LHC Status

2nd July 2009

Steve Myers

Topics

- LHC Shutdown work
  - Sector 34 repair
  - Consolidation in Other Sectors
  - “Collateral damage” work
  - Vacuum Work
  - New Quench protection system
  - Single Event Upset (radiation to electronics shielding etc)
- Splice Measurements
  - At superconducting temperatures
  - At non-superconducting temperatures
- Powering
  - Tunnel access restrictions
- Schedule and Strategy
- Future Work Programme

S34 repair

Status S34

Sector 3-4:

- 39 dipoles and 14 quadrupoles re-installed
  - (last magnet in the tunnel 30.04.09)
- last M electrical connection finished 2nd June (13kA)
- Finished electrical ELQA tests
- 3rd June weld last N electrical connection
- All the PIMs are welded (28th May 09) and RF ball has cleared the aperture
- Vacuum cleaning in 3-4 completed
  - After removing the D-zone, ¾ of them were polluted with super insulation debris
  - In-situ cleaning was mandatory

Magnet transport in the tunnel without a single incident

sector 3-4 : Magnet repair in SMI2

Last Repaired Magnet (SSS) going down (30/4/2009)

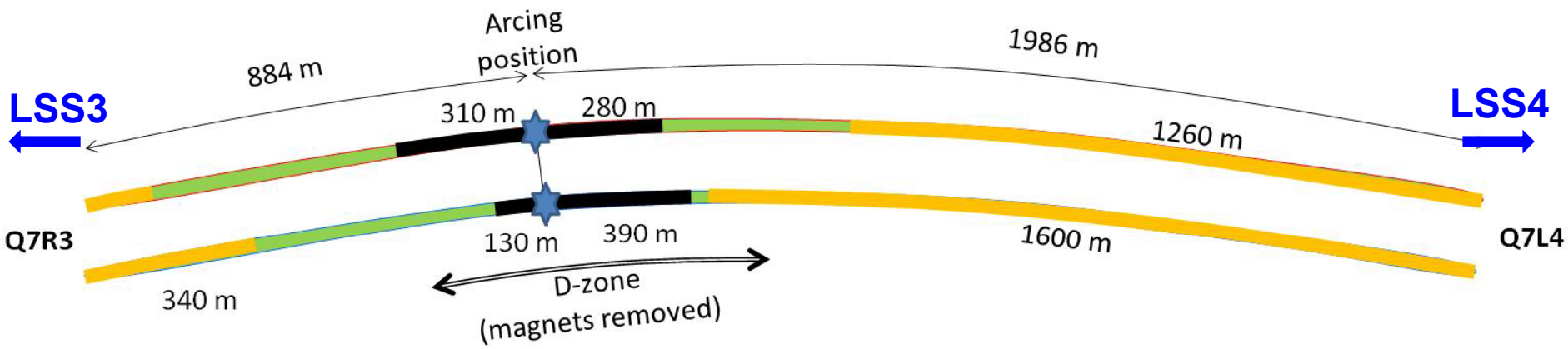
Repair of QRL service module in S3-4

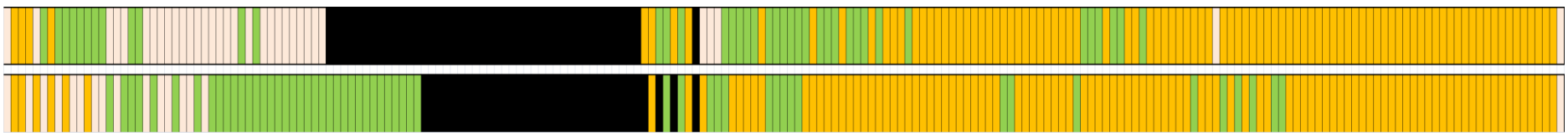
Before repair

After repair

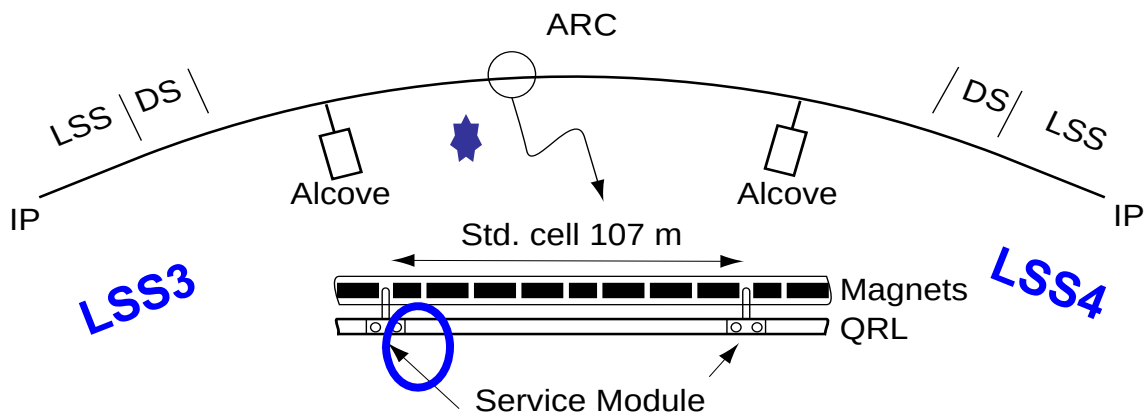
Q27

Beam vacuum recovery in sector 3-4
Review of Damages to Beam Vacuum

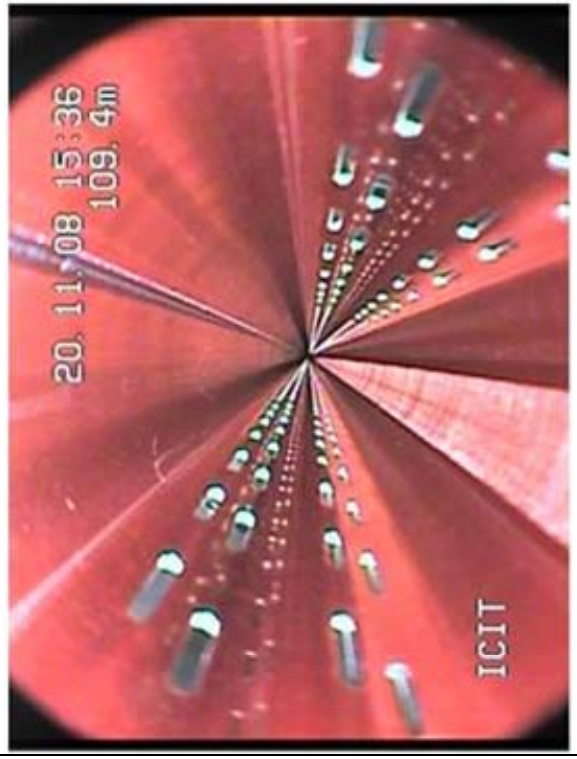
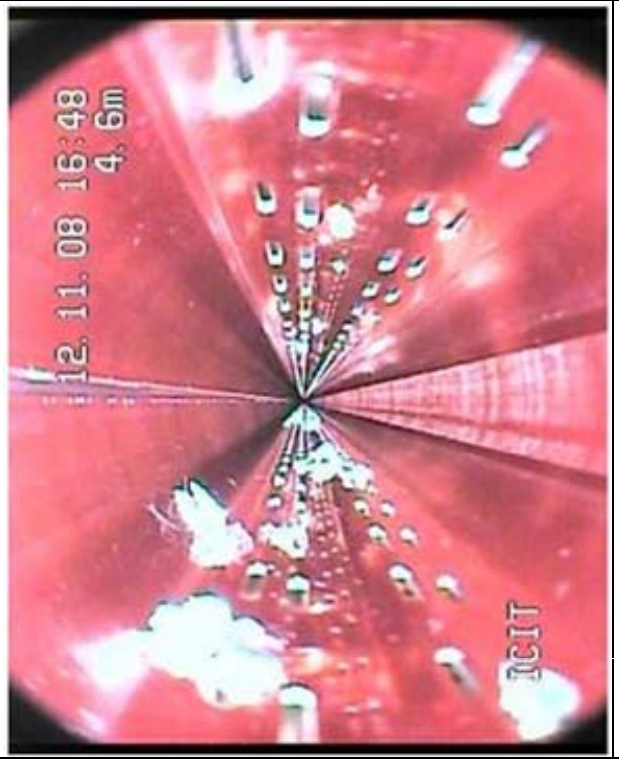
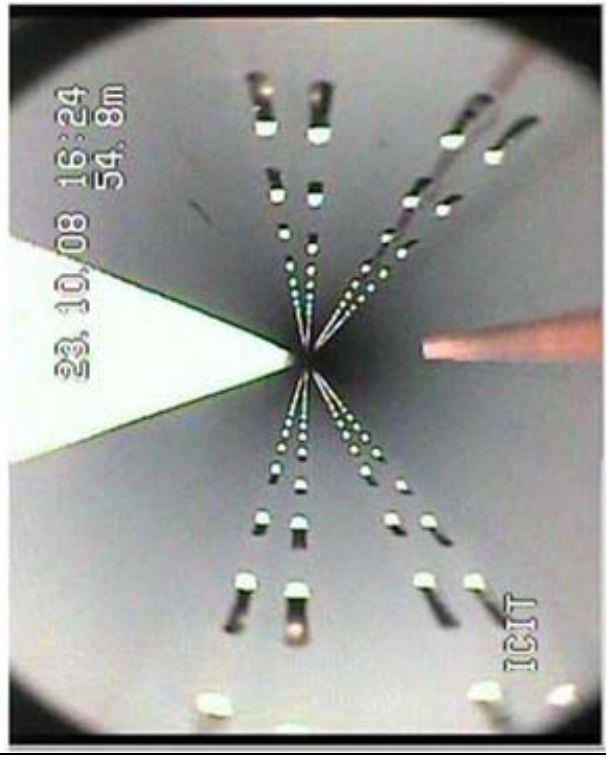




	Ok
	Debris
	MLI
	Soot



Beam vacuum recovery in sector 3-4
Beam Vacuum Contamination

Beam Screen (BS) : The red color is characteristic of a clean copper surface	BS with some contamination by super-isolation (MLI multi layer insulation)	BS with soot contamination. The grey color varies depending on the thickness of the soot, from grey to dark.
		

Beam vacuum recovery in sector 3-4
Beam Vacuum Cleaning

- 78 % (~2.4 km) of the beam pipes in the sector 3-4 were spoiled
  - 19 % by soot, 59 Magnets affected,
    - 53 (14 MQ and 39 MB) within the D-zone were removed
      - 37 (7 MQ and 30 MB) replaced by spare magnets
      - 16 (7 MQ and 9 MB) recovered requiring the exchange of 13 beam screens and a cleaning of the cold bore (wet process, detergent circulation)
    - 6 magnets (half-cells 19R3-20R3) left in the tunnel
      - Only one aperture contaminated by soot
      - Cleaned in-situ mechanically
      - 50 passages per aperture alternating wet (alcohol) and dry foams
  - 59 % by MLI
    - In-situ cleaning was mandatory
      - ~58 km CLEANED and INSPECTED cm-by-cm ! (12 passage)

Today, the cleaning is completed and all magnets are reinstalled, closure and leak detections ongoing

Consolidation in Other Sectors

Sectors 12, 67, 56

Sector 12 and 67: exchange of dipole magnets done (required warming up the sector)

(1-2 : RF ball OK; closed week 23)

(6-7 : RF ball OK; interconnects repaired under progress, will be closed week 27)

Sector 56 repair of connection cryostat

(RF ball OK; closed week 24)

Beam & Insulation Vacuum Bending Sections (Arcs) and Experimental Areas

- Beam Vacuum
  - **All beam vacuum pipes in the bending sections (arcs) are completed**
  - Two sectors 3-4 and 4-5 still pending for the aperture check (ball test)
- Magnet insulation Vacuum
  - 1-2: no delay expected, closing under control
  - 2-3: @ cold
  - 3-4: no delay expected, closing under control
  - 4-5: pending to the aperture check and activities to be made. Activities already scheduled and internalised.
  - 5-6: no delay expected, closing under control
  - 6-7: following interconnection consolidation
  - 7-8: ready for cool down
  - 8-1: no delay expected, closing of the standalone magnet cryostats under control
- Experimental Areas
  - **All are under (pure) Neon atmosphere, pump downs are scheduled**

On schedule and under control

Collateral damage work

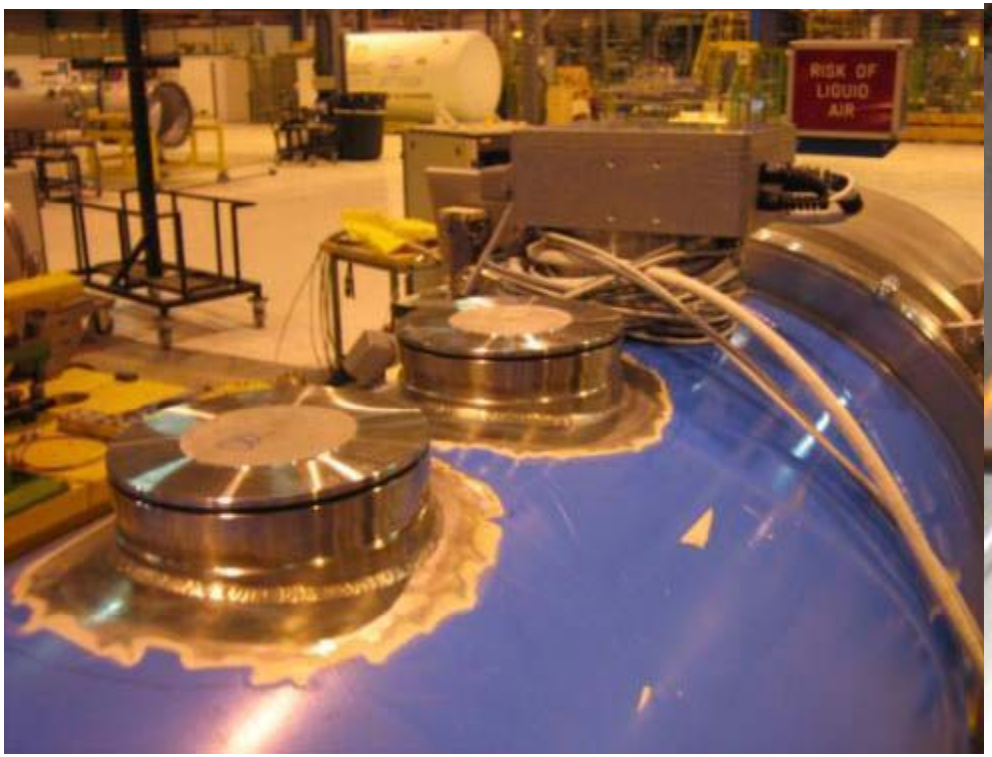
Status Collateral Work

- DN200 installed in 4 sectors (1-2, 3-4, 5-6, 6-7) according to schedule

- DN200 in Inner triplet (last one 12.05.09),
- Standalone Magnets: 100% and DFBs: >80%

- Anchoring:
  - Arc quadrupole (total 104 with vacuum barrier) : >50% done
  - Semi-stand alone magnet : done except 8L
  - Inner triplet and DFBA: started week 23

DN200 installation (Arc + DS)



2 DN200 / dipole (DS and mid-arc)

P6 singularity

Protective measures

Opening W bellows

Protection of the IC

MLI protection

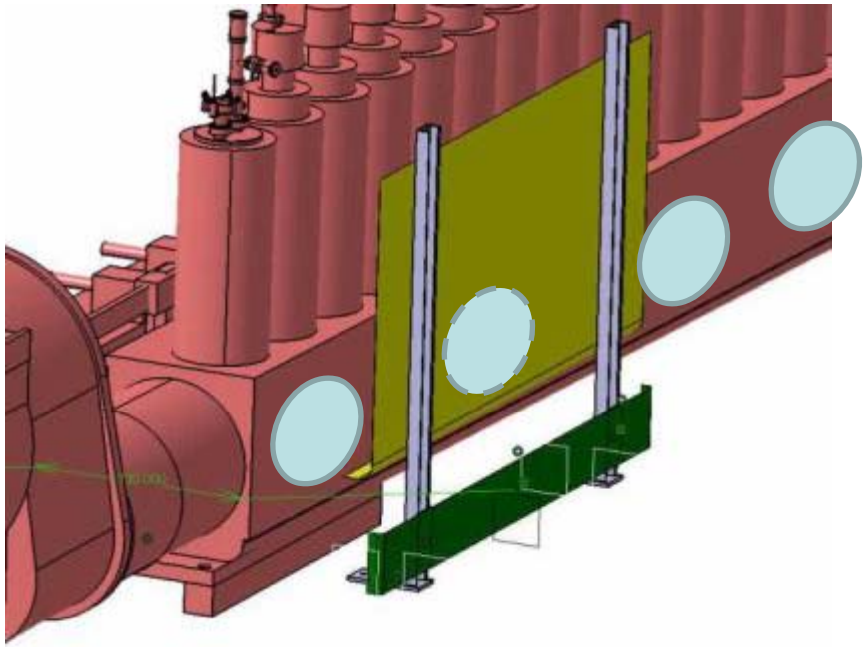
IFS covers

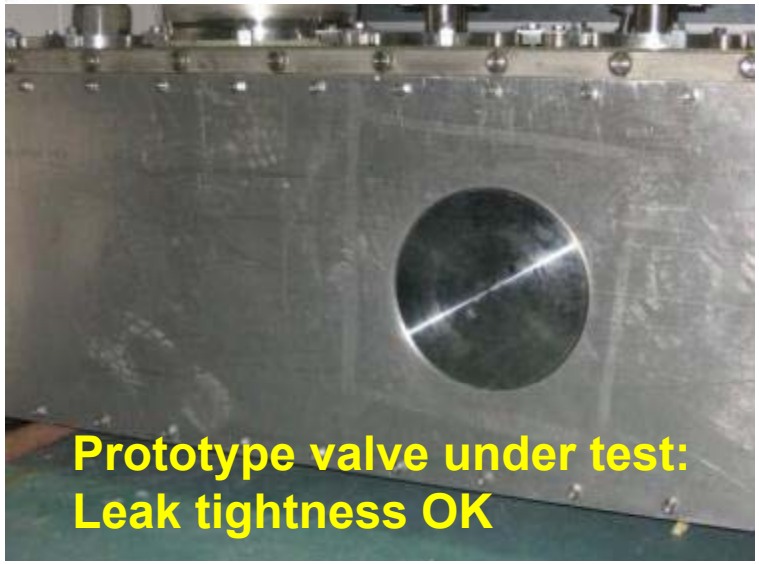
In Triplet DN200

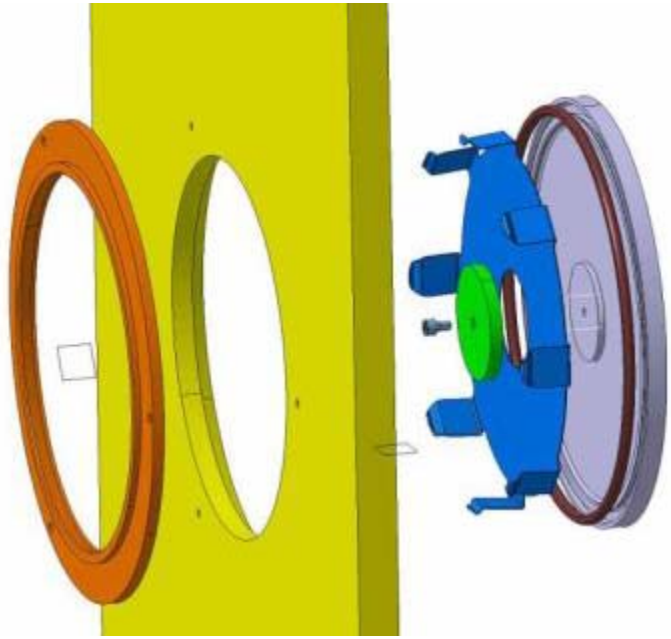
Nozzle for safety valve on the rigid sleeve between Q3 and Q2

Nozzle for safety valve on the rigid sleeve between Q2 and Q1

Main Cryoboxes (DFBA)







- Machining of doors started W23
- Consolidation rate: ~ 1.5 week per sector (including logistics & excluding deflector work)
- Deflector Interference with survey equipment to be studied

Strengthening the anchoring of magnets:

For the triplet bumpers the weak point is anchoring to the floor.

