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DEVELOPMENT OF THE CONTROL SYSTEM FOR PEFP 100-MeV PROTON LINEAR ACCELERATOR

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Proton Engineering Frontier Project
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- Control System (20 MeV linac)
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Introduction

PEFP Proton Engineering Frontier Project

- **Project: Proton Engineering Frontier Project (PEFP)**
  - **21C Frontier R&D Program, MEST, Republic of Korea**

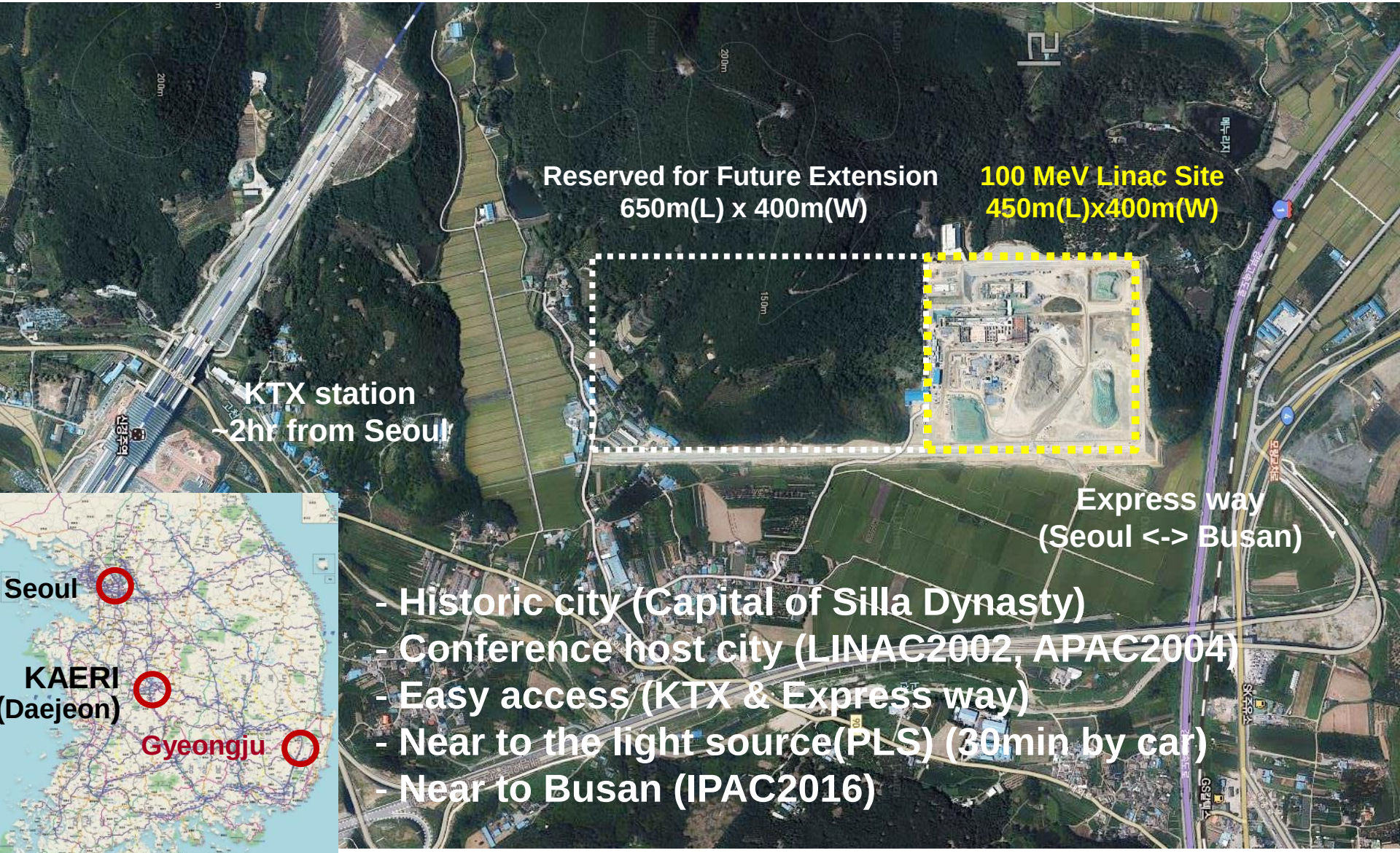
- **Objectives**
  - **To develop a High Power Proton Linac (100MeV, 20mA)**
  - **To develop Beam Utilization & Accelerator Application Technologies**
  - **To Industrialize Developed Technologies**

- **Period: July 2002 – December 2012**

- **Budget: 307.4 B KRW (~275.0 M US$)**
  - **Gov.: 176.3B(57.3%), Local Gov.: 118.2B(38.5%), Industry: 12.9B(4.2%)T**
  - **66B KRW to Accel. & Beamline (including R&D & personnel expenses)**

