LHC Status

HCP 2009 Evian

16th November 2009

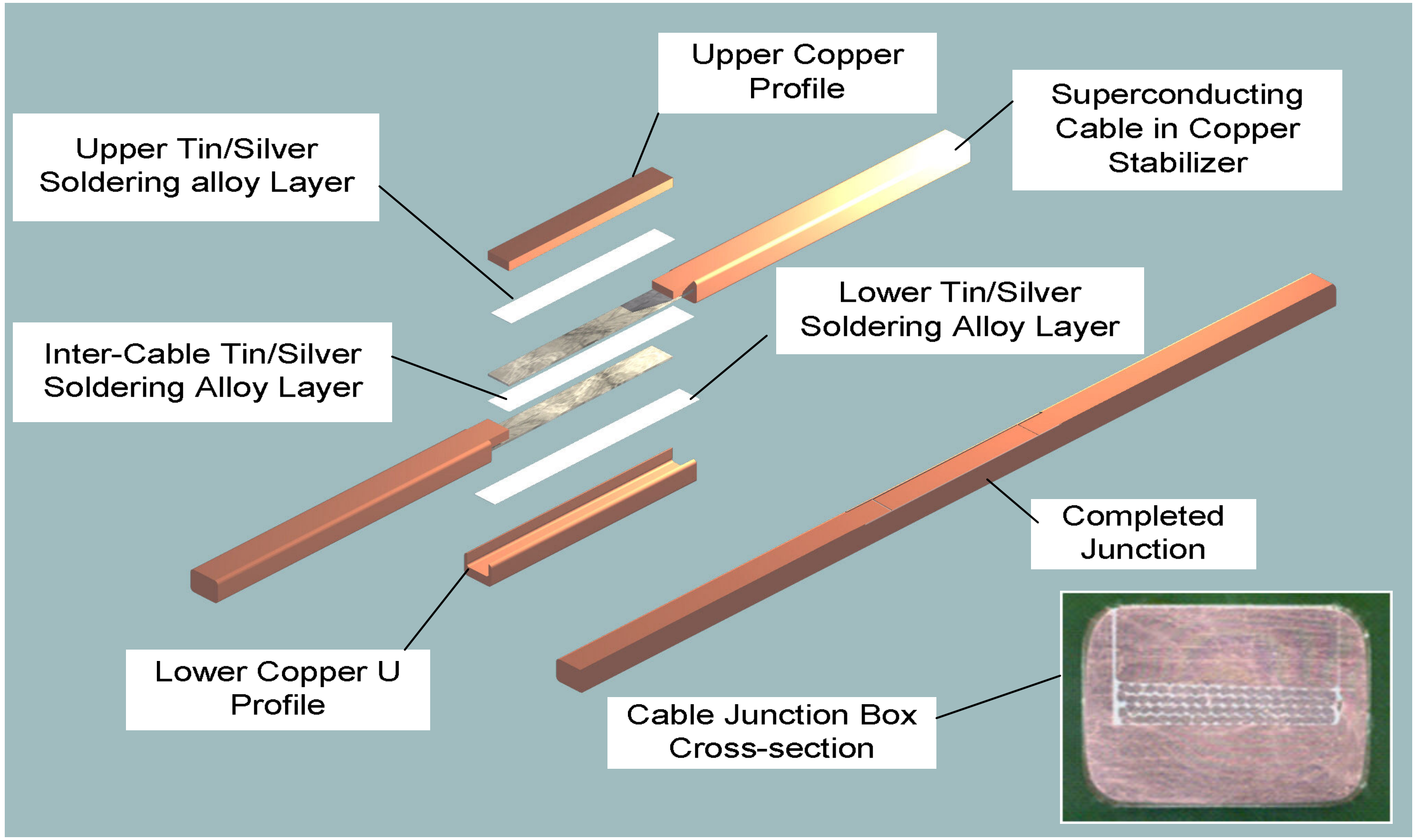
Steve Myers

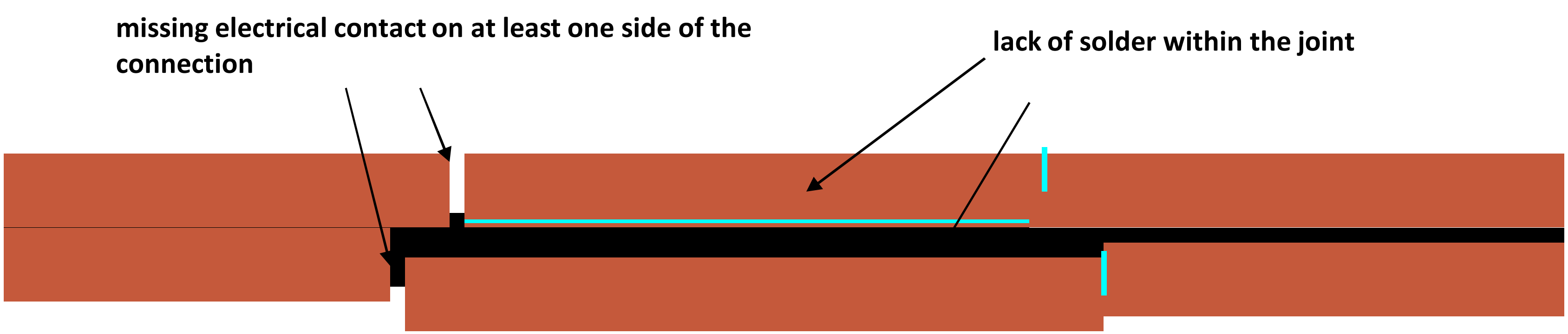
Topics

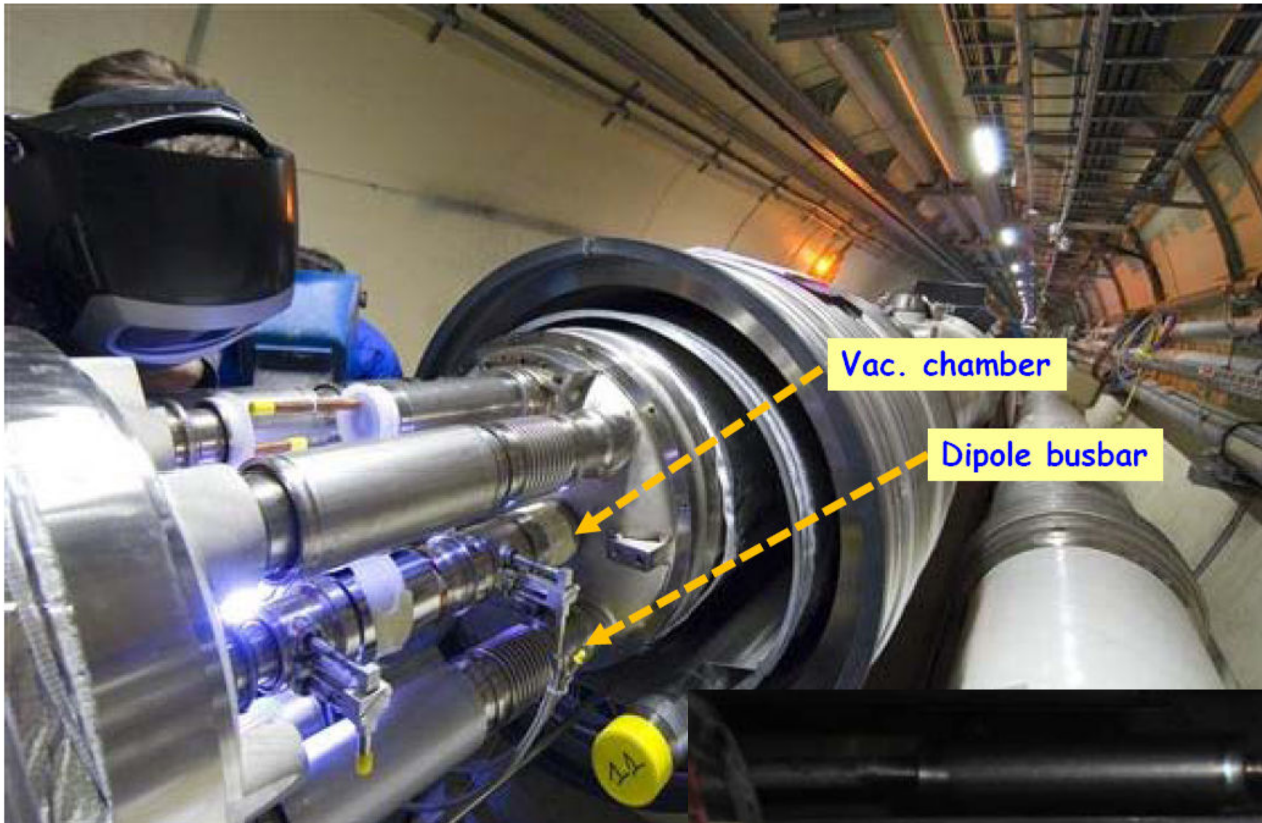
- The 19th September "incident"
- Repair and consolidation
- May 2009 "Copper Stabilizers"
- The decision on the energy at start up (August 2009)
- Since August Decision
- Running with Beam 2009 – 2010
- Recent News
  - injection tests (finished last weekend)
  - Up to the"minute" news

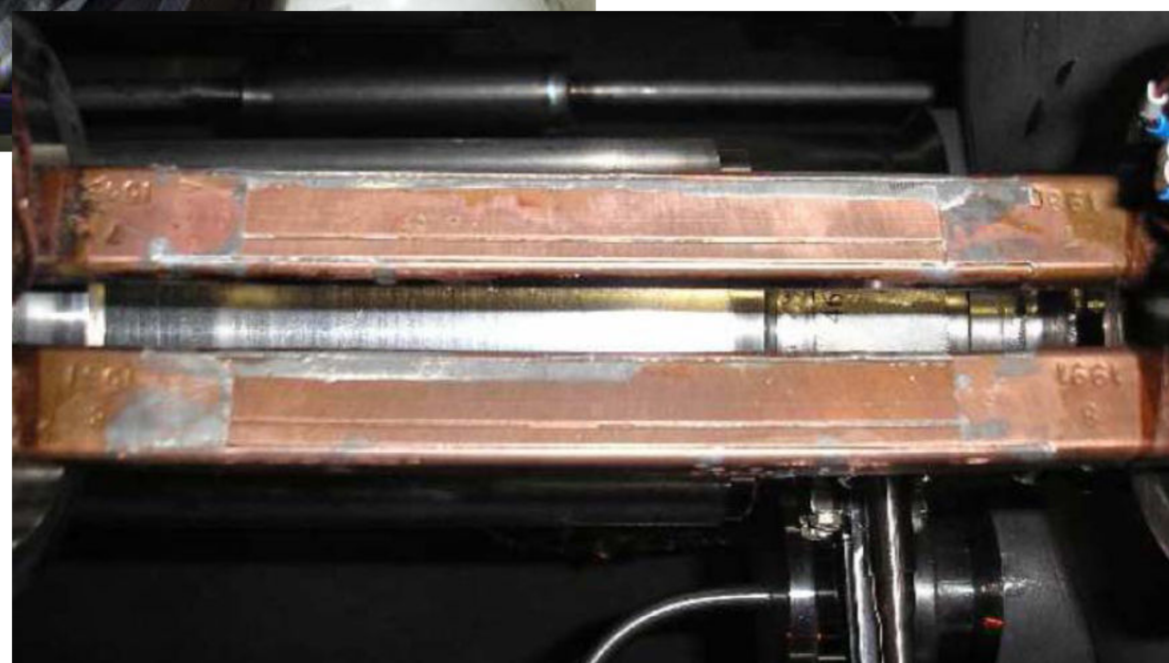
The Sector 3-4 incident

fault tree and corrective measures


Upper Copper Profile
Superconducting Cable in Copper Stabilizer
Upper Tin/Silver Soldering alloy Layer
Lower Tin/Silver Soldering Alloy Layer
Inter-Cable Tin/Silver Soldering Alloy Layer
Completed Junction
Lower Copper U Profile
Cable Junction Box Cross-section

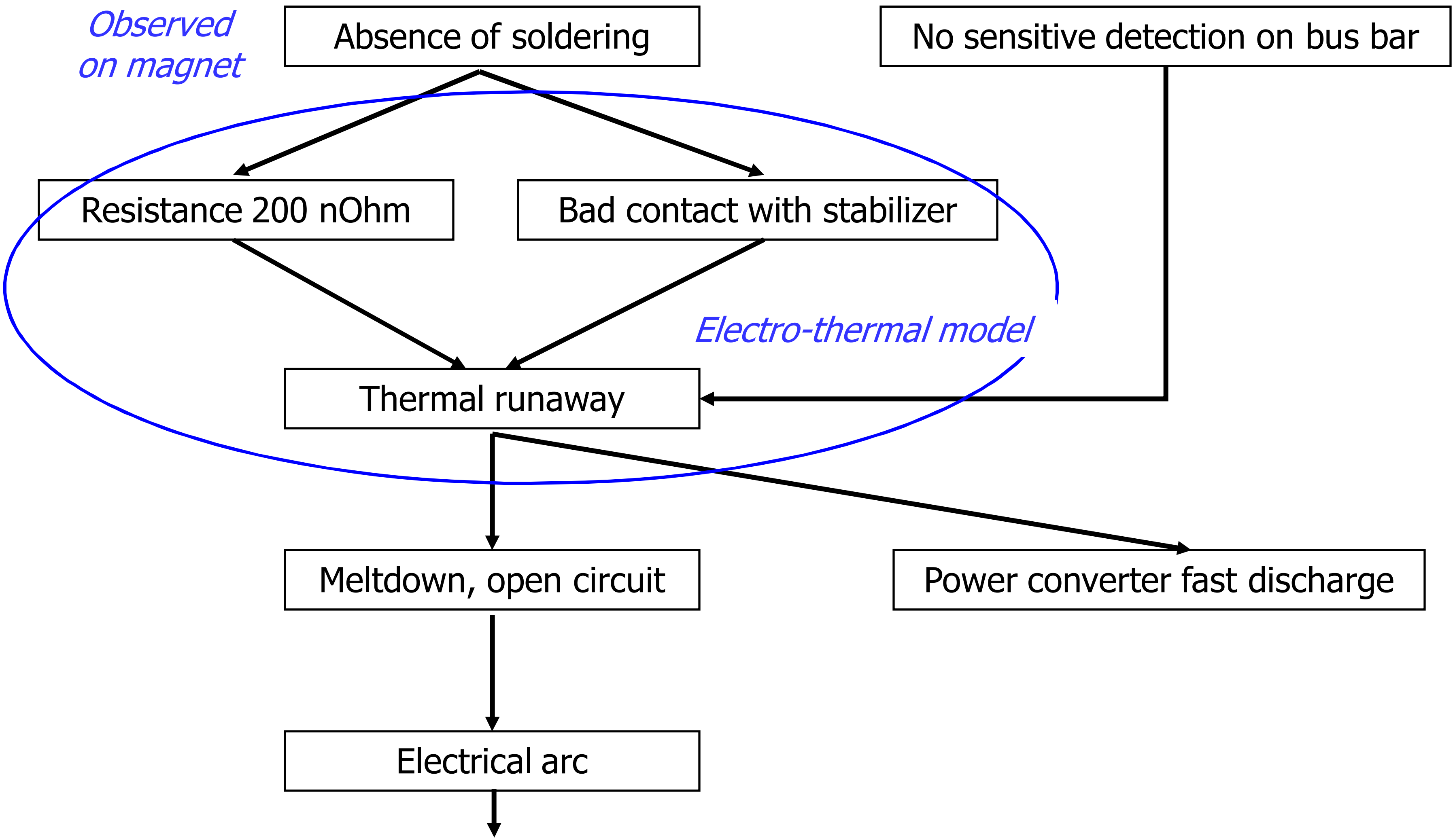

missing electrical contact on at least one side of the connection
lack of solder within the joint


Vac. chamber
Dipole busbar

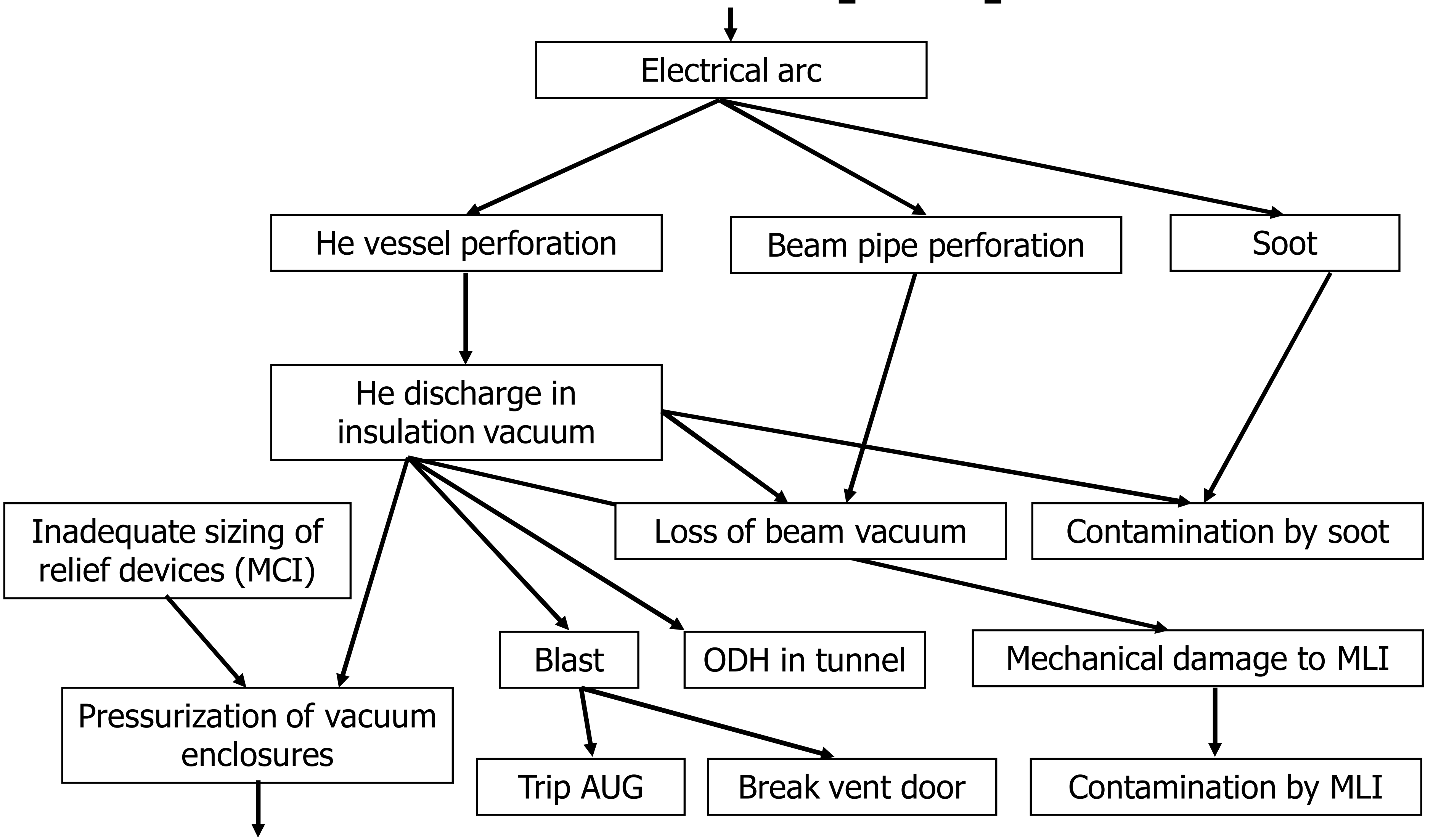


Internal fact finding group (P.Lebrun)

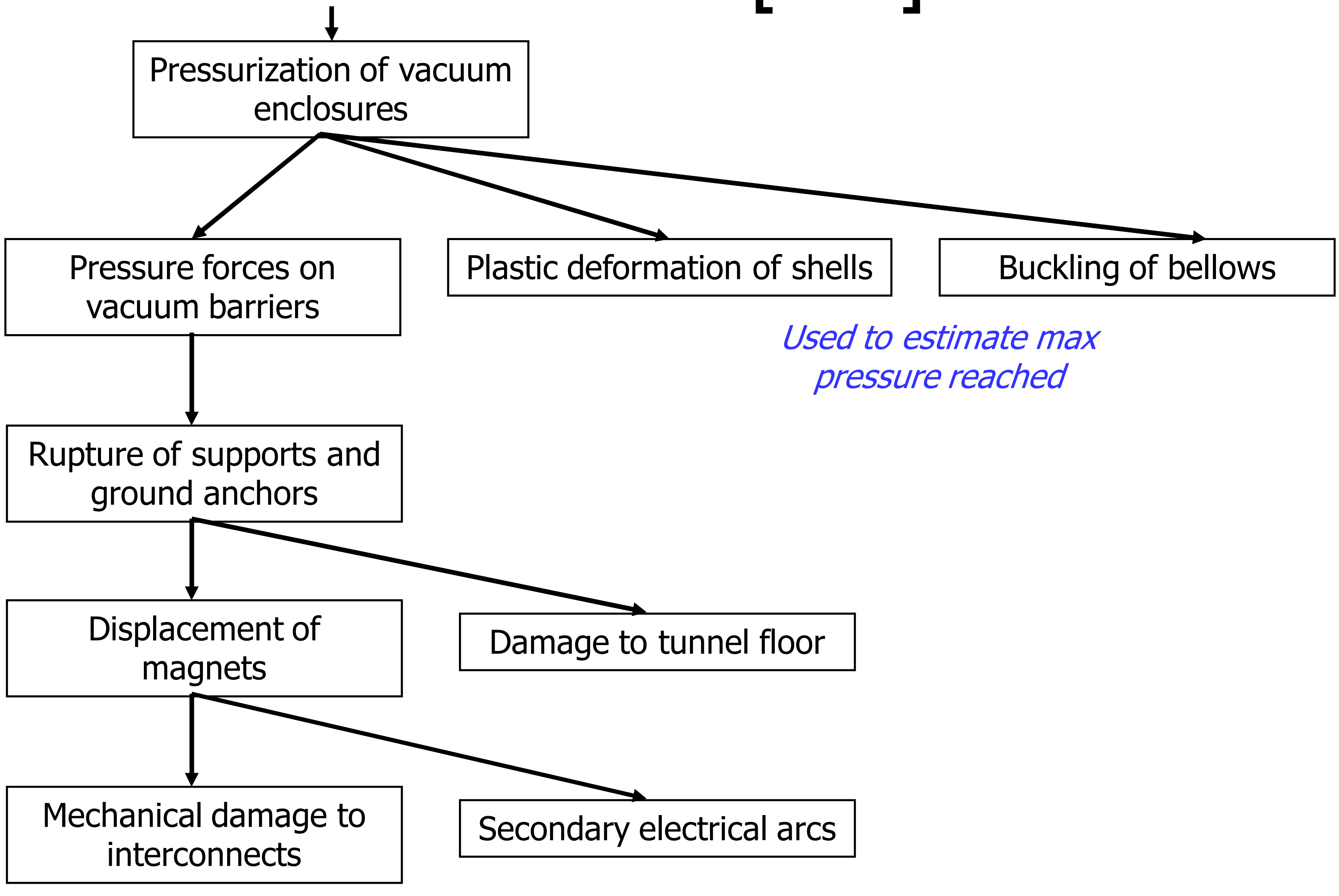
Fault tree [1/3]



