IIFC Activities
at
Bhabha Atomic Research Centre (BARC), India

By

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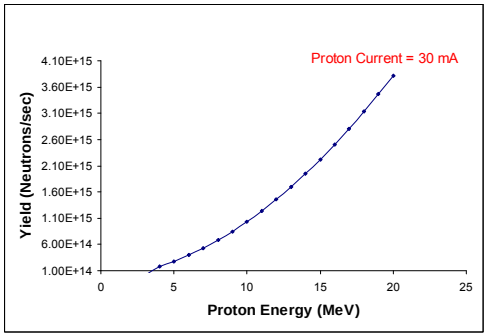
Director, E&I Group

Current Accelerator Programs at BARC

- LEHIPA - Low Energy High Intensity
  Proton Accelerator 20 MeV, 30 mA
  (on going)
- 200 MeV Proton Accelerator (proposed)

20 MeV High Intensity LINAC



LEBT

MEBT

Beam Diagnostics

Ion Source → **RFQ** → **DTL** → **Beam Stop**

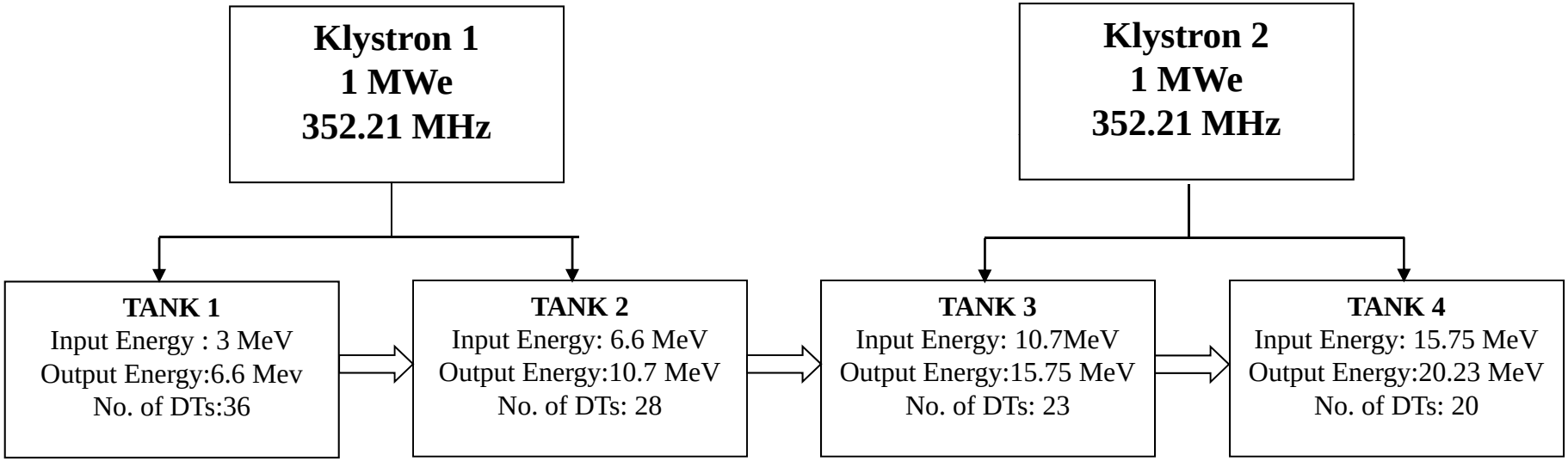
2.45 GHz
ECR Ion source
50 keV, 35mA.

352.21 MHz,
4 Vane type RFQ
3 MeV, 30 mA

352.21 MHz,
20 MeV, 30 mA
Alvarez type DTL

Neutron Target

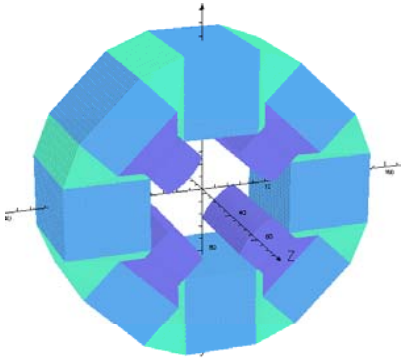
Configuration of Drift Tube LINAC(DTL) for LEHIPA



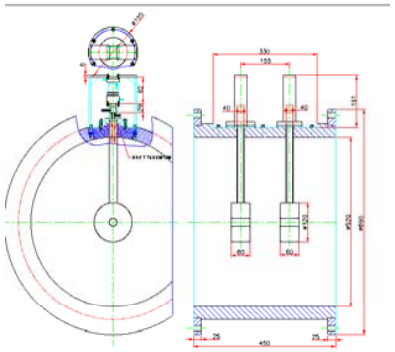
Accelerator Programme at E&I Group

The Drift tube LINAC for Low Energy High Intensity Proton Accelerator

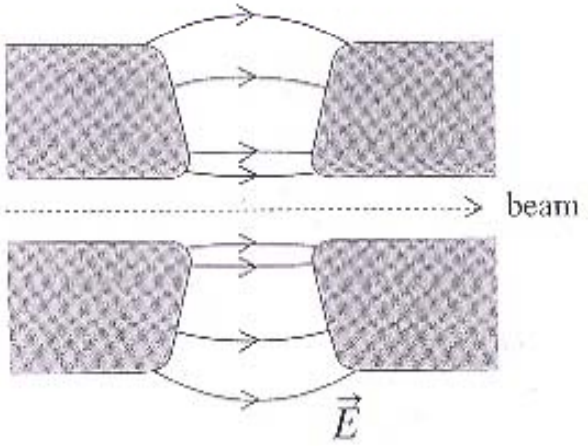
The focussing quadrupole



The drift tube cavity

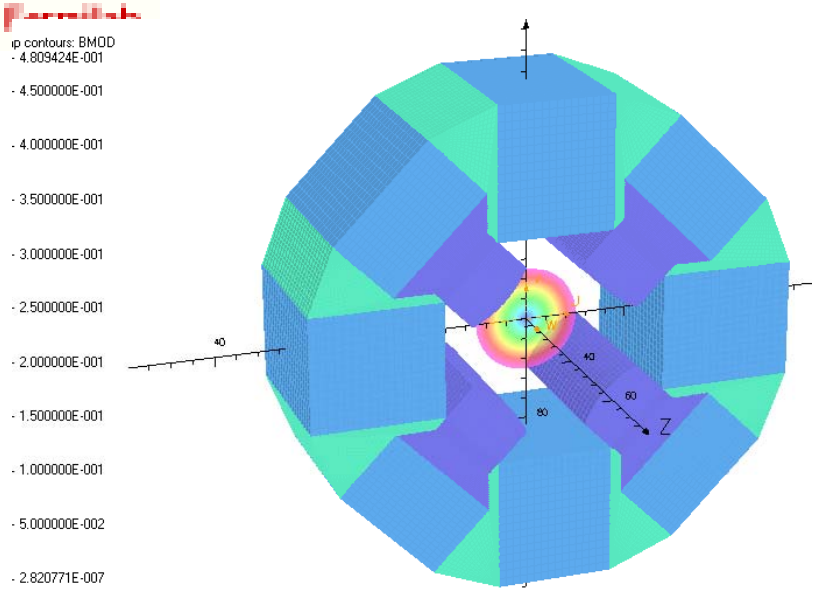


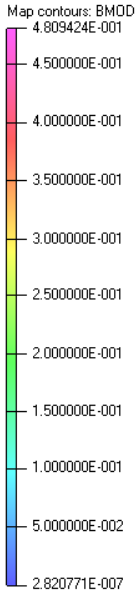
The defocussing effect of the electric field (RF Electromagnetic design of cavity by superfish code)

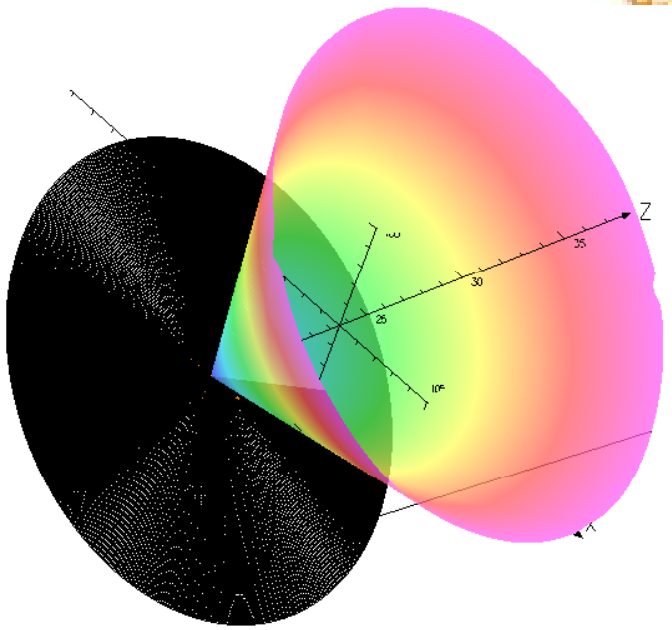


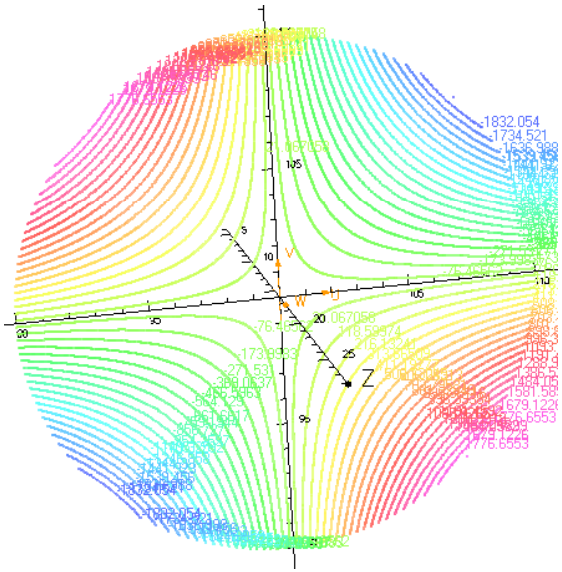
Electric field lines between the ends of two drift tubes in a DTL.

