



HL-LHC Baseline and TCC summary

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

Vancouver – September 25th to 28th

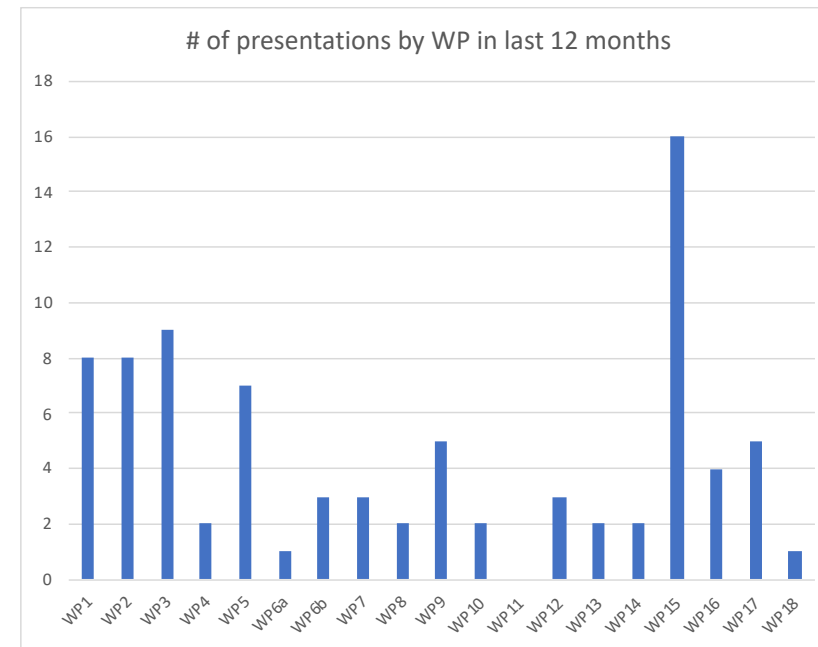
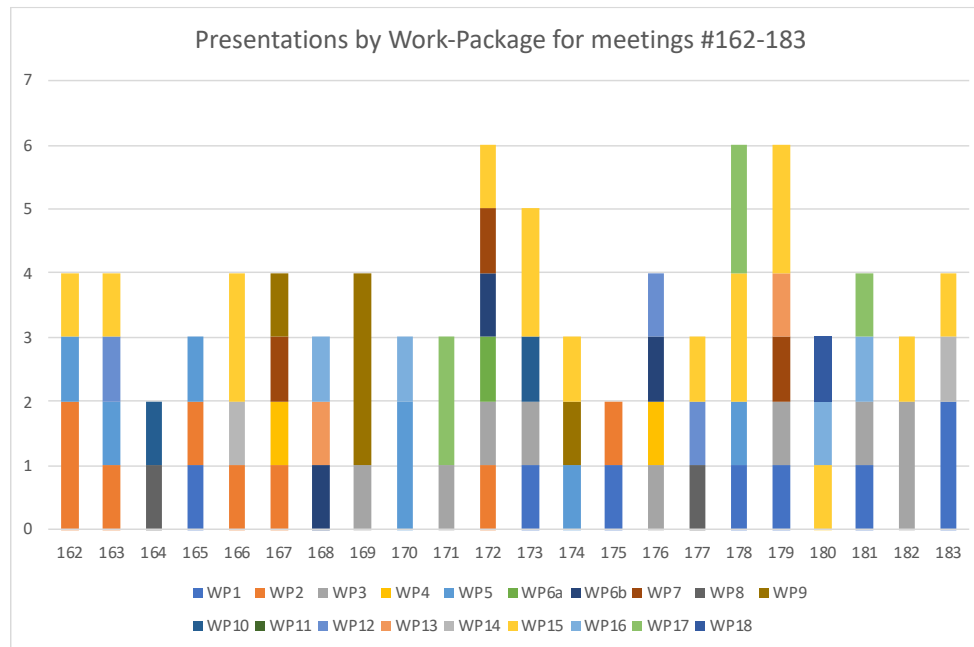


Outline

- TCC summary, main topics and decisions
- Layout and Baseline evolutions and statistics
- Main HL-LHC baseline changes since annual meeting 2022
- Conclusions

Technical Coordination Committee (TCC)

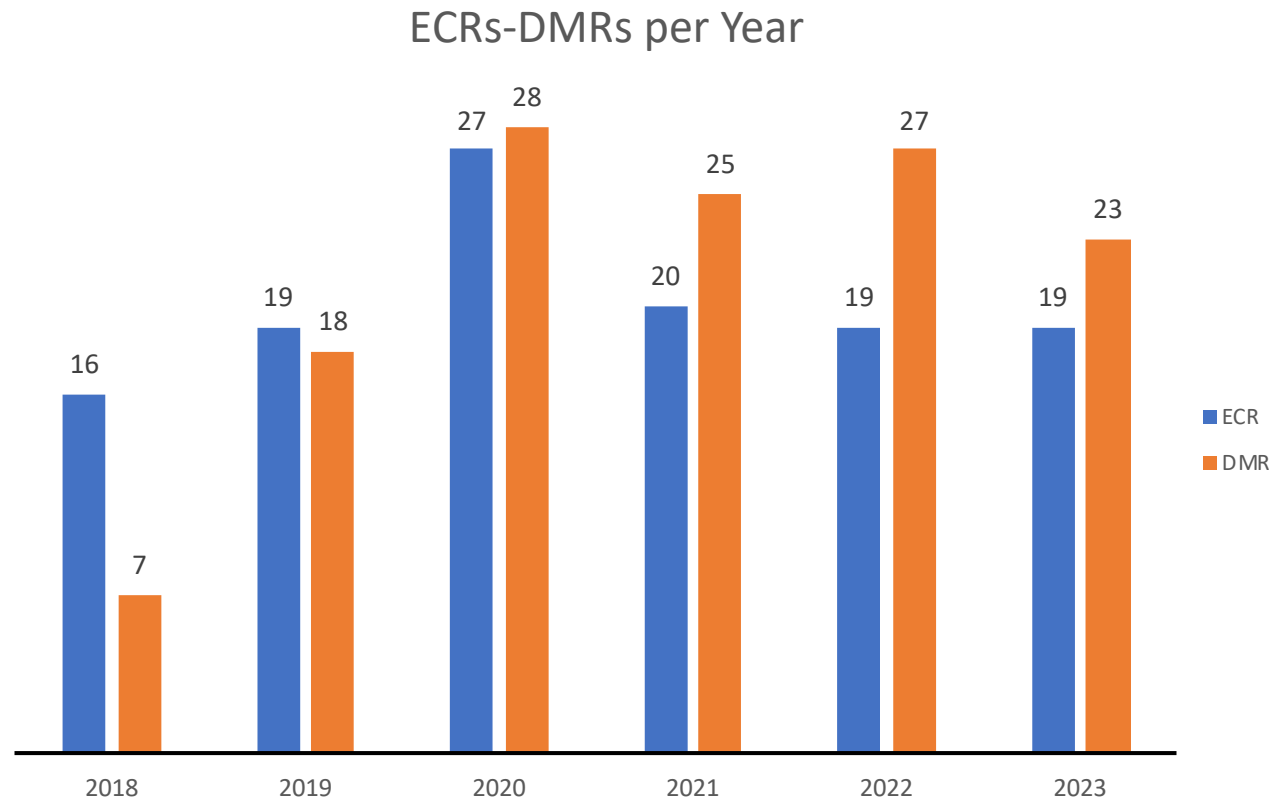
- Technical Coordination Committee continued serving as an important forum to follow-up and approve the evolution of the project's technical baseline
- Organised on a bi-monthly basis with an average participation of ~ 35 people across project
- Meetings today still in hybrid mode, in-turn allowing the regular participation of collaborators



