Brief summary of:

LHC Performance Workshop

Monday February 2nd - Friday February 6th

R.J. Steinhagen

For detailed information/slides see Workshop Web-Site:

http://indico.cern.ch/conferenceOtherViews.py?view=standard&confId=45433

Executive Summary & Overview

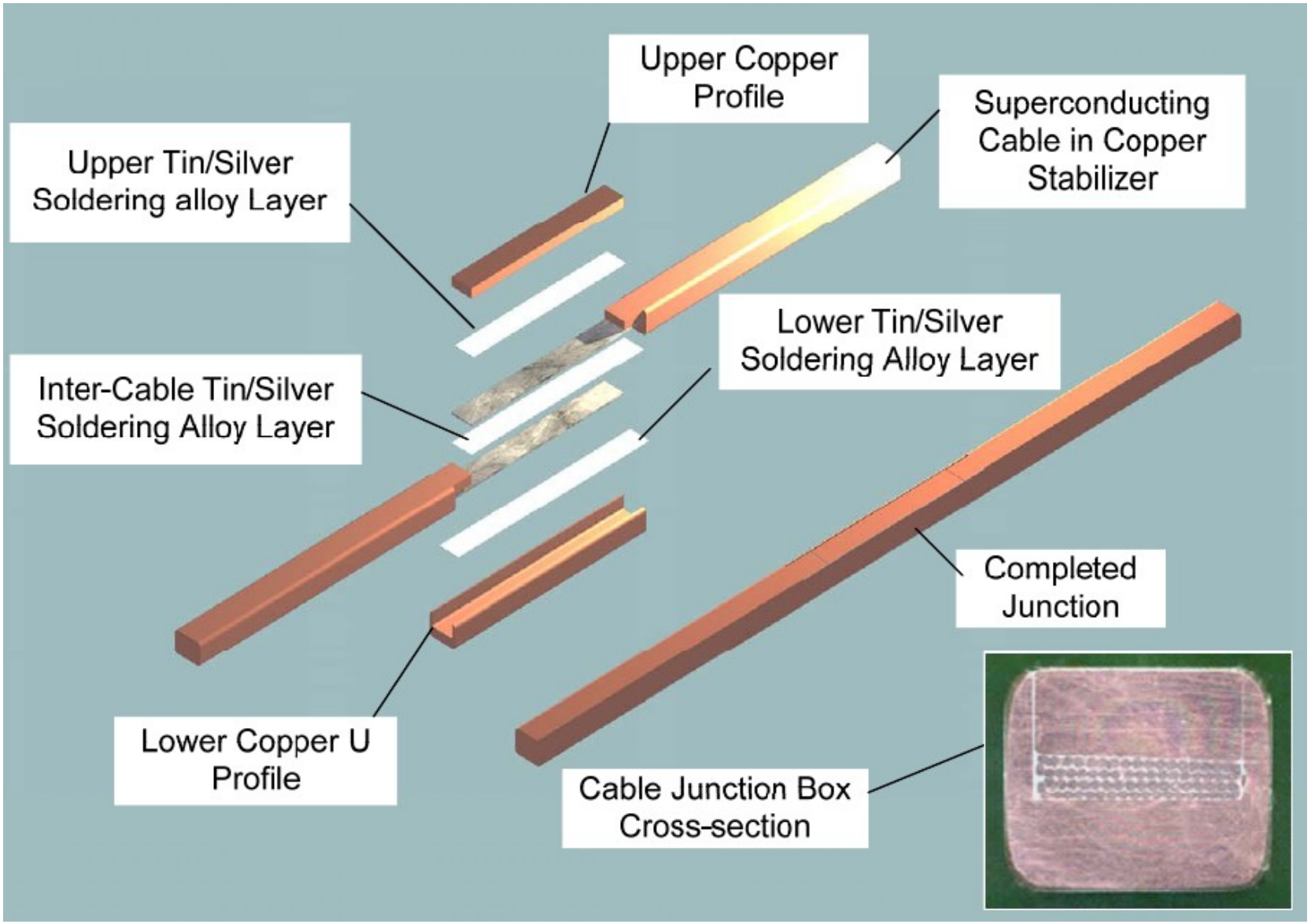
- The good 'ol Chamonix Performance Workshop is back:
  - Old DG: vetoed one → R. Heuer: charged S. Myers the organise one

	Monday	Tuesday	Wednesday	Thursday	Friday
Morning	Session 1	Session 3	Session 5	Session 7	Session 9 Summary
Evening	Session 2	Session 4	Session 6	Session 8	

- Brief programme:
  - Session 1 - What did we learn without beam in 2008
  - Session 2 - Safety
  - Session 3 - Repair of 34
  - Session 4 - Consolidation to avoid incident and limit collateral damage
  - Session 5 - Shutdown Modifications 2008/9 and Future shutdowns
  - Session 6 - What else can go wrong
  - Session 7 - What did we learn with beam in 2008
  - Session 8 - What we will do for beam preparation in 2009
  - Session 9 - What will we do with beam in 2009/10

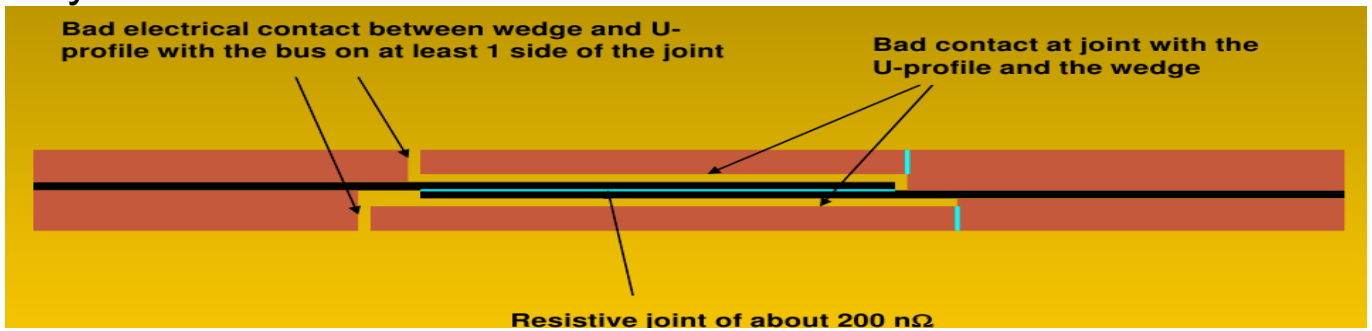
Mechanics of the incident on 19th September I/III

