EPICS-ness at KEKB Injector

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KEKB Injector and Legacy Controls

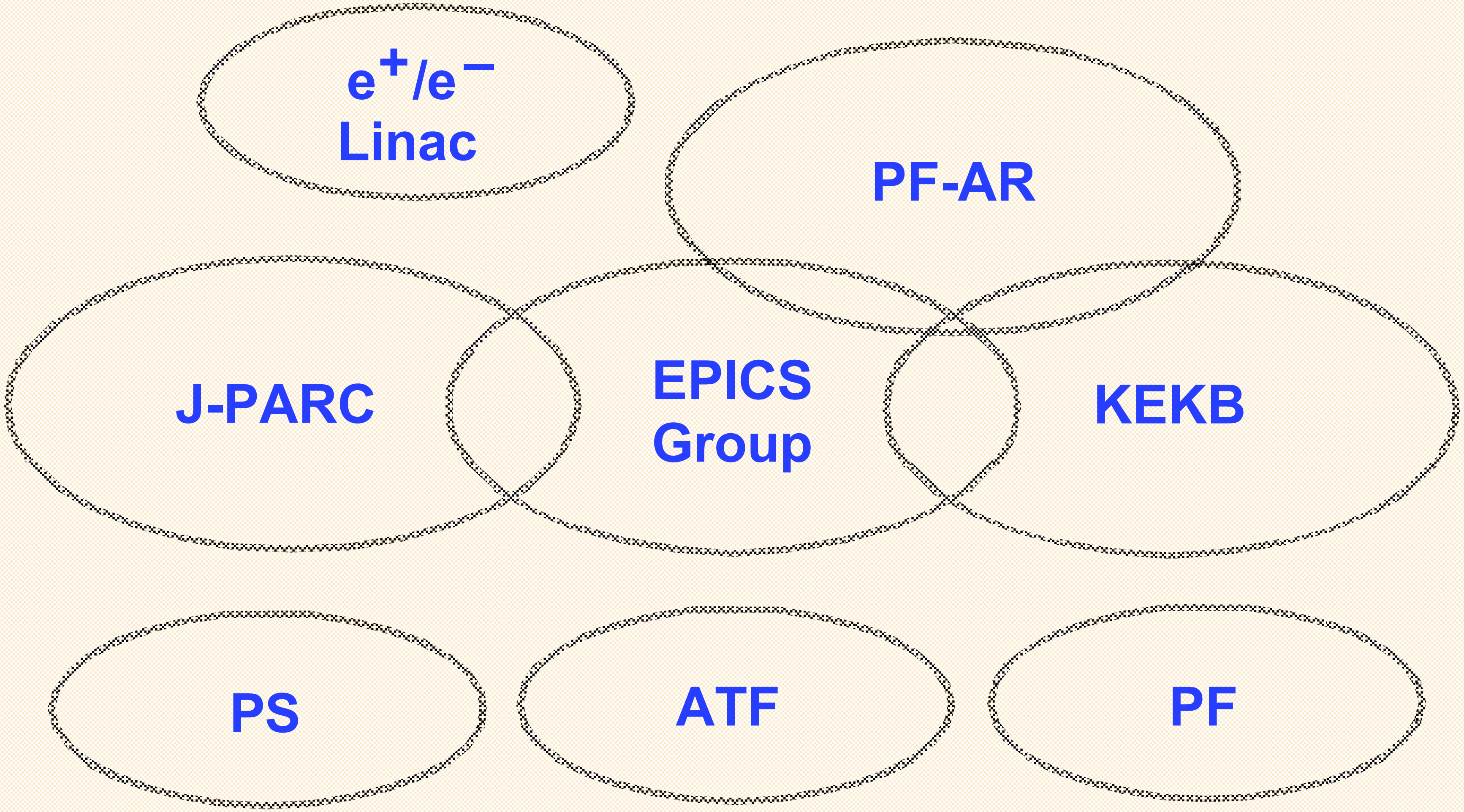
Network Controllers

EPICS Gateways

Timing System

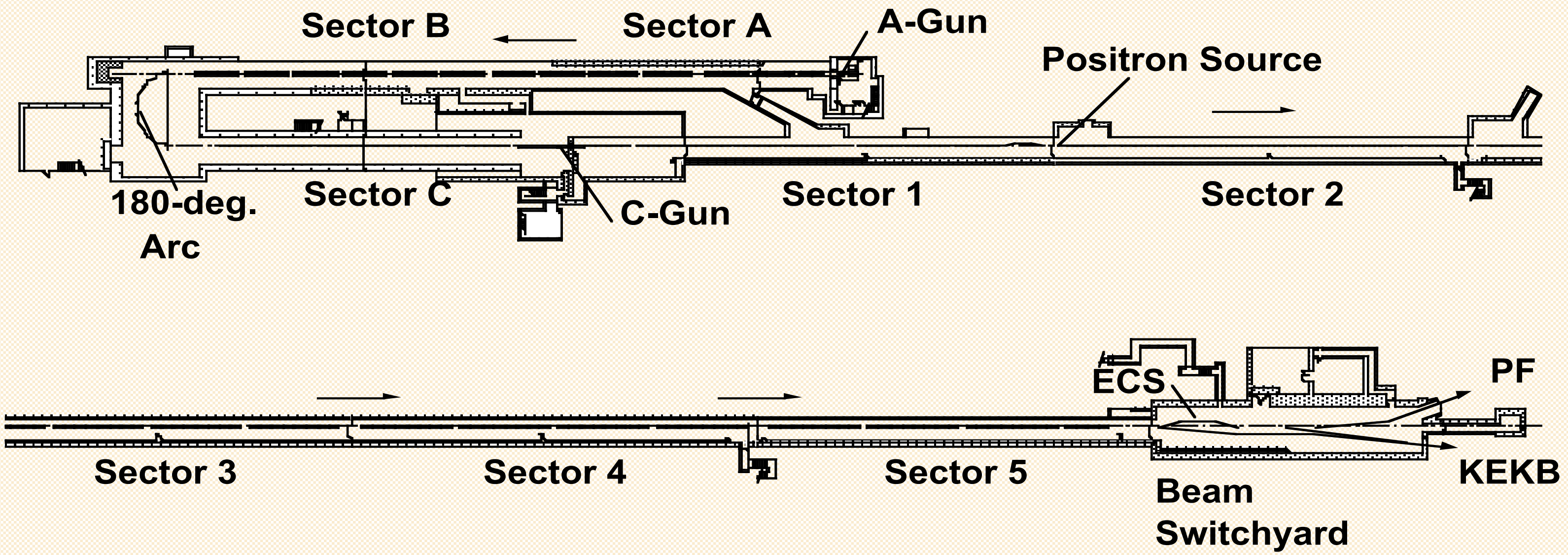
Control Systems at KEK

- There are several Control systems in KEK, Some of them employ EPICS recently



Linac in KEKB Collider Complex

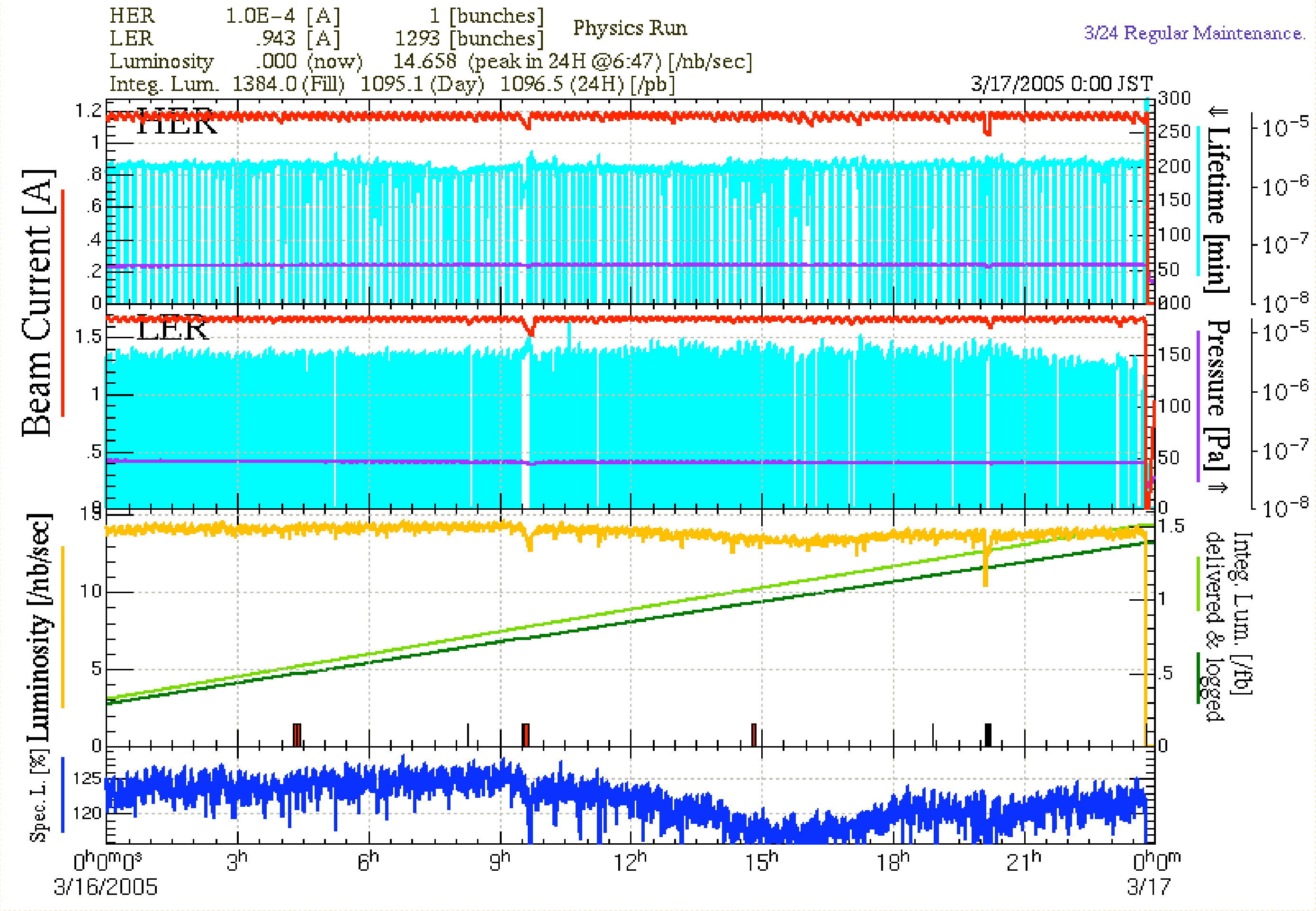
- 8GeV Electron + 3.5GeV Positron for KEKB
- 2.5GeV Electron for PF
- 3.0GeV Electron for PF-AR
- 600m Linac with 59 S-band rf Stations with SLED
- Double Sub-Harmonic Bunchers for 10ps & 10nC
- 2-bunch in a Pulse and Continuous (Top-up) Injection



Performance of KEKB

Staffs in Linac are always Interested in performances in KEKB/Belle

Here is the KEKB daily Performance Page updated Every minute



HER 1.0E−4 [A] 1 [bunches]
LER .943 [A] 1293 [bunches]
Luminosity .000 (now) 14.658 (peak in 24H @6:47) [/nb/sec]
Integ. Lum. 1384.0 (Fill) 1095.1 (Day) 1096.5 (24H) [/pb]

Physics Run

3/24 Regular Maintenance.

