13th International Conference on Heavy Ion Accelerator Technology (HIAT) 2015

Design, Fabrication and Testing of Compact Diagnostic System at IUAC

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Yokohama, Japan

September 11, 2015

Outline..

- IUAC
- High Current Injector
- Compact Diagnostic System

IUAC Overview

Accelerators & Research Facilities at IUAC

Major Accelerators

- 15UD Pelletron
- SC-LINAC
- Positive LEIBF
- Negative LEIBF
- PARAS
- XCAMS
- High Current Injector
- FEL (Upcoming)

Major Research Facilities

- Nuclear Physics
- Material Science
- Radiation Biology
- Atomic Physics
- RBS-AMS
- High Performance Computing System

High Current Injector

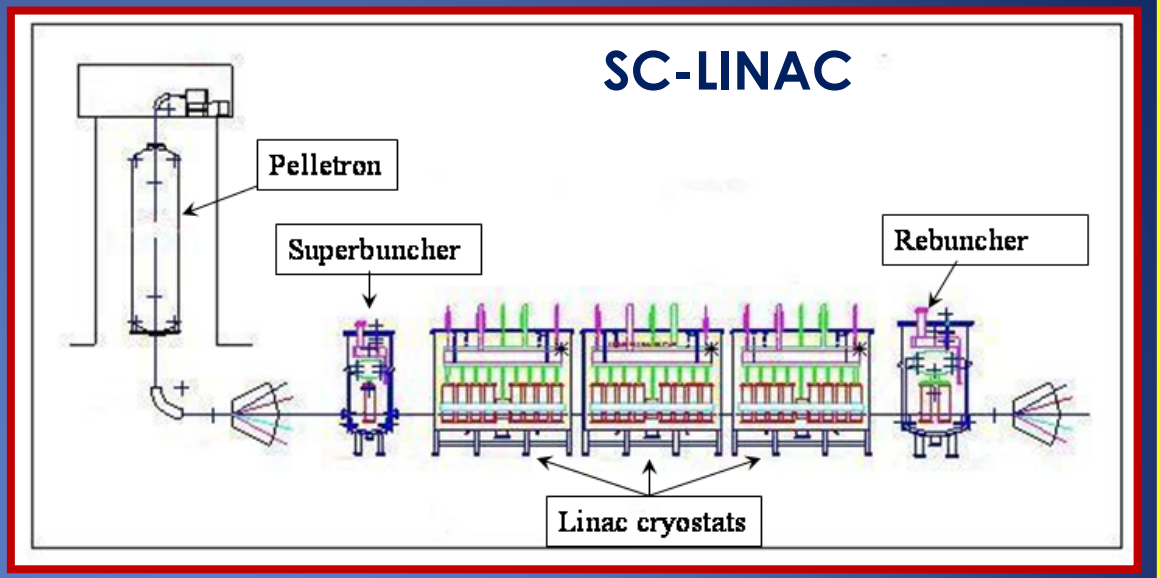
IUAC Pelletron + SC-LINAC Layout

INJECTOR MAGNET

MC SNICS

MULTIHARMONIC BUNCHER (~1 ns)

15 UD PELLETRON



SWITCHING MAGNET

ANALYSER MAGNET

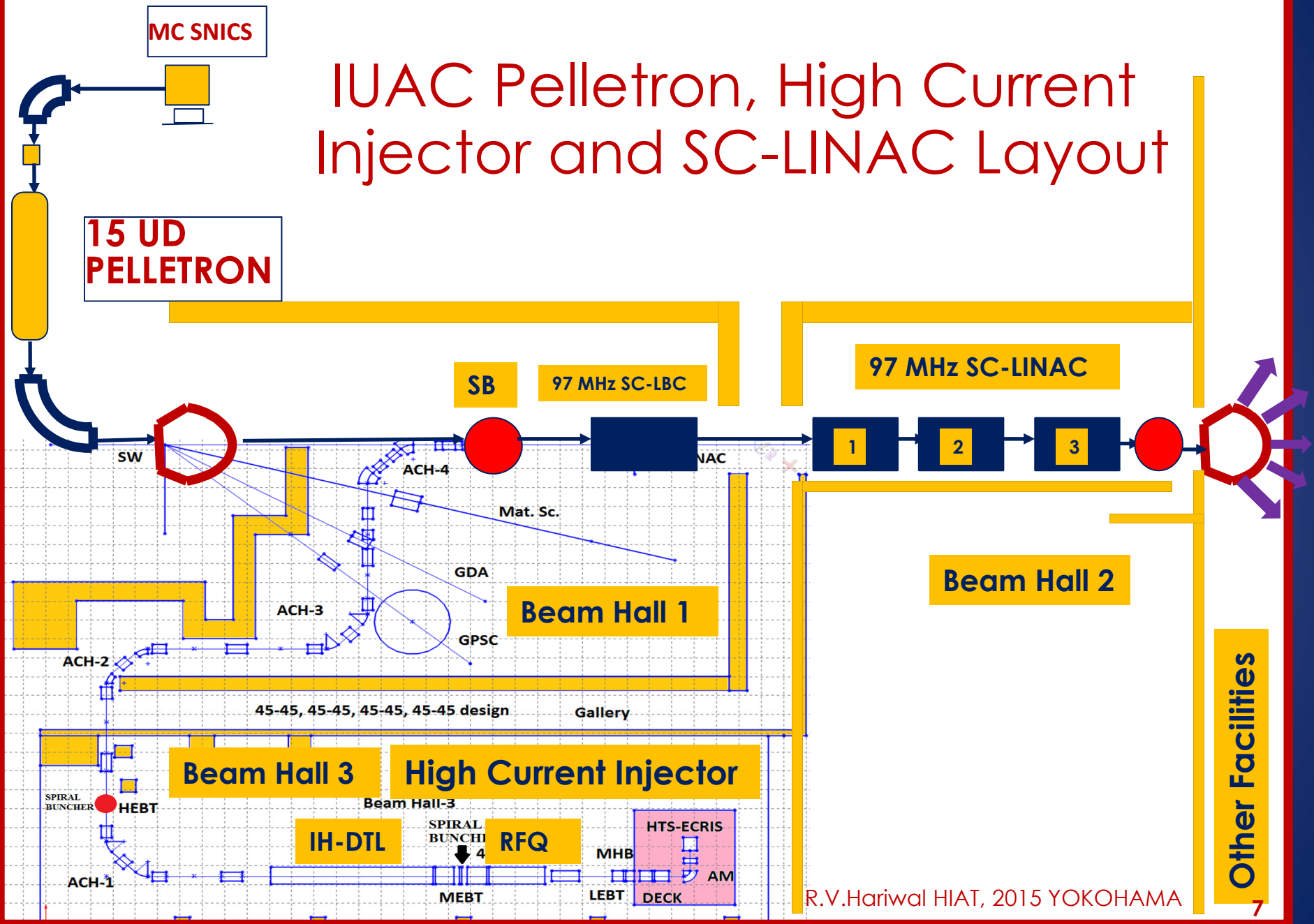
SWITCHING MAGNET

SC BUNCHER (150-200 ps)

LINAC 3 MODULES

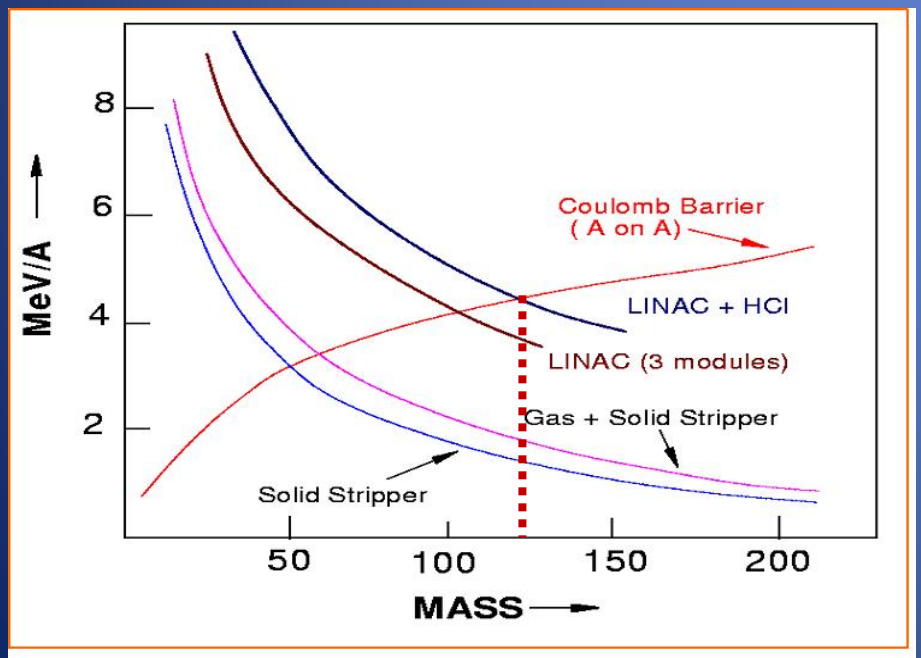
SC-REBUNCHER (350-400 ps)

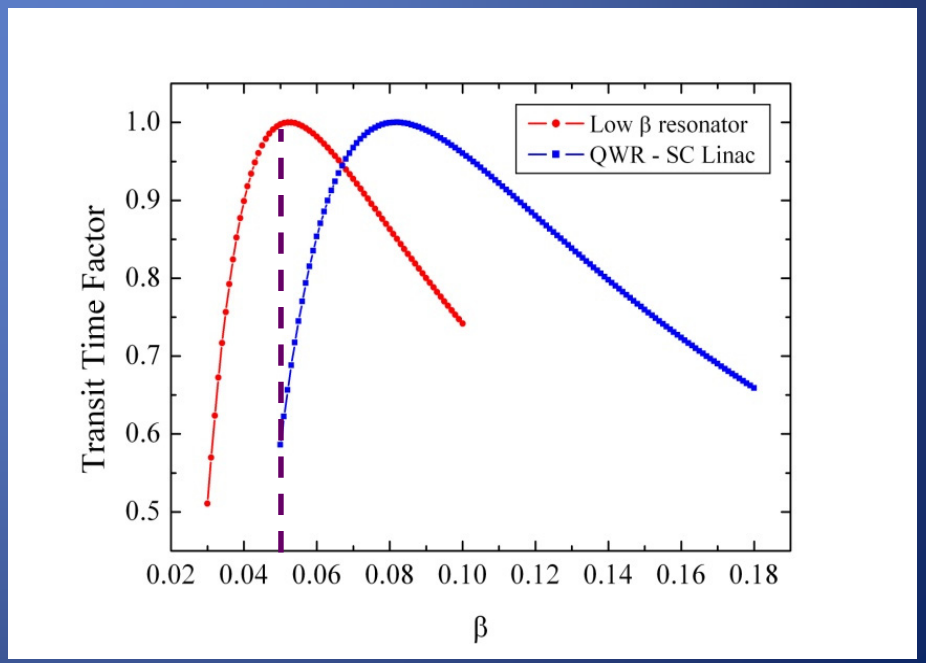
IUAC Pelletron, High Current Injector and SC-LINAC Layout



High Current Injector

- Novel HTSC-ECR Ion Source
- State of the Art Accelerator Development
- High Current ~A Few Hundreds of microAmperes
- Accelerate Ions of Mass <120 A.M.U.
- More Species-Nobel Gases
- Pelletron as a Stand-Alone Operation
- HCI as an Injector for Existing SC-LINAC
- Accelerate Ions with A/q≤6 and Output Energy ~1.8 MeV/ A.M.U.

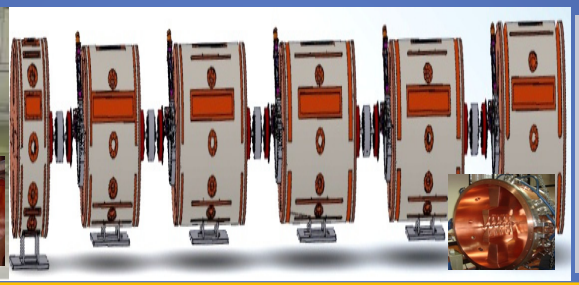




High Current Injector +LINAC

Design Value A/q ≤ 6

ECR	RT RFQ (β<0.02)	RT IH-DTL (0.02<β<0.06)	SC LBC (β ~ 0.06)	SC-LINAC (β ~0.08)



18 GHz PKDELIS High Tc Axial coils Injection 1.8 T Extraction 1.5 T Operating at 23^0 K RF Power 1.7 kW TE ~50 π mm mrad First HTSCECR-GR	48.5 MHz 8-180 keV/u Power ~80 kW 4 Rod Structure 2.5 Meter	97.0 MHz Input 180 keV/u Output 1.80 MeV/u Power ~25 kW (Max) RT IH-DTL Integrated Bunching 6 Tanks ~7 Meters	97.0 MHz SC-QWR 8 Cavities Optimum β ~0.06	97.0 MHz SC-QWR 3 Modules 24 Cavities Optimum β ~0.08 Avg. Electric Field per Cavity~ 3MV/m

