Heavy Ion Accelerator Development at IUAC Delhi

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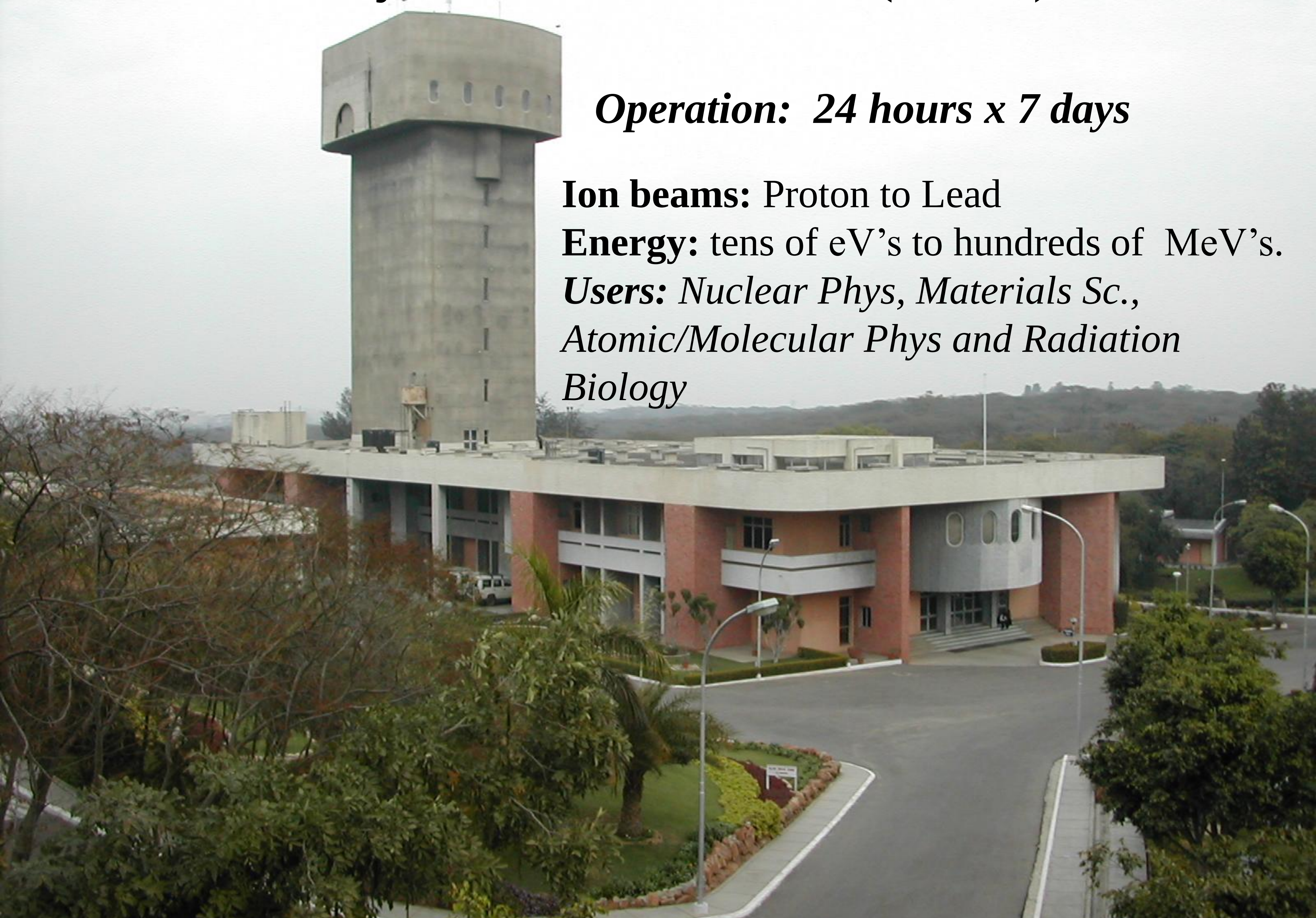
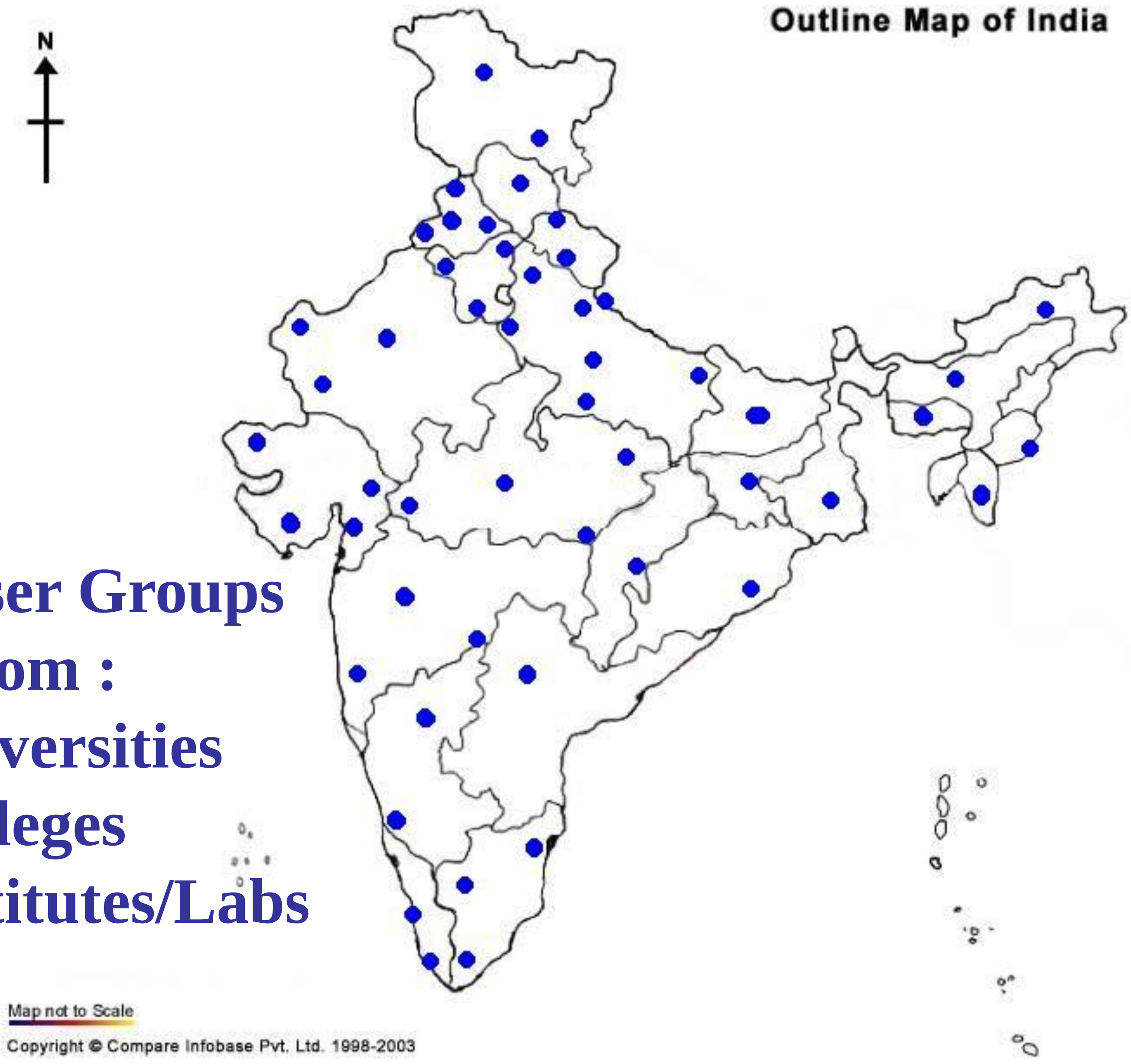
Inter-University Accelerator Centre (IUAC), Delhi



Operation: 24 hours x 7 days

Ion beams: Proton to Lead
Energy: tens of eV’s to hundreds of MeV’s.
Users: *Nuclear Phys, Materials Sc., Atomic/Molecular Phys and Radiation Biology*

User Community of IUAC



> 400 User Groups from :

80 Universities

53 Colleges

58 Institutes/Labs

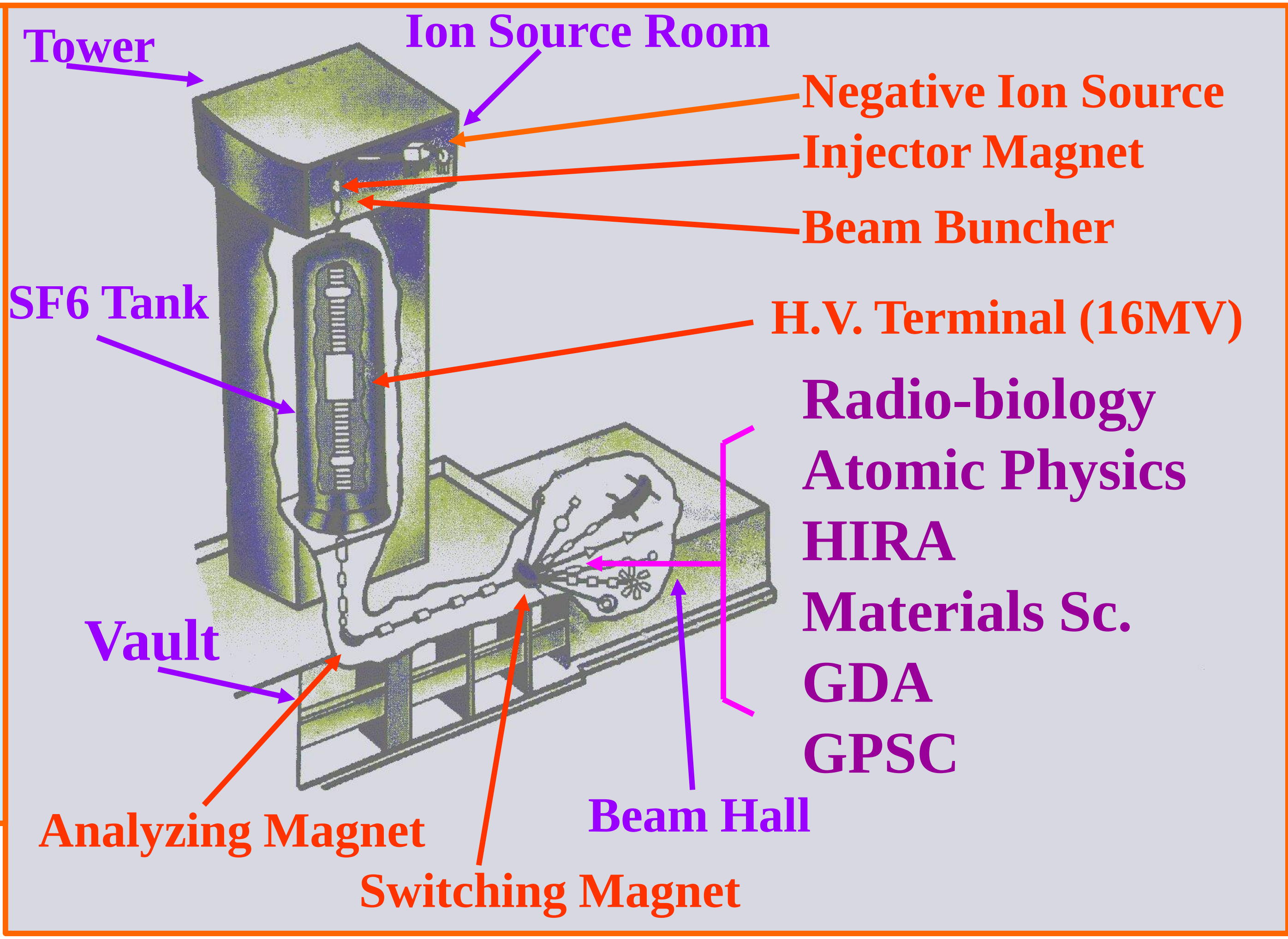
Beam delivered	Utilization (% of total time)		Beam delivered	Utilization (% of total time)
^{6}Li	2.35%		^{30}Si	6.70%
^{7}Li	1.39%		^{31}P	3.79%
^{10}B	2.68%		^{32}S	2.13%
^{11}B	0.08%		^{35}Cl	0.10%
^{12}C	10.34%		^{48}Ti	1.25%
^{13}C	0.61%		^{56}Fe	1.72%
^{14}N	2.75%		^{58}Ni	9.37%
^{16}O	10.37%		^{79}Br	0.46%
^{18}O	5.59%		^{107}Ag	13.88%
^{19}F	6.33%		^{197}Au	5.90%
^{28}Si	12.22%			

15UD Pelletron Accelerator at IUAC Delhi

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

Ions accelerated:
H to Pb beams

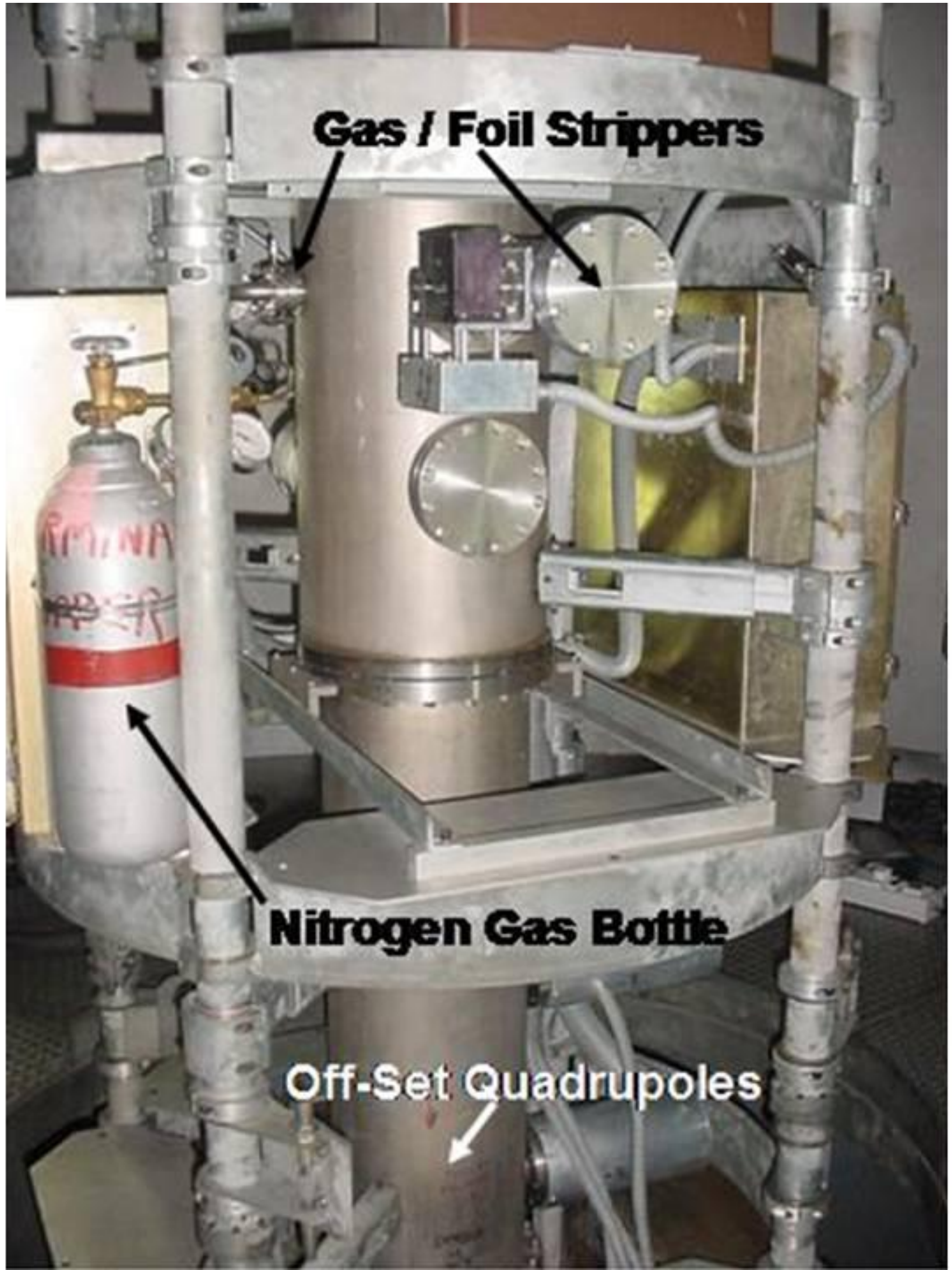
Currents: ~ 1 -50 pnA
Energy : 30 – 270 MeV



