First results – beam energy deposition into superfluid helium

(bump tests 6.10.2010 and DS quench test 6.12.2011)

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Introduction

All coils and cold masses of LHC magnets in arc are immersed in superfluid helium (SFHe).

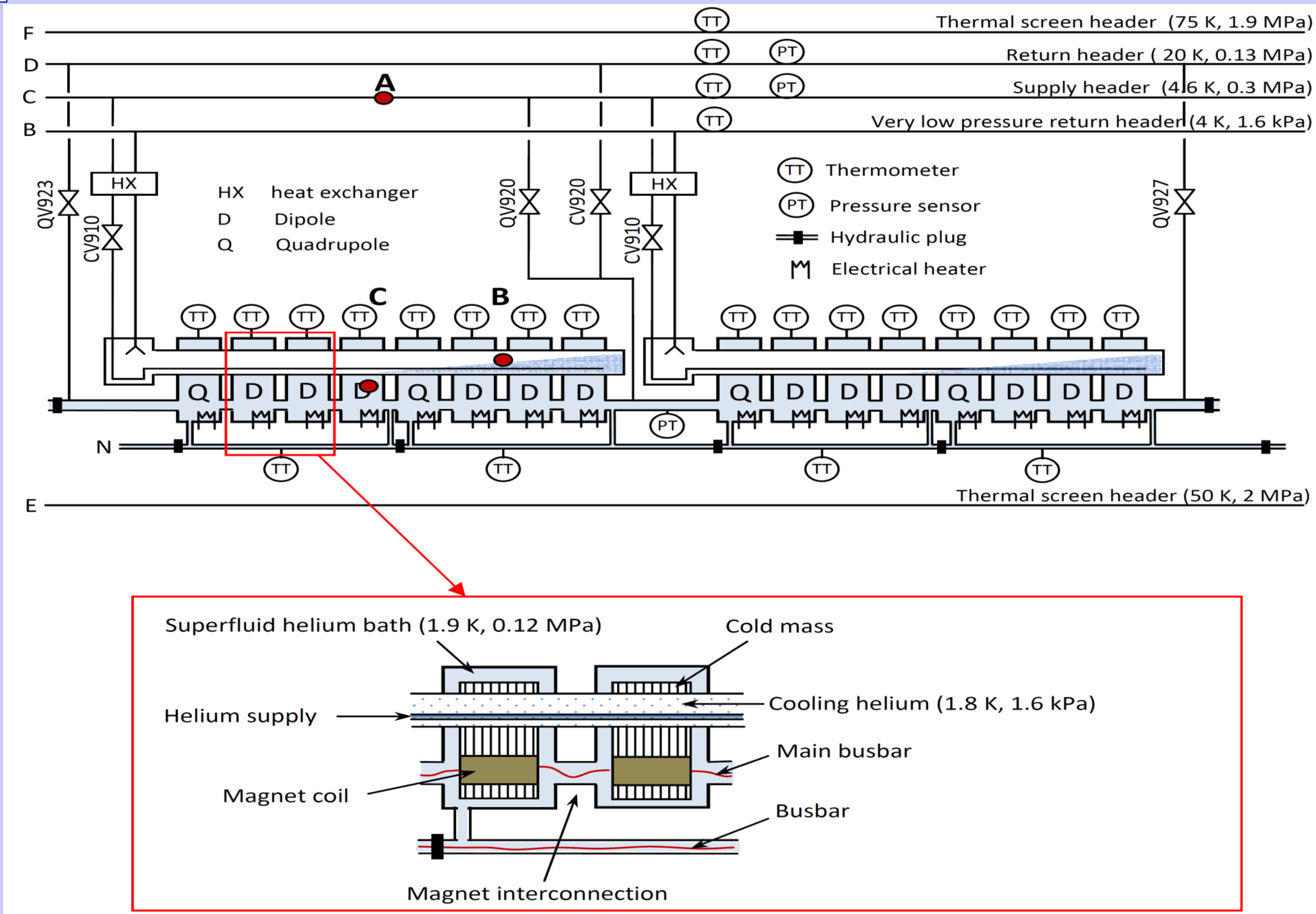
SFHe is maintained at ~1.9 K with active low pressure helium circuit hydraulically independent from SFHe bath.

One bath of SFHe contains (in standard arc part) 4 quadruples and 12 dipoles (~214 m). A bath can be considered as a closed volume up to pressure of ~ 15 bara.

Each quadruple and dipole is equipped with TT and whole bath with one PT.

