Experience of Developing BEPCII Control System

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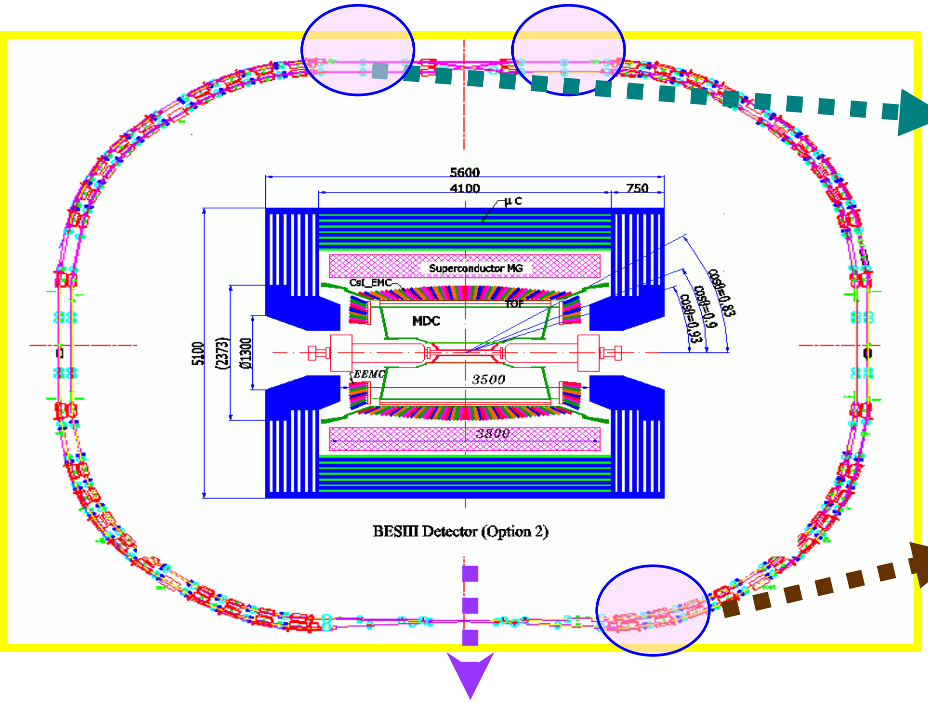
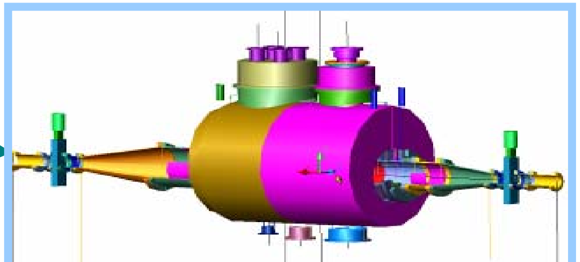
BEPCII Project

- The project BEPCII is for upgrading the BEPC (Beijing Electron Positron Collider) 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.
  - Energy 1.89GeV at Collision mode
  - 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 Linac, Transport line and Storage Ring



