DAE

CMTF consists of following five main sub systems:

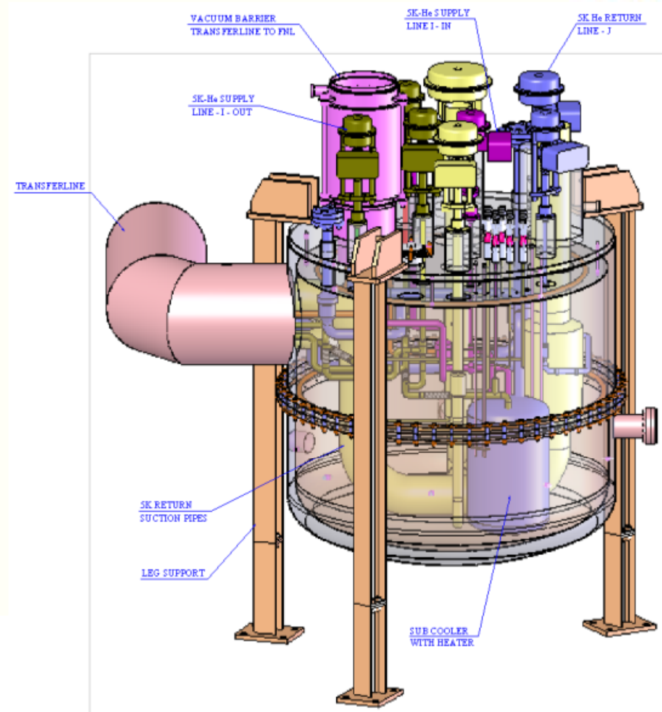
- **(a) Feed box**
- **(b) Feed Cap**
- **(c) End cap**
- **(d) Transfer lines**
- **(e) Mechanical structure with Supporting & alignment facility for Cryo-Module**

(A K Sinha and V.K. Mishra, CDM, BARC)