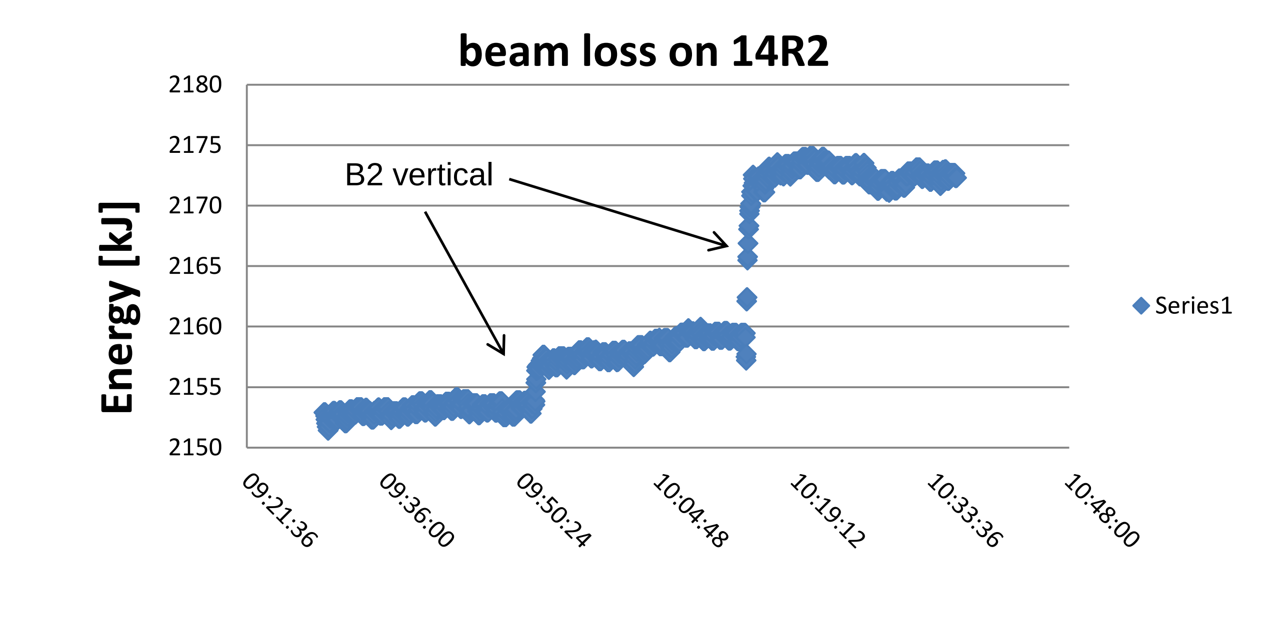
Standard arc cryo architecture

Without beam screen circuit !



Bump tests 6.10.2010

When any energy is deposed in SFHe the pressure and temperature in the bath varies. From these variations, internal energy of helium can be recalculated u [kJ/kg] and knowing helium mass deposed energy can be quantified.

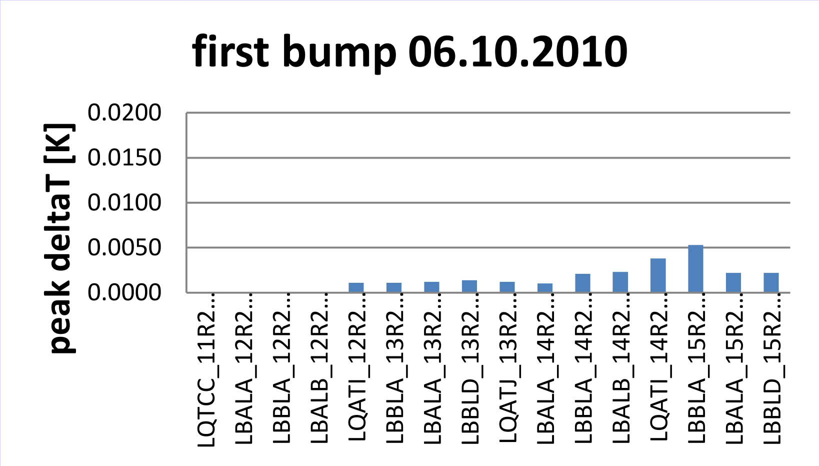


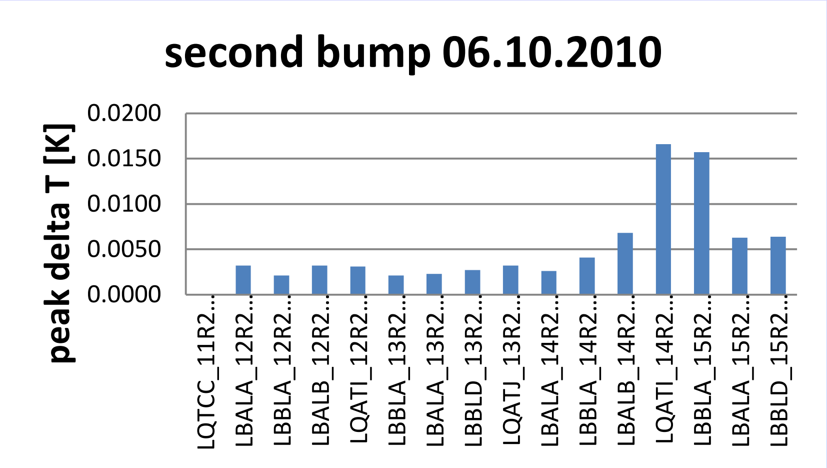
First bump:
beam energy ➔ 6518 J
Energy seen by cryo ➔ 5482 (84% of initial beam energy)

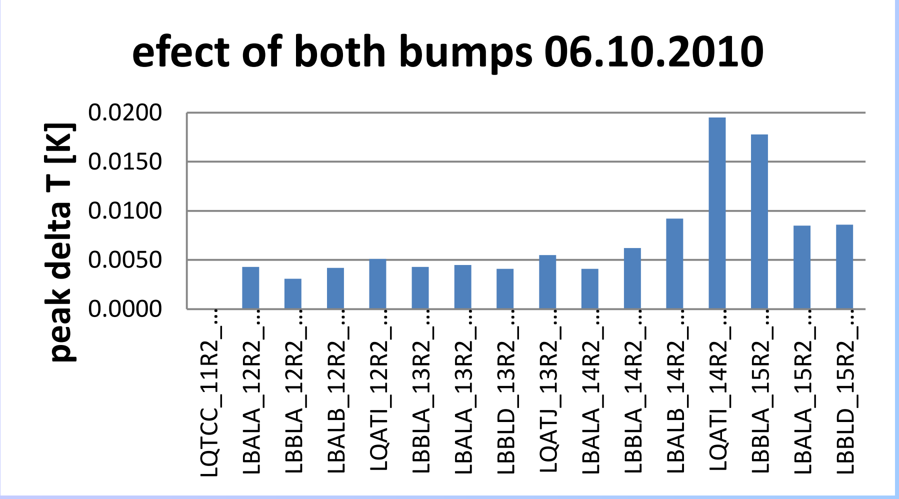
Second bump:
beam energy ➔ 16993 J
Energy seen by cryo ➔ 15872 (93% of initial beam energy)

