CERN

CERN experience and strategy for the maintenance of cryogenic plants and distribution systems

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outline

- Introduction
  - CERN and its cryogenic infrastructure
  - The Large Hadron Collider
- Review of operation and maintenance activities
  - Schedule, scenarios and strategy
  - Operation and maintenance methodology
- Maintenance experience
  - Spare parts management
  - Review of the last five years
- Conclusions

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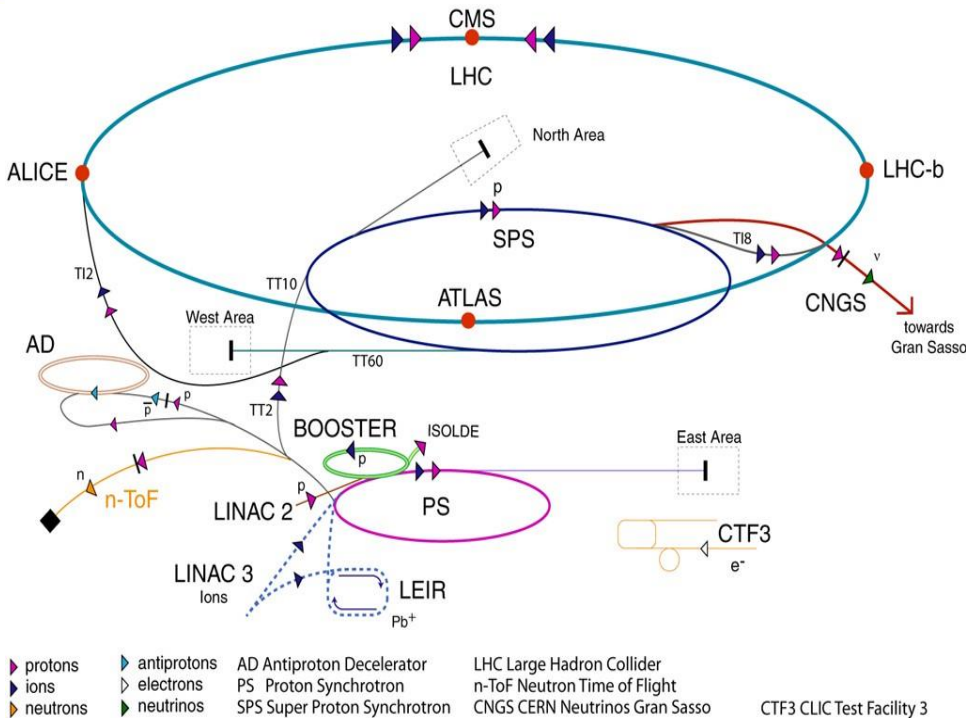
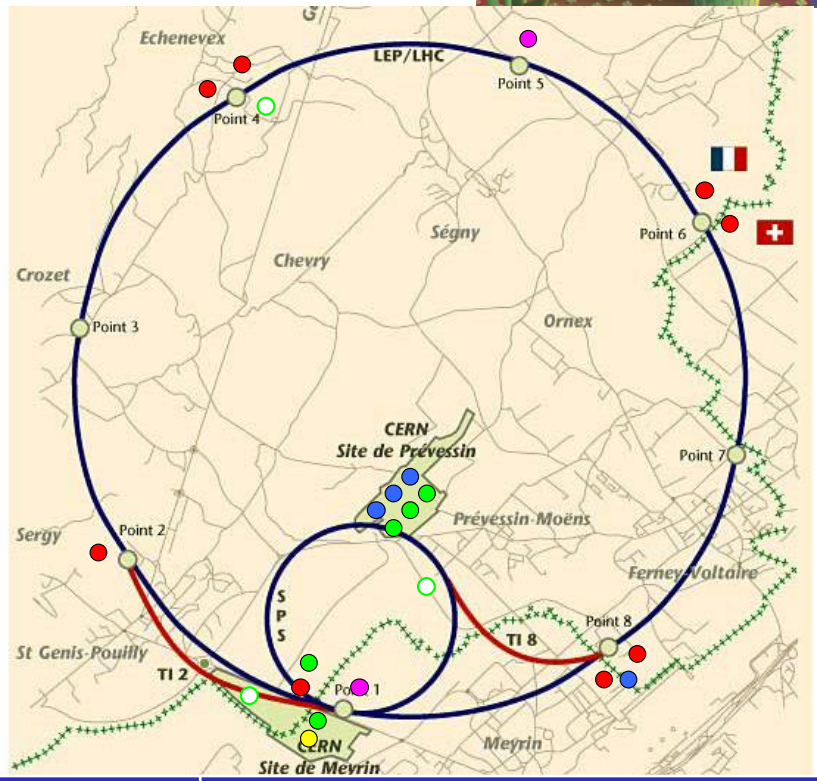
CERN accelerator complex

