ADS Programme and Associated Developments in India- Roadmap and Status of Activities.

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Focus in this talk

- **Indian ADS programme priorities.**
- **Reactor physics studies on ADS.**
- **Experimental sub-critical reactor preparations.**
- **Spallation target & technology studies.**
- **Accelerator programme.**

Indian ADS Programme

- Interest in thorium fueled ADS.
- Started with Roadmap studies from 1999.
- The first Roadmap planning in 2001.
- Physics studies and technology developments funded in 2003 as 5-year plans with INR 390 m.
- First phase of activities are progressing and extended up to 2012 for:
  - Reactor physics codes & nuclear data programme.
  - Setting up 20-MeV high current proton linac.
  - Establishing LBE experimental loop of 120 kg/sec. flow rate and maximum temperature 350^0C.
  - Techniques development to fabricate SC RF cavities.

Summary of Development issues in ADS Programme

ACCELERATOR

- High Intensity
- Reliability
- Stability
- Efficiency
- Activation

HEAT REMOVAL

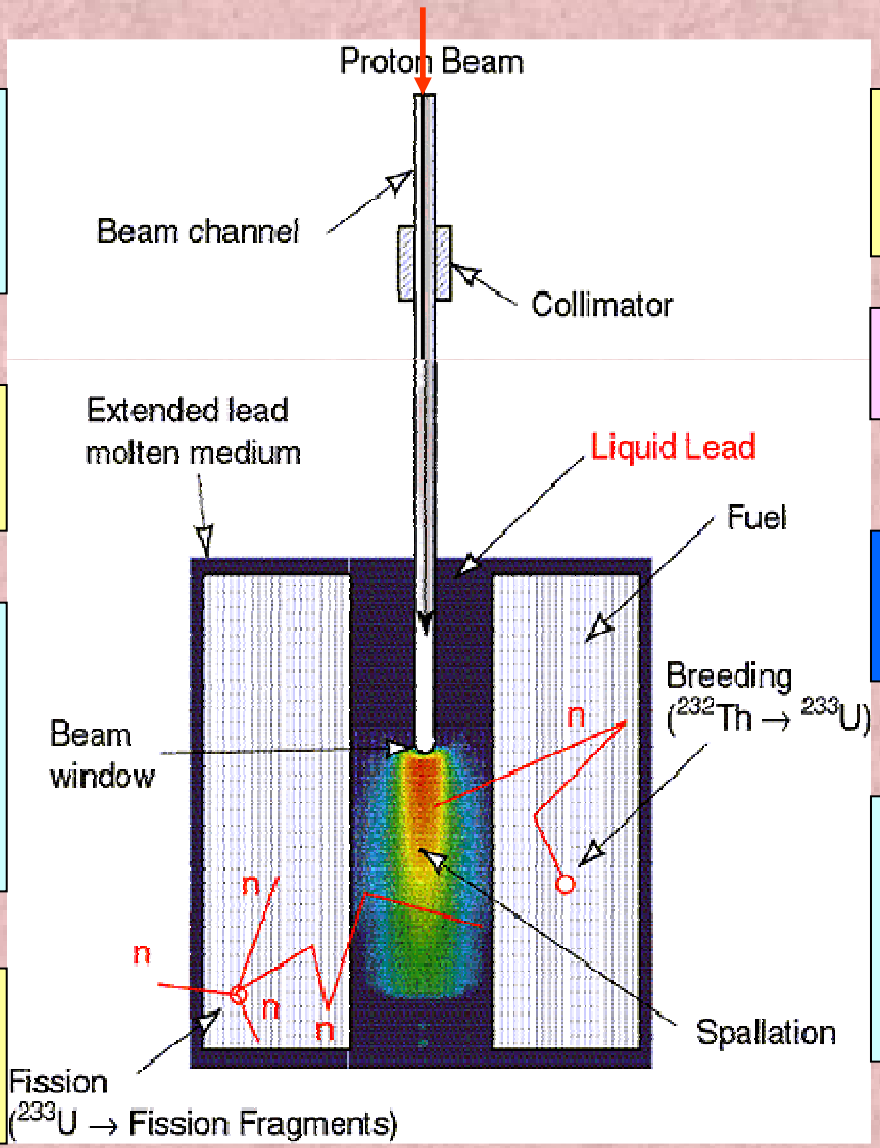
- Heat Transfer
- Thermal cycling
- Coolant

TARGET MODULE

- Thermal hydraulics
- Materials compatibility
- Window thermal stresses
- Radiation effects
- Maintainability

LIQUID METAL

- Corrosion and erosion
- Online instrumentation



BEAM TRANSPORT

- Losses
- Monitoring
- Expansion

SHIELDING

High energy particles

FUEL TYPE & FORM

- Composition
- Fabrication
- Reprocessing

SUB-CRITICAL CORE

- Neutronic Kinetics
- Performance
- Subcriticality Monitoring
- Fuel integrity

McBURN & BURNTRAN Codes

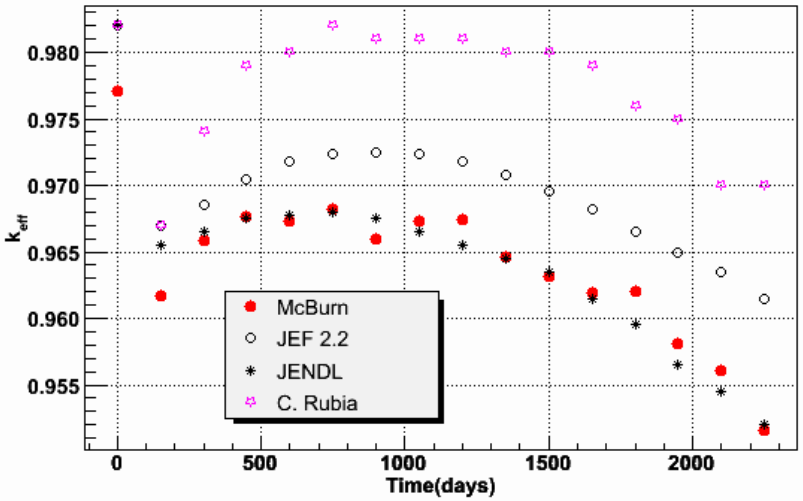
McBurn: A Continuous Energy Monte Carlo Burn up Code

- McBurn : Interfaced with high-energy code CASCADE.4 These programmes can be run together.
- The codes are functional for fixed fuel (one batch fueling)
- Used for evaluating some interesting ADS concepts.

About 300 actinide and fission products can be considered for the following nuclear reactions:

neutron capture, fission, n2n, alpha and beta decay.

