JRA on Development of High Temperature SC Link

- Motivation
- Work Packages
- Partners & resources

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Motivation

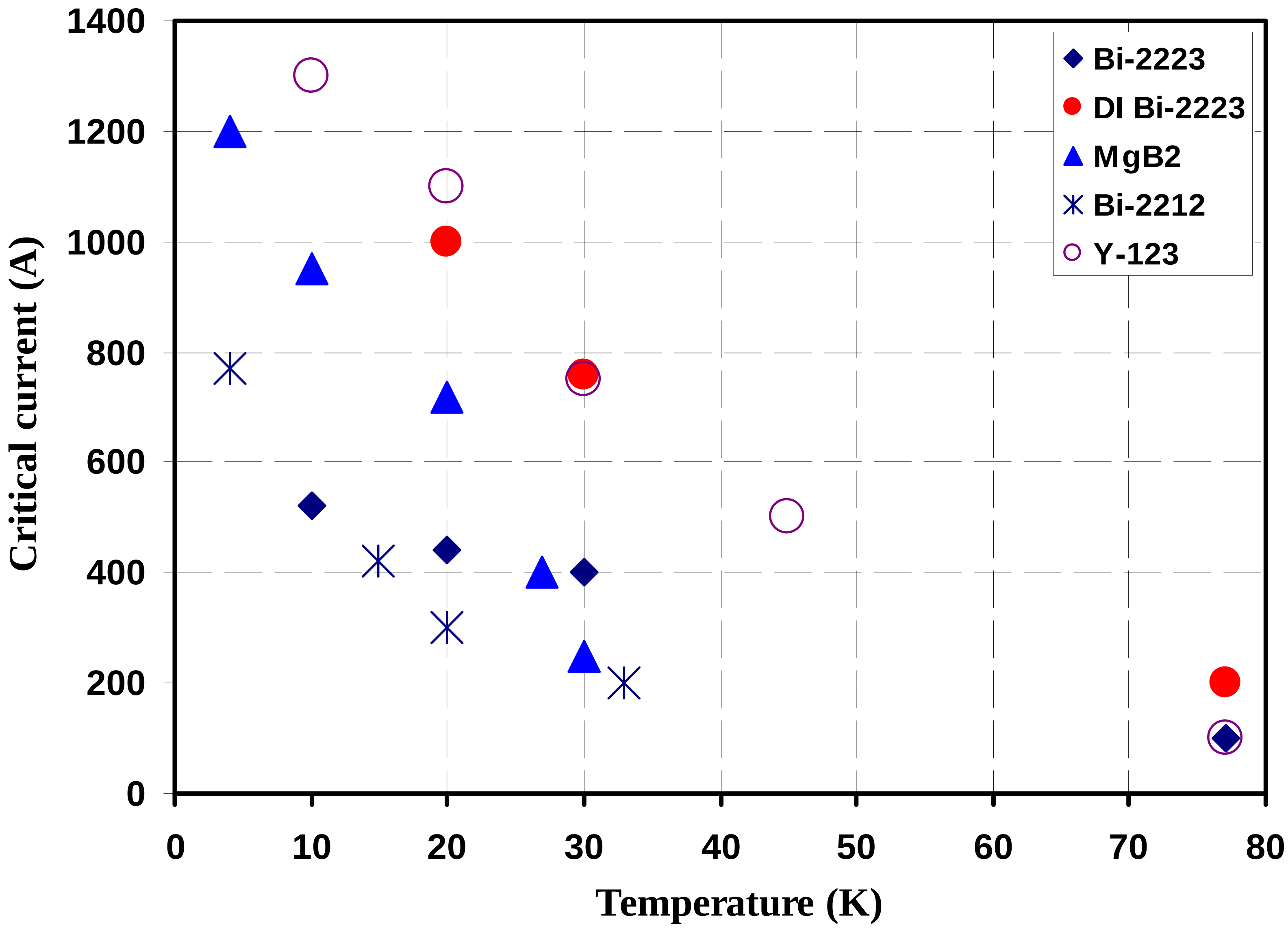
- High Temperature Superconductors (HTS) are new materials, with performance improving ~ 25% per year. The presently achieved performance makes HTS conductors suitable candidates for some **target applications**. When operated at lower temperatures, they have good electrical properties and offer a **generous temperature margin** with respect to low temperature superconductors (LTS).

