



# Accelerator Controls at KEK

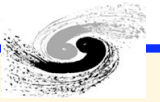
## Mainly KEKB and Linac Evolution

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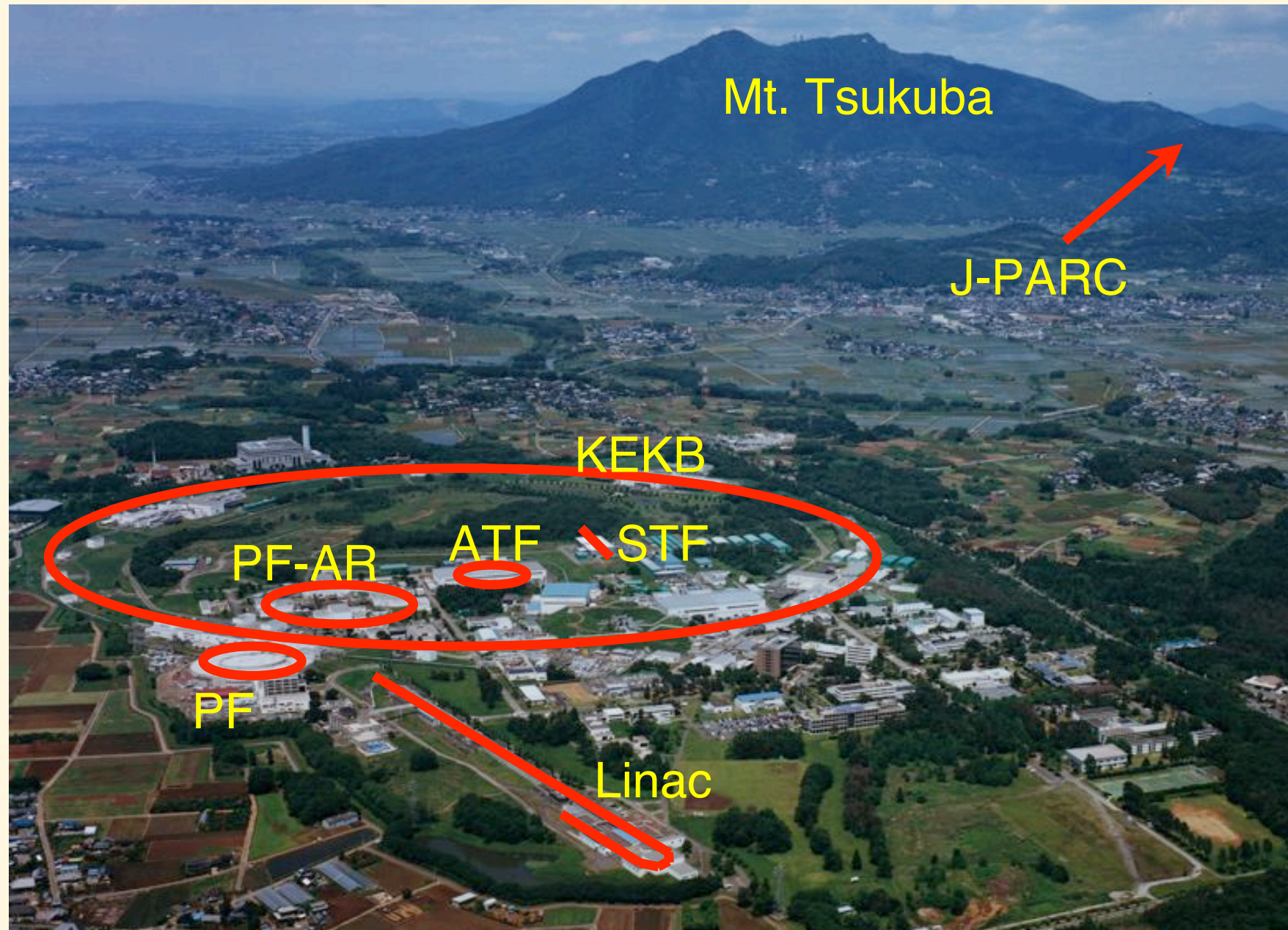
**Dec. 16. 2008.**



