Powering of HL-LHC Triplets and MSs

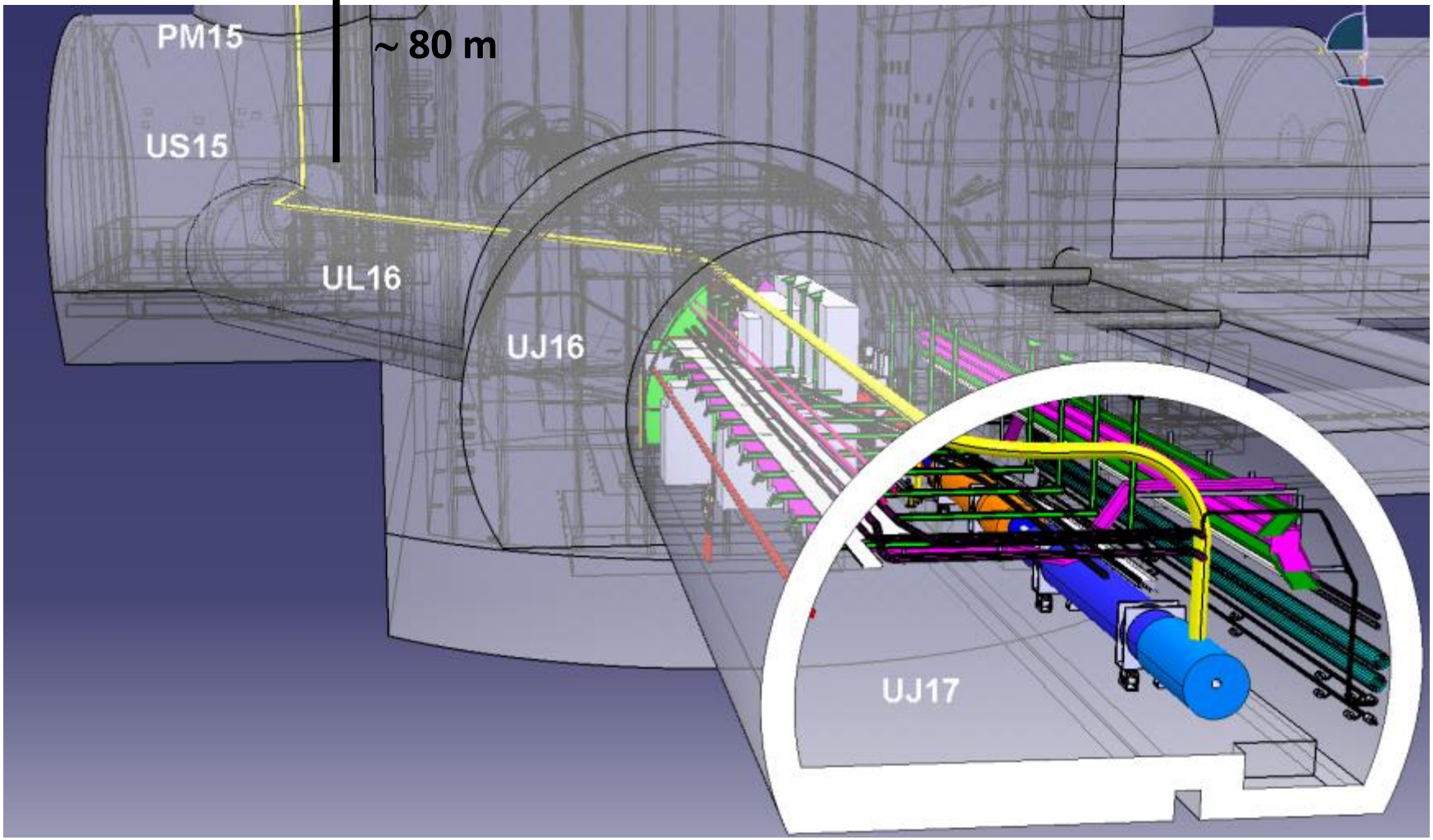
13th HL-LHC Technical Coordination Committee

