LHC Machine Protection Panel meeting

Geneva, 24th April 2009

Interlock Requirements for the Triplet Remote Alignment System

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Acknowledgements: H. Mainaud-Durand, D. Missiaen, J.P. Quesnel

Outline

- Introduction
- MQX alignment system
- Controls aspects
- Interlock requirements
- Conclusions / Timeline

Introduction

- Experimental regions will be highly radio-active after a few years of beam operation
- The super-conducting triplet of the LHC has the tightest alignment tolerance of the machine:
  - *~100 µm instead than the typical 300 µm of other components*
  - *Comparable to natural ground motion at frequencies ≤ 0.1 Hz*
- Therefore, it was decided to equip the LHC triplets with:
  - *A **fully remote control system** of the magnet positions*
  - *A sophisticated **measurement system** for the position survey*
- Implications of LHC operations:
  - *How do we use this system?*
  - *What are the implications for machine safety? → This meeting*

Refs.: H. Mainuad at al., Remote alignment of low-beta quadrupoles with micrometric resolution, EPAC08 (Genova, Italy)
M. Acar et al., The motorized alignment jacks of the LHc low-beta quadrupoles, IWAA2006 (SLAC-R-489)

How do we use the system from the CCC?

Date: 2009-03-26

Engineering Specifications

OPERATIONAL APPLICATIONS FOR THE ACTIVE ALIGNMENT SYSTEM OF THE LHC SUPERCONDUCTING LOW-BETA QUADRUPOLES

Abstract

This document describes the specifications for the applications to be used by the LHC operational team to control the active alignment system of the LHC superconducting low-beta quadrupoles. The main focus of this document is on the monitoring of the magnet position, with particular emphasis on the operational displays and on the logging configuration. Machine protection aspects of the system are also discussed in detail.

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Functional specifications available in EDMS (being engineering checked) to address:

- *Monitoring from the CCC*
- *Definition of beam units*
- *Logging*
- *Interlocks*

New applications will be presented at the LHC commissioning meeting

Outline

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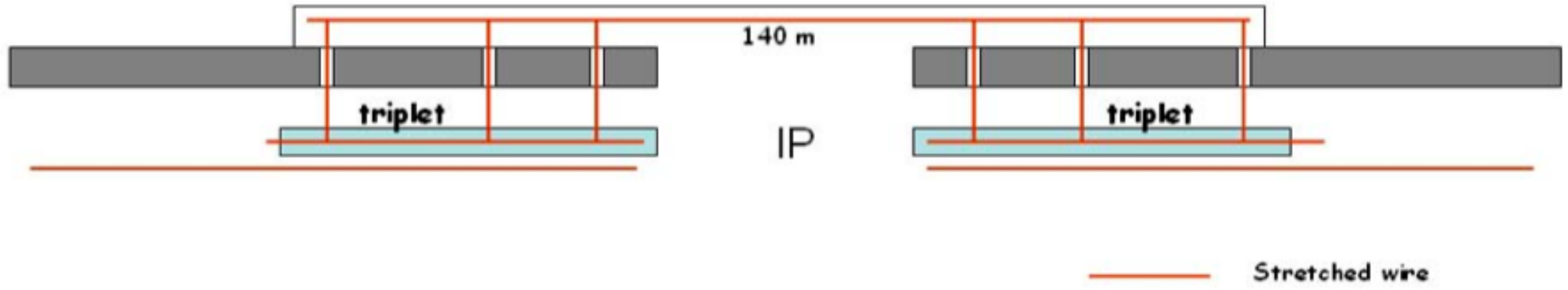
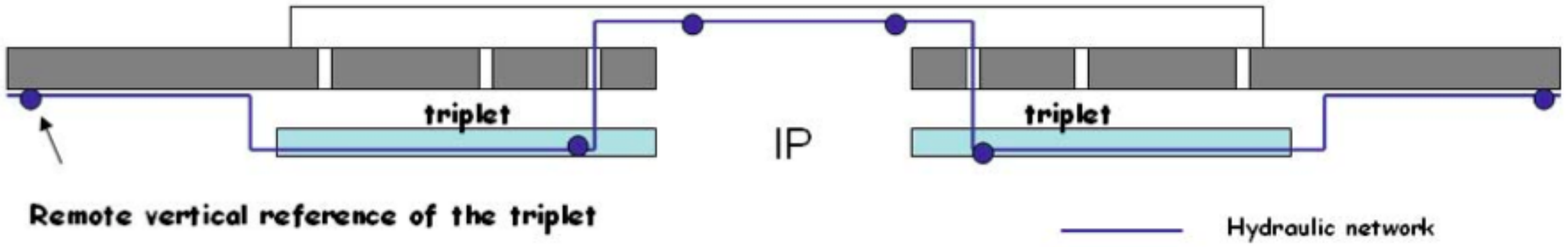
- **MQX alignment system**
- **Controls aspects**
- Interlock requirements
- Conclusions / Timeline

MQX measurement systems (I)



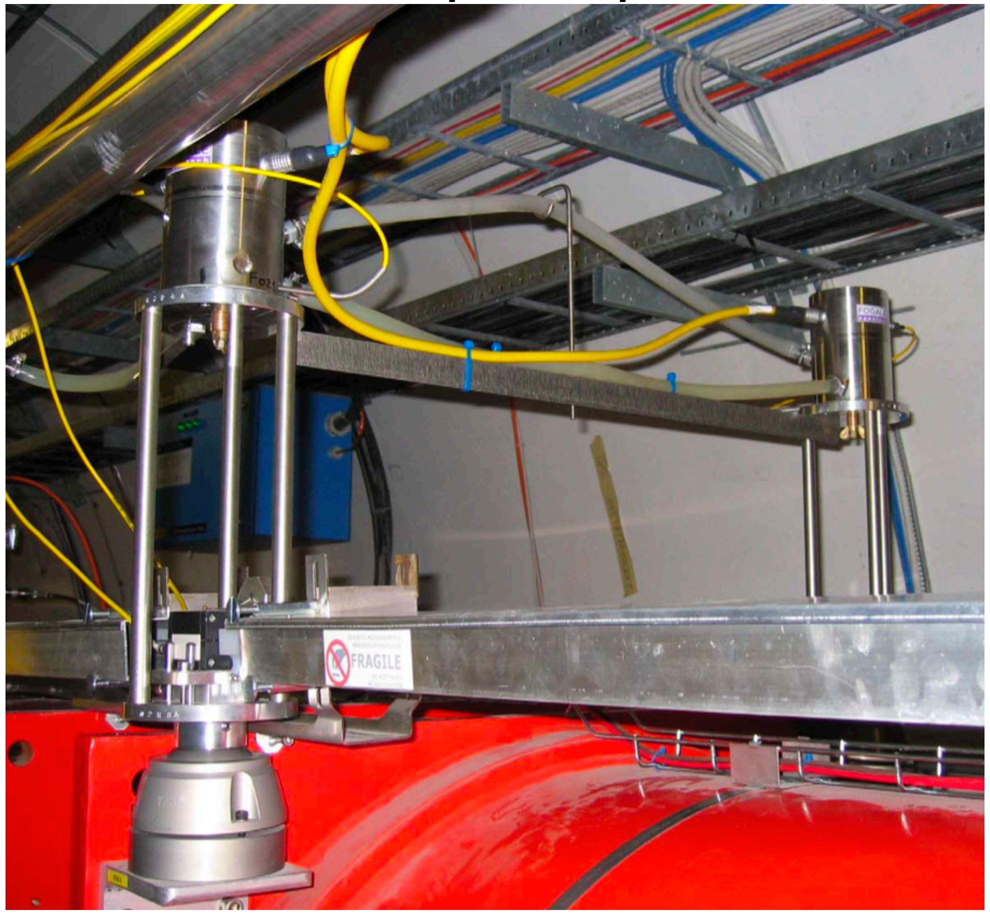
Stretched-wire system (WPS)



Hydrostatic levelling system (HLS)

