Online Luminosity Optimization at the LHC

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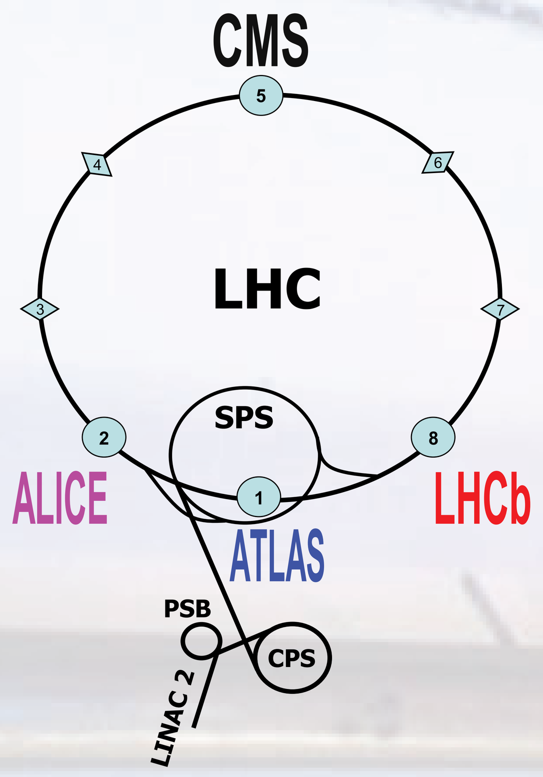
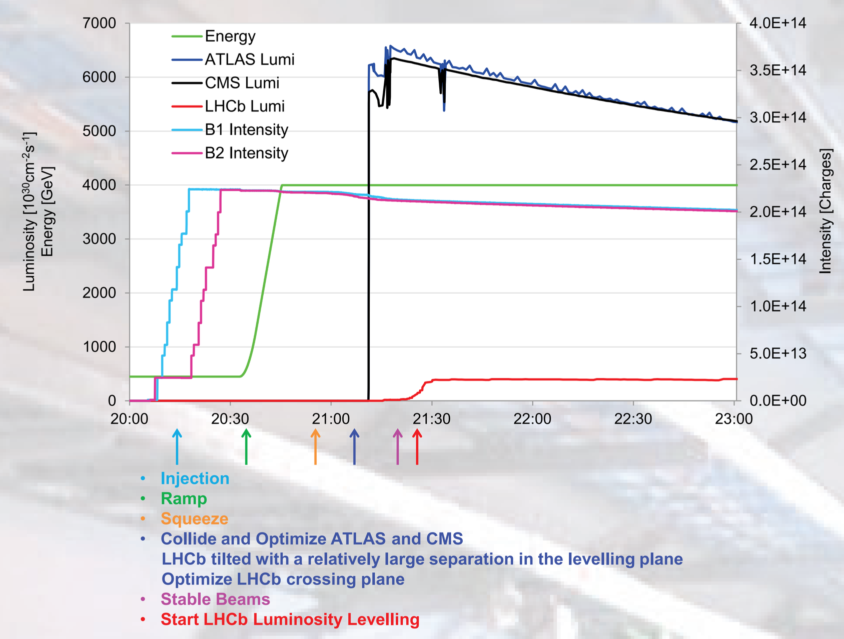
Abstract

The online luminosity control of the LHC experiments consists of an automatic slow real-time feedback system controlled by a specific experiment software that communicates directly with an LHC application. The LHC application drives a set of corrector magnets to adjust the transversal beam overlap at the interaction point in order to keep the instantaneous luminosity aligned to the target luminosity provided by the experiment. This solution was proposed by the LHCb experiment and tested first in July 2010. It has been in routine operation during the first two years of physics luminosity data taking, 2011 and 2012, in LHCb. It was also adopted for the ALICE experiment during 2011. The experience provides an important basis for the potential future need of levelling the luminosity in all the LHC experiments. This paper describes the implementation of the LHC application controlling the luminosity at the experiments and the information exchanged that allows this automatic control.



