2nd International Workshop on
ACCELERATOR-DRIVEN SUB-CRITICAL SYSTEMS & THORIUM UTILIZATION

December 11-14, 2011

Bhabha Atomic Research Centre, Mumbai

Sponsored by

Board of Research in Nuclear Sciences,
Department of Atomic Energy

Ion accelerator and associated developmental activities at IUAC New Delhi

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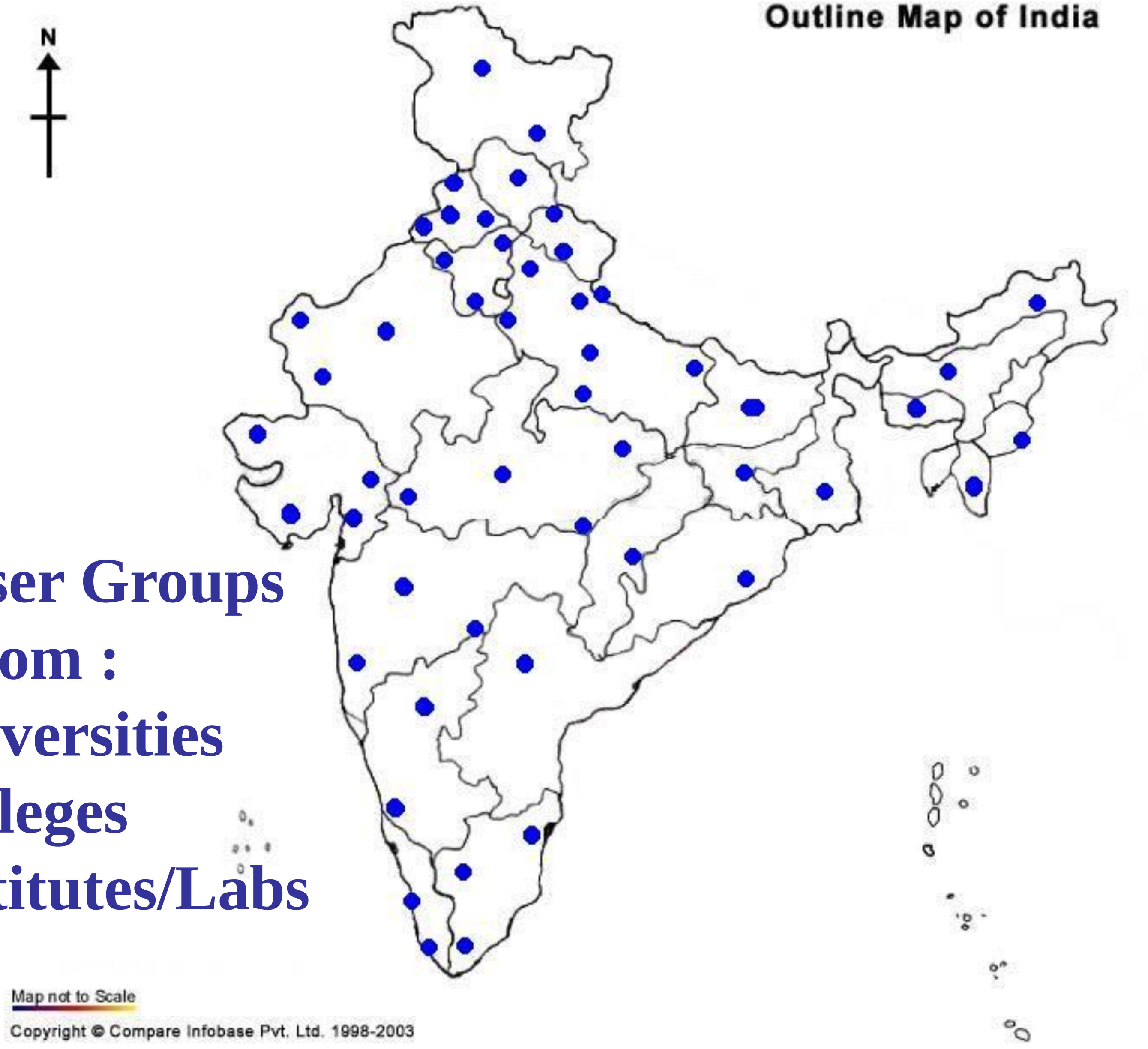
User Community of IUAC



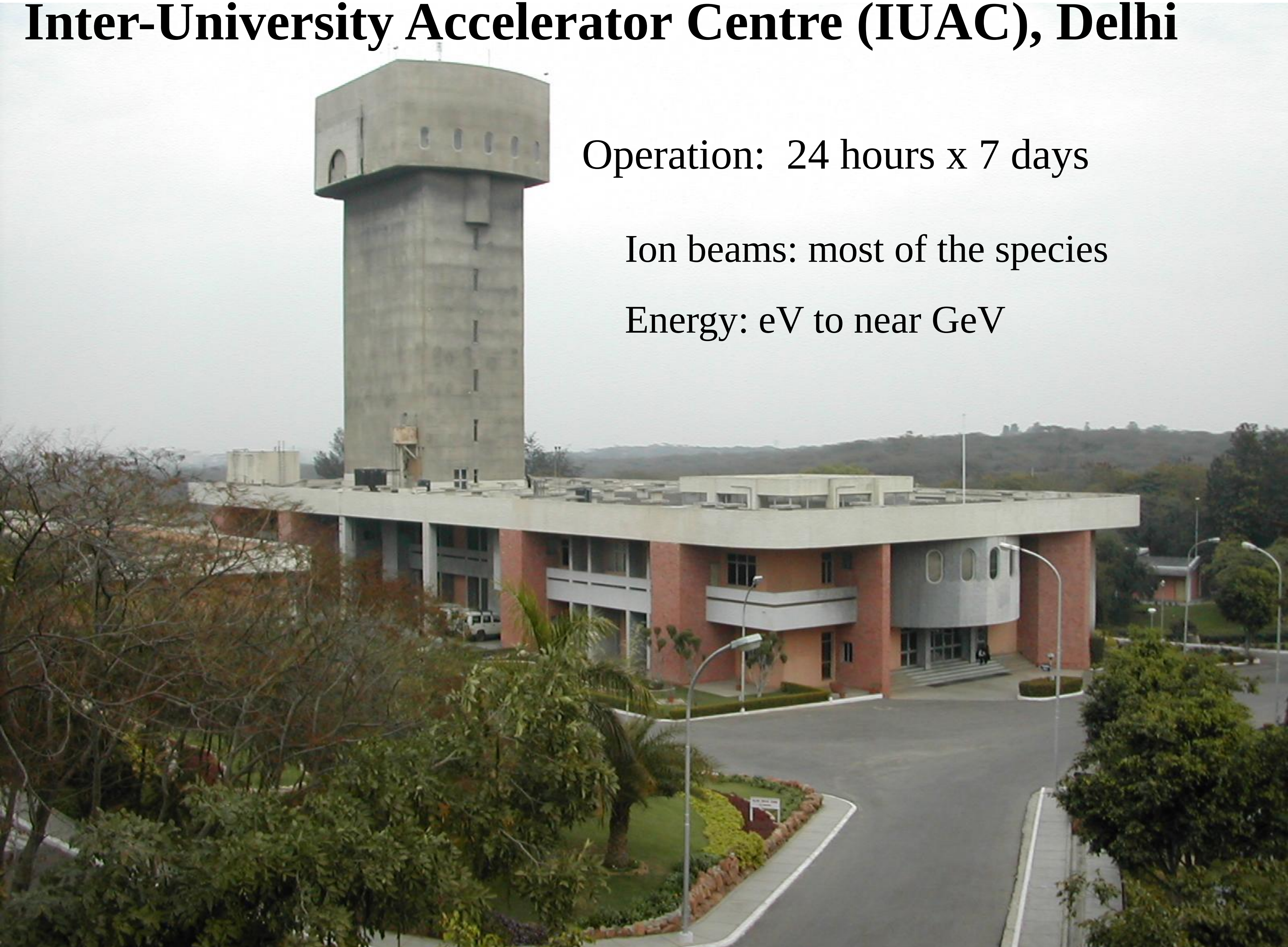
> 400 User Groups from :

80 Universities

53 Colleges

58 Institutes/Labs

Inter-University Accelerator Centre (IUAC), Delhi



Operation: 24 hours x 7 days

Ion beams: most of the species

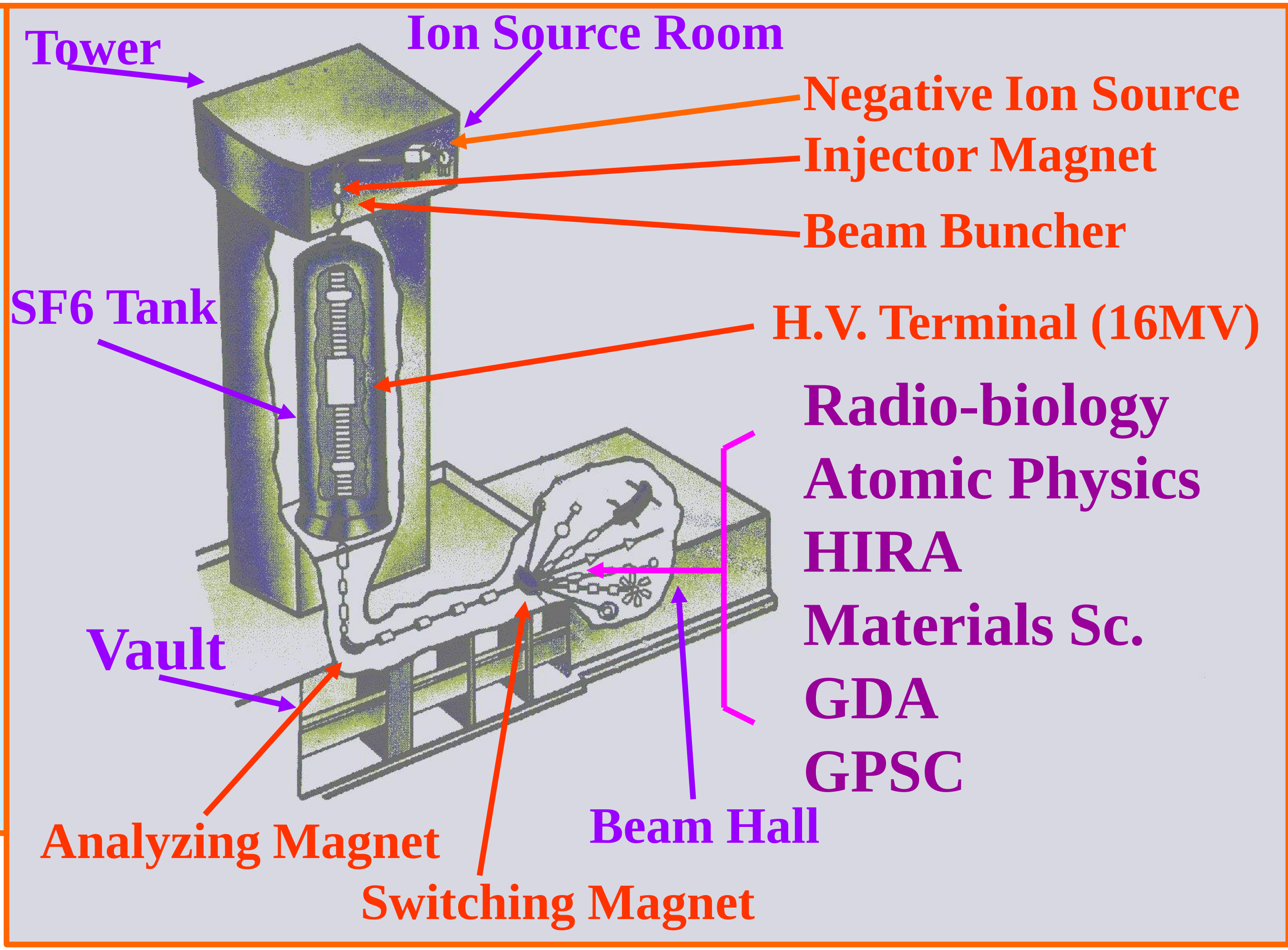
Energy: eV to near GeV

15UD Pelletron Accelerator at IUAC

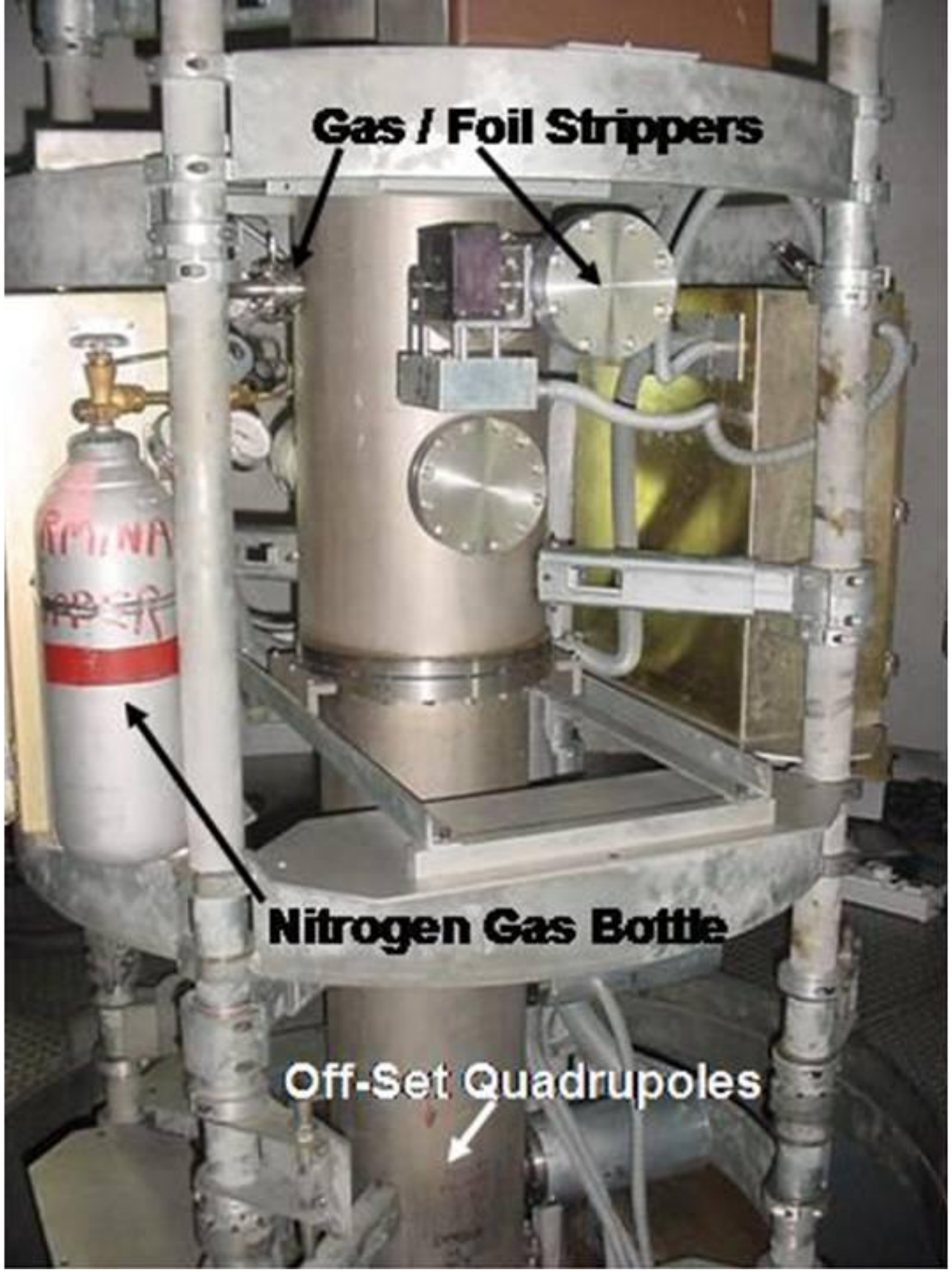
Tank height: 26.5 m
Diameter: 5.5 m
Pressure: 86 PSI
SF_6 gas

