VECC, Kolkata

Implementation of Control Systems for Cyclotrons at VECC: A Status Report

Sarbajit Pal
sarbajit@vecc.gov.in

Introduction

- Sub-systems Control of SCC
- Diagnostic systems
- Modernisation of Control
- Future plans
- Conclusive Remark

VECC and SINP Campus

Superconducting Cyclotron

Sub-systems Control of SCC

- Control Philosophy
- Control Network
- Cryogen Delivery System
- Magnetic Field Mapping
- ECR Ion Source
- RF System
- Vacuum System
- Magnet Power Supplies
- LCW System
- Trim Coil Cooling System
- Radiation Surveillance Monitors
- Central Console
- Beam Diagnostic System

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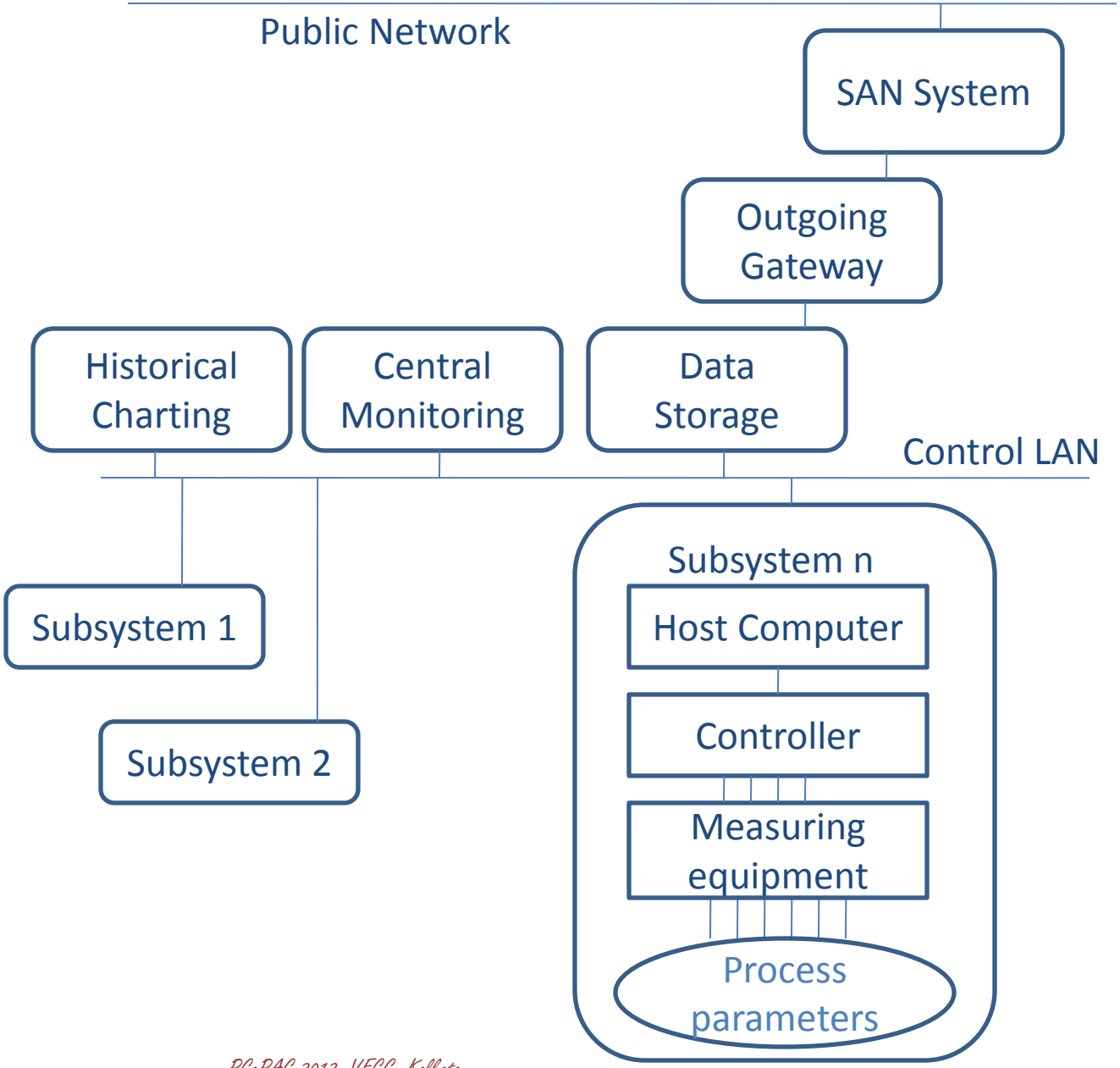
Monitoring and Control Philosophy



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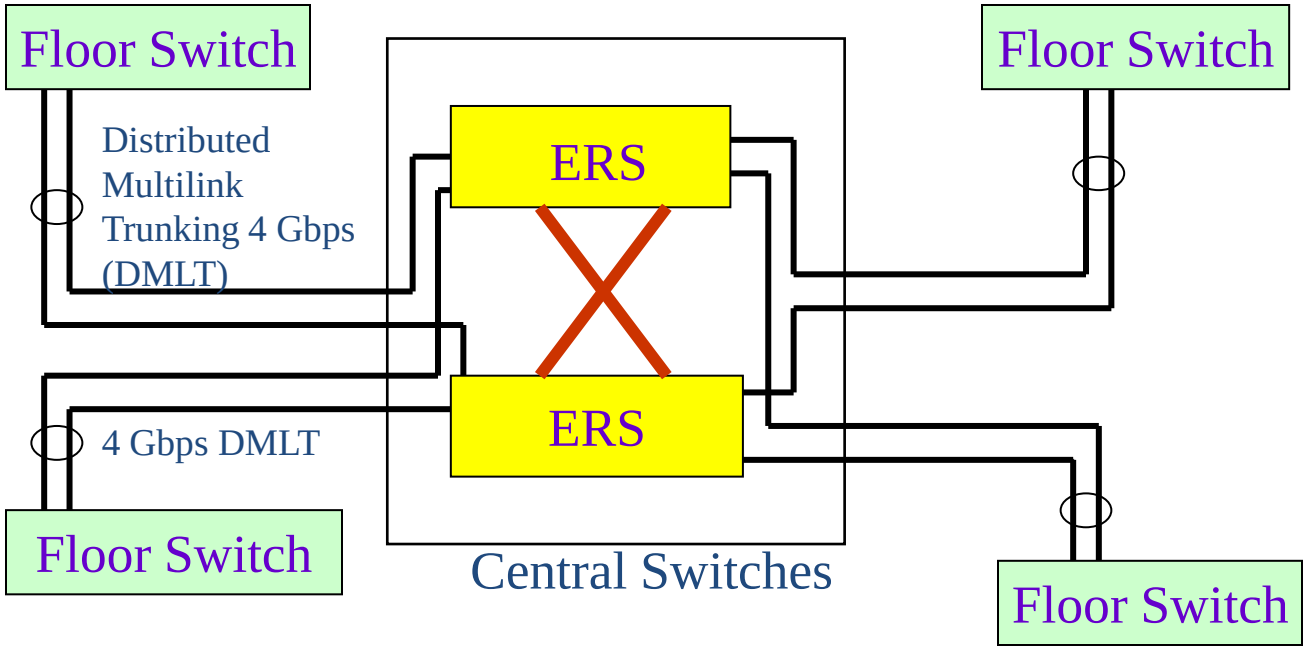
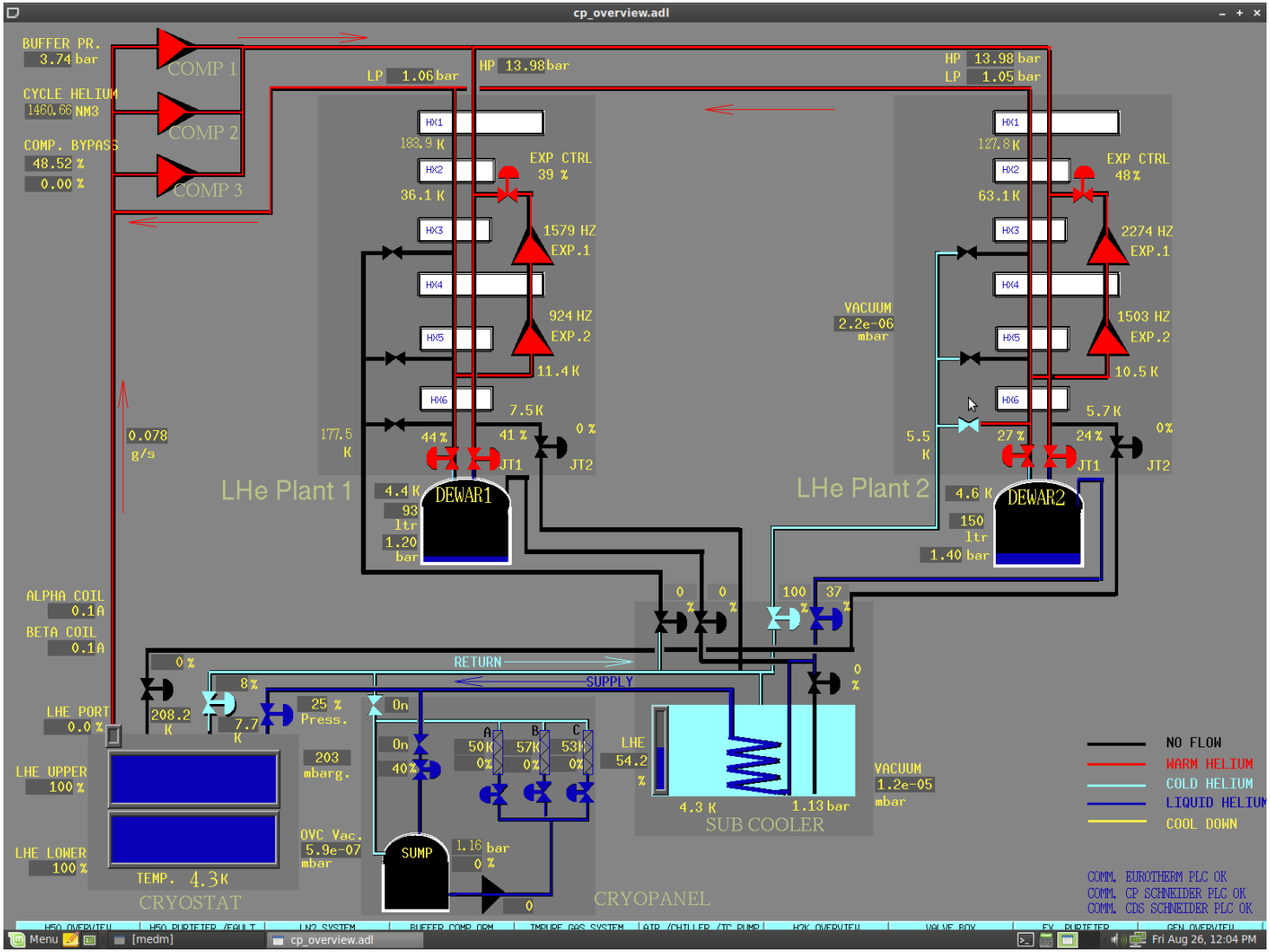
Control Network



- Isolated from VECC Office LAN.
- Star topology: 2-Tier Design
- Fiber Gigabit Backbone and end-to-end connectivity
- Node level speed: 100 Mbps.
- Service zone: CAT5E UTP Cabling
- Tolerant to single switch / link failure
- Network Management Software (NMS)

TOTAL CRYOGENIC PROCESS



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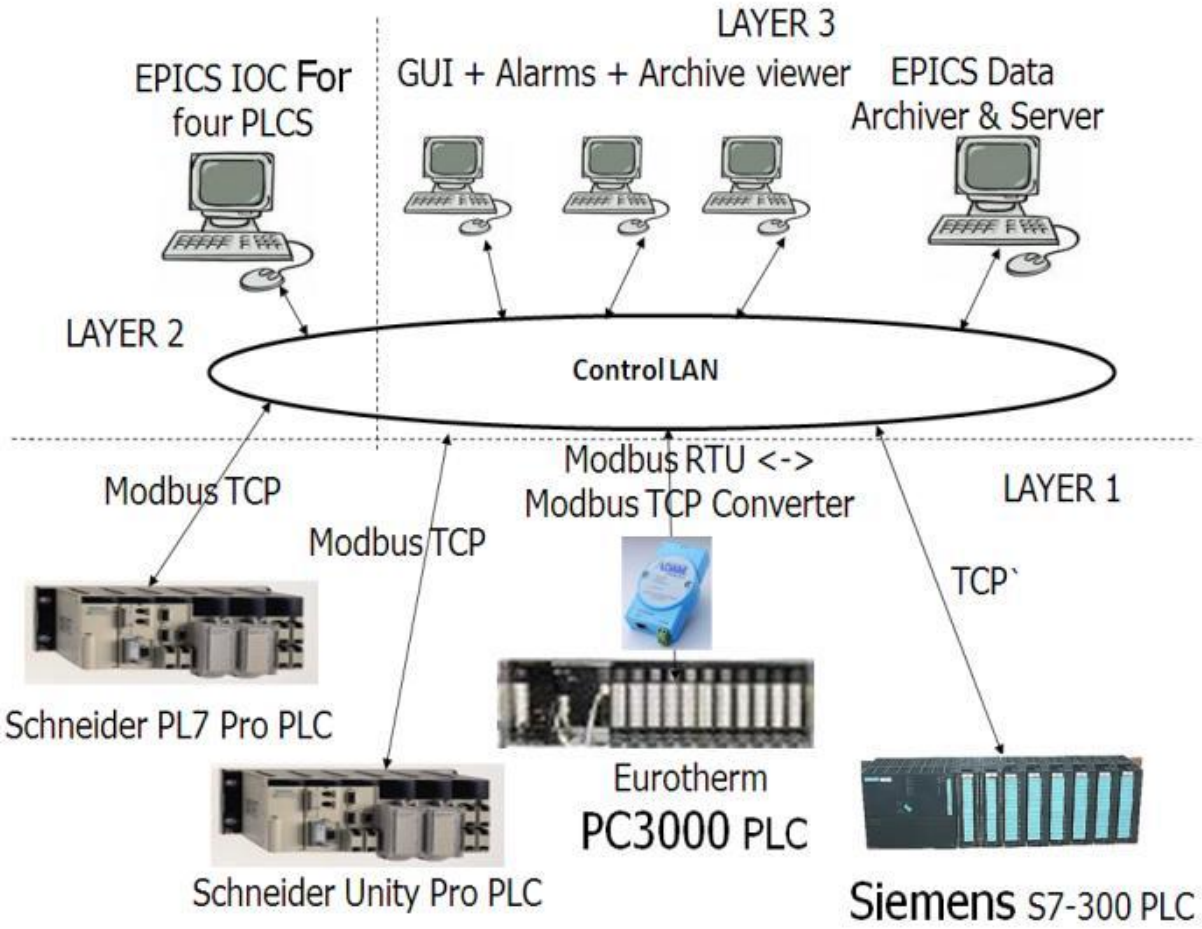
Overview of cryogenic plant control system



