Summary of Chamonix 09

S. Myers

Topics for Discussion/Decisions

- Road Map and Schedule
- Repair Scenarios (two)
- Dipole Field for Operation
  - Training/re-training
- "Precautions for Running"
- Beam Conditions for Physics
- Future Improvements to convert LHC into an "Operational" Machine
- Safety Considerations

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Road Map and Schedule (1)

- Physics Discovery Potential $D_p \approx \eta_{LHC}.L_{avg}.T_{run}.F(E)$

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

$\eta_{LHC}(E)$ is the operational efficiency (time in physics/scheduled time)

L_{avg} is the average luminosity during the physics run

F(E) is given by the cross-section of the process being studies

- T_{run} is the scheduled running time, is independent of energy, and should be maximised

Physics Running Time

With Strictly No running of the machines in the winter months

- Present baseline schedule
  - schedule allows very limited physics in 2009/2010 (24 weeks)
  - Any slip of >1 month in the S34 repair will delay first LHC physics till August/September 2010!!
  - Repair schedule has no contingency (comments from L. Rossi/F. Bertinelli/R. Denz, all "suggested" for 4 extra weeks)

Year	2009											2010											
Month	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Baseline	Shutdown								SU	PH		Shutdown (Relief V)						SU	PH				SH
	24 weeks physics possible																						

- **Must** have the possibility of running during winter months

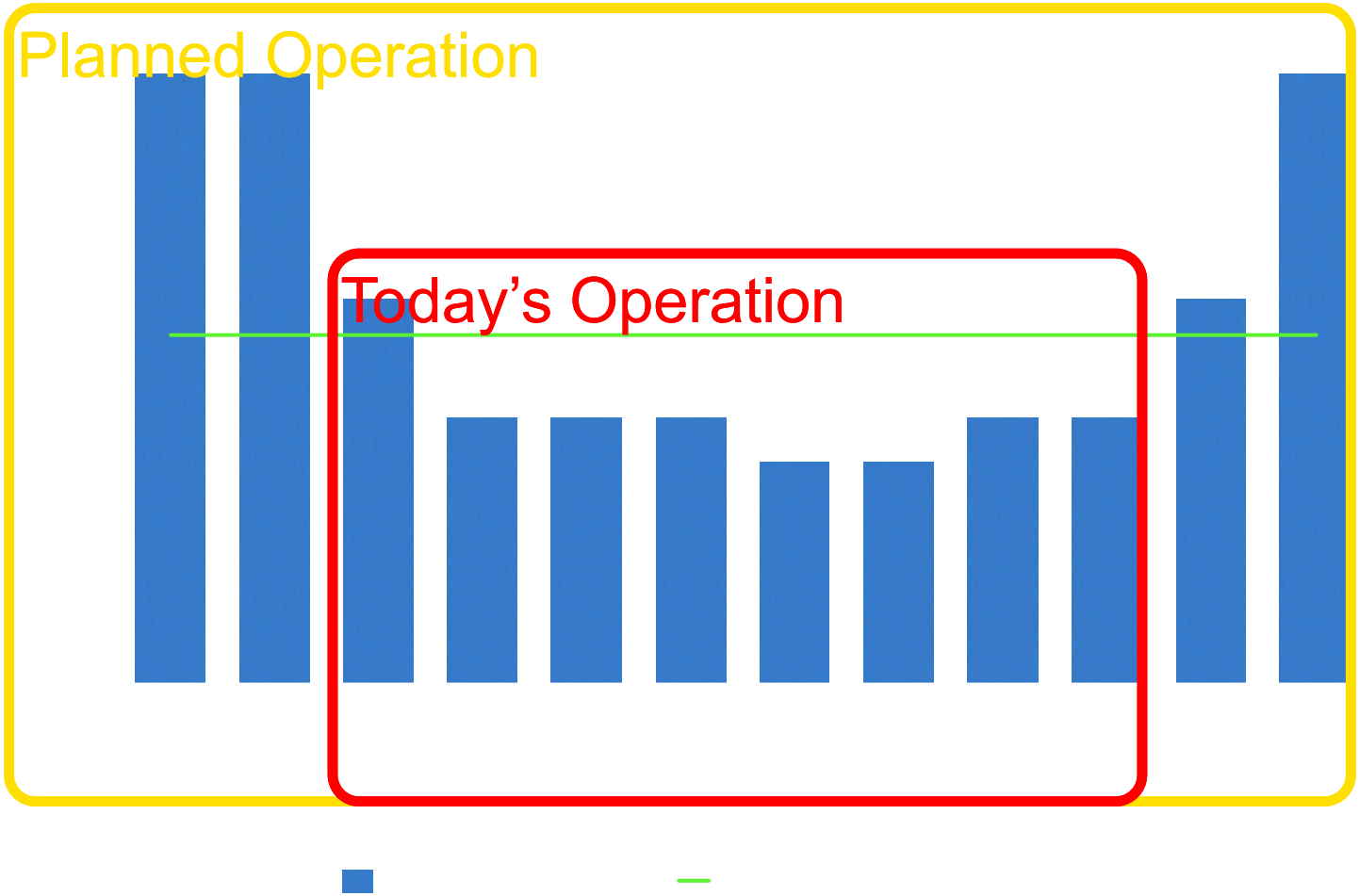
- From F. Bertinelli's talk
- no holidays (Easter, May …): is this realistic?
- ignore experience on delays (e.g. humidity for PAQs, Cu/Sn/Ag pollution of some TIG welds, leaks with W closing …)
- no (more) extra work (… additional sectors …)

Schedule with running in winter months

- Gains 20 weeks of LHC physics (independent of "slip")

Year	2009											2010														
Month	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Baseline	SH	SH	SH	SH	SH	SH	SH	SH	SU	PH	PH	SH	SH	SH	SH	SH	SH	SU	PH	PH	PH	PH	SH	SH	SH	SH
	24 weeks physics possible																									
Base '	SH	SH	SH	SH	SH	SH	SH	SH	SU	PH	PH	PH	PH	PH	PH	PH	PH	PH	PH	PH	SH	SH	SH	SH	SH	SH
	44 weeks physics possible																									
	Gain 20 weeks of physics in 2010 by running during winter months																									
	HIGH price Electricity																									
Delay (4W)	SH	SH	SH	SH	SH	SH	SH	SH	SH	SU	PH	PH	PH	PH	PH	PH	PH	PH	PH	PH	PH	SH	SH	SH	SH	SH
Delay (8W)	SH	SH	SH	SH	SH	SH	SH	SH	SH	SH	SU	PH	PH	PH	PH	PH	PH	PH	PH	PH	PH	PH	SH	SH	SH	SH