Since there are no guidelines for cracked concrete it was decided to follow the HILTI recommendations and add an extra safety margin of 1.5

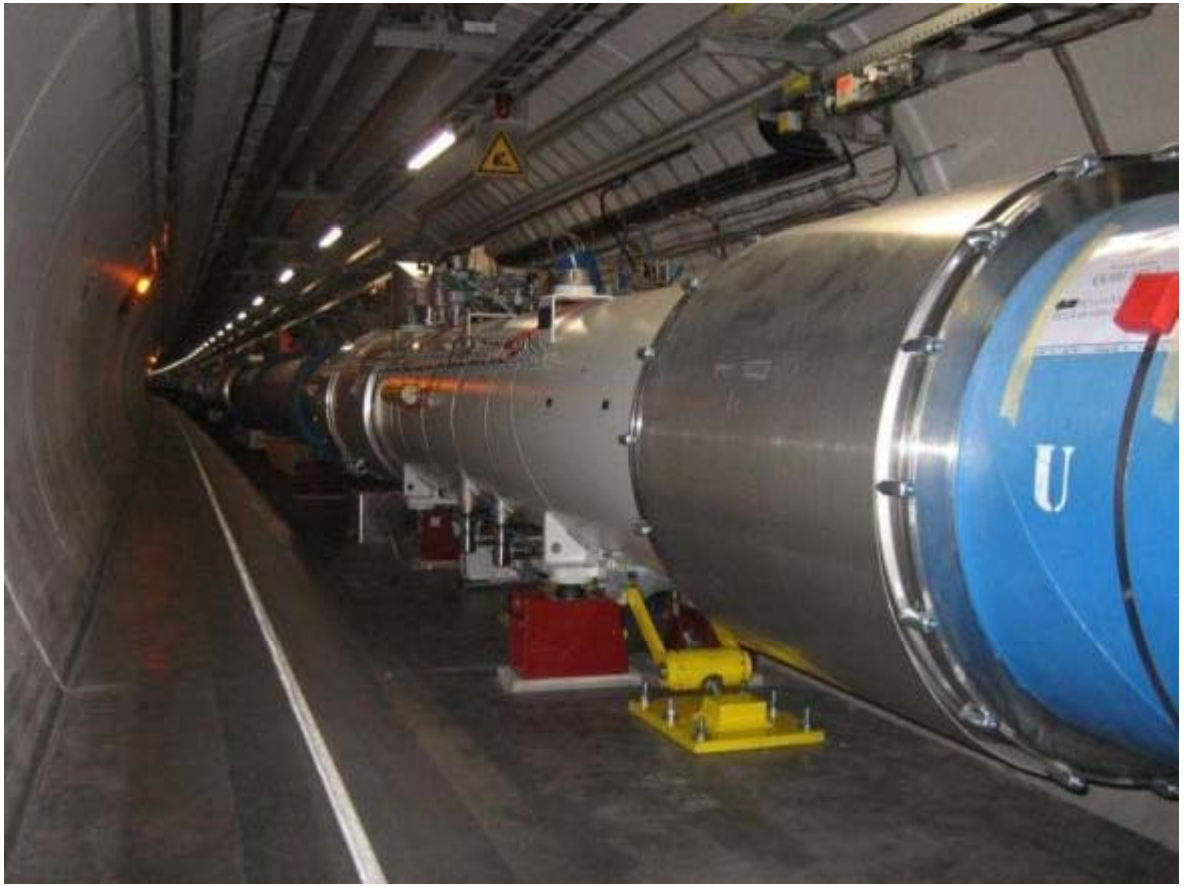
All Q1 bumpers improved Q3L5 and Q3R8 bumpers are to be modified, and the DFBX in P1 and P5 have to have new bumpers (install w23).

The semi-SAMs were given top priority since the worst case load is generally present, not just in the event of an MCI.

For the DFBAs in cold sectors the reinforcements are to be added.

SSS with vacuum barrier anchoring

- Withstand longitudinal load of 240 kN
- A total of 104 SSS with vacuum barrier in 8 sectors



Q15L2

IT anchoring consolidation
→ “case by case” approach

Q1 bumpers

Q1 in 2L

DFBX in 2 and 8

Q3 in 8R

DFBX

D1

Up to the Minute Status

Tunnel News

- Sector 3-4: last W closed Tuesday 23 June
- Sector 5-6: last W closed Friday 26 June
- Sector 1-2: cool-down started
- Sector 6-7: objective all closed for end W28
  - Large workload: overall 67 M to be rewelded and W to be closed, 46 busbar splices to be resoldered, 25 (x5) spools for US welding

Tunnel News: Sector 4-5

- Connection Cryostat intervention started Monday 23 June:
- Resistance measurements (R-long), MB and MQ at 300K
  - Measurements noisy but confirm the 2 dipole outliers (quads very noisy)
- RF Ball Test: passed Wednesday 24 June
- There will be no PIM intervention (no preventive replacement in QQBI.7R4, QQEI.11L5, QBQI.8L5)
- DN200 work started paint removal (ALARA)
- Open W and cut M3 for 2 dipole outliers, Monday 29 June
- Splice Quality Control, R16 measurements, gammas
- Start splice repair Wednesday (yesterday), ELQA Friday
- Plan to close 4-5 end W28

Enhanced QPS

Role of the Enhanced QPS System

- To protect against the new ‘problems’ discovered in 2008
  - The Aperture-Symmetric Quench feature in the Main Dipoles and
  - Defective Joints in the Main Bus-bars, inside or in-between the magnets.

Reminder

QPS Upgrade also allows

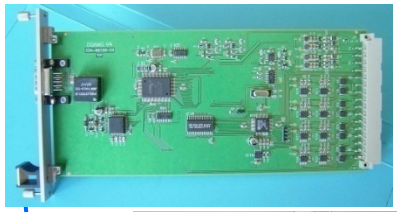
- precision measurements of the joint resistances at cold (sub-nΩ range) of every Busbar segment. This will allow complete mapping of the splice resistances (the bonding between the s.c. cables).

- To be used as the basic monitoring system for future determination of busbar resistances at warm (min. 80 K), to measure regularly the continuity of the copper stabilizers.

The nQPS project

DQQTE board for ground voltage detection

(total 1308 boards, 3 units/crate)

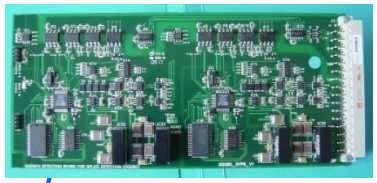


DQAMG-type S controller board

1 unit / crate, total 436 units

DQLPUS Power Packs

2 units / rack (total 872 units)



DQQBS board for busbar splice detection

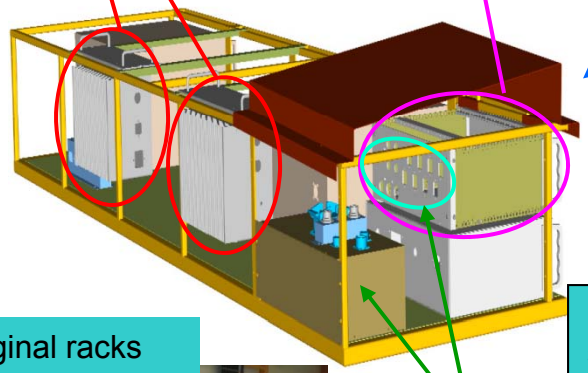
5 such boards / crate, total 2180 units

DQLPU-type S crate

total 436 units

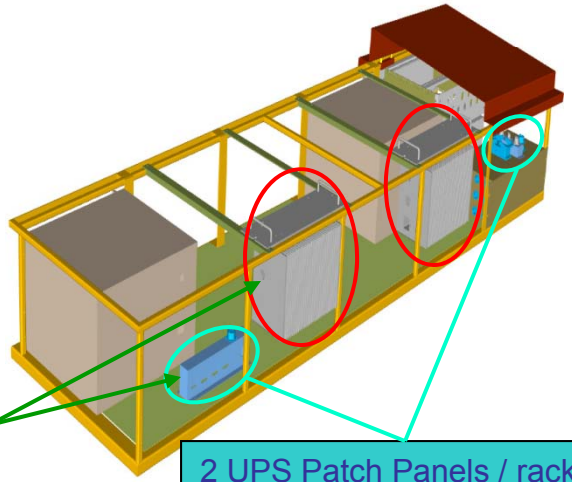
DQQDS board for SymQ detection

4 boards / crate, total 1744



Original racks

'Internal' and 'external' **cables** for sensing, trigger, interlock, UPS power, uFIP (10'400 + 4'400)



2 UPS Patch Panels / rack &
1 Trigger Patch Panel / rack
total 3456 panel boxes

Preliminary Results from Powering Tests – Weekend of 27-28 June

- One standard nQPS crate installed and connected in position B12.R2 and a special monitoring crate for SymQ monitoring was installed and connected in B13.R2.
- Discharge Time Constants: 67 s for dipole circuit and 28 s for QF/QD.
- Noise Levels at zero DC current
  - Values from 2008 were confirmed: 4-6 microV peak-peak noise floor for RB busbar segments. For the Quad segments the value is typically 25 microV.

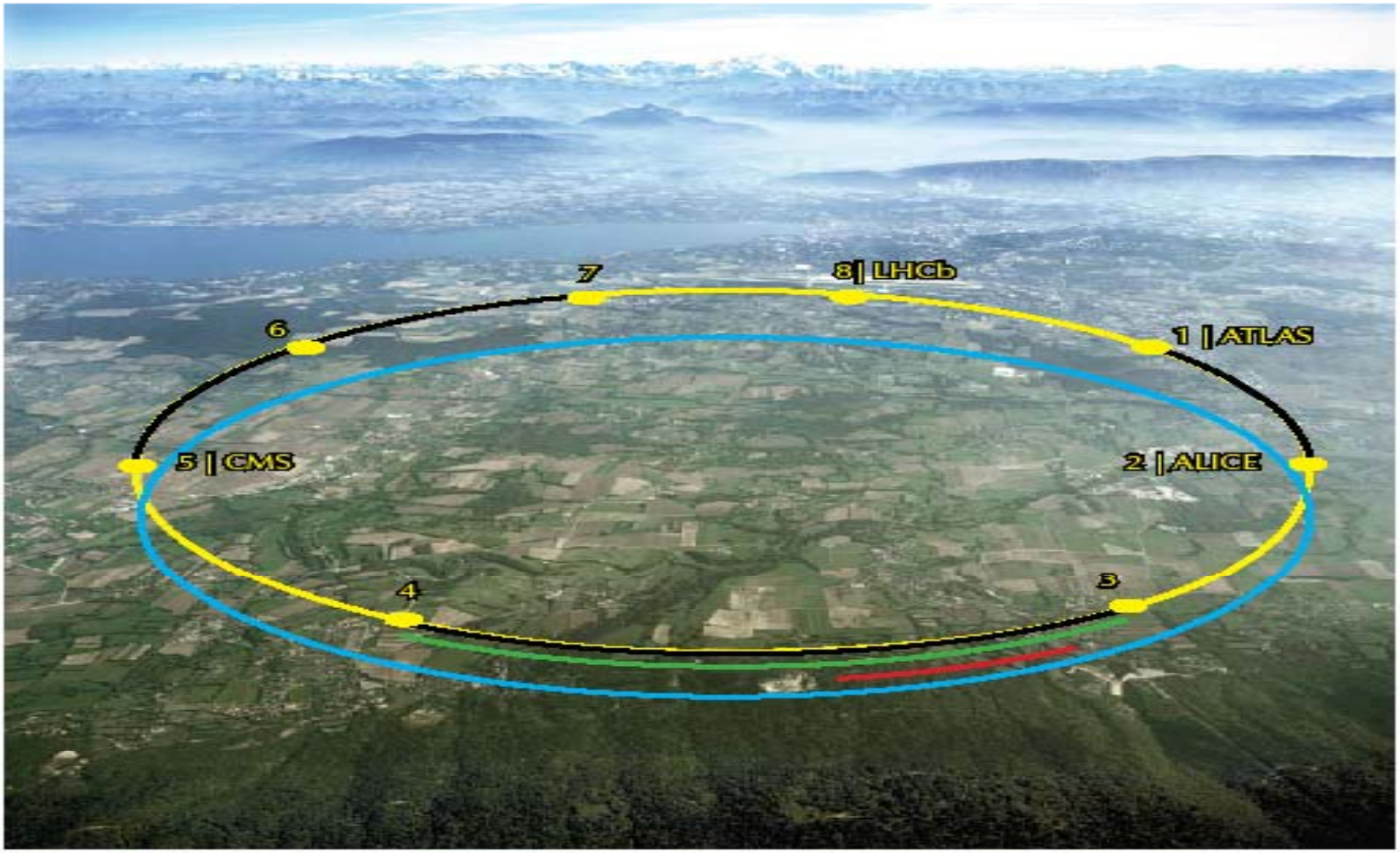
Preliminary Results from Powering Tests – Weekend of 27-28 June

- Inductive Compensation:
  - Fully adequate Compensation could be applied to all three circuits.
  - The pre-programmed parameters were sufficient for steady ramps (constant dI/dt).
- Precision Busbar Splice Measurements:
  - Very satisfactory results were obtained immediately in the RB circuit.
    - 1.28 nOhm for segment DCBA.13R2.L (long segment including 3 joints) with measuring plateau of 10 mins
  - (Powering both QF/QD circuits gave resistances
    - typically 10 nOhm for the 110 m long busbar segment with 8 splices.

Preliminary Results from Powering Tests – Weekend of 27-28 June

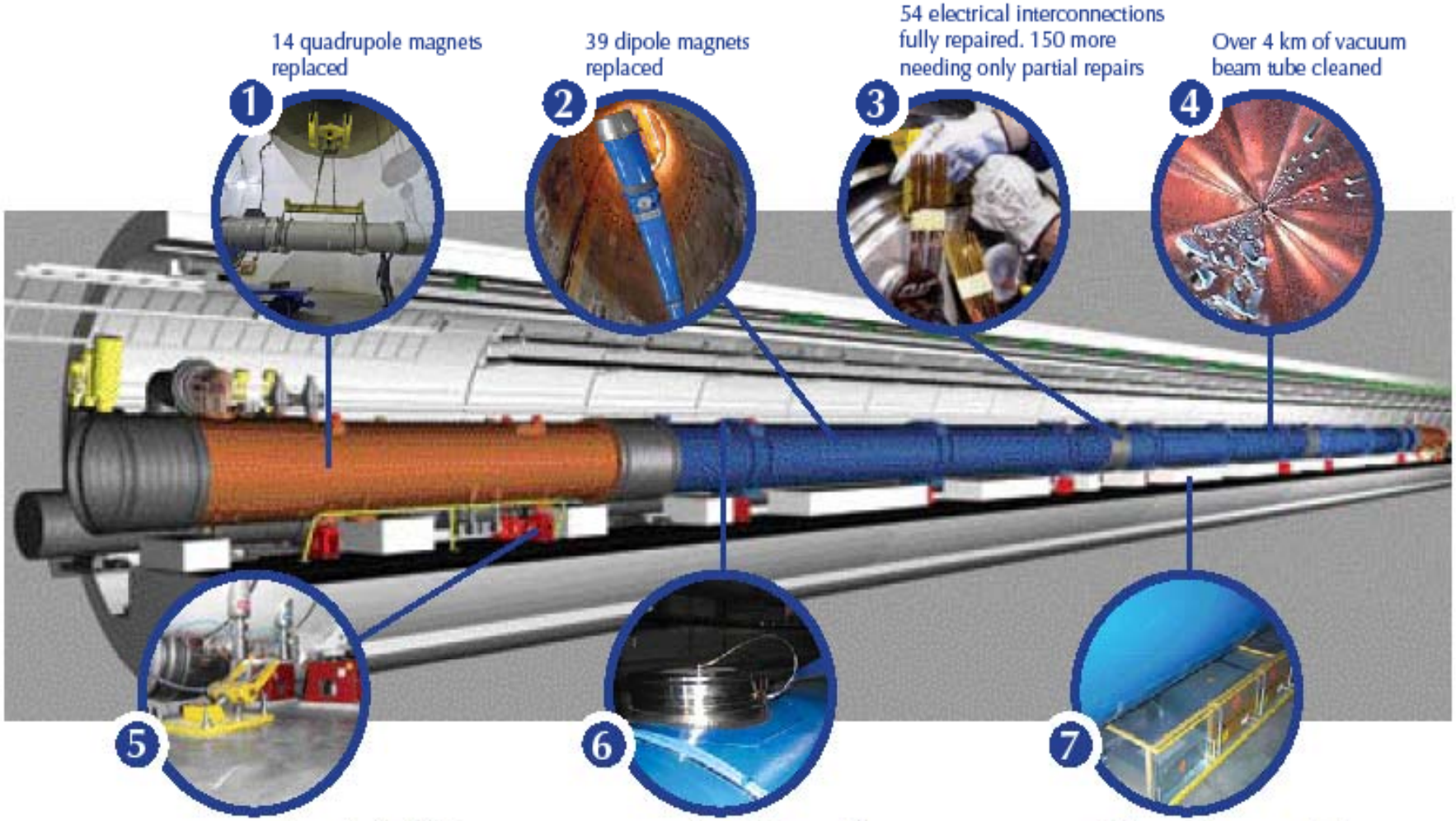
- SymQ:
  - Verified in Standard crate and Studied through Labview application with separate monitoring crate.
  - The 4-dipole algorithm operates correctly
  - During ramping with up to 10 A/s the residual signals remains insignificant.
- The nQPS crate powering system (the two Power Packs), the new WorldFip link and all the new Software tools worked perfectly.