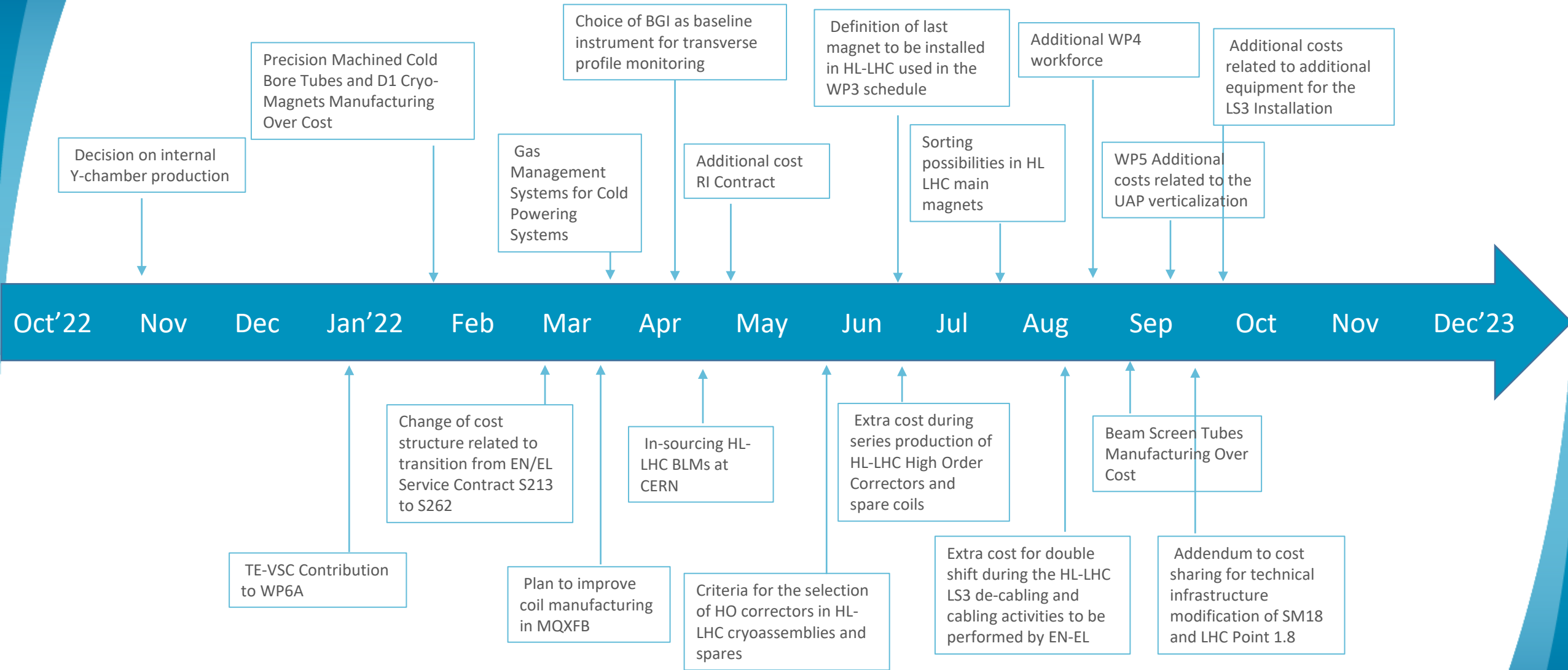
TCC topics and decisions since last annual meeting

- Collimator jaw material options (Tungsten for Tertiaries and Cu coated graphite for secondaries) – [LHC-TC-ES-0011](#), [LHC-TCL-ES-0002](#)
- Impact of construction works on LHC tunnel
- Vacuum layout freezing – [LHC-LV-ER-0001](#)
- Descoping of aC coating for 3 stand-alone magnets in IR2/8 – [LHC-VS-EC-0002](#)
- Vacuum valve choice of 63mm for Q4 – [LHC-V-EC-00030](#)
- TCLM4 Mask in front of Q4, radiation test results for corrector magnets – [LHC-TCL-ES-0002](#)
- IT Current monitoring scheme – [LHC-DQ-EC-0011](#)
- LS3 schedule – [LHC-MS-0003](#)
- MS@Q10 and BETS upgrade – [LHC-M-EC-0007](#), [LHC-MKCB-EC-0001](#)
- Temperature margins in MQXF and heat exchanger for IT magnets – [LHC-QXL-EC-0001](#)
- BGV/BGI review
- Descoping of 60A DCCTs [LHC-RP-EC-0010](#)
- D2 baseline protection scheme [LHC-MBRD-EC-0003](#)
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- Cryostat deformation and alignment errors
- FRAS functional spec and hazard analysis: baseline optimization [LHC-SR-0001](#), [LHC-ES-0047](#)
- D1 and D2 magnetic center [LHC-LM-EC-0001](#), [LHC-LMBRD-EC-0002](#)
- CT-PPS2 [LHC-EC-0044](#)

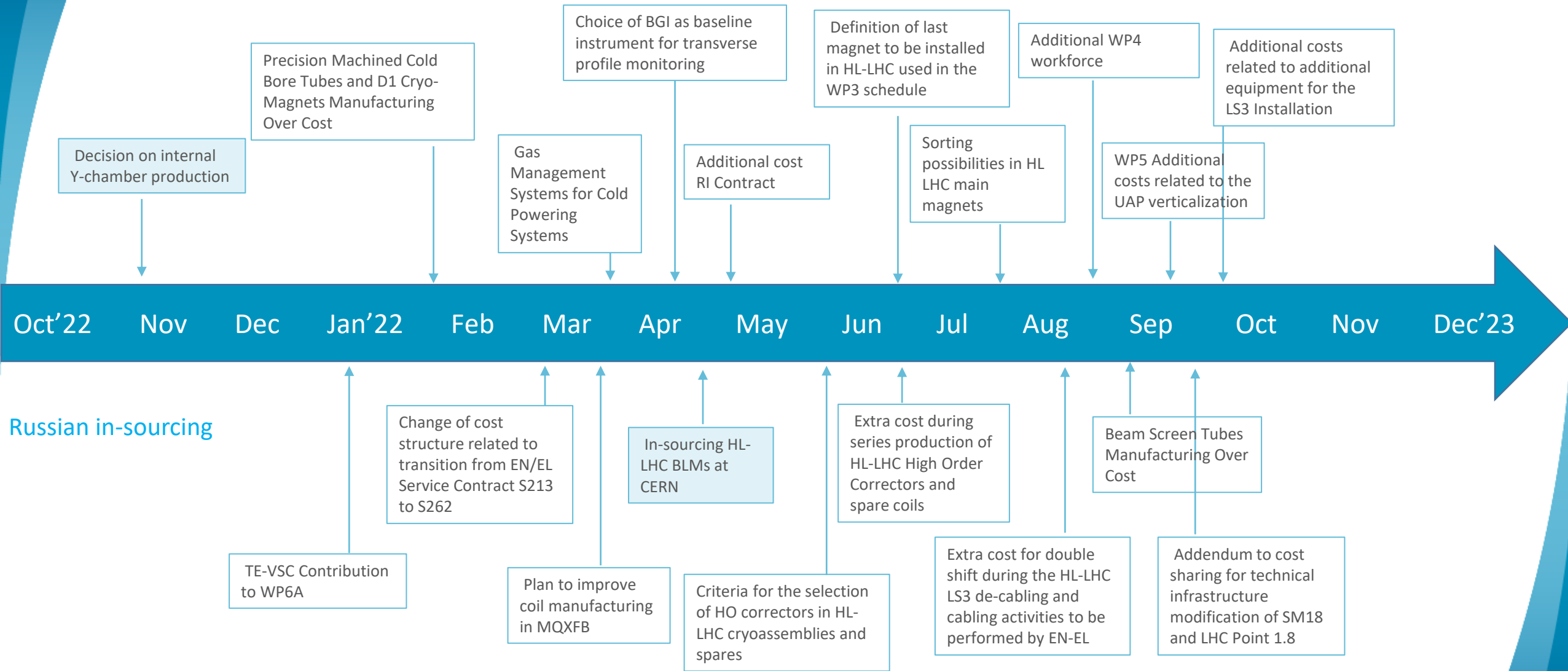
ECRs and DMRs since last Annual Meeting



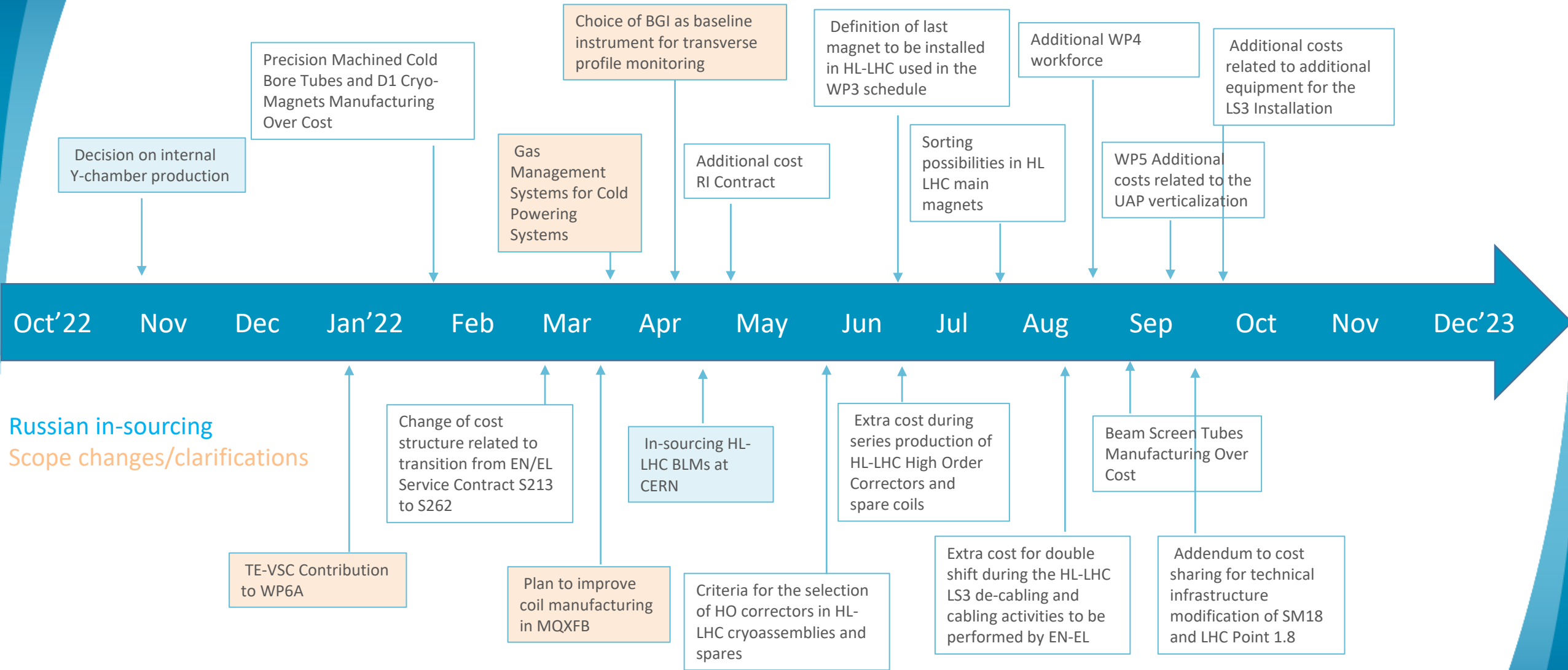
HL-LHC Baseline Changes (via DMRs/TCC)