Today's cheapest applicable EDF Tariff



Impacts of Running During Winter Months (2009-2010)

- Electrical Costs!!
  - Assuming Full running through December to February
  - dedicated running of the injectors during winter and
  - reduced cryo power from 8MW to 5MW/sector

  → **additional electricity bill of 8MEuros (+ possible 8%)**
- Impact on Scheduled Shutdown Work on other CERN accelerators
- POPS
- LINAC4 connection to PSB
- …
- Impact on Necessary Maintenance
- Cooling towers
- Electrical Network
- …

FIRST PROPOSAL

Plan Electricity Provision for Running in Winter 2009-2010

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Repair Scenarios

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

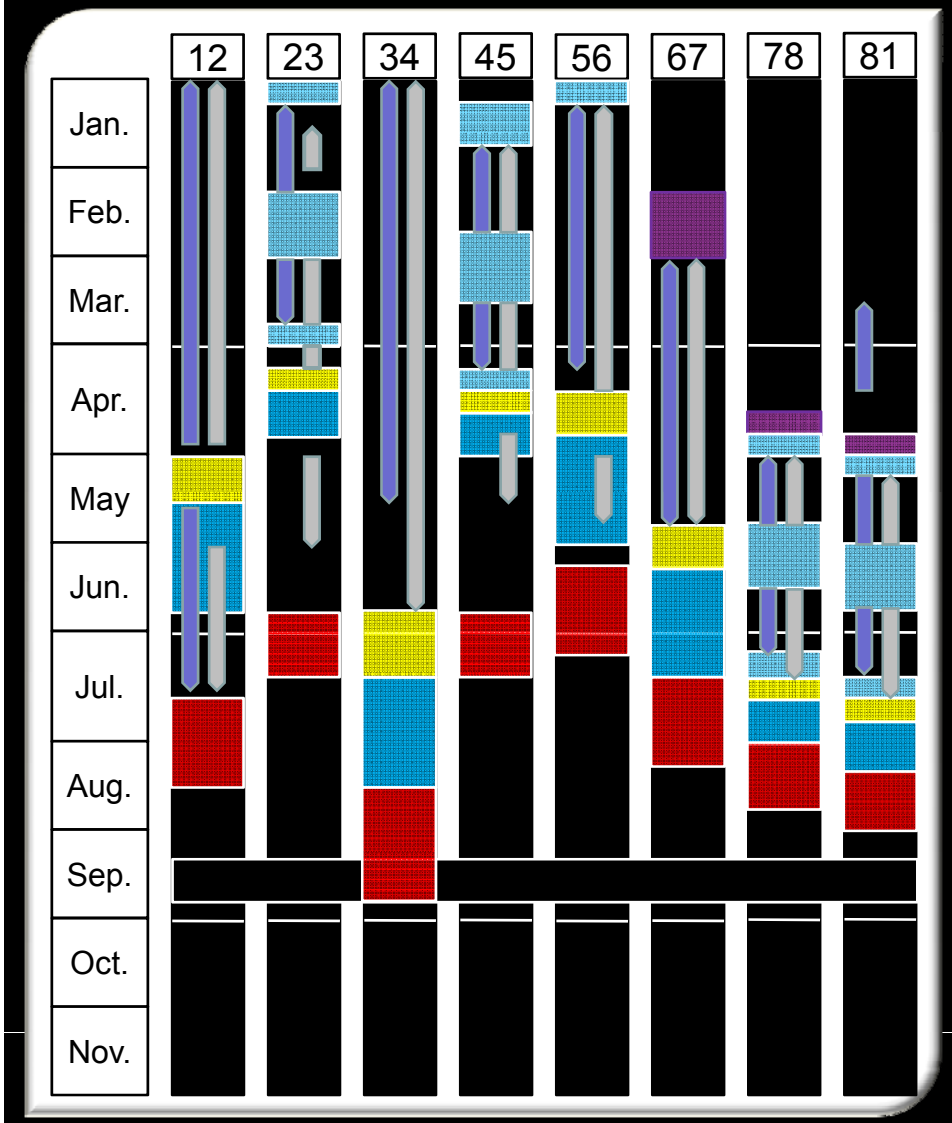
B: Installation 8 sectors (09-10)

+ 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

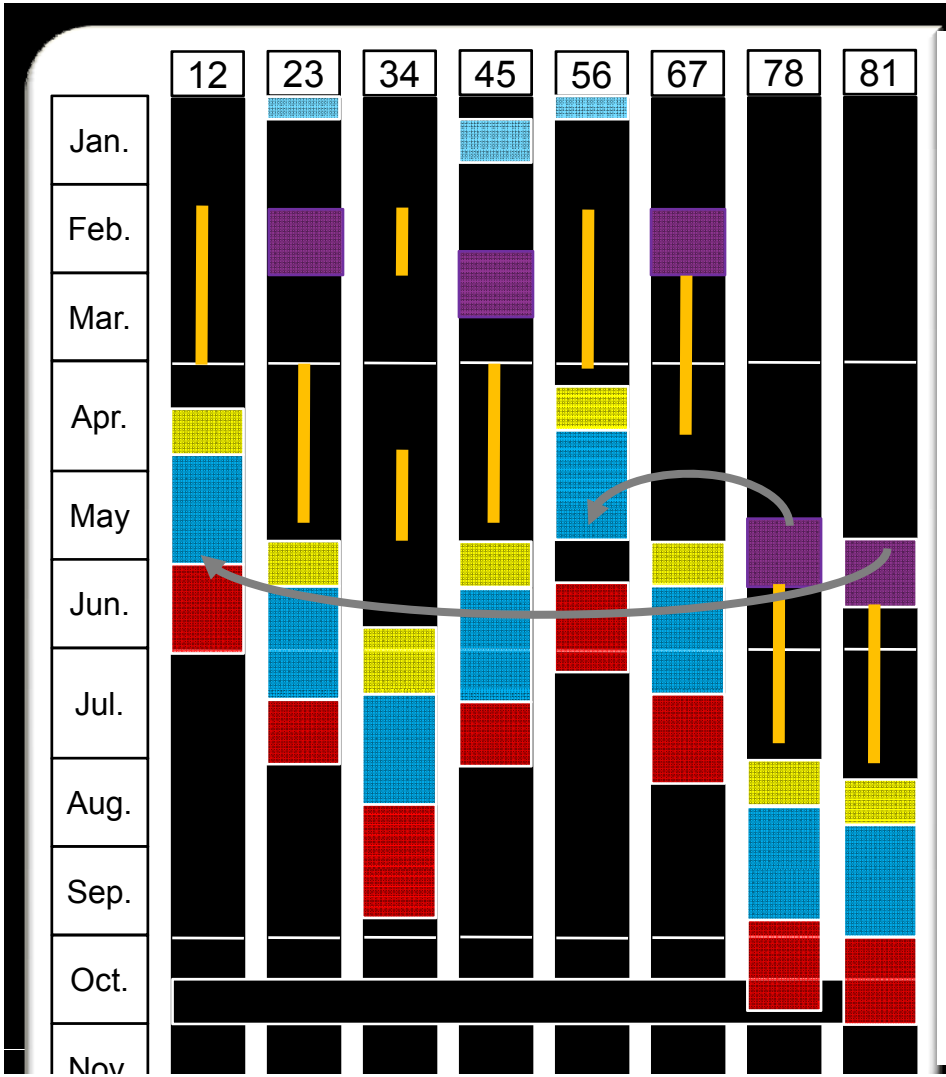
LHC should not be operated unless the FULL Quench System is tested and operational (my opinion, but open for discussion)

