Recent progress on the high-current testing facility for superconducting cables at CERN

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Advisory Committee Meeting

IASS – Potsdam

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Outline

- Introduction
- MgB_2 electrical transfer lines: CERN activity in 2012
  - Superconducting links for the LHC machine
  - Conductor development and characterization
  - Development of cables for electrical transmission
  - Design of novel test station
- Plan for future activities
- Conclusions

Introduction

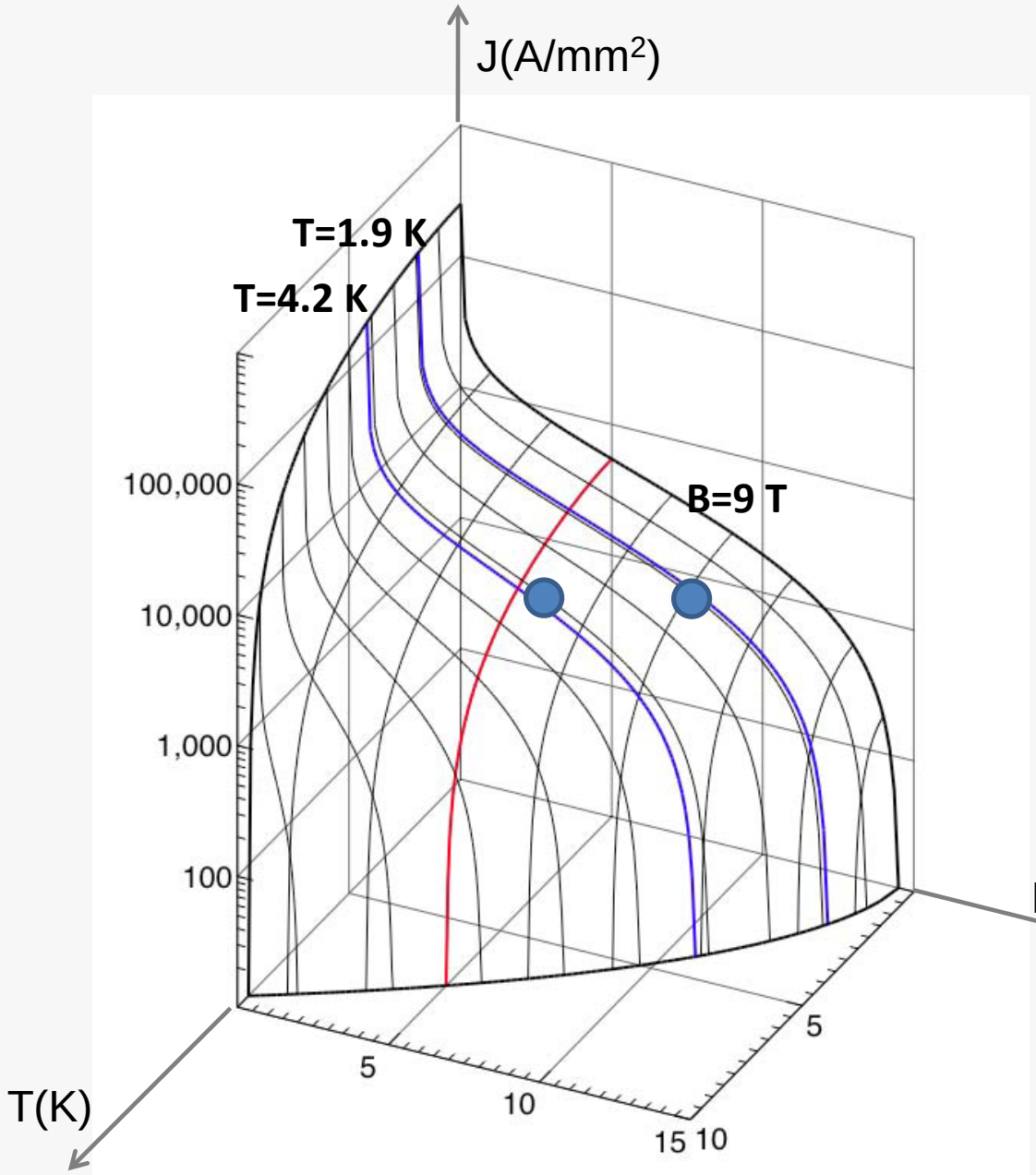
- Superconductivity at CERN $\rightarrow$ high-field magnets

- LHC: Nb-Ti @ 1.9 K
  Very high and uniform current density
  Small superconducting filament size
  Precise dimensions
  Appropriate and controlled Cu/non Cu ratio

  In LHC: more than 240 000 km of Nb-Ti strand

- LHC upgrades: Nb_3Sn @ 1.9 K

LHC Strands



Nb-Ti (LHC Machine)

Jc(4.2 K, 6 T)~2300 A/mm^2

Jc(1.9 K, 9 T)~2300 A/mm^2

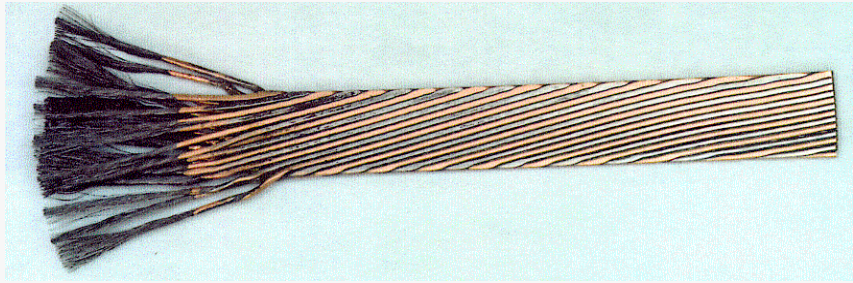
Nb_3Sn (LHC Upgrades)

