Consolidation of the LHC SC magnets and circuits during LS1

- Consolidation of splices *[Second LHC Splices Review Nov 2011]*
  - Consolidation of the main arc splices
  - Consolidation of the DFBA splices
  - Other splices ?
- Special interventions
  - Exchange of cryomagnets
  - Consolidation of connection cryostats
  - Installation of the remaining pressure relief devices
  - In-situ repair (Issues on circuits and on cryomagnets)
- Organisation of the consolidation of the SC magnets & circuits
- Planning, Resources
- Open issues
  - Reinforcement of spider insulation
  - Diodes
  - CSCM
  - Radioprotection
  - New thermal shield design
- Conclusions

Work presented here is the continuation of the tremendous and detailed work done by F Bertinelli

Consolidation of the main splices

Technology Department

Second LHC Splices Review (Nov 2011)

The Review committee:
- ✓George Ganetis / BNL
- ✓*Claude Hauviller / CERN*
- ✓Toru Ogitsu / KEK
- ✓**Jim Strait / Fermilab : Chairperson**
- ✓Howard Pfeffer / Fermilab
- ✓Pierre Vedrine / CEA Saclay
- ✓*Chen-yu Gung : ITER*

General mandate:

The TE Department Head confirms the composition of the Review Committee with the general mandate "***to review CERN's plans and consolidation actions concerning the superconducting splices in the LHC machine for 7 TeV operation***".

Specifically:
- To work in close liaison with the CERN Splices Task Force, Chairperson JPh Tock.
- To consider ***all splices over complete circuits***, within and between equipment
- To ensure "best practice" knowledge existing in ***world Laboratories*** and Industries has been duly considered.
- To ensure that an ***integrated, systems approach is being followed***, covering both electrical and mechanical issues, neighboring systems, operations, …

- ➢40 participants
- ➢ 4 departments
- ➢16 presentations
- ➢18 (+30 old) recommendations

The splices TF members:
- ✓Antonio Perin
- ✓Arjan Verweij
- ✓Cedric Garion
- ✓Christian Scheuerlein
- ✓Delio Duarte Ramos
- ✓Francesco Bertinelli
- ✓Frederic Savary
- ✓Gerard Willering
- ✓Herman ten Kate
- ✓Jean-Philippe Tock
- ✓Nuria Catalan Lasheras
- ✓Paolo Fessia
- ✓Said Atieh
- ✓Serge Mathot
- ✓Stefano Sgobba

Mandate of the second review: To (re)assess:
- ❖ the final design for the consolidation of the main 13 kA interconnection splices
- ❖ the status and risk analysis of all superconducting splices in LHC
- ❖ the quality control procedures and plans
- ❖ the update of the plans for the work organization, quality control, resources, schedules

Third review: Production Readiness Review : Septem

Fourth review: Quality Audit : March 2013

https://indico.cern.ch/conferenceDisplay.py?confId=157231

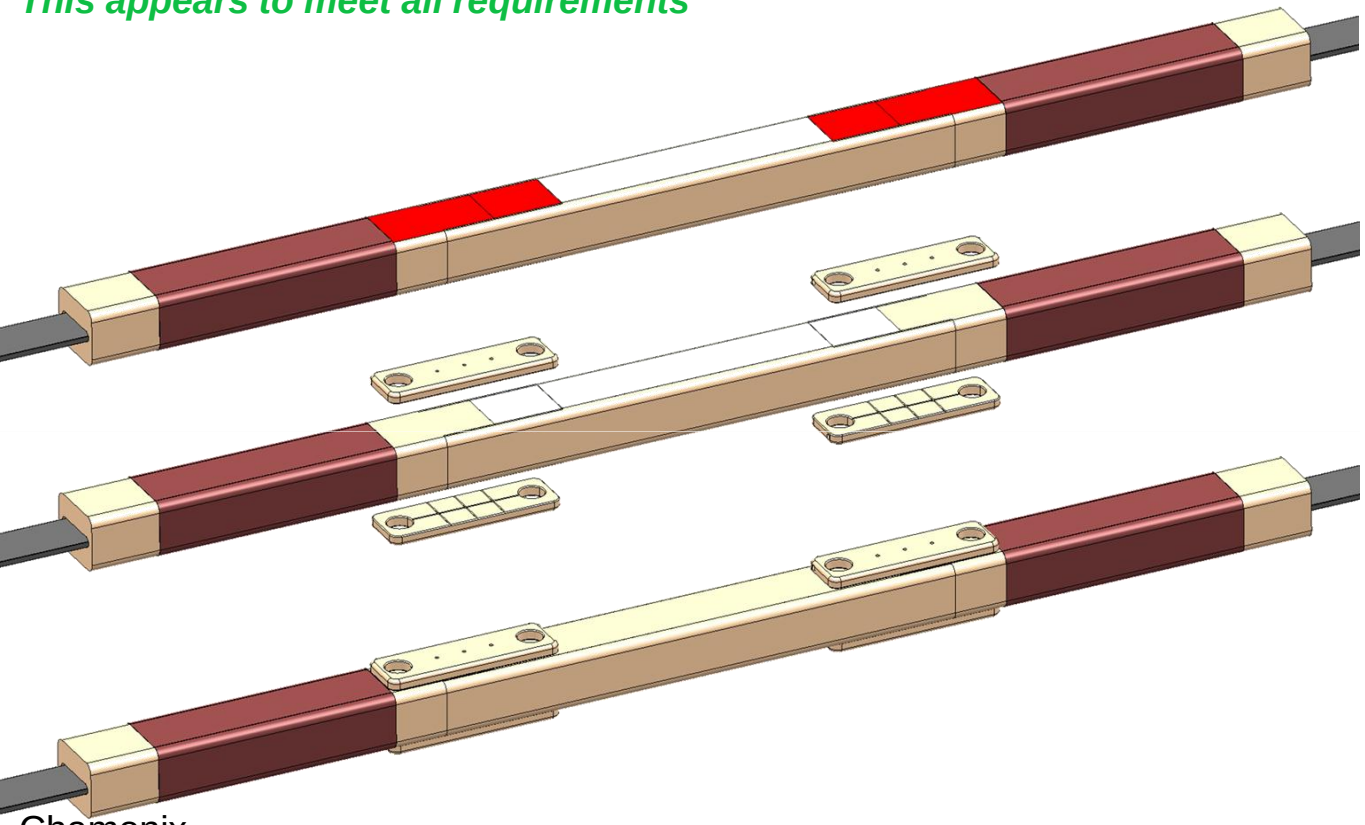
Consolidation of the main splices

Technology Department

What's new since Chamonix 2011?

1. Functional specification has been edited [P Fessia: EDMS 1171853]
2. The consolidated "shunt" design has been endorsed by the Review Committee "The design of the shunts and the techniques for soldering them across the joints are well done and have been fully tested under an array of conditions.

This appears to meet all requirements



CERN
CH-1211 Geneva 23
Switzerland

the Large Hadron Collider project

LHC Project Document No.: LHC-QBBI-ES
CERN Div./Group or Supplier/Contractor Document No.: TE-MSC
EDMS Document No.: 1171853

Date: 18/11/2011

Functional specification

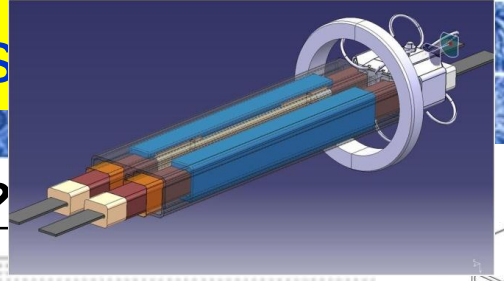
SPECIFICATION FOR THE CONSOLIDATION OF THE LHC 13 kA INTERCONNECTIONS IN THE CONTINUOUS CRYOSTAT

Abstract

This document summarises the functional specification and the derived engineering specification for the consolidation of the 13kA interconnections that connect in series the LHC Main Dipole magnets (MB) in the RB (3390 interconnections) circuit and the LHC Main Quadrupole magnets (MQ) in the RQ circuit (6780 interconnections).

Prepared by :	*Checked by :*	*Approved by :*
Paolo Fessia	The splice task force (A. Perin, A. Verweij, C. Garion, C. Scheuerlein, D. Duarte Ramos, F. Bertinelli, Frederic Savary,F. Lackner, G. Willering, H. Ten Kate, H. Prin, JP. Tock, N. Catalan Lasheras, P. Fessia,S. Mathot, S. Sgobba) G. Dangelo, R. Mompo, A. Siemko, L. Bottura, S. Atieh, R. Principe, F. Cerutti, S. Roessler, E. Cennini, Ralph Trant	*F. Bordry*

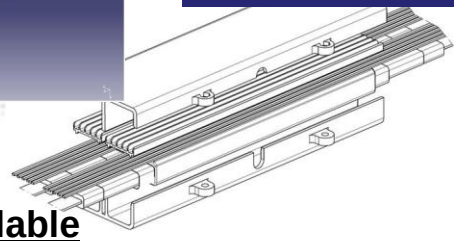
Consolidation of the main splices



Courtesy:
H Prin
F Lackner

TE Department

What's new since Chamonix 2011?



3. Design ALMOST final

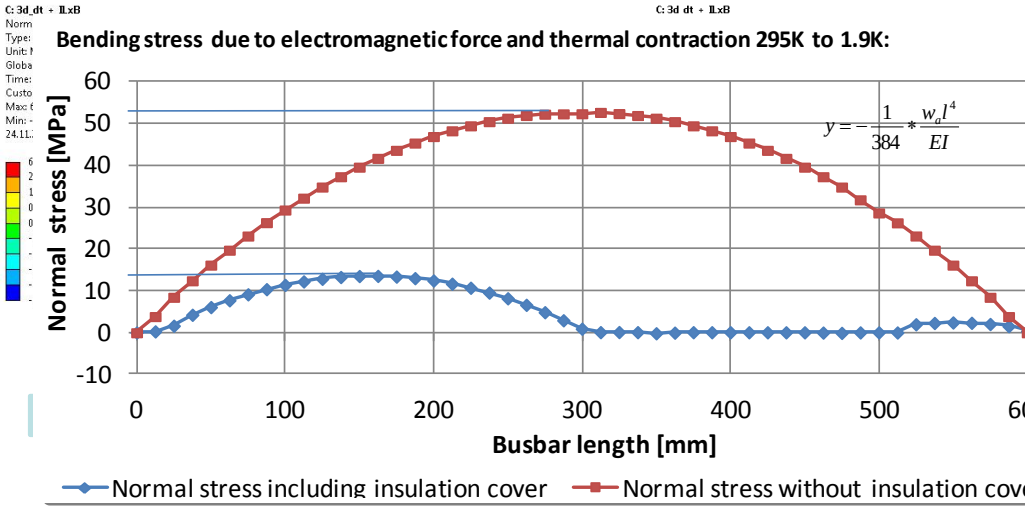
Insulation cover was to be finalised at the time of the review, now, **final concept is available**

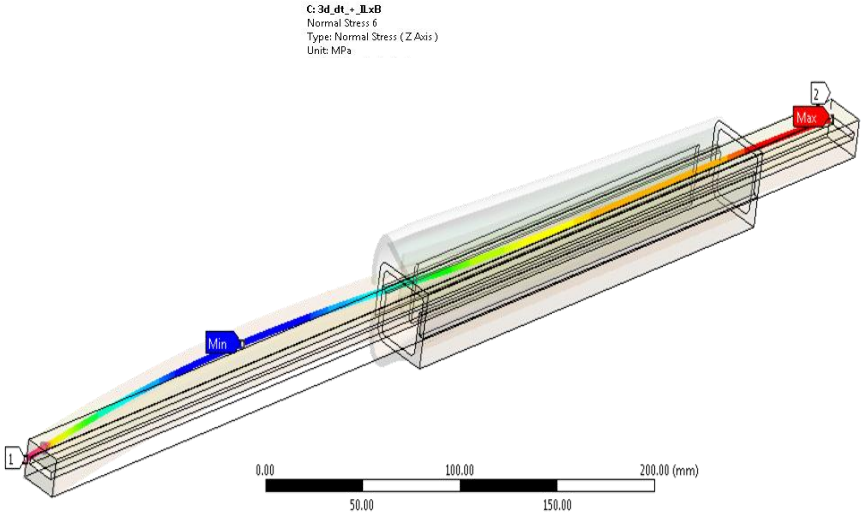
"This is a clever design which provides the required functionality in the presence of non-negligible splice-to-splice dimensional variations. However, the precise implementation of this scheme still needs to be developed"

❑The insulation cover must be adequate to reduce the mechanical stresses on the splices and the shunts so that they do not degrade over time.

❑ Modeling of shunt insulation cover is not yet sufficient to show that it is effective as a mechanical constraint, and we have doubts that the existing cover design is adequate.

Insulation cover; Stress induced by electromagnetic forces and the thermal contraction 295K to 1.9K:





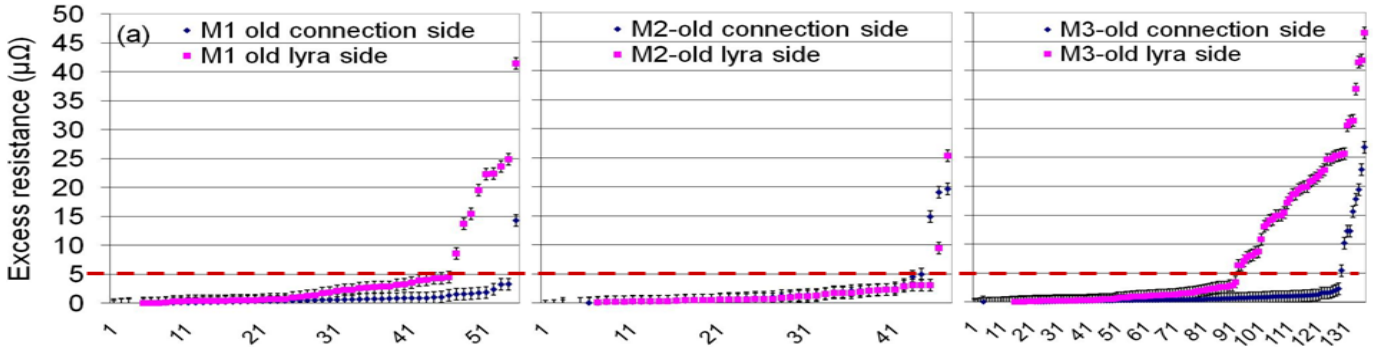
Consolidation of the main splices

Courtesy C Scheuerlein

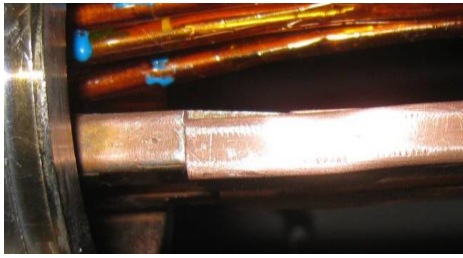
Technology Department

What's new since Chamonix 2011?

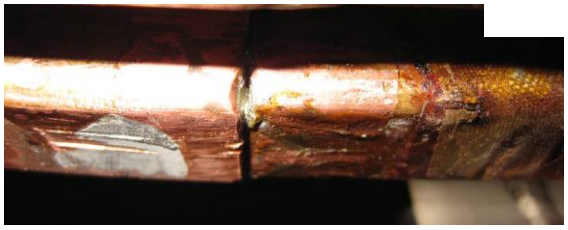
4. ***The splices "rebuilt" criteria were found adequate:***
   a) R8_excess > 5 μΩ (RT measurements)



   b) Outlying splices resistance at 1.9 K [Max 123 splices to repair ≈ 1%]
   c) Go/no-go gauges for geometrical defects
      To ensure optimum shunt install-ability
   d) Visual inspection based on a library of defects
      or obvious lack of mechanical strength



Step between U-piece and busbar



Gap between U-piece and BB stabiliser

Gap between U-piece and busbar tongue

Redoing a splice requires resources, time and generates some risks
⇒ Avoid it if not necessary

Consolidation of the main splices

Technology Department

What's new since Chamonix 2011?