3/17/2005 0:00 JST

Linac Controls

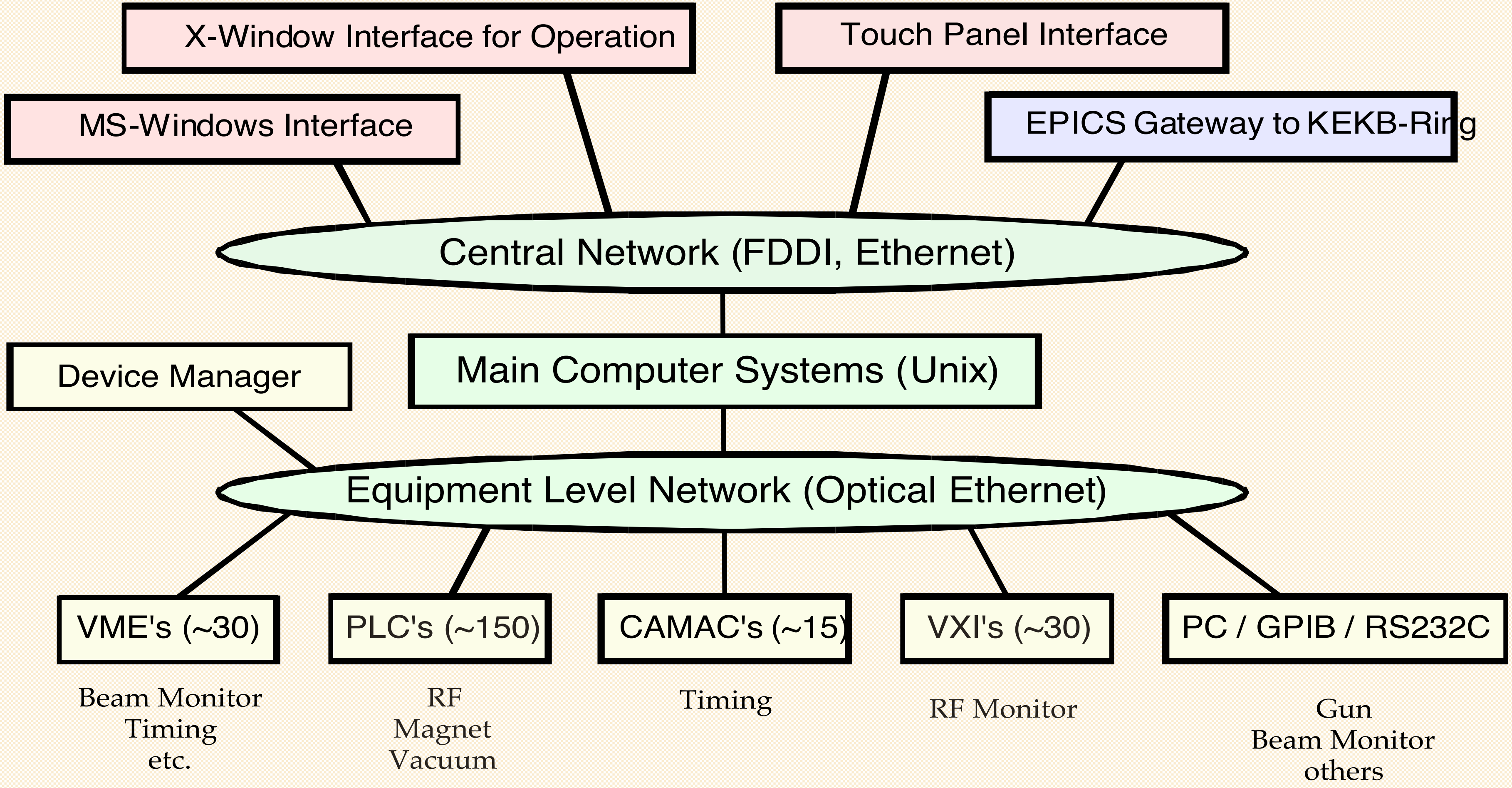
- KEKB = Factory Machine => Reliable Operation
- Controls should be Robust and Flexible
- ~1000 devices and ~10000 signals
- Frequent Beam Mode Switches; Four very Different Beam Modes, 300 times/day
- Precise Controls of Beam Parameters, Energy, Orbit, Emittance, Charge, Energy spread, Timing, etc.

History and Design Concept

- History
  - 1978-1982: Construction of First Computer-controlled System with 8 mini-computers, >200 micro-computers, >30 optical loop networks
  - 1989-1992: Design of the next system
  - 1993-1997: Installation and expansion for KEKB
- Design Concept
  - Use of International and/or de-facto Standards
  - Use of Optical IP Networks for every Device controllers
    - No new field Networks, only IP Network (to be inherited by J-PARC)
  - Both of above should make future upgrade easier
  - (EPICS was not available widely at that time)

Physical Structure

- Multi-tier, Multi-hardware, Multi-client, …



X-Window Interface for Operation

Touch Panel Interface

MS-Windows Interface

EPICS Gateway to KEKB-Ring

Central Network (FDDI, Ethernet)

Device Manager

Main Computer Systems (Unix)

Equipment Level Network (Optical Ethernet)

VME's (~30)

PLC's (~150)

CAMAC's (~15)

VXI's (~30)

PC / GPIB / RS232C

Beam Monitor
Timing
etc.

