# LHC Status

2 July 2009

Jim Strait

Edited version of the talk
given at CERN today
by Steve Myers

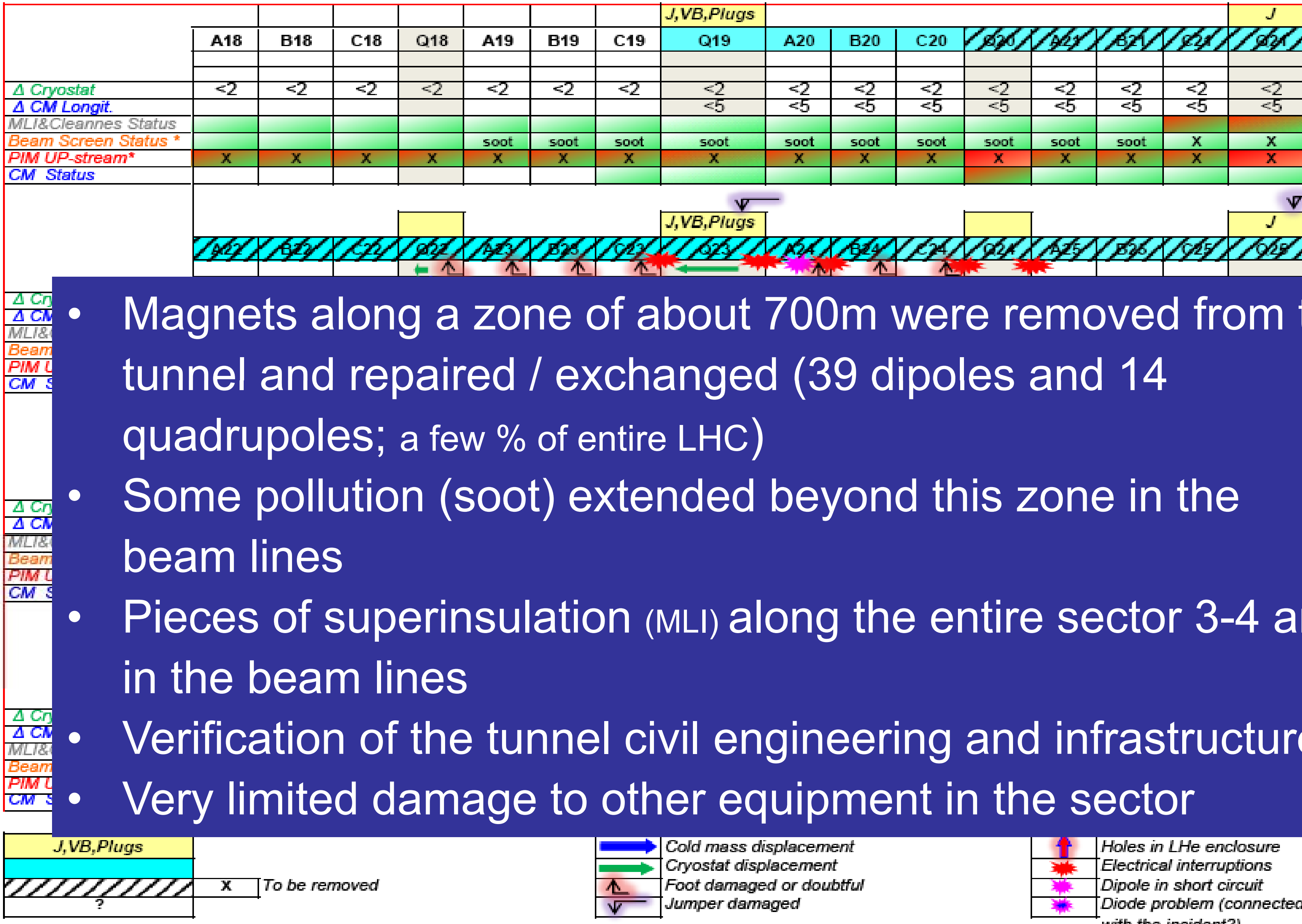
# Topics

- LHC Shutdown work
  - Sector 34 repair – magnets and beam vacuum
  - Protection against “collateral damage”
  - New Quench protection system
  - Consolidation in Other Sectors
  - Single Event Upset (radiation to electronics shielding etc)
- Main Magnet Bus Splice Measurements
  - At superconducting temperatures
  - At non-superconducting temperatures
- Powering
  - Tunnel access restrictions
- Schedule and Strategy

# Sector 34 Repair

# Sector 3-4 Event Findings and Observations Summary

(Based on investigation and measurements by AT-MCS, AT-MEI, AT-VAC, TS-MME and TS-SU)




- Magnets along a zone of about 700m were removed from the tunnel and repaired / exchanged (39 dipoles and 14 quadrupoles; a few % of entire LHC)
- Some pollution (soot) extended beyond this zone in the beam lines
- Pieces of superinsulation (MLI) along the entire sector 3-4 arc in the beam lines
- Verification of the tunnel civil engineering and infrastructure
- Very limited damage to other equipment in the sector

M.Modena, TE-MSC

30-Jan-09

# Status S34

## Sector 3-4:

- 39 dipoles and 14 quadrupoles re-installed
  - (last magnet in the tunnel 30.04.09)
- last M-line electrical connection finished 2nd June (13kA)
- Finished electrical ELQA tests
- 3rd June weld last N-line electrical connection
- All the PIMs are welded (28th May 09) and RF ball will circulate this week
- 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)

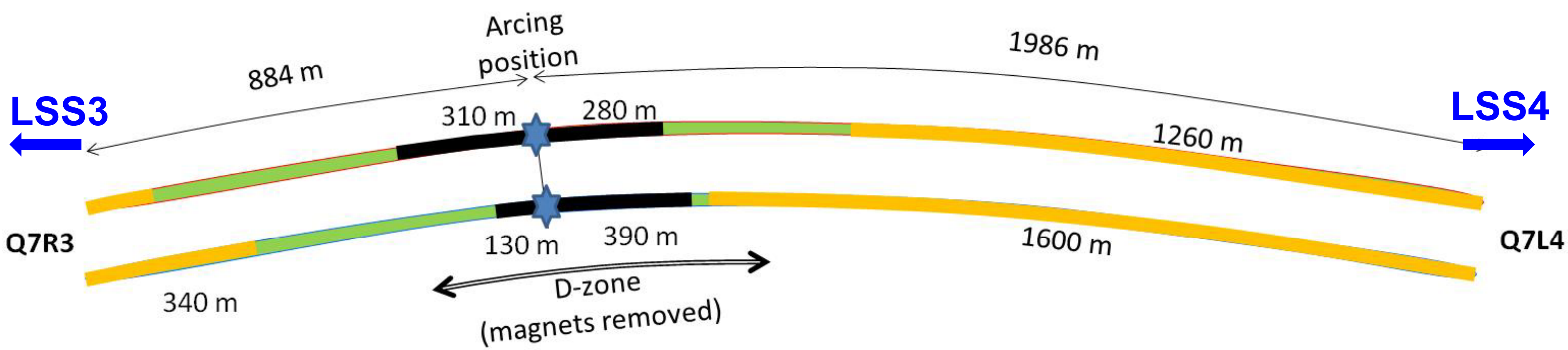
# Repair of QRL service module in S3-4

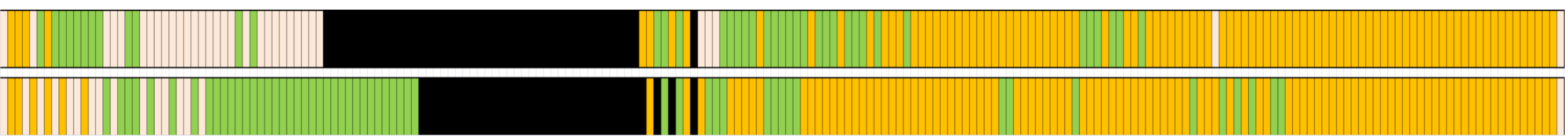

Before repair

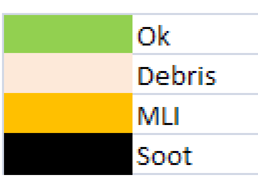
After repair

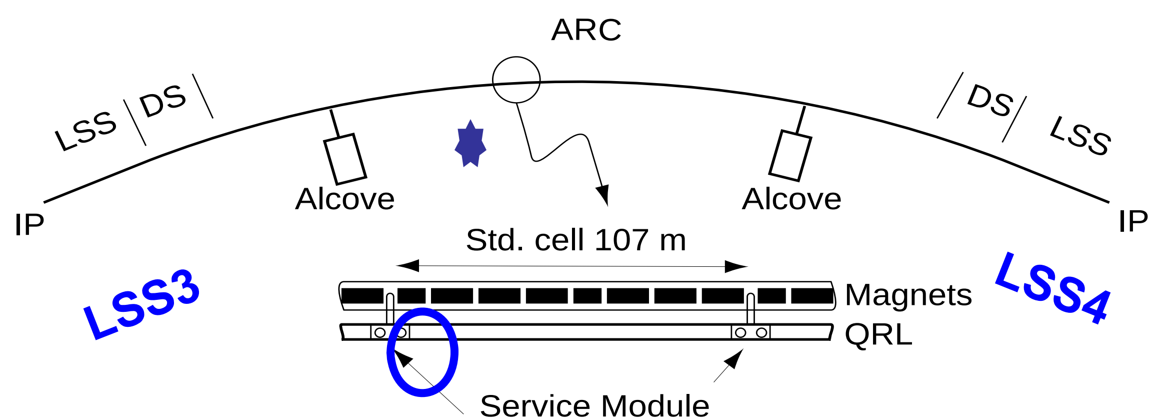
Q27

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





# 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. |
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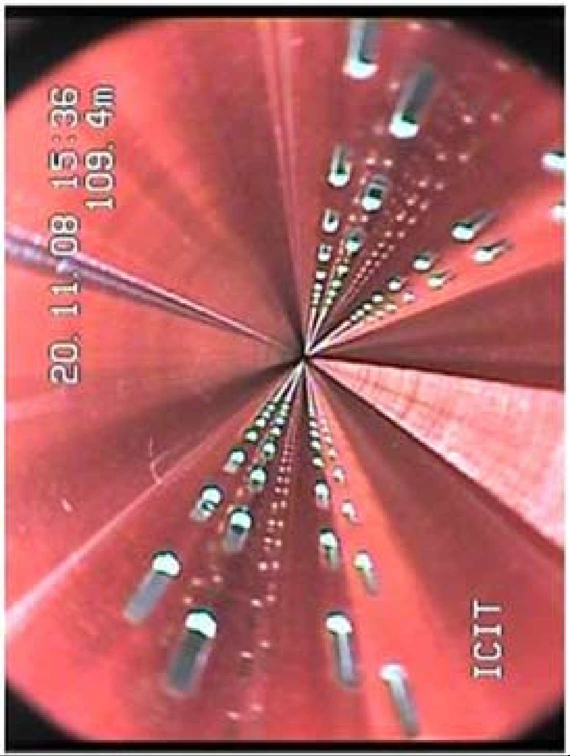
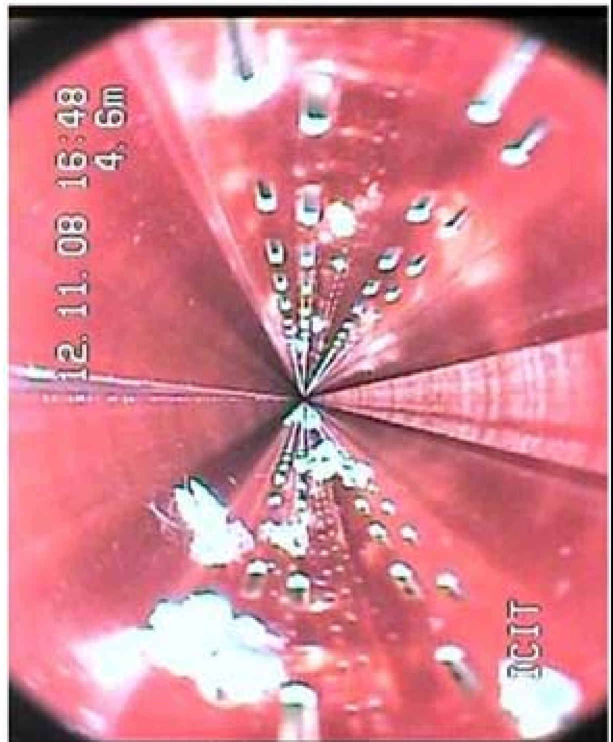
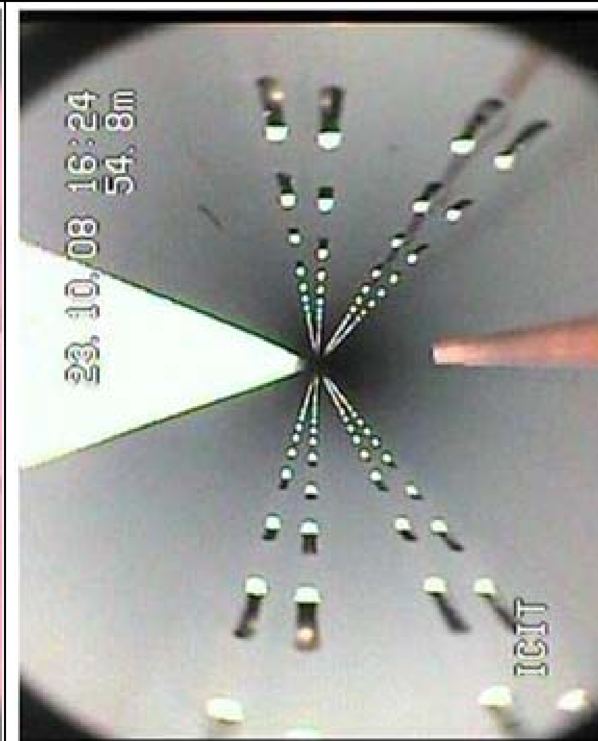
|  |  |  |

# 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)

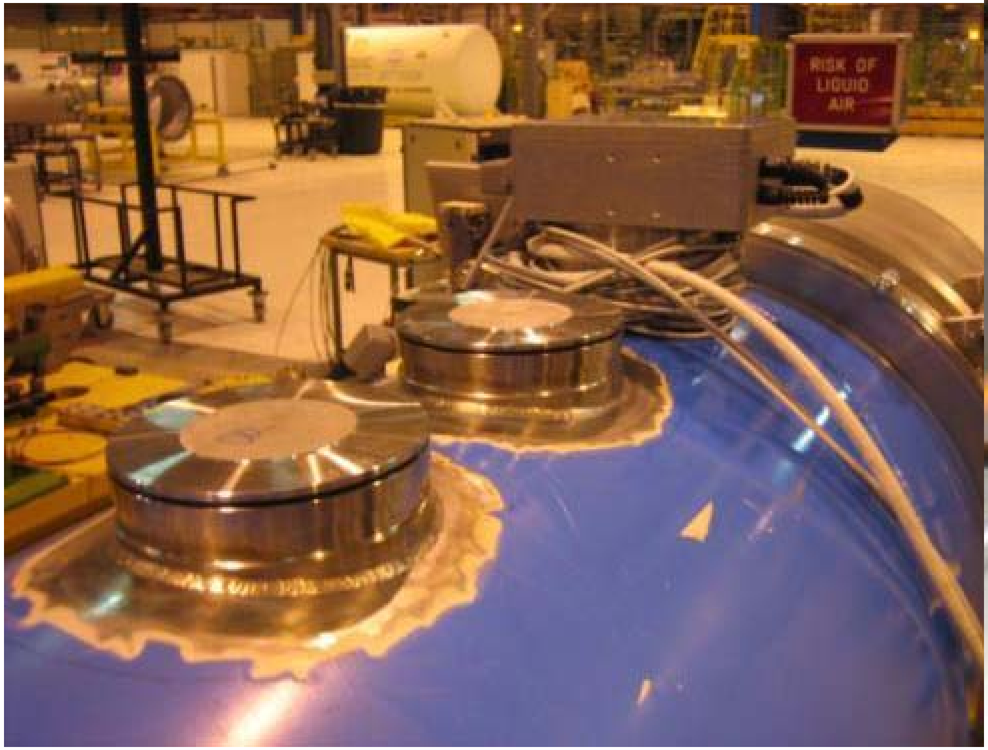
Today, the cleaning is completed and all magnets are reinstalled, closure and leak detections ongoing

