What did we learn without beam in 2008 ?

Roberto Saban & Mirko Pojer

Training the dipoles	A.Werveij
Superconducting electrical circuits	K-H.Meß
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LHC Cryogenics: What did we learn from cool-down to first beams	S.Claudet
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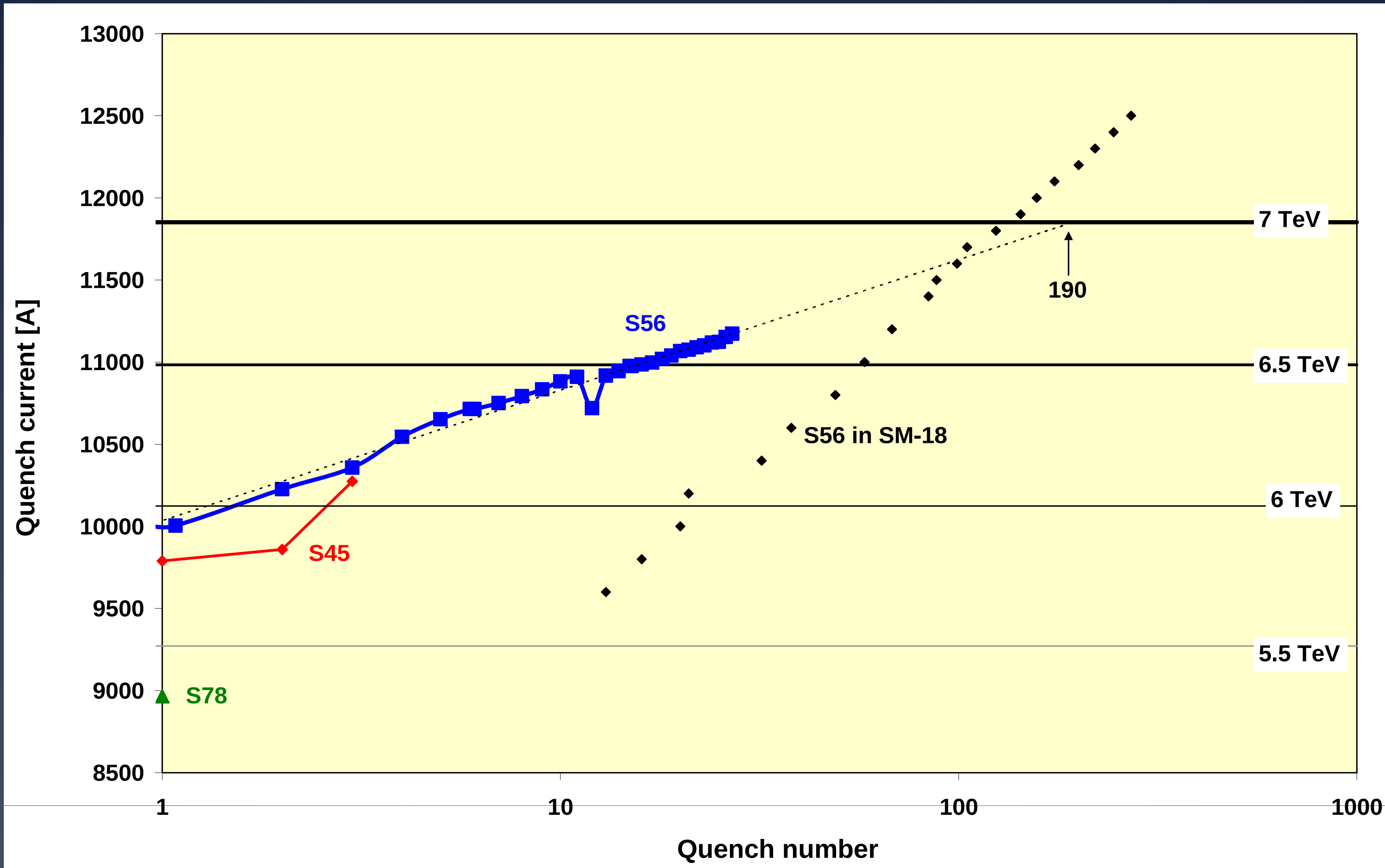
Training the dipoles