Where the repairs are happening



- New pressure release ports fitted
- Upgrade of magnet protection system
- Cleaning ofvacuum beam tube
- Dipole and quadrupole magnets replaced and electrical interconnections
- LHC ring

The LHC repairs in detail

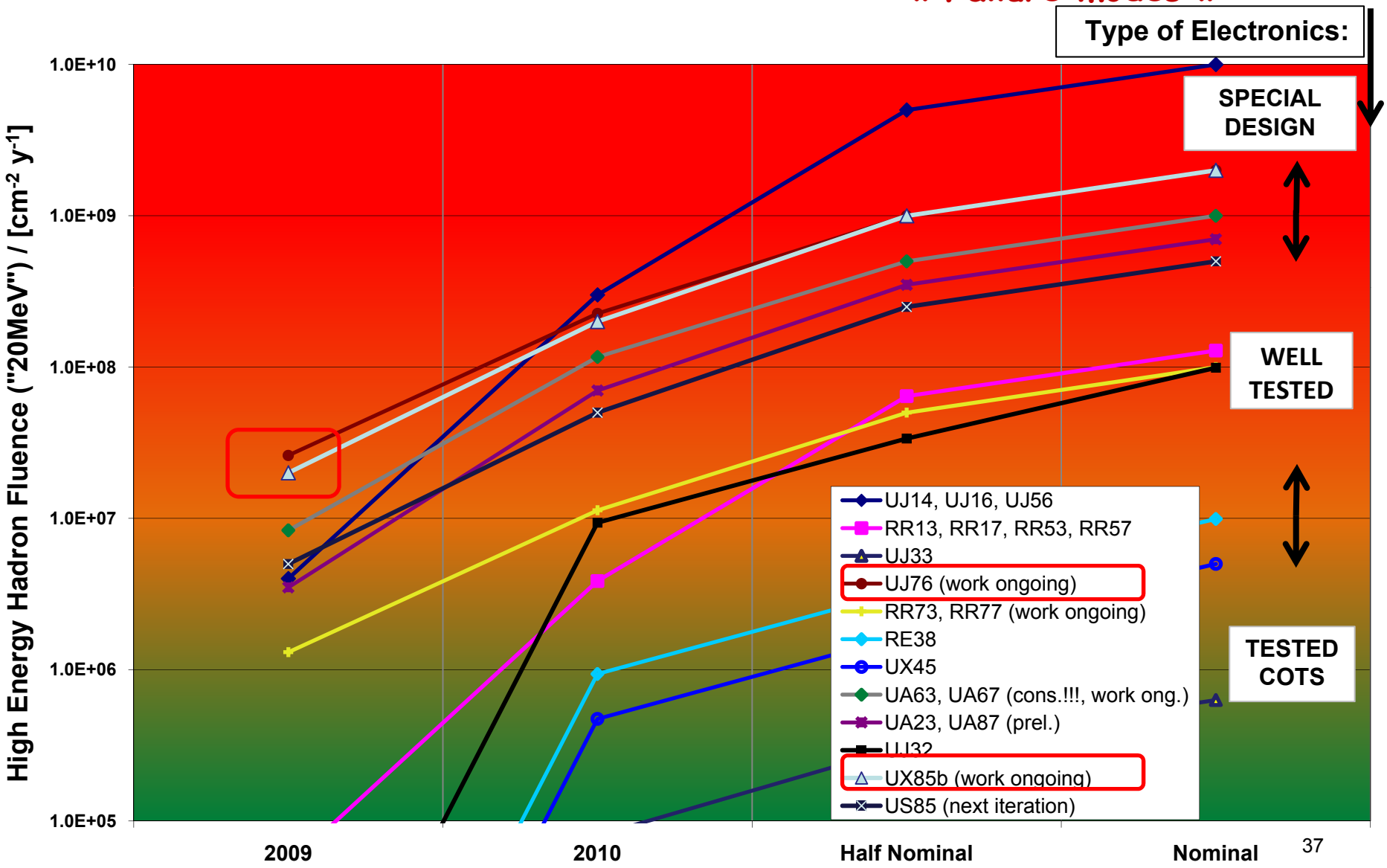


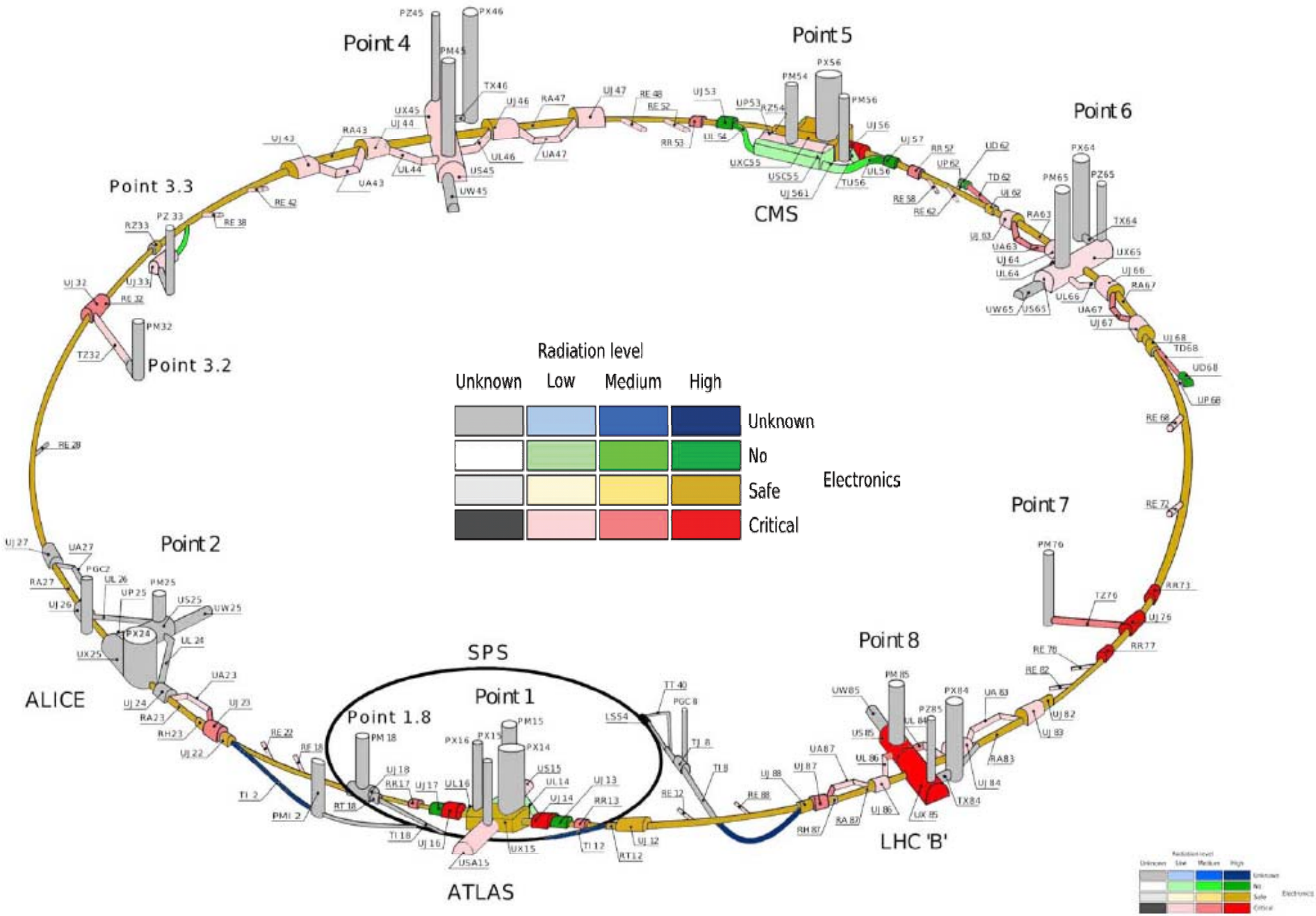
Protection of Electronics from Radiation

(Single Event Upsets)

Radiation Levels – Evolution

!! Simulations Only !! !! Loss Assumptions !! !! Failure modes !!





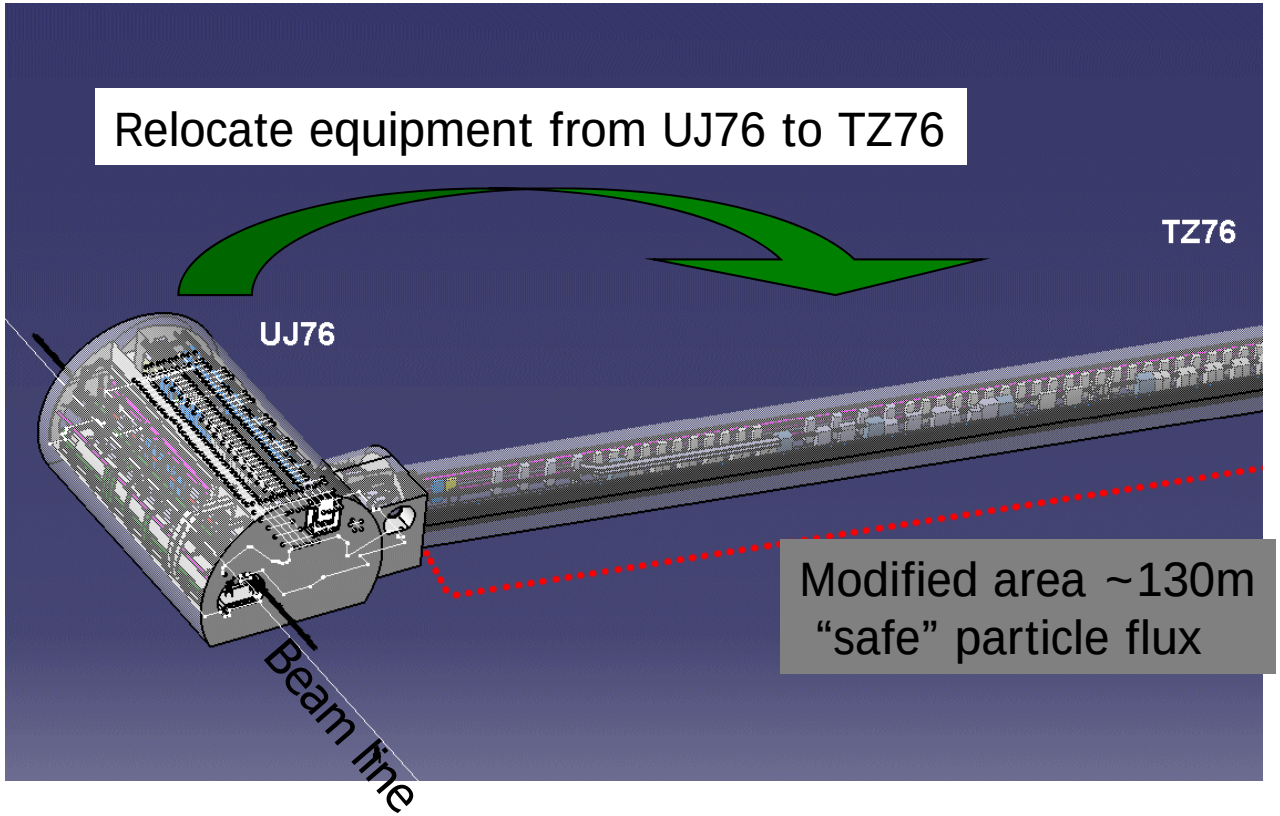
Overview of Regions – Colour Coded

Mitigation of Single Event Effect

(perturbation of equipment due to the passage of a single particle through its control electronics)

Strategy:

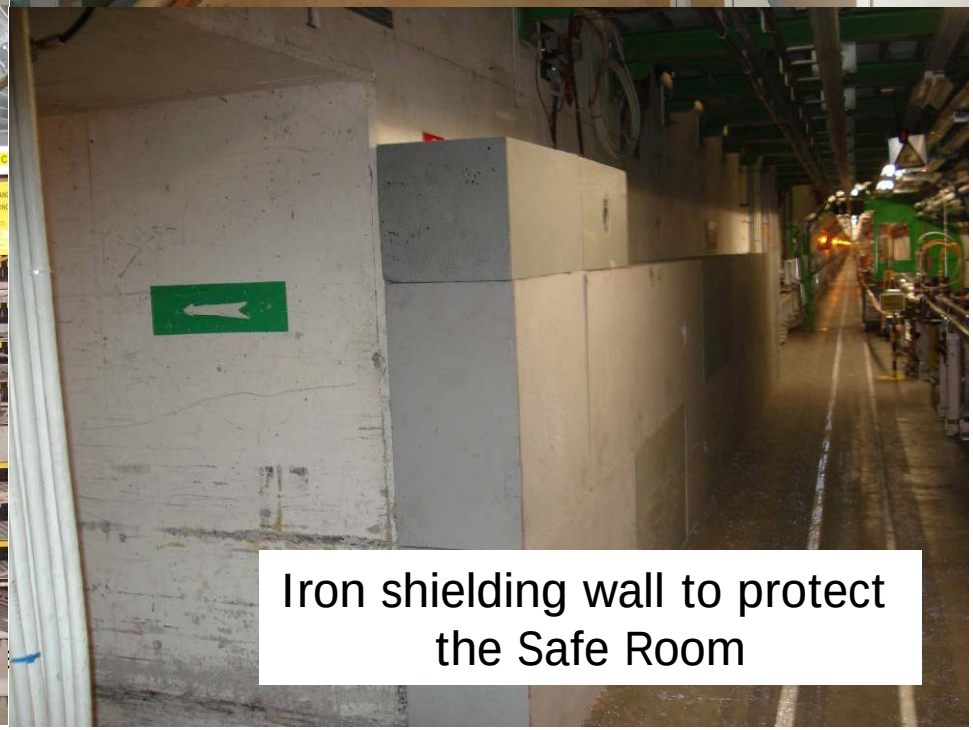
- Re-locate now to low radiation area the most critical equipment (ex UPS)
- Prepare relocation (space, cabling, cooling, network, etc.) of other equipment for next LHC shut-down (ex Power Converters)
- Shield with iron blocs whatever cannot be relocated (ex Safe room)



Preparation of space in TZ76

UPS re-installed in TZ76

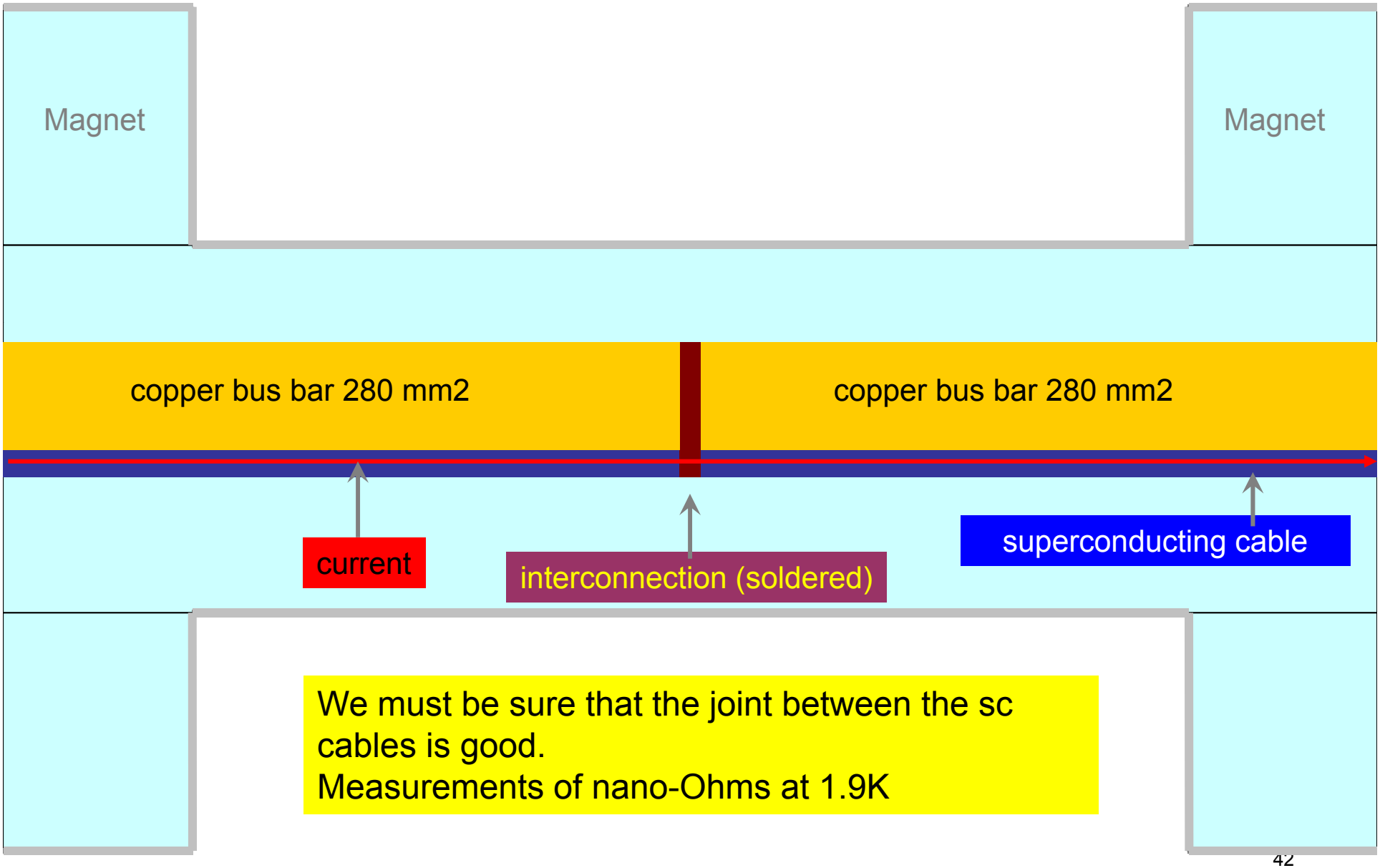
Installation of services to relocate the Power Converters



Iron shielding wall to protect the Safe Room

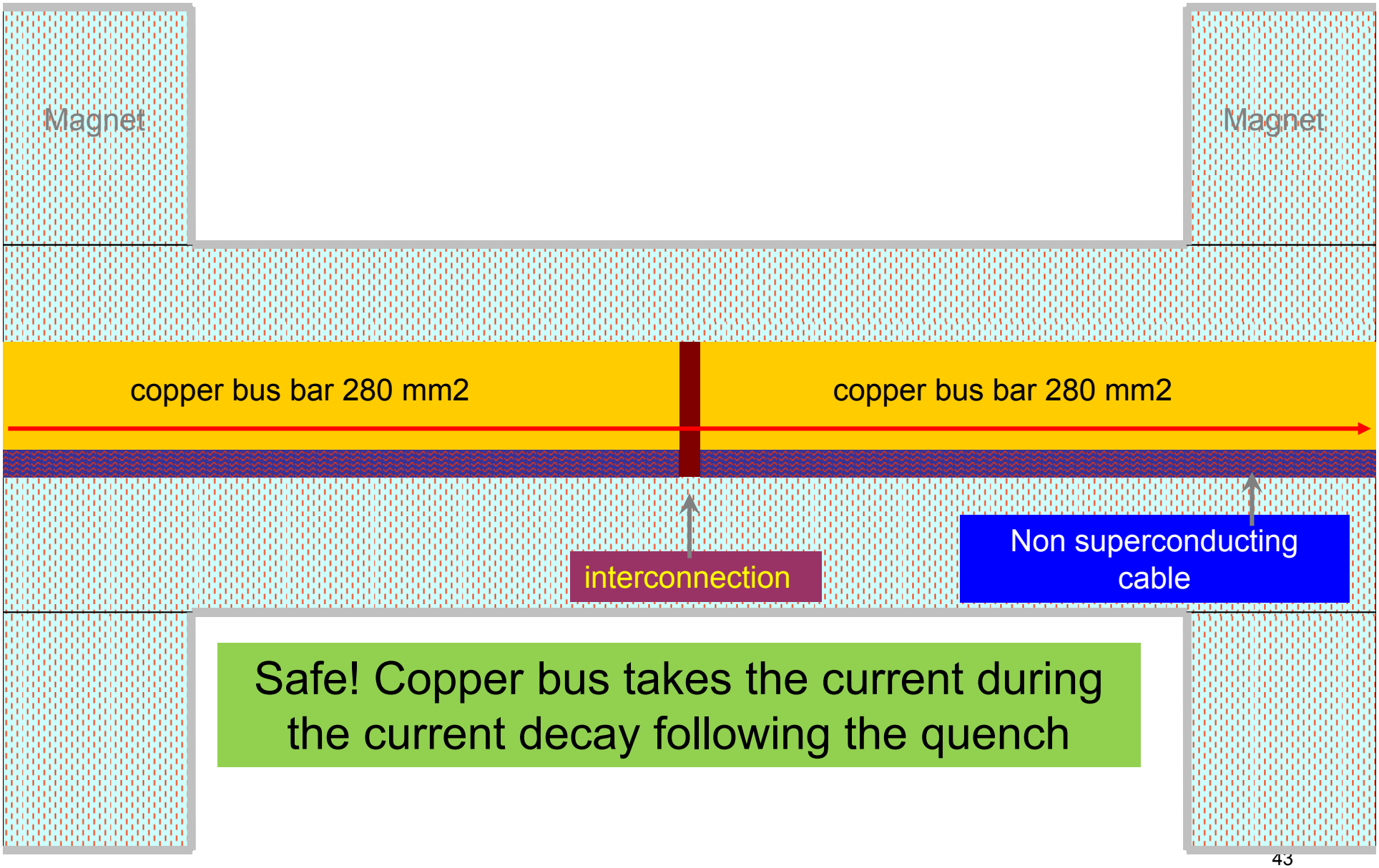
Splice Resistance Measurements

Good interconnect normal operation (1.9K)