# Improvements to reduce “Collateral damage” risk

# Status Collateral Work

- 200 mm relief ports added to cryostats of magnets in 4 sectors + long straight sections
  - 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%
- Convert available ports on SSS to be relief devices in other 4 sectors.
- Improved anchoring of to the tunnel floor:
  - Arc quadrupole (total 104 with vacuum barrier) : 50% done
  - Semi-stand alone magnet : done except 8L
  - Inner triplet and DFBA: started week 23 (*1 June*)

# DN200 installation (Arc + DS)

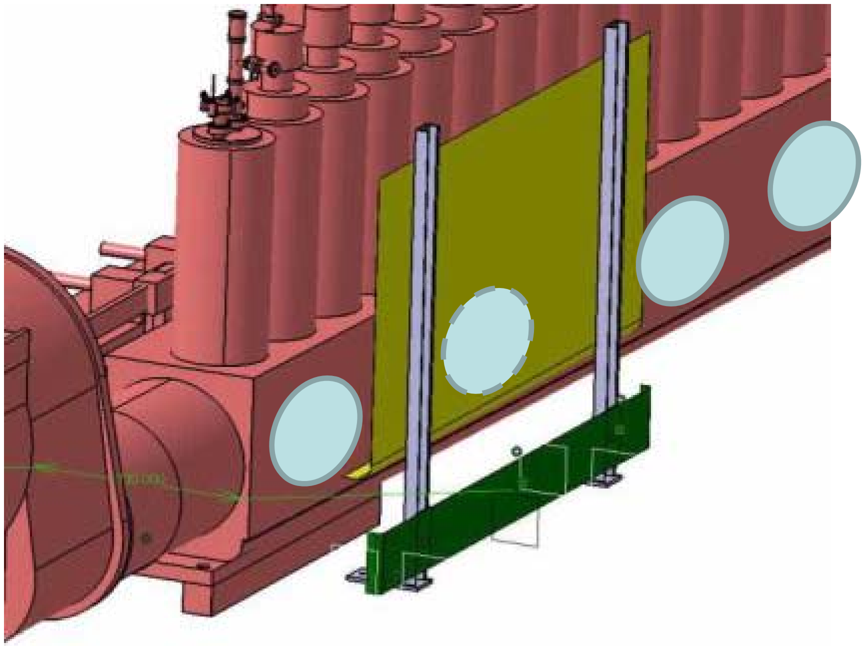


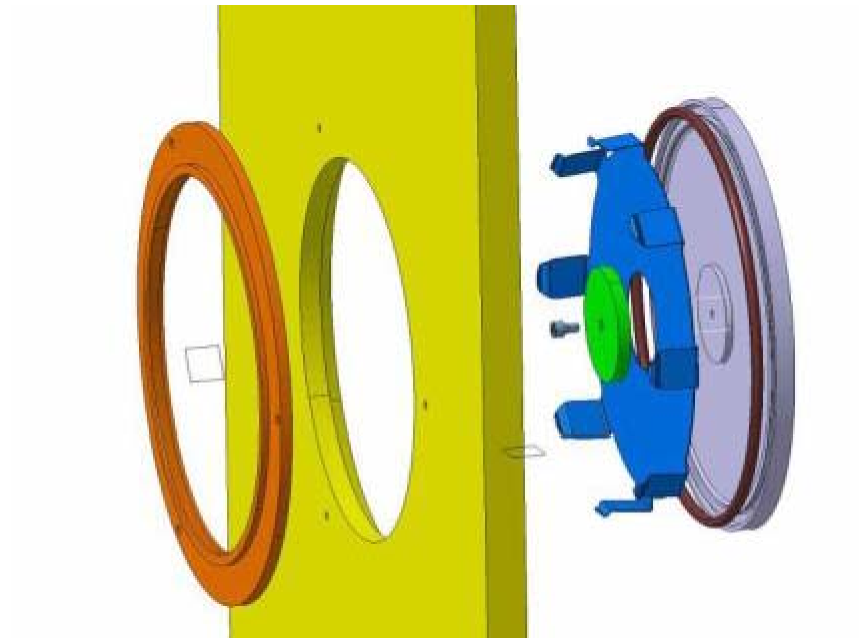

2 DN200 / dipole (DS and mid-arc)

P6 singularity

# Inner Triplet DN200

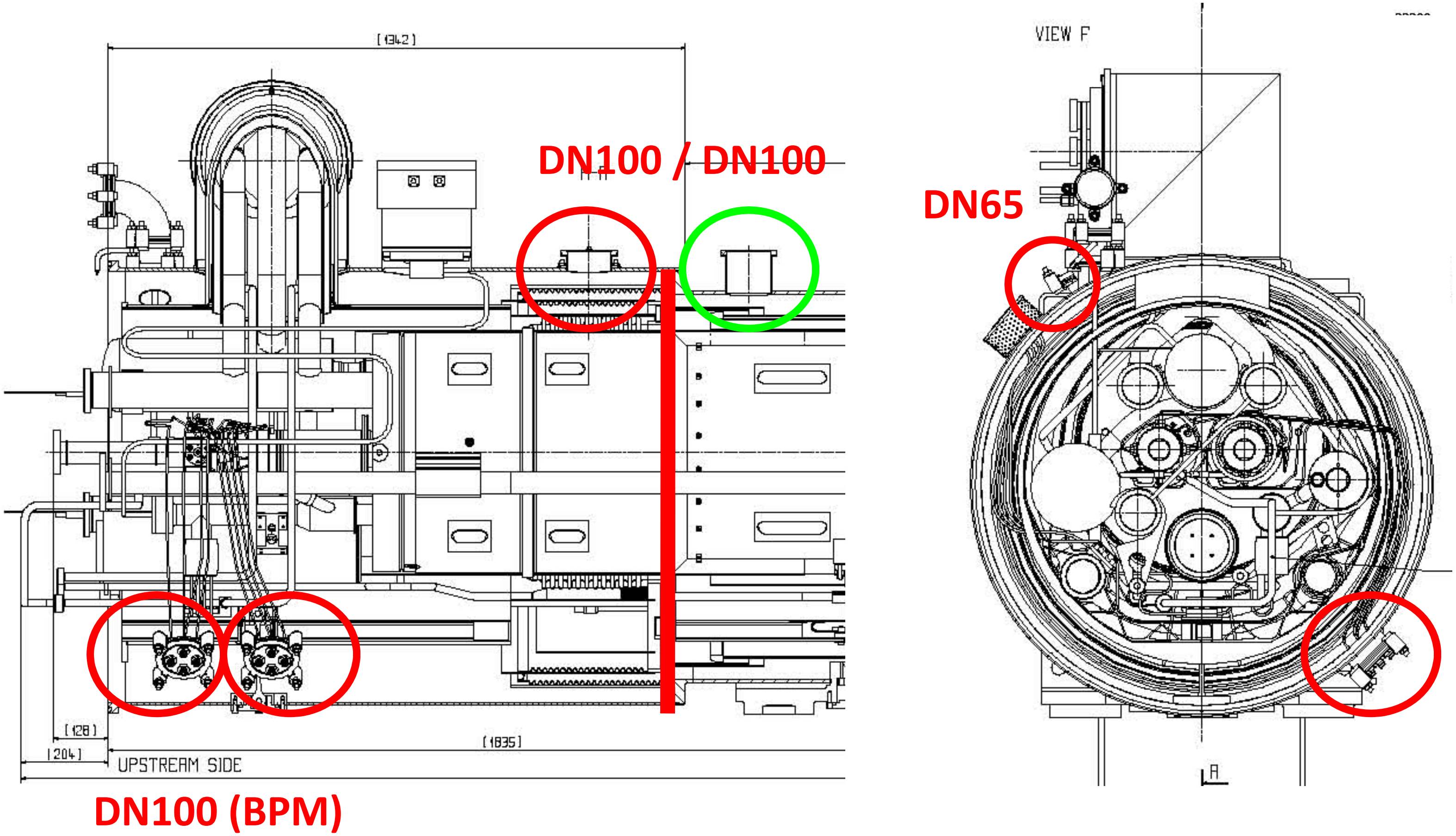
# Main Cryoboxes (DFBA)



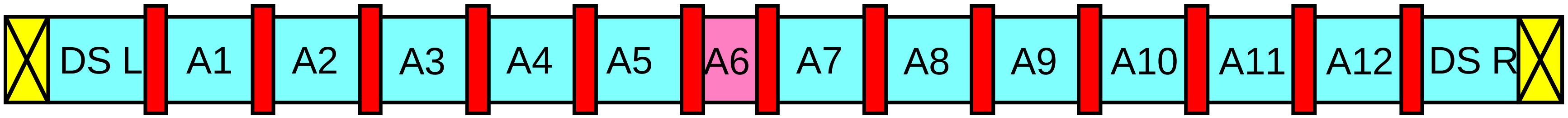



- Machining of doors started W23 (*1 June*)
- Consolidation rate: ~ 1.5 week per sector (including logistics & excluding deflector work)
- Deflector Interference with survey equipment to be studied

# Available ports on SSS at Q31R



# Opening by-pass at mid arc sub-sector?




| Ports | DS L | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | A10 | A11 | A12 | DS R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DN100 free | 6 | 5 | 5 | 5 | 5 | 5 | 2 | 5 | 5 | 5 | 5 | 5 | 5 | 8 |
| DN90 existing SV | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| DN100 BPM standard | 4 | 6 | 8 | 8 | 8 | 8 | 4 | 8 | 8 | 8 | 8 | 8 | 8 | 4 |
| DN100 BPM specific (Q7, Q9, Q11) | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| DN65 cryo-instrumentation | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 4 | 4 | 4 | 4 | 4 | 5 |
| DN100 sub-sector by-pass valve | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pressure (MCI, 60 K) [bar] | 3.6 | 3.3 | 3.2 | 3.2 | 3.2 | 3.2 | 5.5 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.0 |
| Pressure (MCI/2, 60 K) [bar] | 1.8 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 2.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.6 |

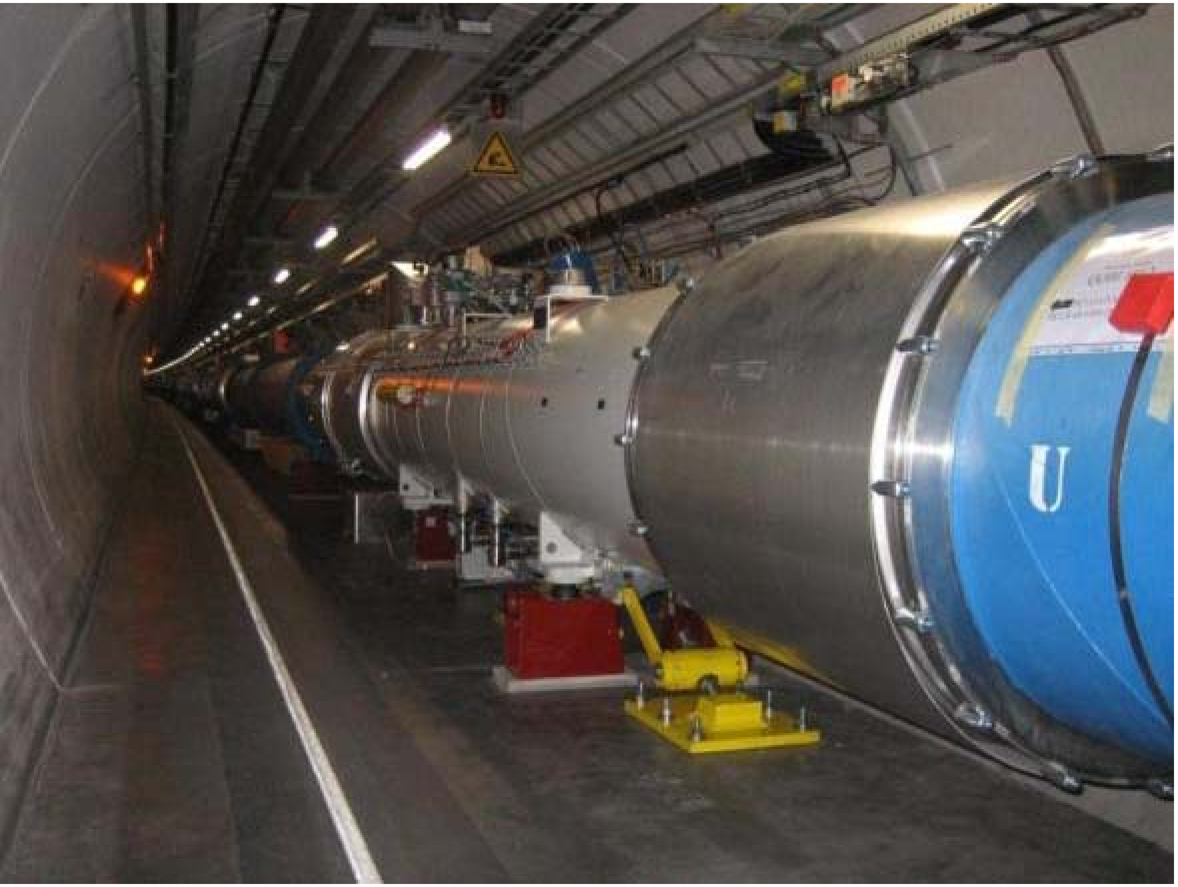
**Recommendations:** Green: to be used
Red: Keep as it is

-Risk of collateral damages in the mid-arc sub-sector ?

-Applies to non-consolidated sectors only 2-3, 7-8, 8-1, (4-5) at position Q31R

# SSS with vacuum barrier anchoring

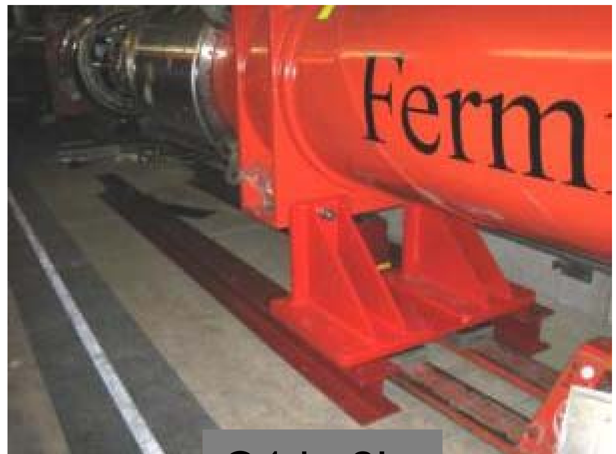
- Withstand longitudinal load of 240 kN
- A total of 104 SSS with vacuum barrier in 8 sectors



***Q15L2***

# IT anchoring consolidation
# → "case by case" approach

Q1 bumpers




Q1 in 2L

DFBX in 2 and 8

Q3 in 8R

DFBX

D1

# Enhanced QPS

# Role of the Enhanced QPS System

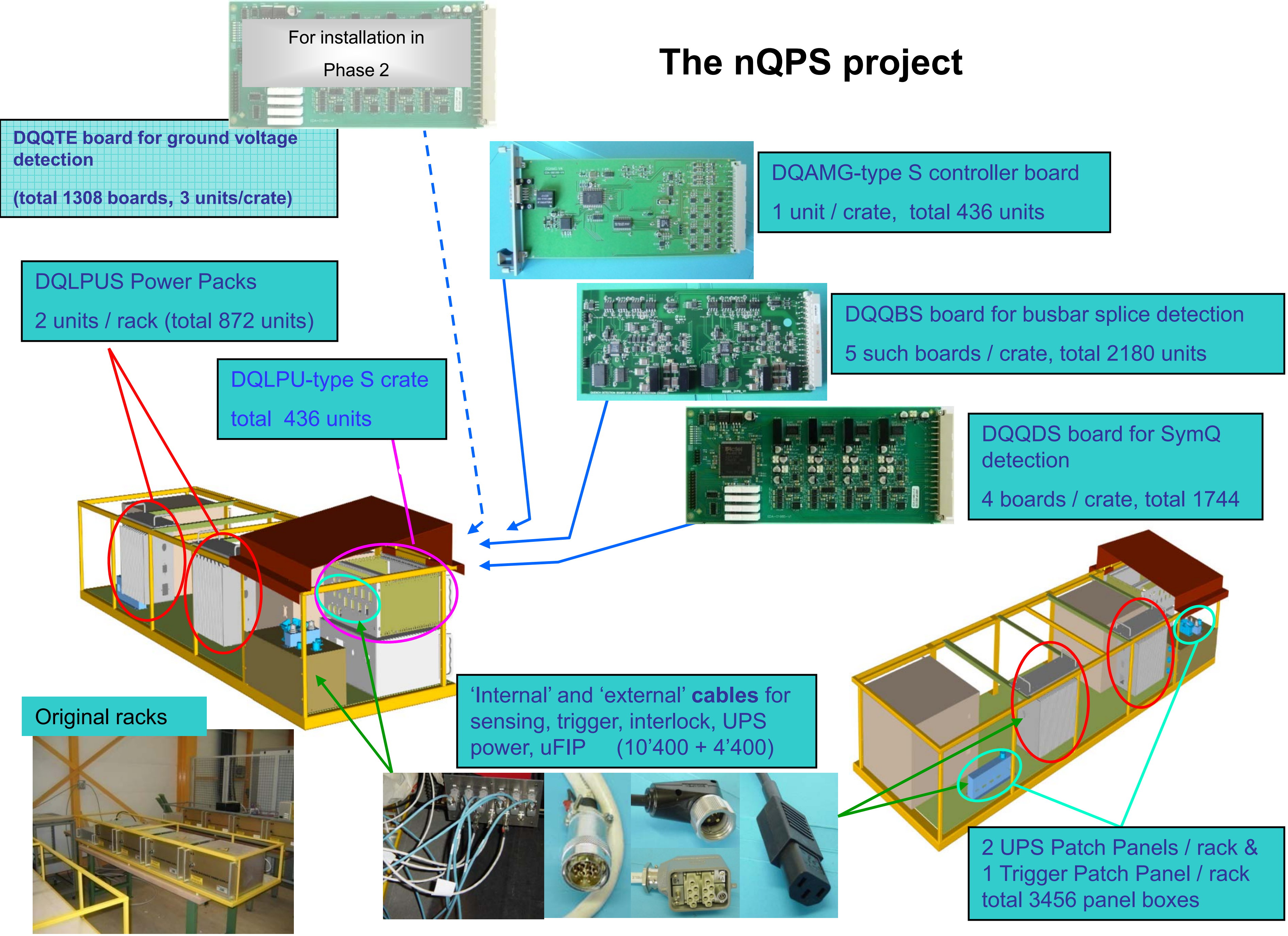
Reminder

- 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.