- Thanks to the experience gained at CERN with the HTS LHC current lead project, **CERN has a recognized know-how in the HTS field** and a **large well-established network** with HTS material manufacturers and users – industry and laboratory – world-wide. It is vitally important to maintain and extend this expertise.

- Thanks to the year-to-year performance improvements, **HTS materials are destined to play an important role in the accelerator field** (final goal: application to very high field magnets and special magnets operating in a high background field, exposed to intense radiation heating or conduction cooled). It the meantime there are **important intermediate applications of HTS which are relevant for the consolidation and upgrade of LHC.**

- The **LHC cryogenic system** provides favorable conditions for using HTS.

- **HTS are very different from LTS !**

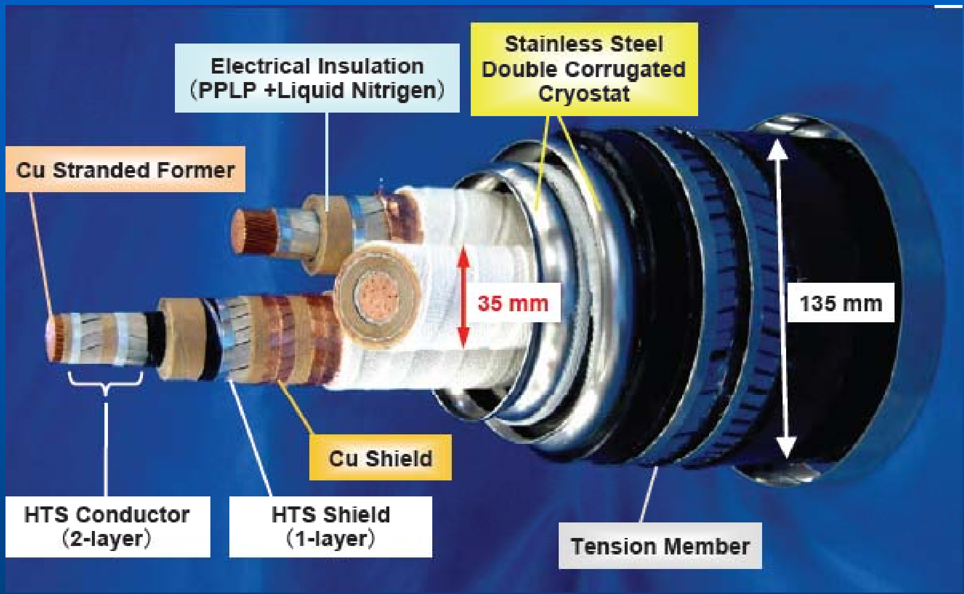


Critical current (A)
1400
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
70
80
Temperature (K)
Bi-2223
DI Bi-2223
MgB2
Bi-2212
Y-123

Self-field

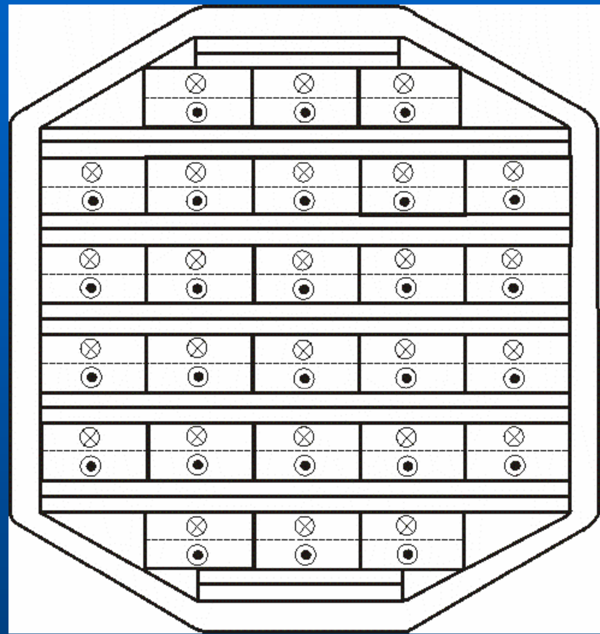
Relevance to LHC

- HTS technology can be applied to superconducting bus-work in order to:
- Provide long distance connections between power converters and superconducting magnet systems in replacement of warm or LTS cables.
  - Possible replacement of 500 meter LTS link in IR3.
- Provide flexibility in the location of the cryostats supporting the current leads (DFBs) in cases where space is limited and radiation environment harsh – making possible removal of bulky warm cables and sensitive elements from the tunnel and easier accessibility also during machine operation.
  - Inner Triplet cryostats for the LHC luminosity upgrade.
- Link cold magnets electrically – in replacement of “connection cryostat” bus.
- In such cases, increased temperature margin makes the system more tolerant to transient heat loads, and also relaxes the requirements for the cryogenic system.