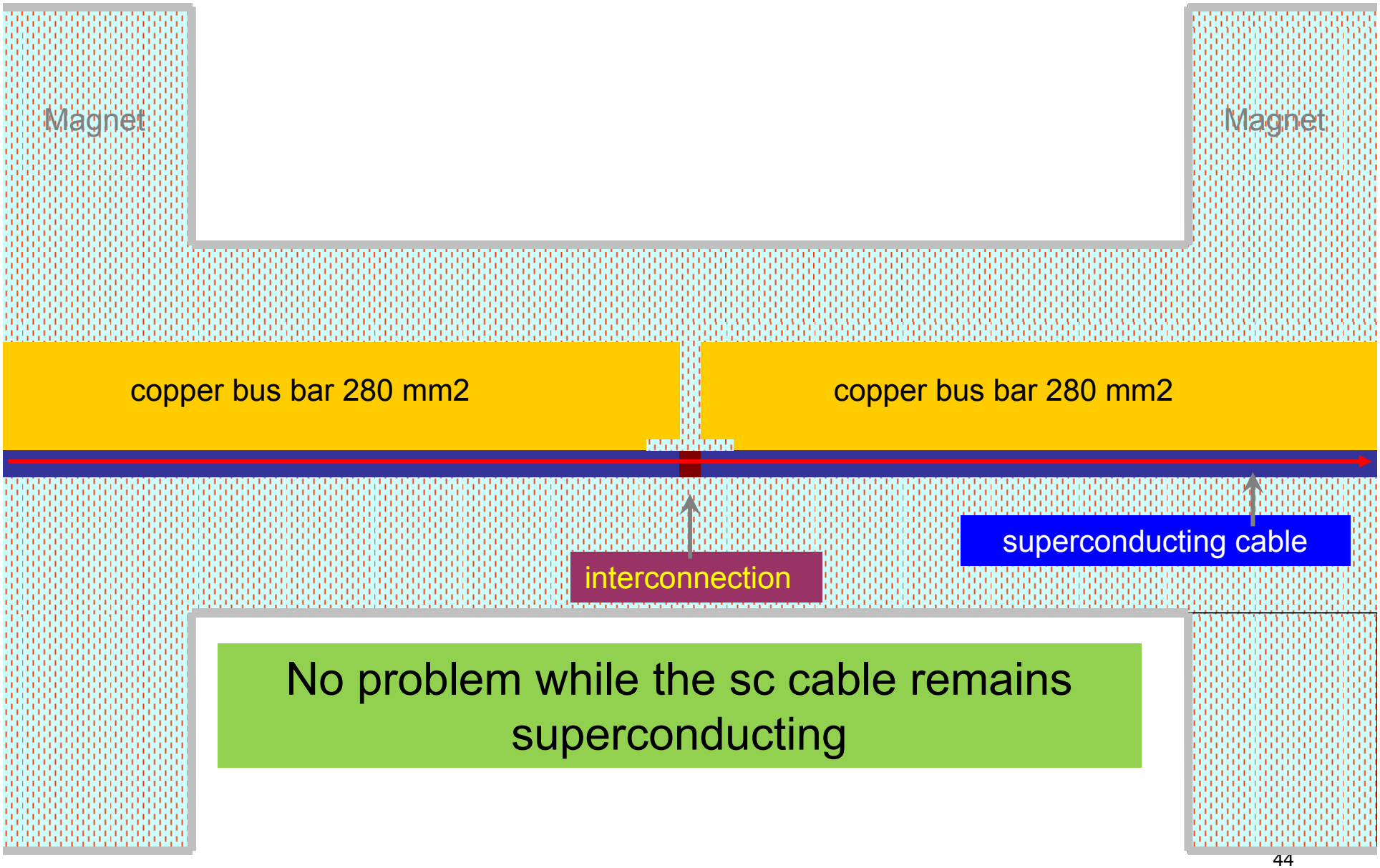
We must be sure that the joint between the sc cables is good.
Measurements of nano-Ohms at 1.9K

good interconnect, after quench (>10K)



Safe! Copper bus takes the current during the current decay following the quench

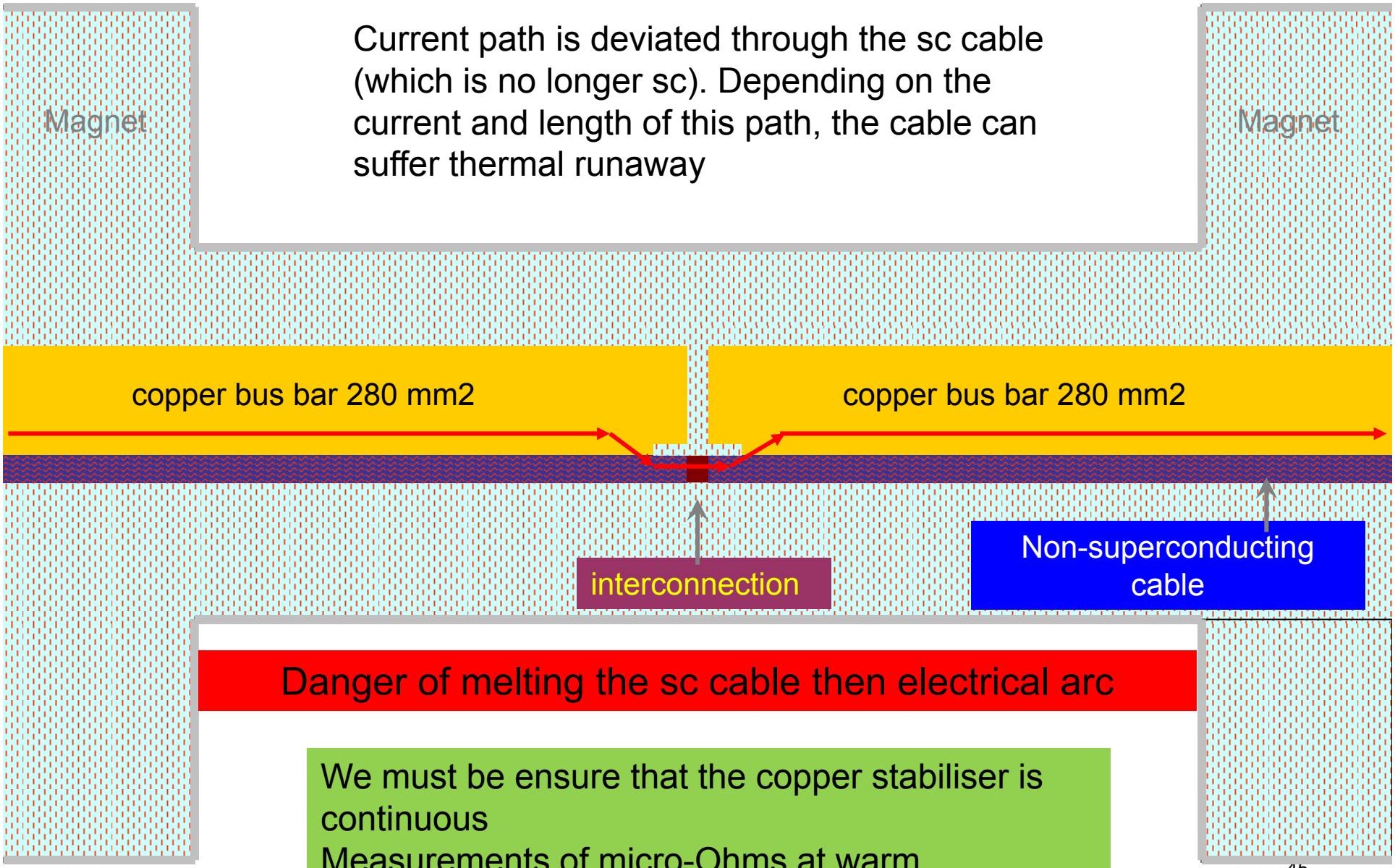
Bad interconnect, normal operation 1.9K



No problem while the sc cable remains superconducting

Bad interconnect, after quench

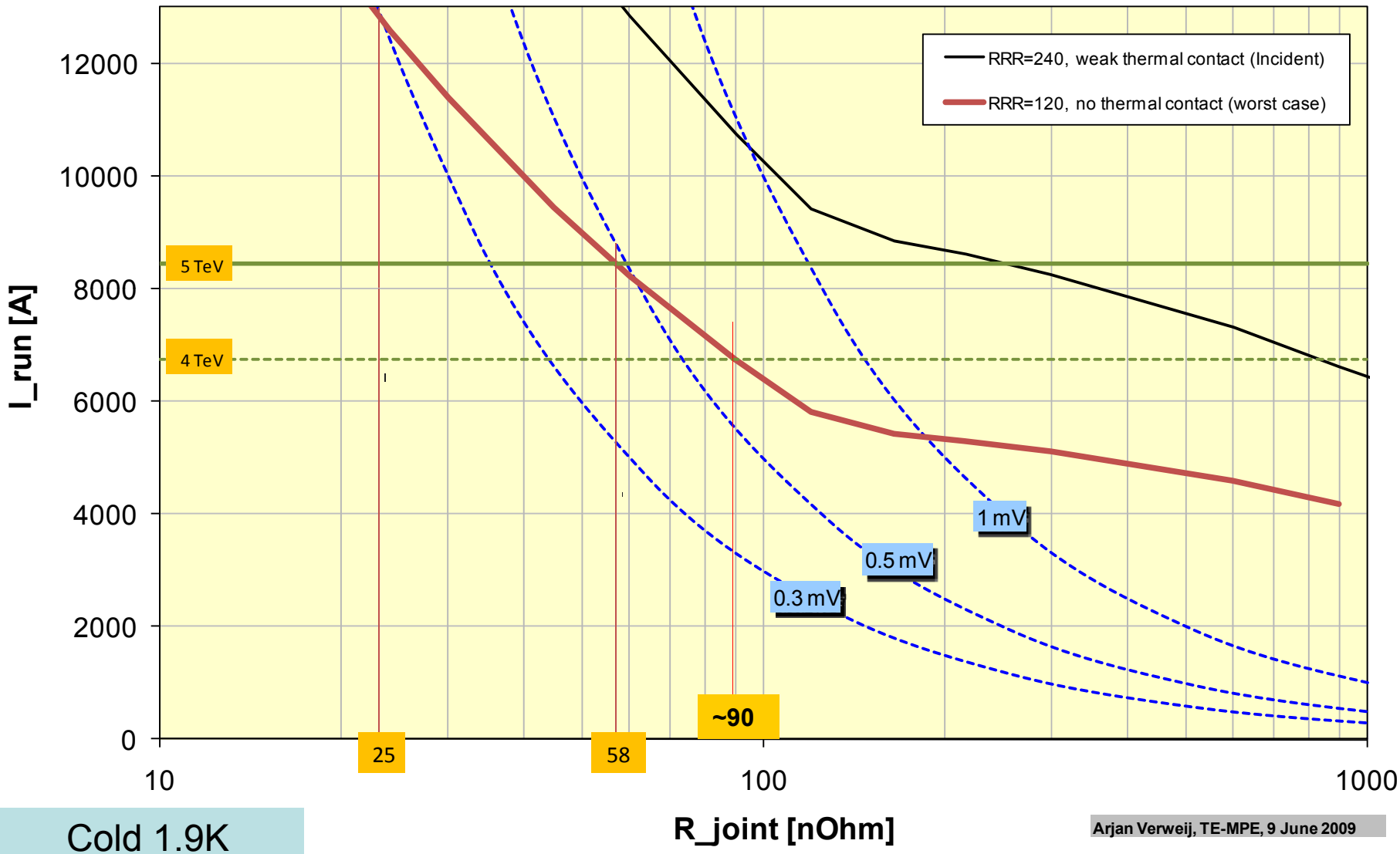
Current path is deviated through the sc cable (which is no longer sc). Depending on the current and length of this path, the cable can suffer thermal runaway



Danger of melting the sc cable then electrical arc

We must be ensure that the copper stabiliser is continuous
Measurements of micro-Ohms at warm

Simulations: Maximum dipole current vs sc joint resistance



Cold 1.9K

Approximate superconducting splice detection limits of LHC calorimetric & QPS measurements

Detection limit of splice resistance for MB and MQ (nano-Ohm) Red: thermal measurements, blue QPS				
	Interconnect splice		Magnet splice	
Sector	MB	MQ	MB	MQ
A12	40	60	10	60
A23	60	60	60	60
A34	60	60	60	60
A45	60	60	60	60
A56	40	40	5	5
A67	40	40	15	5
A78	40	40	10	5
A81	40	40	10	5

N. Catalan Lasheras, Z. Charifoulline, M. Koratzinos, A. Rijllart, A. Siemko, J. Strait, L. Tavian, R. Wolf
Electrical and calorimetric measurements and related software

Z. Charifoulline, Int Comm.

Testing of a (Magnet) High Resistance sc Cable Splice

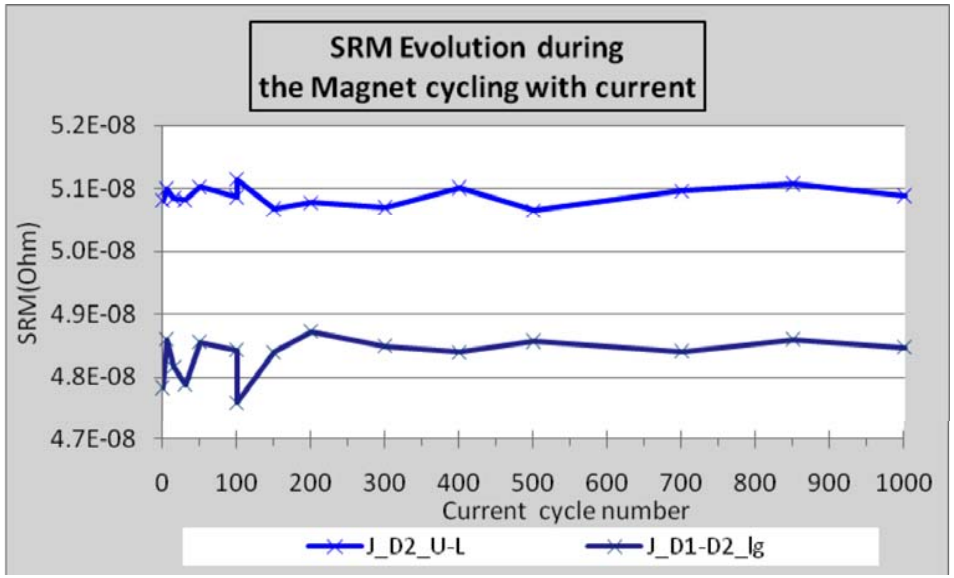
MB2303 Cold Testing

After 10h @ 9000 A
Before test: **51.1** nOhm
After test: **50.6** nOhm

After provoked quench @ 9000 A
Before test: **50.6** nOhm
After 6 quench: **51.1** nOhm

After Thermal Cycling (1.9 K – 300 K – 1.9 K)
Before test: **51.1** nOhm
After thermal cycling: **51.6** nOhm

Training up to 11850 A
Before test: **51.6** nOhm
After quench @10898 A: **51.5** nOhm
After this quench, the magnet reached 11850 A.



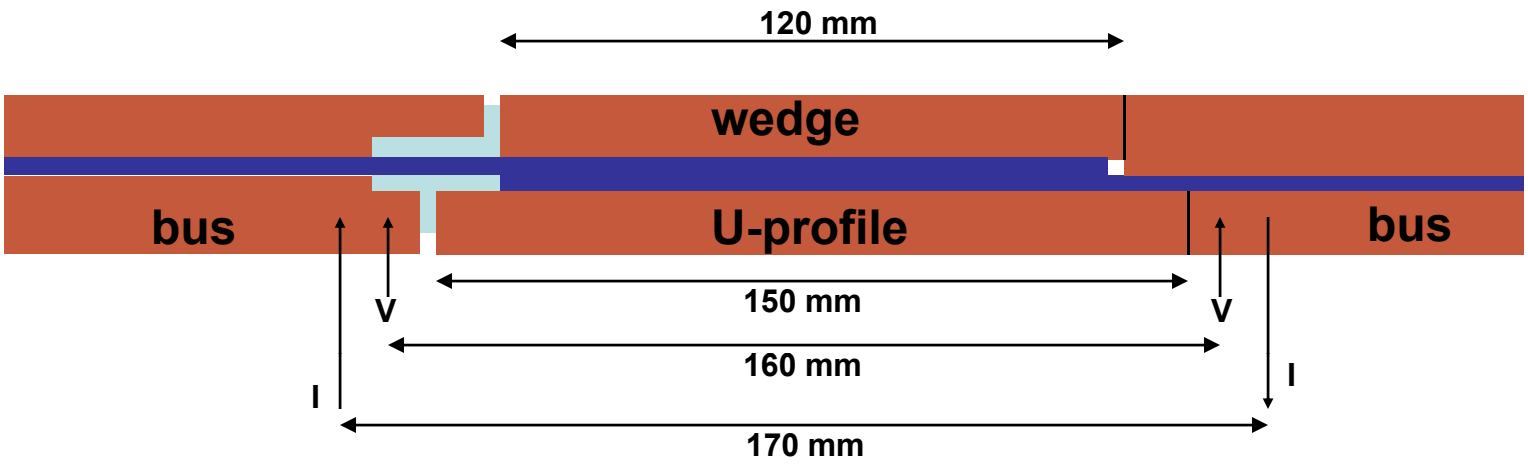
After 500/500 cycles @ 5000-11850-5000 A
Initial Value : **53.4** nOhm (cycle measurement : 5000-8500-11850-8500-5000 A)
After 170 cycles: **53.9** nOhm

Courtesy M. Bajko

Electrical Resistance Measurements at Warm Temperatures

- New electrical tests have been developed
  - Warm measurements of R^{long} give possibility to detect surplus joint resistance larger than about 20-30 $\mu\Omega$ (RB).
    - Tests have been done for four sectors at room temperature and one sector at 80 K.
    - Remaining 3 sectors still to be measured
  - Warm measurements of the joint resistances (so-called local R^{16} measurement) give possibility to detect surplus joint resistance of a few $\mu\Omega$.

R-measurement at 300 K



The "R^{16} method" will give some indication whether wedge, U-profile, and bus stabilizer are in good electrical contact.