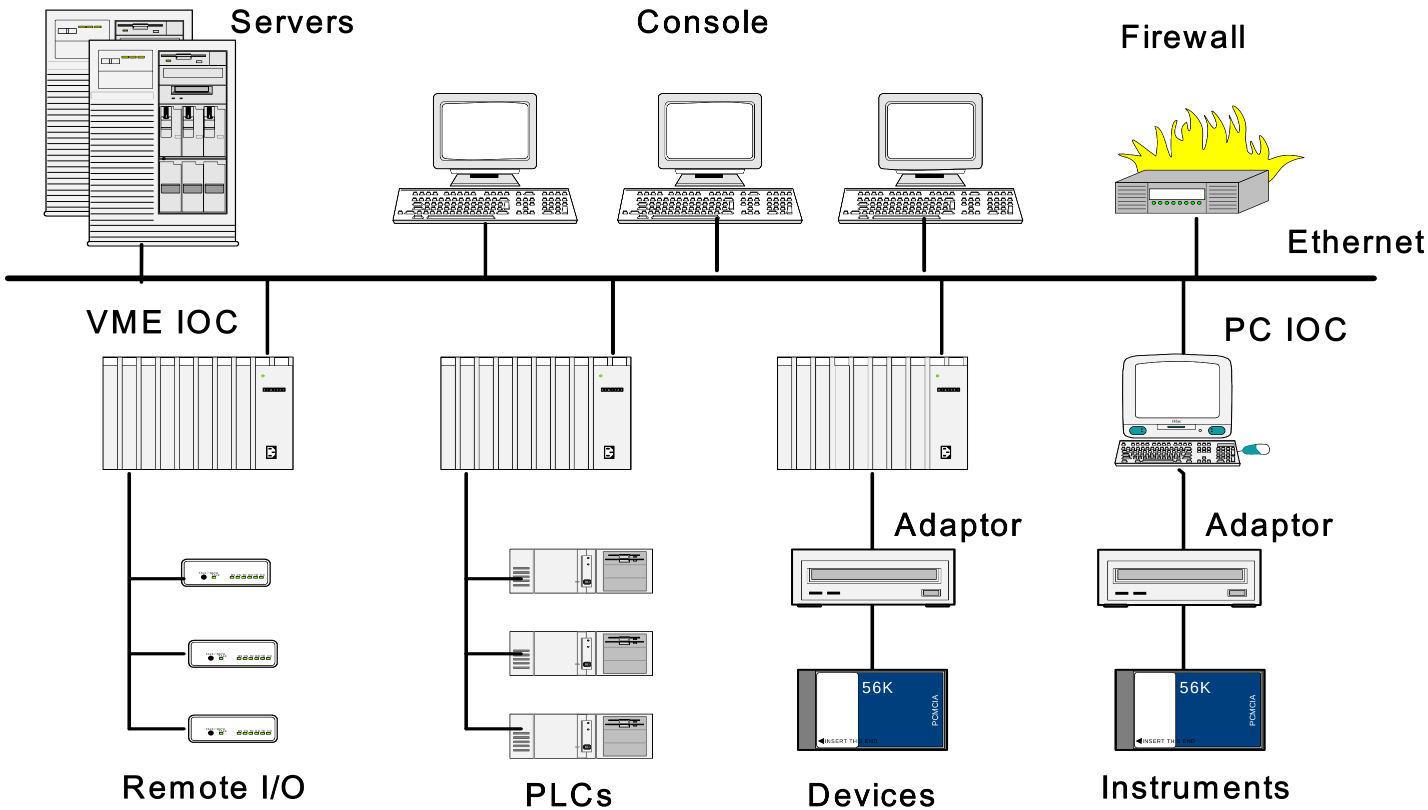

Superconducting RF Cavity


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



System 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

Design philosophy

- BEPCII control system should be
  - delivered on time,
  - within the budget
  - Meet the accelerator physical requirement
- The following design philosophy should be considered
  - Adopt distribution architecture
  - Using system integration tools to develop the system
  - Using commercial hardware as many as possible
  - Selection of standard hardware and software
  - Adopting advanced and mature technology
  - System extension
  - Cost & performance

System Integration Tools

- The system integration tools should be used
- We have evaluated SCADA products and EPICS
- BEPCII has decided using EPICS to develop the control system
- For
  - EPICS is wildly used in Accelerator field
  - Which Support VME hardware
  - We can get HEP lab's help and share the high level applications
  - SCADA can be used for slow control and interlock system etc.

Standardization

Standardization is very important

We spent a lot of time to select standard hardware and software to build the system

Host computer system

- SUN Cluster system consists of
  - 2 SUN V880 servers，each of them has:
  - 8 CPU, 32GB memory,shared disk array
  - Serve as EPICS server, NFS system,running high level applications etc.
- EPICS data server（PC server）
- Oracle server（PCserver）
- 28 console computers – SUN WS and Linux PCs

SUN V880 Cluster

Standard 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
- 1G/100M Ethernet
  - using Cisco C4506 switch, redundancy
- Field Buses
  - ControlNet, CANbus, RS232, RS485

Standard Software

- Host
  - SUN Solaris and PC Linux
  - EPICS host tools:

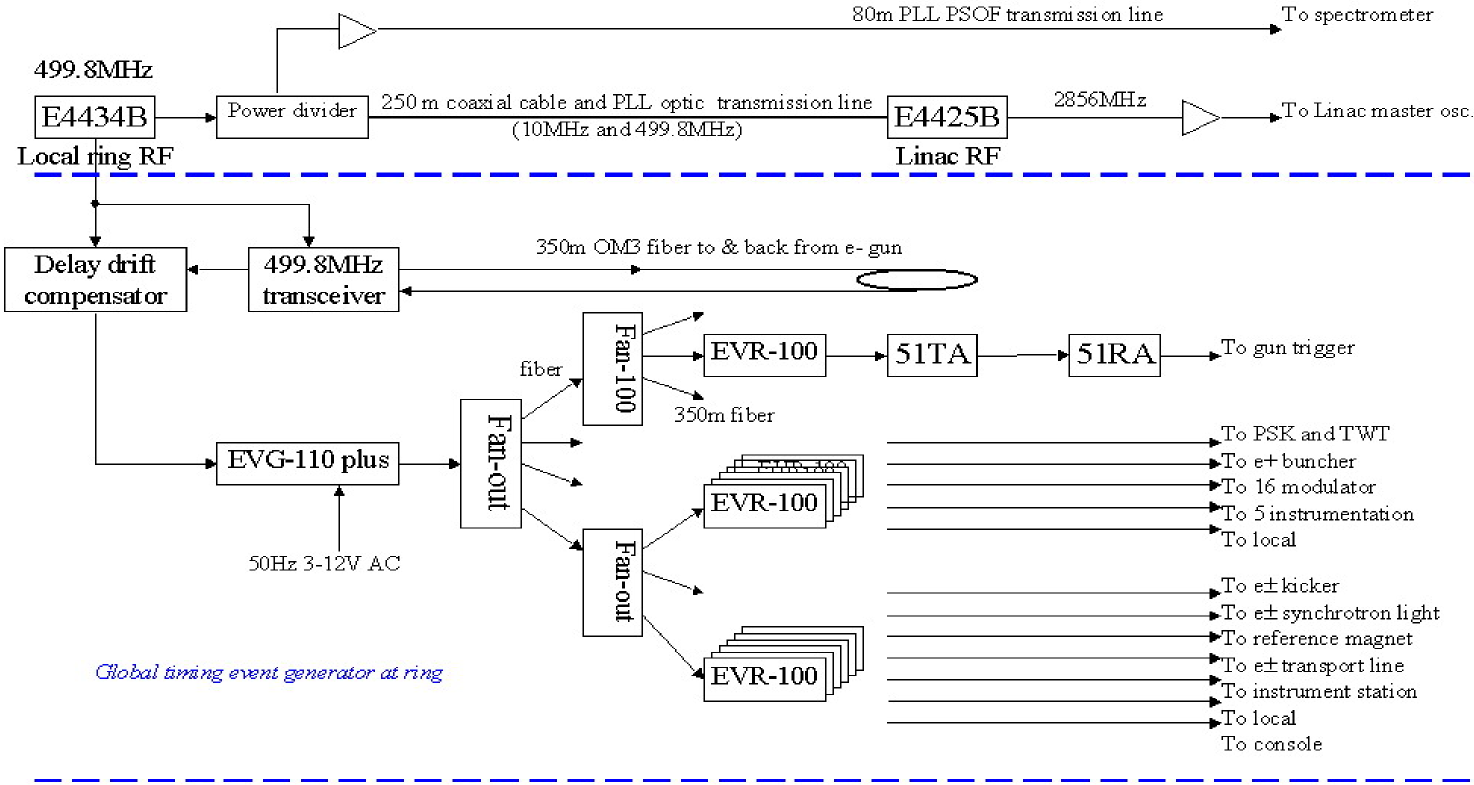
    EDM, VDCT, SNL, Tcl / Tk, ALH,Channel Archiver, Cmlog, Prob, StripTool, SAD, Python etc.
  - CVS and NFS
- IOC
  - VxWorks 5.4
  - EPICS Base R3.13.8 for VME IOC
  - EPICS Base R3.14.7 for PC IOC
- HLA is developed and transferred from KEKB with SAD environment, after evaluation of HLA for SNS, PEP-II,APS and KEKB
- Oracle database store history data