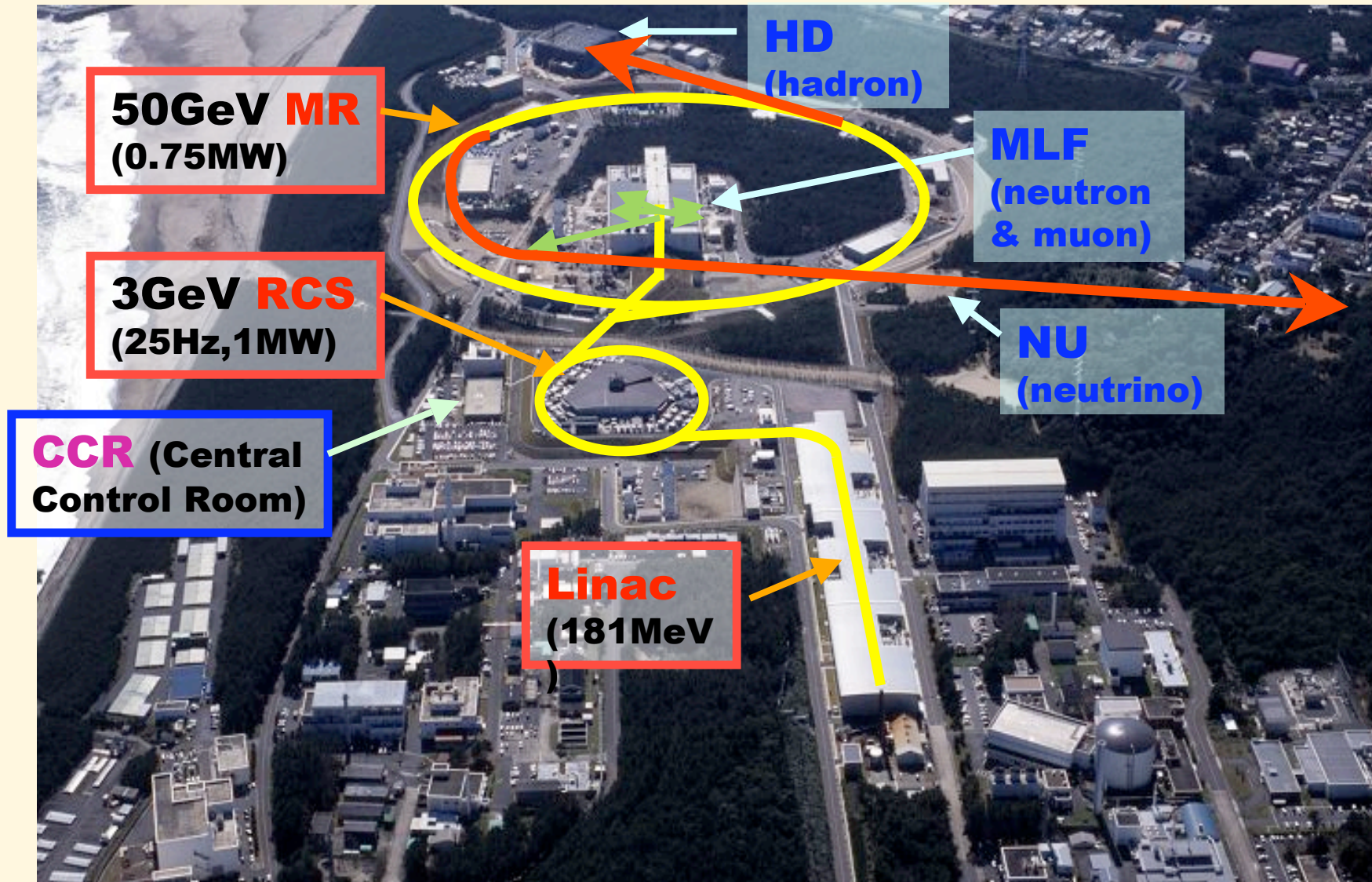
# ◆ Several aspects of Evolution of the Accelerator Controls at the KEK

- ❖ Communication Networks
- ❖ Equipment Controllers
- ❖ Gradual Approach to EPICS
- ❖ Scripting Languages

## ◆ Summary



# J-PARC at Tokai Campus





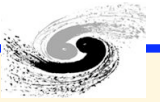
# J-PARC Controls

- ◆ **We started the design in 1998**
  - ❖ But nobody was dedicated at the beginning
- ◆ **EPICS was chosen**
  - ❖ The same reason as KEKB, EPICS was successful at KEKB
- ◆ **IP/Ethernet-only field network was chosen**
  - ❖ It was successful at Linac
- ◆ **Device support**
  - ❖ Development was started with Network-based device supports
  - ❖ WE7000, FAM3 PLC, EMB-Lan etc.
  - ❖ Later, Integrated into NetDev by Odagiri
- ◆ **Mixed application environment with Java, SAD, XAL, Python**
- ◆ **Good practice for inter-institute developments with different cultures**
- ◆ **Under commissioning, soon to commission MR beam**



# EPICS Software Environment

Accelerator	OPI Applications		IOC/VME OS,H/W	Drivers (slightly old)
	Basic	High-Lvl.		
Linac	Java +MEDM	XAL /JCE	VxWorks PowerPC Adv7501	- VME I/O Modules mainly by Advanet - TeraDev for PLC
RCS	Java +MEDM	SAD	VxWorks PowerPC Adv7501	- VME I/O Modules mainly by Advanet - TeraDev for PLC
MR	MEDM (or EDM)	SAD Python	Linux Intel-based GE Funac and Sanritz	(Network Devices) -NetDev for PLC, BPMC, EMB-LAN -WE7000 Drivers



