Beam Energy

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Session's Overview

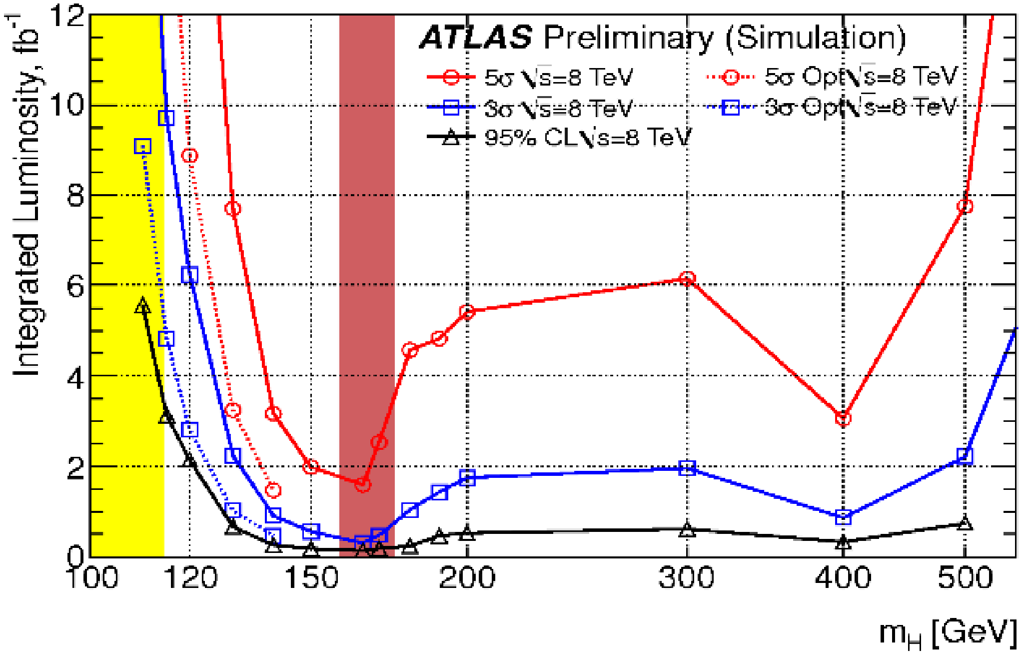
Scope

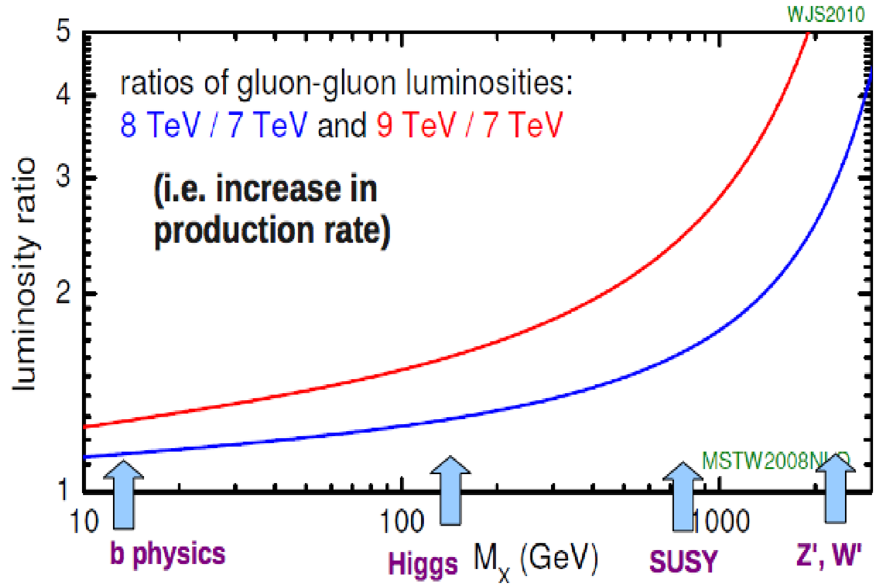
- **Explore the benefits for the physics reach, the consequences, the limitations and the implications of physics operations at $\sqrt{s}$ > 7 TeV**
- **Gather the necessary information for a reliable risk analysis**