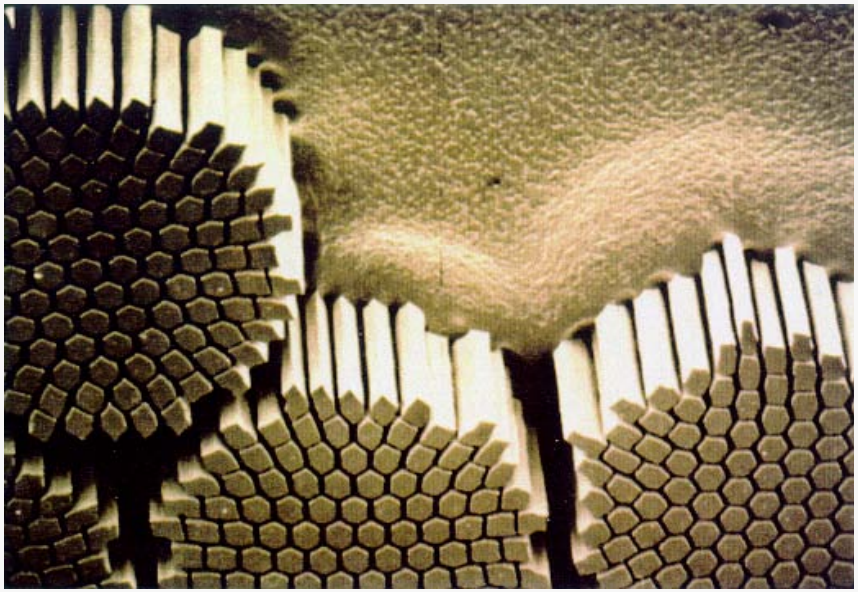
Jc(4.2 K, 12 T)~2500 A/mm^2

Cables for LHC Dipole Magnets

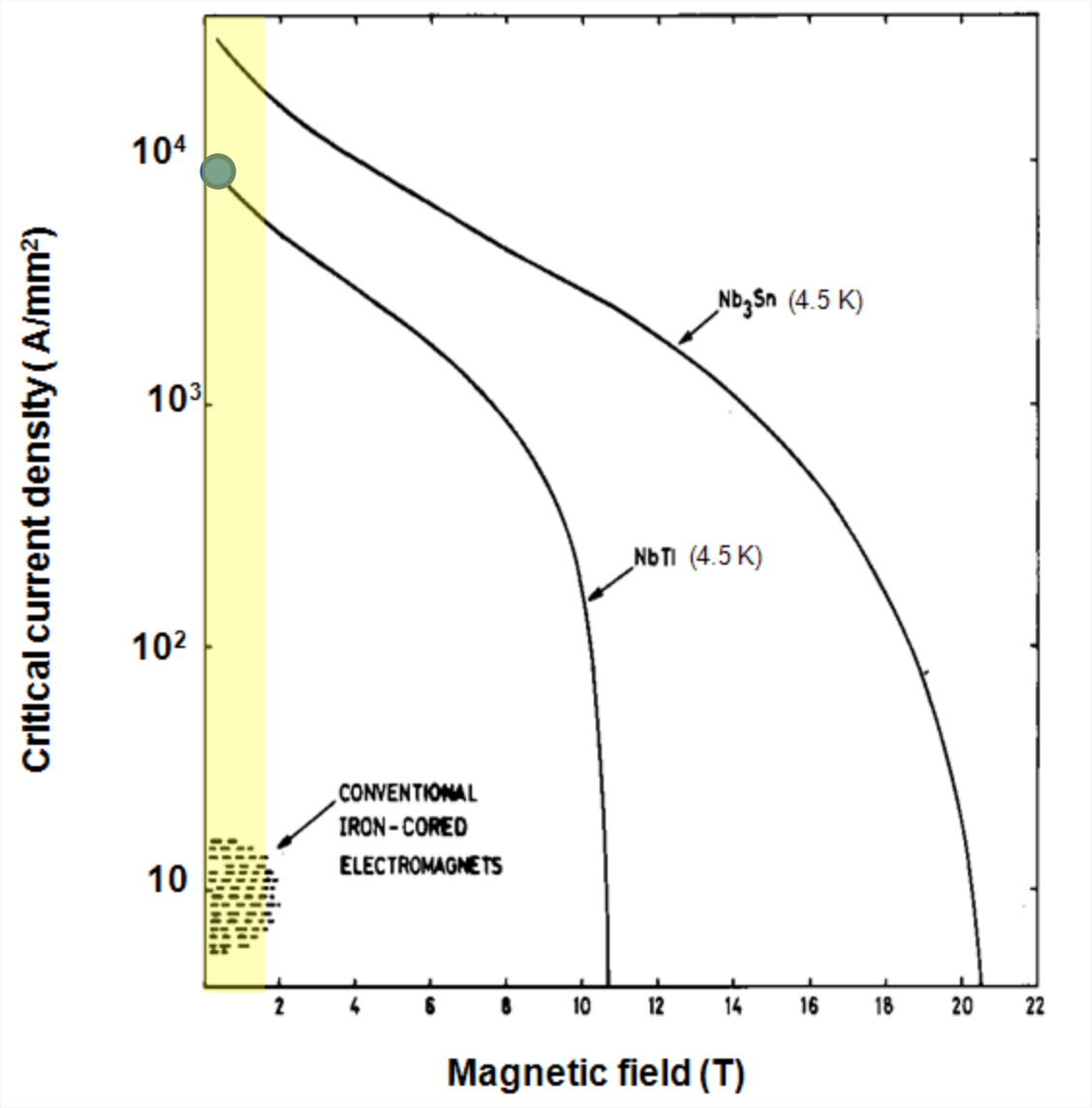
Performance specification

STRAND	Type 01	Type
Diameter (mm)	1.065	0.82
Cu/NbTi ratio	1.6-1.7 ± 0.03	1.9-2.0 ±
Filament diameter (μm)	7	6
Number of filaments	8800	642
Jc (A/mm^2) @1.9 K	1530 @ 10 T	2100 @
μ_0M (mT) @1.9 K, 0.5 T	30 ±4.5	23 ±4
CABLE	**Type 01**	**Type**
Number of strands	28	36
Width (mm)	15.1	15.1
Mid-thickness (mm)	1.900 ±0.006	1.480 ±(
Keystone angle (degrees)	1.25 ±0.05	0.90 ±(
Cable Ic (A) @ 1.9 K	13750 @ 10T	12960 (
Interstrand resistance (μΩ)	10-50	20-8





Cable compaction ~ 91 %



Jc(MgB_2, 4.2 K, s.f.) ~ 10000 A/mm^2

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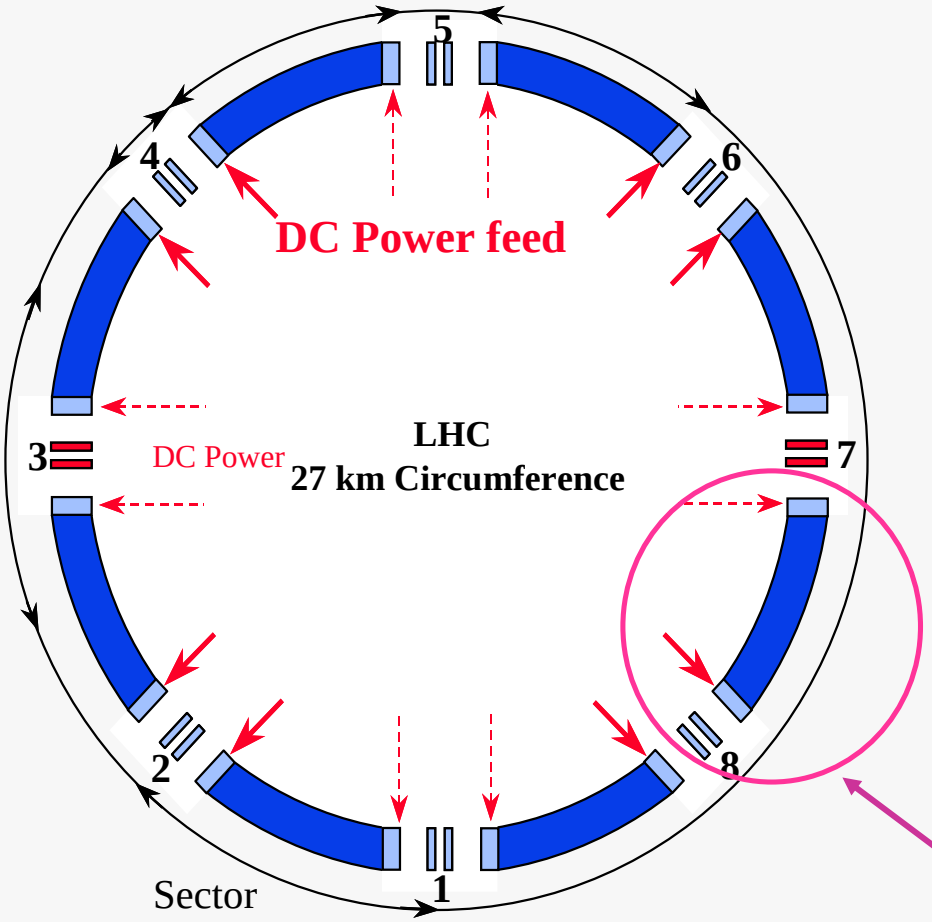
Powering of LHC Machine

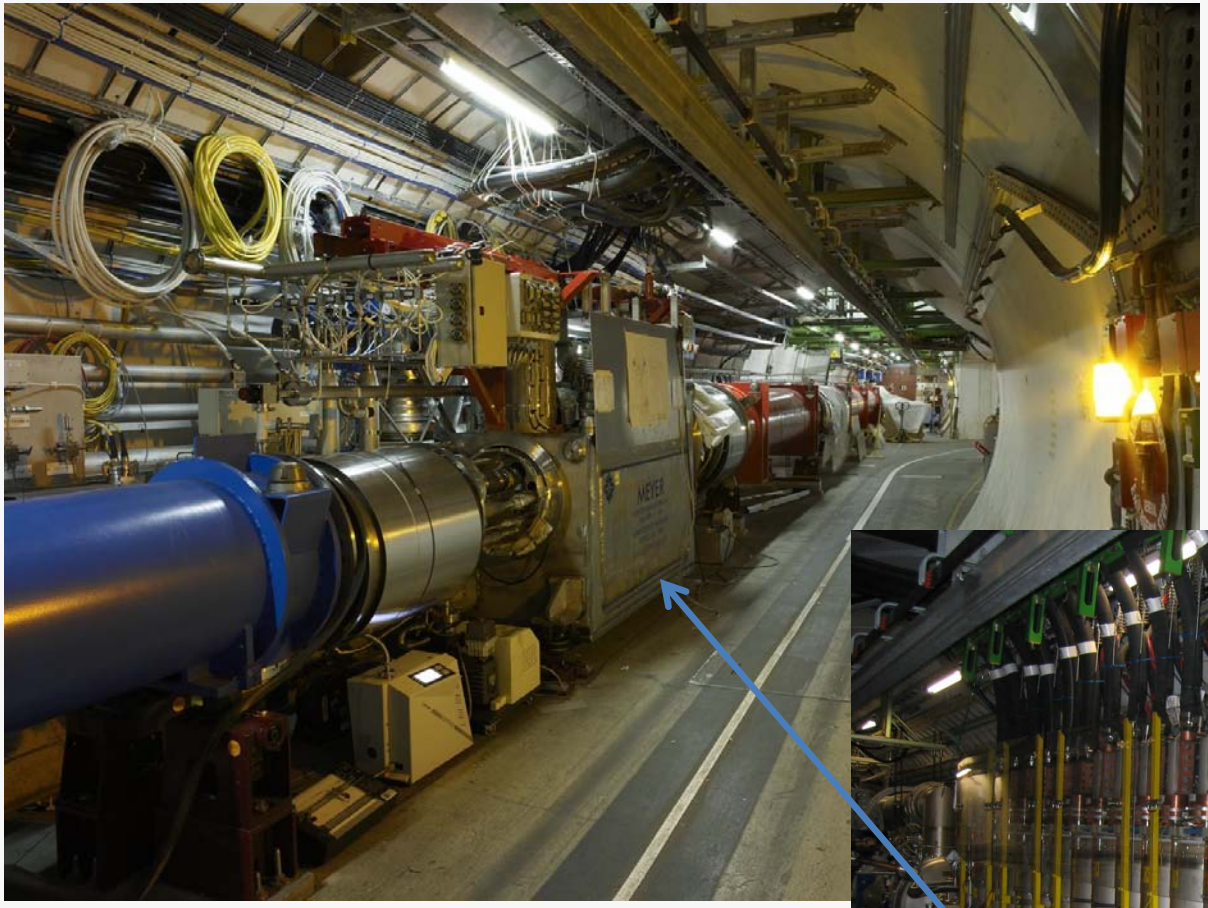


- To limit the stored energy within one electrical circuit, the LHC is powered by sectors
- The main dipole circuits are split into 8 sectors to bring down the stored energy to ~1 GJ/sector
- Each sector (~2.9 km) includes 154 dipole magnets (powered in series) and ~50 quadrupoles