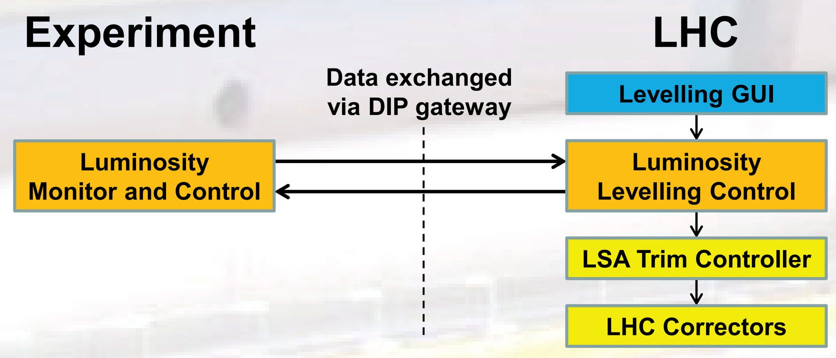
INTRODUCTION

The LHC experiments have different objectives and different luminosity needs. Whereas CMS and ATLAS can work at the LHC design luminosity with the beams colliding head on, the LHCb and ALICE experiments need two or four orders of magnitude lower luminosity to reduce the event pileup (number of collisions per bunch crossing). The concept of a real-time luminosity control based on adjusting the beam transversal overlap was proposed and tested in July 2010 at the LHCb interaction point. This concept became a direct tool to maximize the LHCb physics yield since the optimal pileup and luminosity were always under control, stable fill after fill and over months.

