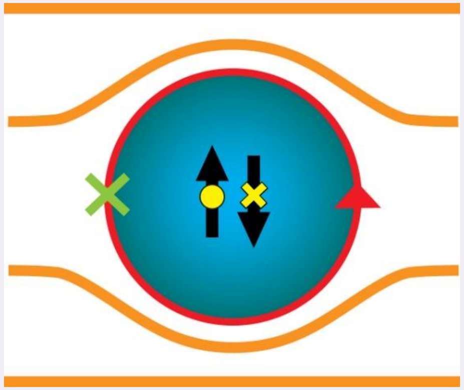


Superconducting Links for the Hi-Lumi Upgrades

A. Ballarino
CERN, European Center for Nuclear Research, Geneva
Switzerland

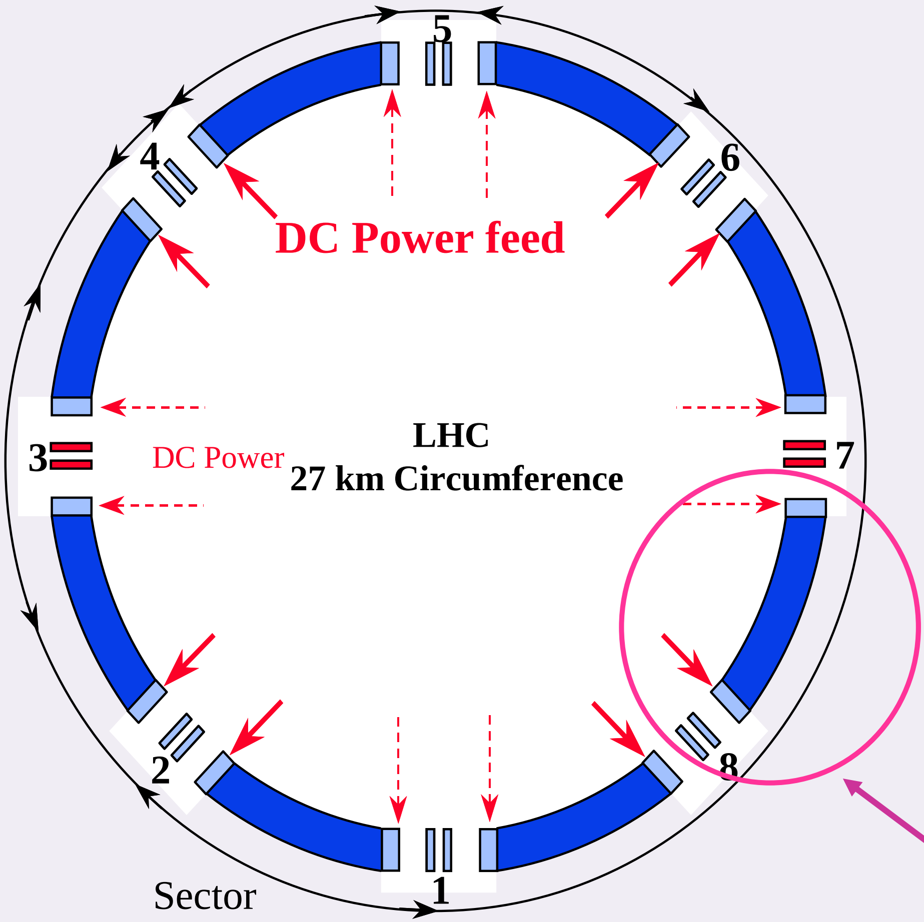
Superconducting Technologies for the Next Generation of Accelerators
CERN, Globe of Science and Innovation
4-5 December

Outline

- Application of SC links to the LHC machine
- Modifications to the LHC powering layout
- R&D Activity at CERN
- Plan for future activities
- Conclusions

A. Ballarino

Powering of LHC Machine

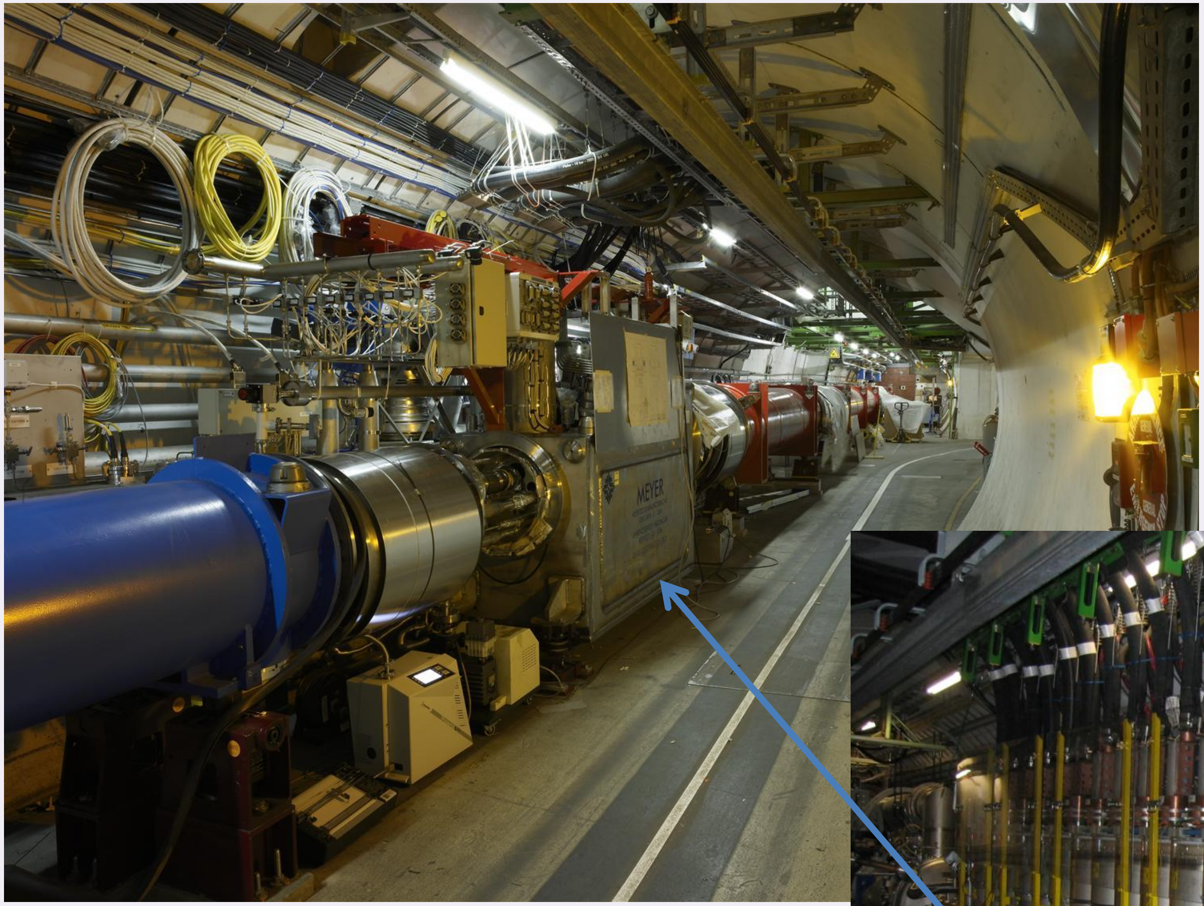


- To limit the stored energy within one electrical circuit, the LHC is powered by sectors
- The main dipole circuits are split into 8 sectors to bring down the stored energy to ~1 GJ/sector
- Each sector (~2.9 km) includes 154 dipole magnets (powered in series) and ~50 quadrupoles