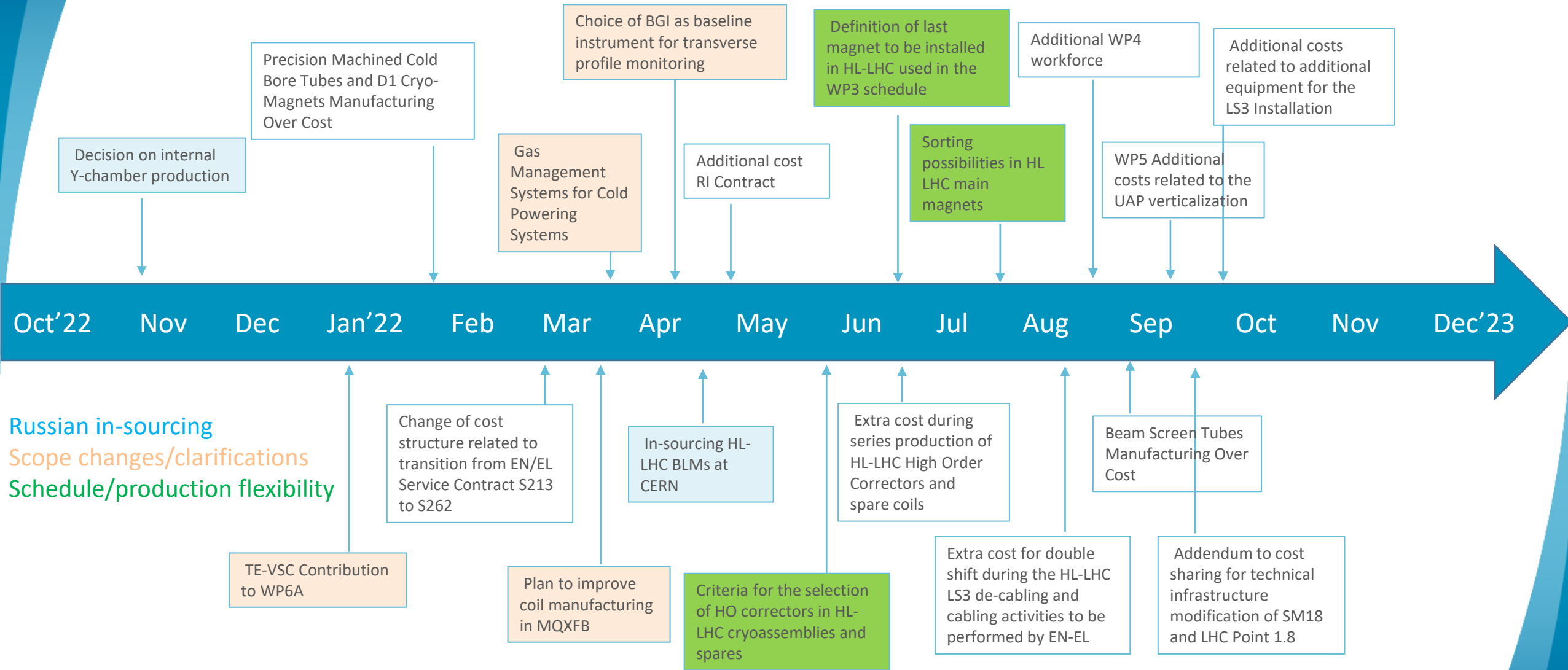
HL-LHC Baseline Changes (via DMRs/TCC)



HL-LHC Baseline Changes (via DMRs/TCC)

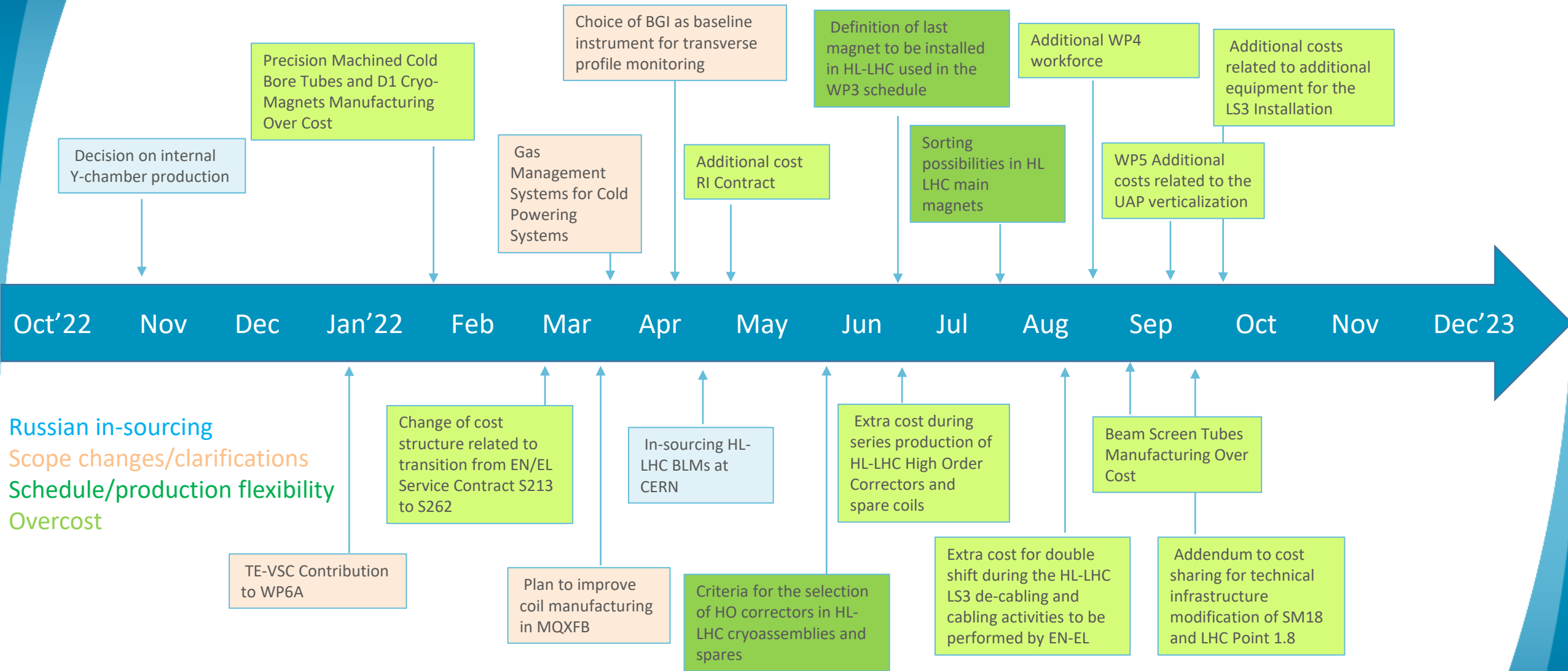


HL-LHC Baseline Changes (via DMRs/TCC)