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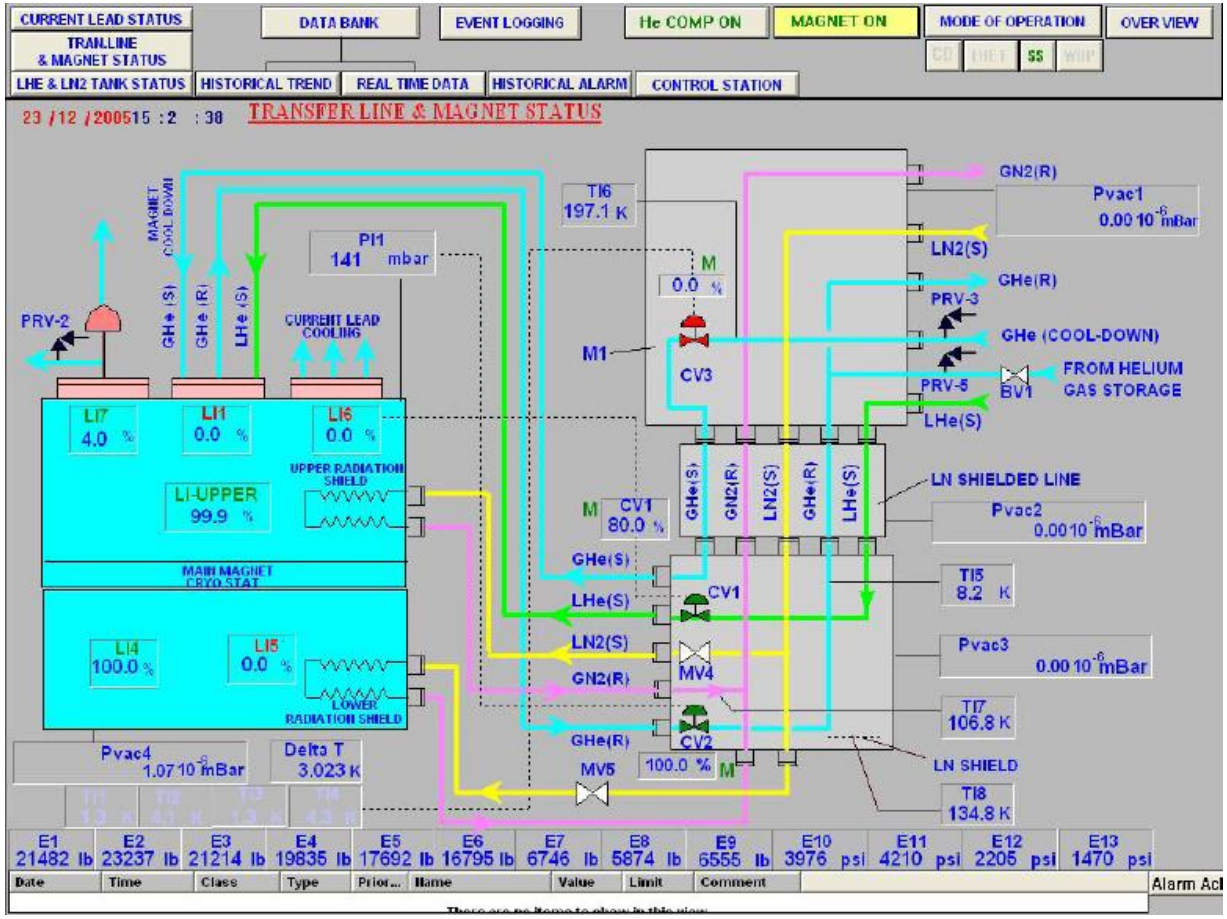
Cryogen Delivery System



- Vacuum jacketed cryogenic transfer lines
- Liquid nitrogen shielded cryogenic transfer line
- Distribution manifolds

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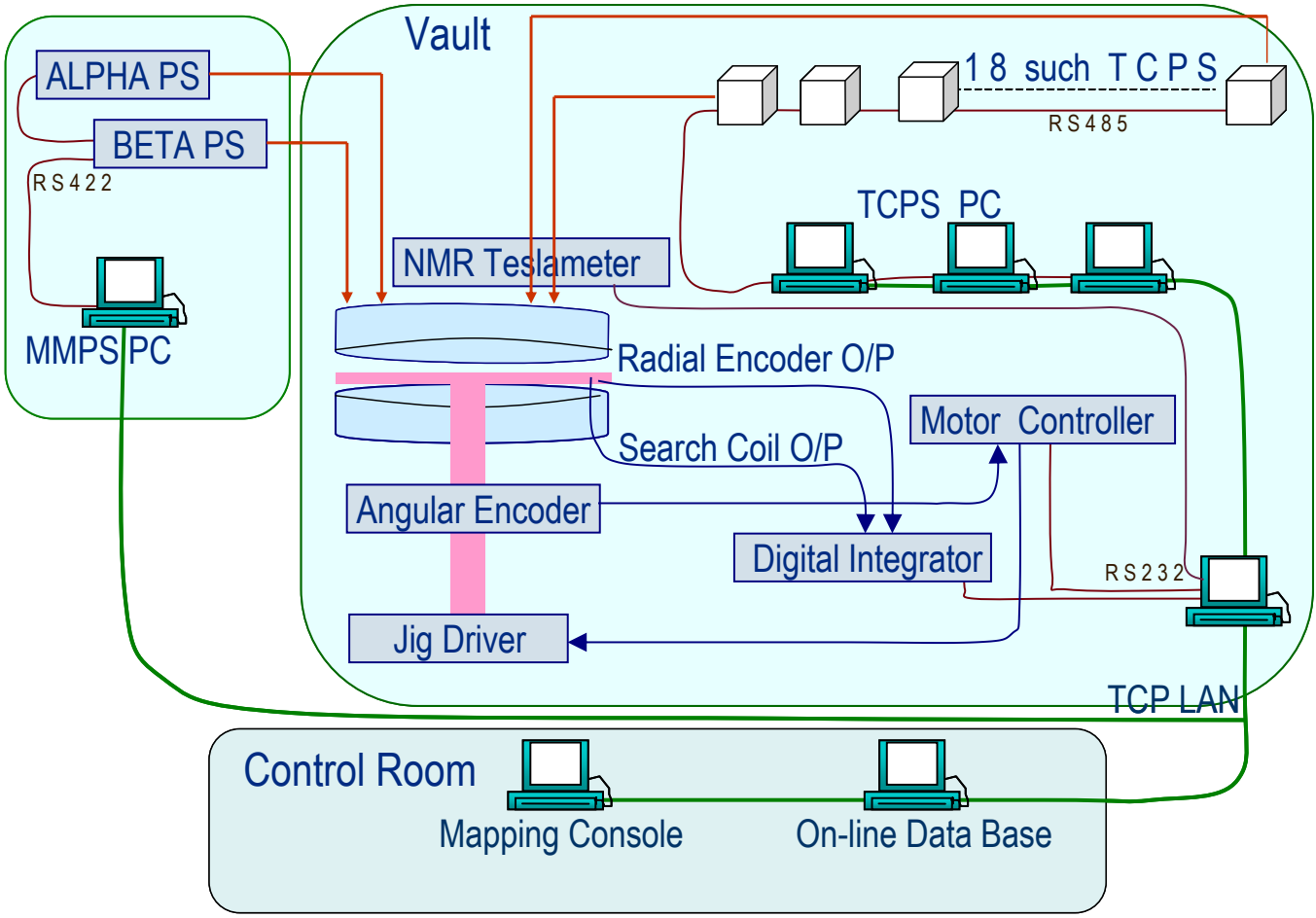
Magnetic Field Mapping



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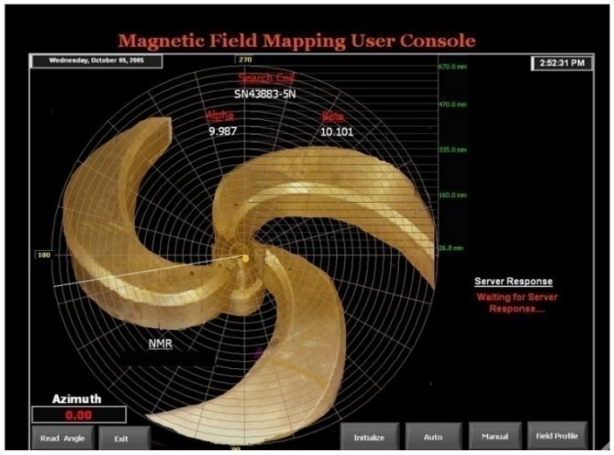
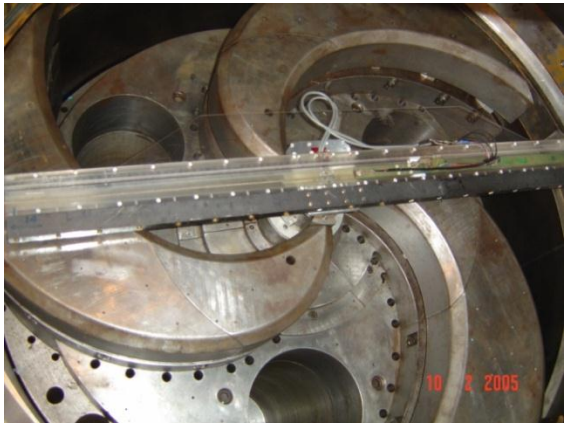


MFM Instrumentation



- Field measurement at different excitations up to ~26” radius & on discrete azimuthal bands beyond 26” radius
- Correction of average iron field distribution,
- Minimization of first harmonic component,
- Coil centering by support link force balance
- Automated High speed data taking - ~ 90 min per 100K Data Points
- 70 micron radial encoder resolution
- 0.004 deg. Angular Encoder resolution

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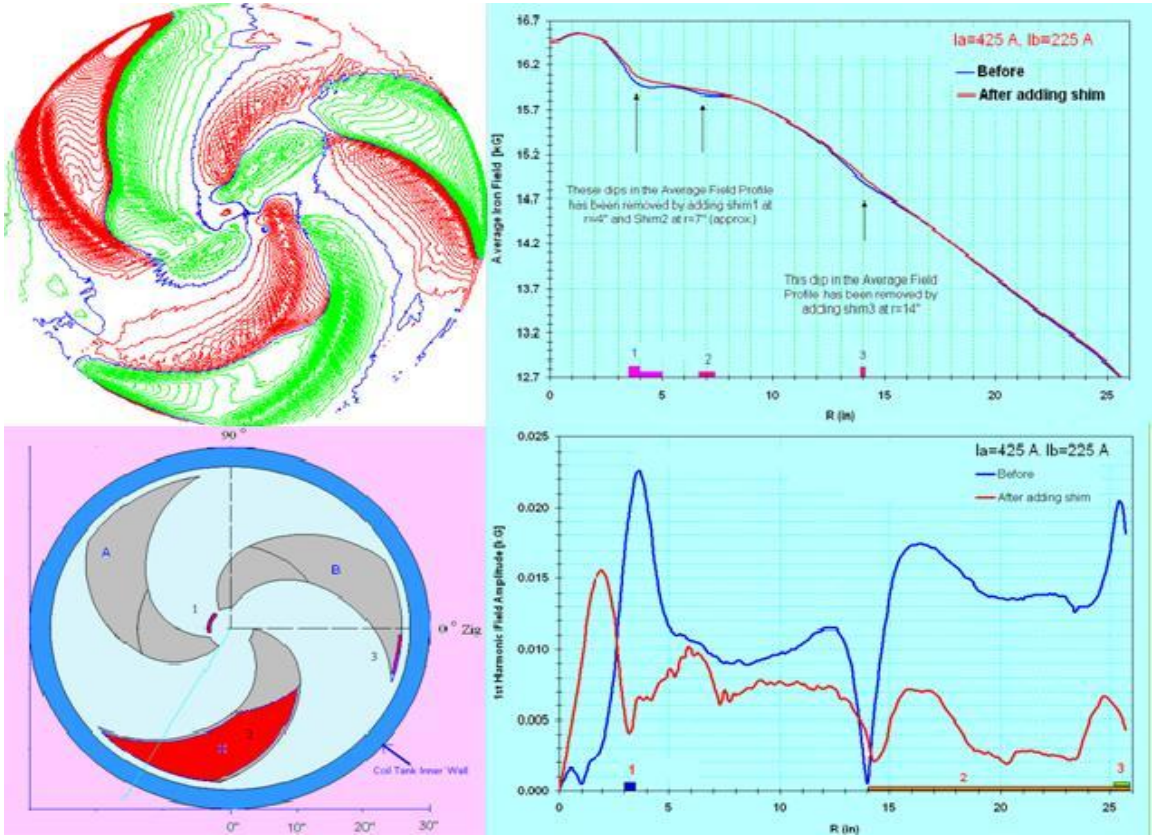
Result of MFM



- Deviation from three fold symmetry - Contour Plot
- Shimming to Correct Average Field Profile
- Shimming for First Harmonic Field Correction
- First Harmonic minimization by adding iron shims

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ECR Ion Source & Injection Line

- Power Supplies for different units such as ECR coil, solenoid, extraction electrode, analyzing and bending magnets
- Vacuum Pumping modules, Gate valves and Gauges.
- Beam diagnostic elements like Faraday cup, collimator, slits etc.

