

## LHC INTERACTION REGION UPGRADES AND THE MACHINE-EXPERIMENT INTERFACE

E. Tsesmelis, CERN, Geneva, Switzerland

### Abstract

Schemes for increasing the luminosity delivered to the ATLAS and CMS experiments at the LHC, based on the implementation of modified or additional inner triplet quadrupoles and/or dipoles close to the interaction points, are being developed and result in the need to upgrade the interaction regions around Point 1 and Point 5. This paper presents some of the challenges for the experiments and for the LHC Collider resulting from such schemes and provides some suggestions for further studies.

### INTRODUCTION

Discussions on upgrades to the LHC interaction regions required to follow the increase in LHC luminosity have been taking place in regular working group meetings between the machine and experiment groups during 2007 [1,2]. The interaction region upgrade options considered in the working groups consist of:

- Assuming the baseline LHC optics with stronger and/or larger aperture inner triplets.
- Moving the existing/modified inner triplets closer to the interaction point (IP).
- Incorporating additional 'thin' quadrupoles (Q0) between the existing or modified inner triplets and the IP.
- Including a dipole (D0) in close proximity to the IP.

Several issues resulting from modifications to the interaction regions have been highlighted in these working groups. For the experiments, this includes the displacement, mechanical interference and/or removal of components of the particle detectors, particularly in the forward region; the effect of the magnetic fields of the machine magnets on the spectrometer magnets; and the scattering and albedo of particles into the particle detectors, especially in the Muon Systems, from the inclusion of additional machine elements inside the particle detectors. On the machine side, issues related to the R&D and production of magnets with the required material (NbTi and Nb<sub>3</sub>Sn) and performance will need to be carried out and the minimisation and removal of the heat deposited in the magnets from the products from the high-energy collisions at the IP would need to be addressed. Issues at the machine-experiment interface include an overall design that will enable the particle detectors to open for maintenance and modifications and the implementation of stable mechanical supports and technical services (cryogenics, power and cooling) for the machine magnets within the particle detectors.

### INTEGRATION OF MACHINE ELEMENTS IN ATLAS AND CMS

In the case of ATLAS, the Forward Calorimeter is relatively close to the IP and thus machine magnets can be installed on the non-IP side. Servicing the calorimeter would require that the experimental beam pipe be of constant diameter which would, however, result in an increase of the background in ATLAS. The ATLAS spectrometer solenoid is short and relatively weak (2T) and so is expected to have a correspondingly small effect on the machine Q0 and D0 magnets. After careful optimisation, the dense shielding around the ATLAS experimental beam pipe could become an integrated machine magnet and radiation shielding structure but care must be taken not to decrease the radiation shielding by the insertion of machine magnets. Figure 1 shows an example of integrating the Q0 quadrupole magnets in ATLAS.

Issues of integration in CMS differ considerably from those in ATLAS. The CMS Forward Calorimeter is relatively far away from the IP at 10 m. and machine elements cannot be installed in front. Therefore, integrating the Q0 and D0 magnets will require major modifications to the CMS detector because of the need to move the Forward Calorimeter closer to the IP. Moreover, as the CMS solenoid is relatively long (6 m.) and strong (4T), the fringe field close to D0 is expected to be important.

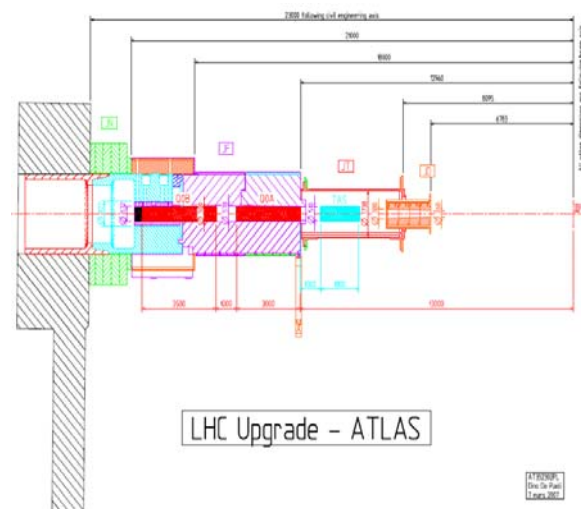


Figure 1: Integration of Q0 quadrupoles in ATLAS.

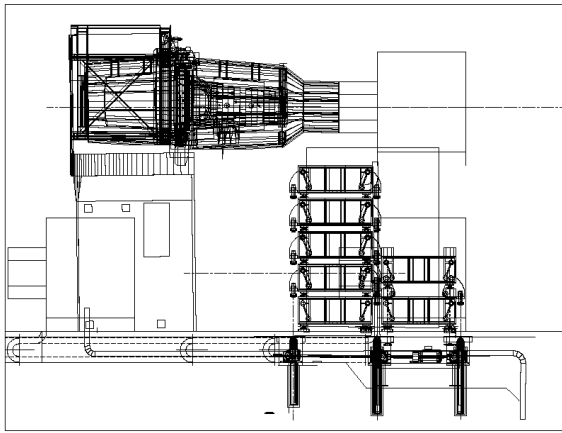


Figure 2: Supplementary structure for the CMS Forward Shielding.