Bump test 6.10.2010

Temperature profiles over 214 m



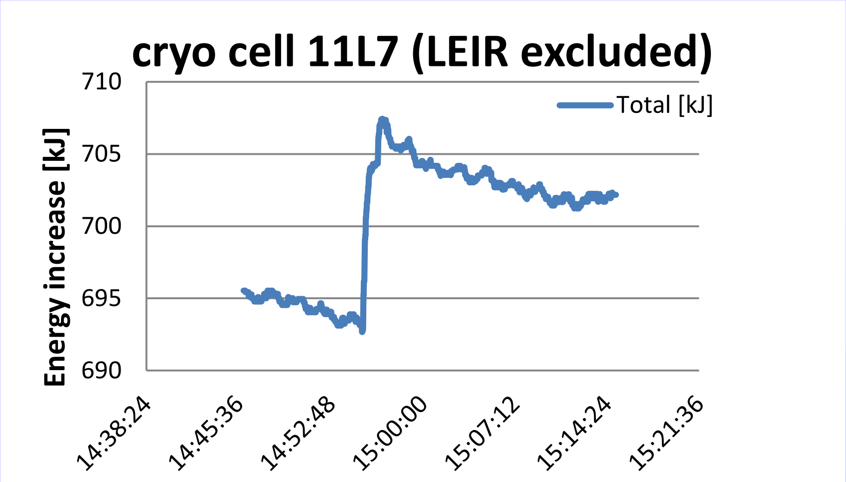


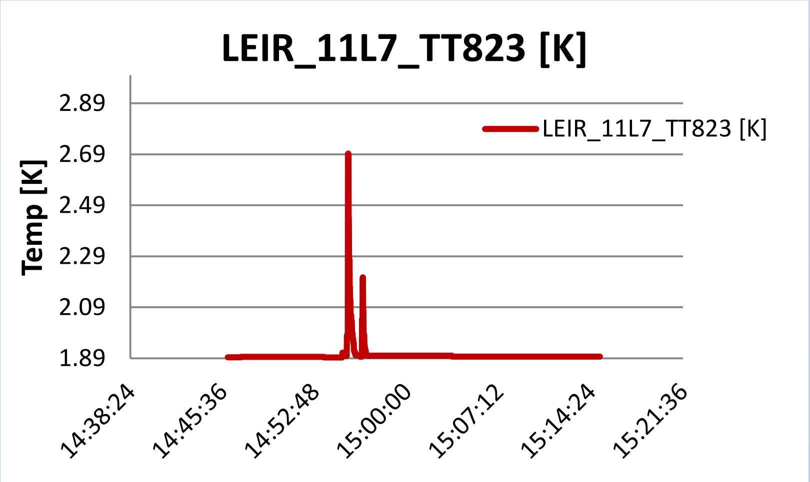


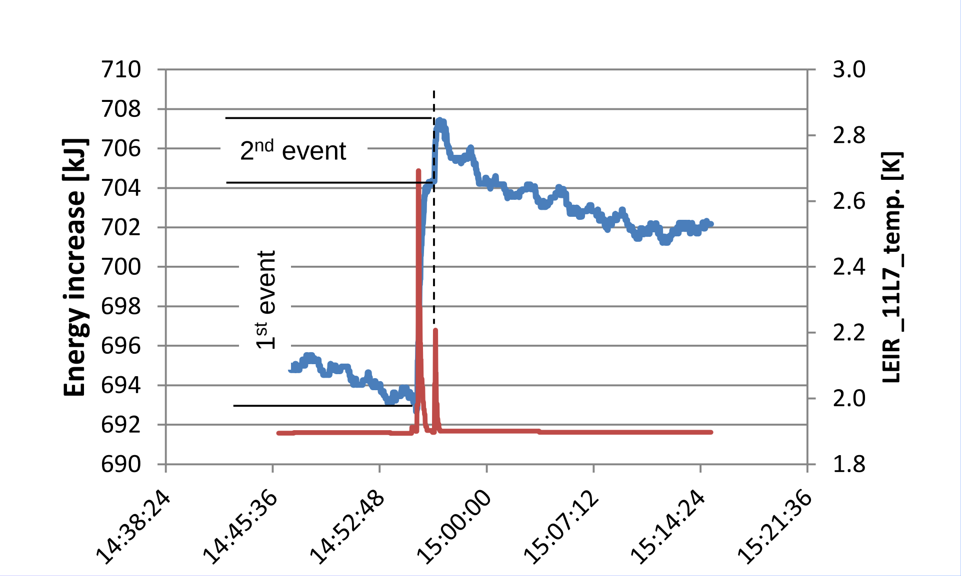
Looking on the profile – beam hit either LQATI_14R2 either LBBLA_15R2