## 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
For installation in Phase 2
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
'Internal' and 'external' cables for sensing, trigger, interlock, UPS power, uFIP (10'400 + 4'400)
Original racks
2 UPS Patch Panels / rack &
1 Trigger Patch Panel / rack
total 3456 panel boxes

# 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.

# Enhanced QPS

❖ In spite of many additions since the original conception, project is on schedule

❖The collaboration strategy (as from March 2009) has allowed the schedule to be maintained

TE-EPC for Power Pack development and Burn-in tester design

PH-ESE for the Crate and SymQ Board development

PH-DT for help in QA, tester construction, commissioning

PH-CMS for help in radiation tolerance tests, mainly at PSI, Willigen

BE-OP and PH-CMS for LHC tunnel cable qualification

EN-ICE for electrical, electronics and mechanical drawing support

BE-CO for extension of the QPS software tools (a significant task) etc.

TE-EPC for tendering support and mass production follow up

Plus help from labs and institutes from all over the world

# Consolidation in Other Sectors

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

(1-2 : RF ball OK; closed 1st week of June)

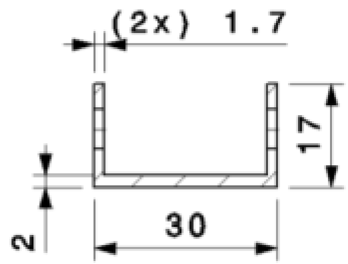
(6-7 : RF ball OK; interconnects repaired under progress, will be closed next week)

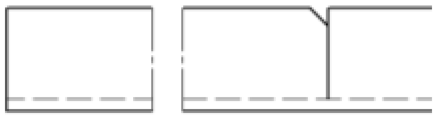
Sector 56 repair of connection cryostat

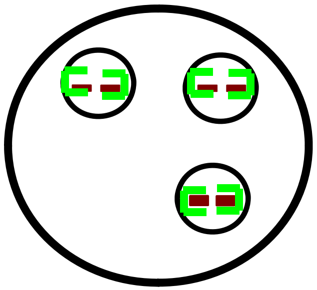
(RF ball OK; closed week 24)

Sectors 12, 34, 45, 56, 67: Measurement and repair of high-current bus joints

# Connection cryostats







# Up to the Minute Status

# Tunnel News

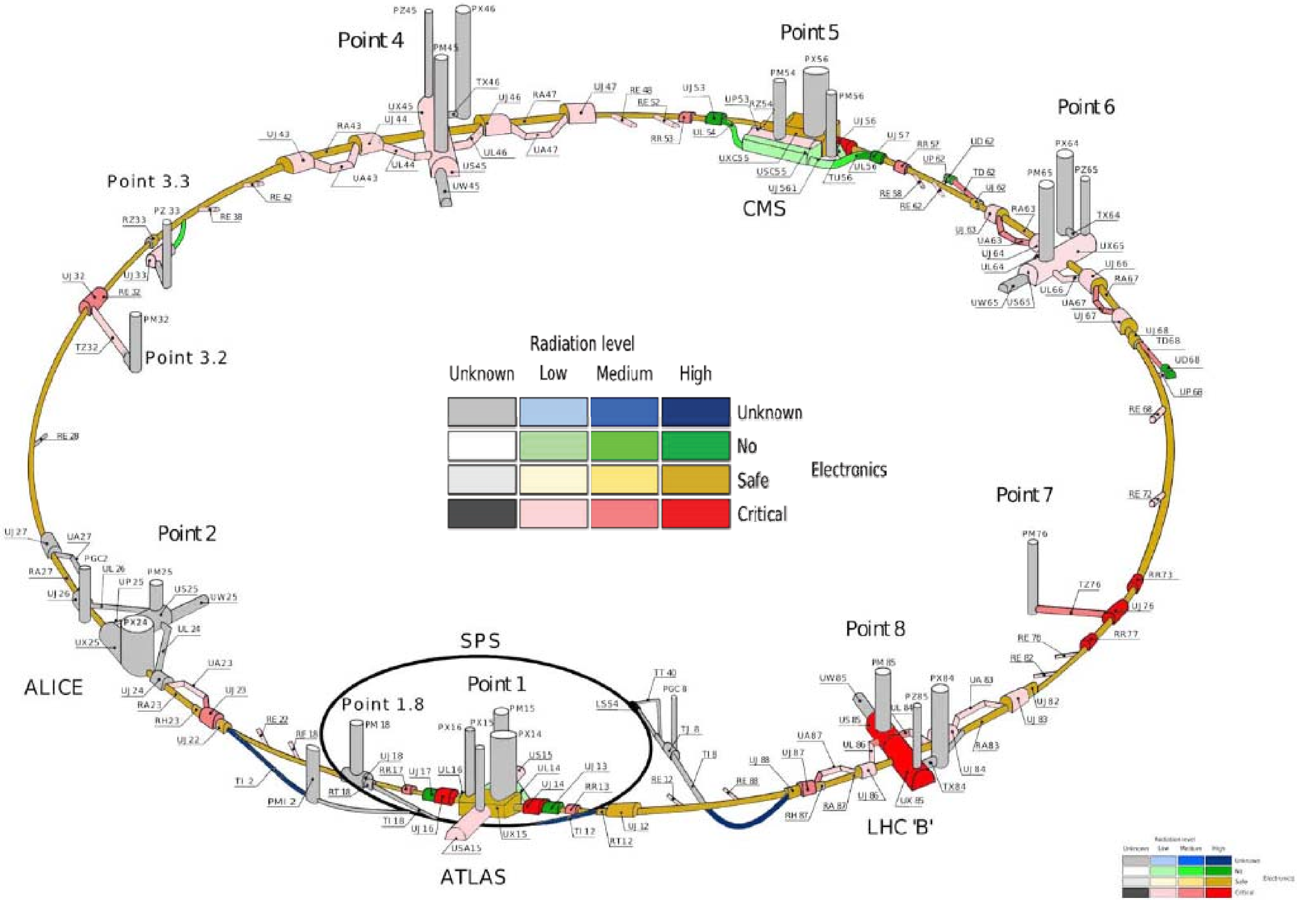
- Sector 3-4: last cryostat vacuum bellows closed Tuesday 23 June
- Sector 5-6: last cryostat vacuum bellows closed Friday 26 June
- Sector 1-2: cool-down started
- Sector 6-7: objective all closed by 10 July.
  Large workload:
  - 46 busbar splices to be resoldered, 25 (x5) spools for US welding
  - 67 bus-bar connection bellows to be rewelded and cryostat vacuum bellows to be closed

# 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

# Protection of Electronics from Radiation

(Single Event Upsets)