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

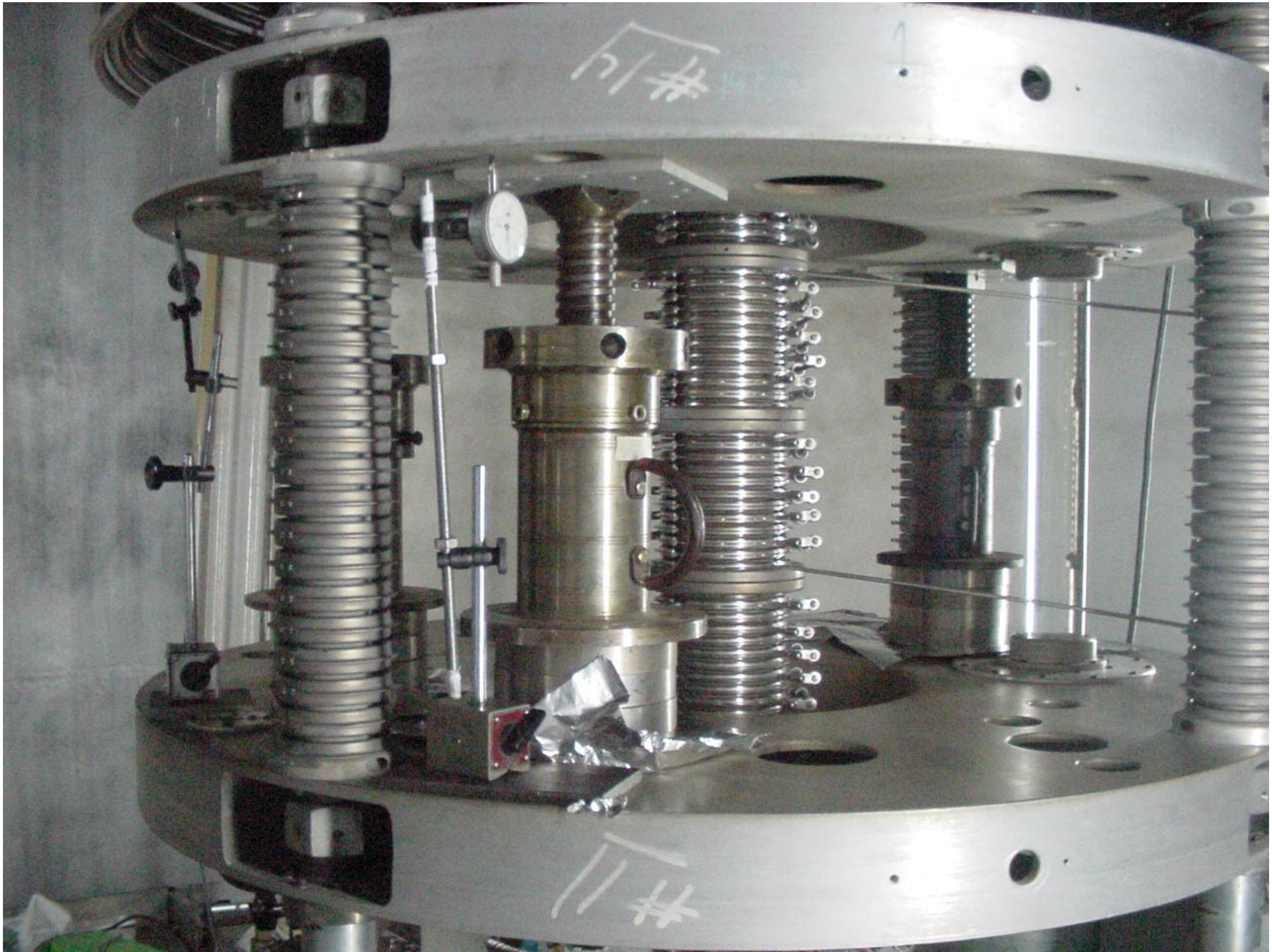
Off-set quadrupoles in HV terminal after strippers for charge selection

Four Earthquake Protection arms

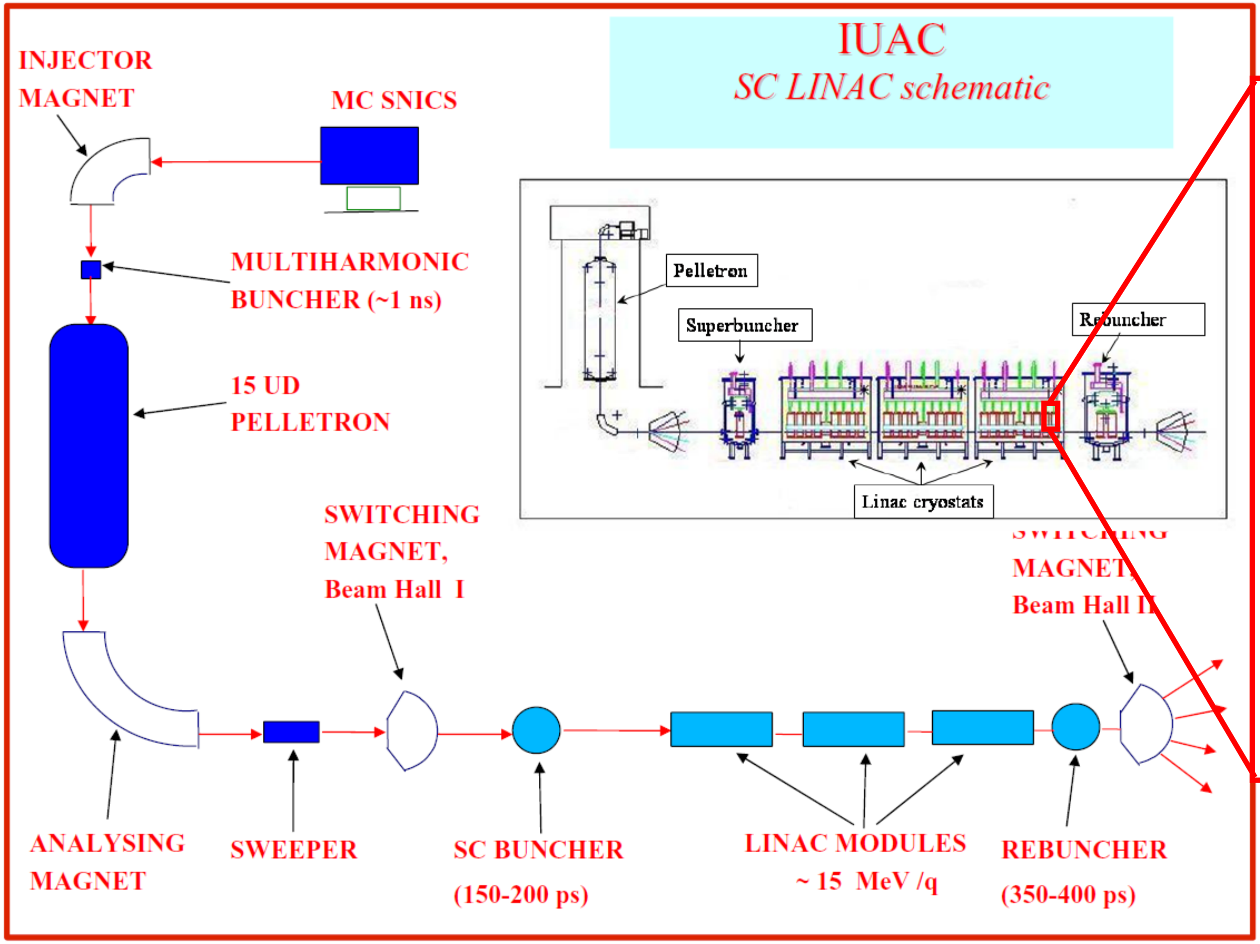


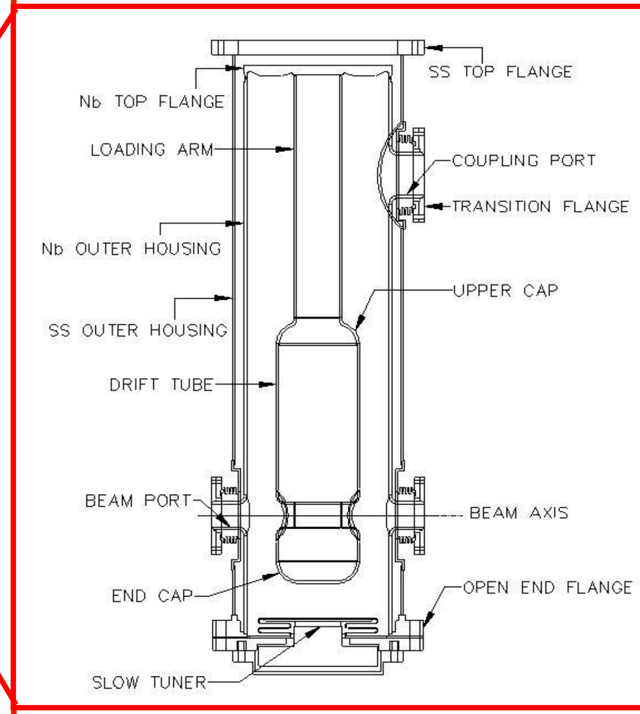
Foil Stripper at the Tank Bottom before analyzing Magnet

Replacement of damaged column support posts



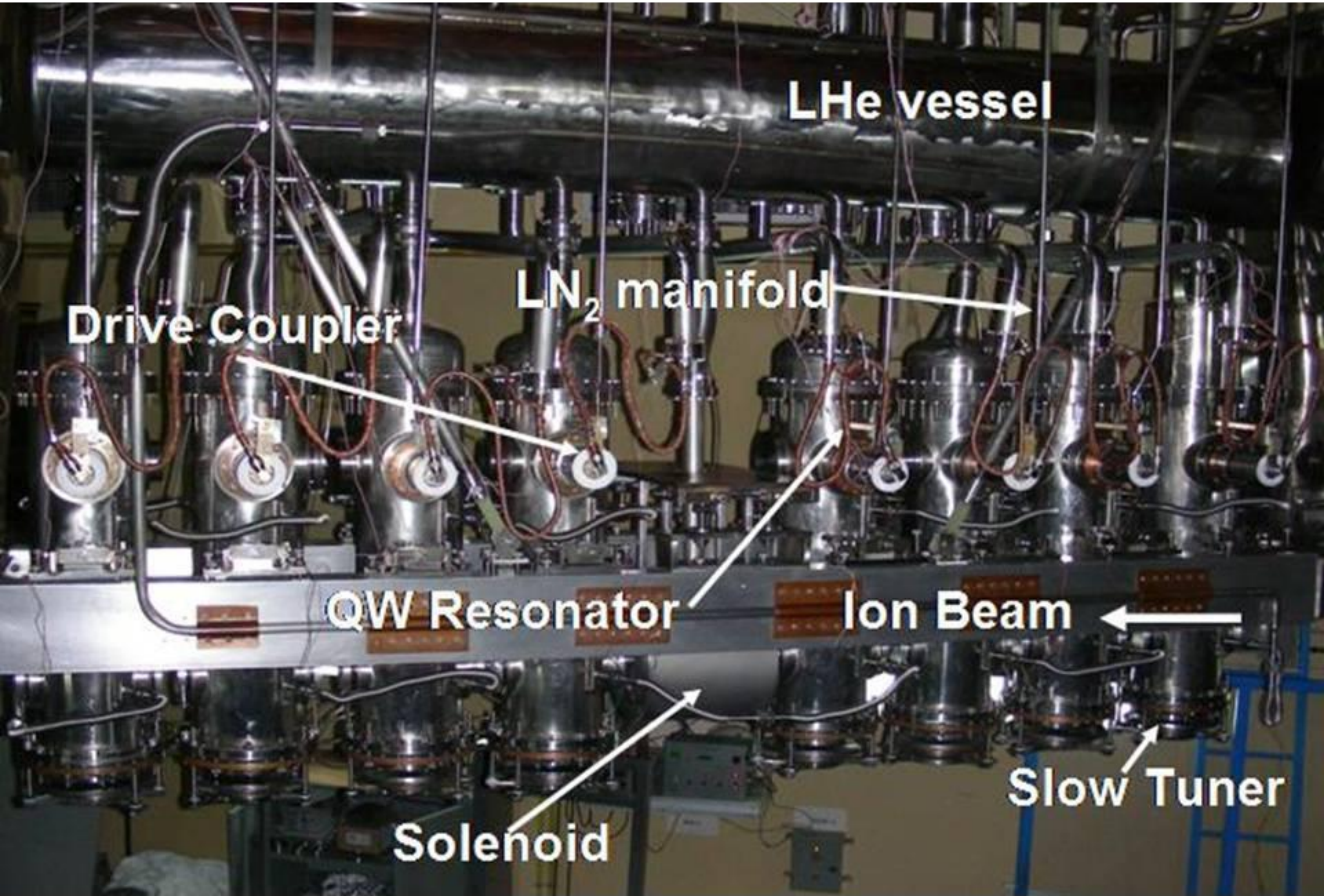
IUAC superconducting LINAC



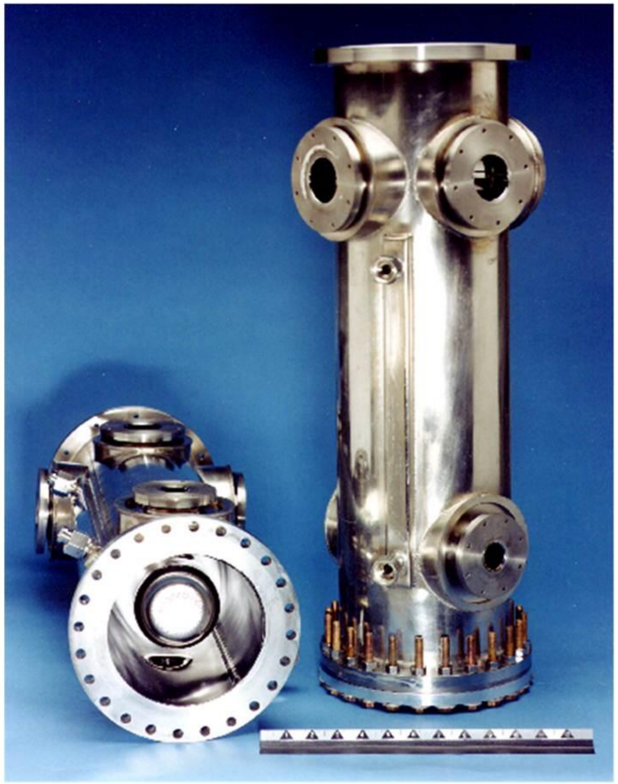


Nb Quarter Wave Resonator.