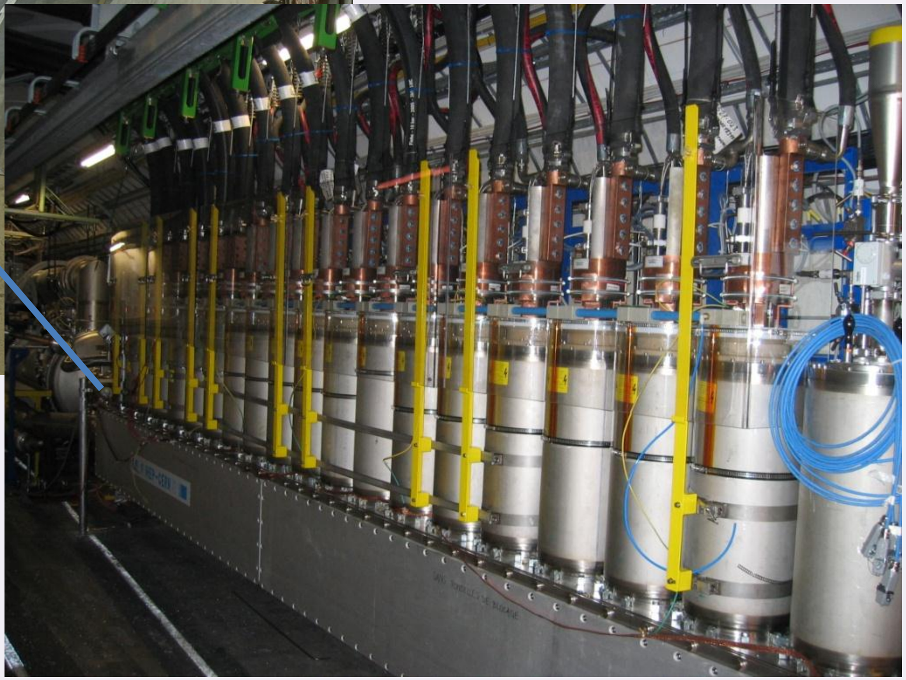
Powering Sector

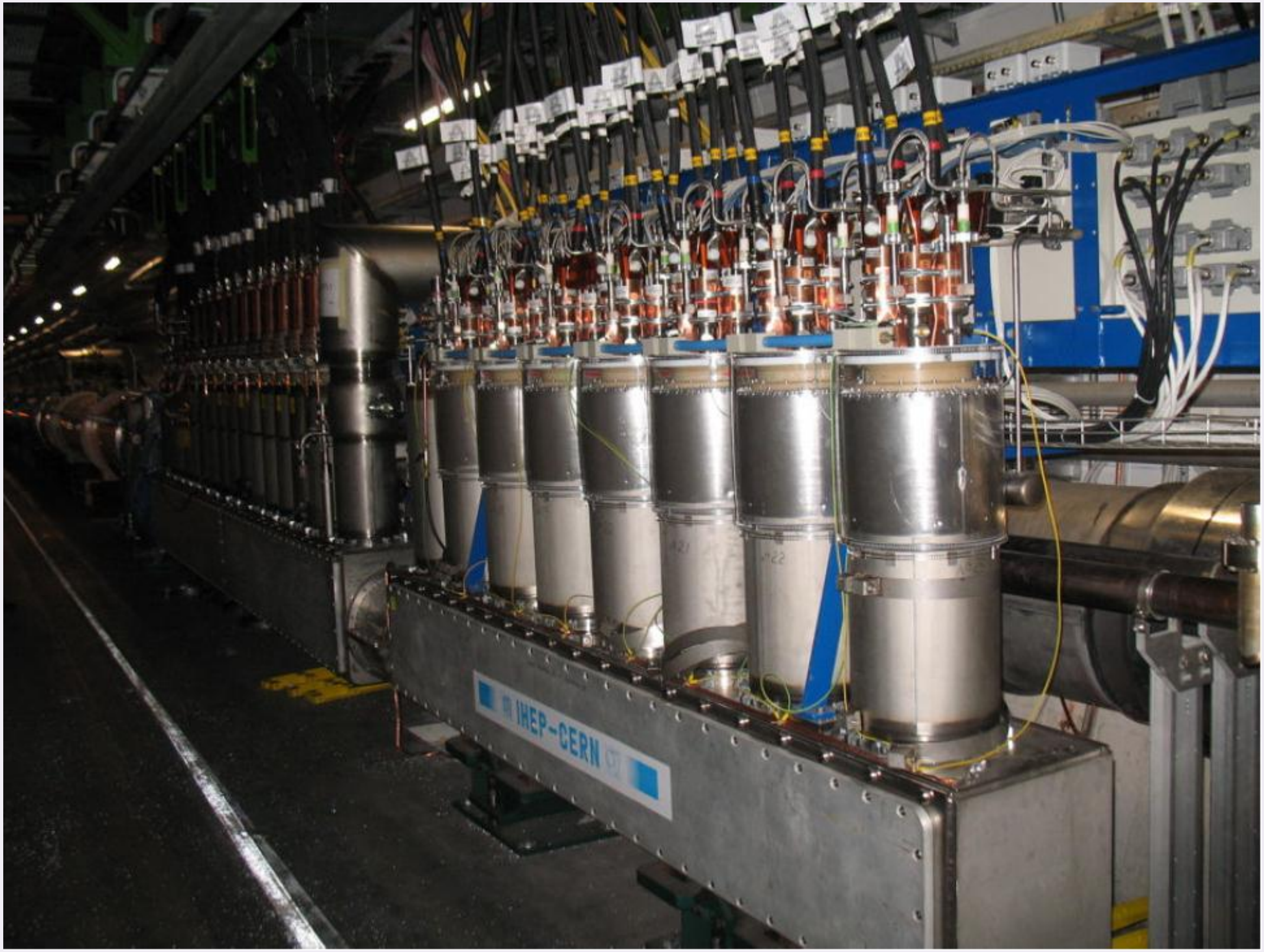
~ 3.4 MA, > 3000 Current Leads, ~ 1500 Electrical Circuits

LHC Tunnel

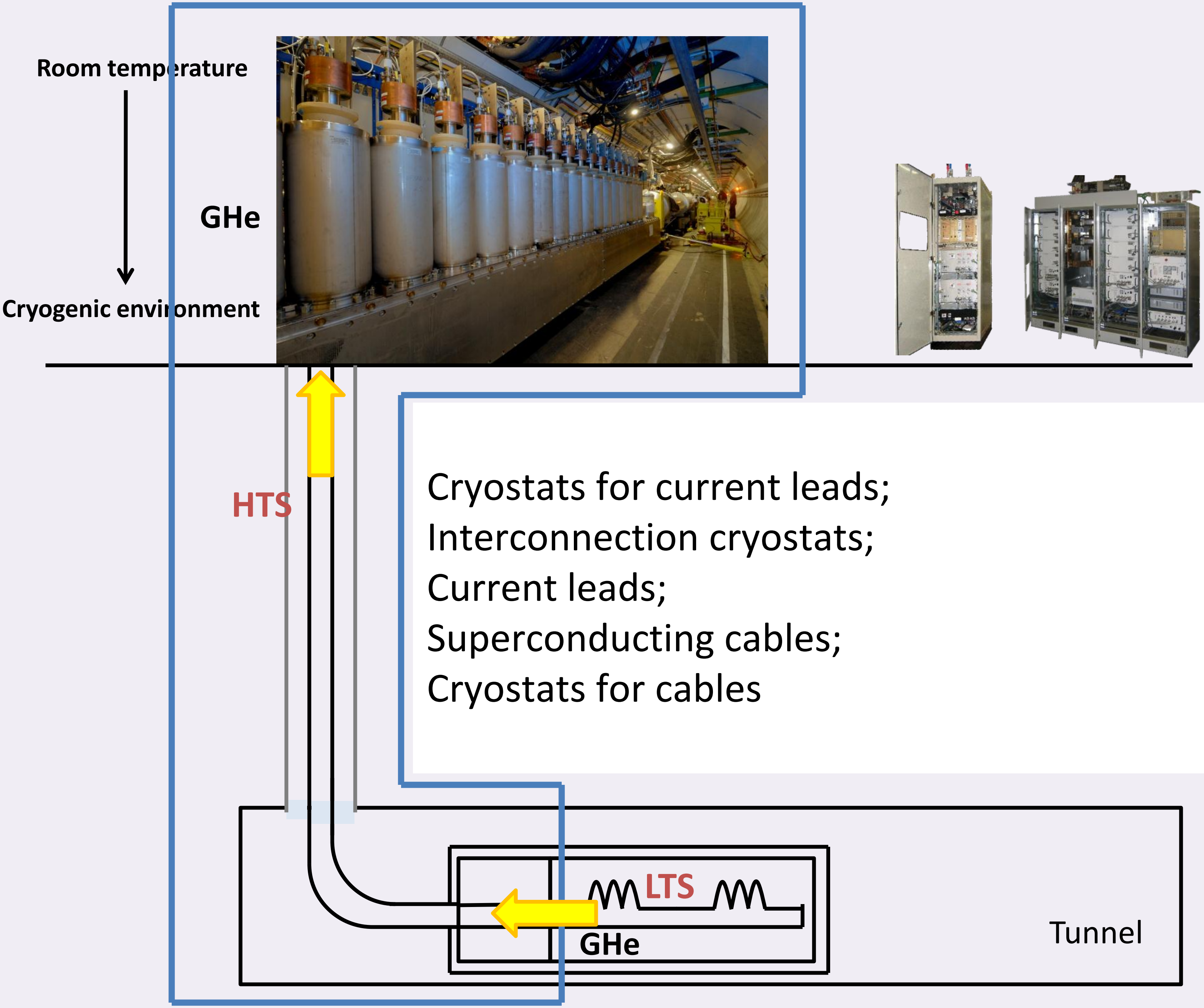


In tunnel alcoves





DFB in the tunnel at P1 L



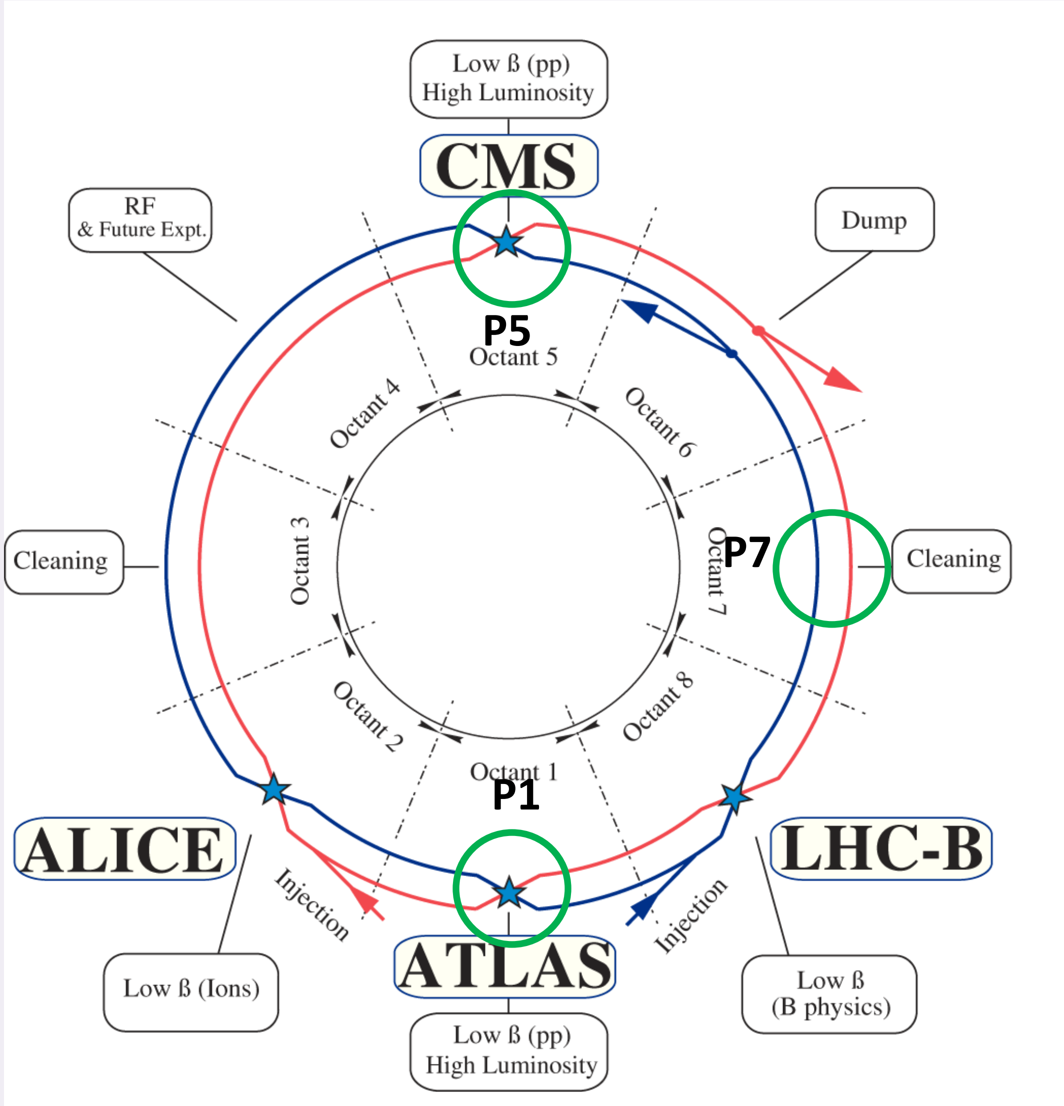
Cryostats for current leads;
Interconnection cryostats;
Current leads;
Superconducting cables;
Cryostats for cables

Rationale

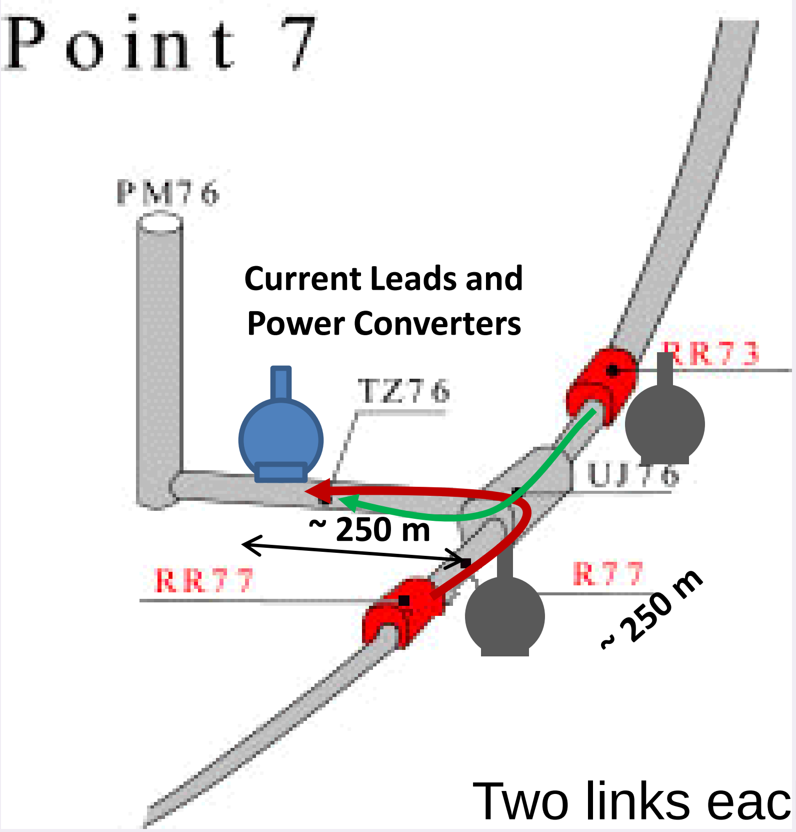
Powering via superconducting links and remote power converters → removal of

- **Free space** in the beam areas;
- Safer long-term operation of **powering equipment** located in **radiation-free** environment;
- **Safer and easier access of personnel** to power converters, leads and control equipment;
- **Reduced time of interventions** (maintenance, repair, diagnostic and routine tests) →
- Gain in machine availability

Where in the LHC ?