Shutdown 08-09



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

Total warm-up



- The emptying of sectors 78 & 81 can only occur when the first 2 sectors are cold: i.e sectors 12 & 56
- Critical points - Changes
  - Gaining 5 wks margin on sector 34
  - Sectors 12, 56, 78 & 81 on the critical path
- Delay w.r.t current schedule = + 5wks

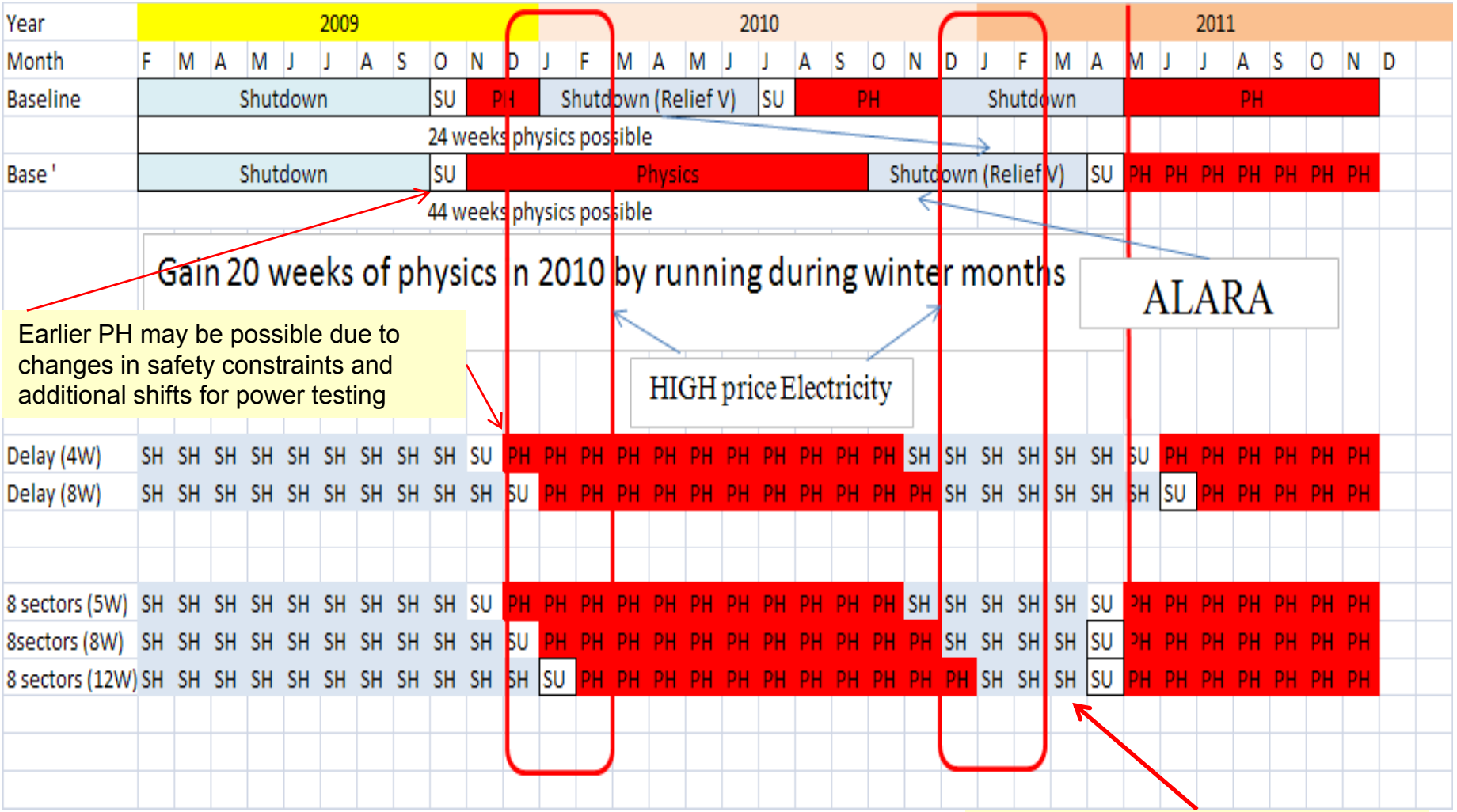
❖Flushing / warm-up ❖Consolidation ❖Cool-down

❖Intermediate CD ❖ELQA & flushing ❖Powering tests

Discussion on Schedule

- Key Drivers for schedule;
  - Safety constraints, access, transport,…
  - Helium storage
  - Maintenance: cooling towers, electrical network…
  - Cryo maintenance, PIMs…
- “Blowing Off” Helium in 78/81 gains 2 weeks and would cost 1.2MCHF

Schedule Scenarios



Earlier PH may be possible due to changes in safety constraints and additional shifts for power testing

Here it is assumed that these shutdowns will be long enough in case of problems seen during the preceding PH running

Stop here for discussion

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- Energy Level for Operation
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Energy Level for Operation

- Dipole field which can be reached
  - Time needed, reliability, and efficiency
- Risks associated with operating at field
  - Splices stability (thermal runaway…)
  - Detection of poor splices (see later)
  - New effect of beams (?)
- Operational efficiency of other systems
  - Cryo recovery time etc

Dipole quenches during HWC

Sector	1st training quench [A]	I_max [A]	# training quenches	Starting in:		
				# ALS	# ANS	# NOE
1-2	-	9310	0	0	0	0
2-3	-	9310	0	0	0	0
3-4	-	8715 (bus)	0	0	0	0
4-5	9789	10274	3	0	0	3
5-6	10004	11173	27	0	1	26
6-7	-	9310	0	0	0	0
7-8	8965	9310	1	0	1	0
8-1	-	9310	0	0	0	0

Excluding S34, all sectors reached 8965 A (5.3TeV) without a quench
Excluding S34, all sectors reached 9310 A (5.5TeV) with 1 quench

Estimated dipole training to reach 6 and 6.5 TeV

Sector	Number of magnets			Number of quenches	
	ALS	ANS	NOE	@ 6 TeV (±2)	@ 6.5 TeV (±30%)
1-2	49	96	9	0	4
2-3	56	60	38	1	8
3-4	56	65	33	1	8
4-5	46	46	62	2	12
5-6	28	42	84	1	15
6-7	57	36	61	2	12
7-8	54	40	60	2	12
8-1	64	24	66	2	13
Total	**154**	**154**	**154**	**11**	**84**

Estimated 11 (84) quenches to reach 6 (6.5) TeV

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.