QWRs, SC Solenoid, etc of the first Linac module



Niobium QWRs for IUAC Linac



Superconducting Niobium Quarter Wave Resonators (QWR) fabricated at ANL(left) and several QWRs fabricated at IUAC Delhi.

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

Production of QWRs – 2nd & 3rd Modules

Niobium Central Conductor assemblies.

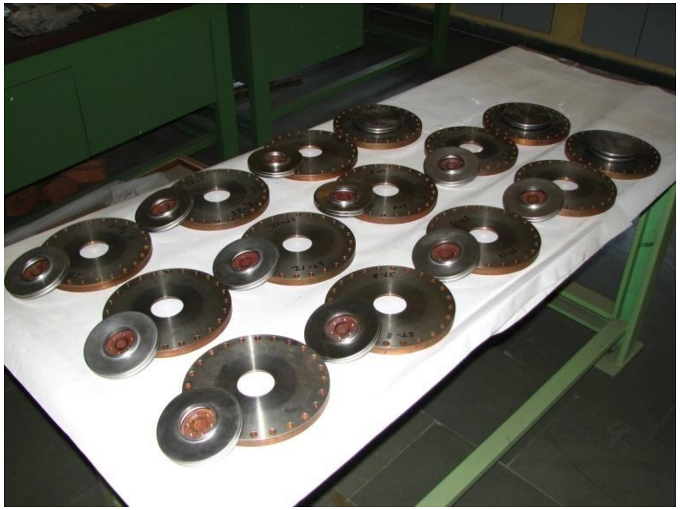
Niobium Top Flanges.

Niobium Outer Housings.

Production of QWRs – 2nd & 3rd Modules

Bare niobium QWRs.

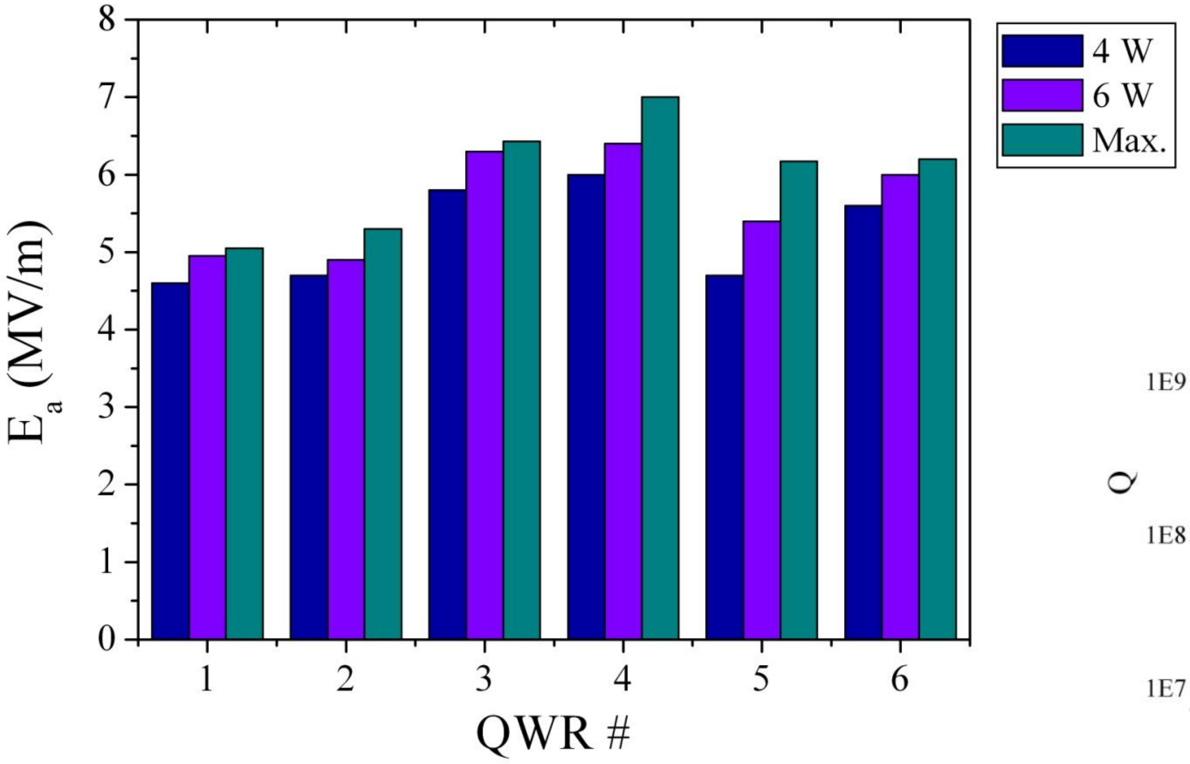
One dozen Production QWRs.



Slow Tuner components.

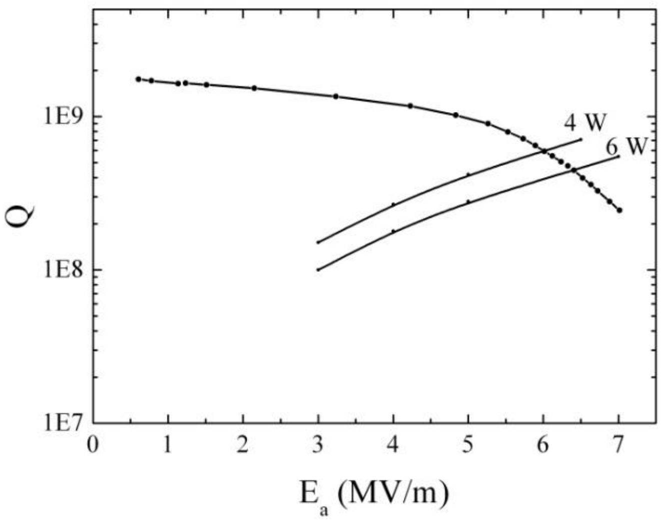
Niobium Slow Tuner bellows.

Performance of Indigenously built Nb QWRs



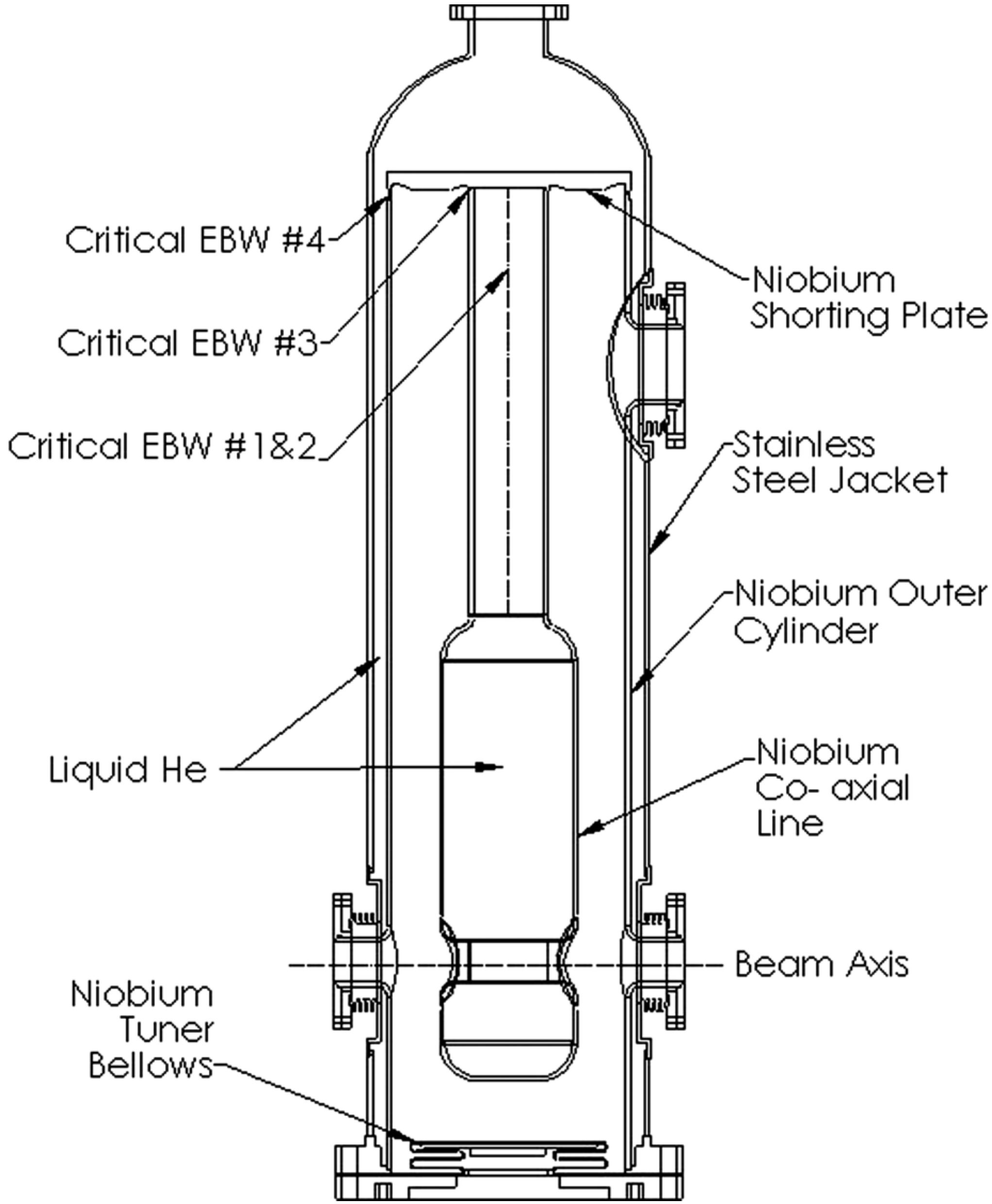
Accelerating gradient E_a achieved in different QWRs indigenously built at IUAC, for the Superconducting Linac.

Best performance of a QWR built at IUAC. The pulsed gradient was ~9 MV/m corresponding to B_{peak} ~116 mT.

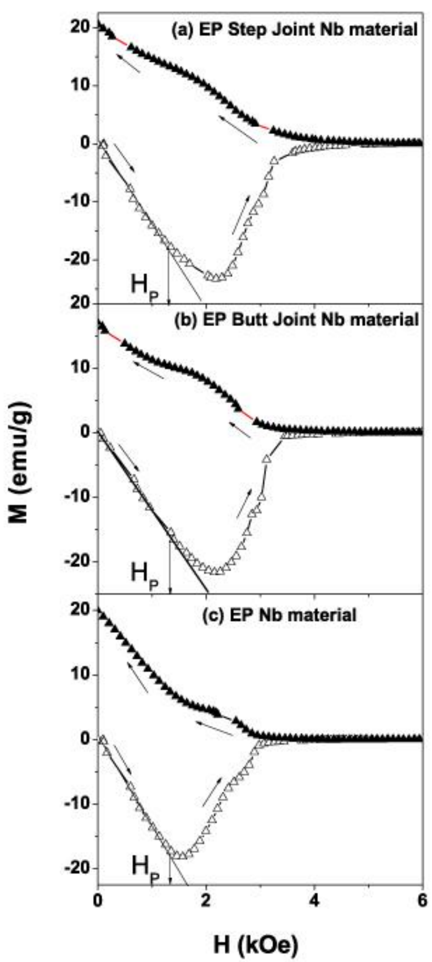


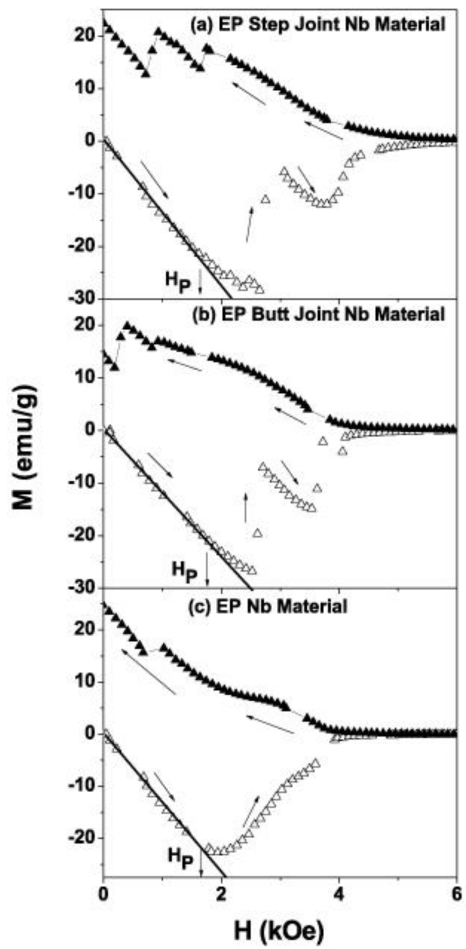
Resonator Q as a function of the accelerating gradient E_a (CW) at 4.2 K (for QWR # 4).

Superconducting response in the electron beam welded region

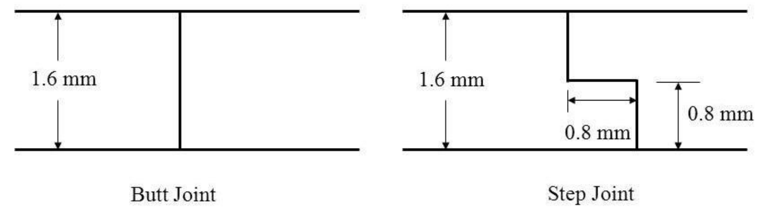


Effect of EP & EBW on Niobium





Isothermal M-H plots of electron beam welded and electropolished fine grain niobium materials 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>