Focusing Quadruple magnet Design using OPERA electromagnetic code

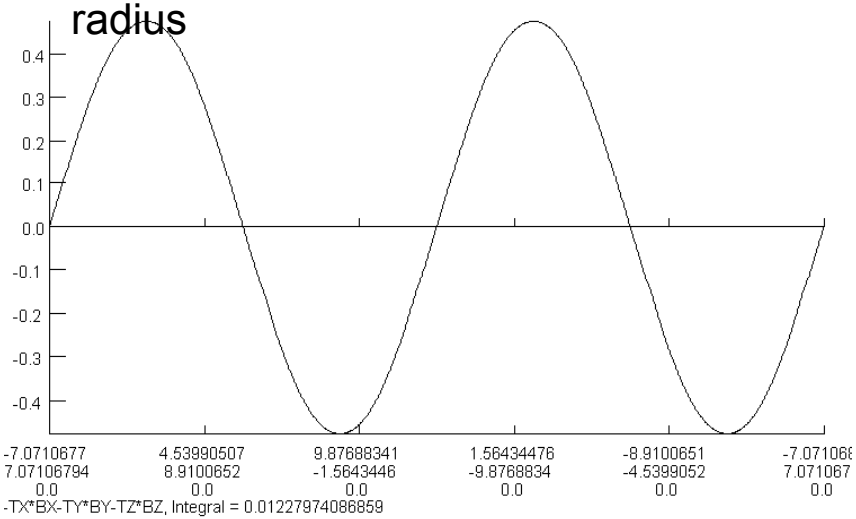




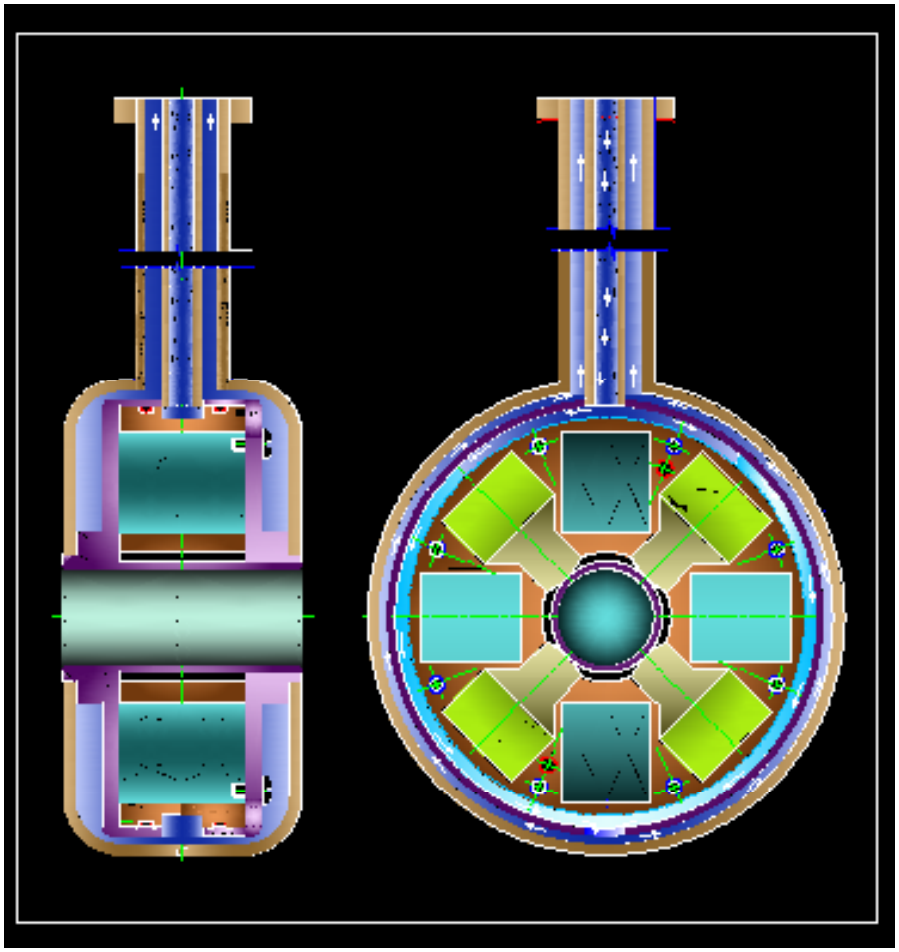


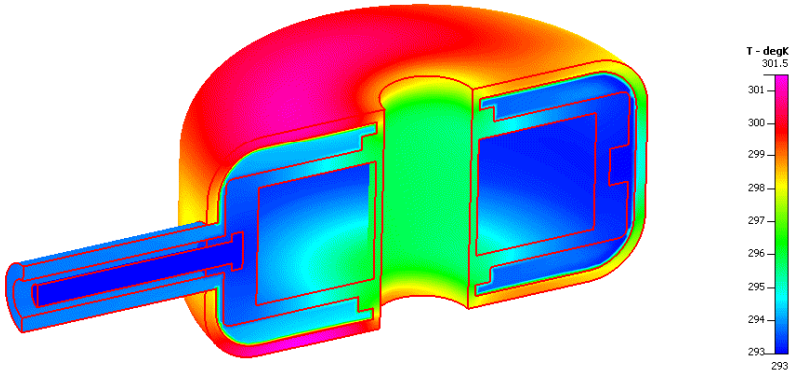


Magnetic field in the aperture @ 10 mm radius



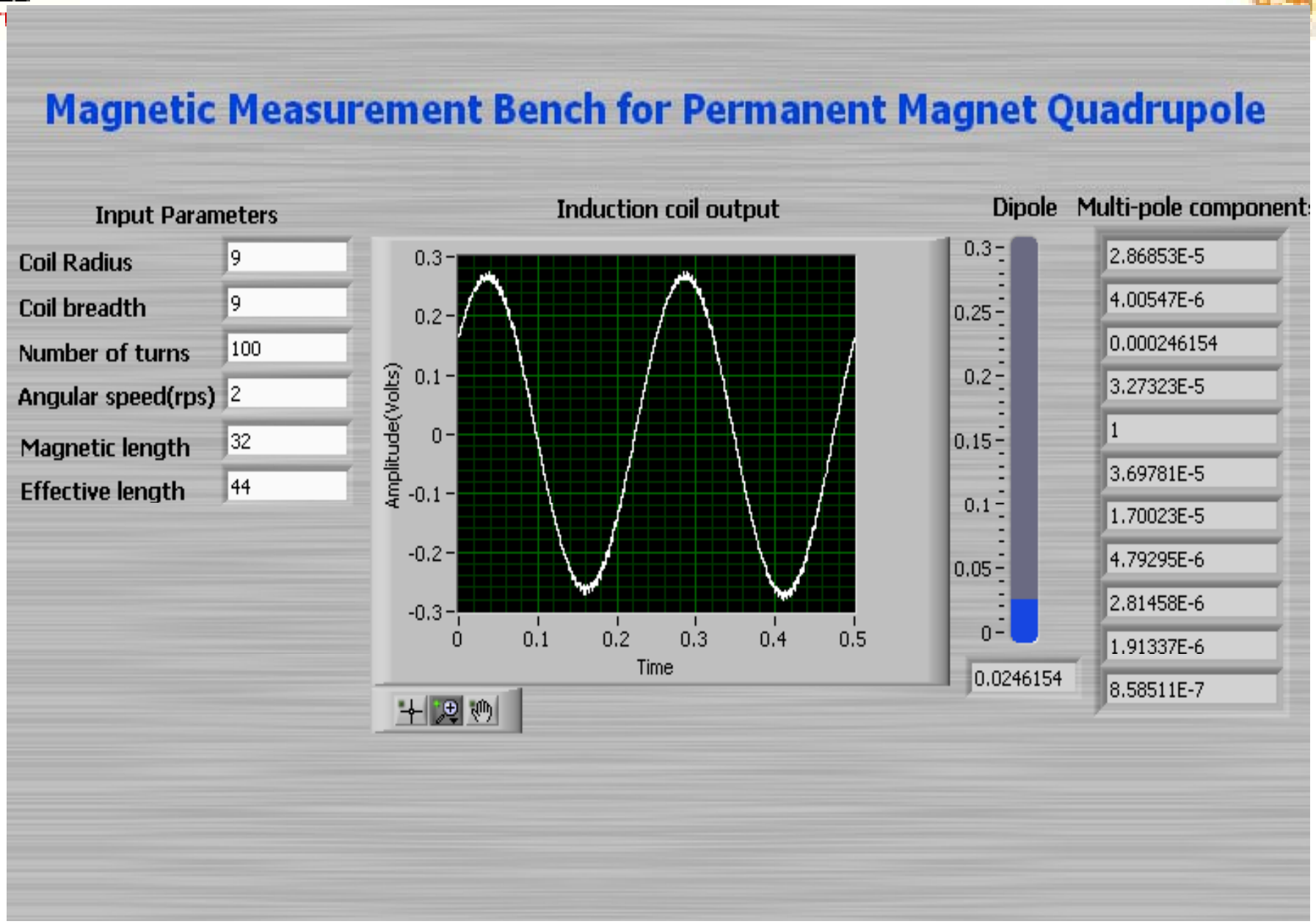
The Thermal-Hydraulics of the drift tube assembly



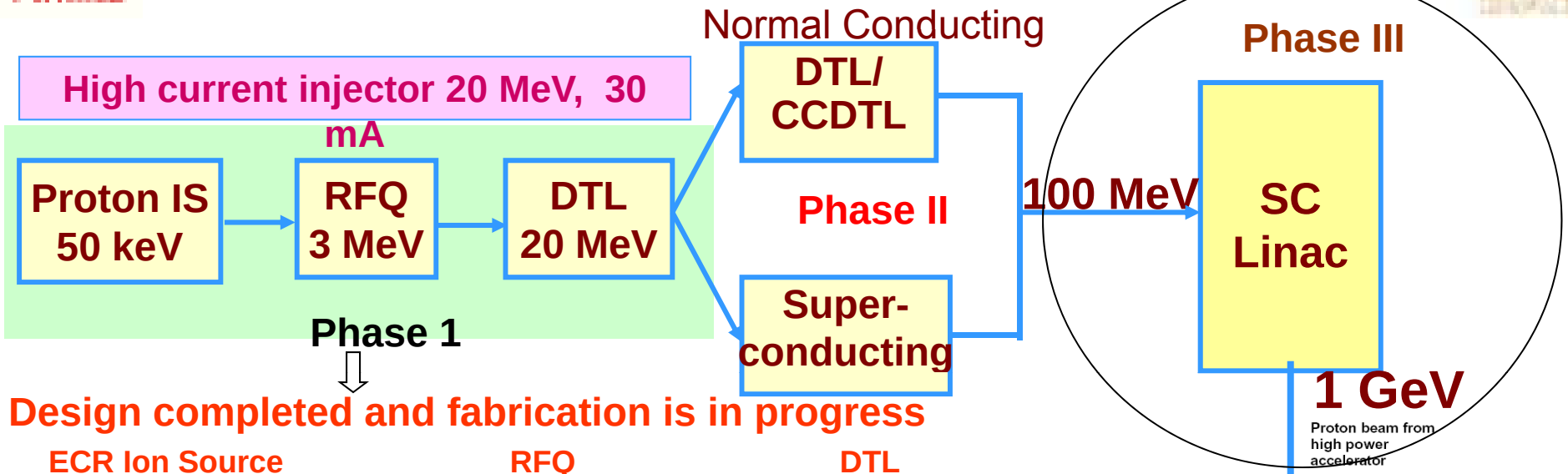


Magnetic Measurements Bench for field harmonic measurements on accelerator magnets