DS quench test 6.12.2011

Energy increase in He bath over 214 m



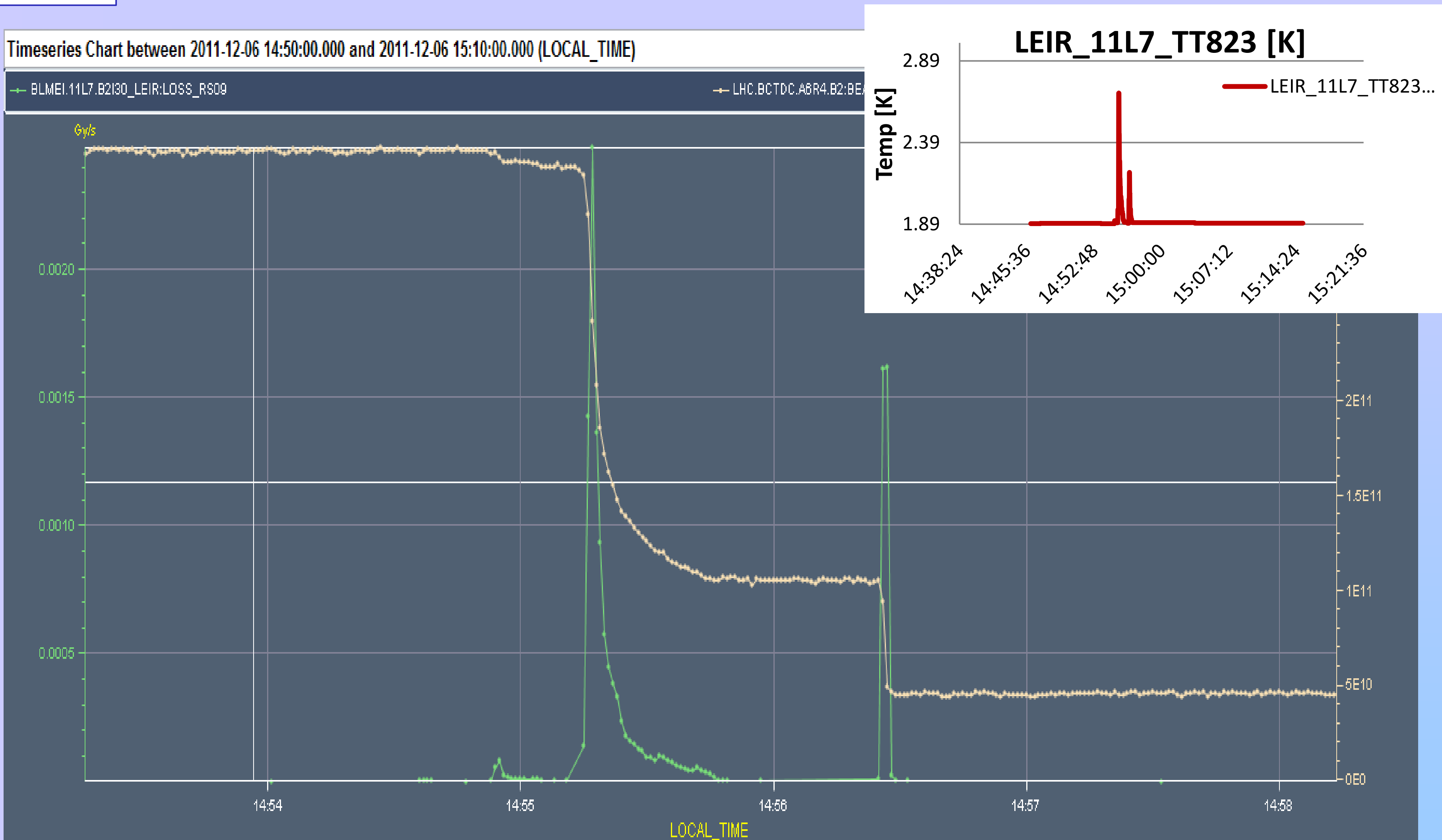




1st event at ~14h55m30s:
Energy seen by cryo ~ 11 kJ

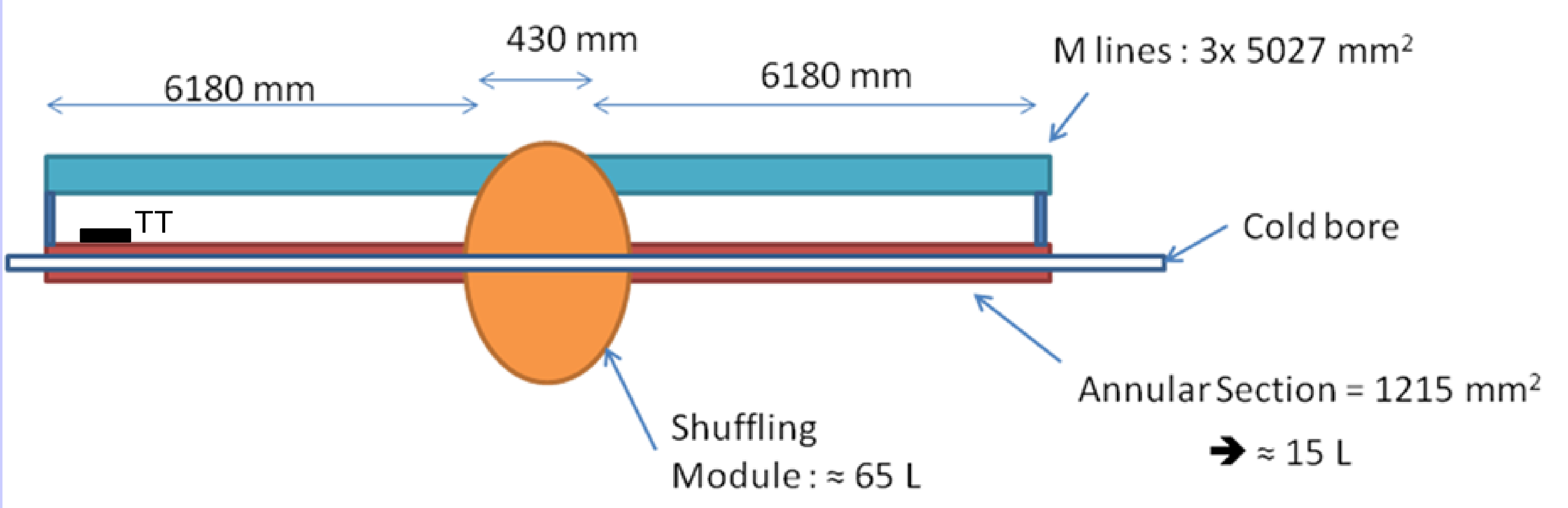
2nd event at ~14h56m30s:
Energy seen by cryo ~ 3.8 kJ

