Short report from Chamonix 2018 LHC Performance Workshop

HL TCC 46

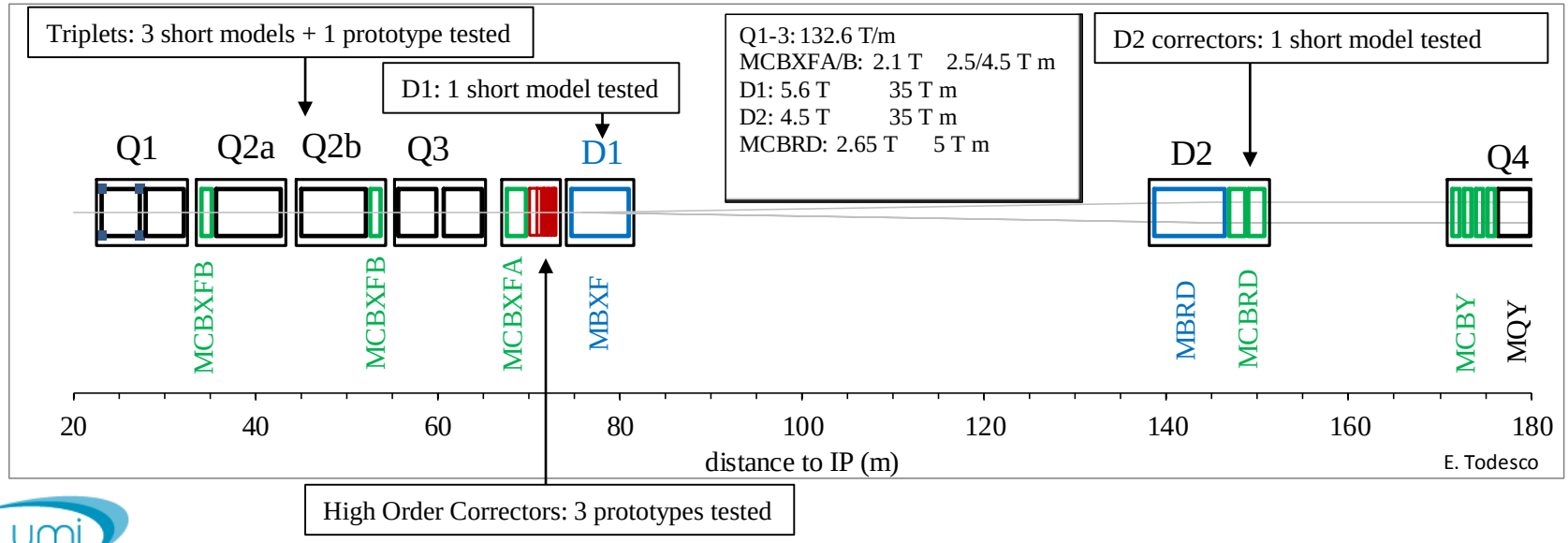
Lucio Rossi

Summary of the Session 4: HL-LHC developments

- Scope: to review status of main HL equipment requiring development (Crab Cavities and 11 T shifted to session 6)
  - Chairs: Susana Izquierdo Bermudez – Lucio Rossi
  - HL-LHC Magnets for IRs. Ezio Todesco
  - HL-LHC Cold Powering
    - Challenges and Progress on baseline. Amalia Ballarino
    - Are there viable options? Arnaud Devred
  - Heat deposition & dose on SC magnets. Francesco Cerutti.
  - Update on Collimation. Stefano Redaelli
  - ATS optics: MD results and outlook. Stephan Fartoukh