- Schematic Procedure:



Mechanics of the incident on 19th September II/III

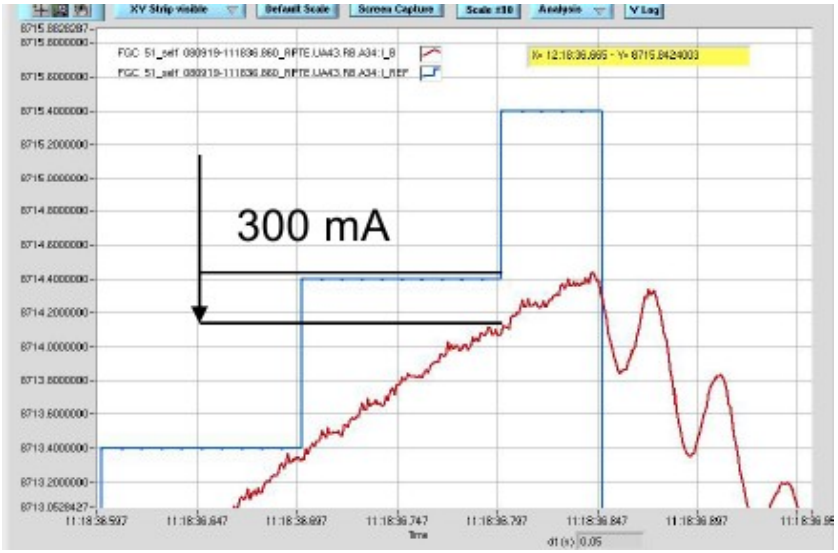
- A. Verweij: “Bus bar joints Stability and Protection”, Session 04
- The mechanic/facts:
  1. Estimated power of 10.7±2.1 W at 7 kA → 175-260 nΩ
  2. Maximum current of 8715 A.
  3. Fast voltage increase during incident: ~0 to 1 V in about 1 sec
  4. possible small voltage increase (~ 10 mV) during 30 sec before incident.
  5. Bus-bar QPS threshold reached before any voltage increase on the magnets.
  6. Origin probably in or near bus-bar joint
- Most likely scenario:

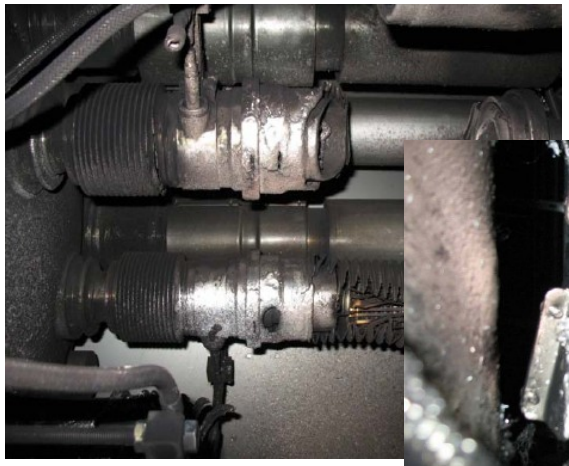


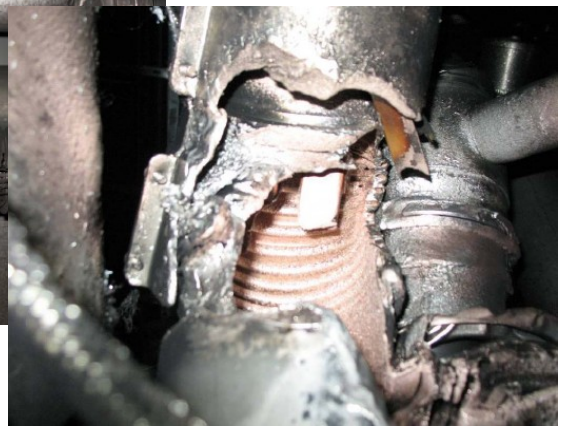
- However (Ph. Lebrun):
  - Experiment: reproduce interconnect with 200 nΩ resistance
    → only omission of soldering can account for such high resistance
    → proposal of additional clamping of interconnects (A. Verwei)
  - 90 nΩ inter-aperture splice resistance confirmed on examined magnet

19th September 2009 - 11:18:36.798

- Some of the observables....







QQBI.27R3

Mechanics of the incident on 19th September III/III

- Conclusion:

The original design 1 V QPS threshold was much too high to safely protect the dipole busbars..

Two possible origins of the incident are identified, that fulfill the observed facts (about 11 W @ 7 kA, Imax=8.7 kA, Dt_runaway≅1 s), namely:

1) Resistive joint with very bad bonding to wedge and U-profile, and longitudinal discontinuity of the copper (bus).

2) Resistive cable with bad contact to bus at the start of the joint, and longitudinal discontinuity of the copper (bus). The cable can be resistive due to strongly reduced critical current or due to mechanical movement below 7 kA.

Both origins would have been detected with a QPS threshold voltage <1 mV long before the start of the thermal runaway.

A QPS threshold of 0.3 mV is needed to protect the RB bus and the joints in all imaginable conditions.

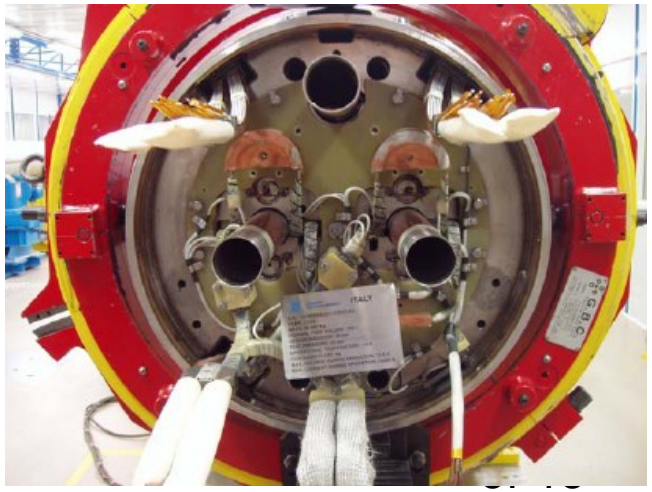
Fast thermal run-aways resulting from sudden transient disturbances (without intermediate stable heating) are unprotectable by any QPS system (whatever the threshold).

To avoid such fast thermal runaways one needs to assure a good thermal contact between joint and U-profile/wedge (by means of clamping) or to assure a good electrical and thermal contact between bus and joint (perfect soldering between bus and joint).