A. Ballarino

04/08/2016

Until mid 2015

Ex. LHC P1



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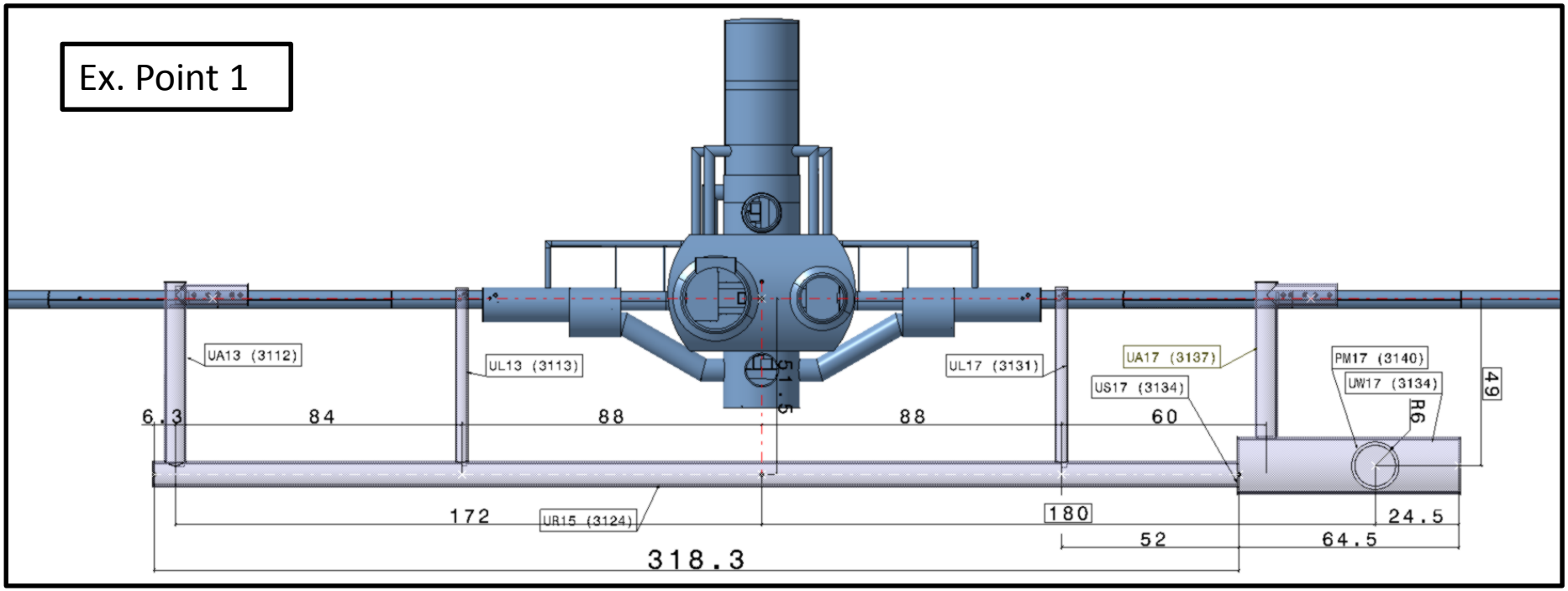
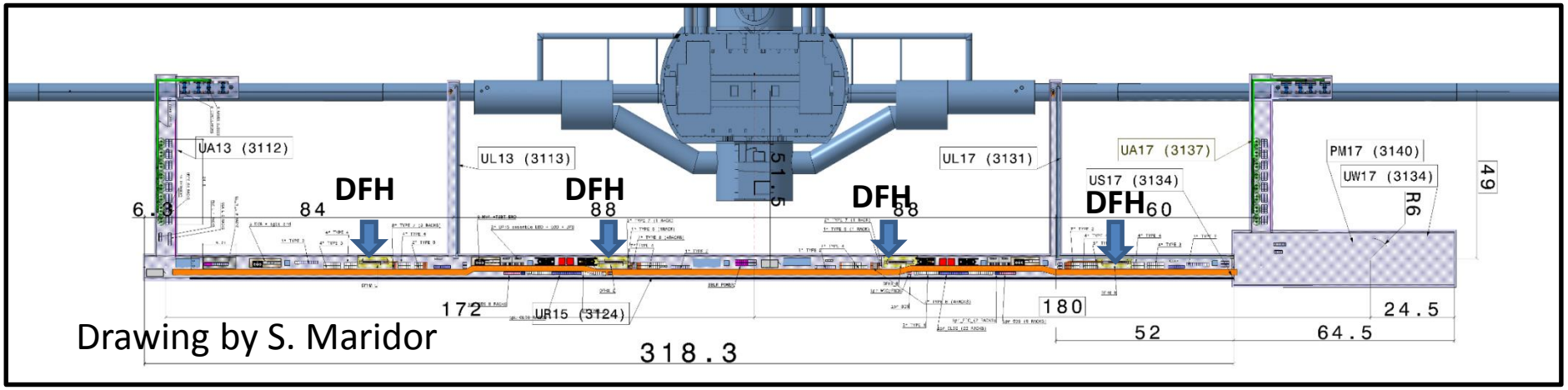
In March 2016 – Circuits Review





Drawing by S. Maridor

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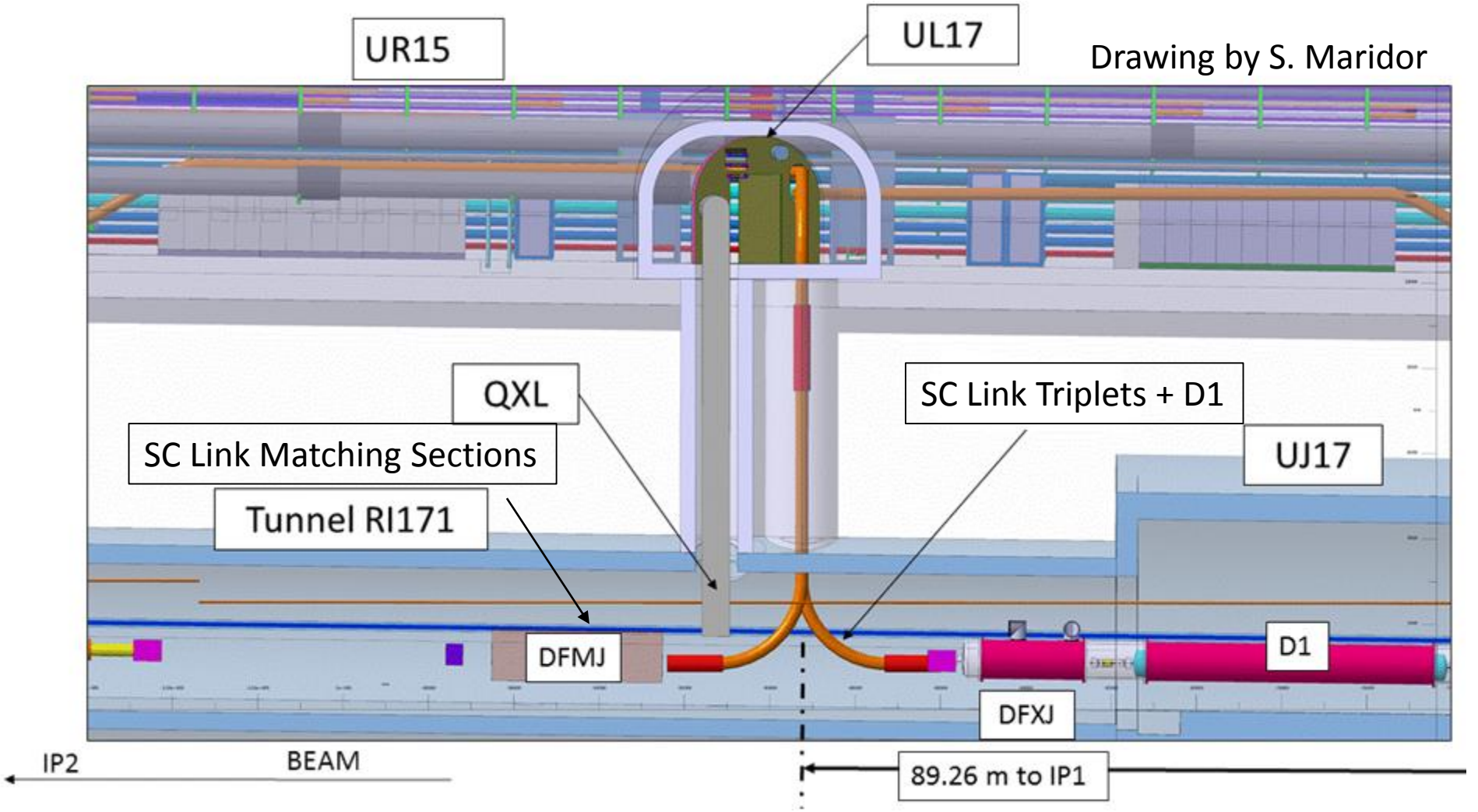
In March 2016 – Circuits Review



