CSCM Project
Status and Prospects

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Introduction

- The major factor for limiting the LHC energy at 3.5TeV is the continuity of the copper stabilizer close to a (non-perfect) superconducting joint.
- This continuity has been measured in 2009. The measurements are partial and have large errors.
- The measurements are also indirect, so we need to rely on simulation, which, to compensate for the lack of knowledge of the joint condition, has deliberately been made rather conservative.
- Even if the 2009 measurements were accurate, there is no guarantee that a joint cannot deteriorate with time

A reminder of recommendations and proposals regarding the CSCM:

Conclusions of Steve Myers from Chamonix 2011:

Proposal

Stay at 3.5TeV for 2011

We should operate in 2011 with the "snubber" capacitors to reduce further the possible number of quenches (SIL4)

Small performance benefit due to reduced need for luminosity calibration

Thermal amplifier to be developped during 2011 to allow measurements during Christmas shutdown for a deterministic decision on a possible energy increase for 2012.

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Recommendations of the 3rd MAC meeting:

Recommendation:

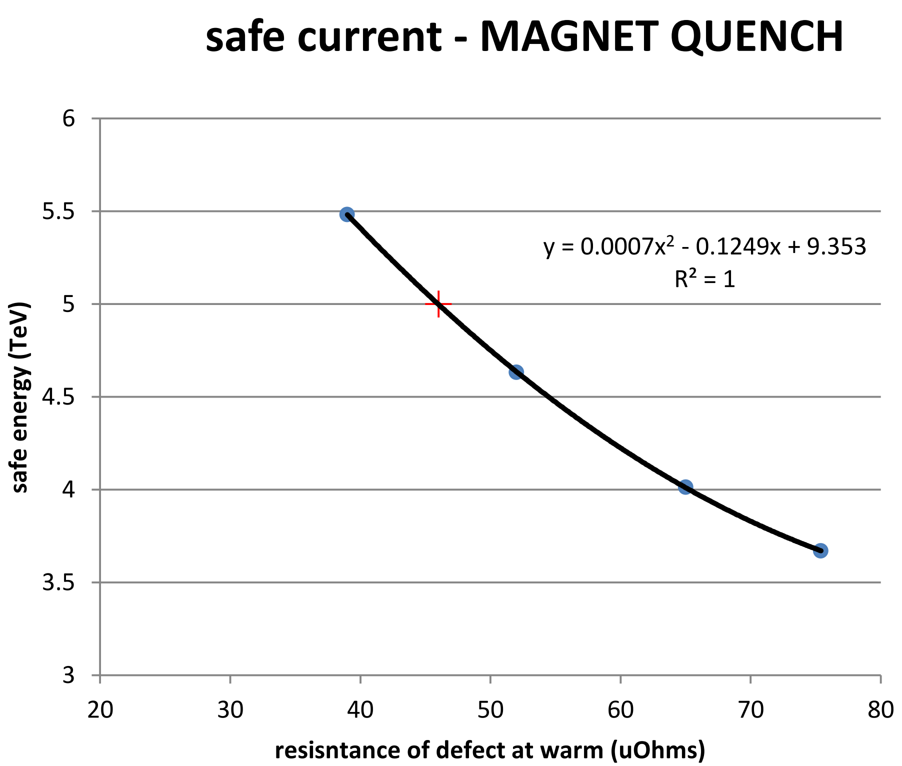
(R9) Launch the Copper Stabilizer Continuity Measurements Project aimed at the measurement of all the copper stabilizer joints in all the LHC sectors during the technical stop at the end of 2011. On the basis of these measurements the safe 2012 operation beam energy can then be determined.

The CSCM Project

- The CSCM (Copper Stabilizer Continuity Measurement) is a qualification tool that can determine the maximum safe energy per sector by testing the main circuits, RB and RQ.
- It measures the very process we are trying to avoid during operation, the thermal runaway of a joint.
- It manages to do this by using similar conditions to those during a quench, but has no energy stored in the magnets so that the thermal runaway can safely be stopped by an interlock process.
- This is achieved by doing the test at a temperature of about 20K, so that the magnets are no longer superconducting and the current passes through the bypass diode connected to all main magnets.

Reminder of simulation of safe energy – what are we aiming for?

- New simulation using the latest, best known values for RRR, lengths, etc.

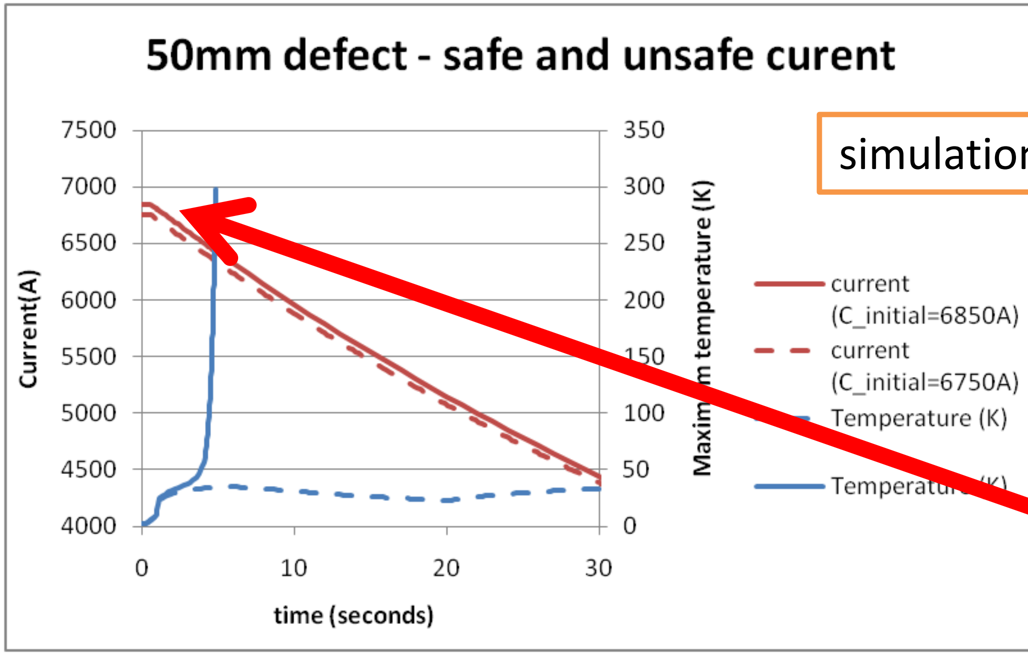


For Magnet quenches (propagation through the bus bar) and EE time constant of 68sec