Validation of the code has been carried out by - study of the IAEA ADS benchmark (fast system)



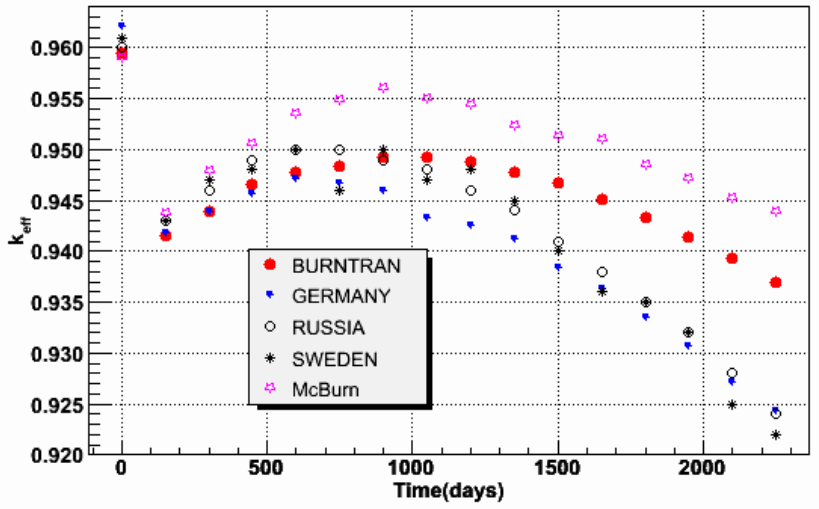
BURNTRAN: A Transport Theory Burnup Code

BURNTRAN will be quite useful for quick investigative studies of various ADS configurations.

- It Uses 172-group WIMS neutron data library.
- A number of modifications were carried out in the transport theory modules.

Validation of this code has been done by studying ADS benchmarks and 19 rod and 37 rod PHWR clusters and comparing the results with other codes.

"In-core Fuel Management Benchmarks of PHWRs" *Report* IAEA-TECDOC-887 (1996).

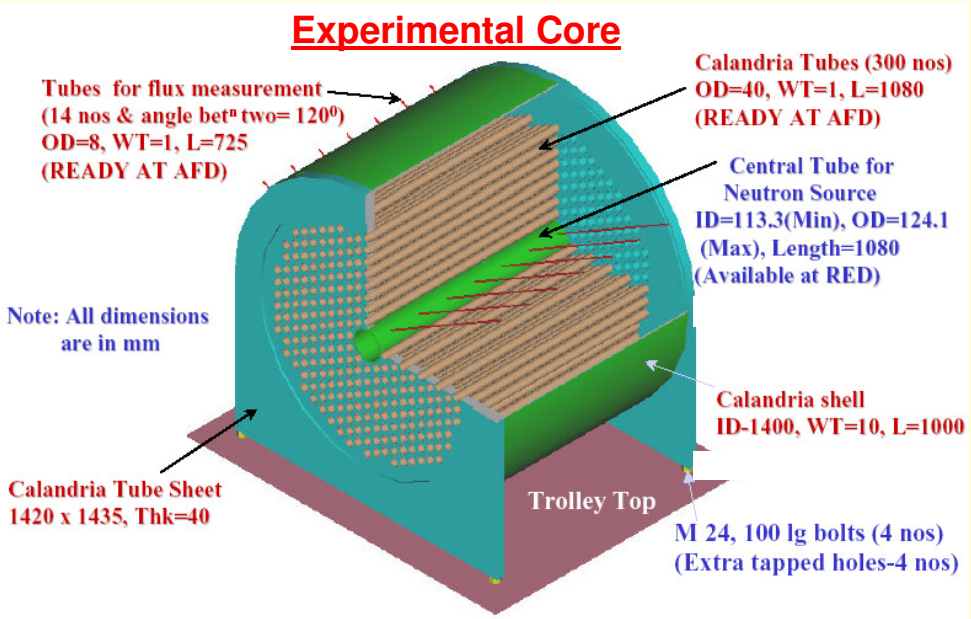


Nuclear Data

- Compilation of data
  - Data files for Monte Carlo calculations.
  - Fission product yields.
  - Wims update 69 &172 group libraries.
- ENDF data processing codes
  - Capability to use NJOY and produce data in formats required by various codes
- Generation of Data Files
  - Fission product cross section data generated for use in McBurn

Experimental ADS Reactor Physics Programme

Experimental Core



14-MeV neutron generator

Experiment Measurements:

- Flux distribution & spectra,
- Total fission power,
- Source multiplication factor
- Degree of sub-criticality- real time measuring of the k_{eff} in pulsed source mode.

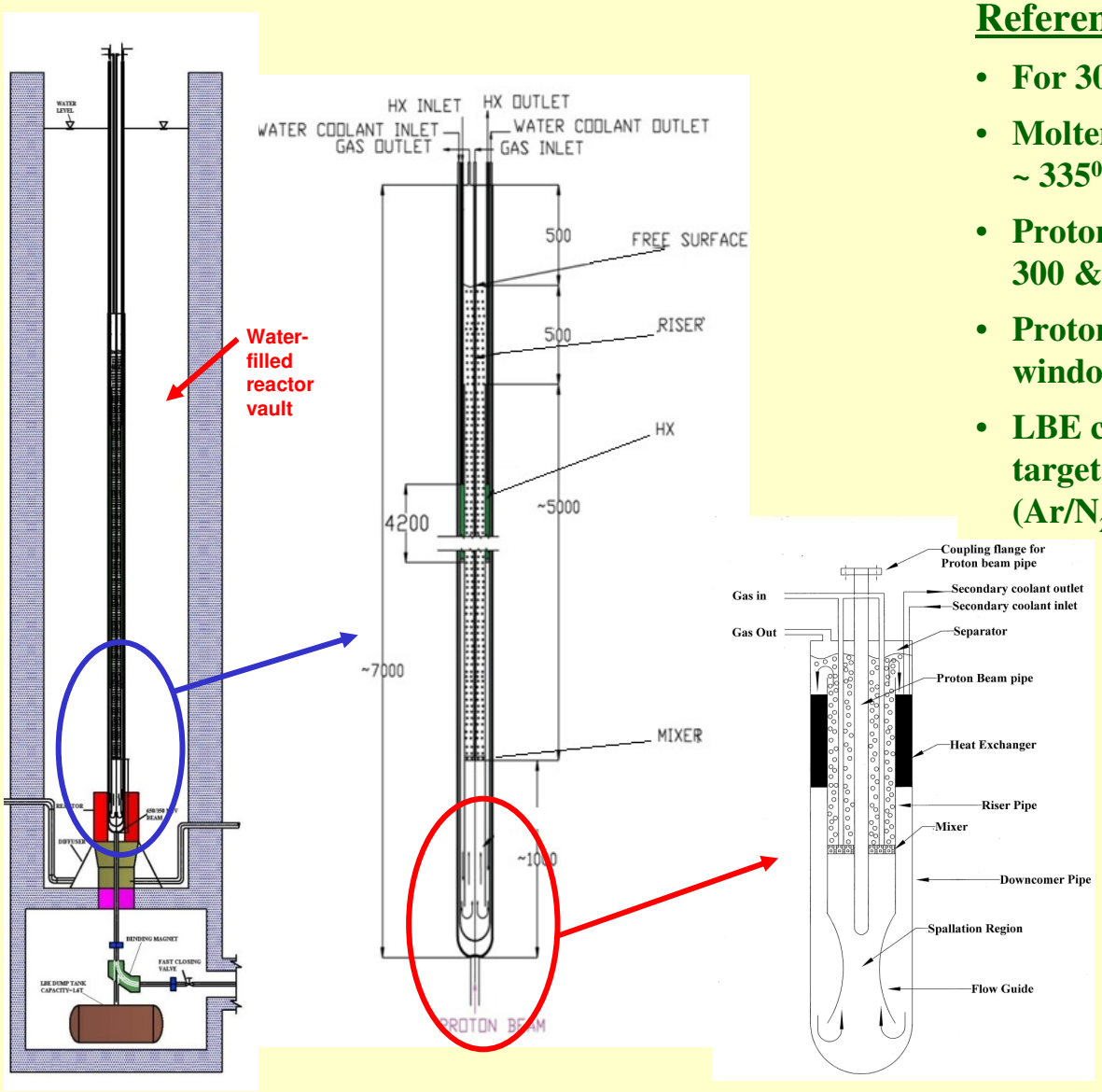
Neutrons by : D-T fusion reaction with pulsed as well as cw neutron source of about 3×10^9 n/s with a 5-curie tritium target.