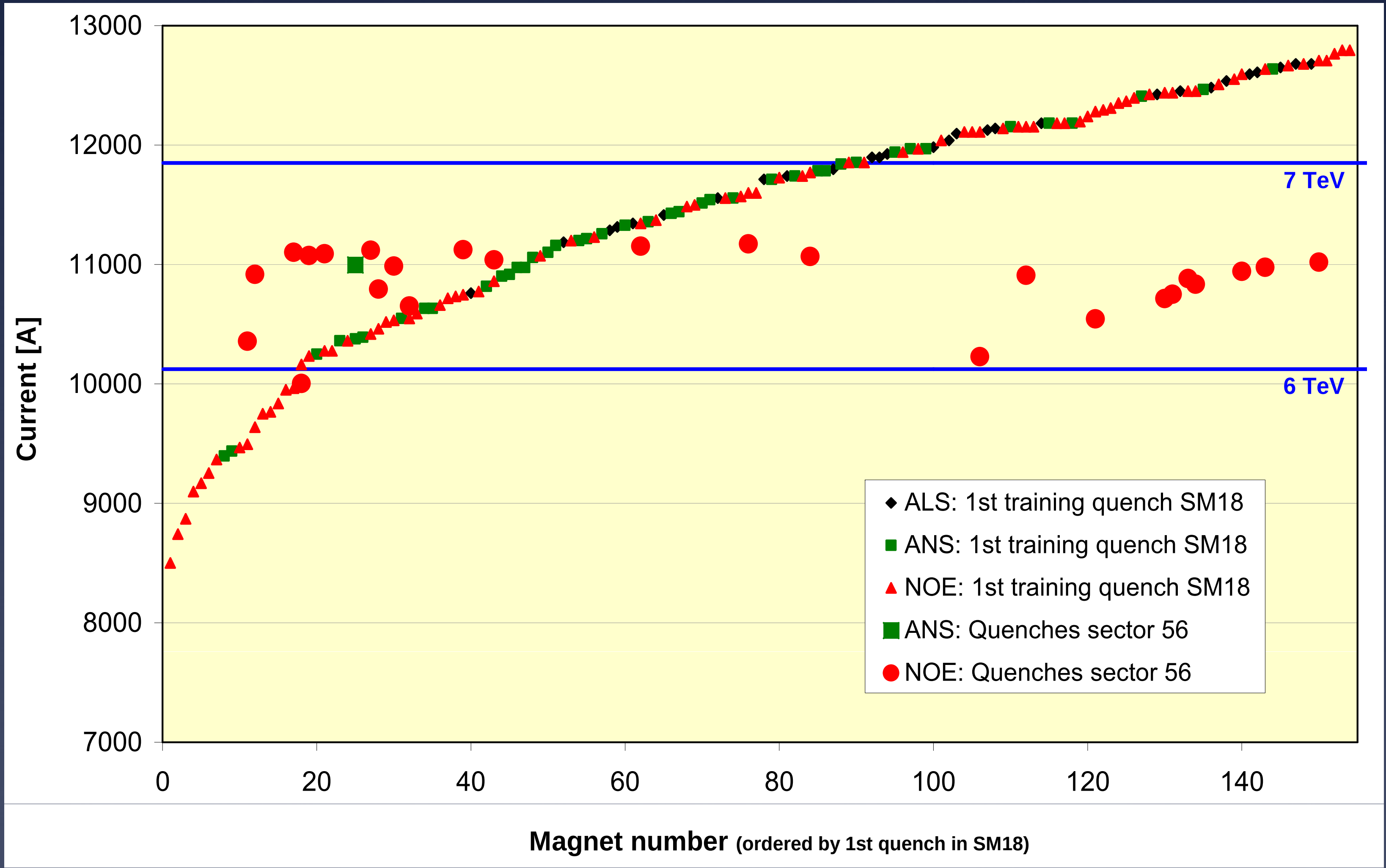
in sector 56



A.Verweij

Training the dipoles

in sector 56



A.Verweij

Training the dipoles

in sector 56

Number of magnets

Sector	ALS	ANS	NOE
1-2	49	96	9
2-3	56	60	38
3-4	56	65	33
4-5	46	46	62
5-6	28	42	84
6-7	57	36	61
7-8	54	40	60
8-1	64	24	66

A.Verweij

Est. 1: Based on 115 MB's that have been submitted to a thermal cycle in SM-18 (2008 before HWC, P. Xydi and A. Siemko)

Est. 2: Extrapolation from sector 5-6 data + estimate 1 for ALS & AN

Est. 3: 2 quenches per NOE magnet + estimate 1 for ALS & ANS

Est. 4: 3 quenches per NOE magnet + estimate 1 for ALS & ANS

993 / 8 = 124

124 / 3 = 41

Superconducting electrical circuits

Surprises

Harmless

- The third current lead shared by two circuits (Kirchoff's Law)
- Short inside the dump resistor on the QF of Sector 45
- Short to ground on the dump resistor on the QD of Sector 56
- Missing resistor on one of the poles of an undulator which gave a very exotic transfer function
- Leveling of the DFB to properly wet the superconducting cable

Potential inconvenience to operation

- Distribution of the conductors on cables sharing the same DFB but on different circuits – symptom: apparent detraining
- The reference magnet puzzle – magnetization cycle

Potentially dangerous

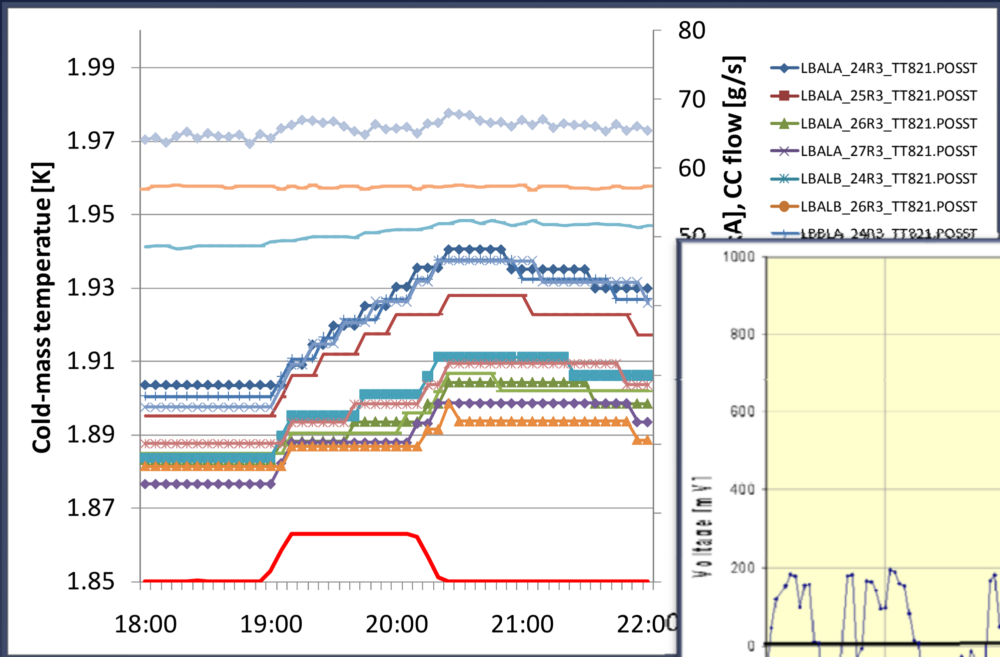
- Symmetric quenches
- Transient spike when the dump switch opens due to the difference in Eddy currents in the two apertures
- Quench back in corrector circuits inducing coupling on other circuits … up to quenching the main magnets
- Pending: splice and voltage tap non-conformities