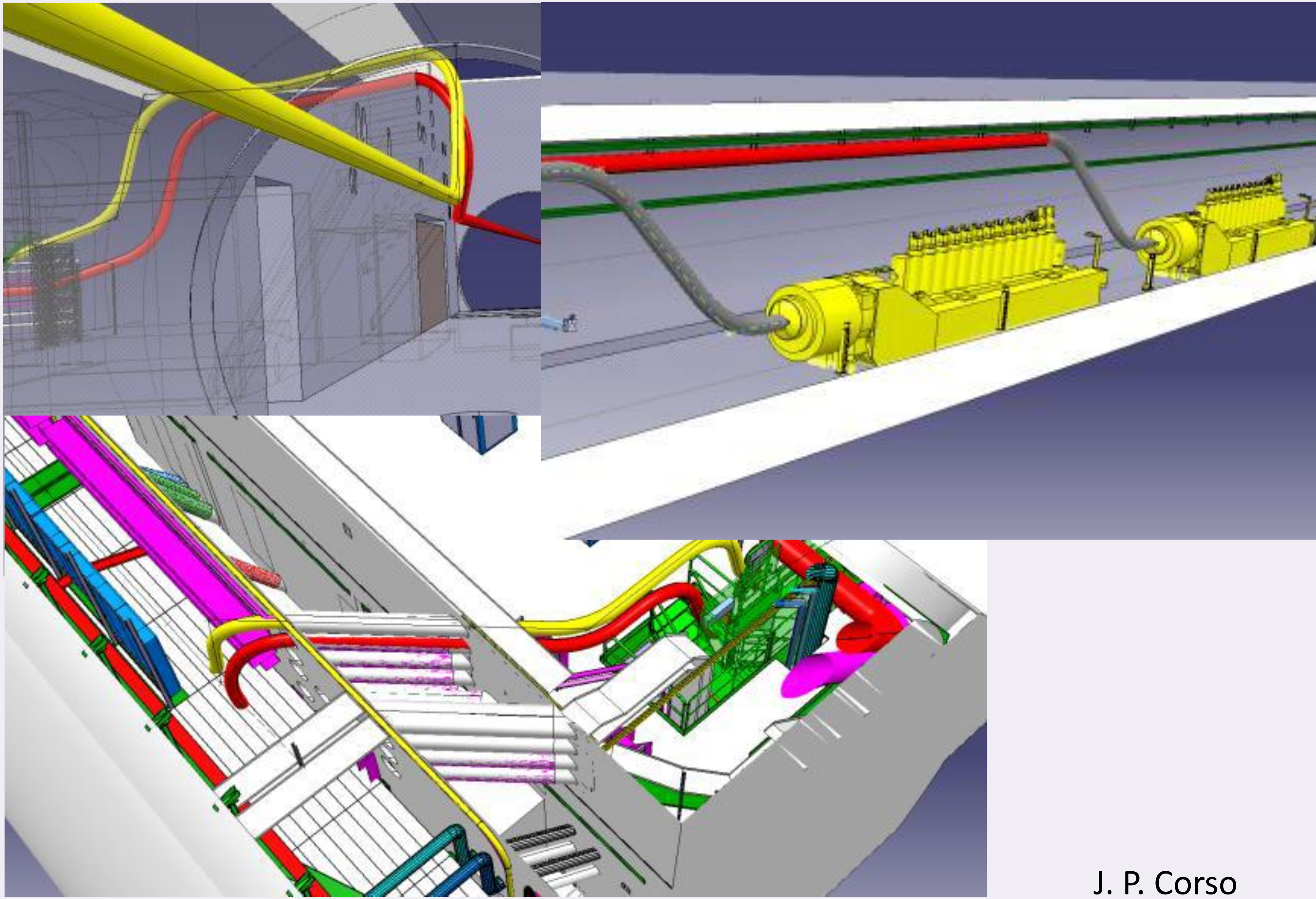
P7: Underground Installation



Two links each about 500 m long

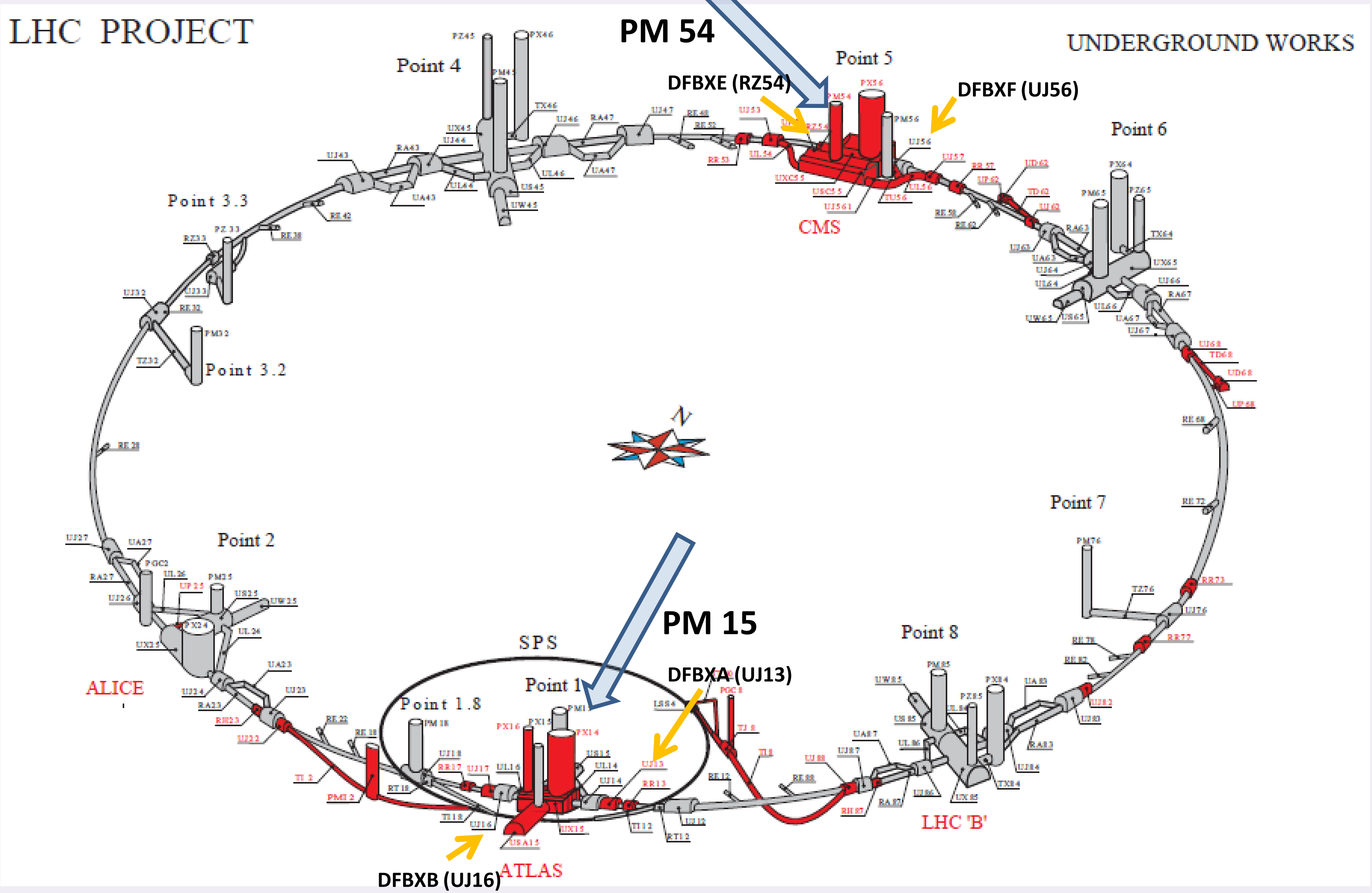
48 cables rated at 600 A per link

P7: Integration in LHC Tunnel



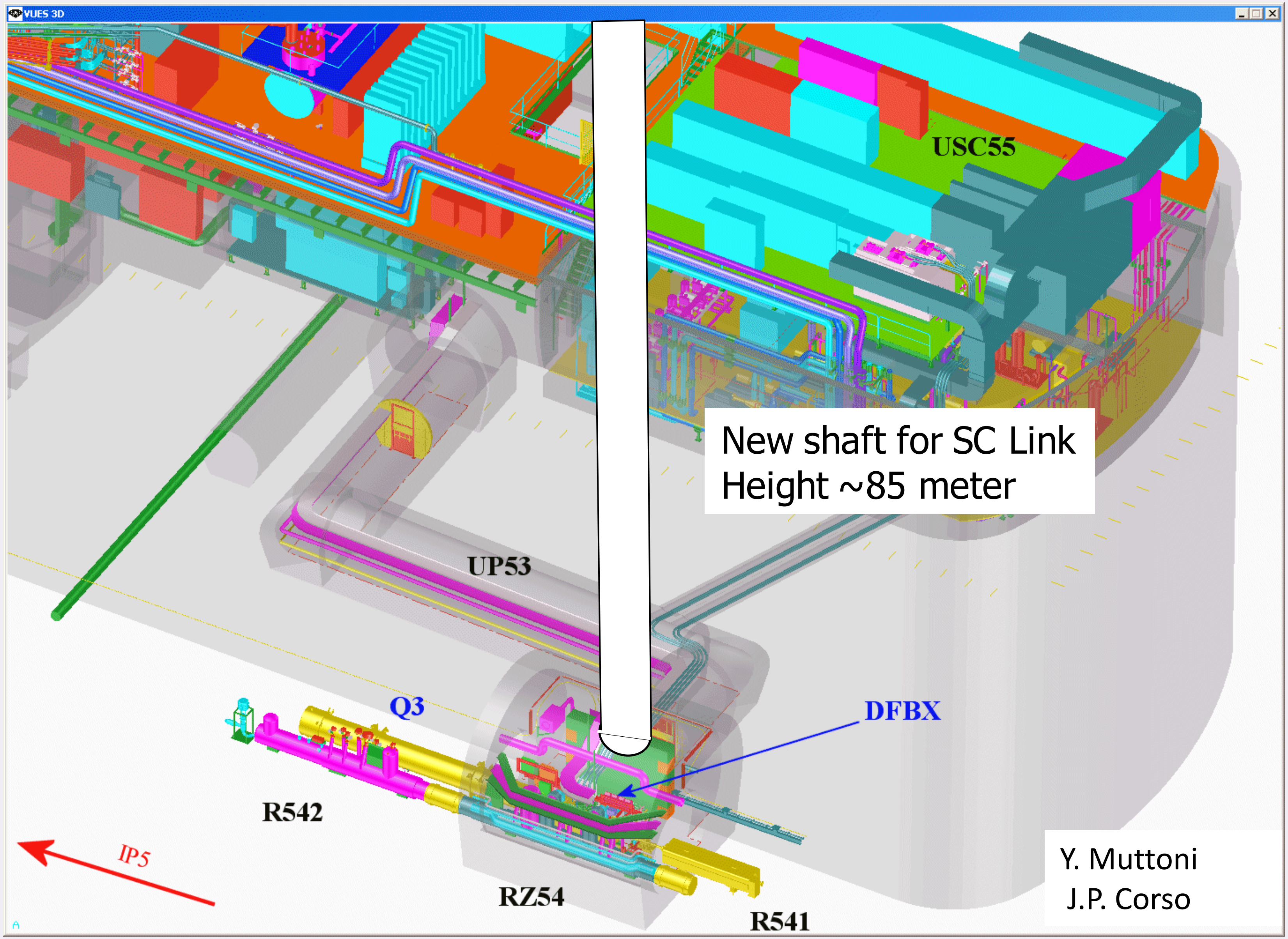
J. P. Corso

P1 and P5: Surface Installation

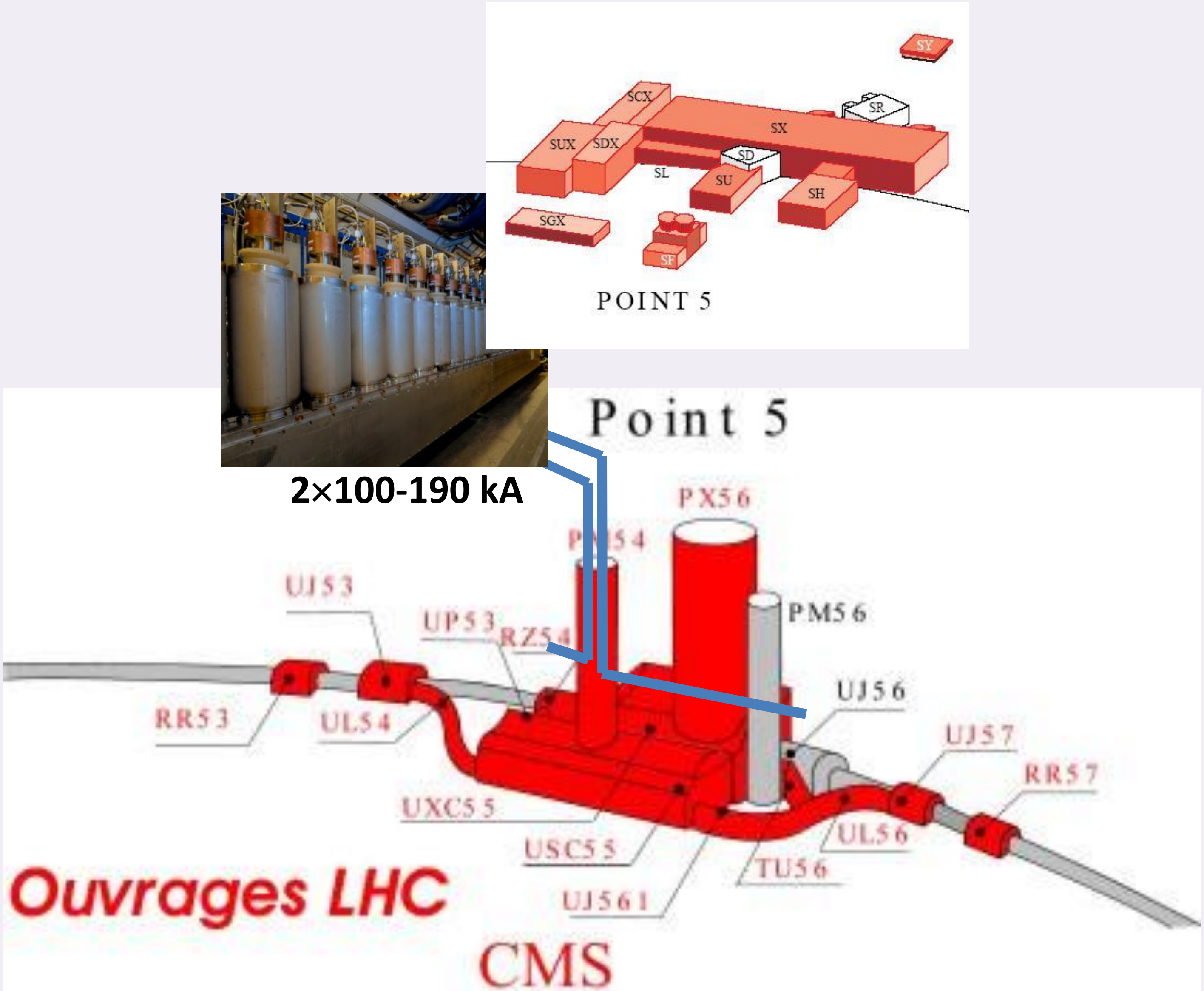


P1 and P5: Surface Installation

Point 5



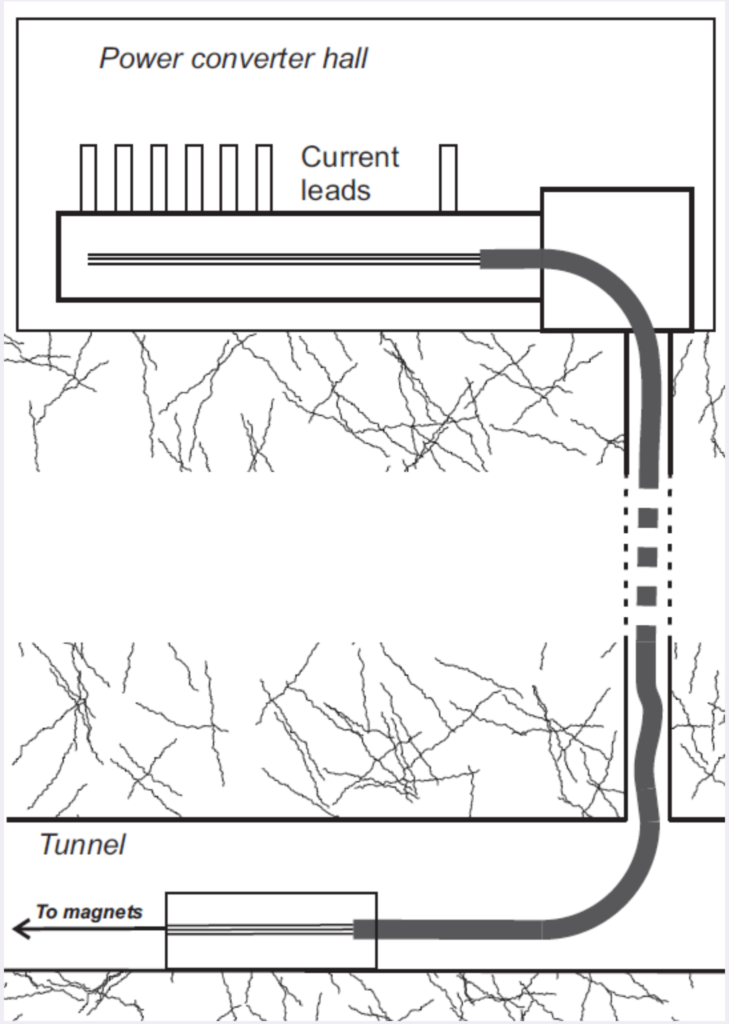
P1 and P5: Surface Installation



Requirements

Total currents to be transferred: **up to ~ 190 kA DC** per line (multi-cable assemblies)

Length: from a minimum of about **200 m** to a maximum of about **500 m** - with a significant **vertical transfer** for the locations where the power converters are to be located at the surface



A. Ballarino, Proceed. ASC 2010

Conductors

MgB_2, **YBCO** and **Bi-2223**

MgB_2: good electrical properties at low field and $T \leq 25$ K, low cost

YBCO : superior mechanical properties, higher operating temperature