For Reactor Noise Analysis : neutron pulse ~10 μsec long at ~500 Hz rep. rate. Each burst ~ 10^4-10^5 neutrons (for thermal systems).

Integral type experiments for:

- **validation of calculation tools and,**
- **neutron cross-section data.**

Design Studies of Target for ADS



Reference ADS Design for LBE Target:

- For 30 MWt high flux thermal reactor.
- Molten LBE spallation target Max. Temp. ~ 335^0C.
- Proton beam of diameters 7 and 10 cm at 300 & 650 MeV
- Proton Beam entry from bottom through window of T91, at max. Temp. 400^0C
- LBE circulation @ 50 Kg/s through the target effected by means of gas-injection (Ar/N_2 @ 2 gm/s) driven buoyancy.

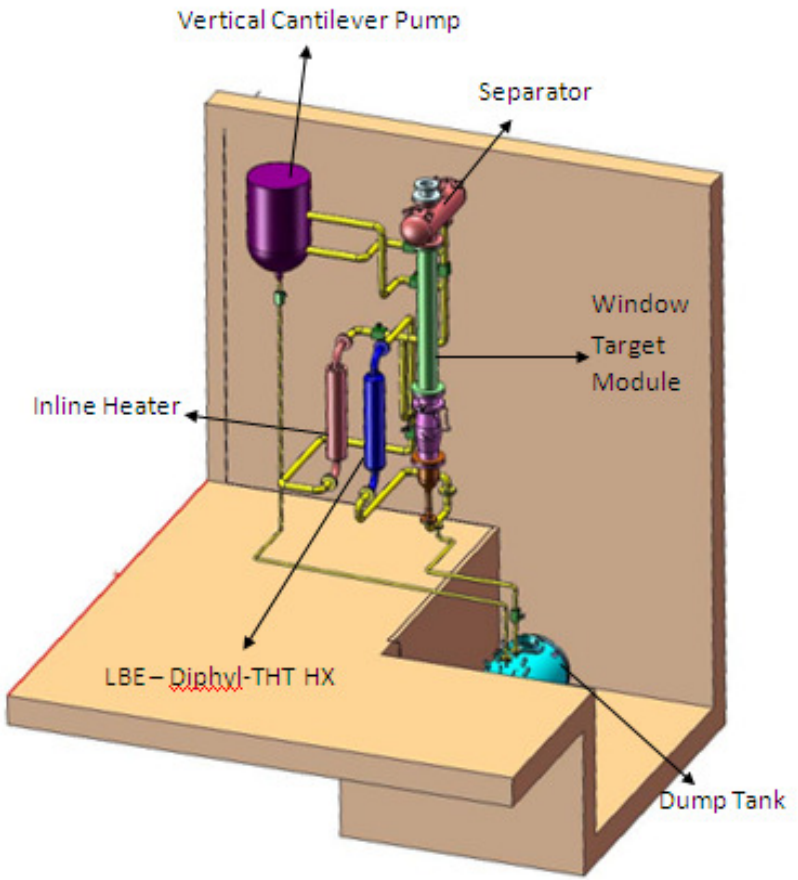
CASCADE.4 Calculations:

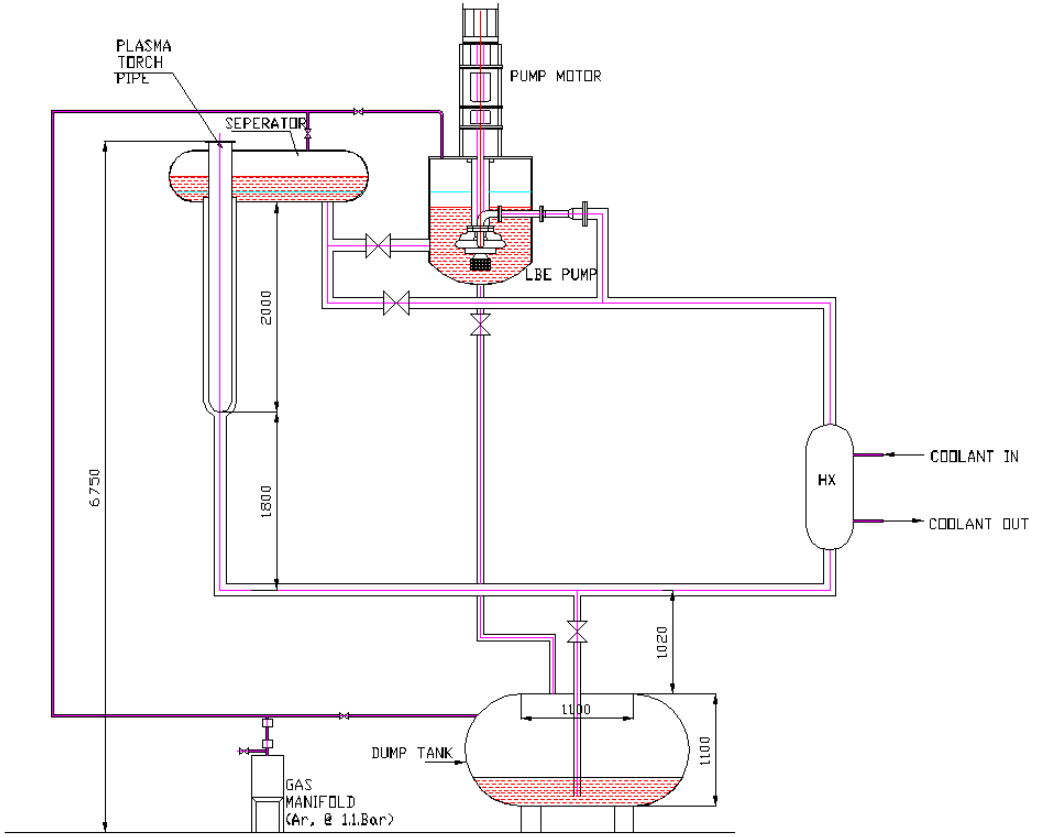
- Neutron yield, angular and energy spectra, production of ^{210}Po, shielding requirements.
- Spatial heat deposition rate distribution obtained was Output used as input for CFD code for window cooling simulations.

