International Review of the HL-LHC Collimation System

Status of the 11 T Dipole Project

Timing: 20’ + 10’

F. Savary on behalf of WP11

With contributions from L. Bottura, G. de Rijk, A. Devred, P. Ferracin, A. Foussat, F. Lackner, S. Izquierdo Bermudez, D. Schoerling, J.C. Perez, H. Prin, D. Ramos, G. Willering, S. Yammine

CERN – Auditorium TE 30/7-018 – 2019-02-11 – https://indico.cern.ch/event/780182/

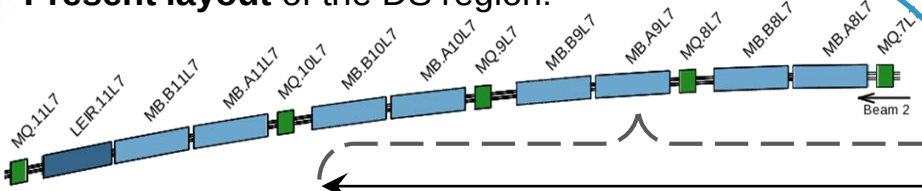
Outlook

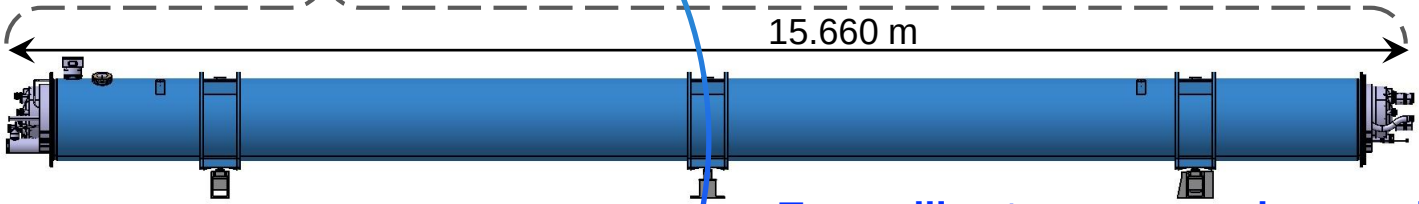
1. Introduction to the 11T dipole
2. Status and plan for LS2
3. Final configuration of cold masses and corrector package in new locations
4. Summary of LS2's ECRs
5. Concluding remarks

What?

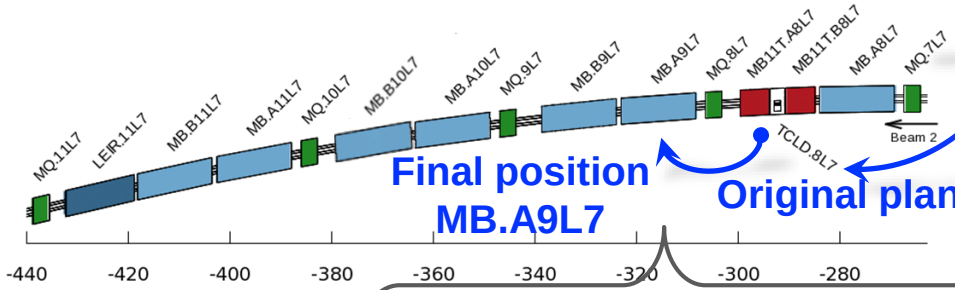
Where?

Present layout of the DS region:





New layout with one collimator and two 11T dipoles:

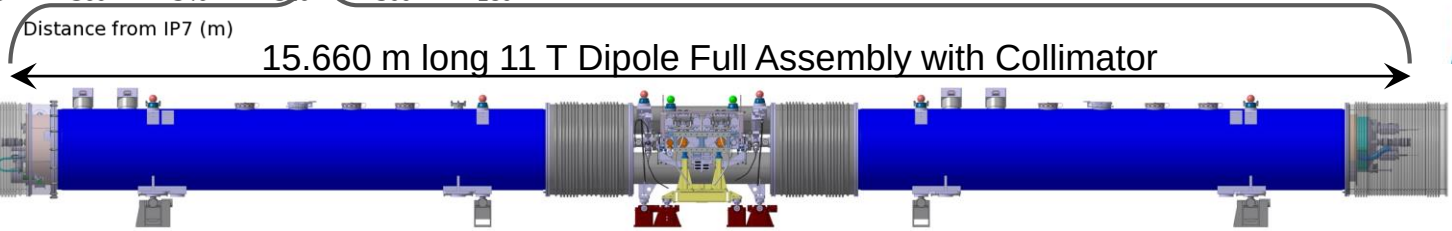


Final position
MB.A9L7

Original plan

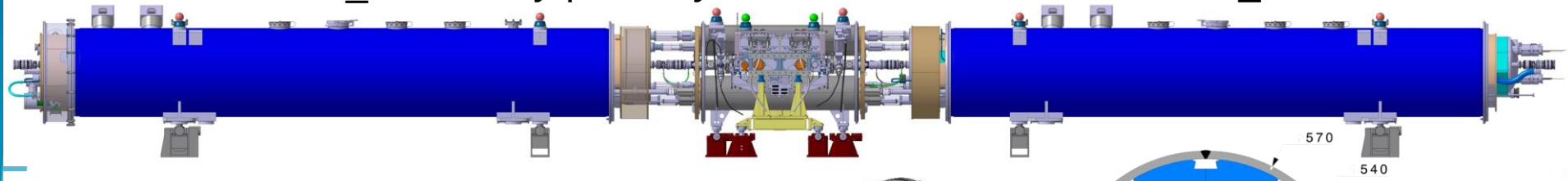
Two collimators, one per beam, will be installed on either side of interaction point 7 in order to absorb both proton and heavy-ion collimation losses

