



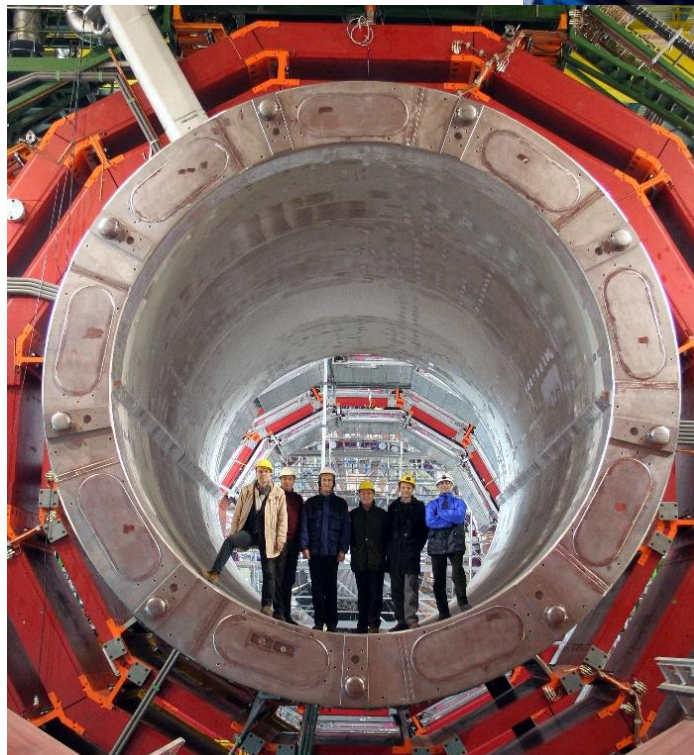
# **Self-Protecting HTS Current Lead**

## **- Demonstration of a new technology -**

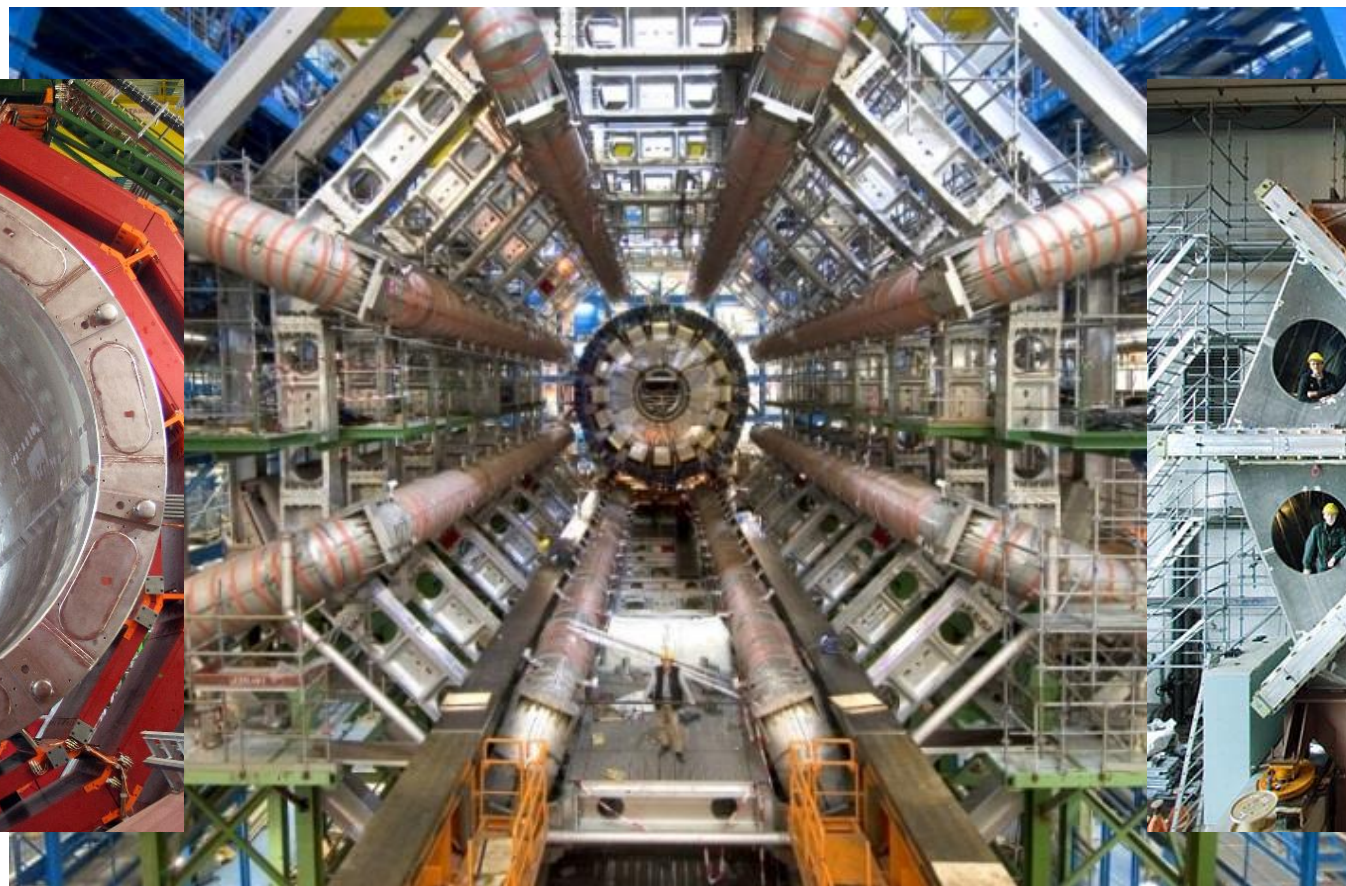
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***Joris