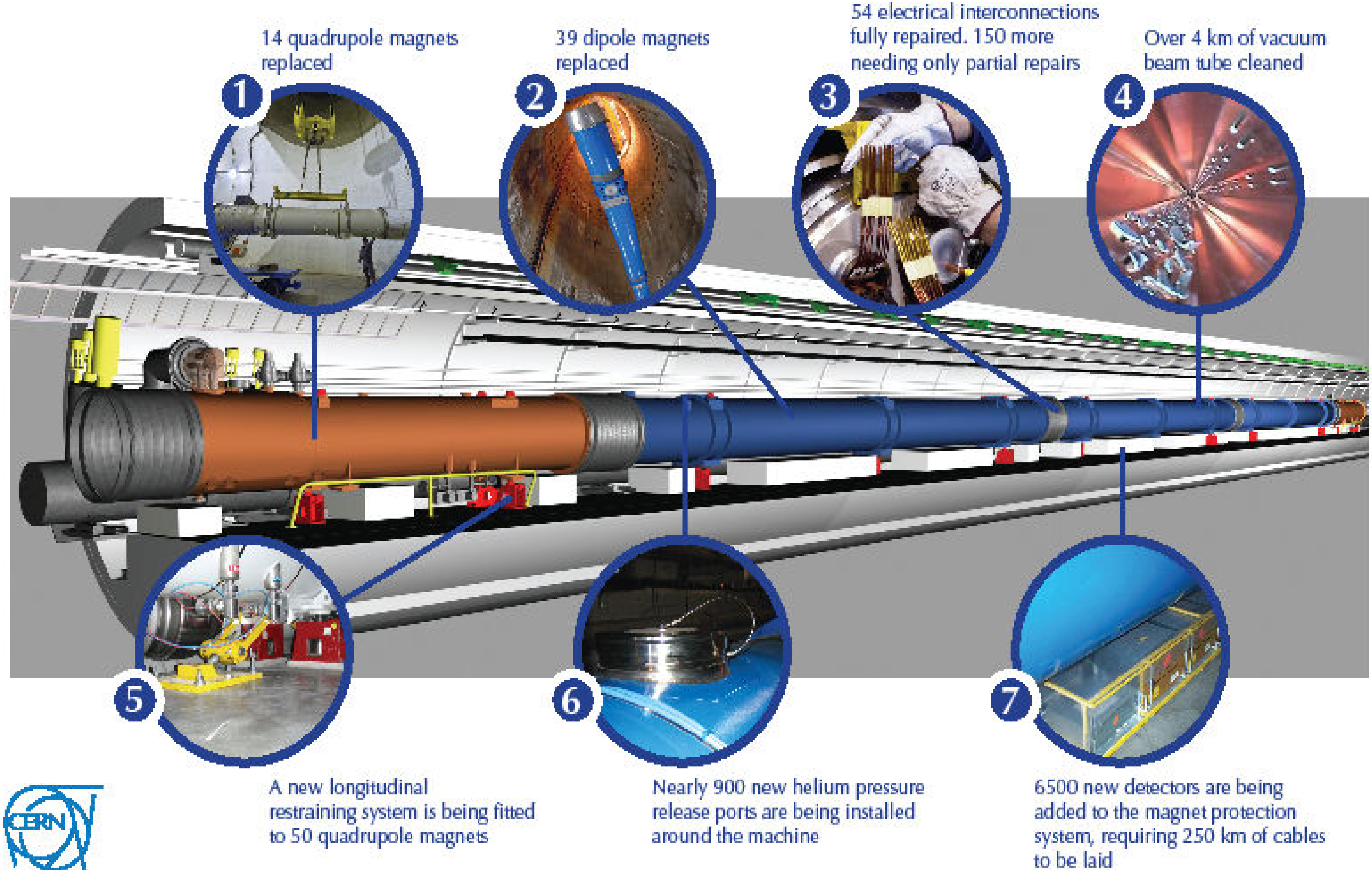
Fault tree [2/3]



Fault tree [3/3]



The LHC repairs in detail



Magnet transport in the tunnel without a single incident

sector 3-4 : Magnet repair in SMI2

11

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

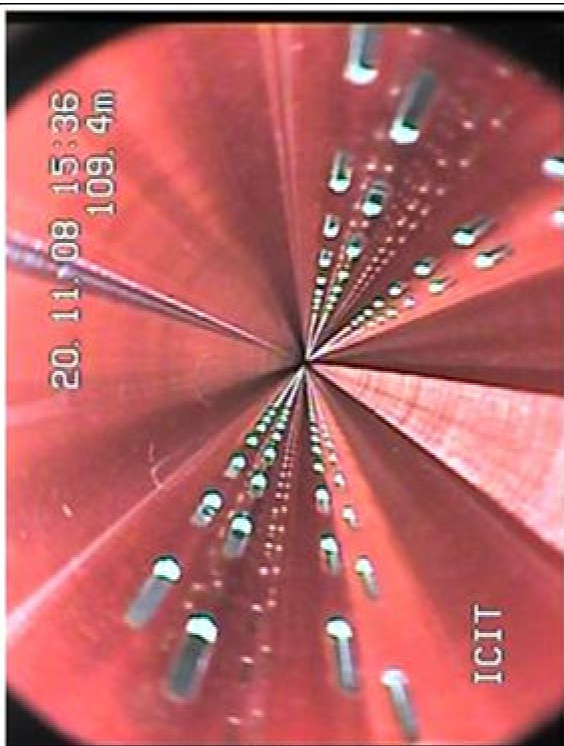
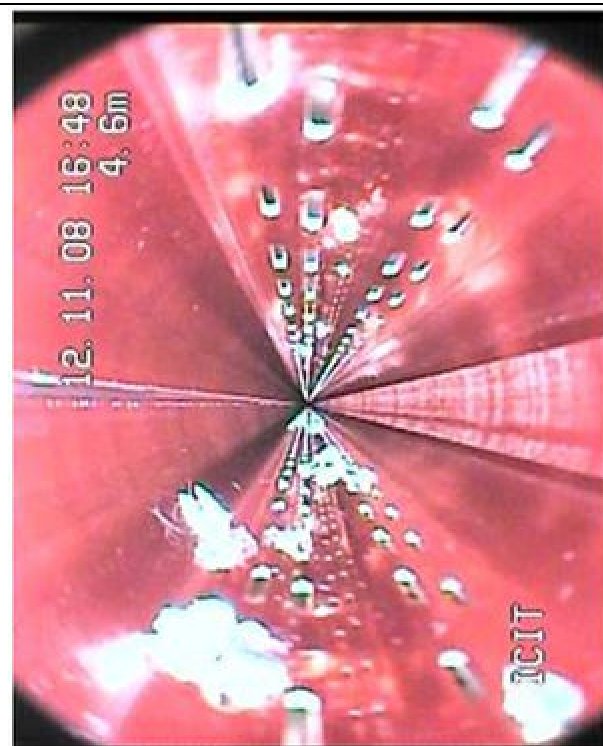
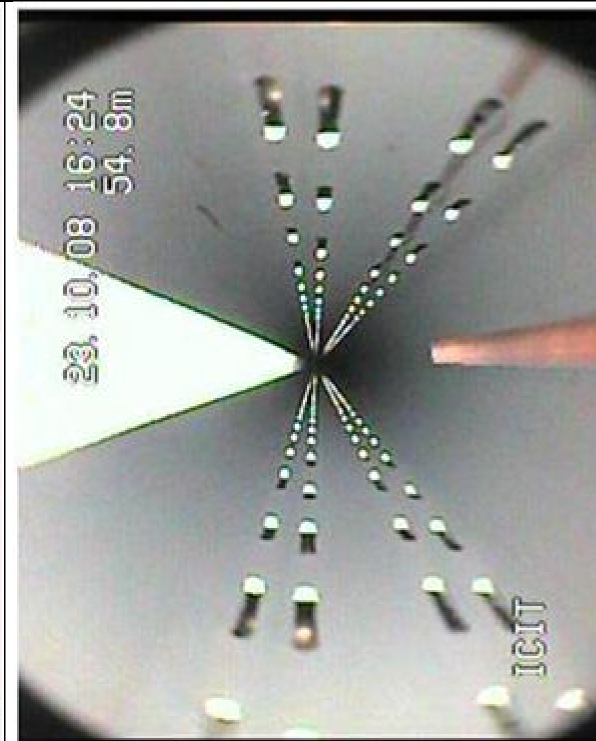
Repair of QRL service module in S3-4

Before repair

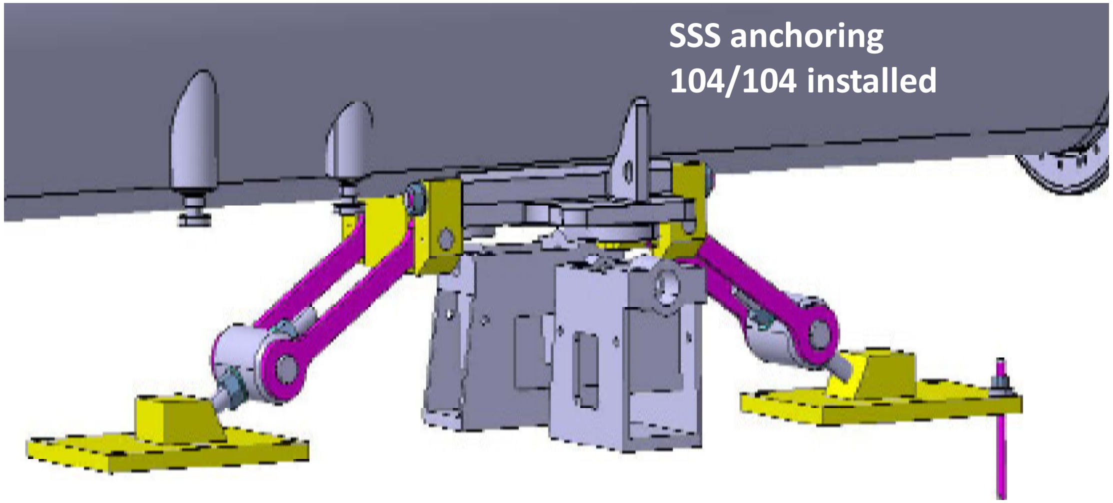
After repair

Q27

Beam vacuum recovery in sector 3-4
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.
		

Magnet protection and anchoring



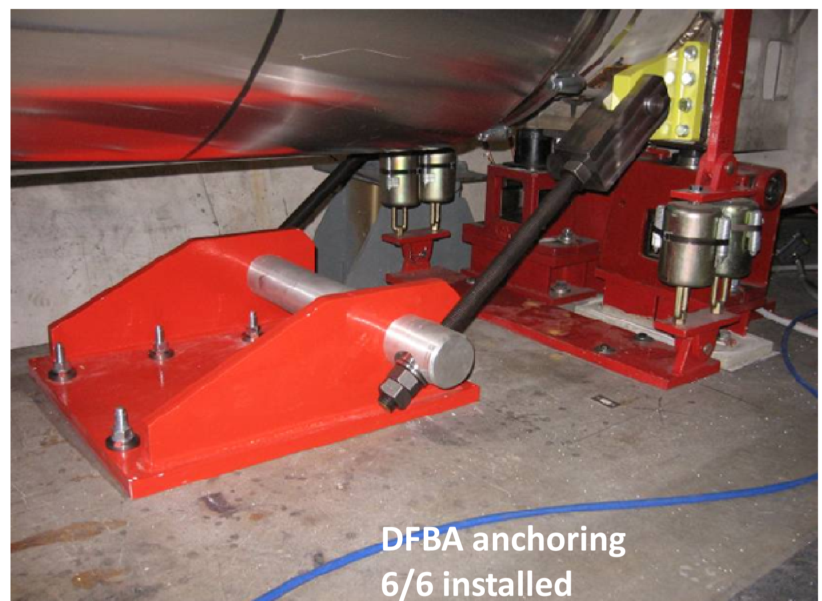
DFB protection and anchoring

DN 200 on DFBL
5/5 installed

DN 230 on DFBA HCM
40/64 installed


DN 200 on DFBA LCM
7/9 installed

DN 200/100 on DFBM link
25/29 installed


DFBA anchoring
6/6 installed

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.

What did we observe?

Spare magnets connections (April 2009)

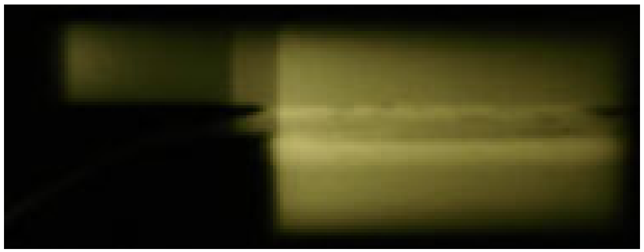
12 samples tested (2 interconnections), those 4 are representative of the total

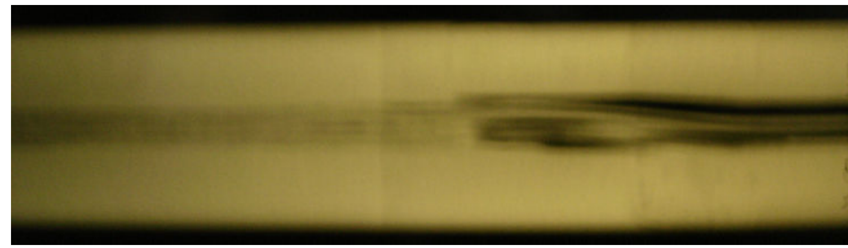
before connection
8-04-09

after connection
16-04-09

MB2433

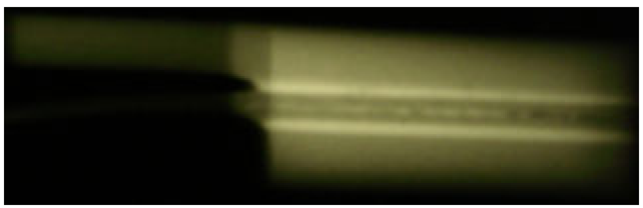
in QBBI.A23R3
M3 ext

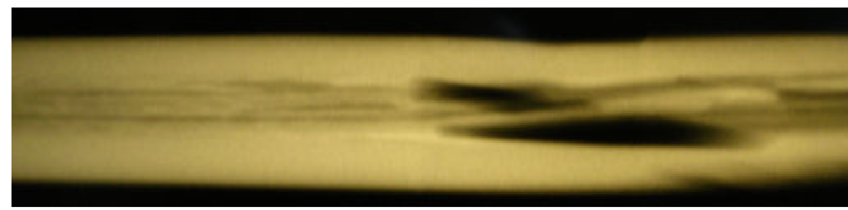




MB2433

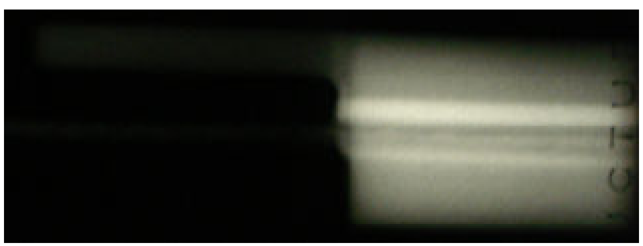
in QBBI.A23R3
M2 int

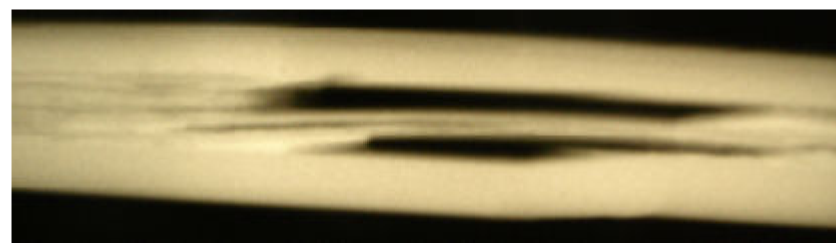




MB2439

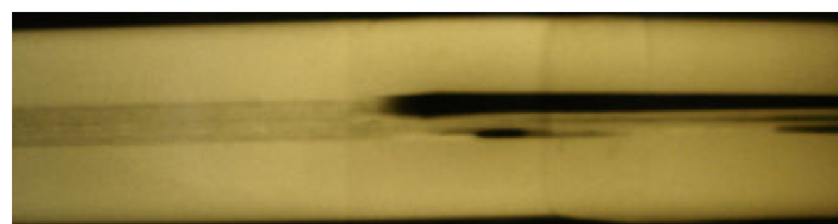
in QBQI.24R3
M1 ext



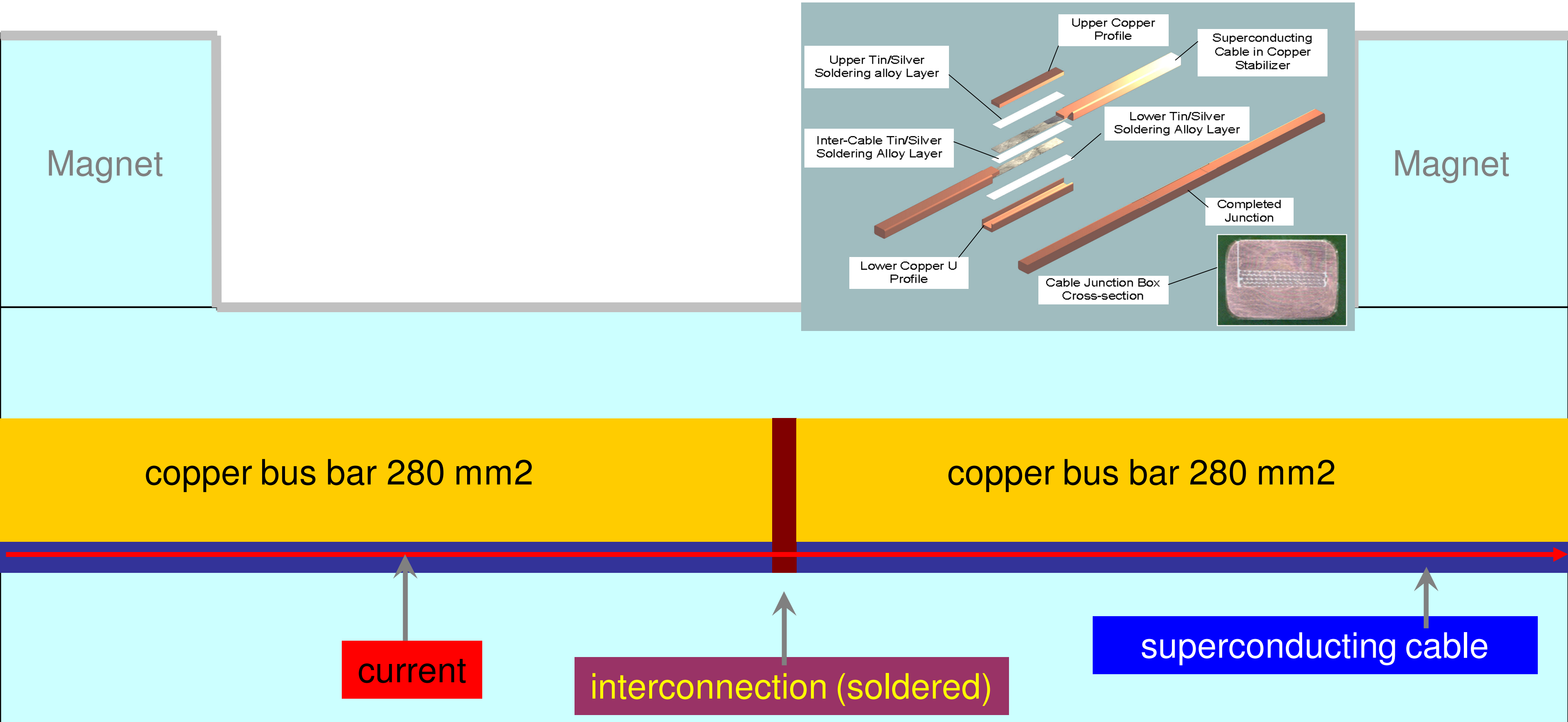


MB2439

in QBQI.24R3
M3 int

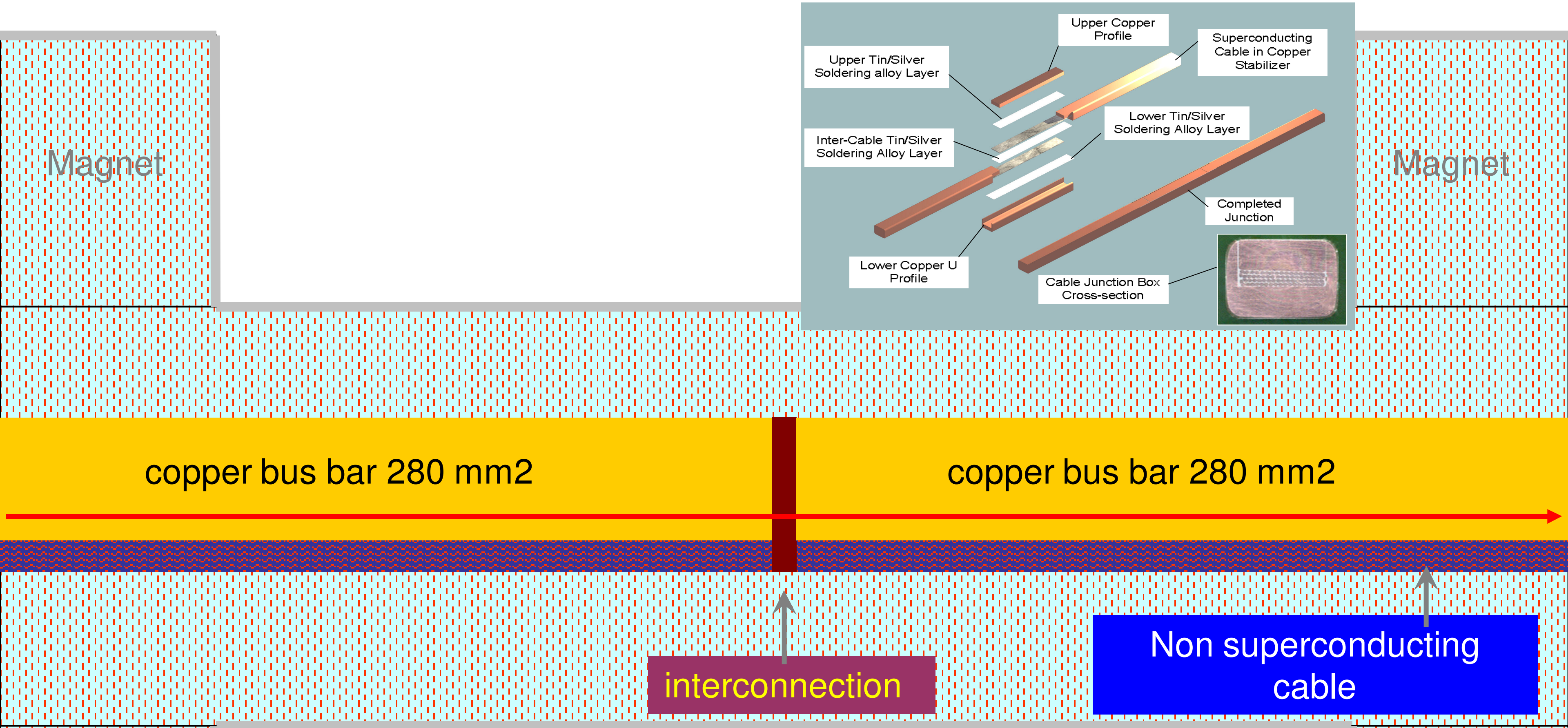


Good interconnect normal operation (1.9K)



