國家同步輻射研究中心
National Synchrotron Radiation Research Center

Status of TPS Control System

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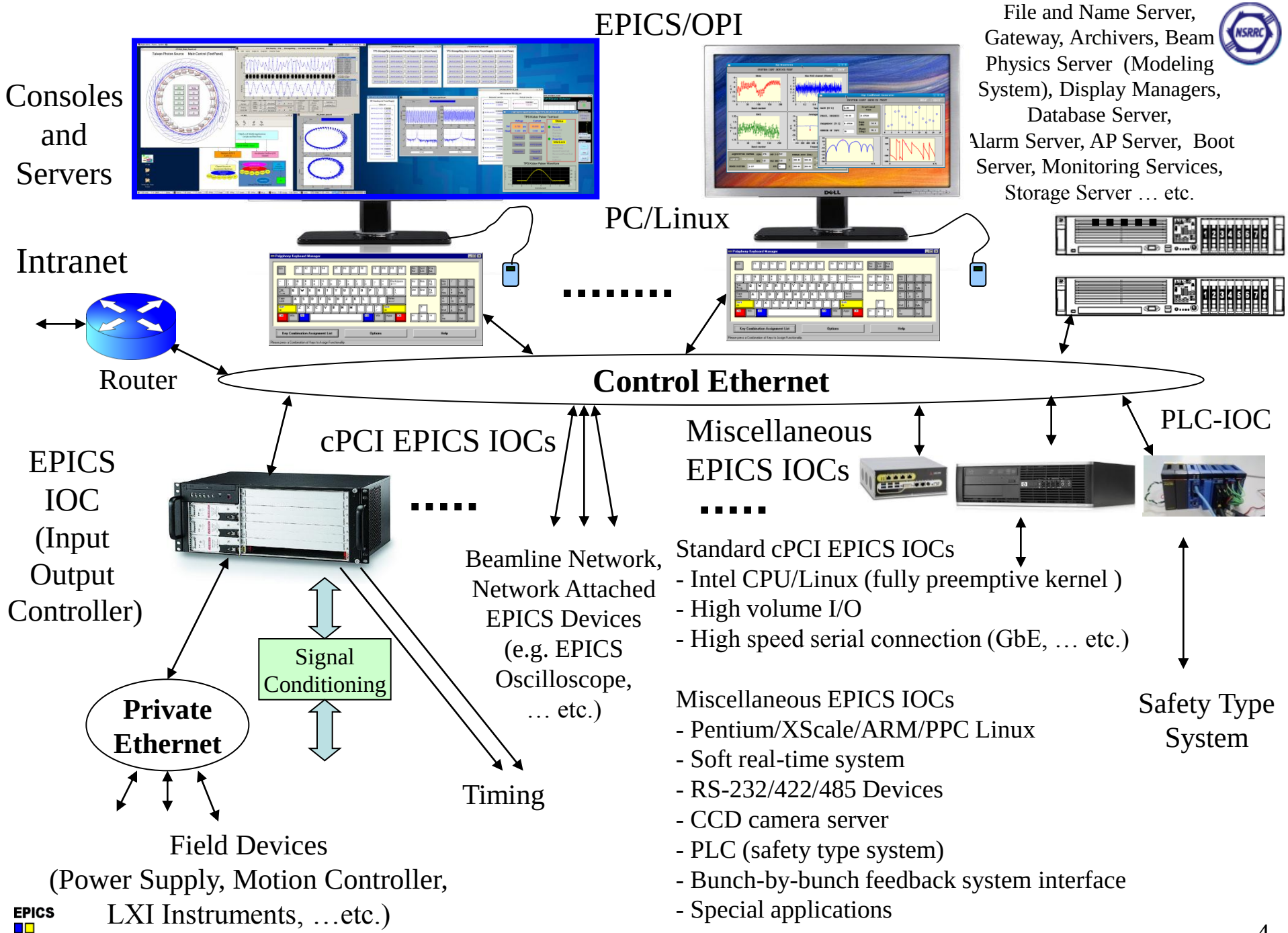
Outline

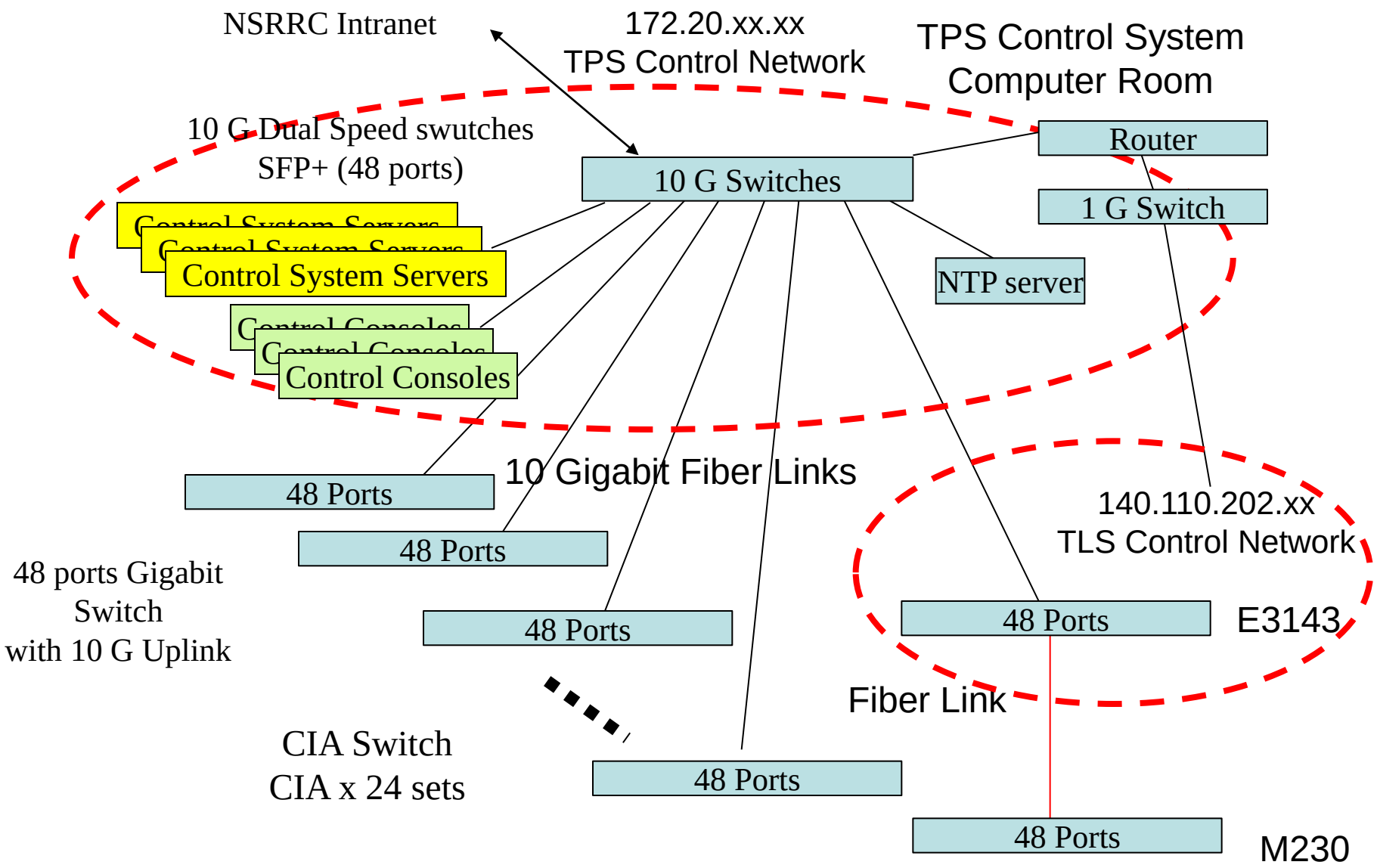
- Introduction
- Connectivity
- Control Room layout
- Subsystem Interfaces
  - ✓ Status of Controls to Subsystems
  - ✓ Power Supply Controls
  - ✓ Insertion Device Controls
  - ✓ RF, Beamline, Vacuum, Front-end
  - ✓ Machine Protection System
- Software Development
  - ✓ GUI Development
  - ✓ Database
  - ✓ Application program interfaces
  - ✓ Various applications
- Summary

Control System Infrastructure

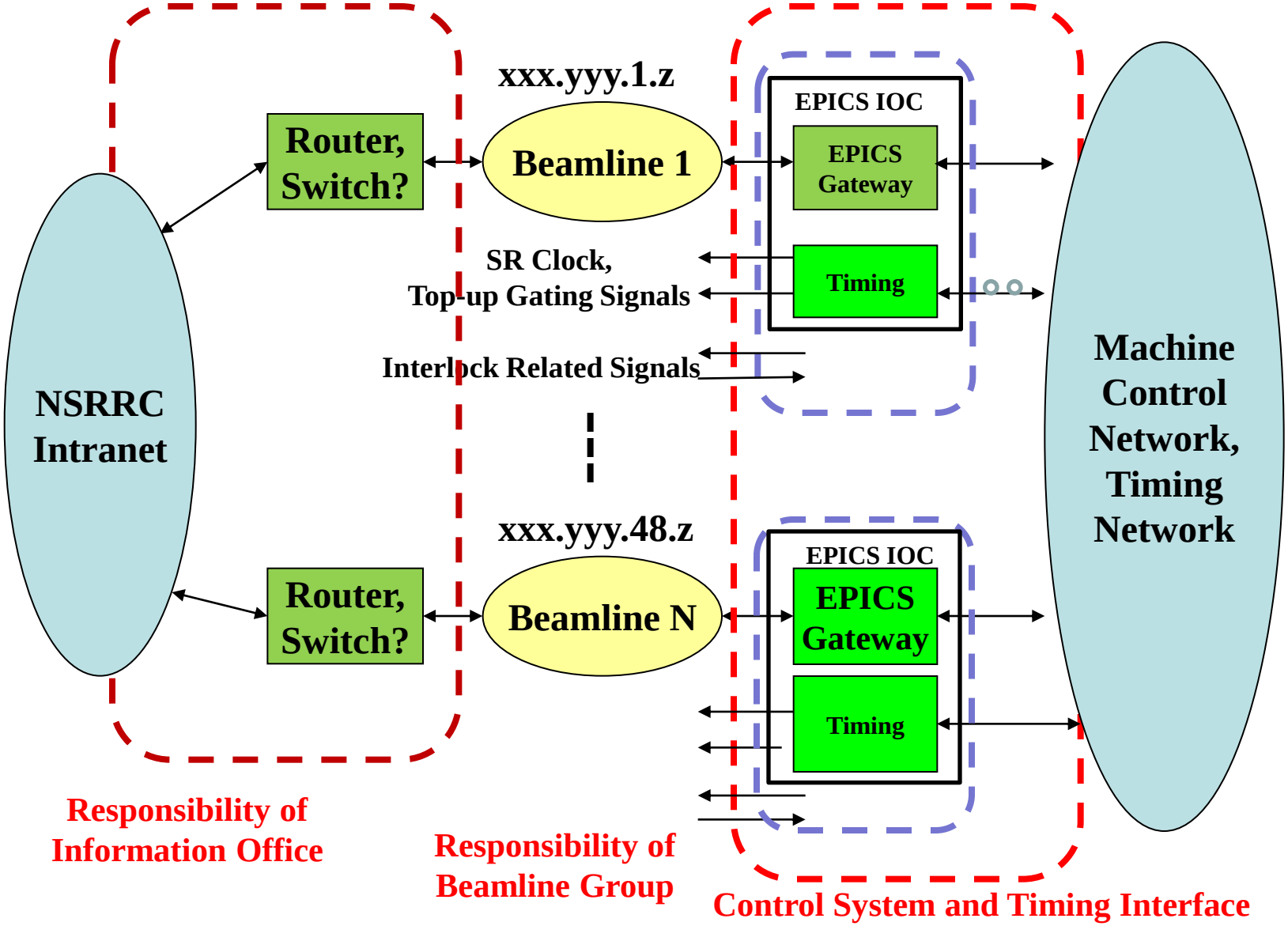
- EPICS toolkit framework
- Control system standards development
  - Naming convention
  - Control network infrastructure and IP addressing scheme
  - Operating system
    - Linux as standard operating system for servers, control consoles, EPICS IOCs
    - Hard real-time => FPGA based system
    - A few system are Windows based system
  - User interface standards
  - I/O standards
  - Motion control connectors
  - Coordinate system
- Various subsystems interface integration


EPICS/OPI
File and Name Server, Gateway, Archivers, Beam Physics Server (Modeling System), Display Managers, Database Server, Alarm Server, AP Server, Boot Server, Monitoring Services, Storage Server … etc.
Consoles and Servers
PC/Linux
Intranet
Router
Control Ethernet
EPICS IOC (Input Output Controller)
cPCI EPICS IOCs
Miscellaneous EPICS IOCs
PLC-IOC
Beamline Network, Network Attached EPICS Devices (e.g. EPICS Oscilloscope, … etc.)
Standard cPCI EPICS IOCs
- Intel CPU/Linux (fully preemptive kernel)
- High volume I/O
- High speed serial connection (GbE, … etc.)
Signal Conditioning
Private Ethernet
Timing
Safety Type System
Miscellaneous EPICS IOCs
- Pentium/XScale/ARM/PPC Linux
- Soft real-time system
- RS-232/422/485 Devices
- CCD camera server
- PLC (safety type system)
- Bunch-by-bunch feedback system interface
- Special applications
Field Devices
(Power Supply, Motion Controller, LXI Instruments, …etc.)

TPS Control Network Infrastructure



Control Interface for Beamlines and Experimental Stations



IP Address Planning

IP address inherent node locations

TPS Control Network

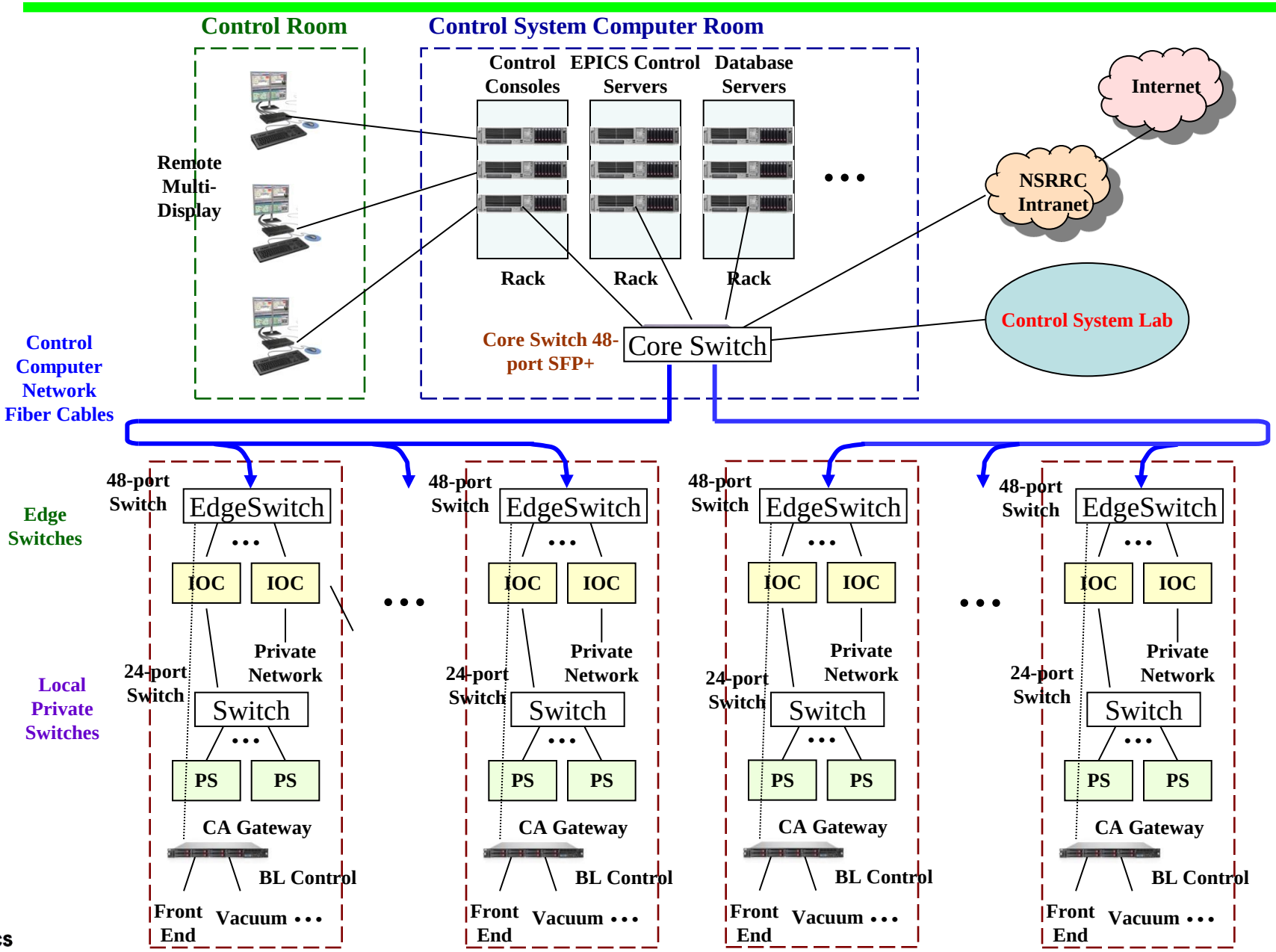
One Class B Network 172.20.xx.xx/16

172.20.0.x	EPICS Development	
.1 ~ 149	IOCs, Network-attached Instruments and Devices	
.150 ~ 199		Clients / Users (PC, NB)
.200 ~ 229		Servers, Console Workstations
.230 ~ 253		Switches, Routers
172.20.1.x	CIA#1 (SR PS Control IOC, Temperature Monitoring…)	
.1 ~ 10		IOCs, PS IOC, ACQ164, 2F IOC, ID IOC, PLC IOC, RF IOC ? , …
.11 ~ 199		Spare
.200 ~ 229		SNMP Devices
.230 ~ 253		Switches, Routers
172.20.2.x	CIA#2 (SR PS Control IOC, Temperature Monitoring…)	
….		……
172.20.24.x	CIA#24 (SR PS Control IOC, Temperature Monitoring…)	
172.20.25.x	Grouping IOCs (BPM, …etc.)	
172.20.26.x	Control System Servers, Control Consoles	