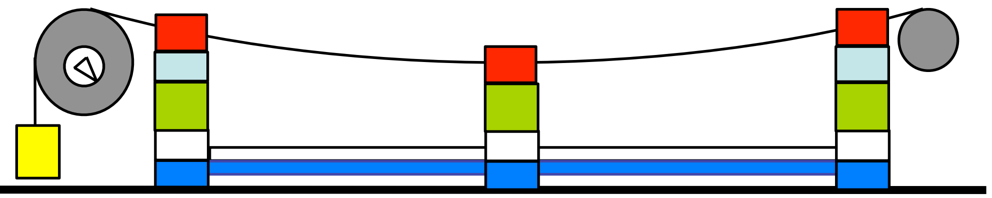
WPS pick-ups

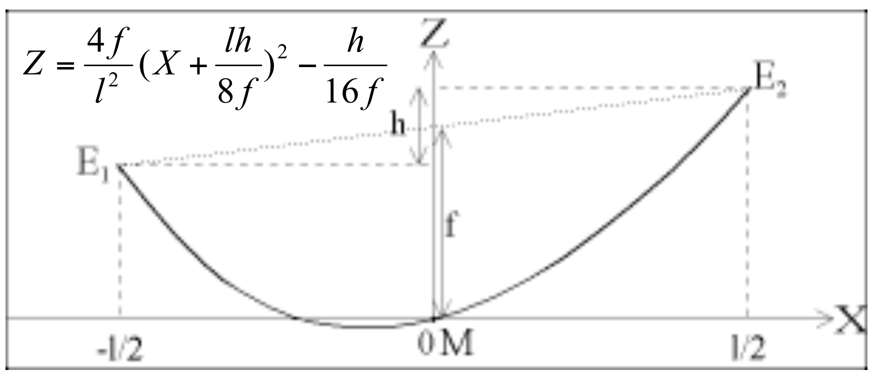
HLS pick-ups

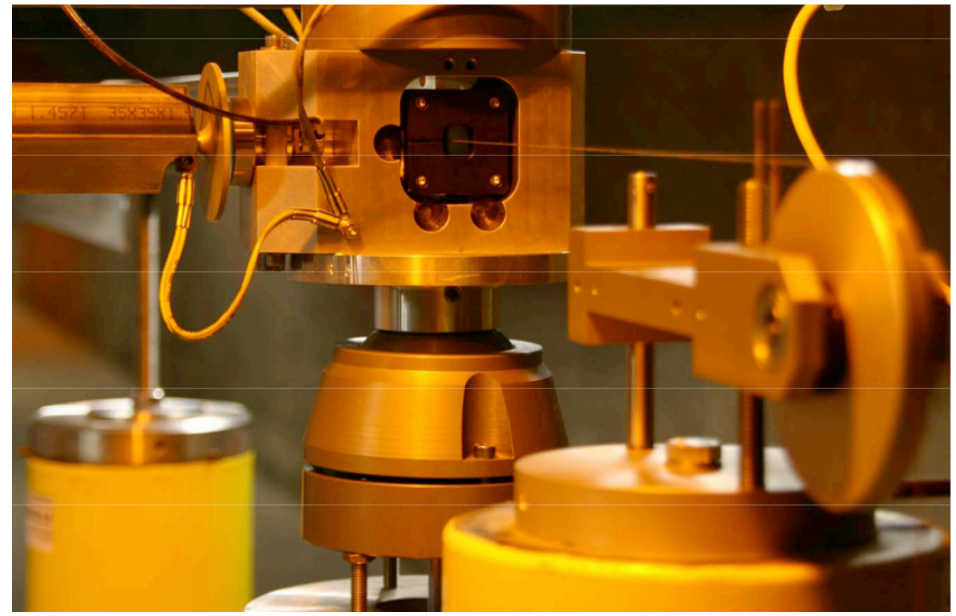


MQX measurement systems (II)

Stretched-wire system (WPS)



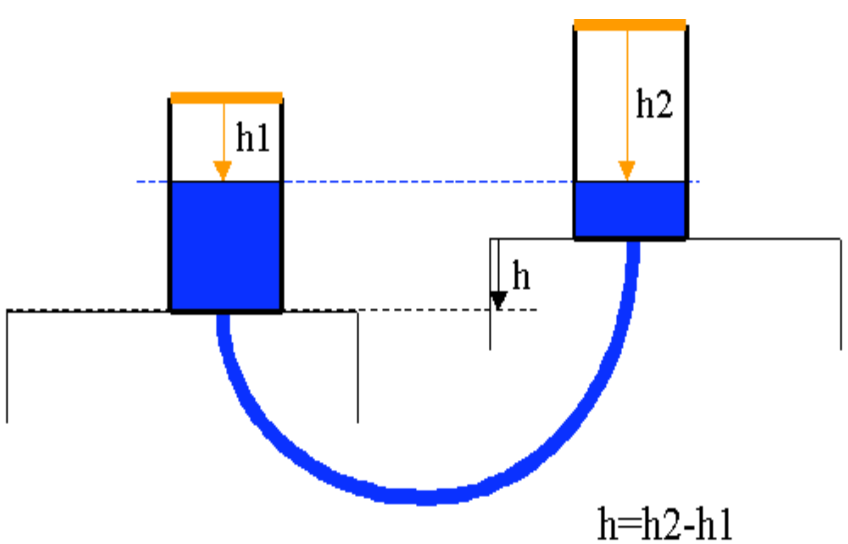




Both based on **capacitive position measurements**

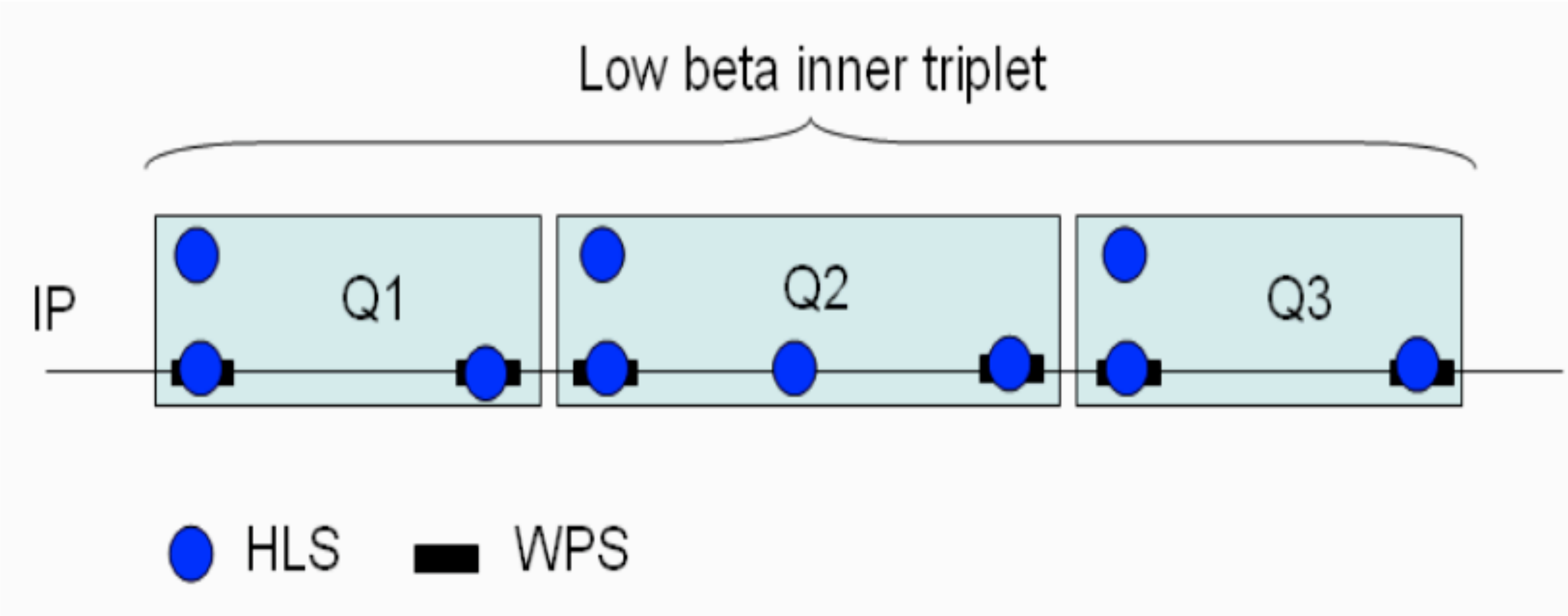
Resolution: 0.2 µm
Range: 10 x 10 mm^2
Reproducibility: 1 µm
Bandwidth: 10 Hz

Hydrostatic levelling system (HLS)

