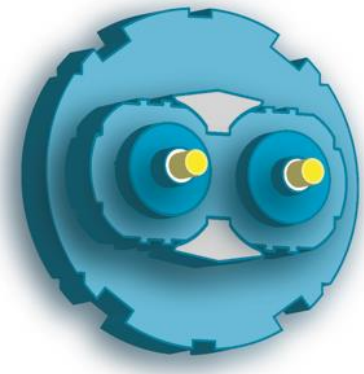


High Luminosity LHC

Collaboration Meeting on DS 11T Dipole Grounds

Current baseline design, project status and plan

F. Savary, on behalf of WP 11

23 September 2015

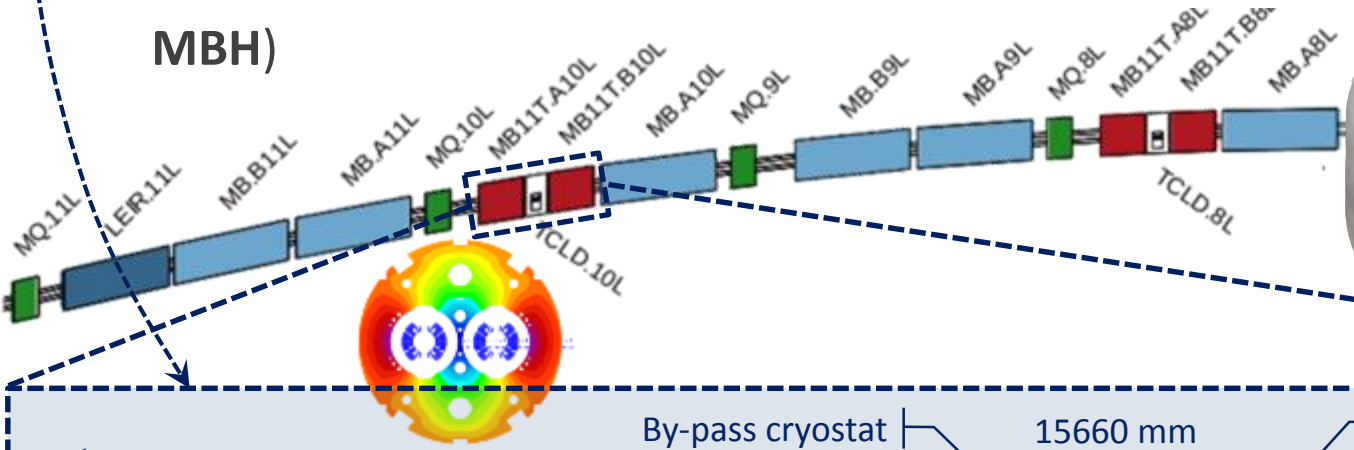
The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404.

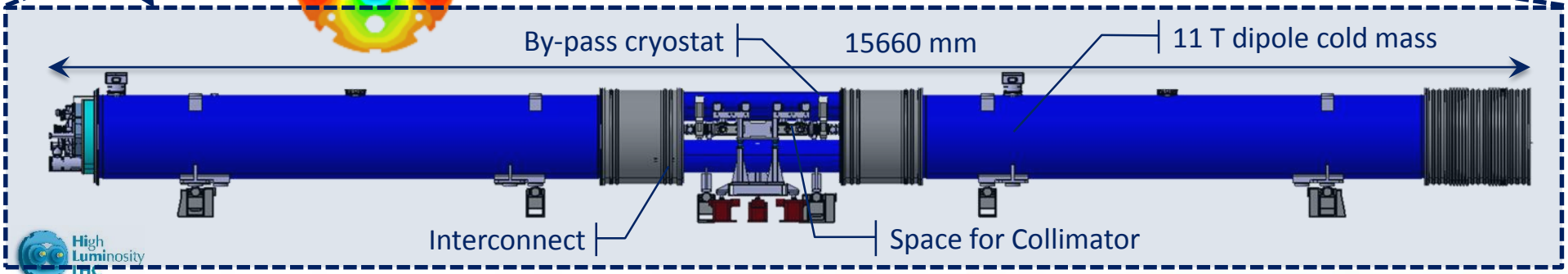
OUTLOOK

- Terminology and HL-LHC time line
- Part I: Current baseline design
  - Cable
  - Cross section
  - Cold mass assembly
  - Integration, powering, trim
  - Quench heaters and protection
- Part II: Project status and plan
  - Overall plan
  - Model program
  - Prototype
- Conclusions

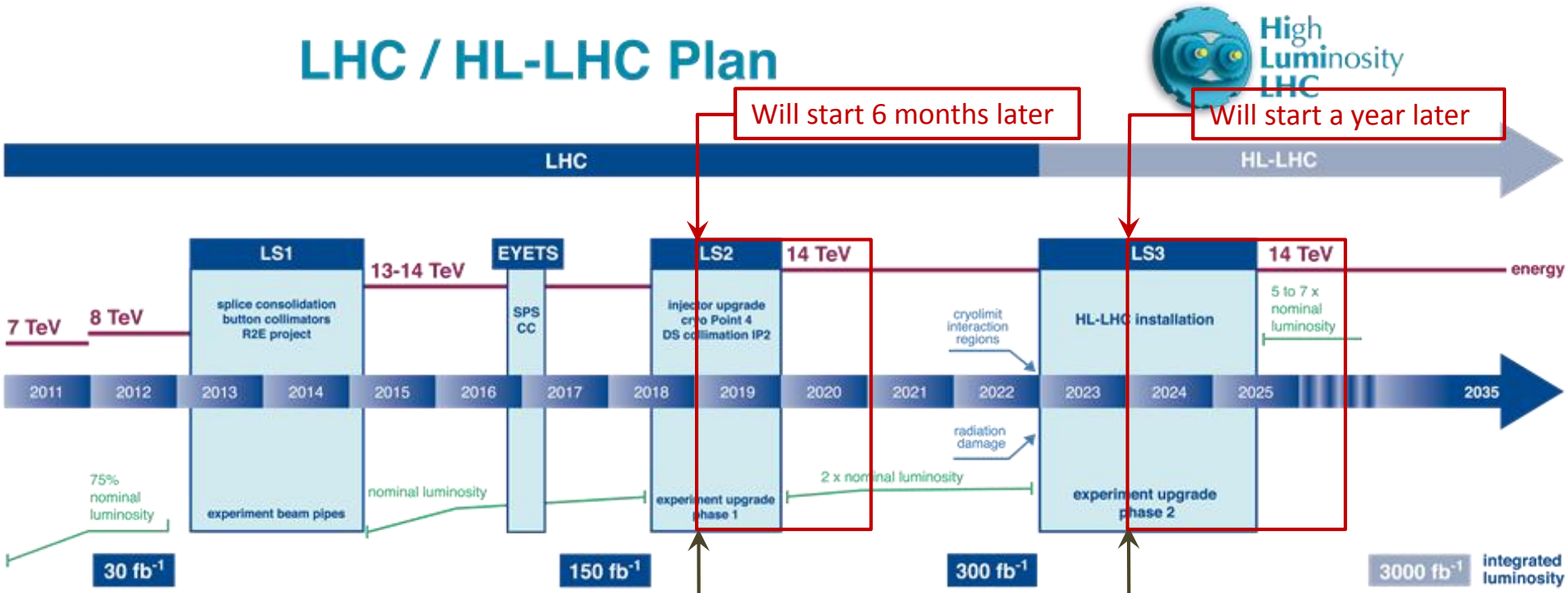
Reminder on terminology – CRYO-ASSEMBLY

- **Create space in the dispersion suppressor regions of LHC, i.e. a room temperature beam vacuum sector, to install additional collimators (TCLD)**, which are needed to cope with beam intensities that are larger than nominal, such as in the High Luminosity LHC (HL-LHC)
- **Replace a standard MB by a pair of 11T dipoles** (the 11T dipole is also called **MBH**)





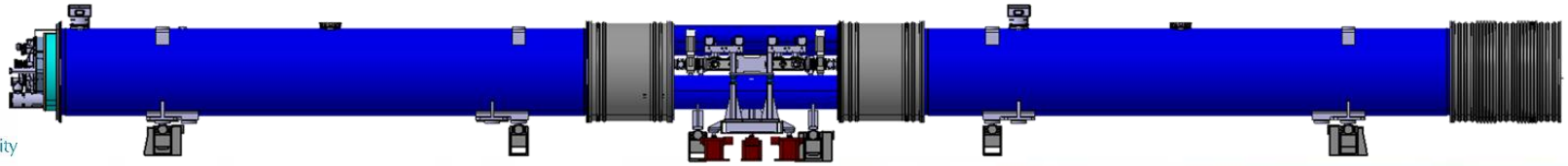
The DS 11T dipole on the HL-LHC timeline



- First-of-a-kind shall be made before starting LS2
- 2nd unit immediately after
- **Possibly for IP2, however, installation during LS2 NOT ANYMORE in the baseline**

In total up to 8 units
4 to 6 units to be installed
+ 2 spare units

- 6 additional units, of which:
  - 4 for installation in IP7
  - 2 spare units



Another solution under study for IP2 – Heavy ions

J.M. Jowett, Collimation Upgrade Meeting, 20/3/2015

- Following 2013 Collimation Review:
  - First installation (2 TCLD units) foreseen for ALICE Pb-Pb in LS2, subject to confirmation after 2015 Pb-Pb run and tests of bump mitigation techniques
- Because of the form of the dispersion function in IR2, there is a possibility that we can combine bumps and an alternative location of the TCLD in the connection cryostat (missing MB)
  - No 11 T magnets required
  - Different but apparently simpler integration
  - Significant orbit bump during luminosity operation!
  - Option to include an additional horizontal corrector beside it

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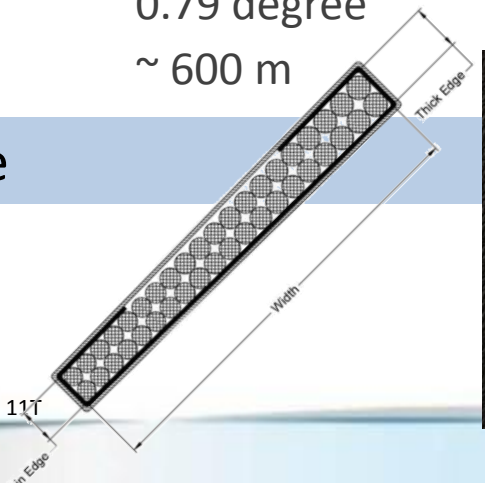
Conductor, cable and insulation scheme

