HiLumi
HL-LHC PROJECT

TCC summary and HL-LHC Baseline evolution

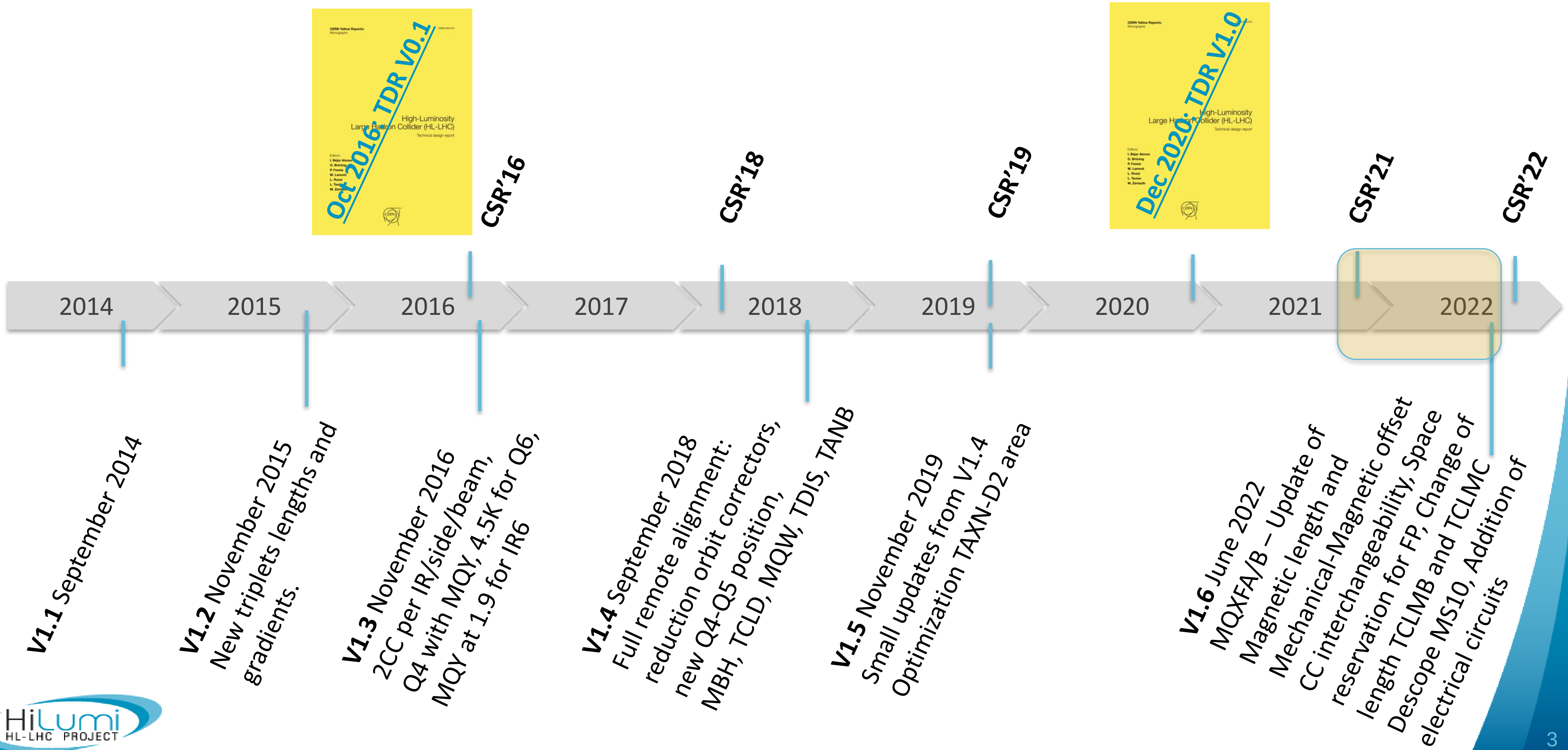
Markus Zerlauth – CERN
On behalf of the HL-LHC project

Uppsala – September 19th to 23rd

Outline

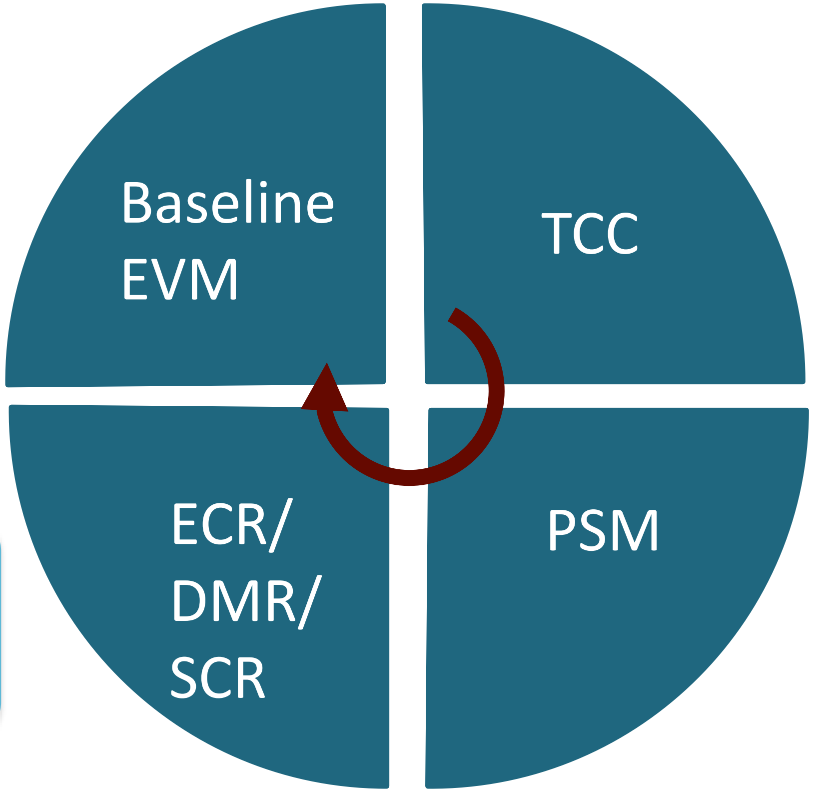
- Overview and managerial process of Layout and Baseline evolutions
- HL-LHC baseline evolution since Annual Meeting 2021
  - Approved/implemented baseline changes
- Upcoming baseline changes under preparation
- Conclusions

Evolution of Project Baseline (Machine Layout Versions)



Managerial process

Baseline EVM:
Implementation of changes in WP's Cost-to-completion



Technical Coordination Committee:
Technical assessment and decision on **scope changes** and consequences on schedule/cost

Engineering Change request:
scope change assessment & approval
Decision Management Report:
Cost/schedule change

Schedule Change Request:
change impacting master schedule of WP/project

Project Steering meetings, per WP:
Assessment and decision on **budget changes** and **schedule changes**

Courtesy: G. Vandoni

Project Organization for Managing the Process

PSM
Project Steering Meetings

- Started in 2017
- Scope: review of each WP by HLPO with GL & Dep. Head concerned, of: budget, MS & DLV, procurement and production plan
- **Chaired by HLPL**
- **So far 205 PSMs**
  - **40 in 2017**
  - **38 in 2018**
  - **70 in 2019**
  - **71 in 2020**
  - **48 (+7) In 2021 / not counting C&SR preparation**
  - 4 times :WP3 / WP4 / WP5 / WP6A / WP17
  - 3 times: WP6A / WP7 / WP8 / WP9 / WP12 / WP13 / WP15 / WP16
  - Twice: WP2 / WP10 / WP14 / WP18

TCC
Technical Coordination Committee

- Installed in 2016 (merging TC and PLC of HiLumi)
- Chaired by DPL
- In total 162 meetings (ca. 28/y)
- 540 presentations
- Average attendance of ca. 60 people in remote! Since May this year very successful return to in-presence meetings with similar attendance!

