LHC/LARP Application Development

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Who

- **Accelerator and Beams Department [AB]**
  - **Controls**
  - **Operations**
    - **Beam [LHC, PS, SPS, AD, LEIR, BOOSTER etc.]**
    - **Technical control room**
    - **Cryogenics**
  - **Accelerator physics**
  - **RF**
  - **Power Converters**
  - **Beam instrumentation**
  - **Beam Transfer (kickers, septa, transfer lines)**
  - **Targets and dumps (inc. collimators)**

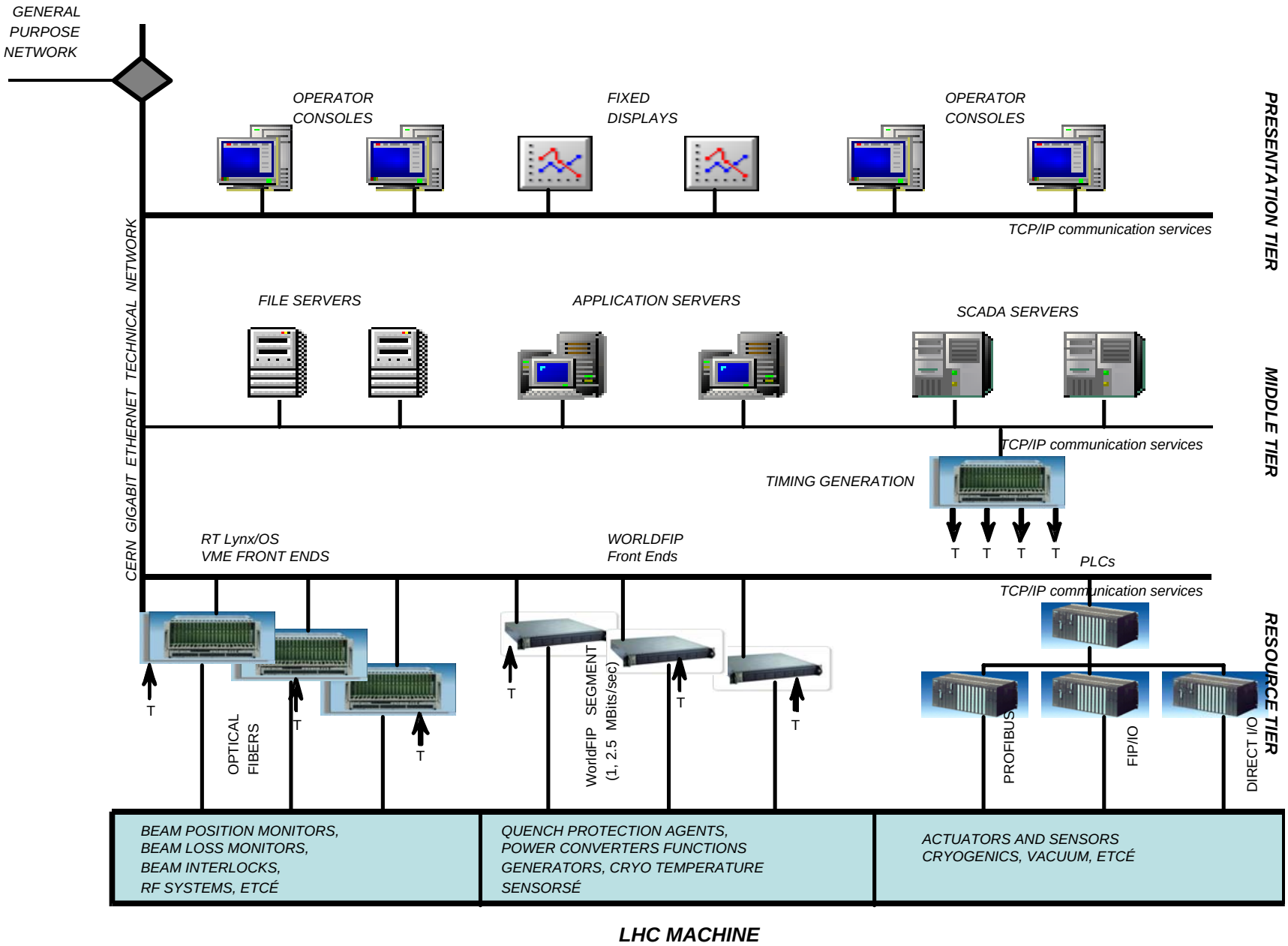
Controls

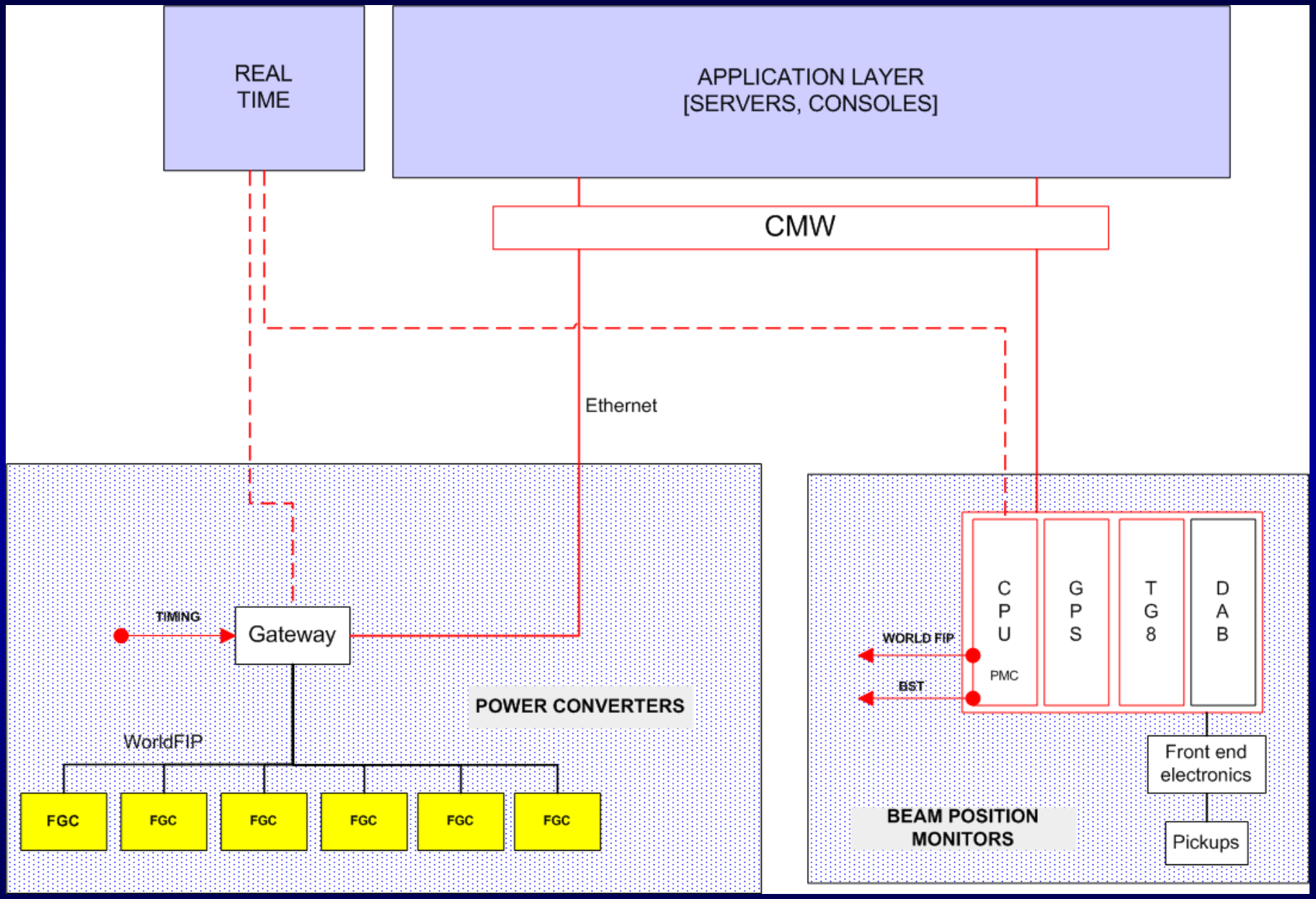
- Timing & Hardware
- Front ends and communication
- Industrial controls
  - PVSS: cryogenics, vacuum, Power Interlock Controller, Quench Protection
- Data management (databases etc.)
- Application software
- Infrastructure

- Complicated by
  - Merge of PS & SL. Consolidation in progress.

- Aiming for common solutions for
  - Front ends
  - Middleware
  - Application software
  - Timing etc.