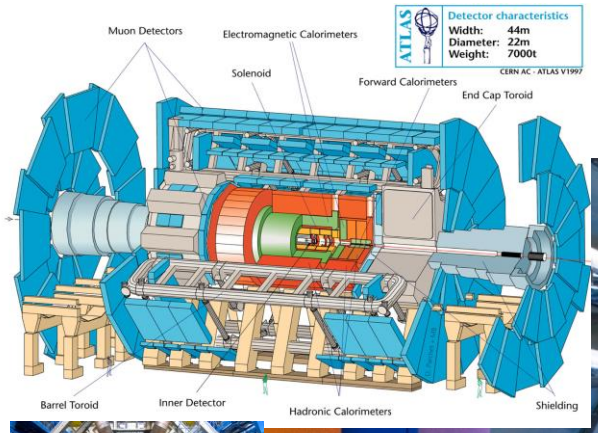


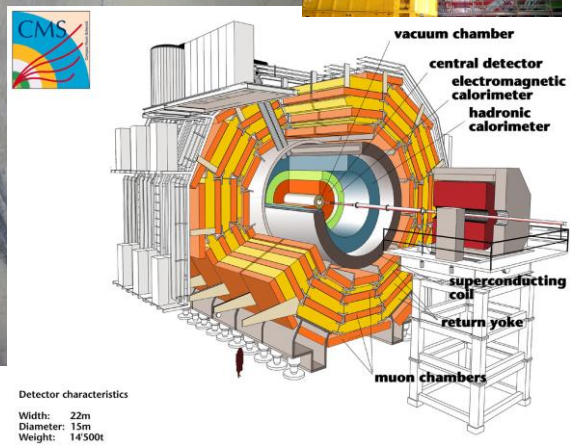


T level	Installed capacity	# of plants
80 K	5 MW	9
4.5 K	164 kW	23
20 K	60 W	2
1.8 K	19.6 kW	9
300 mK	350 mW	1


LHCb
ATLAS
CERN Meyrin
CERN Prévessin
SPS 7 km
SUISSE
FRANCE
ALICE
CMS
LHC 27 km

23 km of high-field superconducting magnets operating in superfluid helium at 1.9 K