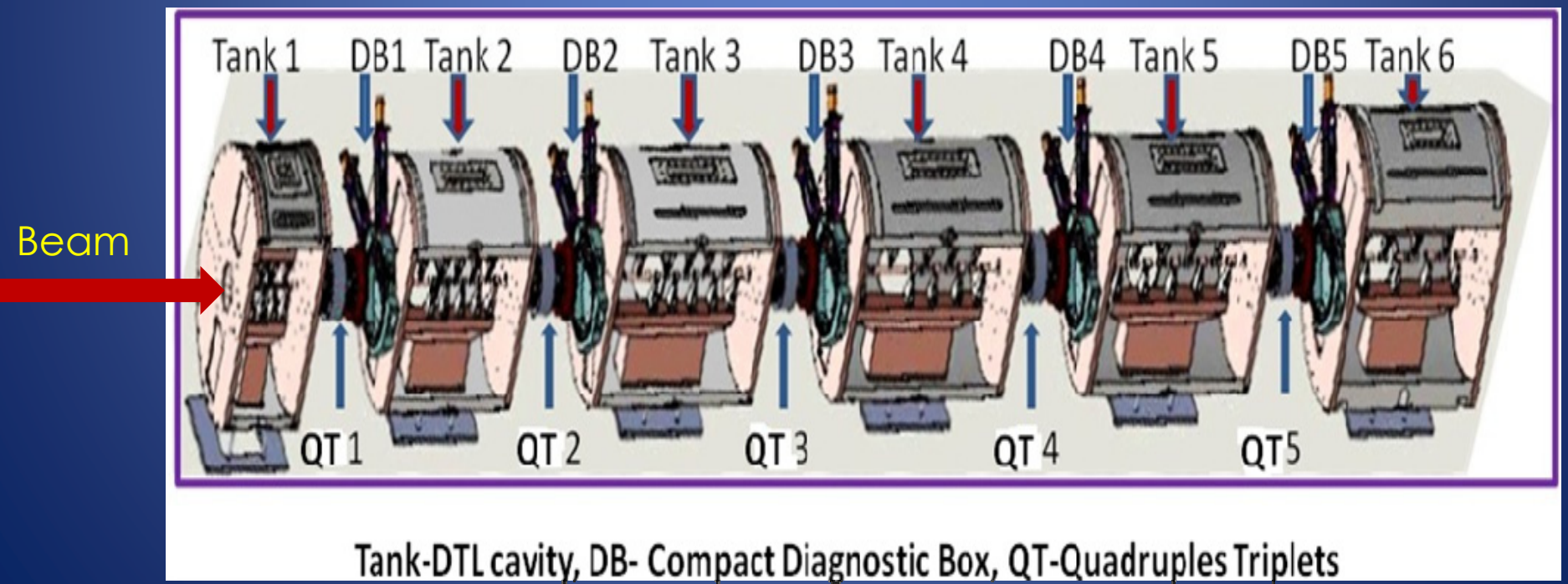
Compact Diagnostic System

Major Beam Parameters

- Current
- Profile
- Position

- Energy
- T. Emittance
- L. Emittance

- Bunch Length
- Energy Spread
- Phase/Time Spread



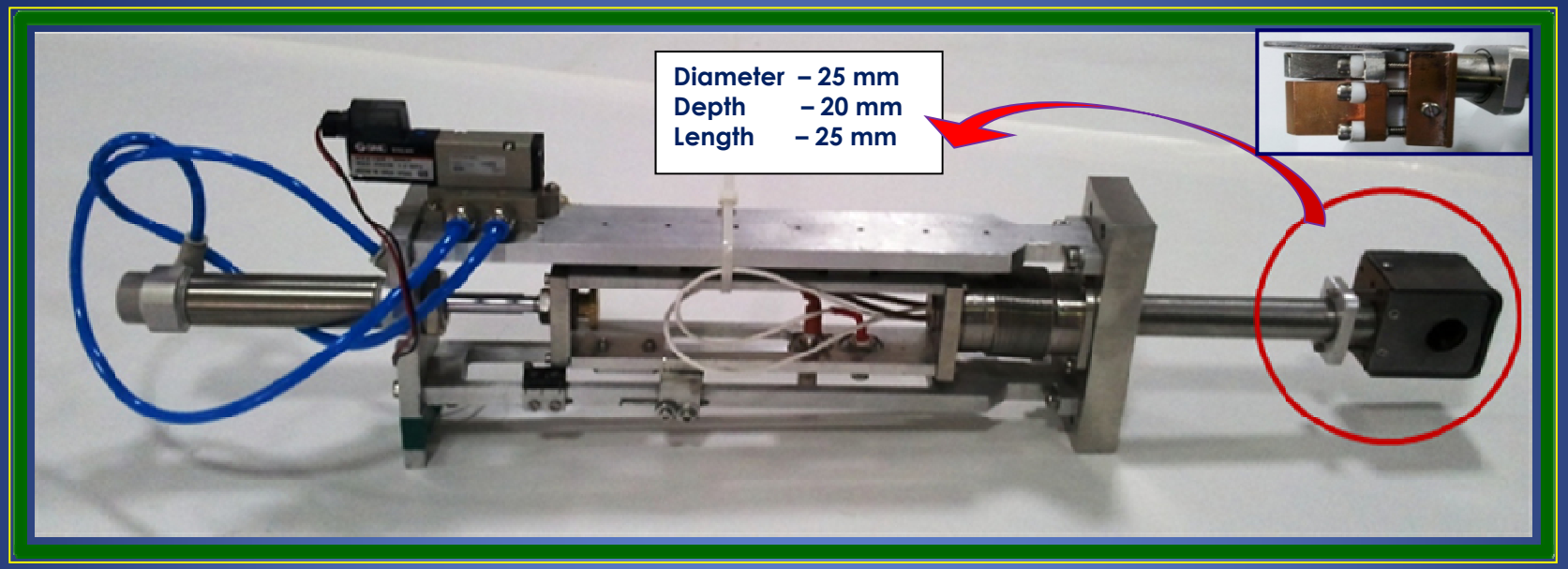
Tank-DTL cavity, DB- Compact Diagnostic Box, QT-Quadruples Triplets

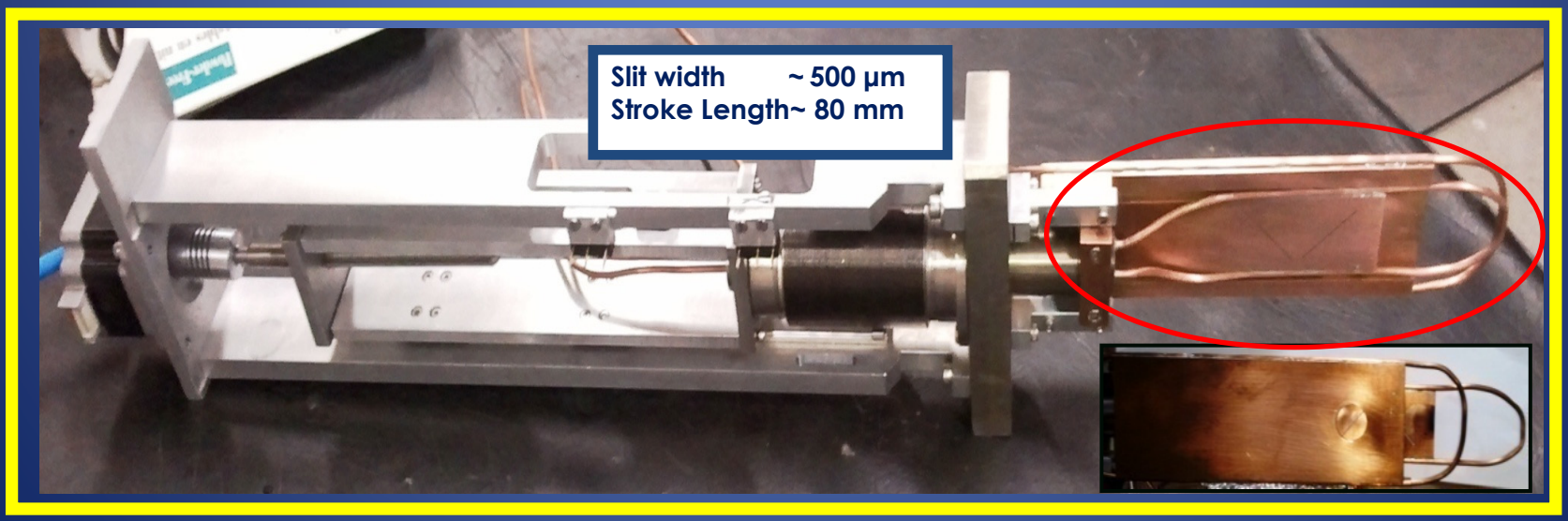
PRESENT STATUS

WORK	STATUS
Prototype Compact Diagnostic Box	
Alignment in LEIBF	Complete
Beam Centre Calibration	Complete
Online Beam Test and Validation	Complete
First Compact Diagnostic Box	
Modification	Complete
Design and Fabrication FC and SSC	Complete
First DTL Assembly & Compatibility	Checked and Done
Stepper Motor Controller and Electronics	Complete
Fabrication of First Diagnostic Box	Under Process

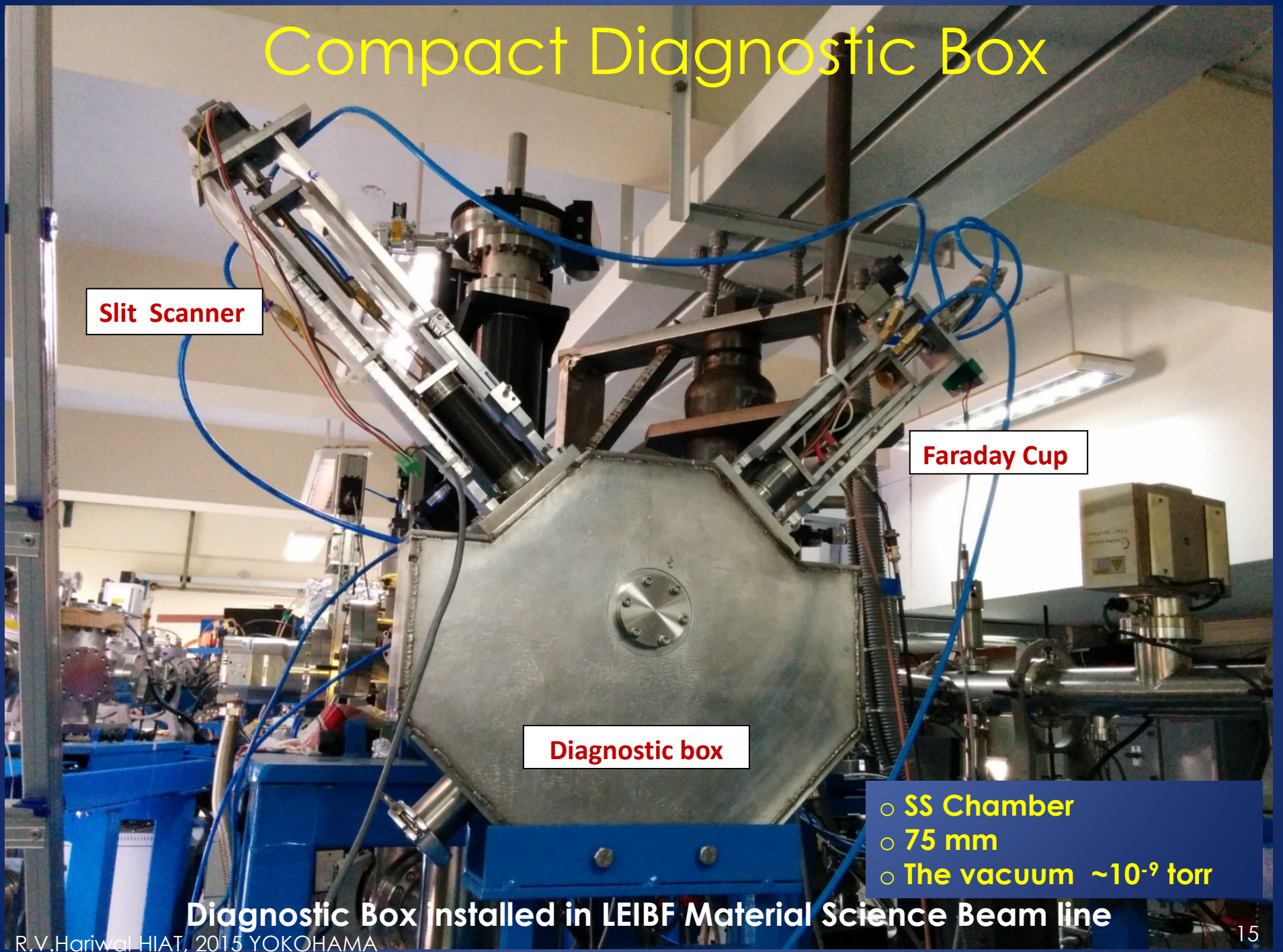
Prototype
Compact Diagnostic Box

Faraday Cup (FC) and Slit Scanner (SSC)