Correlation BLM – LEIR TT



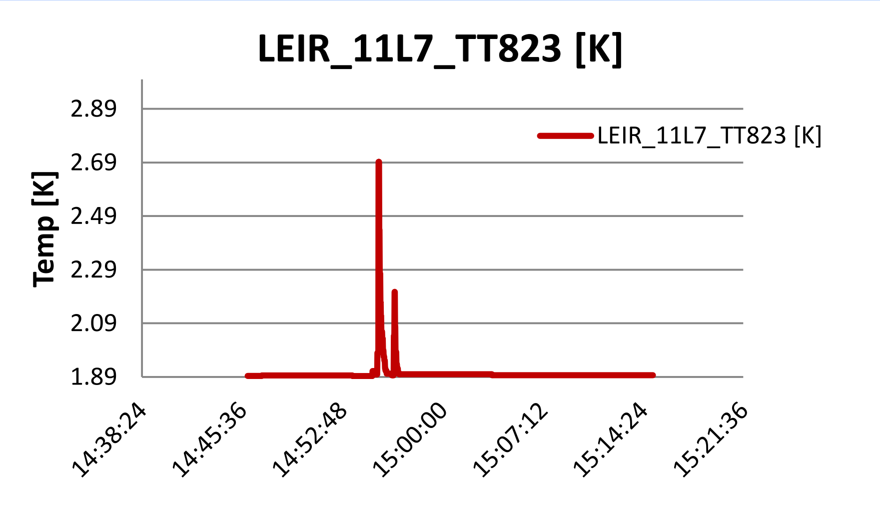
BLM signals – courtesy of A.Priebe and M.Sapinski.

Empty cryostat



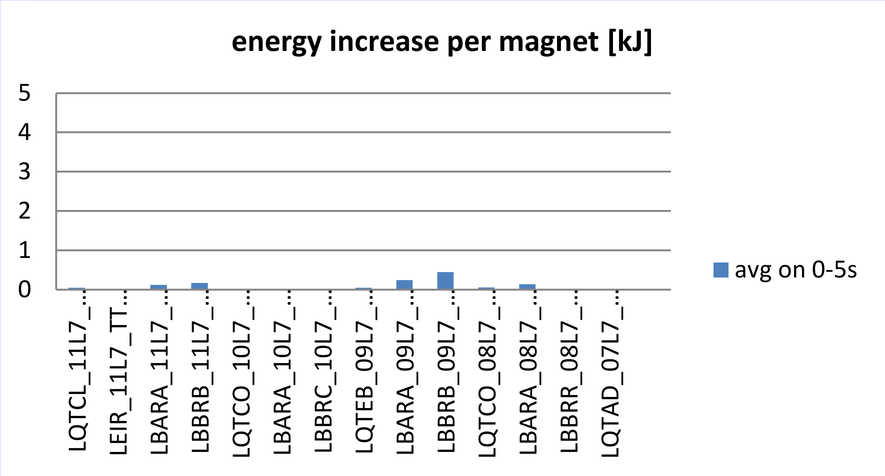
Position of TT and lower SFHe inventory makes empty cryostat very sensitive on energy deposition. But estimation of deposed energy stays difficult since heated helium inventory is difficult to be correctly estimated. Analysis on this cryostat stays as open point for further investigation.

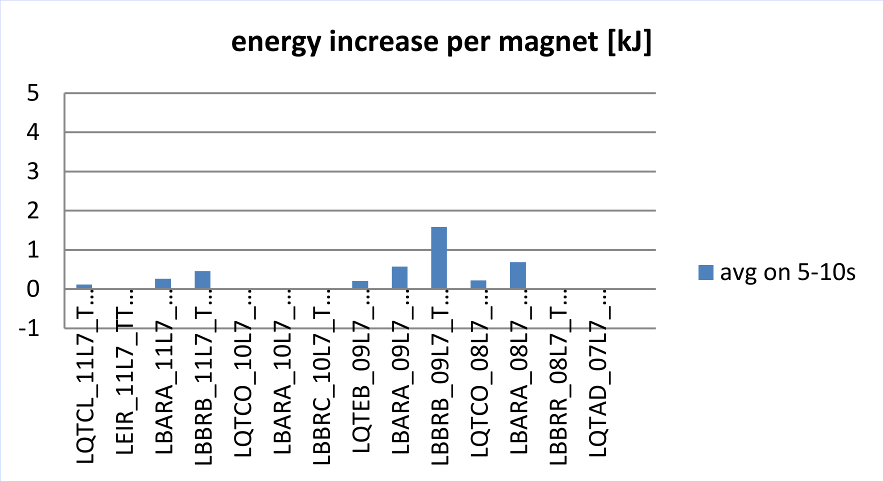
Picks seen on LEIR_TT823 are in perfect time accordance with BLM signals.