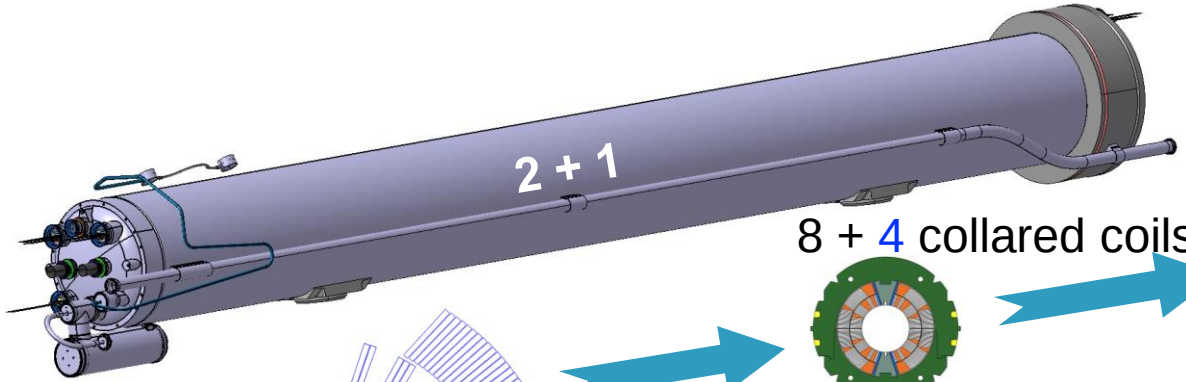
The **11 T DFA provides space for the new collimators**. It produces the same integrated field as the MB, **119 T·m @ 11.85 kA**

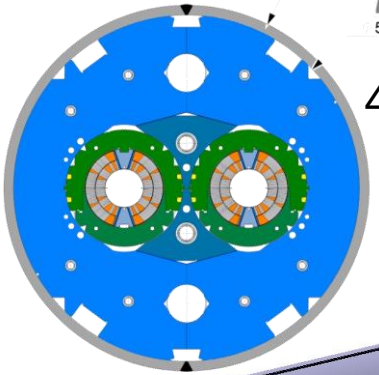


The Main Elements of the 11T Dipole Full Assembly

LBH_**A** By-pass cryostat with collimator LBH_**B**

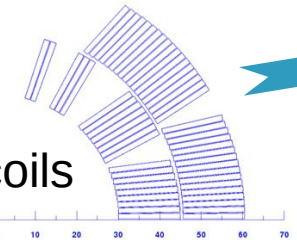






4 + 2 cold masses

8 + 4 collared coils

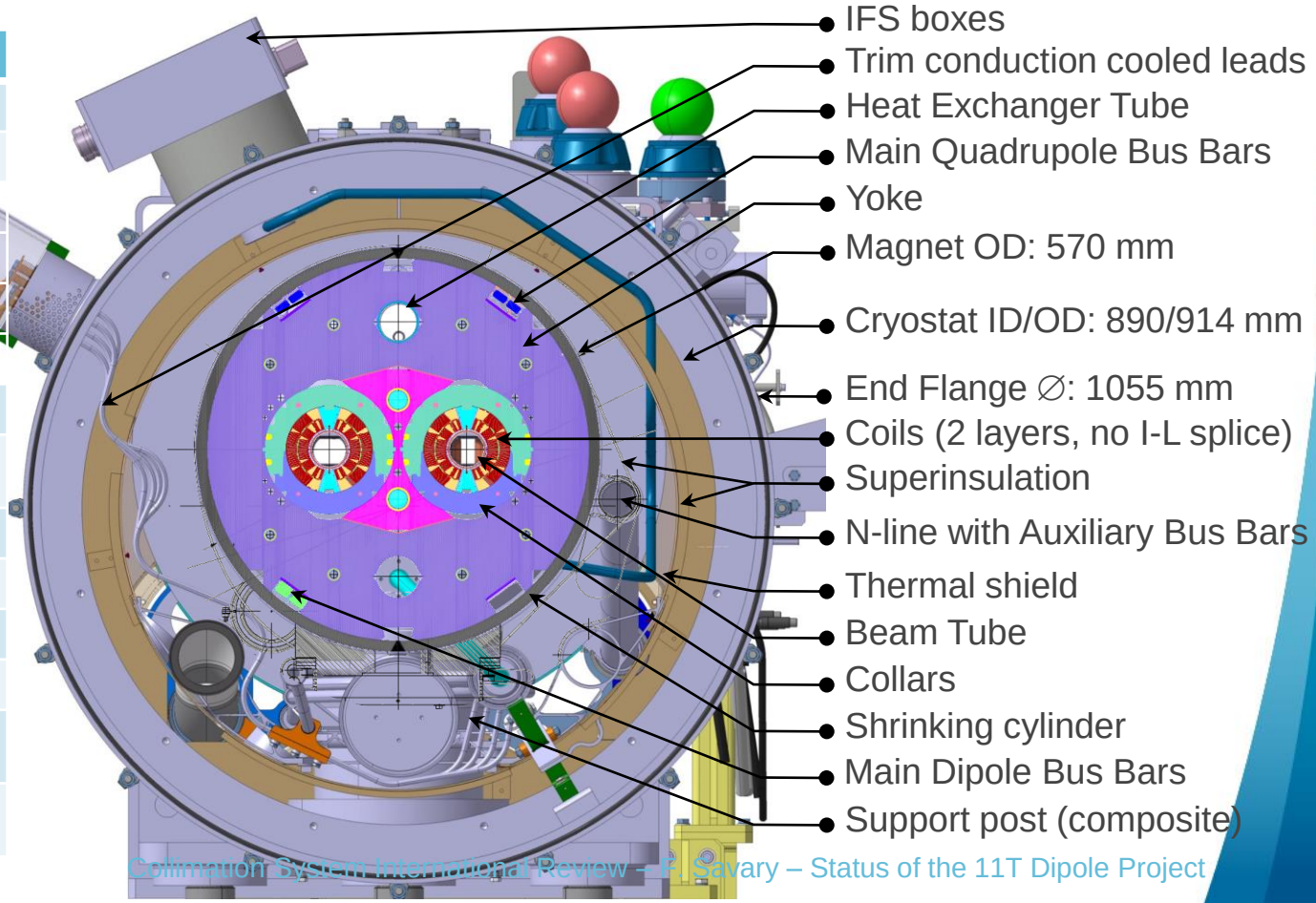


16 + 8 + 6 coils

Colli

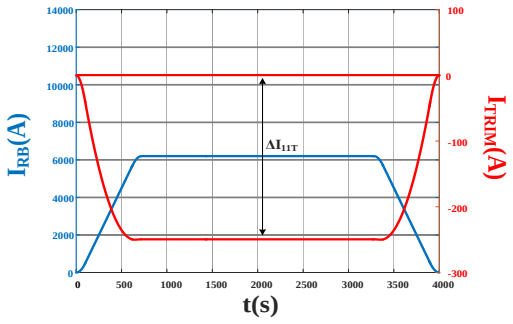
A X-Section of the 11T DFA … with more details

