Superconducting Links for the LHC machine

A. Ballarino, CERN

JRT-CERN Collaboration Workshop
CERN, 27 January 2014

Outline

- **Introduction to the activity**

- **SC Links for LHC: project overview**
  - Motivations, application to LHC upgrades
  - Conductor, cables and system development
  - Project timeline

- **Funded European Projects**
  - Collaborations (industry and laboratory)
  - Electrical transmission via SC links: from accelerator technology to smart energy network

TE-MSC

Magnets, Superconductors & Cryostats
Staff Members

L.	BOTTURA	Group Leader
G.	DERIJK	Deputy and Project Coordination
D.	TOMMASINI	Resources planning
J.Ph.	TOCK	LHC consolidation, Industrial services
P.	FESSIA	HL-LHC

Secretariat: R. DECREUSE-MICHAUD, L. ORMESHER

Superconductors & Devices SCD
A. BALLARINO
A. BONASIA
B. BORDINI
P. DENIS
A. GHARIB
J. HURTE
A. JACQUEMOD
P. JACQUOT
S. LAURENT
L. OBERLI
G. PEIRO
D. RICHTER
C. SCHEUERLEIN
E. SEILER

SC Magnet Design & Technology MDT
G. DE RIJK
N. BOURCEY
S. CLEMENT
D. COTE
C. FERNANDES
P. FERRACIN
R. GAUTHIER
P. HAGEN
S. IZQUIERDO BERMUDEZ
M. KARPPINEN
G. KIRBY
L. LAMBERT
G. MAURY
J. MAZET
J. PEREZ
D. SMEKENS
E. TODESCO

Large SC Magnet Facility LMF
F. SAVARY
P. CANARD
N. DALEXANDRO
M. DURET
D. ETIEMBRE
R. FAES
L. FAVIER
J. GOMES DE FARIA
L. GRAND-CLEMENT
J. HUBERT
F. LACKNER
Ch. LOFFLER
S. LUZIEUX
P. MARTINS
M. POZZOBON
H. PRIN
R. PRINCIPE
S. TRIQUET

Superconducting Magnet Test Facilities TF
M. BAJKO
M. CHARRONDIERE
G. DIB
J. FEUVRIER
C. GILOUX
P. VIRET
G.P. WILLERING

Magnets Normal Conducting MNC
D. TOMMASINI
J. BAUCHE
D. BODART
M. BRUYAS
P. CATHERINE
O. CRETTIEZ
M. DUMAS
P. FESSIA
C. LOPEZ
R. LOPEZ
A. MILANESE
M. MODENA
A. NEWBOROUGH
G. PERRIN-BONNET
V. PRIETO HERMOSILLA
D. SCHOERLING
P. SCHWARZ
M. STRUIK
P. THONET

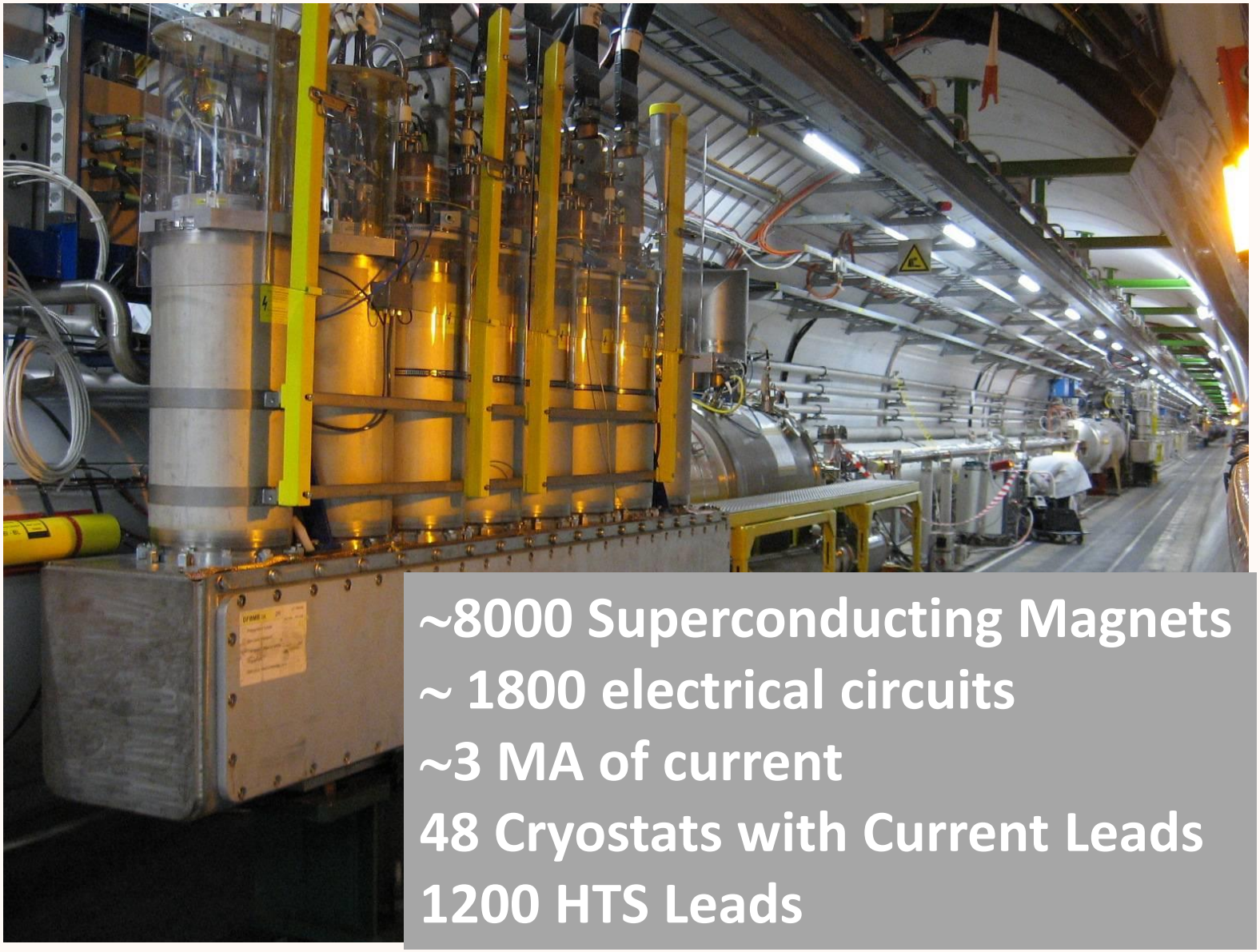
Magnetic Measurements MM
S. RUSSENSCHUCK
R. BELTRON MERCADILLO
M. BUZIO
R. CHRITIN
G. DEFERNE
O. DUNKEL
L. GABORIT
P. GALBRAITH
J. GARCIA PEREZ
D. GILOTEAUX
D. OBERSON
V. REMONDINO
T. ZICKLER

