LHC experience with installation

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QAP

History

Lessons learned

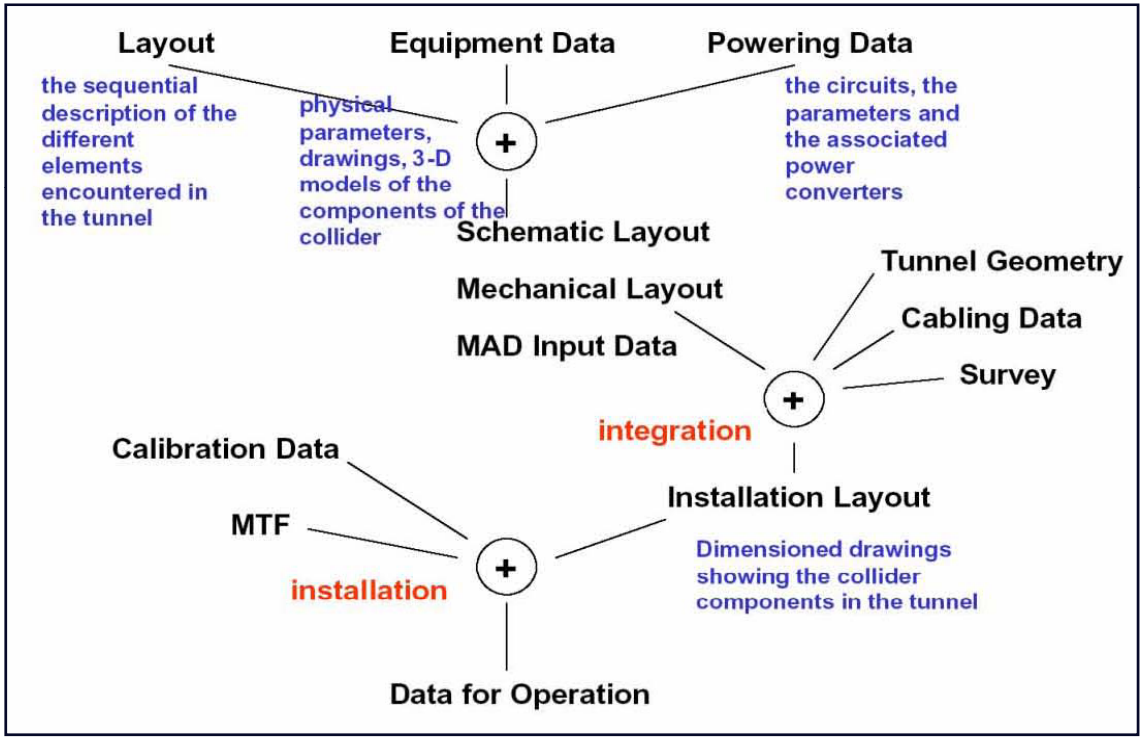
QAP

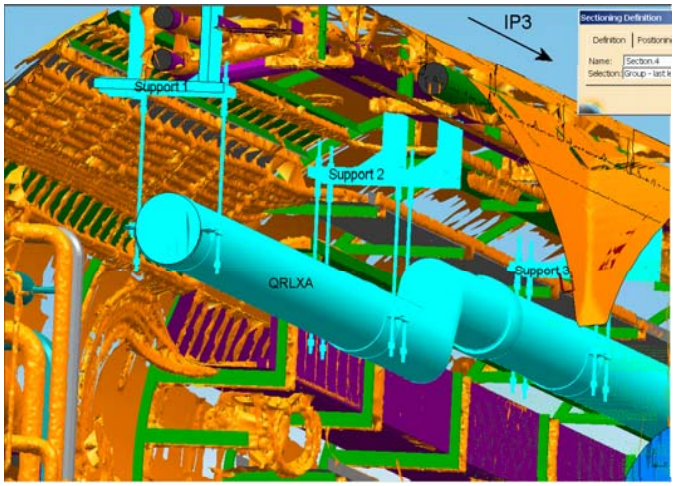
- Quality Assurance Plan
  - Based on ISO 9000 (documents distributed to all project engineers, contains all the code definitions, procedures) - EDMS
    - Engineering Specifications: functional and interface specifications and design files
    - Engineering Change Request
    - Engineering Drawings
    - Technical Description for Market Survey
    - Technical Specifications

- Manufacturing tool management
  - ➢ to follow the prod. & inst. activities:
  - – Components traceability,
  - – follow-up of non conformity
  - – Step sequence of a process.