Parameter	Value
Bore field @ I_{NOM}	11.23 T
Nominal current	11.85 kA
Operating T	1.9 K
Load line margin	20 %
Magnet aperture	60 mm
# turns (inner/outer)	56 (22/34)
Cable bare width	14.7 mm
Cable bare mid-thickness	1.25 mm
Keystone angle	0.79°
Strand diameter	0.7 mm
# strands per cable	40
Cu to non Cu ratio	1.15 ± 0.1
RRR on strand after reaction	> 150
Minimum strand critical current, Ic (12T, 4.222 K)	438 A

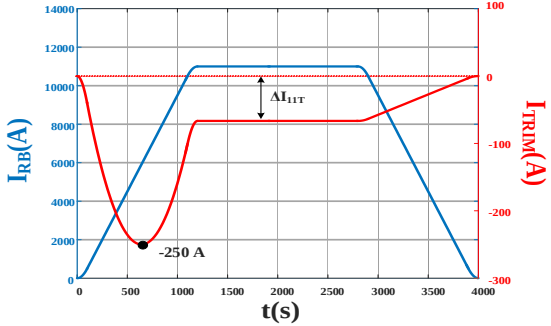


Trim and operation scenarios

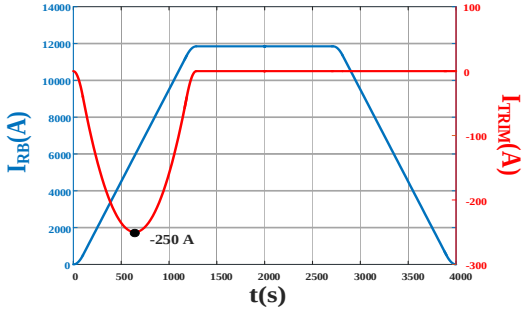
3.5 TeV (Special Op) / I_{RB} = 6 kA / ΔI_{11T} = -250 A



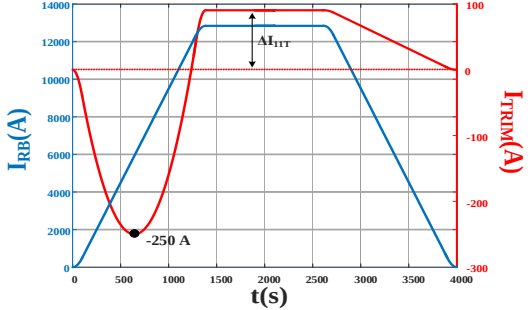
6.5 TeV / I_{RB} = 11 kA / ΔI_{11T} = -67 A



7 TeV (Nominal) / I_{RB} = 11.85 kA / ΔI_{11T} = 0 A



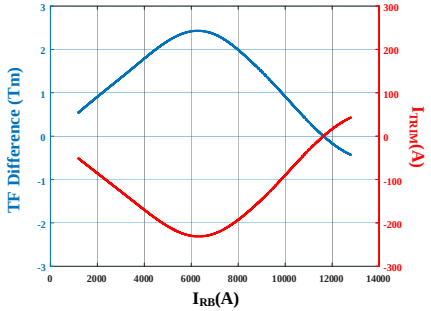
7.5 TeV (Ultimate) / I_{RB} = 12.84 kA / ΔI_{11T} < 100 A



Most critical operation points:

1. Itrim = -250 A and I_{RB} = 6 kA, 10 A/s
2. Itrim ≈ 50 A and I_{RB} = 12.84 kA 0 A/s

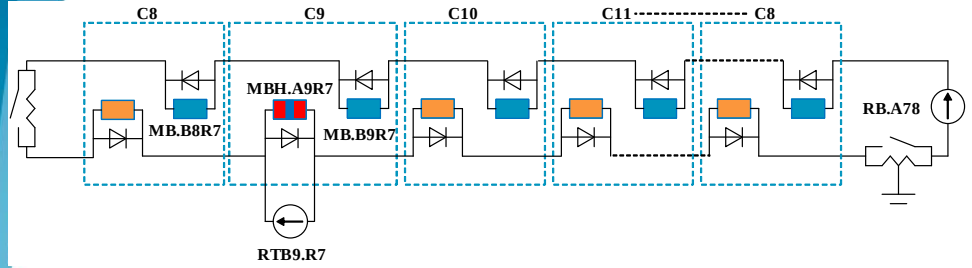
Data from WP11 Sharepoint



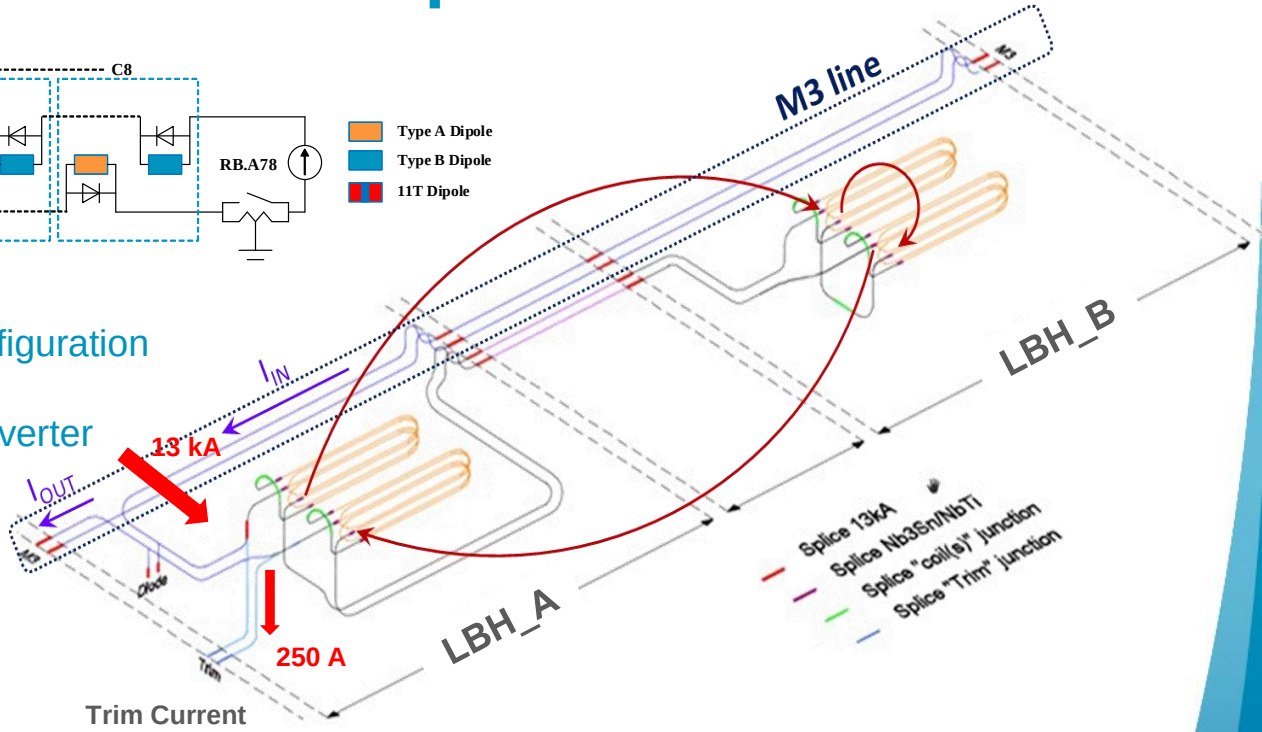
Difference in transfer function (TF) between MB and MBH and trim current needed for compensation