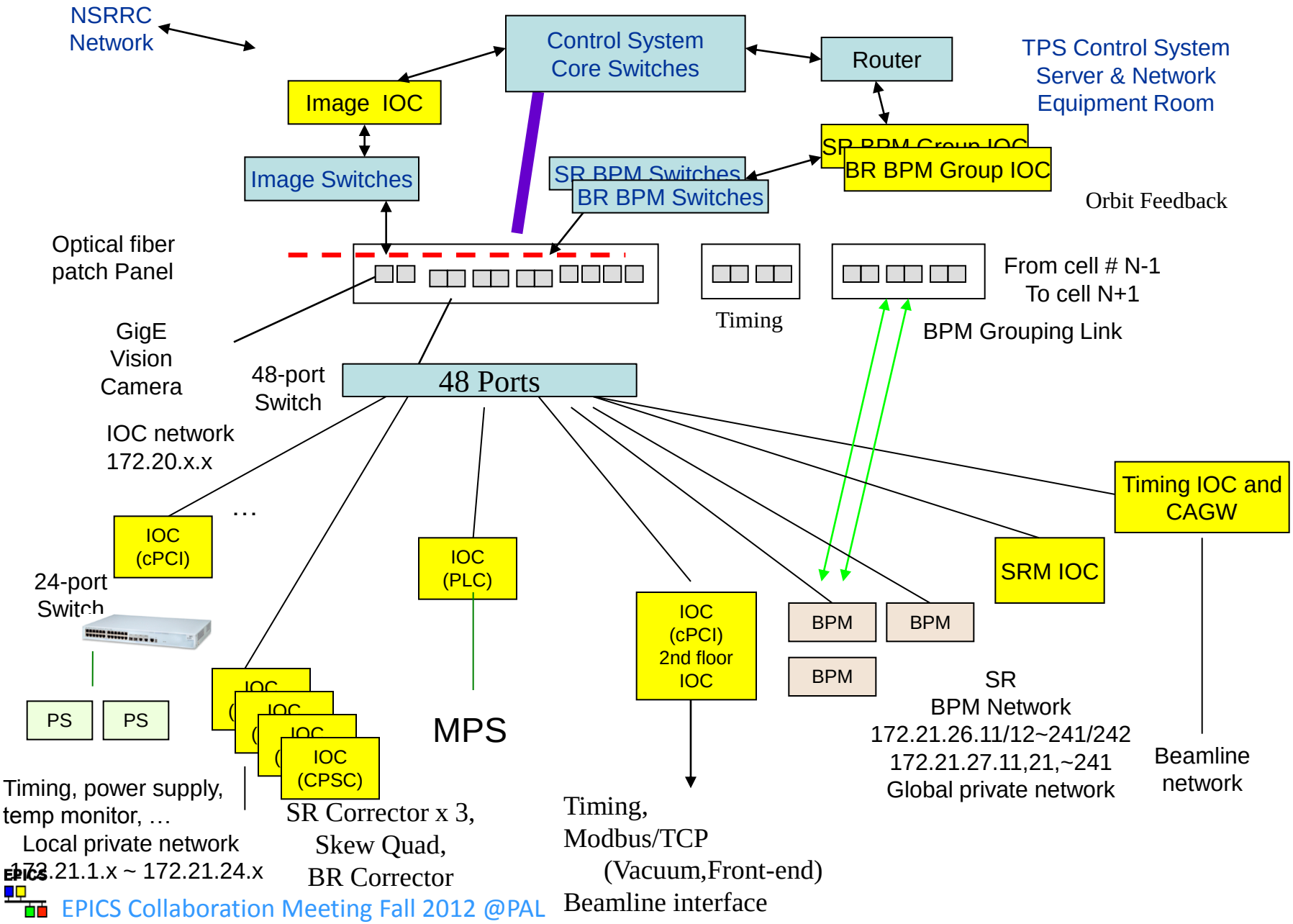
Multiple Class C Network 172.21.xx.xx/24 Private Network

172.21.0.x	EPICS Development
172.21.1.x	CIA#1 Private Network (SR Dipole、Quadrupole & Sextupole PS) Network-attached Instruments and Devices
172.21.2.x	CIA#2 Private Network (SR Quadrupole & Sextupole PS)
….	……
172.21.24.x	CIA#24 Private Network (SR Quadrupole & Sextupole PS)
172.21.25.x	Spare RF IOC ?
172.21.26.x	Booster Ring Private Network (Booster Dipole & Quadrupole PS)
172.21.27.x	BPM Electronics Private Network
172.21.28.x	Storage Ring Private Network (GigE Vision, ...)
172.21.29.x	IP Camera & IP Phone Private Network
172.21.30.x	SNMP Devices Private Network
….	……

TPS Control Network Infrastructure



Network Layout for TPS Control System



Connectivity

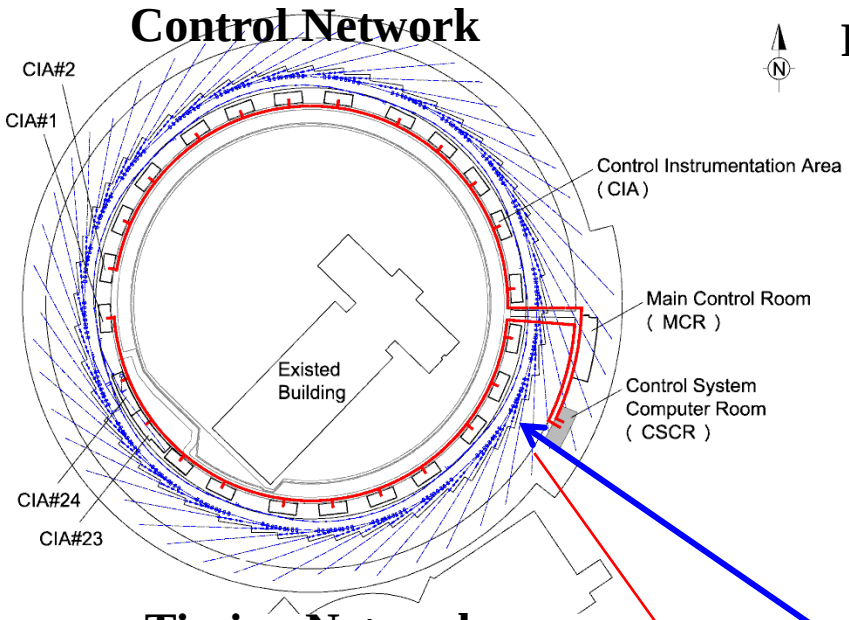
Long Distance Links and Fast Speed Links: All Fiber Links

Control network : 10/1 Gb/s single-mode fiber network
Timing network : 2.5 Gb/s OM3 fiber network
BPM fast data network: 6.5 Gb/s OM3 fiber network
Fast corrector setting: 2.5 Gb/s fiber link (AURORA)
MPS network: 10 Mb/s fiber network
BPM and miscellaneous diagnostics
RF reference single mode fiber links (500 MHz、low phase noise、drift compensated)

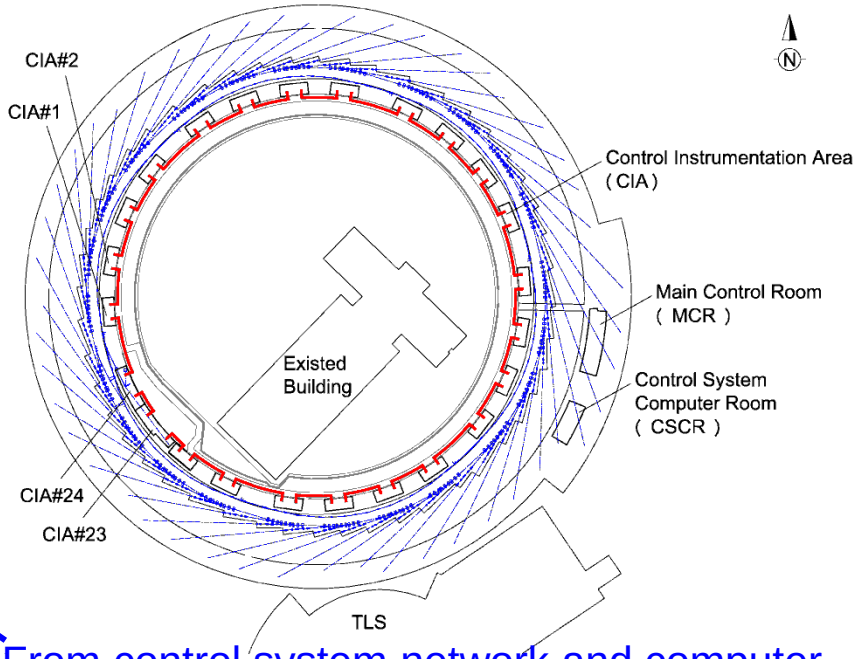
Short Distance to Subsystem Links:
Copper links
Fiber links

Accelerator Control System Fiber Network

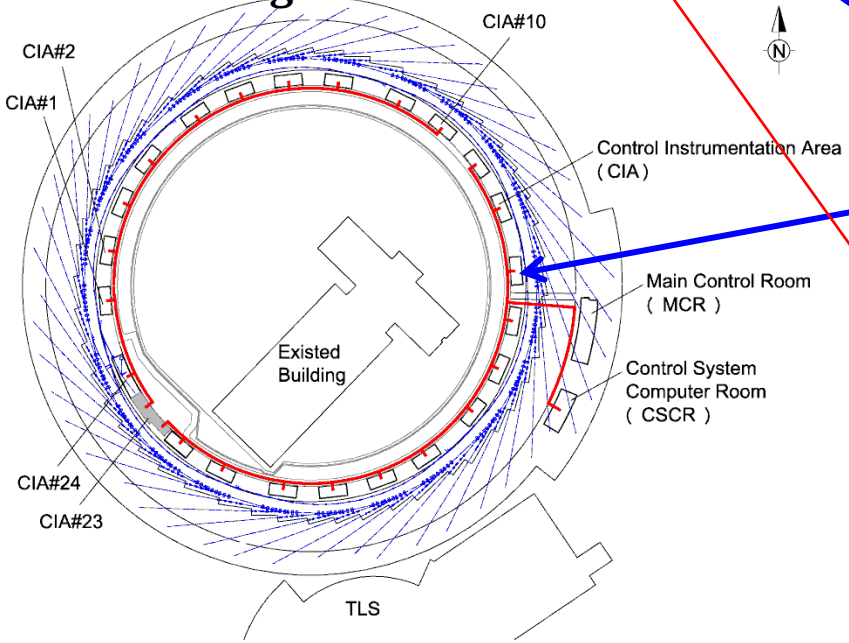
Control Network



Fast Orbit Transfer Network + MPS Network



Timing Network



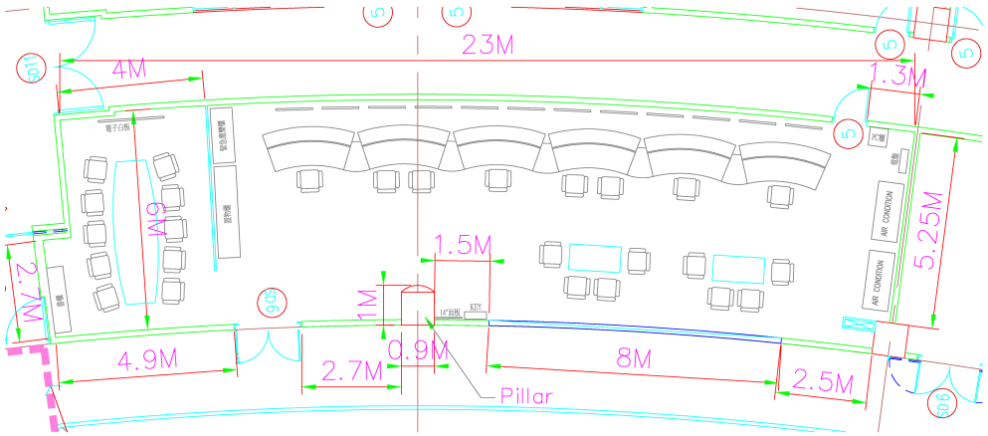
From control system network and computer room to all CIAs

From CIA #23 to all CIA equal length fibre links

E143 (TLS Control System Network and Computer Equipments Room)

Control Room Layout (Subject to Change)

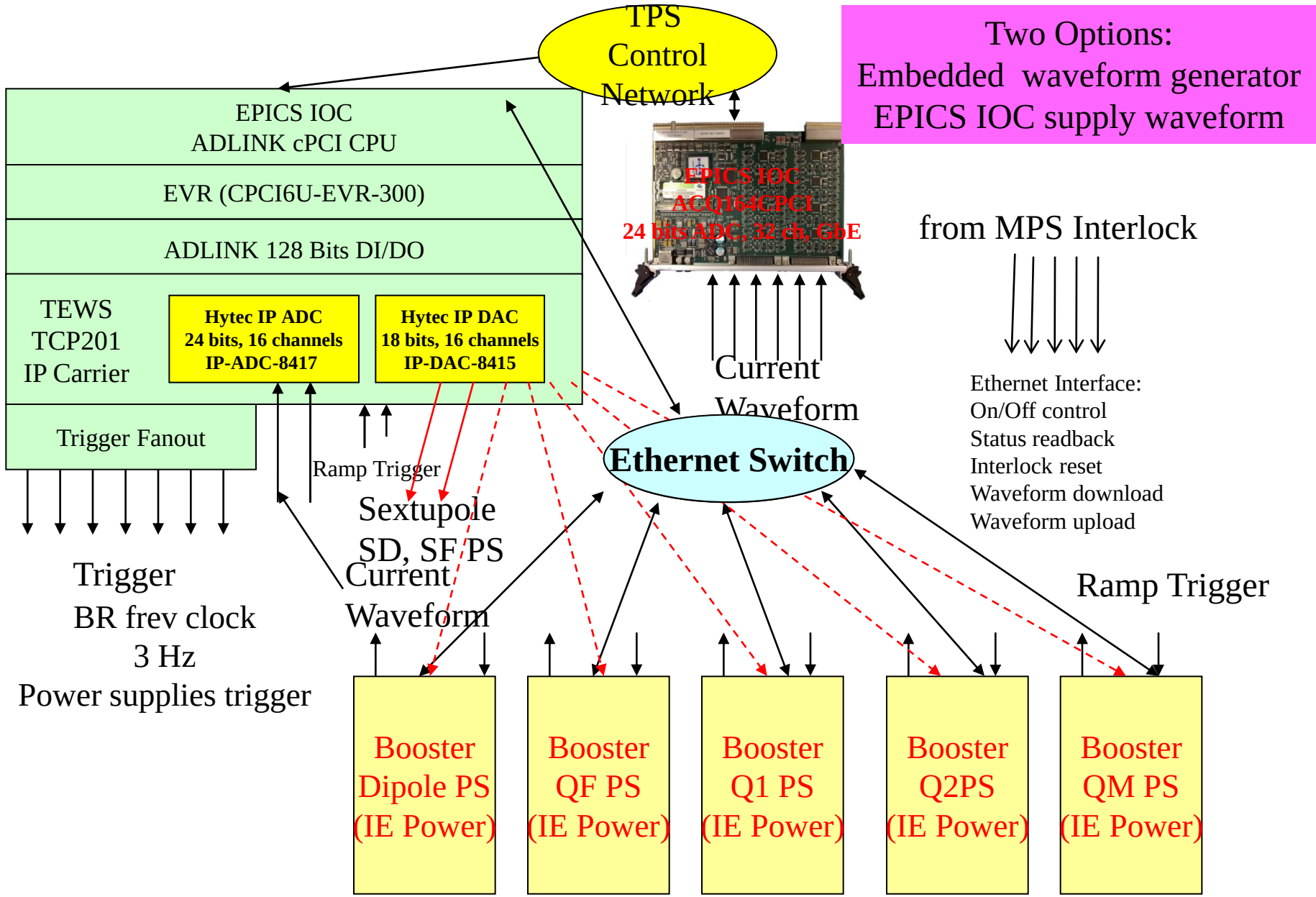
- Available room space: 23m x 6m
- Remote multi-display graphics for 24/7/365 environments:
  - Space Saving
  - Ergonomics
  - Noise free
  - Better Thermal Management
  - Better Cable Management