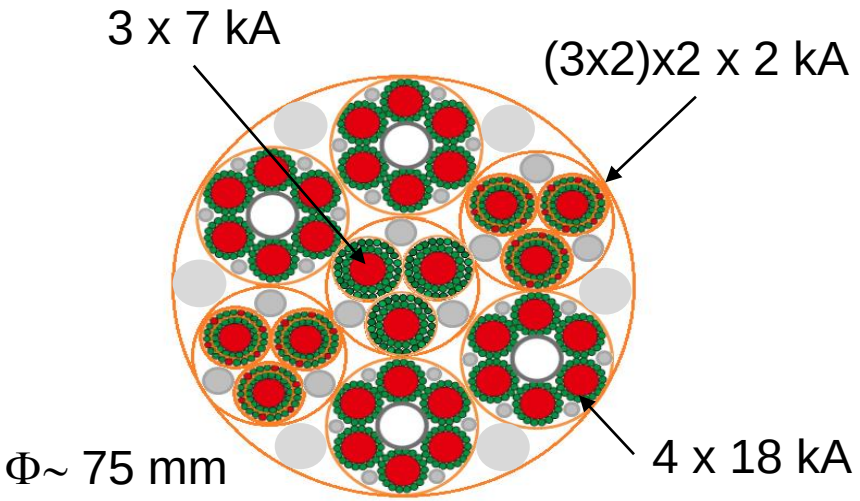
HL-LHC Magnets for IRs

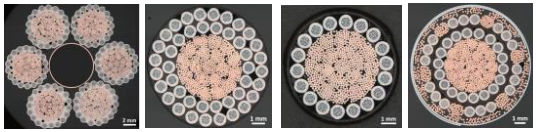
- 11 types of magnets to be built (4 mains and 7 correctors)
  - Agreements with US (Q1/Q3), CIEMAT (MCBX) and INFN (High Order Correctors) to make the series magnets.
  - The prototype and series production of D1 is under negotiation with Japan.
- **6 out of the 11 magnets have been built and tested, confirming the validity of the design.**
  - The rest (5 magnets) will be completed and tested in 2018.
  - Reproducibility of performance is a key issue for Nb_3Sn models not yet fully resolved
- Options under consideration:
  - Re-use of Q4 and Q5 as present LHC (also same correctors), needs full remote align.
  - Increase high order correctors strength to cope with actual Nb_3Sn field quality



Cold Powering System for HL-LHC: baseline, progress on design and challenges

- Innovative robust solution relaying on MgB_2:
  - **Industrial production of MgB_2 wire started** (180 km procured, 300 km being delivered).
  - **First stage of the industrial cable production started** (~3.1 km of wire successfully cabled).
  - SC Link Test Cryostat under test.
  - DFX and DFH (novel concepts) demonstrators under construction.
  - Intensive studies on-going for the development and qualification of the splices.
- **Key Milestone: Test of a 60 m long demonstrator** system by end of 2018 to confirm the viability of whole system.



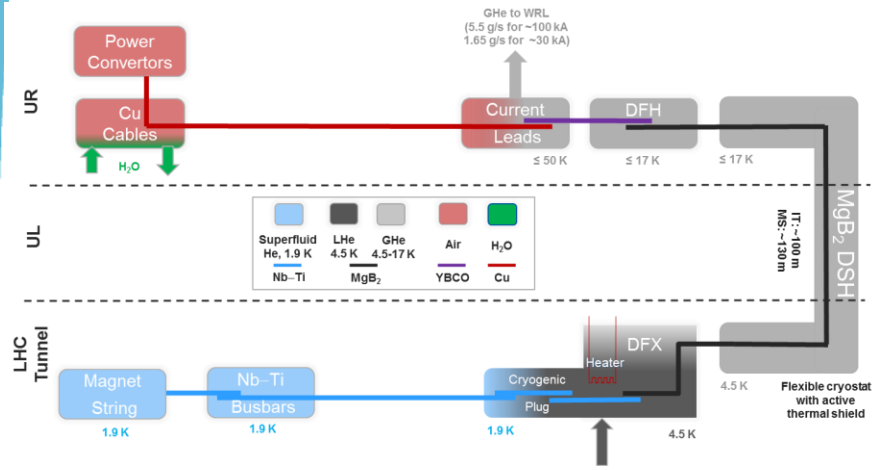


First industrial cabling of MgB2 cable for HiLumi Sc links

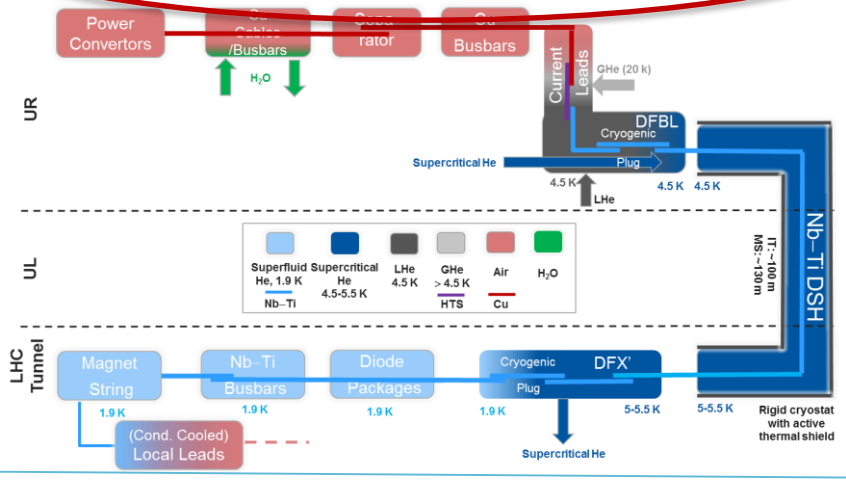
SC links demonstrator test prepration in SM18

HL-LHC Cold Powering: are there viable options?

