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Development of Superconducting Cavities & Associated Technologies at RRCAT

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Outline

- Motivation for SCRF R&D Activities
- Major Objective under the Plan Project
- Cavity Design simulation and Measurement setup
- Facilities planed
- Collaborative Activities

Motivation: Link to Major Programs (Domestic and International)

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1. **Development of SCRF Science and Technology,** including setting up **facilities useful for High Energy Accelerators**
2. **Indian participation in ILC/XFEL/Proton Driver**
3. **Superconducting Materials R & D** for SCRF cavity related research.
4. **Application of SCRF** in Accelerator Science and Technologies, including development of an infrared source to give coherent radiation at wavelengths down to ~30 microns, using a superconducting post-accelerator.

Project Objective

- Technology development and setting up of an infrastructure for the SCRF cavity fabrication, chemical processing, cleaning, assembly and testing at required accelerating gradient for accelerator applications like XFEL, SNS, ERLs etc.
- Establish Cryogenic Infrastructure to operate large systems
- Experimental research in bulk and thin film superconducting materials from the point of building accelerating cavities with high gradient and high quality factor.
- Exploit SCRF technology for building an infrared source providing coherent radiation at wavelengths down to around 30 microns, using superconducting post-accelerator.

Methodology for Development of SCRF Cavity

- Design SC-RF cavity structures + beam physics.
- Fabricate SC-RF cavity structures & also try new designs.
- Establish facility for Chemical and thermal treatments of SC-RF cavities .
- Evaluate and characterize superconducting materials.
- Establish Cavity testing & characterization facility
- Study Surface science of superconductors; New materials for SCRF Cavities.
- Pursue R&D in cryogenics & RF aspects.

Characterization of Prototype Cavity in Copper

- EM Field Simulation of Single Cell Cavity
- Bead-pull setup
- Frequency and E Field measurement of single cell cavity

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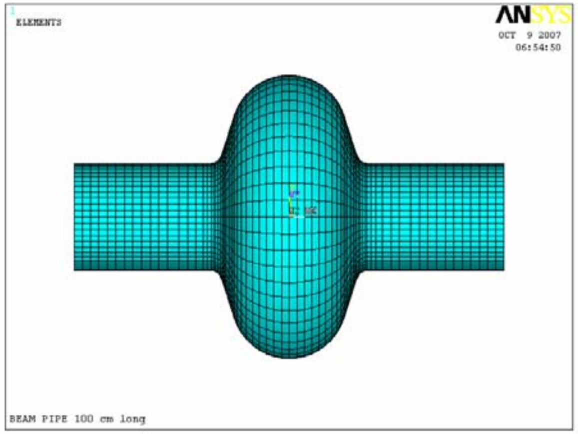
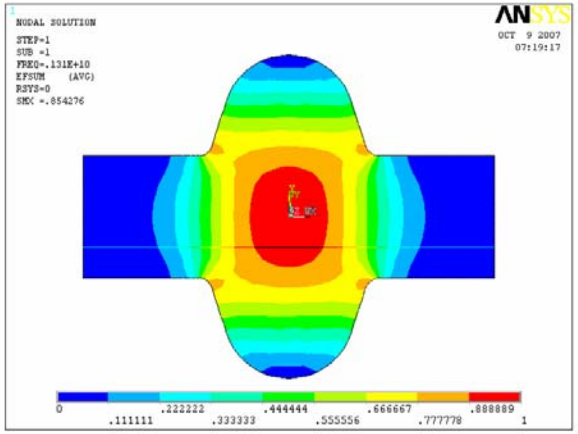
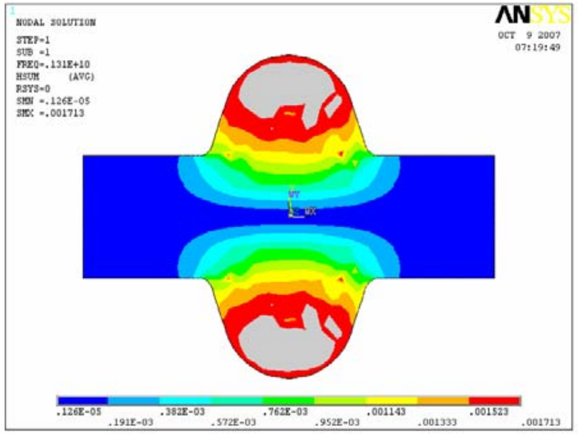
Simulation of Single Cell SCRF Cavity