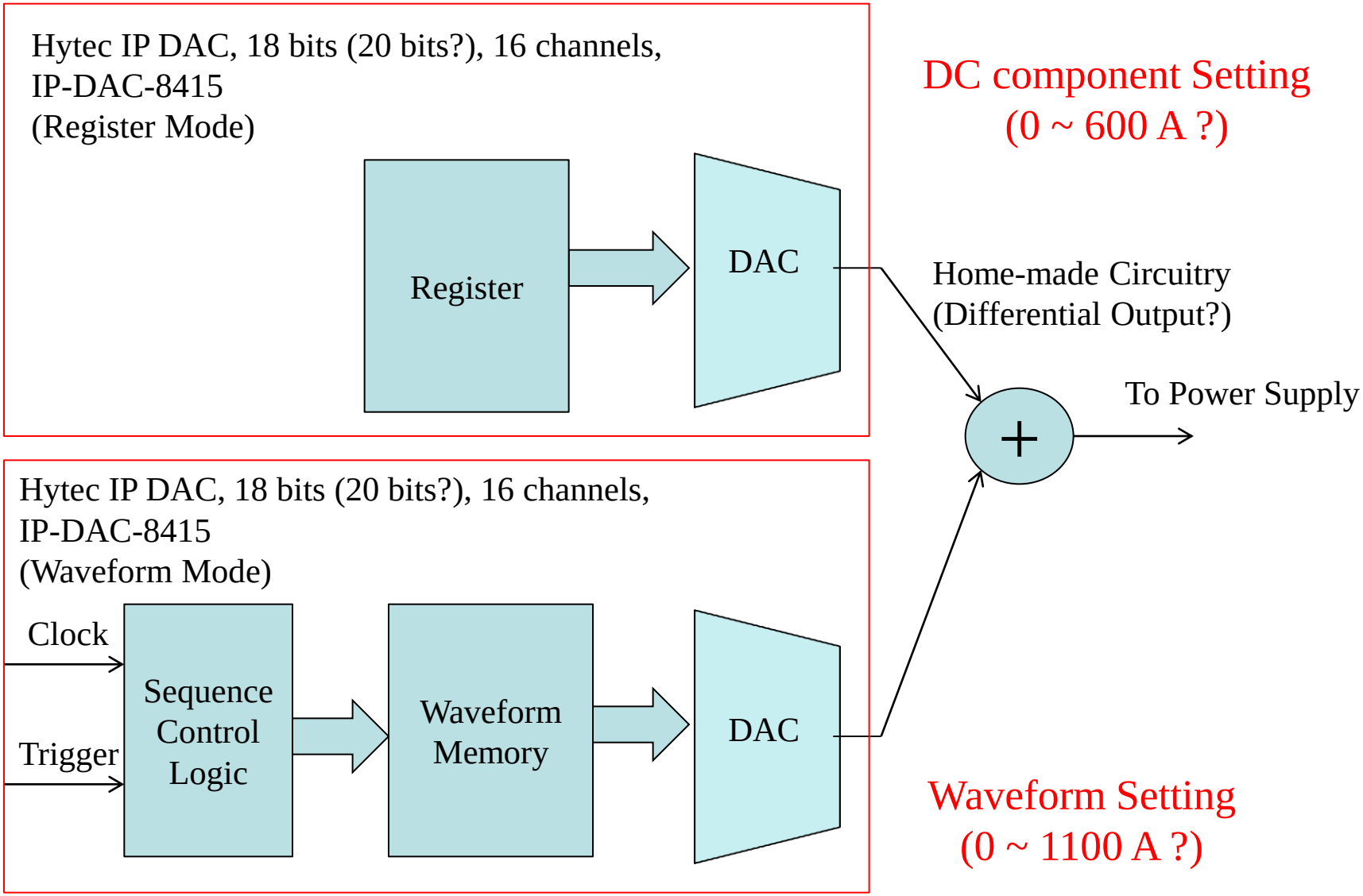
Subsystem Interface – Still in Progress (Subject to Change)

Subsystem	Control Interface	Connectivity to TPS Control Network	Responsibility
Timing system	EPICS IOCs	Direct	Control team
Linac	Linac control EPICS IOC	Direct	Linac's vendor
	Timing IOC	Direct	Control team
Pulsed magnet pulsers	EPICS IOC	Direct	Control ream
Magnet power supply	EPICS IOC	Direct	Control team
Diagnostics	EPICS IOCs	Router, Grouping EPICS IOCs, (BPM has its own private network)	Control team
RF system	RF group's own EPICS IOCs	EPICS Gateway	RF group
	EPICS IOCs (LLRF interface)	Direct	Control team
Cryogenics	Cryogenic own EPICS IOC	EPICS Gateway	Cryogenic group
Vacuum system	Vacuum group's EPICS IOC	EPICS Gateway	Vacuum group
Insertion devices	EPICS IOC	Direct	Control team
Front-end	Front-end own's EPICS IOC	EPICS Gateway	Front-end
Girder system	Girder owns's EPICS IOCs	EPICS Gateway	Girder system
Utility	Utility group own's EPICS IOC	EPICS Gateway	Utility
Radiation safety	Safety own system	EPICS Gateway	?
Beamline and experimental stations	Beamline group own EPICS IOCs	EPICS Gateway	Beamline and experimental stations

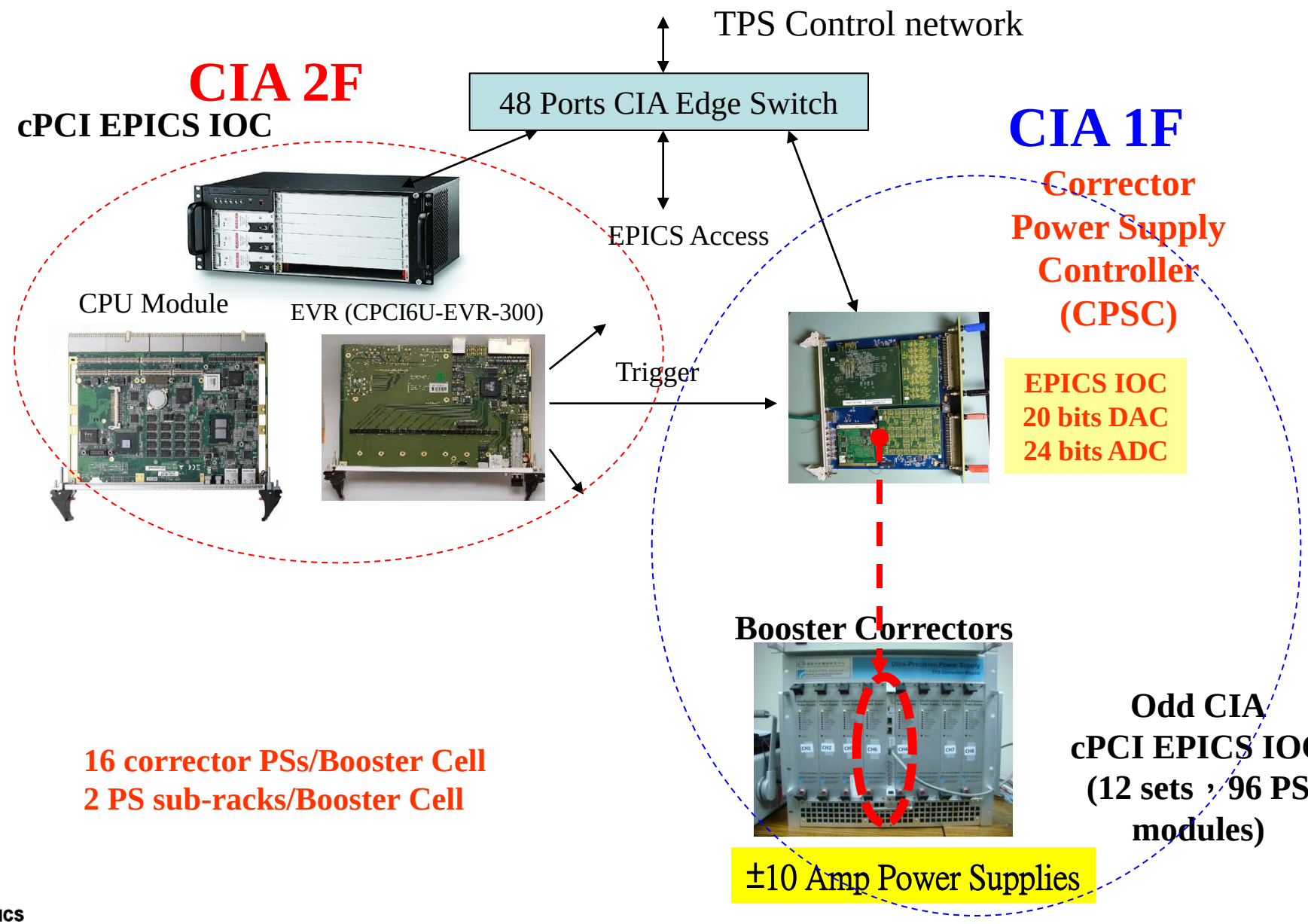
Booster Main Power Supply Control Interface (Subject to Change)



Solution for External Waveform for Booster Synchrotron Dipole Power Supply

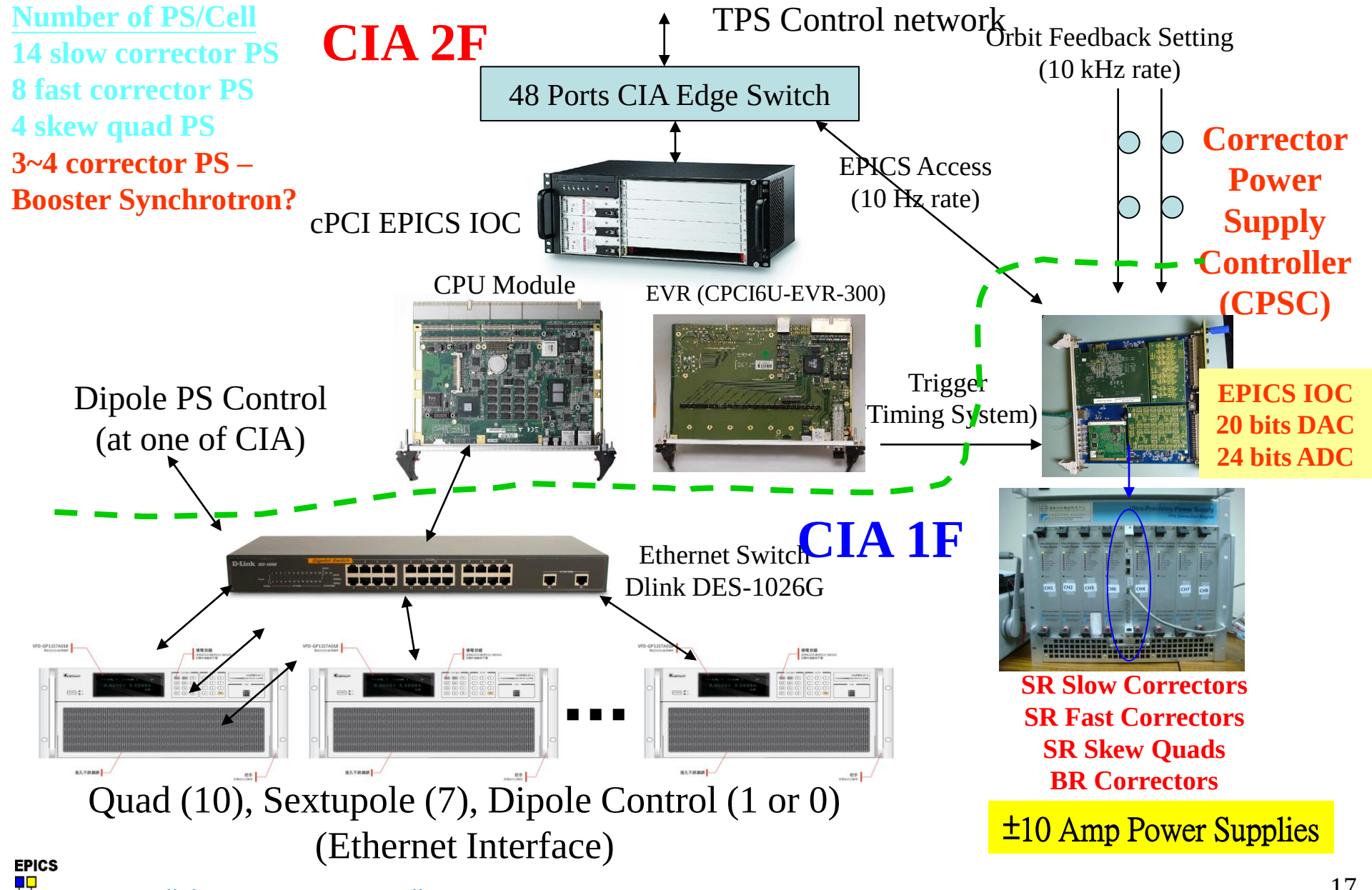


Booster Corrector Power Supply Control Environment (12 stations)

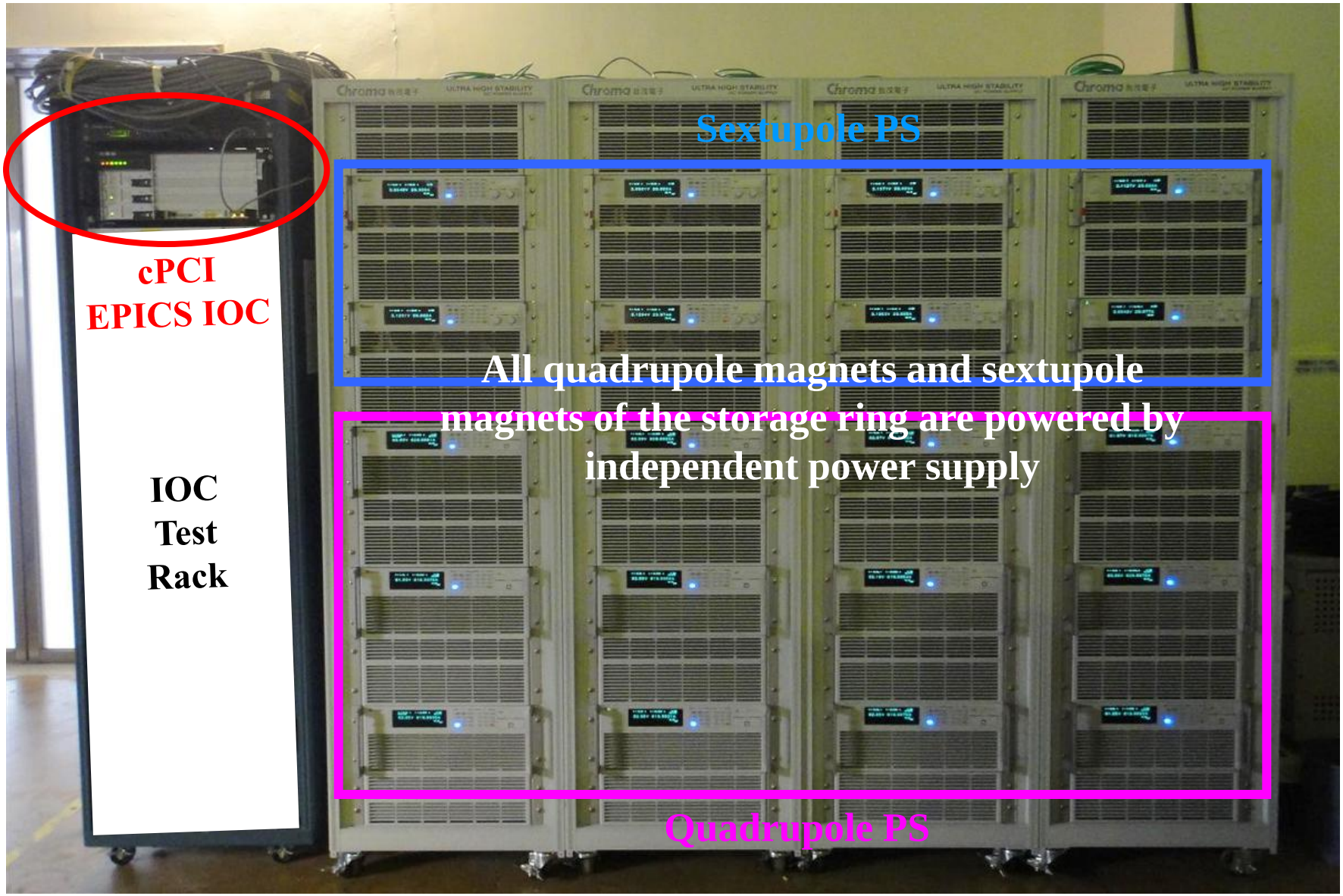


Storage Ring Power Supply Control Environment (24 stations)

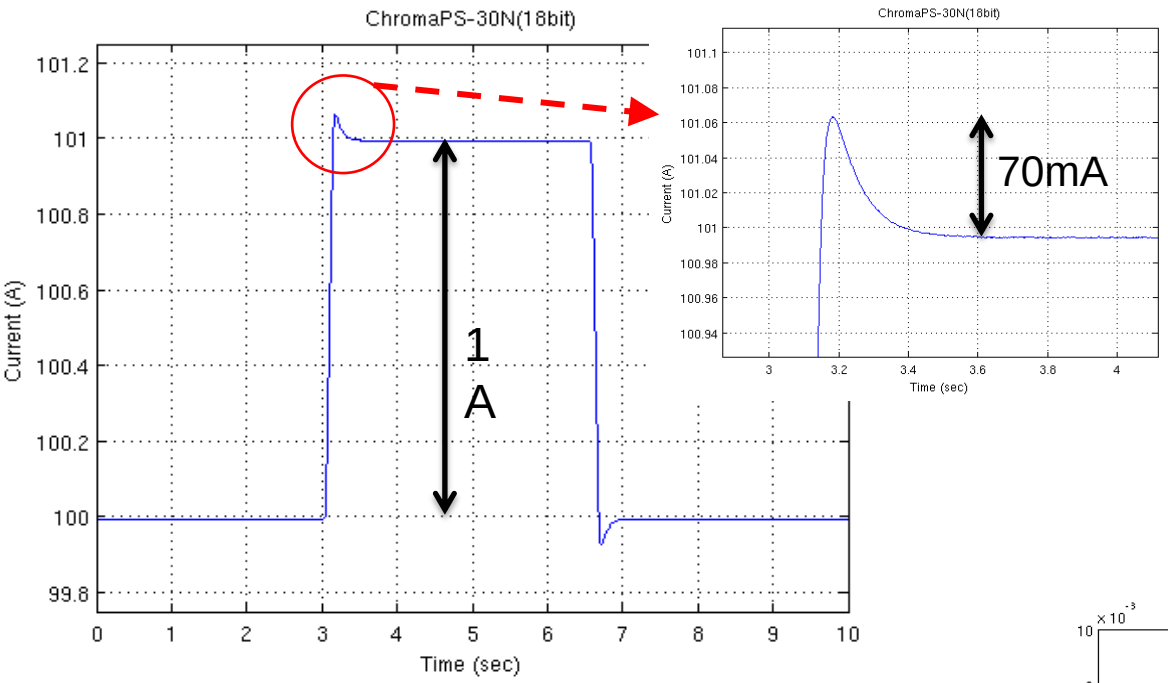
Number of PS/Cell
14 slow corrector PS
8 fast corrector PS
4 skew quad PS
3~4 corrector PS – Booster Synchrotron?