- **MgB_2** (Baseline, with novel DFH/X layout)
  - Viable and innovative option
  - Does not have technical showstopper
  - **Design and development to be completed by end of 2019.**



- **Nb-Ti variant** (but with Hilumi layout for DFH/X)
  - Back up solution relaying on well known technologies (proved in DSL for LHC)
  - Lower operation margin
  - Nb-Ti strand and cable development program needed.
  - **Requires design studies and R&D: decision needed before end of 2019 for installation in LS3**



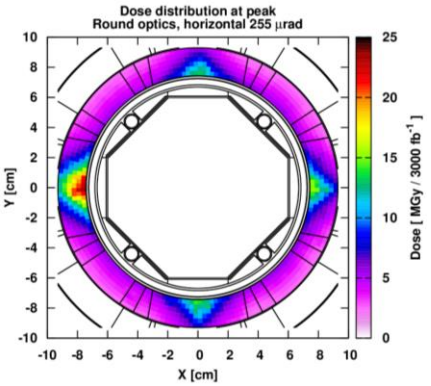
- **Copper variant** (not viable option at this stage)
  - Needs changes of the civil engineering
  - Additional power consumption of ~4 MW, and extra cooling and ventilation capacity.
  - Maintenance issue due to activation in DFBX area of the LHC tunnel.

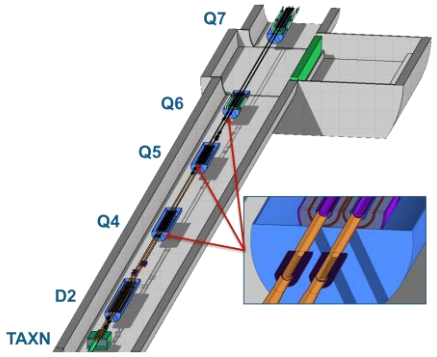
Heat deposition and radiation dose vs operation mode and mitigation schemes

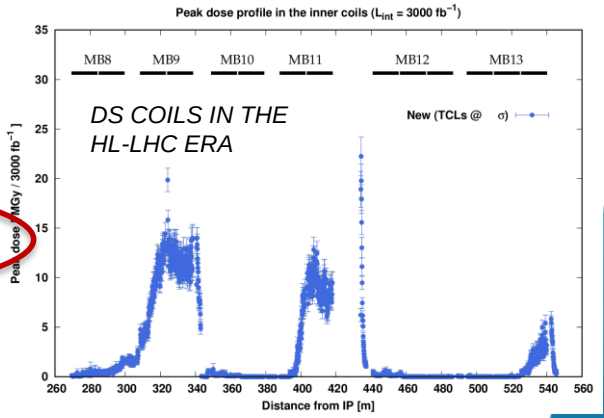
- Inner Triplet Region (Q1 to D1)
  - Peak dose < 30 MGy after 3 ab^{-1} (less than LHC after 300 fb^{-1})
  - The crossing angle variation along the fill offer a 10% gain for the considered schemes.

- Matching Section
  - Despite the weaker TAXN effectiveness, collimators and masks can offer a reasonable protection to the matching section (Peak dose < 9 MGy after 3 ab^{-1})
  - The use of the present LHC Q5 (option under consideration) can be acceptable despite the increased dose due to its smaller aperture.

- Dispersion suppression
  - Losses are expected to respect lumi scaling, inducing for an ideal aperture profile a max dose of about 15 MGy after 3 ab^{-1}, with sensitivity to imperfections.
- **All elements withstand ultimate lumi of 4 ab^{-1}**







Collimation update

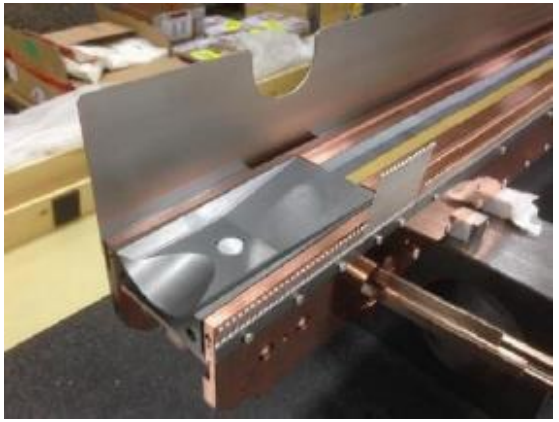
- Solid baseline, with important collected results in 2015-2017 which demonstrated the key solutions for LS2.
- Key prototype activities were carried out successfully

TCLD (Dispersion suppressor collimator)

Prototype completed, design finalized for LS2 production (4 units + 1 spare)

TCSPM (low impedance prototype)

Impedance measurements with LHC beam confirmed that the baseline Mo coating is adequate, ambitious plan to asses robustness in 2018.