Cryostats & Machine Integration CMI
V. PARMA
G. BARLOW
A. BASTARD
J.B. DESCHAMPS
D.L. DUARTE RAMOS
S. LE NAOUR
A. MUSSO
M. SOUCHET
J.Ph. TOCK
A. VANDE CRAEN
L. WILLIAMS

JANUARY 2014

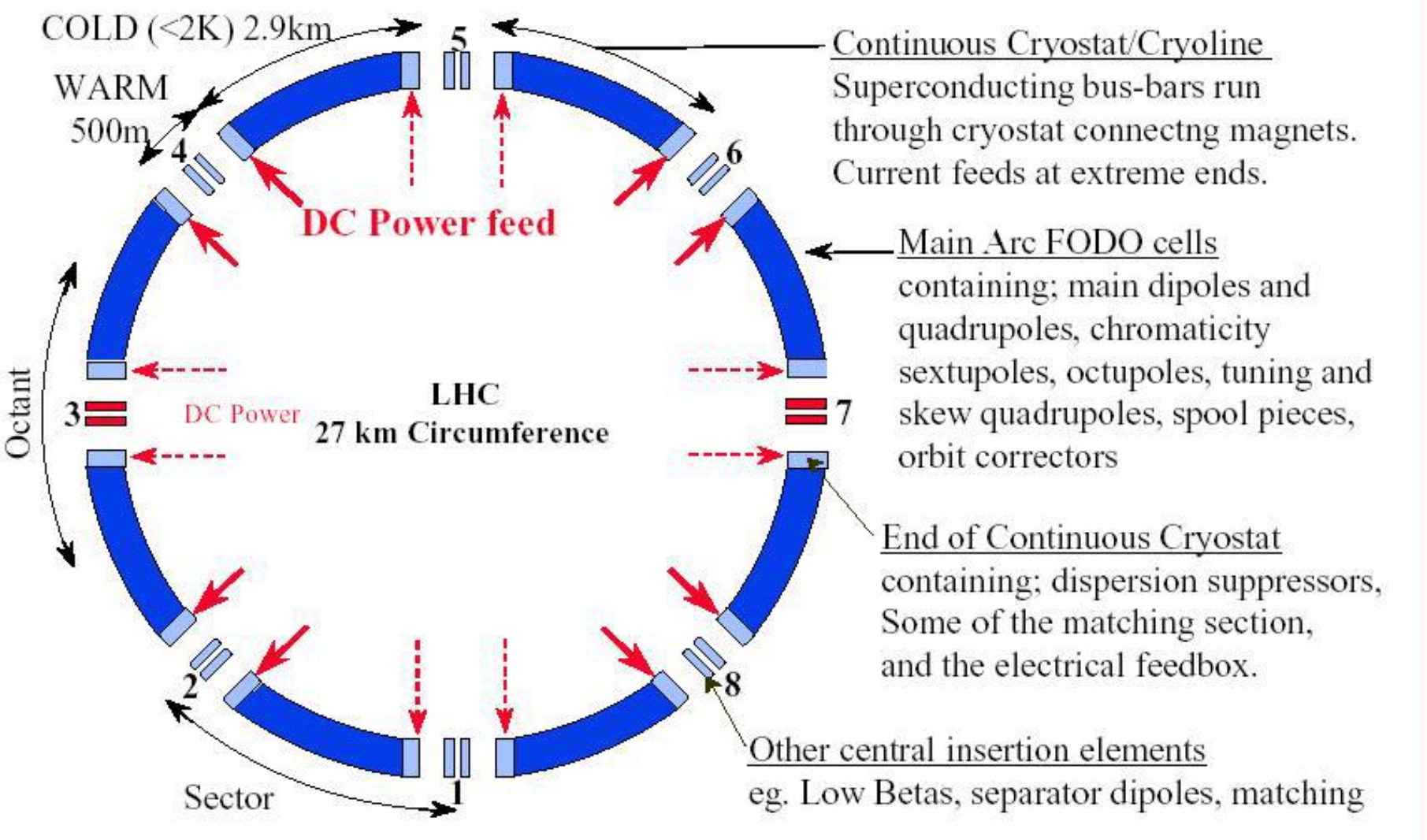
Superconductors & Superconducting Devices:
SC materials, wires, tapes and cables for the CERN accelerators (HTS and LTS).
SC devices.
SC laboratory. ITER Reference Laboratory

Electrical transfer in LHC



~8000 Superconducting Magnets
~ 1800 electrical circuits
~3 MA of current
48 Cryostats with Current Leads
1200 HTS Leads

