LHC machine integration experience

PicoSEC-MCNet System Integration Training

26th May 2014 - Julie Coupard

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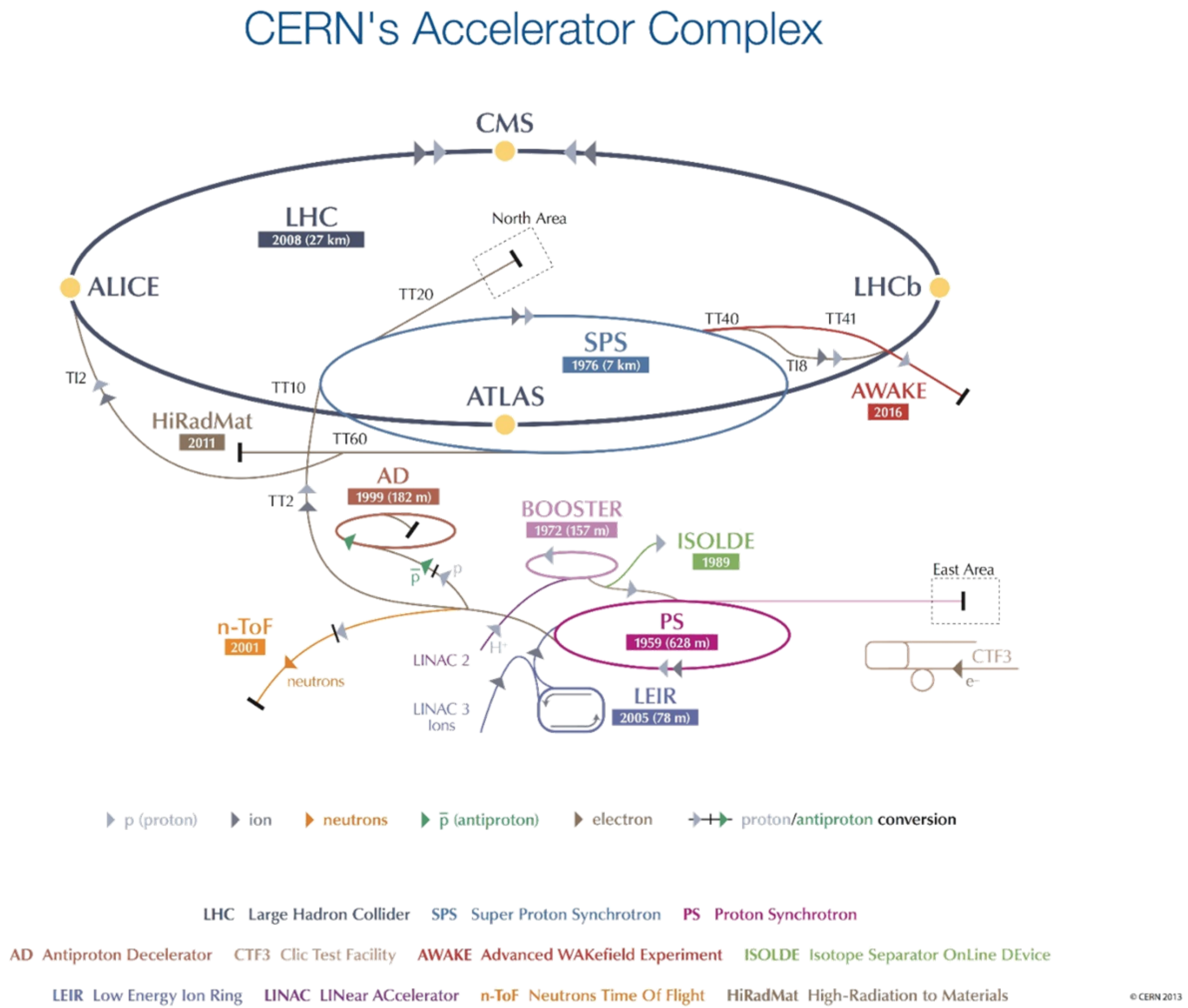
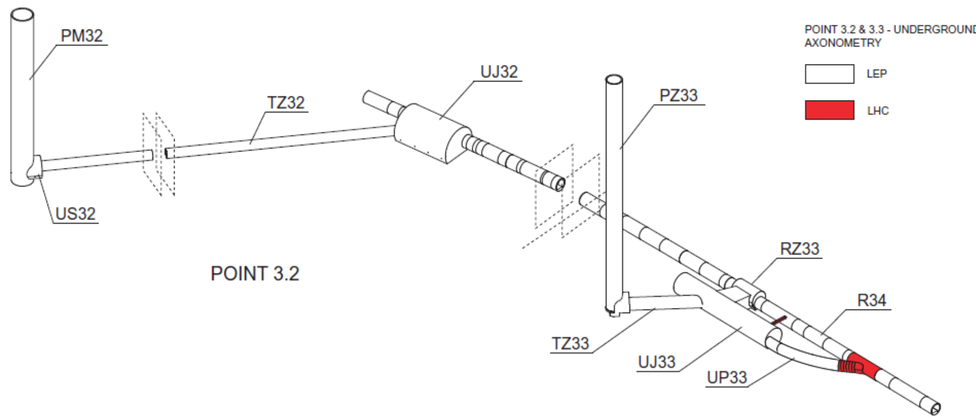
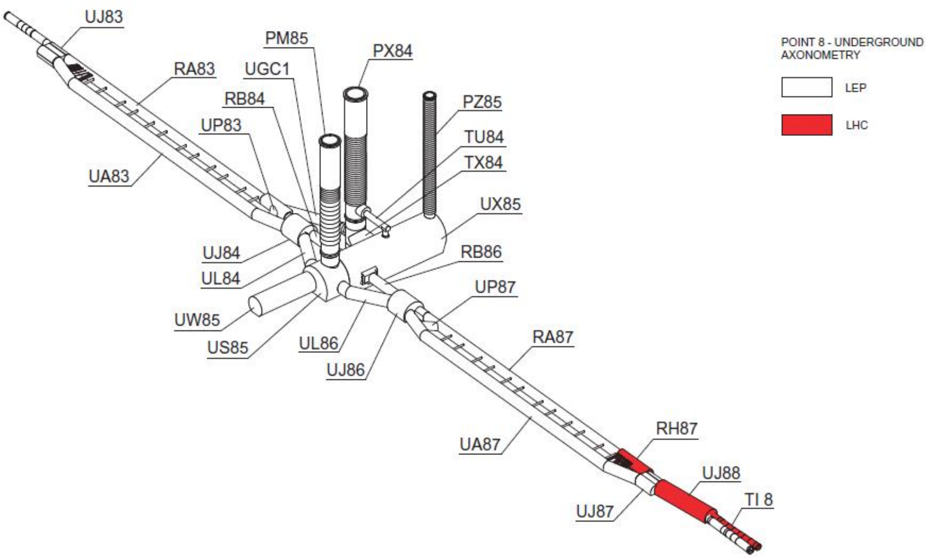
Introduction to the LHC machine

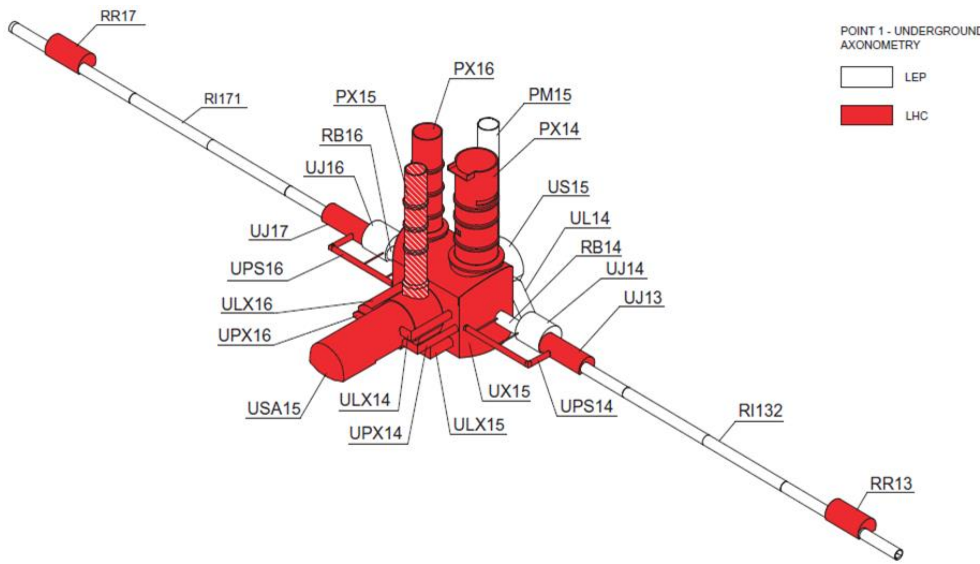


The LHC machine

- LEP tunnel



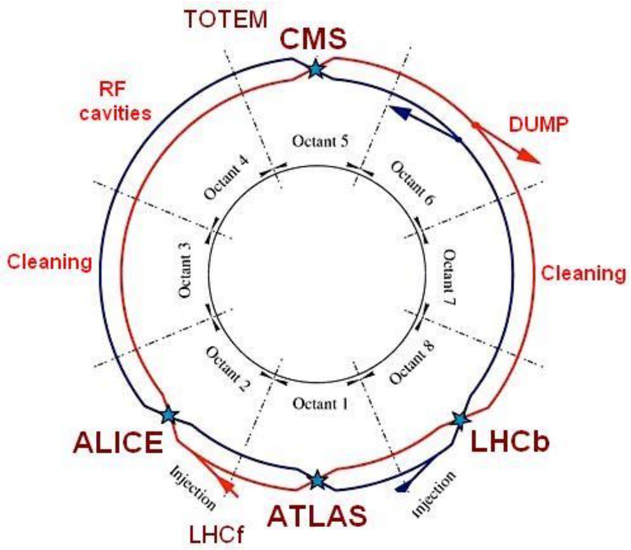


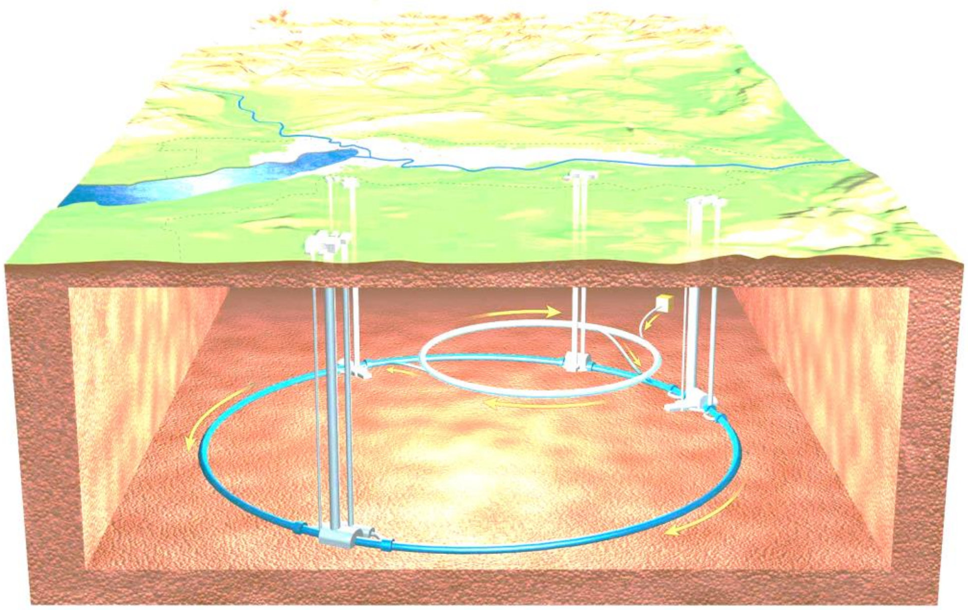


The LHC machine

- 27km of circumference composed of 8 sectors of ~3,3km
  - 8 arcs of 2,4km
  - 8 long straight section of 2x440m