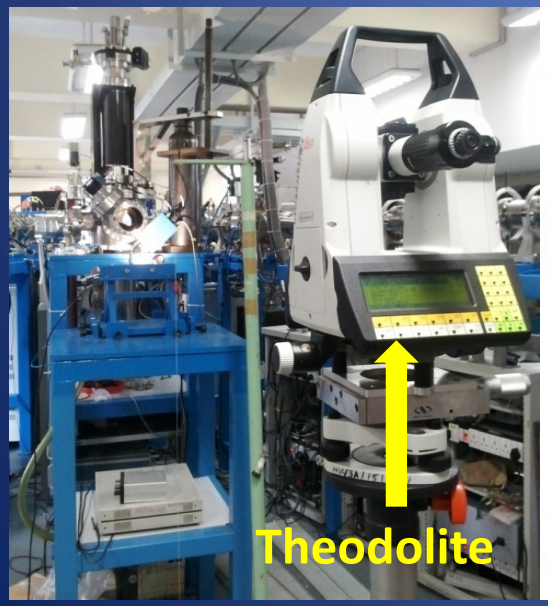
Compact Diagnostic Box

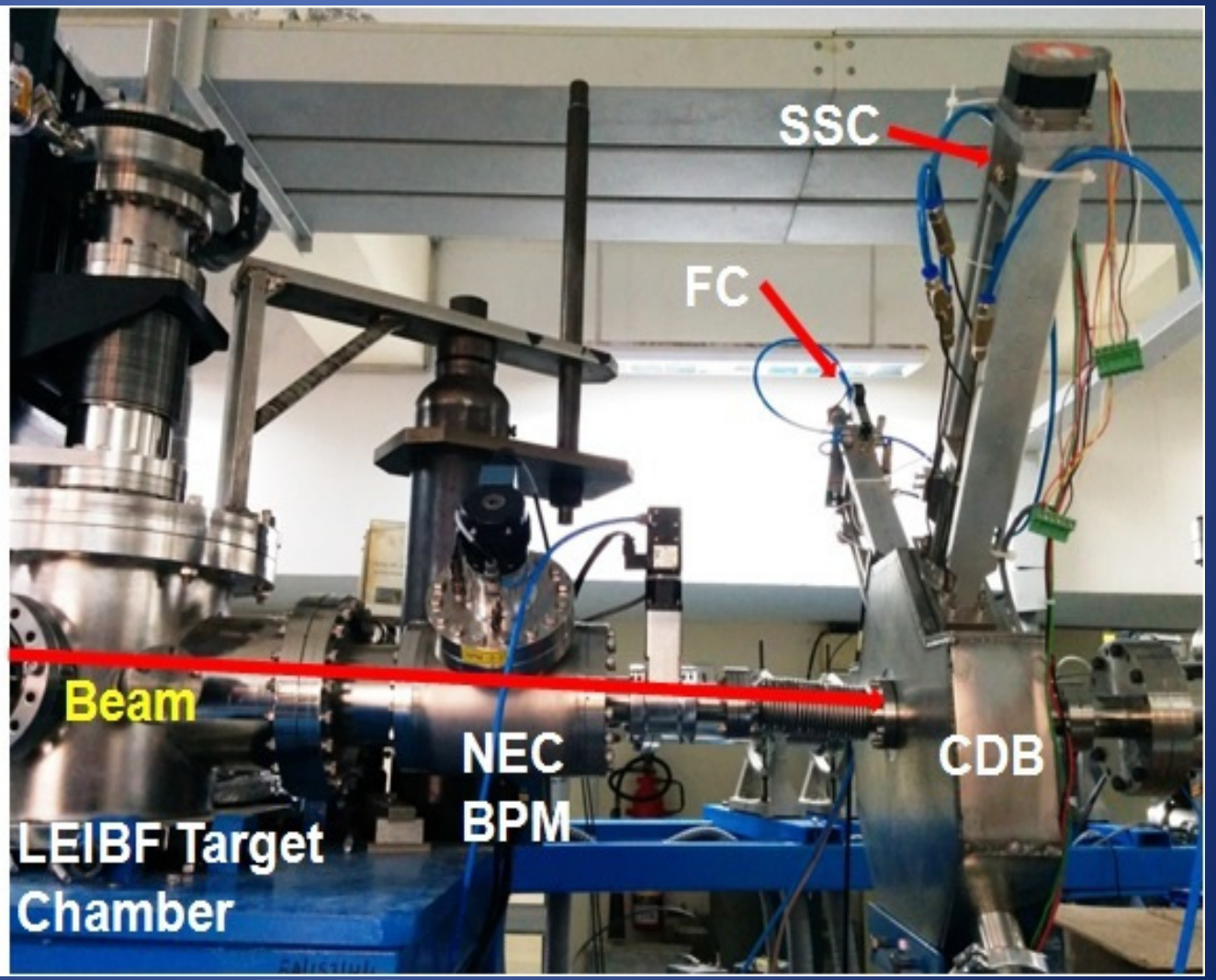


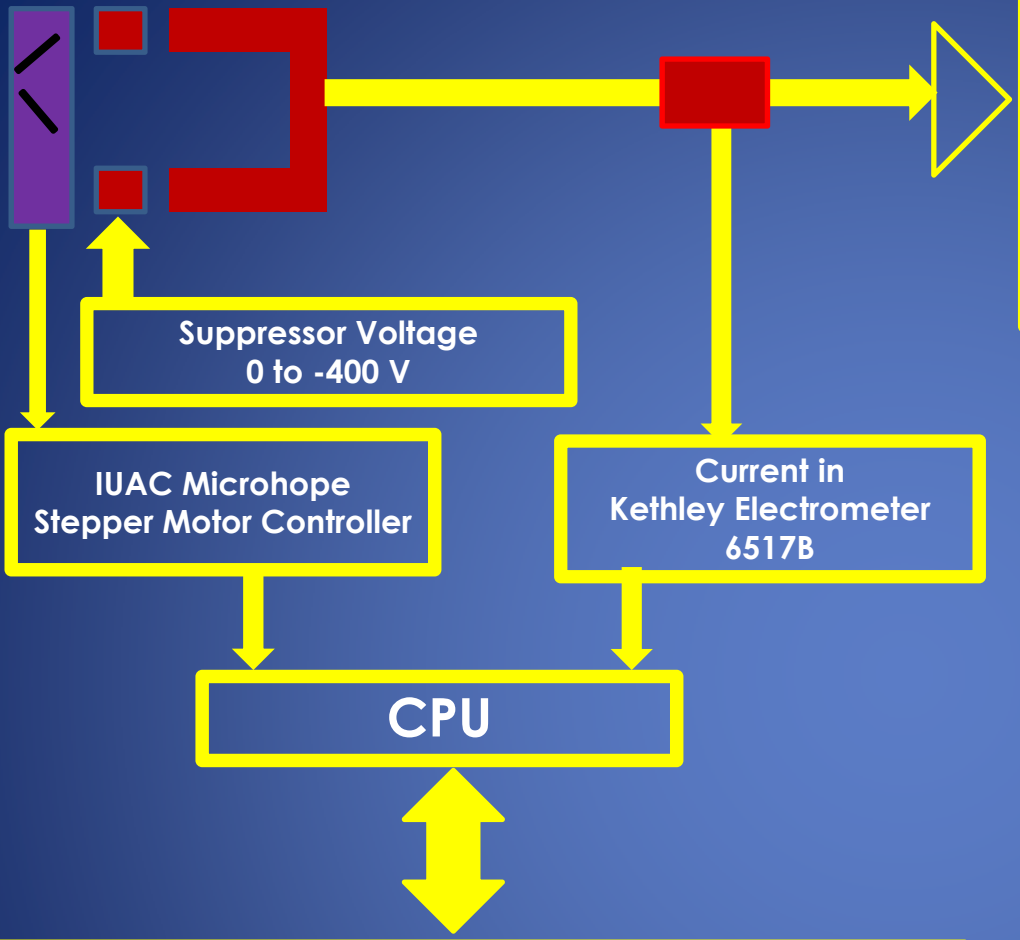
- SS Chamber
- 75 mm
- The vacuum ~10^{-9} torr

Diagnostic Box installed in LEIBF Material Science Beam line

CDB Installation & Alignment in LEIBF

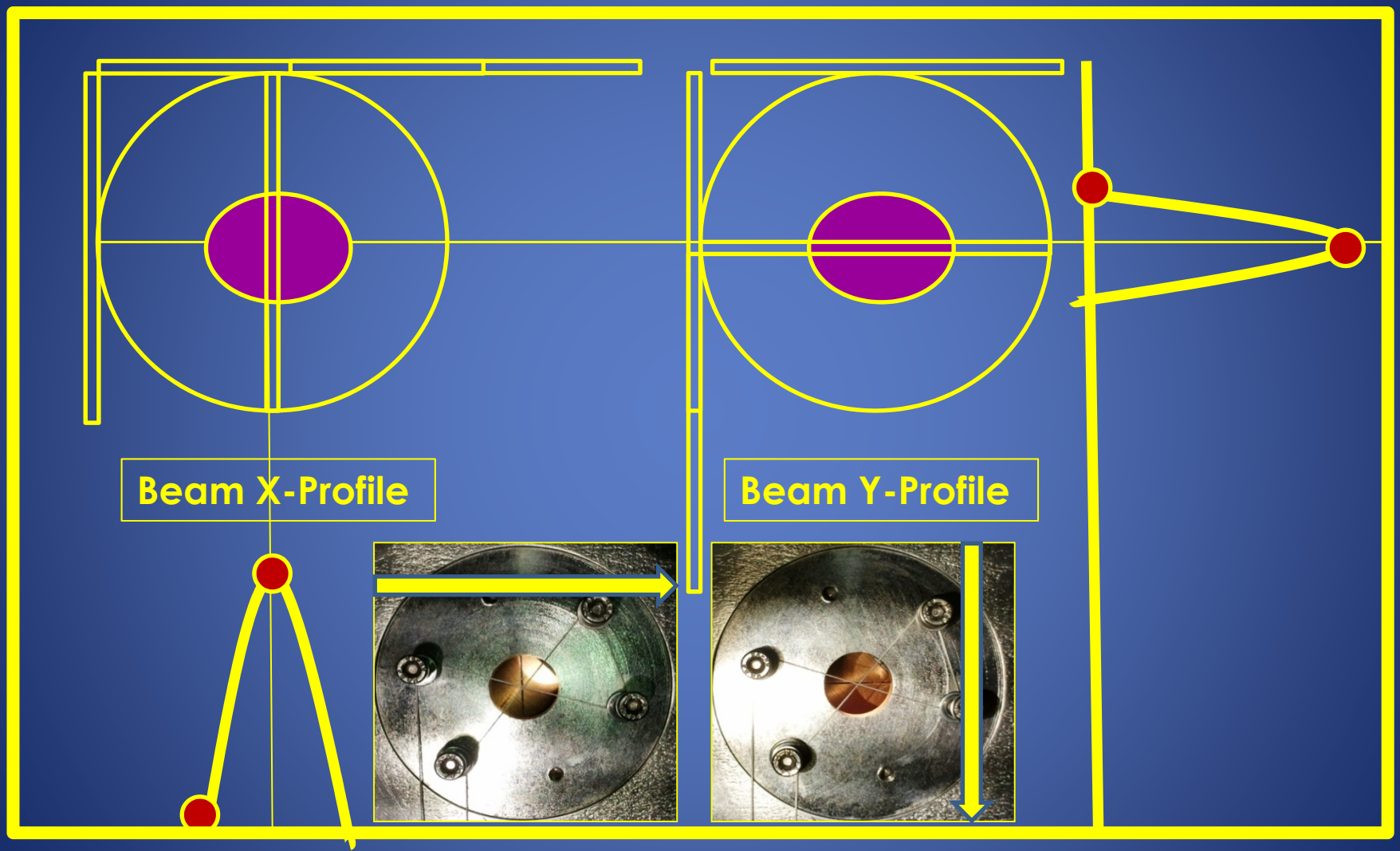






Beam Current, Profile, Spot Size and Position Measurement Set-up

Beam Centre Calibration



Beam Centre [X(0), Y(0)] ⇨ (L=36 mm and L=56 mm) on 0 mm to 70 mm Scale

Ion Beam Test

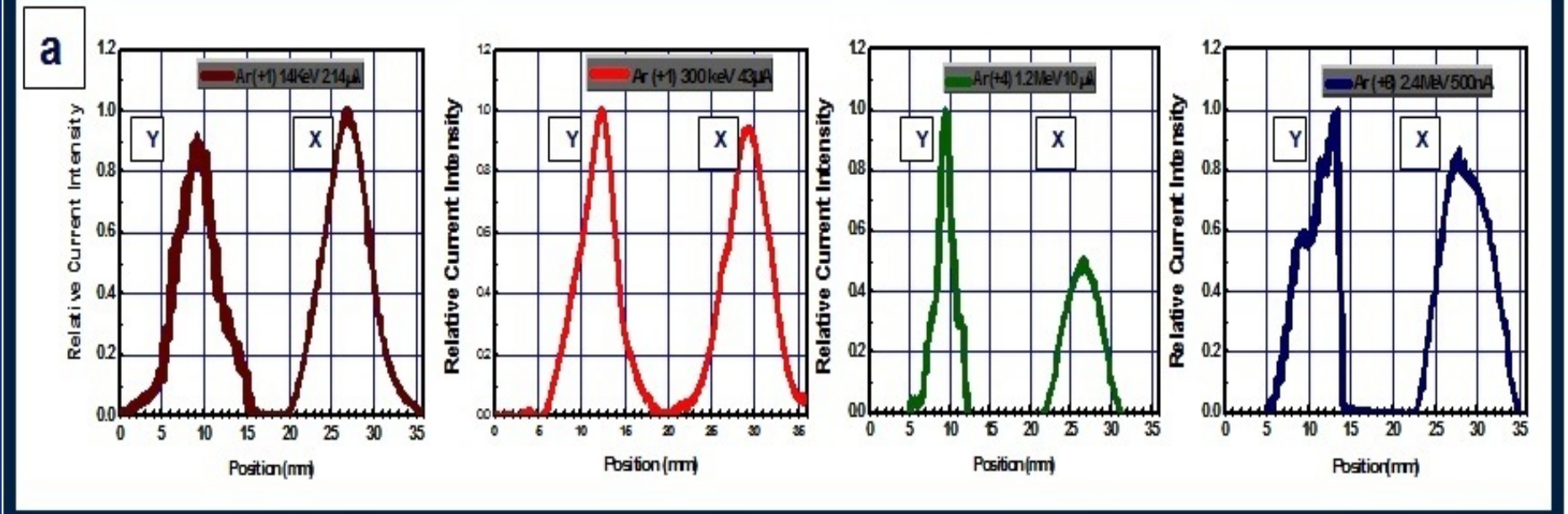
Sr.No.	ION BEAM		Energy (keV)	Current (μA)	Remarks
1	**Argon**	Ar^{+1}	14	2.14	LE
		Ar^{+1}	300	43.4	LE-HC
		Ar^{+4}	1200	9.8	
		Ar^{+8}	2400	0.5	HE-LC
2	**Carbon**	C^{+1}	250	0.025	LC
		C^{+1}	300	31	LE-HC
		C^{+4}	1200	0.35	HE
3	**Nitrogen**	N^{+1}	250	74	LE-HC
		N^{+5}	1250	1.3	HE-LC
4	**Oxygen**	O^{+1}	250	2.77	LE
		O^{5+}	1250	0.421	HE