LHC Powering Layout

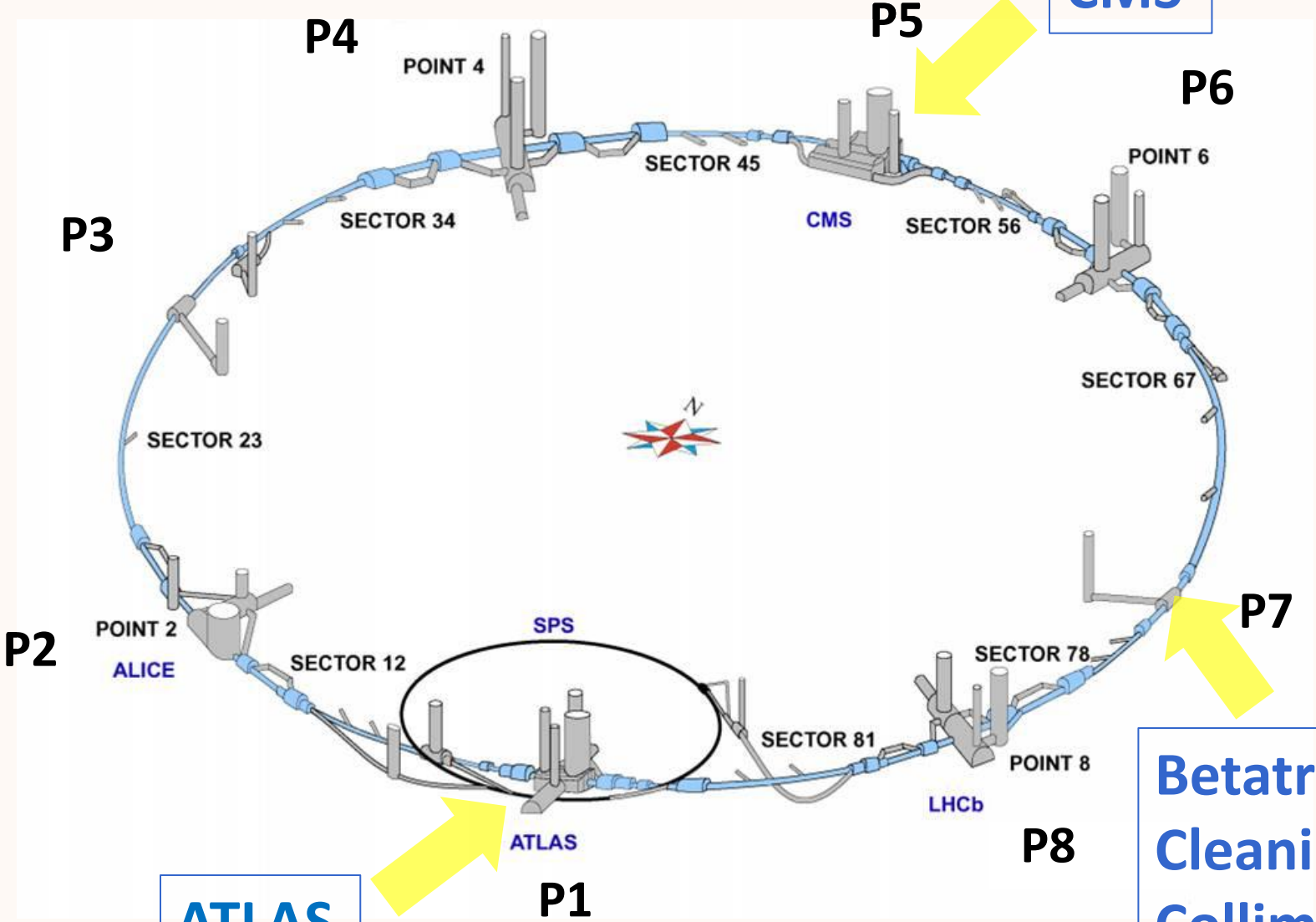


Superconducting Links for LHC:

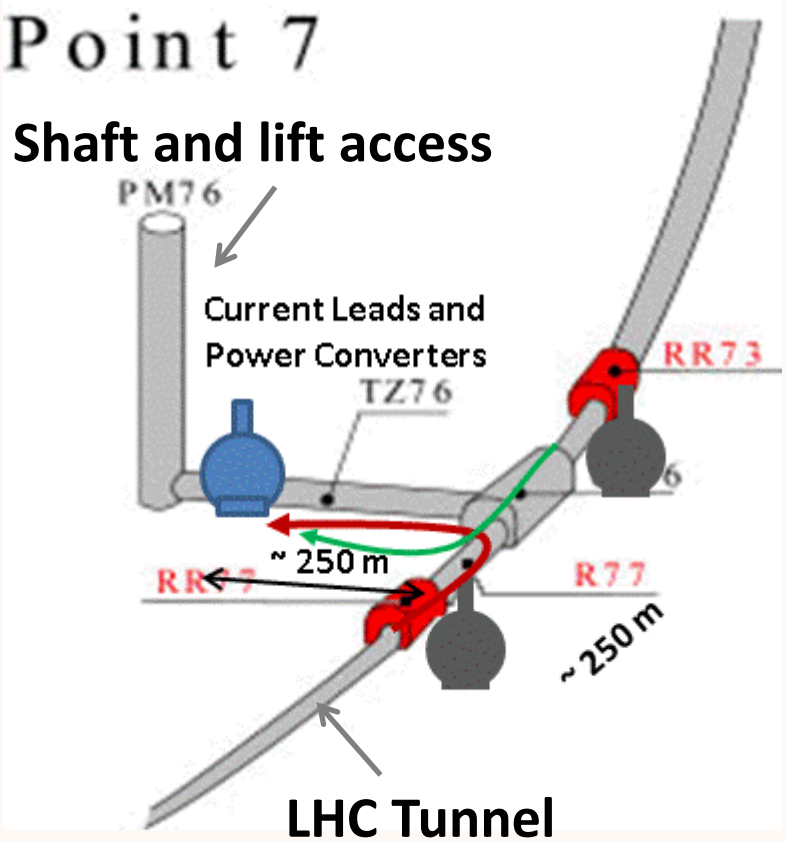
Remote powering of LHC superconducting magnets

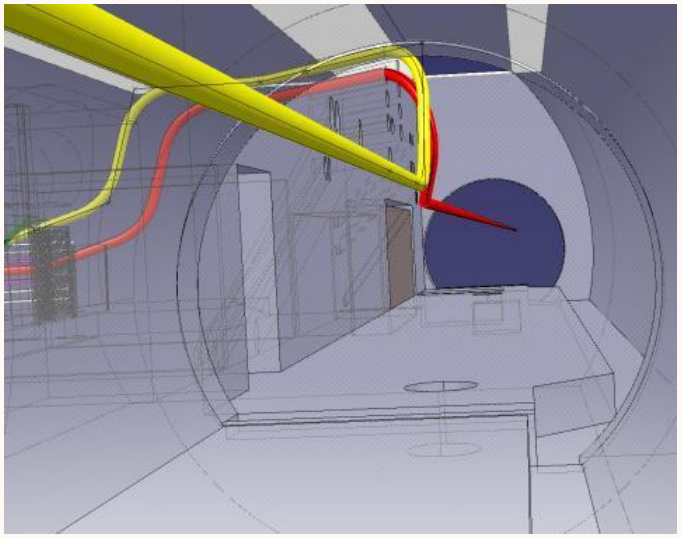
Removal of current leads and **power converters** to easily accessible radiation-free areas

