Plans and goals for remote alignment and impact on collimator designs (only IR1 and IR5)

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Summary

- New Full Remote Alignment in the HL-LHC
- Which collimators are impacted from the requirement point of view
- Developing the elements to be added to the collimators to provide remote alignment capabilities
- Some key dates and moments

Full Remote Alignment

Full Remote Alignment and Matching Section Optimization

Objectives

- Reduce dose to alignment team
- Cope with Experiment vs. machine misalignment in RUN IV after the machine and experiment installation completion
- Yearly correct ground motion drift without man intervention in the machine
- Provide tool to eliminate or at least minimize the residual alignment error using beam as reference
- Cope with unexpected source of misalignment avoiding losses in performance of physics time

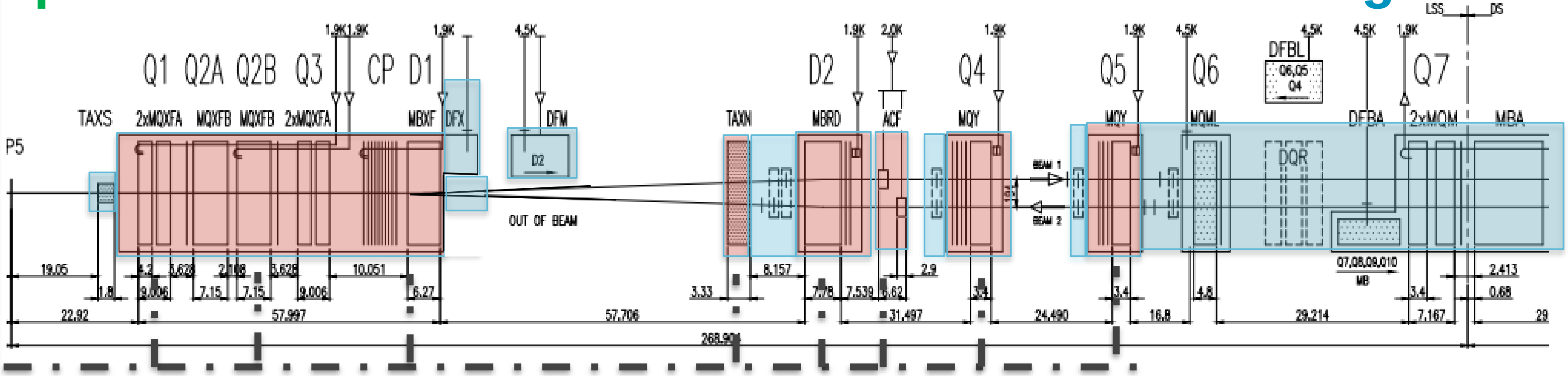
FRA

By products

- Gain aperture margin in various equipment: i.e. simplification collimator design
- Matching Section Optimization
- Reduce the requirement on the Matching Section orbit Corrector System
- Mitigate spurious orbit deviations in the triplet (simplifying non linear corrections)

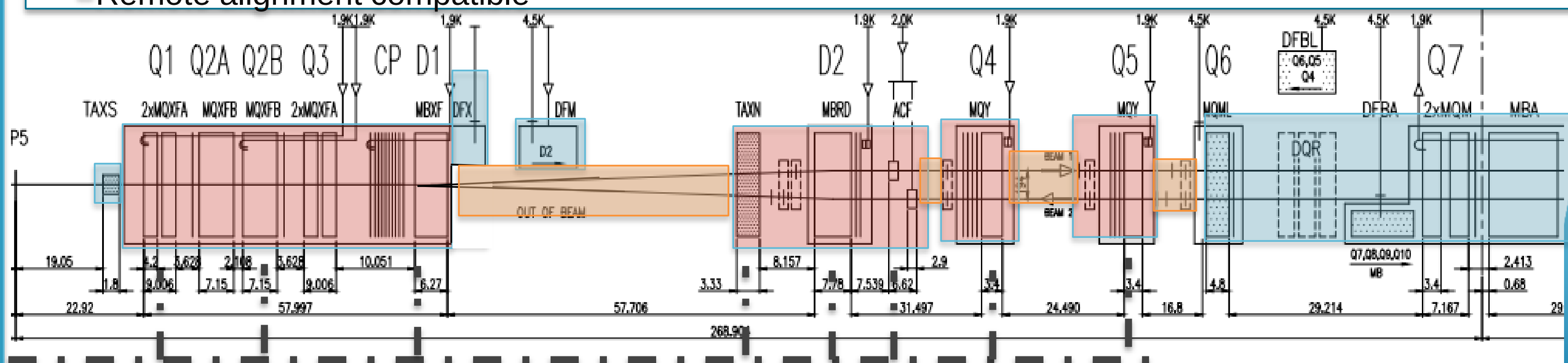
IP1 and IP5 HL-LHC
Synoptic of adjustment system only
previous baseline vs. version with Full Remote Alignment