Project Site : Gyeongju

PEFP Proton Engineering Frontier Project



Site Plan

PEFP Proton Engineering Frontier Project

Accelerator Building & Experimental Hall

PEFP Proton Engineering Frontier Project

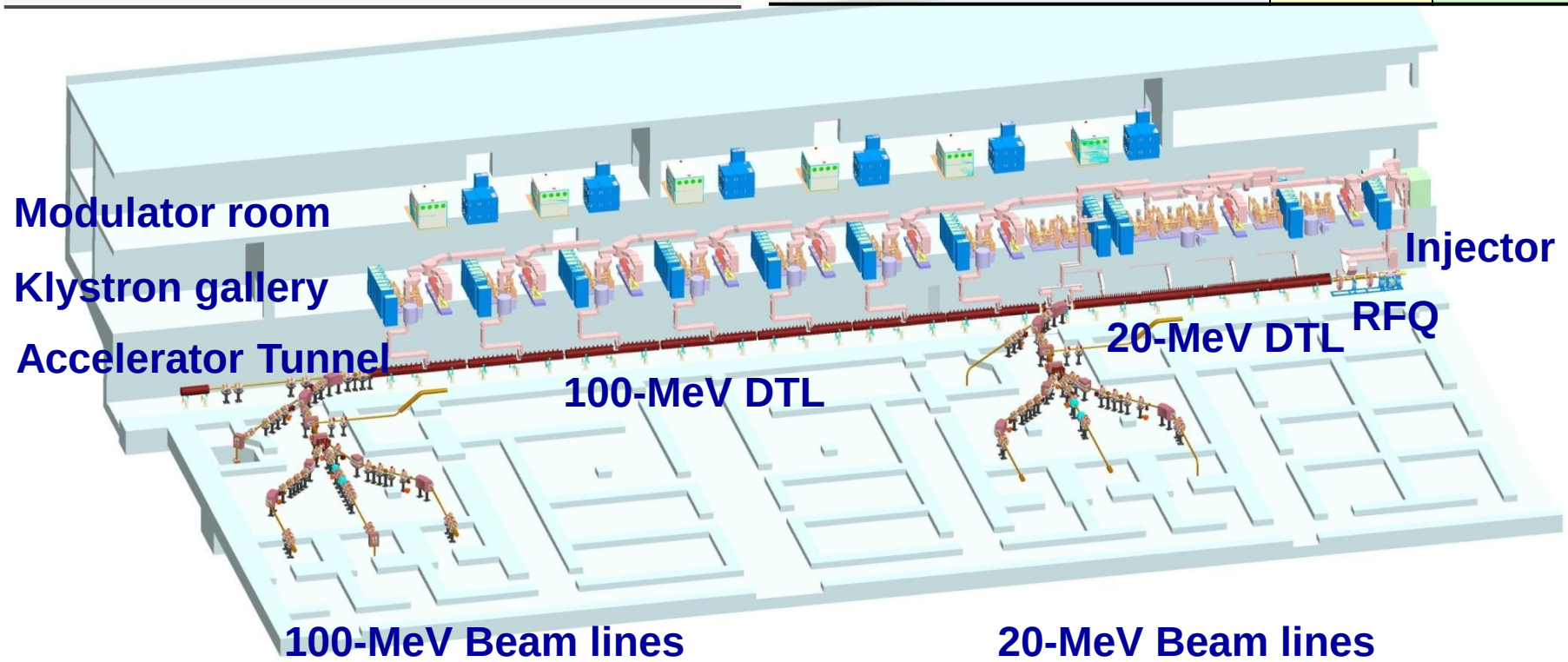
PEFP 100-MeV Linac

PEFP Proton Engineering Frontier Project

Features of the PEFP 100MeV linac

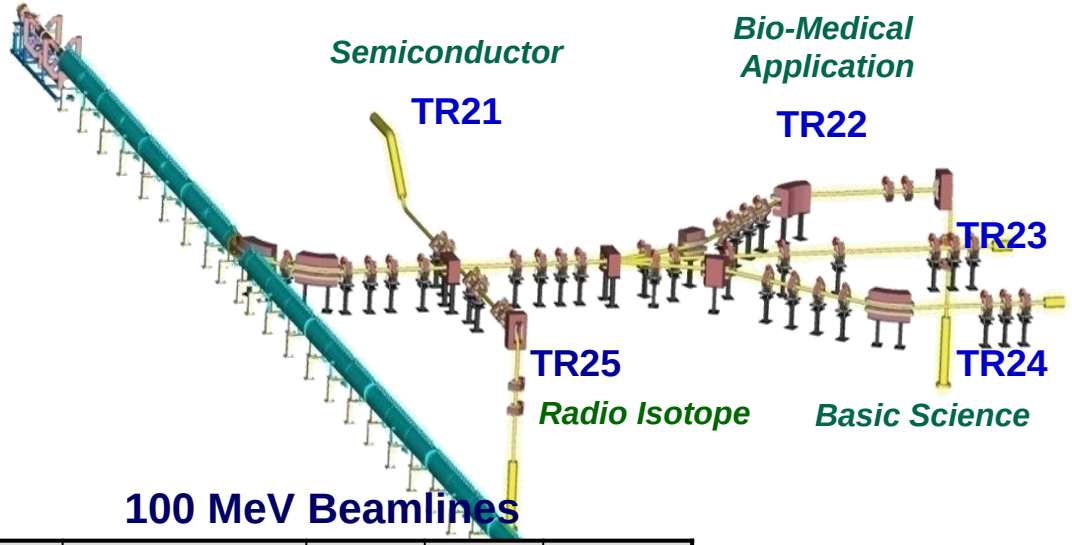
- 50 keV Injector (Ion source + LEBT)
- 3 MeV RFQ (4-vane type)
- 20 & 100 MeV DTL
- RF Frequency : 350 MHz
- Beam Extractions at 20 or 100 MeV
- 5 Beamlines for 20 MeV & 100 MeV

Output Energy (MeV)	20	100
Max. Peak Beam Current (mA)	1 ~ 20	1 ~ 20
Max. Beam Duty (%)	24	8
Avg. Beam Current (mA)	0.1 ~ 4.8	0.1 ~ 1.6
Pulse Length (ms)	0.1 ~ 2	0.1 ~ 1.33
Max. Repetition Rate (Hz)	120	60
Max. Avg. Beam Power (kW)	96	160



PEFP Beam Lines

- ❑ Designed by reflecting user's requirements (through User Program)
- ❑ Developed components: QM, ACM, DM & beam instruments, Beam window

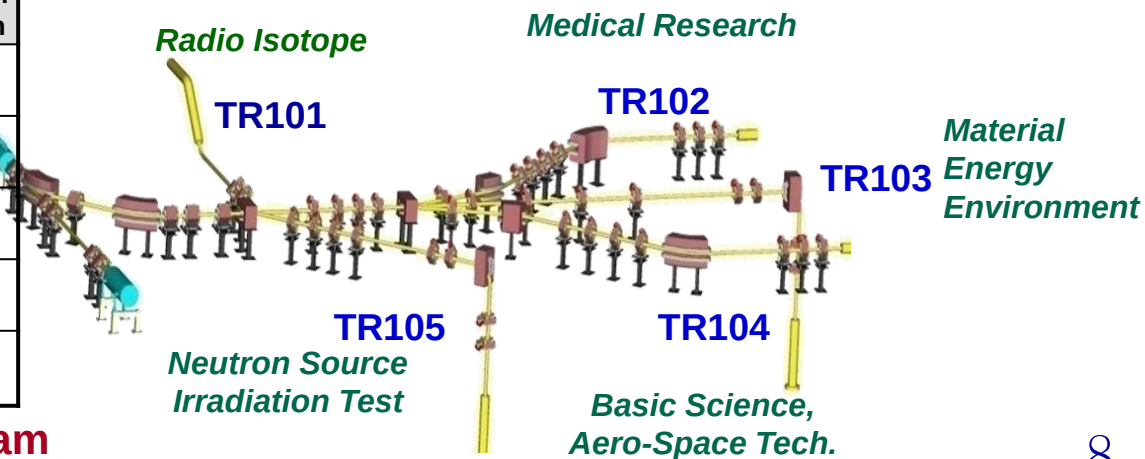


20 MeV Beamlines

Beam Line	Application Field	Rep. Rate	Avg. Current	Irradiation Condition
TR21	Semiconductor	60Hz	0.6mA	Hor. Ext. 300mmØ
TR22	Bio-Medical Application	15Hz	60μA	Hor. Ext. 300mmØ
TR23	Materials, Energy & Environment	30Hz	0.6mA	Hor. Ext. 300mmØ
TR24	Basic Science	15Hz	60μA	Hor. Ext. 100mmØ
TR25	Radio Isotopes	60Hz	1.2mA	Hor. Vac. 100mmØ

100 MeV Beamlines

Beam Line	Application Field	Rep. Rate	Avg. Current	Irradiation Condition
TR101	Radio Isotopes	60Hz	0.6mA	Hor. Ext. 100mmØ
TR102	Medical Research (Proton therapy)	7.5Hz	10μA	Hor. Ext. 300mmØ
TR103	Materials, Energy & Environment	15Hz	0.3mA	Hor. Ext. 300mmØ
TR104	Basic Science Aero-Space tech.	7.5Hz	10μA	Hor. Ext. 100mmØ
TR105	Neutron Source Irradiation Test	60Hz	1.6mA	Hor. Vac. 100mmØ



☞ 33, 45, 57, 69, 80, 91, 100 MeV beam

20-MeV Linac

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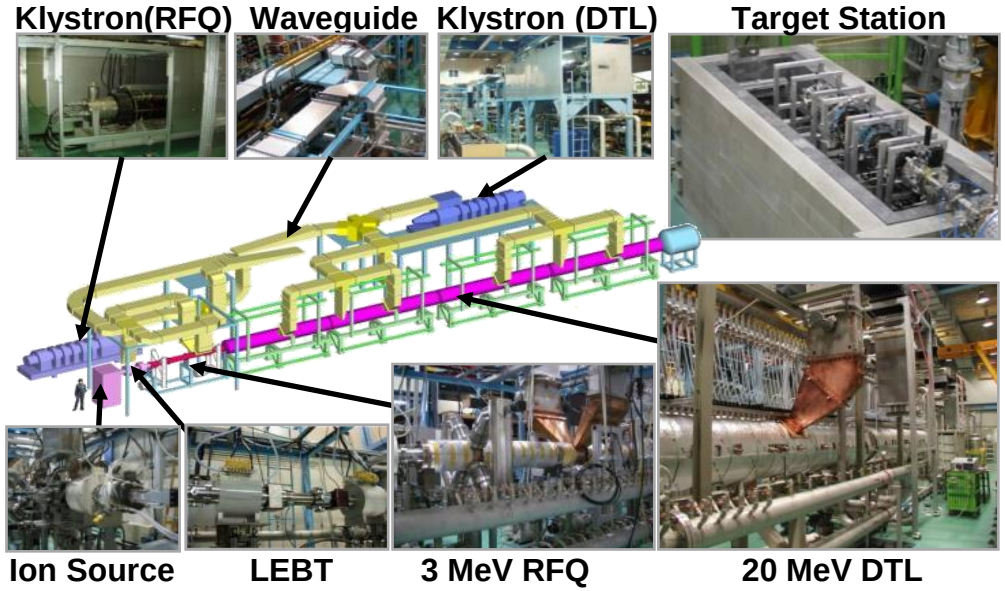
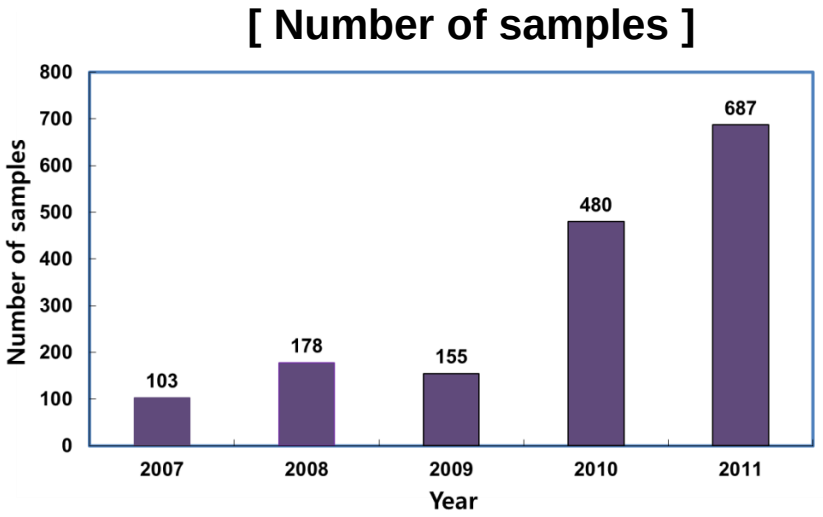
- Operation at KAERI in Daejeon : Linac test and Beam supply to users
  - RFQ, DTL : designed (PEFP), fabricated (domestic company)
  - Integrated (May 2005)
  - First beam extraction (July 2005)
  - Operation license (June 2007) : Avg. Current 1 μA, 4-hour/week
  - User beam service (from July 2007)
  - Operation finish (Nov. 2011)
  - Installation at project site in Gyeongju (Feb. 2012)





20-MeV Linac Disassembly and Movement

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- Disassembly of the 20-MeV linac from Dec. 2011
- Movement from Daejeon to Gyeongju (~200km apart)
- DTL and klystron was trasported by using the vibration free truck through express way.
- No notable field distortions in DTL before and after (~ 3%)
- Special supporter with oil jack and caster was used in the tunnel.