QAP

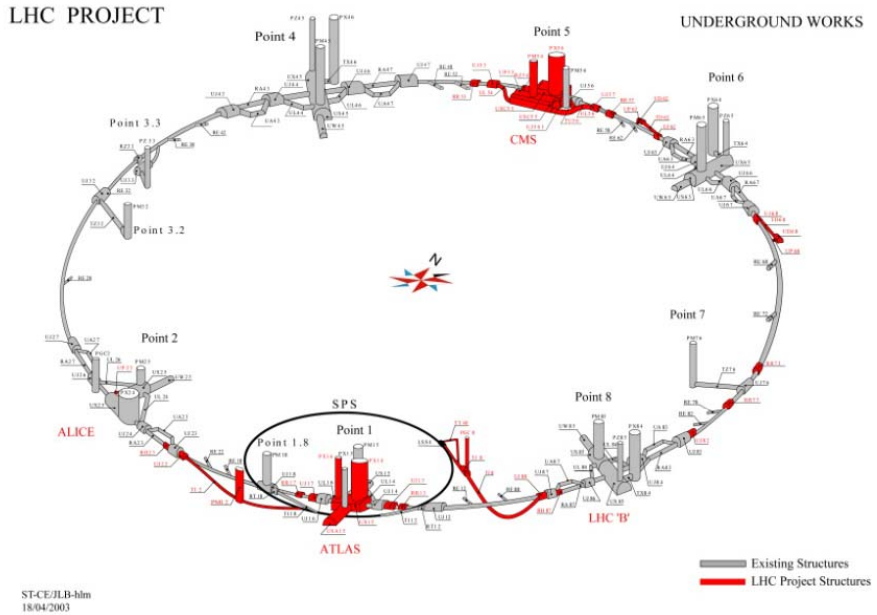
- Unique Reference database :





History

- 5 main phases
  - Civil engineering
  - General services
  - Cryogenics
  - Machine
  - Hardware commissioning



Civil engineering phase

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Scope

- Surface buildings
- Underground:
  - 2 injection tunnels ~5km
  - 2 beam dump tunnels
  - 2 new experimental areas
  - Other tunnel modifications: RR..

240’000 cubic meters

4 main contracts

TI2

DUMP

CMS

ATLAS

Civil engineering phase

Main problems encountered

- From CE side
  - Modification of scope while contracts were signed
    - New buildings
    - Modification of design
  - Introduction of 35h law in France

➔Impact on contractors planning and resourcing…

  - Discussions with contractors

➔Target cost mechanism

  - Some geological problems :
    - PM54,
    - Water leaks in UD68 and sector 34

- From coordination side
  - Lots of dust
  - Endless ends

General services Phase

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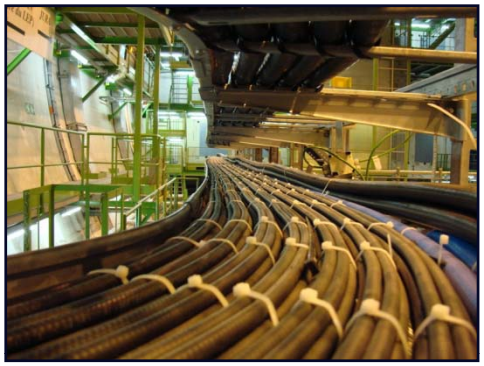
Electrical general services and cabling



- More than 4’500km of cables
- 2 Industrial Services Contracts
  - Benefit: Fast intervention possible
  - Disadvantage: limited resources
- Main problems encountered:
  - For EL
    - At the beginning: integration not fully done
    - Late request from users
    - Availability of cables (other contracts…), and otl
  - From coordination side
    - Lots of delay …. Endless ends

General services Phase

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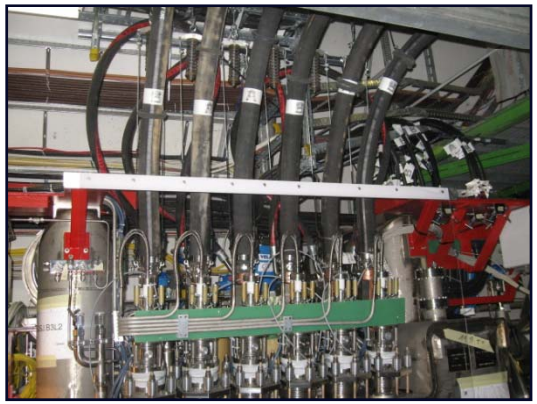
- Optical fibers
  - Skilled contractor and very good contract follow-up – Easy coordination
  - Could we have replace some of the control cables by optical fibers ?

