BEPCII Control System

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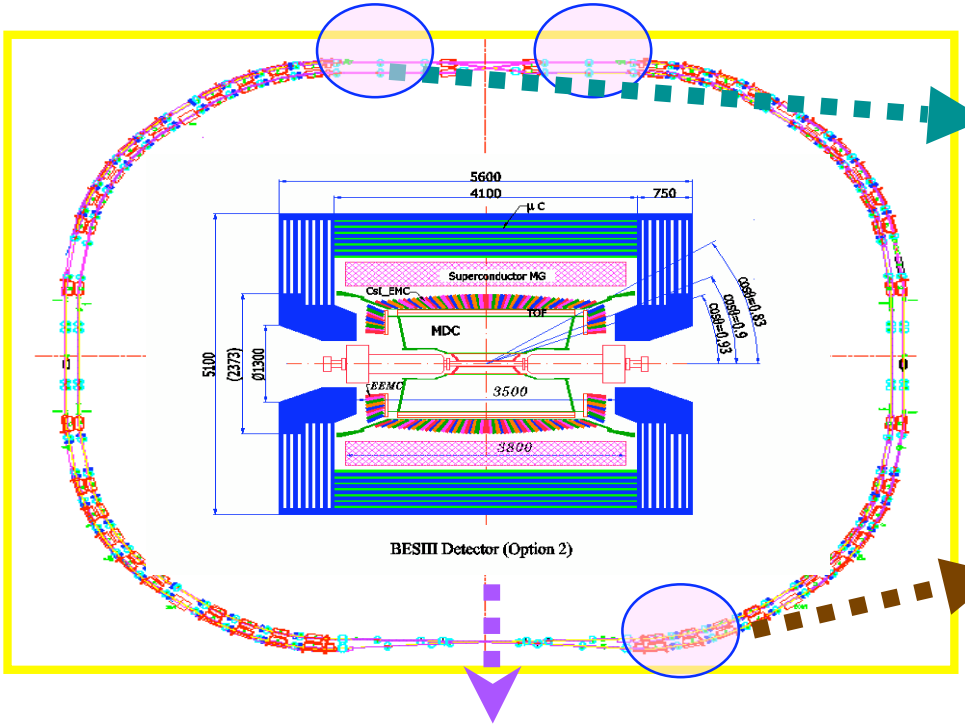
BEPCII Project

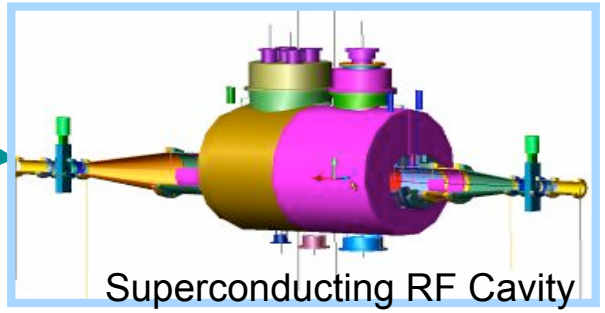
- The project BEPCII is for upgrading the BEPC to reach a higher luminosity, $1*10^{33}cm^{-2}s^{-1}$,100 times to the BEPC.
- BEPCII still serves high energy physics experiments and synchrotron radiation research. (total budget 650M CNY)
  - Energy 1.89GeV at Collision mode (→1.85Gev)
  - Energy 2.5GeV at Synchrotron radiation mode

- The project was started in August 2001
  - Project proposal
  - Conceptual design
- R&D started in October 2002
- System development started in Jan. 2004
- First beam into storage ring in November 2006

BEPCII

BEPCII consists of the Linac, Transport line and Storage Ring





Superconducting RF Cavity

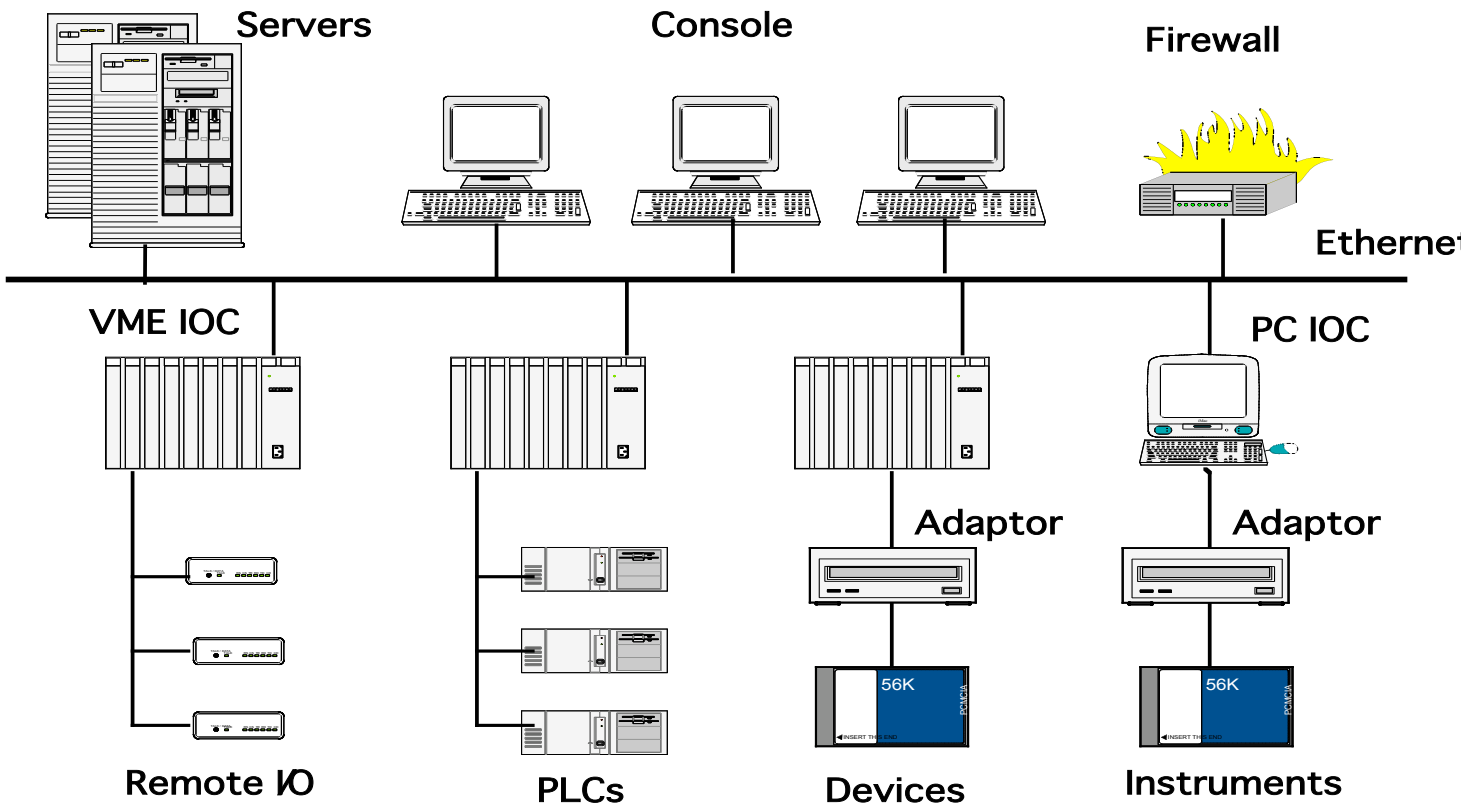
Double Storage Ring

- BEPCII adopted Double ring schema and super-conducting devices
- The old control system has been removed. We have to build a new control system and there are 20,000 channels in the control system

System architecture

Adopt “Standard mode” and EPICS system

It’s the first time that EPICS was adopted officially



Systems Components

- Host computer system
- Control network
- Sub-systems
  - Power supply control
  - Vacuum control
  - RF control
  - Cryogenic control
  - Linac control
- Timing system
- High level applications
- Oracle database
- Central console

Host Computer system

Host computer system in MCC building

- SUN Cluster system (v3.0)
  - 2 SUN V880 servers
    - 8 CPU each (1.2GHz Ultra SPARCIII)
    - 32GB memory each
    - 6*73GB disks each
    - 12*73 shared disk array: RAID 5 + 1 hot spare, NFS
    - Used as EPICS server and for HLA Calculations
- EPICS/ChannelArchiver data server
- Oracle server
- 28 Console computers – SUN Blade2000 and Linux PCs

SUN cluster installing and testing

Computers in main control room

Hardware

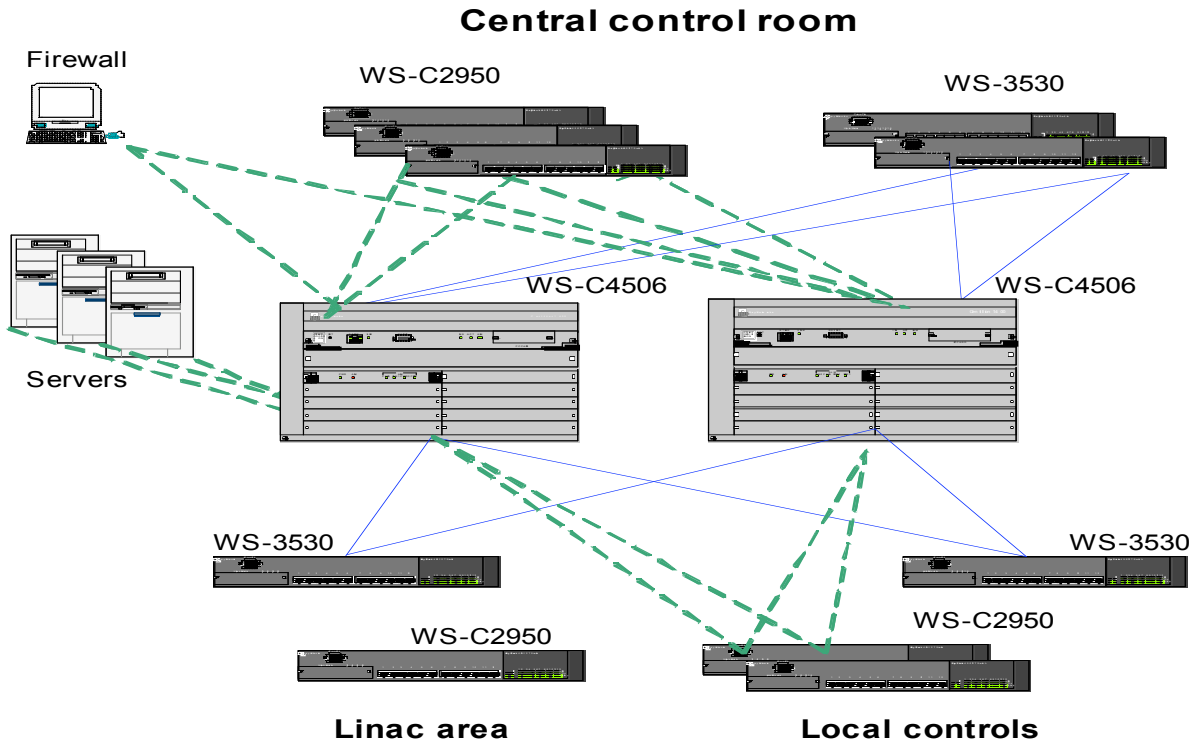
- More than 30 VME IOCs (MVME 5100 / 2431)
- And about 25 PC IOCs
- Device control and interface
  - Remote I/O: Power supply and linac control
  - Intelligent controller: Vacuum pumps, gauges
  - VME I/O modules: RF control
  - AB-PLC for cryogenic and Vacuum control
  - Omron PLC for machine protection system
- 1G/100M Ethernet
  - using Cisco C4506 switch, redundancy
- Field Buses
  - ControlNet, CANbus, RS232, RS485

Software

- EPICS Base R3.13.8 for VME IOC
- EPICS Base R3.14.7 for PC IOC
- Host
  - SUN Solaris 8 and PC Linux red hat 9
  - EPICS host tools:
    MEDM, EDM, VDCT, SNL, Tcl / Tk, ALH,Channel Archiver, Probe, StripTool, SAD, etc.
  - Third party software
  - CVS for software management
  - File server with NFS
- IOC
  - VxWorks 5.4
  - Tornado 2.0 development environment
- HLA
  - developed and transferred from KEKB with SAD environment, after evaluation of HLA for SNS, PEP-II,APS and KEKB
- Oracle database store history data