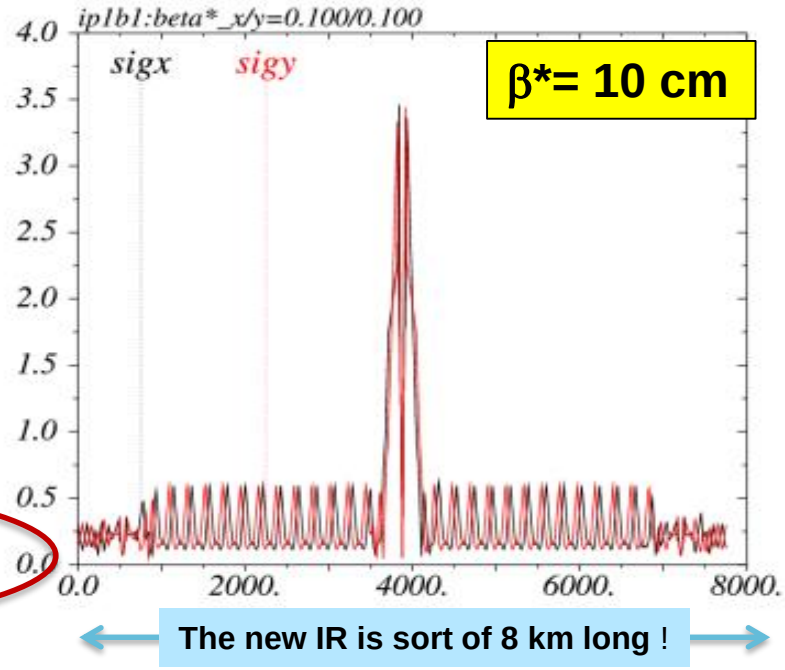


- DS collimation in P7 (11 T): Very good with protons. Further improvement of ion cleaning maybe be required (2016 re-baselining has reduced the collimators and 11 T).
  - More quench test with ions needed in 2018!
  - If needed **crystal collimation system, very effective for ions**, may be implemented (decision by beginning 2019).

Experience with ATS optics in 2017: LHC nominal operation and MD's

- Achromatic Telescopic Squeezing **is a vital ingredient for HL-LHC.**
  - A kind of generalized squeeze involving 50 % of the ring.

- So far, regardless of the ATS, the beam follows precisely the MADX expectations
  - ATS MD's in Run I (2011-12) demonstrated the basics
  - **ATS MD's in Run II (2016-17-..18) studied a new version of the ATS optics** (optimized for machine protection aspects)



- Challenges are ahead, such as preserving state-of-the-art optics correction at large telescopic index. Next steps for ATS 2018 MD's:
  - Flat optics development with a few trains for BBLR studies
  - Round optics with large telescopic index at full intensity for e-cloud studies with tele-optics
  - Preparation of the decision making process for the Run III optics: **flat vs. round optics.**

HL-LHC open issues and options

- Scope:
  - Review of the baseline scenario after the re-baselining in June 2016.
  - Analysis of open issues and mitigation of the corresponding risks
  - Required studies and developments
  - Options
- Chairs: Gianluigi Arduini – Dario Pellegrini

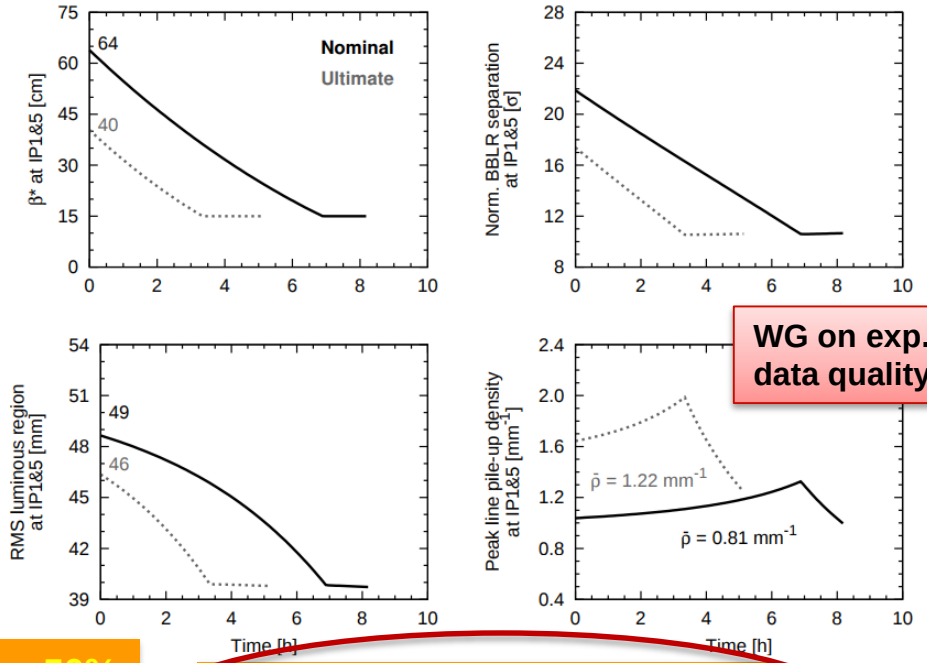
- Programme:
  - Summary of the HL-LHC baseline and operational scenario (L. Rossi)
  - Digesting the LIU high brightness beam: is this an issue for HL-LHC? (G. Iadarola)
  - Optics correction strategy, cycle optimization and implications for power converter and magnetic measurements performance (R. Tomas)
  - Long Range Beam-Beam effects for HL-LHC (Y. Papaphilippou)
  - Possible further simplification of the matching section (R. De Maria)
  - Alignment: is this an issue for HL-LHC? (P. Fessia)
  - Outcome of the recent review on the e-lens (O Bruning)