Field errors measurements using harmonic bench



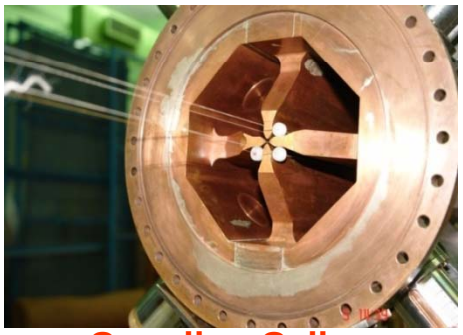
Scheme for Accelerator Development for ADS



Design completed and fabrication is in progress

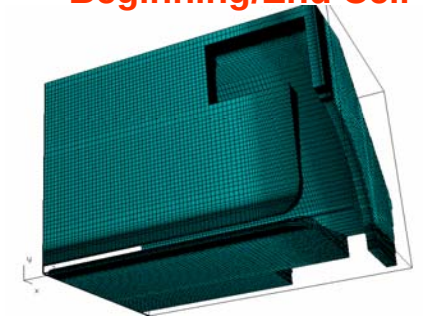
ECR Ion Source

RFQ



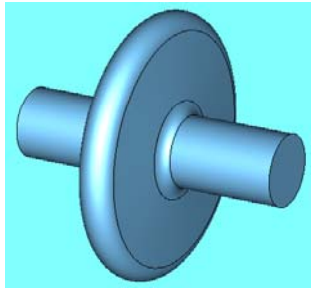
DTL

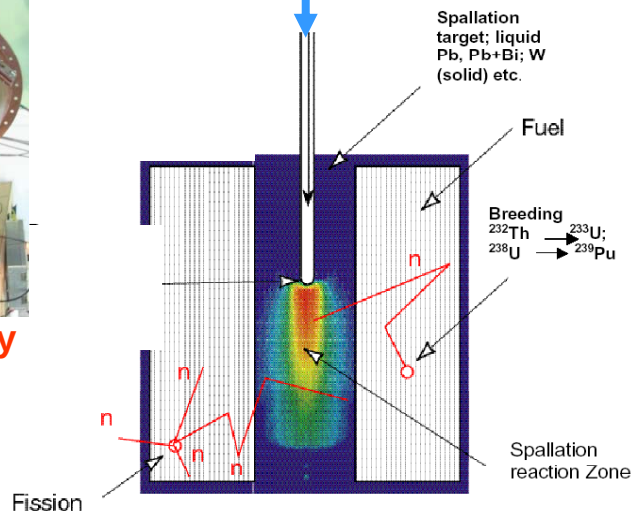
Beginning/End Cell



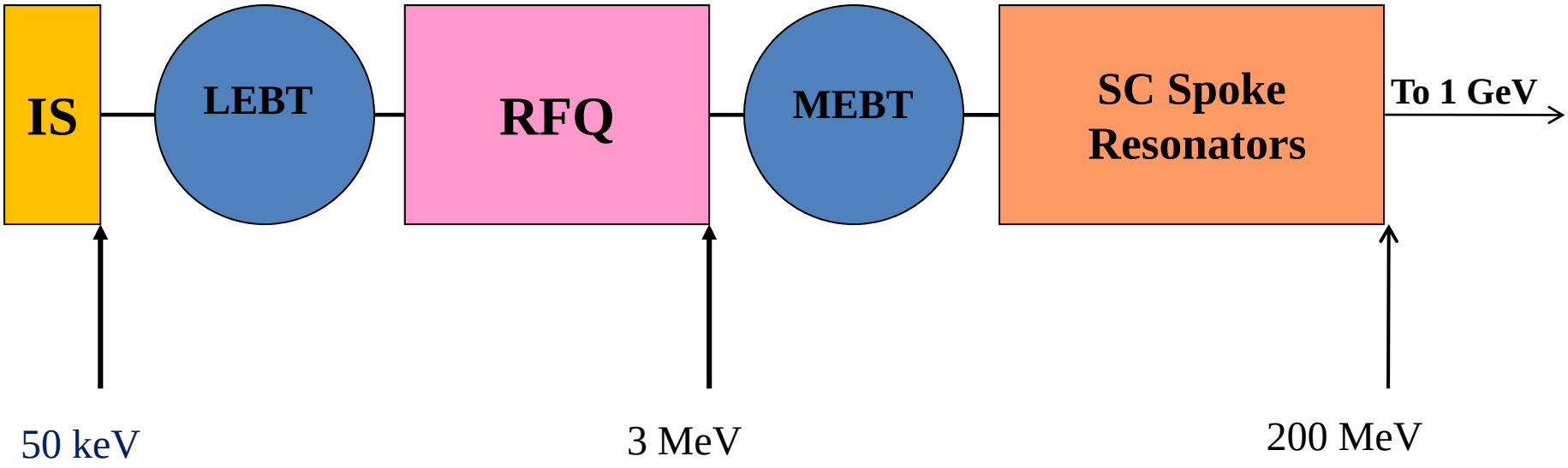
Coupling Cell

Elliptical SC Cavity





Proposed Layout of the 200 MeV Linac



Operating frequency: 325 & 650 MHz

Beam current: 30 mA

Spoke Resonators

Activities for IIFC at BARC

- Physics Design for Project X
- Cryo Module Test Facility (CMTF)
- RF Power Amplifiers
- Beam Position Monitor for HINS
- RF Coupler

Accelerator Physics issues

- **Design of the linac (Study several options & configurations)**
- **Beam Dynamics simulations with different codes**
- **Space charge & Halo studies**
- Error studies
- **HOM in Superconducting Cavities**
- **Microphonics**

Solid-State Amplifiers Development at 350 MHz

Under our departmental plan program, development of a Solid-State high Power Amplifier (SSPA) @ 350 MHz has been taken up.

Under this the following technologies are being developed

1. High efficiency rugged power modules
2. power combiners and splitters technology at different power levels and different number of ports
3. Development of protection and control for high reliability operation

700 W, 350 MHz Amplifier

- As an initial development phase , a solid-state power amplifier is developed by combining 4 modules up to 700 Watt. Its components are:
  a. Amplifier modules
  b. Power combiners /splitters

Test Results:

- Total no of modules: 4 +1 drive module
- Power Gain (1 dB) :19 dB
- Combined Power Output :700 w
- Band width (3 dB) : 7 MHz

Solid-State Amplifier Development at 350 MHz as our plan program

As a next phase, a 2 kW amplifier development is in progress.

Status:

- Water cooled assembly for 2 kW, ready
- Interlock circuit integrated
- DC Power supplies installed
- Recently, 4 RF modules combined to achieve 1000 Watt.
- Two such sets of 4 modules each, will be combined shortly

Water cooled Heat sink assembly

2 kW Rack Assembly

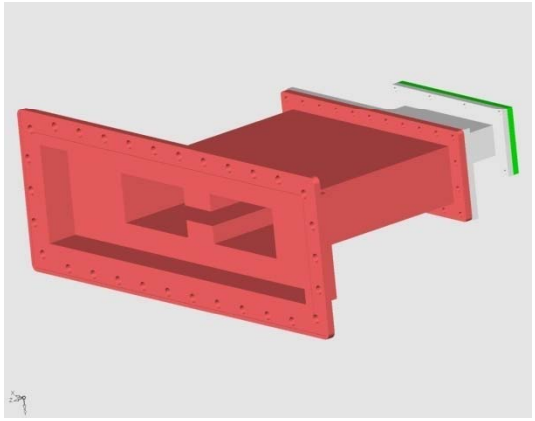
**** Almost same technology can be extended for 325 MHz Solid state RF amplifier development ****

RF Power coupler development for LEHIPA

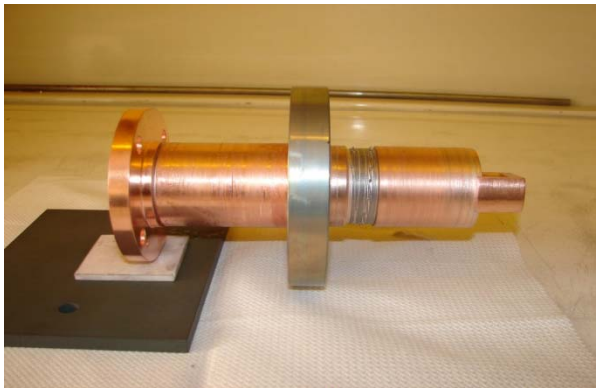
Present Status

1. Coaxial loop type coupler- 50 kW CW, 350 MHz (2 Nos. required) – *RF window and cooling circuit fabricated and tested for vacuum and water leak, complete assembly under fabrication*
2. 50 kW Pulsed Power coaxial loop type power Coupler- *fabricated and vacuum tested, RF Conditioning on test bench in progress*
3. Waveguide type iris couplers- 250 kW, 352.2 MHz (10 Nos. required)- *under fabrication*