BSCCO 2223: well known conductor, higher operating temperature

Conductors Specification

		Φ (mm)	W (mm)	Th (mm)	Tmax (K)	Ic [‡] (A)
[†] MgB_2	wire	< 1	-	-	25	≥ 400
MgB_2	tape	-	3.7	0.67	25	≥ 400
YBCO	tape	-	4	0.1	35	≥ 400
BSCCO 2223	tape	-	4	0.2	35	≥ 400

[†] bending radius $R_B \leq 80$ mm
[‡] at applied field $B \leq 0.5$ T

Reacted wires

Current Ratings and Conductor Needs

Number of links and quantity of conductor:

2 at LHC P7
Itot~ 30 kA/link
50 cables rated at **600 A**

~150 km of conductor

4 at LHC P1
4 at LHC P5
Itot up to 190 kA/link
Up to **50 cables** rated at **600 A, 6000 A, 20000 A**

~850 km of conductor

Ltot ~ 1000 km of conductor for series production

On-going and past development of HTS cables for electrical transmission:

1) AC cables for operation in the network
2) First and second generation HTS conductors
3) LN_2 operation
4) Cables operated at max. up to about 3500 A max
5) One or there cables in the cryogenic envelope
6) Horizontal transfer
7) High-voltage

SC links for the LHC machine:

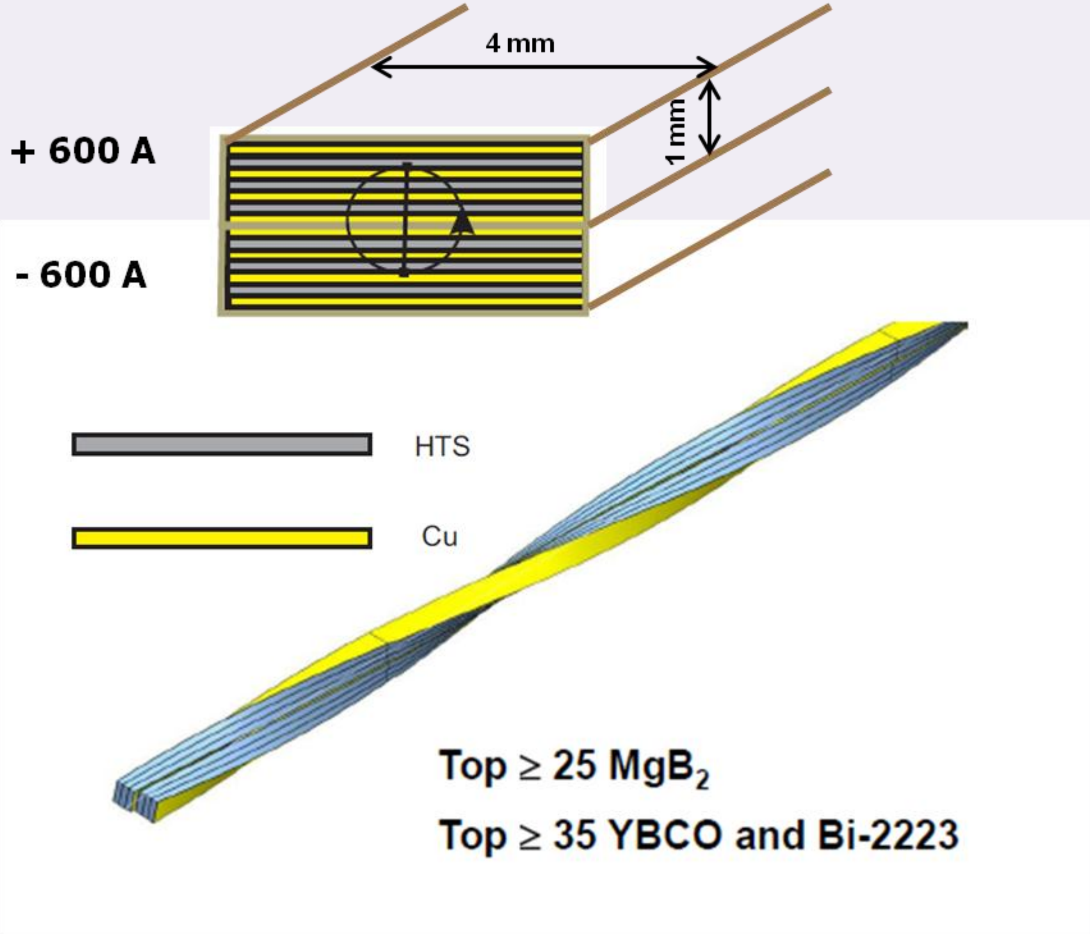
1) Quasi-DC operation
2) Study of MgB_2 potentials
3) GHe operation
4) Cables operated at up to 20 kA
5) Multi-cable (~ 50 high-current cable) assemblies
6) Horizontal + Vertical (~ 80 m) transfer
7) 1.5 kV – 2 kV electrical insulation

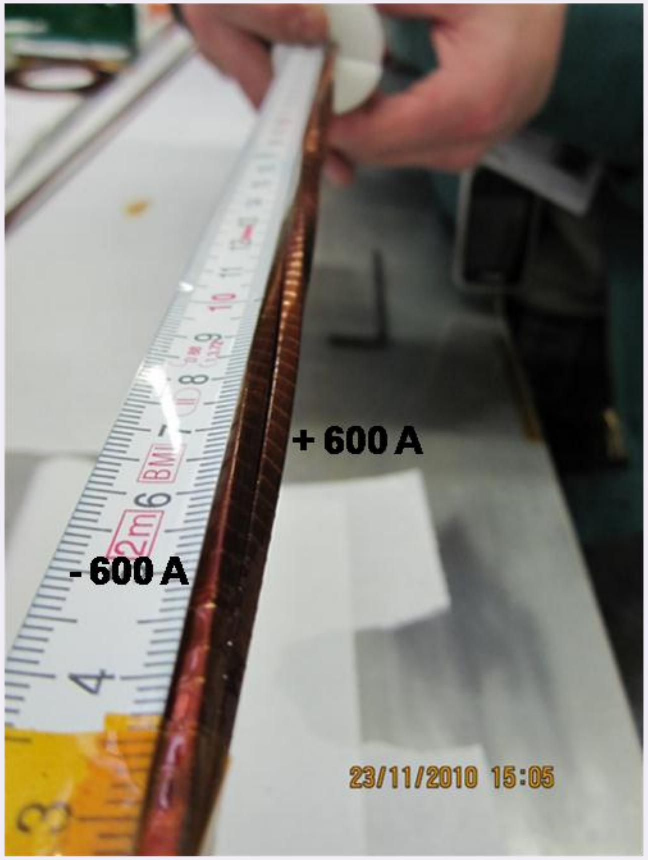
Φ = 62 mm

120 kA @ 30 K

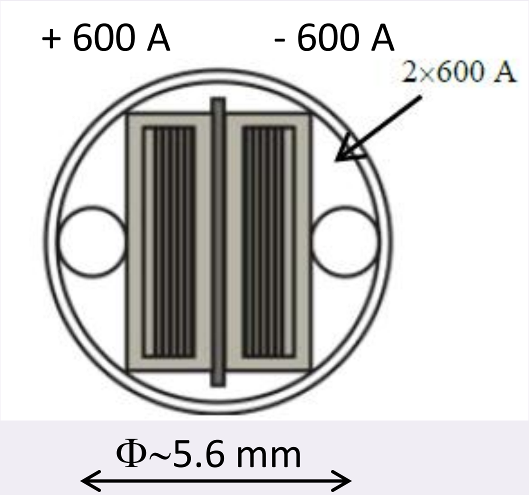
Cable Development (1 kA range)

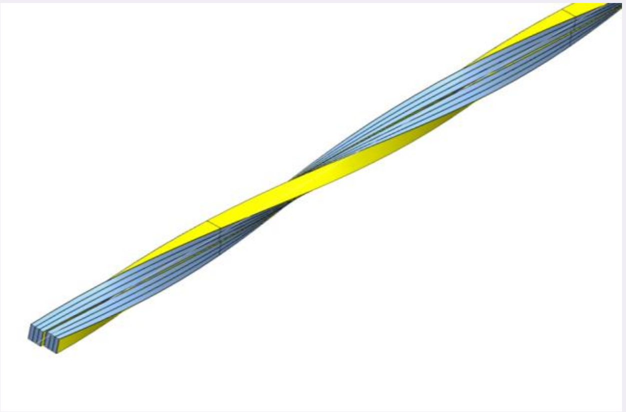
Twisted-pair cables made from tapes

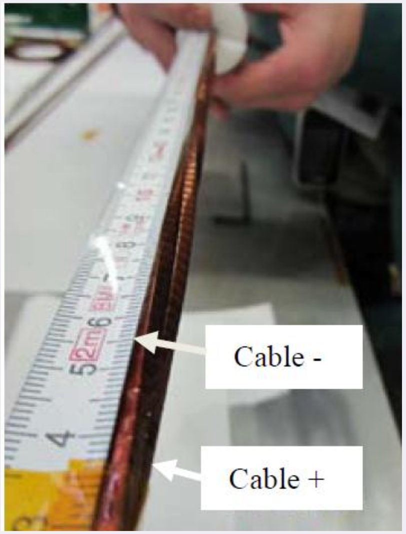


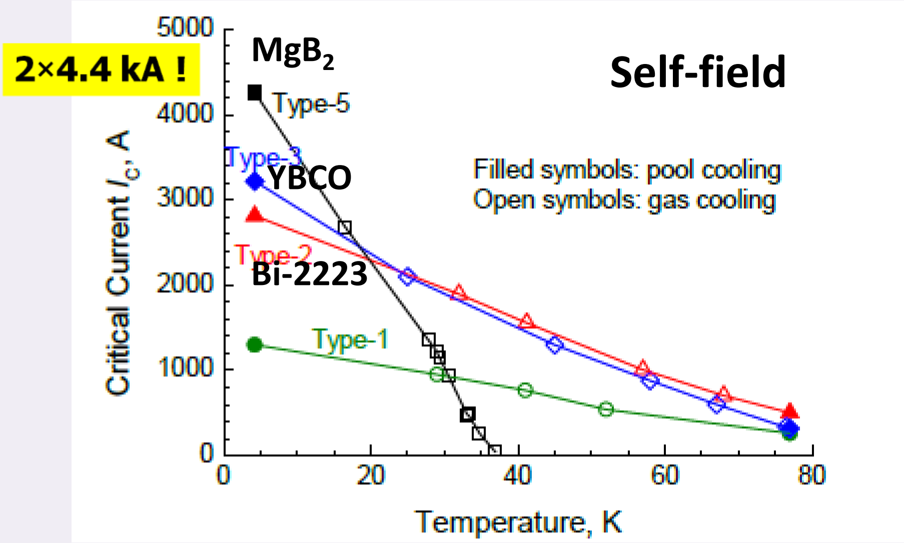


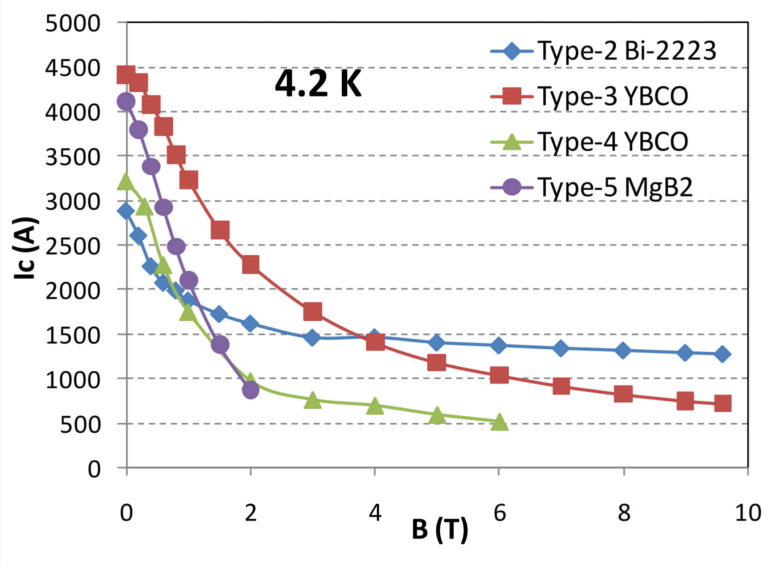
Cable Development (1 kA range)







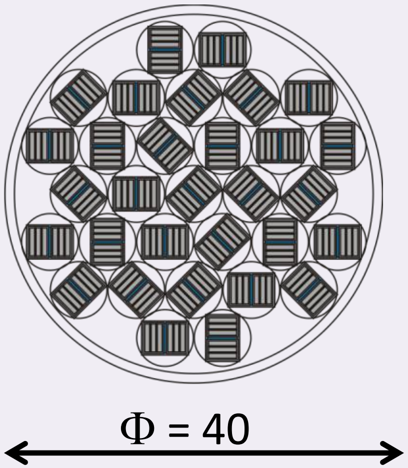




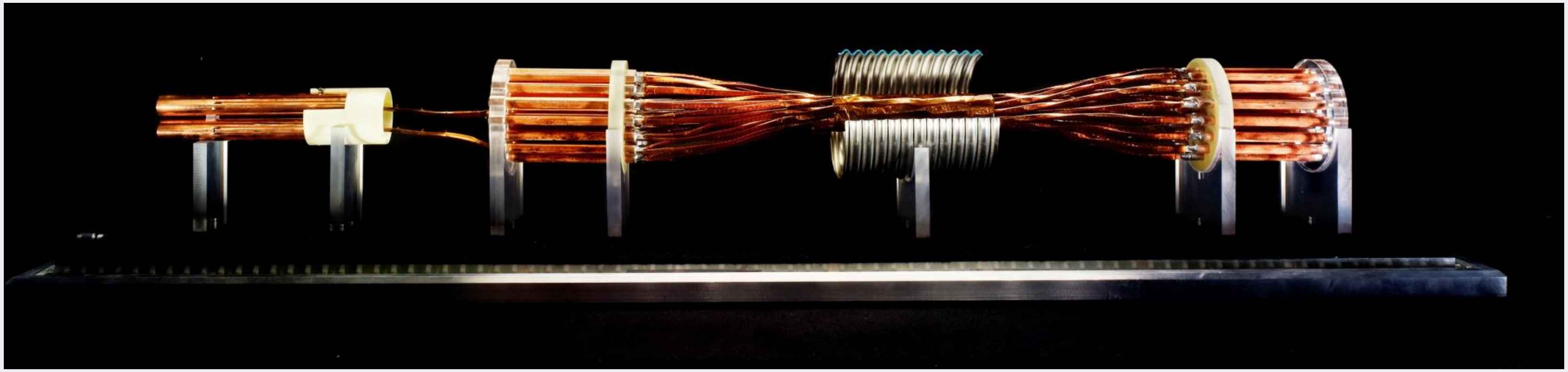
Measurements performed on cable lengths of 2 m