'Perfect' values for R^{16} are: (T=18 °C, gap is 0.1 mm fully filled with SnAg, perfect bonding everywhere, uniform current)

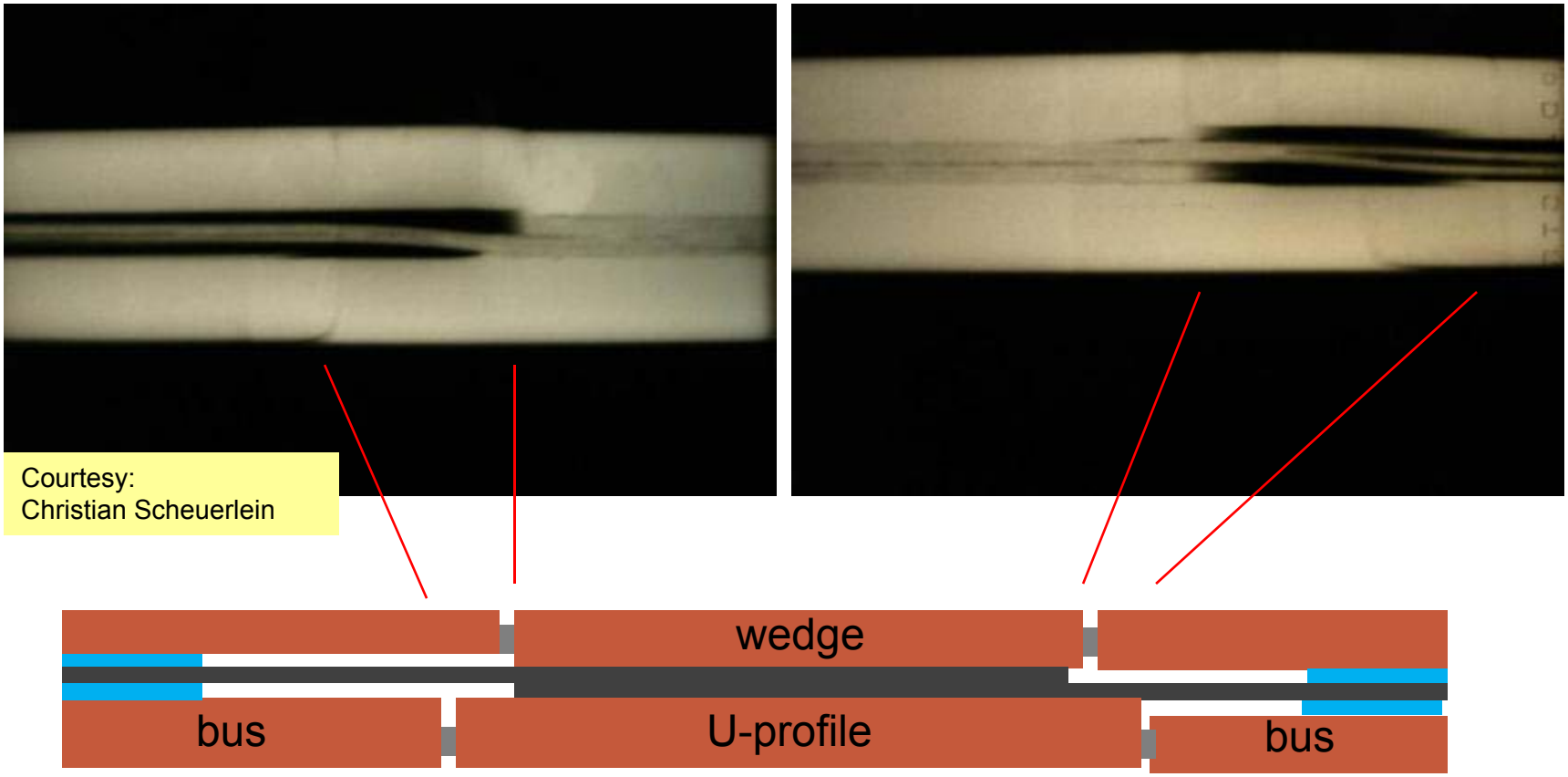
RB: 9.45 $\mu\Omega$

RQ: 16.0 $\mu\Omega$

Due to point-like current insertion the measured resistances are about 1 $\mu\Omega$ higher.

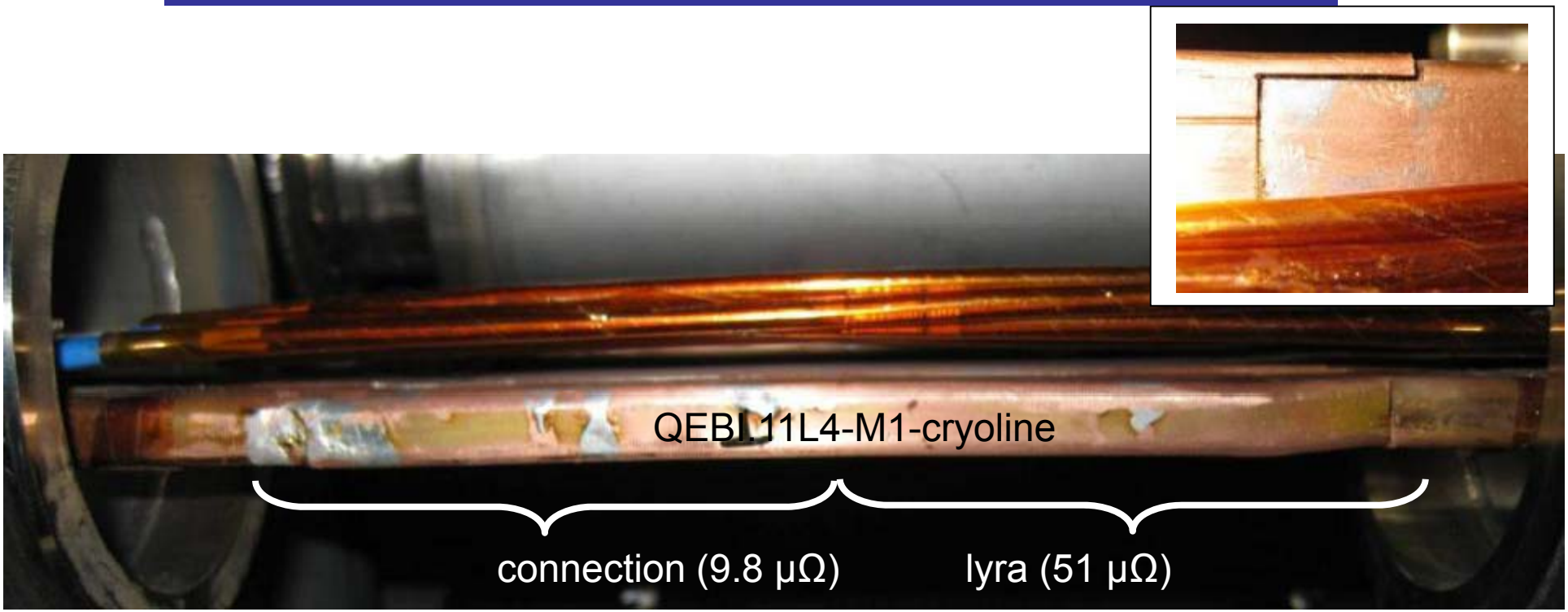
Bad surprise after gamma-ray imaging of the joints: Void is present in most of bus extremities because SnAg flows out during soldering of the joint

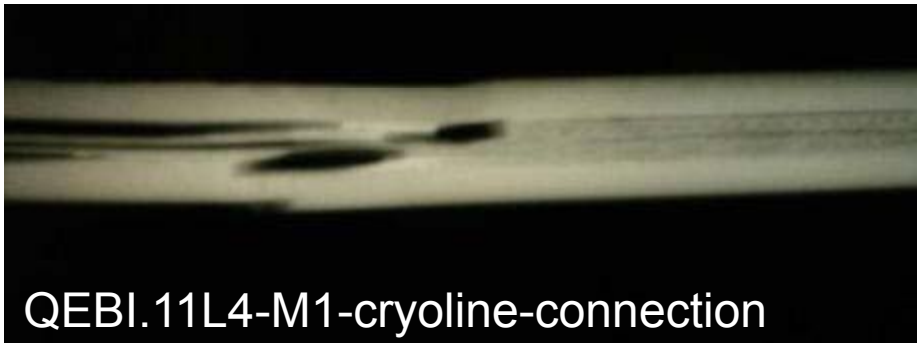
Gamma rays QBBI.B25R3-M3 before disconnection (QRL connection & QRL lyra sides)

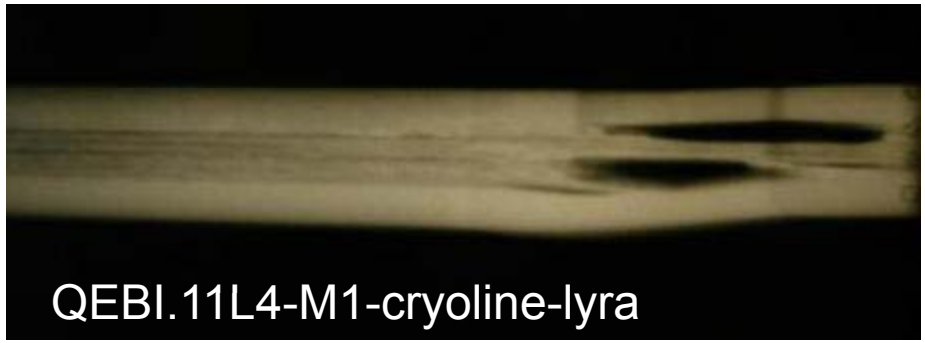


A. Verweij, TE-MPE. 28 April 2009, TE-TM meeting

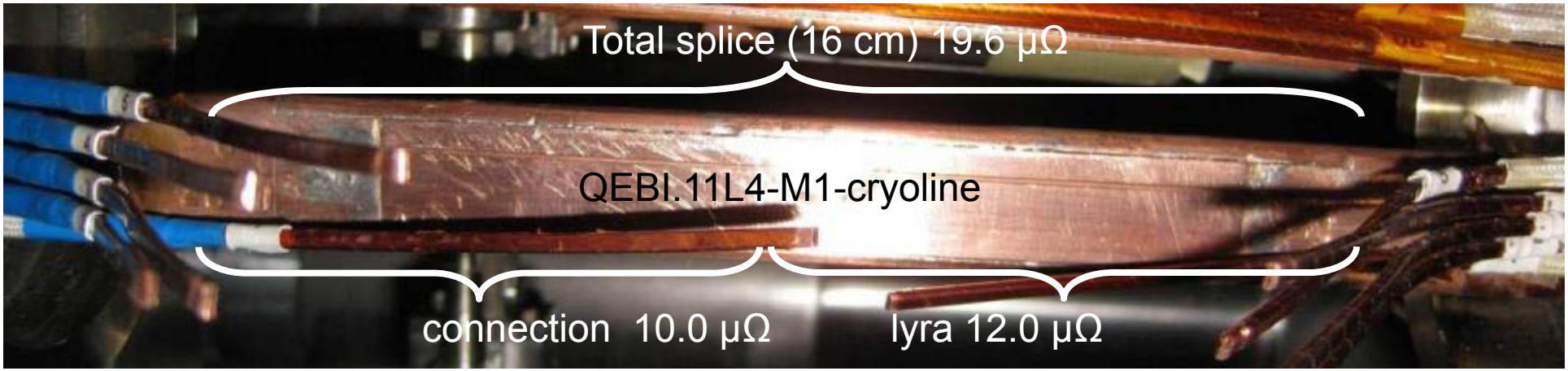
Sector 3-4 : QEBI.11L4-M1-cryoline before repair

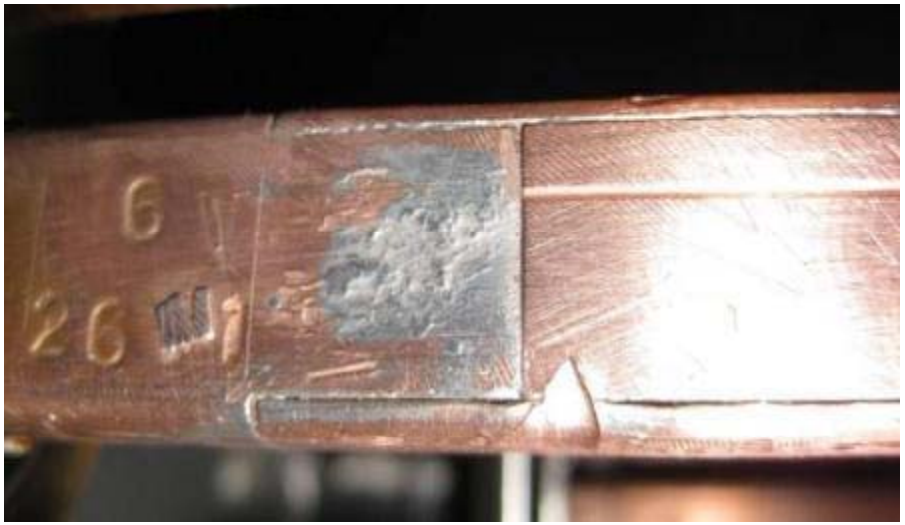




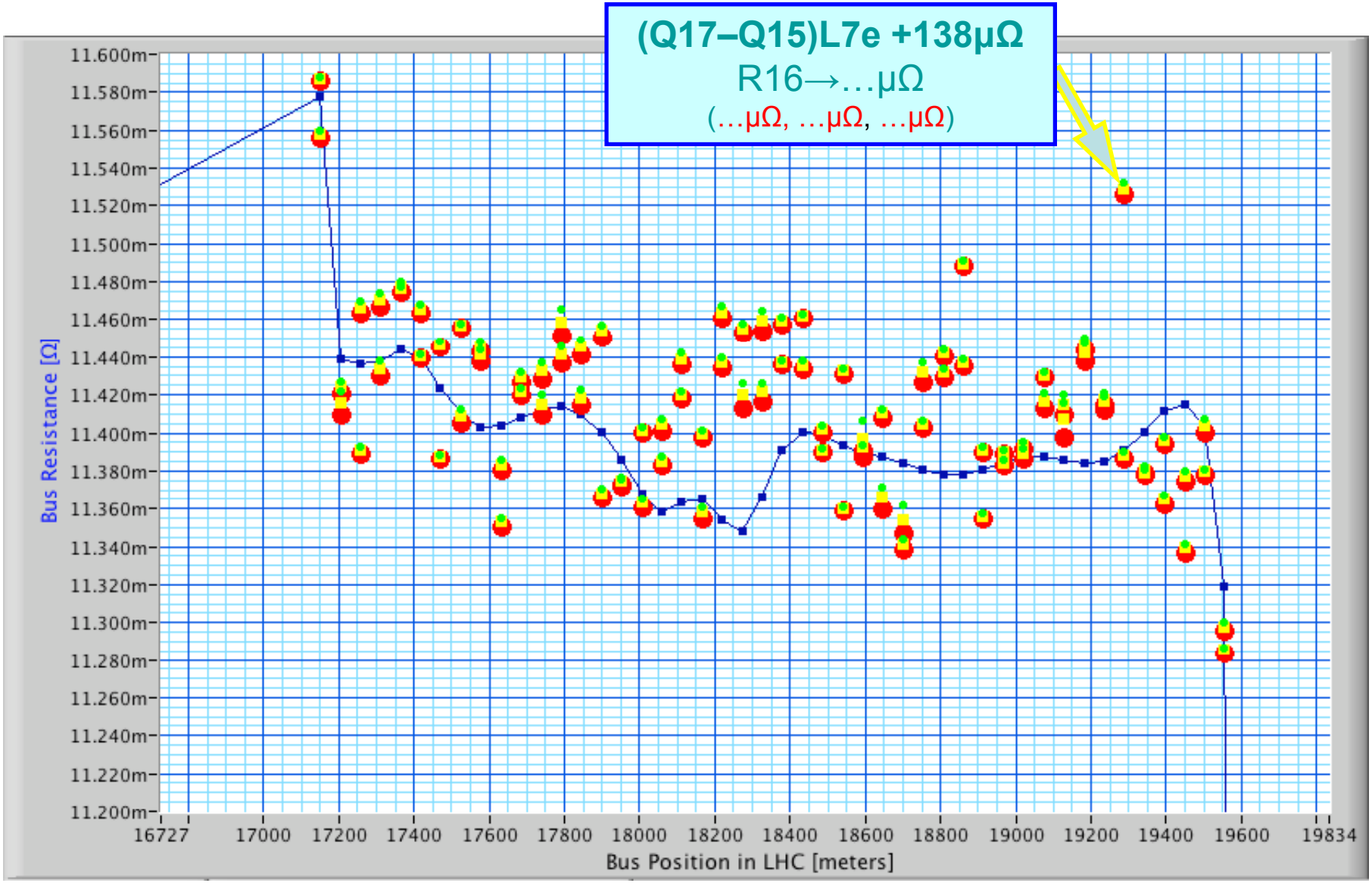


Sector 3-4 : QEBI.11L4-M1-cryoline repaired





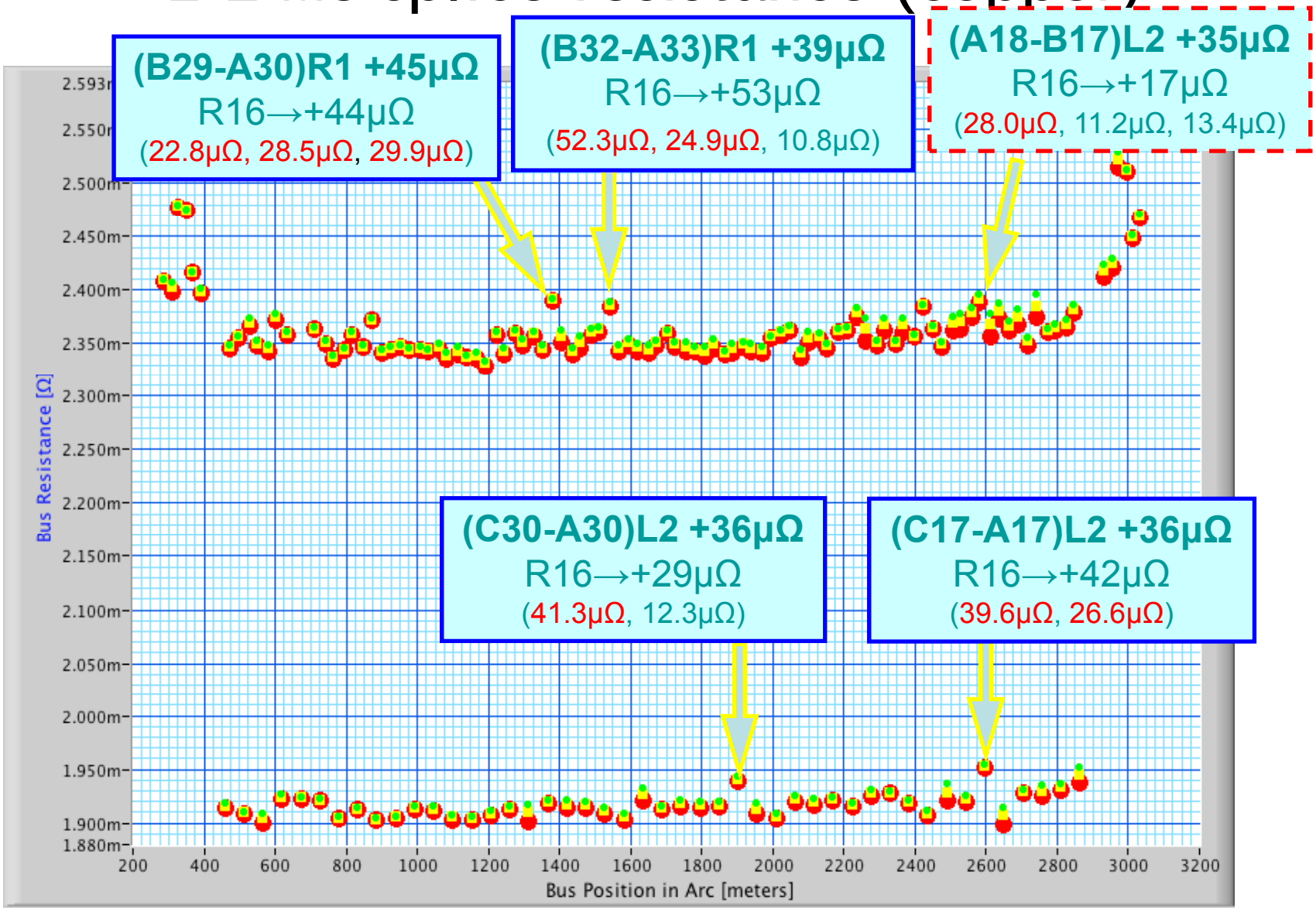
6-7 Quads splice resistance (copper)



