HL-LHC
Challenges in Upgrading the Experiments

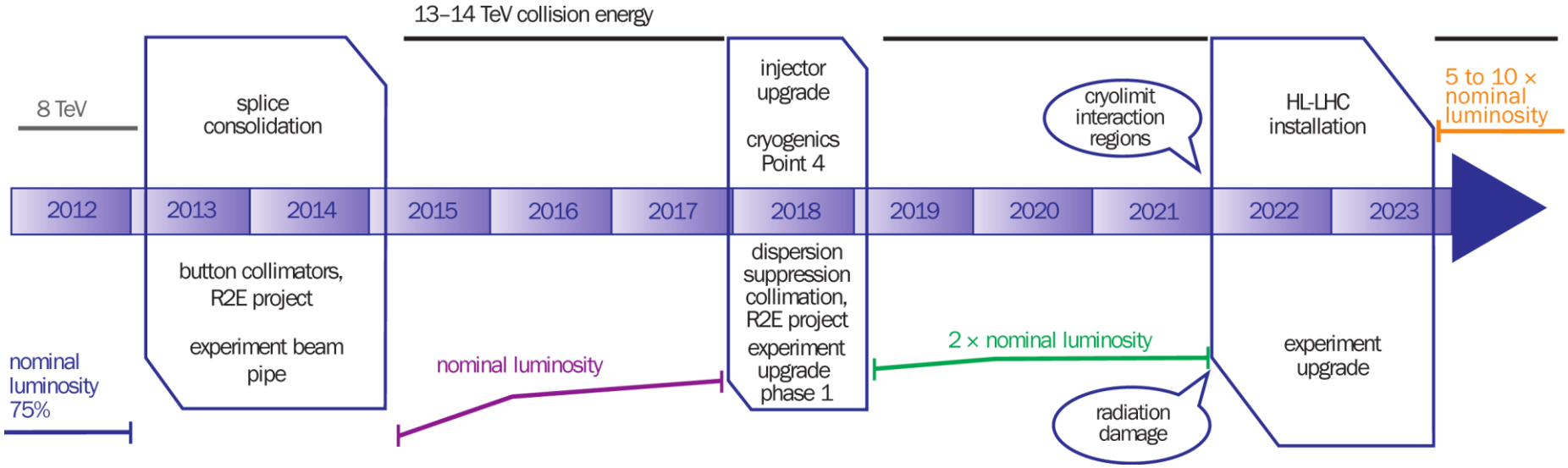
ECFA Workshop Oct. 1-3 2013, Aix-les-Bains

W. Zeuner CERN

- **Scheduling**
- **Constraints from Infrastructure**
- **Radiation Issues**
- **Resources**
- **Summary**

Scheduling

Current Official Time Line



LS1
2y

LS2
14m

LS3
~2y

ALICE

Main Detector upgrades

- New central beam pipe
- New Inner Tracker System,
- Replacement of MWPC in TPC by GEMs
- Upgrade of readout electronics, trigger, computing

- Upgrade will be installed in LS2
- The Upgrade installation requires a shutdown of 18 months
- Alice plans for LS2 starting in Dec. 2017, a delay by max. 1 year would add important contingency
- Small scale upgrade proposals for LS3 are presently discussed

Scheduling

LHCb

Change from 1MHz to 40MHz readout with a fully software-based trigger
→ replace all FE-electronics, event builder and enlarge the farm by a factor three

Requires to change all sub-detectors with silicon sensors

Velo	→ VeLoPix
RICH HPDs	→ MaPMT
Silicon Tracker Stations	→Fiber Tracker down stream of the magnet
	→Silicon sensors up stream of the magnet

- For this upgrade one single shutdown of ≥18 months during LS2 is mandatory!
- Doubling time for statistics requires the upgrade to be in place after LS2.
- LS3 is mainly for maintenance and consolidation.

