Embedded LLRF Controller with Channel Access on MicroTCA Backplane Interconnect

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- LLRF controllers at KEK, MicroTCA
- EPICS at KEK, Channel Access Everywhere
- New LLRF controller
- RF control configuration

Digital LLRF Controllers at KEK

RF Group

- J-PARC
  - CompactPCI-based DSP/FPGA system
    - Since ~2003
- ILC and STF development
  - Started with CompactPCI-based controller
    - Based on J-PARC experiences
      - Ten 16bit ADC, two 14bit DAC, Virtex2pro
  - ATCA-based controller
    - For ILC “baseline” design large card was required at that time
      - Large card (14bit ADC x “32”, 16bit DAC x4, FPGA, etc)
      - Reliability for large number of components
- Choice of bus for the next generation was difficult
  - VME was old
  - No good standard was available for cPCI with PCIe

MicroTCA (μTCA)

- ATCA (2003)
  - New computing standard for telecommunication and industry
    - After CompactPCI (1993)
  - Many serial interconnects on backplane
    - 2.5Gbps each (10Gbps in the future)
  - IPMI surveillance/remote-management for reliability
- AMC (Advanced Mezzanine Card for ATCA)
  - Serial interconnects, IPMI, good part of ATCA
- MicroTCA (2008)
  - AMC card itself is powerful
  - Direct slot-in AMC cards in a Box
- MicroTCA for LLRF should be a good choice

New LLRF Controller at KEK

RF Group

- cERL (Compact Energy Recovery Linac (Test Facility))
  - CW, under construction, for future ERL
  - AMC or MicroTCA-based LLRF Controller
    - Future stability of 0.01% in amplitude, 0.01degree in phase
    - For now, 0.1% in amplitude, 0.1degree in phase, 1μs loop delay
- SuperKEKB
  - CW, under designing, starting part of construction
  - For higher luminosity, higher stability and feedback capability is required
  - Synergy between projects - MicroTCA
- STF/ILC for S1 global
  - ATCA control
    - For Clustered RF scheme
  - New RF system configuration , “DRFS” (Distributed RF Scheme)
    - For single tunnel scheme
  - MicroTCA can be adequate

Control Progress at KEK

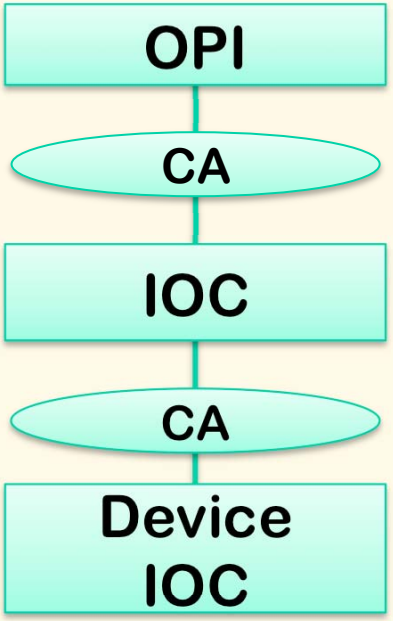
- VME + Unix (1990~)

- Every controller on IP network (1993~)

- Every controller with EPICS IOC (2005~)
  - Channel Access everywhere (CA Everywhere)
    - Good for rapid development and smooth maintenance

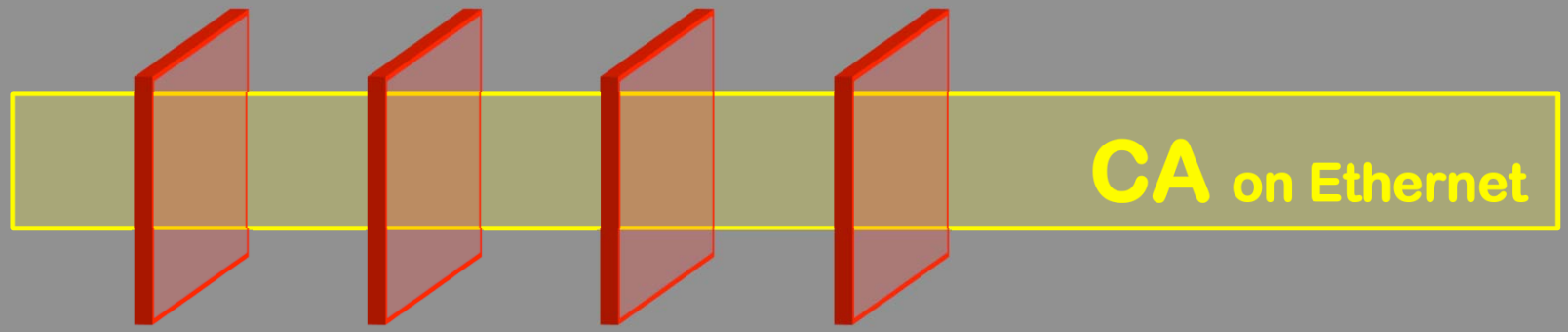
"Channel Access Everywhere"

- The same software framework on every controller
  - Rapid development and smooth maintenance
- Embedded EPICS IOCs at (Super)KEKB
  - Yokogawa PLC: Linux CPU
  - Oscilloscope 50Hz measurement: Windows
  - MPS management :Linux/FPGA
  - Timing TDC: Linux/Arm
  - Power modulator: Linux/FPGA
  - Libera singlepass BPM at 50Hz: Linux/FPGA
  - NI cRIO : CAS/FPGA
  - Many more…