Collaboration Steering Committees

- Organized for each Collaboration
- **Chaired by Collaboration partner and PL**
- **At least once per year per collaboration**
- **In total ca. 42 Meetings so far, 9 in 2021**

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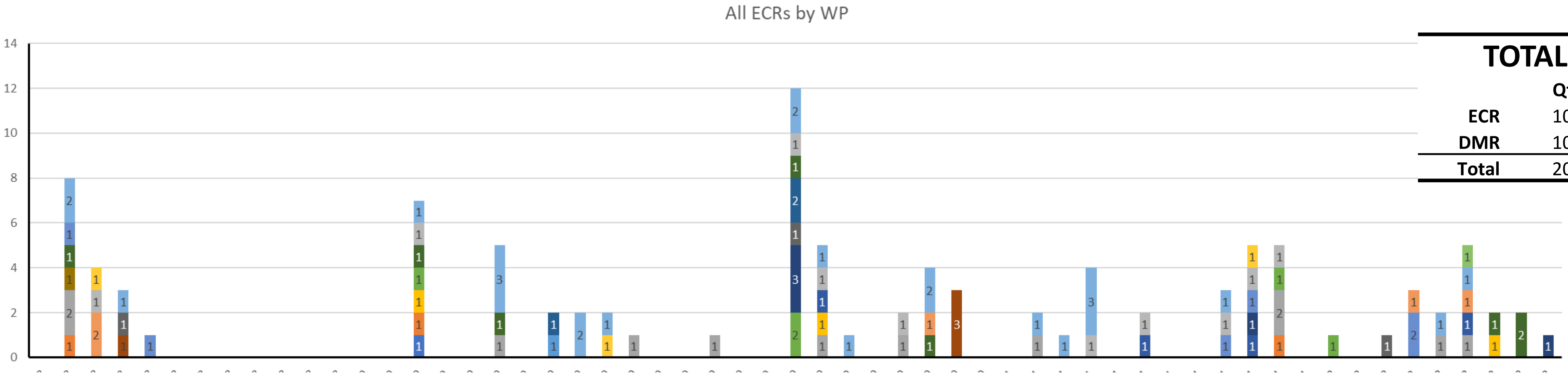
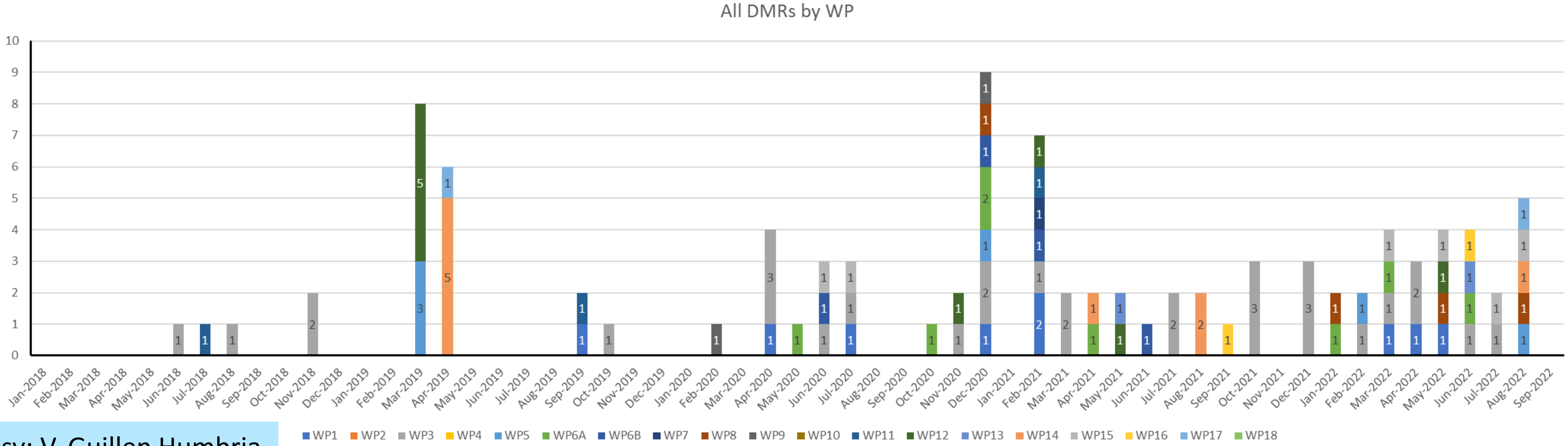
ECRs and DMRs by WPs throughout the project

