The Status of the LHC Controls System Shortly Before Injection of Beam

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on behalf of
CERN Accelerator and Beams
Controls Group

Motivation of this talk

- Present the controls challenges of the LHC machine
- Give an overview of the LHC Controls Infrastructure
- Propose links to further ICALEPCS'07 presentations

MOAB01

Relativity

- "When you sit with a nice girl for two hours, you think it's only a minute. But when you sit on a hot stove for a minute, you think it's two hours. That's relativity" Albert Einstein

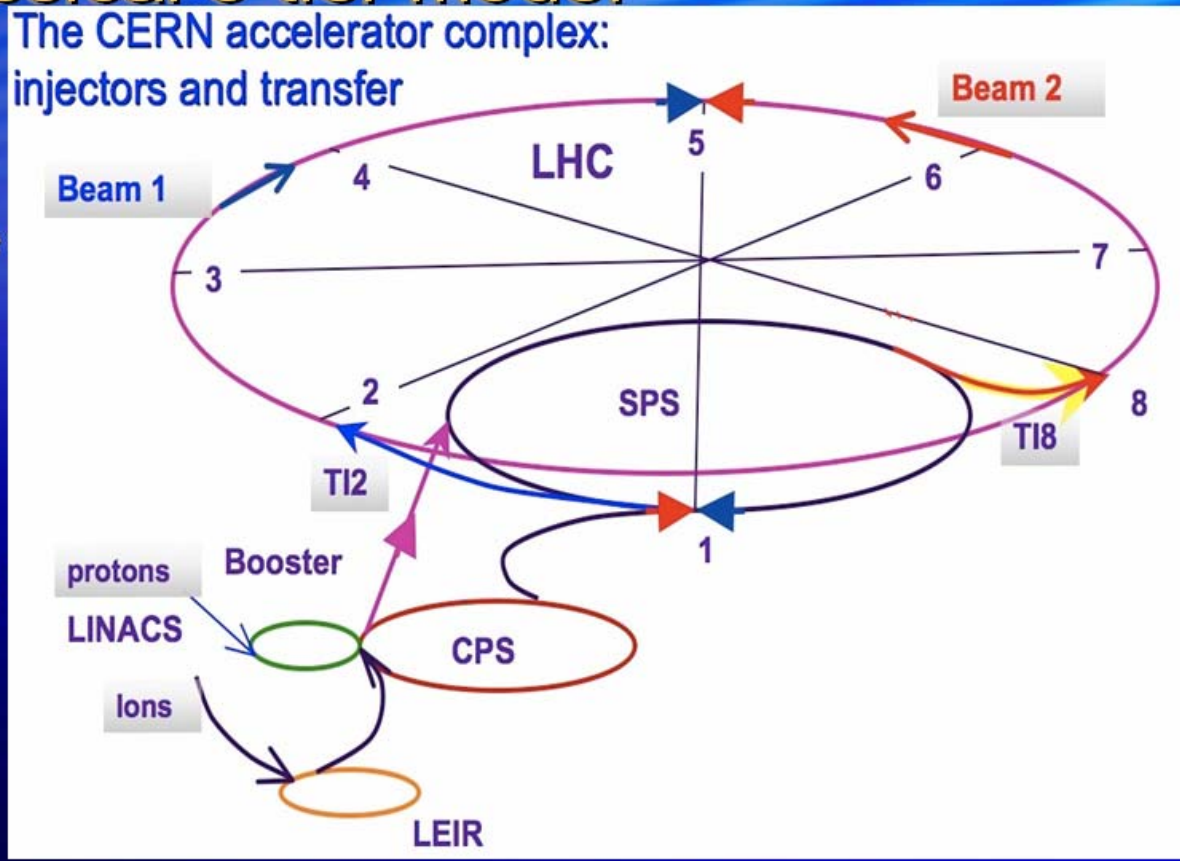
- Hence the title "LHC controls "shortly" before beam injection" for us means:
  - a few months before LHC Beam Commissioning
  - 9 months after start of LHC Hardware Commissioning

Outline

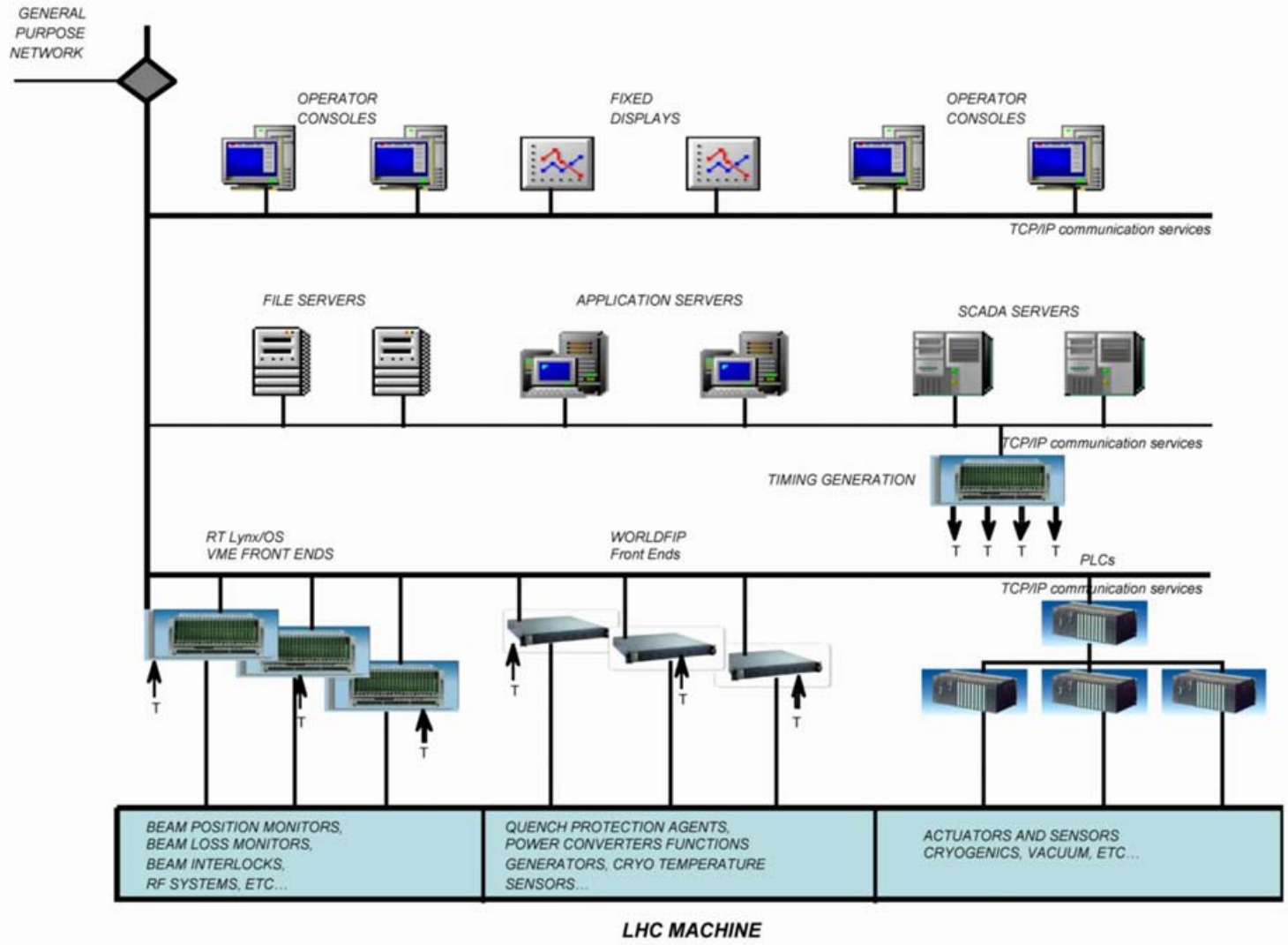
- LHC controls infrastructure
- The major LHC challenges
- Technical Solutions to the LHC challenges
- Results
- Summary

The LHC Controls Infrastructure

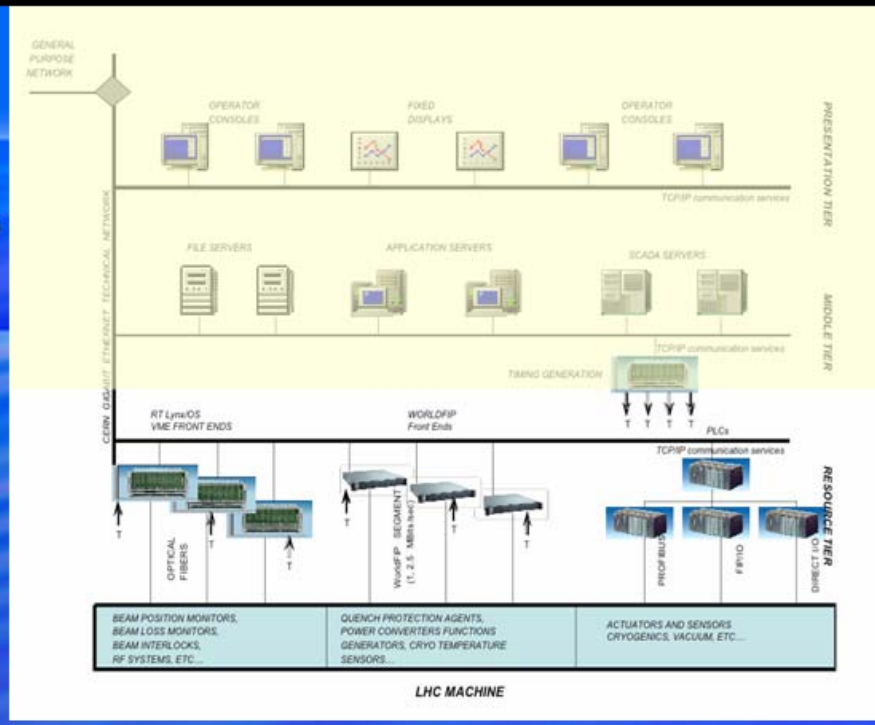
- Based on the classical 3-tier model
  - The LHC Controls Infrastructure is a new software and hardware architecture built with the experience of controlling the CERN injector chain
  - Level of effort: 300 my, 21 MSFR



