Full Remote Alignment System (FRAS) specification and interfaces

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Review of HL-LHC Alignment and Internal Metrology (WP15.4)

Outline

- Introduction to the FRAS
- Associated aspects
- Impact on equipment

Introduction to FRAS

- The Full Remote Alignment System (FRAS) will allow:
  - Aligning rigidly and remotely all the components from Q1 to Q5 on both sides of the Interaction Point within ± 2.5 mm
  - Moving independently the components within the stroke of the corresponding bellows.
- Its feasibility was confirmed in a thorough study led in 2018 by Jan Hansen, Andreas Herty and Paolo Fessia.
- An Engineering Change Request (ECR) was agreed in April 2019 : EDMS 2083813
- A functional specification was submitted for approval in August 2019: EDMS 2166298

Introduction to FRAS: life cycle
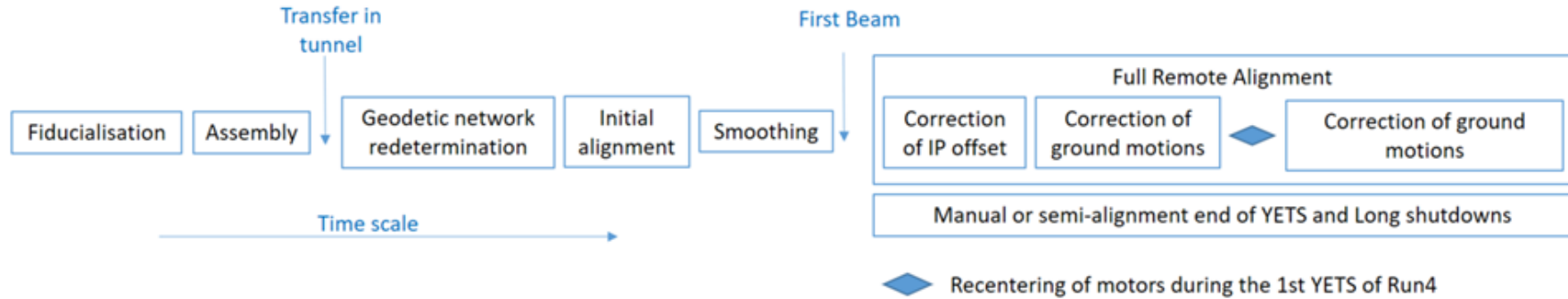
- The initial alignment will be performed w.r.t underground geodetic network
- The smoothing will be performed along an "ideal" line from Q7 left – Inner tracker detector – Q7 right to make the first pilot beam pass through
- After a few weeks of operation, a rigid remote re-alignment will be performed from Q5 left to Q5 right according to the offsets seen in the inner tracker
- During the first year, all motors will be re-centered to benefit from the maximum stroke
- The compensation of ground motion will take place preferably during TS, as a machine requalification is required after. Small machine movements could be allowed without requalification during the operation of a pilot beam.