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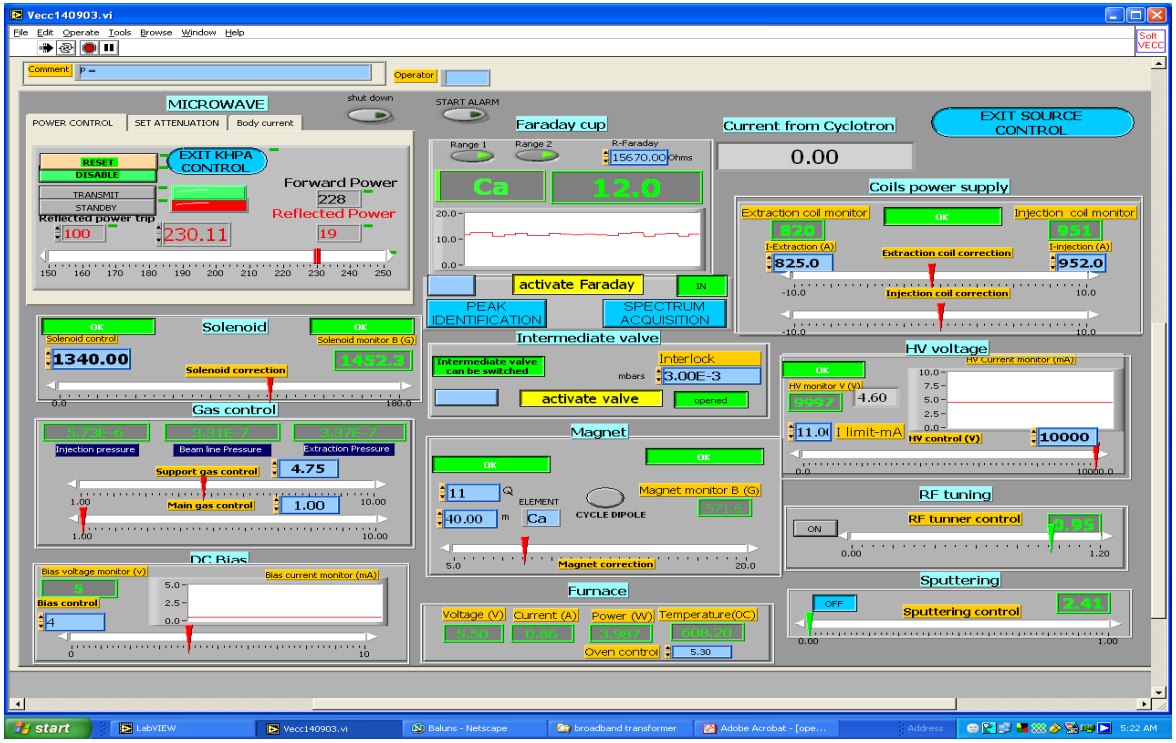
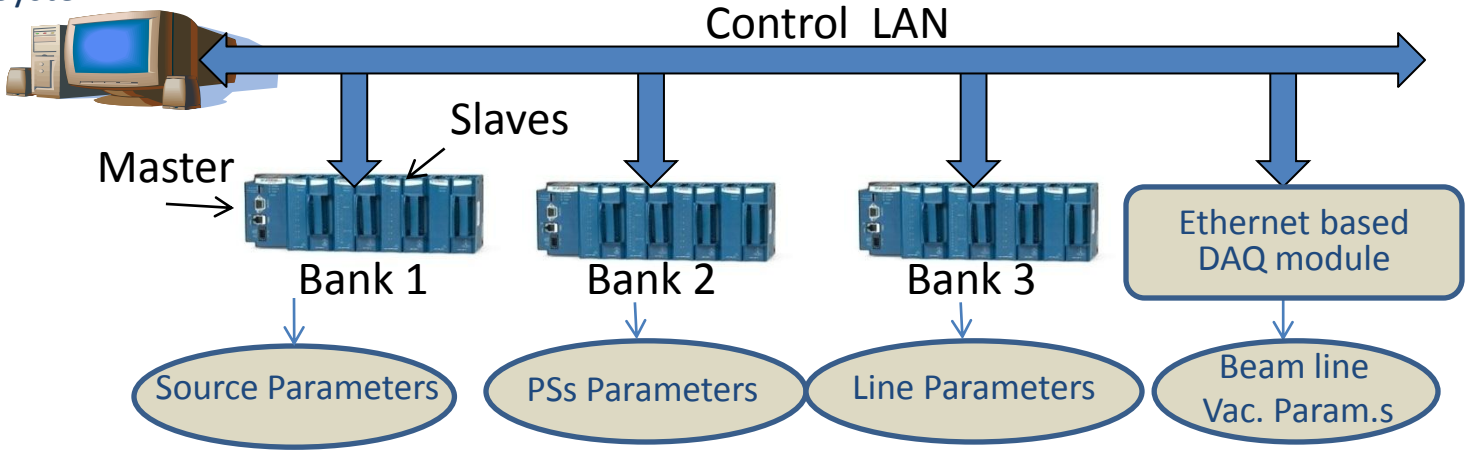
GUI of ECR Ion Source Control





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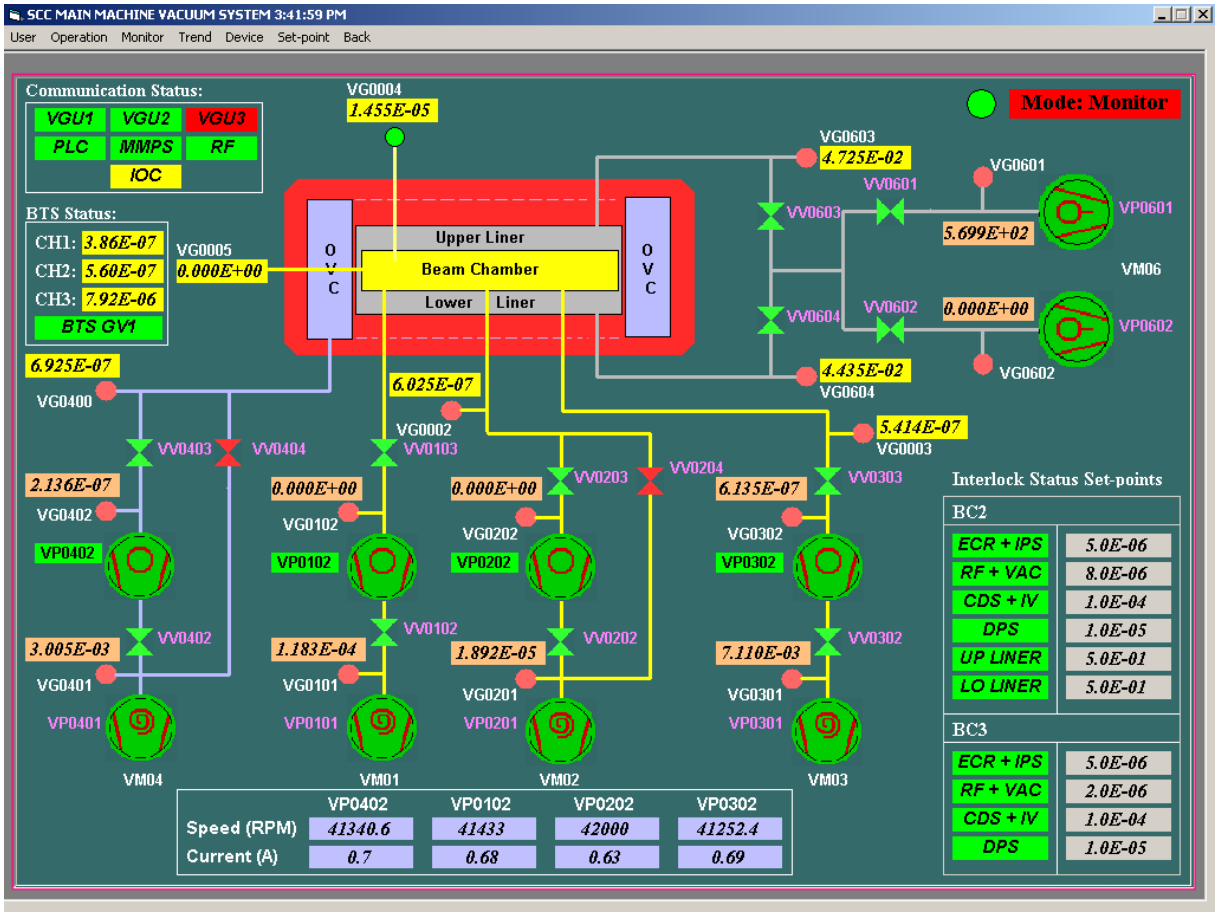
Vacuum Control



- Beam chamber : 10^{-8}mbar
- Liner : 10^{-2}mbar
- Turbo-pumps backed by Scroll pumps, Rotary pumps, VPI valves, gauges

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Loop Control in SCC Vacuum System

- Control logic for operational sequence of roughing pump during sudden pressure rise SCC beam chamber
- If pressure BC2/3 ≥ $1x10^{-4}$mbar
  - HV gate close
  - TMP ON
- If pressure BC2/3 ≥ $2x10^{-4}$mbar
  - Scroll pump start
- If pressure BC2/3 ≥ $5x10^{-2}$mbar
  - Roughing valve open
- If pressure BC2/3 < $5x10^{-2}$mbar
  - Roughing valve close
  - HV gate valve open
- If pressure BC2/3 < $5x10^{-4}$mbar
  - Scroll pump switch off

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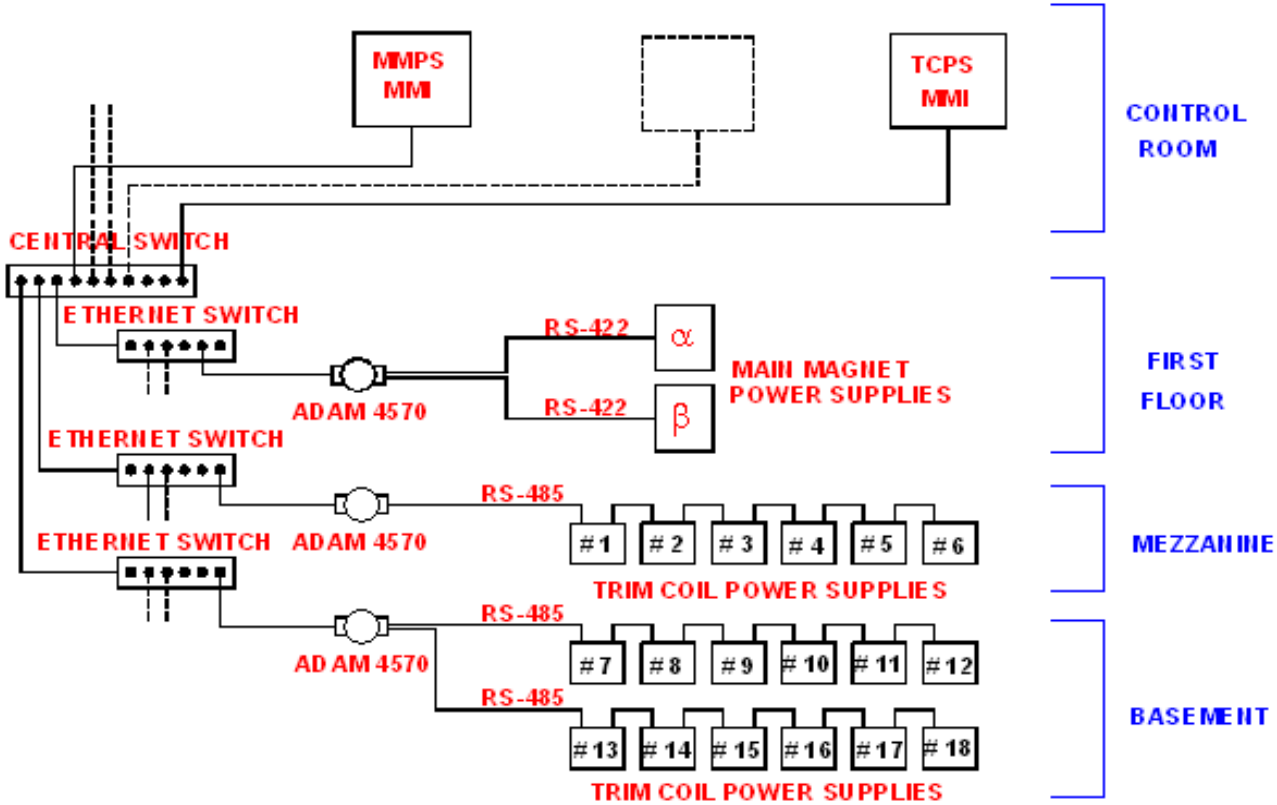
Control Architecture of MPSs



- Main Magnet Power Supplies (Nos. 2)
  - 20 V, 1000 A, 10 ppm
- Trim Coil Power Supplies (Nos. 18)
  - 400 A, 10 ppm
- Windows based GUI developed in VB 6
- PS with intelligent controllers and serial interfaces

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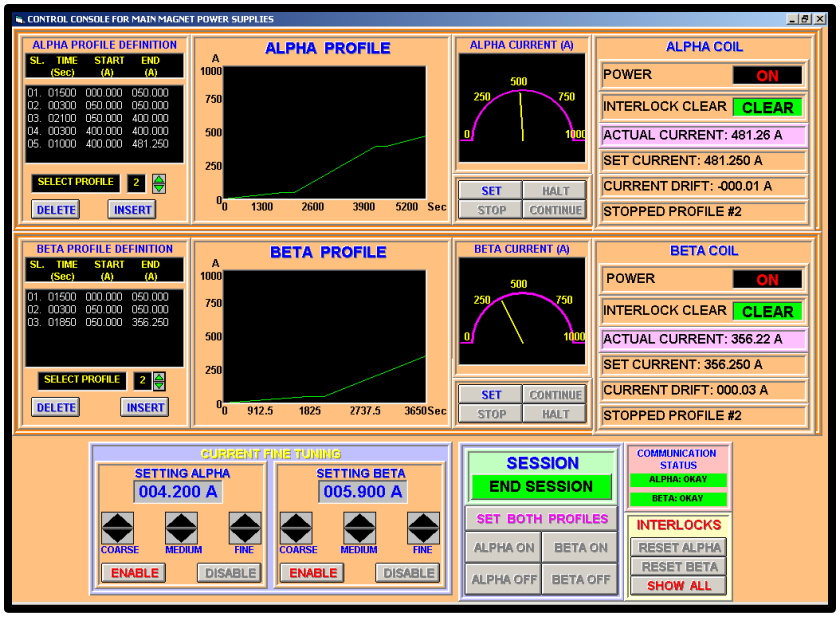
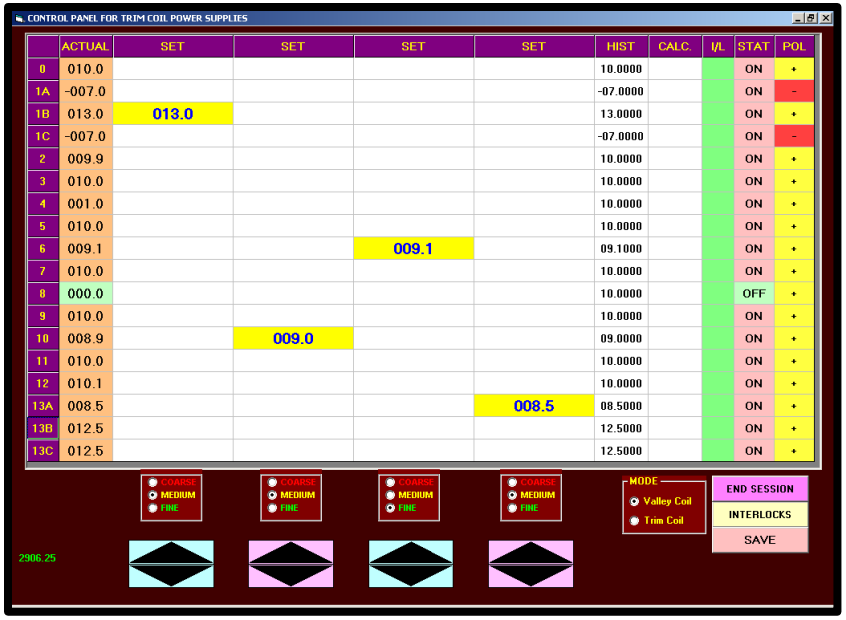
GUI of MMPSs & TCPSs





