Nb-Ti busbars design and interfaces

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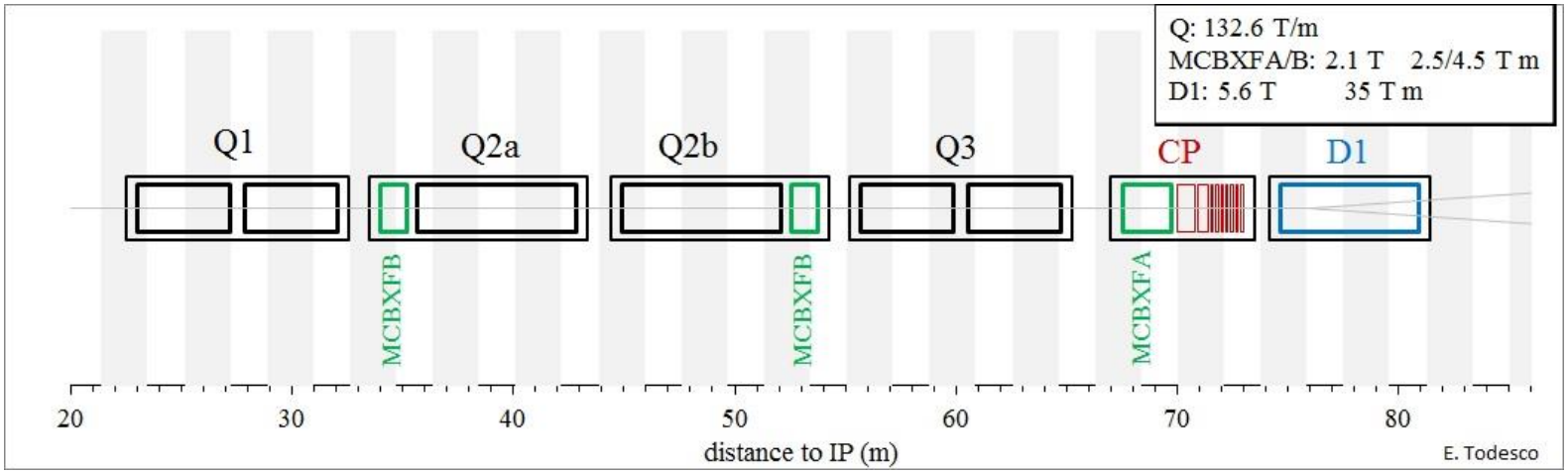
CONTENTS

- IR magnets features and choices
- Baseline for busbars
- Work in progress

OVERVIEW OF IR MAGNETS

- From Q1 to D1: 150 mm aperture
- Triplet: four magnets Nb_3Sn, current 16.4 kA, peak field 11.5 T
  - In series plus trim on each magnet
- Orbit correctors: three magnets, nested, Nb-Ti, current 1.4/1.6 kA
  - Independently powered (six circuits)
- High order correctors: 9 magnets, Nb-Ti superferric, 200/100 A
  - Independently powered
- D1: Nb-Ti, current 12 .0 kA, bore field 5.6 T



OVERVIEW OF IR MAGNETS

- Boundary condition
  - Space for integration in the cryostat is limited
- Protection strategy
  - When a quench is detected in the triplet, protection for the four quadrupoles is activated (all quadrupoles, plus orbit correctors, will quench)
    - This also in case of cold diodes (see talk by S. Yamine, MCF 31th October)
- Three technical choices
  - A mixture of round and flat busbars
  - Some busbars inside the magnets, others in parallel lines
  - Keeping same design for Q1 and Q3 (reduce spares, flexibility in installation) at the cold mass level – Same for Q2a and Q2b

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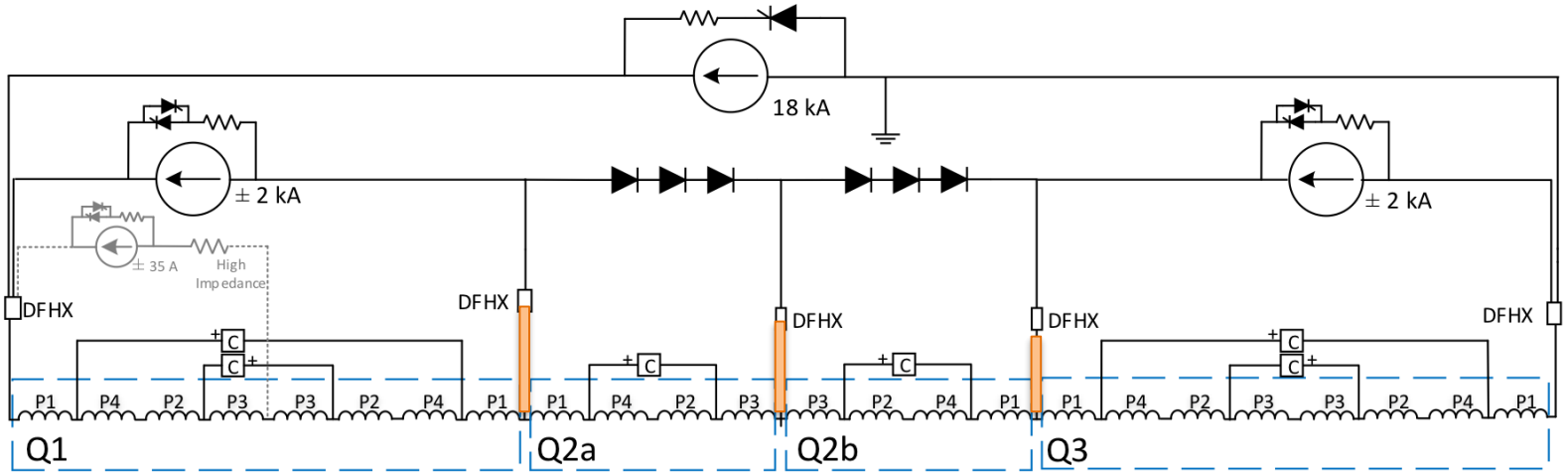
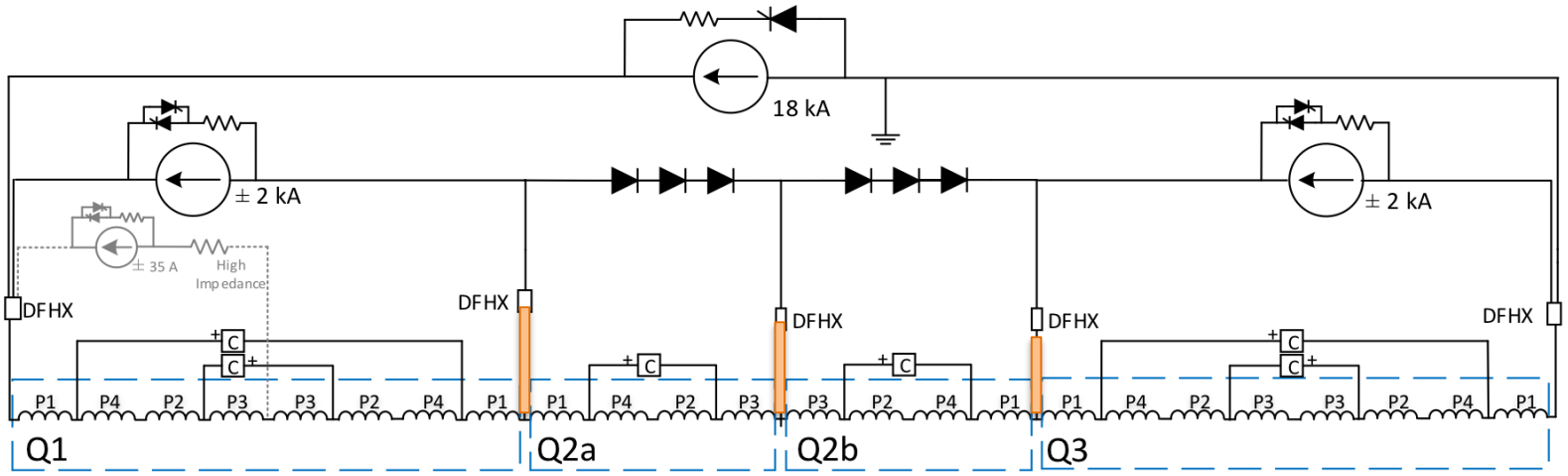
CIRCUIT BASELINE

