Possible HTS wire implementation

Amalia Ballarino

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Use of HTS wire for the correction of the long-range beam-beam effect in the LHC

Requirements:

-The HTS wire shall be able to transport ~80 A m*, in dc mode, at a “convenient” temperature;

-The HTS wire will be integrated between D2 and D1, both sides of IP1 and IP5, where at the moment warm beam pipes are used. The system shall provide the cryogenic conditions required for the operation of the wire in a compact and cost-effective set-up;

- The design of the HTS wire and associated electrical devices (current leads) shall be such as to ensure optimized cryogenic and electrical performances and reliable operation

*J. P. Koutchouk, Correction of the long range beam-beam effect in the LHC using electro-magnetic lenses, Proceedings of PAC 2001, Chicago

HTS conductors

• BSCCO 2223 (Tc=110 K) tape and YBCO 123 tape (Tc=95 K). Typical Ic at 77 K in self-field of 100-150 A, for a tape of about 4 mm width and 0.1-0.2 mm thickness. They are both delivered as fully reacted conductors

BSCCO 2223 tape: multi-filamentary HTS filaments (f~30 %) in a Ag alloy matrix (PIT)
YBCO 123 tape: thin (1-3 μm) superconducting layer on a metallic substrate

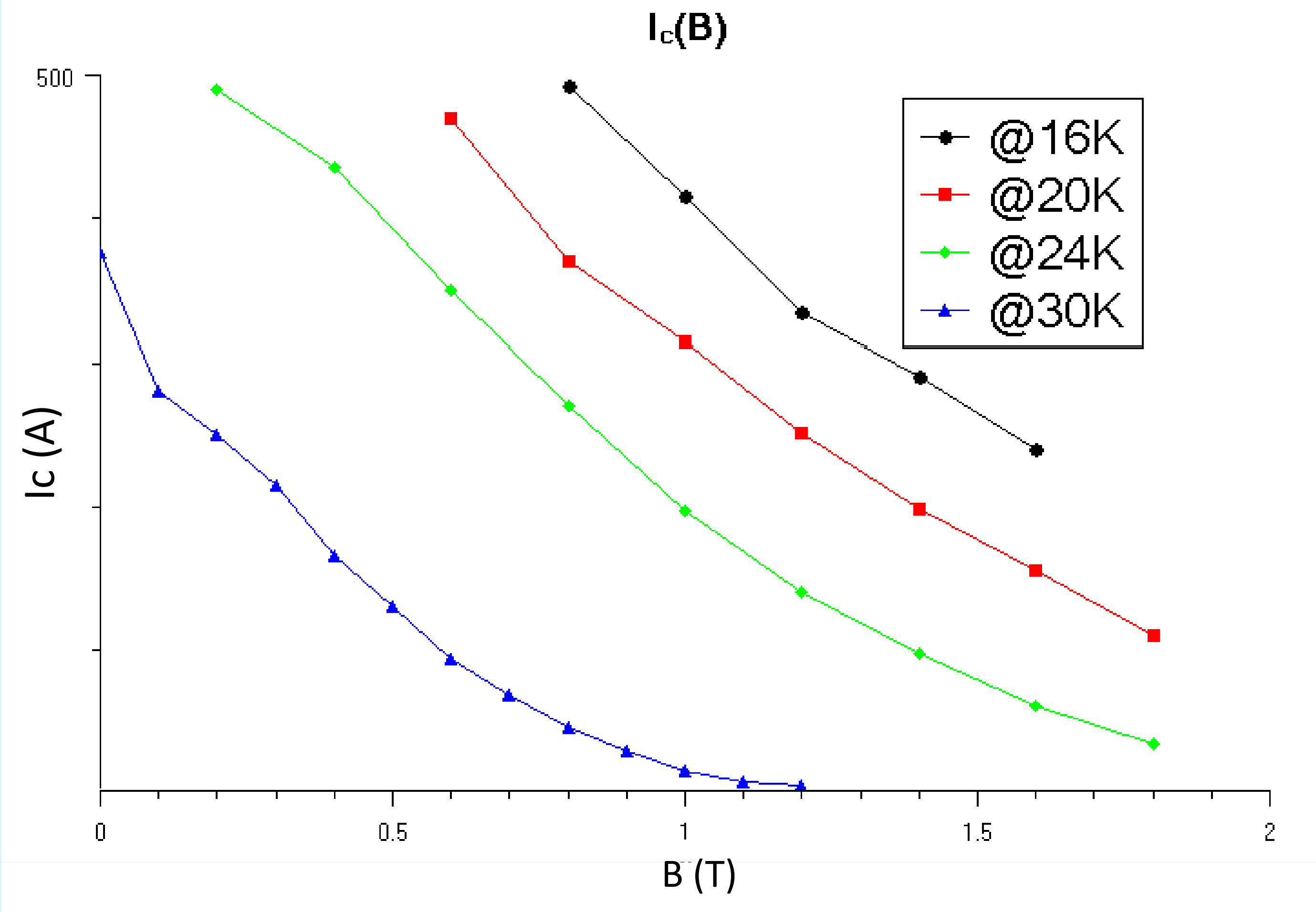
•BSCCO 2212 wire (Tc=85 K). Multi-filamentary HTS filaments in a Ag alloy matrix.
It is suitable mainly for applications that use the wind-and-react technology (T<20 K and high fields)