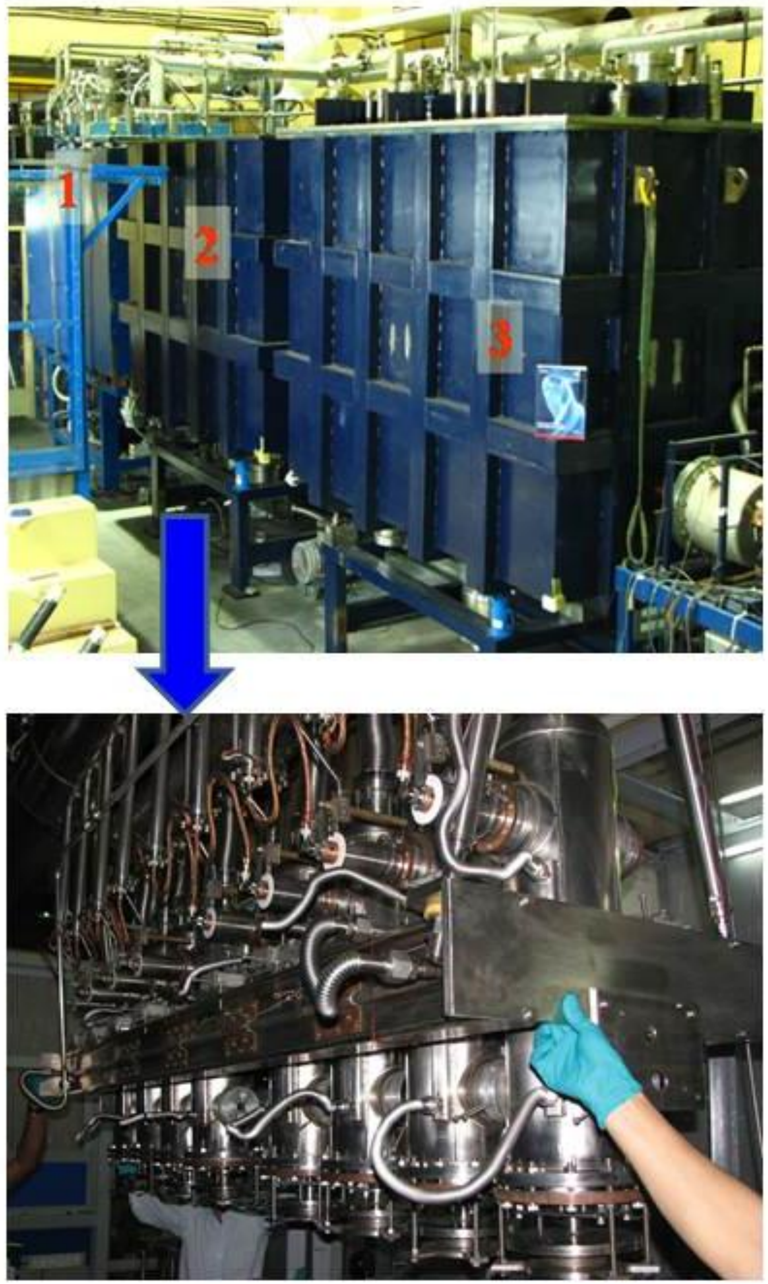
- H_P Step Joint & EP – 1650 Oe
- H_P Butt Joint & EP – 1700 Oe
- H_P as-received EP – 1700 Oe

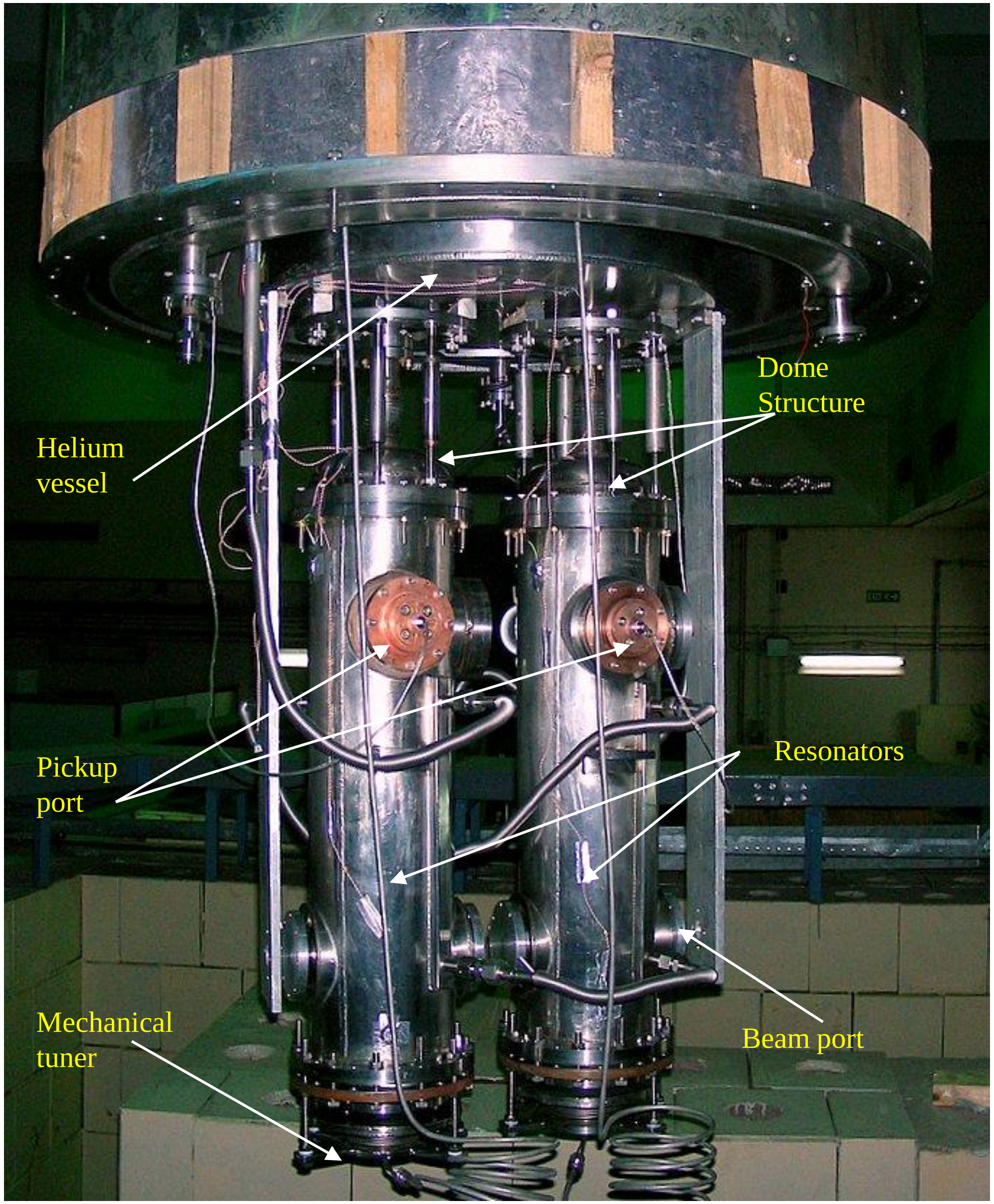
Pure Niobium: H_{C1} @ 4 K ~ 1400 Oe
@ 2 K ~ 1800 Oe

The 4 K results compare very well with accelerating gradients obtained in IUAC-QWRs.

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

Three accelerating modules and resonators of the second cryostat

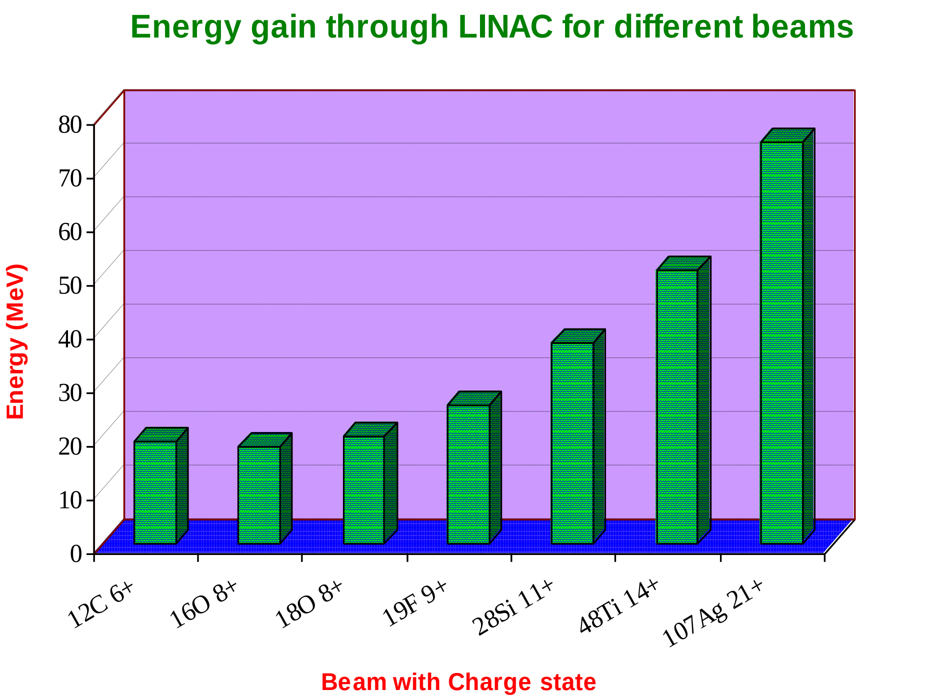




Rebuncher having two QWRs (350-400 ps)

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



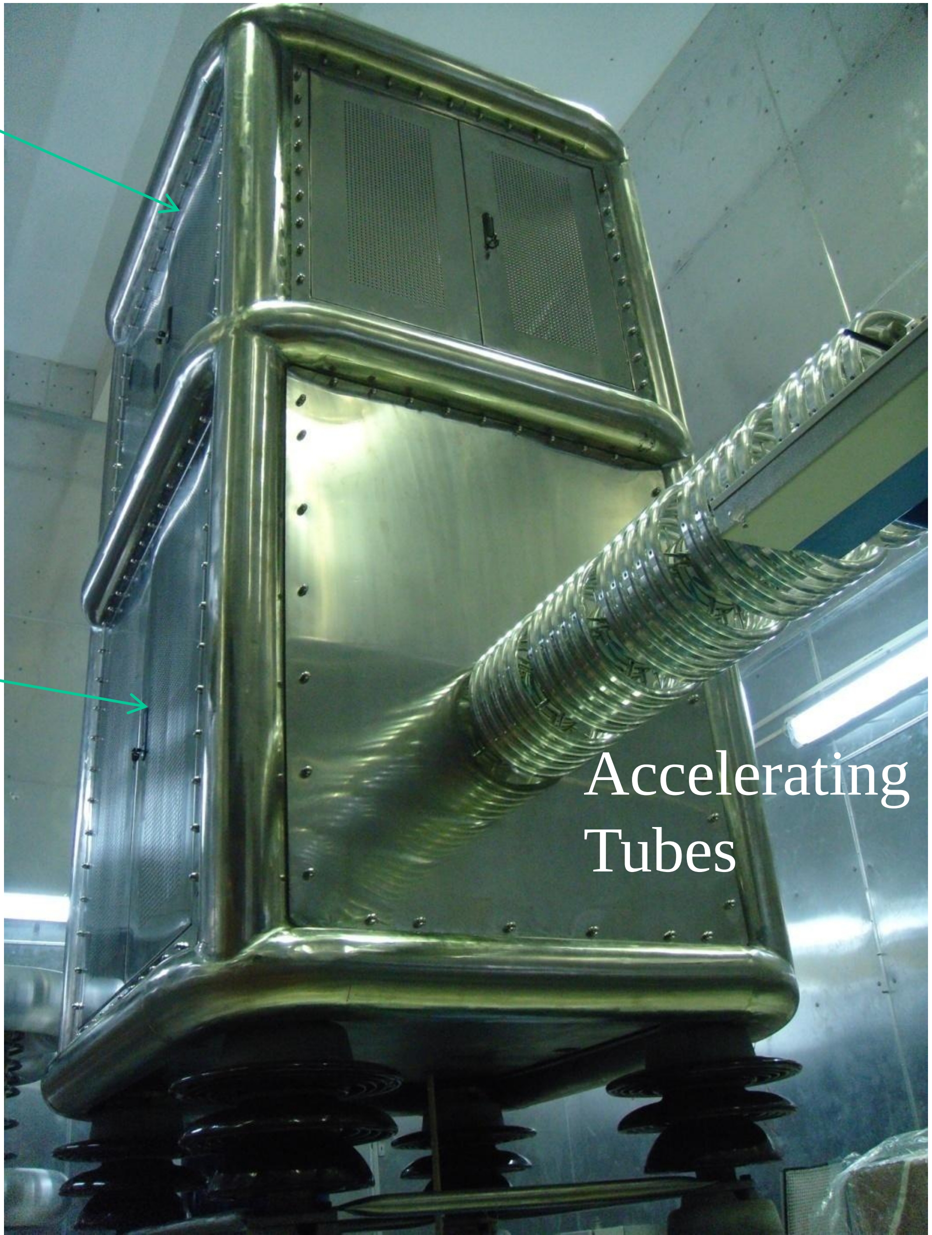
Beam	Pell. energy (MeV)	Linac energy gain (MeV)	Total energy (MeV)	Beam Line
$^{19}F^{+7}$	100	37	137	NAND
$^{28}Si^{+11}$	130	60	190	Linac Scatt. chamber
		56	186	HYRA
$^{31}P^{+11}$	130	58	188	HYRA

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

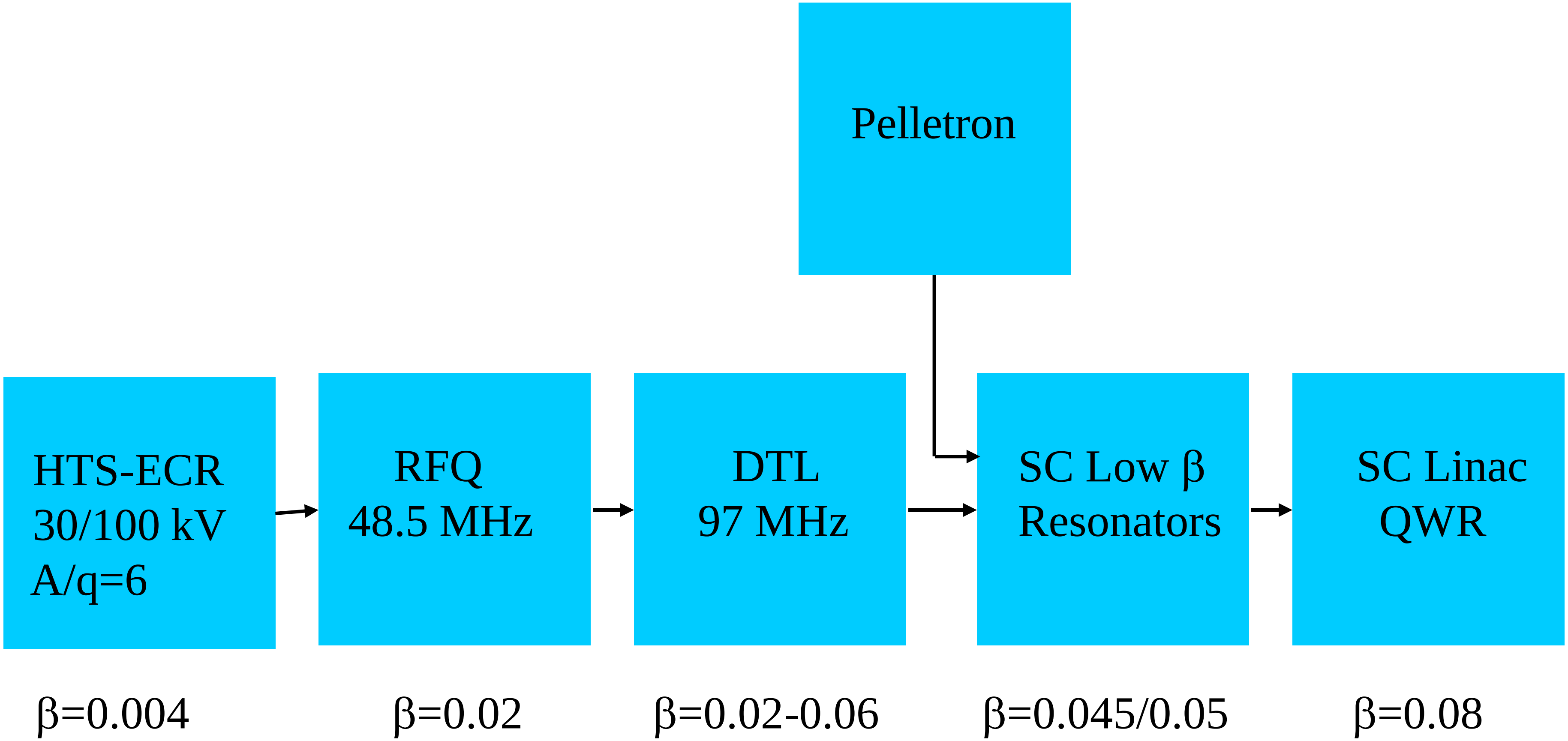
Accelerator Mass Spectrometryn – on going program