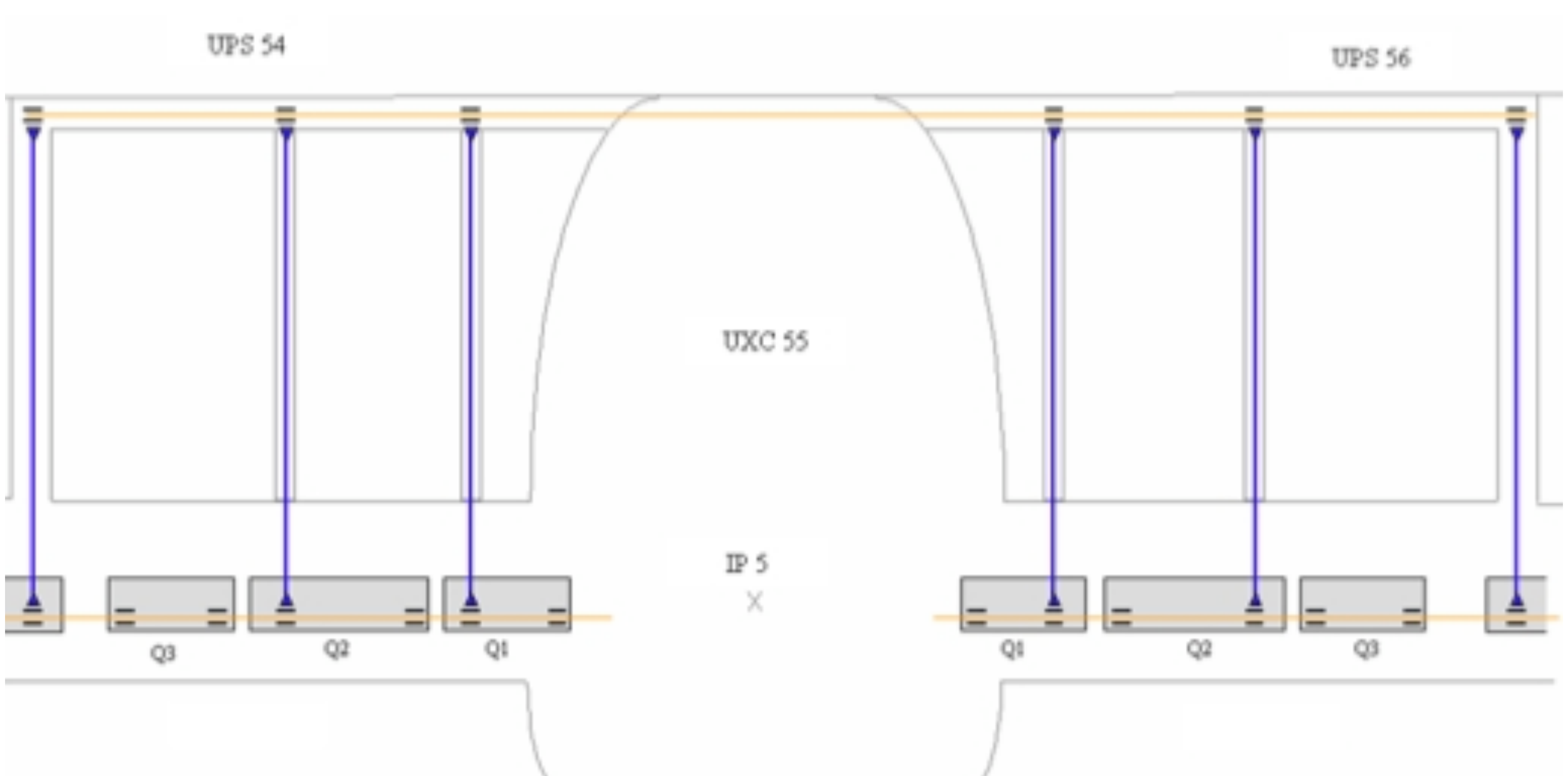


Resolution: 0.2 µm
Range: 5 mm
Reproducibility: 1 µm
Bandwidth: 10 Hz

LHC installation layout

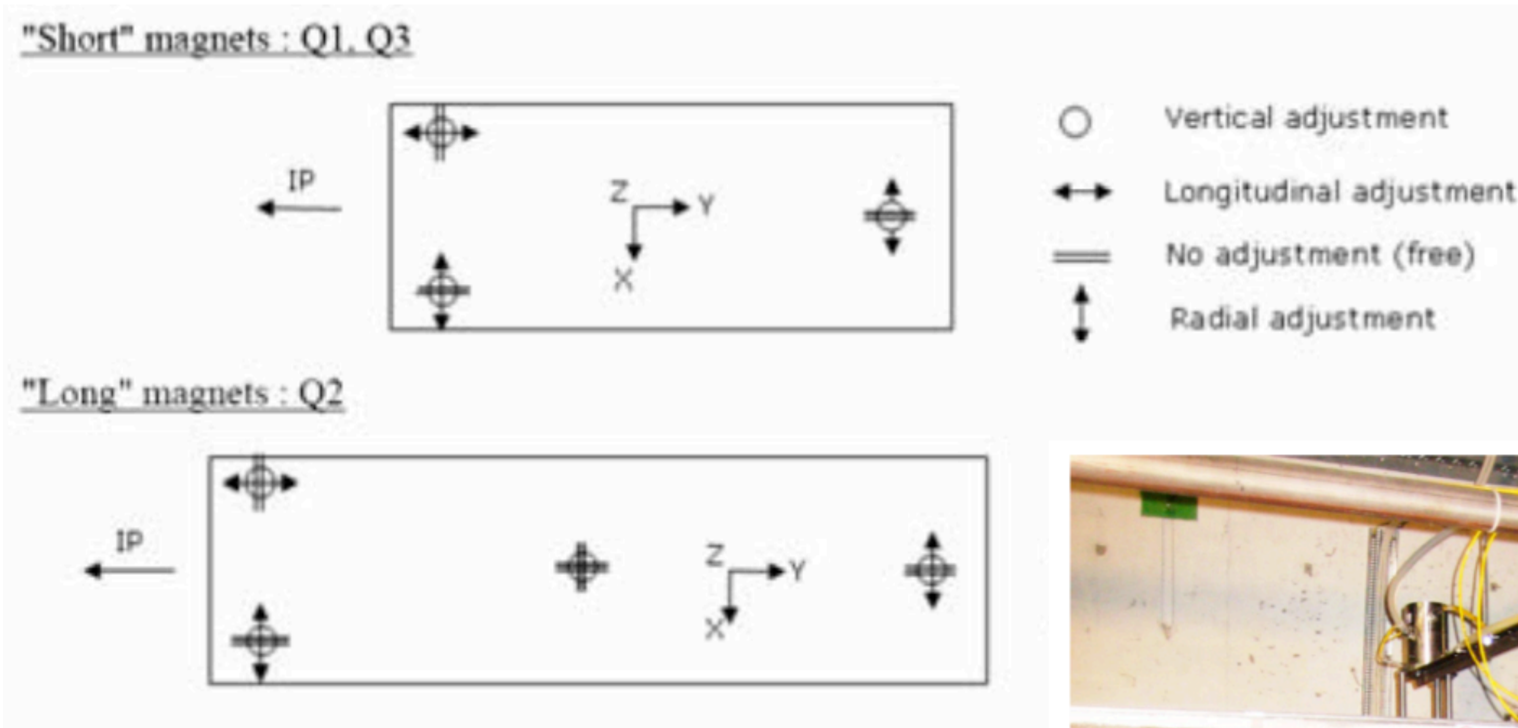


In ALL IPs:
- 3-4 HLS sensors
- 2 WPS sensors
per cryostat

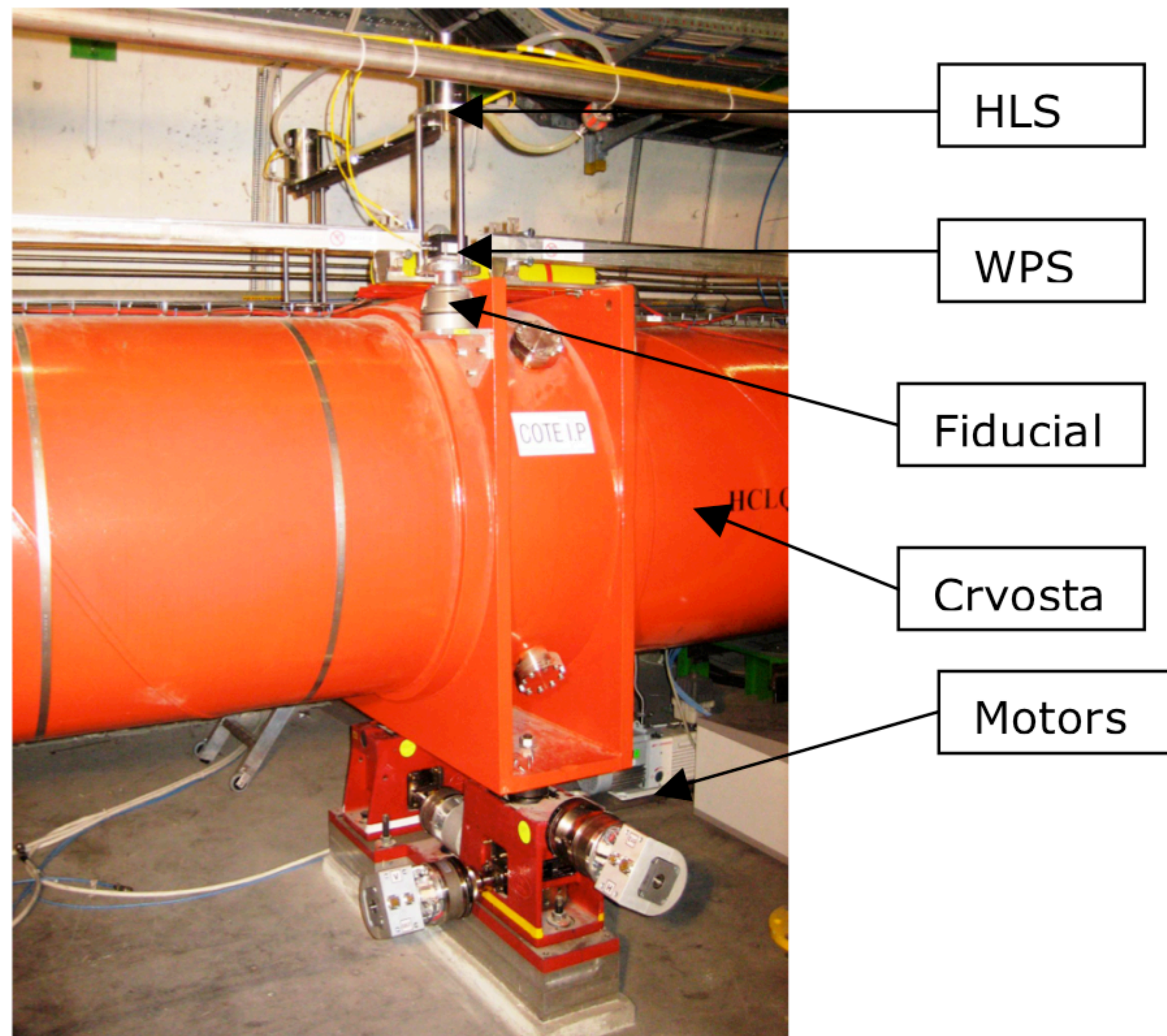


In IP1 and IP5: Additional stretched wire for relative offsets left/right + DOMS (differential offset measurement system)

Remote positioning system



Total of
16 stepping motors
per IP side
Max speed (hor.) =
60-80 μm/s

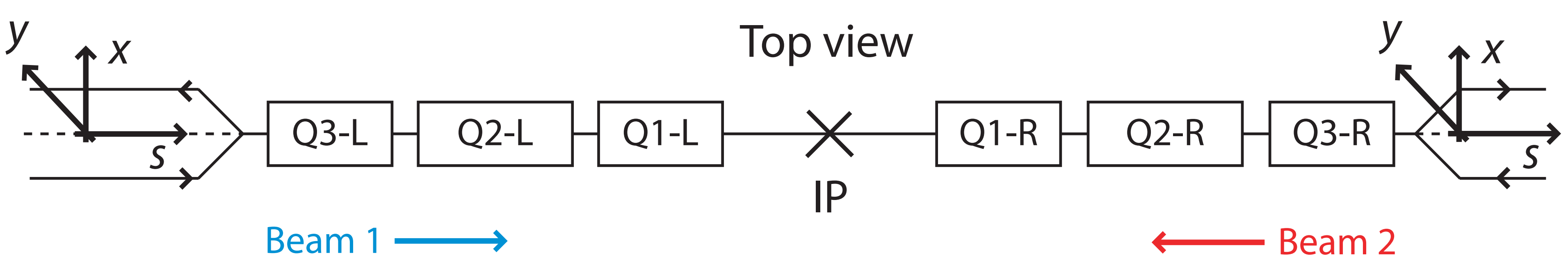


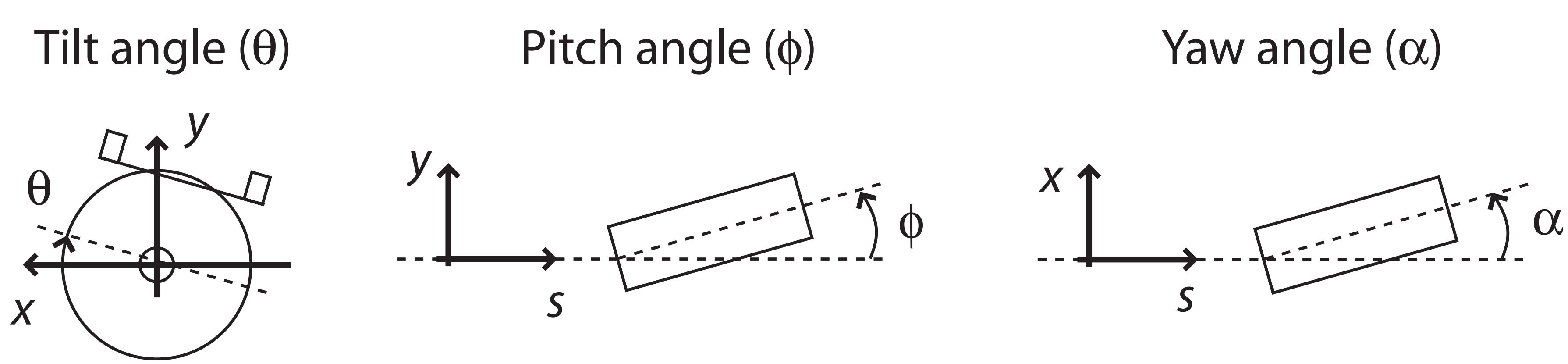
Some numbers...

