# Beam-induced Quench Tests of LHC Magnets

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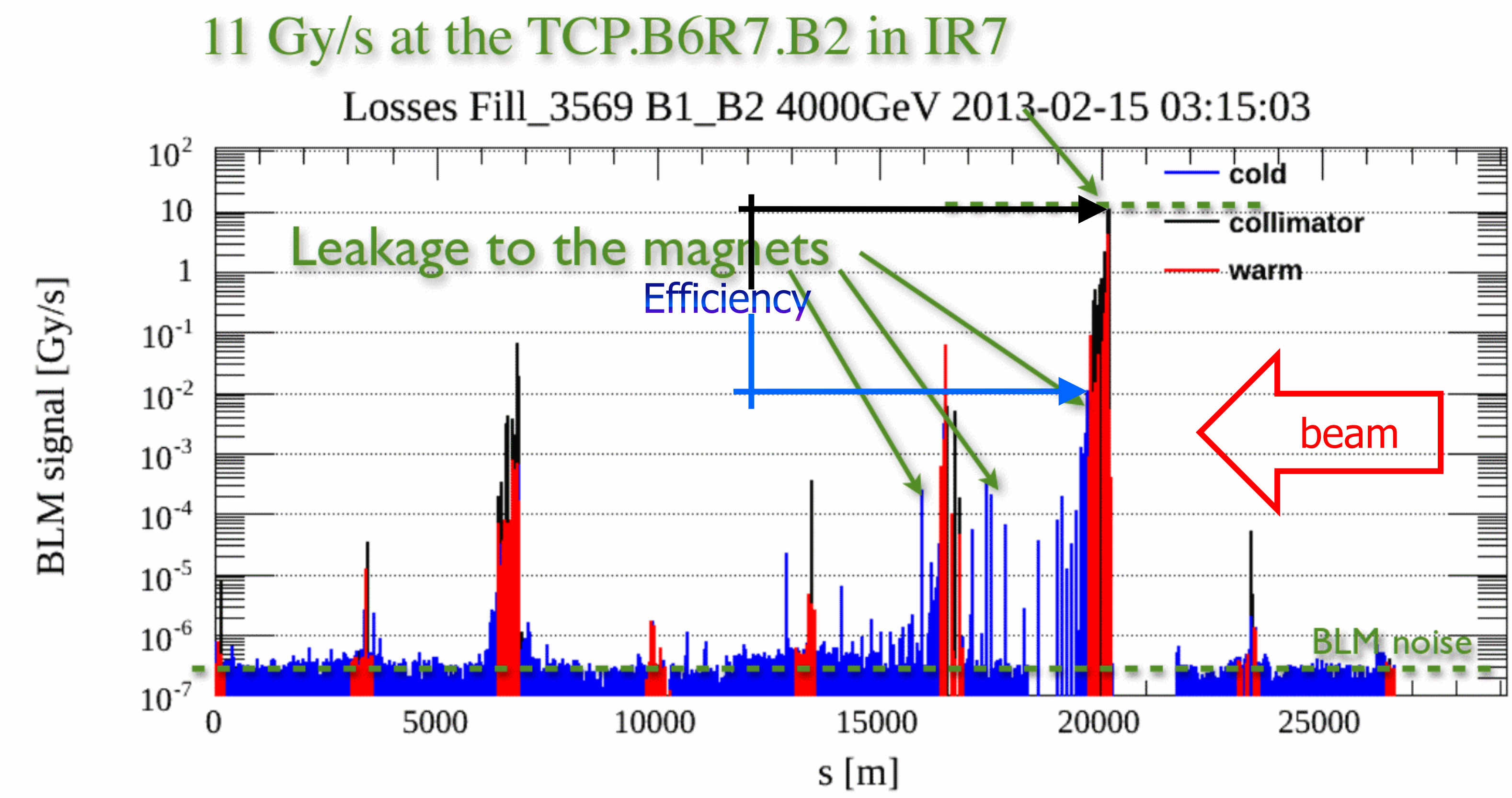
# Content