Courtesy R. Flora

1-2 M3 splice resistance (copper)

Courtesy R. Flora, C. Scheuerlein



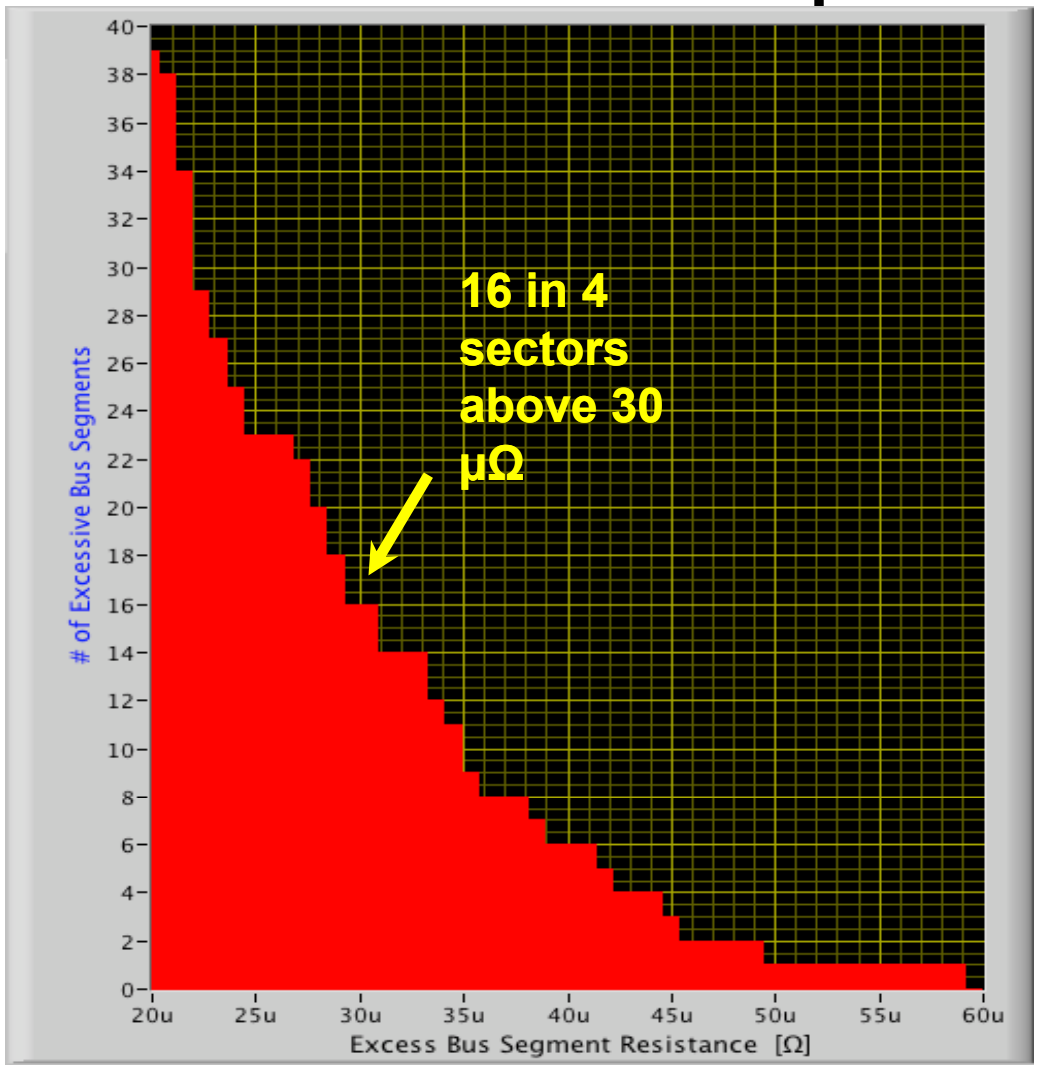
The cool-down of S12 was delayed in order to perform this “warm” measurement

1-2 M3 splice repair

Inter. number	Main busbars	Photos (before unsoldering)	US-test (before unsoldering)	R-16 before unsoldering	Gamma ray control (before unsoldering)	Visual inspection and photos after repair	US-test after repair	R-16 after repair	Gamma ray control after repair	QC insulation main bus bars	QC insulation spools
1-2											
QBBI.B29R1	M3-corridor	done	4 out of 4 OK	11.7	done 8.5.09, J.D.					OK, 2.6.09, C.S.	
	M3-cryoline	done	4 out of 4 OK	22.8	done 8.5.09, J.D.	OK, 28.5.09, G.T.	4 out of 4 OK	10.0	done, 2.6.06, J.D.	OK, 2.6.09, C.S.	
QBQI.29R1	M3-corridor	done	4 out of 4 OK	12.2	done 8.5.09, J.D.					OK, 2.6.09, C.S.	
	M3-cryoline	done	4 out of 4 OK	28.5	done 8.5.09, J.D.	OK, 28.5.09, G.T.	4 out of 4 OK	11.5	done, 2.6.06, J.D.	OK, 2.6.09, C.S.	
QQBI.29R1	M3-corridor	done	3 out of 4 OK	25.2	done 8.5.09, J.D.	OK, 29.5.09, C.S.	OK, 2.6.09, G.T.	10.7	done, 2.6.06, J.D.	OK, 2.6.09, C.S.	
	M3-cryoline	done	4 out of 4 OK	29.9	done 8.5.09, J.D.	OK, 29.5.09, C.S.	OK, 2.6.09, G.T.	10.4	done 2.6.06, J.D.	OK, 2.6.09, C.S.	
QBBI.B32R1	M3-corridor	done	4 out of 4 OK	24.9	done 14.5.09, J.D.	OK, 29.5.09, C.S.	OK, 2.6.09, G.T.	10.2	done 2.6.06, J.D.	OK, 2.6.09, C.S.	
	M3-cryoline	done	4 out of 4 OK	11.2	done 14.5.09, J.D.					OK, 2.6.09, C.S.	
QBQI.32R1	M3-corridor	done	3 out of 4 OK	52.3	done 14.5.09, J.D.	OK, 29.5.09, C.S.	OK, 2.6.09, G.T.	10.2	done 2.6.06, J.D.	OK, 2.6.09, C.S.	
	M3-cryoline	done	4 out of 4 OK	12.5	done 14.5.09, J.D.	OK, 29.5.09, C.S.	OK, 2.6.09, G.T.		done 2.6.06, J.D.	OK, 2.6.09, C.S.	
QQBI.32R1	M3-corridor	done	4 out of 4 OK 2.2.09	10.8	done 19.5.09, J.D.	OK, 29.5.09, C.S.	OK, 2.6.09, G.T.	10.3	done, 2.6.06, J.D.	OK, 3.6.09, C.S.	
	M3-cryoline	done	4 out of 4 OK 2.2.09	10.8	done 19.5.09, J.D.	OK, 29.5.09, C.S.	OK, 2.6.09, G.T.	10.5	done 2.6.06, J.D.	OK, 3.6.09, C.S.	
QBBI.B30L2	M3-corridor	done	4 out of 4 OK	12.3	done 14.5.09, J.D.					OK, 2.6.09, C.S.	
	M3-cryoline	done	4 out of 4 OK	12.7	done 14.5.09, J.D.					OK, 2.6.09, C.S.	
QBBI.A30L2	M3-corridor	done	4 out of 4 OK	41.3	done 14.5.09, J.D.	OK, 29.5.09, C.S.	OK, 2.6.09, G.T.	10.2	done 2.6.06, J.D.	OK, 3.6.09, C.S.	
	M3-cryoline	done	4 out of 4 OK	13.3	done 14.5.09, J.D.					OK, 3.6.09, C.S.	
QBQI.18L2	M3-corridor	done	4 out of 4 OK	28.0		OK, 3.6.09, G.T.	OK, 3.6.09, G.T.	10.2		OK, 3.6.09, C.S.	
	M3-cryoline	done	4 out of 4 OK	25.6		OK, 3.6.09, G.T.	OK, 3.6.09, G.T.	10.6		OK, 3.6.09, C.S.	
QQBI.17L2	M3-corridor	done	4 out of 4 OK	11.2						OK, 3.6.09, C.S.	
	M3-cryoline	done	4 out of 4 OK	16.9		OK, 3.6.09, G.T.	OK, 3.6.09, G.T.	10.4		OK, 3.6.09, C.S.	
QBBI.B17L2	M3-corridor	done	4 out of 4 OK	13.4	done 8.5.09, J.D.					OK, 3.6.09, C.S.	
	M3-cryoline	done	4 out of 4 OK	26.6	done 8.5.09, J.D.	OK, 29.5.09, C.S.	OK, 2.6.09, G.T.	10.5	done 2.6.06, J.D.	OK, 3.6.09, C.S.	
QBBI.A17L2	M3-corridor	done	4 out of 4 OK	13.0	done 8.5.09, J.D.					OK, 3.6.09, C.S.	
	M3-cryoline	done	4 out of 4 OK	39.6	done 8.5.09, J.D.	OK, 29.5.09, C.S.	OK, 2.6.09, G.T.	10.3	done 2.6.06, J.D.	OK, 3.6.09, C.S.	

Courtesy C. Scheuerlein

Results – Dipoles at warm

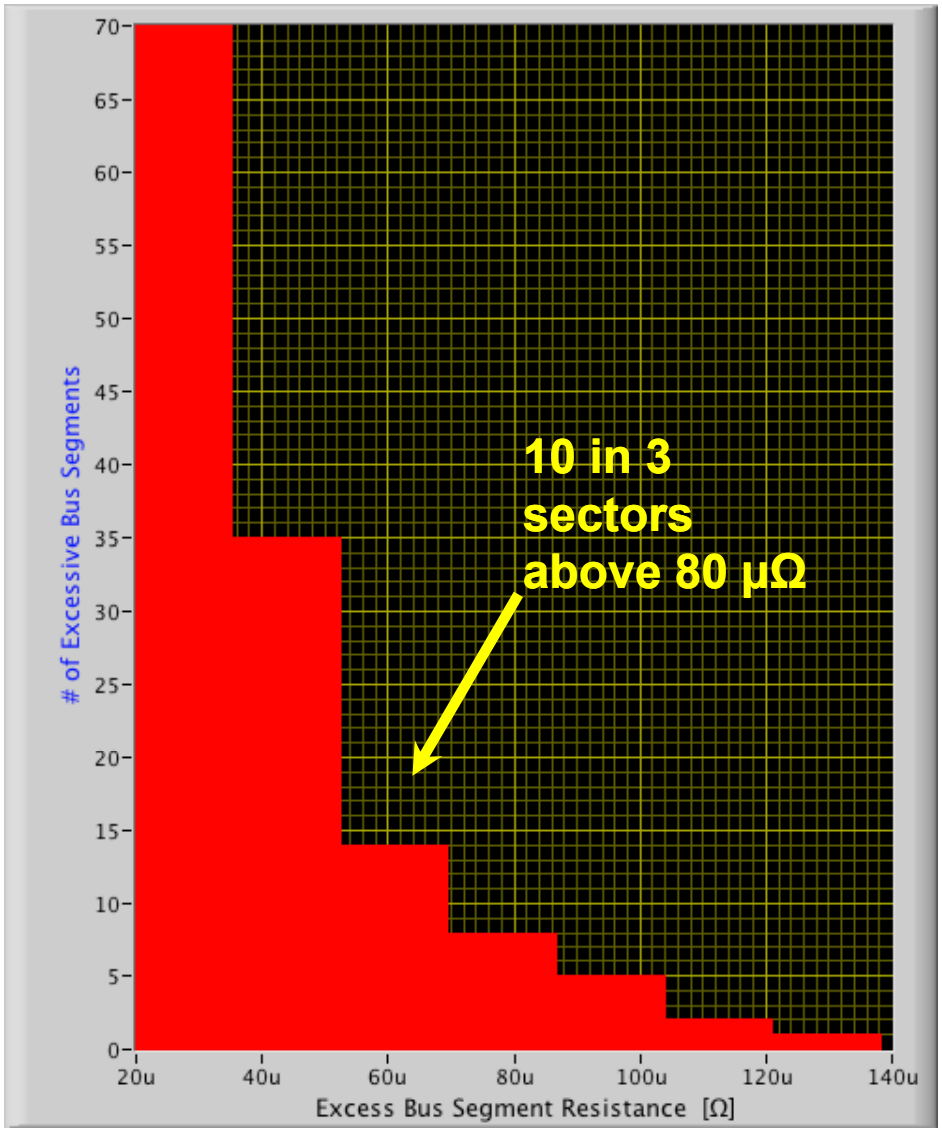


Hit List

∂R [Ω]	x [m]	Bus Segment Span
59.9u	17331	RBAR.[A16R6<->C16R6]
49.7u	17369	RBAR.[C16R6<->B17R6]
45.4u	1380	RBAR.[B29R1<->A30R1]
44.9u	8029	RBBL.[A29R3<->C29R3]
42.3u	18469	RBAR.[B32L7<->C31L7]
42.1u	18416	RBBR.[B33L7<->C32L7]
39.3u	1541	RBBR.[B32R1<->A33R1]
38.8u	18309	RBBR.[B34R6<->C34L7]
35.7u	1899	RBBR.[C30L2<->A30L2]
35.6u	2594	RBAR.[C17L2<->A17L2]
35.3u	8831	RBAL.[C25L4<->A25L4]
34.8u	2578	RBBR.[A18L2<->B17L2]
33.8u	17347	RBBR.[B16R6<->A17R6]
33.7u	18149	RBAR.[B31R6<->A32R6]
31.5u	18454	RBBR.[C32L7<->A32L7]
30.9u	2418	RBAR.[A21L2<->B20L2]

10 repaired with > 35 μΩ

Results – Quads at warm

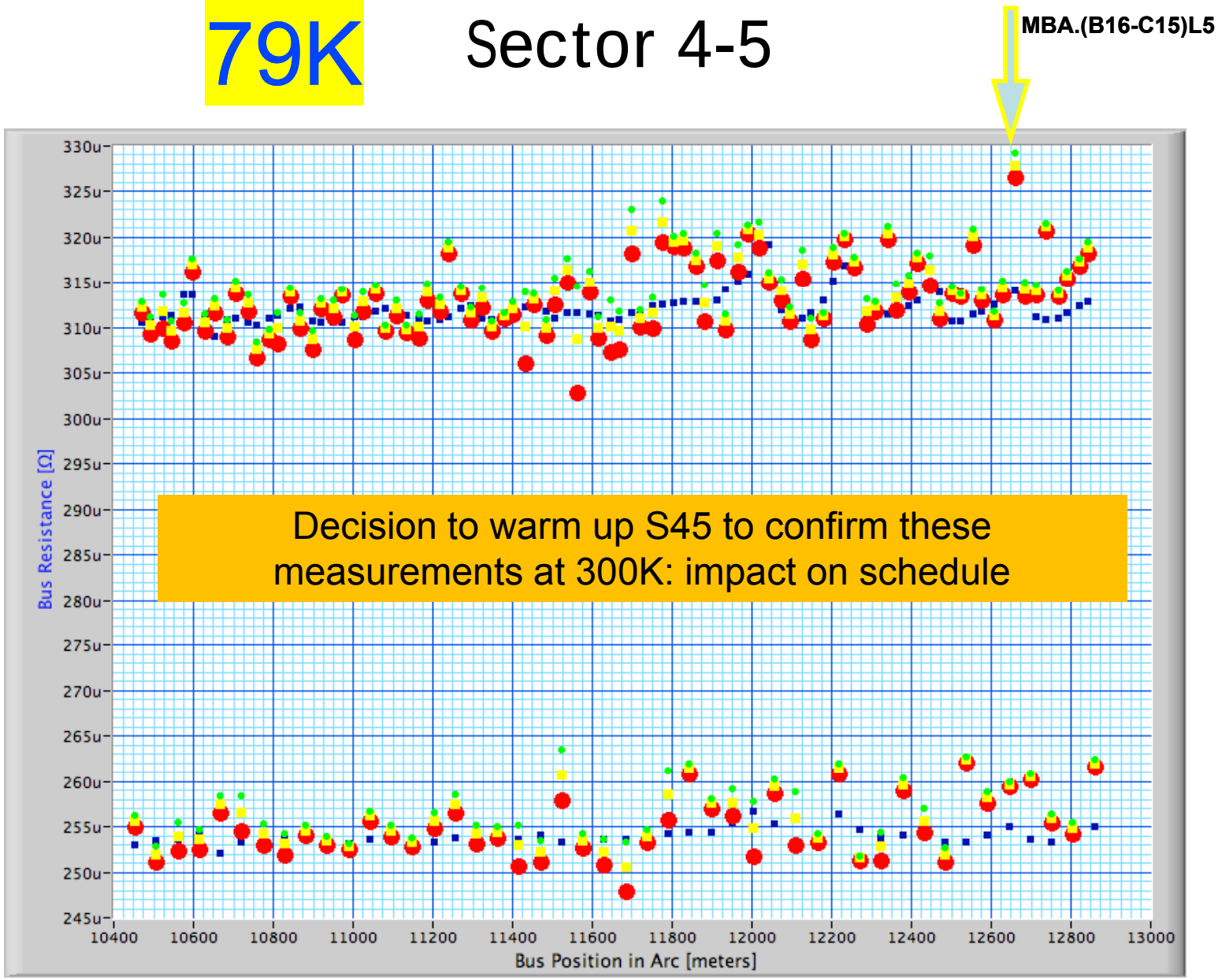


Hit List

∂R [Ω]	x [m]	Bus Segment Span
138.1u	19287	RQAT.[Q17L7<->Q15L7]e
111.6u	18859	RQOA.[Q25L7<->Q23L7]e
110.2u	18218	RQOA.[Q31R6<->Q33R6]e
107.6u	18271	RQOB.[Q32R6<->Q34R6]e
93.5u	18325	RQOA.[Q33R6<->Q33L7]e
89.9u	13977	RQAT.[Q14R5<->Q16R5]e
89.1u	14084	RQAT.[Q16R5<->Q18R5]e
85.4u	1824	RQOA.[Q32L2<->Q30L2]e
83.7u	18218	RQOA.[Q31R6<->Q33R6]i
83.4u	14832	RQOA.[Q30R5<->Q32R5]e
79.2u	13870	RQAT.[Q12R5<->Q14R5]e
75.3u	18111	RQOA.[Q29R6<->Q31R6]e
71.9u	18271	RQOB.[Q32R6<->Q34R6]i
69.0u	18378	RQOB.[Q34R6<->Q32L7]e
66.3u	15687	RQOA.[Q22L6<->Q20L6]e
65.0u	1824	RQOA.[Q32L2<->Q30L2]i
64.6u	968	RQAT.[Q20R1<->Q22R1]e
64.2u	18806	RQOB.[Q26L7<->Q24L7]e