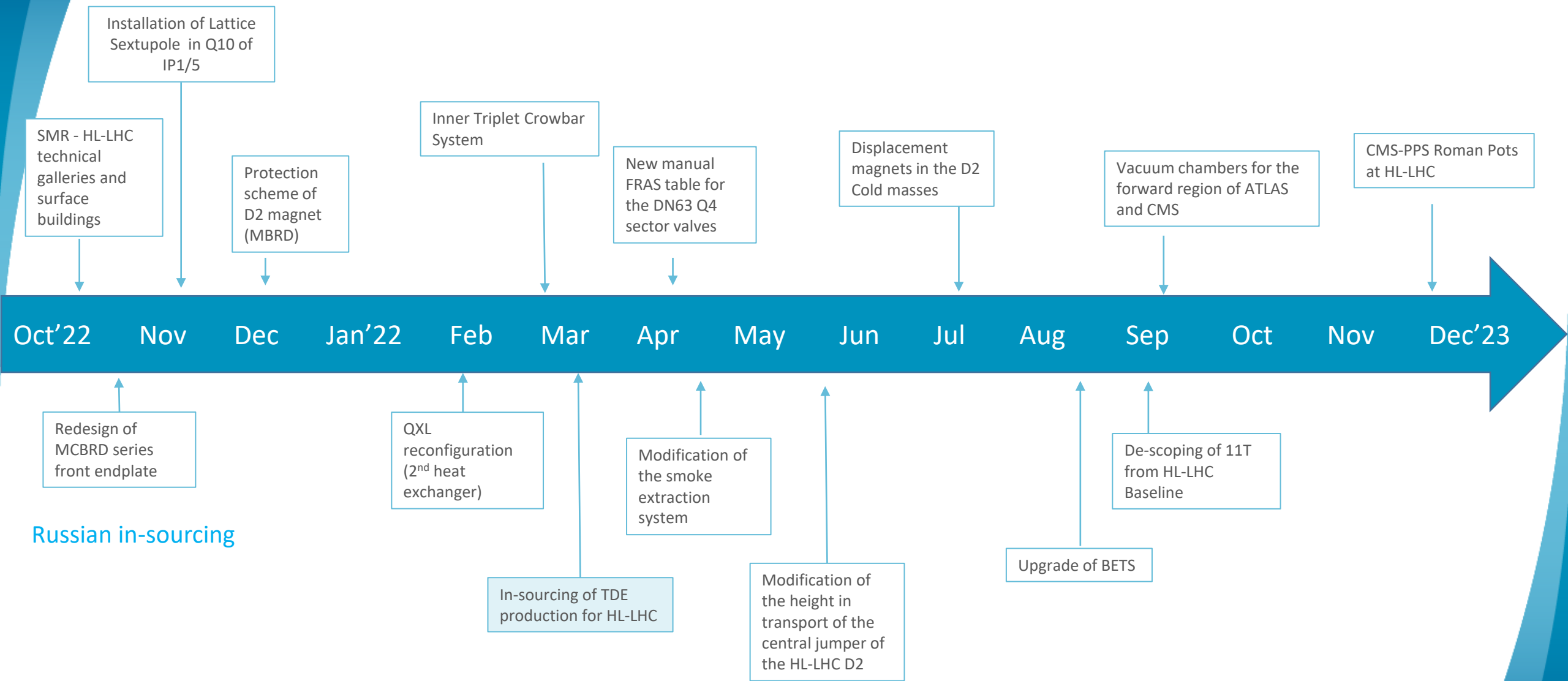


Russian in-sourcing
 Scope changes/clarifications
 Schedule/production flexibility

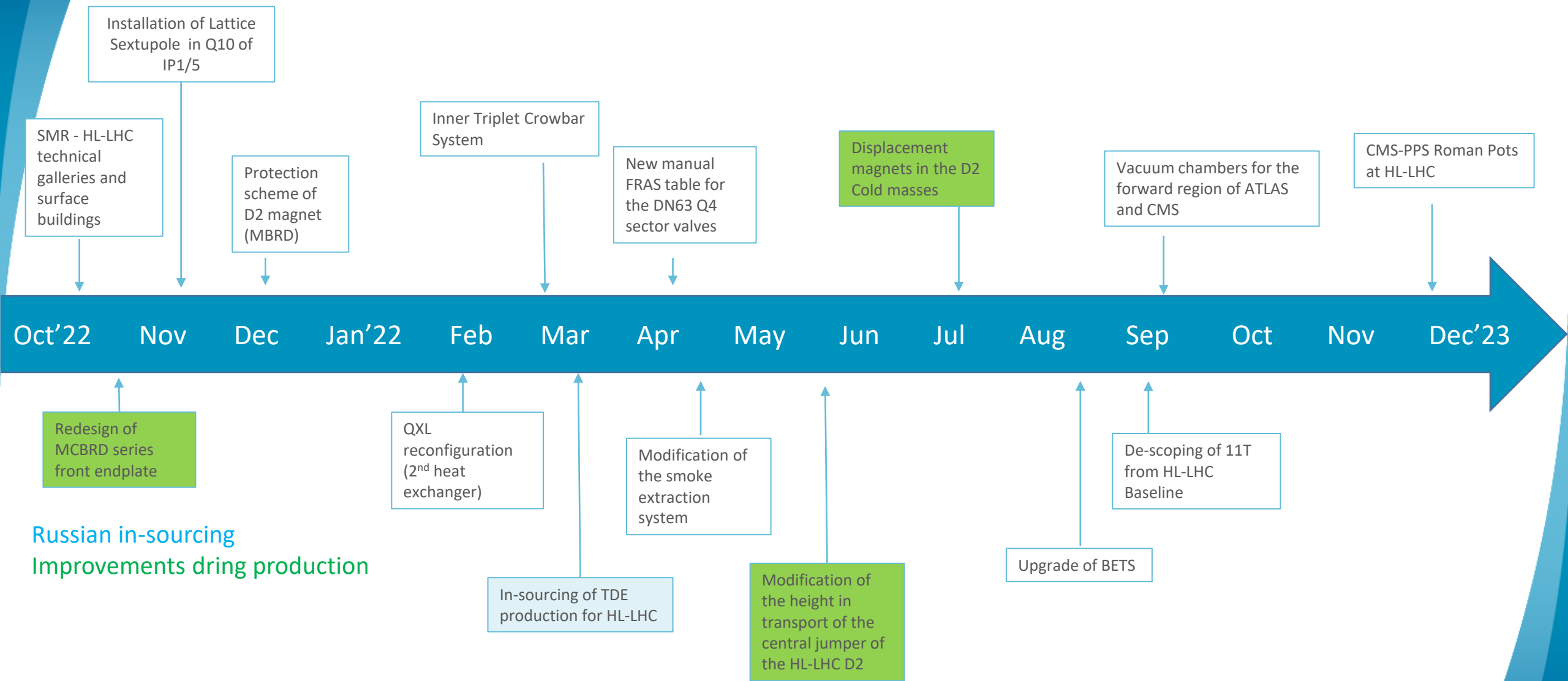
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HL-LHC Baseline Changes (via ECRs/TCC)

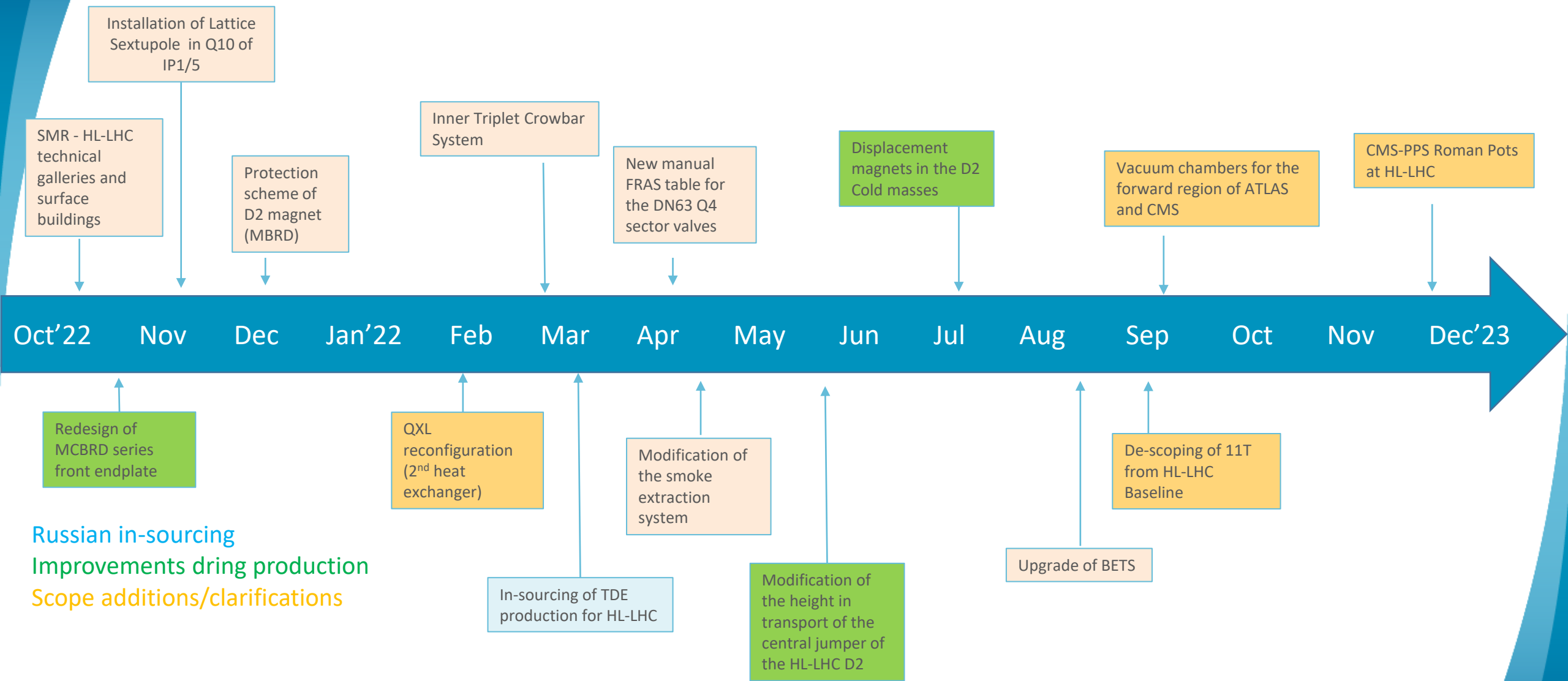


HL-LHC Baseline Changes (via ECRs/TCC)