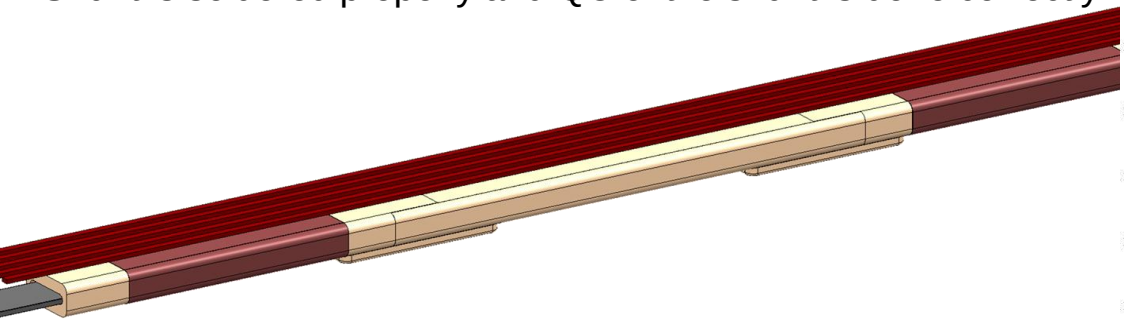
5. The endorsement of installing a **single shunt on the RQ BB** is conditioned to compensatory measures:

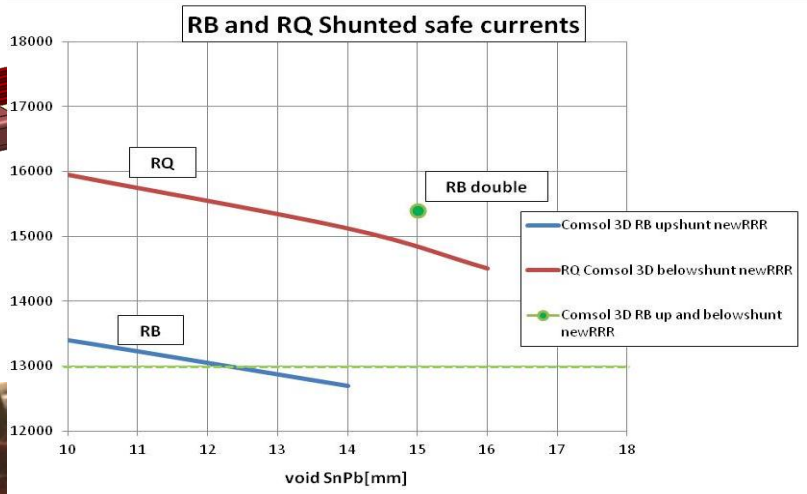
Rev 1 Rec 3.1: "The Committee recommends that a double shunt be applied to the quad bus"

Rev 2: Rec 1) "If a single shunt is to be used on the quadrupole bus, then the following must be met:
- The "rebuilt" criteria are met
- Clamp is effective in limiting the deflection and stress on splice, to prevent [illegible]ture degradation of the copper stabilizer connection
- Energy extraction time constant is reduced to ≤ 20 sec
- Shunt is soldered properly and QC of the shunt is done correctly"

See further presentation by R. Denz: QPS upgrade and machine protection during LS1

"Deal between redundancy and margin"





The safe operating current as a function of the defect length of the shunt solder

d circuits during LS1

Consolidation of the DFBA splices

Technology Department

Reference: (https://indico.cern.ch/conferenceDisplay.py?confId=157231)
DFBA Consolidation scenarios, A. Perin, 2nd LHC Splices review

- It has been decided to consolidate the 13 kA splices inside the DFBAs (23.11.2011 EDMS: 1173236)
  Same standard as the magnet to magnet ones
  Same crew for the repair of splices
- Important differences exist wrt to the arc splices so specific design has to be **quickly initiated**
- 2 out of 16 DFBAs will be very difficult to repair in-situ
- Failure in the DFBA would lead to a very long repair time
- Mock-ups are necessary to define and test tooling and procedures

Task	Group in charge
Project management and coordination with the magnet splice consolidation. Global follow-up	TE-CRG
Mockups, mechanical interventions, cutting, tooling	TE-CRG
Busbar work: busbar machining, soldering, insulation,..	TE-MSC
Welding, welding tooling, welding inspection	EN-MME
Splice Quality Control	TE-MSC
Reclose vacuum envelope	TE-CRG
Quality Assurance & documentation	TE-CRG

Rev 2 Recommendations:

- Apply shunts to the 13 kA splices in all DFBAs, including the most difficult circuits. Repair these joint up to the same standards and based on the same designs as in the magnet to magnet interconnect. Splice repairs should be done by the same crew that repairs the magnet to magnet interconnects.

-Investigate methods and/or procedures that would lower the risk of repair of the two DFBAs that require re-location to perform the work

Huge technical developments to carry out NOW

Other splices? Other issues?

Pool of experts lead by H Ten Kate **screened all electrical superconducting magnet circuits** in the LHC from + current lead to - current lead (Report: EDMS: 1176186)

Reviewers and sessions				Reviewers presence								
Magnets Circuit	Date of Review Meeting	Sequence	Presentor	Herman ten Kate (chairman)	Francesco Bertinelli	Nuria Catalan-Lasheras	Alexey Dudarev	Paolo Fessia	Michele Modena	Antonio Perin	Davide Tommasini	Arjan Verweij
MB (main dipoles)	25-Nov-11	3	R. Principe	1	1	1	1	1	1	1	1	1
MQ (main quads)	13-Apr-11	8	R. Principe	1	1		1	1		1		1
Insertion quads and correctors	11-May-11	9	N. Catalan-Lasheras	1	1	1	1	1	1	1	1	
6 kA stand alone magnets	22-Jun-11	12	S. Russenchuck	1			1	1	1			1
MCS (sextupole correctors)	10-Jun-10	1	H. ten Kate	Presented to entire task force, screening meeting persons present								
MCO(octupole correctors)	06-Oct-11	2	D. Tommasini	1			1				1	
MCD (decapole correctors)	02-Mar-11	4	D. Tommasini	1	1	1	1				1	1
MQT-TL-S	09-Mar-11	5	M. Bednarek	1	1	1	1	1	1	1		1
MO-MS-MSS	23-Mar-11	6	M. Modena	1	1	1	1	1	1	1		1
MCB-BC-CY-BX-BXA	18-May-11	10	S. Russenchuck	1	1	1		1	1	1		1
Current Leads	25-May-11	11	A. Ballarino	1	1		1	1	1	1		1
DFB (distribution valve boxes)	08-Apr-11	7	A. Perin	Presented to entire task force, screening meeting persons present								
6 kA splices	Oct-10	0	J.-P. Tock	Presented to entire task force, screening meeting persons present								

- 24 "practical" recommendations formulated.
- Most of them are accepted in full and being executed.
- Others still require further study to come to a final assessment to allow a management decision.
- High risk issues concern mainly 13kA splices in standard interconnects; diodes mechanical connections; 13kA splices in the DFBA areas and current leads.
- Low risk issues concern the correctors circuits where less energy is available for creating damage provided no main circuits are harmed

- Rev 2 Rec 8: Provide sufficient resources to make splice measurements on the inner triplet and matching section circuits well before the beginning of the long shutdown. On-going : TE-MPE
- Rev 2 Rec 12: Continue to explore ways to insulate the spider from ground potential and to increase the creep path of the buss to metal support of the spider. On-going : TE-MSC : See later (open issue)
- Rev 2 Rec 13: Continue to explore external methods to insulate the lyras from ground potential

On one hand, LS1 is the last chance to make a massive consolidation but on the other hand, priorities have to be defined in view of the limited time and resources available

Exchange of cryomagnets with high inner splices resistance

Technology Department

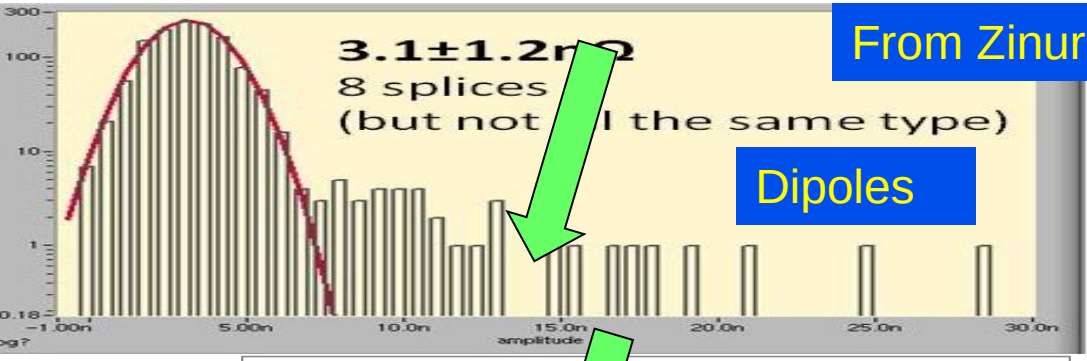
Chamonix 2011

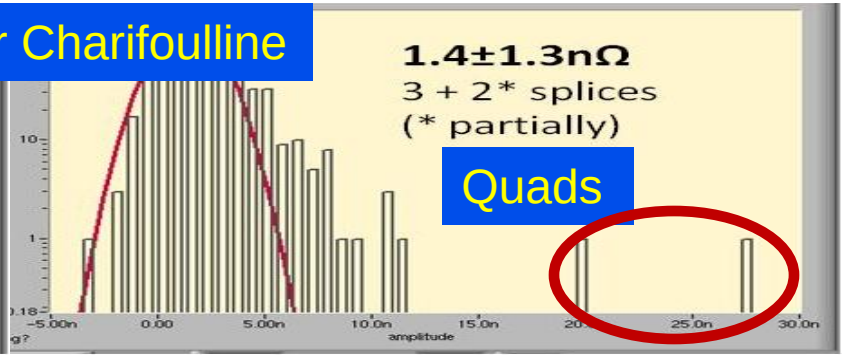
 # to exchange (proposal)

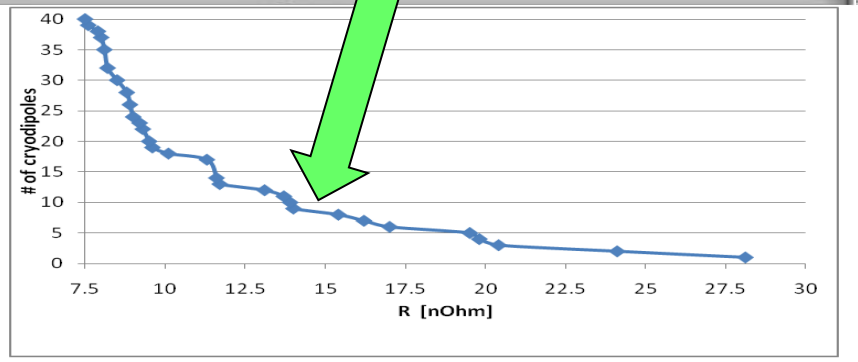
+ 8 dipoles (4A&4B) in (S12&23) & 1 SSS (in S34)
+ Test programme

⇒ Reduction by 50 % of inner resistance

From Zinur Charifoulline







Should have been disconnected for installing the collimators in DS IR3

So extra work

Exchange of cryomagnets with high inner splices resistance

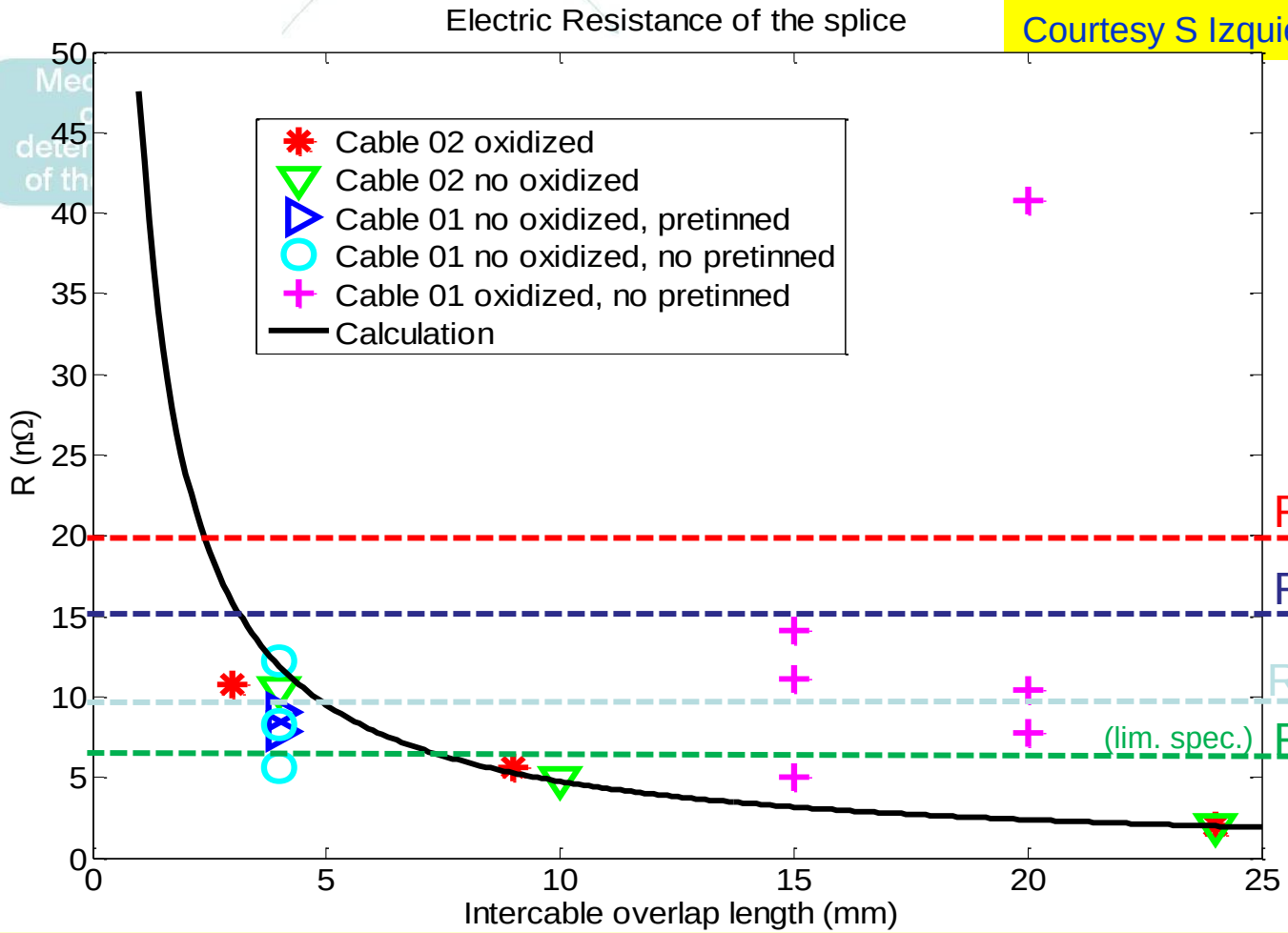
High inner splice electrical resistance in MB

High inner splices resistance

TEST PROGRAMME

https://espace.cern.ch/lhcsplices/Meeting%2054/default.aspx

Courtesy S Izquierdo Bermudez (TE-MSC-LMF)



Number of magnets to be changed for a certain resistance threshold

R>20nΩ: 1MBA + 2 MBB

R>15nΩ: 4MBA + 4 MBB

R>10nΩ: 6MBA + 14 MBB

(lim. spec.) R>7nΩ: 13MBA + 26 MBB

The high resistance values can be justified by:

- Very short interconnection length -> FEA to determine the impact in terms of mechanical stress
- Presence of oxide in the cable

Exchange of cryomagnets with high inner splices resistance

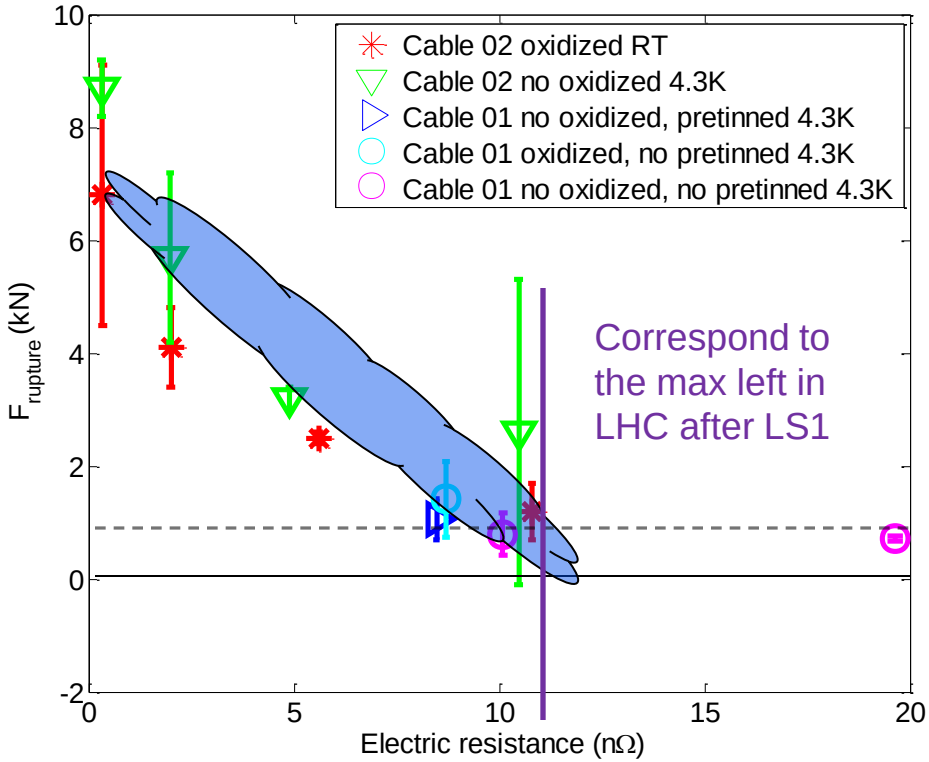
Technology Department

High inner splices resistance

TEST PROGRAMME

https://espace.cern.ch/lhcsplices/Meeting%2054/default.aspx

Courtesy S Izquierdo Bermudez (TE-MSC-LMF)

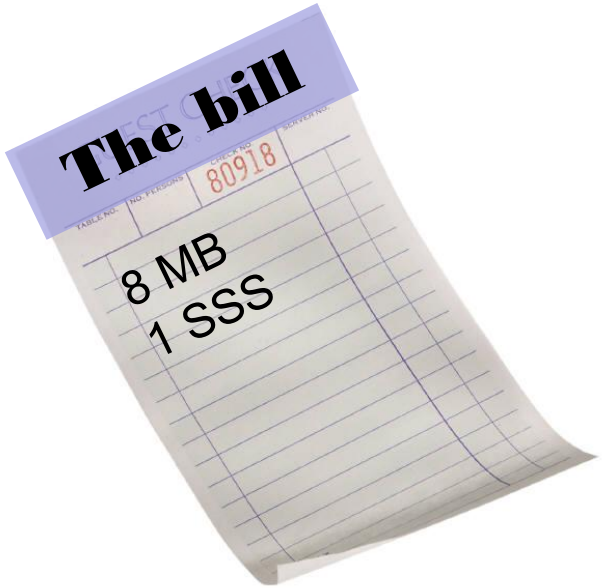


Rupture traction force at RT and 4.3K at as function of the electric resistance of the splices. Cable 02 measurements taken form C. Scheuerlein and S. Heck

- Several samples were studied
- The influence of the overlap length is determined.
- A too small overlap length is one possible cause of high resistance and so lack of mechanical strength.
- There could be other causes.
- The electrical resistance is the only accessible value.
- The forces applied on the splices are depending on the location of the soldered portion. The **worst case** is at the extremity, where the value can be 10 times larger than if is in the middle.
- The contribution of the copper pieces is not taken into account (favorable). This could explain why, despite some high resistance splices, there is no issue detected neither in the LHC nor during the test in SM18.
- Conservative approach is kept.