Introduction to FRAS: requirements from WP2
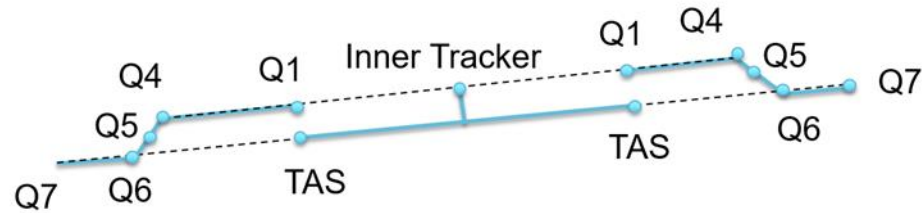
- FRAS allows to re-align remotely the machine mechanically from Q1 to Q5
- Half displacement considered for Q5 to smooth the connection with Q6, using orbit correctors from Q4 to Q8 with immediate feedback on the beam
- The orbit corrector budget assumes quadrupole fields (from Q7 left to Q7 right) aligned to ± 0.5 mm w.r.t. the "ideal" alignment line.
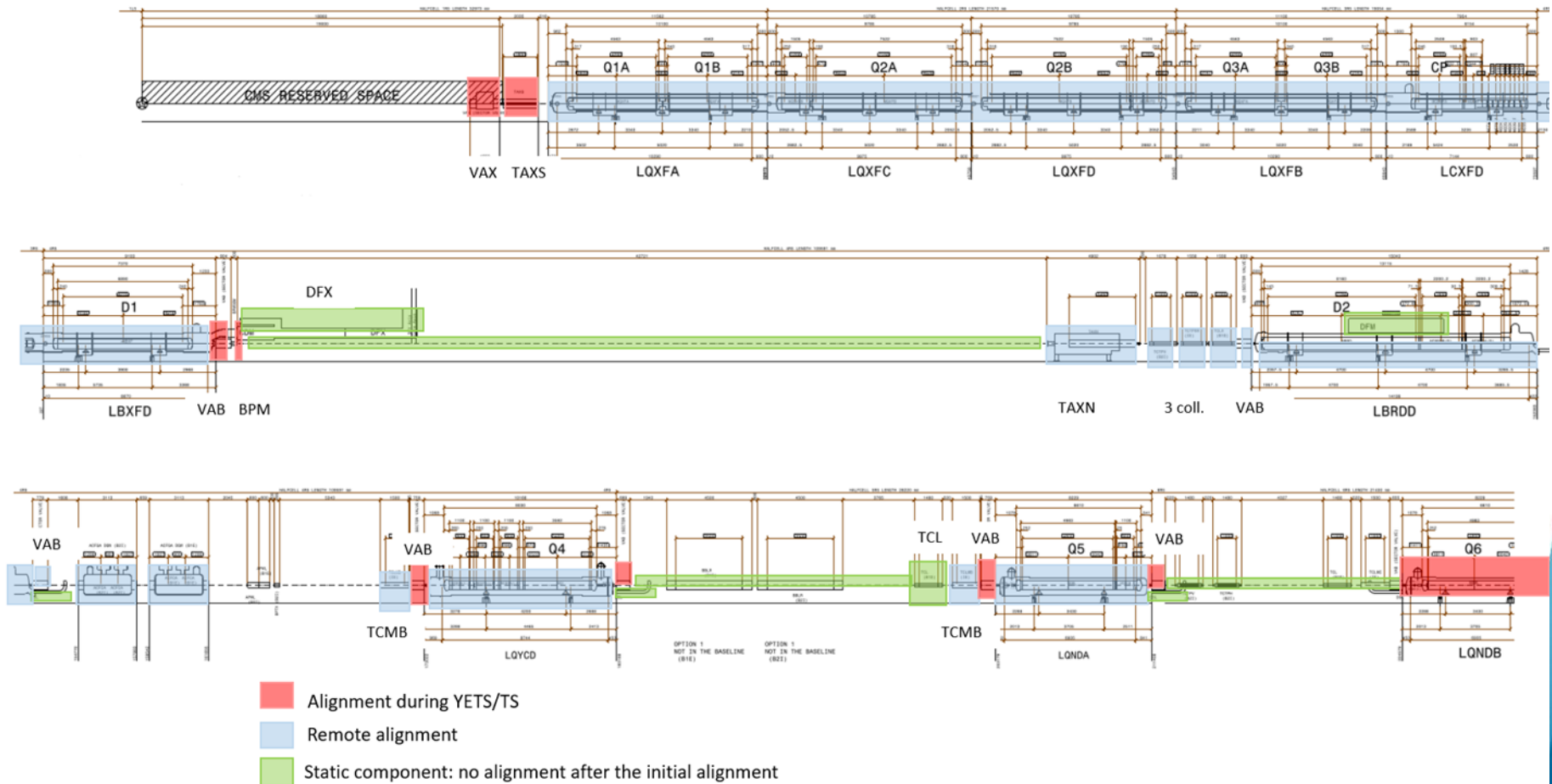
Introduction to FRAS: some definitions

- Alignment of a component: determination of its position and adjustment of its position.

- Manual alignment: alignment requiring human intervention in the tunnel

- Semi-manual alignment: alignment requiring human intervention in the tunnel, made faster by installing temporary motors for the adjustment.