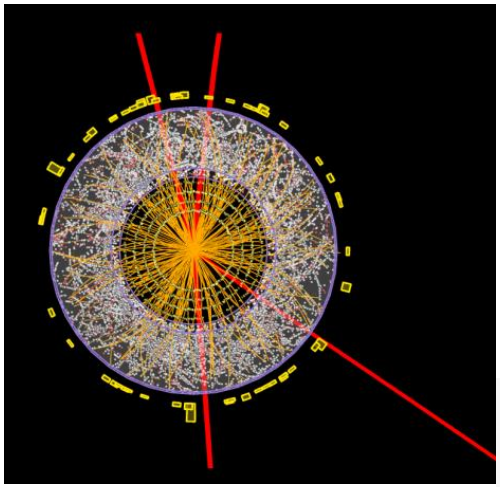


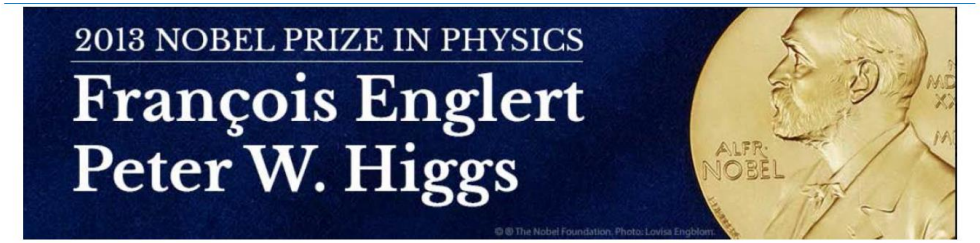


The LHC cryogenic system and infrastructure

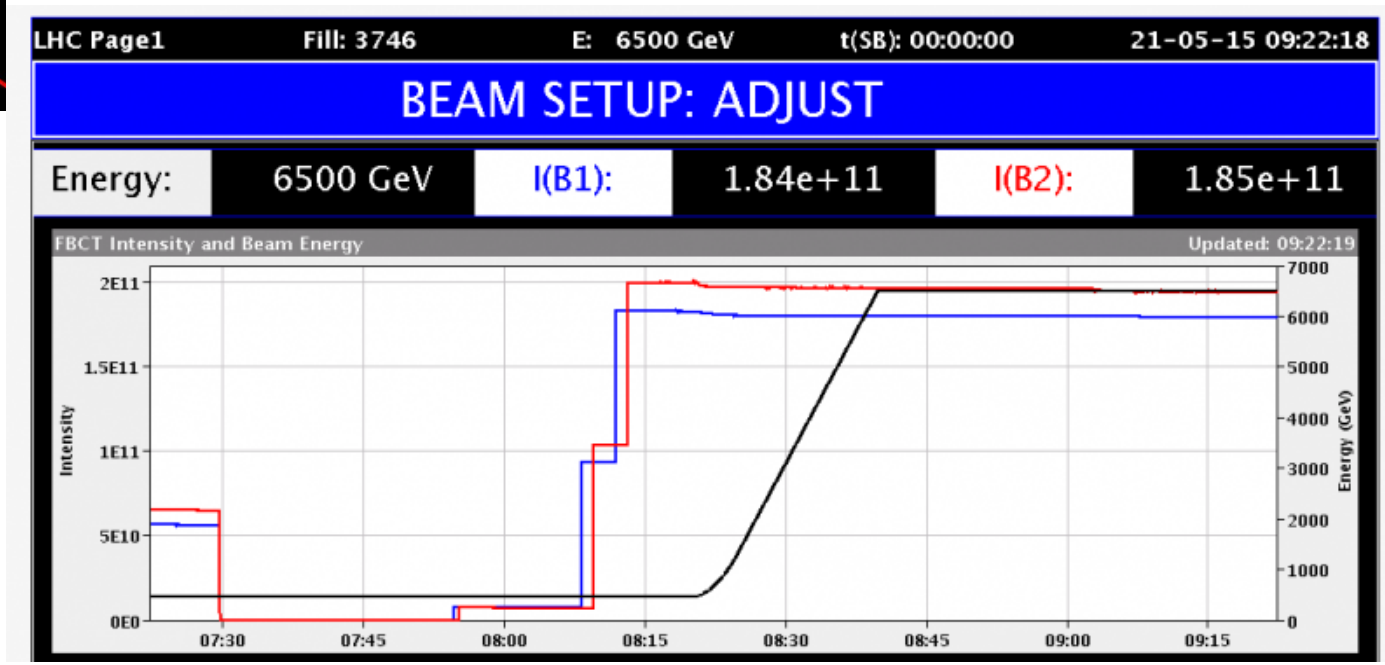
8 x 18 kW @ 4.5 K units
8 x 2.4 kW @ 1.8 K units
5 underground interconnection boxes
155 t of helium
6 & 1.5 kW @ 4.5 K units for detectors

Now operating at 13 TeV





for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle,
by the ***ATLAS and CMS experiments at CERN's Large Hadron Collider"***