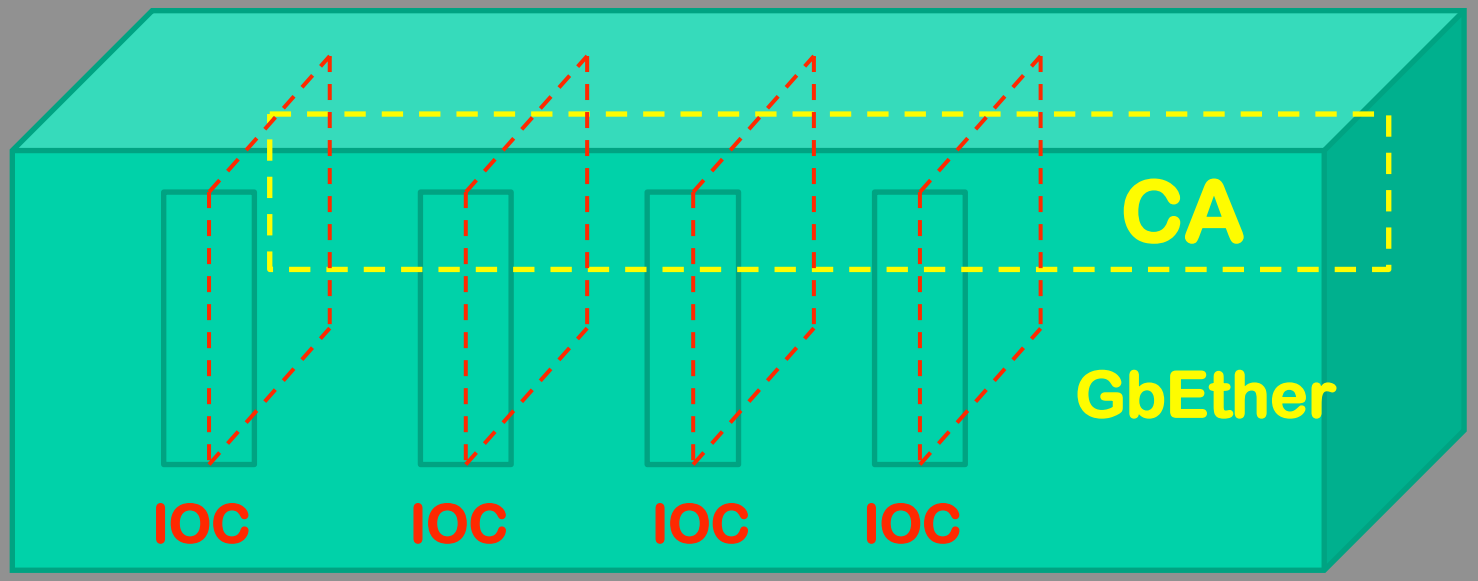
Standard EPICS

EPICS Channel Access (CA) as "Software bus"



Channel Access on MicroTCA Backplane

CA on Hardware "bus"



MicroTCA box

Picture by J.Odagiri

- It was natural to think in the following way
- Let's employ Channel Access on μTCA Backplane !
- Let's embed EPICS IOC on to Each μTCA/ AMC Card !

Miura and Furukawa

IOC on MicroTCA

- Natural to put IOC on μTCA LLRF Controller
  - Shared among STF, cERL, and SuperKEKB
- Chose GbEthernet as a main media on the backplane interconnect
  - Link to global control is straightforward
- Chose PowerPC core on Virtex5
  - ML507 of Xilinx as a good reference
- Linux on PowerPC
  - No realtime processing is necessary for now