- Triplet
  - One circuit rated at 18 kA plus trims (before we had two circuits, decision was taken in 2015/2016)
  - Three trims (2 kA rating needed) are rated at 7 kA to allow overcurrents during quench
  - Trim separating Q2a from Q2b not necessary for the beam dynamics, but needed for keeping the voltage to tolerable value
  - One 35A Trim Q1A 35A



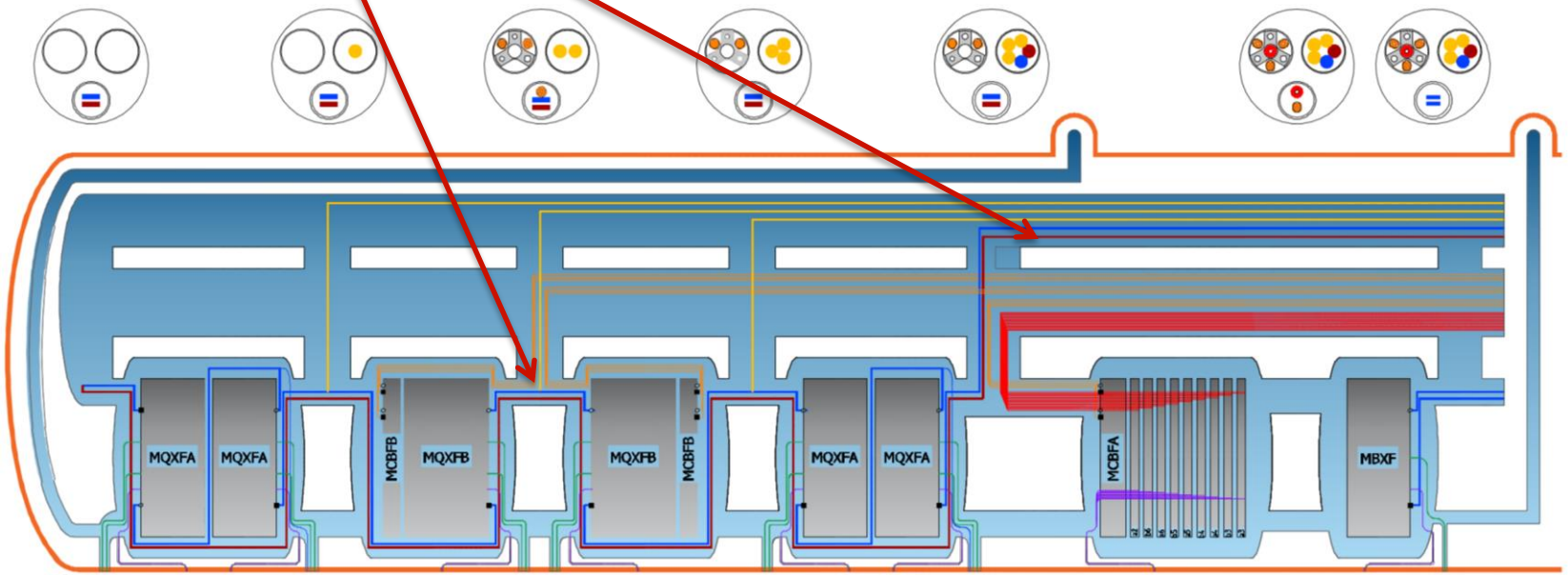
CIRCUIT BASELINE

- Triplet – «warm» diodes
  - Necessary to keep the voltages to tolerable values
  - Design will be compatible with the «cold» diode option



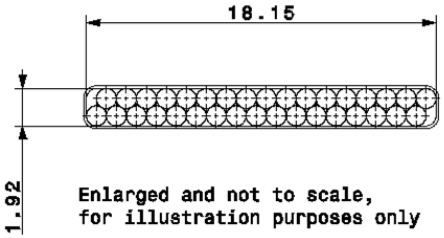
CIRCUIT BASELINE

- Triplet 18 kA main busbar: a mix of flat and round
  - Flat busbars made of two Nb-Ti Rutherford cables inside the triplet, (see next slide)
  - In the parallel line bypassing D1 and the corrector package we will have a round busbar