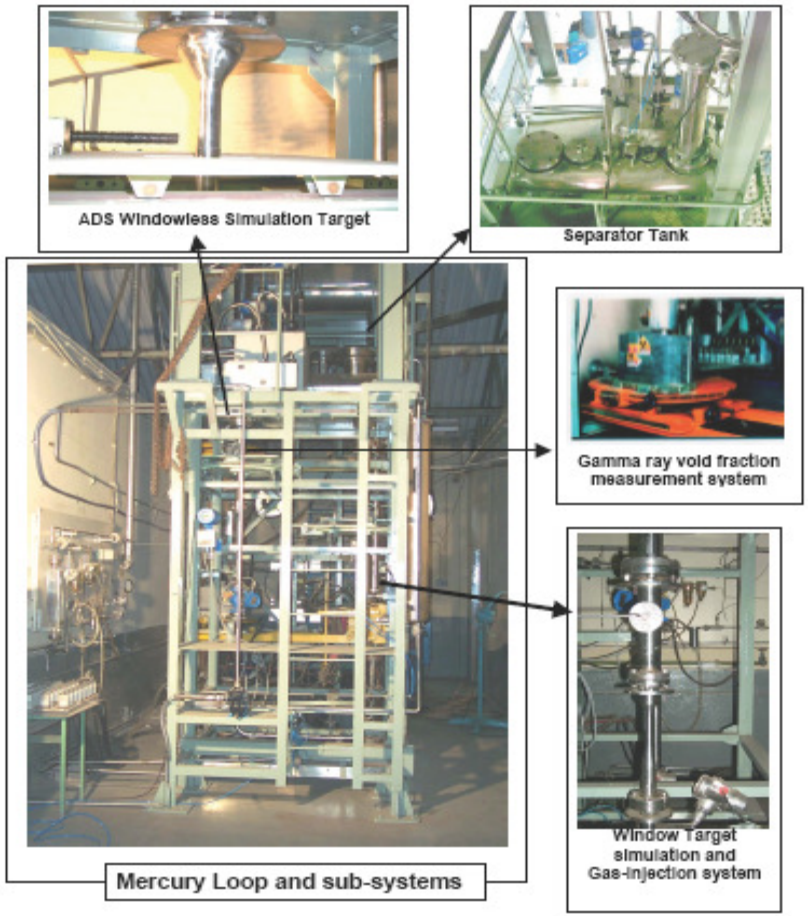
Experimental LBE Loop Facility

For Experiments on:

- ❖ **Validation of thermal hydraulics code for HLM circulation.**
- ❖ **Pump driven 120 Kg/s LBE flow operation @ 350^{0}C max.**
- ❖ **Beam heating simulations by plasma torch or Electron beam.**
- ❖ **Corrosion tests- flowing HLM on samples- SS 316, T91.**
- ❖ **Active online oxygen monitor development.**

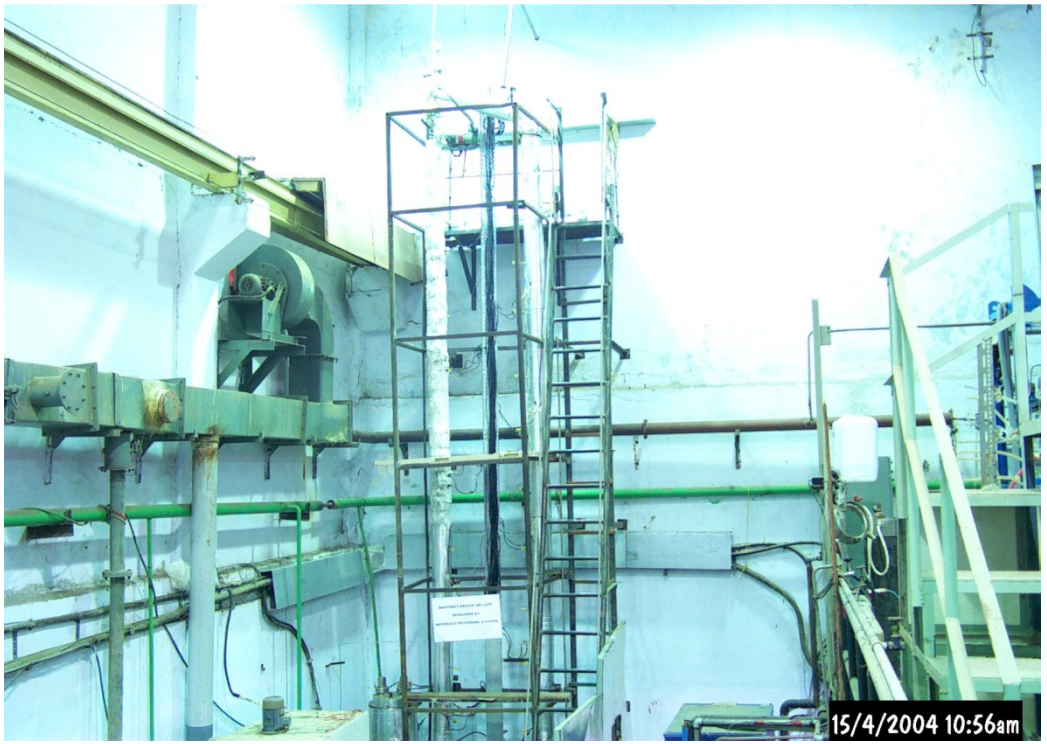






Mercury Loop

- Simulation of Window/Windowless Target
- Velocity field mapping by UVP monitor
- Carry-under studies
- Two-phase flow studies by Gamma Ray
- Laser-triangulation for free surface measurement
- CFD code validation
- Gas-driven flow studies