A. Verweij,

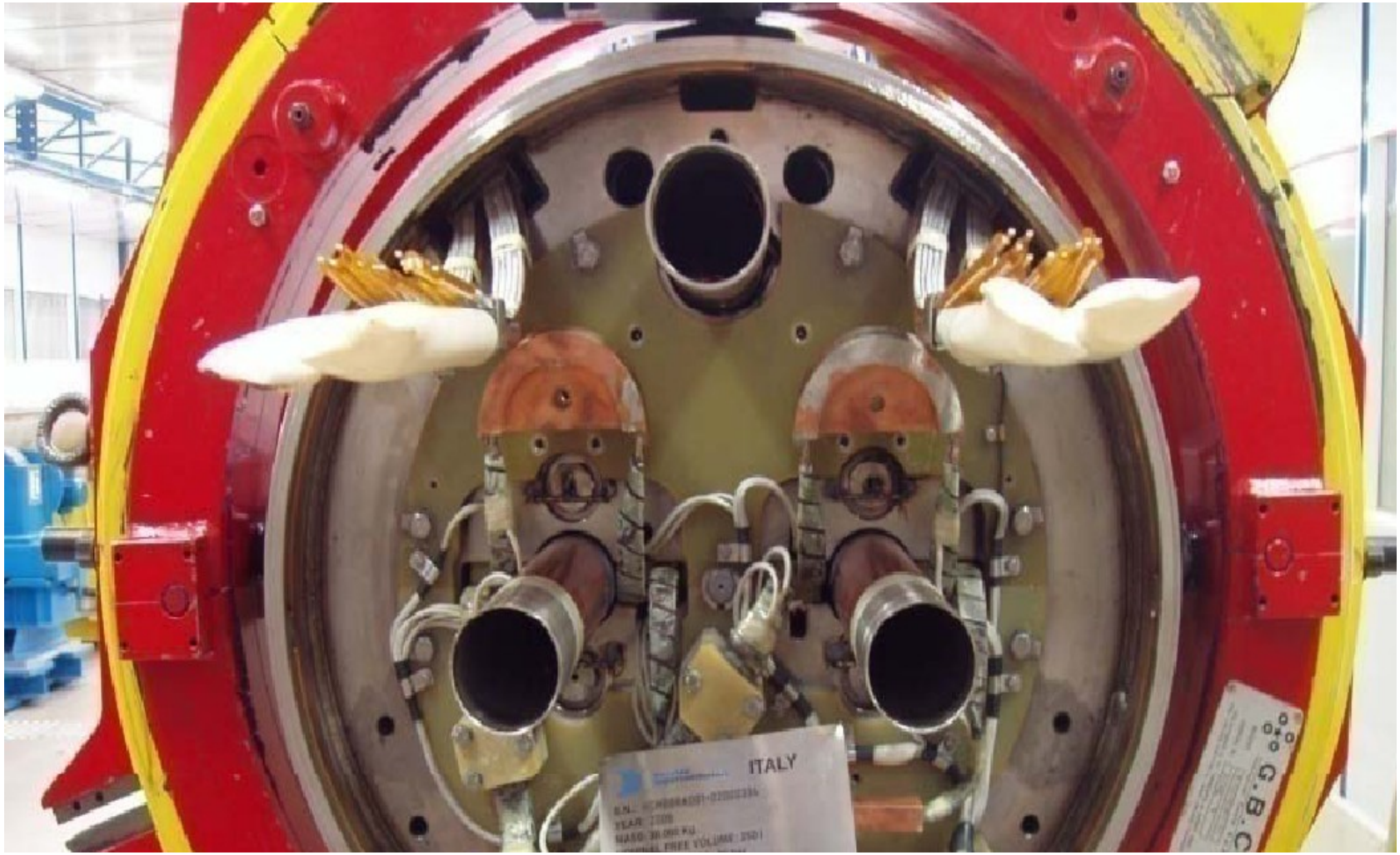
Minimisation of Maximum Credible Incidents (MCI) I/II - Quality Assurance

- Additional splice quality control measures:
  - Visual inspection of each splice by member QC team prior to soldering operation and soldering operation (before insulation)
  - Dimensional measurement of finished splice
  - Systematic ultrasonic testing of 13 kA splices
  - Record temperature cycles during soldering kA splices
  - … and don't be blind to other potential problems …



- Calorimetric measurements using the cryo-system temperature increases
  - used as indication, final verification using the QPS

Minimisation of Maximum Credible Incidents (MCI) I/II - Quality Assurance: Visual Inspection

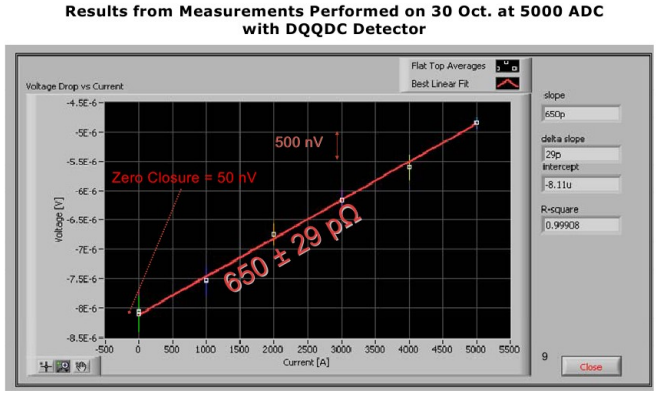


- LHC-BPMs (BLMs?): should continue taking photos after each modification!
  - Proposal: semi-automatic image recognition (nice project for Tech. St.!)
    - However: does not replace connectivity tests of N-connectors

Minimisation of Maximum Credible Incidents (MCI) II/II - QPS Upgrade

- R. Denz: “QPS Upgrade and Re-commissioning”, Session 4
  - Feasibility tests with prototype units in sector 12:

325 ± 15 pΩ / Splice



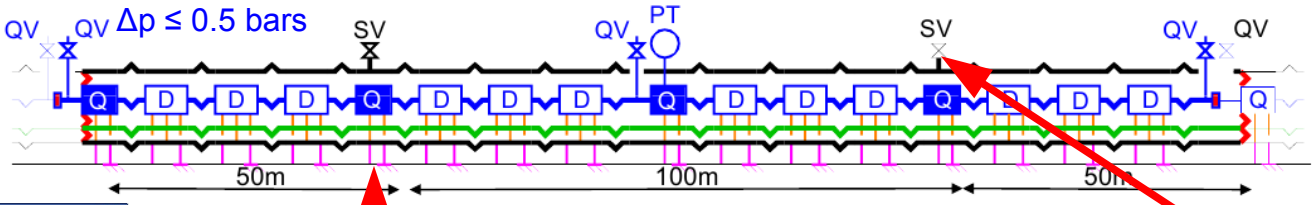
Z. Charifoulline, B. Flora

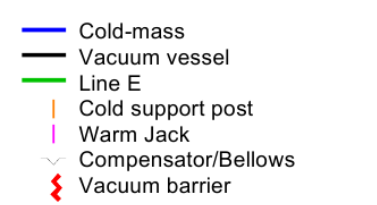
  - Detection threshold reduced from 1 V to ≤ 0.3 mV!
  - Local, rather than global fault detection.
  - Implemented with “symmetric quench” detection system.
  - Proposed to perform regular (weekly?) verification without beam.