Albany 3-phase AC

Bi-2223 cable



Multi-conductor HTS bus

WP2: Studies & computations

- **<u>Subjects:</u>**

- **HTS Materials:**
  - **analysis of potential candidates: MgB_2, Bi-2223, Bi-22212 and Y-123 (long-length availability with uniform electrical and mechanical properties),**
  - **definition of operational temperature (10 K - 25 K) as function of material properties and availability of cooling,**
  - **optimization of geometry for application to multiple electrical circuits,**
  - **study of electrical insulation of conductors operating in cold helium gas,**
  - **choice of material type and geometry (tape or wire).**

- **Mechanical design:**
  - **engineering study of cable designs using real wire parameters,**
  - **study of interface and installation issues.**

- **Stability and quench protection:**
  - **definition of requirements for stabilization of HTS material,**
  - **modeling of quench propagation,**
  - **specification of requirements for quench protection electronics.**

- **Electrical terminations:**
  - **design of electrical terminations (HTS-HTS, HTS-Cu, HTS-LTS) ,**
  - **definition of methods for testing electrical joints.**

WP3:HTS Link

- **Goals:**
- **development of a DC HTS superconducting link for potential replacement of the LTS link in IR3 (26 pairs of conductors transporting 600 A). Extrapolation of the design to higher currents (up to 13000 A).**
- **Challenges:**
- **long lengths (final goal 500 m) of multiple electrically insulated HTS conductors;**
- **development of a design compatible with the material electrical and mechanical properties (study of possible means for compensation of thermal contraction).**

	Year 1	Year 2	Year 3	Year 4
Materials/Tests	Study-Test of materials	Test of sub-components	Design-Assembly of test station	Test of prototype(s)
HTS link	Design	Design-Assembly of sub-components	Assembly of prototype(s)	Design of long-length link

WP3:HTS Link

- <u>**R&D phase:**</u>
- **choice of conductor(s),**
- **optimisation of geometrical configuration,**
- **design of short (20 meters) and long (500 meters) links,**
- **optimization of mechanical design.**

- <u>**Hardware tests:**</u>
- **measurement of HTS materials in a cryostat providing the LHC cryogenic conditions (critical current, contact resistance and stability behaviour of short (~ 20 cm) samples as a function of temperature in the range 5 – 25 K). Critical currents up to ~ 1.5 kA are expected,**
- **measurement of prototype short link(s) (10 -20 meters) in nominal cryogenic conditions (powering up to nominal current, measurement of contact resistances, measurement of stability and quench propagation),**
- **validation of mechanical properties of prototype links (critical current as a function of applied stress).**

WP4: Envelope for HTS link

- **<u>Goal</u>:**
- **design of the mechanical envelope that houses the HTS link (vacuum insulation jacket, thermal screen, mechanical compensation),**
- **characterization of the system (HTS link in envelope) in a test station providing the LHC cryogenic boundary conditions (powering of multiple circuits at nominal current, measurement of heat loads),**
- **measurement of electrical resistance of current terminations,**
- **validation of quench protection system,**
- **validation of mechanical properties of prototype link in mechanical envelope (critical current as a function of applied stress).**

Partners and resources (1/2)

		WP1	WP2	WP3	WP4
CERN		X	X	X	X
Uni Southampton (GB)	Studies Tests	X	X	X	X
Columbus (I)	Materials (MgB_2)	X		X	
EHTS (D)	Materials (Bi-2223,Y-123)	X		X	
Desy (D)	Studies	X	X		
CESI (I)	Characterization	X			

Partners and resources (2/2)

		WP1	WP2	WP3	WP4
EDISON (I)	Tests Materials	×		×	
NKT (DK)	Design Assembly	×		×	×
Ansaldo (I)	Assembly			×	
Theva (D)	Design Assembly	×		×	×
AMSC (USA)	Materials Y-123	×			
Superpower (USA)	Materials Y-123	×			
BINP (Russia)	Assembly	×		×	×

1 MEuros