5th Joint Hi-Lumi LHC-LARP Annual Meeting 2015

Cold Powering New Baseline

A. Ballarino

27/10/2015

High Luminosity LHC

LARP

Contributions from:

Powering baseline: Mr Circuit (F. M. Rodriguez) and J. P Burnet (WP 6a);

WP6 contributors:
Y. Yang and the team at SOTON;
F. Broggi from INFN-Milano;
S. Giannelli, A. Jacquemod; J. Hurte, R. Betemps, B. Bordini
S. Weisz, G. Montenero (CERN)

Integration studies:
P. Fessia and S. Maridor (CERN)

- **New Powering baseline**

- **Cold Powering System**

  Integration baseline
  Superconductor and Superconducting cables
  Thermal stability and quench propagation studies
  System design
  BestPaths project
  Conclusions

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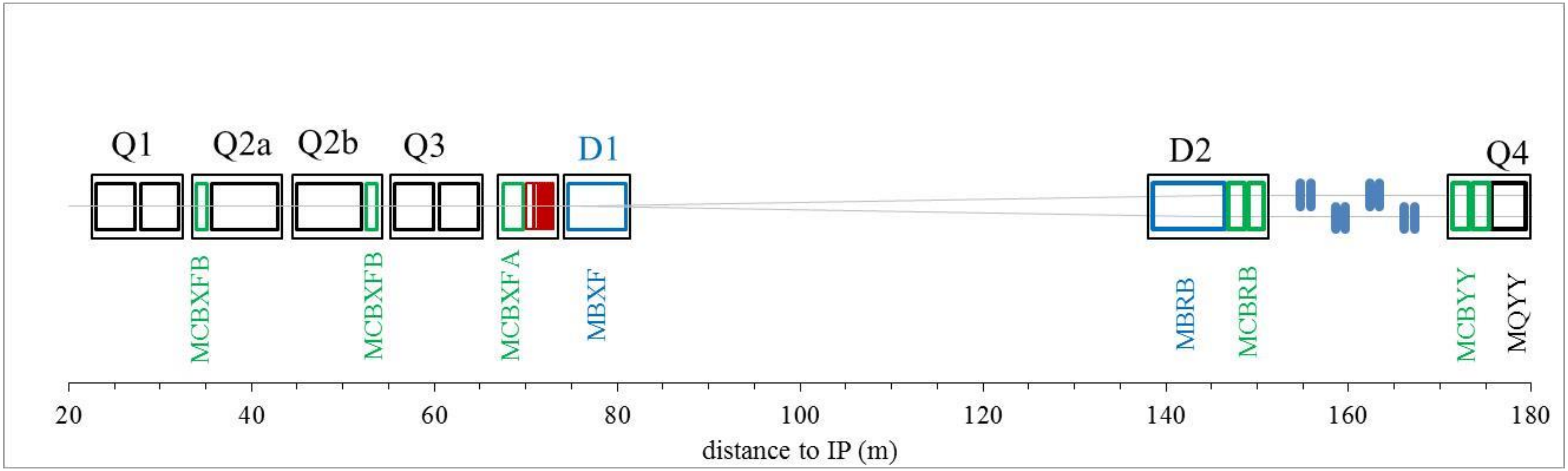
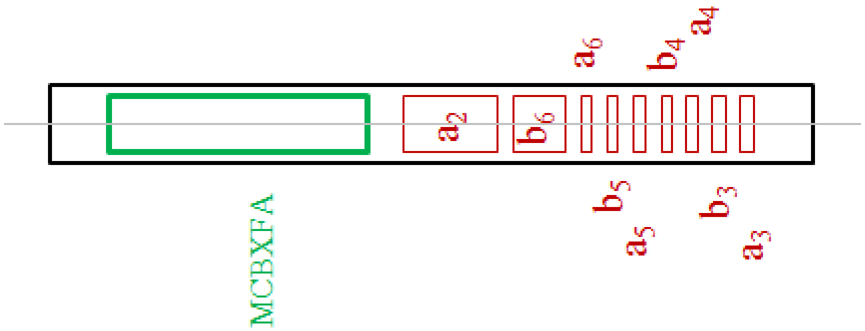
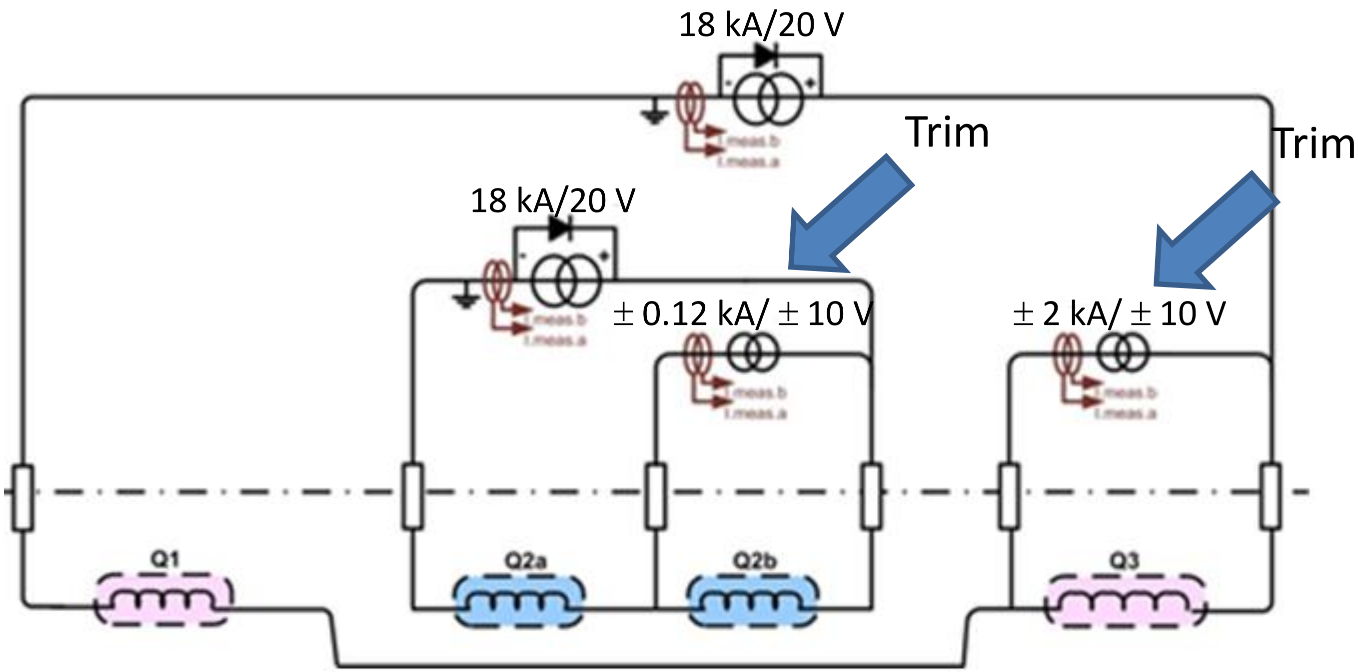
Hi-Lumi Triplets and Matching Section





+ Q5 and Q6

Baseline Powering Layout: MQXF quadrupoles



All other circuits are individually powered

EE still in the present baseline - but convergence on no use of EE
Ramp down time with no EE (~ 1500 s) being optimized by power converters regulation (J. P. Burnet): current control + voltage control

Power Converters for Hi Lumi

Power converter	Current	Voltage	Quantity per IP side	Quantity per UR	Total Quantity
Type 1	18kA	20V	2	4	8
Type 2	13kA	18V	2	4	8
Type 3	6kA	8V	6	12	24
Type 4	±2kA	±10V	7	14	28
Type 5	±600A	±10V	8	16	32
Type 6	±200A	±10V	9	18	36
Type 7	±120A	±10V	9	18	36
Total			43	86	172

J. P. Burnet, updated in Oct 2015

7 Types

172 PCs per IP

Itot (per IP)= 478 kA

Power Converters for Hi Lumi

Power converter	Current	
Type 1	18kA	Q1/Q3 – Q2a/Q2b
Type 2	13kA	D2, D1
Type 3	6kA	Q4, Q5, Q6
Type 4	±2kA	Orbit correctors Q3 and Q2, Trim on Q3
Type 5	±600A	Orbit correctors D2 and Q4 (2×MCBRD, 2×MCBYY)
Type 6	±200A	CP, Trim Q2
Type 7	±120A	Correctors Q5 , Trim on Q2b

Changes in baseline under study:

- powering of **all MQXF quadrupoles in series**
  → One main circuit plus two trims
- powering of **D2 in series with D1**

Recent changes in magnets/circuits current

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

> - DC Current reduced of ~ **70 kA per IP**
> - Cost reduction of powering system – mainly on power converters

- New Powering baseline
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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

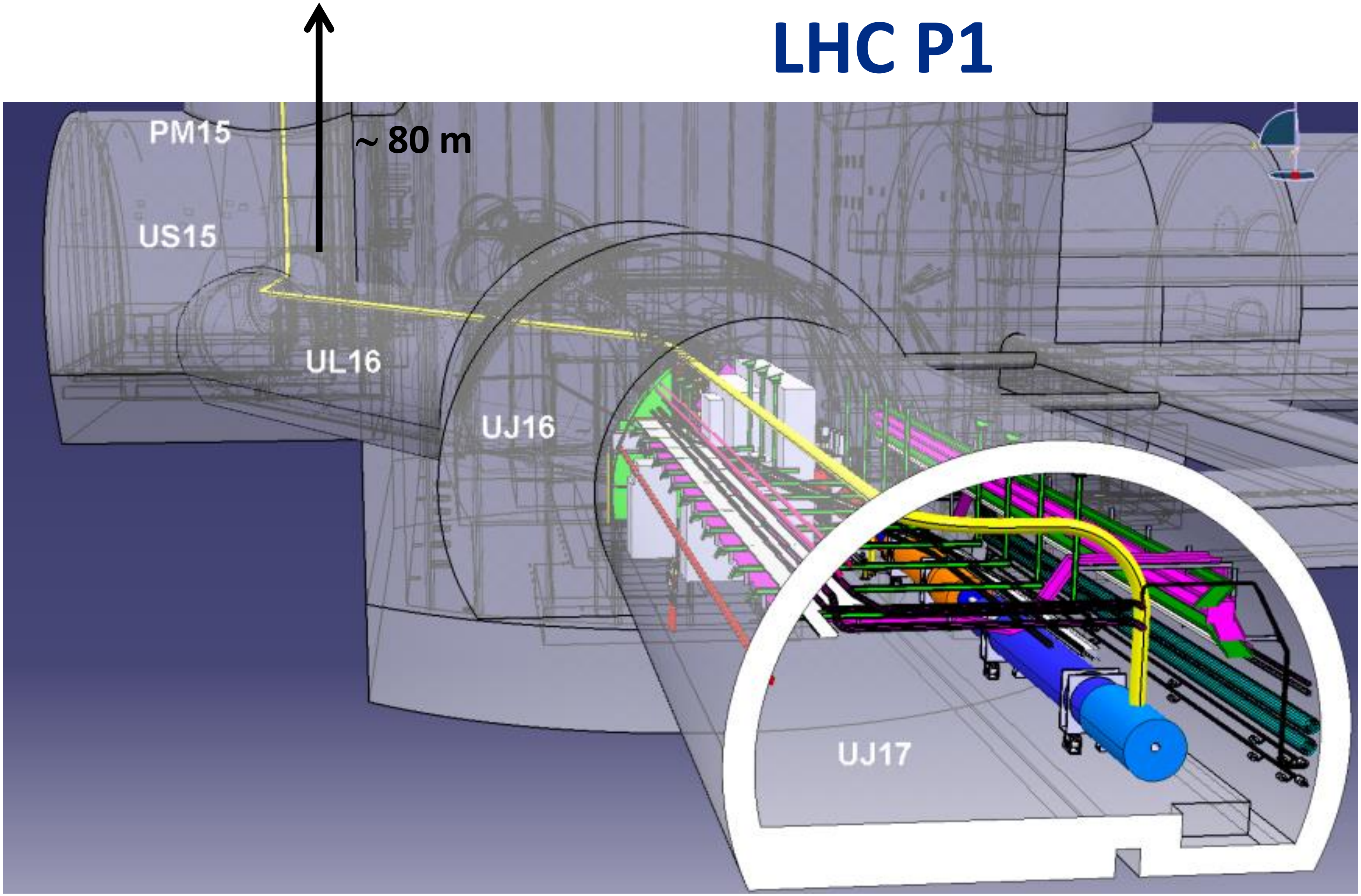
Type	N_IPside
18 kA	6
13 kA	4
6 kA	12
2 kA	13
0.6 kA	16
0.2 kA	18
0.12 kA	19