Not traditionally a strong point


GENERAL PURPOSE NETWORK
CERN GIGABIT ETHERNET TECHNICAL NETWORK
OPERATOR CONSOLES
FIXED DISPLAYS
OPERATOR CONSOLES
PRESENTATION TIER
TCP/IP communication services
FILE SERVERS
APPLICATION SERVERS
SCADA SERVERS
MIDDLE TIER
TCP/IP communication services
TIMING GENERATION
T T T T
RT Lynx/OS VME FRONT ENDS
WORLDFIP Front Ends
PLCs
TCP/IP communication services
RESOURCE TIER
T
OPTICAL FIBERS
T
T
T
WorldFIP SEGMENT (1, 2.5 MBits/sec)
T
T
PROFIBUS
FIP/IO
DIRECT I/O
BEAM POSITION MONITORS, BEAM LOSS MONITORS, BEAM INTERLOCKS, RF SYSTEMS, ETCÉ
QUENCH PROTECTION AGENTS, POWER CONVERTERS FUNCTIONS GENERATORS, CRYO TEMPERATURE SENSORSÉ
ACTUATORS AND SENSORS CRYOGENICS, VACUUM, ETCÉ
LHC MACHINE


REAL TIME
APPLICATION LAYER [SERVERS, CONSOLES]
CMW
Ethernet
TIMING
Gateway
POWER CONVERTERS
WorldFIP
FGC
FGC
FGC
FGC
FGC
FGC
WORLD FIP
BST
CPU
PMC
GPS
TG8
DAB
Front end electronics
Pickups
BEAM POSITION MONITORS

The challenge

- **EQUIPMENT**
  - Collimators/TDI/TCDQ etc.
  - Beam Dump
  - Power converters,
  - Kickers
  - RF, TFB, LFB
  - Spectrometers & compensation
- **INSTRUMENTATION**
  - Distributed systems:
    - BLMs, BPMs,
  - Standalone:
    - BCT, BTV, AGM, BIPM, BWS, Schottky..
  - Tune, Chromaticity, Coupling
  - Luminosity monitors
  - Radiation Monitors
- **REFERENCE MAGNET SYSTEM**
- **MACHINE PROTECTION**
- **VACUUM, CRYOGENICS, QPS**

⊗

Settings, functions, monitoring, display, post mortem, control, acquisition, concentration, archiving, alarms, interlocks

⊗

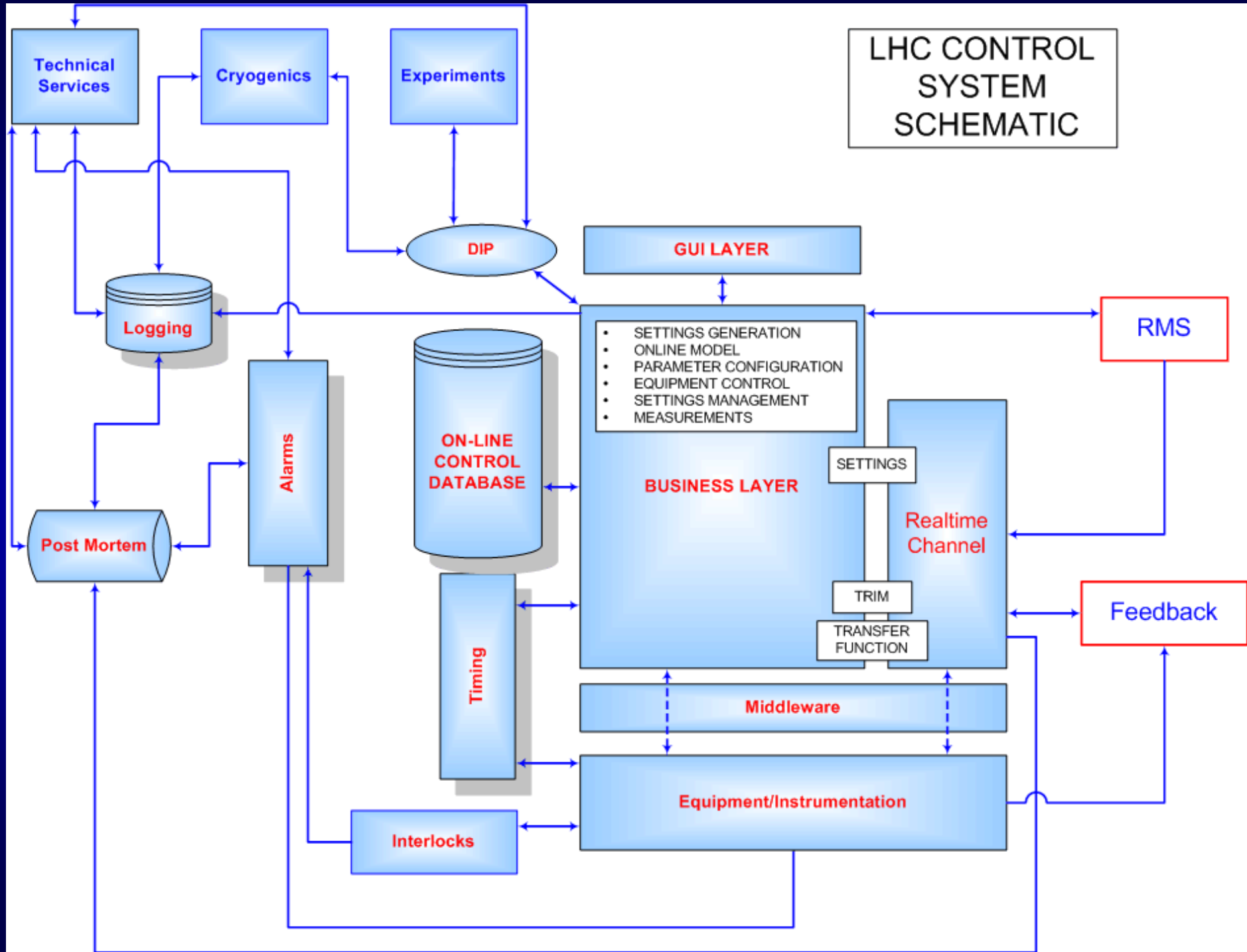
Driving the machine through the cycle

Magnet errors, crossing angles, snapback, ramping, squeezing, colliding, orbit, parameter control, optimisation etc. etc.

Standard facilities

- SETTINGS GENERATION AND MANAGEMENT
- TRIM
- MEASUREMENTS
- EQUIPMENT ACCESS
- LOGGING
- FIXED DISPLAYS
- ALARMS
- ANALOGUE ACQUISITION
- POST MORTEM
- REAL TIME
- MACHINE MODEL
- SEQUENCER
- TIMING
- INTERFACE WITH EXPERIMENTS
- ANALYSIS TOOLS
- SCANS – COMPLEX MEASURE/TRIM PROCEDURES

- STANDARD OPERATIONAL FACILITIES (LOGBOOK/CONSOLE MANAGER etc.)


LHC CONTROL SYSTEM SCHEMATIC
Technical Services
Cryogenics
Experiments
DIP
GUI LAYER
Logging
RMS
SETTINGS GENERATION
ONLINE MODEL
PARAMETER CONFIGURATION
EQUIPMENT CONTROL
SETTINGS MANAGEMENT
MEASUREMENTS
Alarms
ON-LINE CONTROL DATABASE
BUSINESS LAYER
SETTINGS
Realtime Channel
Post Mortem
TRIM
TRANSFER FUNCTION
Feedback
Timing
Middleware
Equipment/Instrumentation
Interlocks

How?

- **Three pronged attack**
  - **Analyze requirements (& use institutional memory)**
  - **Establish core architecture & validate [TI8, SPS, LEIR, HWC]**
    - **Equipment & instrumentation access**
    - **Configuration, optics**
    - **Settings, trims**
    - **Measurements, logging, fixed displays…**
  - **Push novel control components**
    - **Post mortem**
    - **Real time**
    - **Injection control**

Analysis

- **LHC Software Analysis Team** [cern.ch/lhc-software-analysis]
  - Use Case the operational sequence
    - How do we tie every thing together?
    - Confirm systems provide relevant functionality
  - Detail high level controls requirements
  - Push prototyping of components
    - Post-mortem, Equipment access, Instrumentation
    - Looking forward: real-time integration, machine model, timing
  - Input to LSA

Core architecture

- Analyse the requirements of accelerator operations
- Factor out the common functionality:
  - generic model
- Implement once
- Reuse for the control of several accelerators

What is covered so far?

- Optics
  - Layout, Twiss, strengths
- Settings Management
  - Functions or values for all parameters (physics to hardware)
- Settings Generation
  - Generation of the functions based on the optics
- Trim
  - Coherent modification of functions, revert, history
- Hardware & Instrumentation Exploitation
  - Equipment Control,
  - Measurements: log, archive & display
- Operational Exploitation
  - Sequencing, Super Cycle changes

How are we trying to do it?