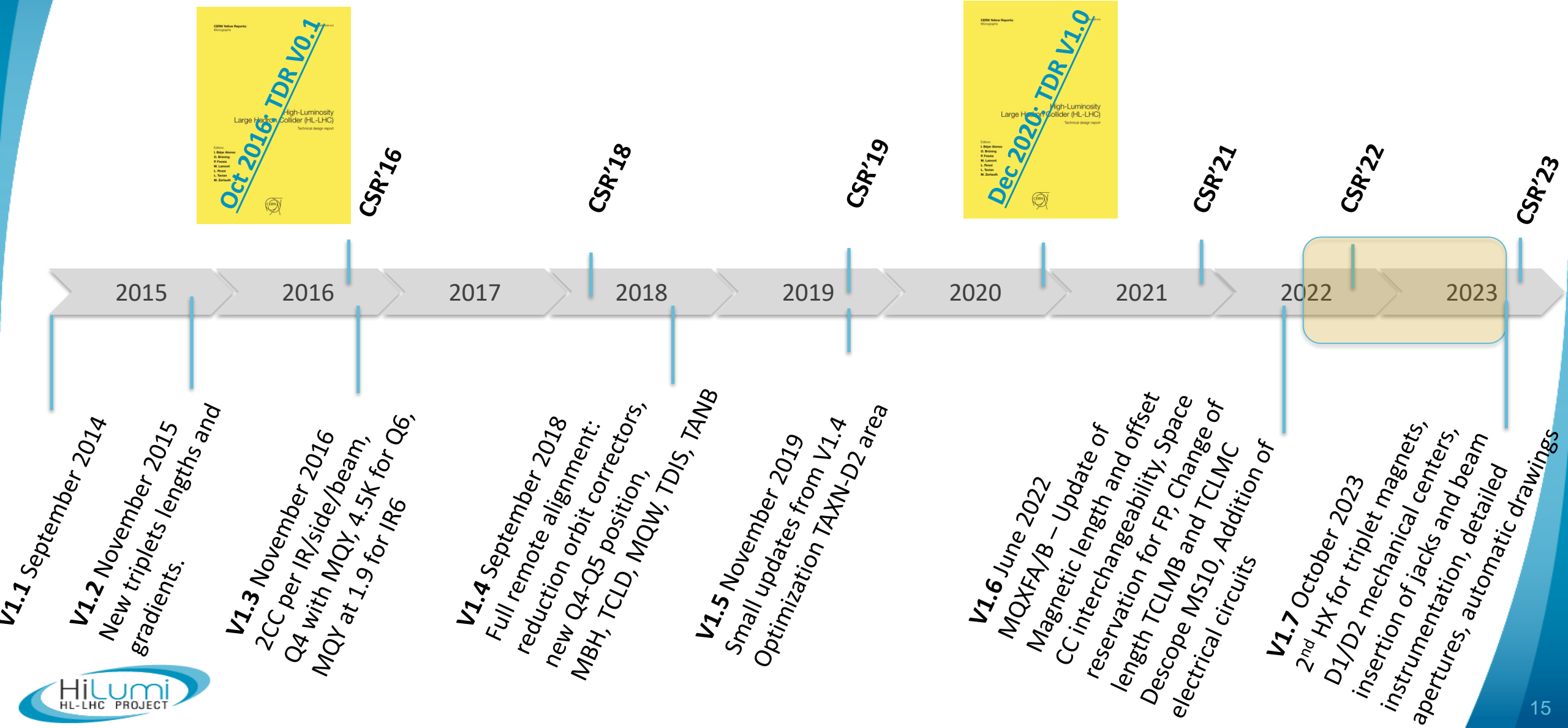
Russian in-sourcing
Improvements during production

HL-LHC Baseline Changes (via ECRs/TCC)



Russian in-sourcing
 Improvements dring production
 Scope additions/clarifications

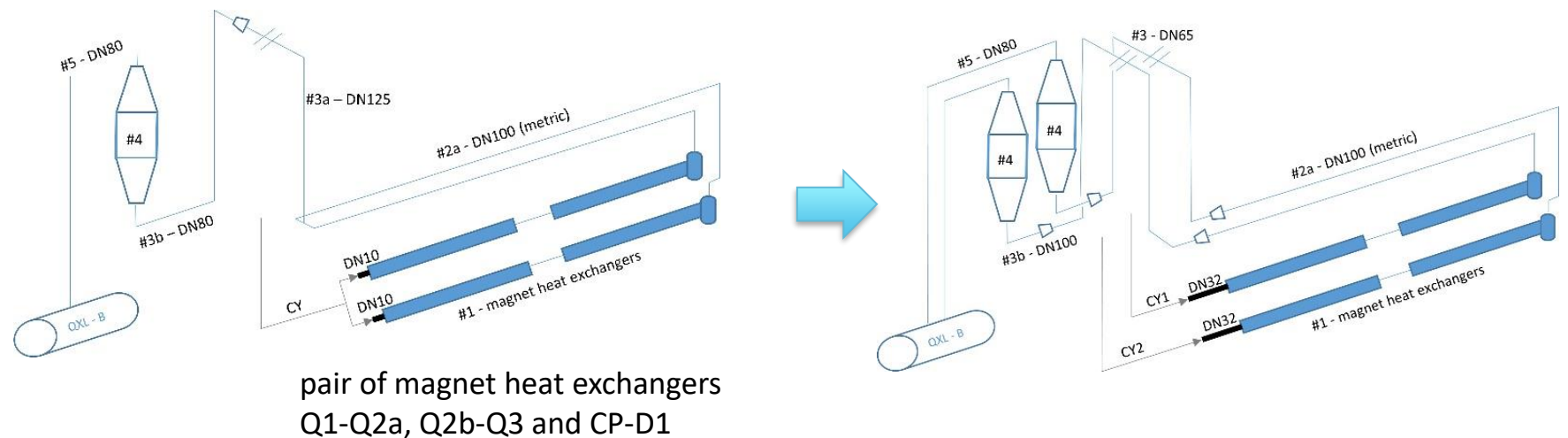
Evolution of Project Baseline (Machine Layout Versions)



Doubling of sub-cooling HX in triplet magnets

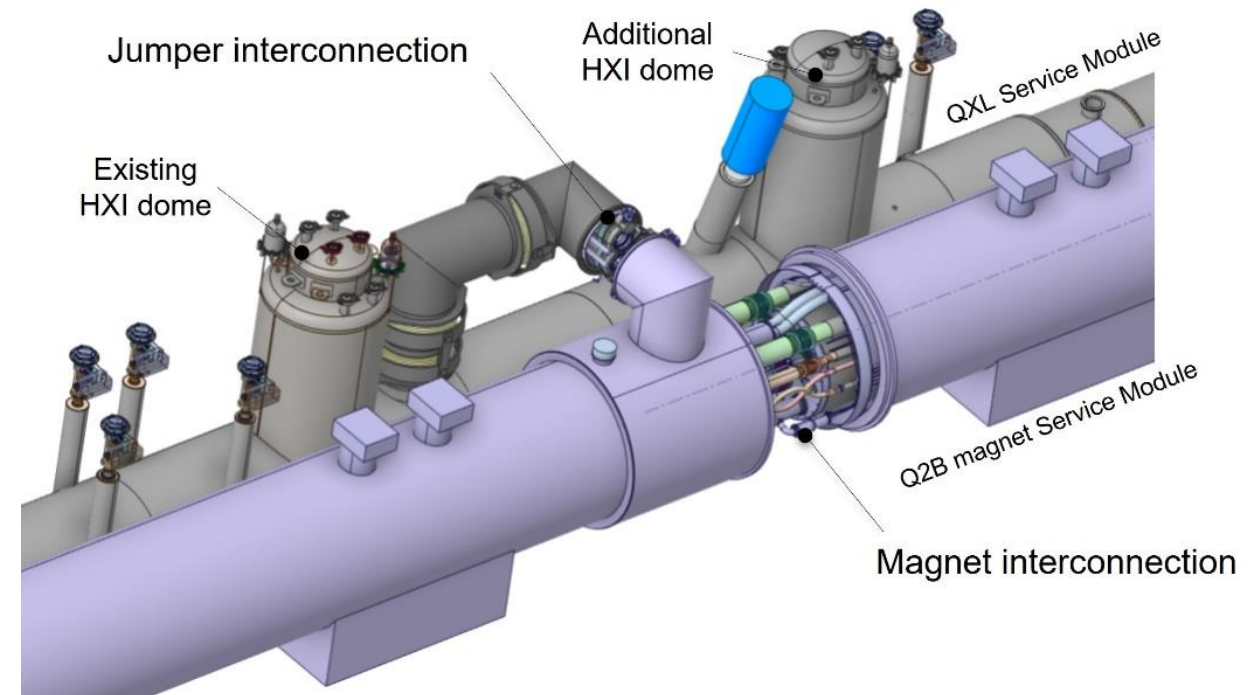
- Capacity test campaign on the QRL-like sub-cooling heat exchangers used for inner triplet string revealed possible limitation of installed local capacity of the cooling circuits
- Refined studies highlighted potential distribution issues of helium flow between the pair of magnet heat exchangers as well as space limitations and unacceptable forces at the magnet interface
- Study to assess feasibility of two independent cooling lines on each cooling circuit was carried out and retained for the Q1-Q2a and the Q2b-Q3 circuits, while for the CP-D1 circuit only injection line configuration is modified