Ions accelerated:
H to Au beams

Currents: ~ 1 -50 pnA
Energy : 30 – 270 MeV



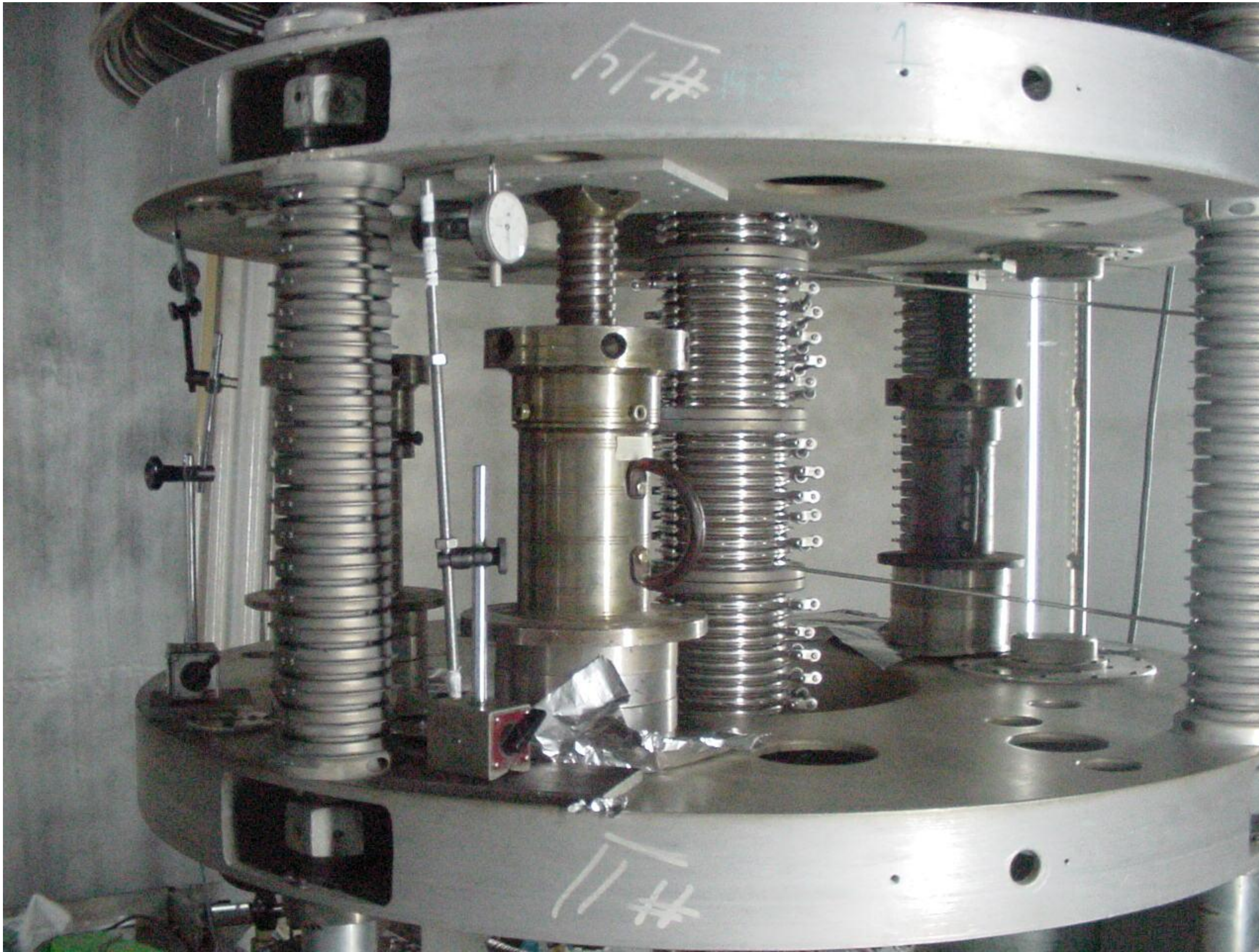
Special Features: 1. Off-set QP in Terminal
2. Earthquake Protection
3. Compressed Geometry Tubes



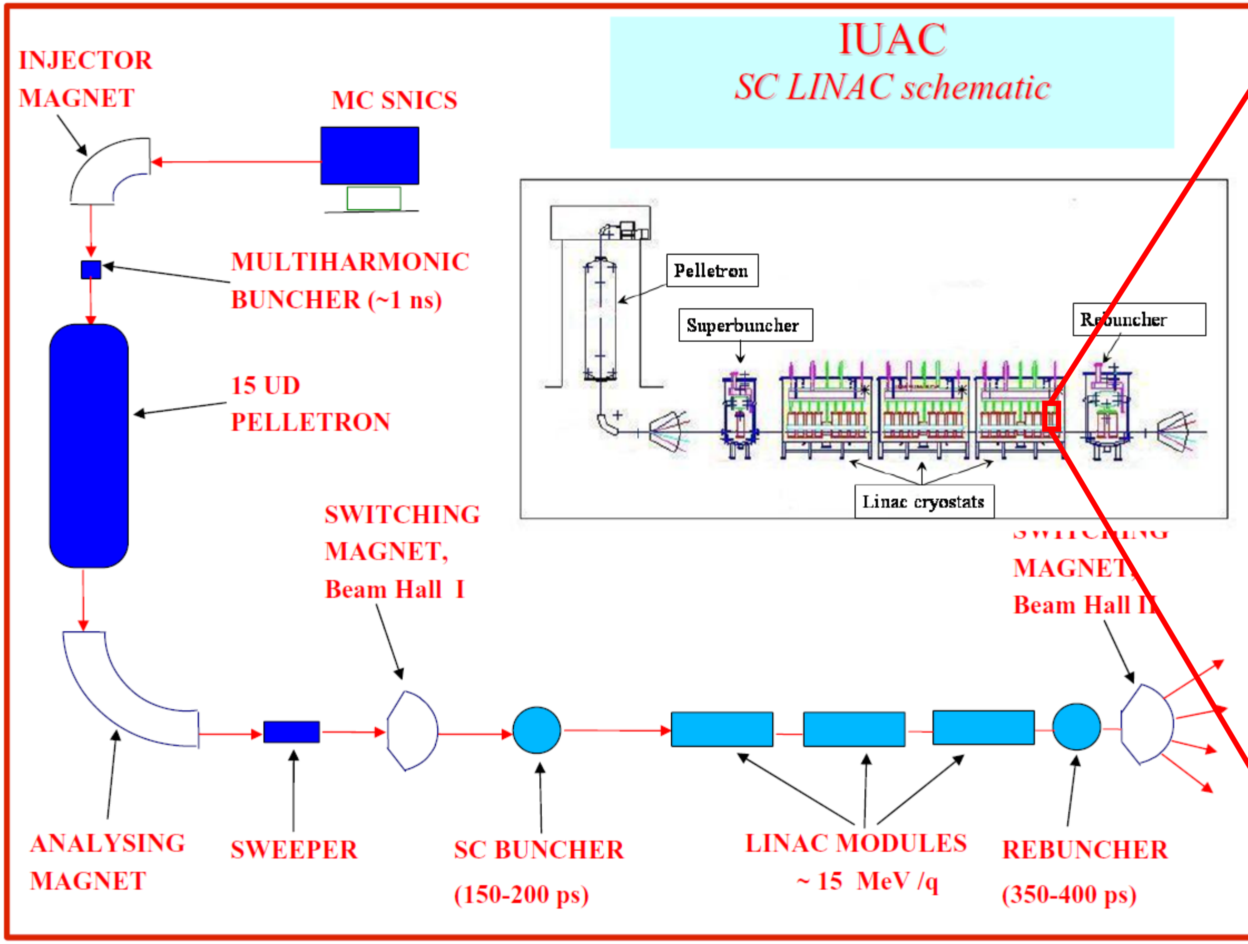
Off-set quadrupoles after strippers in terminal

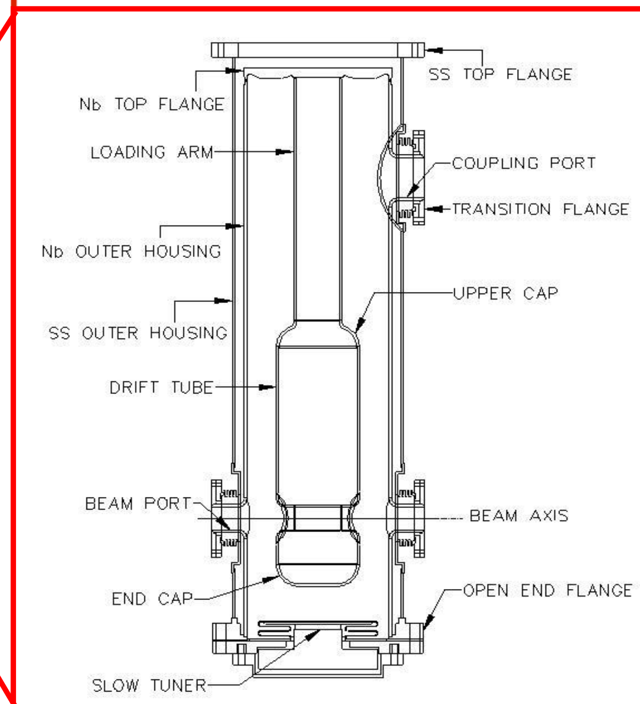
Foil Stripper at the Tank Bottom before analyzing Magnet

Replacement of column support posts

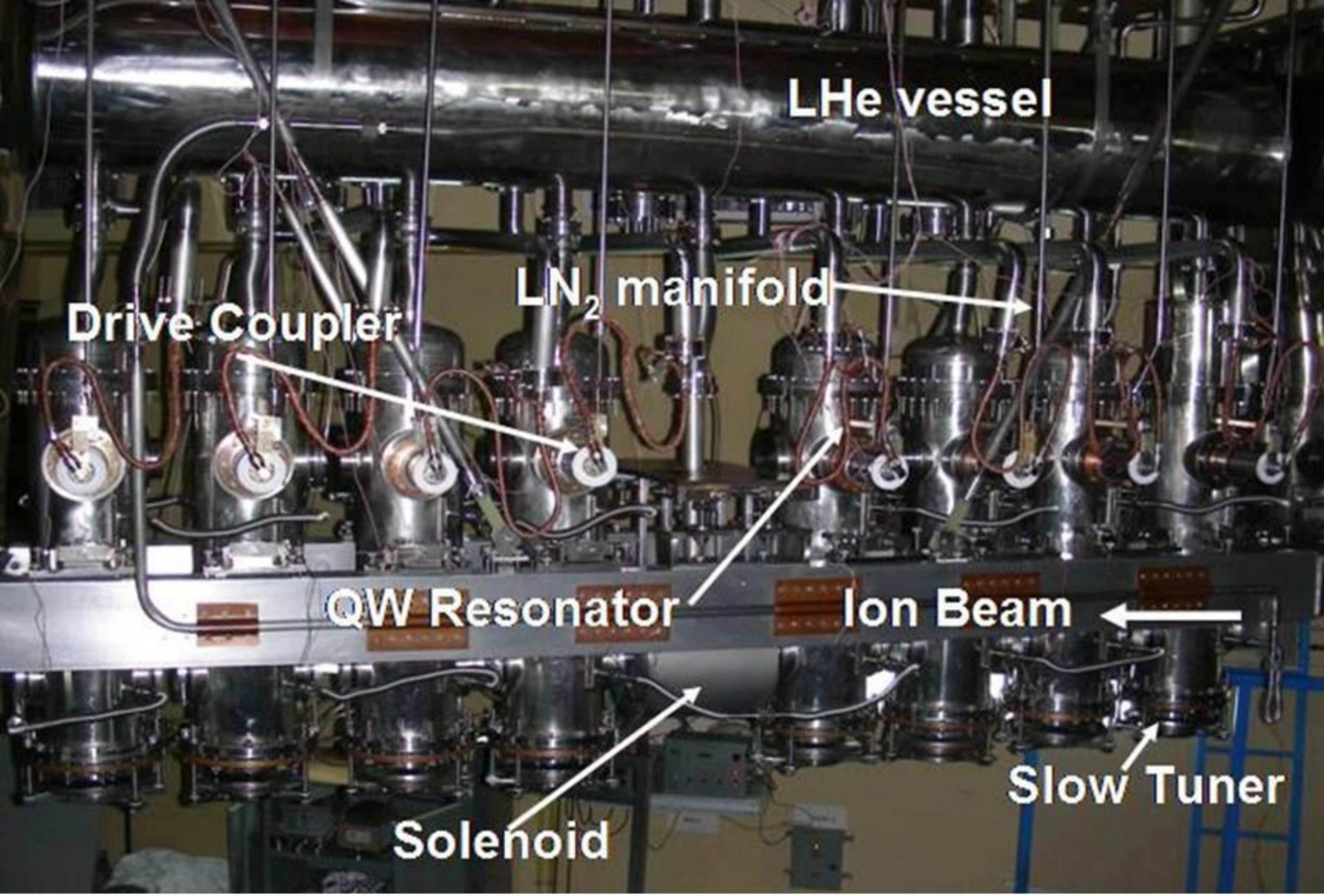


IUAC superconducting LINAC





Nb Quarter Wave Resonator.



Eight QWRs, SC Solenoid, etc of the first Linac module

First Indigenous QW Resonator of IUAC (v/c=0.08)

Production of QWRs – 2nd & 3rd Modules

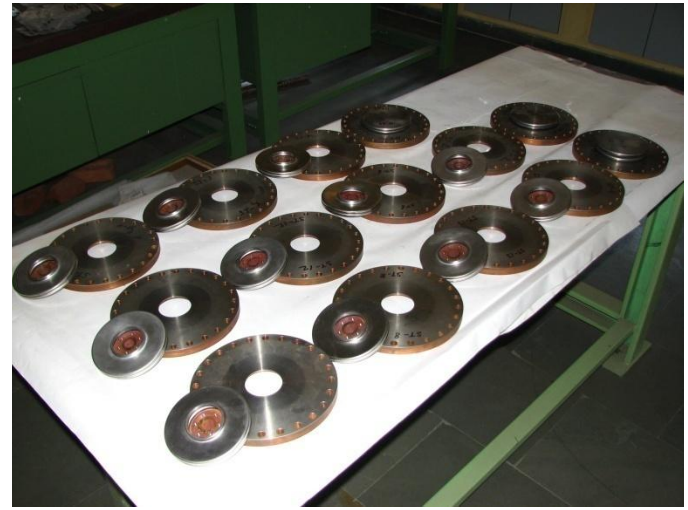
Niobium Central Conductor assemblies.

Niobium Top Flanges.

Niobium Outer Housings.

Production of QWRs – 2nd & 3rd Modules

Bare niobium QWRs.