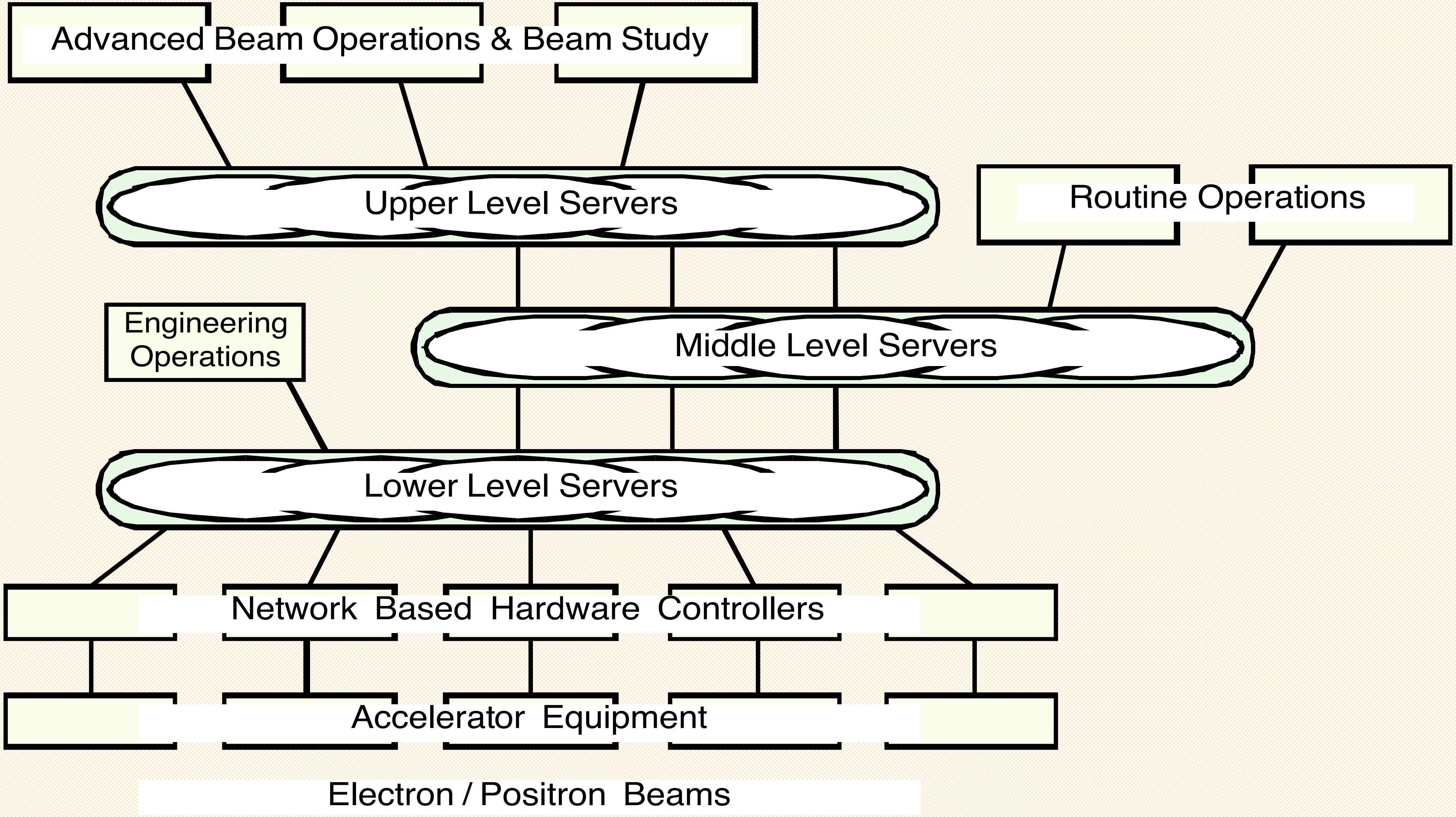
RF
Magnet
Vacuum

Timing

RF Monitor

Gun
Beam Monitor
others

Multi-tier Logical Structure



Advanced Beam Operations & Beam Study

Upper Level Servers

Routine Operations

Engineering Operations

Middle Level Servers

Lower Level Servers

Network Based Hardware Controllers

Accelerator Equipment

Electron / Positron Beams

Software Architecture

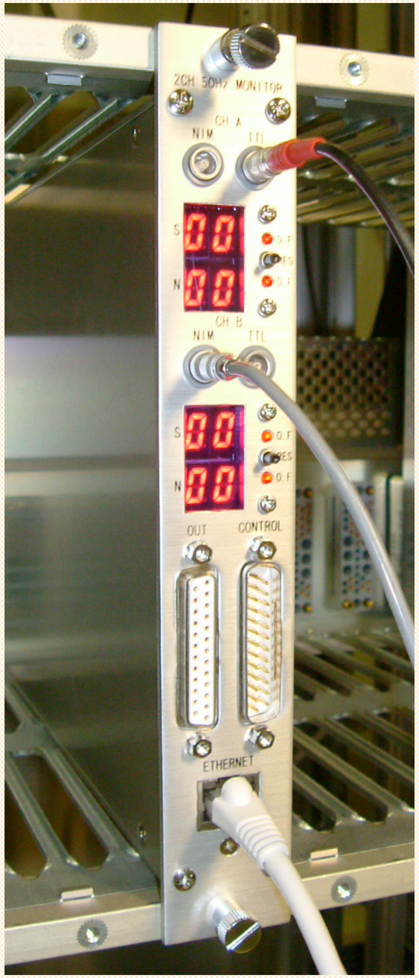
- Base control software structure for Multi-platform
  - any Unix, OS9, LynxOS (Realtime), VMS, DOS, Windows, MacOS
  - TCP - UDP General Communication Library
  - Shared-Memory, Semaphore Library
  - Simple How-grown RPC (Remote Procedure Call) Library
  - Memory-resident Hash Database Library
- Control Server software
  - Lower-layer servers (UDP-RPC) for control hardware
  - Upper-layer server (TCP-RPC) for accelerator equipment
  - Read-only Information on Distributed Shared Memory
  - Works redundantly on multiple servers
- Client Applications
  - Established applications in C language with RPC
  - Many of the beam operation software in scripting language,
    - Tcl/Tk and SADscript/Tk