Adopting advanced and mature technology

- The accelerator control system is complex and large scale system
- To ensure the project successful,we should consider adopt both of advanced and mature technologies
- For example:
  - Event timing system
  - Interface for Power supply control

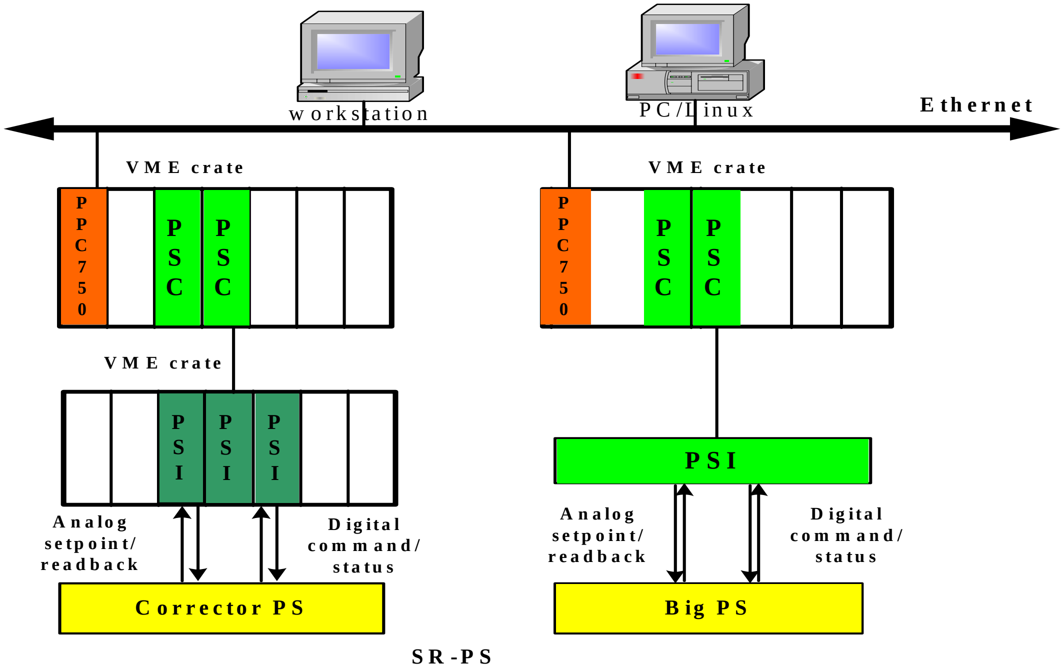
Event Timing System

- Event timing system with EVG/EVR 200 modules
- Which is following the experience of APS, SLS,SSRF, Diamond
- hardware: VME IOCs, EVG and EVRs
- Software: EPICS



Power Supply Interface

- Original we have 3 plan:
  - embedded processor, VME IP module and PSC-PSI module
- We have built test bench for them,finally selected the PSC-PSI plan
- Which follows BNL and SNS’s design



User Requirement

- System design and development follows concept of software engineering
- First thing is to make user requirement
  - Control people discuss with
    - Accelerator Physicists
    - Equipment engineers
    - Operators
  - provide outline and forms for users
  - Appoint the contact persons
    - who are from control group and other groups
    - They work together to finish the user requirement

附件一

BEPCII 控制系统用户需求调查提纲

2001 年 11 月 15 日

一、 **用户需求陈述**

请用一段文字描述本系统设备的基本情况（种类、数量），提出对控制系统的总体要求，指出控制系统应该"做什么"，以及要达到的基本技术指标等。

二、 **系统功能要求**

请列出控制系统必须完成的所有功能和系统任选的功能，包括：

1. 是否具有中央/本地两级显示和控制功能，要不要本地手动控制功能
2. 设备上的哪些物理量需要监测
3. 需要哪些设备控制功能（开关机、升降流、Ramp 等）
4. 是否要闭环控制，什么部分需要闭环，及对闭环控制的要求
5. 系统故障报警和恢复的要求
6. 对设备、系统的安全连锁要求
7. 历史数据的记录打印要求（记录数据的时间间隔，要不要自动打印）