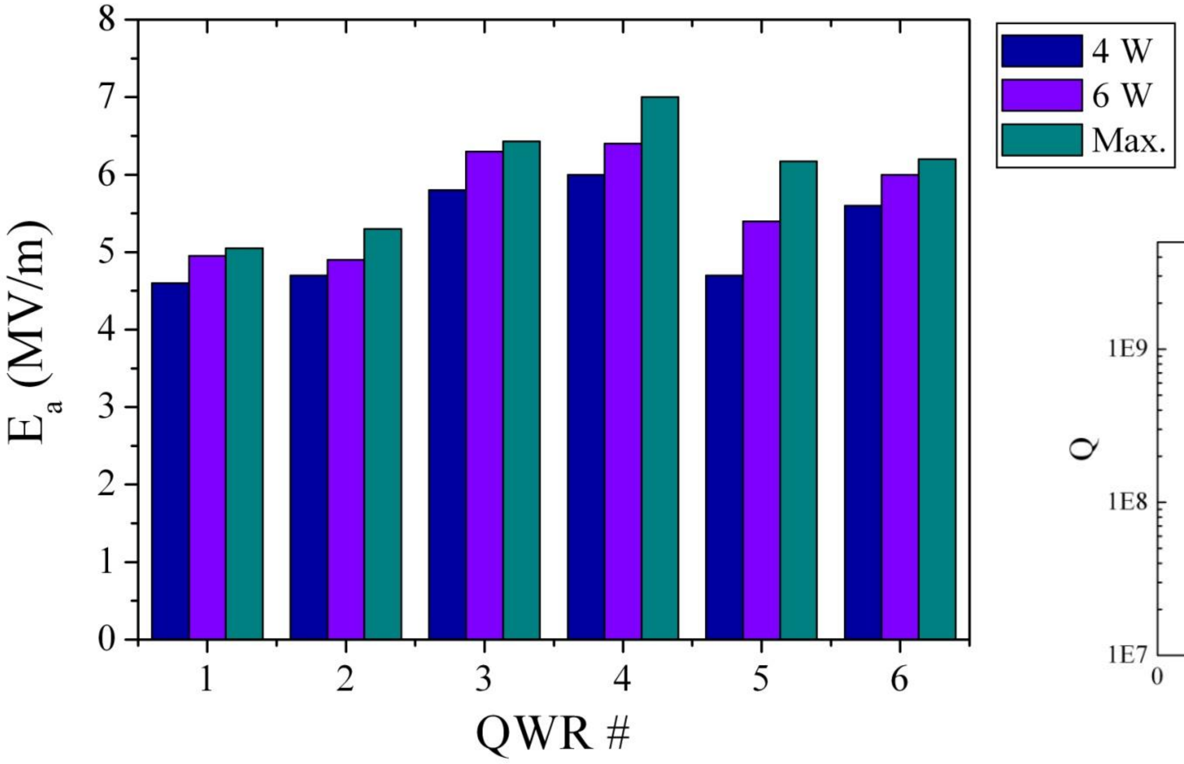


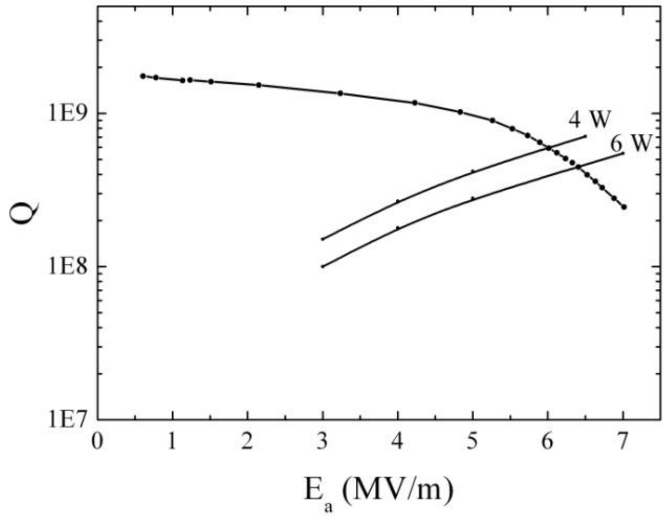
Slow Tuner components.

One dozen Production QWRs.

Niobium Slow Tuner bellows.

Performance of Indigenously built Nb QWRs

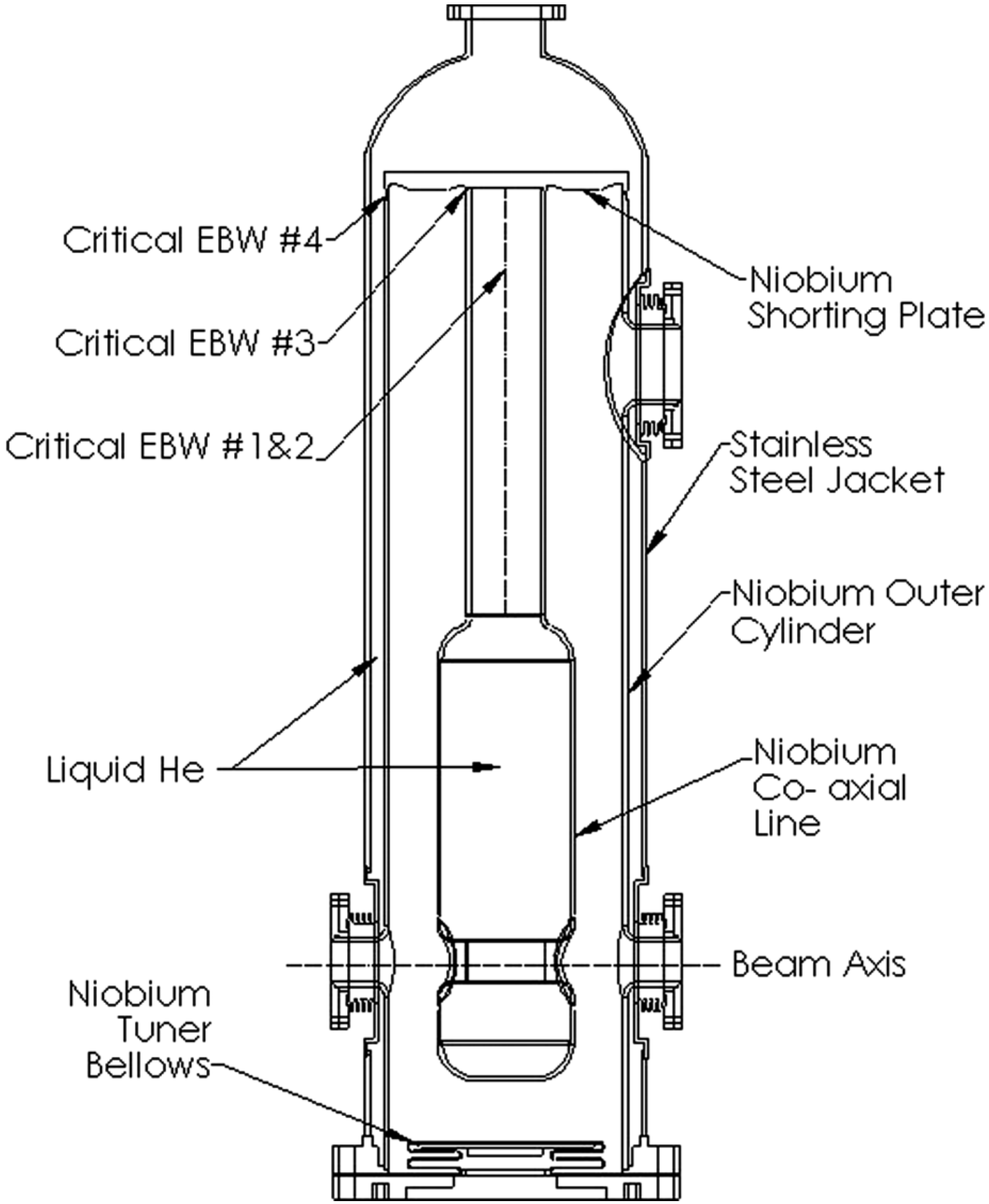




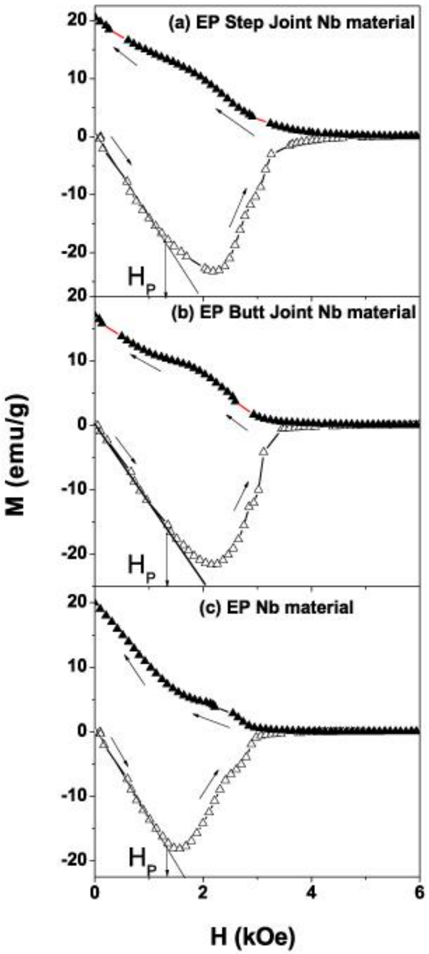
Accelerating gradient E_a achieved in different QWRs indigenously built at IUAC, for the Superconducting Linac.

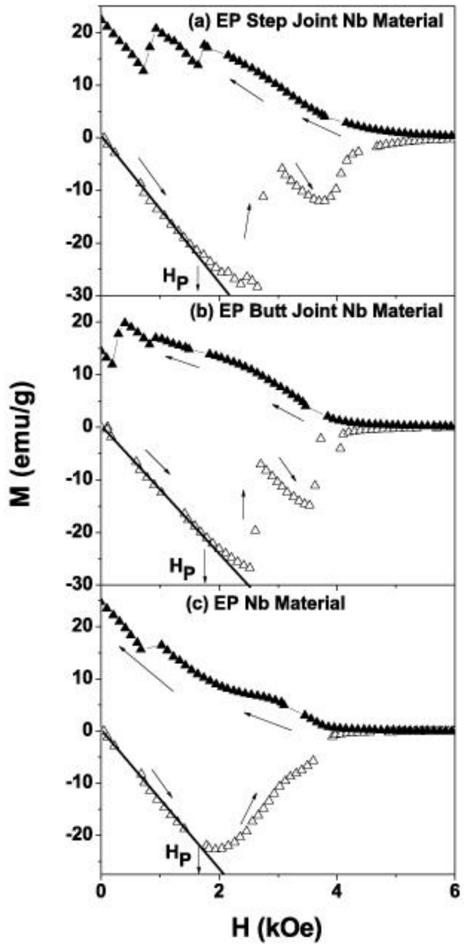
Resonator Q as a function of the accelerating gradient E_a at 4.2 K (QWR # 4).

Superconducting response in the electron beam welded region



Isothermal M-H plots of electron beam welded and electropolished niobium at 4 K (left) and 2 K (right)





<u>4 K Results</u>

- H_P Step Joint & EP – 1300 Oe
- H_P Butt Joint & EP – 1350 Oe
- H_P as-received EP – 1350 Oe

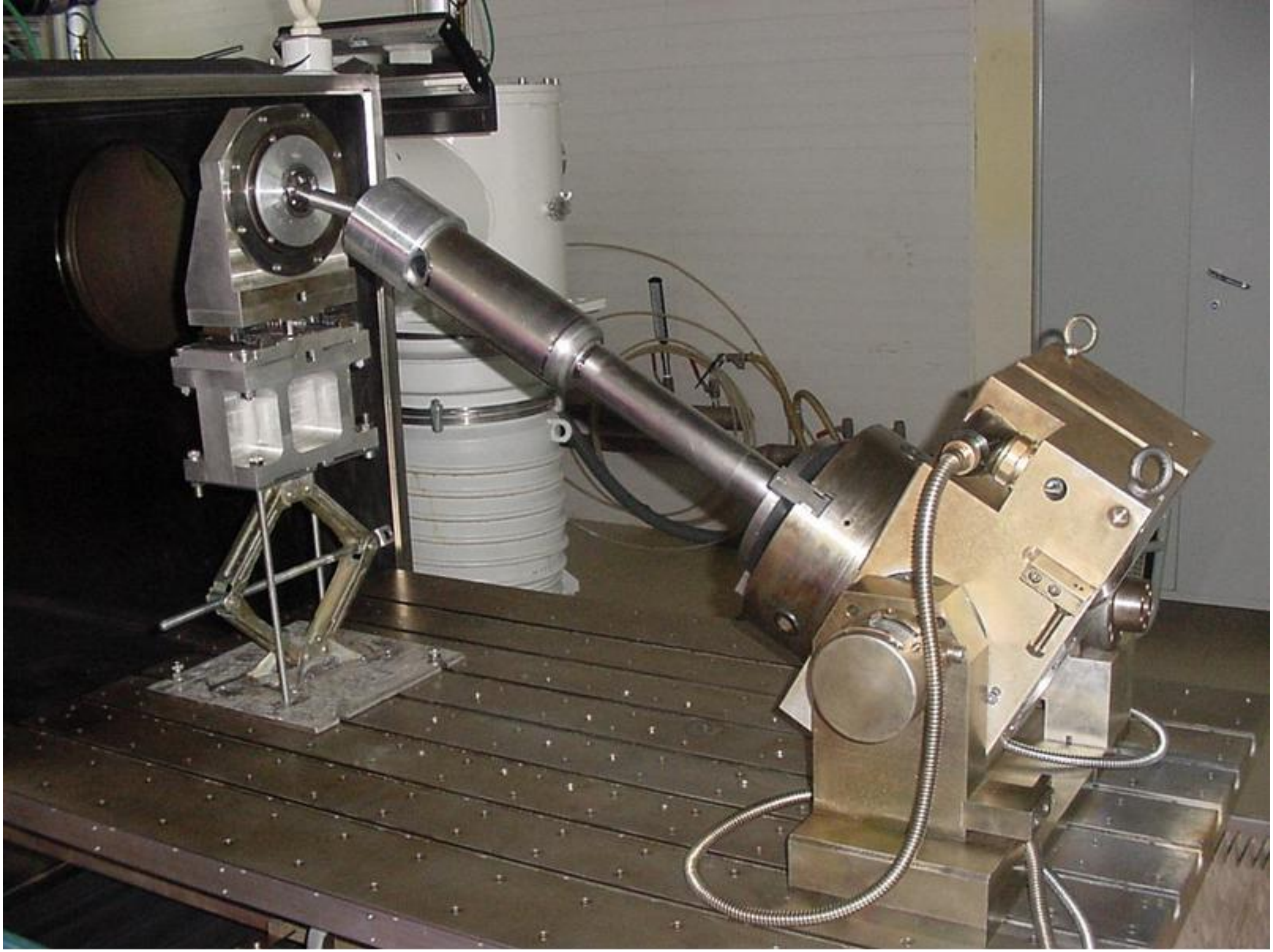
<u>2 K Results</u>

- H_P Step Joint & EP – 1650 Oe
- H_P Butt Joint & EP – 1700 Oe
- H_P as-received EP – 1700 Oe

Pure Niobium: H_{C1} @ 4 K ~ 1400 Oe
@ 2 K ~ 1800 Oe

1. ***Limiting accelerating gradient is close to the intrinsic limit.***
2. ***HP can be used for characterization of niobium material and various processes employed in the fabrication of SCRF cavities***