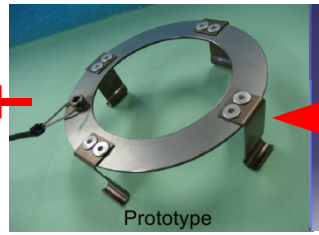
- Important: further measures mitigate but do not remove the risk
  - Steve's conclusion:
    - enforce QPS upgrade (~ recommended/mandatory)
    - Implement mitigations compatible with QPS installation schedule

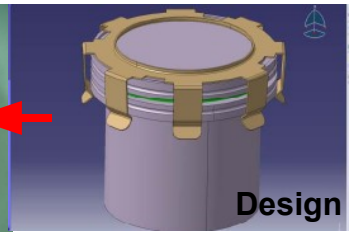
Mitigation of MCI consequences: Pressure Wave → additional Valves

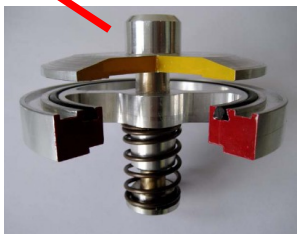
- Present temporary solution: open up DN100 and BPM ports







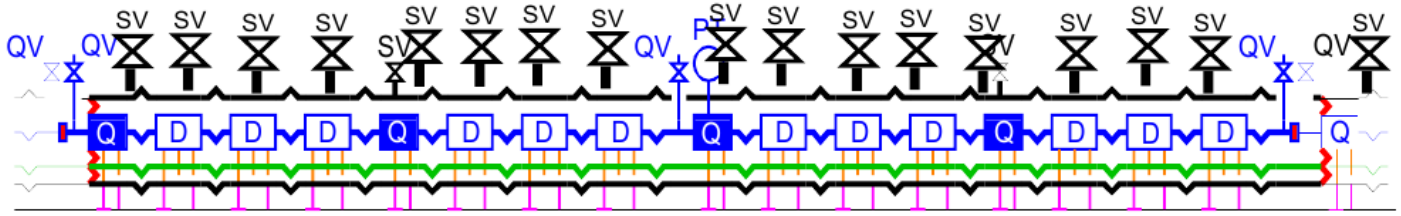




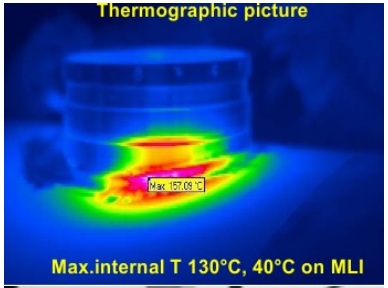
→ Cross-section: x10

V.Parma: "Use of instrumentation ports should be temporary, until warming up of sectors" (Obvious implication: BPM/BLM re-cabling!?!)

- Base-line: one DN200 port per dipole
  - parts ordered and tb installed in warmed-up sectors

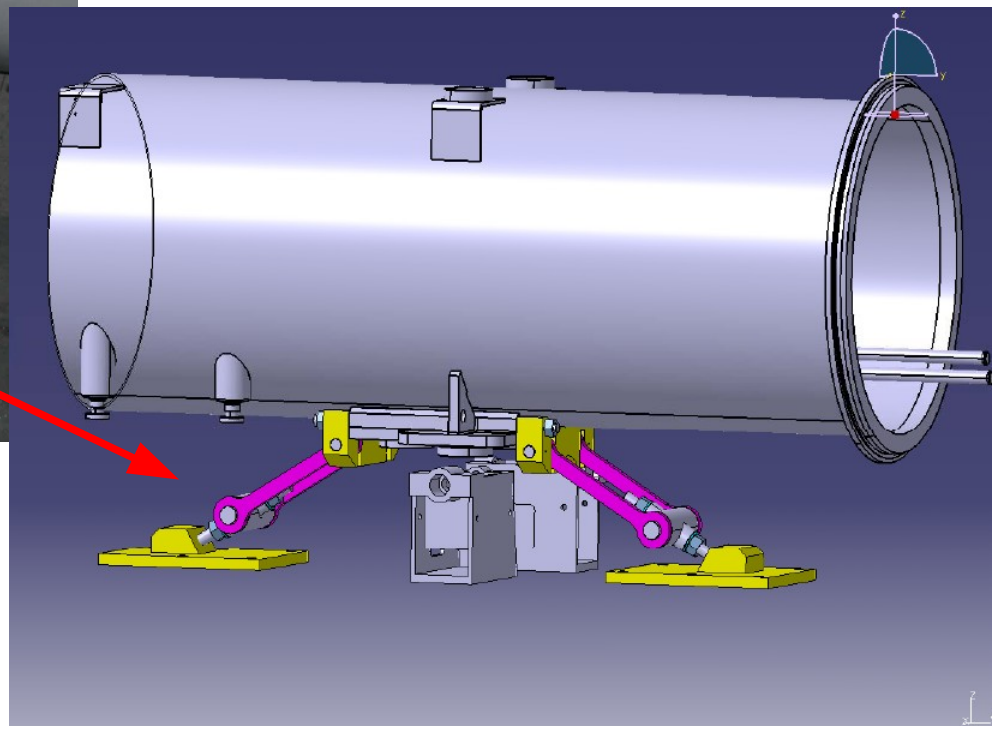


Cross-section: x 33



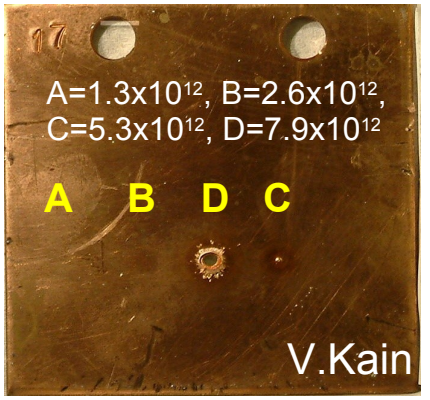
Mitigation of MCI consequences: Magnet Movement → Reinforcement of Magnet Jacks

- O. Capatina: Incident on 19th of September 2008 => failure of some supports of SSS in sector 3-4 due to longitudinal loads



- Proposed solution
  - Withstands 240 kN
  - ~ 2 weeks/sector
  - ~900kCHF
- Important consideration: probable next “weak point” – DFBA... ?