Courtesy M. Karppinen, S. Yammine

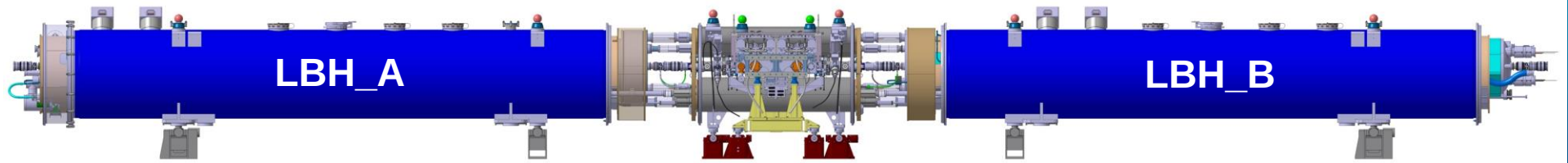
RB circuit and current path in 11T DFA



Main dipole circuit RB.A78 configuration
for the HL-LHC
with the 11T trim power converter



Courtesy H. Prin, S. Yammine



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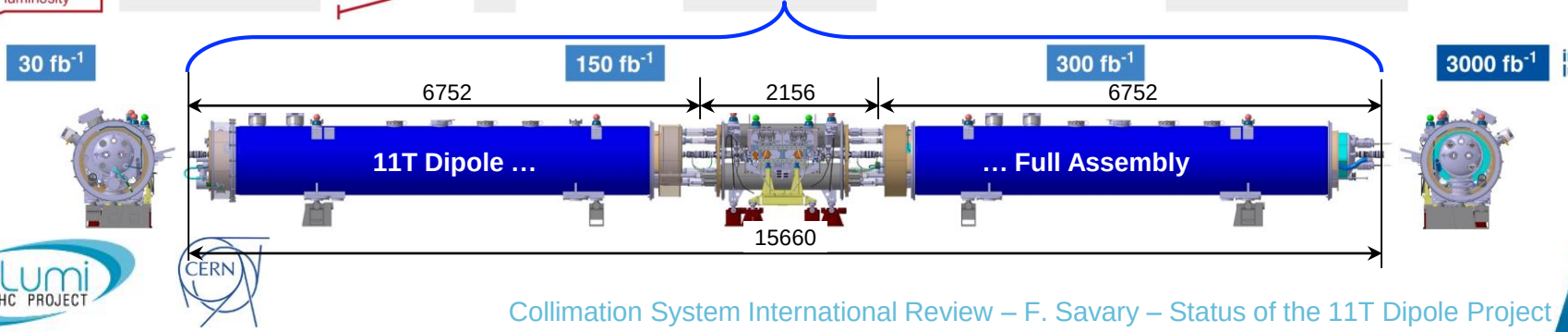
LHC / HL-LHC Plan



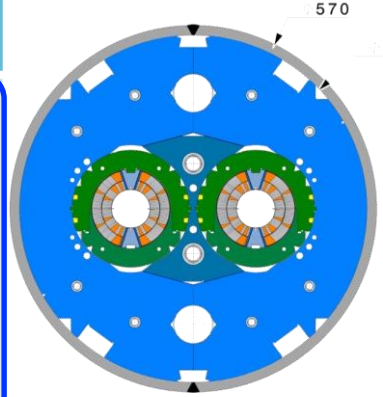
Deliverables (numbers)

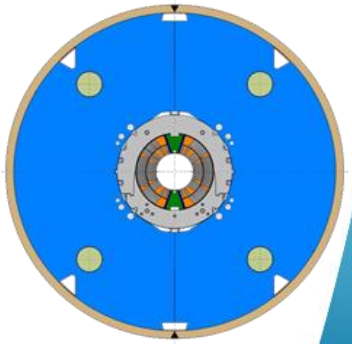
	Baseline March 2018

IP7 – 11T dipole full assembly	• **2 for installation during LS2**
	  • 2x LMBHA + 2x LEN + 2x LMBHB
	  • (2+2)x2 = 8x collared coils
	  • 8x2 = 16x coils (+4 spares)
	• **1 spare**
	  • 1x LMBHA + 1x LEN + 1x LMBHB
	  • (1+1)x2 = 4x collared coils
	  • 4x2 = 8x coils (+2 spares)

IP2 – Connection cryostats for collimators	• 2 for installation during LS2 • 1 spare
11T dipole prototype	• 1 made up of RRP conductor • 1 hybrid assembly with 1 aperture “series”

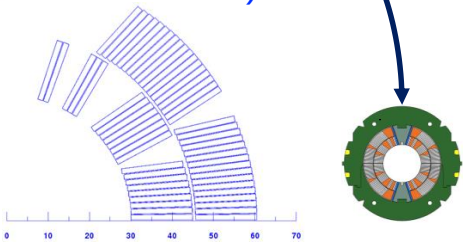
11T dipole **models**	• 12
	  • 1 single coil (2 coils, but only 1 tested)
	  • 9 single aperture, of which **three with the conductor of the series production**
	  • 2 two-in-one