Overall, the system includes:

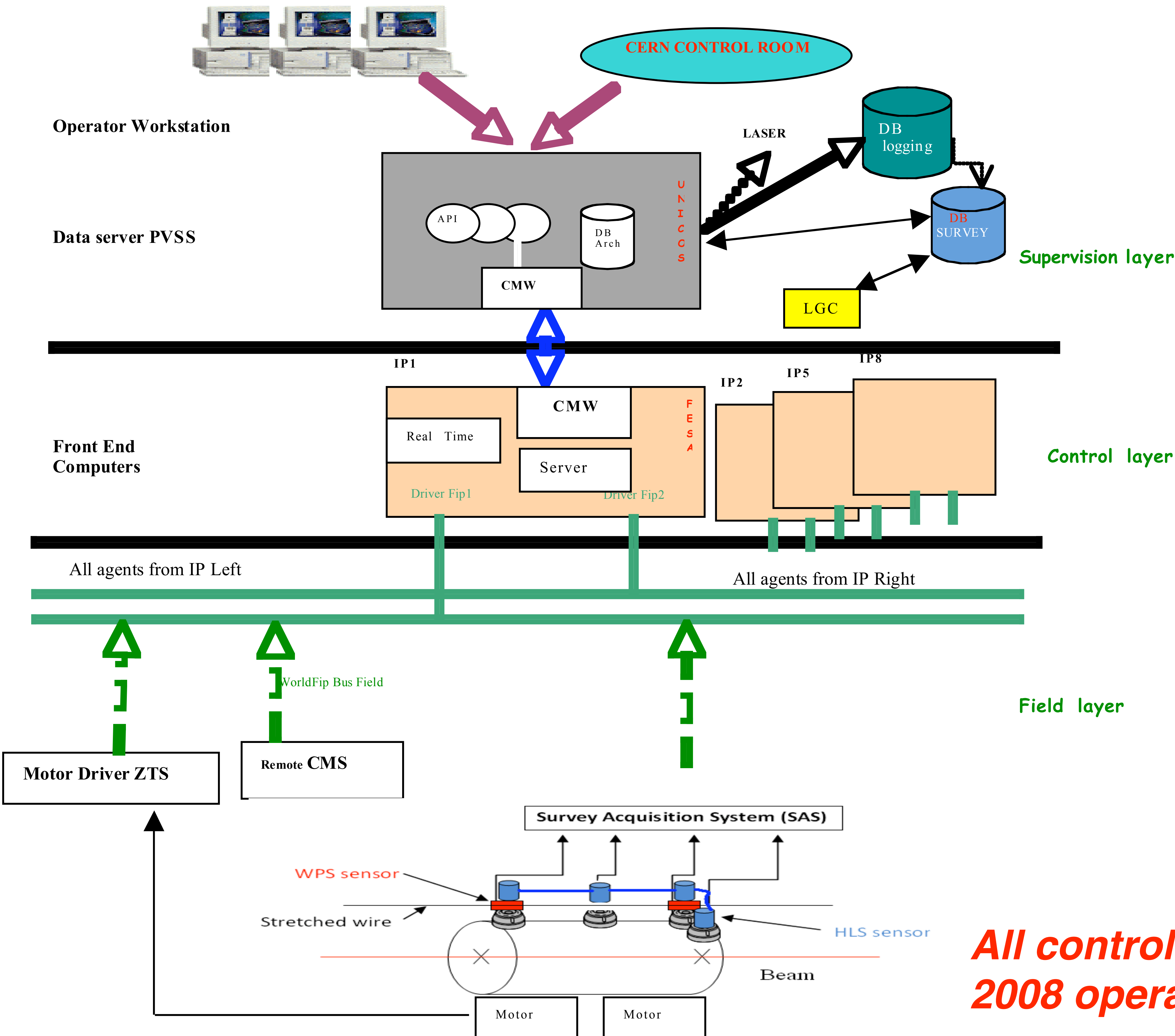
- WPS (Wire Positioning System)	**136**=68x2 measurements (2 axes)
- HLS (Hydrostatic Leveling System)	**100** measurements (1 axis)
- DOMS (Differential Offset Measurement System)	**24** measurements (1 axis)
- Stepping motors for motorized jacks	**128 axes** (16x2 per IP)
- Temperature sensors	**128** measurements

... big and distributed system!
Required appropriate controls infrastructure
BUT enables a very complete set of measurement!





Controls architecture



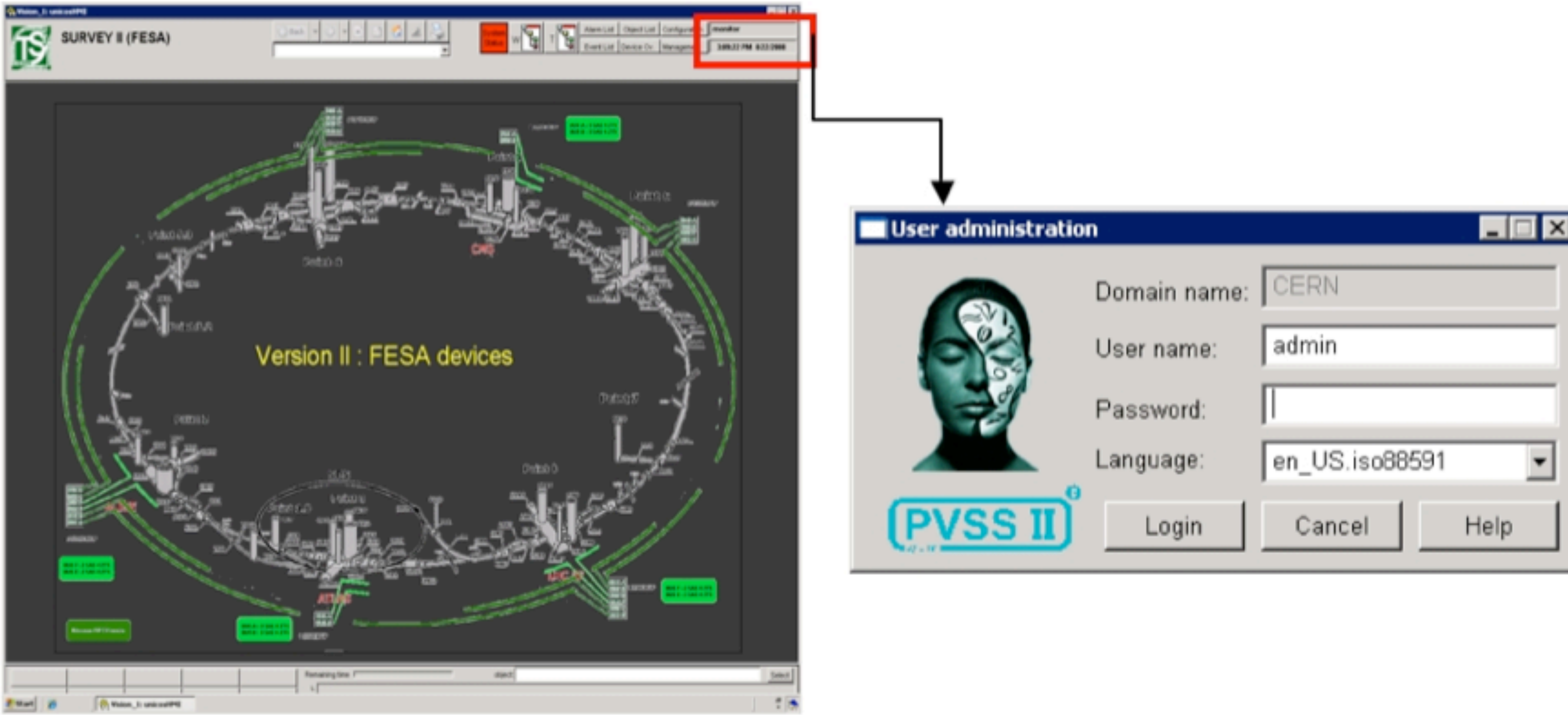
PVSS application

FESA

Low-level

All controls layers deployed for 2008 operation (expert mode)