- Routing of Nb-Ti bus-bars of Triplets and D1 inside magnets cold masses

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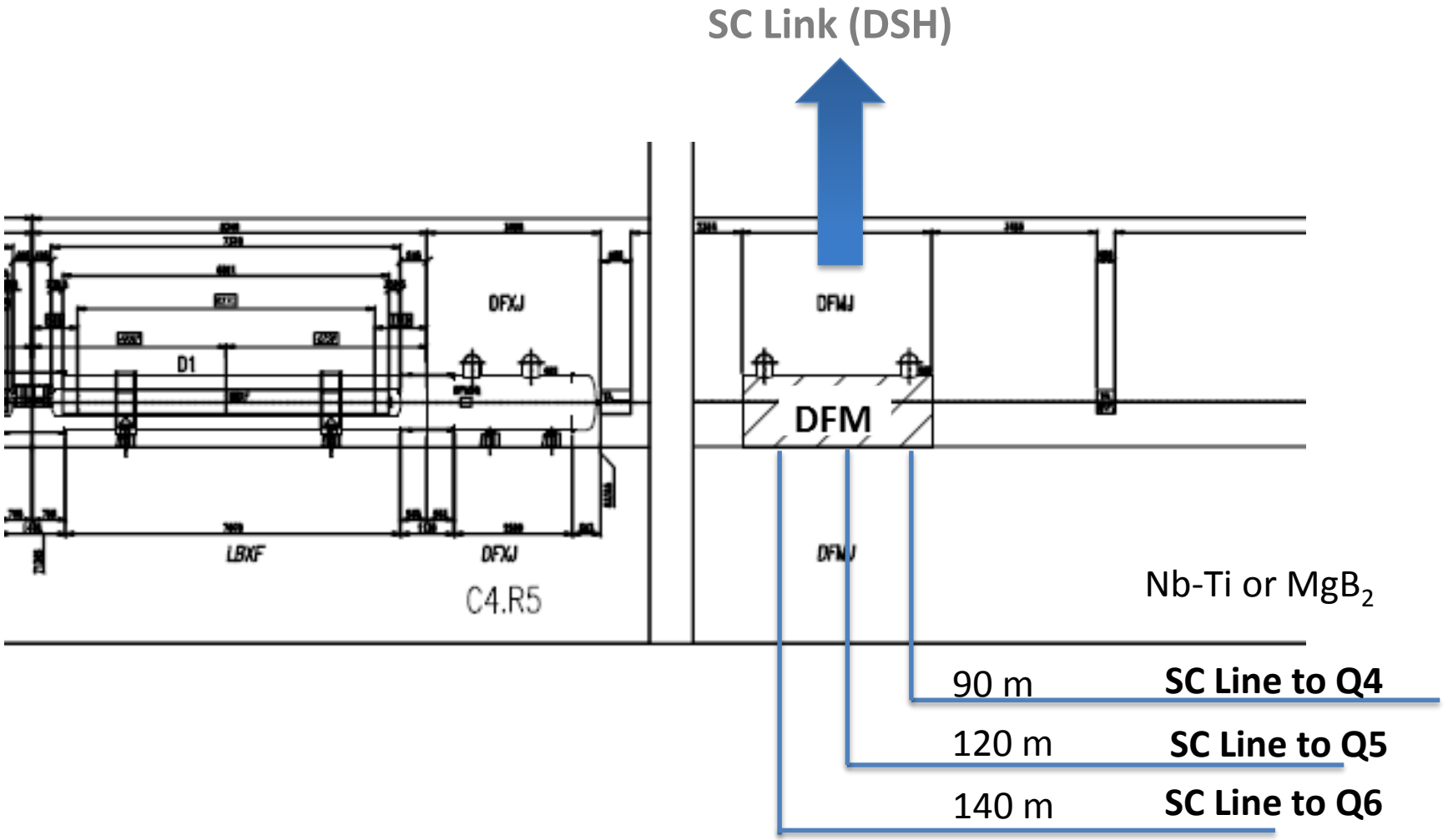
In March 2016 – Circuits Review



SC Lines to Q4, Q5 and Q6 included in WP6

Presented at Cost &Schedule Review, March 2015

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In March 2016 – Circuits Review

Power converter	Current
Type 1	18kA
Type 2	13kA
Type 3	6kA
Type 4	±2kA
Type 5	±600A
Type 6	±200A
Type 7	±120A
Total	

- Q1/Q3 – Q2a/Q2b ~~20 kA~~
- D2, D1
- Q4, Q5, Q6 ~~Q4 16 kA~~
- Orbit correctors Q3 and Q2, Trim on Q3
- Orbit correctors D2 and Q4 ~~2 kA~~
- CP
- Correctors Q5 and Q6, Trim on Q2

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Overview of Cold Powering System
Number of Leads and of SC cables, Current Rating

Triplets, D1 and CP – per IP Side

6 × 18 kA
13 × 2 kA
18 × 0.2 kA
1 ×0.12 A

→ 38 Units
2×68.5 kA

Matching Sections – per IP Side

2 × 13 kA
12 × 6 kA
16 × 0.6 kA
18 × 0.12 kA

→ 48 Units
2×54.8 kA

Type	N_IPside
18 kA	6
13 kA	4
6 kA	12
2 kA	13
0.6 kA	16
0.2 kA	18
0.12 kA	19

Per IP side : **2×123 kA** , 86 Leads/SC Cables

Hi-Luminosity Upgrade: **2×492 kA,** 344 Leads/SC Cables

Presented at Circuits Review, March 2016

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More recent modifications – as from May 2016

Triplets and D1

Present baseline – after Circuits Review

	Circuits for HiLumi	Magnet Type	Number of circuits per IP side	Number of circuits	I_nominal [kA]	I_ultimate [kA]	I_rated [kA]
Inner Triplet	Triplet Q1, Q2a, Q2b, Q3	MQXFA / MQFXB	1	4	16.5	17.8	18.0
	Trim Q1				2		2.0
	Trim Q3				2		2.0
	Trim Q2a				0.12		2.0
	Orbit correctors Q2a/b - vertical	MCBXFBV	2	8	1.6	1.73	2.00
	Orbit correctors Q2a/b - horizontal	MCBXFBH	2	8	1.47	1.59	2.00
	Orbit correctors CP - vertical	MCBXFAV	1	4	1.6	1.73	2.00
	Orbit correctors CP - horizontal	MCBXFAH	1	4	1.47	1.59	2.00
	Superferric, order 2	MQSXF	1	4	0.182	0.20	0.20
	Superferric, order 3, normal and skew	MCSXF / MCSSXF	2	8	0.105	0.11	0.12
	Superferric, order 4, normal and skew	MCOXF / MCOSXF	2	8	0.105	0.11	0.12
	Superferric, order 5, normal and skew	MCDXF / MCDSXF	2	8	0.105	0.11	0.12
	Superferric, order 6	MCTXF	1	4	0.105	0.11	0.12
	Superferric, order 6, skew	MCTSXF	1	4	0.105	0.11	0.12
D1[2]	Separation dipole D1; MBXF	MBXF	1	4	12	13.0	13.0[3]