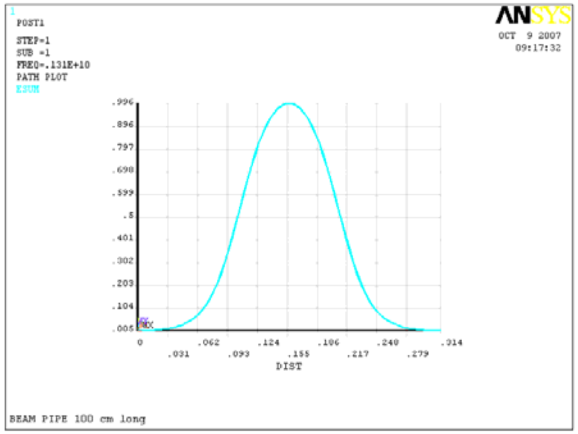




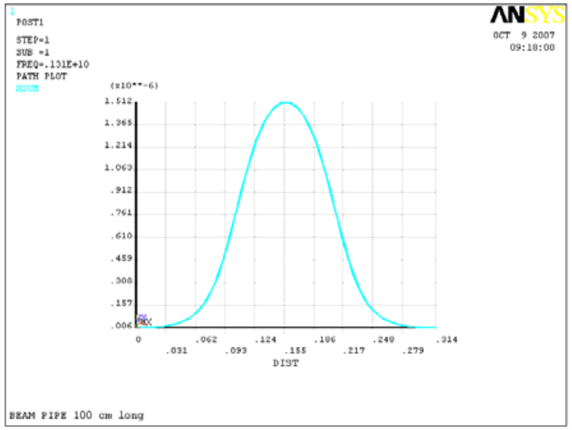
Electric field along the axis



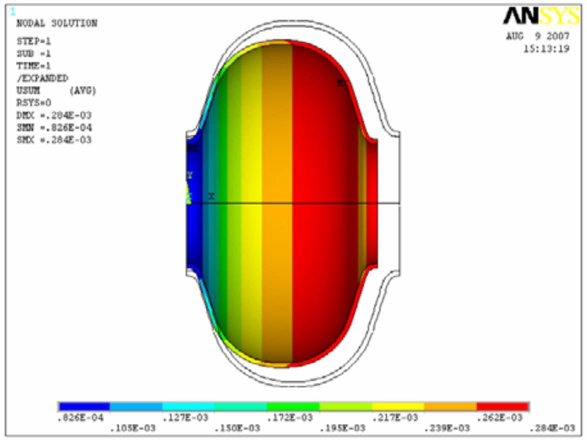
Magnetic field along the axis



Electric field along the axis

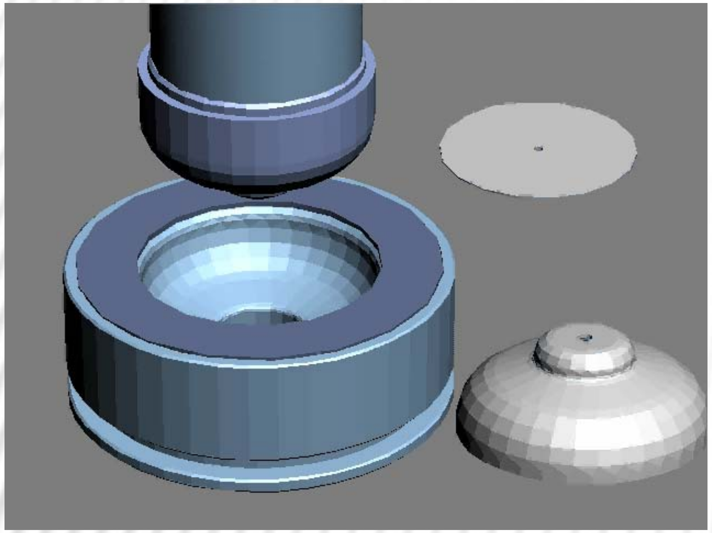


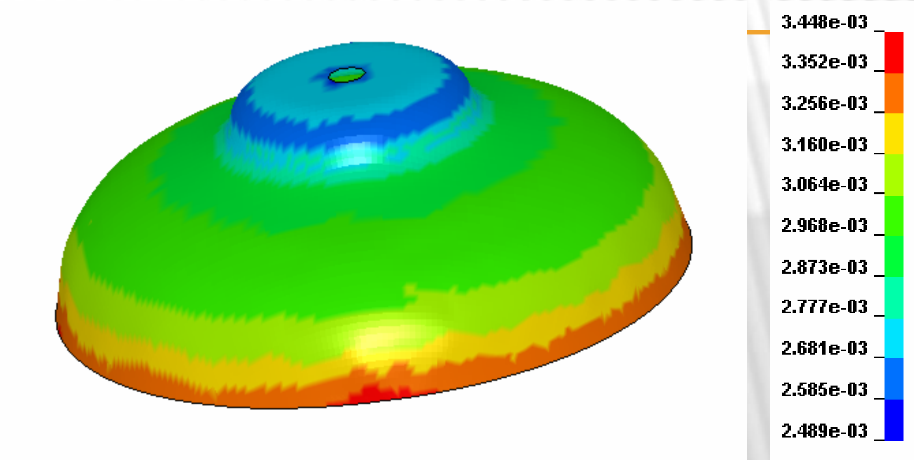
Magnetic field along the axis



Cool down from 300 -2K

Forming Simulation of Half Cell