Conductor (batch of 500 km)	
• Type	**RRP 108/127**
• Diameter	0.700 ± 0.003 mm
• RRR	**> 150**
• Cu/non-Cu ratio	1.15 ± 0.1
• Minimum strand critical current, I_C (12T, 4.222 K)	438 A

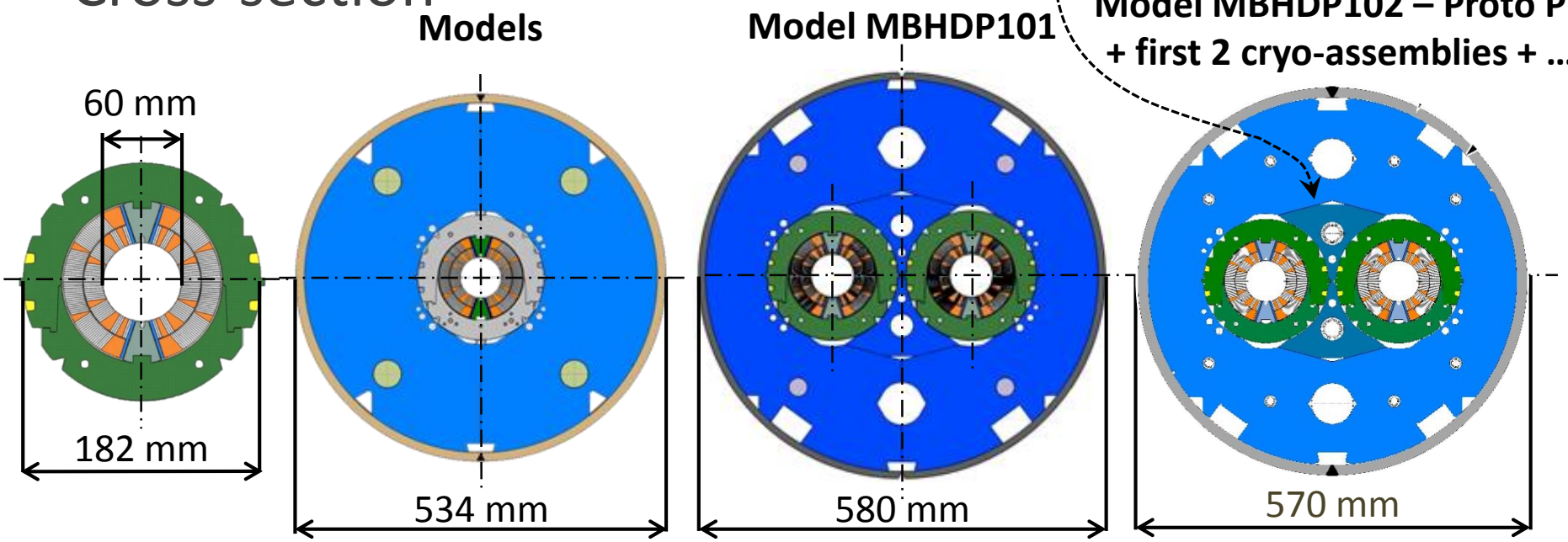
Cable		
• Number of strands		40
• Width before reaction	B. Bordini	14.7 mm
• Mid-thickness before reaction		1.25 mm
• Keystone angle		0.79 degree
• Cable unit length		~ 600 m

Insulation scheme	
• Mica tape, COGEBI FIROX®, thickness 80µ	
• S2 glass gleeve	D. Smekens
• Resin impregnation, CTD-101K	



Cross-section

Shim added between central yoke and laminations to allow adjustment



Collared coils → Single aperture model → Two-in-one original → Two-in-one baseline

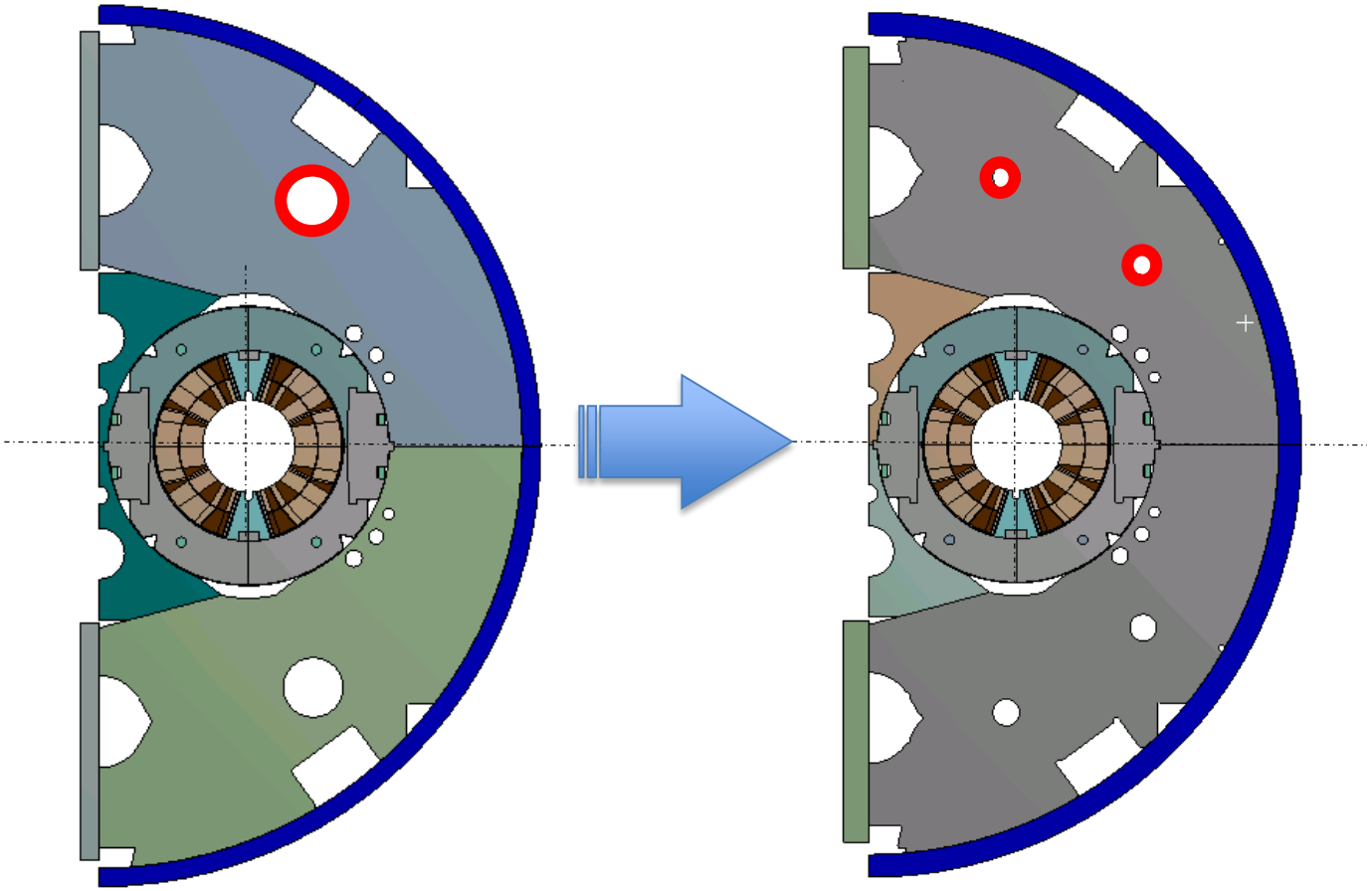
- 6 block **Nb_3Sn** coils of Ø 60 mm aperture
- 56 turns, 22 in inner layer, 34 in outer layer, no interlayer splice
- Removable poles made of Ti
- Separate stainless steel collars for each aperture
- Vertically split iron yoke
- Stainless steel shell of 15 mm thickness (2-in-1)

Structural assessment

F. Lackner, T. Lyon

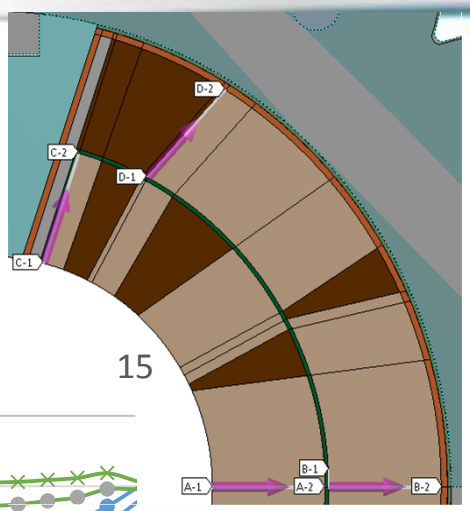
- Yoke Outer Radius: *275 mm*
- Shell thickness: *15 mm*
- 1 rod hole

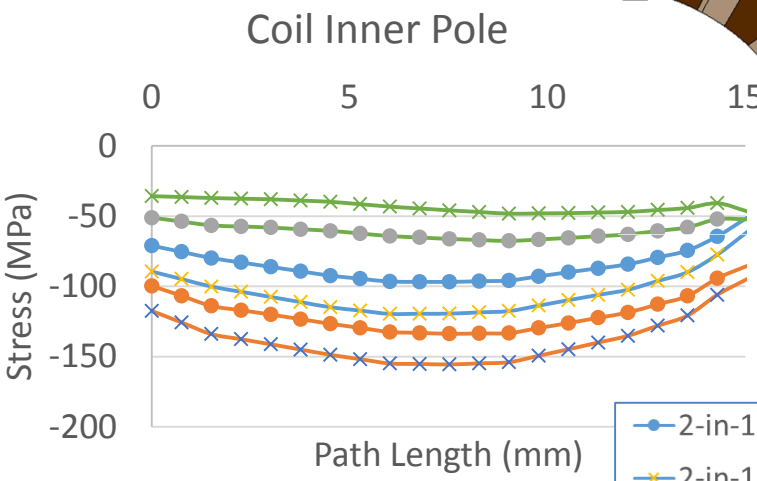
- Yoke Outer Radius: ***270 mm***
- Shell Thickness: *15 mm*
- **2** rod holes