# PF, PF-AR, ATF, STF

## ◆ PF-AR

- ❖ Mostly the same environment as KEKB
  - ✧ Still many CAMAC installations

## ◆ PF

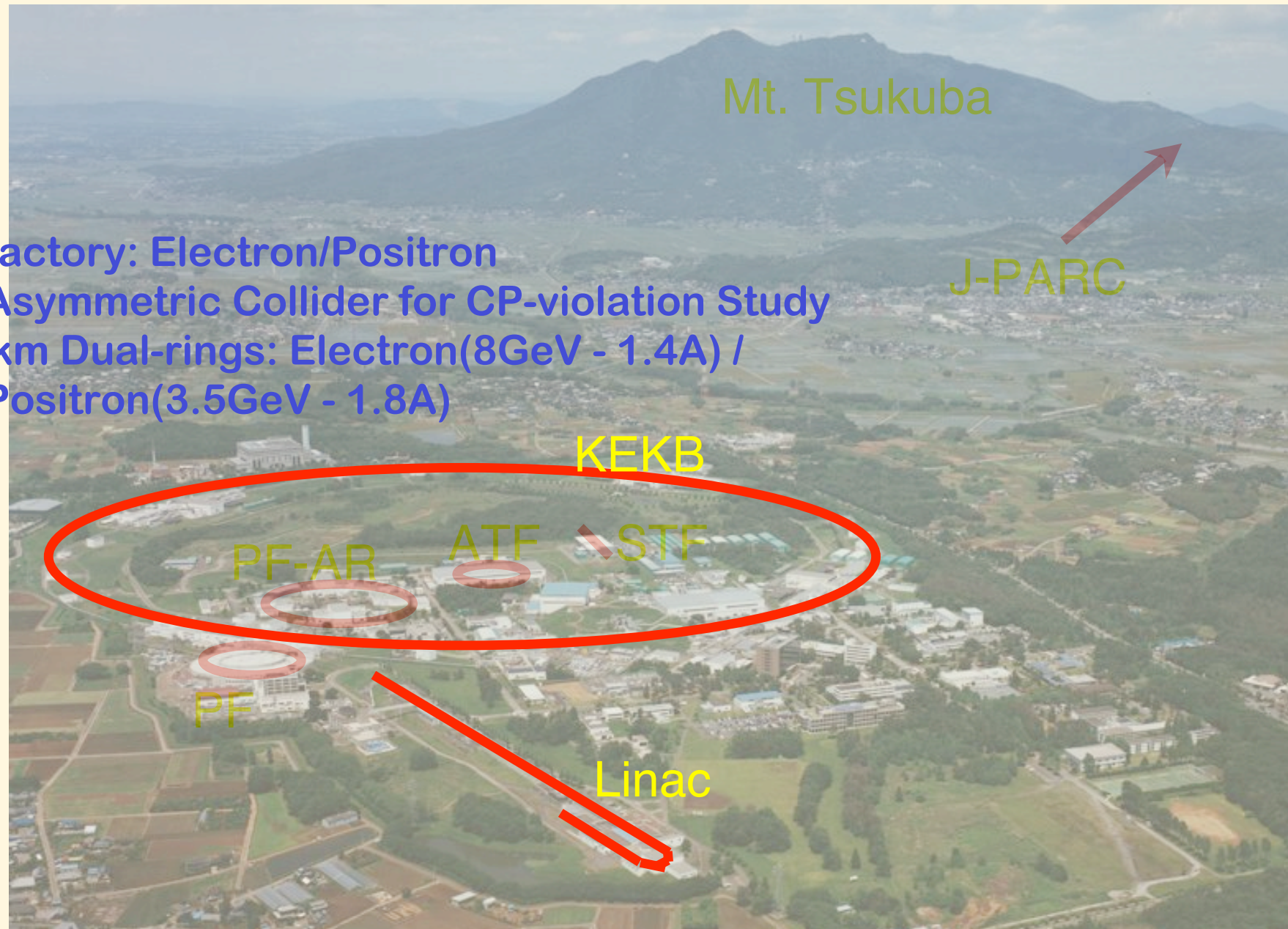
- ❖ Moved to EPICS environment
  - ✧ Mainly with Linux-VME

## ◆ ATF

- ❖ Vista environment with CAMAC
- ❖ Linux and socket environment

## ◆ STF

- ❖ Test accelerator for ILC
- ❖ Linux, ATCA test



**B-factory: Electron/Positron  
Asymmetric Collider for CP-violation Study  
~3km Dual-rings: Electron(8GeV - 1.4A) /  
Positron(3.5GeV - 1.8A)**