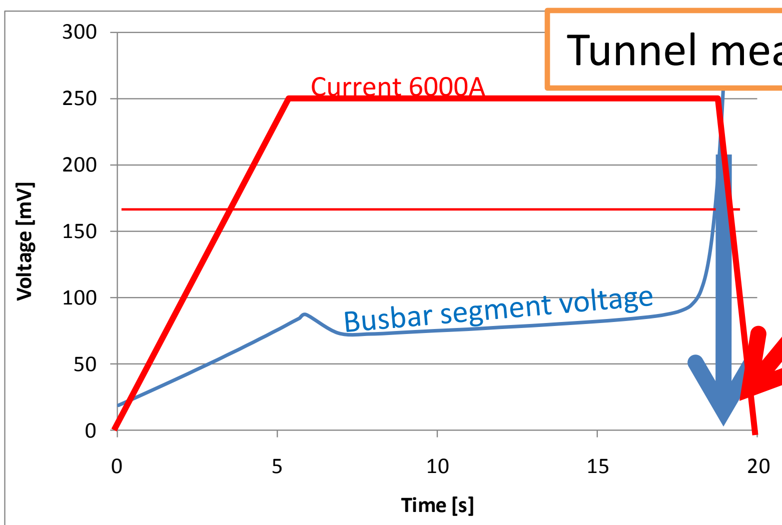
Energy	R_defect_max
3.5TeV	-
4TeV	66uOhms
4.5TeV	54uOhms
5TeV	45uOhms
5.5TeV	39uOhms

This is for magnet ‘busbar propagation’ quenches. Semi-prompt quenches very similar.

The principle of the method



simulation



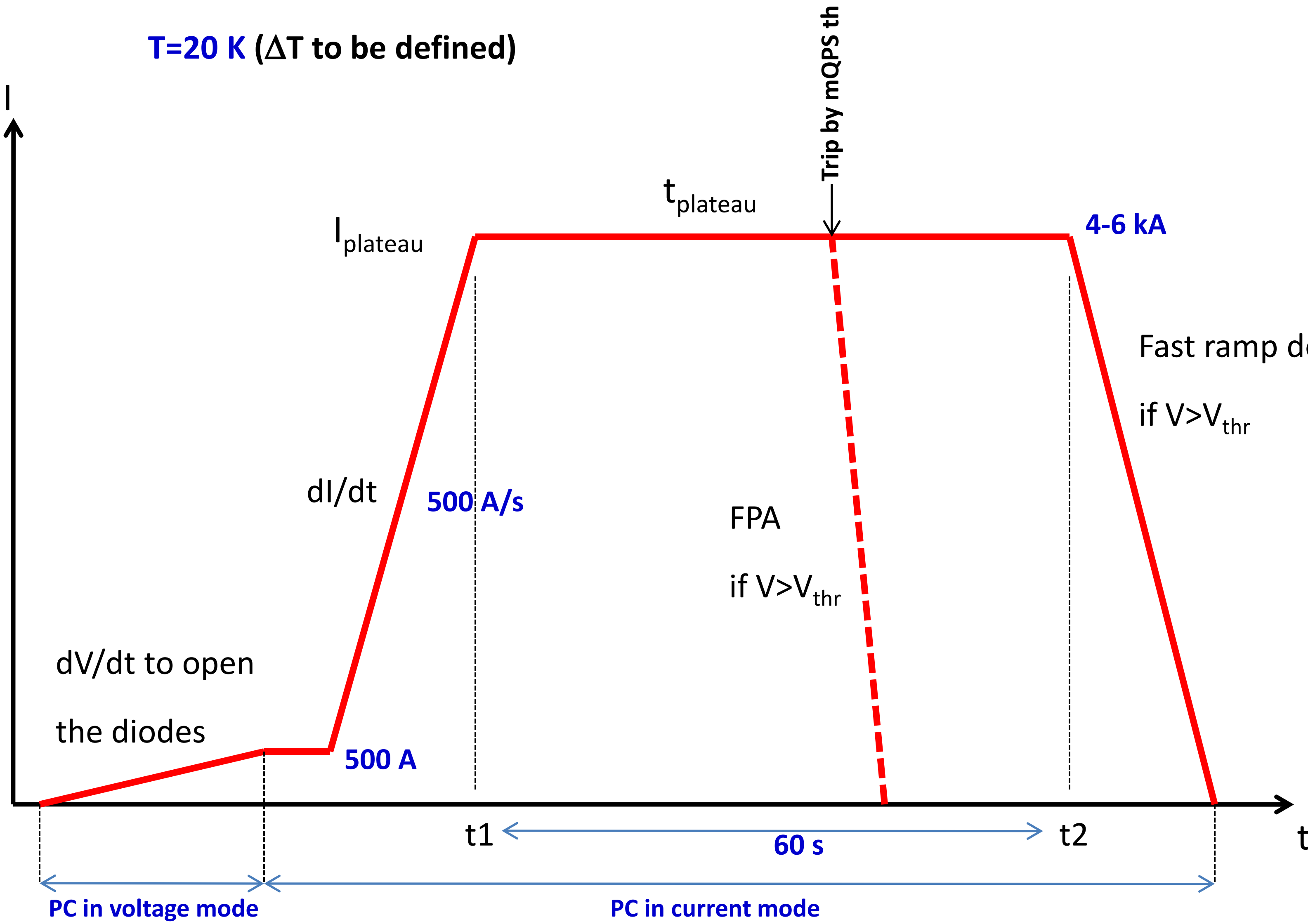
Tunnel measurement

There is a relatively simple correlation between the time before the thermal runaway and the highest safe energy of a sector. This is derived from simulation but a lot of uncertainties cancel out (RRR of the bus, RRR of the cable, if it is a single or double-sided defect, if the defect is concentrated in one or two splices, etc.)

