



Alignment requirements: status, requirements and impact on performance

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On behalf of the members of the Working Group on Alignment

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Outline

- Introduction
- The Working Group on Alignment
 - Mandate
 - Membership
 - Planned activities
- Outlook

Introduction

- Alignment is a broad concept. Dealing with 3D objects (mainly magnets, but not only) one has to consider
 - Centre (transverse and longitudinal)
 - Orientation (three angles)
- These concepts can be
 - Local, i.e., varying over the longitudinal co-ordinate
 - Global, i.e., integrated over the length of the object

Introduction

- These concepts apply to
 - Mechanical structure
 - Magnetic fields
- The relevance of **alignment** for the accelerator is because of its impact on **performance**
 - (Mis)alignment of mechanical structure
 - Reduction of **beam aperture** -> limit on **β^* reach**
 - (Mis)alignment of magnetic field
 - Generation of **feed down effects** with impact on
 - Requirements of **corrector's strength** (to mitigate the feed down)
 - **Optics** thus *in fine* limiting **beam aperture**

Introduction

- In the design of a new ring the usual approach consists of
 - **Providing *desiderata*** on alignment based on beam dynamics considerations (aperture, correctors' strength etc.)
 - **Analysing** the **means to measure** and **qualify** the alignment of the various components
 - **Ensuring** the **control** and, if needed, the **correction** of alignment during various stages of hardware life cycle (prototyping, production, installation, and operation)
- For the case of the LHC most of these aspects have been part of the activities related with the **Magnet Evaluation Board**

Introduction

- For the case of the HL-LHC an essential point is
 - **Review** of the LHC experience for what concerns
 - Specification work
 - Hardware production
 - Hardware installation
 - Beam operation
 - In this respect consider this fact
 - LHC Design report: nominal β^* **55 cm**, currently LHC is operated with β^* **30 cm...**

The LHC experience has to be incorporated in the HL-LHC design and specification work

The Working Group on Alignment

- The **specification of tolerances for geometry, alignment, and interconnection** requirements of HL-LHC equipment in direct view of the beam are the focus of the newly created HL-LHC Working Group on Alignment (WGA).
- The goal of the WGA is to **maximise the beam aperture** in the frame of the **approved HL-LHC hardware baseline**.
- More specifically, the WGA has the **mandate**:
 - To summarize and review the current HL-LHC baseline of tolerances for geometry, alignment, and interconnection requirements.
 - To define criteria and to validate proposed procedures for the alignment of HL-LHC components in the insertion regions during prototyping and testing phase and until installation in the tunnel and the following beam operation periods.

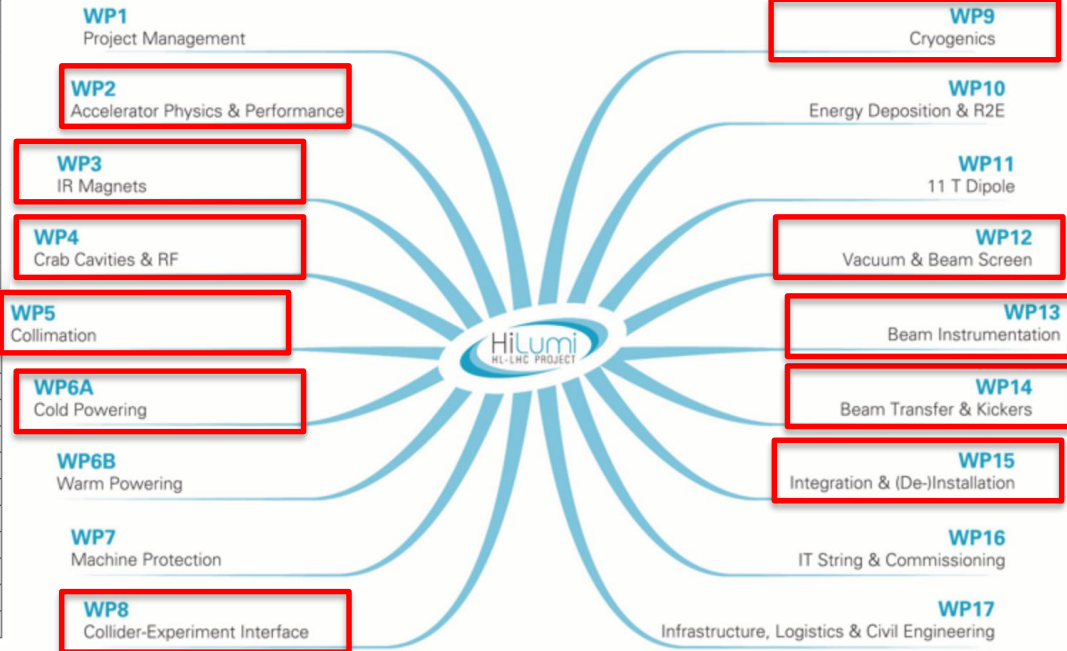
The Working Group on Alignment

- More specifically, the WGA has the **mandate**:
 - To optimise the current baseline proposing a coherent and cost efficient set of tolerances allowing to reach the HL-LHC project objectives. This means, e.g.
 - **Minimising risks related to radiation doses and oxygen deficiency hazards**
 - **Minimising downtime to avoid impact on HL-LHC (integrated luminosity)**
 - To elaborate recommendations and to document the outcome of the working group activities.
 - To monitor and coordinate progress in the above listed matters during the whole period from HL-LHC design until beam commissioning.
- The Working Group on Alignment **reports** to the **HL-LHC Technical Co-ordination Committee**.
- Regular meetings started on 13th of September, twice per month.

Membership

- The Working Group on Alignment is composed by
 - **Alignment team**
 - **Experts** from the **various work-packages** of the HL-LHC project with the aim to provide the appropriate expertise covering the various domains.