- Motivation
- Superconducting magnet
- Short duration losses

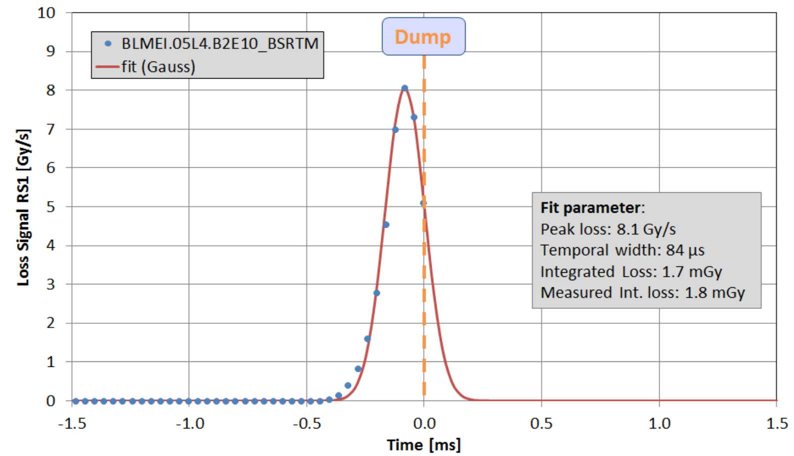
# Efficiency of LHC collimation



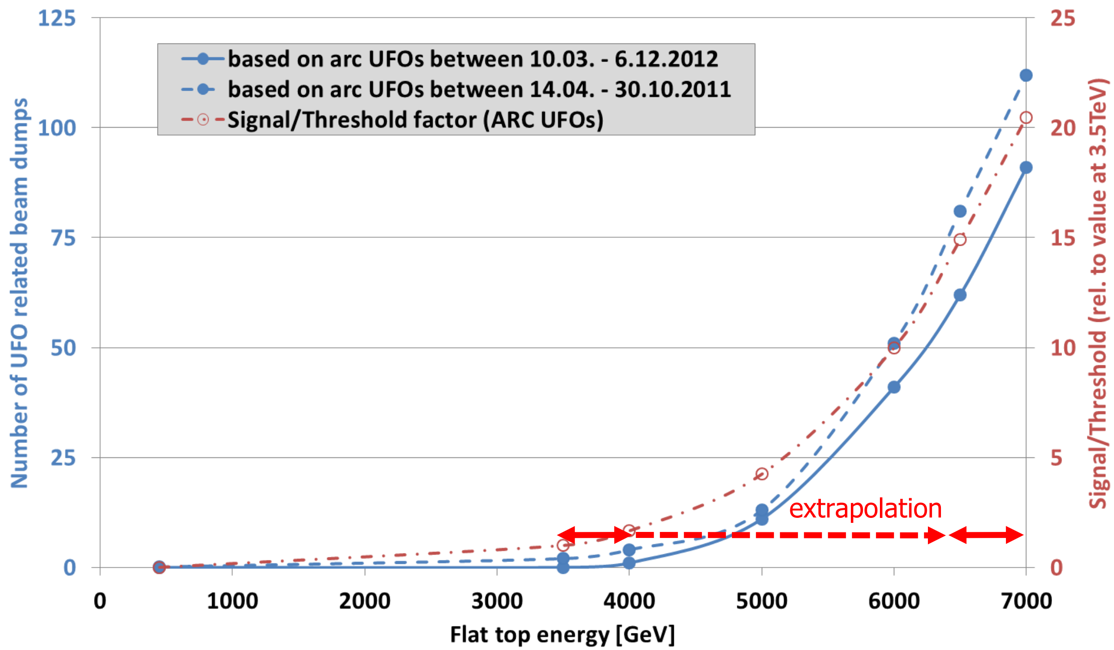

Determination of efficiency needed to plan upgrade requirements for collimation system

# Dust particle and LHC operation

- Observation from 2011 to 2013
- Beam loss created with a duration between 100 us to several ms