*Prakash N. Potukuchi et al., Phys. Rev. ST - AB, **14**, 122001 (2011)*



Before welding using EBW

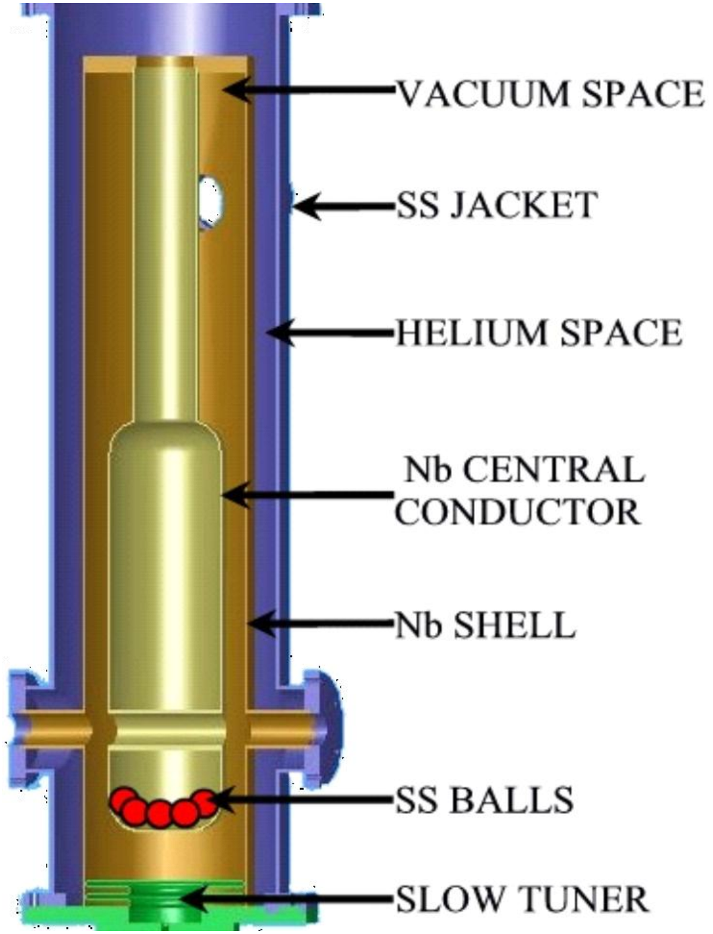
In-House Fabrication of Resonator

High Vacuum Furnace

Max Temp. 1200 C
 @ 5.0 x 10^{-7} torr

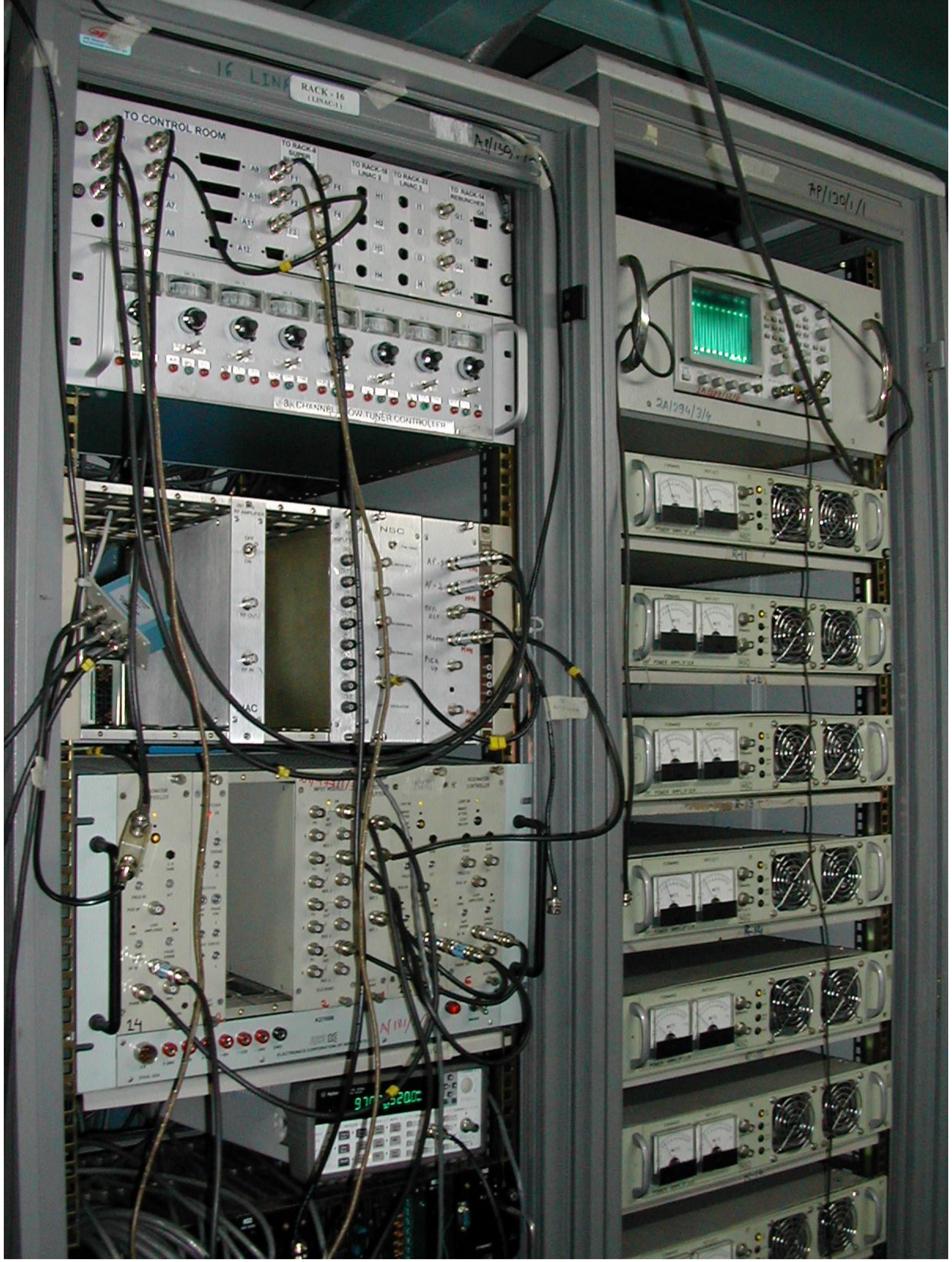
Hot Zone –
ϕ600mm x 1000mm

Damping of Micro-harmonics



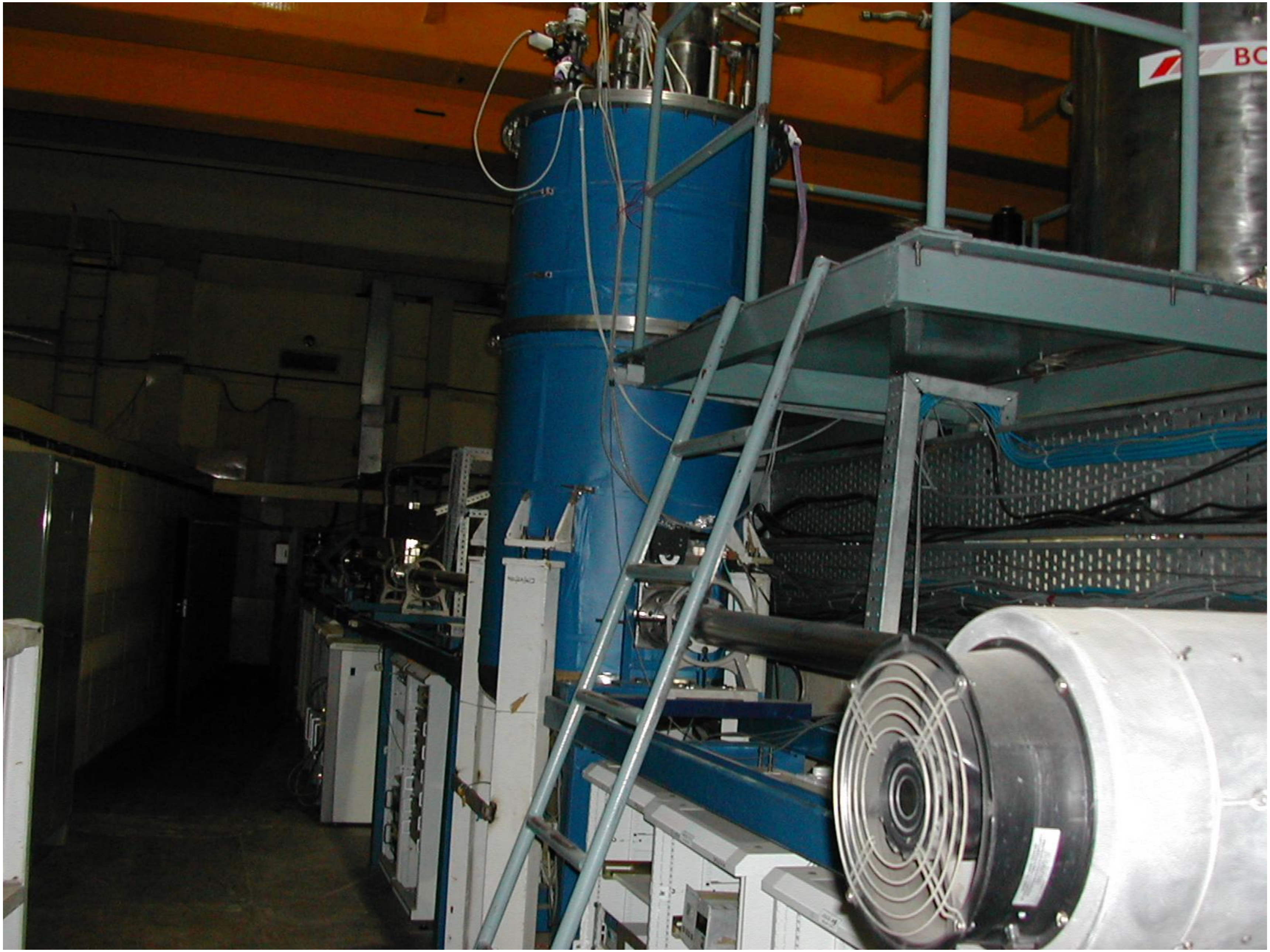
Resonator along with SS-balls

S. Ghosh et al., Phys. Rev. Spcl. Topics – Accl. & Beams 10, 042002 (2007)



RF Amplifier and Control system

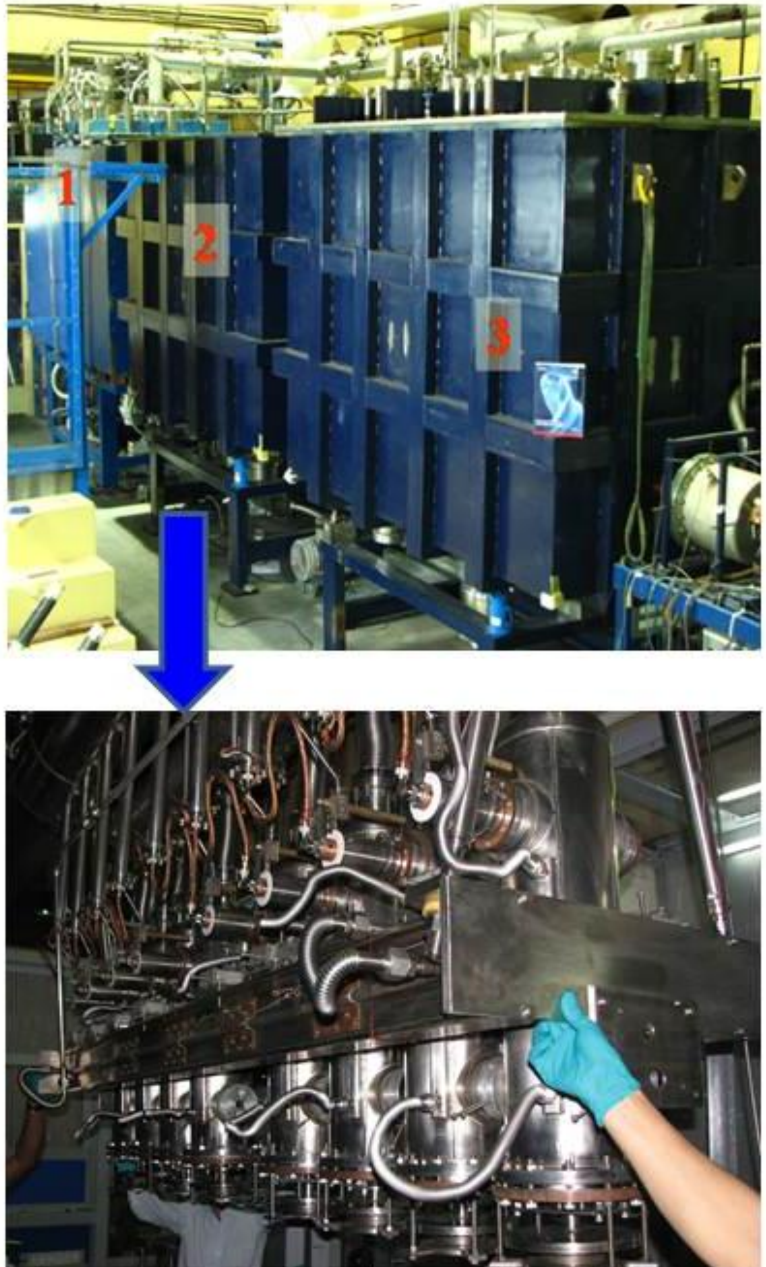
Power supplies for beam transport systems



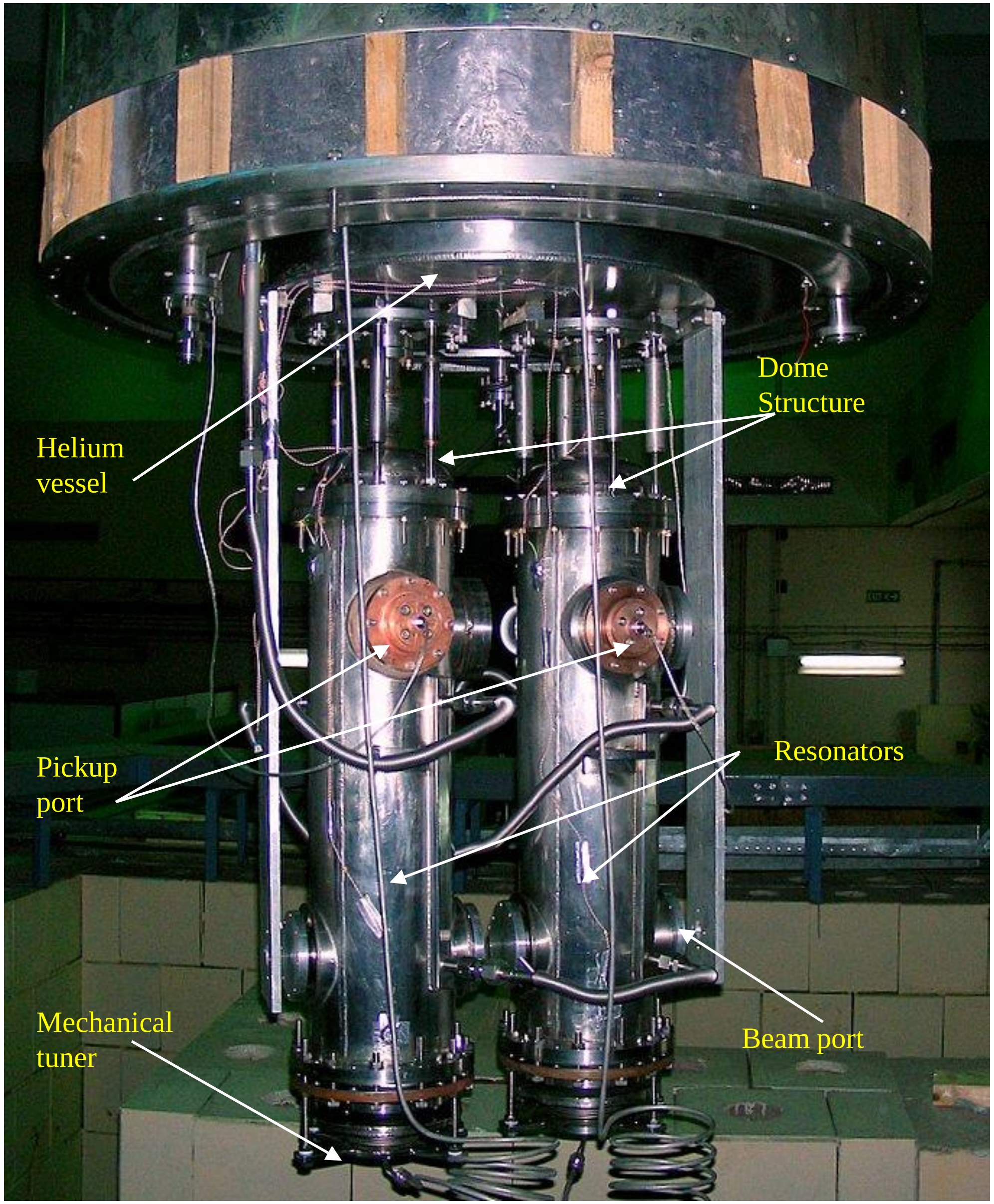
Superbuncher in the beam line (FWHM~170 ps)