•MgB_2 tape and wire (Tc=39 K) The "ex-situ" PIT conductor is delivered fully reacted and can be used with the react and wind technology

For the present application the round wire is the preferred geometry. In view of the weak mechanical properties of BSCCO 2212 when used in a reacted state, MgB_2 is the preferred conductor

MgB_2 conductor: electrical properties

Ex-situ, 1.1 mm Φ MgB_2 wire (Columbus)

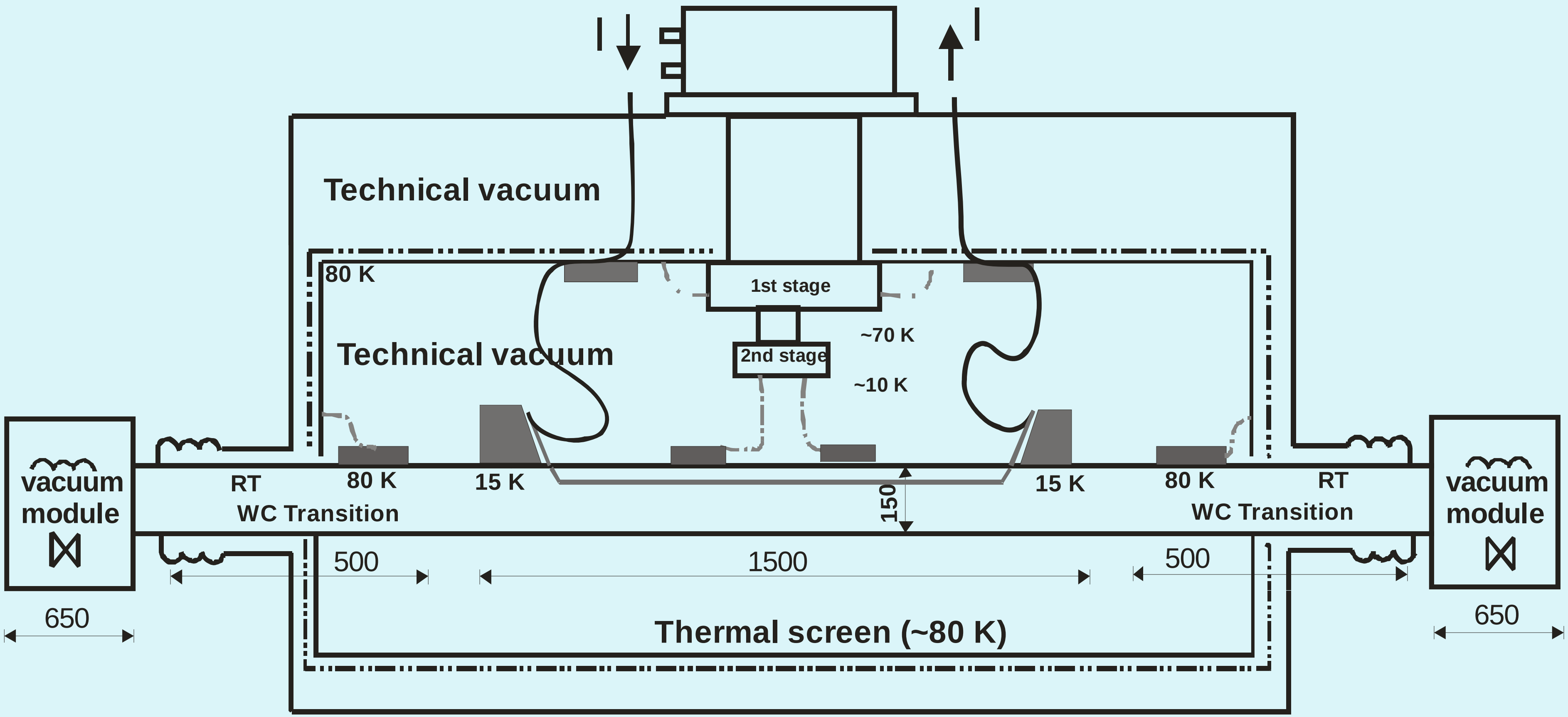


Measurements performed by Columbus in July 2008

Ic(24 K, 0.4T)=436 A. J_{ce}=357 A/mm^2
Measured at CERN an Ic ~ 800 A (4.2 K, 1.5 T)