# KEKB and Linac

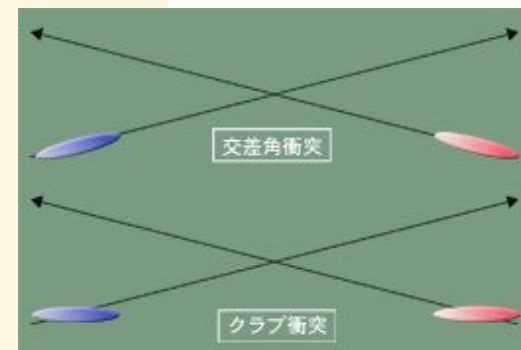
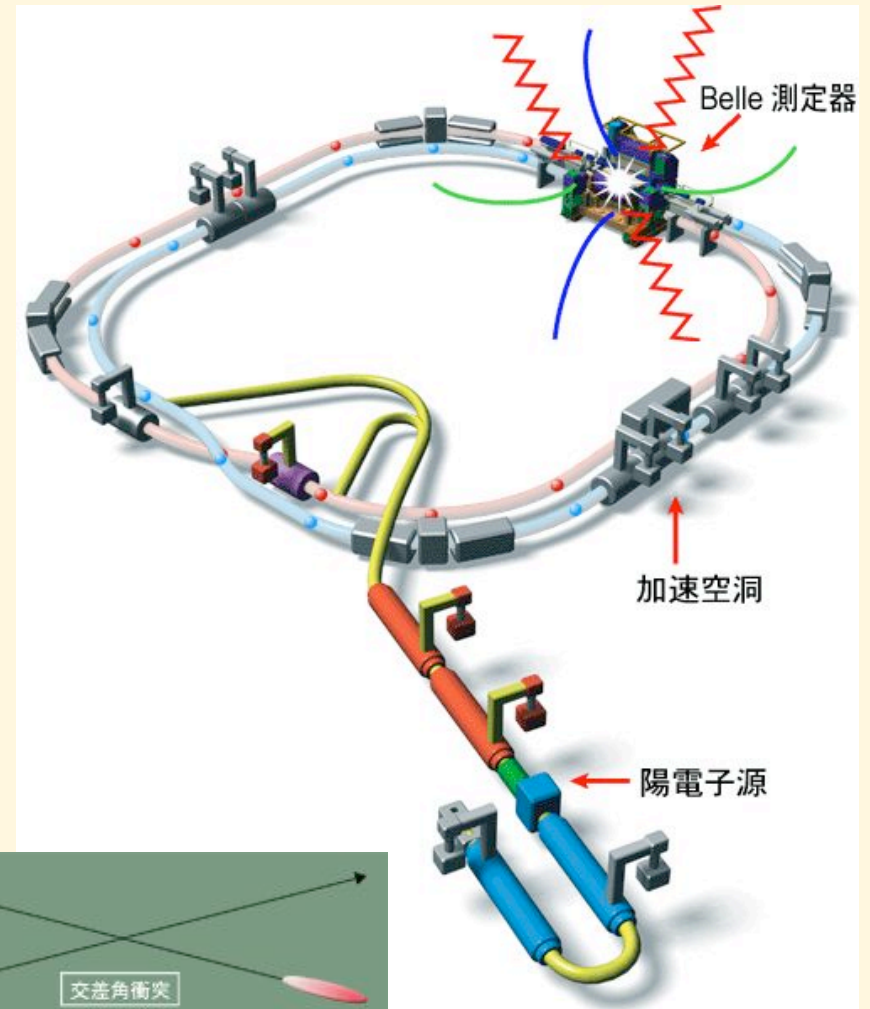
## ◆ KEKB B-factory: Electron/Positron Asymmetric Collider for CP-violation Study

❖ ~3km Dual-rings: Electron(8GeV - 1.4A) / Positron(3.5GeV - 1.8A)

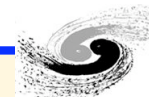
- ❖ Stable and Robust Operation
- ❖ Many Active Operation Parameters
- ❖ Importance of Controls

## ◆ Linac:

- ❖ ~600m, 50Hz
- ❖ 8GeV 2nC Electron, 3.5GeV 1.2nC Positron
- ❖ Beam switchings for PF and PF-AR rings



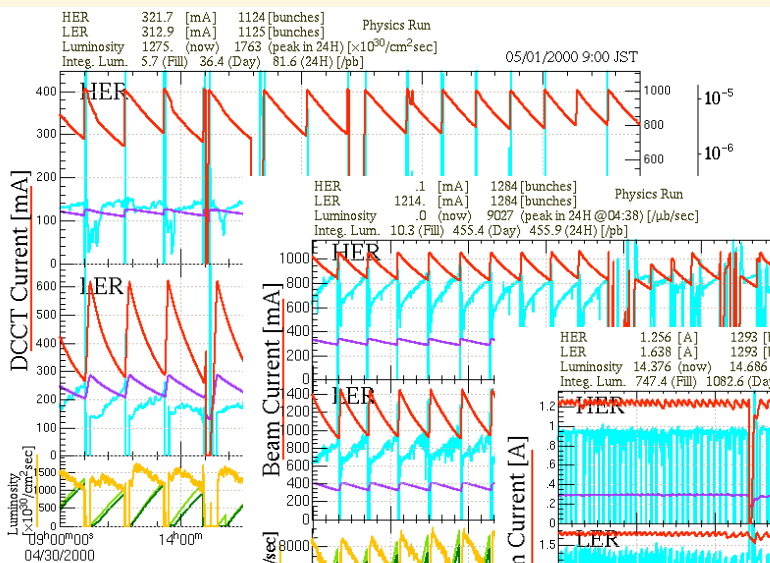
Increase of Luminosity with Crab Cavities



