Superconducting Links

A. Ballarino

CERN, Geneva

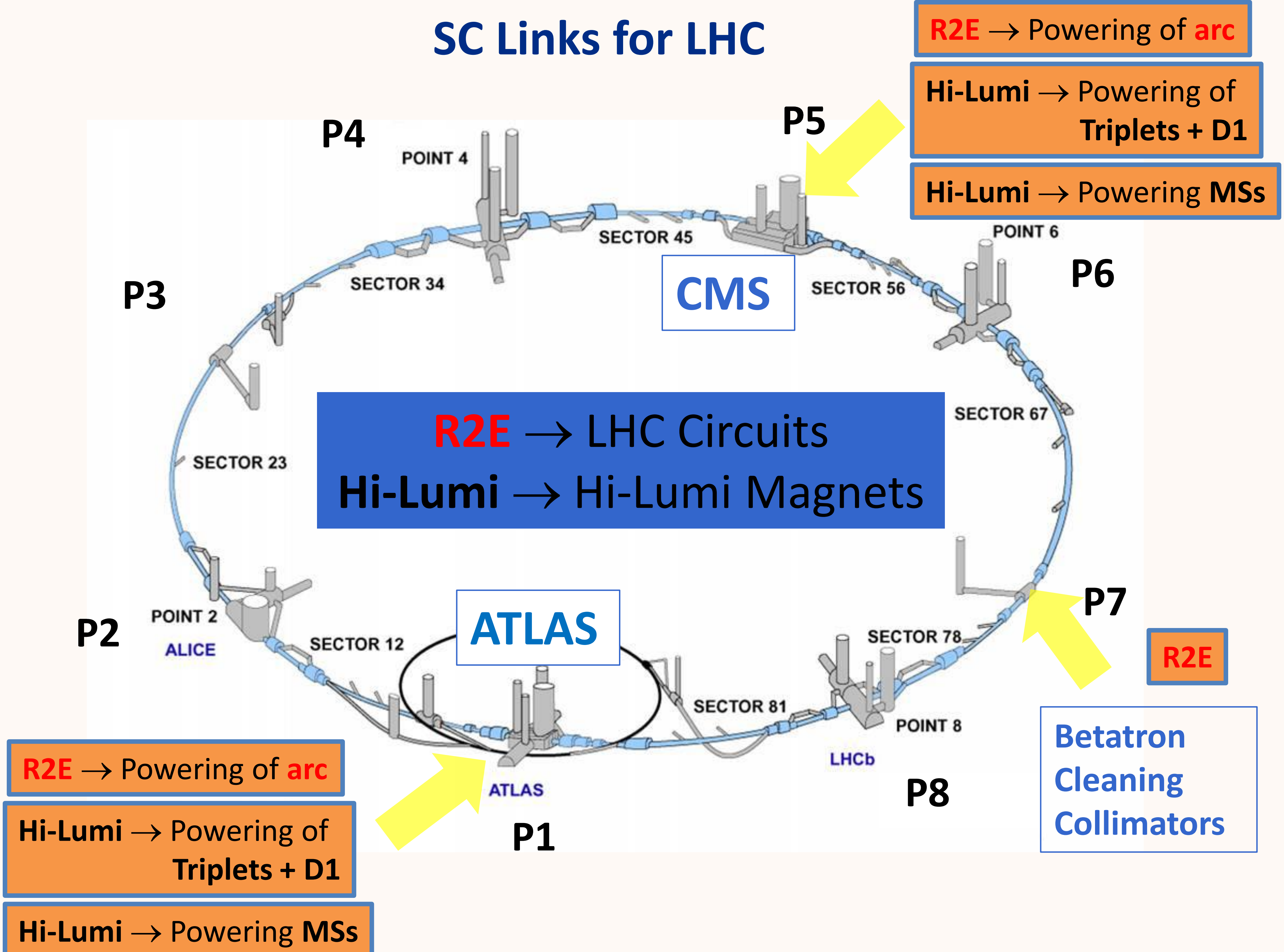
4th Joint LHC-LARP Annual Meeting

18th November 2014

Outline

- **Introduction**
  - Cold Powering Systems with SC Links for R2E
  - Cold Powering Systems with SC Links for Hi Luminosity LHC
- **Status of development (LHC P7)**
- **Project timeline and future milestones (LHC P7)**
- **SC Links for P1 and P5**

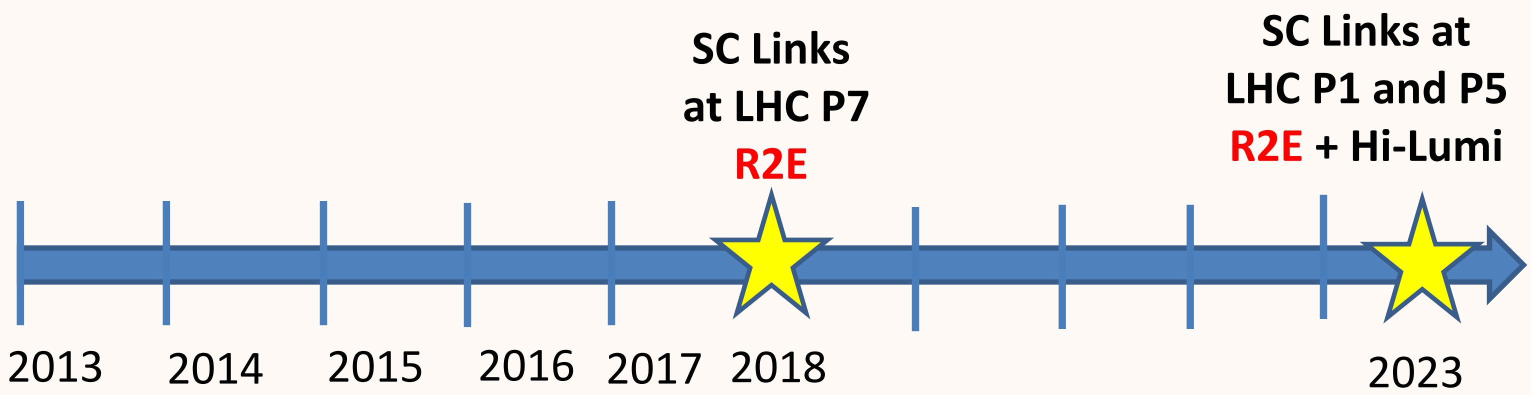
SC Links for LHC



A. Ballarino, 18/11/2014

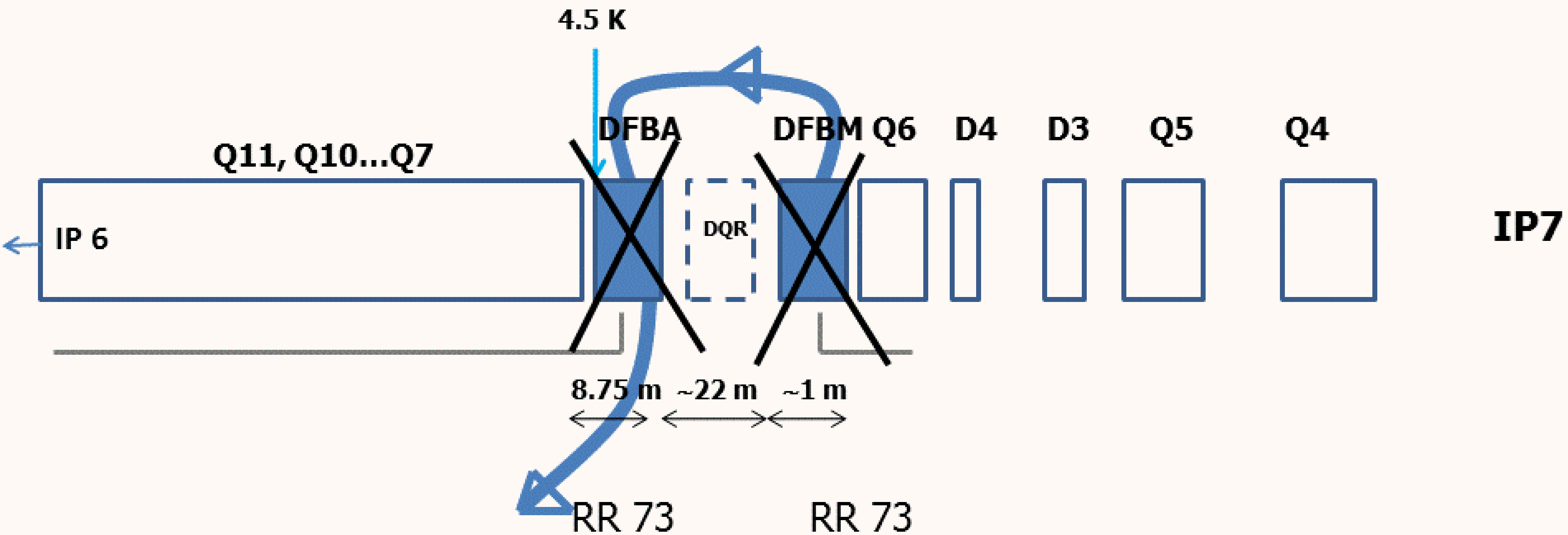
SC Links for LHC

Dates of installation of cold powering systems in the LHC machine



SC Links for LHC P7

Removal of DFBA (2) and DFBM (2)

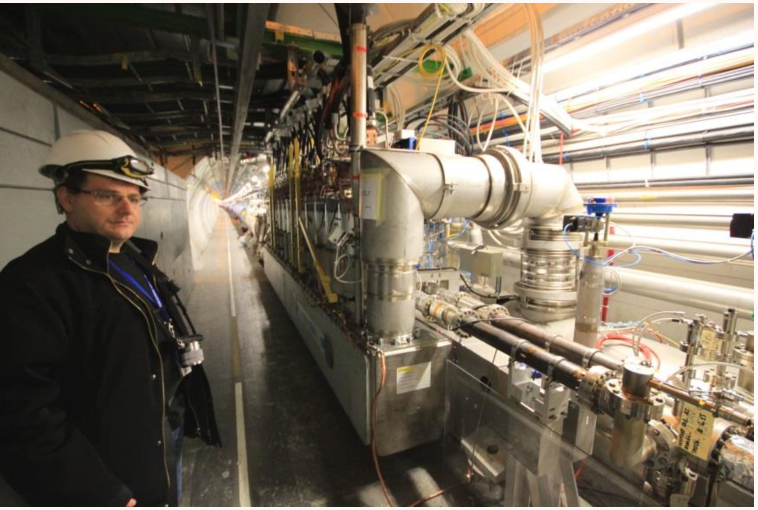


SC Links (DSH)
+ **New re-located "DFBs"**(DFH)
+ **Connection cryostats replacing the DFBs** (DFA/M)
(with the 2 leads 13 kA for EE of MB)
+ (associate cryo, control, protection,…)