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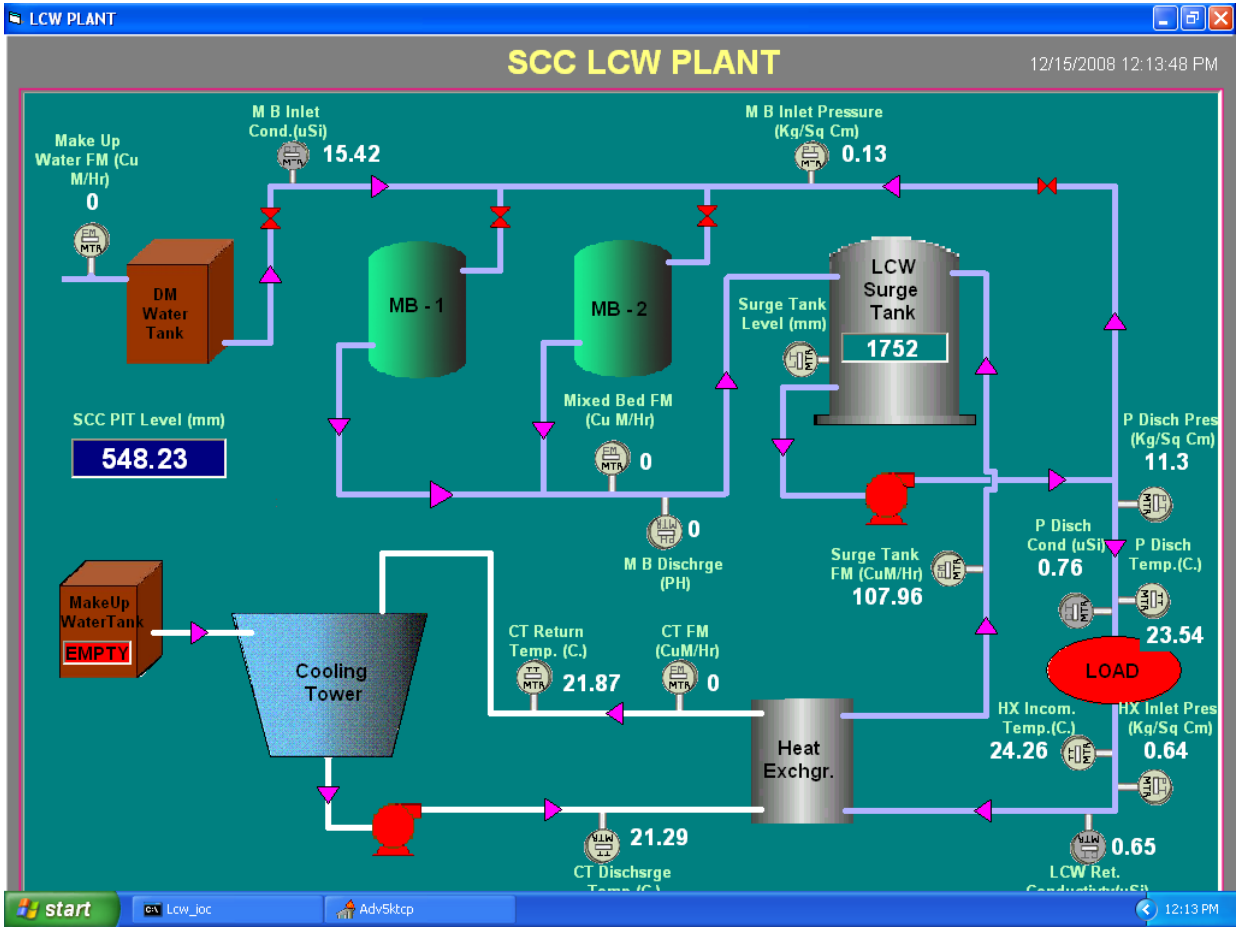
LCW Plant



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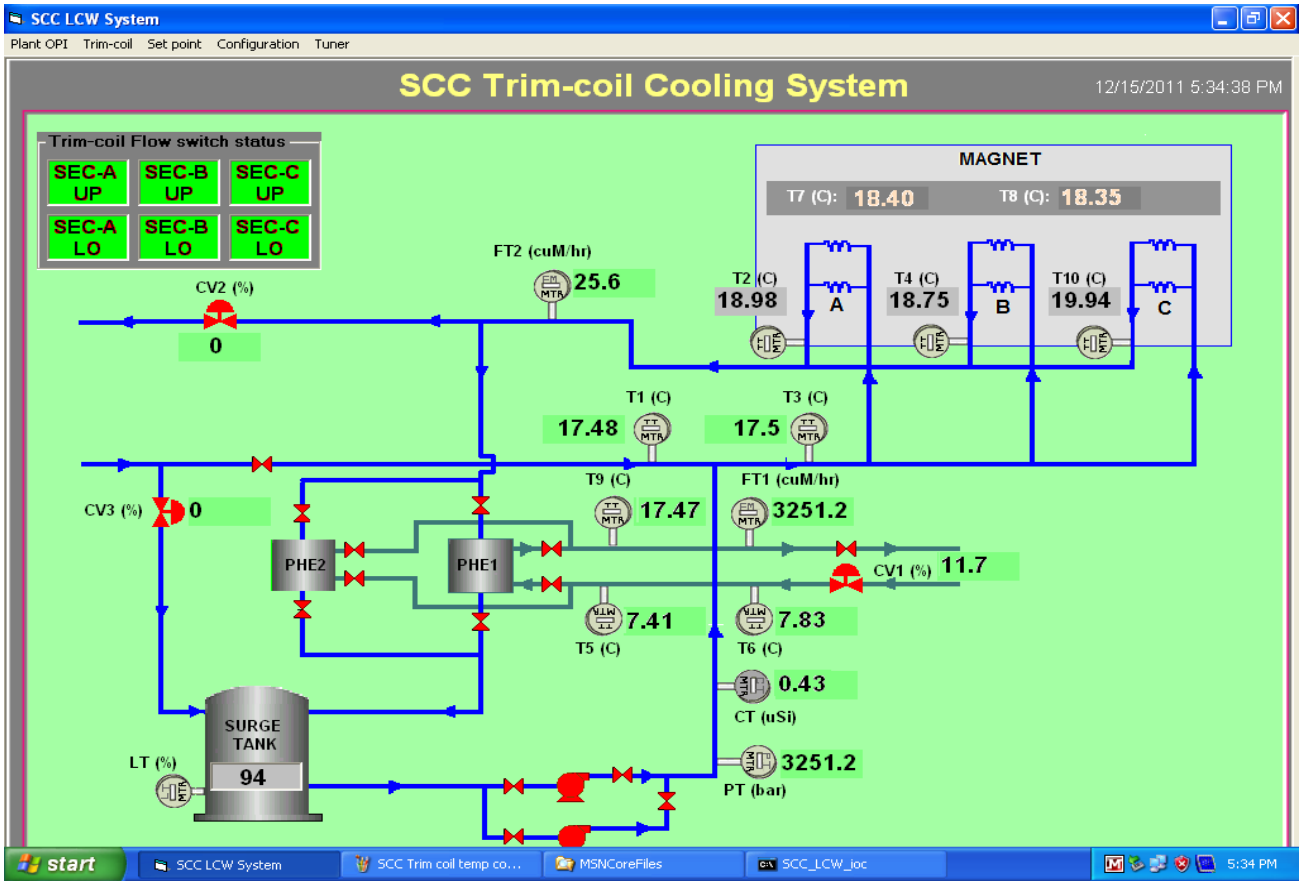
Trim Coil Cooling System



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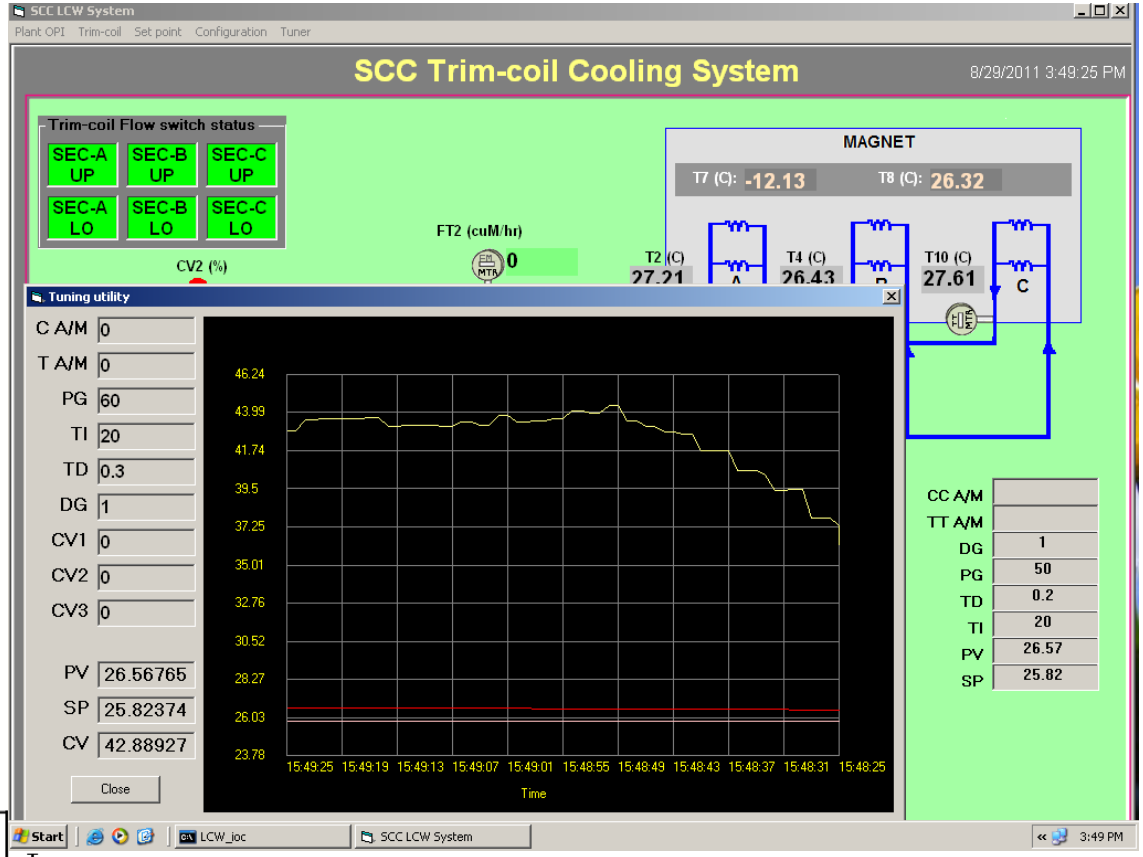
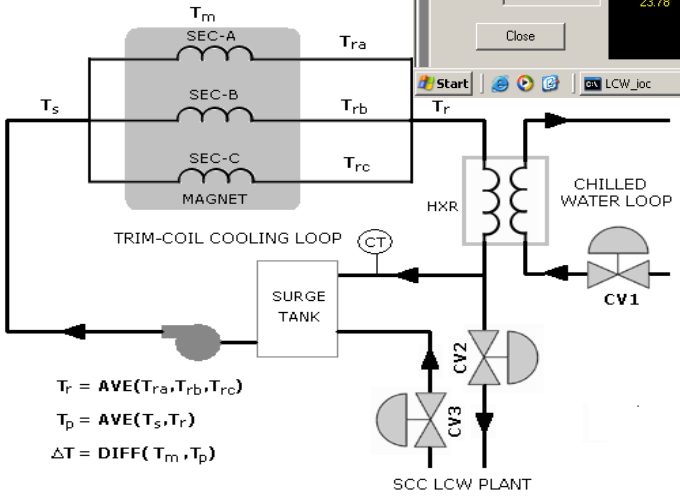
Loop Control TC Cooling System





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Central Console of SCC

- LAN based two layer architecture
- PC based soft meters for monitoring of all parameters
- Assignable soft knobs for controlling multiple parameters
- On-line numerical trending of important parameters
- MySQL Database for control parameter logging and historic analysis

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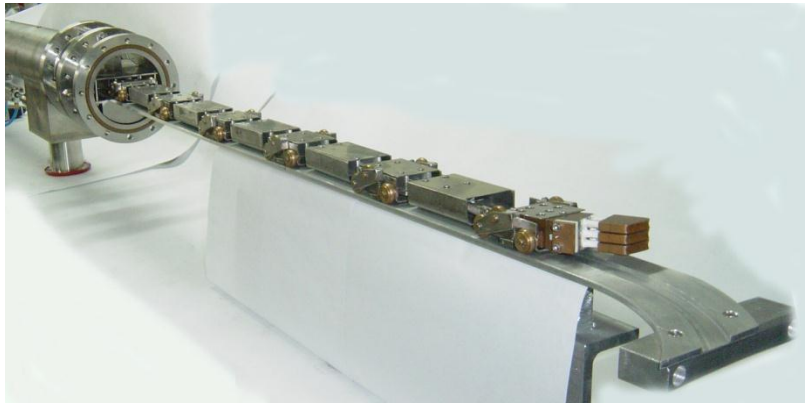
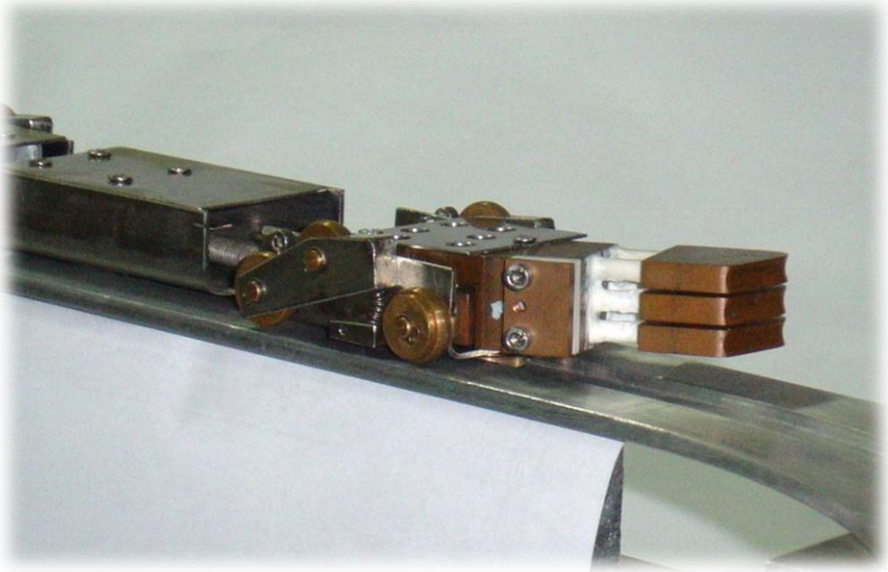
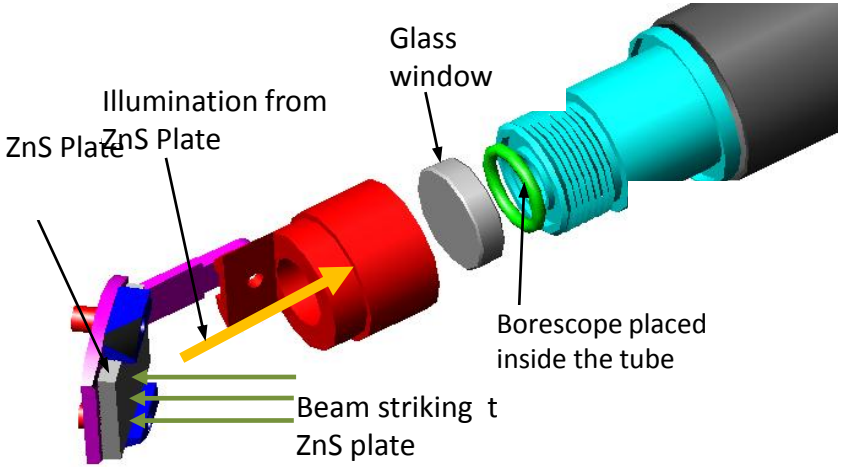
Beam Diagnostic Components