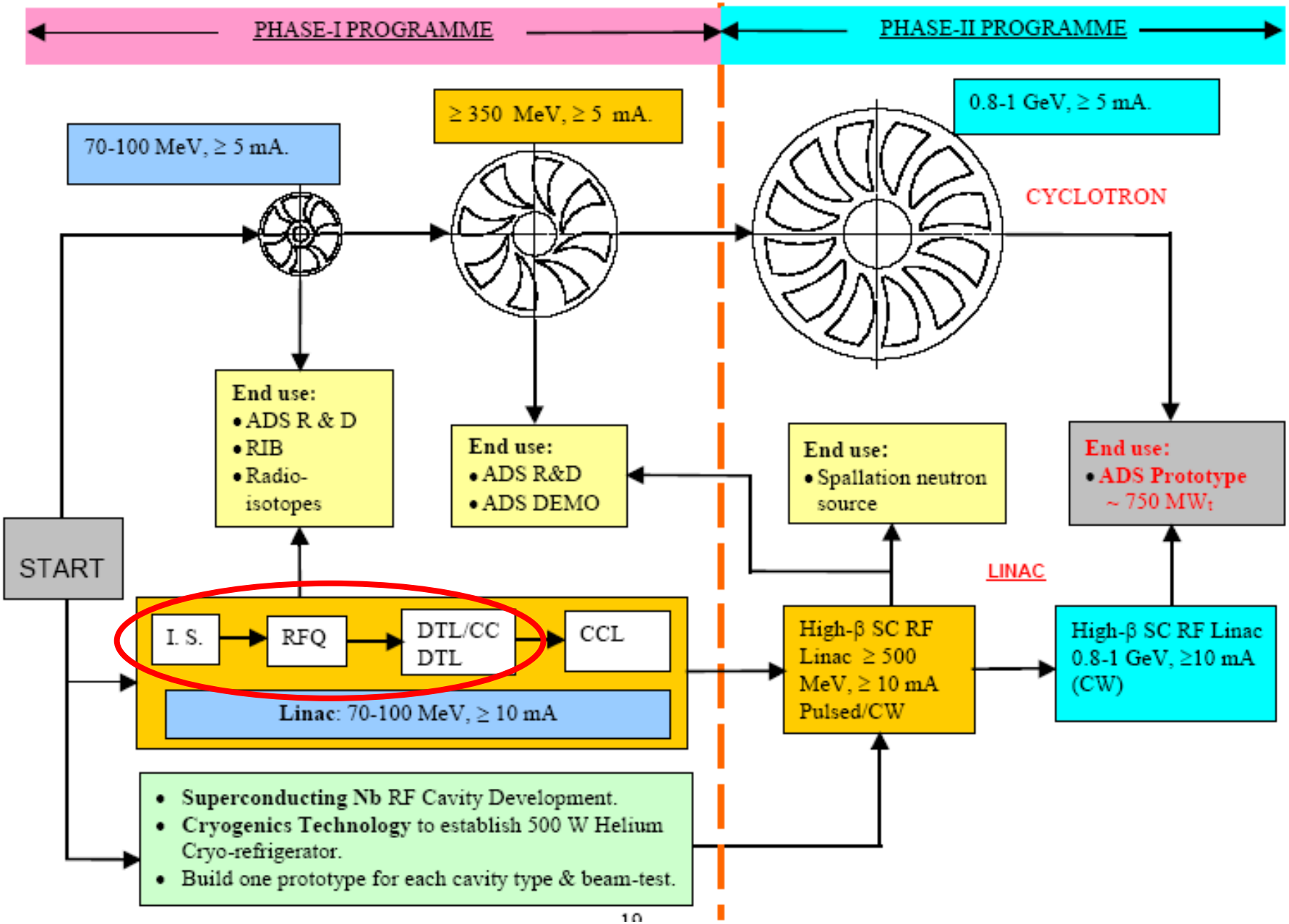


LBE Corrosion Loop

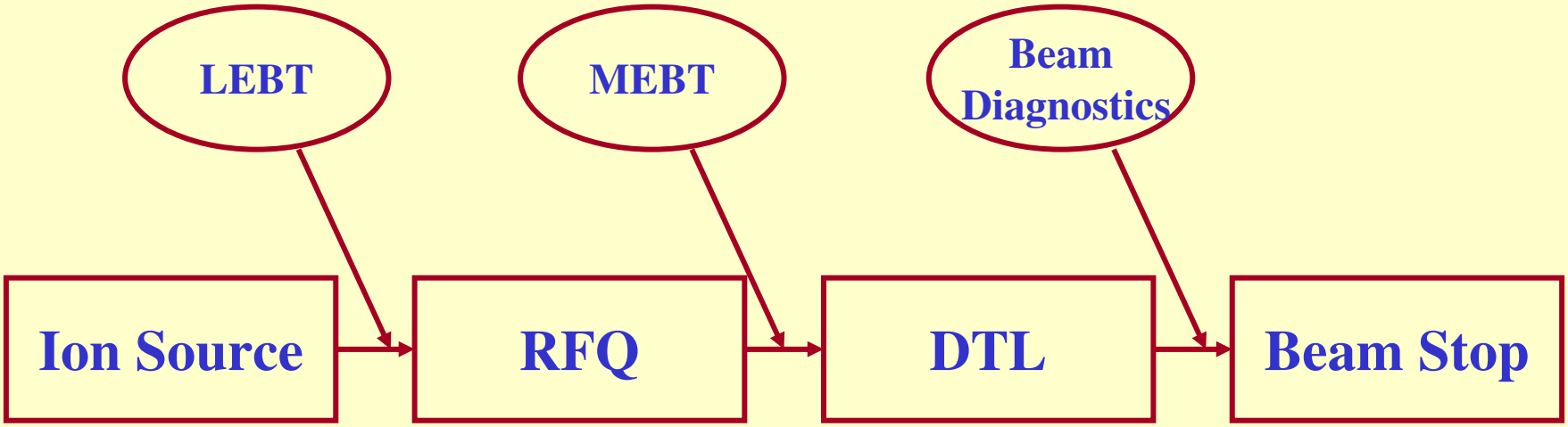
Height ….. ~ 7m
Flow Rate ….. ~1.7 kg/s
Temp ….. : 550^{0}C and 450^{0}C
Velocity in the Samples : 0.6 m/s
Corrosion Tests : Charpy and tensile tests after 3000 hrs in the flow