Scheduling

ATLAS

LS2 – Final Phase I upgrades

Rebuild small muon wheels

Work on calorimeter R/O electronics

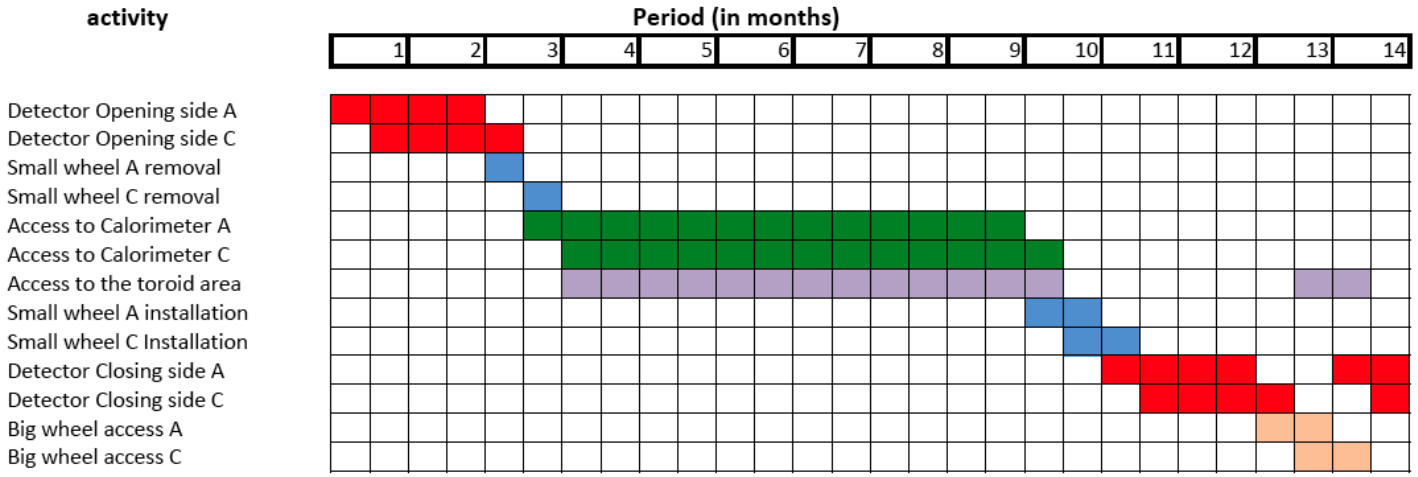


Figure 8.1. Items assigned to the various activities over the 14 months of access

Scheduling

ATLAS

LS3

- New all Silicon Tracker
- New trigger architecture
- New R/O electronic to practically all components
- Under investigation – Will the performance of the Hadron Endcap Calorimeter and the Forward Calorimeter deteriorate beyond acceptable limits?

If the endcap cryostat will NOT be opened – 27 months of shutdown will be sufficient

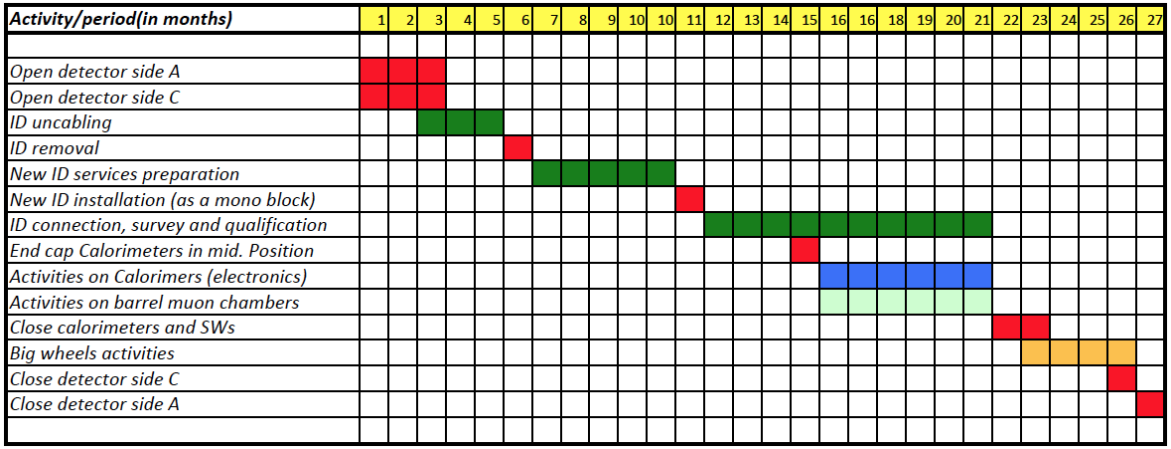


Figure 9.1: Items assigned to the various activities over the 27 months of access, scenario without considering the LAr end-caps cryostats opening