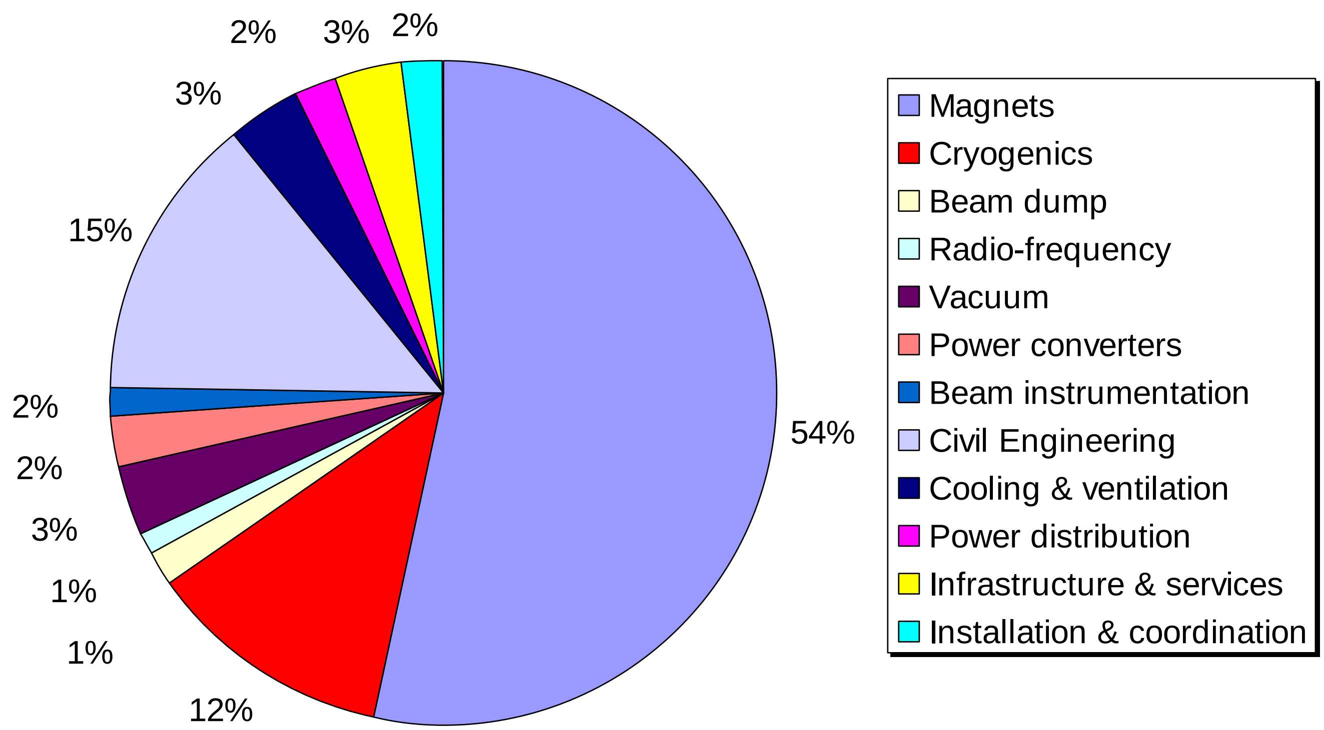
- From 50 to 175m underground





Cost structure of the LHC main ring

LHC project: ~ 5 BCHF (2008)
Personnel: ~ 1.2 BCHF
Materials: ~ 3.8 BCHF



Installation

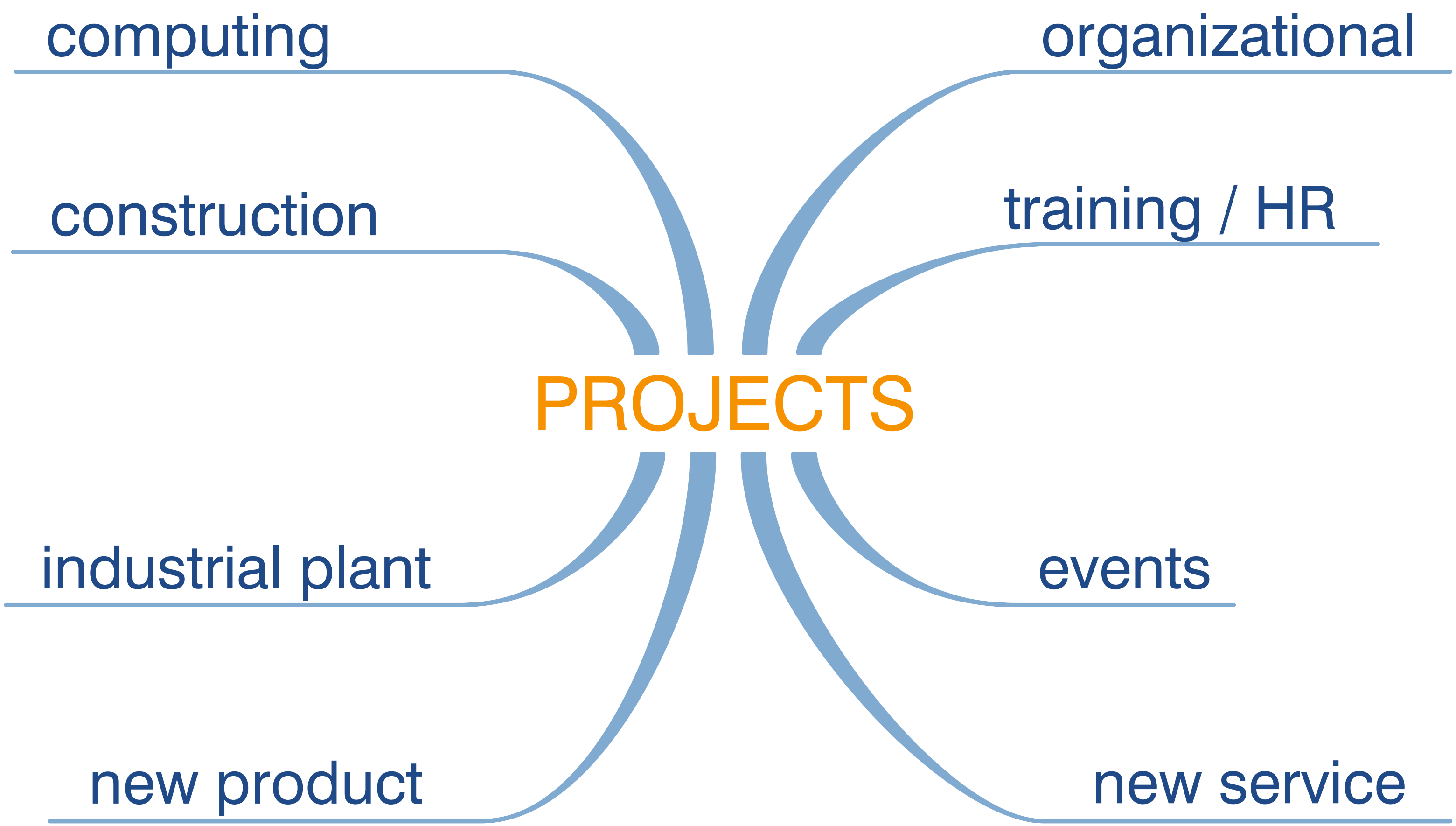
- The first idea of the LHC started in the **80s**, during the LEP construction.

- **The Project has been fully approved in December 1994 by the CERN Council**.

- Between 1994 and 1998
  - Tests of prototype
  - Publication of the Technical Design Review
  - Approval of the Experiments
  - Financial contribution of the member States

- **Construction and Installation from 1998 to 2008**

Challenge to carry out a MegaProject



Challenge to carry out a MegaProject

Mega project factors

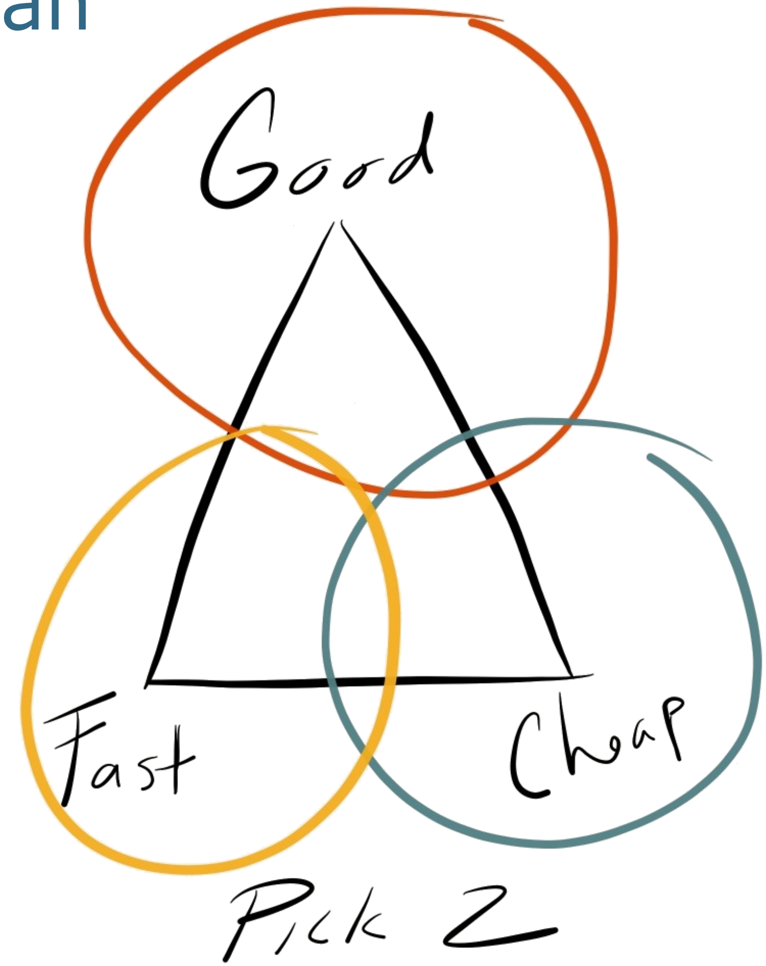
- **Time Horizon**
  - Multi-years
  - Multi-phases
- **Chain of Command**
  - Multi-layers organization
  - Matrix Structure
- **High-degree of Specialization**
  - Subject Matter Expertise
  - Cutting-Edge Technology
- **Dispersed Teams**
  - Virtual teams in multiple locations
  - Outsourcing to other countries

Impact on the Project

- **Risks** had to be properly analyzed
- **Responsibilities** had to be clear
- **Coordination** was crucial
- As well as clear and transparent **communication**

The aspects of the Mega-project

- Project management plan
- Organization
  - Scheduling and coordination
  - Integration studies
  - Configuration management
- Risks assessment
- Issues example

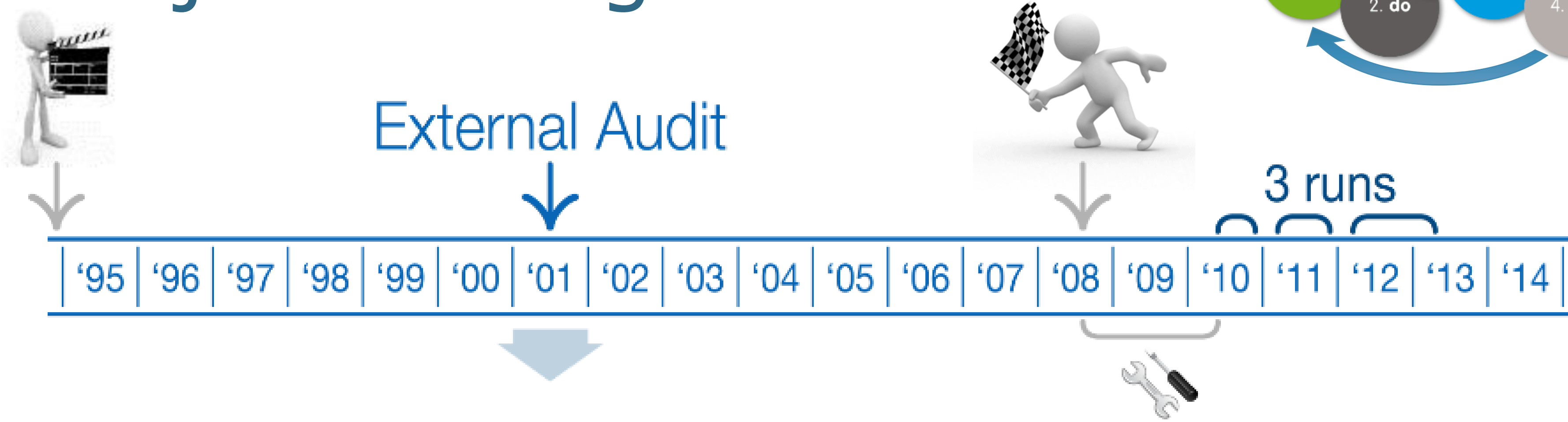


Project management

- **P**roject **A**ssurance **Q**uality (**PAQ**) put in place in 1995 based on PMBoK
  - Project Integration Management
  - Project Scope Management
  - Project Time Management
  - Project Cost Management
  - Project Quality Management
  - Project Human Resource Management
  - Project Communications Management
  - Project Risk Management
  - Project Procurement Management
  - Project Stakeholders Management

with large-scale projects, one PM plan shall not impose a PM methodology.