Rb_{min} ~100 R_{wire}

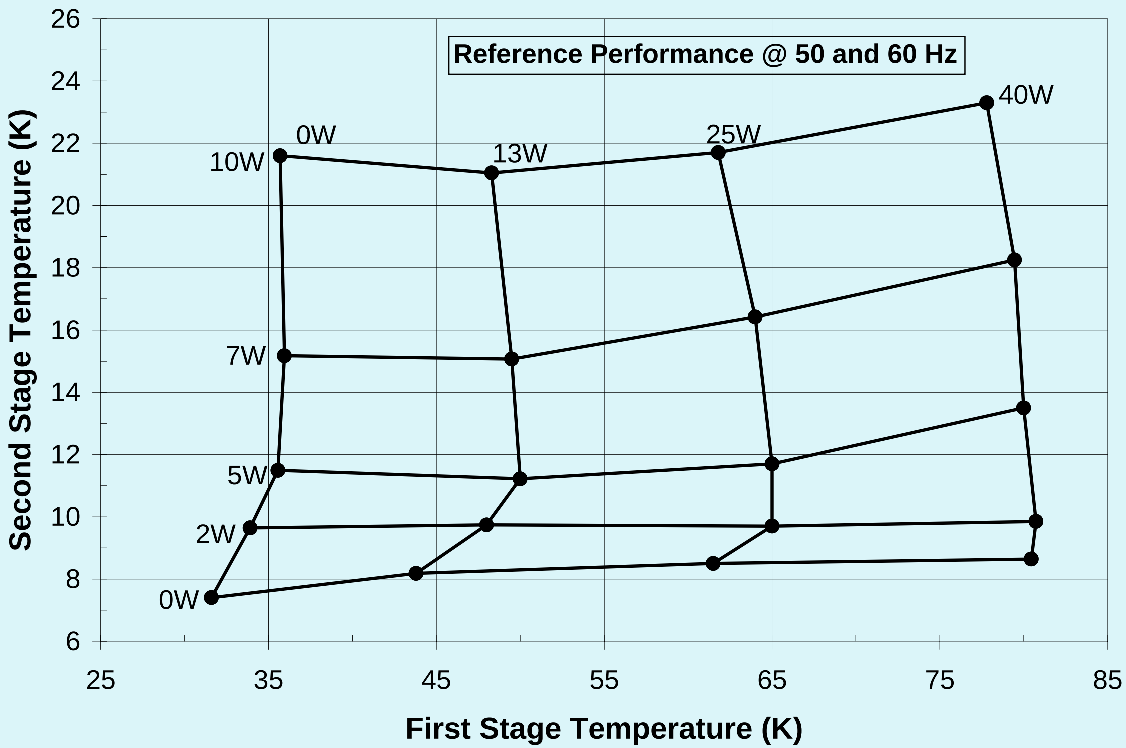
Cryostat around cold beam pipe