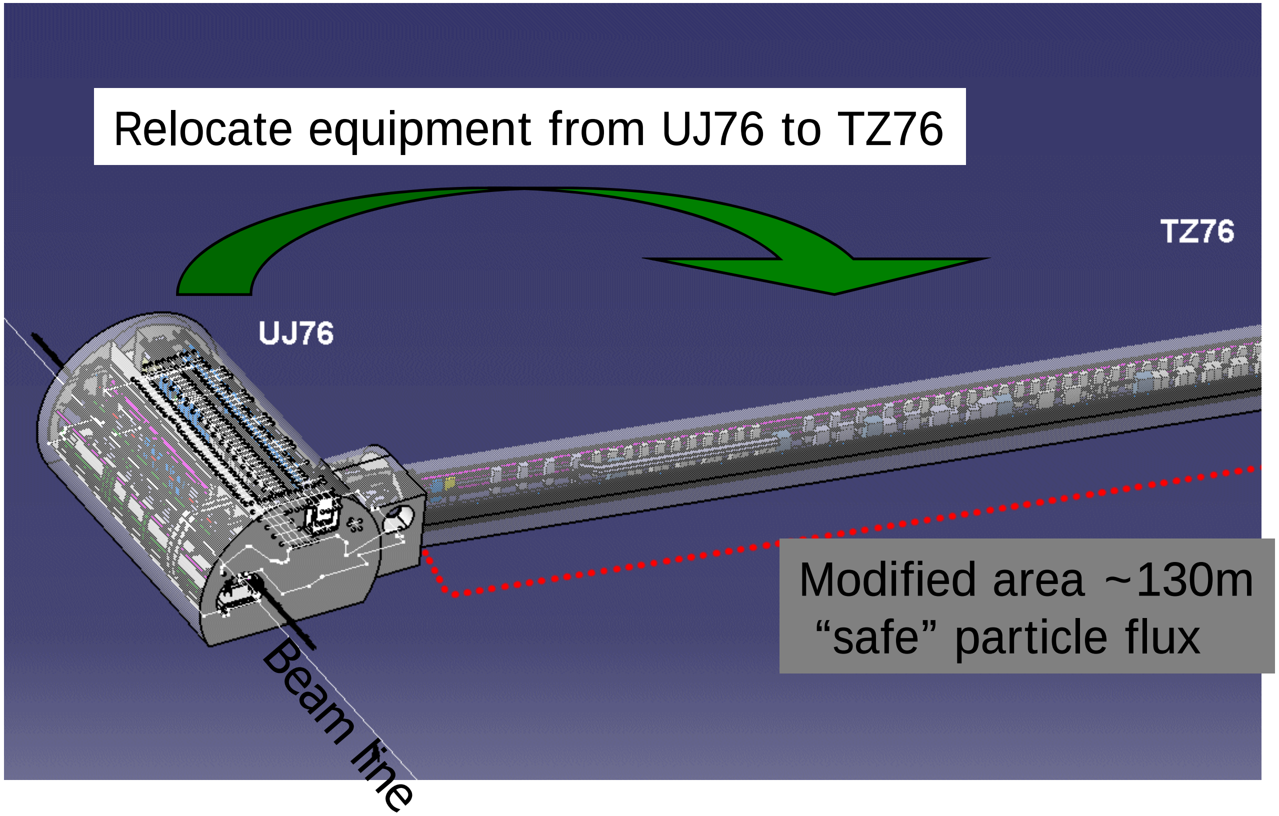

# Overview of Regions – Colour Coded

# 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

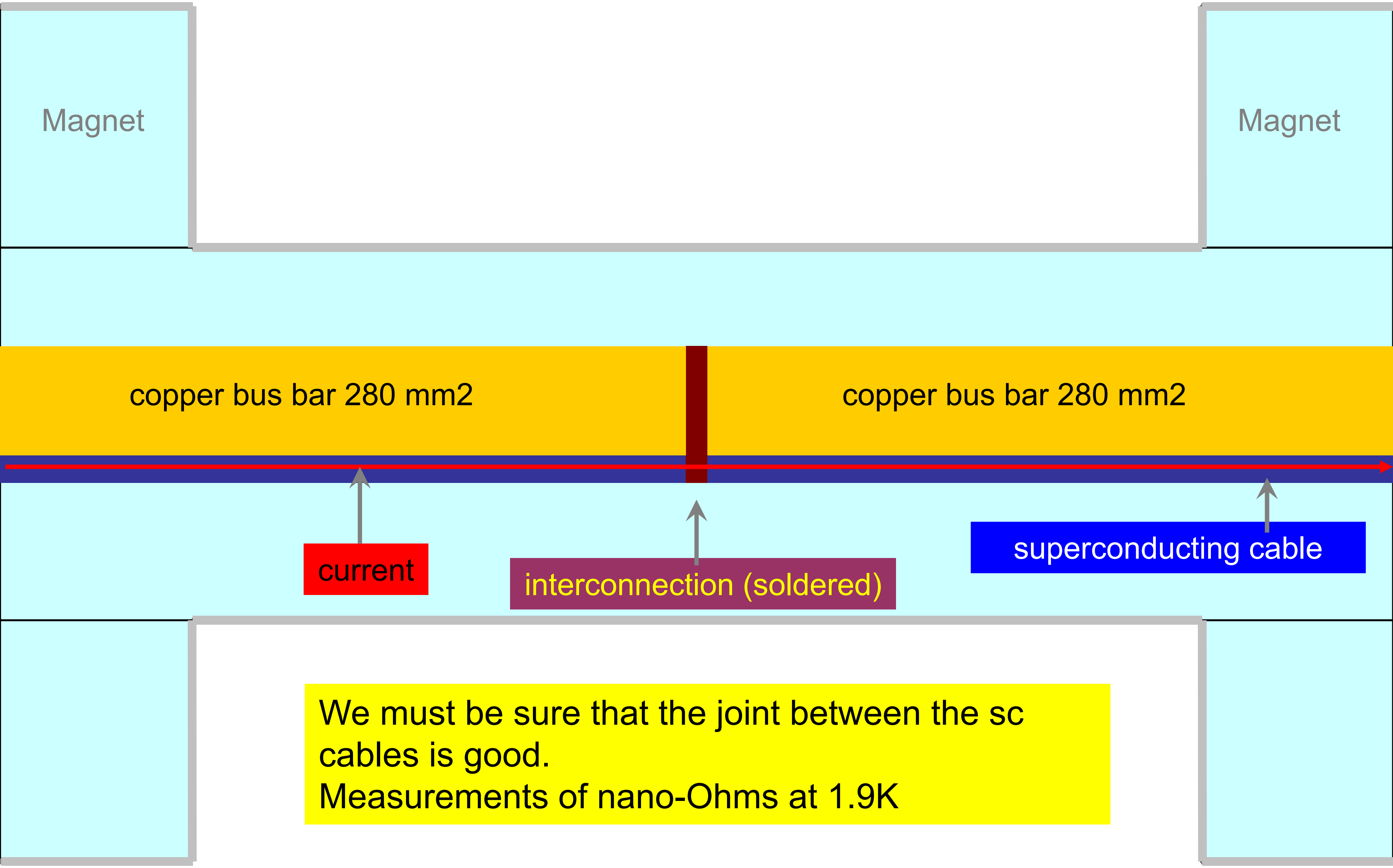
UPS re-installed in TZ76

Installation of services to relocate the Power Converters

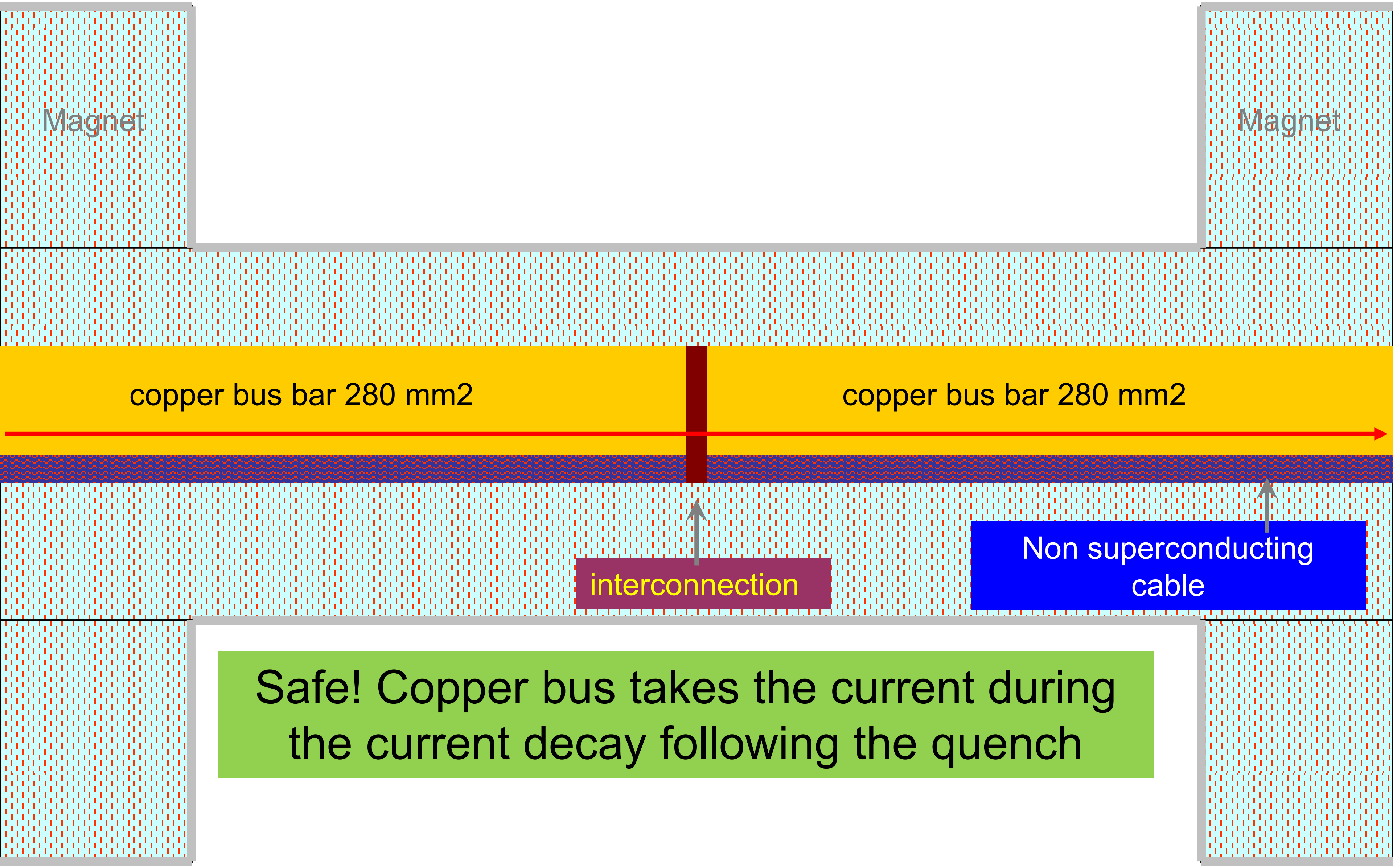
Iron shielding wall to protect the Safe Room

# Splice Resistance Measurements

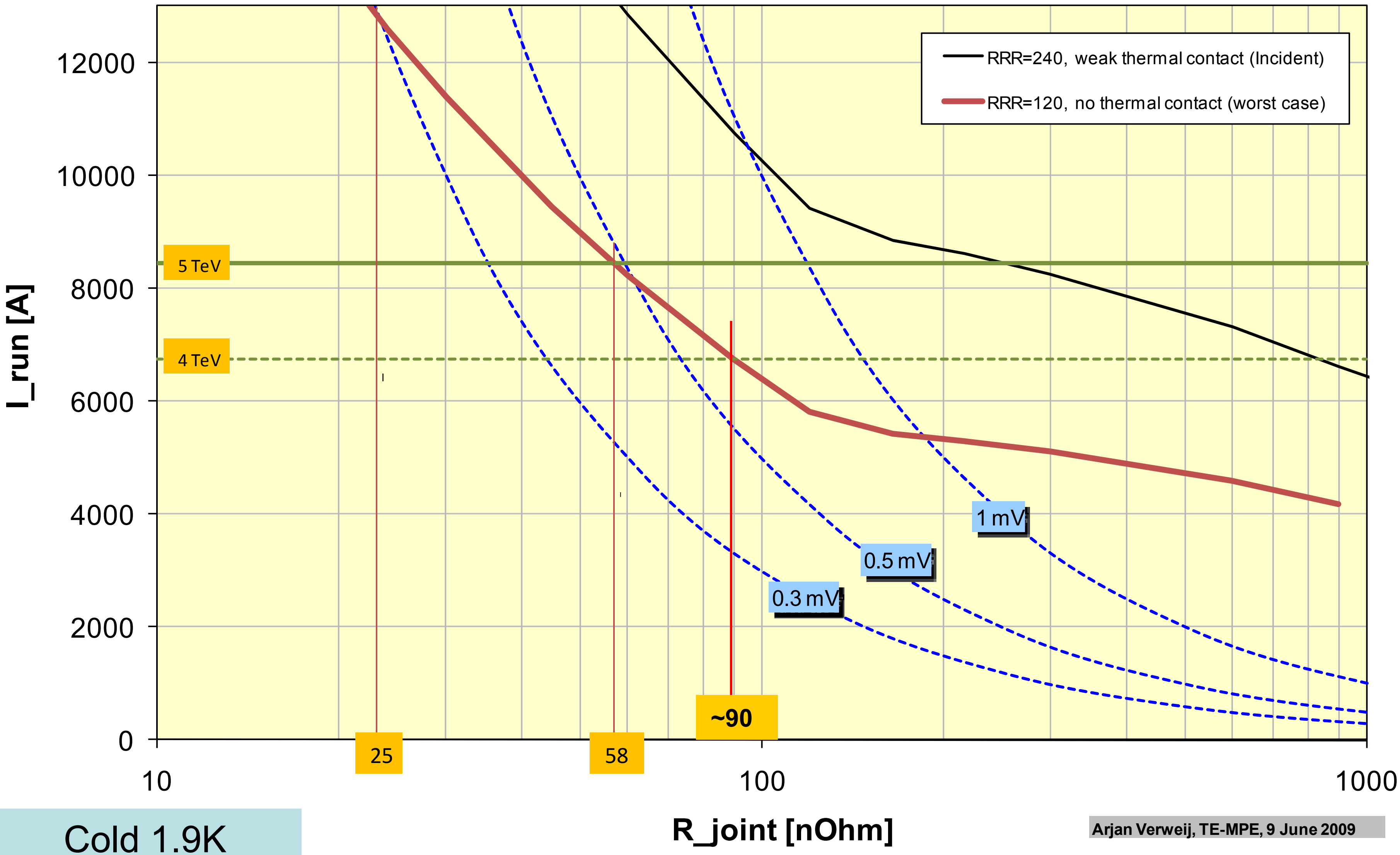
# Good interconnect normal operation (1.9K)



# good interconnect, after quench (>10K)



# 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)<br>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

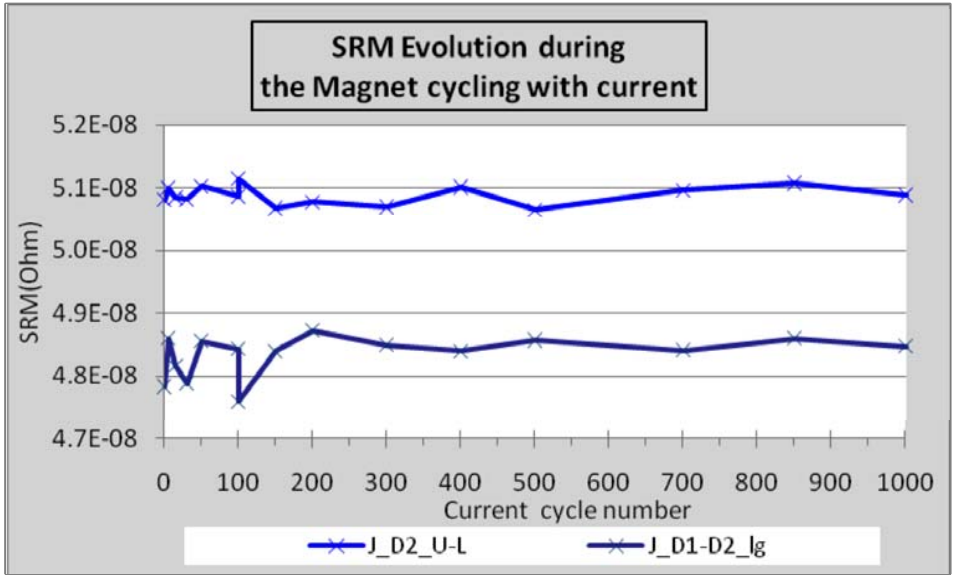
MB2303 Cold Testing

**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

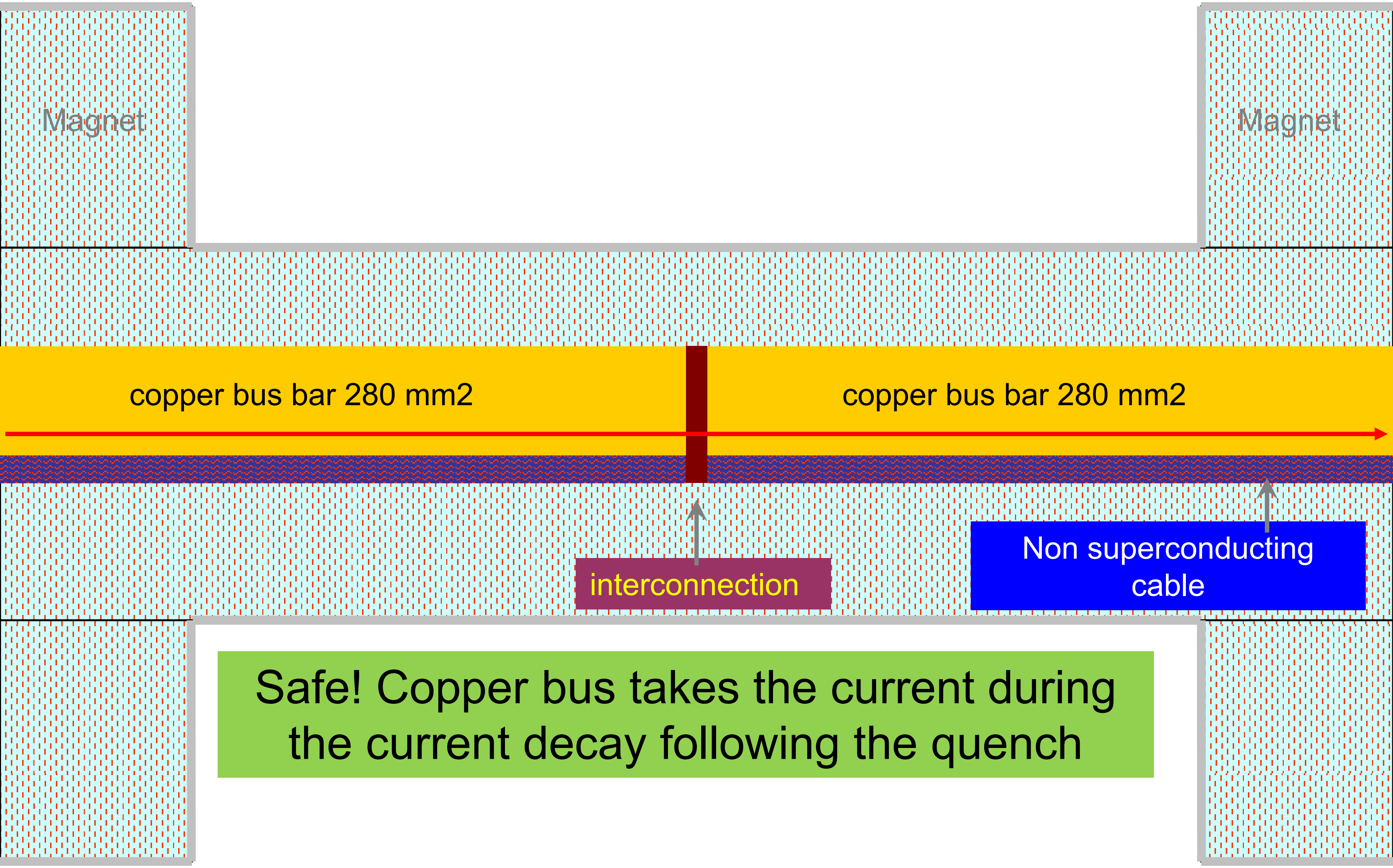
**Training up to 11850 A**
Before test: **51.6** nOhm
After quench @10898 A: **51.5** nOhm
After this quench, the magnet reached 11850 A.