TILL NOV 2018



- Motorized adjustment system, remotely controlled : adjustment during run, from CCC
- Manual adjustment system: adjustment during LS,YETS,TS, personnel in the tunnel, access in front of element (special for TAXS)
- Remote alignment compatible

NEW BASELINE



Full Remote Alignment applied to HL 1.3 optics not to new 1.4

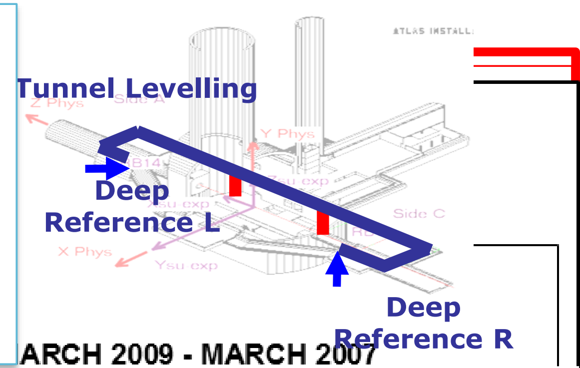
Possible alignment strategies with fully remote alignment

	Scheme 1: During operation or TS up 2.5 mm	Scheme 2: During TS Larger than 2.5 mm	Scheme 3: During YETS	Scheme 4: During LS 2 year RP cool down
Machine conditions	Machine operating conditions	Magnet cold but empty during movement	Magnet cold but empty during movement	Warm
Max stroke	+/- 2.5 mm	±10 mm (jack excursion other limits apply)	±10 mm (jack excursion other limits apply)	more
Time required per IP side Q1 to D1	30 min No access	60 min No access	60 min No access	
Time required per IP Q1 to Q5	30 min No access	2(L)+2(R) days Access for int. components. De-interconnection of the RF guides (from time point of view this fits into a TS)	2(L)+2(R) days Access for int. components. De-interconnection of the RF guides (from time point of view this fits into a TS)	
	CD: NA	CD: >12 mSv	CD: 2.8 mSv	CD:0.3 mSv
Time required per IP side Q1 to Q6	Not possible	2 TS TS1: measure Between TS1 and TS2 compute TS2 realign	Measurement, computation and re-alignment in the YETS	
	NA	CD: >13 mSv	CD: 3.2 mSv	CD:0.4 mSv

The needed stroke

The Survey team has linked the experiment cavern movement with the ones of the LSS

- For the vertical plane via the deep references (GITL) that are in machine tunnel for ATLAS and CMS
- For the radial plane via the GISB references points that are in the UPS survey galleries



	Δz [mm/y]	Δr [mm/y]	Observations
IP1	0.3	0.3	
IP5	0.2	0.2	Δz 0.7 mm/y locally at 150 m from IP where the "new" LHC civil engineering join the LEP tunnel

The proposed value of ± 2.5 mm would allow covering the movements from LS to LS with a safety factor at least 2 (vs. 0.3 mm) avoiding major realignment intervention during other time slots.

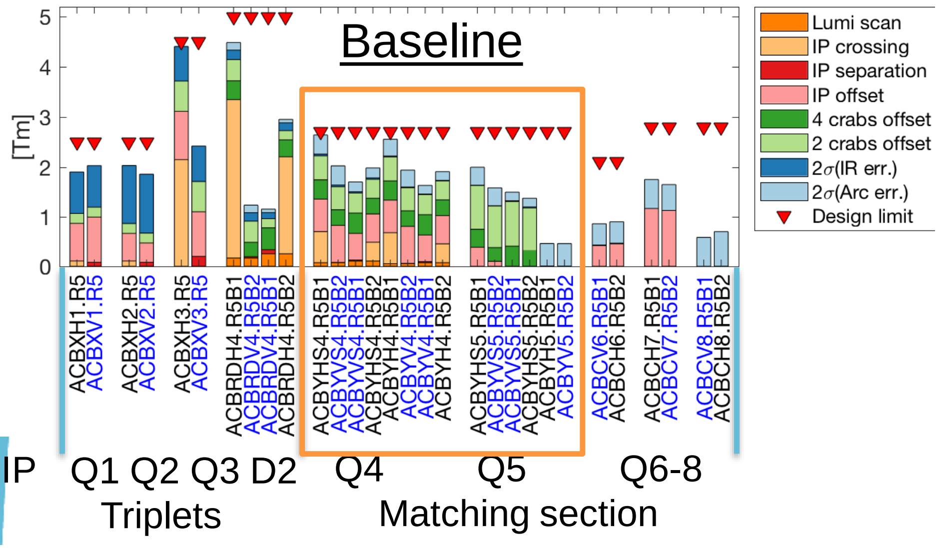
Yearly changes shall be much smaller in the range of 0.2/0.3 mm