Session 6 - What else can go wrong?



- The word of the week: '**M**aximum **C**redible **I**ncident' (MCI)
- Beam induced damage: 350 MJ/beam nominal
  - Most 'primary' effects affecting machine protection are believed to be identified and secured against
  - What remains:
    - secondary effects, collateral damage (e.g. thermal shock, …)
    - handling of multiple failure scenarios (e.g. "bad orbit" + "kick")

'Safe Beam' = "set-up" intensity, **not** intensity which can be safely lost **under all conditions**!

- Biggest risks comes from magnet operation itself: 1.2 GJ/arc
  - Most damages are "collateral" effects due to He pressure waves
    - Critical candidate: DS, DFBA, inner triplet, …

- Main outcome: We should neither be careless nor blinded by fear of "what else could go wrong" - Risks are known, we should learn and not repeat them.

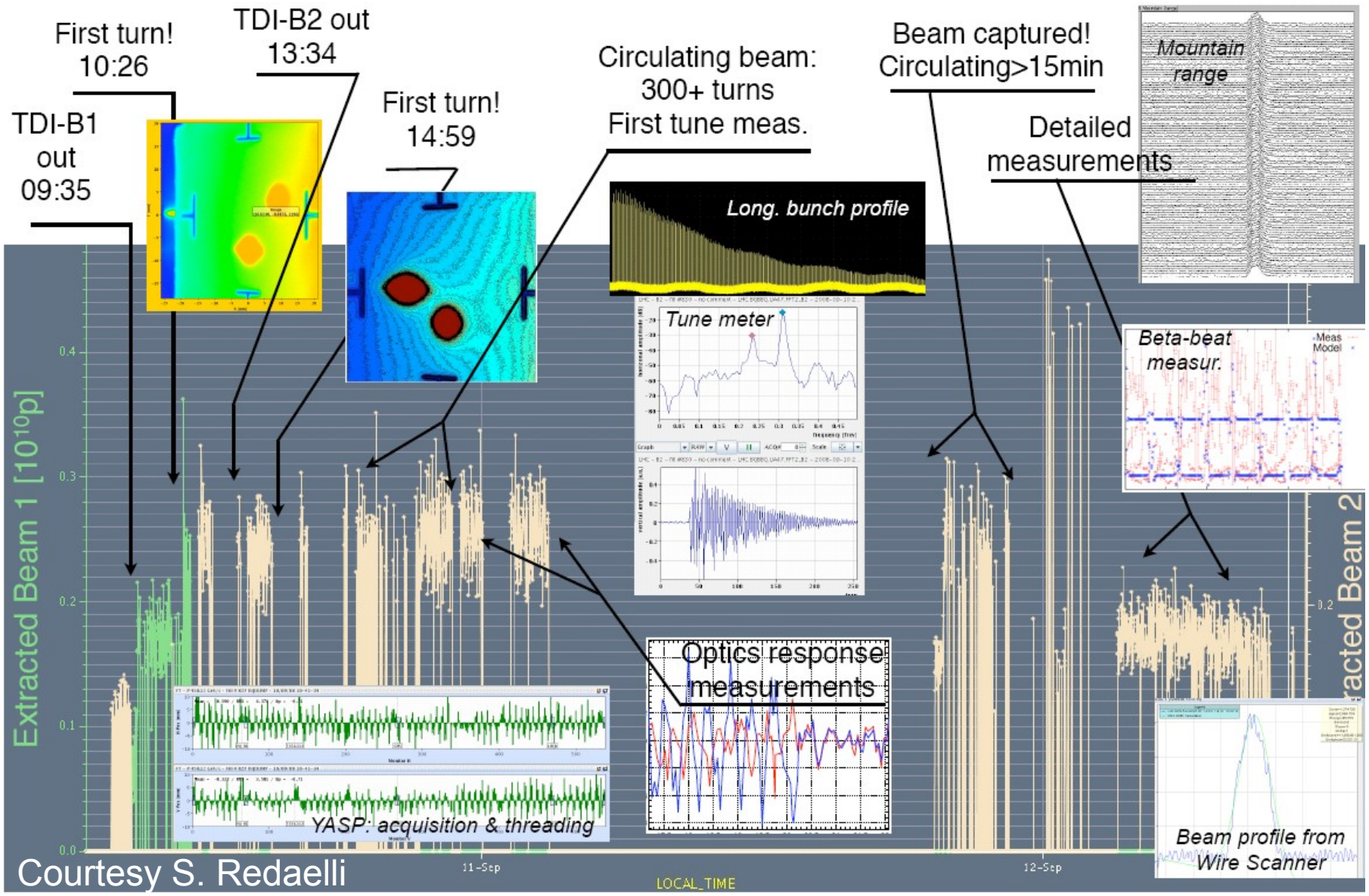
- Jim Strait quoting Franklin Delano Roosevelt (First Inaugural Address, 1933):

"We have nothing to fear but fear itself."

