The Long Shutdown1 (LS1) consolidation program for LHC

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CERN | EN ENGINEERING DEPARTMENT

Contents

- Goal
- Preparation phase
- What has been done
- Implementation phase
- Lessons learnt
- Summary

LS1 goal

► to perform the necessary consolidation and upgrade activities and the full maintenance of equipment and in order to ensure a **safe and reliable operation** of the LHC at the design Energy of ~13TeV, taking into account essential rules: safety first, quality, second and schedule third.

- Main activities
  - SMACC
  - R2E (mainly Pt1, Pt5 and Pt 7)
  - Maintenance of all the systems after 3 years of operation
  - Consolidation and upgrades

Preparation is crucial

"The man who is prepared has his battle half fought"

Miguel De Cervantes

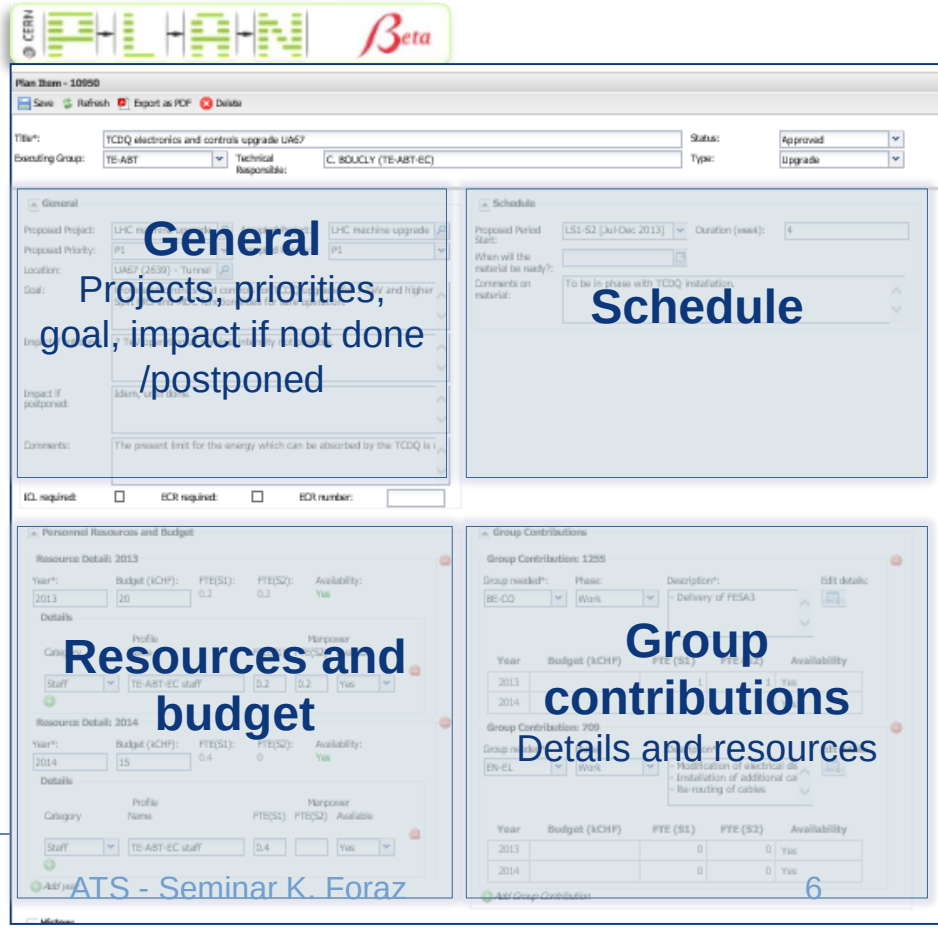
Preparation - Priorities

- Activities to be performed according to the following priorities:
  - P0: Safety
  - P1: Beam to 7TeV, nominal performance
  - P2: Reliable operation improvement
  - P3: CERN approved projects
  - P4: CERN non approved projects

Preparation - Declare

1. Collection and prioritization of activities: - Plan.cern.ch

   + Unique repository, useful for communication between groups
   + Attenuate bad surprises
   + Ease the prioritization process for LS1 team, focusing only on discordance points
   - Some concerns expressed being treated in new version of Plan: timeline, quality….

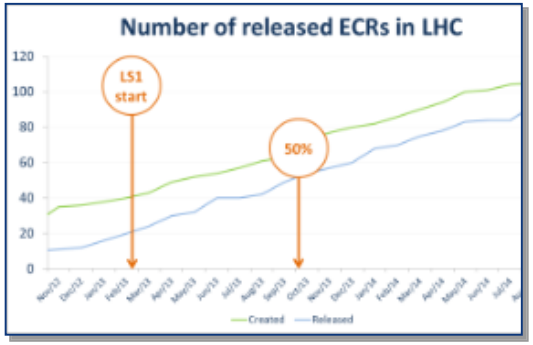


Preparation - Decide

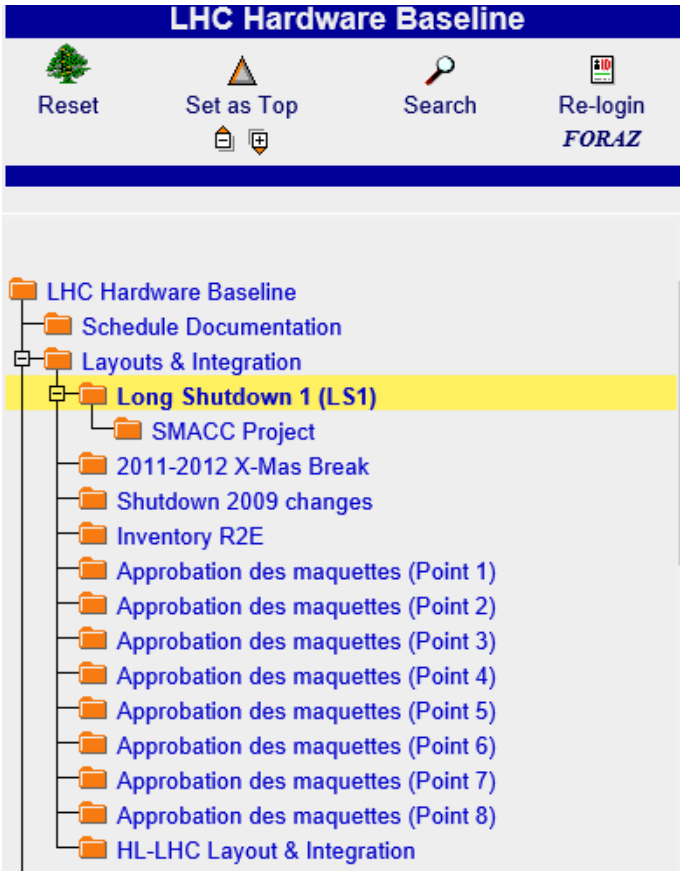
LS1 day
Tuesday, 12 June 2012 from 08:00 to 18:00