三、 **系统性能要求**

请提出系统的技术性能指标

1. 联机响应时间的要求
2. 控制精度和稳定度的要求
3. 系统安全性的要求

四、 **运行和操作模式要求**

1. 设备有几种运行或操作模式，分别写出或画出各模式的工作流程
2. 说明各操作模式之间的关系，如
   - ✓ 按时间先后顺序执行
   - ✓ 当某条件改变时进行模式切换，并指出切换条件
   - ✓ 切换方法（自动、手动）
   - ✓ 由硬件信号触发执行
3. 定时和时间同步的要求（硬件触发还是软件触发）

五、 **对操作员界面的要求**

1. 需要监测的物理量以什么方式显示
   （表格、文字、二维曲线、直方图、设备直观图形显示、语音提示等）
2. 设备控制页面的要求（用表格、按钮、图形操作设备？）
3. 故障报警方式
4. 数据图形的打印要求

六、 **系统运行环境**

设备运行周边环境和设备自身的电磁场干扰情况等。

七、**系统发展的可能性** 即说明本系统将来进一步扩充和修改的可能性

Outline

- General descriptions
- Functionalities
- Control requirement:

  Response time,

  Accuracy,

  Stability ……
- Working mode and sequencing
- GUI requirement
- Timing requirement and jitters
- EMI issue etc.
- Possibility of expansion

Device and channel list

附件 2

表一：储存环被控设备调查表

子系统名称:　　　　填表日期:　　　　填表人:　　　　附表一 第　页 共　页

序号	设备中文名称	设备英文名称	台数	输出稳定度	控制精度	调节分辨率	要求控制方式				设备安装位置
							监测	控制	闭环	手动	

Note: The f

附件 3

表二：被控设备信号调查表

子系统名:　　　　设备名称 :　　　　填表日期:　　　　填表人:　　　　附表二 第　页 共　页

序号	信号名（暂不填）	信号代表的物理量	物理量单位	信号源头	信号目的地	数据类型			模拟量填此栏			参与控制的方式			
						模拟	数字	波形	值域	精度	分辨率	监测	控制	闭环	手动

Note: The form is used to list the hardware channels of one device. (User just need to fill one form for the same kind of device)

DB Naming convention

附件 5 BEPCII 设备信号名约定和设备名定义表

数据库信号名定义

BEPCII 控制系统数据库记录名（也称信号名）由四级组成，即装置级、子系统级、设备级和信号级。记录名总长度为 28 个字符。

数据库记录名定义如下：

<装置名>：<子系统名>：<设备名><序号>：<信号类型名>< 序号>：[说明字段]

数据库记录名是大小写敏感的，记录名允许使用下列字符：

大写字母 A - Z, 小写字母 a - z, 符号 _ — [ ] <> ： 和；

- 装置名区分注入器、贮存环和输运线，用 1-2 个英文大写字母表示。
- 子系统名标识分总体内的子系统，如磁铁电源系统、真空系统等。用 1-3 个英文大 、小写字母表示。
- 装置名和子系统名由工程指挥部统一命名。（见左侧表格）
- 设备名标识子系统中不同种类的设备，如真空泵电源、真空计等。用英文大 、小写字母和下划线表示设备，1-99 两位阿拉伯数字表示设备的序号。
- 信号类型名标识控制系统输入输出信号的种类，如模入、模出、开入、开出，计算量等，必须使用 EPICS/IOC 数据库规定的名称。用英文大、小写字母书写，1-99 两位阿拉伯数字表示该设备上信号的顺序号。
- 说明字段为可选项，使用英文大小写字母，可对本信号代表的物理量进行说明
- 例 RO：RF：Cavity_East:ai1:Volts

第一级（装置）	第二级（子系统）
储存环 R 储存环 RI 内环 RO 外环	PS 磁铁电源 RF 高频 VA 真空 BI 束测 IR 对撞区 MP 安全连锁
输运线 TE e—线 TP e+线	PS 磁铁电源 VA 真空 BI 束测 IN 注入 MP 安全连锁
直线 L	PS 磁铁电源 MK 功率源 PO 正电子源 MW 微波系统 VA 真空
公用设施 U	
其他系统	