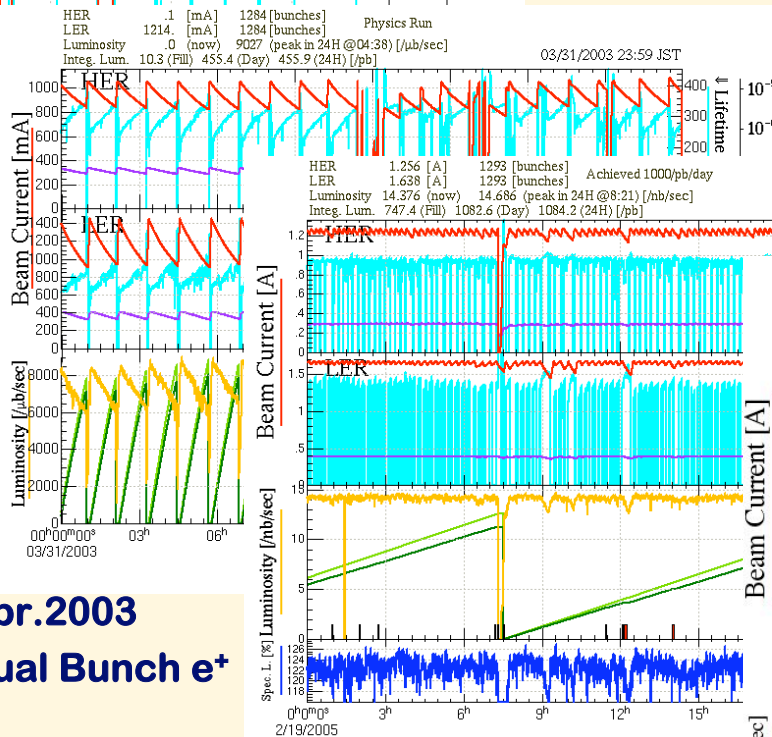
# Increase of the Luminosity

## percent by percent

### Feb.2005 Continuous Injections

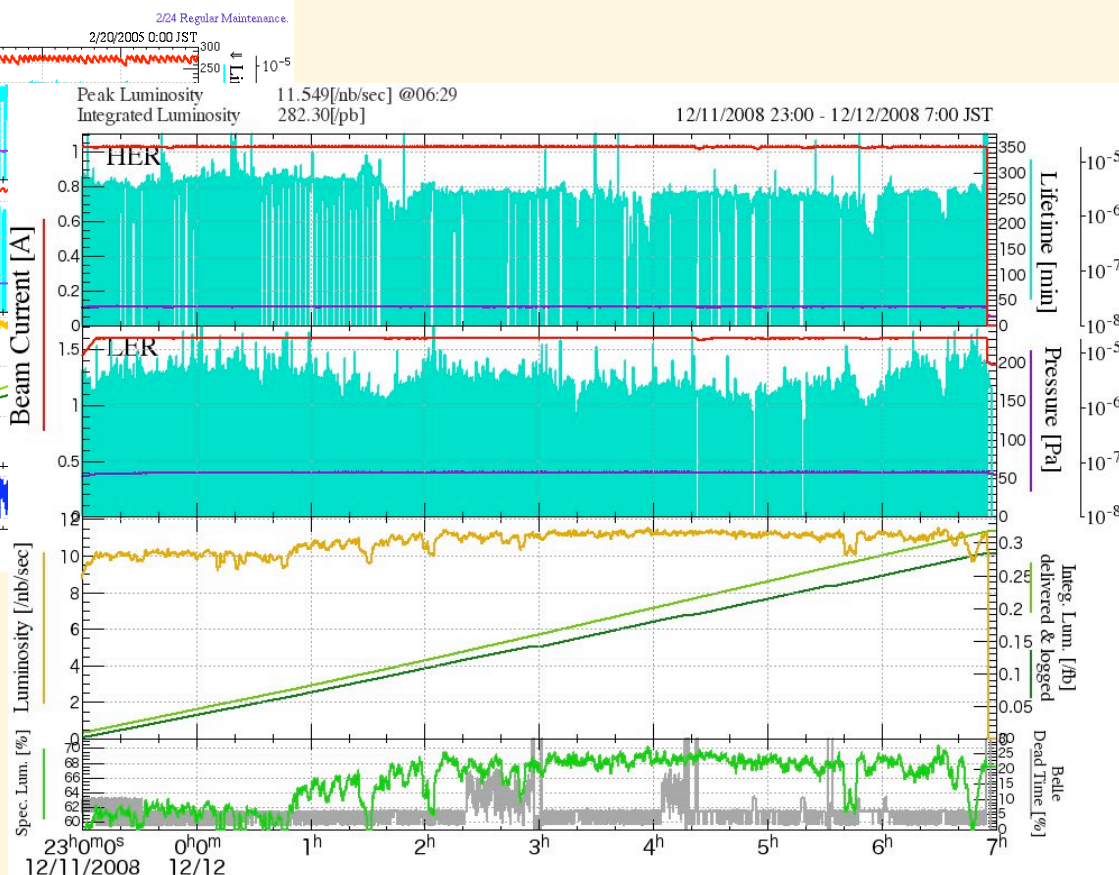


### May.2000



### Apr.2003 Dual Bunch $e^+$

### Now, Collision with Crab Cavities and with Quasi-simultaneous Injection





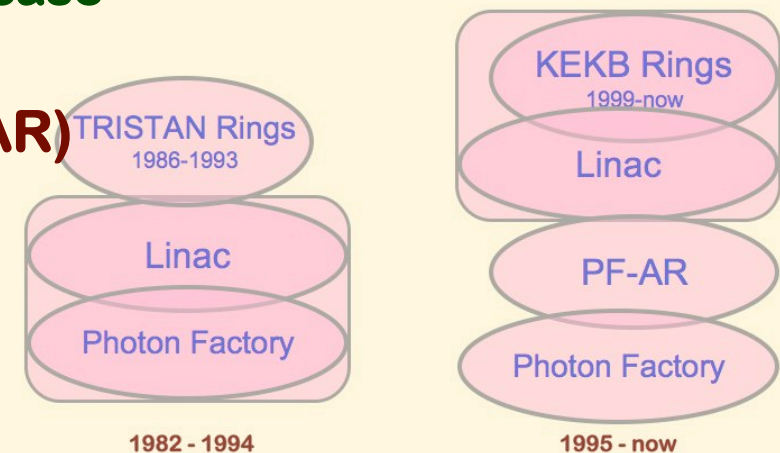
# KEKB and Linac Control Systems

## ◆ Linac

- ❖ Controls Upgrade (1990~)1993
  - ✧ De-facto (and International) Standards, IP-only Networks
- ❖ No long Shutdown for KEKB upgrade
  - ✧ 3.5-times Energy increase, 10-times current increase
- ❖ Division changed at the end of Upgrade
- ❖ Three indirect User Facilities (KEKB, PF, PF-AR)
- ❖ Fewer resources

## ◆ KEKB

- ❖ 5-year Shutdown after TRISTAN 1994-1998
  - ✧ Precision requirements were much different for KEKB
- ❖ Complete transition of Controls
  - ✧ from Nodal at TRISTAN to EPICS+SAD at KEKB
- ❖ Basically Single-user (Belle)





# Communication Network at Linac

## ◆ Fiber-optic Networks (1982~)

- ✧ Because of High-power modulators for rf systems
- ✧ ~30 Loops to connect many equipment controllers
- ✧ However, the fiber-optic Technology was not mature enough yet
  - ◆ Often Failed and Loop Topology made it difficult to identify the trouble

## ◆ All IP network (1993~)

- ✧ Still all Fiber-optic
  - ✧ (Faster Ethernet enables shorter packets and less failures)
- ✧ Inherited at J-PARC Controls as well

## ◆ Gradual Transition of Technologies

- ✧ From FDDI + 10Base-FL to 1000Base-LX + 100Base-Fx