- Water cooled cables
  - Supply contract
  - Hard time for planning
  - Technical problems….. “Fire brigade”



General services Phase

Cooling and ventilation

- Scope:
  - Piping: more than 160 km of pipes ,
    ~ 8km of flexible
  - Cooling and ventilation
    - Lots of work in surface buildings and experimental areas
    - New Cooling and ventilation systems in alcoves (UA, RR), modification in surface (upgrade, controls…)

- Main problems:
  - Technical or and commercial

Cryogenic phase

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- Cryo Islands
  - Upgrade or new installation
    - ➢ « stand-alone » Works

- Cryogenic Line installation
  - Started in June 03
  - After few months: Serious technical and quality problems
  - Worksites stopped in July 04, CERN repaired and re-installed all the faulty elements already at CERN
  - Started again in November 04
  - Finished in December 06

Cryogenic phase

Impacts induced by QRL delays

- Technical: Skip systematical cold tests on each sector
- Logistics:
  - Cryo-magnets storage
  - Cryo-magnets transport in parallel with QRL installation and interconnections works
- Organizational
  - Change of the sector sequence
  - Squeeze time dedicated to the machine phase

-> change the scope of contracts which were already signed (human and material resources to be added)

  - Squeeze the hardware commissioning phase by almost a factor 2 -> find resources to parallelize

Machine phase

Cryo-magnets transport

- Most of cryo-magnets transported through a unique shaft: PMI2 (+PX65 & PX24)
- More than 1'700 magnets transported
- Main problems encountered:
  - Cross working sites in a narrow areas
  - Some breakdown at the very beginning teething problems
  - Delays in magnet's deliveries: most of the time, no margin between surface readiness and transport
- Dedicated task force to ease the process (technical and organizational)

Machine phase

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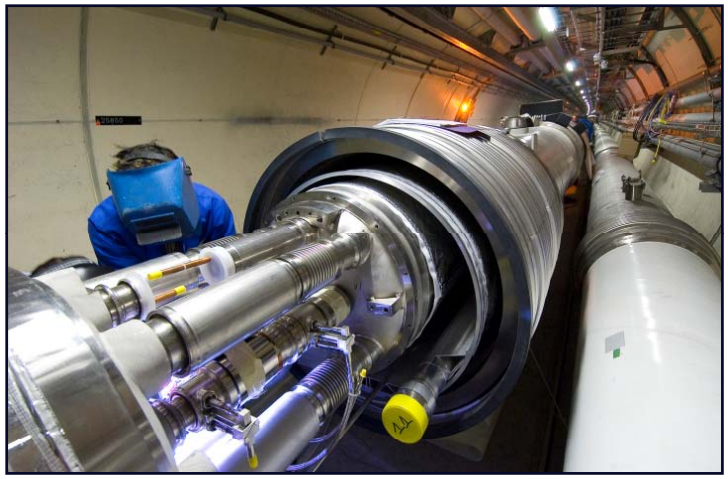
Interconnections

- Including:
  - more than 1'900 interc.
  - vacuum tests
  - electrical tests



- Slow start-up: missing magnets, co-activities
- Got organized on the 3rd sector while continuous sequence of magnets were available.

Machine phase

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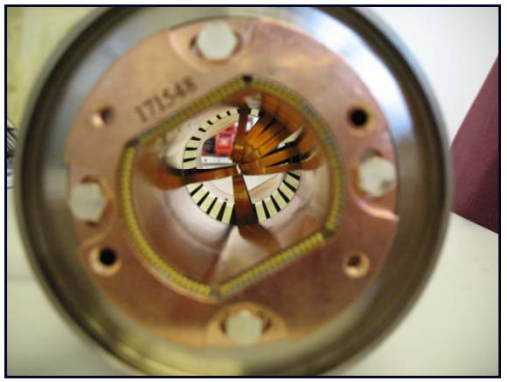
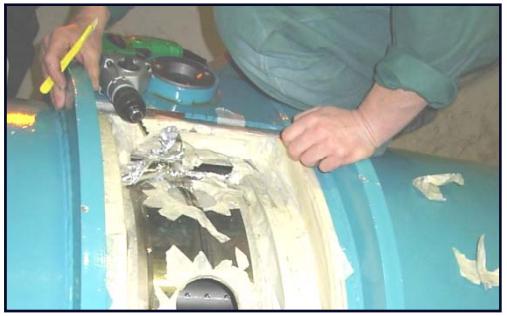
Interconnections Major incidents

- November 06 - Inner Triplets failure: heat exchanger tube
- Few weeks later after repair : Inner triplets spiders failed



► Sector 78 cooled and power test without IT in order to gain experience.