Willem Blokker, Nikolay Bykovskiy, Tim Mulder, Helder Filipe Pais Da Silva,  
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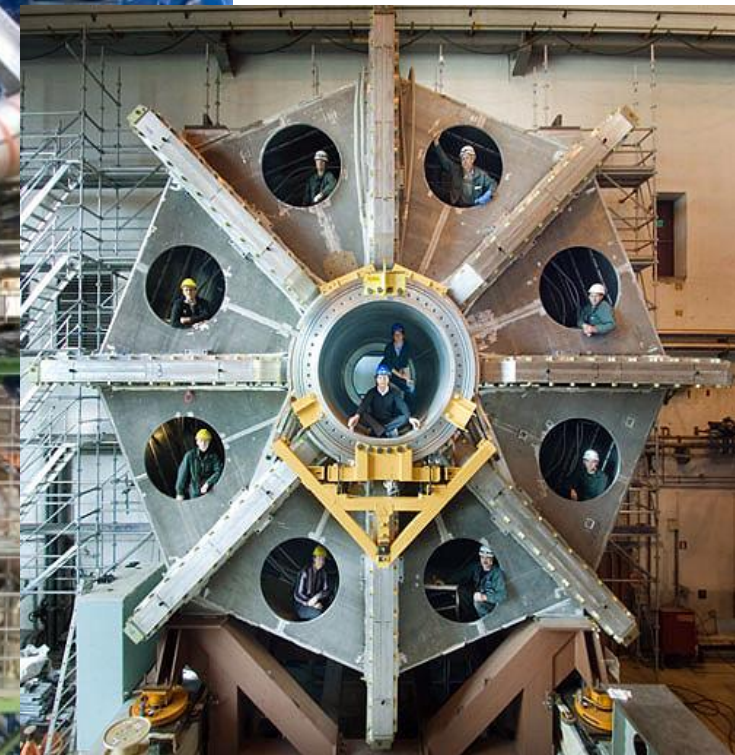
# Detector magnets and HTS leads?