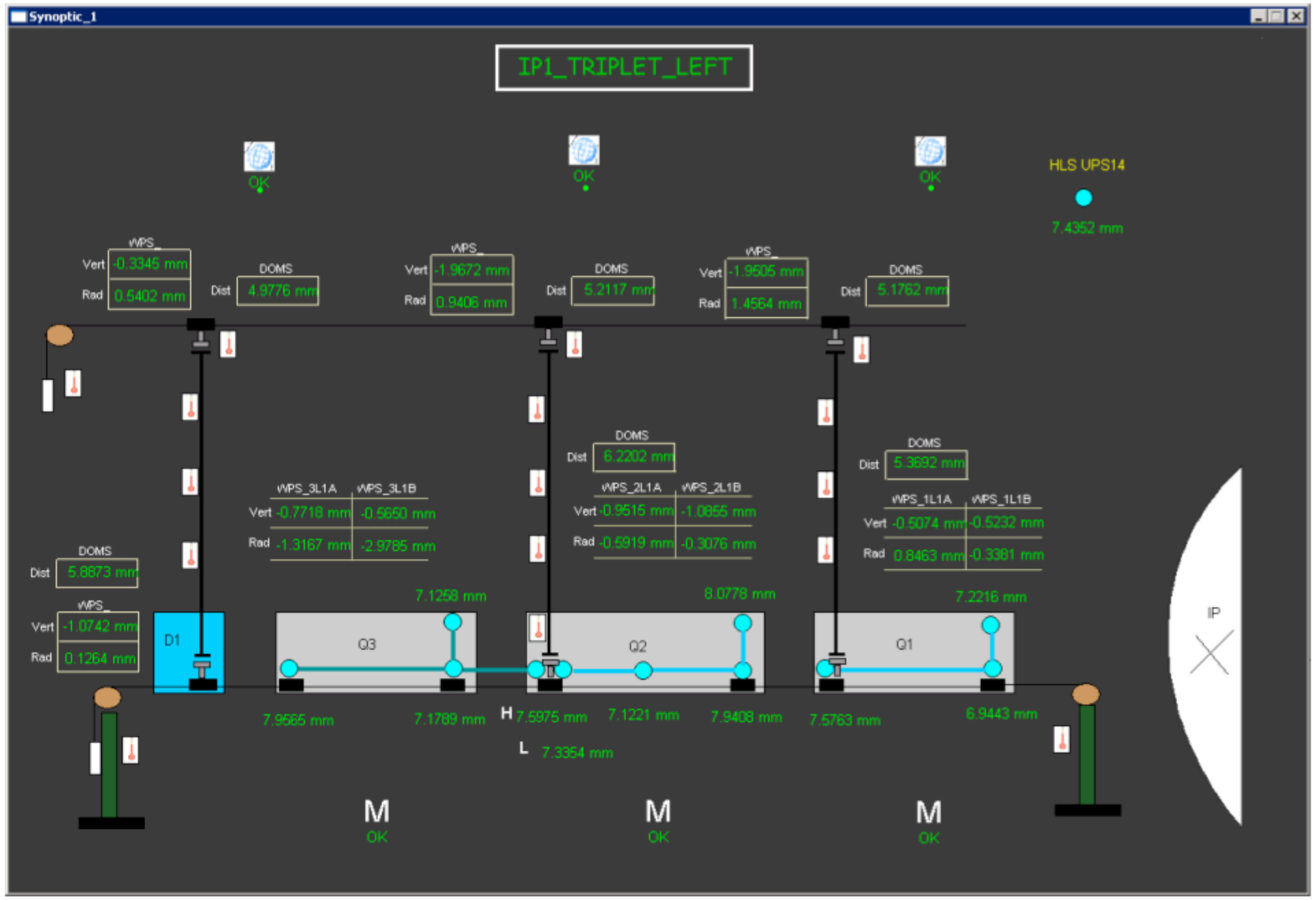
Role-based access in PVSS



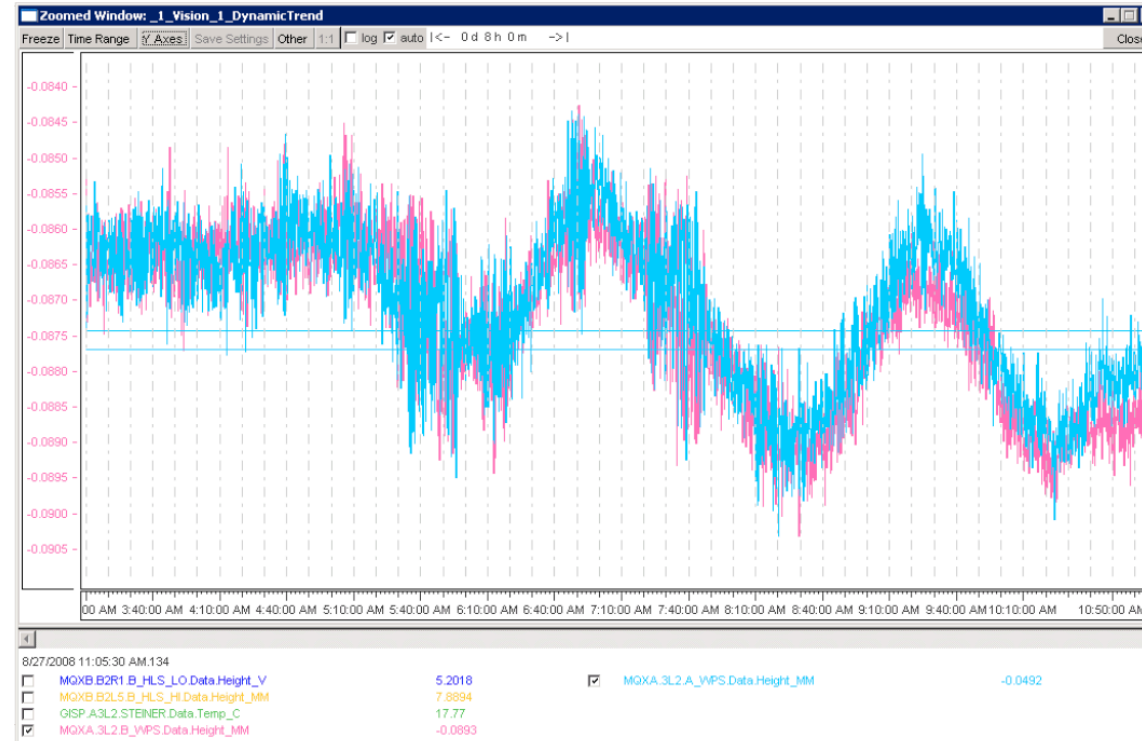
Possible roles available within the PVSS system:
“ADMIN” / “EXPERT” / “OPERATOR” / “MONITOR”

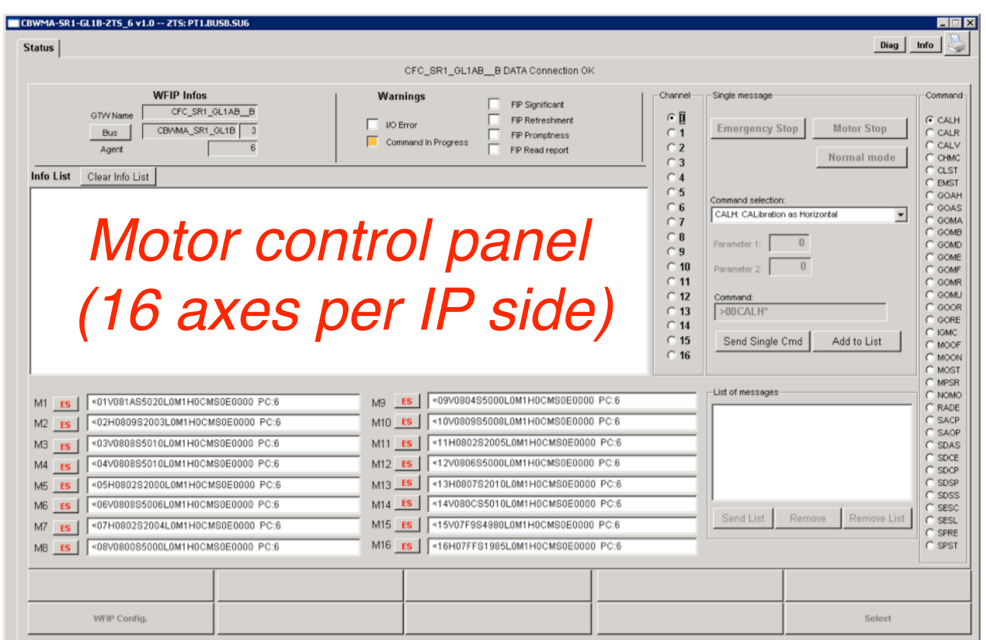
Examples of expert tools

Control panel for one side of the IP (PVSS)

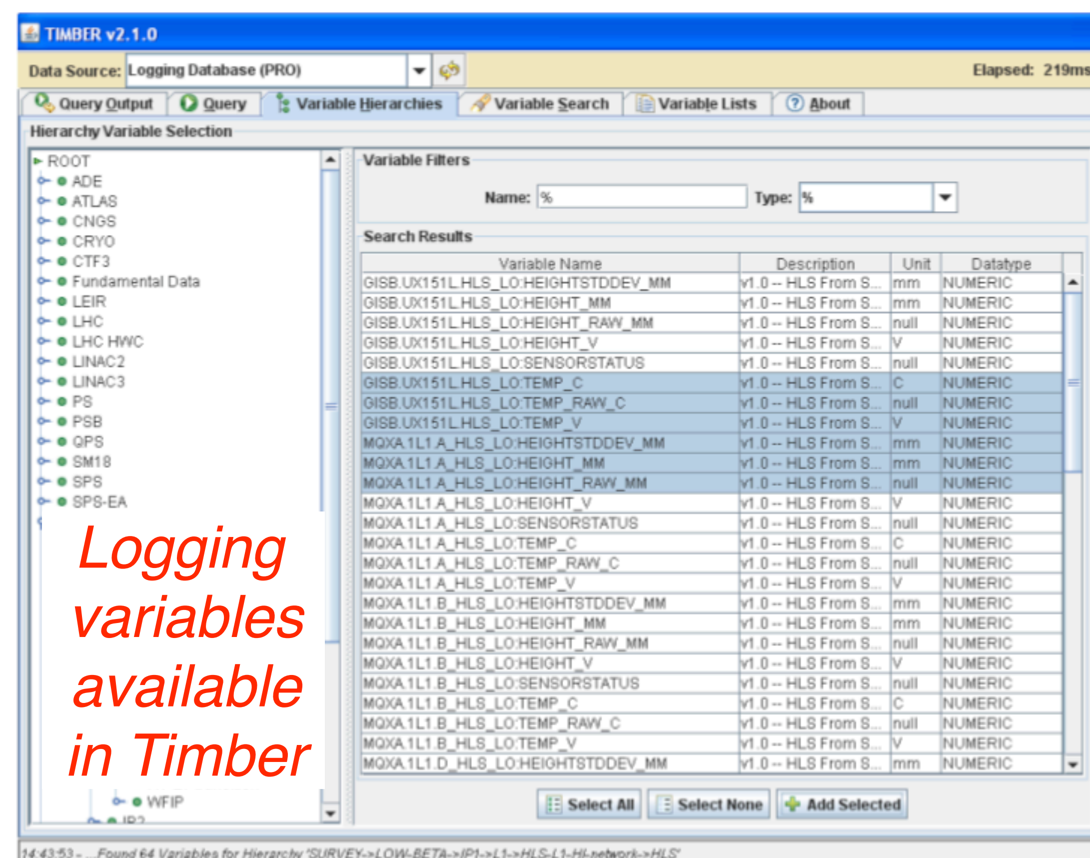


PVSS history buffer (raw data in mm)