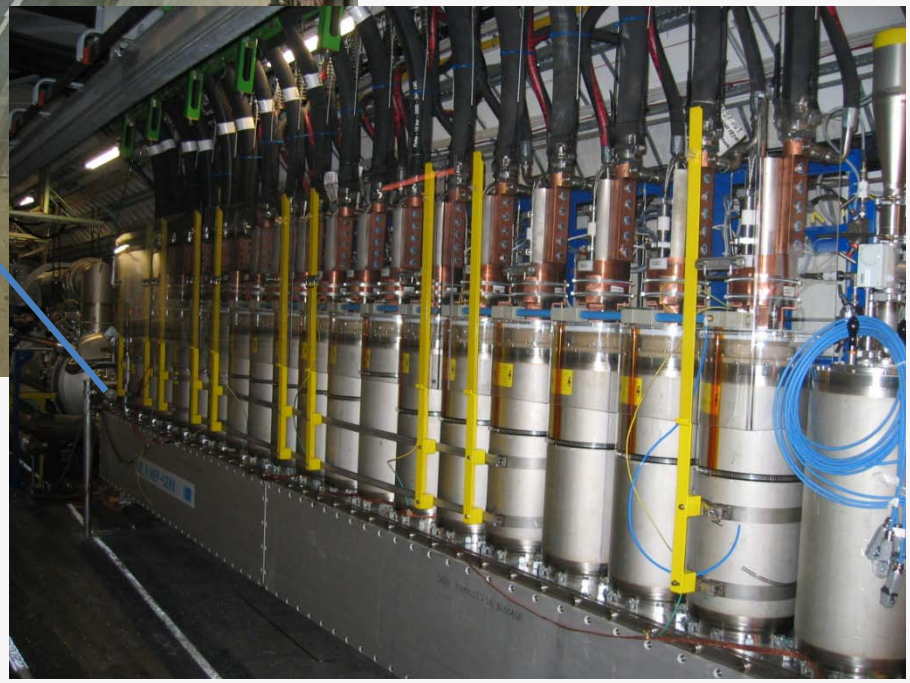
Powering Sector

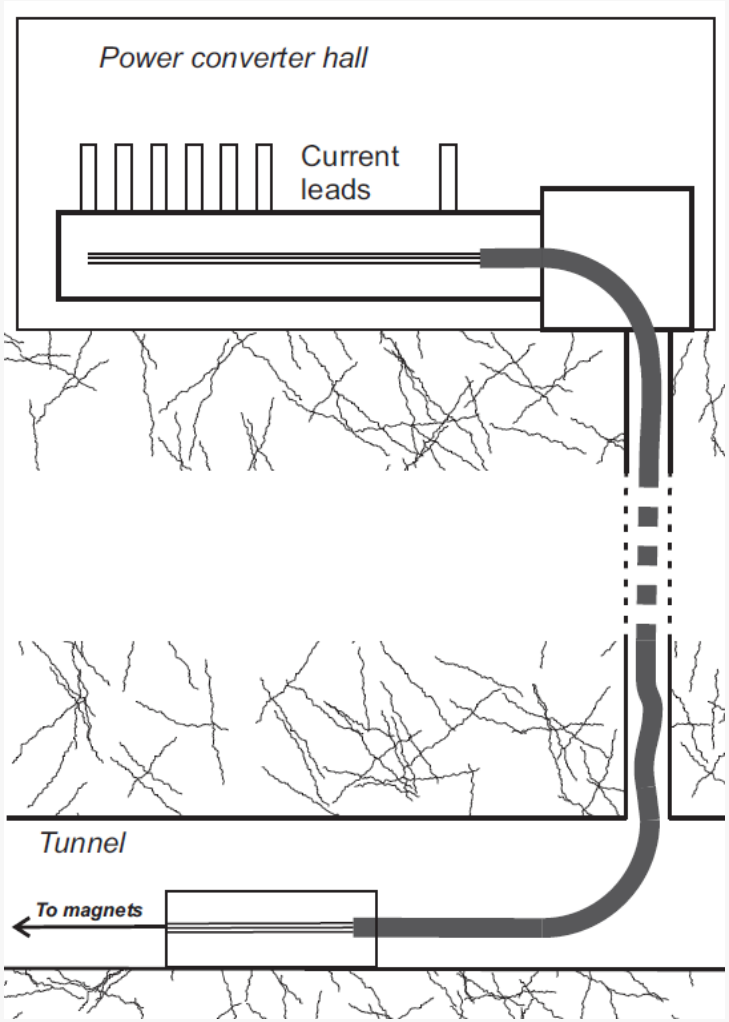
~ 3.4 MA, > 3000 Current Leads, ~ 1500 Electrical Circuits

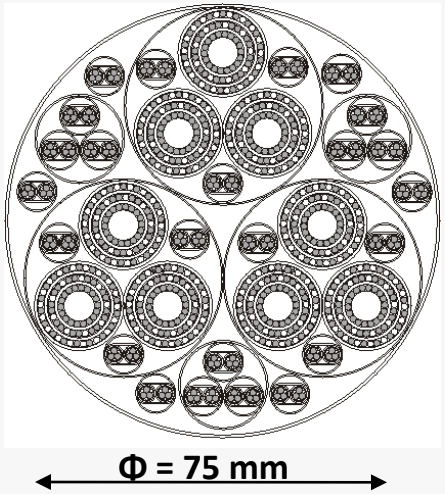
LHC Tunnel



In tunnel alcoves







27 × 6000 A
48 × cables 600 A
Itot = 190 kA

Multi-cable assemblies
He gas cooling

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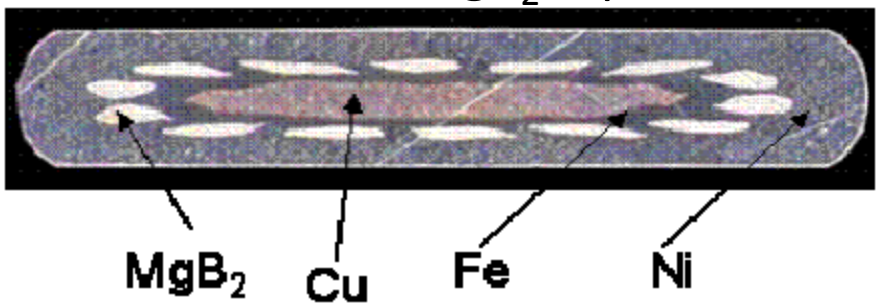
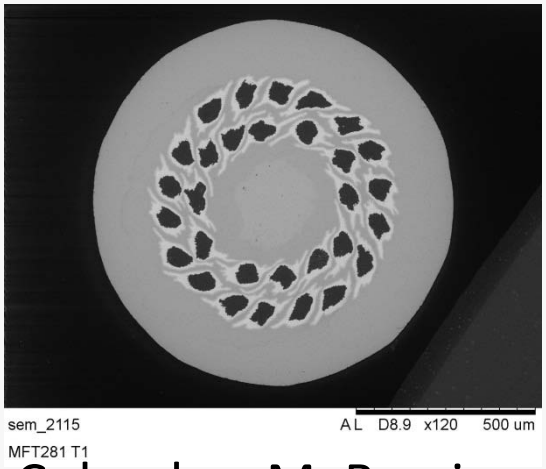
Columbus MgB_2 tape



4 × 0.67 mm²



Columbus MgB_2 wire

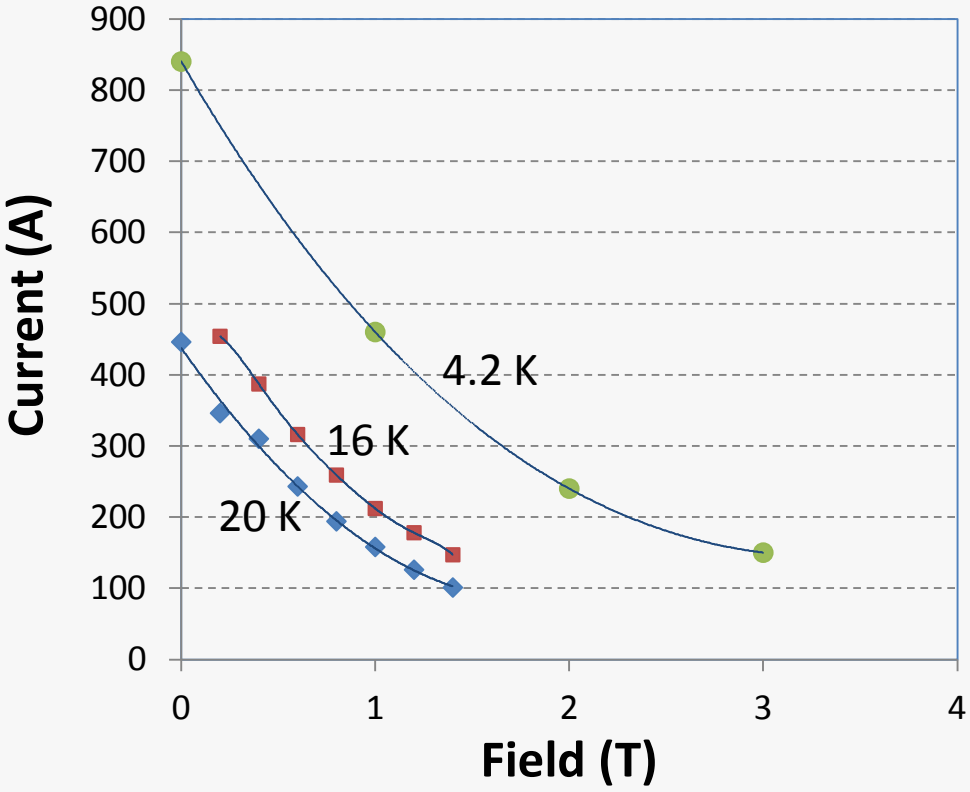
Atot = 0.8 mm²
Asc = 0.0028 mm²
ff = 10 %