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

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

Integration baseline till mid 2015

LHC P1

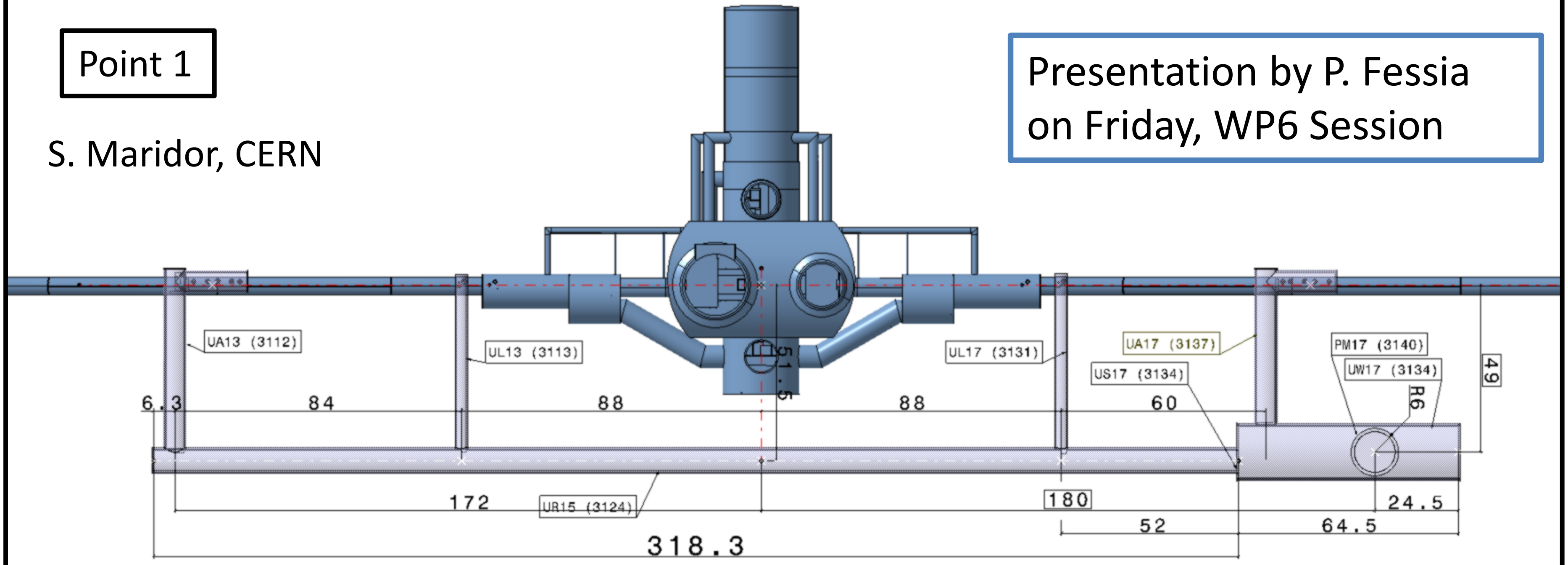


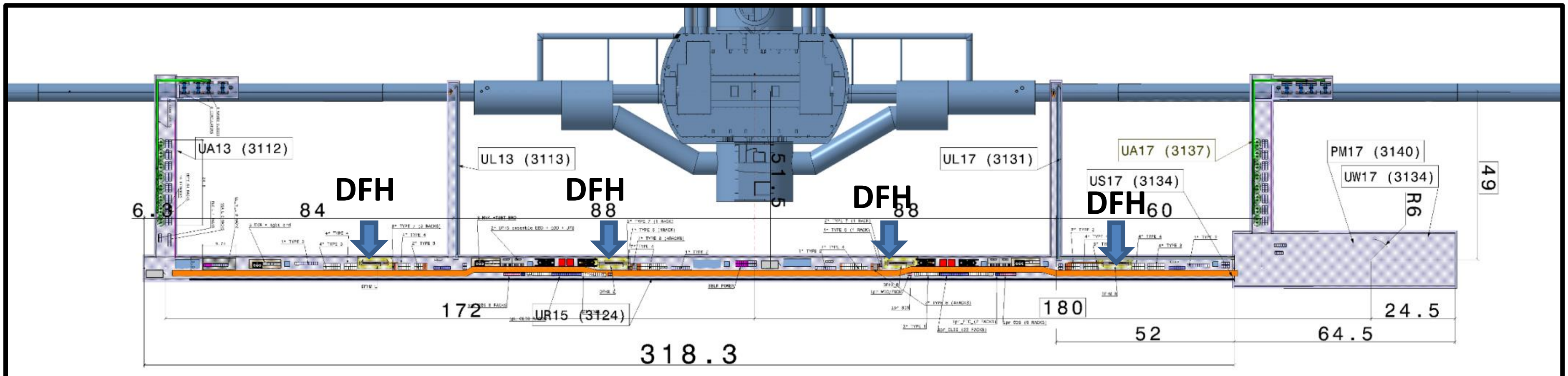
Integration: new baseline

Point 1

S. Maridor, CERN

Presentation by P. Fessia on Friday, WP6 Session





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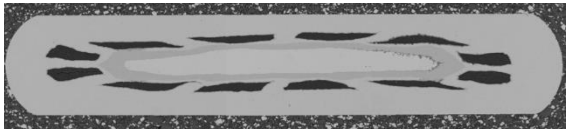
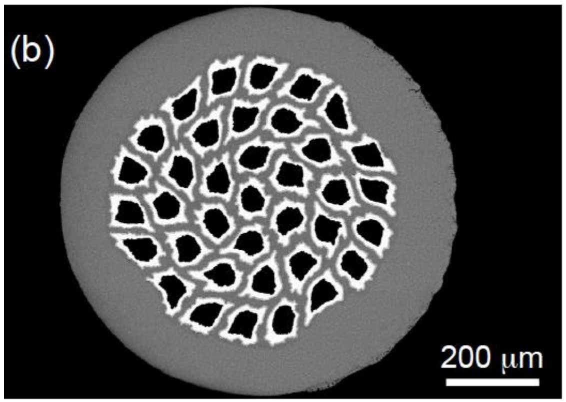
Superconducting Material

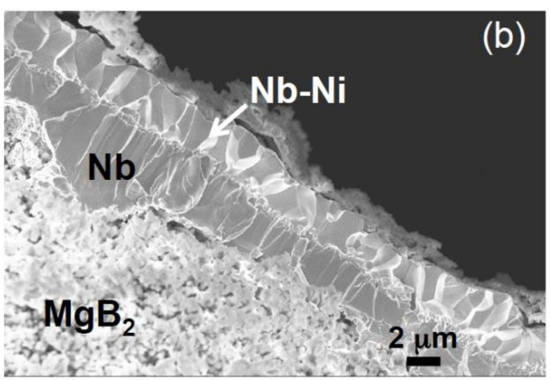
3.6×0.67 mm^2



Product commercial at Columbus when the project started: MgB_2 tape

Launched development of MgB_2 round wire





Use of Nb barrier

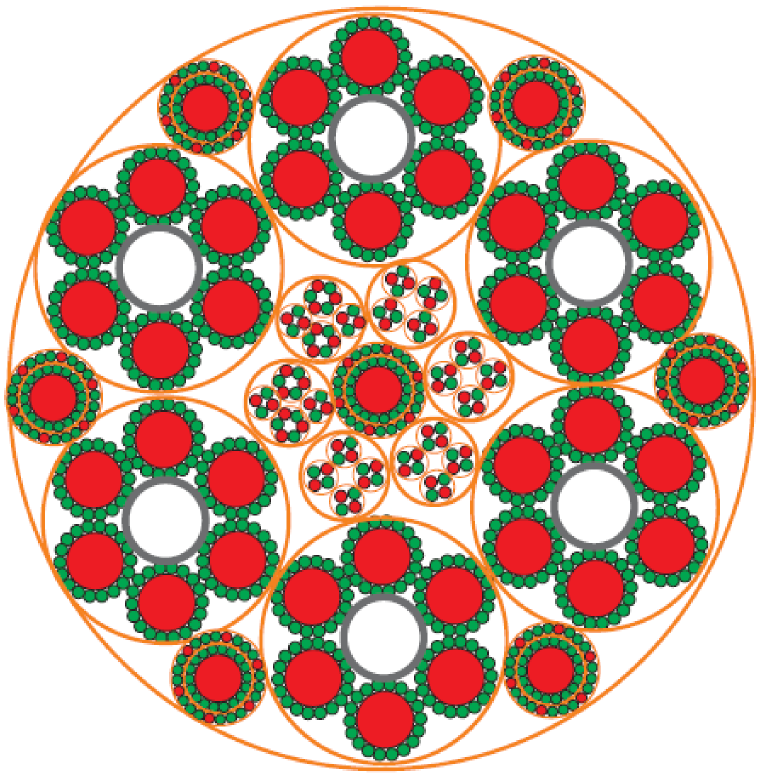
- Φwire = 1 mm
- 37 MgB_2 filaments
- Twisted filaments (LT=100 mm)
- Φeq_MgB_2 = 56 μm
- ACu ~ 5 % Awire (th=30 μm)
- Cu plating
- Sn coating of Cu surface

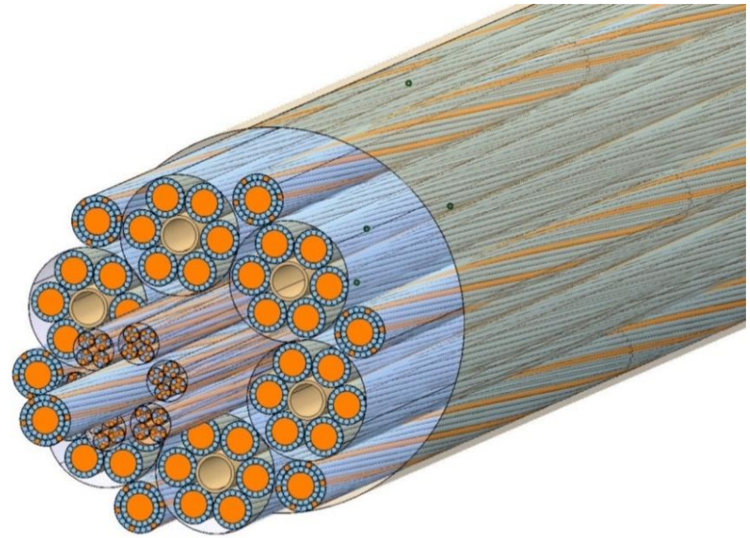
Ic(25 K, 0.9 T) > 186 A

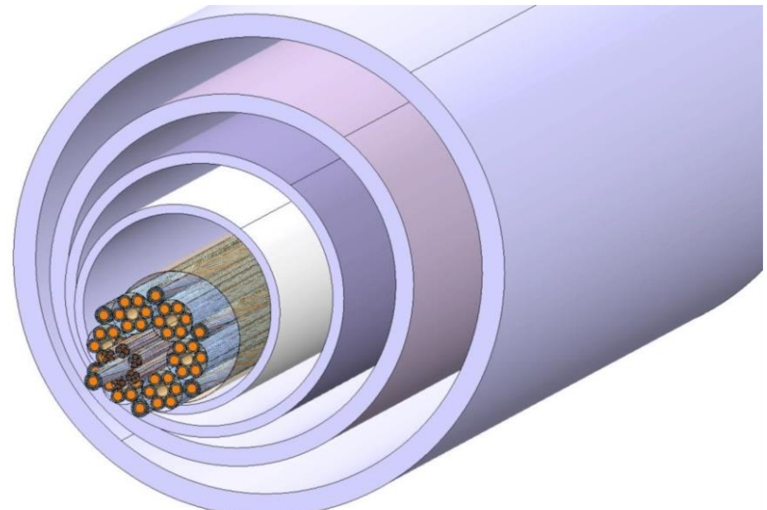
Launched procurement of 80 km of wire
Unit lengths ≥ 500 m
20 km at CERN
60 km delivered before end 2015