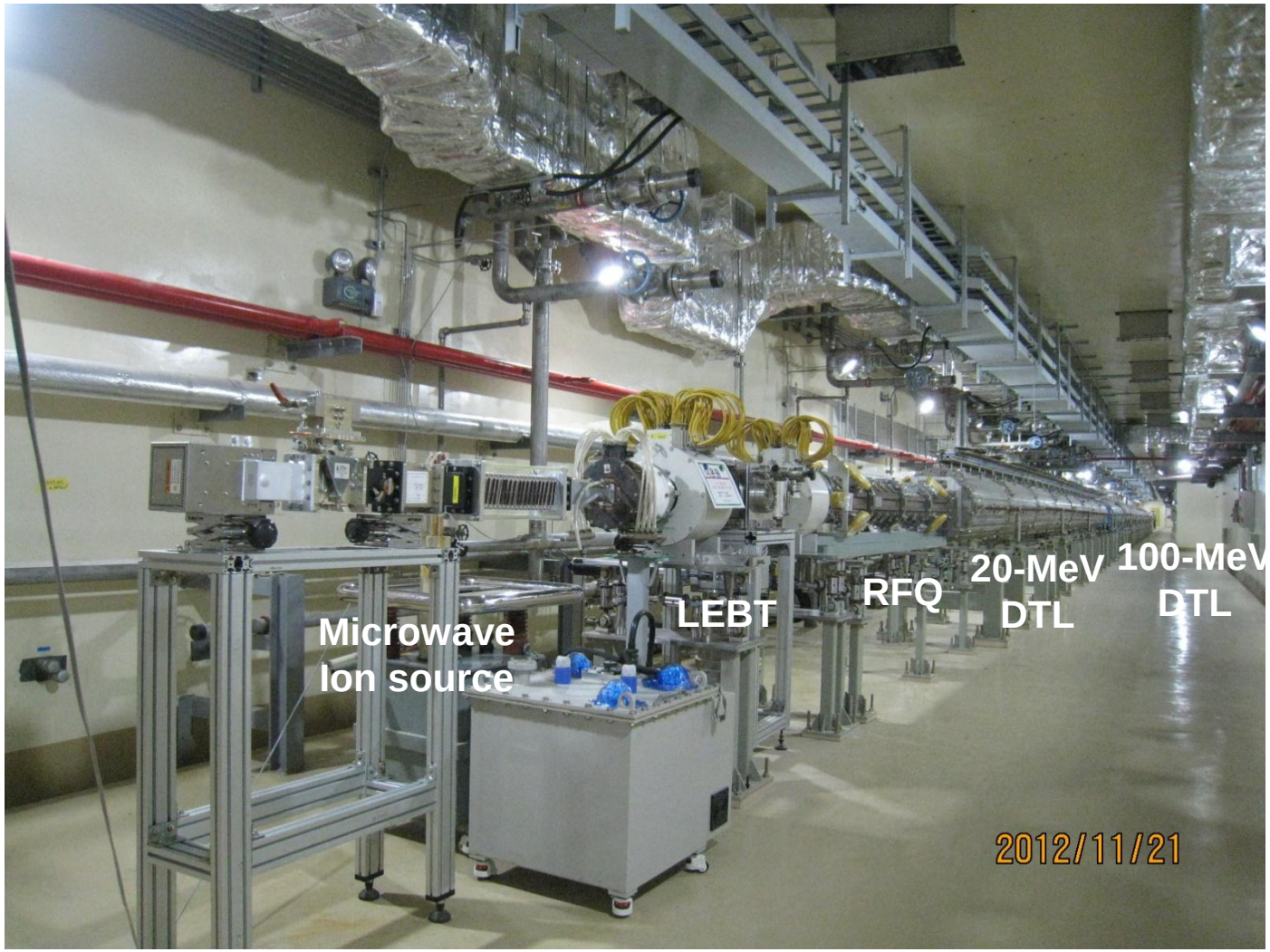
DTL tanks inside vibration free truck

Special supporter inside tunnel

Accelerator Installation

PEFP Proton Engineering Frontier Project

- Installed inside tunnel at March, 2012



Beam line Installation

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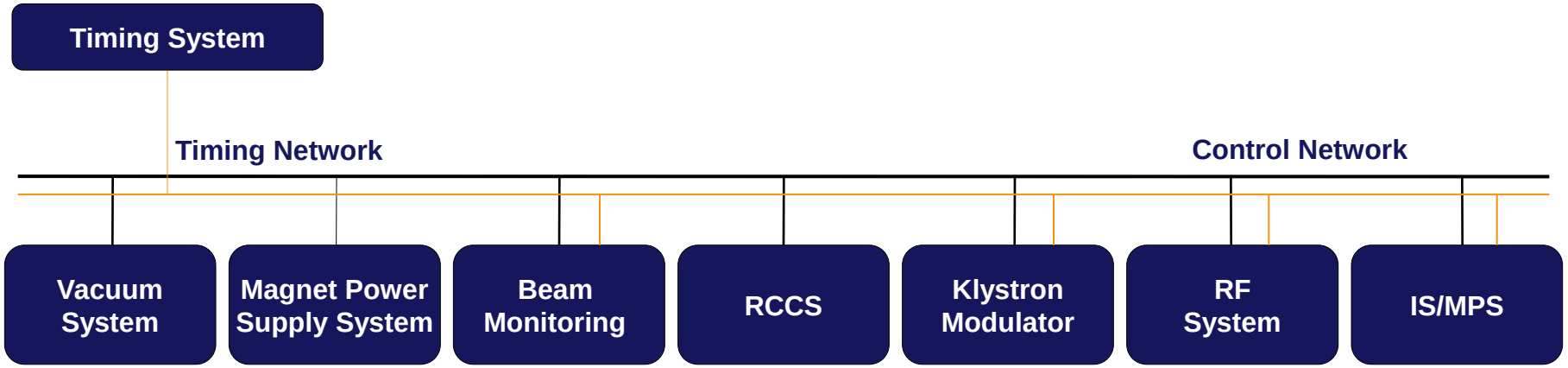
- Magnet Installed inside experimental hall at May, 2012

20-MeV Beam line hall

100-MeV Beam line hall

PEFP Control System

- Large proton accelerator has many devices
  - distributed control system
  - integrated operation
- Adopt EPICS toolkit http://www. aps.anl./gov/epics/index.php
  - a set of open source software tools, libraries, and applications
  - network-based server/client model
  - cost-effective and high reliability



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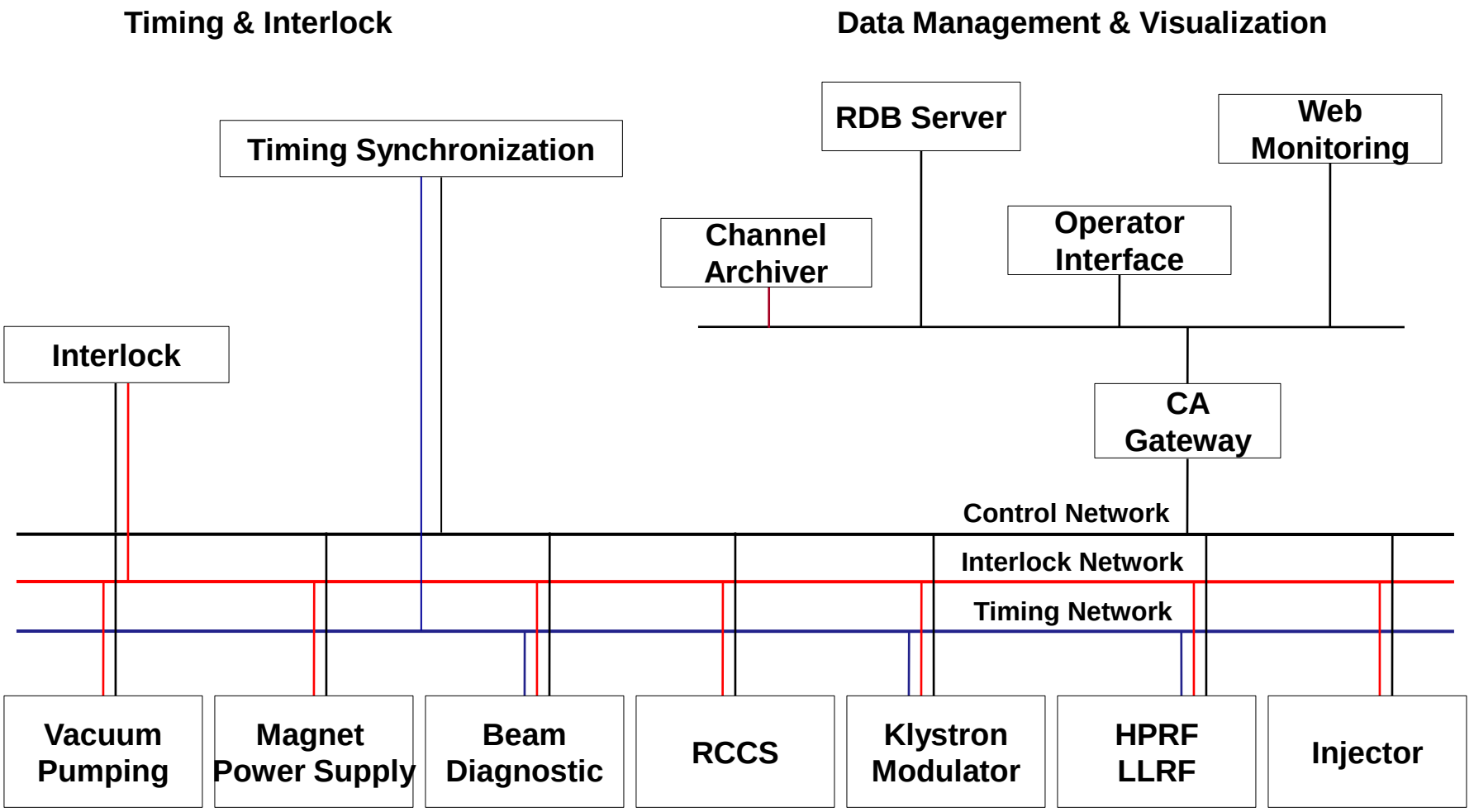
Configuration of 20-MeV Control System