Φ ~ 1 mm

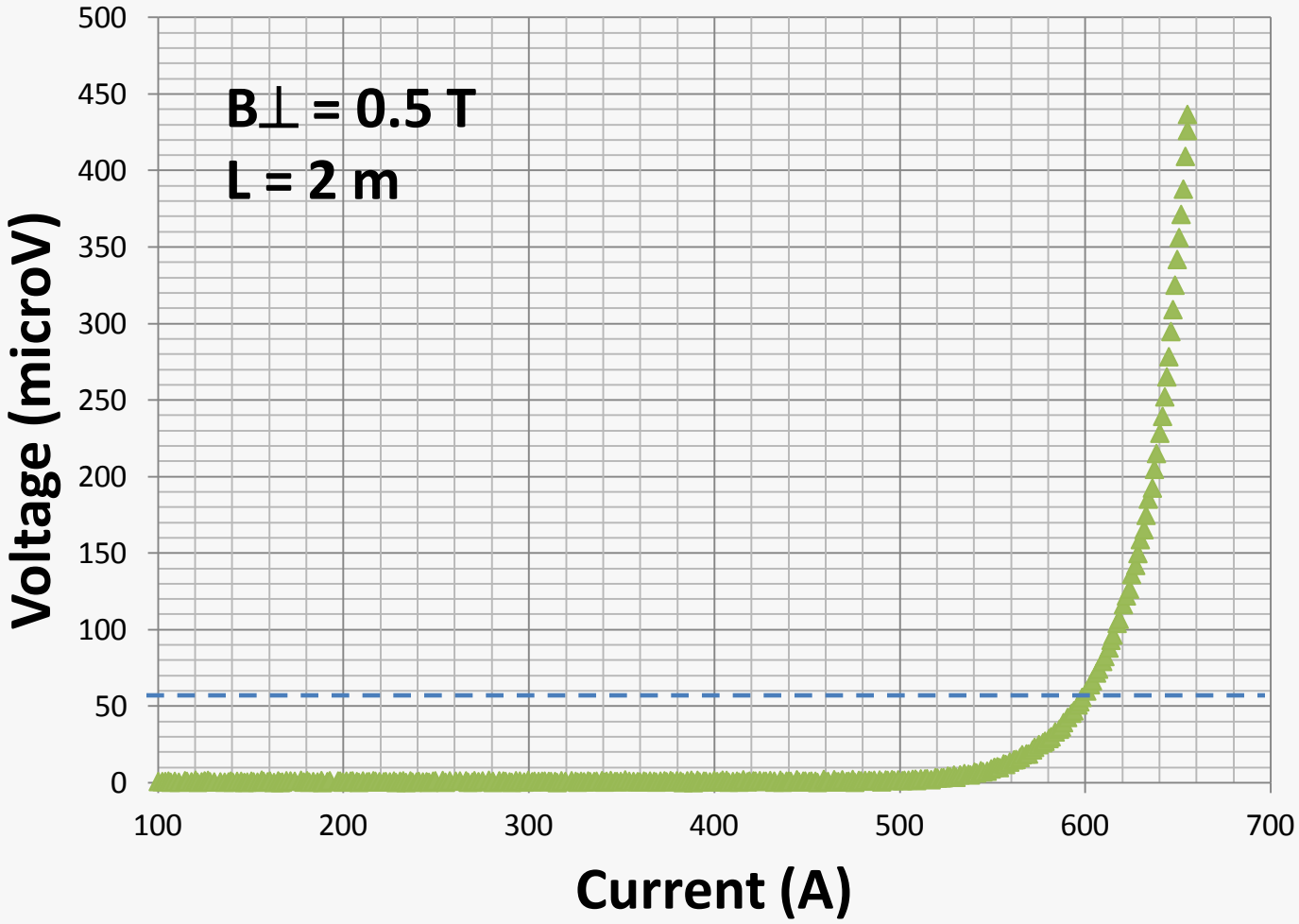
Target performance characteristics

Ic(20 K, 0.5 T)	> 500 A	A
Ic(25 K, 0.5 T)	> 400 A	A
Ic (30 K, 0.06 T)	> 300 A	A
Jc,eng(20 K, 0.5 T)	> 630	A/mm^2
Jc,eng(25 K, 0.5 T)	> 500	A/mm^2
Jc,eng(30 K, 0.06 T)	> 380	A/mm^2
n-value (25 K, 0.5 T)	> 30	
Φext of strand	< 1	mm
Number of filaments*	37/61/91	
Φext of MgB_2 filaments	< 50	µm
Copper stabilizer	≥ 12	%
RRR Copper stabilizer*	> 80	
Twist pitch of filaments*	≤ 100	mm
Bending radius*	< 100	mm
Critical tensile strain (RT)*	> 0.3	%
Unit length	1000	m

*Reacted wires



Measurements @ CERN (4.2 K) and Columbus (16 K and 20 K)


B⊥ = 0.5 T
L = 2 m
Voltage (microV)
Current (A)
500
450
400
350
300
250
200
150
100
50
0
100
200
300
400
500
600
700

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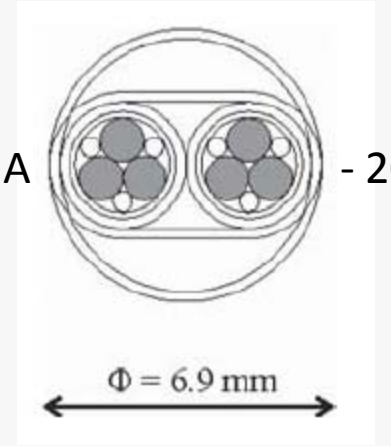
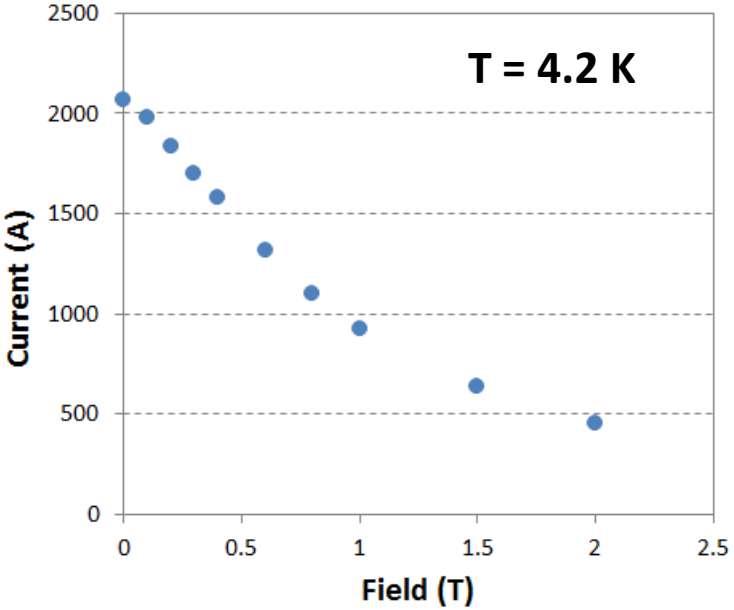
1-kA Range Cables