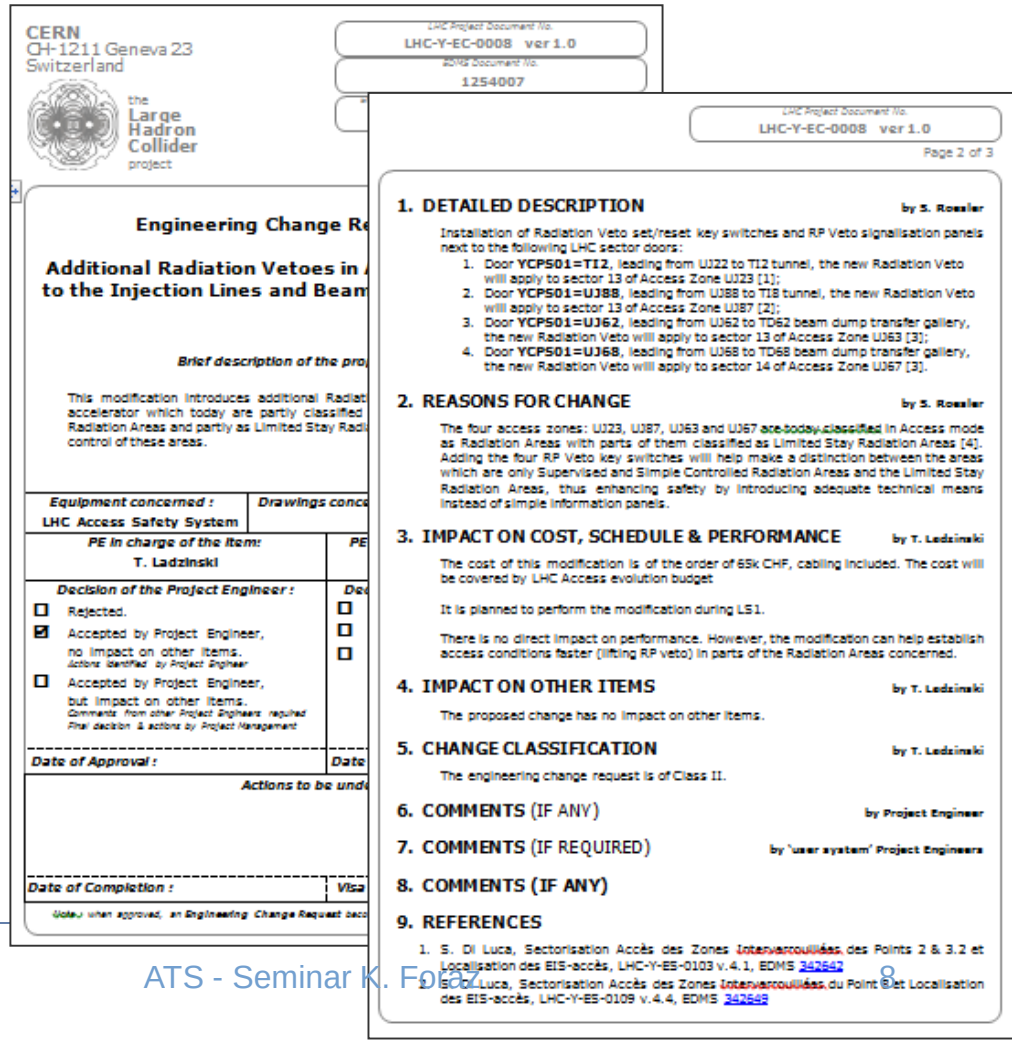
The aim is to announce the results of the survey and analysis of which activities will be performed during the first long shutdown (LS1), which activities might be performed subject to the availability of resources (call for extra manpower), and which activities will be postponed. The LS1 day will also provide the latest update on LHC & injector planning. The support groups will present their activities and organization during LS1. The aim is to crosscheck the requests from other groups and experiments, to avoid missing something and misunderstandings. A summary of the LS1 day will be presented at the LMC meeting on June, 27th.

Preparation - Approve



Engineering Change Requests




CERN
CH-1211 Geneva 23
Switzerland

the Large Hadron Collider project

LHC Project Document No.
LHC-Y-EC-0008 ver 1.0

EDMS Document No.
1254007

Engineering Change Re

Additional Radiation Vetoes in
to the Injection Lines and Beam

Brief description of the pro

This modification introduces additional Radiat
accelerator which today are partly classified
Radiation Areas and partly as Limited Stay Radi
control of these areas.

Equipment concerned :
LHC Access Safety System

PE in charge of the item:
T. Ladzinski

Decision of the Project Engineer :
- ☐ Rejected.
- ☑ Accepted by Project Engineer, no impact on other items.
- ☐ Accepted by Project Engineer, but impact on other items.

Date of Approval :

Actions to be und

Date of Completion :

Note: when approved, an Engineering Change Request

LHC Project Document No.
LHC-Y-EC-0008 ver 1.0

Page 2 of 3

1. DETAILED DESCRIPTION by S. Roesler

Installation of Radiation Veto set/reset key switches and RP Veto signalisation panels next to the following LHC sector doors:

1. Door **YCPS01=TI2**, leading from UJ22 to TI2 tunnel, the new Radiation Veto will apply to sector 13 of Access Zone UJ23 [1];
2. Door **YCPS01=UJ88**, leading from UJ88 to TI8 tunnel, the new Radiation Veto will apply to sector 13 of Access Zone UJ87 [2];
3. Door **YCPS01=UJ62**, leading from UJ62 to TD62 beam dump transfer gallery, the new Radiation Veto will apply to sector 13 of Access Zone UJ63 [3];
4. Door **YCPS01=UJ68**, leading from UJ68 to TD68 beam dump transfer gallery, the new Radiation Veto will apply to sector 14 of Access Zone UJ67 [3].

2. REASONS FOR CHANGE by S. Roesler

The four access zones: UJ23, UJ87, UJ63 and UJ67 are today classified in Access mode as Radiation Areas with parts of them classified as Limited Stay Radiation Areas [4]. Adding the four RP Veto key switches will help make a distinction between the areas which are only Supervised and Simple Controlled Radiation Areas and the Limited Stay Radiation Areas, thus enhancing safety by introducing adequate technical means instead of simple information panels.

3. IMPACT ON COST, SCHEDULE & PERFORMANCE by T. Ladzinski

The cost of this modification is of the order of 65k CHF, cabling included. The cost will be covered by LHC Access evolution budget

It is planned to perform the modification during LS1.

There is no direct impact on performance. However, the modification can help establish access conditions faster (lifting RP veto) in parts of the Radiation Areas concerned.

4. IMPACT ON OTHER ITEMS by T. Ladzinski

The proposed change has no impact on other items.

5. CHANGE CLASSIFICATION by T. Ladzinski

The engineering change request is of Class II.

6. COMMENTS (IF ANY) by Project Engineer

7. COMMENTS (IF REQUIRED) by 'user system' Project Engineers

8. COMMENTS (IF ANY)

9. REFERENCES

1. S. Di Luca, Sectorisation Accès des Zones Intervarrouillées des Points 2 & 3.2 et Localisation des EIS-accès, LHC-Y-ES-0103 v.4.1, EDMS 342642
2. S. Di Luca, Sectorisation Accès des Zones Intervarrouillées du Point 8 et Localisation des EIS-accès, LHC-Y-ES-0109 v.4.4, EDMS 342648

Preparation - Detail

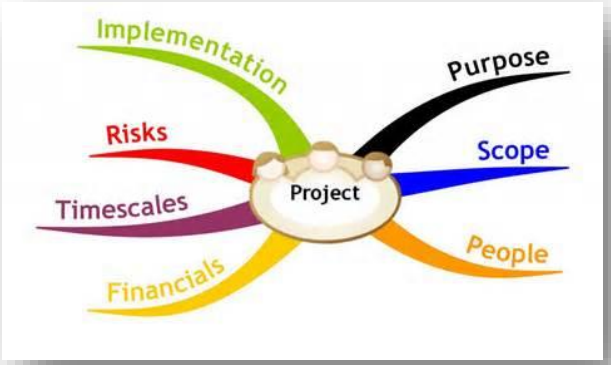
- **Work Package analysis meetings**
  - Organized by coordination teams
  - Gathered all stakeholders around the table
  - Gave the opportunity to understand what other groups intend to do and how
  - Lots of points clarified

Items covered:

- ✓*Description*
- ✓*Conditions prior to start*
- ✓*Schedule*
- ✓*Perimeter of worksites*
- ✓*Storage areas*
- ✓*Logistics*
- ✓*Risks & compensatory measures*
- ✓*Radiological management*

Preparation - When

- Main projects
  - SMACC project: 4 years of preparation
  - R2E: 3 years of preparation

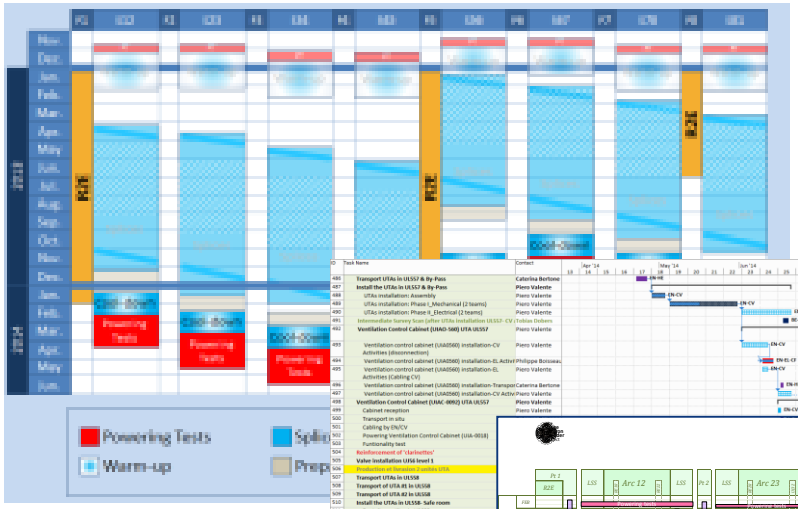


- Contracts: Up to 30-40wks to get a contract
  ► technical specification from clients shall be ready in due time