QRL-like sub-cooling heat exchanger, housed in the QXL service modules



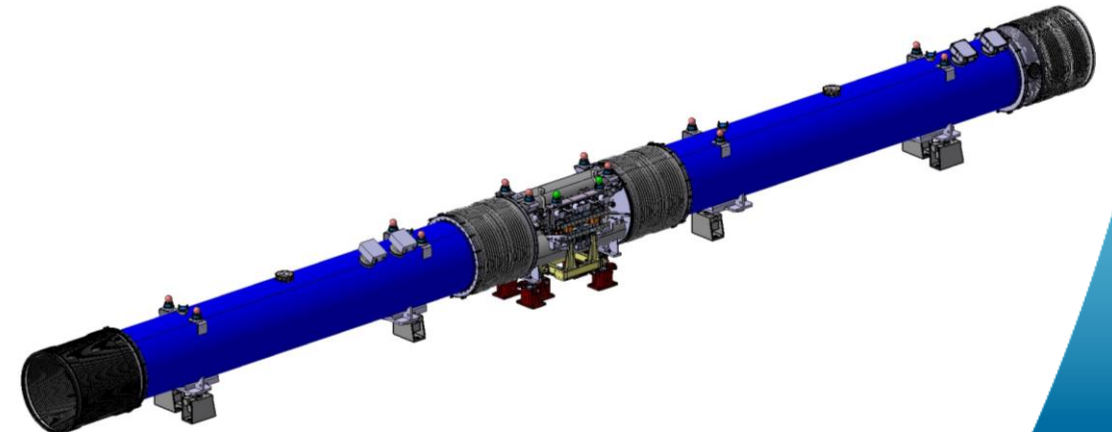
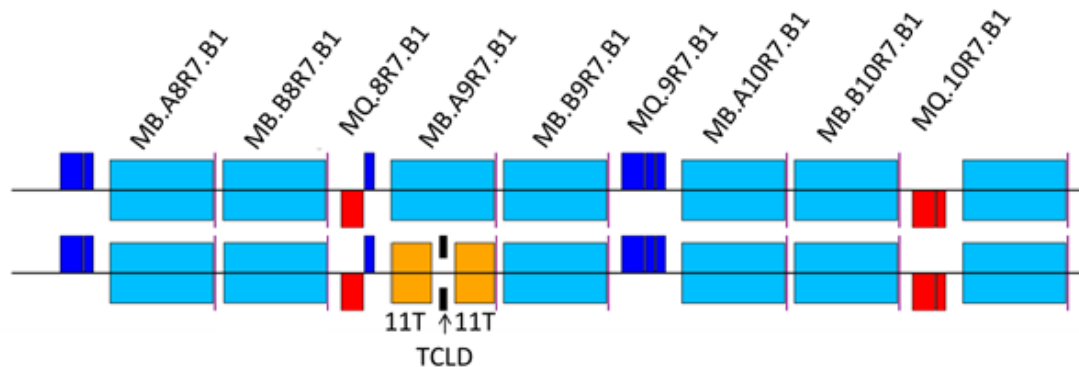
Doubling of sub-cooling HX in triplet magnets

- Addition of additional sub-cooling heat exchanger + two cryogenic valves lead to an updated design of the QXL service modules of the IT region, fulfilling as well the need of broadening access volume
- Change involved major changes for
 - QXL jumpers of IT magnet string
 - QXL service module
 - QXL jumper interconnections
 - Magnet String (injection and pumping lines)
 - Layout and integration
- [EDMS 2827006](#)



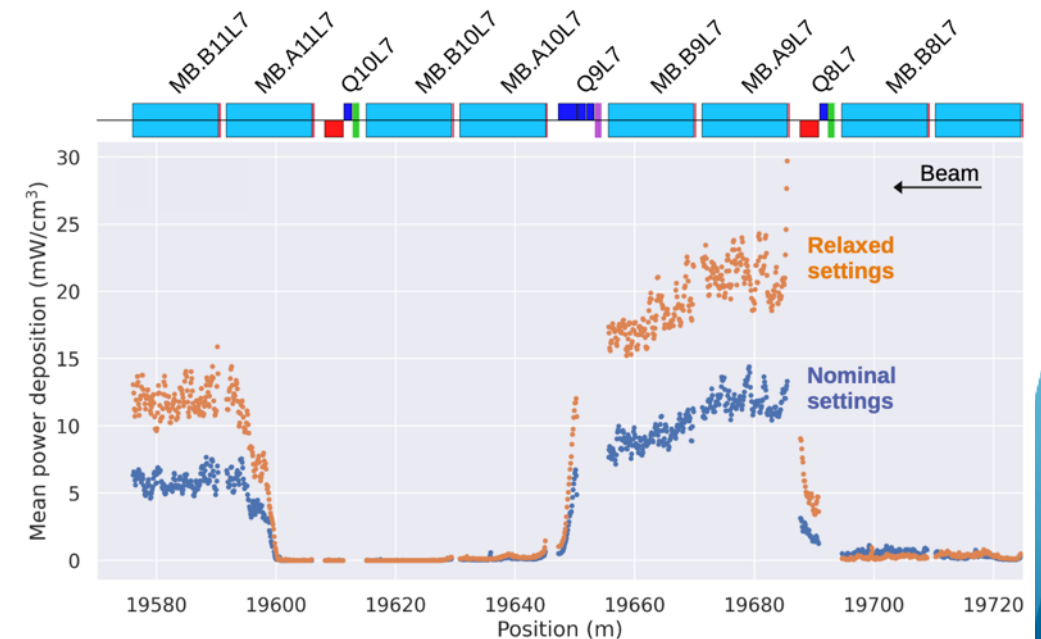
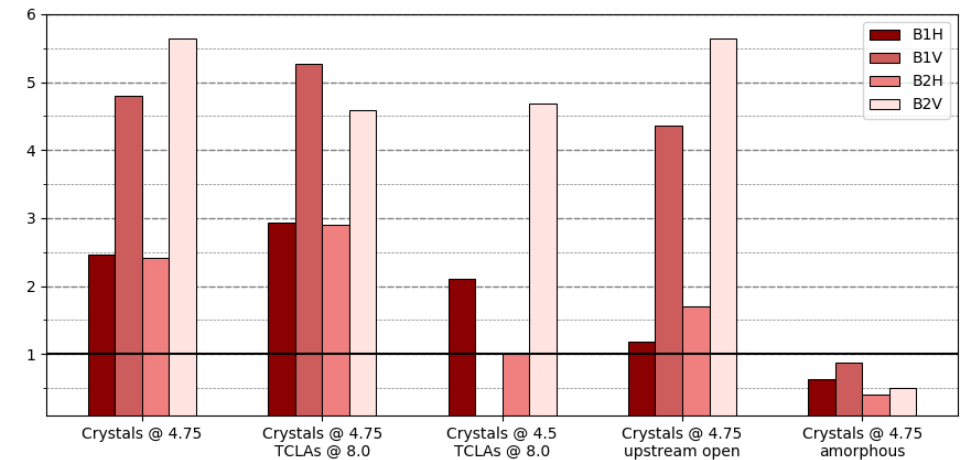
Descoping of 11T from HL-LHC project

- Following observed performance limitations of 11T dipole magnets, installation of 11T initially deferred to LS3 (EDMS 2441244), but **today still part of project scope**
 - **In-depth investigation was launched**, followed by construction of hybrid magnet (short and long model) – phase 2 still ongoing with first results from short model being analysed
 - **Crystal collimation adopted in HL baseline already for ions in Run 3** – Ongoing these days!
 - **Comprehensive set of MDs being performed during Run 3 to assess potential limitations for proton operation** ('quench' tests, improved IR7 optics and collimation settings,...)
- Operational experience and MD results from Run 3 confirm HL-LHC performance even in absence of 11 T dipoles
- **11T installation descoped from HL project** (installation in LS3) [EDMS 2938368](#)



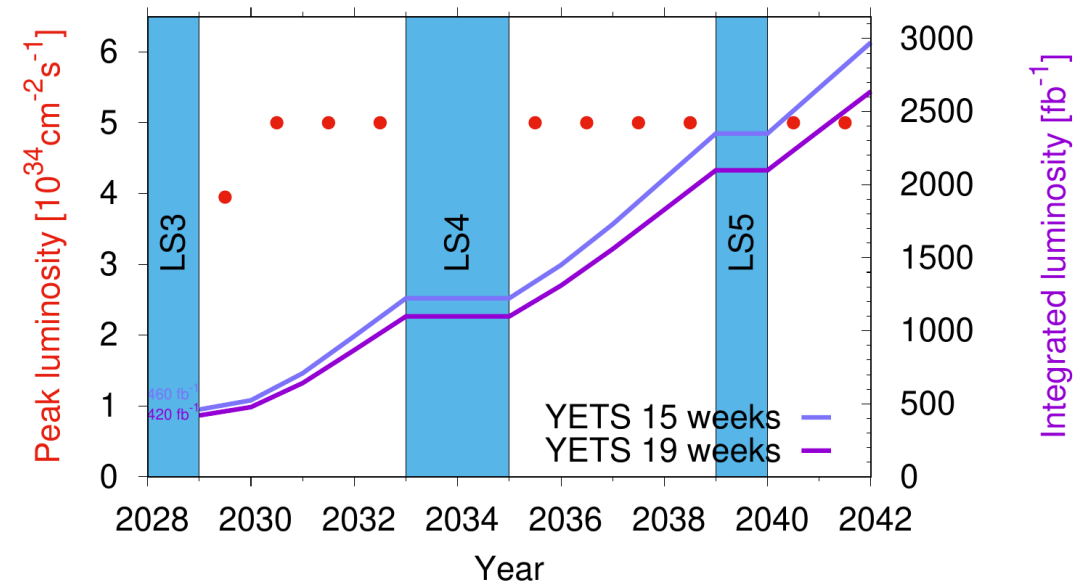
Descoping of 11T – performance risk mitigations