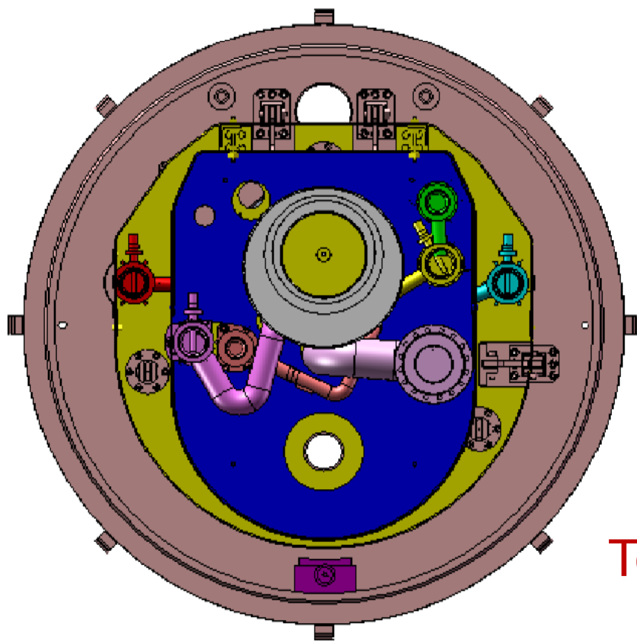
Feed box



Normal view

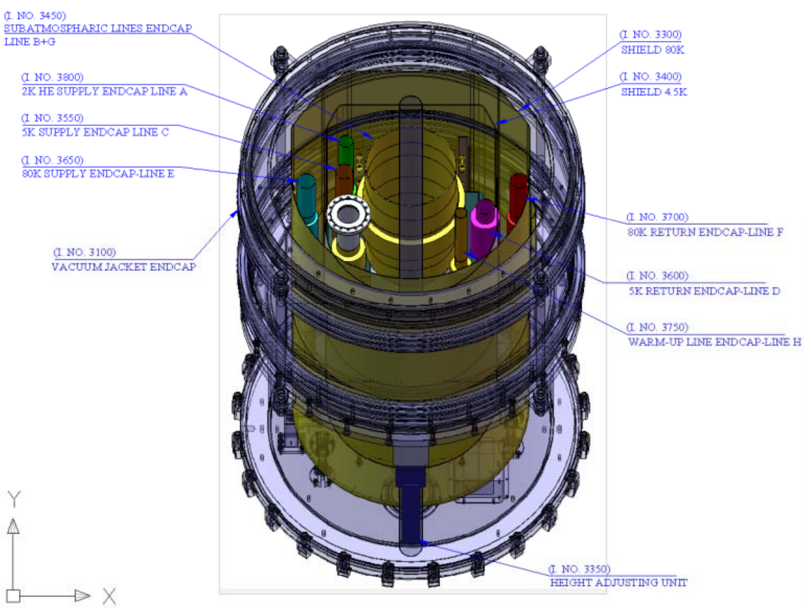


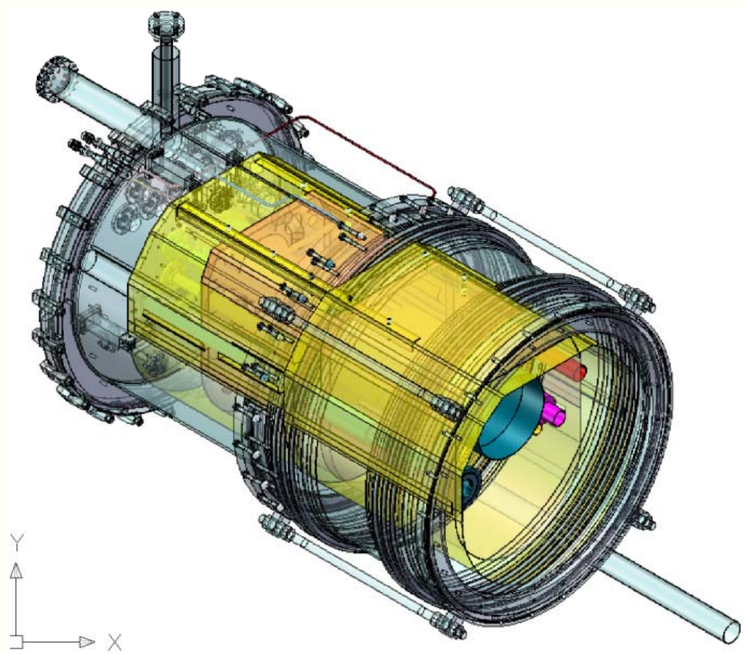
Transparent view



Top view

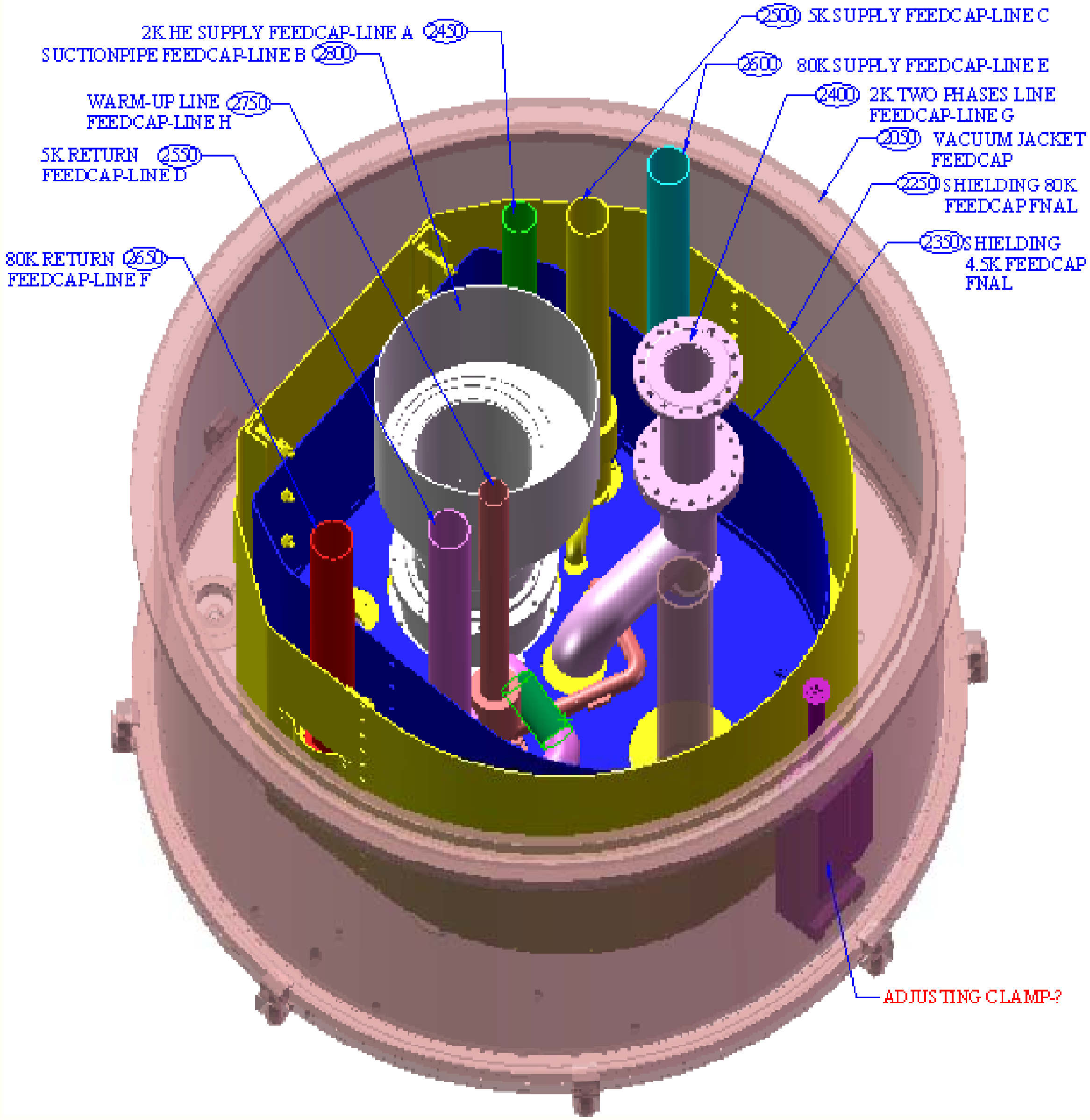
END CAP SUBASSEMBLY





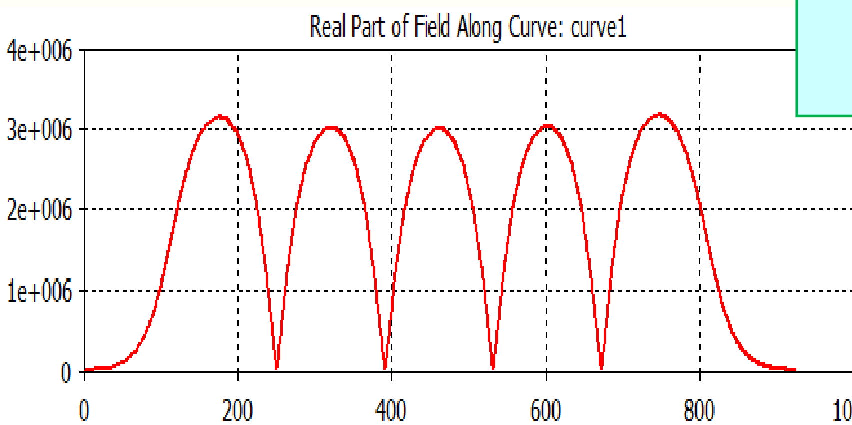
END CAP SUBASSEMBLY

FEEDCAP SUB ASSEMBLY



650 MHz, β=0.61, elliptical cavity simulation at VECC

Accelerating mode



Field flatness: Very good!

Data: Generated by VECC

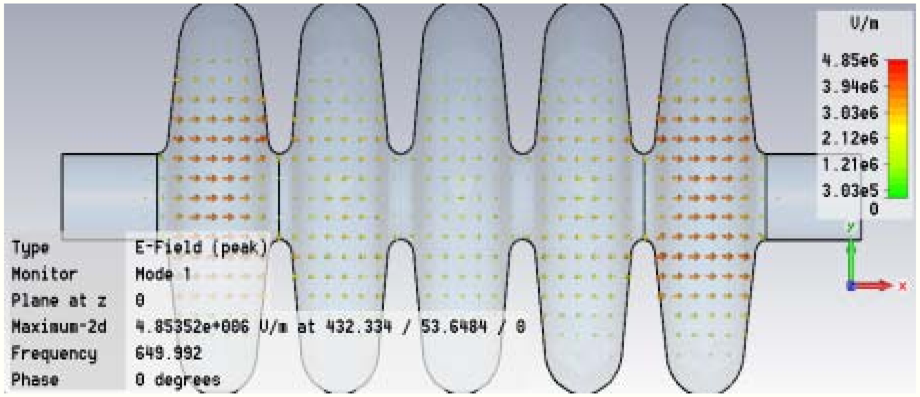
Results: Very good!

kc = 1.24%

(Riris=48 mm.)