CMS Solenoid



ATLAS Barrel Toroid

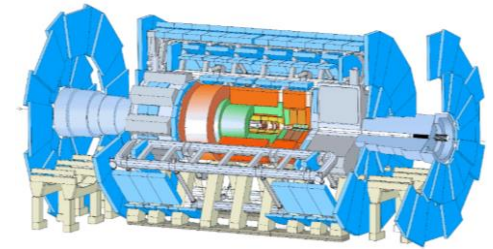


ATLAS End-Cap Toroid

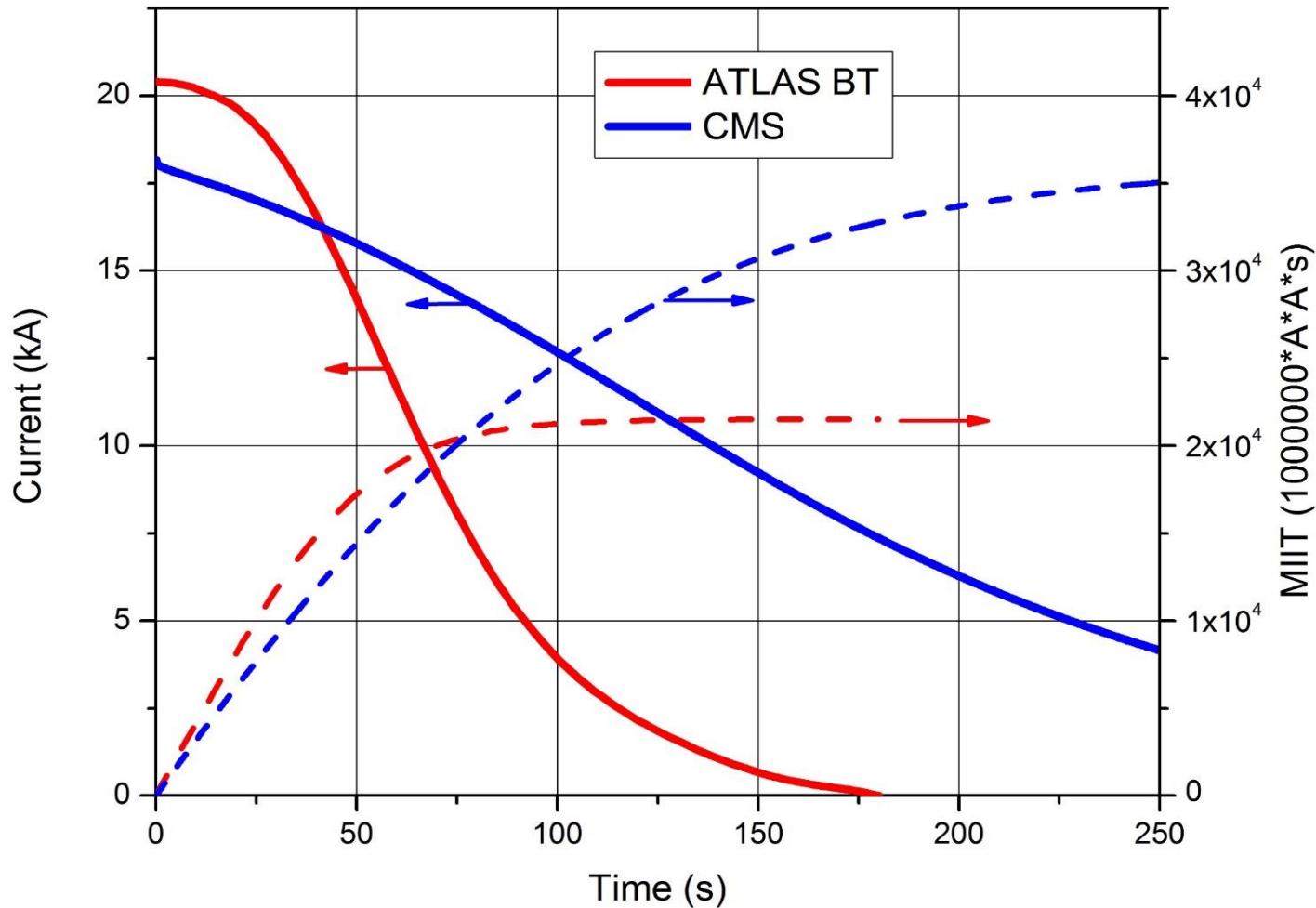
*What is specific for magnet systems in detectors?*

# Detector magnet features related to current leads

- Magnets for detectors are mainly designed as low voltage systems with no fast changes of magnetic field. It results in **hundreds of seconds of fast discharge** even at a quench event.
- Physicists will never accept the interruption of detector operation during a physics run. Magnet recovery after fast discharge stops the detector for a week! So every element in the magnet system (including controls, protection etc.) has to be **100 % reliable**.
- As detector magnets are always ON, the dominating reason of slow energy discharge lasting for many hours, is a power cut. During a slow-discharge the magnets are kept cold by using many cubic meters of stored liquid He.
- Using **50 K helium gas for cooling CL heat exchangers is not an option** and liquid nitrogen cooling may be considered.



