

Introduction

Since the startup in 2009 the LHC has been smoothly commissioned and reached an outstanding performance. The 2011 target integrated luminosity of 1.0 fb^{-1} was already reached in June and currently increased to a total of 4.0 fb^{-1} . This was to a great extent achieved by the two-step reduction (initial 1.5m and 1.0m as of 09'2011) of β^* , the extremal optical β -function in the interaction point (IP). New settings had to be generated for the LHC for each of these β^* reductions. A flexible, extendable and maintainable framework was required, which allows the transfer of simulation data to the control system and verification of the generated settings which are based on this input.

Online modeling is needed to estimate the impact of setting changes before applying to the machine and for the handling of a variety of complicated operational configurations, especially in the IP's. The design and usage of the toolchain core and application developed to address individual problems are presented. It also provides the software modules used for the *Aperture Meter* [1]. The work is based on an initial implementation of a framework for the commissioning of the transfer lines [2] which was extended for the LHC commissioning [3] in 2010.

Environment

The online modeling main purpose is the establish the connection between:

Accelerator Physics Simulation JMad [4] the JAVA API to MAD-X – the de facto standard accelerator lattice design and simulation software at CERN – is used to perform simulations from nominal and current settings of the machine.

Control Infrastructure LHC Software Architecture (LSA) [5] provides access to optics data, machine settings, online measurement data and the framework for settings generation for all LHC devices.

Operation Creation and verification of new operational configuration, visualization of current beam configuration and machine settings as well as simulation of setting changes.

Requirements

The following features need to be available to perform online modeling:

- handling of the different machine optics configuration and data transfer to LSA
 - definition of optics models and tools to follow their evolution
 - automatic creation of optics and knobs
 - transfer of optics/knob data to the control system
 - verification of generated settings in LSA
- provide the information of the mechanical aperture for the whole machine, including the information available from cold bore measurements and the movable device positions (e.g. collimator's and roman pots)
- create a simulated machine, based on the current state and settings driven to the hardware
- merge measurement and simulation data (e.g. orbit interpolation)
- simulate parameter changes (virtual knobs)
- extraction of all control system settings and measurements required to build a simulated model for any given time in the past

Knobs and Optics

Large number of **Optics** (twiss) functions are required for the LSA settings generation for the LHC (see Table 1). High-level parameters – **Knobs** – are needed for the adjustment of key machine parameters like tune, chromaticity, coupling and orbit deviation. These are managed, created and uploaded by the *Knob and Optics Manager* (Fig. 1). Optics models are defined in the framework of JMad model definitions.

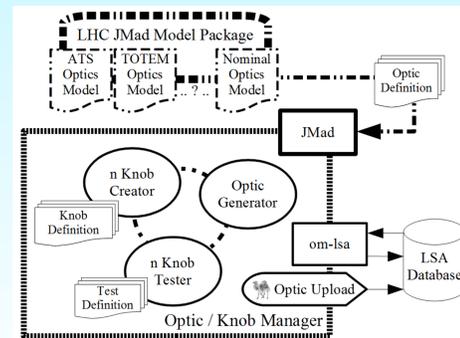


Figure 1: Knob/Optic Manager components

Table 1: Required optics and knobs for operation.

| Config | Nb. of Optics | Nb. of Knobs |
|--------------|---------------|--------------------|
| Nominal | 14 + T | 50 |
| ATS | 26 | 40 |
| TOTEM | 17 | 20 |
| Total | 57 + T | 2080 + T×50 |

A flexible architecture was implemented for automatic creation, testing and upload to LSA of knobs and optics for:

Nominal operational cycle up to physics conditions.

($T \approx 70$ optics required for testing and optimization)

ATS *Achromatic Telescopic Squeezing Scheme* [8] a machine development study for the LHC upgrade

TOTEM *90 m Un-Squeeze* [9] cycle for e.g. the **TOTAL** cross section, Elastic scattering and diffraction dissociation Measurement experiment

New optics can be made available by adjusting the optics models in JMad and new knobs can be defined by implementing the two main interface for knob creation: **KnobDefinition** and **KnobCreator**.

Setting Verification

After optics are uploaded to in LSA, they are used to define a beamprocess as a sequence of optics that should be reached while the generated setting functions are driven to the machine. The generated settings are then checked with the online model manager which allows, beside other functionality to:

- plot and compare optics functions (Fig. 2)
- check correct definition of beamprocesses (Fig. 3)
- extract settings to MAD-X input and run MAD-X scripts



Figure 2: ATS optics comparison in the manager.

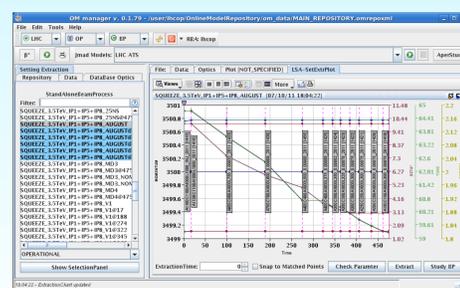


Figure 3: Beamprocess view with optics sequence and key parameter evolution in the manager.

The following setting checks can be performed:

- extraction of full power converter settings and calculate the optics functions in MAD-X and comparison to the nominal
- trim of knob in LSA followed by setting extraction and MAD-X run to check the knob shape
- scan over the settings of a beamprocess: the evolution of the optics parameters based on the generated settings is checked over the time of the beamprocess.

Architecture

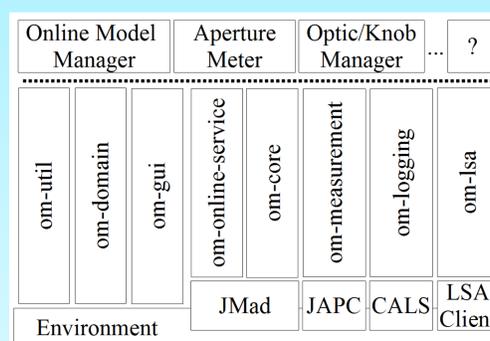


Figure 4: Online modeling toolchain project overview.

Suitable project layout (see Fig. 4) and software management has been put in place for the toolchain:

- 8 core projects/packages, dedicated for each of the systems the online modeling has to interact with
- currently three main application which use the available packages
- build project for automated release of the toolchain and the applications
- continuous integration and code testing with BAMBOO [6] automatic build plans which execute JUNIT [7] test cases for core functionality

Conclusion and Outlook

The online modeling toolchain was successfully used for the preparation of all LHC optics configuration for physics production as well as machine development studies. The usability was shown in applications presented in this paper and as basis for the aperture meter [1]. Further developments will include the full integration of new features provided by LSA and the toolchain itself and changes towards a strict distribution of the functionality into the packages of the toolchain architecture.

References

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