The 3-tier LHC Controls Infrastructure

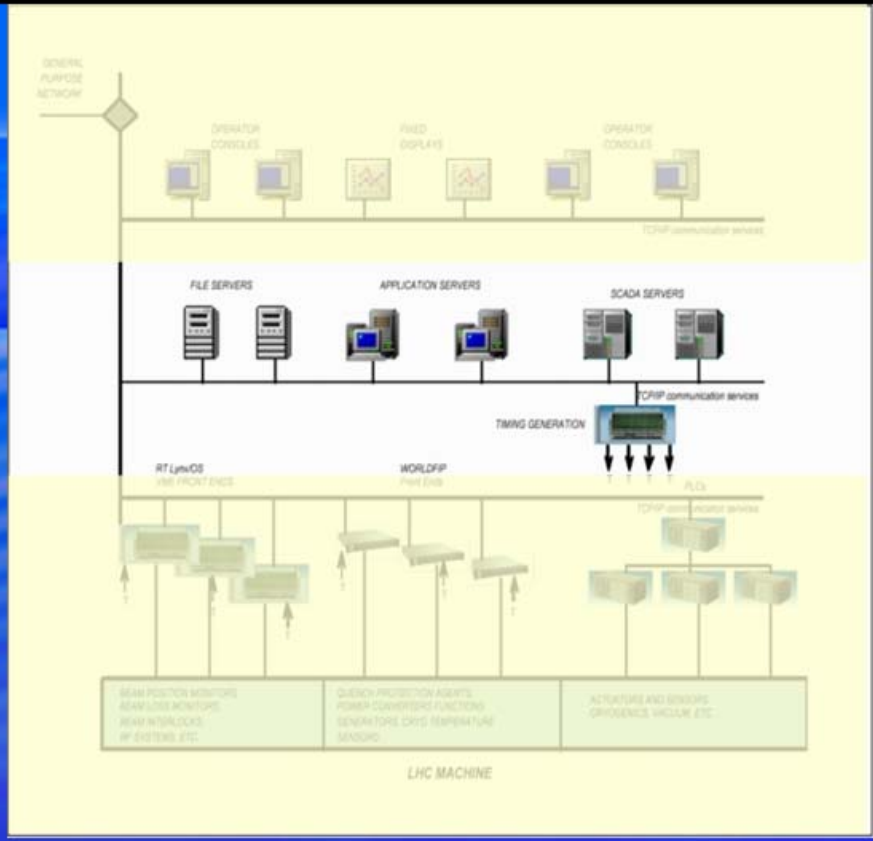


The Resource Tier



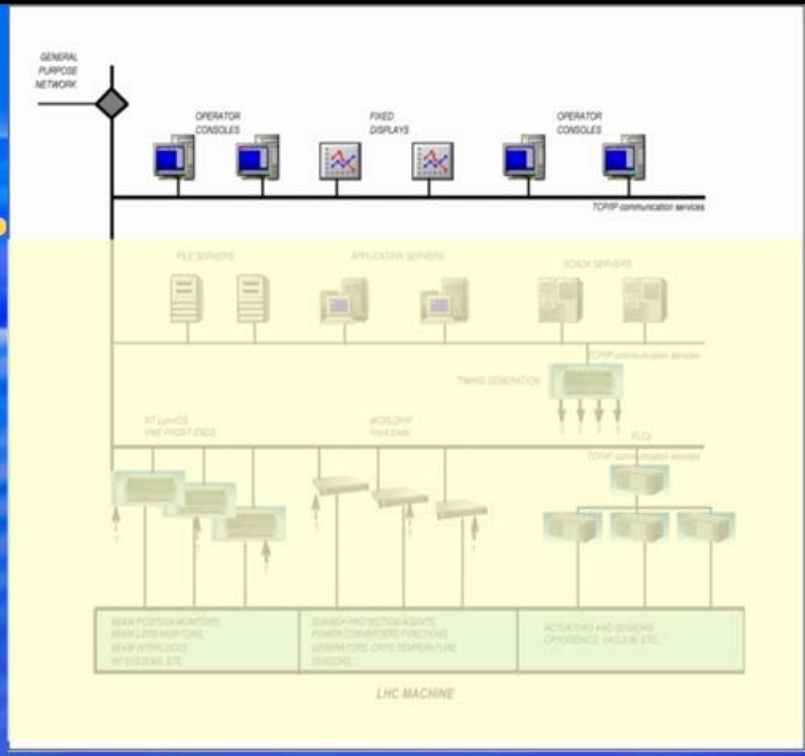
- VME crates dealing with high performance acquisitions and real-time processing
  - e.g. the LHC beam instrumentation and the LHC beam interlock systems use VME front-ends
- PC based gateways interfacing systems where a large quantity of identical equipment is controlled through fieldbuses
  - e.g. LHC power converters and LHC Quench Protection System
- Programmable Logic Controllers (PLCs) driving various sorts of industrials actuators and sensors for systems
  - e.g. LHC Cryogenics systems or the LHC vacuum system.
- Supported FieldBuses for local connections
  - e.g. Mil1553, WorldFIP, Profibus

The Middle Tier



- **Application servers** hosting the software required to operate the LHC beams and running the Supervisory Control and Data Acquisition (SCADA) systems
  - *HP ProLiant dual CPU with 3Gbyte RAM running LINUX.*
  - *Dual hot pluggable RAID-1 system disks*
  - *Redundant dual hot pluggable power supplies.*
- **Data servers** containing the LHC layout and the controls configuration as well as all the machine settings needed to operate the machine or to diagnose machine behaviors.
- **File servers** containing the operational applications
- **Central timing** which provides the cycling information of the whole complex of machines involved in the production of the LHC beam and the timestamp reference

The Presentation Tier



- At the control room level, consoles running the Graphical User Interfaces (GUI) will allow machine operators to control and optimize the LHC beams and to supervise the state of key industrial systems.
- Dedicated fixed displays will also provide real-time summaries of key machine parameters
- Operational consoles specifications :
  - PCs with 2 Gbyte RAM running either LINUX or WINDOWS
  - One PC, one keyboard, one mouse, and up to 3 screens
  - Console capable of running any type of GUI software for LHC (and PS and SPS) such as JAVA, WEB, SCADA or X-MOTIF.