**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

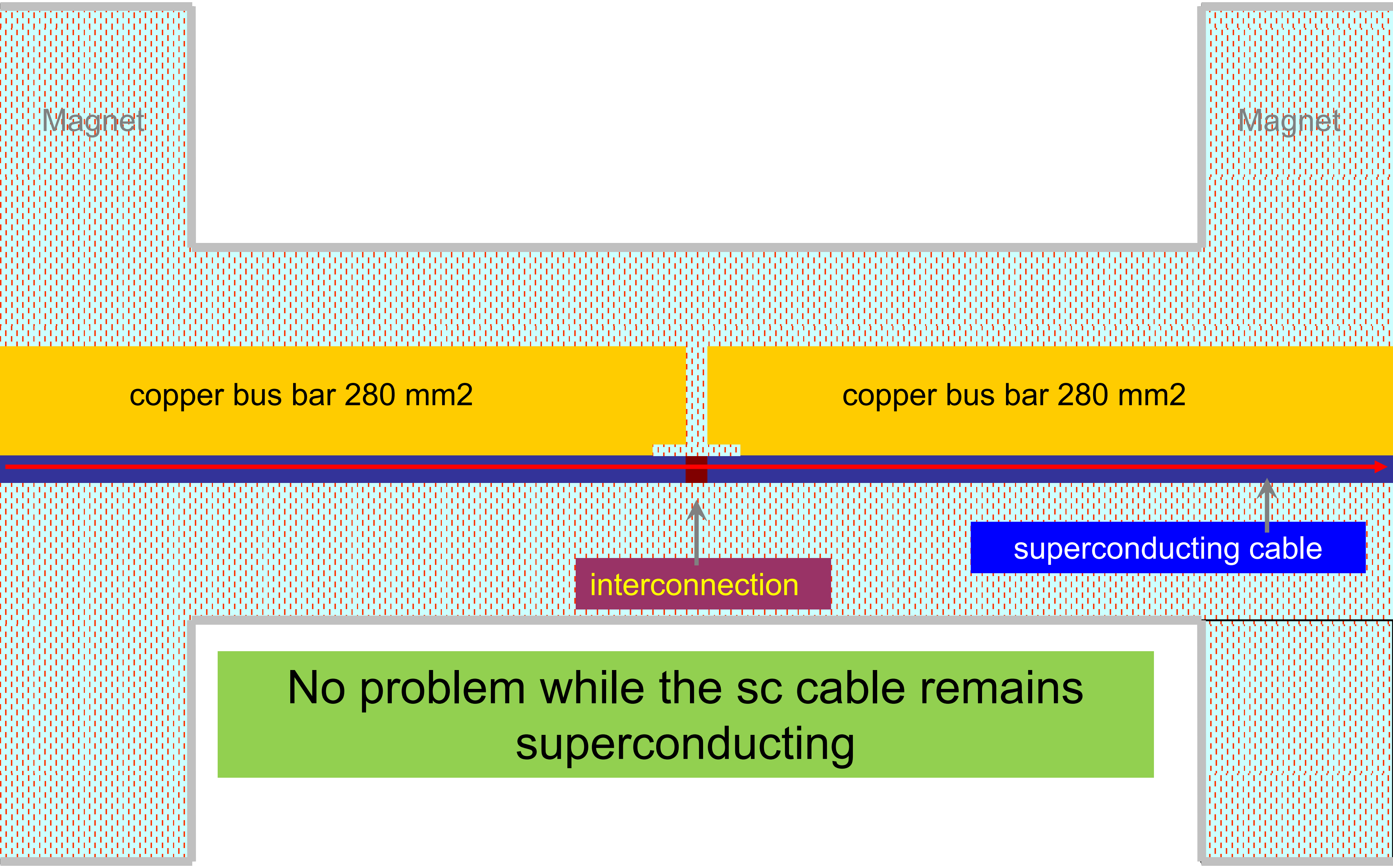
Courtesy M. Bajko

# good interconnect, after quench (>10K)



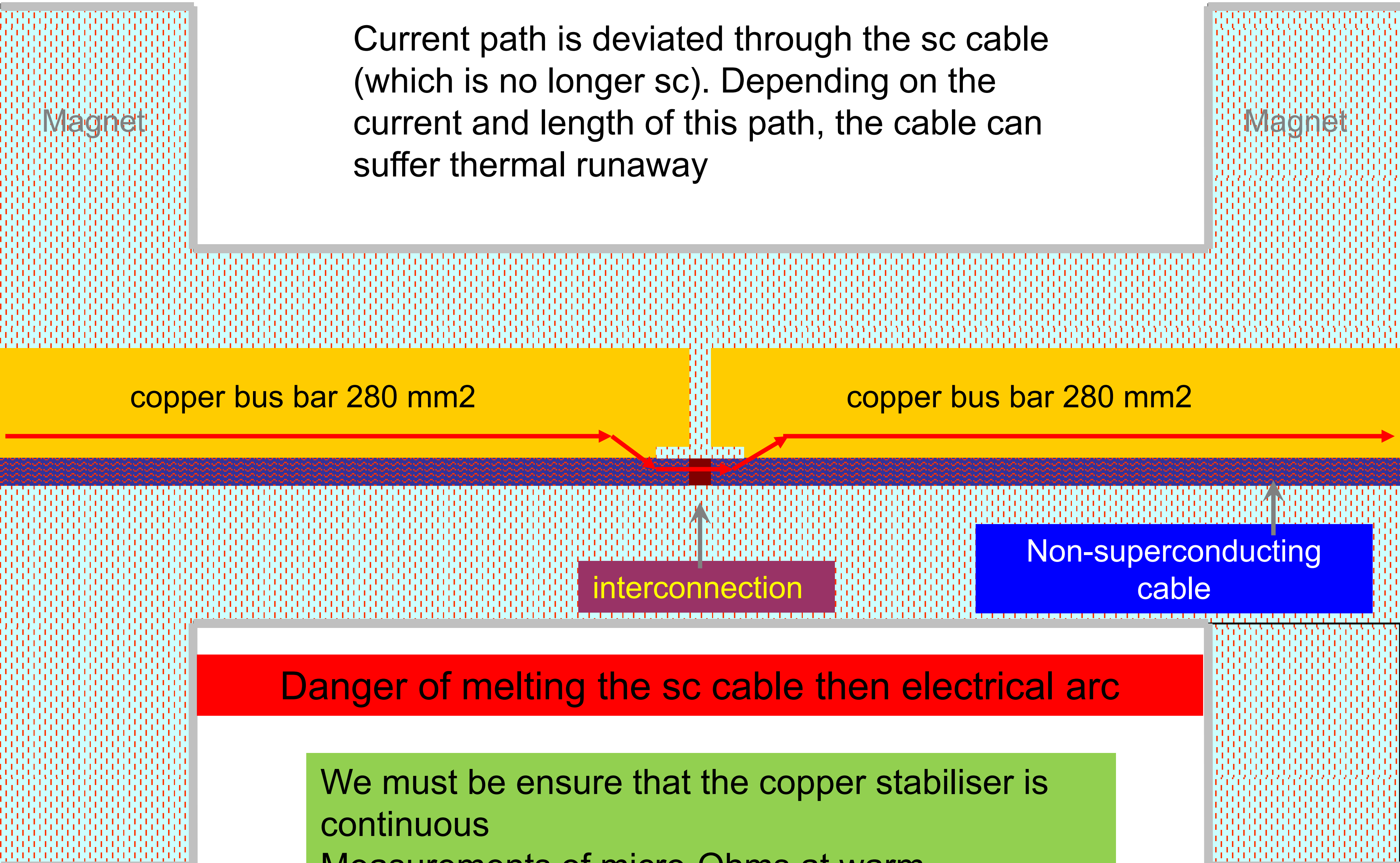

Safe! Copper bus takes the current during the current decay following the quench

# Bad interconnect, normal operation 1.9K



# Bad interconnect, after quench

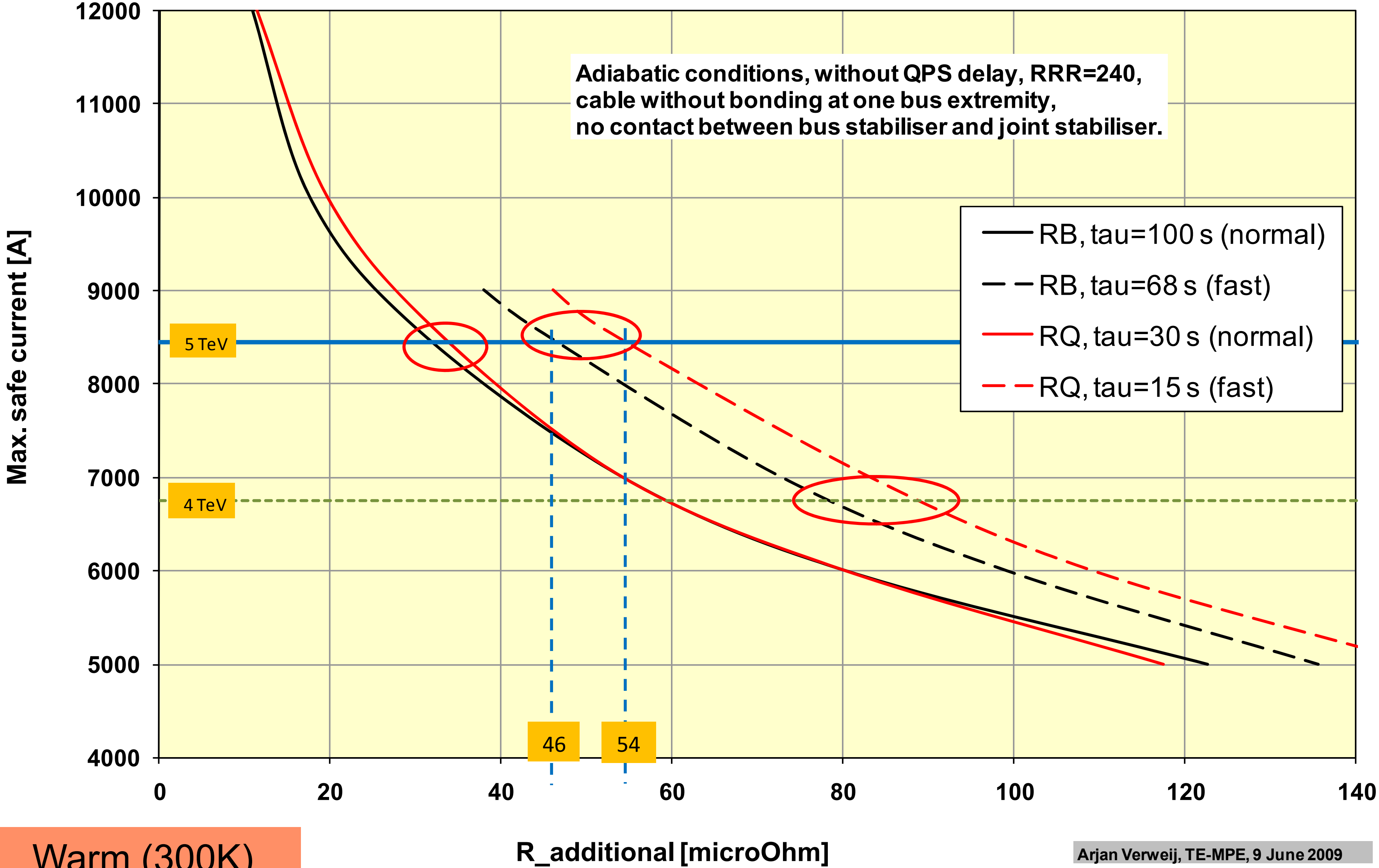
Current path is deviated through the sc cable (which is no longer sc). Depending on the current and length of this path, the cable can suffer thermal runaway




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 safe currents vs copper joint resistance

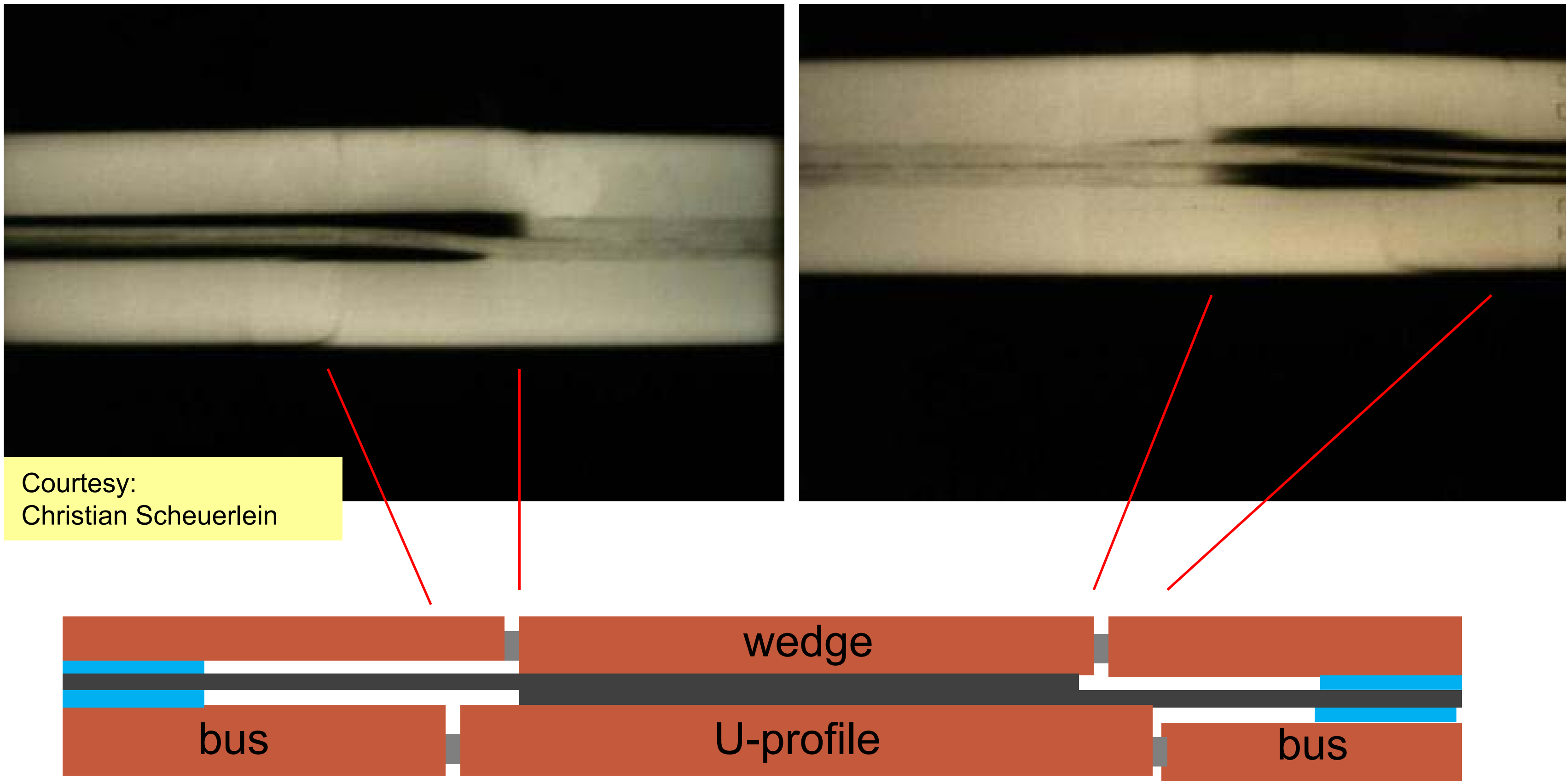



Warm (300K)

Arjan Verweij, TE-MPE, 9 June 2009

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

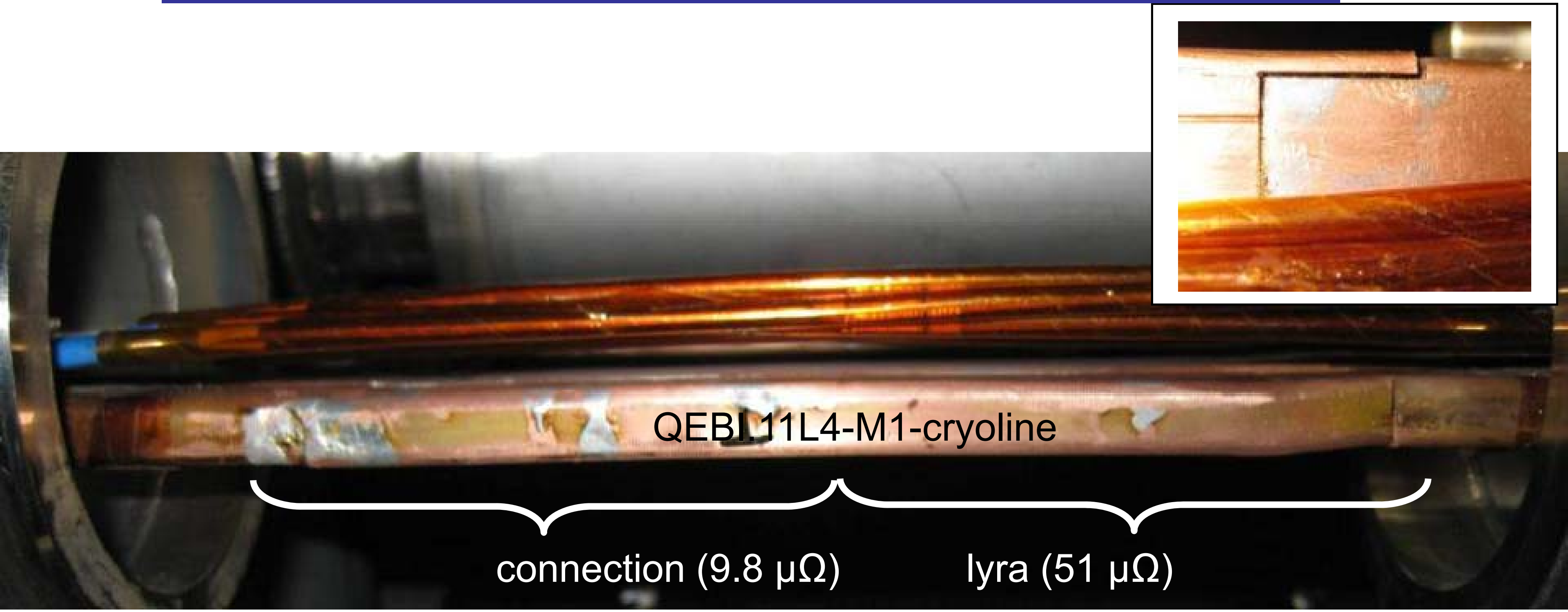
Gamma rays QBBI.B25R3-M3 before disconnection (QRL connection & QRL lyra sides)

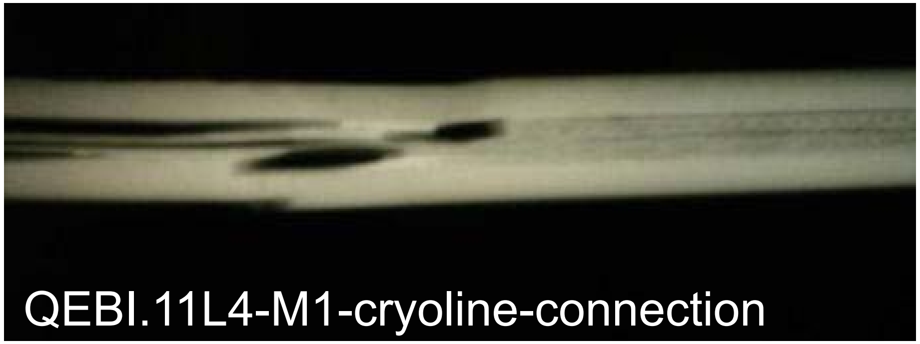


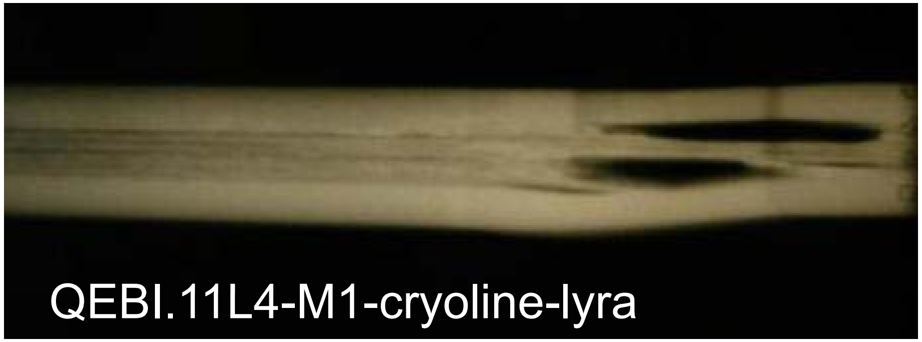
# Electrical Resistance Measurements at Warm Temperatures

- 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 $\mu\Omega$.