Experimental set ups on target technology

ROADMAP FOR PHASED INDIGENOUS DEVELOPMENT OF ACCELERATORS FOR ADS



Layout of 20 MeV Linac - LEHIPA

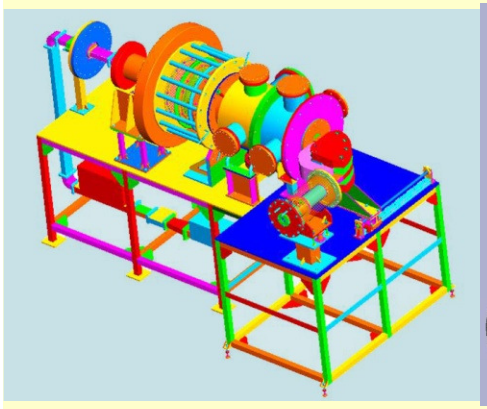


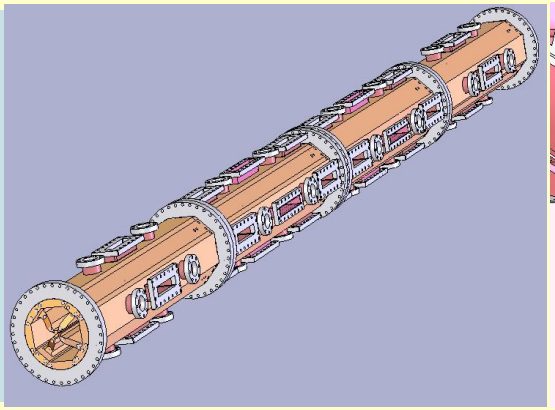
2.45 GHz
ECR Ion source
50 keV, 35mA.

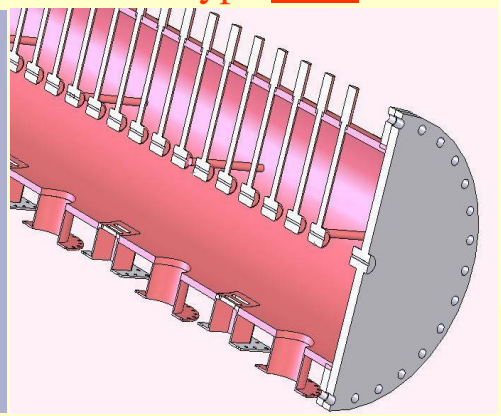
352.21 MHz,
4 Vane type **RFQ**
3MeV, 30 mA

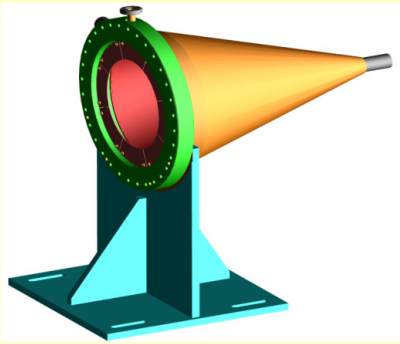
352.21 MHz,
20 MeV, 30 mA
Alvarez type **DTL**