Superconducting Cable Assembly

Hi-Lumi Triplets and D1







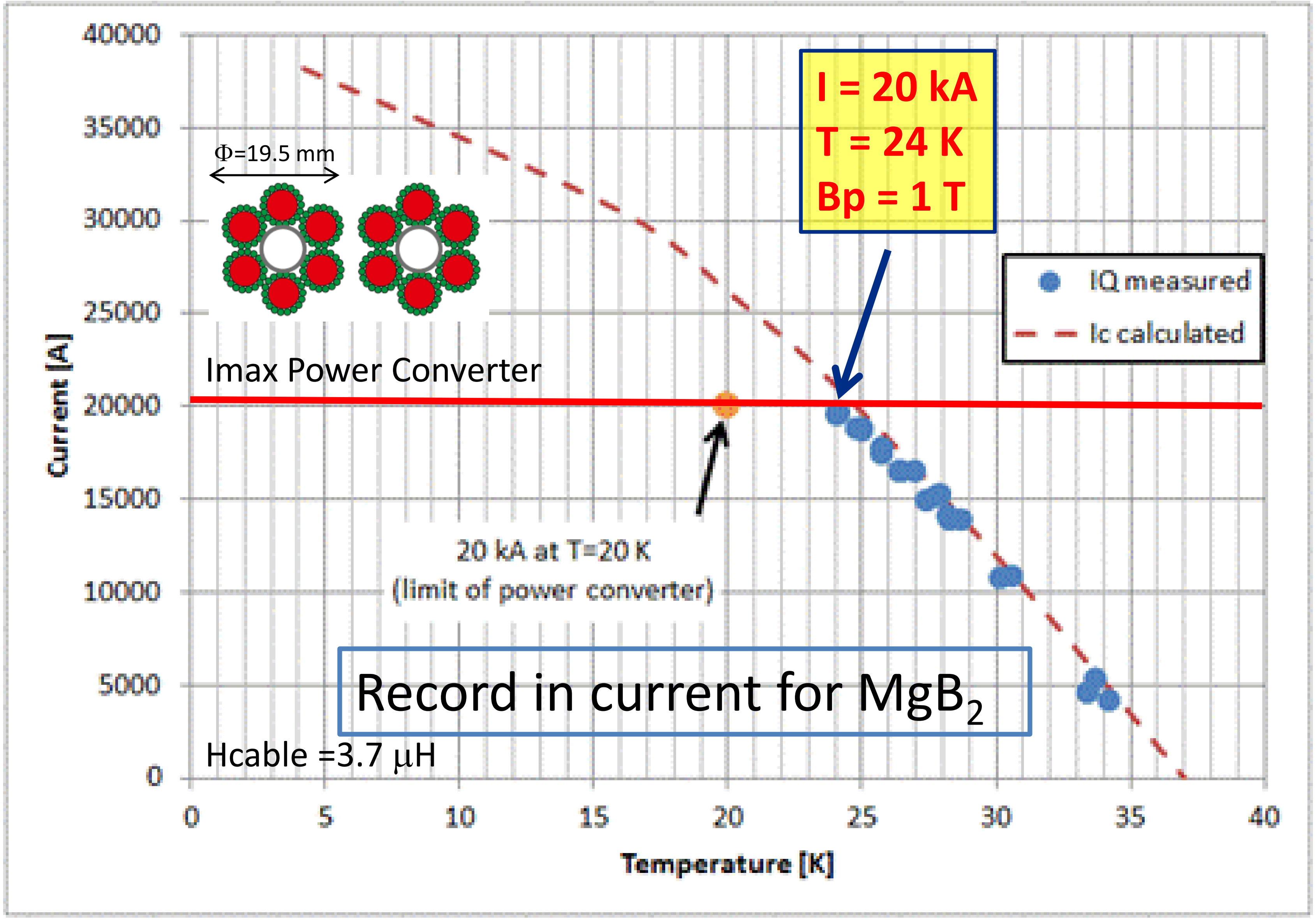
Φext ~ 65 mm

Mass ~ 11 kg/m

(880 kg for ΔH=80 m)

Φext ~ 220 mm

High Current Cable



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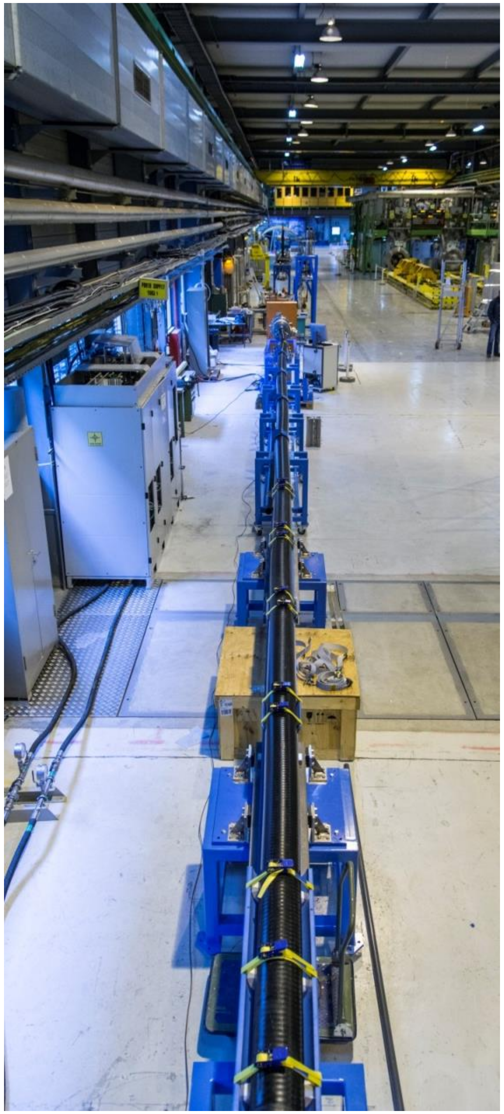
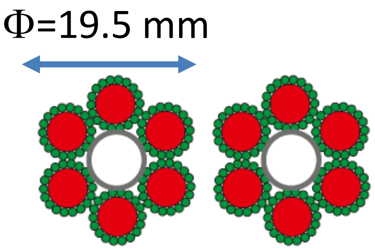
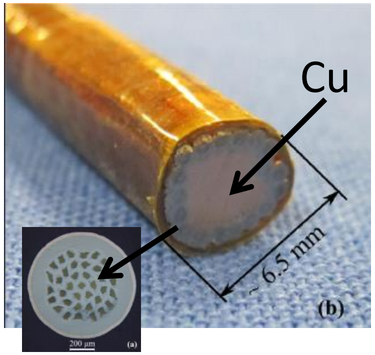
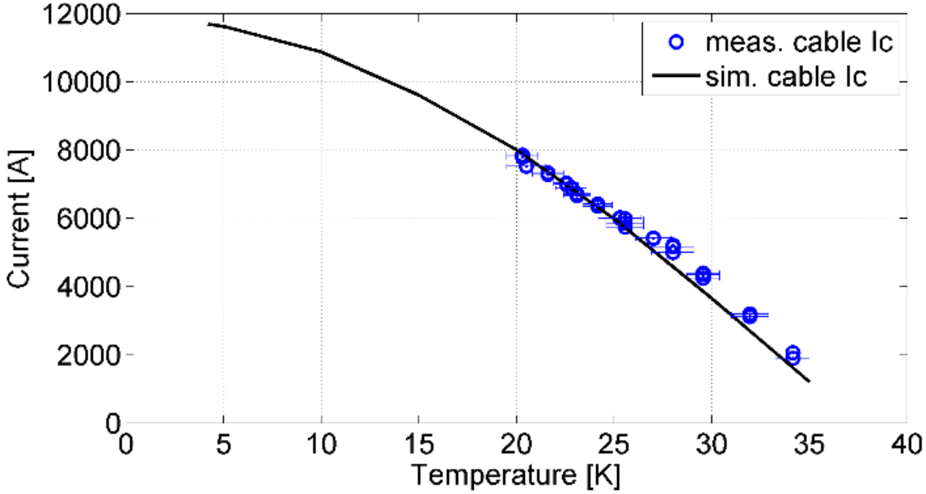
Recent results: quench studies





20 kA at 24 K @CERN
40 m long cable

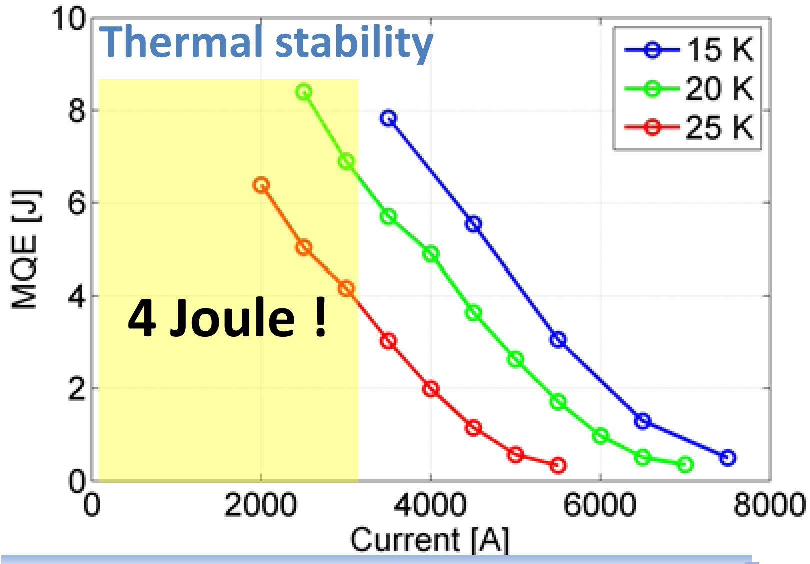


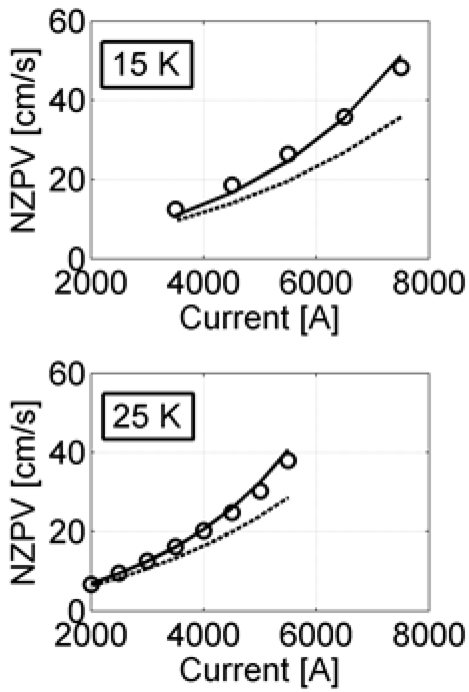


Quench propagation in helium gas cooled MgB_2 cable, S. Giannelli, G. Montenero, A. Ballarino – EUCAS 2014

