ISSUES IN QXF PROTECTION

E. Todesco

With contributions from
H. Bajas, H. Felice, T. Salmi, M. Sorbi

QXF: DUMP RESISTOR

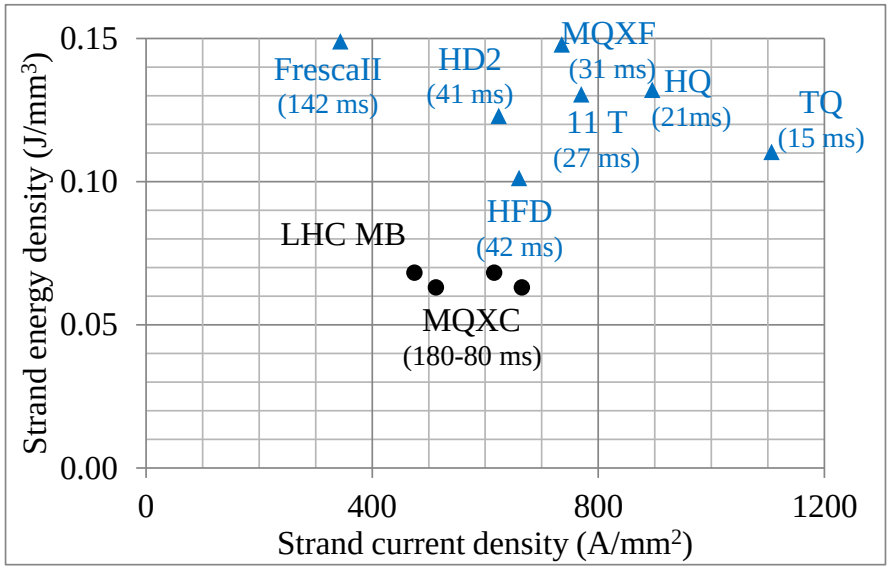
- Short magnets have been always tested with extraction through dump resistor
  - Non negligible fraction of energy extracted
  - For long magnets situation can be different
- Estimate for the QXF
  - 800 V as maximal voltage on the magnet, current of 17 kA, 50 mΩ dump resistor
  - 1-m-long → half of energy extracted
  - 8-m-long negligible effect

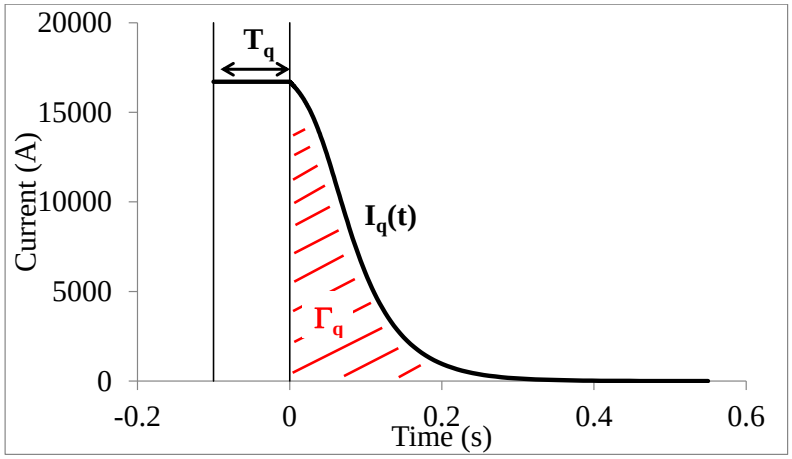
MQXF			
Lenght (m)	Energy (MJ)	Extracted energy (MJ)	(%)
1.0	1.56	0.76	49%
4.0	6.24	0.94	15%
8.0	12.48	0.97	8%

- We must work in the hypothesis of no (negligible) dump resistor

QXF: HOTSPOT TEMPERATURE

- Time margin for protection: how long we can stay at nominal
  - Before having all magnet quenched
  - And before reaching T_{max}=300 K at I(t)=0