M. Koratzinos

CSCM typical current cycle

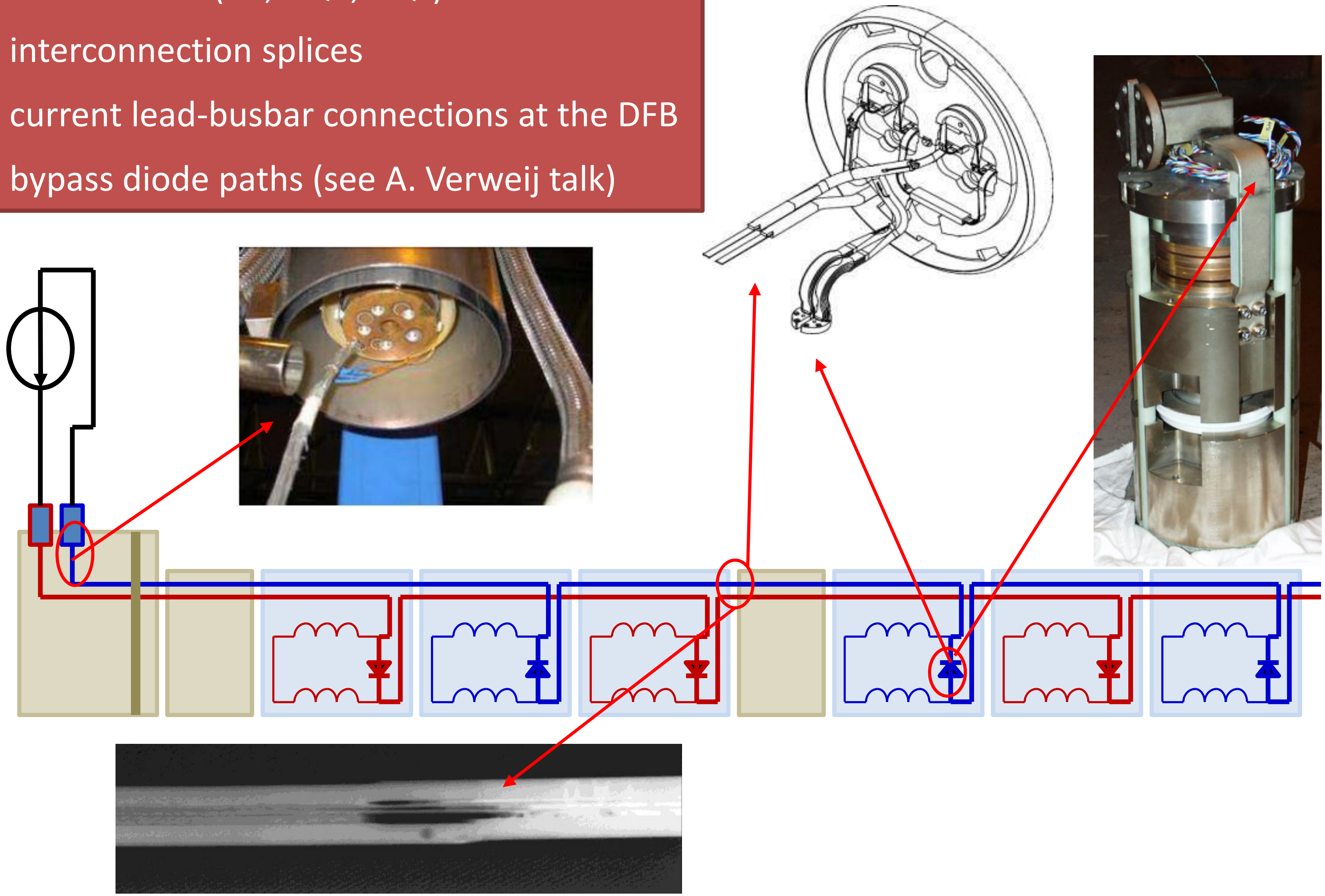
T=20 K (ΔT to be defined)



To qualify for 5TeV operation, interlock should come >~20 seconds into the 6kA cycle

What will the CSCM measure?

- All main circuits (RB, RQD, RQF)
- All interconnection splices
- All current lead-busbar connections at the DFB
- All bypass diode paths (see A. Verweij talk)



Major engineering challenges

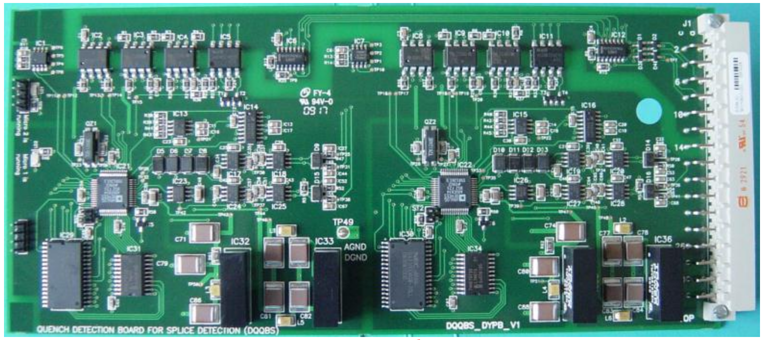
- Need to develop a new interlock system
- Need a special power converter configuration
- Needs non-standard cryo conditions (20K)