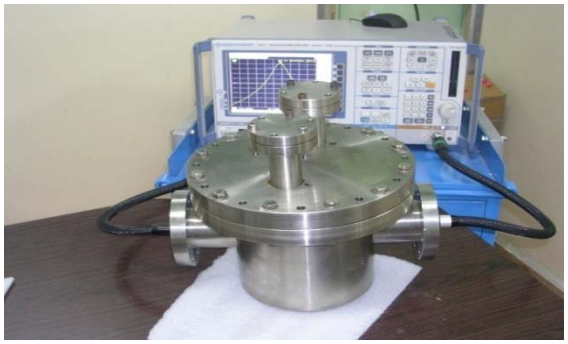
RF Couplers for LEHIPA



250 kW, 352.2 MHz waveguide ridge loaded iris coupler



50 kW, 350 MHz pulsed power coupler with integrated window



RF Test bench cavity for coaxial coupler testing

BARC's proposal for RF Power coupler development for Project-X

BARC will develop power couplers for 325 MHz spoke resonators of Project X (5 kW to 35 kW CW)

Beam Position Monitor

- Provides a measurement of beam position, also used for the measurement of phase and energy of the beam
- Coupling of RF field of the beam to the capacitive electrodes generates signals for deriving beam position
- Consists of sensor, front-end analog processing followed by digital processing and computer interface

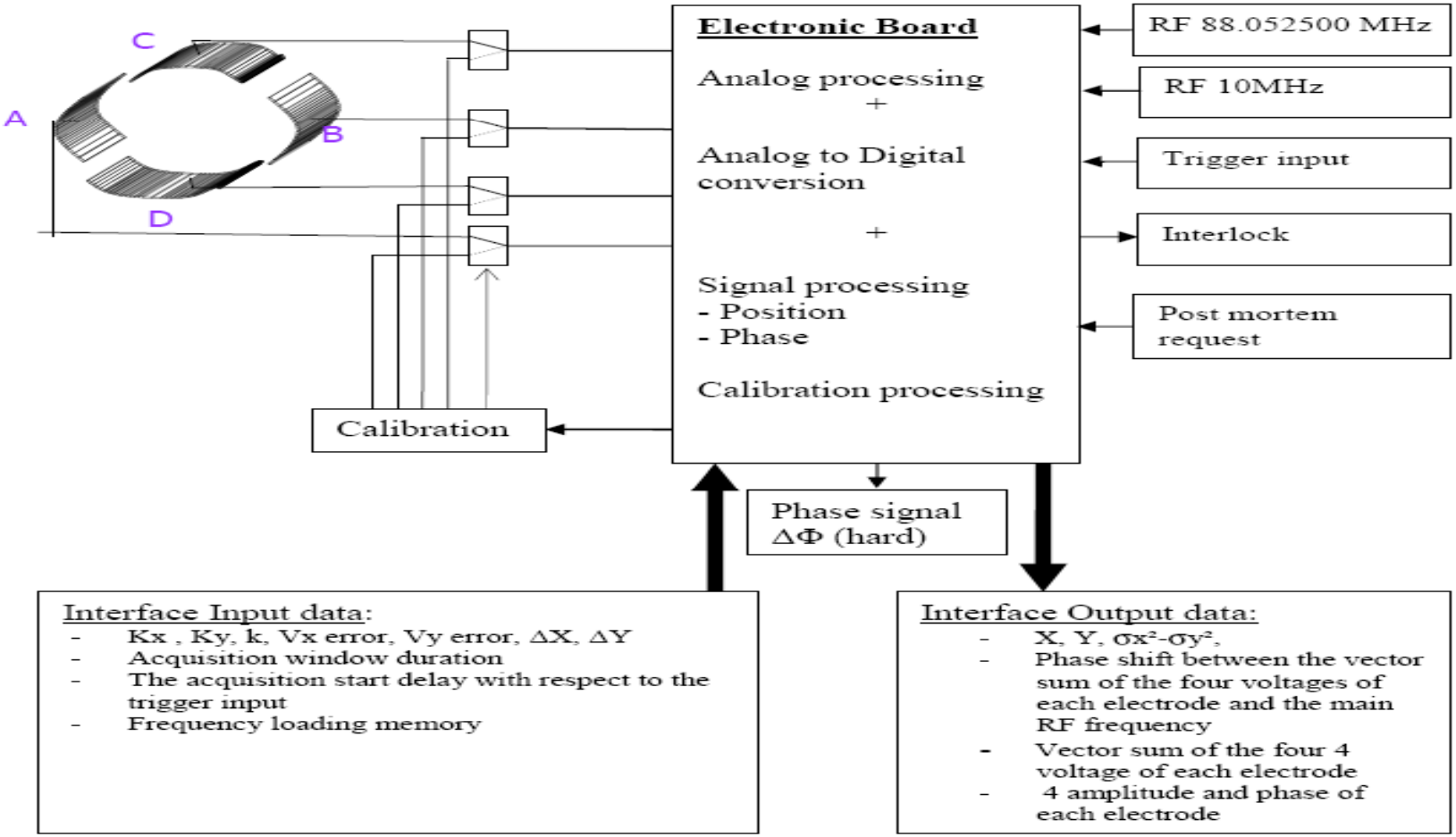
Beam Position Monitor

- Currently BPMs for Spiral2 (GANIL, France), LEHIPA under design and development
- Proposal to develop BPM for HINS (High Intensity Neutrino Source)
- Specification to be provided by Fermilab

BPM for the SPIRAL2 LINAC

GANIL (Grand Accelerateur National d'Ions Lourds) in Caen, France

- Specifications – GANIL
- Design and Development – BARC in collaboration with GANIL
- BPM Electronics based on VME Board (22 units to be supplied)
- MVME5500 , VxWorks6.8 , Spiral2 EPICS IOC, EDM GUI



GANIL (SPIRAL 2) BPM Design Issues

Processing frequency:

Fundamental – 88.0525 MHz
Ist Hamonic -176.105 MHz
Both on the same analog card

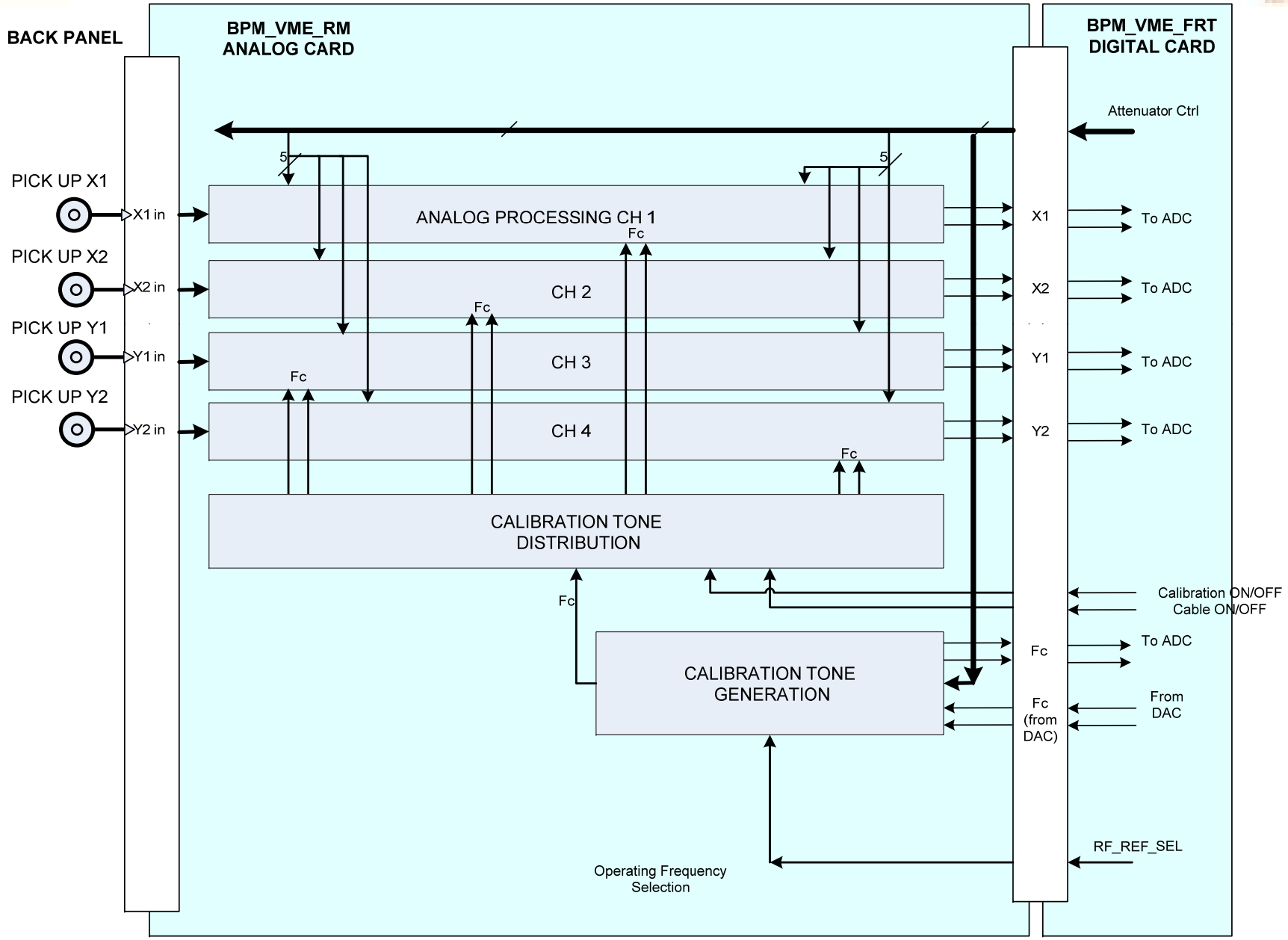
Beam Current: 150 micro-amp to 5 mA
Dynamic Range -
Weakest Signal - -63 dBm
Strongest Signal - -16 dBm
Sensitivity (min.)– 1.4 dB/mm
Additional Measurements – Individual Phases,

Resolution 50 microns
Measurement Time 15 μs
Operating Temperature 15^0 to 35^0 C

an electronic system system based on offset tone based gain equalisation with gain switching in analog channels proposed