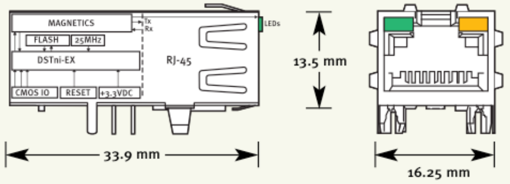
Recent Development

- Application software for Two-bunch in a Pulse
- Application software for Continuous Injection
- C-band Acceleration Project (for future SuperKEKB)
- More PLC adaptation, mainly by hardware groups
- Many slow feedback loops, including energy spread
- Slow Positron Facility inside Linac (60MeV e-)
  - Intel-Linux-VME with Linac software and EPICS IOCcore
  - CC/Net (embeded Linux CAMAC CC) for possible replace of Hytec (sorry)
- Evaluation of fast Waveform Digitizers
  - Especially for 50Hz data acquisition
- Network connected RAS module, etc.
- Upgrade of EPICS gateway

Simple Ethernet Interface - 50Hz Monitor

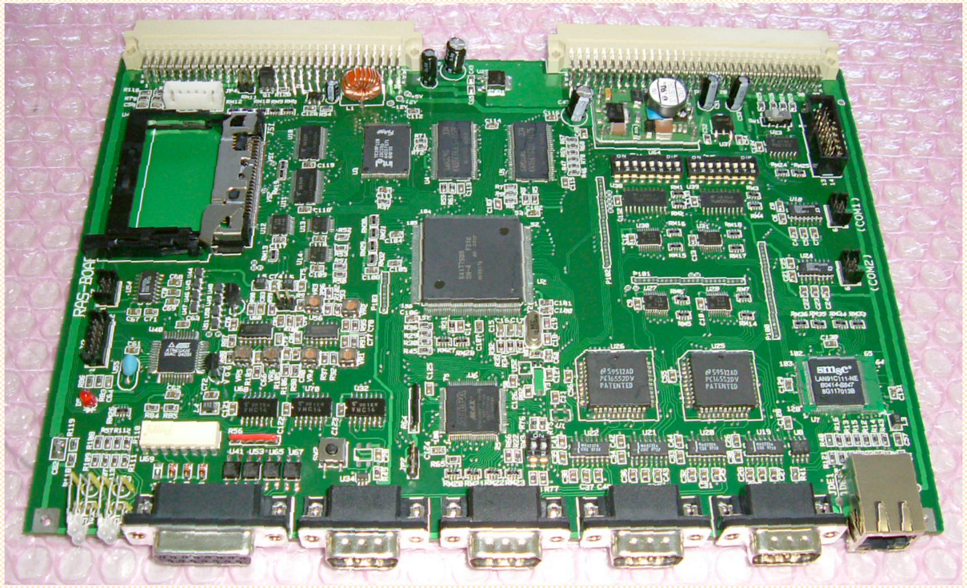
- Timing signals of ~150 TD4/TD4V/TD4R used in linac
- If a signal is missing beam loss and possible damage to devices
  - There was a problem in comparators in TD4/TD4V
- A monitor module was built to monitor specific timing requirement
- PIC processors and a X-Port from Lantronics
- Monitored over Ethernet
- Now two other kinds of modules were developed





VME RAS Module with Ethernet Interface

- For reliability of VME crates (~25)
- Currently Hardwired modules are used: wiring issues
- Ethernet/IP connectivity is preferable
  - Power voltage, temperature, fan
  - Watchdog timers
  - Four RS232C ports for CPU, Network, etc
  - TTL inputs/outputs
  - VME reset
- Firmware environment
  - Micro-iTRON, or Linux
  - SH4, 16MB RAM
  - peripherals over I2C
- Interface to EPICS
  - TCP communication with IOCs
  - Possible Embedded EPICS on iTRON or Linux



Why EPICS in my case

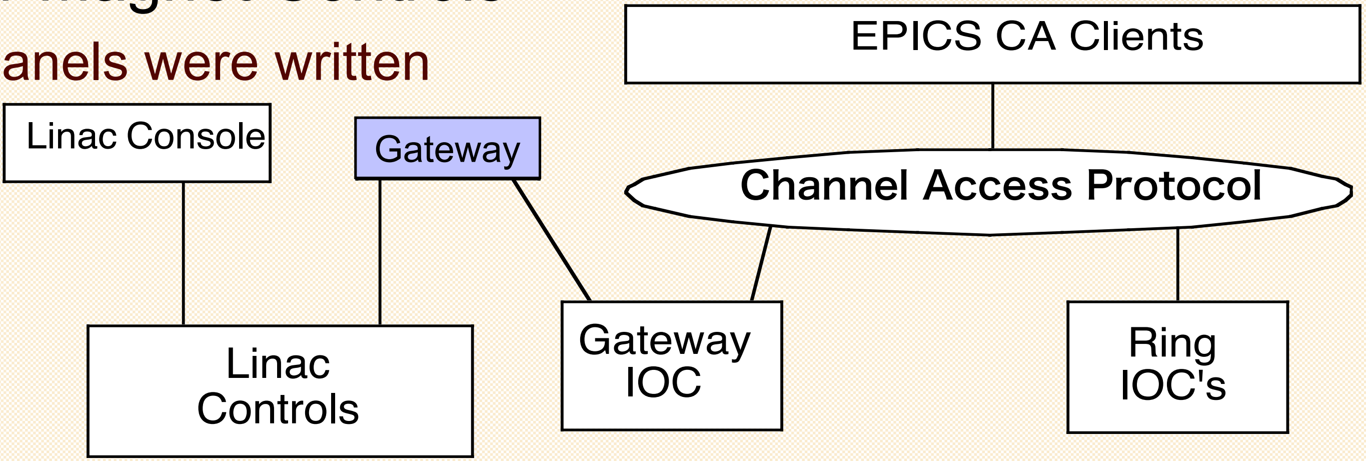
- We made too much effort on duplicate development on many control systems
- Our goal is to achieve high performance in the accelerator and the physics experiments
- Reuse of available resources is preferable
- Devices in Linac have been modernized, and development of EPICS device supports became possible
- Anyway we need interface to down-stream accelerators esp. KEKB
- Want to merge several archive formants in Linac
- May expect (?) man-power from other groups
- May contribute to world-wide EPICS collaboration