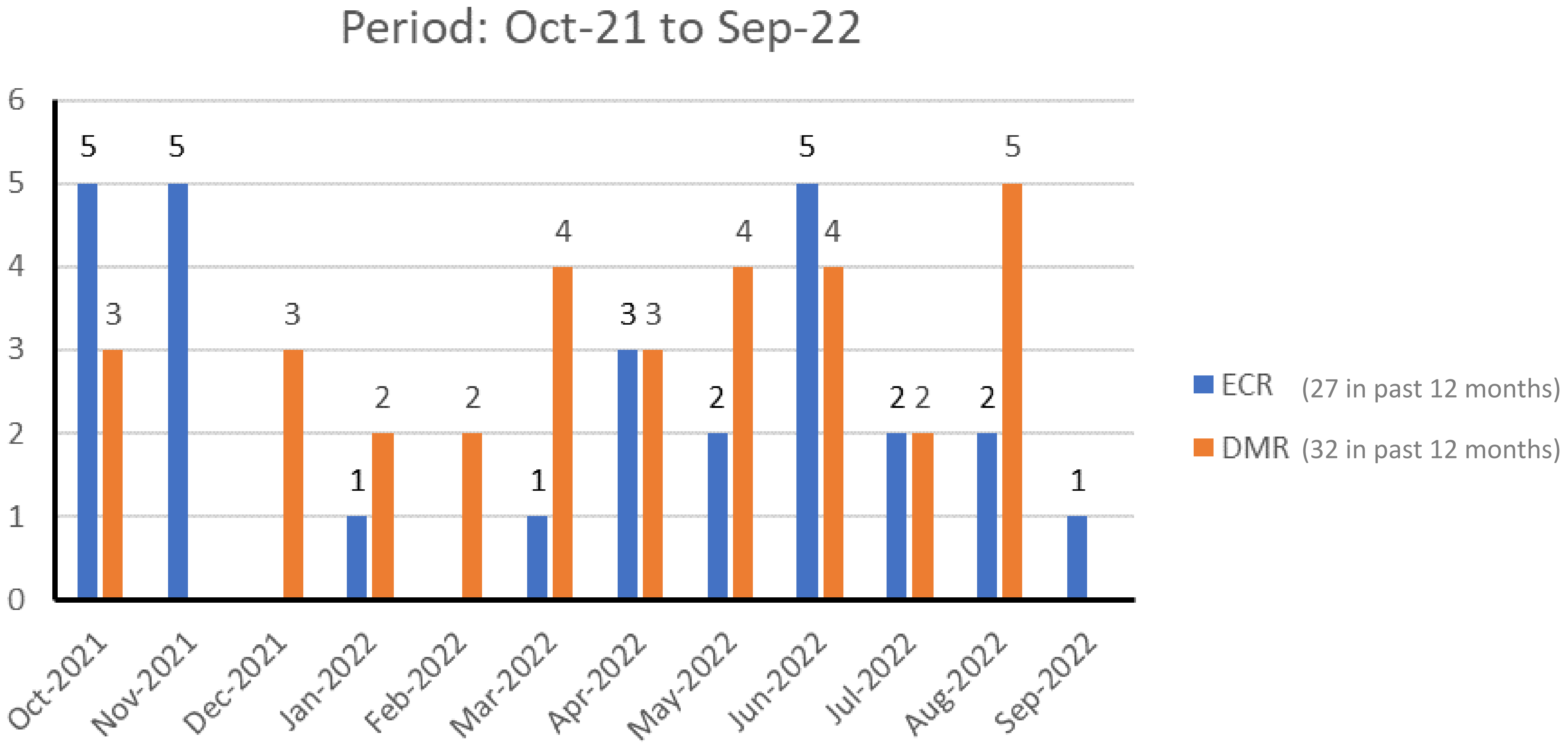


TOTALS	
	Qty
ECR	102
DMR	105
Total	207



Courtesy: V. Guillen Humbria

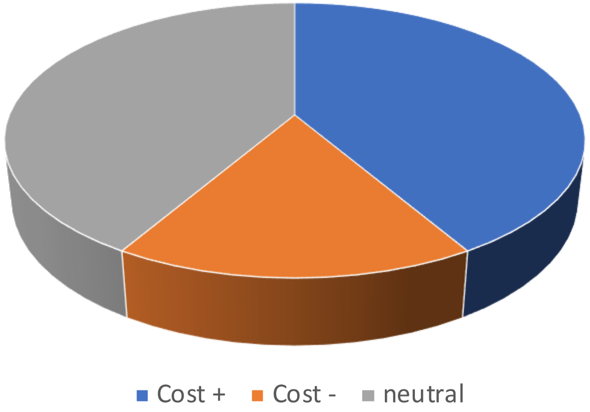
ECRs and DMRs since last Annual Meeting

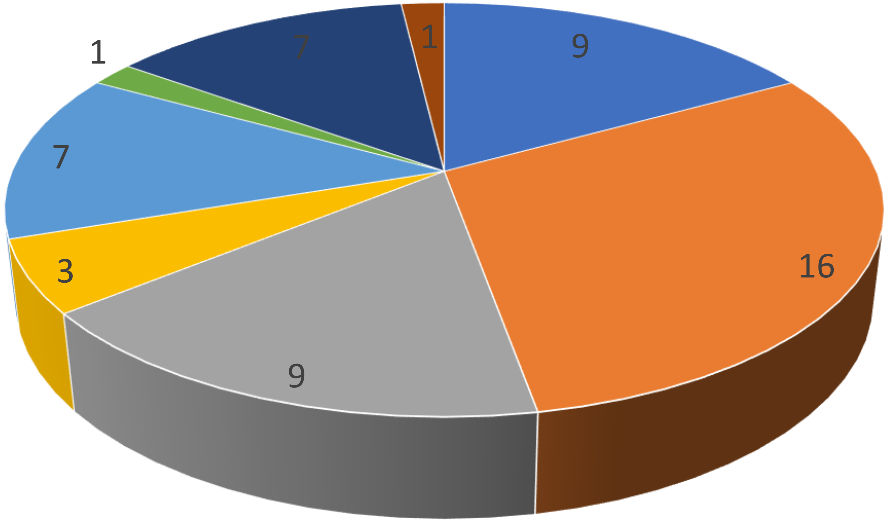


Courtesy: V. Guillen Humbria

Reasons for Baseline changes can be varied

- Performance Risk mitigation (design optimisations,..)
- Schedule risk mitigation (in-sourcing of late in-kind contributions)
- Descoping (in-kind, deferrals not necessary for LS3, coating options…)
- Additional scope (managerial decisions, controlled CD/WU, access bridges,...,
- Overcost (tenders in current market situations)
- Missed scope (typically at interfaces)
- Overcost risk mitigation
- Other





HL-LHC Baseline Changes (via ECRs/TCC)

Oct'21 | Nov | Dec | Jan'22 | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec'22

Oct'21
- New baseline for IT String Utilities and Measurements
- Controller for FGC3 power converters

Nov
- Cable Routing for CP package ad ELQA rack
- Updated design of inner layer for MCBXFB
- Access bridges over beam line elements
- Deferral of Installation of Lattice Sextupole in Q10 in Points 1 and 5 to LS4

Dec
- Descoping of BPMQSWZB
- WP6a controlled WU/CD

Jan'22
- Change of conceptual Layout of DFHX/DFHM

Feb
- Crab Cavity Instrumentation (APWL pick-ups)
- Double QXL and suppression of QUIG

Mar
- FRAS functional software specification
- BPM specification
- Replacement of BPTX by BPTQX

Apr
- Installation of DIS readers
- Update of MQXFA/B length

May
- High-performance variant of the DI/OT platform for the Full Remote Alignment System
- New UR layout and WCC/ACC
- High Current DC busbars for the IT and MS magnet strings

Jun
- Update of magnet delivery plan to IT String
- Energy extraction systems for the HL-LHC RQSX3 circuits

Jul
- Naming conventions for functional position codes for HL-LHC buildings and galleries

Aug
- Vac equipment support modification
- Maintaining option of swapping X-plane for CC in Layout V1.6

Sep
- Descoping of dedicated Interlock channels for very fast failure cases
- Descoping of a-C coating in the standalone magnets

HL-LHC Baseline Changes (via ECRs/TCC)

Cable Routing for CP package ad ELQA rack

New baseline for IT String Utilities and Measurements

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Descoping of BPMQSWZB

FRAS functional software specification

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Controller for FGC3 power converters

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High Current DC busbars for the IT and MS magnet strings

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Energy extraction systems for the HL-LHC RQSX3 circuits

Maintaining option of swapping X-plane for CC in Layout V1.6

Descoping of a-C coating in the standalone magnets

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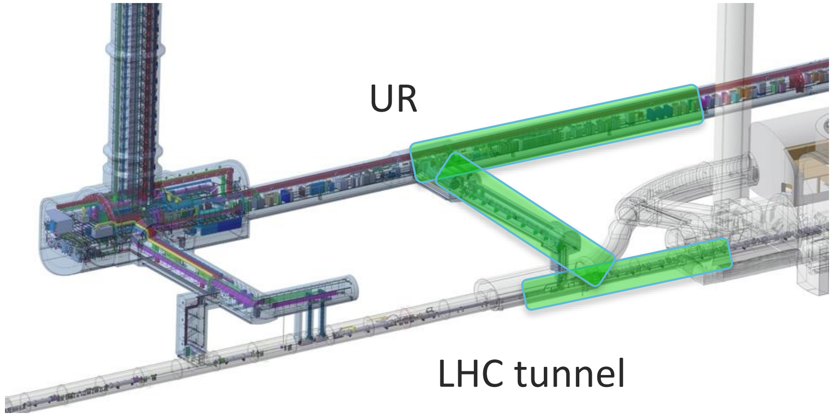
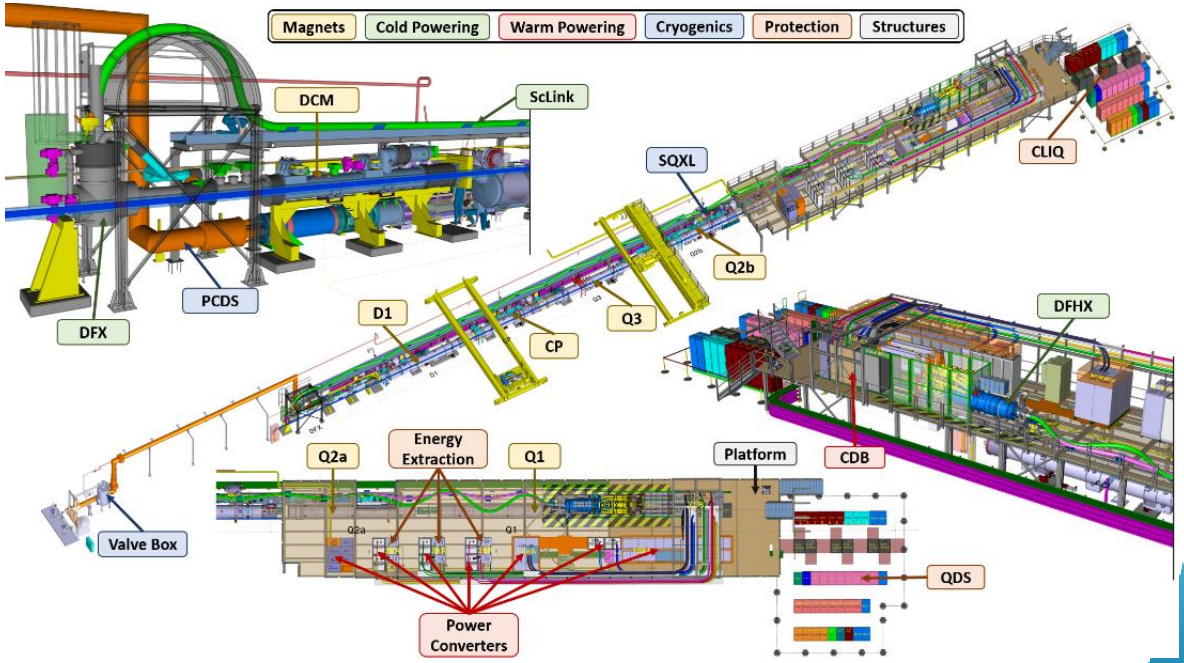
WP16 – IT String

LHC-XMSAH-EC-0001 v.1.0 New Baseline for IT String utilities



Modifications of the IT String utilities to be conform to the integration and the technical design of the HL-LHC inner triplet equipment in the tunnel (AC distribution, WCC and busbars, power converters and integration, signal cabling...). As such, the HL-LHC IT String integration will be preserved to be as close as possible to the installation of the IT zone in the tunnel to validate and solve potential issues that might arise during installation and operation in the final tunnel configuration.