Name	Group/WP	Function
O. Aberle	EN-STI	Collimation and masks (installation and operation)
M. Bajko	TE-MSD/WP3	Alignment and cold masses
A. Bertarelli	EN-MME/WP5	Collimation and masks (design)
P. Bestmann	EN-ACE	Survey and alignment
C. Bracco	TE-ABT/WP14	Injection and dump
R. Bruce	BE-ABP/WP5	Aperture and collimation
R. Calaga	BE-RF/WP4	Crab cavities
O. Capatina	EN-MME/WP4	Crab cavities
M. di Castro	EN-STI	Remote alignment
S. Claudet	TE-CRG/WP9	Cryogenics interfaces
R. De Maria	BE-ABP/WP2	Optics
D. Duarte Ramos	TE-MSD/WP3, WP6	Cryostat, interconnects, and DFBs
P. Ferracin	TE-MSD/WP3	Triplet magnets
P. Fessia	ATS-DO/WP15	Integration – Co-chair
L. Fiscarelli	TE-MSD/WP3	Magnetic measurements
C. Garion	TE-VSC/WP12	Vacuum components and bellows
M. Giovannozzi	BE-ABP/WP2	Optics – Co-chair
I. Lamas Garcia	EN-STI	Collimation and masks (installation and operation)
S. Le Naour	TE-MSD	Cryomagnet co-ordinator
T. Lefevre	BE-BI/WP13	Beam instrumentation
H. Mainaud	EN-ACE	Survey and alignment
E. Montesinos	BE-RF/WP4	Crab cavities
V. Parma	TE-MSD/WP3/6a	Cryostats and DFBs
A. Perillo Marcone	EN-STI/WP14	Injection and dump
D. Perini	EN-MME/WP5	Hollow Electron Lens
H. Prin	TE-MSD/WP3	Cold masses and interconnects
B. Salvant	BE-ABP/WP2	Implications on impedance
F. Sanchez Galan	EN-EA/WP8	Machine detector interface
G. Schneider	BE-BI/WP13	Beam instrumentation
M. Sisti	TE-CRG/WP9	Cryogenics interfaces
M. Sosin	EN-ACE	Survey and alignment – Scientific secretary
E. Todesco	TE-MSD/WP3	IR magnets
J. Wenninger	BE-OP	Operation



List of topics

Green: topics already discussed at WGA meetings

■ Triplets

- Longitudinal positioning
 - Definition of the longitudinal magnetic centre
 - How we measure the magnetic centre and how we refer it to the cold-mass external side
 - Longitudinal accuracy in positioning of jacks and their adjustment capacity
 - Longitudinal tolerances of cryostat on the jacks and related tolerances of cryostat respect to the cold-mass reference system
 - Monitoring of longitudinal positioning
 - Tolerance requirements on position and capability of adjustments

List of topics

Green: topics already discussed at WGA meetings

- **Triplets, corrector package, D1**
 - Transverse positioning
 - Tolerances (mechanical, alignment) for beam screen, including impact of supporting system of cold mass
 - Monitoring of transverse positioning
 - Tolerance requirements on position and capability of adjustments
- Repeat these analysis for
 - **Matching section quadrupoles**
 - **D2**
 - **Crab cavities**
- **Vacuum system**
 - Strategy for alignment of vacuum chambers and monitoring of bellows
 - Final alignment tolerances

List of topics

Green: topics already discussed at WGA meetings

■ General

■ The fiducialisation procedures

- Review of what was done for LHC magnets
- Ideas for HL-LHC magnets

■ Tunnel movements

- Review of measurement results

■ Situation of experimental caverns for ATLAS and CMS

- Review available measurements of cavern movement
- Review situation of TAXS in terms of alignment
- Planned for discussion by end of November

List of topics

■ General

■ Remote alignment system

- It is already in the baseline
- It has a **very high potential** in terms of impact on HL-LHC performance
 - The strength budget in the IR orbit correctors for alignment could be drastically reduced: **the system of IR orbit correctors could be considerably simplified**
 - Less aperture should be allocated for coping with IR misalignments: **potential impact on β^* reach**
- However, to exploit such a potential we need
 - **Functional specifications** of the remote alignment system
 - **Critical review** of conditions needed to **apply remote alignment** (consider mechanical efforts on bellows in presence of complex misalignments)
 - **Strict control** of all hardware between Q1 and Q6 **to ensure compatibility** with remote alignment
 - **Review** of procedures to **use remote alignment in operation, i.e., also with beam**
- **After all this, an assessment of the impact on performance will be carried out**

Some observations

- **Managing alignment** implies an **excellent co-ordination** between several work packages and with **experiments**
- The **requirements** for **magnetic measurements** are extremely **challenging**: to date we are close to targets, but **further developments are needed**
- **Procedures** developed at CERN **should be transferred to collaborating institutes** to ensure the same standards
- It is **essential** that **all data relative to alignment** (mechanical and magnetic) for all stages of assembly are **collected at CERN** for analysis and quality assurance reasons
- Need to **consolidate measurement databases** (survey and magnetic) for optimal use
- **Quantitative tolerance tables should be compiled** for the various devices and construction steps.

Outlook

- Activities of Working Group on Alignment are in fully swing
- Identified a number of paths to
 - **Preserve performance** by
 - **Reviewing** LHC criteria and experience and applying them to HL-LHC
 - **Reviewing** means to measure and control alignment **to meet** beam requirements throughout the whole hardware life cycle (design, prototyping, production, installation, operation)
 - **Boost performance** by
 - **Developing** the baseline option of **remote alignment**
- **Documentation and review** of tolerances is also an essential task of the working group!



Thank you for your attention!