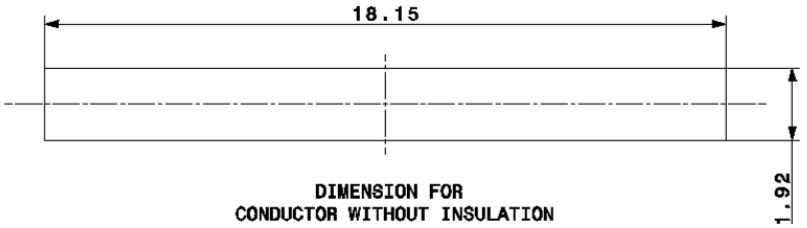
CIRCUIT BASELINE

- Triplet 18 kA main busbar
  - Strand: Nb-Ti 1.065 mm diameter, 1.65 Cu/no Cu (LHC inner cable strand)
  - One cable made with 34 strands to have the same width of MQXF cable
  - Flat busbar is a double cable (as the US cables used for Nb-Ti leads in the magnets)
  - Round busbar is a round cable with the same number and type of strands (to be developed)



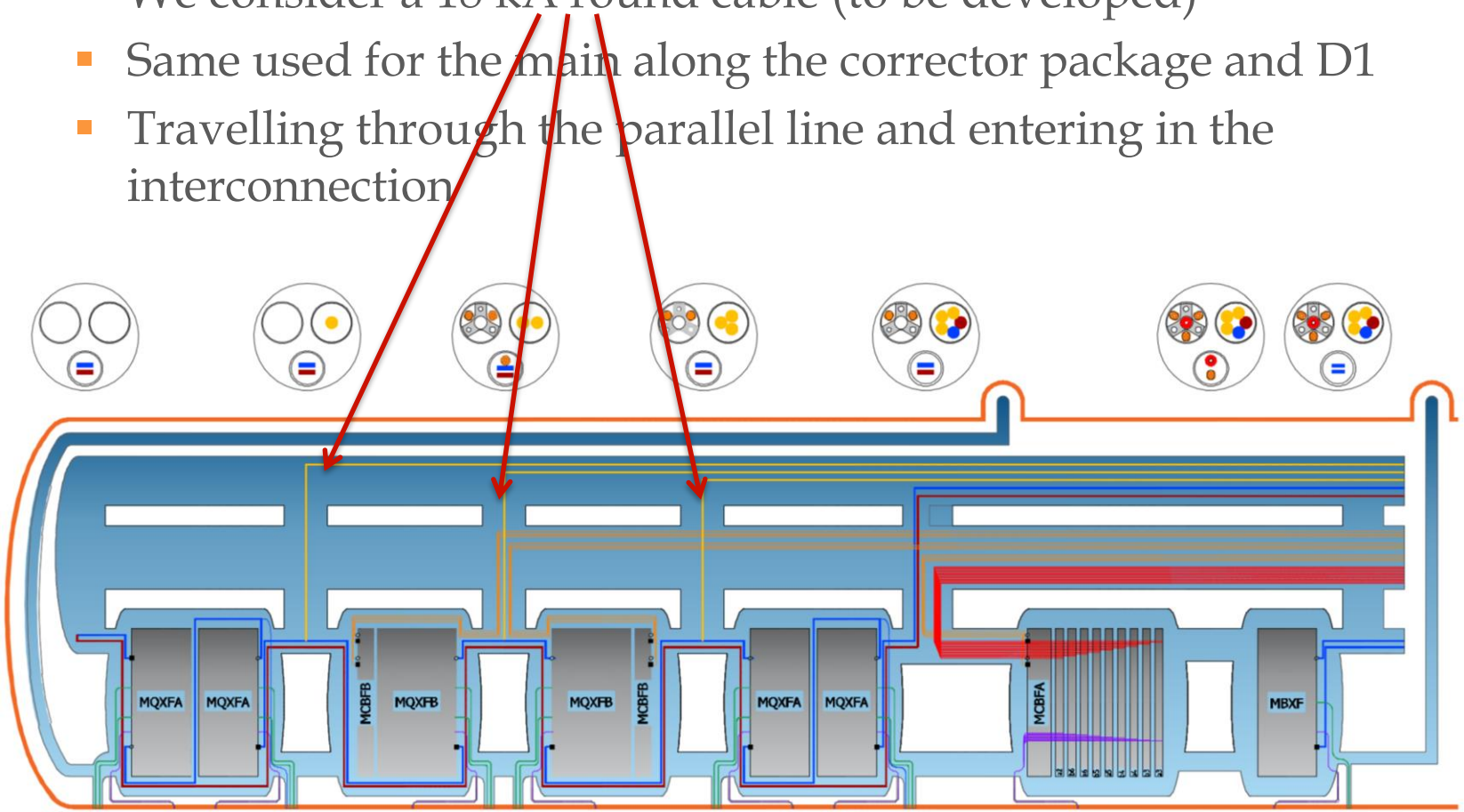
UNREACTED CABLE DIMENSIONS	
Strand Type	NbTi
Strand Diameter	1.065
Number of strands	34
Width	18.15 mm
Height	1.92 mm

  - Cu surface: 38 mm^2
  - Sc surface: 23 mm^2
  - Cable surface: 61 mm^2
  - 265 MIITs at 300 K
  - 200 MIITs at 200 K