# Is the discharge really fast?

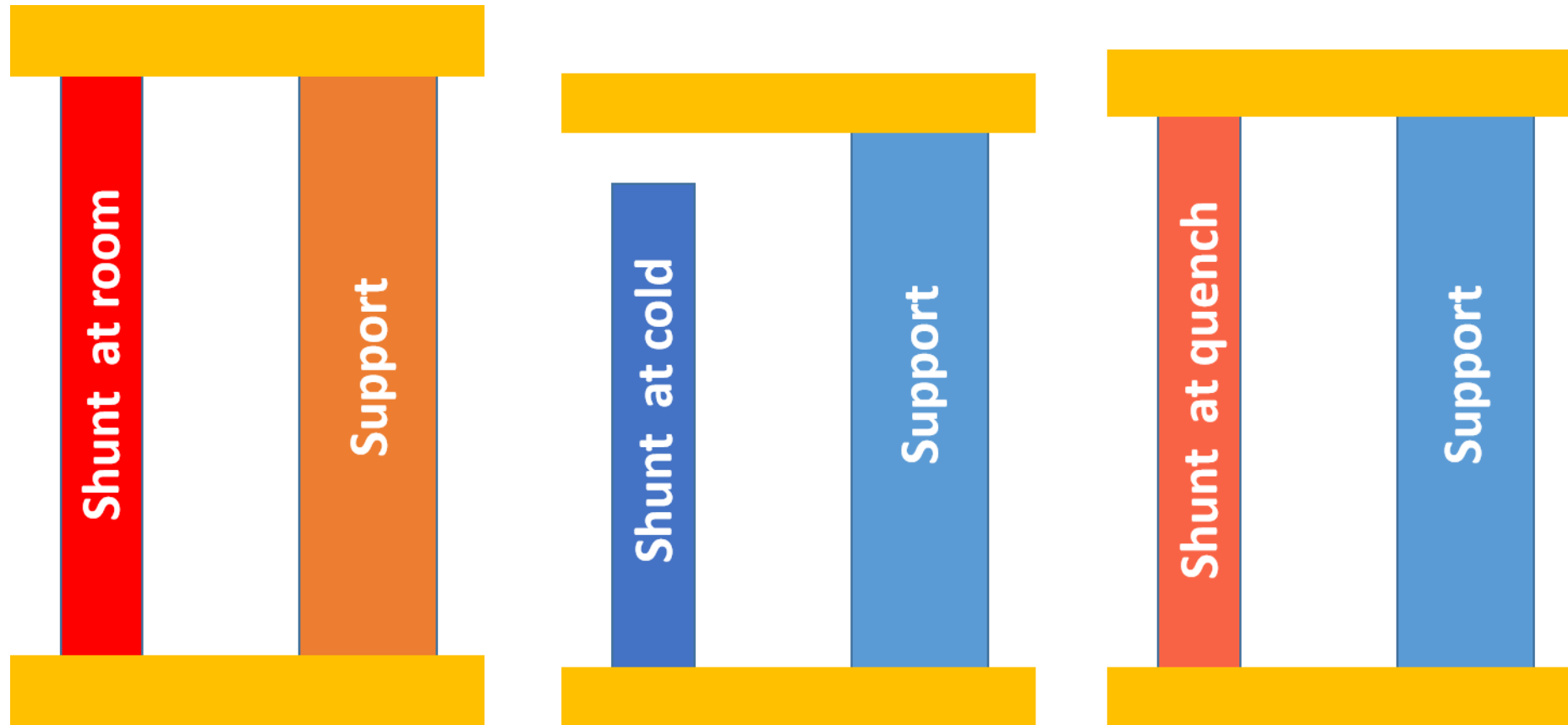


Fast discharge of ATLAS Barrel Toroid and CMS Solenoid  
(courtesy of B. Cure for data of CMS Solenoid)

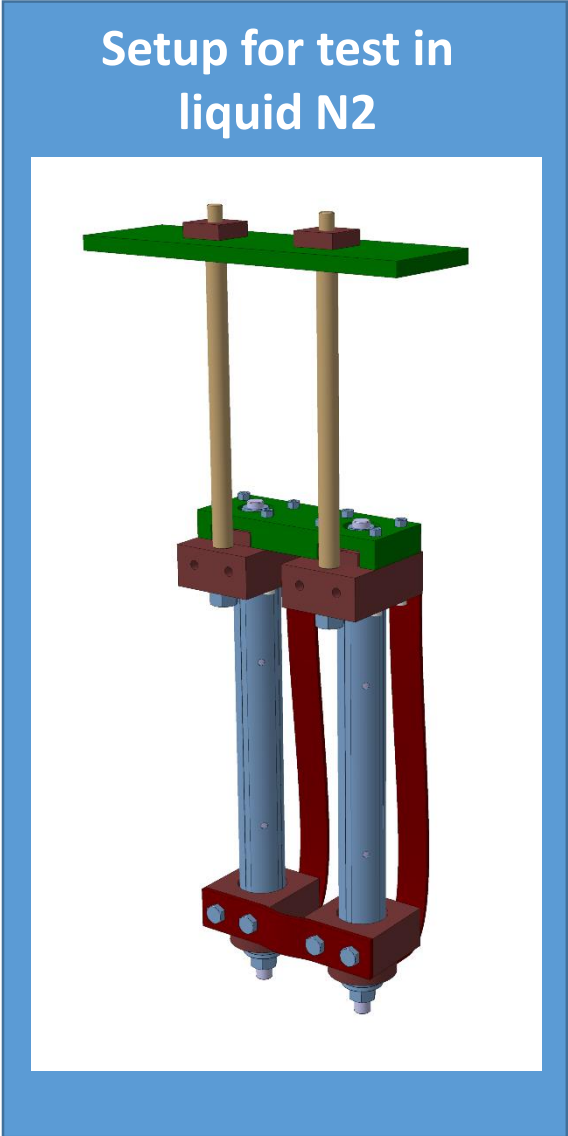
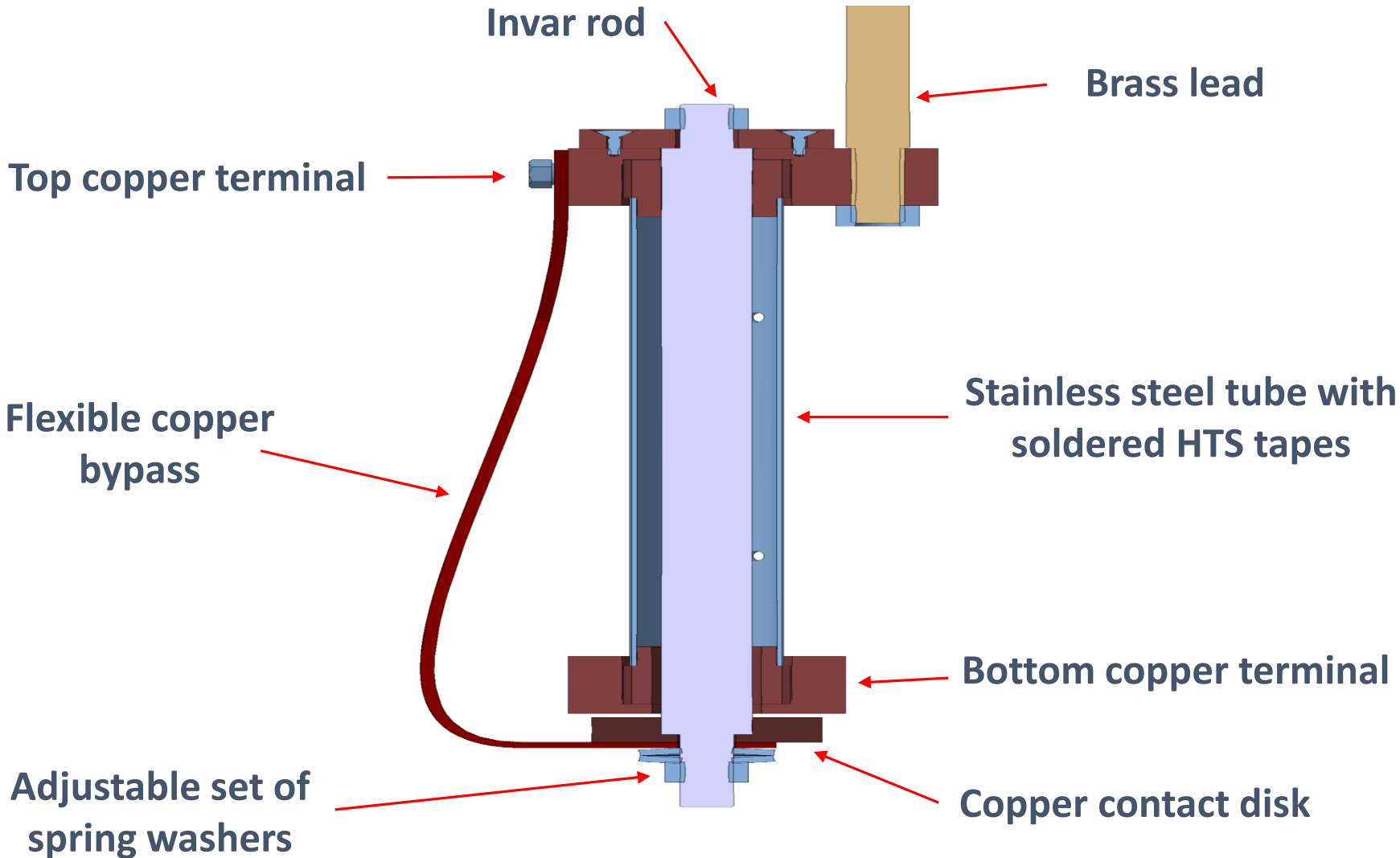
- Assuming zero cross-section of HTS tape shunted by stainless steel, and choosing 200 K of maximum temperature of the HTS bus bar, we may get the dimensions of the shunt depending on the heat load choice.
- With a typical HTS length of 0.5 m the ATLAS and CMS leads would conduct 0.2 W/kA and 0.3 W/kA respectively.
- An obvious improvement can be an increase of length **but is there another way to reduce the heat load? YES**