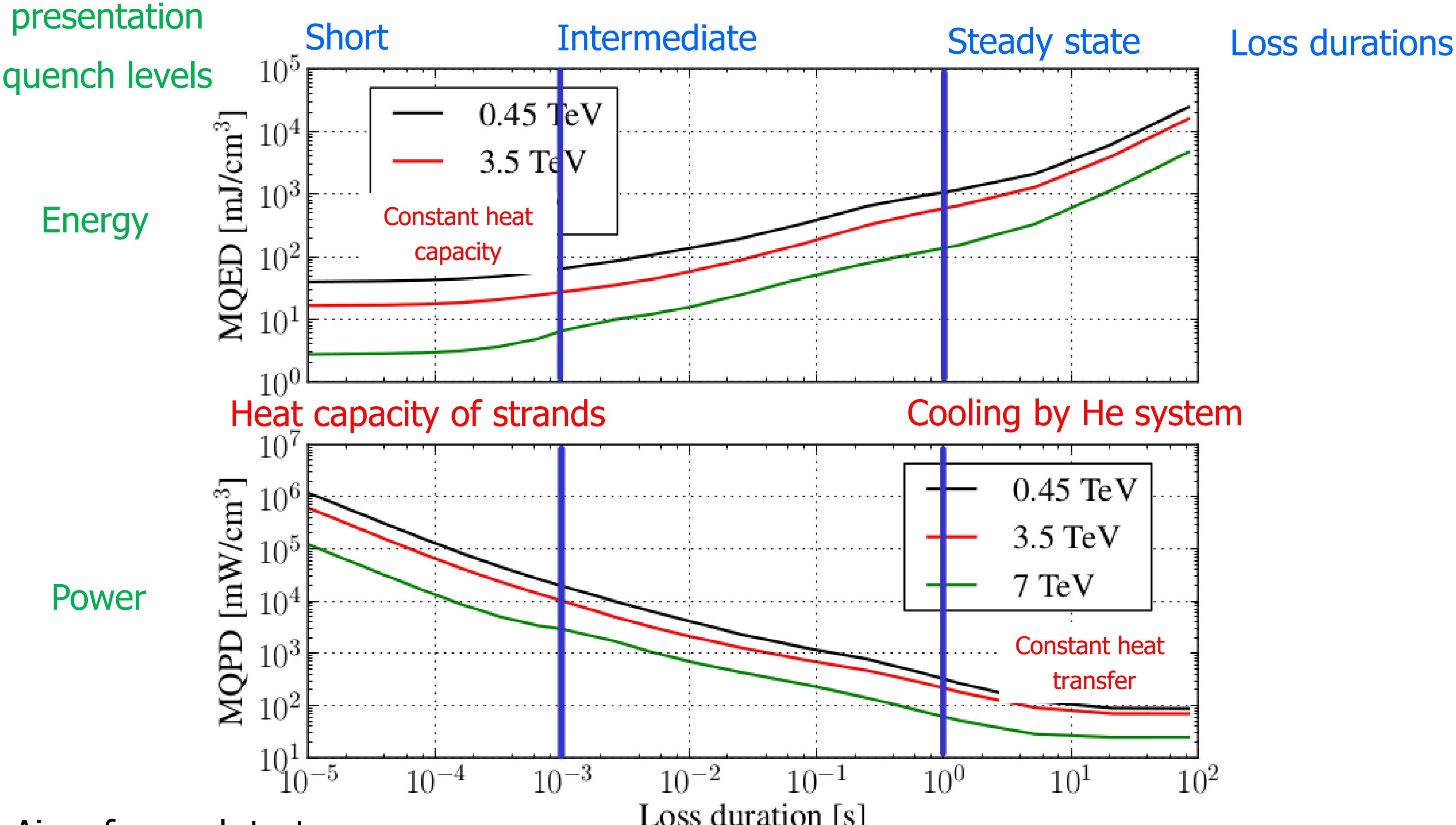

- Extrapolation of event rate to operation at 7 TeV
- Number of events would cause significant downtime due to recover from quench of magnet




Increase of knowledge in the sub and millisecond range required for down time estimates