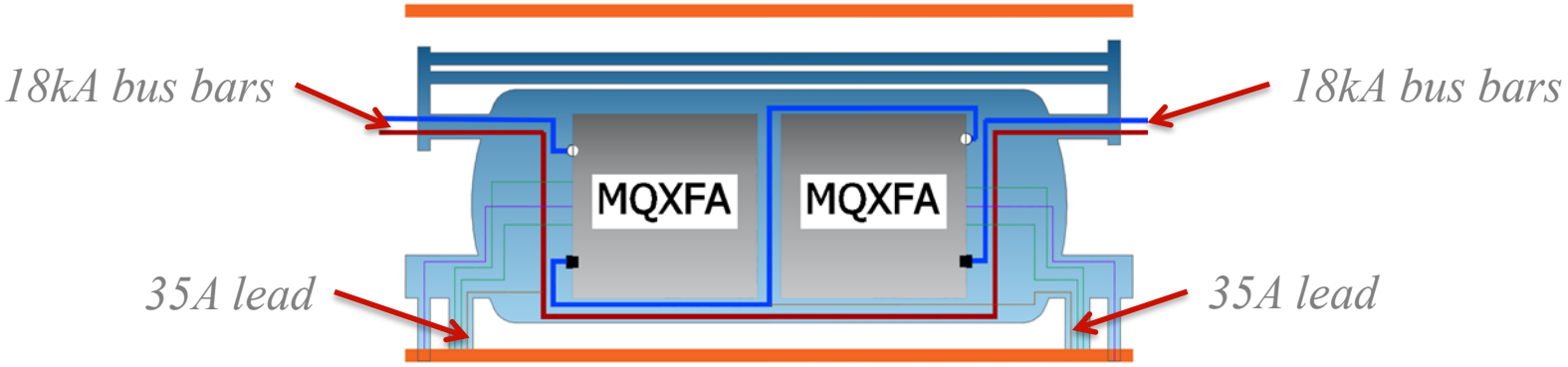
CIRCUIT BASELINE

- Triplet trim busbars
  - We consider a 18 kA round cable (to be developed)
  - Same used for the main along the corrector package and D1
  - Travelling through the parallel line and entering in the interconnection

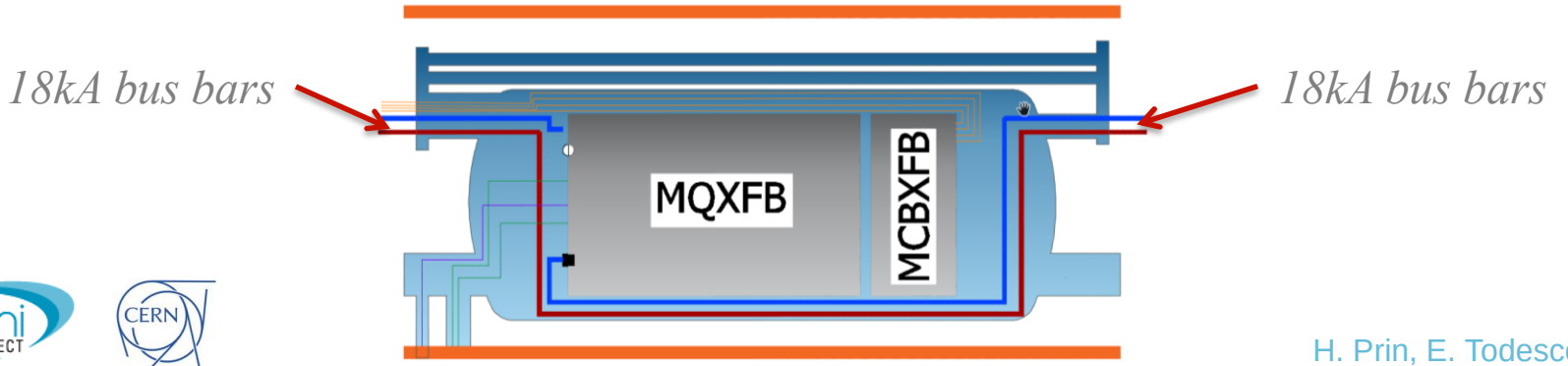


THE BUSBAR IN THE Q1/Q3

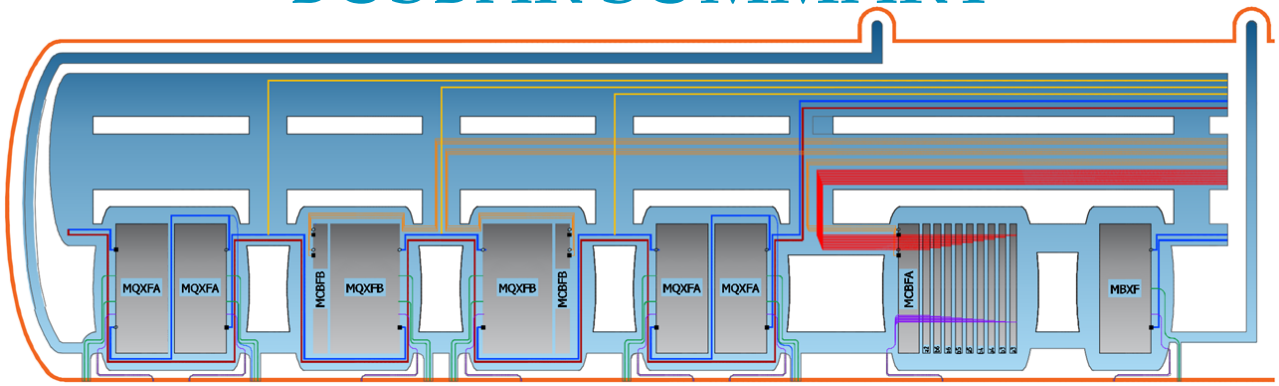
- Q1/Q3 are split in two magnets (made in US)
  - Busbar cartridge goes through the cold mass, and one of the two busbars is spliced to the magnets on each side
  - This busbar is needed for mid 2019 (first US cold mass)



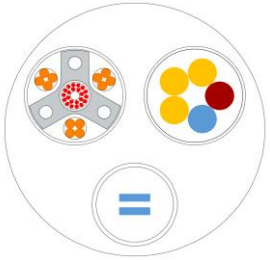
  - The busbar version for Q2 is needed for fall 2018

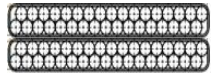


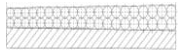
BUSBAR SUMMARY



	I_{nom} (kA)	I_{ult} (kA) / I_{max} *	Busbar	Sc wire	Cu/Sc ratio	Bubar Cross Section	Stabilsation
IT Main Circuit inside the cold masses	16.5	17.82	***New***	34 Nb-Ti wires type 01 LHC strand Ø1.065mm	1.6	18.15 x 1.92mm x2 with stab	Doubled cable Or same copper cross section
D1 Circuit	12	12.96	Present LHC 13kA cable	36 Nb-Ti wires type 02 LHC strand Ø0.825mm	1.9	15.1 x 1.48mm X2 with stab	Doubled cable Or same copper cross section
IT Main Circuit along the cold masses	16.5	17.82	***New***	*To be devloped*			
Trim leads	2	2 / 6.8*					
Orbit Corrector	1.6 /1.47	1.73 /1.59	***New*** *or Present LHC 6kA cables*	*To be developed*			
High Order Correctors	0.182 /0.105	0.2 /0.12	Present LHC 600A cables	7 Cu wires Ø0.96 mm	9.5	42x600A wires in Ø16.7mm	N/A
CLIQ leads	2.8 (12Hz fast decay)		***New***	N/A	N/A	Ø5.14mm	Silver Platted copper