Circuits for HL-LHC MSs, A. Wollmann and F. M. Rodriguez, June 2016

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Triplets and D1

Circuits Review (March 2016)

Triplets and D1– per IP Side

6 × 18 kA 13 × 2 kA 18 × 0.2 kA 1 ×0.12 A	→ 38 Units 2×68.8 kA

Present Baseline

4 × 18 kA 14 × 2 kA 2 × 0.2 kA 16 ×0.12 A	→ 36 Units 2×52 kA

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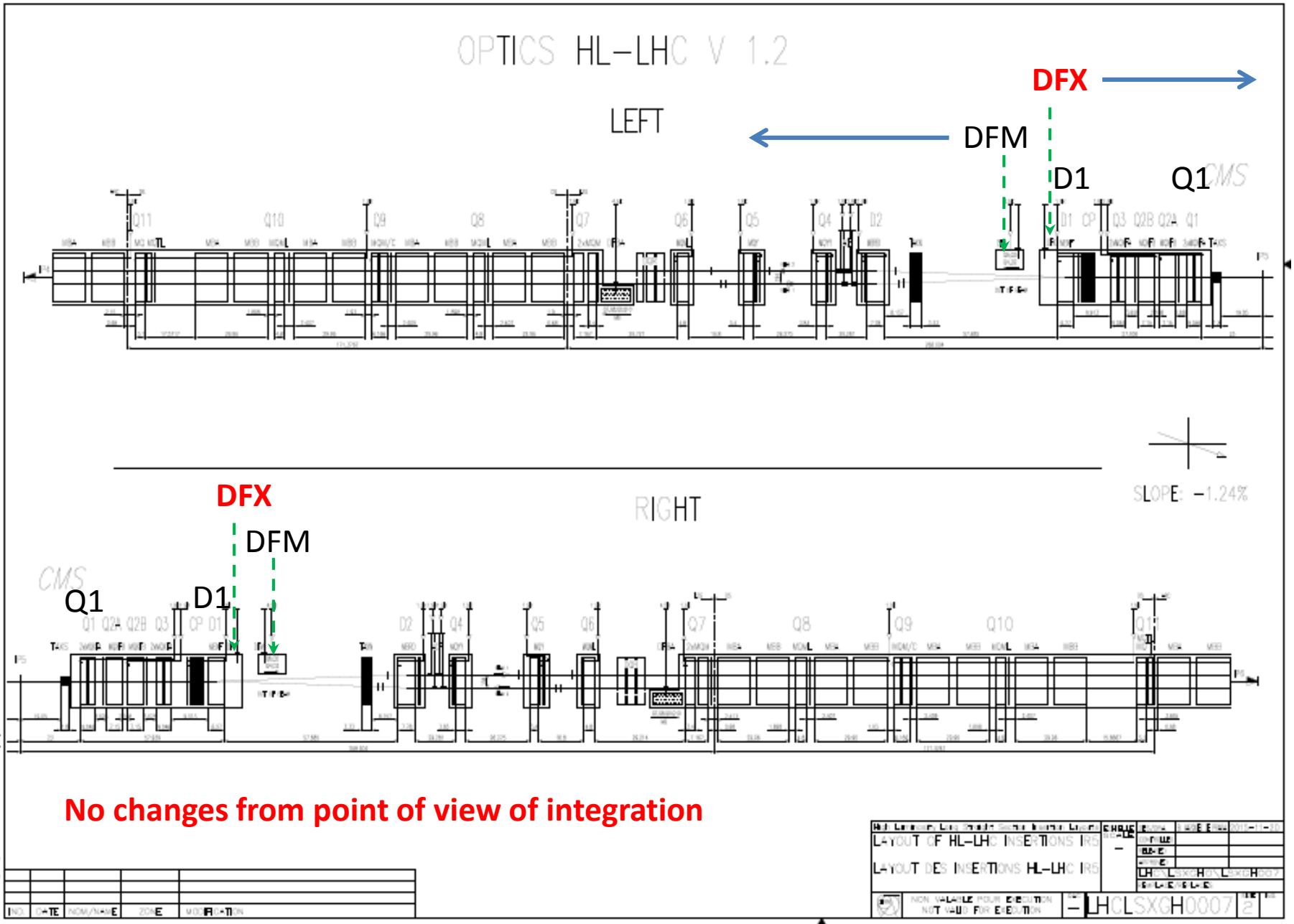
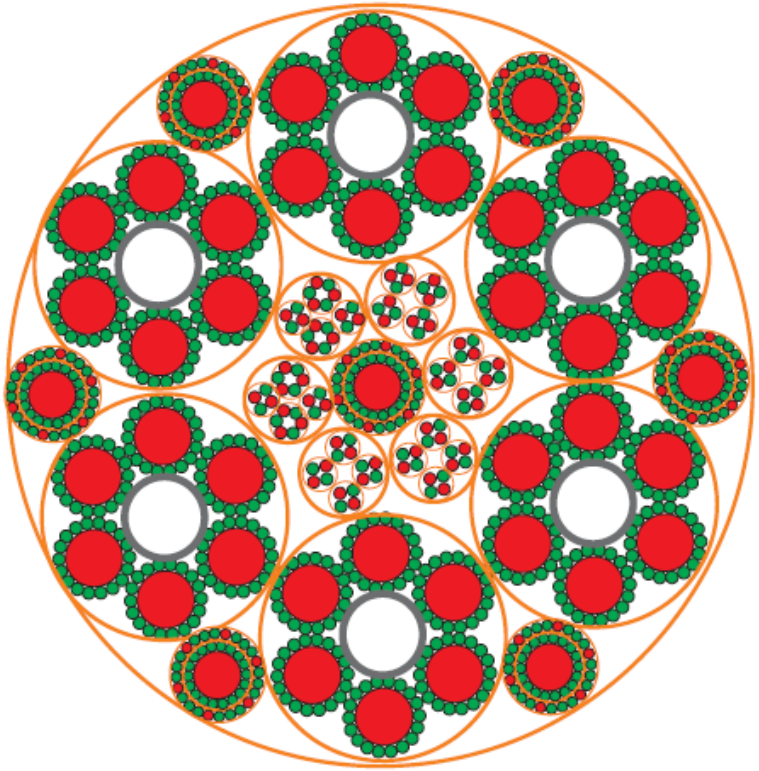
Triplets and D1