Unresolved

- MCBX and MCBY mystery: unexplainable transfer functions
- The hunch on the MCBYs
- Fast quench propagation observed on only the dipole circuits

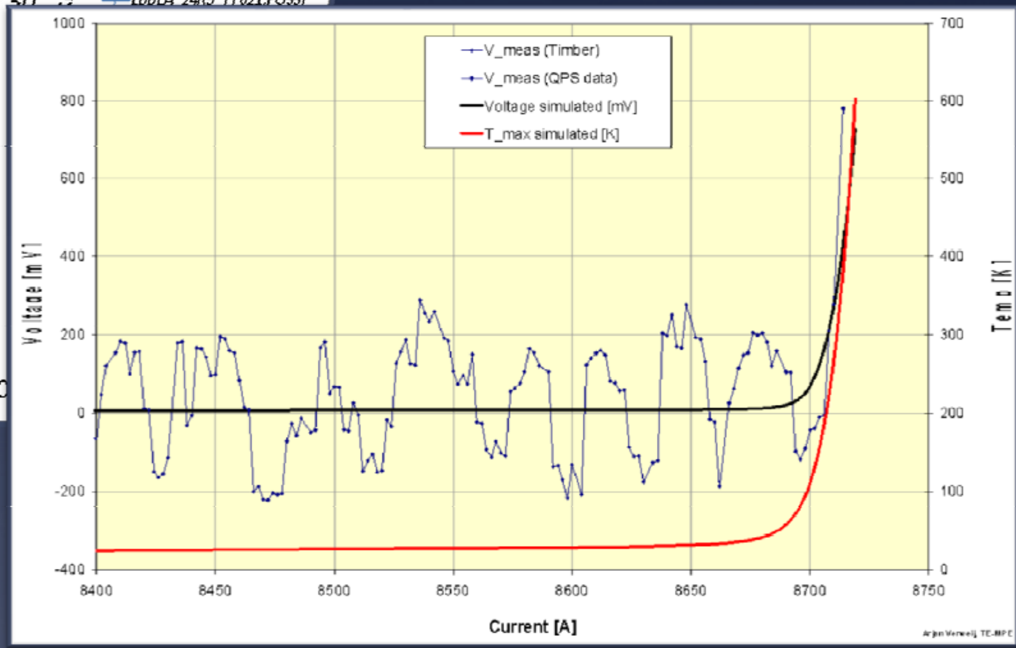
K-H.Meß

The Sector 34 Incident



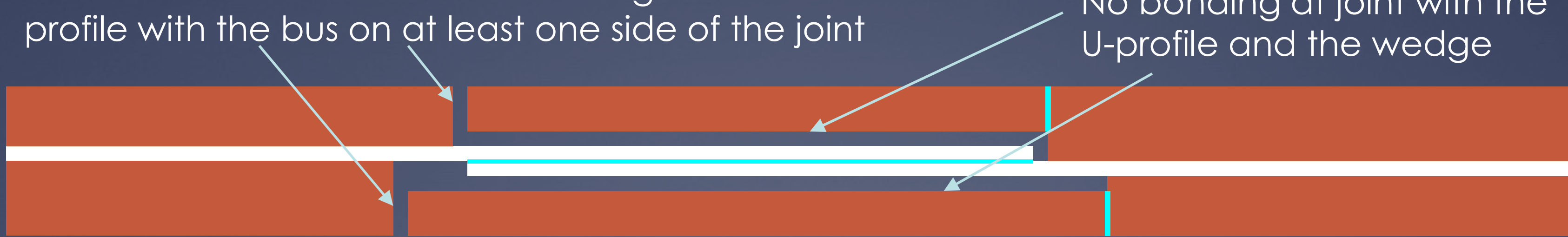
Temperature drift during the 7 kA current flat top (15 Sep 2008)

Measured versus simulated incident with 220 nΩ joint and bad contact with U-profile and wedge



No electrical contact between wedge and U-profile with the bus on at least one side of the joint

No bonding at joint with the U-profile and the wedge



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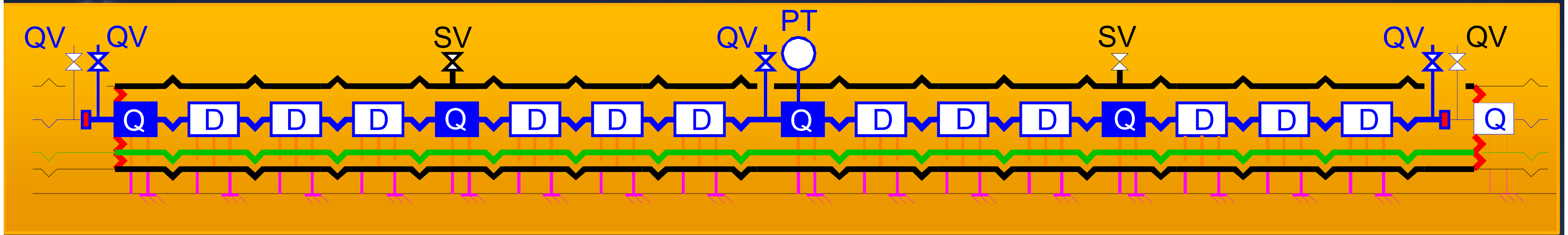
The Sector 34 Incident