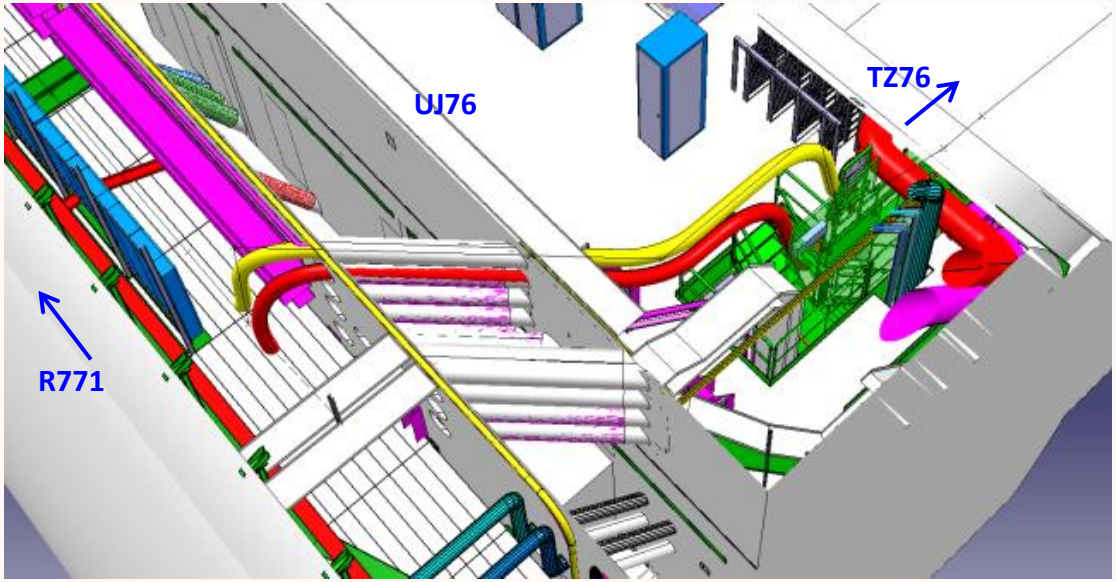
Where in the LHC ?