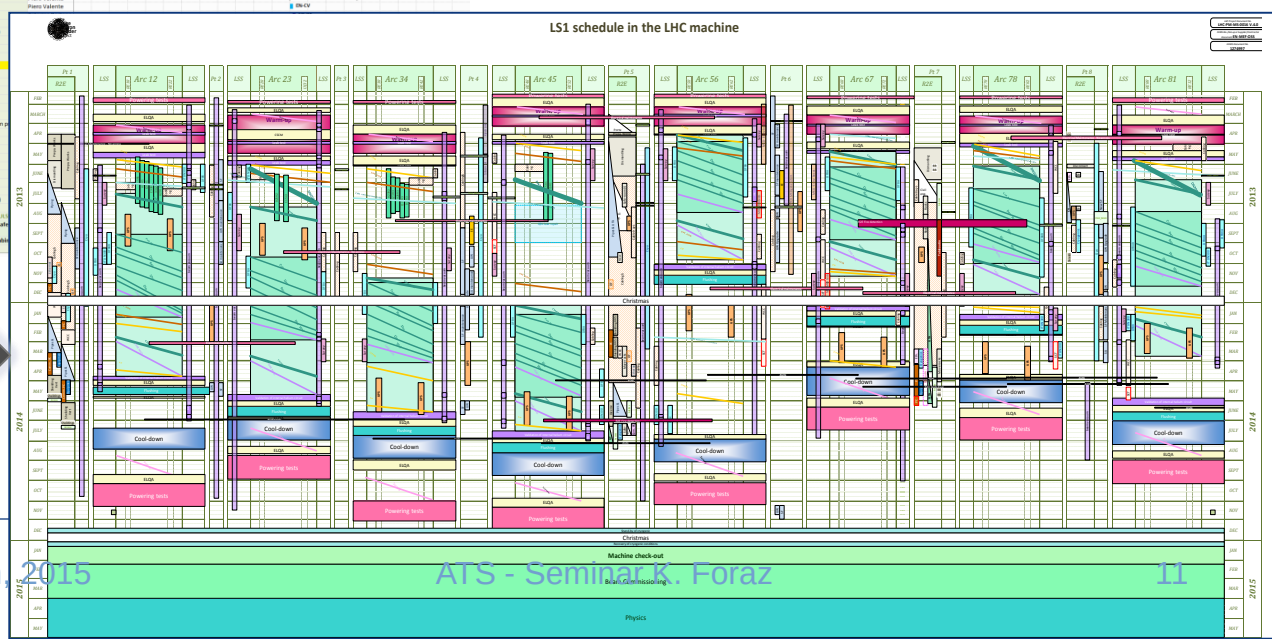
- Recruitments : staff have to be hired 1.5-2.5 years prior to a shutdown

Preparation – Schedule

From big blocks to detailed schedules



Resources leveling
Logistics
Safety



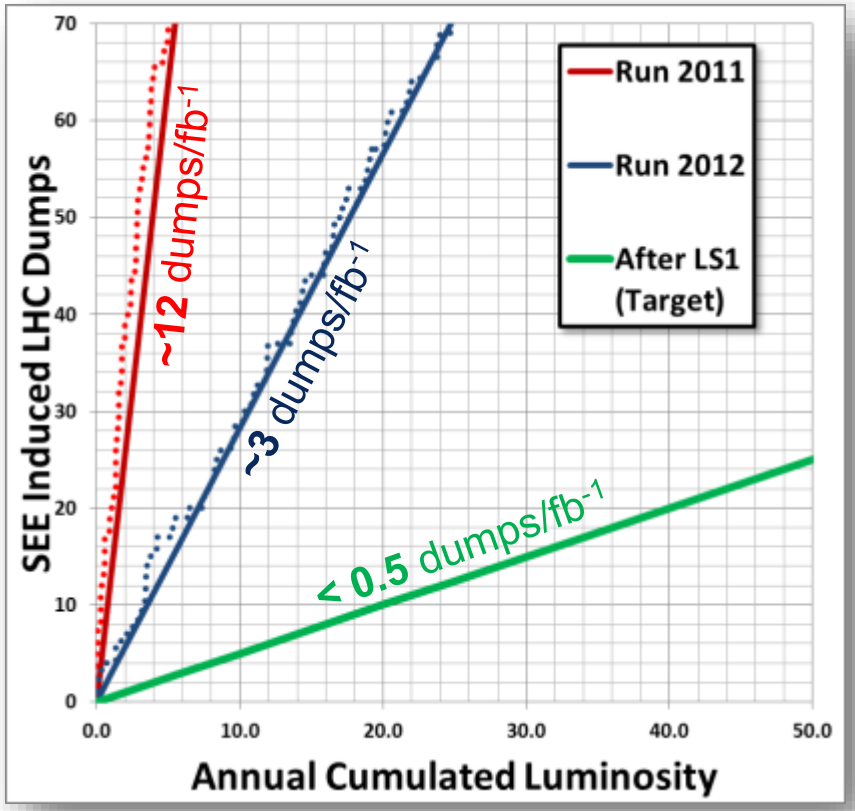
Automated

What has been done

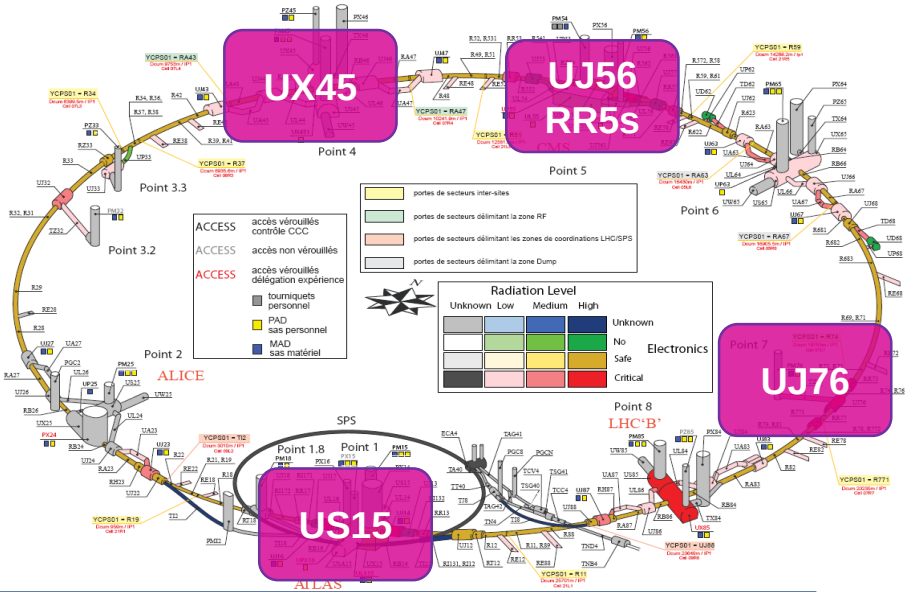
- SMACC ➲ see. Presentation of J.-P. Tock
- R2E project
- Maintenance
- Upgrades and Consolidations