Agenda

1. How much physics benefits from running at higher energies? *Bill Murray*
2. Update on calculations of max. excess resistance allowed as a function of energy for the case of prompt/semi-prompt/adjacent quenches. *Arjan Verweij*
3. Current state of copper stabilizers and methodology towards calculating risk. *Mike Koratzinos*
4. Implications of increased beam energy on QPS system, EE time constants, PC. *Jens Steckert*
5. What needs to be done to reach beam energy above 3.5 TeV? Commissioning of essential magnet powering and machine protection systems. *Nuria Catalan Lasheras*
6. Consequences of a hypothetical incident for different sectors. *Laurent Tavian*
7. Operational consequences of running at a higher energies. *Mike Lamont*

LHC discoveries in the next run





W. Murray

- Higgs (single experiment):
  - At 8 TeV, 3σ sensitivity for the whole mass range with 5/fb
  - Same sensitivity at 7 TeV with 6/fb
- New physics (heavy objects) benefits more from increase in energy
  - Less data needed for same sensitivity, e.g. SUSY 40%, W'/Z' 50%
- Statistics (luminosity) is critical, increase in energy is beneficial
- Possible to combine results at different √s

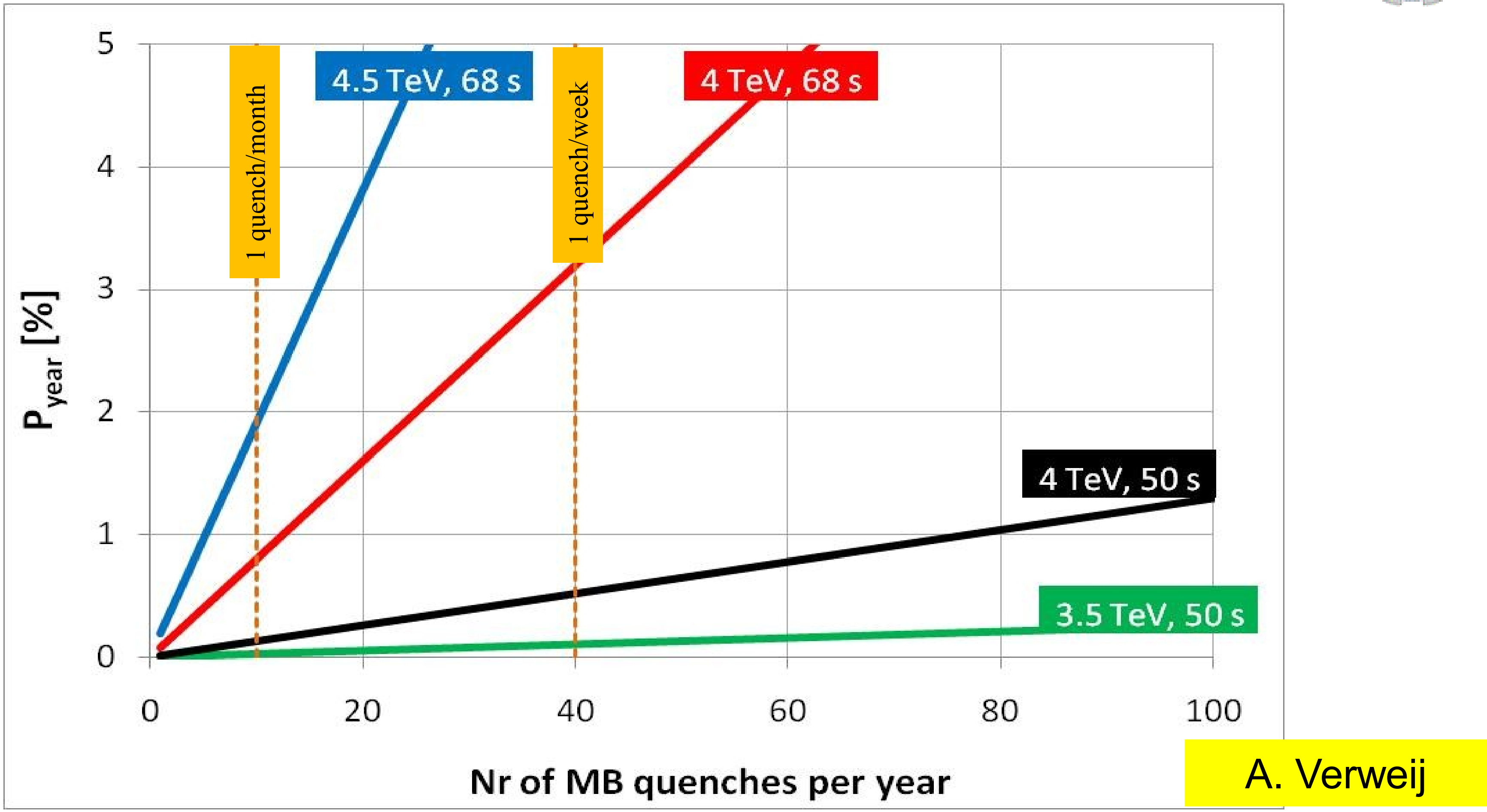
What has changed since last year?