- For ion operation, four new goniometers housing bent crystals have been produced and installed during LS2 and the YETS 2022/23
- Set of 4 new crystals was commissioned with proton beams and indicated a performance well within specifications, indicating an improved cleaning by up to a factor 5 or more in the baseline configurations
- Proton collimation ‘quench’ tests were carried out with high priority in 2022, achieving losses on the primary collimators exceeding 600 kW (1 MW design loss rates)
- Special configuration with relaxed collimator settings designed to enhance DS loss per proton lost in IR7 by about 50 %
- Quench limit established $\geq 15 \text{ mW/cm}^3$ at 6.8 TeV



Baseline parameters

- Recent operational experience in Run 3 (e-cloud) and descoping's (hollow e-lens, MKBH, 11T) dictate an [update and re-validation of the HL-LHC baseline parameter sets + optics variants](#) (25ns 15cm round baseline, BCMS + 8b4e options)
- [Current LHC situation already limits LHC operation](#) (hybrid schemes 25ns + 8b4e used) and will limit [HL-LHC capabilities by ~ 30%](#) ([see R. De Maria Chamonix 2023](#))
- Mitigations for (partial) recovery being studied :
 - Beam screen treatment project
 - Flat optics (lower beta*) - BETS, MS@Q10, COLL jaw material, TCLM4 Mask in front of Q4
 - Pile-up of up to 200 already at start of Run 4
 - Exceed $5 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$
- Work on [updated and more detailed breakdown of physics days in HL era](#) for different scenarios [EDMS 2902691](#) (Draft!)

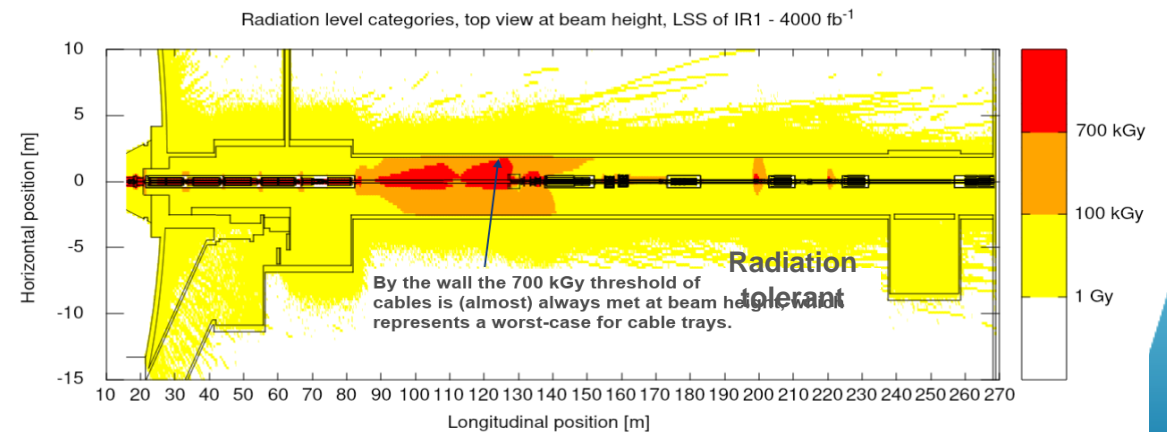


[WP2 – HL-LHC Parameters and Assumptions](#)

Option of radiation tolerant cables

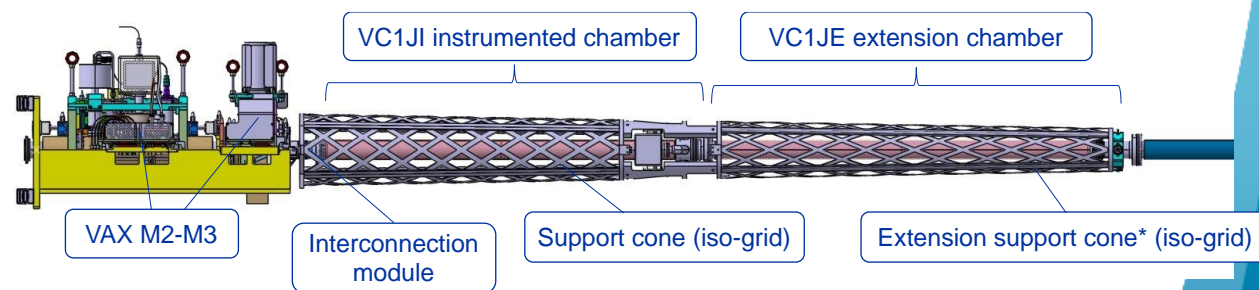
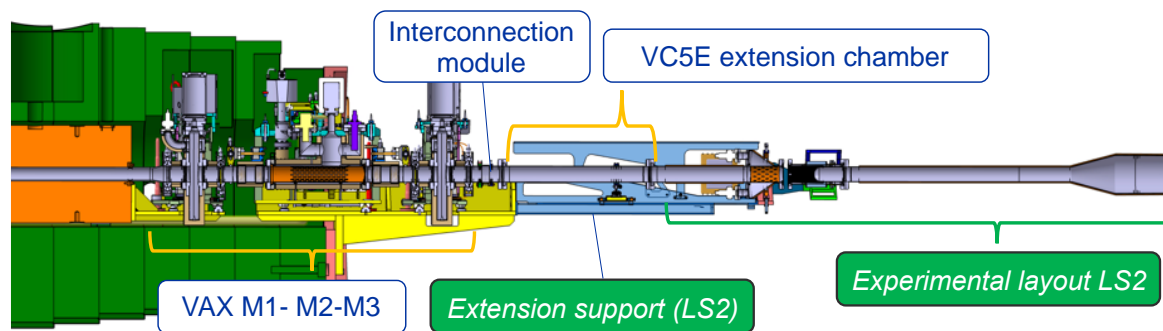
- To avoid need of recabling for ultimate luminosity (and beyond), project had made proposal to adopt category of cables with increased radiation tolerance in most exposed locations of IRs of P1 and P5
- Market Survey for cable procurement concluded, now preparing IT
- Decision taken by CERN Mgmt not to pursue option of radiation tolerant cables for installation
- IT will be prepared with general purpose cables only
- Efforts allowed re-establishing within CERN an appropriate set of QA tests to be executed on cable samples
- Results of ongoing radiation tests will be analysed in coming weeks to assess/confirm present operational limit of 500 kGy and associated safety factor

Cable categories for 4000 fb⁻¹ - right of P1 (top view)



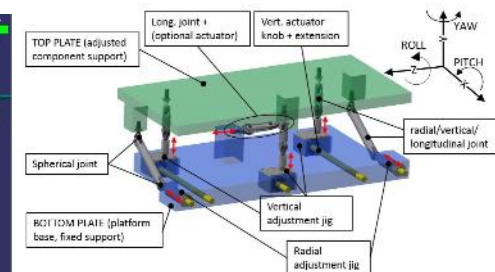
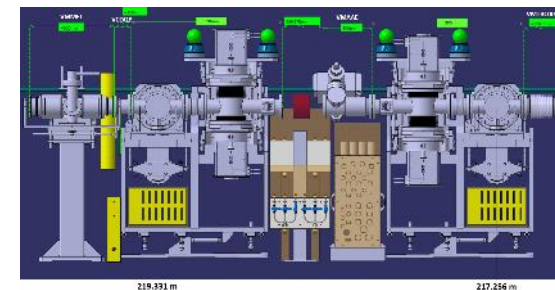
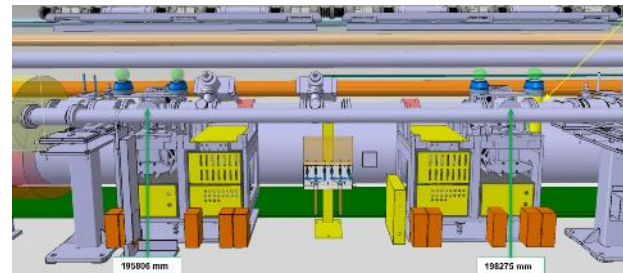
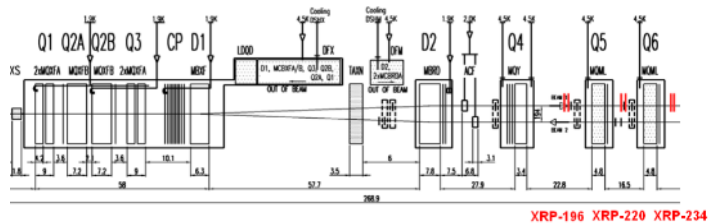
Vacuum Chambers in FR of experiments

- Vacuum chambers in the forward region of the ATLAS and CMS experiment need to be adapted, to remain compatible with the new layout of HL-LHC inner triplet region + VAXS
- Scope of work known in past, detailed cost estimate missing
- Decision taken to include this in BaC of HL-LHC project under WP12, in close synergy with WP8 and TREX, see DMR [2938377](#)



PPS2 in HL-LHC era

- An upgrade of the CMS Precision Proton Spectrometer (PPS2) for forward physics in IR5 has been endorsed by CERN Mgmt (pending final clarification of cost sharing)
- PPS2 is an experiment, and will as such not be included in the baseline nor BaC of the HL project, but has big impact on HL Layout of IR5 and represents additional scope for equipment groups, in particular for vacuum layout, inclusion of PPS2 in FRAS, DQR relocation, instrumentation and cabling, upgraded cooling system,...
- ECR EDMS [2915345](#) details current understand of system changes is circulating for final comments/approval by groups for completeness and availability or resouces
- PPS2 not yet included in present Layout V1.7, but will appear in next one (V1.8 or V2.0)



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- CT-PPS2 [LHC-EC-0044](#)

Conclusions

- Two years ahead of starting LS3, technical baseline has converged on all major aspects
 - 19 Engineering Change Requests (ECRs) + 23 Decision Management Reports (DMRs) approved
 - New Layout V1.7 to be approved in October 2023
- Update and re-validation of the baseline parameter set(s) ongoing in view of recent changes (Russian in-sourcing/descoping, 11T, e-cloud, PPS2,)
- Confirmation and further scrutiny of HL baseline to continue based on Run 3 experience and MD results (grateful for continued support by OP and Mgmt!)