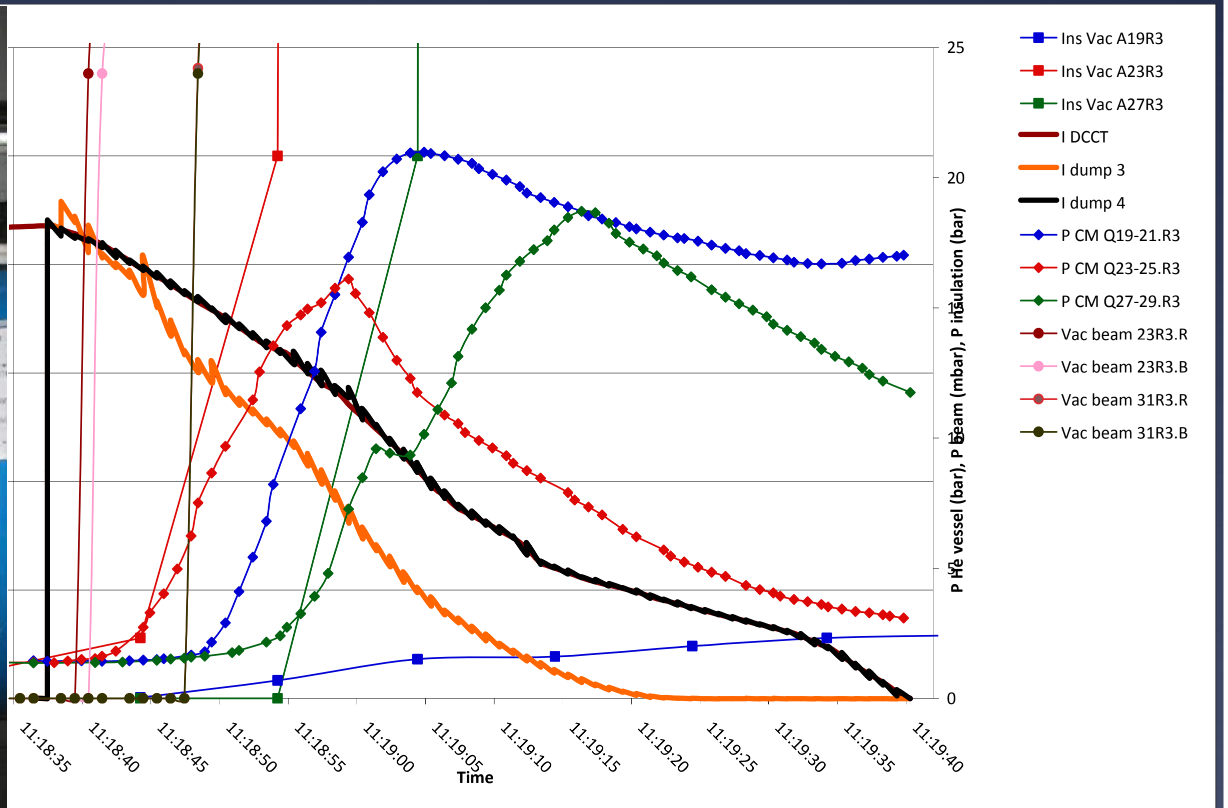
The current decay from 8700 A

	MJ	%
agnets	595.0	100
Dissipated in UJ33	71.0	12
Dissipated in UA43	104.8	18
Dissipated in cold mass	144.4	24
Dissipated in electrical arcs	274.8	46

Ph.Lebrun

The Sector 34 Incident





Ph.Lebrun

The Sector 34 Incident

Recommendations

Prevention of initial fault

- Calorimetric measurements
- Electrical measurements on «suspect» cells/subsectors powered at limited current
- During further power tests, track temperature evolution in normalized conditions
- Modify quench detection system to include interconnects and bus bar splices
- Consider option to measure currents in 13 kA circuits at both ends of sector and detect differentials
- Review possible improvement of mechanical clamping of interconnects and gradually implement whenever possible

Mitigation of consequences

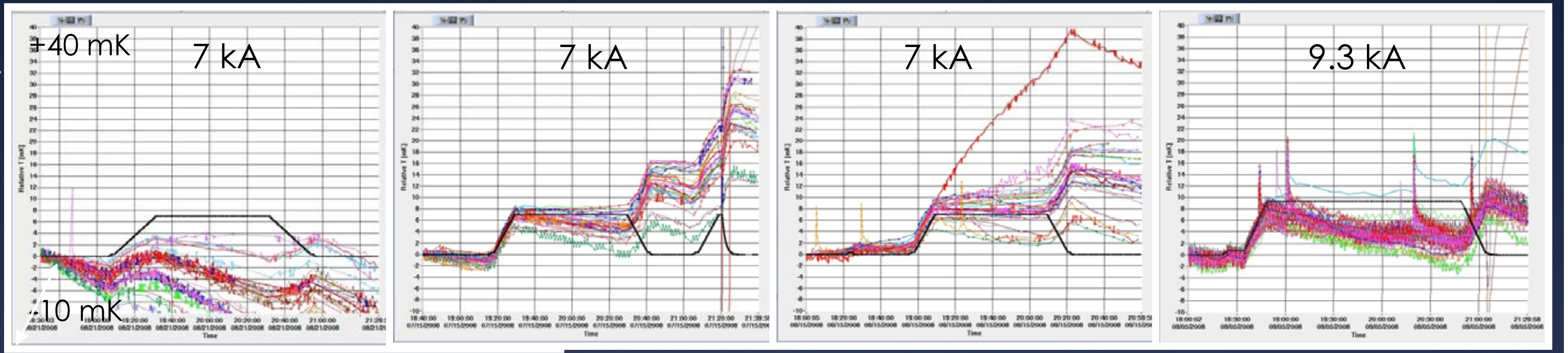
- Increase number/size of relief devices on cryostat vacuum vessels
- Review number, size & position of pressure relief devices on beam vacuum system
- Review closure logic of beam vacuum sector valves
- Consider possibility of triggered opening of quench relief valves below set pressure
- Consider general firing of quench heaters
- Reinforce external anchoring at locations of vacuum barriers
- Reexamine personnel underground access rules
- Review location of AUG in tunnel and protection from blast
- Review recorded signals, recording frequency and time stamping coherence among different systems