R2E project

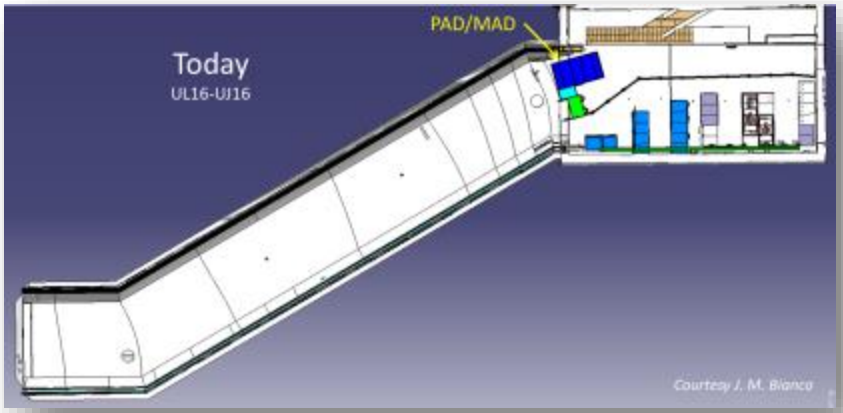
Project leader: A.-L. Perrot

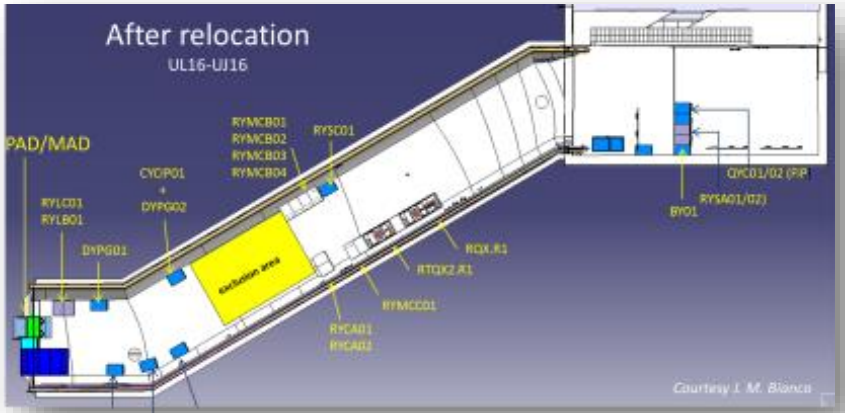


Relocate and protect the SEE sensitive equipment identified by the RADWG



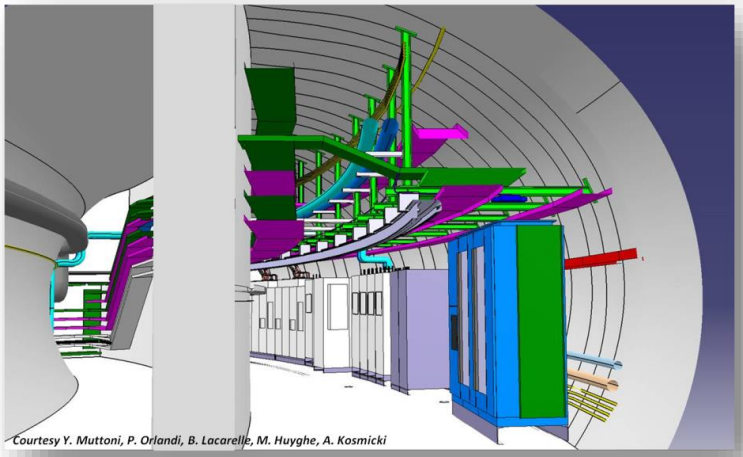
R2E – Point 1

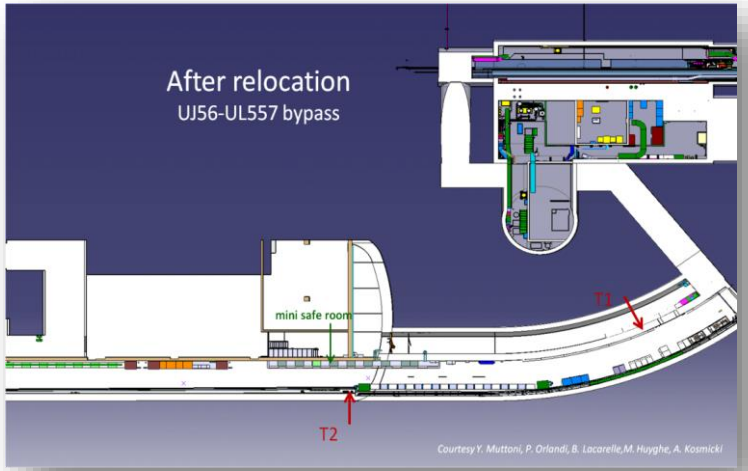




10 groups involved
57 weeks of activities

R2E – Point 5

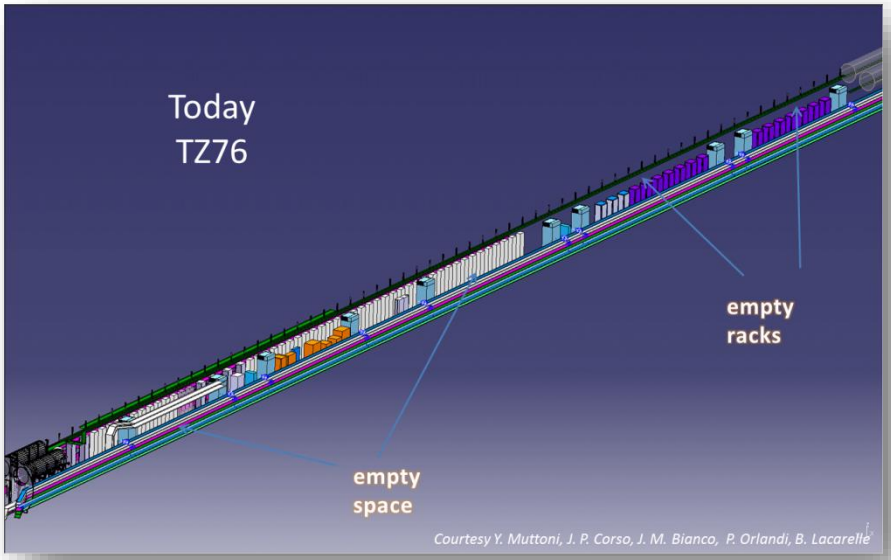


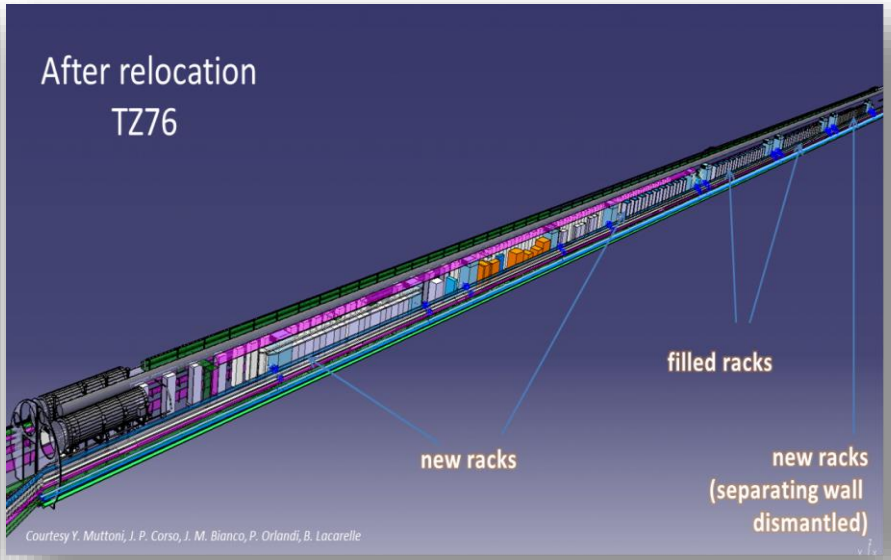


12 groups involved

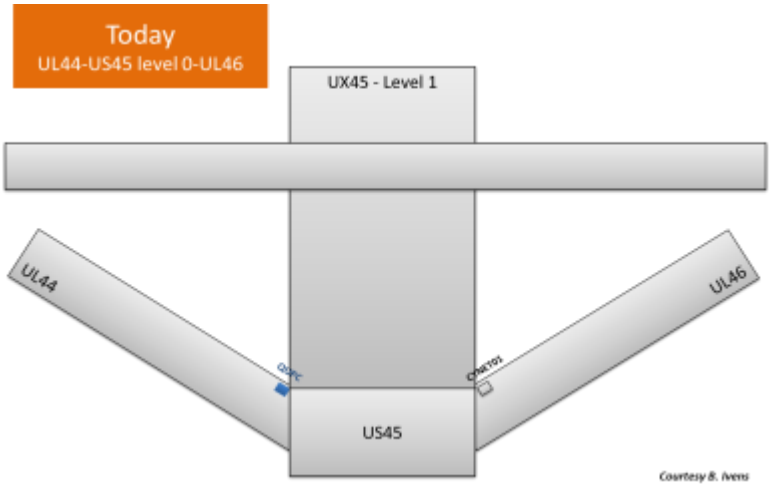
74 weeks activities

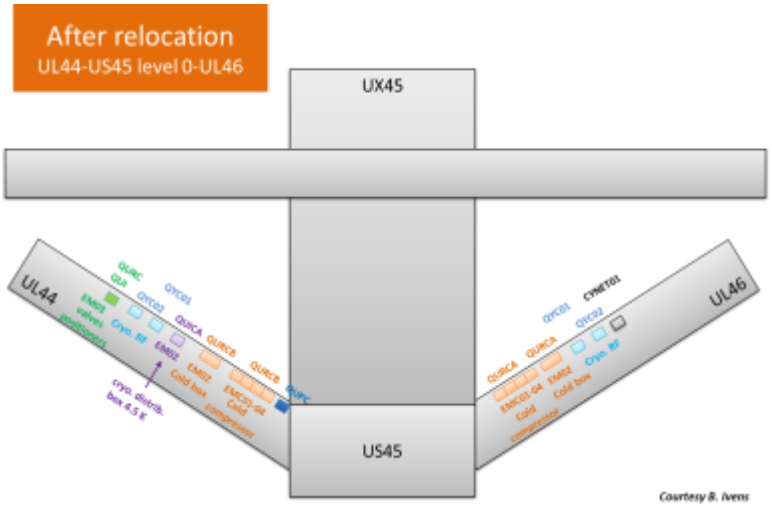
R2E – Point 7


Today
TZ76
empty
racks
empty
space
Courtesy Y. Muttoni, J. P. Corso, J. M. Bianco, P. Orlandi, B. Lacarelle


After relocation
TZ76
filled racks
new racks
new racks
(separating wall
dismantled)
Courtesy Y. Muttoni, J. P. Corso, J. M. Bianco, P. Orlandi, B. Lacarelle

R2E – Point 4


Today
UL44-US45 level 0-UL46
UX45 - Level 1
UL44
UL46
US45
Courtesy B. Ivens


After relocation
UL44-US45 level 0-UL46
UX45
UL44
UL46
US45
Courtesy B. Ivens

Major Overhaul

Main Power station

Cryogenics

Collimators

Quench detection

Kickers

UPS

Cooling Towers

Vacuum

Generators

Beam Instrumentation

Quench protection

Power converters

Maintenance

Pumping Stations

Inspection

Power distribution

Lifts

Cranes

Pumping systems

Access systems

Electronics

Ventilation

Klystrons

Cavities

Fire Detection

ODH

Radmon

Consolidation & upgrades

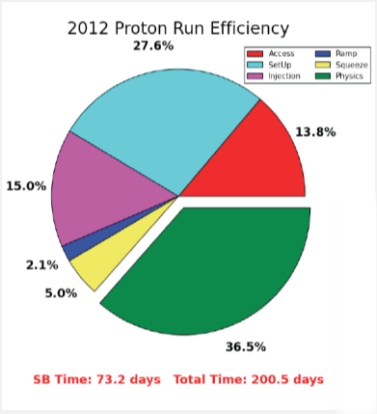
Safety

Improve safety for personnel & machine

