



## HL-LHC WP8 – 1<sup>st</sup> WORKSHOP COLLIDER-EXPERIMENTS INTERFACE

30 November 2012 at CERN – 9:00 to 17:30

### EXECUTIVE REPORT

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The 1<sup>st</sup> Workshop Collider-Experiments Interface – Work Package 8 (WP8) was held on the 30<sup>th</sup> November 2012 at CERN. The first session in the morning was dedicated to the presentations of the “desiderata” from the LHC experiments in the framework of the High Luminosity – LHC (HL-LHC) Project. The second session in the afternoon was devoted to the technical requirements from the machine side. The one day workshop ended with a discussion on potential limitations and constraints.

Here, we mainly focus on potentially critical points, which require further follow up.

All talks can be found on [indico](#).

### AGENDA

- Introduction - WP8 Collider-Experiments *by S.Myers*
- Layout Change Request (LCR) from ALICE *by W. Riegler*
- LCR from LHCb *by R.Lindner*
- LCR from ATLAS *by D.Macina*
- LCR from CMS *by A.Ball*
- LCR from TOTEM *by J. Baechler*
  
- Overview from LHC Experiment Beam-pipes (LEB) *by M.A.Gallilee*
- Machine layout for HL-LHC *by B.Holzer*
- Movable devices *by S.Redaeli*
- Energy deposition & TAS diameter *by F.Cerruti*
- Radiation Protection Aspects *by S.Roesler*
- Hardware implications of the IR upgrades *by A-L. Perrot*
- Machine Protection Issues – Progress *by D.Wollmann*
- Discussion – Potential limitations & Constraints
- Summary & Next steps *by L.Rossi*

### INTRODUCTION (*Steve Myers*)

In the welcome/introduction the director of accelerators Steve Meyers reminded that the LHC machine (collider) and LHC Experiments often have conflicting requirements like the need for a large aperture on the machine side and requests for reduced chambers for detectors closer to the beam on the experiments side. We need a coherent plan, finding the best compromise between both sides as soon as possible and should avoid “last minute” changes with negative impact on performance and cost.



The main requirements expressed by the LHC Experiments are summarized in the following sections.

### **ALICE** (*Werner Riegler*)

Since the time, that the LHC started operating with 1380 bunches of over  $1.5 \times 10^{11}$  protons / bunch, ALICE has been severely affected by beam-gas backgrounds in proton-proton operation. This is caused by local pressure bumps which exceed  $10^{-8}$  mbar in the TDI region. This can be expected to be improved by NEG coating in the ZDC chambers. Pressures below  $5 \times 10^{-9}$  mbar are required for good background conditions in ALICE in the present LHC. ALICE expects that the TDI will be completely refurbished during LS1 to avoid outgassing and that the TDI's will be replaced between LS1 and LS2.

This was not confirmed by F. Bordy, who said, that the TDI's cannot be changed between long shutdowns. The refurbished TDI's for LS1 will be identical to the present design except for the beam screens. New TDI's, compatible with LIU, will only be installed in the LS2.

The ALICE upgrade was endorsed by the LHCC. It requires an 18 month shutdown. Implementation will be in LS2. ALICE will continue data taking for several years after LS3. The luminosity requirements for lead-lead operation have been defined. This will probably require faster SPS injection kickers and the installation of collimators in the dispersion suppressors around IR2 and in IR3/IR7. It remains to be verified, that the smaller central beam pipe with a diameter of 34.4 mm to be installed in LS2 will be compatible with HL-LHC operation after LS3. A few weeks of data taking during p-p operation will be required each year and require 10 times better vacuum levels then at present. Details for the proton running remain to be worked out. High-beam gas backgrounds also cause problems with radiation to ALICE even if the detector is turned off.

### **LHCb** (*Rolf Lindner*)

The upgrade of the LHCb detector was endorsed by the LHCC. Similar to ALICE, it will require an 18 month shutdown and will be finalized in LS2. With the present design the LHCb experiment will collect about  $7 \text{ fb}^{-1}$  by the end of 2017. The main requirements for the detector upgrade are:

- Increasing capability of the readout 1 MHz (now) to 40 MHz (after LS2)
- Full software trigger (better yields for charm and hadronic triggers)
- Instantaneous luminosity up to  $2 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$  collecting  $50 \text{ fb}^{-1}$  (starting in 2019)
- Bunch spacing of 25 ns in order to limit the pile-up at the higher luminosity

The main layout change request from the LHCb experiment is the reduction of the central beam pipe radius in the VELO (Vertex Locator) region to an inner radius of 3.5 mm. The request was presented in the LEB working group in July 2012. LHCb requires operation with both magnet polarities. An external crossing angle is required to avoid parasitic collisions. Details of the crossing, compatibility with 25 ns bunch spacing and the possibility for a need to change the beam screen will require further follow up.