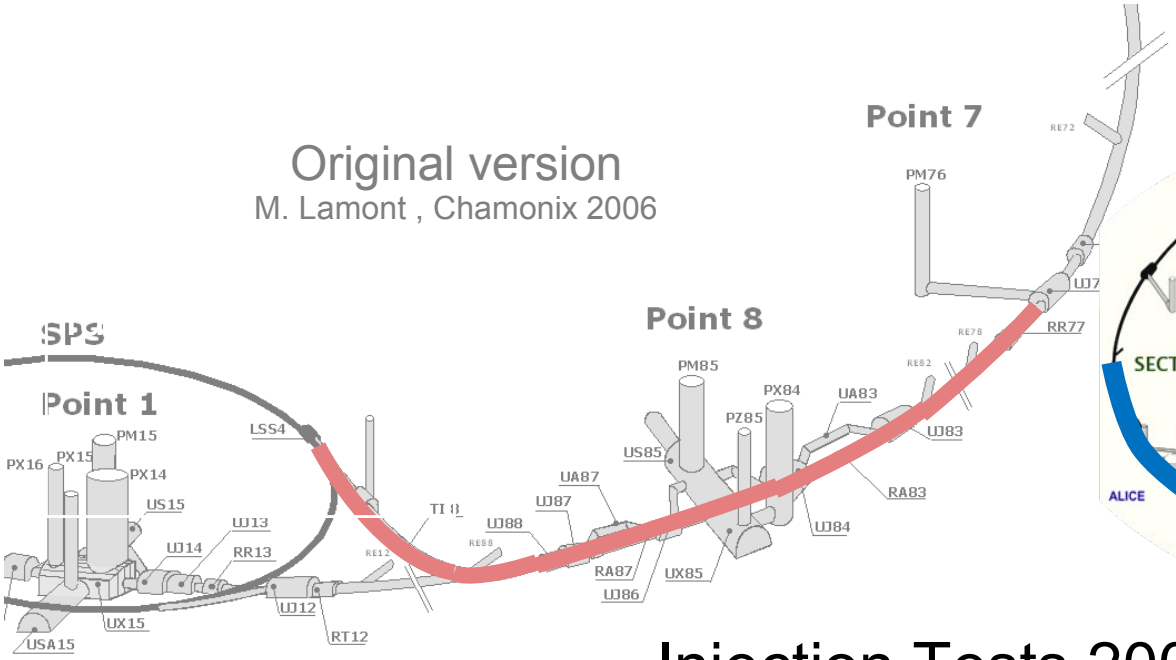
What else can go Wrong?
– Intermediate Conclusion – Steve Myer's reply:

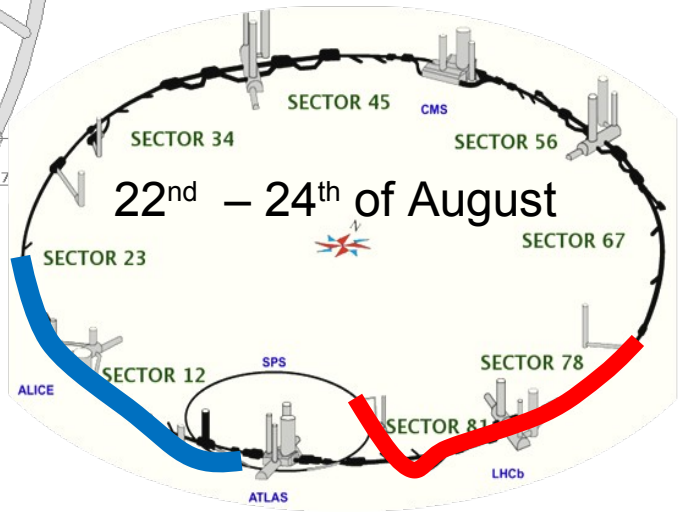
"A ship in harbour is safe, but that is not what ships are built for.",
John Augustus Shedd, *Salt from My Attic, 1928*

Session 7 - What did we learn with beam in 2008
Milestones of 50 Hours of LHC Beam Operation

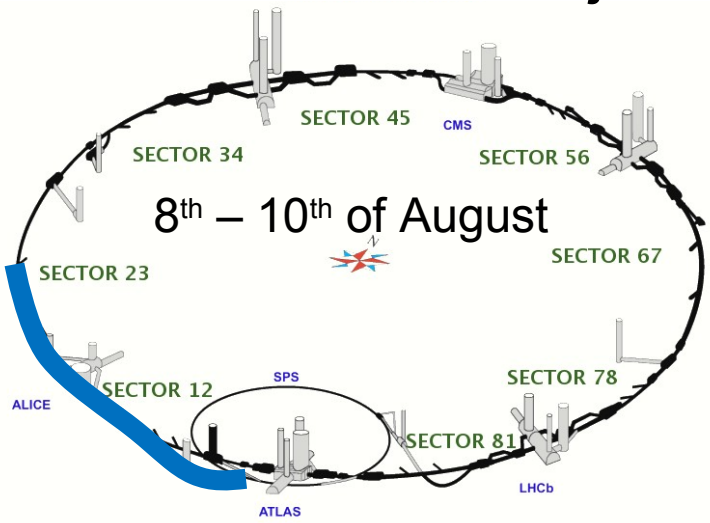


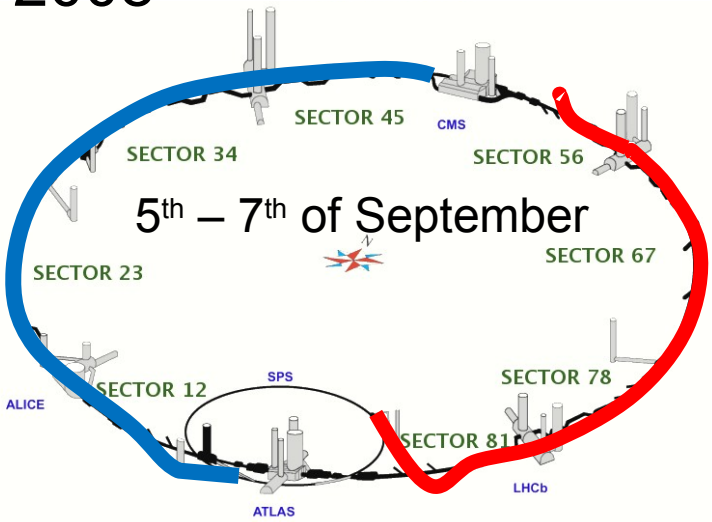
Session 7 - What did we learn with beam in 2008
Success was no Accident: LHC Injection Tests





Injection Tests 2008





Courtesy V. Kain

We got overwhelmed with positive BI related feedback!

A very big thank you!

This success was not an accident,
but a result of a combined, high-quality, and meticulous preparation prior to the 10th of September!