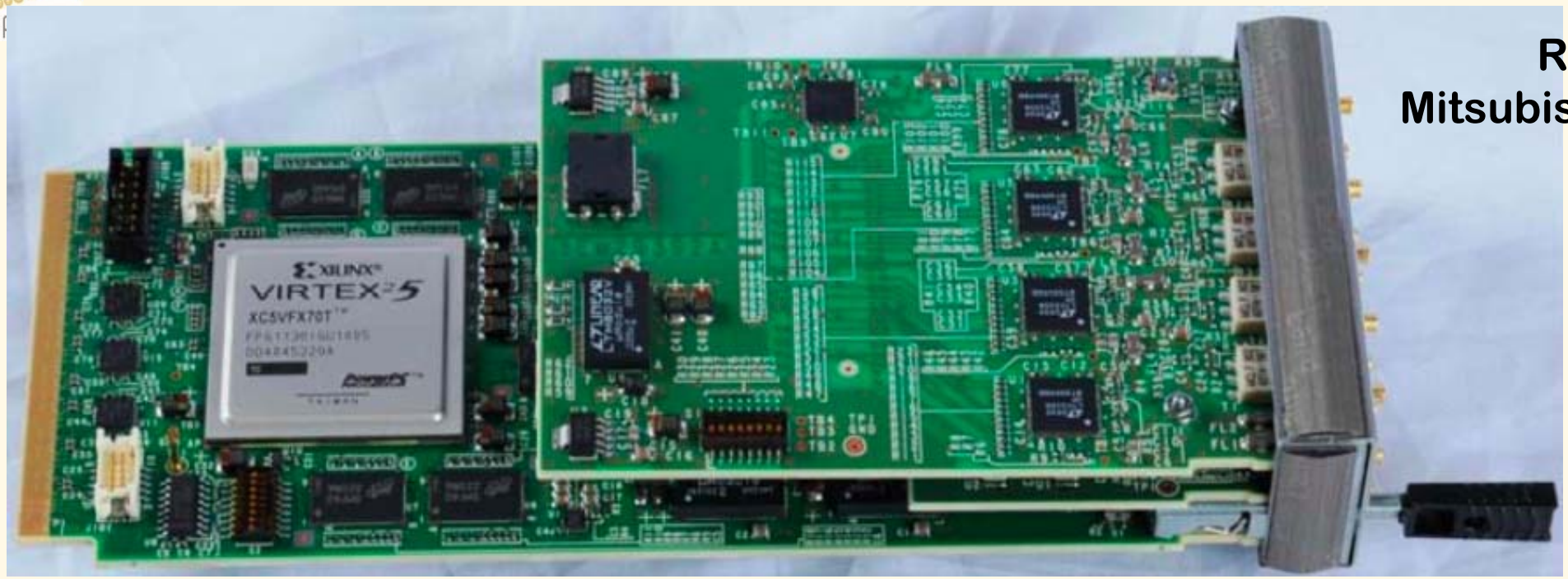
EPICS IOC on MicroTCA LLRF Controller

- Linux 2.6.9 on PPC/Virtex5
  - Boot from Flash (or over network)
  - EPICS and application software from NFS server disk
  - Relatively straight forward
- EPICS 3.14.9
  - Driver to FPGA (with mmap())
  - Channel access on backplane interconnect
  - Directly connected to outside at first
- Collaboration between RF group, Mitsubishi Elec. Tokki System Co. Ltd., and Control group