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

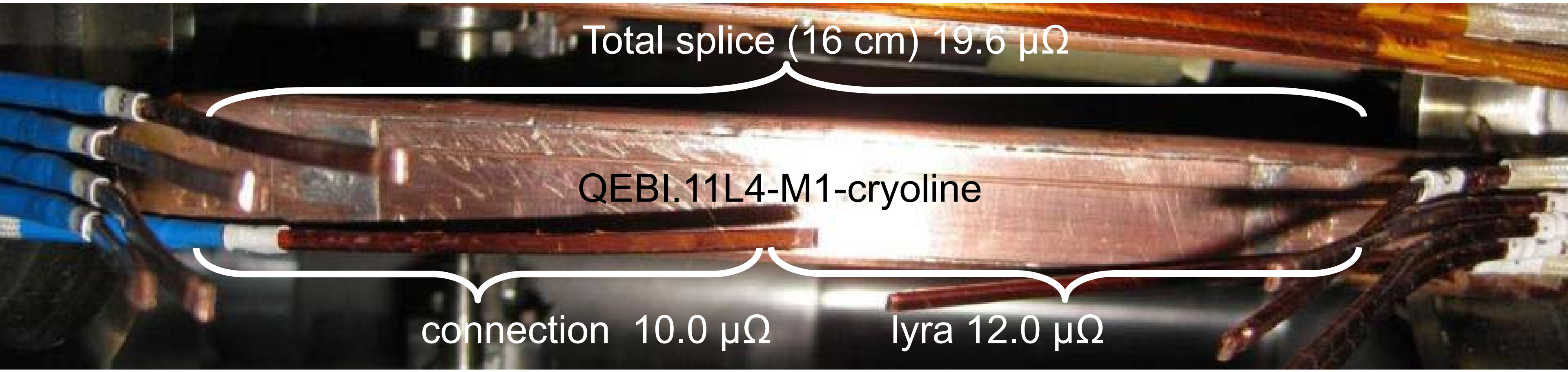


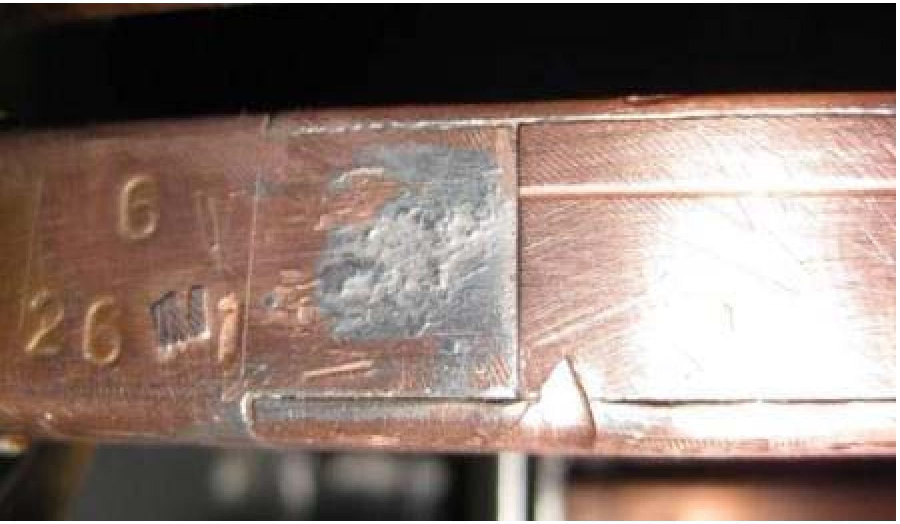




C. Scheuerlein TE-MSC

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

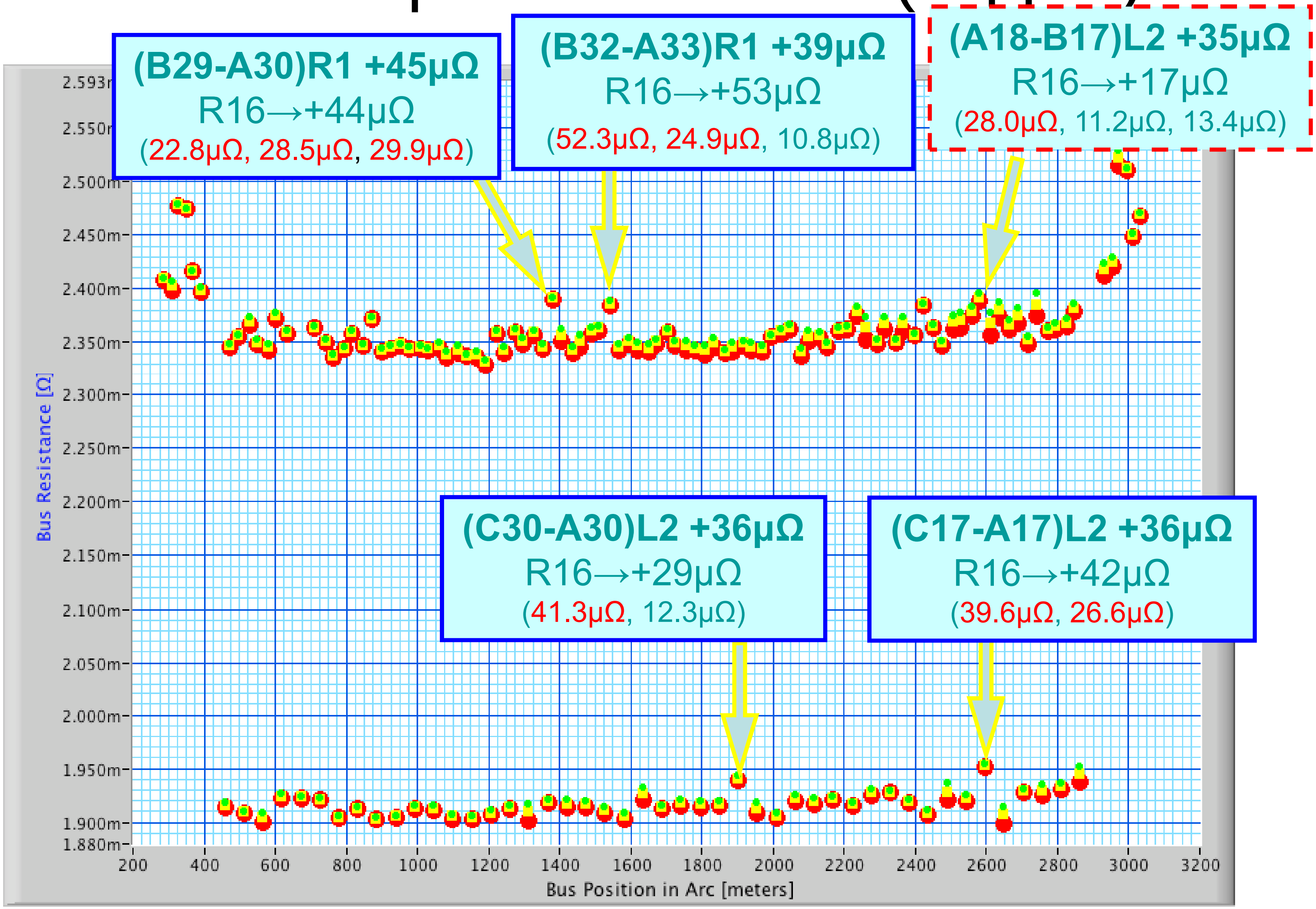


C. Scheuerlein TE-MSC

# 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

# Dipole Bus:  Fit Gaussian to Left Part of Distribution

Fit region:

$-32 < R_{exc} < +12\ \mu\Omega$

Require the integral = # samples in the fit region.

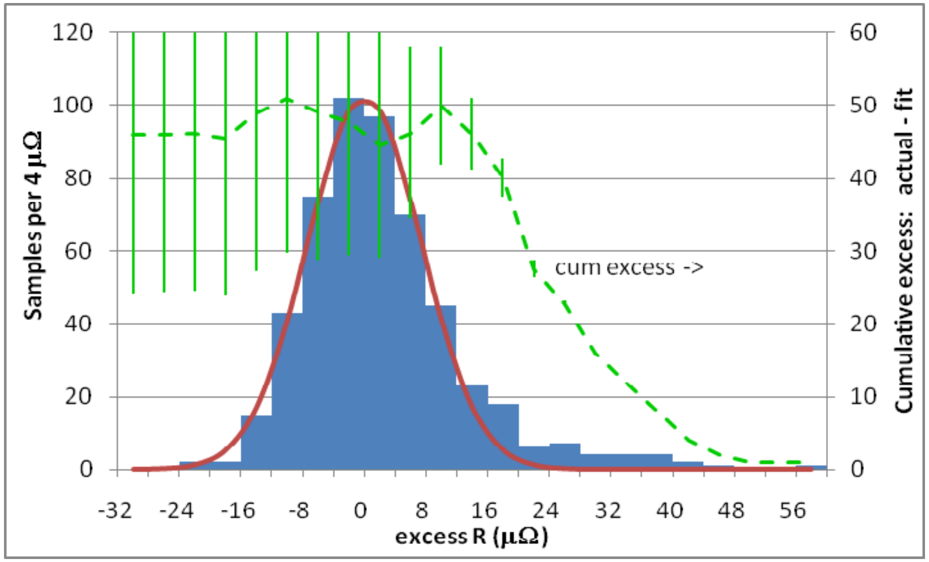
Resultant rms = 7.4 $\mu\Omega$;
chi-square = 3.9 for 9 d.o.f.

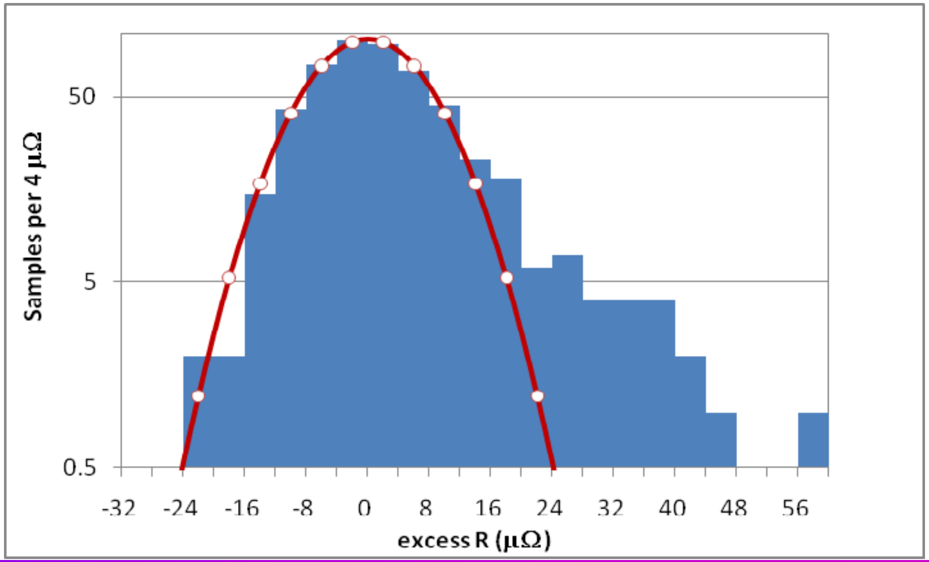
Estimate # segments with faulty joints from excess number of measured versus fit segments in the right-hand tail:

$R_{exc} > 12$:  47±5 (+23 "good") segm.

16:  40±3 (+7 "good") segm.

20:  28±1 (+1.5 "good") segm.



# Difference Between Interior and Exterior Buses

Try to cancel some errors from T correction and unaccounted systematic length differences.

Fit region:

$-40 < \Delta R_{exc} < +40\ \mu\Omega$

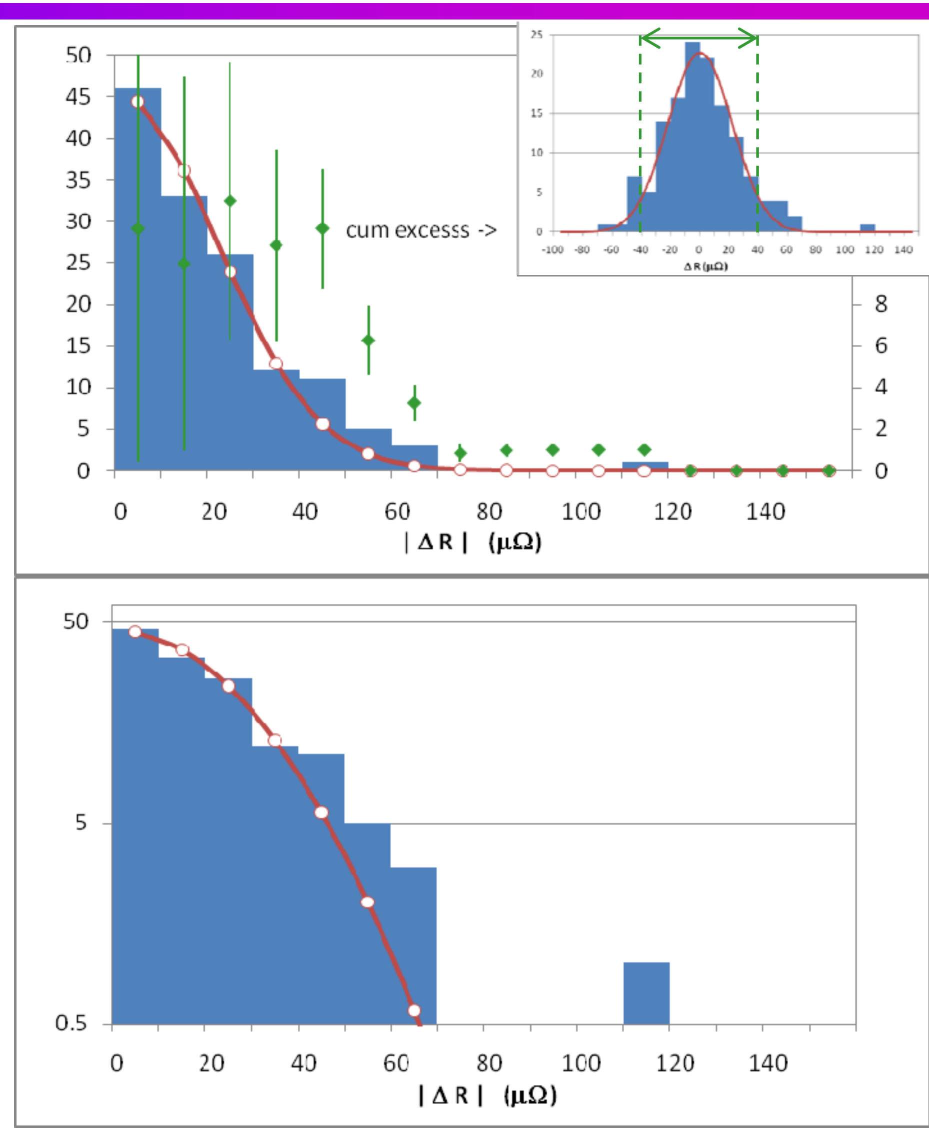
Resultant rms = 22 $\mu\Omega$;
chi-square = 4 for 6 d.o.f.