- September 07: PIM crisis
  - Ingenious solution for diagnostic : RF ball
- February 08: connection cryostat crisis



Hardware Commissioning Phase

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Short Circuit Tests & Individual System Tests

- Each system individually commissioned with relevant performance assessment
- IST Include:
  - cryogenic line pressure and leak tests,
  - collimators tests,
  - Powering Interlock System tests,
  - Energy Extraction tests,
  - Beam Instrumentation tests,
  - Injection and Beam Dump systems tests,
  - Cryogenics Instrumentation tests,
- Had to fit within tight constraints of the LHC installation planning

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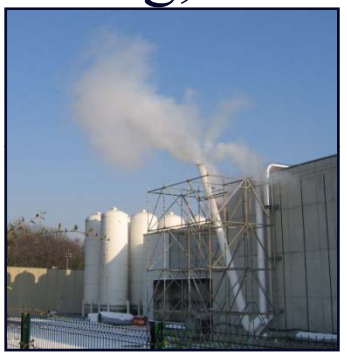
Cool-down

- Started in January 2007. painful beginning, but weak points identified:
  - Cryogenics
    - Cold compressor tuning
    - Cryo commissioning of stand alone magnets
    - DFB's : condensation and thus frost
  - Services
    - Power cuts
    - Faulty relays
    - Network problems
    - CV consolidations



Hardware Commissioning Phase

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Powering tests

- Object: power test each sector independently to ensure a safe and efficient machine start-up without being plagued by technical problems.
- Reminder: in 2003, ~10wks/sector and one sector at a time
- Beginning of 2007, after QRL and IT crisis, decision was taken to increase the number of sectors being commissioned in parallel from 2 up to 6 !

Hardware Commissioning Phase

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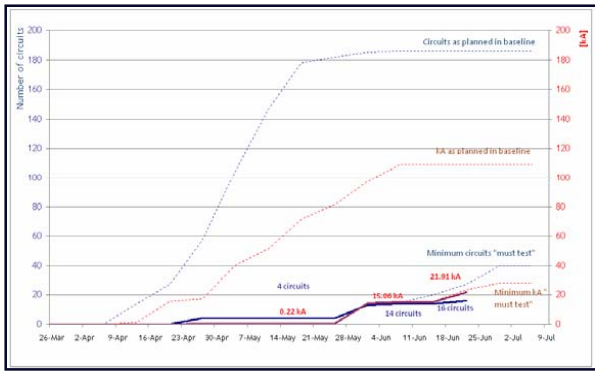
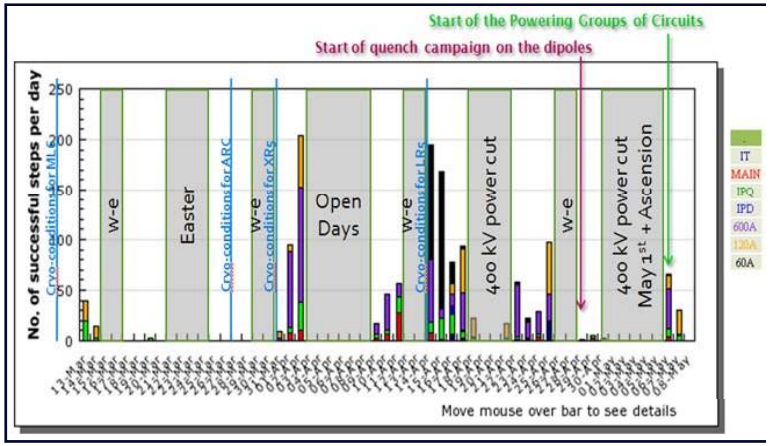
Powering tests



- Started in March 2007: painful beginning due to low Mean Time Before Failure and High Mean Time To Recovery
- March 2008: Taking into account the recent delays, and in order to meet the target of a beam in LHC before the end of this summer, decision was taken to qualify circuits at least for 5TeV.



- Situation in May 08:
  - Sector 45 commissioned partially
  - Sector 56: commissioned to 5TeV
  - Sectors 78 & 81: progressing
  - From mid-June: every 2 weeks, a sector will be available for powering tests

Lessons learned

- Keep baseline documentation is essential through the lifetime of the project
- Integration vs. Installation

- Safety
- First 25% of installation (2/8 sectors) are longer
- Gain experience asap for each phase is a benefit
- Fast Internal Intervention team is crucial