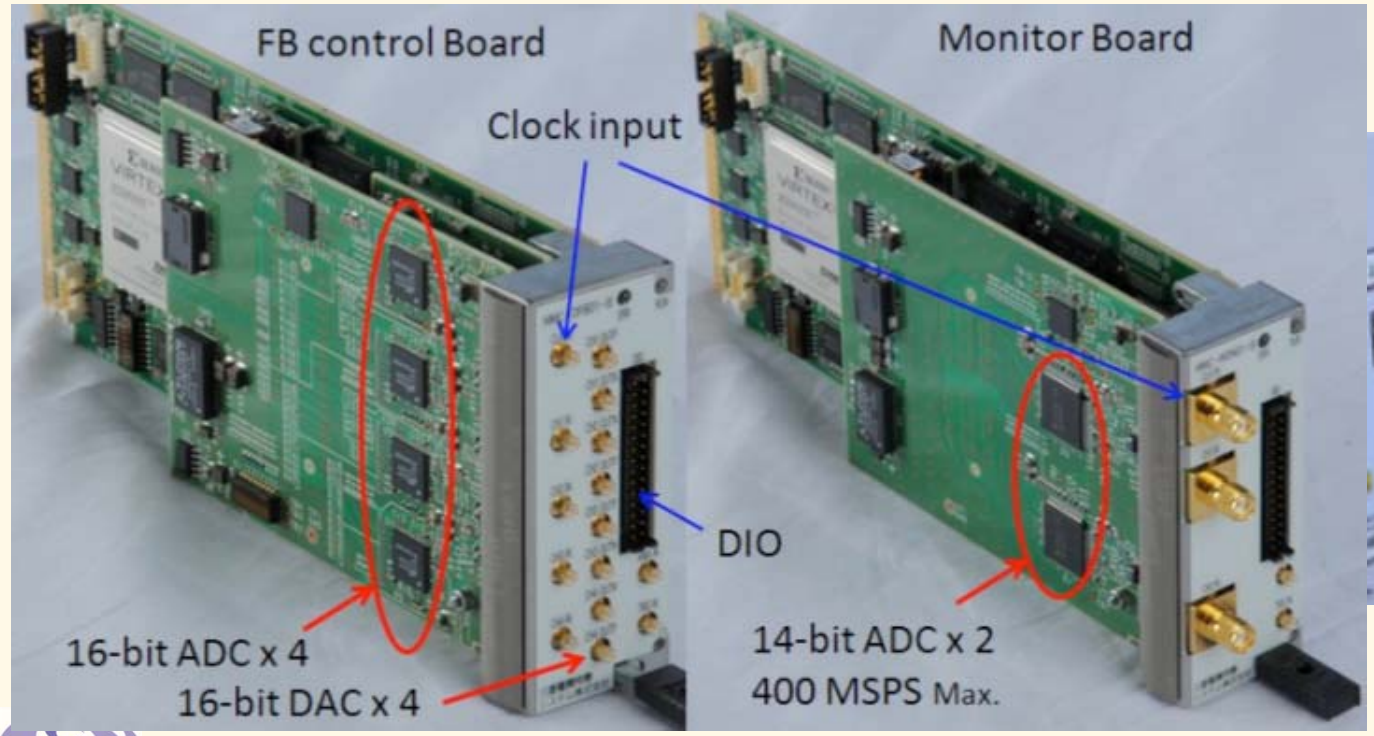
MicroTCA based LLRF Controller

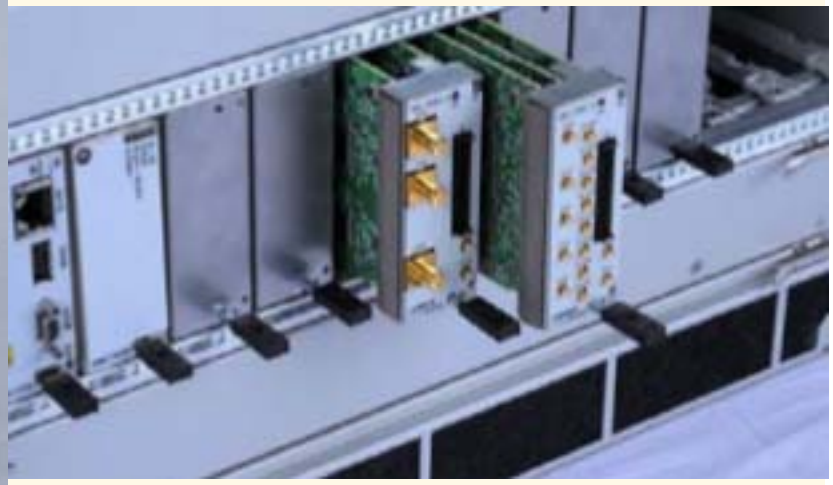
- Single-width full-height module
- Without physics experiment extension (MTCA.4)
  - We started earlier
  - Front-panel connectors only (rather busy)
- Digital part and Analog part are on isolated cards
  - ADC 16bit, 130Msps, x4
  - DAC 16bit, 500Msps, x4
  - Virtex5 with PPC440
  - RAM 640MB, Flash 64MB
  - Also monitor card employing the same digital part
    - ADC 14bit, 400Msps, 1.4GHz, x2
- Fabrication was carried at Mitsubishi Electric Tokki System