Ph.Lebrun

Calorimetric and electrical measurements

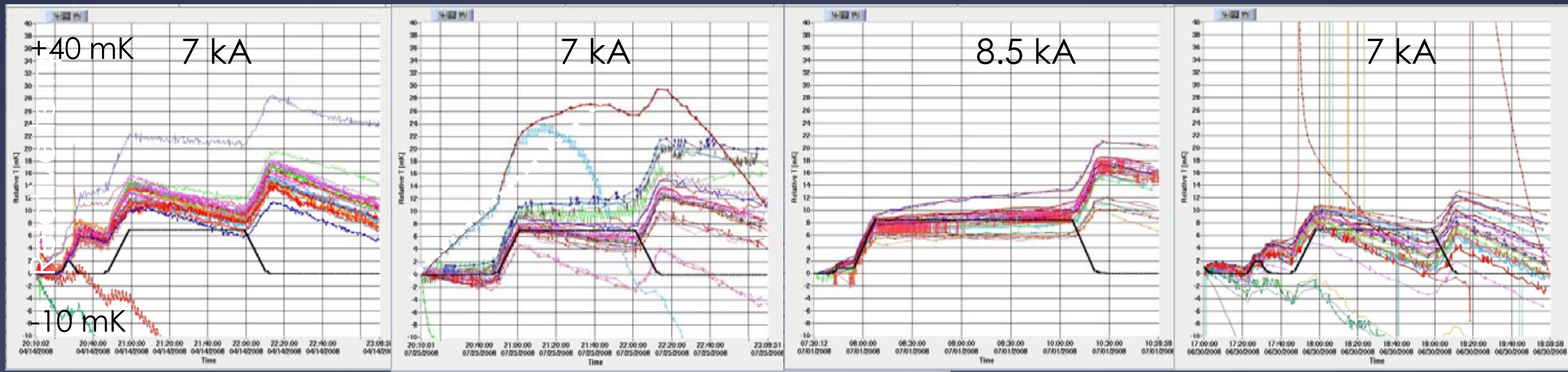
Relative temp

Sector 12 | Sector 23 | Sector 34 | Sector 45



Relative temp

Sector 56 | Sector 67 | Sector 78 | Sector 81



N.Catalan-Lasheras

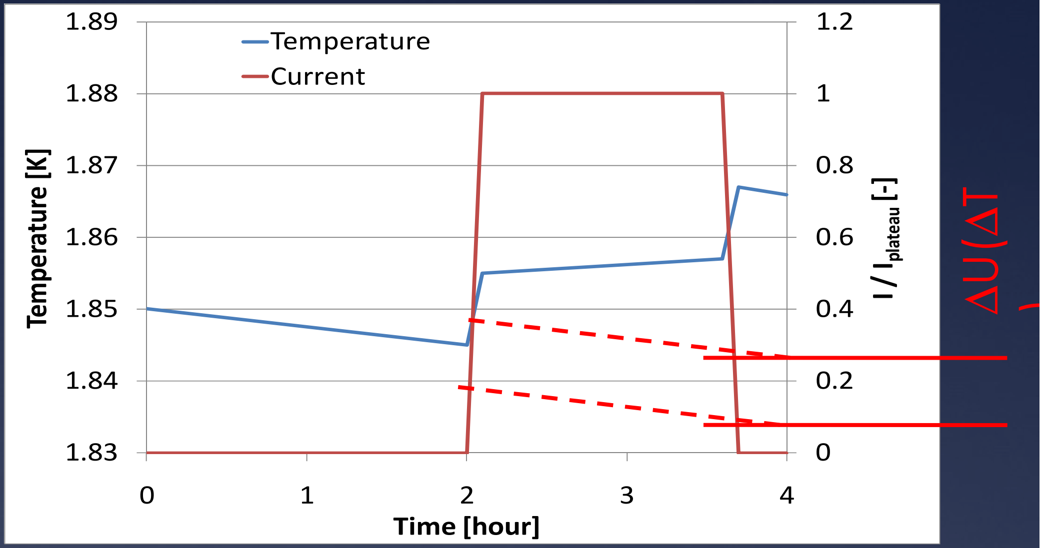
1 or 2 hour flat tops

- All the current plateaux were scrutinized for suspect temperature increase
- Unstable conditions and dynamic temperature control prevent accurate calculations.