	$\frac{A}{B}$ mm./ mm.	$\frac{a}{b}$ mm./ mm.	Equator radius D/2 mm.	Iris radius R_{iris} mm.	Half-cell L/2 (inner) mm.	$\frac{R}{Q}$ Ω	G=Q.R_S Ω	E_{acc} MV/m	$\frac{E_p}{E_{acc}}$	$\frac{B_p}{E_{acc}}$	$f_{\pi-mode}$ MHz	Remarks
VECC Design1 Result	$\frac{54}{58}$	$\frac{11.99}{27}$	198.175	48	70.335	290	197	16.95	3.34	4.90	650.000	2D SUPERFISH 3D CST MWS $\left(\frac{a}{b}\right)_{end} = \frac{20.66}{46.54}$ $\left(\frac{A}{B}\right)_{end} = \frac{45.94}{49.35}$ α=3.6 deg Energy=118.8 J Mesh size=0.05
VECC Design2 Result	$\frac{54}{58}$	$\frac{13.68}{30.82}$	197.4	48	70.335	296	200	17.00	3.00	4.84	649.99869	2D SUPERFISH 3D CST MWS $\left(\frac{a}{b}\right)_{end} = \frac{10.67}{24.02}$ $\left(\frac{A}{B}\right)_{end} = \frac{54}{58}$ α =2.4 deg (mid) =4.5 deg (end) Energy=118.8 J Mesh size=0.05

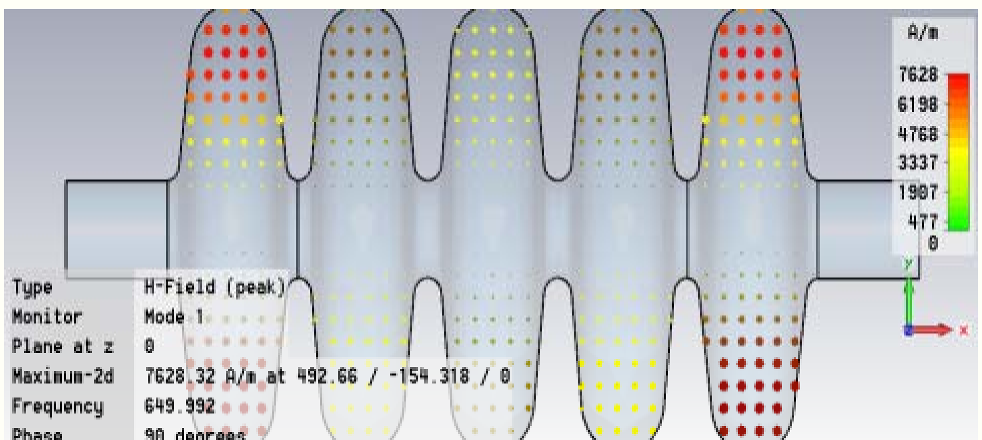
CST MWS simulation for elliptical SCRF cavity at VECC



Electric field lines inside the cavity

Frequency : 650 MHz

β : 0.61



Magnetic field lines inside the cavity

Latest Design Results

Half-cell Length = L/2 = 70.335 mm.

Iris radius = R_{iris} = 48 mm.

Equator radius = D/2 = 197.4 mm.

Equator ellipse ratio = A/B = 54 mm./ 58 mm.

Iris ellipse ratio = a/b = 13.68 mm./30.82 mm.

= 10.67/24.02 (for end-cell)

Wall angle = α = 2.4 deg. (mid-cell)

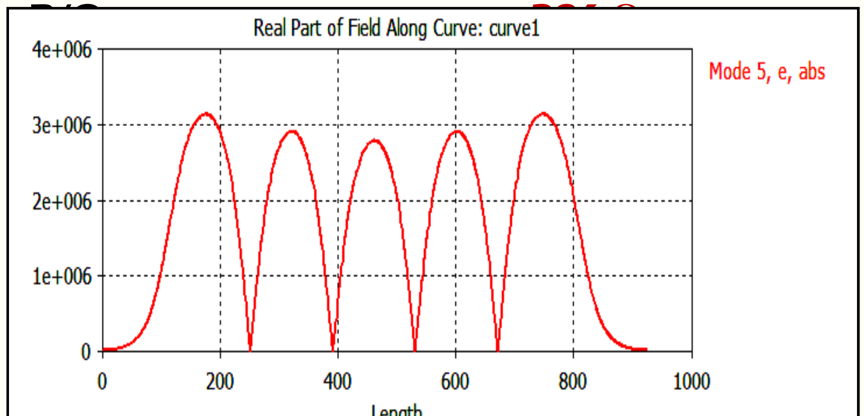
= 4.5 deg. (end-cell)

Ep/Eacc = 3.00

Bp/Eacc = 4.84

Eacc = 17 MV/m

Stored Energy (U) = 118 Joule



Plot of E-fields along the axis

INSPECTION OF SCALED DOWN CAVITY FORMER UNDER CMM at VECC Workshop

NIOBIUM SHEET

- Dimension: 600 mm. x 600 mm. x 4 mm.
- Tolerances: ±1.5 mm. x ±1.5 mm. x ±0.125 mm.
- RRR value: 300 or better
- Surface texture: better than 3.175 µm finish
- Surface roughness: better than 1.6 µm
- Deep drawing quality, grain size ASTM#5 or finer, local grain sizes ASTM#4 allowable, min. 90% recrystallized
- Grain size: Typically 50 µm
- Yield strength > 50 N/mm^2
- Tensile strength > 100 N/mm^2
- Elongation > 30%,
- Vicker Hardness < 50 N/mm^2
- ATI Wah Chang, USA.
- 15 Nos. Nb sheet Received.
- Prcurement of further 15 Nos. in progress.

Specs matches with Fermilab Specs.