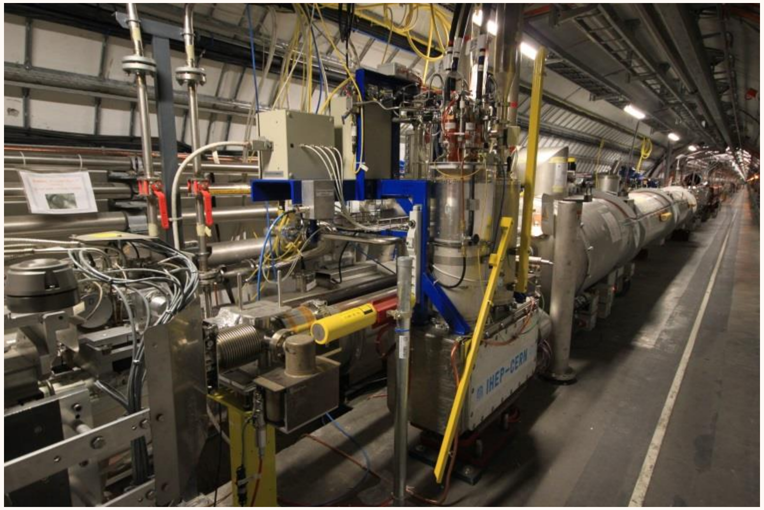
Cold Powering System

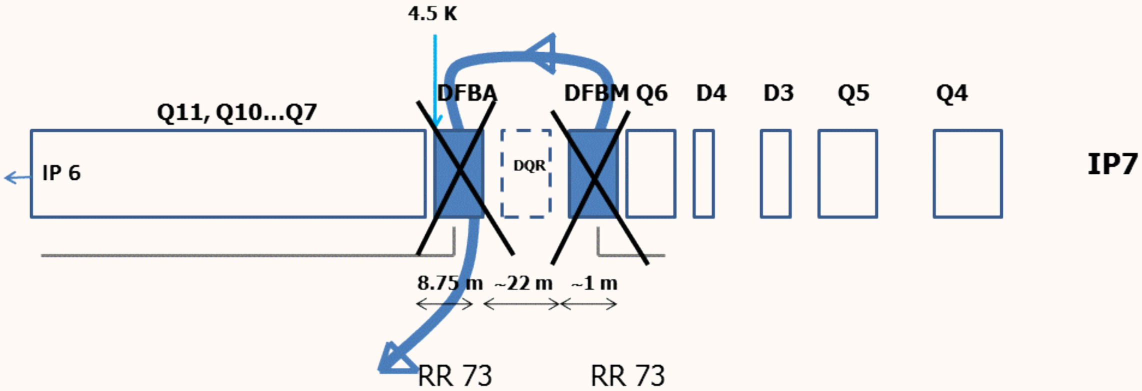
Powering at LHC P7

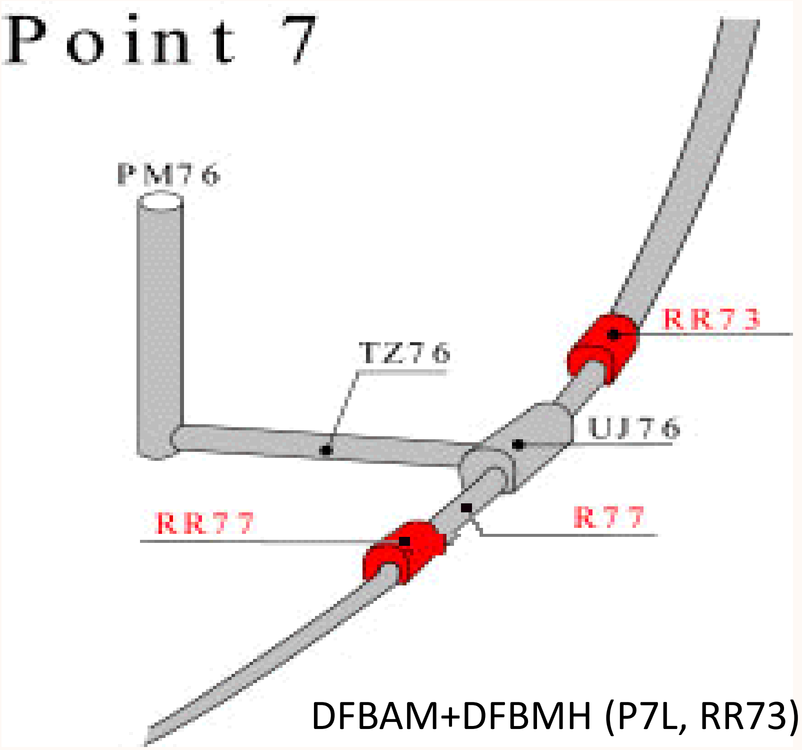
DFBA



DFBM

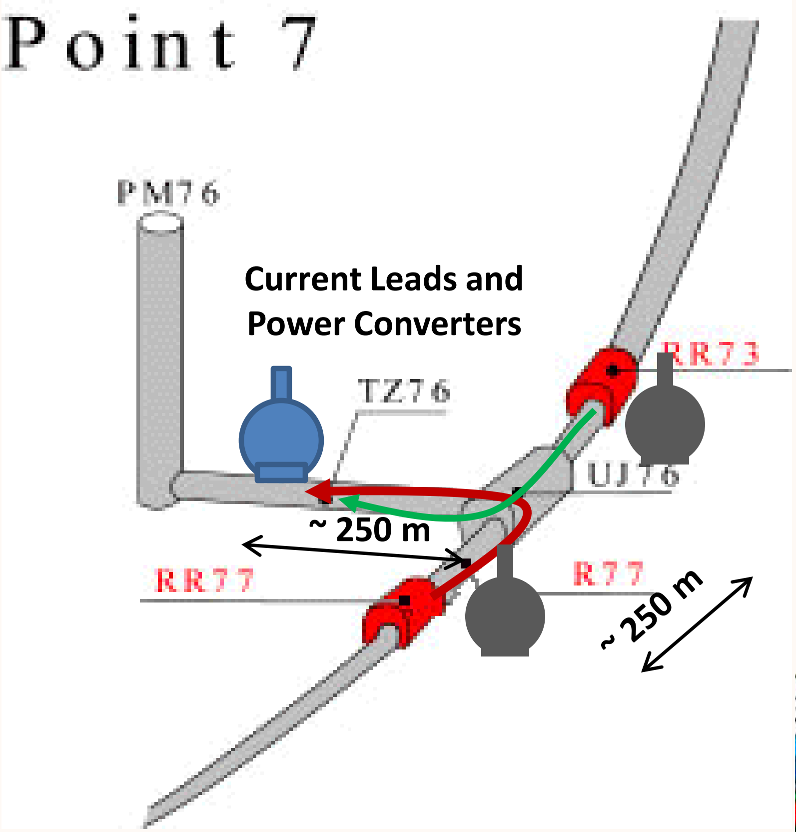


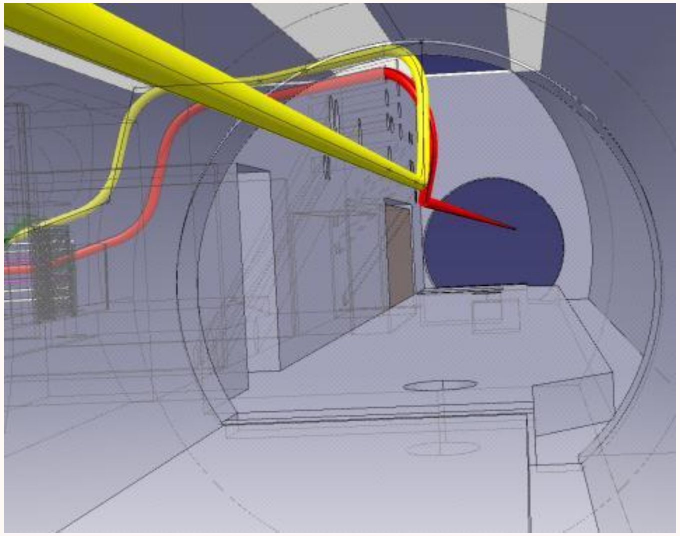


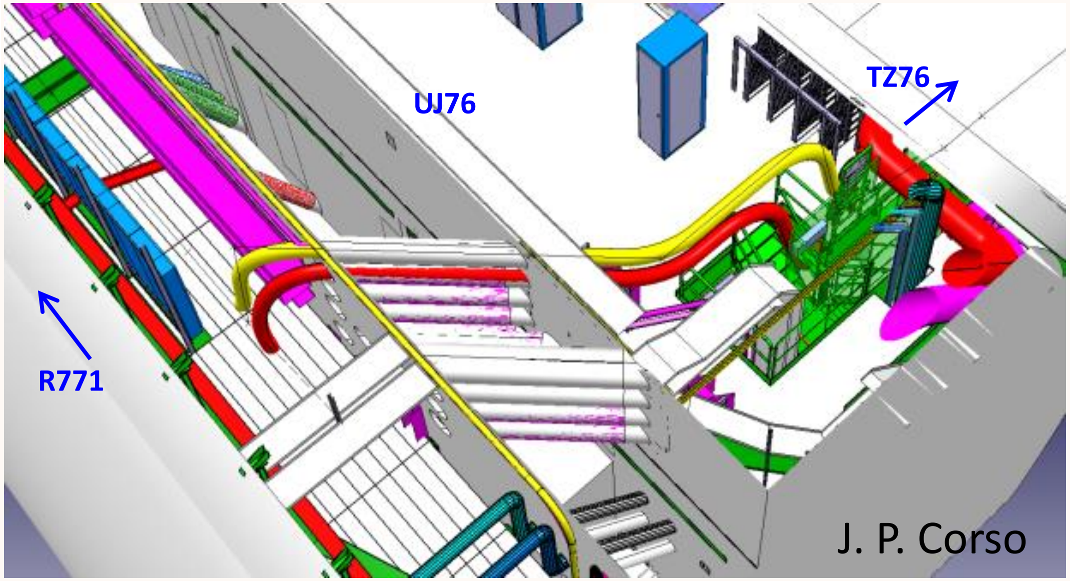


DFBAM+DFBMH (P7L, RR73)
DFBAN+DFBMH (P7R, RR77)