- Increase of knowledge of copper bus bar segments:
  - Measurements of RRR in the whole machine justify to assume in the simulations significantly higher RRR (RRR=200 instead of RRR=100)

- Measurement of the resistance of all superconducting splices:
  - Contrary to copper joints, the superconducting splices are very good, R_{max} = 2.7nΩ for main dipoles and R_{max}= 3.2nΩ for main quads (to be compared with R_{max}~200 nΩ that caused Sept 19th incident)

- Simulation of burnout limits:
  - quenches due to heat conduction through the busbar, including heat generated due to by-pass diodes, have been studied in detail (this had not been studied last year) and give somewhat lower limits

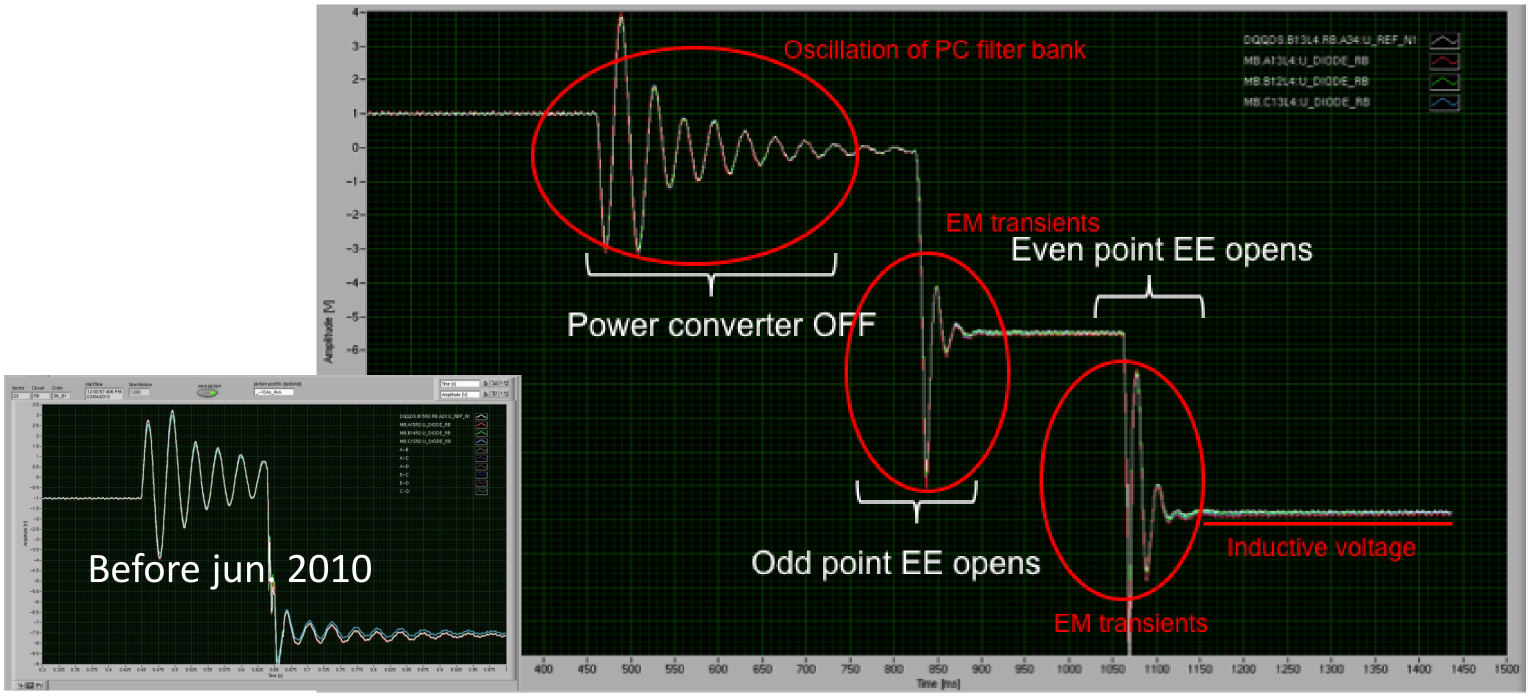
Burn-out probability



- In 2010 we had NO unintentional beam-induced quenches
- However there have been about 20 quenches of the RB circuits above 5000A due to various reasons