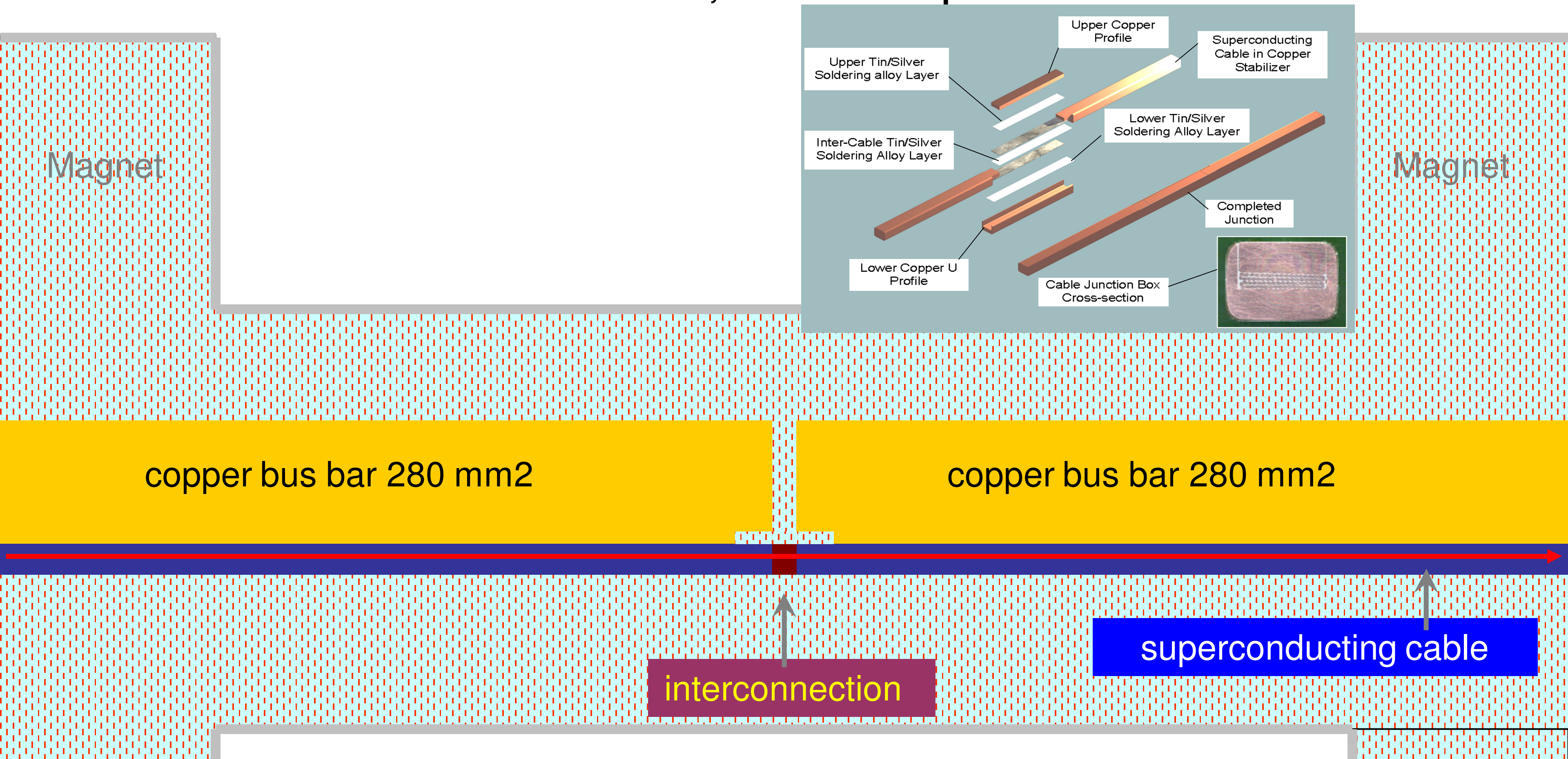
We must be sure that the joint between the sc cables is good.
Measurements of nano-Ohms at 1.9K

good interconnect, after quench (>10K)



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

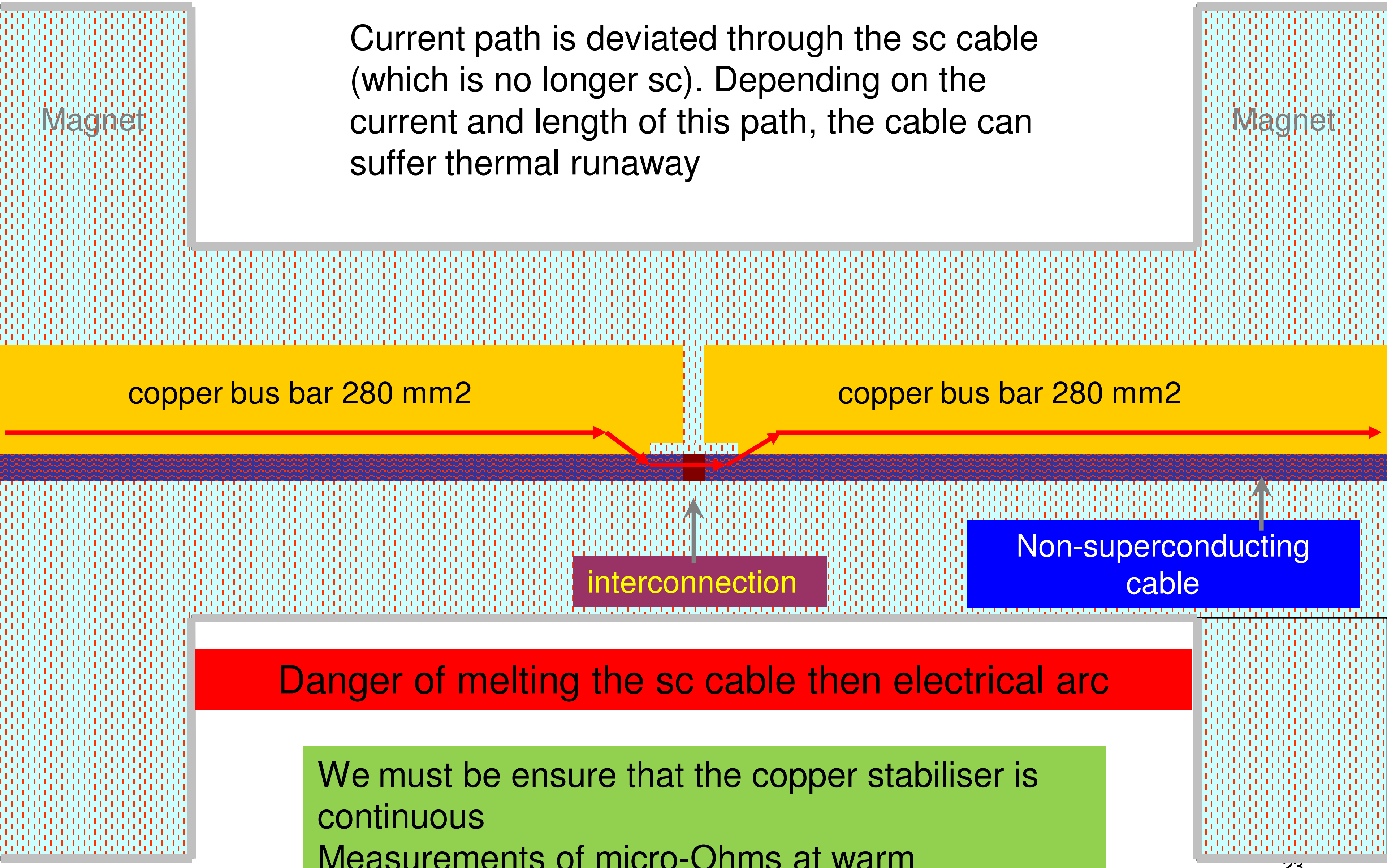
Bad interconnect, normal operation 1.9K



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

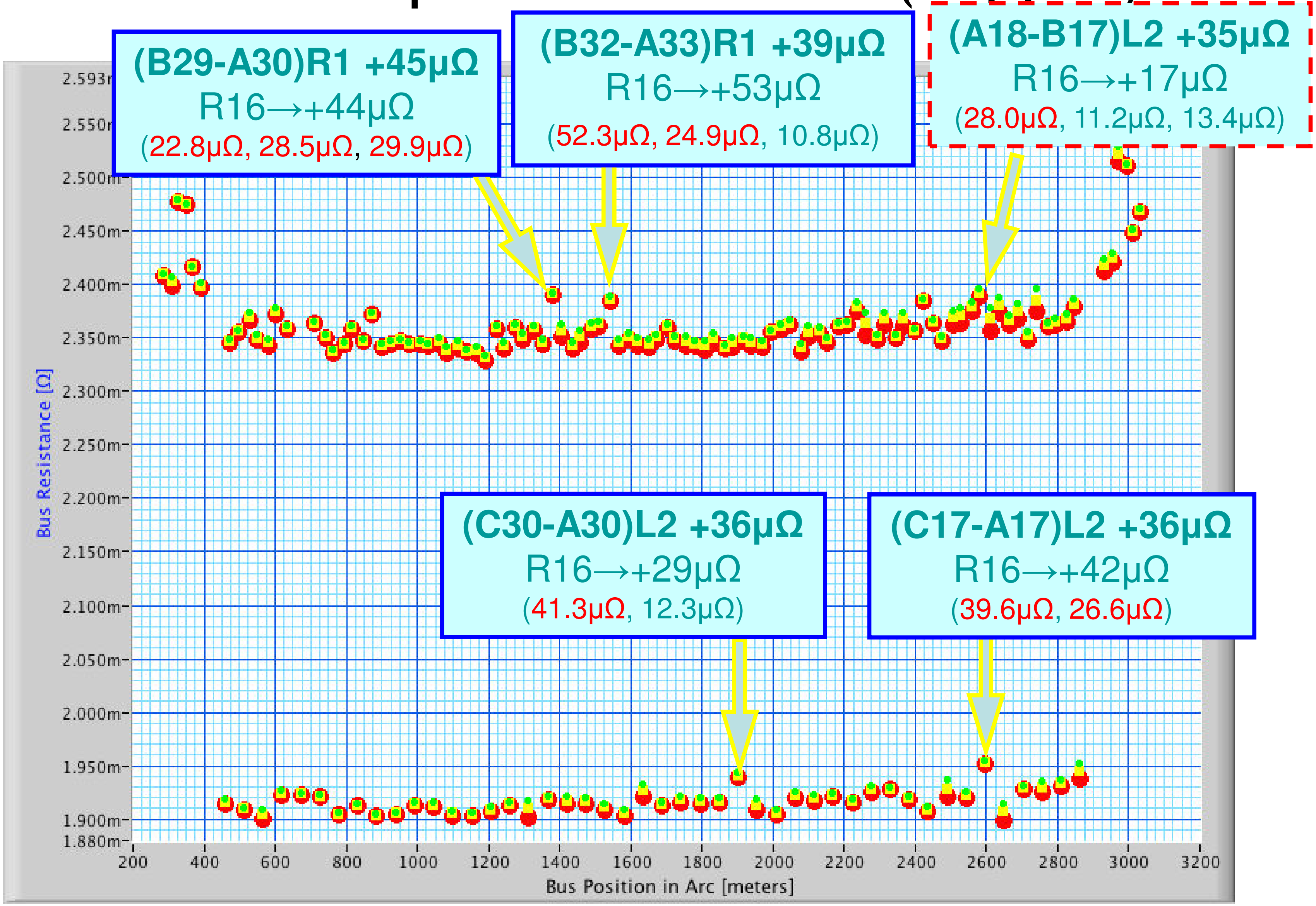
We must be ensure that the copper stabiliser is continuous
Measurements of micro-Ohms at warm

Electrical Resistance Measurements at Warm Temperatures

- New electrical tests were 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 five sectors at room temperature and three sector at 80 K.
  - Warm measurements of the joint resistances (so-called local R^{16} measurement) give possibility to detect surplus joint resistance of a few $\mu\Omega$.

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.B29 R1	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.	
QBQI29R1	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.	
QQBI29R1	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.B32 R1	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.	
QQBI32R1	M3-corridor	done	4 outof 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 outof 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.	
Q BBI.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.	
Q BBI.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.	
Q BBI.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.	
Q BBI.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

Summary on Copper Stabilisers

- The enhanced quality assurance introduced during sector 3-4 repair 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 produce voids which prevent contact between the superconducting cable and the copper
- This can cause danger for the joint in case of a quench
- Quality of the copper stabiliser joint determines maximum safe energy

  ⇨ Splice resistance measurement campaign
- Possible Mitigation
  - Faster discharge of the energy from circuits

Decision; Beam Energy at Start-up (August 2009)

Choices

1. Stick to 5TeV/beam and repair all necessary Cu stabilizer joints => warm up of several sectors and delay start of physics till 2010
2. Aim for maximum safe energy with no additional repairs on CU stabilizers => allows us to gain experience up to this maximum energy (accelerator and detectors)

- Maximum safe current flowing in joint (beam energy)
  - Electro-magnetic, thermo-dynamic simulations
  - Probability of simultaneous quench in magnet and joint (?beam losses FLUKA)
  - ?Quench propagation time from the magnet to the joint
- Resistance of the copper stabilizers (measurements)
- Quality of the copper in the sc cable and the Cu stabiliser (RRR)
- Energy extraction time (modification of dump resistors quads and dipoles)
- Gaseous cooling of the joint?

Decision on Initial Beam Operating Energy

(August 2009)

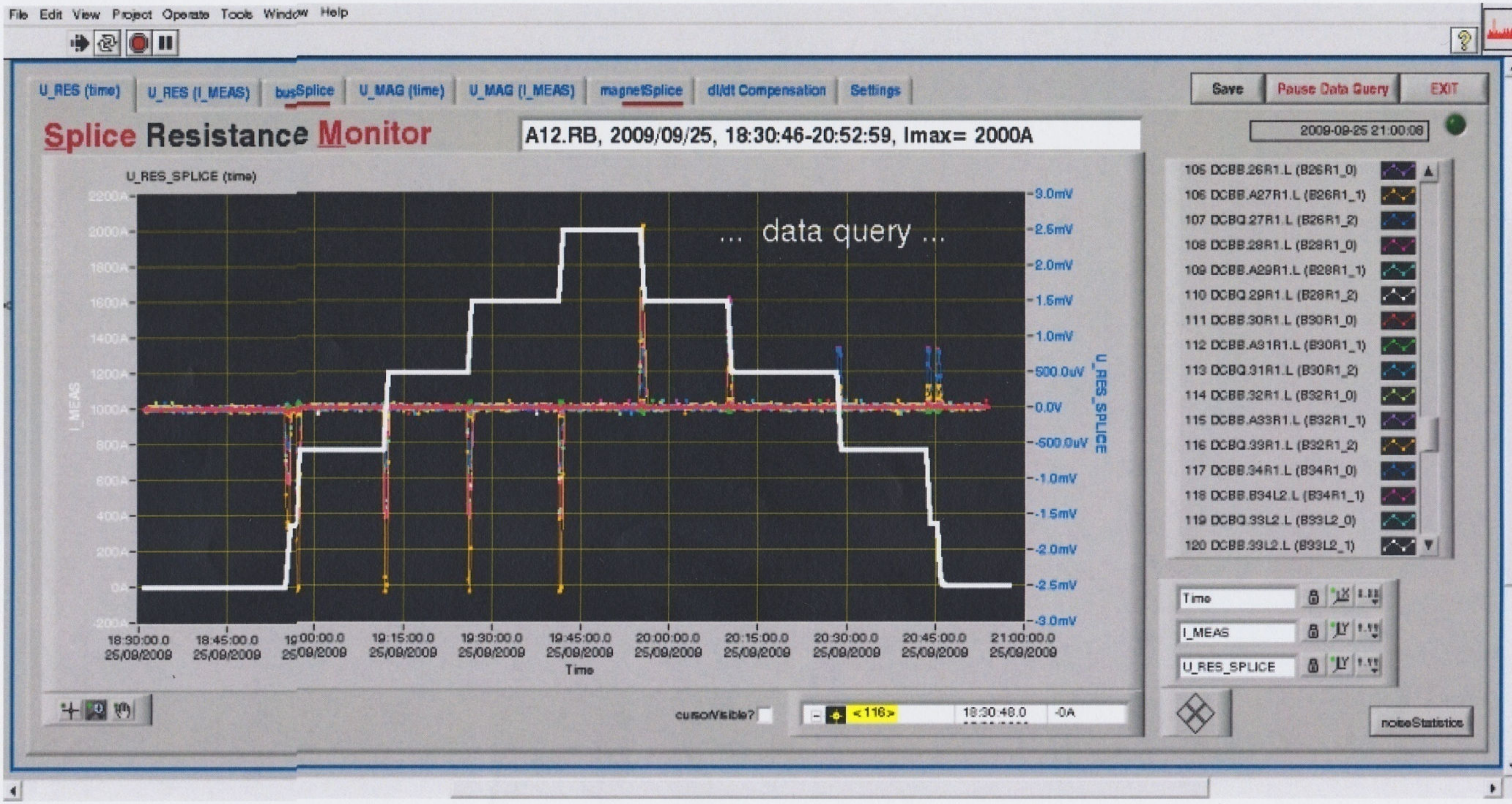
- Highest measured value of excess resistance (R_{long}) in 5 sectors measured at 300K was 53$\mu\Omega$.
- Operating at 7TeV cm with a energy extraction times of 50s, 10s (dipoles and quadrupoles)
  - Simulations show that resistances of $\leq$120$\mu\Omega$ are safe from thermal runaway under conservative assumed conditions of worst case conditions for the copper quality (RRR) and no cooling to the copper stabilizer from the gaseous helium
- Operating at 10TeV cm with a dipole energy extraction time of 68 s
  - Simulations show that resistances of $\leq$67$\mu\Omega$ are safe from thermal runaway under conservative assumed conditions of worst case conditions for the copper quality (RRR), and with estimated cooling to the stabilizer from the gaseous helium
- Decision: Operation initially at 7TeV cm (energy extraction time of 50s,10s) with a safety factor or more than 2 for the worst stabilizers. During this time
  - monitor carefully all quenches to gain additional information.
  - Continue simulations and validation of simulations by experimentation (FRESCA)
- Then operate at around ~10TeV cm.

Decision Taken Jointly by Management, Accelerator and Detector People

Since August

- Start of re-establishment of spares situation as it was before the incident
- Helium leak (flexible in the DFBs) in S45, S23, and S81. All repaired
- Magnet/busbar short to earth in S67 (detected and repaired)
- Vacuum “leak” (insulating vacuum) in S34 (mitigated by additional pumping)
- “bugs” associated with nQPS (delay in going to 6kA (3.5TeV)

New Results

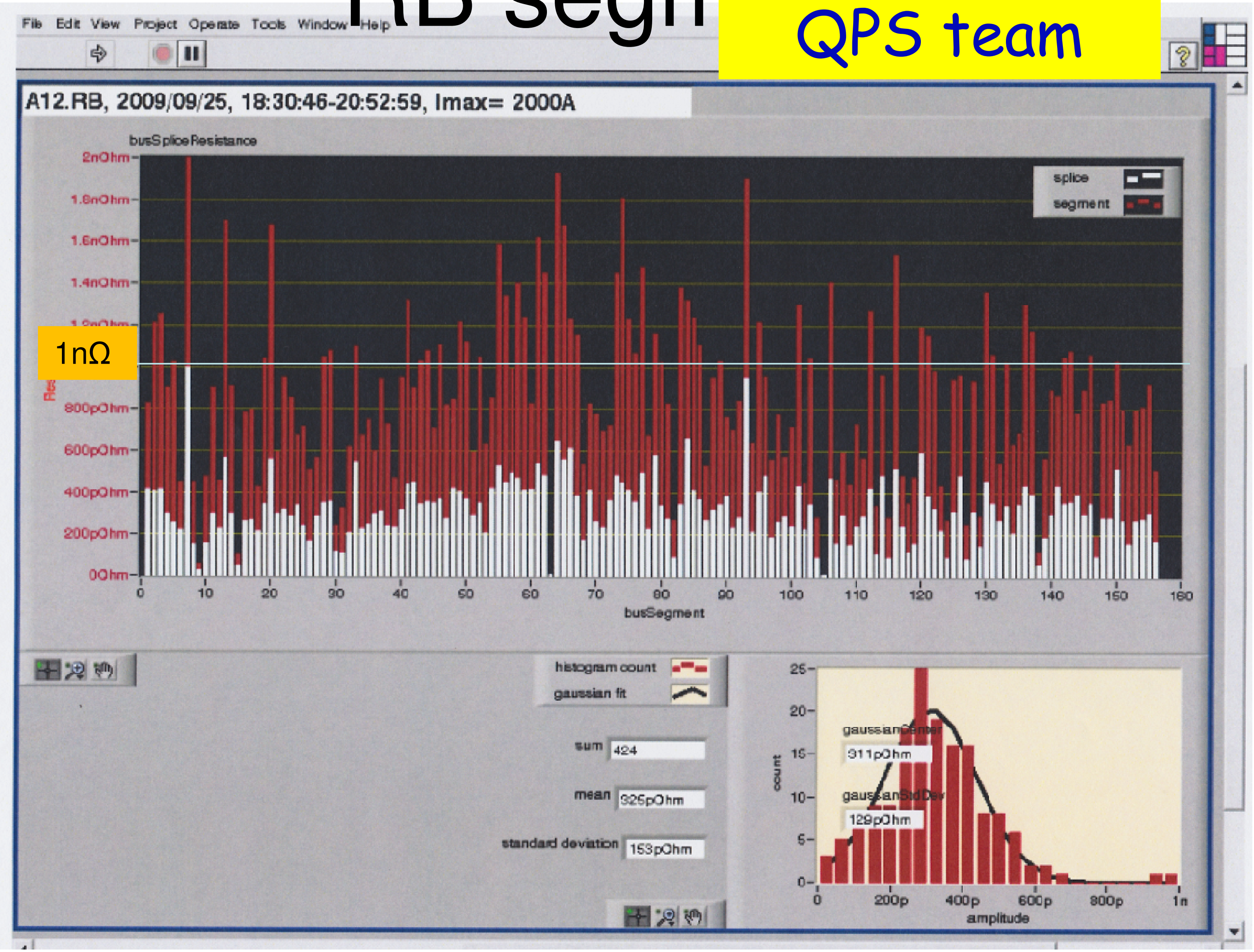


Current profile and all Dipole Busbar voltages during inductive compensation tuning.