SC Links for LHC P7



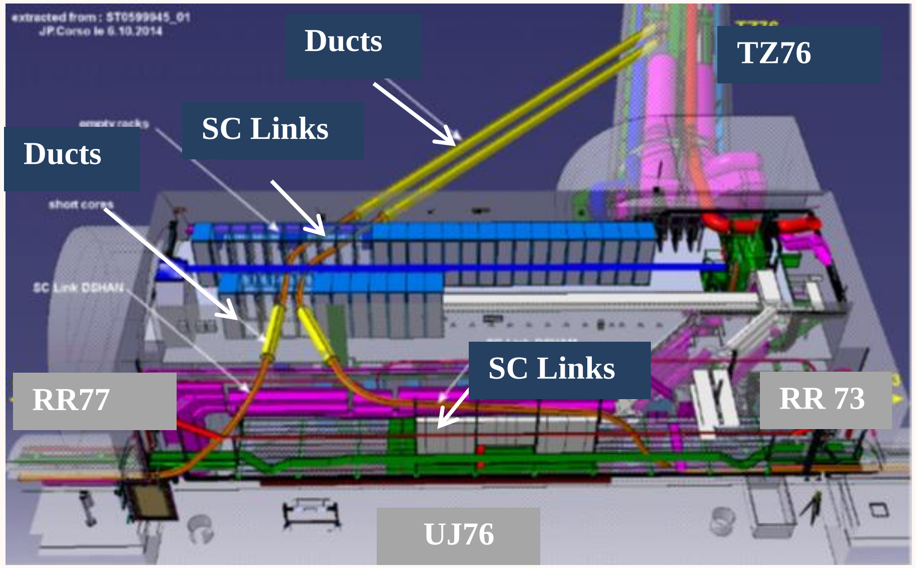




Underground Installation

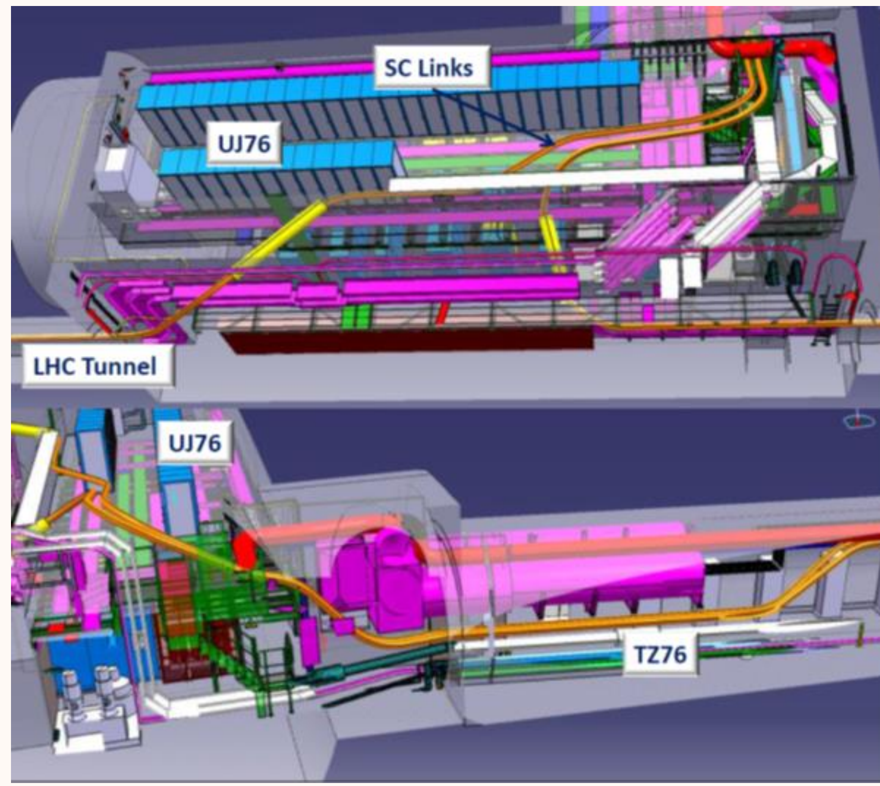
Two SC Links, each ~ **500 m** long

SC Links for LHC P7



Option 1: simplified routing

Option 2: more complex routing routing



SC Links for LHC P7

LHC Electrical Circuits

Number of leads	Current Rating (A)	Circuit	
DFBAM			
2	13000	EE	MB Energy Extraction
4	600	RQS	Skew Quadrupoles
20	600	RQTL	Trim Quadrupoles
8	600	RQT	Trim Quadrupoles
4	600	ROF	Focusing Octupoles
4	600	ROD	Defocusing Octupoles
4	600	RSS	Skew Sextupoles
DFBMH			
4	600	RQ6	Quadrupoles in MSs

Tot. 48 Leads rated 600 A
48 cables **600 A (28.8 kA)** in the link

Status of System Development (LHC P7)

- **Cold Powering System**
- **Cryogenics**
- **Superconductors**
- **Superconducting Cables**
- **Superconducting Links**
- **New DFBs and Current Leads**

Status of System Development (LHC P7)

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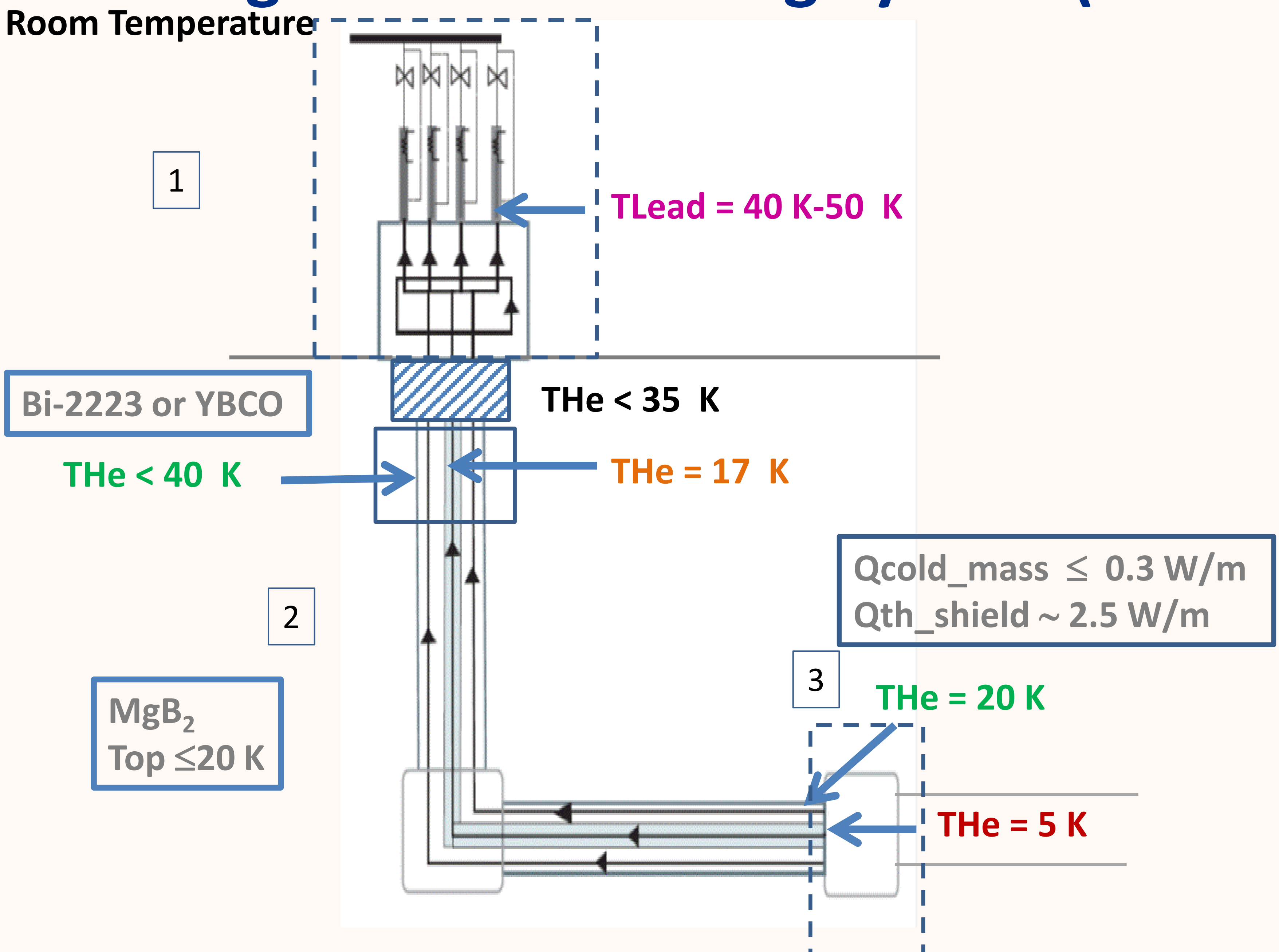
Cooling of Cold Powering System (LHC P7)



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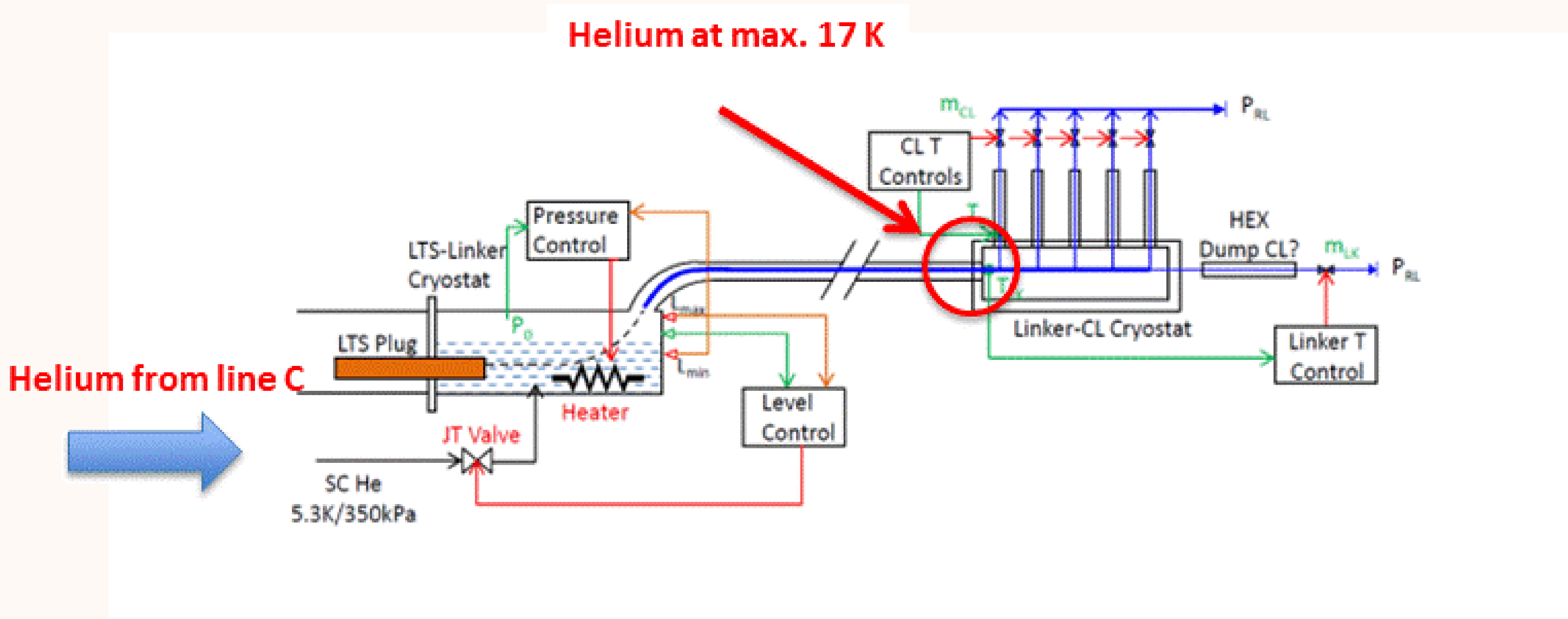
Cold Powering System (LHC P7)