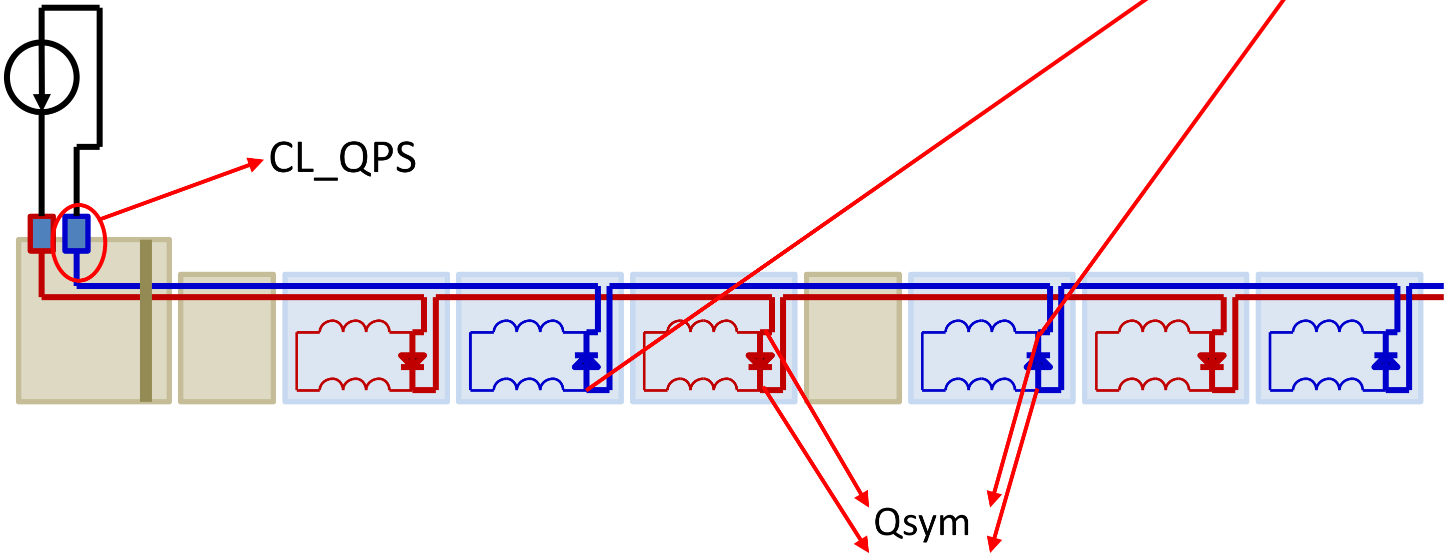
But also

- Rigorous testing programme (SM18 tests)
- Complete analysis and simulation package

Circuit protection

- The circuit is protected by redundant hardware interlock electronics
- New QPS card developed
- Circuit also protected by the QPS Qsym cards
- Current leads are protected by standard QPS

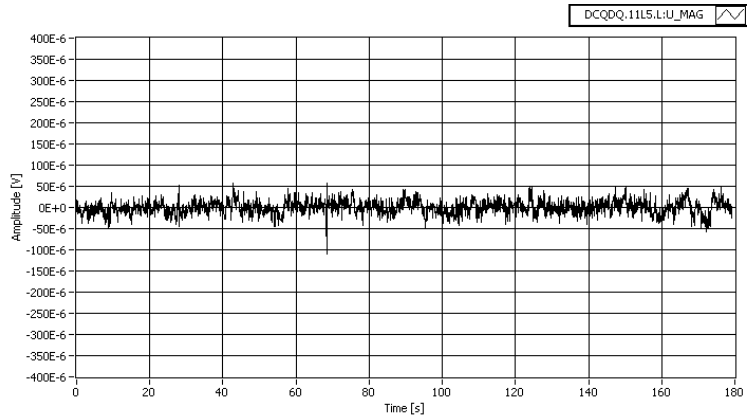




The new QPS card

- Based on an existing nQPS design
- Four prototype boards ready and tested in the tunnel
- Components for 1000 boards ordered (good for 3 sectors)
- Last delivery date (ADuC834): end of August
- Limited tender is started
- Delivery expected in November 2011
- Card tester needs to be developed (adapted from an existing tester)

Noise well within expectations (well below 0.1mVolt – between 100 and 1000 times smaller than the detection voltage)