LINAC Module ready for delivering beams

S. Ghosh et al., Phys. Rev. Spcl. Topics – Accl. & Beams 12, 040101 (2009)



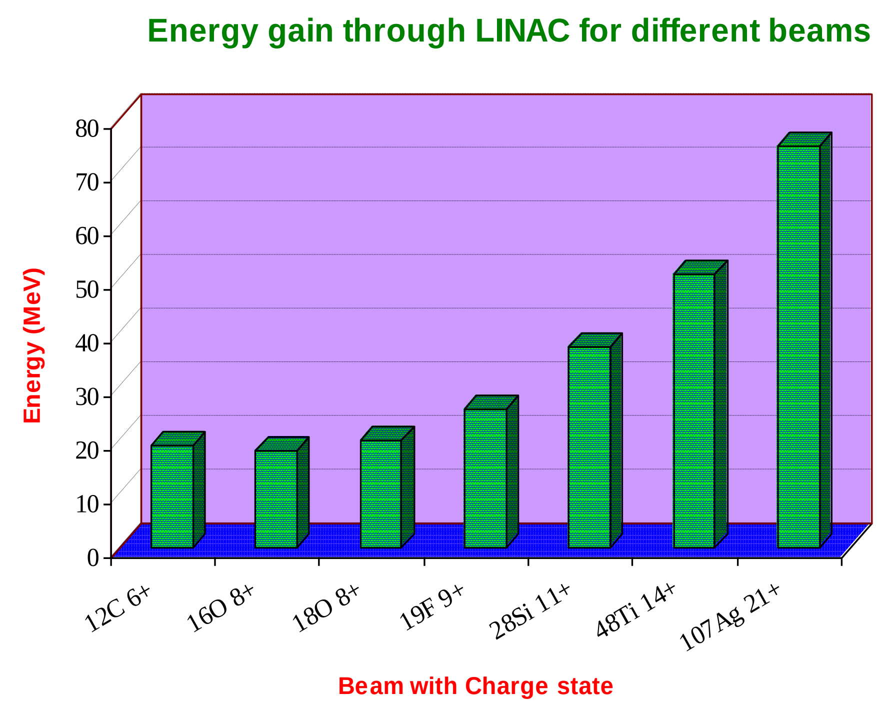
Three accelerating modules and the second cryostats with resonators



Rebuncher having two QWRs (350-400 ps)

LINAC Beam Run

Beam	Energy from Pelletron (MeV)	Energy from LINAC(MeV)	Total Energy (MeV)
12 C, 6+	87	19.2	106.2
16 O, 8+	100	20.02	120
		18	118
		10.25	110.25
18 O, 8+	100	20.026	120
		16	116
		12.25	112.25
		8	108
19 F, 9+	115	25.8	140.8
		22.2	137.8
28 Si, 11+	130	37.5	167.5
48 Ti, 14+	162	51	213
		36	198
107 Ag, 21+	225	75	300



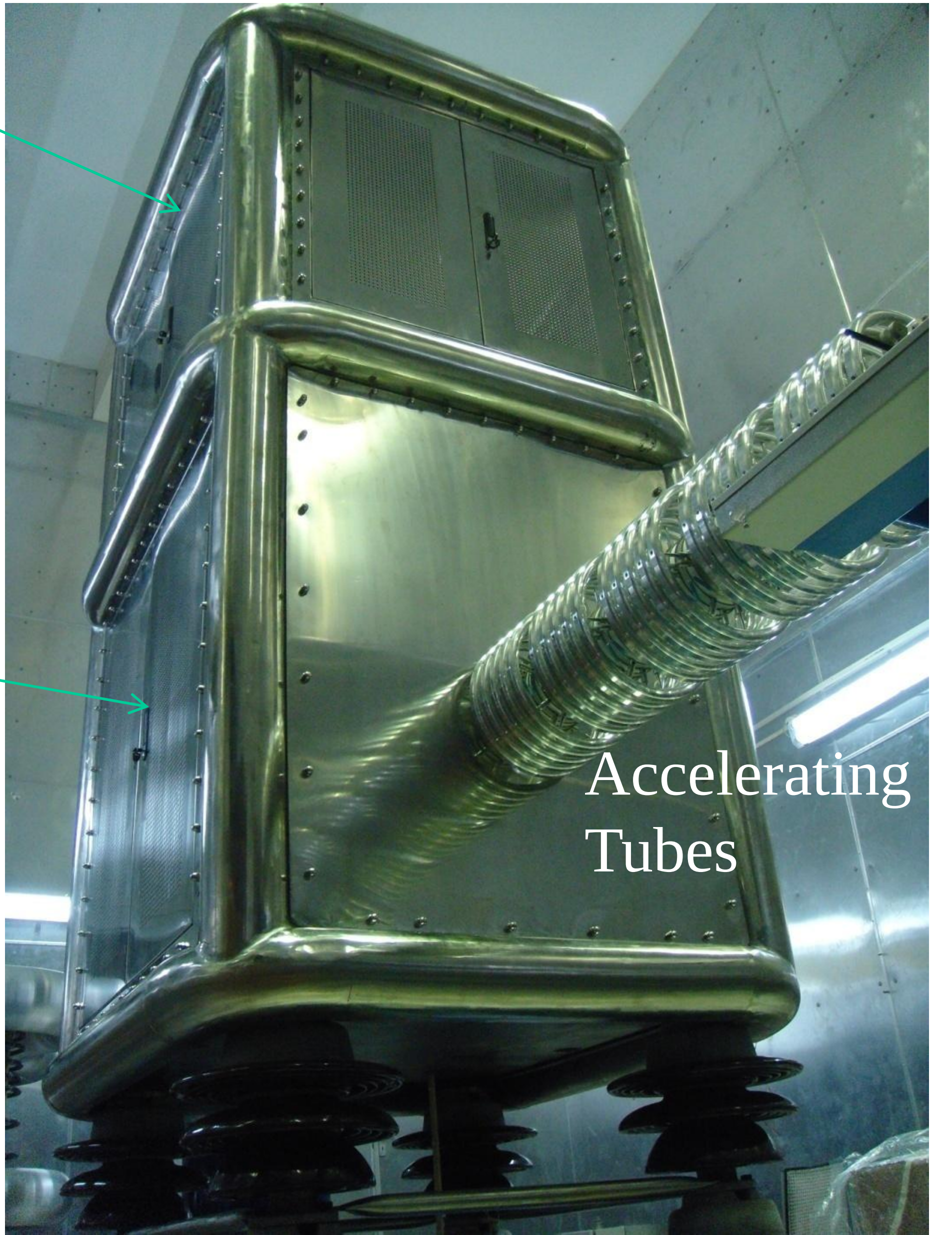
Beam	Pell. energy (MeV)	Linac energy gain (MeV)	Total energy (MeV)	Beam Line
$^{19}F^{+7}$	100	37	137	NAND
$^{28}Si^{+11}$	130	60	190	Linac Scatt. chamber
		56	186	HYRA
$^{31}P^{+11}$	130	58	188	HYRA

ECR Ion Source with associated components on 400 kV HV Platform

400 kv HV Platform with Accelerating Tubes

Electronics and Control

ECRIS



Three beam lines of ECRIS on 400 kV platform based facility

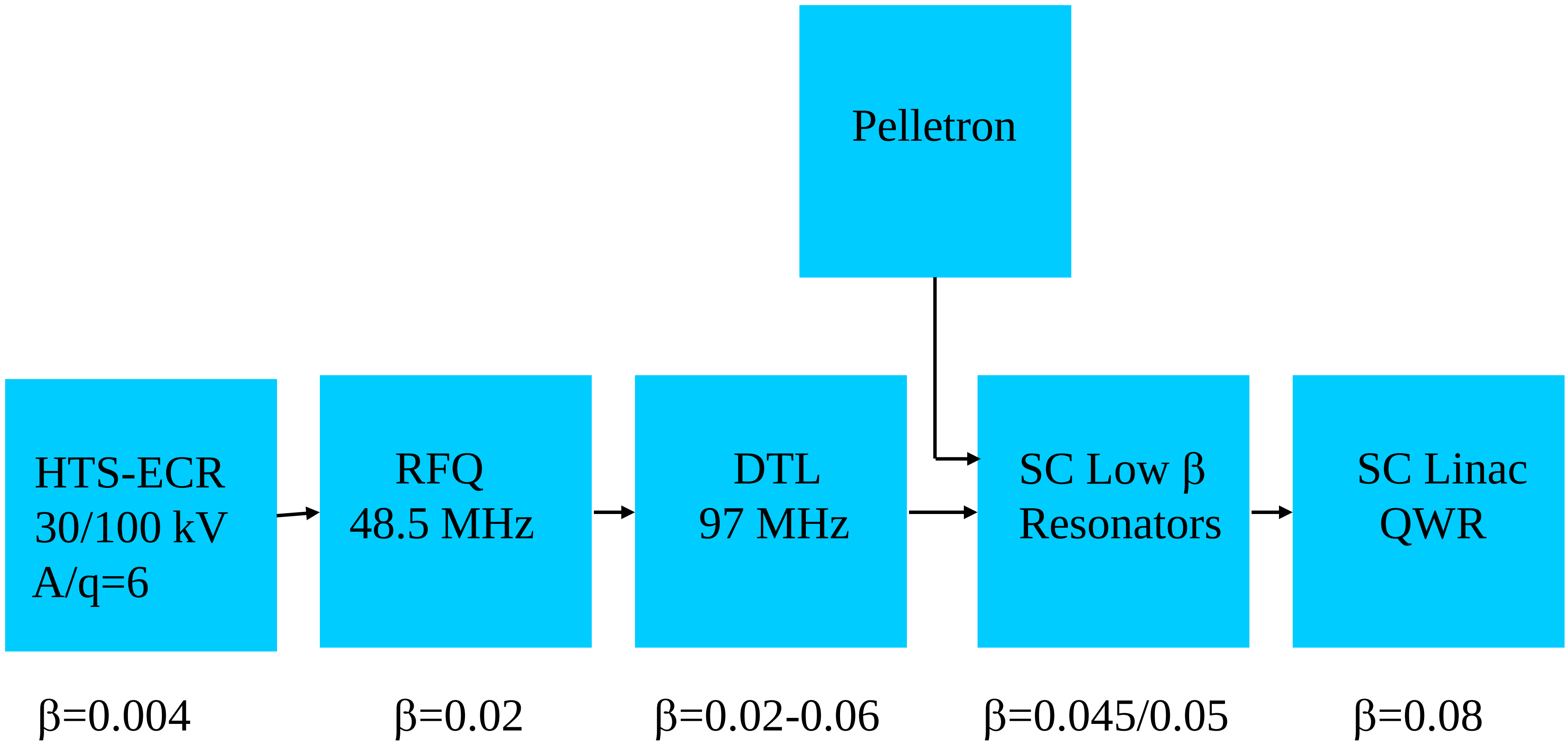
1.7 MeV Tandem Pelletron Accelerator with Experimental Facilities

Accelerator Mass Spectrometry

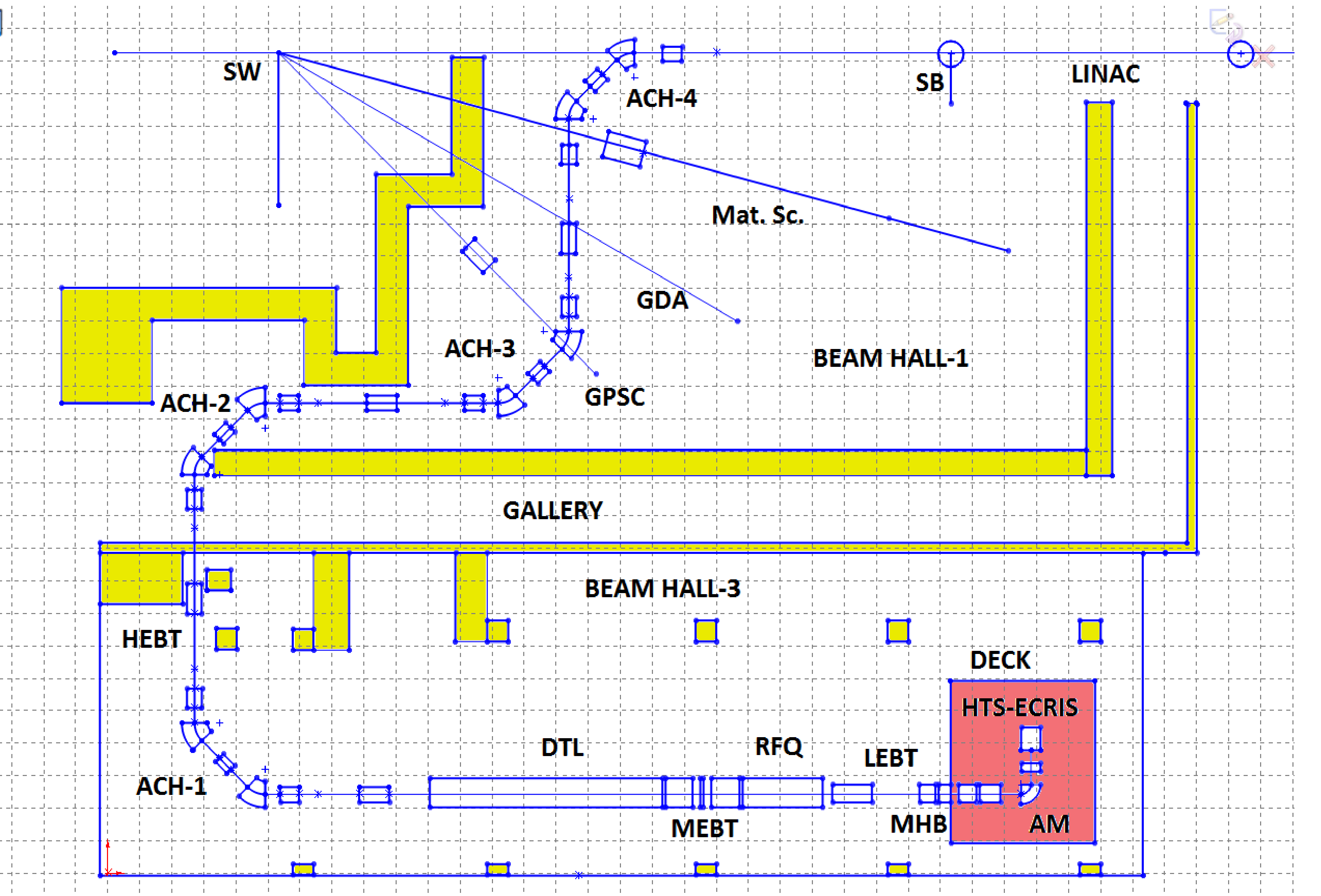
^{10}Be and ^{26}Al isotopes for geological and climatological studies