# Super conducting magnet quench levels (LHC bending magnet)

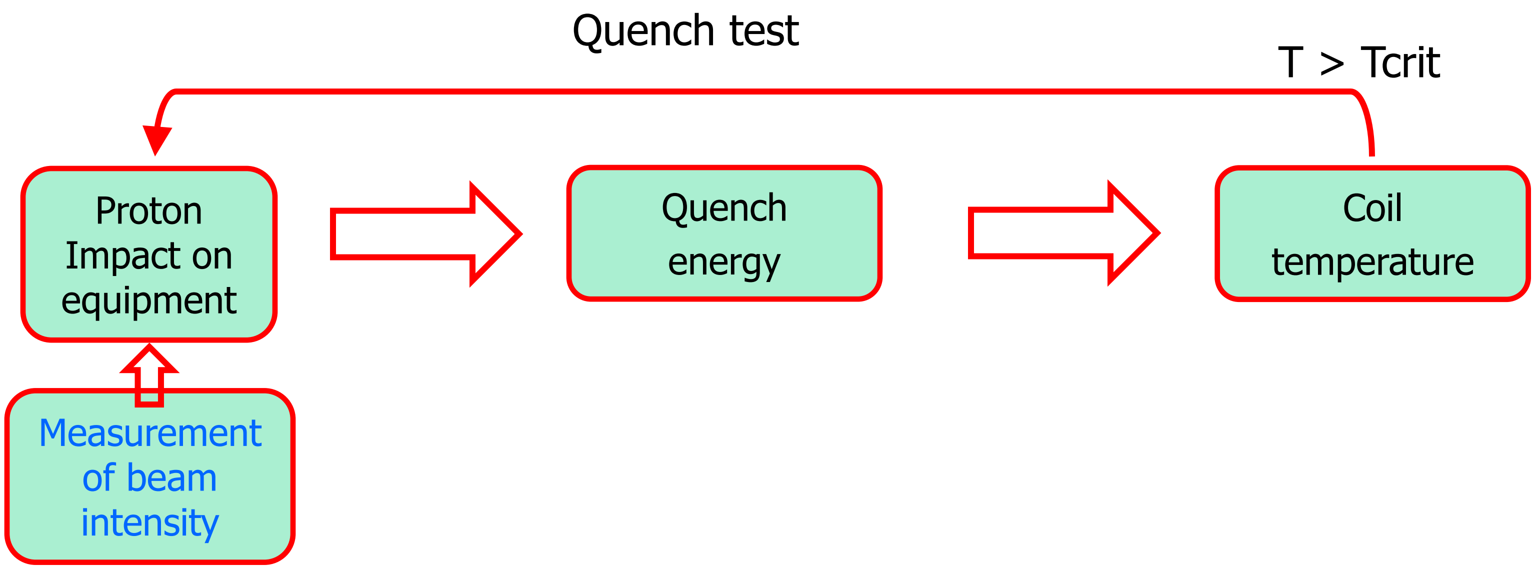
Equivalent presentation quench levels




Aim of quench test:

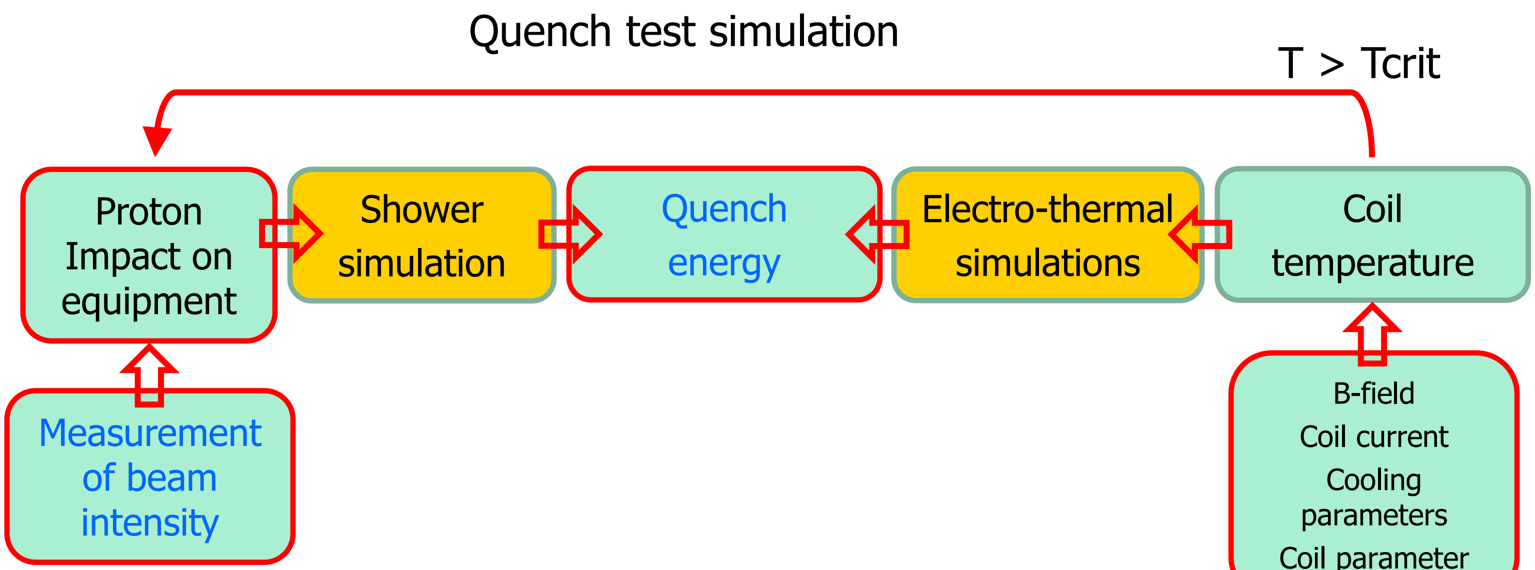
How much of beam intensity could impact on equipment and not quench a magnet