Beam Power
600 kW

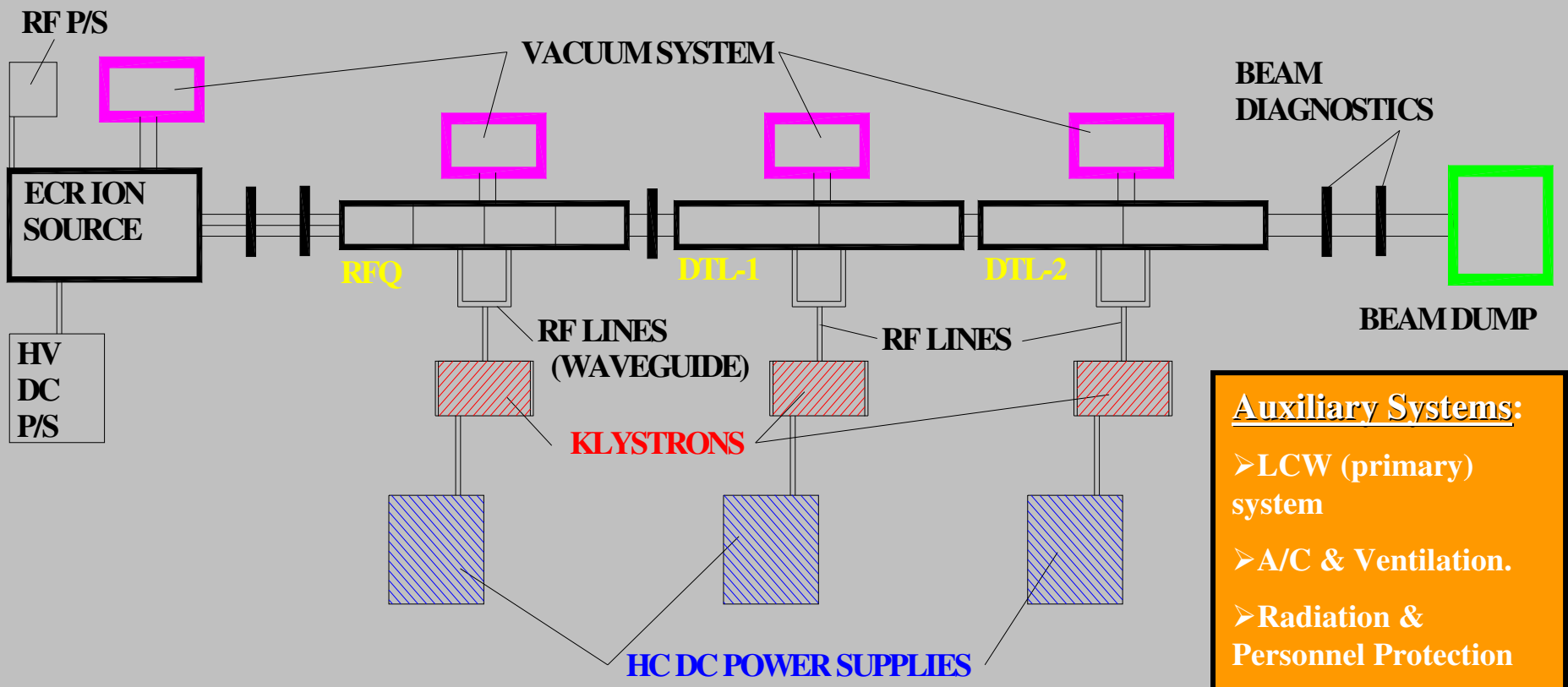








EQUIPMENT DIAGRAM OF LEHIPA

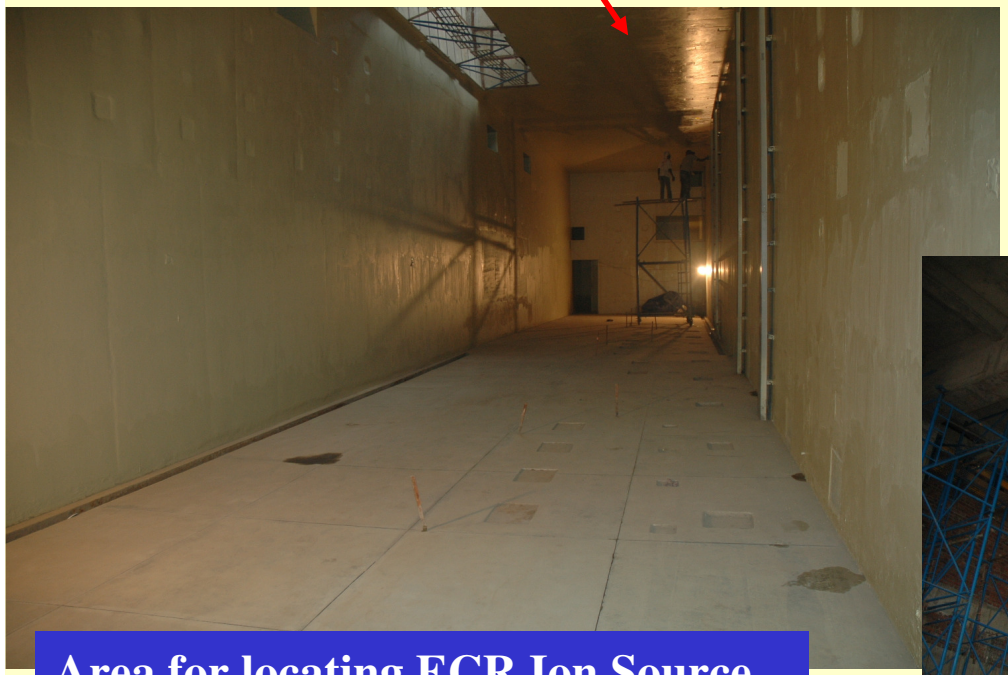


Auxiliary Systems:

- LCW (primary) system
- A/C & Ventilation.
- Radiation & Personnel Protection
- Cooling water with towers

Construction of LEHIPA building

Basement for LEHIPA tunnel



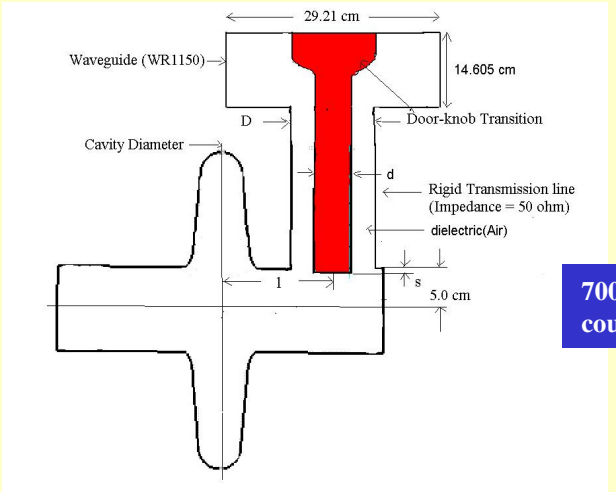
Area for locating ECR Ion Source, RFQ, DTL and klystrons (in adjacent gallery)

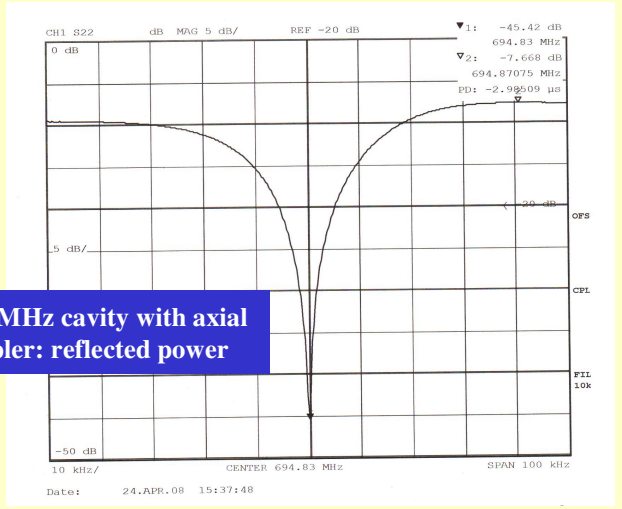
Common facility building under construction

Area for locating HV DC power supplies for klystrons, cooling water plant and for access into basement through floor openings.

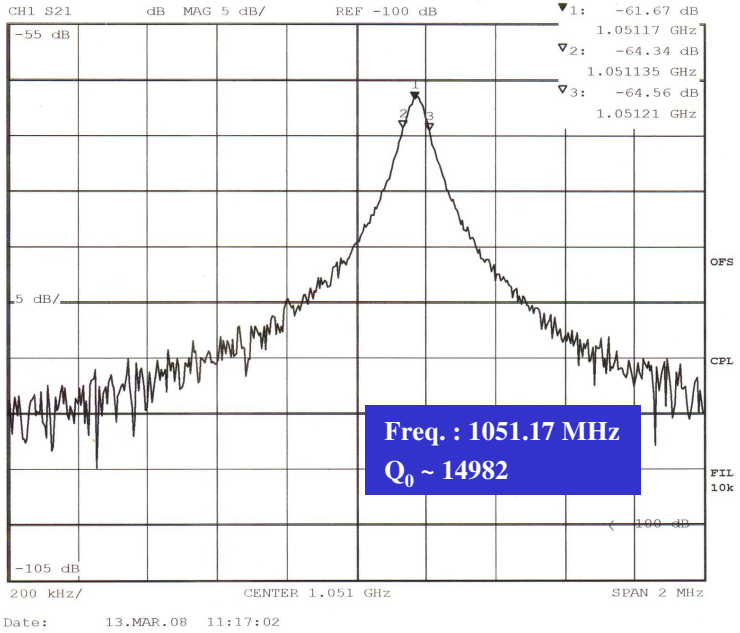
SC RF cavity R&D

- SC RF accelerating section in 1-GeV proton linac is designed from 100 MeV onwards.
- Multi-cell elliptical cavities in three velocity groups (β_g) are envisaged. Lowest β_g ~ 0.49.
- Copper cavity prototypes for single cell cavity & its RF input coupler fabricated & tested.
- The prototypes were at frequencies 1050 and 700 MHz.