- Use a modern OO development method
- Implement using appropriate technology
  - Java, Oracle, Hibernate, Spring…
- Using CO standards
  - CVS, Eclipse…
- Using standard components where possible
- Aim for simplicity
- Aim to validate with TI8, HWC etc and for re-use in LHC domain

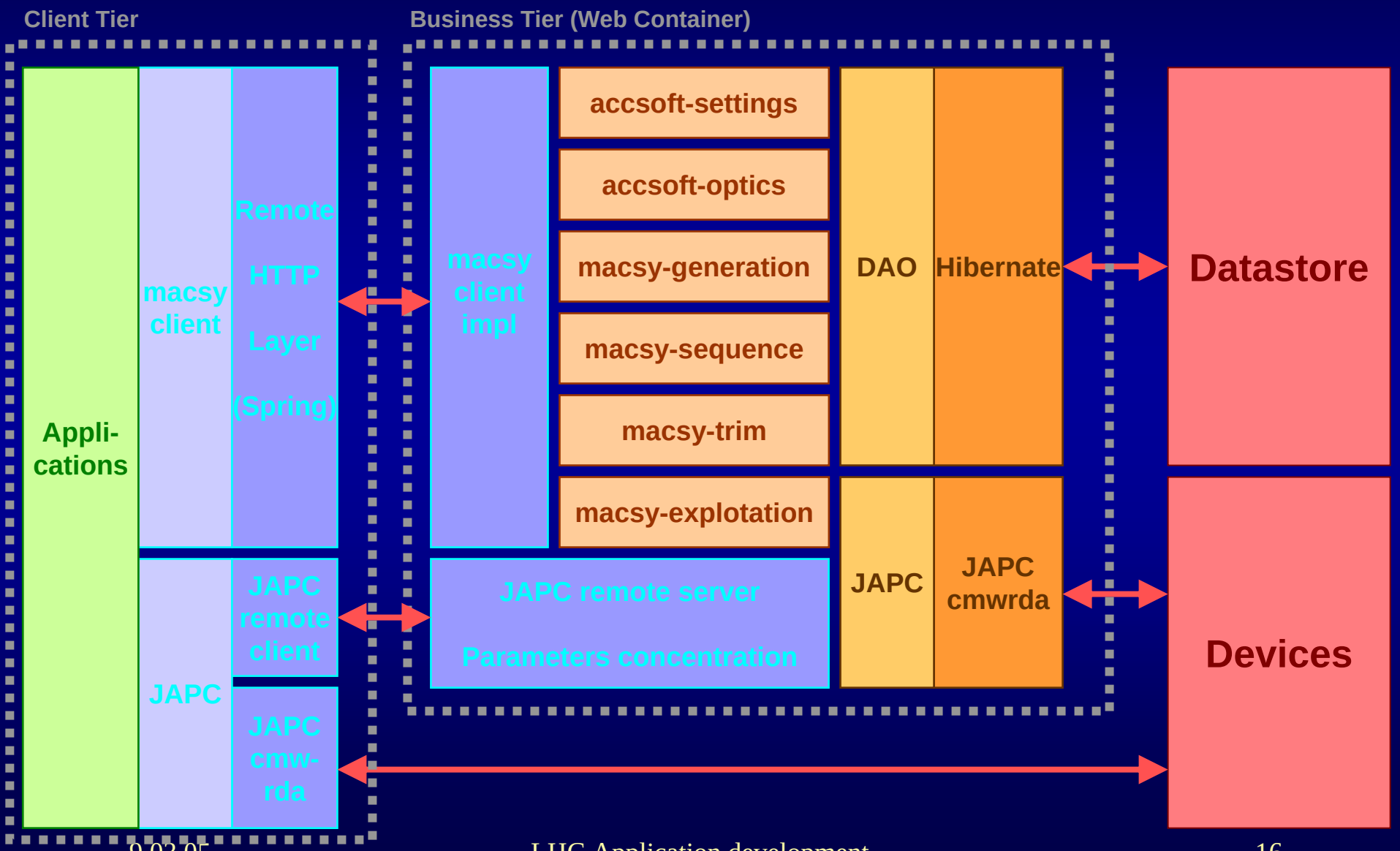
What we have today ?

- The data model has been defined and implemented
- Software components and applications have been designed and implemented
  - Based on requirements from SPS, Transfer Lines (TT40/TI8) and with LHC in mind
- Used successfully for the control of TT40 and TI8
- Applied successfully to model LEIR control
- Work started to model LHC
  - Developments in place for HWC – reuse for beam based operation

Architecture - Key Points

- **Principles**
  - **Modular**
  - **Distributed**
  - **Layered**
- **Database Layer (Oracle)**
  - **Settings, trims, configuration, commands, optics etc. etc.**
- **Business Layer : all functionality required by applications**
  - **trim: change of parameter, conversion to hw parameter, record of changes, rollback, send to hardware etc.**
  - **measurement, acquisition, combination, filtering etc.**

Architecture – Physical View



Generic Equipment Control

Equip State

Current sequence - S653v1

C1044

Categories: SPSRING, TI8, TT40

Cycle: C1044 (0->14400)

Sequence - S653v1

S653v1 (Active)
S540v2 (Resident)
S543v1 (Resident)
S546v1 (Resident)
S950v1 (Resident)
S954v3 (Resident)
S543v2
S543v3
S543v4

Refresh

Filtering on TI8

Device Type	HWName	Status
BCT	MCIAH8260	OFF
BLM	MCIAH8320	OFF
BPM	MCIAH8340	OFF
BTV	MCIAH8400	OFF
MUGEF	MCIAH8420	OFF
VIDEO_SWITCH	MCIAH8480	OFF
	MCIAH8500	OFF
	MCIAH8560	OFF
	MCIAH8580	OFF
	MCIAH8640	OFF
	MCIAH8660	OFF
	MCIAH8720	OFF
	MCIAH8740	OFF
	MCIAV8010	OFF
	MCIAV8070	OFF
	MCIAV8130	OFF
	MCIAV8150	OFF
	MCIAV8210	OFF
	MCIAV8230	OFF
	MCIAV8290	OFF
	MCIAV8310	OFF

Select All

Command	Parameter	Value
[M] READ-TABLE		
[M] PCCURRENTS		
[R] DETAILED-STATUS		
[R] EVLIST		
[R] MAG-CONNECTION		
[R] READ-CHECK-FNCT		
[R] READ-POLARITY		
[R] TEMPERATURE		
[S] STATUS		
[L] LOAD-FUNCT		
[L] LOAD-ZERO-FUNCT		
[L] LOAD-TEST-FUNCT		
[W] CONNECT-MAG-1		
[W] CONNECT-MAG-2		
[W] HARD-INIT		
[W] INIT-ACQ		
[W] INIT-SOFTWARE		

Execute

Console | Running tasks

```
09:04:37 - Executing command STATUS on cycle S653v1.C1044.C0 on MBI8160M-M, MBI8160M-M, MBIAV8110M, MBIBV8774M, MCIAH8020, MCIAH8080,
MCIAH8100, MCIAH8160, MCIAH8180, MCIAH8240, MCIAH8260, MCIAH8320, MCIAH8340, MCIAH8400, MCIAH8420, MCIAH8480, MCIAH8500, MCIAH8560,
MCIAH8580, MCIAH8640, MCIAH8660, MCIAH8720, MCIAH8740, MCIAV8010, MCIAV8070, MCIAV8130, MCIAV8150, MCIAV8210, MCIAV8230, MCIAV8290,
MCIAV8310, MCIAV8370, MCIAV8390, MCIAV8450, MCIAV8470, MCIAV8530, MCIAV8550, MCIAV8610, MCIAV8630, MCIAV8690, MCIAV8710, MCIAV8770,
MCIBH8040, MQID8010, MQID8030, MQID8710M, MQID8730, MQID8750, MQID8770, MQIF8020, MQIF8700M, MQIF8720, MQIF8740M, MQIF8760, MSIB8813M
```

Executing command STATUS on cycle S653v1.C1044.C0 on MBI8160M-M, MBI8160M-M, MBIAV8110M, MBIBV8774M, MCIAH8020, MCIAH8080, MCIAH8100, MCIAH8160, ...