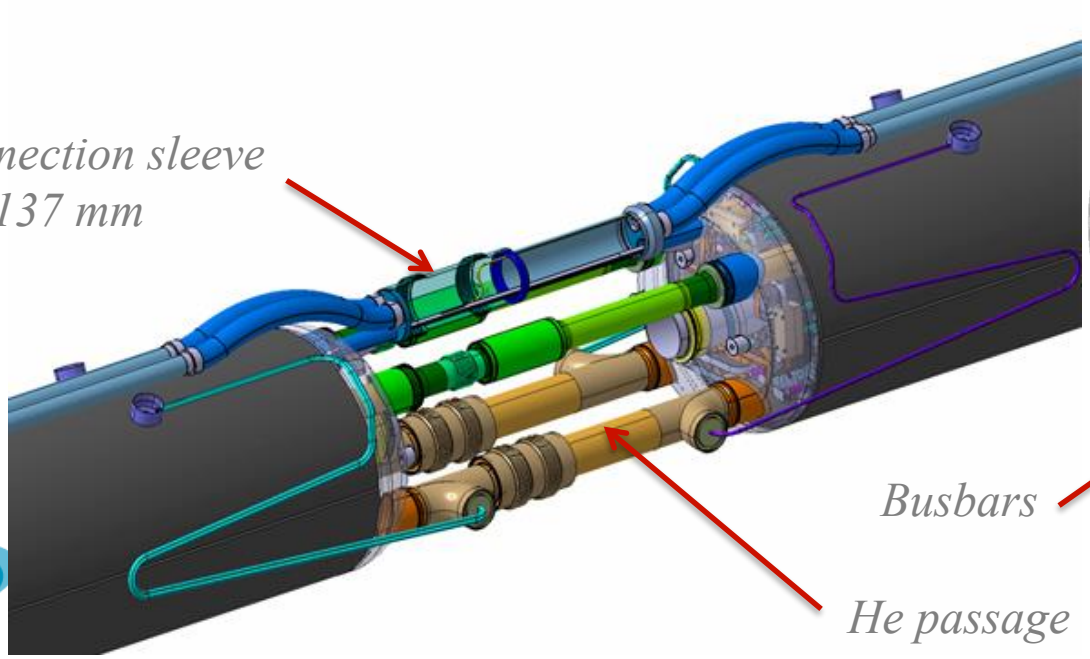


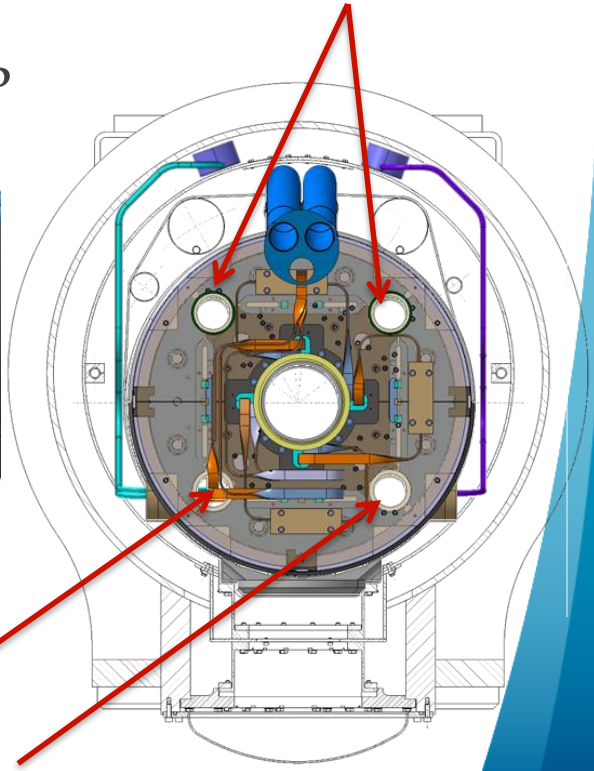




INTERCONNECTIONS AND PARALLEL LINES

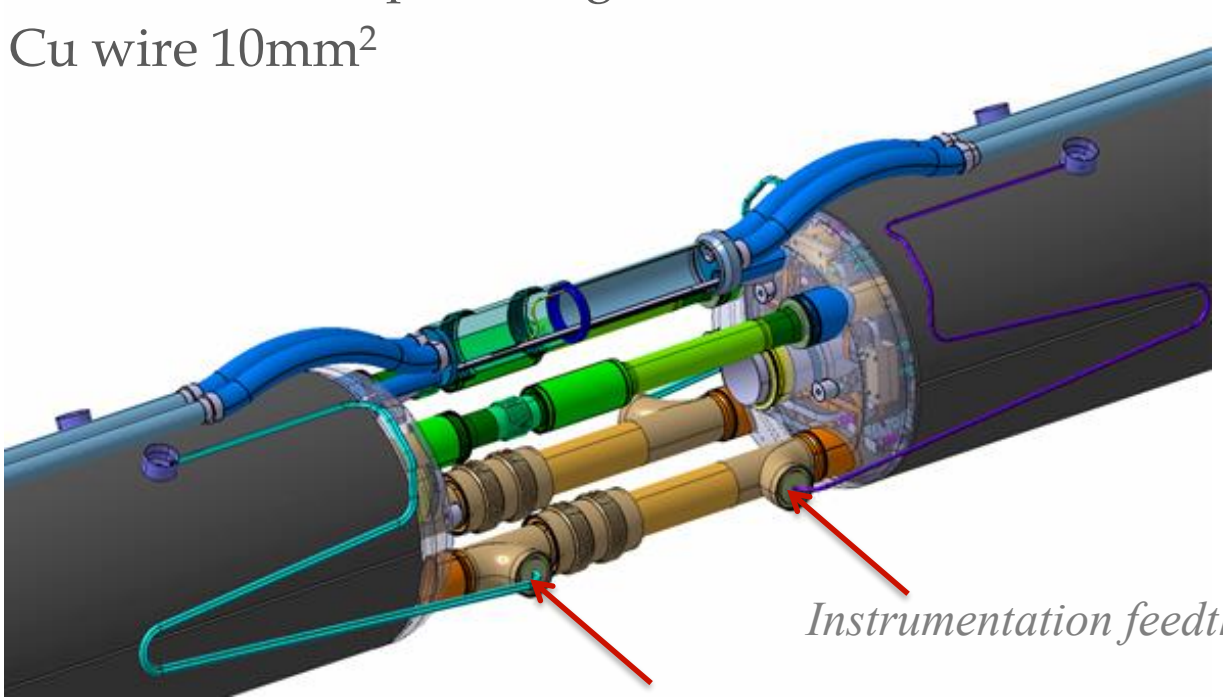
- The parallel lines have interconnection in the vertical plane
- Flat 18 kA main busbars (cartridge) go through one of the lower yoke holes
- Upper yoke holes used by heat exchanger
- Fourth hole used to carry through He
  - 150 mm^2 between triplet, 100 mm^2 D1 and CP