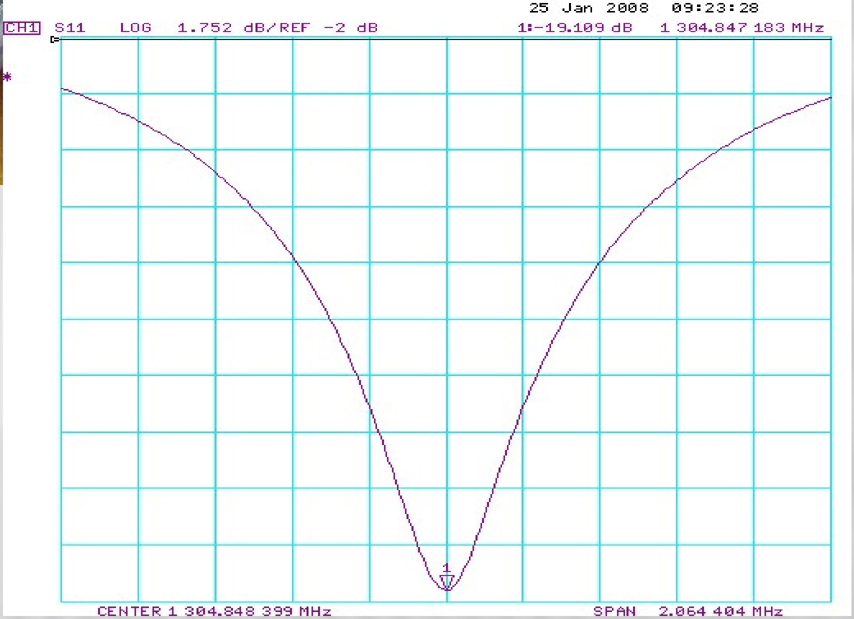


Half Cell with beam pipe & Flanges

Single Cell Cavity Assembled with beam pipe & Flanges

Bead Pull Measurement Setup with Single Cell Cavity

Frequency Measurement



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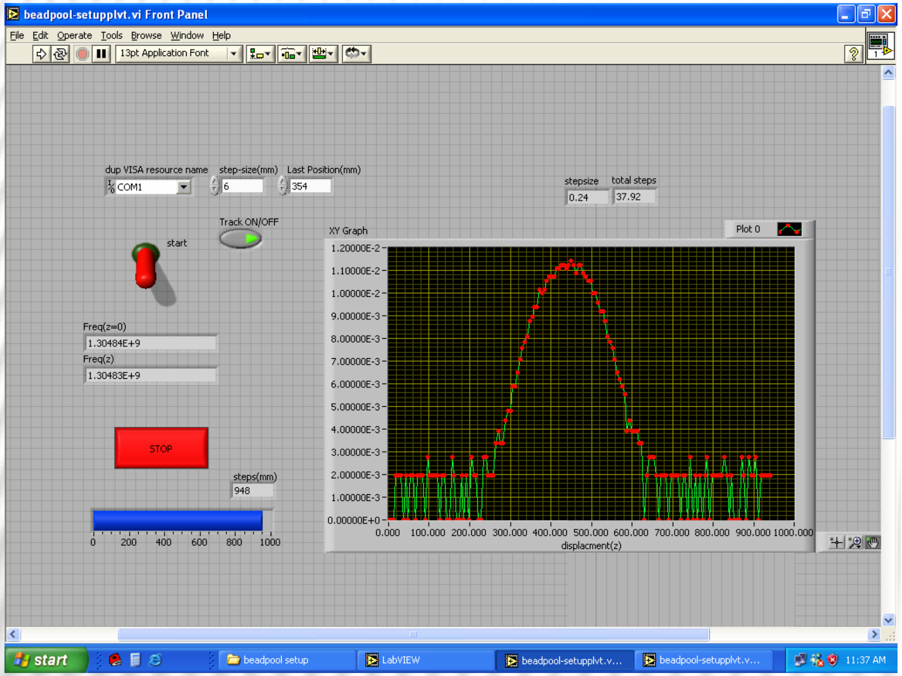
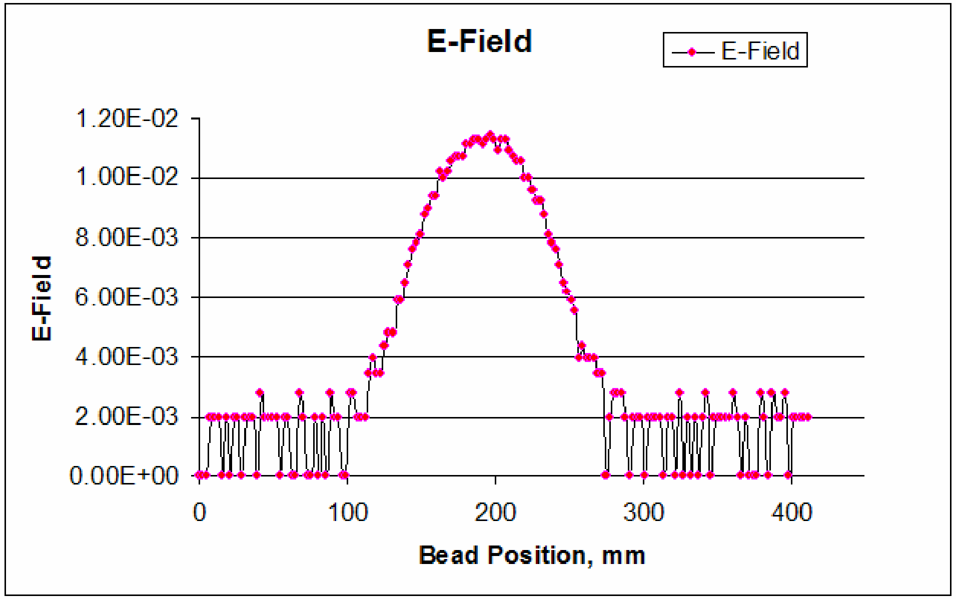
Bead Pull Measurement Program