Cryogenics for Cold Powering System (LHC P7)

Cooling requirements are satisfied by the existing LHC cryogenic system

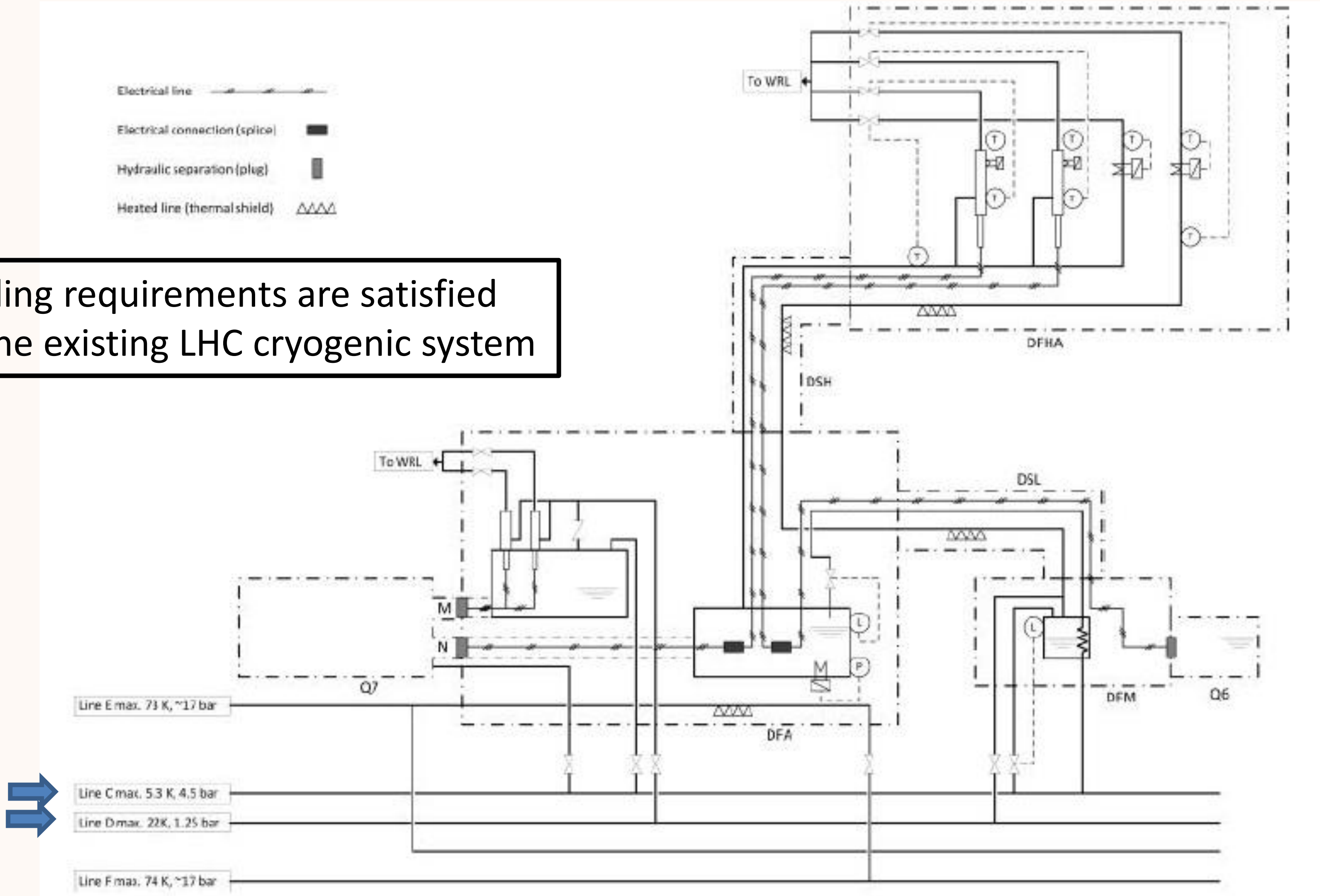


Figure 2: Simplified flow scheme for the cooling of the Cold Powering System at LHC P7

U. Wagner, from CERN-ACC-2014-0065, Milestone Report of WP6

Status of System Development (LHC P7)

- Cold Powering System
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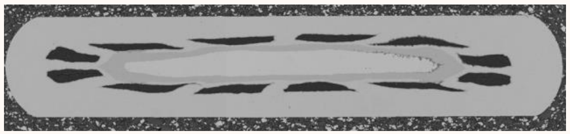
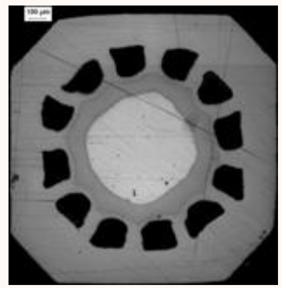
MgB_2 Wire Development

Product commercially available before
development for SC Link Project (R&D CERN-Columbus)

3.6×0.67 mm²

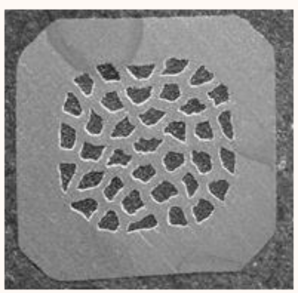


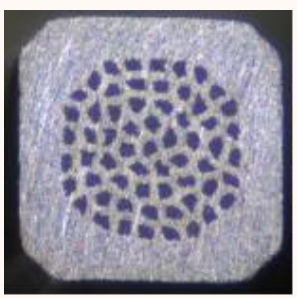
1.6×1.6 mm²
1.1×1.1 mm²



Ni Matrix
12 MgB_2 **filaments**
Cu core – **Fe barrier**
ff ~ 14 %

1.1×1.1 mm²



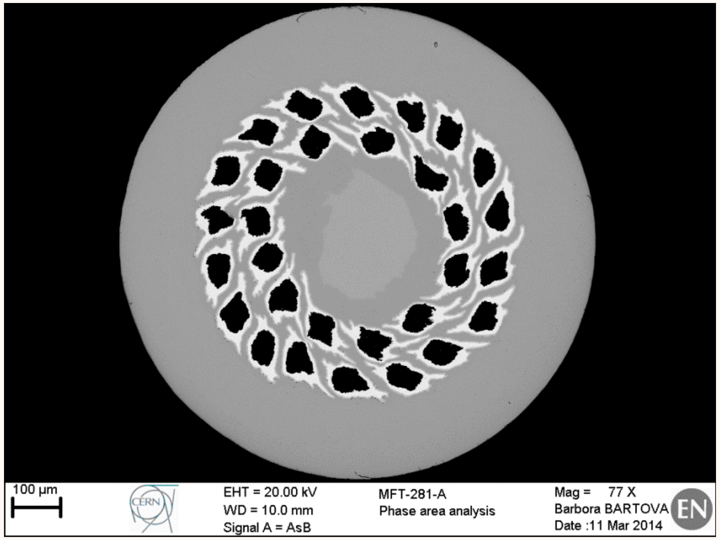


37 filaments   61 filaments

Monel Matrix
12/19/37/61/91 MgB_2 **filaments**
Ni barrier
ff up to ~ 24 %

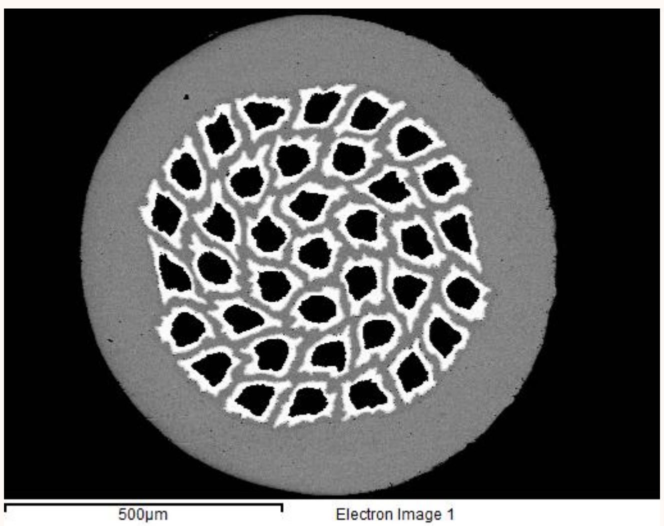
Wire produced at Columbus Superconductors

MgB_2 wire – State of the art development



Φwire = 0.99 mm
30 MgB_2 filaments
Twisted filaments (LT=100 mm)
Φeq_MgB_2 = 62 μm
ACu ~ 5 % Awire

Baseline wire



Φwire = 0.85 mm
37 MgB_2 filaments
Twisted filaments (LT=100 mm)
Φeq_MgB_2 = 56 μm
ACu ~ 5 % Awire (th=30 μm)
Cu plating
Sn coating of Cu surface

Wires produced at Columbus Superconductors

MgB_2 wire

- Following Market Survey, launched in September 2014 procurement of **150 km** of **MgB_2 round wire** (previous material was produced via R&D contracts)

Diameter of MgB_2 wire, Φ	$0.8 \text{ mm} \leq \Phi < 1 \text{ mm}$
Diameter of superconducting filaments	$\leq 60\ \mu m$
Filaments twist pitch	≤ 100 mm
Filaments twist direction	Right-handed screw
Critical current at 25 K and 0.9 T	≥ 186 A
Critical current at 25 K and 0.5 T	≥ 320 A
Critical current at 20 K and 0.5 T	≥ 480 A
Bending radius (after final heat treatment)*	≤ 100 mm
Tensile strain at room temperature*	$\geq 0.28\%$
Copper fraction of the wire total cross section	$\geq 12\%$
RRR of copper stabilizer	> 100
*n-value*** @ 25 K and 0.9 T	> 20