<http://www-linac.kek.jp/cont/epics/mtca/>

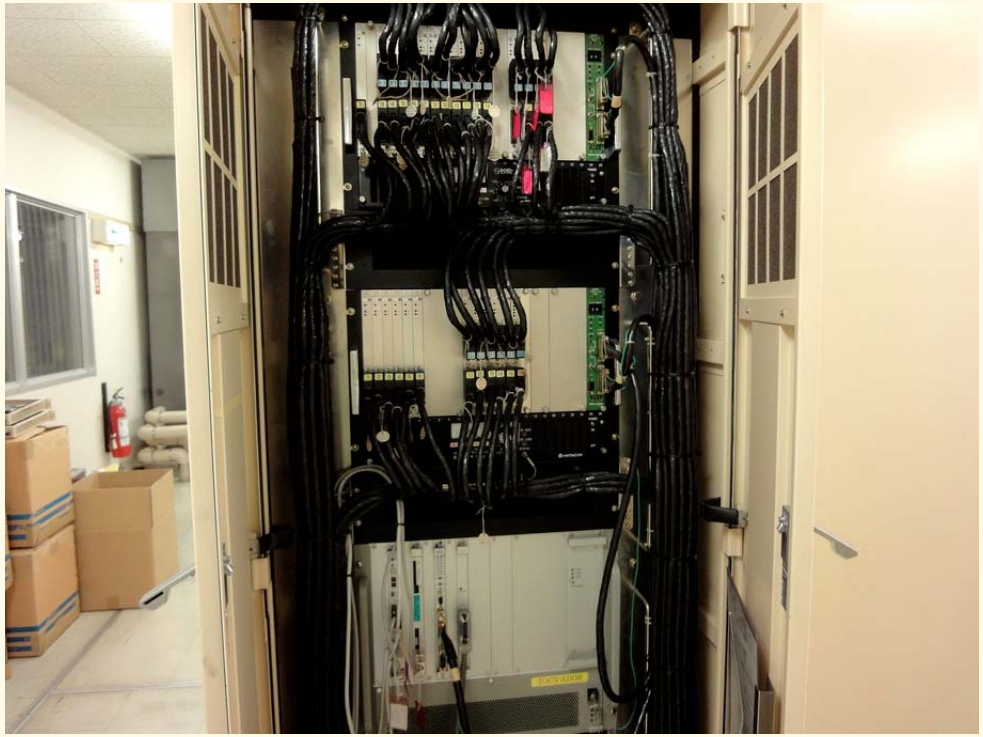


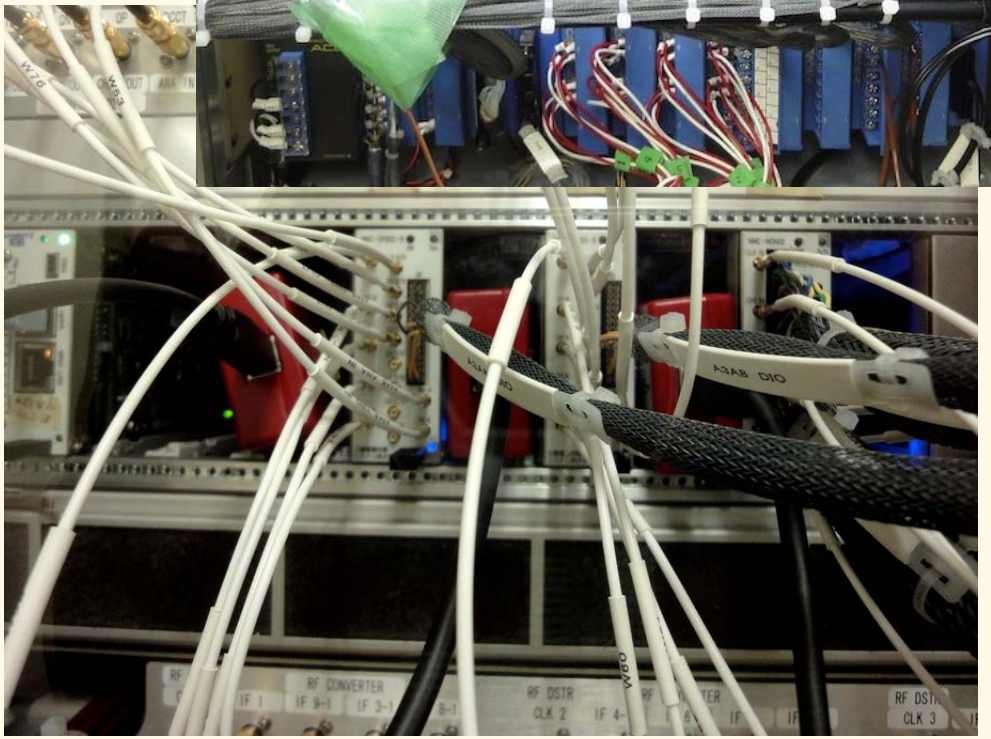
RF Group
Mitsubishi Tokki





RF Controls



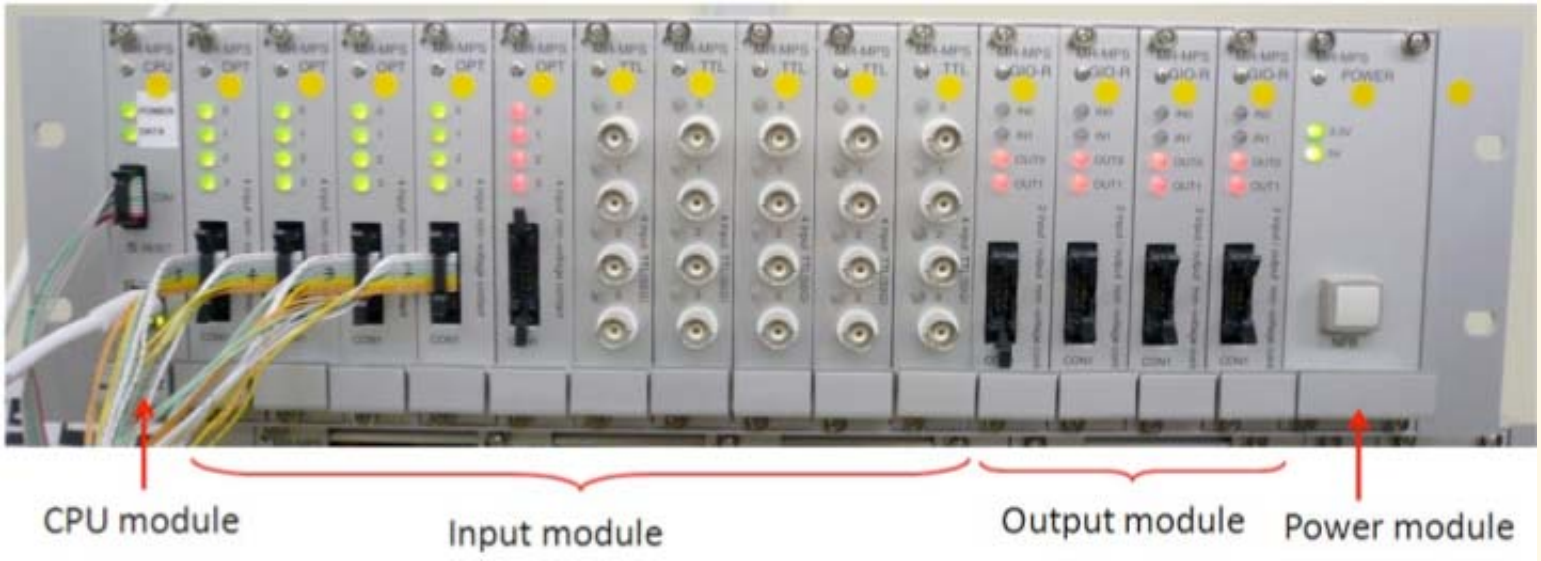


CAMAC and NIM modules

gradually

MicroTCA and PLC

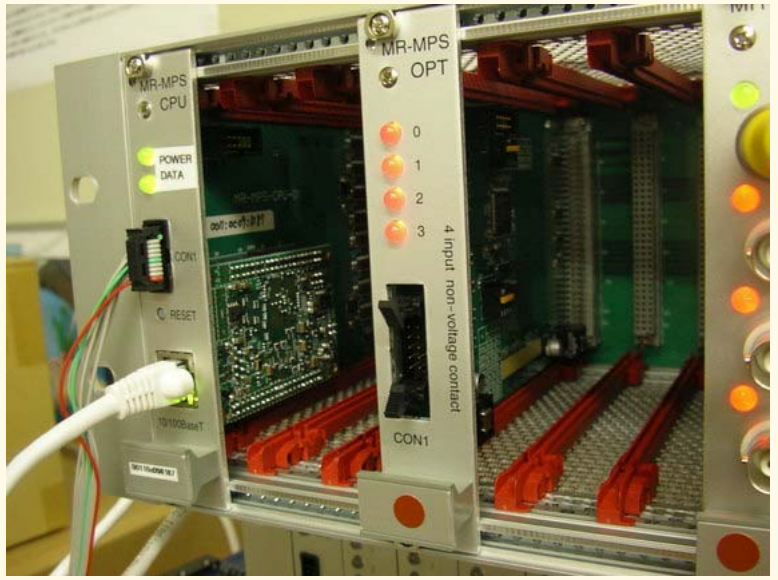
- Slow control with PLC
  - Embedded IOC
- MPS with FPGA/PPC
  - (For cERL and STF)
  - Embedded IOC