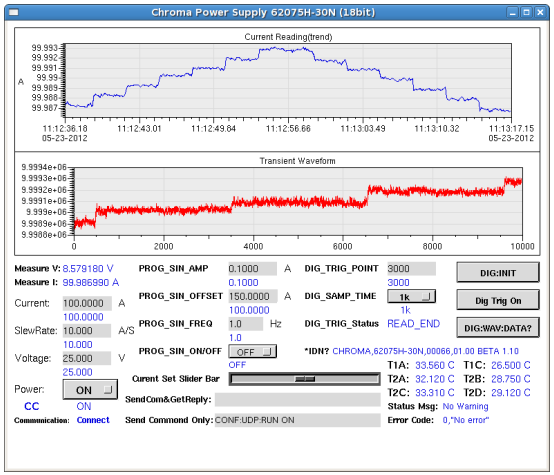
Quadrupole and Sextupole Power Supplies for One Cell Prepared for Test



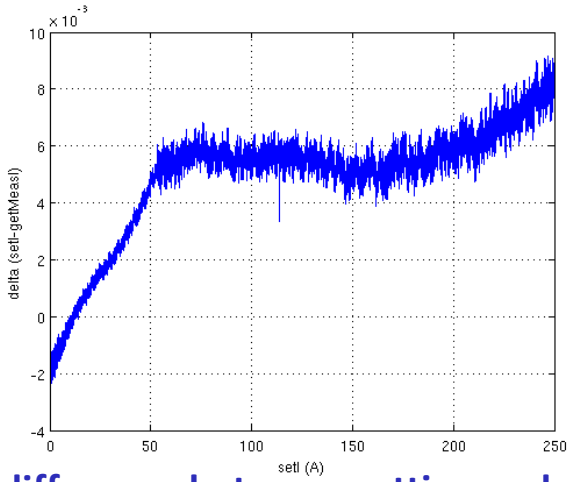
Performance Measurement of Quadrupole Power Supply



Transient waveform acquisition shows the overshot variation when quadrupole power supply current changed.

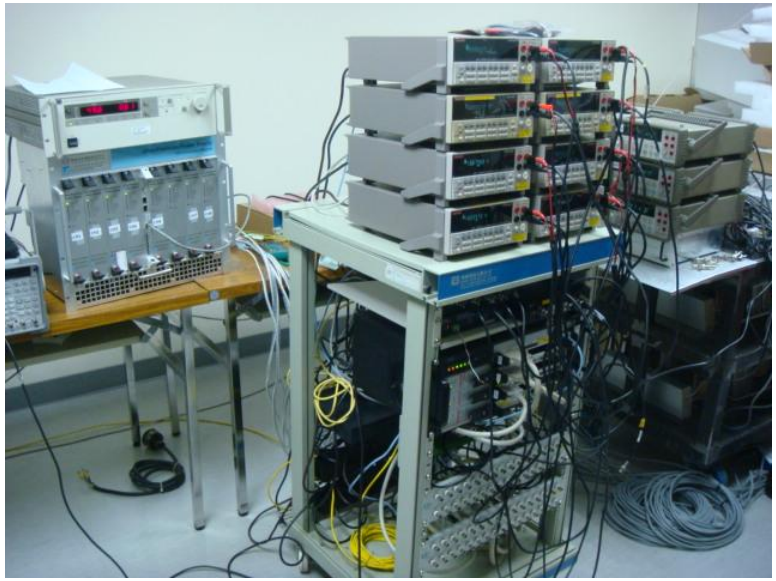


Transient waveform acquisition shows the current stability of quadrupole power supply is about ±1mA.

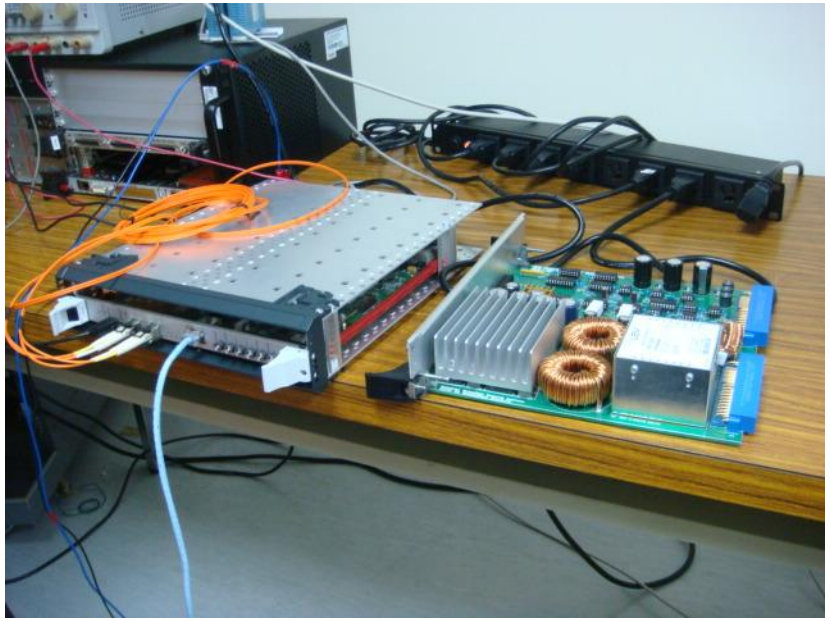


The difference between setting and reading current when setting current is from 1A to 250A with 1mA step.

Corrector Power Supplies Control Interface Prototype Test

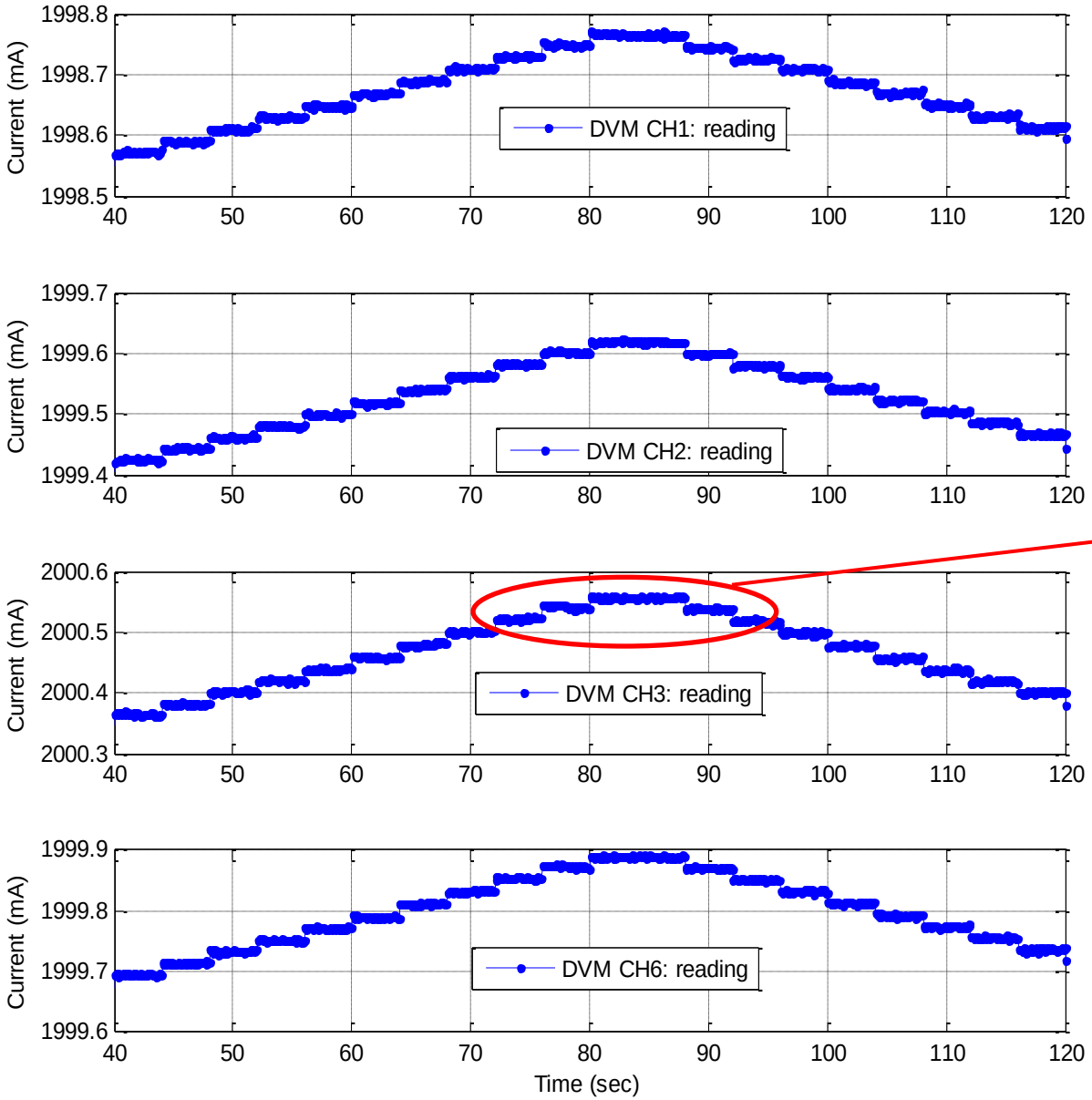


Works in proceed
Performance improvement
Software development

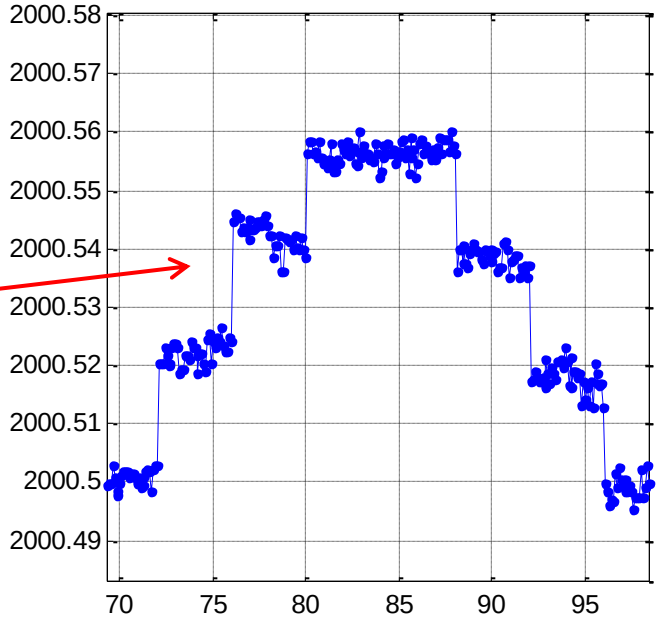


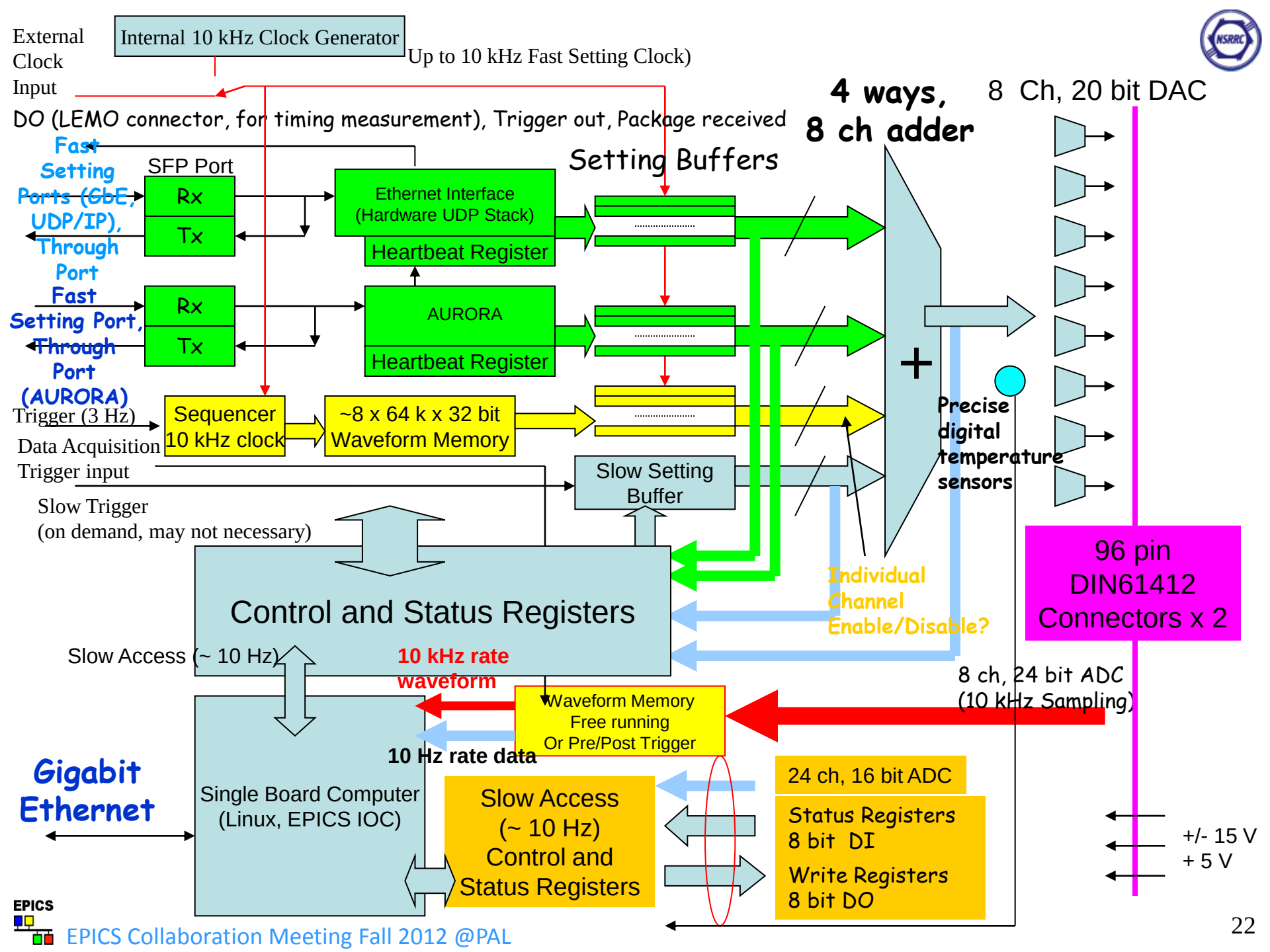
That's one small step for man, one giant leap for mankind.

20 uV step change observation at DVM



19 bit (20 bits – 1 sign bit) performance achieve!