Impurities:

H_2 ≤ 2 Wt. ppm	W ≤0.007%
C ≤ 10 Wt. ppm	Ti ≤0.005%
N_2 ≤10 Wt. ppm	Fe ≤0.003%
O_2 ≤10 Wt. ppm	Si ≤0.003%
Ta ≤ 500 Wt. ppm	Mo ≤0.005%
	Ni ≤0.003%

DESIGN OF TEST CRYOSTAT at VECC
(Besides IIFC Collaboration activities)

- Design has been done for Test Cryostat that can accommodate the 5-cell elliptical shape 650 MHz,

  β=0.61 cavity
- Overall dimension of the Test Cryostat:

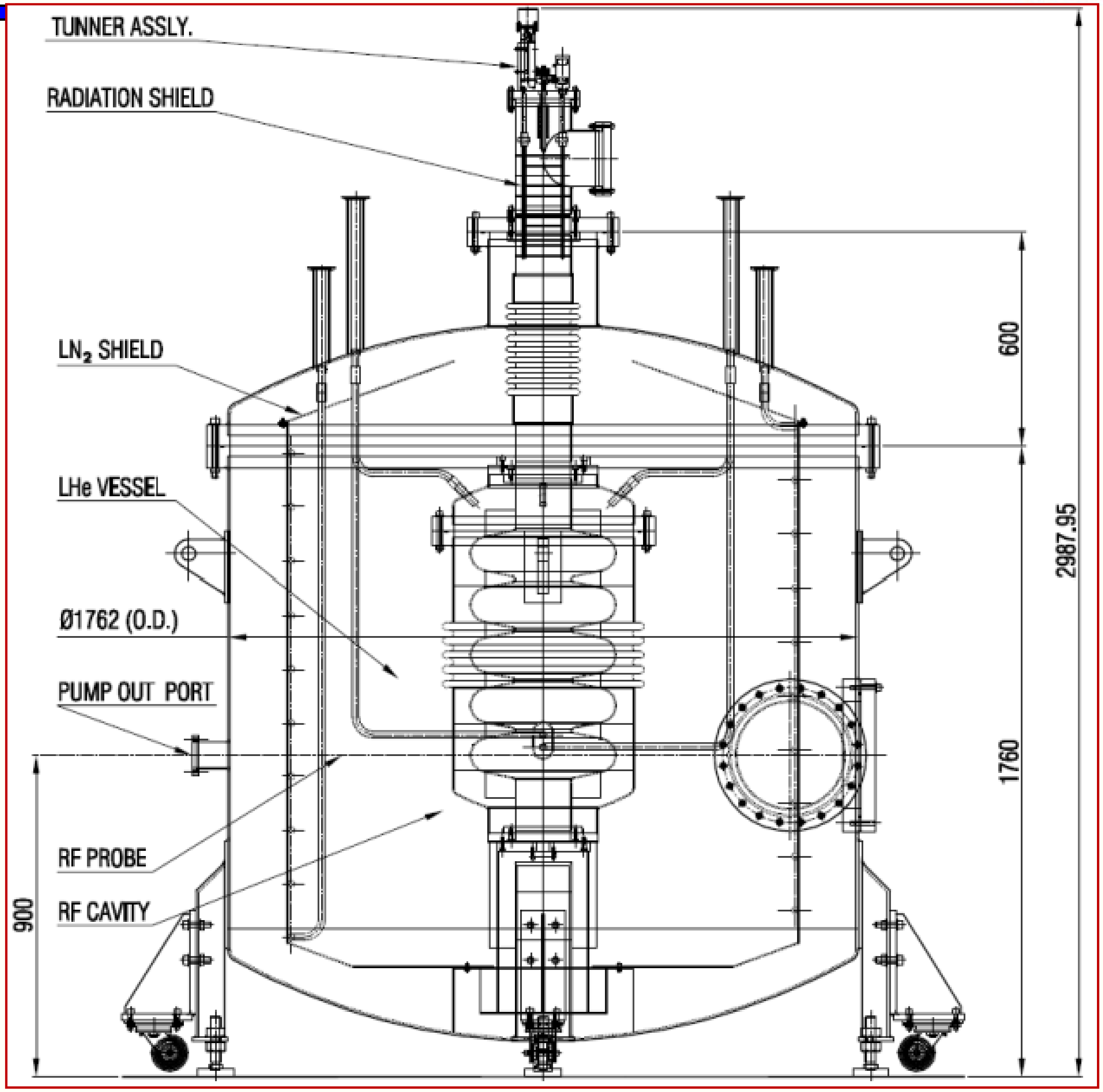
  2360 mm. Height x 1762 mm. Diameter
- LHe vessel dimension of the Test Cryostat:

  1050 mm. Length x 512 mm. Diameter
- Cryostat consists of:
  - LHe vessel, LN2 shield
  - Internal & external magnetic shielding
  - Pump out port
  - LN2/LHe in, LN2/LHe gas out, Safety port,
  - LN2/LHe instrumentations
  - RF probe in/out --- adjustable from outside
  - RF power coupler arrangement etc.

CAVITY PLACED VERTICALLY IN CRYOSTAT

- **SCRF cavity can be placed in the same CRYOSTAT in two possible ways**
  - **Vertically**
  - **Horizontally**

- **Future modification:** **CRYOSTAT can be operated at 2K (for cavity placed horizontally) adding components (Heat Exchanger, JT valve etc.) – provision for space**