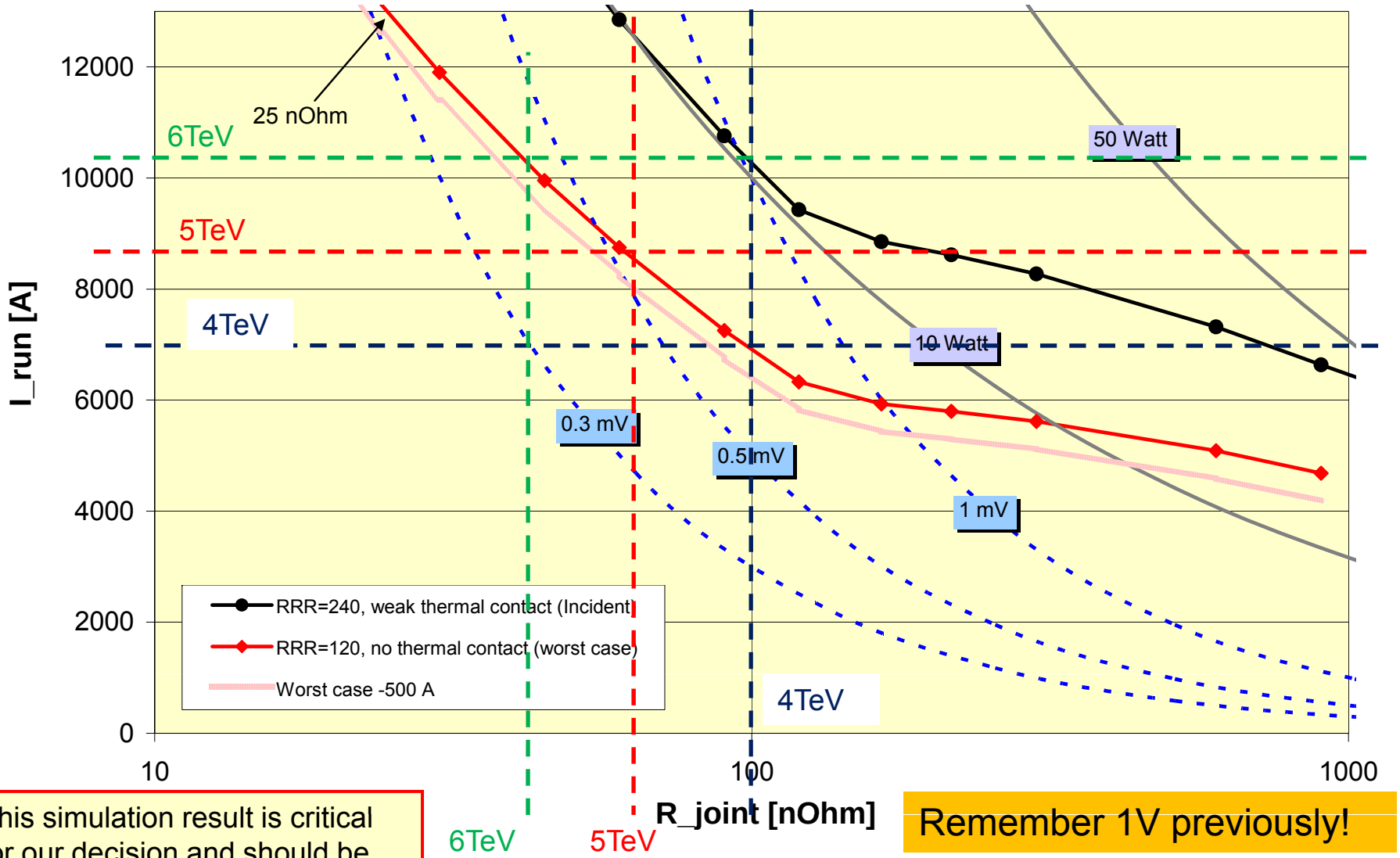
Both origins would have been detected with a QPS threshold voltage <1 mV long before the start of the thermal runaway.

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).

Setting for the new QPS upgrade



This simulation result is critical for our decision and should be independently confirmed

Remember 1V previously!