Generic Measurement

Equip State

Current sequence - S653v1

C1044

Categories | Cycle

SPSRING
TI8
TT40

C1044 (0->14400)

Sequence - S653v1

S653v1 (Active)
S540v2 (Resident)
S543v1 (Resident)
S546v1 (Resident)
S950v1 (Resident)
S954v3 (Resident)
S543v2
S543v3
S543v4

Refresh

Filtering on SPSRING

Device Type	HWName	Status
BLRING	LSDA	
MUGEF	LSDB	
	LSFA	
	LSFB	

Command
[M] READ-TABLE
[M] PCCURRENTS
[R] DETAILED-STATUS

Parameter	Value
End time (ms)	13000
Start time (ms)	0
Step (ms)	50

Console | Running tasks

```
16:23:54 - Executing command Losses in mGray on
16:24:19 - Executing command Screen Position on
16:24:38 - Executing command PCCURRENTS on cycle
16:24:55 - Executing command PCCURRENTS on cycle
16:24:59 - Executing command PCCURRENTS on cycle
```

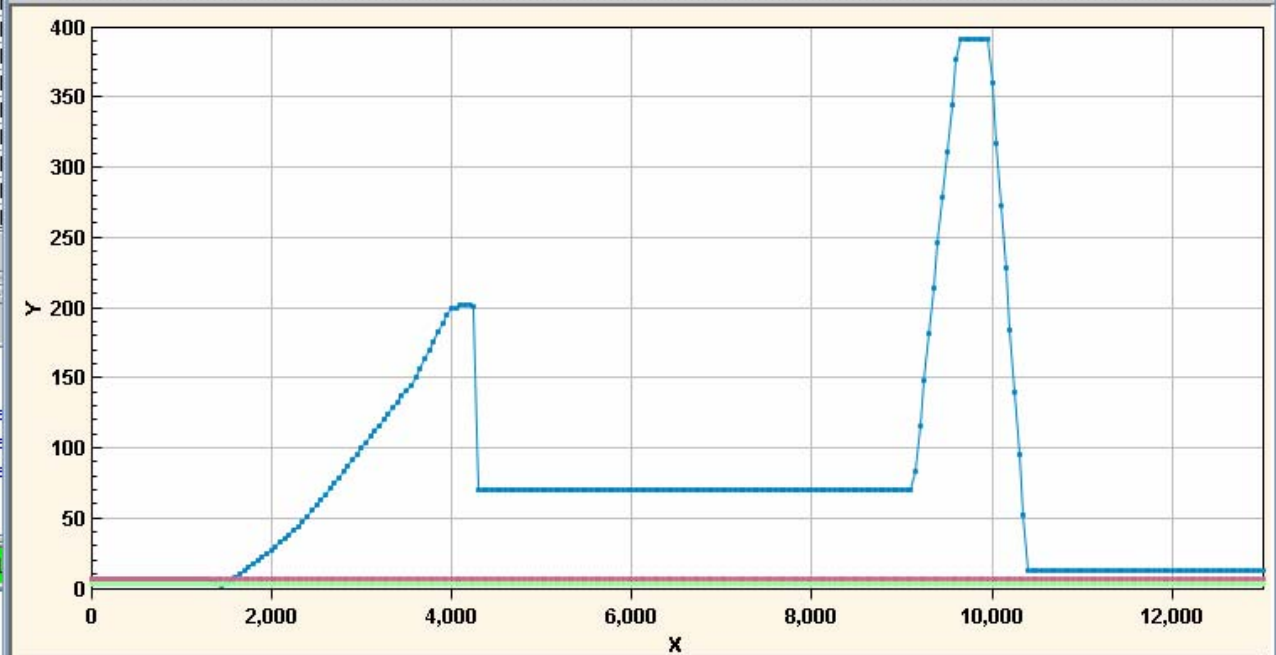
Executing command PCCURRENTS on cycle S653v1.C1044.C0 on

Measurement Display

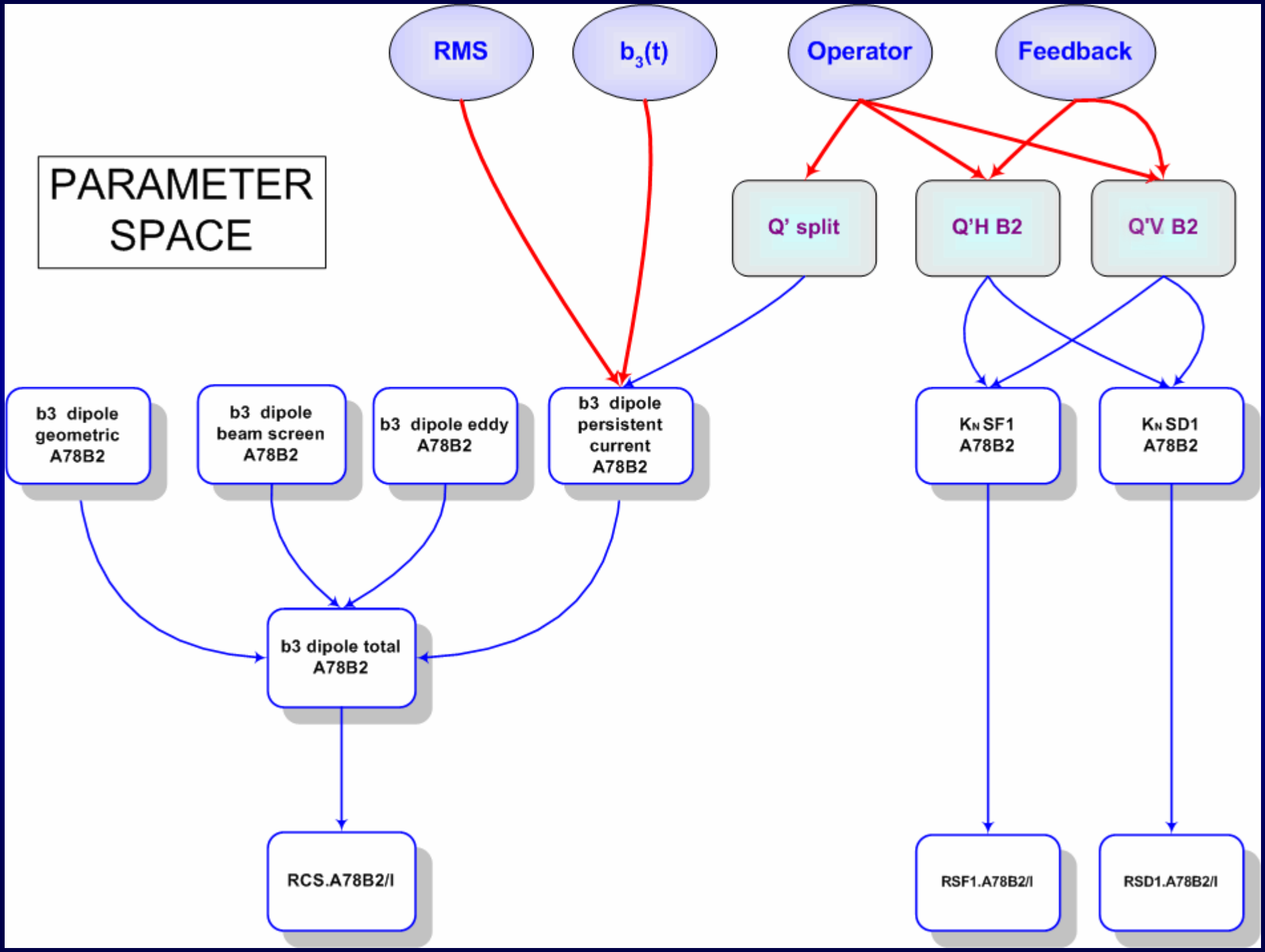
LSFB @ Cycle 21410101 — Update 16:27:21 113

Name	Type and Value	Axis
outputCurrent	(double[]:261) -> 3.0762659156251835, 2....	Y
referenceCurrent	(double[]:261) -> 6.564531730664454, 6.5...	Y
theoreticalCurrent	(double[]:261) -> 6.550798400683984, 6.5...	Y
time	(int[]:261) -> 0, 50, 100, 150, 200, 250, 300,...	X

Active keys : [X] -> x axis, [Y] -> y axis, [Z] -> z axis (image), [D] -> display line, [H]->display histogram, [SPACE] -> clear