BPM for the SPIRAL2 LINAC

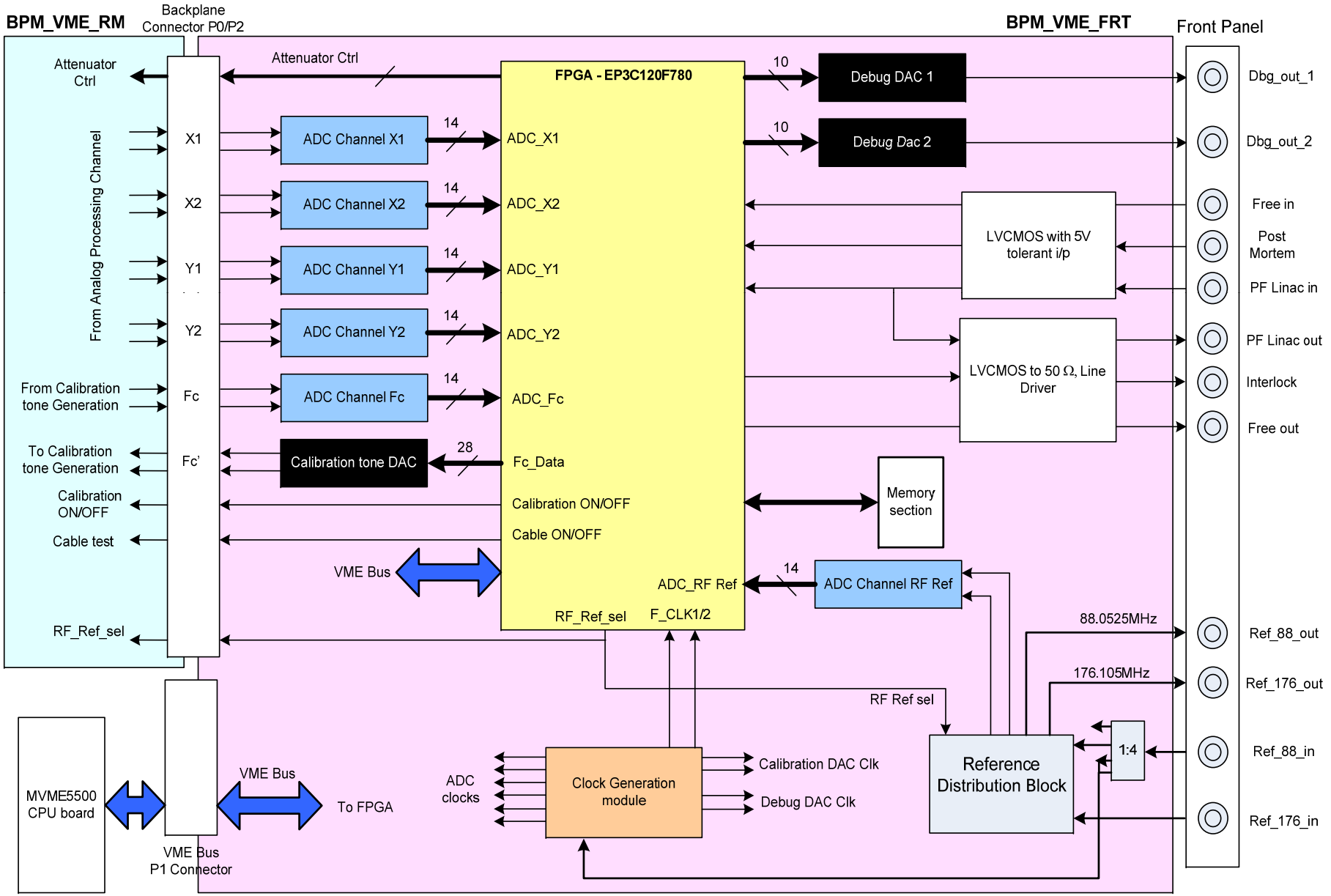
Proposed Design: Functionalities on Analog Card



BPM for the SPIRAL2 LINAC

Proposed Design: Functionalities on Digital Card

Block Diagram of Digital board (BPM_VME_FRT)



SOFTWARE DEVELOPMENT FOR SPIRAL2 GANIL

- Instrument Front End : VME with MVME 5500CPU
- Software Environment at Instrument front End : EPICS IOC on VxWorks
- Operator Front End: EPICS over Linux , EPICS edm GUI
- Epics CA server on VxWorks to access VME Hardware

BPM for LEHIPA

- Frequency – 352.52 MHz
- Architecturally similar to GANIL BPM–except additional down-conversion
- Presently under design phase – design of BPM for HINS will follow a similar approach.
- A good amount of documentation received from Fermilab on BPM electronics for ATF damping ring – very useful for HINS and LEHIPA

Cryo-module Test Facility (CMTF)

- Cryo-module Test Stand (CMTS)
- LLRF Control System
- RF Protection Interlock System
- Cryogenic Temperature Monitoring System
- CMTF Control Software in EPICS (interface to ACNET to be provided by fermilab)

Under Project X of IIFC CDM (BARC) is involved in Development of Cryo-Module Test Stand (CMTS) for Fermi Lab

Cryo-Module Test stand (CMTS) is used for functional testing of SCRF Cavities & also Cryo-Module. For this CMTS provides the necessary facilities for maintaining the 2K temp around the SCRF Cavities, which are held in particle free UHV condition.

CMTS consists of following five sub-assemblies:

(a) Feed box with transfer lines.
(b) Feed Cap with transfer lines.
(c) End cap with transfer lines.
(d) Transfer line
(e) Mechanical structure with alignment facility for supporting & aligning the Cryo-Module.

CMTS contd.

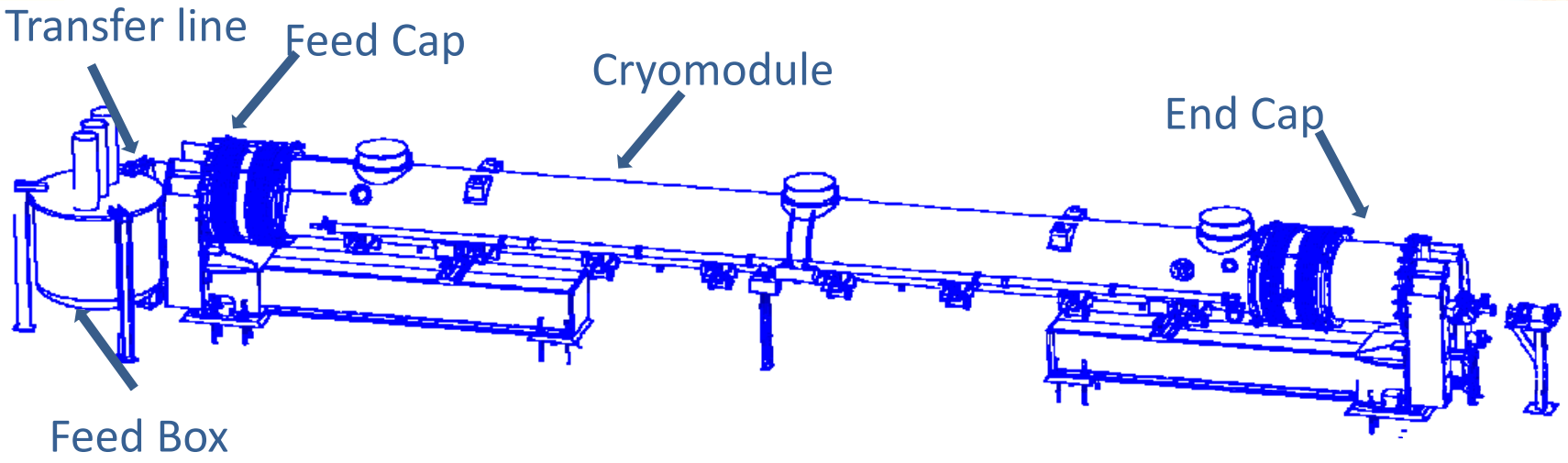
Out of five Sub-assemblies, CDM has started working on the design and drawing work of following three sub-assemblies:

(a) Feed box with transfer lines.

(b) Feed Cap with transfer lines.