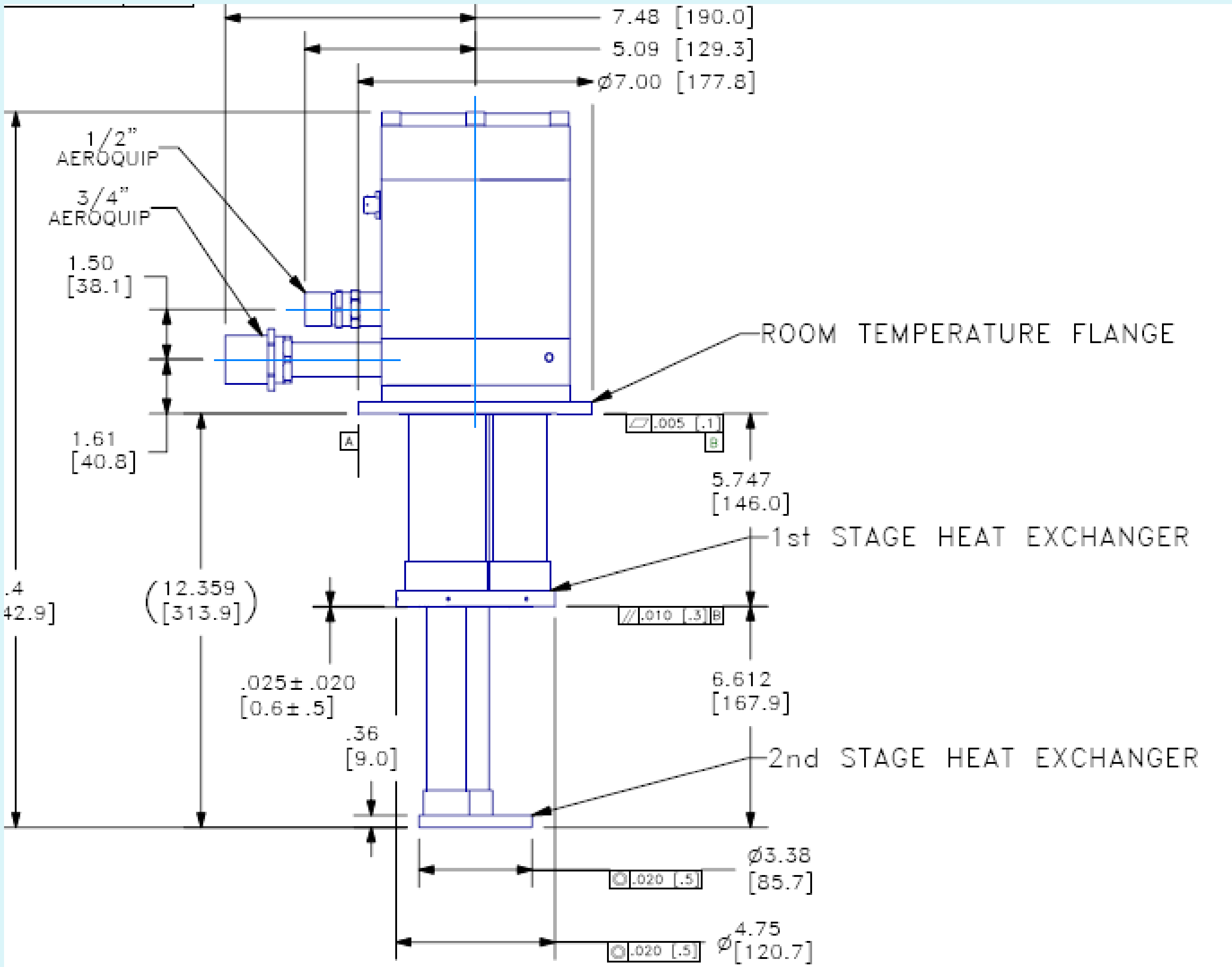
LTOT ~4 m (including vacuum modules)
Lcryostat ~2.5 m
HTOT ~1.2 m