Estimate # segments with faulty joints:

$R_{exc} >$ 40: 12±3 (+8 "good") segm.

50: 6±2 (+4 "good") segm.

60: 3±1 (+1 "good") segm.



# Local Joint Resistance Measurements

Data through 15 June

RB segments contain 2 or 3 joints.

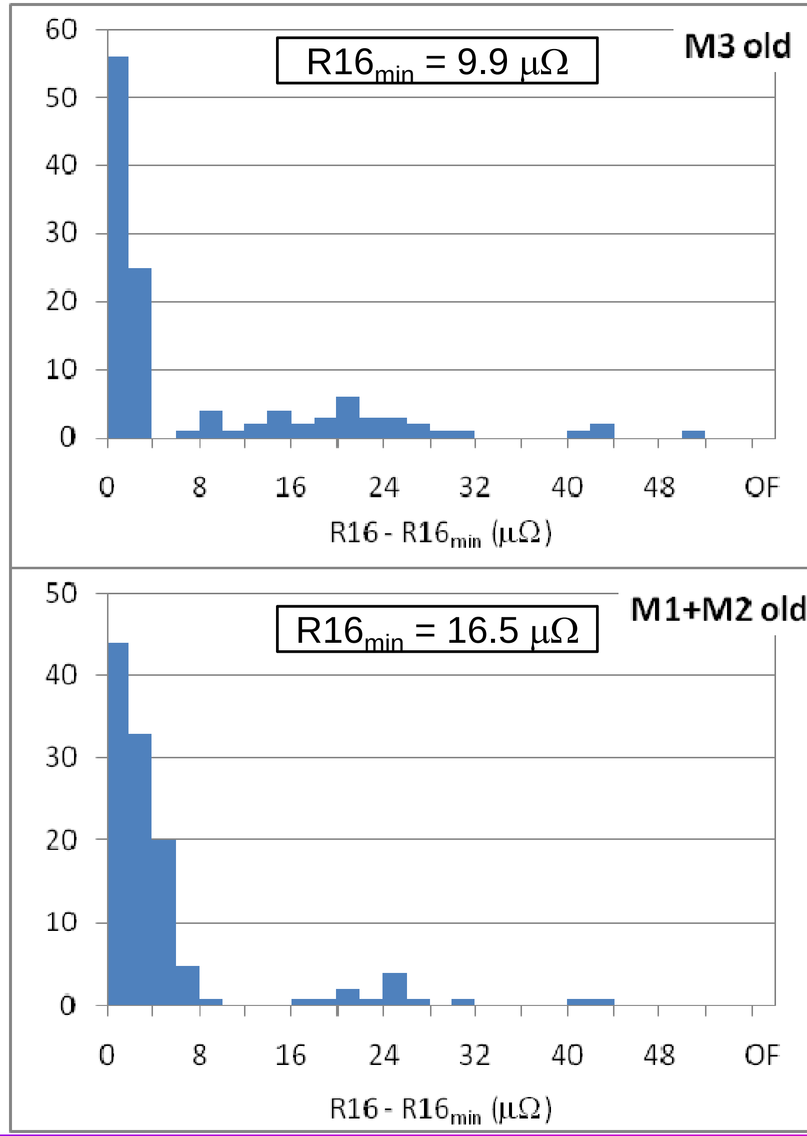
RQ segments contain 8 joints.

=> Need to understand what is maximum individual joint resistance in the machine.

Plot R16 for "old" joints relative to the smallest measured for each bus type, including "new" joints.

Observations:

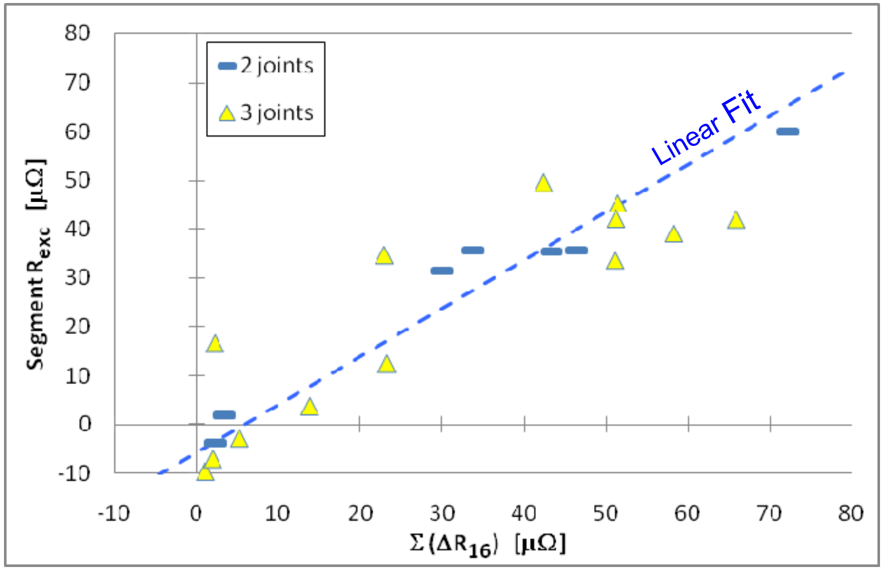
- $\Delta R16_{max} = 50.4\ \mu\Omega$
- Narrow peak near $\Delta R16 = 0$.
- Separate broad distributions
  $\langle R \rangle \sim 19\ \mu\Omega$, rms $\sim 6.5\ \mu\Omega$ (M3)
  $\langle R \rangle \sim 24\ \mu\Omega$, rms $\sim 4\ \mu\Omega$ (M1, M2)
- 2nd "peak" around 40~50 $\mu\Omega$ ??



# Comparison or Segment and Individual Joint Resistance Measurements (M3 only)

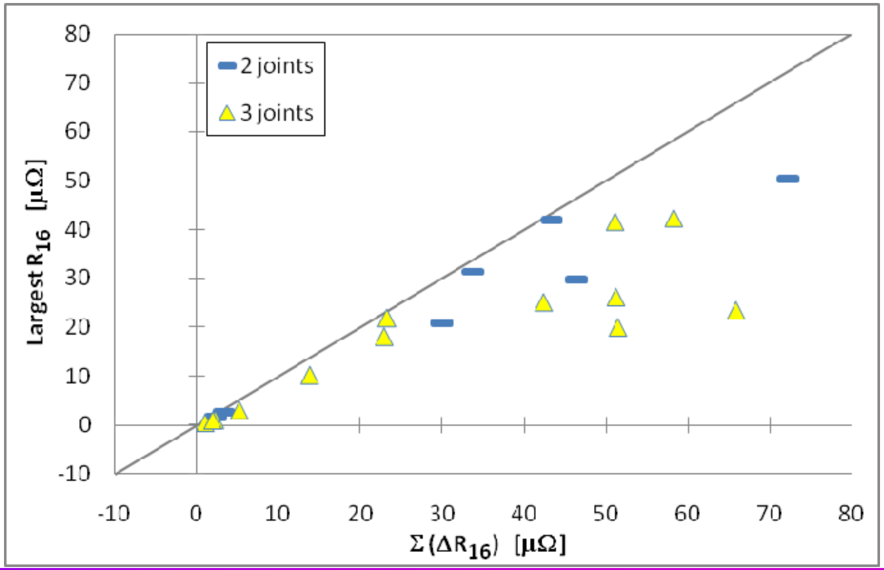
20 RB bus segments have been identified in which all joints have been individually measured.

- There are 4 more segments with Rexc > 30 μΩ, for which I have not found the R16 measurements.

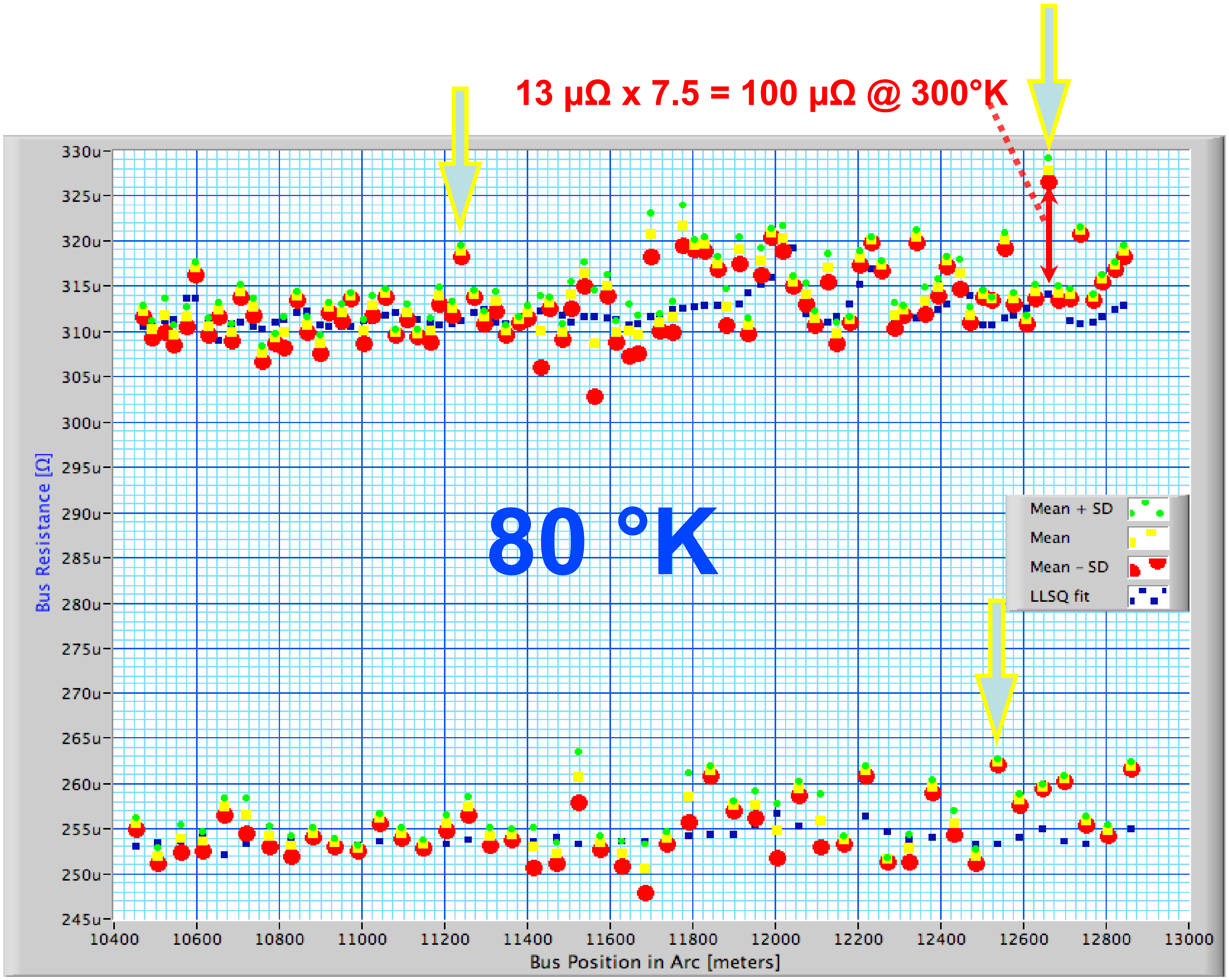



Observations:

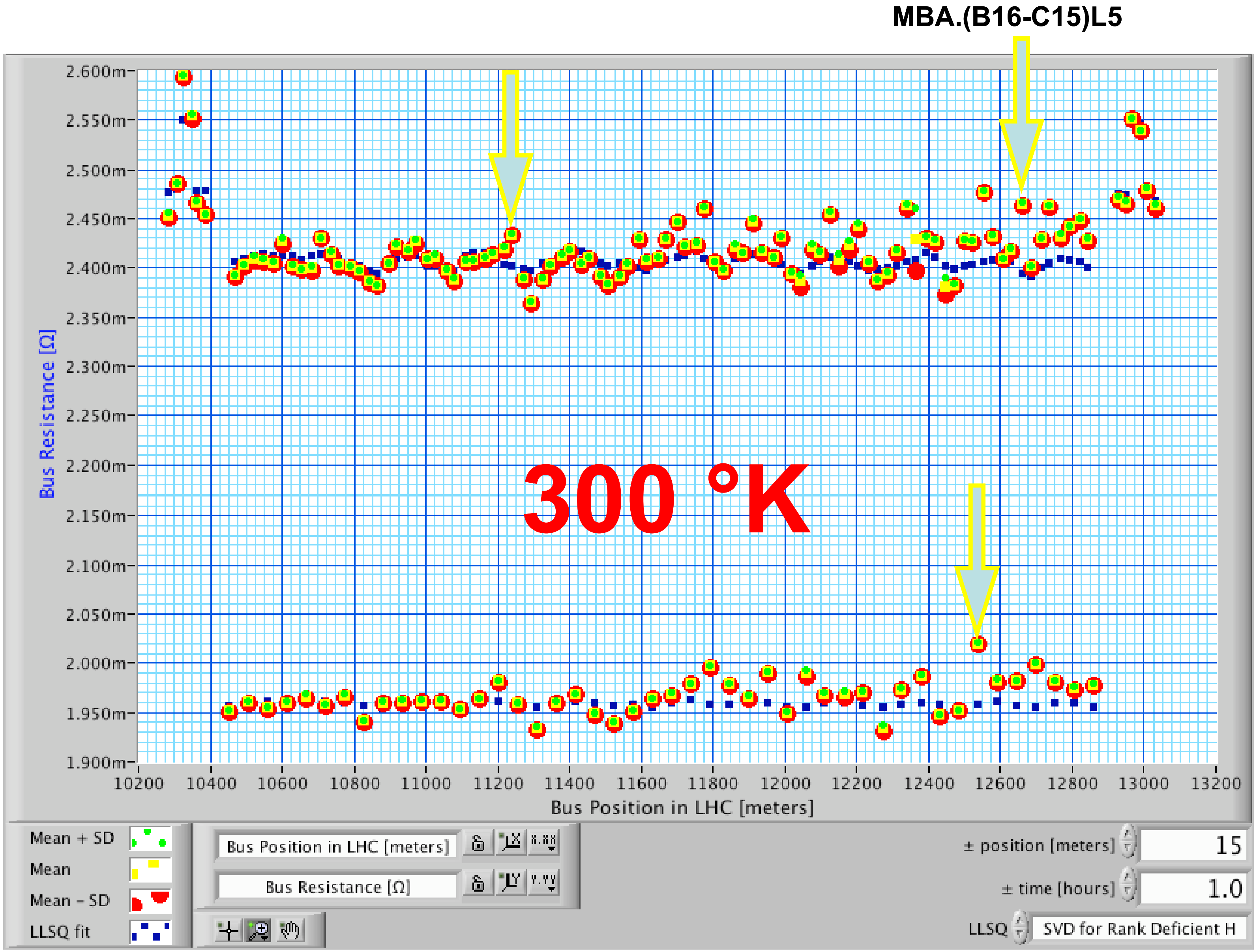
- Good correlation between the two measurement sets:
  - Slope = 1, 6 μΩ offset.
  - rms = 10 μΩ (a little large?)
- For $R_{exc} \lesssim 30$ μΩ, generally one joint is at fault.
- For $R_{exc} \gtrsim 40$ μΩ, generally more than one bad joint is involved.