(c) End cap with transfer

Conceptual Arrangement of Feed Box, Feed Cap, End Cap & Transfer Line



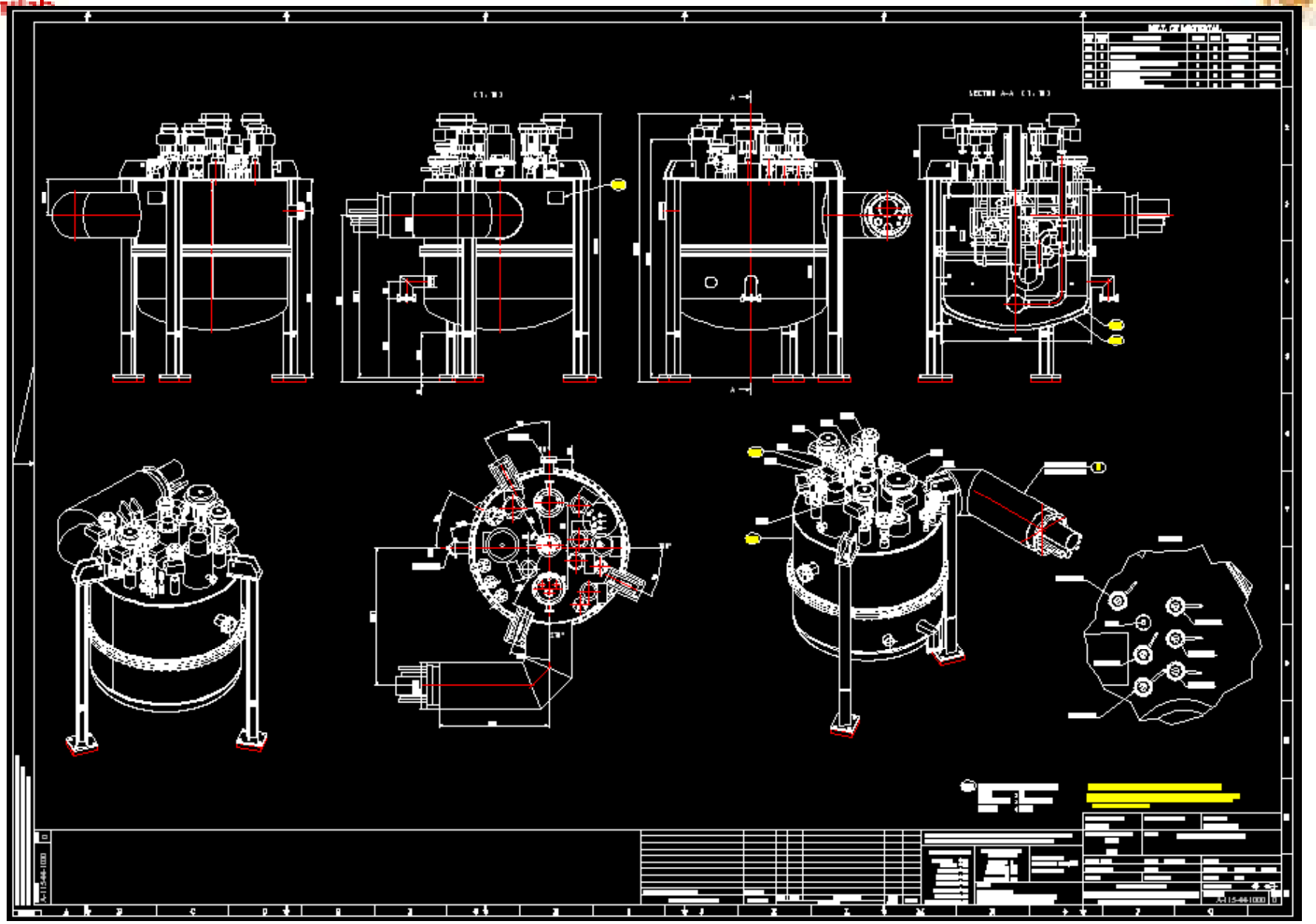
CMTS End View

CMTS View from Feed End

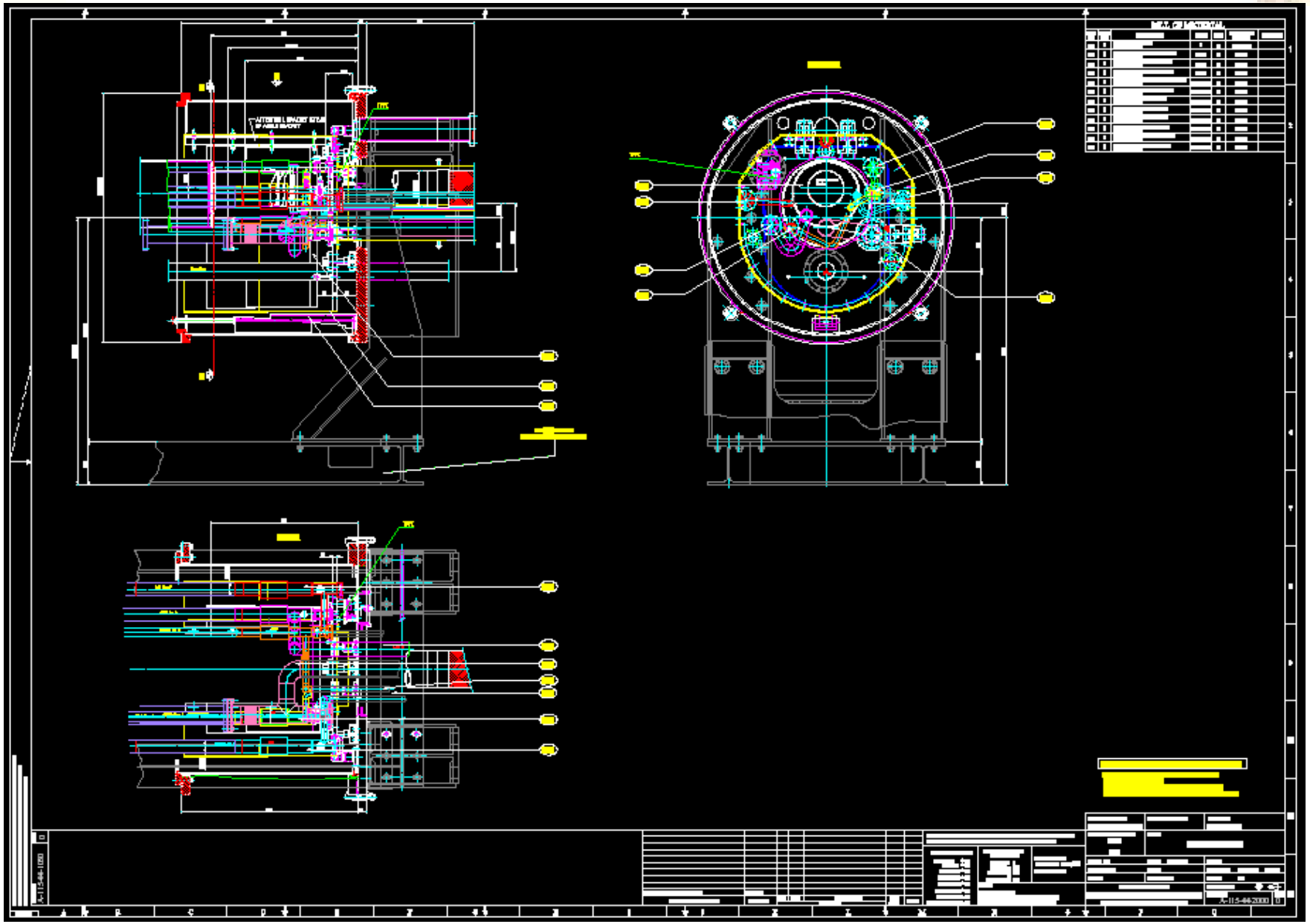
Cryo-Module Test Stand at DESY

CMTS Outer Bellows pulled back to access piping

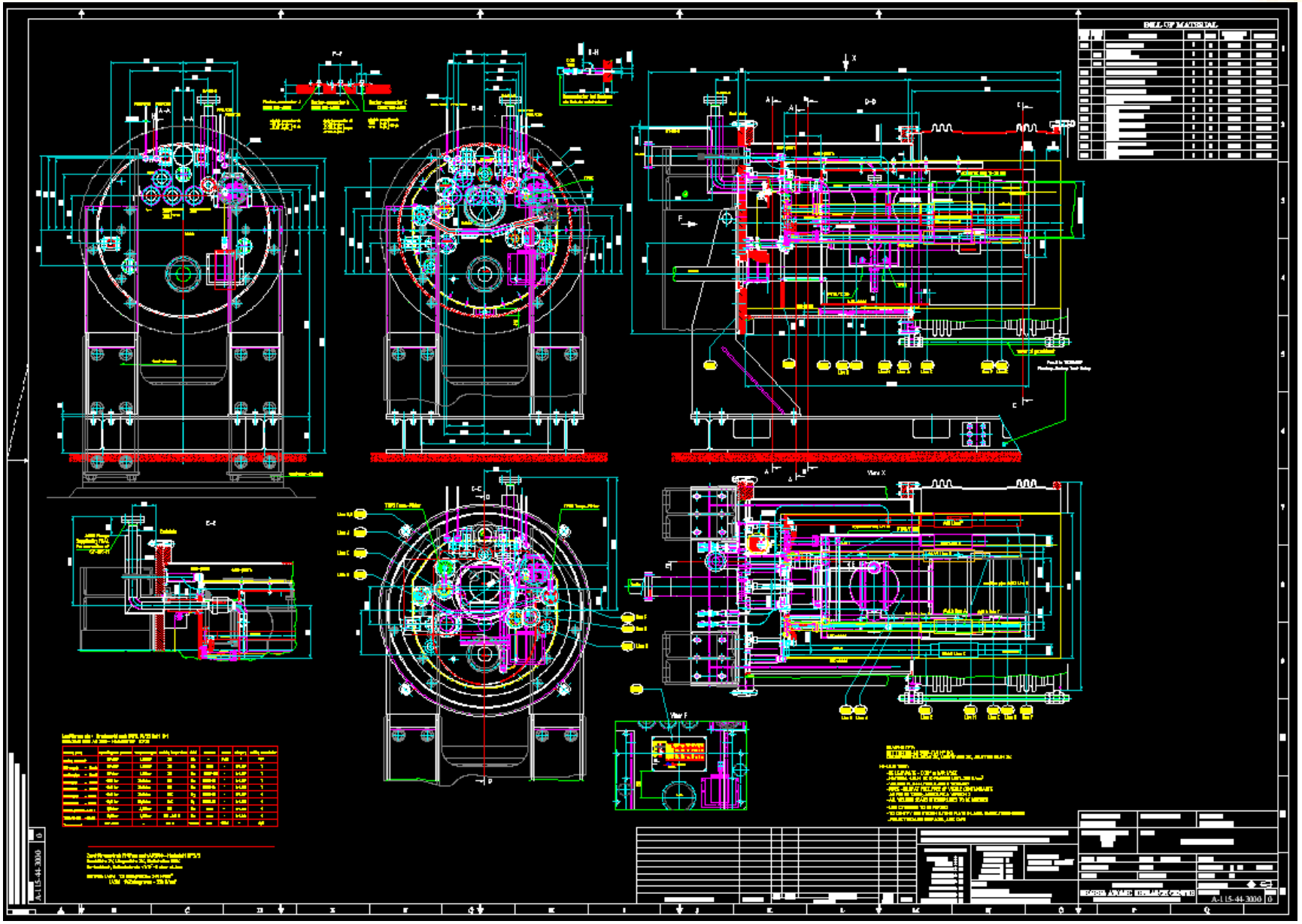
FEED BOX ASSEMBLY



FEED CAP ASSEMBLY



END CAP ASSEMBLY



STATUS of present work at CDM

Completed activities:

- Assembly Drawings (2D) of all three systems were completed.
- Sub-assembly Drawings of all three systems were also completed.

Design & detail Drawings of all three sub-assemblies are under preparation:

- 90 % German drawings of CMTS were translated into English.
- 70 % of the lists of Bill of materials were translated to English, remaining BoM lists are not clear. Preparation of Bill of Materials (where ever clear to us) are under progress.
- 70 % of Detail drawings are also completed. Preparation of 3D drawing (Solid modeling), for better understanding, are under preparation.

CMTS - Points Which Are Not clear

Points Which Are Not clear:

- Some of the drawings are not clear.
- Some of the items in bill of materials are given in code word, hence not clear.
- Function of each Sub-Systems is not clear.
- Pipes & tubes sizes are not as per standard. Decision is to be taken about the sizes of pipes & tubes.
- Cryogenic circuit & about the flow rates of Cryogenic fluids are not clear.
- Sensors & Instrumentation parts are not clear.

CMTS: Requirements for better understanding

- A dedicated multi disciplinary (Mechanical, Cryogenic & Instrumentation) team of working engineers need to be made.
- Exposure to complete working System at Fermi lab is needed.
- Good communication system (Video conference) with Fermi lab is needed.