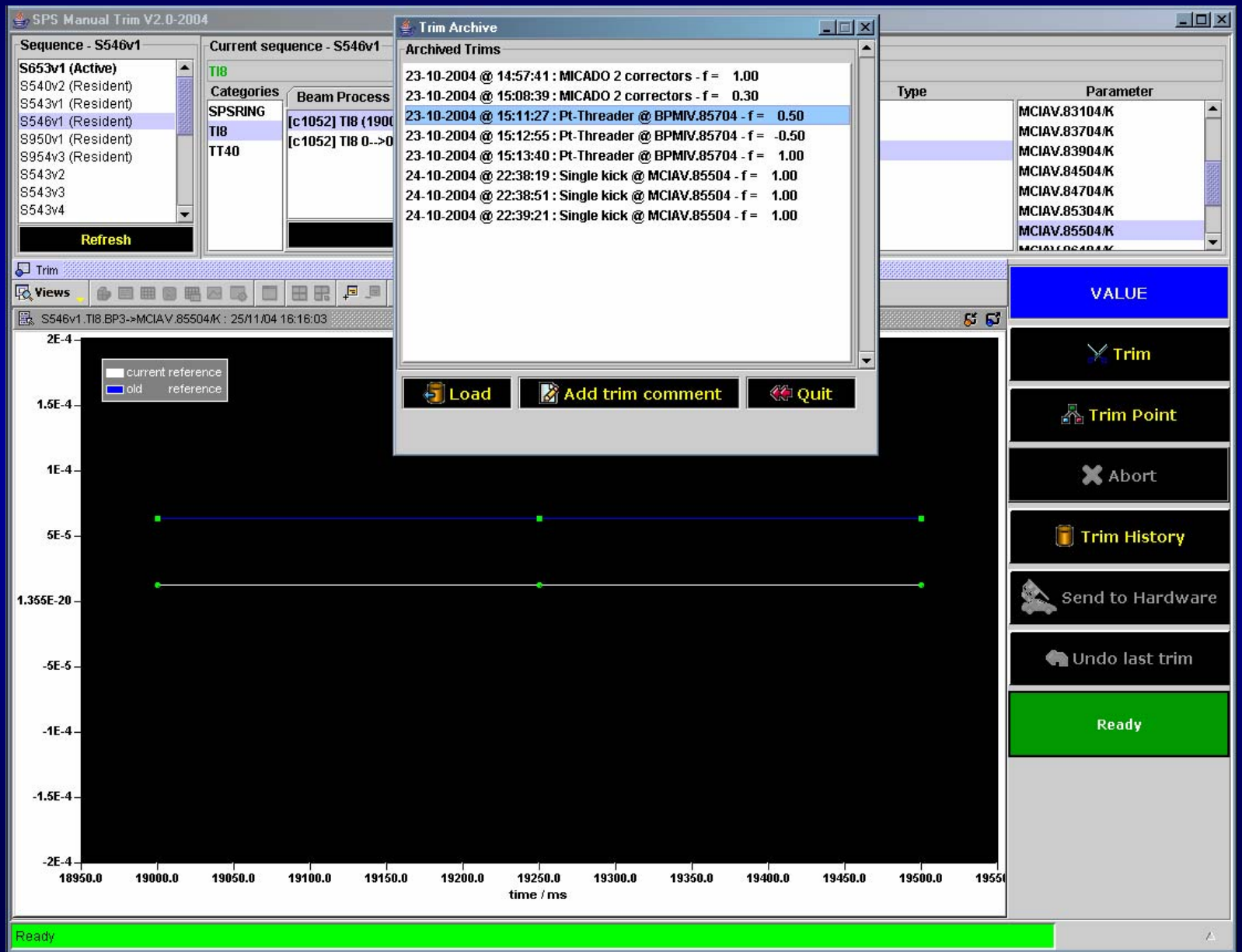
Point # X Y Z


PARAMETER SPACE
RMS
b3(t)
Operator
Feedback
Q' split
Q'H B2
Q'V B2
b3 dipole geometric A78B2
b3 dipole beam screen A78B2
b3 dipole eddy A78B2
b3 dipole persistent current A78B2
KN SF1 A78B2
KN SD1 A78B2
b3 dipole total A78B2
RCS.A78B2/I
RSF1.A78B2/I
RSD1.A78B2/I

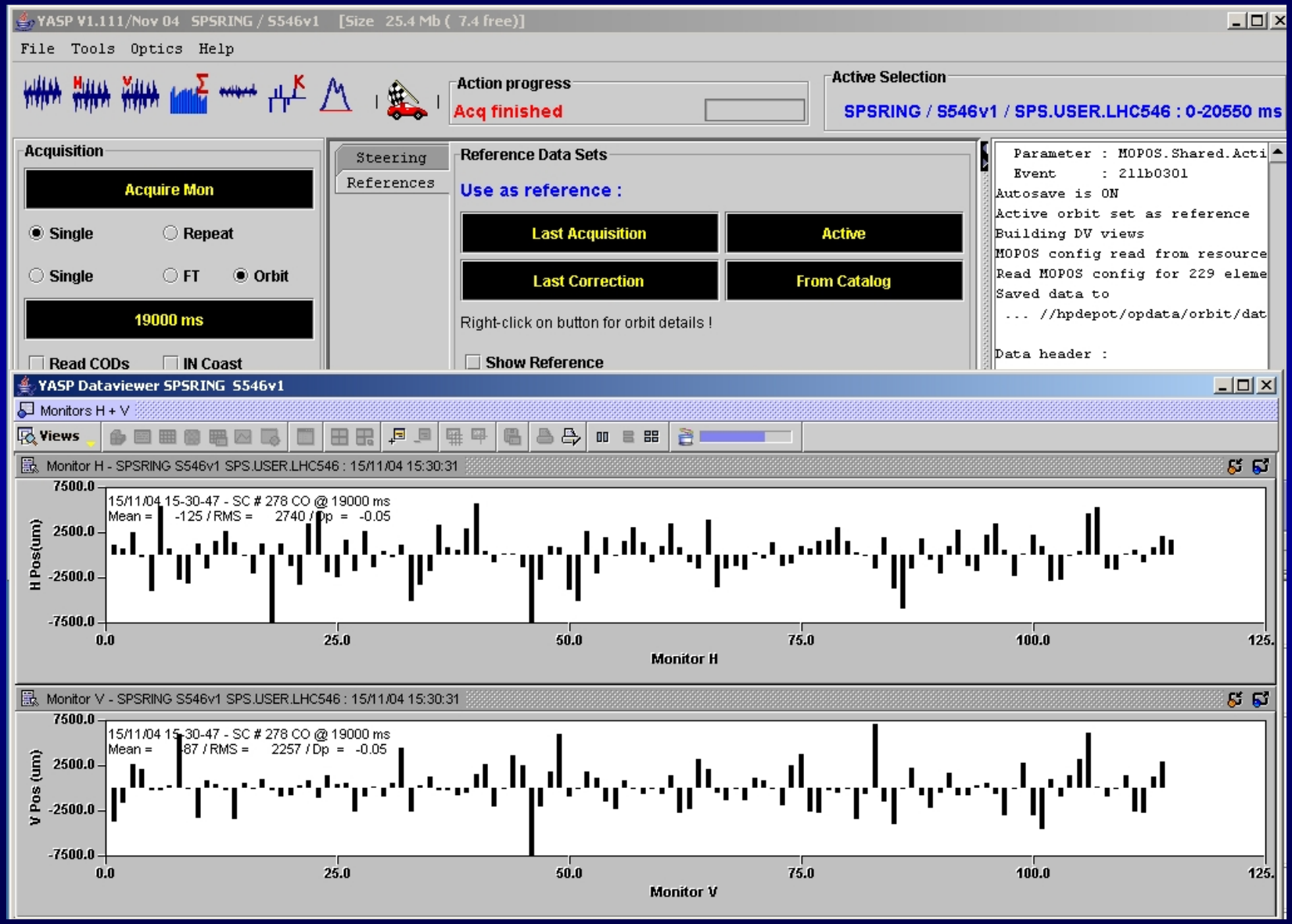
Trim

SPS Manual Trim V2.0-2004
Sequence - SEQ1
SEQ1 (Active)
Refresh
Current sequence - SEQ1
test
Categories
LHC
Beam Process
Cycle
[test] test (0->1600)
Select All
Parameter selection - LHC
RB.A12.UA23/I
System
CHROMATICITY
MOMENTUM
TUNE
Type
I
IREF
K
MOMENTUM
Parameter
RB.A12.UA23/I
RB.A23.UA27/I
RB.A34.UA43/I
RB.A45.UA47/I
RB.A56.UA63/I
RB.A67.UA67/I
RB.A78.UA83/I
Trim
Views
BP1->RB.A12.UA23/I : 18/01/05 17:54:06
current reference
current / A
time / ms
VALUE
Trim
Trim Point
Abort
Trim History
Send to Hardware
Undo last trim
Ready
Console
17:55:49 - Trimming setting for RB.A12.UA23/I from 0 ms to 1600 ms
Ready

Trim history



Steering


YASP V1.111/Nov 04 SPSRING / S546v1 [Size 25.4 Mb (7.4 free)]
File Tools Optics Help
Action progress
Acq finished
Active Selection
SPSRING / S546v1 / SPS.USER.LHC546 : 0-20550 ms
Acquisition
Acquire Mon
Single
Repeat
Single
FT
Orbit
19000 ms
Read CODs
IN Coast
Steering
References
Reference Data Sets
Use as reference :
Last Acquisition
Active
Last Correction
From Catalog
Right-click on button for orbit details !
Show Reference
Parameter : MOPOS.Shared.Acti
Event : 211b0301
Autosave is ON
Active orbit set as reference
Building DV views
MOPOS config read from resource
Read MOPOS config for 229 eleme
Saved data to
... //hpdepot/opdata/orbit/dat
Data header :
YASP Dataviewer SPSRING S546v1
Monitors H + V
Views
Monitor H - SPSRING S546v1 SPS.USER.LHC546 : 15/11/04 15:30:31
15/11/04 15-30-47 - SC # 278 CO @ 19000 ms
Mean = -125 / RMS = 2740 / Dp = -0.05
H Pos(um)
7500.0
2500.0
-2500.0
-7500.0
0.0
25.0
50.0
75.0
100.0
Monitor H
Monitor V - SPSRING S546v1 SPS.USER.LHC546 : 15/11/04 15:30:31
15/11/04 15-30-47 - SC # 278 CO @ 19000 ms
Mean = 87 / RMS = 2257 / Dp = -0.05
V Pos (um)
7500.0
2500.0
-2500.0
-7500.0
0.0
25.0
50.0
75.0
100.0
Monitor V

SDDS Browser & Viewer

SDDS Browser

File Options

SDDS root directory: \\hpdepot\opdata4\SDDS_LOGGING\23_10_04 Choose directory...