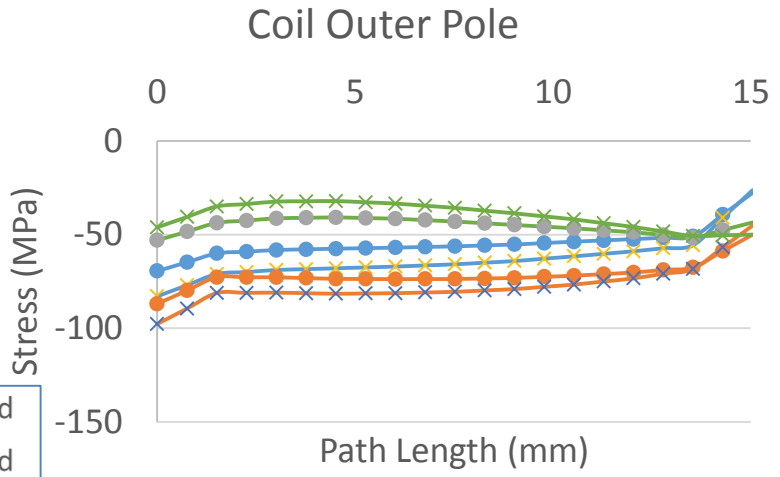


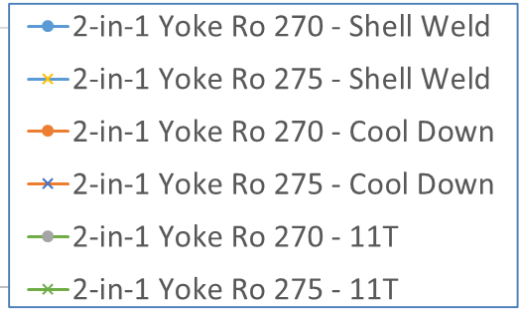
Structural assessment, 2

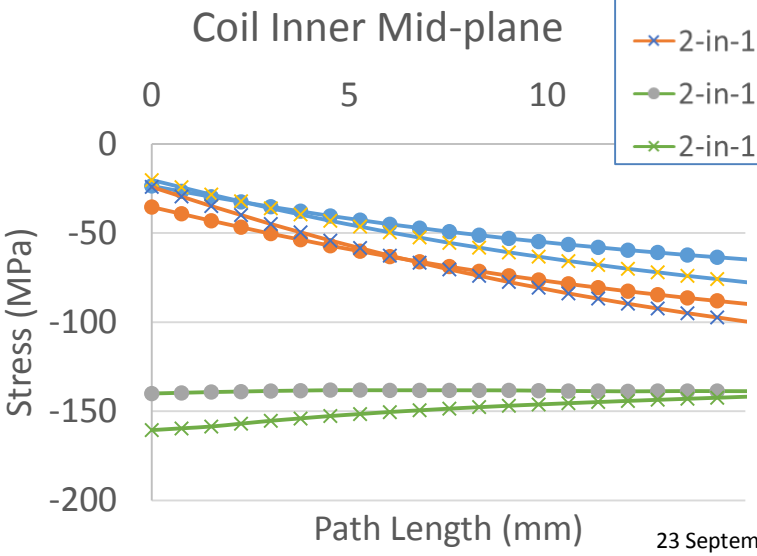
F. Lackner, T. Lyon

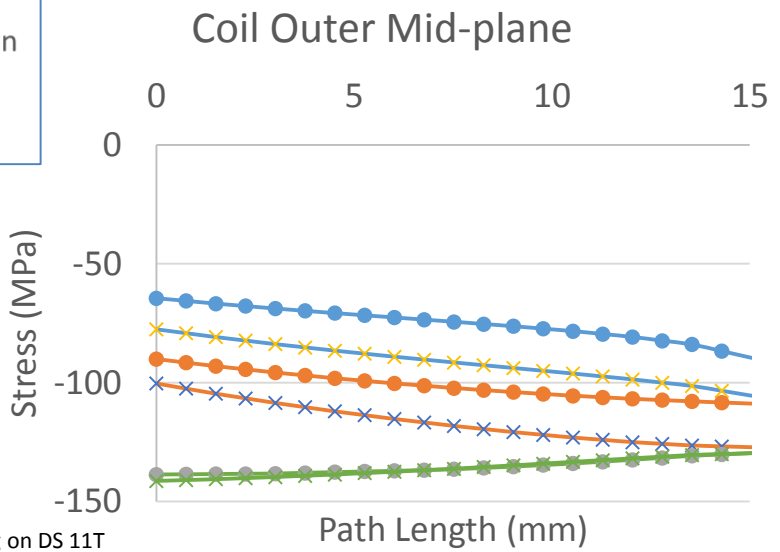






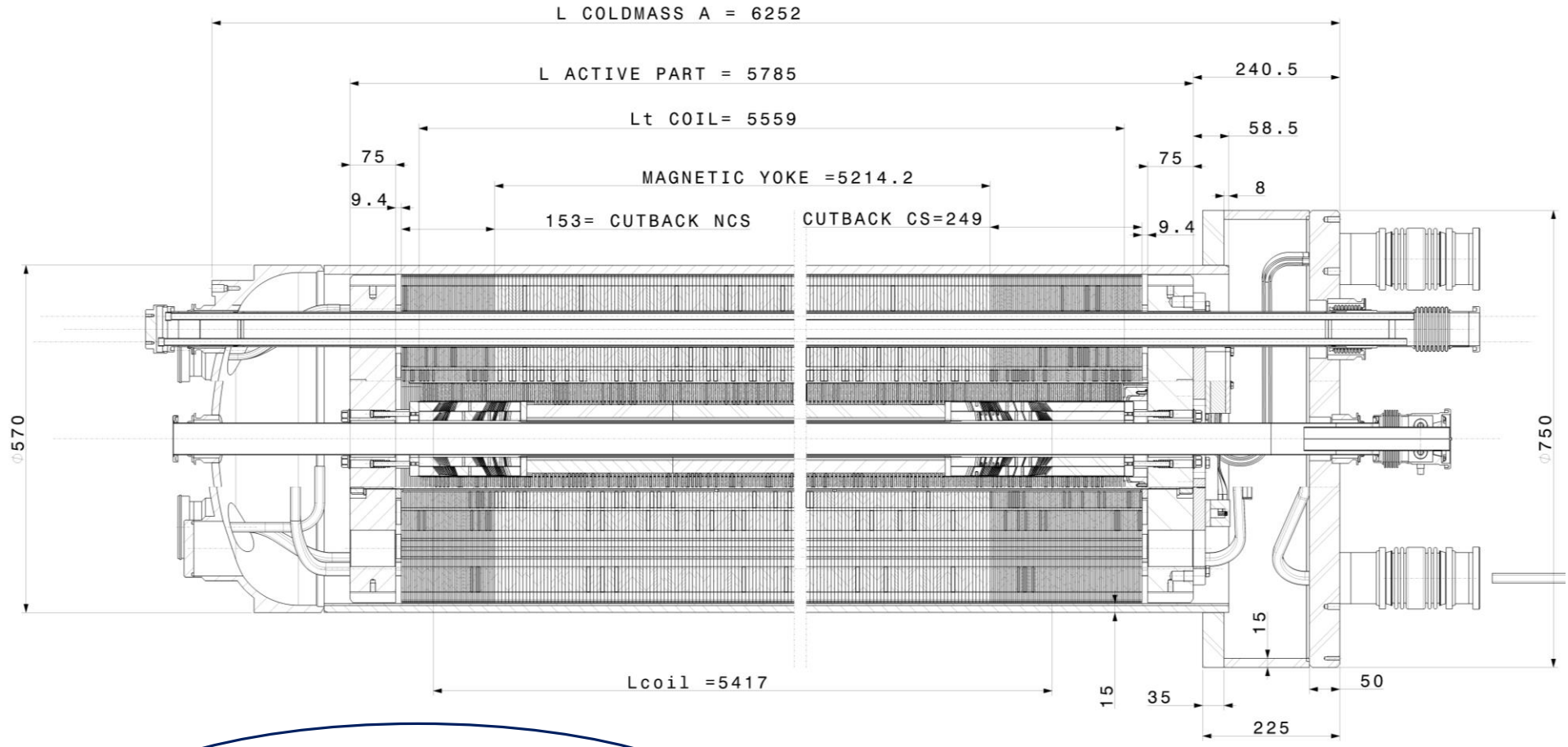


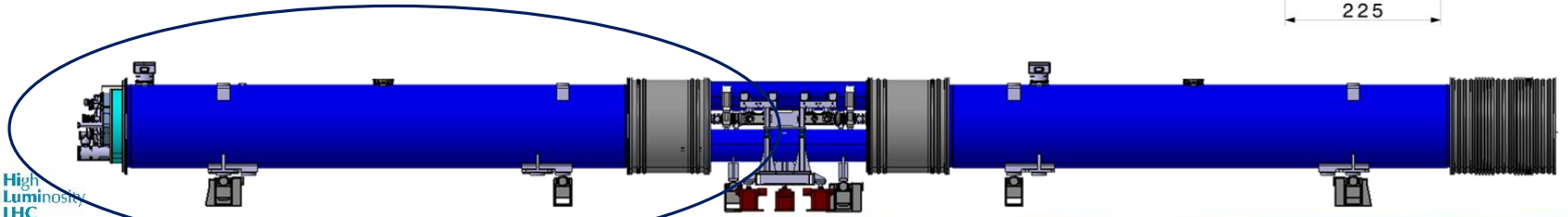




H. Prin, D. Smekens, A. Temporal

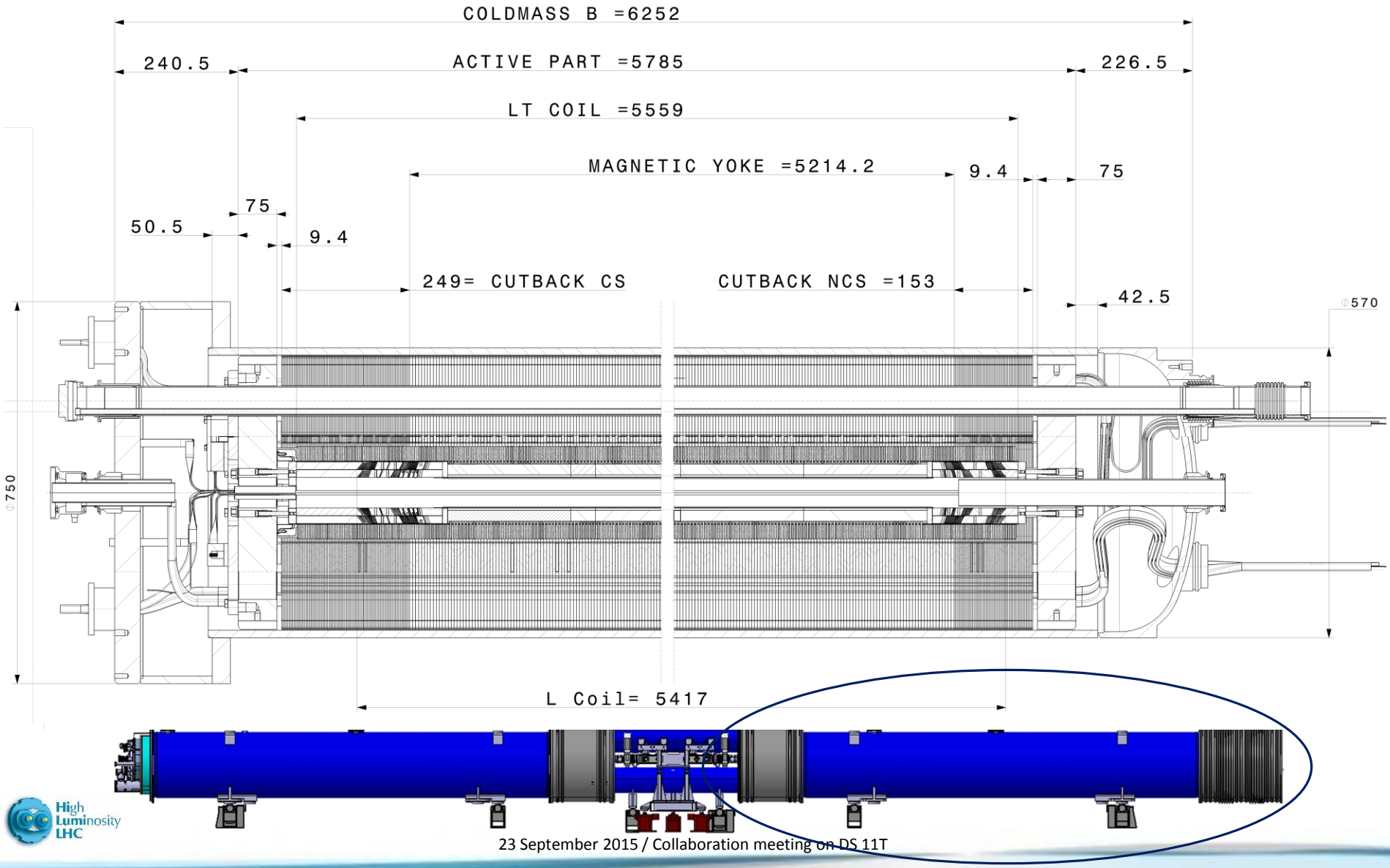
Cold mass assembly – LMBH_001

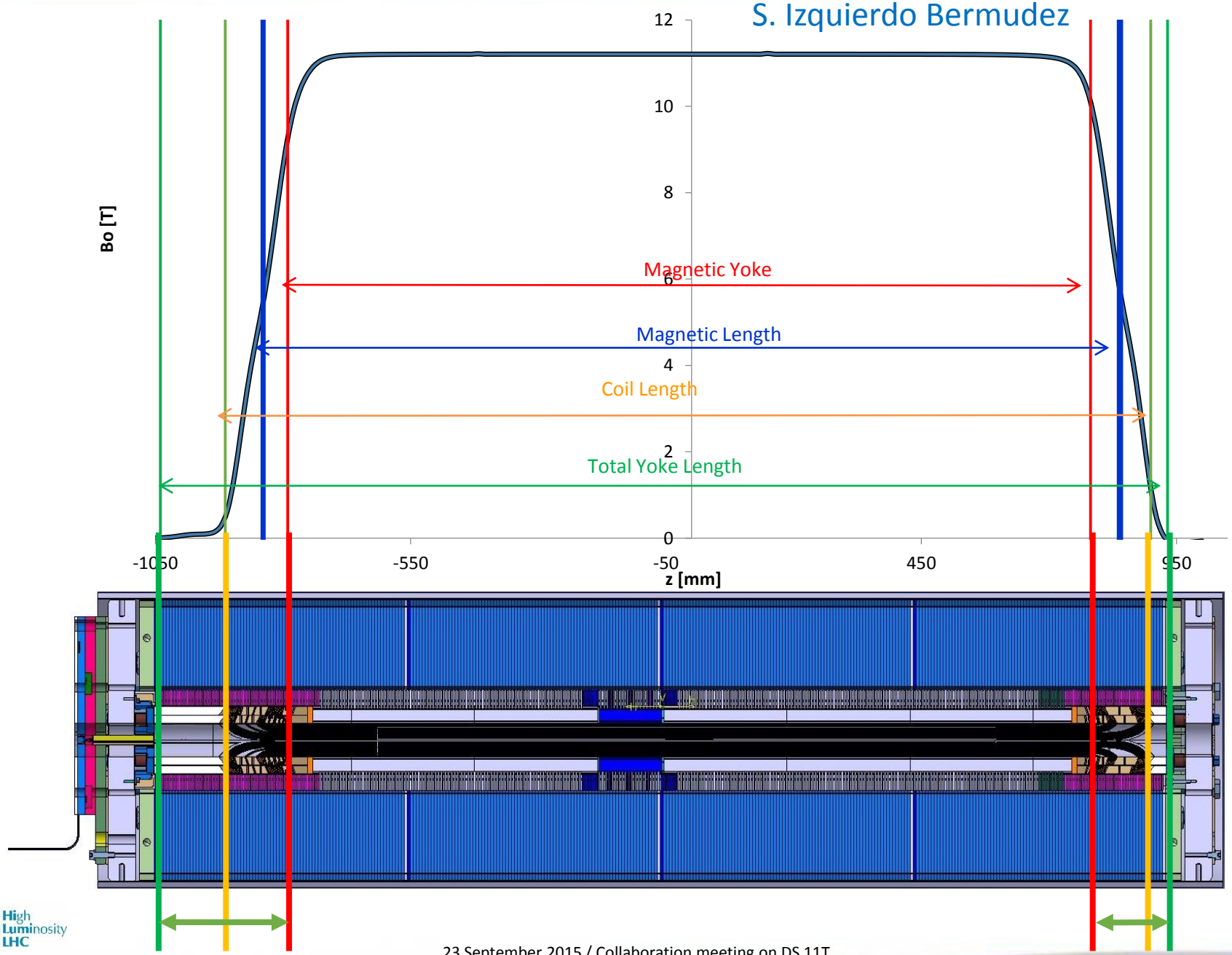




H. Prin, D. Smekens, A. Temporal

Cold mass assembly – LMBH_002

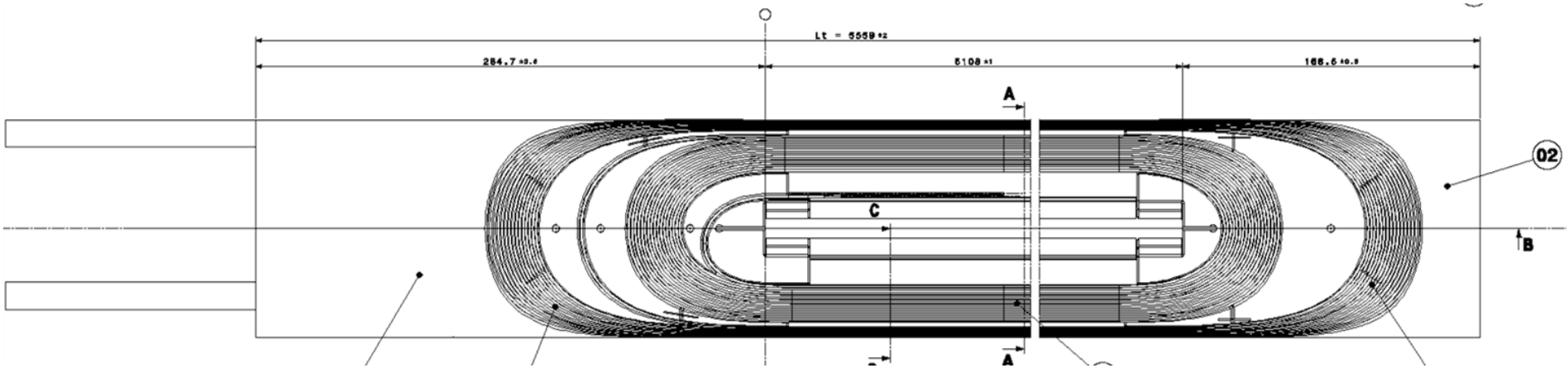




250 mm non magnetic

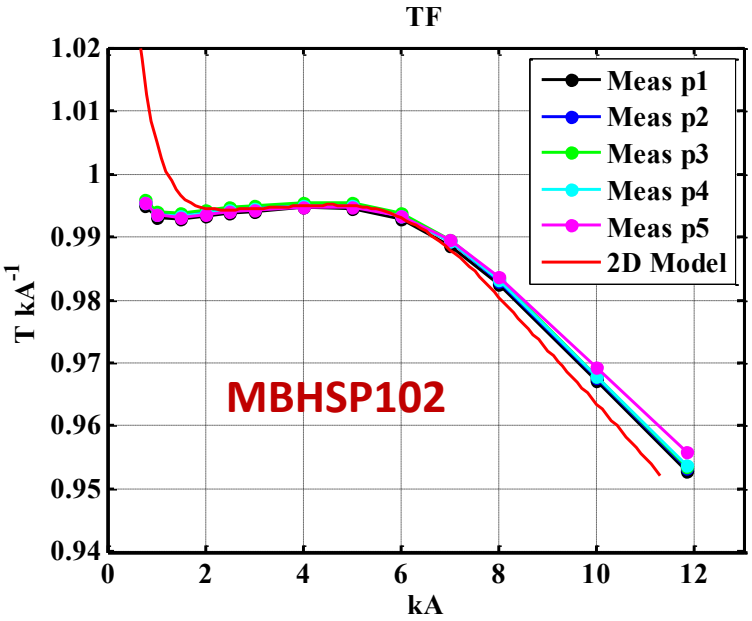
150 mm non magnetic

Longitudinal section of the coil



- The length of the coil is not finalized yet, as there are still uncertainties, and there are key parameters that need to be determined:
  - The variations of length during/after binder curing and reaction need to be determined on long coils
  - The introduction of the cut-back (non-magnetic laminations in the ends) to avoid peak field in the transition region between the straight part and the ends, means that the coils shall be ~ 20 mm longer
  - Also, the reduction of the yoke OD shall be compensated by an increase of the coil length of ~ 5 mm
  - A stacking factor of 98.5 % ± 0.25 % will be implemented (coils will have to be slightly longer)
  - The transfer function shall be checked
- Final length will be determined when the magnetic measurements are done on the prototype P1