Conclusion

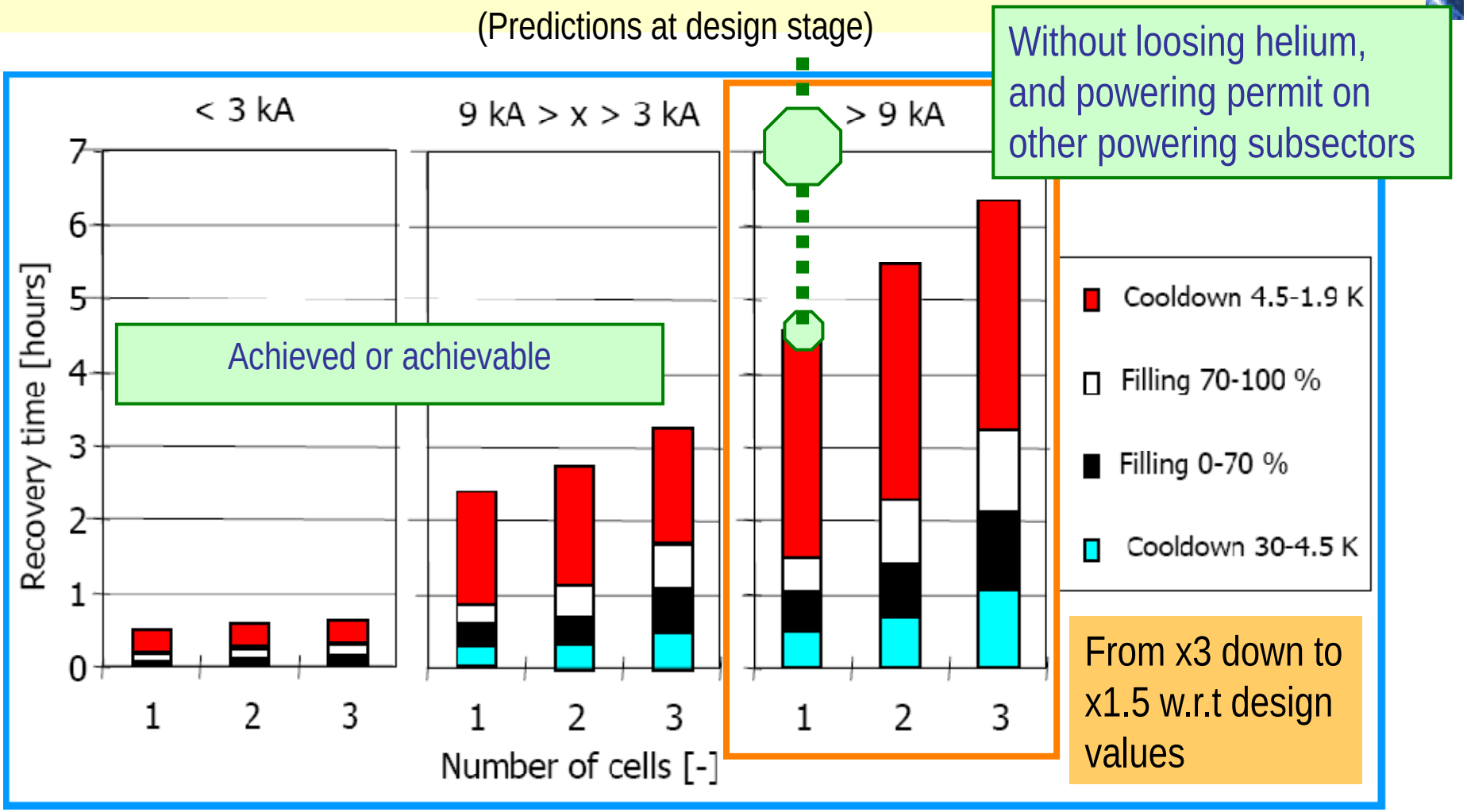
A small gap (up to a few mm) between bus and joint is acceptable as long as there is a good thermal contact between joint and U-profile/wedge.

Of course, the QPS system cannot protect the circuit in case of a sudden mechanical opening of the joint (without precursor 100 sec before).

Very similar conclusions hold for the RQF/RQD circuits, but what about all the other joints, busbars, pigtails, ...

Recovery Time after Limited Resistive Transitions

(Predictions at design stage)



- More than 14 cells or full sector: recovery up to 48 hours
- In case of fast discharge (even w/o quench): 2 h recovery (heating due to eddy currents).

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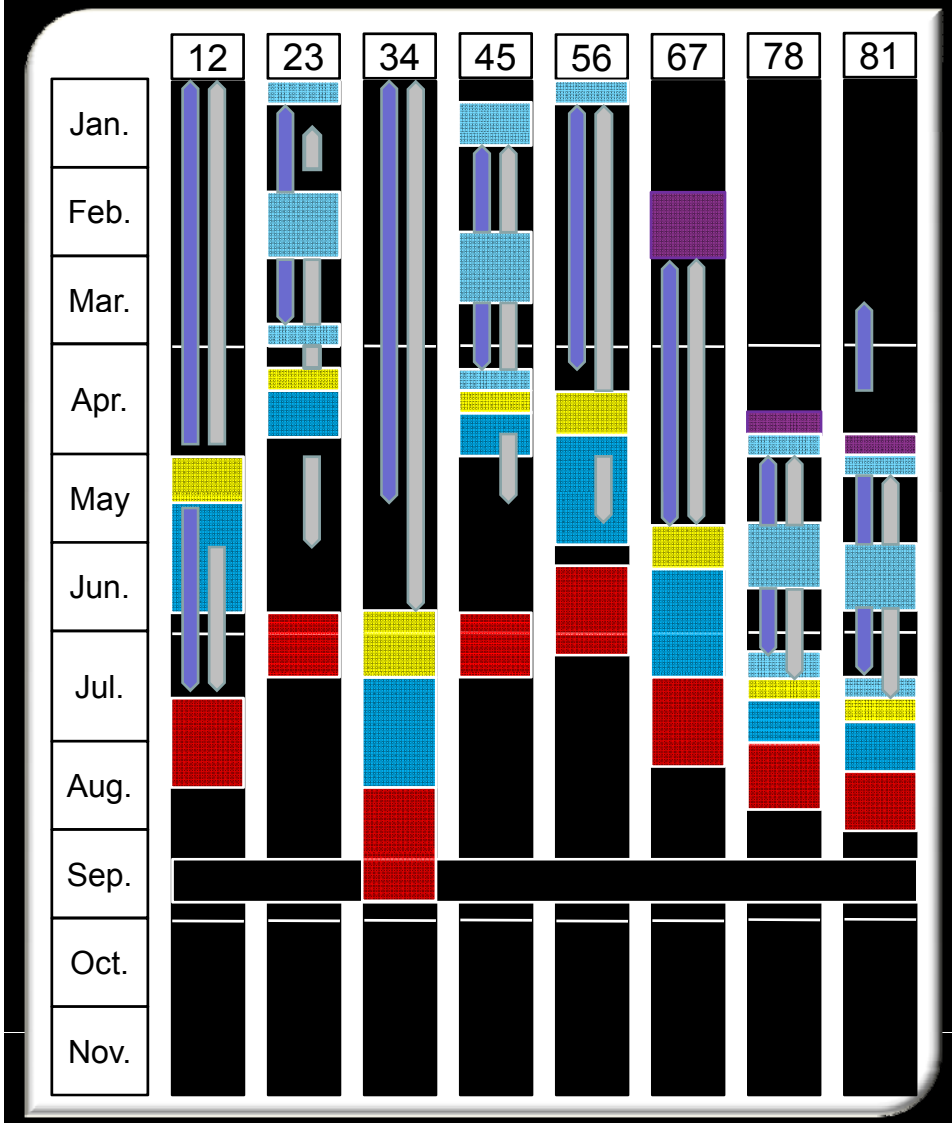
Precautions before Running with Beam