Building EPICS Gateway

- Common Control System at the Top (of Linac and Ring)
  - Needs too much resources
- Port EPICS onto our VME/OS9-LynxOS
  - Failed to get support/budget for LynxOS at Linac
  - (EPICS Maintenance with an unsupported Platform ?)
- Special Gateway Software, which interfaces to both the Linac Controls and EPICS IOCs as a Client
  - Built to ensure the feasibility at 1995
- Portable Channel Access Server
  - Implemented with EPICS 3.12 and being used on HP-UX since 1996
  - It is being used for several application software including Alarm display
- Software IOC
  - Being used and being extended on Linux since 2003

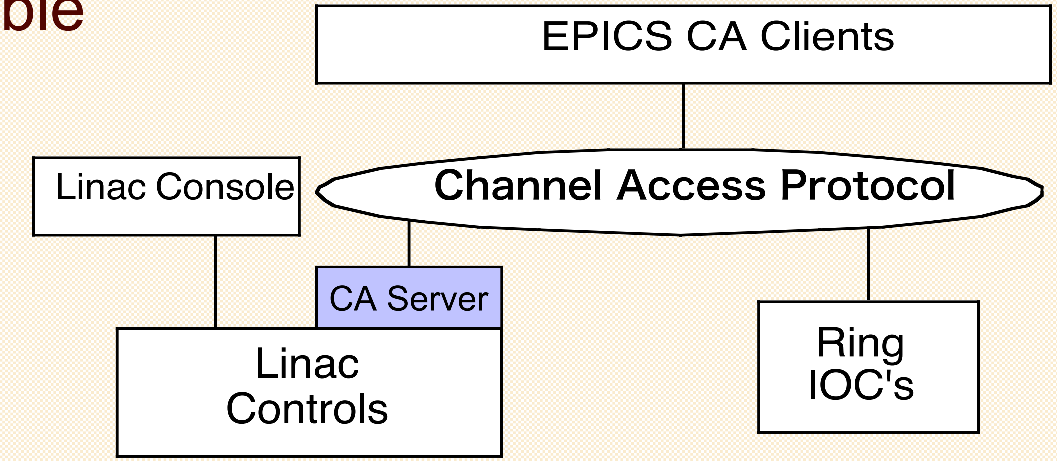
Use of Existing EPICS IOC (Gateway IOC)

- Software availability
  - Portable Channel Access Server was not available at around 1995
- Channel Access Server Emulation with Available Software Components
  - New gateway software which is clients to the both Linac and EPICS, and group of EPICS soft records
  - Real-time Operation is possible both ways using Monitors
- Tested for Magnet Controls
  - MEDM panels were written



Portable Channel Access Server (PCAS)

- Protocol Conversion
  - Client to Linac Controls with Home-grown RPC and Cache Memory, Interface to Upper-level Servers (not directly to Lower-level Hardware Servers)
  - Server to EPICS environment, with some Name wrapping
- Implemented for Linac in 1996-
  - for Magnets, RF, Beam Instrumentations
  - >4000 Records are available
  - Write-access Possible, normally Read-only
  - Still used for KEKB Unified Alarm, Operation Status, etc.



Soft IOC

- IOCcore is available on Unix in EPICS 3.14
  - We have Tru64unix, Linux, HP-UX
- Simple
  - IOCcore hides the complexity of Channel Access, etc
  - We design the device support to Upper-level Linac Servers, as we access to hardware in normal IOC
- All standard EPICS facilities are available
  - Alarms, Operation Limits, Links, Periodic processing, Monitors, etc.
- Implemented for Linac on Linux since 2003
  - For RF, Beam Instrumentation, Vacuum, etc.
  - >2200 Records are available and extending
- All the records are archived in Channel Archiver and KBlog
  - KBlog is used to analyze correlations between Linac/Ring
  - Developing Java viewer of the archive