10Be and 26Al isotopes for geological and climatological studies

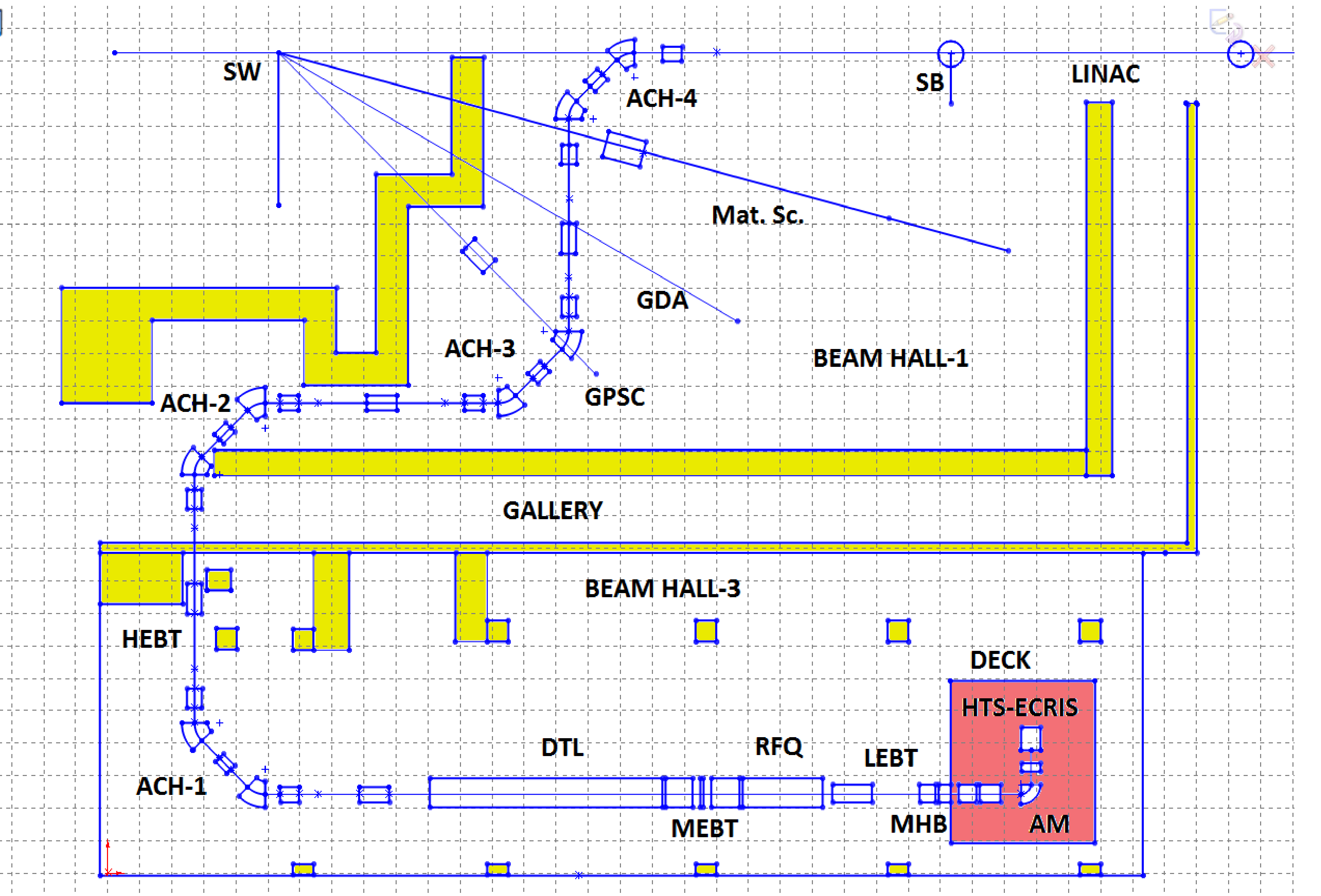
Clean Chemistry Laboratory:

Planing to have another Tandem E;ectrostatic Accelerator dedicated to AMS Program

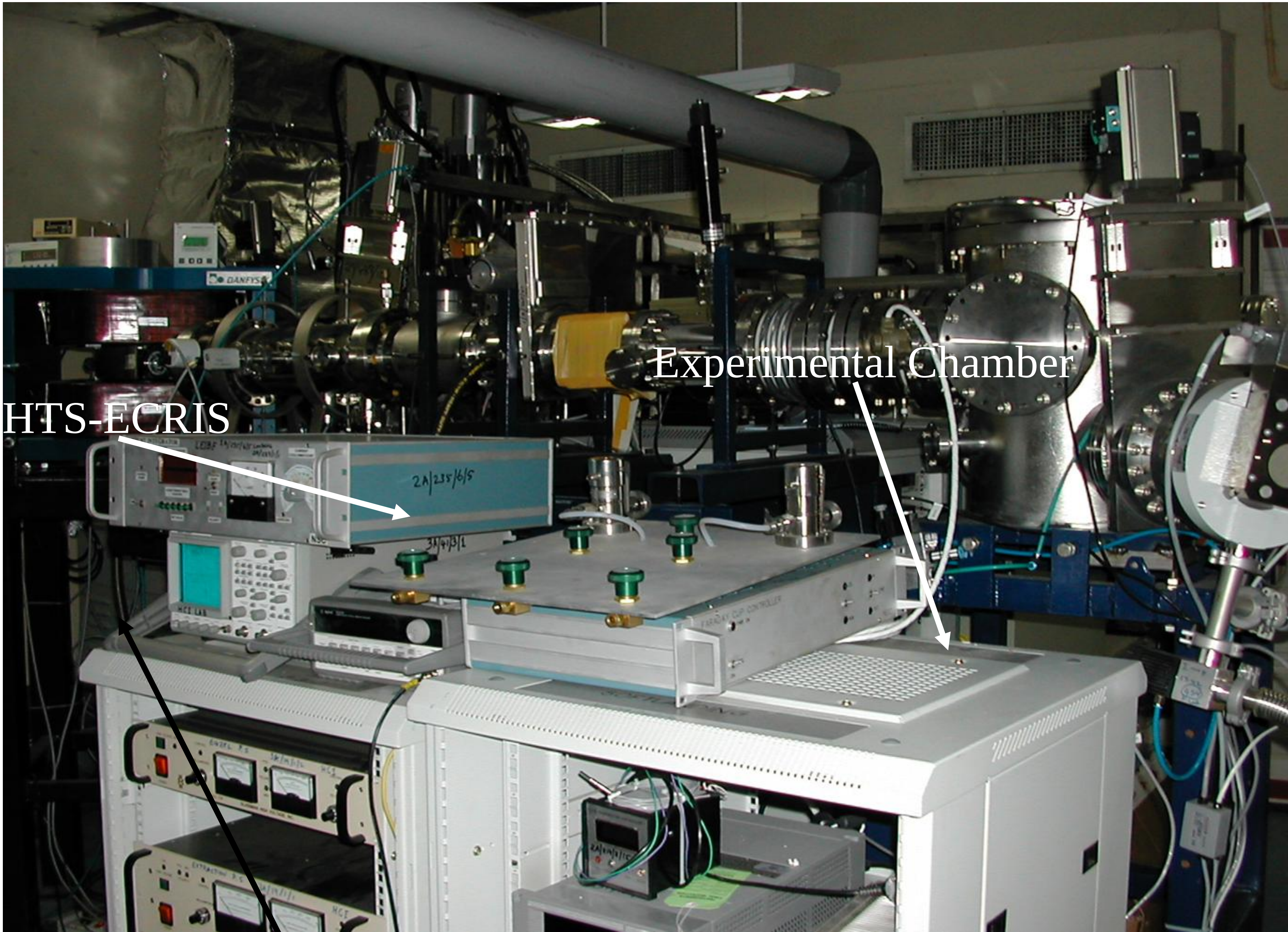
High Current Injector



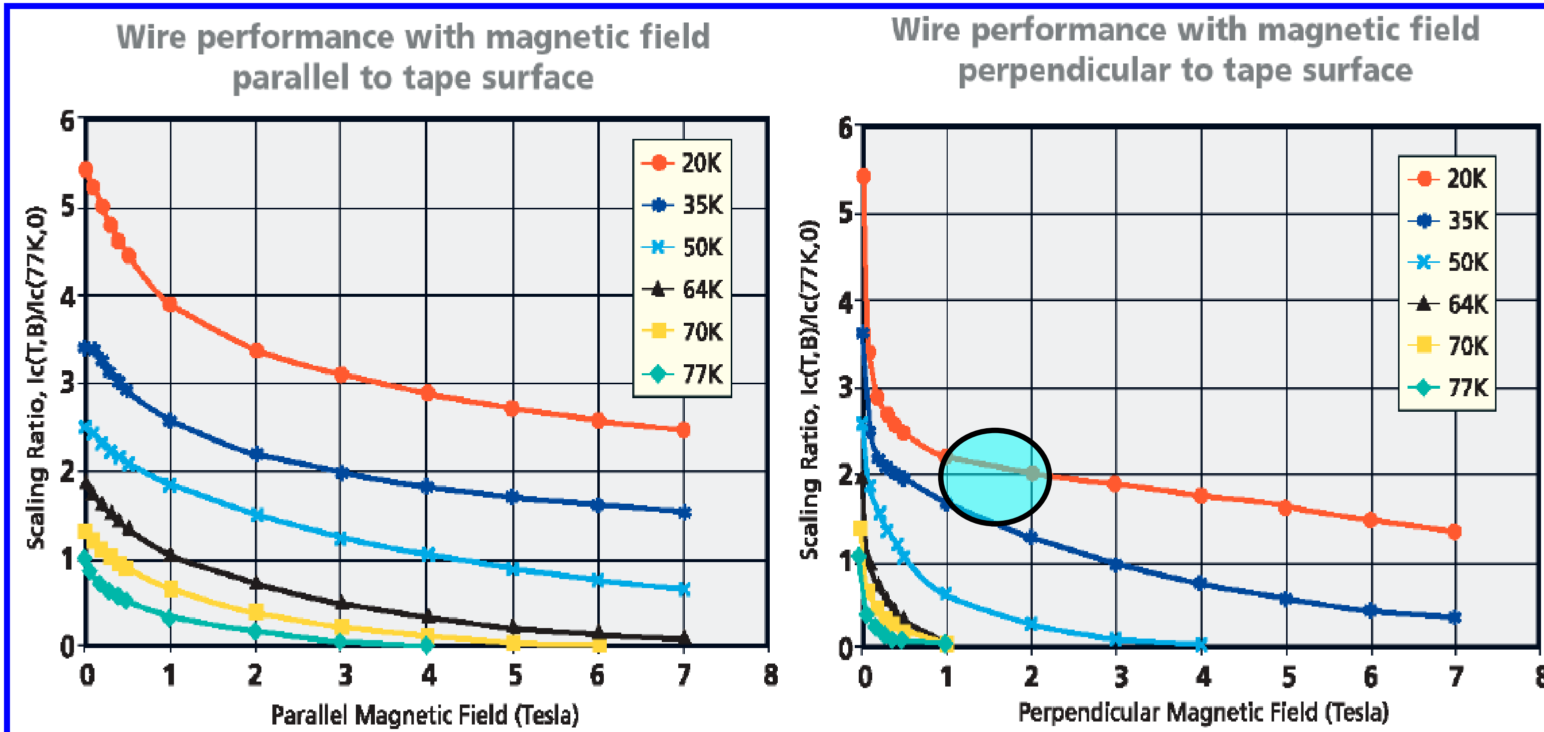
High Current Injector Beam Line Layout



HTS-ECRIS PKDELIS at IUAC



Characteristics of HTS (BSSCO) tapes



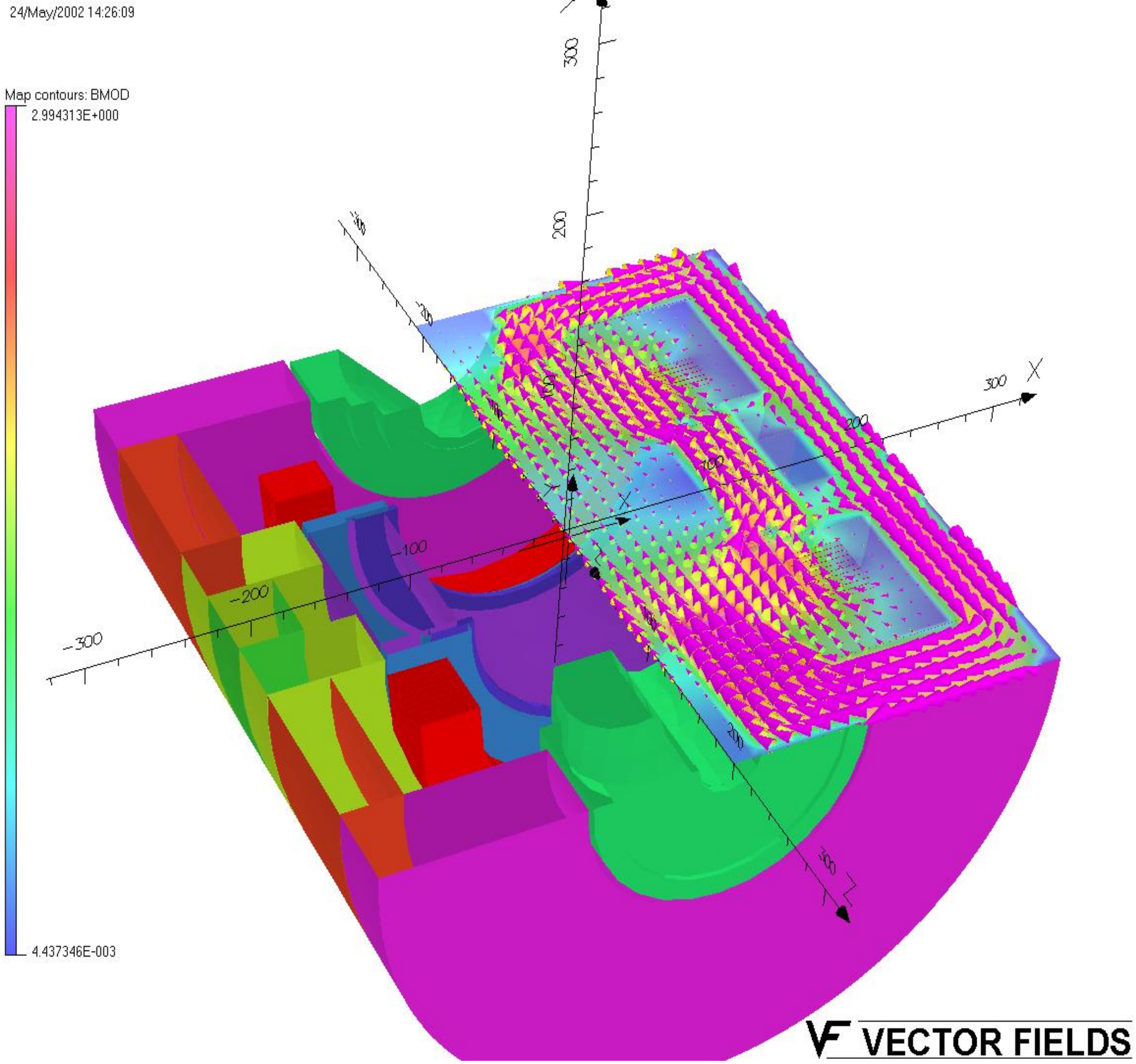
American Superconductor™
REVOLUTIONIZING THE WAY THE WORLD USES ELECTRICITY™