- Pre-detection of Poor splices in untested sectors
  - Analysis of SM18 data + calorimetry at 7kA →
  - Early running of S23 and S45 (weekend calorimetric run in April/May??) →
- QPS fully operational
- QPS in event of trip of UPS
- Pressure valves in DFBs and inner triplets
- Quench Protection during magnet ramp down
- Protect RF and injection kickers (vacuum valves)
- Water cooled cables
- Anomalies in electric circuits (K-H. Mess)
- Xray machine available Aug/Set ?sooner
- Undulator (left of point 4) availability and necessity

Shutdown 08-09



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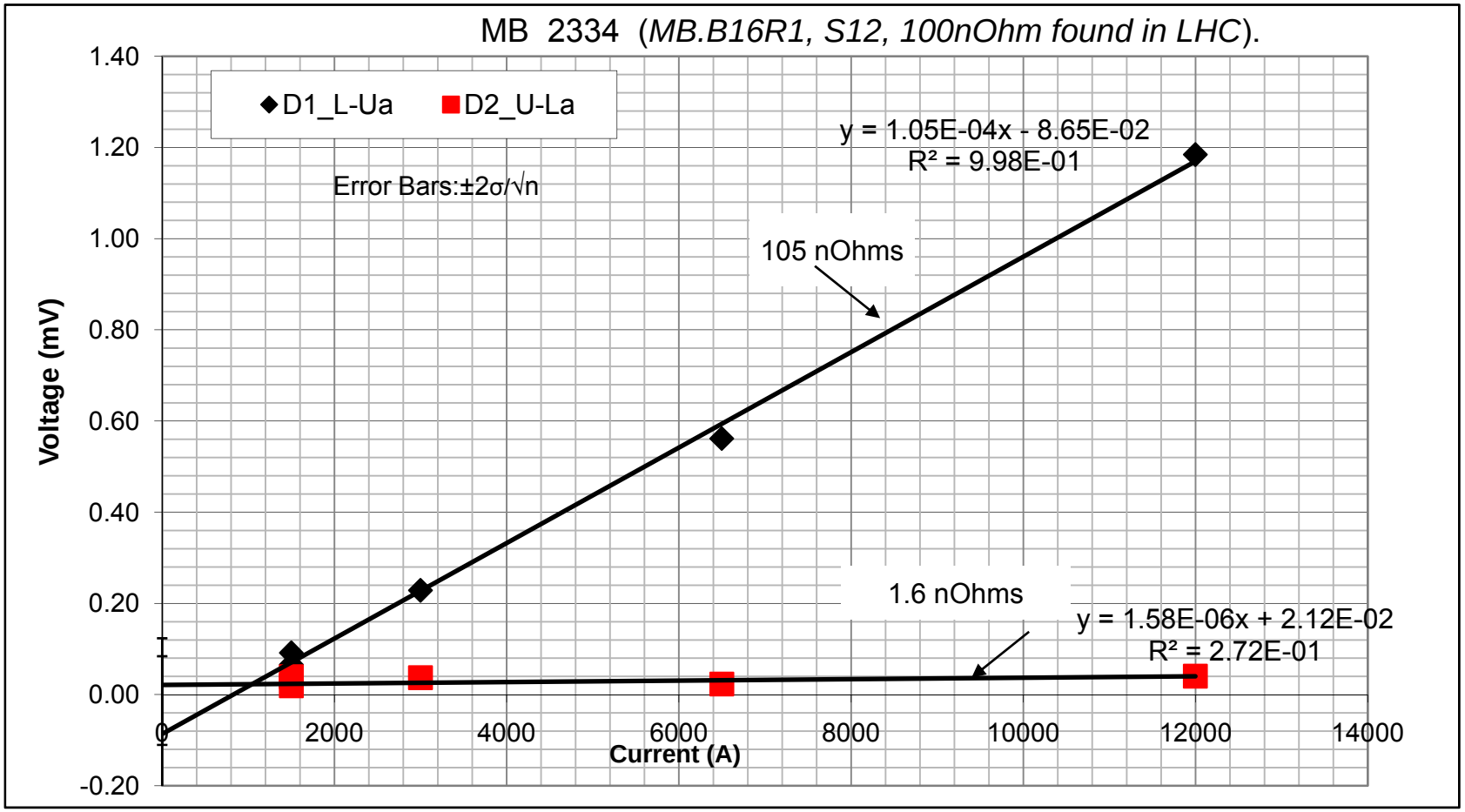
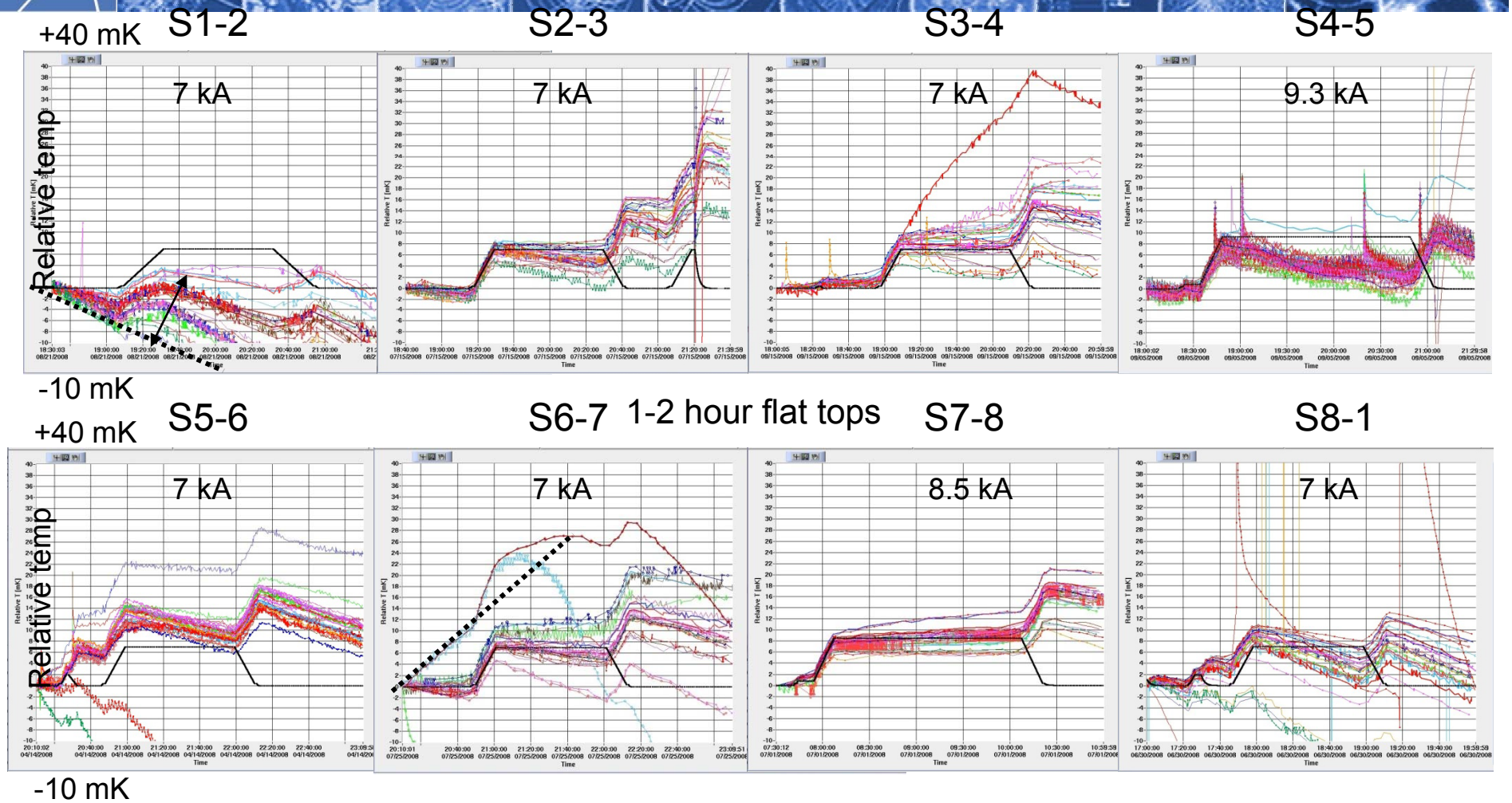
Verification from SM18 data on magnet 2334