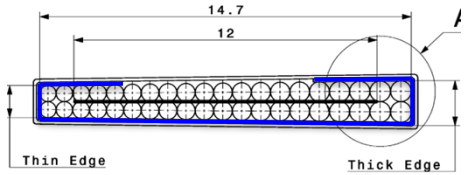


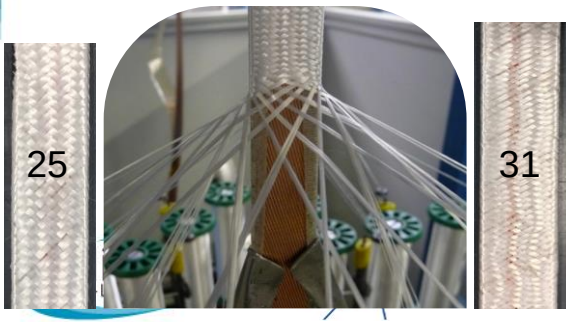


11T Dipole models / prototype made @ CERN to date

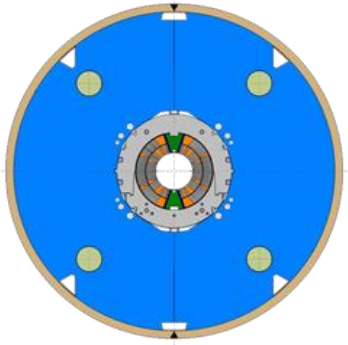
- 6 blocs
- 56 turns (22 in IL, and 34 in OL)





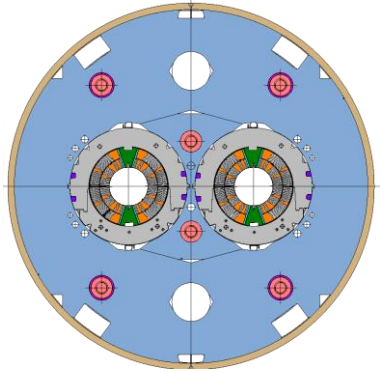


Single Aperture
OD 534 mm



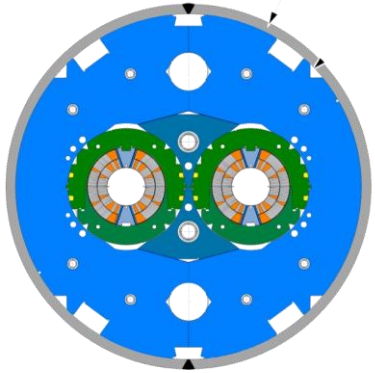
- MBHSP101
- MBHSP102
- MBHSP103
- MBHSP104
- MBHSP105
- MBHSP106
- MBHSP107
- MBHSP108 to be built
- MBHSP109

Two-in-One
OD 580 mm



MBHDP101

Two-in-One
OD 570 mm

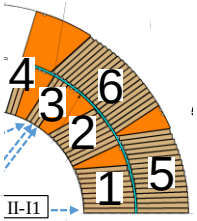


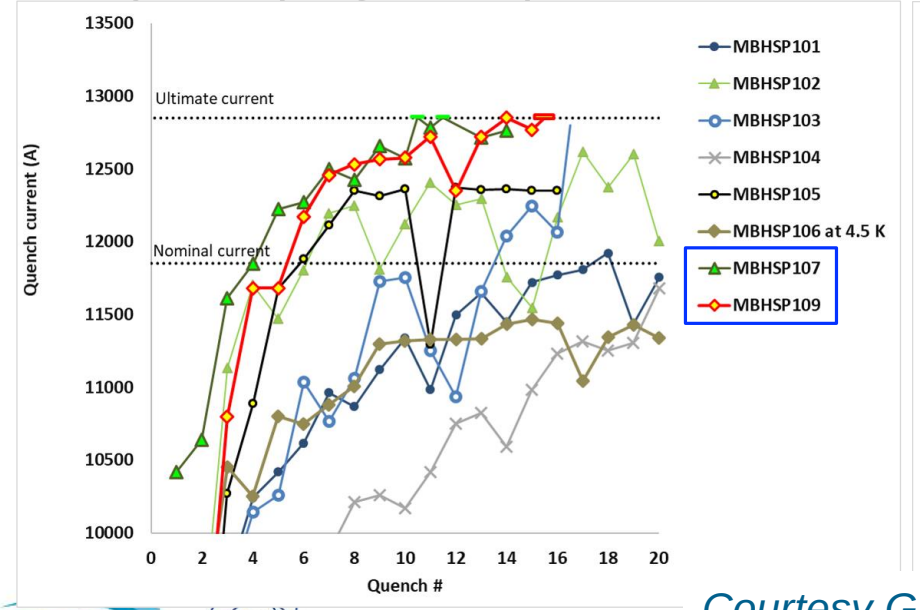
- MBHDP102
- Prototype LMBHB001
- **Hybrid Proto LMBHP001 equipped with one aperture from the series**, tests at cold to start in the coming days

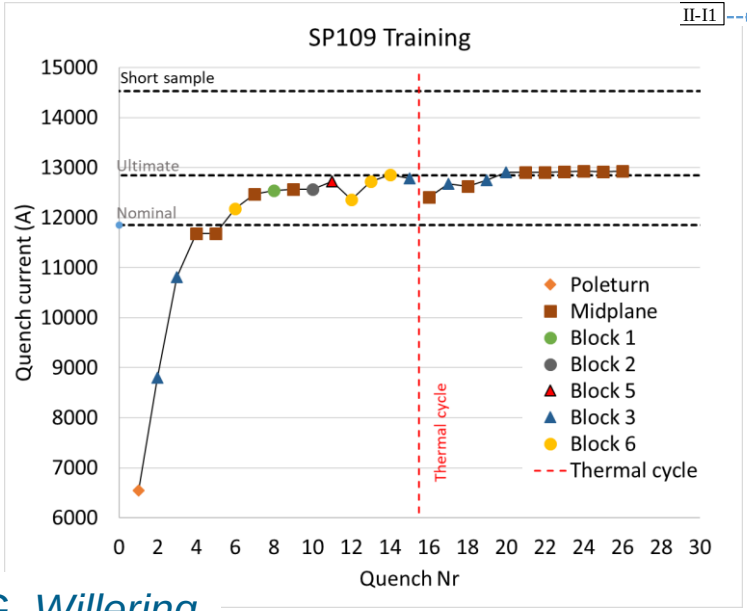
- **Series conductor**
- **Task Force (as from November 2017):**
  - ✓ New cable insulation
  - ✓ Optimized shimming and collaring process

Cold tests results – Short models

- In addition to training, field quality, and protection performance studies, current cycles (target 2000) and quench heater firing cycles (target 200) are carried out on SP109