IT String control room in SM18



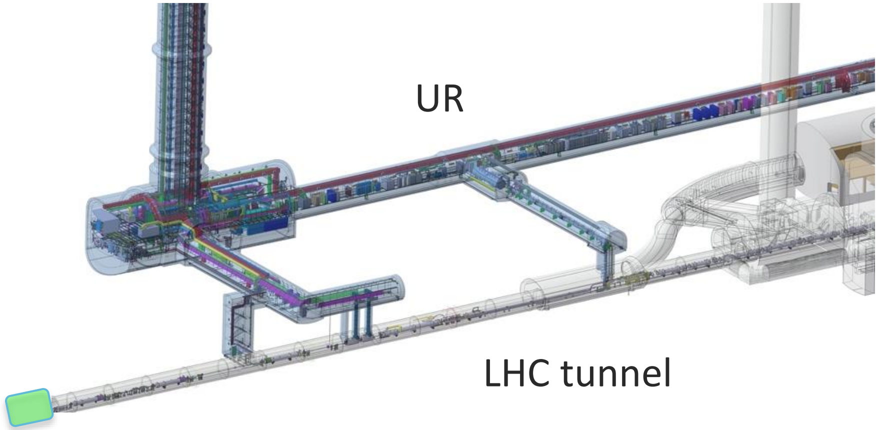
HL-LHC IT String Day II on 15/09

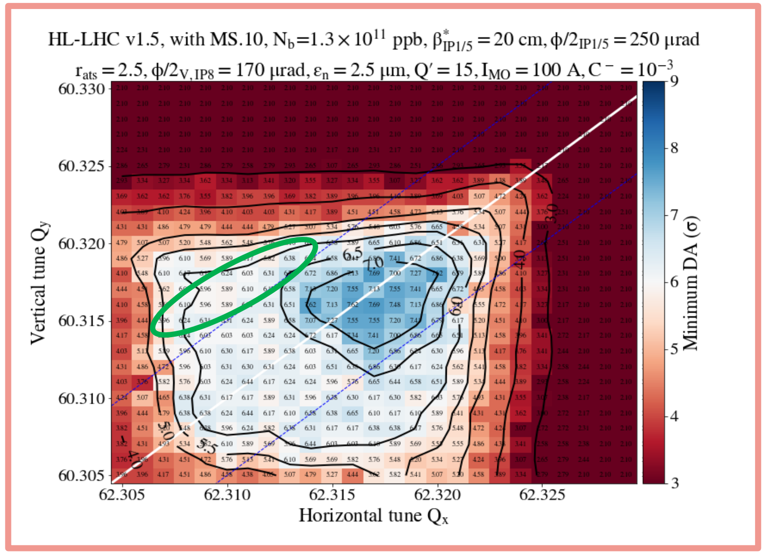
IT String and infrastructure integration in SM18

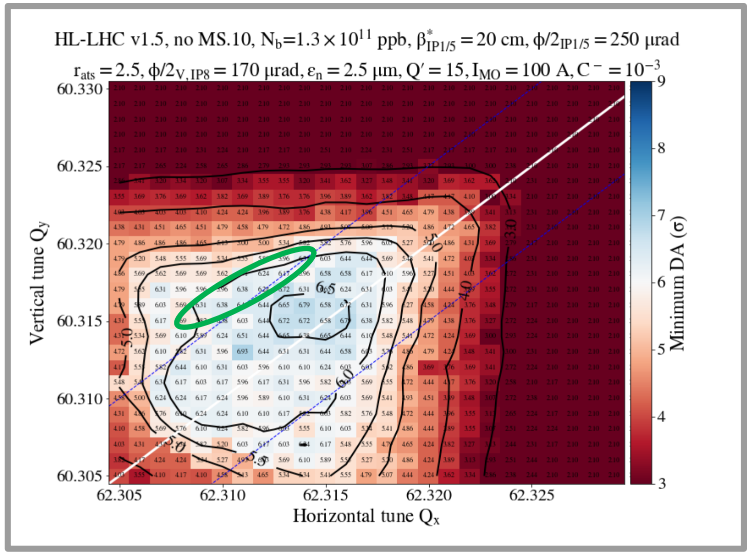
Beam optics and magnet system (WP2/WP3)

LHC-M-EC-0005 v.1.0 Deferred Installation of additional sextupole at Q10 in P1 and P5

Simulations showed that this modification is not absolutely required to meet the performance goals of Run 4 (i.e a beta*=20cm). It was therefore agreed to defer the installation of the MS in Cell 10 in Points 1 and 5 from Long Shutdown 3 (LS3) to LS4 in order to alleviate the workload for de-/installation and magnet refurbishment activities during LS3.







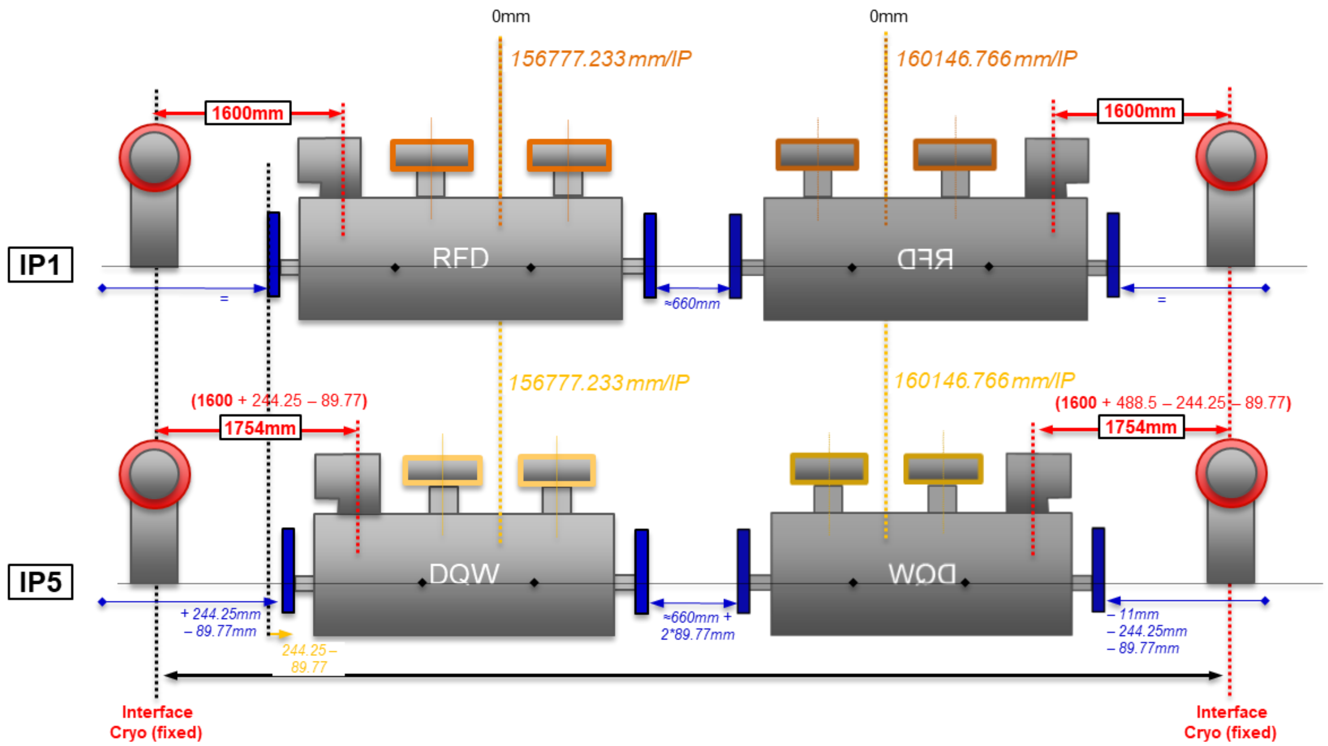
Dynamic aperture with (left) and without (right) additional lattice sextupole at Q10

Lower beta* represents important performance risk mitigation in view of bunch intensity limitations!
Proposed for re-inclusion in baseline following shift and extension of LS3

Crab Cavities in optics version 1.6

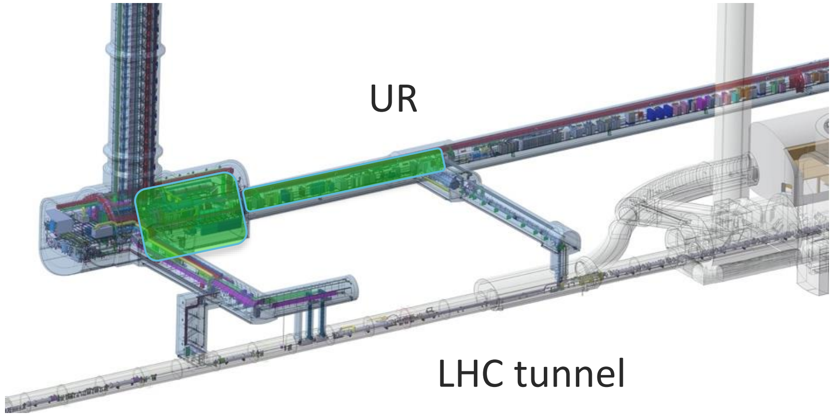
[LHC-ACF_A-EC-0001v.1.0](#) Crab Cavities in optics version 1.6 – Shift of Civil Engineering cores, adaptation of cryogenic and of vacuum elements

Two types of crab cavities and, therefore, cryomodules are required: the Double Quarter Wave (DQW) in IP5 and the RF Dipole cryomodule (RFD) in IP1 where the crossing angle is implemented in the horizontal plane. To maintain interchangeability of the crab cavities between IP1 and IP5 following a revised cryo-module design, interfaces and integration are updated.