Embedded EPICS

MPS/Suzaku/atmark-techno

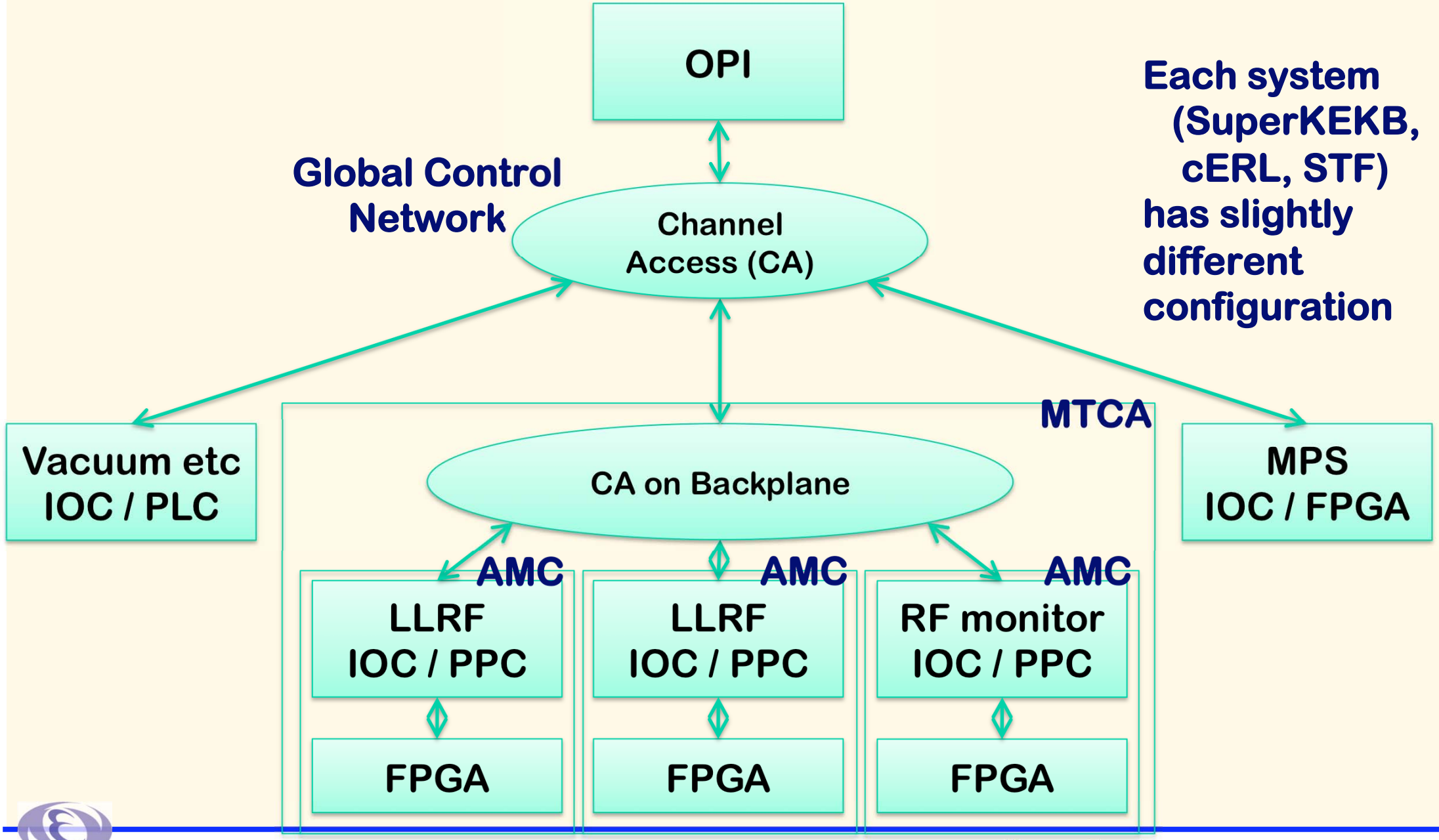
- FPGA Virtex-4
- PPC Linux-2.6
- 64MB, Ethernet
- EPICS 3.14



PLC/F3RP61/Yokogawa

- PowerPC 533MHz
- Linux-2.6 PREEMPT_RT
- 128MB ram, Ethernet x2
- PCI, USB, IEEE1394, Serial
- EPICS 3.14