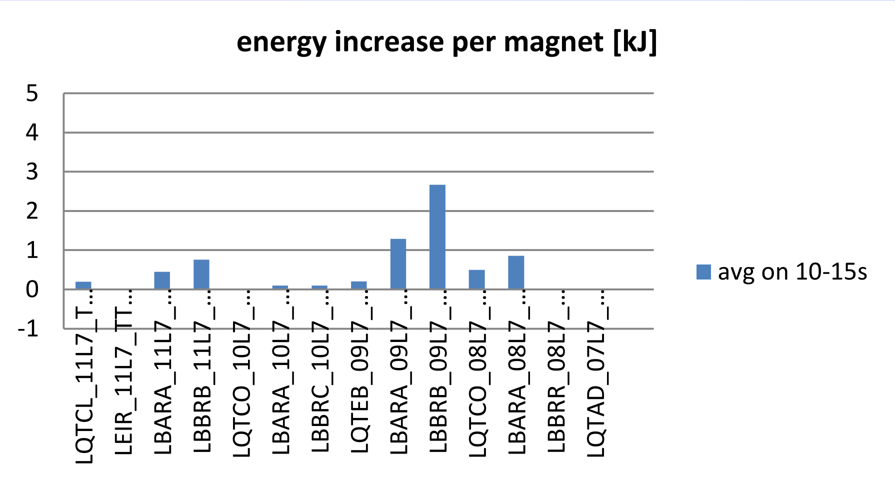


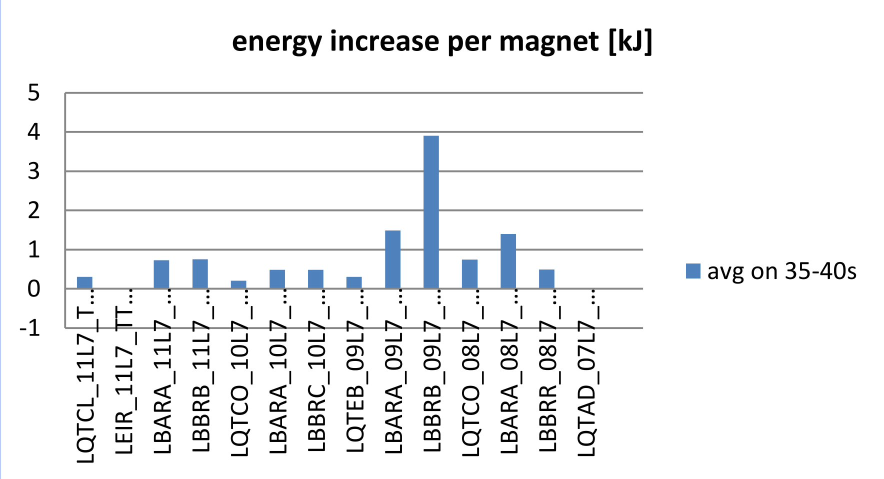
Energy increase in time

Charts show energy increase per magnet.