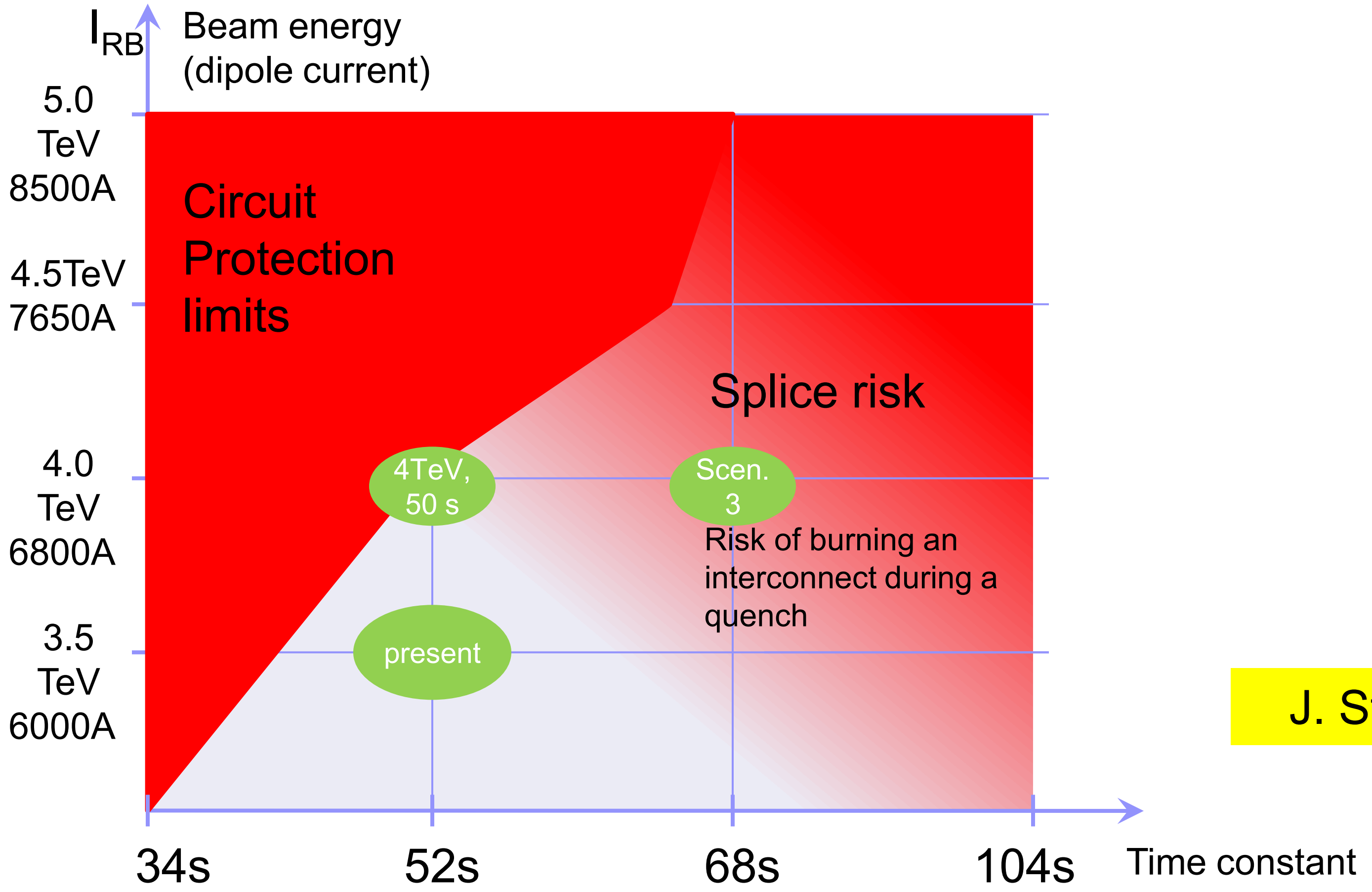
Superconducting Circuits Protection

- Reduction (better elimination) of high current quenching is crucial, both at 3.5 TeV and 4 TeV
  - Quenching due to UFO phenomenon can show up with increasing beam intensity and energy
  - Transient EM perturbation can trigger the QPS and provoke spurious quenches. This effect must be reduced by deploying snubber capacitors (being commissioned)



J. Steckert

Circuits Protection – Burnout Risk



J. Steckert

- Circuits Protection works in marginal conditions at 4 TeV, 52 sec EE time constant