LHC P7







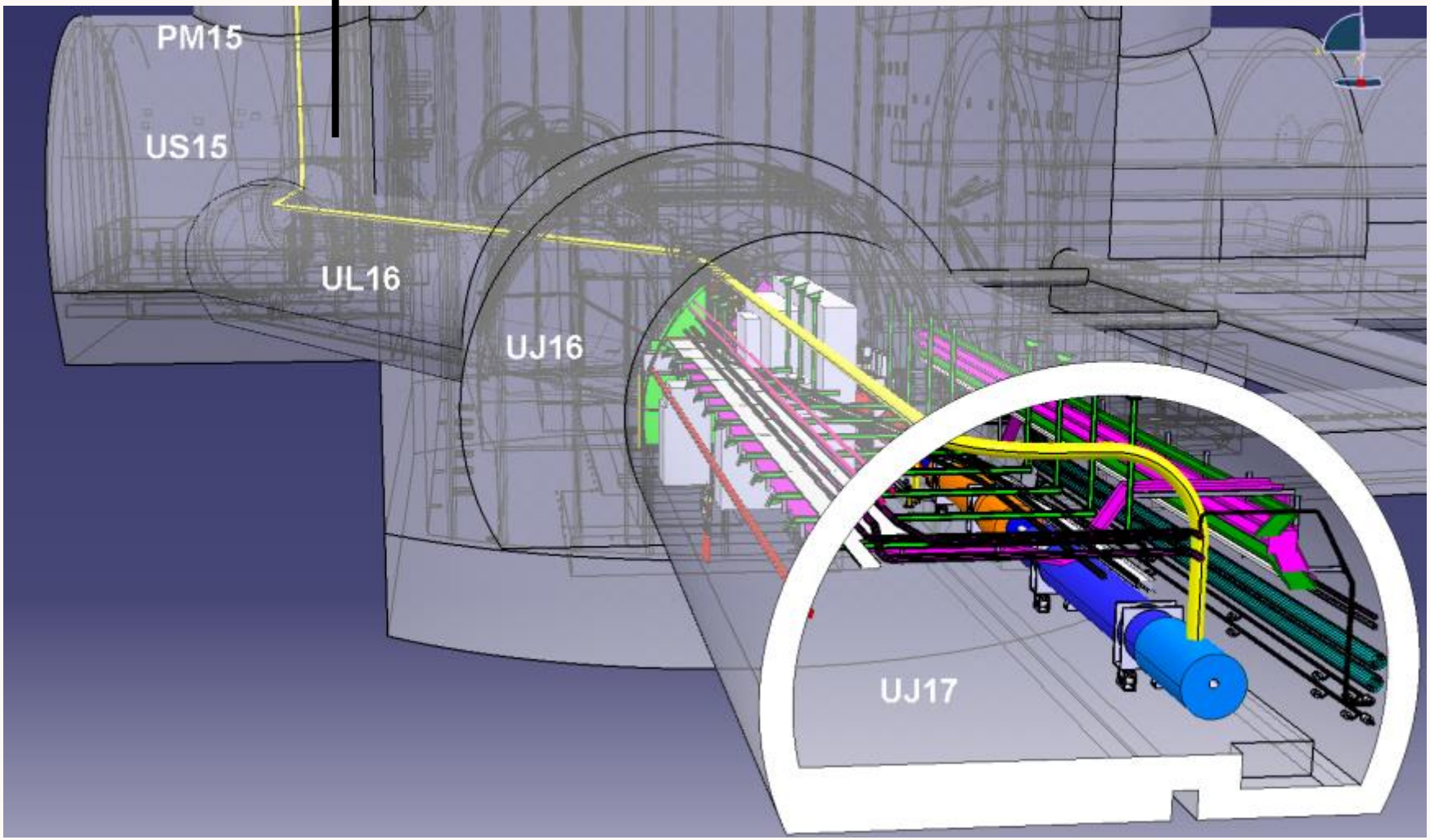
LHC P7: Cleaning Insertions

Underground Installation

Superconducting Link at LHC P1 and P5

Power converters and leads at the surface

SC Links span 80 m of vertical distance



Superconducting Links Characteristics

LHC P7

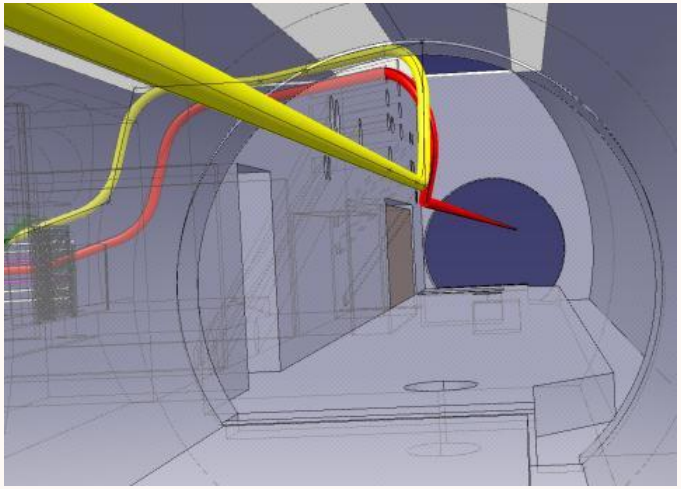
2 Links, Each ~ 500 m long

50 Cables per link rated at 600 A

| Itot | = 30 kA

Removal of LHC cryostats from tunnel