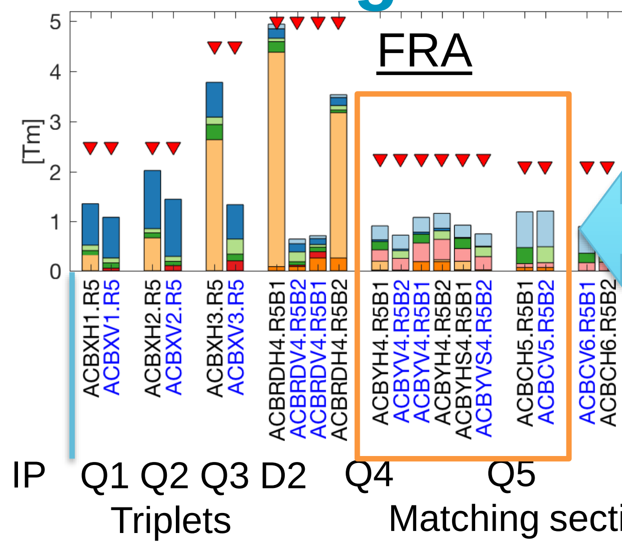
This meets the requirement of the experiment that asks for the possibility to compensate +/-2 mm of IP shift and fits with the experimental vacuum system design and capability

In addition at LS3 partial overcompensation in the vertical plane (even in the assembly position of the inner tracker as proposed by CMS) could be applied on the base of the measurement that will be taken during LHC RUN III,

allowing to factorize in possible impact of the HL-LHC excavation that will have been completed in LS2

Orbit corrector strength requirements and aperture without and with remote alignment





Increased corrector margin here applied already to reduce set of correctors

Right Point 5, H crossing.

Crossing: ±295 μrad
Separation: ±0.75 mm
IP Offset: ±2.0 mm
Luminosity scan: ±100 μm
Crab knobs: ± 1-0.5 mm (baseline only)
Imperfection (2σ): from uniform distribution of mainly ±0.5 mm quad. Alignment and 0.5 mrad / 20 units dipole errors.

FRA:

- orbit bumps reduced at the crab cavities
- IP offset performed by alignment
- Limited crab beam adjustment still possible

	Base	FRA	Base	FRA
	Round β*=15 cm		Flat β*=7.5 cm	
TAXS	16.3	16.3	14.0	14.0
IT	12.0	13.1	11.8	12.7
TAXN	15.4	17.3	12.4	13.9
D2	15.5	18.6	12.9	14.7
Q4	14.5	18.3	10.4	13.0
Q5	24.8	28.2	17.6	19.9
Q6	25.5	25.9	18.0	19.3