Current carrying capacity of HTS depends on:

- Temperature
- Magnitude of the field

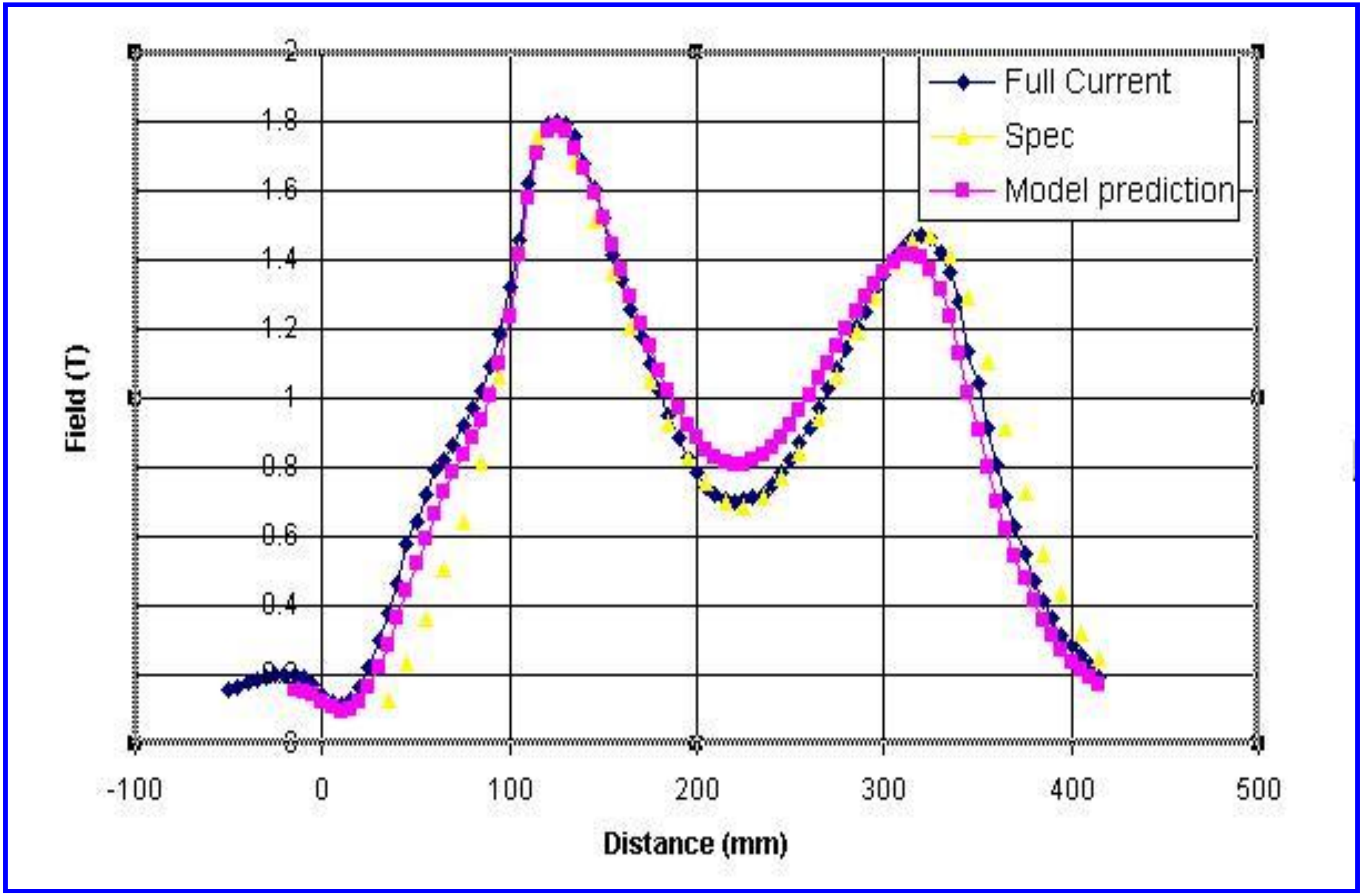
and also on the direction of the field

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



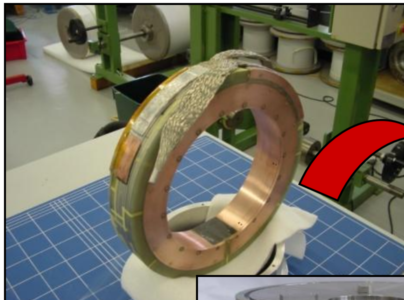
Field vectors on the yoke cross section

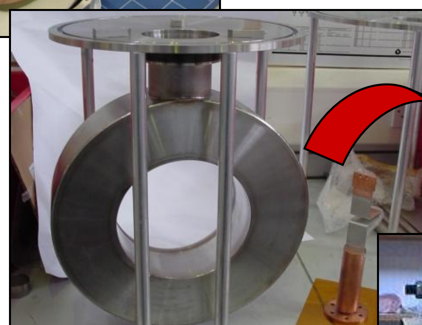
Axial field measurements



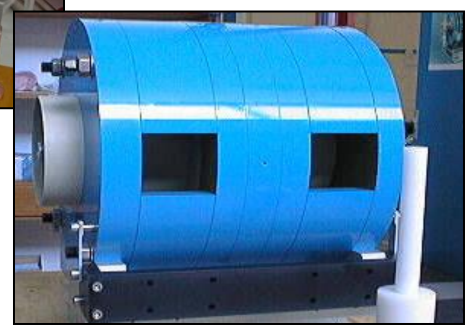
Various Stages of Development of HTS-ECRIS