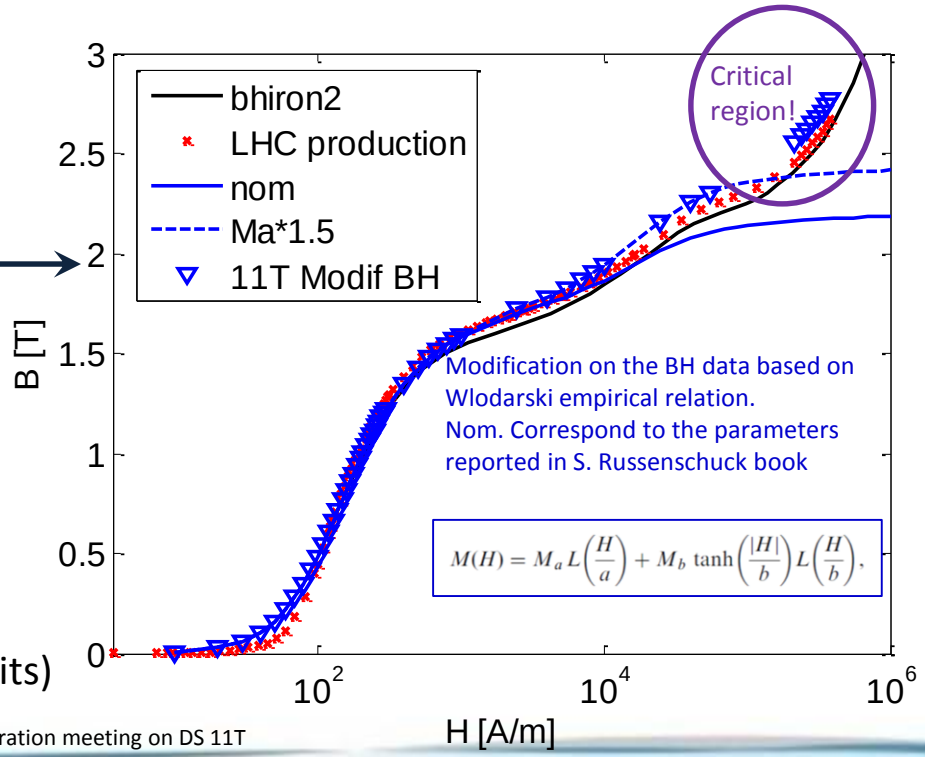
Transfer function



L. Fiscarelli, S. Izquierdo Bermudez

Possible sources of errors:

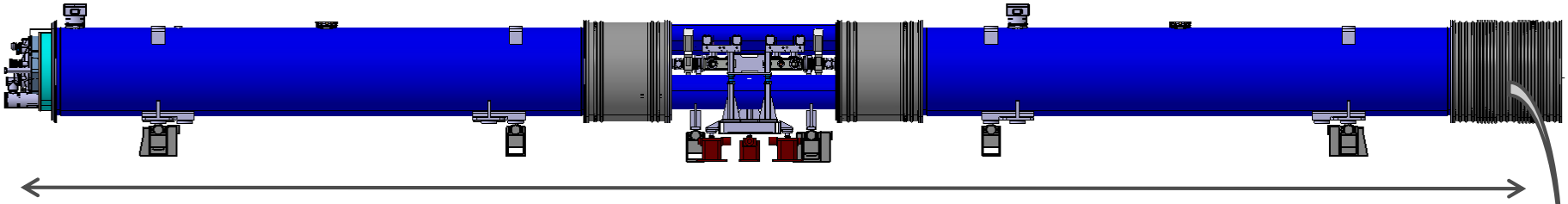
- Iron properties (the main source of errors)
  - When using data measured during the LHC production, discrepancy decreases by 20 units (from ~70 to ~50 units)
- Stacking factor of the yoke laminations
  - Can explain up to ~15 units
- Geometric
  - Rather big displacements are needed to explain other 35 units (350 µm smaller coil gives ~15 units)



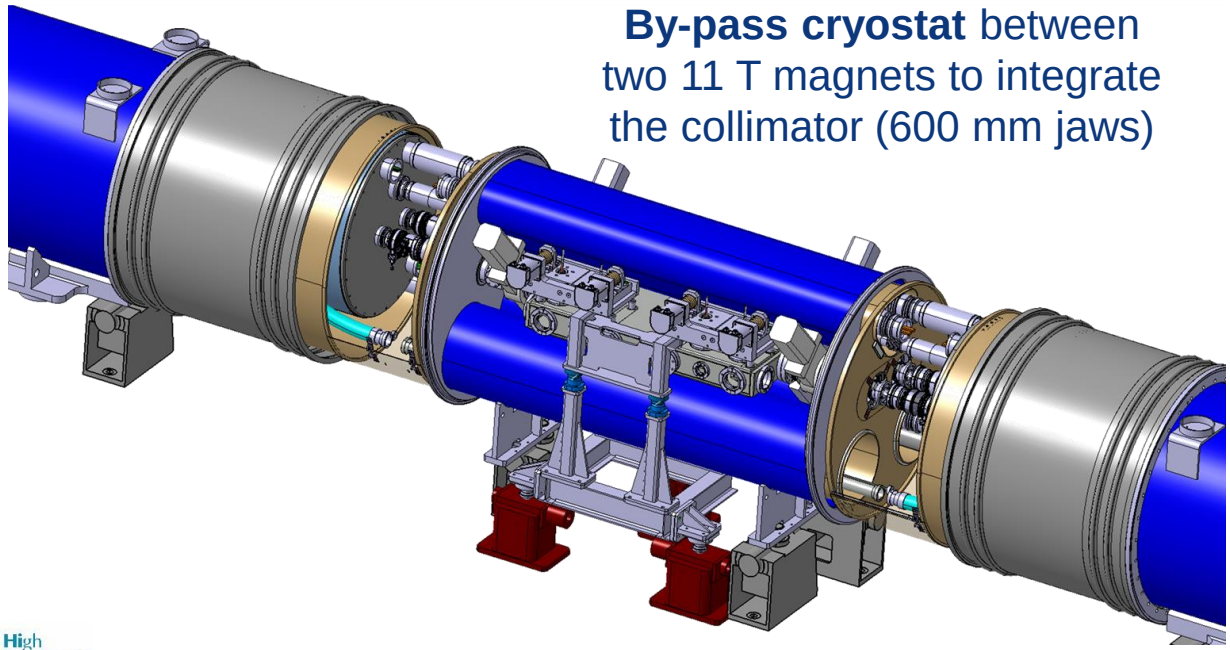
Integration

D. D. Ramos

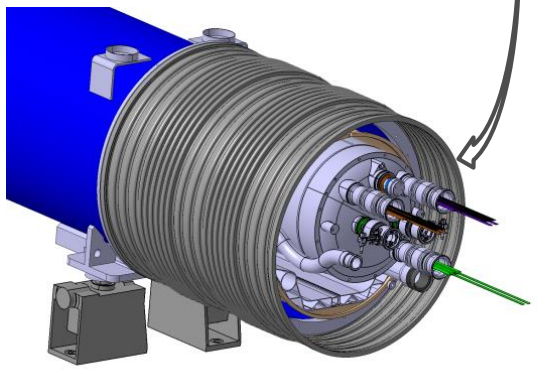
LHC MB cryostat replaced by **3 cryostats + collimator**, all independently supported and aligned



Same 15660 mm length between the interconnect planes as an in the LHC Main Dipole



By-pass cryostat between two 11 T magnets to integrate the collimator (600 mm jaws)



Same interfaces at the extremities: **no change to nearby magnets**, standard interconnection procedures & tooling