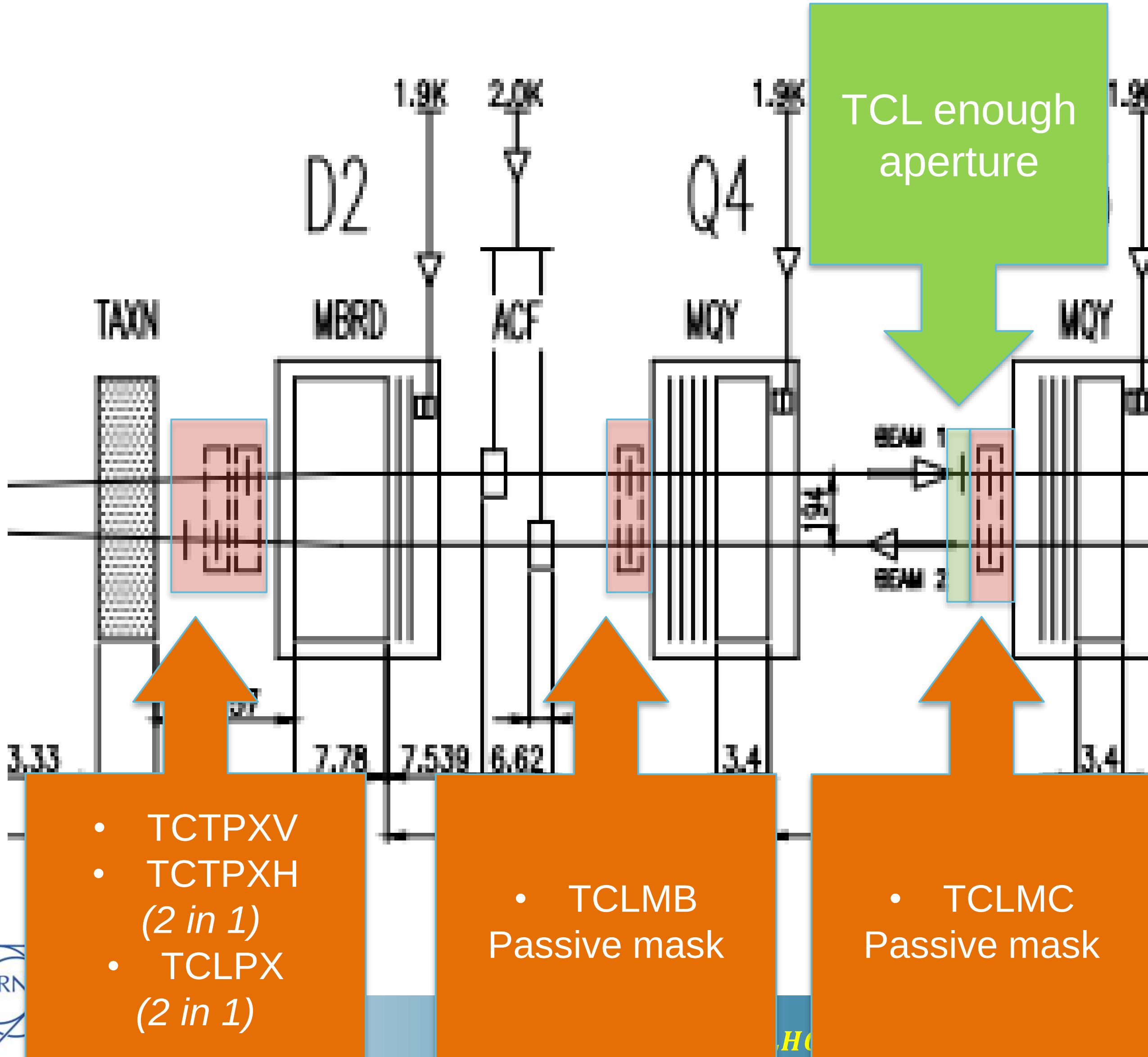
Courtesy R. De Maria, D. Gamba

Full Remote Alignment conclusion

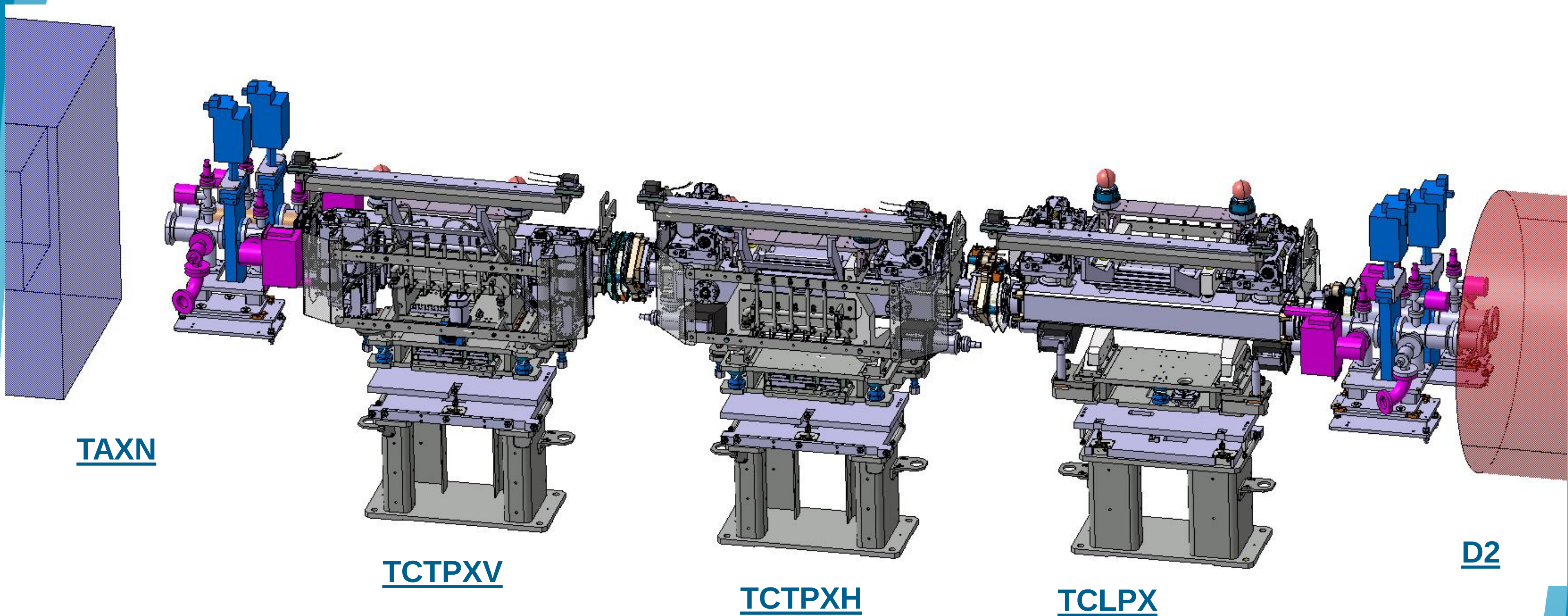
- The deployment of the full remote alignment is feasible:
  - It satisfies the requirement and boundary conditions imposed by the experimental vacuum and experiment requirements
  - It can be made compliant with the Machine Protection requirements
  - All the systems between Q1 and Q5 can be made Full Remote Alignment compliant meaning
    - The vacuum system can be made Full Remote Alignment compliant with
      - Fix sections that provide sufficient aperture to move the beam inside in the ±2.5 mm range
      - Using when required Deformable RF bridge bellows
      - Having 2 sectors valves per IP side remotely moved on dedicated supports (total 8)
      - Having part of the vacuum system around the crab cavities fixed to the crab cavities and moved with them
      - Allowing to recover more sector valves from the LHC and allowing simplification in very tricky areas as the TAXN-D2
    - 5 collimators/masks per IP side will be equipped with their own dedicated alignment platforms (20 in total)
    - The equipment already foreseen on the triplet will be made more redundant and robust in order to be compliant with the requirement of a system that becomes an operational knob
  - The total cost the deployment is in the original ballpark figure presented at Chamonix 2018