Work Content

- Procurement of raw materials & standard items, including instrumentation also.
- Detailed manufacturing drawings of all sub-assemblies & components for manufacturing.
- Finalization of inspection & testing stages (weld test, vacuum test, cryo-tests etc).
- Manufacturing & Assembly of sub-systems. Functional testing of each sub-systems. (If it does not meet the requirements, necessary modifications are to be done to meet the final requirements).
- Assly of the system, inspection & final functional testing of the complete system.
- Dismantling, packing & shipment to Fermi Lab. Installation of CMTS at Fermi-Lab.
- Installation of Cryo-Module on CMTS at Fermi-Lab for further testing.
- Final functional test with Cryo-Module at Fermi lab.

LLRF Control System

Low Level RF Control System

- Stabilization of amplitude and phase of RF field in the resonator as per set points
- Performs resonant frequency stabilization, Pulse conditioning and Testing of Resonators
- A number of systems developed for India BARC-TIFR LINAC, IUAC LINAC, 400 keV RFQ and Australian National University LINAC.

BARC-TIFR Super-conducting LINAC

Based on signal processing in analog domain

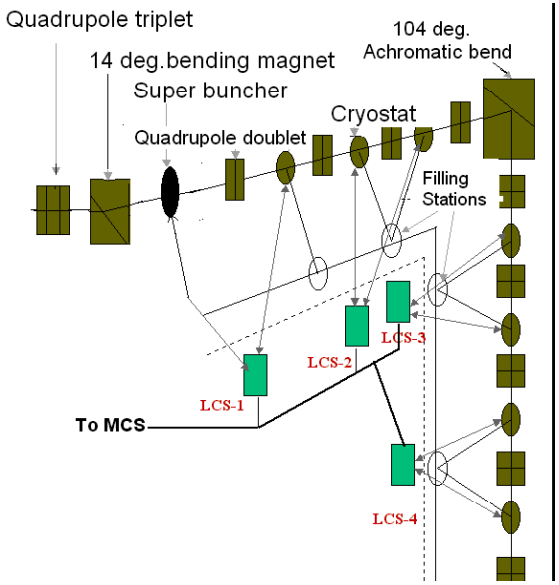
Resonator Controller

Input Module

RF Multiplexor

Reference Splitter

Some of the RF signal processing modules



Architecture of Computer control

Instrumentation Racks at TIFR

RF Control - signal processing in digital domain

single channel system

Four Channel System: Digital Processing Card

Features:

High speed High Density FPGA

Fast ADC –14 bits,105 MSPS, 4 nos

.

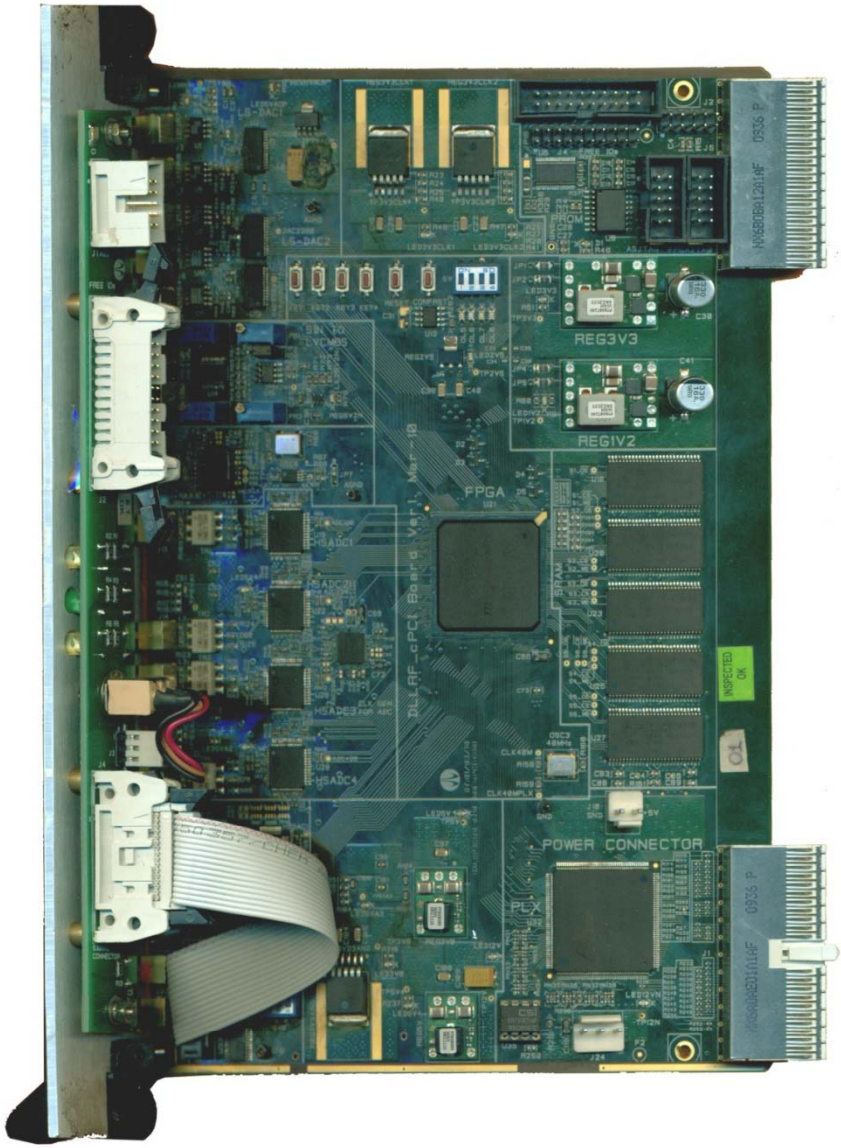
Fast DACs –14 bits, 300 MSPS, 2 nos

Slow DACs –Dual,40 MSPS,10 bits, 3 nos.

Clock Generation – PLL synthesizer

Memory – 1 MB, 6 nos.

cPCI Interface



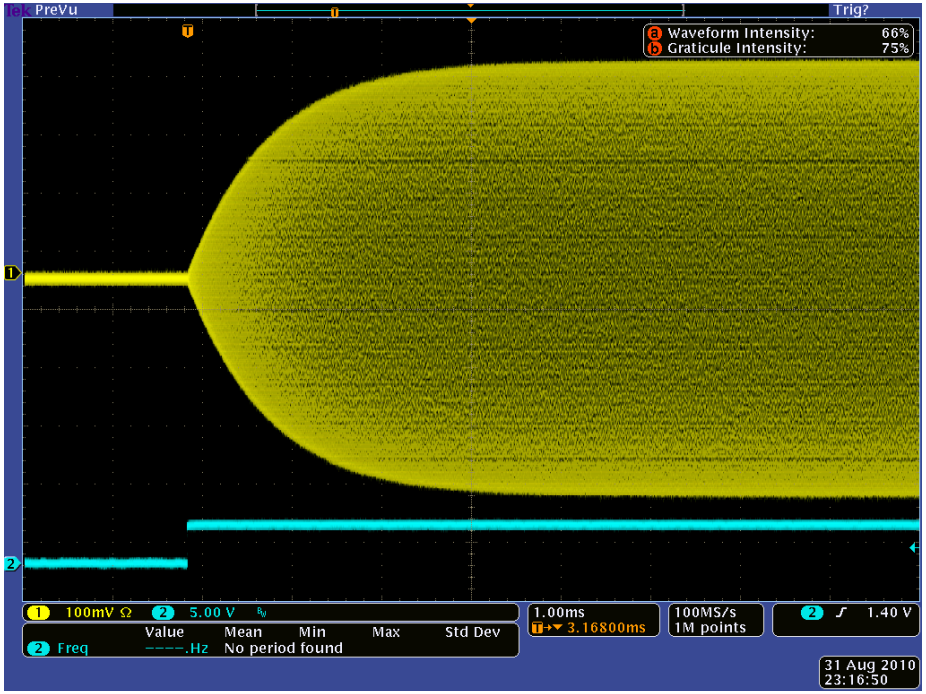
DLLRF board in Compact PCI chassis

Testing at TIFR – free running Digital SEL

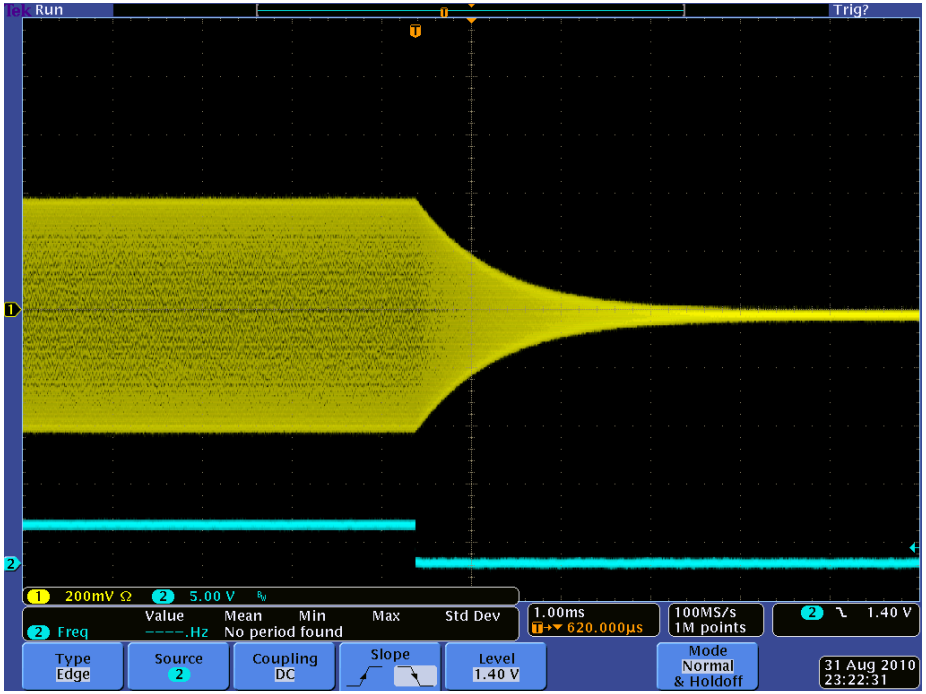
Operating quality factor: 5×10^5 , Low Field Operation

Very smooth operation

Oscillations initiate from the noise in the circuit



Turn-on transient



Turn-off transient

LLRF Control System for Fermilab

- VXS based system with VxWorks Real Time O.S.
- Requirements to be provided by Fermilab.