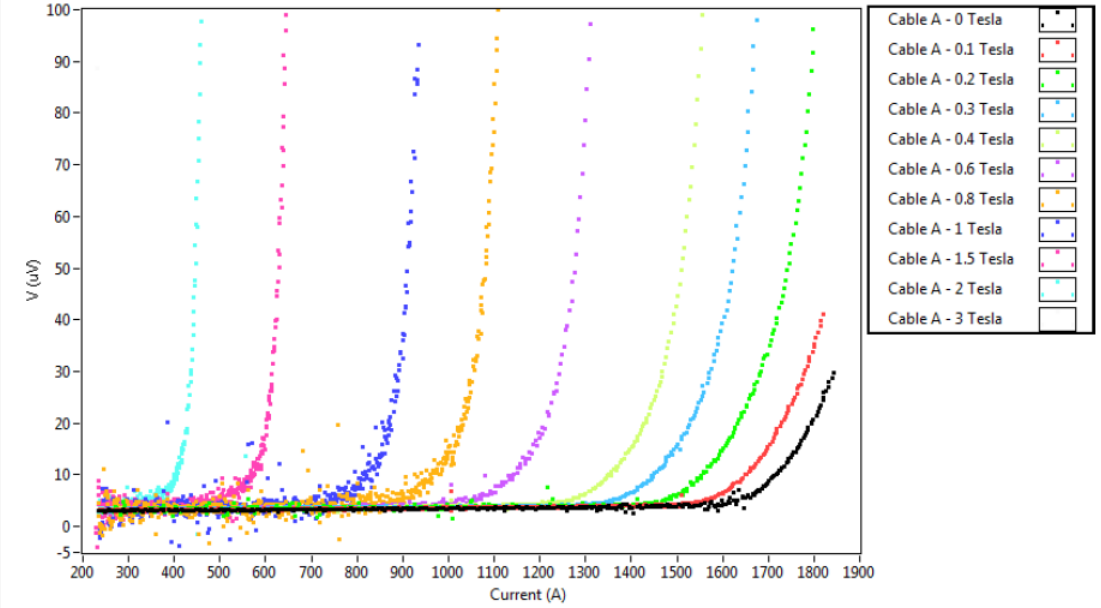
Ic(4.2 K, s.f.) = 2070 A

+ 2070 A

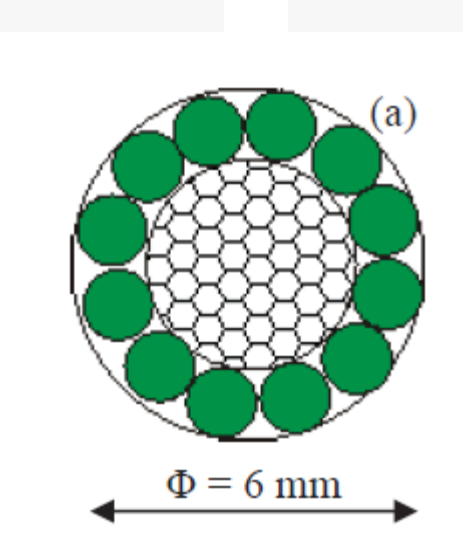


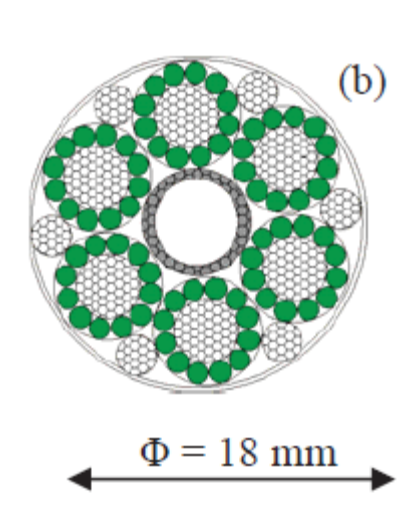
- 2070 A





10-kA Range Cables





1 cable → 12 MgB_2 wires

Ic(4.2 K, s.f.) ~ 7300 A

Ic(16 K, s.f.) ~ 5100 A

6 cables

Ic(16 K, s.f.) ~ 21000 A

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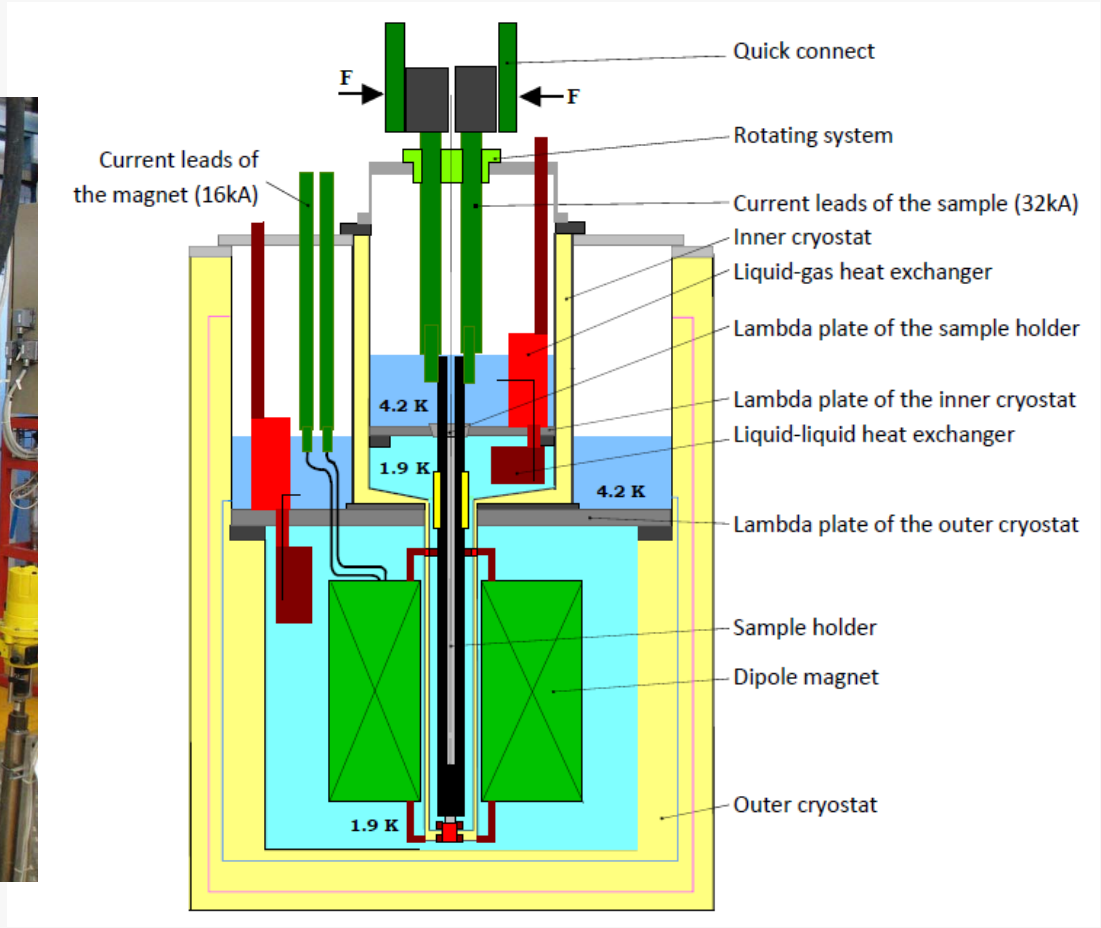
Conductor Characterization in Existing Test Stations



Test stations (4)
Ic measurement of wires
4.2 K or **1.9 K**, **4 kA**, 15 T
LSC ~**20 cm** (straight samples)

Fresca test station
Ic measurement of wires or cables
4.2 K or **1.9 K**, **32 kA**, 10 T
LSC up to **2 m**

Development of a novel test station

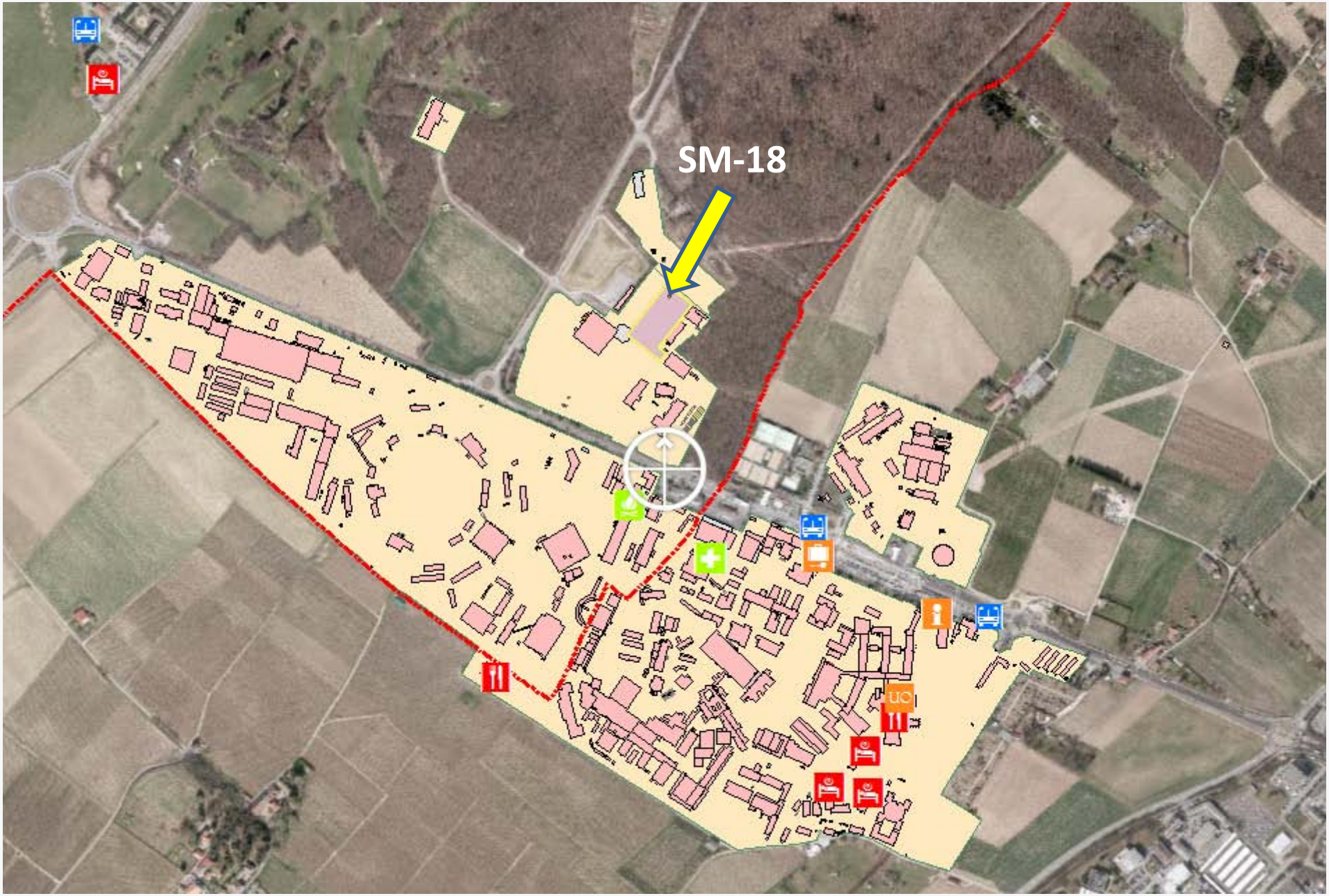
Design a **new test station** for the electrical characterization of superconducting cables operated in **helium gas** at various temperatures in the range **5 K** to **70 K**

Use of existing cryogenic and electrical infrastructure available in the laboratory SM-18:

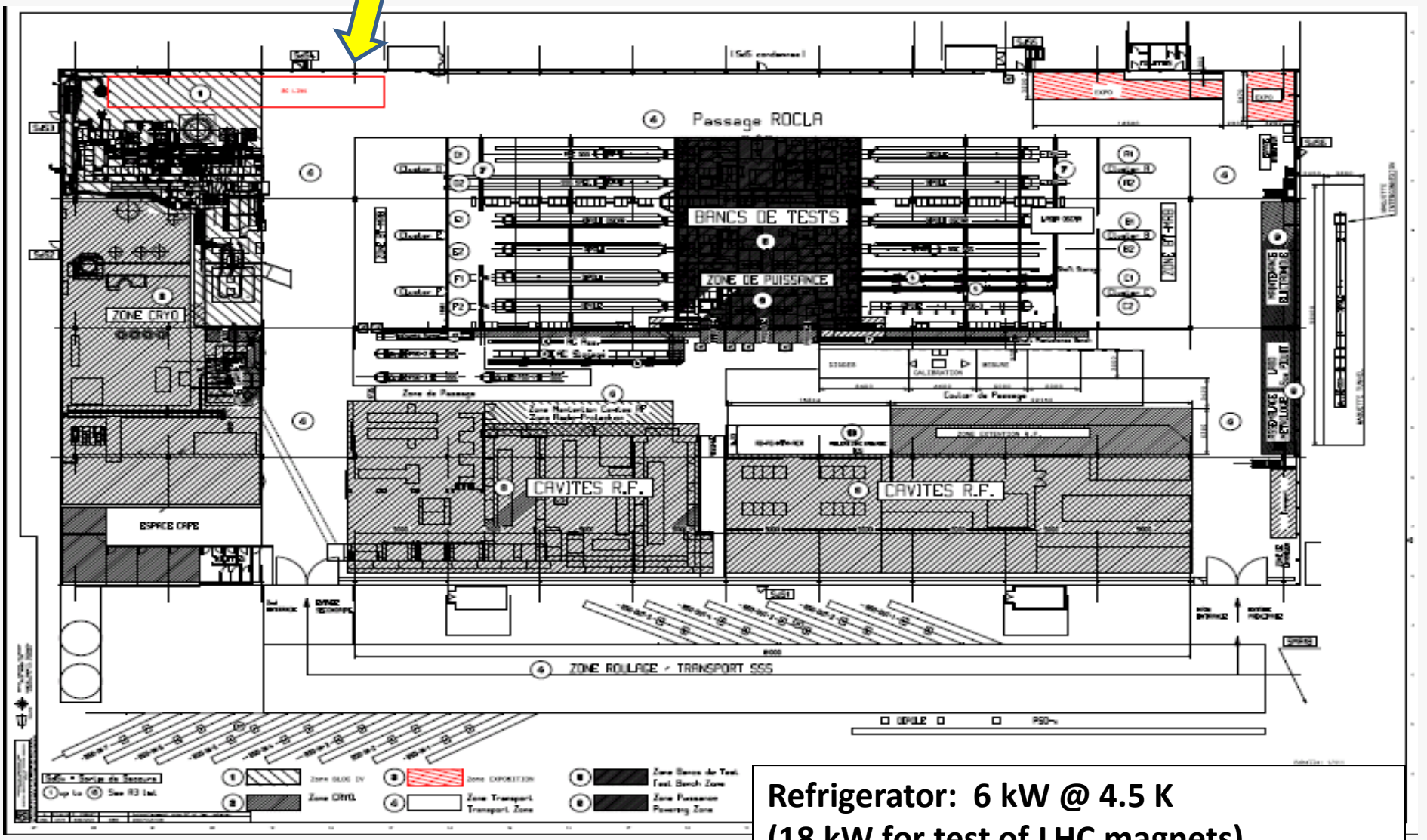
20 kA DC power converter;
liquid He (**6 kW He refrigerator**);
as well as the space required for integration of long transfer lines