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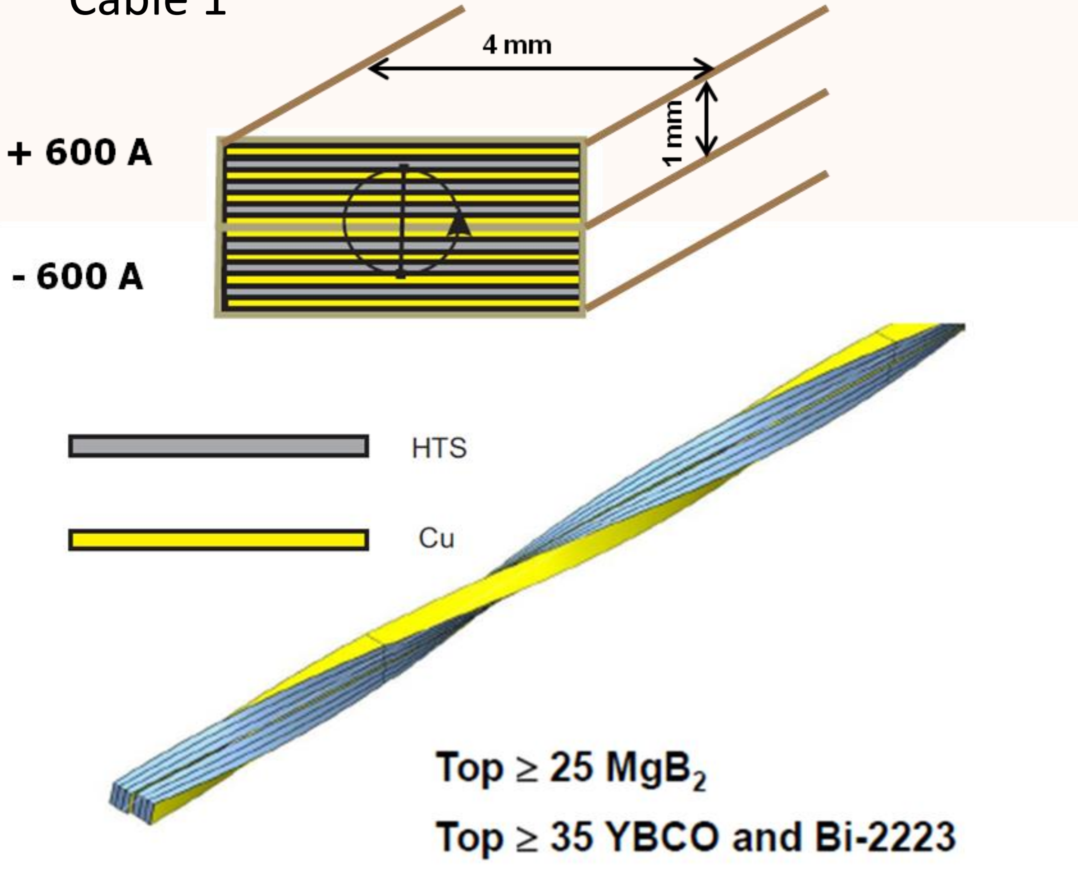
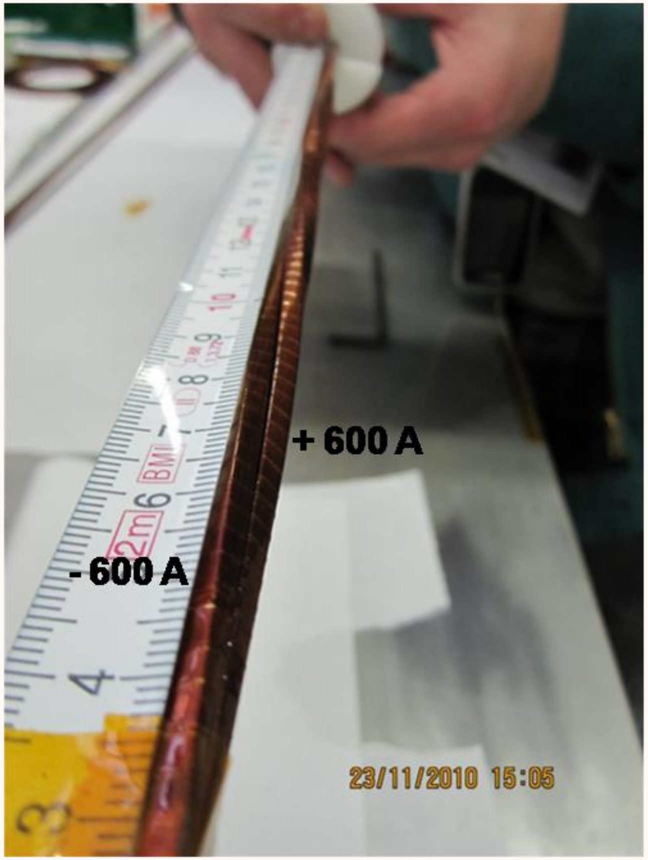
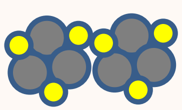
Cable-Twisted Pairs

Cable 1





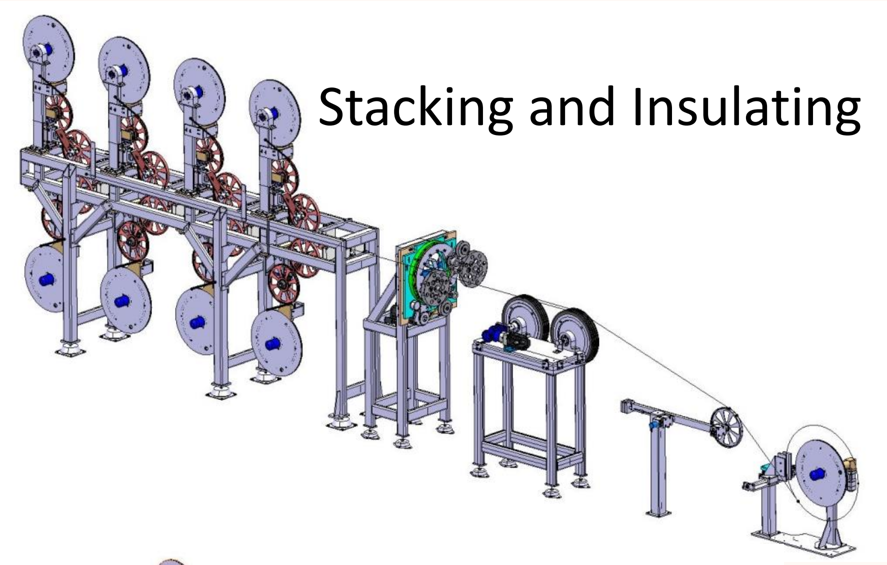
Cable 2



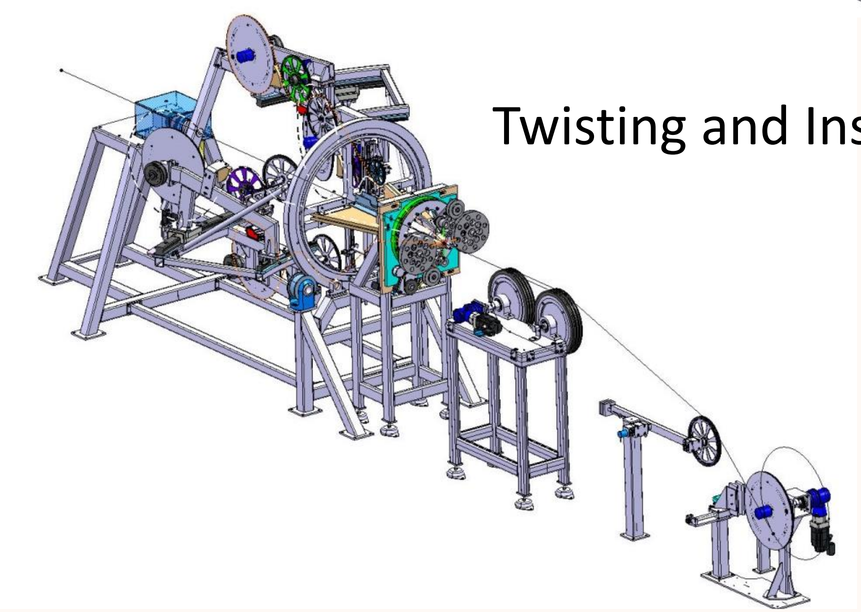
On both types of cables :
Measured **Ic > 600 A** per cable at **30 K**
CERN Test Station in SM-18
Cable length = 20 m