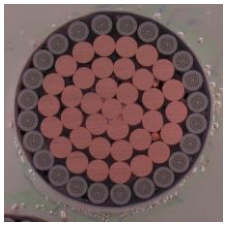


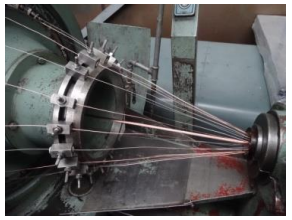
No changes from point of view of integration

Triplets and D1

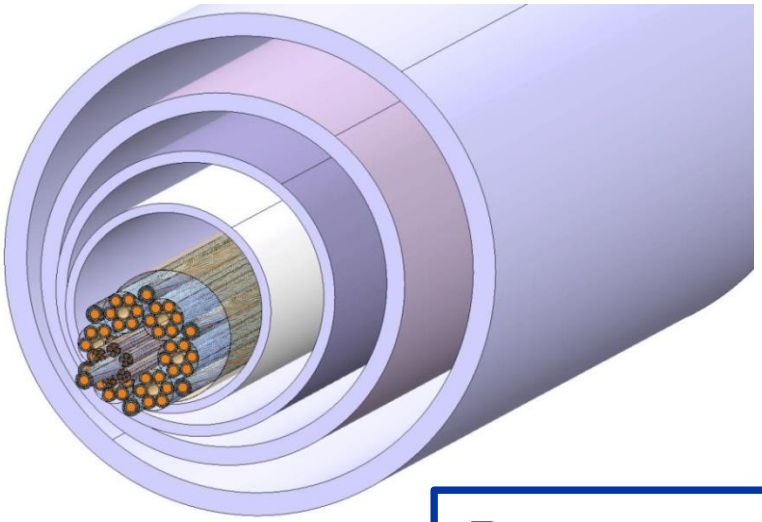
Hi-Lumi Triplets and D1







MgB_2 18-strand cable



Φext ~ 65 mm

Mass ~ 11 kg/m

Φext ~ 220 mm

No changes from point of view of Current Leads design, DFH and DFX design, and SC Link layout

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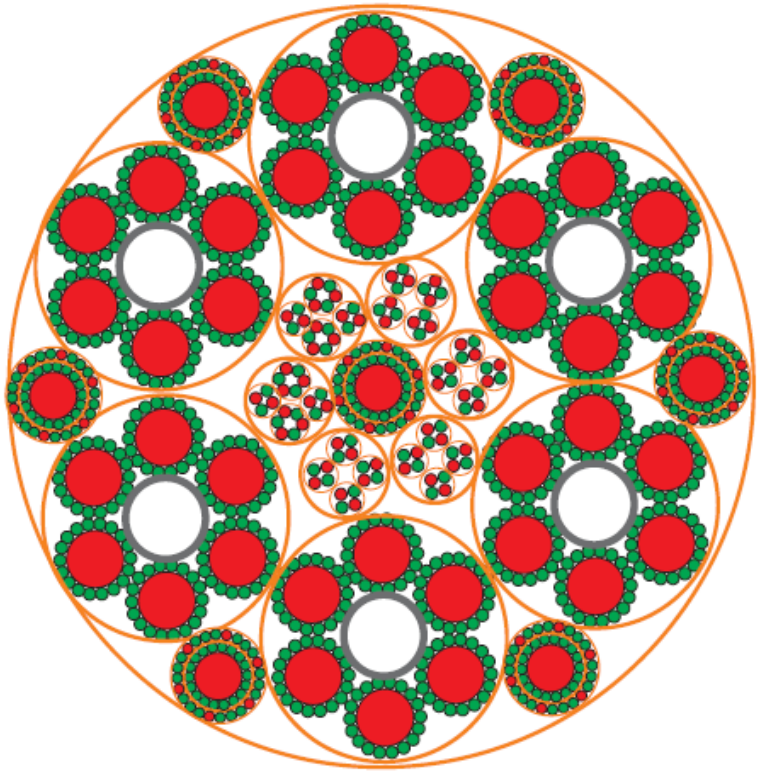
Triplets and D1



Required

4	× 18 kA
14	× 2 kA
2	× 0.2 kA
16	×0.12 kA

Available

4	× 18 kA + 2 spares
14	× 2 kA
2	× 0.2 kA + 8 spares
16	×0.12 kA

- 2 kA Current Leads are concentric
- **Spare cables** will be installed in the SC Link cold mass
- **Spare leads** will be available for installation

A. Ballarino

Matching Sections

	Circuits for HiLumi	Magnet Type	Number of circuits per IP side	Number of circuits	I_nominal [kA]	I_ultimate [kA]	I_rated [kA]
Q4	Large aperture 2-in1 Quad; Q4	MQYY	2	8	4.50	4.9	6.0
	Orbit correctors Q4	MCBYY	4	16	0.5	0.54	0.6
Q5[1]	Present LHC Q4 magnet	MQY	2	8	4.51	4.9	6.0
	Orbit correctors present Q4	MCBY	6	24	0.072	0.08	0.12
Q6	Insertion Quad, 2-in1 aperture; Q6	MQML	2	8	4.31	4.7	6.0
	Orbit correctors Q6	MCBC	2	16	0.08	0.09	0.12
D2[2]	Separation dipole D2;MBRD	MBRD	1	4	12	13.0	13.0[3]
	Orbit correctors D2	MCBRD	4	16	0.5	0.54	0.6

Circuits for HL-LHC MSs, A. Wollmann and F. M. Rodriguez, June 2016

- D2 at 1.9 K and **12 kA** $\Rightarrow$ Required new powering
- For Q4, Q5 and Q6 consider use of existing DFBL and associated DSL