Underground installation



LHC P1 and P5

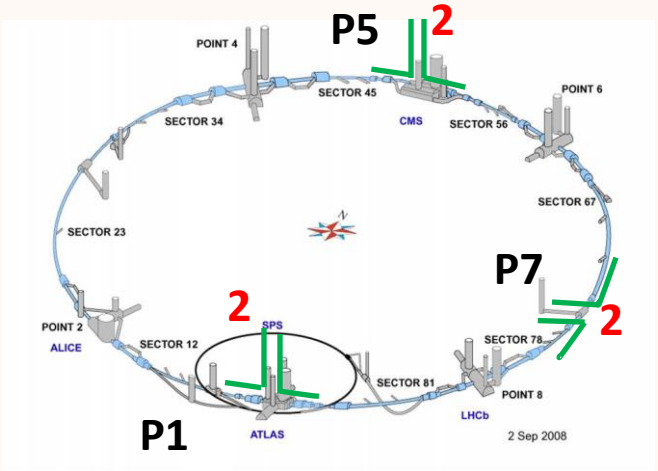
2+2 Links, Each ~ 300 m long

42 Cables per link rated at up to 20 kA

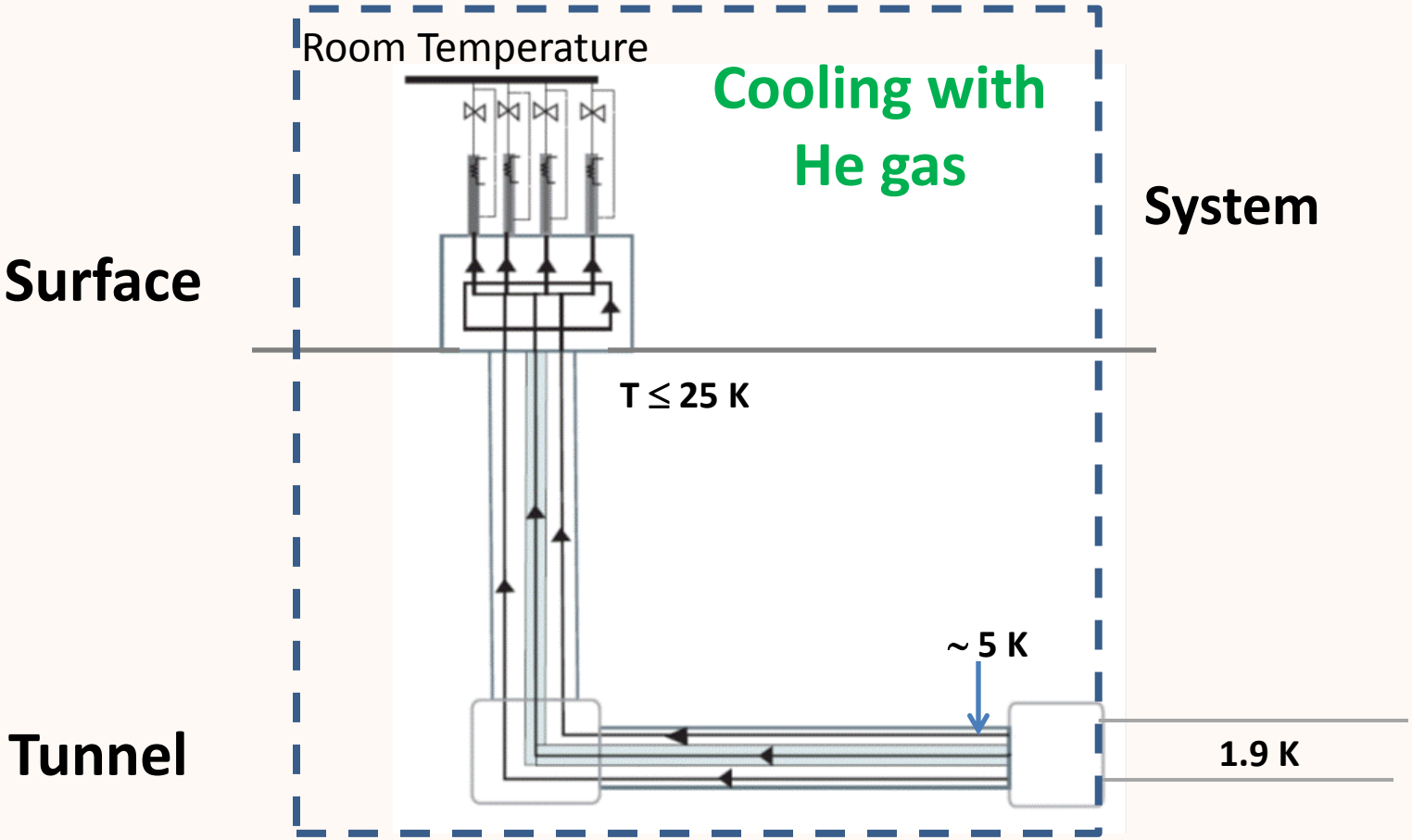
| Itot | = 150 kA

Upgrade of Hi-Luminosity Triplets

Surface Installation



Superconducting Links Characteristics



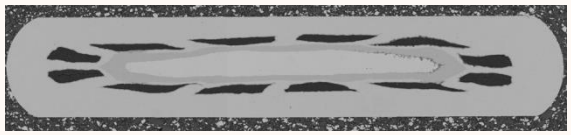
Maximum operating temperature of the cable = 25 K
Operation in self-field (B <1 T)