Two-stage Pulse Tube cryocooler

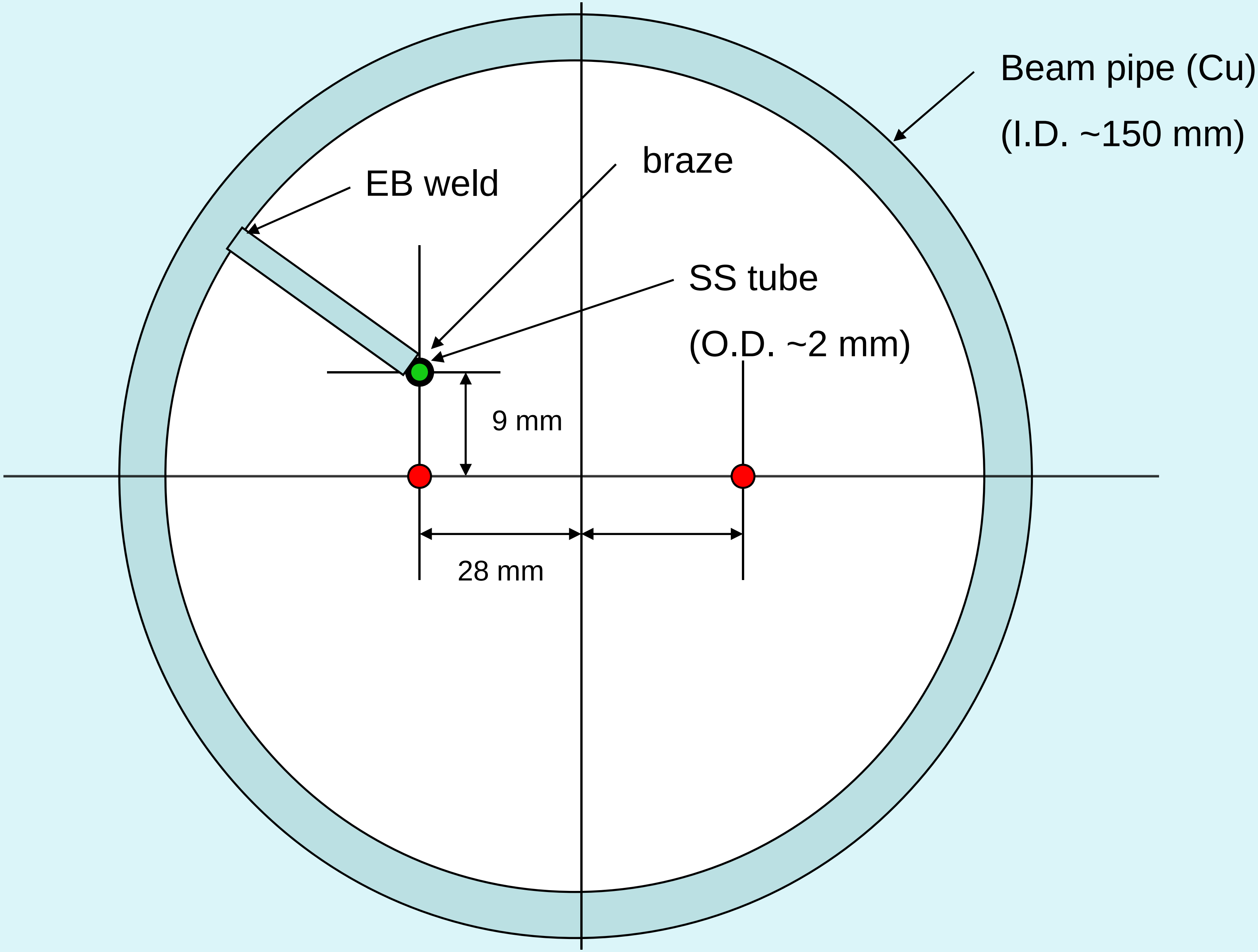
Cryomech, 40 W @ 80 K, 8 W @ 20 K- 0 W @ 8 K