Recent results: quench studies

Measurements @ CERN



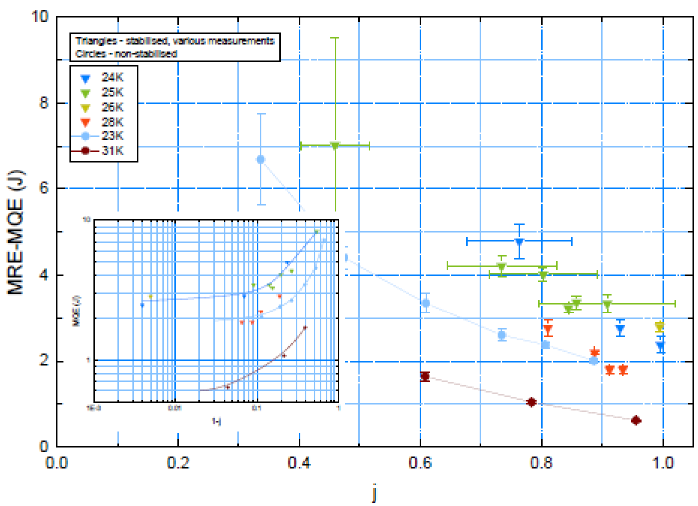


Quench propagation in He gas

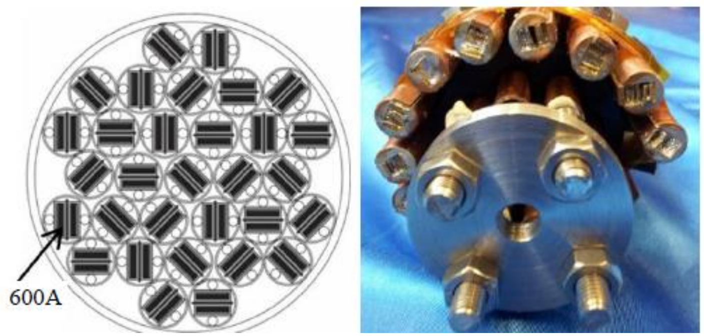
o measured data
.... adiabatic model
____ adiabatic model with contact resistance

At **3 kA** NPVZ = **7.3-12.6 cm/s** for T = **5K -25** K

Measurements @ SOTON



J = Normalized Current Density



Quench property of twisted-pair MgB_2 superconducting cables in helium gas

J. Spurrell, E.A. Young, I. Falorio, J. Pelegrin, A. Ballarino*, and Y. Yang
University of Southampton, United Kingdom, *Technology Department, CERN, Switzerland

Twisted-Pair MgB_2 Cables Study for LHC P7

Recent results: quench propagation in He gas

University of Southampton

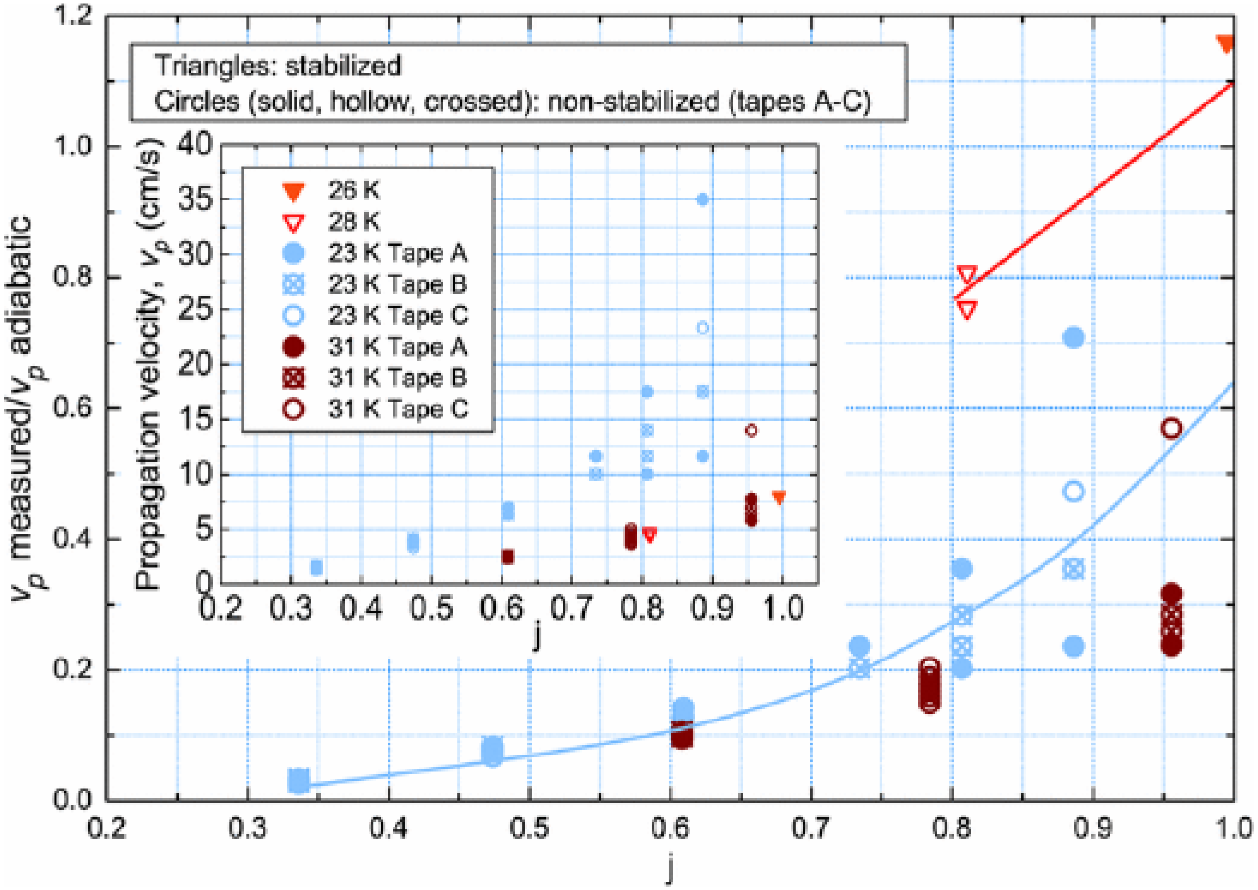
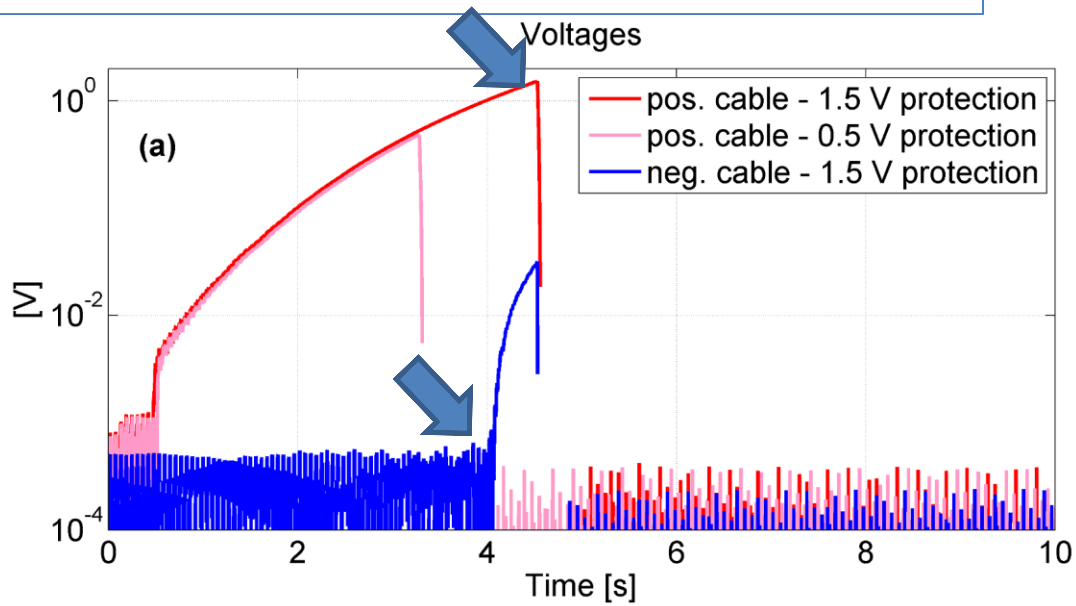


Fig. 1: Quench propagation velocity of MgB_2 twisted-pair cables as a function of current load factor $j=I/I_c$.

- Little effect of He gas on quench propagation
- Propagation velocity according to adiabatic model
- Effect of current sharing contact resistance

Recent results: protection of multi-circuit superconducting system

Effect of radial quench propagation among cables



- Max hot-spot temperature reached T_{hs}~340 K with no degradation of cable performance
- 25 K, **3 kA**, **100 mV detection threshold** → 15 MIITS of "quench capital" before detection → final T_{max} ~ 150 K with **3 s time constant of the circuit**

Recent results: modelling of thermal stability

Effect of current margin, increased stabilization and enhanced cooling

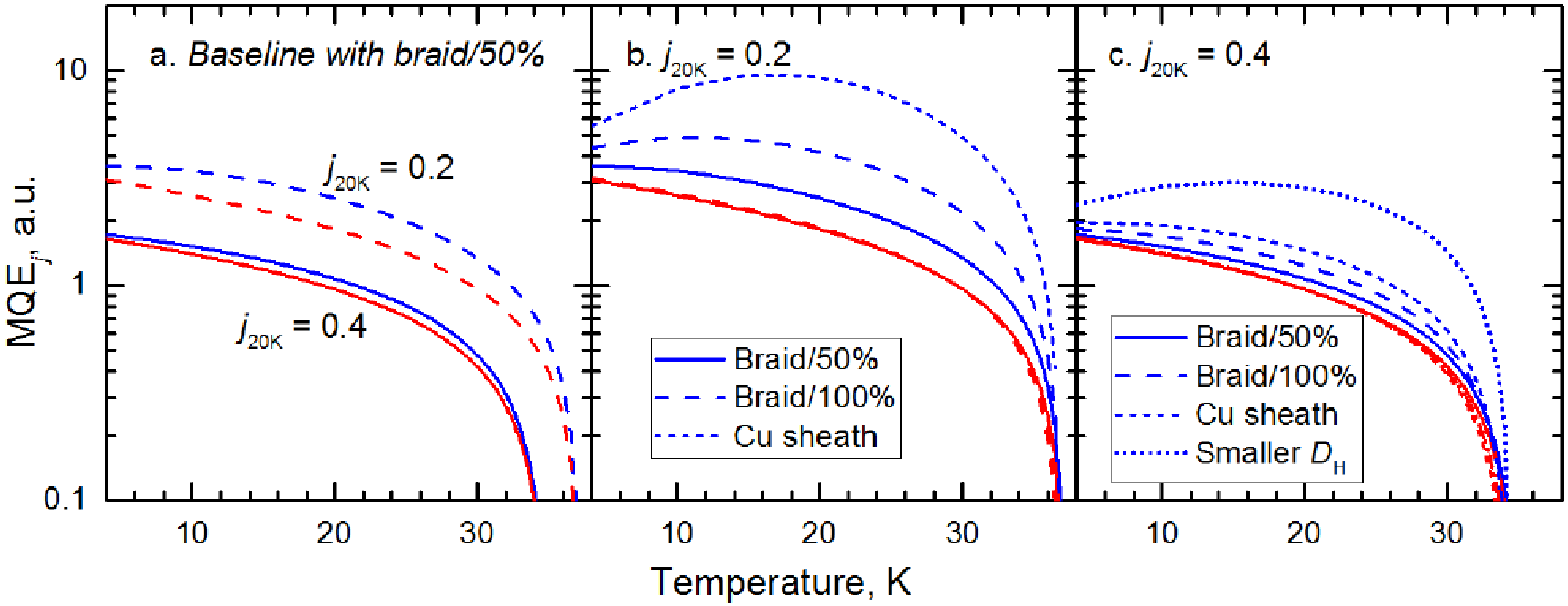


Fig. 8, MQE enhancement (blue lines) by lateral cooling for 5kA reference cable due to effect on the current scaling (MQE_J as in the parentheses of (30)) for (a) the baseline cable configuration and cooling, (b-c)by enhanced stabilisation at j(20K) = 0.2 and 0.4 respectively, and the dotted line in (c) for enhanced cooling with a reduced D_H=3mm. The adiabatic counterparts are shown in red lines for comparison.