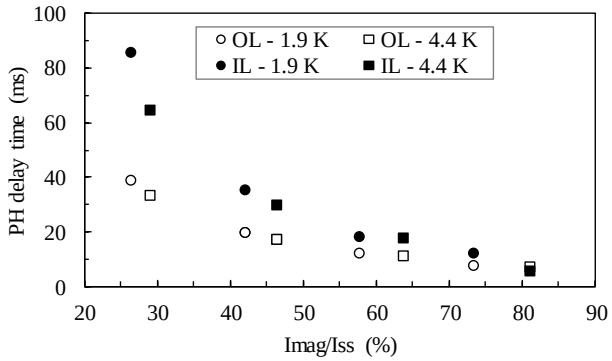




- Time is ~30 ms: improved situation w.r.t. HQ and TQ, similar to 11T

QXF: HOTSPOT TEMPERATURE

- We have ~33 ms to quench all magnet
  - Quench detection (time to reach 100 mV): typically 1-2 ms in HQ
    - [but up to 7 ms in one case at CERN]
    - With 30% larger cable cross-section, this time should increase by 30%
  - Validation window: 10 ms in LHC, possibly to be reduced at 5 ms
  - Switch opening: 2 ms (hardware)
  - Delay between firing heaters and quench onset: ~7 ms (HQ data)

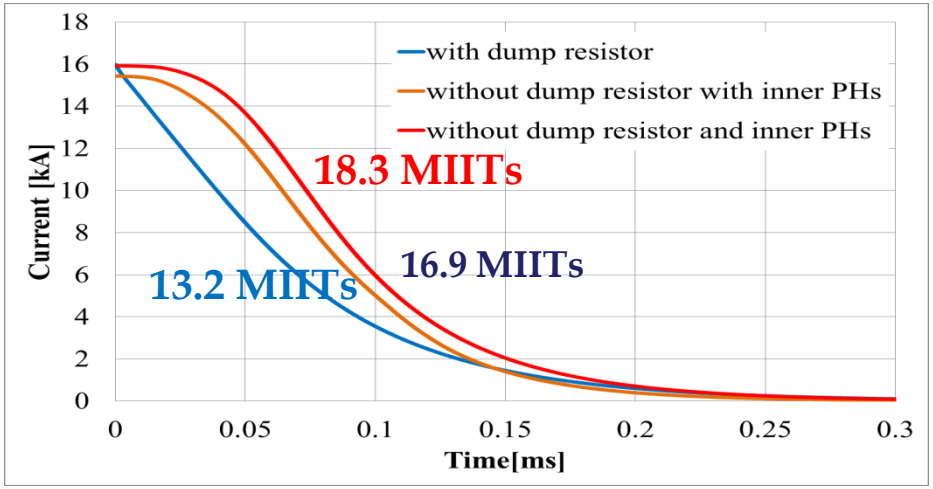


Measured delay [H. Felice, T. Salmi, et al.]

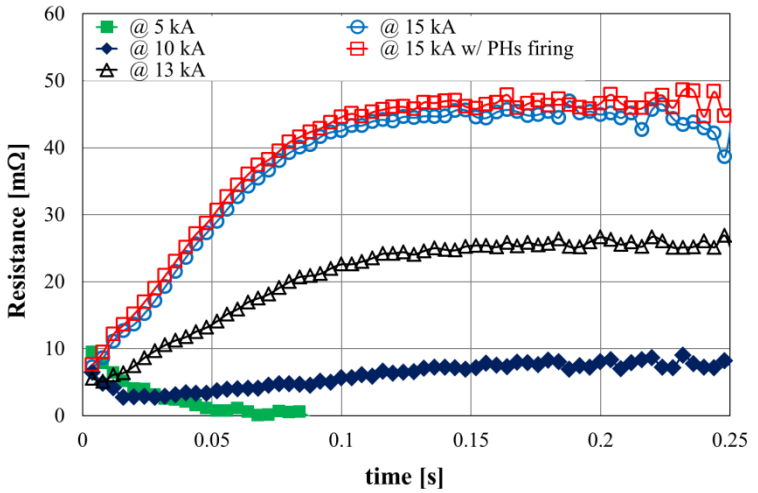
- So ~15 ms to start quench outer layer
- Another ~15 ms available to quench the inner layer
  - Data analysis of HQ needed
- We still plan to avoid the inner layer quench heater