HL-LHC open issues and options

- Questions for the CMAC
  - Is our approach for preserving the brightness against blow-up and instabilities realistic? Do we have sufficient margin?
  - Are the back-up scenario and mitigation measures adequate (electron cloud, stability, emittance preservation)?
  - Is there any suggestion on the machine studies that should be performed to address the potential issues?

Recovery of full HL-LHC performance

- New baseline scenario after 2016 re-baselining:
  - optimization of MKD-TCT phase advance for β* reach in any crossing plane configuration
    - smaller protected aperture
    - **smaller β* (15 cm)**
  - detailed analysis of orbit corrector budget and crab cavities re-alignment needs
  - Combined ramp and squeeze based on LHC experience (reduced cycle time)
  - Reduced crossing angle: 500 μrad



WG on exp. data quality

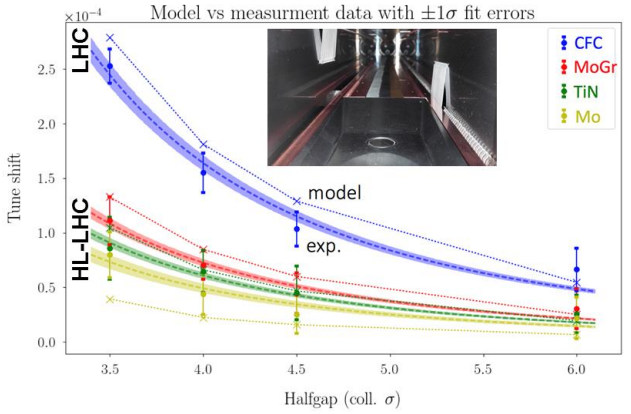
Recovered pre-rebaseline performance with efficiency=50%
(with 58% efficiency we would reach 370 fb-1/y at ultimate)
BUT WITH LESS BEAM MARGIN!!! (margin are on days)

260 fb^{-1}/160 days (nominal)
320 fb^{-1}/160 days (ultimate)

From LHC to HL-LHC

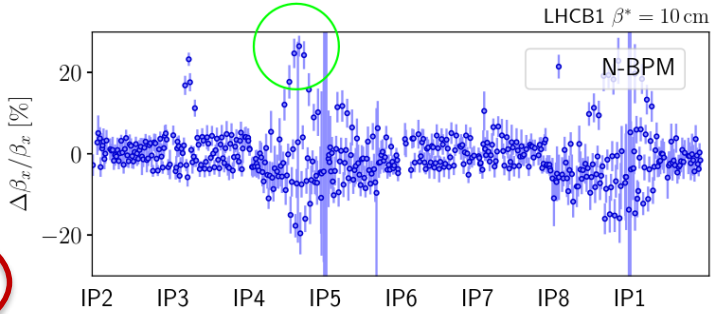
- Difference in heat loads among sectors: identification and suppression of the source is fundamental for HL-LHC
- Validation of the scaling of electron cloud with bunch population is vital: tests in 2018 (8b4e) and Run 3 with LIU beams!
- Backup plan (8b+4e and hybrid schemes) to mitigate performance loss

- Collimator impedance reduction and a-C coating of triplets and matching sections are key ingredients for digesting LIU beams
- Sources of emittance growth in the LHC need to be understood ➔ critical for HL-LHC ➔ Need to keep a low-noise environment for HL-LHC (power converters, transverse feedback, crab cavities)

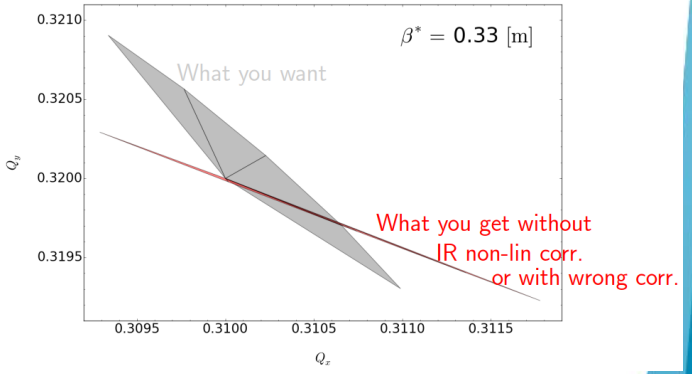


From LHC to HL-LHC

- Excellent measurement and correction of linear and non-linear optics achieved but further improvement required for HL-LHC at low β*.