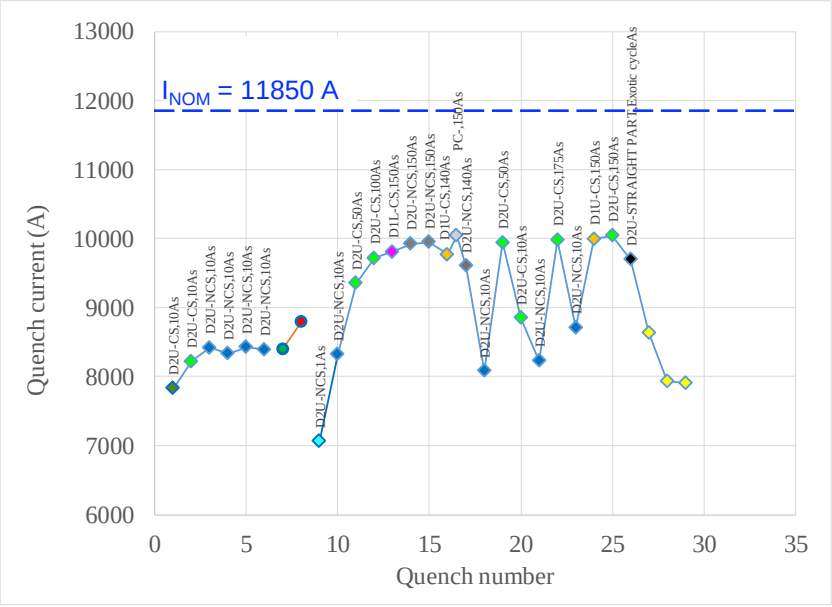




Courtesy G. Willering

Cold tests results – Prototype LMBHB001

- Due to the conductor issues (mechanical) training difficult to study and plots can be misleading
- From the plot below we identify quench 1, 13, 16 and 24 as training quench since a large vibration precursor is seen at the start of the quench. For all other quenches likely the conductor degradation plays an important role



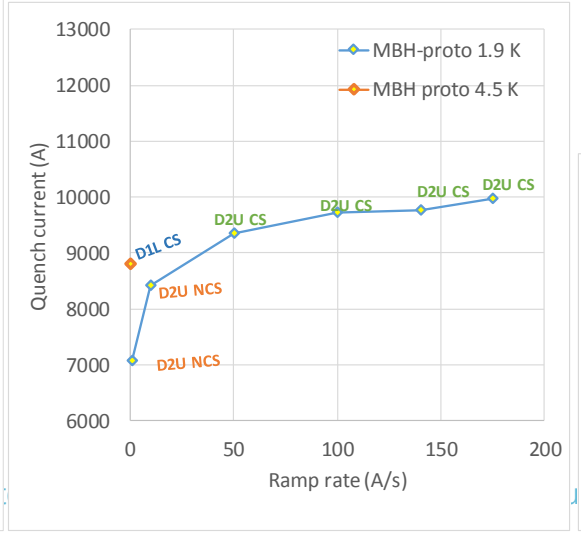
The magnet shows 2 clear limits:

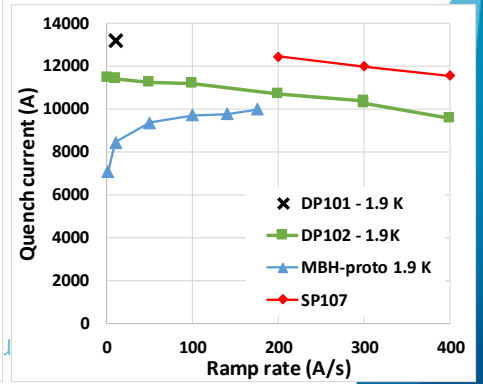
1. Low ramp rates: D2U head, non-connection side
2. Higher ramp rates: D2U head, Connection side

Courtesy G. Willering

In comparison:

1. The model DP102 had a normal dependency on ramp rate
2. The prototype has an inversed dependency, non-homogeneous defects are causing non-homogeneous current distributions and unusual quench effects