PEFP Proton Engineering Frontier Project

❑ Purpose : 20-MeV Operation and 100-MeV Control System Test



Control Room (20-MeV Linac)

PEFP Proton Engineering Frontier Project

20-MeV Control Room

EPICS OPI

RF & Beam Monitor

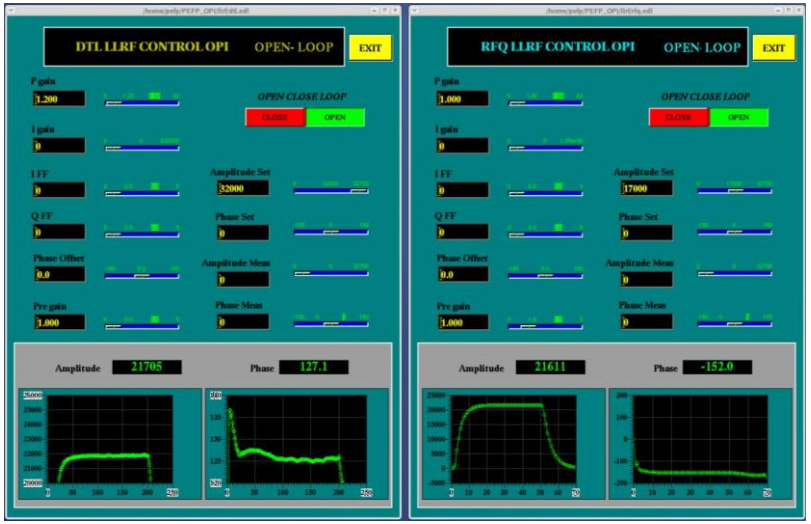
LLRF Control System

EPICS OPI Server

Low Level RF

- RF amplitude and phase requirements within 1% and 1 degree
- Digital RF feedback control system
- Pentek 7142 Four 125 MHz 14-bit A/Ds One 500 MHz 16-bit D/A Xilinx Virtex-4 FPGAs
- Control software : PI implemented in FPGA and EPICS OPI by PEFP
- Digital LLRF was tested at the 20-MeV linac (2010)
  - Monitor amplitude, phase, and waveform
  - Control PI gain, amplitude, and phase

Operator Interface



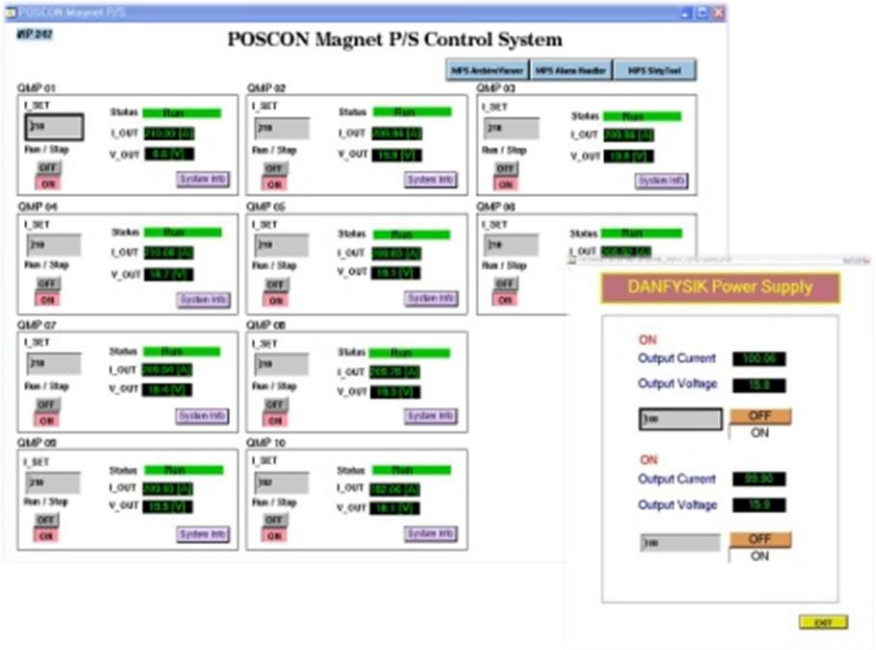
PMC Board

VME CPU Board

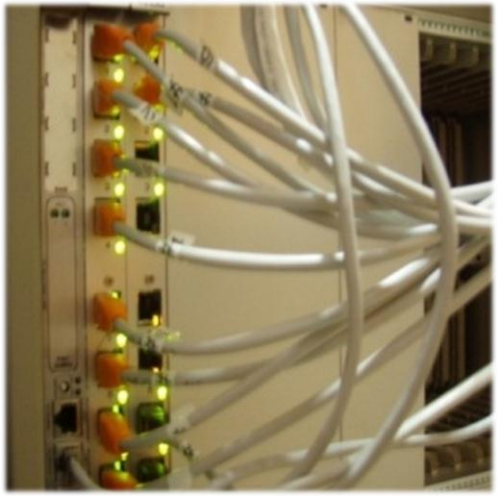
Magnet Power Supply Control System

- Monitor current and status (on/off, local/remote, normal/alarm)
- Control on/off, settings of current, permissible setting range, and knobs
- Connection of Modbus/RTU and RS232
- Using SNL for programming sequential operation on external events
- VME IOC
  - MVME5100 and VME multi-serial IO board
  - EPICS device/driver
  - vxWorks operating system

OPI



VME Serial IO Board

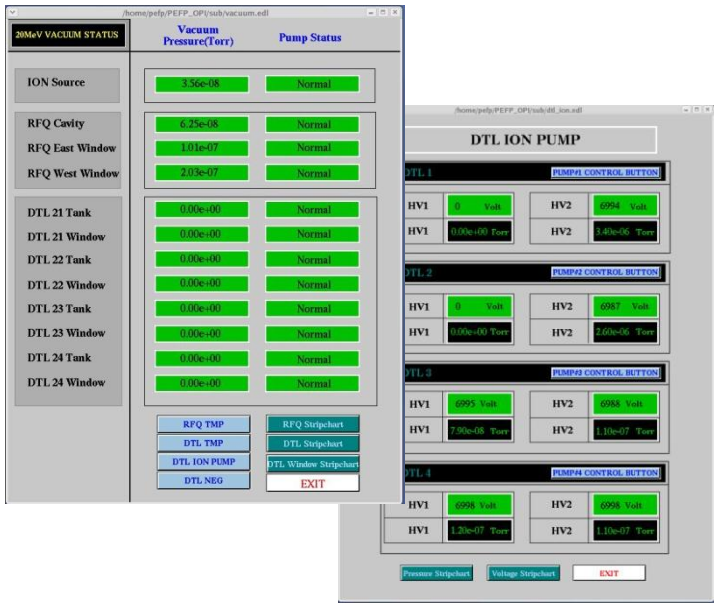


Multi-Serial

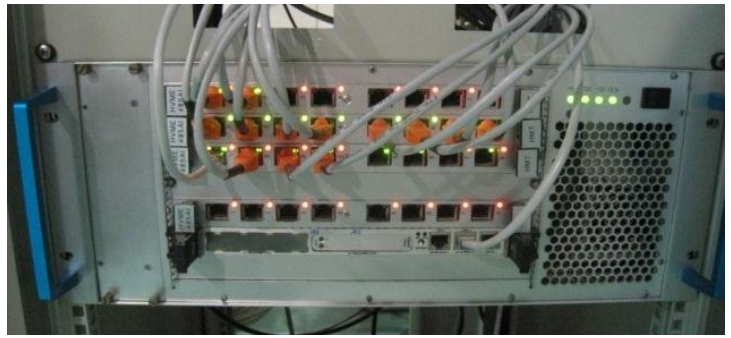
Vacuum Control System

- Monitor pressure, current, voltage, and status (on/off, normal/alarm)
- Control HV on/off, settings current, voltage, and start/stop
- Interlock of vacuum pressure with section valves
- VME IOC
  - VME multi-serial board
  - EPICS device/driver
  - vxWorks operating system