# Methodology



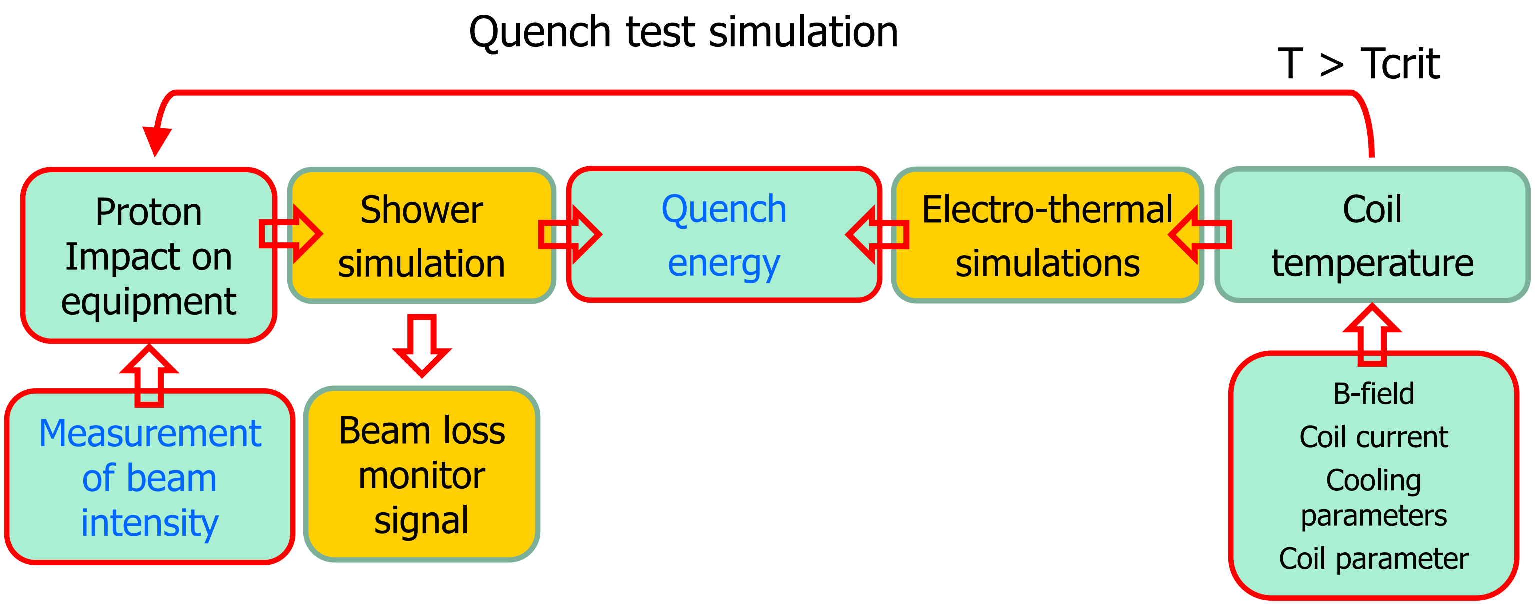

- Test results in upper and lower bound of quenching beam intensity

# Methodology




- Shower simulation of local quench energy density
- Lower and upper intensity bound => lower und upper local quench energy density bound
- Electro-thermal simulation of local quench energy density
- Quench test allows to validate combined result of shower and electro-thermal simulations