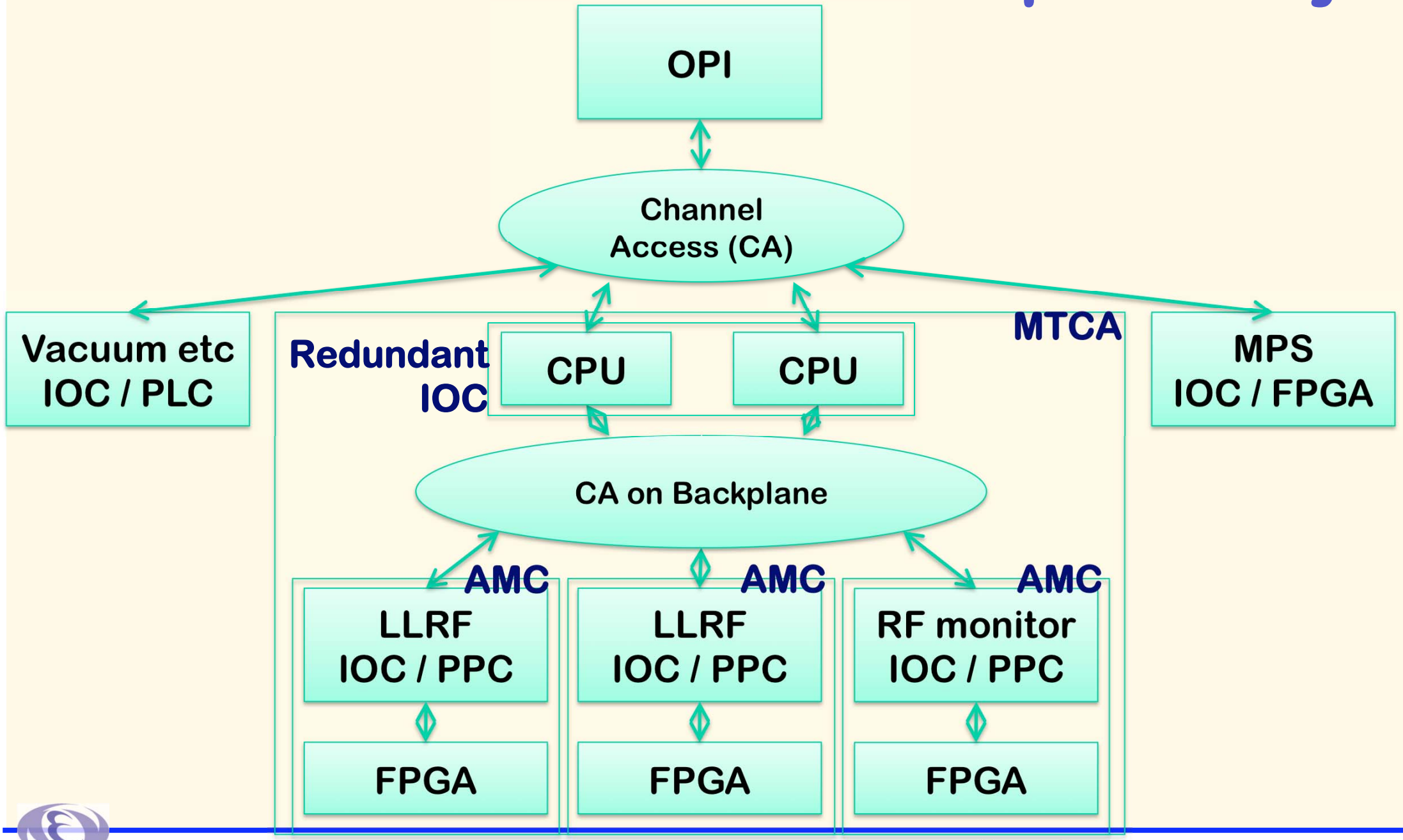
Control Architecture – EPICS Channel Access Everywhere



MicroTCA Management Capability

- At the beginning, we will not depend on the shelf management facility much
  - We will not depend on a CPU module !
- Separately, redundant power supply, MCH, CPU, are evaluated, and redundant EPICS IOC will be combined

Control Architecture – future possibility

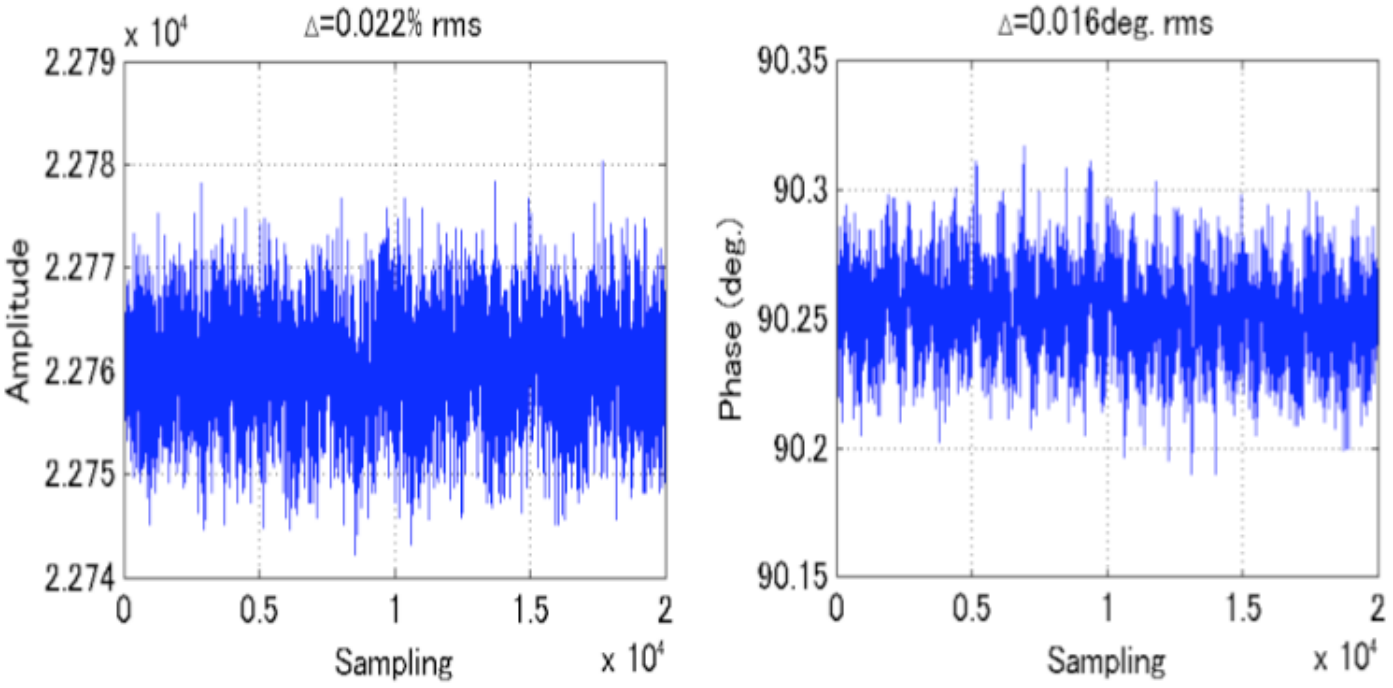


Present Status and Further Development

- Base hardware/software were evaluated
  - Another PCB fabrication to remove patches
- FPGA and EPICS (mostly SNL sequencer) application programs are being evaluated
- Operator interfaces via standard EPICS tools
  - EDM at first, moving towards CSS
- Commissioning in 2011-2012 for STF & cERL
- Commissioning in 2014 for SuperKEKB