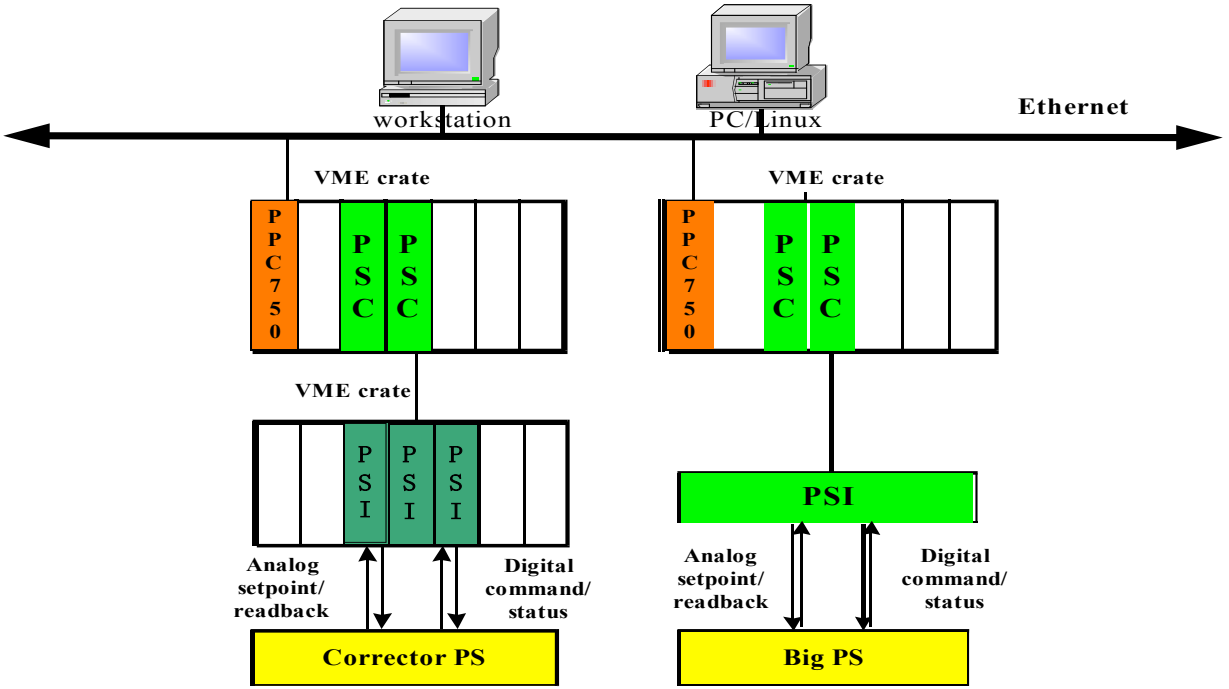
Control Network

- Cisco 4506 series products, redundant system
- 200 nodes in the network, 2 VLANs
- Ethernet and Star Topology with 1G/100M Ethernet



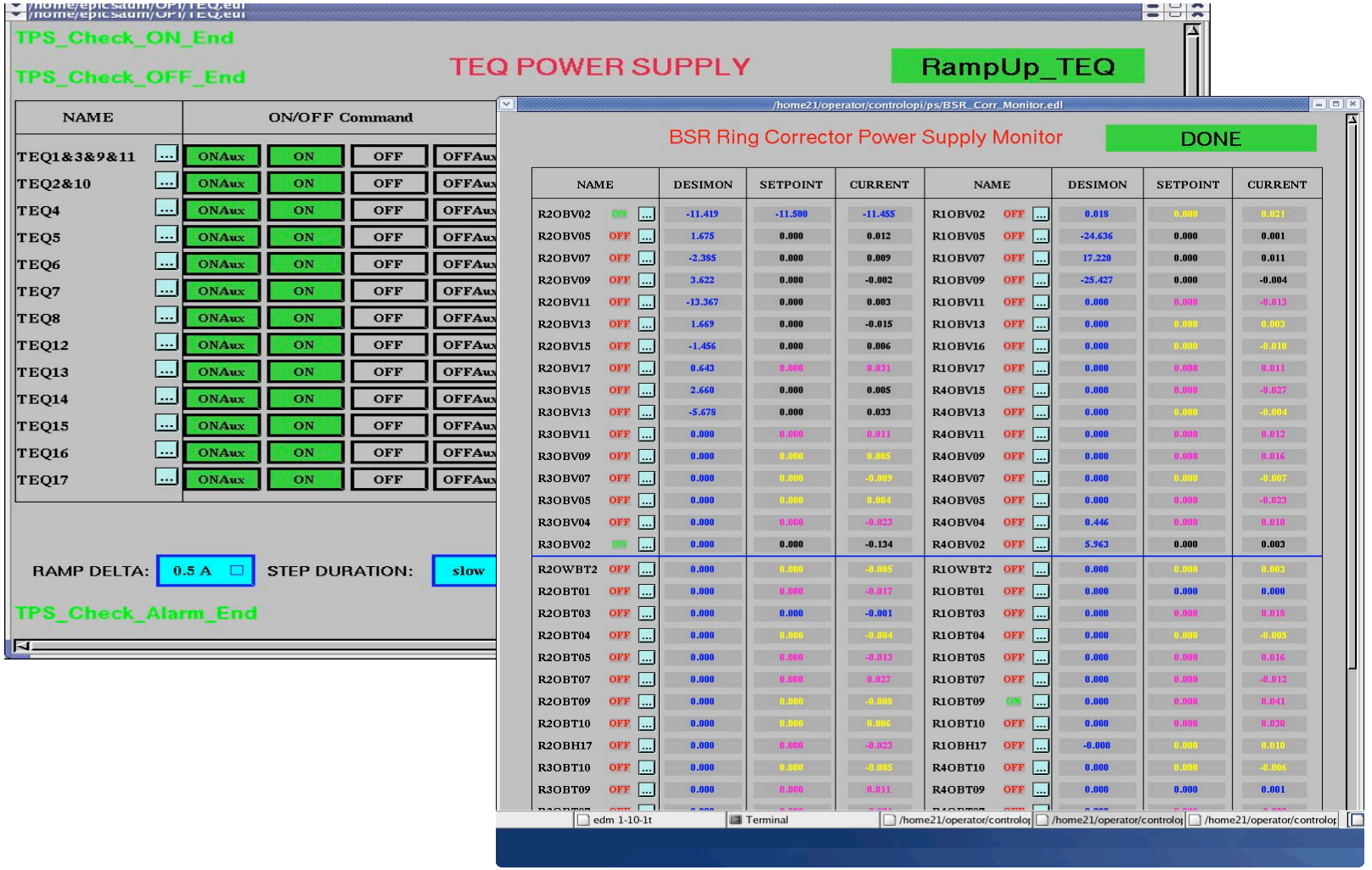
PS Control

- About 420 PS on Storage ring and TL
  - including SC magnets PS in IR regin
- 13 VME IOCs
- Remote I/O module PSC-PSI for PS on Storage Ring
- PSC and PSI were designed by BNL



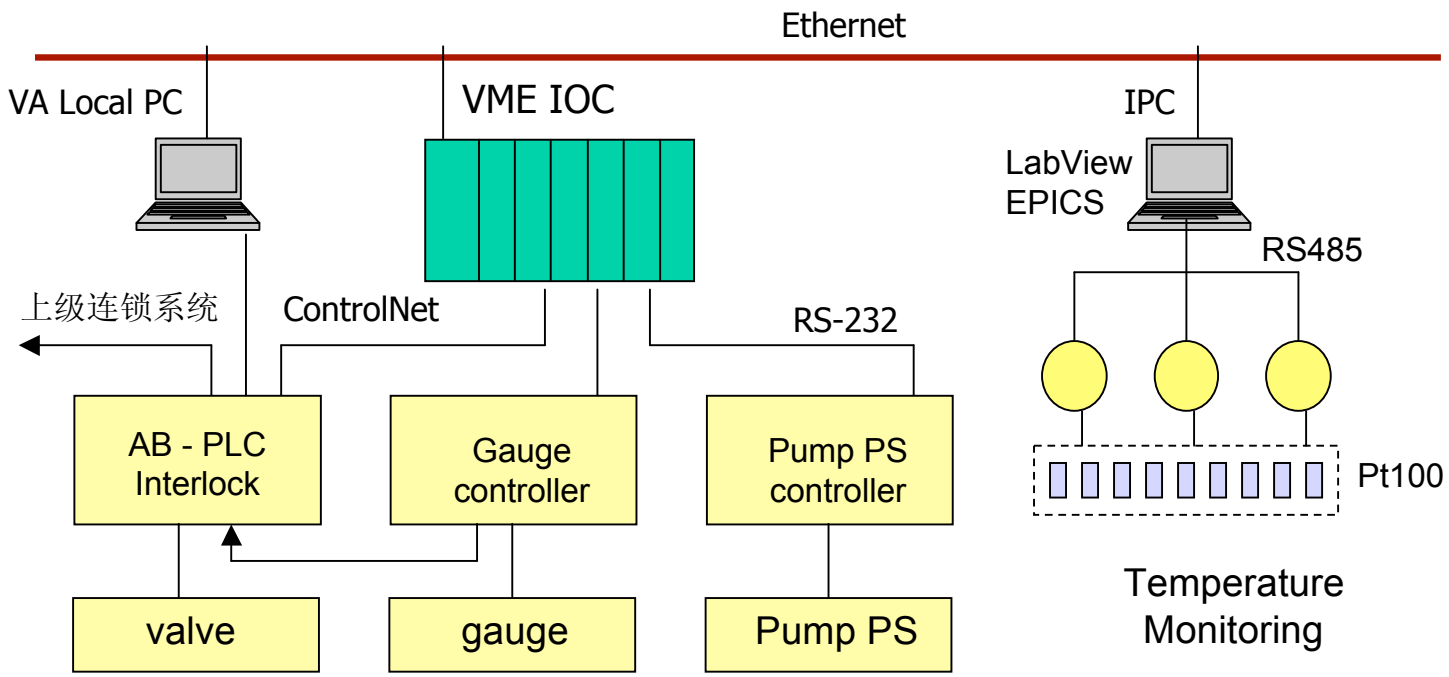
PS Local Control Station

PS Control panels



Vacuum Control

- 48 point for vacuum pressures
- 360 pump ,18 valves interlock with vacuum pressure,
- 1000 channel for temperature monitor of vacuum chamber