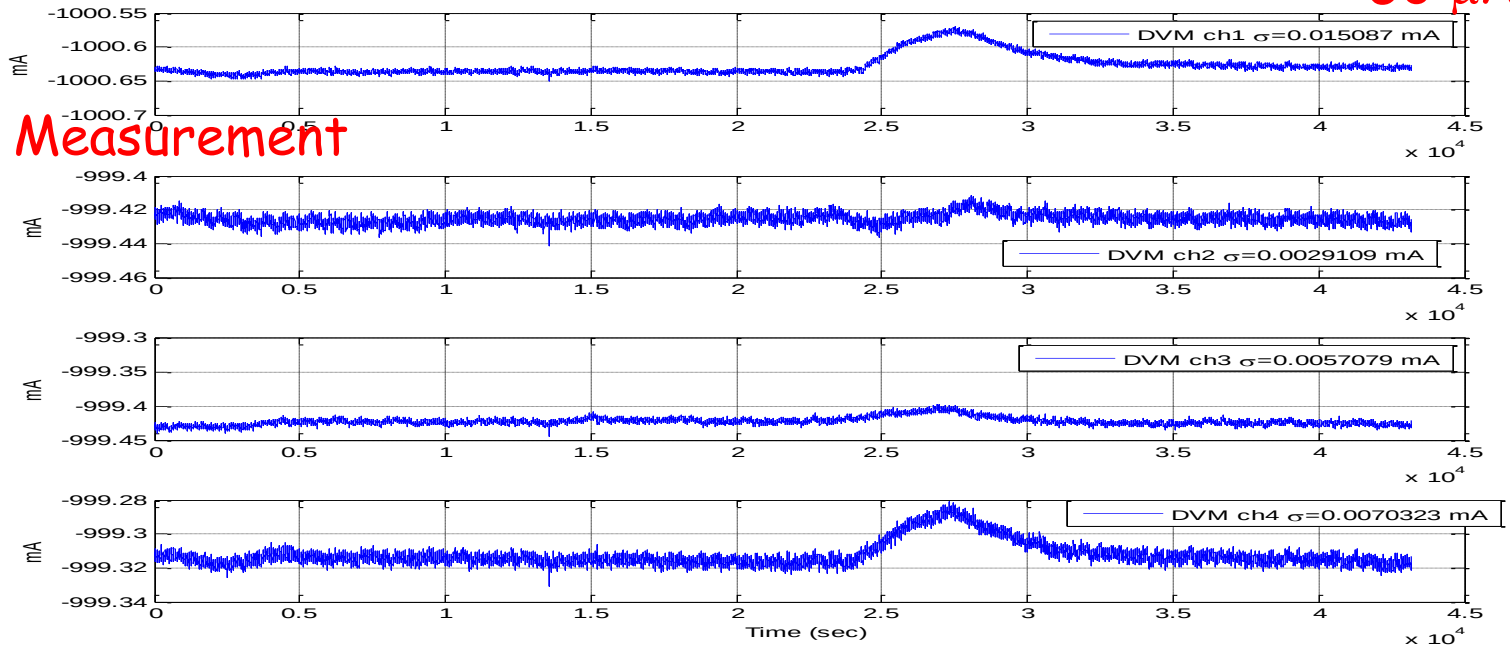



External Clock Input
Internal 10 kHz Clock Generator
Up to 10 kHz Fast Setting Clock)
DO (LEMO connector, for timing measurement), Trigger out, Package received
4 ways, 8 ch adder
8 Ch, 20 bit DAC
Fast Setting Ports (GbE, UDP/IP), Through Port
SFP Port
Rx
Tx
Ethernet Interface (Hardware UDP Stack)
Heartbeat Register
Setting Buffers
Fast Setting Port, Through Port (AURORA)
Rx
Tx
AURORA
Heartbeat Register
Trigger (3 Hz)
Sequencer 10 kHz clock
~8 x 64 k x 32 bit Waveform Memory
Data Acquisition Trigger input
Slow Setting Buffer
Slow Trigger (on demand, may not necessary)
Precise digital temperature sensors
Control and Status Registers
Individual Channel Enable/Disable?
96 pin DIN61412 Connectors x 2
Slow Access (~ 10 Hz)
10 kHz rate waveform
8 ch, 24 bit ADC (10 kHz Sampling)
Waveform Memory Free running Or Pre/Post Trigger
10 Hz rate data
Gigabit Ethernet
Single Board Computer (Linux, EPICS IOC)
Slow Access (~ 10 Hz) Control and Status Registers
24 ch, 16 bit ADC
Status Registers 8 bit DI
Write Registers 8 bit DO
+/- 15 V
+ 5 V

Ambient Temperature Effects

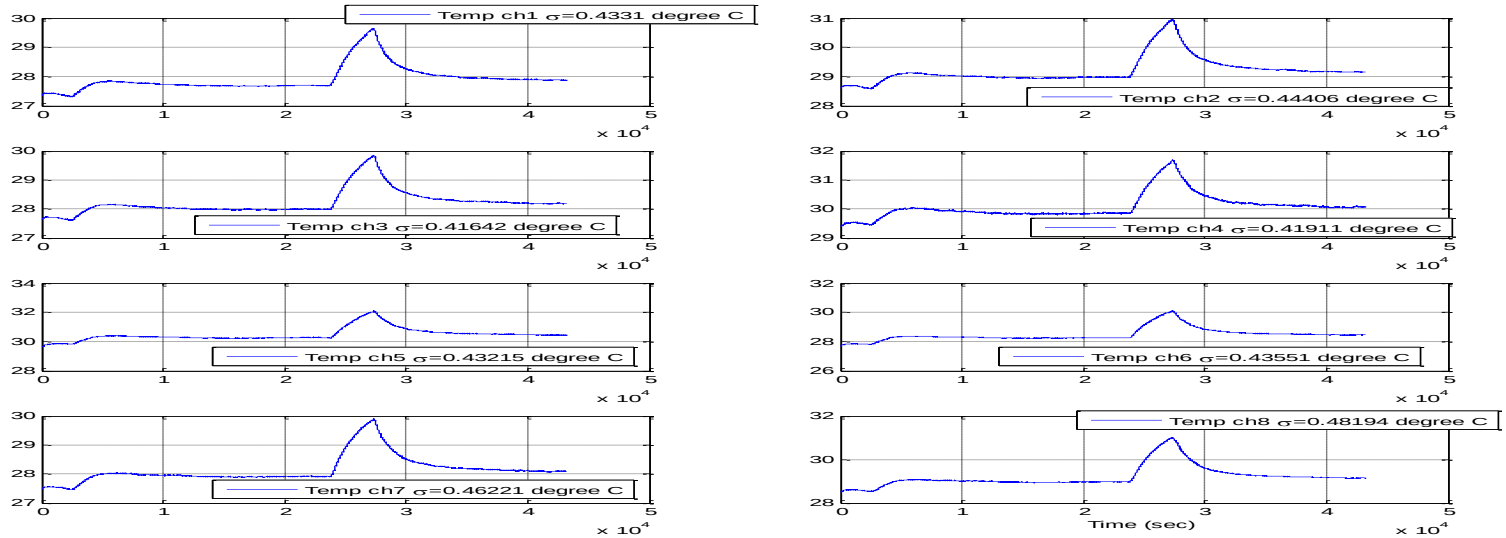
50 μA/div

DVM Measurement

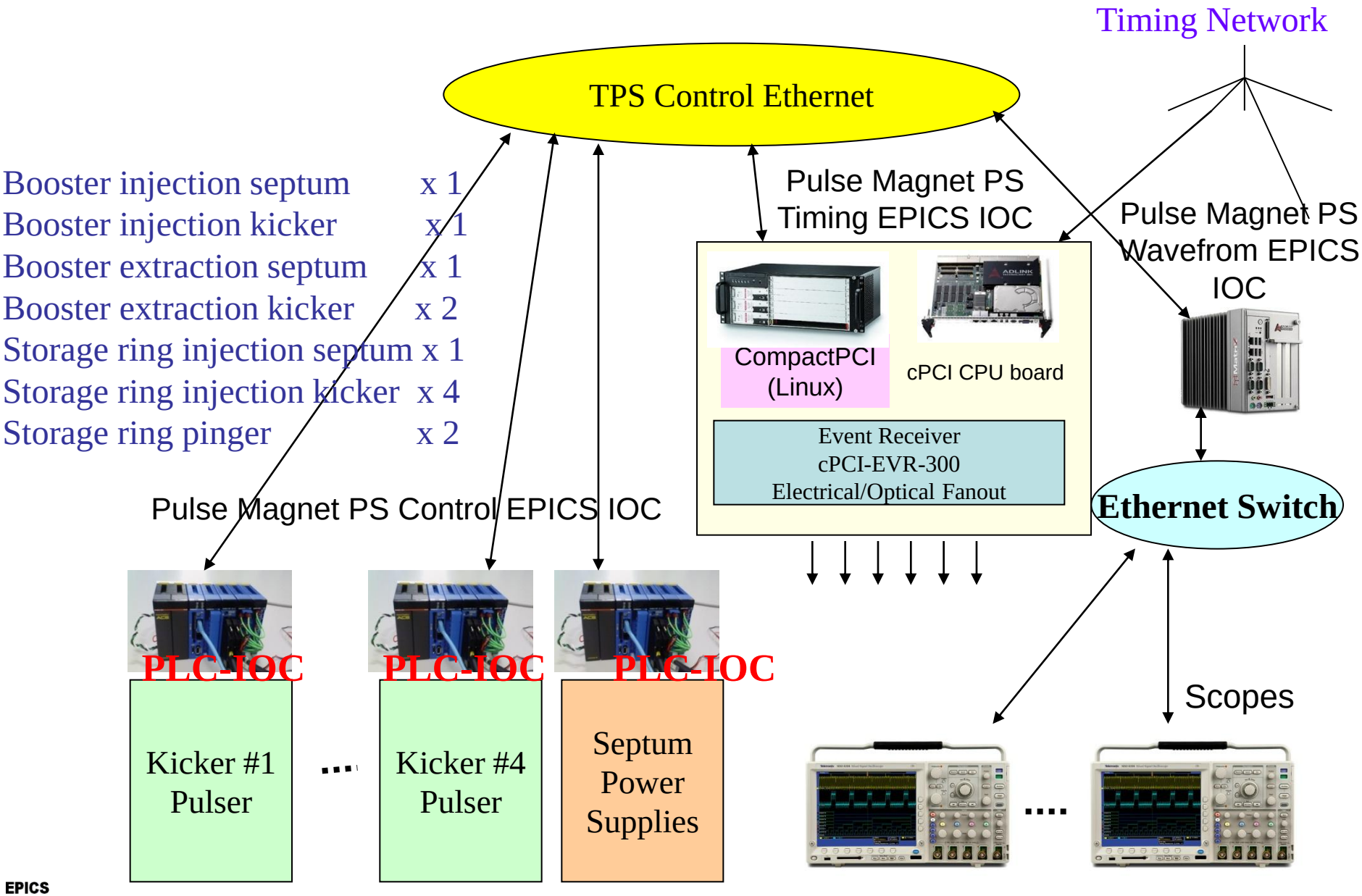


Temperature of PS module

1°C/div



Pulse Magnets' Pulser Control Interface



Pulse Magnets' Power Supply Control Interface – cont.

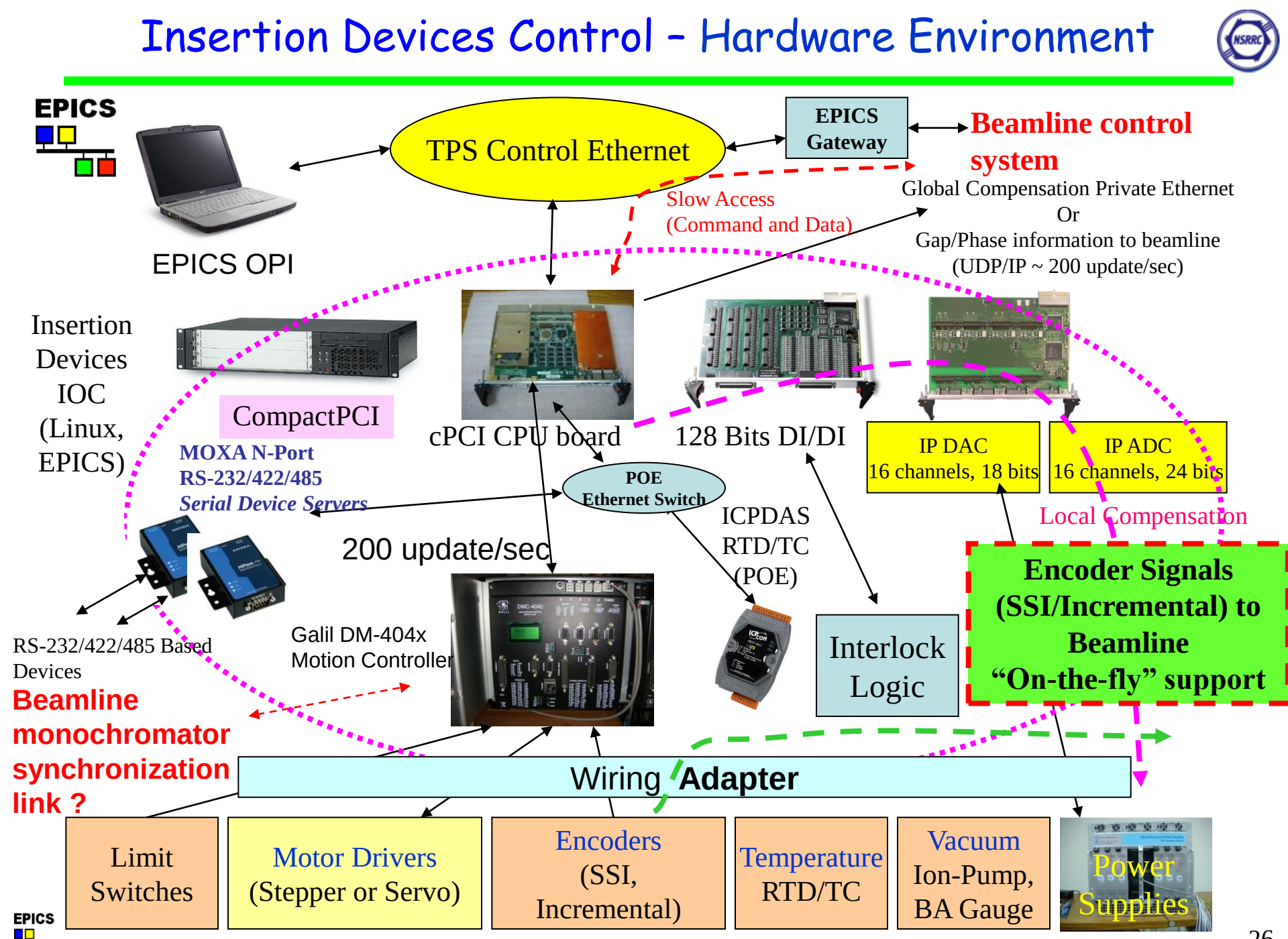
Pulse magnets
pulser control EPICS IOCs

Waveform Acquisition

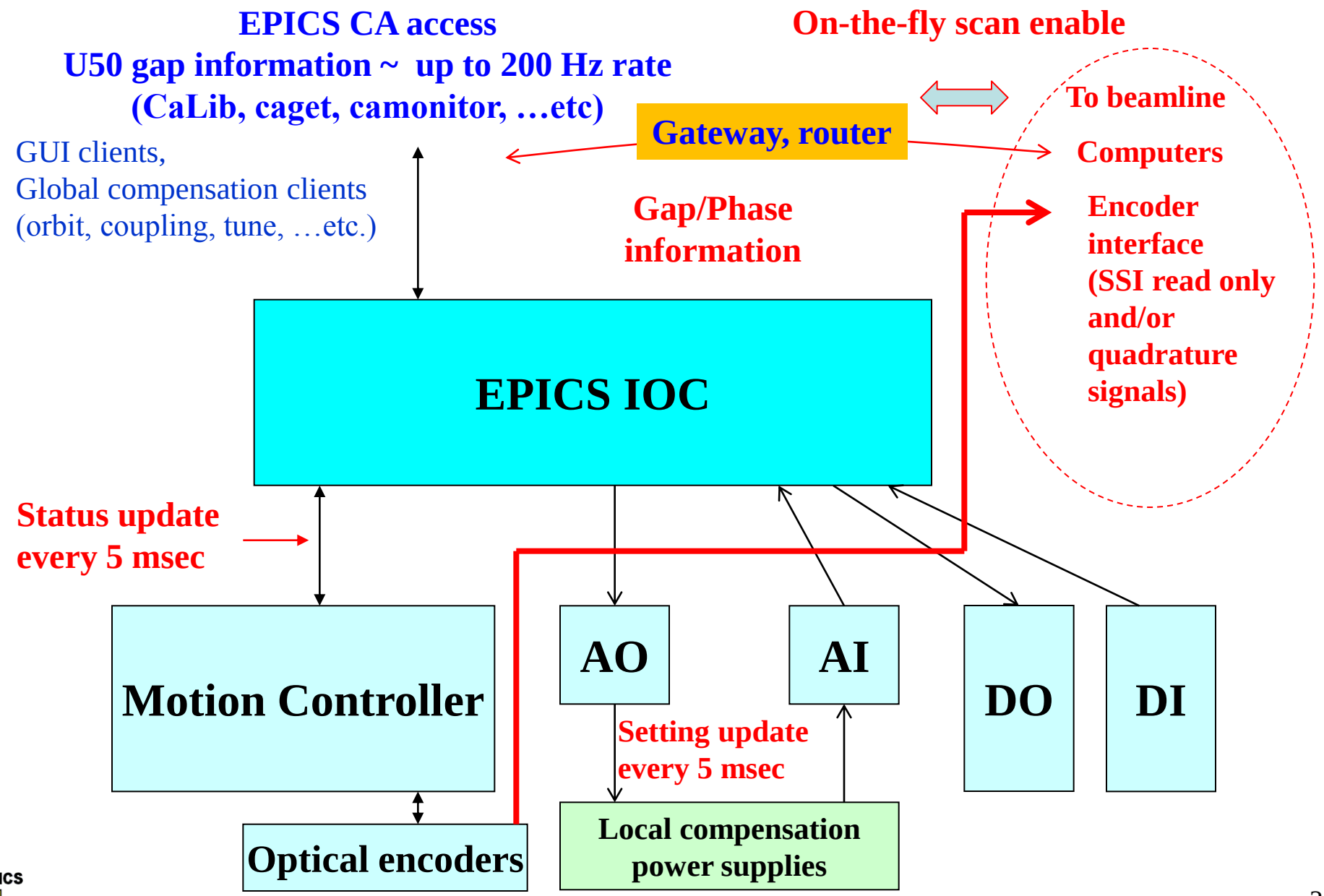
Timing

Booster injection septum	x 1
Booster injection kicker	x 1
Booster extraction septum	x 1
Booster extraction kicker	x 2
Storage ring injection septum	x 1
Storage ring injection kicker	x 4
Storage ring pinger	x 2

Insertion Devices Control – Hardware Environment

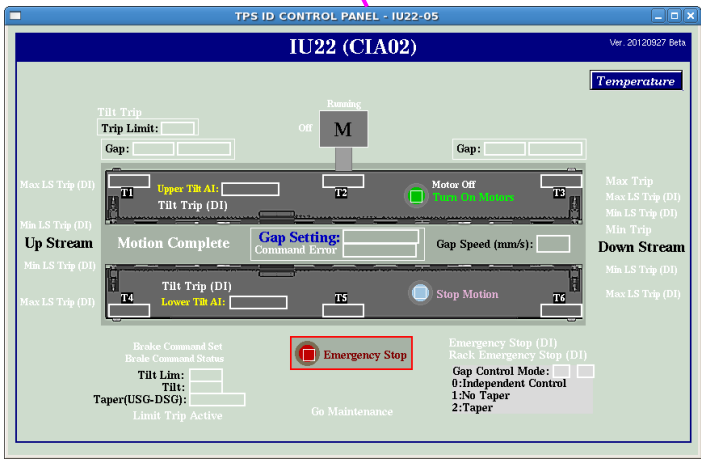


TPS Insertion Devices Control Environment



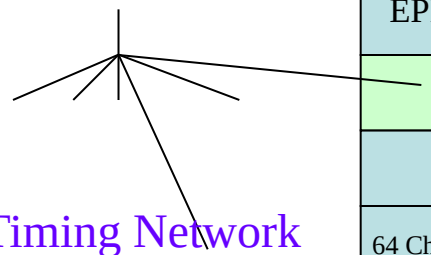
ID Controls (2012-2013)