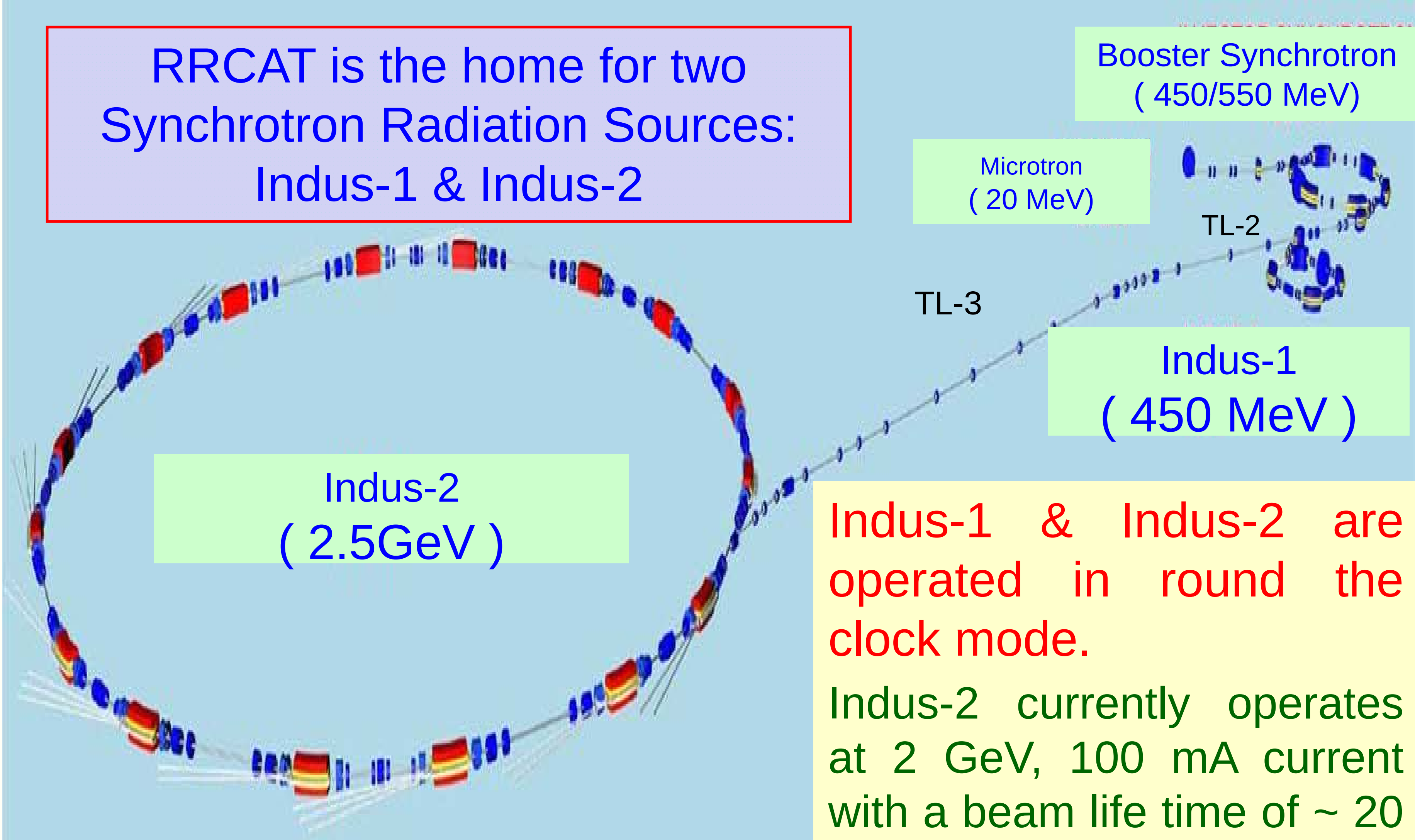


Accelerator R & D Activities at RRCAT

- Synchrotron radiation sources :
  - 450 MeV Storage Ring Indus 1
  - 2.5 GeV Booster cum storage ring Indus 2
  - Beamline and their utilization
- 10 MeV Linac for irradiation of agricultural products
- 700 keV DC accelerator for industrial applications
- High energy proton accelerator technology development
- SCRF Science and Technology program
- THz Free Electron Laser activity
- Laser plasma wake field accelerator R & D
- R & D in super conducting materials and cryogenics
- International collaboration

Schematic View of Indus Complex

RRCAT is the home for two Synchrotron Radiation Sources: Indus-1 & Indus-2

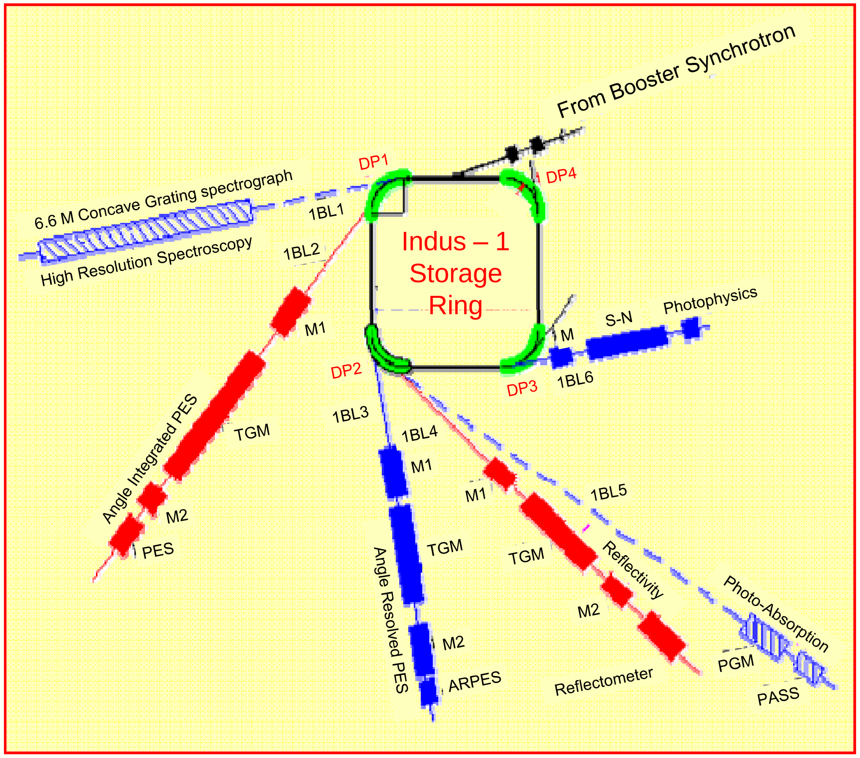


Indus-1 & Indus-2 are operated in round the clock mode.

Indus-2 currently operates at 2 GeV, 100 mA current with a beam life time of ~ 20 Hrs.

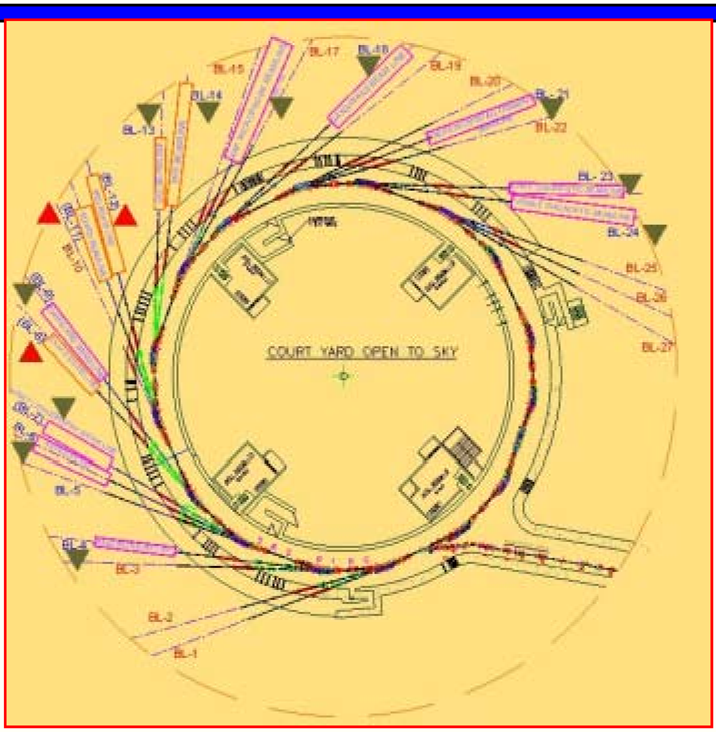
Indus-1 : Synchrotron Radiation Source

- Indus-1 regularly operated at 450 MeV, 100 mA
- Five beamlines are operational and made available to users