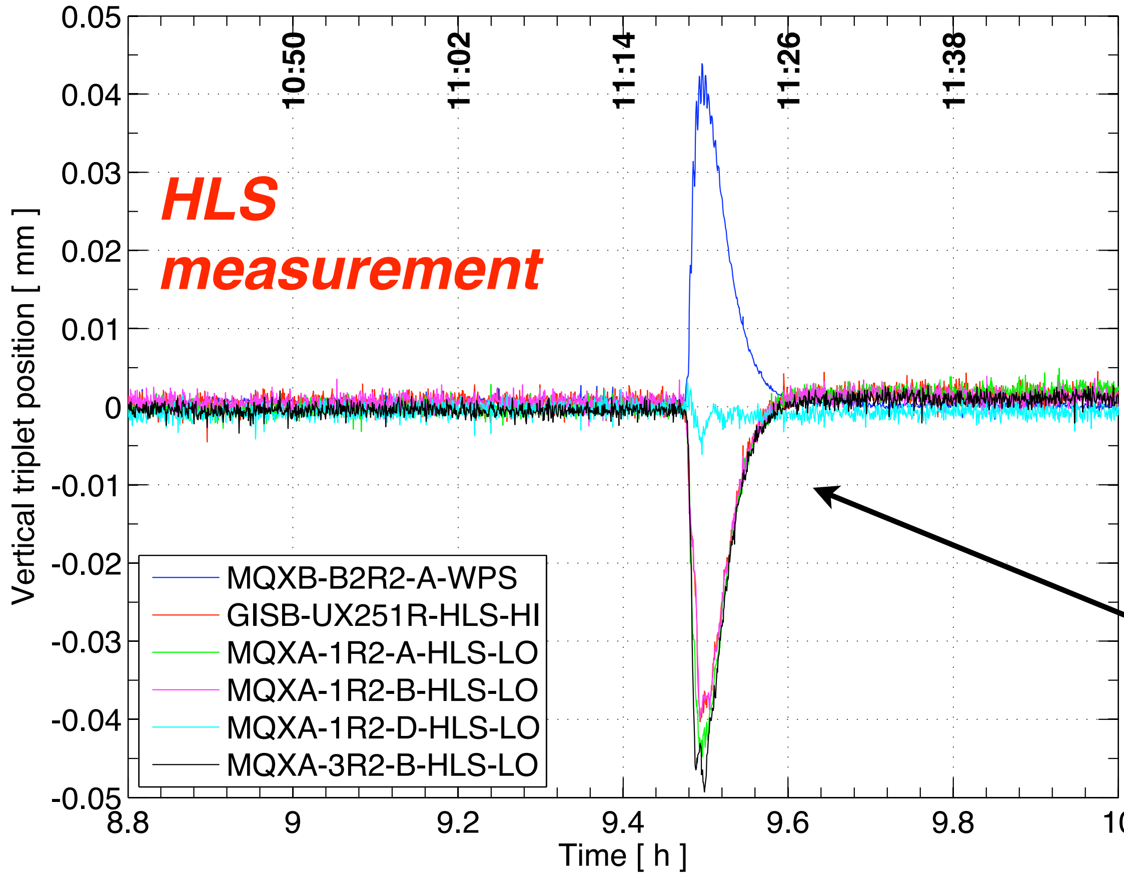
Motor control panel (16 axes per IP side)

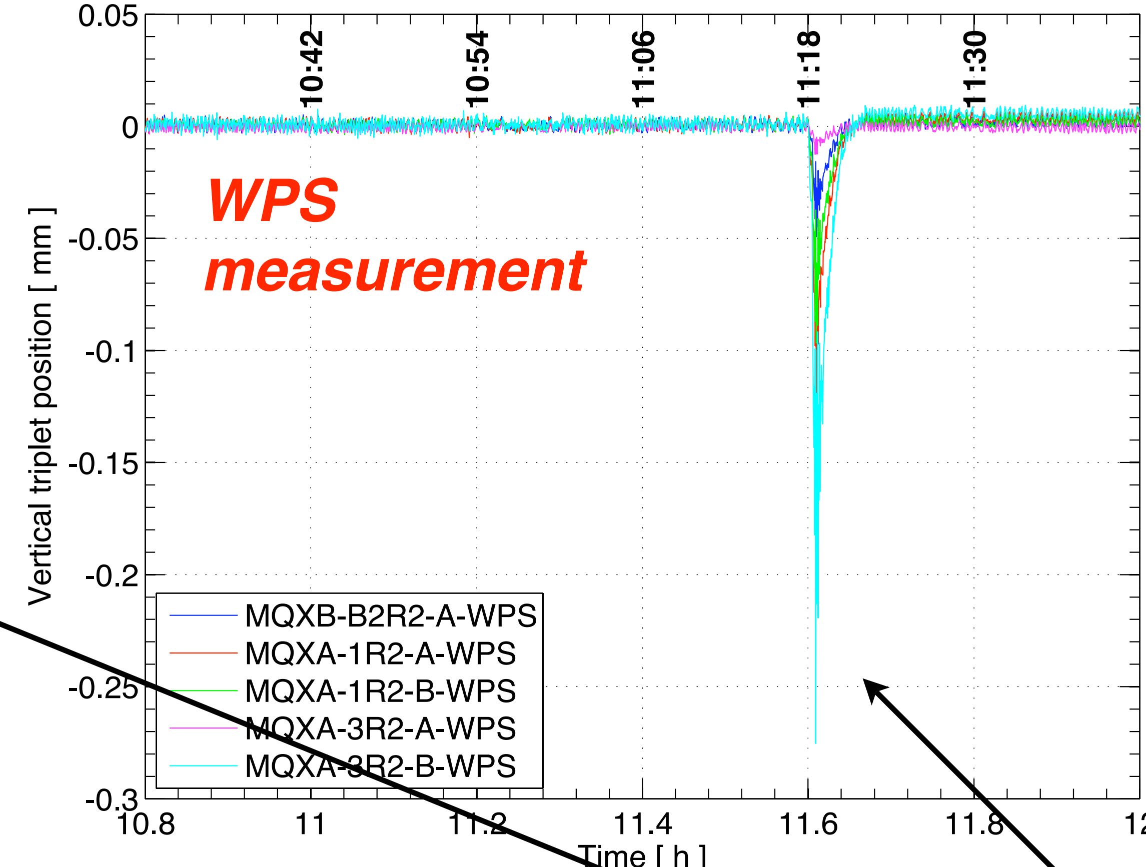


Logging variables available in Timber

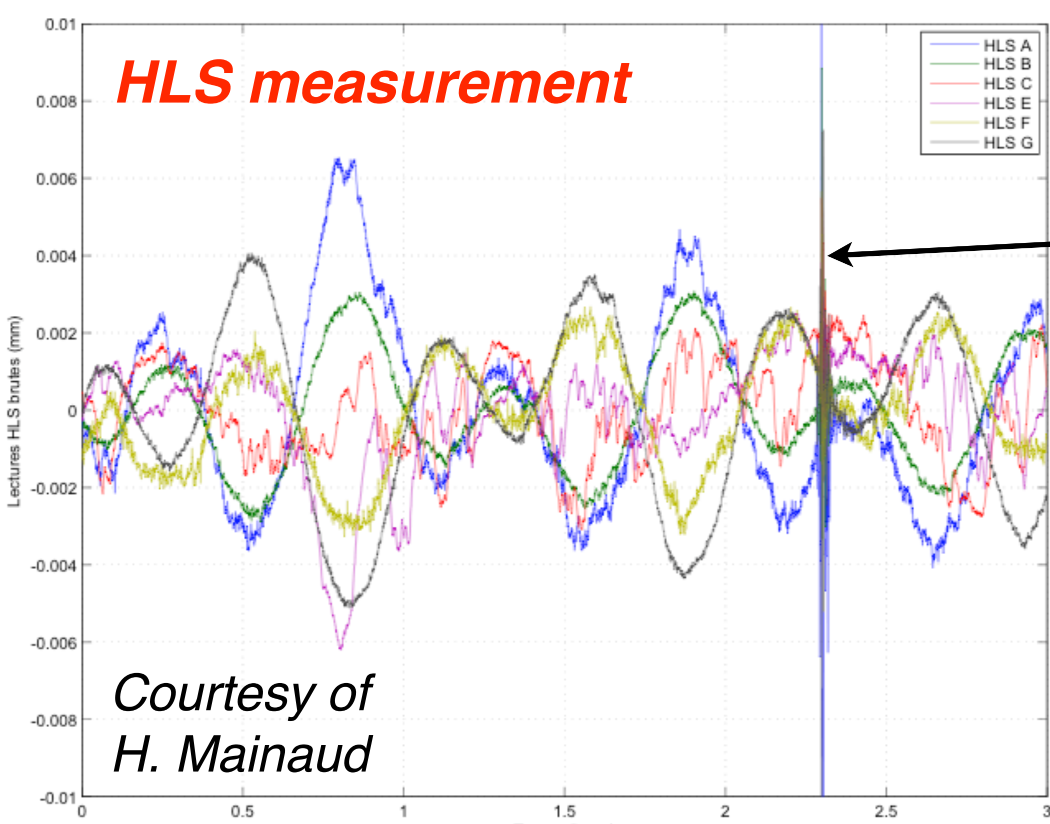
Example of measurements

Magnet positions: Sep. 19th





Problem of sector 3-4 seen in **IP2**



Earthquake in China, spring 2008

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- ☑ Introduction
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- ☑ Controls aspects
- ☑ **Interlock requirements**
- ☑ Conclusions / Timeline