- 1 M APU testbed (Done, 2012)
- U50 Rebuild , re-build controls to EPICS (Done, 2012.08)
- U90 Rebuild , re-build controls to EPICS (Plan, 2013~2015)
- EPU46 (Current control environment is in TLS system,
  re-build to EPICS is scheduled in 2013.)
- EPU48 x 2 sets (in construction, 2013)
- IU22 (2m) x 2 sets (late 2012~early 2013)
- IU22 (3m) x 4 Single servo motor
- IUT22 (3 m) x 1 Two servo motors



Storage Ring RF System Interface (@ RF #2 & RF# 3, total 2 sets)

	LLRF	SRF	Transmitter
Digital Input	x 48	x 128	(EPICS)
Digital Output	x 16	x 16	
ADC	x 48	x 400	
DAC	x 16	x 16	



BRF #1	CIA #12
SRF #1	(RF #1) CIA #14
SRF #2	(RF #2) CIA #15
SRF #3	(RF #3) CIA #17
Landau Cavity	(RF #4) CIA #18

TPS Control Network
172.20.xx.yy

172.20.15.40

EPICS IOC (172.20.15.41, 172.20.17.41)

EVR (CPCI6U-EVR-300)

128 Bits DI/DO

64 Channels ADC (172.20.15.42 , 172.20.17.42)

IP Carrier

16 channels, 18 bits IP-DAC-8415

Trigger

EPICS Gateway

RF Network

EPICS IOC (ACQ196)

EPICS IOC (ACQ196)

EPICS IOC (ACQ196)

EPICS IOC (ACQ196)

EPICS IOC Transmitter

ACQ196 (transition, non-EPICS)

Siemens S7-300 PLC (Thales)

RF Group

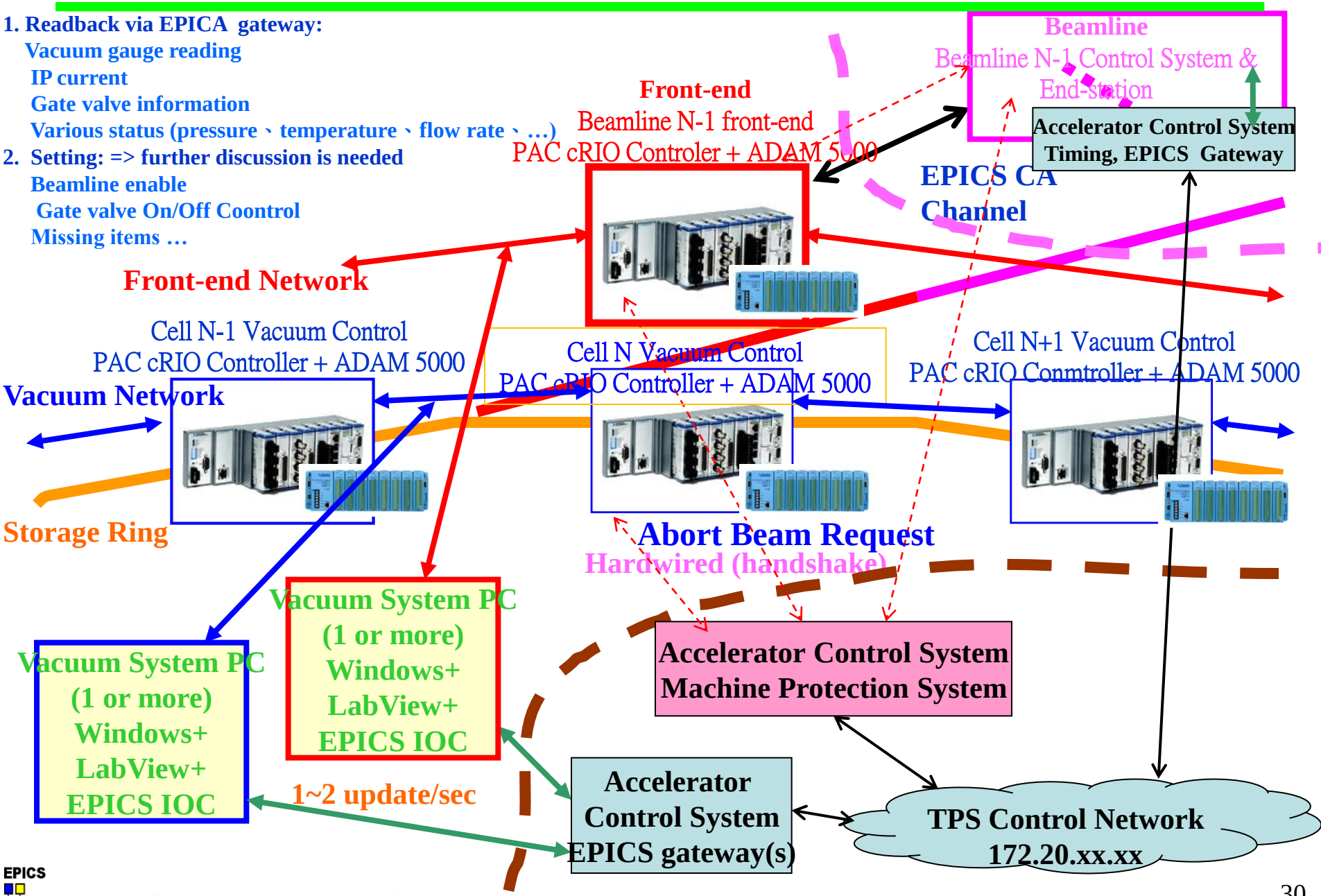
Cryogenic Electronics

Storage ring RF system LLRF

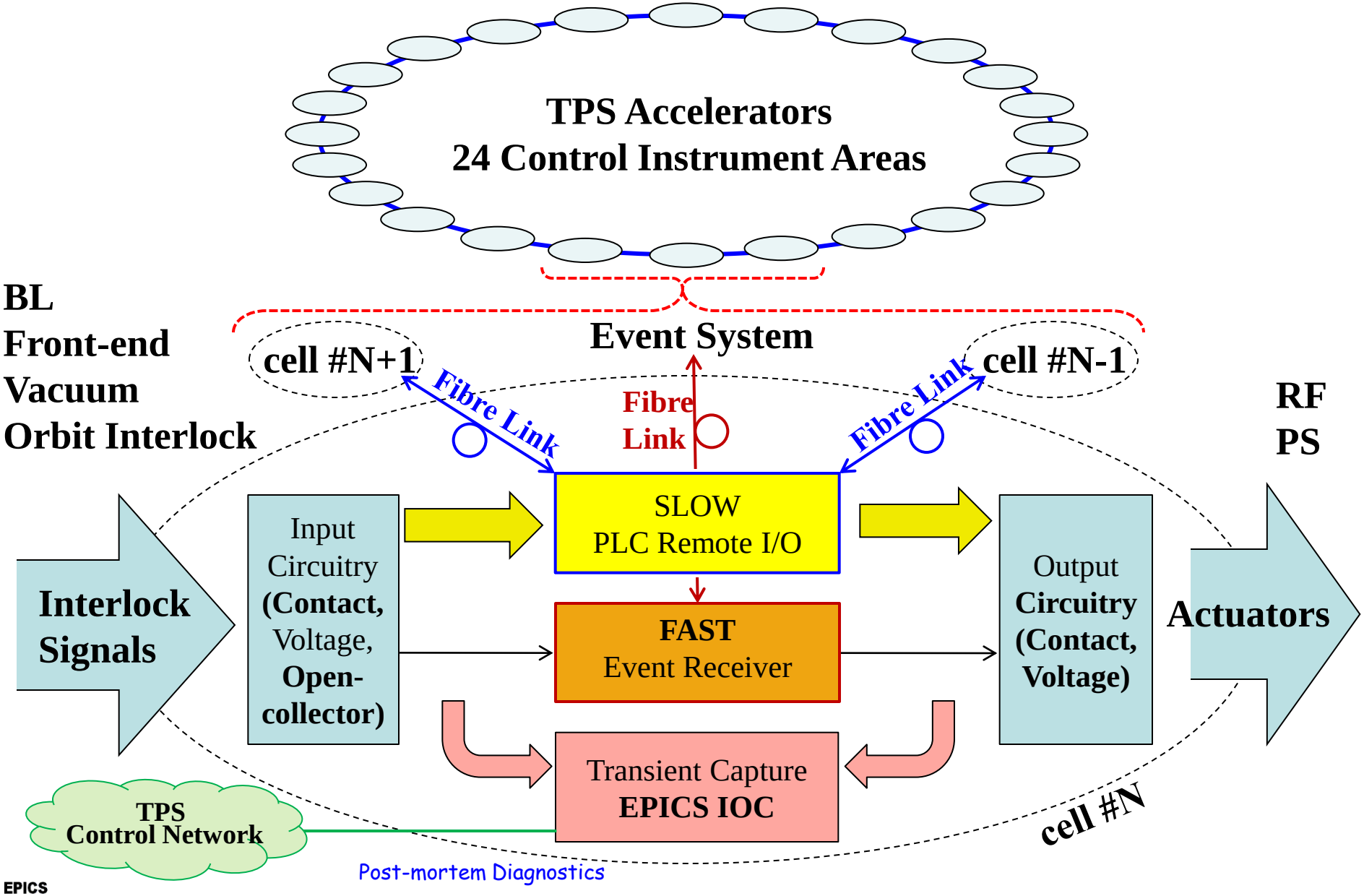
RF Transmitter (Thales)

Vacuum System、Front-end system、Beamline Control System Interface

1. Readback via EPICA gateway:
   - Vacuum gauge reading
   - IP current
   - Gate valve information
   - Various status (pressure、temperature、flow rate、…)
2. Setting: => further discussion is needed
   - Beamline enable
   - Gate valve On/Off Coontrol
   - Missing items …



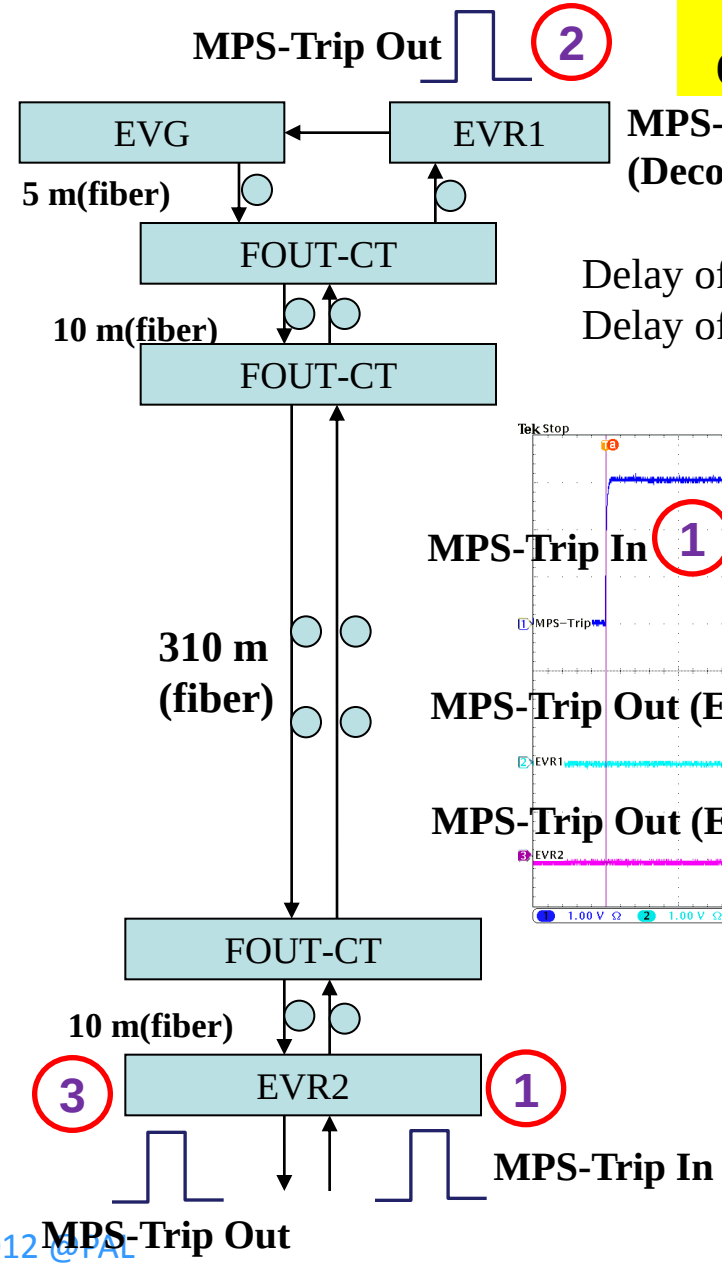
Machine Protection System Network



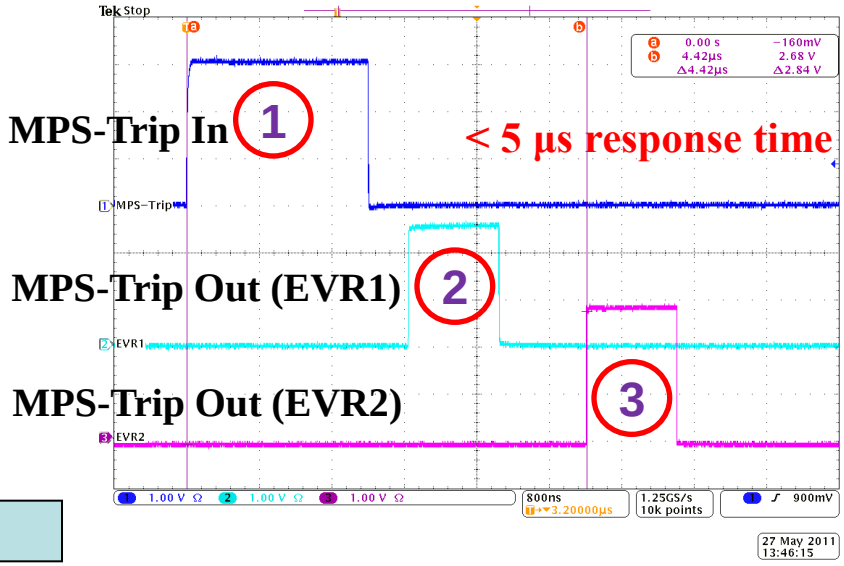
Machine Protection System Test

Slow MPS test bed
(8 msec response time guarantee)

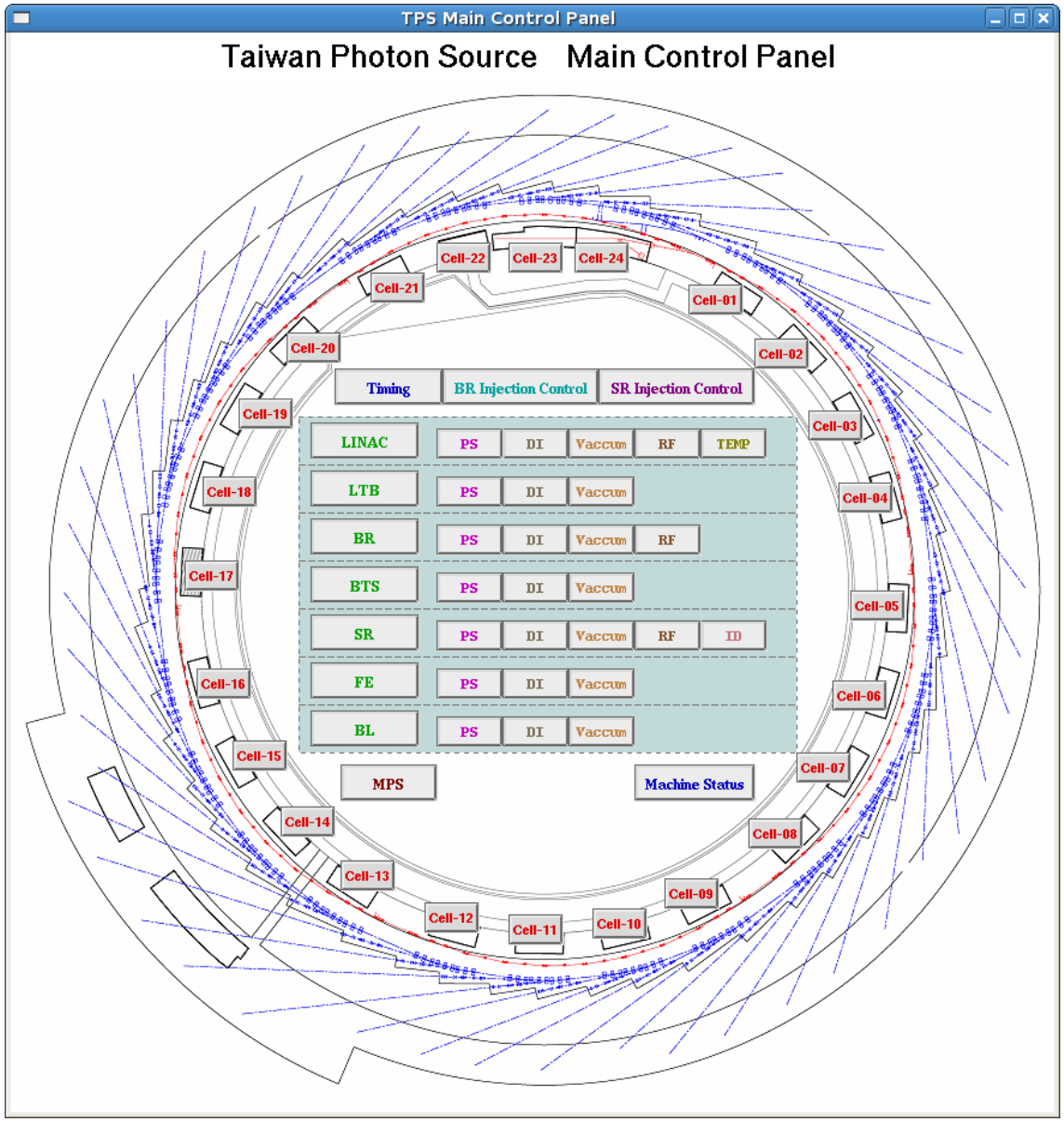
Fast MPS test bed
(5 μsec response time guarantee)