New Results

RB segments

QPS team

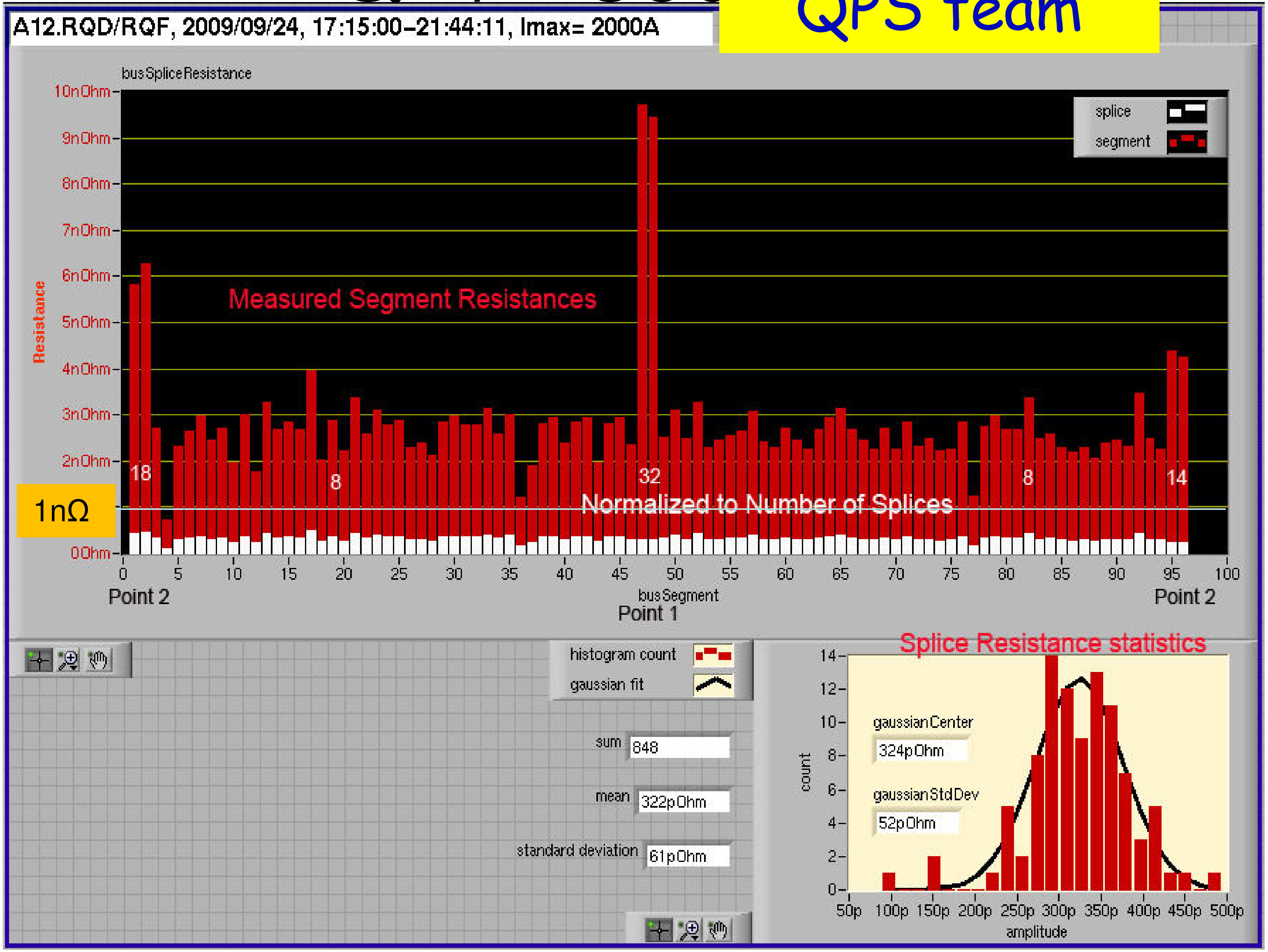


First Dipole Busbar Resistances from first scan to 2 kA

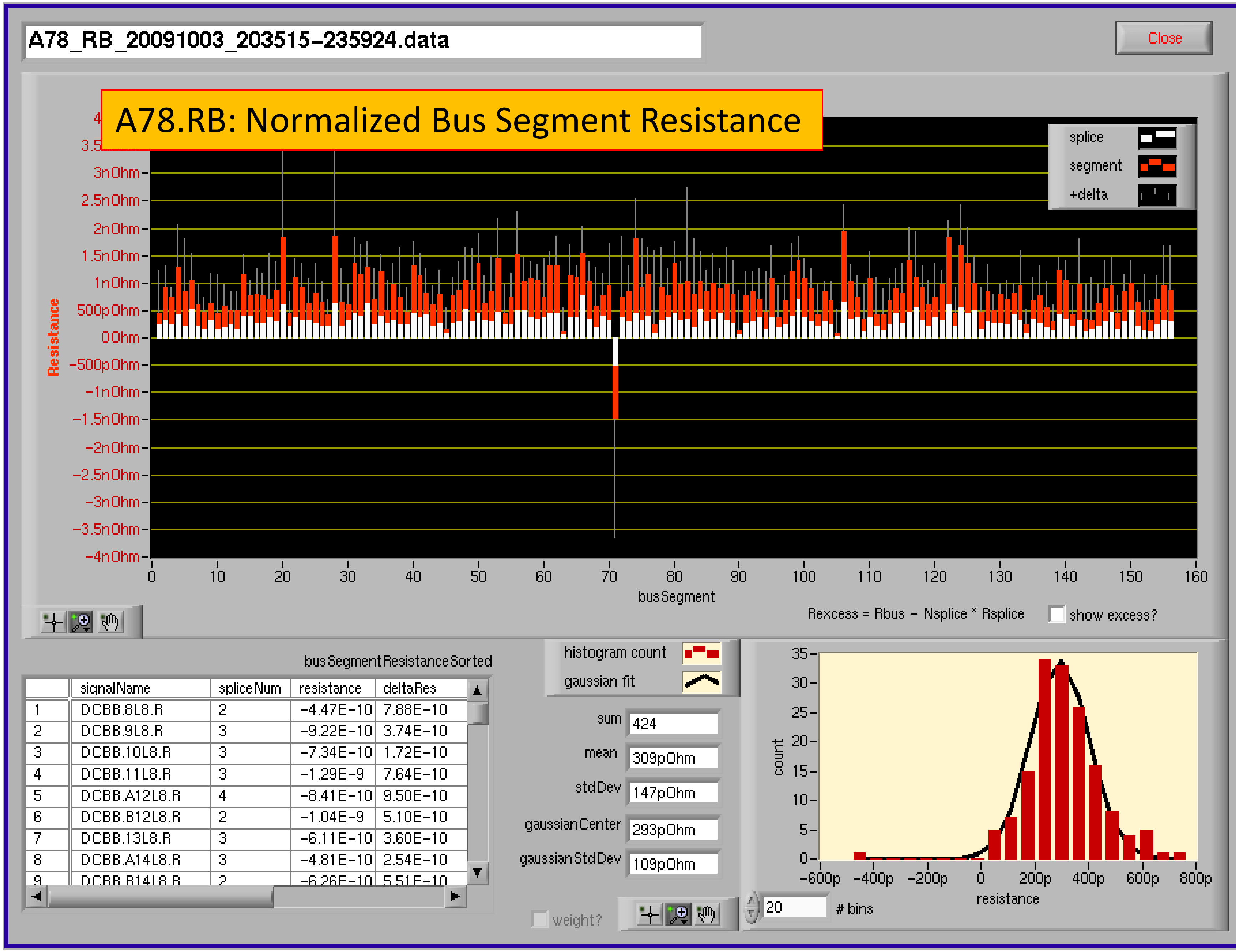
New Results

RQD/F segments

QPS team

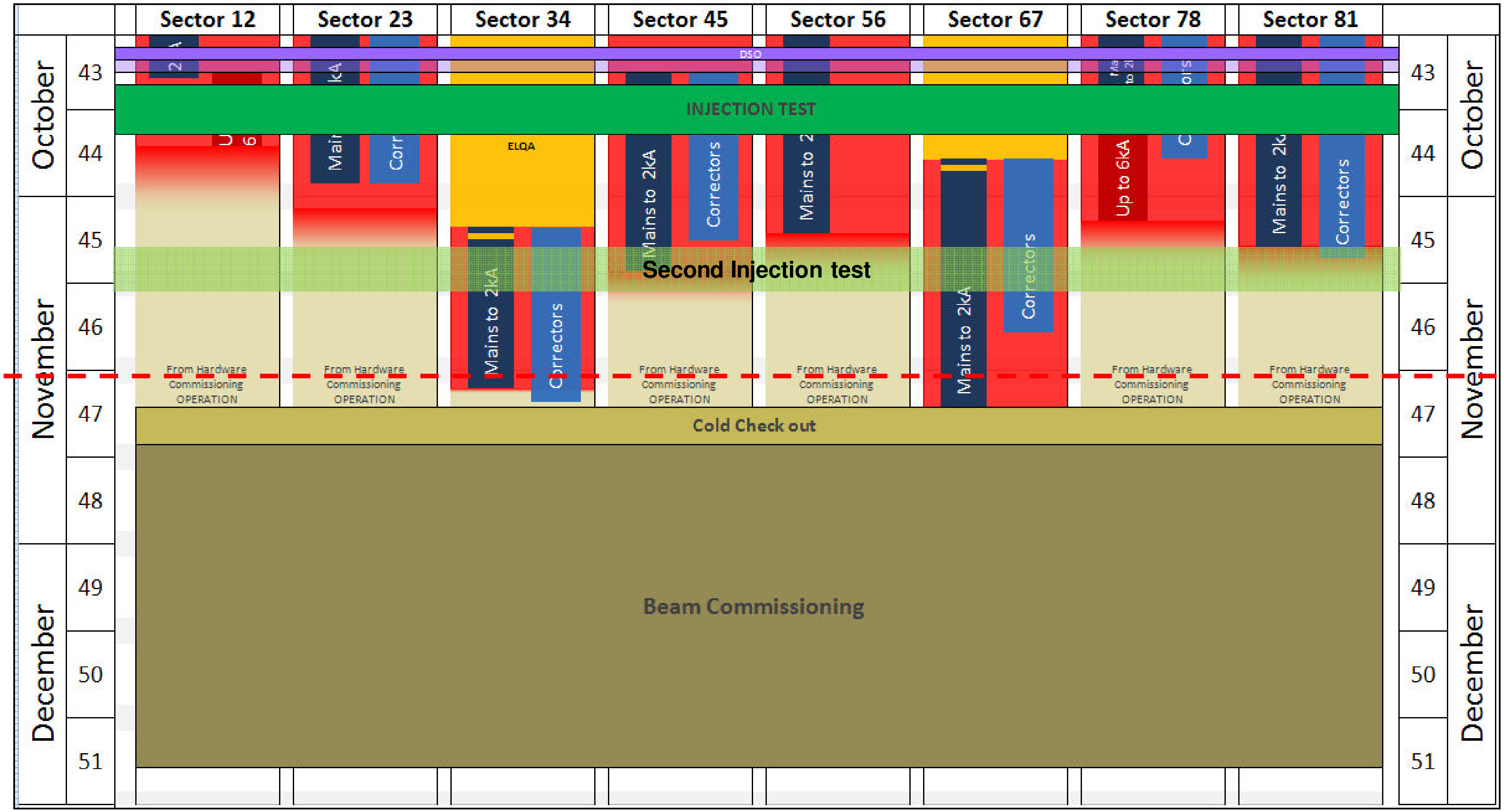


A78.RB: Normalized Bus Segment Resistance



LHC Schedule

Schedule



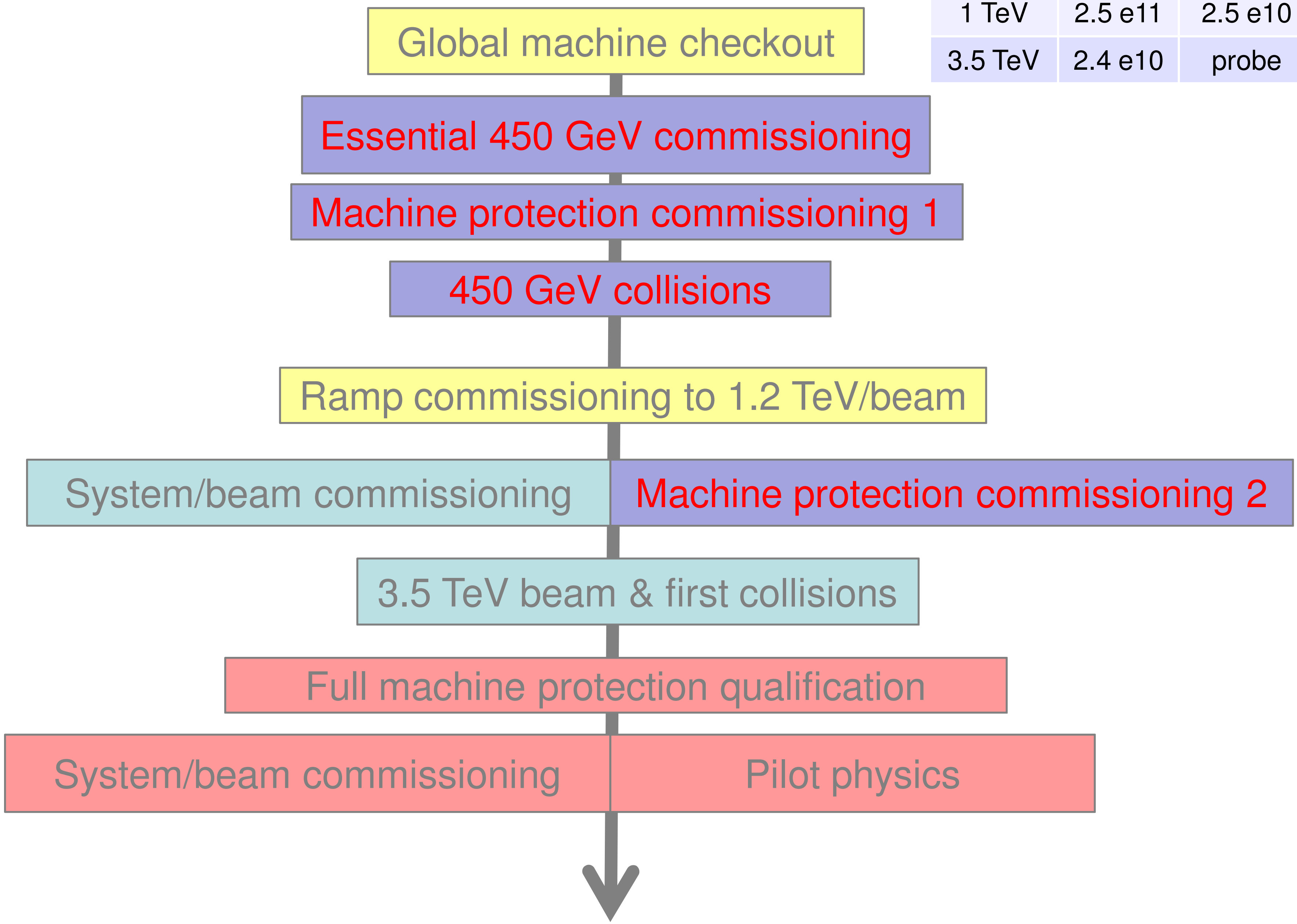
Sector 12
Sector 23
Sector 34
Sector 45
Sector 56
Sector 67
Sector 78
Sector 81
October
November
December
43
44
45
46
47
48
49
50
51
DSO
INJECTION TEST
ELQA
Mains to 2kA
Correctors
Mains to 2kA
Up to 6kA
Second Injection test
From Hardware Commissioning OPERATION
Cold Check out
Beam Commissioning

LHC 2009/2010 – running scenarios

this is the present plan which will almost certainly be modified on a daily/weekly basis once we start with beam commissioning.
BUT we need a plan!

LHC beam commissioning

Energy	Safe	Very Safe
450	1 e12	1 e11
1 TeV	2.5 e11	2.5 e10
3.5 TeV	2.4 e10	probe



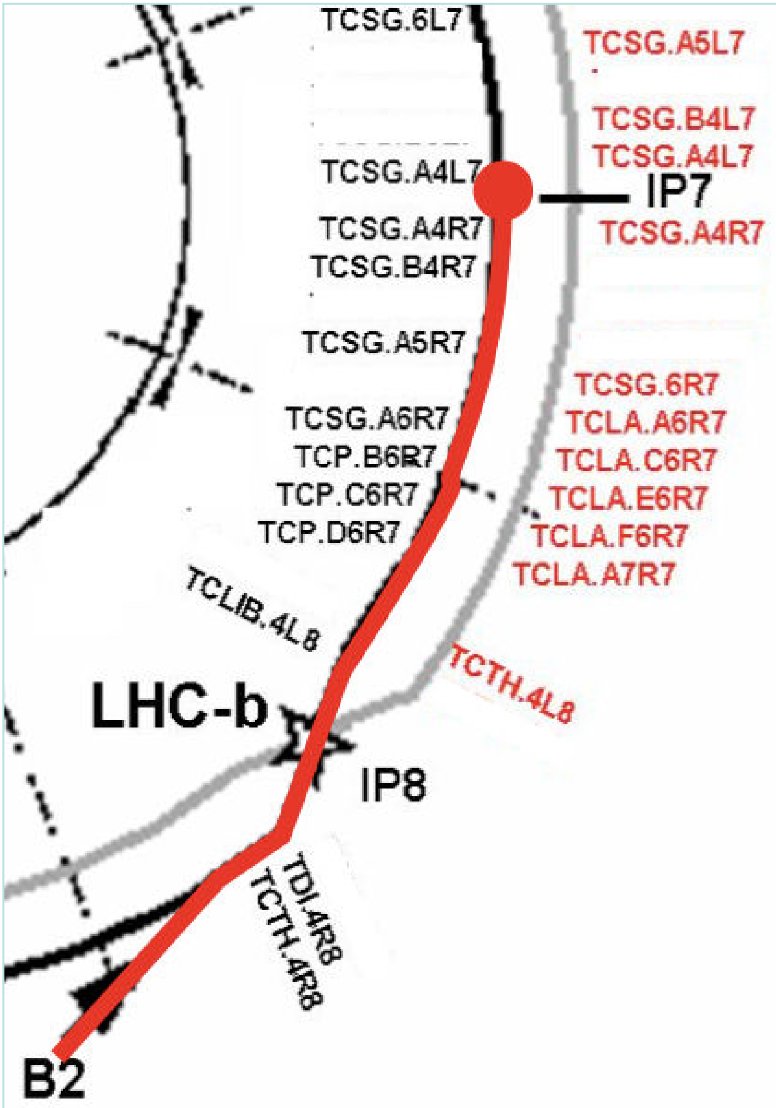
Plugging in the numbers with a step in energy

Month	OP scenario	Max number bunch	Protons per bunch	Min beta*	Peak Lumi	Integrated	% nominal
1	Beam commissioning						
2	Pilot physics combined with commissioning	43	3×10^{10}	4	8.6×10^{29}	~200 nb^{-1}	
3		43	5×10^{10}	4	2.4×10^{30}	~1 pb^{-1}	
4		156	5×10^{10}	2	1.7×10^{31}	~9 pb^{-1}	2.5
5a	No crossing angle	156	7×10^{10}	2	3.4×10^{31}	~18 pb^{-1}	3.4
5b	No crossing angle – pushing bunch intensity	156	1×10^{11}	2	6.9×10^{31}	~36 pb^{-1}	4.8
6	Shift to higher energy: approx 4 weeks	Would aim for physics without crossing angle in the first instance with a gentle ramp back up in intensity					
7	4 – 5 TeV (5 TeV luminosity numbers quoted)	156	7×10^{10}	2	4.9×10^{31}	~26 pb^{-1}	3.4
8	50 ns – nominal Xing angle	144	7×10^{10}	2	4.4×10^{31}	~23 pb^{-1}	3.1
9	50 ns	288	7×10^{10}	2	8.8×10^{31}	~46 pb^{-1}	6.2
10	50 ns	432	7×10^{10}	2	1.3×10^{32}	~69 pb^{-1}	9.4
11	50 ns	432	9×10^{10}	2	2.1×10^{32}	~110 pb^{-1}	12

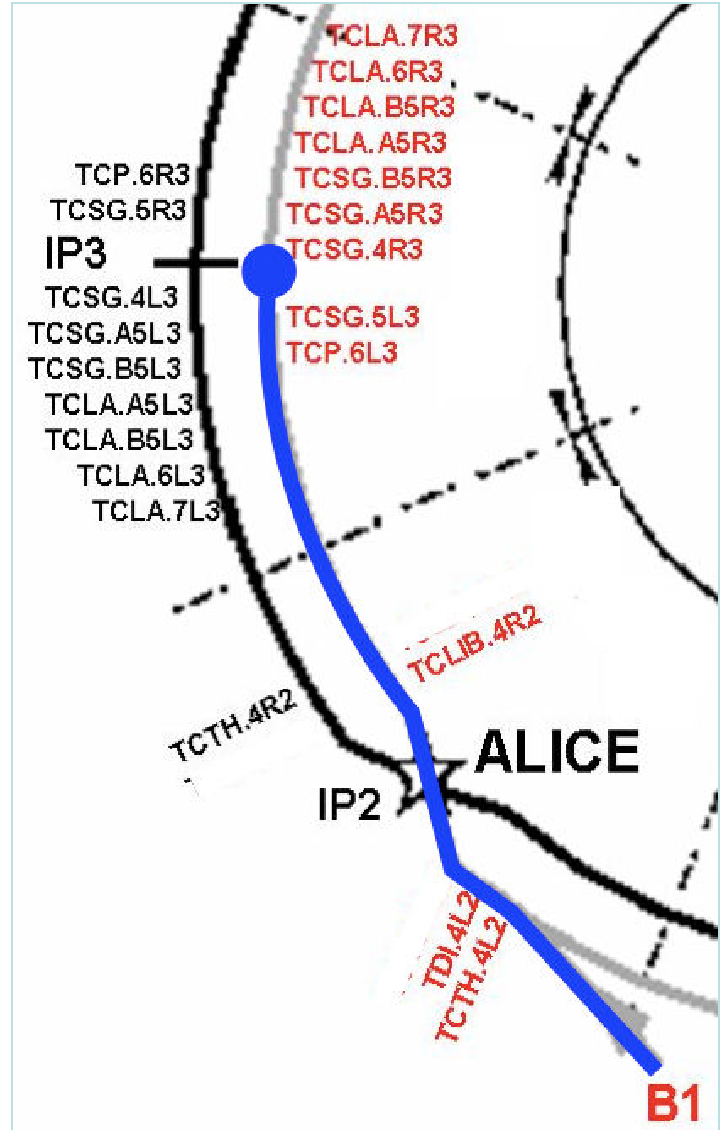
Recent News

- Injection test 24-45 October
- Injection tests 7-8 November
- Where are we today?