Performance

Nominal performance of LHC ► 7TeV

Reliability

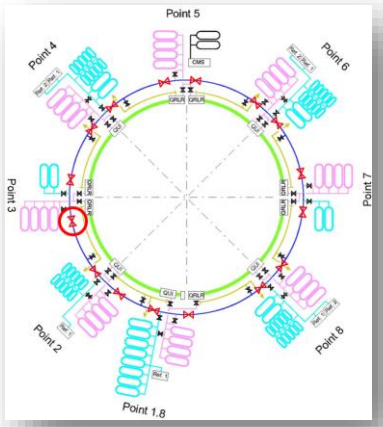


Safety Consolidation / Upgrades (1)

- **Safety for personnel**

  Based on run1 experience and forecast activities, consolidation activities were performed in order to ease and protect our personnel

  - Installation of DFB deflectors, platforms to access service modules, Helium ring line (HRL) sectorization…
  - Permanent bake-out reconfigured in order to reduce the dose received by personnel in IR3 and IR7

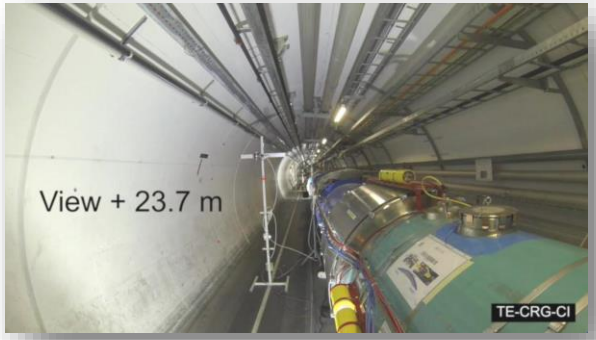


HRL sectorization

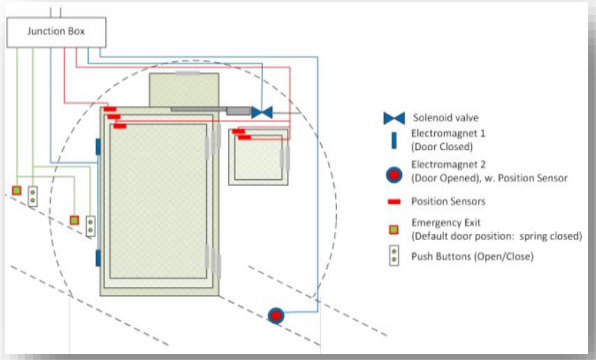

DFB passerelle

Safety Consolidation / Upgrades (2)

- **Safety for personnel**
  - Helium spill tests ►better understand the phenomena and adapt accordingly safety procedures
  - Access sectorization reviewed, w.r.t ALARA
  - Change of the Interlocking of Powering and Access Systems
  - …



Helium Spill tests



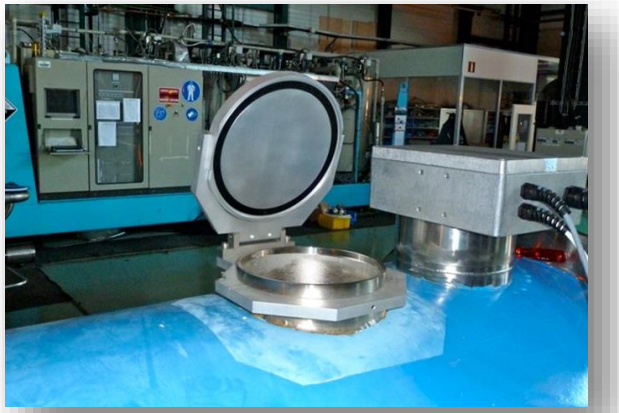
P7 enclosure doors

Safety Consolidation / Upgrades (3)

Safety for machine (&personnel)

- Following s34 incident, installation of **Pressure relief valves**, flap valves and half shells, **Additional rupture disc** in order to protect beam vac. against overpressure….
- New **interlocks** on TCDI, TDI, MSI…
- New TCDQ: Prevent damage to absorber and improve protection of Q4 in the event of unsynchronized dumps

Protective half shells

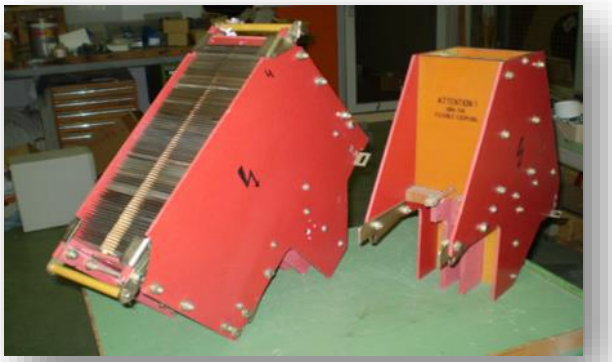


Flap Valves

Safety Consolidation / Upgrades (4)