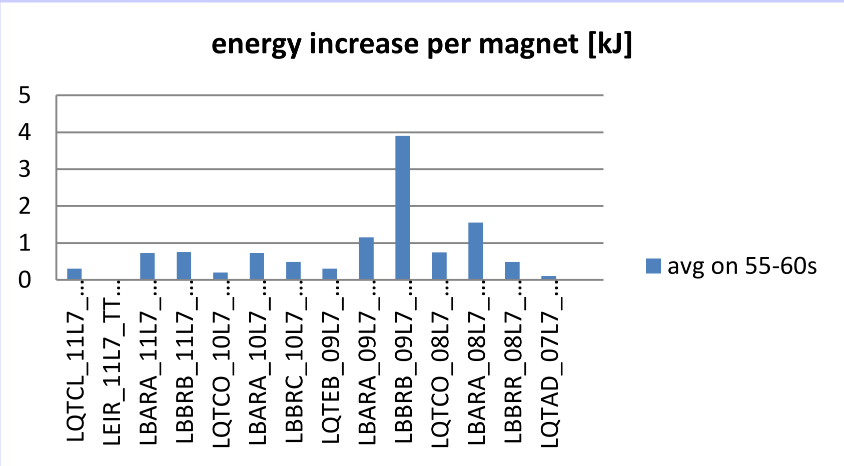


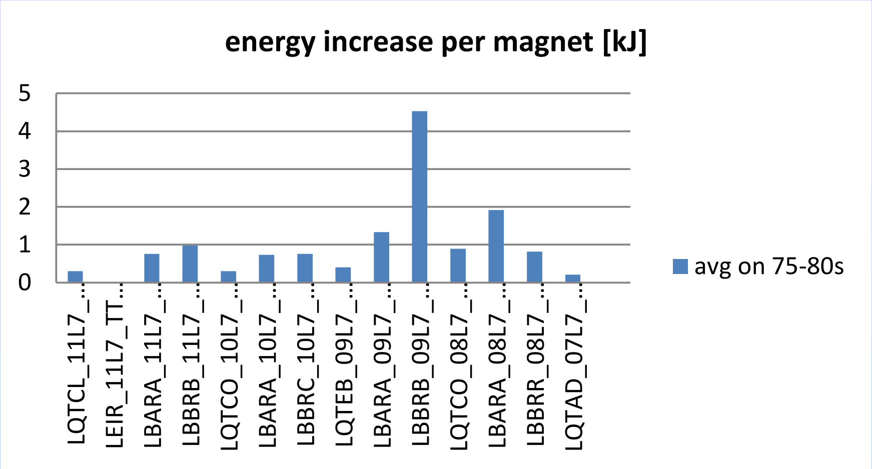


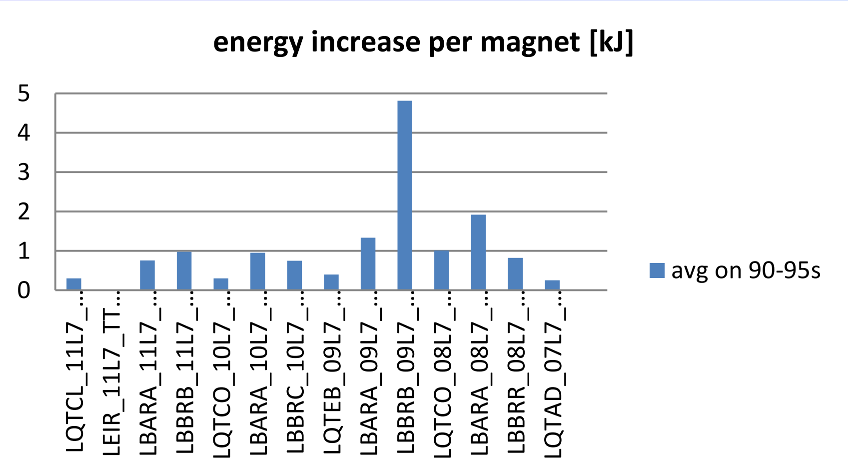


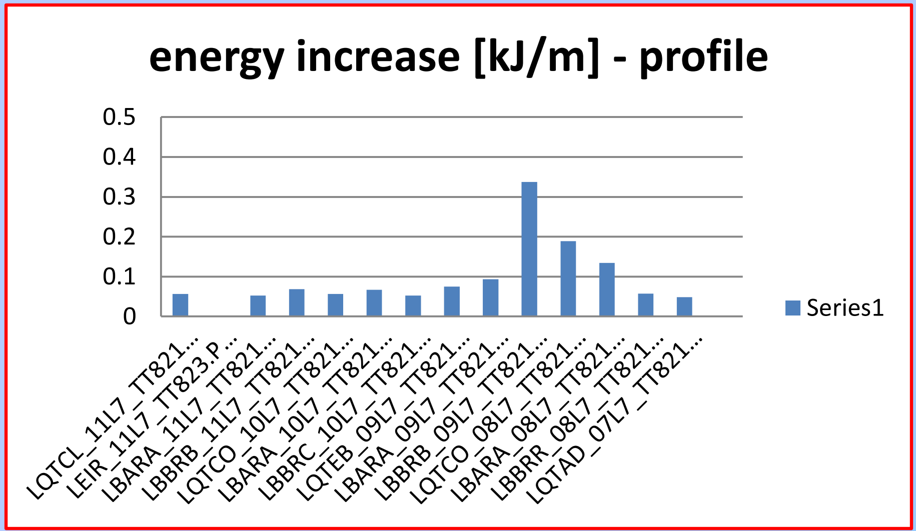
Energy increase in time

Charts show energy increase per magnet (except red framed chart).