Screen Shot

Plot of Measured E-Field distribution in the Single Cell Cavity

New Facilities Planned at RRCAT

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Setting up of SCRF cavity fabrication (120 Ton Hydraulic Press, Facility for Nb machining, EBW Machine etc.),

Chemical & thermal processing facilities (EP/BCP/CBP, HPR & Annealing Furnaces etc.),

Assembly & testing set up. (Clean-room, Test cryostats, RF sources etc.)

Cryogenic infrastructure, (Bigger Liquid He Plant, Liquid N2 Plant and Accessories for Larger Cryogen & Gas Handling Systems etc.)

Experimental facilities for superconducting materials research. Add to presently available (magnetic, electrical & thermal conductivity measurements)

Facility to support cavity design, fabrication & processing (UTM, CMM, SIMS, Eddy Current Scanner etc.)

Building Plan for SCRF Cavity R&D

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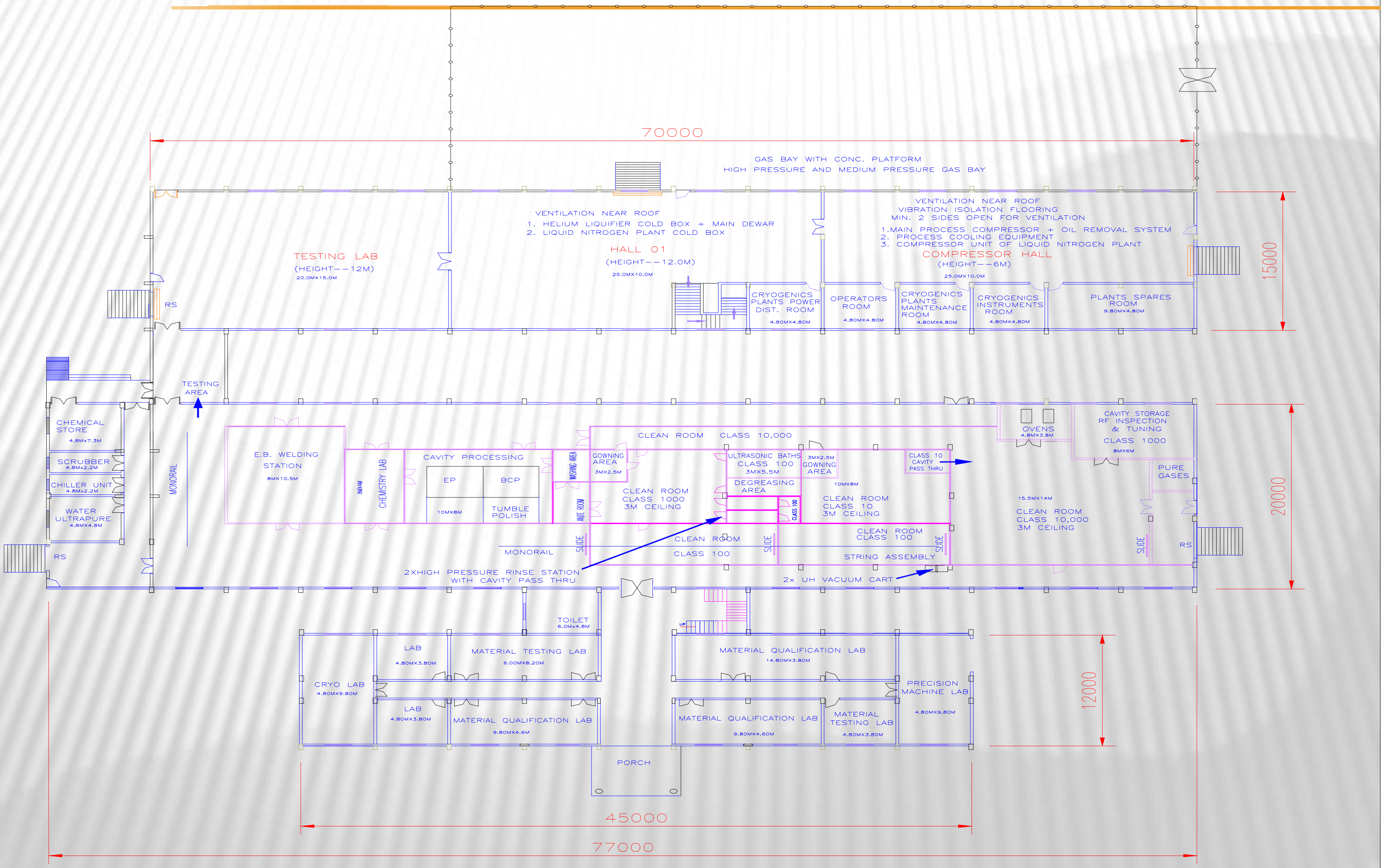