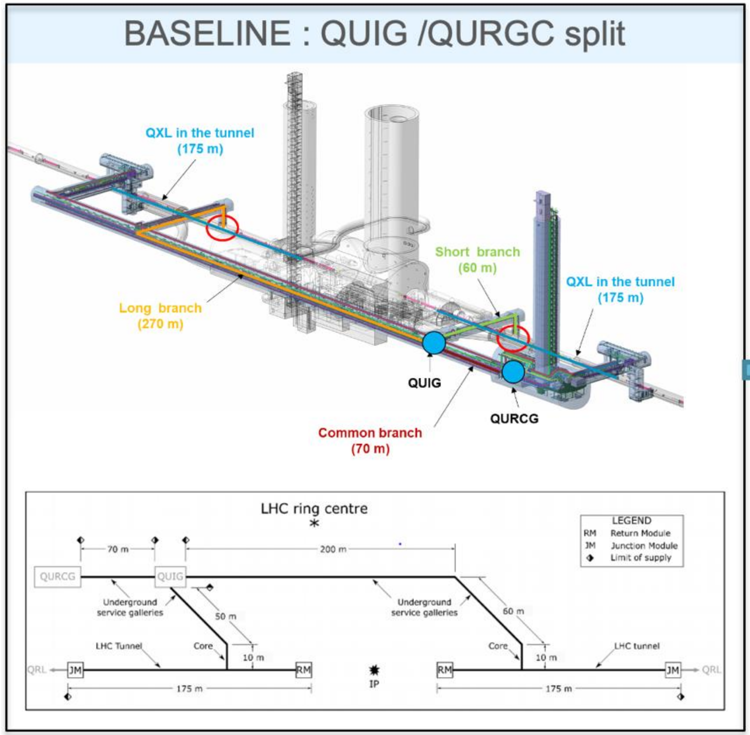
Cryogenics (WP9)

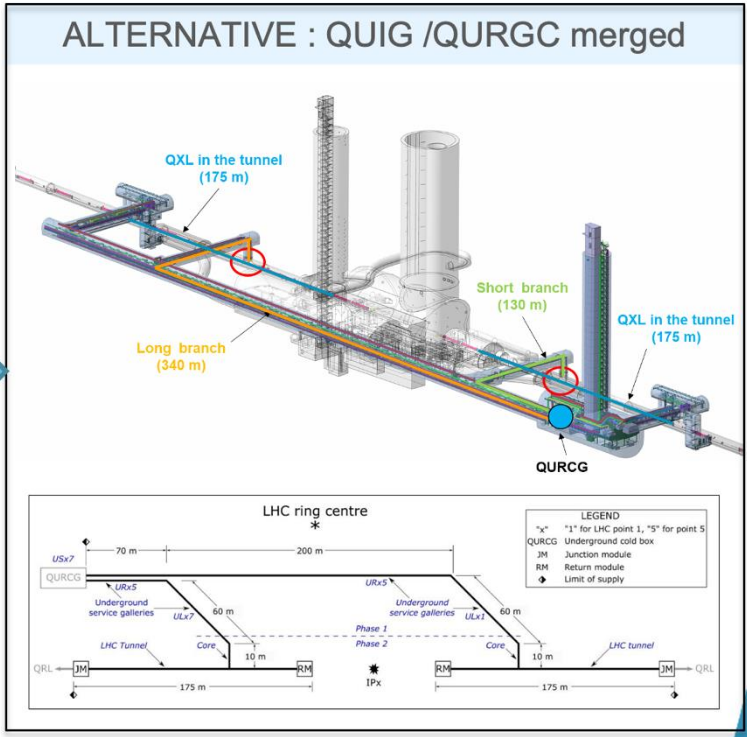
LHC-QUIG-EC-0001v.1.0 Suppression of interconnection box QUIG



Proposed simplification of the cryogenic architecture and suppression of the independent QUIG in the HL-LHC Layout version 1.6.

- Functions at the origin of QUIG were studied and attributed to other sub-systems (or simply not retained)
- study was started with double QXL directly from US cavern, both for process and integration aspects

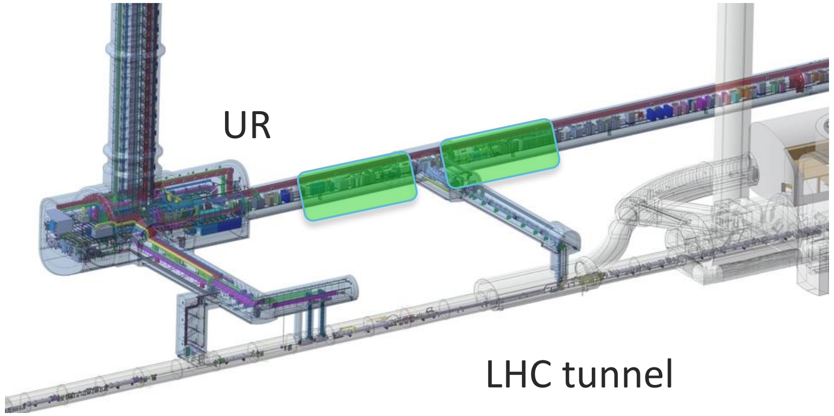




Powering System – UR side (WP6a/b)

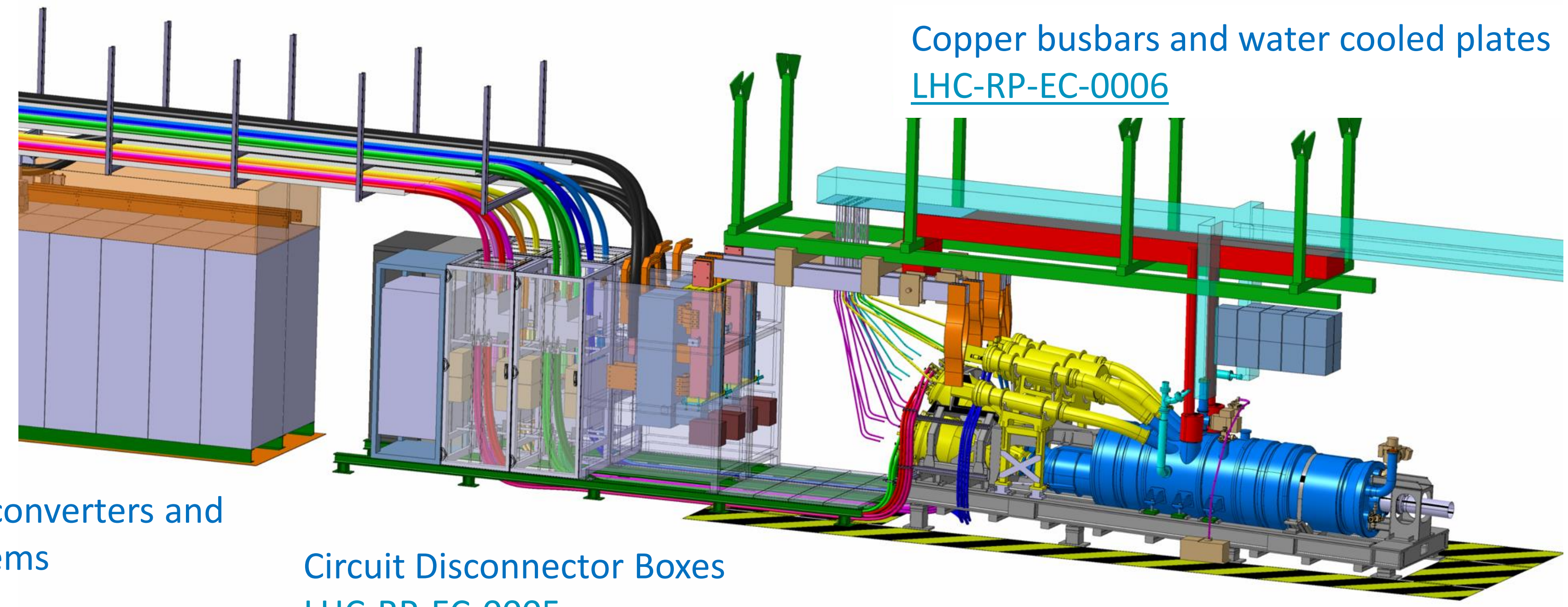
Warm Powering system and interface to DFHX/M now fully defined, incl