# Thermo-mechanical heat breaker

- When using the difference in the thermal expansion between materials, we can built a thermal switch that is in OPEN state at cold temperature but turned CLOSED when heated.
- The HTS section is shunted by stainless steel. The support structure made of Invar will shrink 1.2 mm less for 500 mm of lead length, thus providing a good break in the heat conduction.

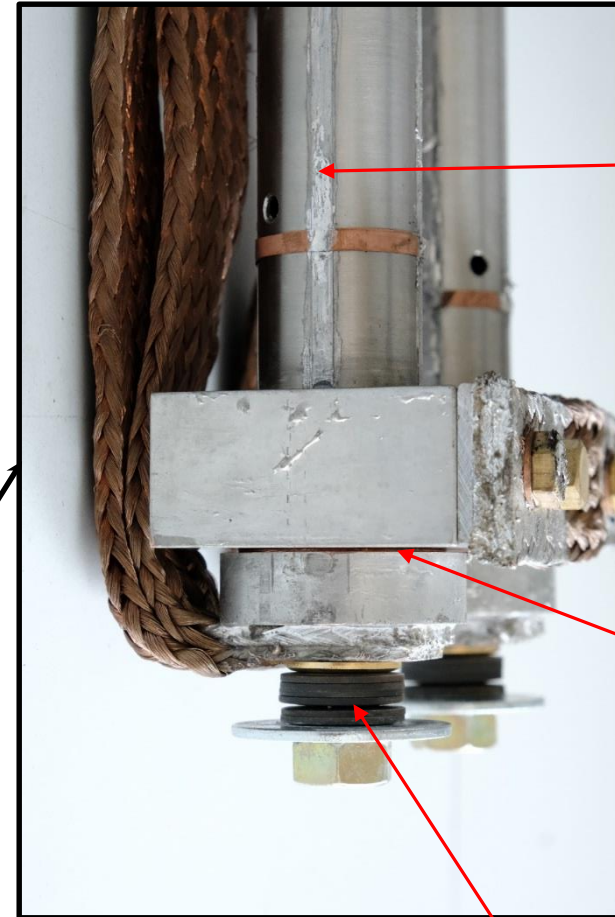
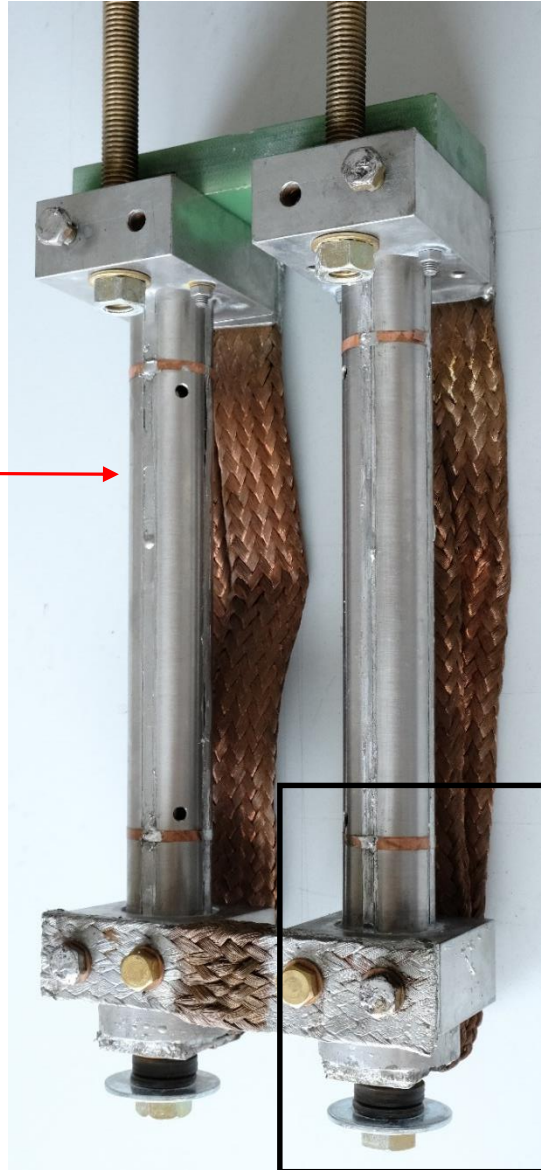


# Layout of a first prototype for 800 A



# Prototype as built

24 cm long  
stainless steel tube  
 $\text{\O} 33.7 \times 1.5$  mm  
with  $\text{\O} 20$  mm invar  
rod inside



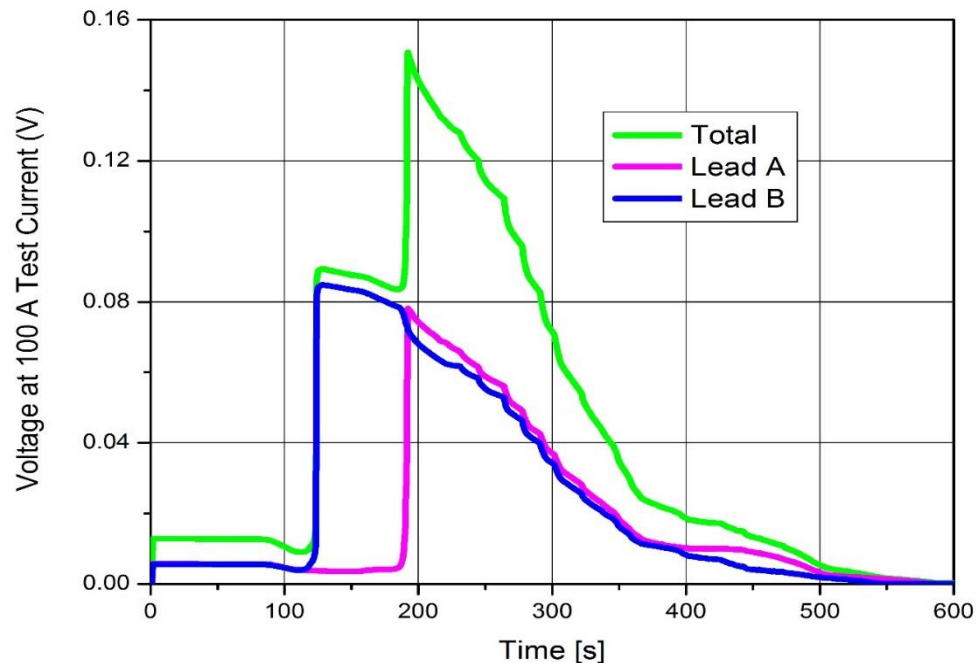
4 soldered BSCCO  
tapes type G of  
"Sumitomo Electric"