Delay of uplink：2.45 μs
Delay of uplink and downlink：4.42 μs

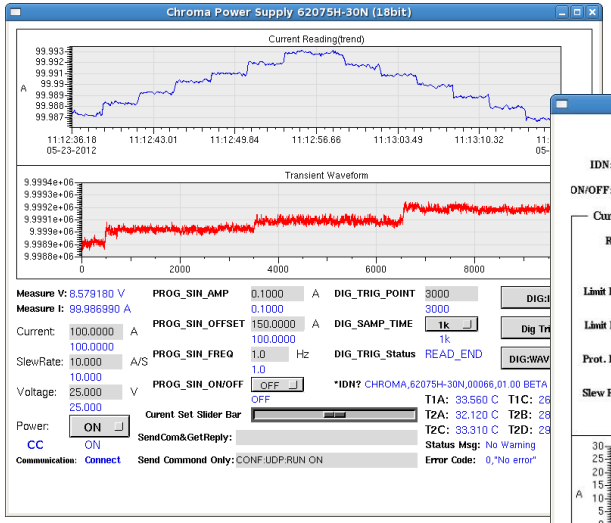


GUI Development – TPS Launching Main page (EDM based)

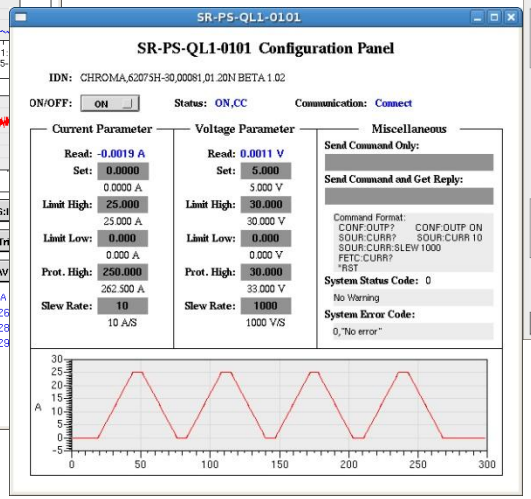


GUI Development (EDM based)

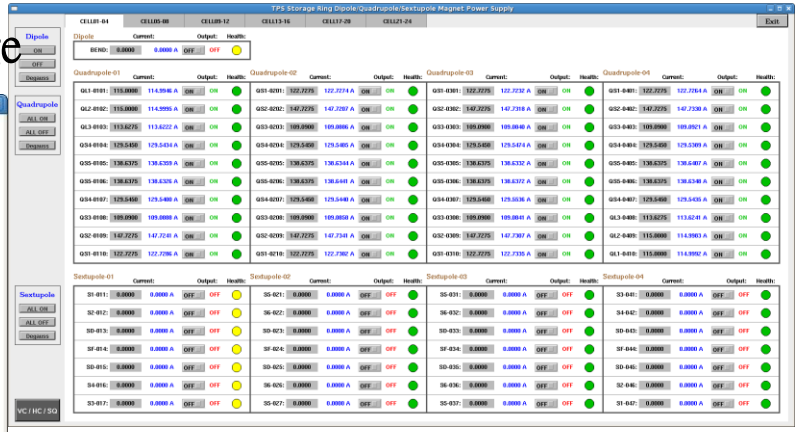
Single PS Control Page



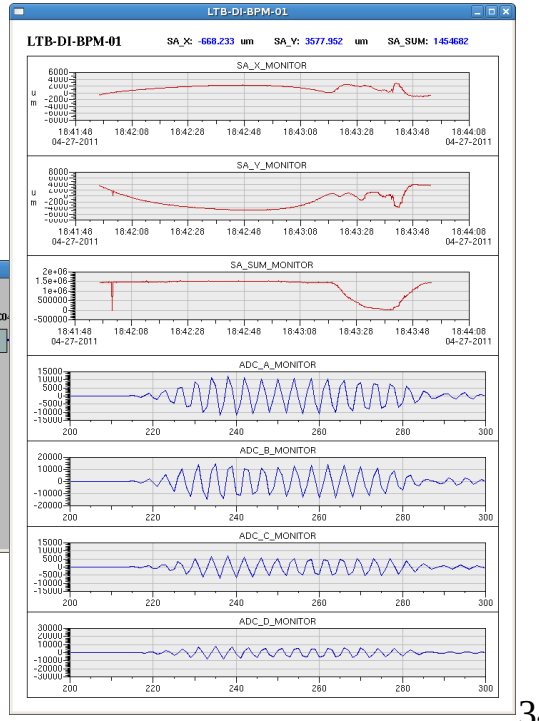
Degaussing Control Page



SR all PS launch page

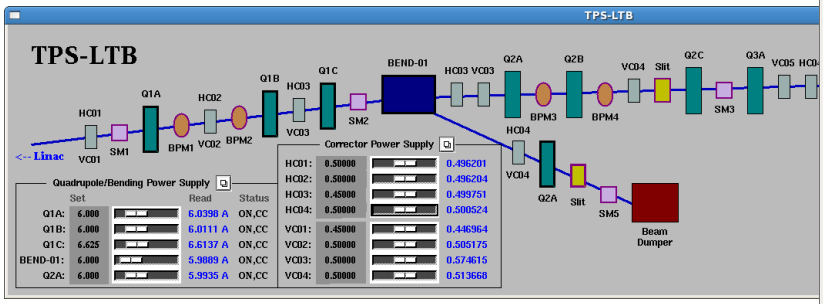


Single Pass BPM



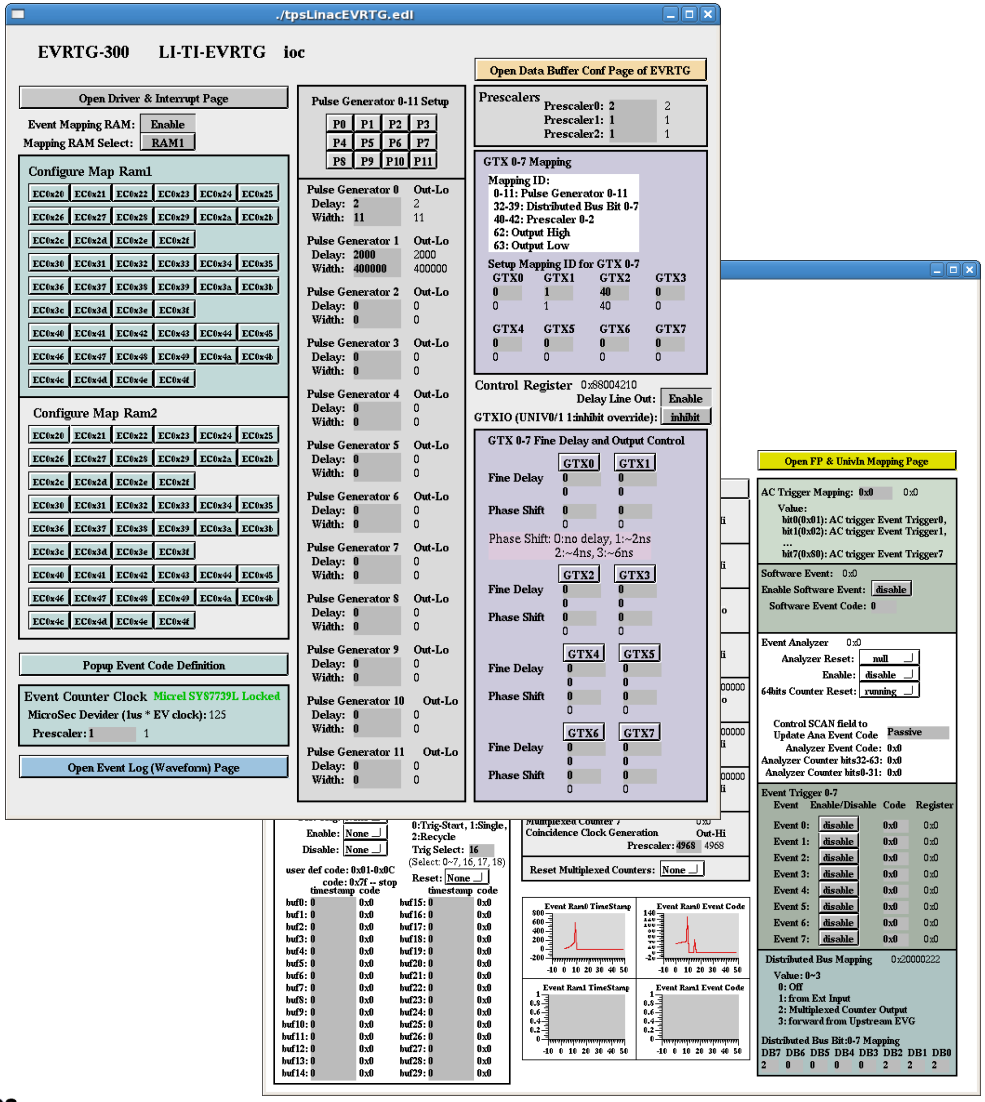
Kicker Pulser Control

TPS LTB Test Page

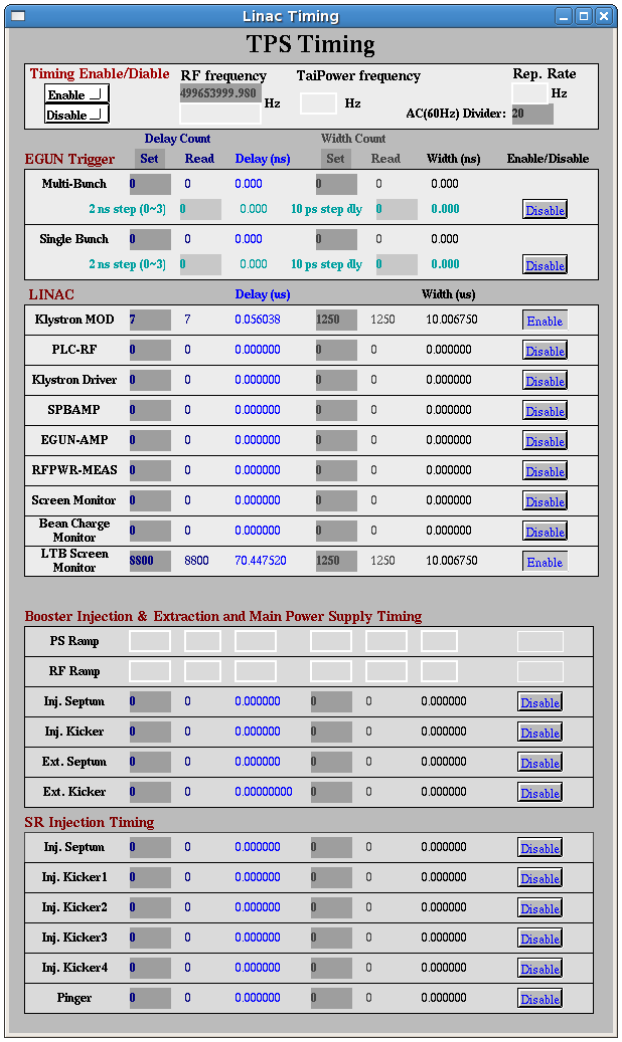


GUI Development (EDM based) – cont.

TPS Timing Hardware Configuration Page

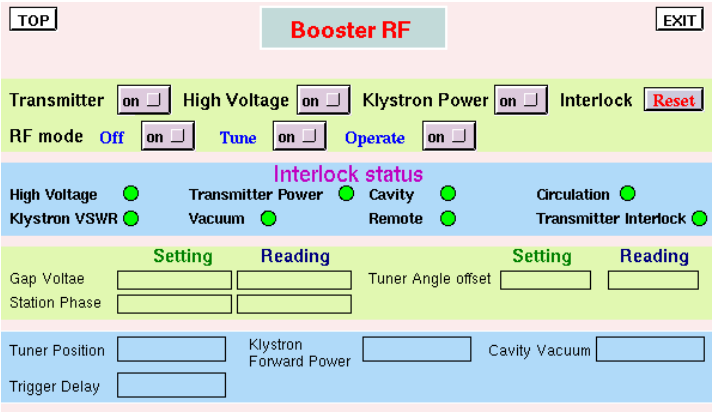


TPS Timing Summary Page

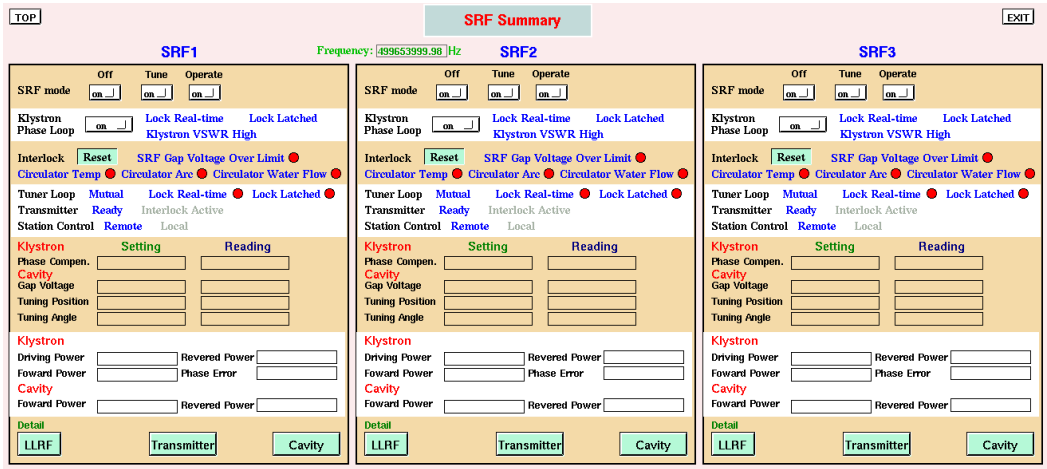


GUI Development - Conceptual RF Control Main Pages and Vacuum Pressure Distribution