Project management



- Some issues in the PM plan:

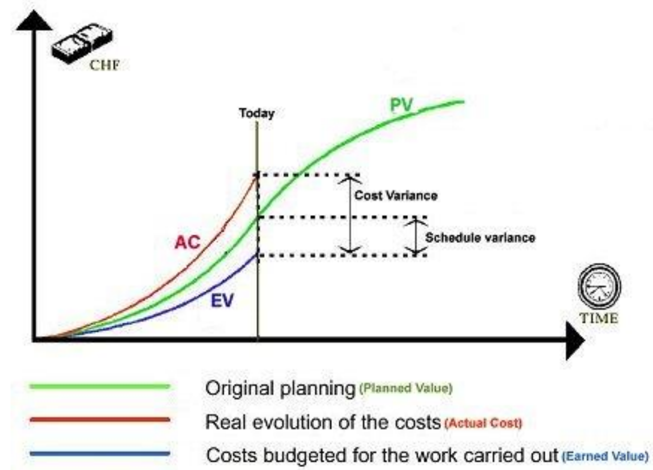
  No link between the cost control system (cost packages) **and the scheduling system** (work packages)

  - Technical Coordinator "*the project is behind schedule*"
  - Project Administrator "*the project is under-running*"

Need an appropriate Project control system

Project management

- Project control 2.0
  - Multi-levels planning and scheduling
  - Earned Value Management-based
  - Interfaced to accounting system: Actual Costs
    - Payment milestones of result-oriented contracts refer to effective deliveries *Finish dates of contract activities are always known!*
  - Interfaced to contract management system
  - Interfaced to human resource management system
  - In-kind contributions
  - Collaborative and web-based
  - Reporting
    - Transparency of the physical progress reporting *A "10 magnets out of 20" physical progress statement is more informative than a "50% complete" statement!*



Organization

The project is defined in a **W**ork **B**reakdown **S**tructure (**WBS**)

- Organize the people with their roles and responsibilities
- Organize the requirements and the procurements

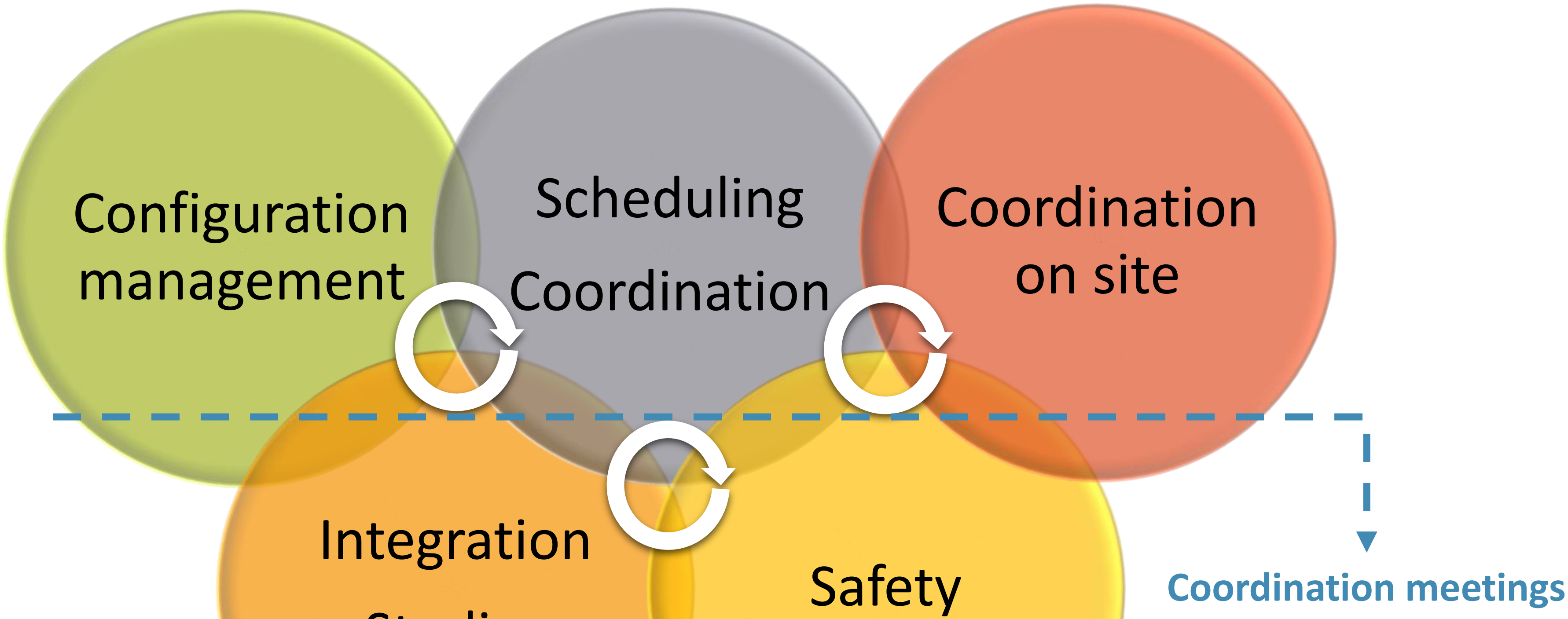
- Work Unit (WU):

A Work Unit is synonym with activity, an element of work performed during the course of a project. A Work Unit consists of one or several resource assignments that have a cost estimate or a manpower estimate and one or several deliverables.

- Deliverables (DE):

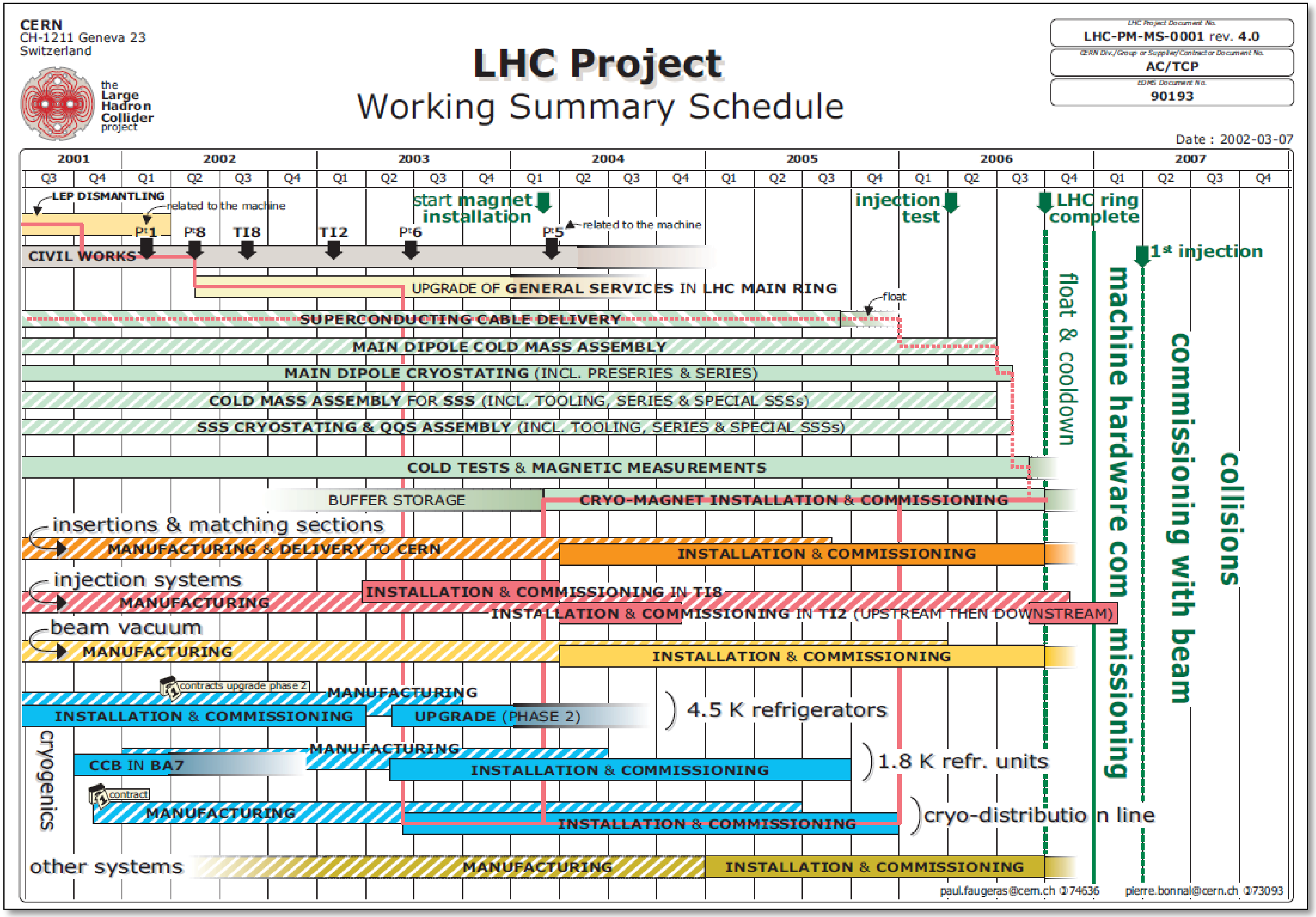
Any measurable, tangible, verifiable outcome, result or item that must be produced to complete a project or part of a project.