General Comparisons

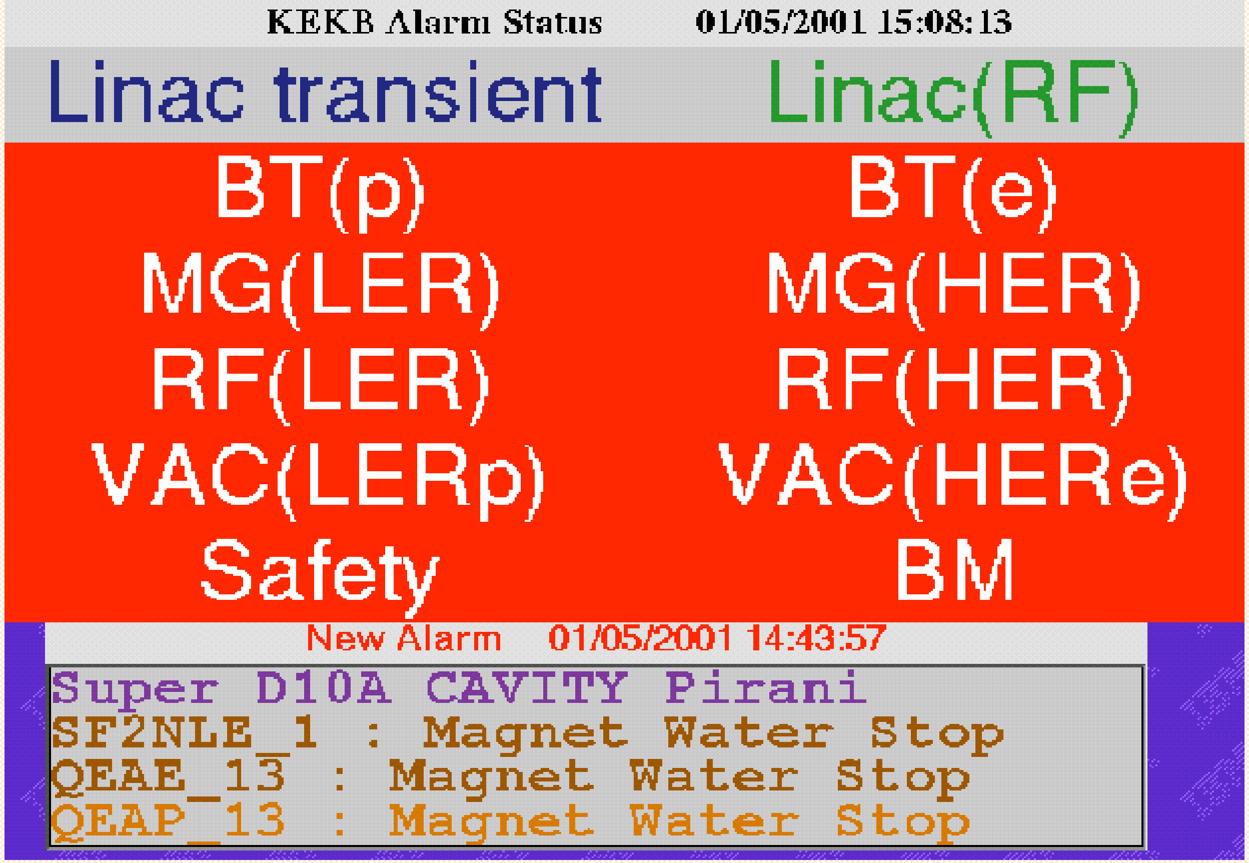
- Symmetry
  - Gateway IOC is Symmetric between outside and inside of EPICS
    - Accessing from/to EPICS goes thru the same Gateway
  - Others are (somewhat) asymmetric
- Name Resolution
  - PCAS can resolve names dynamically (at run-time)
    - Consumes less memory (?)
  - SoftIOC has to be prepared with static database
    - May be expected to give better response
    - Can be impossible for a large installations
- Database processing and associate fields
  - SoftIOC provides EPICS database Facilities like Limits, Alarms, Links, etc.
    - If we archive them, Archive Deadband is most necessary
- Implementation of Gateway
  - SoftIOC is relatively straight forward
    - Simply adding device supports

Application software

- All the records from the Linac Soft IOC are archived both in Channel Archiver and in KBlog
  - KBlog is used to analyze correlations between Linac/Ring
  - (Developing Java viewer of the archive)
- KEKB Alarm is connected to Linac PCAS
  - May migrate to Linac SoftIOC at Summer Shutdown (Linac PCAS is currently based on EPICS 3.12)
- Some other applications utilize PCAS as well
  - (Many others access Linac Controls directly now)
- Small number of Records are going thru Gateway IOC, historically

KEKB Alarm Panel

- Below is the KEKB Alarm Main Panel, which covers Linac Alarms as well. Detailed alarm information/history is available in a separate panel



KEKB Alarm Status 01/05/2001 15:08:13

Linac transient	Linac(RF)
BT(p)	BT(e)
MG(LER)	MG(HER)
RF(LER)	RF(HER)
VAC(LERp)	VAC(HERe)
Safety	BM