- Adaption to latest UR layout and DFHX/M design
- Optimisation and standardisation of DC cables and ventilation needs
- Definition of high current DC copper busbars, their cooling system and interfaces with DFHX/M



New UR layout: impact on DC cables and ventilation
LHC-DFH-EC-0006 v.1.0

Copper busbars and water cooled plates
LHC-RP-EC-0006



Power converters and EE systems

Circuit Disconnector Boxes
LHC-RP-EC-0005

Change of Conceptual design of DFHX/M
LHC-DFH-EC-0006 v.1.0

HL-LHC Managerial Decisions (via DMRs)

- Quench Heaters Design for MQXFB
- SM18 Bench-Reconfiguration for testing of WP3 magnets and WP6A SC Links
- Production of two MCBRD magnets at CERN with IHEP components
- Software support for cold powering tests of HL-LHC magnets in SM18
- Production in-house of HL-LHC HTS Current Leads
- Thermal Cycle for the HL-LHC IT String
- Strategy for the procurement of cables for higher radiation tolerance for HL-LHC
- Integration of Minor Civil Engineering works to HL-LHC activities
- Updated EN/EL Manpower Plan for WP17.2 / WP15
- Re-scheduling of ATLAS JFC3 shieling machining
- Decision for descoping of Cu Coating of TAXN Y-chamber

Oct’21 | Nov | Dec | Jan’22 | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec’22

- Construction of a fourth D2 corrector prototype at CERN
- Agreement for the extra costs of HOC and spare coils
- Manufacturing of one Y-chamber unit
- De-scoping of mechanical components of 4 series DFHX from Uppsala University
- Manufacturing of 4 TCPCs in-house
- Differential longitudinal pressures across the HL-LHC IT Cold Masses
- Strategy for the procurement of transport devices after the opening of IT-4579
- Strategy for CP cold masses
- Strategy for the procurement of Vacuum Sector Valves (WP12 & WP4)
- Strategy for the D2 Series manufacturing
- In-sourcing of HL-LHC BPMs at CERN
- Purchase of additional 100 km of MgB2 wire
- In-sourcing of LS3 Collimators and Masks
- De-scoping of additional horizontal dilution kicker magnets
- De-scoping of hollow e-lens

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HL-LHC Managerial Decisions (via DMRs)

Oct'21 | Nov | Dec | Jan'22 | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec'22

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Purchase of additional 100 km of MgB2 wire

In-sourcing of LS3 Collimators and Masks

De-scoping of additional horizontal dilution kicker magnets

De-scoping of hollow e-lens

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Russian in-kind contributions

- Following the non-funding of Russian in-kind contributions, disucssions have been initiated with WPs and groups/departments to assess re-profiling/descoping options, considering performance impact for Run 4 along with their (resource) constraints and over-heads (follow-up, raw material price increase, risk) when in-sourced
- Key components have been in-sourced or are being disucssed for alternative in-kind contributions in coherence with the schedule constraints
- Additional horizontal dilution kickers and hollow e-lens have been descoped from HL-LHC project (as resource constraints don't allow for their completion by LS3)
  - For hollow e-lens: Engagements with in-kind partners and critical R&D and prototypes of key components will be completed within scope of 'soft-landing'
  - Dilution kicker: Update of design and production documentation supported by project to ensure capturing of know-how and expertise from LHC construction

Russian in-kind contributions

- Desoping of hollow e-lens and dilution kickers represents a performance risk for Run4 , which can only be fully assessed/quantified following beam experience with target performance during Run3
  - HEL: important feedback to come from beam lifetime and halo population studies with LIU beams / brightnesses (standard operation and dedciated MDs)
  - Dilution kicker: Additional consolidation done during LS2 to reduce probability of critical failures; material studies and results from operational LHC dump are encouraging for an HL compatible dump design to be within reach.
- Re-integration of items for long-term operation of (HL)-LHC kept as a future possibility, should Run 3 experience confirm their criticality
  - Coordinated, project wide technical review proposed for mid-end 2023 to review Run 3 experience/MD results to confirm HL baseline choices and assess expected performance impact of descoping decisions

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Russian in-kind contributions – Status of Plan B

WP	Item	Decision by	Comments
WP5	Crystal collimators	Done	In-house production already done, descope double jaw version
WP6A	HTS current leads	Done	MME already produced 1/3 of series items as risk mitigation, now extended to complete series production taking place in-house. Procurement of raw materials ongoing. Estimated to remain within CORE value.
WP13	BPM bodies	Done	MME successfully produced prototypes and to produce as well series.
WP5	Collimators	Done	Production with member state industry under CERN lead. Procurement of raw materials and MS for assembly ongoing. Overhead in manpower for design and production (currently being assessed in detail).
WP14	Beam dump kickers	Done	Defer (promising beam experiments and results from operational LHC dump indicating reliable HL-design)
WP8	TAXN, TAXS	Ongoing	Y chamber prototype being built in industry and options for series being explored, either fully in industry or by MME. New in-kind being explored for purchase of raw material and machining of passive absorbers.
WP13	BLMs	Done	Built to print as LHC design, in-sourcing plan defined.
WP4	Solid state amplifiers	Ongoing	Decision to remain with IOTs as by baseline. New in-kind being explored, market survey in European industry in parallel
WP14	Beam dumps	Ongoing	Studies ongoing, core material to be decided following outcome of recent (promising) HighRadMat test and needs for reliable long-term operation.
WP4	RF transmission chain	Ongoing	RF power distribution lines, circulators and loads – New in-kind being explored, market survey in European industry in parallel
WP5	Hollow electron lenses	Done	Defer (installation after LS3 if need confirmed by Run3 experience), as not compatible with current resources in MSC. Options for installation during Run4 being assessed.

Upcoming baseline changes (being formalised)

WP6b	Descoping of radiation tolerant DCCTs for 60A converters
WP5	Descoping of hollow e-lens from HL-LHC project
WP7	Descoping of dedicated additional (BIS) interlock channels for fast failures
WP8	Descoping of Cu Coating of TAXN Y-chamber
WP14	Descoping of additional horizontal dilution kickers from HL-LHC project
WP15/WP17	Radiation tolerant fibres in HL scope

Conclusions

- Technical baseline continues to evolve, albeit at an increasing level of granularity and detail
  - 27 Engineerig Change Requests (ECRs) + 32 Decision Management Reports (DMRs) approved over the past 12 months
- New Layout V1.6 approved in July 2022
- Confirmation and further scrutiny of HL baseline to continue in 2023 based on Run 3 experience

Thank you for your attention!
Questions?

HL-LHC Managerial Decisions (via DMRs)

EDMS	Description	Date	WP
2631530	Construction of a fourth D2 corrector prototype at CERN	Oct-21	WP3
2646046	Quench Heaters Design for MQXFB	Nov-21	WP3
2604419	Agreement for the extra costs of HOC and spare coils	Dec-21	WP3
2669588	De-scoping of some mechanical components of 4 series DFHX from Uppsala University	Jan-22	WP6A
2637180	SM18 Bench-Reconfiguration for testing of WP3 magnets and WP6A SC Links	Feb-22	WP1 WP3 WP6A
2688784	Production two MCBRD magnets at CERN with components provided by IHEP	Feb-22	WP3
2645981	Manufacturing of 4 TCPCs in-house	Mar-22	WP5
2595741	Production in-house of HL-LHC HTS Current Leads	Mar-22	WP6A
2724922	Software support for cold powering tests of HL-LHC magnets in SM18	Mar-22	WP1 WP3
2675955	Differential longitudinal pressures across the HL-LHC IT Cold Masses	Mar-22	WP3
2717815	Thermal Cycle for the HL-LHC IT String	Apr-22	WP16
2694690	Strategy for the procurement of transport devices after the opening of IT-4579	Apr-22	WP15