Proposed Clean Rooms for Superconducting Cavity R&D

Proposed Clean Rooms

- A set of 4 clean rooms are planed as a part of Superconducting cavity processing and assembly facility.
- Clean rooms will be as per FS-209E/ISO standard
  - Class 10000 General assembly area,
  - Class 1000 Ante Clean room and
  - Assembly clean room divided in Class 100 and Class 10.

  The division between class 100 and class 10 area will be with plexiglas panel divider from ceiling, as short as possible to permit easy access between the adjoining areas of class 100 and class 10.
- The sizes indicated for the clean rooms are tentative.
- Federal Standard FS-209E/ ISO classification system or equivalent will be used for the clean room class specifications.

- The temperature & relative humidity inside the clean room shall be regulated through the use of a clean room compatible HVAC system. The temperature shall be controlled at 21 degree C(+/- 1 degree C) and relative humidity at 50% (+/- 5%) .
- Air circulation for all rooms shall have air flowing directly to the clean areas from ceiling mounted Fan Filter units. Air shall be returned from the rooms through air return units mounted on side walls under the raised perforated floor. Laminar (unidirectional) flow shall be established from the ceiling to the perforated floor of the clean rooms.
- Pressure differential shall be maintained between different class of clean rooms. The class 10 area will be at higher pressure (~10Pa) relative to the building ambient.
- The maximum air velocity shall not exceed 1200 fpm.
- To prevent charge buildup & resultant particle attraction , static dissipative floor, wall and door materials shall be used in the clean rooms.
- The building Floor will be epoxy coated concrete slab.
- Height of clean room required is 10 ft (~ 3 meters) except HPR, degreasing area and Ultra Sonic bath (~4.5 m).

CLEAN ROOM FACILITY

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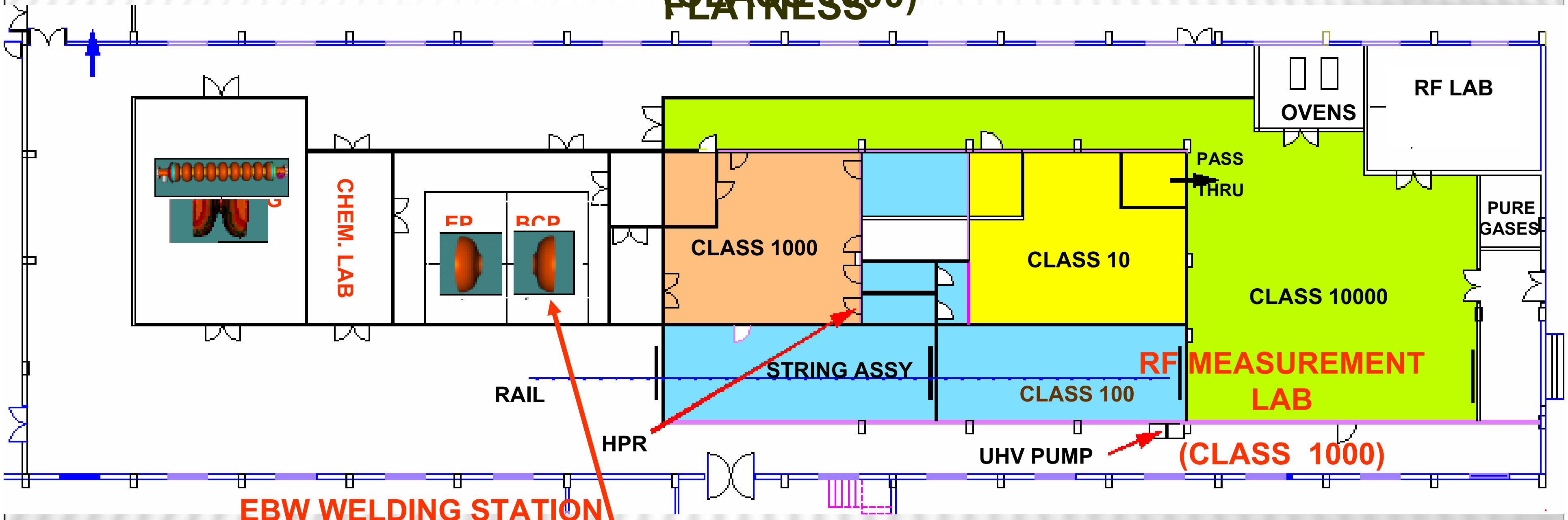