Cabling machines

Developed at CERN

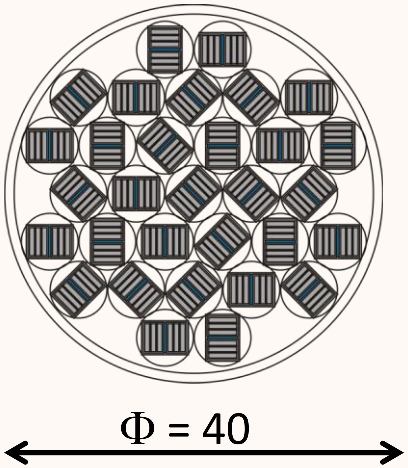


Stacking and Insulating

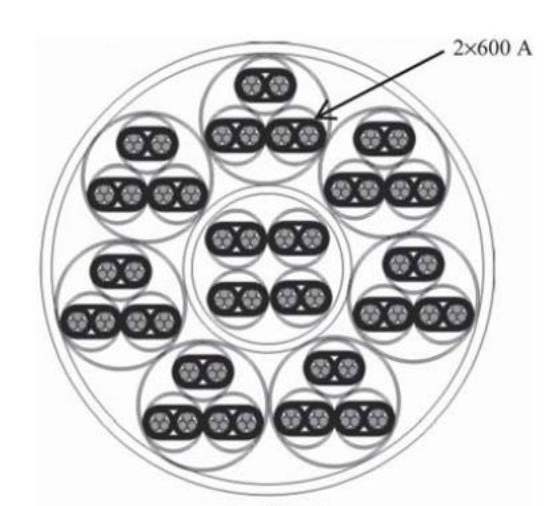


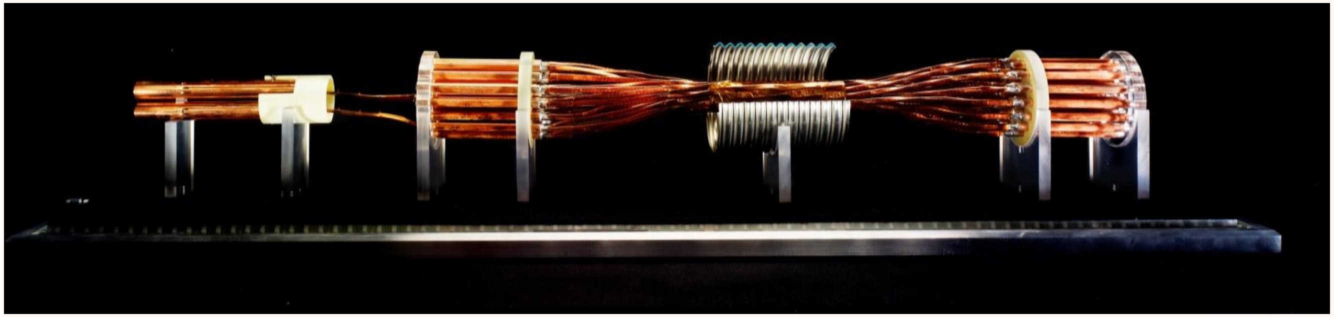
Twisting and Insulating

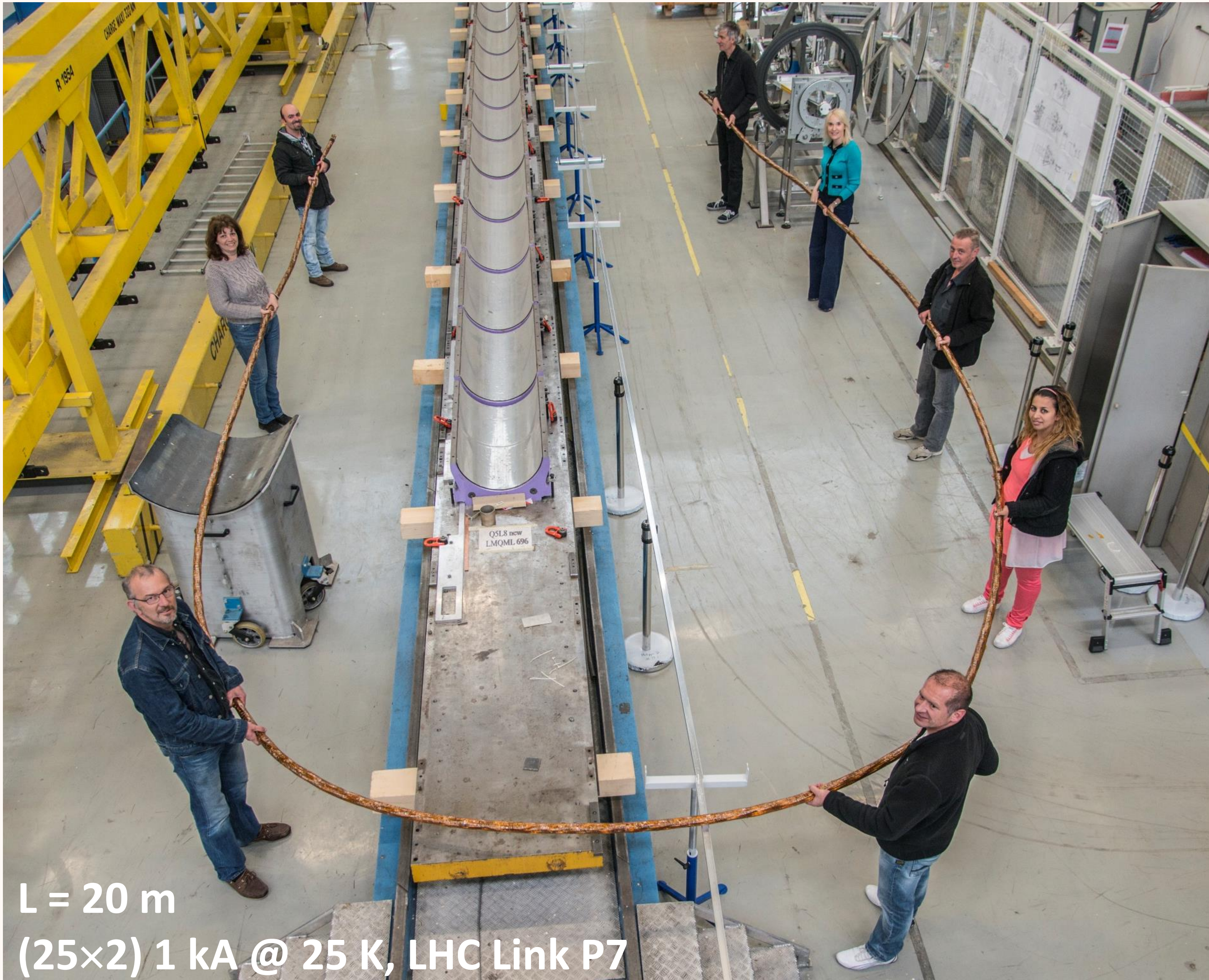
Multi-Cable Assembly



30 kA
~2 kg/m






Q5L8 new
LMQML 696
L = 20 m
(25×2) 1 kA @ 25 K, LHC Link P7

Status of System Development (LHC P7)

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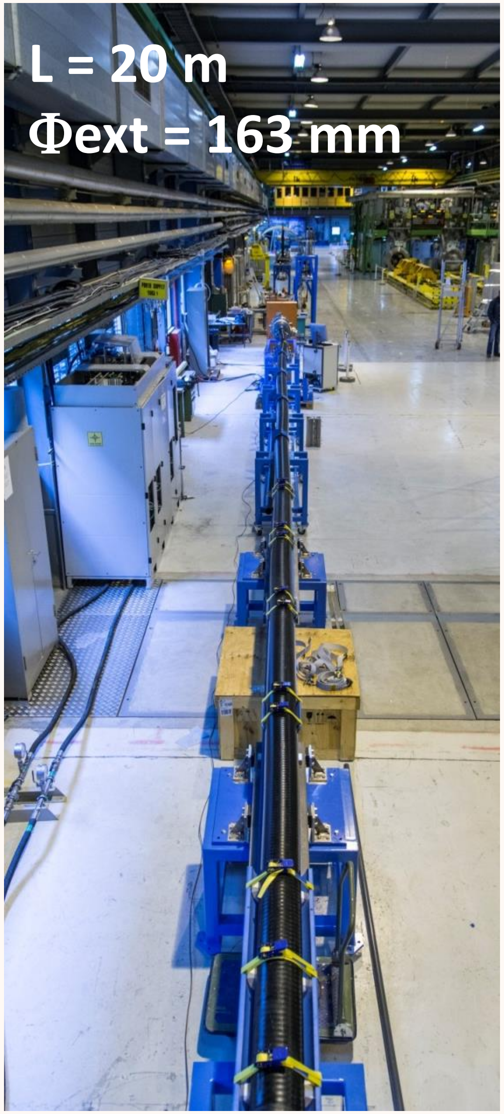
Cryostat for SC Link

Nexans Semi-Flexible Cryostat (L=20 m)

Test Station at CERN



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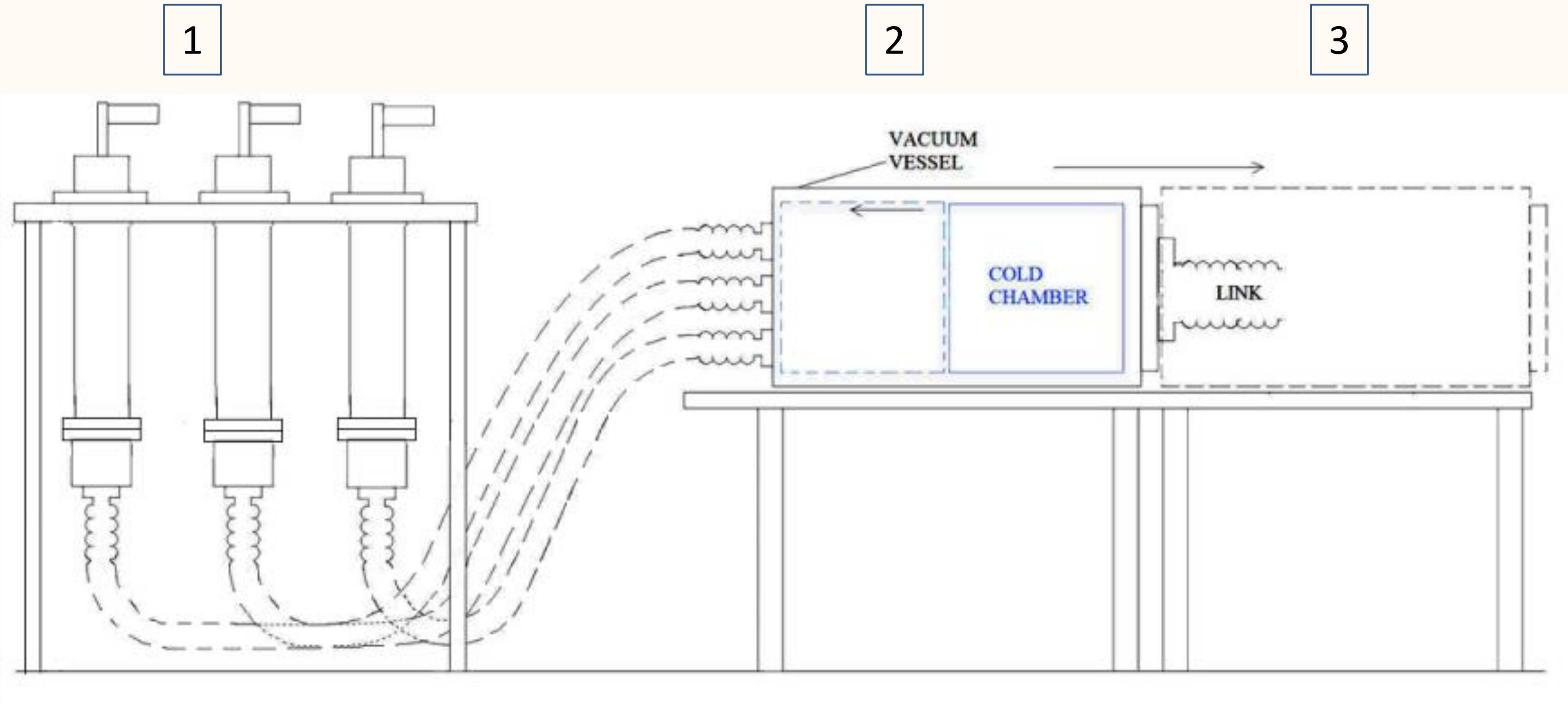
- **New DFBs and Current Leads**

Cold Powering System

Needs for transport in the tunnel has driven the concept of the system



New concept: no DFB cryostat

Conceptual design at
University of Southampton, Task 3 of WP 6

Connection Cryostats

- Minimise work in the tunnel
  - Assemble and test before LS2 starts
  - Aim for installation within short time slot (radiation cooldown time may be long..)
- Remove HCM only and replace with DFA
  - Keep 2x13 kA leads in current position
  - Keep cryo jumper in current position
  - Vertical link connection
  - Keep existing support beam and shuffling module
- Remove DFBMH and link Q6 to DFA
  - Possibly with no changes to Q6 QQS and jumper
  - Link routed above QRL

Delio Ramos, WP 6 Meeting, 5/03/2014

Future Milestones

- Test of **SC Link**, 20 m long, containing the full assembly of 50 cables

  December 2014

- Construction and Test of **Cold Powering System** (new DFB with a set of current leads and 20 m long SC Link)