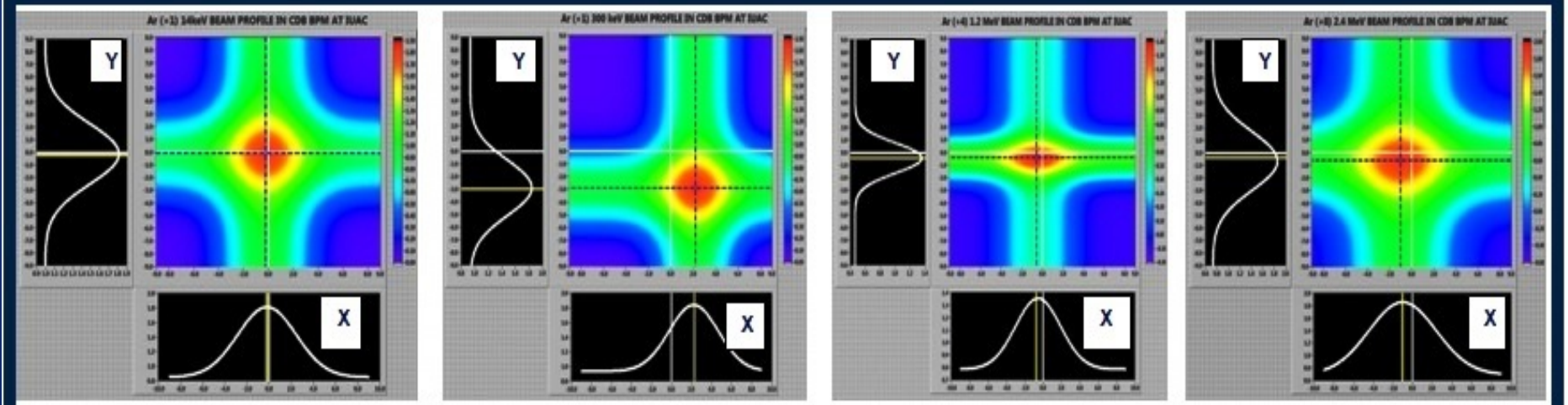
L-Low ,H-High, C-current, E-Energy

Currents in FC Vs NEC-FC

Beam Specification	Energy	Current Measured by NEC Faraday Cup	Current Measured by Faraday Cup	Difference
C^{+1}	300 keV	30 μA	30 μA	Match
N^{+1}	250 keV	74 μA	72.5 μA	2 %
Ar^{+1}	14 keV	2.15 μA	2.15 μA	Match
O^{+5}	1.25 MeV	440 nA	440 nA	Match

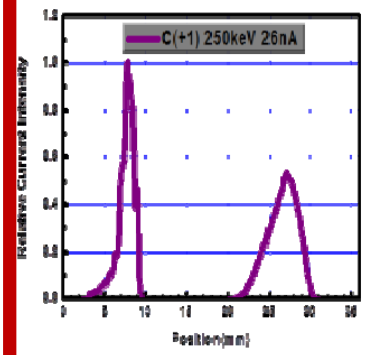
Beam Profiles and Beam Positions Measured online with LabVIEW for Ar

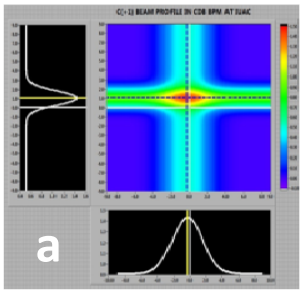




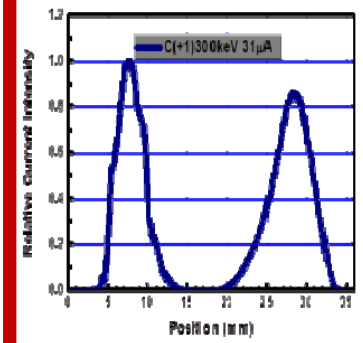
b CDB BPM YX Profiles and Beam positions of Ar ion beams across the beam line center

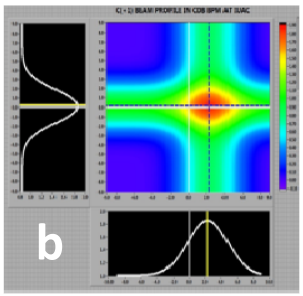
Online Beam Test for C,O and N

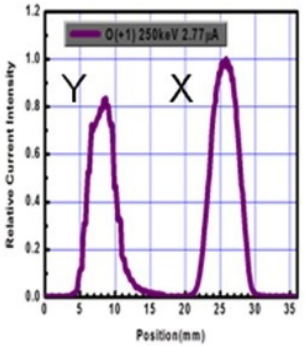


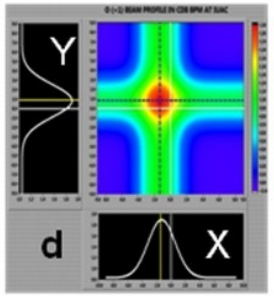


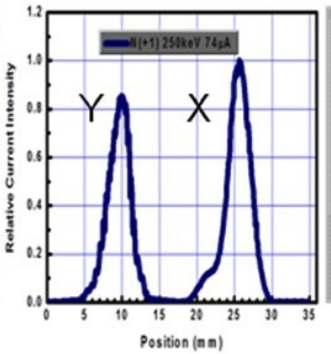
Beam YX Profiles and Beam Positions of Carbon, Oxygen, and Nitrogen Ion Beam