- Remote alignment: alignment of a component performed remotely (with no human intervention in the tunnel), using sensors to determine the position of the component and motors to adjust it.
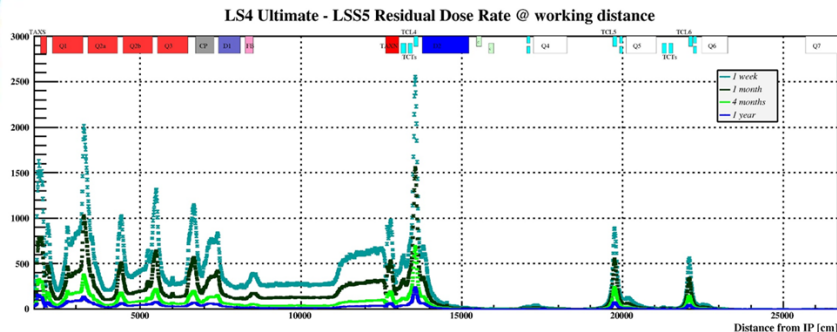
Introduction to FRAS: solution proposed

LSS components classified into different types, considering the level of radiation in the area, the ground motion expected, the associated alignment requirements and their aperture:

- Components needing to be aligned from the CCC (remote alignment)
- Components aligned only during LSs or YETS (semi-manual or manual alignment)
- Components that will not be aligned anymore after their initial alignment (static alignment)

Q1A Q1B Q2A Q2B Q3A Q3B CP

CMS RESERVED SPACE

VAX TAXS LQXFA LQXFC LQXFD LQXFB LCXFD

DFX

D1 D2 DFM

LBXFD VAB BPM TAXN 3 coll. VAB LBRDD

VAB TCL VAB VAB

VAB Q4 Q5 Q6

TCMB TCMB

LQYCD OPTION 1 NOT IN THE BASELINE (B1E) OPTION 1 NOT IN THE BASELINE (B2I) LQNDA LQNDB

■ Alignment during YETS/TS

■ Remote alignment

■ Static component: no alignment after the initial alignment

Introduction to FRAS: context

LS4 Ultimate - LSS5 Residual Dose Rate @ working distance

Total HL-LHC dose 60cm below the beam in the LSS of IP1 and IP5

Ambient dose equivalent rate profile in the LSS5 after 1 week, 4 weeks, 4 months and 1 year cooling time during LS4 (ultimate scenario considered: 3 years of running at 7.5. 1034 cm-2.s-1 integrating 300 fb-1/year).
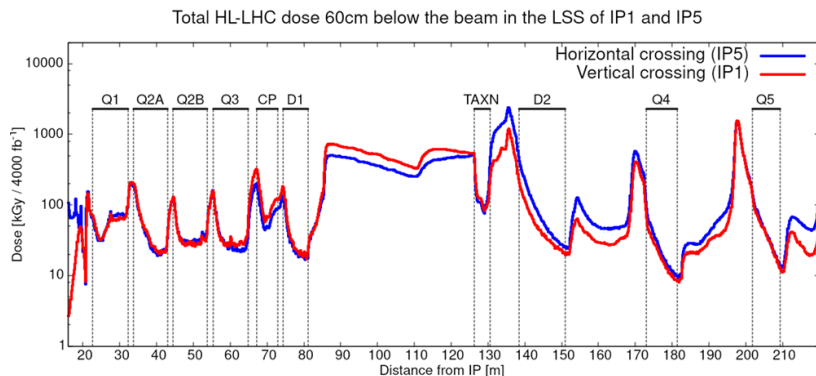
HL-LHC total dose in LSS1 and LSS5, 60 cm below the beam, for an ultimate value of the integrated luminosity, according to the longitudinal position of the LSS components.