  December 2015

  Collaboration Agreement with Univ. of Southampton

- Procurement of **60 m long SC Link cryostat**

  Nov.2014-April 2015

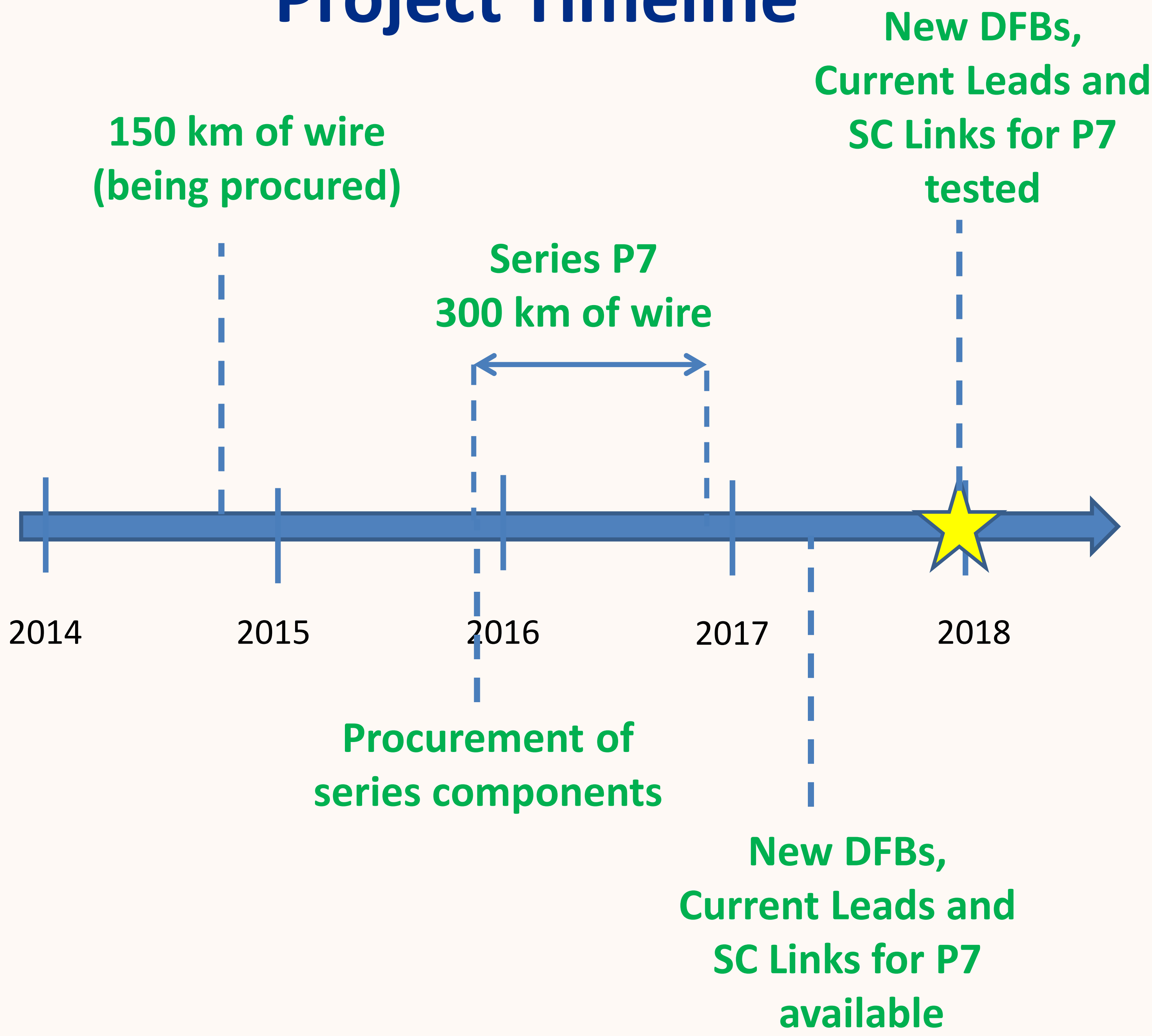
- **Integration test at CERN** using 60 m long SC Link cryostat (decision on need for civil engineering)

  May-June 2015

- Test of **Cold Powering System** (new DFB with, full set of current leads and 60 m long SC Link)

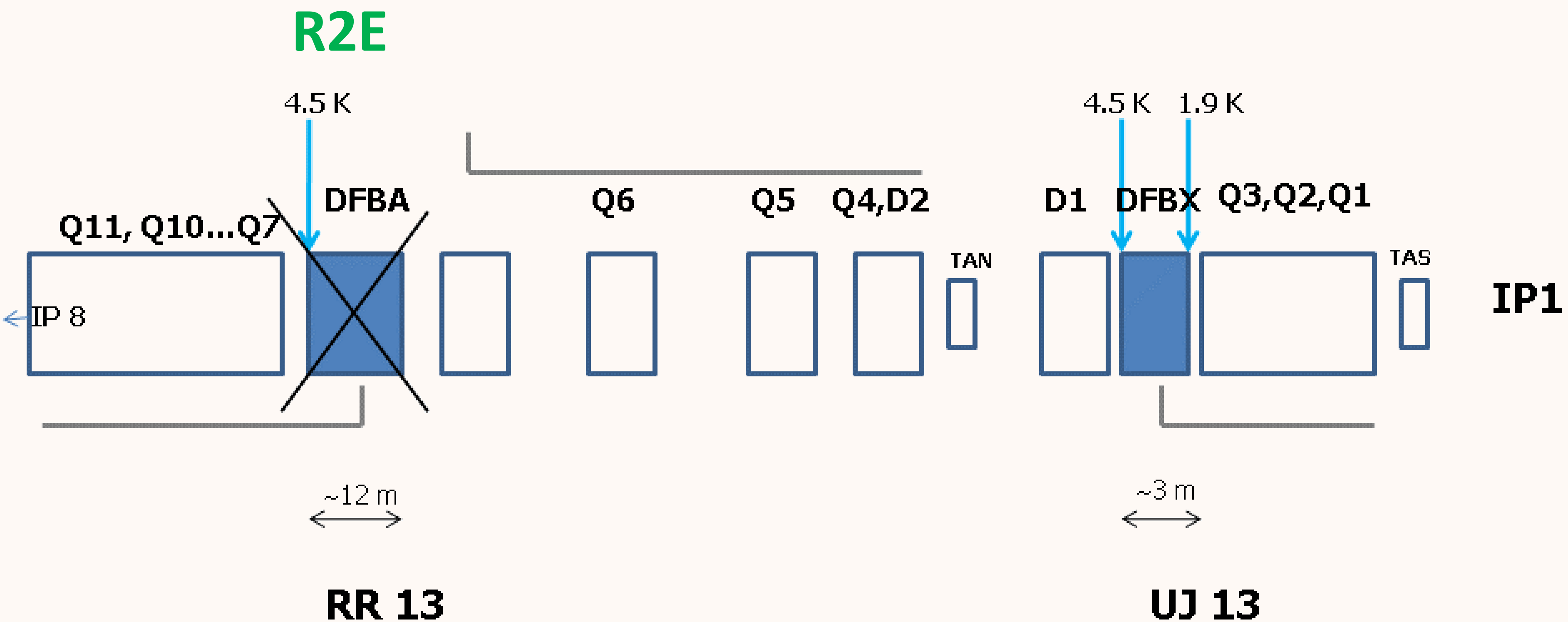
  November 2016

Project Timeline



A. Ballarino, 18/11/2014

Superconducting Links for LHC P1 and P5



Superconducting Links for LHC P1 and P5

Number of leads	**Current rating**	**Circuit**
DFBAA (P1L)/DFBAI (P5L)		
2	13000	EE
12	**6000**	RQ7,RQ8, RQ9, RQ12
28	**600**	ROF,ROD,RSSRQT13, RQTL11 RQT12,RQS

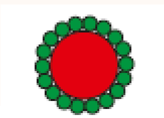
High-Current Cables –Synergy with the work done on the the SC Links needed for re-locating the DFBL and DFBX at P1 and P5 (Hi-Luminosity Upgrade)