EBW WELDING STATION

CAVITY PROCESSING AREA

Proposed Clean Room Facility	
Class-10	80 sq m
Class-100	120 sq m
Class-1000	130 sq m
Class-10,000	230 sq m

HYDRAULIC PRESS

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<u>CAPACITY</u>

MAIN RAM : 120 TONS

MAIN RAM STROKE : 400 MM

DIE CUSHIONING: 40 TONS

DIE CUSHINING STROKE: 200 MM

CLAMPING : 20 TONS

DAYLIGHT : 600 MM

BOLSTER PLATE SIZE : 900MM X 900 MM

<u>EXPECTED DELIVERY:</u>

DECEMBER, 2008

Proposed EBW Machine

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Major Specifications

- Electron Gun– 15 kW – 70 kV,
- Welding chamber Suitable for a job size: 1300 mm (L) x 1000 mm (W) x 1000 mm (H) with two suitable pumps for vacuum ~1×10^{-7} mbar and run out platform.
- Y axis, by the Electron Gun, 200 mm travel, CNC controlled.
- X axis, by the worktable, 1300 mm travel, CNC controlled.
- CNC Rotary Manipulator with tail stock
- Motorized Tilting system, 0° to 90°
- General Control System with CNC

Plan for EP Setup

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•Electro polishing Bench (Single cell / Multi cell)

•Acid Storage, refrigerator and handling system

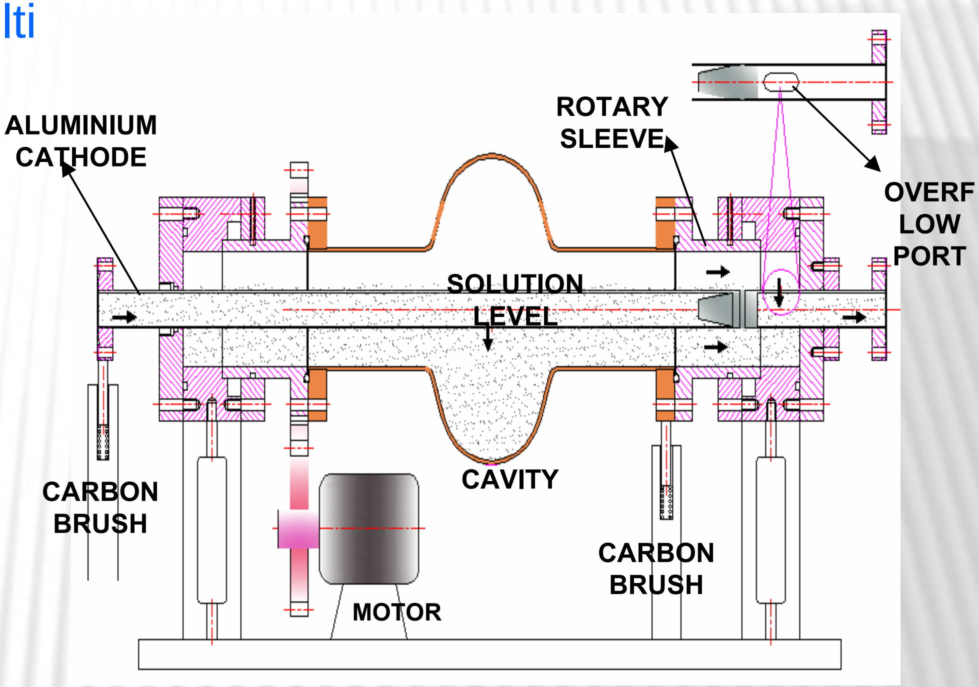
•Heat Exchanger for EP solution

•Scrubber Unit (Acid fumes from EP)

•Chemistry Lab support for EP,BCP

•Used Acid and affluent Collection & neutralization

•PLC Control Power supply (0-25 V, 1000 A)