Organization

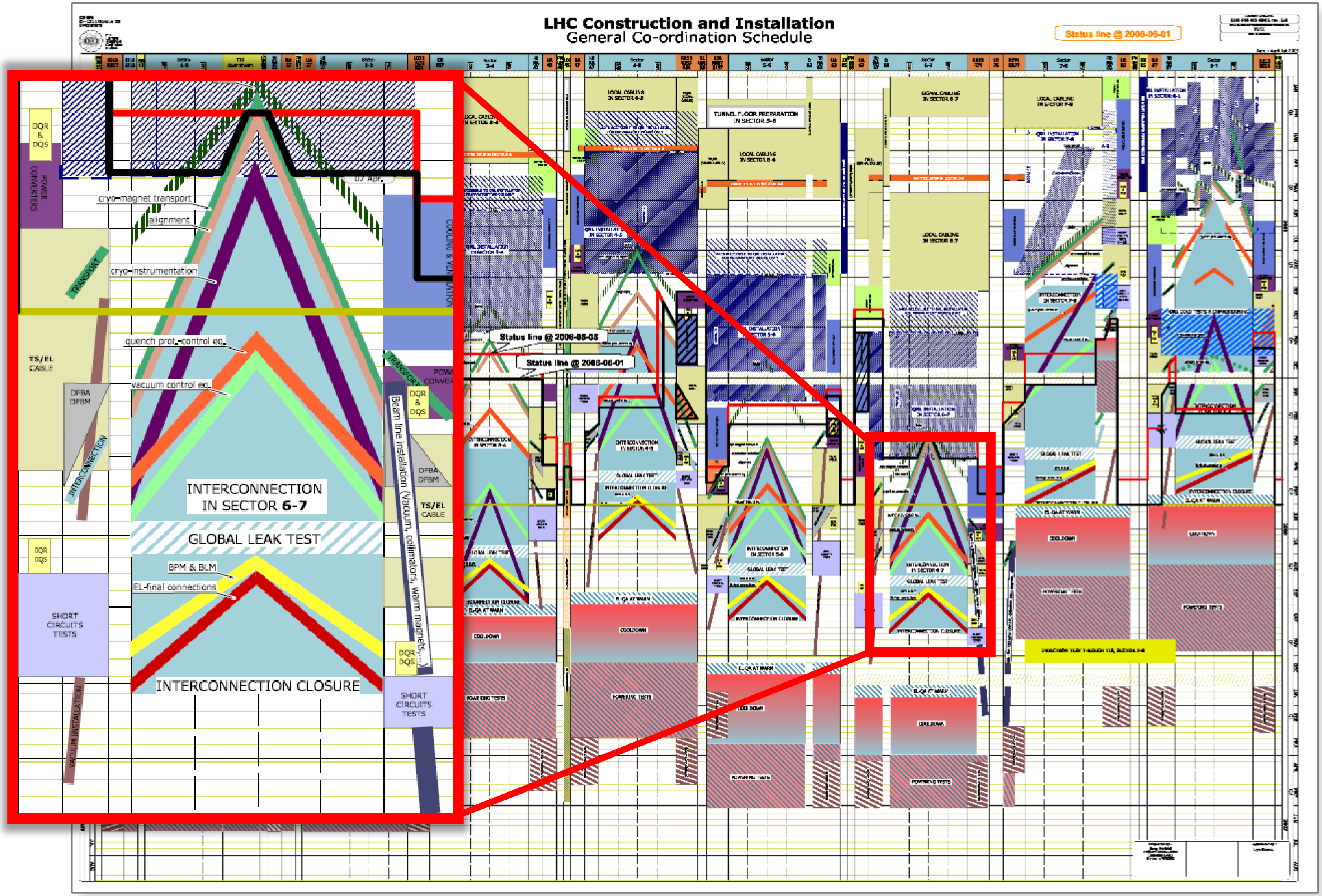


Pillars of coordination

Scheduling and coordination

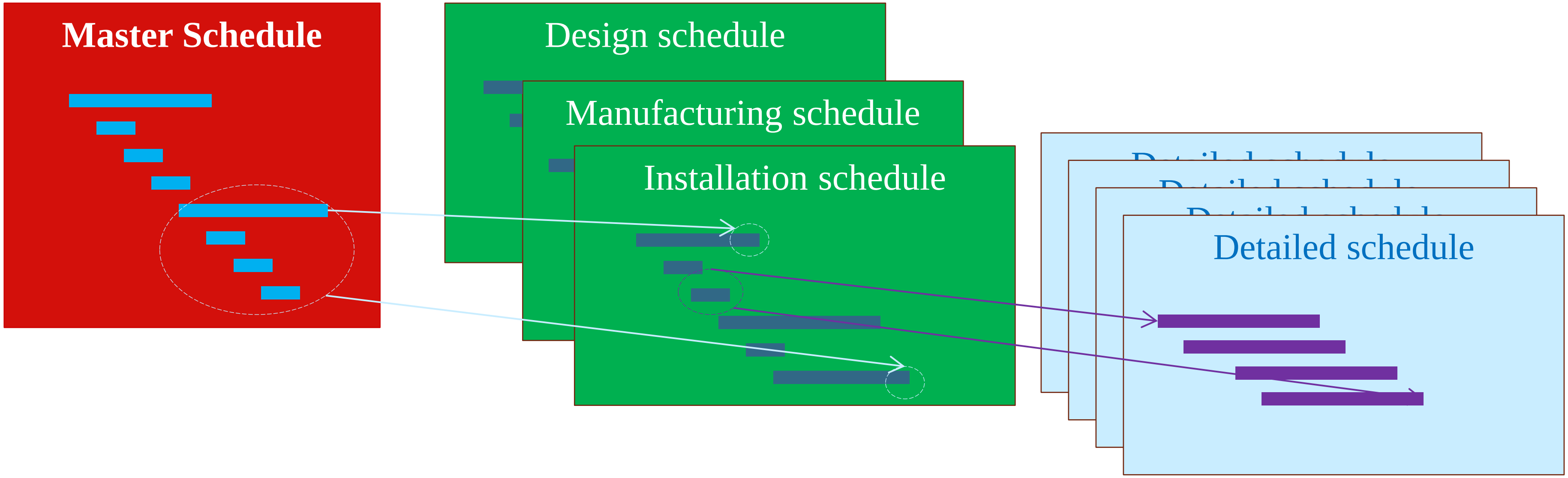


Scheduling and coordination



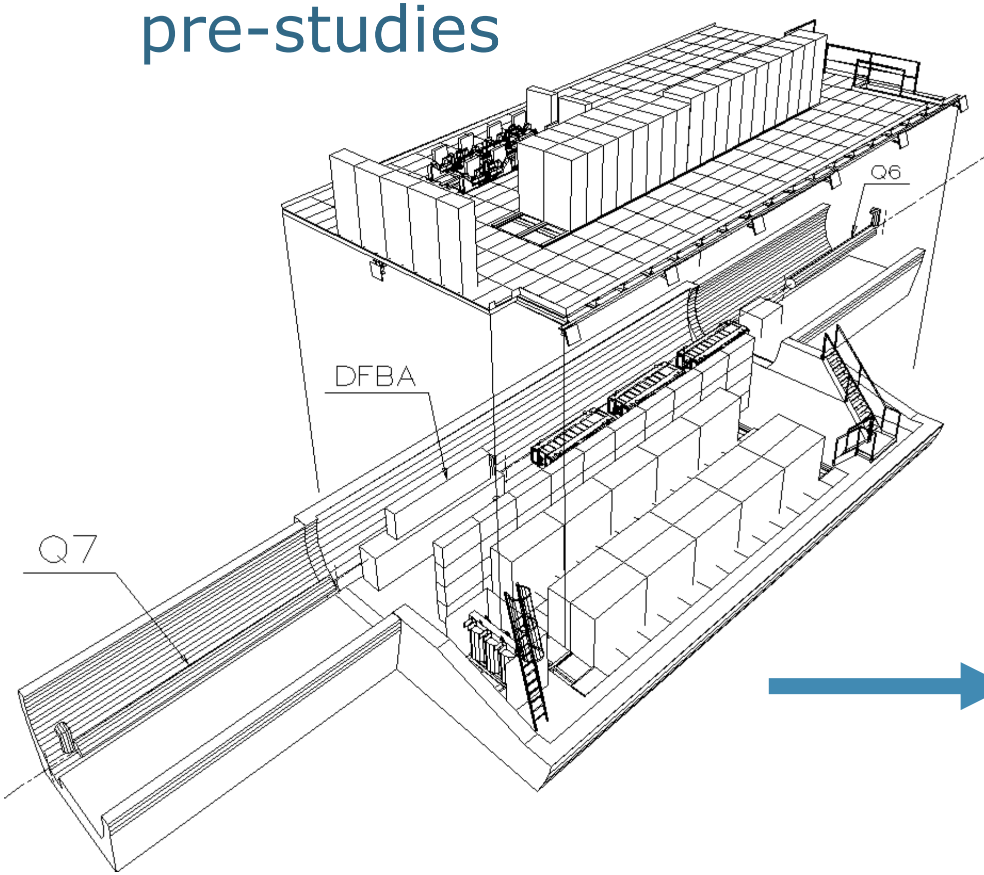
Scheduling and coordination

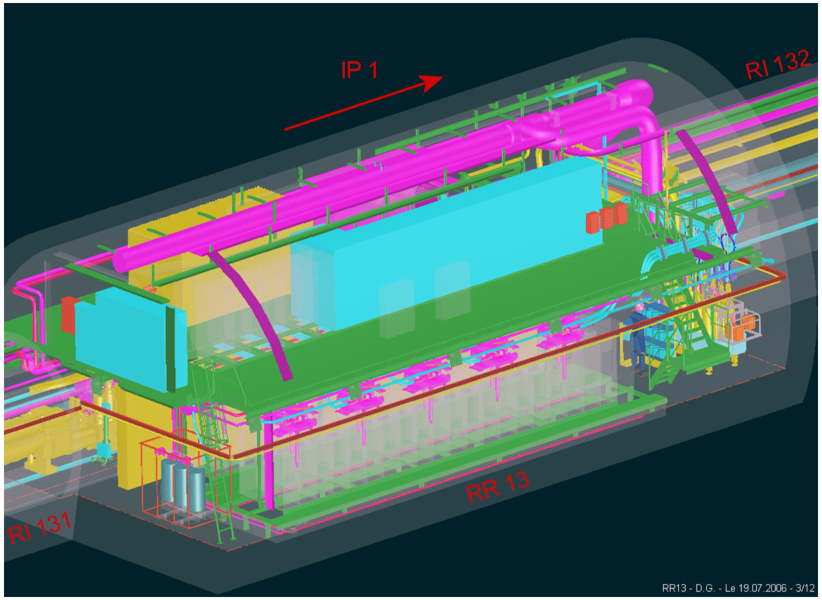
- Multi-level planning
  - Have a coherent information up-to-date
  - Be able by experience to identify the over/under-estimation
  - Contingencies have to be taken into account at one level



Integration studies

- The integration office designs the first draft and determine the volumes for the design offices = pre-studies





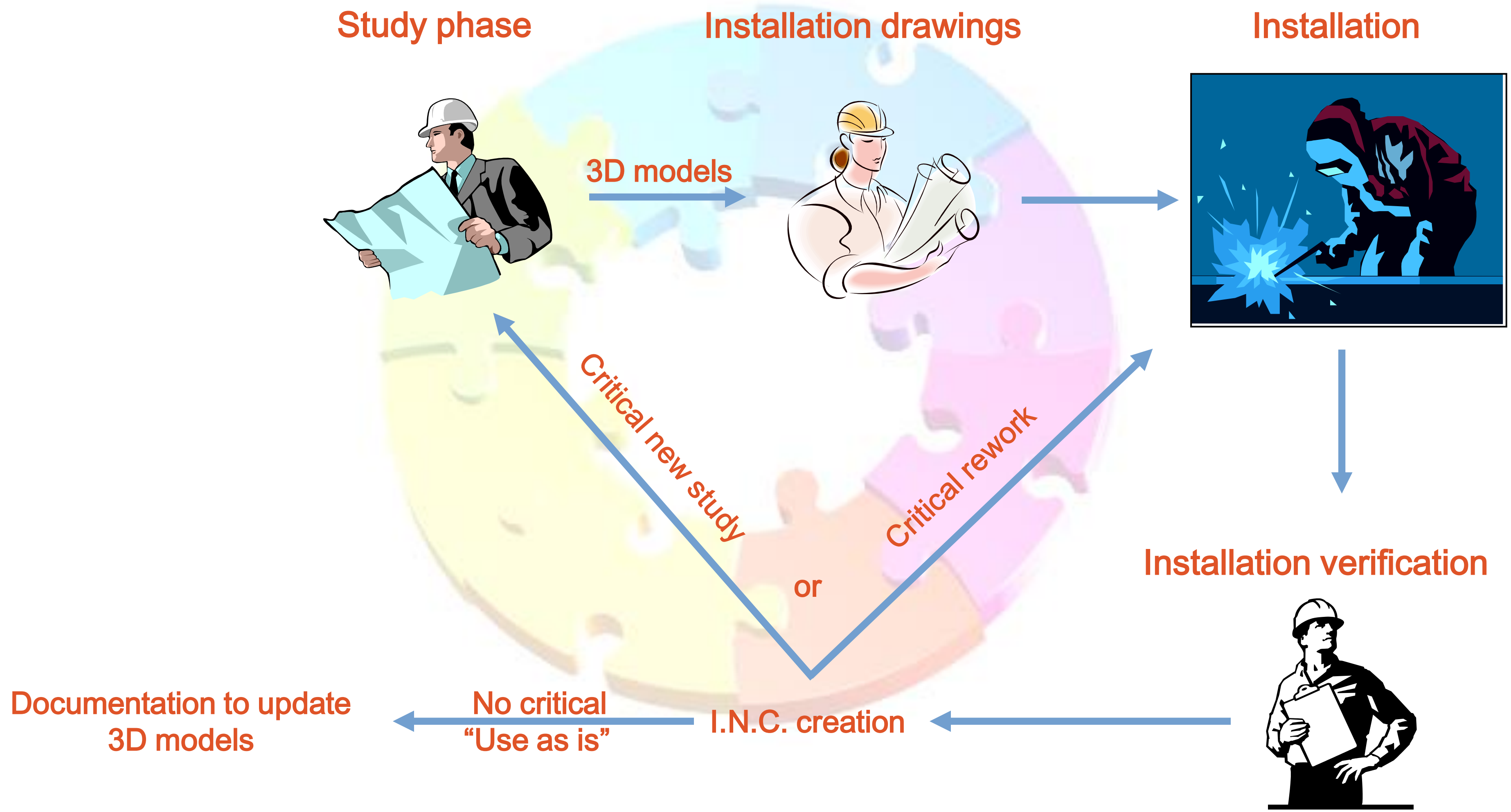
Integration studies

- **The design offices provide their 3D models to integration office**
  - Civil engineering and metallic infrastructure
  - General services and power devices
  - Machine equipment