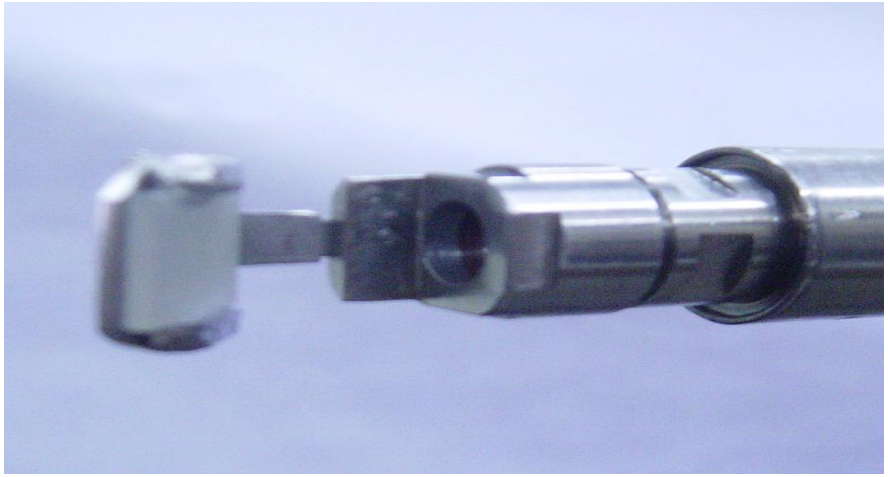
- Acceleration Chamber
  - Main Components
    - Main Probe
    - Beam viewer Probe
    - Slit
  - Auxiliary Components
    - Magnetic Channel
    - Inflector
- Beam Line
  - Faraday Cup
  - Beam viewer
  - Slit