Exchange of cryomagnets with high inner splices resistance

TE Technology Department



TASK FORCE CONCLUSION ENDORSED BY TE MANAGEMENT

- Extremely conservative approach used for the test and cor
- No sign of degradation noticed neither in LHC nor in SM18

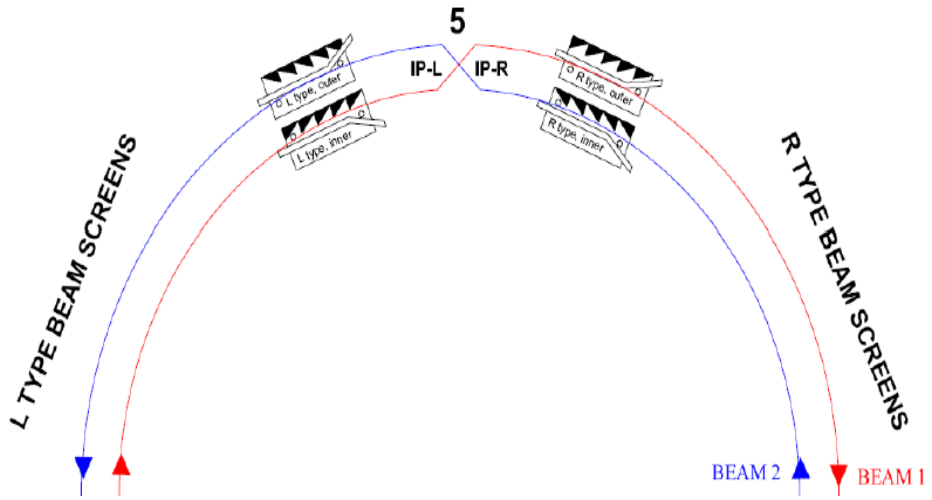
- Leaving in the LHC cryodipoles with an excess resistance > 14 nOhm total [Corresponding to 8 cryodipoles] is too risky.
- There is a very limited risk in leaving cryodipoles with an excess resistance > 7 nOhm total) [Corresponding to 20 cryodipoles].
- The present baseline presents a small acceptable risk.
- The analysis on the removed magnets will bring more information, allowing to complement the present statistics (8 more magnets with high inner resistance wrt to the 3 available so far) and consequently support the definition the strategy for LS2.

Exchange of cryomagnets for electrical integrity issue

Cryodipole	Issue	NCR	Present solution	LS1 intervention
2007 (B21L8)	QH damaged	1017215/ 925045	2	Replace cryodipole
2138 (B31R4)	QH damaged	1061212	2	Replace cryodipole by 1061
2214 (C17R4)	QH damaged	961338	2	Replace cryodipole by 1132
2413 (A22R1)	QH damaged	1004191	2	Replace cryodipole by 2171
1372 (C32R1)	QH circuit	1004185/ 947915	2 LF QH replace 1 HF QH	Will be repaired in-situ
3708 (A21L3)	QH circuit	942550	2 LF QH replace 1 HF QH	Will be repaired in-situ
2395 (C15R1)	QH circuit	1004184/ 947913	2 LF QH replace 1 HF QH	Replaced for high inner splice resistance
1007 (B30R7)	Low voltage withstand	1060444	OK up to 1.6 kV (>4 TeV)	Try to fix in-situ, if not replace cryodipole Spare will be prepared

Exchange of cryomagnets with wrongly oriented beam screens

Issue	EDMS	#	Location
Dipole with inner BS in wrong direction	985318	4	All in 34 (A21R3, B21R3, A22R3, B22R3)
Dipole with both BS in wrong direction	985318	8	All in 34 (B25R3, A26R3, B26R3, B27R3, B28R3, C31R3, B32R3, C32R3)
SSS with both BS in wrong direction	746471 & 807494	2	Q25R5 & Q19R2
Total : 12 dipoles and 2 SSSs		14	



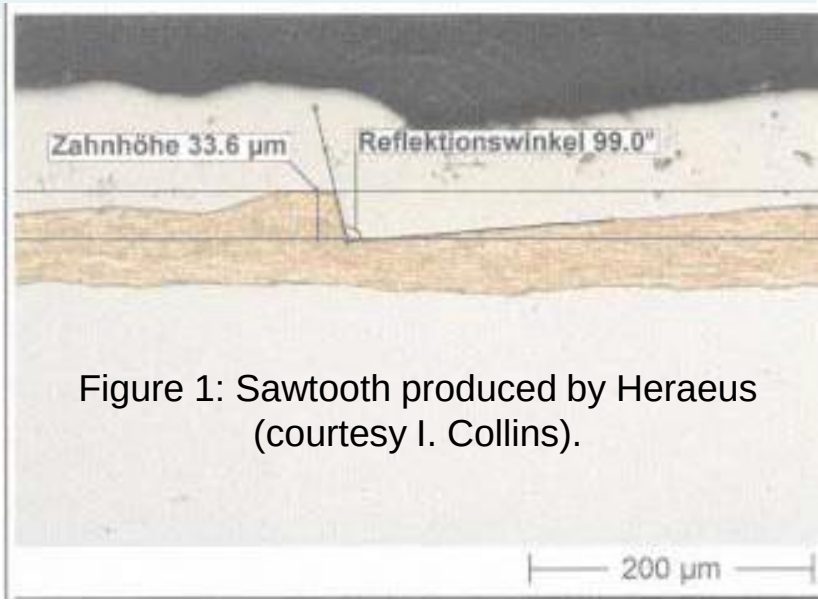


Figure 1: Sawtooth produced by Heraeus (courtesy I. Collins).

Exchange of cryomagnets with wrongly oriented beam screens

Impact was evaluated

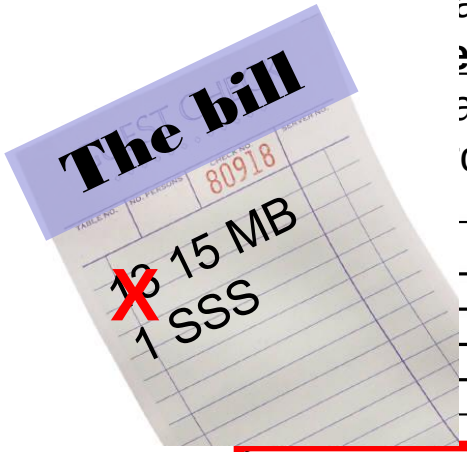
TE Technology Department

ATS/Note2011/129 (TECH)

Electron Cloud with Inverted Beam Screens 2011-12-06

Humberto Maury Cuna, CINVESTAV; Frank Zimmermann, CERN

At 2.5 or 7 TeV energy and for maximum secondary emission-yield values below 1.5, with **the entation about ten times higher heat load is expected than for the** and the wrongly oriented sawtooth chambers could lead to a local heatload ocess of surface conditioning at 25-ns bunch spacing



V1 (8 off)	V2 (12 off)
	A21R3
	B21R3
	A22R3
	B22R3
B25R3	B25R3
A26R3	A26R3
B26R3	B26R3
B27R3	B27R3
B28R3	B28R3
C31R3	C31R3
B32R3	B32R3
C32R3	C32R3

Recommendation: correcting the inner and outer beam-pipe sawtooth orientation at least for two dipole magnets in cells 26 and 32 R3, so that,no half-cell will contain more than one cryodipole (out of three) with the wrong orientation of the beam screen.

Exchange of cryomagnets for beam optics reasons

As in Chamonix 2011

Wrong SSS types (S34):

[LHC-LQA-EC-0004 M Modena]

- 2 circuits are degraded (one is missing) (Q23,27,28,32 R3)

  - MQS: Q23,27 [with jumpers and vacuum barrier]
  - MO: Q28,32

Q5L8 : Warm corrector installed (78)

RCBCHS5.L8B1 NC 831927

- To be replaced by a new Q5 L8

Baseline:

-Replace Q23, Q27 R3 (first priority)

-Replace Q5 L8 (second priority)

-Postpone replacement of Q28 & Q32 R3 to LS2 if need confirmed

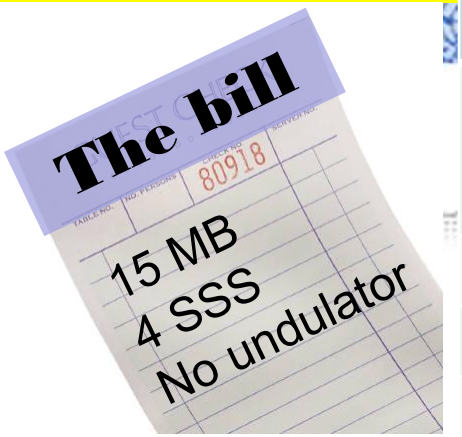
Exchange of cryomagnets because of leaks ?

TE Technology Department

Sector		VACSEC.xxxxx.M																		
8-1		A1R	A4R	A5R	A6R	A7R	A11R	A15R	A19R	A23R	A27R	A31R	A31L	A27L	A23L	A19L	A15L	A11L	A7L			A4L	A1L	
7-8					A6R	A7R	A11R	A15R	A19R	A23R	A27R	A31R	A31L	A27L	A23L	A19L	A15L	A11L		A6L	A5L	A4L	A1L	
6-7			A4R	A5R		A8R	A11R	A15R	A19R	A23R	A27R	A31R	A31L	A27L	A23L	A19L	A15L	A11L	A7L	A6L				
5-6		A1R	A4R			A7R	A11R	A15R	A19R	A23R	A27R	A31R	A31L	A27L	A23L	A19L	A15L	A11L	A8L		A5L	A4L		
4-5	A.ACS5R	B.ACS5R	A5R	B5R	A6R	A7R	A11R	A15R	A19R	A23R	A27R	A31R	A31L	A27L	A23L	A19L	A15L	A11L	A7L	A6L	A5L	A4L	A1L	
3-4				DSLC.A34	A6R	A7R	A11R	A15R	A19R	A23R	A27R	A31R	A31L	A27L	A23L	A19L	A15L	A11L	A7L	A6L	B5L	A5L	B.ACS5L	A.ACS5L
2-3		A1R	A4R	A5R	A6R		A11R	A15R	A19R	A23R	A27R	A31R	A31L	A27L	A23L	A19L	A15L	A11L	A7L	A6L				
1-2		A1R	A4R			A7R	A11R	A15R	A19R	A23R	A27R	A31R	A31L	A27L	A23L	A19L	A15L	A11L		A6L	A5L	A4L	A1L	

- For each leak, the subsector is localised
- Experience so far has shown that it was always possible to repair in-situ, without exchanging
- Only one really non acceptable leak (sector 34)
- All known leaks will be searched and fixed if possible

Exchange of cryomagnets : the undulator



RU.L4	RU.R4
EC 988910: one missing resistor / External resistor added	NC 1061232 Problem with DCCT that creates a fake DIDT and a fake U_res. Inductive correction disabled in the QPS
No training quench	3 training quenches in 2008 (422, 445, 450 A)
Operate @ 400 A	Operate @ 400 A
0.2 A/s	0.08 A/s

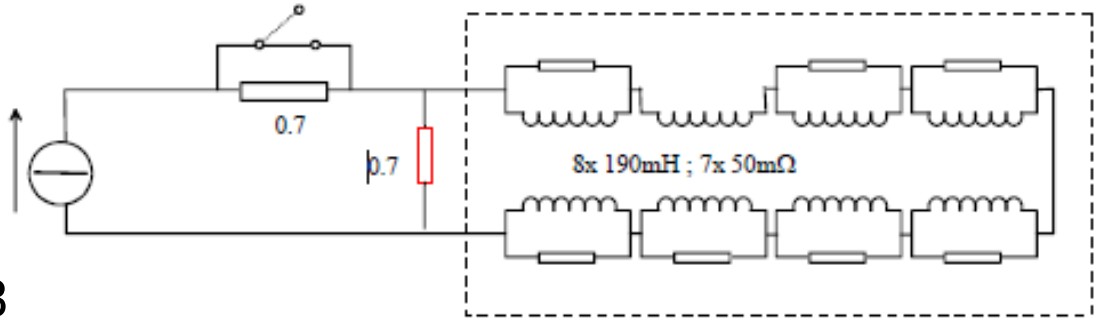
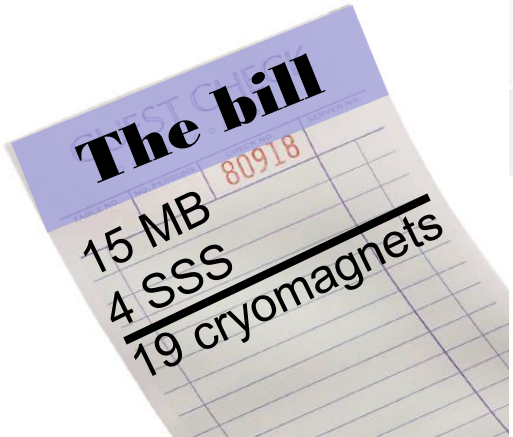


Figure 4: MU-L4 Simplified circuit layout modified

- ❑ Spare cold mass is available
- ❑ Cryostat components under procurement for cold test in SM18
  Universal spare will be available
- ❑ Extensive testing in 2012
- ❑ Impact on operation to be assessed by BE
- ❑ **<u>Decision on replacement to be taken in 2012, before LS1</u>**

Exchange of cryomagnets: Summary

Reason	dip	SSS	Tot	Remark
High inner splice R	8	1	9	For possible low mechanical strength (2336-2395)
Damaged QH circuit	4	0	4	7 in total but 3 can be repaired in-situ (IFS)
Wrongly oriented BS	2	0	2	Out of 12 dip and 2 SSSs New
Restore RQS in 34	0	2	2	EDMS 103939 (Q23 & 27R3)
Low voltage withstand	1(0)	0	1(0)	1.6 kV instead of 1.9 kV, maybe in-situ repair : beginning of LS1
Replace RCBCHS5.L8B1	0	1	1	Q5 L8 / NC 831927 / 2nd priority New
Leaks	0	0	0(1)	Hopefully repairable in-situ or acceptable
Undulator	(1)	0	0	New
	15	4	19	



Exchange of cryomagnets: Preparation of spares

Problem type	#	Assigned (Ready)
DIPOLES		
Electrical	5	5 (4)
Beam Screens	2	To be assigned by MEB
Inner Resistance > 15ΠΩ	8	To be assigned by MEB
TOTAL	15	
QUADRUPOLES		
No MQS	2	2 (Cold Test to perform)
Q5.L8	1	To assembly
Q7.R3 (Inner Res 26.9ΠΩ)	1	To assembly
TOTAL	4	

Dipoles					
Spares:	44	A type:	21		
		B type:	23		
Tested OK:	**33**	With cryostat:	25	A type:	14
				B type:	11
		Without cryostat:	8	A type:	3
				B type:	5
		Ready to cold test:	2	A type:	1
				B type:	1
		To be repaired:	9	A type:	3
				B type:	6

Dipoles: 7 A type – 8 B type

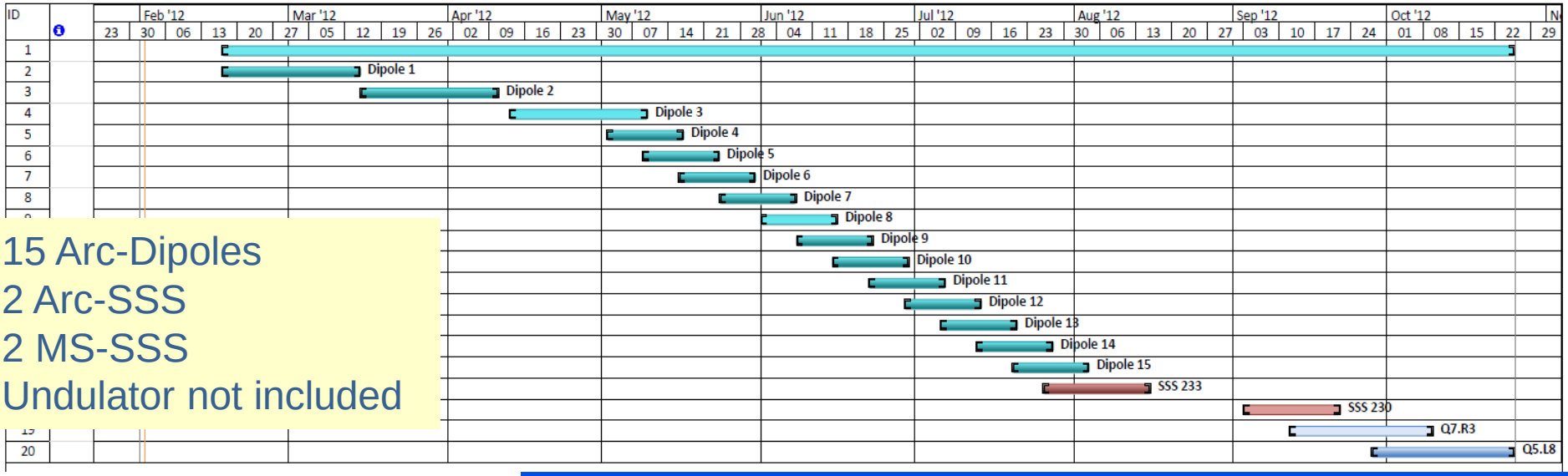
Quadrupoles:

- Q5.L8 and Q7.R3 are being assembled
- 230 (with MQS) is cryostated, to cold test
- 233 (with MQS) is repaired, to be cryostated

Exchange of cryomagnets: SMI2 schedule (2012)

Technology

Groups: TE-MSC / TE-VSC



15 Arc-Dipoles
2 Arc-SSS
2 MS-SSS
Undulator not included

Cryomagnets coordination workspace :
https://espace.cern.ch/cryomagnet-coordination/default.aspx

CRYO-MAGNETS TO BE REMOVED DURING LONG SHUTDOWN 1

	Type		Magnet	Problem	Input	EDMS	Slot	IC Up	IC Down	Sector	Ch ?	Remarks 1	From LMF	Location	Activity	Remarks 2
1	Dip	BR	2387	High Resistance	Zinur		LBBRD.33R1	QBBI.B33R1	QBQI.33R1	12	Yes	Res. 20.4∩Ω				
2	Dip	AR	2373	High Resistance	Zinur		LBARB.30R1	QBBI.B30R1	QBQI.30R1	12	Yes	Res. 19.8∩Ω				
3	Dip	BR	2395	High Resistance	Zinur		LBBRD.15R1	QBBI.B15R1	QBQI.15R1	12	Yes	Res. 17.0∩Ω				See also NCR 1004184
4	Dip	BR	2377	High Resistance	Zinur		LBBRA.33L2	QBBI.B33L2	QBBI.A33L2	12	Yes	Res. 16.2∩Ω				
5	Dip	AR	2372	High Resistance	Zinur		LBARB.29L2	QBBI.A29L2	QBQI.29L2	12	Yes	Res. 15.4∩Ω				
6	Dip	AR	2413	QH damaged	ELQA	1004191	LBARA.22R1	QQBI.21R1	QBBI.A22R1	12	Yes	Will be replaced by				

Courtesy A Musso(TE-MSC-CMI

Consolidation of the connection cryostats

Details in ECR: LHC-LE-EC-0003

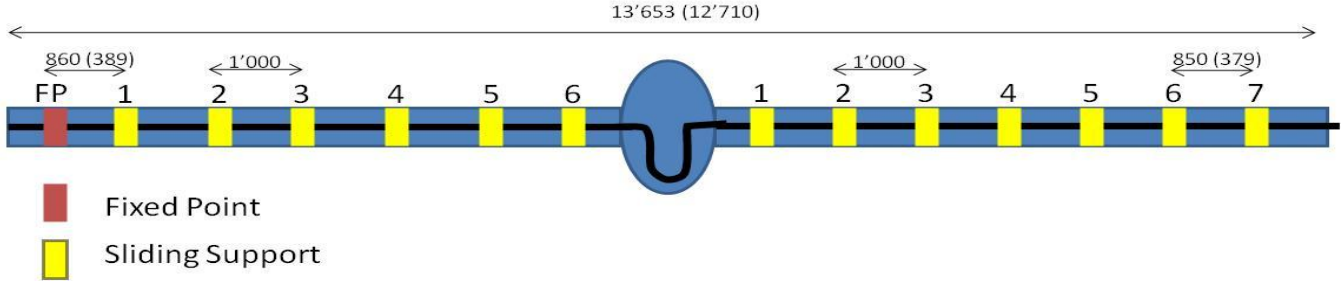
Technology Department

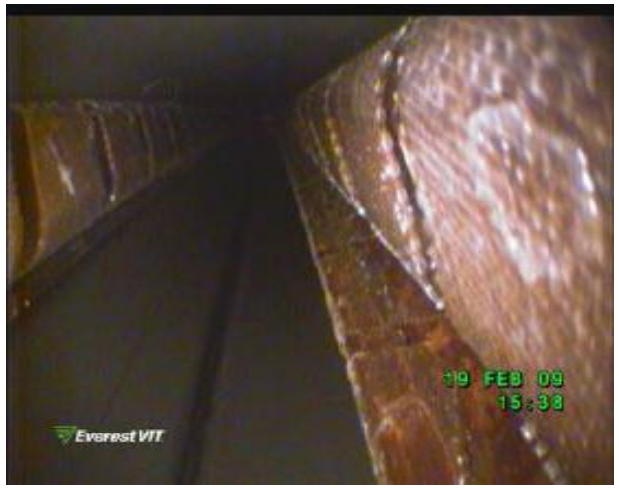
The proposed plan is :

- Measure and if necessary consolidate the CC 11L8
- Consolidate the CC in 11L3 & 11L1
- Measure / ***inspect all the CCs to check no displacement***

No info on 11L8 !

- Risk of short to ground on main BB due to supports displacement
- Addition of extra insulation to go up to ultimate energy

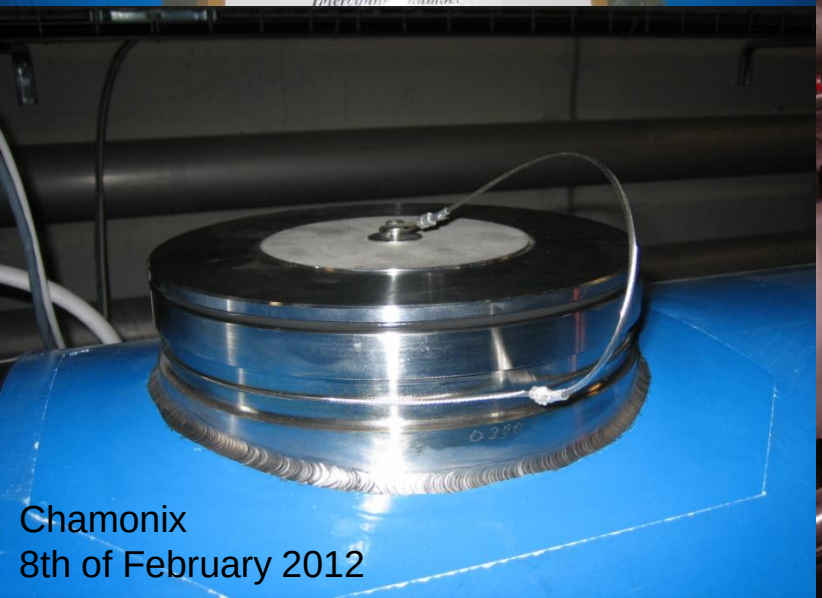


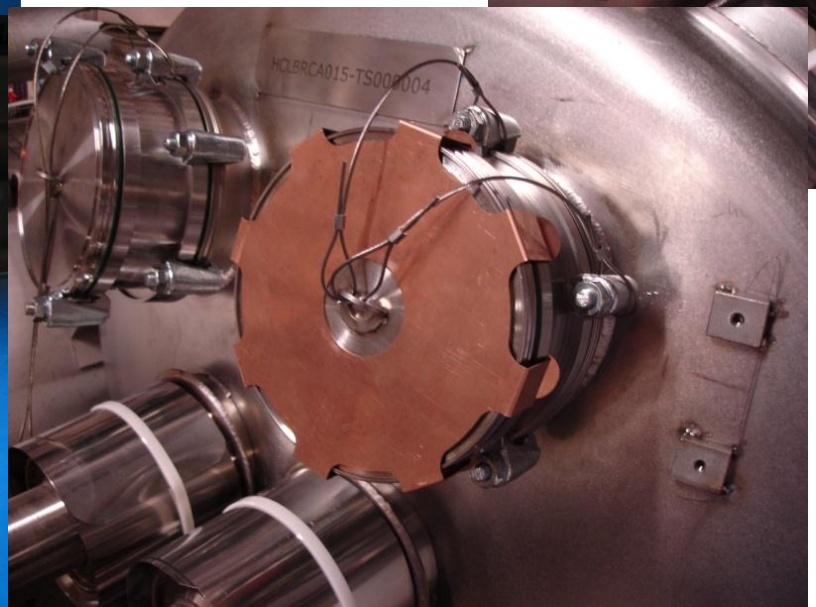


Installation of the remaining pressure relief devices (DN200/160)

To be installed on cryodipoles (DN200) during next shutdown in 23, 45 (part), 78 & 81: ≈ 600 units and on 2 SAM (DN160)

Self reclosing valves will be installed
(See M Jimenez's presentation)





In-situ repair :

Installation of beam lines protection shells

Details in ECR: LHC-QBBI-EC-0001

PIMs :
Tot about 45

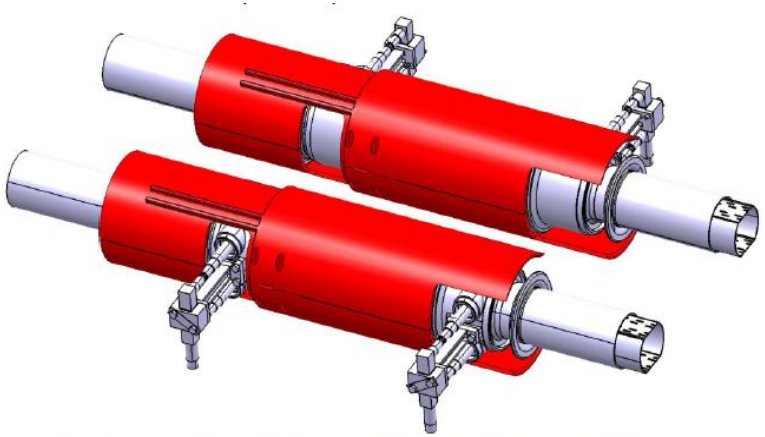
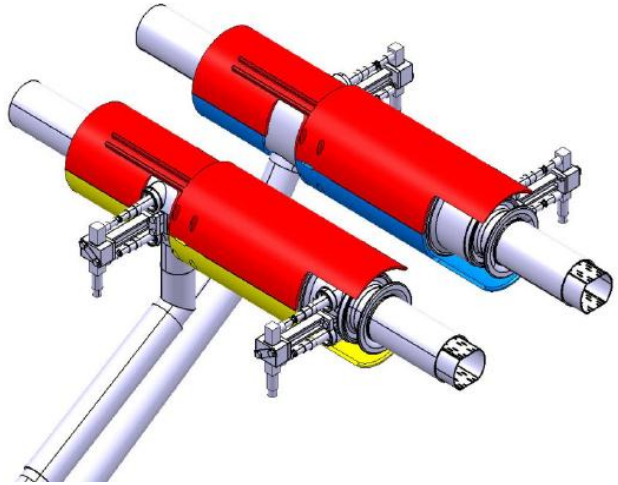


Fig. 1 Protective half shells for the MB-MB or MB-SSS interconnections



-Buckled during warm-up : based on last warm-up after SSS displacement :
≈ 14-18 (RF ball test)
-Heavily damaged : ≤ 10
-Preventive replacements :
+ Arc extremities 18/32 in baseline

	1-2		2-3		3-4		4-5		5-6		6-7		7-8		8-1	
	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
QQBI.7R	1.0	1.0	0	0	1.0	1.0	0	0	1.0	1.0	0	0	1	1	0	0
QBQI.8L	1.0	1.0	0	0	1.0	1.0	0	0	0	0	1.0	1.0	0	0	0	0

Nested bellows : None planned

Inspection at the opening of the interconnections

QBQI.10L5, NCR 831037, nested bellows V2

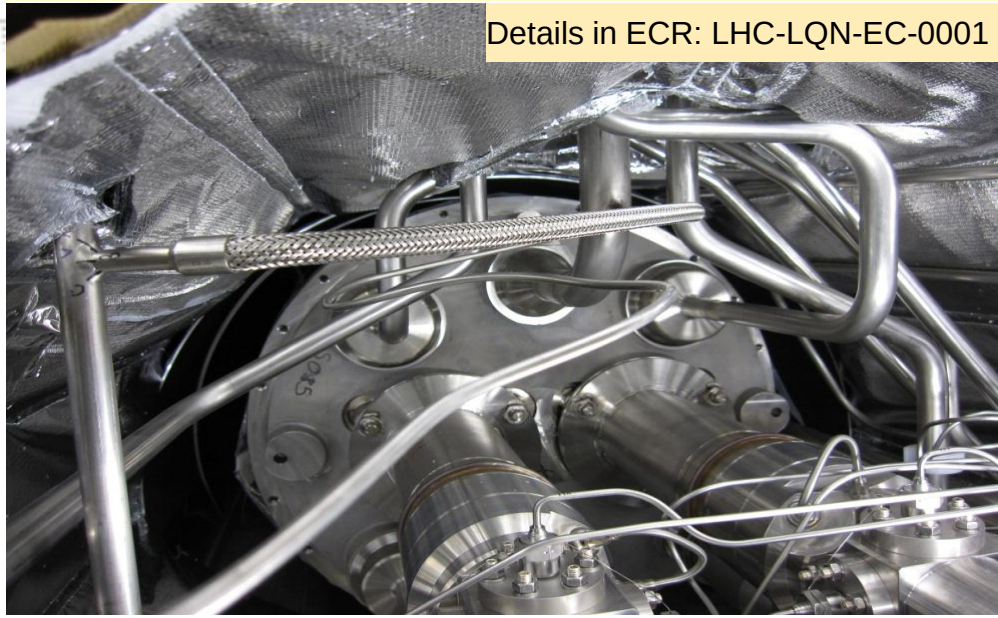
In-situ repair :

Leaking Y-lines

It is planned to consolidate the 2 known cases (S78:17-19R7 & S81:19-22R8)

Consolidation of SAM Helium level gauges

Details in ECR: LHC-LQN-EC-0001



It is planned to consolidate the 2 last ones: Q6R2&L8 [*Support from MME]*

Known Circuits Issues

References Chamonix 2011:
“Which systems (except main circuits) should be commissioned/tested for 7TeV operation before the long shutdown?”, M Pojer
“What needs to be done to reach beam energy above 3.5 TeV? Commissioning of essential magnet powering and machine protection systems.” N Catalan Lasheras

Circuit	Issue	Action LS1	Remark
RD2.R8	4 training quenches up to 6.8 TeV eq.	None	
RQ4.L8	7/8 quench heaters Can be used as is	None	NC 832580 & 1020189
RQX.R1	Weak insulation on QH	Intervention in-situ by QPS team?	NC 1017174/ Increase C / decrease V to get the same protection level
RCO.A78B2	Resistive splice	Investigation and possible repair in-situ by SIT	NC 1029807 Quenched @ 55A Condemned presently
RCO.A81B2	CL and coil resistance	Investigation and possible repair in-situ by SIT	NC 955048 Open between B12L1 and B11L1 Condemned presently
RQT12.R7B1	R > nom, increasing	Dedicated test, and possible repair	NC 1027412, to monitor
RQTL10.R7B1	R > nom, increasing	Dedicated test, and possible repair	NC 1026729, to monitor
RCBCHS5.L8B1	R = 22 nOhm (too high)	Cryomagnet will be replaced	NC 831927 (See previously)
RCOSX3.L1	Circuit open	Investigation and possible repair in-situ by SIT	NC 948545

Known Circuits Issues

Courtesy M Pojer

Training (2-quenches rule was introduced to shorten commissioning)

600 A

- RCD.A45B1 - NC 1035252 - quenched twice (at 300 and 391 A); limited to 400 A
- RCD.A56B2 - NC 1026728 - quenched twice (at 479 and 496 A); limited to 450 A
- RCD.A81B1 - NC 1043522 - quenched twice (at 351 and 484 A); limited to 450 A
- RQTL11.L2B2 - NC 1020622 - quenched (544.85 A); limited to 500 A
- RQTL11.R5B1 - NC 1027448 - quenched twice (at 501 and 492 A); limited to 450 A
- RQTL11.R5B2 - NC 1027413
- RQTL11.L6B1 - NC 1026809
- RQTL11.L6B2 - NC 1026747 ted to 300 A
- RQTL8.L7B1 - NC 1046464 - quenched twice (at 240 and 257 A
- RQTL9.R3B2 - NC 1046992 - quenched at 359, 399.9 and 396.1 A; limited to 400 A
- RQT13.L5B1 - NC 1060679 - this magnet shows a strange behavior; I_PNO reduced to 400 A

RQTL8.L7B1 showed detraining:
+ 300A/245A in 2008, 240A/257A in 2009

80-120 A

- RCBCV5.R5B2 - NC 1029792 - quenched twice (at 69.4 and 76.9 A); limited to 72A
- RCBCH7.R3B1 - NC 1046994 - quenched twice (at 98 and 95 A); limited to 80 A
- RCBYH4.R8B1 - NC 1051795 - quenched at 55.6 A; limited to 50 A
- RCBYV5.L4B2 - NC 1049055 – 3 quenches w.o. training (63.3, 65.7 and 64.7 A); limited to 50 A
- RCSSX3.L1 - NC 1053719 - the circuit trips when it reaches 62.9 A; this has been proven 4 times (circuit is now locked)
- RCBYHS5.R8B1 - NC 1063839 - circuit quenches when coming down from +-nominal current to zero; the control of the current also shows high instability (see EDMS 1053978)
- RCBYHS4.L5B1 - NC 1053709 - circuit can not handle di/dt : weak magnet known since 2008 (see MP3 meeting 4/11); tested with reduced I_PNO up to 60 A and OK so new I_PNO defined at 50 A

Splices, shorts and open circuits (investigations to be carried on)

- RQT12.R7B1 - NC 1027412 - high splice resistance after PNO test
- RQTL10.R7B1 - NC 1026729 - magnet resistance slightly outside limits (202nΩ per splice) and increasing from last year
- RCBCH6.L2B2 - NC 1020424 - cold part of the circuit appears too resistive (about 10 mΩ)
- RCBCV6.L2B1 - NC 1020423 - cold part of the circuit appears too resistive (about 10 mΩ)
- RCBCH7.L2B1 - NC 1084848 - slightly high resistance measured (3.04mΩ instead of 3mΩ)
  RCBCV7.L2B2 - NC 1084849 - slightly high resistance measured (3.04mΩ instead of 3mΩ)
- RCBH31.R7B1 - NC 1017094 - the Hi current lead resistance (DFLDS.31R7.2) is too high (1.14e-3 Ω) and coil seems to be too resistive

Known Circuits Issues

Strategy :

-Test circuits before LS1 to identify real limitations to go to 7 TeV
-Perform extra diagnostics at cold and at warm
-Define real operation requirements for these circuits
-Repair if possible and needed
-Add warm corrector (As done in 5L8) if possible

NB Exchange of more cryomagnets will be almost impossible

A lot of work !