Parameters

BCTFI_TI8DWN/BCTFI.Shared.Actions.acquisit
BCTFI_TT40/BCTFI.Shared.Actions.acquisition
BLMI_TI8/BLMI.ClassGlobalCommactionList.b
BPMI_TI8/BPMI.Shared.Actions.dabCrateAver
BPMI_TI8DWN/BPMI.Shared.Actions.crateBur
BPMI_TI8UP/BPMI.Shared.Actions.crateBuncl
BTVI_LSS4.41831/getImage
BTVI_LSS4.41831/getProfiles
BTVI_LSS4.41895/getImage
BTVI_LSS4.41895/getProfiles
BTVI_TI8.81204/getImage
BTVI_TI8.81204/getProfiles
BTVI_TI8.81306/getImage
BTVI_TI8.81306/getProfiles
BTVI_TI8.84304/getImage
BTVI_TI8.84304/getProfiles
BTVI_TI8.84404/getImage
BTVI_TI8.84404/getProfiles
BTVI_TI8.84604/getImage
BTVI_TI8.84604/getProfiles
BTVI_TI8.87437/getImage
BTVI_TI8.87437/getProfiles
BTVI_TI8.87604/getImage
BTVI_TI8.87604/getProfiles
BTVI_TI8.87750/getImage
BTVI_TI8.87750/getProfiles
BTVI_TT40.400105/getImage
BTVI_TT40.400105/getProfiles
BTVI_TT40.400222/getImage
BTVI_TT40.400222/getProfiles
BTVI_TT40.400343/getImage
BTVI_TT40.400343/getProfiles

BTVI_TI8.84404/getImage

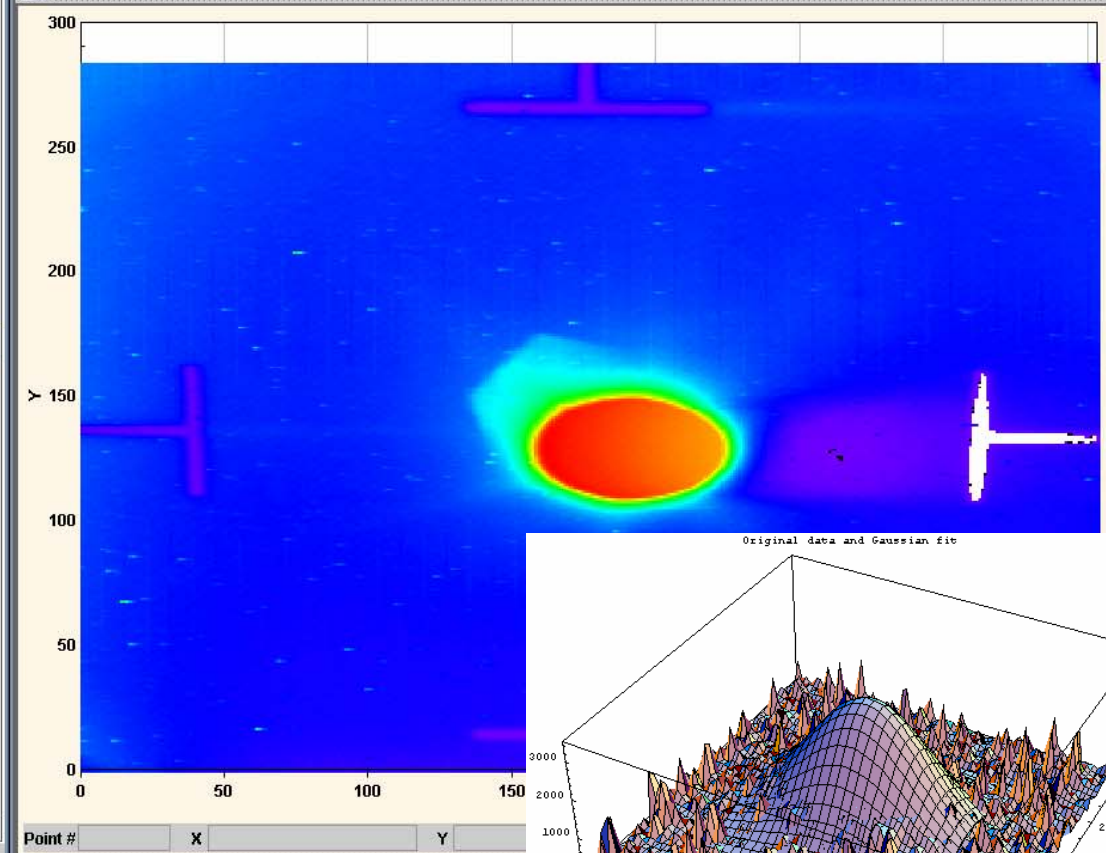
Time	CycleID
19:14:40	11227
19:15:08	11228
19:15:37	11229
19:16:06	11230
19:16:35	11231
19:17:04	11232
19:17:32	11233
19:18:01	11234
19:18:30	11235
19:18:59	11236
19:19:28	11237
19:19:56	11238
19:20:25	11239
19:20:54	11240
19:21:23	11241
19:21:52	11242
19:22:20	11243
19:22:49	11244
19:23:18	11245
19:23:47	11246
19:24:16	11247
19:24:44	11248
19:25:13	11249
19:25:42	11250
19:26:11	11251
19:26:40	11252
19:27:08	11253
19:27:37	11254
19:28:06	11255
19:28:35	11256
19:29:04	11257
19:29:32	11258
19:30:01	11259
19:30:30	11260
19:30:59	11261
19:31:28	11262
19:31:56	11263
19:32:25	11264
19:32:54	11265
19:33:23	11266
19:33:52	11267
19:34:20	11268

SDDS Default View

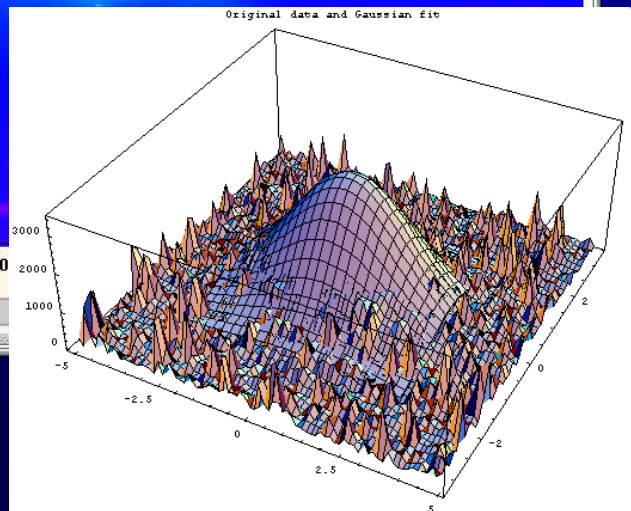
BTVI_TI8.84404 @ Cycle sdds.19:19:56 Update 13:07:48 925

Name	Type and Value	Axis
sizeX	(long:-1) -> 354	X
sizeY	(long:-1) -> 284	Y
timeStampNSec	(long:-1) -> 687951803	
timeStampSec	(long:-1) -> 1098551995	
videoGain	(short:-1) -> 0	
zoom	(short:-1) -> 0	