# Sector 45 BEND Bus Segments

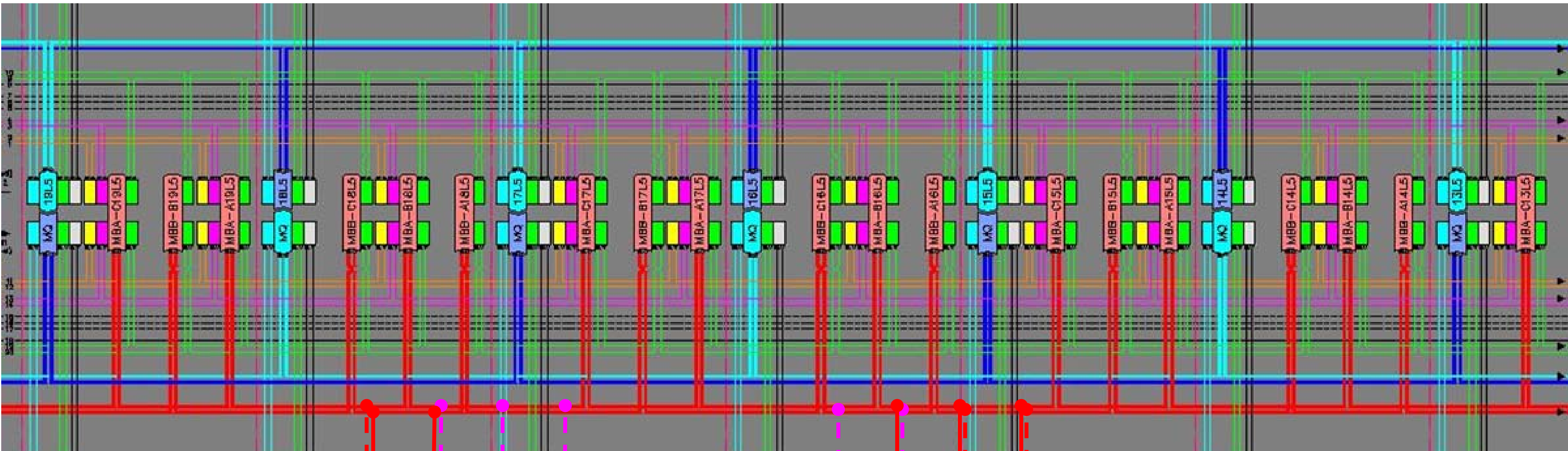


# Sector 45 BEND Bus Segments



# Sector 45 BEND Bus Segments

## Local "R16" measurements



**(C18–A18)L5 +62μΩ**
R16→+61 μΩ
M3 corridor side

23.3μΩ

59.8μΩ

11.6μΩ

42.7μΩ

…μΩ

…μΩ

**(B18–C17)L5 +71μΩ**
R16→+… μΩ
M3 cryoline side

69.8μΩ

36.9μΩ

10.4μΩ

…μΩ

51.8μΩ

14.7μΩ

27.1μΩ

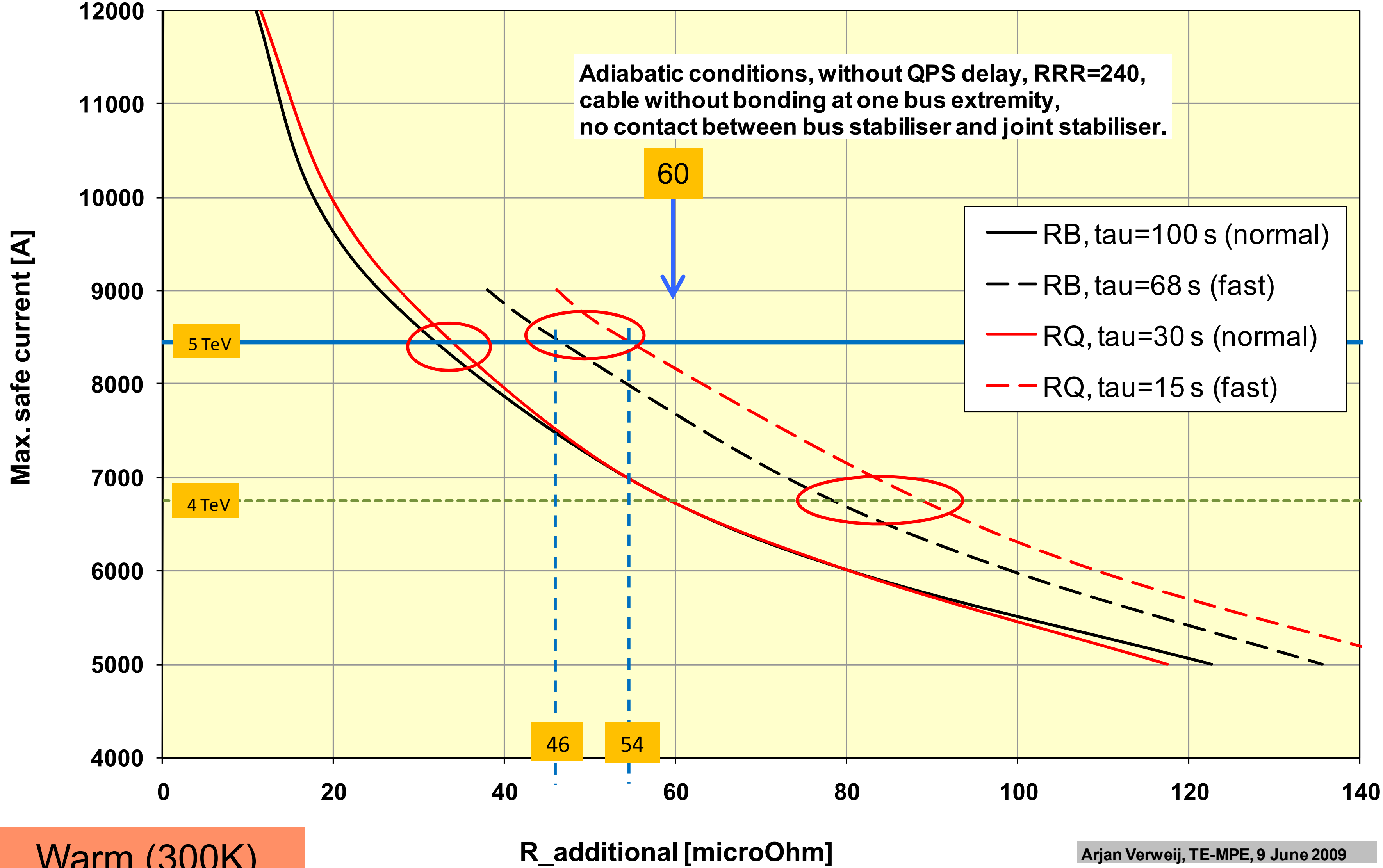
**(C16–A16)L5 +…μΩ**
R16→+… μΩ
M3 corridor side

**(B16–C15)L5 +70μΩ**
R16→+84 μΩ
M3 cryoline side

*R = 10 μΩ*
*for a good joint*

**Courtesy F. Bertinelli**

# Simulations: Maximum safe currents vs copper joint resistance




Warm (300K)

Arjan Verweij, TE-MPE, 9 June 2009

# Summary – Copper Bus Joints

- 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:
  - Faster discharge of the energy from circuits
  - To find a safe limit for the measured joint resistance as a function of the current in magnet circuits (max energy in the machine)

# Powering and Tunnel Access Restrictions

# 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**

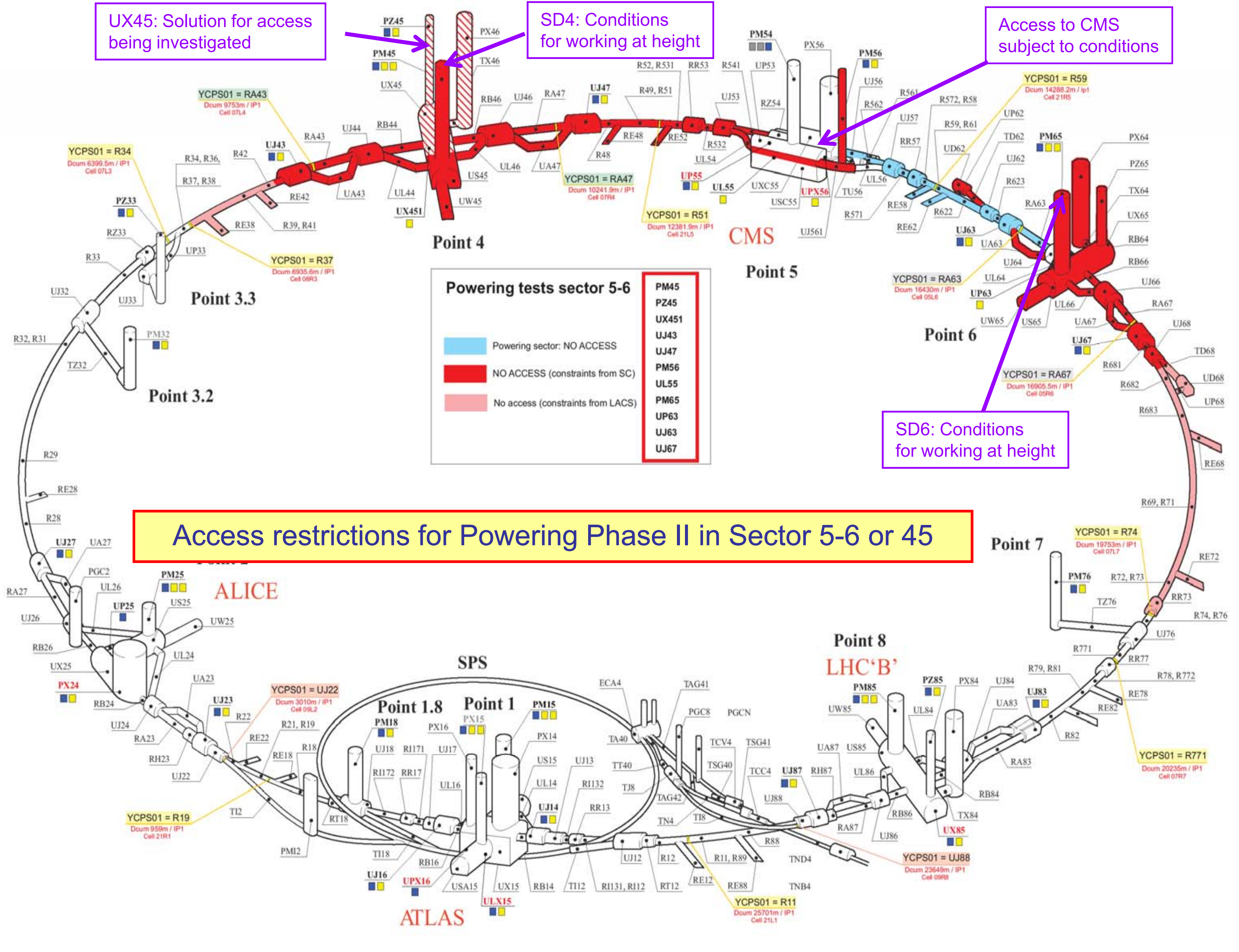
**For powering phase II, define the areas that cannot be accessed**

# **Maximum current** in the different

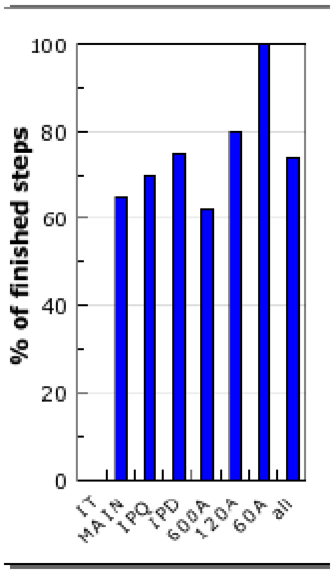
| Circuit type | L [H] | Maximum current level | Energy [J] | Corresponding powering test step |
|---|---|---|---|---|
| main dipoles | 15.708 | 0A | 0.0E+00 | PIC1 |
| main quadrupoles | 0.263 | 760A | 7.6E+04 | PLI1 |
| arc individually powered quadrupoles | 0.06 | 900A | 2.4E+04 | PLI2 |
| 600A circuits | 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<br>L2 = 0.038<br>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 Sector 23




**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

As of the beginning of 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

Since then

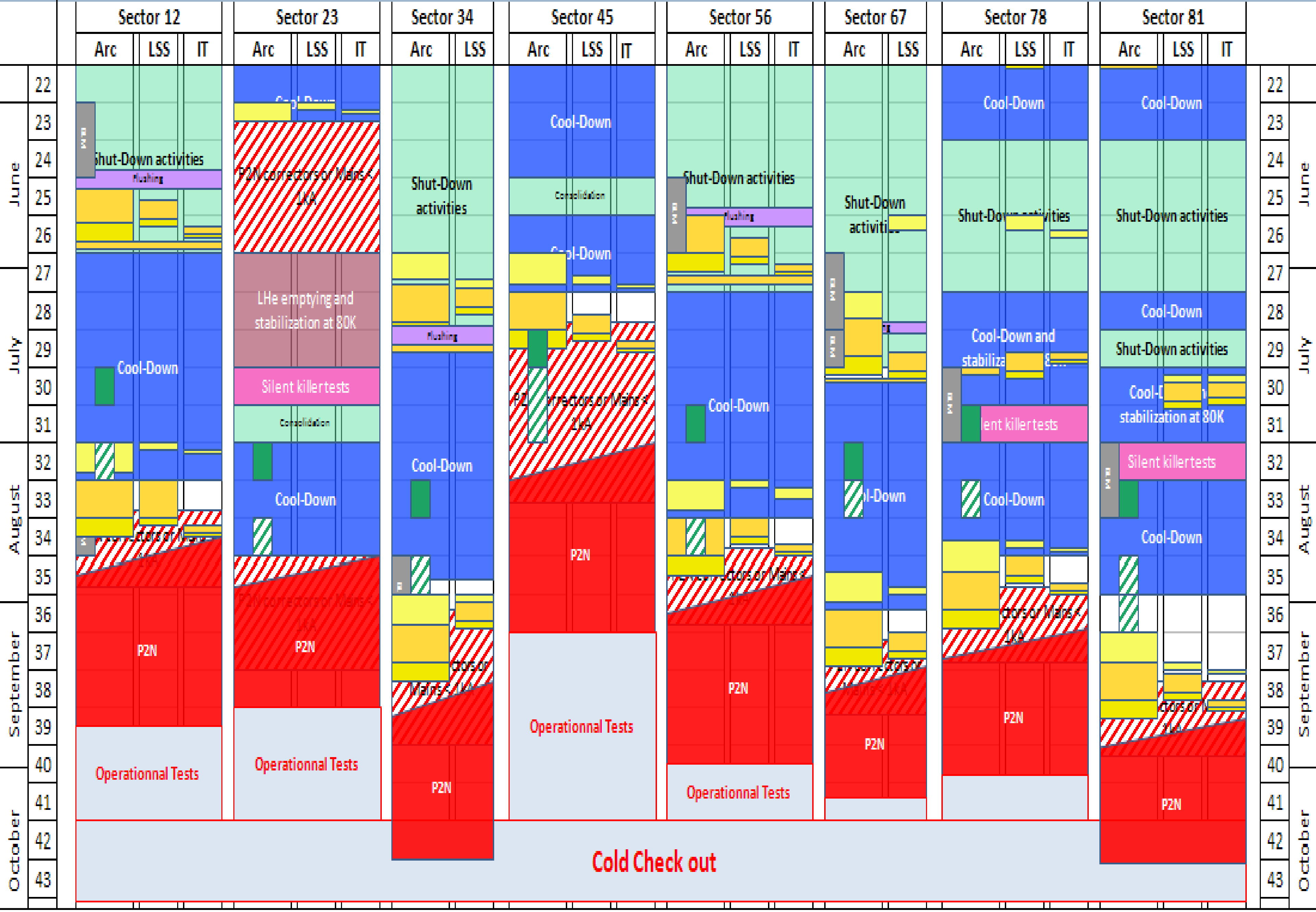
- the cool-down of S12 had been delayed (2 weeks) to do R16 measurements (to confirm the R-long measurements)
- Many more measurements (and repairs) have since been done and the understanding greatly improved.
- Measurements at 80k in S45 indicated high resistance splices:
- Decision to warm up S45 to 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
    - “Bench tests” being prepared

# Strategy

- Measure S45 at 300k (DONE)
  - will be redone next week (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




Before decision to warm S45 (June 3, 2009)

# Summary

- Repair of sector 34 is complete.
- Improvements to protect against another incident – cryostat relief, improved anchoring, new QPS are on schedule.
- Quality of joints in the high-current bus bars is a major concern
  - Measurement and repair are on-going.
  - Work continues to understand how this will limit the energy of the LHC in its initial operation.
- Work has begun to re-commission the hardware, leading to beam (re)commissioning.