Interlock requirements

- **Background**:
  - *No connection of this system to the LHC hardware interlock*
    → only ***SIS surveillance*** *possible*
  - *Baseline operational mode:*
    MQX should NOT be moved with beam in the machine*!*
  - *Movements with beam shall be possible with safe beams during* ***special studies*** *(MDs, alignment optics)*

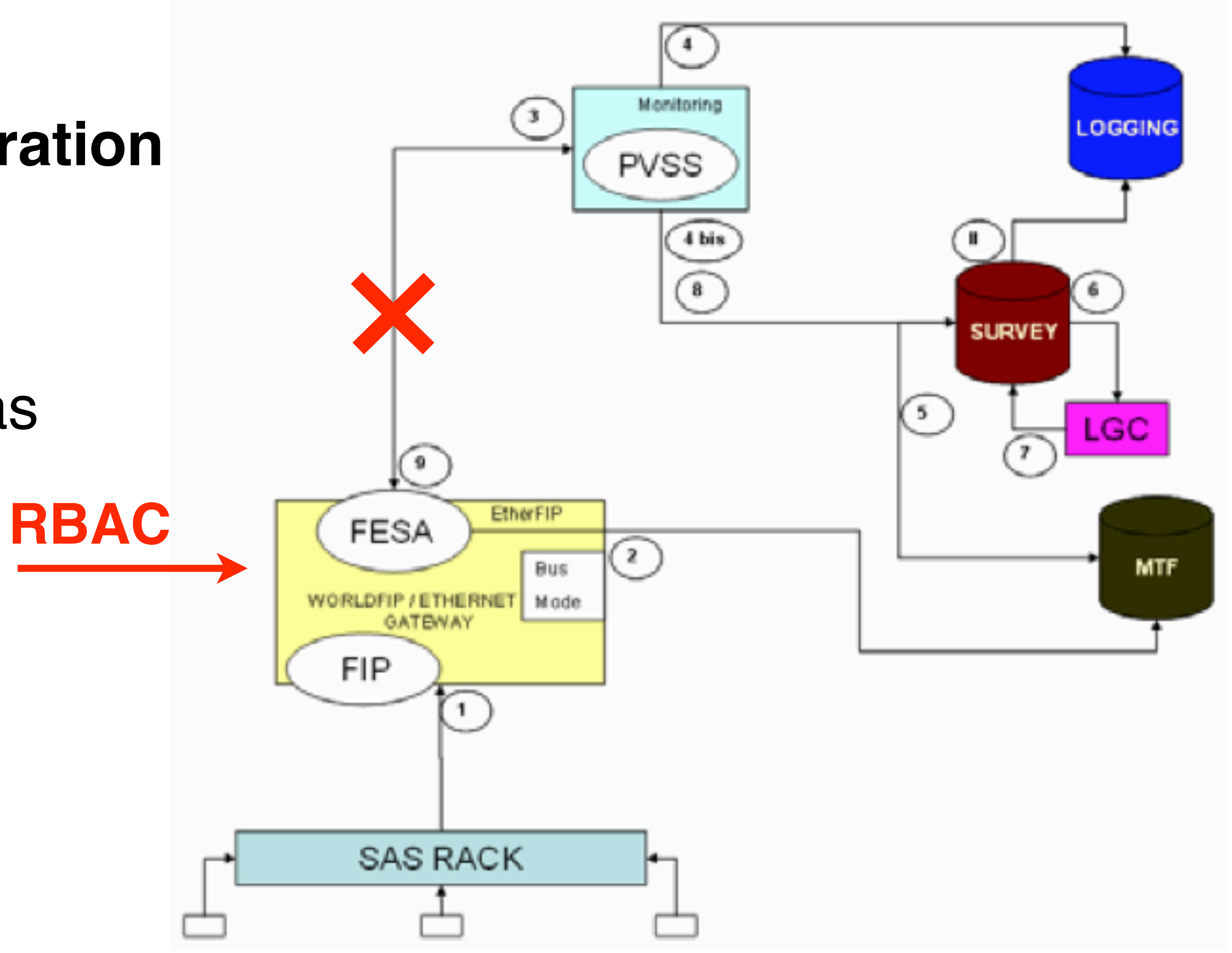
- Three main **critical aspects** were identified:
  (1) Protection against movements by unauthorized people
  (2) In standard operation, dump the beams if the magnets are being moved
  (3) Inhibit injection in case of "large" position drifts with respect to the positions of the previous store

(1) Implementation of access control

- **Protect the FESA properties** related to motor positions with **RBAC**
- Same roles presently available in PVSS will be configured:
  MONITOR / OPERATOR / EXPERT
- Only expert will have rights to move magnets - not an operational tool!
- Development of RBAC functionality in PVSS is in progress (Enrique B.V.)
  Foreseen delivery for tests: **1.5 months**
  Only DOMAIN (by machine) restriction available

- **No machine-mode dependent configuration** for the moment

- MD mode will be possible by logging-in as EXPERT and by masking SW interlock



(2) Interlock on motor status

With the present architecture, it is not easy to detect motor movements...

A **summary status** property will be added in the FESA class of the motor controller to identify the "**MOVING**" status

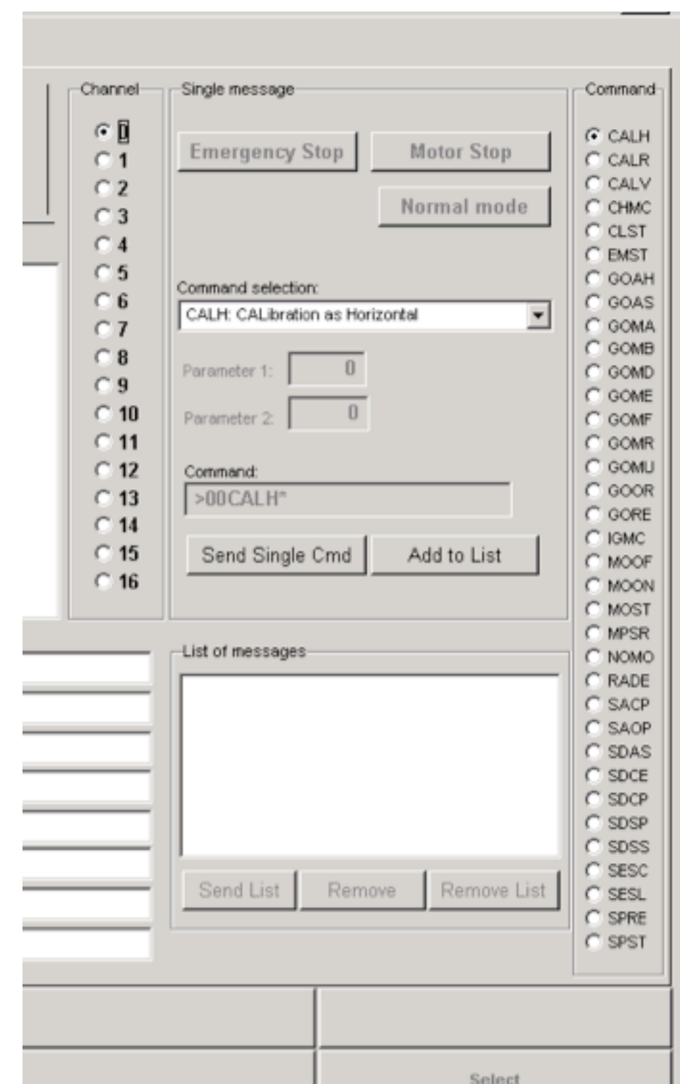
One status per IP side, calculated for the class that controls 16 motor axes → **8 statuses**

Implementation detail:

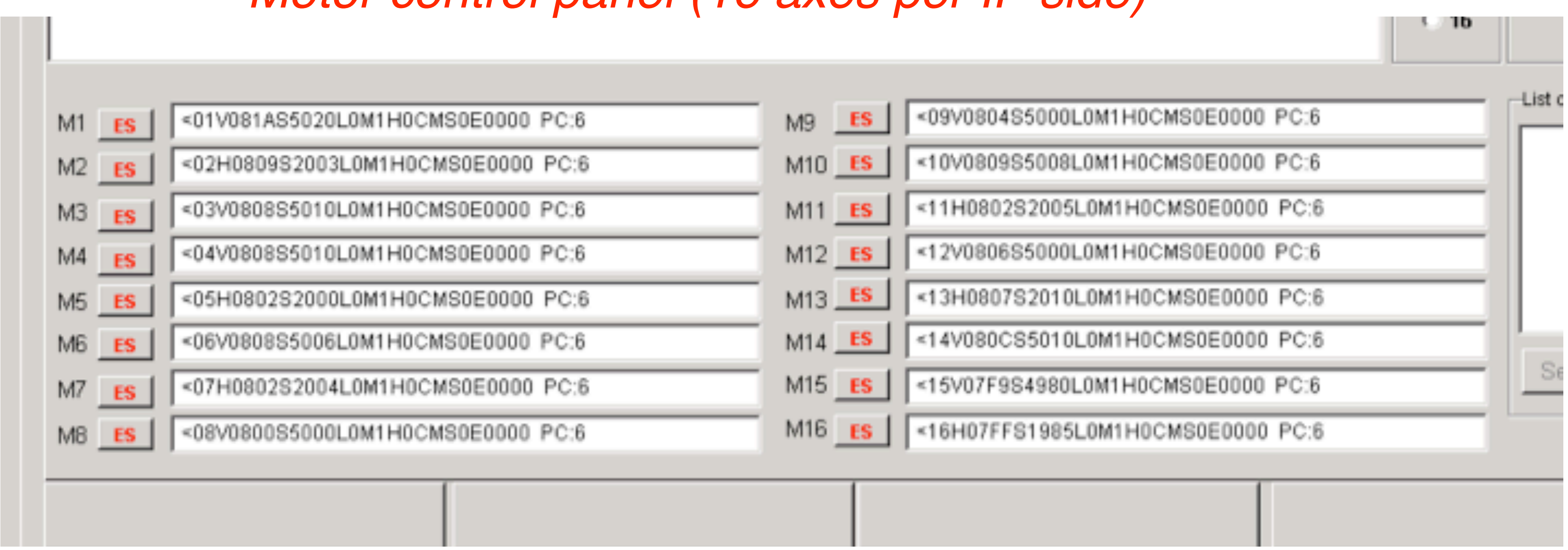
The "MOVING" status of each degree of freedom will be identified by looking simultaneously at command execution flag, motor step counter and resolver counter.