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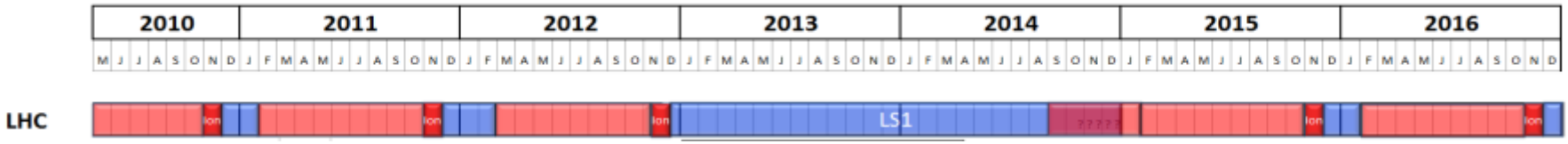
Schedule and scenarios

- Continuous operation over the year
  - By CERN's staff
  - With the support of industrial contractors for
    - Routine operation
    - Maintenance and spare parts management
- Few short technical stops for critical corrective maintenance interventions
- Preventive maintenance performed
  - During one month yearly shutdowns
  - Or every four to five years during major year-long shutdowns



Effective maintenance program

- Progressively implemented for the LHC and retroactively for older installations

- Supported by a Computer Aided Maintenance Management System
  - Infor EAM™
    - Assets inventory and management
    - Maintenance Procedures and documentation management
    - Spare parts analysis and management
    - Work management, control and optimization via KPIs

- Since 1994 partnership with industry to perform the preventive and corrective maintenance of the cryogenic infrastructure