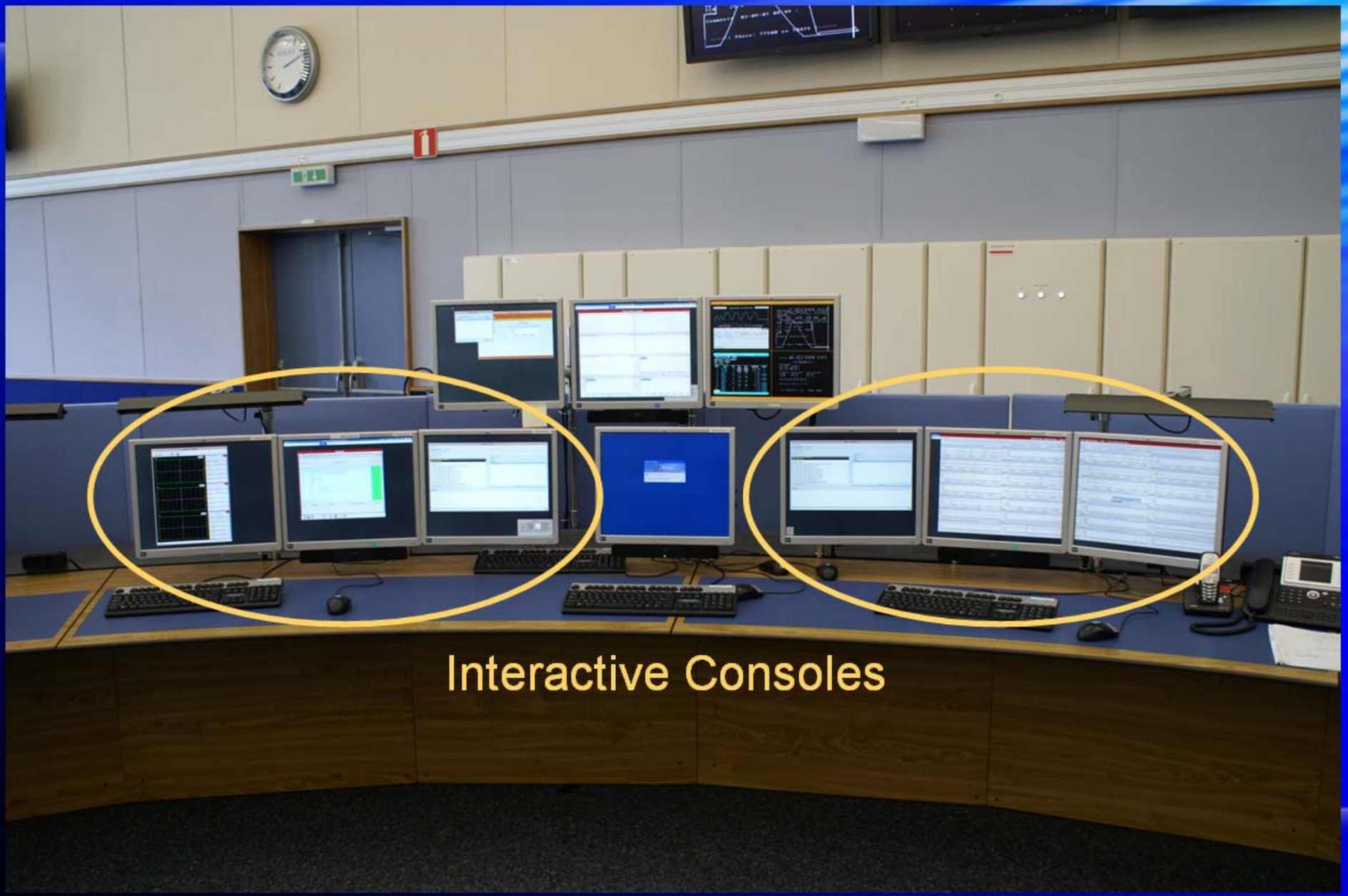
Inside CCC

RPPB01

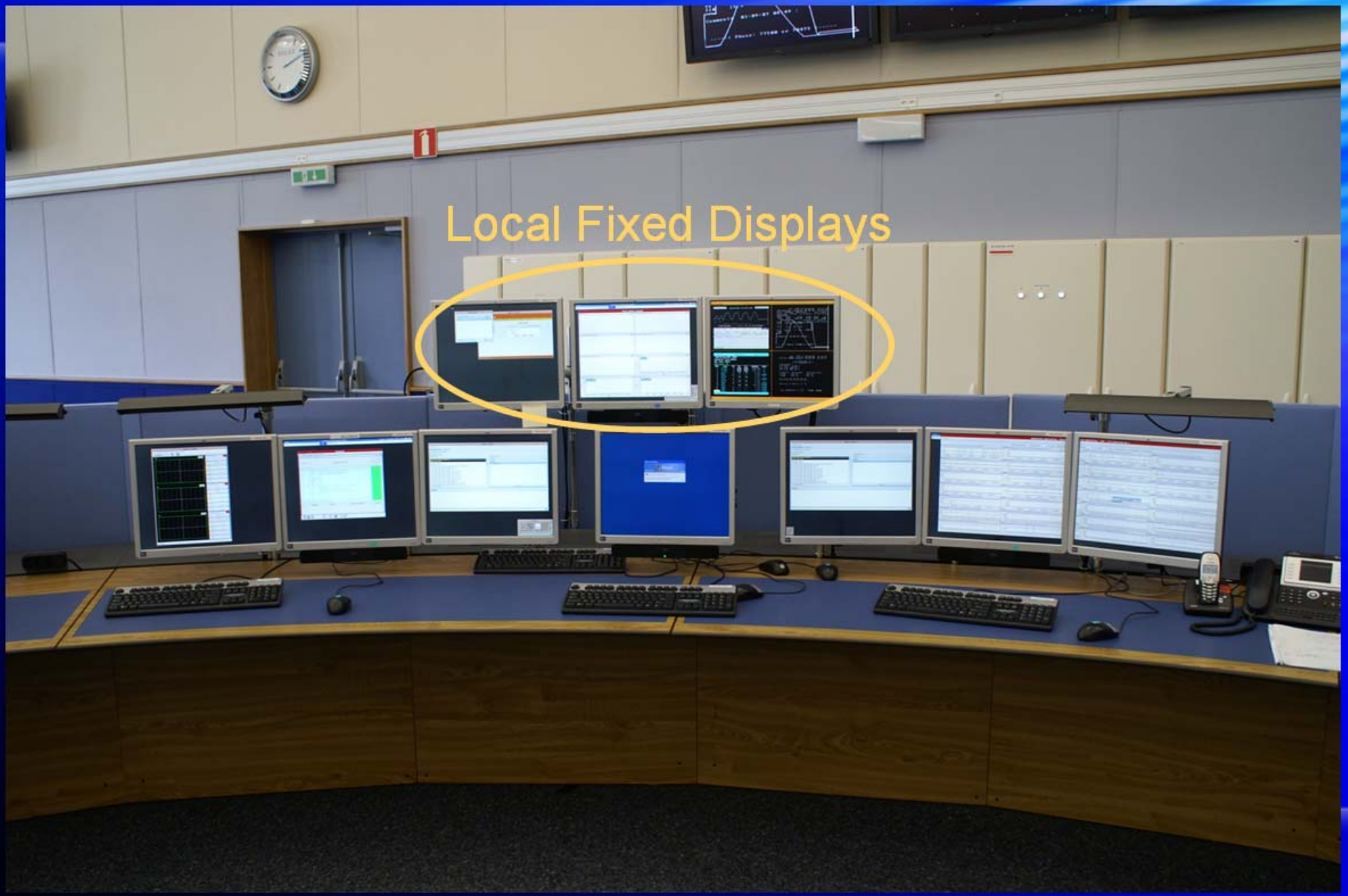
Inside CCC

RPPB01

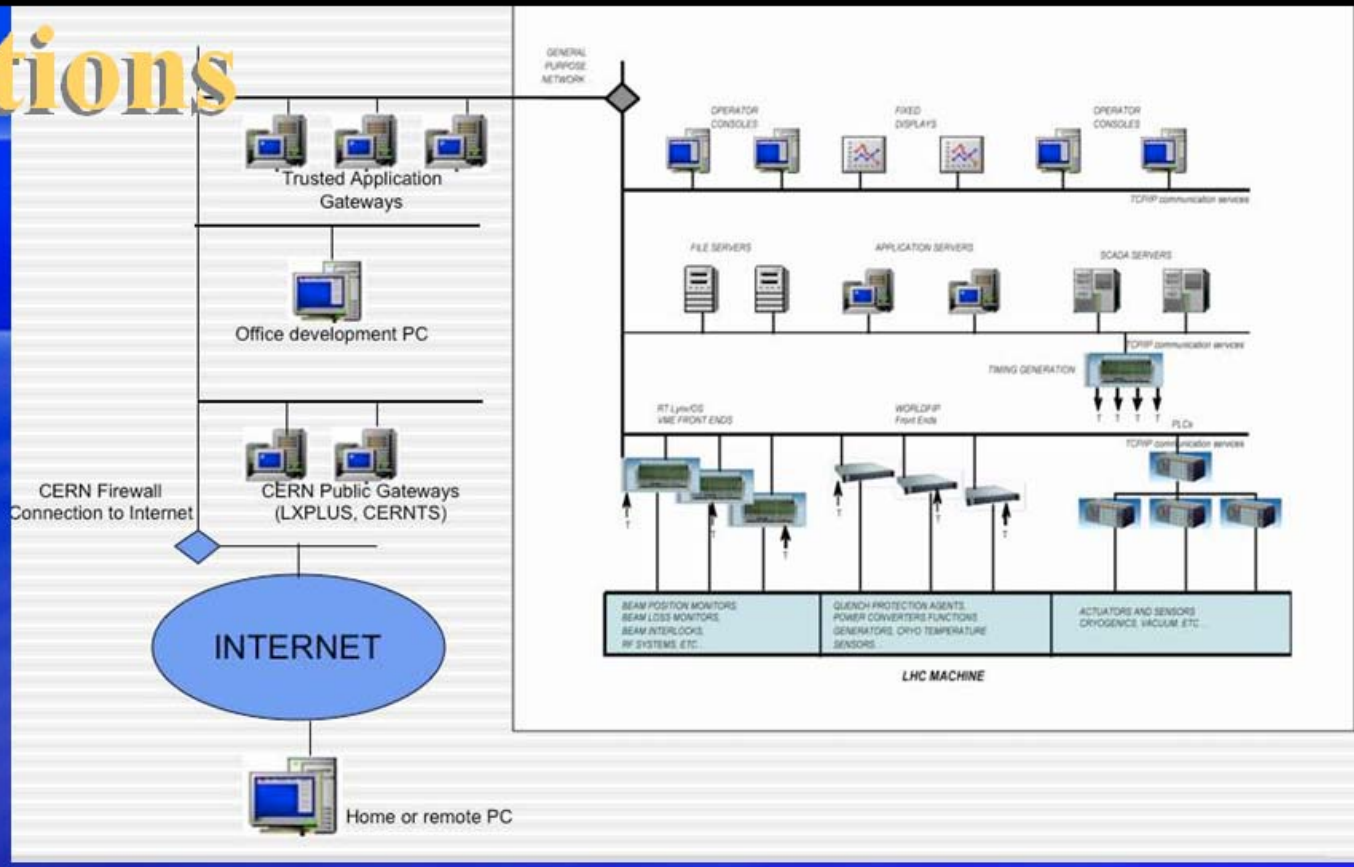
A typical Operator Console



A typical Operator Console

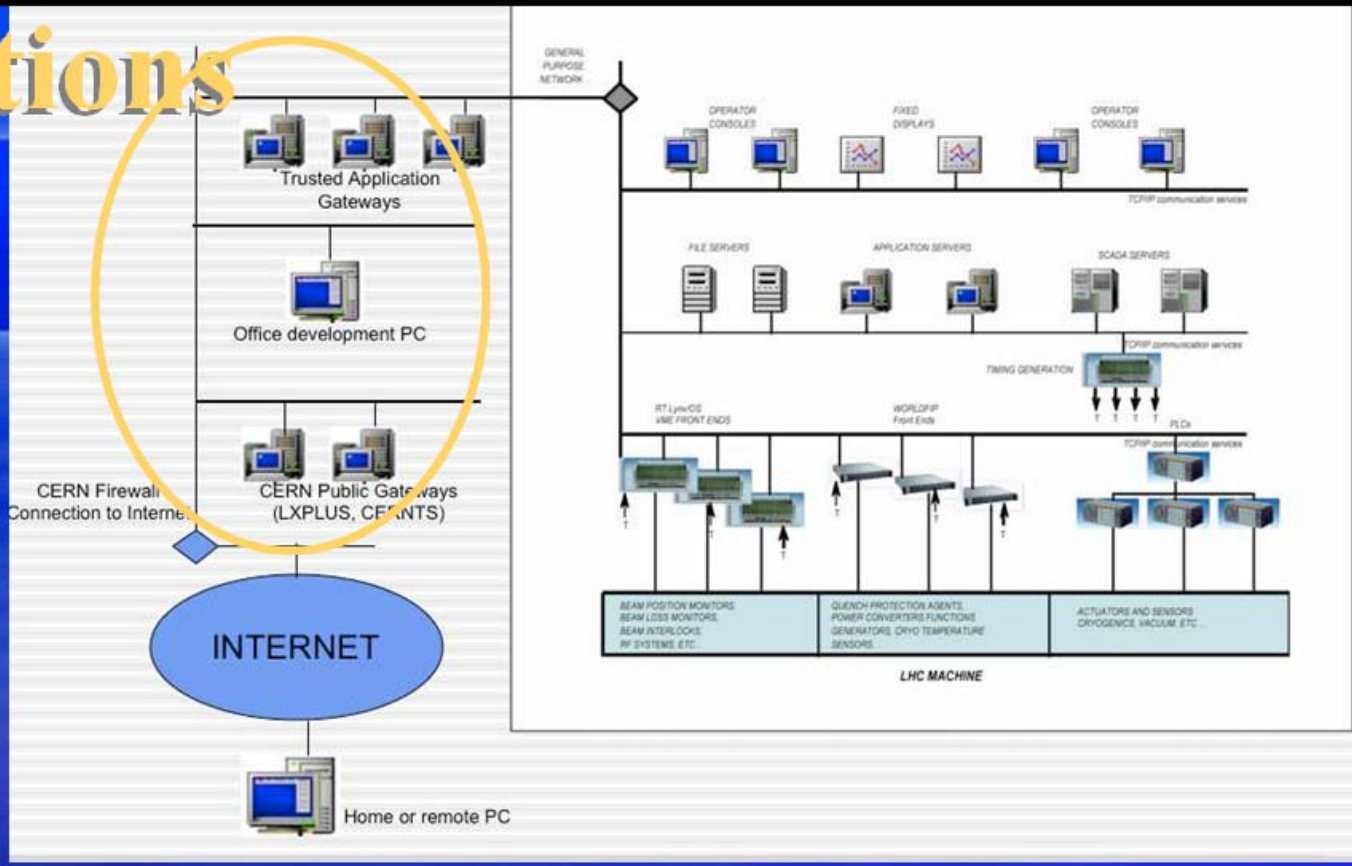


Communications



Communications

- General Purpose Network (GPN)
  - For office, mail, www, development
  - No formal connection restrictions



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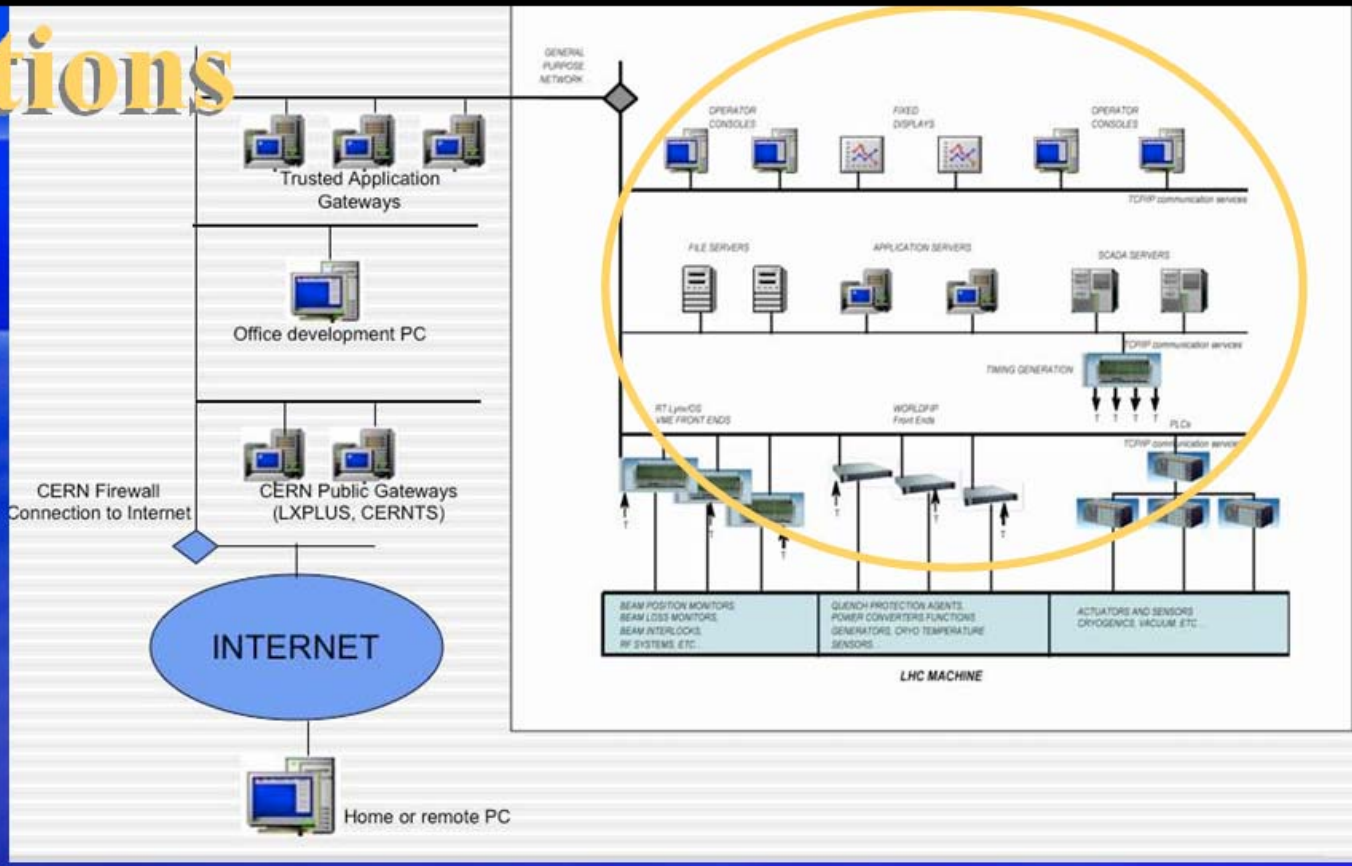

- Technical Network (TN)
  - For operational equipment
  - Formal connection and access restrictions
  - Limited services available (e.g. no mail server, no external web browsing)
  - Authorization based on MAC addresses
  - Network monitored by CERN IT Department

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The LHC Challenges (1/3)

- The LHC is the largest accelerator in the world
  - number of components
  - diversity of systems
- The complexity of operation will be extreme:
  - very critical technical subsystems
  - large parameter space
  - need for online magnetic and beam measurements
  - real time feedback loops.
- Some 500 objects are capable of moving into the aperture of either the LHC Ring, or the transfer lines, ranging from passive valves up to very complex experimental detectors

P. Collier - AB/CO LHC Workshop January, 2005

- The complexity of the accelerator is unprecedented and repair of damaged equipment would take long, for example, the exchange of a superconducting magnet takes about 30 days

R. Schmidt - http://cern.ch/rudi/docs/VisitLHCWuppertal2006.ppt

The LHC Challenges (2/3)

- The energy stored in the beams and the energy stored in the magnets exceed present machines by more than 2 orders of magnitude
- The LHC machine must be protected at all costs
- In the case of an operational incident operation should be able to analyze what has happened and trace the cause.
- Moreover no operation can be resumed if the machine is not back in a good state

Energy Stored in the Beam

Energy stored in one beam at 7 TeV: 362 MJoule

The energy of one shot (5 kg) at 800 km/hour corresponds to the energy stored in one bunch at 7 TeV.