Clean Chemistry Laboratory:

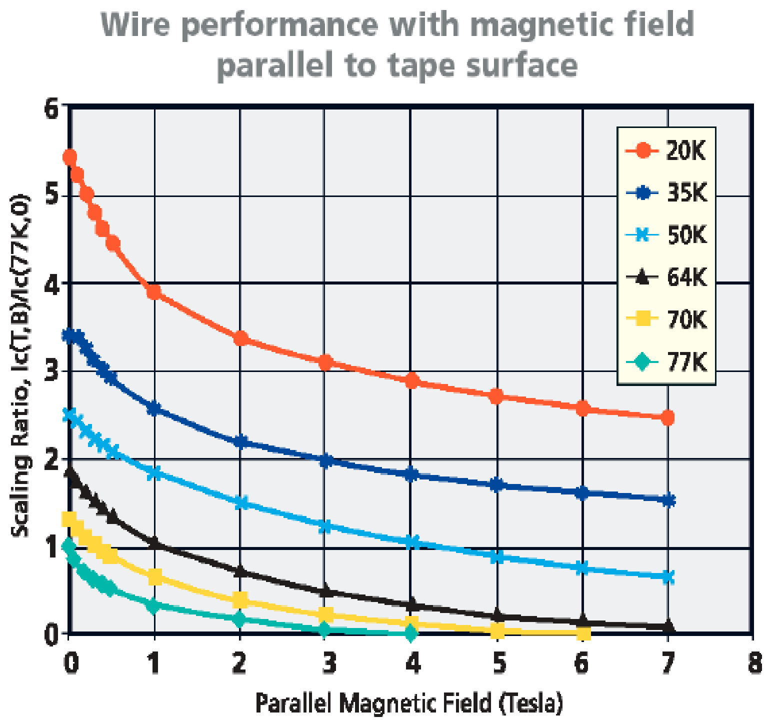
High Current Injector

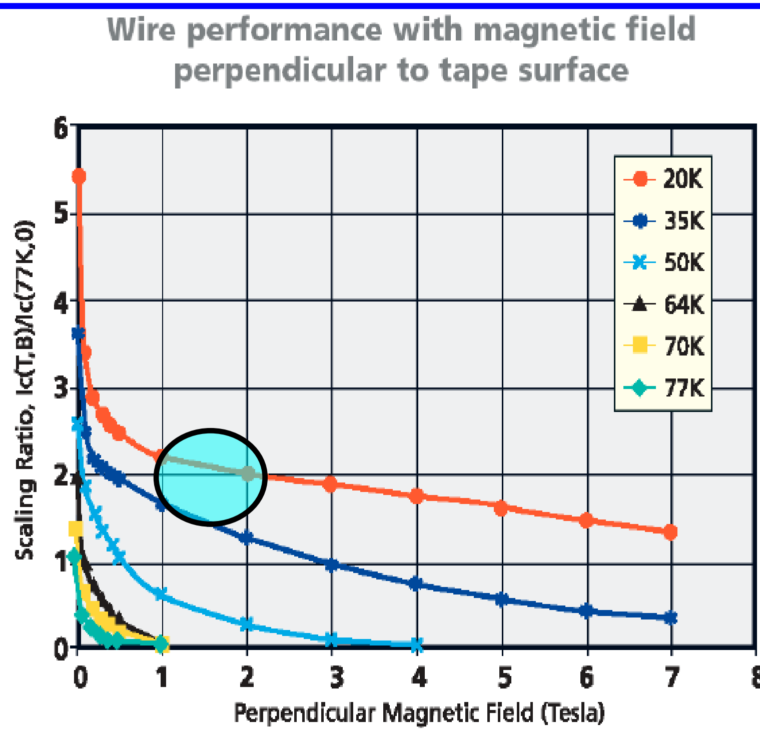


High Current Injector Beam Line Layout



Characteristics of HTS (BSSCO) tapes





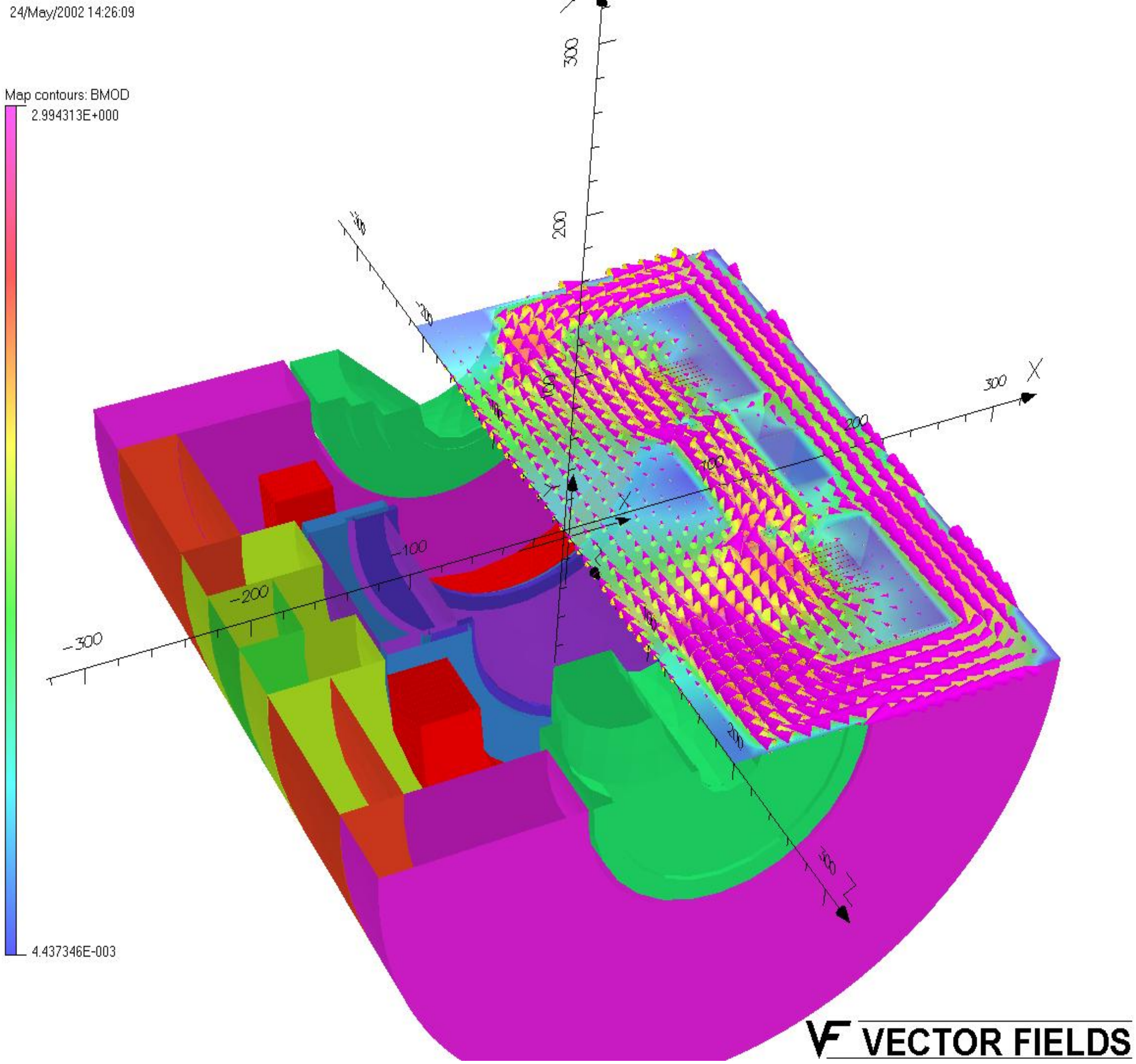
American Superconductor™
REVOLUTIONIZING THE WAY THE WORLD USES ELECTRICITY™

Current carrying capacity of HTS depends on:

- Temperature
- Magnitude of the field

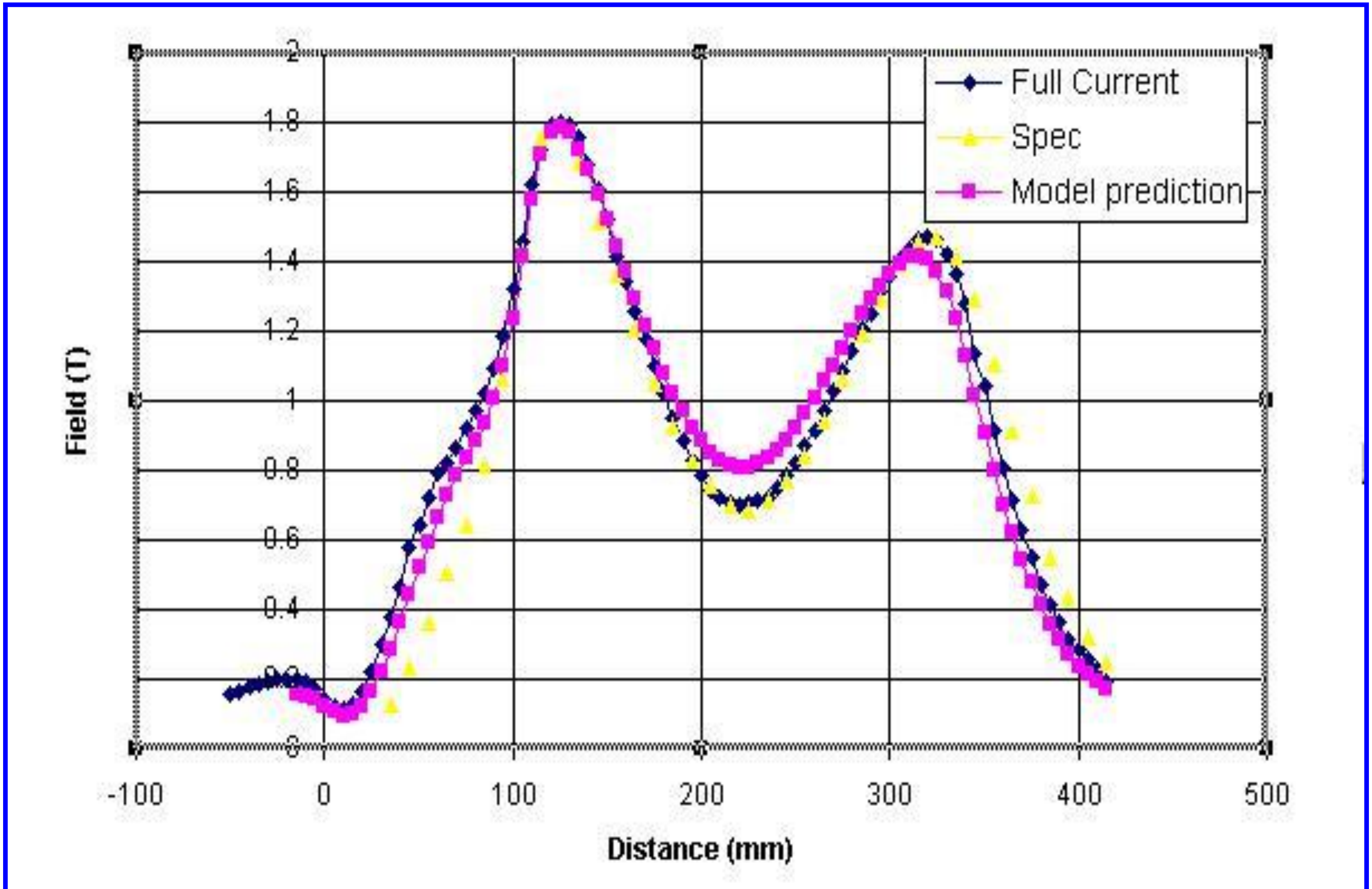
and also on the direction of the field

Maximum operating current	**181 A**
Maximum radial field	**1.4 T**
I_c @ 77 K,0B	**110 A**