MgB_2 Conductor

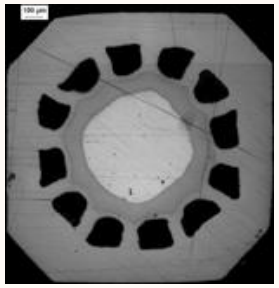
- Low cost (Euro/kA·m). This makes possible applications where a significant quantity of conductor is required
- Good electrical performance in the fields of interest for electrical transfer lines (< 1T)
- Possibility of operating at higher temperatures (Tc=39 K) – relaxed conditions for the cryogenic system (temperature margin)
- Possibility of using He gas for cooling the cold powering system – from room temperature down to the liquid helium magnets environment

MgB_2 Round wire development

3.6×0.67 mm²

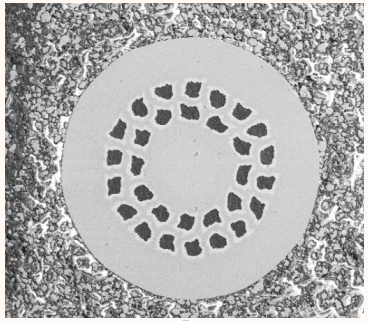


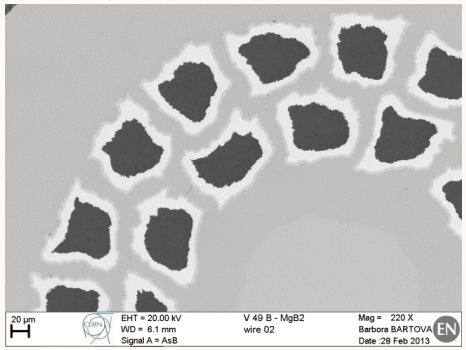
1.6×1.6 mm²
1.1×1.1 mm²



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

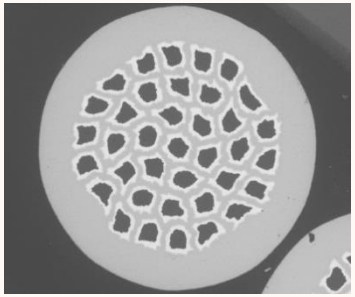
Φ = 0.98 mm





Monel Matrix
30 MgB_2 filaments
Nb + Ni barrier
ff ~ 10.4 %

Φ = 0.85 mm

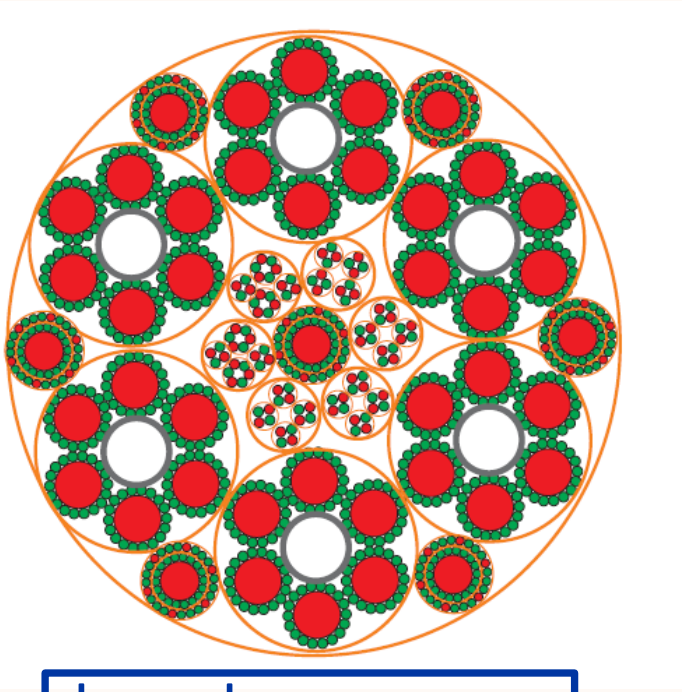


- With Cu stabilizer
- With Coating for controlled surface resistance

Monel Matrix
37 MgB_2 filaments
Nb + Ni barrier
ff up to ~ 18 %

4 years of development with Columbus Superconductors

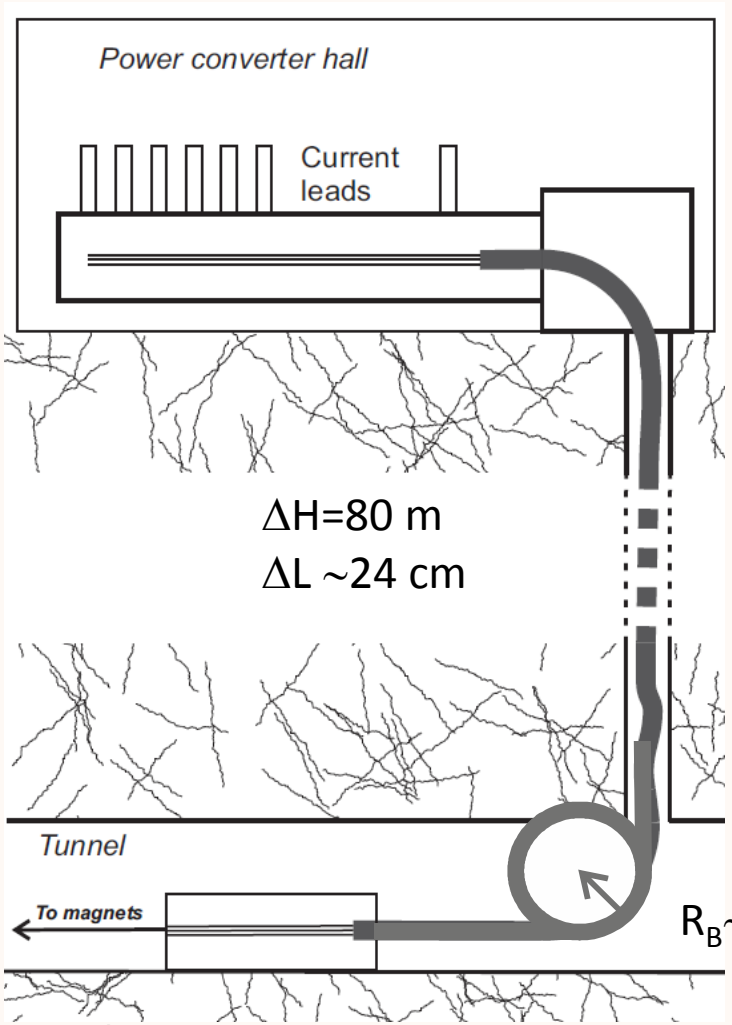
MgB_2 Cables



|Itot| = 150 kA

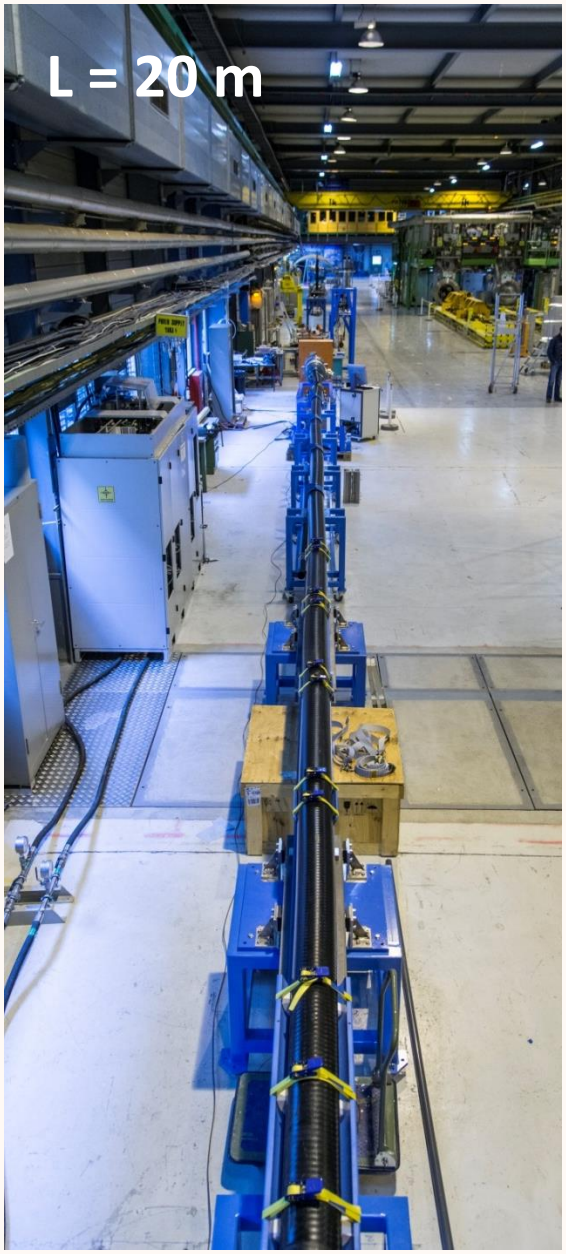
Mass ~ 11 kg/m

(880 kg for ΔH=80 m)