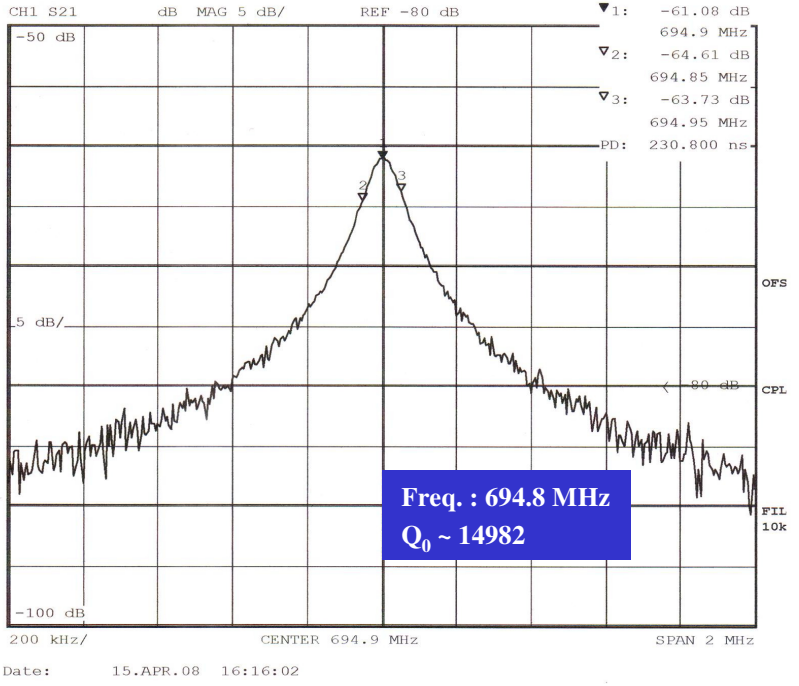




700 MHz cavity with axial coupler: reflected power

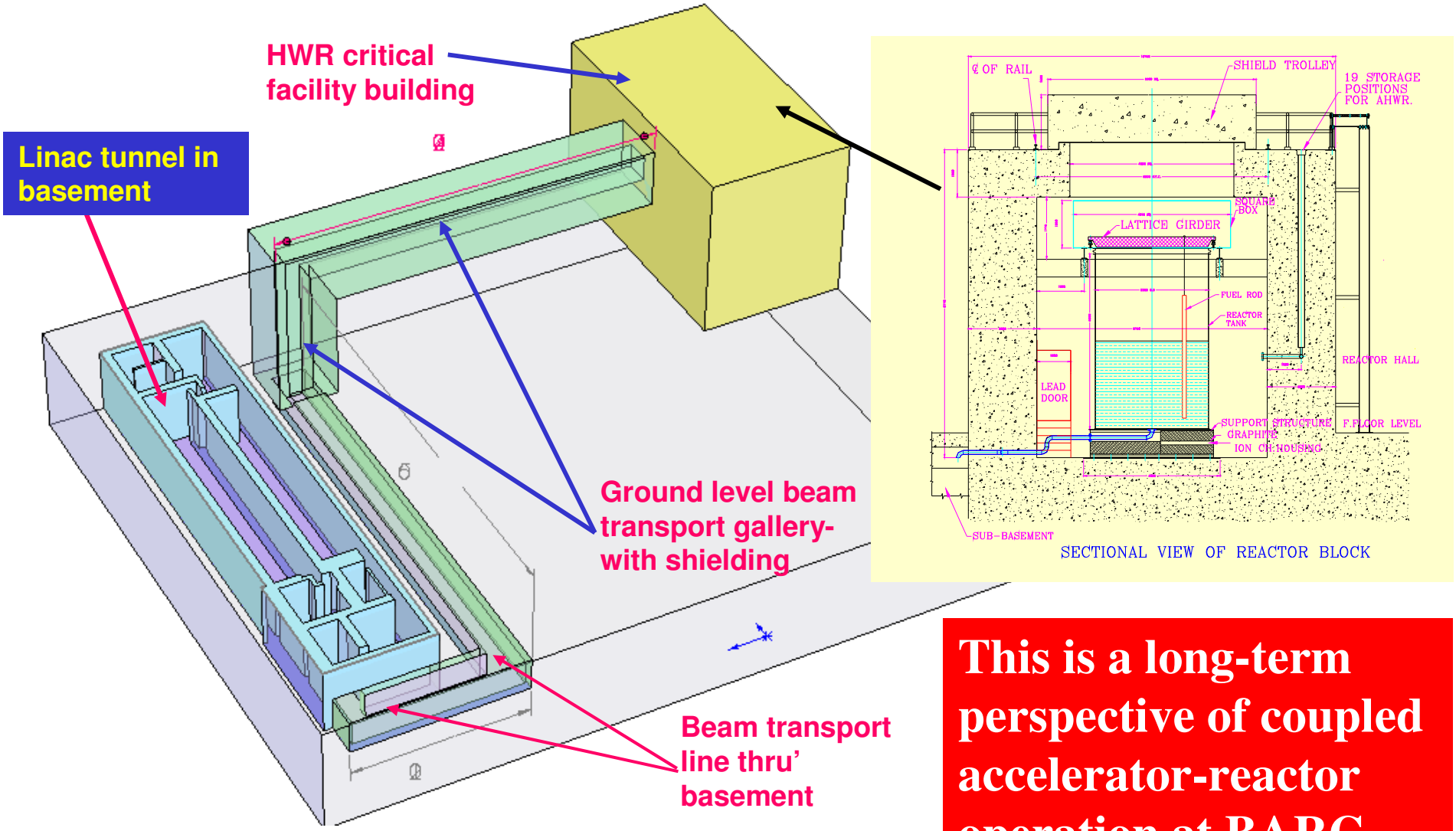


Freq. : 1051.17 MHz
Q_0 ~ 14982



Freq. : 694.8 MHz
Q_0 ~ 14982

20-MeV Proton beam for ADS experiments in HWR critical facility



This is a long-term perspective of coupled accelerator-reactor operation at BARC.

Summary

- **Knowledge & technology development activities on ADS initiated since 2003 in priority areas.**
- **Reactor physics, target reactions and thermal hydraulics design codes are operational.**
- **Stand-alone facilities of (i) 20-MeV proton accelerator, & (ii) LBE systems will be set up which also have linkages with other programmes-**

  (e.g.: SNS for neutron beam research applications and LBE technology for HTR programme)
- **For first phase of R&D, INR ~300 m. already spent by 2008;**
- **By year 2012, when all first phase projects complete ~ INR 1000 m. would be spent.** **(INR 50 ~ 1 US $).**


Thank You !