- **The integration office creates the puzzle**
  - Identification of the interferences with proposal of solution
  - Space reservation

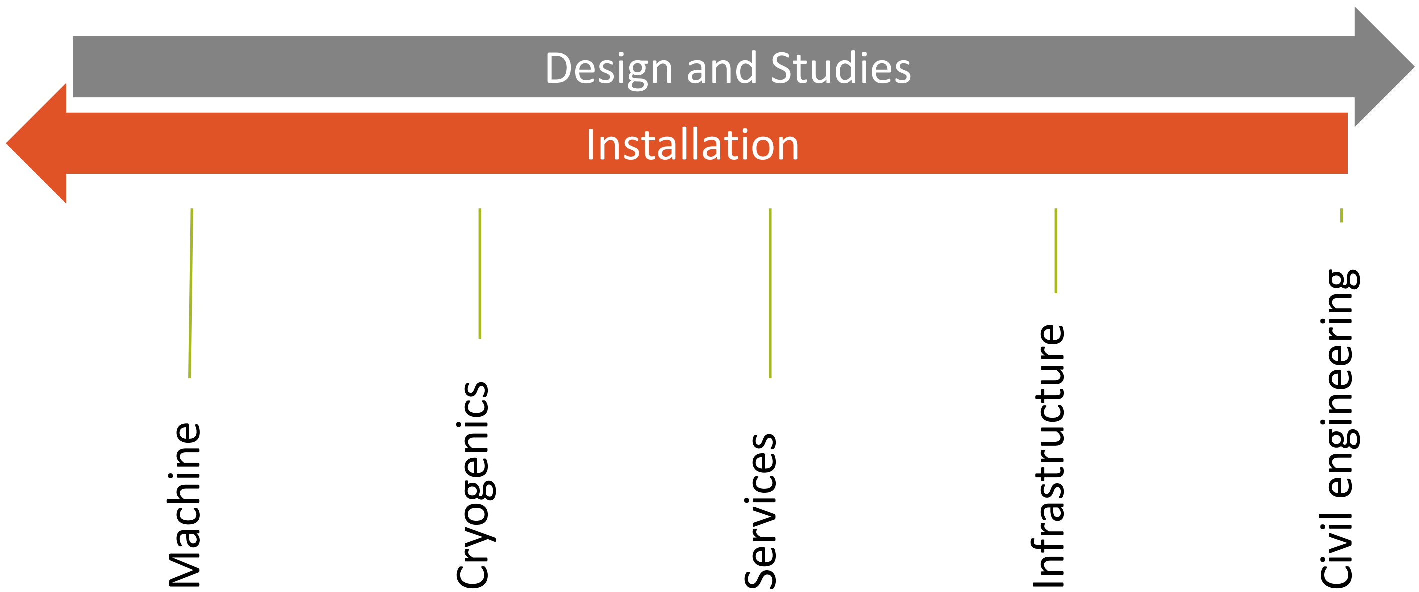
- **Once the integration is approved, the integration team follows-up the installation**
  - Identification of non-conformities of installation
  - Scans
  - Update of the 3D models

Integration studies



Integration studies

- Major difficulties

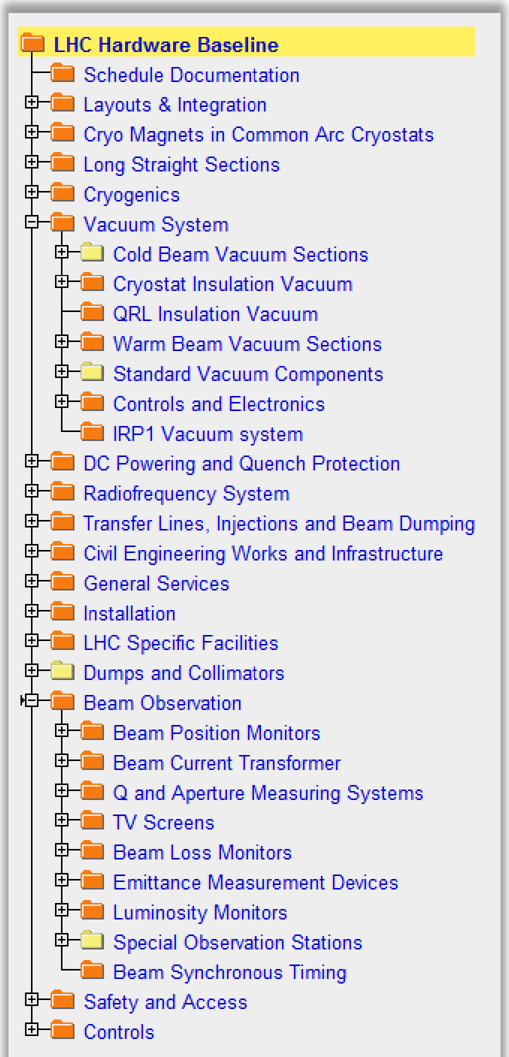


- During integration studies
  - ⚠ Volume of transport
  - ⚠ Volume for the survey

Configuration management

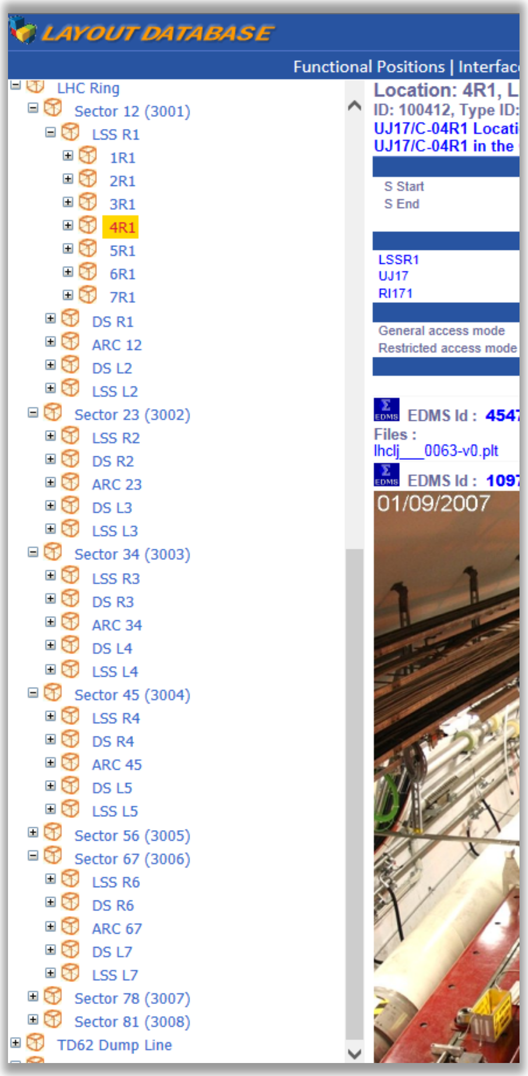
- Provides a clear and coherent picture of the status of a project or machine at a given point in time.
- In order to achieve this, we use three important tools
  - Changes to the machines and transfer lines are documented, circulated and approved in the **Hardware Baseline** (also known as a Product Breakdown Structure)
  - We register the layouts of the accelerators and all changes to them within the **Layout Database** that has to remain up-to-date.
    - Sequence of functional positions = space management
    - Integration and Installation Drawings match the recorded layout to ensure that envelopes of reserved space still match the physical equipment dimensions
  - Naming is critical throughout the lifecycle of the machines/projects. To store and manage naming, we use the Naming Portal
- Keyword is **coherence** between the tools.

Configuration management



- **Hardware Baseline**
  - …is an EDMS (Electronic Document Management System) based tool.
  - The hardware baseline contains all the information needed to re-build the machine, including:
    - Engineering Specifications, Drawing Folders, ECR, Procurement Documents
    - LHC Baseline was the first to be issued
    - SPS and PS Complex Hardware Baselines are in progress
  - Logical structure of nodes, based on hardware types and functions
  - Documentation can be linked to multiple locations

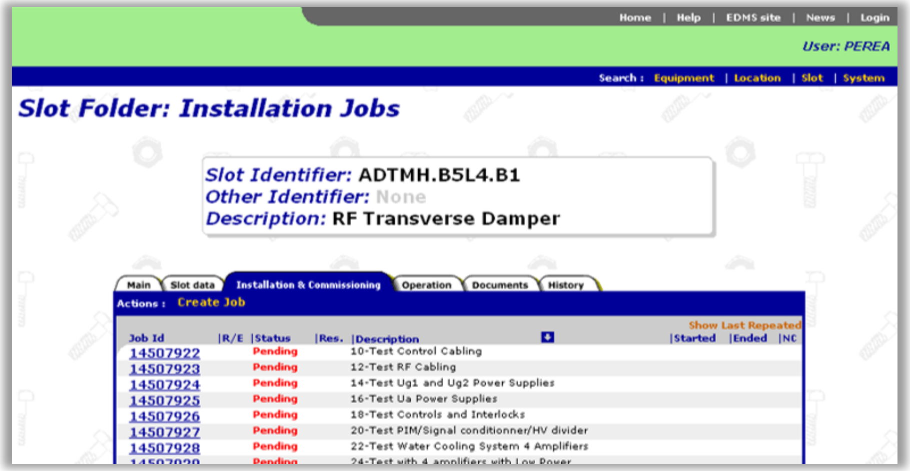
Configuration management



- **Layout Database**
  - Stores the sequence (layout) of accelerator and transfer line components.
  - Equipment types and details
  - Functional positions for mechanical and electrical layouts
  - Asset names – functional position is exported to MTF database and associated to an asset. Layout just shows the result.
  - Expert name – optional, alternative functional name

Configuration management

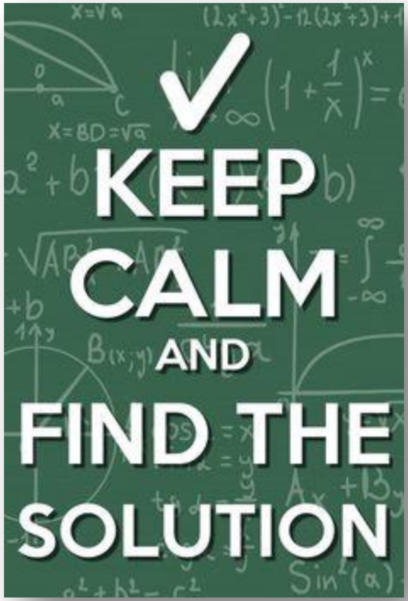
- The link with the manufacturing tool
  - The *MTF* is an integral tool of the CERN *EDMS* that allows a detailed follow-up of the equipment during the manufacturing and test processes. Predefined workflows with tasks and technical measurements can be logged and followed-up in a fully configurable manner for each type of equipment. The Non-Conformity management is another important module for the manufacturing follow-up, which allows formalized procedures for solving problems discovered during production.
  - For the LHC project, over 600.000 components were individually followed up with *MTF* during the manufacturing and test phases.