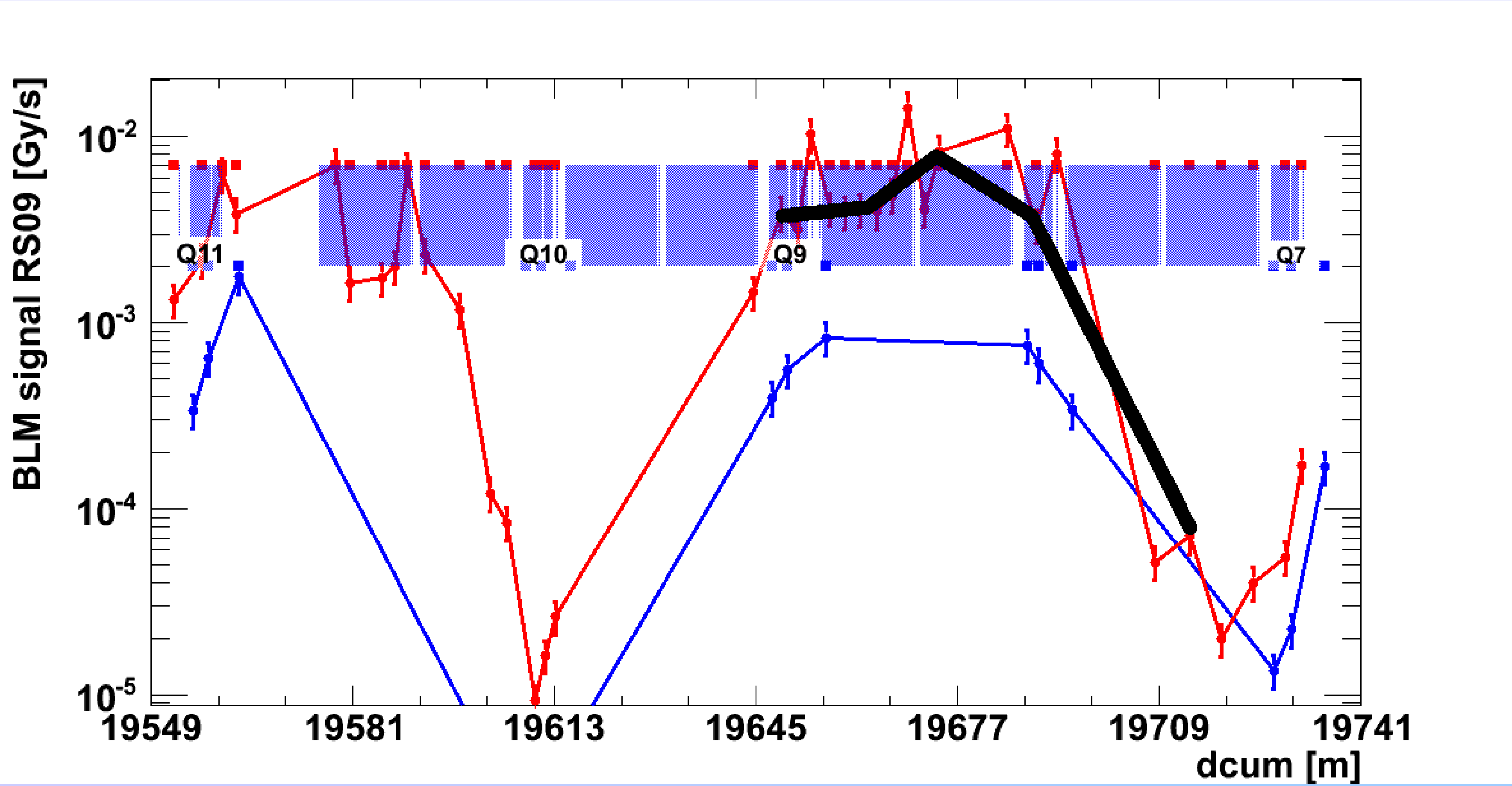






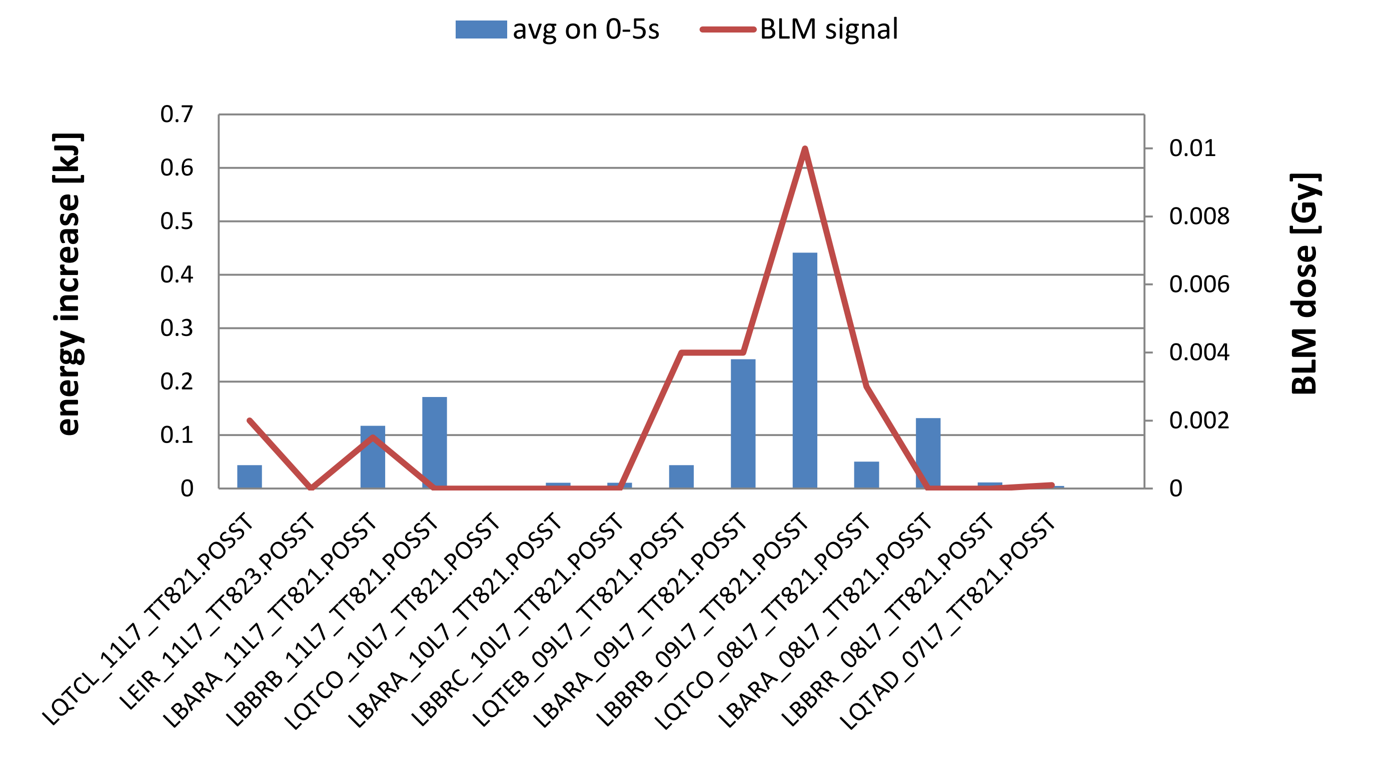


BLM signals



BLMs signal with marked chosen profile – thanks for consultancy with BLM team A.Priebe and M.Sapinski.

Cryo and BLM profiles

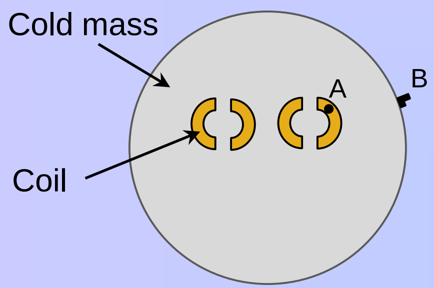


(energy increase per magnet)

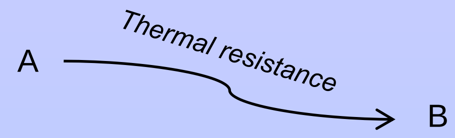
BLM signals – courtesy of A.Priebe and M.Sapinski.

Modelling principle – critical coil T

Schematic sketch of LHC cold mass



Thermal path from point A to B



We know from cryo measurement:

- temperature of point B = TT821,
- energy deposition on a magnet can be quantified and compared with beam loosed energy,
- maximum temperature at point B is obtained after 39 s from beam loss,

- geometry and material property of a magnet – to be known and properly modeled

Then:

- temperature at point A can be estimated,
- correlation between beam loss (BLM signal) and temperatures at points B and A can be found
(BLM threshold to be set < then critical temperature of point A)

The model construction is complex and not so trivial to be correctly prepared, however proposed principle is valid (open for further detailed discussion).

Summary and conclusions

Directions could be developed for coming MDs (suggestions):

1. Bump and quench tests with progressively increased beam energy (more statistics needed)

2. Dedicated model to extend understanding of thermal processes from point B to point A could be developed.

3. Analytical approach for LEIR cryostat is to be developed ➔ Analysis with empty cryostat is interesting since there is only a film of SFHe in place of standard coil and TT installed on standard coil diameter …

Conclusions

- Energy deposition from lost beam entering SFHe bath can be recalculated (steps not lower than 5 kJ can be clearly visible),
- Results from both tests could be used as an information input for model build, critical coil temperature evaluation, then with existing correlation for … calibration of BLMs ...
- More MD tests and modeling is necessary to have more precise measurements and calculations

Thanks to Agnieszka Priebe and Mariusz Sapinski for their input and explanations of physics behind BLMs ☺ !