At the SIS level, a **beam dump** for both circulating beams will be triggered if the magnets are moved with beam in the machine.

Selection of command types



Motor control panel (16 axes per IP side)



(3) Fill-to-fill magnet stability

- **All WPS sensors** attached to the magnets will be used as input for the software interlock

  136 sensor readings for horizontal and vertical!

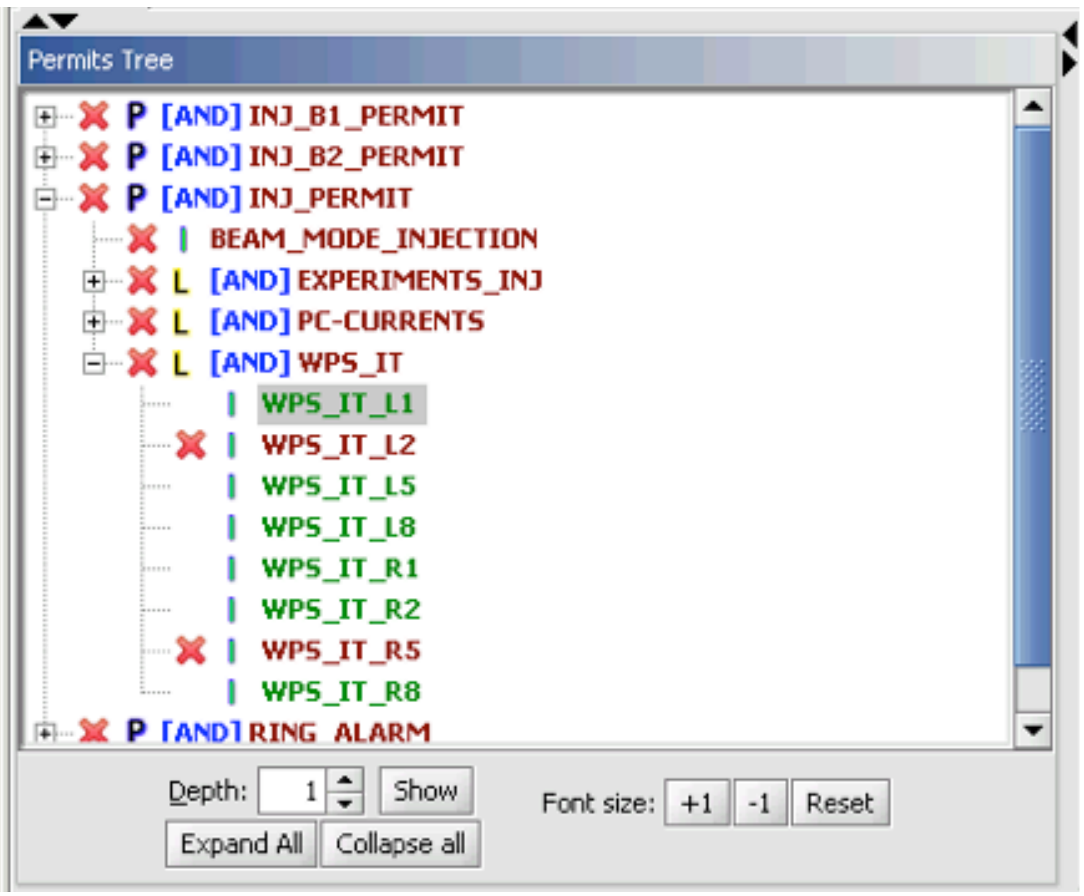
- Interlocks will be set on the "raw" position measurements in millimetres

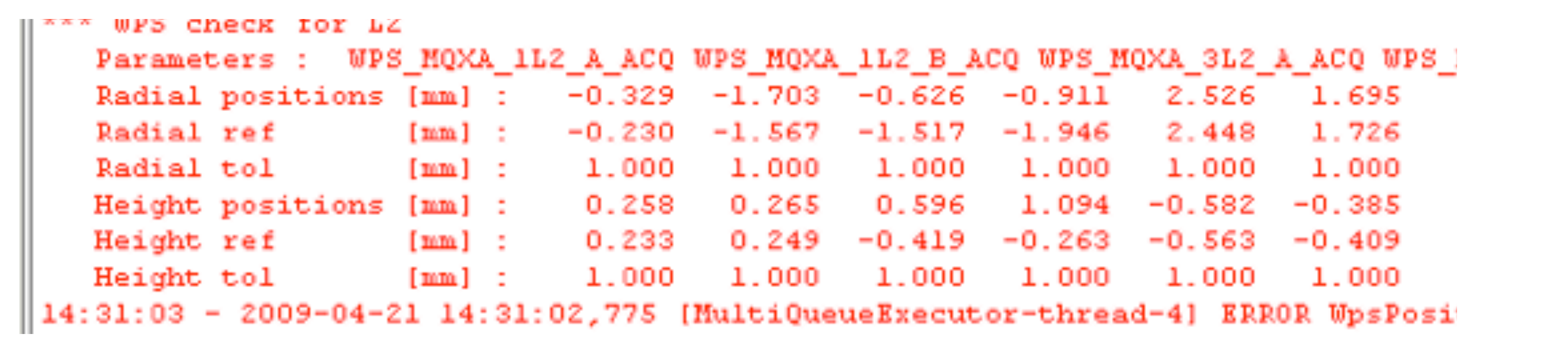
  Published by the FESA (direct connection to the middleware, no PVSS)

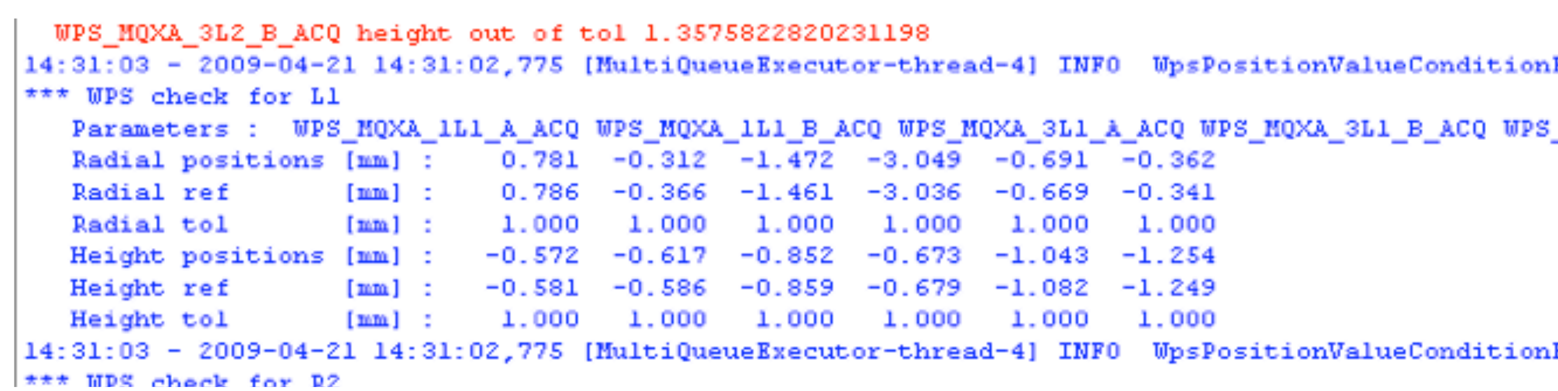
- Zero reading after magnet survey need to be stored in the database as **SIS references**
- **Tolerances** window of **0.5-1.0 mm** set around readings.

  Experience on the stability of measurements needs to be gained in order to fine tune the system (usual compromise between protection and efficiency).

- From magnet strength, "standard" tolerance for COD is equivalent to ~ **1 mm MQX error**.
- First implementation by Joerg available and under test. Need further tests with larger loads







Additional aspects

Maximum motor speed:

*Present settings: $v_{vertical}$ = 25 μm/s; $V_{horizontal}$ = **80 μm/s***

Seems okay for a SIS acquisition at 0.5-1.0 Hz

Can reduce further v_{max} if necessary.

***Switch OFF the motor power** during beam operation?*

Possible (AUG), should be done!

Remote ON is possible.

Can do that as a default before beam operation

*Direct connection to **BIC** for hard interlock?*

No feasible before 2009-2010 operation.

2 year experience with beam + SW interlock will tell if it is really needed...

Conclusions / Outlook

- The MQX alignment system is the first example of dynamic alignment in colliders of the LHC scale
  - *State of the art survey and remote control systems*
- This system will need to be operated CAREFULLY!
- Critical interlock requirements have been identified and are being addressed
- Timeline for tests:
  - *1.5 months to start testing RBAC*
  - *Deployment of operational applications from July*
  - *Interlock tests in August*
  - *Second report to MPP at the beginning of September*