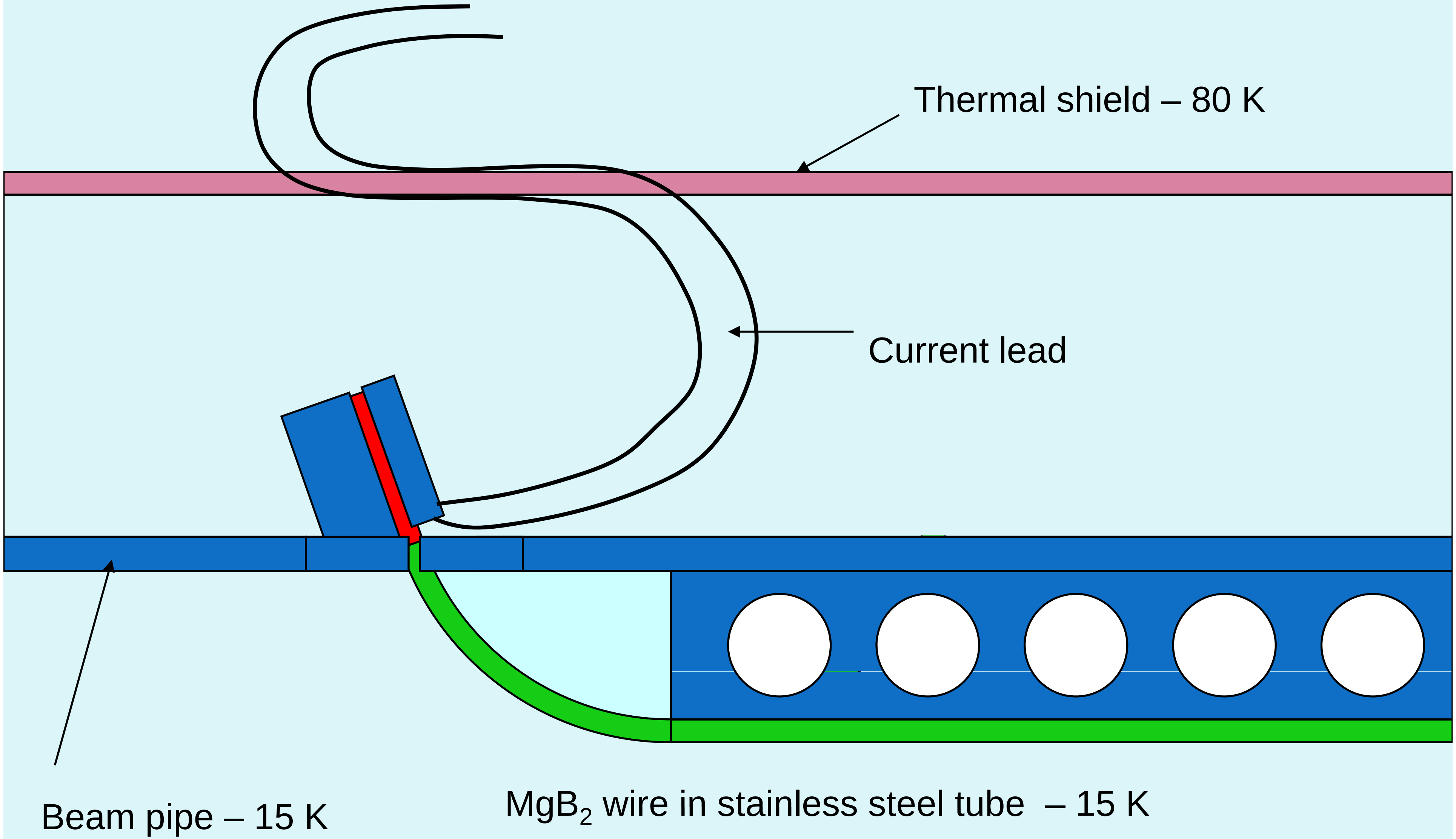
Two-stage Pulse Tube cryocooler



Conductor support structure – cross-section



Conductor support structure – connection



-The current leads and the HTS wire are in the technical vacuum insulation of the cryostat

-The HTS wire is electrically insulated and fitted inside the pre-shaped stainless steel pipe. The unit is positioned inside the beam pipe, welded and electrically connected to the cold end of the leads

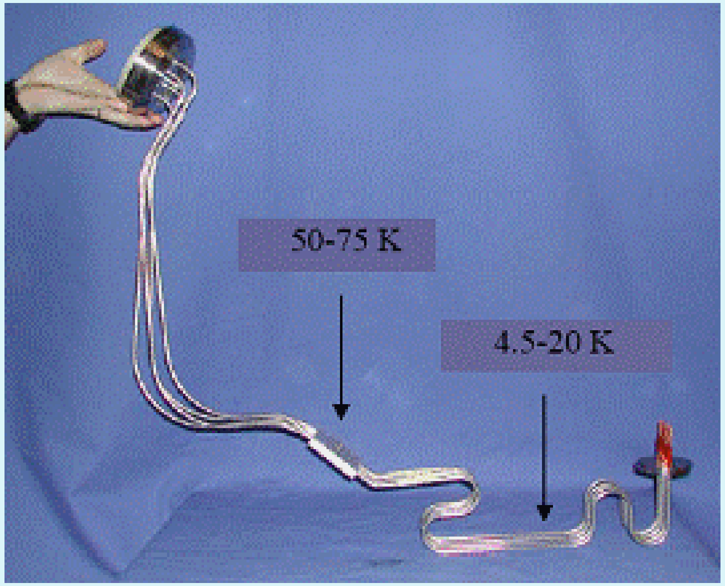
-The separation between the technical vacuum of the cryostat and the beam pipe is assured by welds

-The heat sinks for the current leads are respectively on the thermal screen (T~ 80 K, 3.6 W/lead at 80 A), and on the outer wall of the beam pipe (T~ 20 K, 1 W/lead at 80 A)

-The current leads have a design similar to that of the leads powering the LHC dipole corrector circuits

Current leads for the 60 A and 120 A LHC dipole correctors

There are about 2000 conduction-cooled current leads in the LHC machine. They are incorporated in the SSSs for the powering of the 60 A and 120 A dipole corrector magnets. They are thermalized in the cryostat vacuum insulation against the thermal shield (50-75 K) and on the 5-20 K line C[I].