- Soft X-ray reflectivity
- Angle Integrated Photoelectron Spectroscopy
- Angle Resolved Photoelectron Spectroscopy
- Photophysics
- High resolution VUV

Indus–2 Synchrotron Radiation Source



Beamlines already commissioned =5

Beamlines under commissioning =3

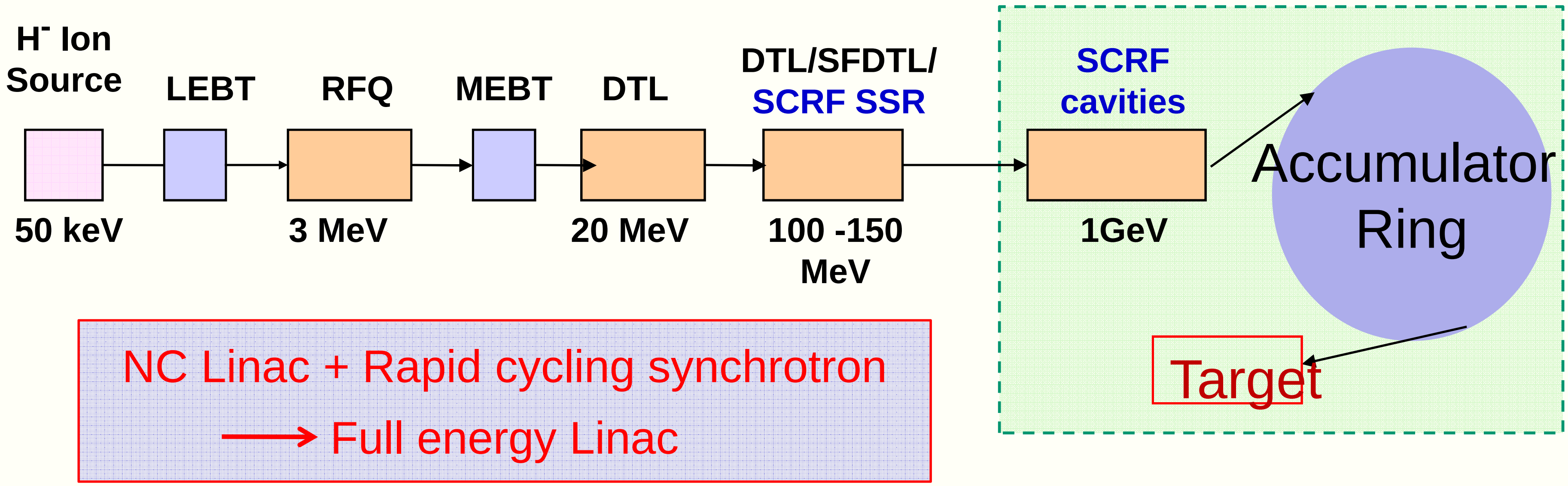
No. of straight sections for insertion devices =5

It is planned to setup 8 additional bending magnet beamlines and 5 on insertion devices

Development of Sub-systems of Proton Accelerator

- A long term program on setting up of a 1GeV Proton Accelerator is envisaged for the development of a Pulsed Spallation Neutron Source

Schematic of 1 GeV pulsed proton linac for SNS



- Super conducting RF cavity technology development.
- Development of low energy front end part (H^- ion source, 3 MeV RFQ).

Development of Frontend Components

Plasma chamber for H- ion source

NdFeB magnets for generating multi-cusp field geometry

Beam extraction

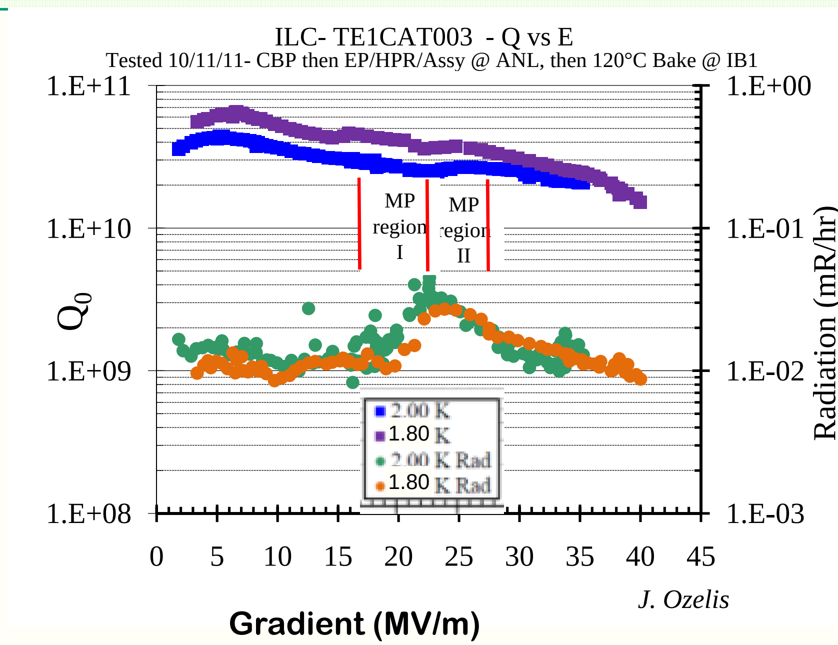
This will house beam extraction electrodes

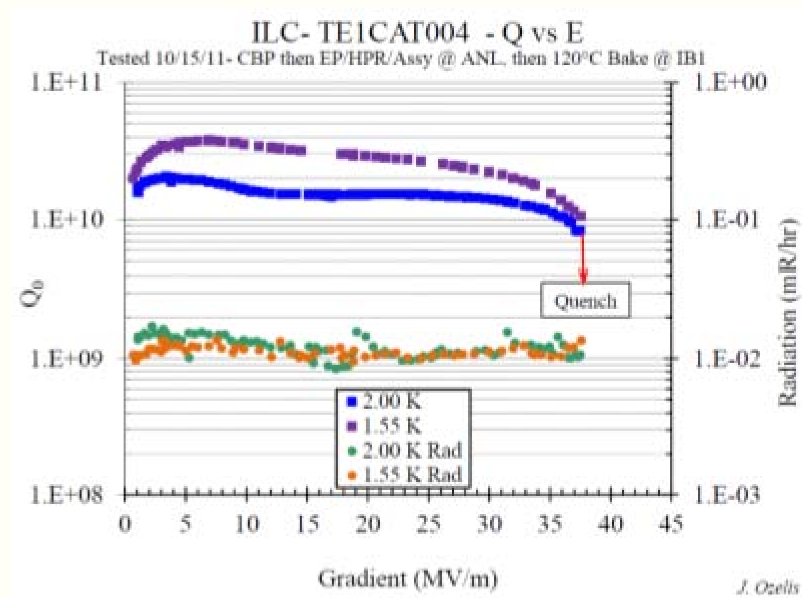
First segment of prototype 352 MHz RFQ

Fabricated in Al to validate the design

Development of Single Cell 1.3 GHz SCRF Cavities under IIFC

- During 2009–10, two single cell Nb cavities were jointly developed under IIFC which exhibited acceleration gradient up to 23 MV/m.
- Subsequently two more cavities have been fabricated and processed under IIFC to improve the cavity performance.
- These cavities have exhibited accelerating gradients of ~ 35-37.5 MV / m with a high Q at 2 K.