Injection test(s) 2009



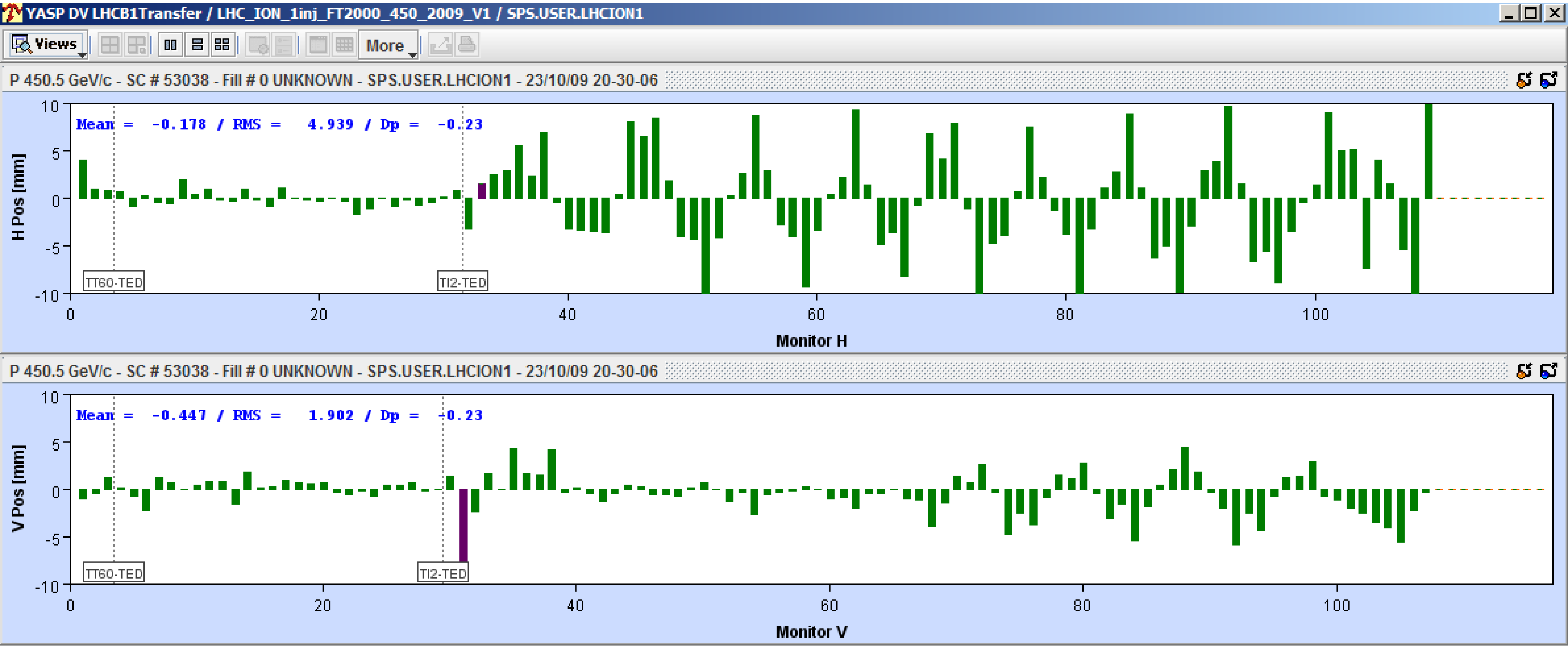
Injection tests 2009



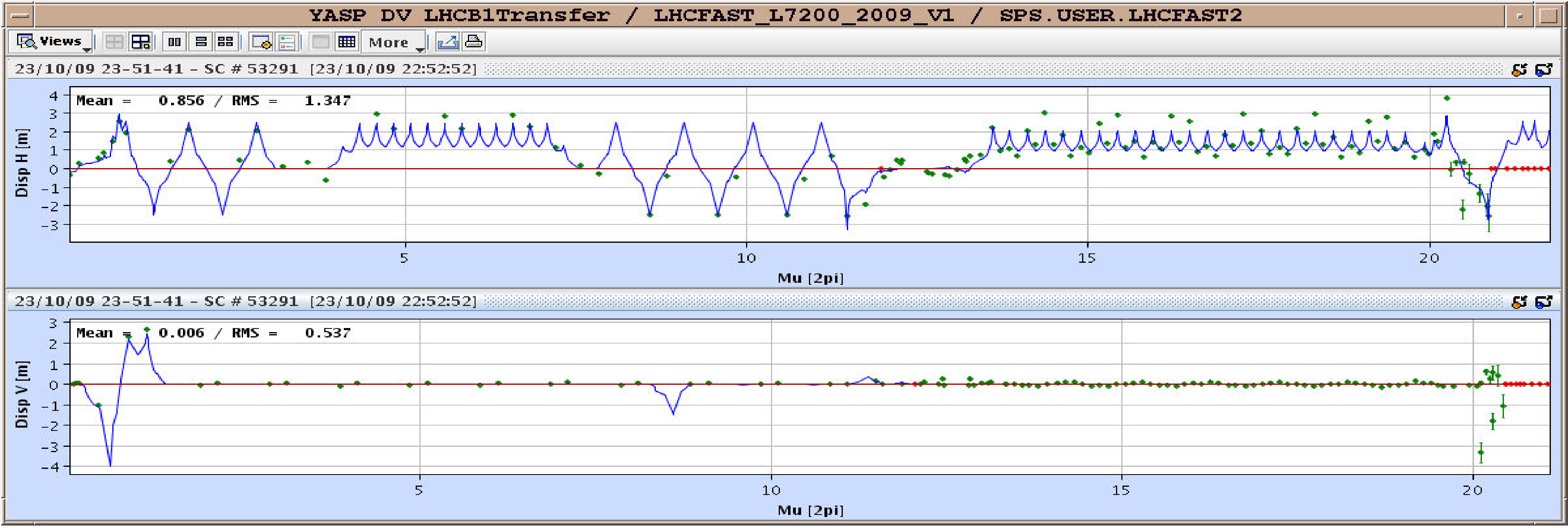
Main Objectives

- Injection region
  - aperture, protection, kickers
- Threading, energy matching
- Optics measurements
  - check re-matched lines and dispersion into LHC
  - polarities
- Beam instrumentation system response
  - BLMs, BPM (BST triggered acquisition)
- Aperture checks
- Check spectrometers

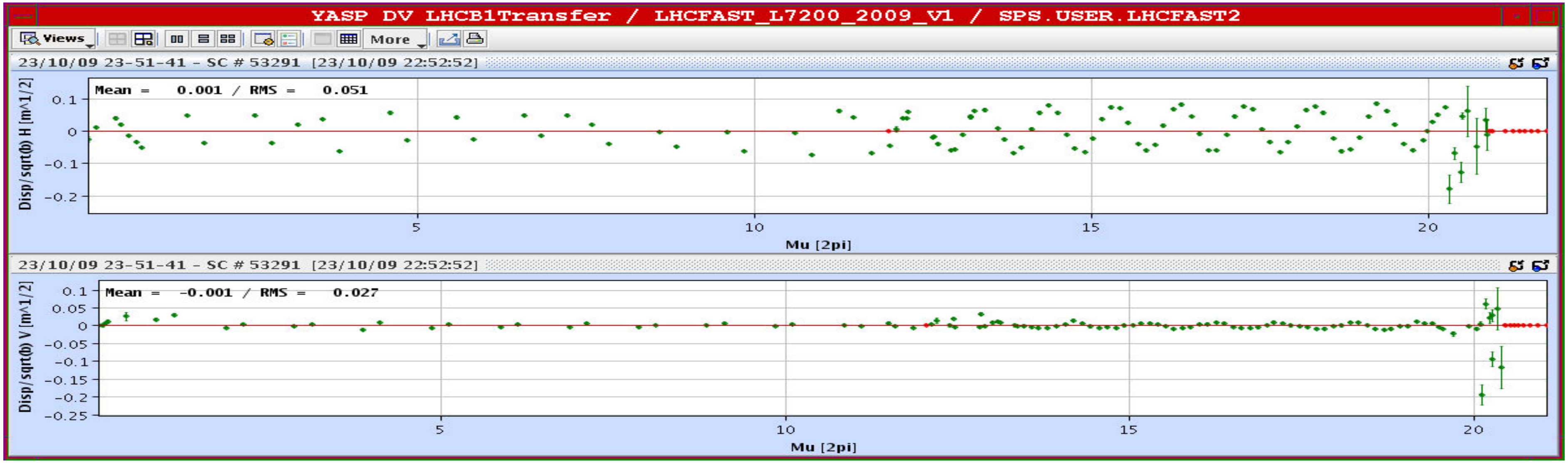
Pre-requisites and procedures detailed



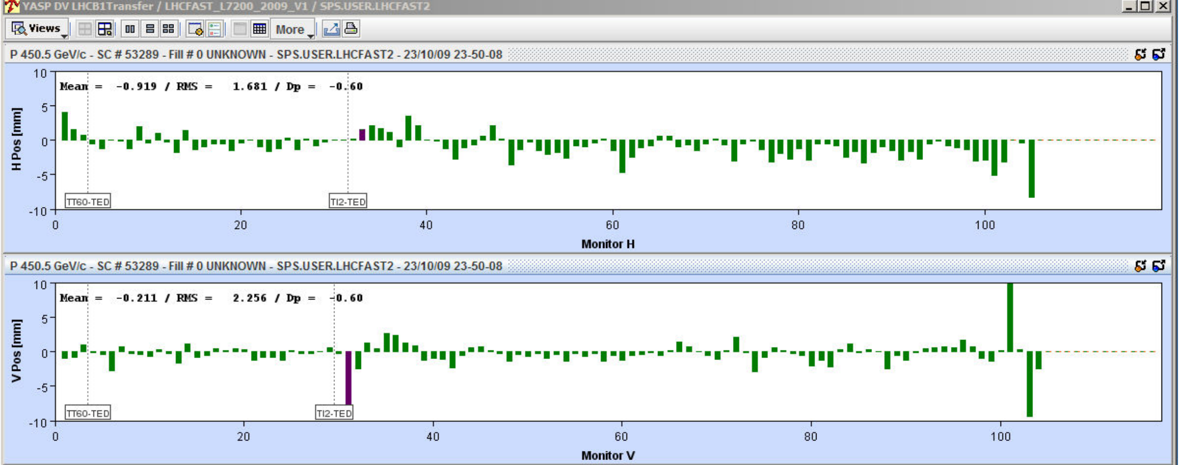
First Trajectory with Ions in the LHC



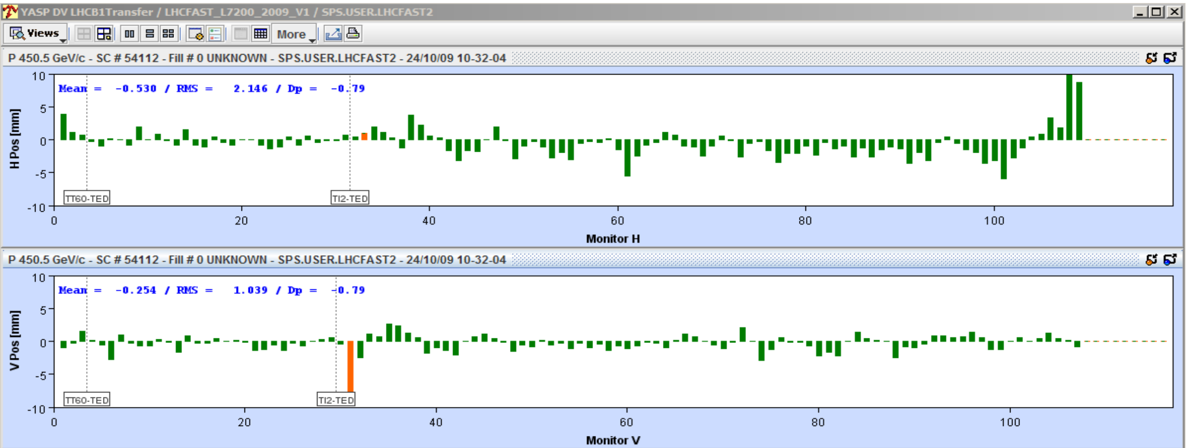
First dispersion measurement (lead ions)



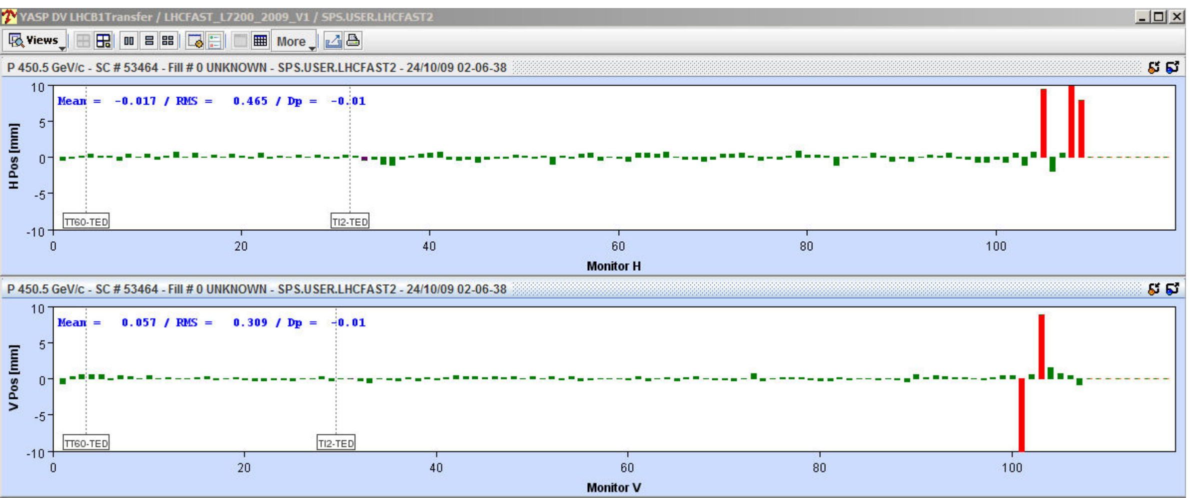
Normalized Dispersion difference to model shows a nice sine ;-) So maybe mainly initial conditions



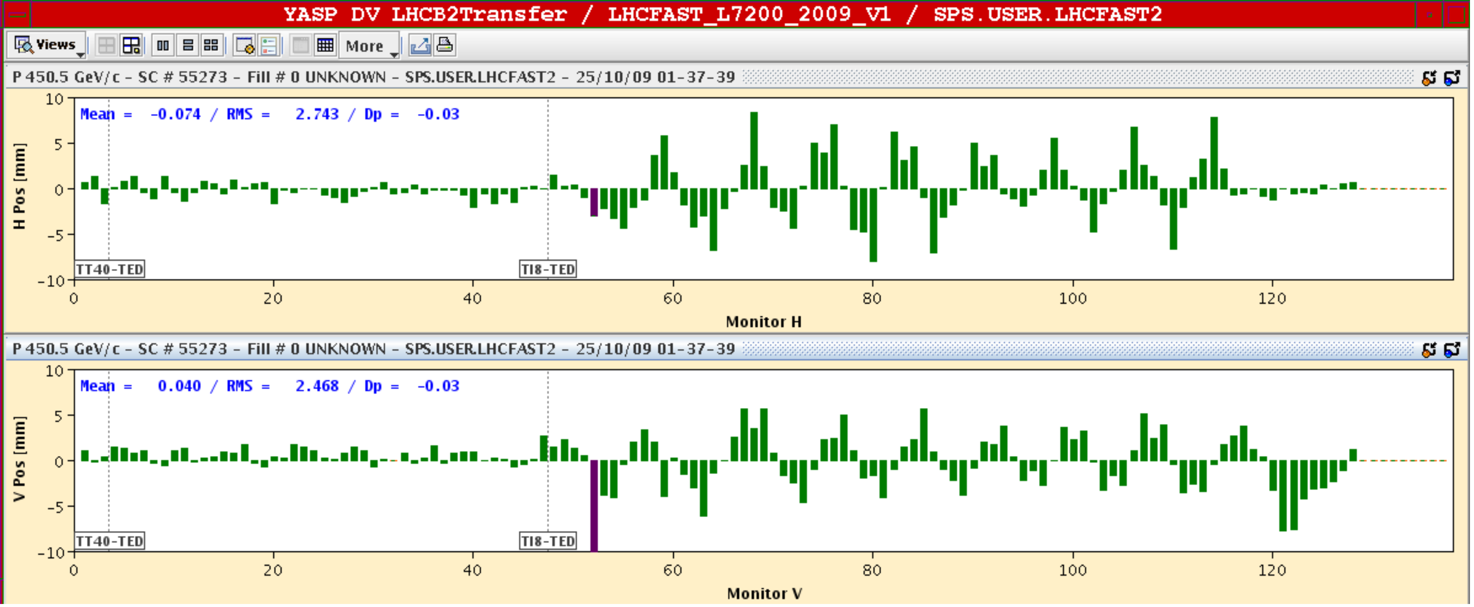
Protons TI2 before cycling magnets



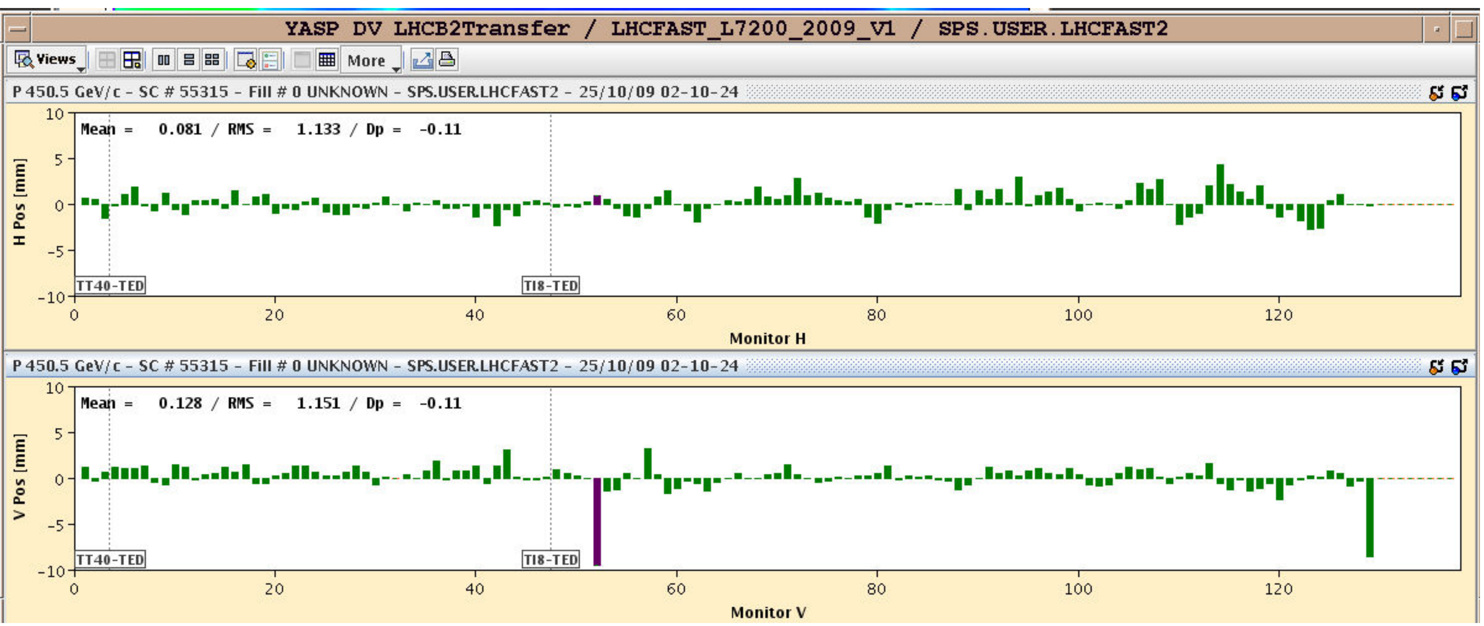
Protons TI2 after cycling magnets



Difference between before and after cycling

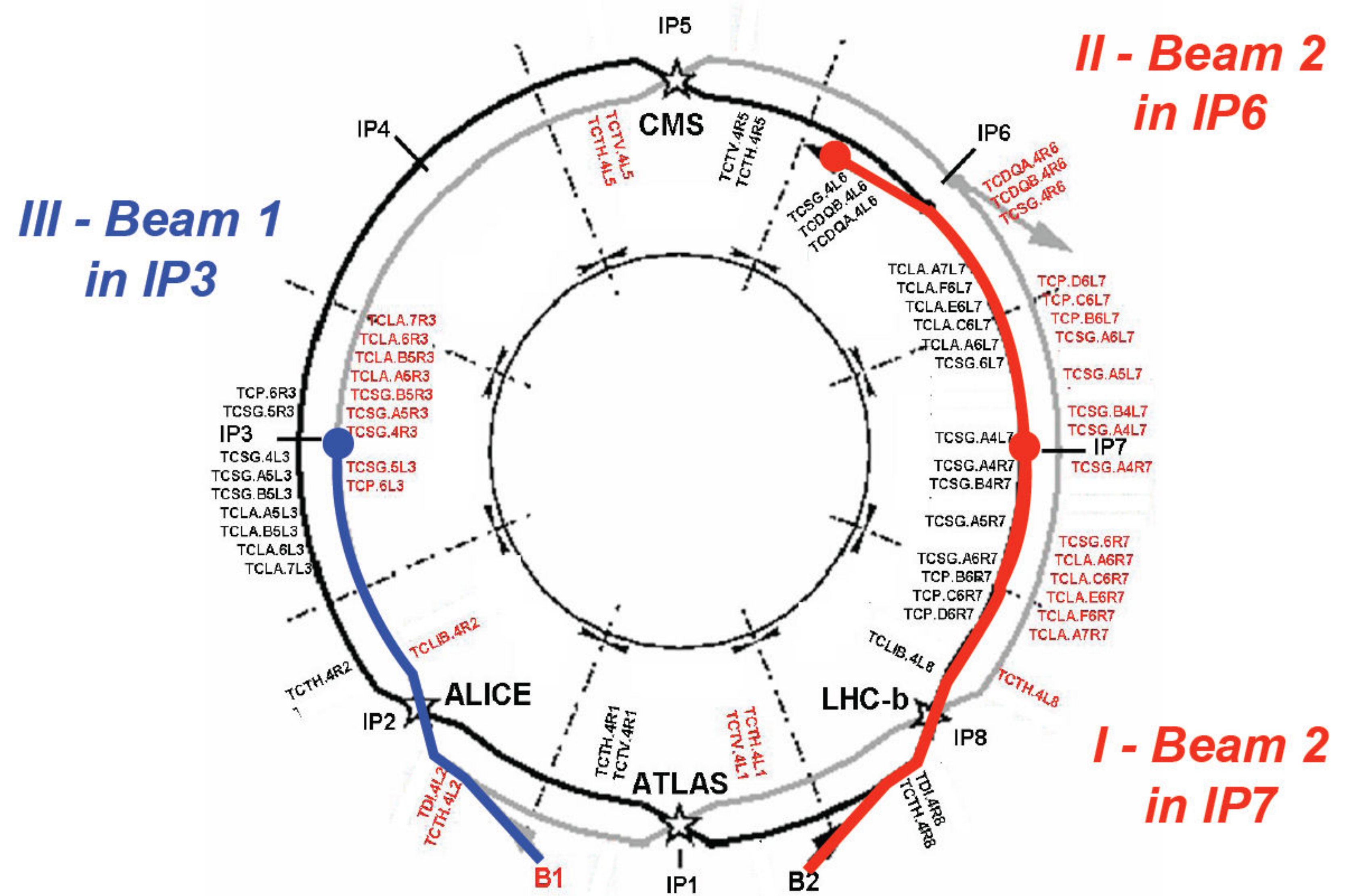


First TI8 + LHC Trajectory

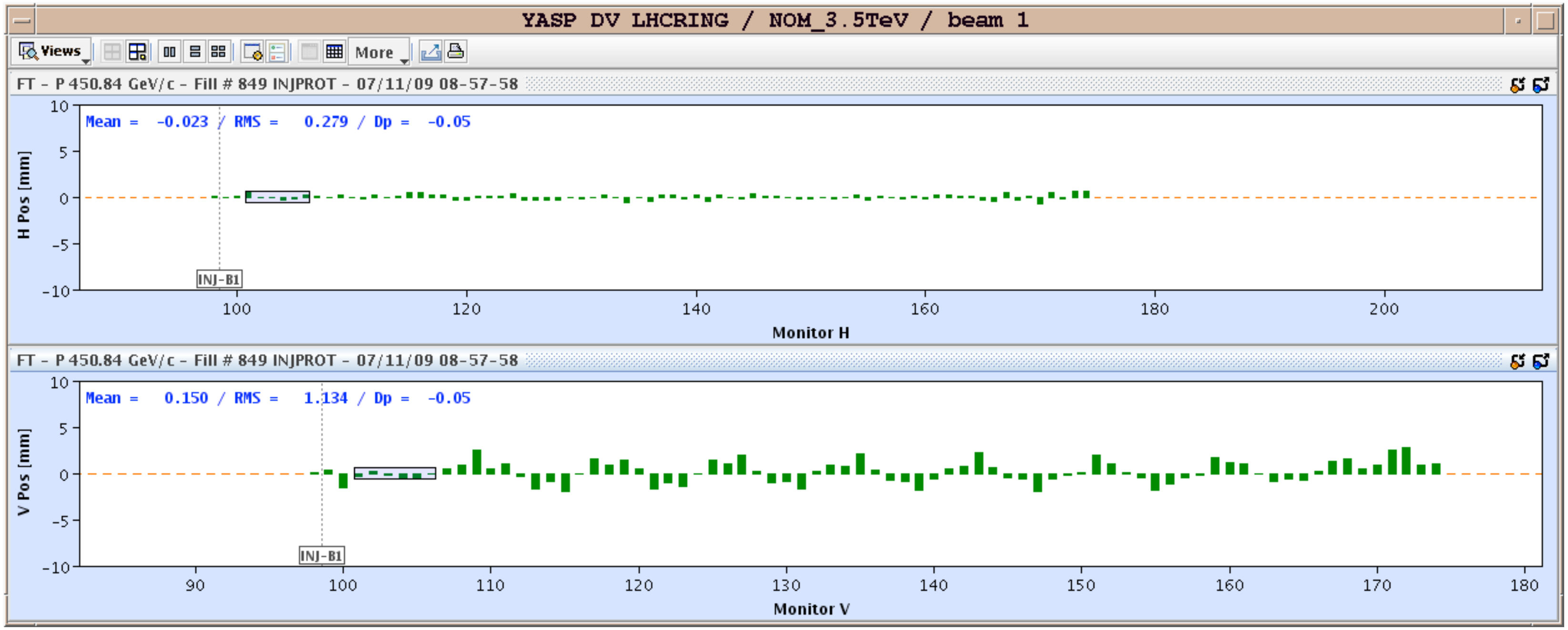


After correction with 1 H and 1 V corrector at end of TI8

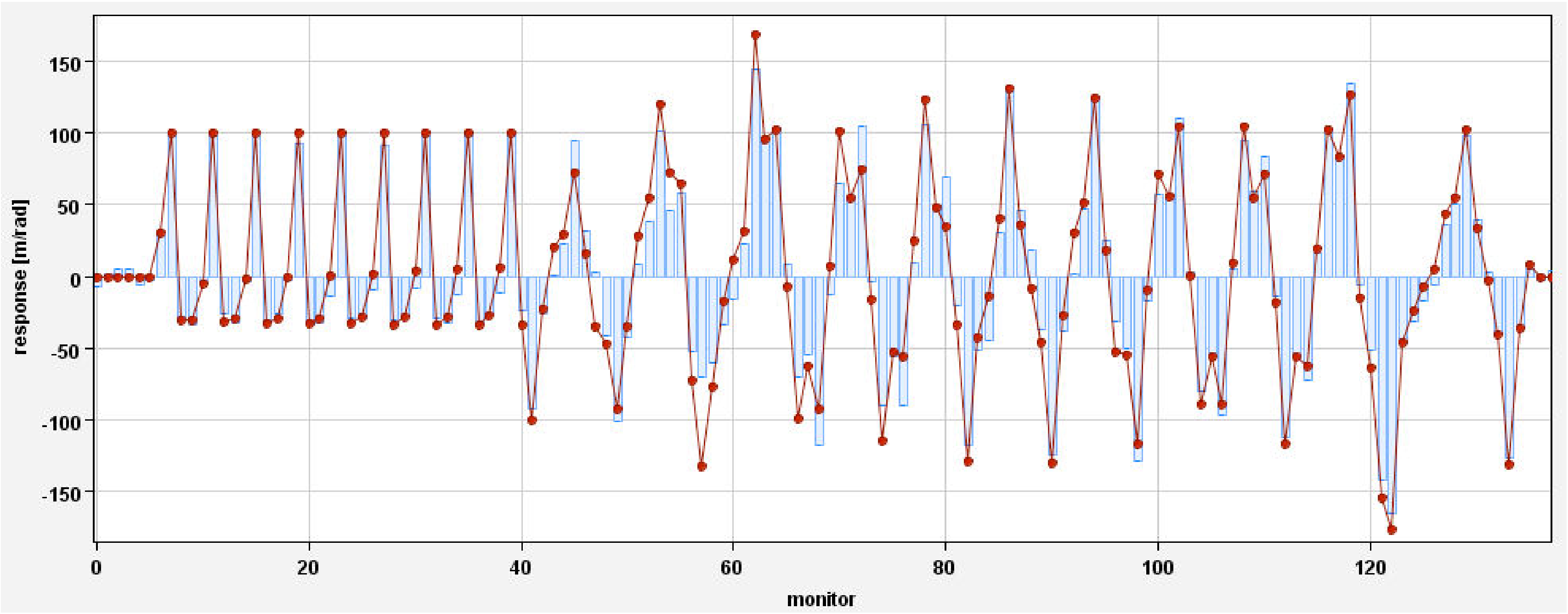
Extended transfer line tests..