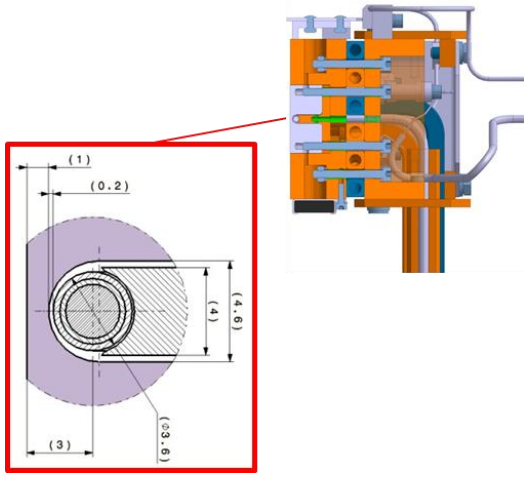


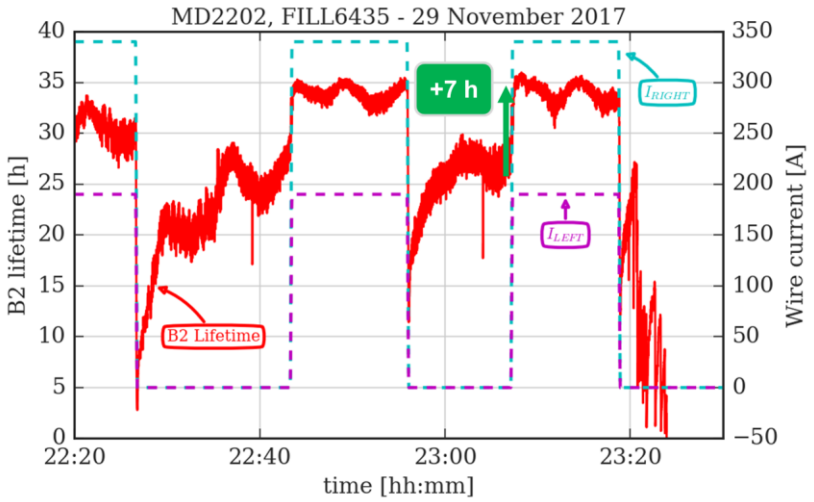
- Rely on:
  - New trim circuit for Q1a (included in the baseline)
  - excellent alignment and magnetic measurements accuracy
  - 2018 experience with β* levelling
  - low tune ripple (option of upgrading of dipoles power converters in Sectors 12/45/56/81)



Developments and Options

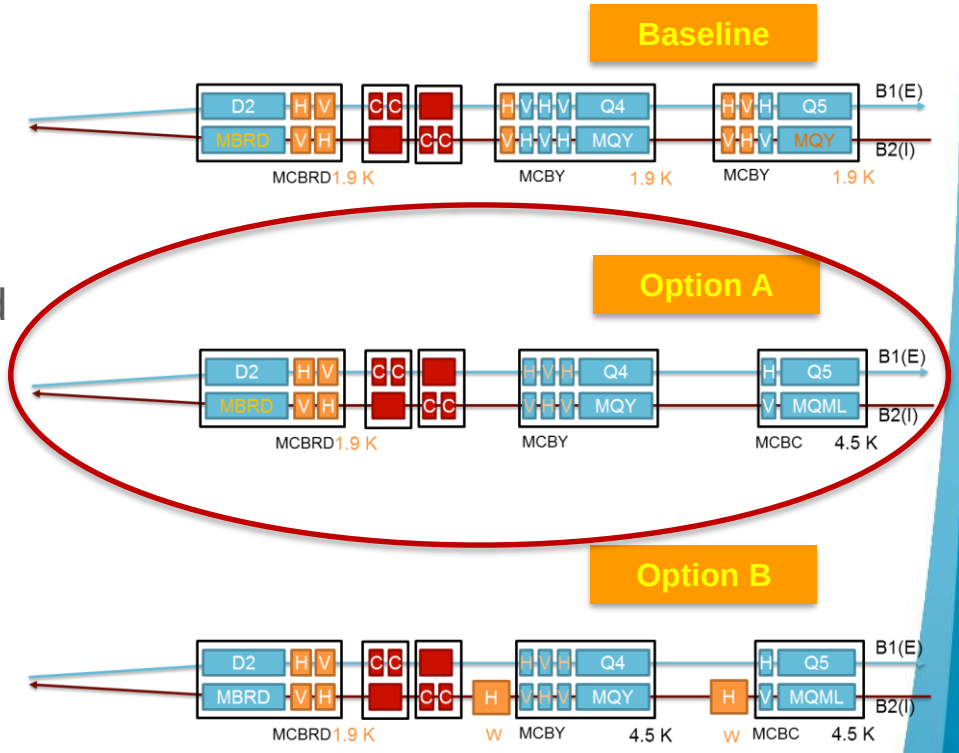
- Possible performance improvements:
  - Adaptive crossing angle ➔ reduction of the pile-up density and triplet radiation by ~10%
  - Upgrade of the triplet power converters in IR2/8 (option) ➔ reduction of turn-around time ➔ performance improvement ~3%.
- First experimental demonstration of BBLR compensation by means of wires as a back-up scenario (option)
  - Experimental program continuing in 2018
  - HW solutions towards the HL-LHC era to be further investigated together with their impact in terms of performance