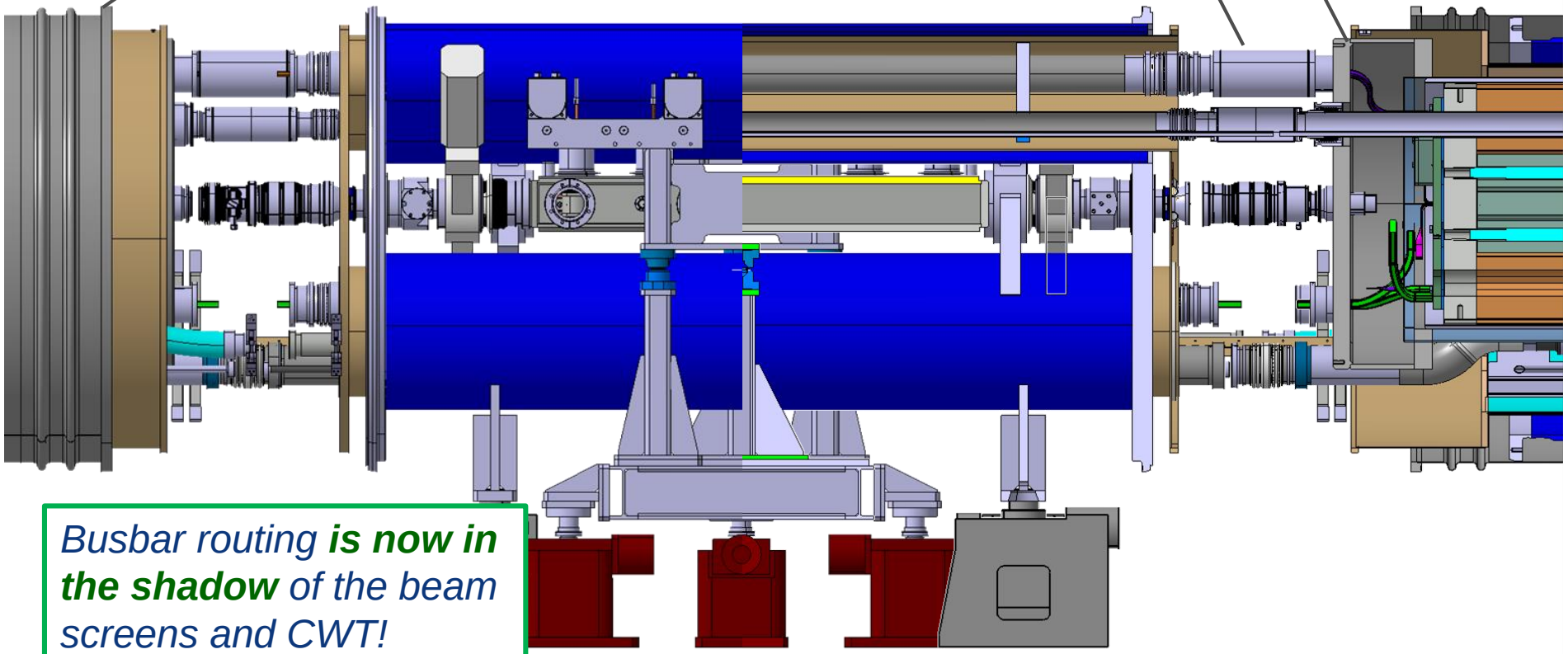
Integration 2

D. D. Ramos

Cold mass enlarged to Ø750 on the collimator side

Constant LHC arc outer flange diameter: Ø1055

Flexible interconnects for alignment independency and thermal contraction

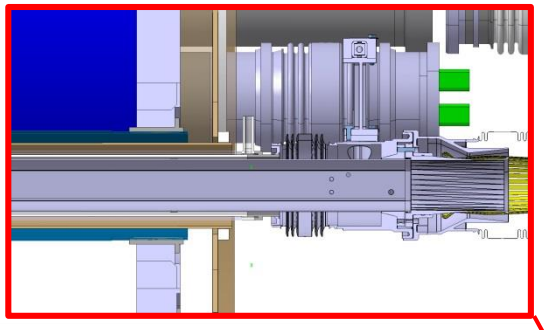


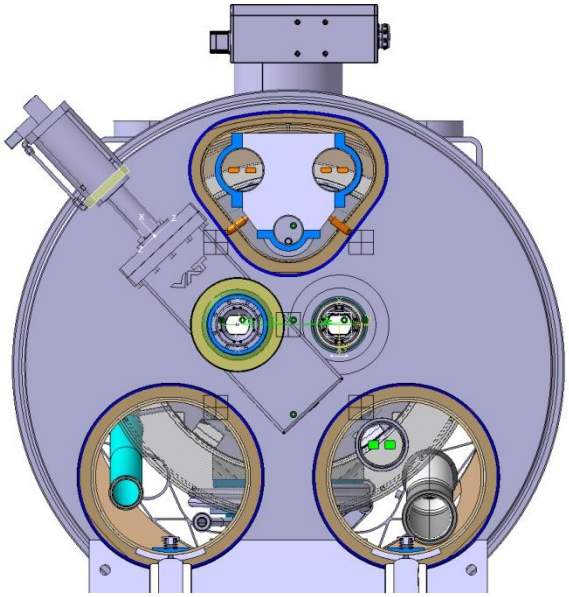
*Busbar routing **is now in the shadow** of the beam screens and CWT!*

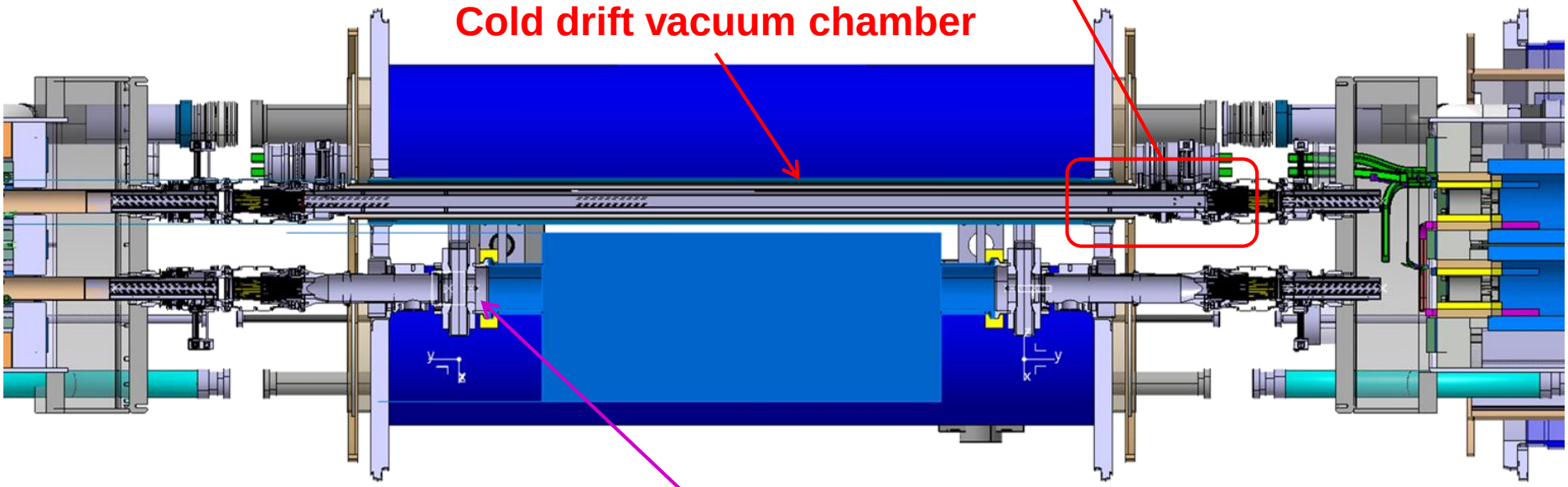
Integration 3

D. D. Ramos

- Interconnects become longer because of the beam screens
- Very compact cold line because of the sector valve RF shielding







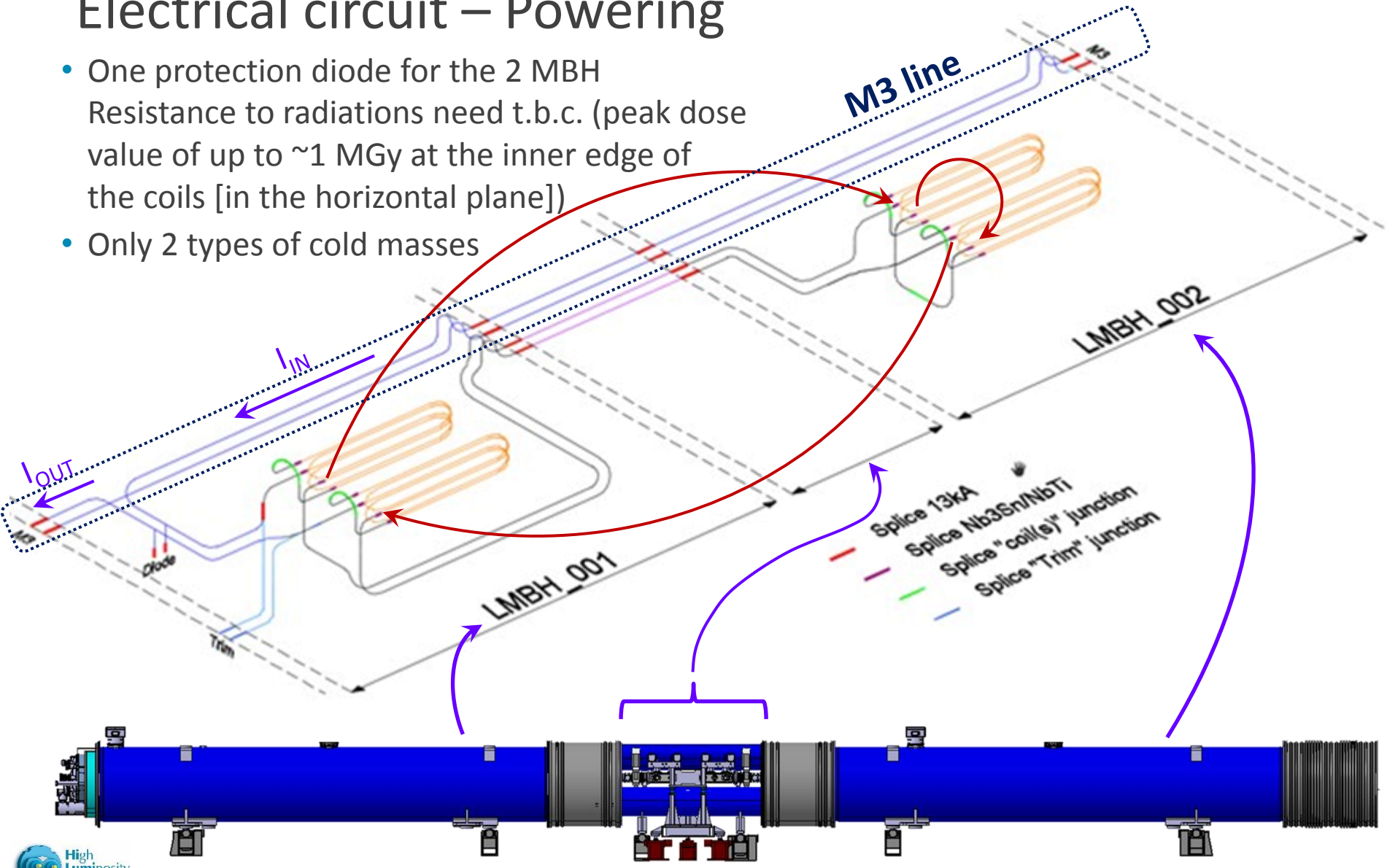
Vacuum group opts for cold line: “simpler” system, no failure prone sector valves