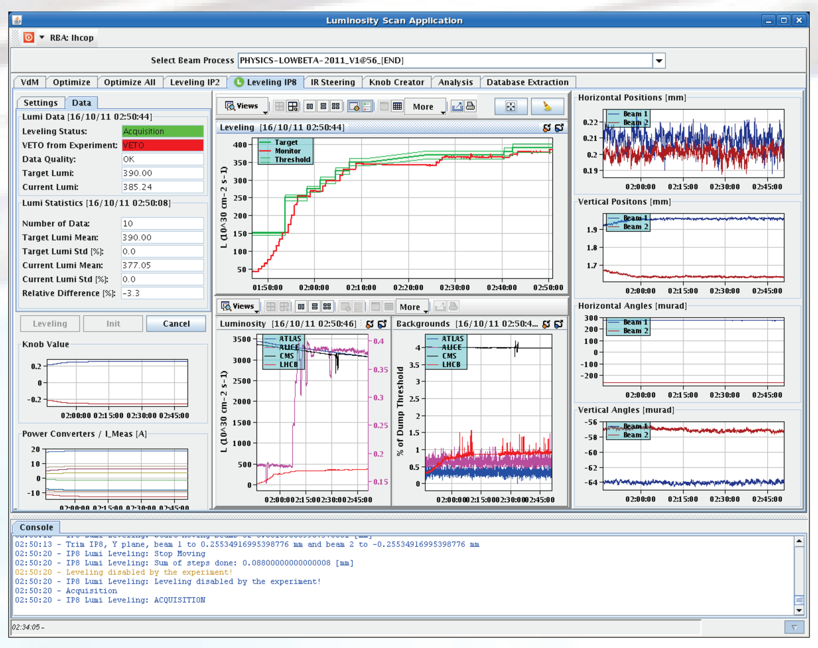


LHC Cycle from Injection to Stable Beams

LUMINOSITY CONTROL SOFTWARE

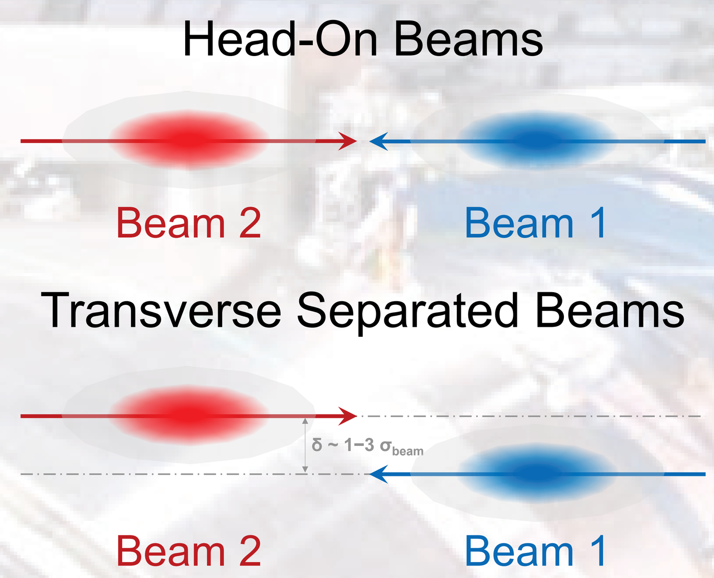


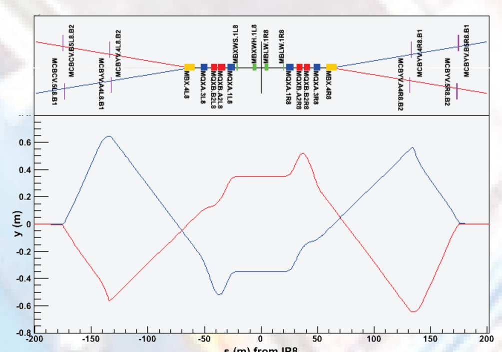
Luminosity Control Software Diagram



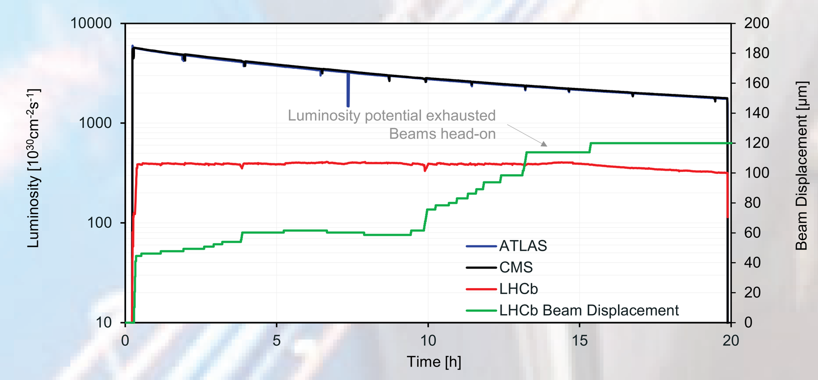
Luminosity Control Application

The luminosity control and monitoring software is composed of two well differentiated parts, on the side of the experiment, a luminosity monitoring and control system measures the luminosity with the help of dedicated detectors. Based on the running conditions, the application computes the target luminosity and the control parameters. The parameters are sent to the LHC luminosity levelling control driver at the Cern Control Centre (CCC) over a dedicated Data Interchange Protocol (DIP) that is used for all software communication between the LHC and the experiments. On the LHC side, the luminosity levelling control driver is part of a more general JAVA luminosity control application. The luminosity levelling control driver runs a levelling algorithm that determines when the beam separation has to be adjusted to reach the target luminosity as received from the experiments. The luminosity control application is client of the LHC Software Architecture (LSA), which provides a homogenous application software suite to operate most of CERN accelerators. The beam separation at the interaction point is achieved by a set of four dipole correctors per beam and per plane which are located on the long straight sections of all the LHC experiments. Initially when the bunch intensities are large and the emittances are small, the beam separation is kept large. As the intensity drops and the emittance grows during the fill, the beam separation is reduced successively to maintain a stable luminosity.