Courtesy G. Barlow

Hybrid prototype LMBHP001 leaving SMI2, after cryostating, on 29 January

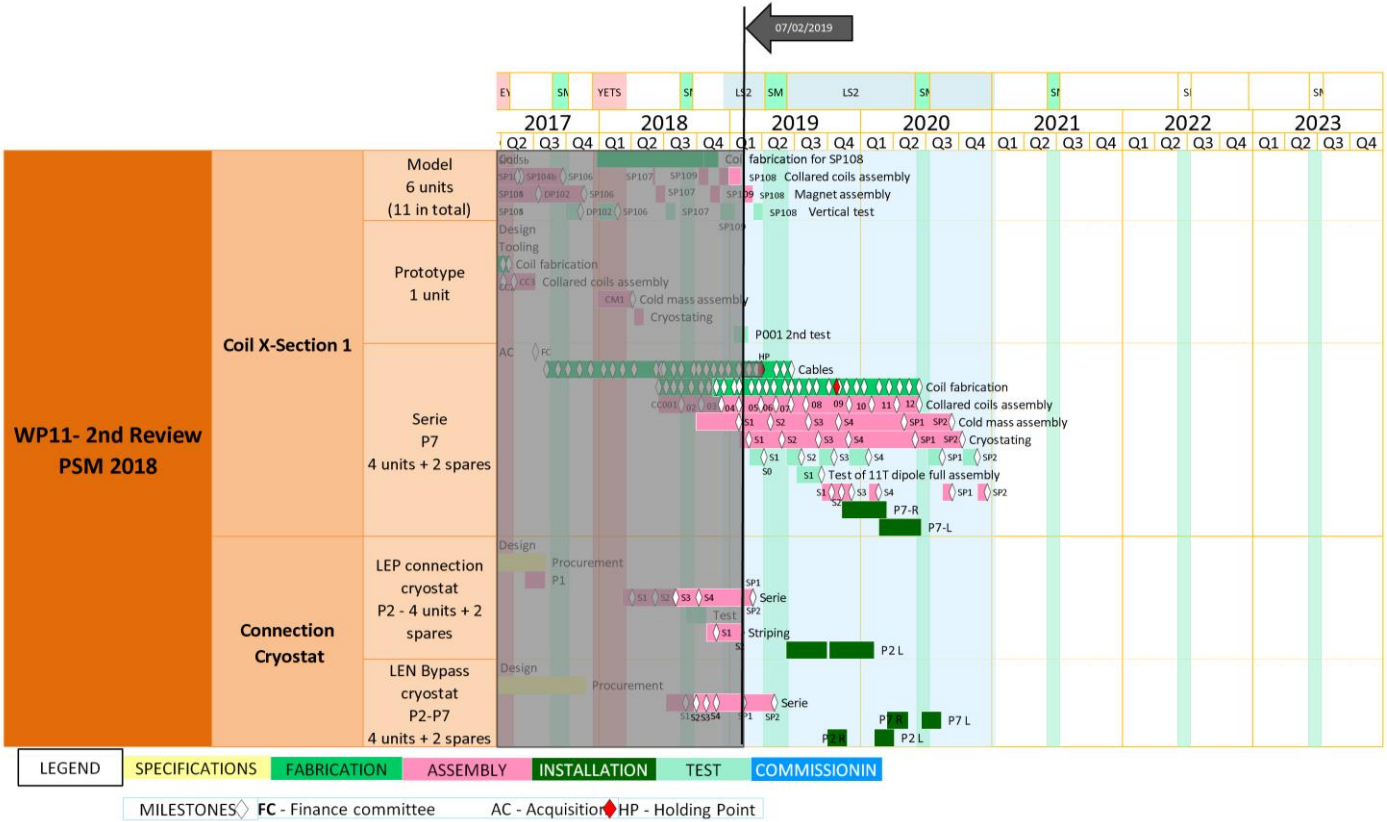
Courtesy G. Willering

Hybrid prototype LMBHP001 in SM18, moved on to the test bench on 1st February

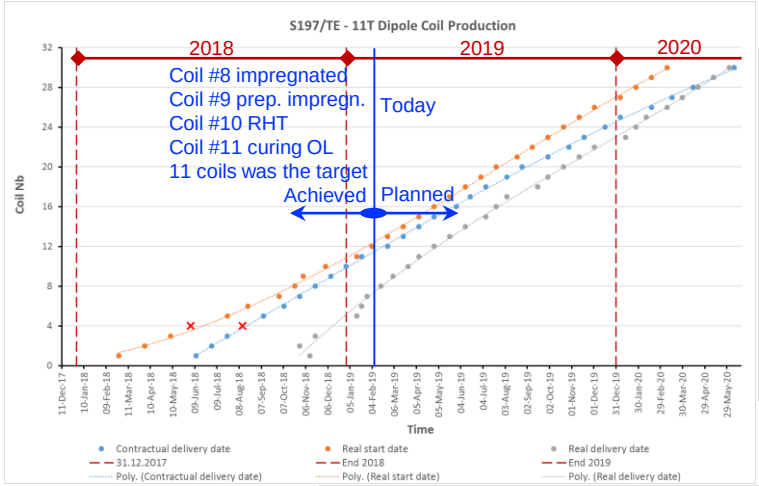
Production plan

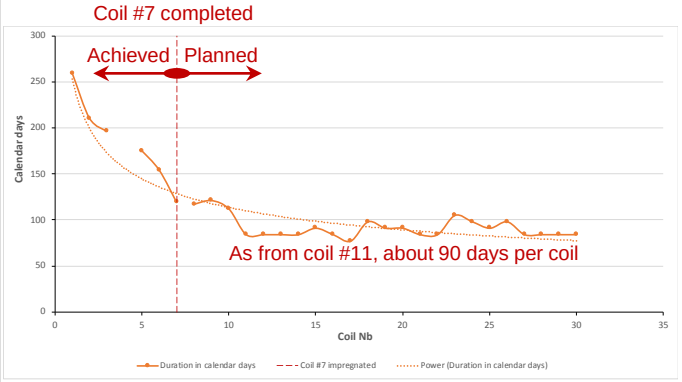
- A **service contract** was placed with the firm GE, formerly Alstom Belfort, (contract S197/TE/HL-LHC). It includes the manufacturing at CERN of **30 coils (WP1)**, and the assembly from these coils of **12 collared coils (WP2)**
- **WP1, and WP2 include visual inspection, electrical tests, and metrology**. The corresponding test reports are uploaded in MTF by GE
- The **RRR measurements, the critical current measurements, and the warm magnetic measurements are carried out by CERN**
- The **other activities**, i.e. cold mass construction, cryostating, cold tests, and stripping, are **carried out by CERN**, with staff, associates, and contract labor people