Transitions avoided because there are no sector valve on the other beam lines

Electrical circuit – Powering

L. Grand-Clement, H. Prin

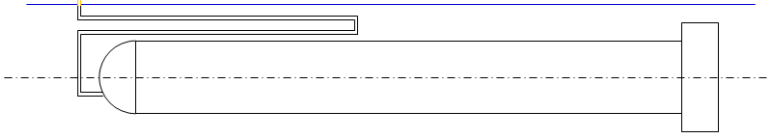
- One protection diode for the 2 MBH
  Resistance to radiations need t.b.c. (peak dose value of up to ~1 MGy at the inner edge of the coils [in the horizontal plane])
- Only 2 types of cold masses

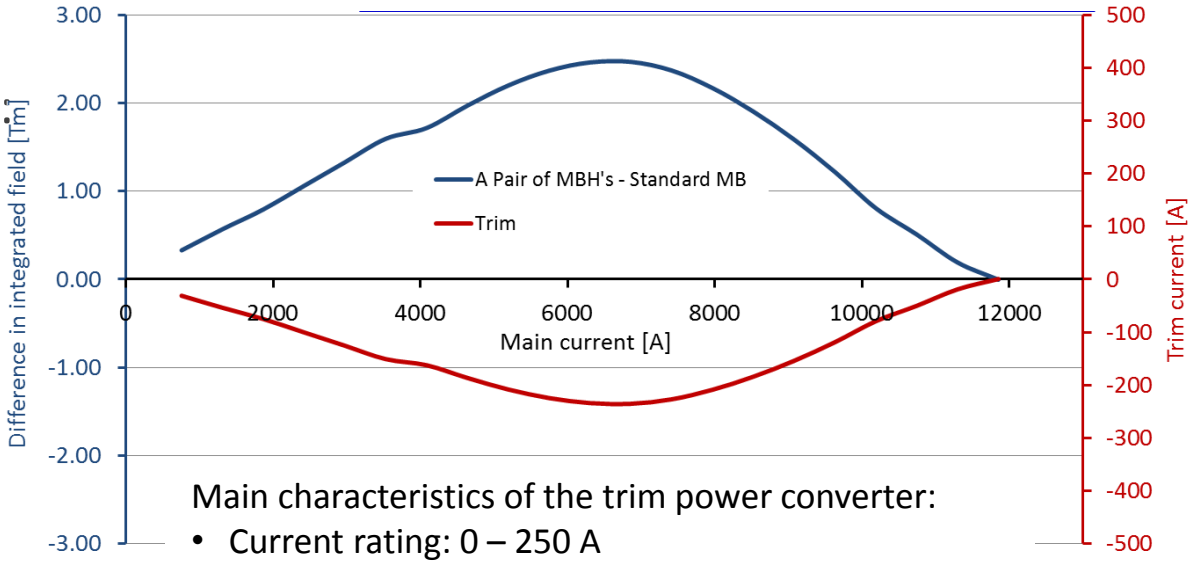


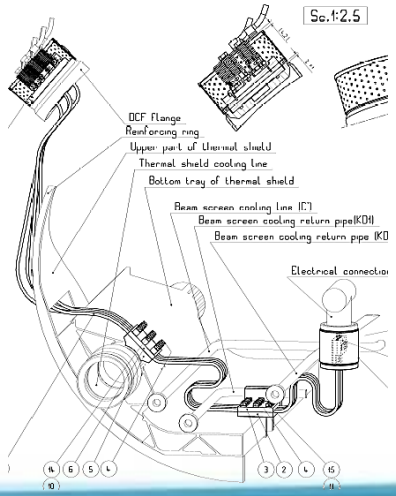
Electrical circuit – Trim

- The integrated field of a pair of MBH's is 119 Tm at 11.85 kA
- **The MBH is stronger than the MB below nominal current** with a peak difference in integrated field around 6.5 kA
- **A trim current is used** to correct for this and avoid deformation of the beam closed orbit
- Conduction cooled leads: about 3.6 W/kA to 1.9 K

RT copper cables → towards power converter





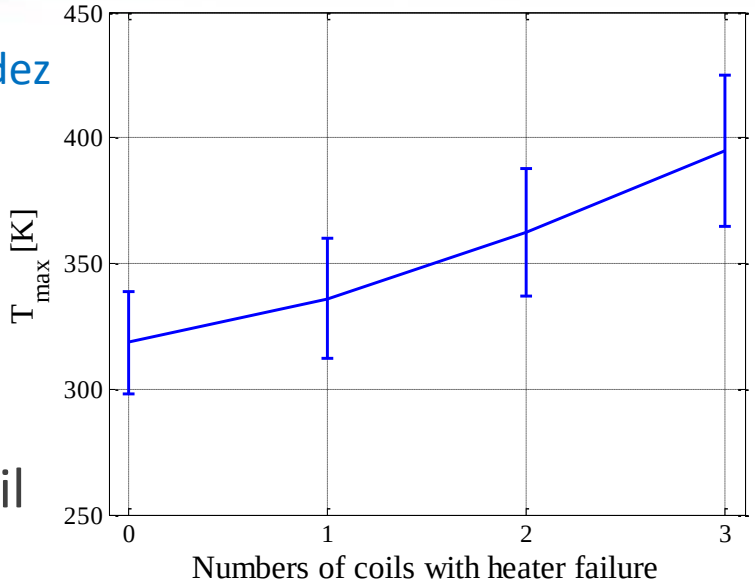


Main characteristics of the trim power converter:

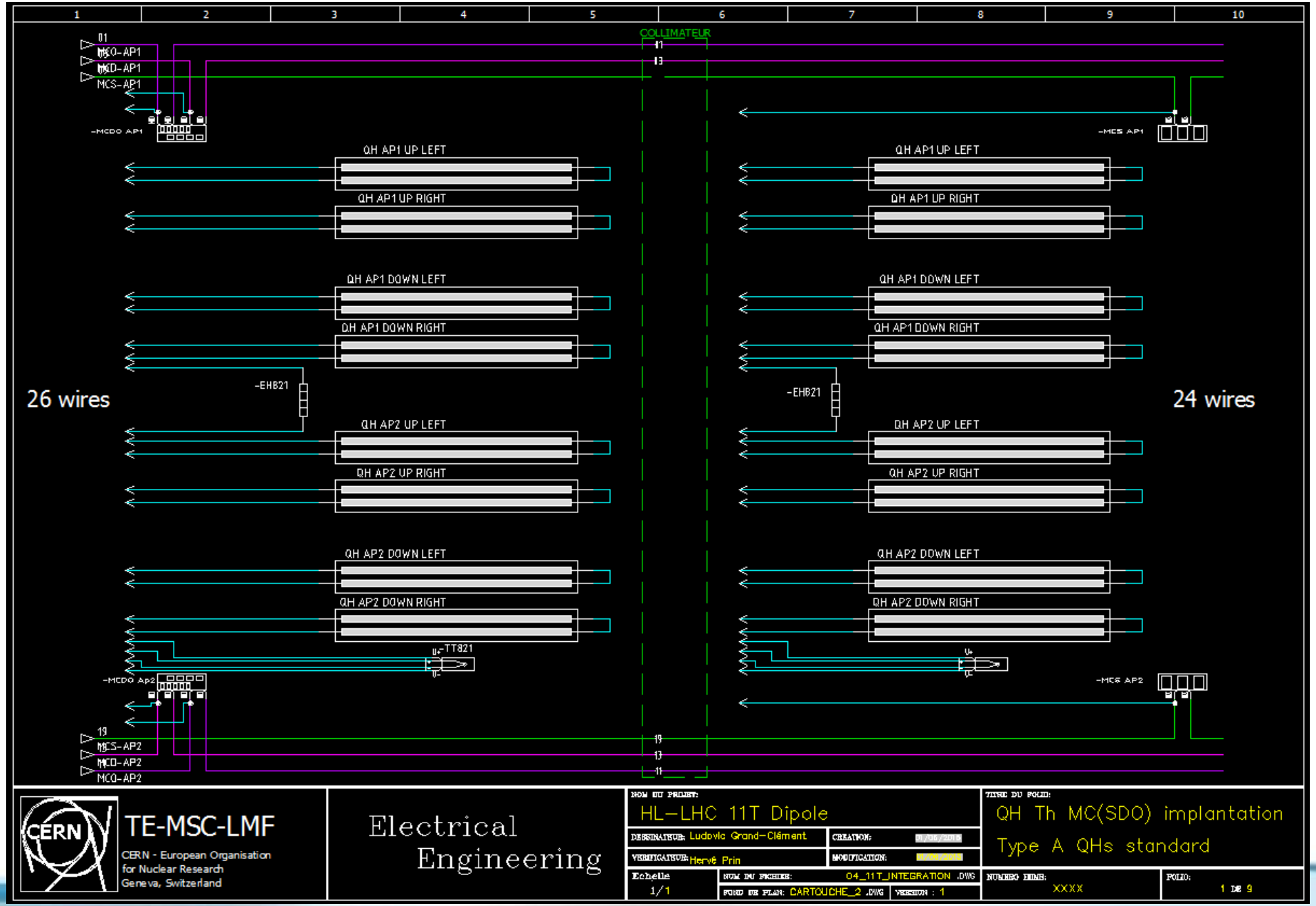
- Current rating: 0 – 250 A
- Voltage rating: ± 1.5 V + V_cable (< ± 40 V)
- Accuracy: 40 ppm (12 mA)

Quench heaters

S. Izquierdo Bermudez



- Baseline after review of the analysis and test results
  - QH located on the outer surface of the outer layer, and impregnated with the coil
- Inter-layer QH are under development
  - Will not be tested/available before we start the fabrication of the coils for the prototype P1. However, will be hopefully available for the first series magnets
- Quench heater circuit(s) redundancy needs to be defined, e.g.
  - Protection still effective when one (or two) of the QH is (are) lost
    - OR
  - Additional circuit is available and may be connected in case there is a failure in the already connected/used circuit