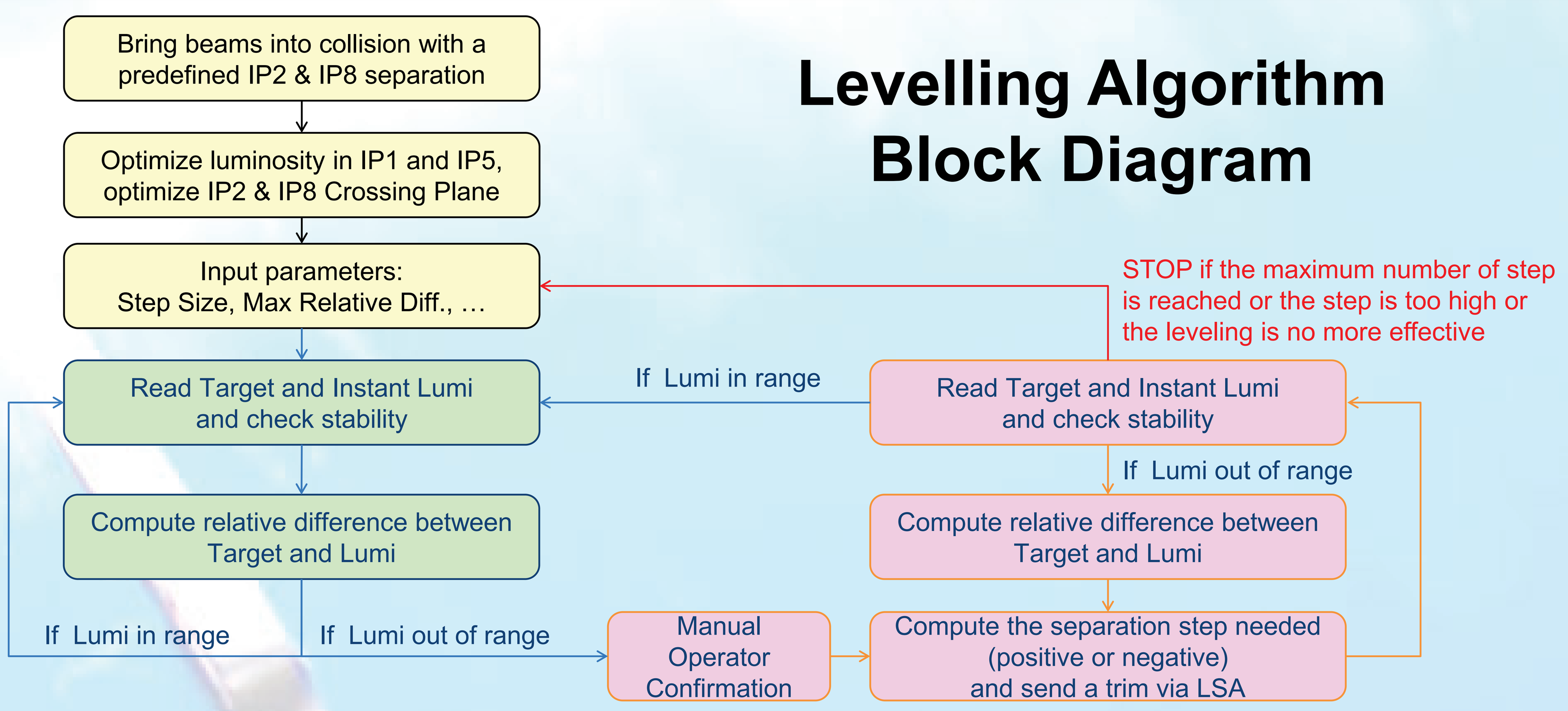


LHCb Beam Separation



Example of ATLAS, CMS and LHCb instantaneous luminosity

Levelling Algorithm Block Diagram



Typical Parameters Sent from the Experiments

- **Target Luminosity** [$cm^{-2}s^{-1}$]
  LHCb proton typical target = 400 [10^{30} $cm^{-2}s^{-1}$]
  ALICE proton-Lead typical target = 100 [10^{27} $cm^{-2}s^{-1}$]
- **Instant Luminosity** [$cm^{-2}s^{-1}$]
- **Levelling Step Size** [σ] (optional)
  LHCb levelling step size during luminosity ramp = 0.2 σ (10.3 μm)
  LHCb levelling step size when stable luminosity = 0.03 σ (1.5 μm)
- **Data quality**
  If bad quality the levelling is not permitted
- **Levelling Request**
  If no request from the experiment the adjustment to the target is not permitted

CONCLUSIONS

The real-time luminosity control based on an iterative feedback loop between a luminosity control application in the experiment and a luminosity driver application in the LHC has become a direct tool for maximizing the physics yield of the LHCb and the ALICE experiments. The luminosity control is based on the adjustment of the beam transversal overlap at the experiment's interaction points. The optimal pileup and luminosity were always under control, stable fill after fill and over months. Thanks to this experiment-accelerator system, LHCb and ALICE have been able to run with increasing performance at a pileup of four times the design value. While several options are considered for the actual control of the luminosity, including a variable beam focussing, this very positive experience puts confidence into the possibility of dynamically controlling the luminosity for all experiments in the future, if needed.