Note: The database naming convention, which was discussed with leaders

表 4 BEPCII 控制系统数据库信号设备名表

子系统： 第 页 共 页

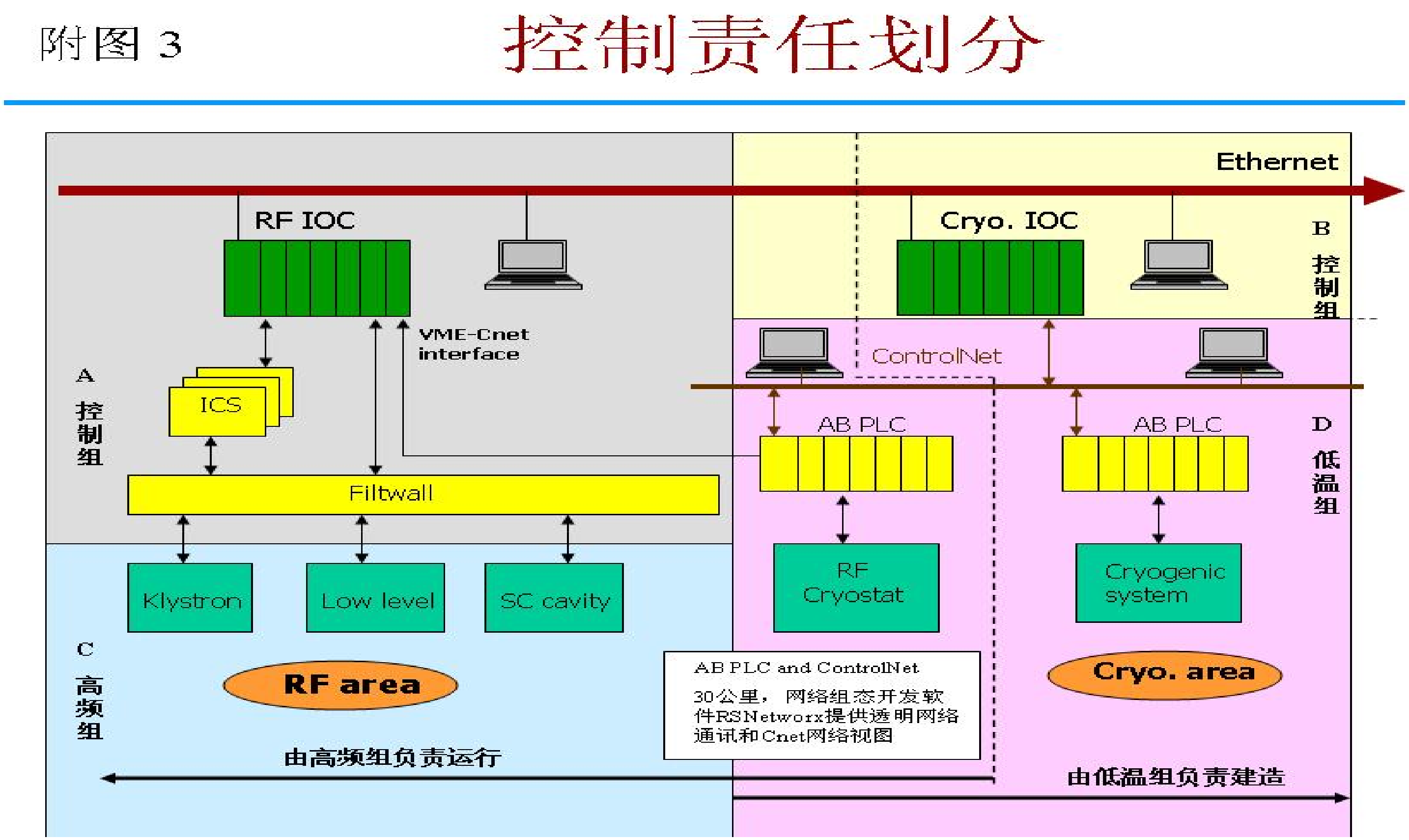
序号	设备中文名	设备英文名	数据库设备名	编号方法	
				顺序	对称

填表人(Signature): 填表日期(Date):

Note: Table4 is to ask user giving the device name and the corresponding database name, which could be an abbreviator of the device name.

Interface Definition

- During the design stage, we have made interface definitions
- Between internal components and to other systems
- The duty partition for each groups or divisions has been made



R&D

- We spent one year for R&D
- Aim is to solve the key technology and select hardware products.
- We built a prototype system to
  - Install EPICS system
  - Developing all of I/O driver and communication drivers that we needed
- The prototype for power supply control
- Transferring SAD environment from KEKB HP machine to SUN solaris

System Development

- We spent more than 2 years to developing the system in laboratory
- Make off-line and on-line test at Lab