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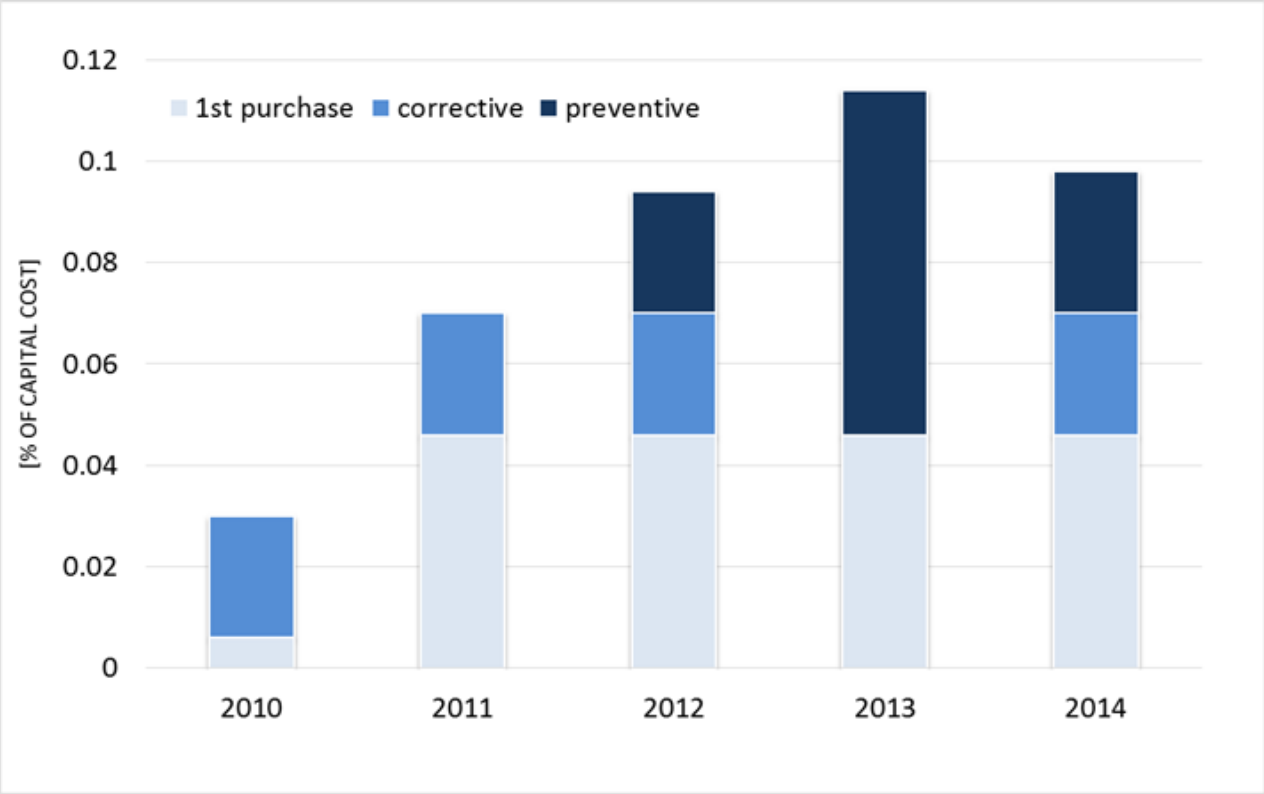
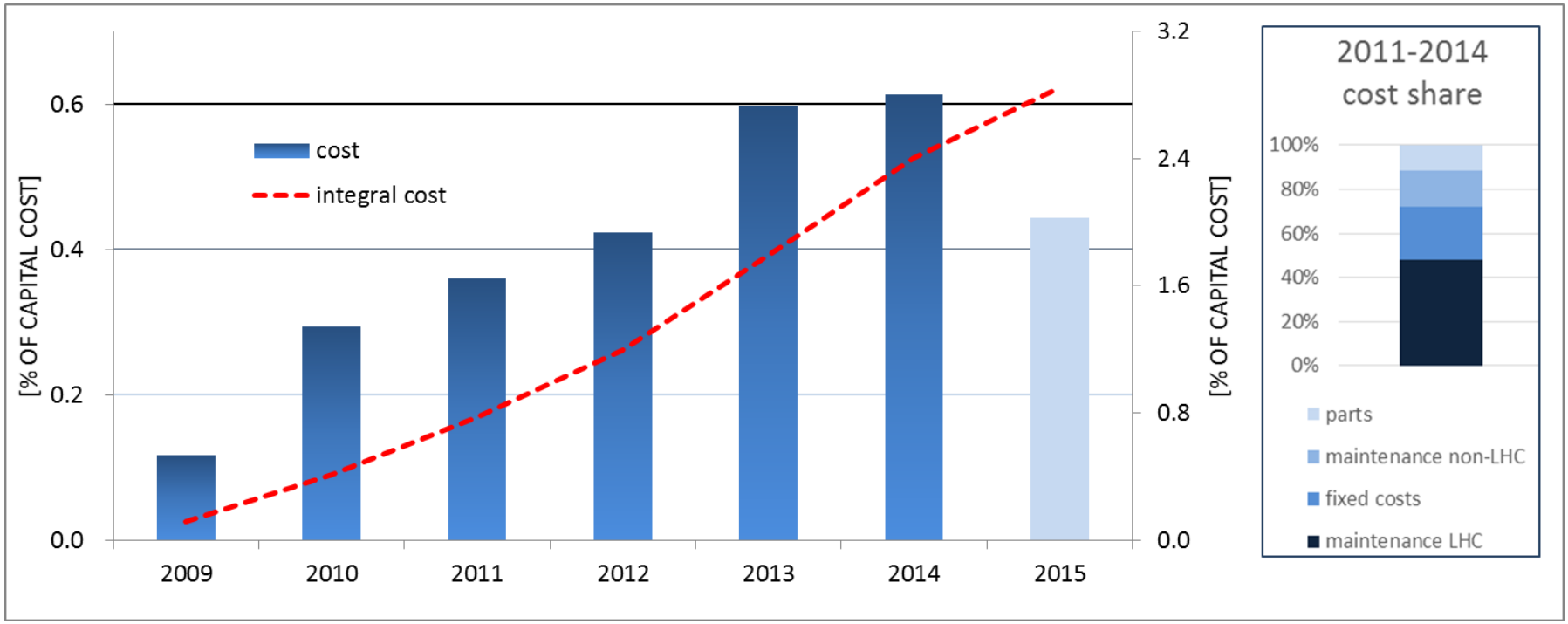
LHC spare parts management



Continuous review of the required spares to optimize inventory based on criticality

- frequency, number and type of used spares,
- procurement delays and detectability of the fault,
- installed quantities and cost.