## ◆ Redundancy (1996~)

- ✧ At more than 40 Ethernet links
- ✧ Helped continuous operation in spite of a failure at night
  - ✧ Redundant Transceivers, then Rapid Spanning-tree and HSRP/VRRP



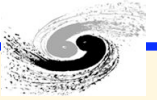
# Communication Network at KEKB

## ◆ TRISTAN

- ❖ **Token Ring and CAMAC Serial highways**
  - ✧ Token ring between mini-computers
  - ✧ CAMAC serial highways to equipment controllers

## ◆ KEKB

- ❖ **IP Network for EPICS**
  - ✧ FDDI+10BaseT to GbE+100Base-Tx
    - ◆ Sometimes unnecessary excess broadcast
- ❖ **ARCNet for equipment controllers**
  - ✧ More than 200 network segments
- ❖ **MXI-2 for VXI-based frames**
  - ✧ 20 segments
- ❖ **Keep some CAMAC Serial highways**
  - ✧ About 50 Crates



# Equipment Controllers at Linac

## ◆ 1982~(1997) (1st generation)

- ❖ 300 microprocessor-based controllers
  - ✧ Linked together with home-grown fiber-optic network

## ◆ 1993~now (upgrade of controls)

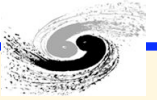
- ❖ 150 PLCs (programmable logic controller)
  - ✧ Linked via only Fiber-optic Ethernet/IP
    - ◆ Control communication with servers and program development

## ◆ 1995~now (upgrade for KEKB)

- ❖ 30 VXI for rf measurement
- ❖ 5 VME / 10 CAMAC for Timing
- ❖ 20 VME for Beam monitors

## ◆ 2006~ (upgrade of BPM readout)

- ❖ 24 Oscilloscopes with WindowsXP IOC for 100 BPMs
  - ✧ 10Gs/s, 50Hz acquisition, local processing with 20 calibration parameter/BPM