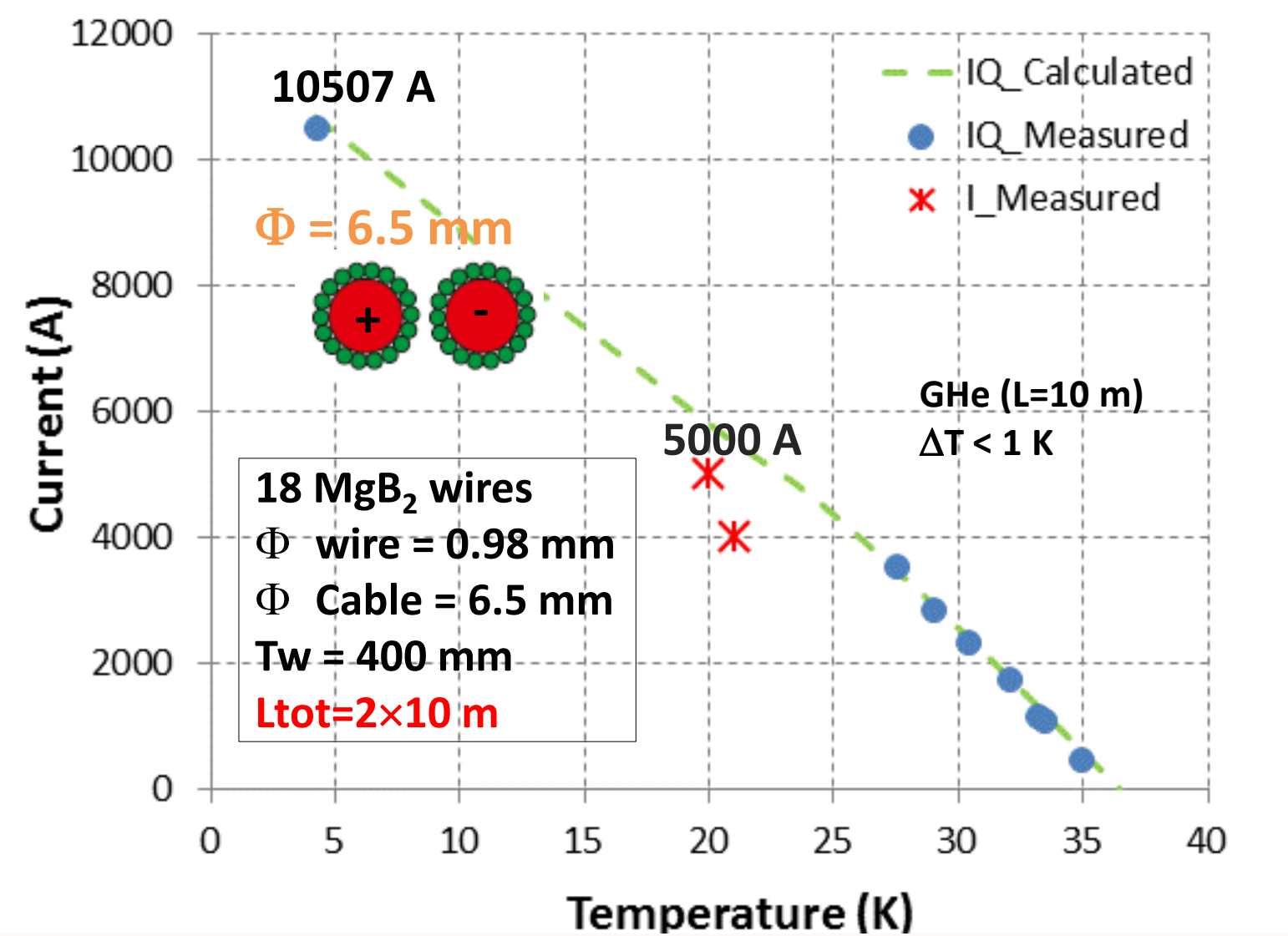


Semi-flexible cryostat external diameter = 220 mm

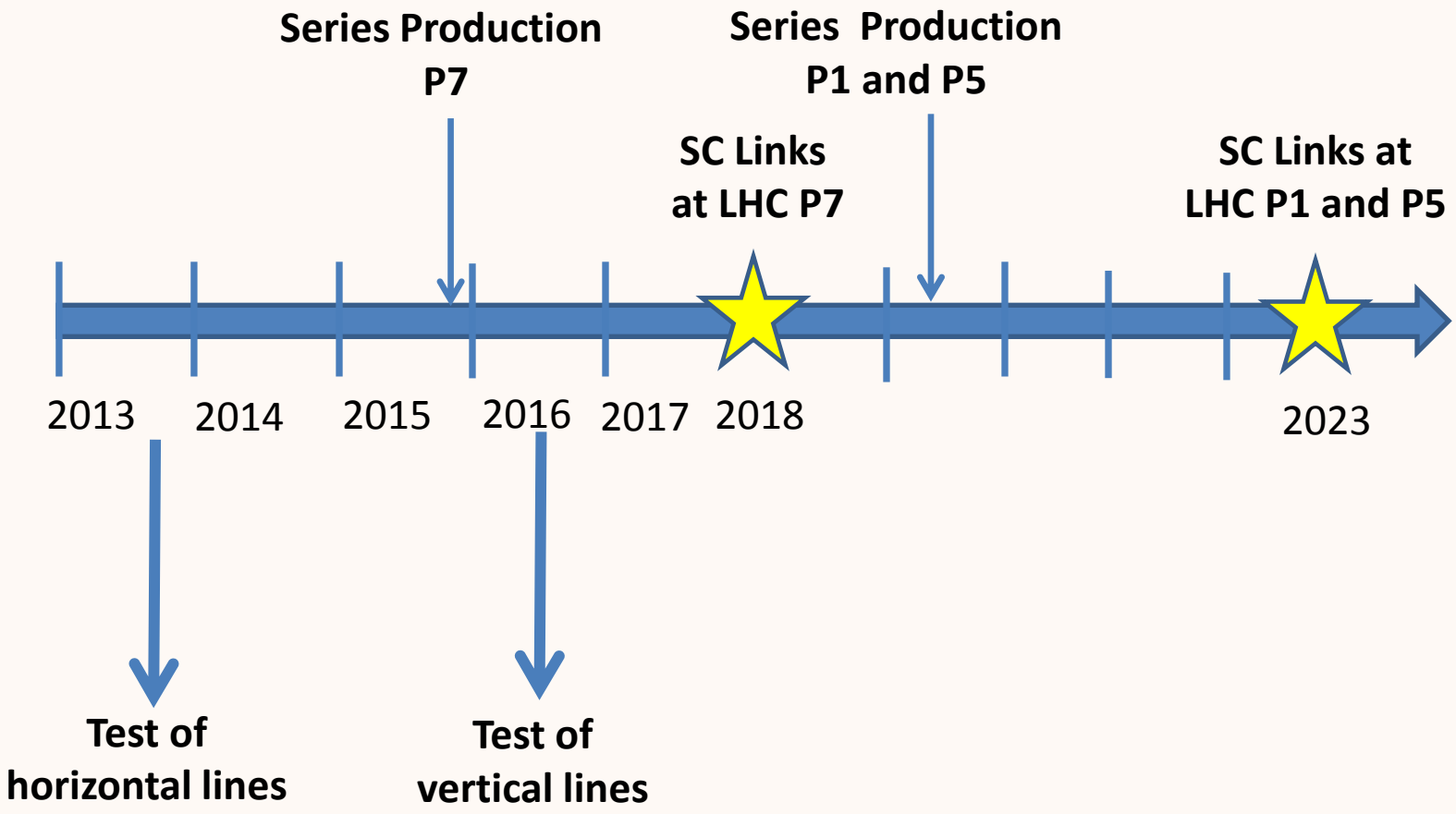
Superconducting Link Test Station at CERN



Recent demonstration at CERN
5 kA @ 20 K in 10 m long MgB_2 cables



Superconducting Link Project-Timeline



Development Program

SC Links: European funded Projects

- **FP7-EuCARD 1** (April 2009-March 2013), WP 7 (High Field Magnets), Task 5: **HTS Link for LHC** P7 (I~30 kA). Coordinated by CERN with participants from industry and laboratories

- **Hi-Lumi LHC FP7** Design Study (Nov 2011-Oct 2015), WP6: Cold Powering **HTS Link for LHC** P1 and P5 (I~150 kA, MgB_2 links). Coordinated by CERN with participants from laboratories

- **Smart energy network FP7** proposal (Jan 2014- Dec 2017) **Innovative prospective for electricity transport**. High power, long distance MgB_2 links. Coordinated by Nexans, with participants from industry (RTE French Transmission System Operator,..) and laboratories (CERN, IASS Institute for Advanced Sustainability Studies, …)

Smart Energy Network FP7 proposal

- From **high-voltage AC** cables to **high capacity DC superconducting** power transmission cables (> 5 GW)

CERN: **20 kA @ 20 K** MgB_2 demonstrator
Nexans: 320 kV DC system design and test
RTE: integration into transmission grid, reliability
Columbus: MgB_2 conductor
IASS: scientific coordination and dissemination

With hydrogen cooling (**~ 20 K**): hybrid lines transferring **electric energy** via superconducting cables, transporting **hydrogen as fuel** and providing intermediate **energy storage** at the site of energy production (use of intermittent energy sources)

Acknowledgments

The CERN SCD team
The CERN SM-18 team

The collaboration with:
IASS (institute for Advanced Sustainability Studies)
the University of Southampton
the team at Columbus Superconductors