Installations

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

Console Installation

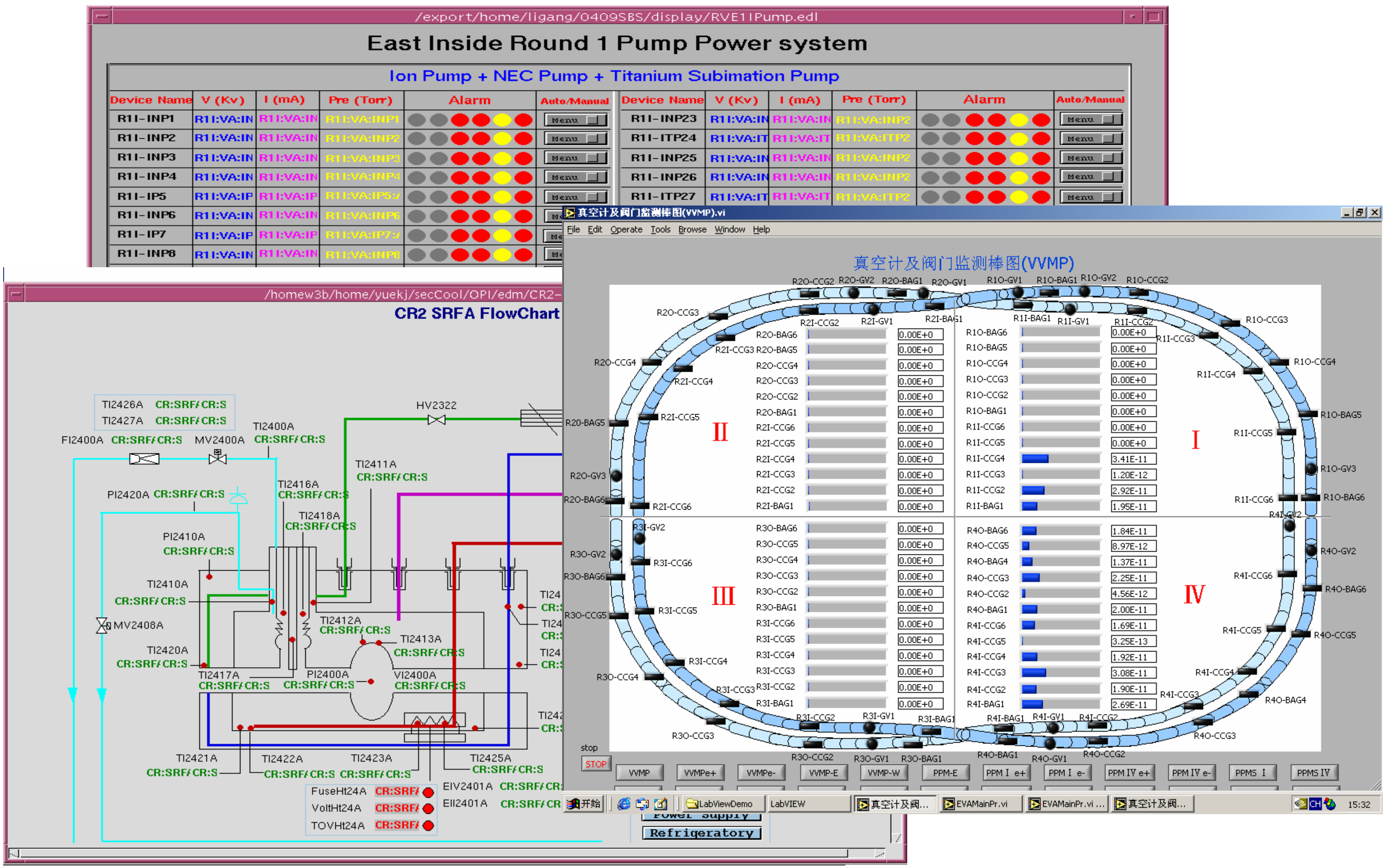
Test and commissioning

- Test sub-systems on site BEPCII

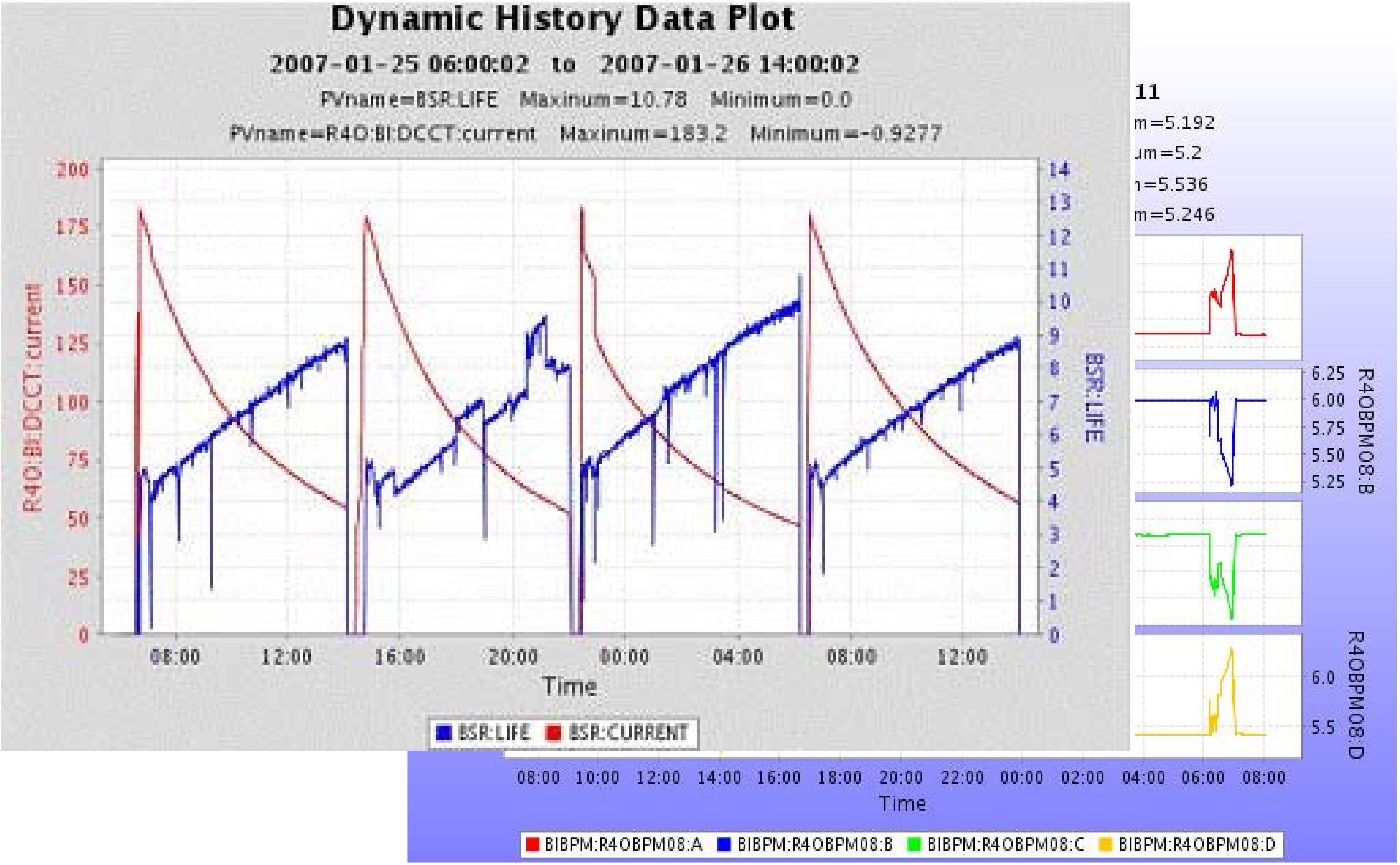
Test and commissioning

- Integral system test in central control room
- Fixed system configurations, save IOC database, applications
- The control system was put into operation in Nov. 2006, it works well