# Equipment Controllers at KEKB

## ◆ TRISTAN

### ❖ Mostly CAMAC

✧ Equipment group responsibility: CAMAC module and outside

## ◆ KEKB

❖ 100 VME/IOC without Analog processing

❖ 200 VXI/MXI mainframes for 900 BPMs

❖ 50 CAMAC crates are kept for rf and vacuum

❖ ARCNet boards for Magnet ps. settings, and others

❖ GPIB for Magnet ps. readback, and others

❖ PLCs for Magnet interlocks, and others



# EPICS Transition at Linac

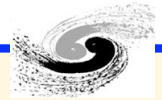
- ◆ **Home-grown RPC at Linac (1990~/1993~)**
  - ❖ **Bad timing but no choice because of end of old mini-computer support**
- ◆ **No real transition to EPICS yet at Linac**
  - ❖ **There are middleware and applications**
- ◆ **LynxOS Transition was developed (1994~1996)**
  - ❖ **To cover both RPC and EPICS with pthread, posix**
    - ✧ **Mostly working, Failed to get funding for Hardware/Software upgrade**
- ◆ **Gateways to EPICS in several ways**
  - ❖ **Software-only IOC and Gateway (Clients to both RPC/CA)**
  - ❖ **Portable Channel Access Server of EPICS-3.12 (1995~)**
  - ❖ **Soft-IOC with device support to Linac RPC (2002~)**
- ◆ **Real IOCs are increasing**
  - ❖ **PLC(rf,vacuum,magnet) and Linux, Oscilloscope(bpm) with Windows, VME(IIrf and timing)**
  - ❖ **RPC servers read EPICS IOCs, EPICS gateways read RPC servers**





# EPICS Transition at KEKB

- ◆ **Some candidates discussed after Nodal at TRISTAN**
  - ❖ **RPC/CORBA based control design**
  - ❖ **Reflective memory (hardware shared memory) design**
- ◆ **No other choice than EPICS for KEKB**
  - ❖ **No man-power for control system software**
  - ❖ **The choice at SSC**
  - ❖ **International collaboration was attractive**



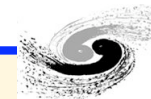
# Archiver/Logger

## ◆ Linac

- ❖ Several archivers with different filters and stored in ascii
- ❖ Replaced with two EPICS archivers (2002)
  - ✧ Channel archiver, with Java viewer, and Web-based viewer
  - ✧ KEKBlog, SADscript-based viewer
    - ◆ Both ~500MB/day, Dynamic ADEL changes

## ◆ KEKB

- ❖ KEKBlog, since 1998
  - ✧ Once there was a plan to replace it with Channel Archiver
    - ◆ Data conversion, no much performance difference
  - ✧ Only ADEL-based filter
    - ◆ ~4GB/day
  - ✧ SADscript-based viewer is one of the most-used applications
    - ◆ With Data analysis capability, easy manipulations



# Scripting Languages

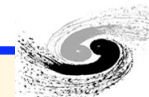
## ◆ Heavy use because of rapid prototyping

## ◆ Linac

- ❖ (1992~) Tcl/Tk as Test tools on Unix
- ❖ (1997~) Tcl/Tk as Main Operator Programming Tool
- ❖ (Now) Mixture of Tcl/Tk, SADscript/Tk, Python/Tk
  - ✧ SADscript has most accelerator design capability
    - ◆ Covers many features like MATLAB, Mathematica, XAL, MAD

## ◆ KEKB

- ✧ (Nodal interpreter and Fortran covered everything at TRISTAN)
- ❖ Python covers many areas which is not covered by medm
- ❖ SADscript is used by operators and physicists everyday
  - ✧ Realization of novel ideas in hours
    - ◆ Only some ideas are effective, so rapid prototyping is important