Full Remote Alignment and collimation system: impact on the requirements

IP1 and IP5 HL-LHC
ZOOM on the affected collimators
5 units X 4 IPs =20 units



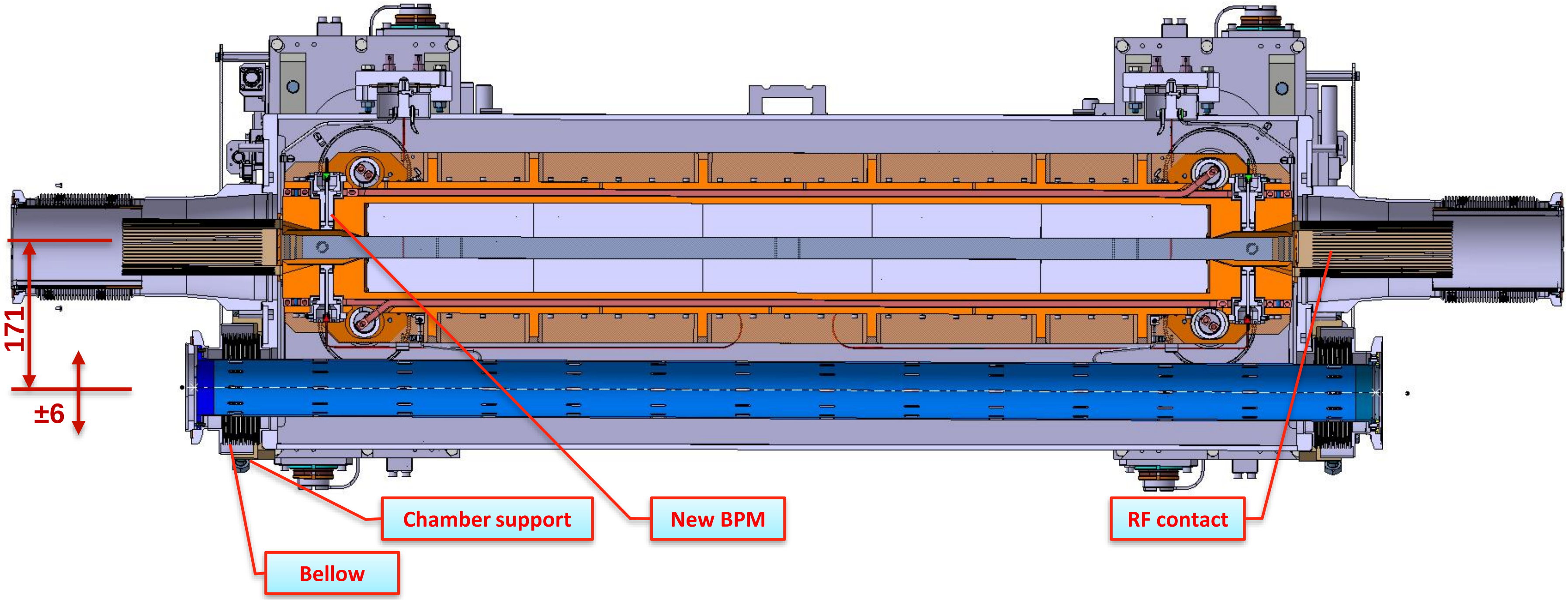
TAXN – D2 AREA



Courtesy L. Gentini

The introduction of the remote alignment has opened the door to perform a re-optimization of the lay-out that is being ran in these days (not shown above)
Such optimization could allow bringing the TCLPX slightly nearer to the dipole in the D2 cryostats and move the TAXN towards the D2. All changes should go in the direction of increasing the magnet protection
The lay-out above is not yet the optimized one