Safety for machine

- **Quench Protection** :
  - Replacement of all arc chambers on the same quadrupole switches – new 1 kV version in order to admit higher discharge resistances at higher currents
  - Reconstruction of the 1232 LPU (dipoles) in order to improve the QHS supervision and diagnostics capabilities and to have a redundant powering scheme
- …



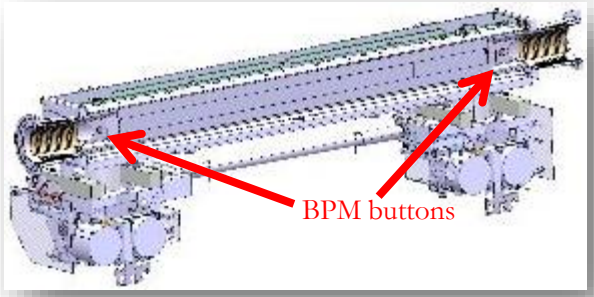
Arc chambers: new and previous

DYPB – dipole, with nQPS crate

Performance Consolidation / Upgrades (1)

- Mitigation of electron cloud
  - non-NEG coated components ► Optimization of the cold/warm transition
  - «Coating» of warm equipment
  - 6 NEG pilot sectors ► estimation of the NEG parameters in presence of beam
- Beam Position Monitor consolidation: TAS region, BGI, collimators (alignment of jaws without touching the beam)
- BLM consolidation
  - Reduce noise on detectors
  - Improve reset and test function of electronic cards
  - Connect to WorldFIP....

Vacuum Pilot sectors (L8)



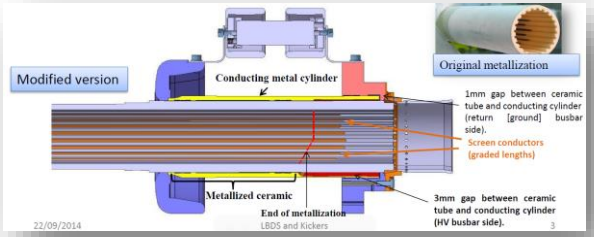
Collimator with integrated BPM

BLM - Improved backplane

Performance Consolidation / Upgrades (2)

- Repair and consolidation of «sick» equipment: BTVs, BWS, BGI, BSRT, BQS, TDI, ACS…
- TCL collimators in P1 & P5 ►To reduce losses
- MKI
  - Beam screens ►To reduce induced heating
  - Cleaning procedure ►To reduce dust ► UFOs effect
- Dilution kickers: 1 tank (2 magnets) per beam of vertical dilution kickers MKBV was outstanding from cost spreading ➲ installed during LS1
- Pumps replacement in UWs

ACS module transport



MKI improvement

Dilution Kickers tank

Reliability Consolidation / Upgrades (1)

- Vacuum
  - Leak tests
  - PIMs exchange
  - Replacement of non-conforming RF inserts in bellow modules of the LSS
  - Additional turbo at the QRL extremities
- ADT transverse dampers upgrade: Installations of additional pick-ups (►to reduce noise)
- High Power RF
  - Silicon oil reconditioning
  - Thyratrons replacement
  - Tetrodes replacement
  - Klystrons collectors redesigned

Buckled PIM


Leak tests


Tetrode replacement

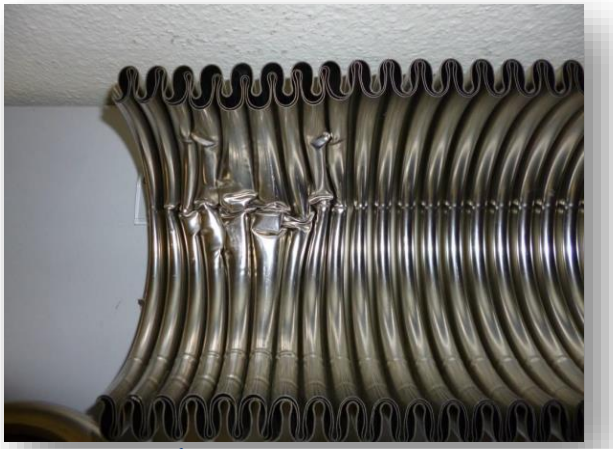
Reliability Consolidation / Upgrades (2)

- Quench Protection System: Improve the immunity to ionizing radiation & to EMI and simplify the configurations
- 13 kA EE – snubber capacitors installed to eliminate the perturbations and transients from the electrical arcs during the commutation process
- 600A EE - Fixation of the 'holding coil" – 95% of failures for this system

13kA EE – Snubber capacitor

- Warm bus bars measurements
- CSCM

- DFBs consolidation: Splice, DFBX CL, flexible hoses, NC…
- QRL leaks



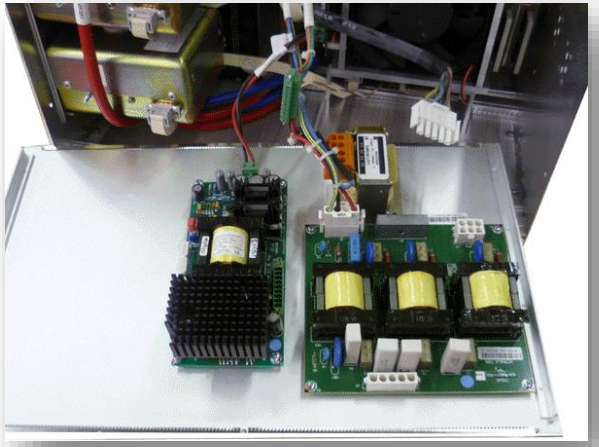
QRL damaged compensator

Reliability Consolidation / Upgrades (3)

- RQD, RQF consolidation
- FWT Displacement in order to avoid voltage oscillations
- 60A - Upgrade the Aux PSU with new capacitors
- RQX, RTQX converter type consolidation: *Improve the stability of the Inner Triplets to perturbation Improve the ramp down speed*

- Replacement of water cooled cable hoses in 3 LHC sectors
- Replacement of non radiation-resistant fibres
- UPS replacement

- PM32 Raising system



60A – Aux PSU upgrade

PM32 raising pumps

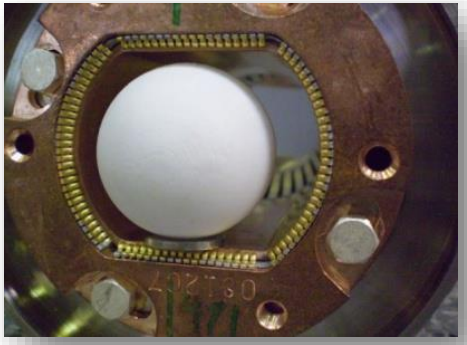
EL cabling *(entire accelerator complex)*

- **Extraordinary increase of cabling projects**
  - ~**4 times** the workload of 2011
  - ~**1300 km** of copper and optical cables
- **Increased manpower and contracts**
  - **~100 contractor staff** at the activity peak
  - **35 CERN staff** (x 2.5 section size before LS1)
- **Organisation of the work**
  - **~2000 "jobs"** (affaires) to organize for execution through external contractors
  - **~370 worksites**
    - In overloaded cabling areas
    - In ALARA areas
    - In coactivity with other teams

Cabling campaign @P1

Optical fibbers

And many other activities



RF ball test

- Transport
- Survey
- Radio Protection
- Tests
- Operationnal activities: cool-down, ELQA, lift, cooling….
- Cleaning
- New maintenance doors for Surface Access Points
- …..