Univ. of Southampton

Presentation by y. Yang on Friday, WP6 Session

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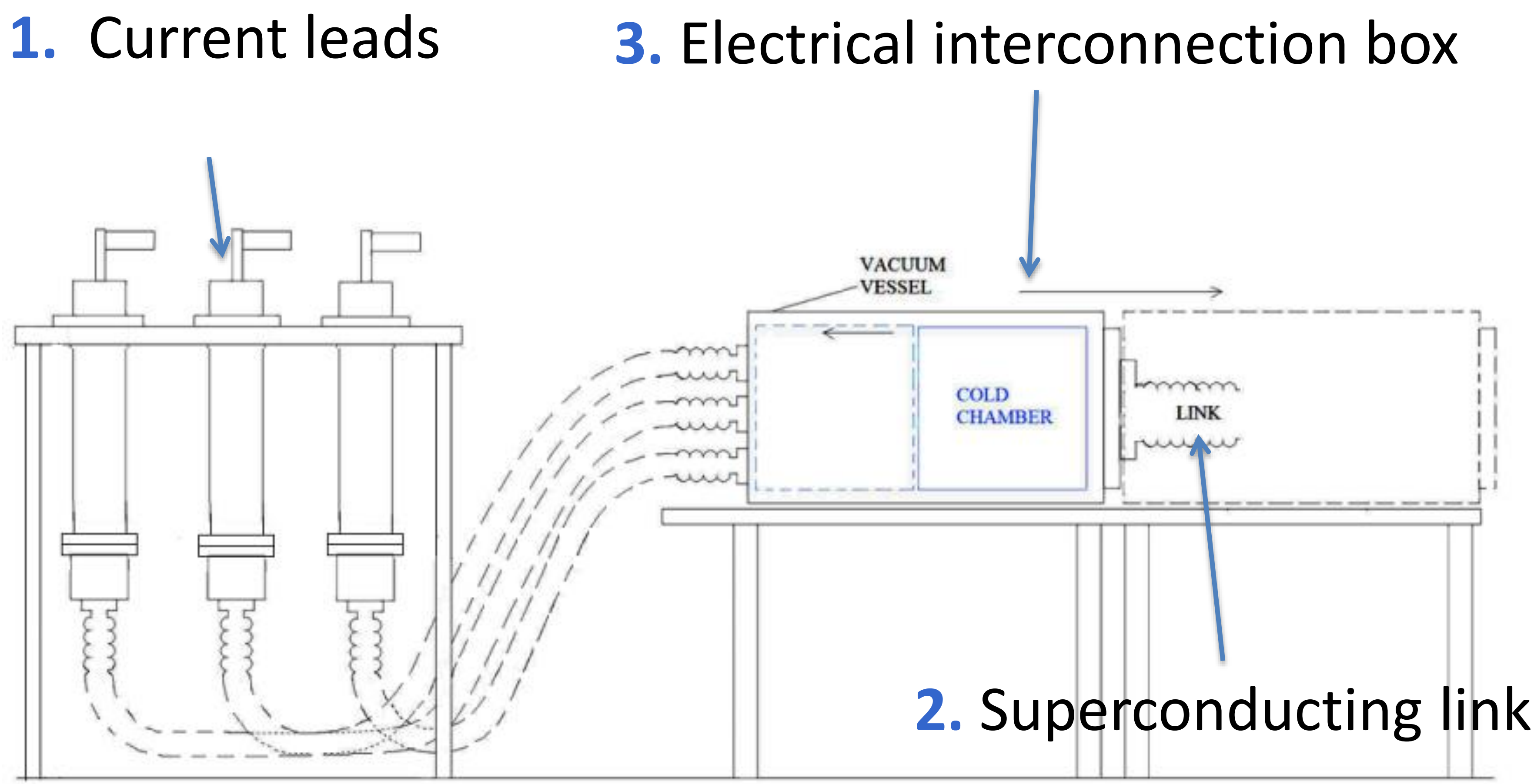
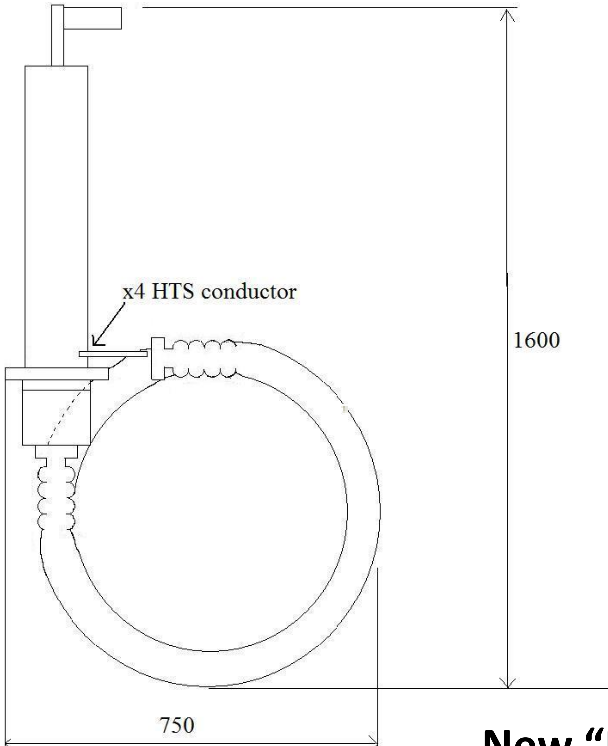
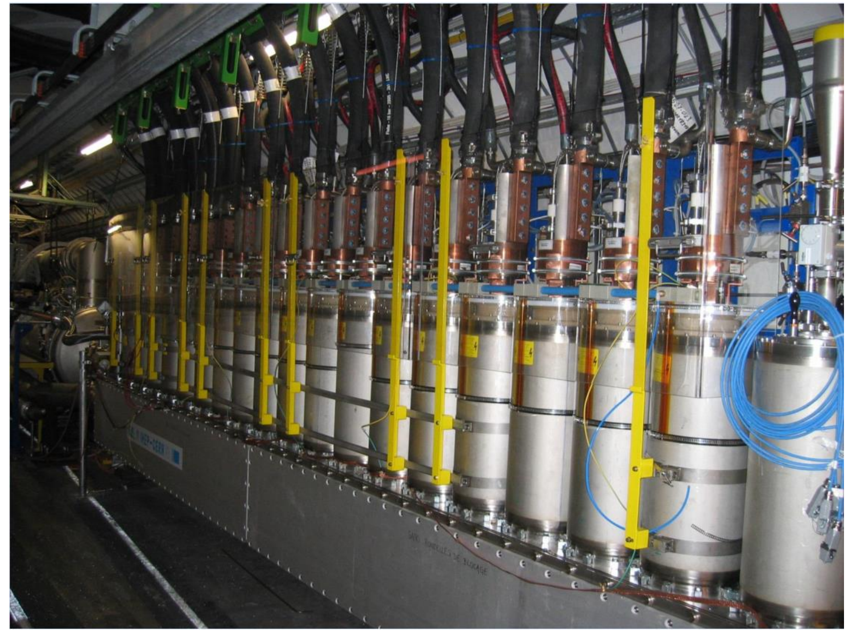
System design



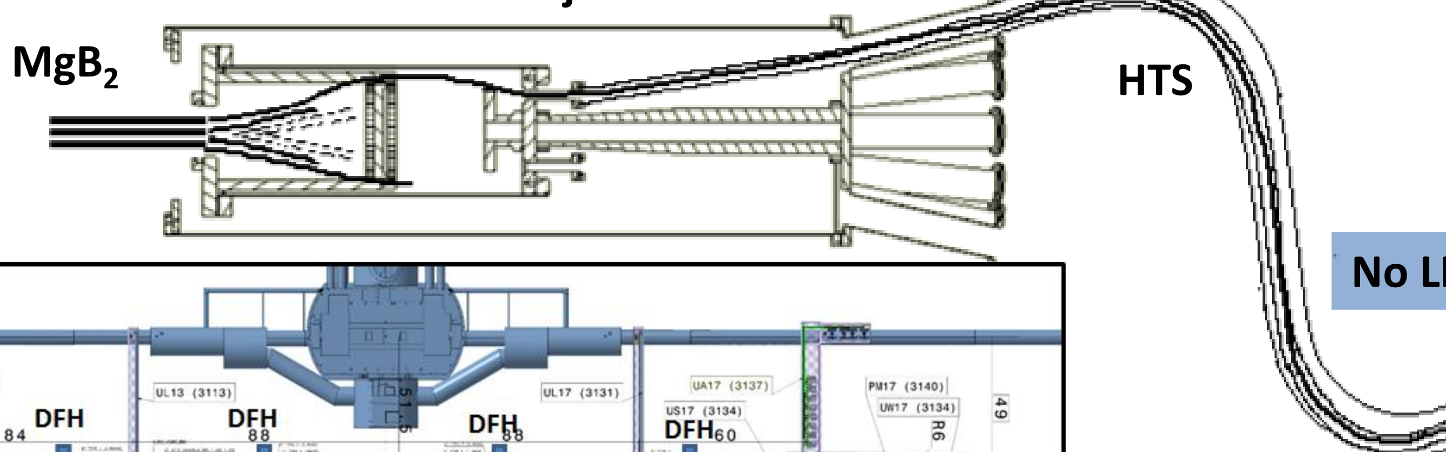
Concept developed for LHC P7 and being studied for LHC P1 and P5