- 4.5 TeV and 62 sec not excluded from CP point of view

Hardware Limitations beyond 3.5 TeV

- Overall NO critical HW limitations for operations at 4 TeV

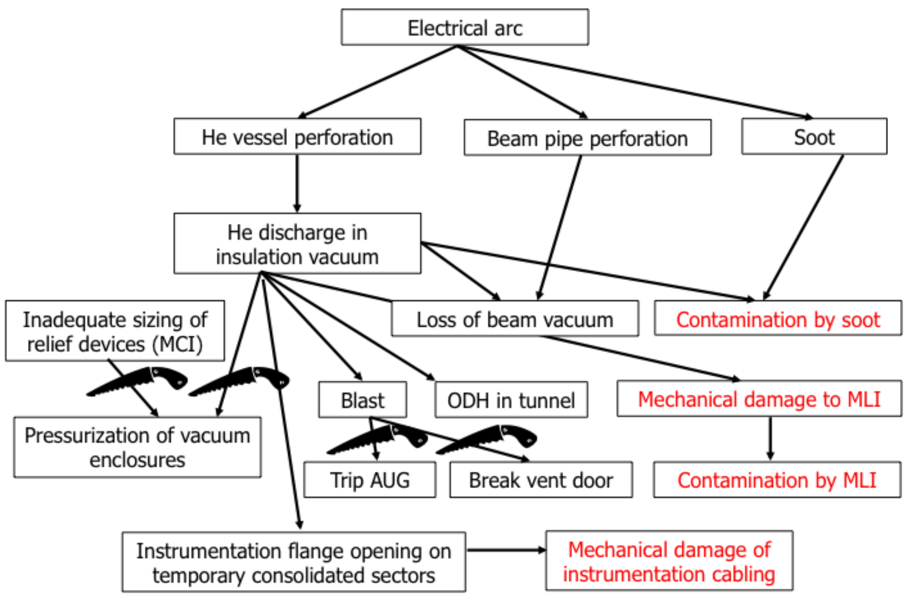
- Reviewed HV withstand levels, including cross-talk between circuits need to be applied in future
- Also to be addressed:
  - Faulty quench heaters in MB magnets
  - Bus-bar measurements on IPQ, IPD and IT
  - RQX1.R1 QH circuit
  - Dipole in sec67 (MB1007) insulation weakness (needs to be changed for E>4 TeV)