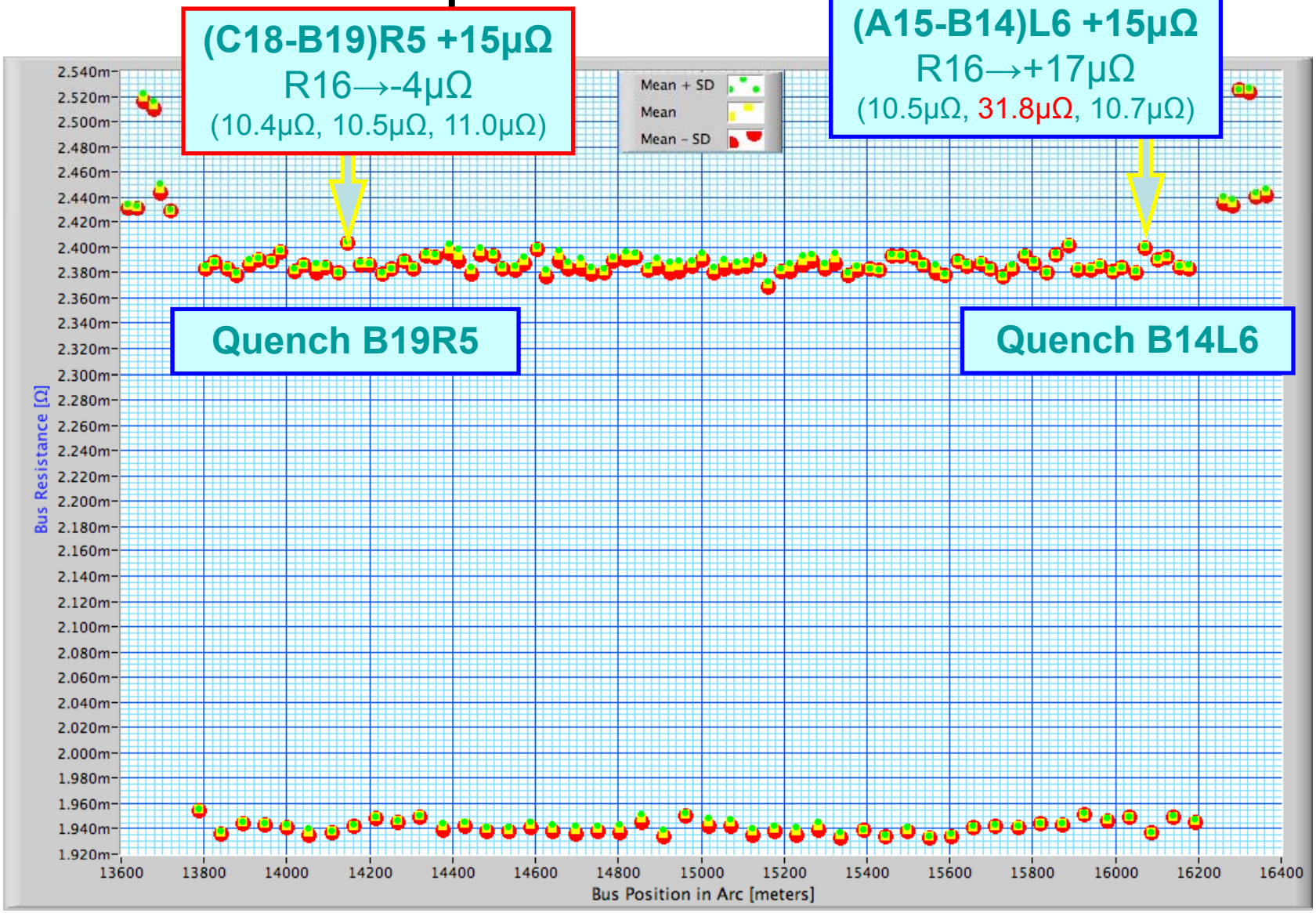
10 repaired above 80 μΩ

79K Sector 4-5



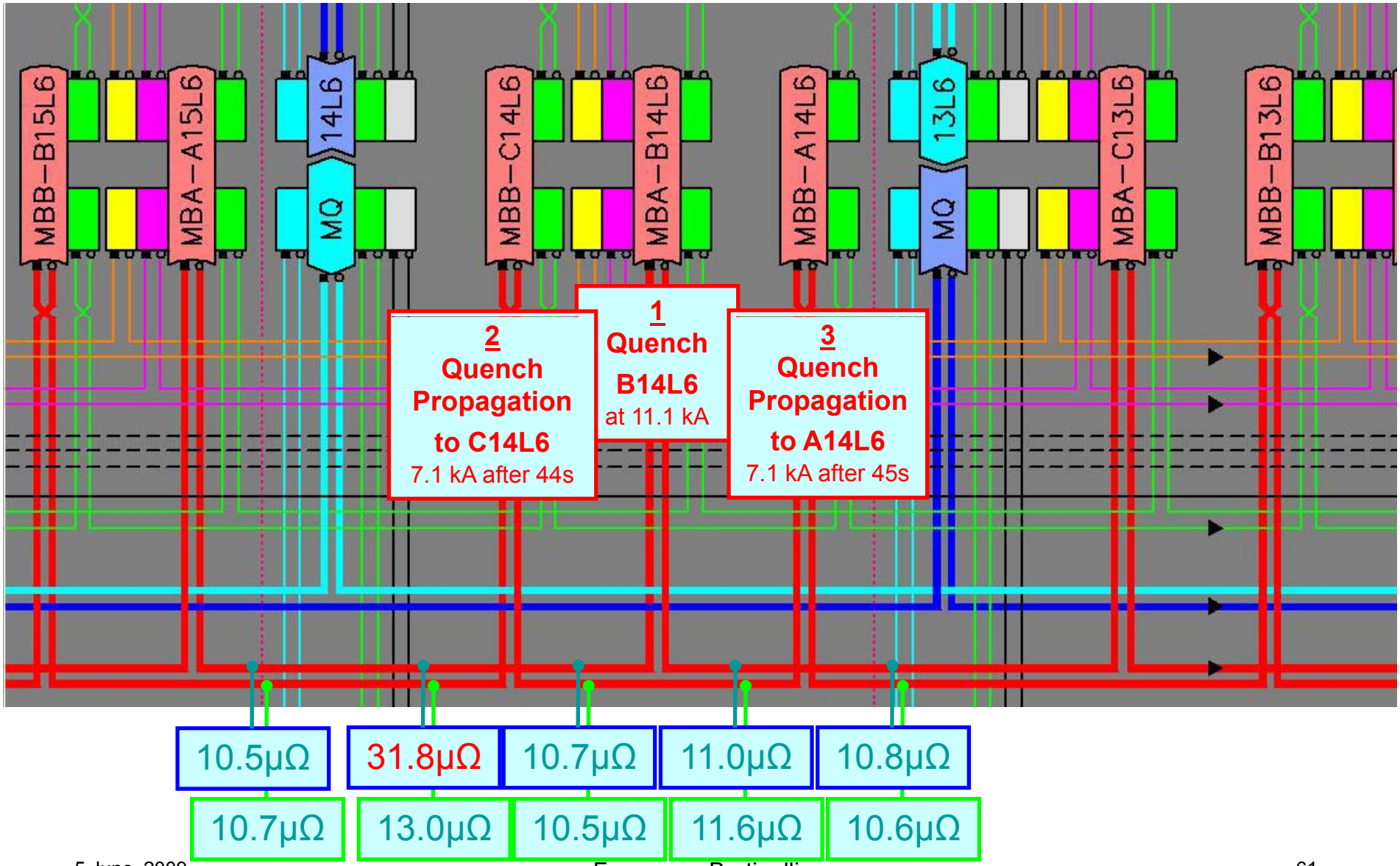
Decision to warm up S45 to confirm these measurements at 300K: impact on schedule

5-6 M3 splice resistance (copper)



Courtesy R. Flora, G. Trachez

5-6 M3 R16 vs quench data



Summary

- The enhanced quality assurance introduced during sector 3-4 repair has revealed new facts concerning the copper bus bar in which the superconductor is embedded.
- Tests have demonstrated that the process of soldering the superconductor in the interconnecting high-current splices can cause discontinuity of the copper part of the busbars and voids which prevent contact between the superconducting cable and the copper
  - Danger in case of a quench

- Studies are now going on to allow:
  - To find a safe limit for the measured joint resistance as a function of the current in magnet circuits (max energy in the machine)
  - Faster discharge of the energy from circuits

New RQ dump resistors; preparation launched

Powering and Tunnel Access Restrictions

New QPS and powering strategy

To power the circuits needs a commissioned QPS/nQPS, but to commission the QPS/nQPS needs the circuits powered (chicken and egg syndrome).

The documented strategy

1. Powering up to 2 kA can be made without risk of damage to the magnets,
2. The existing QPS functionality will be available from the start of powering;
3. The new QPS layer to measure and interlock intermagnet splice resistance will be commissioned at low currents
4. The symmetric quench detection will be commissioned before going to currents higher than 2 kA;
5. At each step the resistance of joints and temperature increase in the sector will be measured
6. Steps are spaced such that the calorimetry and splice resistance measurements performed on each step permit to decide to proceed with negligible risk.

Two phases during the powering tests

- **PHASE I - Low current powering tests:**
  - Current limited to a value to be defined, with negligible risk of massive helium release
    - Restricted access to the tunnel, to powering sub-sectors where no test is ongoing
    - Access during powering tests only for people involved in the tests (PO, QPS and ELQA teams)
- **PHASE II - High current powering tests:**
  - The current in the circuits is not limited, massive helium release cannot be fully excluded
    - Access is closed & all necessary areas (tunnel AND service areas) are patrolled

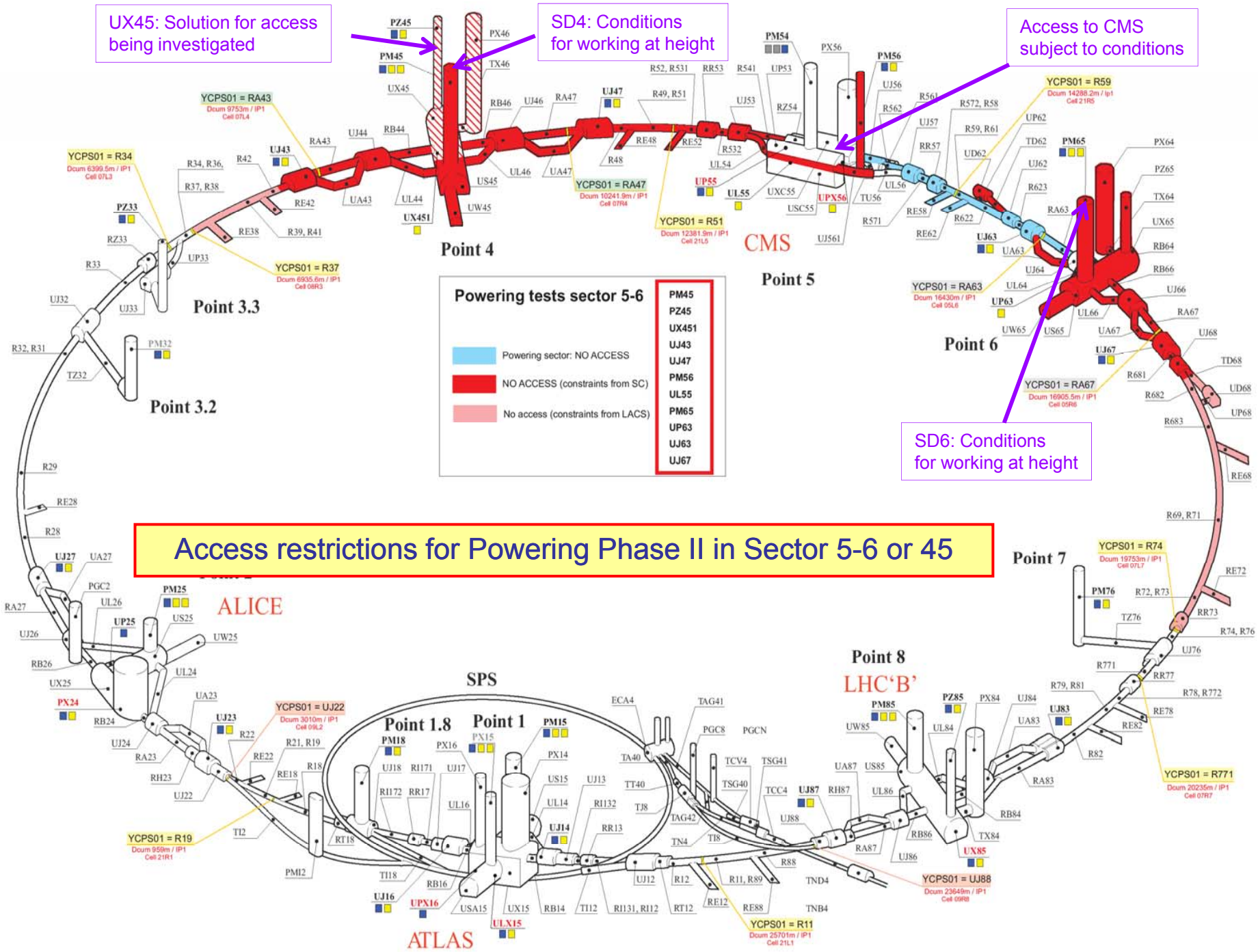
For each circuit (type), defined the maximum current in powering phase I

For powering phase II, define the areas that cannot be accessed

Maximum current in the different

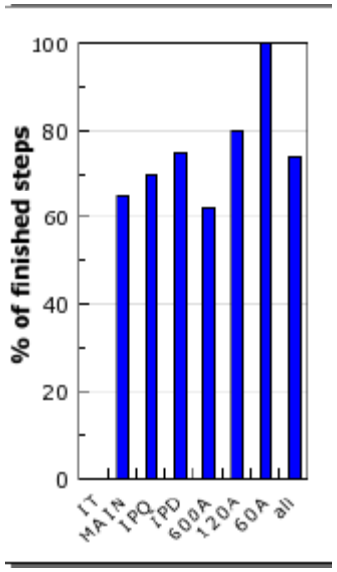
Circuit type	L [H]	Maximum current level	Energy [J]	Corresponding powering test step
main dipoles	15.708	0A	0.0E+00	PIC1
main quadrupoles	0.263	760A	7.6E+04	PLI1
arc individually powered quadrupoles	0.06	900A	2.4E+04	PLI2
600A circuits	0.432 (400A)	400A / 550A	3.5E+04	PNO
120A orbit correctors	2.84	120A	1.4E+04	PNO
60A orbit correctors	6.02	60A	9.1E+03	PNO
Stand alone quadrupole	0.296	600A	5.3E+04	PLI2
Stand alone dipoles	0.052	1000A	2.6E+04	PLI2
inner triplet quadrupoles (Q1+Q3/Q2a+Q2b)	L1 = 0.09 L2 = 0.038 L3 = 0.09	n.a.	5.9E+03	PCC

- Very similar to last year's limit **of 1000 A, except RB**.
- For the 600 A circuits, the maximum stored energy will be substantially below (35 kJ). Since the last test step is PLI2 for many circuits, the energy in other circuits is also far below 100 kJ.



Access restrictions for Powering Phase II in Sector 5-6 or 45

Results Powering Tests



Performed 74 % of the Phase I + Phase II steps

- 60A – all commissioning
- 80/120A – most commissioned
- 600A – many circuits commissioning started, some issues
- IPQ/IPD – commissioned for step in phase I
- RB – commissioned to 1 kA
- RQ - commissioned to 1 kA
- Inner triplet – not started

LHC Schedule

Schedule Status at beginning May

- In spite of the significant additional amount of work being done, the baseline schedule of February had been held due to
  - Additional manpower from inside and outside CERN (fantastic spirit of collaboration)
  - Re-optimization of the schedule on a regular basis
- In the meantime:
  - the cool-down of S12 had been delayed (2 weeks) to do R16 measurements (to confirm the R-long measurements)
  - Many more measurements (and repairs) have since been done and the understanding greatly improved.
  - Measurements at 80k in S45 indicated high resistance splices:
  - Decision to warm up S45 to 300K
    - To confirm the 80K measurements
    - In the shadow of this work: repair connection cryostat, prepare sector for DN200 (ALARA), and install twelve DN200 relief valves in mid arc

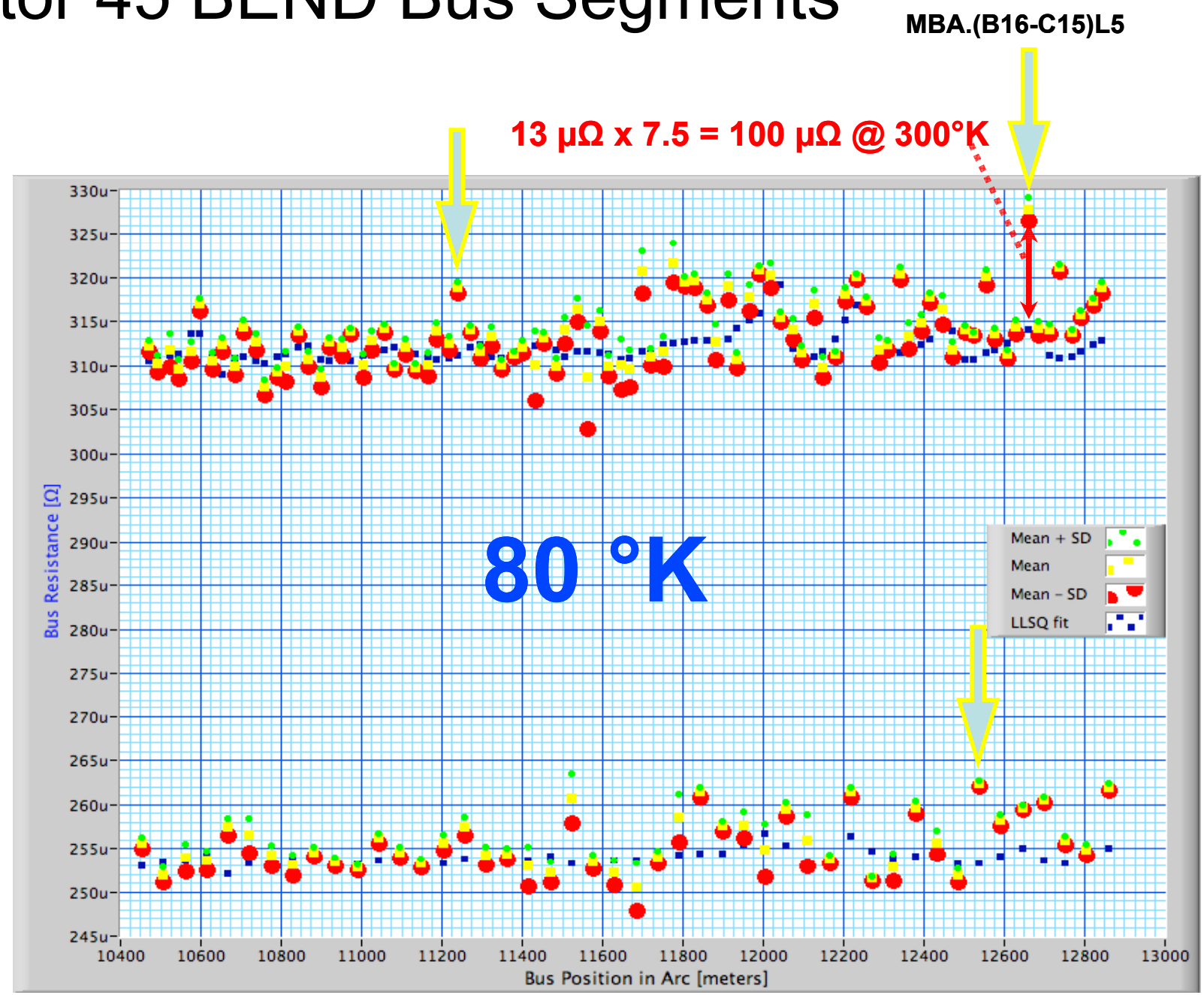
Strategy for Start-Up

- ~3 weeks delay with respect to baseline due to
  - R-long and R-16 measurements
  - Splice repairs
  - Delay in cool down of S12 and repairs of splices
  - (Re-warming of S45)
- BUT the story of the copper stabilizers goes on
  - Need to measure the remaining sectors (S23, S78, and S81) ?at 80K
  - Need to understand the extrapolation of measurements at 80K to 300K
    - Measurement of variation of RRR with temperature
  - Need to gain confidence in the simulations for safe current
    - Compare different simulation models/codes