RF Protection Interlock

- RF protection Interlocks system switches off the fast RF switch connecting the LLRF output to the klystron/IOT based RF amplifier under fault conditions.
- Interlock to prevent power mismatch, sparks, over-voltages, etc. in the high power RF distribution system between transmitter (klystron, IOT) and cavity input coupler.
- Real time system based on VXS with Vxworks OS.
- Documents received under study. Fermilab to provide specifications .

Cryogenic Temperature Monitoring System

- Sensors to be provided by fermilab
- Continuously monitors the temperature at different point
- Provides interlock and alarms
- VXS based System with Vxworks OS
- Some documents already received from Fermilab – under study

CMTF Control Software

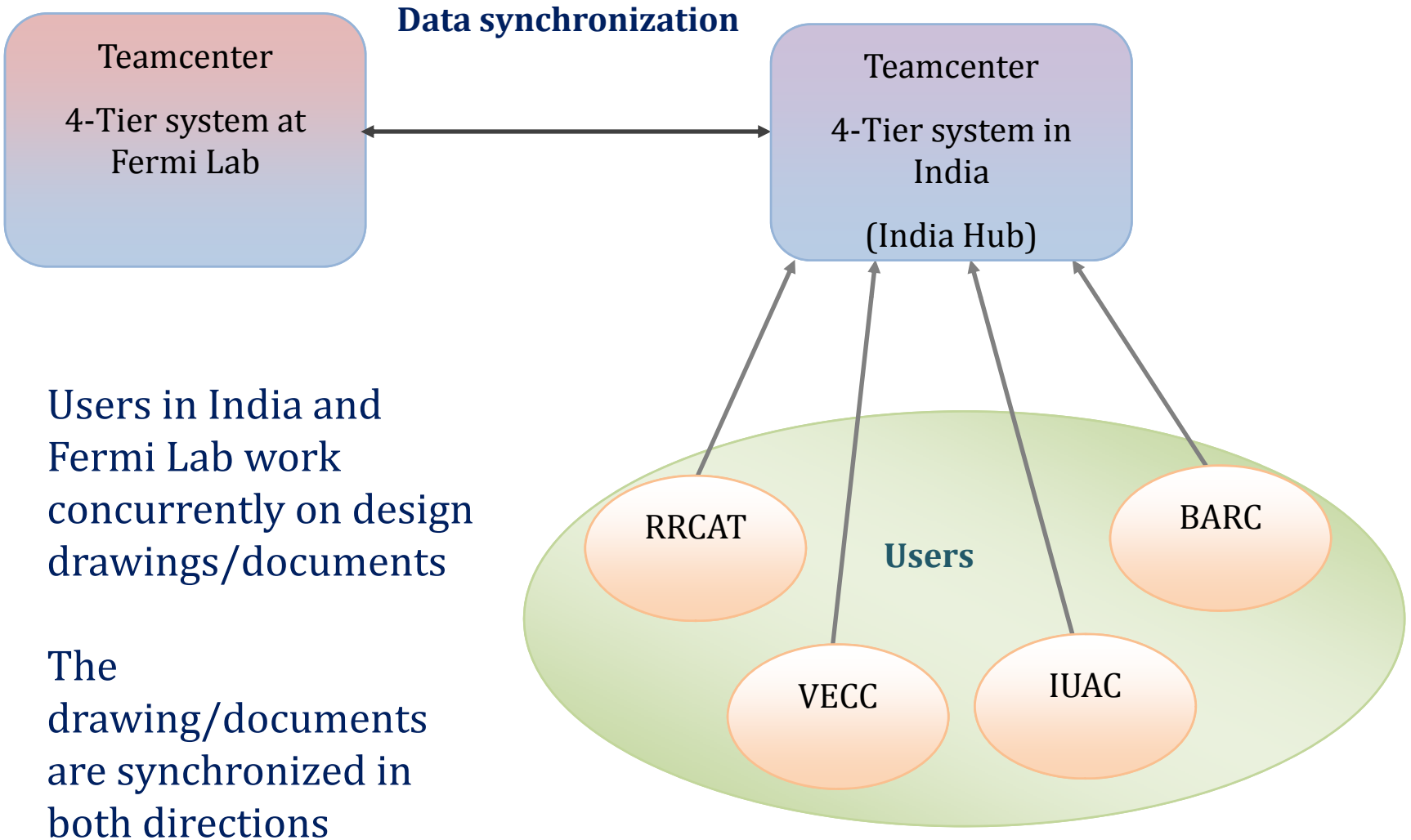
- EPIC Based Software which provides display of various parameters and facility to modify operational parameters.
- Trend, History
- Alarm messages, Diagnostics
- Interface to ACNET to be provided by Fermilab

Teamcenter Engineering Data Management System (EDMS) for IIFC

Introduction

- Fermilab along with members of India-Fermi lab Collaboration (IIFC) would like to setup Teamcenter EDM multisite system in India to aid sharing engineering work, to promote better communication and to allow concurrent engineering.
- The plan is to use the Fermilab Teamcenter as the primary site, implement multisite setup with a hub in India and have all institutions log into this hub to access engineering data.

Proposed architecture



Users in India and Fermi Lab work concurrently on design drawings/documents

The drawing/documents are synchronized in both directions

Status

- A meeting was held on 30.10.2010 in India to discuss technical and logistic issues. It was attended by Mr. A.G. Apte and Mr. C.S.R.C. Murthy from Computer Division, BARC and Mr. Rich Stanek from Fermilab.
- Later, status updates were exchanged over email and over webex meetings.
- BARC has forwarded technical queries to Siemens India team (Mr. Sampat Sridhar and Mr. Ashok Natarajan) and got replies.
- As per Siemens, multi-homing (multiple network interfaces in the same system) is not supported by Teamcenter. As we expect the server to be accessible from multiple networks, an alternate network plan requires to be made.

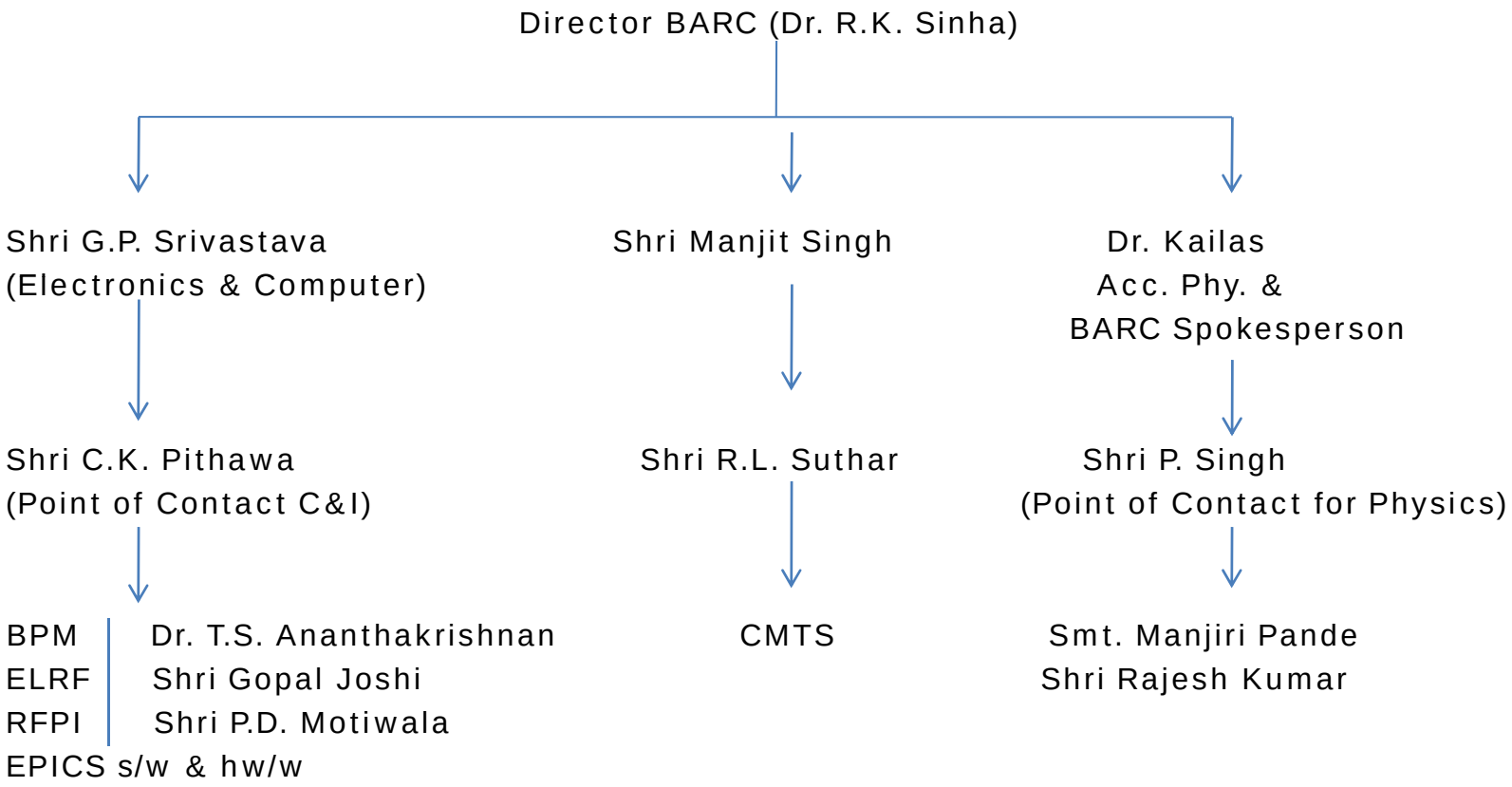
Status

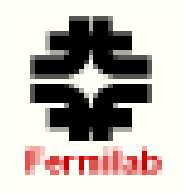
- For the setup, hardware like servers, SAN/NAS storage systems, backup storage systems and software like Teamcenter collaboration suite, Oracle database server etc are required.
- A meeting of collaboration partners needs to be arranged for assigning procurement, commissioning and operation & maintenance responsibilities. This includes identification of location.
- Outsourcing the setup, operation and maintenance of Teamcenter hub to M/s CSC, Bangalore, India would also be considered as an option.

Mode of Working - IIFC

- The Detailed Specifications will be prepared jointly with Fermi lab & time schedules will be worked out.
- Fermi Lab has know-how and expertise for the systems under collaboration.
- Experienced engineers from BARC to join Fermi Lab, understanding of the technologies involved.
- Systems can be tested at Fermi lab/BARC

ORGANISATIONAL CHART FOR IIFC





THANK YOU