HTS coil

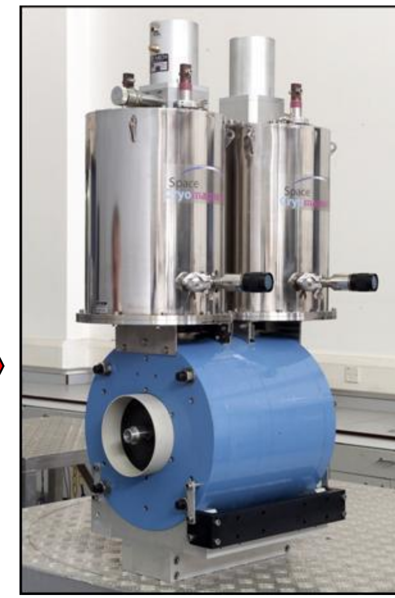




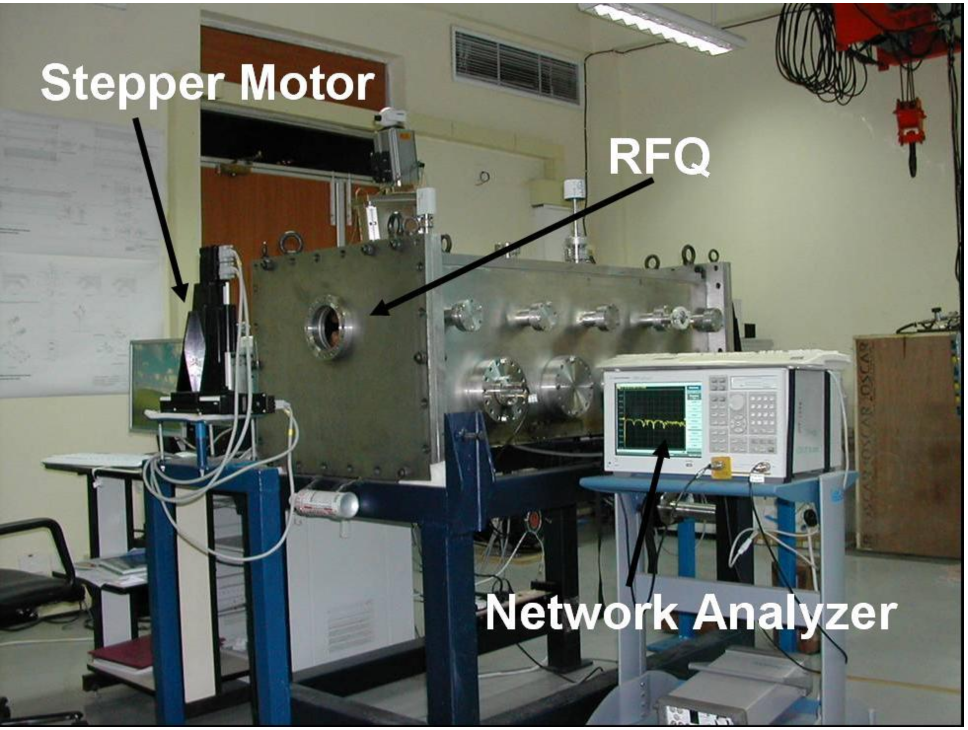
Coil cryostat



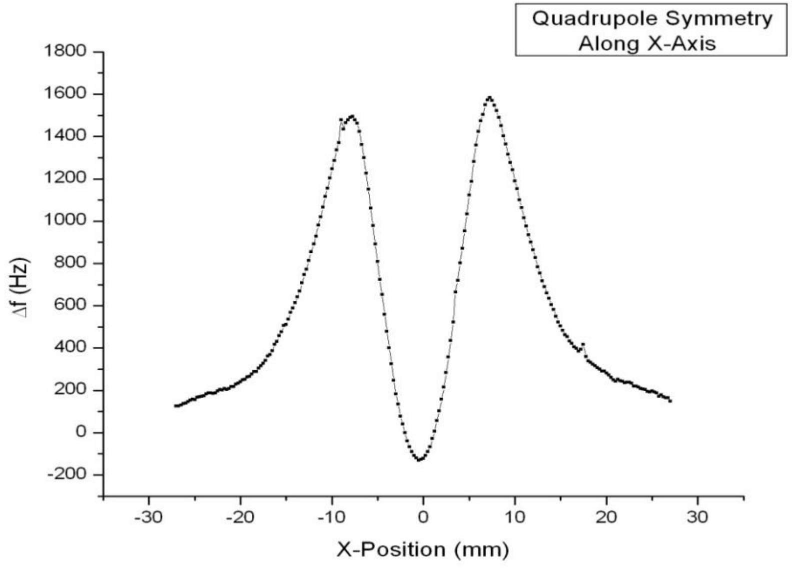
Iron yoke

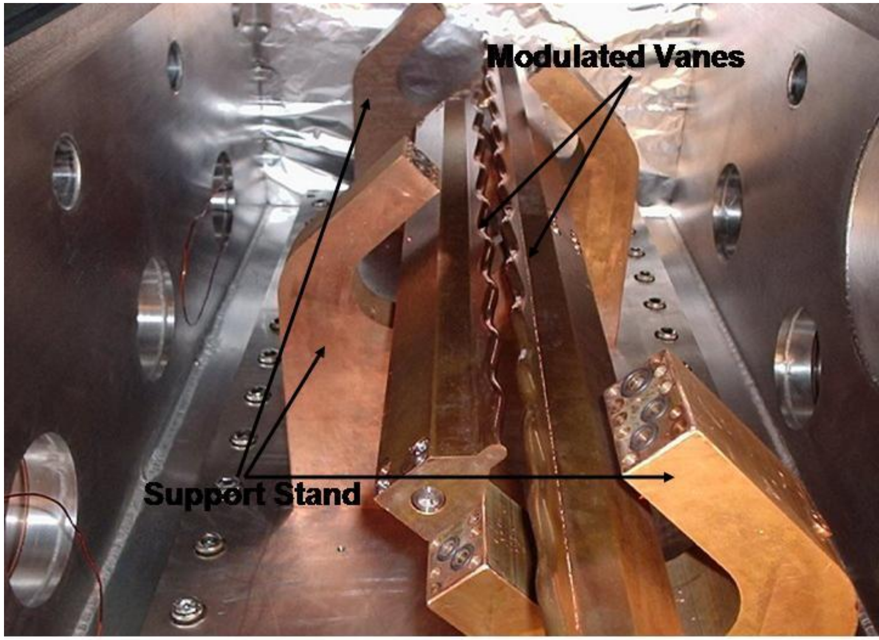


Prototype RFQ (f=48.5MHz) for A/q o f 6 for acceleration from 8keV/A to 180keV/A



Bead pull test of RFQ



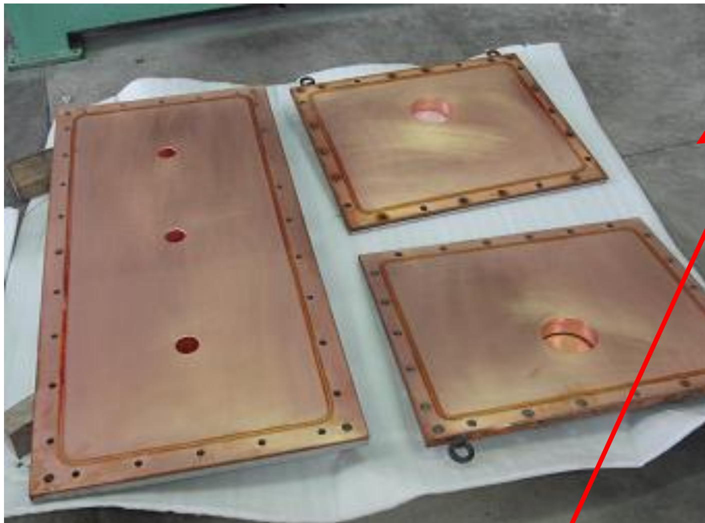


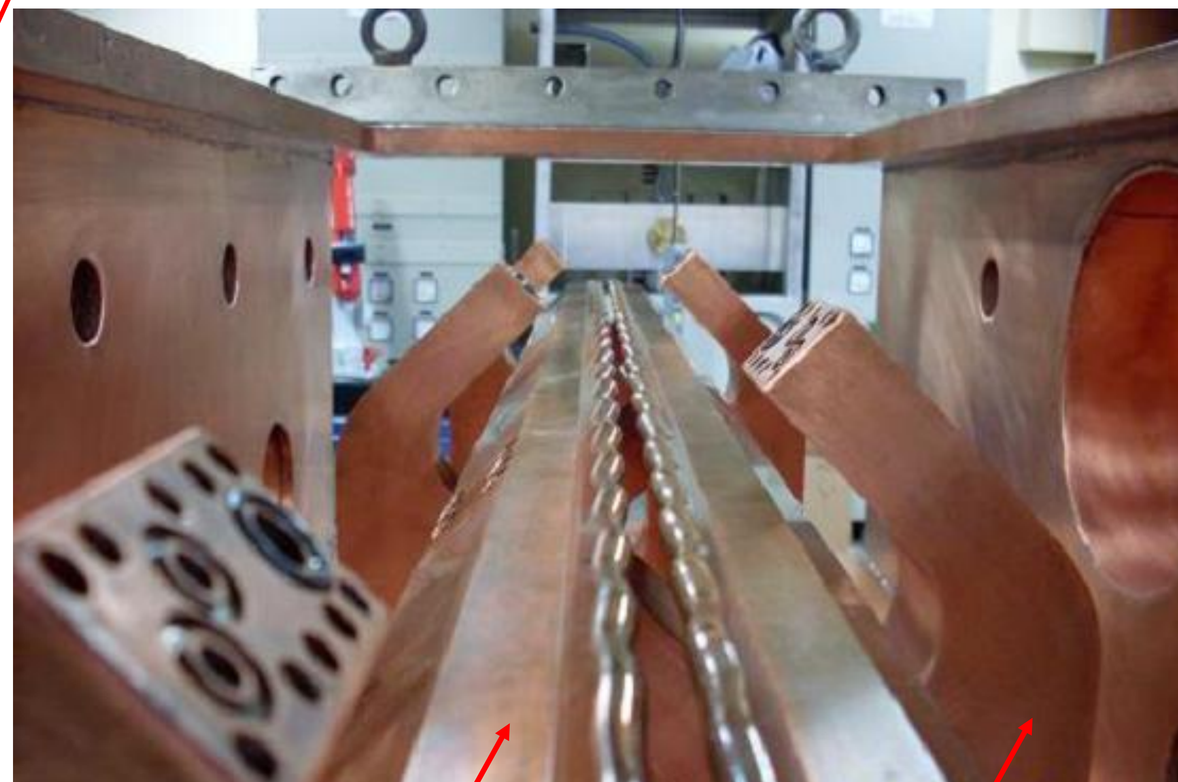
Modulated vanes of RFQ

Prototype RFQ Development

Length = 1.17 m

Cu Plating of chamber and end plates done at RRCAT, Indore



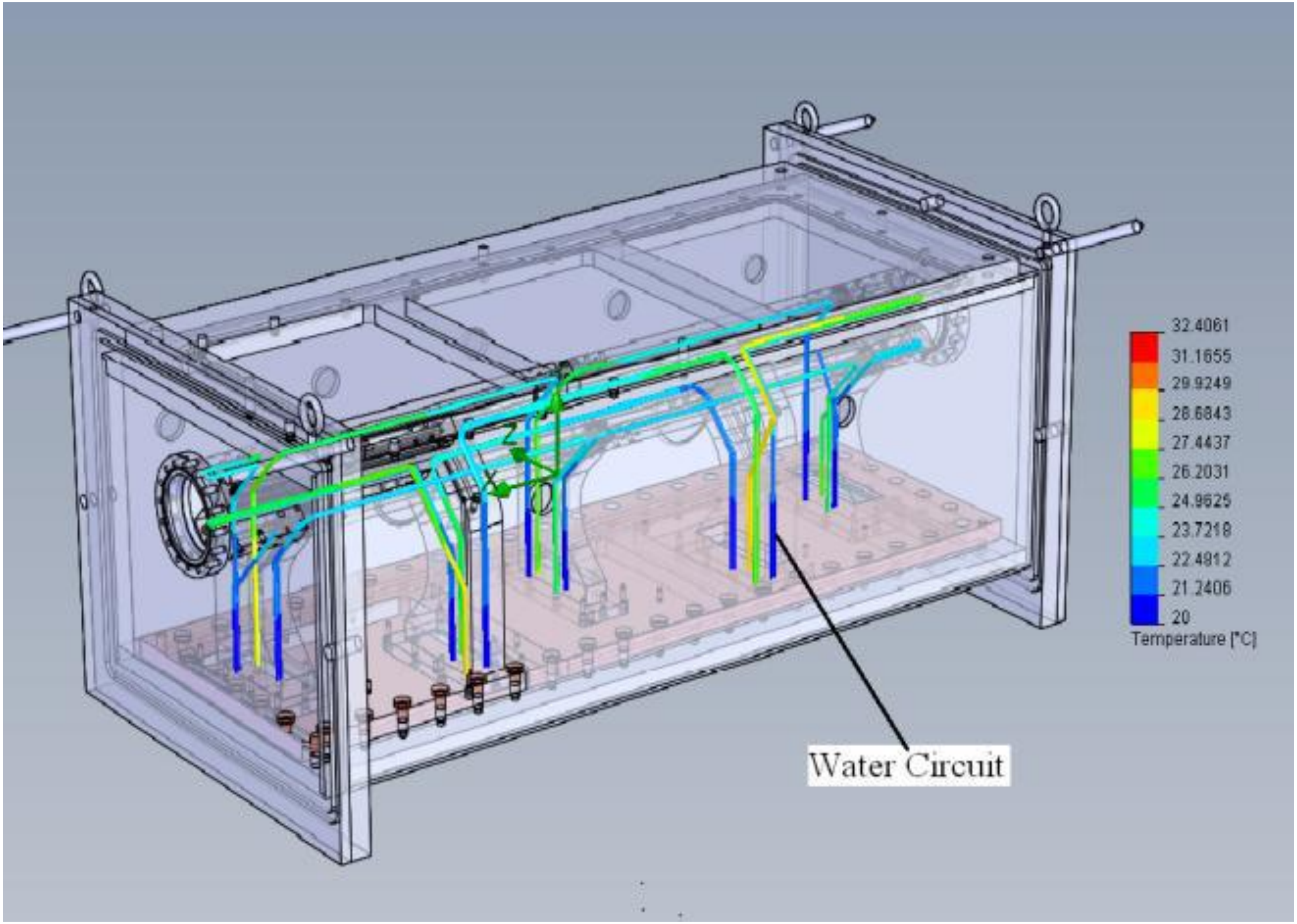


Modulated Vanes

Vane Post


Stand
Chamber

Thermal Simulation For 35kW Powered Prototype RFQ



RFQ Prototype tested at 18 kW for 3 days

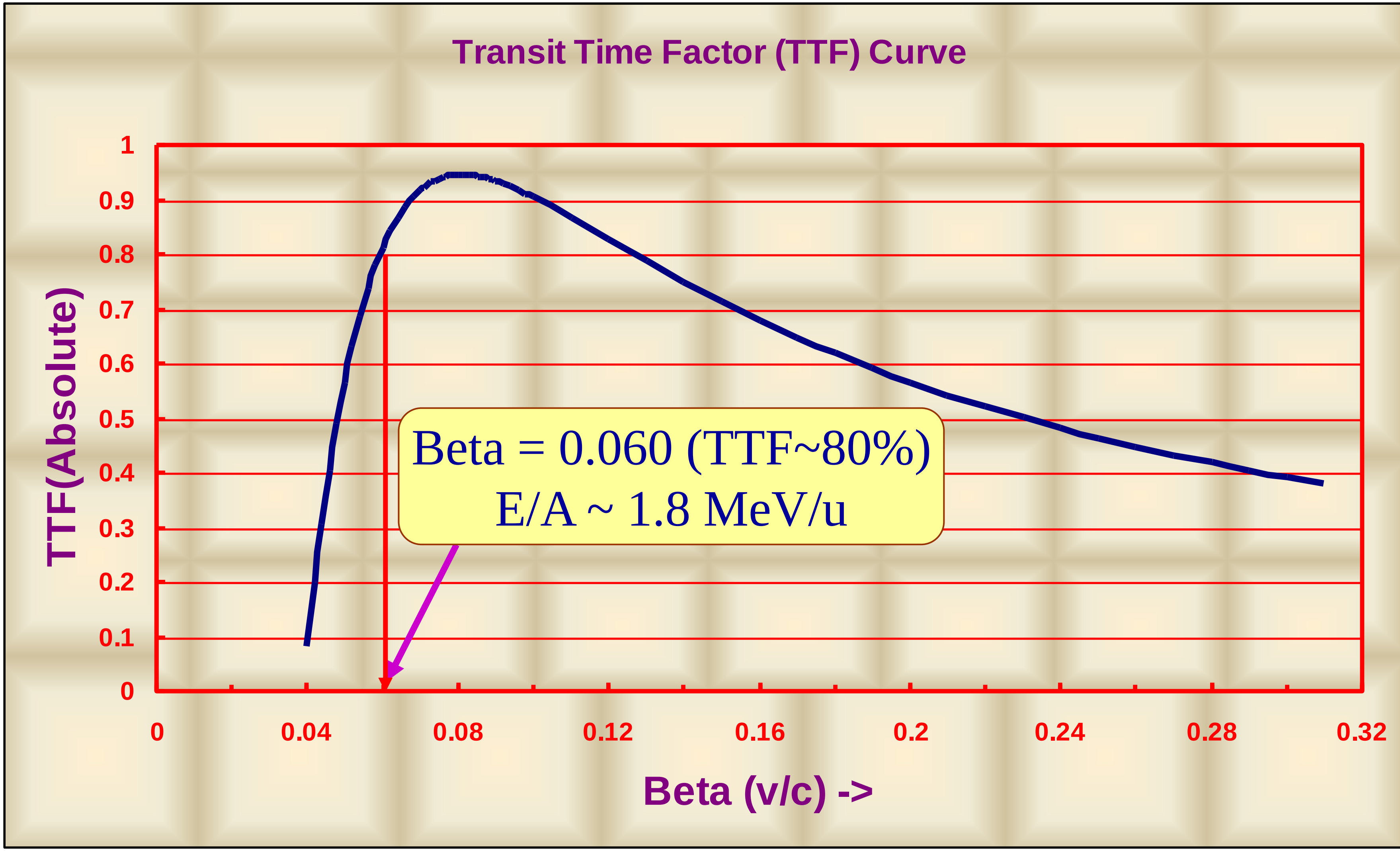
Drift Tube Linac

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

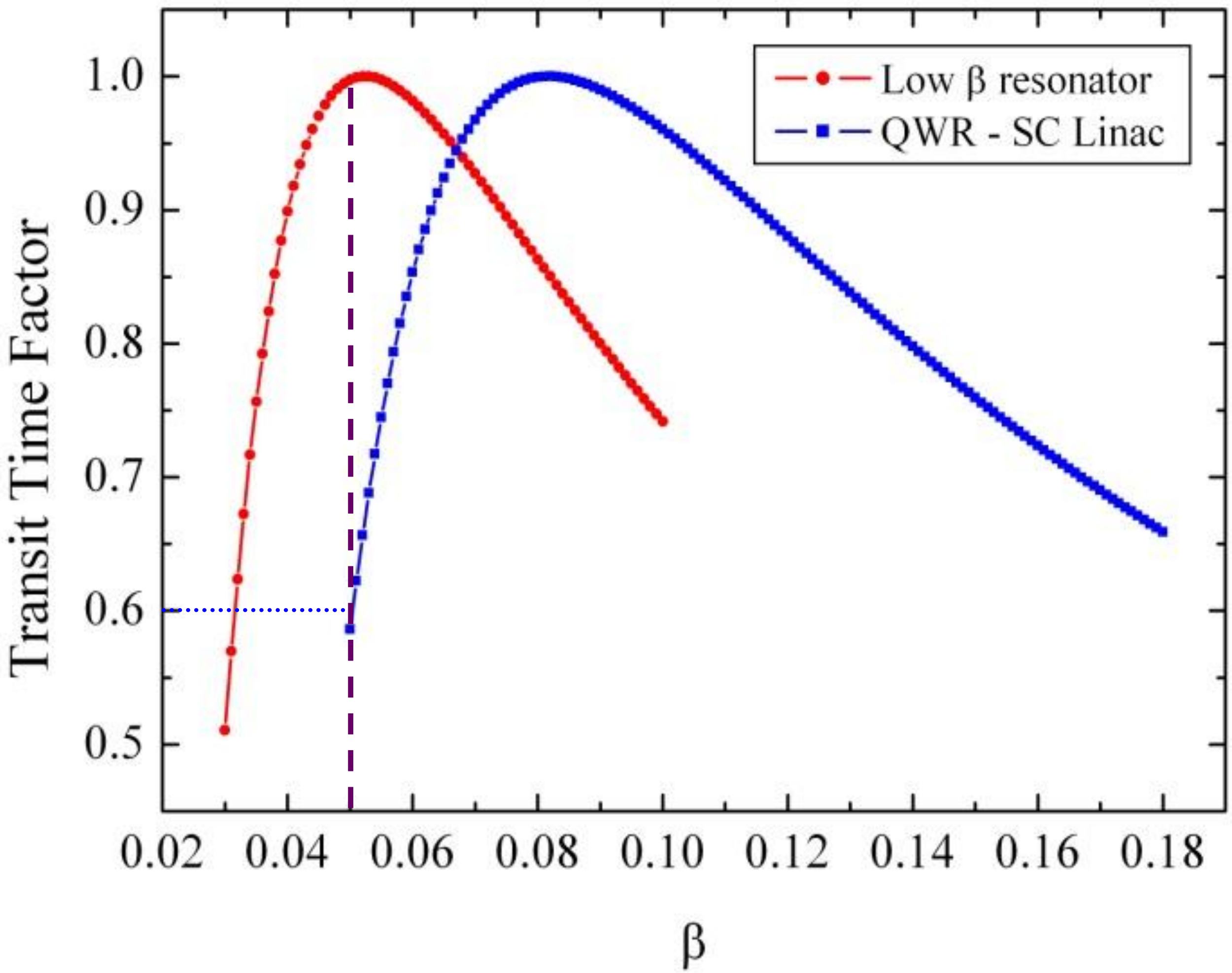
Prototype DTL Resonator

Complete design validation has been done on full scale prototype resonator

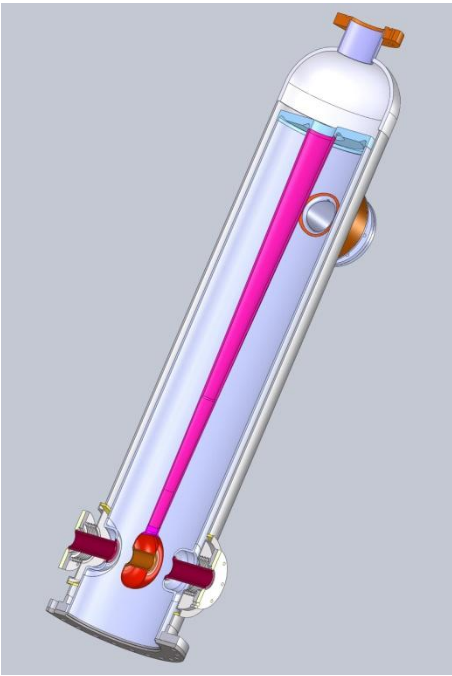


Transit Time Factor (TTF) Curve
TTF(Absolute)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.04
0.08
0.12
0.16
0.2
0.24
0.28
0.32
Beta (v/c) ->
Beta = 0.060 (TTF~80%)
E/A ~ 1.8 MeV/u