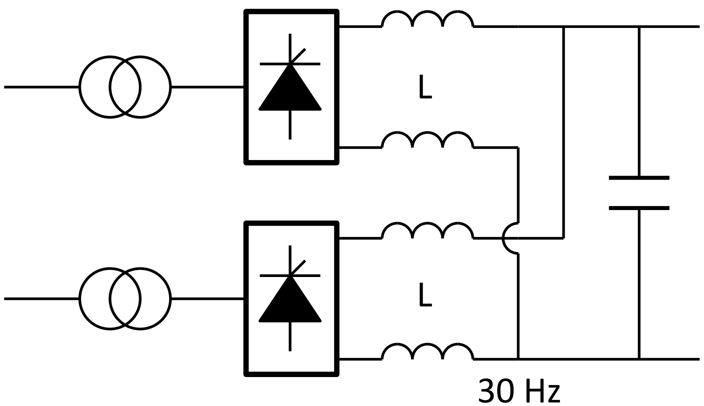


Power converter issues

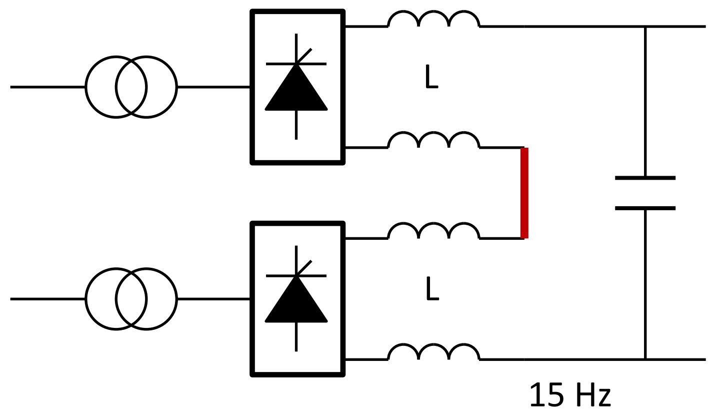
• the standard RB power converter is rated at 13kA/190V – not sufficient for the CSCM, as all diodes need to be opened

•Modification needed: To reach the requested output voltage, the 2 SCR bridges have to be connected in series

•This modified converter will be used for both the RB and for the (RQD and RQF combined) circuits



Normal configuration

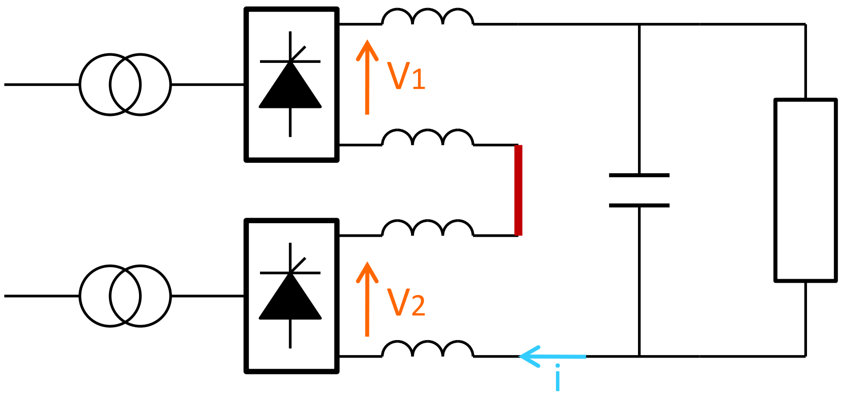


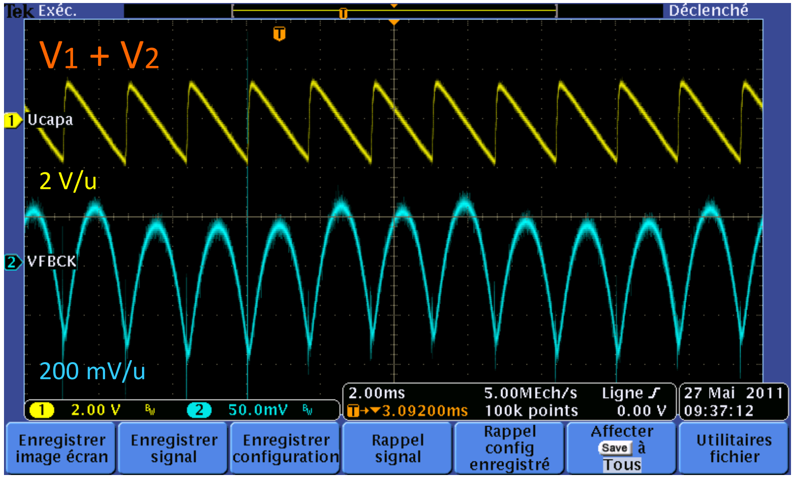
CSCM configuration

- Put in series the 2 bridges
- Modify the output voltage sensor (divide by 2 the gain)
- Modify the power converter voltage loop ($F_{filter}/2$)

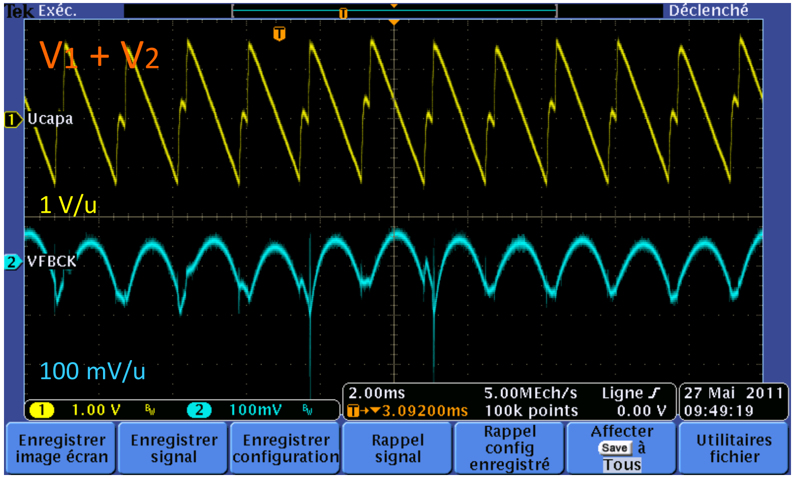
Configuration tested successfully in P-hall