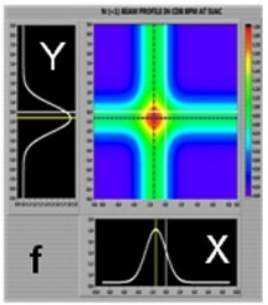


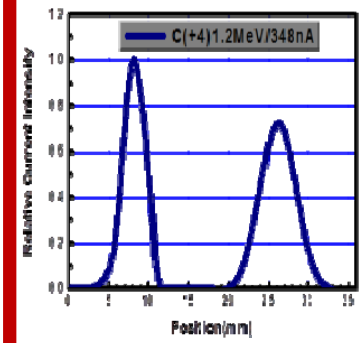


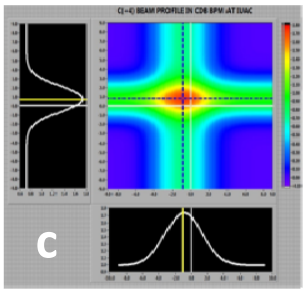


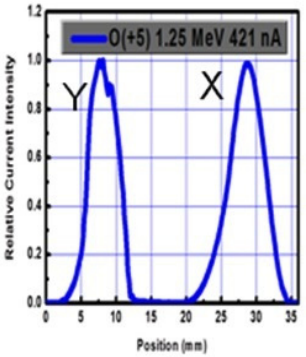


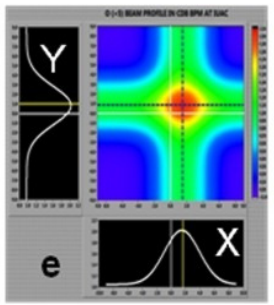


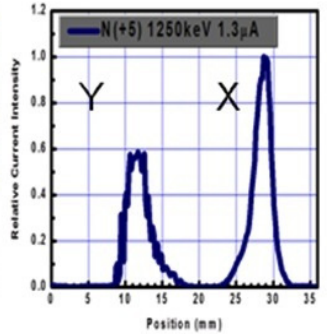


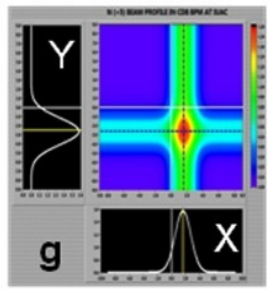




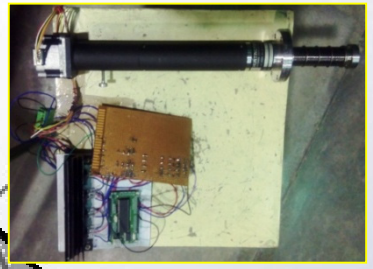




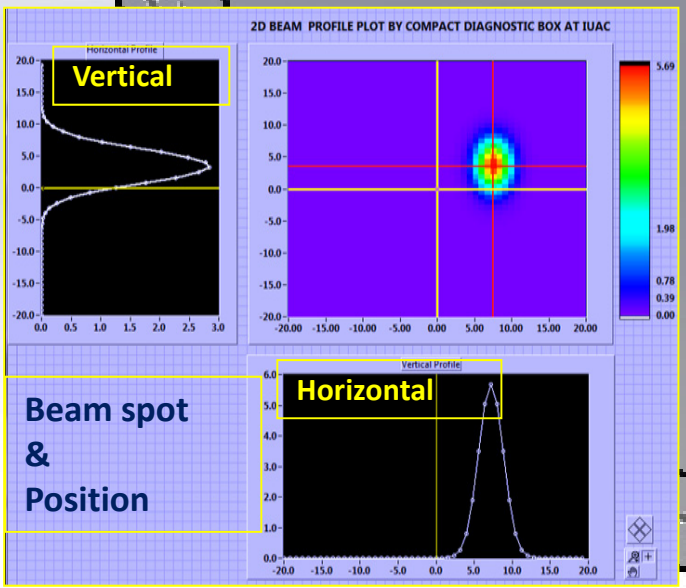


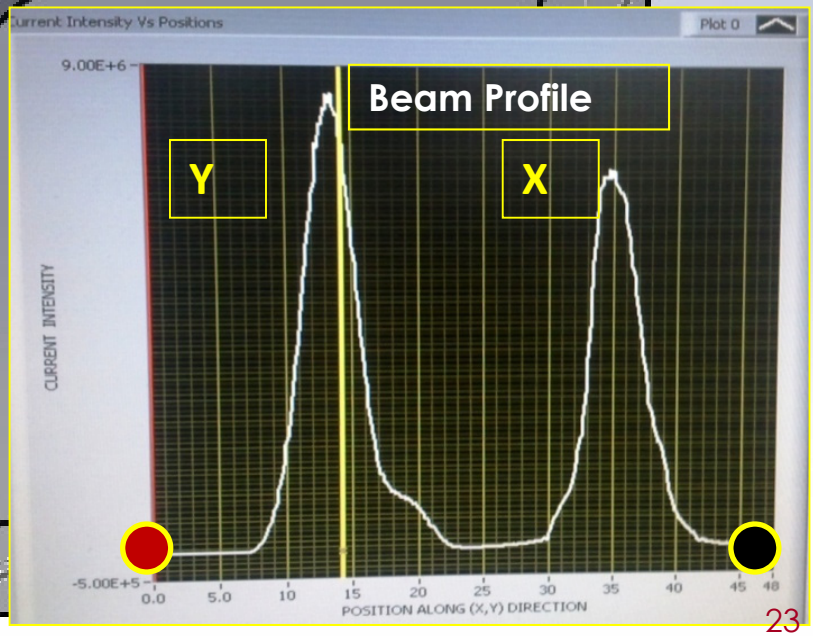


YX Beam Profiling by BPM

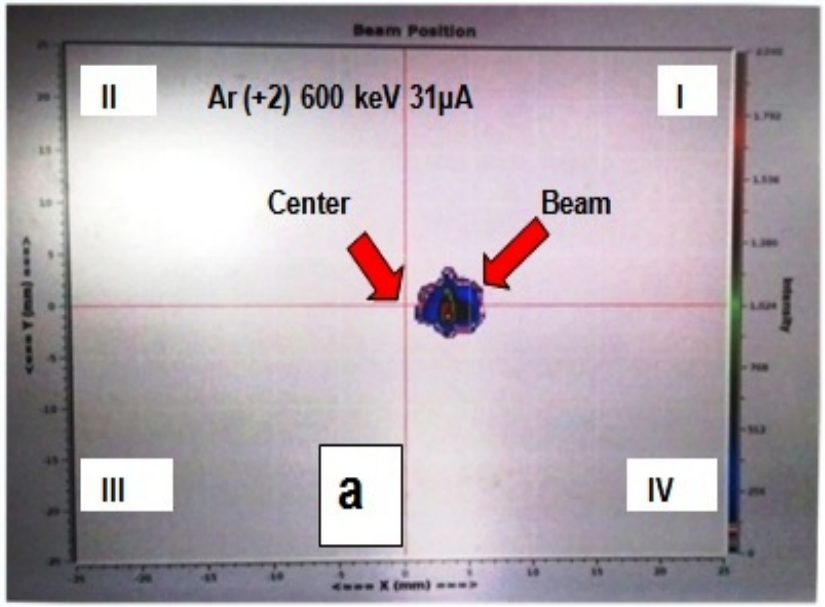


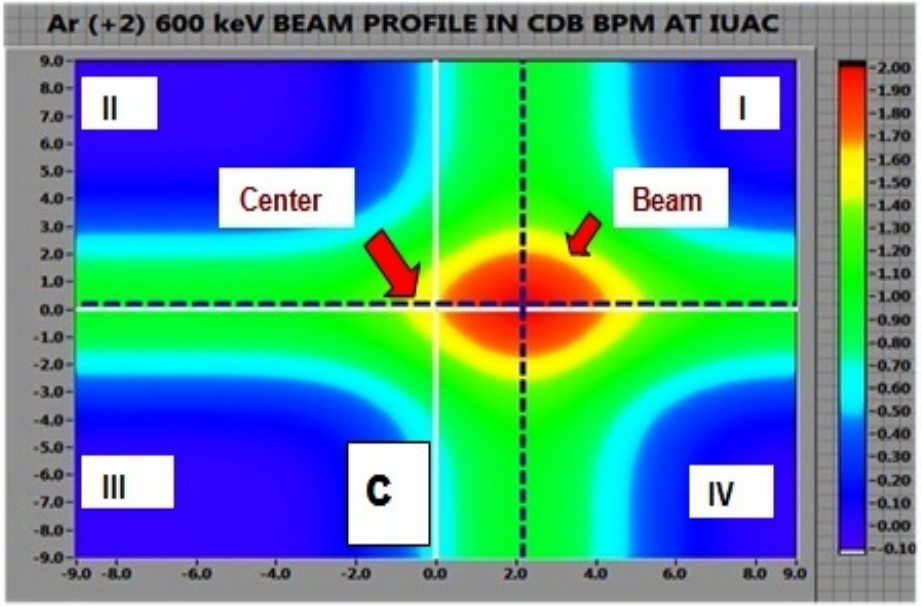
Microcontroller

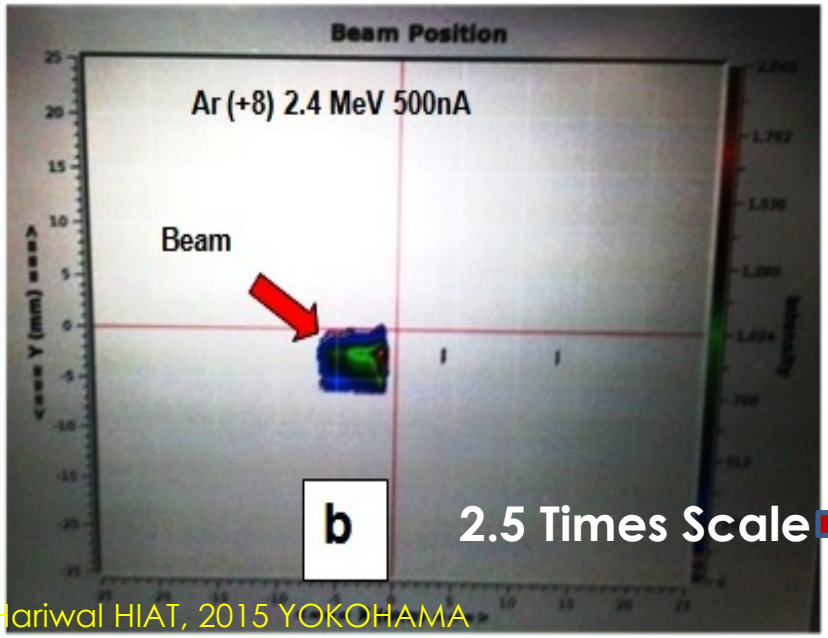




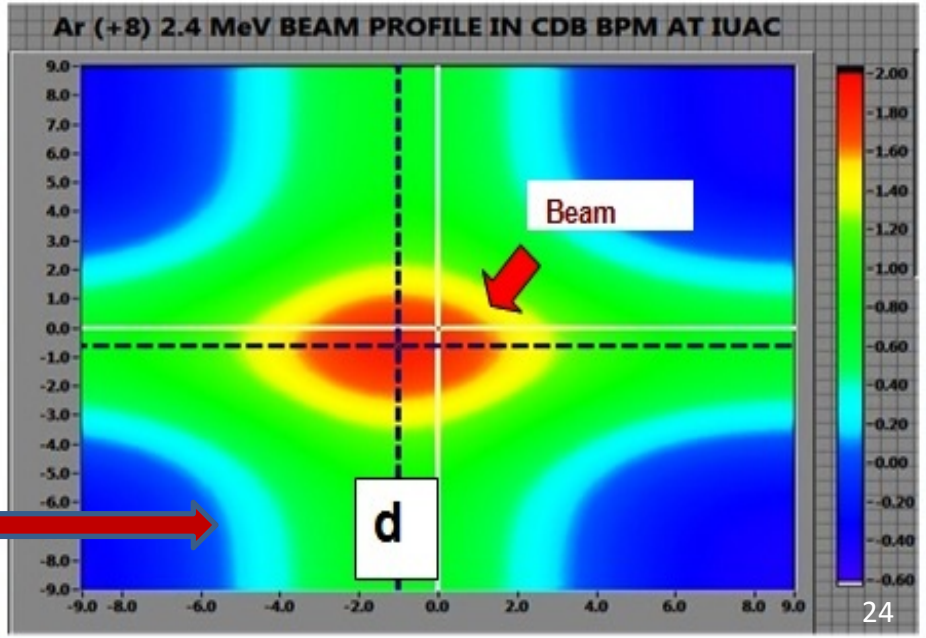
Beam Digitization and Matching from NEC BPM to Compact BPM





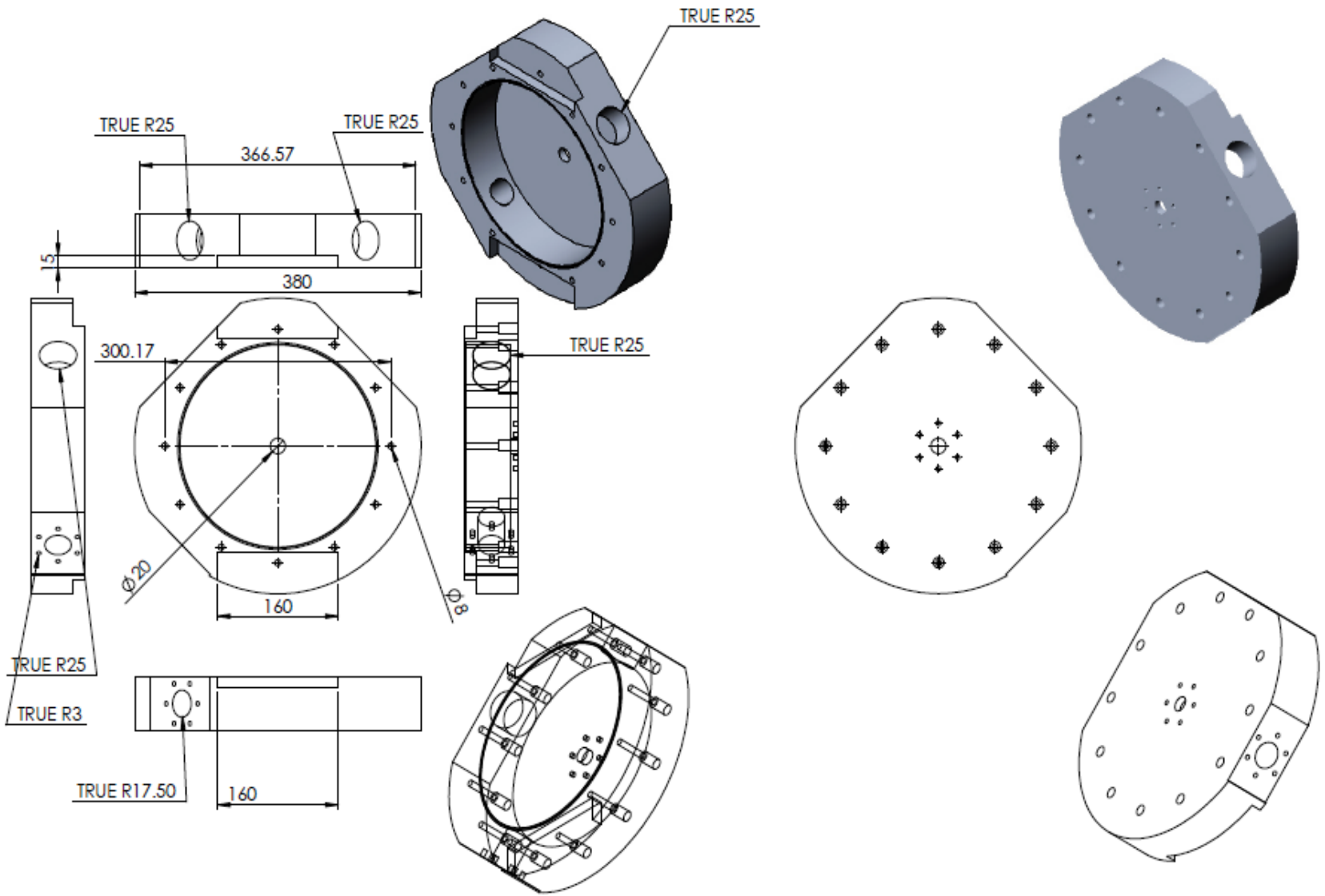


2.5 Times Scale

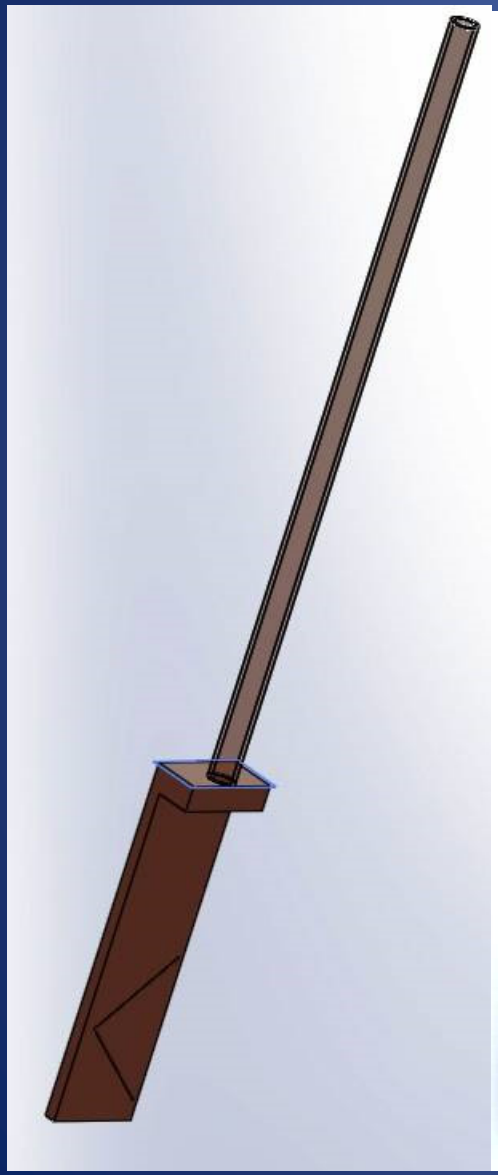


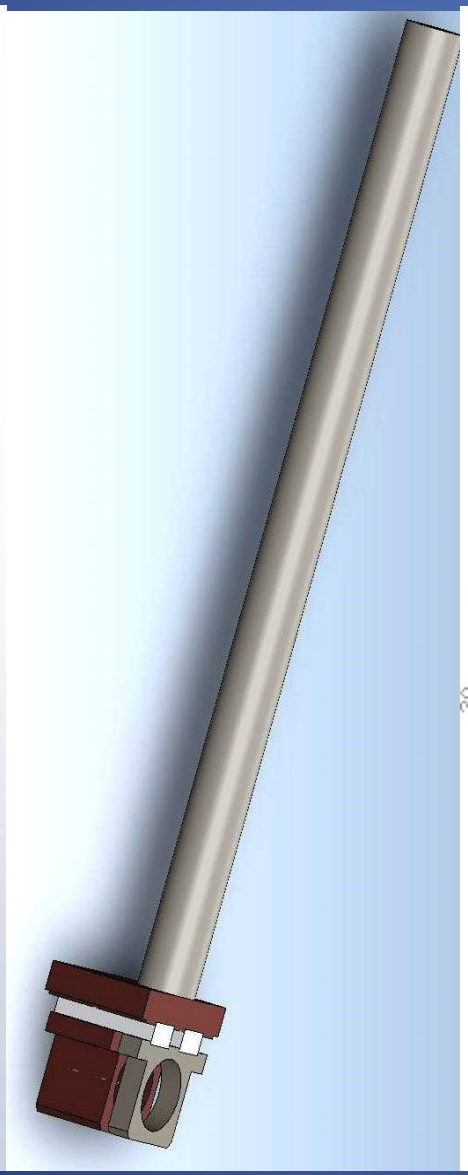
First Compact Diagnostic Box Development