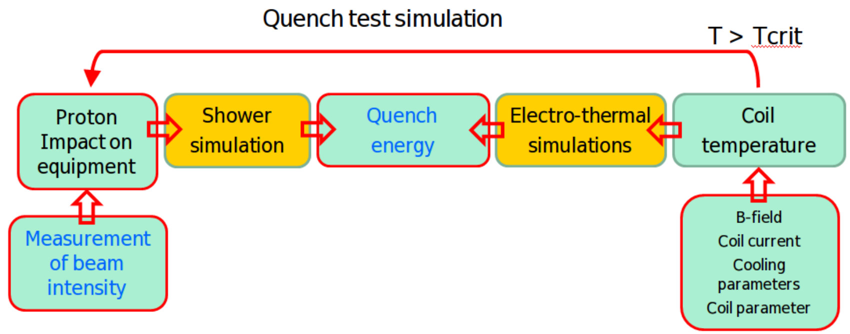
# Methodology

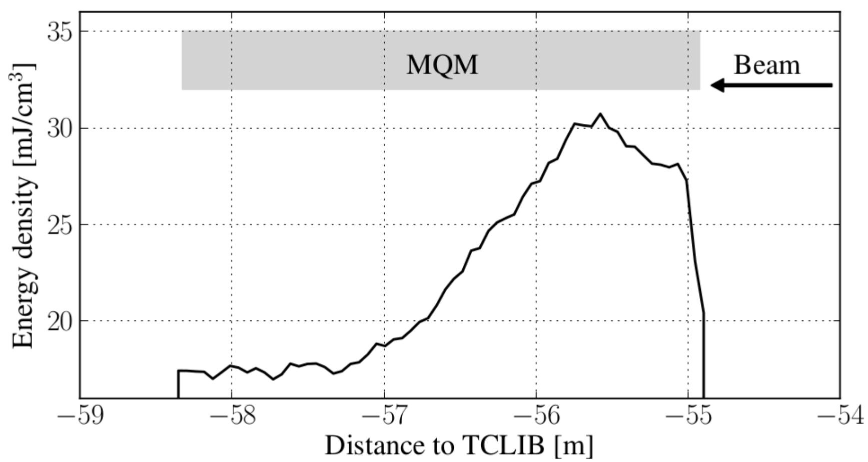



- Shower simulation of local quench energy density
- Lower and upper intensity bound => lower und upper local quench energy density bound
- Electro-thermal simulation of local quench energy density
- Quench test allows to validate combined result of shower and electro-thermal simulations
- Shower simulations are also validated by beam loss measurements

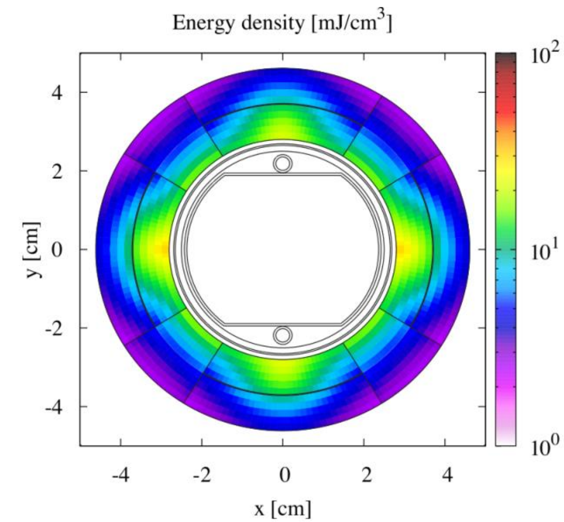
# Short loss duration

- Experiment
  - Injected beam (6.5E10 p.) dumped on collimator (TCLIB)
  - Quadrupole (Q6.L8, 4K) magnet exposed to shower particles
  - Magnet current scanned to initiate quench




Maximum energy density peak inside magnet




Symmetric energy distribution

- Result

| Current [A] | FLUKA LB [mJ/cm$^3$] | FLUKA UB [mJ/cm$^3$] | MQED [mJ/cm$^3$] |
|---|---|---|---|
| 2000 | 29 | n/a | 20 |
| 2500 | n/a | 31 | 16 |