- Tests of the new configuration of the RB power converter





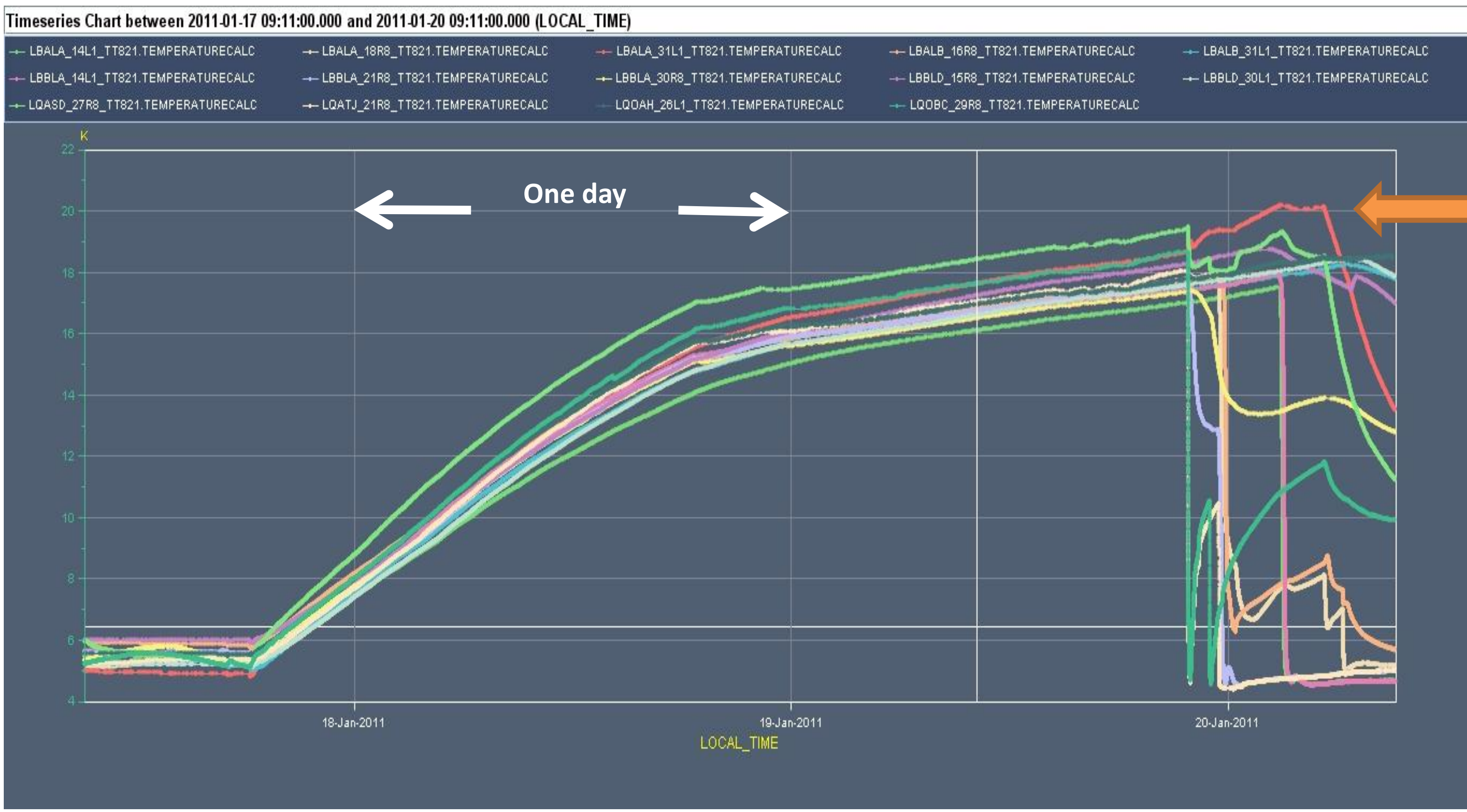
Test at nominal voltage
400 V and 100 A



Test at nominal current
6.5 kA and 20 V

Cryogenics issues

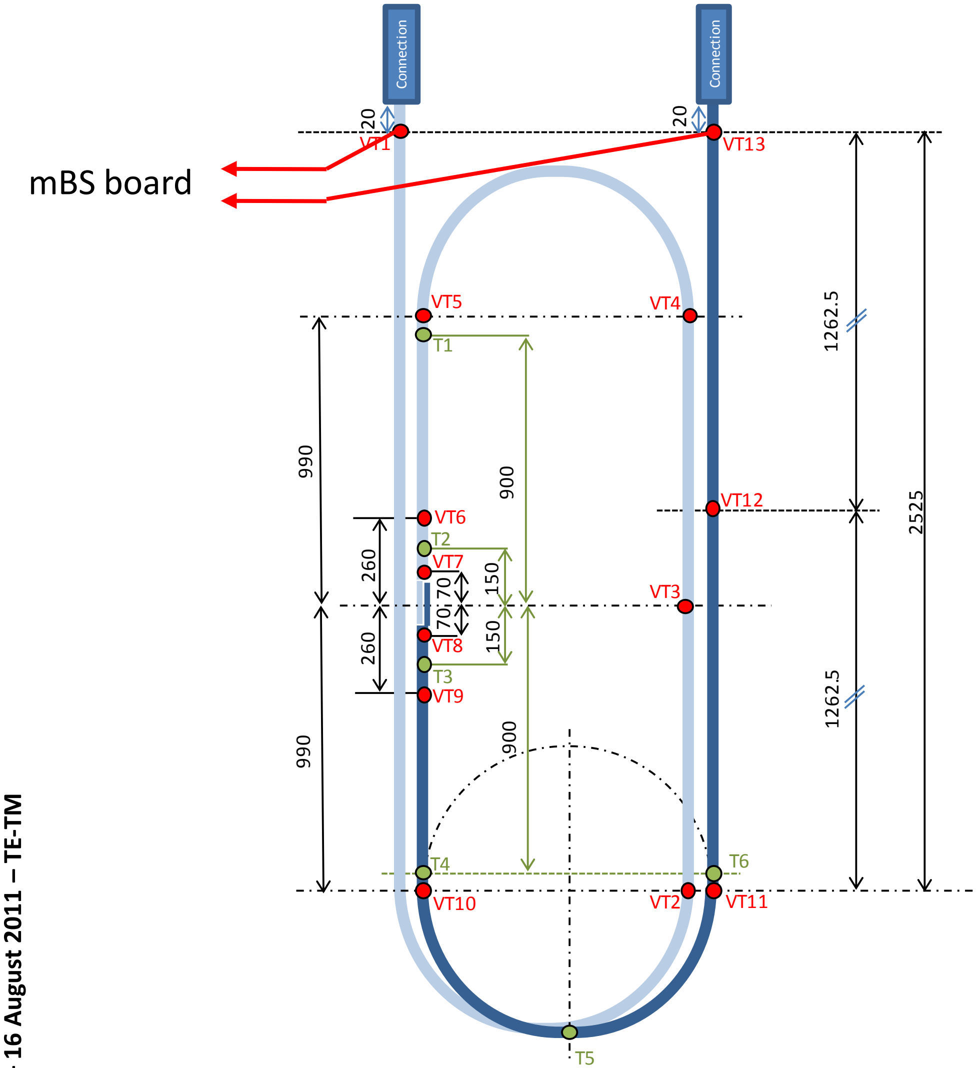
- Cryo will have to be regulated as per the RRR measurements during the last Xmas technical stop (20K)
- This was performed in all 8 sectors very efficiently.
- Additional requirement is that the DFBs will be maintained at 20K and Current Leads at nominal condition. An initial test has demonstrated that this is possible, but it will represent a new challenge for the Cryo team.
- The proper test lasts less than 60 seconds, estimated recovery time around 6 hours