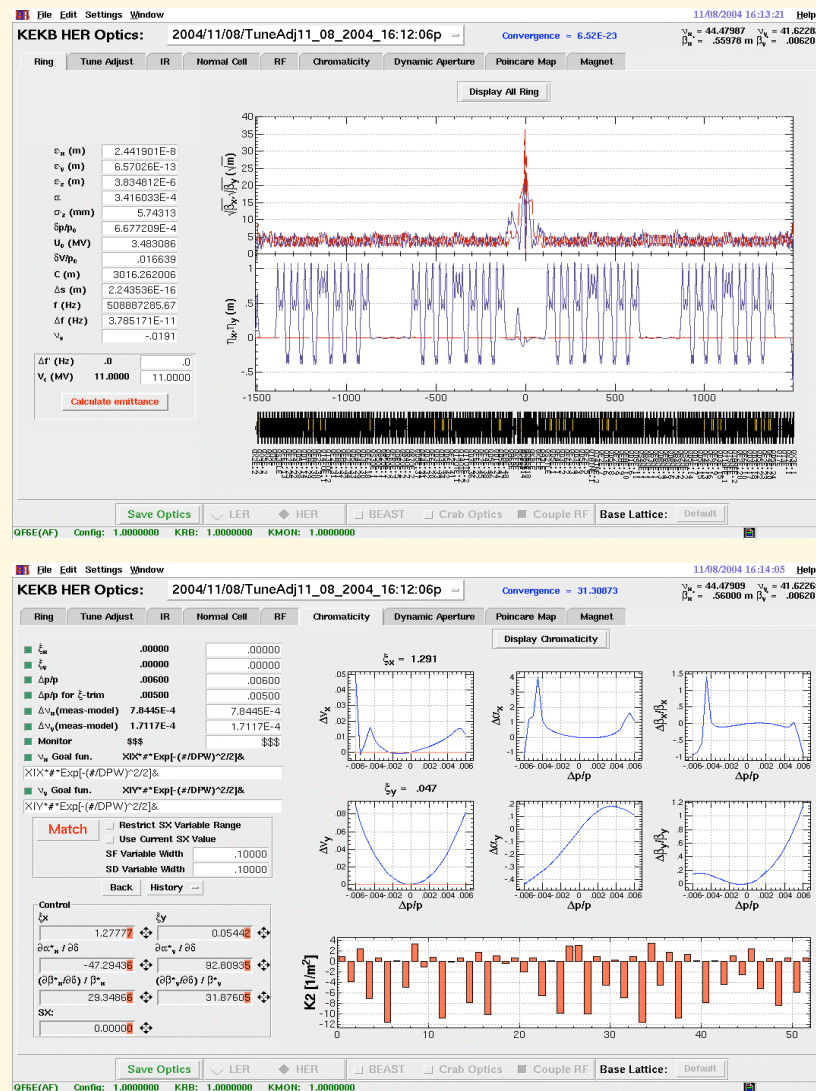
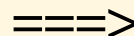
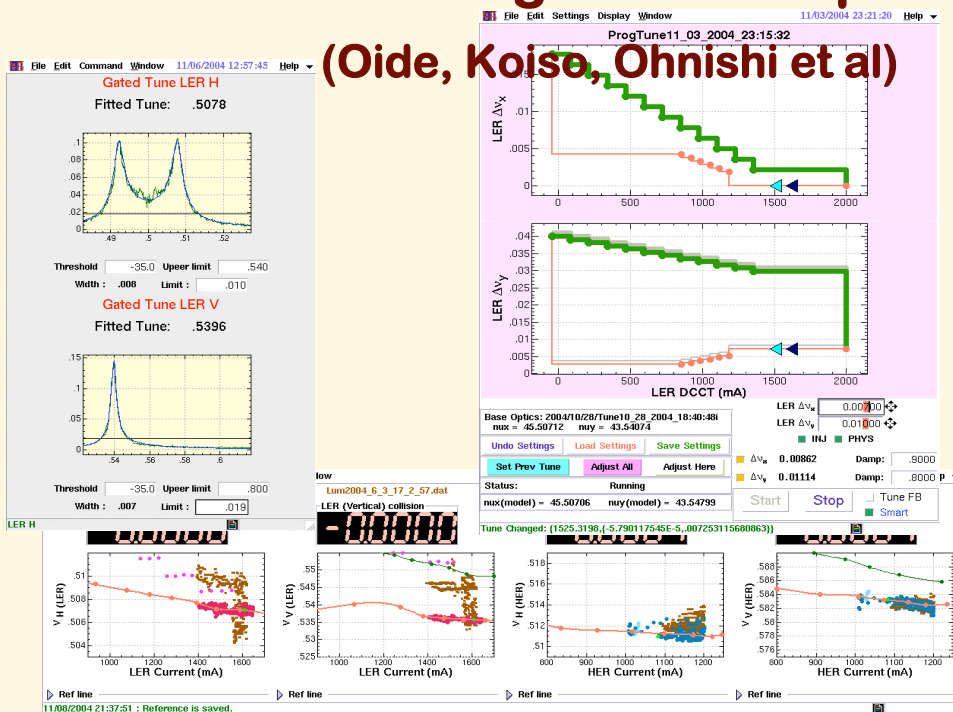


# Virtual Accelerator in SADscript

## ◆ For Example in KEKB

- ❖ most Beam Optics Condition is maintained in the Optics Panel
- ❖ Other Panels Manipulate Parameters Communicating with the Optics Panel

(Oide, Koiso, Ohnishi et al)



## Tune Measurement/Changer

## Optics Panels



# Near Future

## ◆ SADscript

- ❖ Will be maintained, but should look more at XAL - CSS

## ◆ EPICS

- ❖ Still many hopes waiting to be realized

## ◆ More integration between control systems

## ◆ PLC usage

- ❖ IEC61131-3 Standards

## ◆ FPGA usage

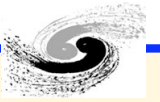
- ❖ More embedded controllers / instrumentations

## ◆ More reliability considerations

- ❖ Testing environments, Surveillance, Redundancy, etc.

## ◆ More operation side developments

**Linac and KEKB groups will share the tasks**



# Summary

- ◆ **Linac had slow and gradual modernization**
  - ❖ **No long Shutdown time, loosing good timing**
- ◆ **KEKB made big transition at the Construction**
  - ❖ **5-year Shutdown, Big help from EPICS community**
  - ❖ **Runs without much modification ever since**
- ◆ **Control system design needed a balance between many aspects**
  - ❖ **Large and Small group differences**
- ◆ **EPICS and Scripting Languages brought a success to the both KEKB and Linac Beam Operations**
- ◆ **Linac and KEKB groups are ready to share more tasks for the future**



**Thank you**