Calorimetric and electrical measurements

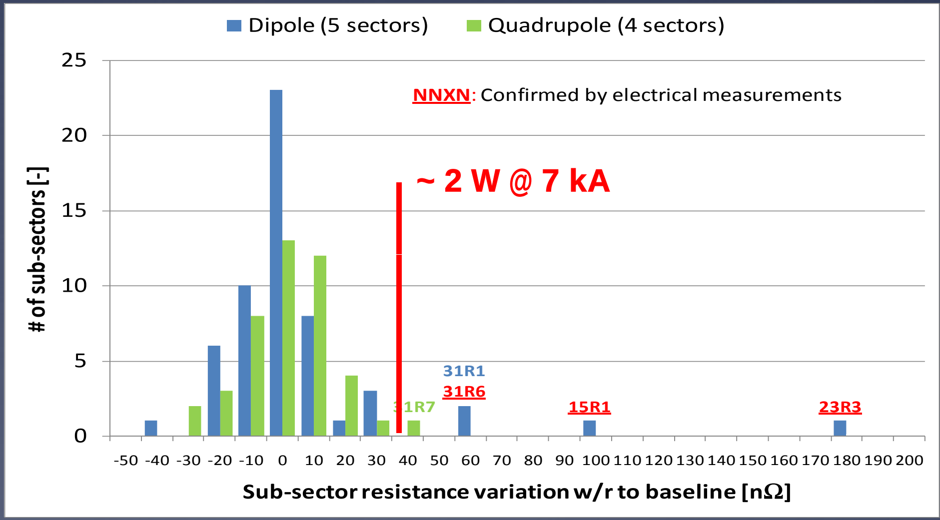
Assessment of

- the baseline slope (valve opening mismatch)
- the temperature increase during powering plateau
- the internal energy variation (J/kg)
- the deposited energy assuming a mass of 26 l/m of He



	Before heating	With heating
ΔU [J/kg]	-1.1	78
M [kg]	823	
ΔU [kJ]	-0.92	64.2
t [s]	2880	6600
W [W]	-0.3	9.7
ΔW [W]	10	

The new powering procedures will demand mandatory calorimetric and electrical tests in ALL sectors at the beginning of the next LHC powering campaign



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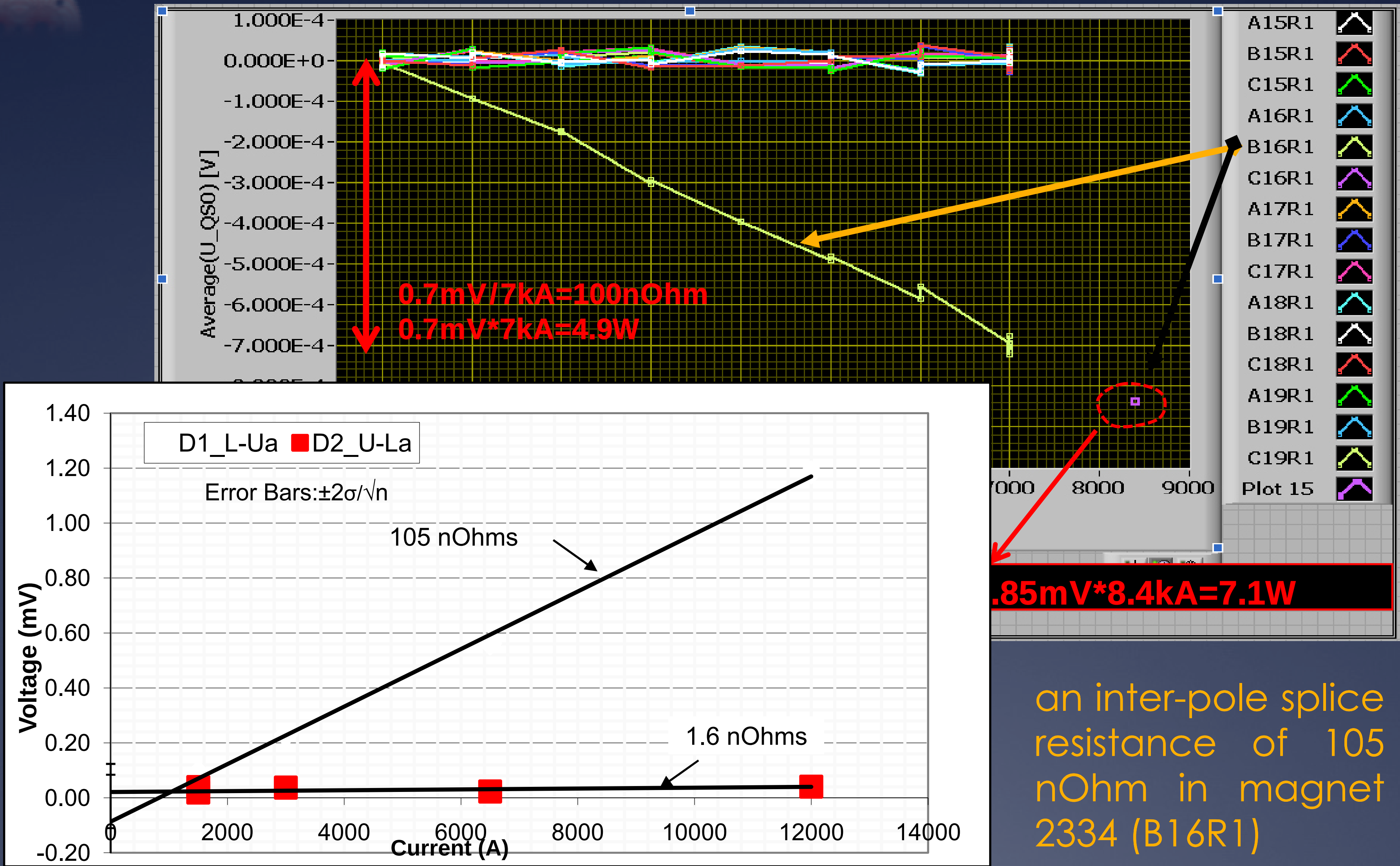
Calorimetric and electrical measurements