Multi-Cable Assembly

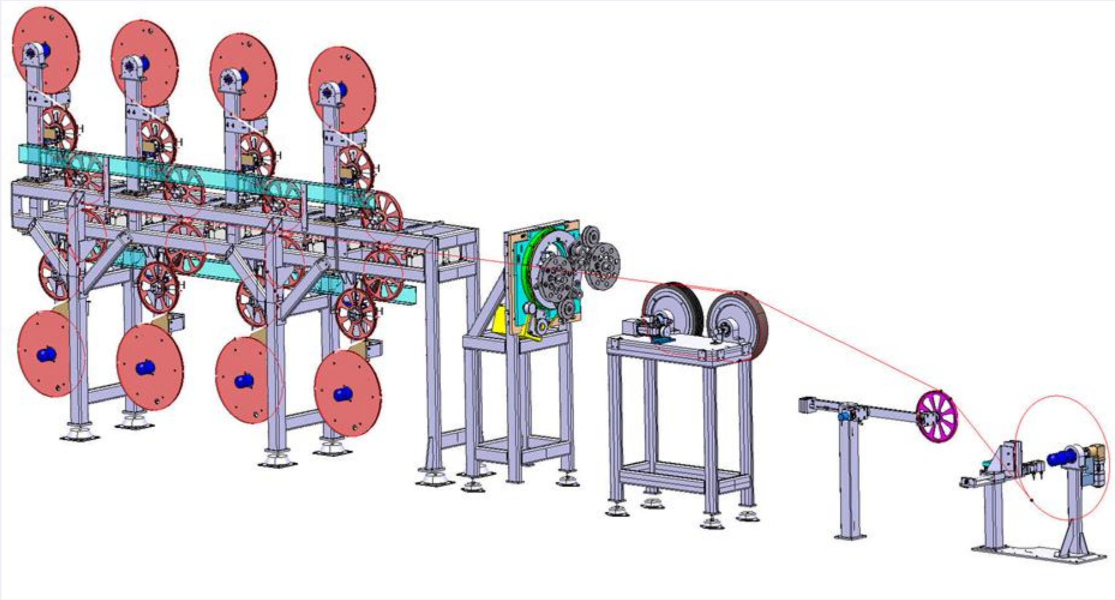
25 × 2 × 600 A (2 × 15 kA)
@ 35 K MgB_2
@ 65 K (YBCO and Bi-2223)

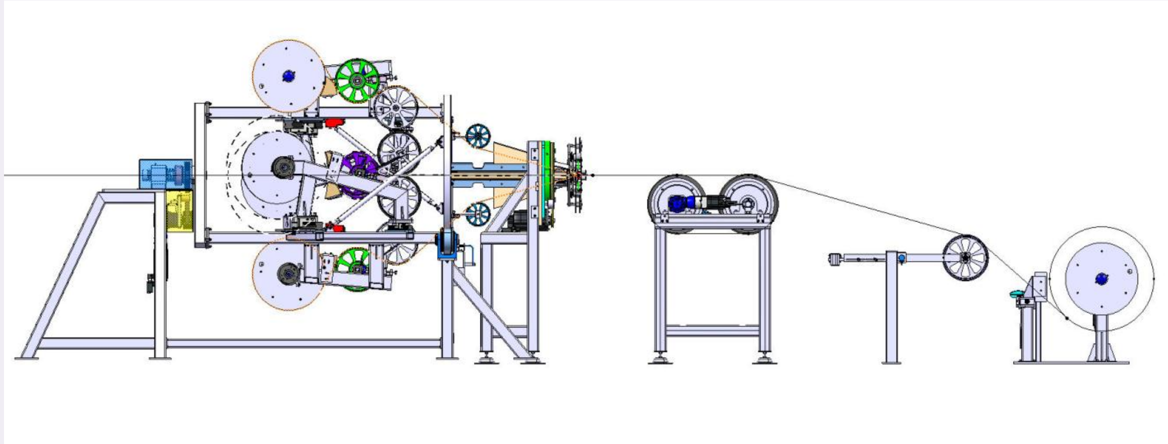


30 kA
~2 kg/m
~ 150 m_{HTS}/m_{cable}

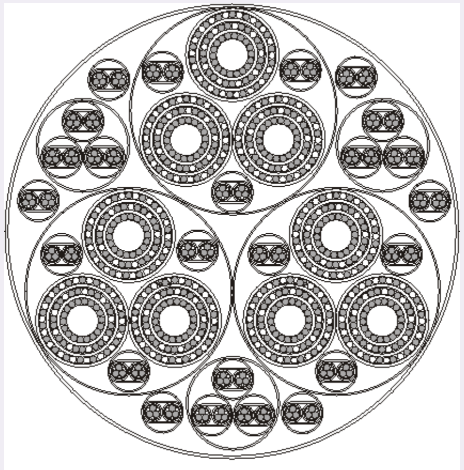


Cabling machines for long-lengths of twisted-pair cables





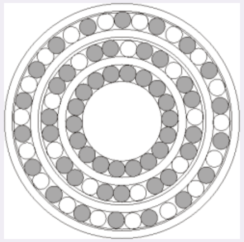
High-Current Cables



Φ = 75

27 cables 6000 A
48 cables 600 A
Itot = **190 kA @ 20 K**
(~2 × 95 kA)

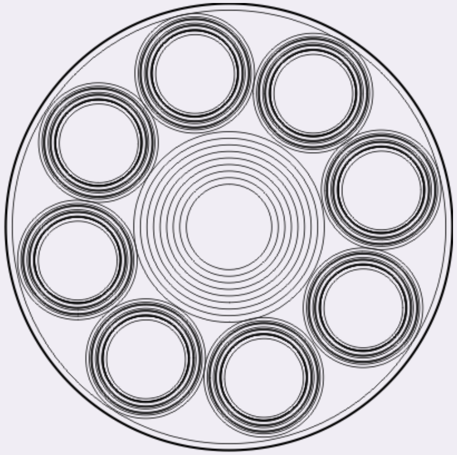
3 × 6 kA



Φ = 15.5

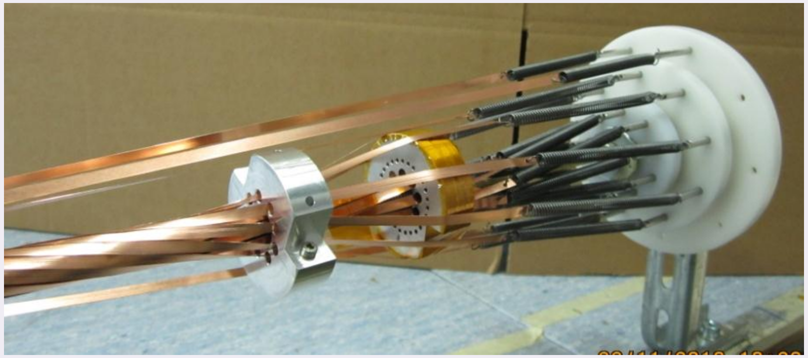
~**7 kg/m**

~ **900 m_{HTS}/m_{cable}**

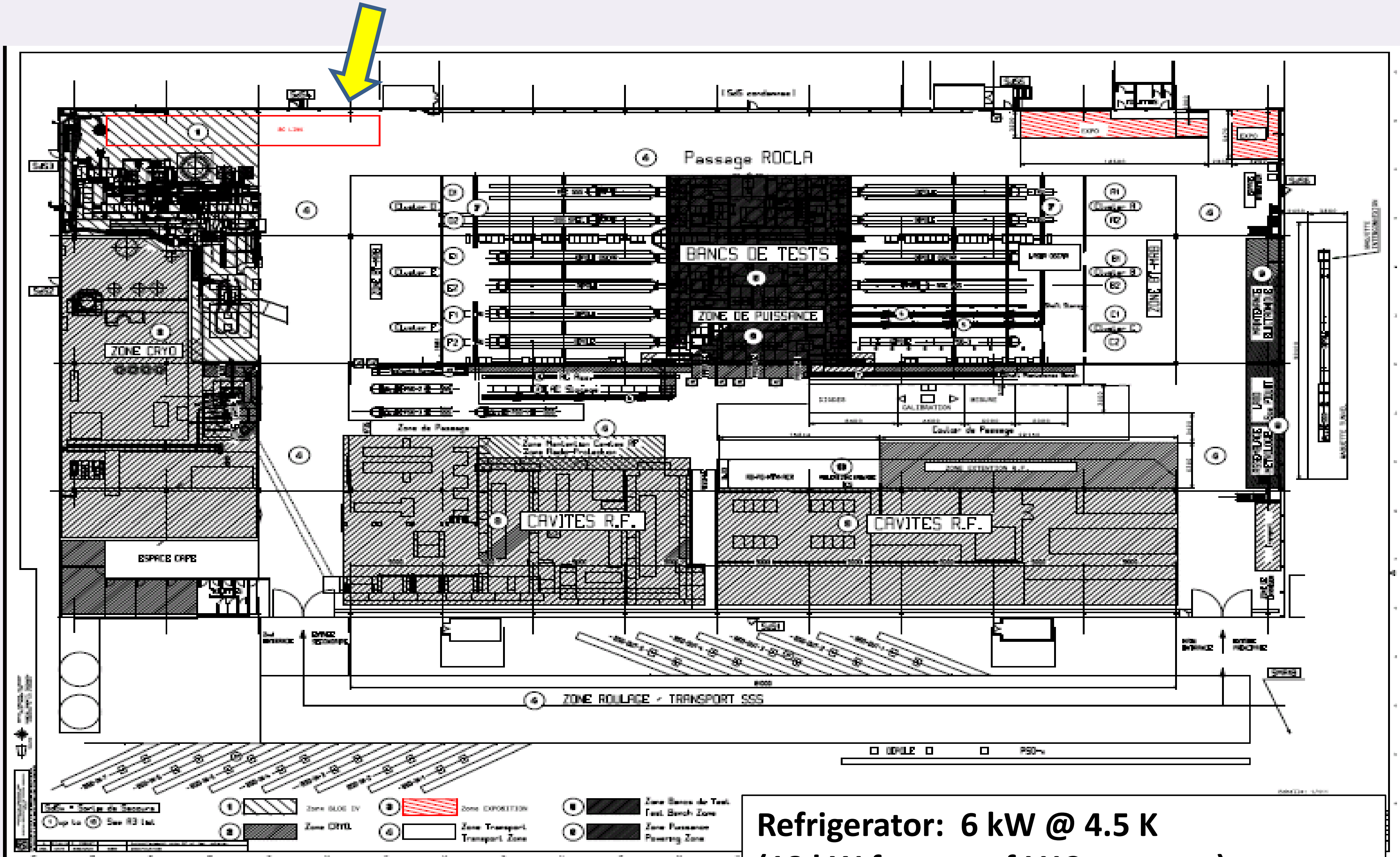


Φ =70

24 × 6000 A
42 × 600 A
Itot = **169 kA & 20 K**
(~ 2 × 84.5 kA)