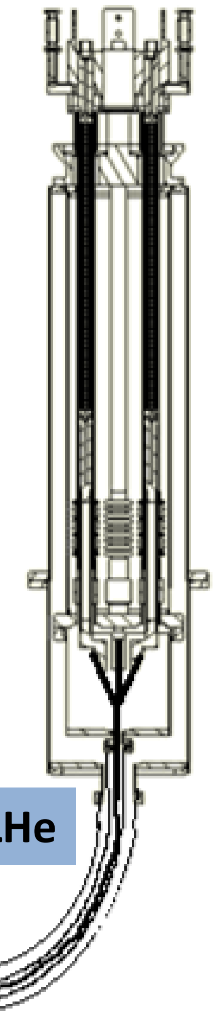
System design: new concept

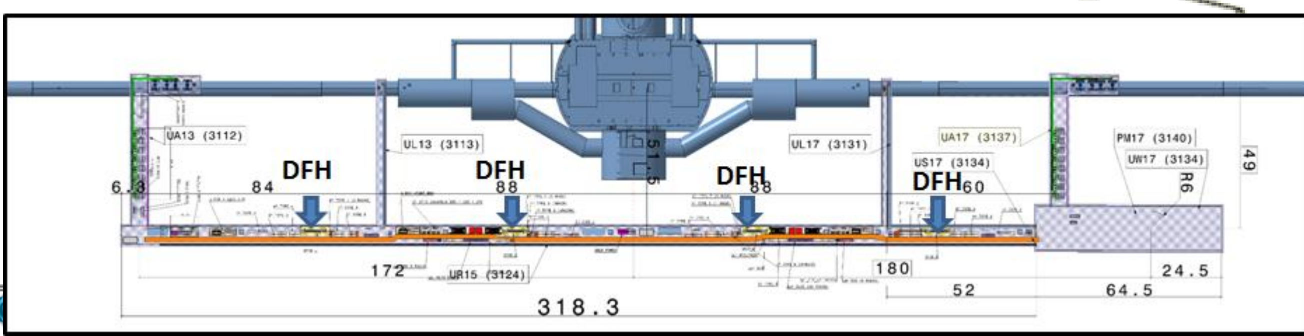




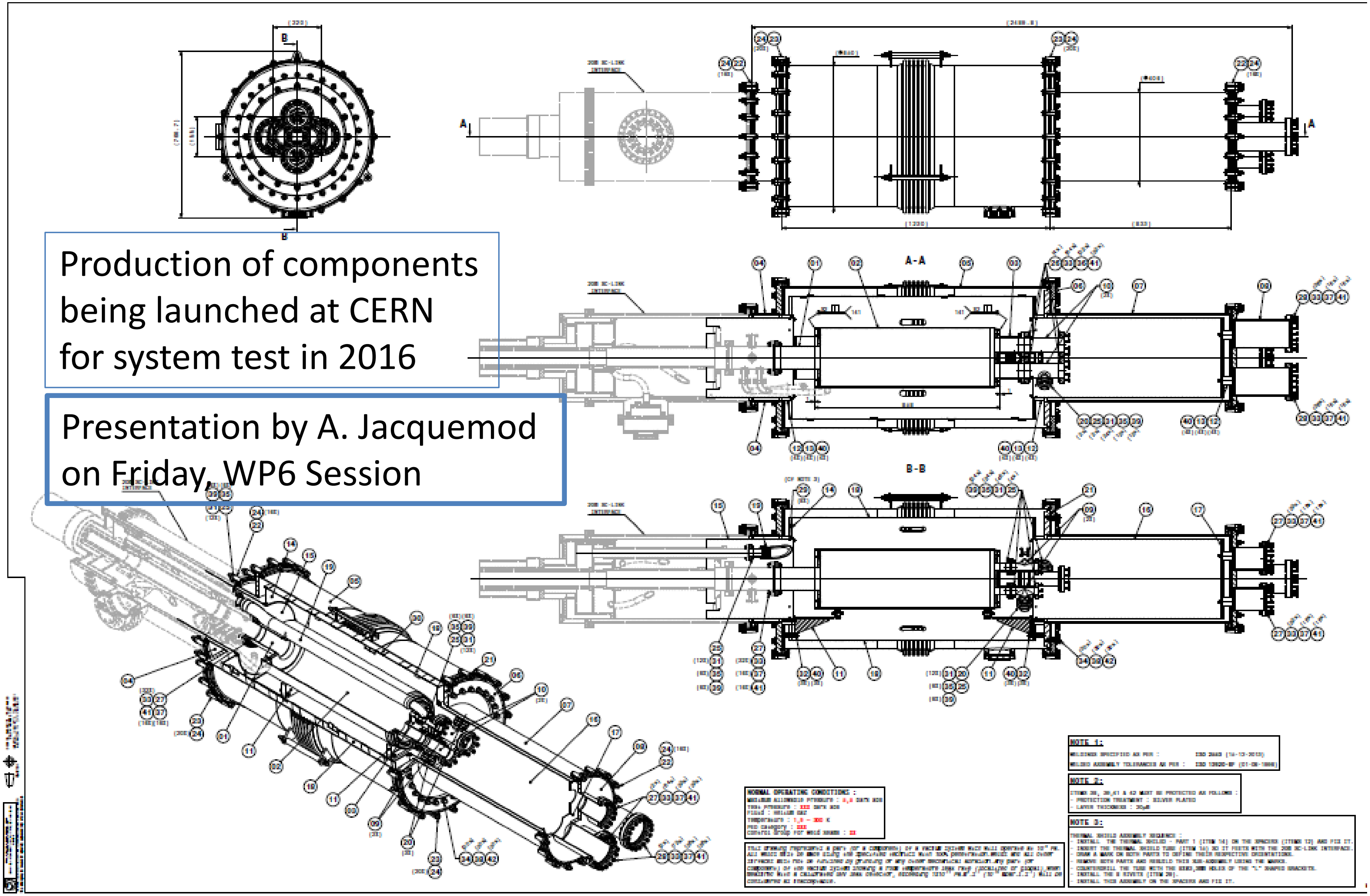
New "DFB": joint box







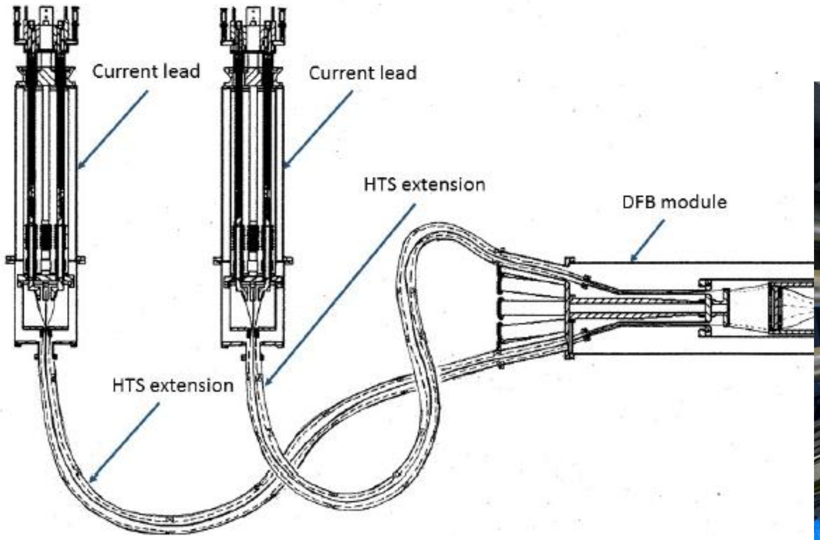
System design: new DFB concept

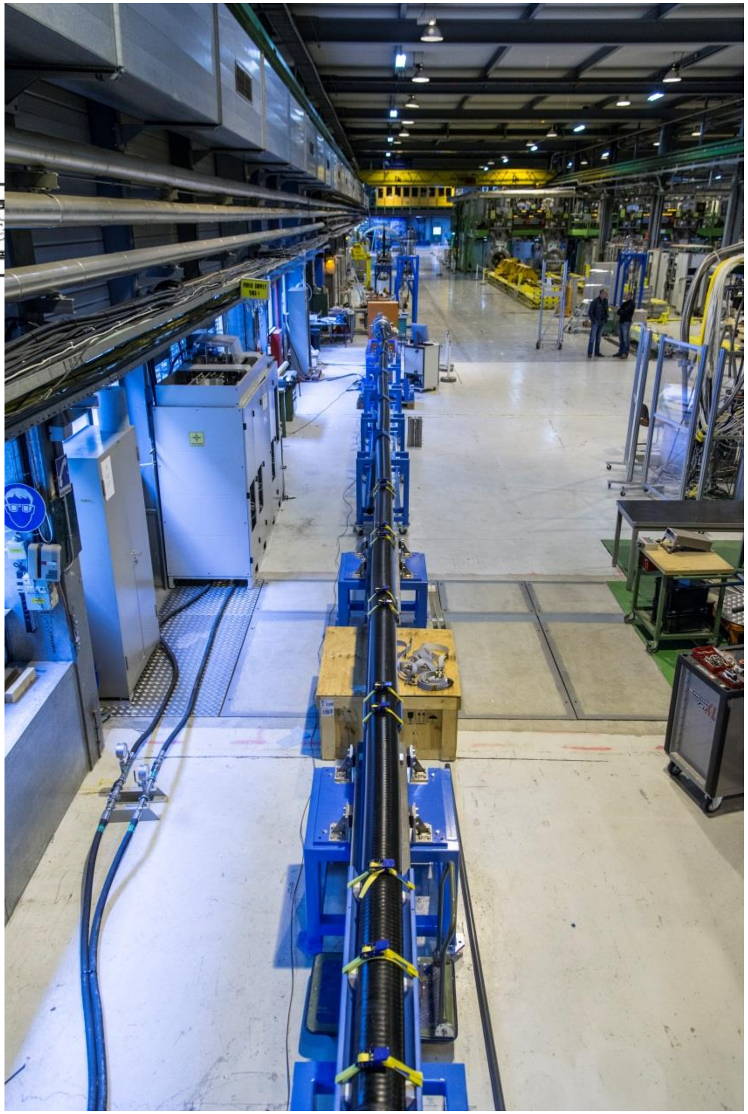


Production of components being launched at CERN for system test in 2016

Presentation by A. Jacquemod on Friday, WP6 Session

System test in SM-18

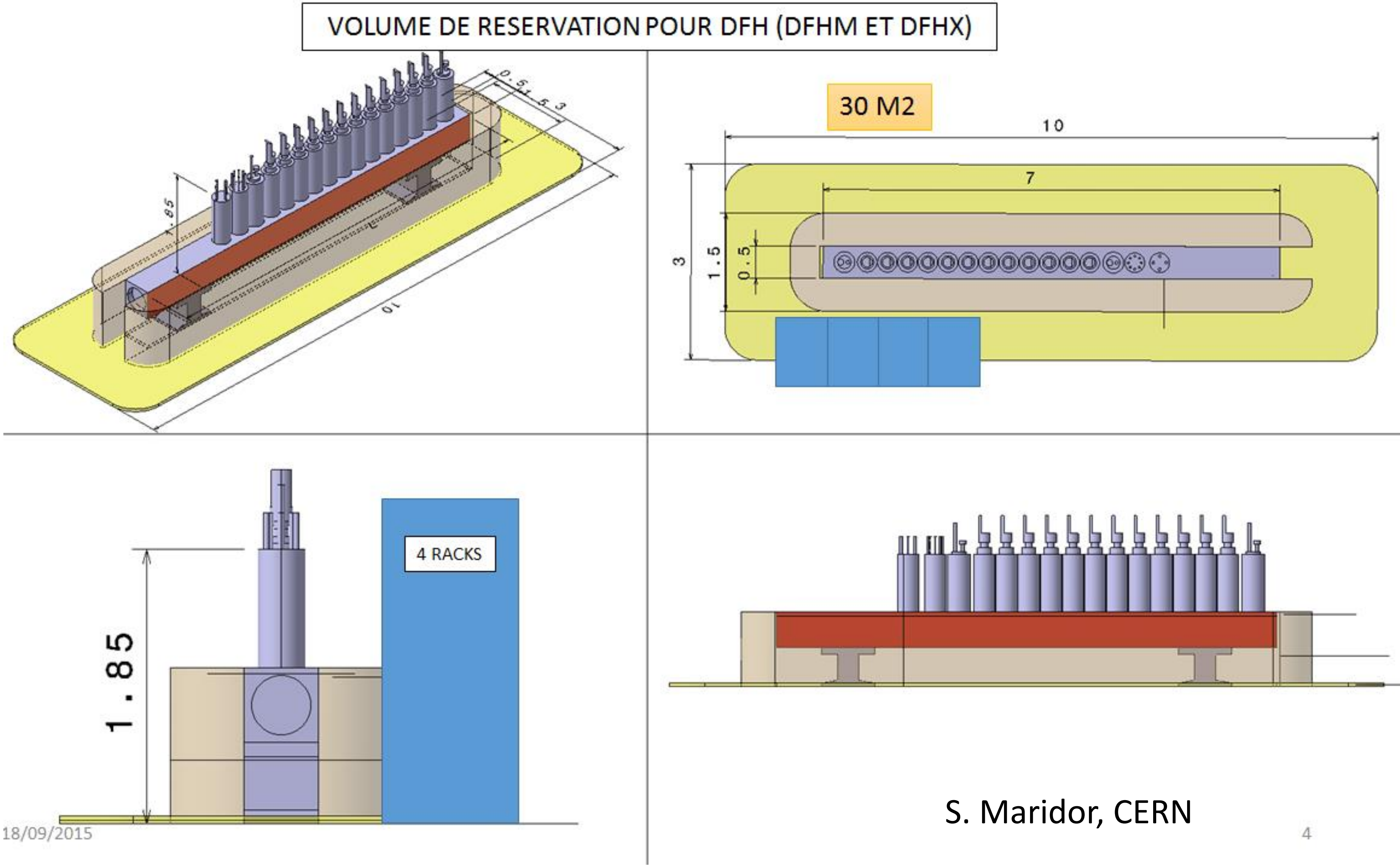




Modification of existing test station and cryo-electrical test of Cold Powering System in 2016