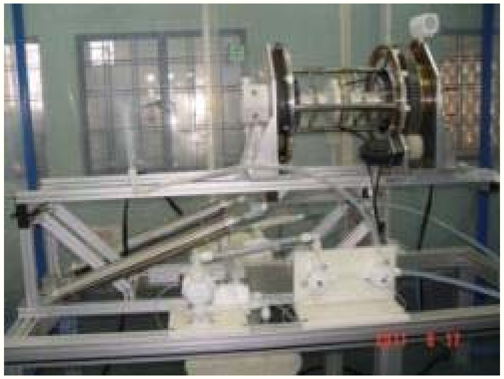




Infrastructure for SCRF Cavity Fabrication and Processing

- 120 T cavity forming facility
- Electro-polishing setup for 1.3 GHz
- Centrifugal barrel polishing machine for 1.3 GHz single cell cavities
- High pressure rinsing

Cavity forming facility installed



Electro-polishing setup developed

Centrifugal barrel polishing machine developed

High pressure rinsing Set up developed

- Electron beam welding machine (15 kW) and a vacuum annealing furnace are under procurement. These are expected to be installed by December 2012

Infrastructure for SCRF Cavity Characterization

- Secondary Ion Mass Spectrometer (SIMS)
- 3D Laser Scanning Confocal Microscope
- Large 3D Coordinate Measuring Machine
- Optical Bench for internal surface inspection
- RF Measurement Setup

3D CMM installed

SIMS setup installed

Laser scanning confocal microscope installed

Optical bench developed

Building for SCRF Cavity Development

Cavity Fabrication, Assembly & Processing Building (1400 Sq. m)

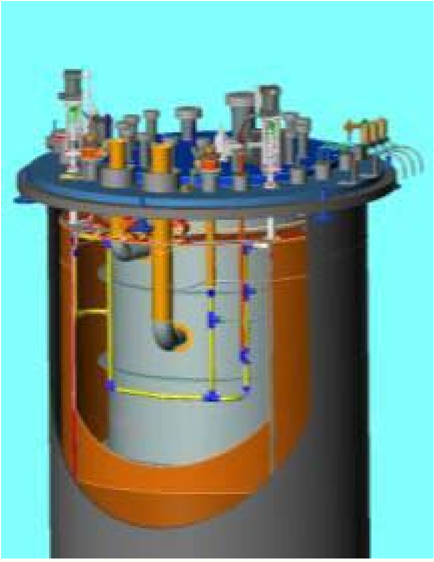
- The building will house clean rooms, Electron beam welding machine. High vacuum annealing furnace, Electro-polishing setup, Centrifugal barrel polishing machine, RF measurement set up etc.
- Building is ready.

Lab Building (~ 800 Sq. m)

- It will house CMM, SIMS, material testing facility, thin film deposition facility etc
- Building is ready, facilities under commissioning.

Development of Vertical Test Stand

- RRCAT & Fermi Lab jointly carried out design of various components of 2K VTS Cryostat:
  - Liquid Helium Vessel
  - 80K shield
  - Vacuum Vessel
  - Top Insert Plate
  - Magnetic shielding (2K + room temperature)
  - Piping layout for liquid helium
  - 3-D model of the complete VTS-2 assembly
- Three VTS cryostats are under fabrication at US vendor under joint supervision of engineers from Fermi Lab and RRCAT.

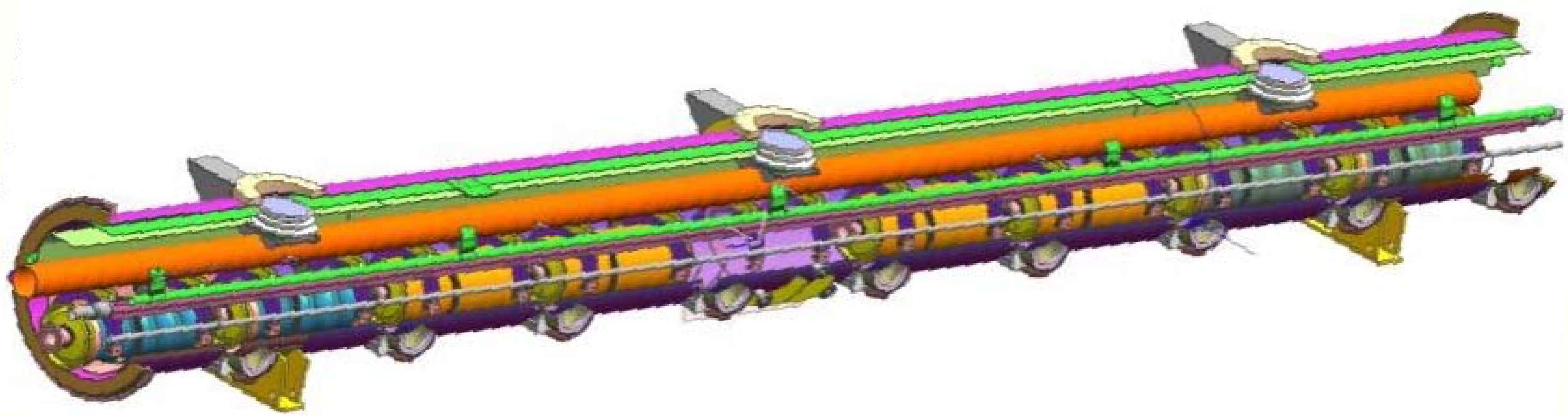


3D model of VTS

- Expected delivery schedule : December 2011.
- Building to house VTS at RRCAT is under construction and expected to be ready by December 2011
- Cryogenics system under process
- Components of RF and DAQ system for RRCAT VTS is under process and expected to be ready by Dec 2011.