### EXPERIMENTAL BEAM PIPES

The experimental beam pipe is one of the major sources of background in ATLAS. In order to mitigate the effect, together with reducing the material activation, an aluminium beam pipe replacing the stainless steel structure has been proposed for installation prior to running at nominal luminosity. An ATLAS experimental beam pipe composed entirely of beryllium should also be considered for higher luminosities as the activation of the beam pipe then becomes negligible and the decrease of the background rate in the ATLAS Muon System is significant.

As the CMS experimental beam pipe is tapered, the background to the detector is reduced and since the solenoid magnet return yoke shields most of the Muon System, there is less need for an extensive shielding around the experimental beam pipe. CMS does not expect any modification to their experimental beam pipe. Together with the forward beam pipe on the non-IP side of the Forward Calorimeter having a diameter of 400 mm and being in the shadow of the Forward Calorimeter, the present beryllium beam pipe around the IP and the stainless steel beam pipe elsewhere are expected to serve the needs of the LHC upgrade.

### MACHINE MAGNET CHALLENGES

The total heat load and the peak power deposition in the machine magnet coils from debris from high-energy collisions at the IP are potentially issues of concern. Methods to remove this heat must be implemented. The development of  $\text{Nb}_3\text{Sn}$  magnets will be required for any significant luminosity increase. Such magnets have higher temperature margins but further R&D is needed.

Moreover, the interaction of unshielded magnets with the solenoidal fields of the spectrometer magnets and the neighbouring iron, particularly in the case of CMS, is an issue as is the integration of the dense radiation shielding with the services of the machine magnets. Issues related

to forces, torques, field disturbance and quench forces should be studied.

Mechanical support structures need to be designed to support the new machine magnets in the forward positions of ATLAS and CMS. The integration of the technical services (cryogenics, power and cooling) of the machine magnets in the particle detectors need to be studied further.

### RADIATION SHIELDING

The CMS Forward Shielding, located at the two ends of the UXC55 underground cavern, is designed to reduce the background radiation in the experimental area and in the CMS detector. The Forward Shielding is near the limits of mechanical strength and a new concept or supplementary system is needed. In the case of the latter option, insertions for a second set of jacks at each end are already built in to the UXC55 floor and would thus form the basis for supporting a supplementary structure closing around the existing shielding (see Figure 2).

TAS absorbers have been designed to reduce the heating of machine magnet coils by absorbing the energy of the beam debris from the IP and to shadow the coils by reducing the number of particles hitting them. However, the neutron production in the TAS absorbers will fill the cavern like a gas and will be a major source of background in the Muon Systems of the experiments, thus requiring much care in the design of new TAS absorbers. Studies on the energy deposition and conceptual design of new TAS absorbers is underway [3].

### MACHINE-INDUCED BACKGROUND

The impact of the machine-induced background to the experiments, resulting from beam-gas and beam halo, will be studied as of the initial LHC running period. The determination of the background's spectrum will be used to benchmark the extensive simulation studies which in turn can be used with more confidence to make predictions of the machine-induced background at the upgraded LHC. This will provide a good judgement on whether an increase of this background at an upgraded LHC is tolerable.

### EXPERIMENT INSTALLATION, COMMISSIONING AND EXPLOITATION

Installation and commissioning of new particle detectors, machine elements (magnets and their supports /services) and other equipment (experimental beam pipes, vacuum equipment and radiation shielding) would need to be carefully planned in order to least disrupt LHC operation as all activities will be carried out inside the experimental areas. Fitting all work inside one standard machine shutdown period should be analysed.

The increased activation of material in the experimental areas is expected to seriously affect the maintenance of the particle detectors given the restrictions arising for access scenarios. Remote handling might become

mandatory in the design of new particle detectors and probably should be developed for existing ones.

### CONCLUSIONS

The present studies show that the integration of new machine elements inside the experimental areas and particle detectors is feasible but challenging. The work on developing modified interaction regions at Point 1 and Point 5 should continue and in particular should concentrate on studies regarding the energy deposition in the TAS absorbers, integration of magnet systems and their associated services (cryogenics, power and cooling), the experimental beam pipe and the radiation shielding. The backscattering to the particle detectors from additional machine elements needs also to be studied.

### ACKNOWLEDGEMENTS

We would like to thank the organisers of the workshop for the invitation to make this contribution and for the excellent organisation of this very interesting and useful event.

### REFERENCES

- [1]<http://indico.cern.ch/categoryDisplay.py?categId=1450>
- [2]<http://indico.cern.ch/categoryDisplay.py?categId=1462>
- [3]E. Wilner, CARE-HHH-APD Mini-Workshop IR'07 (Interaction Regions for the LHC Upgrade, DAFNE and SuperB), Frascati, November 2007