Luminosity levelling for LHCb is mandatory. LHCb would prefer luminosity levelling by changing  $\beta^*$  for the HL-LHC. Luminosity spikes by insufficient levelling may become a failure scenario at HL-LHC luminosities.

A TAS (Target Absorber Secondary particles in front of the IP8 triplets) is not needed for LHCb running at the target luminosity of  $2 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ . Instead some kind of (minimal) TAN will be required.



### **ATLAS & FORWARD DETECTORS** (*Daniela Macina*)

This presentation was prepared together with B. DiGirolamo (the future technical coordinator) and M. Nessi (the current ATLAS technical coordinator).

ATLAS requires a beam spot length between 50 and 75 mm.

With the new high field triplets, a new aperture and layout of the TAS is required for the HL-LHC. These issues are fundamental for ATLAS in order to specify the final inner beam-pipe diameter in the central part. The innermost detector layer will need to be at 30-40 mm from the interaction point.

The requests from ATLAS about the TAS optimization are summarized as follows:

- Identify and simulate all possible failure scenarios (beam very near or hit to the beam-pipes)
- Estimate the beam associated backgrounds from the machine at the front face of the UX15 cavern.
- Re-optimize the effectiveness of the forward shielding with the new TAS
- Understand the implication of the new TAS installation to the overall schedule and to other LS3 activities.

### **ATLAS FORWARD DETECTORS** (ZDC, ALFA, AFP Project)

The ATLAS forward detectors will be used for physics until the LS2 and beyond if requested. Cooling for ALFA will be installed in LS1. Operation after LS1 at a maximum  $\beta^* > 2000$  m requires the installation of few water cooled cables as discussed in LMC#150.

The current plan for the AFP project is to install the Hamburg Beam Pipe (HBP) during the winter shutdown 2015-2016. ATLAS is also interested in looking at the possibility of extending AFP to 420 m which implies a modification of the actual connection of the cryostat.

ATLAS is aware of the LSS1 layout change during the LS3. The future physics results will show if the forward detectors are needed beyond the LS3 or not. If needed ATLAS will adapt the forward detectors to the new layout and would like to be informed of the all changes as soon as possible.

F. Bordry reminds that the AFP installation is not yet approved for LS1,2.

A review of the TCL collimators is planned for the collimation workshop in 2013.

### **CMS** (*Austin Ball*)

Austin Ball recalled that a major part of the CMS upgrade program is on consolidation to ensure the longevity of the detector and full exploitation of the existing physics performance. In addition, a major upgrade of the detector and readout is required in LS3 to handle the rates and radiation loads resulting from the luminosities up to 5x the original LHC design. CMS plans two main phases in the detector consolidation and upgrade. Phase 1 in LS2 will include the installation of the new 4 layer pixel tracker for CMS around the new beam-pipe central beam pipe with a reduced radius to be installed in LS1. Further upgrade items are to replace the HCAL electronics and to implement a new L1-Trigger.



The main goal for the phase 2 upgrade of CMS, scheduled for LS3, is to enable the detector for data taking beyond  $500 \text{ fb}^{-1}$ . The technical proposals for this will be submitted in 2014. The major revision of the beam-pipes and shielding systems will be mandatory in order to accommodate the increased quadrupole and TAS apertures.

The consequences of a larger aperture TAS will have to be studied in more detail, including backscattering from the TAS and machine protection aspects for failure scenarios leading to losses in the central detector region. Austin asked what is known about the lifetime of the current triplet. L. Rossi says the estimates are based on a complex evaluation. The expected limit corresponds to an integrated luminosity of 300 to  $500 \text{ fb}^{-1}$ .

#### CMS FORWARD DETECTORS (TOTEM, ZDC, High Precision Spectrometer)

TOTEM is approved to operate at full energy (14 TeV). This will be done using the roman pots located at 220 m from the IP5. The roman pots located at 147 m will be removed and make space for additional TCL collimators. Austin mentioned also that new ideas to operate very forward detectors in IR5 at high luminosity are under consideration : a CMS High Precision Spectrometer (HPS) with 2 Hamburg beam-pipe systems at 240 m from the IP and discussions between CMS and TOTEM on the possible used and installation of the removed 147 m roman pots in the region 200-220 m from the IP.

The speaker ended his presentation by suggesting a common project/engineering office, providing a pool of resources for radiation simulations, engineering and instrumentation studies.

#### **TOTEM** (*Joachim Baechler*)

Joachim Baechler presented the TOTEM program at high  $\beta^*$  in special runs and their involvement for p-A. The Research Board has approved the Physics program of TOTEM at full LHC energy. During the LS1 the detectors will be prepared for the new phase of LHC after LS1. The Roman pots (RP) at 147 m will be removed and adapted such that they could be used as spare detectors for the roman pots at 220 m from the IP. TOTEM is in discussion with CMS on the subject of using roman pot detectors for diffractive physics at low  $\beta^*$  with high luminosities.