- Worst case scenario, if both HEC and FCAL have to be changed shutdown length will be 35 months – unlikely according to new rad. Calc. (There are more scenarios with times between 30 and 32 months)

Scheduling

CMS

Final Phase I upgrades and consolidations

- New 4-layer pixel detector installation in an extended YETS 16/17
- New L1-Trigger – starting in LS1, running in parallel with current system
  Transition will not require a long shutdown
- Forward Hadron Calorimeter new PMT readout YETS 16/17
- **LS2**
  Change photo detectors in barrel and endcap hadron calorimeter
  HPD →SiPM

- If rad. damage develops as predicted - CMS can live with 14 months for LS2
- If hints of anomalous rad. damage confirmed - CMS will need 18 months

- **To collect sufficient physics data with new pixel detector**
  LS2 must not start before summer 2018
  CMS prefers LS2 starting end of 2018

- If LS2 will be 18 months CMS will try to advance projects from LS3.

Scheduling

CMS

LS3

- Exchange Silicon Tracker + Pixel detector
- Exchange Endcap Calorimeters – Electromagnetic & hadronic
  Details still under study
- Install new muon stations at high eta (RPC &GEM)
- New L1 trigger with longer latency and higher rate capability
  Requires refurbishment of all ECAL Barrel Supermodules
- Shielding + High level trigger DAQ, infrastructure ….

Scheduling studies ongoing – 30 months seem feasible
Maybe some activity can be advanced into LS2

Summary on Scheduling

YETS 2016/17

- CMS will install a new 4 layer pixel detector

LS2

- ALICE and LHCb plan for 18 months LS2 – mandatory for their plans
  Start date – 3 out 4 exp. prefer start date between summer and end of 2018
- For planning reasons start date must be fixed soon

- ATLAS and CMS should be able to cope with the currently planned 14 months (Provided no longevity issues arises)
  CMS: To make use of the new pixel det. LS2 must not start before summer 2018

LS3

- ATLAS plans as baseline for 27 months
  Longevity problems with HEC and FCAL might require a few months more.
- CMS estimates ~30 months as baseline

Input from LHC expected at RLIUP workshop end of October
This should lead to an update of the official plan by the end of the year

Shutdown Constraints - Infrastructure

- At LS3 many infrastructures will be 20y or older
- Fernando gave an exhaustive list of possible renewals/upgrades/consolidations
- Current planning of the experiments does not take into account co-activity by infrastructure renovation

Work on the following systems has direct impact on critical path for detector work

- Access system – access control has to be maintained whenever somebody is working underground – first studies indicate that access interruptions could be minimal

- Elevators – Major concern, exchanging them is extremely costly and time consuming
  Some have to be prepared for higher radiation levels after LS3
  Interruption of service prevents access to underground

Shutdown Constraints

- Overhead cranes – any extended maintenance impacts the schedule directly
  some caverns have only single cranes

- Ventilation System – If upgrades require stop of the system underground work cannot continue
  Age of the system and preparation to work at much higher radiation level will require extensive work.
  The high radiation levels after LS3 will make the proper air treatment and distribution mandatory for LHC operation. Details see talk by Olga

- Alarm Systems – At least Level 3 alarms have to be operational to allow work underground.
  Smoke and gas detection systems have to be replaced
  Consider parallel installation of new system

Shutdown Constraints

Major uncertainty
Exchange of TAS is a major project at the interface between ATLAS/CMS and LHC

- ALARA study for the removal of the old TAS exists (EDMS 1254919)

- Studies needed to answer following questions
  Does the new TAS fit into the surrounding shielding (TX1S(ATLAS) or FIN(CMS))?
  What does it mean to rebuild these shielding ?

- The entire forward shielding has to be upgraded – currently only rough place holders are foreseen in the planning

- Any installation around TX1S/FIN will take place in a highly activated area
  ALARA precaution will slow down the work

An engineering study on the TAS replacement and necessary shielding upgrades should be started soon

Shutdown Constraints

- Upgraded detectors need to be tested and commissioned

- Requires infrastructure being available just after installation
  Electricity, cooling, network, gas, monitoring…

- For safety reasons this can slow down the work on the experiment
  Has to be taken into account for the scheduling

- Necessary to synchronize the activities of all experiments, LHC and the technical groups

Observation – For some exp. this worked almost perfectly in LS1, others reported severe difficulties.
But the amount of infrastructure work expected for LS3 will be much larger.