Review of the last years activities



	Operation C/P	*LS1 C/P*	Total C/P	Mechanical C	Mechanical P	Elect/ Instr C	Elect/ Instr P	Vacuum C	Vacuum P
Machine	23 %	8 %	13 %	20 %	40 %	30 %	14 %	5 %	3 %
ATLAS	15 %	13 %	14 %	8 %	12 %	10 %	6 %	2 %	1 %
CMS	25 %	3 %	13 %	8 %	13 %	15 %	10 %	2 %	1 %

Major overhauls ~ 4 % of compressors capital cost per year of operation

The major long shutdown (LS1) 1/2

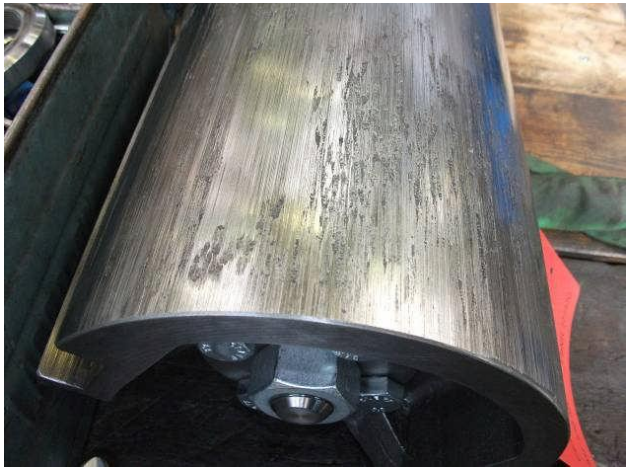
Major shutdown (2013 – 2014) after 40’000 h of operation

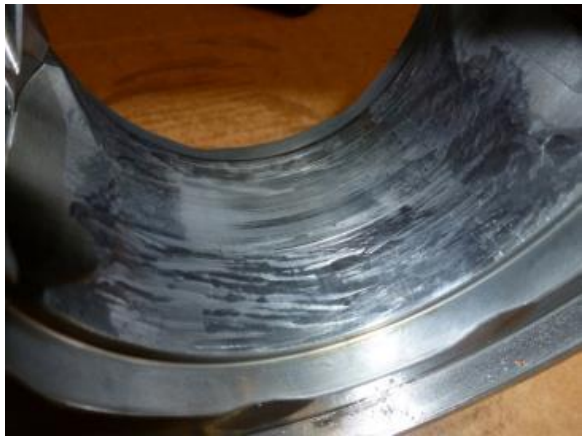
- More than 5000 Work Orders
- Required: Major overhauls and mechanical preventive maintenance
- Reduced: Instrumentation preventive maintenance (only key systems, e.g. interlocks)

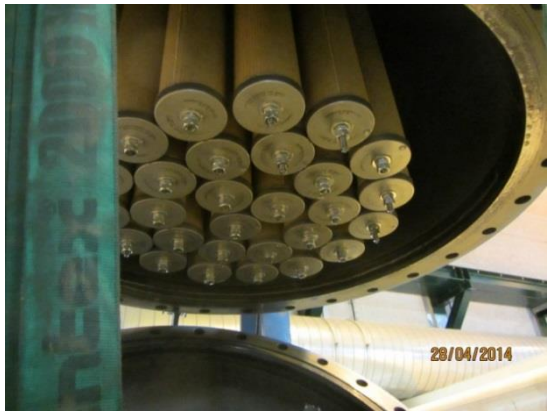
type	quantity	unit
Joints O-ring	3769	pc
Other joints	2919	pc
Filtration cartridges	613	pc
Oil filters	311	pc
Couplings greasing kits	154	pc
Signal transducers	146	pc
Temperature sensors	35	pc
Maintenance kits pumps	47	pc
Activated charcoal	22040	kg
Compressors Breox® oil	16250	l
Pumps oil	919	l
Cleaning acid	1625	l
Solvent	139	l