Unknown Non-conformities

Long Shutdown 1
F. Bordry

TE Technology

Consolidation of the superconducting magnets and circuits: JPh Tock

Open/Close IC [DN200]
A Musso (X) #30
- -Opening/ Closure of IC
  - Partial and complete
  - W bellows & ther. shields
- -Installation of DN200

Special interventions "SIT"
N Bourcey (G Maury) #15
- -Cryomagnets exchange
- -Connect. Cryostat cons.
- -PIMs
- -Specific issues
- -**Heavy NC**

Main arc splices cons.
"The train"
F Savary (H Prin) #52
- -Sleeves cutting (JM Hubert)
- -BB surfacing (M Dumas)
- -Shunt installation (M Pozzobon)
- -Insulation (M Parent)
- -Splice de-&resoldering [15%] (D Etiembre / L Favier)

TIG welding [EN-MME]
S Atieh (X) #18
- - Orbital & manual

DFBA [TE-CRG]
A Perin (X) [#12 (TBC)]
- -Splices and BB

Quality Assurance
R Ostojic (X) #39
- -Electrical QC: #17
  C Scheuerlein (P Thonet)
- -Welding QC: JM Dalin # 6
- -Beam vacuum QC: C Garion #6
- -Open/close IC QC: D Bodart #6
- -QA manager support : M Struik
- -Audits (TBD)

ELQA [TE-MPE]
K Dahlerup
(G D'Angelo) #23
- -Continuity
- -HV test

Leak Test [TE-VSC]
P Cruikshank (X) #19
- -Beam lines
- -Cryogenics lines
- -Insulation vacuum

Project Office M Pojer (X) #11
- -Radiation protection
- -Safety, Access
- -General logistics
- -Pressure test
- -Coordination with
  Survey, BLM, Instrumentation, Transport, LS1 planning, QPS, cryogenics,…
  Test teams on a chain of IC
- -Reporting tools

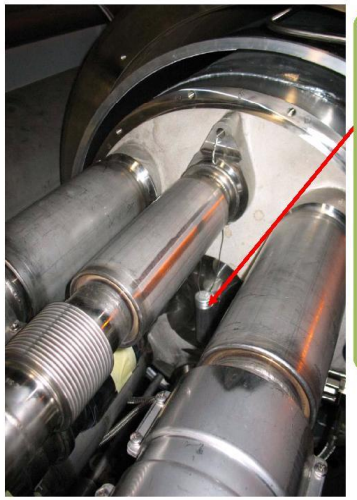
Detailed roles

Technology Department

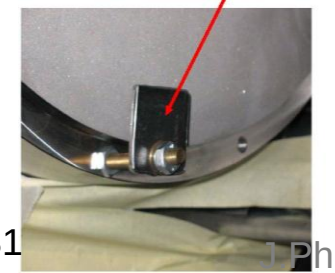
Open/Close IC [DN200]
A Musso #30

-Opening/ Closure of IC
Partial and complete
W bellows & ther. shields
-Installation of DN200

- Open interconnections for :
  - Consolidation of main splices
  - Installation of DN200
    Partial opening first
  - Recovery of RP samples (LHC-LI-EC-0001)
  - Support to special interventions
- Install DN200 (3,5 sectors)
- Reclose interconnections

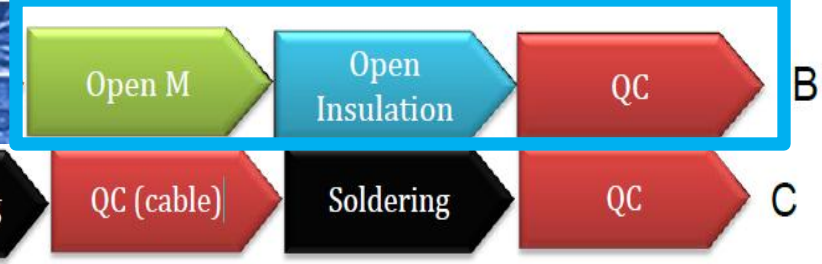


Cylindrical aluminum box with pass-through 3mm holes, fixed with stainless steel cable to X-line. It shall be positioned between the two beam lines. Inside there are: Dosimeter, collar coil sample, superconducting cable sample.

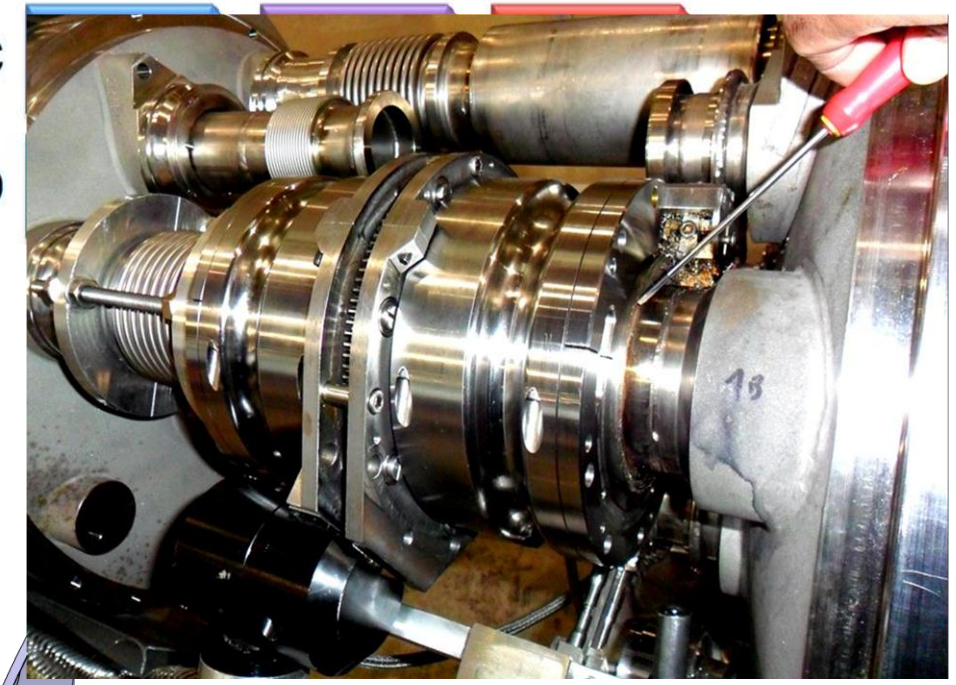


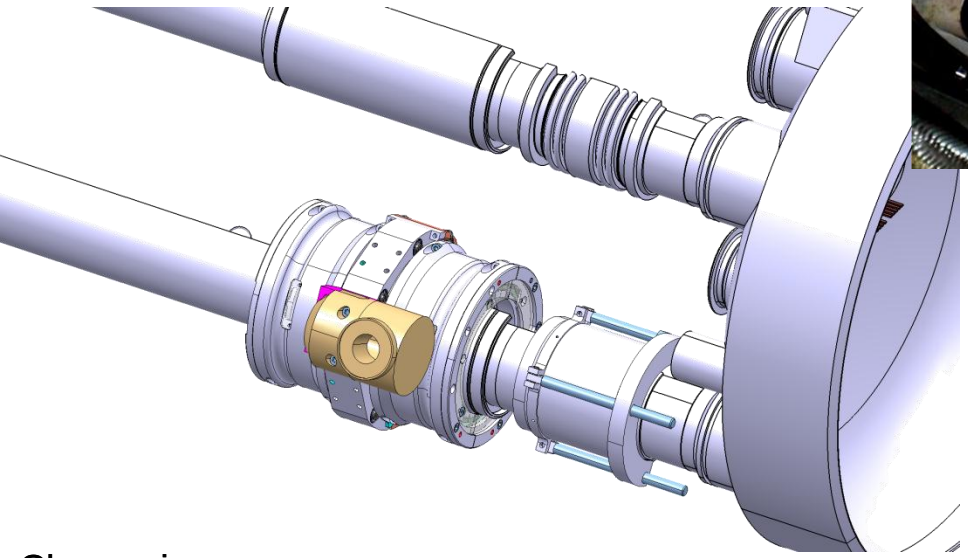
Detailed roles

-Sleeves cutting (JM Hubert)
-BB surfacing (M Dumas)
-Shunt installation (M Pozzobon)
-Insulation (M Parent)
-Splice de-&resoldering [15%]
(D Etiembre / L Favier)



➢Local activities (on one IC)

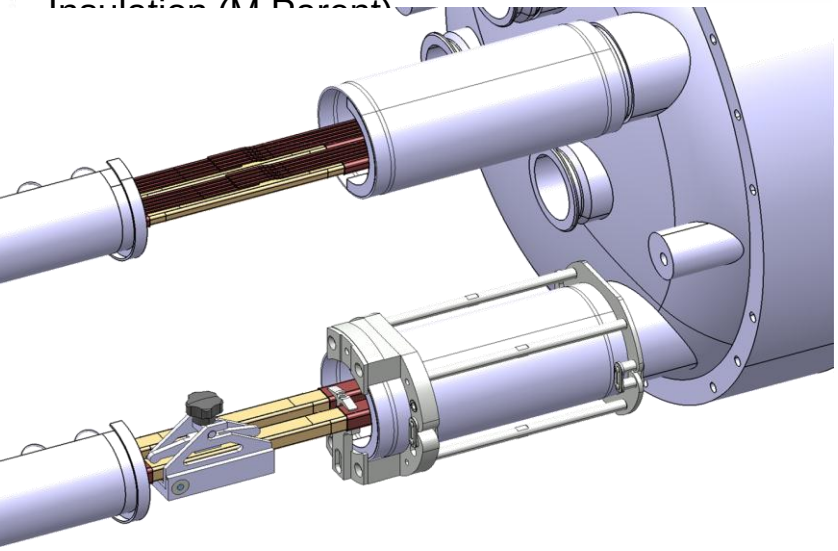


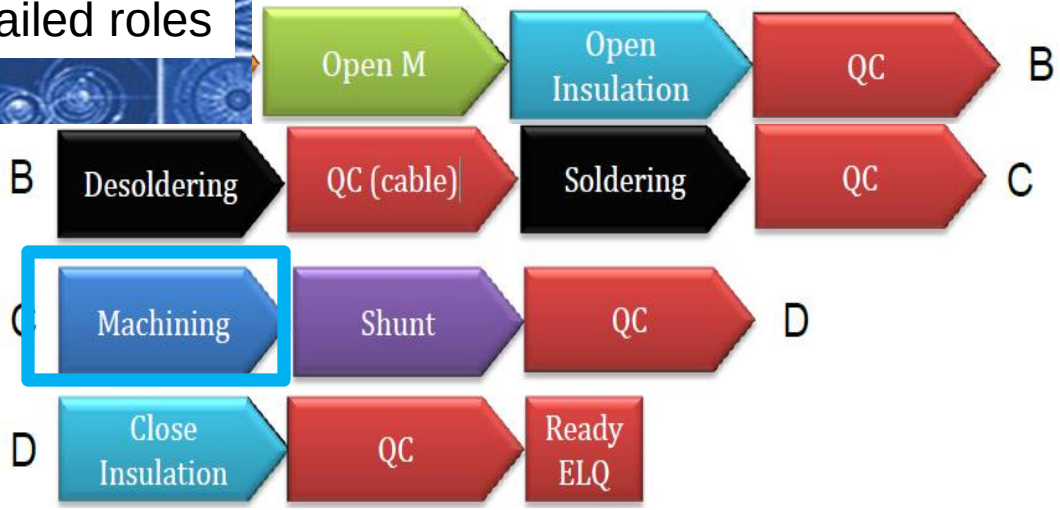


Desoldering / Resoldering is an optional action :
-15 % of the splices based on strict criteria: + R @ 1.9K
+ R_8 @ RT
+ Geometry [Shunt install-ability]
+ Visual inspection

Detailed roles

-Sleeves cutting (JM Hubert)
-BB surfacing (M Dumas)
-Shunt installation (M Pozzobon)

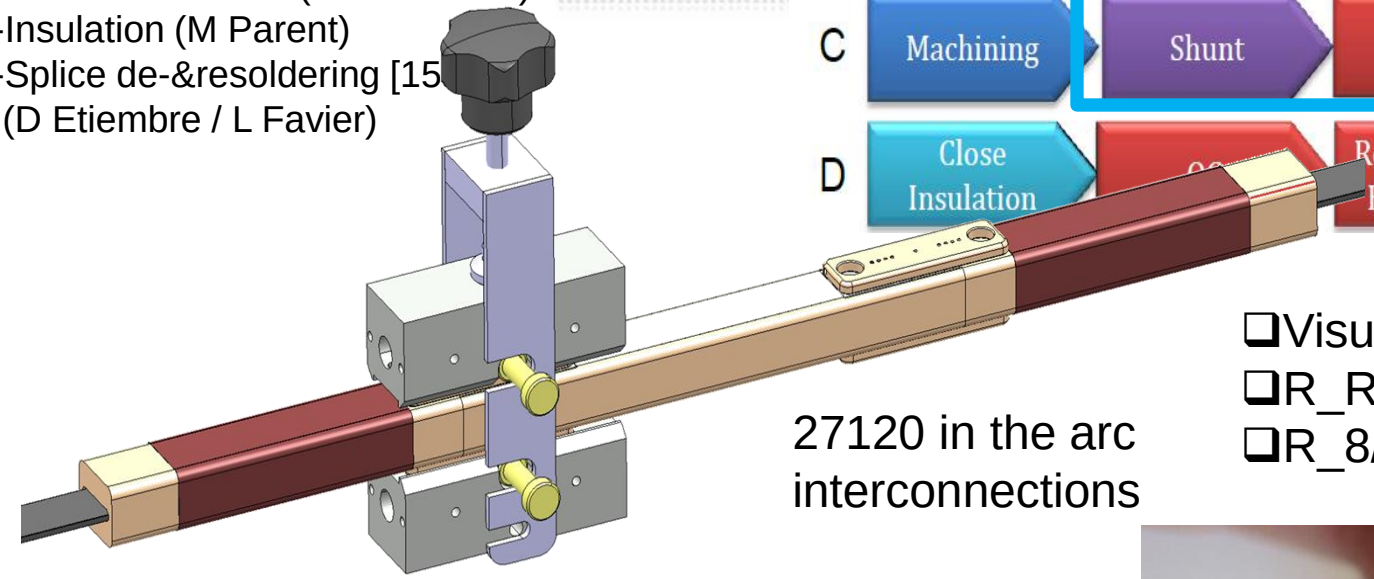


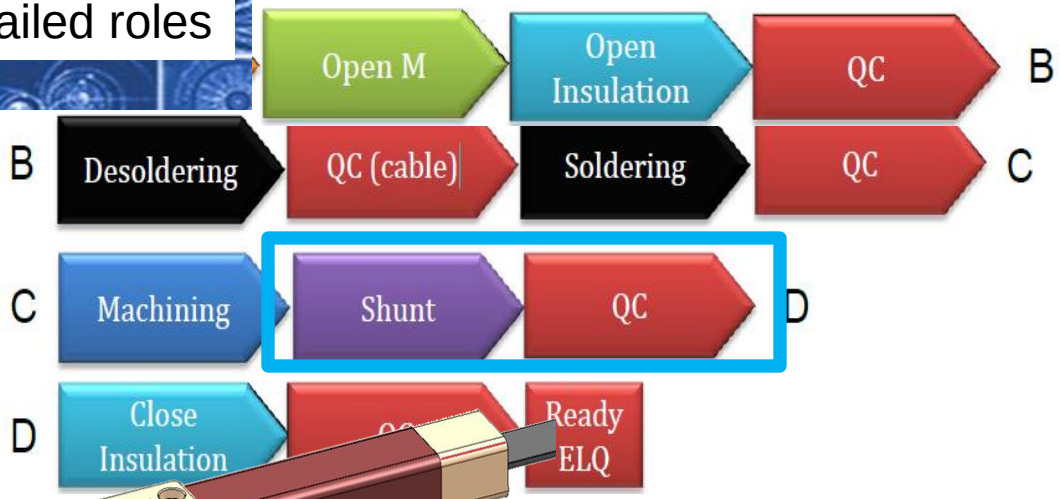


Under TE-MSC-MNC responsibility during LS1
Developments by LMF, training and transfer of know-how in 2012