H.Burkhardt remarks that we made good progress with operation of forward detectors in special low intensity (high  $\beta^*$ ) runs. Operation of forward detectors (PRs, Hamburg beam pipes) close to the beam at very high luminosity remains to be studied in more detail. Attempts to move roman pots closer to the beam at high luminosity resulted in beam dumps in 2012 for reasons which are not well understood at present.

#### **OVERVIEW FROM LEB** (LHC Experimental Beam-pipe) (*Mark Gallilee*)

Mark Gallilee presented a review of the studies carried out by the LEB Working Group. He showed the timeline of the LEB studies with respect to the HL-LHC upgrade and summarized the experimental work packages for the 4 LHC experiments.

Details are given in <https://edms.cern.ch/document/1065775/4>.

Modification to the beam pipes are checked and optimized to minimize any interference with high luminosity operation, in terms of aperture and impedance.



Smaller beam-pipes will already be installed in ATLAS and CMS during LS1. Approval of the smaller beam pipes has so far been limited to operation up to LS3. The compatibility of the reduced central beam pipes with operation for the HL-LHC will have to be studied in more detail.

Remote handling and minimisation of exposure of people working in the experimental areas close to the beam pipes will have to be studied in more detail for the HL-LHC.

### **MACHINE LAYOUT FOR HL-LHC** *(by Bernhard Holzer)*

Bernhard Holzer described the main HL-LHC lattice and optics design considerations. The lattice is optimised to allow for a minimum  $\beta^*$  value. The present design goal for the HL-LHC is  $\beta^* = 15$  cm in IP1 and IP5. The following modifications are needed upgrade from the design value of  $\beta^* = 55$  cm design to  $\beta^* = 15$  cm for the HL-LHC:

- Increased triplet apertures (and D1,Q4,TAS/TAN)
- Re-optimize the position of matching quadrupoles
- Find space for orbit correctors / spool piece correctors
- Find space for crab cavities
- Establish a crossing scenario without changing the crab orbit

He presented the current default HL-LHC optics version SLHC\_V3.1b (with triplet quadrupoles of 150 mm magnet aperture and a gradient of 140 T/m,) and made some comparisons with the earlier version HL-LHC V1.0. The lattice optimisation for the crab cavities requires the repositioning of the quadrupoles Q5 to Q7. Bernhard ended his talk by showing a detailed list of the lattice modifications as known at this point. Further work is in progress and will include fine-tuning of the optics depending on progress on the hardware (magnet) side. The optics studies are extended to all IPs and should be compatible with the ATS optics for IP1/5, which may exclude luminosity levelling by  $\beta^*$  in IP2/8.

### **MOVABLE DEVICES** *(Stefano Redaelli)*

Stefano Redaelli presented a review of the movable collimators in the experimental regions.

First, he reminded about the present layouts (with collimators in all the LHC straight sections except IP4) and their functionalities. Then, he discussed the choices which determine the layouts between LS1 and LS2. Plans for LS3 remain to be defined in more detail and will likely involve collimators in dispersion suppressor regions.

He described the new collimators with integrated BPMs and underlined the new experiment requirements in particular AFP and TOTEM stations at 220 m. The approved TCL strategy for LS1 (by LMC) is a symmetric layout in IR1 & IR5, install TCL-4 both in IR1 & IR5, keep the TCL-5 operational, prepare infrastructure for an installation of TCL-6. Clearly, similar needs for IR collimation are expected for the HL-LHC program.

He reminded that all movable devices are considered as kind of collimators and are controlled from the CCC. This will also have to be applied to “Hamburg beam pipe” devices. TCL4 and TCL5 collimators may shadow the AFP.



## **ENERGY DEPOSITION & TAS DIAMETER** (*Francesco Cerutti*)

Francesco Cerutti described the role of the TAS (Target Absorber of Secondaries). The main role is to protect the Q1 from the collision debris. The TAS also provides some protection of the experimental vacuum chamber from mis-steered beams. The power deposition in the triplet region was estimated by FLUKA simulations for three different TAS apertures of 50, 60 and 70 mm, and found to only weakly depend on the TAS aperture. For the HL-LHC, radiation to the triplet is more limiting than power deposition in the triplet. The TAS is only really effective as shield for the Q1 magnet. A 9 mm tungsten absorber is considered to reduce the radiation in the triplet below 20 MGy. The crossing angle has plays a significant role in the distribution of power and radiation in the triplet.

A neutral absorber (TAN) becomes essential for luminosities above a few  $10^{33} \text{ cm}^{-2} \text{ s}^{-1}$  to protect the D2 magnet. At very high luminosity, TCL collimators are required to protect the Q5 and Q7 collimators from collision debris. The dispersion suppressors around the high-luminosity interaction regions appear not to be too critical in proton-proton running (to be verified for the ATS optics).