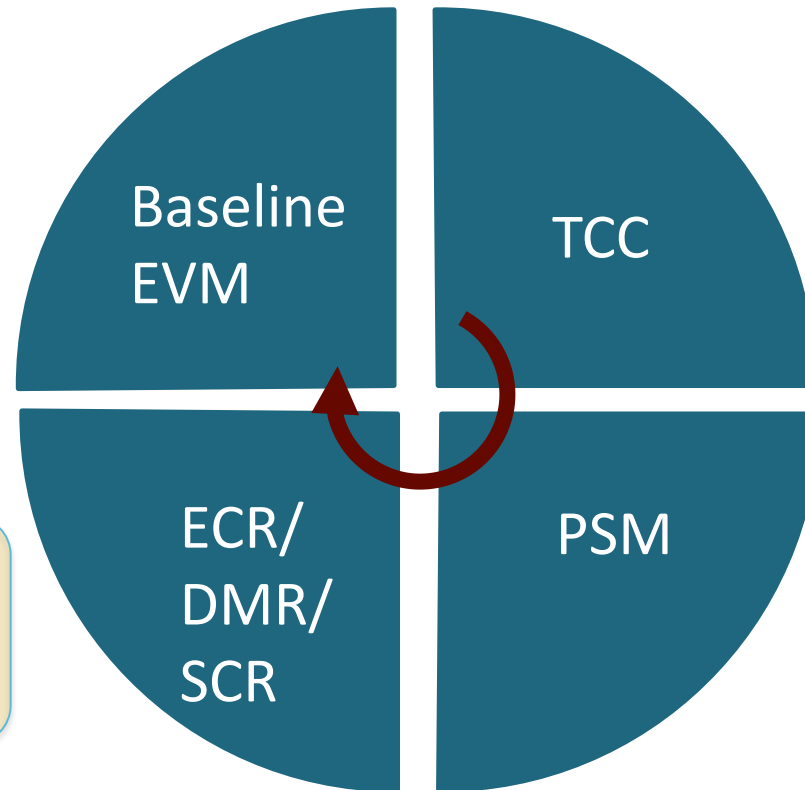


Thank you for your attention!
Questions?

Managerial process

Baseline EVM:

Implementation of changes in WP's Cost-to-completion



Engineering Change request:

scope change assessment & approval

Decision Management Report:

Cost/schedule change

Schedule Change Request:

change impacting master schedule of WP/project

Technical Coordination Committee:

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

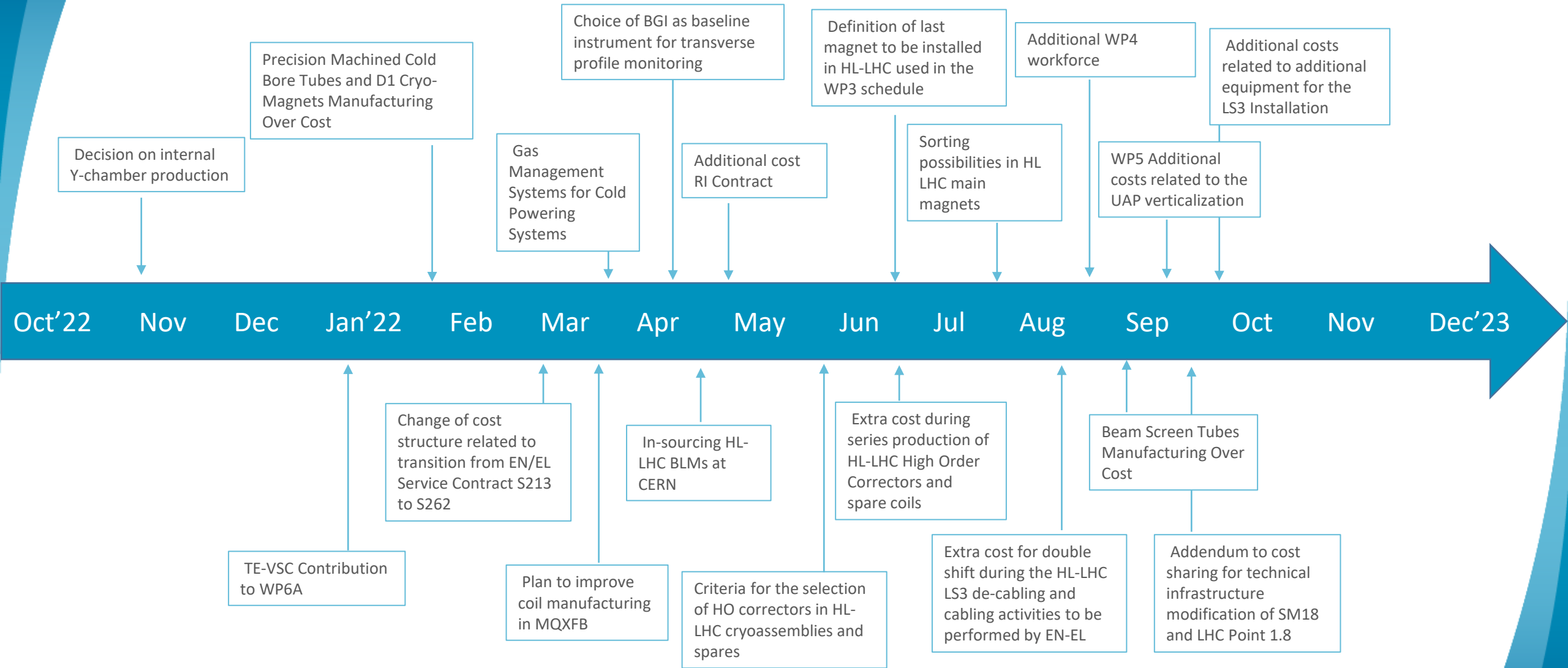
Project Steering meetings, per WP:

Assessment and decision on **budget changes** and **schedule changes**

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.

HL-LHC Baseline Changes (via DMRs/TCC)



HL-LHC Managerial Decisions (via DMRs)

EDMS	Description	Date	WP	EDMS	Description	Date	WP
2631530	Construction of a fourth D2 corrector prototype at CERN	Oct-21	WP3	2685798	Strategy for the procurement of cables for higher radiation tolerance for HL-LHC	May-22	WP1 WP15
2646046	Quench Heaters Design for MQXFB	Nov-21	WP3	2721956	Strategy for D2 series manufacturing	Jun-22	WP3
2604419	Agreement for the extra costs of HOC and spare coils	Dec-21	WP3	2742239	Integration of Minor Civil Engineering works to HL-LHC activities	Jun-22	WP15
2669588	De-scoping of some mechanical components of 4 series DFHX from Uppsala University	Jan-22	WP6A	2736828	Strategy for the procurement of Vacuum Sector Valves	Jun-22	WP4 WP12
2637180	SM18 Bench-Reconfiguration for testing of WP3 magnets and WP6A SC Links	Feb-22	WP1 WP3 WP6A	2726806	In-sourcing of HL-LHC BPMs at CERN	Jun-22	WP13
2688784	Production two MCBRD magnets at CERN with components provided by IHEP	Feb-22	WP3	2740080	Re-scheduling of ATLAS JFC3 shielding machining	Jul-22	WP8
2645981	Manufacturing of 4 TCPCs in-house	Mar-22	WP5	2737787	Updated EN/EL Manpower Plan for WP17.2/WP15	Jul-22	WP15 WP17
2595741	Production in-house of HL-LHC HTS Current Leads	Mar-22	WP6A	2740267	Purchase of additional 100 km of MgB2 wire	Jul-22	WP6A
2724922	Software support for cold powering tests of HL-LHC magnets in SM18	Mar-22	WP1 WP3	2771582	Decision for Cu Coating of TAXN Y-chamber	Aug-22	WP8
2675955	Differential longitudinal pressures across the HL-LHC IT Cold Masses	Mar-22	WP3	2771585	In-sourcing of LS3 Collimators and Masks	Sep-22	WP5
2717815	Thermal Cycle for the HL-LHC IT String	Apr-22	WP16	TBC	De-scoping of HELs and Dilution Kickers	Sep-22	WP1
2694690	Strategy for the procurement of transport devices after the opening of IT-4579	Apr-22	WP15				

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 MQXF A/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

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