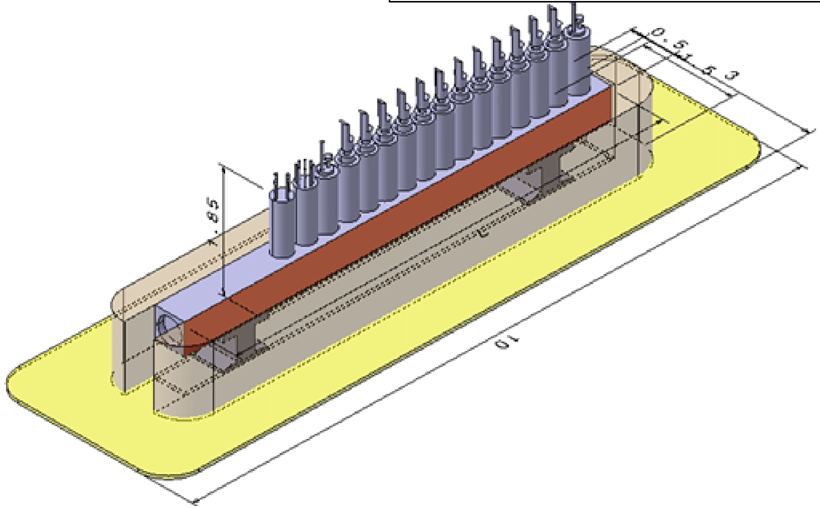
CERN and SOTON

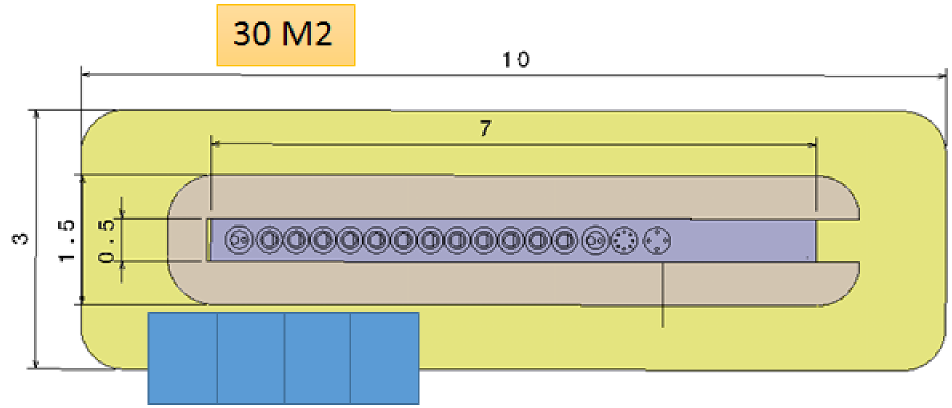
Integration studies



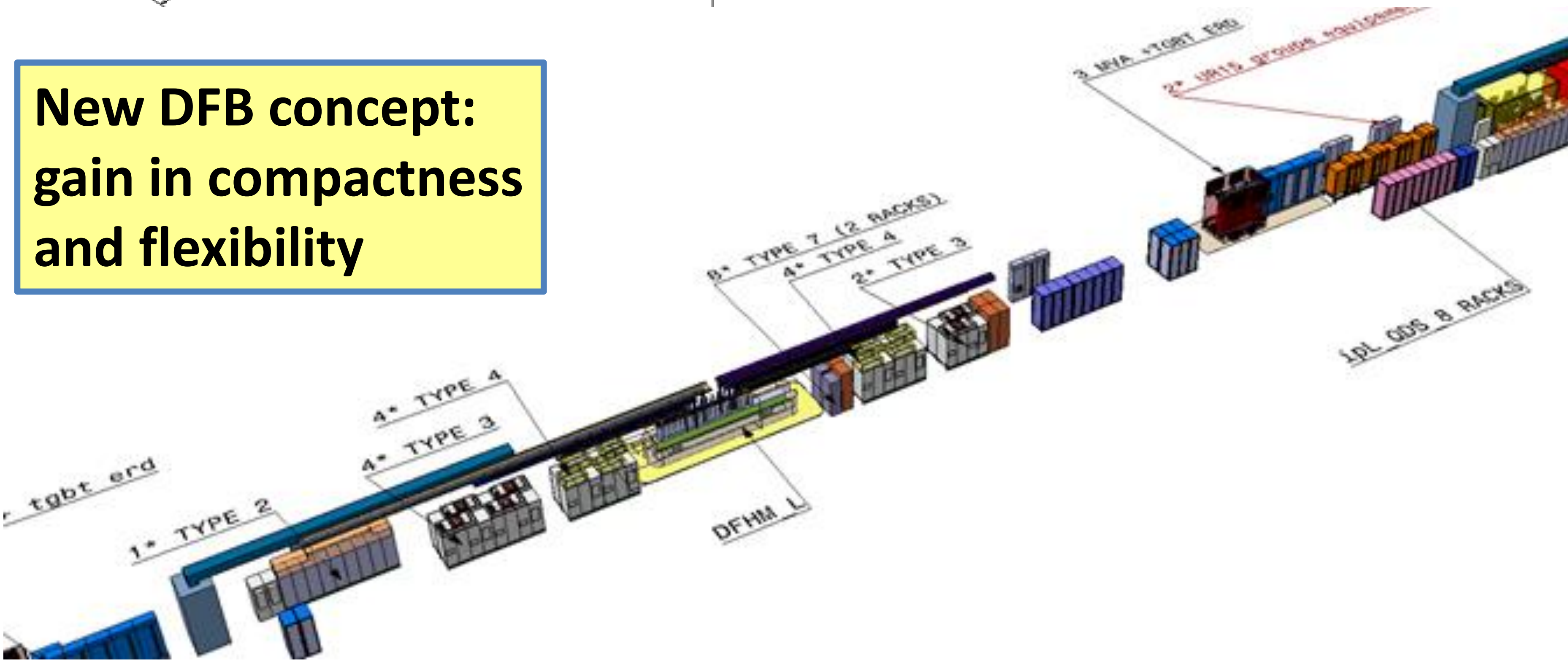
S. Maridor, CERN

VOLUME DE RESERVATION POUR DFH (DFHM ET DFHX)