Gap surface is not  
specially prepared  
for low contact  
resistance

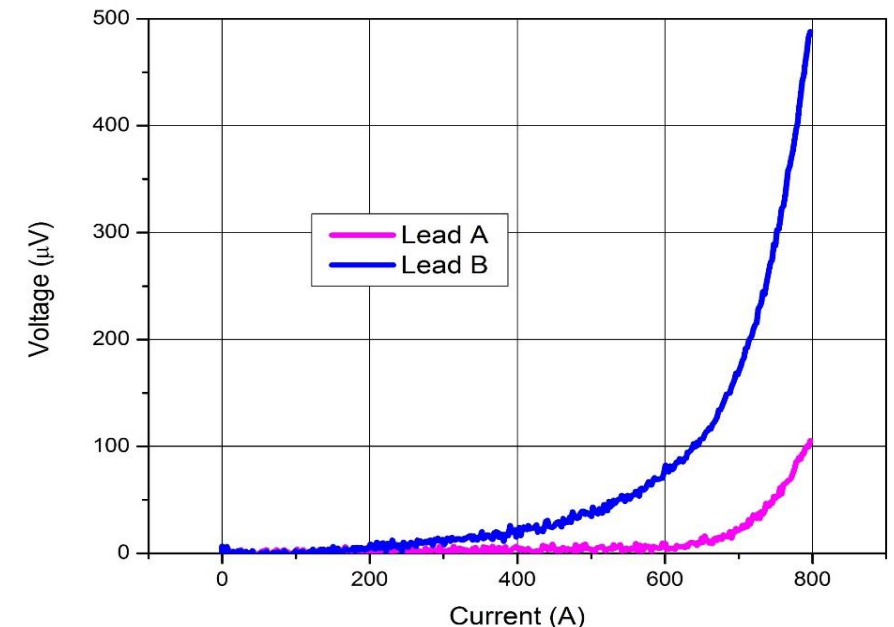
Spring washers are adjusted to insure  
compression of 600 kg without overstressing  
of material during cool down or overheating

# Test in liquid nitrogen

- Open vessel with liquid nitrogen can be lifted or lowered to required level in order to cover the HTS part entirely or to keep only the bottom copper terminal in liquid.
- 50 thermal cycles (sometimes thermal shocks) were done. No degradation of critical current of both leads have been observed.
- There was no precise machining of the gap size yet, causing some variation in opening & closing times of the leads.



Cool down (lowering to liquid nitrogen)

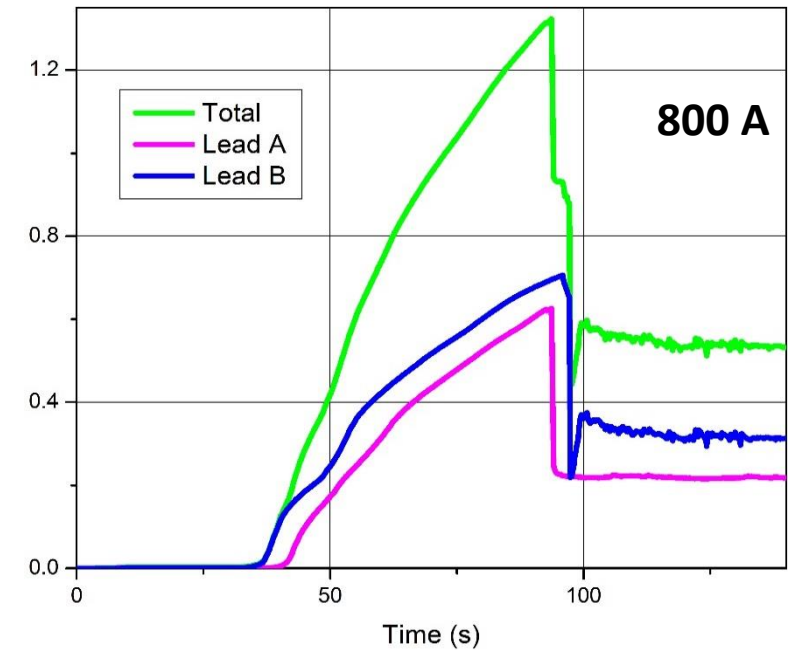
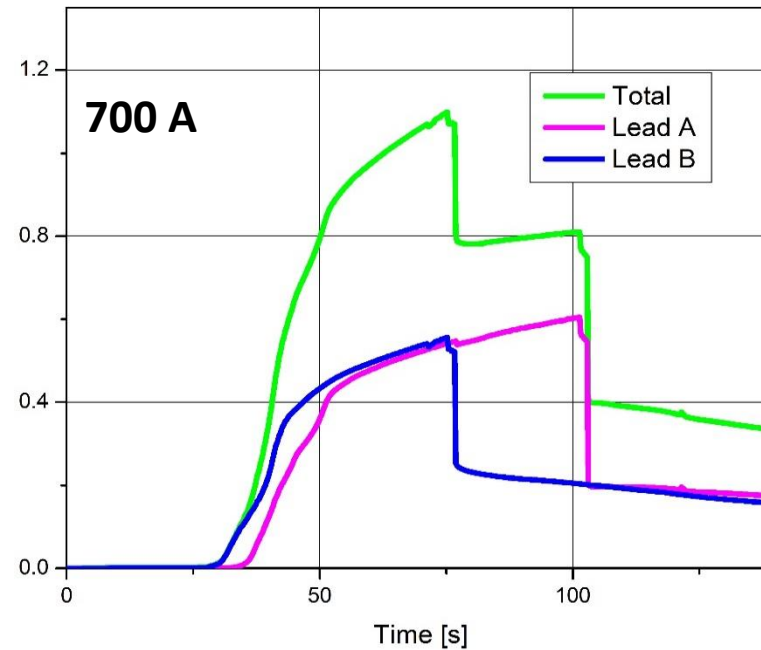
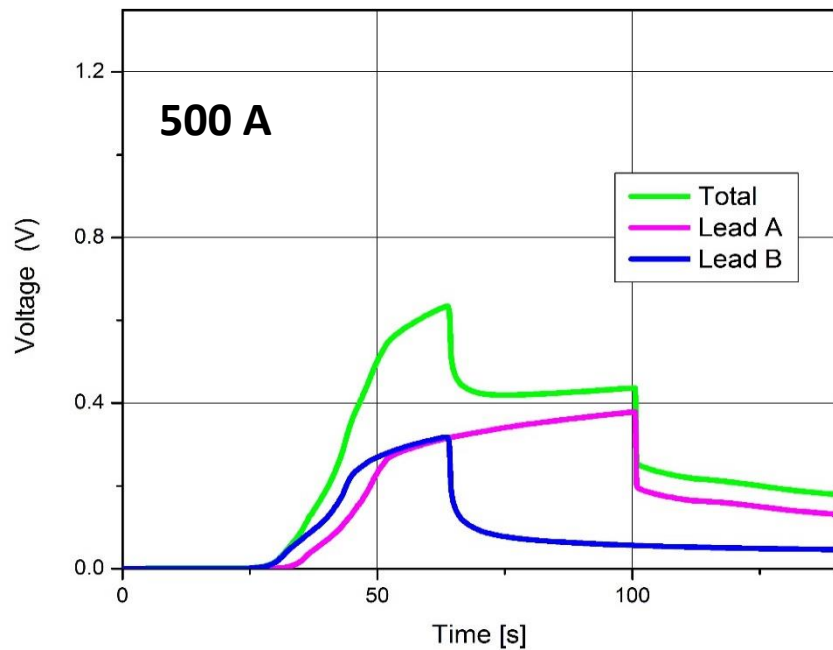