Alice spectrometer



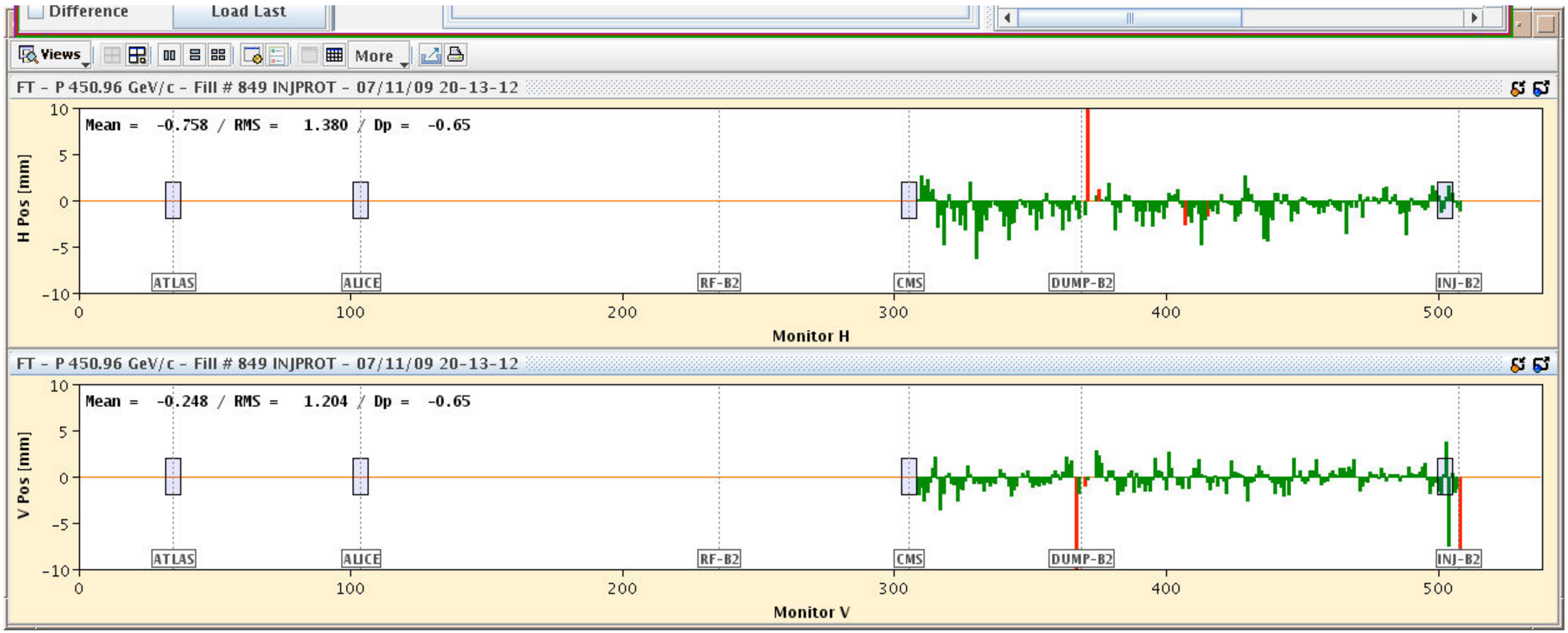
Kick response



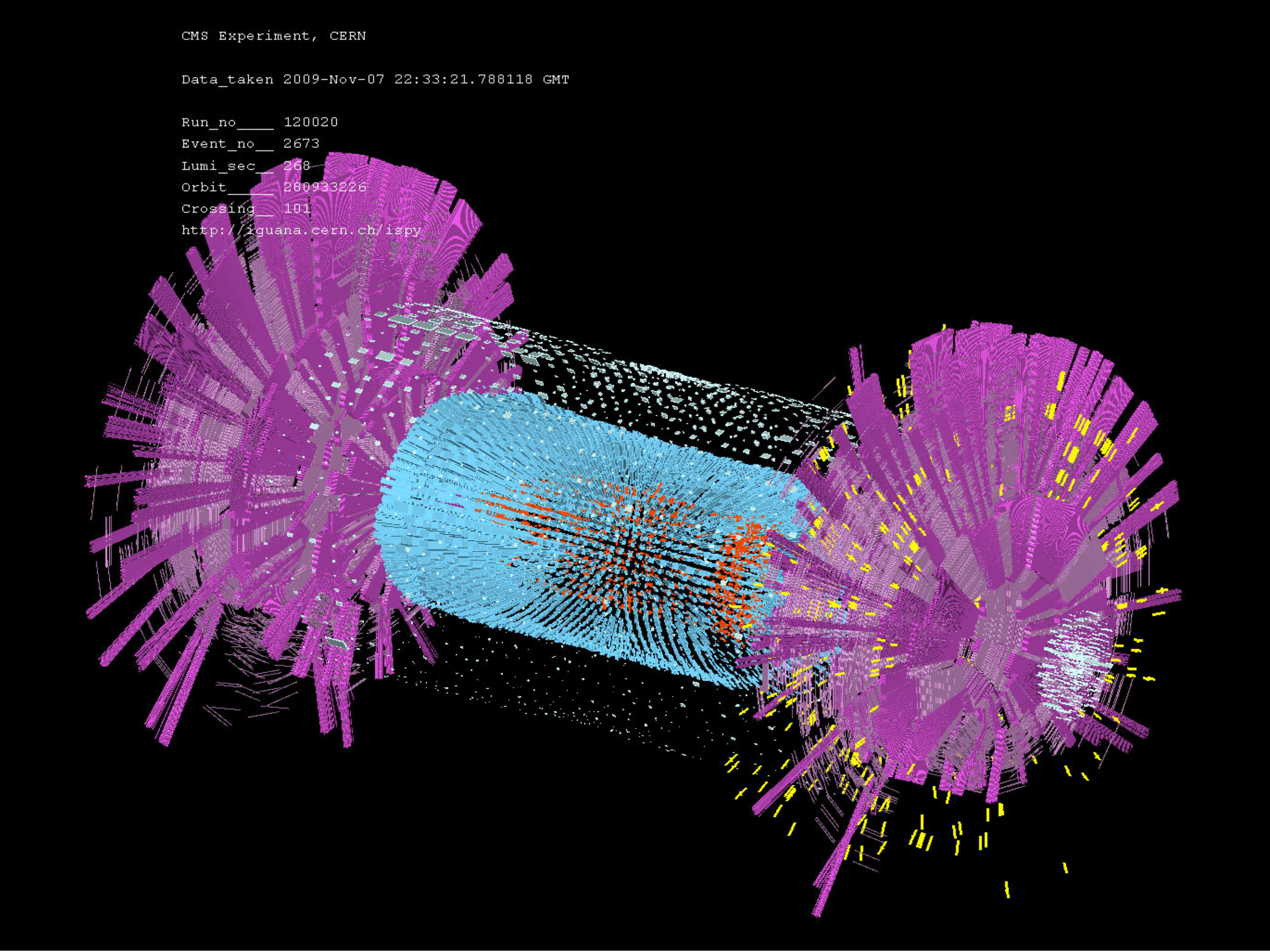
Red simulated Blue measured

Optics is in great shape

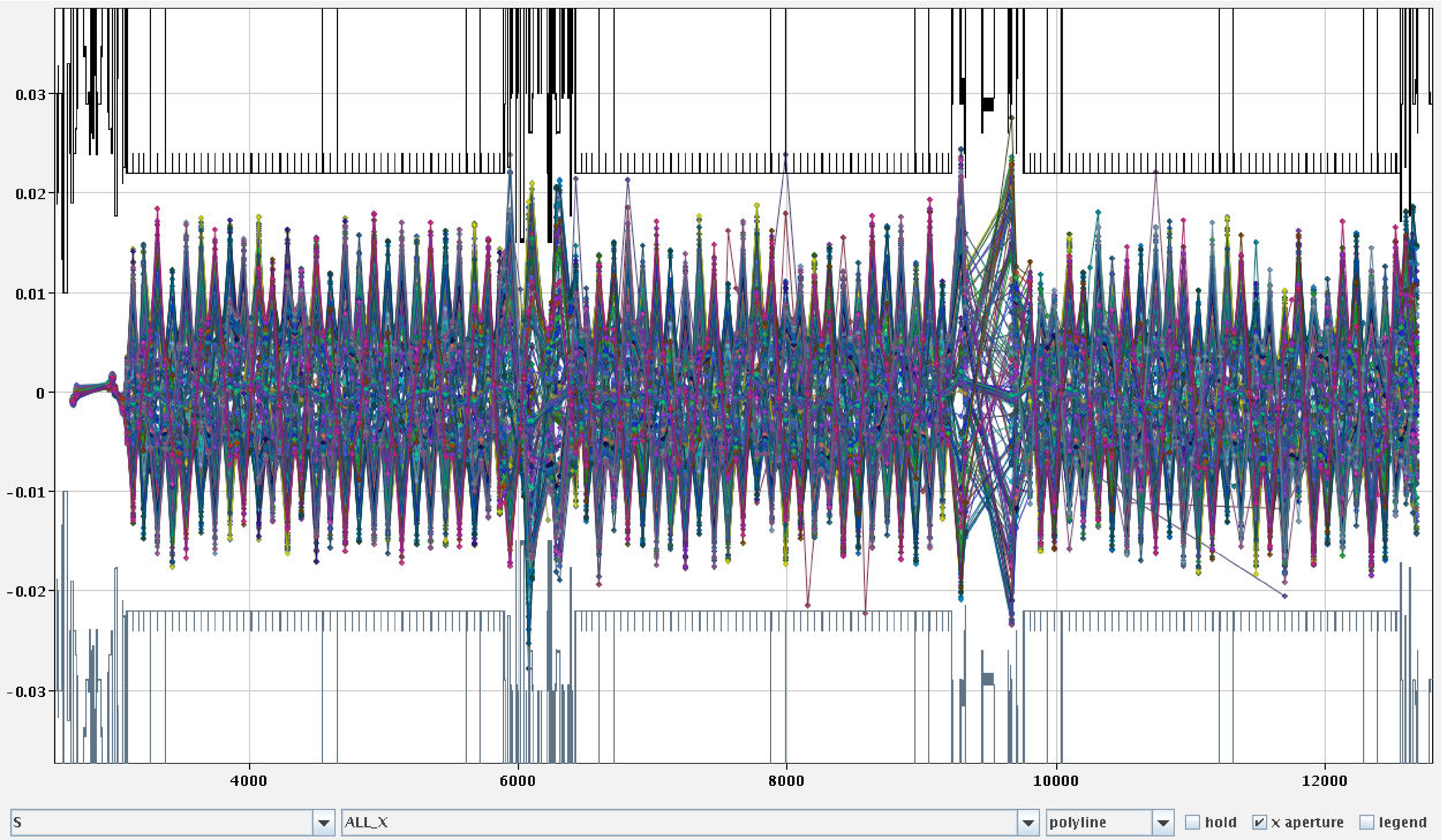
Beam to IR5



Beam 2

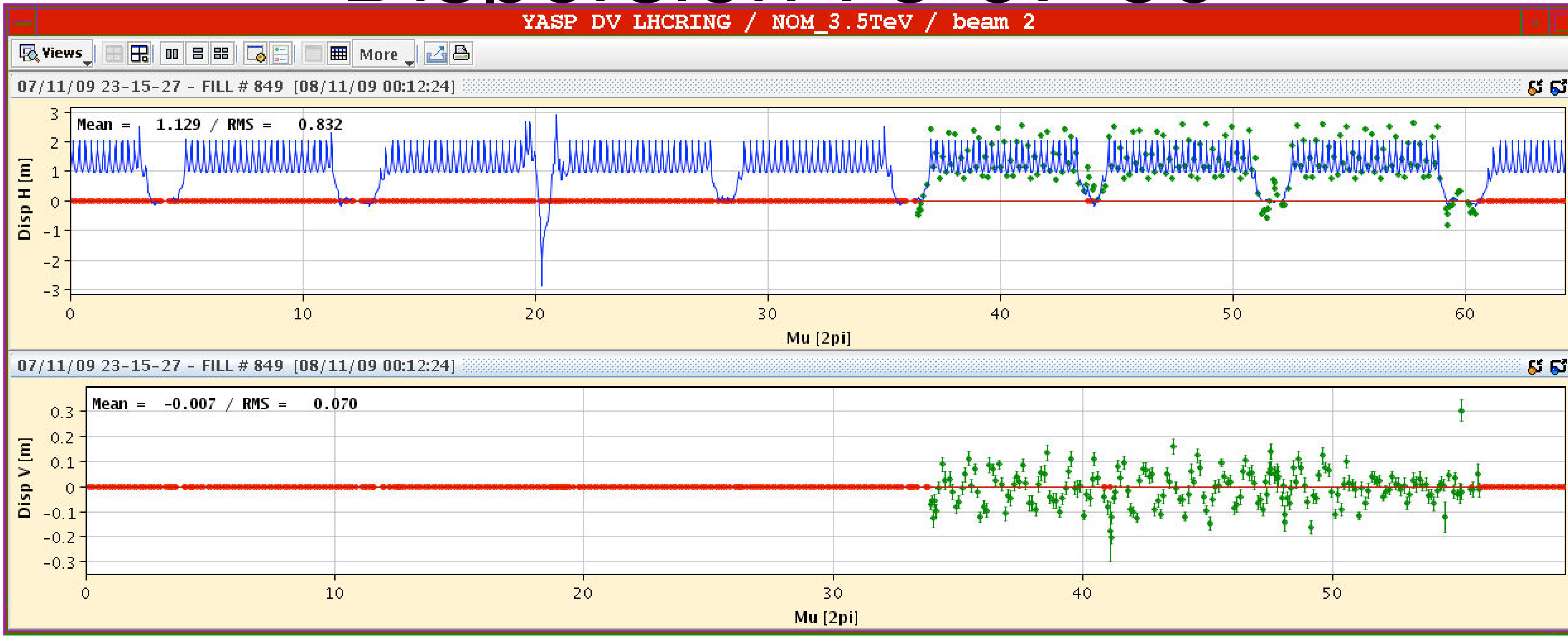

CMS Experiment, CERN
Data_taken 2009-Nov-07 22:33:21.788118 GMT
Run_no____ 120020
Event_no__ 2673
Lumi_sec__ 268
Orbit_____ 280933226
Crossing__ 101
http://iguana.cern.ch/ispy