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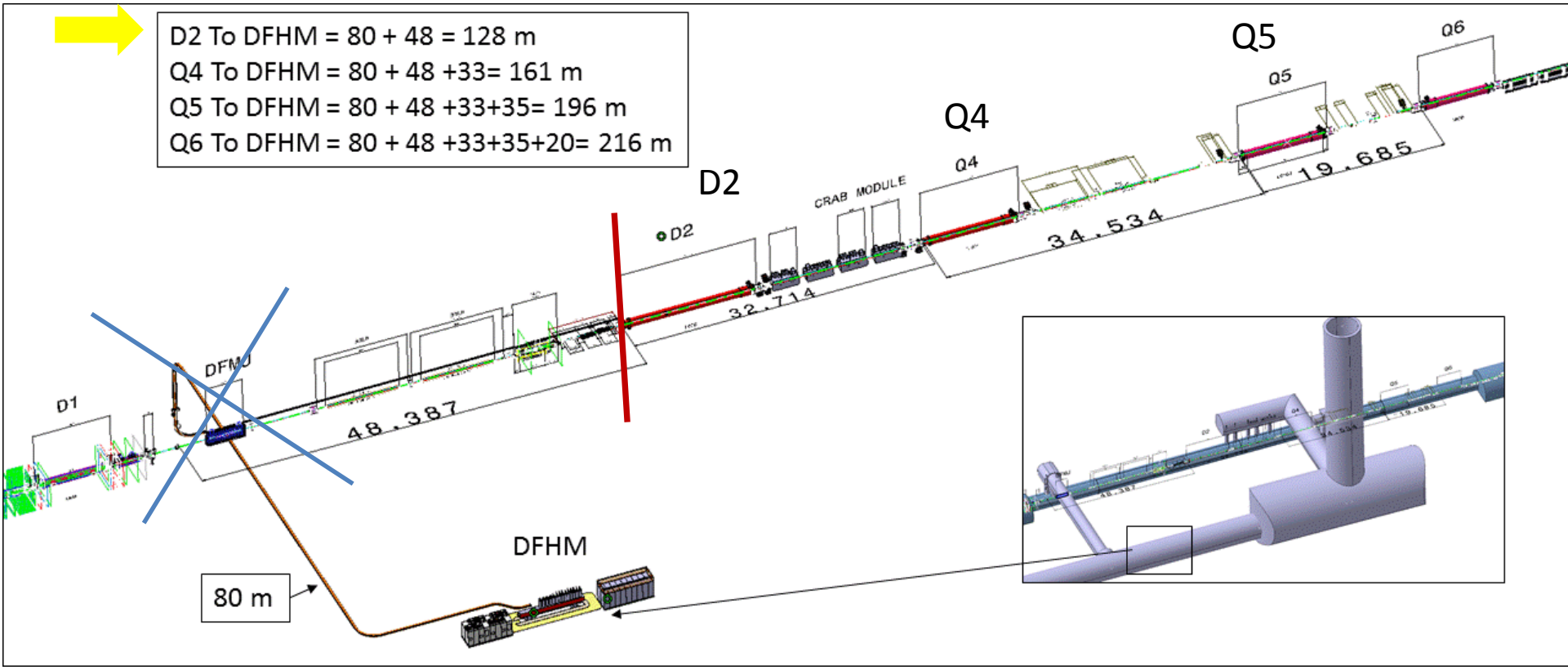
Matching Sections – D2



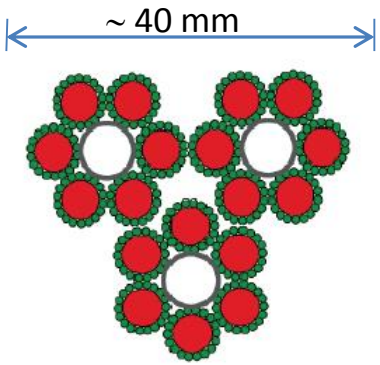
Small DFBM attached to D2

Meeting A. Ballarino, S. Claudet, V. Parma, June 2016

Matching Sections – D2

- Leads/Cables for D2 (separation dipole and orbit correctors):

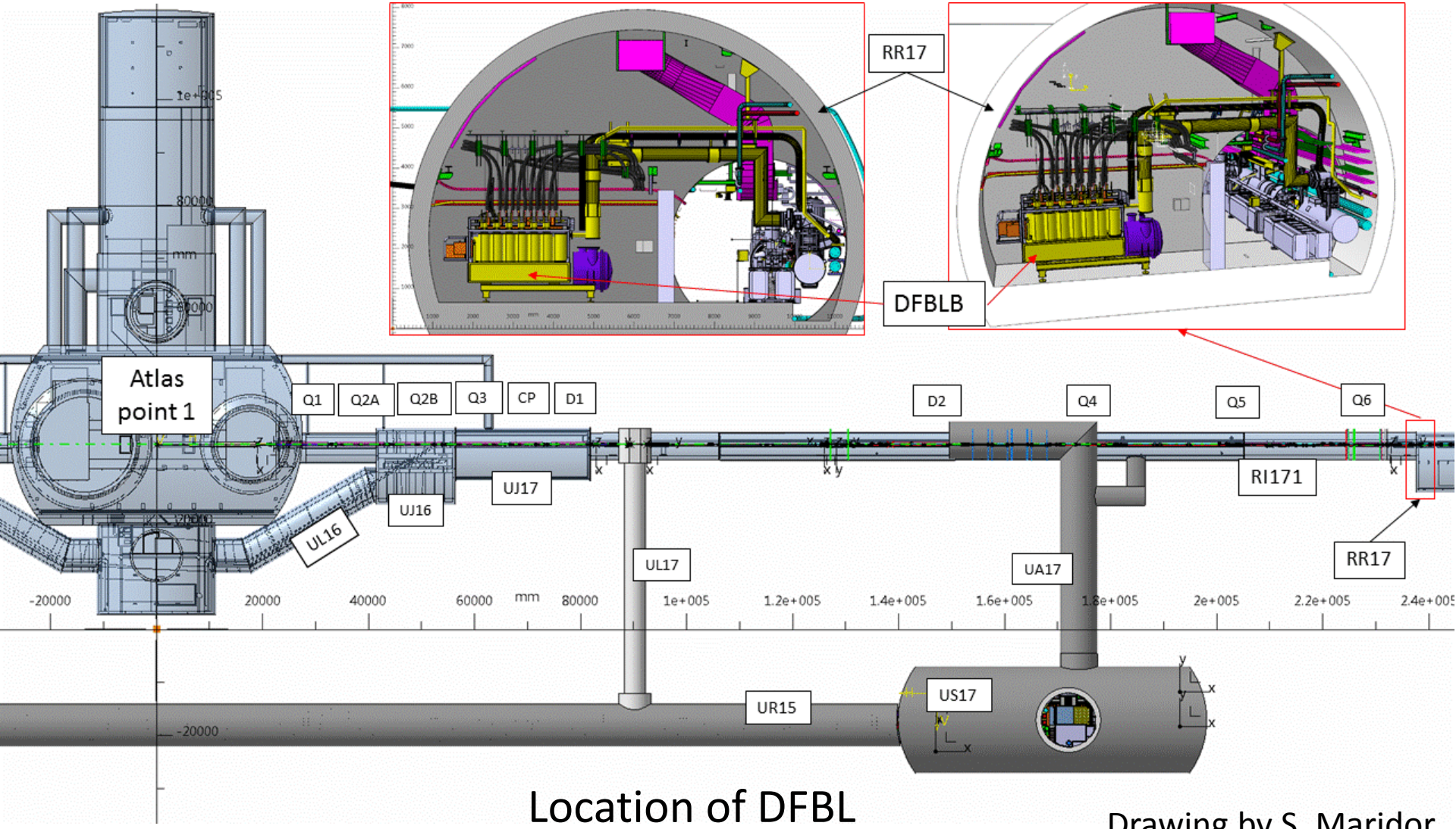
  2×12 kA (+ 1 spare cable in the SC Link)
  8×0.5 kA (+2 spare cables in the SC Link)