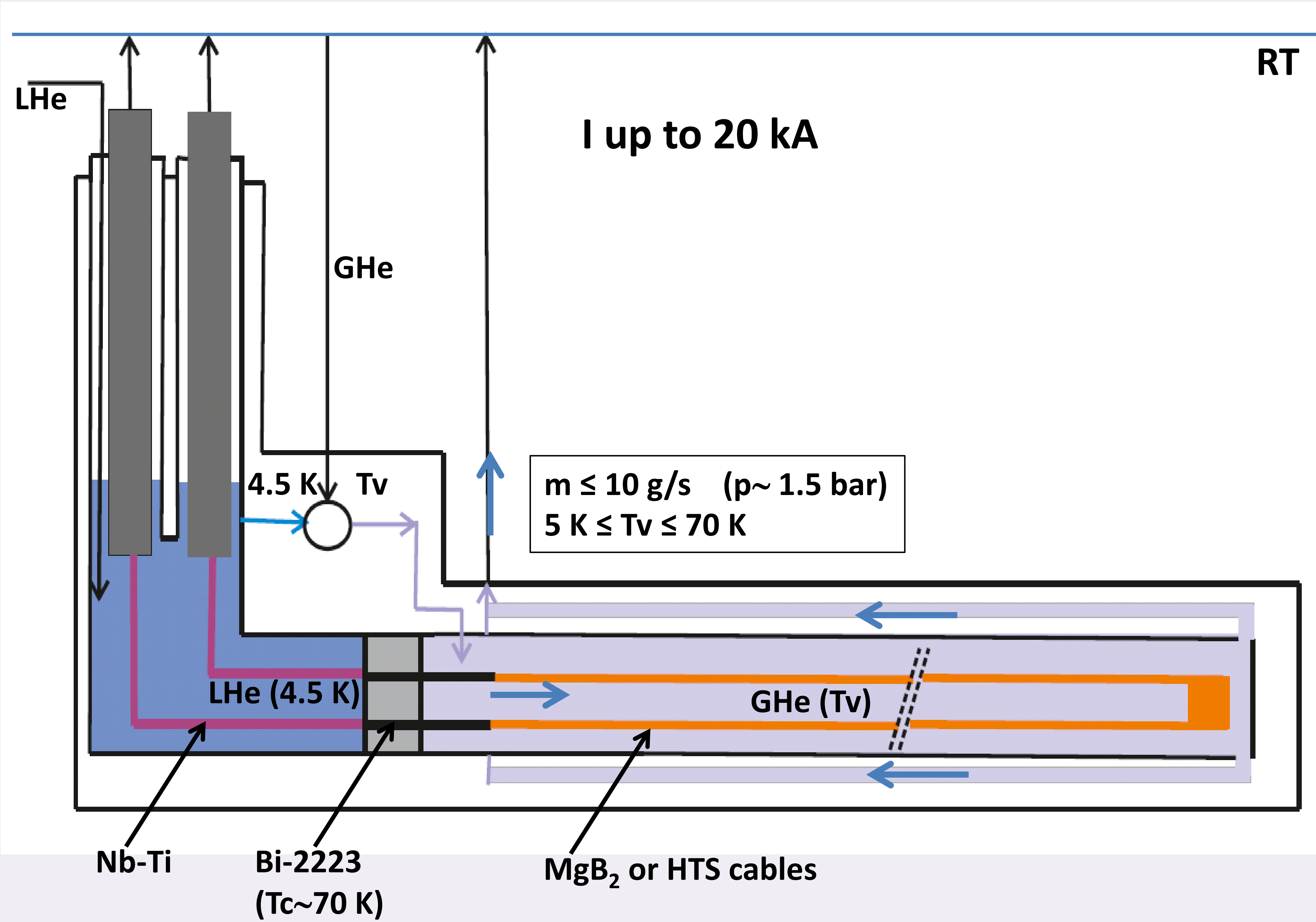
Test Station at CERN (SM-18 Laboratory)



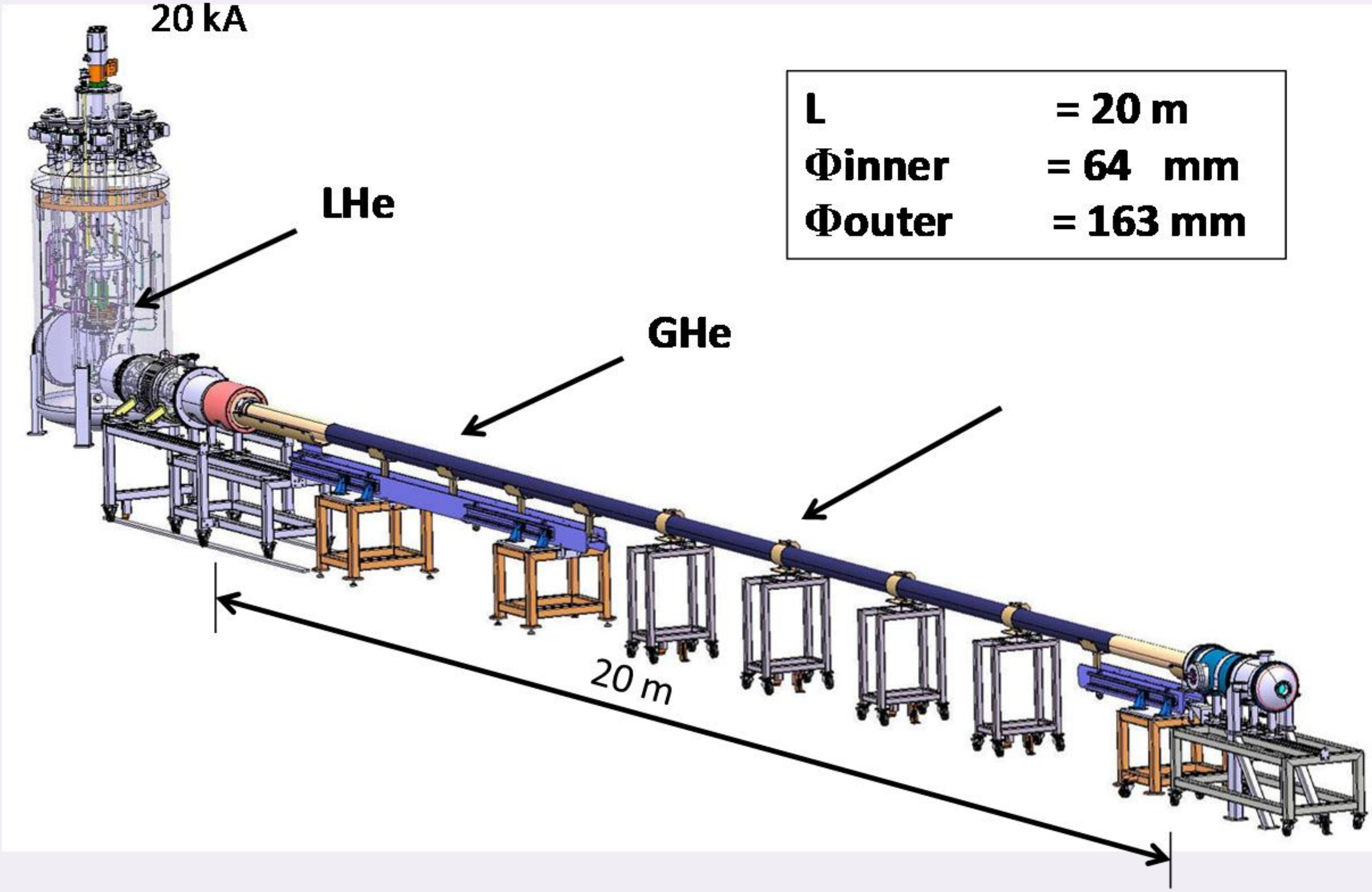
Refrigerator: 6 kW @ 4.5 K
(18 kW for test of LHC magnets)
25 000 LHe Dewar