Need of low beta module…

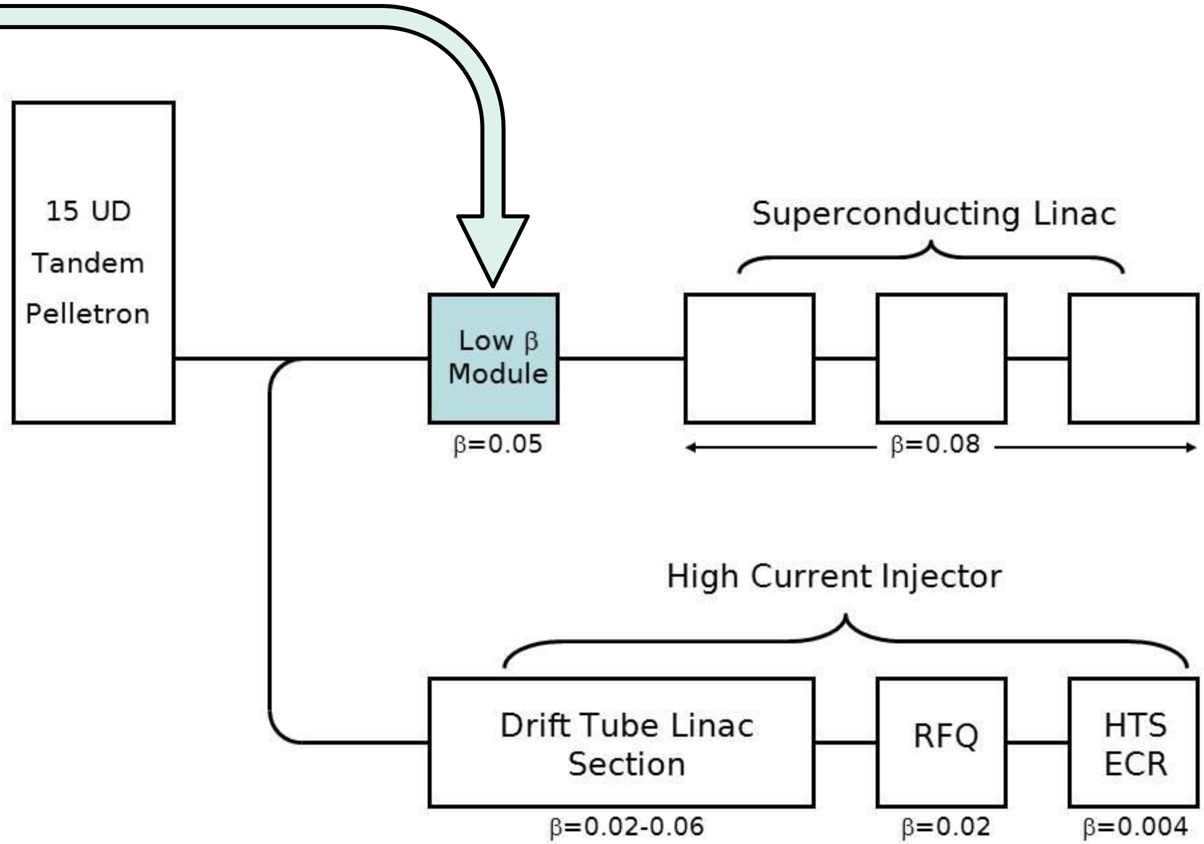


Low Beta Nb Resonator - LBR



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



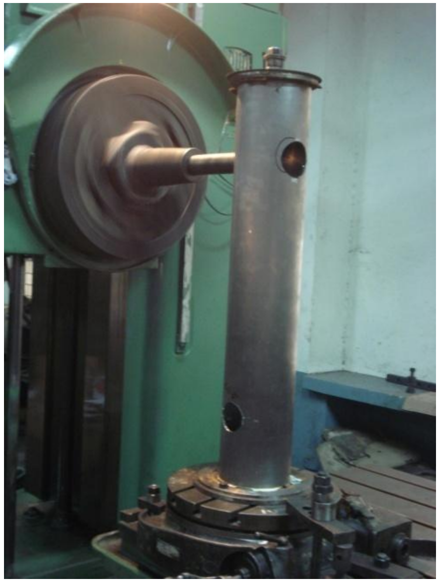
Proposed High Current Injector (HCI) at IUAC

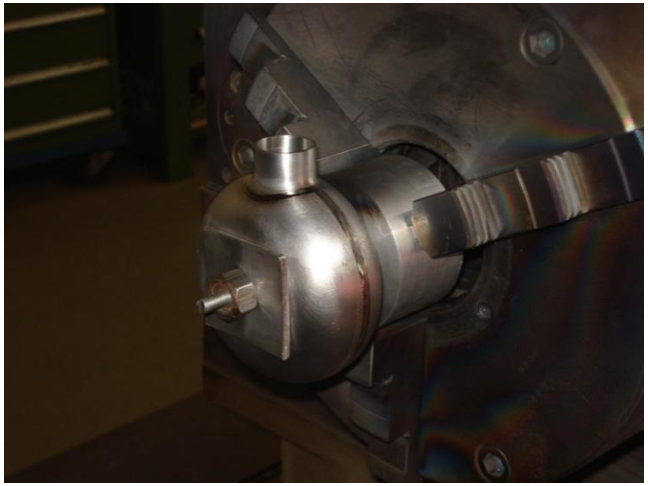
Prakash N. Potukuchi & A. Roy, PRAMANA - Journal of Physics, Vol. 78, No. 4, 565 (2012).

Prototype Low Beta Resonator - LBR


EBW - Central Coaxial Line

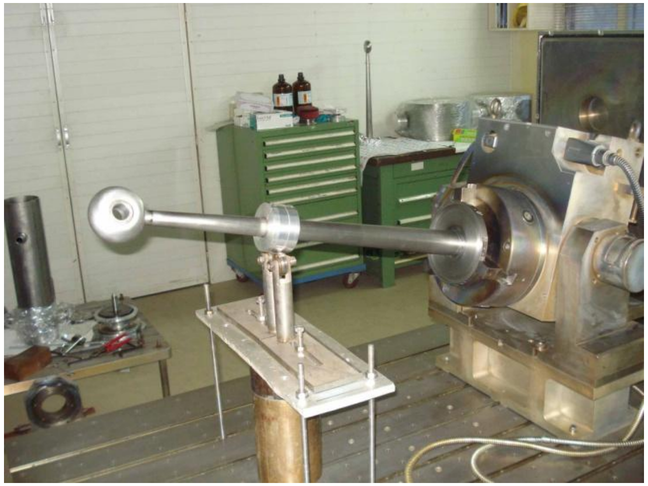

Drift Tubes & Saddles


Outer Housing - boring of Coupling and Beam Ports


EBW – Drift Tube to Saddle


EBW – Saddle to Beam Port

Prototype Low Beta Resonator - LBR



EBW - Tapered Line to Top Flange

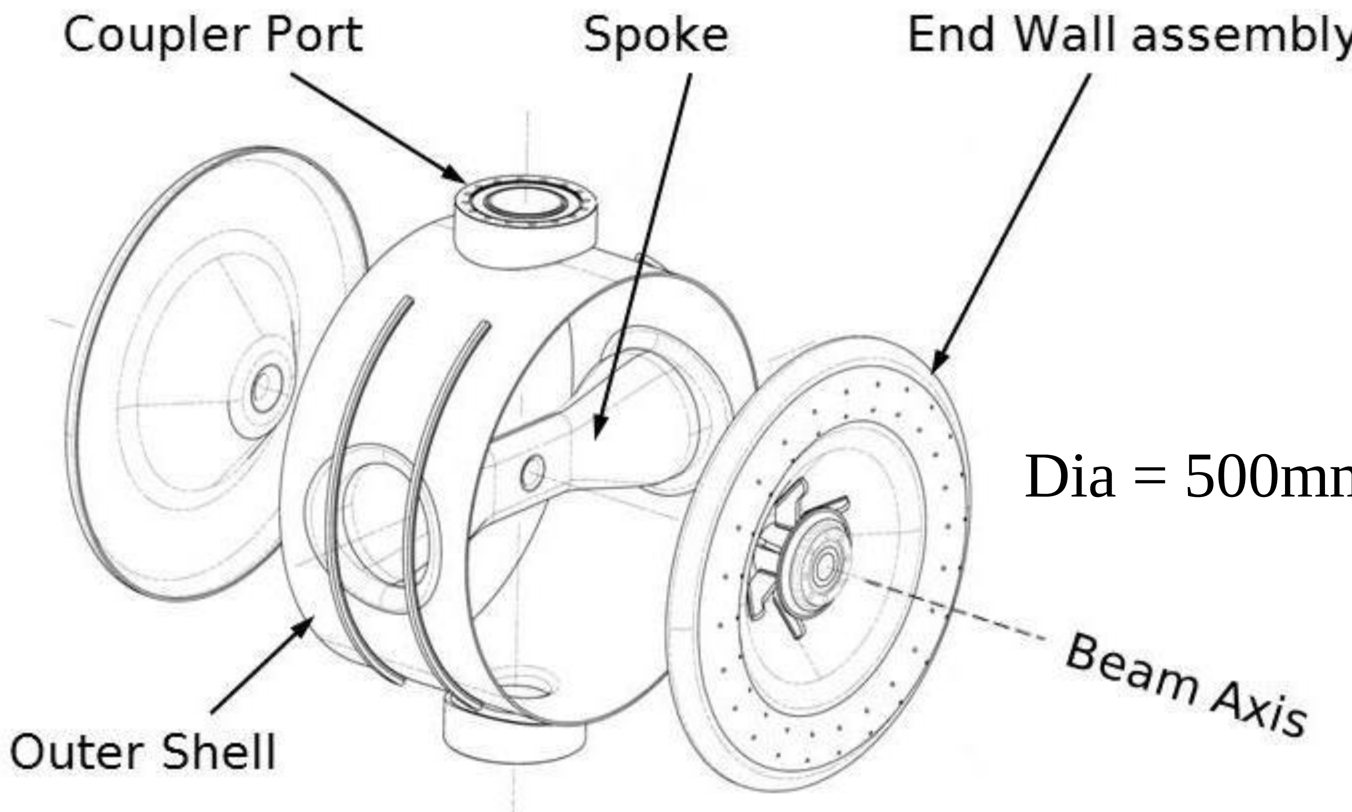
EBW – Closure Weld

The two major sub-assemblies of the niobium resonator - Outer Housing (left) and Central Conductor with Top Flange (right).

Prototype Low Beta Resonator complete with the outer Stainless Steel vessel (May 2012).

Single Spoke Resonator – SSR1

for Project-X at FNAL

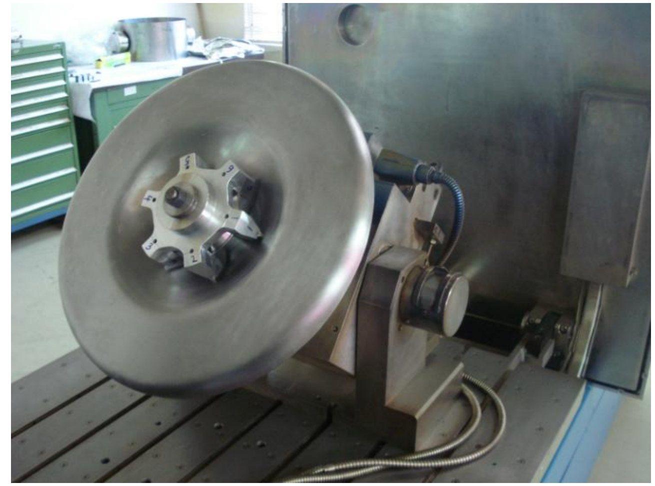


Dia = 500mm

SSR1 - β=0.22, 325 MHz, Niobium Assembly

Single Spoke Resonator – SSR1

Niobium Spoke

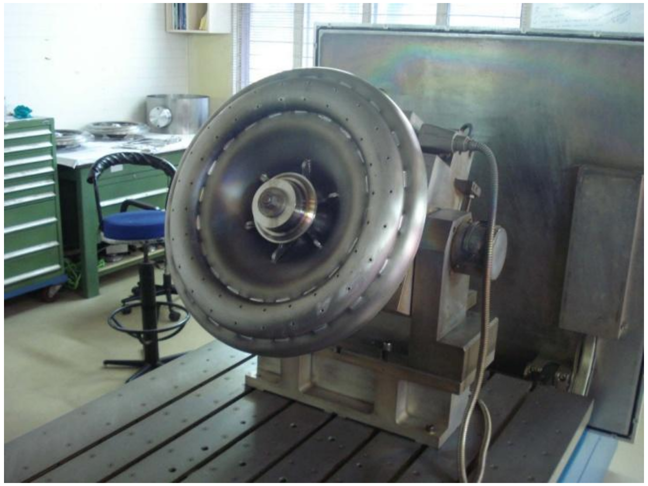


End Wall to Daisy Rib EBW

Coupler Port Flange

Shell with Coupler Ports

Single Spoke Resonator – SSR1



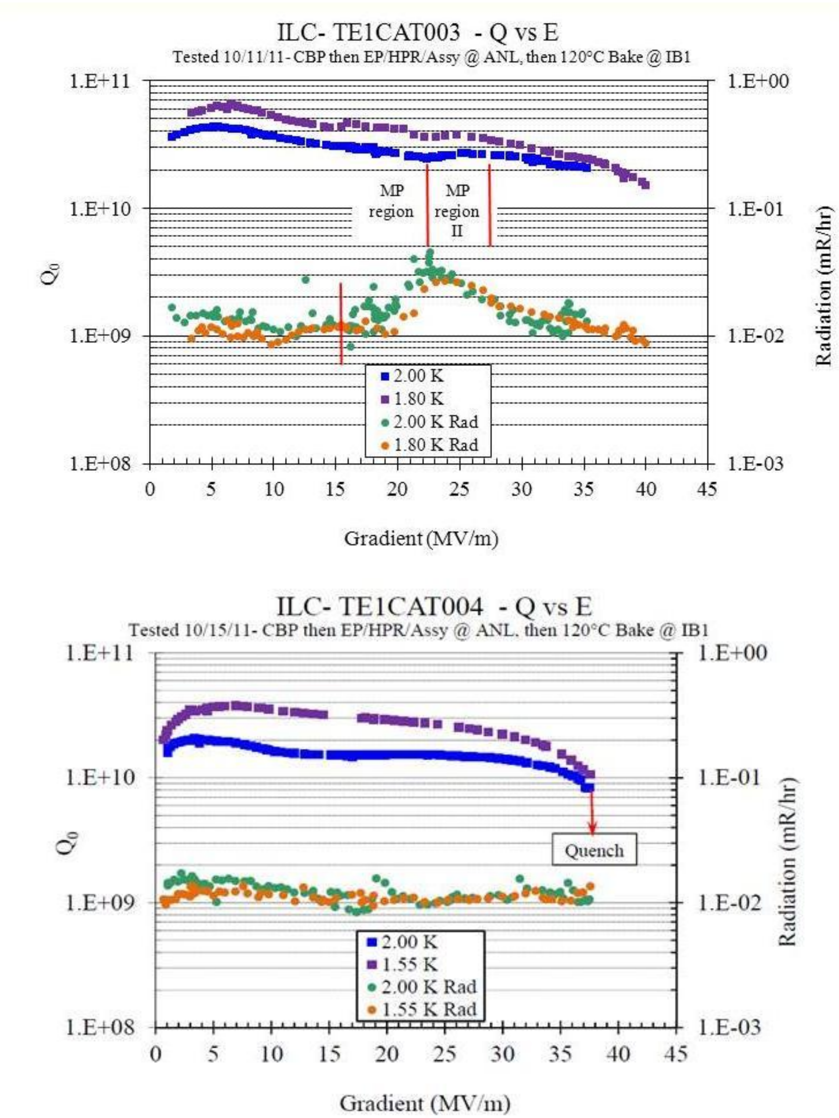
EBW – End Wall to Donut Rib

End Wall assemblies

End Wall EP setup

Outer Shell EP

TESLA-type 1.3 GHz Single Cell Cavities



Accelerating gradients achieved in Cavity #3 & 4

Joint collaboration between Raja Ramanna Centre for Advanced Technology (RRCAT), Indore, India and IUAC, New Delhi.

Niobium Single cell Cavity

Conclusion

Infra-structures and facilities for indigenous development, fabrication and tests accelerators and associated components are being utilized and upgraded regularly.

HTS-ECR ion source on elevated (kV) platform followed by RFQ and DTL, Low Beta Cavities are part of the alternate high current injector (HCI) of Superconducting LINAC.

Technology related to fabrication of niobium resonators has been developed at IUAC successfully.

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

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 projected by user community.

Acknowledgements

Dr. Amit Roy, Director, IUAC Delhi

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

Thank you