There are 2808 bunches.
Factor 200 compared to HERA, TEVATRON and SPS. *

*Rüdiger Schmidt

Energy stored in the magnets

The energy of an AirBus A380 at 700km/hr corresponds to the energy stored in the LHC magnet system*

Kinetic Energy

- One bunch out of 2808 carries the equivalent of a 5kg shot travelling at 800 km/h*
- 1 small aircraft carrier of 104 tons going 30 km/h
- 450 automobiles of 2 tons going 100 km/h**

Thermal Energy**

- melt 500 kg of copper
- raise 1 cubic meter of water 85ºC: "One ton of tea"

Chemical Energy**

- 80 kg of TNT

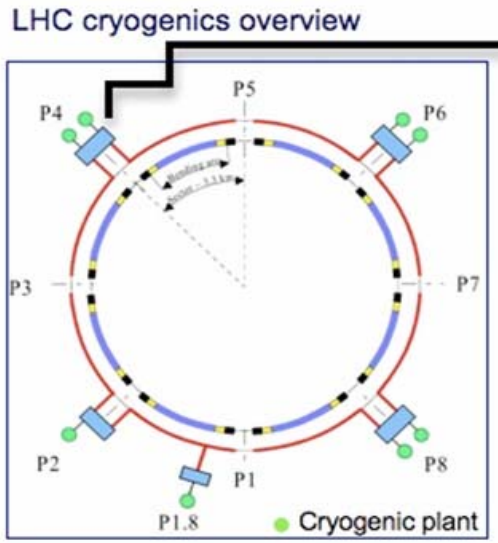
*Rüdiger Schmidt MAC 9 December 2005
**Mike Harrison HCP2006

The LHC Challenges (3/3)

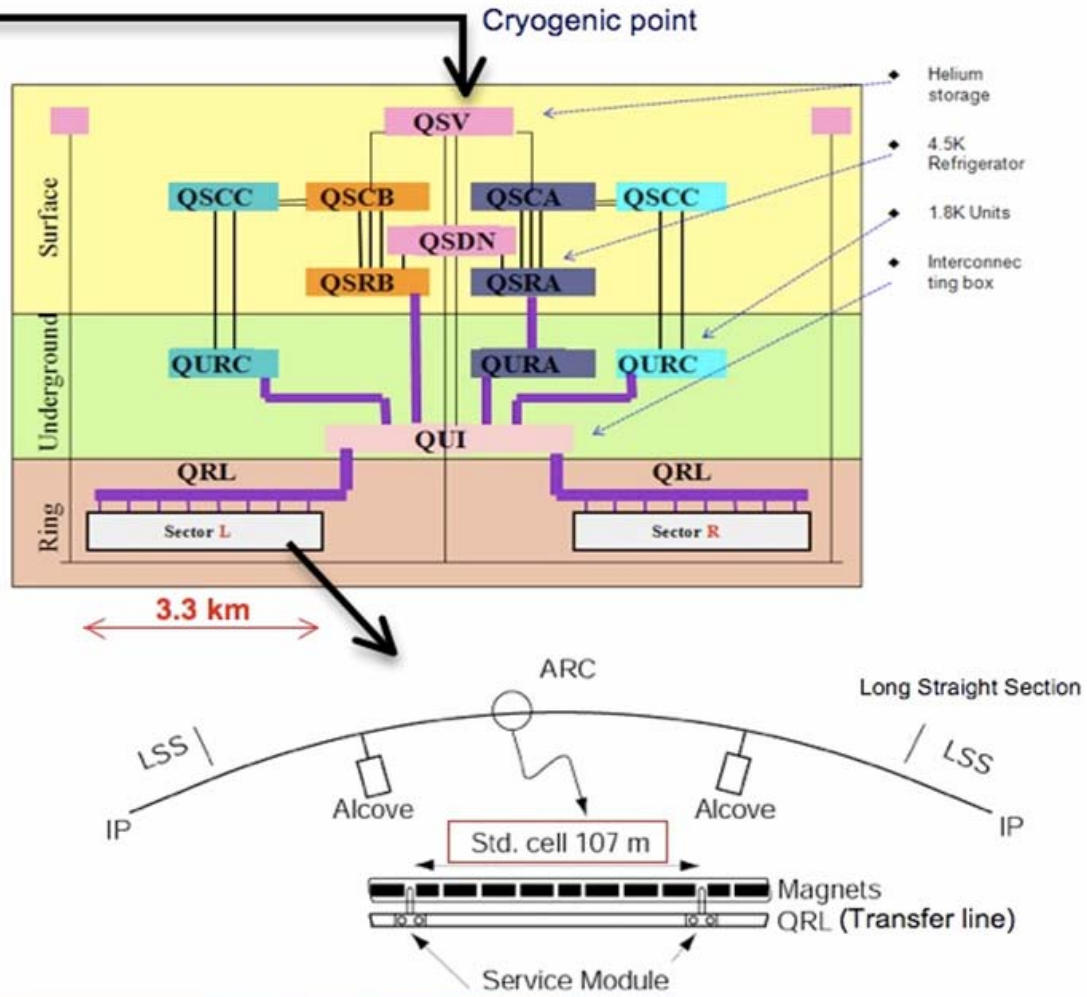
The LHC is the first superconducting accelerator built at CERN

- 4 large scale cryoplants with 1.8 K refrigeration capability

The LHC Challenges (3/3)




LHC tunnel (27 km)



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Technical solutions (1/3)

WPPB38

- Network security (CNIC) and equipment access control (RBAC, Machine Critical Settings)
- Specific tools for the monitoring of the controls infrastructure
  - LASER: general alarm system
  - TIM: monitoring of technical infrastructure
  - DIAMON (in development): monitoring and diagnostics of controls infrastructure

RPPB03

RPPA35

- Post mortem data storage and analysis

RPPB13

- Logging system

Security : RBAC

TPPA04
TPPA12
WPPB08

- Implement a 'role-based' access to equipment in the communication infrastructure
- Depending on WHICH action is made, on WHO is making the call, from WHERE the call is issued and WHEN it is executed, the access will be granted or denied
- This allows for filtering, for control and for traceability on the settings modifications to the equipment

Technical solutions (2/3)

- Integrated suite of control room applications LSA (LHC Software Application)

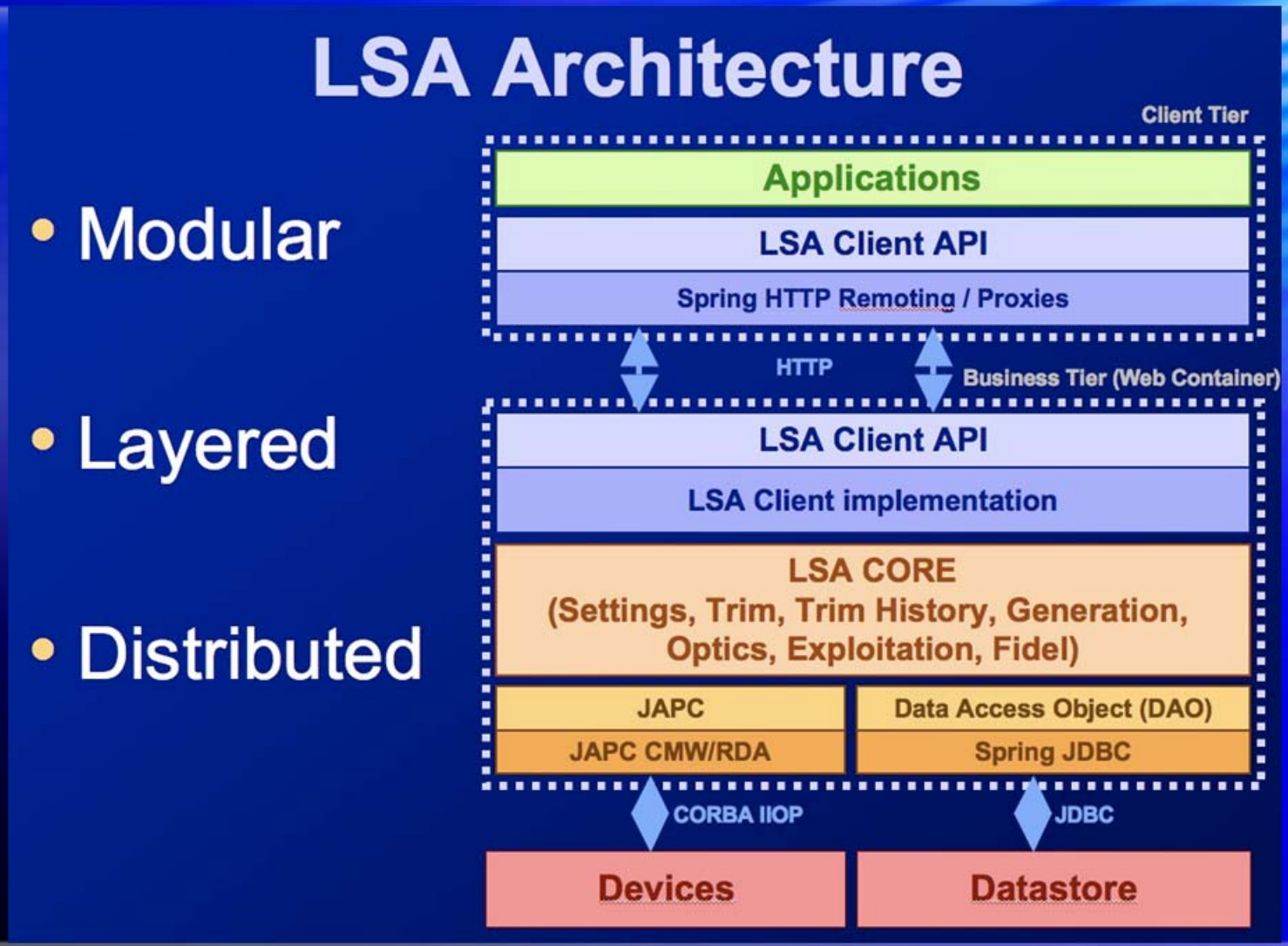
WOPA04

- FESA framework for front-end computers
- UNICOS framework for industrial controls