Internal Beam Diagnostics Components

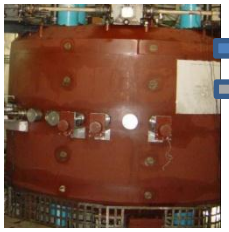








Viewer Probe Control



SUPERCONDUCTING CYCLOTRON

BORESCOPE

CCD CAMERA

LINEAR ENCODER

DRIVING MECHANISM

Stepper Motor Driver

Read-Out System

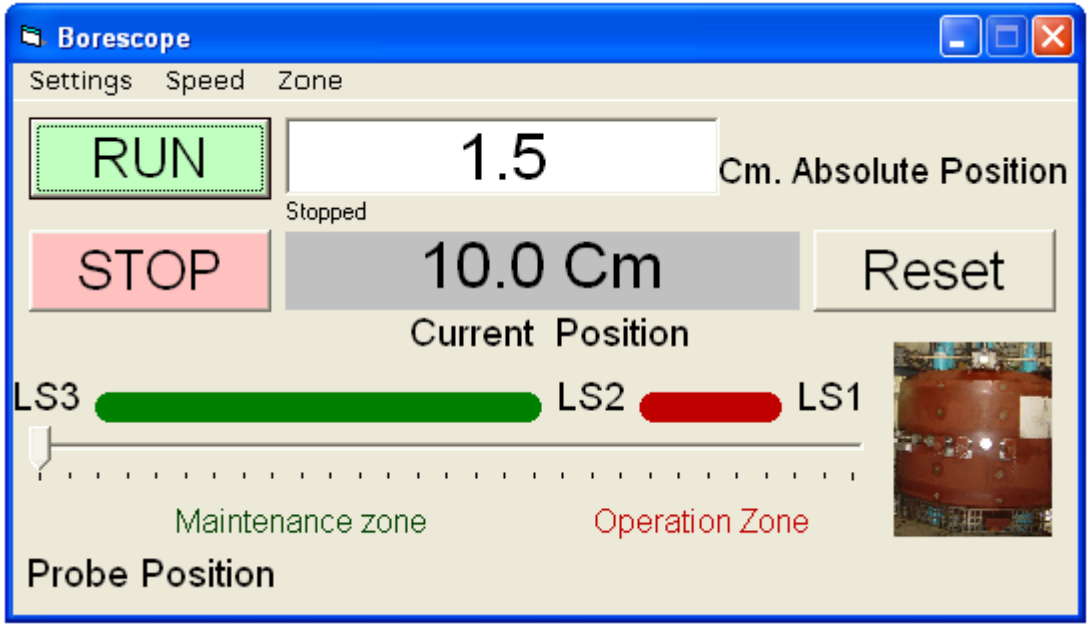
Valve control/Read

RS232

RS485

SERVER PC AT BASEMENT

CONTROL LAN

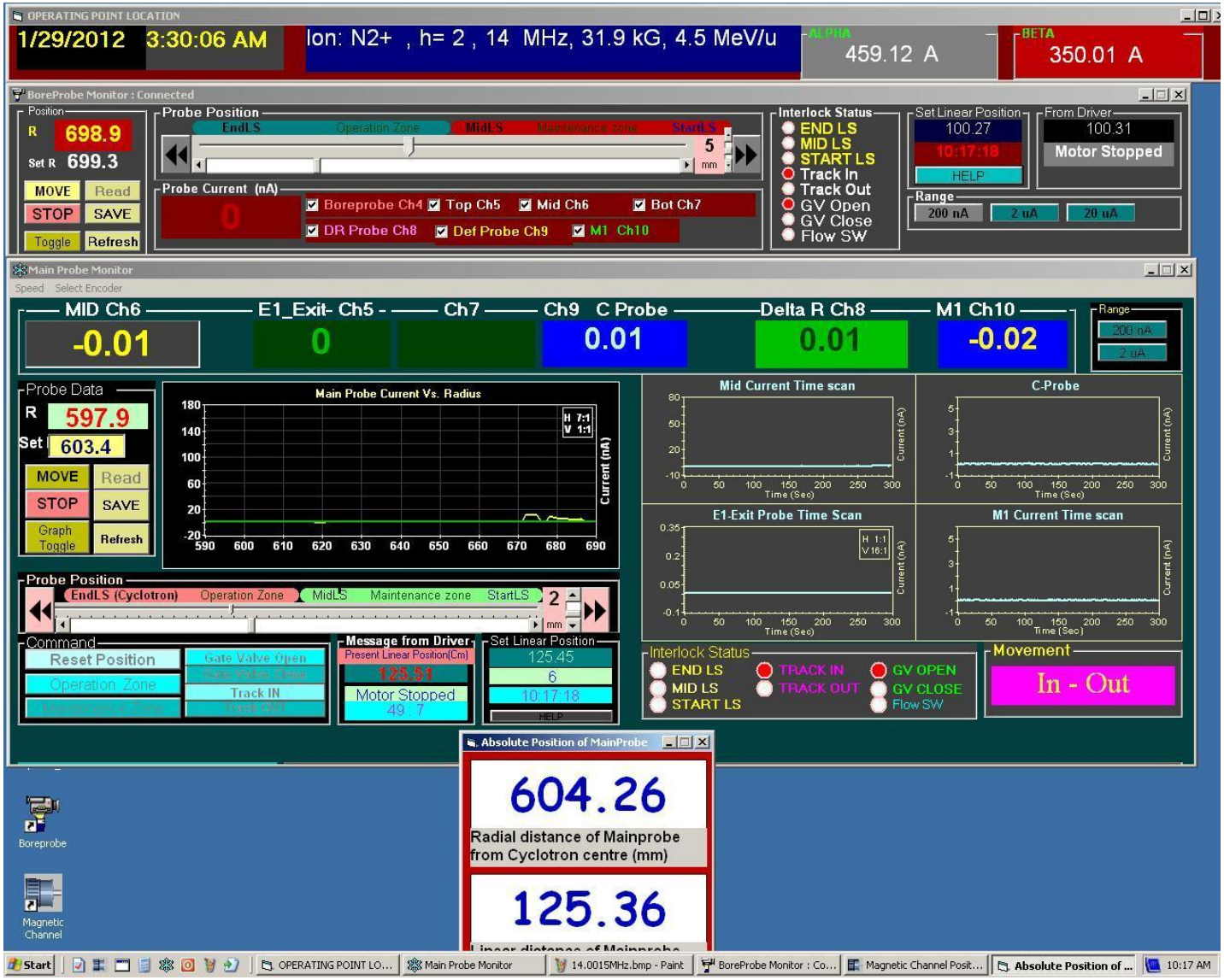


CLIENT PC AT CONTROL ROOM

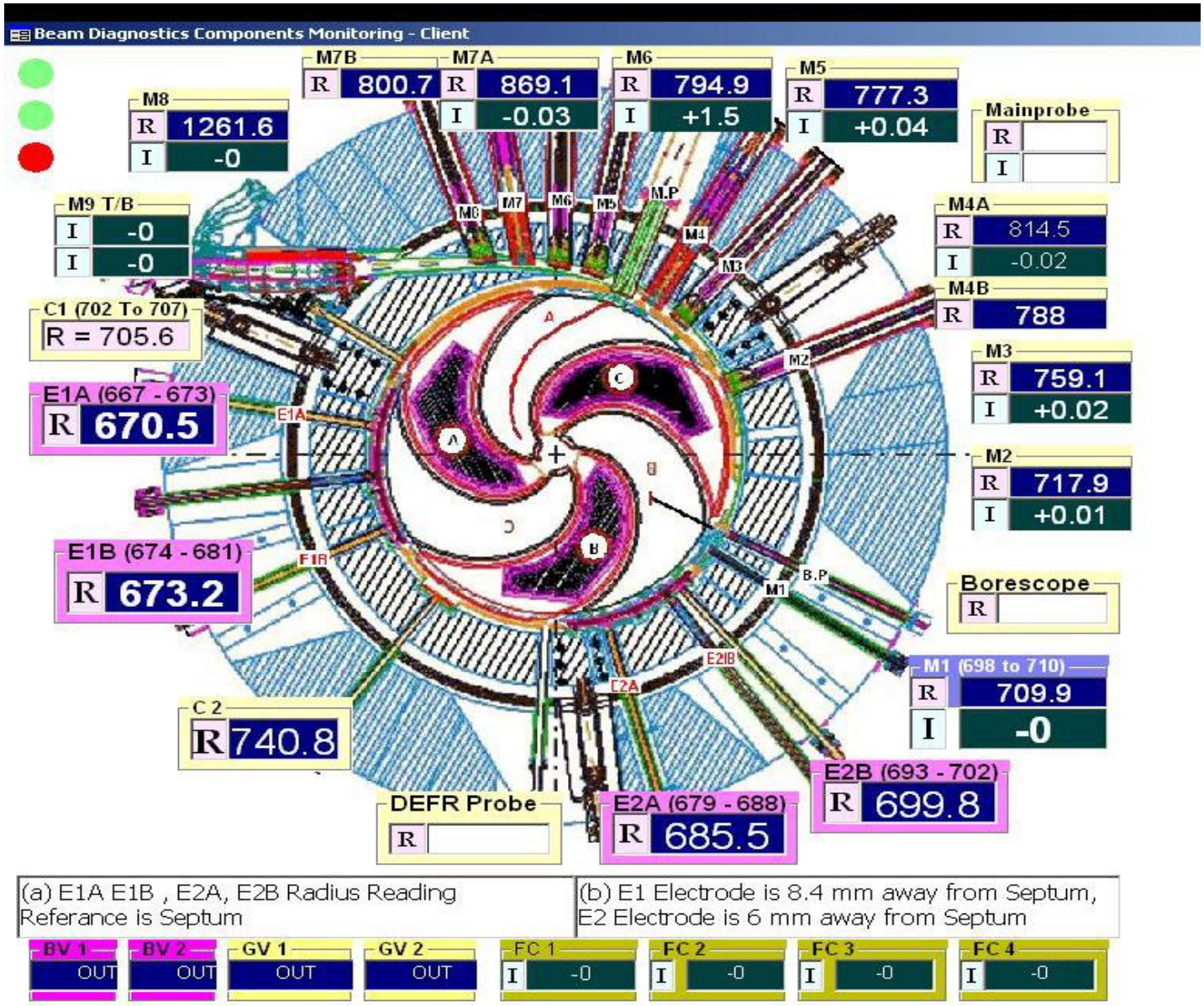
LCD TV

- Diagnostic Component
- Probe Control
- Profile

Internal Probe Control

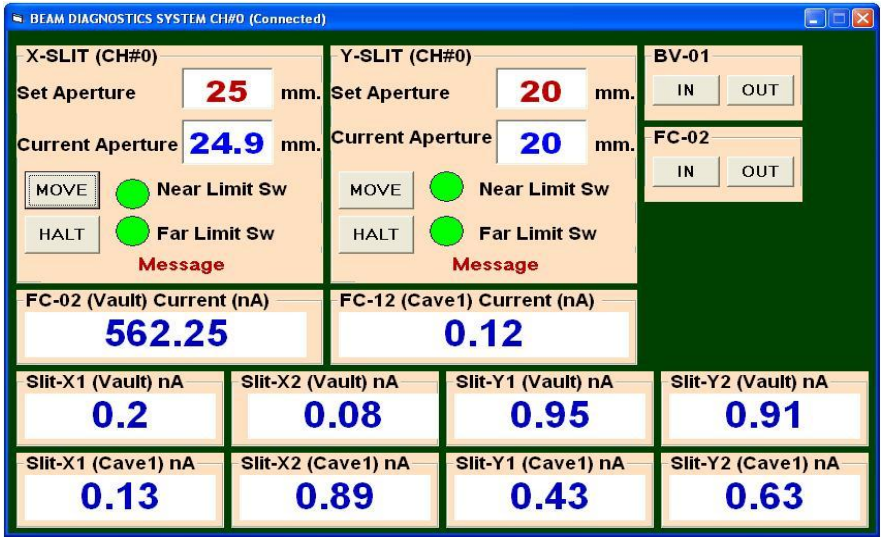


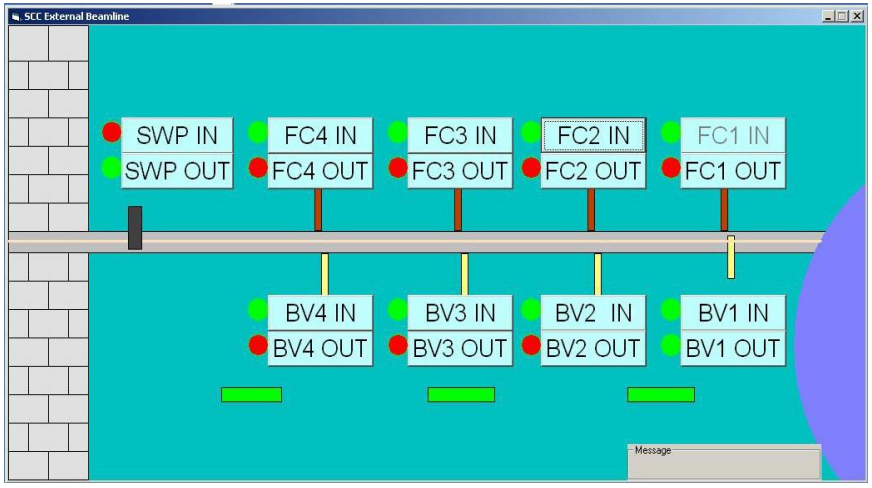
Internal Probes



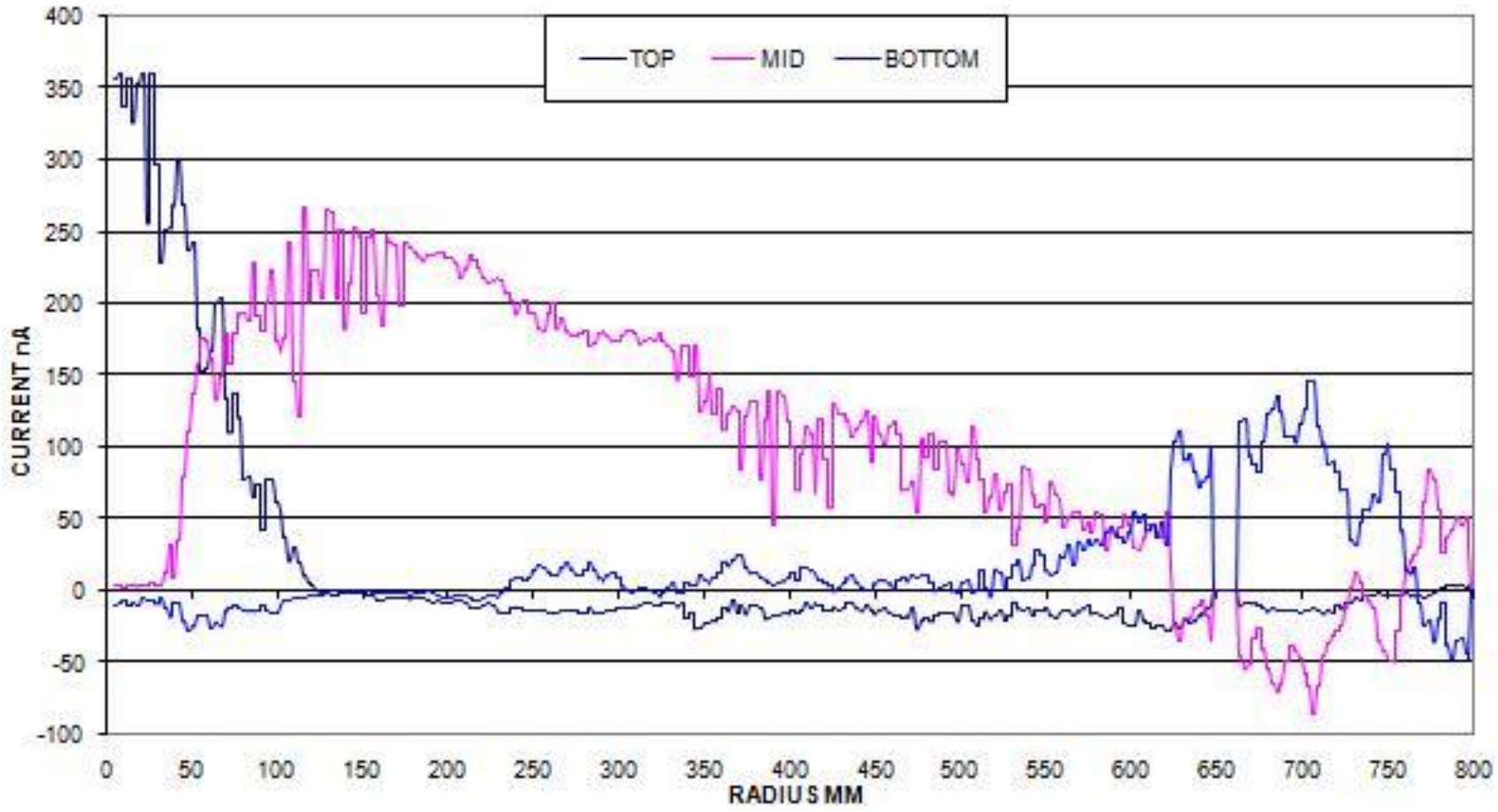
- Diagnostic Component
- Probe Control
- Profile

Probe Monitoring and Control





Three Finger Probe Profile



- Diagnostic Component
- Probe Control
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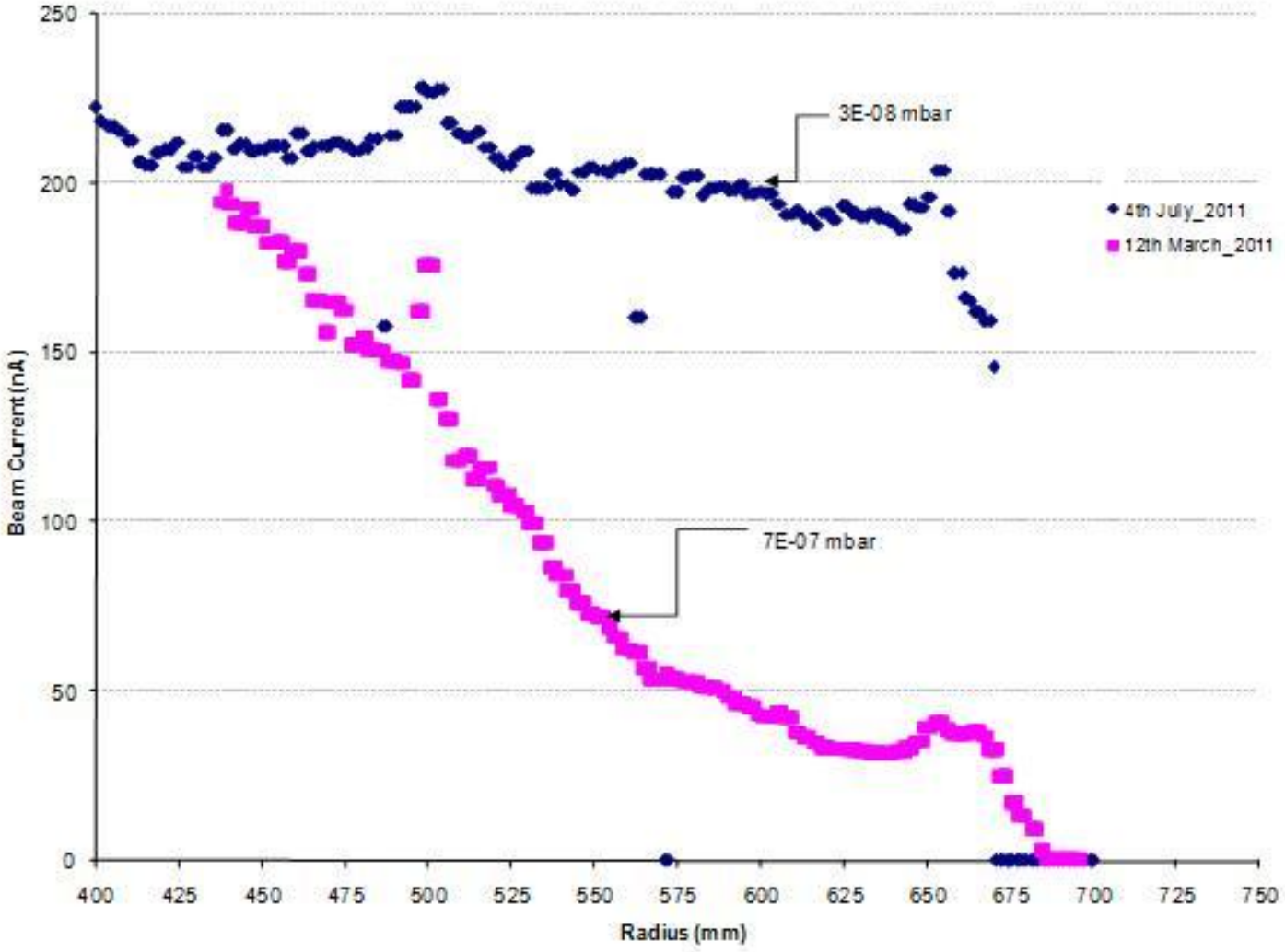
Internal Beam Profile



Modernisation of Control

- EPICS Implementation
- Supervisory Control
- VEC MPSs Control
- VEC Vacuum Control
- Central Console of VEC
- Control DB
- Secured Access

EPICS Implementation

- Vacuum System
- MPS
- LCW System
- Beam Diagnostic

Modernisation of Control

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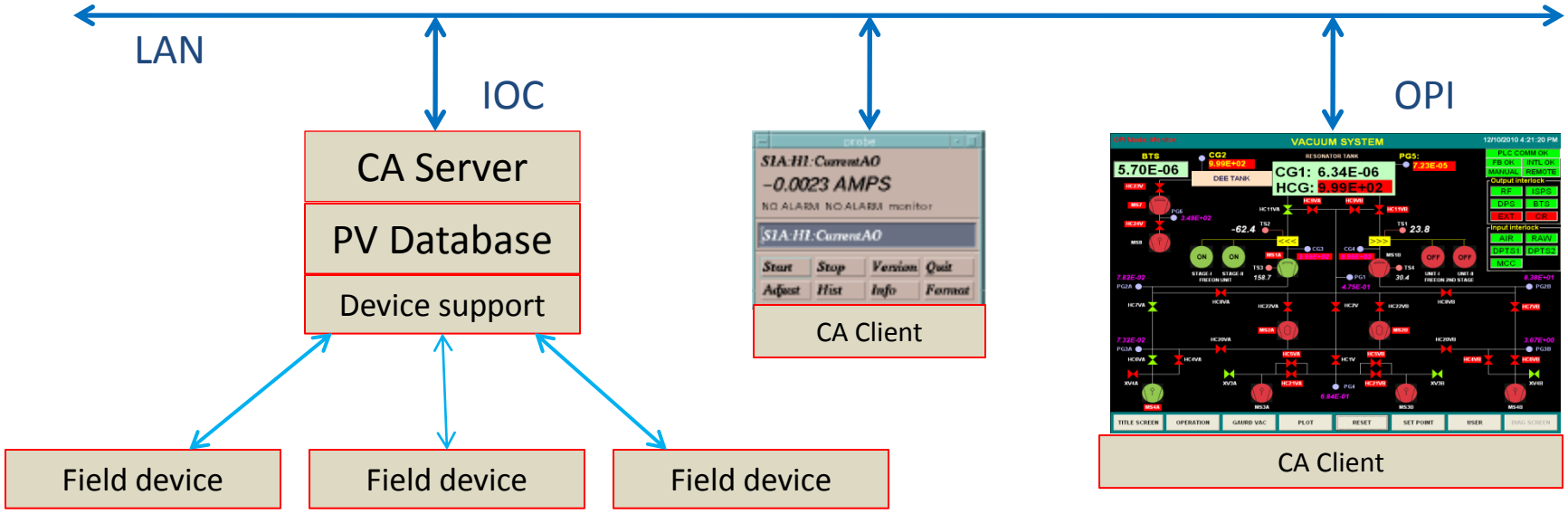
Supervisory Control System - EPICS

- Underneath protocol
  - Channel Access (CA)
- Network transparent protocol
  - Hides communication intricacies of field devices from GUI
- Unique PV names
  - to bridge link between CA server & CA client
- Access security
  - to protect access of crucial parameters
- Event based notification
  - Value is changed



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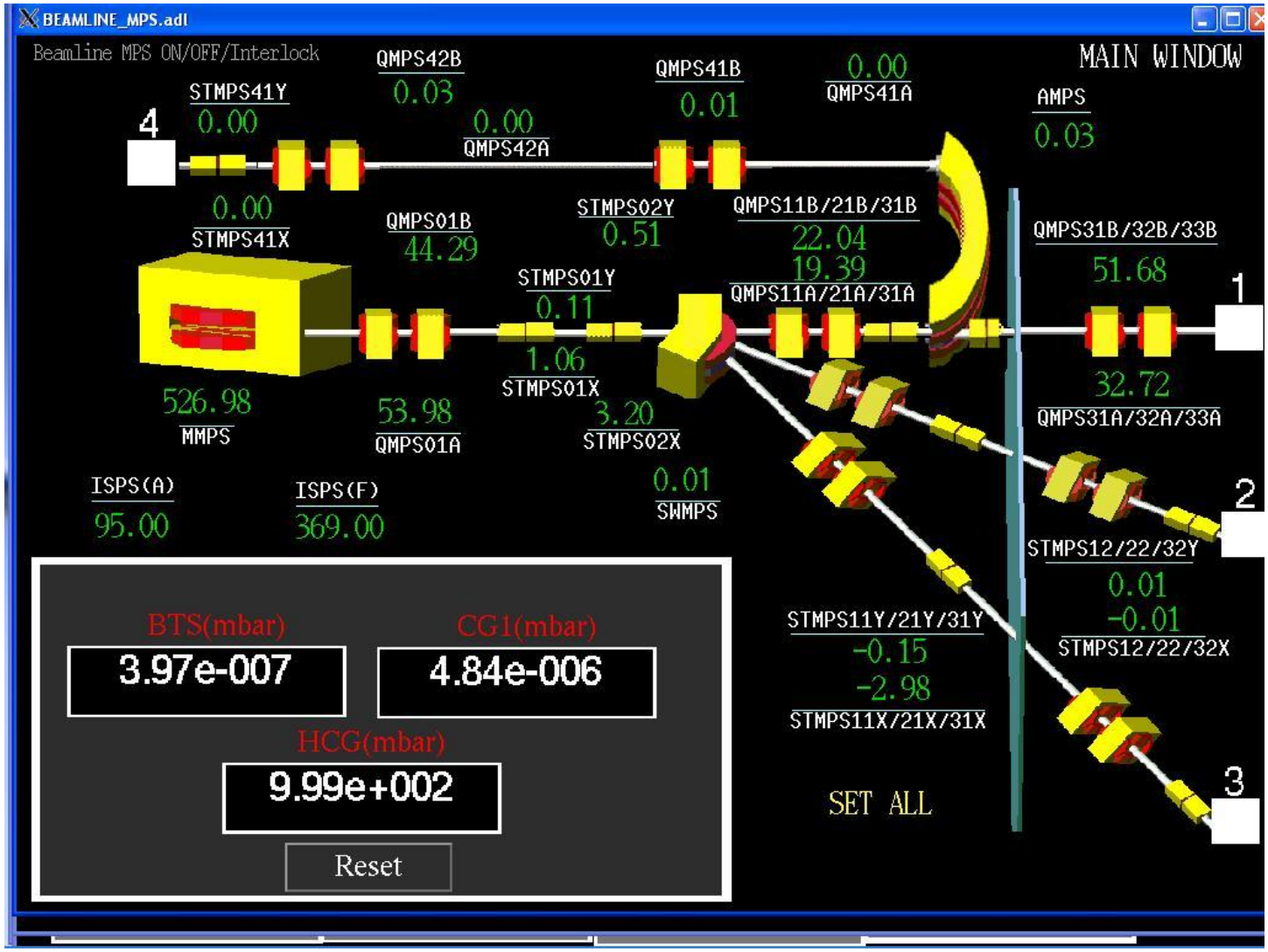
VEC MPSs Control