N. Catalan-Lasheras

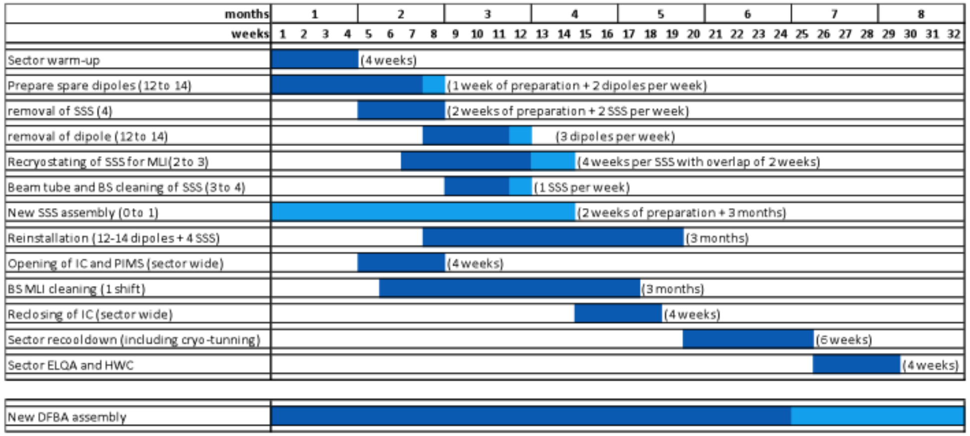
Effects of a hypothetical incident

- Increase of knowledge of consequences of a hypothetical incident in different sectors (with beam energy up to 5 TeV)
  - The present consolidation, up to 5 TeV, suppresses mechanical collateral damages in adjacent sub-sectors
  - Nevertheless damage of the MLI and contamination of the beam pipe(s) could require heavy repair work **(8 to 12 months)**

Updated fault tree up to 5 TeV



Repair schedule following a hypothetical interconnect electrical arc (min 8 month)