High radiation levels (30 MGy on the MBW, 5 MGy on the MQW) are expected for an integrated luminosity of  $300 \text{ fb}^{-1}$  in IR7 and may pose problems with the lifetime of these warm magnets.

## **RADIATION PROTECTION ASPECTS** (*Stefan Roesler*)

Stefan Roesler briefly described the operational scenarios for ATLAS and CMS up to LS3 with numbers that were considered as upper limits for radiation protection (up to  $150 \text{ fb}^{-1}/\text{year}$ ).

He showed the residual dose rates predicted for March 2013 based on the TS3 survey measurements for the two experiments ATLAS and CMS. He explained in detail the FLUKA calculations of the cooling time dependence (1 month, 4 months, 6 months & 1 year) defining the scaling factor for the LS1.

Residual dose rates are expected to increase from LS1 to LS3 by factors of 8-16, after a cooling time of 4 months.

The long straight sections around IP1 and IP5 will be *Limited Stay Areas* during the LS2 and LS3 with local spots classified as *High Radiation Area*, which implies a strict methodology (ALARA procedure, material and technology choices, remote handling) for reducing the intervention doses.

There was a discussion of the acceptable dose to people working in the tunnel. At present a limit of 2 mSv/y was used as a target value, which is below the CERN legal limit of 6 mSv/y for class B Radiation Workers, i.e., most Radiation Workers at CERN.

## **HARDWARE IMPLICATIONS OF THE IR UPGRADES** (*Anne-Laure Perrot*)

Anne-Laure Perrot focused her talk on the hardware implications of the IR upgrades : TAN, TAS and forward detectors installed in the LHC tunnel. First, she reminded us about the locations of the TAS, TAN and the forward detectors at the end of the LS1. She described the functionality and design of the present TAS for ATLAS and CMS. She reviewed the technical issues to remove the TAN, TAS and forward detectors. A preliminary study of the TAS removal was carried out in 2009 by F. Butin (EN/MEF-EBE). A study of the dismantling of the TANs (Target Absorber Neutrals) has started in July 2012, led by S. Evrard (EN/MEF-EBE), with participation from the EN/HE, RP & EN/MEF groups. The removal of the forward detectors are led by the LTEX study group chaired by Anne-Laure Perrot EN/MEF-LE.



### **MACHINE PROTECTION ISSUES** (*Daniel Wollmann*)

This work is coordinated and followed up in the LHC Machine Protection Panel (MPP). Experience so far has demonstrated that the LHC is well protected (with sufficient redundancy). The MP implications of the crab cavities have been reviewed and will require an upgrade of the machine protection system to be effective within half a turn or 40 microseconds. This should also improve the protection of the central beam pipe which will have a smaller radius than the TAS after LS3.

S. Fartoukh reminded us to be careful with dumping only one beam, which will eliminate the beam-beam effects on the other beam resulting in a close orbit jump.

### **DISCUSSION – POTENTIAL LIMITATIONS & CONSTRAINTS** (*all*)

H. Burkhardt showed one slide with points noted during the workshop.

This was followed by a short discussion. Many points will require close follow up.

These include

- Impedance and heating
- Replacement of TAS and TAN devices
- New TAS with larger aperture – Energy deposition
- Small beam-pipes in the central part of the experiments, consequences of larger TAS
- Quality of vacuum – Requirement for a very good vacuum around ALICE.
- Further collimators
- Machine protection for crab cavities and larger TAS.
- Background and radiation from the machine in the experimental areas
- Radiation Protection issues
- Remote handling & Engineering

A key point which requires close follow up are the consequences of a new TAS geometry with larger radius combined with the smaller radii of the central beam-pipes.

The list is non-exhaustive and subjects like for example improved positioning and alignment will have to be added to the list.

The planning for forward detectors should be closely followed up to make sure they are either completed before LS3 or do not interfere with the performance increase required for the HL-LHC.

Detailed considerations of the interaction layout and geometry will have to be followed up closely together with the optics design including crossing angles and plans for luminosity levelling.

### **SUMMARY & NEXT STEPS** (*Lucio Rossi*)

Lucio Rossi closes the workshop with a brief summary at 17:30. He takes the opportunity to thank all the speakers and the audience for their participation to this 1<sup>st</sup> Workshop of the Collider-Experiments Interface (WP8). The one day workshop gave a good overview of the “desiderata” from LHC experiments and the technical requirements from the machine side. It will be challenging to integrate these requirements in an optimal way into the design for an upgraded LHC operating at higher intensities and luminosity. The crucial points will be examined in further meetings of WP8 to define the best compromise for the challenging HL-LHC programme.