Design of Beta= 0.9 Cryomodule for 650 MHz Cavities

- Design effort progressing smoothly
- Major specifications of the cryomodule have been ascertained
- Engineering design has made considerable progress for vacuum vessel, thermal shield ,cavity support system etc.



Cut Section of Cryomodule & subsystems

Horizontal Test Stand (HTS-2)

Design and development work of a horizontal test stand has been taken up in collaboration with Fermilab

3-D Model Completed in UGNX-4

Functional requirements

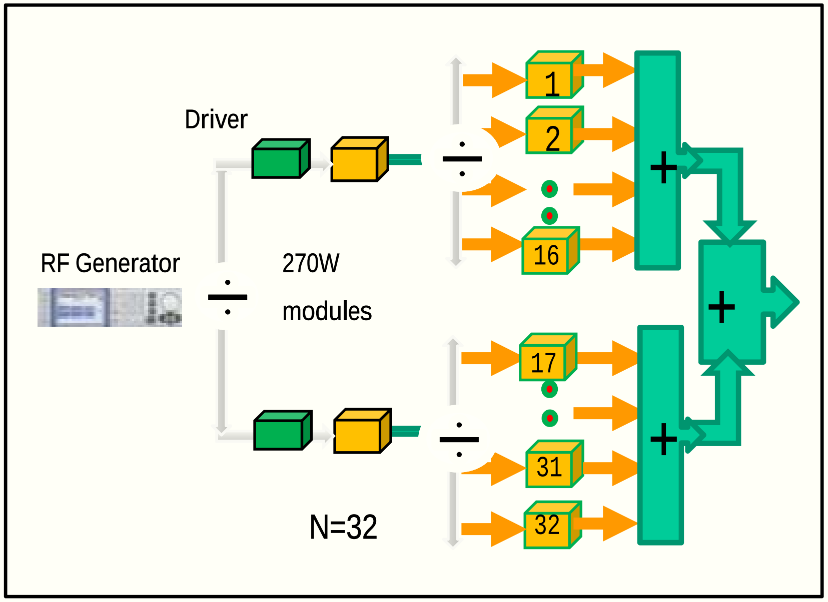
- Capability to test two dressed cavities at a time but separately.
- Testing of both 650 MHz and 1.3 GHz cavities.
- Throughput of 4 cavities in 6 weeks.

An important aspect of this design effort is the improvements made to accommodate operational experience of HTS at Fermilab

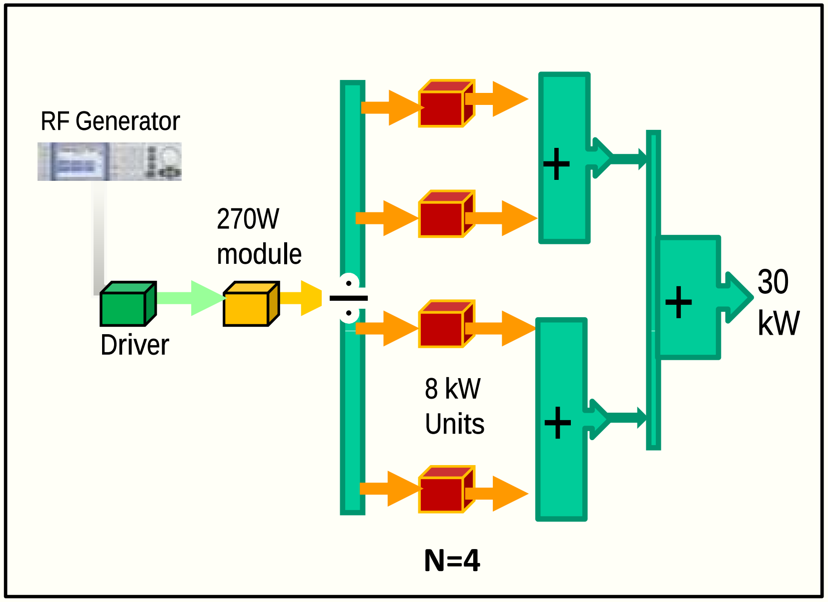
Solid State Amplifier Development at 650 MHz

- We have taken up development of 30 kW CW 650 MHz solid state amplifiers for energizing SCRF cavities

8 kW Amplifier Scheme



30 kW Amplifier Scheme



- 32 Nos. of 270 W RF modules are used with suitable combiners and dividers to make a 8 kW RF amplifier module. Four such modules will be combined to obtain 30 kW RF power output.

15 kW, 505.8 MHz Solid State RF Amplifier Unit in Indus-2

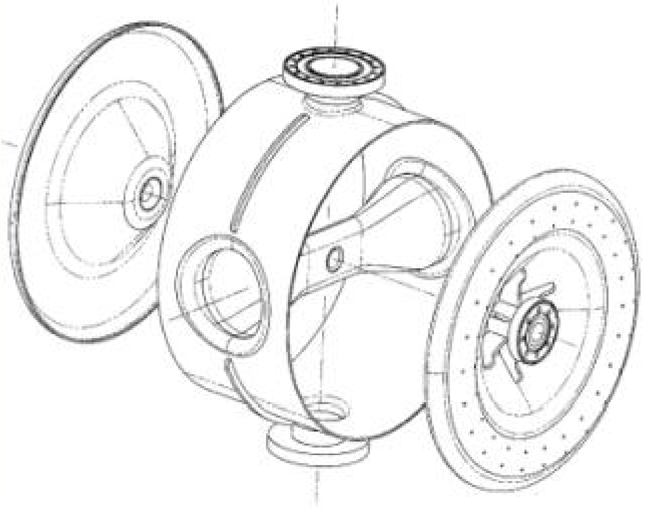
Two units of Solid State RF Amplifiers each of 15 kW output power at 505.8 MHz have been developed and deployed in Indus-2 operating in round the clock mode.

Low Beta Resonator Development for IUAC Linac

Beta = 0.05, 97 MHz

Collaborations on Resonator Developments

Spoke Cavity for Fermilab Project X



β =0.22, 325 MHz

1.3 GHz TESLA type Cavity under IIFC. 4 Single Cells fabricated.
Two have reached > 35 MV/m

Summary and conclusions

1. Accelerator activities at different Indian Centres were discussed
2. The collaboration with Fermilab under IIFC is making good progress and is expected to grow further.
3. Scientists and Engineers from both sides are in touch and discuss regularly through WebEX meetings.
4. We have gone through all the initial drawings provided by Fermilab and now engaged in detailed fabrication discussions with Fermilab.
5. Two cavities fabricated in India and processed and prepared in US Labs reached 35-40 MV/m. Congratulations to all involved.

Fermilab

पऊवि
DAE

धन्यवाद

Thank You !