Under Evaluation

- **Preliminary I/Q control stability results**
  - **Much better than the specification**
    - **~0.022% in amplitude, ~0.016degree in phase**



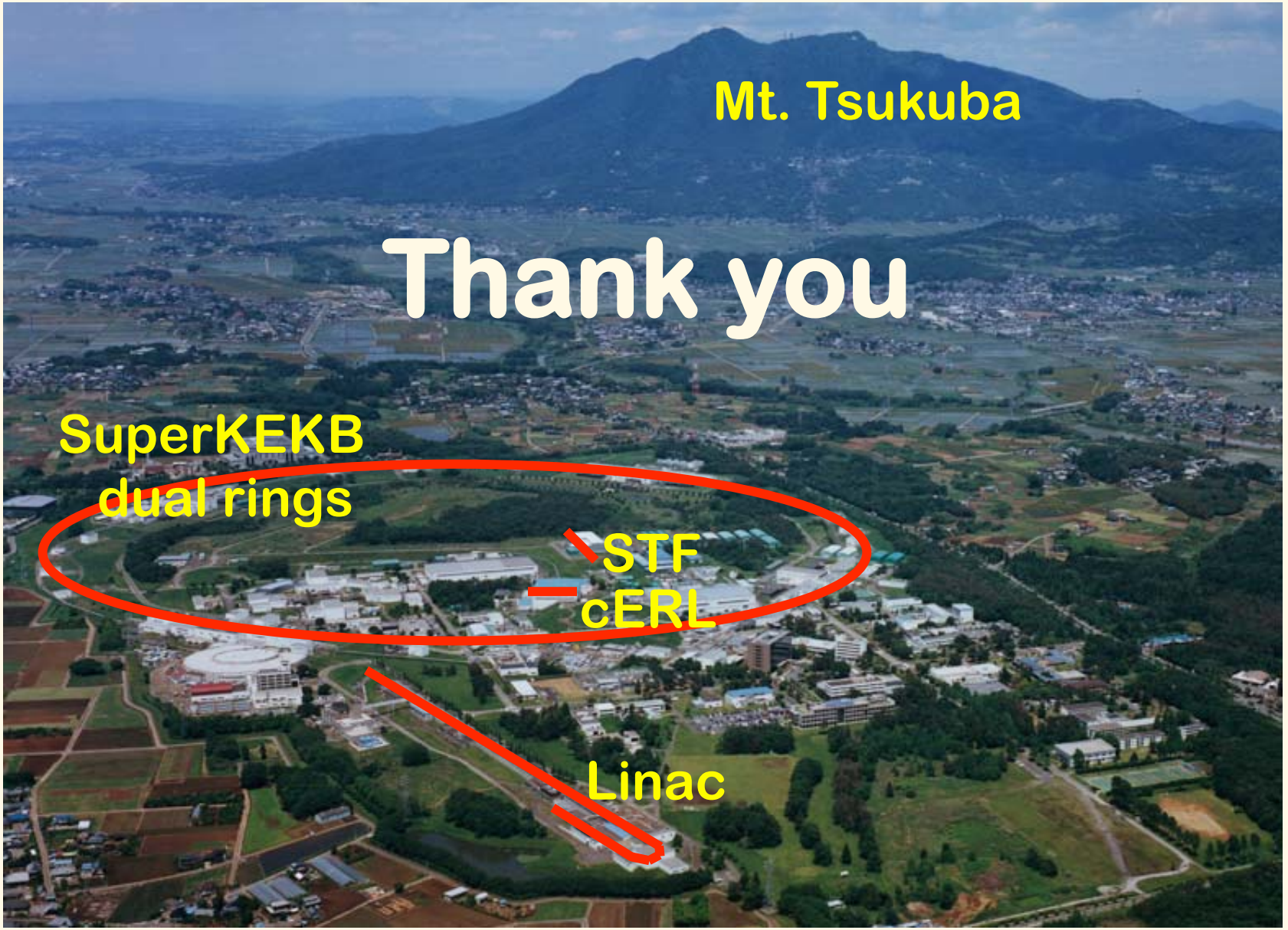
Further Development

- Application to beam instrumentation is planned
  - Monitor AMC (400Ms/s, 14bit, x2)
- MicroTCA Physics Extension (MTCA.4)
  - Possible upgrade candidate
- Comparison to ATCA at STF
- Opensource Linux
- Microblaze on FPGA
- Redundant System
- …

Conclusion

- As a natural consequence of several developments at KEK,
  - LLRF controller for MicroTCA
  - with Channel Access on the backplane

  was developed
- All components embed EPICS/IOC
  - μTCA FPGA controller, PLC controller, MPS controller
- Performance is excellent
- It is being applied for SuperKEKB, cERL, and STF at KEK


Mt. Tsukuba
Thank you
SuperKEKB
dual rings
STF
cERL
Linac

Thank you