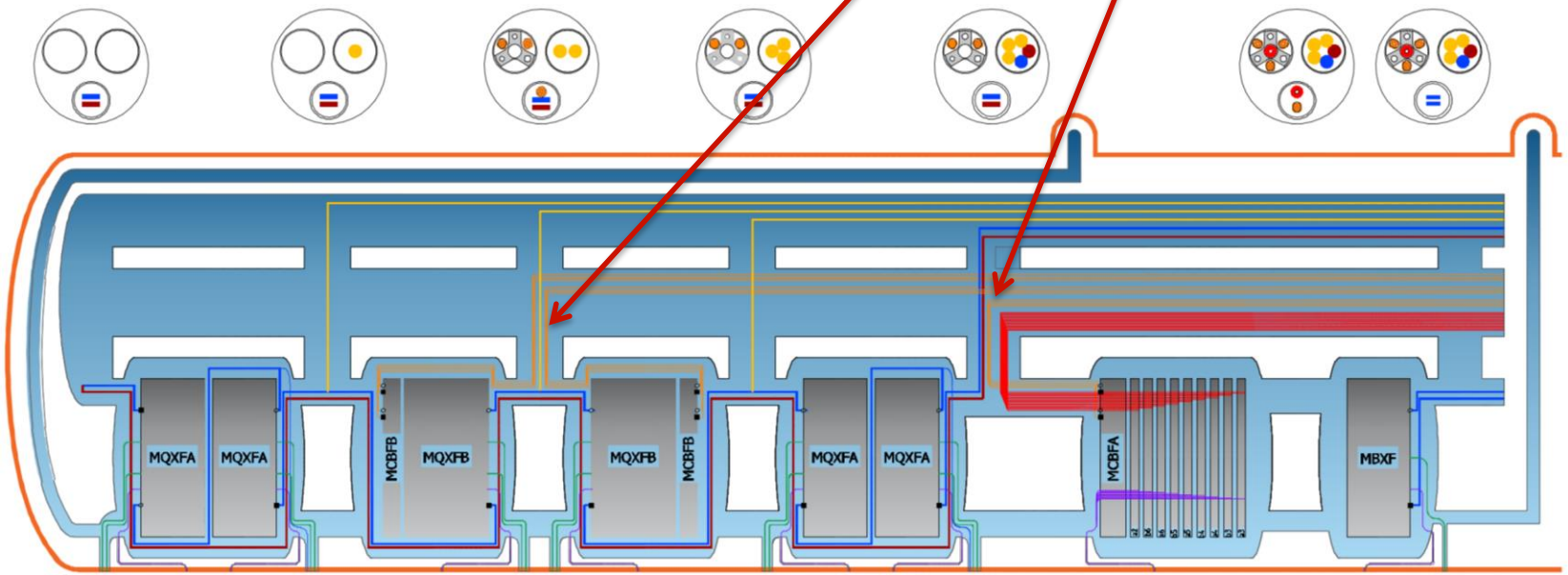
CIRCUIT BASELINE

- Triplet trim on Q1A (recent requirement, low current of 35 A)
  - Resistive lead with local powering 20mm^2
  - The same is put on Q3a to avoid symmetry breaking
- Triplet CLIQ leads (2 kA for short time ≈100 ms)
  - Resistive leads with local powering
  - Standard Cu wire 10mm^2



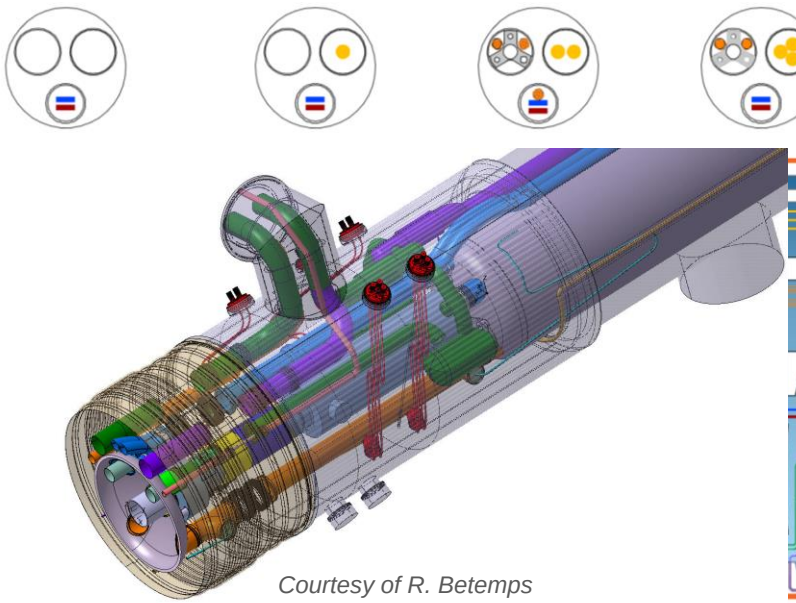
CIRCUIT BASELINE

- Orbit corrector busbars
  - These are 6 × 2 busbars rated at 2 kA
    - Short corrector MCBXFB: Entering Q2a and Q2b at the Q2a/Q2b interconnection from the parallel line, travelling through Q2a/Q2b yoke with main busbar
    - Long corrector MCBXFA: entering the Q3/CP from interconnection