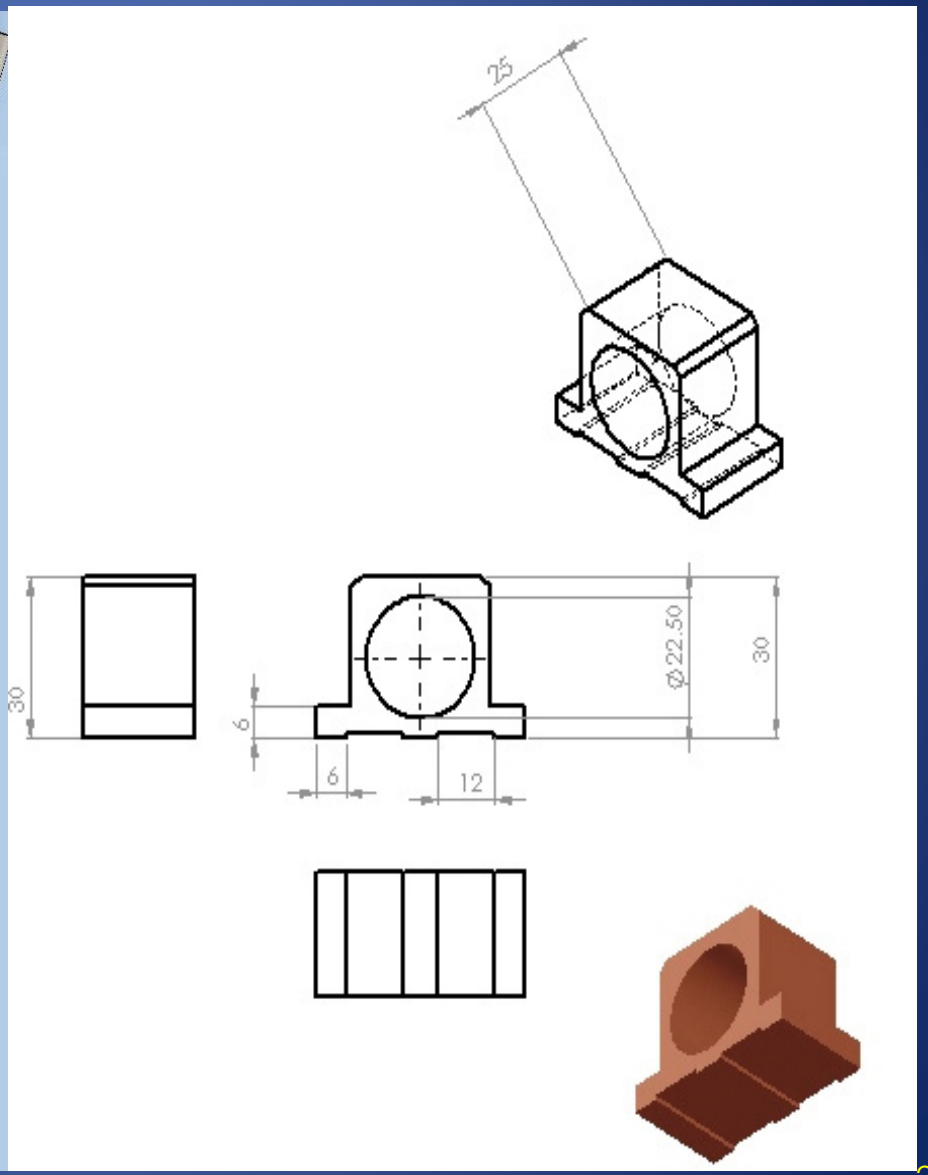
First Diagnostic Box Development



SSC and FC Development



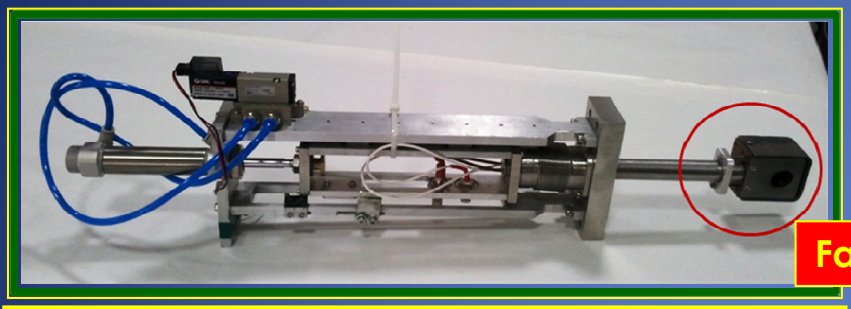




Diagnostic Box Development

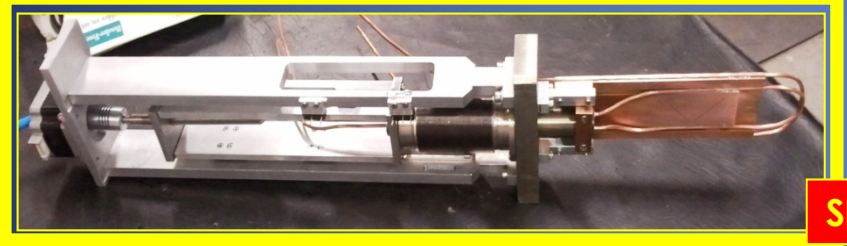
Prototype CDB

First CDB

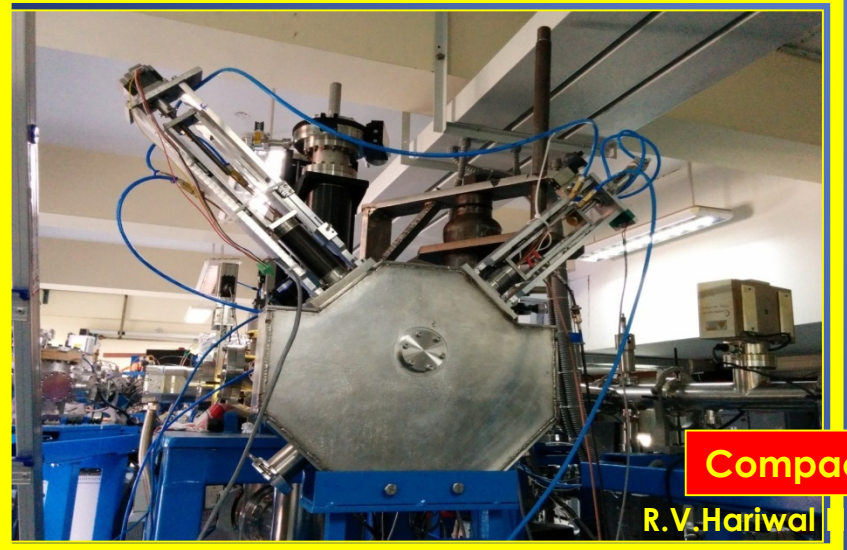


~1kW

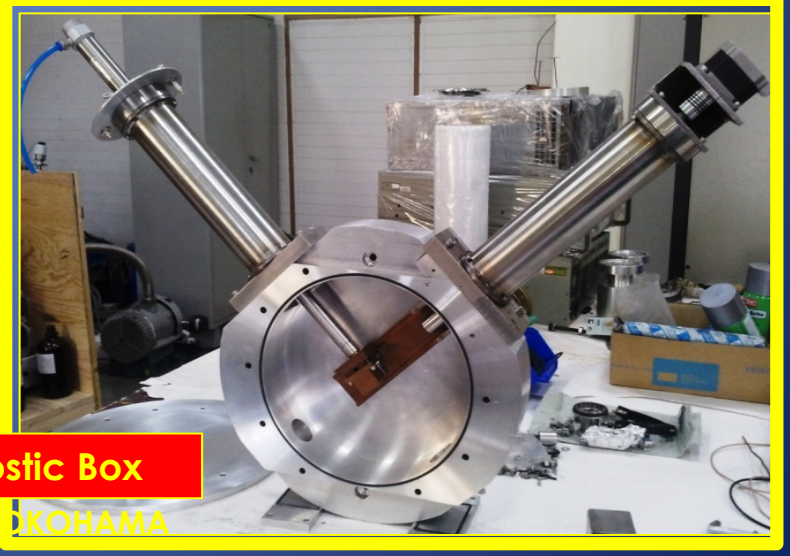
Faraday Cup



Slit Scanner



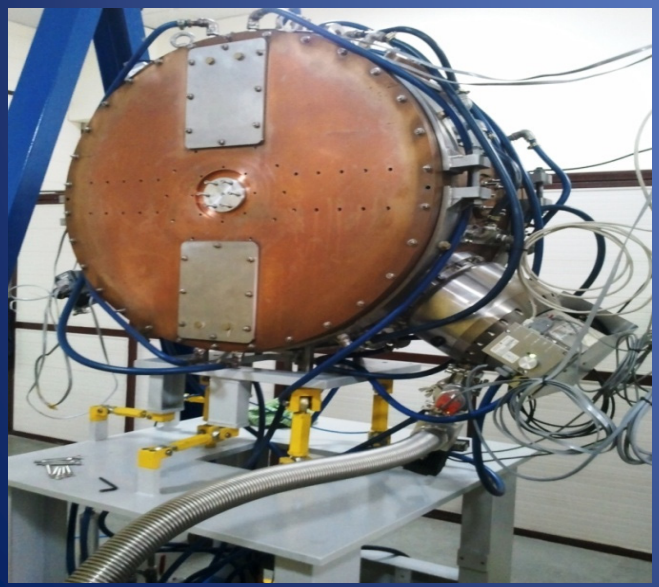
Compact Diagnostic Box

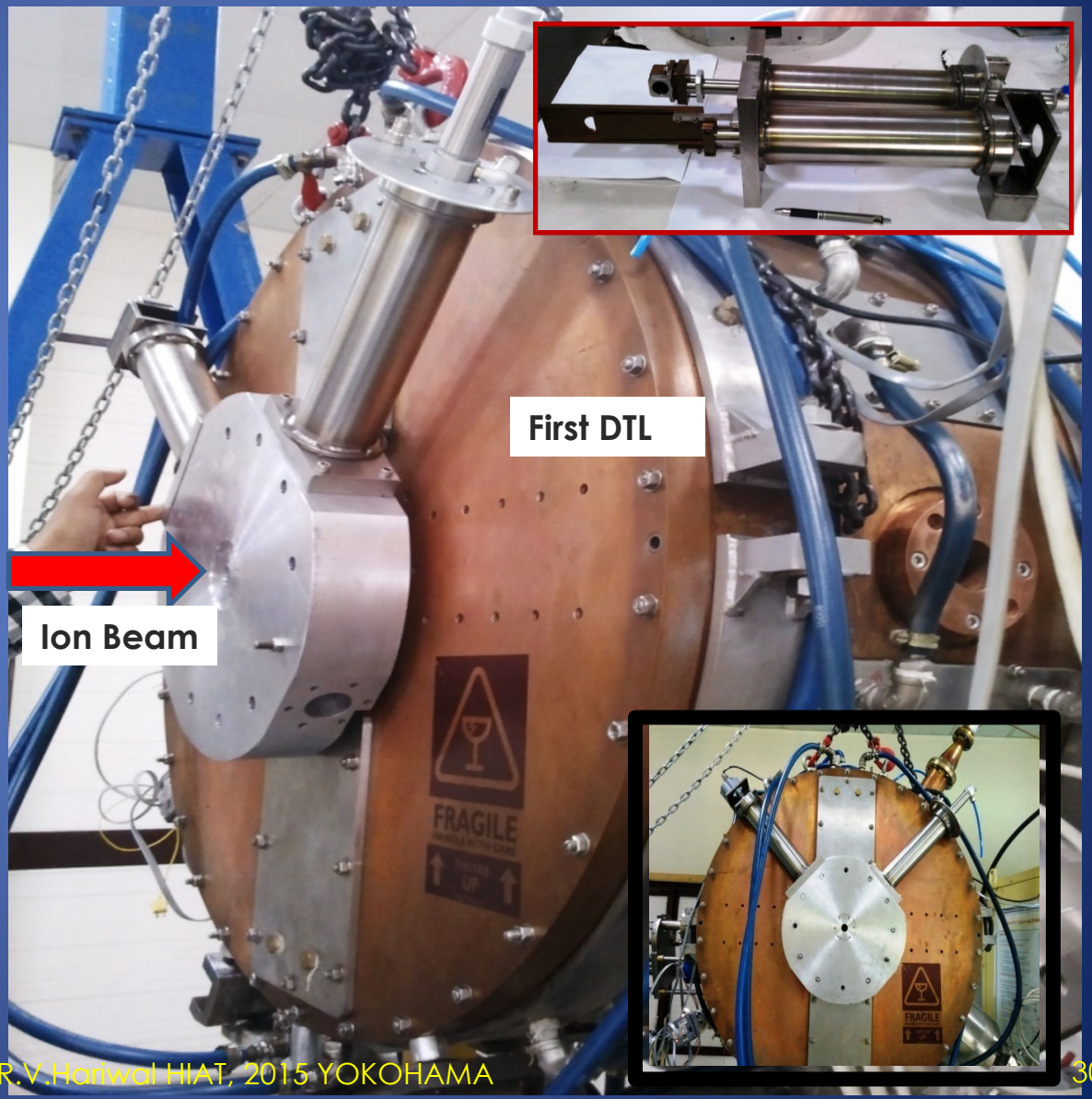


Salient Features of First CDB

- Compact Size (LL)~70 mm
- Approx. 10 pA to 100 µA
- Approx. 1kW Beam Power
- Ease of Machining
- Mechanical Robustness
- Electrical/ Electronics Operation
- Compatible with DTL Tank
- Low Cost and Reliable
- Beam Current, Position, Profile & Spot Size

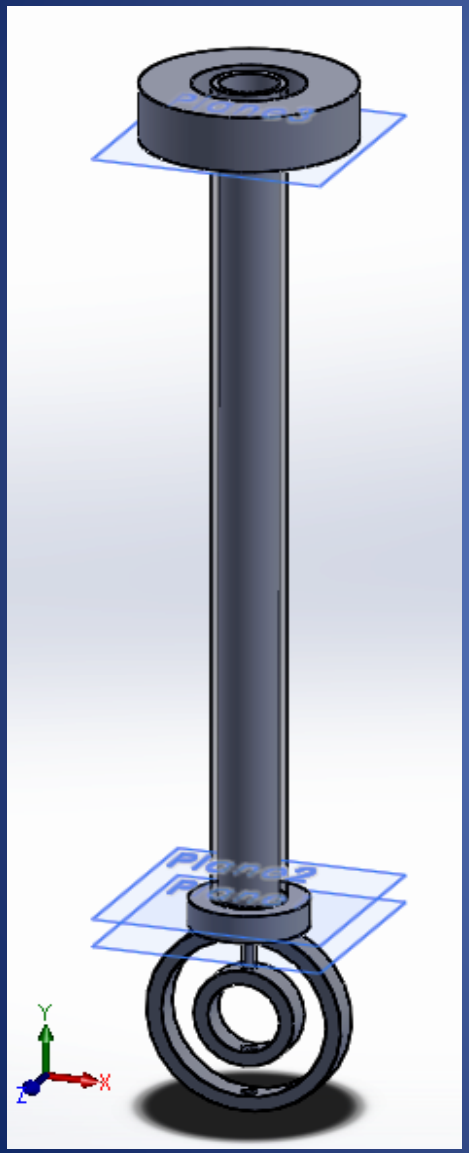
Compact Diagnostic Box with First DTL Resonator