L. Tavian

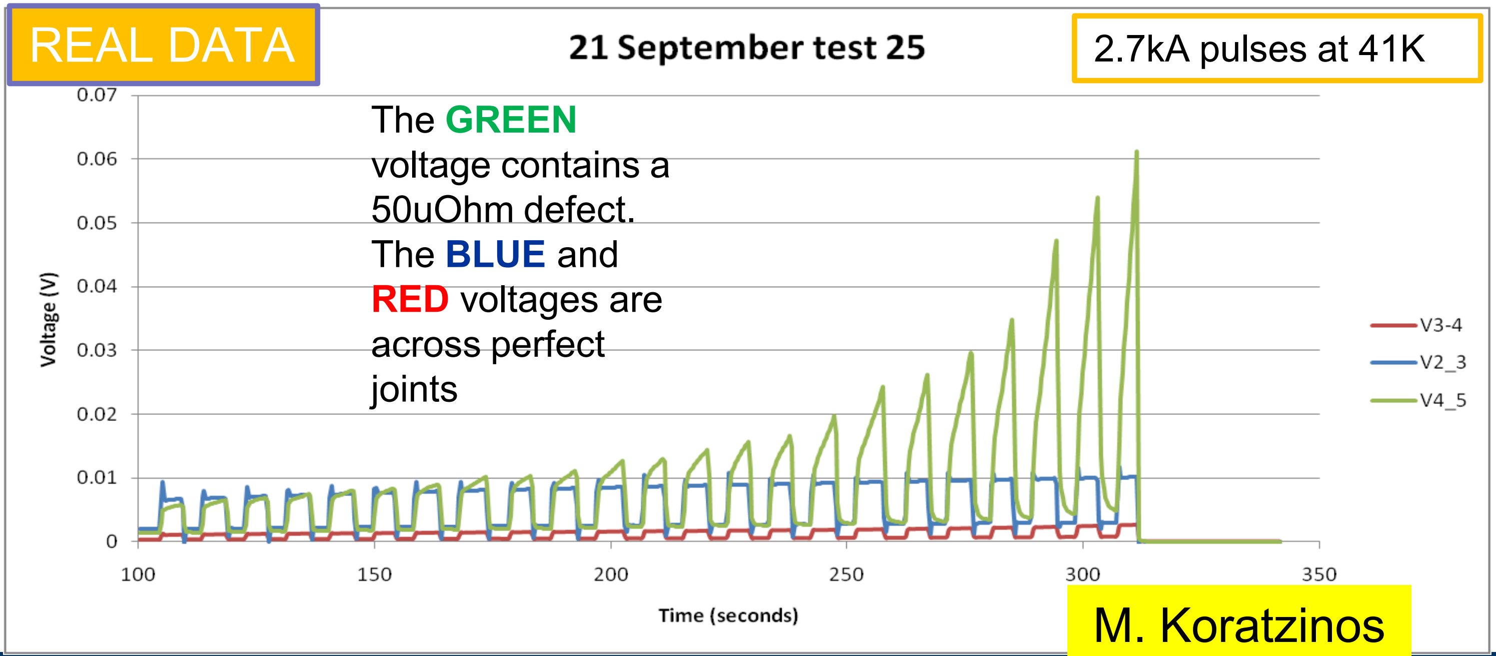
Beam Operation/Commissioning

- Starting a new year at a new energy is almost cost free
  - Full setup from scratch planned anyway
- During run - with squeeze re-scaling
  - Around 1 week re-commissioning (not including HW commissioning)
  - Pre-flight checks in MD could be useful
- Without squeeze re-scaling
  - Collimator setup – around 2 weeks re-commissioning
- To be able to make up for lost time – don't leave it too late.

M. Lamont

Copper Stabilizer Continuity Measurements (a.k.a. "Thermal Amplifier")

- The current safe energy analysis is based on a lot of (mostly conservative) assumptions
  - 134 (out of over 10000) direct resistance measurements of copper stabilizers
- The CSCM is a qualification tool that measures in situ (at ~40 K) the copper busbar resistance and thus can qualify a sector to the maximum current it can safely withstand.
- Feasibility study successfully performed in 2010.



RB: a typical bad joint has excess resistance of 2% - if we warm it up, its resistance grows by ~200 times – easy to detect!

Recommendation

- To allocate the resources and to launch a.s.a.p. the:

Copper Stabilizer Continuity Measurements Project

- With the aim to be ready to measure the copper stabilizers in the machine during 2011/2012 year-end stop

- Only the 'CSCM' in all sectors can qualify the safe operating current in situ

Conclusions

- From main magnet circuit protection point of view, a scenario with 3.5 TeV in 2011, CSCM during 2011/2012 stop and then higher energy (defined by CSCM) run over 2012 implies the minimum **risk of splice burn-out**
- Our present knowledge do not prevent running LHC up to 4 TeV per beam. **There is no hard show-stopper** neither for the hardware nor for OP to start the run at **4 TeV** with 52 s energy extraction time constant, however:
  - the risk of splice burn-out significantly increases (factor 5)
  - hardware parameters are pushed to the limits
  - number of quenches to reach predefined incident probability is very limited (less then 2 for P=0.1%), may need to reduce the energy during the run
- Energies above 4 TeV (requiring τ=68s) are too risky
- From a risk analysis point of view the consequences of an hypothetical incident have to be taken into account. Such consequences are still VERY serious (up to 12 months stop)