Detailed roles

-Sleeves cutting (JM Hubert)
-BB surfacing (M Dumas)
-Shunt installation (M Pozzobon)
-Insulation (M Parent)
-Splice de-&resoldering [15
(D Etiembre / L Favier)

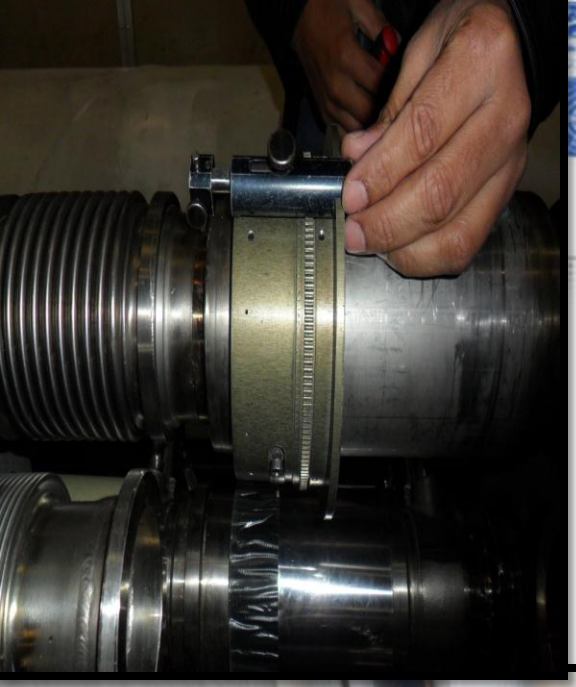




27120 in the arc interconnections

QC

- ❑Visual inspection, photos
- ❑R_RT-top-side
- ❑R_8/R_16



Detailed roles

TIG welding
[EN-MME-AF]
S Atieh (X) #18

Welding QC
[EN-MME-MM]
JM Dalin # 6

- All TIG welding
  - -orbital and manual
  - -all lines (M mainly)
- Ensure availability and maintenance of tooling
- Qualification of welders
- Coordination of the team
- Provide support to DFBA team
- Provide support to special team (SAM, …)

And its associated QC

- Visual inspection
- Audits
- Off-line samples
- …

Detailed roles

Techno
Department

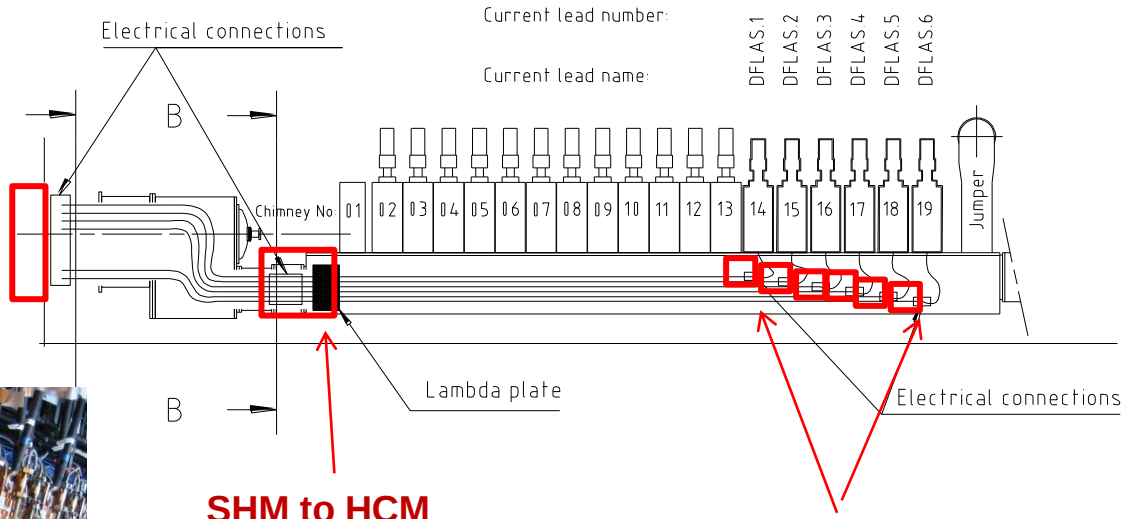
Special interventions "SIT"
N Bourcey #15

- -Cryomagnets exchange
- -Connect. Cryostat cons.
- -PIMs
- -Specific issues
- -**Heavy NC**

DFBA
A Perin [#12 (TBC)]

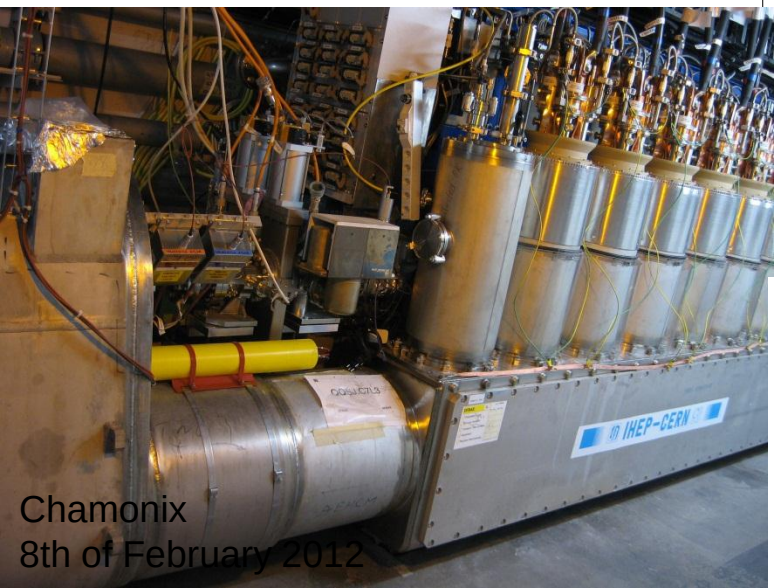
- -Splices and BB

- ➢Was covered in previous slides
- ➢Polyvalent team
- ➢Will intervene on heavy NC to avoid slowing down the work of the main train



SHM to HCM connection

CL (pigtail) to busbar connection



For the 16 DFBA, a first analysis shows that the splices in 14 of them can be consolidated "in situ". SHM-HCM splices of two DFBAs (1 in DFBAP and 6 in DFBAK) cannot be accessed "in situ" for consolidation.

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Quality Assurance
R Ostojic #39

-Electrical QC: C Scheuerlein #17
-Welding QC: JM Dalin
-Beam vacuum QC: C Garion
Protection and inspection of Bellows, PIMs
Endoscopy of beam lines
-Open/close IC QC: D Bodart
Visual inspection
Protection of critical surfaces
-QA manager support
Tooling, inspection, reporting
-Audits

The QA manager will:

- Coordinate QA activities
- Ensure that an adequate level of Quality Assurance is applied, especially in terms of traceability (MTF) and documentation
- Ensure a timely management of the non-conformities, minimizing the impact on the overall schedule
- Ensure that production parameters are analysed in time to give an early warning in case of drift.
- Identify as early as possible critical issues that could jeopardize the consolidation work

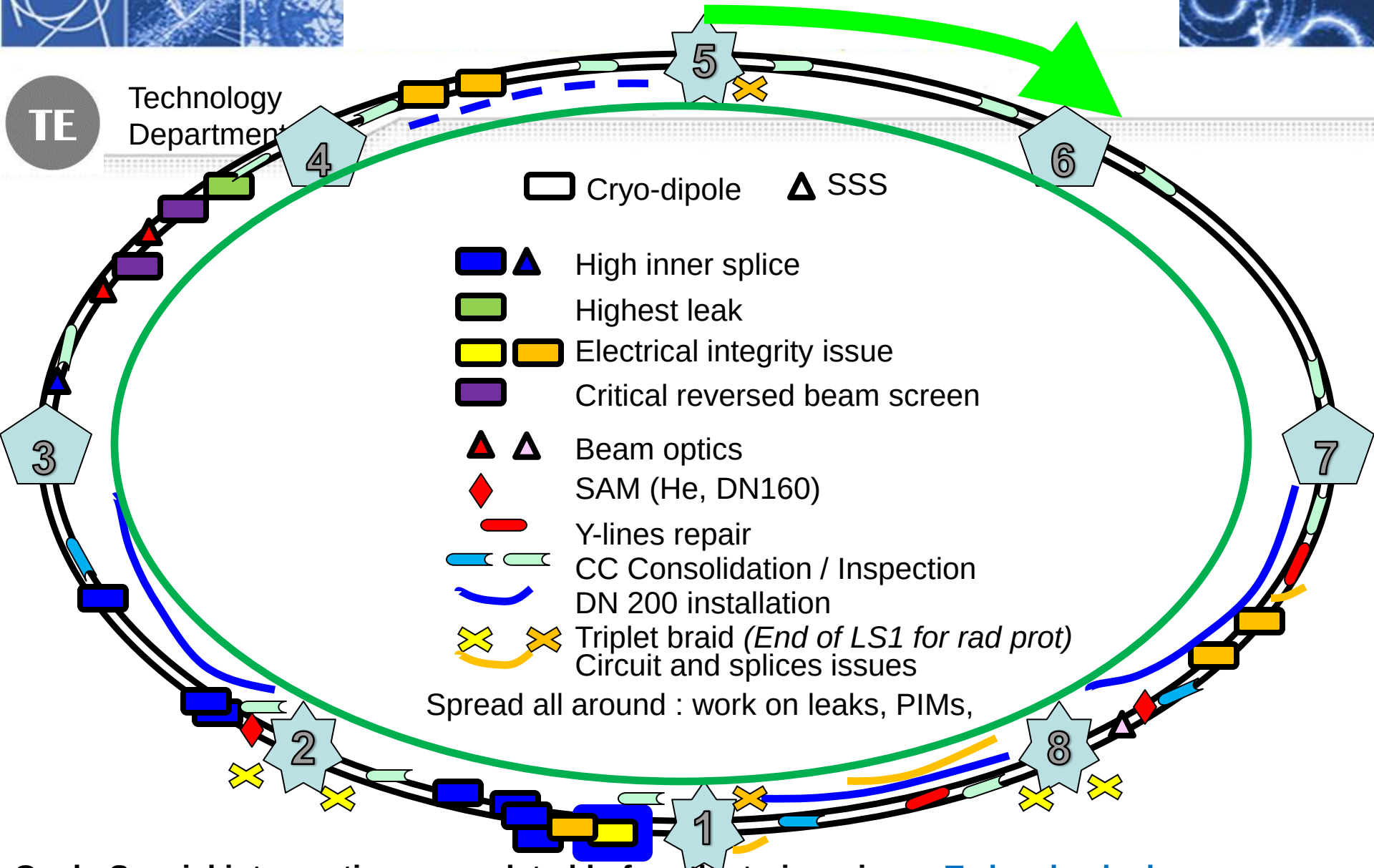
ELQA [TE-MPE]
K Dahlerup
(G D'Angelo) #23

-Continuity
-HV test

Leak Test [TE-VSC]
P Cruikshank (X) #19

-Beam lines
-Cryogenics lines
-Insulation vacuum

START AT P5 / CLOCKWISE



Goal : Special interventions completed before the train arrives : To be checked

Global Planning

Rate: 4 weeks for each activity so 53 IC/week
Dimensioned to 60 IC/week: 10% margin
Remember : Series installation at 30 IC/week !

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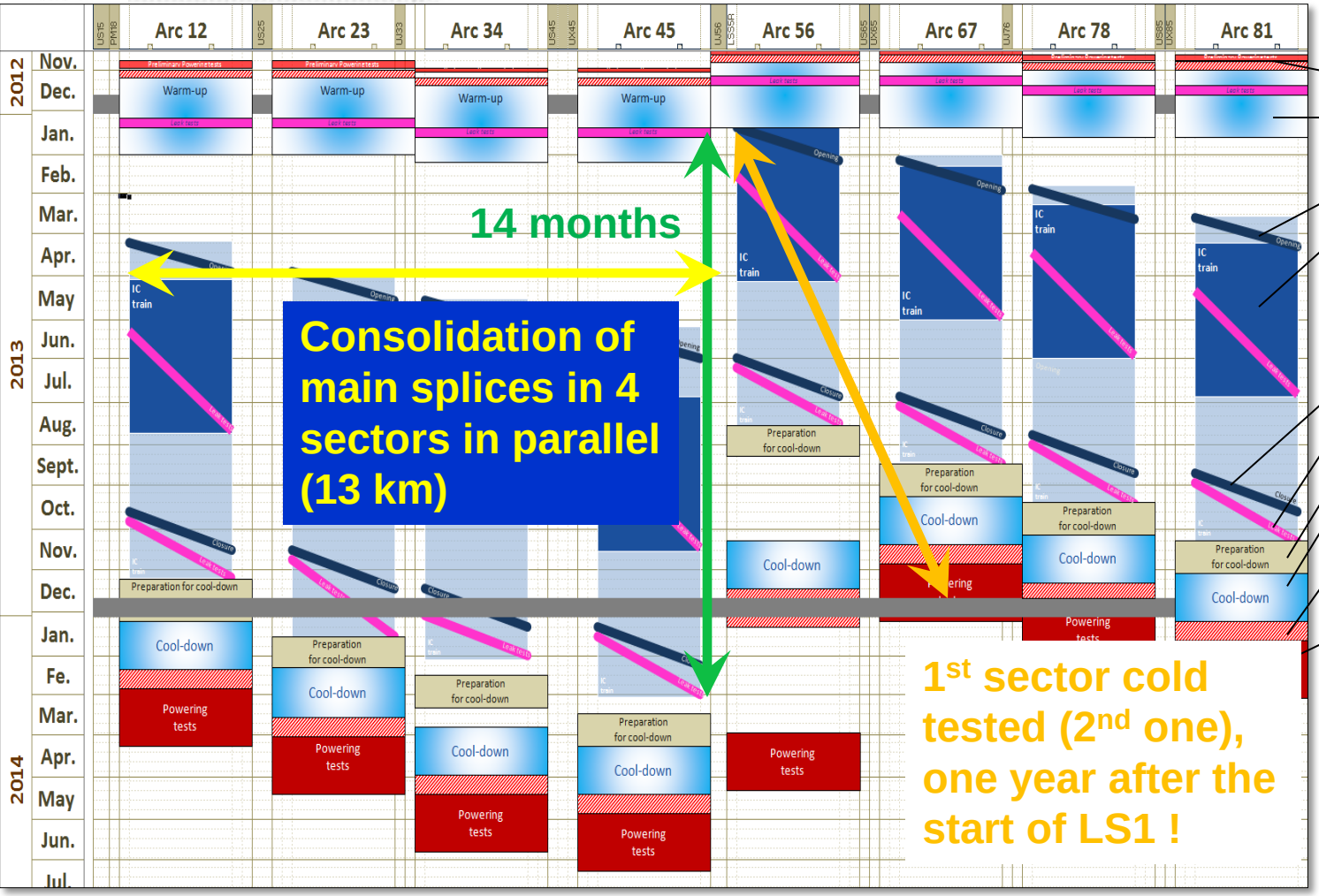
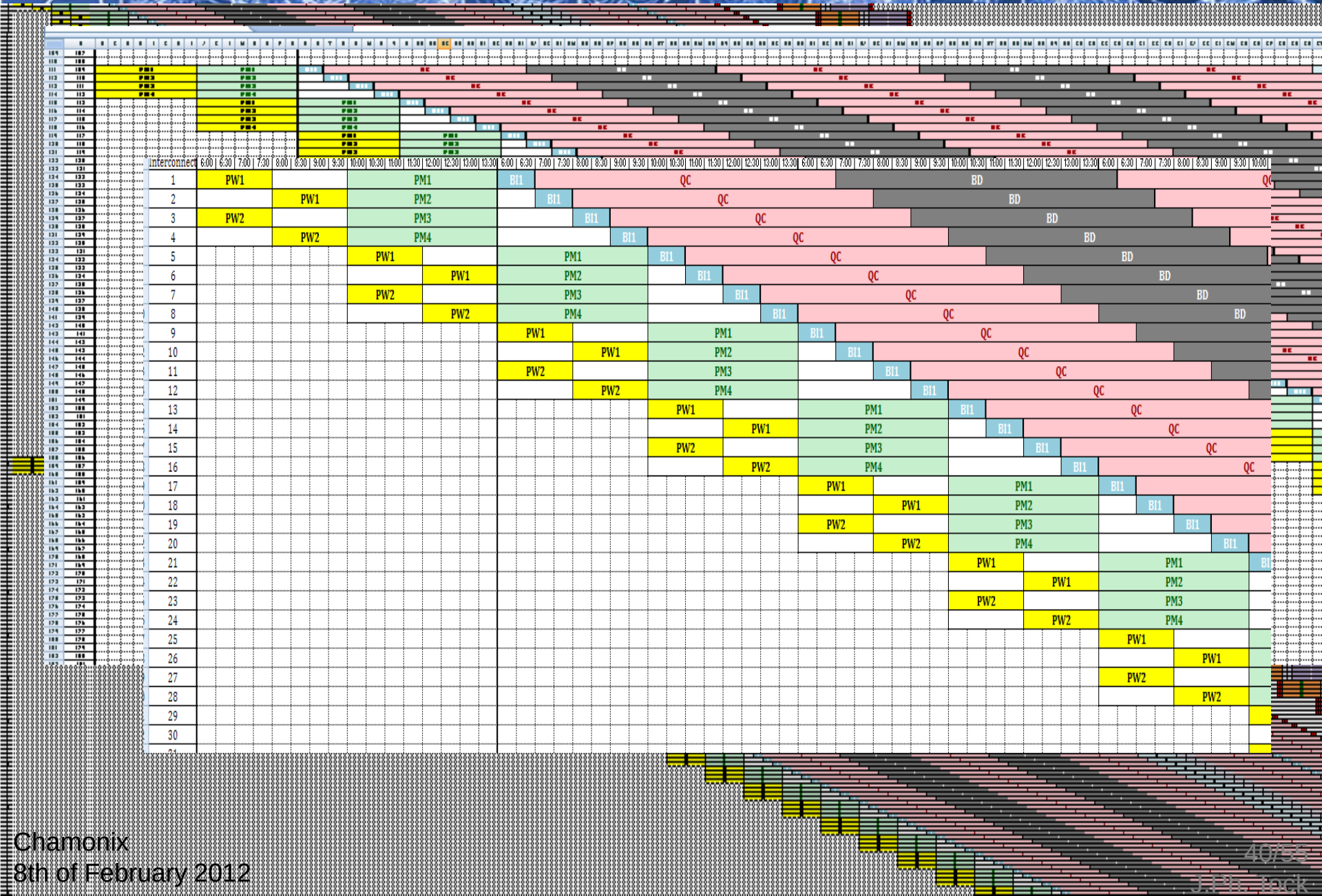