Operator Interface



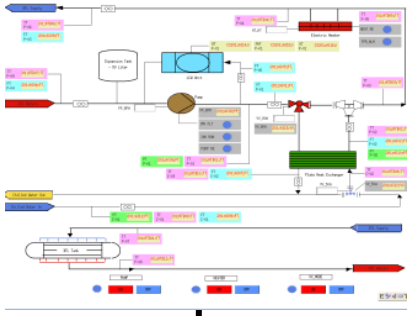
VME Serial IO Board



Resonance Control Cooling System

- Resonance frequency matched to the HPRF driving frequency
- RCCS used to control the resonance frequency of each DTL tank by supplying temperature-controlled water to draft tubes
- RCCS monitors resonance frequency error measured by LLRF system
- Temperature, flow rate, pressure, motor speed & control, valve status & control, alarm status screen, flow chart screen, AutoSave

Operator Interface



Control Network

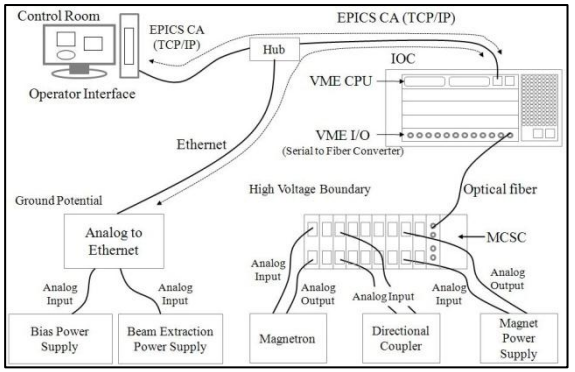
RCCS IOC

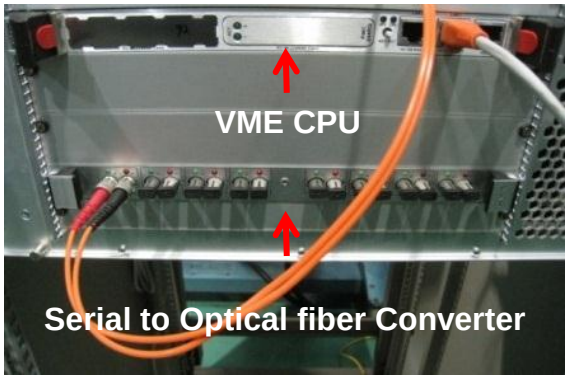
Fabricated water pumping skip

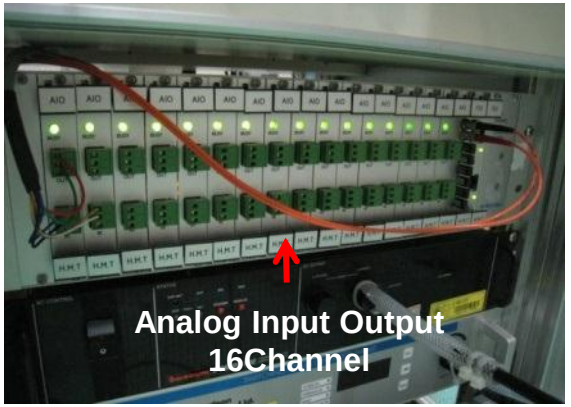
Items	Specification
Case/Slot	19”, 6U USB Backplane Type
CPU	Intel Pentium, 500 MHz
Memory	512 MB
HDD	4 GB Compact Flash Memory
Ethernet	10/100/1000 Mbps
OS	Linux (Fedora Core 8 and over)
Kernel	RT Kernel 2.6.23.1
Software Tool	EPICS base, sequencer, AutoSave
Signal I/O modules	Analog Input Board Analog Output Board Digital Input Board Digital Output Board RTD board

Microwave Ion Source

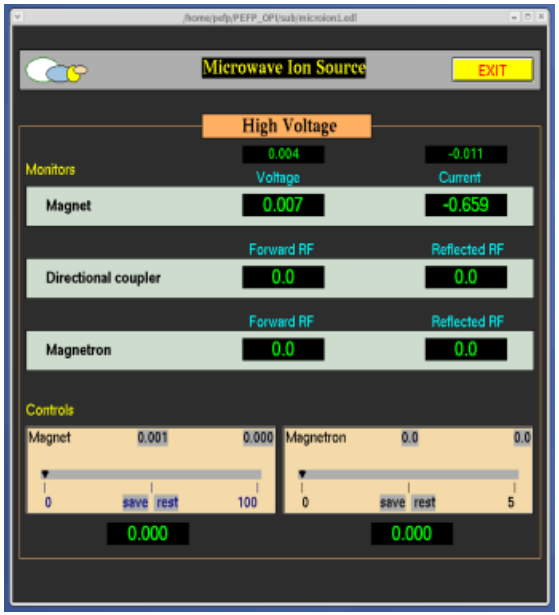
- Control system isolated from high voltage boundary
- VME optical IO board for optical serial link
- IO system of optical to analog transition converter in high voltage boundary
- Monitor forward and reflected RF of magnetron and directional coupler, current of magnet PS
- Control magnetron RF power, PS current