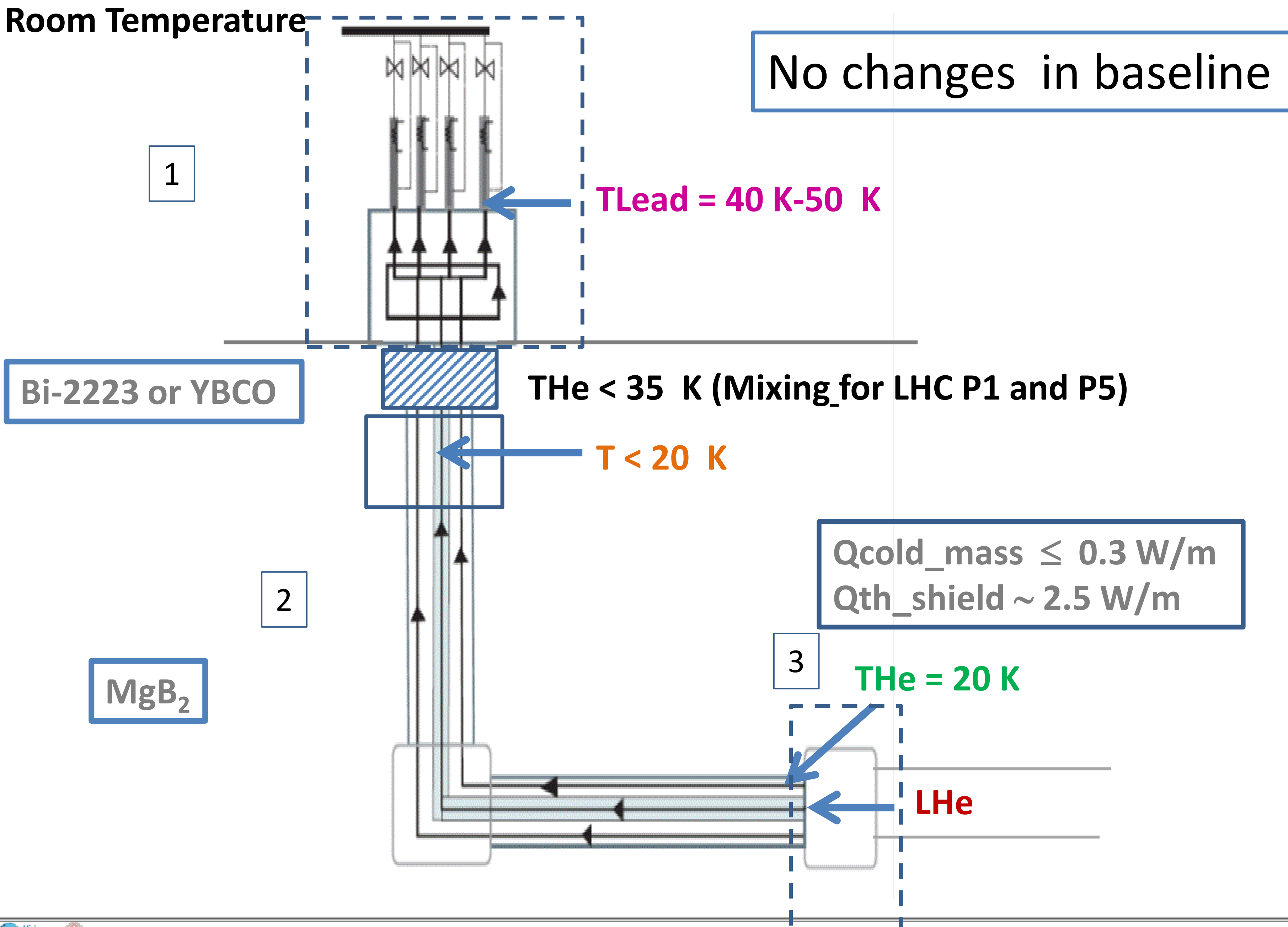




New DFB concept: gain in compactness and flexibility

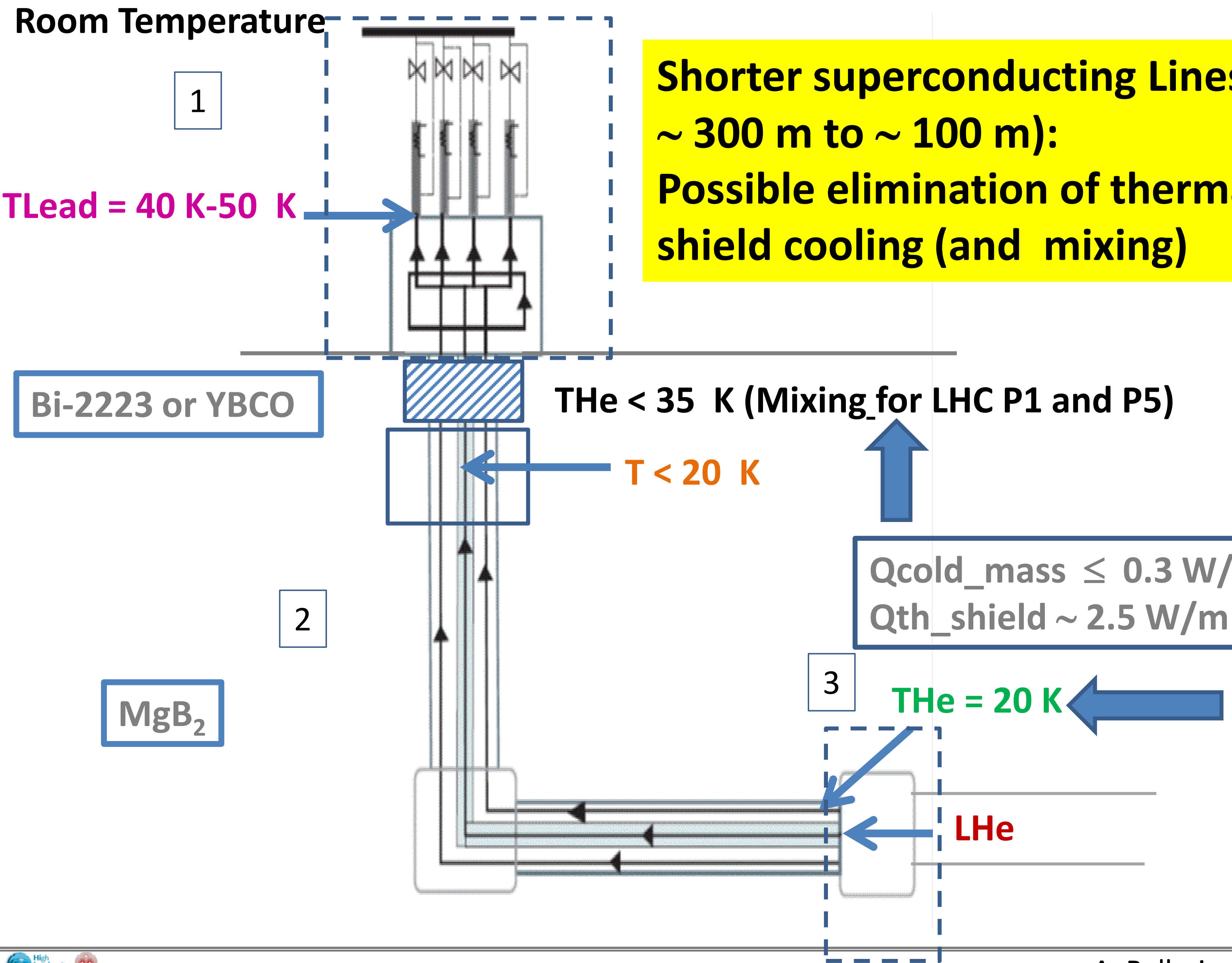


Cryogenics


Room Temperature
No changes in baseline
1
TLead = 40 K-50 K
Bi-2223 or YBCO
THe < 35 K (Mixing for LHC P1 and P5)
T < 20 K
Qcold_mass ≤ 0.3 W/m
Qth_shield ~ 2.5 W/m
2
3
THe = 20 K
MgB_2
LHe

Under evaluation

Shorter superconducting Lines (from ~ 300 m to ~ 100 m): Possible elimination of thermal shield cooling (and mixing)



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BestPaths Project

European FP7 Project

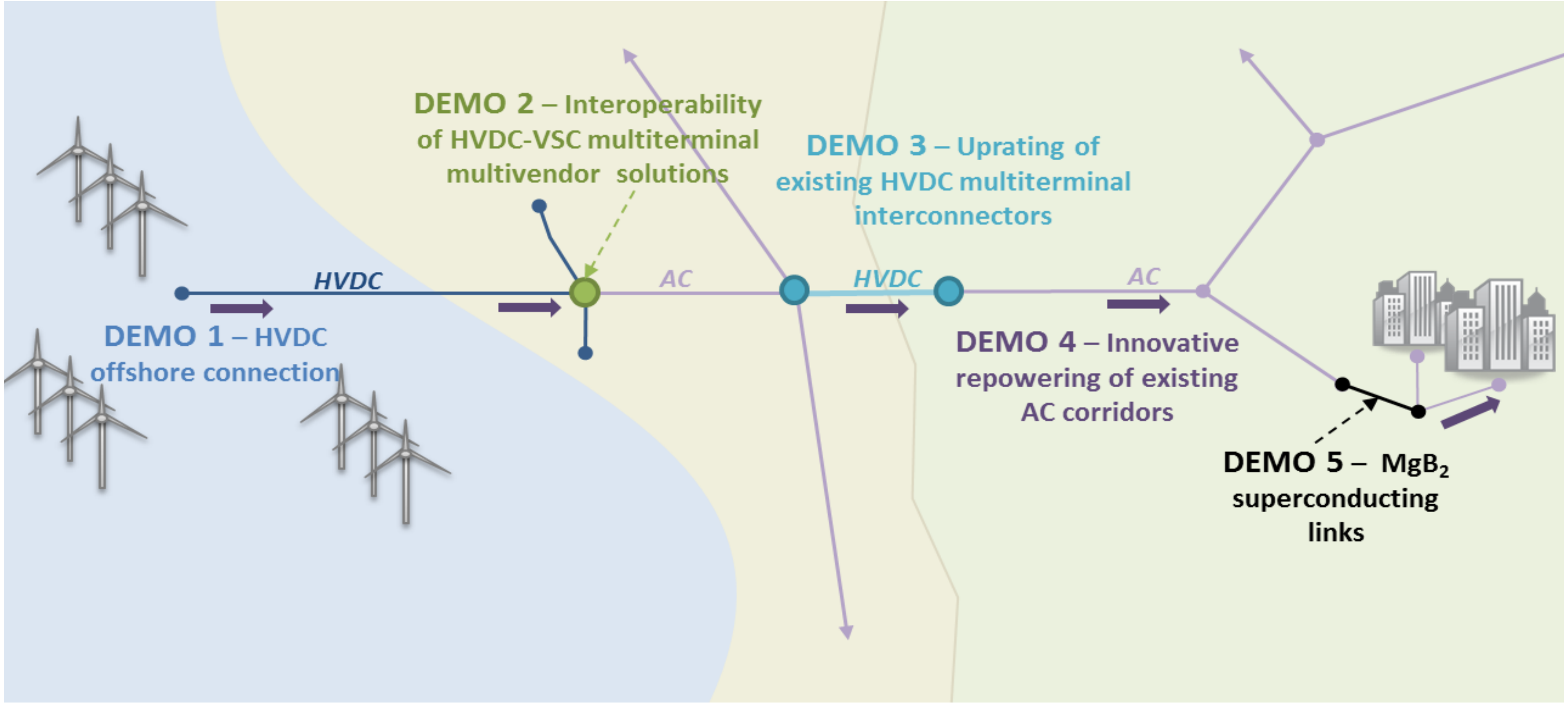
- **BEyond State-of-the-art Technologies for Power AC corridors and multi-Terminal HVDC Systems**
- RD&D project founded by the European commission under FP7
- Period: Oct. 2014 - Sept. 2018 (4 years)

The BEST PATHS project aims at:
"**demonstrating** by 2018 and through real life, large scale demonstrations, the capabilities of several critical **network technologies** required to **increase the pan-European transmission network capacity and** electric system **flexibility**, thus making Europe able of **responding** to the **increasing** share of **renewables** in its energy mix by 2020 and beyond, while **maintaining** its present level of **reliability** performance

Coordinated by Nexans, with CERN, industry, laboratories and network system operators

BestPaths Project

Five top technology demonstrations including a HVDC MgB2 superconducting link



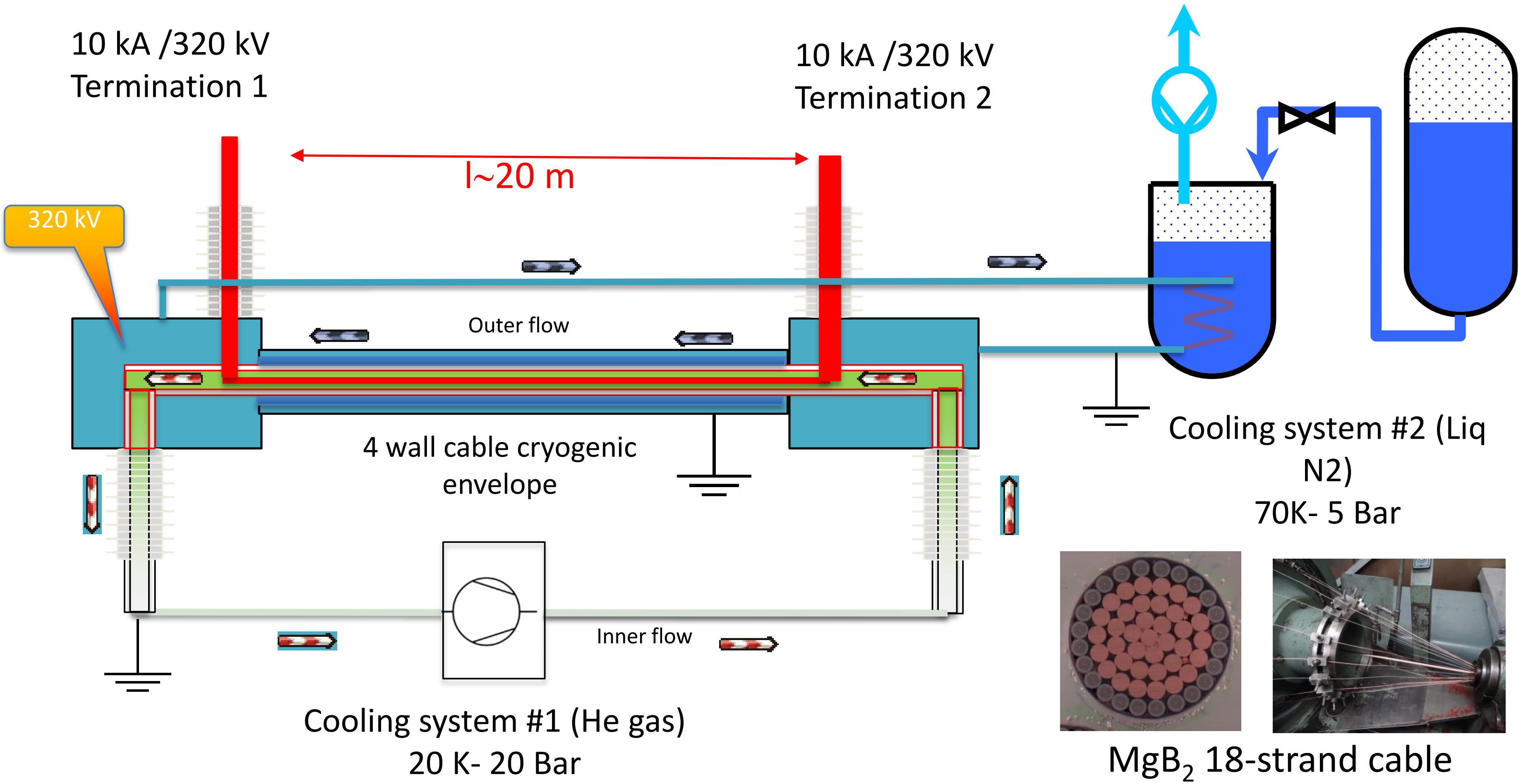
10 kA, 320 kV DC MgB_2 line, 20 K operation

BestPaths Project

1. To develop cable and termination manufacturing processes for **3 GW class HVDC monopole cable** (6 GW for bipolar)
2. To develop a manufacturing process for production of a large quantity of high performance MgB_2 superconducting wires at low cost
3. **To validate cable operations** with laboratory experiments performed in He gas at variable temperature
4. **To demonstrate operations of a full scale cable system** transferring up to 3,2 GW
5. To **propose system integration pathways for HDVC** applications
6. To investigate the availabilities of the cable system and the possible **use of H2 liquid for long length power links**

Presented by Nexans at EUCAS 2015 Conference

BestPaths Project



MgB_2 18-strand cable

Presented by Nexans at EUCAS 2015 Conference

Conclusions

- The work done within the Hi-Lumi WP6 enabled elaboration of a new concept of **powering system** , development of a **MgB_2 industrial wire**, validation of prototype systems/superconductor/cables via **testing and modelling**

- The work has attracted the **interest of industry and power transmission operators** (BestPaths)

- We are ready to enter into the **final system validation** and series production

Thanks for your attention !