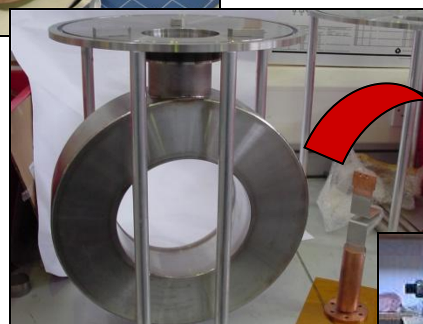
Field vectors on the yoke cross section

Axial field measurements

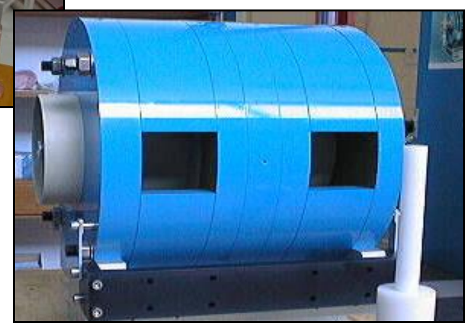


Various Stages of Development of HTS-ECRIS

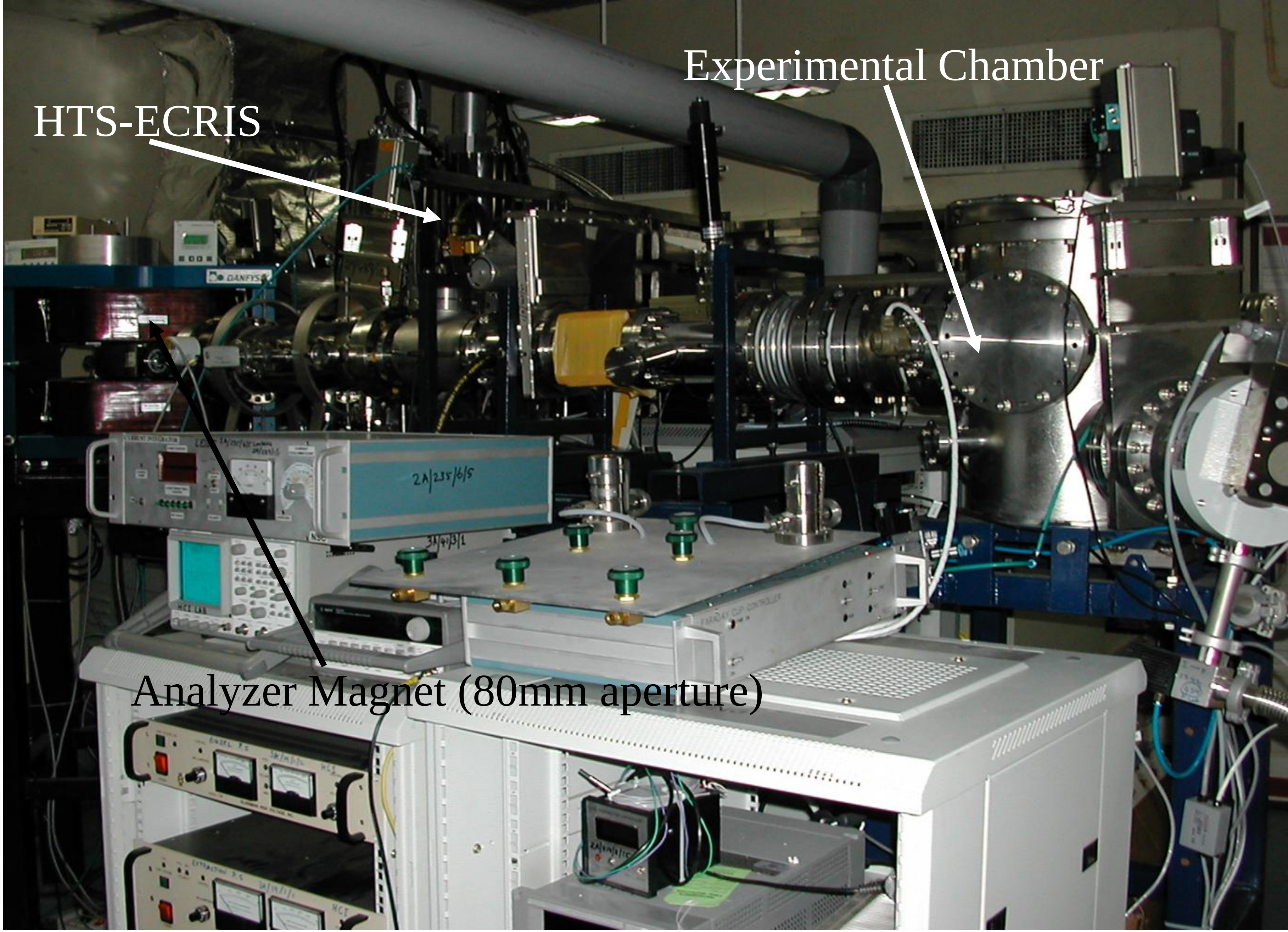
HTS coil



Coil cryostat

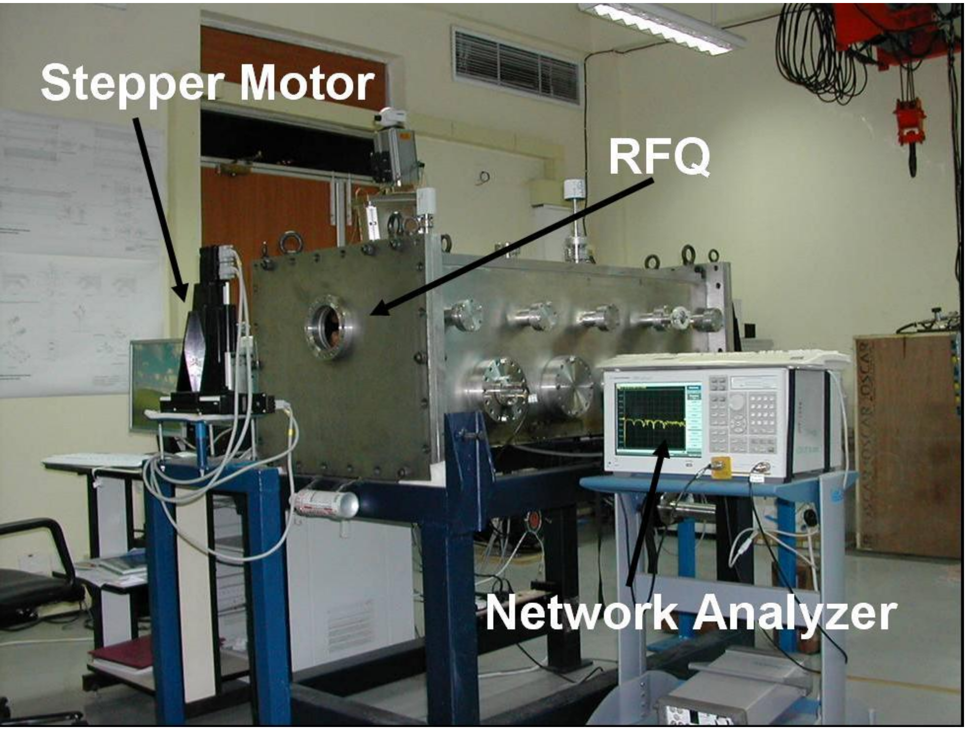


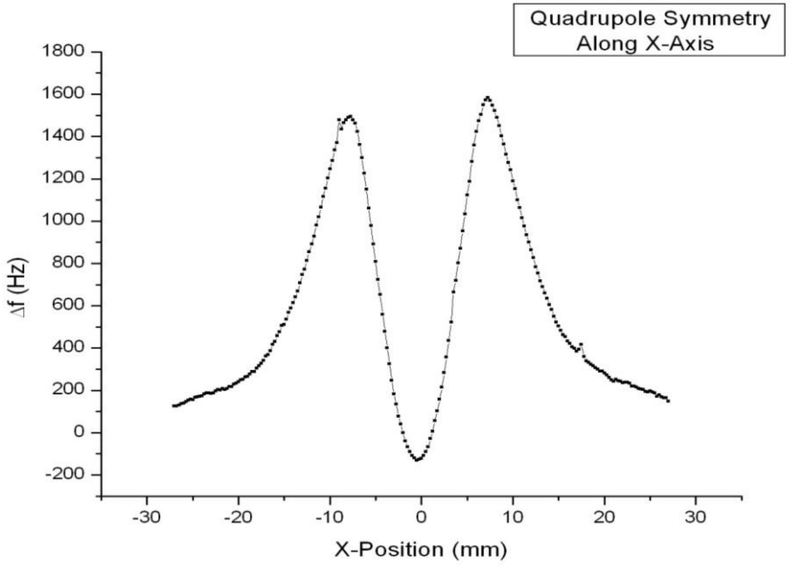
Iron yoke



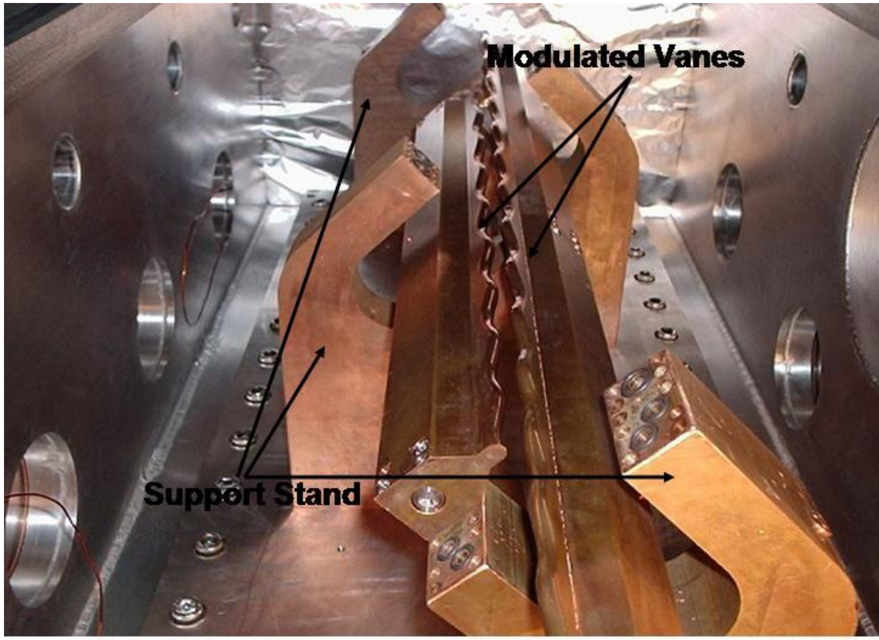
HTS-ECRIS with Experimental Chamber (Operation >38,000 hrs)

Prototype RFQ (f=48.5MHz) for A/q o f 6 for acceleration from 8keV/A to 180keV/A



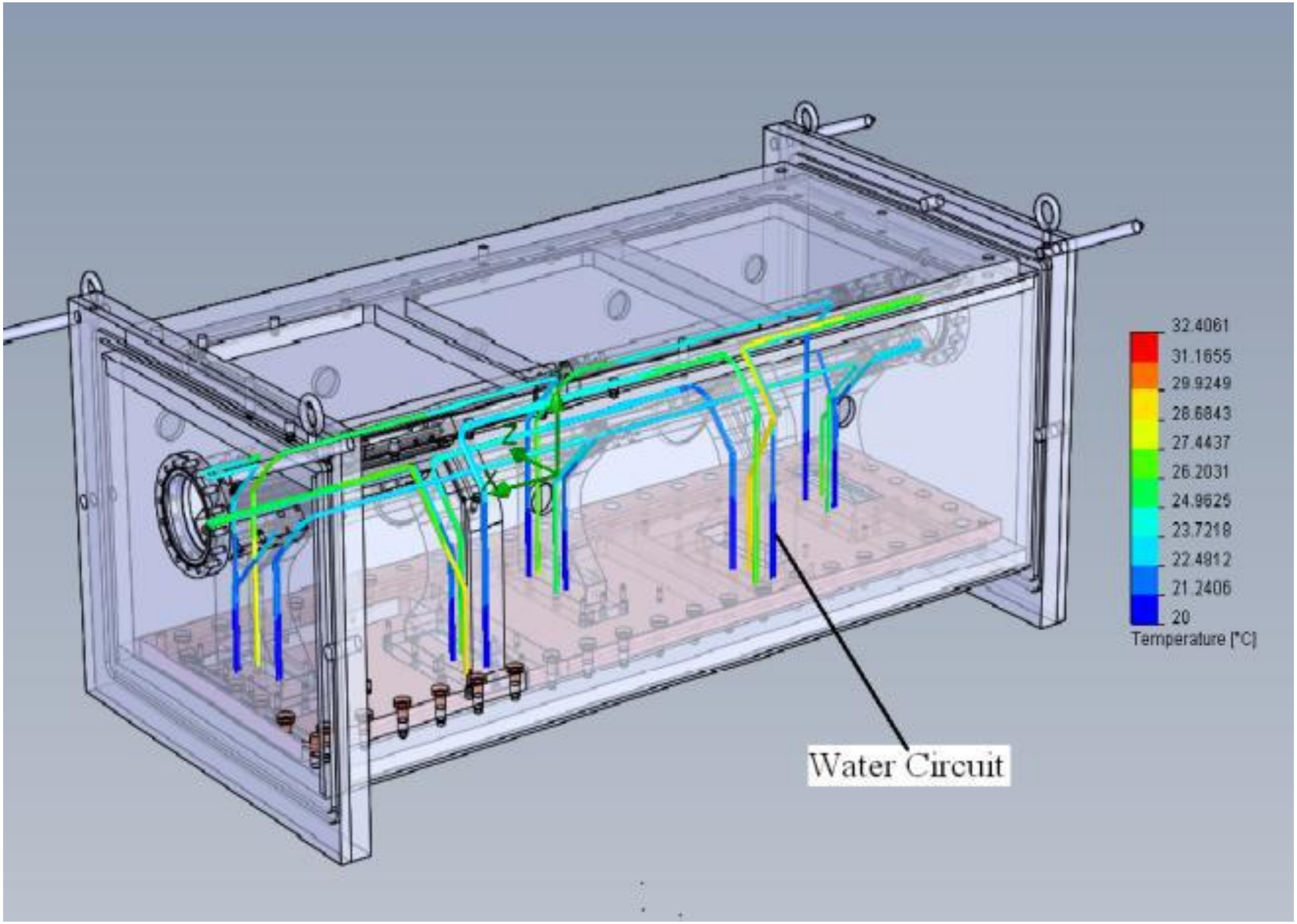


Bead pull test of RFQ



Modulated vanes of RFQ

Thermal Simulation For 35kW Powered Prototype RFQ



Results

- Actual test for RF power compares well with the simulated results.
- The Cooling circuit design is satisfactory for the vanes and posts.
- The chamber and base plate will require additional cooling.
- The RF tests are carried on unmodulated and modulated vanes with and without copper plating. It is found that after copper plating improved the quality factor is improved from 2355 to 4206.
- Power required for 70kV inter-electrode is reduced from 43kW/m to 24.6kW/m.

Drift Tube Linac

Energy: 180 KeV/u to 1.8 MeV/u
A/q = 6, 97 MHz, 6 RF Resonators

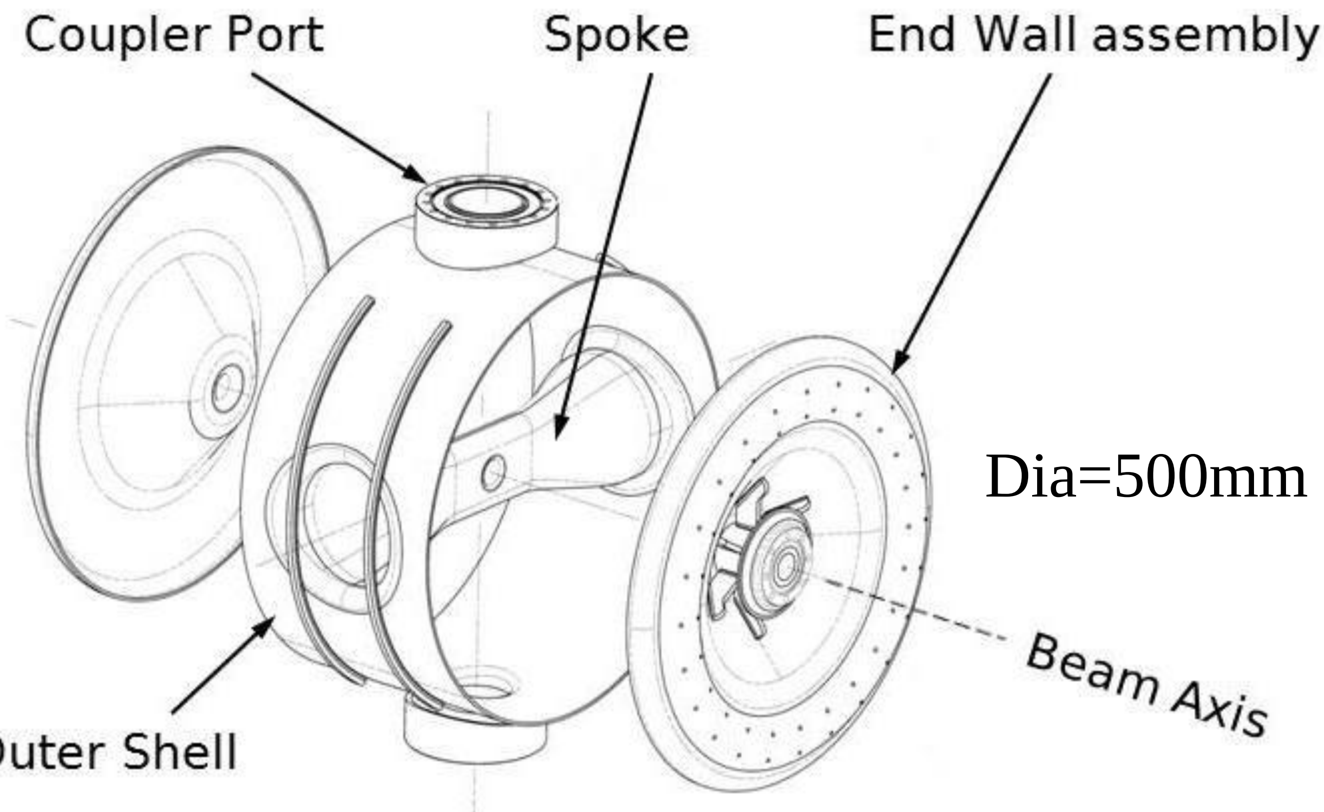
Tank #	Length (cm)	No. Of Cells	Eout (MeV/u)
1	38.5	11	0.32
2	73.4	13	0.55
3	94.4	13	0.85
4	86.5	11	1.15
5	92.2	11	1.46
6	81.6	9	1.80