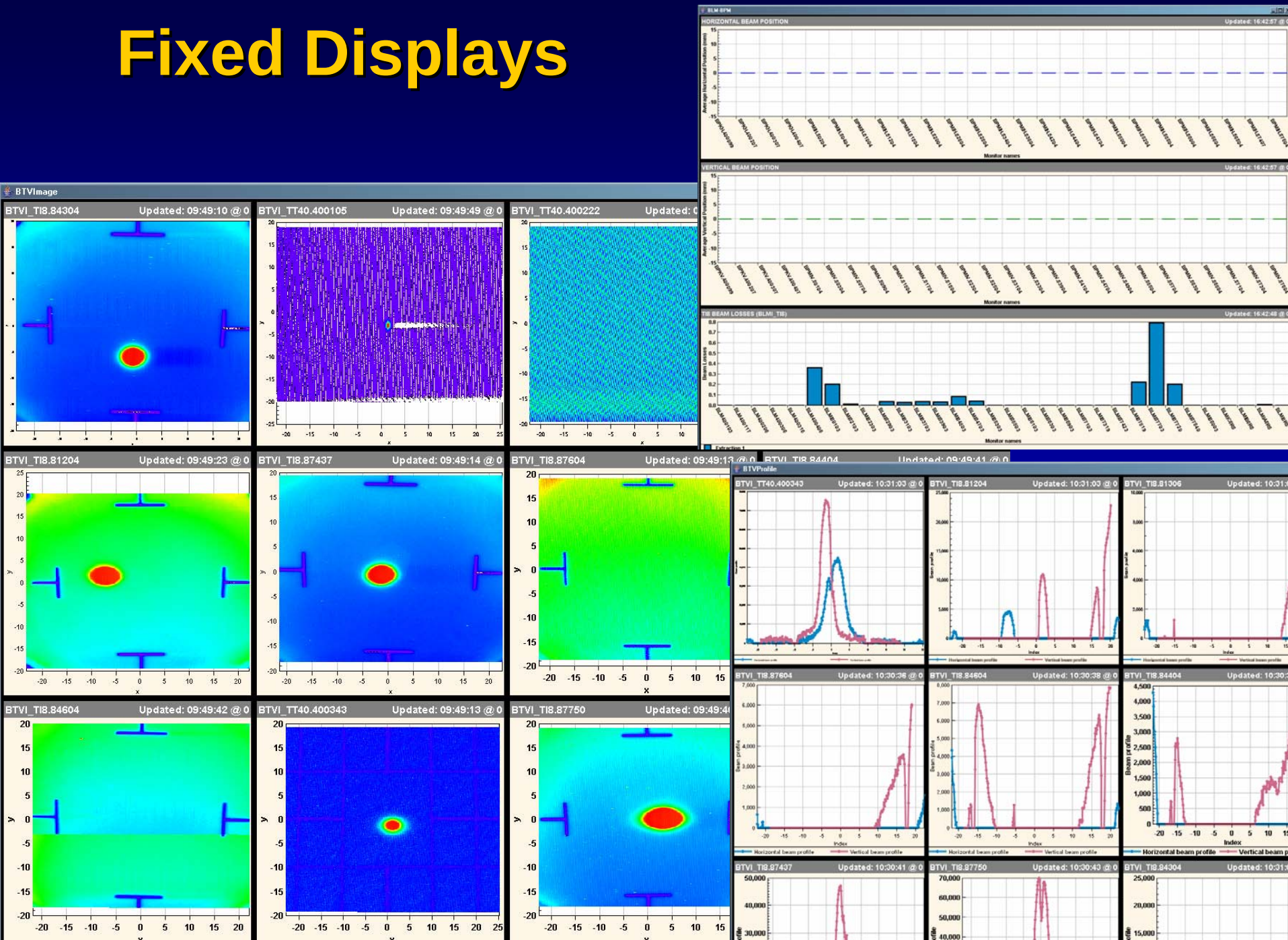
Active keys : [X] -> x axis, [Y] -> y axis, [Z] -> z axis (image), [D] -> display line, [H]->display histogram, [SPACE] -> clear



Point # X Y



Fixed Displays



Planning

		SPS	HWC →	LHC
2005	LEIR Settings, cycle management PS Tune and chromaticity control	Settings, trim, cycle control BDI reimplementation START-UP 2006	**short circuit tests** Sequencer, power converter control, PM, displays **LSS.L8 commissioning** QPS/PIC/PC control & acquisition, PM, logging,	**Prototype** Settings, trim, database Power converter control Distributed BI **Spec Collimators** **Post Mortem**
2006			**Full blown Commissioning** QPS/PIC/PC control & acquisition, PM, logging,	**Sector Test**
2007				**Checkout First Beam**

Remote development

Why bother?

- What's in in for you? What's in it for us?
  - Resources
  - Ideas, experience, the joys of collaboration
  - Ownership

- Why not?
  - Overheads, communication, understanding the problem
  - Maintenance, upgrades, bug fixing
  - Control of the process
  - Deadlines, resource control
  - Adherence to standards
  - Appropriate experience on-site [problem solving etc]

Remote development

Clearly possible

- Well defined
- Reasonably self contained - autonomous
- Testable
- Not core

- Buy into development method and infrastructure
  - Components
  - Standard facilities
  - Version control

- Accept milestones

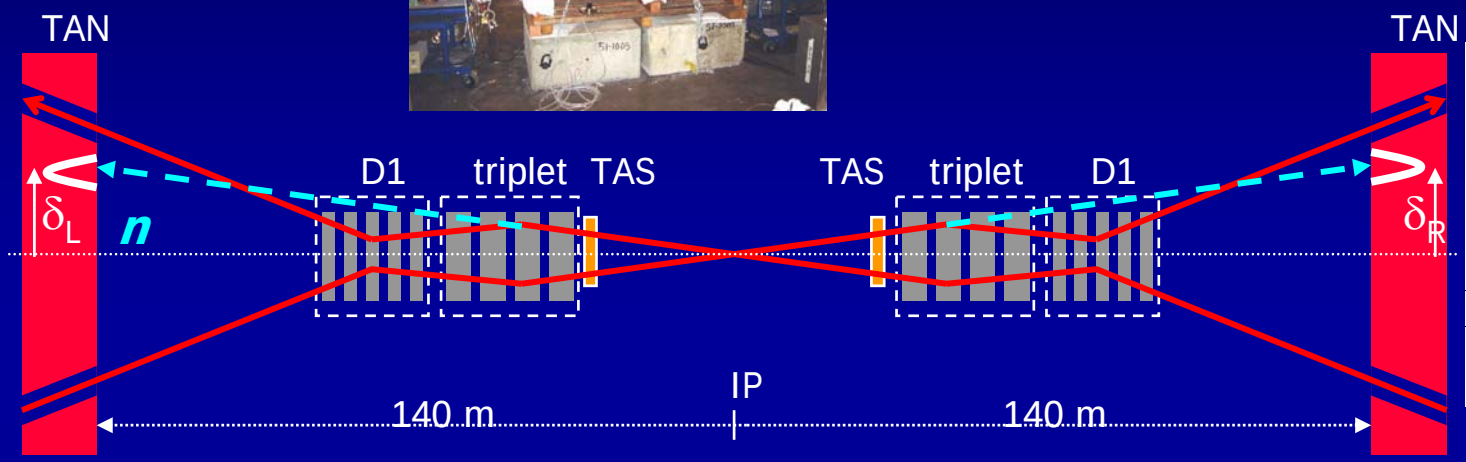
Possibilities

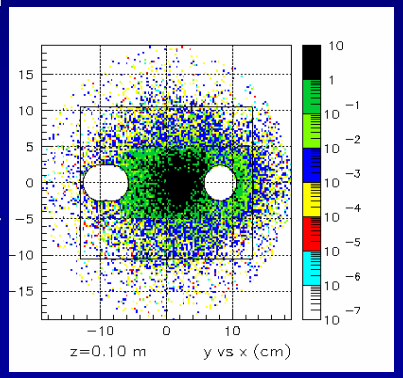
Not Core functionality:
Equipment control, ramp management, sequencing, RT etc., BLMs…

- Hardware Commissioning
- Beam commissioning
- Machine Studies
- Routine Operations
- Operational scenarios
- Understanding & analysis

- Post-mortem analysis
- Measurement Analysis
  - beta beating
  - matching
  - multi-turn analysis
- Stand alone instrumentation
  - Tune – PLL
  - Schottky
- Operational Procedures
  - Luminosity scans

e.g. Luminosity Monitors





ionization chamber

Limited Operations Scenarios

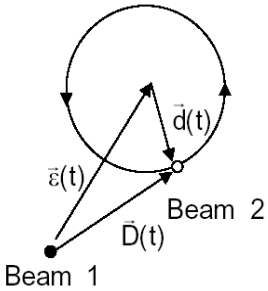
- **Ownership of instrumentation possibly established**
- **Development of operational tools to support specific functions**

US LHC ACCELERATOR PROJECT

brookhaven - fermilab - berkeley

- An intentional transverse sweep of one beam introduces a time dependent modulation of luminosity
  - ε = error offset amplitude
  - d = intentional sweep amplitude

$$L \approx L_0 - L_0 \frac{\varepsilon d}{2\sigma_*^2}\cos(\omega t - \varphi);\ \varepsilon, d << \sigma_*$$



- Define the detector current

$$I(t) = e\alpha\varepsilon_{\text{det}} m\sigma_{inel} L$$

- Integrate to obtain the luminosity and error offset, $0 < t < T$, $T = n\frac{2\pi}{\omega}$

$$L_0 = \frac{\int_0^T I(t)dt}{e\alpha\varepsilon_{det} m\sigma_{inel} T};\qquad \vec{\varepsilon} = -\frac{\hat{e}_x\int_0^T \cos(\omega t)I(t)dt + \hat{e}_y\int_0^T \sin(\omega t)I(t)dt}{\left(\frac{d}{4\sigma_*^2}\right)e\alpha\varepsilon_{\text{det}} m\sigma_{inel} T}$$

Lumi Tools Mini Workshop
15-16 Apr. 1999

W.C. Turner
Concepts for IR Absorber Luminosity Instrumentation

7

7 of 19 11.69 x 8.26 in

LHC luminosity scan from Berkeley?