- Data from SM18 acquired during the cold tests confirms an inter-pole splice of 105 nOhm in magnet 2334 (B16R1)

All sectors quick comparison



All the current plateaux scrutinized for suspect temperature increase

Unstable conditions and dynamic temperature control prevent accurate calculations.

QC splices during production

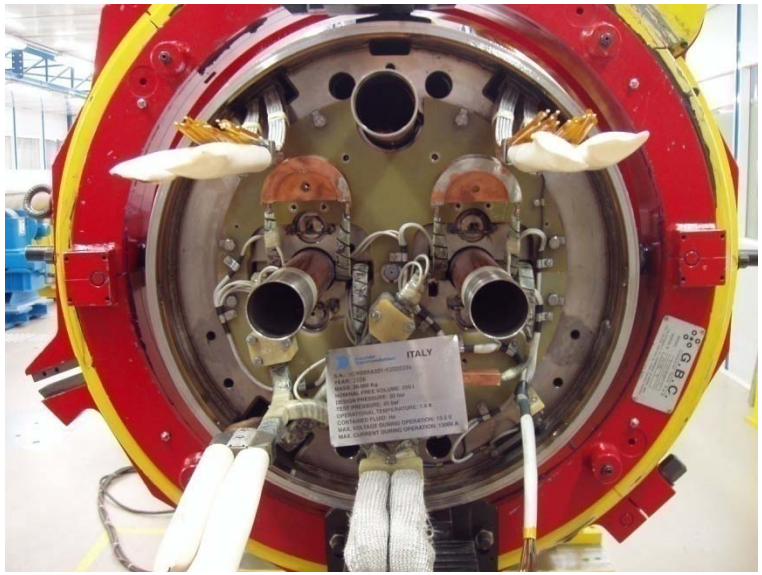
- Visual inspection of each splice by member of QC team prior to soldering operation and after soldering operation (before insulation): take photos NEW
- Dimensional measurement of the finished splice (?): NEW
- Systematic ultrasonic testing of 13 kA splices: NEW
- Record temperature cycles during soldering of 13 kA splices with separate equipment: NEW.
- Possibly record pressure data?
- Production data analysis and storage
- Weekly audits
- Braze BB vs insulate BB and US weld spools by separate teams
- … and don't be blind to other potential problems …

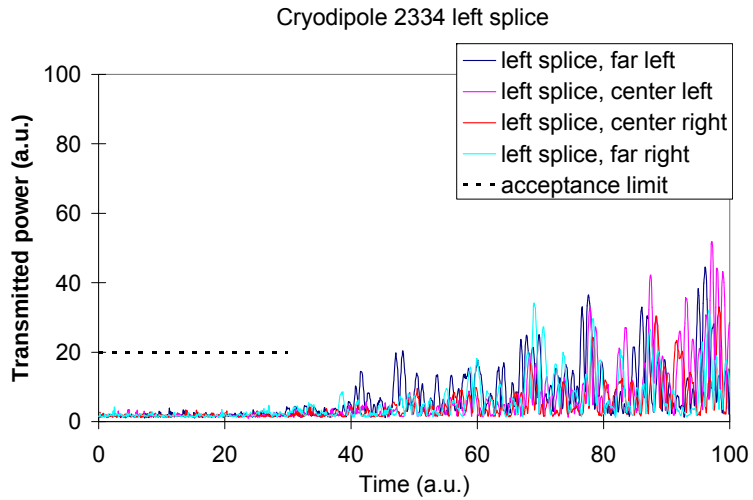
Courtesy C. Scheurlein

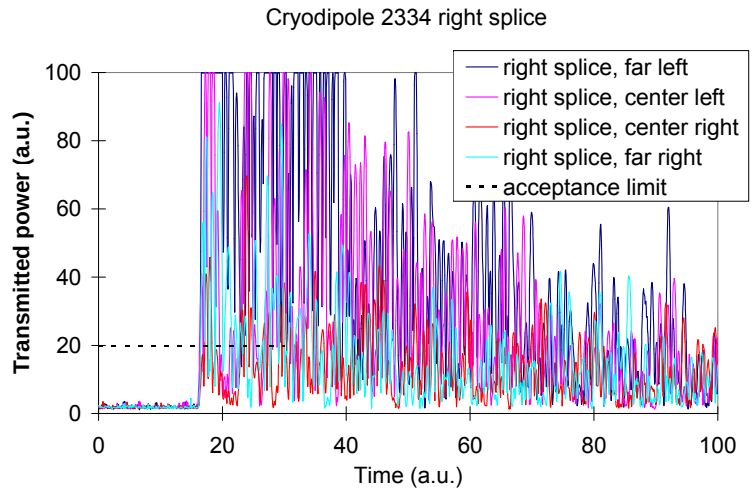
S34 new splices should be perfect!!