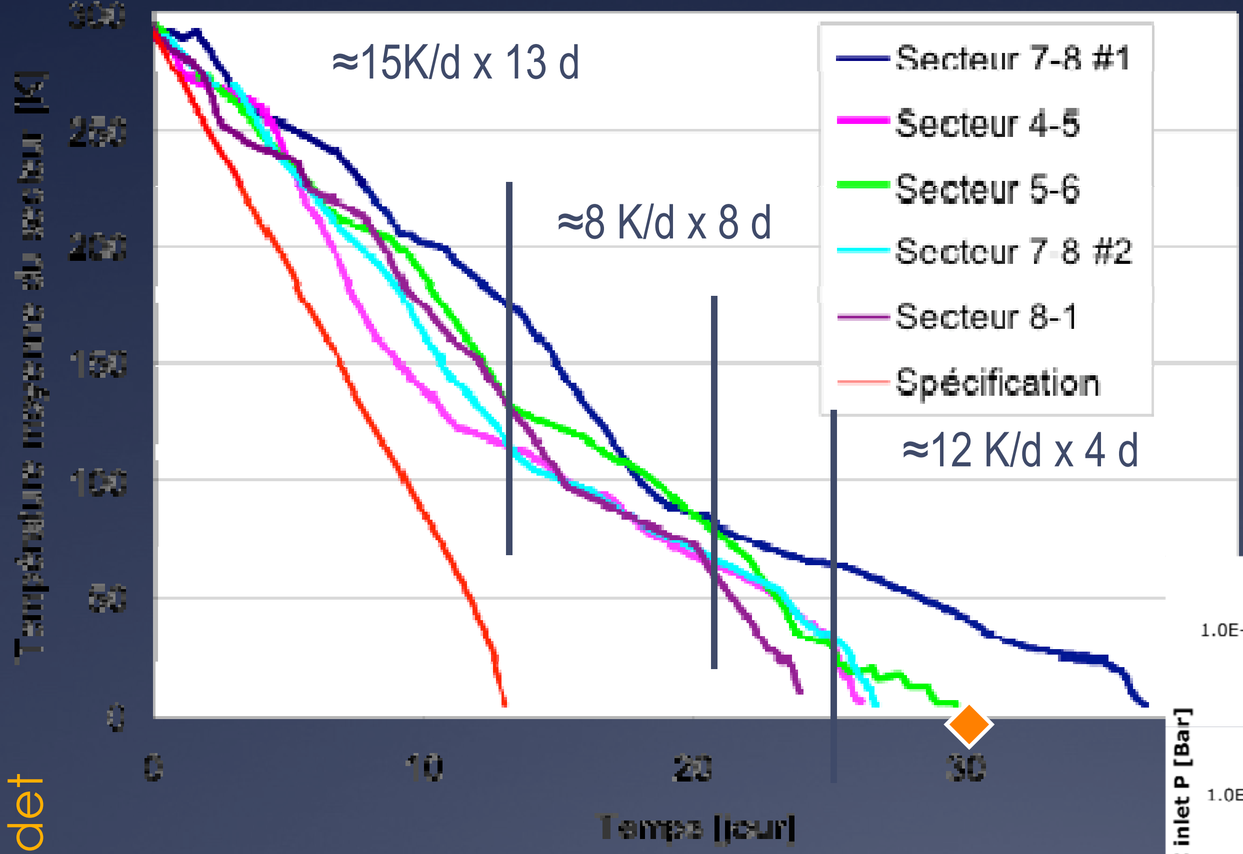
Calorimetric measurements spotted a suspect region in Sector 12



an inter-pole splice resistance of 105 nOhm in magnet 2334 (B16R1)

N.Catalan-Lasheras

Cryogenics: from cool-down to first beams



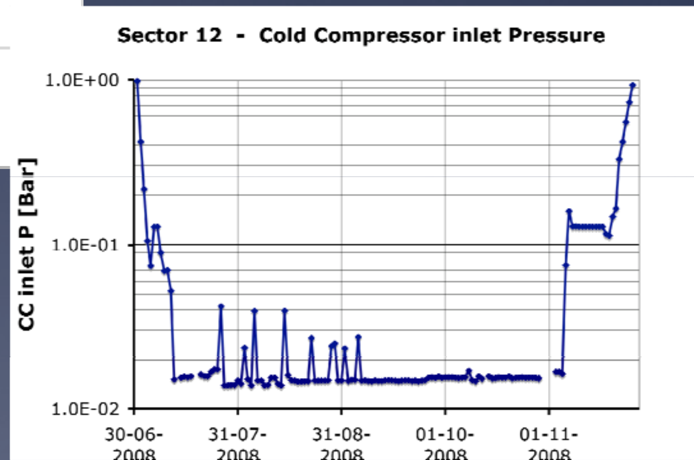
"25 days for 20K"