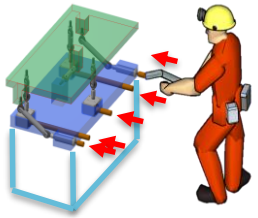


Simplification of the matching section

- Global review of the alignment tolerances and realignment capabilities has been performed
- Two alternative options identified allowing to reuse the existing Q4 and Q5 LHC cold masses:
  - Option A: based on a fully remote alignment system (minor enhancement of the baseline alignment system) ➔ further increase of the available aperture and performance gain
  - Option B: based on the baseline alignment system but requiring the installation of additional warm correctors

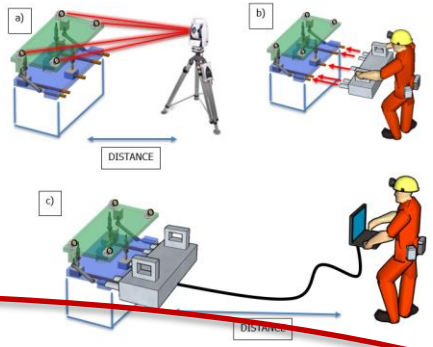


Remote Alignment



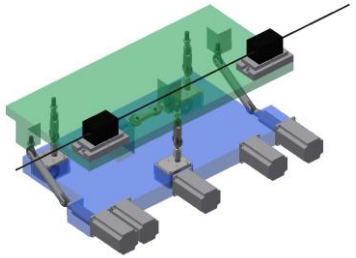
Manual alignment (Dose!)

- Remote alignment system introduced from the beginning of the project to minimize radiation to the personnel
- Thorough review of the alignment scenarios/procedures and of the implications on the HW conducted in 2017:
  - Revealed some missing elements in the baseline
  - Solution found will reduce by more than a factor 10 the collective dose
  - Additional costs estimated



Baseline Remote alignment

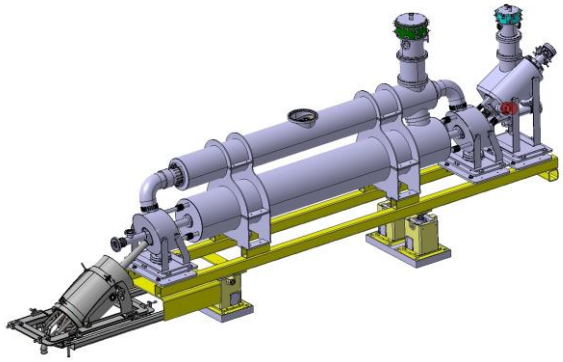
- Enhancement of the alignment system to allow operation from the CCC with safe beams will reduce the modification to the matching section (Option A) and an will provide additional gain in flexibility and performance.
- Analysis of the cost/benefit ongoing



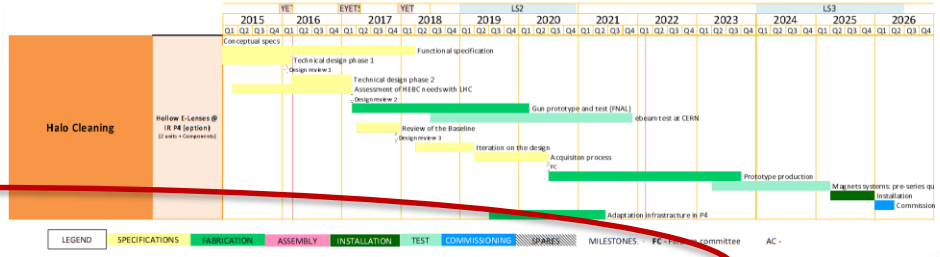
Fully remote alignment from CCC

Hollow Electron Lens

- Necessary tool for halo cleaning and control, machine protection already for the intensity ramp up during commissioning in HL-LHC
- A few more design iterations (inner bore diameter, solenoid field, number and location of gas jet monitors)
- Design (including recent modifications) integrated in IR4. Plan to finalize it in 2018.