Control Panels



History Data in Oracle



First beam accumulated at Storage Ring

Management

People training

- We short of man-power and most developers are very young
- People training is very important
  - Hosted two “Asia EPICS Seminar” with KEK Hosted 4 EPICS training courses, one is in Chinese language
  - Translated EPICS manuals to Chinese language
  - Created the Chinese EPICS web page at IHEP
  - Sent 12 young people go to KEKB and DESY to learn EPICS

EPICS Web Page at IHEP

主页 － 傲游(MyIE2) Beta

文件(F) 编辑(E) 查看(V) 收藏(A) 快捷组(G) 选项(O) 工具(T) 窗口(W) 帮助(H)

地址 http://acc-center.ihep.ac.cn/epics/index.htm

Welcome EPICS系统研究

旨在为加速器中心和高能所用户学习使用EPICS提供必要的资料

主页 | Epics培训 | Epics会议 | Epics文档 | 研究论文

您现在的位置：主页

加速器中心Epics培训（2003.2.27—3.4）

系统简介：

EPICS系统（Experiment Physics and Industrial Contral System）是1987年由美国LANL和ANL实验室联合开发的实验物理和工业控制软件包，是构建分布式的控制系统的系统集成工具，用于分布式的实时数据库的建立、图形人机界面的开发、故障报警系统的建立和管理、历史数据存档管理和各种图形显示等。使用EPICS进行系统集成可以减少软件开发和维护的工作量，延长软件的生命周期，提高系统的可靠性；使用EPICS控制系统可以实现网络数据共享，建立开放的、标准化的系统。

目前国际上有100多家实验室、大学、研究机构的项目使用EPICS系统，包括加速器控制系统高能实验物理数据获取系统、射电天文望远镜和工业过程控制系统，如美国的LANL、ANL、SLAC、BNL、FNAL(DO)、JLAB、SNS、LBL、加拿大的TRIUMF、欧洲的SLS、BESSYII、DESY、日本的KEKB和韩国的PAL等。中科院高能物理研究所、合肥同步辐射光源、上海原子核所于1997年与EPICS国际合作组织签订协议，参加EPICS的合作研究。2001年5月BEPCII 工程指挥部决定使用EPICS开发BEPCII控制系统。本网页旨在为加速器中心和高能所用户学习使用EPICS提供必要的资料。

返回加速器中心主页

Links

http://www.aps.anl.gov/epics/

http://lansce.lanl.gov/lansce8/Epics/

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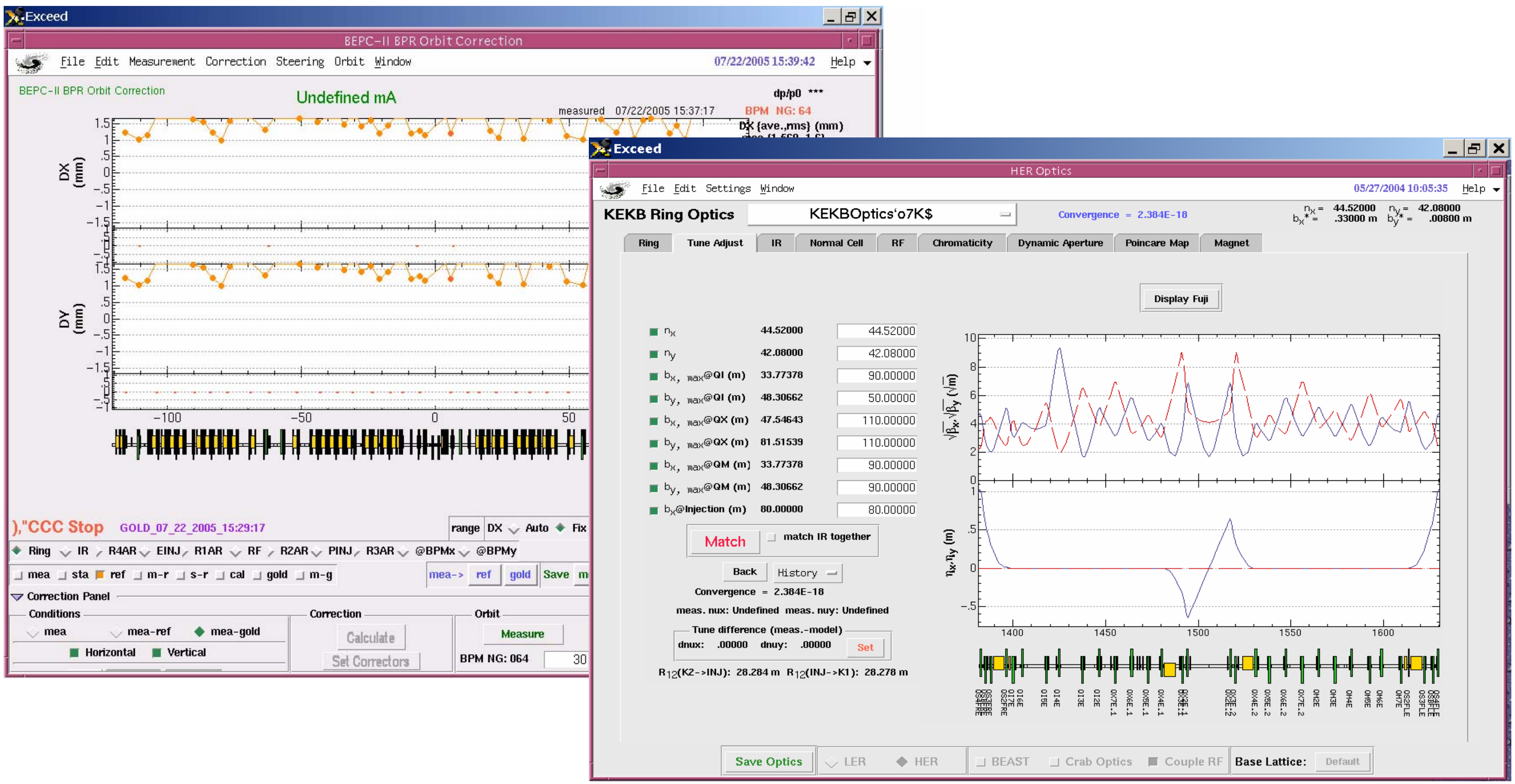
Management