# Results

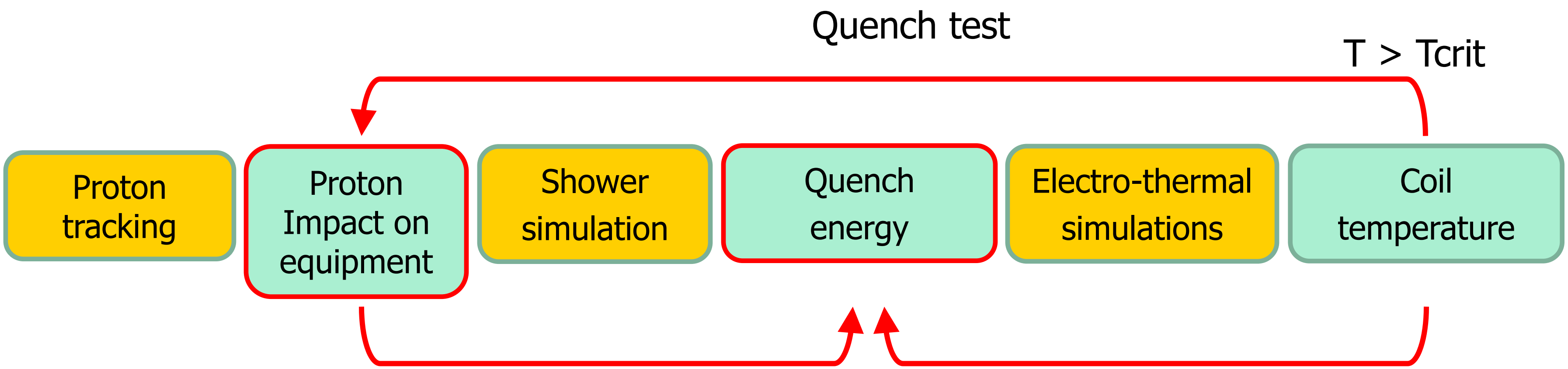
| Regime | Method | Type | Temp. [K] | $I/I_{nom}$ [%] | LB/QL | UB/QL | Comment |
|---|---|---|---|---|---|---|---|
| short | kick | MB | 1.9 | 6 | n/a | $\mathbf{0.47}^{+0.19}_{-0}$ | Tracking uncertainty. |
| short | collimation | MQM | 4.5 | 46/58 | **1.45** | 1.94 | Saturated BLM signals. No FLUKA validation. |
| intermediate | wire scanner | MBRB | 4.5 | 50 | $0.48^{+0}_{-0.21}$ | $\mathbf{0.71}^{+0.44}_{-0}$ | Timing uncertainty. Quench in ends. UB for $N_q/N_w = 45\%$. |
| intermediate | wire scanner | MQY | 4.5 | 50 | 0.96 | n/a | No upper bound. |
| intermediate | orbit bump | MQ | 1.9 | 54 | $\mathbf{2.79}^{+0.46}_{-?}$ | $4.31^{+0.7}_{-?}$ | Timing uncertainty. Nucleate boiling? UB for $N_q/N_p = 62\%$. |
| steady-state | collimation | MB | 1.9 | 57 | $0.36^{+0}_{-0.08}$ | n/a | Peak loss in magnet ends. Cooling. Moderate FLUKA agreement with BLM signals. No upper bound. |
| steady-state | orbit bump | MQ | 1.9 | 54 | $0.33^{+0.36}_{-0}$ | $\mathbf{0.47}^{+0.52}_{-0}$ | Sensitivity to surface roughness. Cooling. |
| steady-state | dyn. orbit bump | MQ | 1.9 | | | | Cooling. |

# Reserve slides

# Short term losses

- At E = injection energy
  - Protection by collimators and quench protection system (QPS)
  - Beam loss system posterior diagnostic
- At  E > injection energy
  - Asynchronous beam bumps
  - Sudden variation warm magnet current variations
  - Collimator losses at and of energy ramp or during optic function the squeeze at the four experiments
- Maximum value of energy distribution along  cable cross section

# Methedology




- Quench test: observation quench at certain number of lost protons
- Shower simulation, ratio energy in coil, BLM to number of lost particles
- QT3: ratio of temperature increase to energy deposit in coil (quench energy)

BLM Time distribution (BLM system)

Magnetic field (

Coil temperature

Cooling conditions

Loss pattern

Beam current monitor