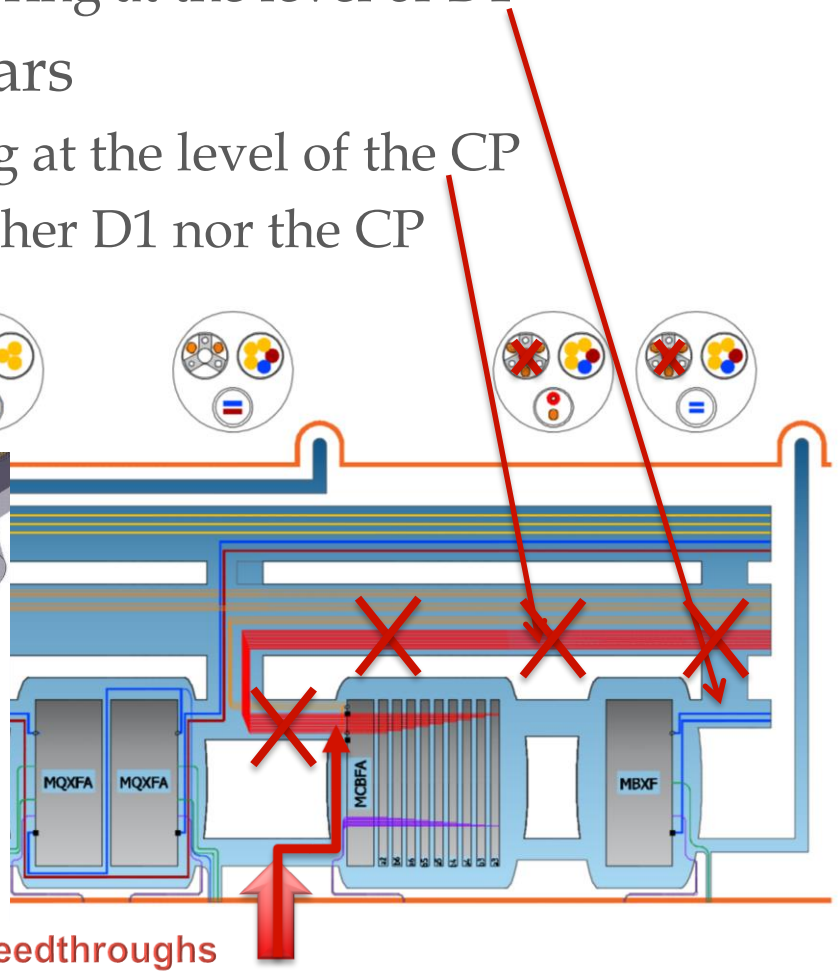


CIRCUIT BASELINE

- D1 busbar
  - The 13 kA LHC busbar, entering at the level of D1
- High order corrector busbars
  - 600 A LHC busbars, entering at the level of the CP
  - No leads going through neither D1 nor the CP



Courtesy of R. Betemps



Local conduction cooled feedthroughs under study for 120 and 200A

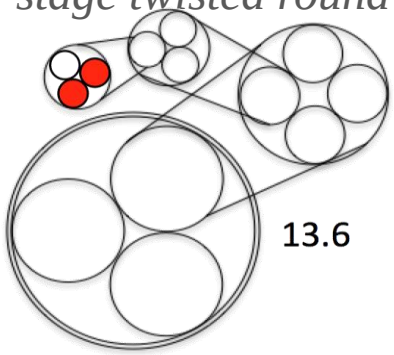
CONTENTS

- IR magnets features and choices
- Baseline for busbars
- Work in progress

18 kA BUSBAR

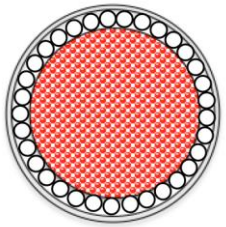
- This cable will be made with 68 Nb-Ti strands of the LHC inner layer cable
  - 1.065 mm diameter, 1.65 Cu/no Cu
  - Present scenario: produced with external contract (contribution being discussed with Russian Scientific Research and Development Cable Institute (VNIIKP))
  - 2 options considered:

multi-stage twisted round busbar



Stage	Twist pitch	Sub-stages
1	25	1xSC + 2xCu
2	55	3 x Stage 1
3	80	3 x stage 2
4	130	4 x stage 3

cable-around-core, round busbar



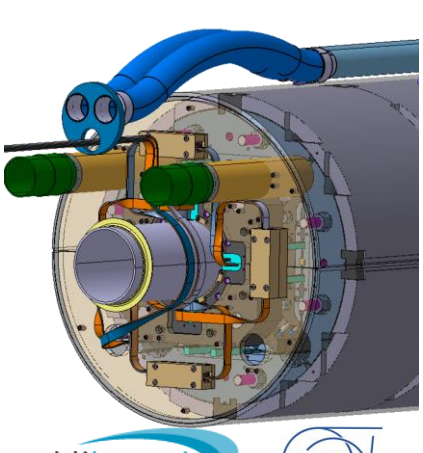
Stage	Twist pitch	Diameter	Sub-stages
1	N/A	10.6	Cu wires
2	130	12.9	34 SC + Cu core

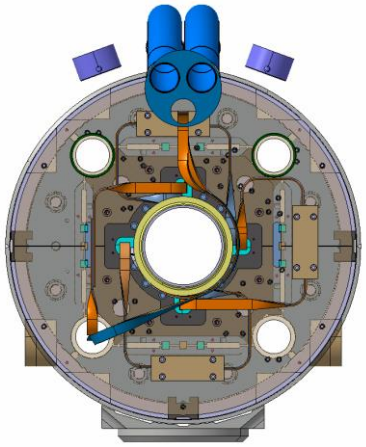
  - Splicing to flat cable to be studied