Prévessin, French CERN site

CERN Test Station



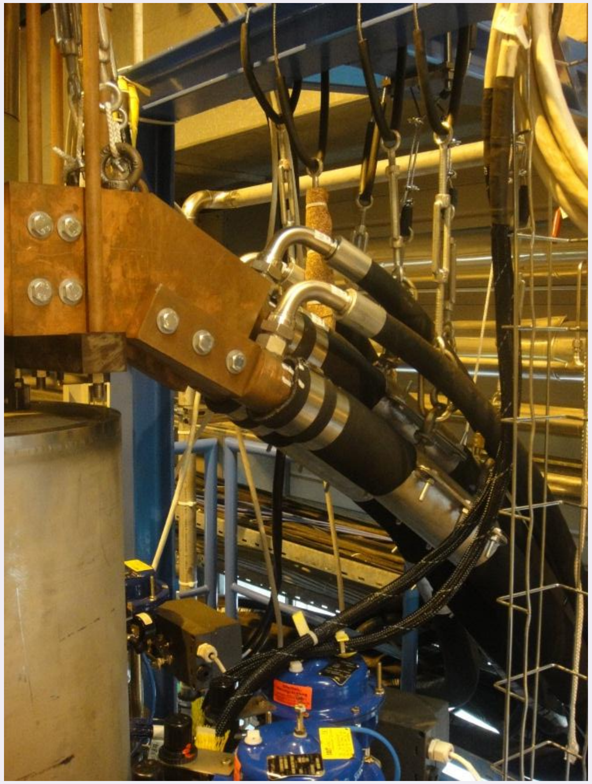
CERN Test Station



Nexans Semi-Flexible Cryostat

20-m Long Nexans Transfer Line

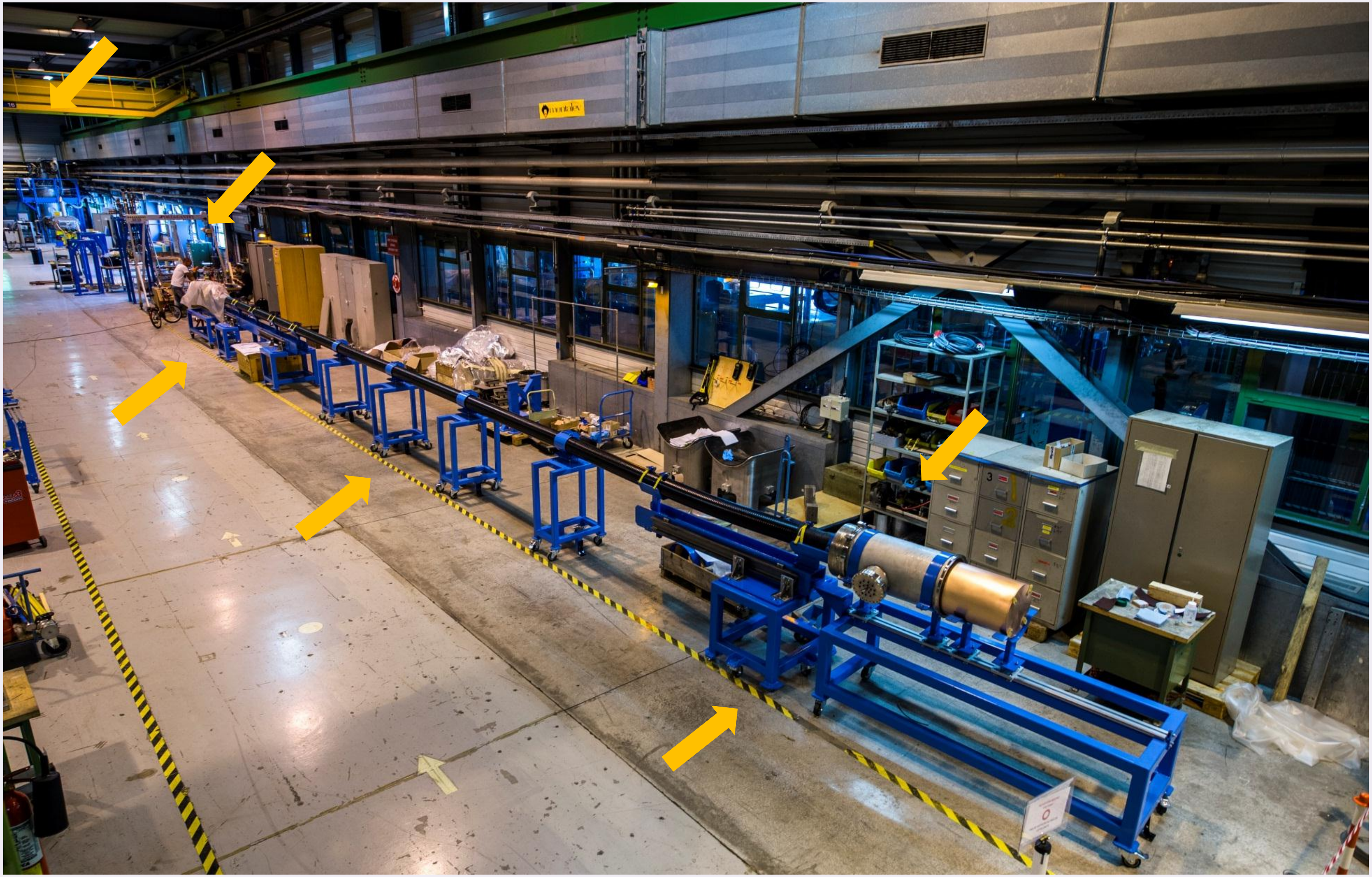

H ~ 4 m
FRAGILE!



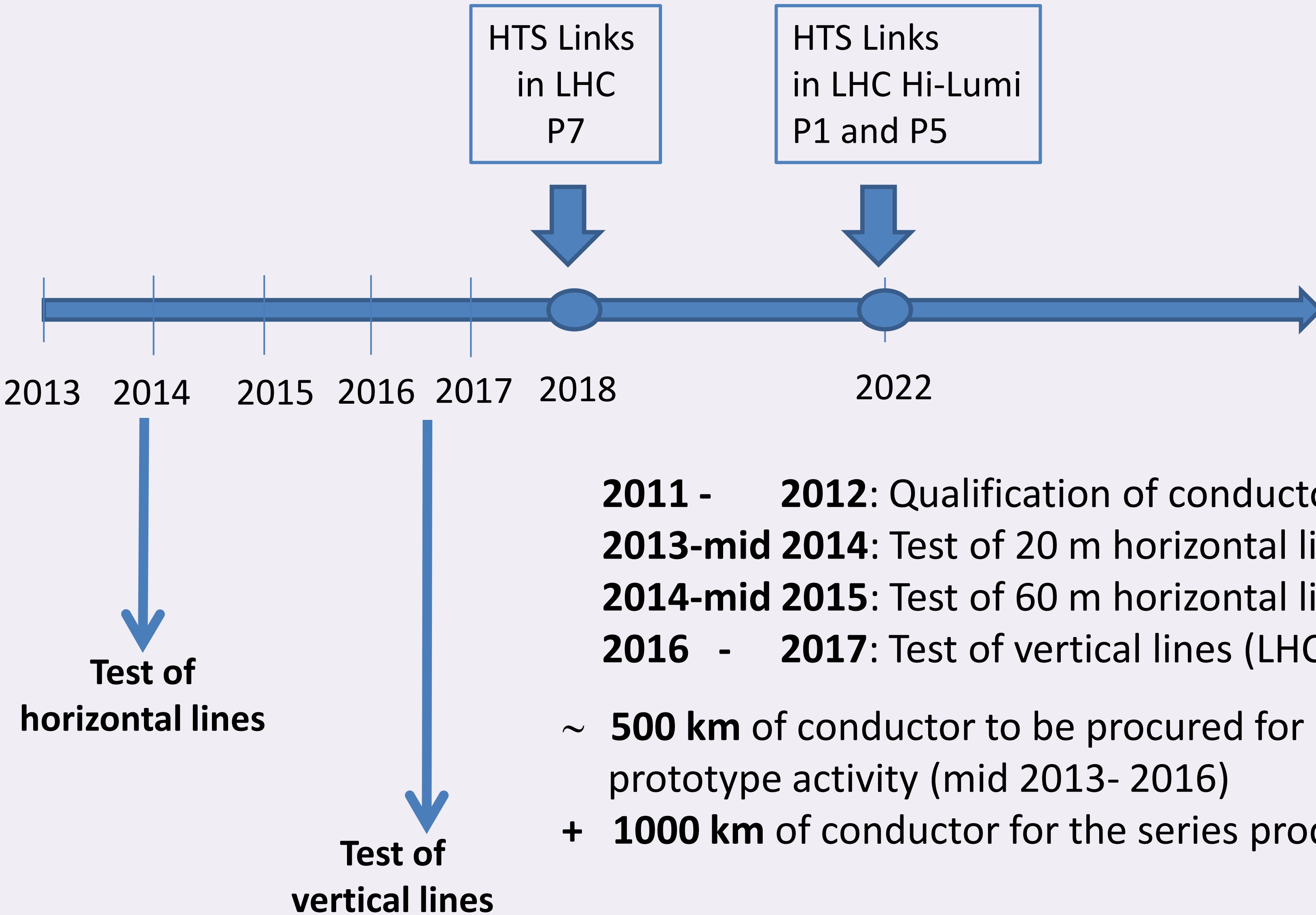

VELAN

CERN Test Station

Commissioning: November 2012

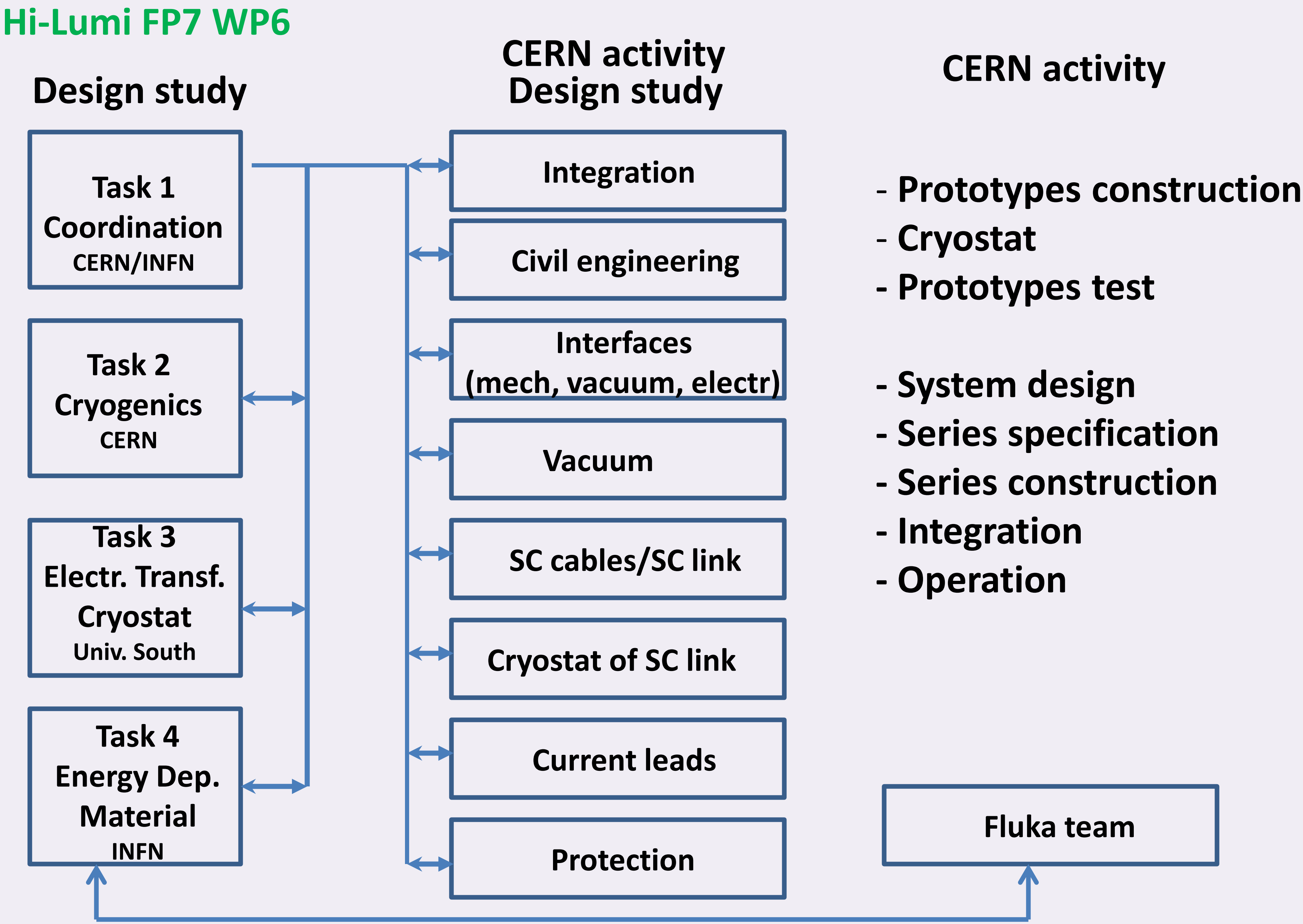


Timeline



2011 - 2012: Qualification of conductor
2013-mid 2014: Test of 20 m horizontal lines
2014-mid 2015: Test of 60 m horizontal lines
2016 - 2017: Test of vertical lines (LHC shaft)

~ **500 km** of conductor to be procured for prototype activity (mid 2013- 2016)
+ **1000 km** of conductor for the series production



Hi-Lumi FP7 WP6
Design study
CERN activity
Design study
CERN activity
Task 1
Coordination
CERN/INFN
Task 2
Cryogenics
CERN
Task 3
Electr. Transf.
Cryostat
Univ. South
Task 4
Energy Dep.
Material
INFN
Integration
Civil engineering
Interfaces
(mech, vacuum, electr)
Vacuum
SC cables/SC link
Cryostat of SC link
Current leads
Protection
- Prototypes construction
- Cryostat
- Prototypes test
- System design
- Series specification
- Series construction
- Integration
- Operation
Fluka team

Conclusions

Superconducting links: potential application of MgB_2 or HTS to the LHC machine. This is a viable target for a medium scale application of HTS material in its present state of development. It requires the supply of significant lengths of material (> 1000 km) to a user specification

In addition to the MgB_2 and/or HTS SC cables, other technologies are required for the superconducting link project: HTS current leads, cryostats for the leads and for electrical interconnections, and cryogenic envelopes for the superconducting cables

Thanks for your attention !