High-Current Rating, LHC P1 and P5

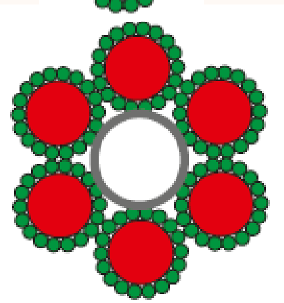
Hi-Lumi Triplets and D1

Cu

MgB_2 , Φ = 0.85 mm



18 MgB_2 wires
Φ = 6.5 mm

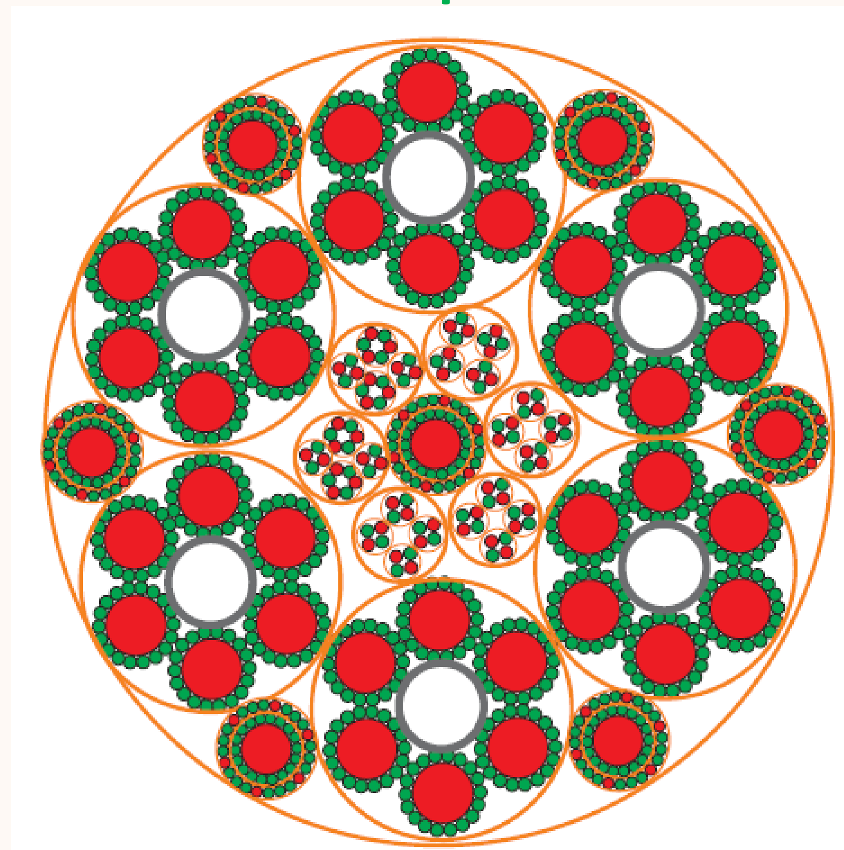


20 kA
Six cables, Φ = 19.5 mm

Concentric ± 3 kA
Seven cables, Φ = 8.4 mm

0.4 kA
Four cables

0.12 kA
Eighteen cables

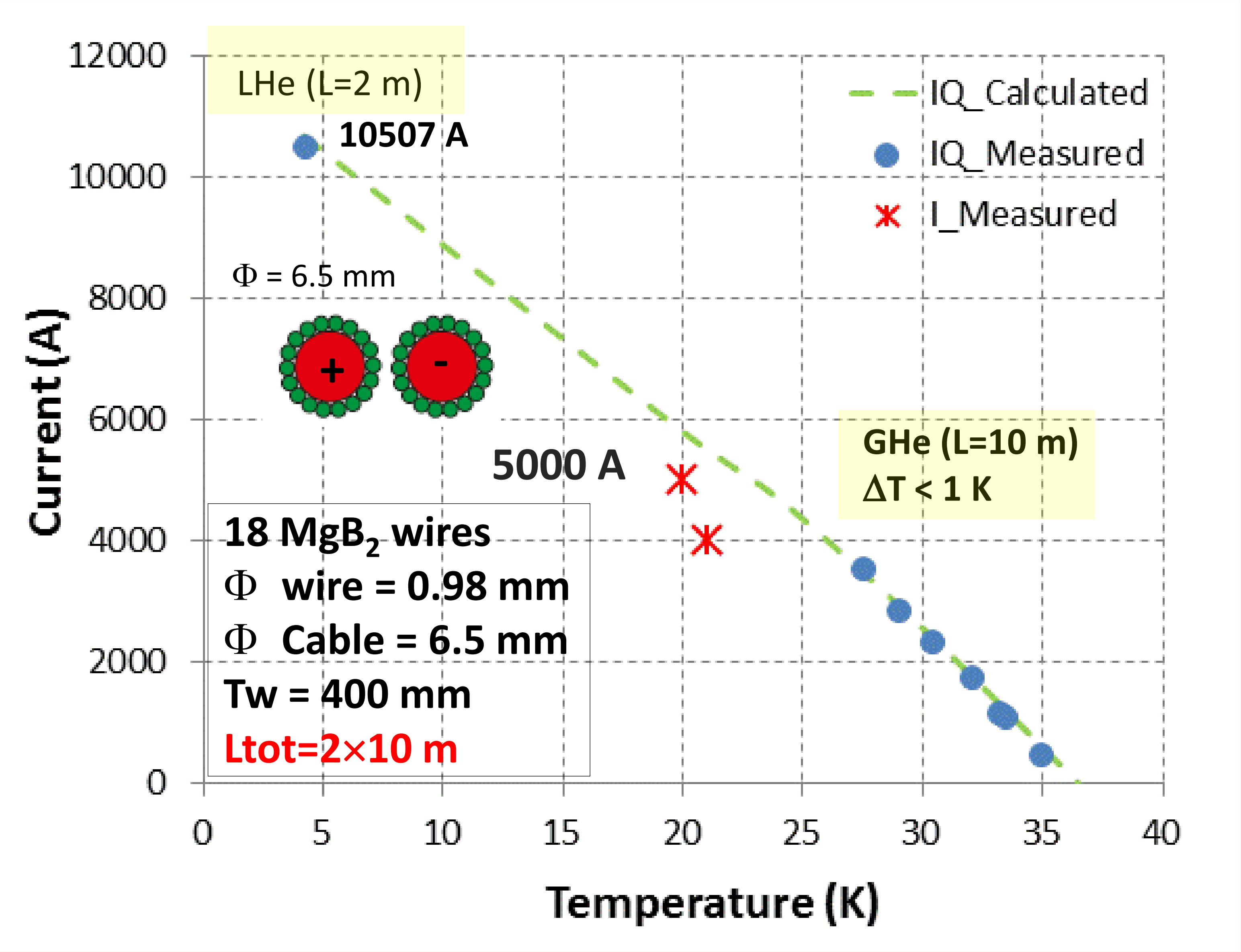


Φext ~ 65 mm

Mass ~ 11 kg/m
(880 kg for ΔH=80 m)

A. Ballarino, 18/11/2014

MgB_2 Cables developed and tested at CERN



A. Ballarino, 18/11/2014

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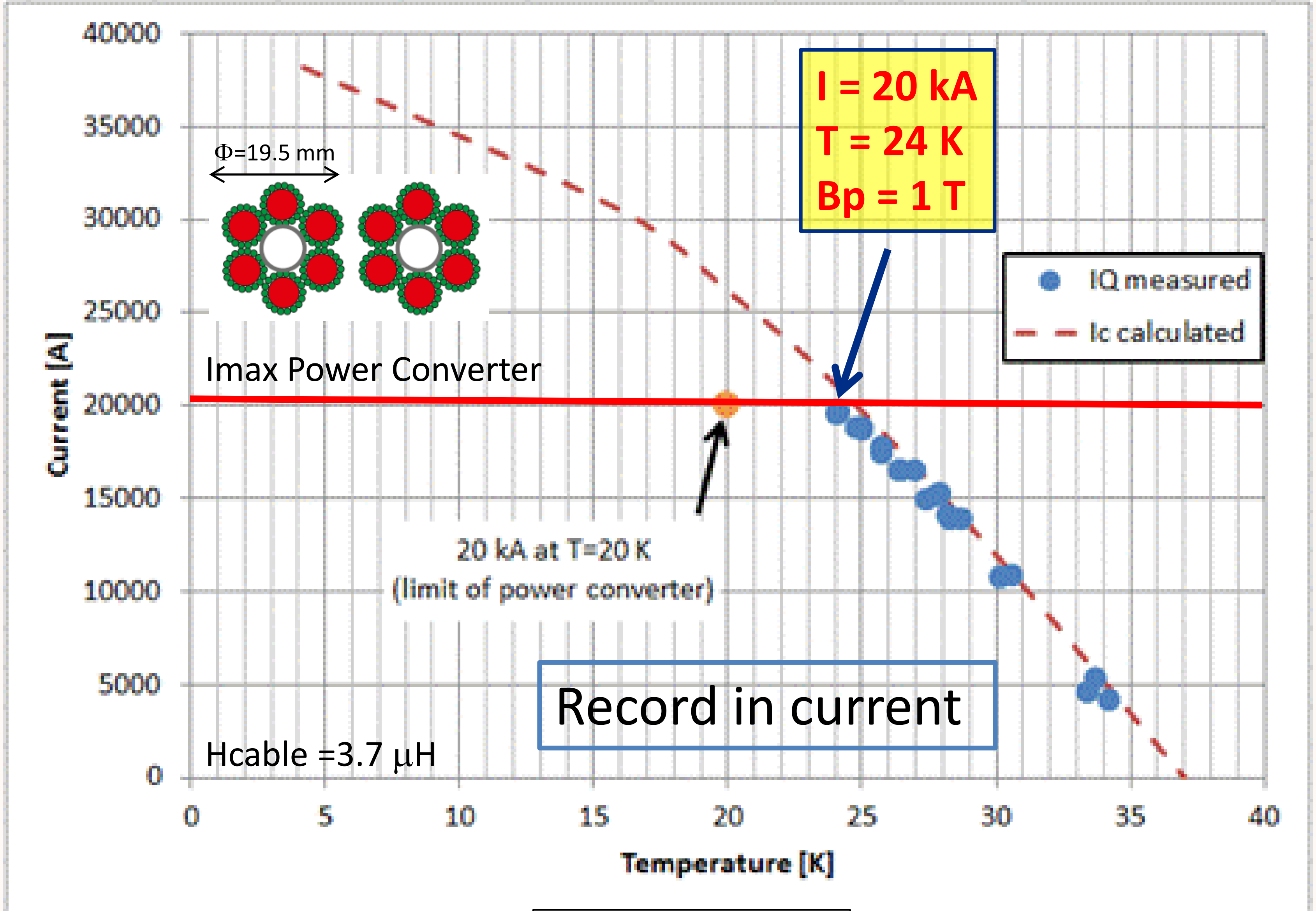
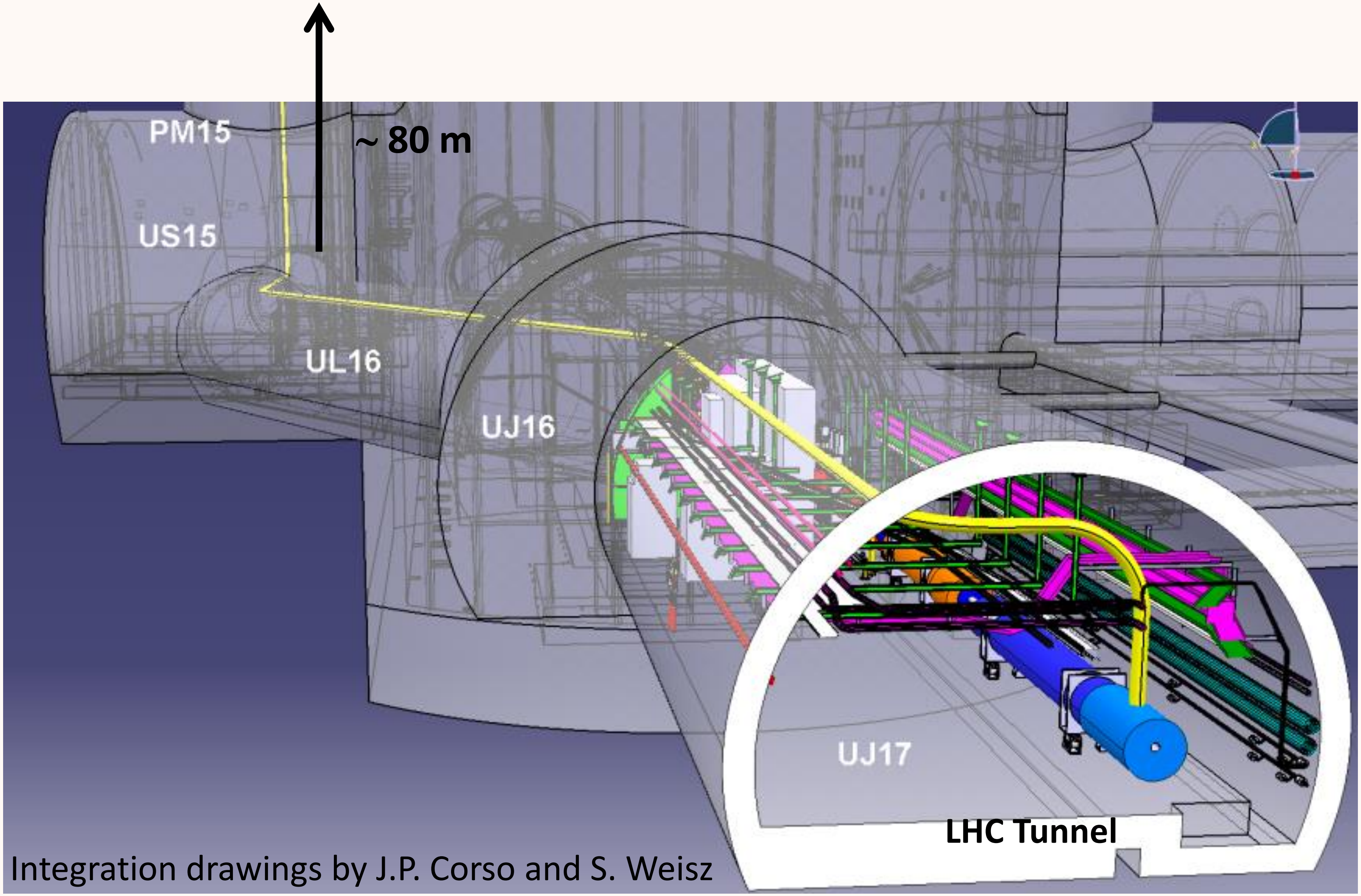


ΔT along line < 1 T

Superconducting Links for LHC P1



Superconducting Links for LHC P1 and P5

- Present baseline: SC Links from the tunnel to the surface

BUT

- On-going studies on need for civil engineering for Hi-Luminosity equipment may offer the possibility of using new underground caverns for housing the new DFBs

Conclusions

- Development of SC Links for **LHC P7** is well advanced. A decision on the integration of the system in LHC in 2018 is going to be taken before end 2014. A prototype Cold Powering System will be built and tested at CERN by end 2015

- The work on the SC links at **P1 and P5** for **R2E** is in synergy with the development done **for Hi-Luminosity LHC** (SC Links replacing the DFBX and the DFBL). SC Links for Hi-Luminosity LHC will be installed in the LHC tunnel during LS3