20K

Example of Cryo regulation in one sector during the RRR measurements last year

SM-18 auxiliary validation tests



SM-18 validation tests:

- ✓ Validate the interpolation between CSCM tests at 20K and real splice quench at 1.9K
- ✓ Validate the interlocking electronics
- ✓ 10 m of MQ busbar (SC + copper) with a 30 mm defect are being prepared
- ✓ Perform several CSCM current cycles at different temperatures (20 to 40 K) and different current levels (1 to 6.5 kA)
- ✓ At 1.9 K (or 4.5 K), quench the splice at different current levels
- ✓ Tests planned to start mid September

Envisaged RB circuit test sequence

- **Test at 1000 A**: **general check** of all signals. Define V_0 and RRR of all the bus segments. After this test the thresholds can be defined.
- **Test at 4500 A**: find the very large defects (**50-100 $\mu\Omega$**) without the risk of a very fast thermal runaway.

If no defect found at 4500 A then:

- **Test at 6000 A**: find defects of the order of **30-50 $\mu\Omega$**.
- **2nd test at 4500 A/6000 A**: ensure that the thermal runaway did not deteriorate the defect

Plateau current (A)	Plateau time (s)	Warm-up bus after $t_{plateau}$ (K)	Stored energy in the sector (kJ)	Dissipated energy in the sector (kJ)	V_0 at t=t1 and t=t2 (mV)	V_{thr} for 30m segments (mV)
1000	60	20.8	2	130	10.4 to 10.6	70
4500	60	30.5	40	3400	48.1 to 80.1	140
6000	60	37	72	7800	65 to 168	220
6000	40	32	72	4300	65 to 120	170

Assuming bus of 30 m, RRR=200, neglecting ramp up and ramp down. L_{RB}=4 mH

Parameters like plateau current and time might be reviewed after SM18 validation tests

CSCM type test planning

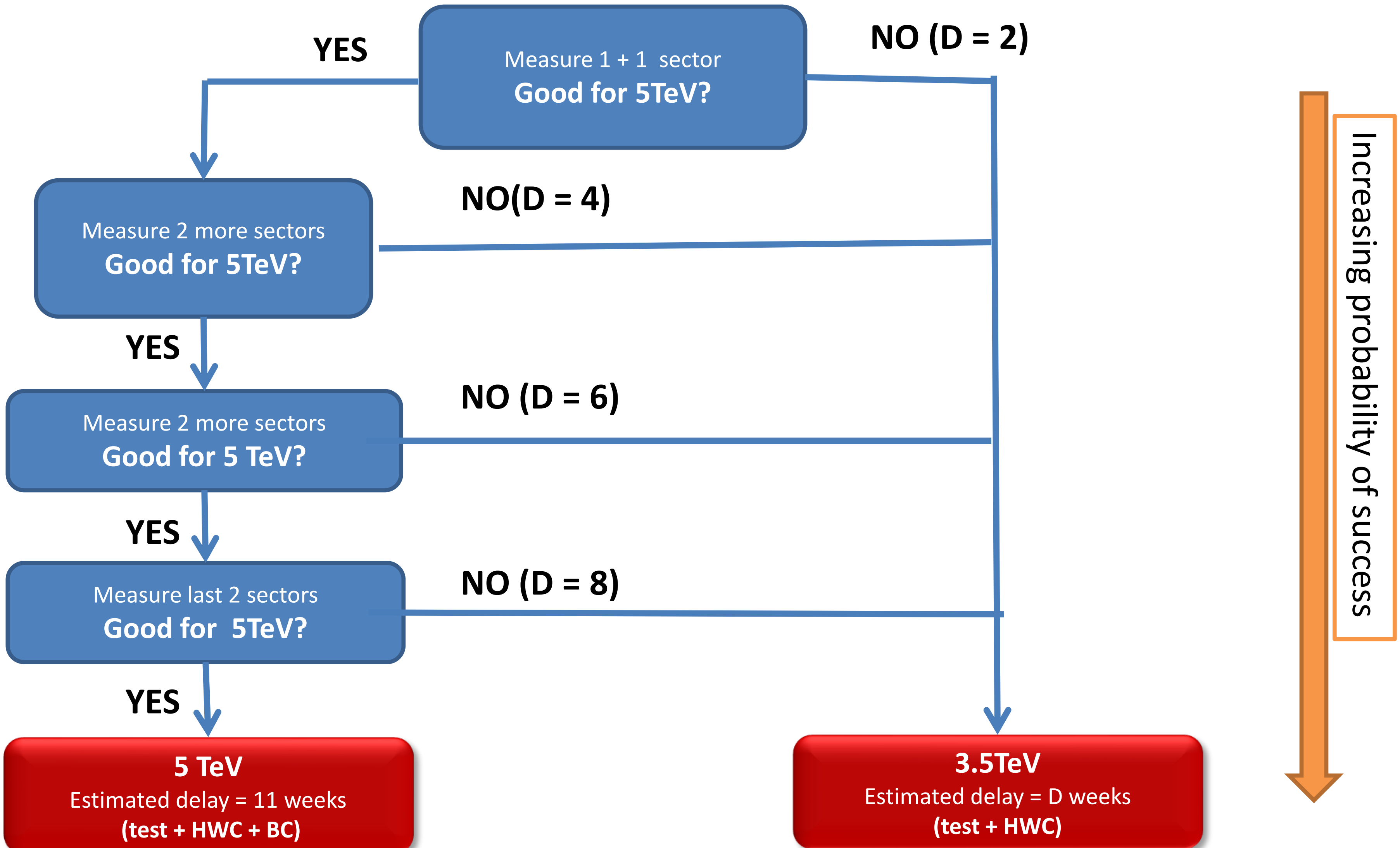
	Dec	Jan	Feb	March
1	Th	S	W	Th
2	F	M	Th	F
3	S	Tu	F	S
4	S	W	S	D
5	M	Th	S	M
6	Tu	F	M	Tu
7	W	S	Tu	W
8	Th	S	W	Th
9	F	M	Th	F
10	S	Tu	F	S
11	S	W	S	S
12	M	Th	S	M
13	Tu	F	M	Tu
14	W	S	Tu	W
15	Th	S	W	Th
16	F	M	Th	F
17	S	Tu	F	S
18	S	W	S	S
19	M	Th	S	M
20	Tu	F	M	Tu
21	W	S	Tu	W
22	Th	S	W	Th
23	F	M	Th	F
24	S	Tu	F	S
25	S	W	S	S
26	M	Th	S	M
27	Tu	F	M	Tu
28	W	S	Tu	W
29	Th	S	W	Th
30	F	M		F
31	S	Tu		S