EP Plan for 9 Cell Cavity

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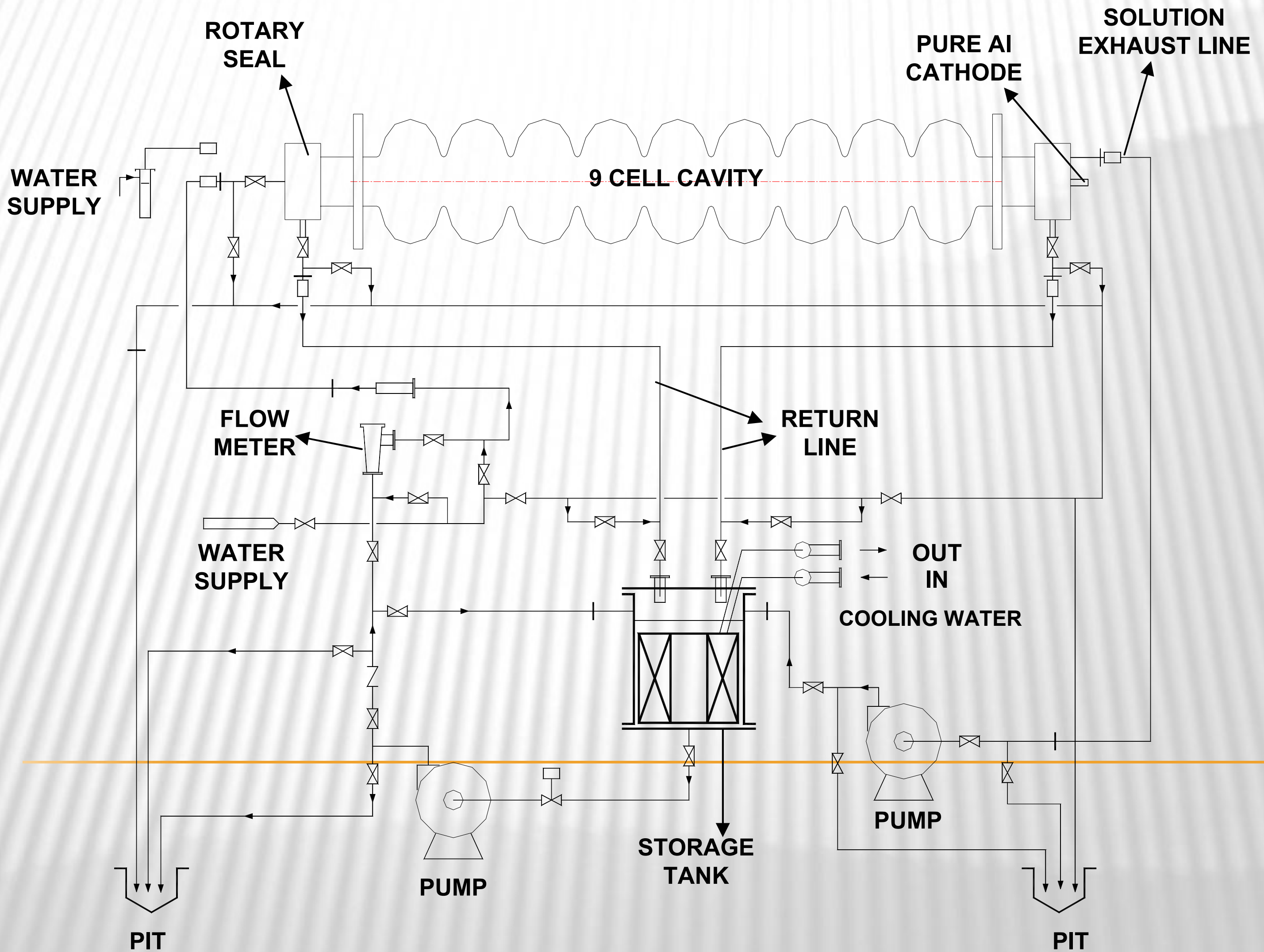

Development of EP in collaboration with KEK

High Pressure Rinsing Stand

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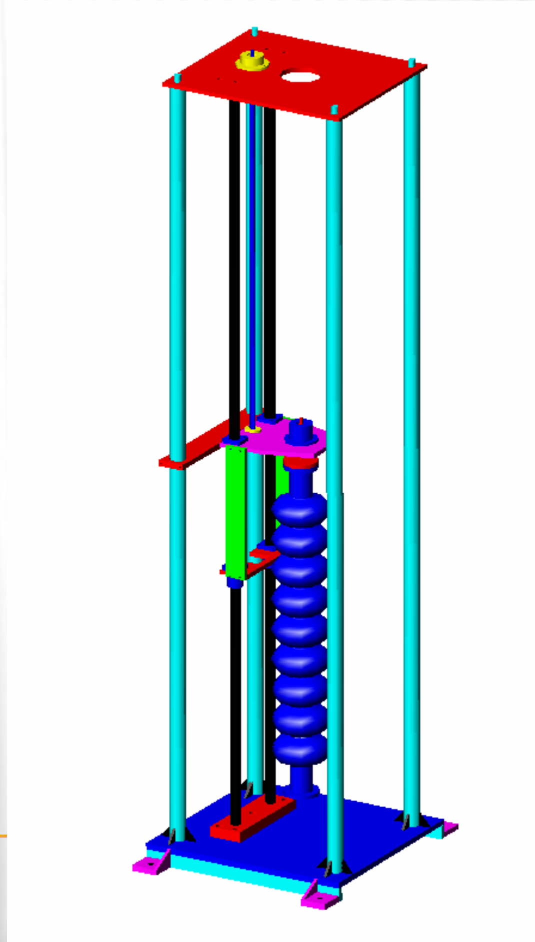
Features:

- Cavity Rotational speed: 10-100 RPM
- Vertical Stroke: 1300 mm
- Vertical movement speed: 300 mm/min
- Ultra-pure water jet pressure: 80 – 100 bar
- Structure made of SS304
- Installed in Class 100 clean room



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Ultra-pure Water System

PRETREATMENT SYSTEM

Flow rate: 10L/hr, TOC: < 30 ppb,
Resistivity: 10-15 MΩ·cm @ 250C

WATER PURIFICATION SYSTEM

Output Specifications:
Flow rate : 10 - 12 L/min
Resistivity : 18 M-Ohm.cm
Organics : < 20 ppb
Bacteria : < 10 cfu/ml
TDS : < 0.03 ppm
Silicates : 0.01 ppm
Heavy Metals : < 0.01 ppm

ONLINE TOC MONITOR

Measurement range : 1 – 999

WATER STORAGE TANK

PE Reservoir of 200 L capacity with conical bottom to drain water.

Plans for Enhancement of Cryogenics Infrastructure

- Development of Saturated bath type vertical Test Cryostats: 4.5 K – 2 K
  (For Sensor calibrations, RRR measurements etc.)
- Development of Saturated bath type vertical Cryostats for testing SCRF Cavities: 4.5 K – 2 K
- Development of Horizontal Test stand for testing/ Characterizing SCRF Cavities at temperatures below 2K.
- Development of Cryomodules

Augmentation of present facility of liquid Helium and Liquid Nitrogen production to Approx. 200 lit/hr Liq Helium Production/ with 5,000 – 10,000 Lit storage capacity and Approx. 400 lit/hr of Liquid Nitrogen.

Vertical Test Stand

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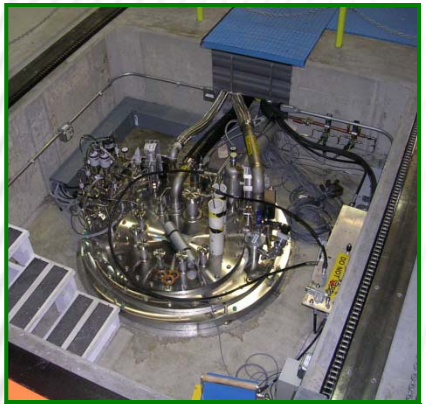

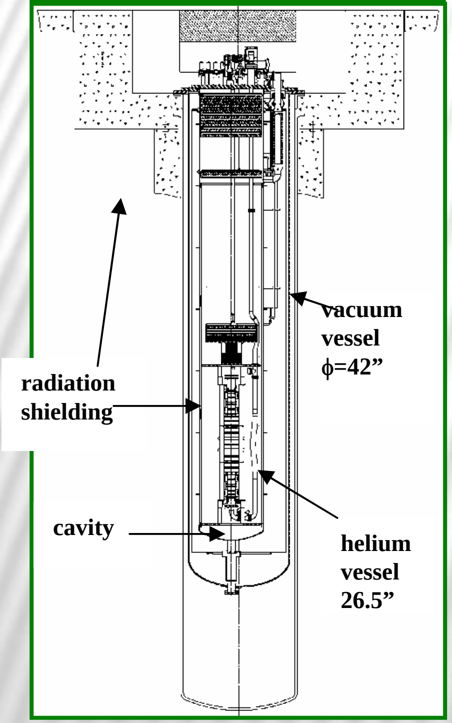

- Single, bare 1.3 GHz 9-cell Tesla-style cavities
  - Measure Q vs. T (T_{min}~1.5 K)
  - Measure Q vs. E_{acc} at 2 K
- RF design parameter: 250 W (CW) max power at cavity
  - $Q>5\times10^9$ and $Eacc<35$ MV/m
    or generally: $P_d = (1.04 \times 10^{-3}) * E_{acc}^2/Q < 250$ W
- cryogenic capacity ~125 W at 2 K
  - 250 W for short periods without excessive helium bath temperature increase
- Magnetically shielded cryostat
  - Ambient field in IB1 pit measured consistent with Earth’s field ~0.5 G
  - External (room-temperature) Amumetal® (80% Ni alloy) and internal Cryoperm 10® magnetic shield, designed to attenuate field to <0.01 G at cavity
- Radiation shielding to maintain “Controlled Area” status
  - < 5 mrem in an hour immediately outside the shielding
  - <0.25 mrem/hr in normal working areas

Development of VTS in collaboration with FNAL

Thank You