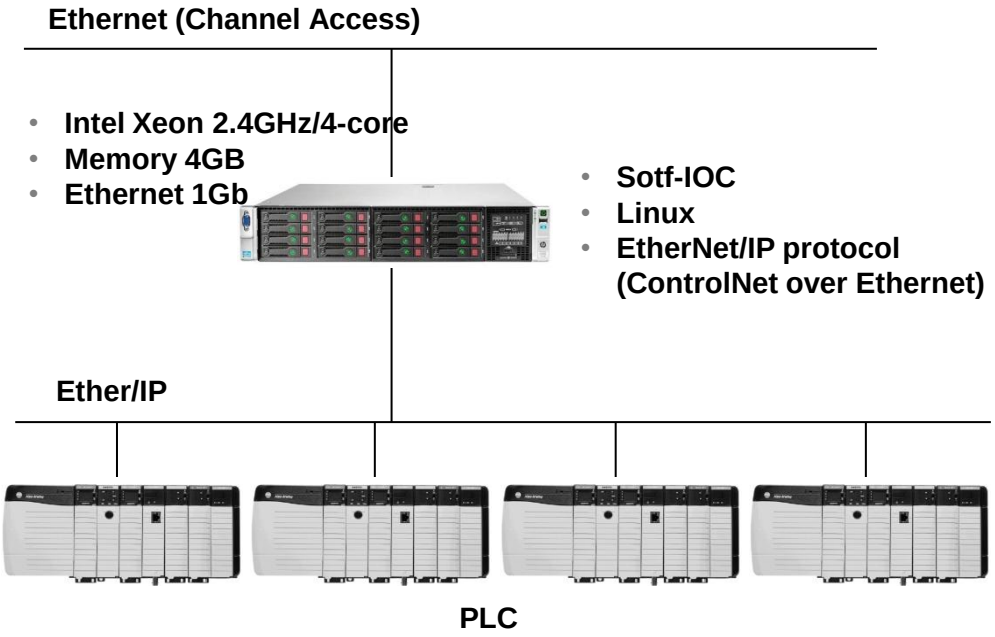
Operator Interface

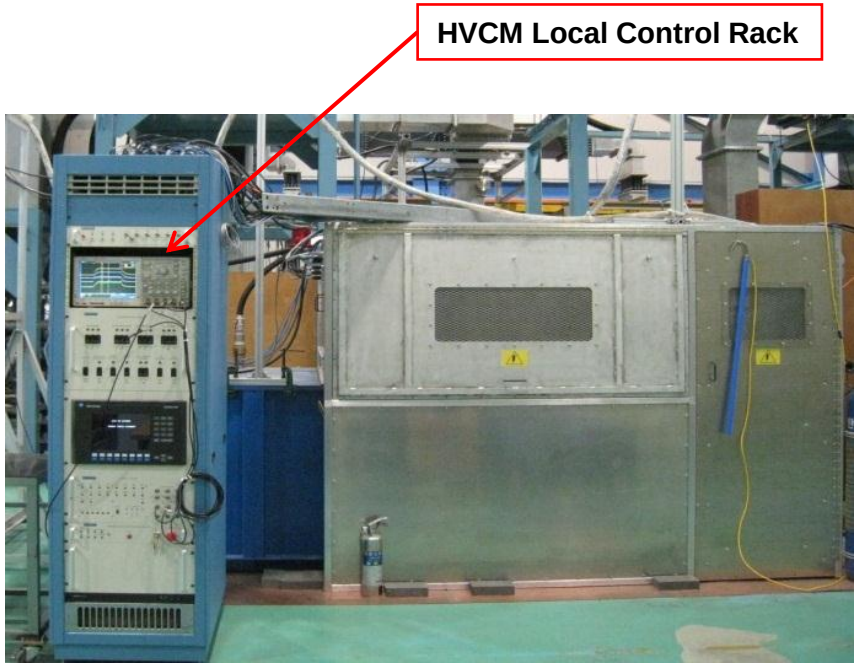


EPICS Channel Access

High Voltage Converter Modulator

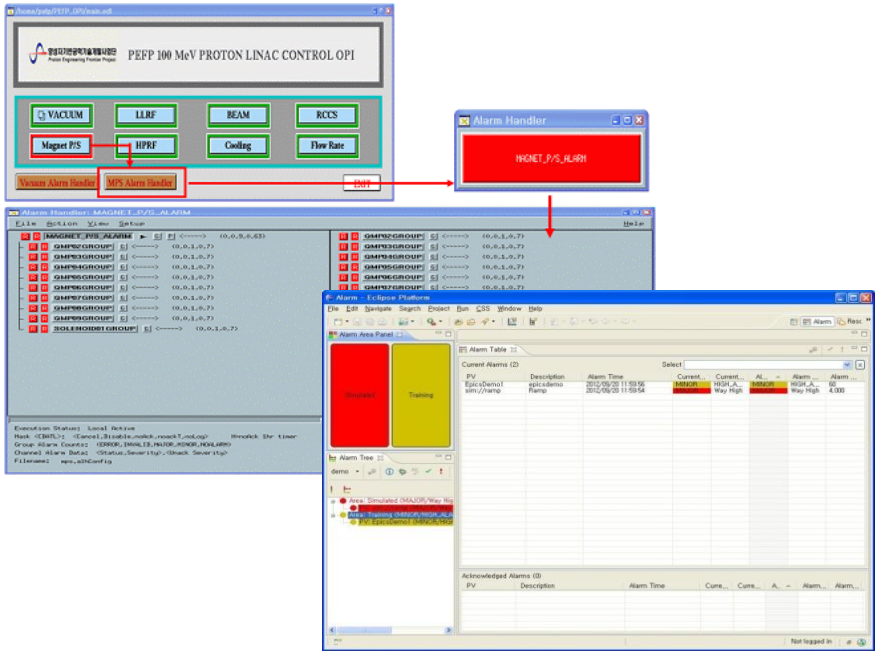
- HVCM used to drive the klystron
  - 5.8MW peak power with 1.5ms pulse, 60Hz repetition rate)
- Soft IOC
  - Linux, Intel Xeon 2.4GHz/4-core
  - EtherNet/IP Driver
- Monitor operation state, voltage, current, equipment fault, personnel fault
- Control settings of voltage and current, limit



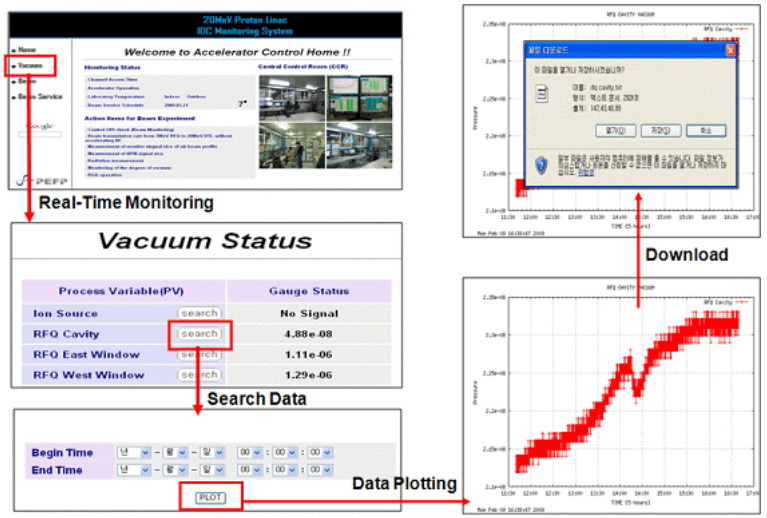


ALH & Data Storage

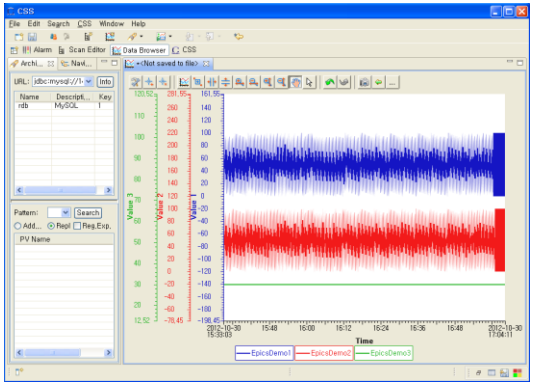
Alarm Handler



Web Viewer



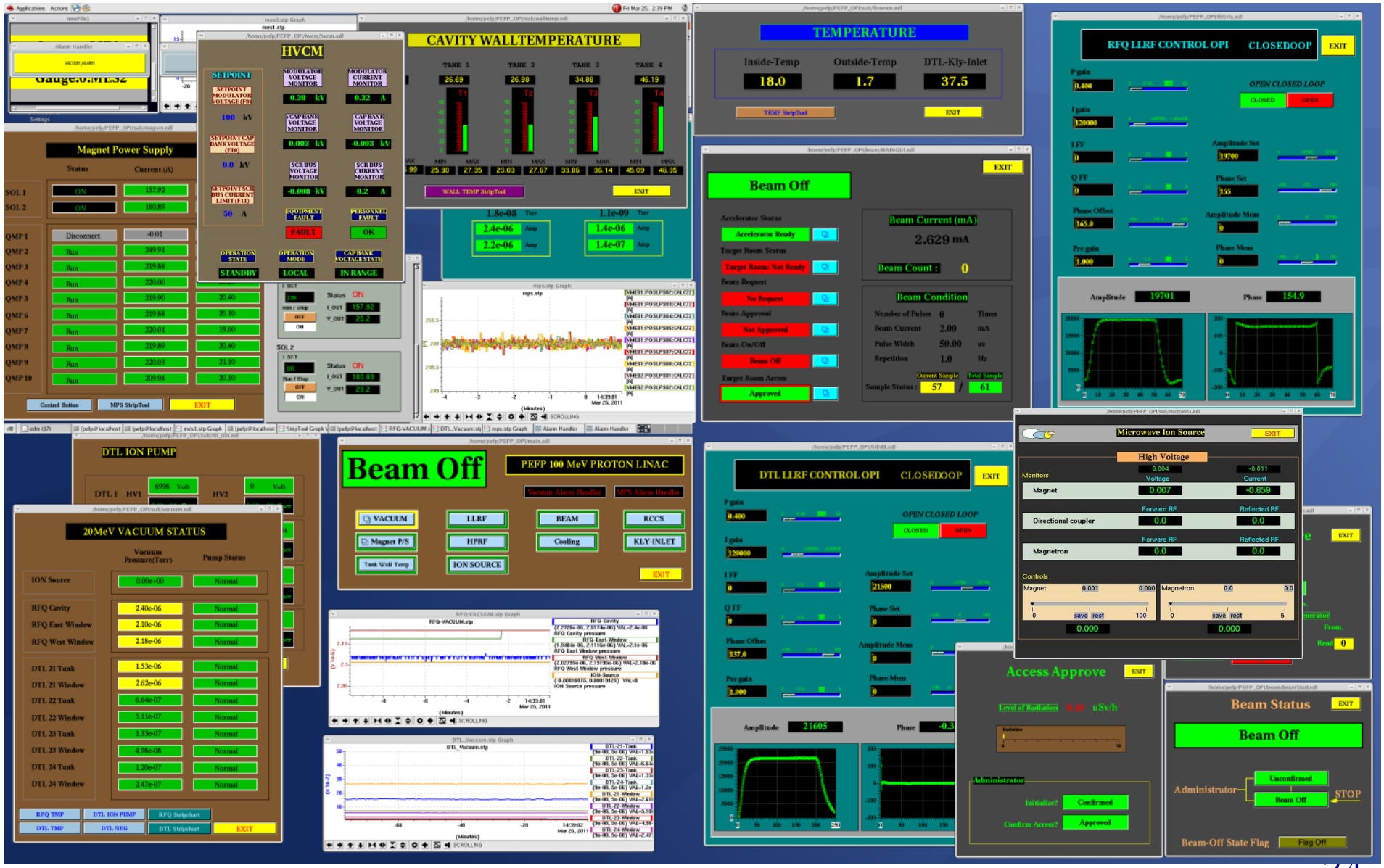
Data Browser



- ❑ Two database systems
  - EPICS Channel Archiver : IOC Real-Time database
  - RDB MySQL
- ❑ Data viewer
  - EPICS Extensions (EDM/MEDM, etc)
  - web viewer
- ❑ CSS BOY and channel archiver engine and alarm