Introduction to FRAS: context

	Radial (mm/year)	Vertical (mm/year)
Around IP5 (CMS)	± 0.3	+ 0.7 in 5L (two specific area) + 0.5 in 5R (two specific area + 0.2 in any other area
Around IP1 (ATLAS)	± 0.2	± 0.3

Ground motion around PT5 from 2006

Maximum displacement in millimetre per year measured between the detector and the machine.
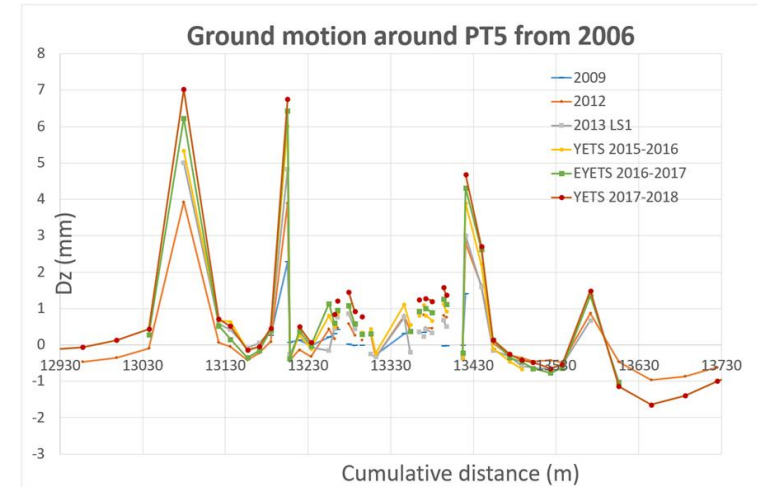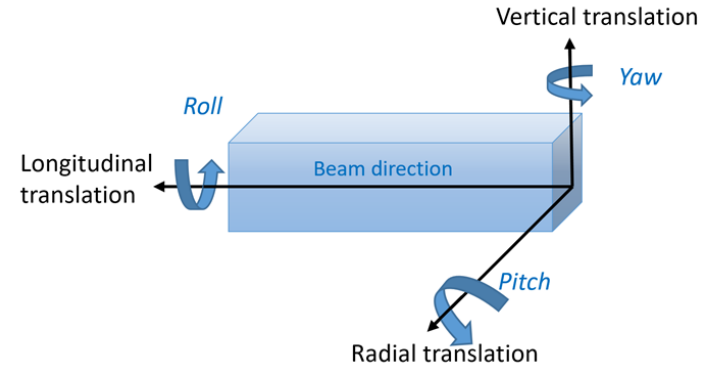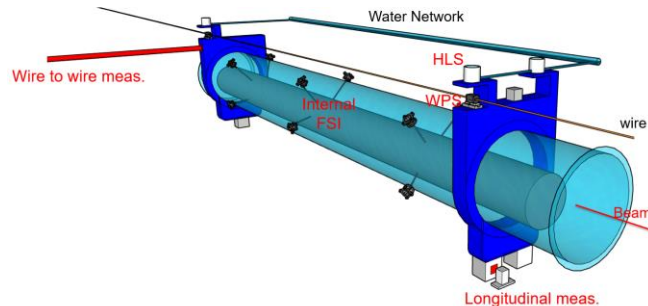
Ground motion around point 5 on the tunnel floor since 2006.

Introduction to FRAS: solutions proposed

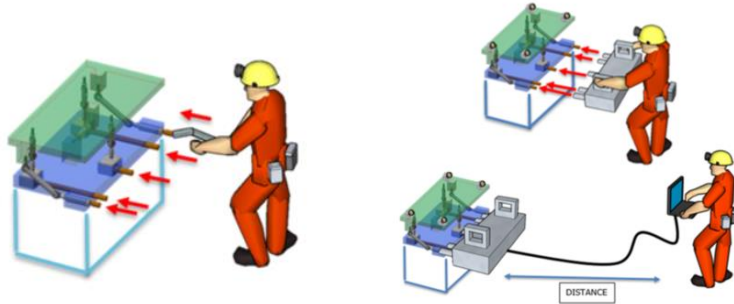For the determination of the position:

- Manual or semi-manual
  - ✓ Using Laser tracker
  - ✓ Using permanent targets

- Alignment sensors
  - ✓ Using permanent sensors
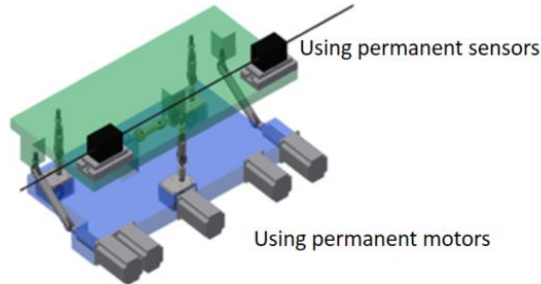
Introduction to FRAS: solutions proposed

For the adjustment of the position:
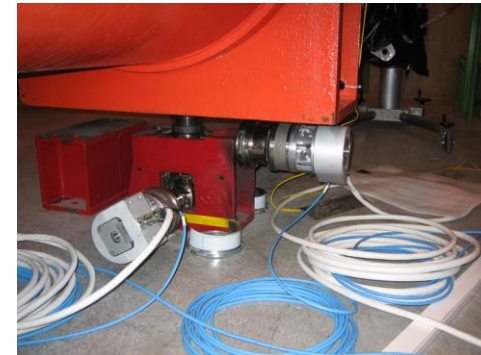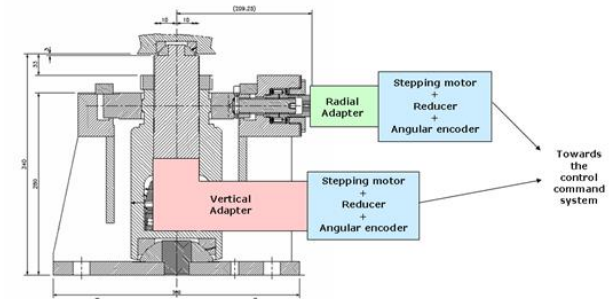- Components < 2 t: UAP platform

Manual adjustment

Semi-manual adjustment

Remote adjustment

For the adjustment of the position:
- Components > 2 t: motorized jacks

FRAS & associated aspects

- Reliability:

  Alignment sensors and motors located in the tunnel shall be free of maintenance during HL-LHC life time, as no corrective maintenance will be possible except at the end of YETS and LS.

- Maintainability:

  All sensors and motors will be designed in such a way that they can be removed (and re-installed) in less than 3' from their supports or interface, using kinematic mounts and/or screws usable by robots.

- Inspectability:

  A final inspectability will be performed on all sensors and motors after less than 1 year of operation, when the level of radiations is still acceptable.

  Possibility to perform later on the inspectability with methods developed on collimators with robots (switch control, grease control).

FRAS & associated aspects

- Installation:

  The installation of all FRAS components will take place when the components are not yet interconnected, at warm, in order to have the possibility to perform in-situ validation tests that will have no impact on bellows or on the alignment of the adjacent components.

- Cabling:

  All cables and associated racks needed for FRAS have been mentioned in DICs issued in March 2019.

- Logistics:

  The FRAS shall not interfere with the areas reserved for the transport of accelerators components in the tunnel. The FRA equipment shall not interfere with the volume reserved for the transport, or it shall be installed after transport, once in the tunnel

  FRAS equipment shall not affect the handling activities and shall be easily dismountable.

FRAS & associated aspects

Machine protection aspects

Protection shall be implemented to avoid that:

- Nearby elements move independently in a critical way, putting at risk the machine integrity
- That the machine can be moved in non-safe conditions

- One first injection interlock shall be on WPS readings (delta between a stop)
- One second interlock shall be a key-type interlock in the CCC to prevent any displacements on motors during operation.
- Maskable hardware interlocks to the LHC beam interlock system shall be provided to set interlocks whenever the remote adjustment systems are powered. Theses interlocks shall ensure that the remote system is only used with setup beam intensity.
- Tracking and logging of the movement of the components/interconnections

FRAS : interfaces between WPs

WP	3	4	5	6a	8	9	12	13
3: IR magnets				X		X	X	X
4: Crab cavities & RF						X	X	
5: Collimation							X	
6a: Cold powering	X						X	
8: Collider-Experiment interface							X	
9: Cryogenics	X	X						
12: Vacuum & beam screen	X	X	X	X	X			X
13: Beam instrumentation	X						X	

Thank you very much