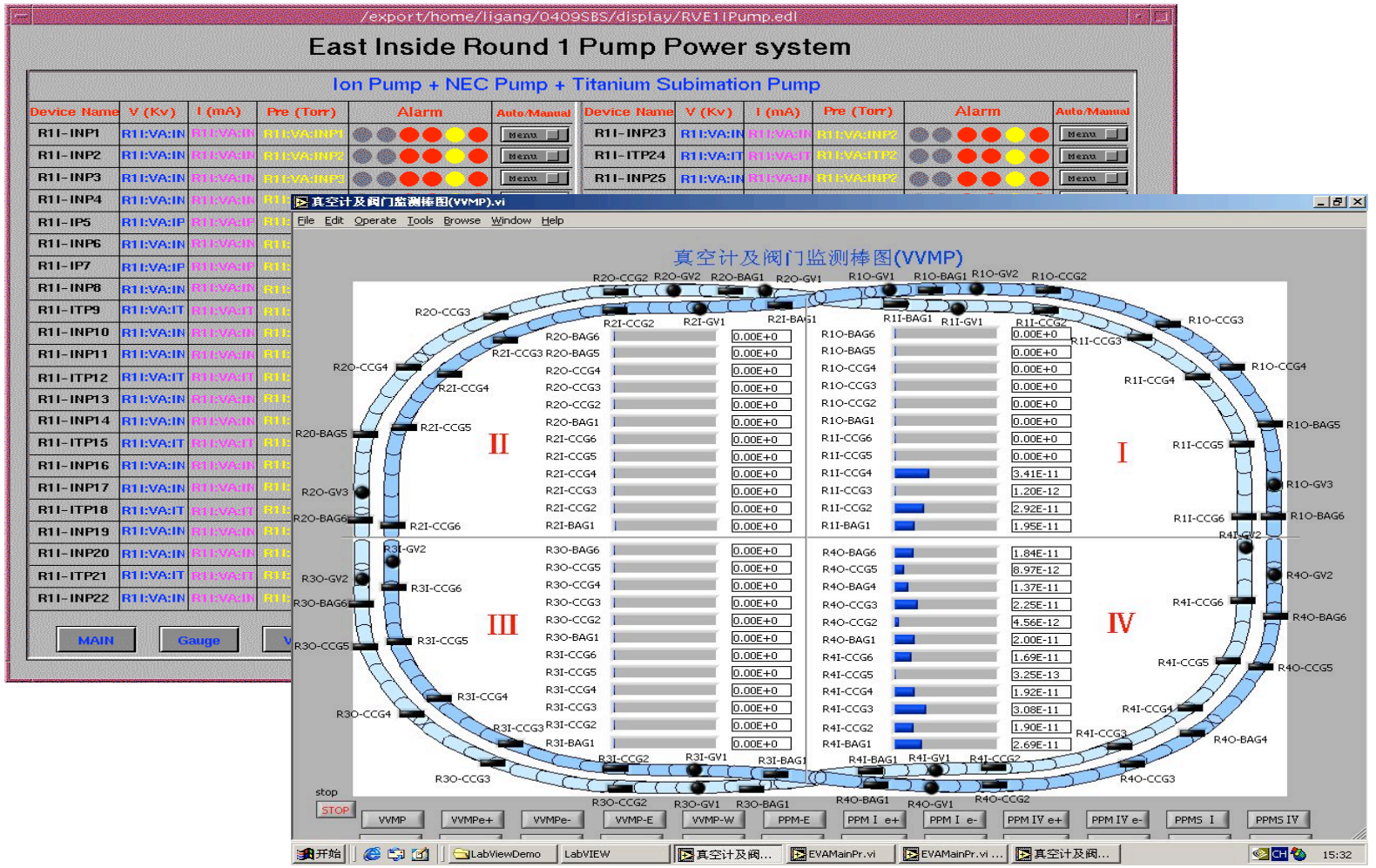
Vacuum control

- 2 VME IOCs

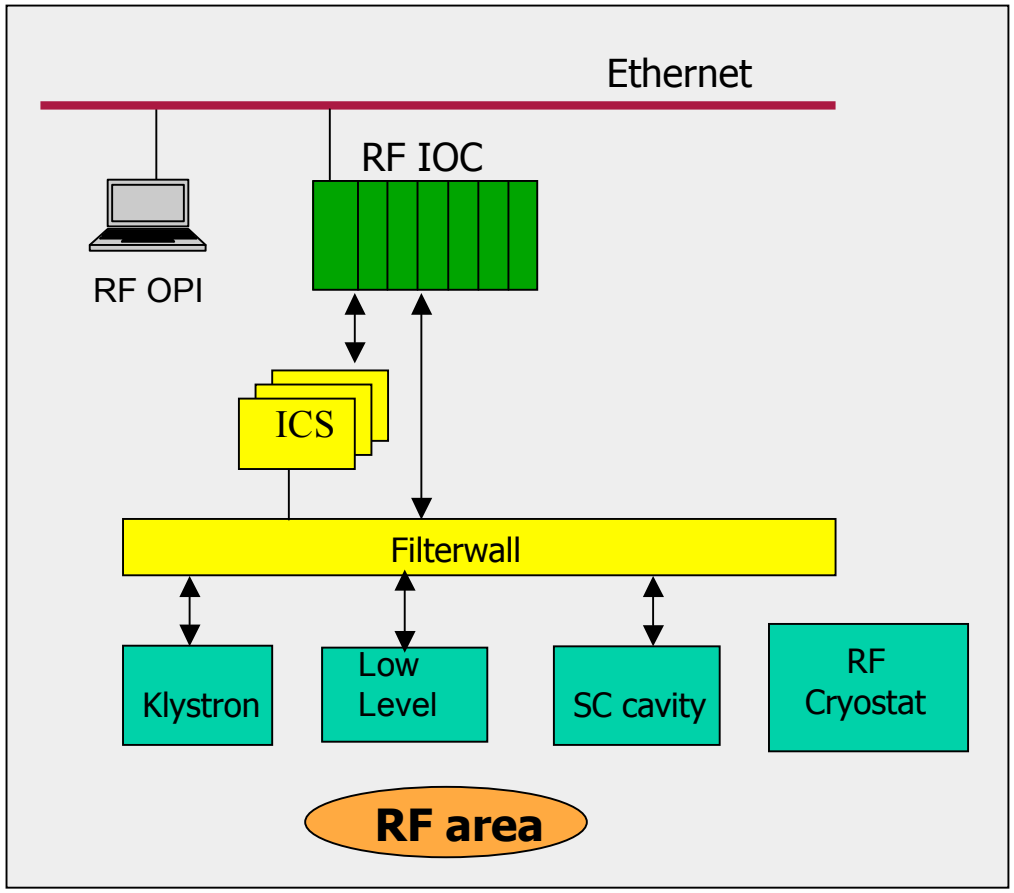
- Vacuum interlock system with AB-PLC and ControlNet
  - ControlLogix 5555 and AB-1756 I/O modules
  - VME-ControlNet adaptor SST-5136CN-VME

- An IPC for temperature monitoring of vacuum chamber
  - An IPC as EPICS IOC
  - Remote controller communication with IPC by RS-485
  - Developed with LabView
  - Installed LabView-EPICS interface “shared memory”

Vacuum panel



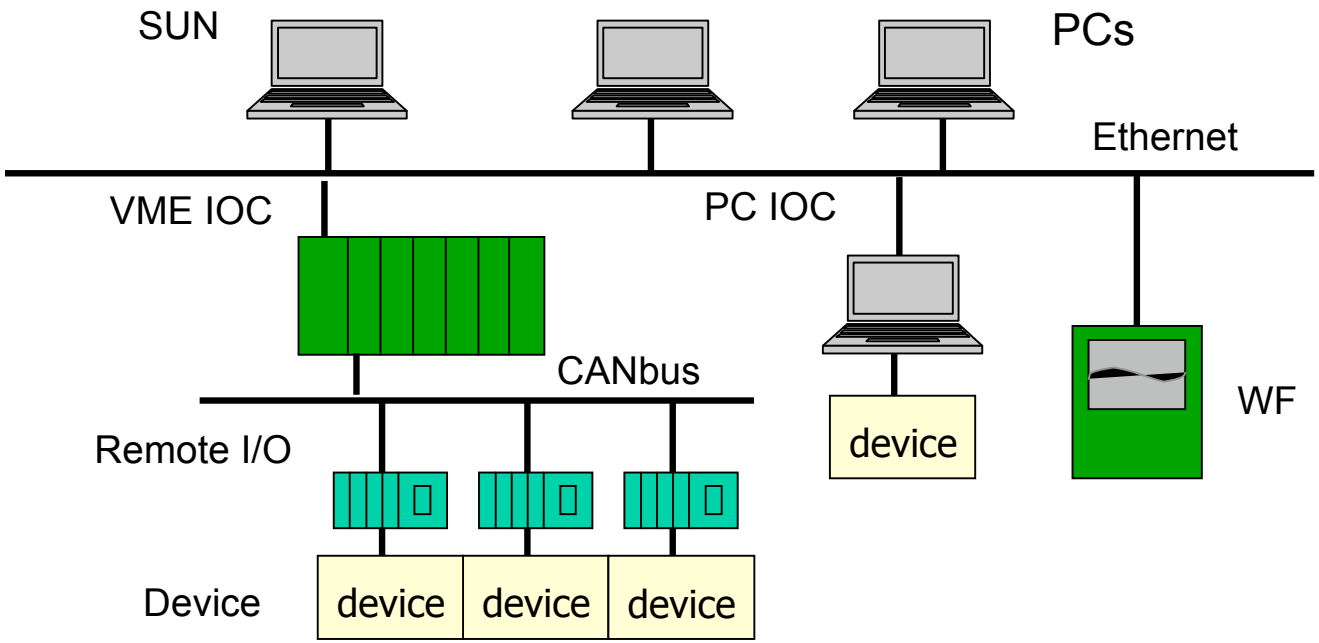
RF Control



- The RF control system is developed by company Thomcast based on EPICS
- 2 Klystrons, 2 SC RF Cavities
- 2 VME IOCs , VME I/O modules, and interlock system with ICS modules
- LLRF system developed by IHEP

Linac Control

- EPICS based system
  - IOC: MVME2431 and Vxworks5.4
  - Remote I/O modules made in China
  - CANbus connect VME IOC and the remote I/O modules
- Linac control system was put into use in Nov. 2003. It's the first EPICS-based control system in IHEP.

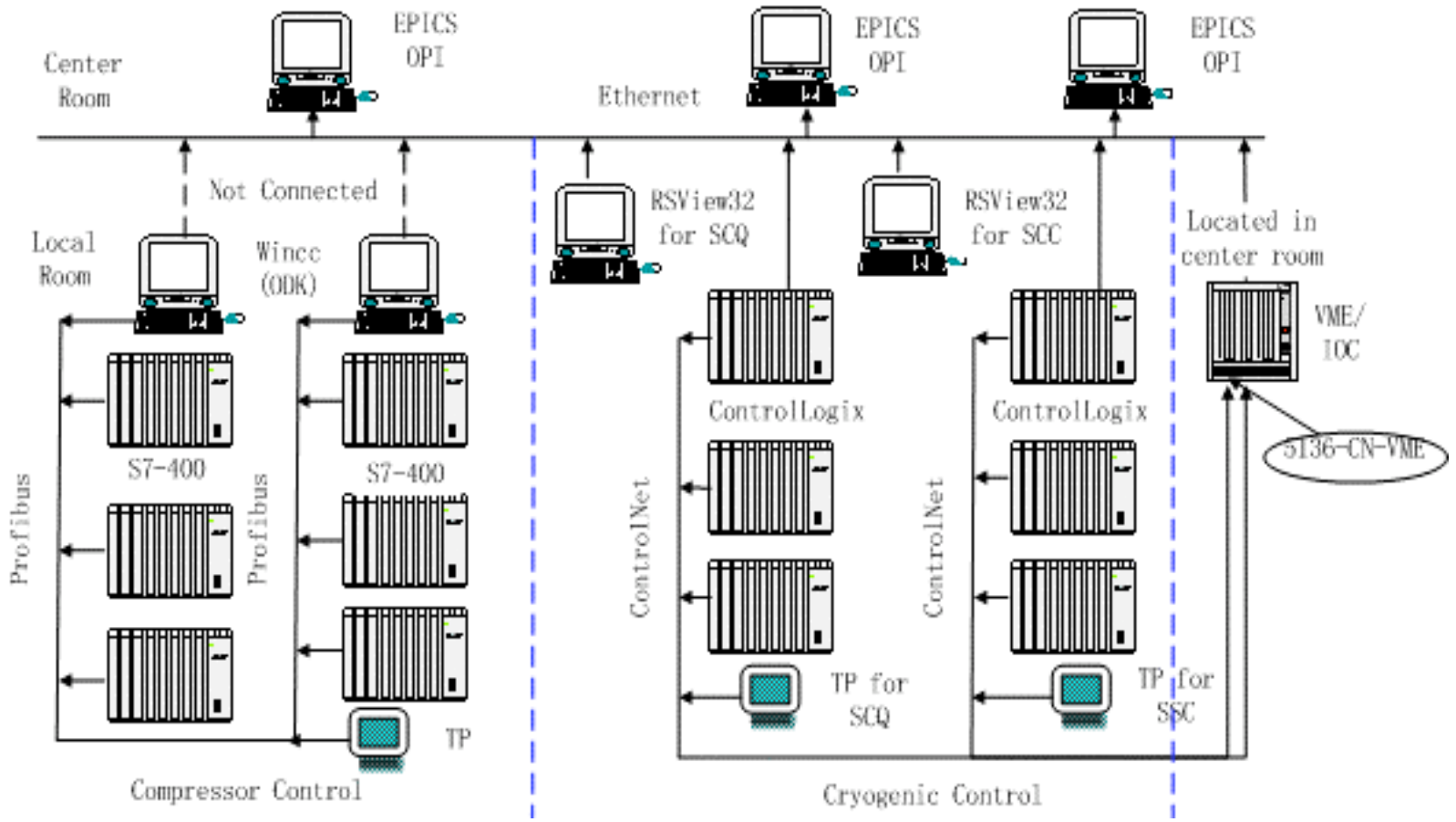


Cryogenic Control

- Cryogenic control is made by IHEP
  - valve boxes, tanks, dewars, coils, cooling pipes
  - 2 local stations for SCQ ,SSM and 2 SCRF cavities
  - **Using AB-PLC, ControlNet, VME IOCs**
  - **VME-ControlNet adapter SST-5136-CN-VME used for data exchange between IOC and PLCs**
- Compressor control is made by Linde company
  - Using Siemens PLC S7, Profibus
- Data communication program has been developed between the two systems with Wincc/ODK and EPICS/CA

Cryogenic control

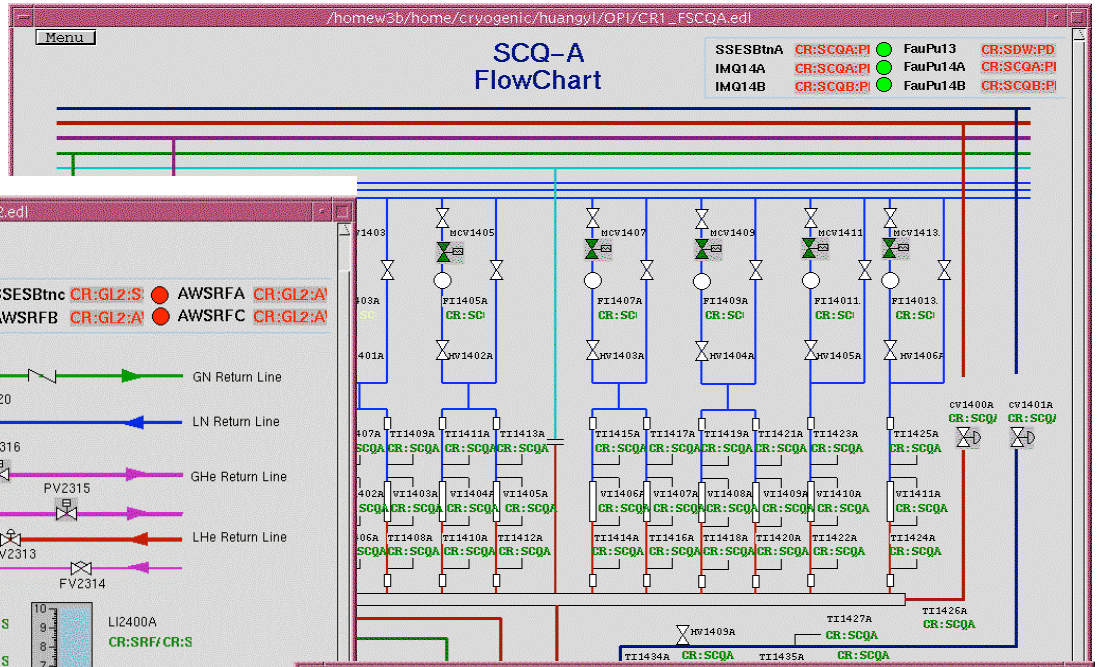
CR control system was put into operation in Jan. 2005