QXF: HOTSPOT TEMPERATURE

- High MIITS test in HQ01e showed that in absence of dump resistor we are below 300 K
  - But this magnet has strong quenchback (quench induced by heat created by cable eddy currents due to dI/dt)
  - So this test is not conclusive
  - Test with cored cable will be conclusive



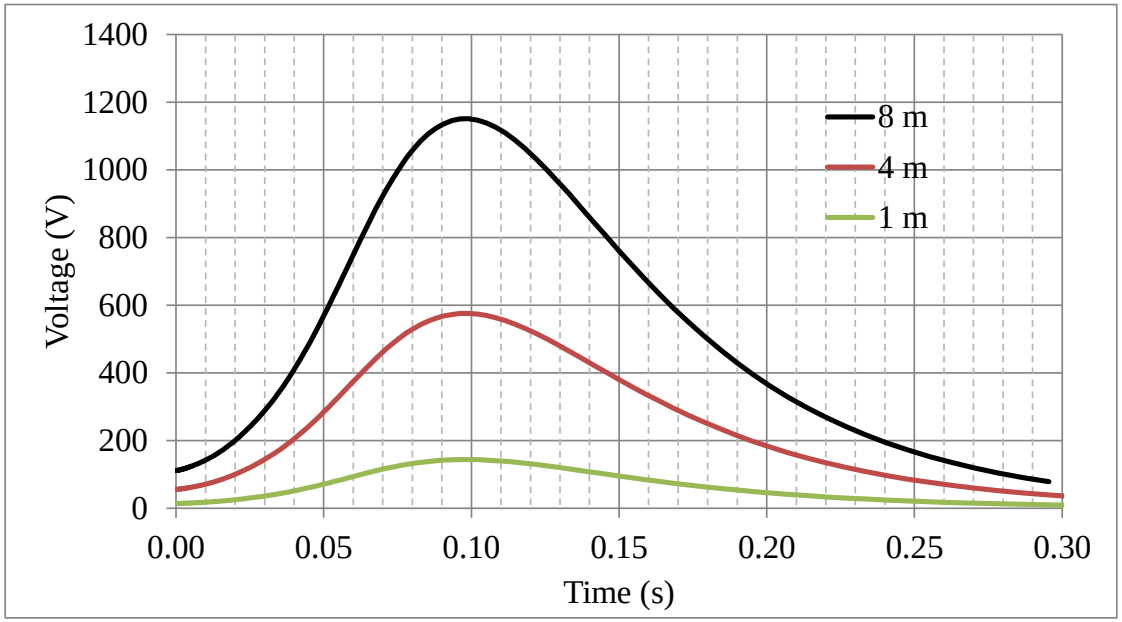
High MIITs test [H. Bajas, M. Bajko, et al.]



Evidence of quenchback[H. Bajas, M. Bajko, et al.]

QXF: VOLTAGE

- Voltage scale with magnet length
  - So we could have effects that we do not see on 3.4-m-long but are a killer at 8 m
  - Analysis of an extreme case: outer layer totally quench, no quench on inner – for 8-m-long QXF we are still safe in this case
    - Anyway inner layer must quench within 20 ms, where we are at 200 V



CONCLUSIONS

- Protection is a very critical aspect for QXF
  - Scheme: little energy can be extracted – we have to work in the scenario of negligible dump resistor
    - Important to test magnets without dump resistor!
  - Hotspot temperature: ~30 ms allowed to quench all magnet to stay below 300 K
    - Main issues:
      - Analysis of time to get above threshold and quench velocity
      - Analysis of propagation from outer to inner
      - Only data for magnet with cored cable will be conclusive
  - Voltage: estimated in a worse case with 8-m-long magnet seem to pose no problem (well within 1kV)
    - Additional verification work is needed to really find the worst case