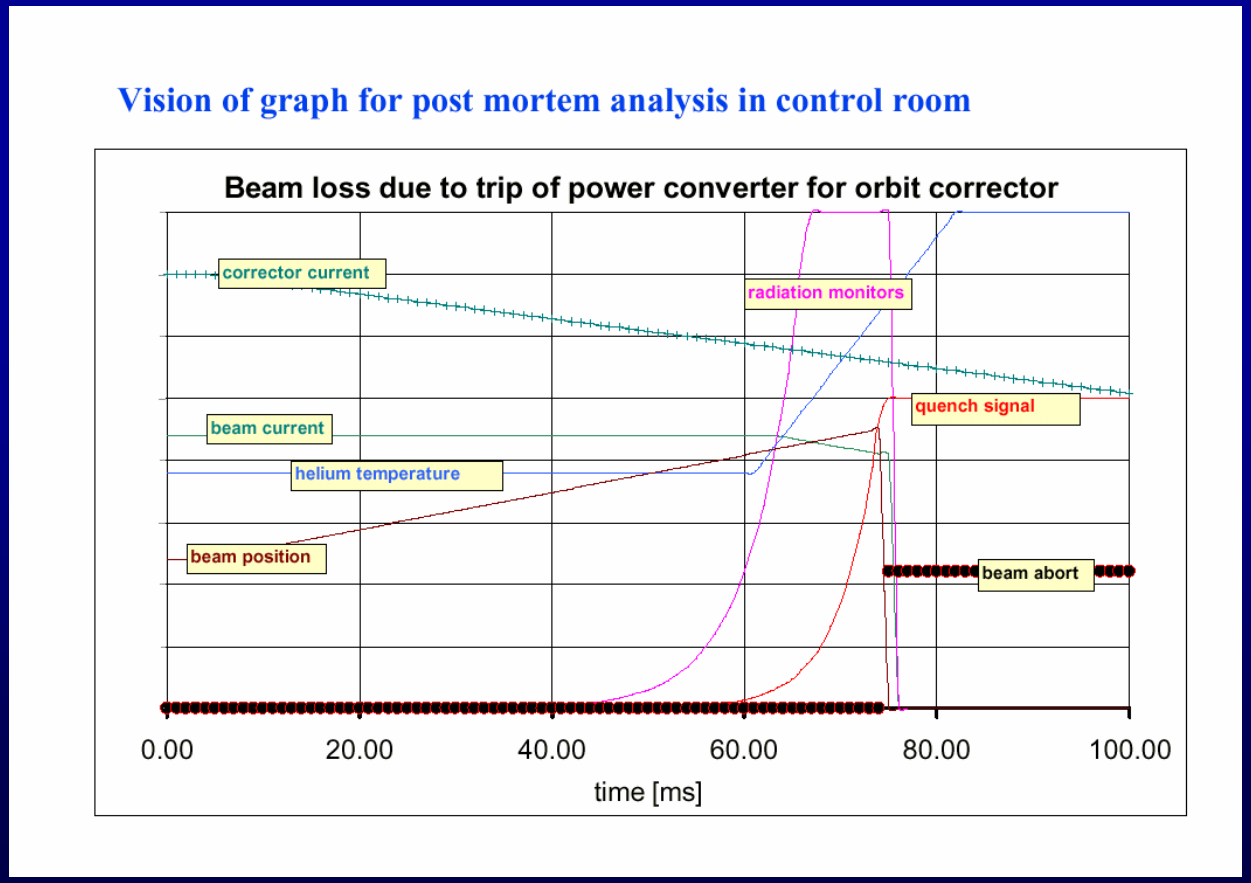
Stand alone instrumentation

- **Develop hardware or instrumentation**
  - **Install it**
  - **Develop software**
  - **Commission it on-site**
  - **Remote monitoring**

e.g. Tune PLL, Longitudinal Density Monitor or Schottky

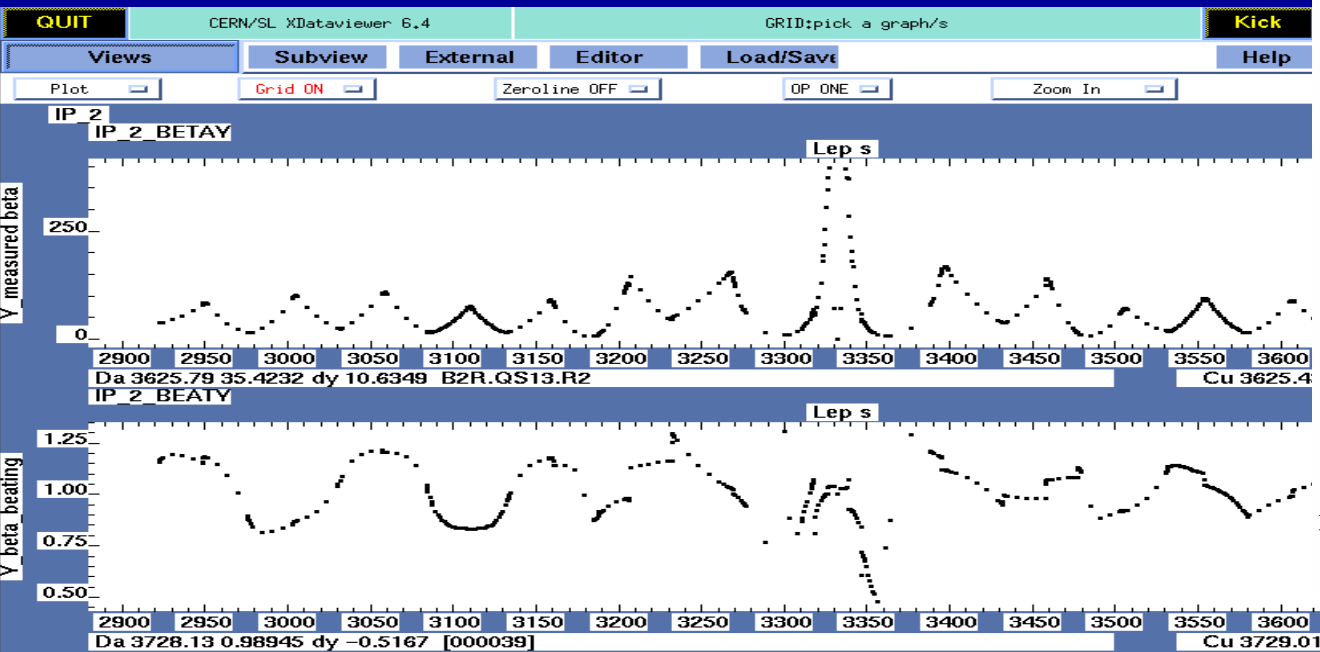
“Off line” systems

- **Key sub-systems need development**
  - Post-mortem analysis for example
  - Development of operational tools
  - Commission it and possibly use it remotely



Analysis tools

- Given remote access to logging, post-mortem data, measurements etc. from
  - Normal operations
  - Machine studies
- Clearly room for remote post-run/post MD analysis
- Development of tools…



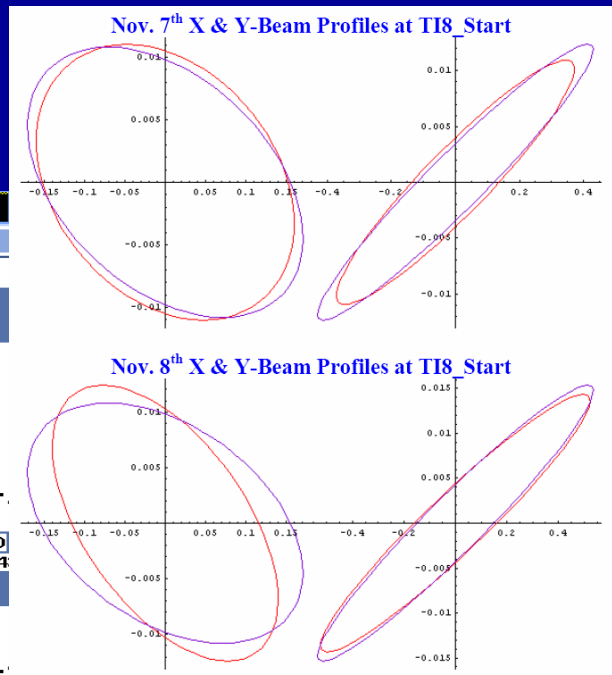


Figure 2. Comparison between Design & Measured Beam Profiles of 07/11 (top) and 08/11 (bottom); Actual beam size; units: mm & mrad (red: measured, blue: design)

Conclusions

- Software development framework well established
- Well defined milestones in place
- LHC requirements capture and prototyping ongoing

- Remote development has not be considered seriously

- Clearly scope for remote collaboration

- Well-defined prototype project(s) with individual responsibilities clearly defined.