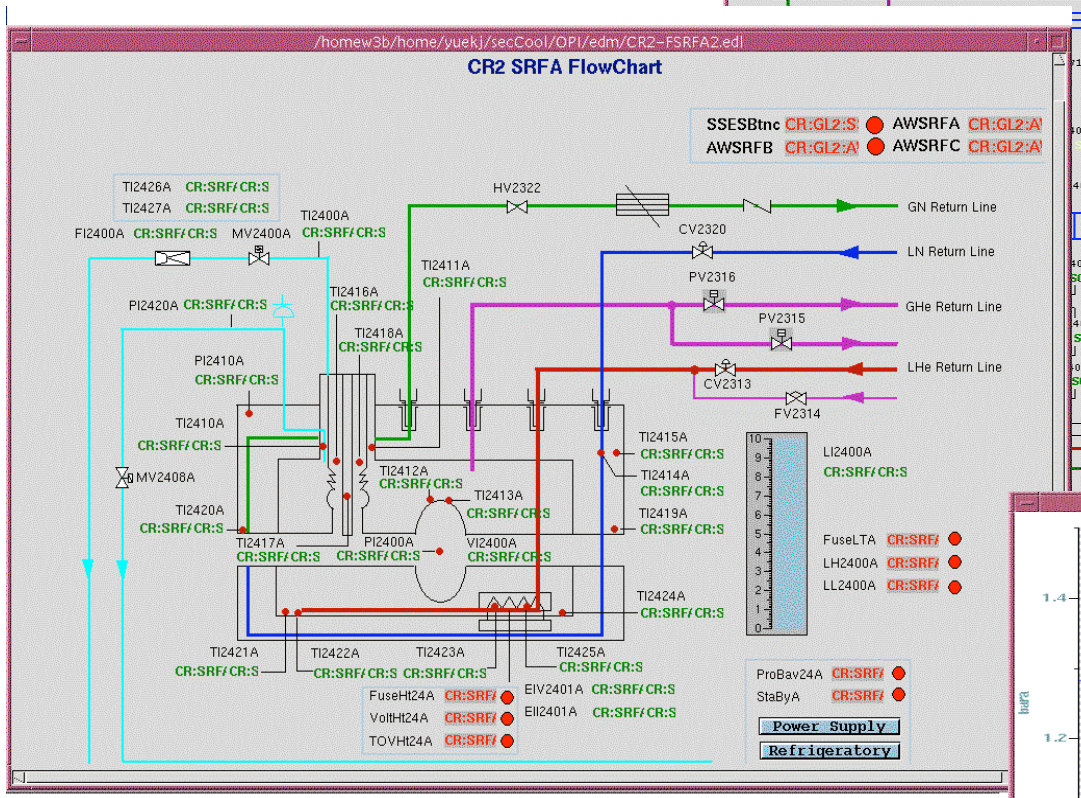


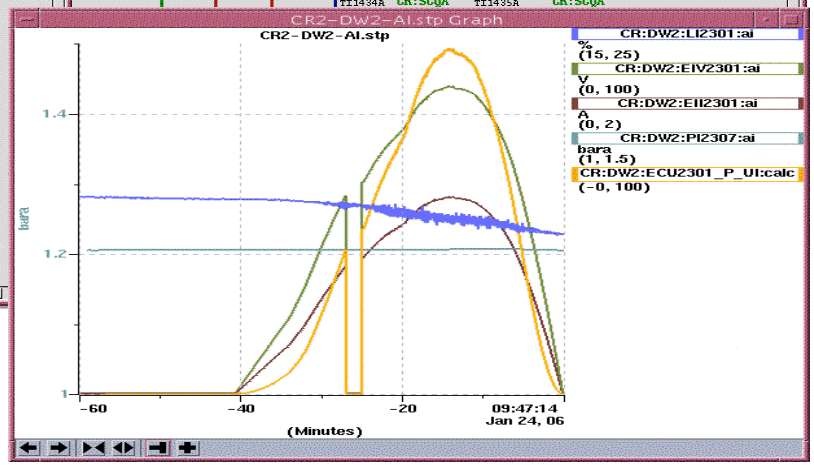
CR local control

Control Panel

SCQ/SSM control







SCRF Cavity control

High level applications

- Most high level applications transferred from KEKB
- Using SAD development environment
- Main components
  - Optics
  - Closed orbit correction
  - IP commissionning
  - Slow orbit feedback control
  - BBA, Respons matrix
  - Injection timing

Panels of Optics and COD applications

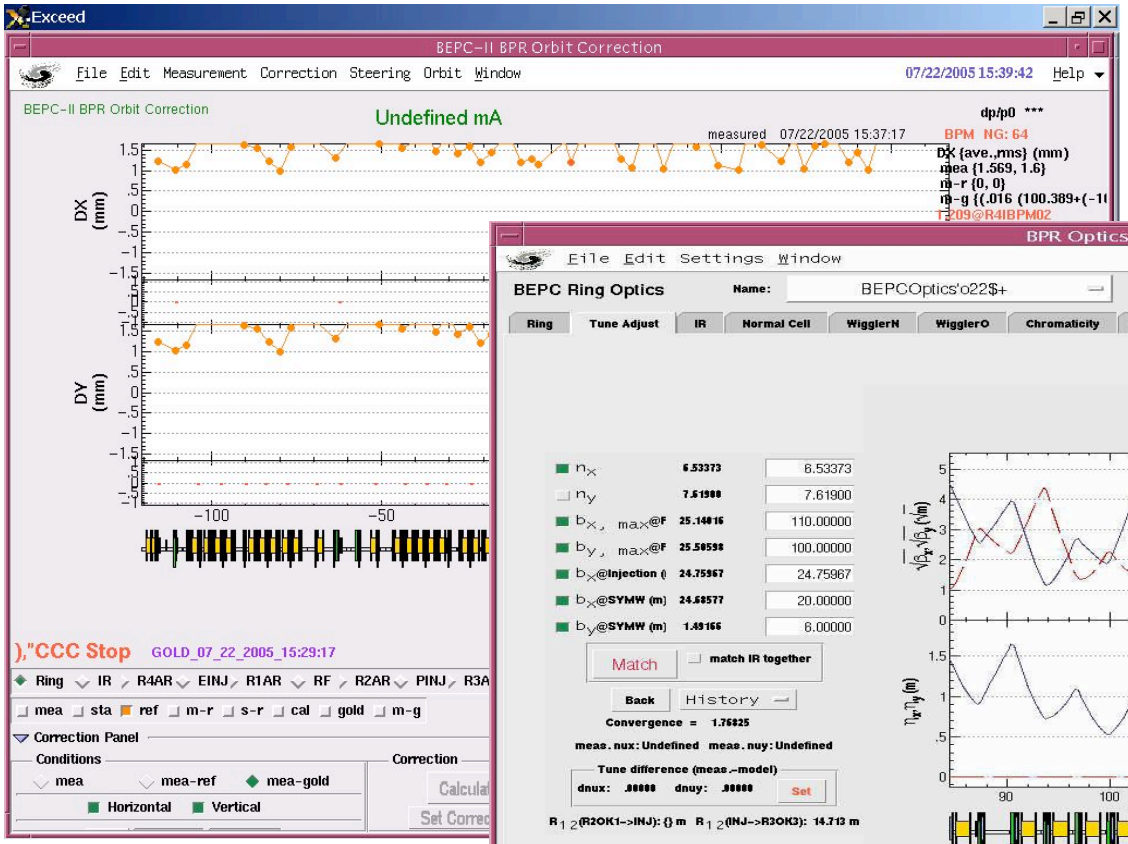
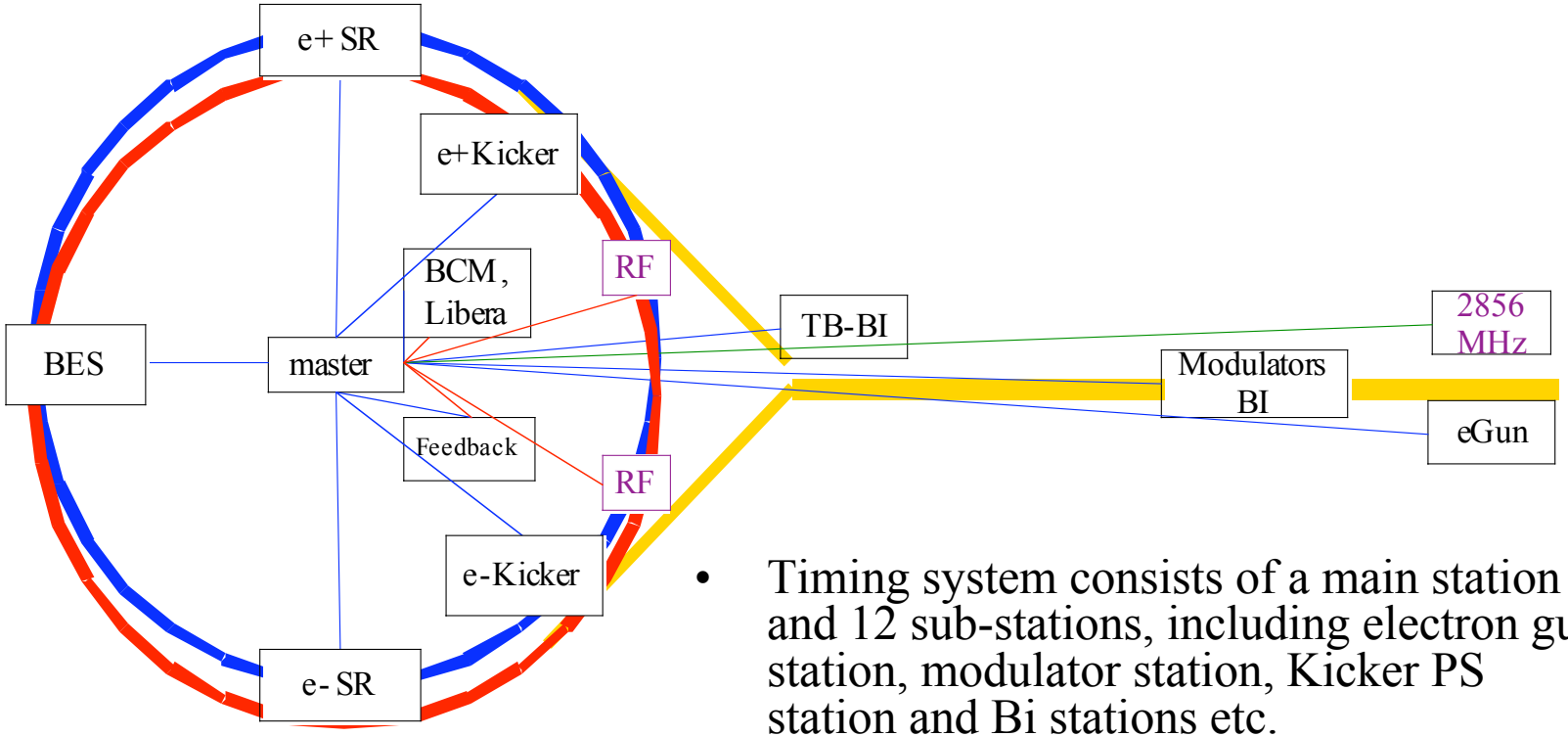