Risks assessment

By definition, **risks can occur** and the prevention is less control for new machine like LHC which stays a **prototype** with unique systems.

- How we prevent risks
  - Anticipation, follow-up, monitoring
  - Strict quality control
  - Long term analysis schedule
  - Flexibility (plan A, plan B)



- When a risk occurs
  - Dedicated task force: correct expertise and appropriate experts !!
  - Being ready for the unexpected and determining your response to it

Issues example

The study and installation of the cryogenics distribution line (QRL)

- The situation:

1 unique firm for the study and installation of around 25 km of QRL

- The issue:

Design of the supports of the QRL underestimated, the installation of the QRL could not be done properly

- Plan B: CERN Task Force

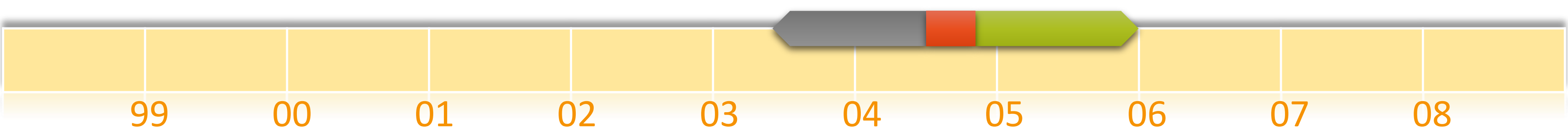
Decided to repair the delivered equipment

Change in the Master Plan

- Impacts:

Delay in the installation of the magnets → storage

Logistic of transport of the magnets



Issues example

The installation of the cryomagnets

- The situation:

The installation has to be carried-out in parallel of works in the tunnel

- The issue:

Co-activities in underground → difficulties with the logistic of transport (only one pits to bring the magnets in underground)

Delay on availability on surface → 1 hour = 1 day

- Plan B:

Transports of the magnets during the night

Coordination with the co-activity to allow the transports

- Impacts:

Long time window dedicated for the installation

Co-activity on several km of tunnel

99 00 01 02 03 04 05 06 07 08

Issues example

The installation of the collimators

- The situation:

The handling volume during installation was not taking into account in time

- The issue:

Interference between the cooling system and the handling of the collimators

- Plan B:

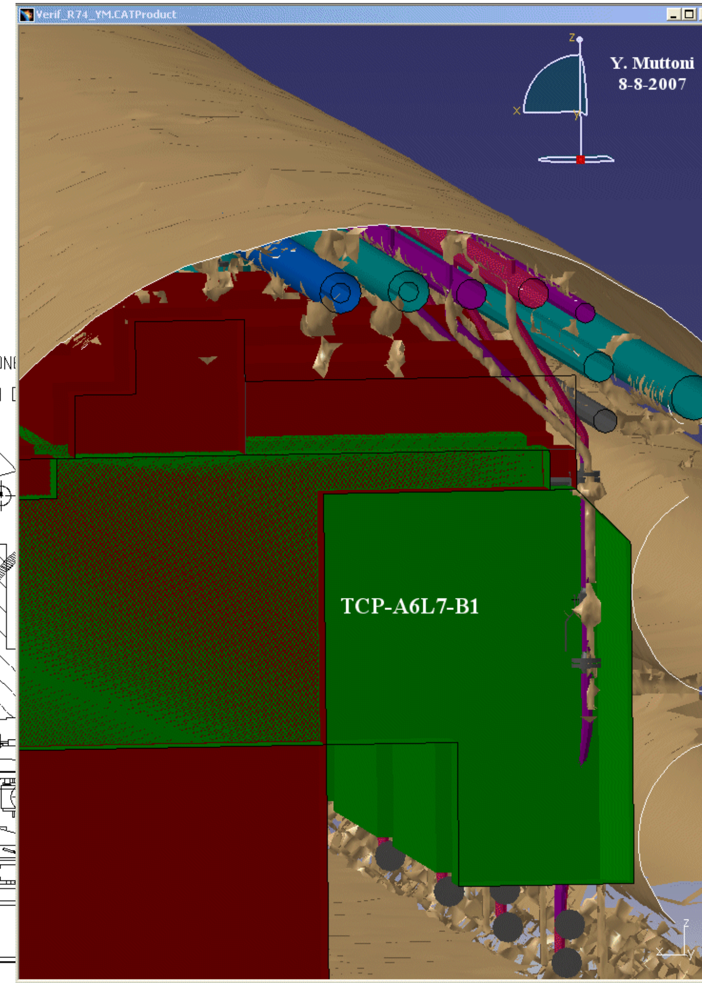
Modification of the cooling system and cable trays

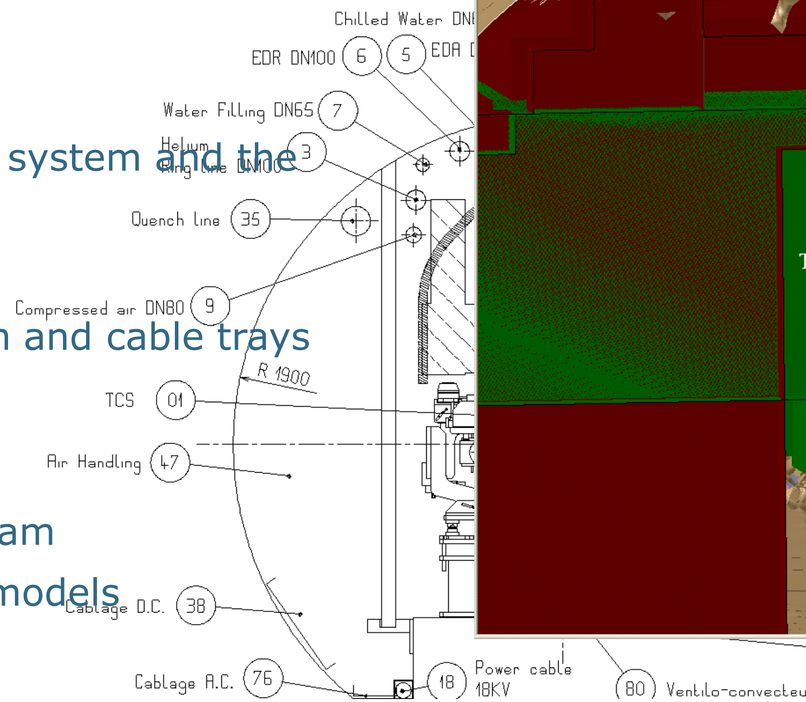
- Impacts:

Storage of the collimators

Additional work for the cooling team

Updating of the drawing and 3D models





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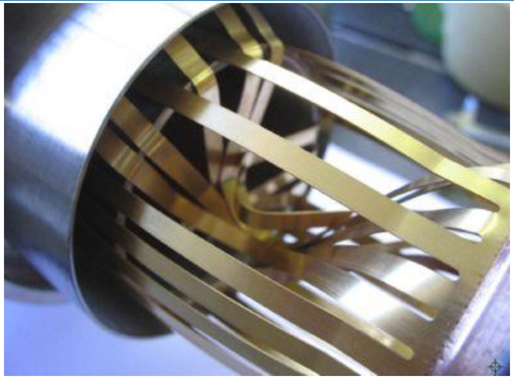
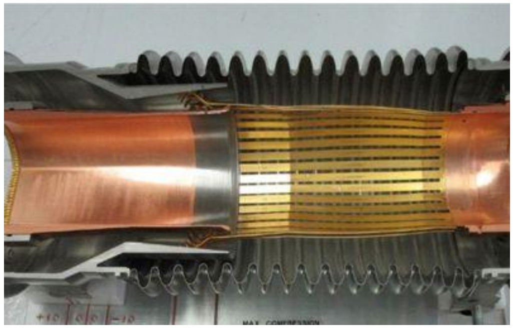
Issues example





Deformation of the plug-in modules contacts during warm-up

- The situation:

PIM contacts did not slide during the magnet warm-up and instead got buckled into the beam pipe aperture

- The issue:

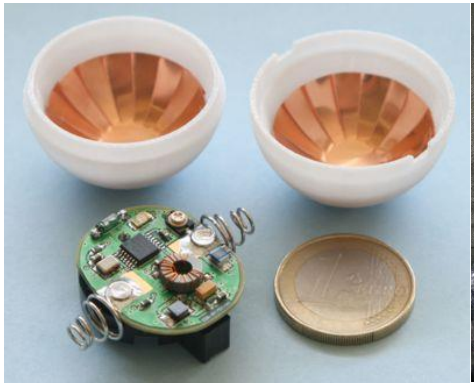
The deformation of the plug-in modules would become an obstruction for the circulating beams

- Plan B: working group

Send inside the beam pipe a ball equipped with a radio-frequency transmitter in order to identify the defective PIMs to repair.

- Impacts:

New task to integer in the schedule after warm-up of a sector



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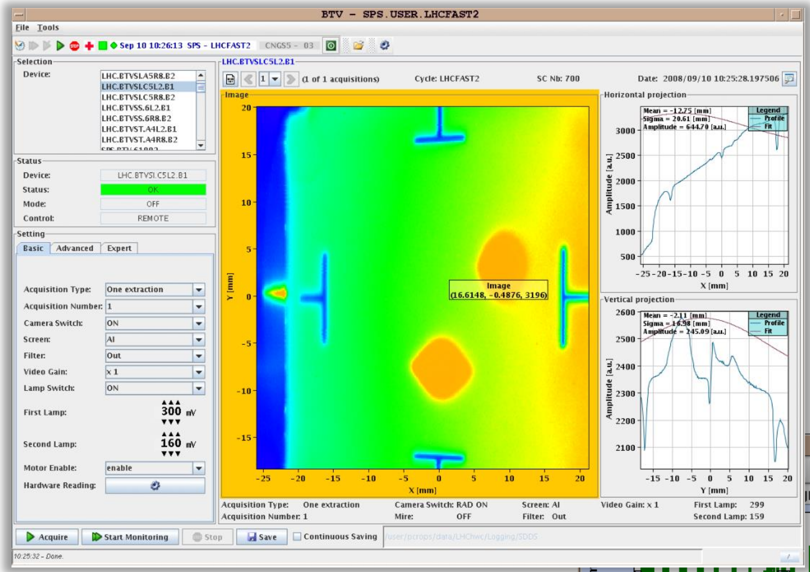
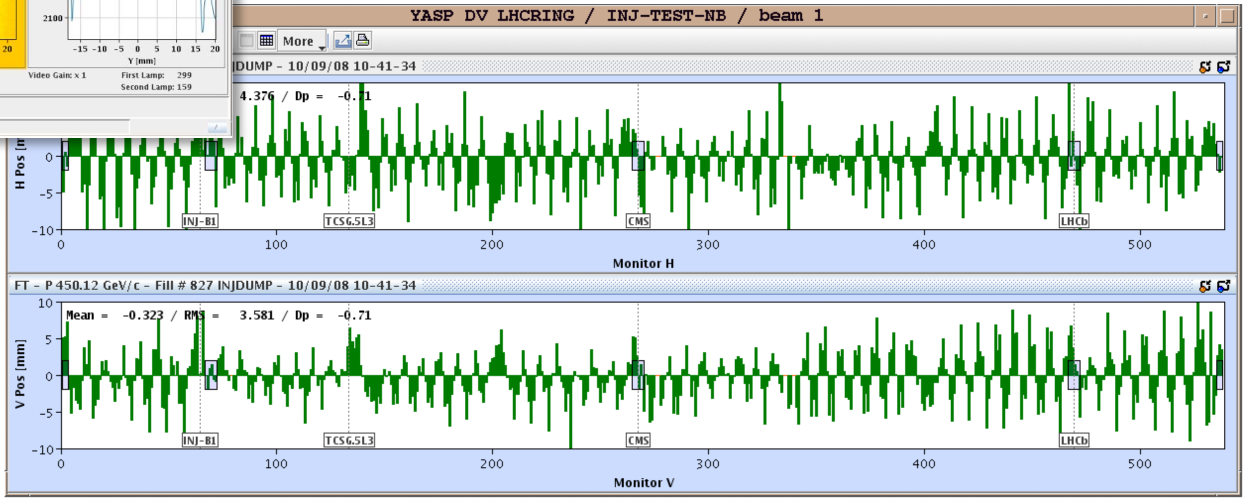
Success – 10th September 2008