Operator Interface (OPI)

PEFP Proton Engineering Frontier Project



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- **Control System (100 MeV linac)**
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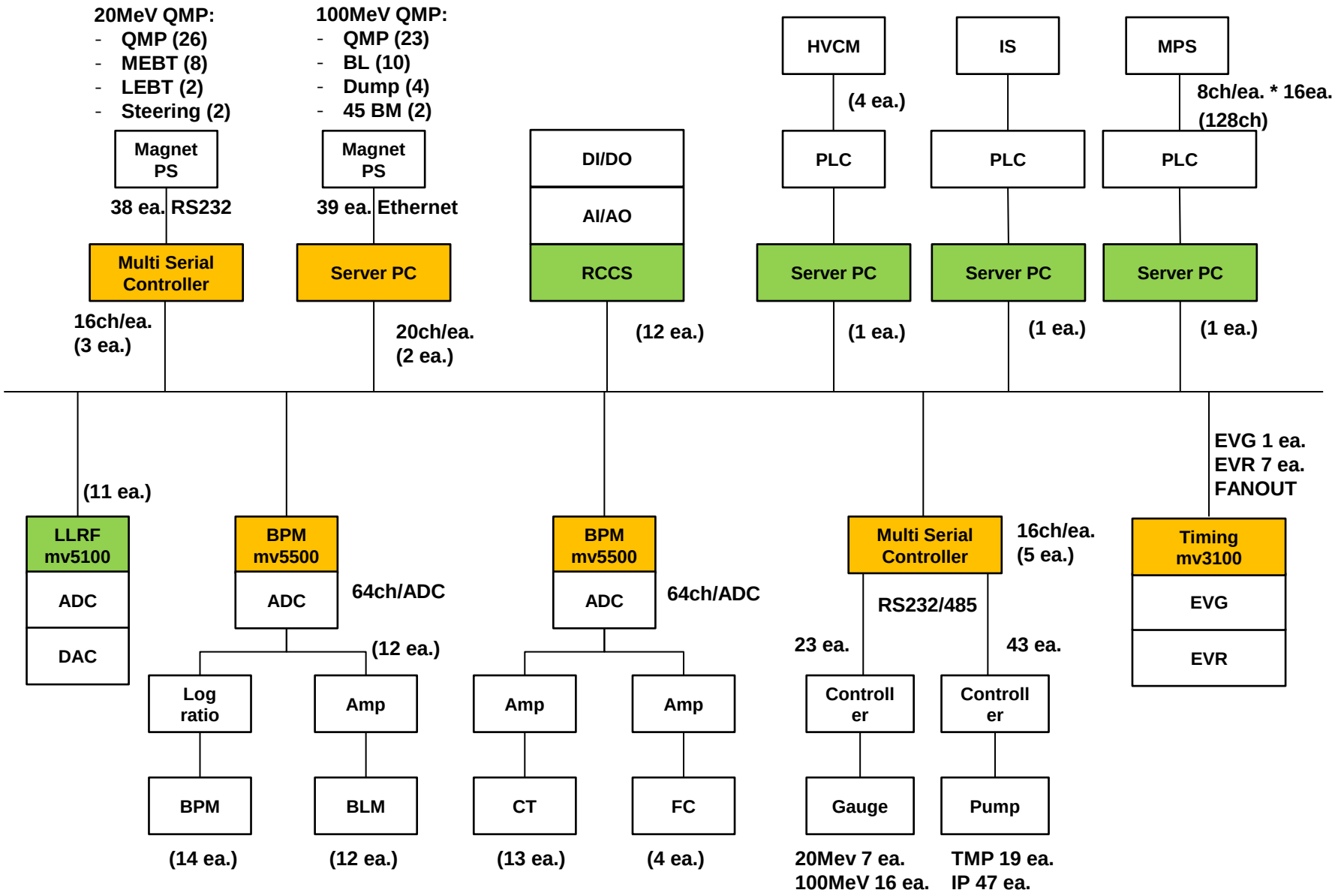
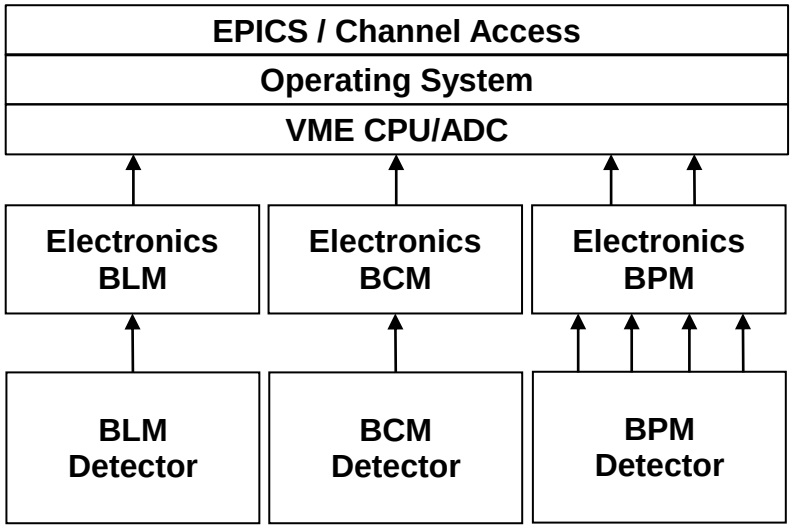
Configuration of 100-MeV Control System



Beam Monitoring System

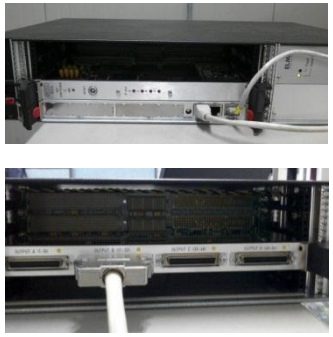
- Data acquisition for BCM, BPM, and BLM
- Industry Pack (IP) ADC board
  - external trigger and clock
  - Max. 200KSPS/channel, input ±5/±10
- EPICS and ASYN modules
  - carrier card and IP module driver
- Create raw data, average, and waveform



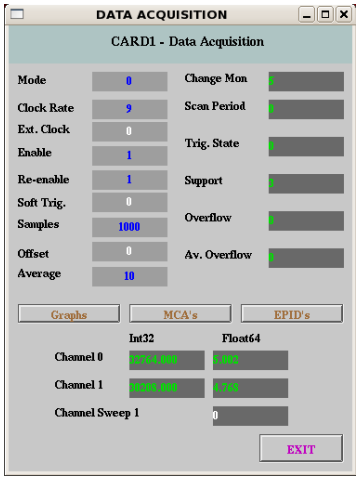
MPC7457 PowerPC

VME Carrier Board
IP-ADC & TR Board

IOC Test Stand



Operator Interface



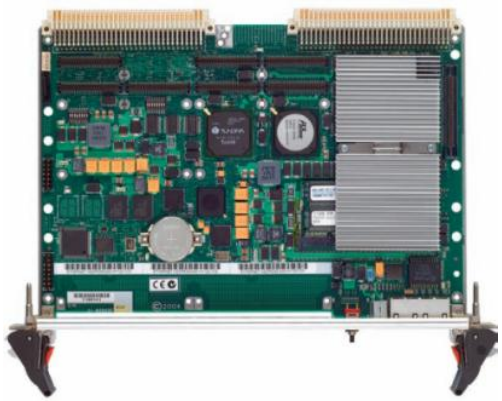
Timing System

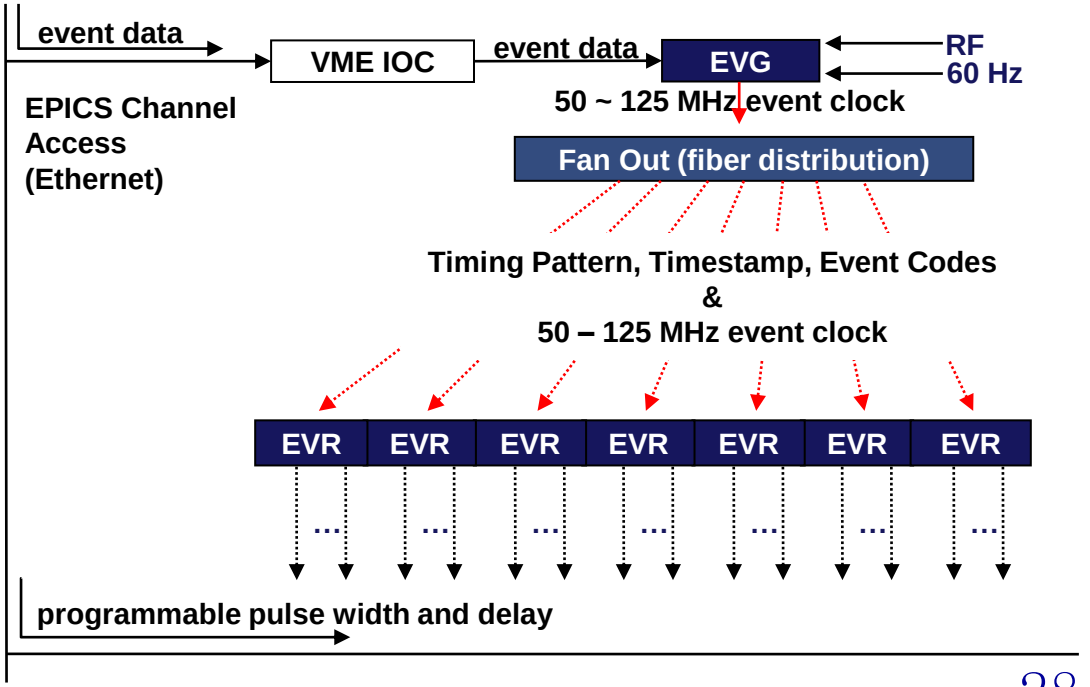
PEFP Proton Engineering Frontier Project