Ic measurements performed after each cycle do not show any degradation. VI curve remains unchanged.



# Response to stop of cooling

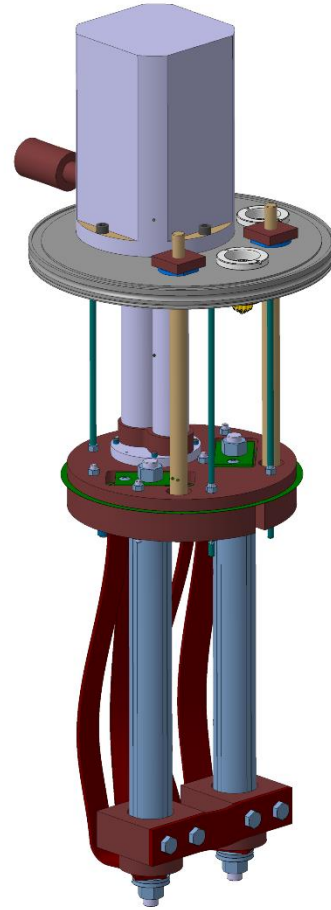
- At high current the thermal switch behaviour corresponds to their cool down: the first once closing is also the first one that opens. The smaller the gap, the faster is the response.
- During this test there was no control of the lifting speed that affects the response time.
- Test at 800 A done after setup reassembly and both leads switched almost at the same time.



✓ **Conclusion:** the first prototype has demonstrated a possible method of HTS lead protection by using a thermo-mechanical bypass of current.

# Next....

- Existing setup will be tested in vacuum and cooling provided by PT60 Cryomech cryocooler.
- While the critical current is expected to be twice more, the maximum test current of a few hundred A is limited by the cryocooler power.
- A heater is placed at the cold head to test effect of temperature variations.
- Also considering a heater on the HTS part to study a possible reduction of switch reaction time.



Lead test  
on PT60  
cryocooler

- A new 4.5 kA prototype will be tested for use in the BabyIAXO magnet. Test setup is currently under construction.
- Setup equipped with two cryocoolers: 1 single stage GM machine for cooldown of the conduction cooled leads and 1 two stage PT cryocooler to provide 4 K at the cold mass.
- Two HTS options are tested: BSCCO tapes soldered to the stainless steel as in the first prototype, and *ReBCO* tapes separated from the bypass and protected by integrated quench heaters.



4.5 kA lead  
test setup