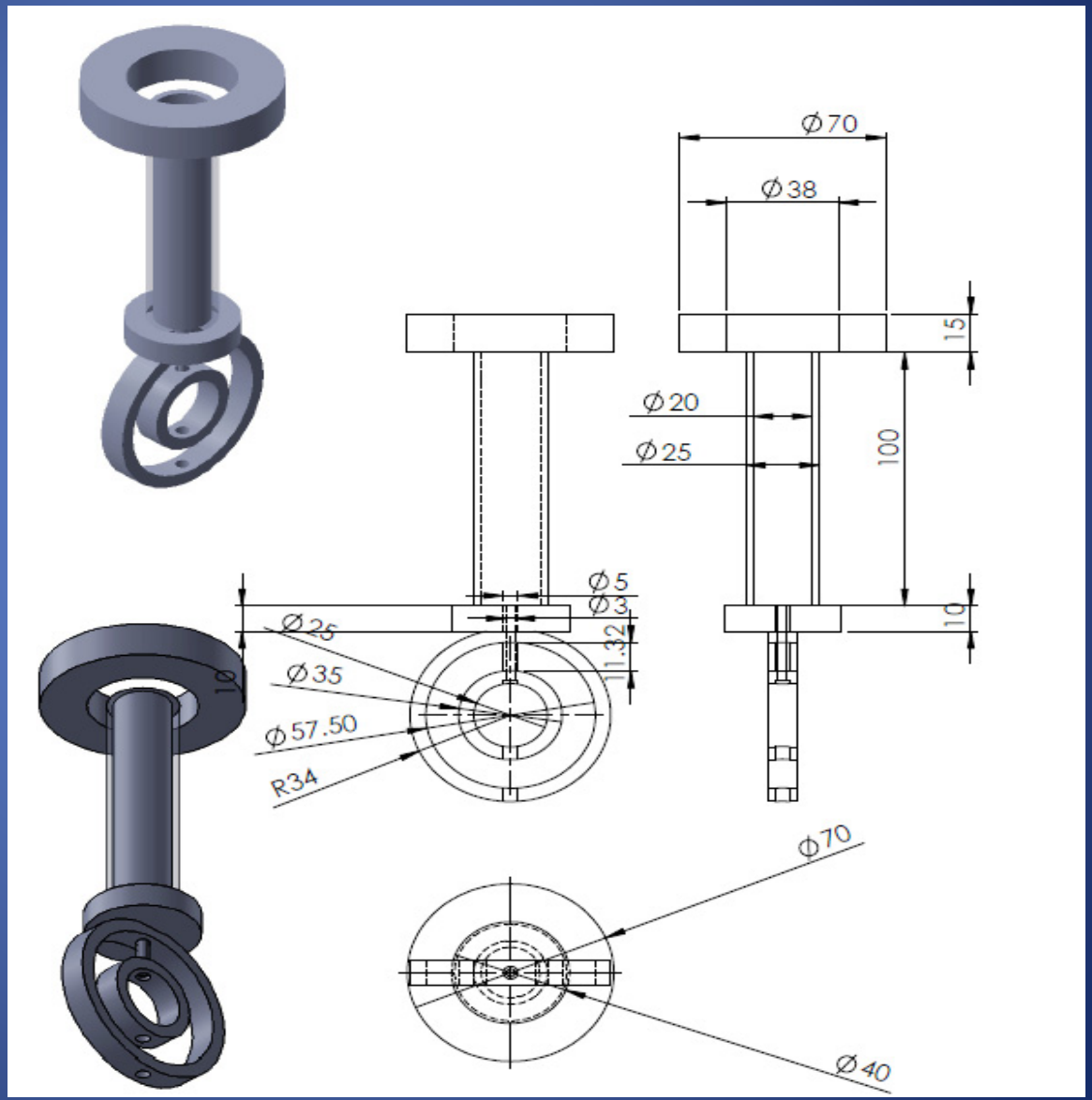




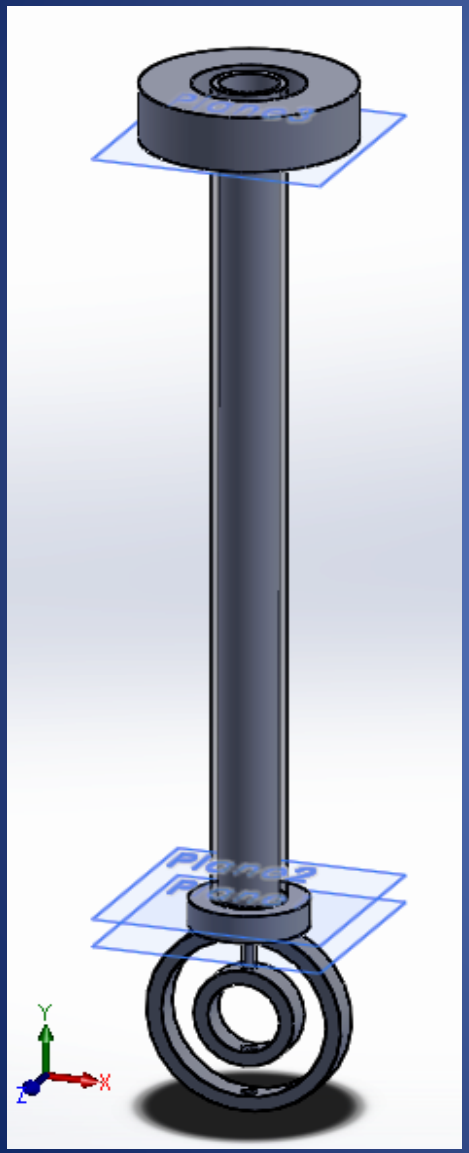
Capacitive Pickup

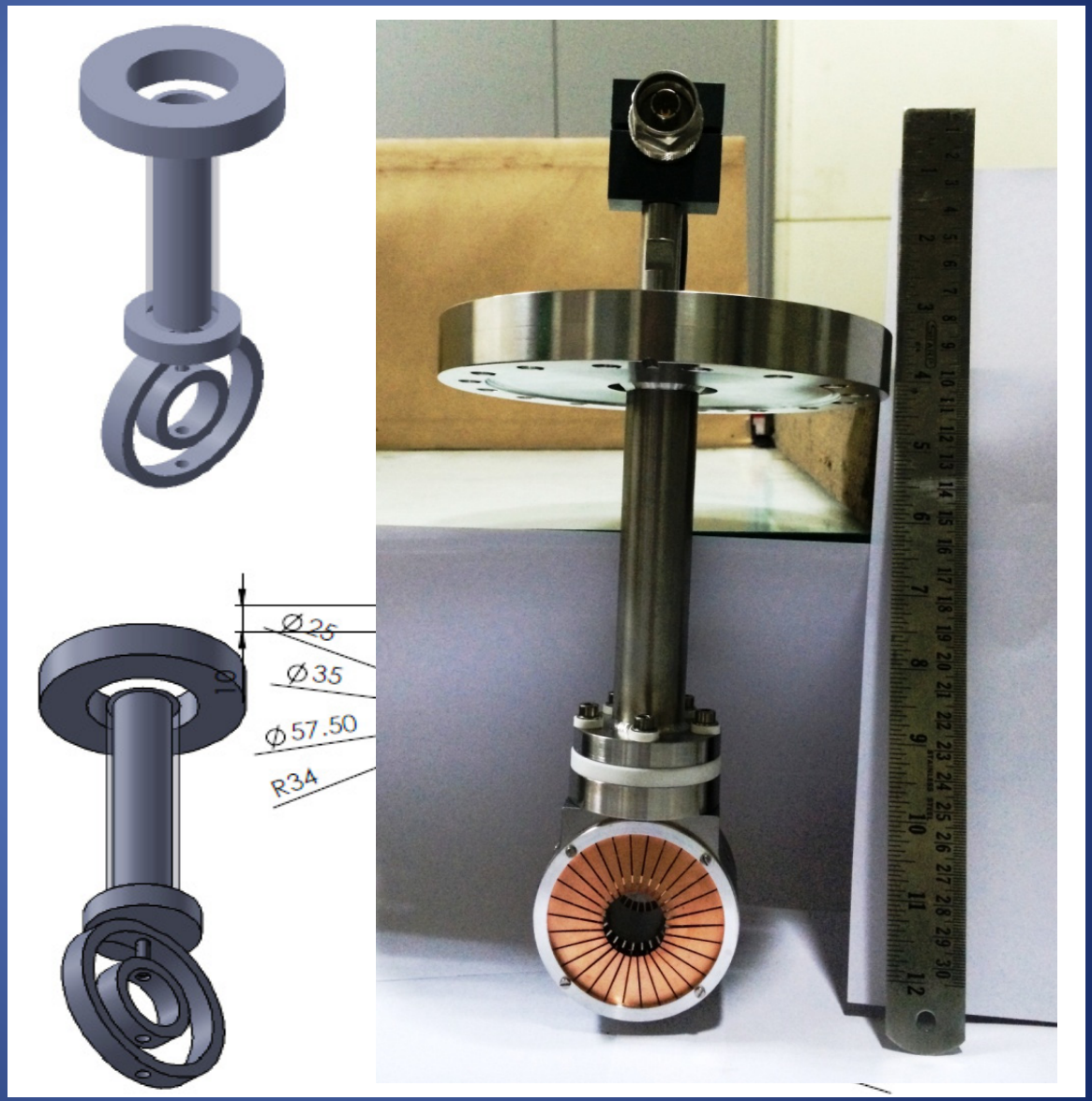
Capacitive Pickup



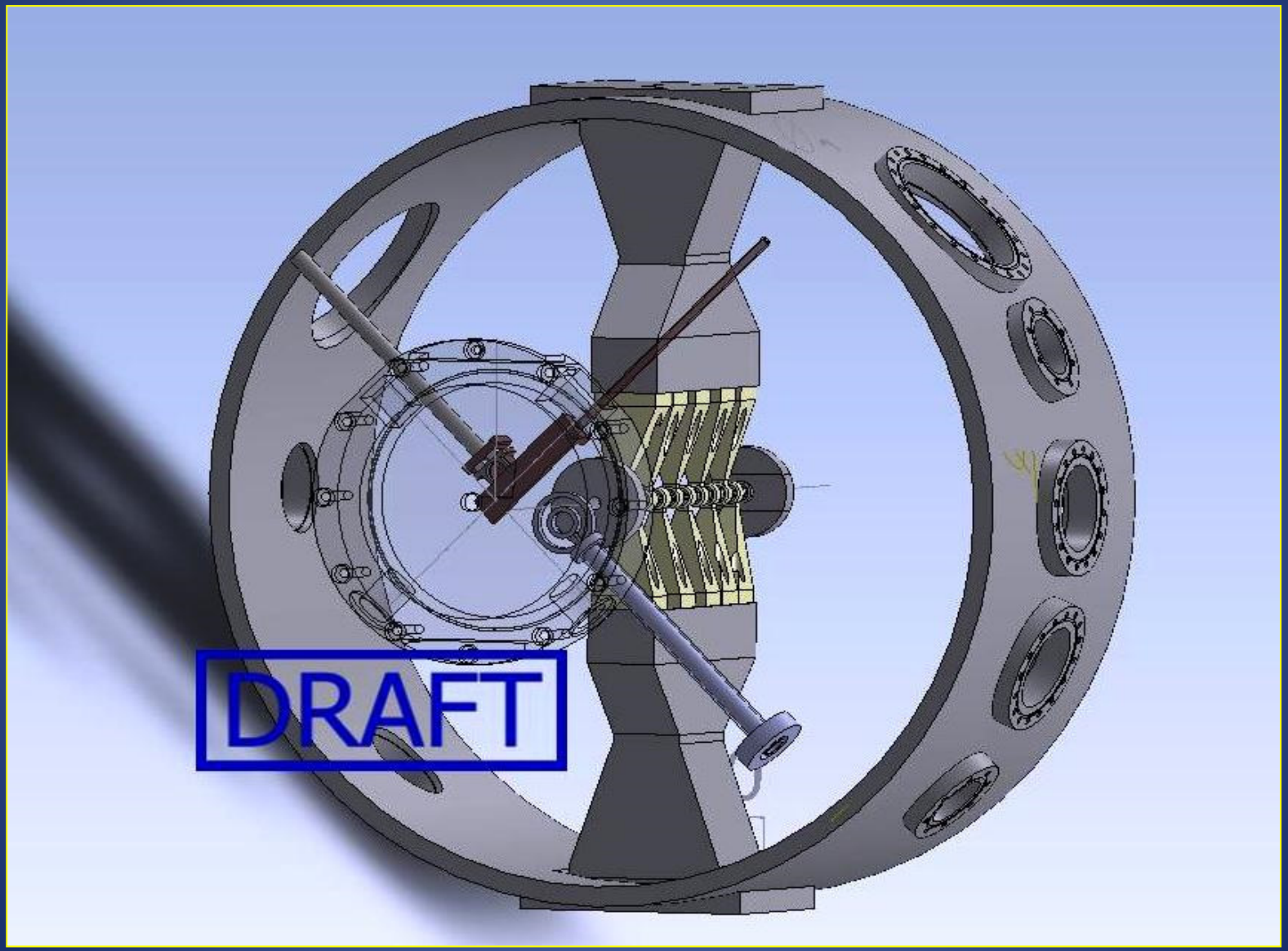


Capacitive Pickup

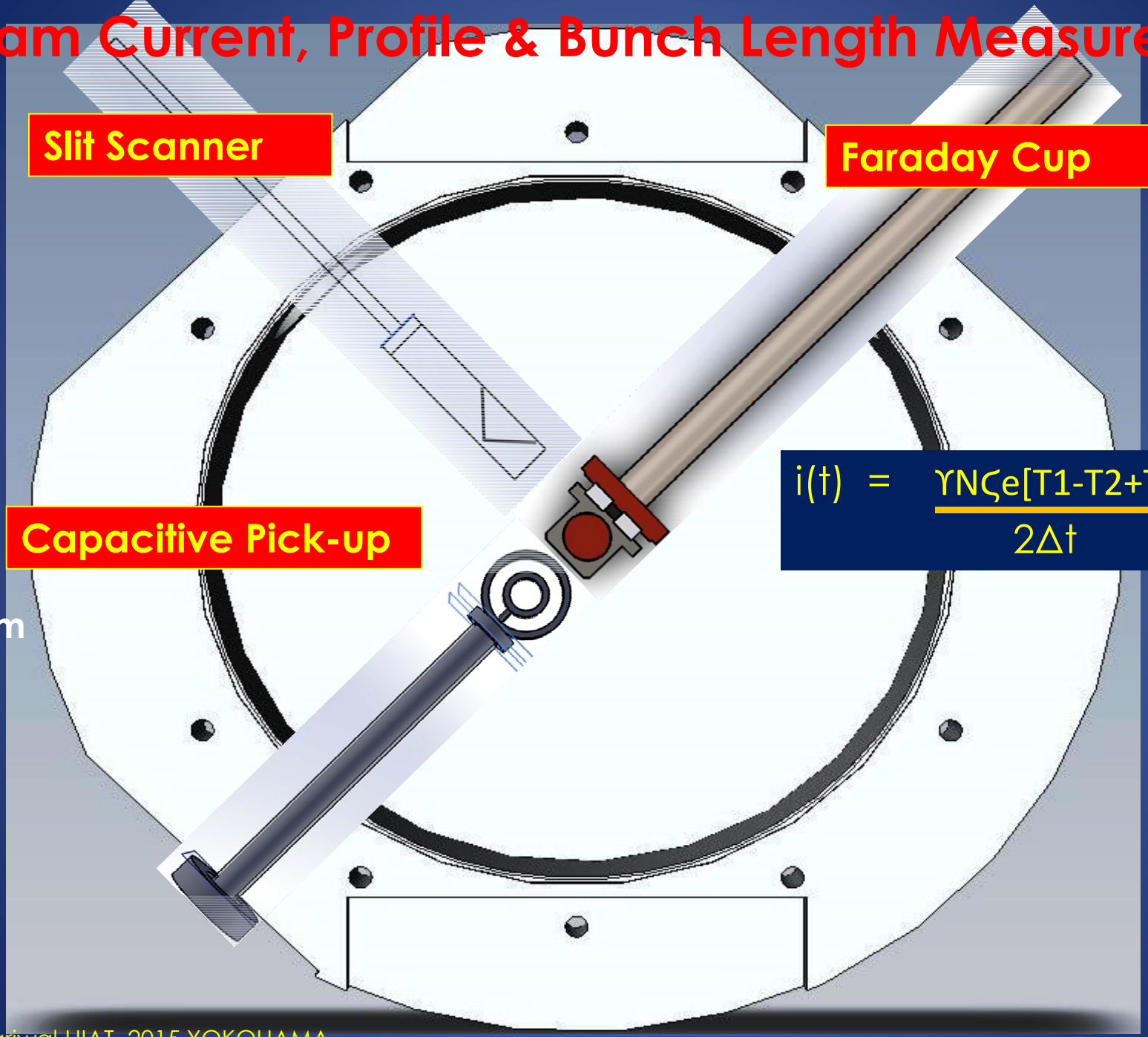




CDB with Capacitive Pickup



Beam Current, Profile & Bunch Length Measurement



$$i(t) = \frac{\gamma N \zeta e [T1 - T2 + T3 - T4]}{2\Delta t}$$

Beam Current, Profile & Bunch Length Measurement

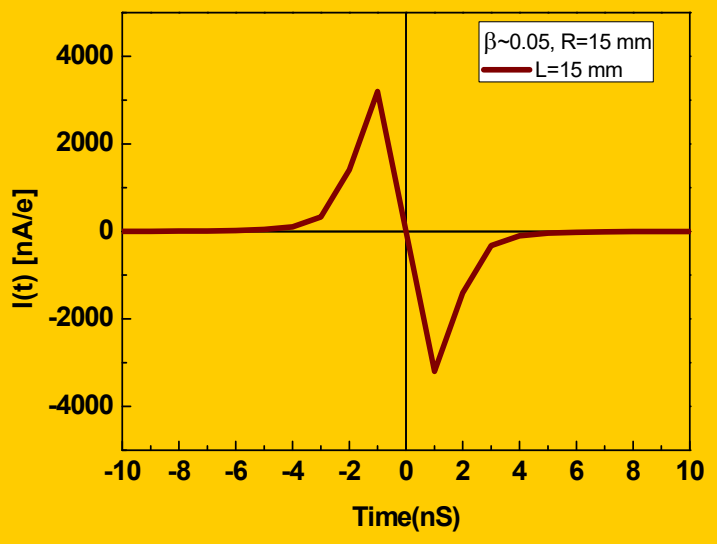
Slit Scanner

Faraday Cup

Capacitive Pick-up

Beam

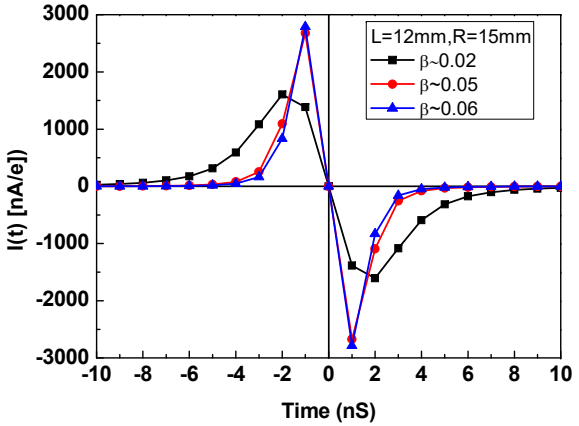
$$i(t) = \frac{\gamma N \zeta e [T1 - T2 + T3 - T4]}{2\Delta t}$$

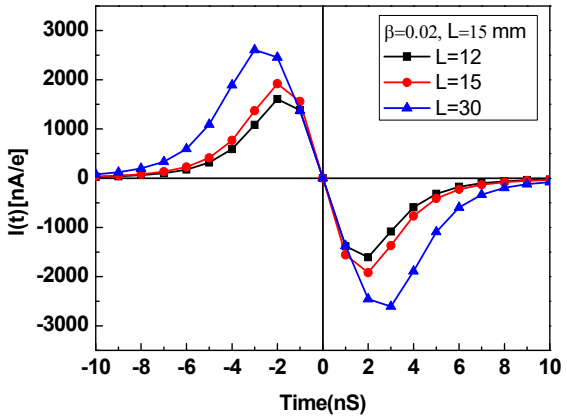


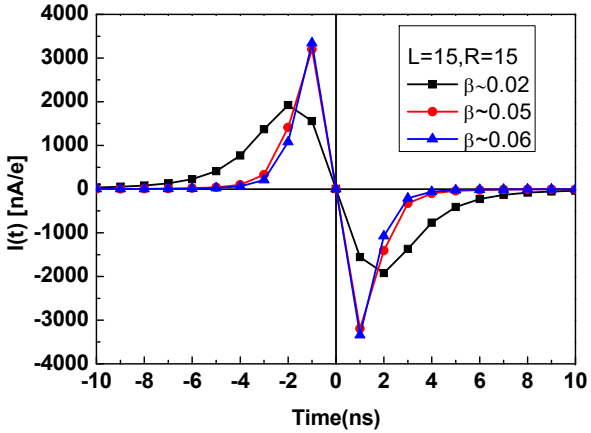
Capacitive Probe Length Calculation

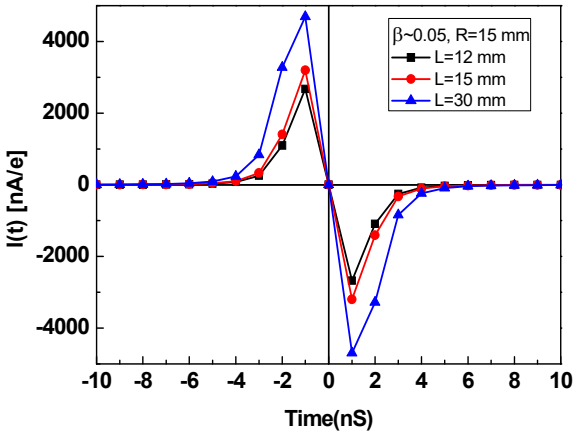
Position	Relative Velocity (β)	Capacitive Pick Up Probe Length L (mm)			
Expected Bunch Length		**0.5 ns**	**1 ns**	**2ns**	**3 ns**