Test of cables with a length of up to **20 m**

Location of SM-18



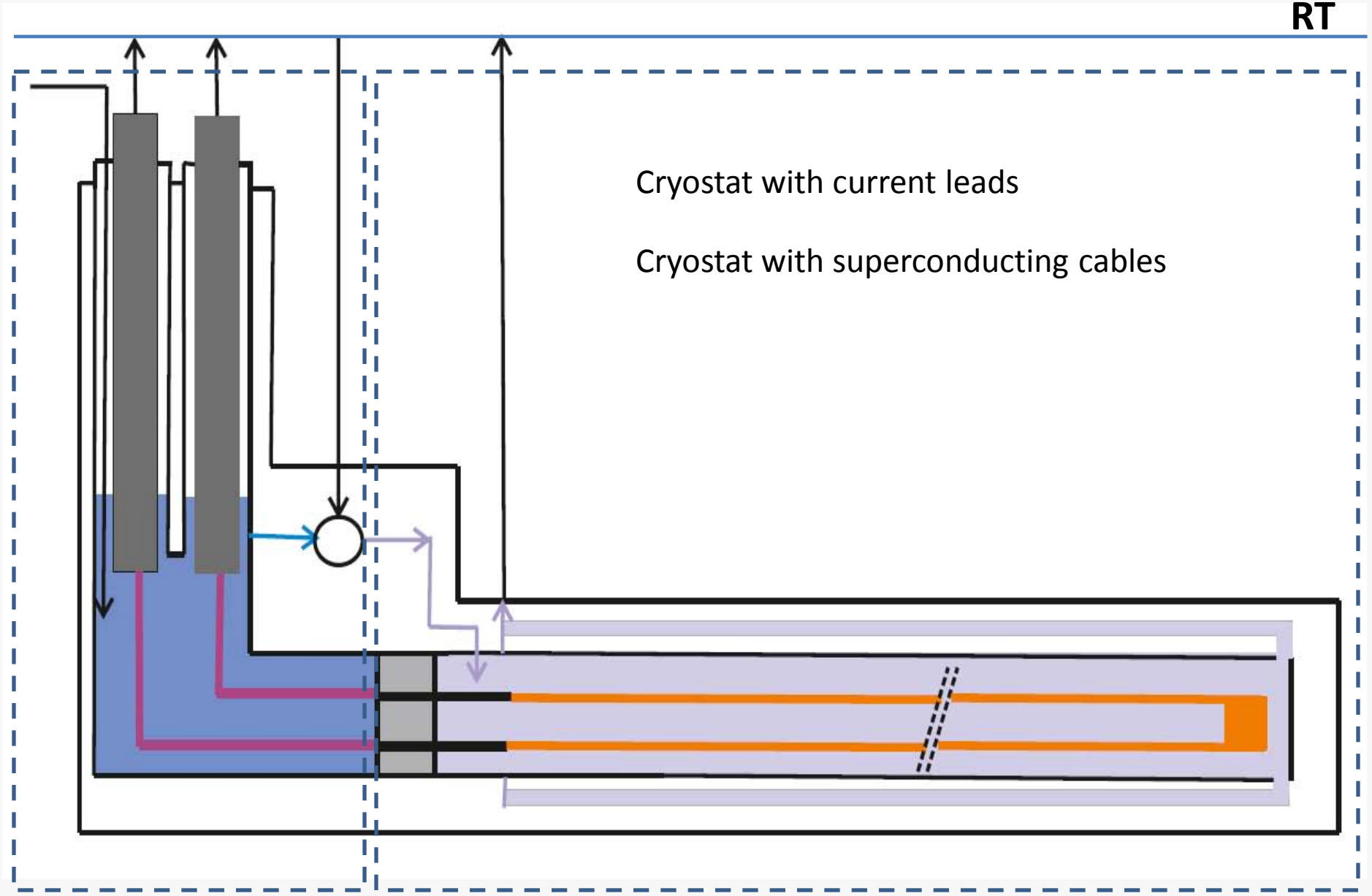
CERN, SM-18 Laboratory



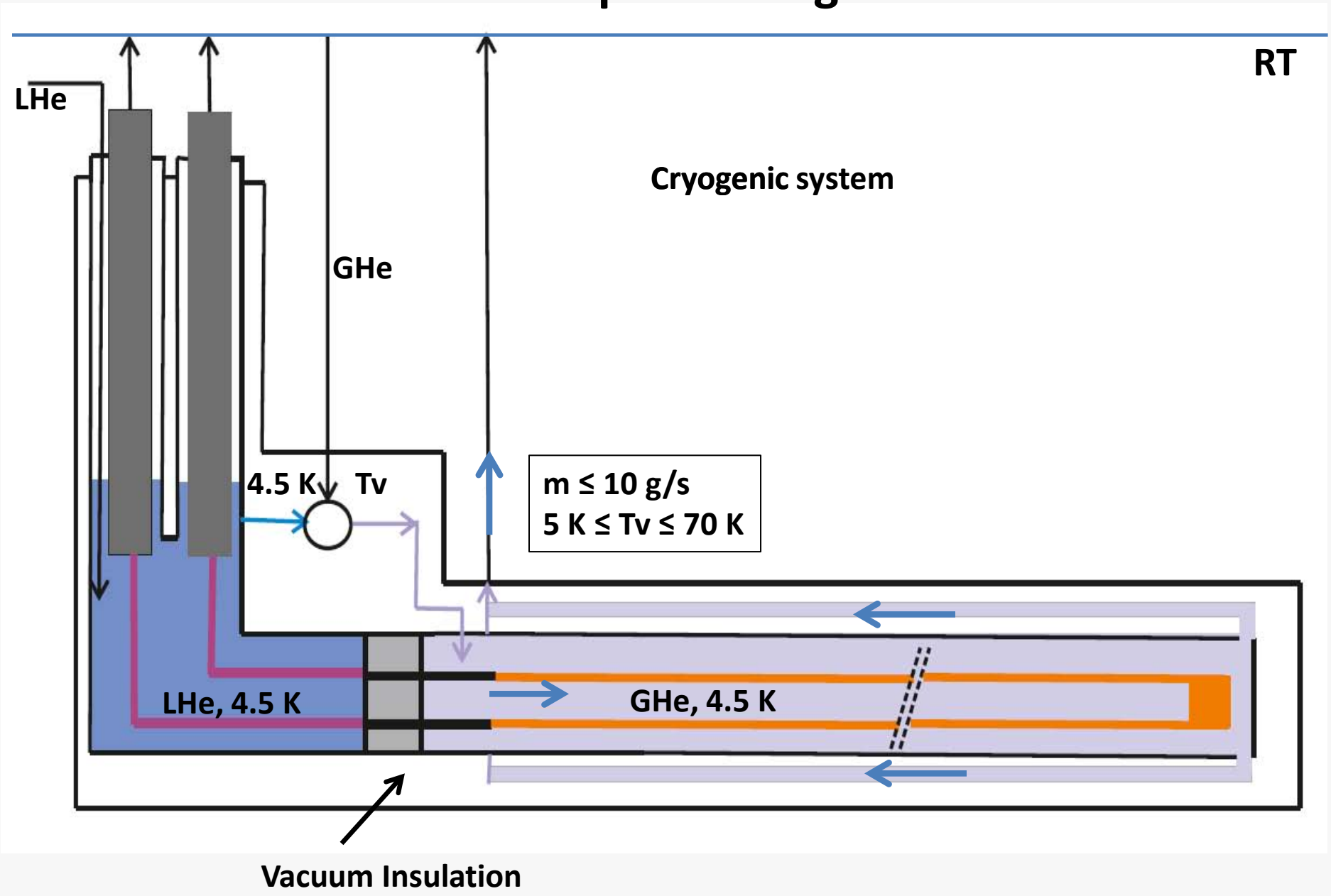
Prévessin, French CERN site

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

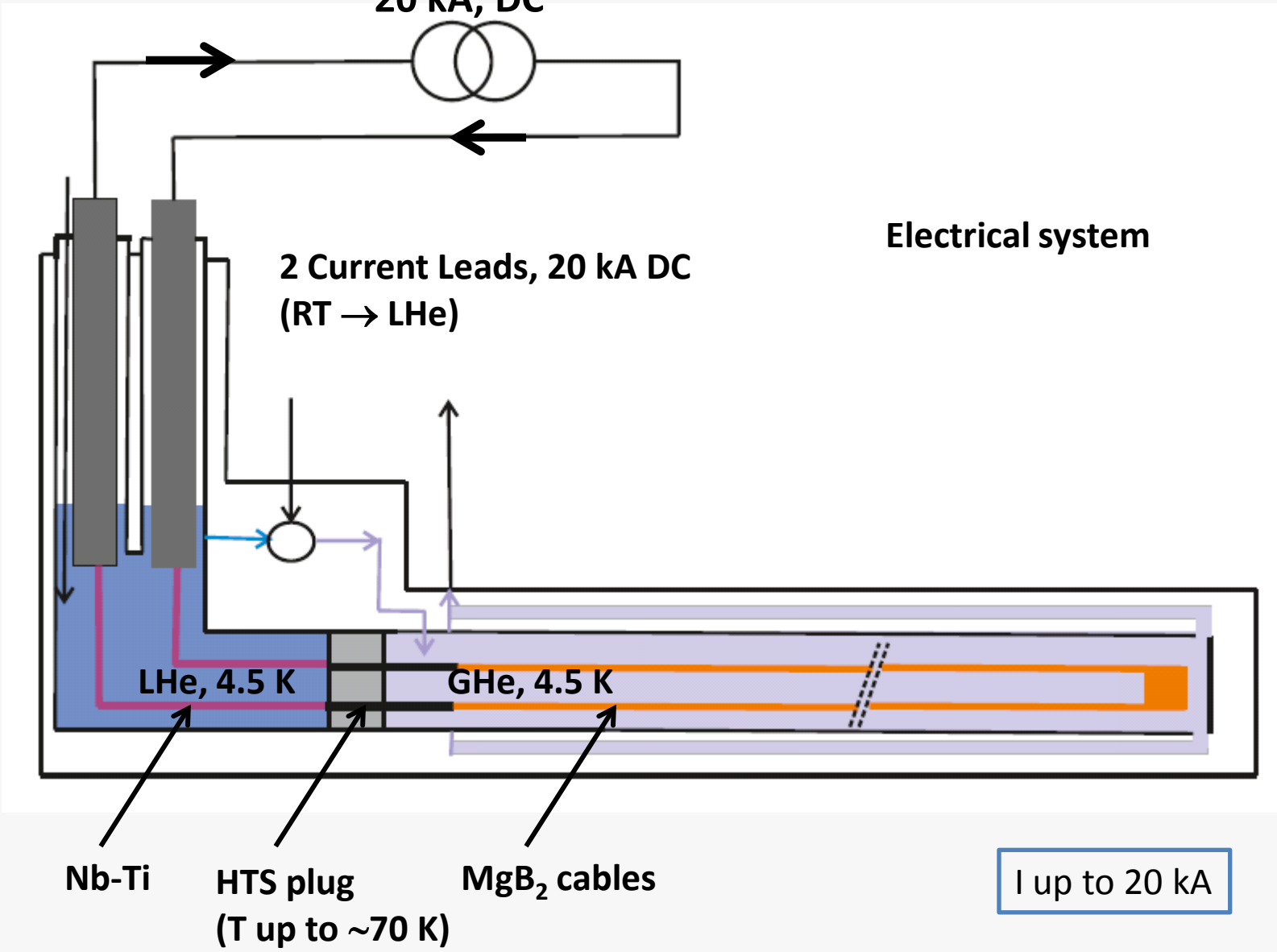
Conceptual design



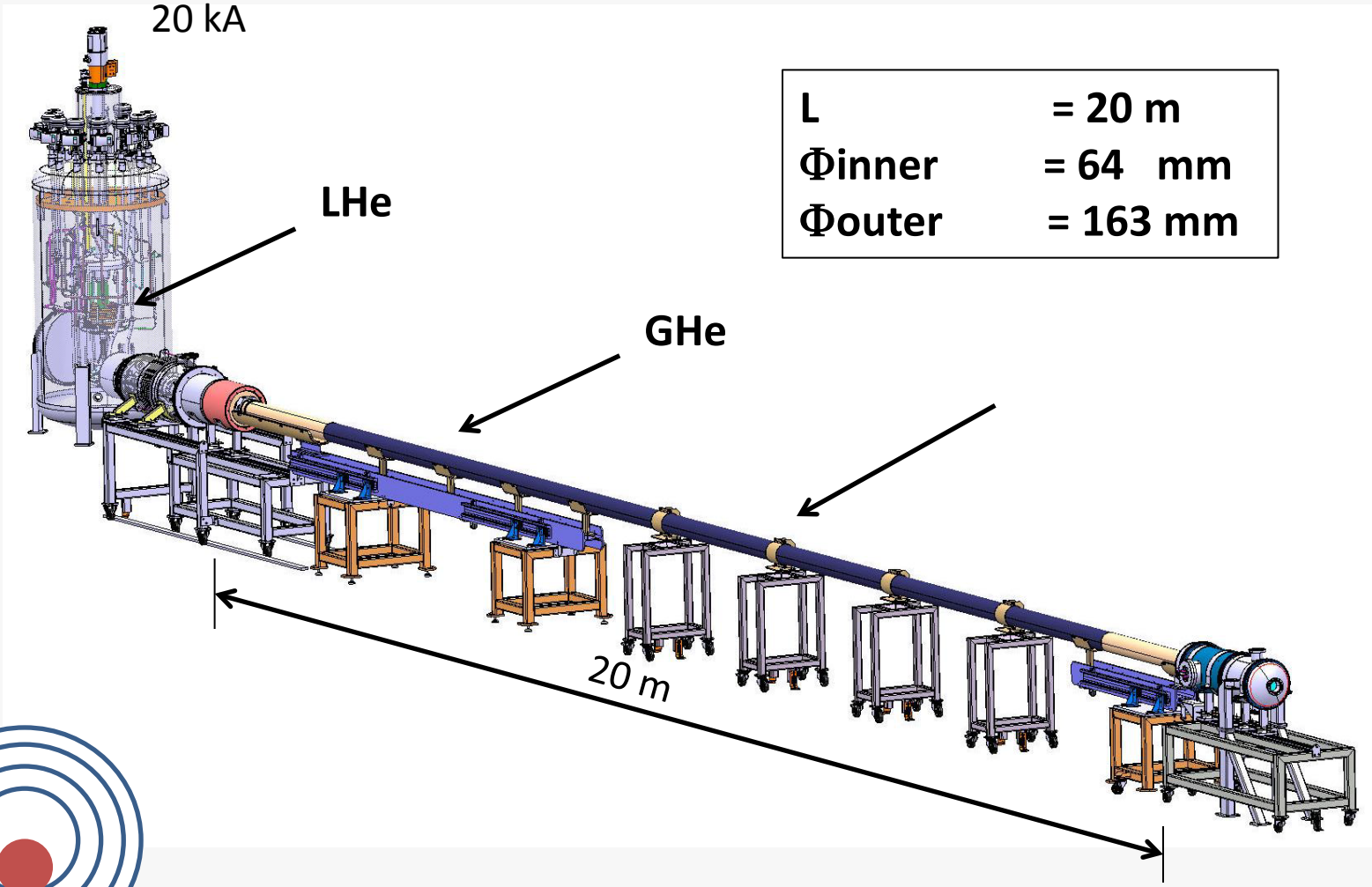
Conceptual design



Conceptual design



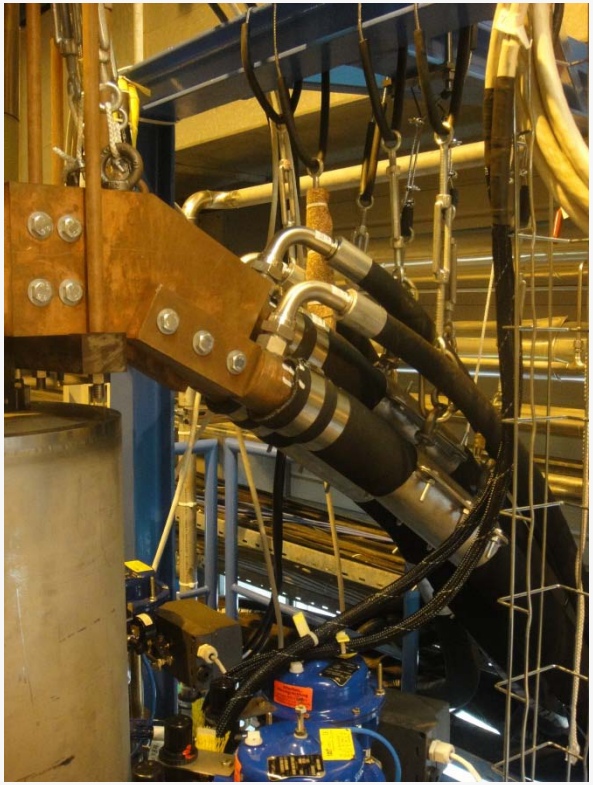
System design



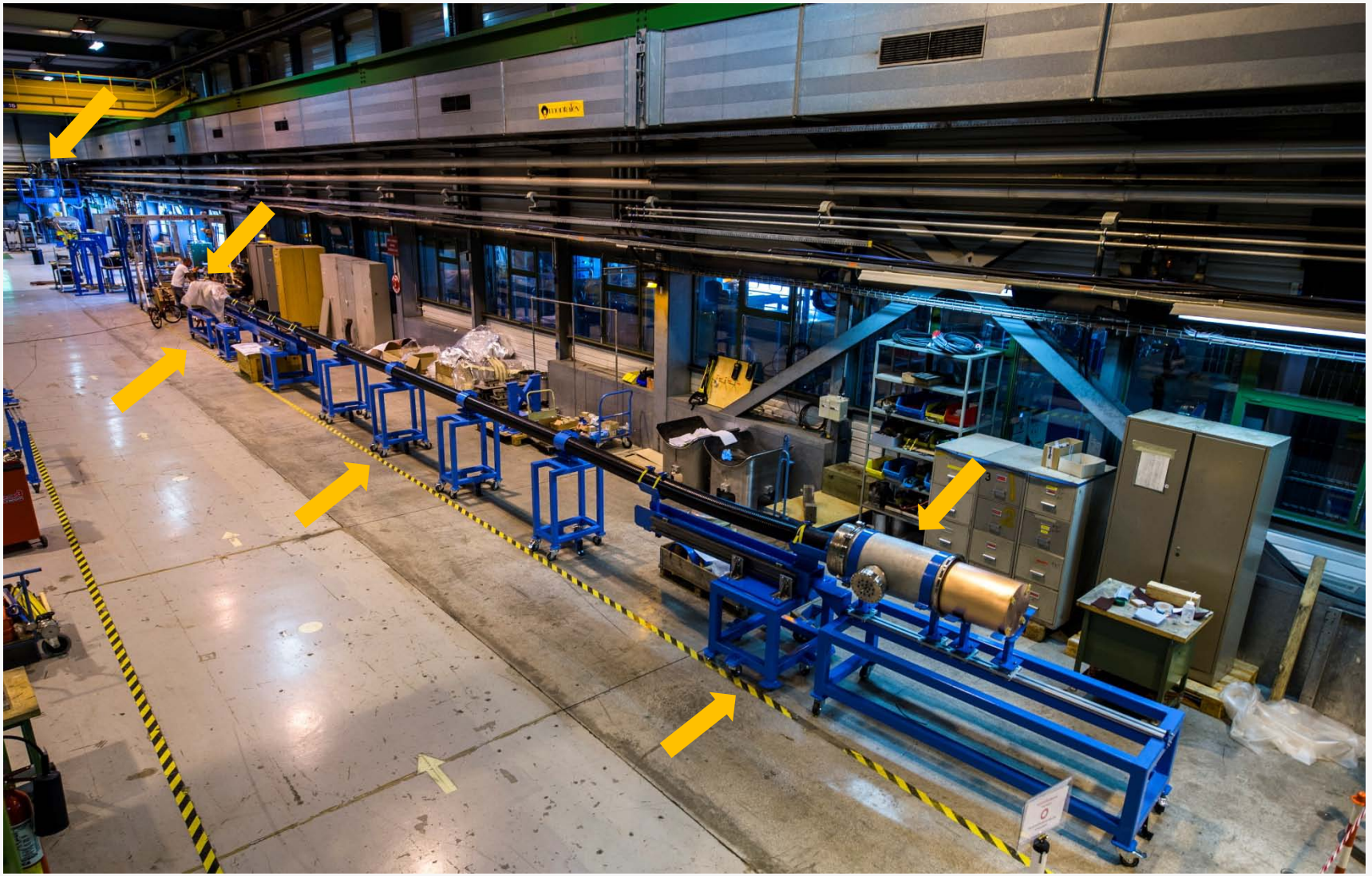
L	= 20 m
Φinner	= 64 mm
Φouter	= 163 mm

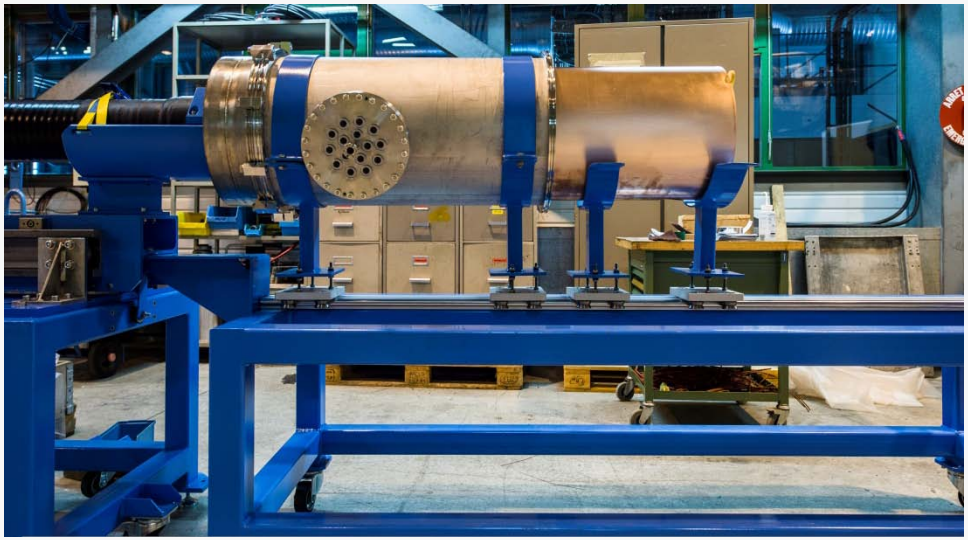
20-m Long Nexans Transfer Line


H ~ 3.5 m
FRAGILE




VELAN





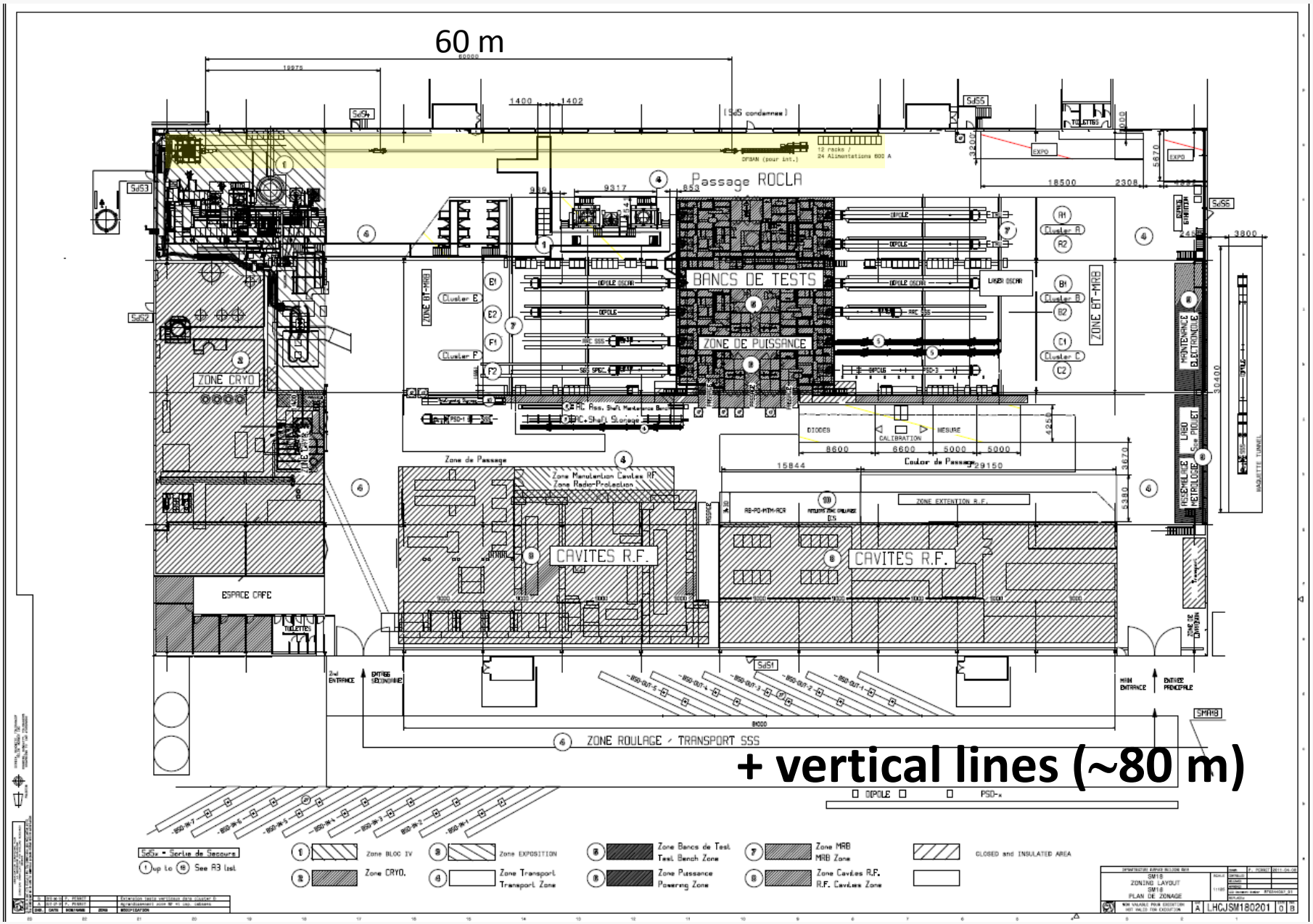
System Commissioning

- The cryostat is completely assembled and under leak test

- Two 20 m long cables, each made from one YBCO tape twisted with two copper strips, are integrated in the line

- The first cool-down is planned to take place before Christmas:
  - commissioning of the cryogenic system;
  - measurements at currents of up to ~ 2 kA

Plan for future activities



Conclusions

- The recent progress made on wire development - at Columbus – and on the design of a novel test station will enable us to test high-current MgB_2 cables in significant lengths (up to 20 m) as from beginning of 2013

- Several geometries of cables have been studied and will be tested

- Measurements will be performed in different operating conditions to fully assess the potential of MgB_2 for application to high-current long distance electrical transmission