EDMS	Description	Date	WP
2685798	Strategy for the procurement of cables for higher radiation tolerance for HL-LHC	May-22	WP1 WP15
2721956	Strategy for D2 series manufacturing	Jun-22	WP3
2742239	Integration of Minor Civil Engineering works to HL-LHC activities	Jun-22	WP15
2736828	Strategy for the procurement of Vacuum Sector Valves	Jun-22	WP4 WP12
2726806	In-sourcing of HL-LHC BPMs at CERN	Jun-22	WP13
2740080	Re-scheduling of ATLAS JFC3 shieling machining	Jul-22	WP8
2737787	Updated EN/EL Manpower Plan for WP17.2/WP15	Jul-22	WP15 WP17
2740267	Purchase of additional 100 km of MgB2 wire	Jul-22	WP6A
2771582	Decision for Cu Coating of TAXN Y-chamber	Aug-22	WP8
2771585	In-sourcing of LS3 Collimators and Masks	Sep-22	WP5
TBC	De-scoping of HELs and Dilution Kickers	Sep-22	WP1

HL-LHC Managerial Decisions (via ECRs/TCC)

EDMS	Description	Date	WP
2612566	Updated design of inner layer for MCBXFB	Oct-21	WP3
2645150	Maintaining option of swapping X-plane for CC	Oct-21	WP15
2640455	Access bridges over beam line elements	Oct-21	WP15
2709180	Access conditions to HL-LHC LSS and sectors as a function of cryogenics and powering	Dec-21	WP1
2499201	Crab Cavity Instrumentation	Feb-22	WP13
2709180	Double QXL	Mar-22	WP9
2589302	FRAS functional software specification	Mar-22	WP15
2387369	BPM specification	Mar-22	WP2
2728908	Update of MQXFA/B length	Apr-22	WP3
2445632	High-performance variant of the DI/OT platform for the Full Remote Alignment System	May-22	WP15
2386350	New UR layout and WCC/ACC	May-22	WP17
2453935	High Current DC busbars for the IT and MS magnet strings	Jun-22	WP6b
2721195	Energy extraction systems for the HL-LHC RQSX3 circuits	Jun-22	WP7
2740898	Update of magnet delivery plan to IT String	Jun-22	WP7
2349917	Naming conventions for functional position codes for HL-LHC buildings and galleries	Jul-22	WP1
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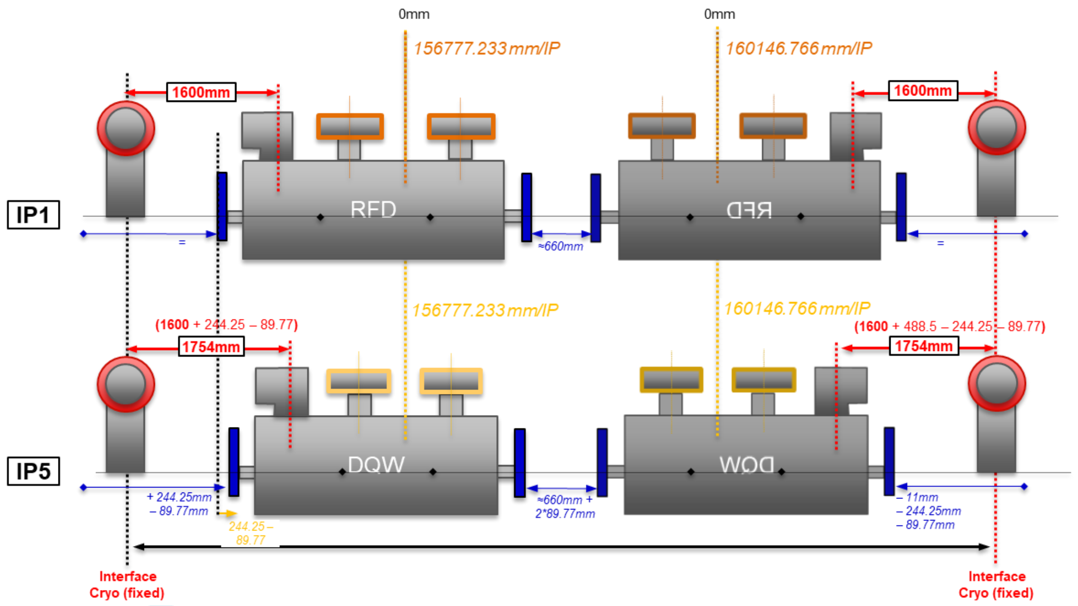
Crab Cavities in optics version 1.6

LHC-ACF_A-EC-0001v.1.0 Crab Cavities in optics version 1.6 – Shift of Civil Engineering cores, adaptation of cryogenic and of vacuum elements

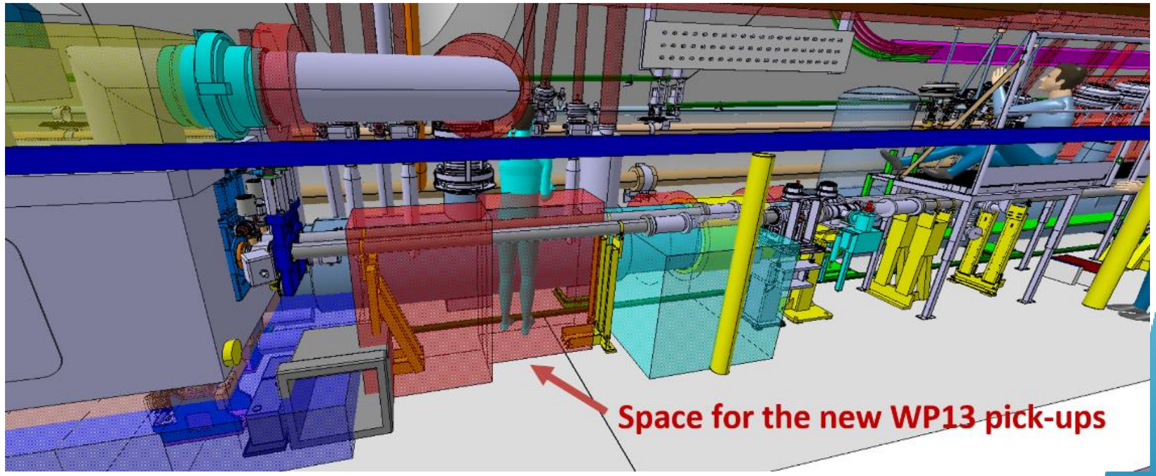
Two types of crab cavities and, therefore, cryomodules are required: the Double Quarter Wave (DQW) in IP5 and the RF Dipole cryomodule (RFD) in IP1 where the crossing angle is implemented in the horizontal plane. To maintain interchangeability of the crab cavities between IP1 and IP5 following a revised cryo-module design, interfaces and integration are updated.



LHC-BPMQ-EC-0001v.1.0 Replacement of APWL pick-ups by a new pick-up designed by WP13

APWL wall current monitors were tentatively foreseen to provide diagnostics needed to safely and efficiently operate the CCs. Now proposed to be replaced by (combination of) new pick-ups managed by WP13. Awaiting final specs, working baseline changed to

- button electrodes for phasing the CC
- button electrodes for filtering the CC antenna direct beam coupling
- stripline electrodes for CC amplitude and noise feedback