+ 3 days for Filling

+ 2 days for 1.9K

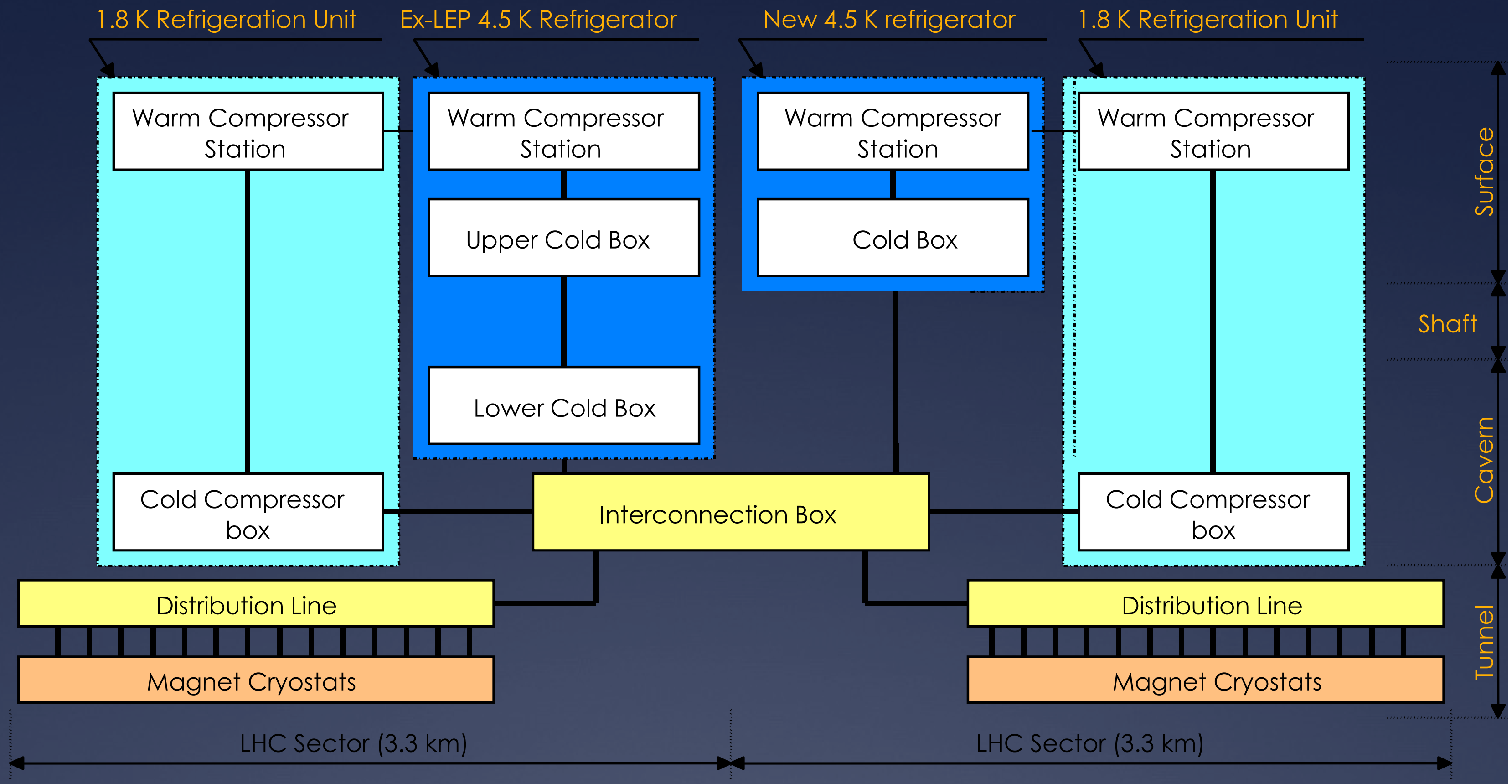
⇒ 30 days

(4 to 5 wks)



S.Claudet

Cryogenics: from cool-down to first beams



- Running two sectors with one cryoplant was tested during powering
- Not valid for large transients, but an interesting alternative for low beam loads. It is a validated fall-back scenario if serious problems with a refrigerator

S.Claudet

Cryogenics: from cool-down to first beams

Non conformities were detected, workarounds found during the run and consolidations actions ongoing level gauges on stand alone magnets, DFBLC heat load, valves on current leads, heat loads on the triplet, etc.

Stability was achieved stable services, global refrigeration mastered, 15mbar established, DFB, current lead and beam screen cooling loops stabilised

Recovery from quenches or failures a lot of experience gained and results obtained

Towards more stable services electricity, cooling water controls, insulation vacuum

Getting ready for round the clock operation

S.Claudet

What else did we learn?

The Procedures

The Tools which implemented the procedures and assisted the operators during the execution and the analysis

- Sequencer
- Post-Mortem browser
- PIC supervision
- QPS supervision
- Powering to Nominal (P2N)
- Databases
- … others were developed during the hc

} efficiency, automation and no compromise

Some teething problems were identified and were corrected or are being corrected remote resets, communications problems, timing, coherence between time stamps, etc.

M.Pojer

What else did we learn?

Hardware problems

600A-10V LHC type power converters

QPS requires a smooth change in current, otherwise it trips

LHC 600A-10V: 0V-crossing distortion

The power converters generate some distortion when crossing through zero voltage with current in the load ➔ QPS trips

Reduced dI/dt and d^2I/dt^2 which could limit operation and physics

600 A-10 V Crowbar Issue

Some PCs don't have the crowbar and are not safe under certain conditions

ECR to add crowbar on those circuits

Frequent clogging of water filters installed on cables and converters lines ➔ flow reduction and stop of the converter

A decision was taken to change all filters around the machine from the present 50 μ to 100 μ mesh

M.Pojer

Conclusions

Many surprises: training & sector 34

During the commissioning the equipment owners and the operation crews gathered the experience which they expected to re-commission, run and debug the equipment

The incident in sector 34 requires modifications of the hardware, upgrade of protection systems and the development of additional test procedures

While during most of the commissioning campaign the observations matched what was expected; in a few cases however, they revealed non-conformities some of which remain to be understood, followed and corrected or coped with