Collaborations

- There are many HEP Lab have good experience to develop advanced control systems
- The overseas and domestic collaboration is very important for succeed of the BEPCII control system
  - Invited more that 20 expert from other lab to discuss the system design and development issues
  - Collaboration with Lab. KEKB, DESY and SSRF
  - A lot of help from EPICS world

Collaborations

Collaboration with KEKB went through 10 years, they provided us most of their HLA, which speeded development of BEPCII



Collaborations

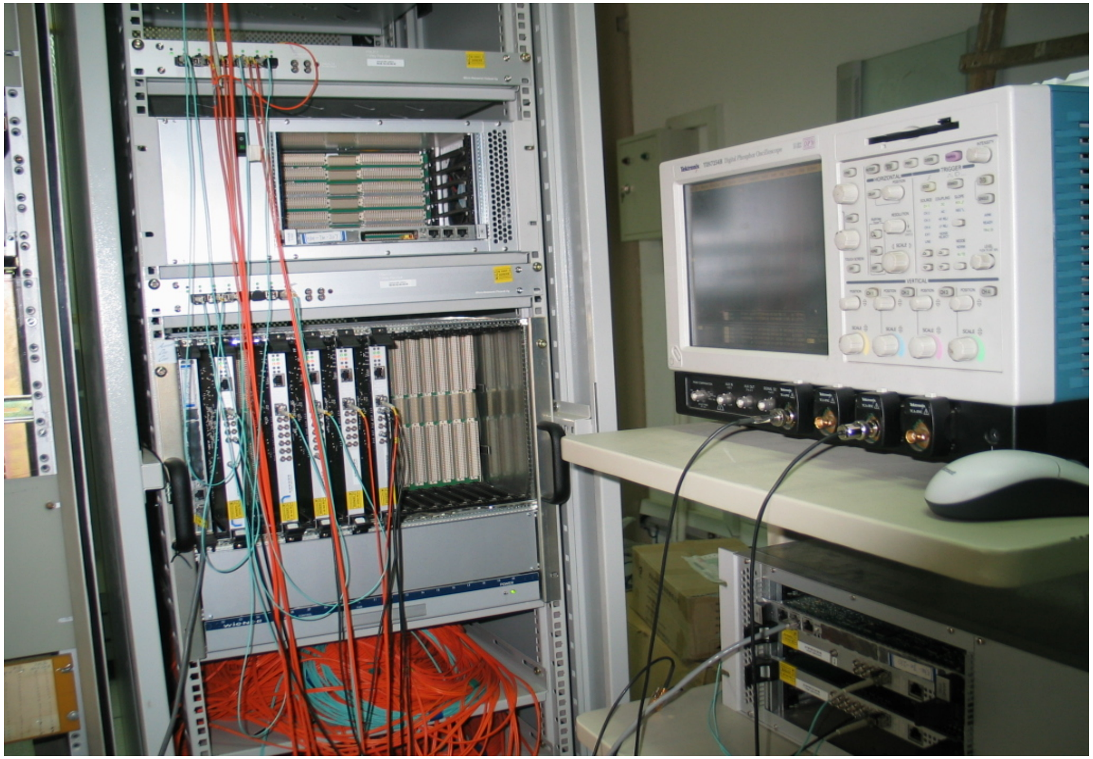
DESY cryogenic control group,gave us valuable advices and transferred some source code, which is very helpful for developing BEPCII cryogenic control system

DESY-IHEP e-Logbook

Transferred e-Logbook from DESY and appended Chinese version

Collaborations

Collaboration with SSRF Lab for timing system development, they suggested using event timing system and lent us the EVG/EVR modules to built our prototype system



BEPCII Timing system at Linac

Lesson

- For the reliability and maintenance reason, the number of device type and protocol should be reduced in a control system
- But there are two kind of PLCs in our cryogenic controls
  - One is Siemens PLCs for compressor and turbines control developed by Linde company
  - Other is AB-PLC and EPICS system for valve, box, tanks, dewars and cooling pipes control developed by BEPCII control group
- Problem is data exchange between the systems, we have to developed the communication driver between WinCC and EPICS
- Reason: the communication between cryogenic group and control group was lacked when contract was discussed with Linde company
- Lesson: control people should pay attention to every part of controls, even for sellers developed system.

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
- Though of what we have done:
  - We have followed software engineering management
  - Adopting EPICS to build the system
  - Using standard hardware and software
  - Good collaboration with HEP lab in the world
  - Team and staff training is also important
- Thanks all of people who have gave us a lot of help in the past few years!

Thank you!