Aperture 78-67-56

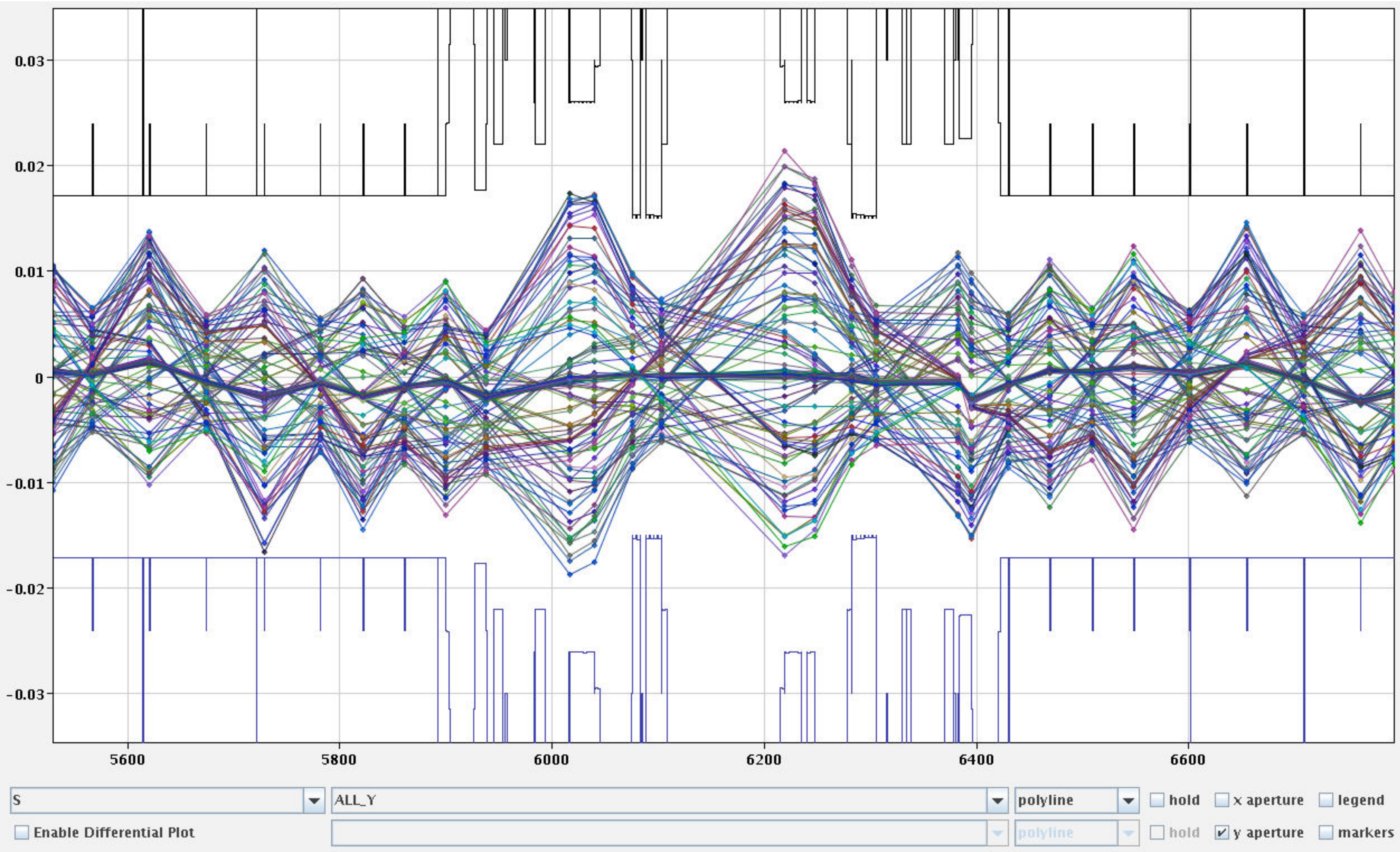


2nd injection test

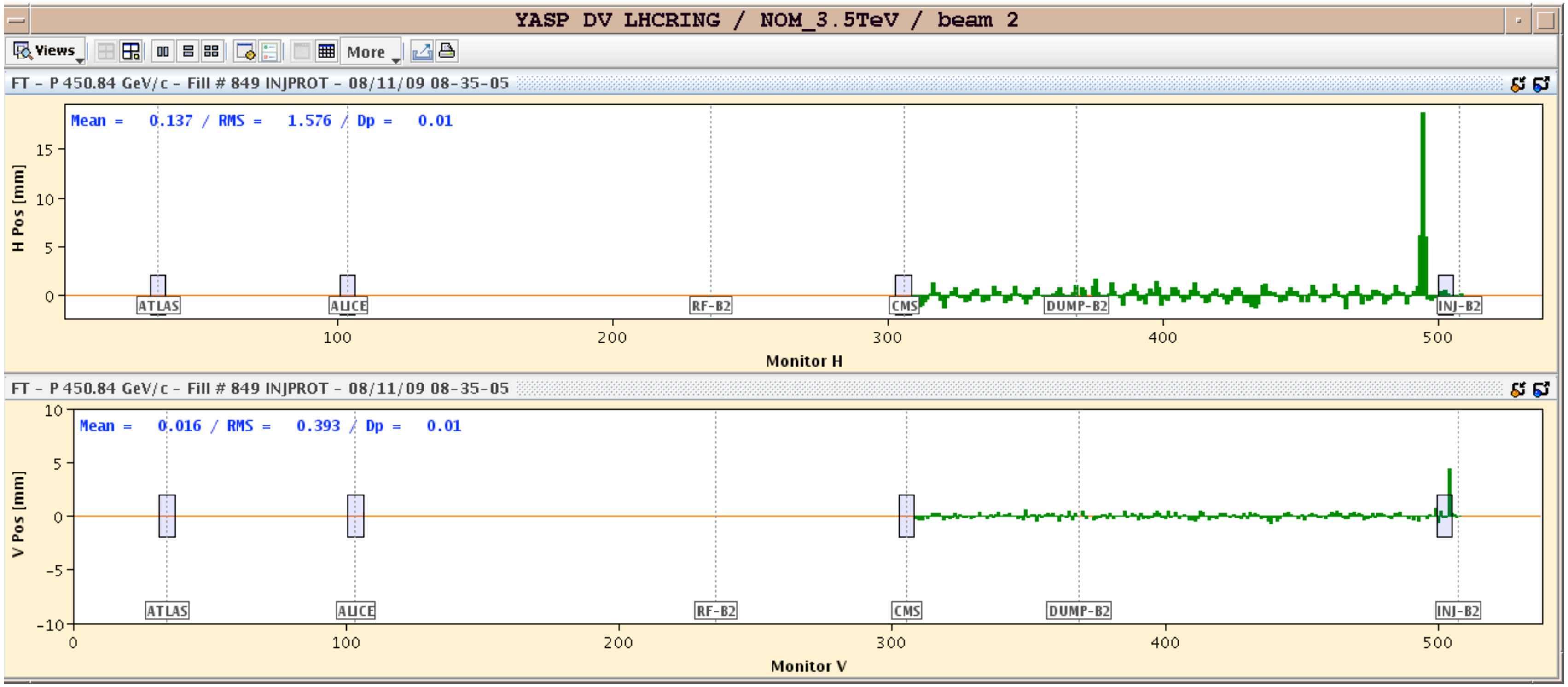
Dispersion 78-67-56



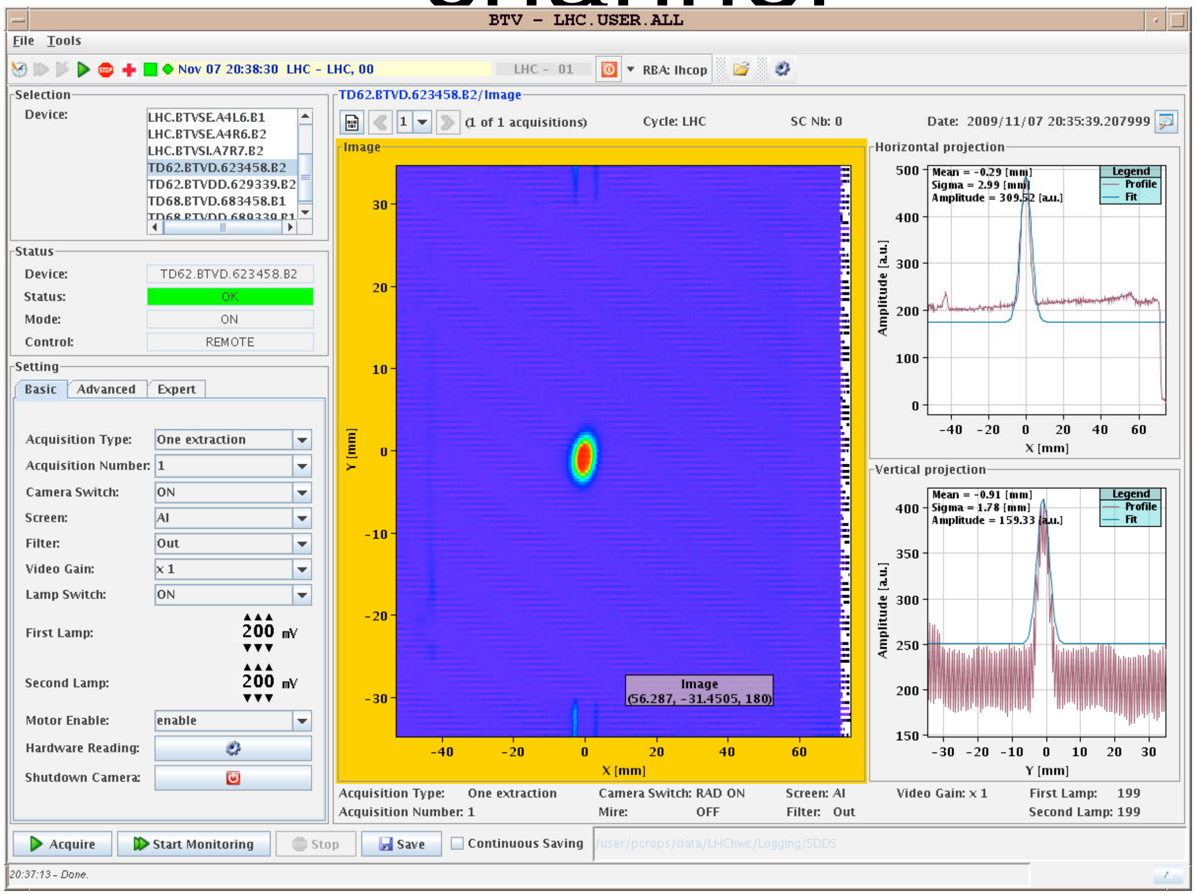
Aperture – V – IP7



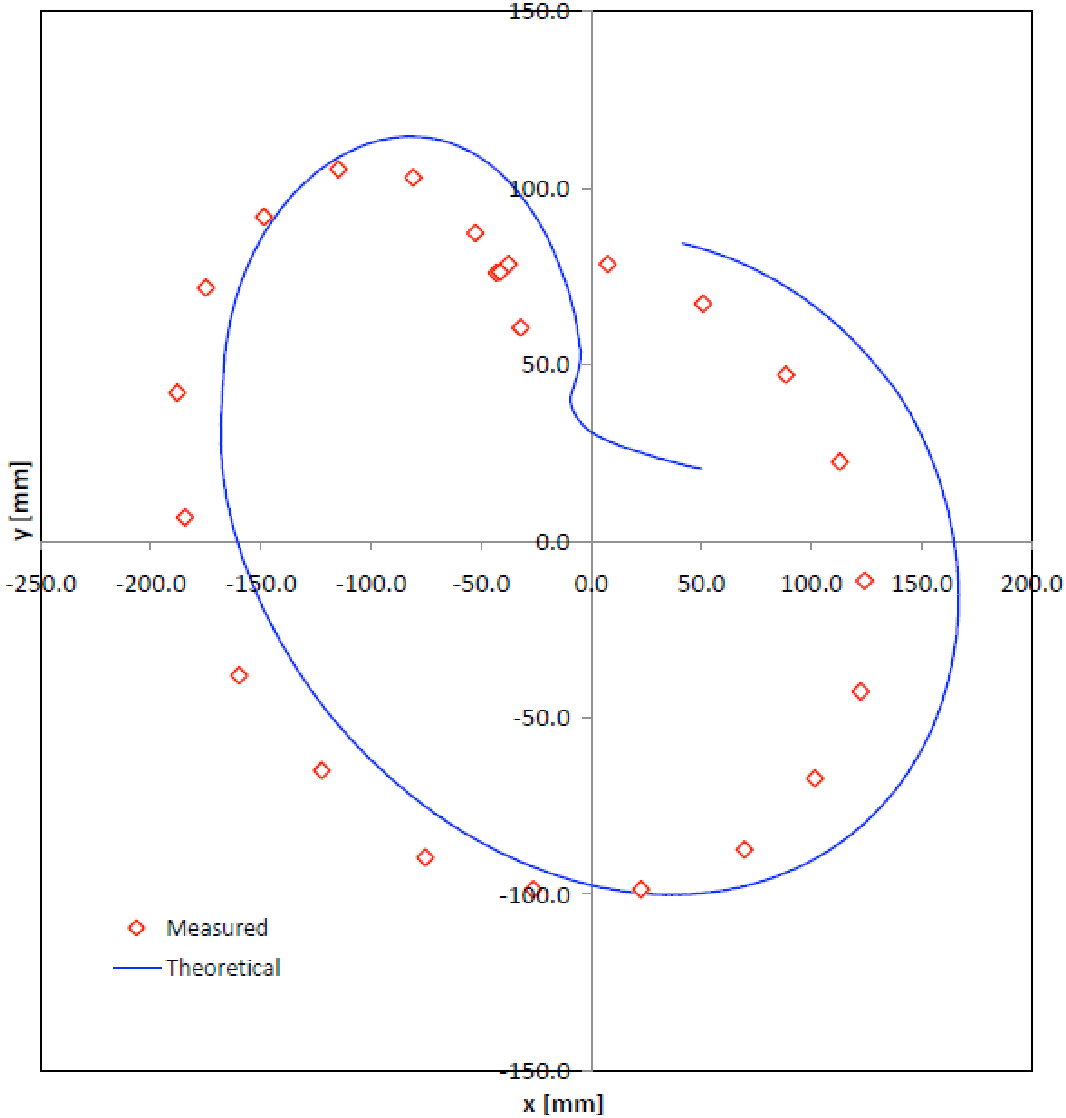
Beam Loss Monitor tests



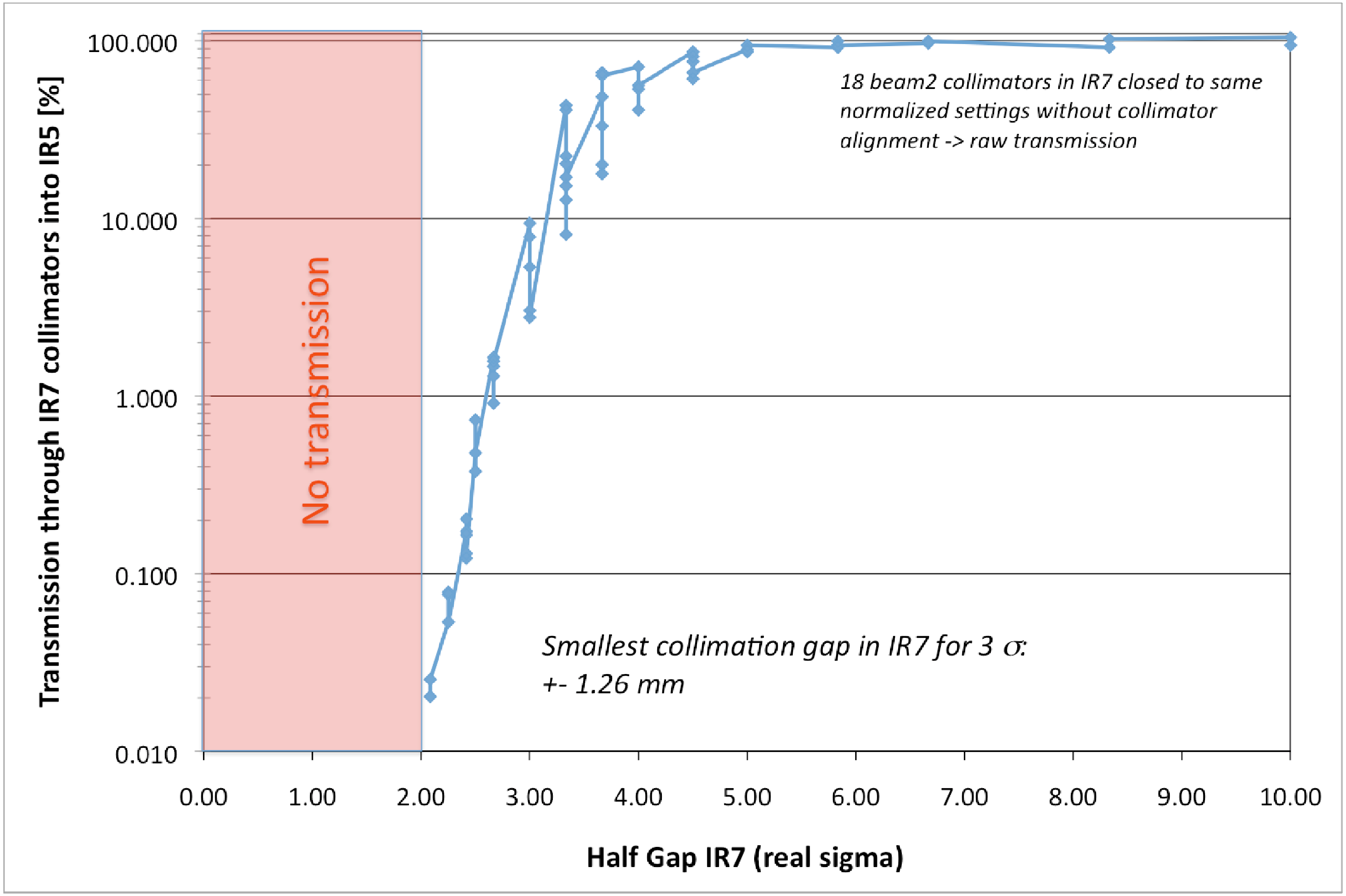
Extraction into beam dump channel



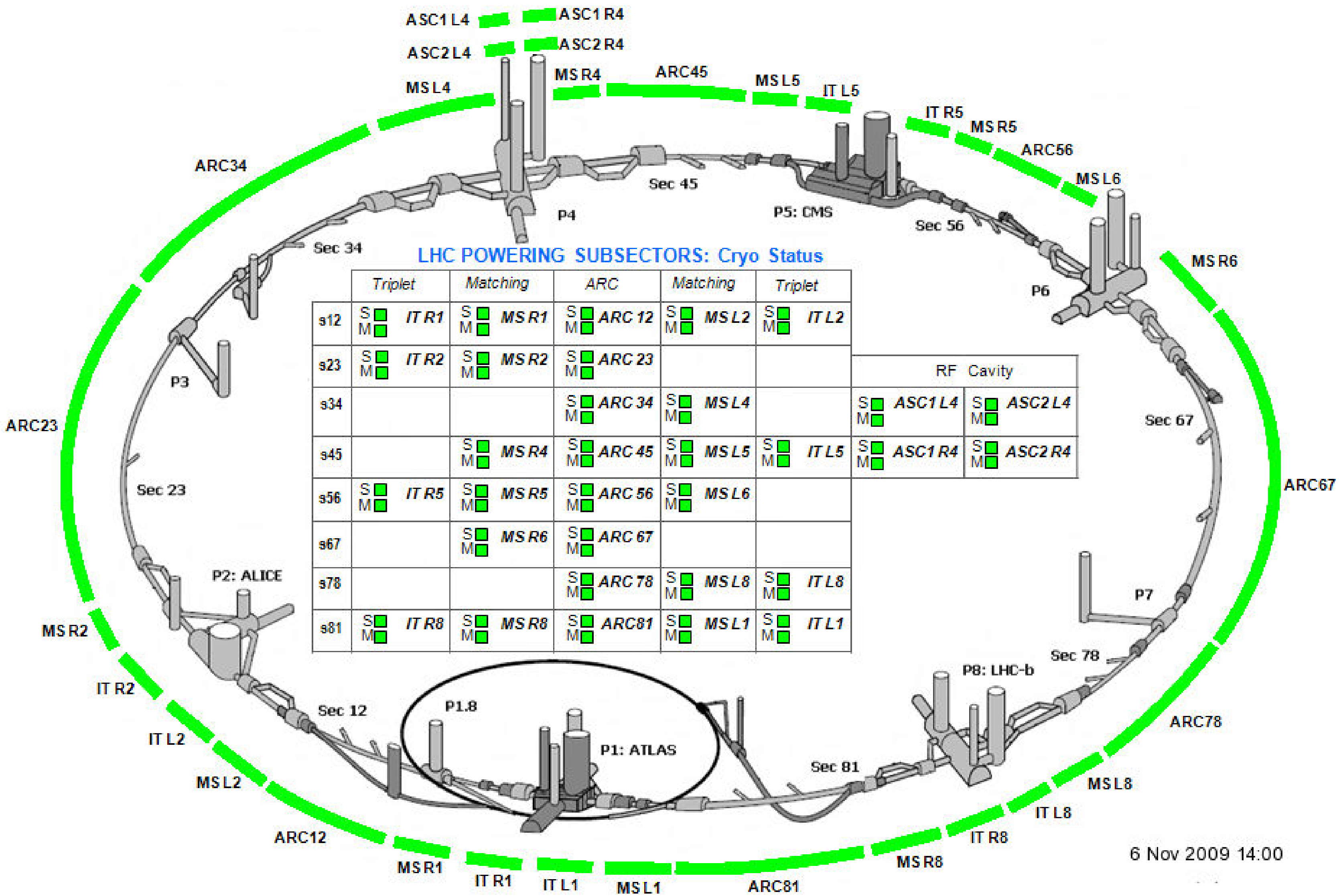
Beam dump sweep



Collimators – IR7



Powering tests – Status



	Triplet	Matching	ARC	Matching	Triplet	RF Cavity	
s12	IT R1	MS R1	ARC 12	MS L2	IT L2		
s23	IT R2	MS R2	ARC 23				
s34			ARC 34	MS L4		ASC1 L4	ASC2 L4
s45		MS R4	ARC 45	MS L5	IT L5	ASC1 R4	ASC2 R4
s56	IT R5	MS R5	ARC 56	MS L6			
s67		MS R6	ARC 67				
s78			ARC 78	MS L8	IT L8		
s81	IT R8	MS R8	ARC81	MS L1	IT L1		

6 Nov 2009 14:00

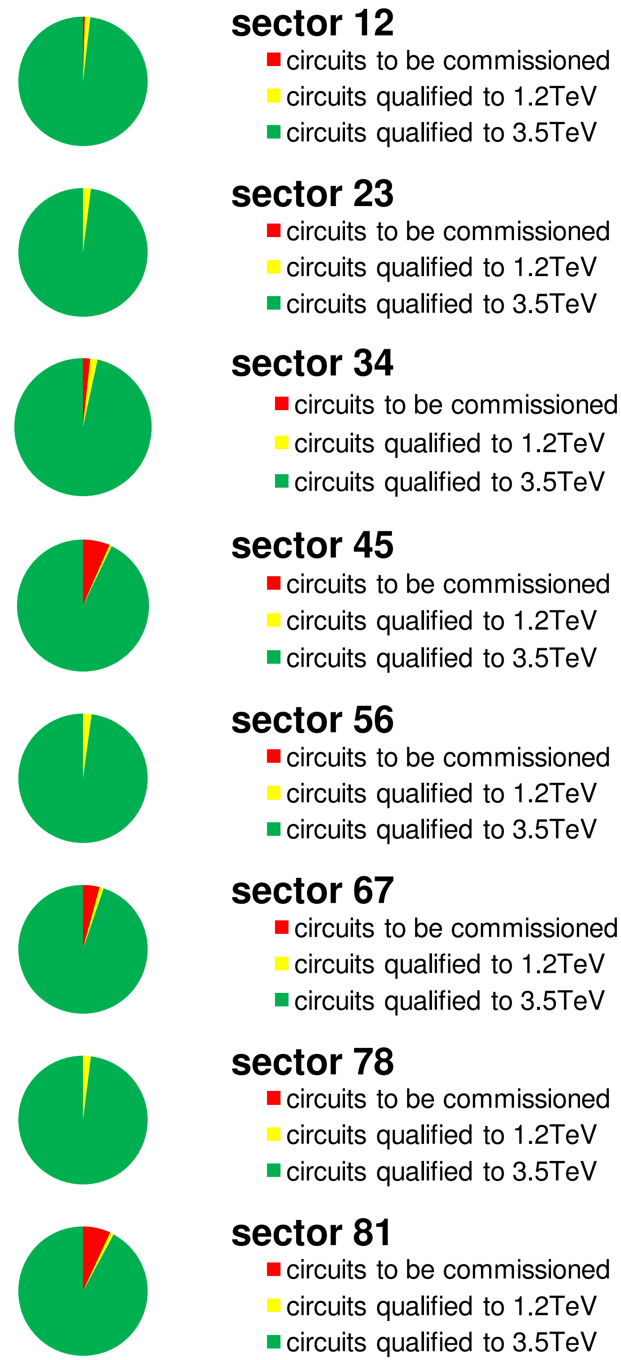
Up to the minute news

Status of splice mapping - preliminary

Sector	Circuit	Missing channels	Noisy channels	Highest excess resistance of outliers (nΩ)	Date of the last measurement
12	RB	0	0	-	16/10/2009
	RQ	0	3	-	29/09/2009
23	RB	0	0	-	01/11/2009
	RQ	0	1	about 2.5±0.3	01/11/2009
34	RB	0	0	about 2.5±0.3	14/11/2009
	RQ	0	3	-	15/11/2009
45	RB	6	1	-	14/11/2009
	RQ	6	0	-	12/11/2009
56	RB	0	0	-	06/11/2009
	RQ	0	1	about 2.0±0.4	07/11/2009
67	RB	0	4	-	15/11/2009
	RQ	0	0	-	12/11/2009
78	RB	0	0	-	06/11/2009
	RQ	0	0	-	10/11/2009
81	RB	1	1	-	15/11/2009
	RQ	2	0	-	15/11/2009
Total	RB	7	6		
	RQ	8	8		

Status overview

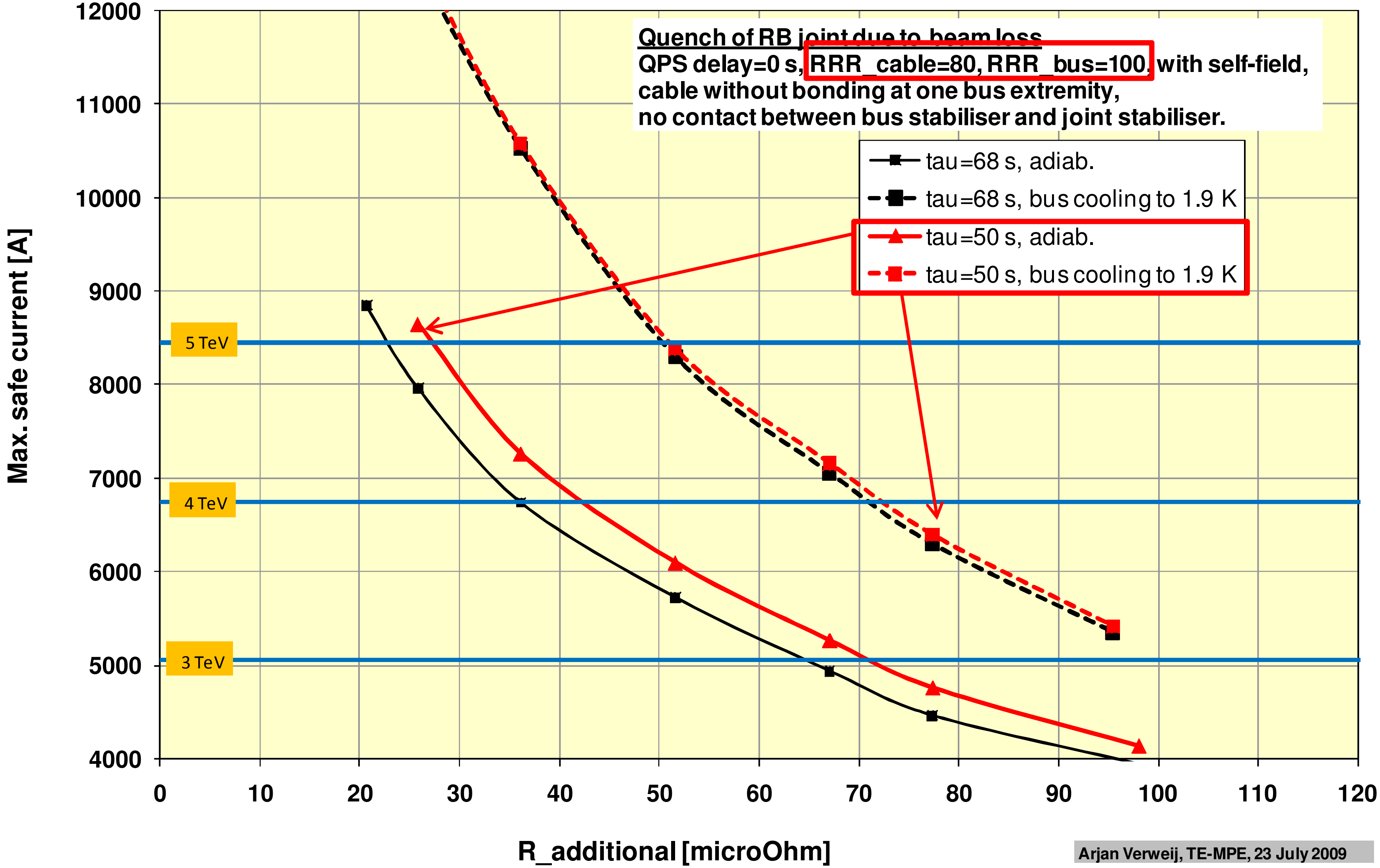
- All Main circuits commissioned up to 2 kA
- Main Bends in Sector 12: commissioned up to 4 kA with nQPS connected to interlock loop and to Quench Heaters.
- Tests status:
  - 97% of all test steps done
  - 97% of the circuits ready for 1.2 TeV
  - 93% of the circuits ready for 3.5 TeV
- Sectors 23/56/78 given to operation