Road Map 2009/2010

- Physics Discovery Potential (S. Myers)

$$D_p \approx \eta_{LHC}(E) \cdot L_{avg.}(E) \cdot T_{run} \cdot F(E)$$

  - η_{LHC}(E): operational efficiency
  - L_{avg}: average luminosity during the physics run
  - F(E): given by the cross-section of the process being studies

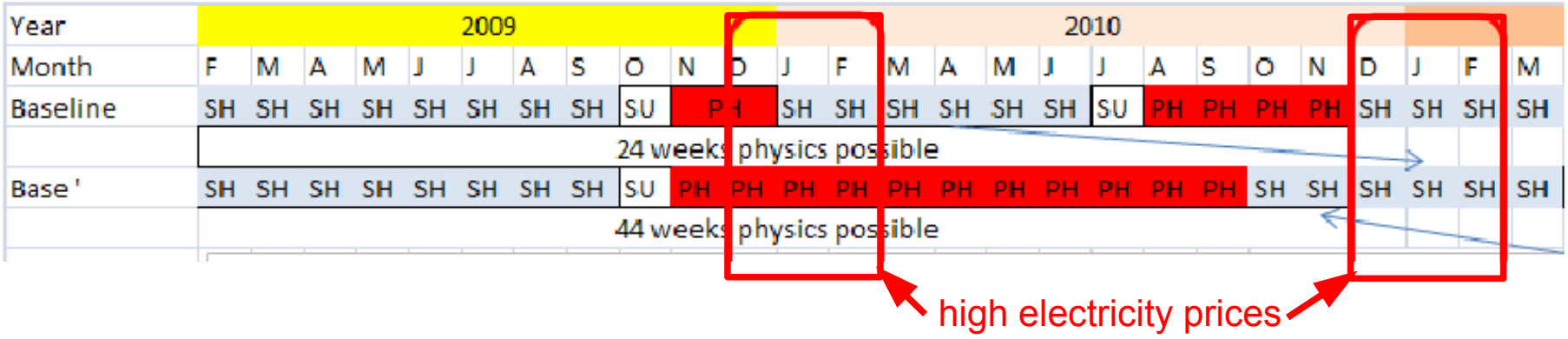
→ S. Myers: "T_{run} is the scheduled running time [..] and should be maximised"

- With Strictly No running of the machines in the winter months
  - Repair schedule has no contingency
  - Any slip of >1 month will delay first LHC physics till Aug./Sep. 2010!

→ S. Myers: "Must have the possibility of running during winter months"

Proposed Schedule 2009/2010

- Proposed preliminary Schedule (will be confirmed by March)



- Impacts of running during winter months:
  - Electricity: + 8MEuros (+ 8% contingency)
    - Considered a 2nd order issue → will be backed up by DG
  - Need to further evaluate impact on
    - injector schedule and shutdown work
    - necessary maintenance
      - Cooling towers
      - Electrical Network
      - ...

Pressure Relief Valves in Arcs

A: install 4 sectors (09-10) + 4 sectors (10-11)
+ present schedule allows calorimetry measurements in 23, 45 much sooner
+ first physics sooner: detectors debugging.. earlier warning
+ first beam sooner: ramp, squeeze, .. Sooner... earlier warning
+ focuses attention of repair teams

B: Installation 8 sectors (09-10)

+ reduced amount of collateral damage in event of a splice problem in 2010
+ reduced additional electricity bill
+ reduced overall shutdown time
+ reduced ALARA problems (2nd order)

- Enhanced Quench Protection (Detection)
  - Busbar Detection (Protection)
  - "Symmetric" quench protection

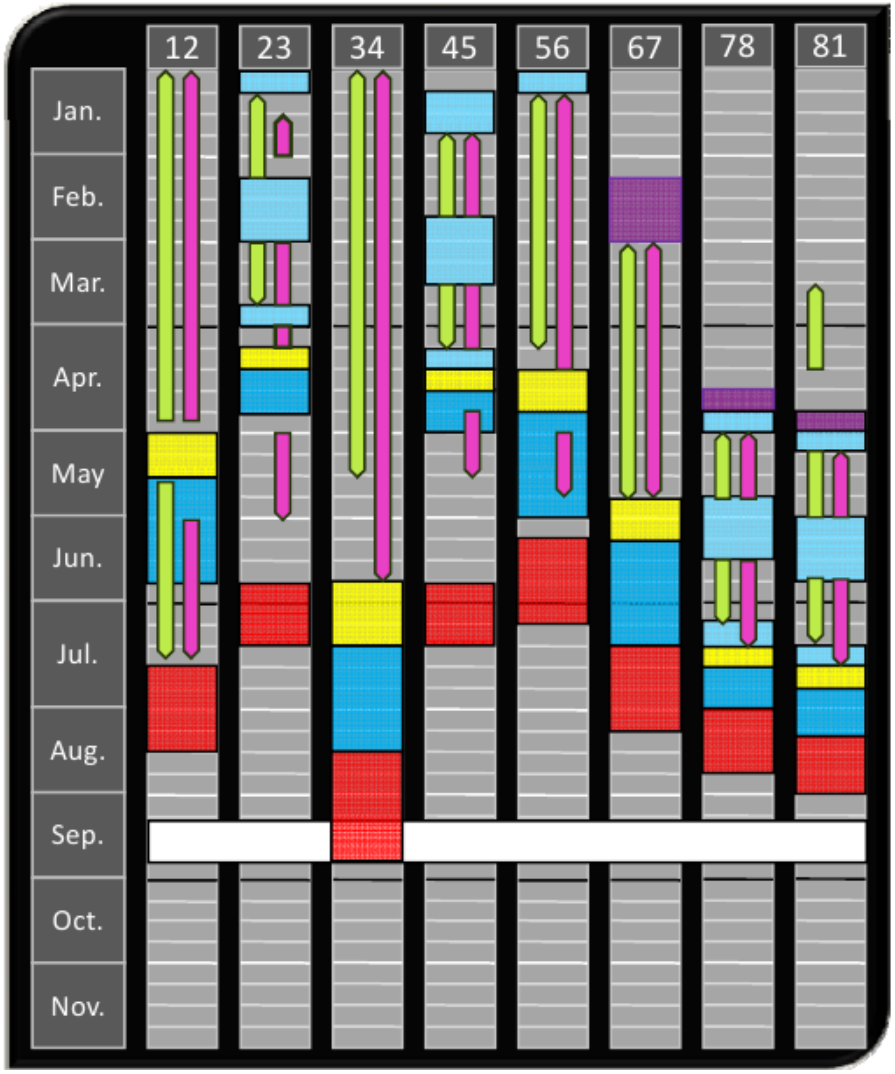
LHC should not be operated unless the FULL Quench System is tested and operational (my opinion, but open for discussion)

S. Myers, Summary

- Decision on 'A' or 'B' will be taken this March

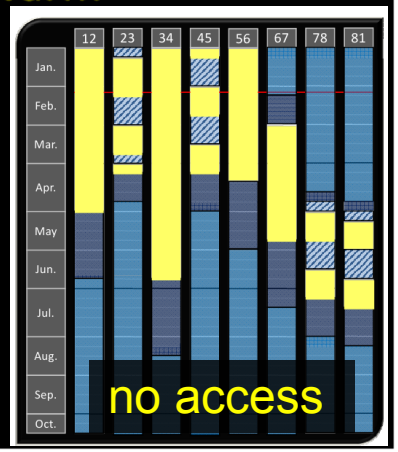
Repair Scenario II/II

- Possible slip of 5 weeks
  - “Blowing Off” Helium in 78/81 gains 2 weeks and would cost 1.2MCHF