Fig1. COD

Fig2. Optics

BEPCII timing system layout

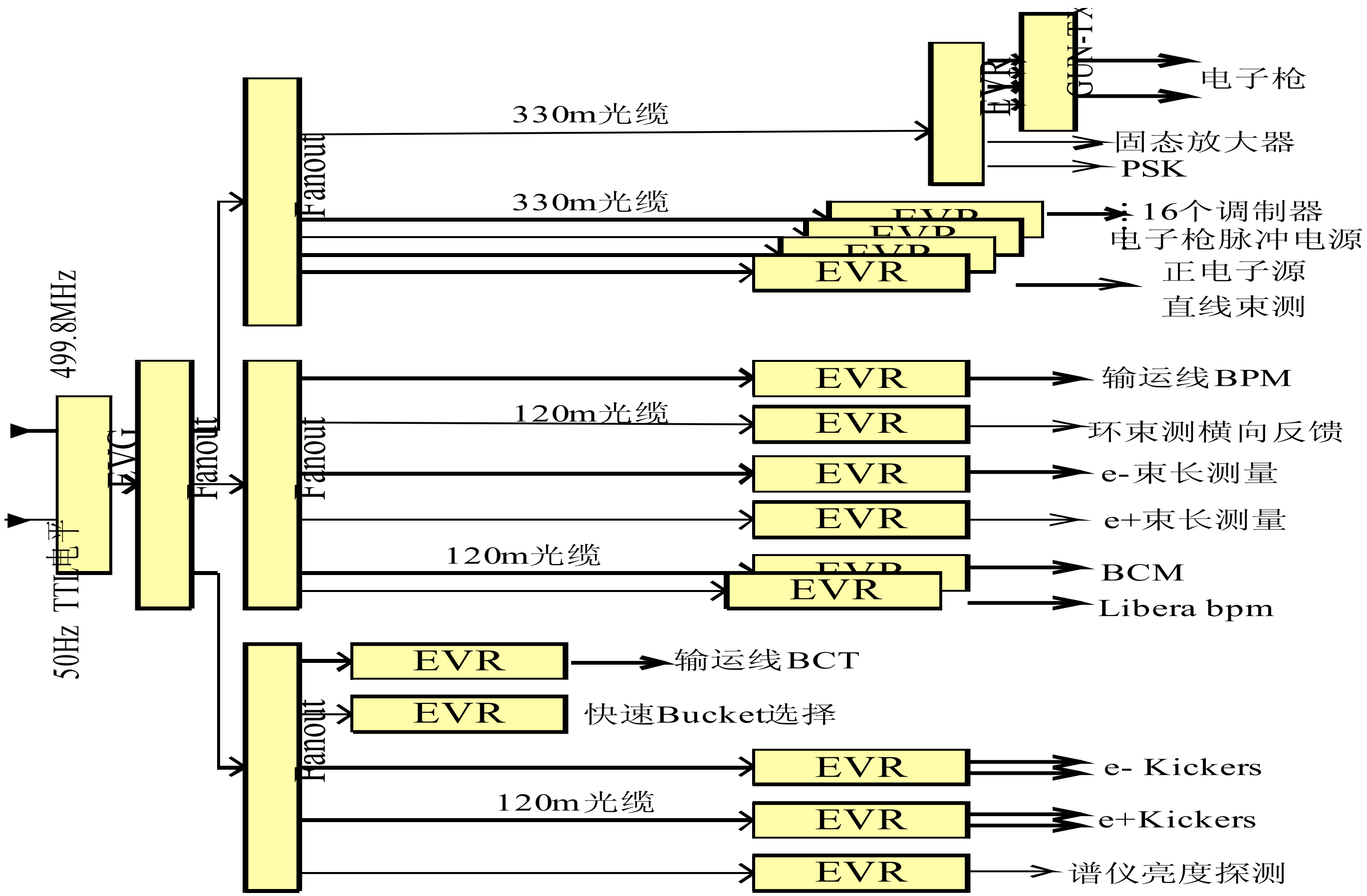


- Timing system consists of a main station and 12 sub-stations, including electron gun station, modulator station, Kicker PS station and Bi stations etc.
- Blue lines: event system optical cables
  Red lines: 499.8MHz signals
  Green line: 10MHz time base synchronized with Linac 2856MHz signal generator

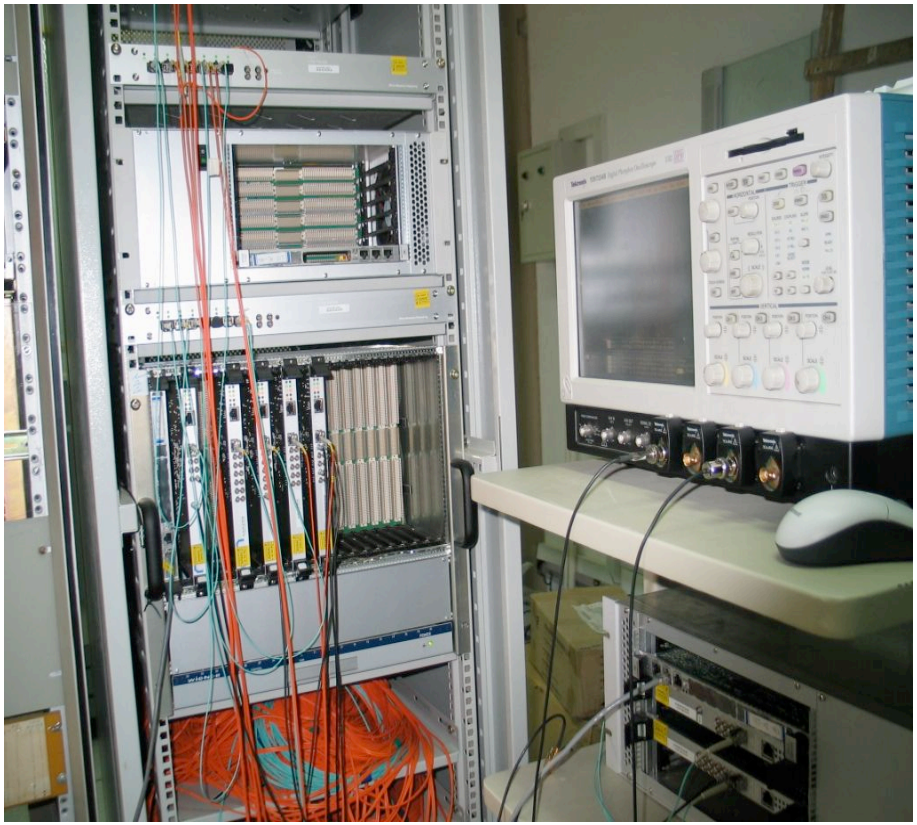
BEPCII timing system hardware

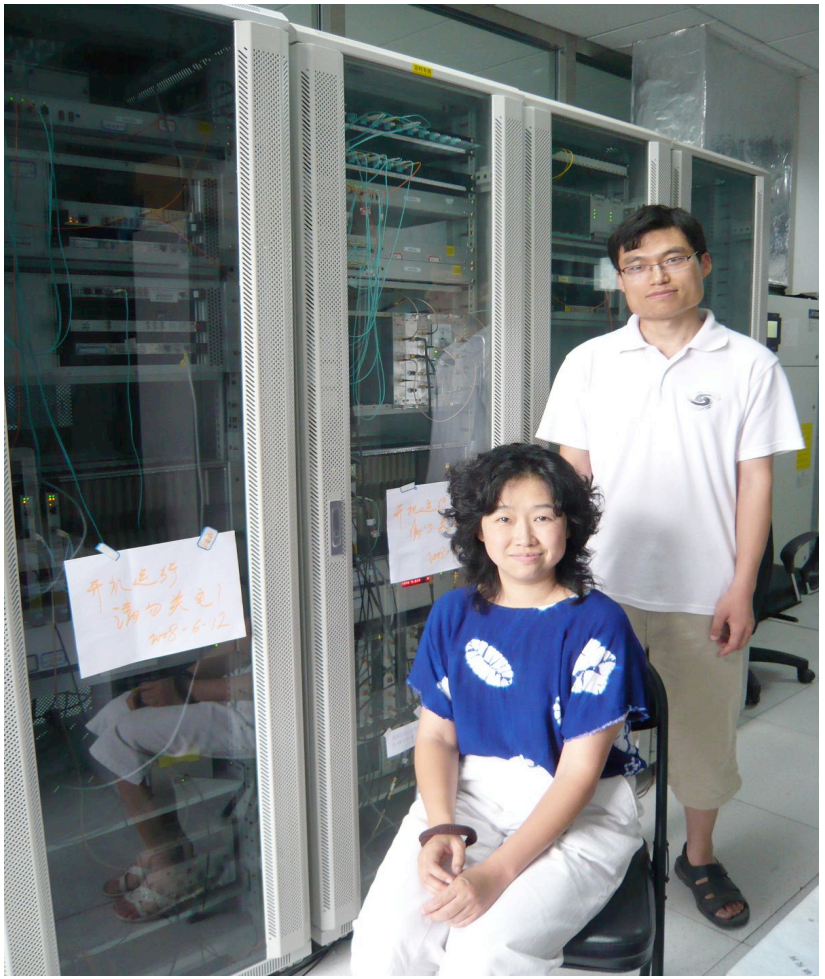
- 2 EVGs, 19 EVRs
- 13 VME crates and controllers,
- 2 levels of fanout, 5 Fout-7 modules in total.
- GUN-TX and Gun-Rx for e-gun pulser timing
- 4 TD-4Vs for Kickers
- 18 sets of home-made E/O and O/E for linac