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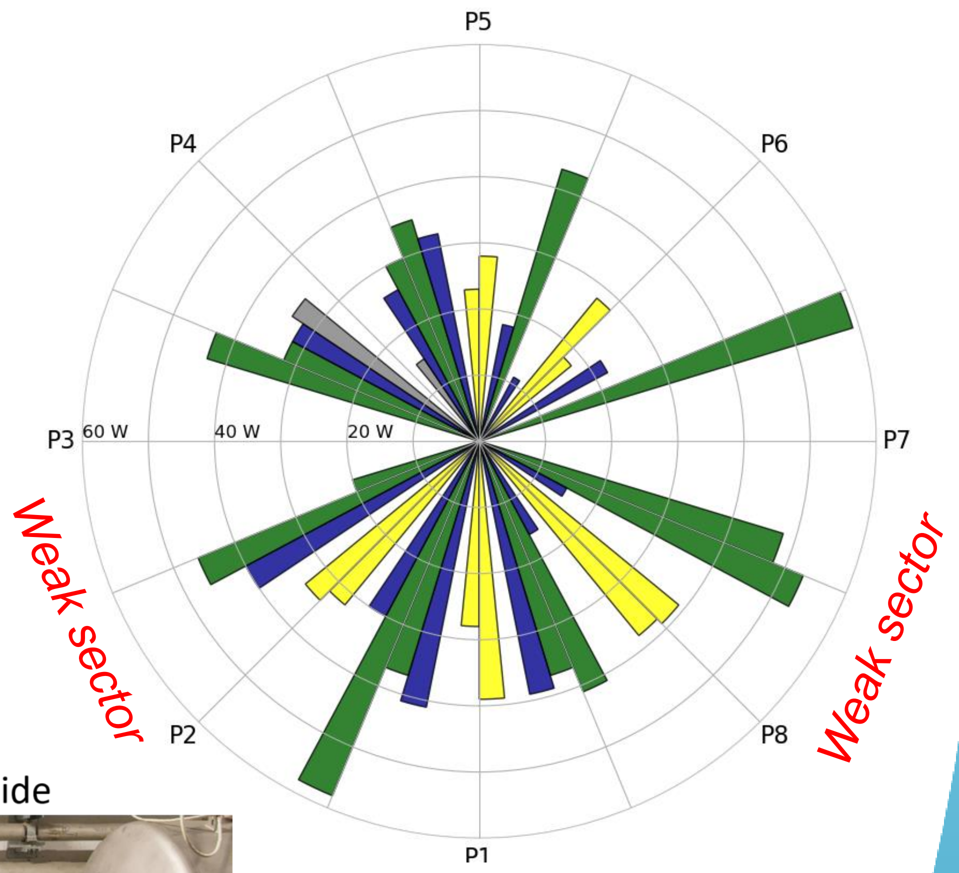
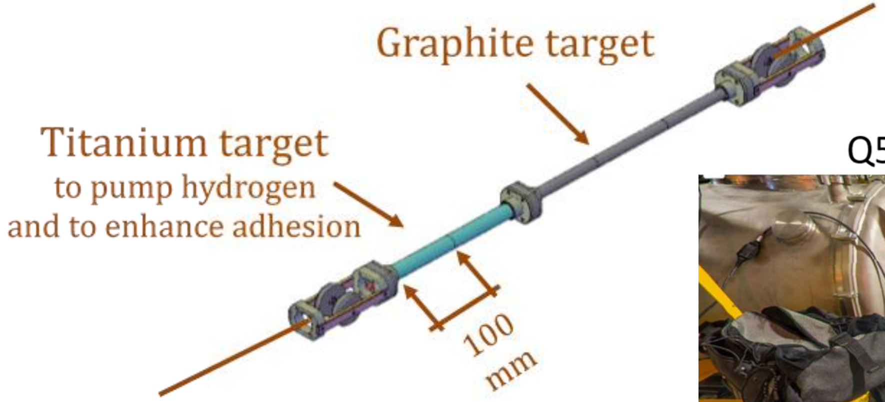
Descoping of aC coating in SAM

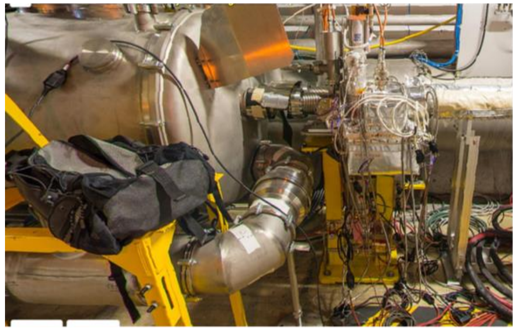
[LHC-VS-EC-0002v.1.0](#) Descoping of amorphous carbon coating in the Q5R2, Q6R2, Q6L8 standalone magnets

A first in-situ coating campaign on shorter magnets was desirable to demonstrate during RUN 3 the efficiency of the surface treatment as well as to allow for an early validation of the procedure, tooling and activity duration. Additional margin in the refrigeration power for the sectors 23 and 78, re-aligning the heat load in these sectors to others was also beneficial. For these reasons, the in-situ coating of Q5L8, Q6L8, Q5R2 and Q6R2 was added during Run 2 in the HL-LHC base line. Due to presence of cryosorbers, only Q5L8 could be successfully coated during LS2.

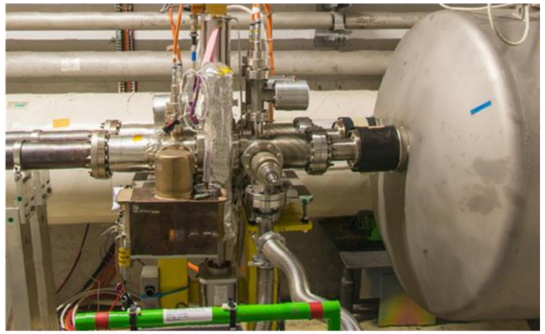




Q5L8 IP side

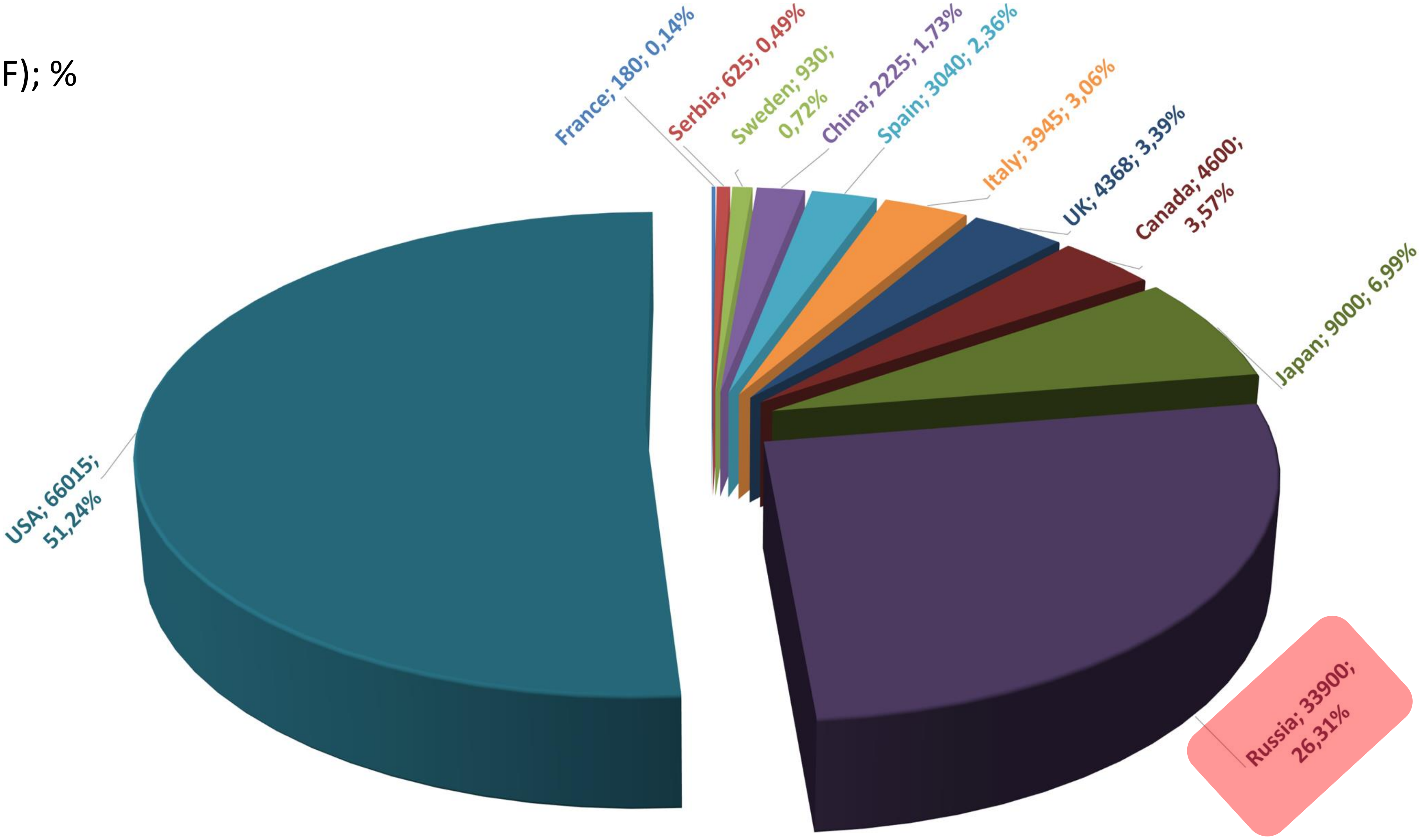


Q5L8 arc side



Graphical summary of the in-kind contributions as by CSR'21

Country; (kCHF); %



HiLumi HL-LHC PROJECT