TCTPXH / TCLPX COMMON DESIGN

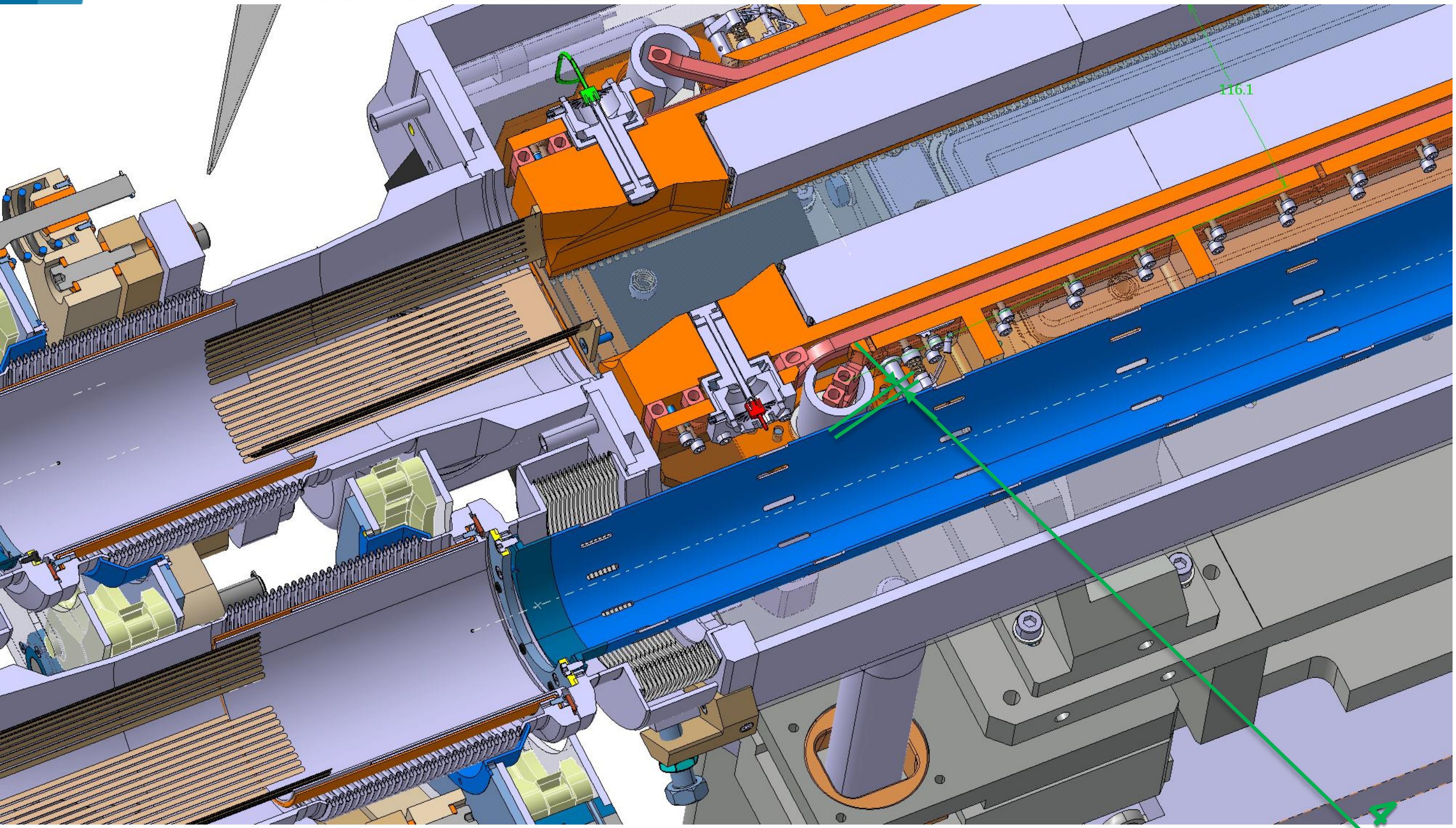


The position of the chamber of the 2nd beam can be adjusted to use the same tank for TCLPX and TCTPXH

Snapshot of ongoing design optimization. Not finalized, not approved

Courtesy L. Gentini

TCTPH / TCLPX COMMON DESIGN



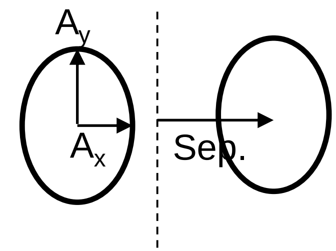
Very limited space between the TCLPX jaw and 2nd beam chamber.
To reduce stroke and chamber dimension the remote alignment is very beneficial .