Event Timing System

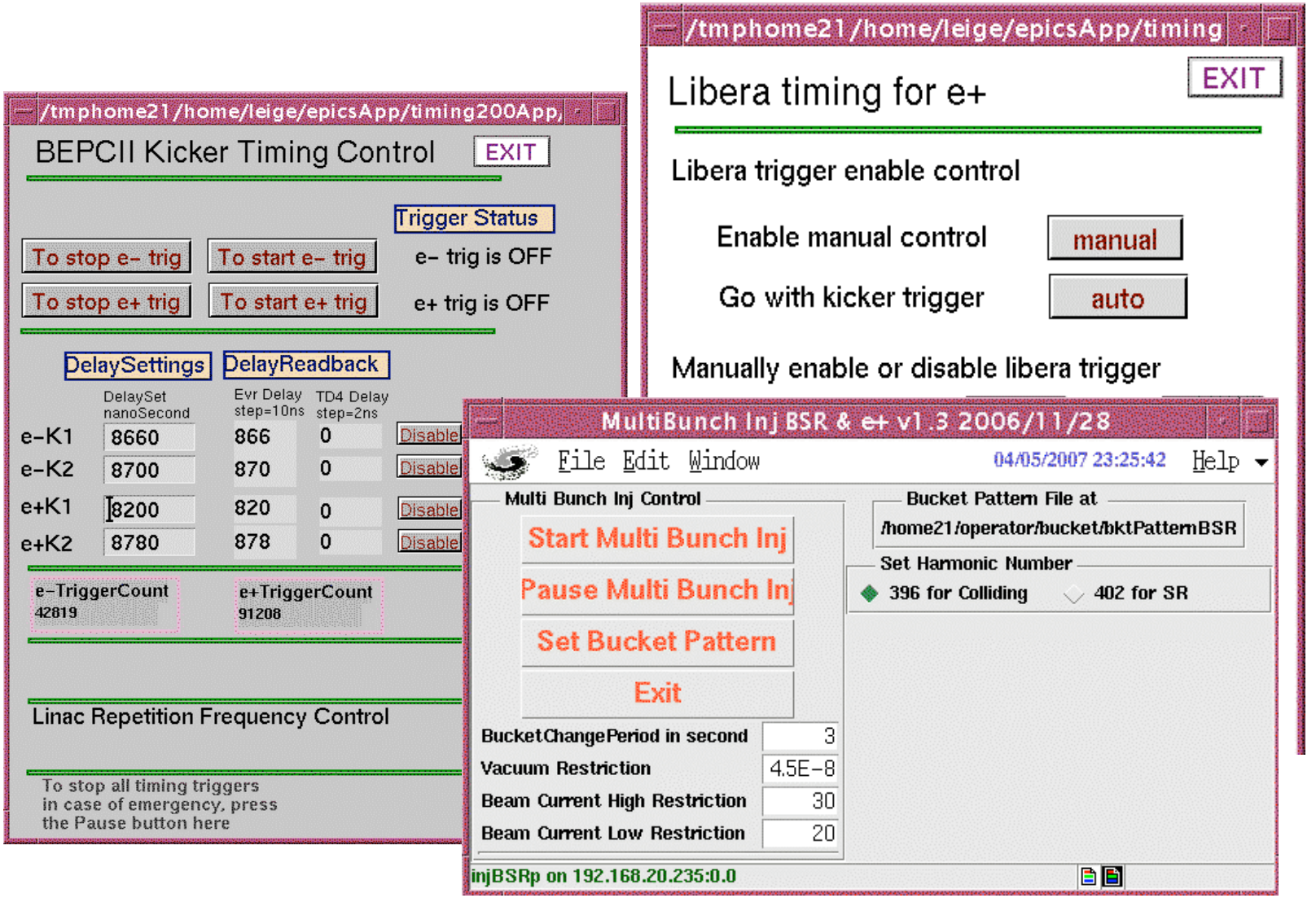


Timing system crates

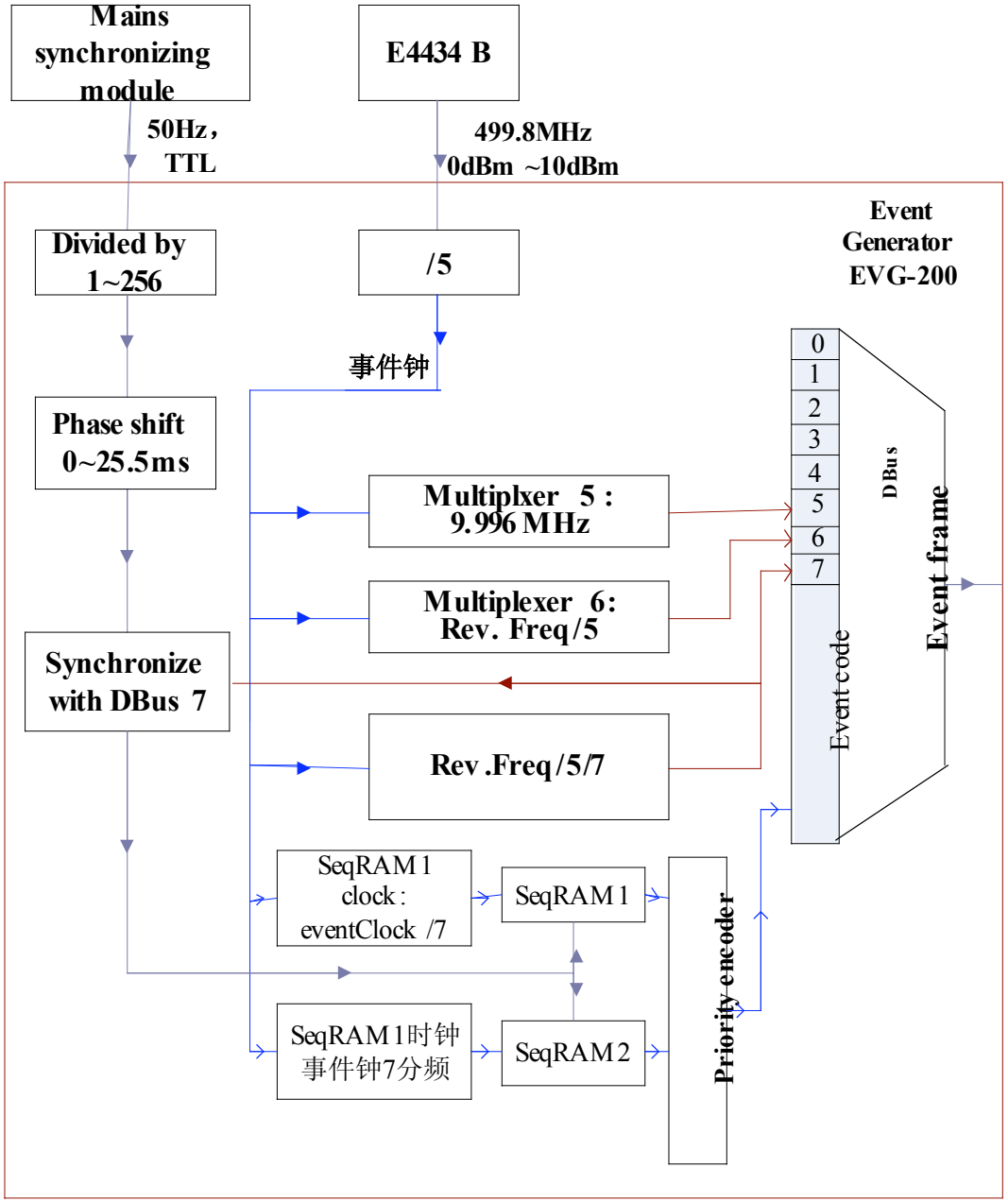




Control Panels



BEPCII event timing clock



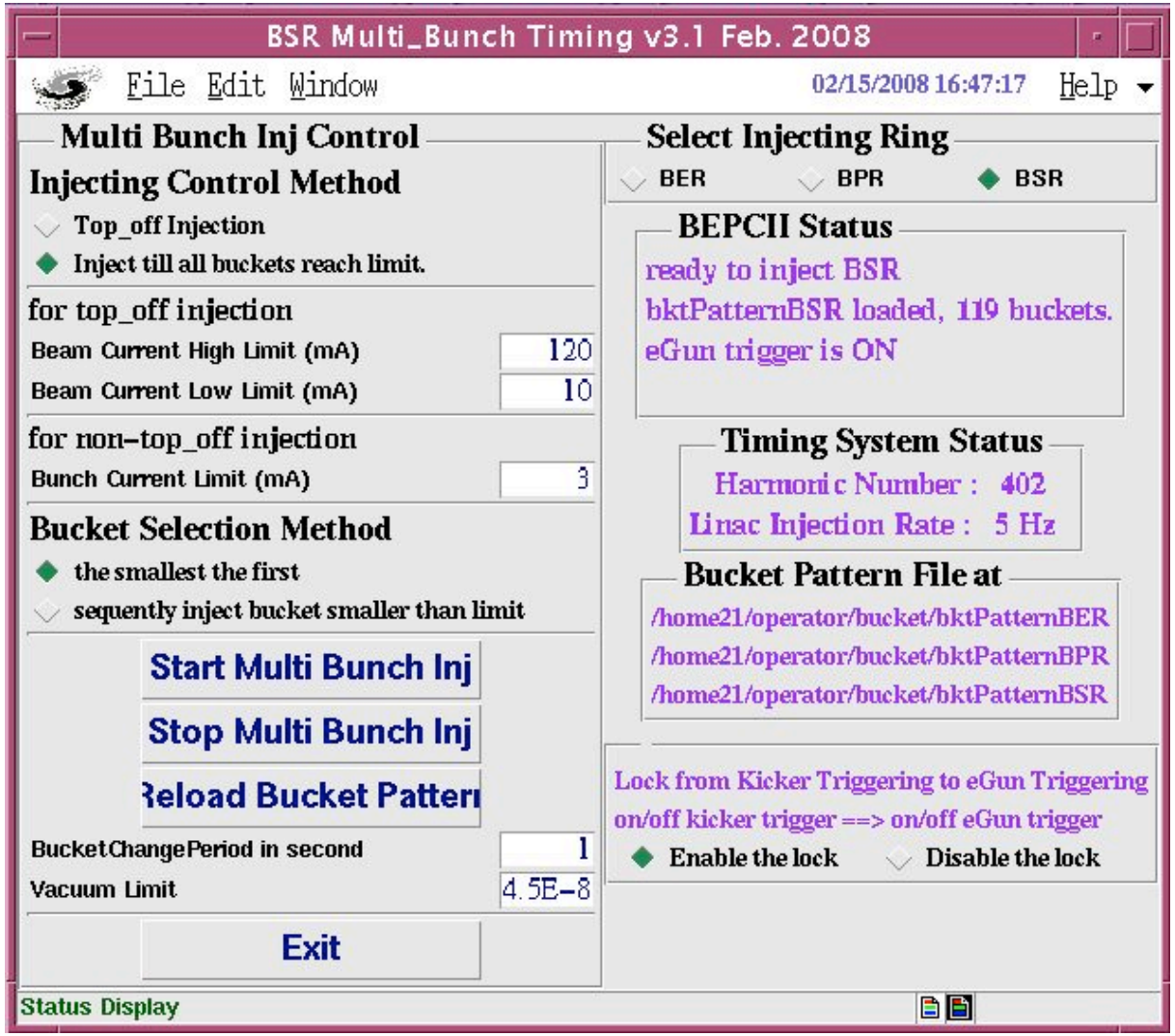
To select any bucket

- The event clock is set to 499.8MHz/5.
  - Reason: In EVG-200, the event clock can be generated from RF divided by 4,5,6,8,10 and 12, among which only 5 is a prime number.
- event-clock/7 is set to be the sequencer clock
  - Reason: 7 is a common factor of BEPCII ring RF and linac RF frequnecy.

To select any bucket

- Bn = MOD(Rn*35, 396), for BEPCII colliding mode
  - Rn is the SequenceRAM unit number, Bn is the bucket number.
  - Using the above formula, any unit from 0 to 395 in SeqRAM can be mapped to one and only one bucket in the ring, which has 396 buckets in total.
- The above formula can generate a table, SeqRAM unit to bucket number. Transform it to a table mapping bucket number to SeqRAM unit number.

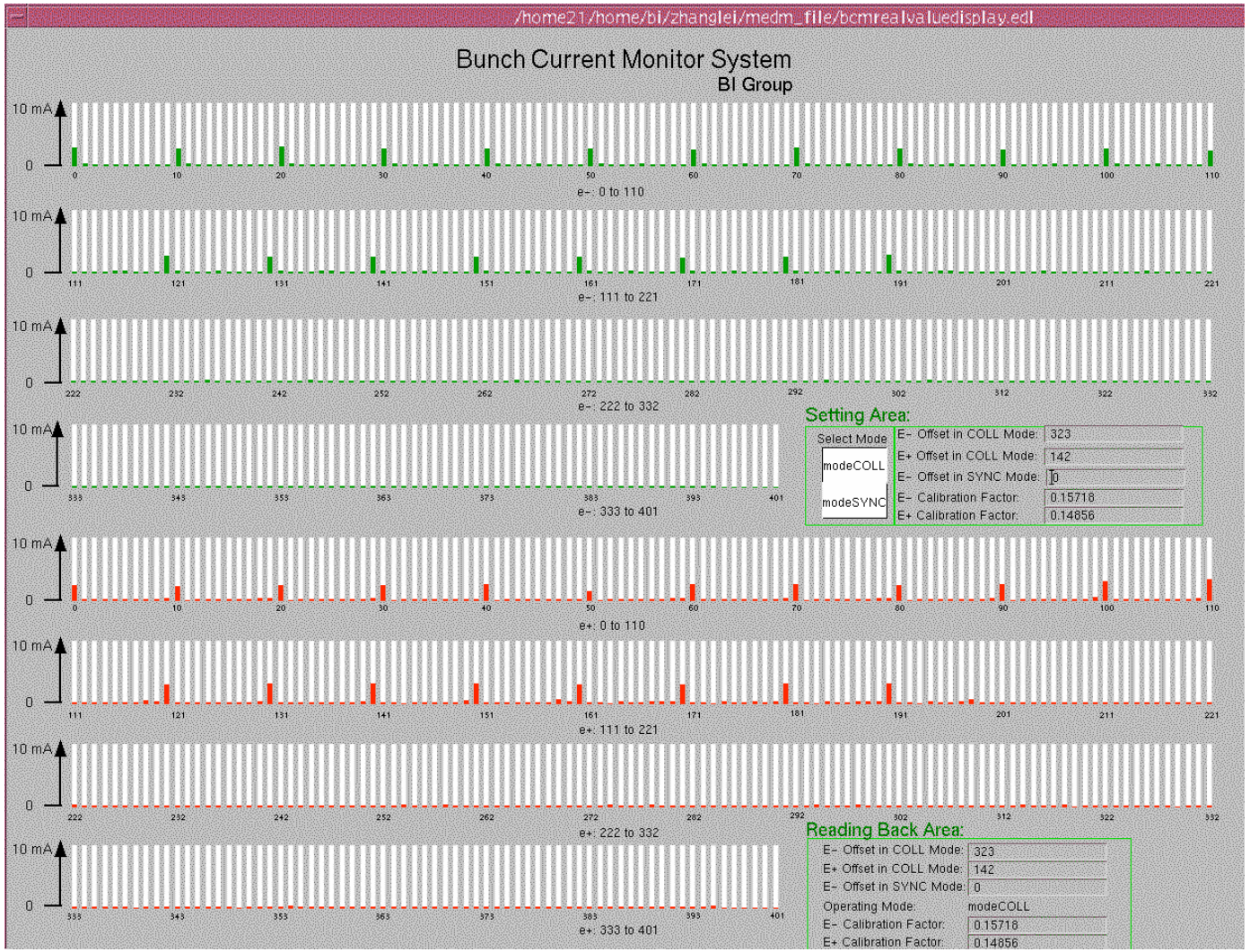
Multi bunch injection control



Multi-bunch injection control

- Control when to inject and when to stop
  - Top-off injection, a control loop
  - Stop injection when all buckets reach the bunch current limit
- Bucket select method
  - The smallest the first
  - Next smaller than the bunch limit, according to the sequence in the injection pattern definition file
- Criterion
  - Beam current from DCCT, or bunch current from BCM
- Injection pattern definition file: ASCII files