The LSA framework

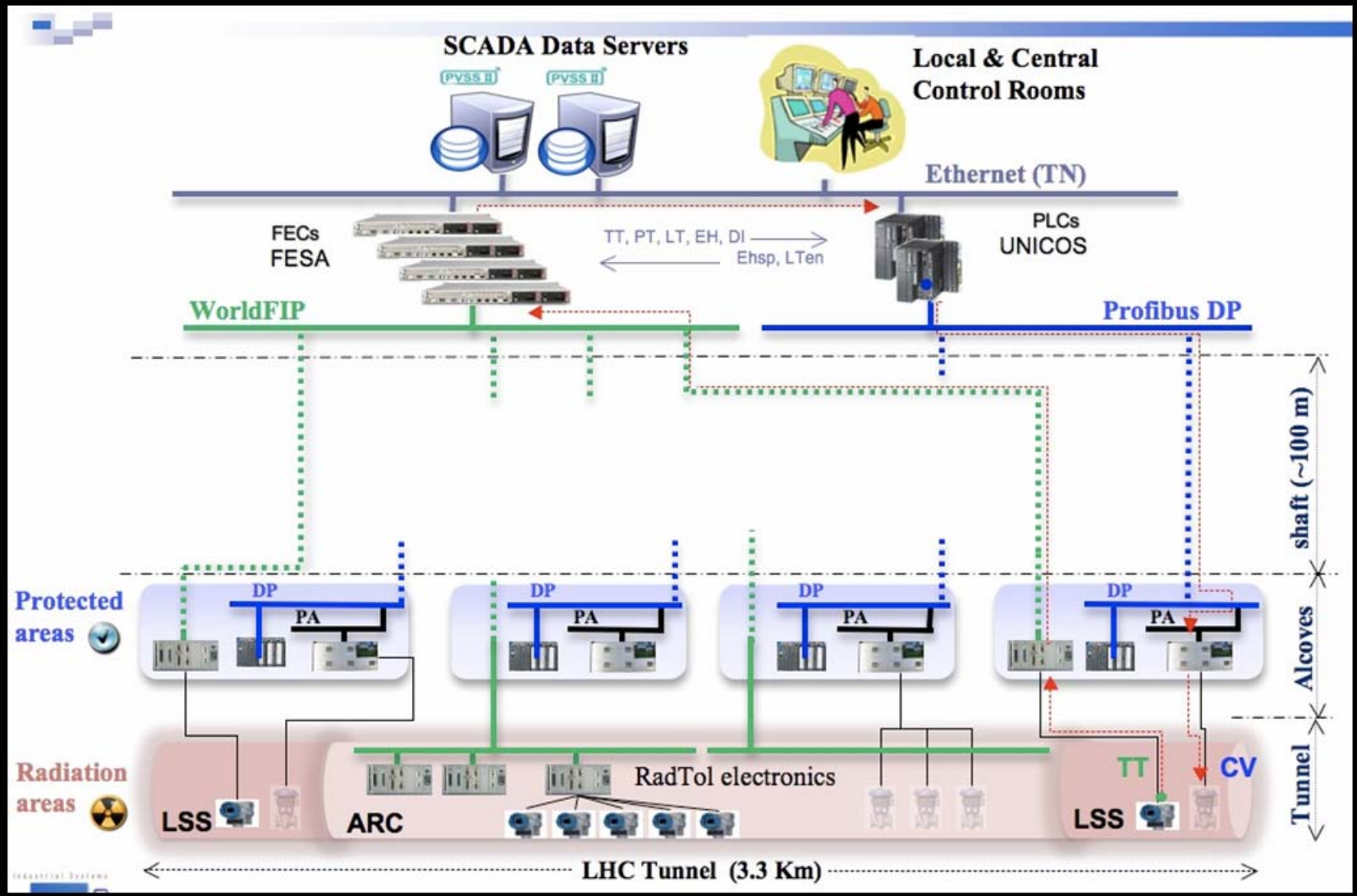
WOPA03
RPPB05

- Modular
- Layered
- Distributed



UNICOS Framework

WOAA03



Technical solutions (3/3)

- Specific hardware developments (high SIL levels) for machine protection (PIC, BIC…) TPPB23
- LHC Software Interlocks System (SIS) WPPB03
- Fully integrated asset, layout, configuration database system RPPA03
- Extension to the Injector timing system WPPB02 RPPB31 FOAA03

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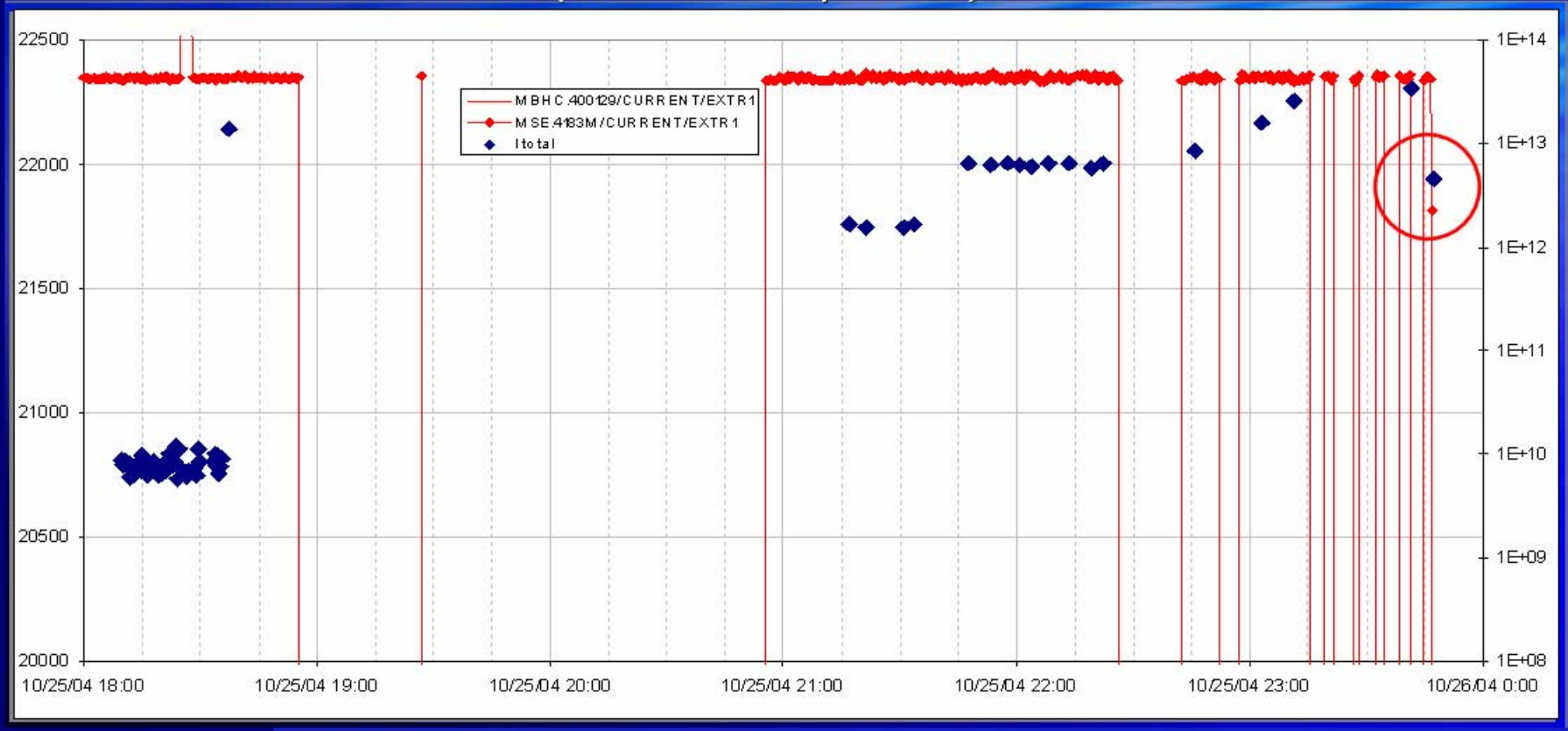
LHC sector 7-8 : Successful cooldown

- The Cryogenics controls system has been a great aid to the operations to achieve this first cooldown