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PLC Based RTC Vacuum System

- Basic requirement
  - Desired vacuum level – 2 x 10^{-6} Torr at Resonator tank, DEE tank and Beam lines
  - Volume of Resonator tank & DEE tank– 23 m3 approx.
- Basic features
  - Commissioned around 1975
  - Available technology – Oil Diffusion Pump, Freon cooled chevron baffle, Roots pump, Rotary pump
  - Hot-cathode, cold-cathode & thermocouple gauge
  - Redundant pumping system to support from Roughing to Backing
  - Relay based Manual Control Logic
- Renovated in 2009
  - Replacement of fifteen crucial gate valves for better isolation
  - Use of new state-of-the-art Pirani , Combination gauges & RTD
  - Replacement of Freon unit & chevron baffles
  - Up gradation of Control system to modern PLC based system

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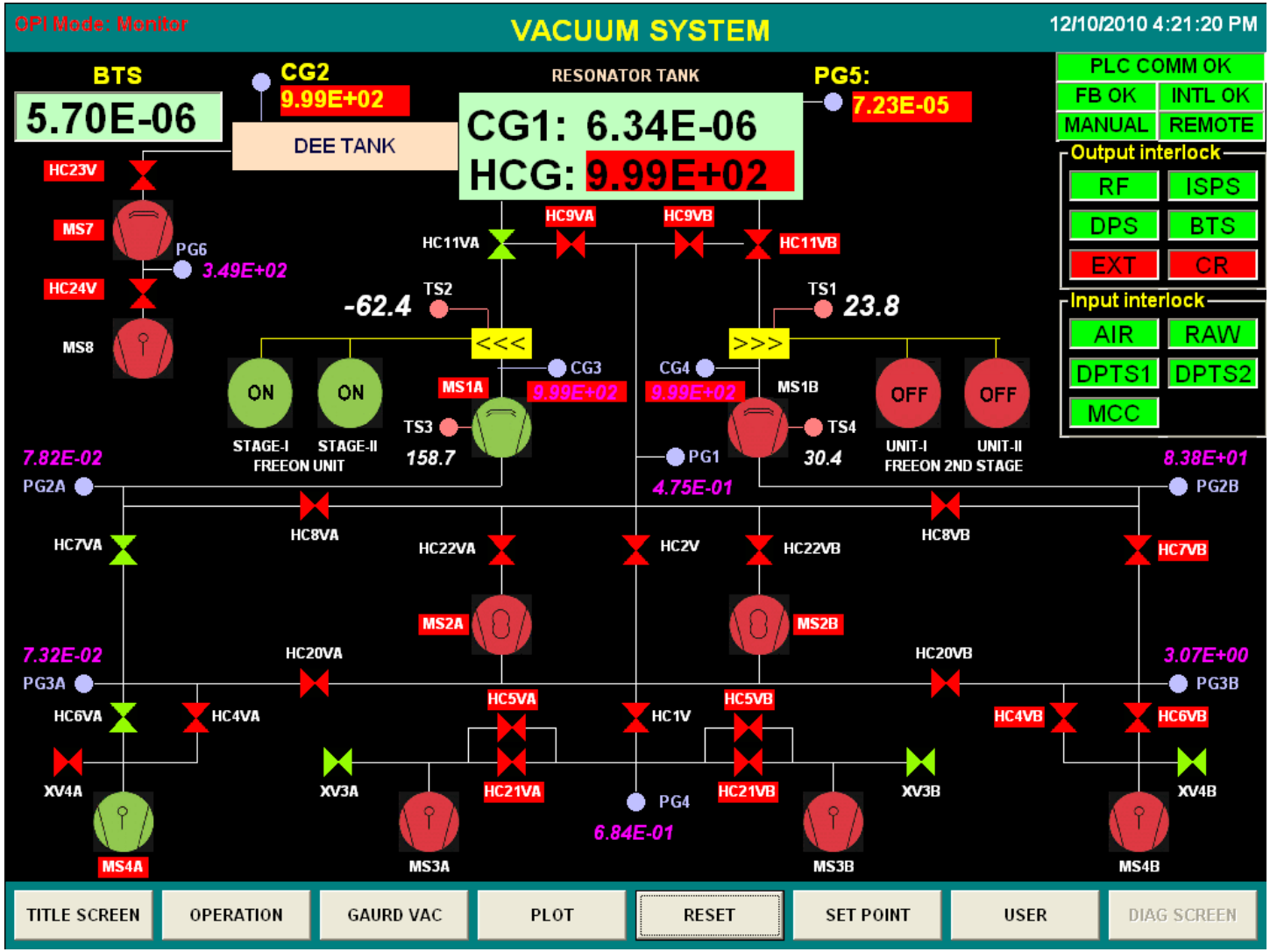
VEC Vacuum Control



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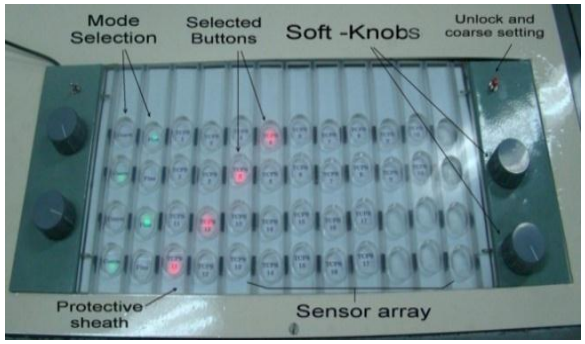
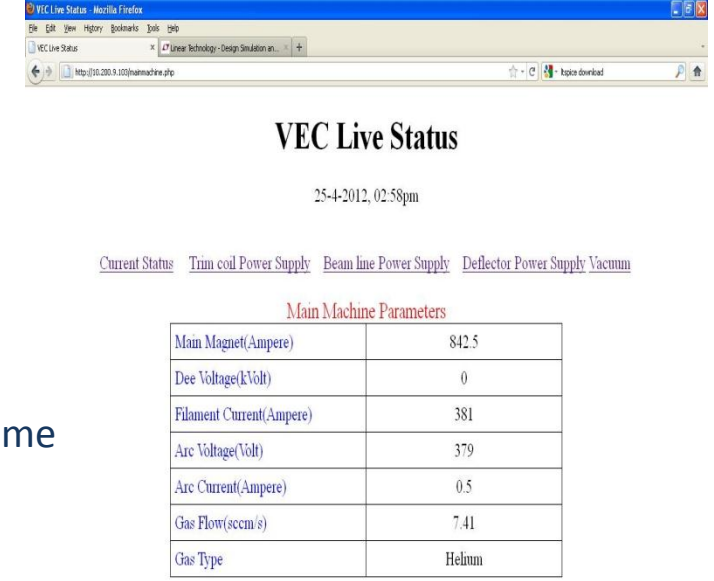
- Secured Access

New look of Central Console of VEC



- Direct measurement by individual cable
- Push buttons, toggle switches, multiturn pots, selector switches
- DPMs, analog meters, measuring instruments and indicator lamps for display
- Manual multiplexing

Implementation of Control Database for SCC & VEC with Secured Access



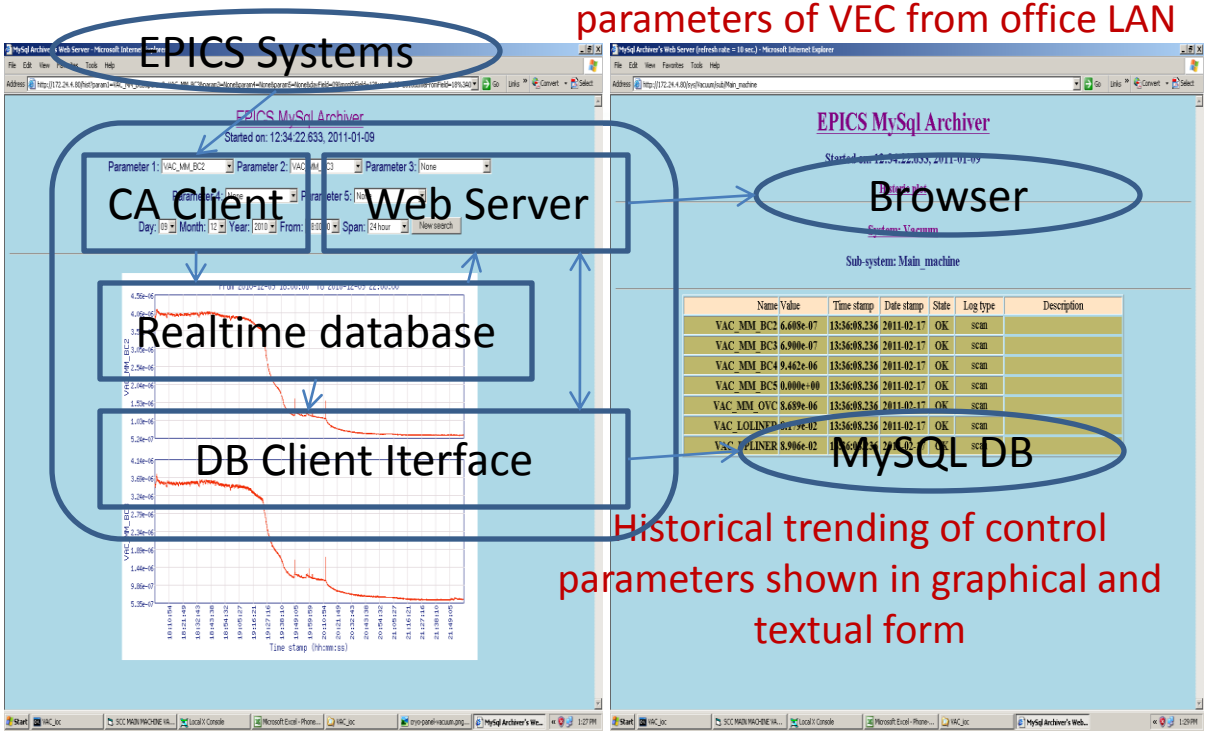
Live monitoring of control parameters of VEC from office LAN

What it does?

- Archiving a large number of control parameters of different subsystems e.g. Cryogenic, Magnet Power Supply, RF system, Vacuum, ECR, Beam Diagnostic etc.
- Provide snap shot view of correlated control parameters over time
- Integration of SCC and VEC control LAN
- Secured access of control parameter from office LAN
- Facilitate archiving of EPICS and non-EPICS system parameters

Important features

- EPICS tool for interfacing database
- Developed in VECC
- Supports polling & event driven types of data logging
- Auto configuration of database
- Inbuilt web server for online distributed viewing
- Historic data analysis
- Graphical comparison among archived data
- Web based online Addition/ Removal/ Modification of data

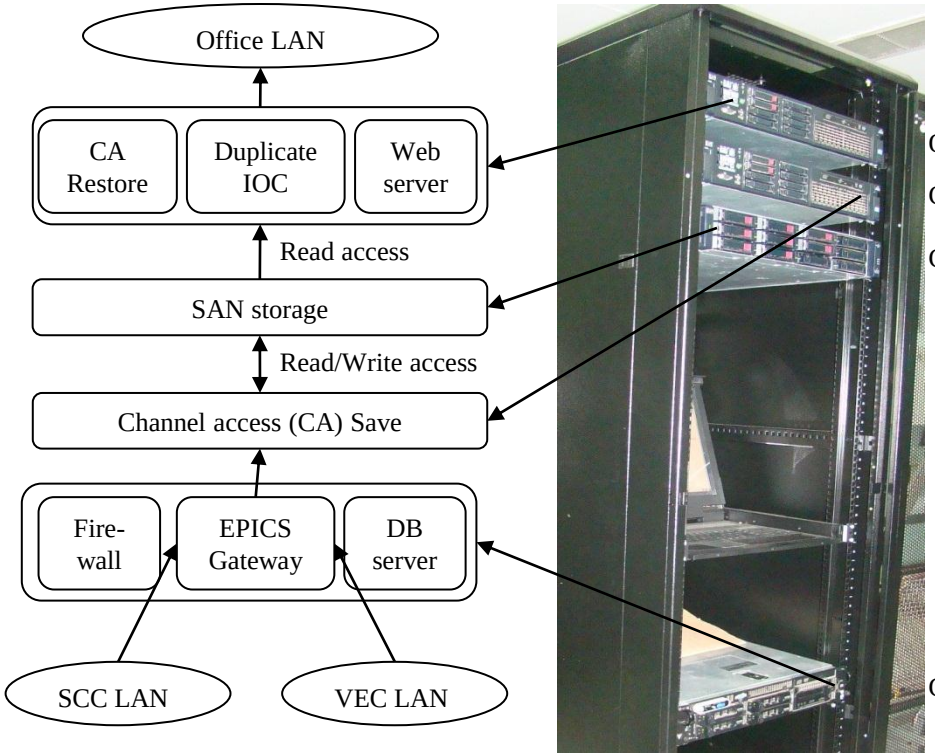


Historical trending of control parameters shown in graphical and textual form

Modernisation of Control

- EPICS Implementation
- Supervisory Control
- VEC MPSs Control
- VEC Vacuum Control
- Central Console of VEC
- Control DB
- Secured Access