BCM display of 20 * 20 buckets colliding



Performance

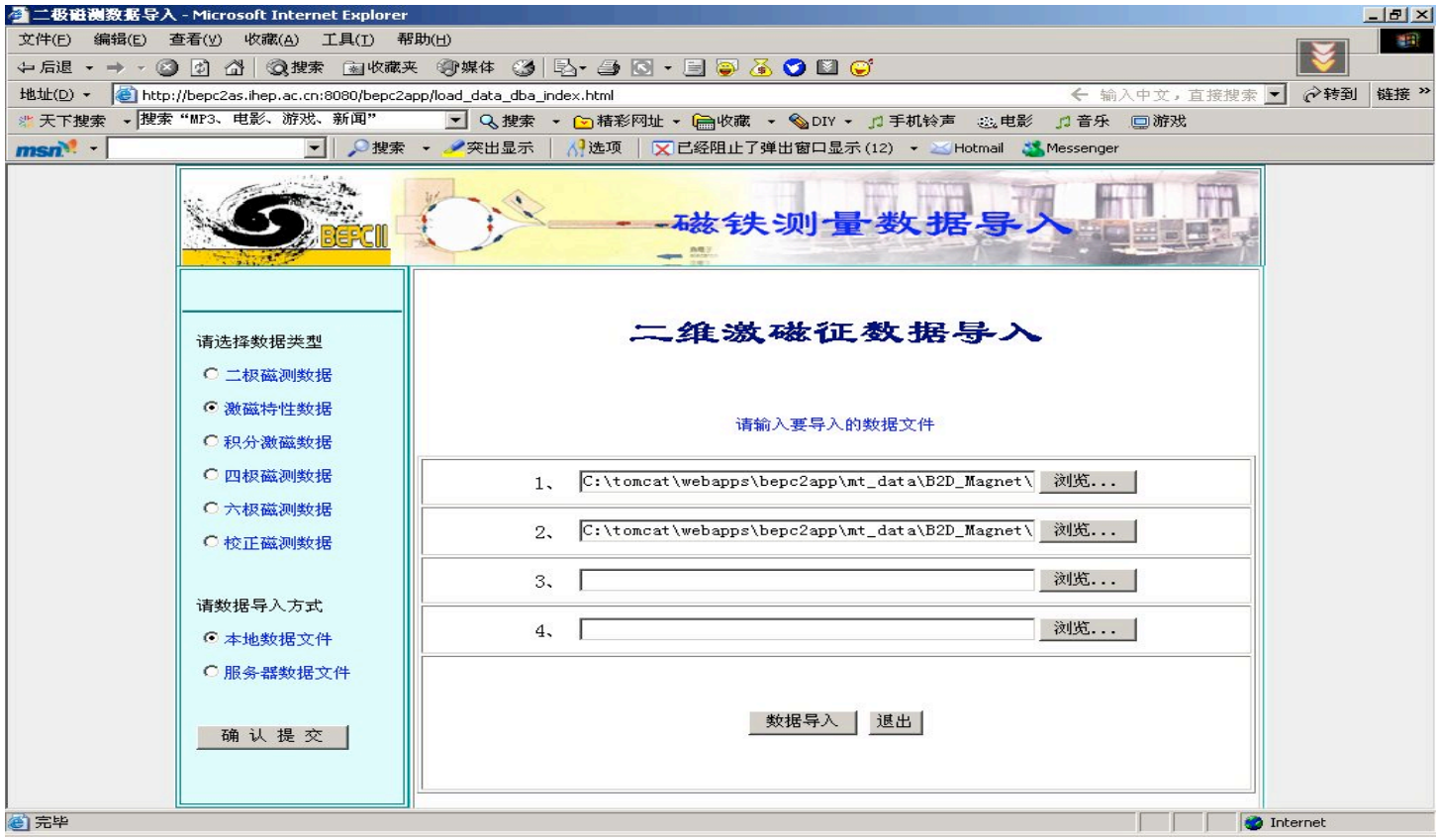
Performance: jitter of transport line beam signal to 499.8MHz RF signal is less then 16 pico seconds

Oracle Database

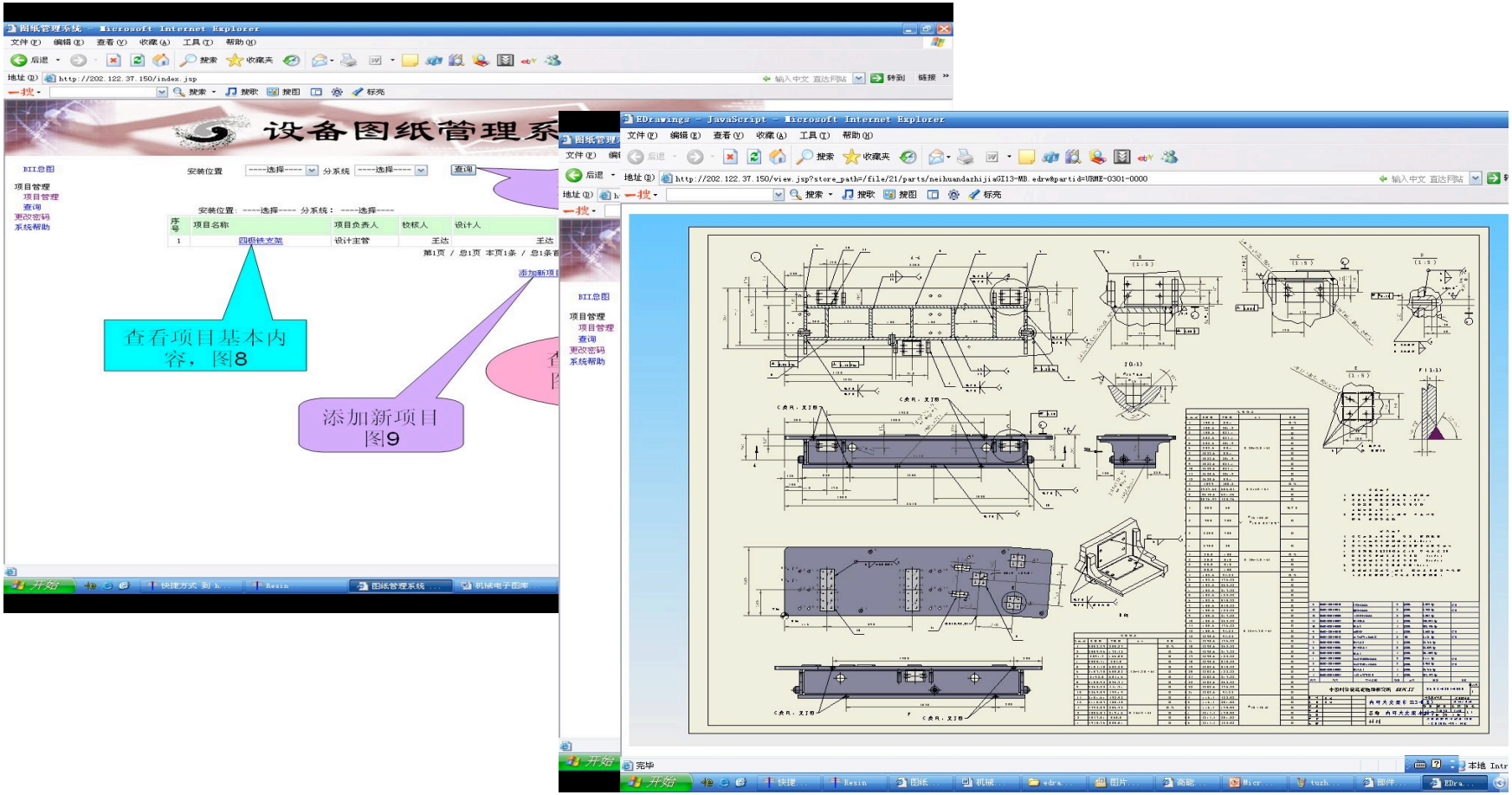
- The Oracle database used to store the machine parameters and control data
- It has a Web interface
- Including
  - Static parameters
  - History data from IOCs
  - Manager information
- We have developed the communication programs
  - Between IOC and Oracle
  - Between ChannelAchiver and Oracle
- e-logbook based on Oracle database

Static Data

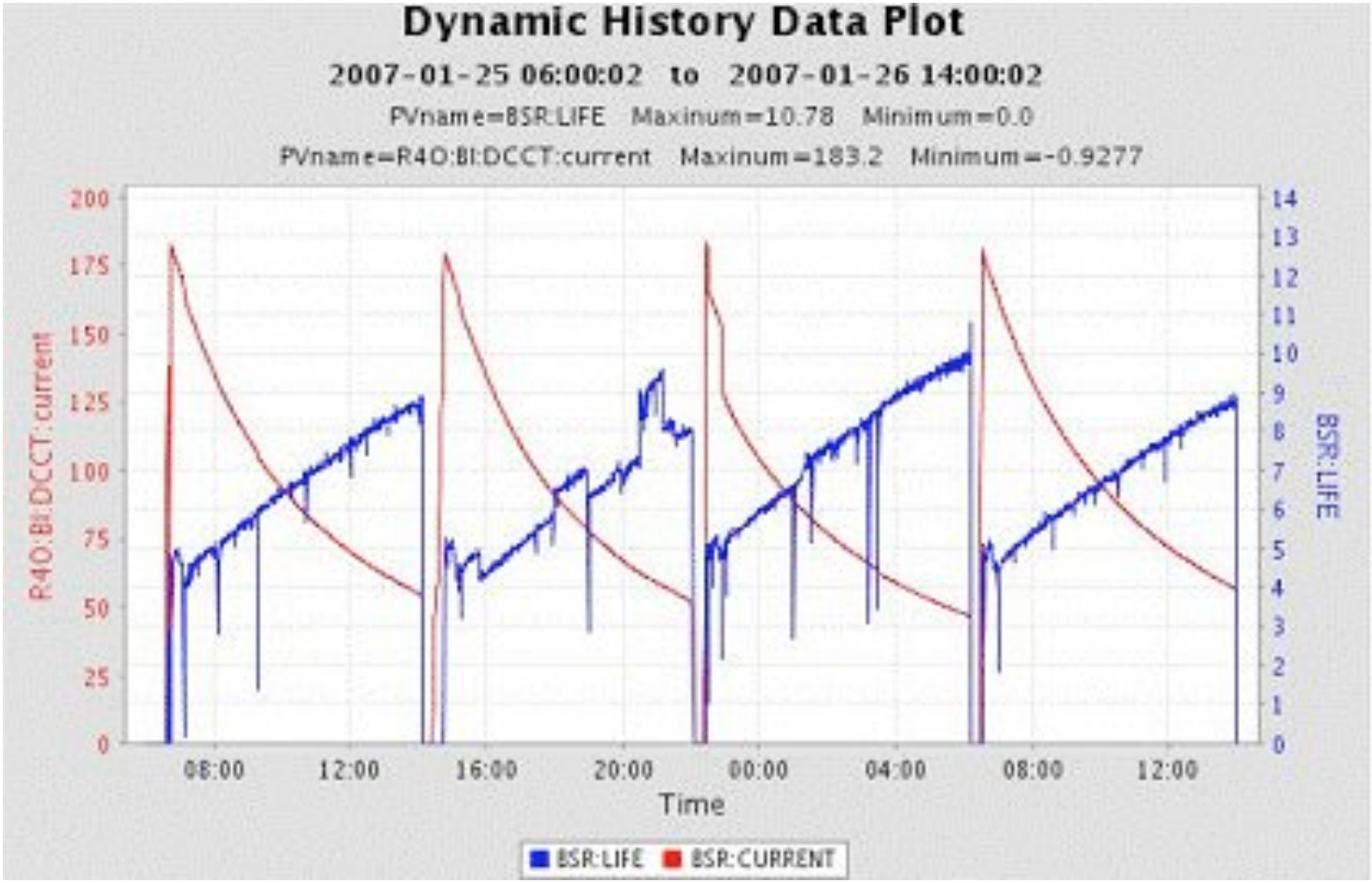
- Magnet measurement data
- Drawings



Drawings



History data



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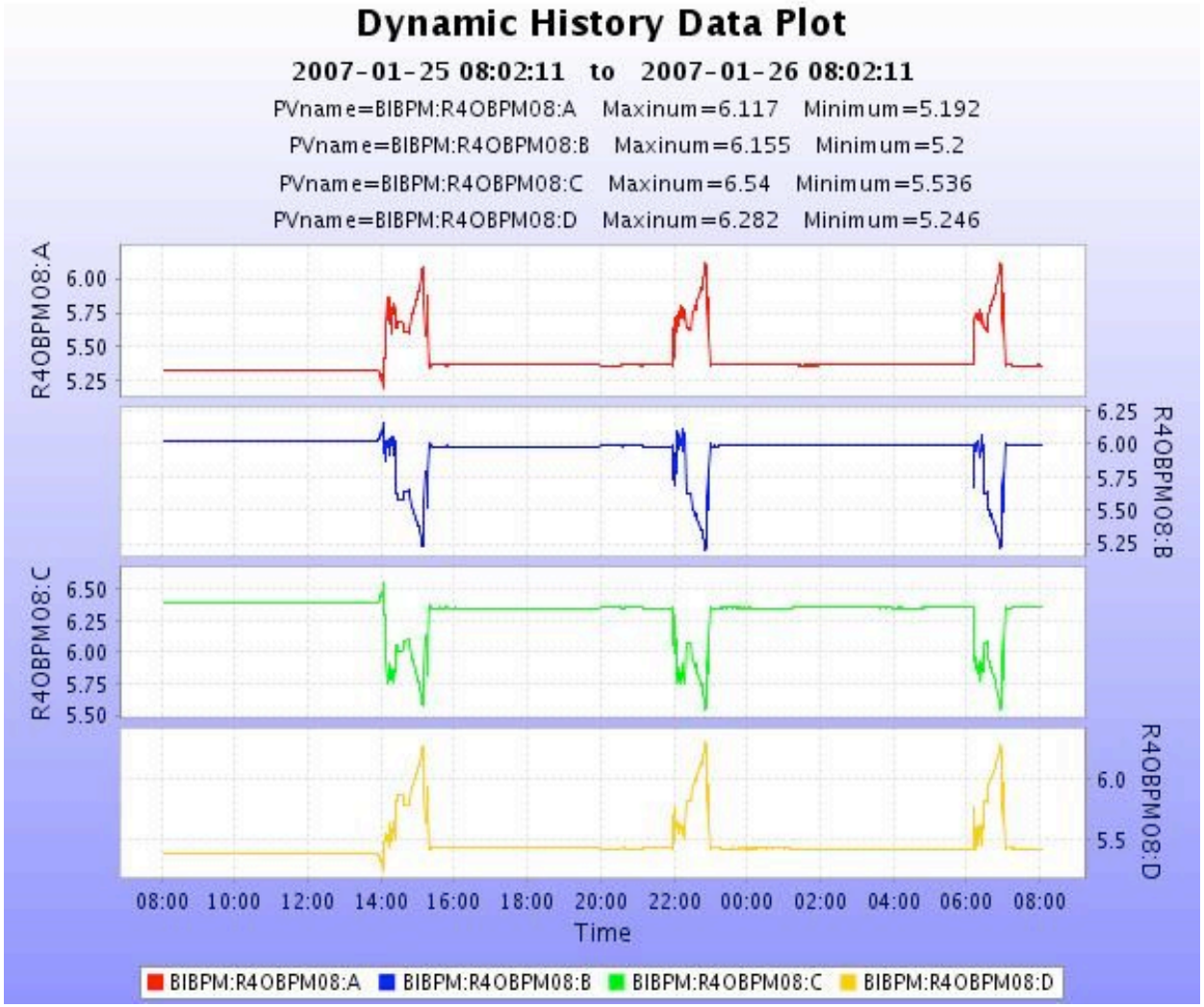


e-loogbook

- Developed BEPCII e-loogbook in Chinese
- E-loogbook saved in Oracle database
- Based on DESY's version