- Current leads in new underground tunnel
  SC Link ~ 130 m long

Separate powering of D2 : yes, possible – no major issues

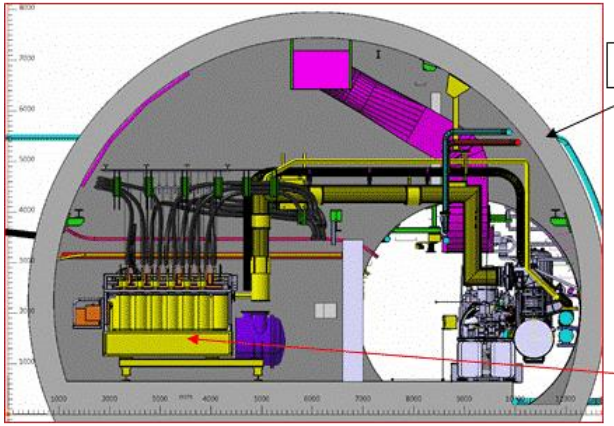
Matching Sections – Q4, Q5 and Q6



Location of DFBL

Drawing by S. Maridor

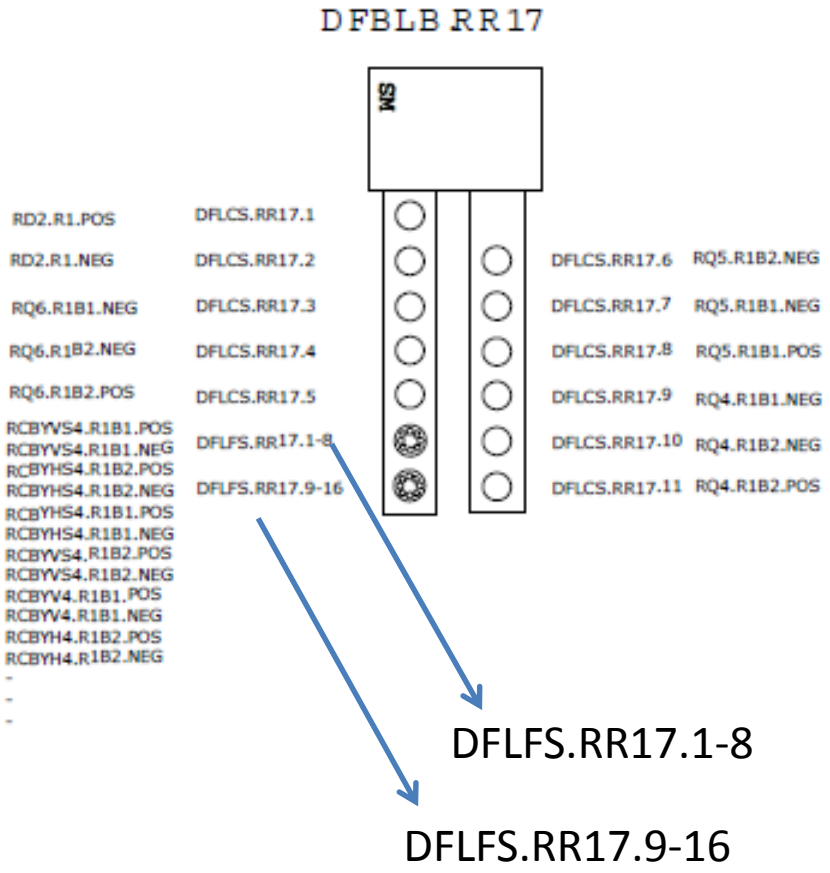
Matching Sections – Q4, Q5 and Q6



Drawing by S. Maridor

DSL in LHC tunnel

Matching Sections – Q4, Q5 and Q6



11×6 kA (HTS)

12×0.12 kA used

16×0.12 kA available

DSL: 12×6 kA

48×0.6 kA

Current Leads in existing DFBL

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Current Leads for HL-LHC Q4, Q5 and Q6

	Circuits for HiLumi	Magnet Type	Number of circuits per IP side	Number of circuits	I_nominal [kA]	I_ultimate [kA]	I_rated [kA]
1.9 K							
Q4	Large aperture 2-in1 Quad; Q4	MQYY	2	8	4.50	4.9	6.0
	Orbit correctors Q4	MCBYY	4	16	0.5	0.54	0.6
1.9 K							
Q5	Present LHC Q4 magnet	MQY	2	8	4.51	4.9	6.0
	Orbit correctors present Q4	MCBY	6	24	0.072	0.08	0.12
4.2 K							
Q6	Insertion Quad, 2-in1 aperture; Q6	MQML	2	8	4.31	4.7	6.0
	Orbit correctors Q6	MCBC	2	16	0.08	0.09	0.12

Circuits for HL-LHC MSs, A. Wollmann and F. M. Rodriguez

12 × 6 kA, but reduced to:

✓ **9 × 6 kA if** 3-leads powering scheme adopted (as in LHC)

✓ **16 × 0.12 kA**

! 8× 0.6 kA (missing)

➢ Dedicated SC Link for the powering of Q4 orbit corrector magnets or local powering of Q4 orbit correctors

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Powering of Matching Sections

Summarizing:

- Individual powering of **D2** $\Rightarrow$ OK;
- Powering of **Q5**, **Q6** and **MQYY** (Q6) via existing DFBL $\Rightarrow$ OK;
- **Missing powering** of 600 A **Q4 orbit correctors** (8 leads)
  - Dedicated SC Link (for Q4 or only for Q4 correctors)
  - Local powering
- To be studied - with cryo - the possibility of a complete or partial re-use of the existing DSL
- If DSL to replaced: new SC Link (Nb-Ti or MgB_2 based)