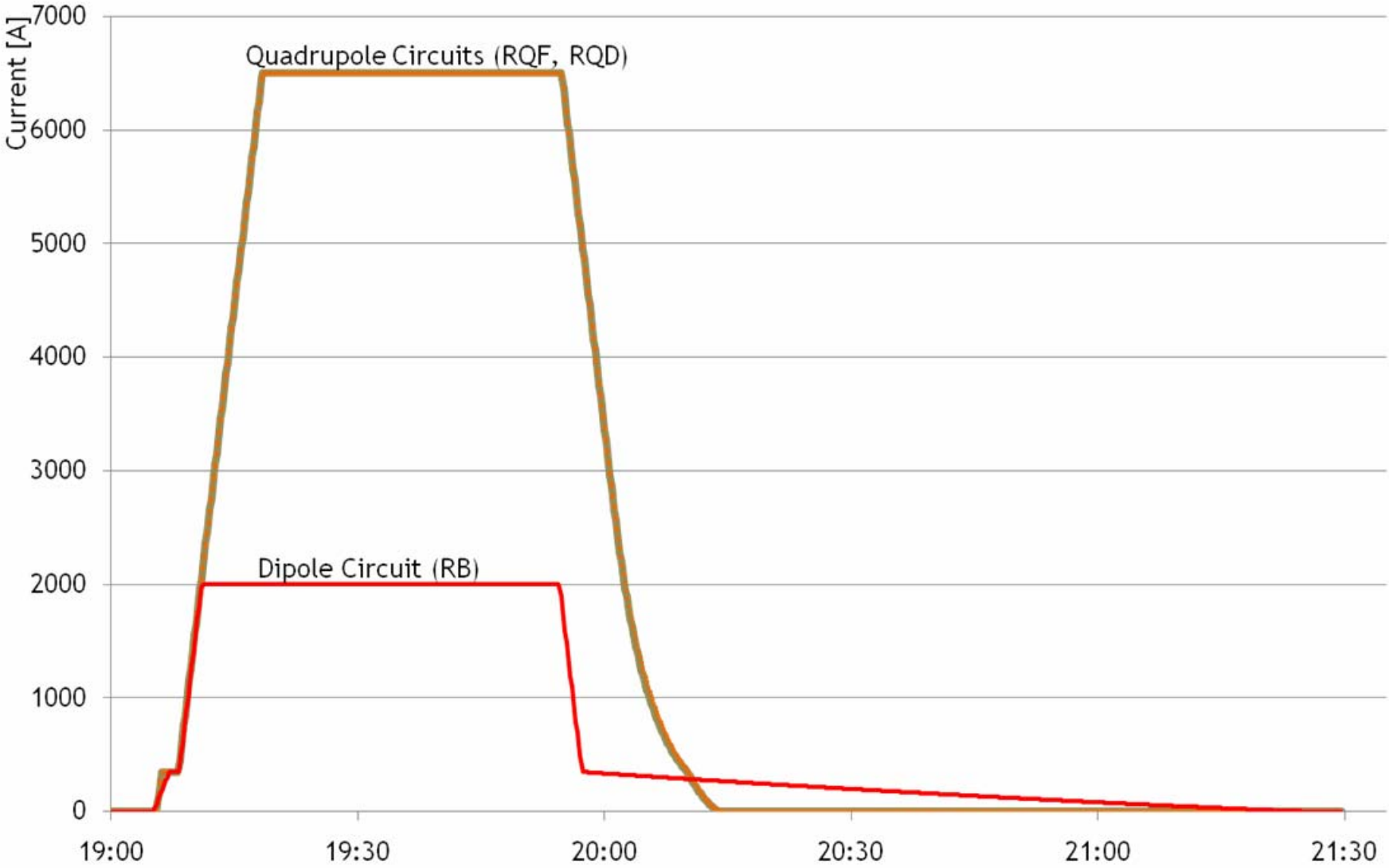
Primary cause of the 2004 TI8 accident identified

- Reconstruction of beam incident from logged data
  - well working logging system
  - SPS at 450 GeV (some 10^13 protons)



Conclusion : MSE current appears to be ~2.5% low at extraction

Tracking between the three main circuits of sector 78



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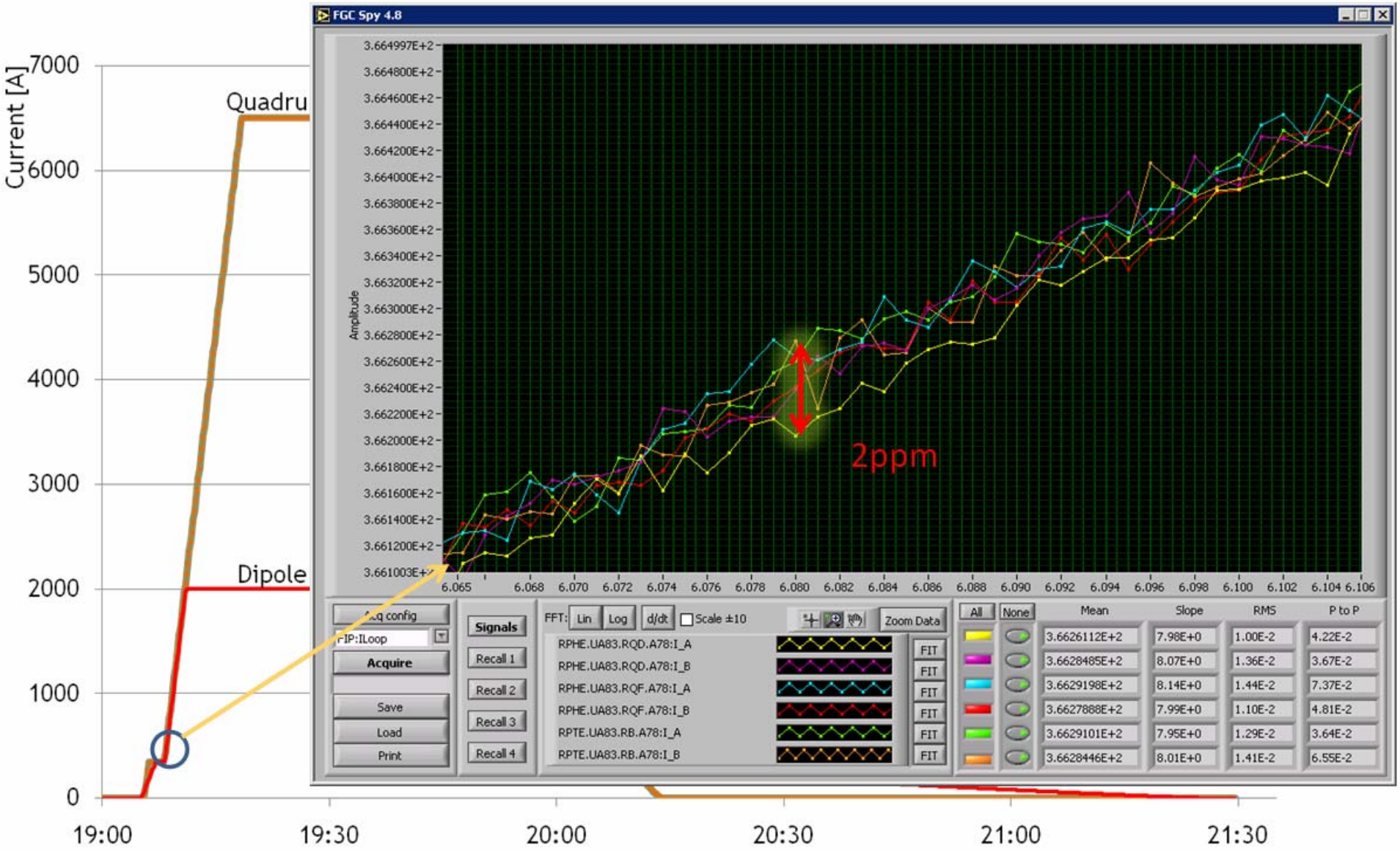