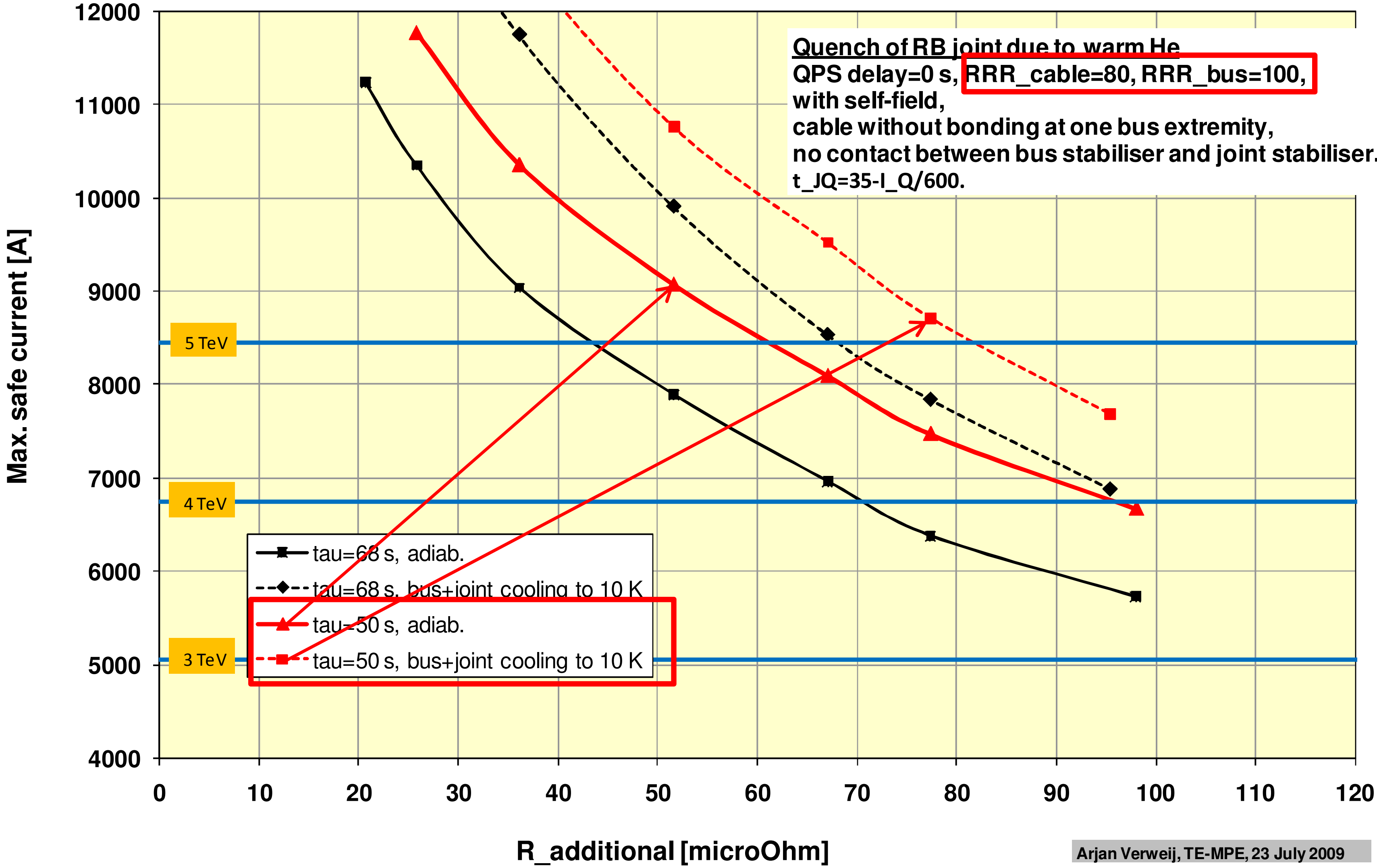
Thank you for your attention

END

RB: case 1 (instantaneous quench in busbar/magnet)



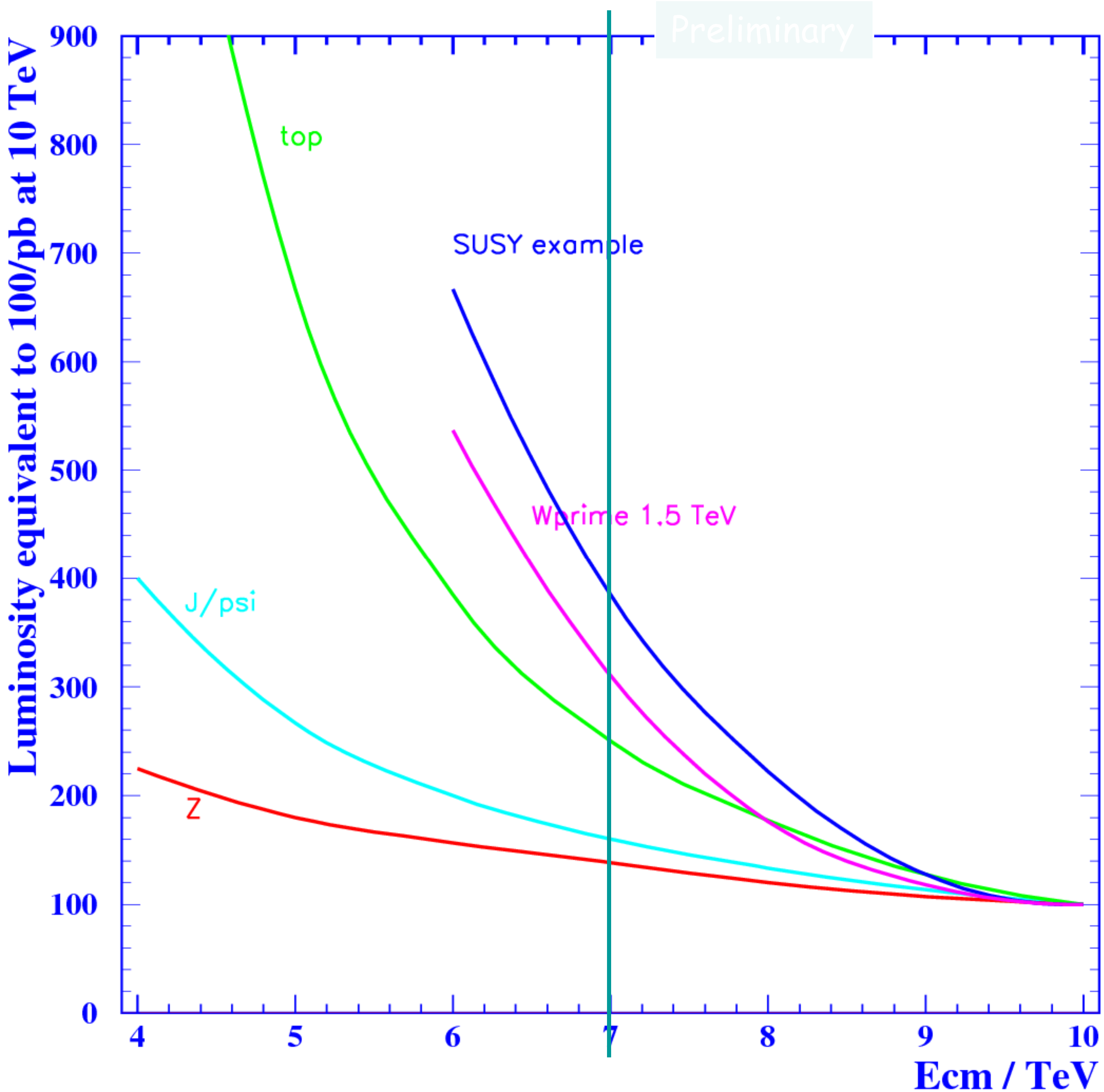
RB: case 2 (quench propagation from magnet to busbar)



Repairs and Consolidation

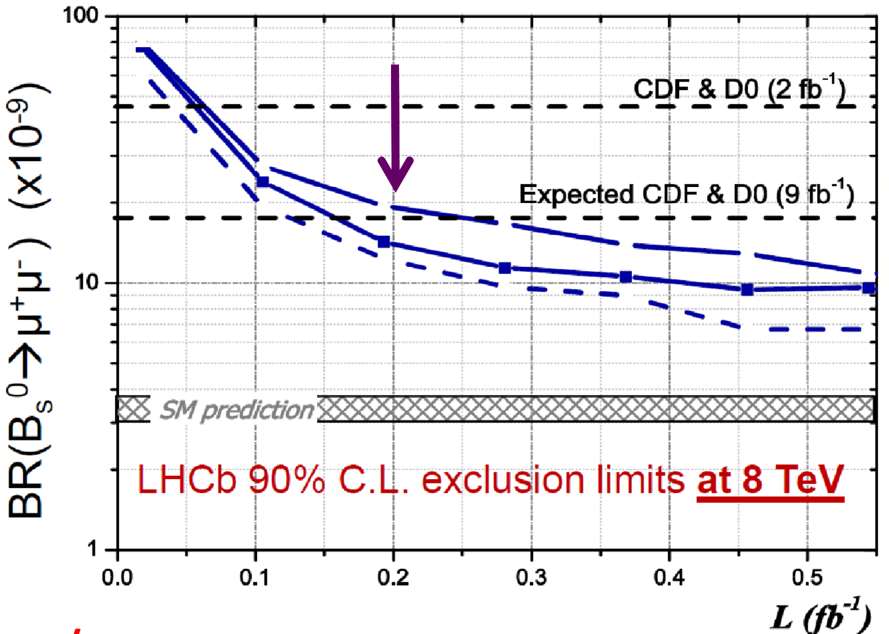
- Sector 3-4 repair
  - Magnets
  - Vacuum cleaning
  - Re-installation
  - Interconnects
  - Anchoring improvements
- Pressure release valves Installation
  - Personnel Safety
- Magnet replacements
- Connection cryostats
- Protection of electronic crates (SEU)
- New Quench Protection System

In parallel with this there was an intensive campaign of measuring the quality of the sc cable joints at cold (calorimetric and electrical)


Preliminary
Luminosity equivalent to 100/pb at 10 TeV
Ecm / TeV
top
SUSY example
Wprime 1.5 TeV
J/psi
Z
0
100
200
300
400
500
600
700
800
900
4
5
6
7
8
9
10

Prospects for most competitive measurements in 2010

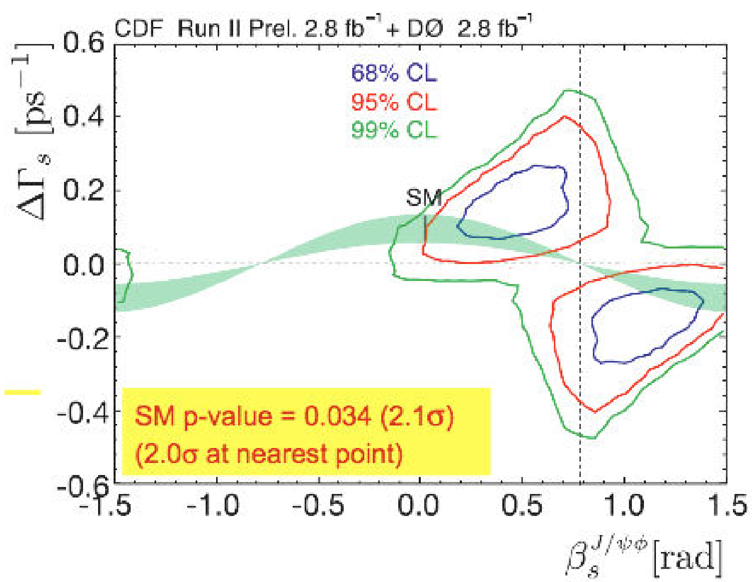
$B_s \rightarrow \mu\mu$

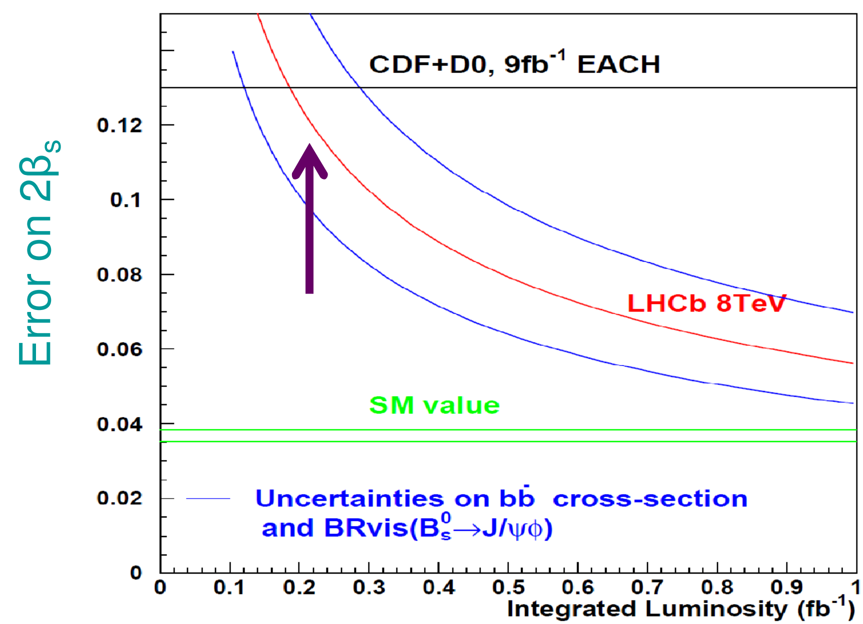


LHCb requests ~200 pb^{-1} int. lumi taken at stable conditions

With this data sample LHCb should be able to improve Tevatron sensitivity for $B_s \rightarrow \mu\mu$ and ϕ_s *(present 'central' value from Tevatron would be confirmed at 5σ level)*

ϕ_s





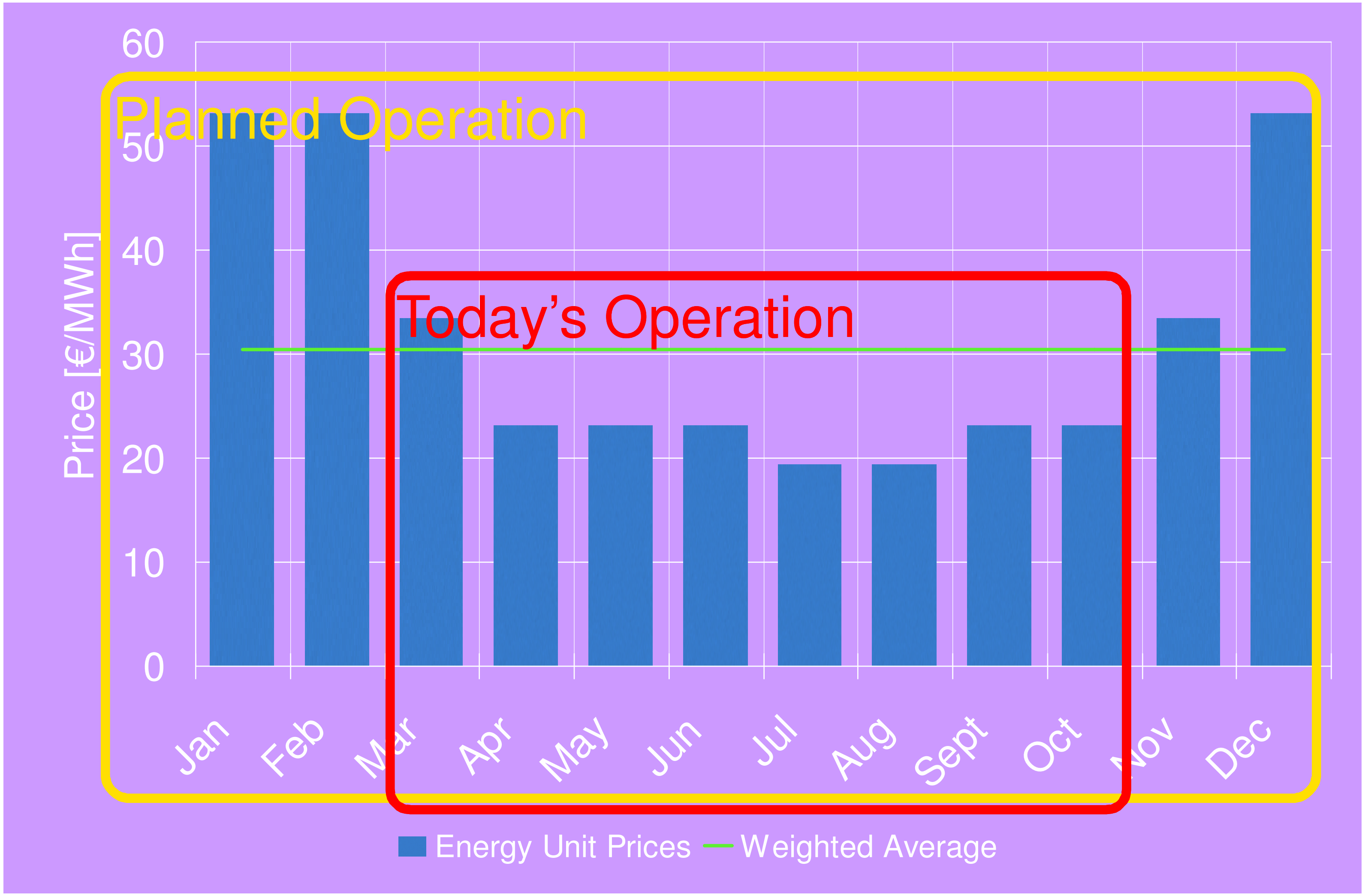
Early 2009

- Chamonix 2009
- Publication of fact finding report on accident
- External Review on LHC Risk
- External Review on the Quench Protection System
- Internal/External review on personnel safety underground
- Setting up many collaborations inside and outside CERN to help get LHC back in shape

Decisions for Chamonix

- Operating LHC through winter months?
- PRV scenarios?
- New QPS?
- Maximum beam energy?

Today's cheapest applicable EDF Tariff



Repair Scenarios

- Enhanced Quench Protection (Detection)
  - Busbar Detection (Protection)
  - “Symmetric” quench protection
  - QPS redundancy (UPS-QPS)

The FULL Quench System must be operational for beam collisions in 2009-2010 (unanimously agreed)

Update →

DN200 Pressure Relief Valves in Arcs

A: install 4 sectors (09-10) + 4 sectors (10-11)
+ first physics sooner: detectors debugging.. earlier warning
+ first beam sooner: ramp, squeeze, .. Sooner... earlier warning
+ focuses attention of repair teams

B: Installation 8 sectors (09-10)
+ reduced amount of collateral damage in event of a splice problem in 2010
+ reduced additional electricity bill
+ reduced overall shutdown time
+ reduced ALARA problems (2nd order)

Immediately after Chamonix the management decided on scenario A

Preparations for the Future

Operational Consolidation

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 is being done by Risk Ranking of the inventory
5. The manpower needed to carry out this programme has not yet been identified

75

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!

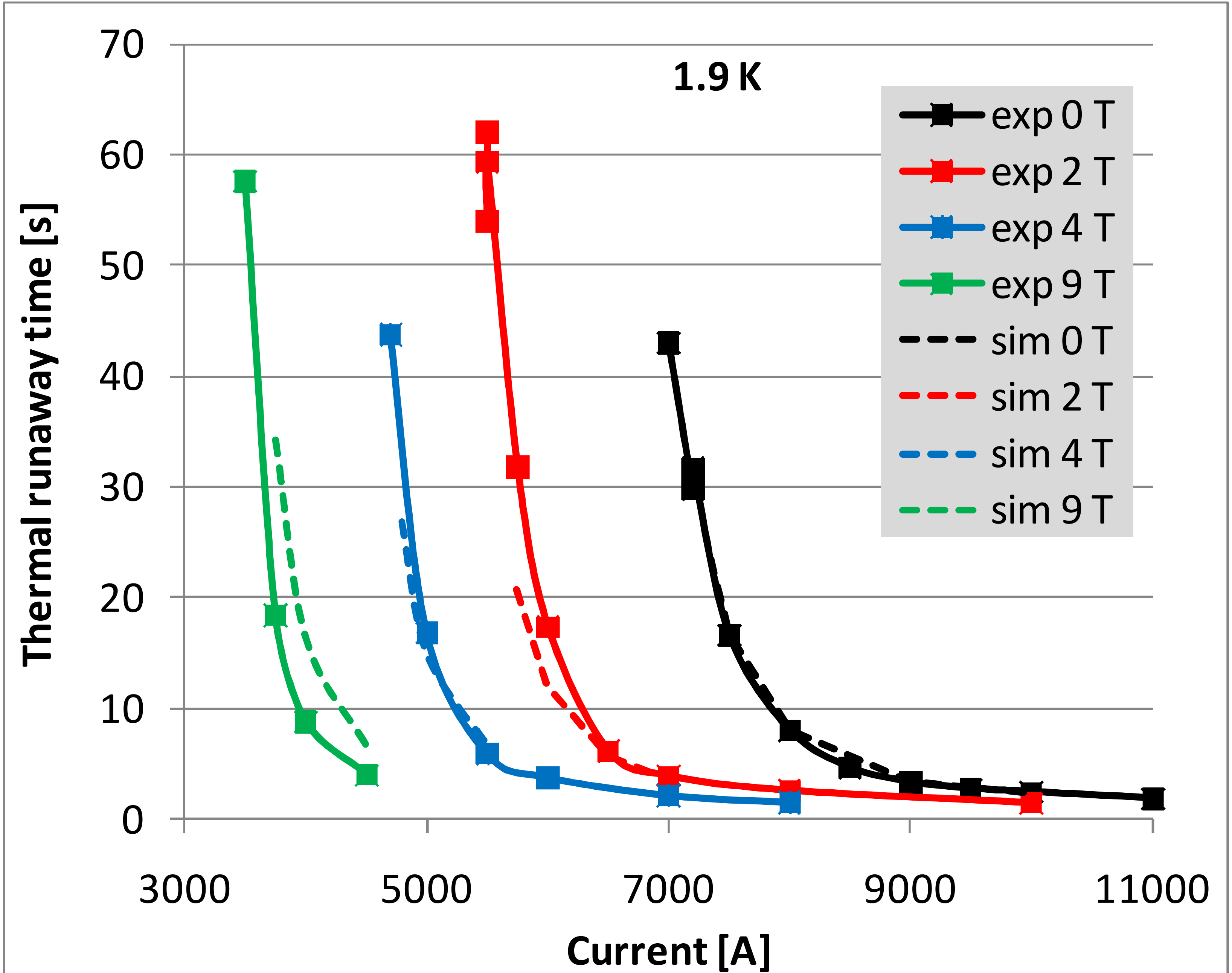
Very preliminary total cost 176MCHF or if shafts needed ~ 200MCHF + vacuum consolidation

Measurements and simulations of splices

New Results

Differences

	FRESCA	Machine
Helium environment	LHe (case 1)	LHe (case 1) and GHe (case 2)
Tube position	Vertical	Horizontal
Tube diameter	72 mm	90 / 103 mm
RRR bus	About 300	100 (worst case)
RRR cable	About 180	120 (worst case) ?
Current profile	Constant	Exponential decay
Interconnect insulation	2 mm G10 + glue (length 24 cm)	2xU profile kapton + 2x U profile G10 (length 21-24 cm)
Effective cooled bus surface	25-60%	90-100%
Field	Self-field + 0-9 T (varying along length)	Self-field
Length NSBC	47 mm (R_{addit}=61 $\mu\Omega$)	Up to ??



Correlation experiment vs. calculation

Conclusion following Analysis of FRESCA test

- **The simulation code (QP3) is now validated!**

- After analysis of the 'FRESCA 61 μΩ test' and taking RRR_{bus}=100, RRR_{cable}=120, tau_{RB}=50 s, tau_{RQ}=10 s, and **assuming a pessimistic maximum R_{addit}=90 μΩ, one can conclude that operating at 3.5 TeV is totally safe.**

- A few more FRESCA tests in a 'machine-type layout' are planned for the coming months.

Powering and Tunnel Access Restrictions

- Personnel safety
- Equipment safety

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

Access restrictions for Powering Phase II in Sector 56 or 45