Ultra-Sound testing 13 kA splices

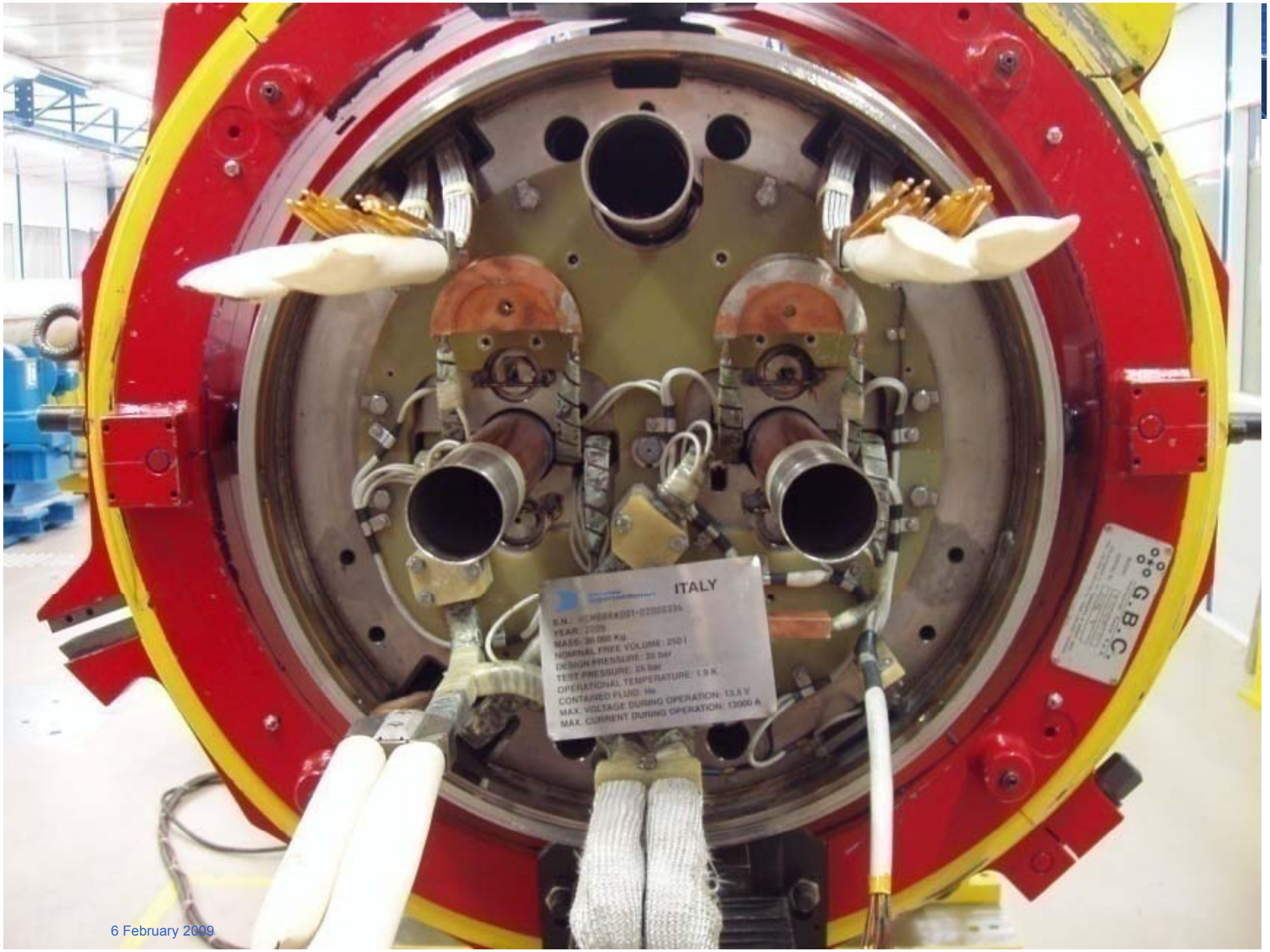
US inspection of defective inter-pole splice in MB 2334 has confirmed the US test to be a very useful QC tool.







Courtesy C. Scheurlein


ITALY
YEAR: 2005
MASS: 30.000 Kg
NOMINAL FREE VOLUME: 250 l
DESIGN PRESSURE: 20 bar
TEST PRESSURE: 25 bar
OPERATIONAL TEMPERATURE: 1.9 K
CONTAINED FLUID: He
MAX. VOLTAGE DURING OPERATION: 13.5 V
MAX. CURRENT DURING OPERATION: 13000 A
G.B.C.

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Precautions for Running 2

- Long Straight sessions: clarification
- Automation of the calorimetry measurements
- Complete set of Omhic measurements of all splices during Power Tests and Cold check-out
- MQM praying hands splices? change

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Beam Conditions for Physics

- Machine Protection Tested with beam (testing at 0.5TeV energy levels)
- 4 TeV “on the way” to 5TeV (no higher in 2010)
- Intensity limited until QPS symmetric mode is completely tested
- Physics at 5 TeV
- Estimated integrated luminosity
    - during first 100 days of operation.. ≈100pb-1
    - During next 100 days of operation.. ≈ 200pb-1??
- Then towards end of year ions (to be planned in detail soon)

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Future Improvements

- ARCOM-RAMSES replacement
- MQM praying hands splice to be replaced
- Clamping of busbar splices, development followed by campaign of replacements?
- Spares, spares, spares
- SEU; continuation of protection
- Helium storage
- Improvement in controlled access system
- Vacuum consolidation to reduce collateral damage in case of splice rupture
- Cooling Tower maintenance (LEP/LHC HVAC)
- Use of new xray machine
- Centralised radiation workshop

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Safety Considerations

- Need safety conditions for access urgently
  - When considering access to service areas during lower current tests, consider the energy in the circuit
- Safety Information Panels needed ?
- Level 3 alarms situation to be looked at by sc
- Emergency Preparedness. We should review the procedures based on the S34 incident
- Cooling Tower maintenance (LEP/LHC HVAC)

Closing Remarks

- Excellent Workshop (My Opinion)
  - Many discussions (focused and unfocused)
  - Networking: colleagues, friends, collaboration seeds planted …
  - Have defined the work programme for the next 12-18 months (to be followed up)
  - Have converged on the schedule (will be finalised early next week)
  - Have defined most likely beam conditions for physics

Closing Remarks

- Thanks!!!
  - Chairs and scientific secretaries: excellent organisation
  - Speakers: many excellent presentations, not a single poor presentation
  - Colleagues (experts) from other labs/panels
  - LHC detectors (Tech coordinators and Spokespersons: making up think twice or 3,4, times)
  - Participants (lively discussions, expert advice)
  - Roger Bailey, Frank Zimmermann, Christian Carli
  - Tjitske!! For everything