First complete turn of the beam



"***It's a fantastic moment,***" said LHC project leader Lyn Evans, "*we can now look forward to a* ***new era of understanding about the origins and evolution of the universe.***"



Issues example

Incident 19th September 2008

- The situation:

Last electrical tests at higher Energy (7TeV)

- The issue:

Collateral damage due to pressure forces

  - Magnets displacement
  - Support displacement and rupture of ground anchors

- Plan B: CERN Task Force

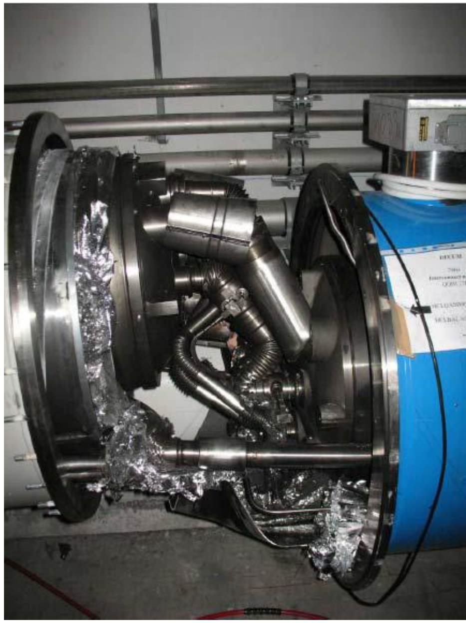
Dismantle, repair and re-install the whole damaged sector and repeat the hardware commissioning with powering test with limit at 3.5 TeV beam energy.

- Impacts:

1 year to repair, consolidate and tests again the machine.

New safety measures put in place.

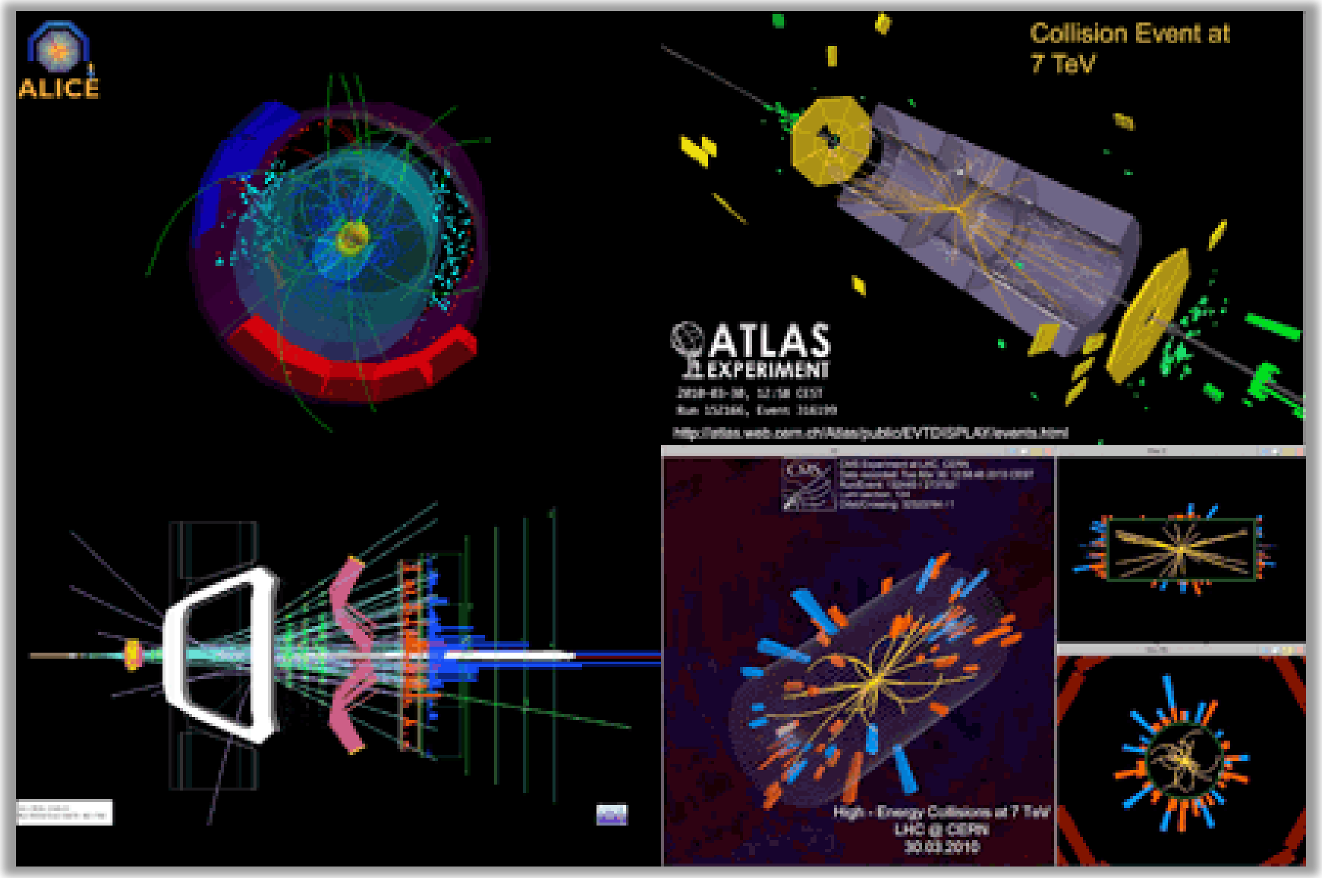
Studies of the issue for next consolidation.



Success – 30th March 2010

7 TeV collision events seen by the LHC's four major experiments

(clockwise from top-left: ALICE, ATLAS, CMS, LHCb)



Success – 4th July 2012

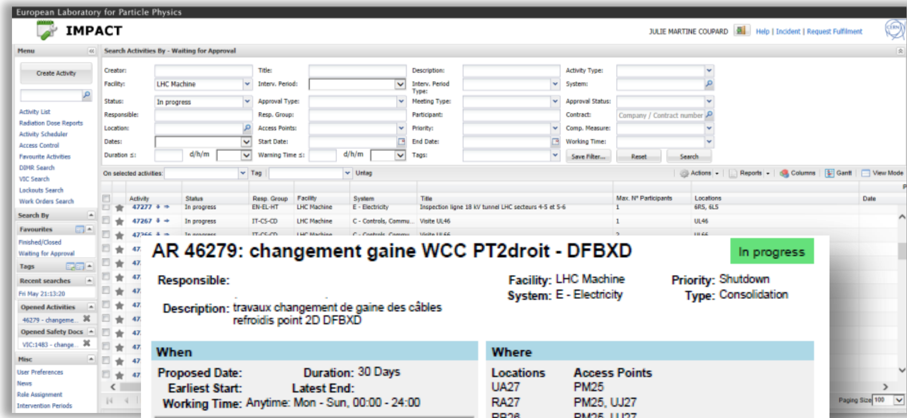
The ATLAS and CMS experiments at CERN's Large Hadron Collider announced they had each observed a new particle in the mass region around 126 GeV.

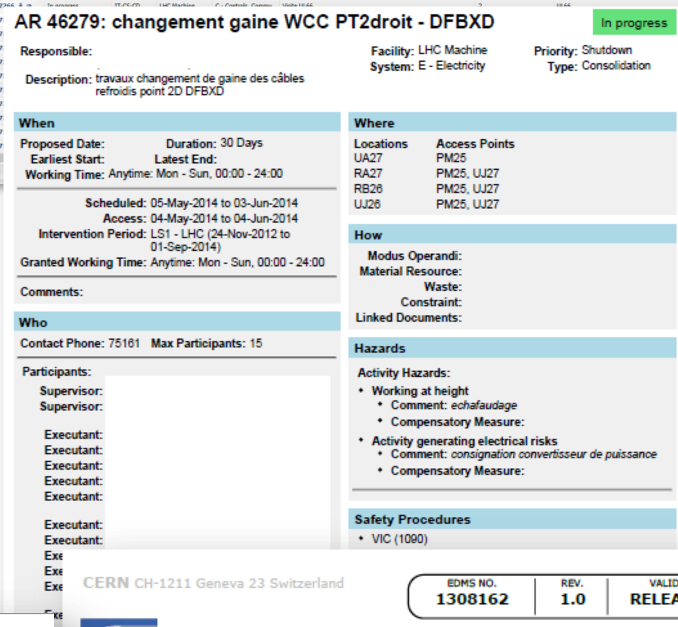
First Long Shutdown

- New challenges

Lessons learnt

- Improvements
  - **I**ntervention **M**anagement **P**lanning & **A**ctivity **C**oordination **T**ool (**IMPACT**)
  - **E**ngineering **C**hange **R**equest template (**ECR**)
  - Dashboards





AR 46279: changement gaine WCC PT2droit - DFBXD

In progress

Responsible:

Facility: LHC Machine
System: E - Electricity

Priority: Shutdown
Type: Consolidation

Description: travaux changement de gaine des câbles refroidis point 2D DFBXD

When

Proposed Date: Duration: 30 Days
Earliest Start: Latest End:
Working Time: Anytime: Mon - Sun, 00:00 - 24:00

Scheduled: 05-May-2014 to 03-Jun-2014
Access: 04-May-2014 to 04-Jun-2014
Intervention Period: LS1 - LHC (24-Nov-2012 to 01-Sep-2014)
Granted Working Time: Anytime: Mon - Sun, 00:00 - 24:00

Comments:

Where

Locations	Access Points
UA27	PM25
RA27	PM25, UJ27
RB26	PM25, UJ27
UJ26	PM25, UJ27

How

Modus Operandi:
Material Resource:
Waste:
Constraint:
Linked Documents:

Who

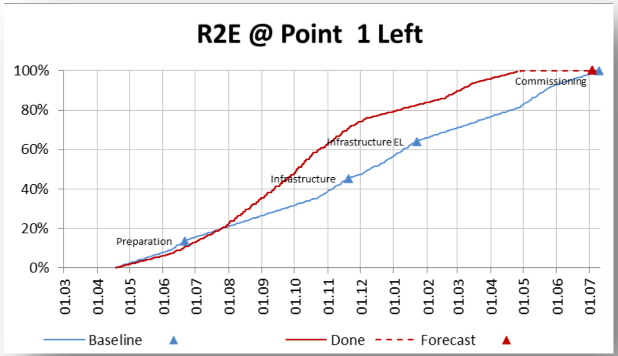
Contact Phone: 75161 Max Participants: 15

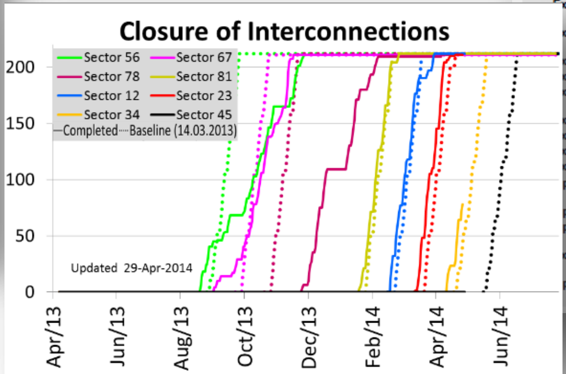
Participants:
Supervisor:
Supervisor:
Executant:
Executant:
Executant:
Executant:
Executant:
Executant:
Executant:

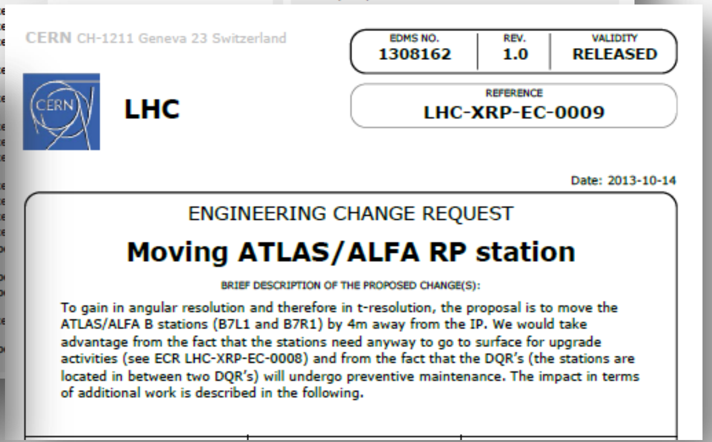
Hazards

Activity Hazards:
- Working at height
  - Comment: *echafaudage*
  - Compensatory Measure:
- Activity generating electrical risks
  - Comment: *consignation convertisseur de puissance*
  - Compensatory Measure:

Safety Procedures
- VIC (1090)







CERN CH-1211 Geneva 23 Switzerland

EDMS NO.	REV.	VALIDITY
1308162	1.0	RELEASED

REFERENCE
LHC-XRP-EC-0009

LHC

Date: 2013-10-14

ENGINEERING CHANGE REQUEST

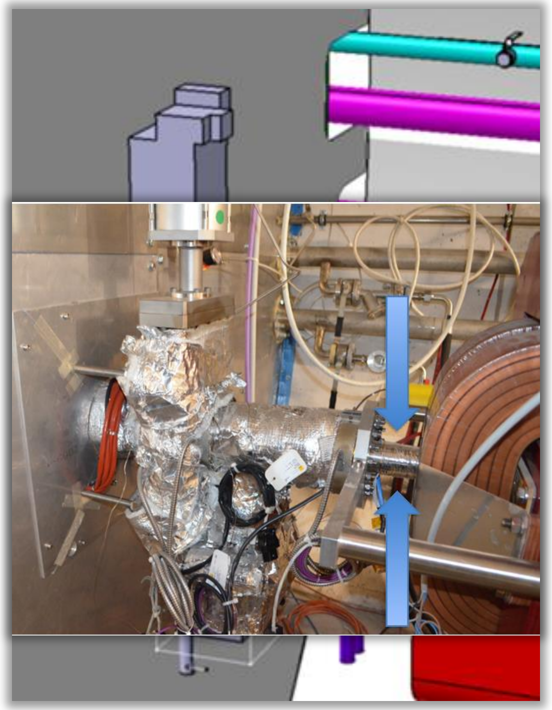
Moving ATLAS/ALFA RP station

BRIEF DESCRIPTION OF THE PROPOSED CHANGE(S):

To gain in angular resolution and therefore in t-resolution, the proposal is to move the ATLAS/ALFA B stations (B7L1 and B7R1) by 4m away from the IP. We would take advantage from the fact that the stations need anyway to go to surface for upgrade activities (see ECR LHC-XRP-EC-0008) and from the fact that the DQR's (the stations are located in between two DQR's) will undergo preventive maintenance. The impact in terms of additional work is described in the following.

Lessons to come

- Remaining difficulties
  - Simplified 3D model and reality
    - Cabling
    - Mechanical pieces
    - Cooling system



  - Communication between meeting of decisions and worker on site
    - Information online
    - Screen on site giving the important news

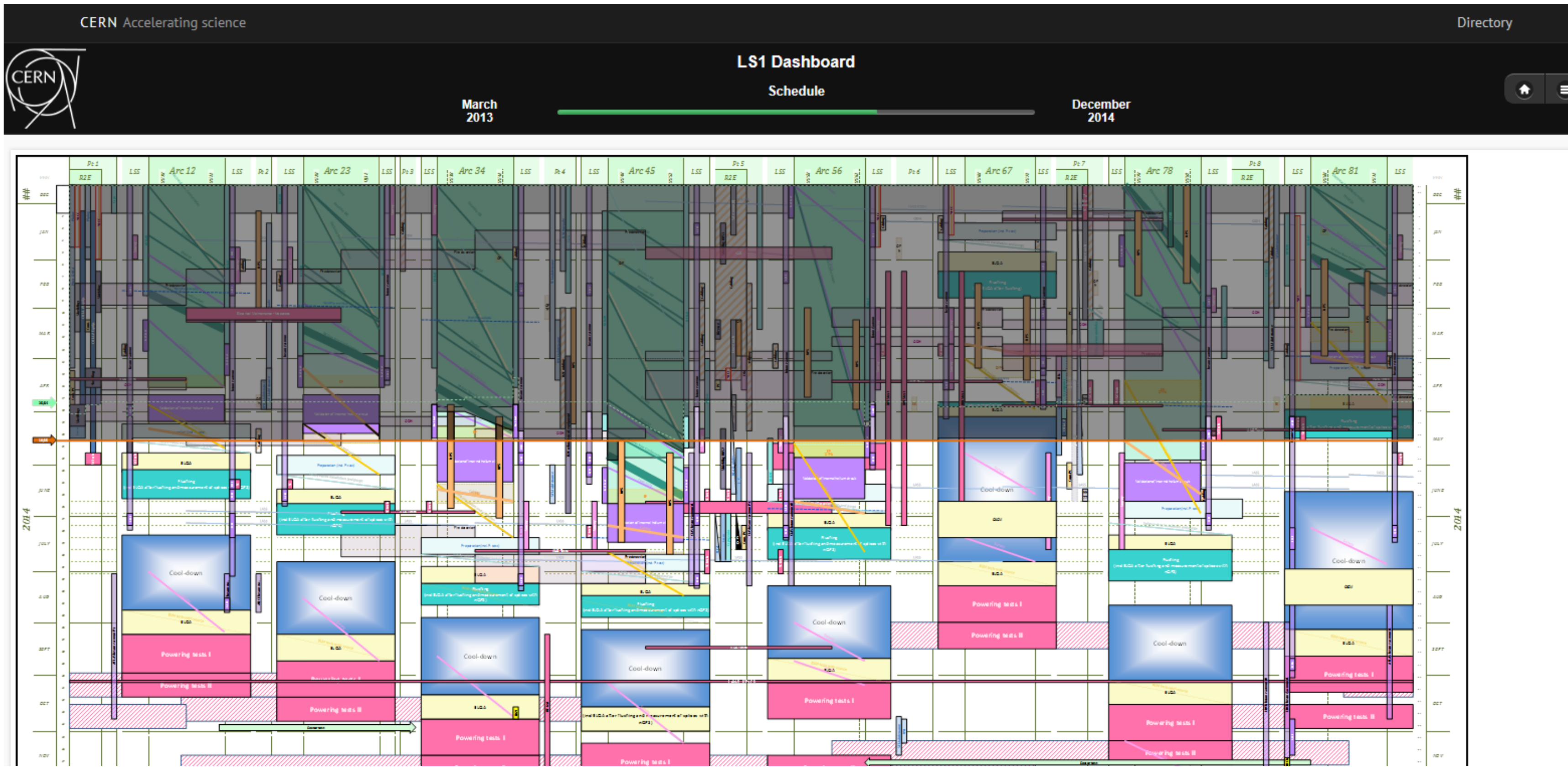
Lessons learnt

- New Projects at CERN after LHC

LIU - LHC Injectors Upgrade Project

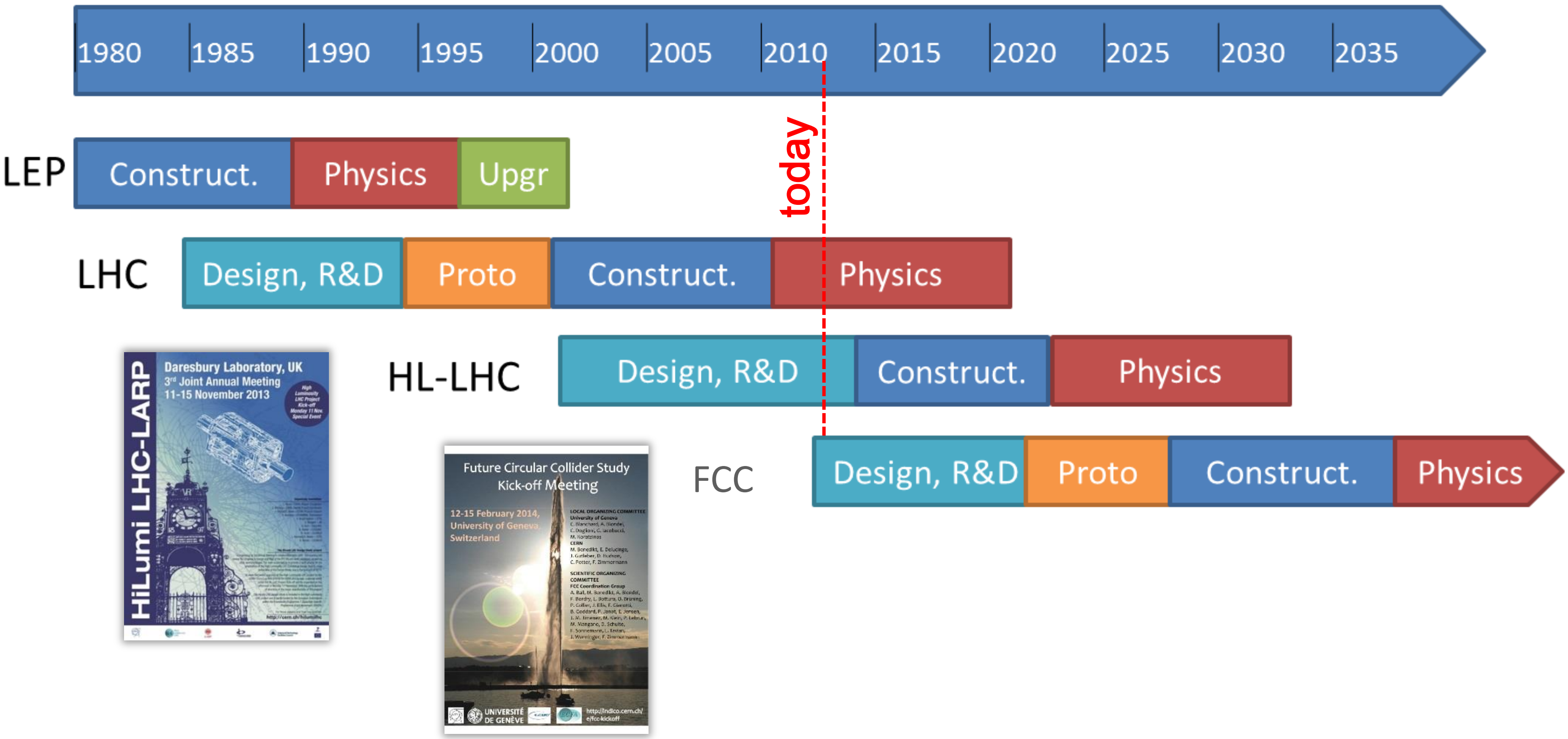
Current situation

http://lhcdashboard.web.cern.ch/lhcdashboard/ls1/



Master schedule in time with forecast

What's next ?



1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
today
LEP
Construct.
Physics
Upgr
LHC
Design, R&D
Proto
Construct.
Physics
HL-LHC
Design, R&D
Construct.
Physics
FCC
Design, R&D
Proto
Construct.
Physics
HiLumi LHC-LARP
Daresbury Laboratory, UK
3rd Joint Annual Meeting
11-15 November 2013
Future Circular Collider Study
Kick-off Meeting
12-15 February 2014
University of Geneva
Switzerland

Summary

- Work Breakdown Structure
- Cost control system
- Reporting

- Product Breakdown Structure
- Risk assessment
- Committee

- Clear information
- Anticipate the logistic on site
- Manage the co-activity

- Multi-level
- Have a coherent information up-to-date
- Be able by experience to identify the over/under-estimation

- Integer from pre-studies
- Involve at all stages
- Work package description
- Visit on site

- Predefinition of the environment
- Puzzle of the design office 3D models
- Volume of transport
- Volume for the survey

- Naming convention
- Link to quality assurance management tool

- Hardware baseline
- Layout database

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