-The resistivity of copper (RRR=120) at 20 K is ~ $1.3 \cdot 10^{-10}$ Ω m – about 100 times lower than at room temperature

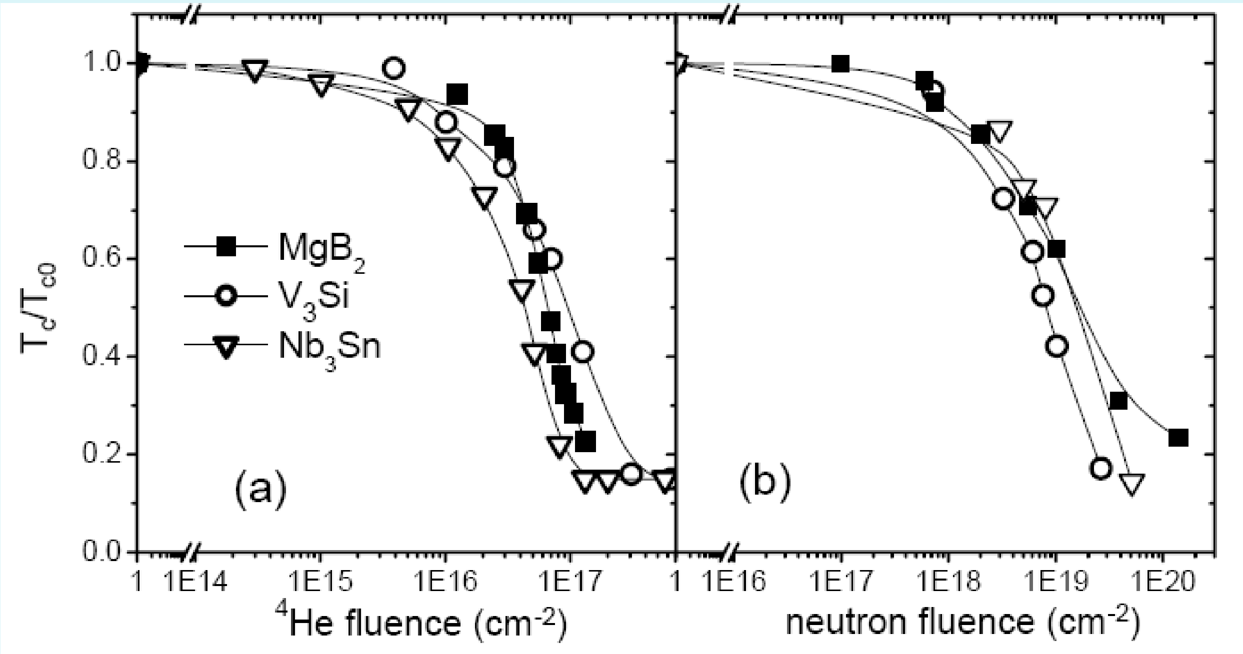
-A copper wire (RRR=120) of about 0.9 mm^2 cross section (Φ~1 mm) would dissipate about 1 W when transporting 80 A in dc mode at 20 K

-At this stage, it may be interesting to consider also the copper wire option (the cryostat, the integration and assembly procedures, and the size of the stainless steel tube would not change –the MgB_2 conductor has a diameter of 1.1 mm)

Open points

-Heat losses from the beam ?
In the present proposal, the MgB_2 conductor operates with a temperature margin of about 10 K

-Radiation in the area where the MgB2 is integrated ?
The radiation resistance properties of MgB2 seems to be good – similar to Nb_3Sn. Neutron irradiation tests were done at very high fluences (up to $3.9 \cdot 10^{19}$ $n \cdot cm^{-2}$, INFM and University of Genova). Up to fluences of $1 \cdot 10^{18}$ $n \cdot cm^{-2}$ no degradation of Tc was observed



Conclusions

-A preliminary study shows that the use and implementation of an HTS wire for the correction of the long range beam-beam effect is feasible

-The preferred HTS superconductor is MgB_2 in the form of wire – BSCCO 2212 and Cu can at this stage also be considered. The final choice of the conductor will not have an impact on the system design

-The electrical and mechanical properties of MgB_2 largely satisfy the requirements for this specific application. A unit length of 100 meters of this wire will be delivered to CERN in October 2008 for a different application

-Detailed drawings and some additional calculations should be done to finalize the present proposal