Before 1st DTL	**0.02**	**3**	**6**	**12**	**18**
After 6th DTL	**0.05**	**7.5**	**15**	**30**	**45**
	0.06	**9**	**18**	**36**	**54**

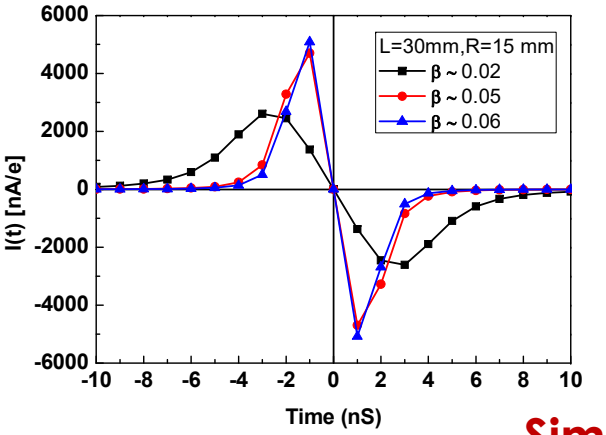
Capacitive Pick-up Parameters

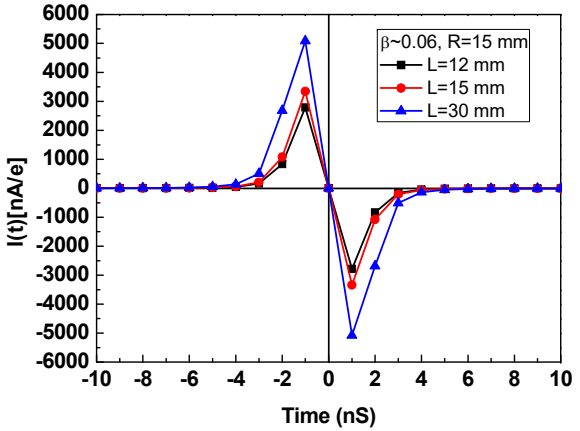






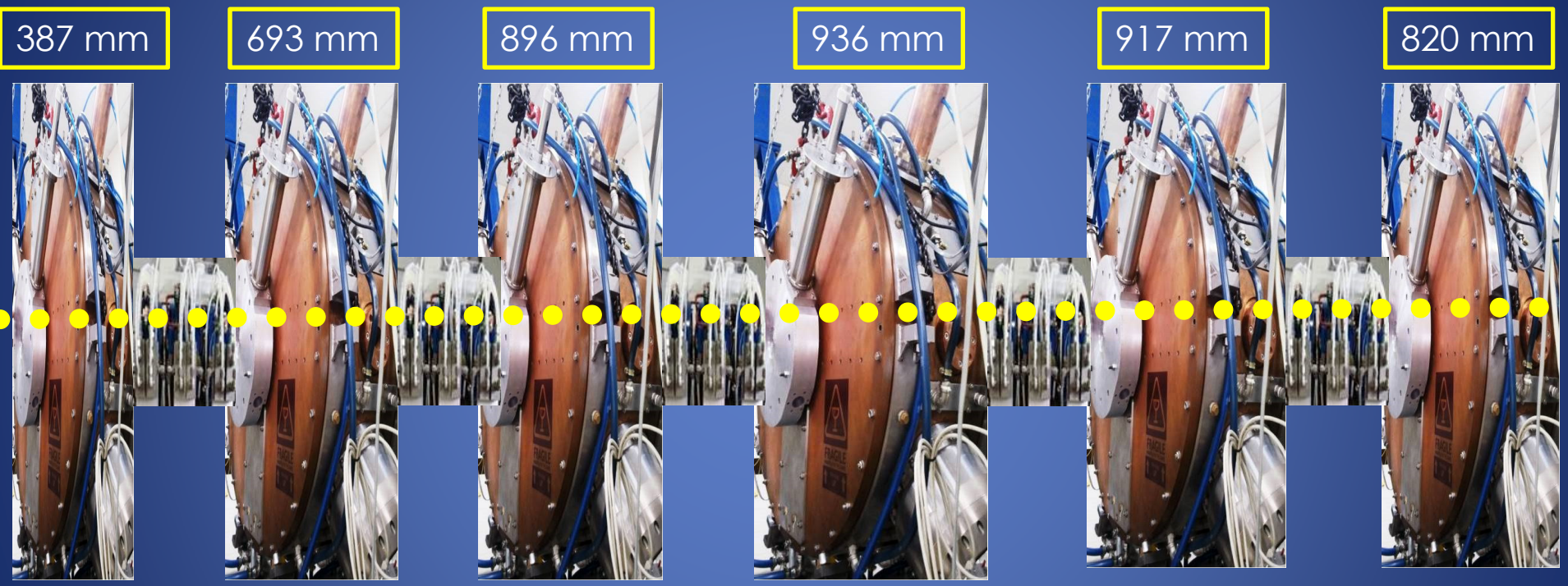






Simulation Results

HEBT (IH-DTL+CDB) Commissioning



Ion Beam

Summary

- Developed Compact Diagnostic Box and its Components
- Tested and validated operational aspects
- Measure beam current, profile, position, spot size and bunch length
- Accurate and Reliable

Thanks Team Members

Victor Verzilov
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Sanjay Kedia
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H. K. Malik
IIT Delhi, India

Rajeev Mehta
IUAC Delhi, India

THANK YOU HIAT 2015

どうもありがとうございます

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Special Thanks

J. Holek, R. Laxdal & L. Merminga
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