Machine Protection system

- Adopt Omron PLC and PC-link
- Central interlock system
  - Interlock of BEPCII machine start up
  - Interlock between systems, such as the accelerator and Detector
  - Publish the BEPCII running information in IHEP campus
- Low level interlock system

  Vacuum, PS and Magnet cooling water, RF interlock……

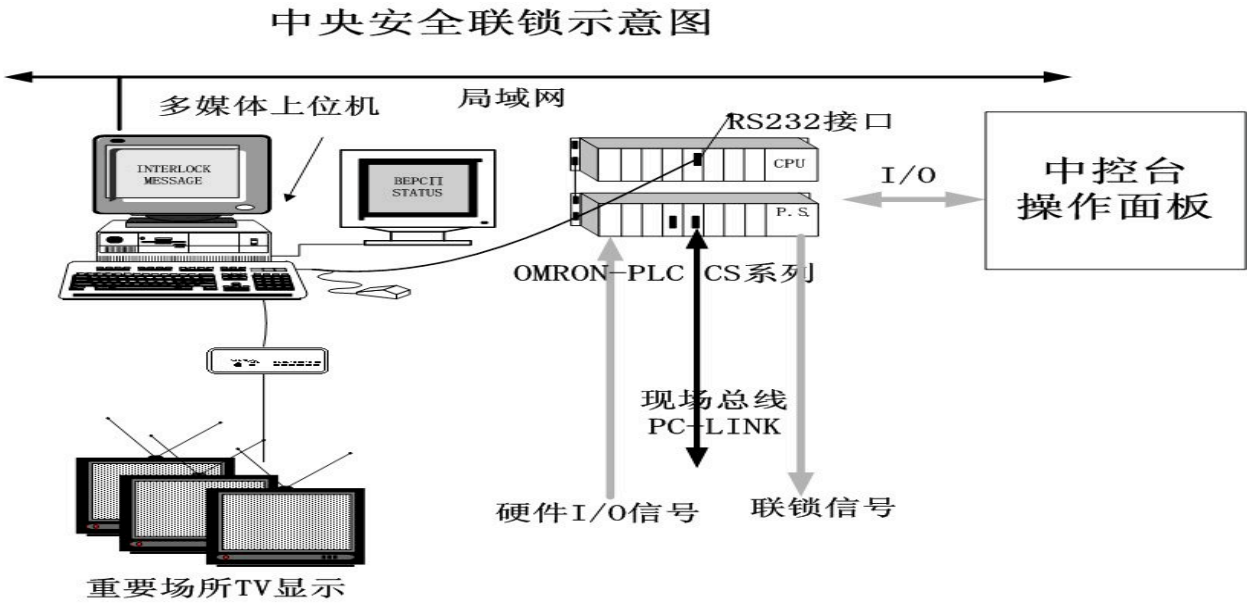


图 8-4-17 中央安全连锁系统示意图

New console installation

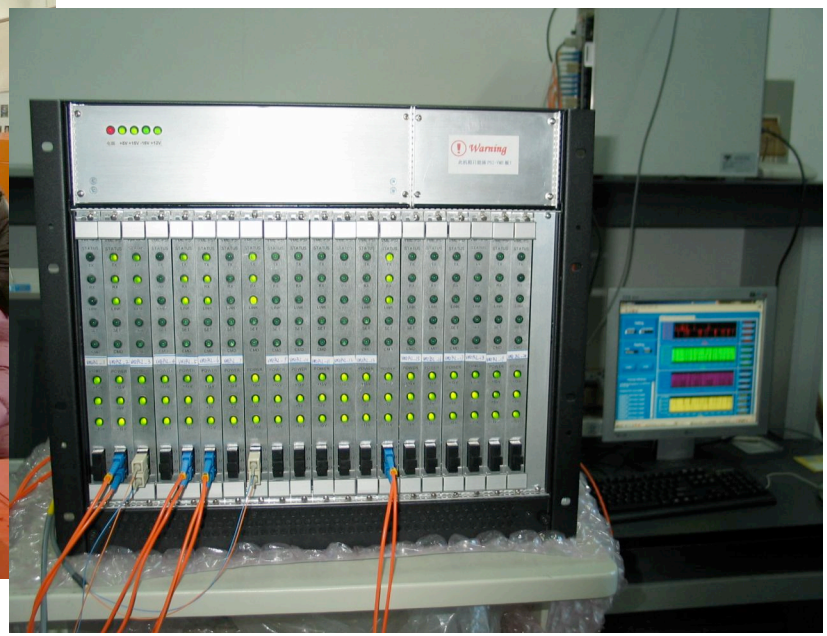
New Control Room

R&D

- From Oct.2002 to Nov. 2003 is the R&D stage
- We built EPICS and Power supply prototype system
- Developing all of I/O driver and communication drivers that we needed
- Transferring SAD environment from KEKB to BEPCII Solaris 8

On line test of prototype for chopper PS

Prototype of Corrector PS



System Development

- We spent 2 years to developing the system in laboratory (Jan.2004 to Dec. 2005)
- Make off-line and on-line test at Lab

- We have built both of hardware and software of the
  - Host computer system and EPICS environment
  - Redundant network system
  - Power supply control system
  - Vacuum control system
  - RF control system
  - Cryogenic control system
  - Event timing system
  - Oracle database
  - Commissioning applications
  - Machine protection system
  - A new console

Installations

In 2006 we spent 8 months to install control system on BEPCII site

System Test

- The system test on site BEPCII from Summer to Oct. 2006

First beam accumulated at Storage Ring

- BEPCII Control system was put into operation in 12 Nov. 2006

BEPCII commissioning

Stages

- Oct.10, 06 - Aug.24, 07 Commissioning backup scheme
- Oct.24, 07 – Mar.28,08 Commissioning with SCQ without detector
- Jun.22, 08 - Dec.18, 08 Commissioning and HEP operation with detector

Milestone

- Nov.12, 06 Start ring commissioning from transport lines
- Nov.14, 06 First turn in the ring
- Nov.18, 06 First e^- beam storage in outer ring (SR ring)
- Nov.25, 06 Start SR beam line commissioning and user operation
- Mar. 25 2007 Collision backup scheme
  - Single bunch collision: 9mA*9mA
  - Multi-bunch collision: 7*7, ~20mA/ring
- Jan.29 2008 Collision with 500mA * 500mA with SCQ
- Jul.19 2008 Collision with detector

Current Result

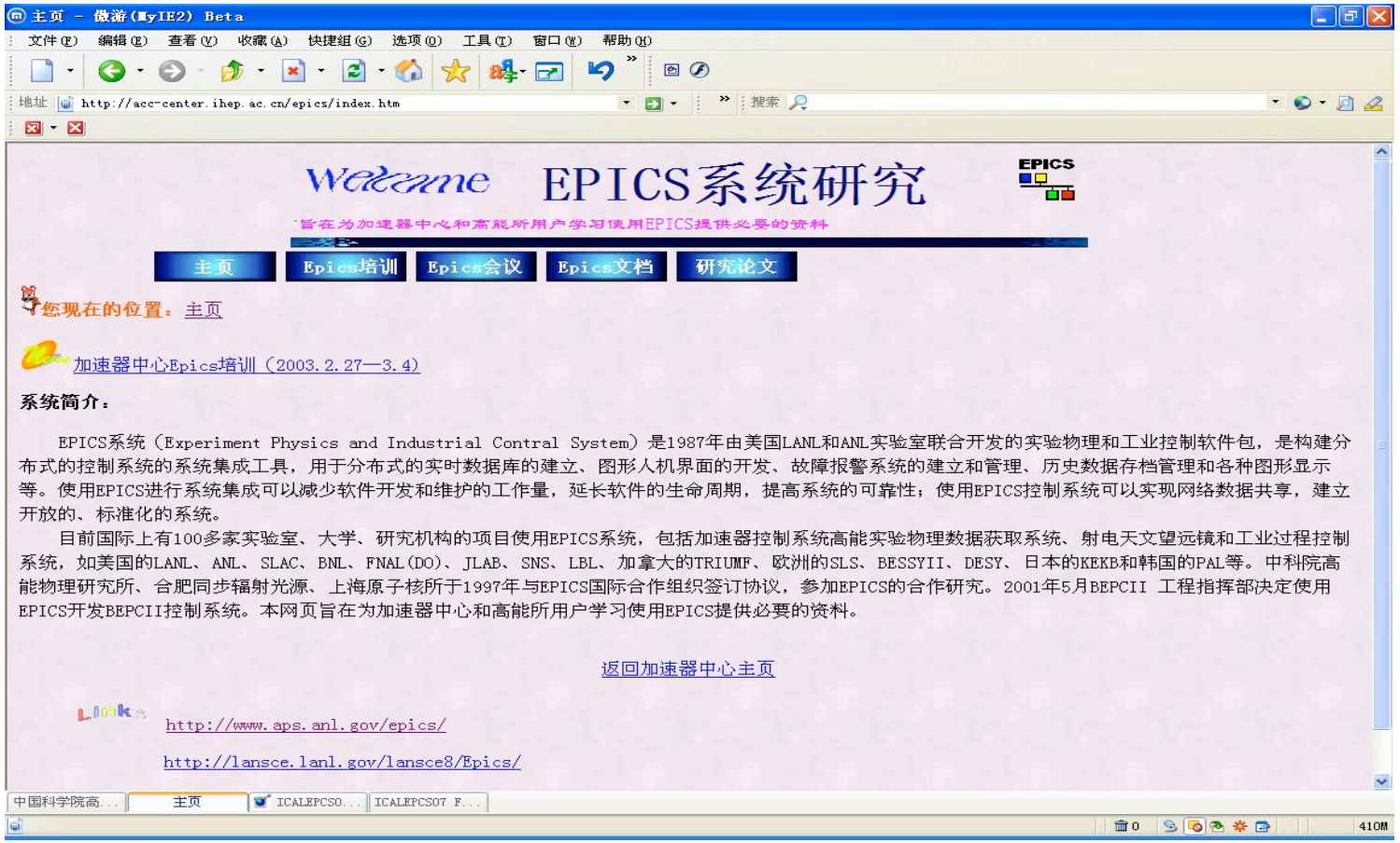
- **Lum record: $1.3\times10^{32}m^{-2}s^{-1}$ @ 489mA×530mA with 90 bunches**
- Max. beam current : 600mA of both of e^- and e^+ beam, Max. 93 bunches
- SR mode: 2.5GeV, 250mA with full energy injection, bean life time is 10 hours

Collaborations

- Collaboration with KEKB went through 10 years, KEKB provided us most of their HLA, which speeded development of BEPCII
- We have sent 12 young people to go to KEKB and learn EPICS system and control technology
- We have hosted two Asia EPICS Seminar and EPICS training course in Beijing in 2001 and 2002
- DESY cryogenic control group gave us valuable advices and transferred some source code, which is very helpful for developing BEPCII cryogenic control system
- SSRF Lab. lent us EVG/EVR modules to build the timing prototype at that time our device have not delivered

EPICS Web Page at IHEP

We join the EPICS collaboration and have got a lot of help from EPICS world



Summary

- Since September 2001, the BEPCII control system has gone a long road for system design and construction
- The project is successful with good quality and reliability
- It has been done on schedule and within the budget

- Thanks all of people who have gave us a lot of help in the past few years!

Control People

Thank you for your attention!