- preparation
- CSCM measurements
- recovery
- re-commissioning
- LHC-HWC

✓ To get some experience before the full campaign a type test is required in one sector

✓ First results can be ready for Chamonix 2012

Success-driven staged approach



10/08/2011

All delays very approximate – for illustration purposes

Summary of progress since the 3rd CERN MAC

- Project defined, core team working efficiently
- Interlock issues addressed successfully: a new QPS card has been developed, tested and 1000 cards have been ordered (sufficient for 3 sectors in parallel)
- Power converter issues addressed successfully: by converting the 13kA/200V main RB power converter to a 6.5kA/400V one. New configuration tested successfully
- Cryo issues addressed successfully: initial test demonstrated that it is possible to maintain arc circuits at 20K and current leads at nominal conditions
- Testing programme in test facilities under way: 10m long busbar segment with a realistic interconnect and defect will be tested in SM18 in mid September

- Has anything been forgotten? We would like to have an international review committee to look at the project (October).

- No show-stopper identified. The project is on target to perform the first test in the tunnel during the coming Christmas shutdown

Concerns

- CSCM tests present some important risks
  - Burning of a splice or a CL can not be excluded
- CSCM tests require to modify several critical protection systems as QPS, 13kA-EE, PIC and PC
  - Thorough re-commissioning is mandatory (time, resources)
- 5 TeV is not guaranteed a priori (if limiting splices found)
- CSCM tests will strongly interfere with other Xmas stop activities
- The full CSCM campaign cannot be performed during the present duration of the 2011/2012 Xmas stop
  - Significant “beam physics” time needs to be (re)allocated

Conclusions

- The CSCM is a qualification tool that can provide measurements for a deterministic decision on the maximum safe energy of the LHC and can increase significantly our knowledge about splices and diodes.
- Engineering challenges are being met and a test and simulation programme is under way.
- No show-stoppers found so far.
- The project will benefit from an international and external reviews
- A success-driven staged approach will ensure maximum time available for physics in 2012.
- Irrespective of the LHC maximum energy issues for 2012, the CSCM will most probably need to be performed in all sectors before LS1 to measure all diode contact resistances (A. Verweij talk) and after LS1 to validate the quality of splice repairs.

EXTRA SLIDES

Current knowledge of 13 kA circuits

- RB circuits measured using hand-held voltmeters (Biddle)

Sector	Measured at 1A at:	Largest R_excess measured (uOhm at warm)	5 magnet quenches per year, 1 incident in 1000 years	Approximate Emax (5 magnet quenches)
			R excess for 0.08 bad joints (uΩ)	
12	At warm	39±9	55	**4.5TeV**
23	At cold	80±25	135	**-**
34	At warm	36±8	50	**4.8TeV**
45	At warm	53±15	80	**3.6TeV**
56	At warm	20±7	35	**5.8TeV**
67	At warm	31±9	49	**4.8TeV**
78	At cold	90±23	140	-
81	At cold	120±25	170	-

Out of the 8 sectors:
- 1 sector can go to 5TeV
- 3 sectors can go to 4.5TeV
- 1 sector can go to 3.5TeV
- 3 sectors not measured

Problems:
- RQ not measured
- 3 sectors not measured
- Possible deterioration over time
- Possible deterioration with current

(RQ circuit knowledge much worse)

Assumptions:

✓ 1 incident in 1000 years

✓ 5 magnet quenches next year