New Alarm 01/05/2001 14:43:57

```
Super D10A CAVITY Pirani
SF2NLE_1 : Magnet Water Stop
QEAE_13  : Magnet Water Stop
QEAP_13  : Magnet Water Stop
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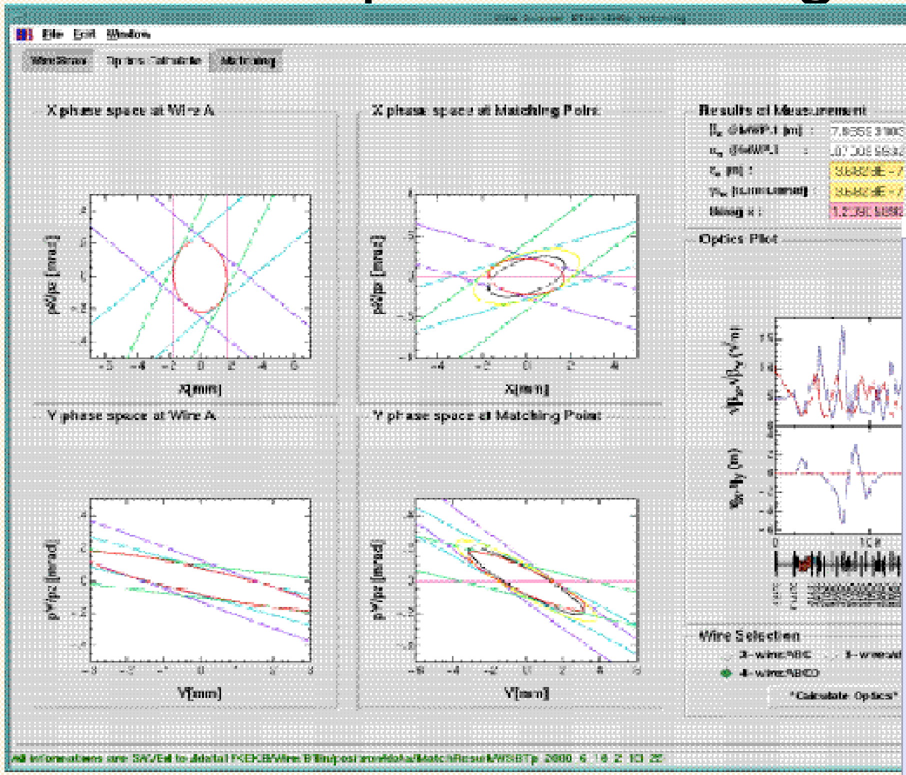
Linac

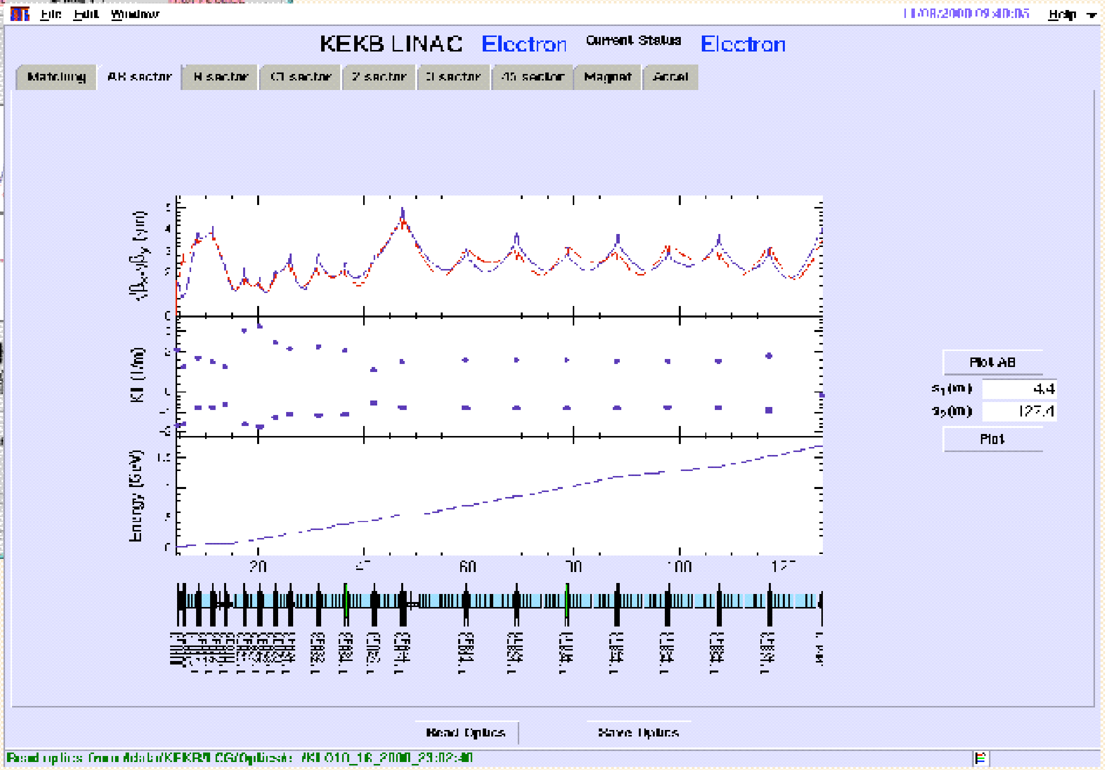
Ring

Beam Optics Panels in SAD

- Beam Optics Matching and Optimization Panels

n SADscript





- Some Parameters goes thru EPICS Gateways, others directly to Linac

Performance

- EPICS Gateway and Channel Archiver
  - are Running on Linux 2.4.20 (Redhat) with Intel Xeon 2.4GHz and Memory of 2GB
    - About 10% of CPU usage
    - Monitors/Archives all of ~2200 Channels (partial in Kblog)
    - Can process 5400~6600 Channel Access Requests over Network
  - Archive size is about 400MB/day (300MB/day in Kblog)
    - Both Channel Archiver and KBlog collect Data

Timing

- Beam timing, 2 locations 4 signals
  - loosely synchlonized to power line within 500 micro seconds
  - Possible pulse-to-pulse interlace between clients
  - for KEKB, 2 signals
    - synchronized to 10.384MHz (common frequency for 2856,571,114,509)
    - < 3 ps jitter now, < 1 ps near future
    - 1Hz to 50Hz, any pattern
  - for PF, 1 signal
    - synchronized to bunch selected 500MHz
    - 1Hz to 25Hz, any pattern
  - for PF-AR, 1 signal
    - synchronized to bunch selected 508MHz
    - 1Hz to 25Hz, any pattern

Timing

- Streak camera at 3 locations, 3 signal
  - synchronized to beam timing within < 1 pico seconds
  - beam pulse selection
- Most Beam monitors (90bpm, 14ws, 31rf) 27 locations 27 signals 40m each
  - synchronized to beam timing within 1 nano seconds
  - 1Hz, 5Hz, 50Hz, and selected beam pulse timing, etc.
- rf (69Klystron) stations 14 locations 101 signals 10m each
  - synchronized to beam timing within 5 ns
  - always 50Hz
- Septum/Kicker
  - for KEKB, PF, PF-AR
  - synchronized to beam timing within 1 ns
  - Beam pulse or 25Hz fixed

Timing

- Pulse-to-pulse changes
  - rf system (phase and timing), pulse magnet (on/off) switching
  - should send beam type just after previous beam timing to switch those equipment parameters
- pattern decision can be static
- pre-program only for now, no dynamic change at the beginning

Summary

- Slow transition towards EPICS
- At Top
- At Bottom