Prototype DTL Resonator

Complete design validation has been done on full scale prototype resonator

Single Spoke Resonator – SSR1

for Project-X at FNAL, USA

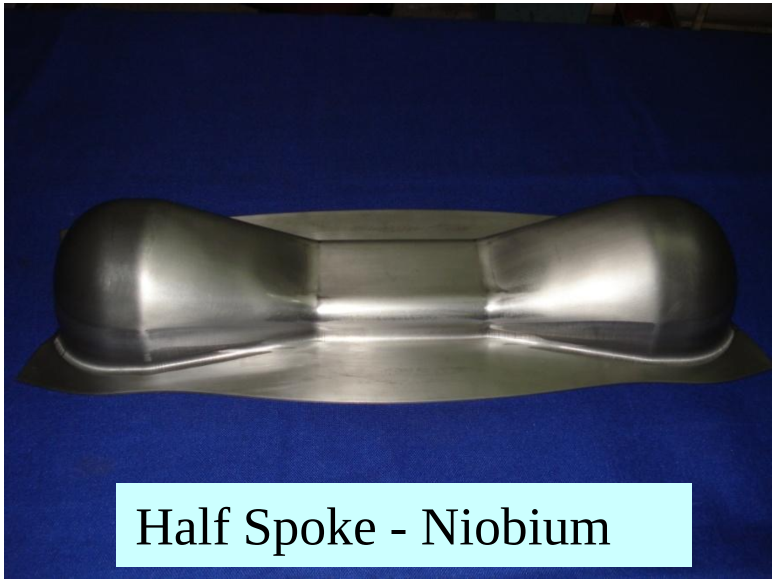


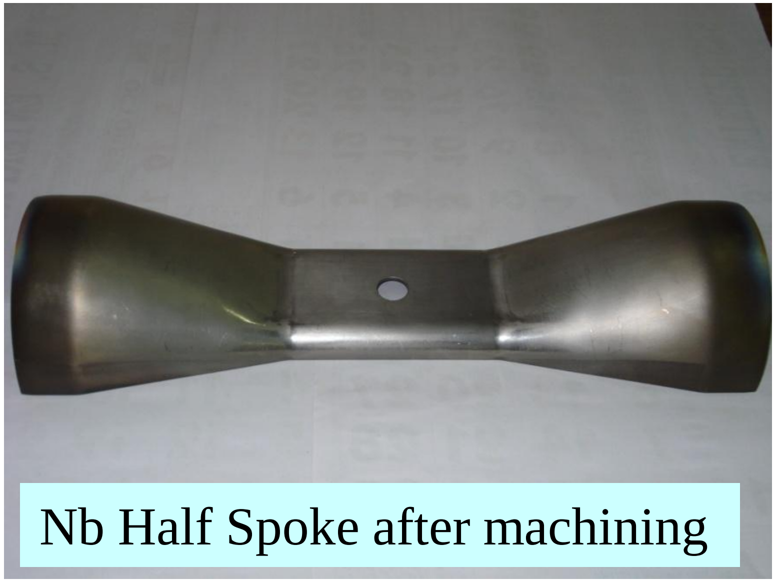
SSR1 - β=0.22, 325 MHz, Niobium Assembly

SSR1 Fabrication


Shell EBW setup


Spoke - Copper


Half Spoke - Niobium


Nb Half Spoke after machining

SSR1 - Fabrication

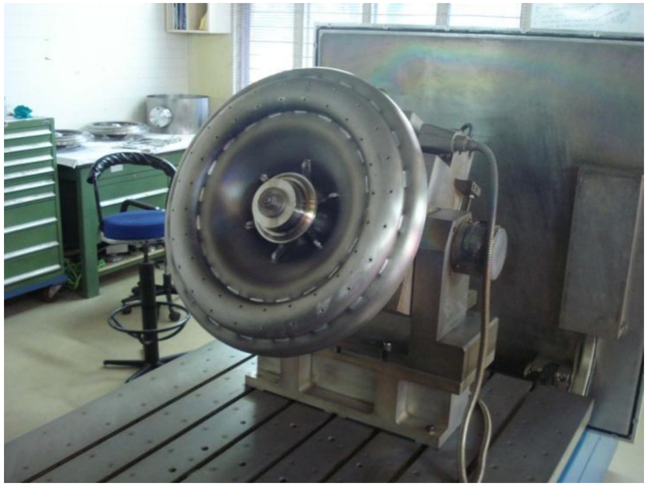

End Wall - Copper


Nb Coupler Port Tubes


Spoke to Shell Collar


Donut Rib Forming Die

Single Spoke Resonator – SSR1



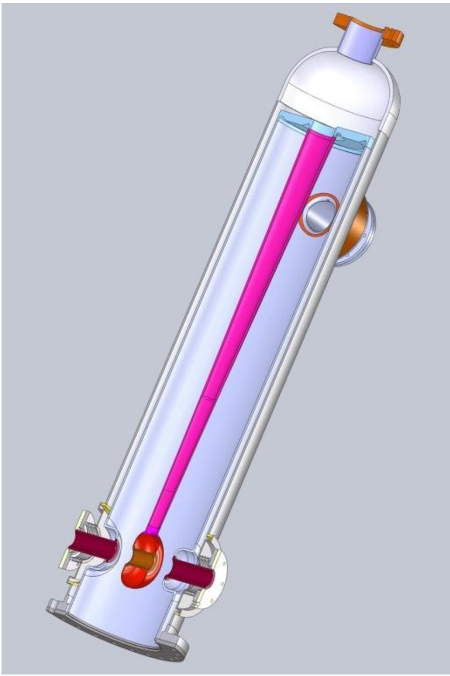
EBW – End Wall to Donut Rib

End Wall assemblies

Close up view of the End Wall assembly

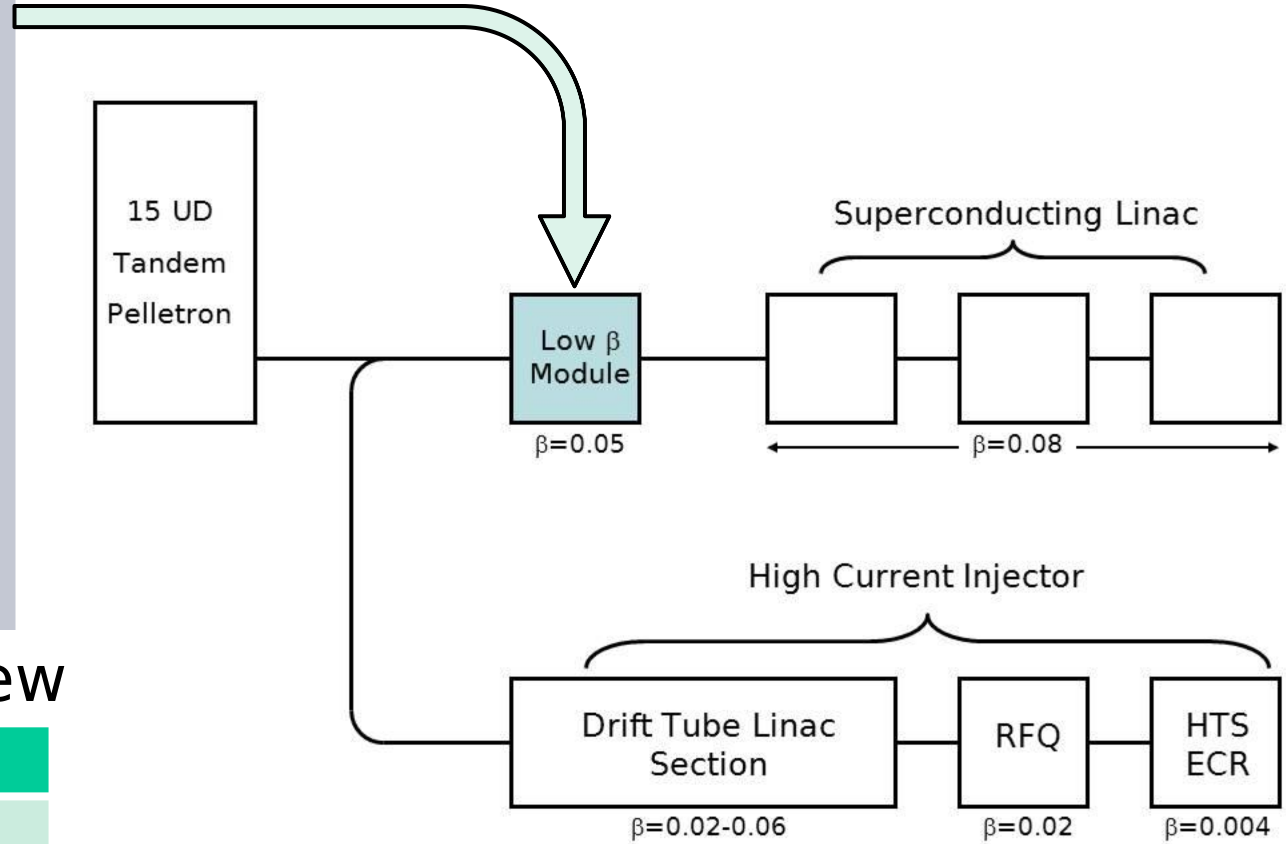
Outer Shell EP setup

Low Beta Resonator - LBR



Cut away 3D view
o

Parameter	Value
β	0.05
f	97 MHz
L_{eff}	~11 cm
U_0	26 mJ
B_{peak}	64 G



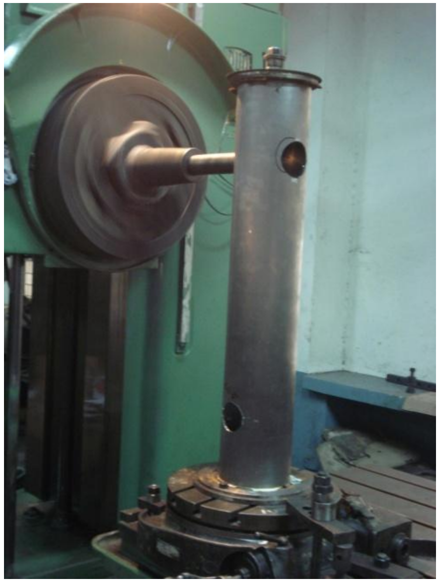
Proposed High Current Injector (HCI) at IUAC

Prakash N. Potukuchi et al, PRAMANA (in press)

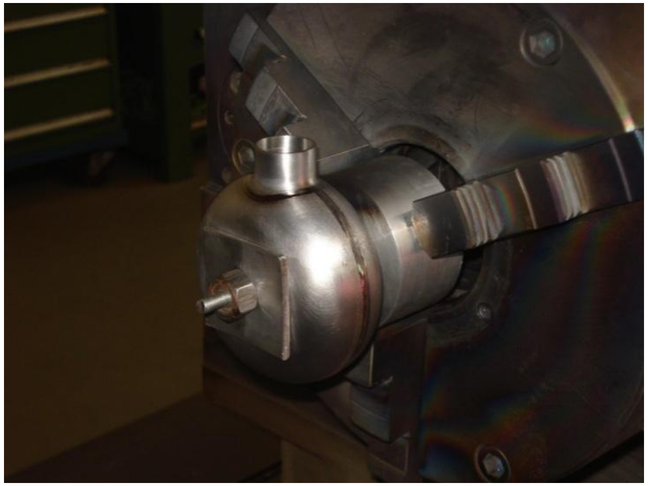
Prototype Low Beta Resonator - LBR

EBW - Central Coaxial Line

Drift Tubes & Saddles



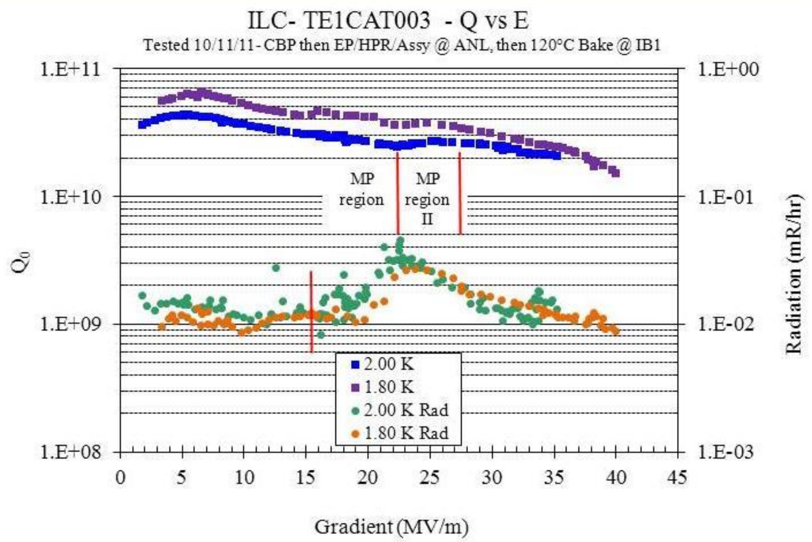
Outer Housing - boring of Coupling and Beam Ports

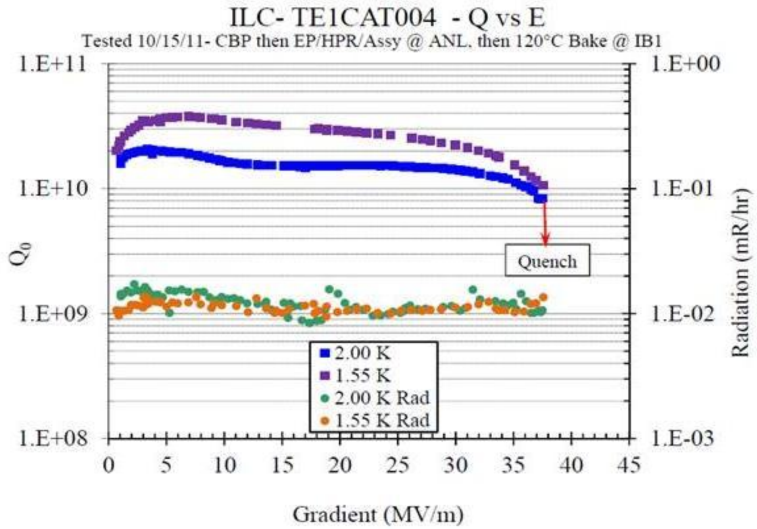


EBW – Drift Tube to Saddle

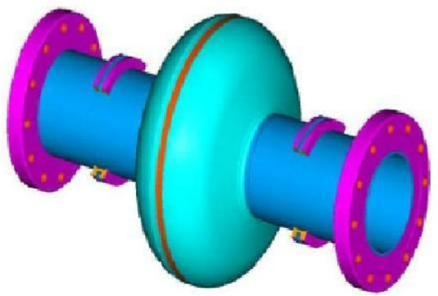
EBW – Saddle to Beam Port

TESLA Type 1.3 GHz Single Cell Cavities





Accelerating gradient achieved in Cavity # 3 & 4



Niobium Single cell Cavity

Control Room for 15UD Pelletron and SC Linac Booster

Conclusion

Long term road map for addition as well as up-gradation of ion beam facilities at IUAC are planned based on the use, results of experiments and future requirements.

Infra-structures and facilities for indigenous development, fabrication and tests of various ion accelerators and associated components are upgraded continuously.

HTS-ECR ion source on elevated (kV) platform followed by RFQ and DTL, Low Beta Cavities will be alternate injector of Superconducting LINAC in future.

Technology related to niobium resonators has been developed successfully.

The two LINAC modules have been completed and used to deliver beams for scheduled experiments.

Acknowledgements

Colleagues involved dedicatedly in the development, operation and maintenance of the Accelerators and associated systems.

Dr. Amit Roy, Director, IUAC

Thank you