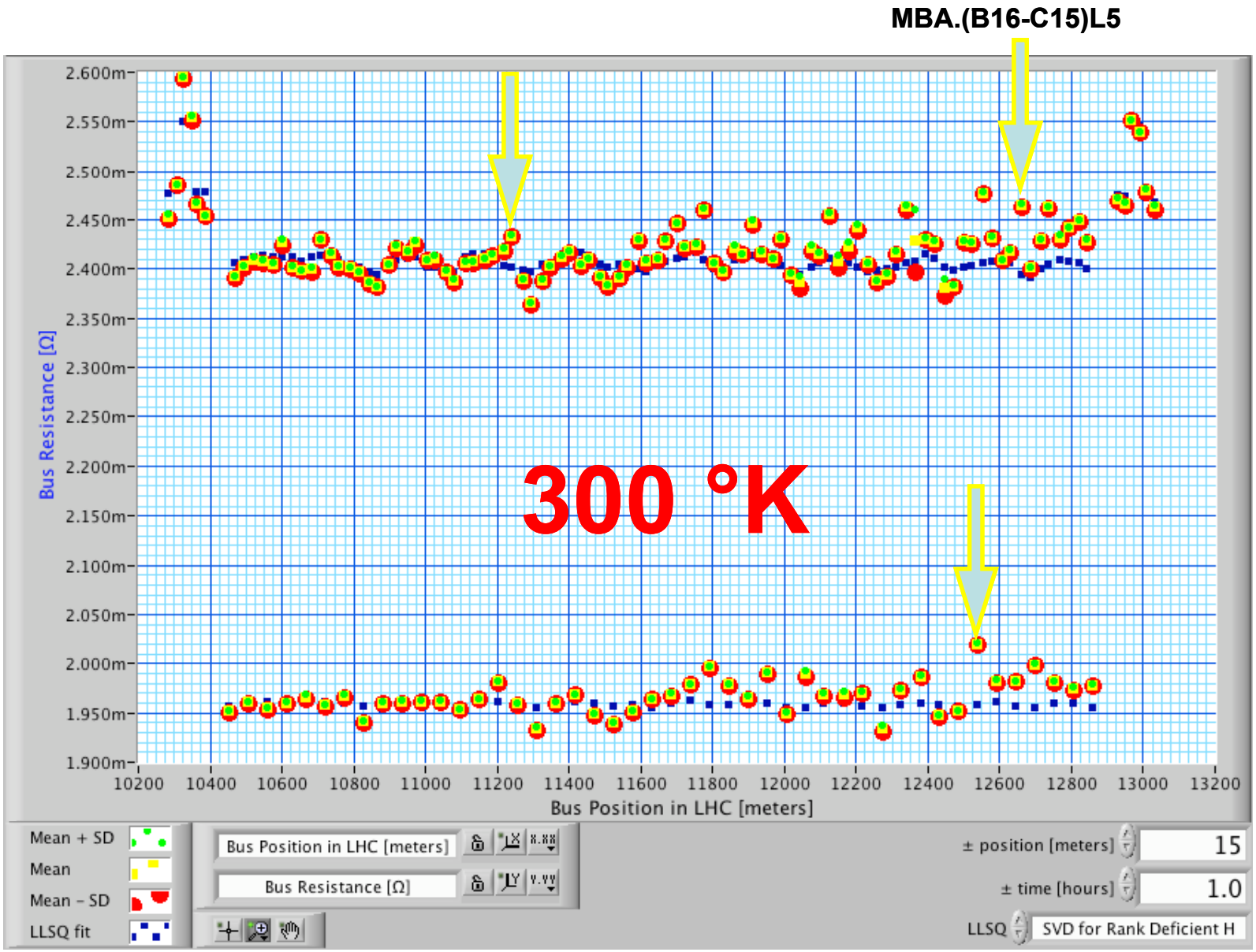
Strategy

- Measure S45 at 300k (DONE)
  - will be redone W28 (better temperature stability)
- Measure remaining 3 sectors (at 80K); last one (81) presently foreseen at beginning August
- Measure variation of RRR with temperature during cool down
- Update simulations (3 simulation models) of safe current vs resistance of splices
  - Decay times of RB/RQ circuits following a quench (?quench all RQs)
- Determine which splices would need to be repaired as a function of safe current (beam energy)
- Evaluate time needed to heat up to 300K and repair these splices
- Prepare scenarios of safe operating energy vs date of first beams
- Discuss with Directorate and experiments and decide on best scenario.
  - Preferred scenario :highest possible energy associated with earliest date
    - (what is the maximum energy with no repairs needed)
- At start-up confirm all splice resistance measurements at cold using new QPS

Sector 45 BEND Bus Segments

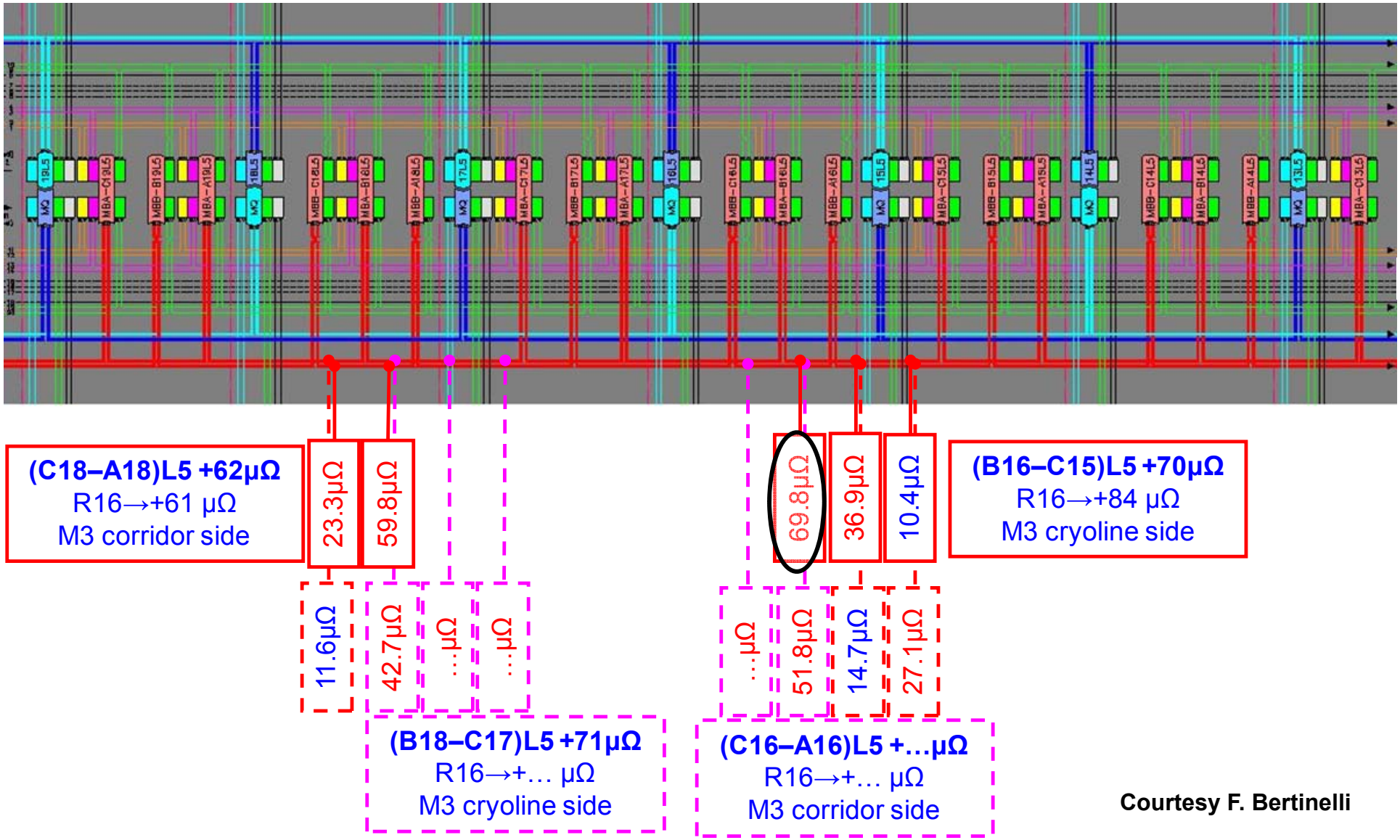


Sector 45 BEND Bus Segments



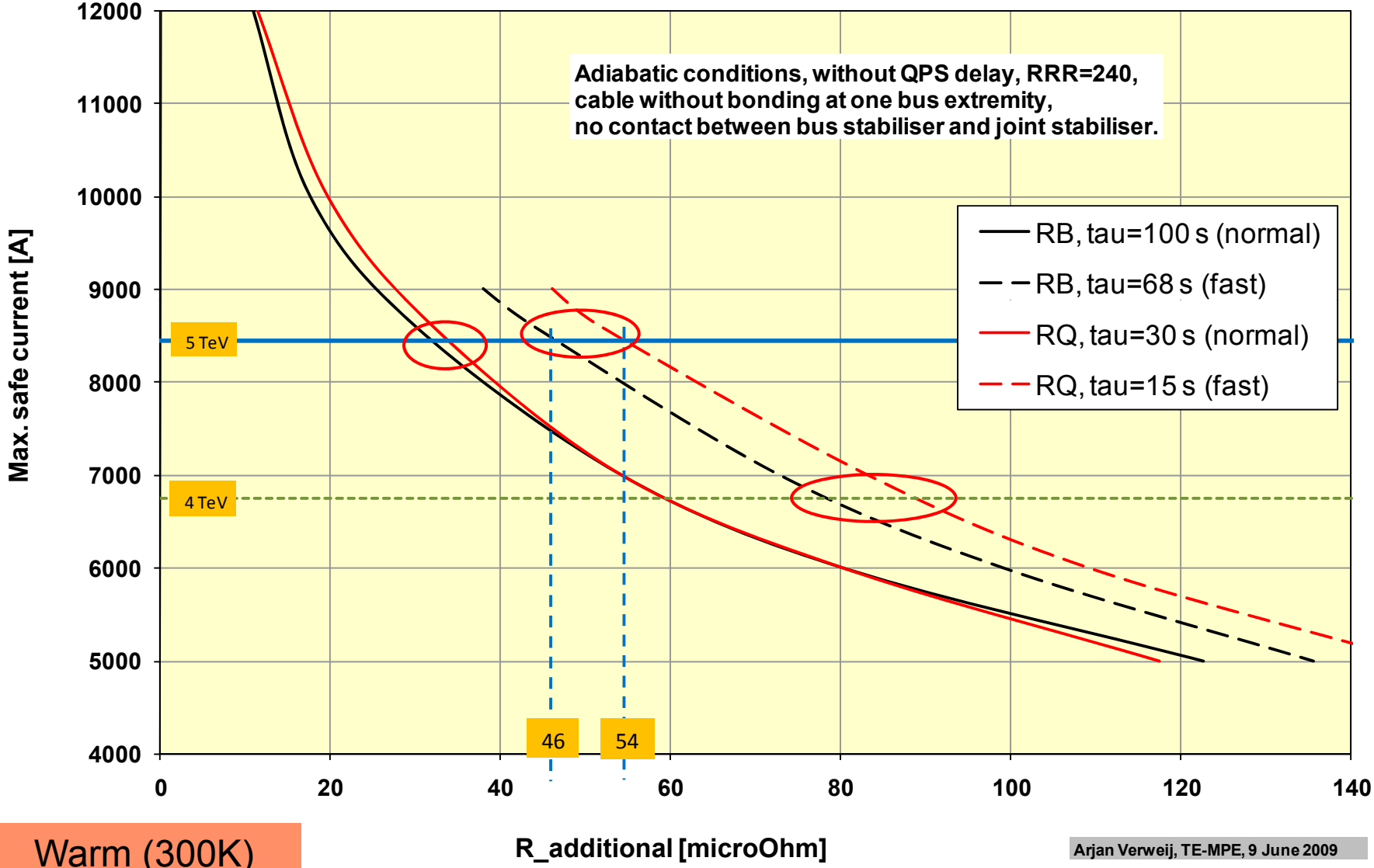
Sector 45 BEND Bus Segments

Local “R16” measurements

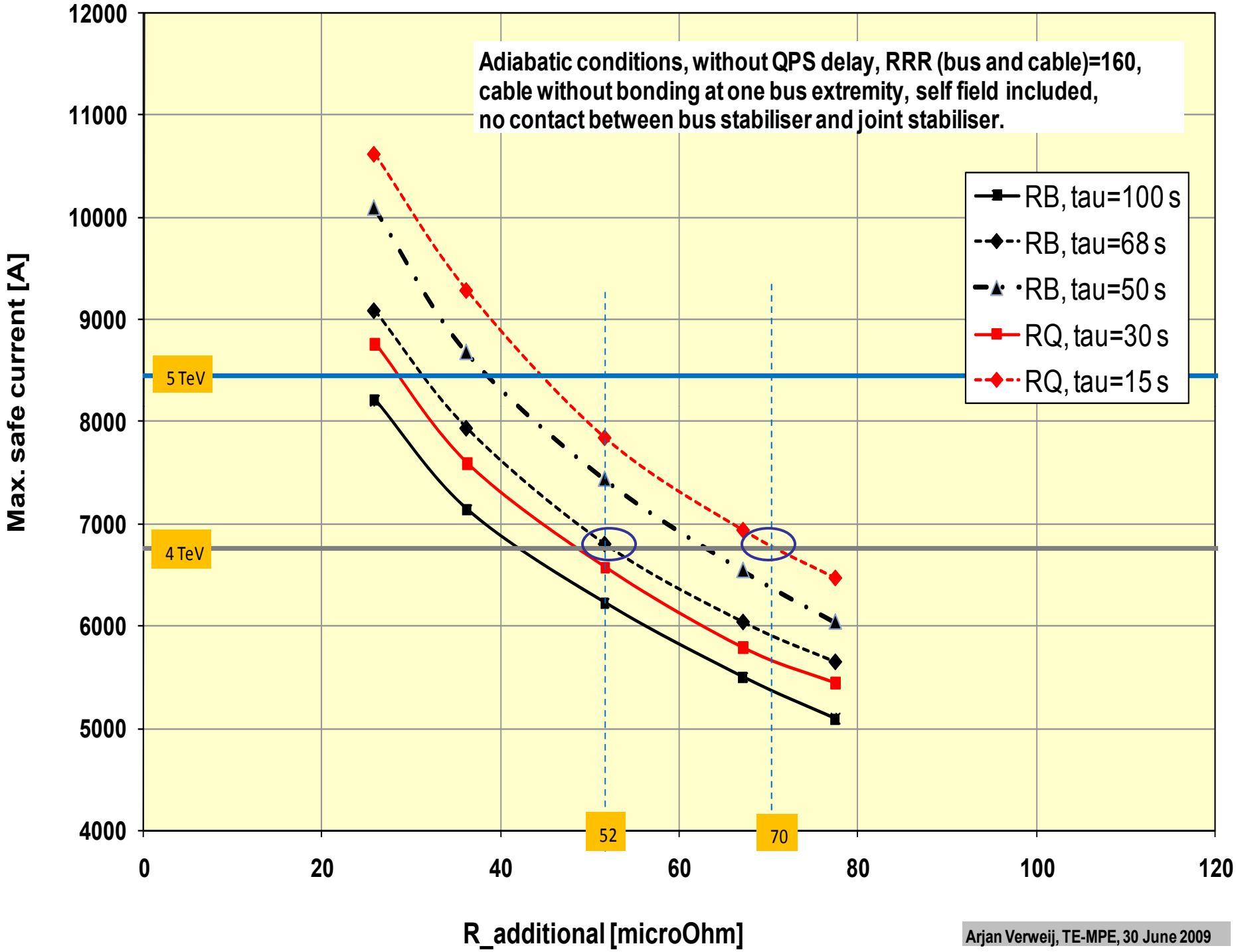


Courtesy F. Bertinelli

Simulations: Maximum safe currents vs copper joint resistance



Warm (300K)



Arjan Verweij, TE-MPE, 30 June 2009

Future Work Programme

Operational Consolidation : Strategy

1. we have prepared an inventory of
   a) the existing spares and spare components for the LHC
   b) the existing spare components of the LHC infrastructure
   c) Consolidation needed to increase the efficiency of safe operation of the machine in the longer term
2. we have prepared a preliminary estimate of the total materials cost
3. In the MTP, we have planned a budget of 25MCHF/year to carry out this programme
4. The time prioritization of the operational consolidation work will be done by Risk Ranking of the inventory (by September 2009)
5. The manpower needed to carry out this programme has not yet been identified

80

Operational Consolidation

Materials cost only

- Spares (29MCHF)
- Helium storage (7.7MCHF)
- Cooling Tower maintenance and consolidation (LEP/LHC HVAC) (33MCHF)
- Electrical network consolidation (43MCHF)
- Radiation to electronics SEU; continuation of protection (4MCHF)

Vertical Pits/shafts (30MCHF)

- Tunnel modifications for overpressure: safety requirements (5MCHF)
- ARCOM-RAMSES replacement (10MCHF)
- Improvement in controlled access system (5MCHF)
- Clamping of busbar splices, development followed by campaign of replacements? (12MCHF)
- Vacuum consolidation to reduce collateral damage in case of splice rupture (+ protection of experiments)

Not yet known how to do technically)

- Centralised radiation workshop (3.0MCHF)
- Consolidation workshops (3) Transport (12.8), Radio protection (4)...19.8MCHF
- Water cooled cable replacement (if FLOHE would not pay).. (4MCHF)

MTP Approved!

Very preliminary total cost 176MCHF or if shafts needed ~ 200MCHF + vacuum consolidation


LIQUID HELIUM
LIQUID H

Thank you for your attention

- LHC Shutdown work
  - Sector 34 repair
  - Consolidation in Other Sectors
  - “Collateral damage” work
  - Vacuum Work
  - New Quench protection system
  - Single Event Upset (radiation to electronics shielding etc)
- Splice Measurements
  - At superconducting temperatures
  - At non-superconducting temperatures
- Powering
  - Tunnel access restrictions
- Schedule and Strategy
- Future Work Programme

END