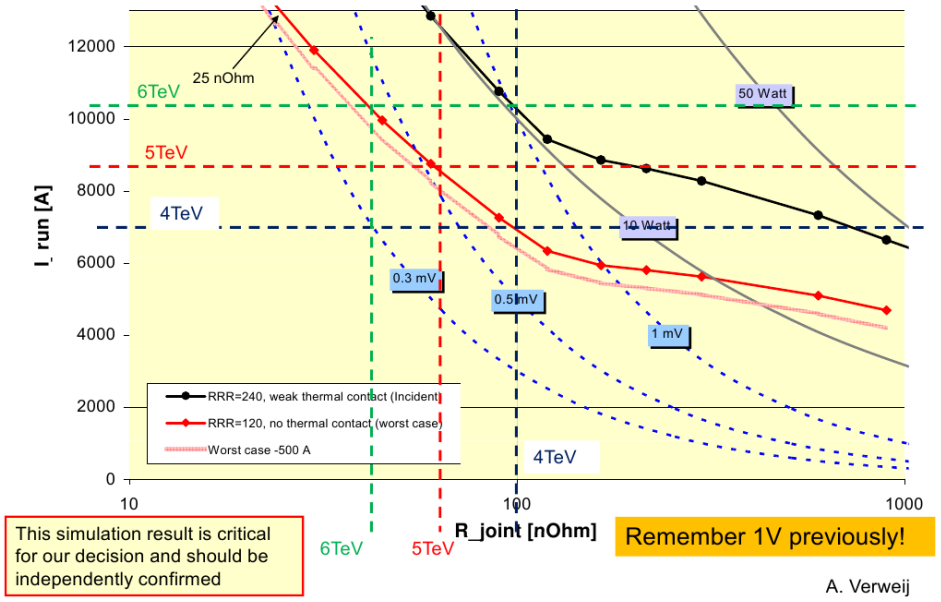
- Intermediate cool-down & QRL warm-up (Stand Alone)
- Activities
  - Arc
  - LSS
- Flushing & ELQA at warm
- Cool-down
- Powering tests
- Cold check-out

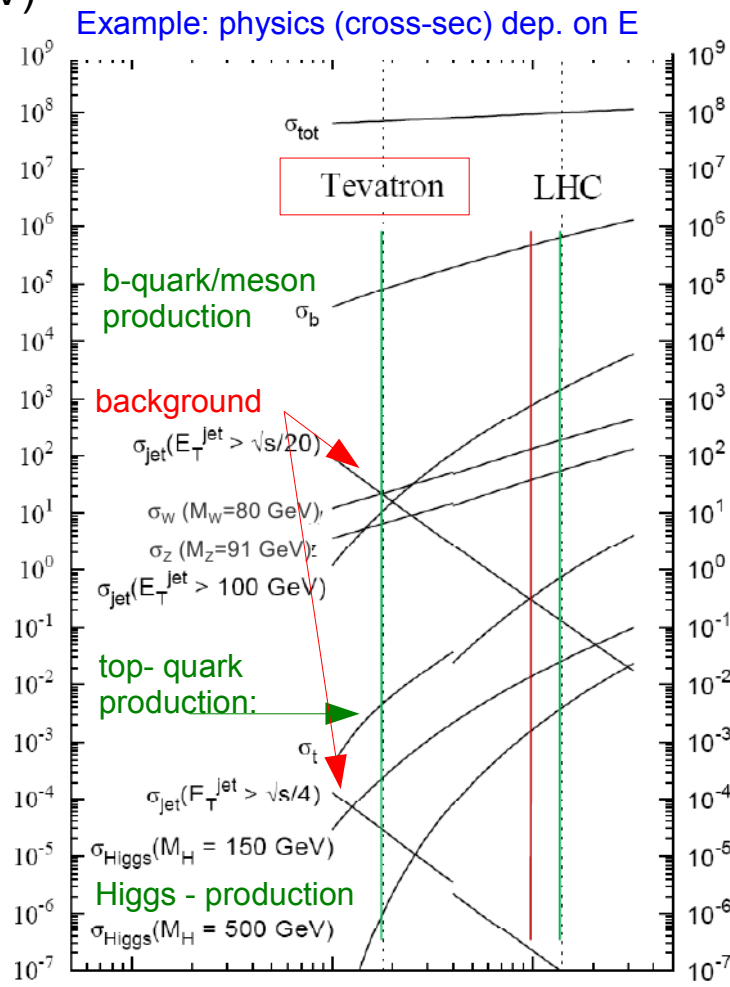
K. Foraz



Which Energy Level for Operation? - An Accelerator and Physics Perspective

- Dipole field which can be reached → 5 TeV seem to feasible
- Risks associated with operating at field → see QPS plot
  - Splices stability (thermal runaway…), poor splice detection, new beam effects
- Operational efficiency of other systems
  - cryo recovery time: ~ 3h @ 5TeV vs. >6h @ 7TeV)
- Useful (Competitive) LHC-HEP requires 2-3 TeV
- Physics: favours collisions > 2-3 TeV





Conclusions and Targets for 2009

Main outcomes:

- Risk of magnet induced and collateral damage has been intensively evaluated
  - Risk minimisation: QPS++ system (protection against slow thermal runaway), clamping of splices (protection against sudden opening of bus bar joints)
  - Collateral damage mitigation: pressure relief valves (DN100, DN200), ...

- Fixed shut-down policy would reduce LHC availability for physics by 20 weeks → planned to run the machine throughout the winter (if necessary)

LHC accelerator physics goals:

- Best/feasible/rel. safe energy option (S. Myers): 5 TeV
- Estimated [targeted] integrated luminosity (S. Myers):
  - During first 100 days of operation ≈ 100 pb^{-1}
  - During next 100 days of operation ≈ 200 pb^{-1}??

  } ↔ 156x156 scheme!
- Let's not forget ion operation! (Same optics and from an BI perspective similar to proton pilot beams)
- Implication for BI – similar to 2008 (re-commissioning of HW & SW), plus:
  - BPM/BLM mapping!, undulator L4 (abort gap), FastBCT (dI/dt feature), BGI and gas injection