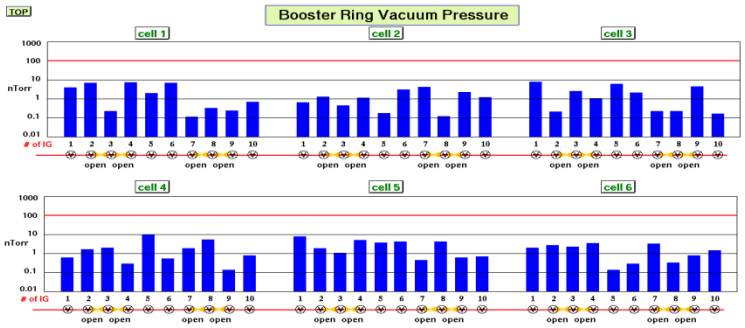
Booster



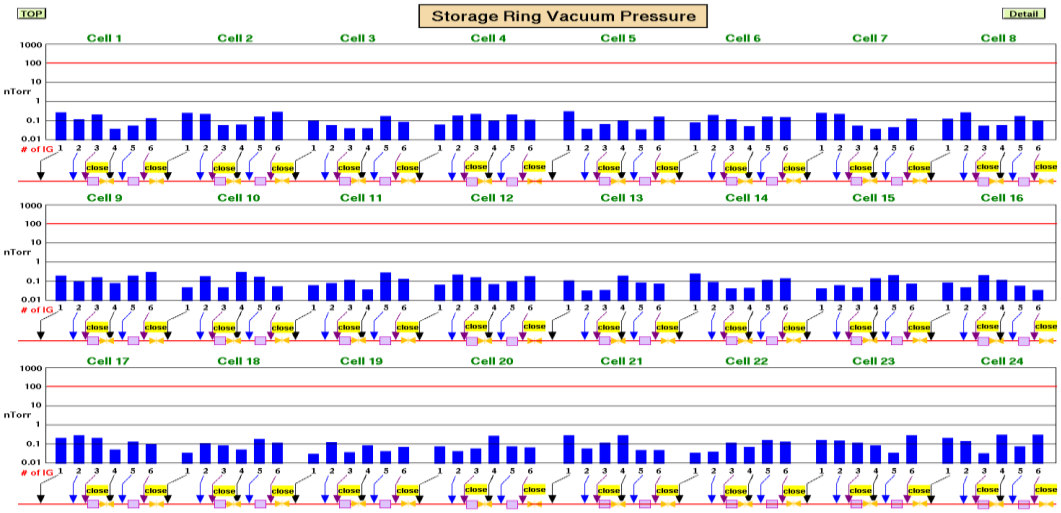
Storage Ring



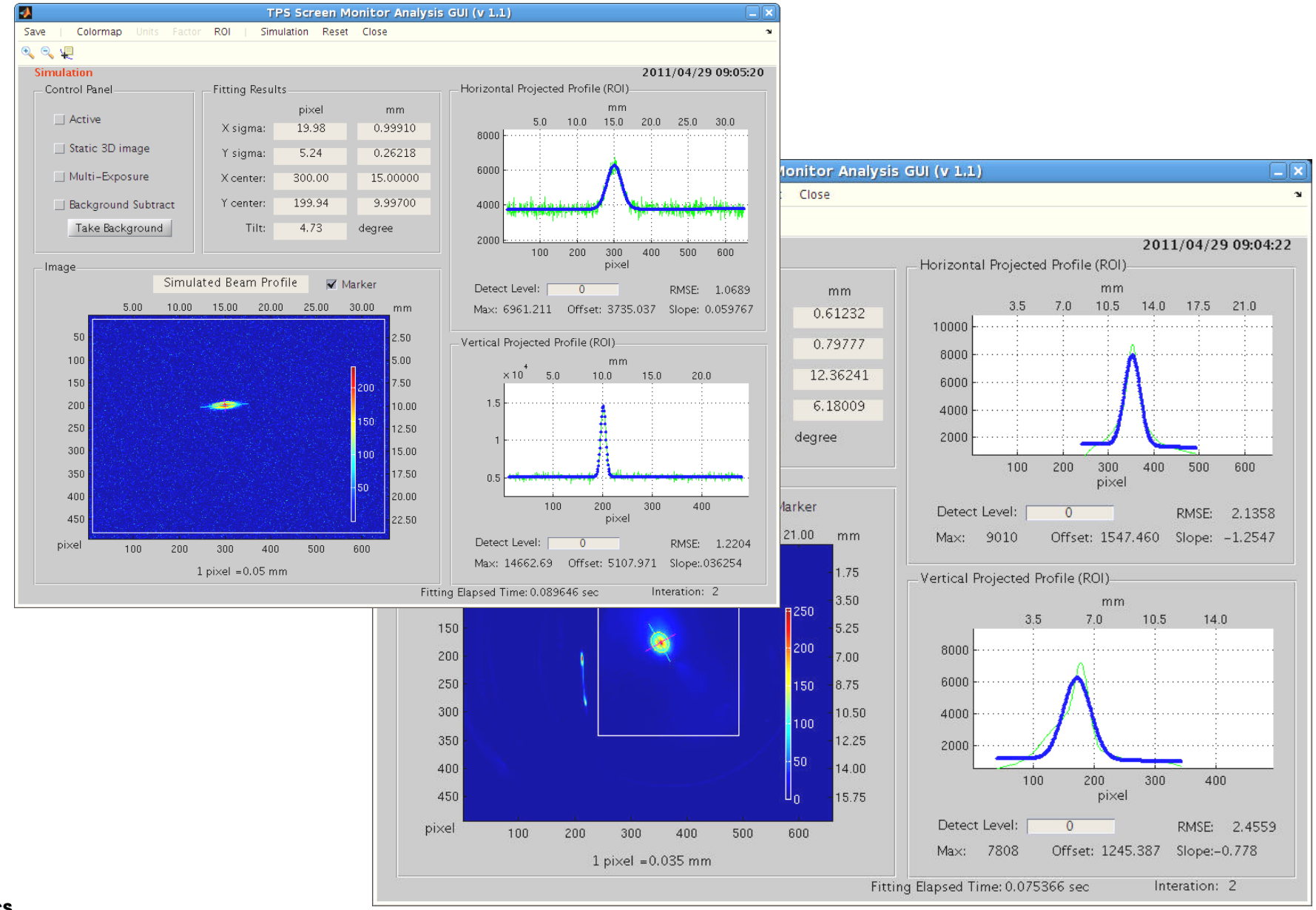
Booster



Storage Ring



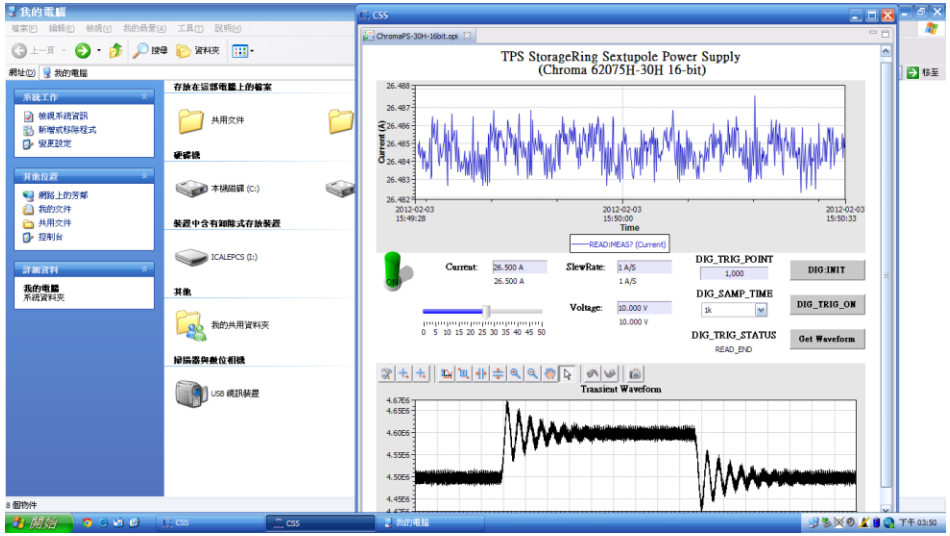
GUI Development – Matlab Based Screen Monitor Data Analysis



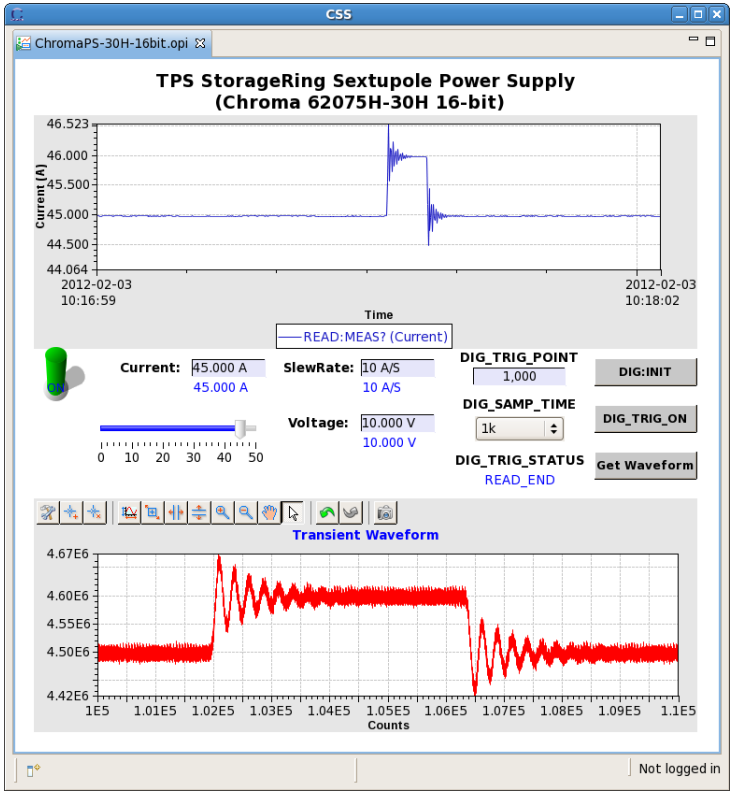
GUI Development - CSS – BOY based

Chroma Sextupole PS Control Page

Windows Version



Linux Version

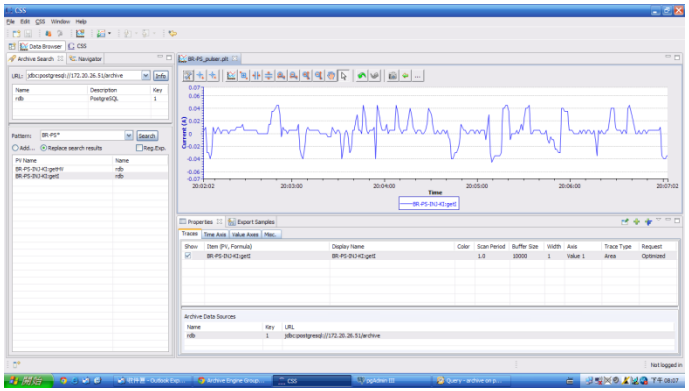


Database Solution

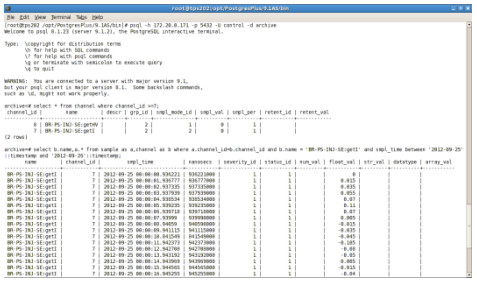
Store machine parameters
Store configuration parameters
Store runtime data
Uniform authentication, uniform data access, good data integrality
Remote access
RDB : PostgreSQL
=> ITER, KEK, …increase popularity recently
=> Archive data storage
=> Lattice and parameter management

Archiver/Browser Solution (Ready at 3th Quarter of 2012)

2012 Ready



DataBrowser (Historic Data, Live Data)



Config.xml

ArchiveConfigTool

CSS Based OPI

PostgreSQL

Other tools for configure & access: Java, C/C++, Matlab, Labview, …

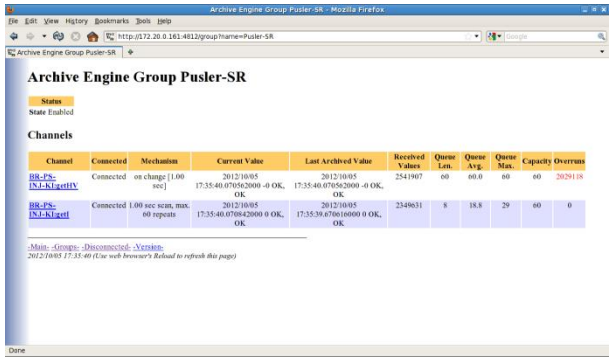
Configure

Samples

Archive Engine

EPICS IOCs

SAN Storage
EMC VNX5300
+
Enterprise DB
(PostgreSQL)



E-Log Study

Several E-Log solution are in study:

weblogs

PSI ELOG

DESY

Olog (FRIB/NSLS-II)

Zlog (KEKB)

Tlog (in-house development, still in study) ?

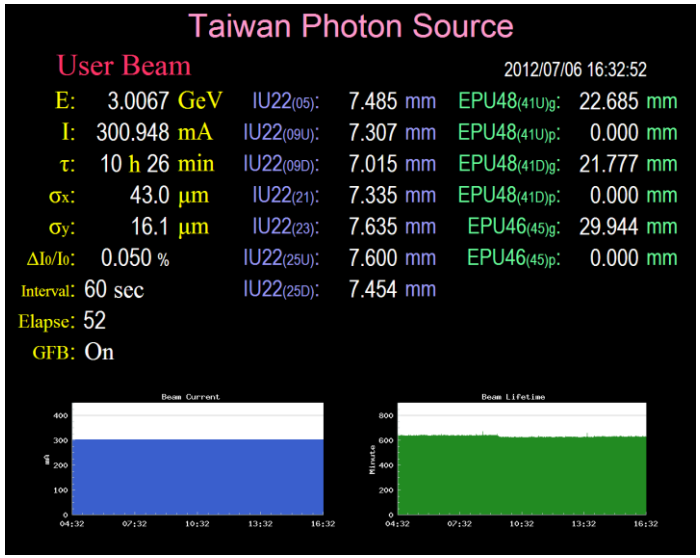
Machine Status Web Page

Web based machine status

Accelerator operation status

ID status

Beam current vs. lifetime



Simulated Page

Application Programming Interface

EPICS CA Clients (C/C++, Matlab, JAVA, Python, LabVIEW, …)

High Level Physics Applications

=> Depend upon preference of Machine Physicists

Diagnostics related applications

C, C++, Matlab, …

Technical system support

C, C++, Matlab, LabVIEW, JAVA, Various scripting languages, …

Miscellaneous applications

JAVA, PHP, Python, ….

Commissioning and Operation Related Applications

- Basic EPICS environment
- Subsystem control
  - Device supports and device drivers
  - User interface (control and status monitoring)
  - Cold start, warm up, shutdown, operation check
  - Save and restore
- Subsystem application programs
  - Gun processing
  - Power supply performance check
  - BPM system diagnostic
  - EPICS IOCs house keeping
  - Network monitoring
  - … etc.
- High level applications
  - Beam diagnostic related
  - ….

Commissioning and Operation Related Applications - Examples

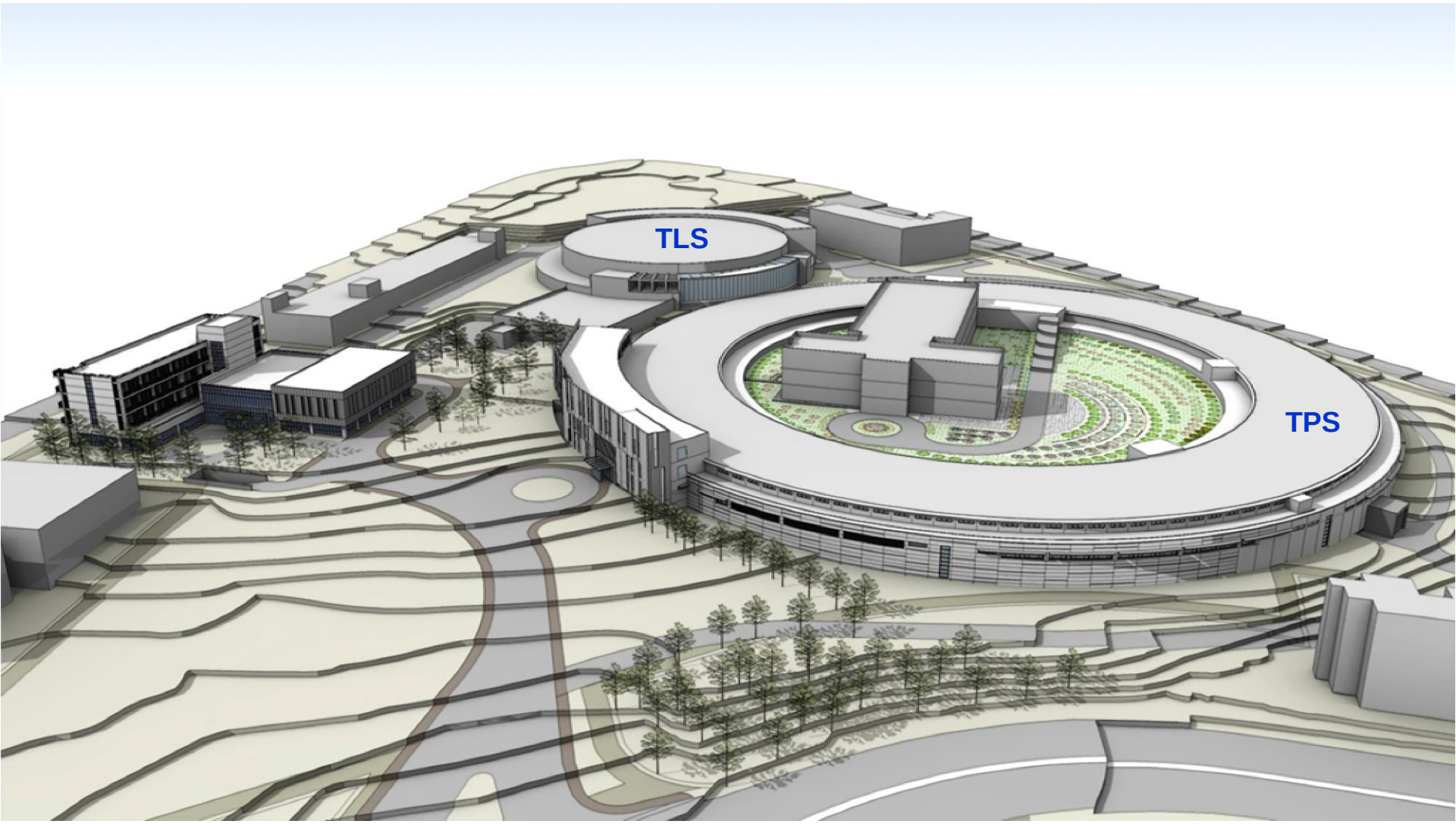
EPICS IOCs house keeping
Network traffic monitoring and diagnostics
Subsystem cold start, warm up, processing, …., shutdown
Magnet degaussing
Save/restore for subsystems
Lattice management
    Save/restore, …
    LTB, BTS, Booster Synchrotron, Storage Ring, …etc.
Booster synchrotron ramping waveform management
    Editing
    Measurement
    Correction
Trend display
Timing control
Waveform display: Pulse magnet current waveform、RF waveform, beam waveform、…
Image display: screen monitor, synchrotron radiation monitor, streak camera, …etc.

Commissioning and Operation Related Applications – Examples (cont)

- Injection control
  - Bucket addressing
  - Injection mode: Injection, Top-up injection
  - Filling pattern control and feedback
    - Multi-bunch
    - Single bunch
    - Multiple single bunch (Isolated bunch)
    - Exotic filling pattern - Camshaft mode, Repeat Camshaft mode, …. Etc.
- Feed-forward table management
- Orbit feedback supports
- Alarm checking
- Archiver and browser
- Safety system status
- Beamline related applications
- Machine status web page
- ….

Summary

- Infrastructure are frozen.
- Major procurements are in proceeding.
- Last chance to revised all major items.
- All difficult technology are addressed.
- Installation and commissioning without beam are expected during 3th and 4th quarters of 2013.



Thanks for your attention!

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