Master schedule

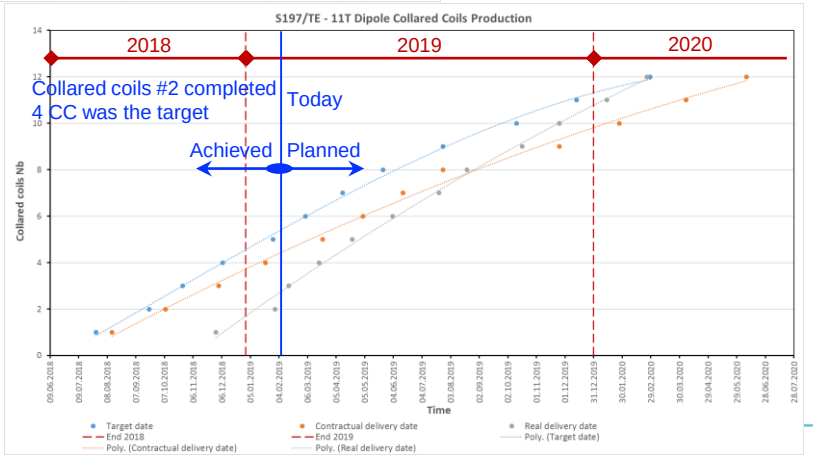


Coils and collared coils production – Key numbers

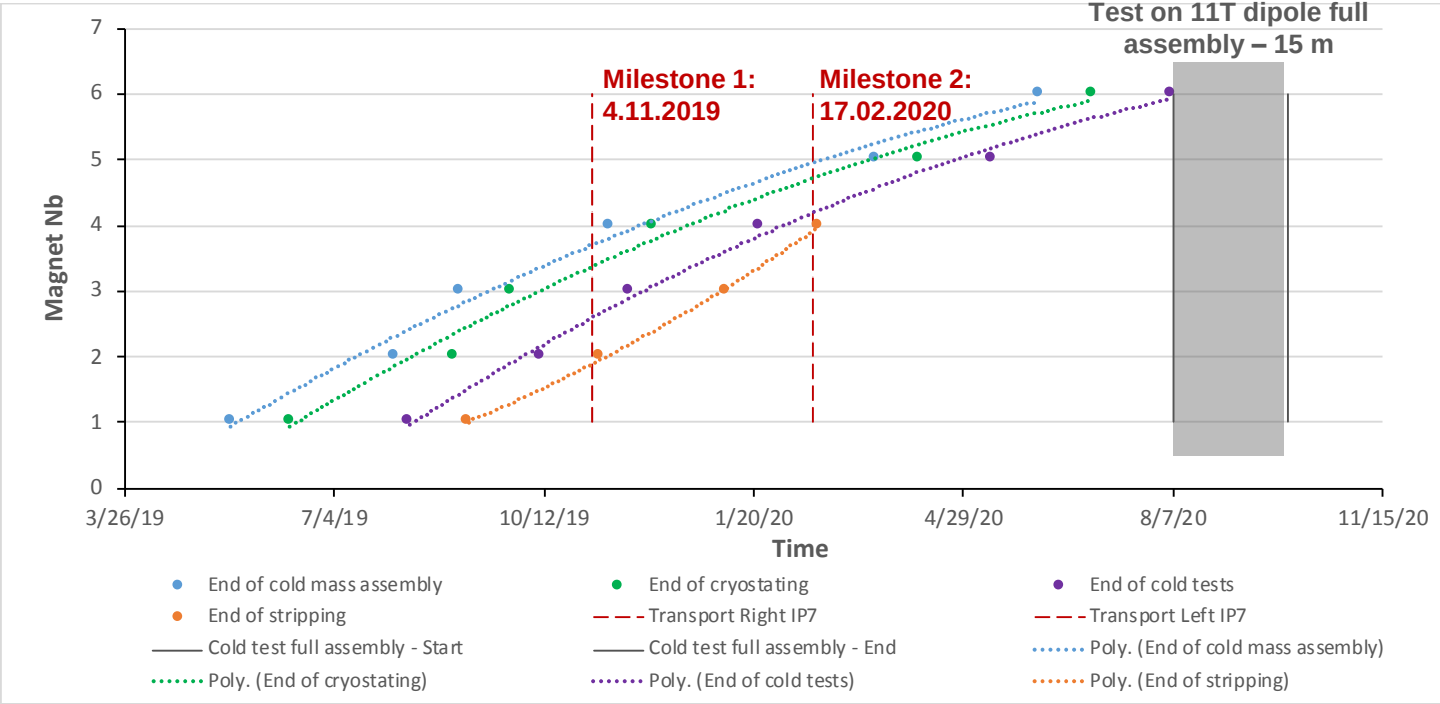




Learning and reduction of production times



CMA, Cryostating, Cold tests, Prep^{n} for tunnel



The **delivery** for installation will be **“just-in-time”!**

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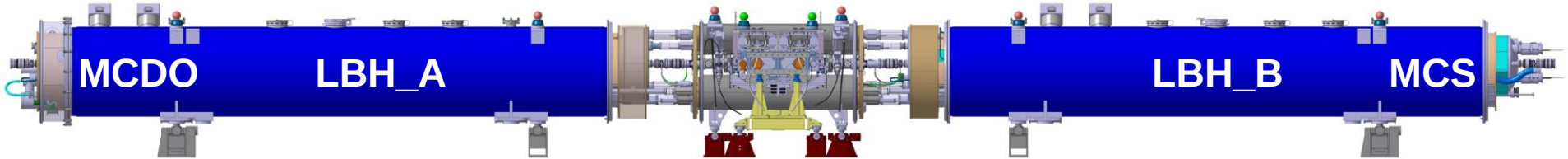
Cold mass configuration

- Replacement of the present main dipoles
  - On the **left side** of IP7
    - MB.A9L7 (replaced MB is of **type B**, only MCS: LBBRB.9L7, circuit RB.A67)
    - TCLD collimator will be on the beam line 2 (internal beam, or passage side)
  - On the **right side** of IP7
    - MB.A9R7 (replaced MB is of **type A**, with both MCDO and MCS: LBARA.9R7, circuit RB.A78)
    - TCLD collimator will be on the beam line 1 (external beam, or QRL side)
- The 11T dipoles LBH_A, and LBH_B, will be both equipped with MCS and MCDO such that they can be installed on either side of IP7



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Reference documents – Engineering check ongoing

- LHC-LBH-EC-0001 v.0.1
  - “Installation of the **11 T Dipole Full Assembly in LHC P7** (HL-LHC WP11)”, https://edms.cern.ch/document/1995306/0.1
  - Integration document by WP15 almost finished (EDMS 1904620): HL-LHC INTEGRATION REPORT FOR INSTALLATION APPROVAL - WP11: 11T Dipole Full Assembly Integration Study
  - The DN200 valve configuration is confirmed by TE/CRG and TE/VSC, and the ECR will be updated accordingly
  - Impact of flux jumps needs clarification: we are currently checking whether voltage peaks from flux jumps are critical for the stability to be guaranteed by the power converter, and whether they have any negative effect on the field stability. This will be discussed on Feb 14 with the relevant experts, and then will be presented to TCC (HL-LHC Technical Coordination Committee).
- LHC-LE-EC-0005 v.0.1
  - “Installation of the **Connection Cryostat Full Assembly in the LHC P2** (HL-LHC WP11)”, https://edms.cern.ch/document/1995583/0.1

Content of the ECR for IP7

- The two locations are specified
- Compatibility vs beam dynamics is explained (trim, flux jumps to be completed, field quality b_3 higher than in MBs, however, dynamic aperture unaffected)
- Implications on vacuum system explained and resulting changes described (new sectorization of vacuum lines, and new cold-warm transitions)
- Implications on cryogenic system explained (increase of hydraulic impedance in the insulation vacuum through the bypass cryostat, and more safety valves are needed)
- Specific process of alignment is described
- The trim circuit and related power converter are described
- There will be modifications to the quench detection system (QDS), a new quench protection system (nQPS), and changes to the quench heater discharge units (racks)
- Finally, the Powering Interlock System (PIC), the protection of the trim current leads, the cabling, and the organization of the work during LS2 are briefly described

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Concluding remarks

- The good results following the cold tests of the last models MBHSP107 and SP109 confirm that the performance requirements are met
- The cold test of the hybrid prototype is of utmost importance, as it is meant to validate the first collared coils assembly of the series production, which has been made according to the recipe applied for the models SP107/109
- Pending the check point above, there is no showstopper to install the 11T dipoles in the tunnel during LS2, albeit the schedule is rather tight

HiLumi HL-LHC PROJECT

Thank you for your attention

CERN