EXPANSION LOOPS

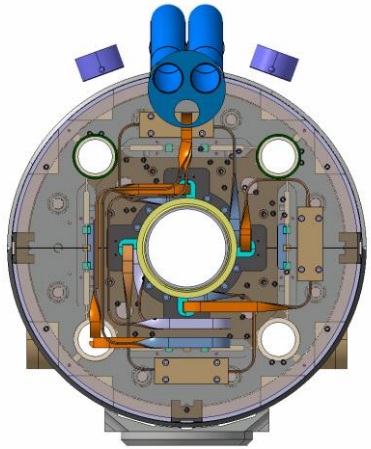
- In the triplet baseline for expansion loops is to have pigtails but the lyra option is not yet excluded
- This is a relevant part of the cold mass design
- US AUP and CERN could adopt the same solution, if not stiffness have to be equivalent

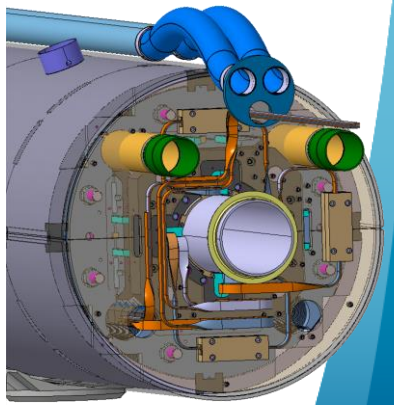
- A technical choice: do we need to stabilize the two cables of the expansion loops?
  - If not necessary, this gives much more flexibility





Pig tail Option





Lyra Option

CONCLUSIONS

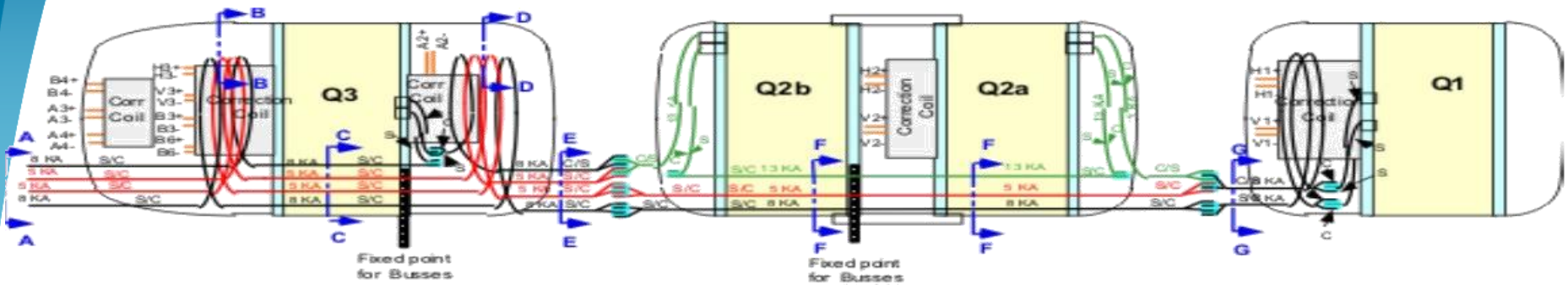
- Busbar baseline has been outlined
  - Two flat 18 kA through the magnets (main circuit)
  - Three round trims also at 18 kA from interconnections
  - Parallel line to avoid crossing of corrector package and D1
  - Busbar protection requires quenching the triplet
- Development in progress
  - Round busbar geometry and production plane
  - Round-flat splices
  - Expansion loops in triplet cold masses
  - Local feedthroughs for the CP 120 and 200A

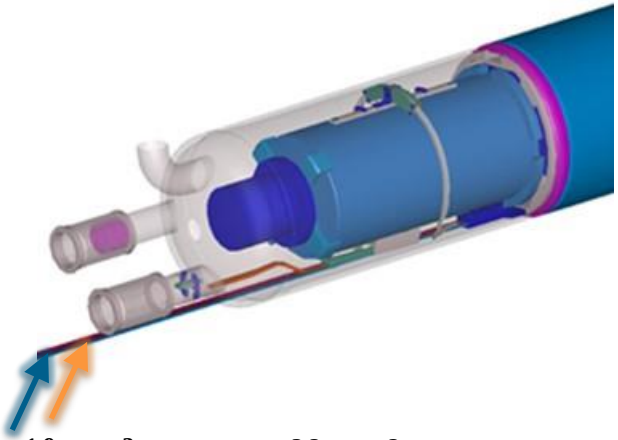
HiLumi
HL-LHC PROJECT

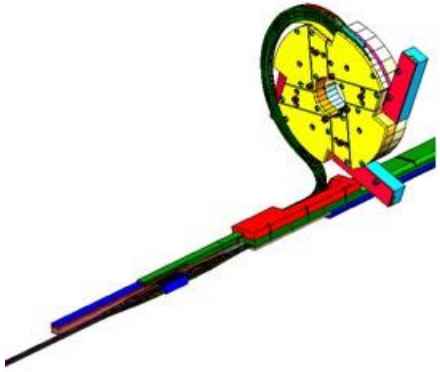
Spare Slides

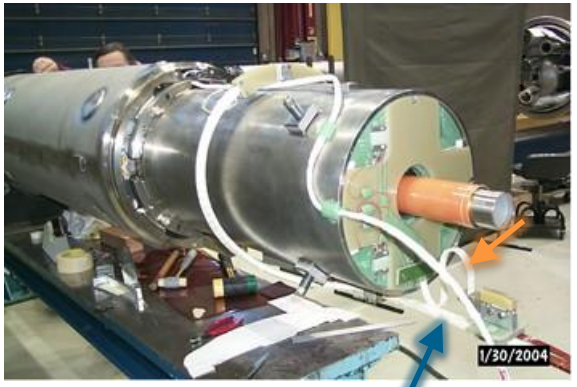
CERN

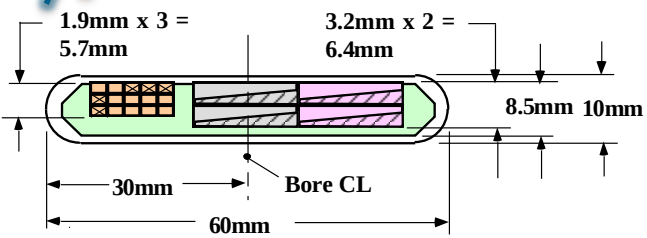
Busbars integration in the present LHC Inner Triplet











Key to cable bus:
Pink = 5KA
Grey = 8 KA
Solid = SC cable (37 strand)
Crosshatched = Copper only cable