type	quantity (pc)
Major overhauling	
Screw compressors	57
Oil pumps	27
Electrical motors	81
Electrical motors (replaced)	33
Mechanical	
Safety valves revision and test	2000
Coalescers inspected	94
Adsorbers treated	12
Chemical cleaning	28
Instrumentation inspections and revisions	
Valves	288
Sensors	2000
Transducers	3500
Vacuum	
Pumps revision	200
Gauges revision	235
Vacuum valves revision	29

The major long shutdown (LS1) 2/2







Normal and abnormal wear of rotating machinery, filters

Maintenance of all control valves

Visual inspection of all coalescers cartridges and replacement where needed

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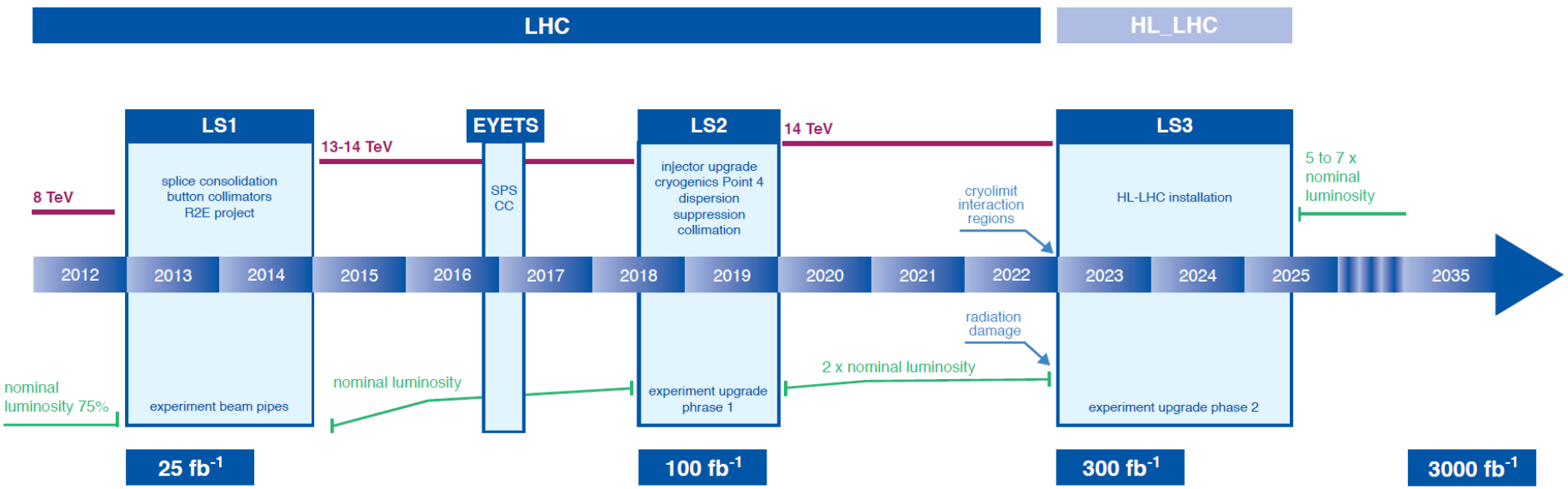
Conclusions 1/2

After two years of consolidation and maintenance work the LHC has started a new physics campaign that will last almost four years

In parallel CERN is working towards the upgrade of the machine to reach an integrated luminosity of 3000 fb^{-1}

New LHC / HL-LHC Plan



Conclusions 2/2

- CERN has accumulated a significant amount of data for the maintenance and operation of large cryogenic plants and distribution systems based on CAMMS and KPIs.

- To be effective maintenance needs solid bases in terms of analysis, methodology, documentation and procedure.

- The review of the maintenance plans and required spares appears in line with standard practice to guarantee a cost effective and high reliability and availability of the machine.

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