- Programmable timing system (EVG, EVR)
  - low level RF control trigger
  - beam gate generation
  - RF gate generation
  - klystron modulator control trigger
  - time referenced to external clock

EVG-230 | EVR-230RF | FANOUT12

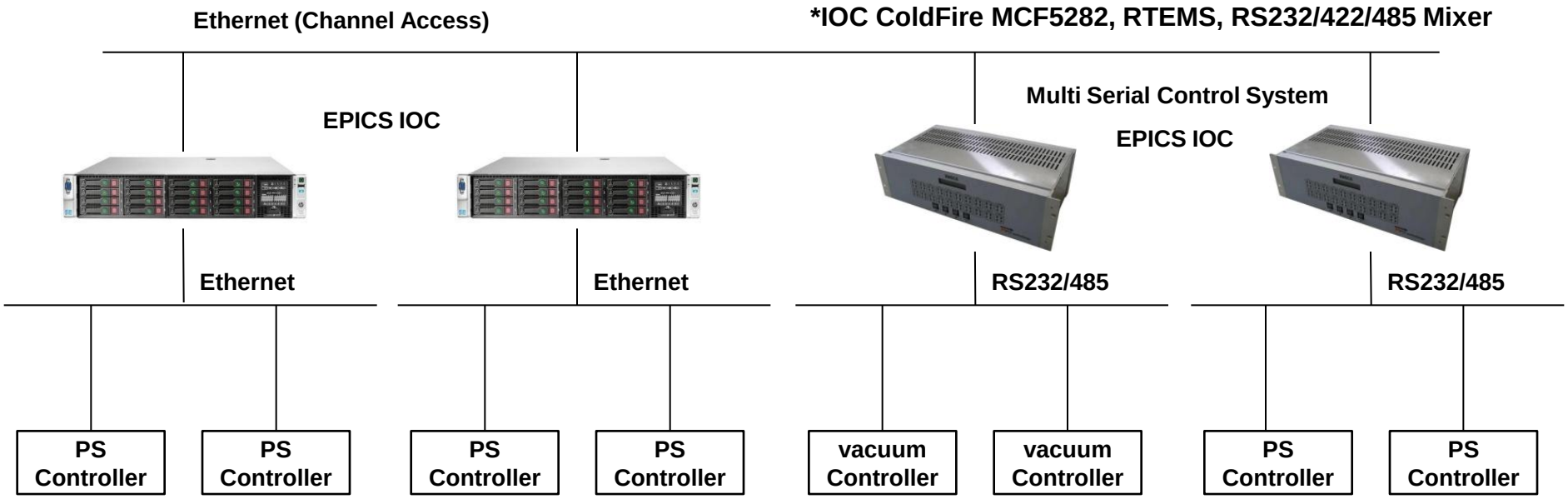
MVME3100 (MPC8540)





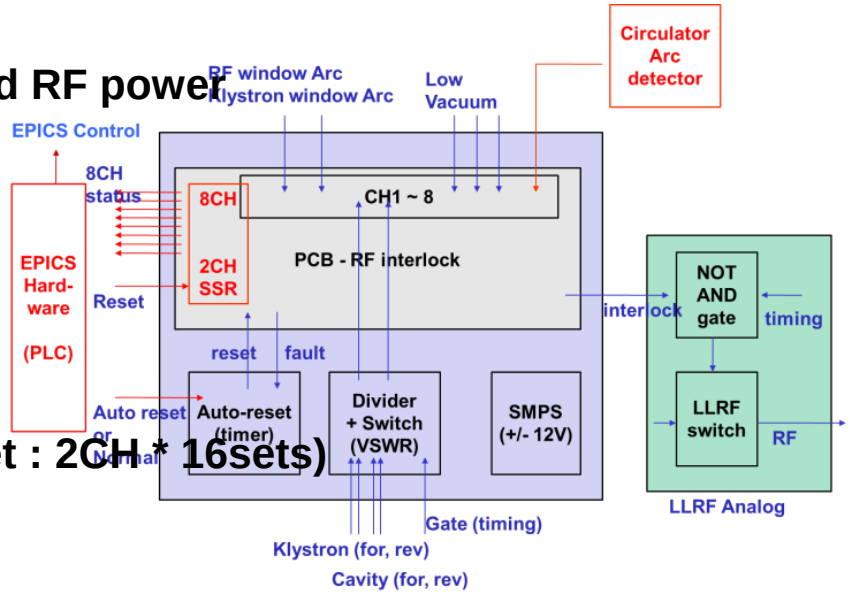
Vacuum & Magnet Power Supply

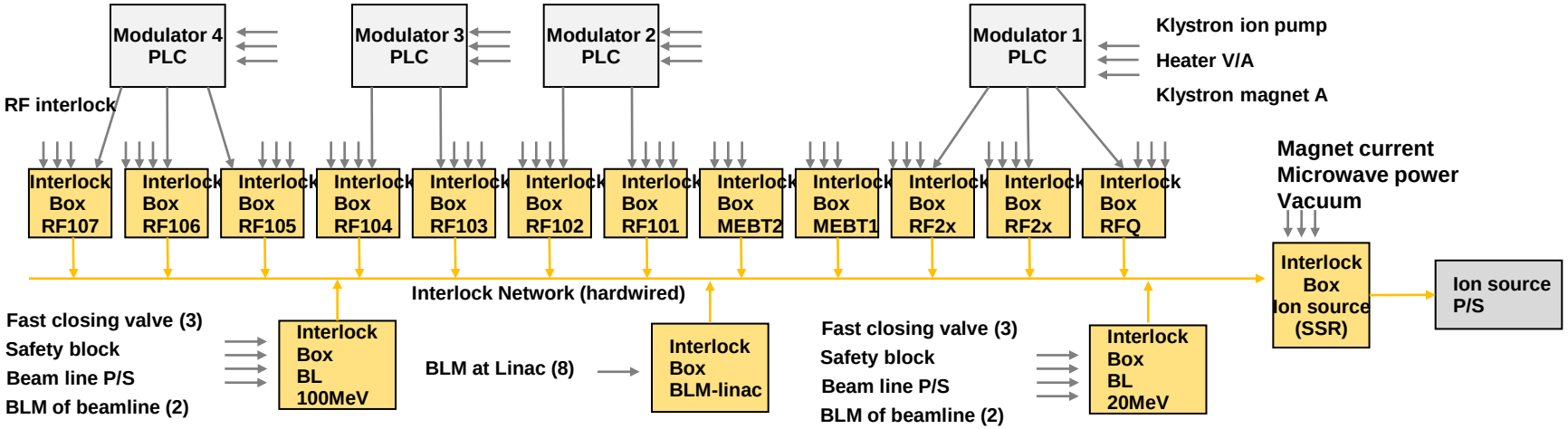
- IOC H/W changed from VME IOC to embedded IOC and Soft IOC
- Monitor vacuum pressure, current, voltage, status (on/off, normal/alarm), PS current, voltage, status (on/off, normal/alarm)
- Control pump HV on/off, settings current and voltage, start/stop, PS on/off, settings of current, permissible setting range



Machine Protection System

- Hardwired MPS for the 100MeV Machine
  - will shut off the beam at the ion source and RF power
- Connected to EPICS control system to monitor the MPS status
  - Interlock box (8CH, 10V DC) 16 sets (RF 12 sets, Beam 3sets, IS 1 set)
  - monitoring (8CH * 16sets),
  - control (remote reset / auto or normal reset : 2CH * 16sets)





PEFP Control Room

- Air conditioning
  - 21 ~ 24°C
- Double floor
- Display
  - OPI 23" LCD 28 ea.
  - CCTV 40" LFD LED 3 ea.
  - safety status (LED) 4 ea.
- Console table
  - U-shaped array
  - console and seating

Contents

Summary

PEFP Proton Engineering Frontier Project

- 100-MeV proton accelerator control system
  - developed using EPICS
  - distributed control system
- 20-MeV control system
  - used to operate the linac for 5 years
  - debugged and upgraded for 100-MeV linac control system
- 100-MeV control system
  - extension system of 20-MeV control system

    (LLRF, RCCS, HVCM)
  - new system

    (timing system, beam monitor system, MPS, vacuum, magnet power supply)

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Thank you for your attention