Snapshot of ongoing design optimization. Not finalized, not approved

Courtesy L. Gentini

Beam Aperture specifications

Offset (X,Y)	Previous baseline	New Baseline with R.A.
Ground Motion + Fiduc.	~2 mm	~0.5 mm
Orbit Error + crab adj.	2.5 mm	2.5 mm
Collimator stroke	15 σ + 10 % (β-beat)	15 σ + 10 % (β-beat)
Protected aperture	12 σ + 10 % (β-beat)	12 σ + 10 % (β-beat)
2 mm IP shift	With orbit correctors	With re-alignment



Round 15 cm	A_x [mm]	A_y [mm]	A_x [mm]	A_y [mm]	Sep. [mm]
TCLPX	36.4	27.9	31.9	26.1	86.0-87.5
VTCLPX	28.0	36.4	26.1	31.9	86.0-87.5
TCTPXH	28.5	37.1	26.5	32.7	83.4-84.9
VTCTPXH	37.0	28.1	32.5	26.4	83.4-84.9
TCTPXV	28.9	38.0	26.9	33.7	80.4-81.9
VTCTPXV	38.1	28.7	33.7	26.9	80.4-81.9

Flat 7.5/18 cm	A_x [mm]	A_y [mm]	A_x [mm]	A_y [mm]	Sep. [mm]
TCLPX	42.8	33.8	38.3	32.0	86.0-87.5
VTCLX	33.9	42.9	32.1	38.4	86.0-87.5
TCTPXPH	34.2	43.5	32.3	39.1	83.4-84.9
VTCTPXH	43.3	34.0	38.8	32.2	83.4-84.9
TCTPXV	34.5	44.3	32.6	39.9	80.4-81.9
VTCTPXV	44.2	34.5	39.8	32.5	80.4-81.9

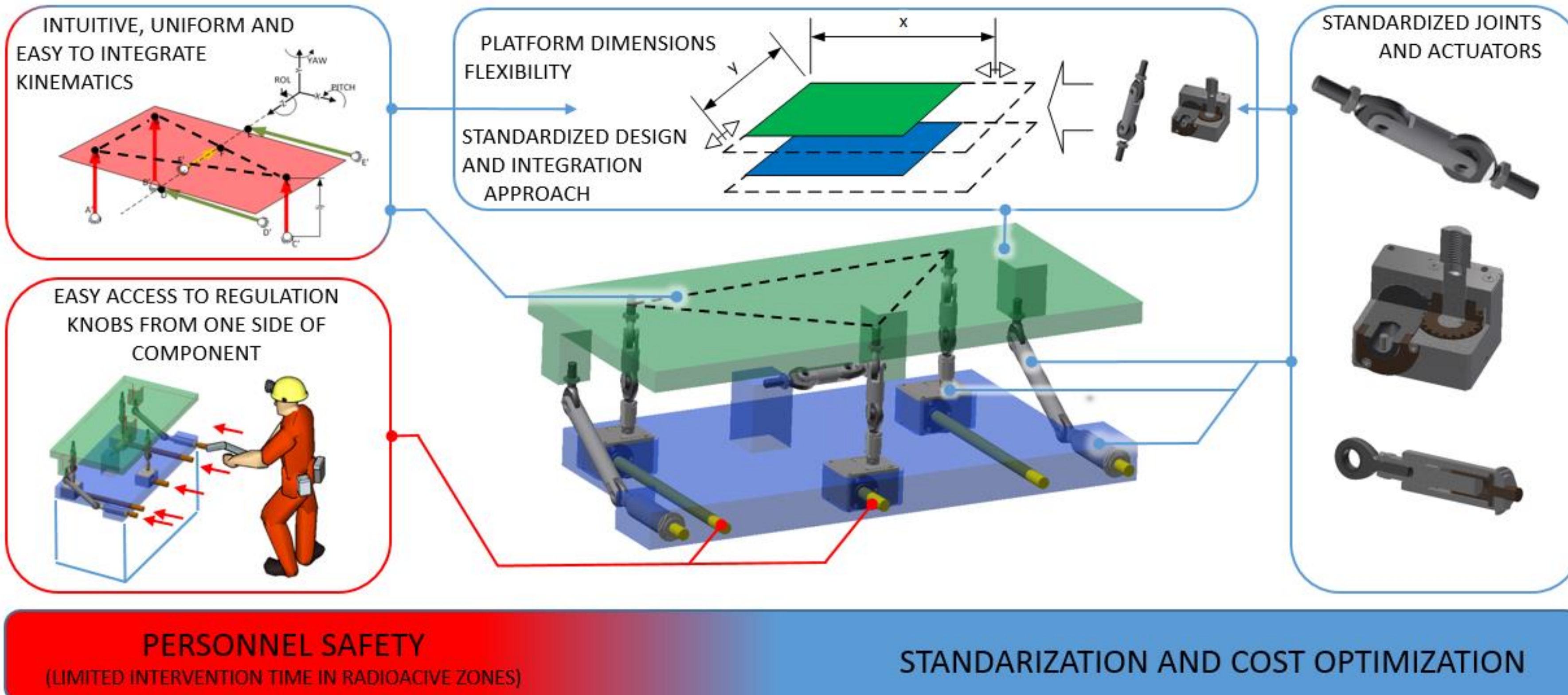
Courtesy R. De Maria (5-2018)

How to bring the full remote alignment into the collimators

Standardized adjustment solution - objective

Definition of set of design rules and development of standardized and modular components to:

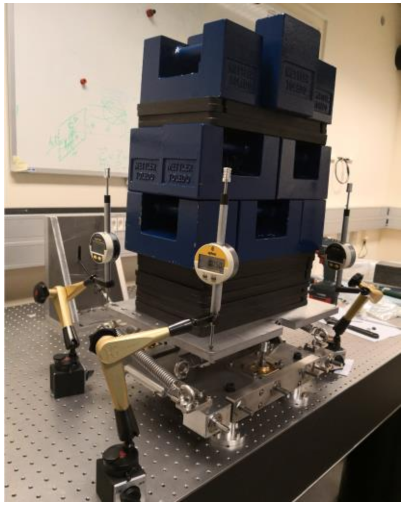
- increase safety of surveyors
- unify the way of small (<2T) accelerator components (not only collimators) adjustment systems is integrated providing a standardized approach through the HL project



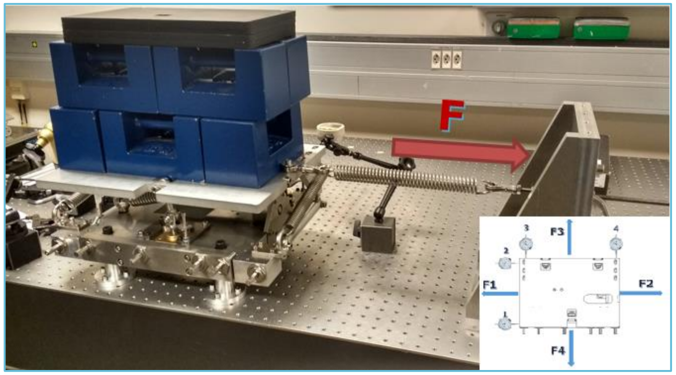
The exact physical interface between the collimator and the alignment platform is still under development and study

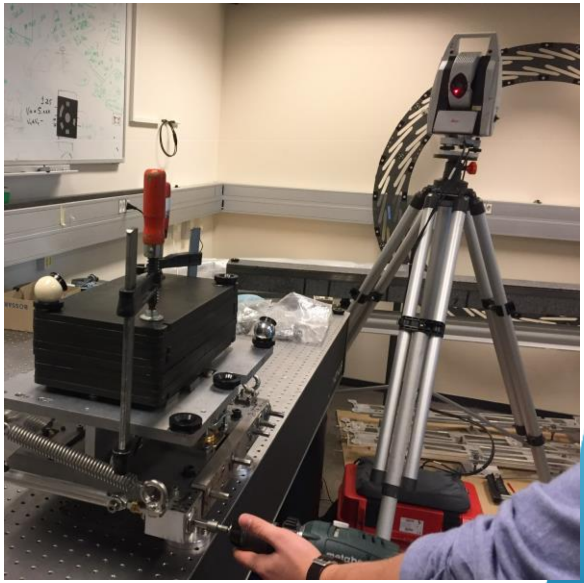
Courtesy M. Sosin

Standardized adjustment solution - status



- Small platform (max load 300..500kg) functional prototype preliminary tests performed 10.2018 – 1.2019:
  - Verification of actuators and different joints types parameters
  - Measurements of platform directional stiffness and backlash
  - Behaviour of platform under different load
  - Verification of overall platform operation, adjustment ergonomics and resolution
- Issues with actuators and joints backlash detected – upgrade is necessary
- Batch of actuator prototypes irradiated in Fraunhofer institute (3MGy step done, 10MGy test ongoing) – no issues detected
- Functional prototype validation targeted end of May 2019 (after final tests with upgraded components)





Courtesy M. Sosin

Implementation of the Remote alignment in the WP5 (Collimation)

- Financial resources have been allocated for the modification of the collimation system to comply with the Full Remote Alignment
- These cover the alignment tables to be integrated in the collimators support, the personnel for the development and the prototype phase
- Actuators and sensors in the table are not going to be procured by the WP5, but by WP15.4 (EN-SMM) in the sake of uniformity and homogenization of the solution through the project and the machine
- As the real cost of the alignment tables is linked to the results of the ongoing development and tests, a provision has been kept in WP1, in case of cost over-run
- We target to have a detailed functional spec of the whole Full Remote Alignment ready for end of May for Project discussion and approval
- We are setting up a review of the alignment system for end of August in preparation for the C&S review 2019

CONCLUSION

- The Remote Alignment has been introduced in the project officially since November 2018 after 6 months of studies
- It has bee endorsed in TCC, budget allocation for each WP agree, the ECR for its formal approval (together with the Matching Section Optimization) has been drafted. It is part of the new HL baseline optics 1.4
- It allowed to re-optimize the Matching Section providing system simplifications, performance improvement and cost reduction
- The collimators are one of the systems impacted by the Remote Alignment and they
  - Need to integrate new alignment capabilities, but
  - They gain in terms of design simplifications
- The development of an alignment table can be lately integrated (if useful) in other collimators, but this is not and it will not be part of the HL project