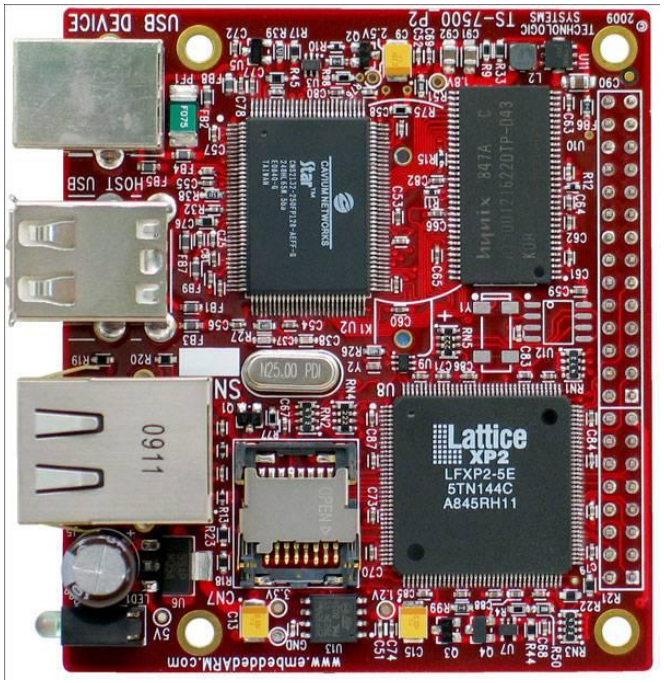
SAN system



Future Plans

- Epics Enabled Controller
- In-house Design
- EPICS Performance Analysis
- Concluding Remark

Epics Enabled Controller



- 250MHz ARM9 CPU, 64MB DDR-RAM, 4MB Flash, Micro SDHC Card slot
- Customizable 5K LUT OpenCore FPGA
- Ethernet, UART, DIO, SPI and I2C interfaces, Watchdog Timer
- Small size, Low power
- Prebuilt Linux 2.6 kernel loaded on micro sd card/flash and boots in than seconds
- Full featured Linux including GNU C/C++ embedded development environment installed in the SD Card

Future Plans

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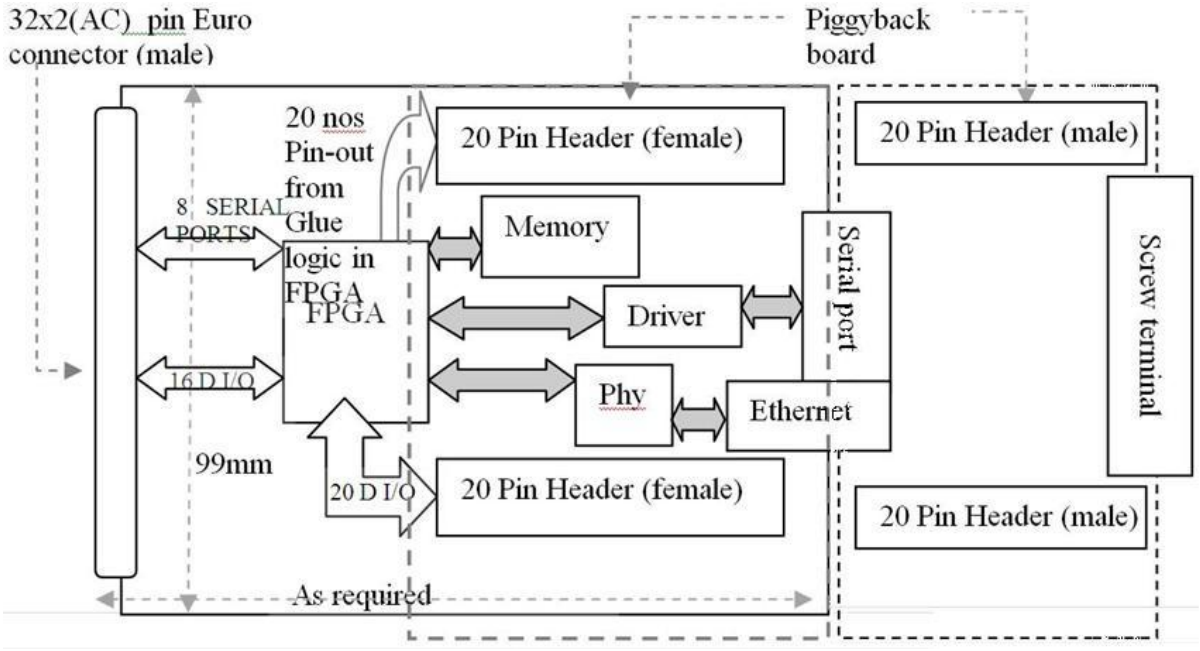
In-house Design of Embedded EPICS Controller



Future Plans

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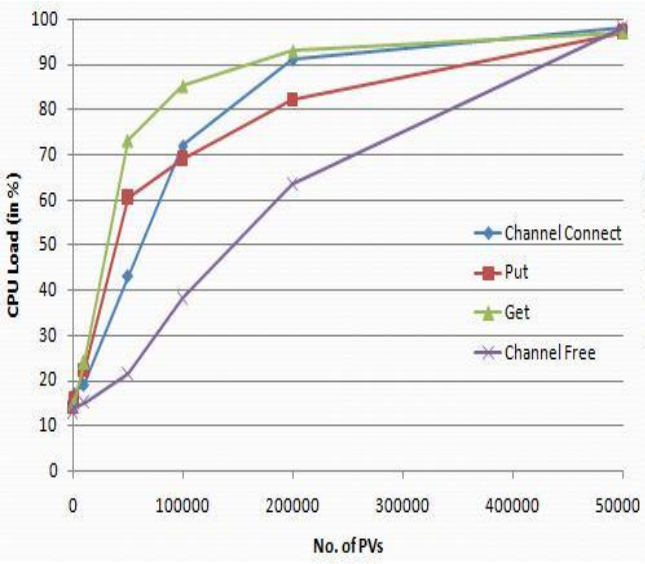
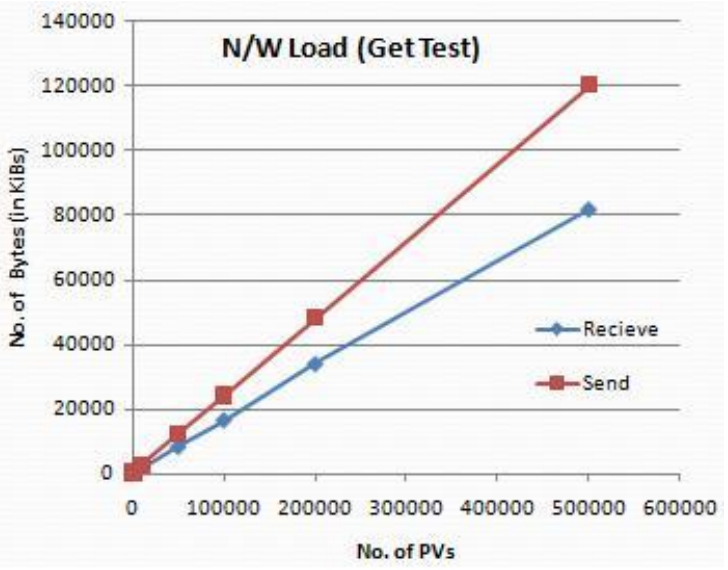
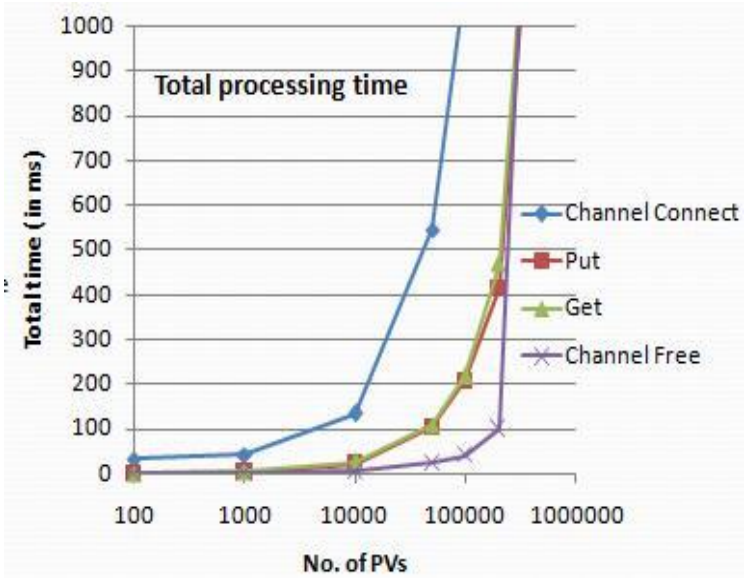
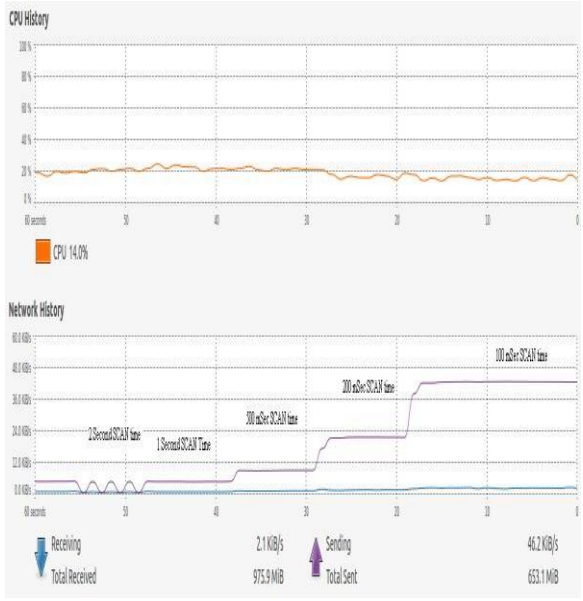
EPICS Performance Analysis





- Performance analysis
  - CPU Load
  - Server Processing Time
  - Network Load
  - Database Performance





Future Plans

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I/O Channels requirement

System Data Statistics	SCC (No. of Parameters)	VEC (No. of Parameters)
Internal Beam Diag.	16	6
External Beam Diag.	40	20
Magnet Power Supply	34x8	40x8
Vacuum (Main & Beam Line	214	216
LCW Cooling	42	34
Radiation Surveillance System	32x6	40x6
Temperature Monitoring	--	25

Future Plans

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Components used for Control/Monitor

- System Components
  - Pump
  - Valve
  - Motor
  - Encoder
  - Camera
- Process Variables
  - Vacuum/Pressure
  - Temperature
  - Level
  - Flow
  - Current
  - Voltage
  - Position
  - Status Flag
- Control H/W Components
  - PLC
  - Controller
  - DAQ Module
  - Field point module
  - Measuring devices
  - Multiplexer
  - Converter
  - Filter

- Supervisory Control S/Ws
  - EPICS
  - LabView
  - VB
  - Proprietary

Future Plans

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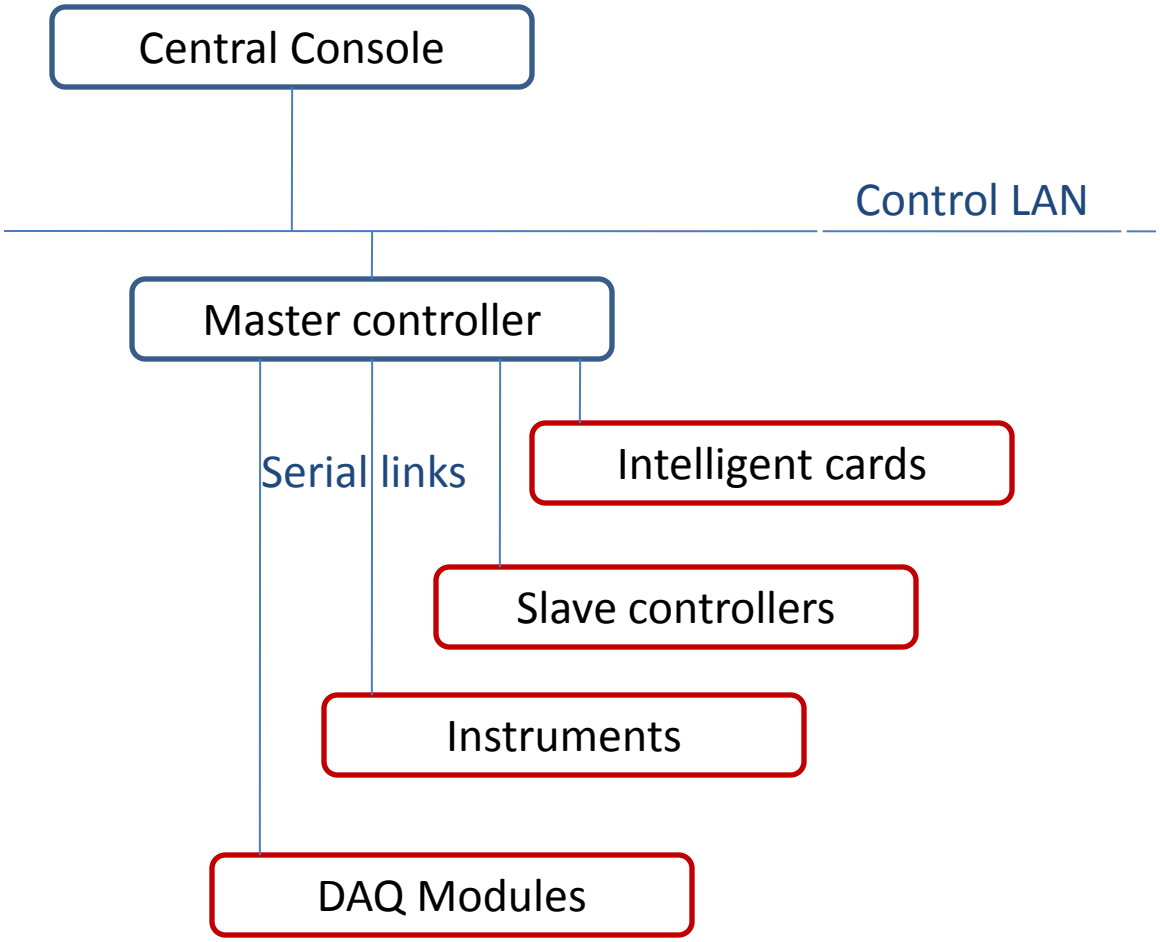
Embedded Controller Scheme



Concluding Remark

The simple equation :-

Reliability of HW/SW

\+ Availability of HW/SW (cost effective)

\+ Maintainability of HW/SW (openness)

\+ Upgradability of HW/SW (openness)

= LONG-LIVED CONTROL SYSTEM

Acknowledgement

- Members, AI&C Section and C&I Group
- Members, ECR Ion Source Facilities Section
- Members, Cryogenic Instrumentation Section
- Members, Accelerator Physics Group
- Head, C&I Group and Head, DA&CC Division

Thank You !