post mortem view of PC tracking

LHC Hardware Commissioning

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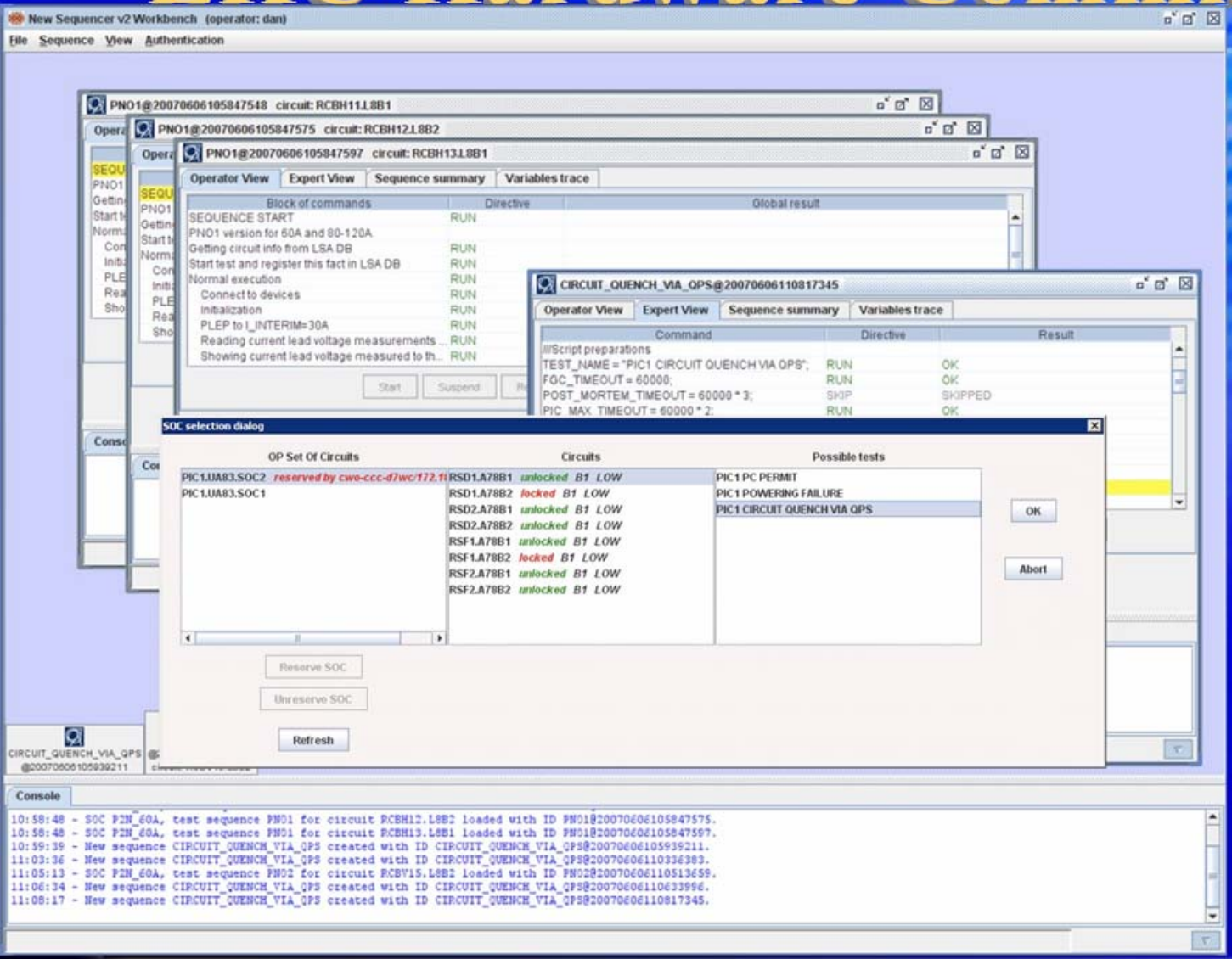
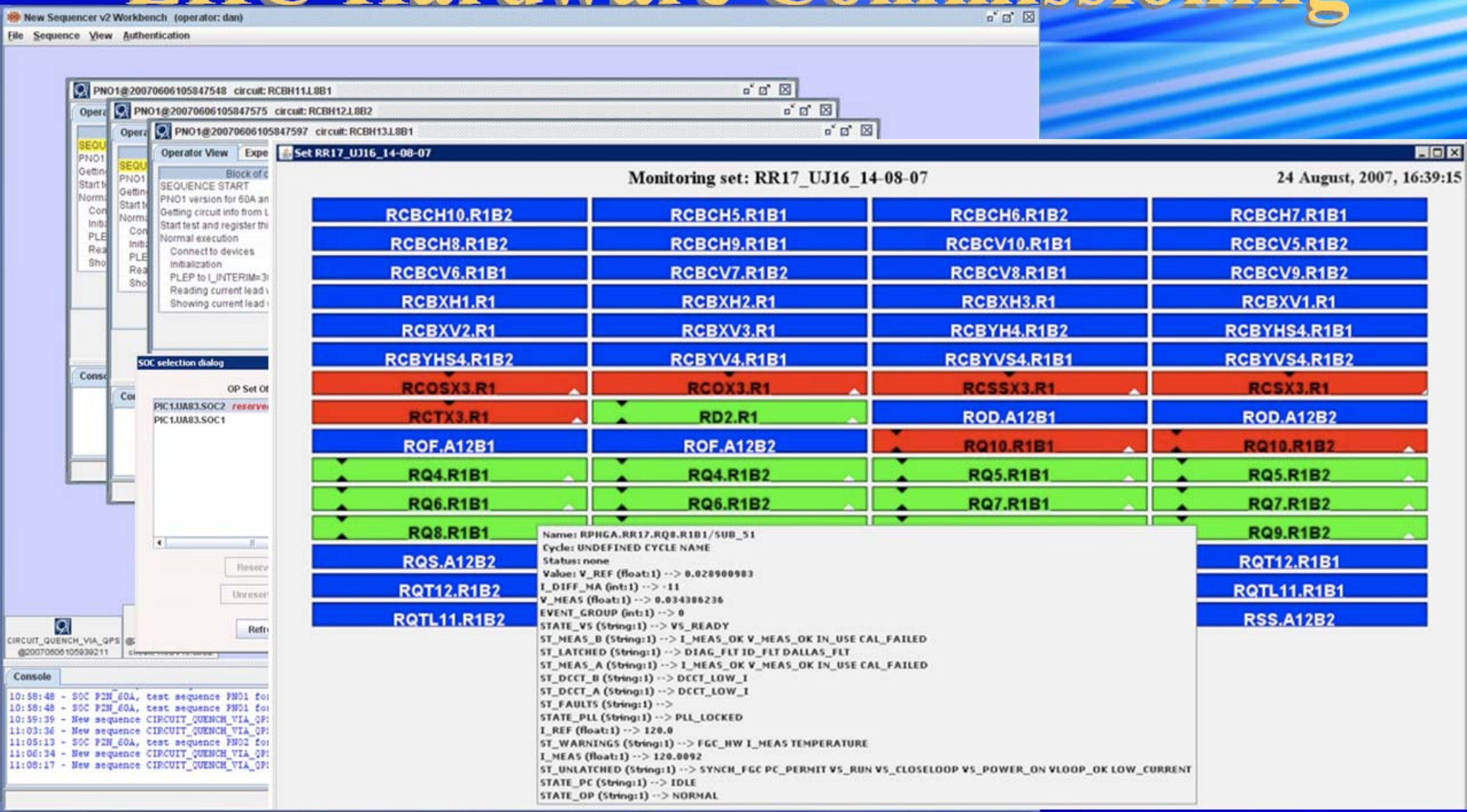


LHC Hardware Commissioning



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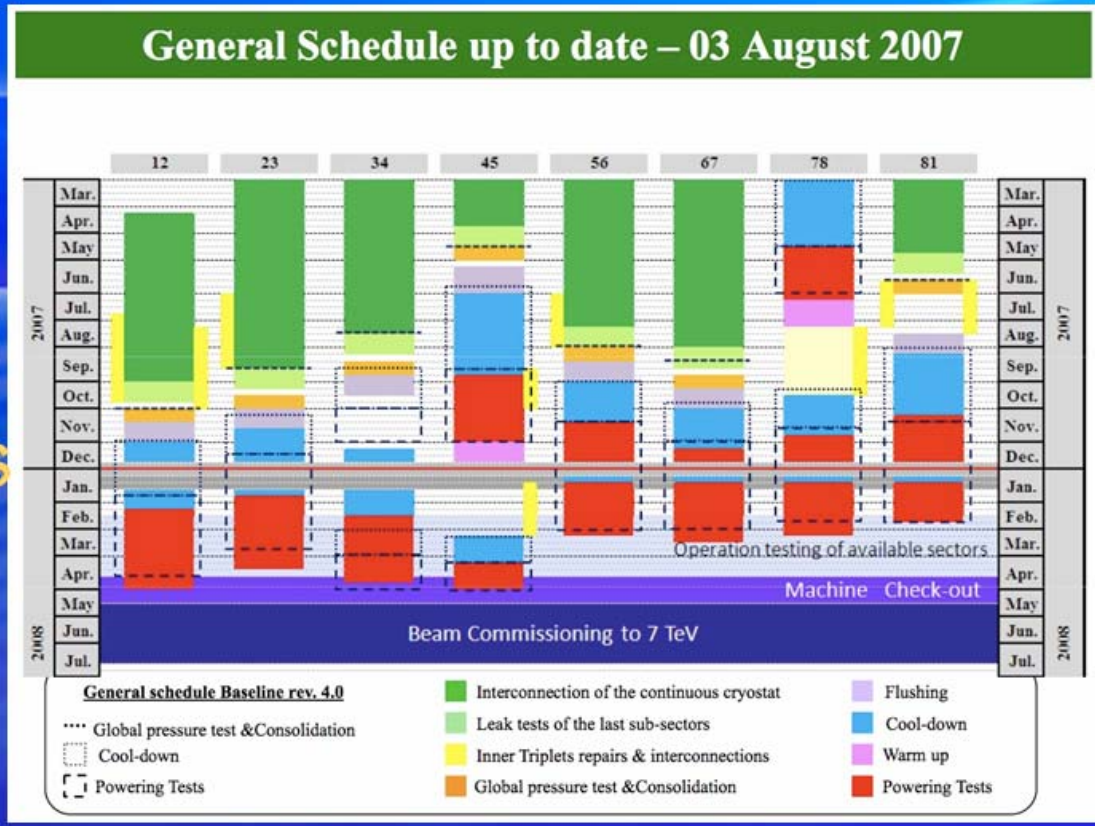
- LHC Transfer Lines commissioning in the coming weeks



- LHC Hardware Commissioning in the coming months, with massive parallelism early 2008
- First LHC beam commissioning for summer 2008

Outline

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Summary

- We have addressed the LHC challenges and appropriate solutions have been deployed
- The LHC infrastructure has been tested almost completely on previous milestones (LEIR, TI2/8 Transfer Lines, CNGS, SPS, LHC HWC)
  - we are confident that we can meet the LHC challenges
- Part of the enormous human resource effort invested for LHC comes from international collaborations
  - Their contribution is highly appreciated
  - Looking forward to more fruitful collaborations
- We have scheduled our efforts for the 450 GeV engineering run in November 2007
  - **We are now ready and eager to see beam in the LHC**