COLLIMATEUR
MCO-AP1
MCD-AP1
MCS-AP1
-MCDO AP1
-MCS AP1
QH AP1 UP LEFT
QH AP1 UP RIGHT
QH AP1 DOWN LEFT
QH AP1 DOWN RIGHT
-EH821
26 wires
24 wires
QH AP2 UP LEFT
QH AP2 UP RIGHT
QH AP2 DOWN LEFT
QH AP2 DOWN RIGHT
-TT821
-MCDO AP2
-MCS AP2
MCS-AP2
MCO-AP2
MCO-AP2
TE-MSC-LMF
CERN - European Organisation for Nuclear Research
Geneva, Switzerland
Electrical Engineering
NOM DU PROJET: HL-LHC 11T Dipole
DESSINATEUR: Ludovic Grand-Clément
CREATION: 01/06/2015
VERIFICATEUR: Hervé Prin
MODIFICATION:
Echelle 1/1
NOM DU FICHIER: 04_11T_INTEGRATION .DWG
NOM DU PLAN: CARTOUCHE_2 .DWG
VERSION : 1
TITRE DU PLAN: QH Th MC(SDO) implantation
Type A QHs standard
NUMERO DIMS: XXXX
FOLIO: 1 DE 9

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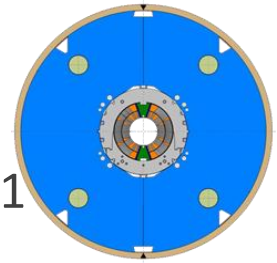
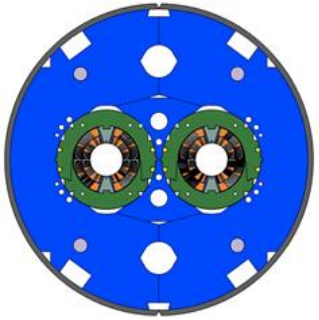
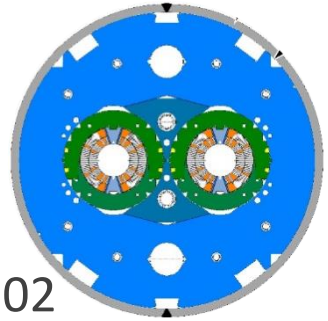
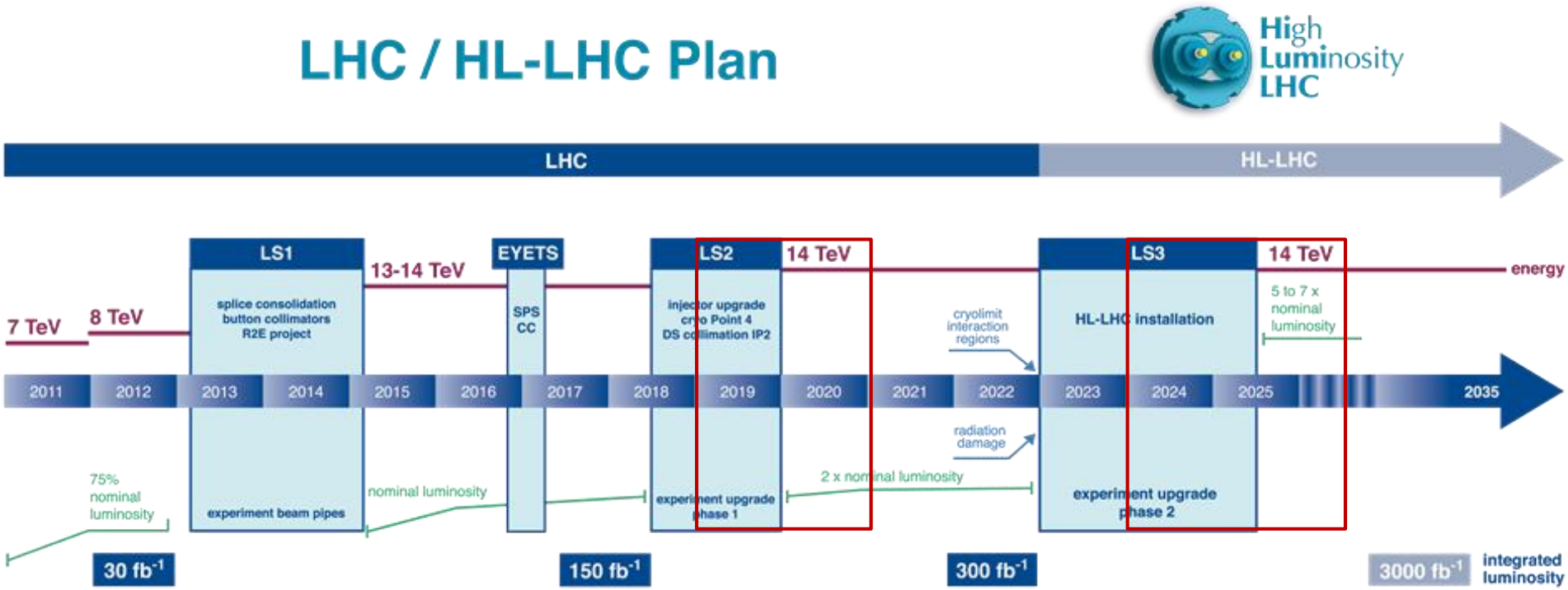
Model programme RRP cable

1. QH/Traces glued on outside surface of OL
2. QH/Traces impregnated on OL
3. QH/Traces impregnated on OL + interlayer QH

Coil	Single Aperture	Two-in-One
		
1: 106, 107, 108, 109, 111, 112, 113	SP101	DP101
	SP102	• Test Dec.15-Jan.16
	SP103	
2: 114, 115	SP104	
	SP105	DP102
3: 116, 117	SP106 (test 3rd Q 16)	• New yoke design
		• Reduced OD

The DS 11T dipole on the HL-LHC timeline



Models RRP cable **On-going / Q4-2016**

PROTOTYPE P1 - RRP **Q1-15 / Q1-17** Cold tests in first quarter of 2017

Production for LS2 **Q4-2016 / Q2-2019** Start after cold tests of SP106 are done (inter-layer QH)

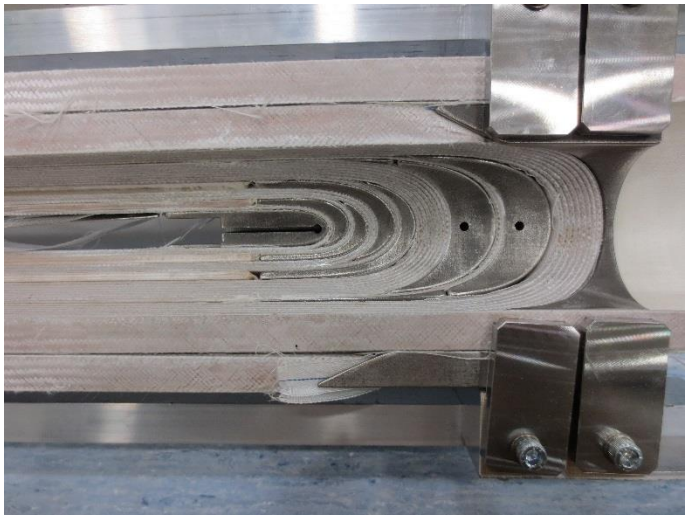
Models PIT cable **Q3-2016 / Q2-2018**

PROTOTYPE P2 - PIT **Q1-19 / Q4-20** Start after coils for LS2 are done

Production for LS3 **Q2-2020 / Q2-2024** PIT and/or RRP

Production of first long coils in B180

2nd coil with braided Cu cable during winding



Detail of the 2nd Cu cable coil after curing

1st Sc coil Wound & cured

3rd coil, with braided **Sc** cable during winding

New clutch / PCS for better control of the tension on cable during winding

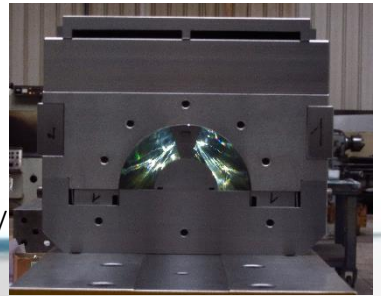
Tooling for the production of the long coils

6.5 m long reaction furnace – fully operational

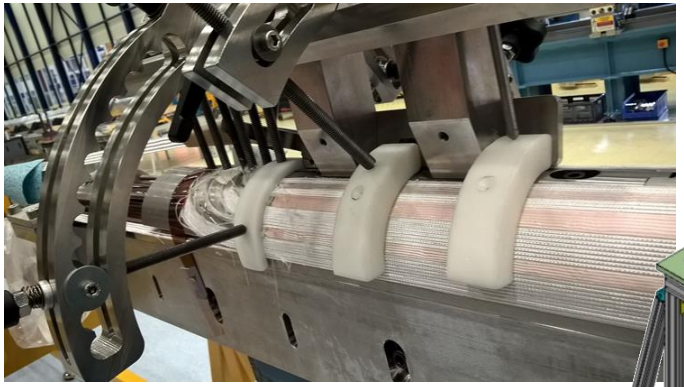
6 m long reaction fixture

10.5 m long impregnation chamber

6 m long impregnation fixture



Other illustrations of tooling



- Terminology and HL-LHC time line
- Part I: Current baseline design
  - Cable
  - Cross section
  - Cold mass assembly
  - Integration, powering, trim
  - Quench heaters and protection
- Part II: Project status and plan
  - Overall plan
  - Model program
  - Prototype
- Conclusions

Conclusions

- The DS 11T dipole plan was updated after the cost and schedule review of March 2015
- The installation in LHC during LS2 is not anymore in the baseline but we are asked to be ready to install 2 cryo-assemblies during LS2 upon request
- The baseline design was further developed with some adjustments. However, no major modifications
- Some items need particular attention:
  - Finalization and construction of the quench heaters
  - Coil length
- The engineering design of the full-length magnet, including the cryostat, is now well advanced
- The major tooling is available in the Large Magnet Facility @ CERN

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