- Schedule compatible with installation in LS3 if launched in 2018 and if overlap with activities in LS2 can be avoided



- Want to integrate HEL into the HL-LHC baseline at upcoming C&S review

HL-LHC: Infrastructure; Test Facilities and 11T

- 3rd of 3 HL-LHC sessions:

  Session coordination: M. Modena and O. Brüning

- Main scope and goal:

  Review the Status of the planning for the new HL-LHC Infrastructures; the preparation of the HL-LHC related Test Facilities and the 11T magnet program

- This Session featured 7 presentations:
  - Update on the HL-LHC CE plans ➔ L. Tavian
  - SPS Crab Cavity test preparation ➔ R. Calaga
  - Update on the 11T magnet development ➔ F. Savary
  - Beam Screen coating for Pt2 and Pt8 ➔P. Chiggiato
  - SM18Facility Readiness ➔ M. Bajko
  - Update on the Pt4/SPS Cryo upgrade ➔ S. Claudet

HL-LHC: Infrastructure; Test Facilities and 11T

C-MAC Charge:

Are the preparations for the technical test facilities on track for the HL-LHC LS2 installation and commissioning schedule?

Do the planned test facilities and test programs address the appropriate technical risks of the new equipment?

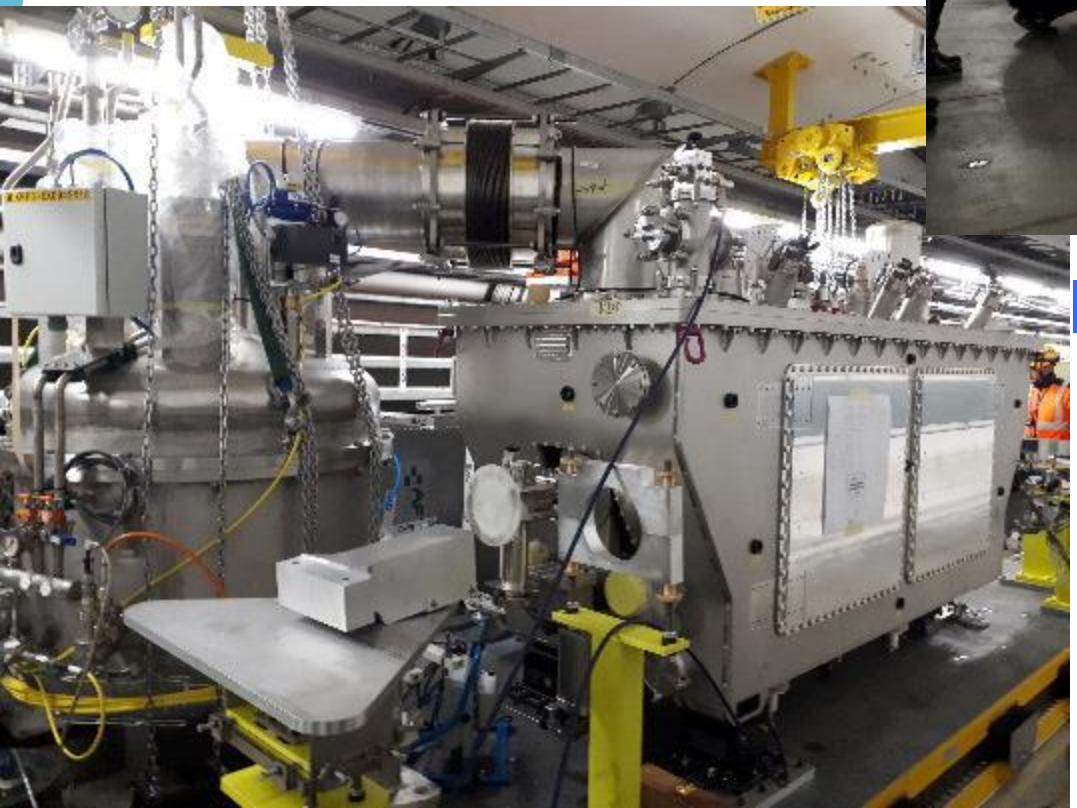
Are the plans for in-situ upgrades of existing LHC technical infrastructure on track for the planning of the HL-LHC project?

C-MAC Findings:

The preparation of the civil engineering works is well advanced and the contracts are going to be placed on time.
Good progress on CC activities despite some technical issues.
The CM is almost ready for the test with SPS beams.

HL-LHC: Test Facilities Readiness

- Crab Cavities in the SPS: Cavities installed, cryo is tackling technical issues (non-conformities & leaks)



- Tests at SPS will provide info and validation for Crab Cavities installation in LHC; Upgrade of LLRF electronics still required for HL-LHC (under study)

HL-LHC: Infrastructure; Test Facilities and 11T

General Observations:

-Civil Engineering is well advanced: opening of bids at beginning of 2018 ➔ signing of contracts by March 2018 (in agreement with actual schedule)

-11T magnet performances not yet at ultimate field but good understanding with short magnet test program!

-String Test preparation and upgrade of SM18 are well underway!

-2 options at hand for beam screen coating: a-C coating could be implemented in Pt2 and Pt8 in LS2; LESS not ready yet for LS2 ➔ a-C coating of standalone magnet in LS2; final treatment in LS3

-Cryogenic Upgrade: baseline for Pt4 changed from new dedicated cryoplant to an upgrade of the existing plant; Pt1 & Pt5 feature new cryoplants; distribution line design under final revision due to change in the magnet baseline