Short update on WP6a last months activities

A. Ballarino

- Launched procurement of six semi-flexible cryostats each 60 m long (DO-29687/TE/HL-LHC)
  Three companies: Nexans, Cryotec and Cryoworld
  Two variants (with and without active thermal shield)

- Launched collaboration with the Main Workshop for the manufacturing and assembly of two units of 18 kA HL-LHC prototype current leads. Raw material procured

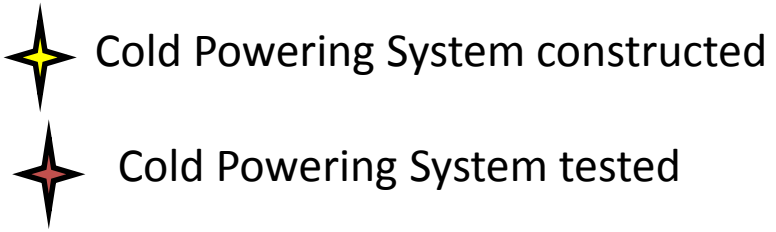
- Launched MS for production of full Triplets + D1 current leads system (collaboration with Main Workshop) – manufacturing of components (raw material and assembly by CERN)

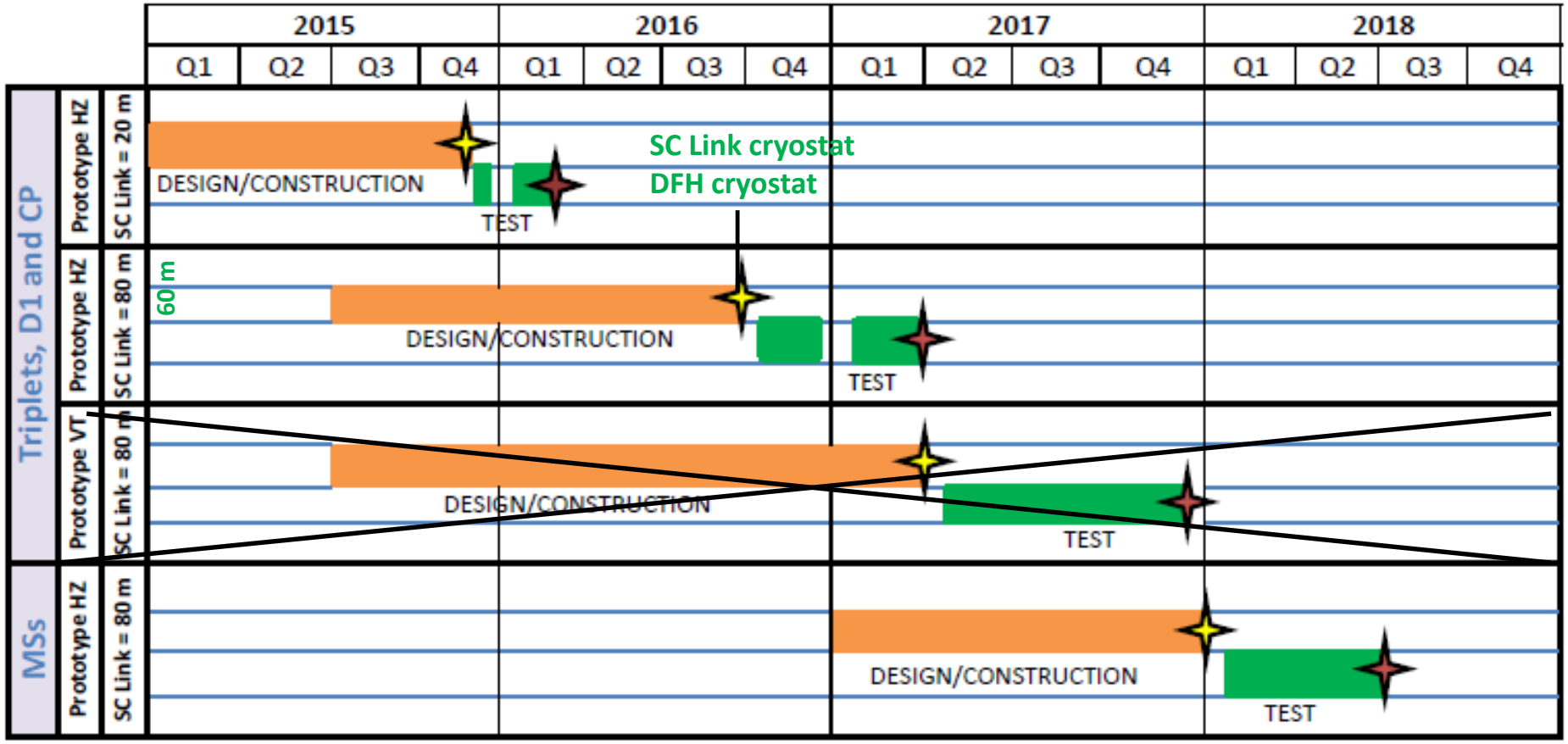
- Launched PE (DO-29821/TE/HL-LHC) for cabling in industry of MgB_2 wire (18-wire cable with flexible Cu core). Several companies contacted (among which Nexans and TRATOS). Answers by end of August 2016
- Launched R&D contract on MgB_2 with Columbus. Scope: reduction of cost of MgB_2 wire via production of longer lengths of wire (billets from ~ 21 to ~ 48 mm outer diameter) - DAI 6378524
- Launched IT for procurement of 200 km of MgB_2 wire delivered in unit lengths of up to 2 km (IT-4253/HL=LHC). Implementation of results from R&D contract. Opening of offer this coming Monday
- Visited (with L. Bottura and M. Benedikt) Russian laboratory in Moscow (VNIIKP, R&D Cable Institute)

- Progress on design of DFX cryostat for Triplets (C. Ferrer and V. Parma). Mock-up of routing of MgB_2 cables for DFX cryostat (SCD, building 288)
- Construction of prototype DFX module in Main Workshop (completed by end of August 2016)
- Production and qualification of MgB_2-MgB_2 and MgB_2-NbTi high-current electrical joints (measurements in He gas and in LHe). Presentation at ASC conference (S. Giannelli)
- Discussions on strategy for testing the 60 m long and the series SC Links (with SM-18 and cryo teams) (EDMS N. 1698461)
- Electro-mechanical measurements of MgB_2 wires and cables, electrical insulation tests of MgB_2 cables, ….
- Space: building 927. Needed latest by mid Sept 2016 (delivery of 60 m long cryostats)

Prototype activity – Phase 1

Cost & Schedule Review, March 2015





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