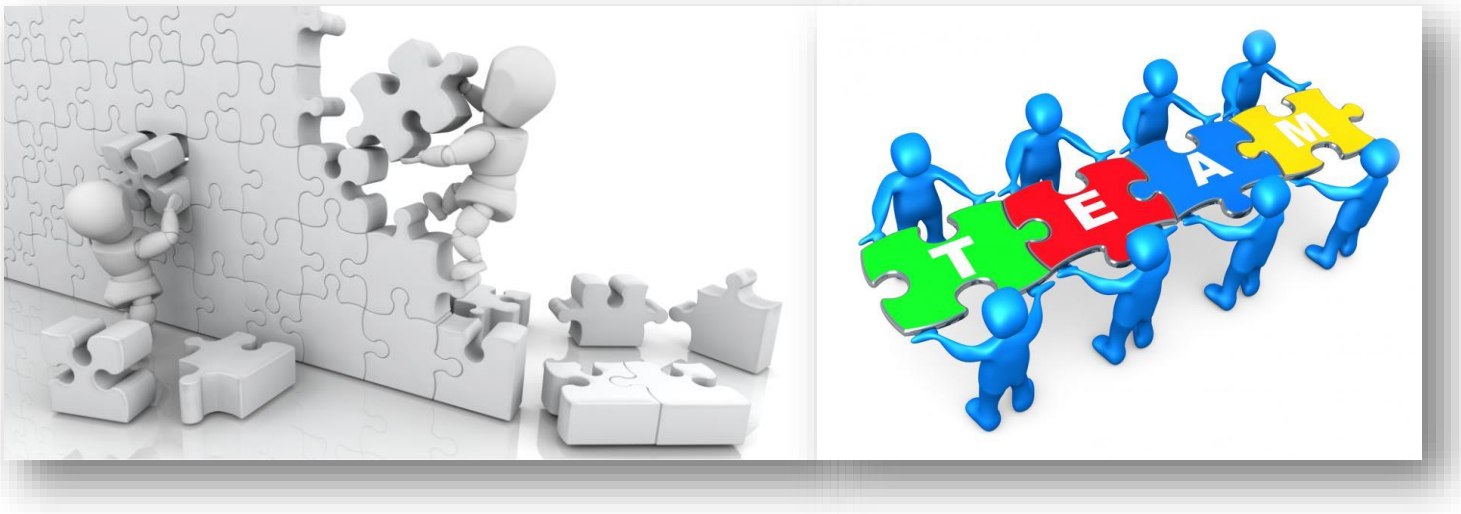
UPS transport

22R5 survey

Lift – speed limiting device

Arc56 - cleaning

Implementation phase



LS1 Implementation phase - Organization

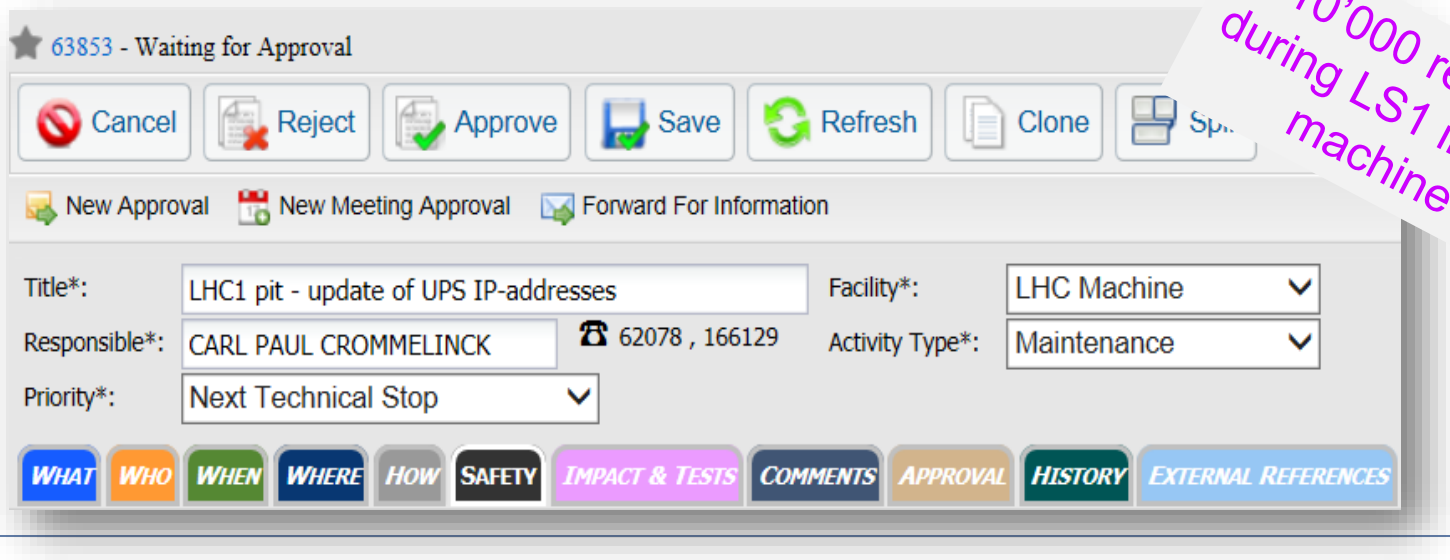
- Coordination
  - Weekly Coordination meetings
  - Dedicated project meetings (SMACC, R2E)
  - Long Shutdown Committee

    - Progress of works
    - Additional activities & impact on resources
    - Issues: delay, safety, logistics….

- Strong field coordination

LS1 Implementation phase -IMPACT

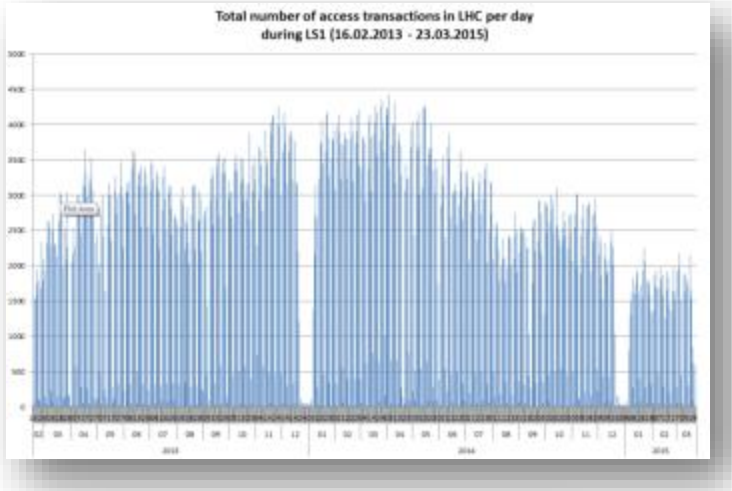
- ***I**ntervention **M**anagement **P**lanning **A**nd **C**oordination **T**ool*
- *Integrated with existing systems: access system, location database, Radio Protection database, InforEAM…*

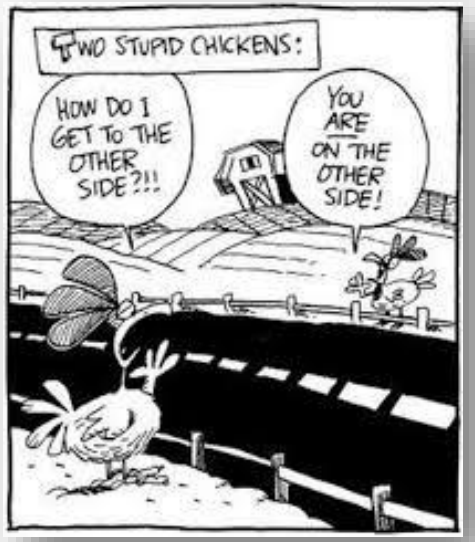


> 10'000 requests during LS1 in LHC machine

LS1 Implementation phase - Access

- … sinew of war
  - 100m underground machine
  - Peak of entries & exits per day in LHC (incl. experiments) : 4’434
  - 10 surface access points, 2 critical systems
    - Material Access Devices
    - Lifts