- Complicates the planning and requires some early collaboration between LHC and experiments already in the planning phase

Radiation Issues

After LS1 the activation level will continuously rise with increasing contributions from long lived isotopes

Olgashowed first estimates

- In LS3 the activation level will be a factor ~10 higher than in LS1
- In LS4/5… the factors will go up to ~30
- ALARA foresees staggered procedures for increasing radiation levels
- LS1 – most activities in Level 1
- LS3 – forward region according to Level 2&3
- LS4/5 – Lots of activities will require Level 2&3

ALARA Committee

Individual dose equivalent	**Level I**	100 μSv	**Level II**	1 mSv	**Level III**
Collective dose equivalent		500 μSv		5 mSv	

Group 1 criteria: determine ALARA Level classification

Ambient dose equivalent rate	**Level I**	50 μSv/hr	**Level II**	2 mSv/hr	**Level III**
Airborne activity in CA		5 CA		200 CA	
Surface contamination in CS		10 CS		100 CS	

Group 2 criteria: can be used by RP to increase (or eventually decrease) classification

Radiation Issues

- From YETS16/17 or LS2 onward ALARA Level 2 & 3 structures have to become routine to avoid unnecessary slow down of work

- Experience from LS1 – ALARA awareness requires continuous training

- Shielding and remote handling devices slow down the work significantly often forgotten in the planning

- Major Concern – Contamination
  No experience yet in LS1
  Candidates: activated fluids, metallic debris, dust
  Counter measure: Cleanliness - this is time consuming

- Waste treatment and buffer zone throughput has to increase significantly for LS3
  Traceability tools have to be adapted to the expected demands
  Requires space and trained personnel
  Observation: In LS1 more radioactive waste than foreseen has to be handled by RP

- Personal dose monitoring would be much simpler if the access system could automatically read the dose every time a person enters and leaves a zone.

Radiation Issues

Summary

- Working procedures have to be defined in more detail
- Radiation protection has to become an integral part of any work procedure
- All planning has to take into account the additional work due to radiation protection

Resources

- Four sources of human resources
  Personnel from the experiments
  Field **S**upport **U**nits (FSU)
  CERN Technical Groups (BE/EN/GS/IT/PH)
  External Companies

- Lot of work done by CERN Technical Groups
  They usually maintain installed equipment

- Observation – CERN groups are notoriously overbooked

- For LS2 – ALICE and LHCb will request many services to be able to perform their upgrade programs

- For LS3 – ATLAS and CMS will request lots of support much beyond that of LS1
- Continuity of experimental specific expertise in the support groups is essential
  e.g. Transport, Vacuum, Cooling….
  CERN must check early enough size and strength of the support groups

- LS3 cannot be handled as a “slightly larger LS1”

Resources

- In LS3 lack of skilled personnel can become a serious problem as it will be a key resource to do an enormous amount of work within a short time
- Realistically resource loaded schedules will be needed at an early stage
- Review of available (human) resources has to take place early enough
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- We will need more flexibility to bring in additional personnel
- Look for new Institutes and consider outsourcing to companies
- Requires early discussions with CERN management and funding agencies

Summary and Outlook

- After the RLIUP workshop with the LHC input a new official schedule should be released
- Alice and LHCb request the length of LS2 being 18 months
- Starting LS2 between Summer and end of 2018 is preferred by 3 out of 4 experiments
- CMS requests an extended YETS 2016/17 allowing installing a new 4-layer pixel detector
  To collect sufficient amount of data LS2 must not start before summer 2018
- LS3 will be a particularly challenging shutdown as **LHC**, **Experiments** and **Infrastructure** will be upgraded in parallel
- The planning on all three frontiers has to be regularly synchronized
- Early resource loading of all schedules will be mandatory to identify shortcomings

Summary and Outlook

- Infrastructure upgrades have to be carefully synchronized with the detector work
- High activation levels and possible contamination will slow down some activities.
- For all tasks ALARA is an integral part of any working procedure and the appropriate time has to be allocated.
- The mechanisms and instruments to bring in skilled personnel have to be reviewed and adapted to the needs of LS3
- A working group of TC from all four experiments should continue addressing the questions raised
- Building Phase 2 of LHC and the experiments is a challenge comparable building it for the first time
  Lets profit from the lessons learnt