- Preliminary powering test
- Warm-up
- Opening
- Splice consolidation (incl. internal leak tests)
- Closure
- Leak tests (Ins vacuum)
- Preparation for cool-down
- Cool-down
- ELQA@cold
- Powering tests

Detailed schedule

Courtesy R Principe



Courtesy : A Musso : Project Responsible
J Pereira Lopes: Implementation & S/W development

Web interface from LHC tunnel during LS1 allows:

- Real-time tasks advancement recording (easier coordination)
- Team and tooling traceability for each single task
- Fast reaction in case of NCR's
- MTF traceability when needed

WISH during LS1 requires:

- 3G data connection (checked with IT experts, this is the best in terms of speed, cost, installation time)
- Tablets (or laptop) for team leaders
- Website specification (work already started)

http://www.youtube.com/watch?v=kVnYkJg-0Rk

APRIL 2012 :
Database design and performance study

JULY 2012
Web setup and programming

AUGUST 2012
Test and debugging

SEPTEMBER 2012
Code revision and training

NOVEMBER 2012
Production

Resources

- Current estimate for IC/magnet work (IC train, SIT, DN200):
  - ~220 persons needed (was ~200 in Chamonix 2011 !)
    + 12 for DFBA, +5 for TIG welding, -3 DS Coll, + 1 (+2 mag exch), +X due to update of procedures, …
  - ~80 % are identified (but not all at CERN and experienced)
  - Still unknowns (DFBA, NC, undulator, open issues,…)

- One collaboration (#39) with a NMS was identified but is reducing to 12 (TBC)
  - 27 persons to find (Other collaboration or FSU)
- Contribution from CERN groups outside TE under finalisation (Keep commitment) and also from other TE groups (EPC, VSC, MPE, CRG,…)
  - BE-OP
  - EN-MME

Resources

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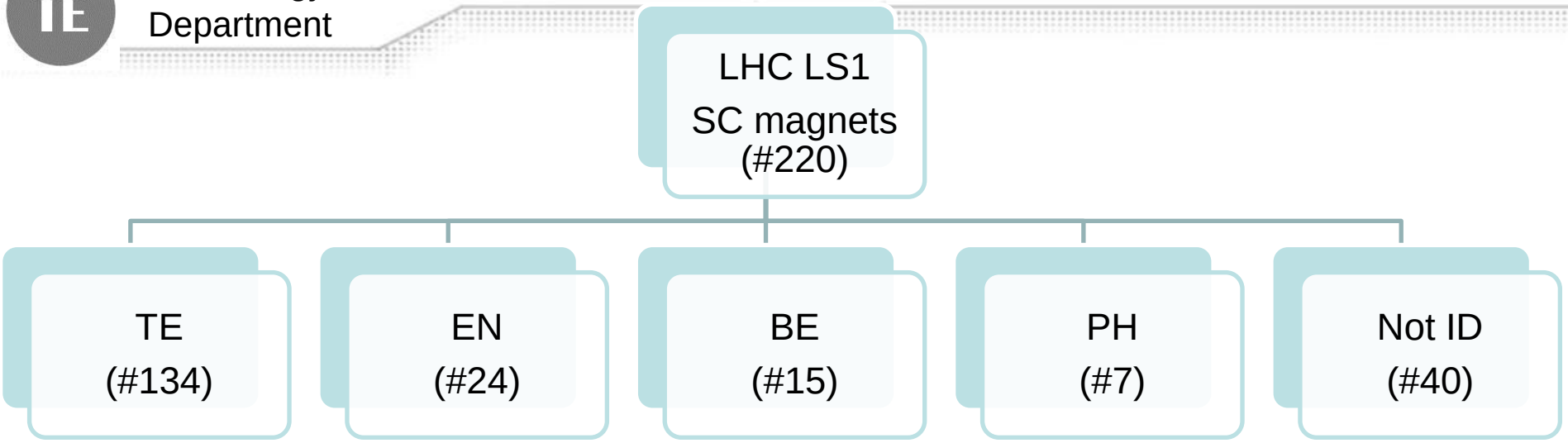

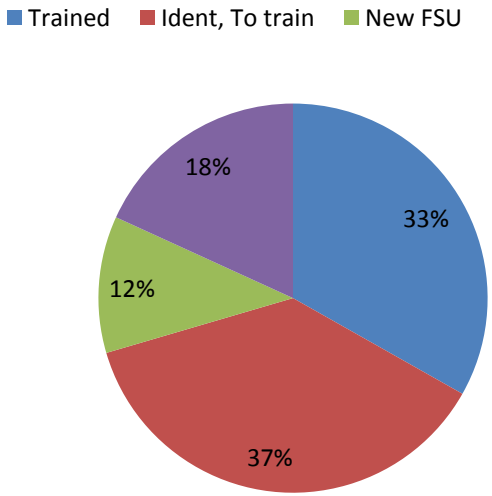

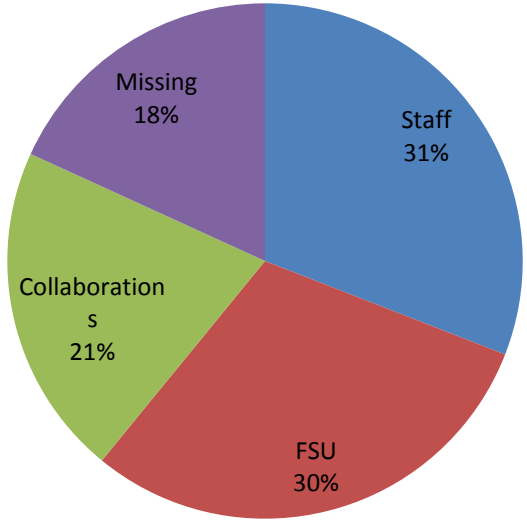

Open issue : The spider insulation

Courtesy H Prin

More info: LHC Splices Review 2 : https://indico.cern.ch/conferenceDisplay.py?confId=157231

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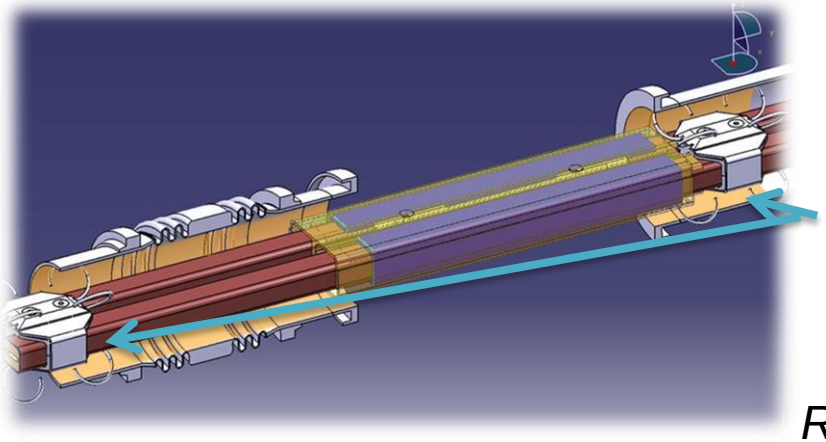
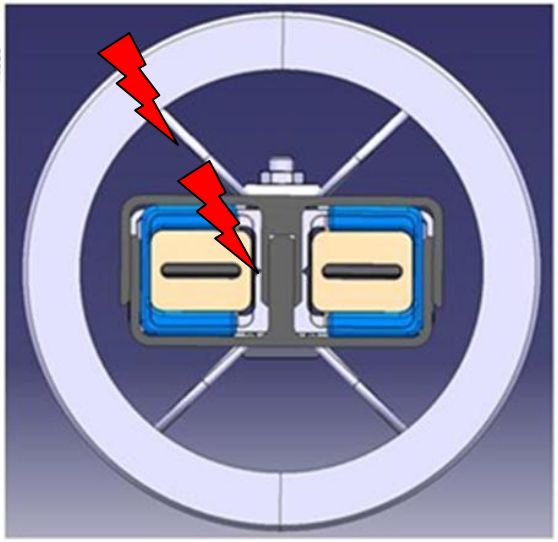
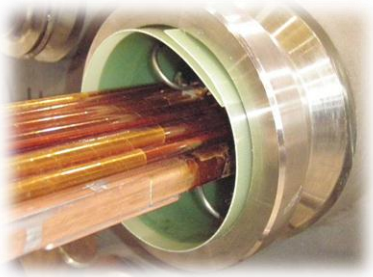
Risk if BB insulation is damaged

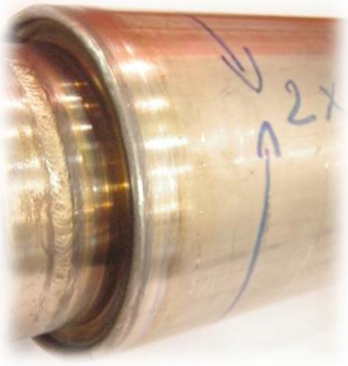


Implementation
Heating during welding (~300 ° C)
Friction during cooling
Fixation to the flange
Behavior during quench
Reliability in time
Remnant in the cryogenics filters



Insertion of dielectric foils between the M-Lines and the spider legs, fixed to the M-line flanges





- ❖No procedure defined yet (on-going)
- ❖Not decided yet (Splices TF)
- ❖Be sure that increase of reliability is not offset by a drawback

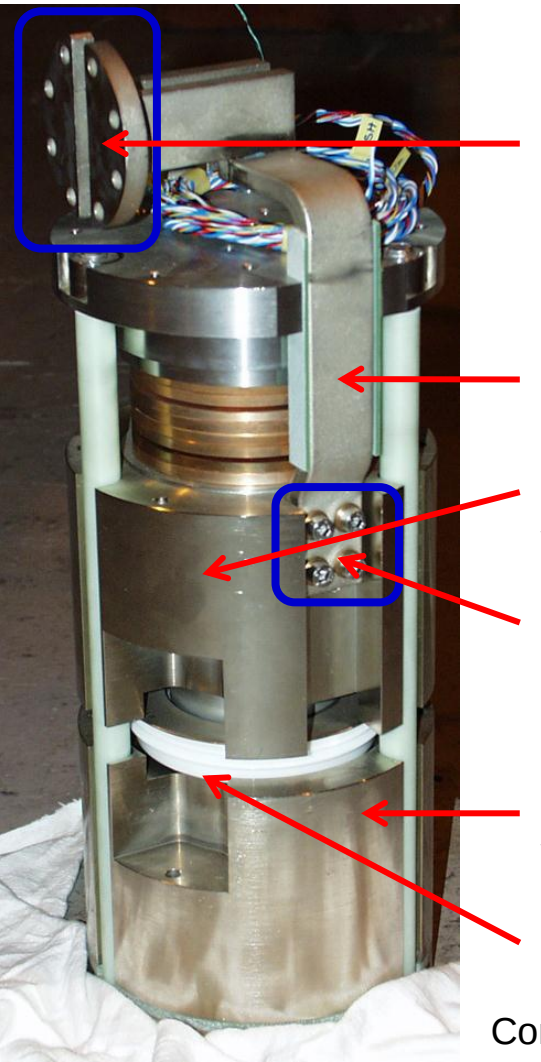
Open issue : The diodes

Courtesy F Savary and the diodes WG …

More info: https://edms.cern.ch/cedar/plsql/navigation.select_tree?cookie=10793751&p_node_id=1119199397&p_open_node_id=1554670541

The diode stack and its 3 contacts (dipole)

- Primarily, bolted contacts with 4 M6 + helicoil, 1 washer, 5.5 Nm
- Later, 4 M6 + helicoil, 4 spring washers, 10 Nm
- Diode compressed to 40 kN by a stack of spring washers



$R_{Bus\text{-}bus}$ ('half moon')

Lower diode bus bar

Upper Heat Sink

$R_{HS\text{-}bus}$

Lower Heat Sink

$R_{Diode\text{-}HS}$

Diode box, He content:~5 l

All copper parts are Ni-plated, 2-3 µm except ½-moon on the magnet side that is Ag-coated, ~1 µm

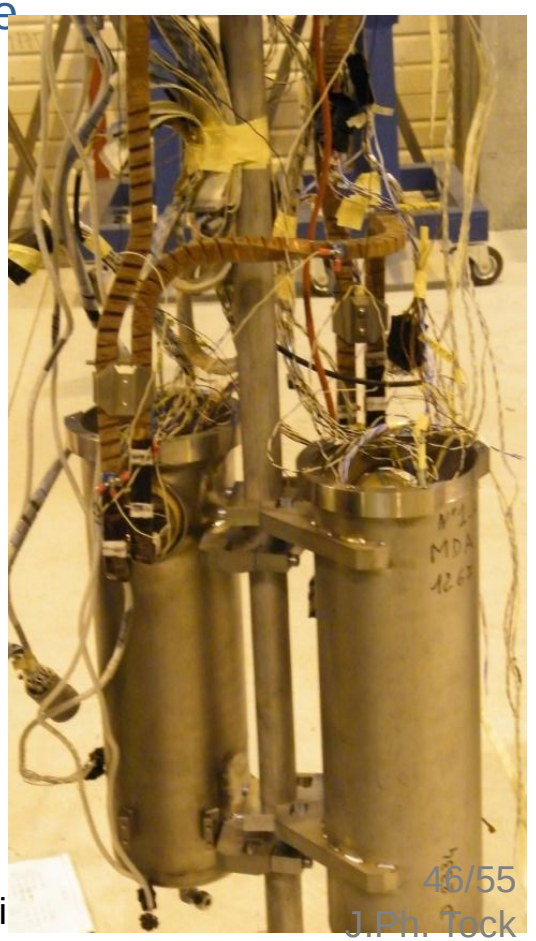
Voltage taps on the diode

Open issue : The diodes

Courtesy F Savary and the diodes WG …

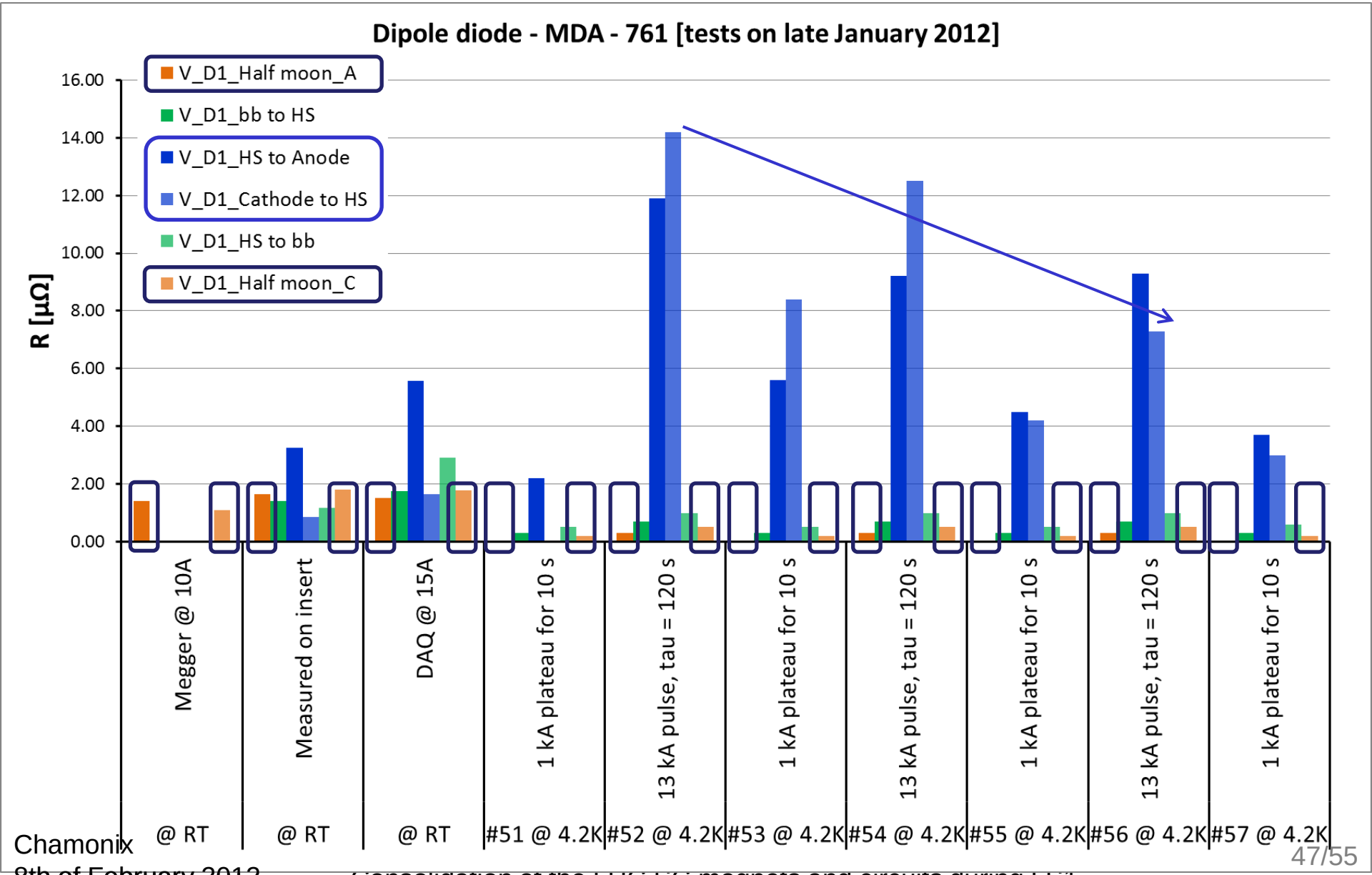
Brief history:

- High resistances measured incidentally in the diode circuits in Sector 5-6 (during the technical stops) during “Quench propagation tests”
- Working Group on Diodes with members from MPE and MSC to conduct off-line (outside the LHC machine) testing of the diode leads is active since early September 2011
- Reporting : 1 interim (15.11. 2011), TE-TM (5.12. 2011), LMC (7.12.2011)
- Comprehensive analysis of the measurements data available from Frascati & Bloc-4 (series production) and more recently from SM18 (spare diodes and diodes from sector 3-4)
- Instrumented diodes tested at 4 K in SM18 between late November 2011 and now



Open issue : The diodes

Courtesy F Savary and the diodes WG …



Open issue : The diodes

Courtesy F Savary and the diodes WG …

Impact on LS1:

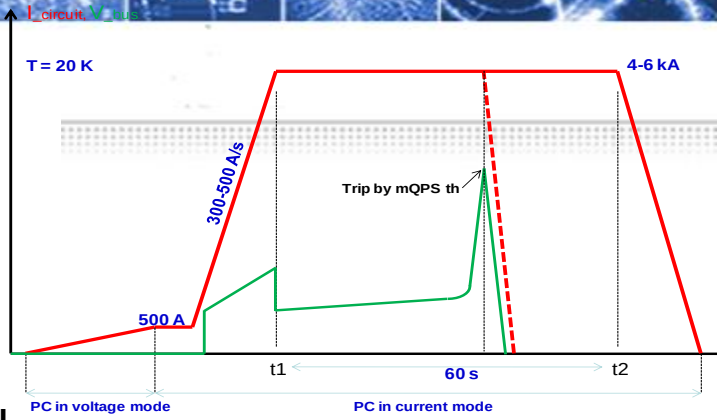
- Typical "training" behavior of the diode circuits observed in Sector 5-6 in 2011 and during the LHC construction confirmed in very recent tests at 4 K in SM18
- The recent tests in SM18 show that the **typical "training" behavior is a characteristic of the diode to heat sink contact**. However this behavior is still not explained. This is not an issue for the LHC operation as the heat sink works fine, i.e. the T peak is limited to 180 K
- **The other contacts** (heat sink to bus and bus to bus, i.e. ½ moon for the dipole and connection pad for the quad) **work fine** and show low R at cold during the tests. In the worst case the T peak does not exceed 90 K
- **No massive intervention** during LS1, local inspections could be scheduled (beg of LS1)
- Possible extra tests on cryomagnets that will be removed (TBC)
- However, we will **check some isolated cases**, e.g. D16R5 a *[Behaviour not understood yet]*

Further tests :

- Test of 2 quadrupole diodes fully instrumented
- Test of 2 dipole diodes fully instrumented, MDA 1267 et MDA 778 already tested and stored in the mean time without specific precaution
- Possibly, test of bolted contact samples (without diode stack)
- Change surface conditions at the diode to heat sink contact, e.g. roughness, coating (silver-tin or gilding in lieu of nickel plating)
-

Open issue : The CSCM

Courtesy H Thiesen et al



❖At 20 K, reproduce quench conditions but without energy stored in magnet (bypass circuits)

❖ Measure not all splices but *the worst one in a sector*

❖ Requires modification of critical systems :
QPS, EE, PIC, PC

❖ Necessary cryogenics conditions can be provided

❖ Extremely small risk to damage a splice or a DFBA CL

❖ Requires time and resources

Review report :

"The CSCM may be useful to qualify the upgraded 13 kA joints at the 7 TeV level. This use of the CSCM will have to be evaluated in order to understand its operation at higher current levels of 9-10 kA, than the 6kA level that have been anticipated up to this point"

Recommendations:

"Since alternatives are not present other than to accept the risk of not having tested certain parts of the circuits, **the use of the CSCM to qualify entire circuits for 12-13 kA level is highly recommended** "

Was reported at LMC on 7.12.2012 (R Schmidt)

Open issue : The CSCM

LHC Splices Review 2:

Action : TE-EPC/MPE

- Rev 2 Rec 7: Consider the utility and practicality of utilizing the CSCM for periodic "requalification" tests of the main (quadrupole) bus circuit
- Comment:

CSCM is not an obviously useful test if it cannot be **run at full current** (due to nonlinearities of the problem). But one could consider utilizing this test with the (quadrupole) bus, which can be run at full current, and in which there is less redundancy and therefore greater risk in the repaired joints (only one shunt planned). This could be done periodically over the life of the LHC. However, we don't have sufficient information to make a definitive recommendation

- *Would be a possible compensatory measures for very inaccessible splices*

-Type test before LS1 on at least one sector
-Systematic test after consolidation
-Periodic test later ?

Open issue : The CSCM

Courtesy H Thiesen et al

Proposal :

•Use this method to qualify the consolidation of the splices (And also other parts of the 13 kA SC circuits) for 7 TeV operation
And validate the whole bypass circuit

Planning:

+ Approval in March 2012
+ Type test to be done in one sector at the end of the run (4 weeks)
In sector 34 in January 2013
+ CSCM campaign at the end of LS1
+ Impact 4 weeks if 8 sectors [Could be 0 if last sector(s) not tested]

Note:

CSCM would be a tool to qualify the main SC circuits for 7 TeV operation (deviation from the original goal).
Necessary conditions to be updated

Open issue : Radioprotection

Courtesy C Adorisio & S Roesler

Technology Department

More info : LHC Splices Review 2, November 28-30, 2011
https://indico.cern.ch/conferenceDisplay.py?confId=157231

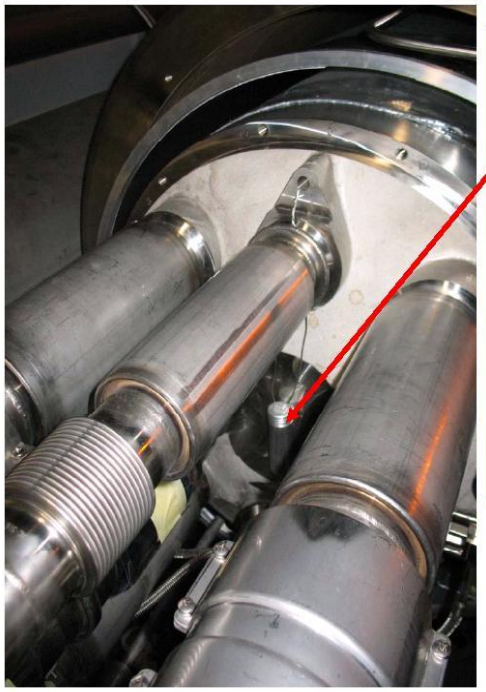
Rev 1 Rec II.5.3: The Splices Task Force should consider the potential hazards for workers associated to the utilization of lead-containing solder, and work with the Safety Commission to plan the work to minimize or eliminate this risk

Barely begun. This is important, since in the original design of the LHC the use of lead-containing solder was rejected on safety grounds

OK: Action F Savary (TE-MSC) and T Otto (DSO): On-going

Rev 1 Rec II.5.2: Radiation safety issues related to the splice repair work should be evaluated and considered in any decision to extend the current run

CLOSED (see next slide)



Cylindrical aluminum box with pass-through 3mm holes, fixed with stainless steel cable to X-line. It shall be positioned between the two beam lines. Inside there are: Dosimeter, collar coil sample, superconducting cable sample.

Aspect to be followed-up and organised:

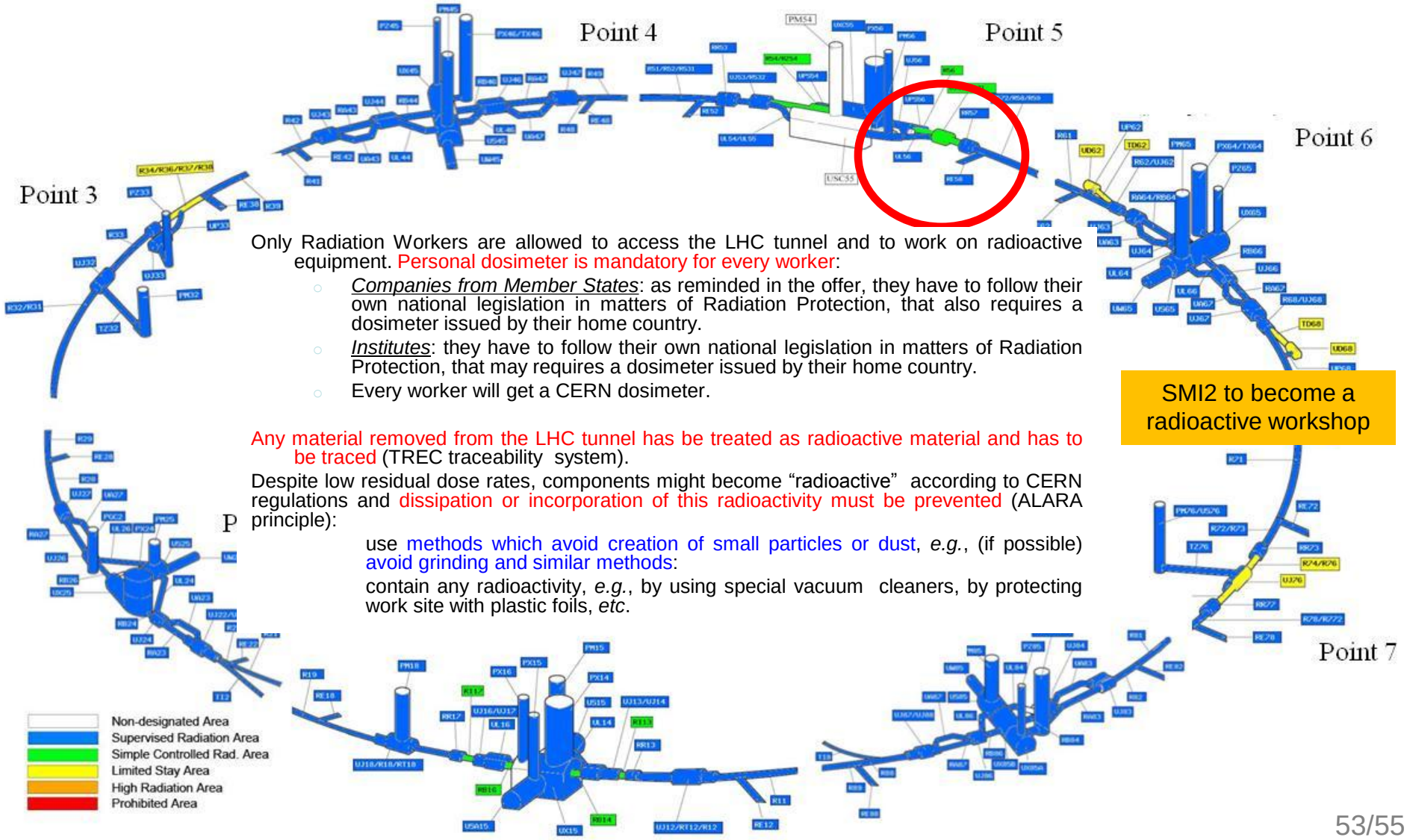
-Detailed estimates
-Verification on samples
-RP inspector at the opening of the interconnections

Open issue : Radioprotection

Courtesy C Adorisio & S Roesler

Technology Department

More info : LHC Splices Review 2, November 28-30, 2011
https://indico.cern.ch/conferenceDisplay.py?confId=157231



Only Radiation Workers are allowed to access the LHC tunnel and to work on radioactive equipment. Personal dosimeter is mandatory for every worker:

- *Companies from Member States*: as reminded in the offer, they have to follow their own national legislation in matters of Radiation Protection, that also requires a dosimeter issued by their home country.
- *Institutes*: they have to follow their own national legislation in matters of Radiation Protection, that may requires a dosimeter issued by their home country.
- Every worker will get a CERN dosimeter.

SMI2 to become a radioactive workshop

Any material removed from the LHC tunnel has be treated as radioactive material and has to be traced (TREC traceability system).

Despite low residual dose rates, components might become "radioactive" according to CERN regulations and dissipation or incorporation of this radioactivity must be prevented (ALARA principle):

use methods which avoid creation of small particles or dust, *e.g.*, (if possible) avoid grinding and similar methods:

contain any radioactivity, *e.g.*, by using special vacuum cleaners, by protecting work site with plastic foils, *etc*.

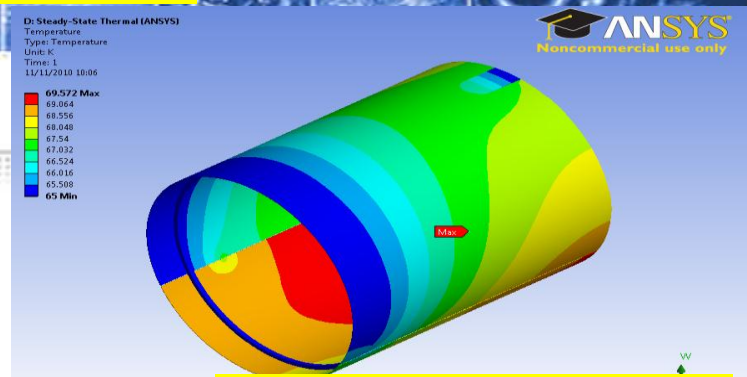
Open issue : New thermal shield design

Courtesy A Musso

TE Technology Department

Why ?

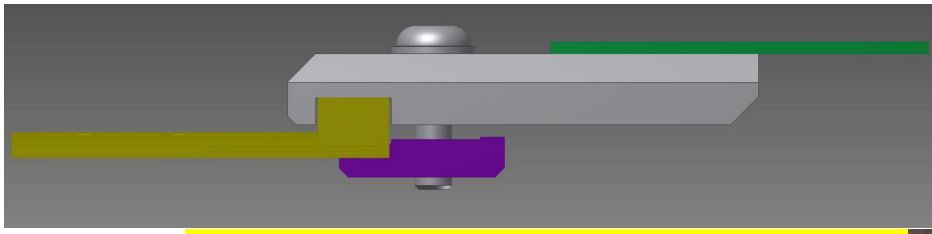
- To avoid blockage (2008-09)
- To avoid MLI ignition and fire
- To minimize the intervention time now and in the future (ALARA, $$$)
- There is margin on the heat load



Thermal modeling

Goals

- Minimise the welds (hence grinding)
- Keep acceptable thermal performance



Test of fixation system

New connection method (hinge, snap fastener, clamp)

What's next ?

- Define new solution
- Model it, test it (samples and mock-ups)
- Choose the best compromise
- Document it and have it approved (ECR by March/April 2012)

CONCLUSIONS

- Decisions in 2012:
  - DFBA consolidation (What, How,…)
  - Reinforcement of spider insulation (Yes?, How,…)
  - New thermal shield design
  - Known circuit non-conformities (Confirmed, How, What, Impact/Need,…)
  - Undulator replacement (Yes or No)
  - CSCM (Go ahead?)
  - Diodes (Intervention ? Not massive)
- From LHC splices review:
  - (Too) ambitious schedule (12 IC/day)
  - Training will be challenging (2/3)
  - 2012 will be a key year for preparation
  - No contingency in resources and schedule