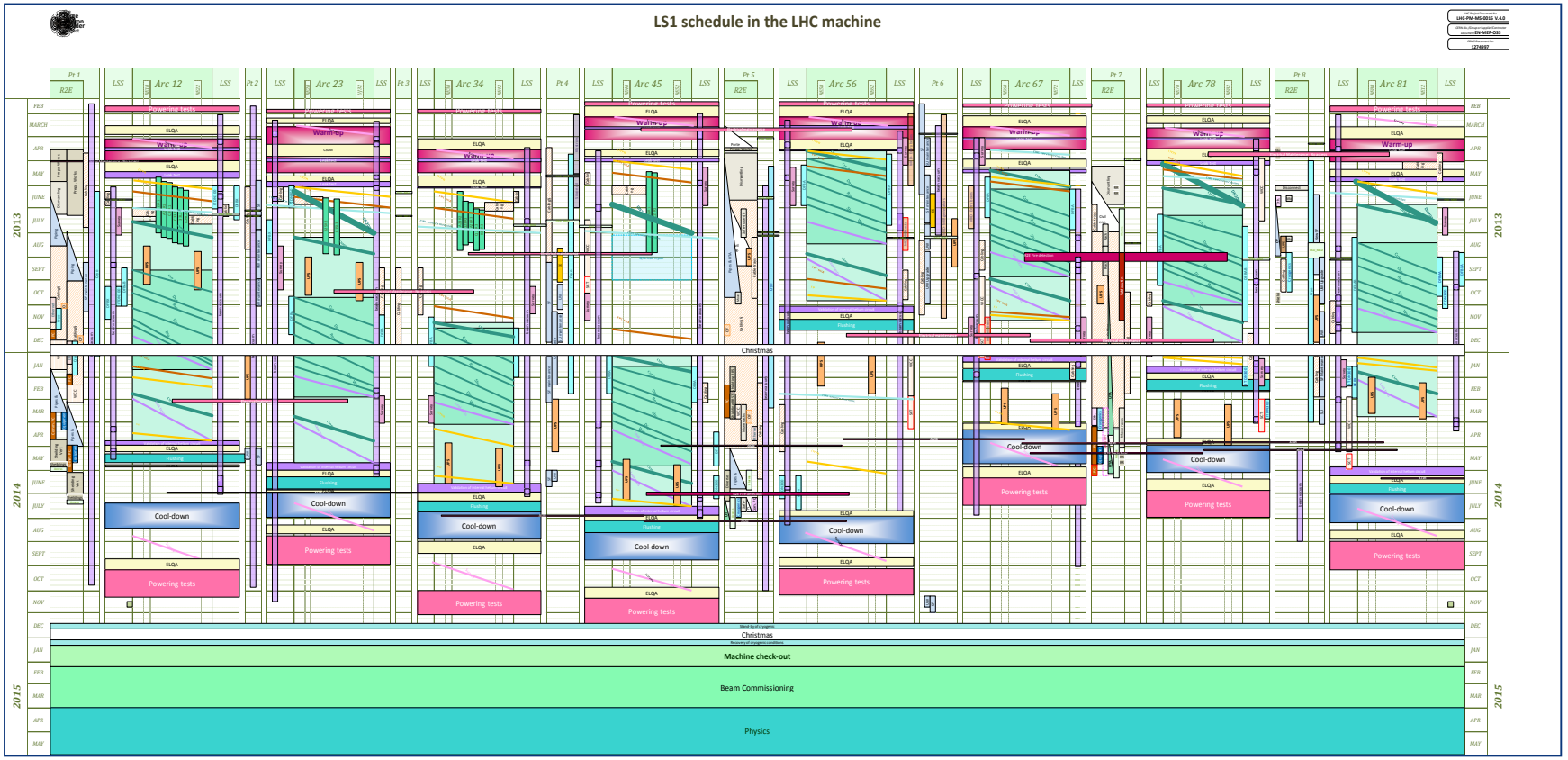
LS1 Implementation phase

Additional activities

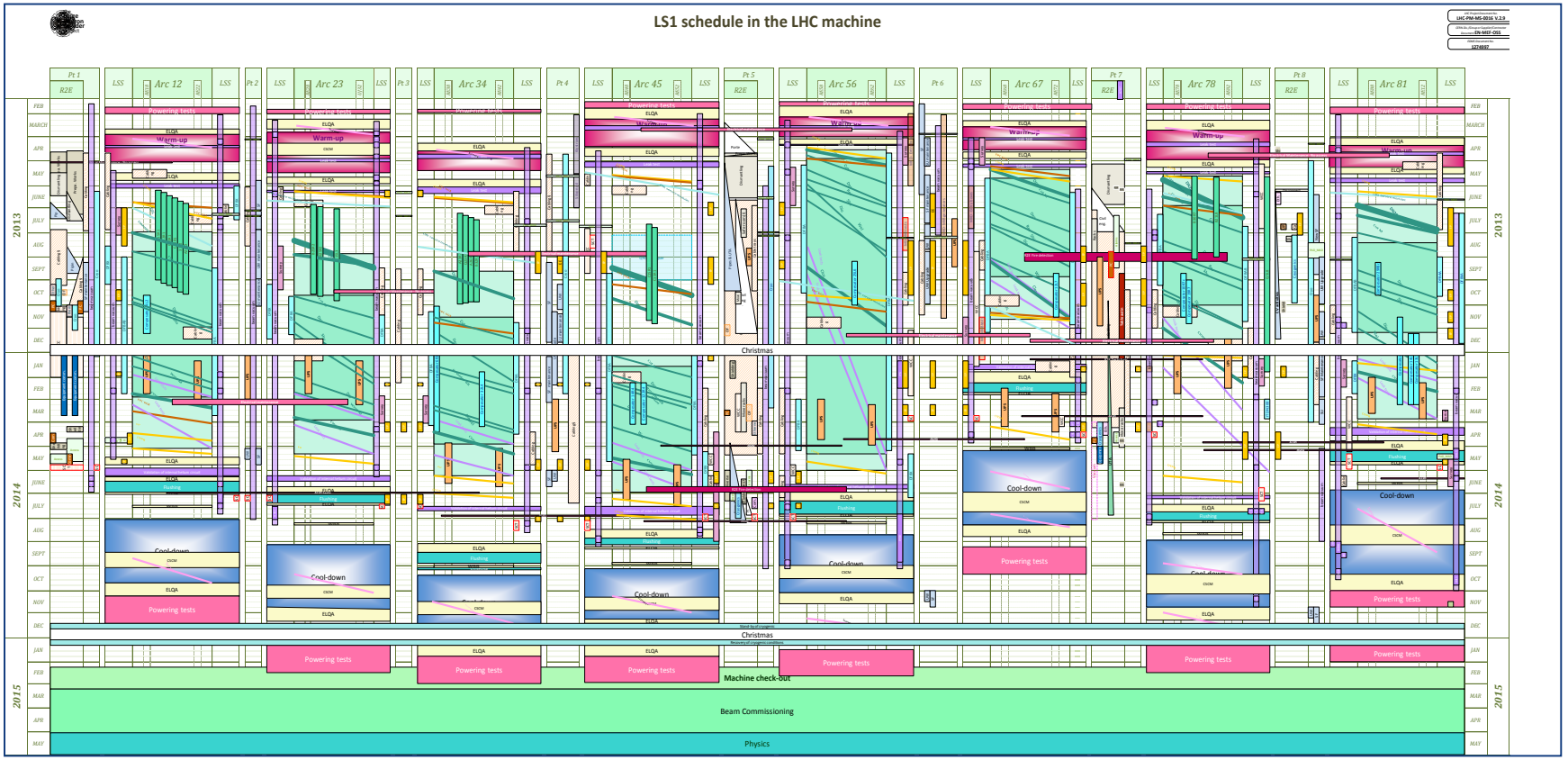
- Inherent to such a Shutdown … there were
  - Those unexpected :
    - LHC QRL leaks, 15%► 30% of splices…
  - Those who «somebody» knew but forgot to inform the community !!
    ➲ induced additional workload to the usual support groups

- Schedule was reviewed accordingly and resources reallocated
  - A 2nd baseline was edited in September 2014, and few weeks were added

Baseline schedule - V2.7 (March 13')



As done schedule - V4.1 (Dec 14')



Lessons learnt on organization

- Scoping phase - Plan tool
  - Unique repository, useful for communication between groups
  - To be reviewed regularly

- Preparation & Implementation phase
  - Work Package Analysis is crucial….. ☹ *documentation and procedures have to be ready in due time*
  - ALARA *As Low As Reasonably Achievable* ➲
    ☹ Activities scheduled as Late as possible….no margin = stress
  - Central coordination point is essential (communication)
  - Additional activities and resources reshuffling
    … effects on other facilities

In summary

LS1 was **a major shutdown** for each area of the accelerator complex

- More than 800 persons joined CERN to achieve the objective
- SMACC was the time driver, but many other activities were performed to ensure a safe and reliable run of LHC at nominal Energy: R2E, full maintenance, consolidation, upgrade…

Despite all the points of improvements mentionned,

the LS1 was a success

And this is thank to you !!