Performance of the LHC magnet system

Vittorio Parma, Lucio Rossi
CERN, Technology Dept.

With contributions of many colleagues from CERN

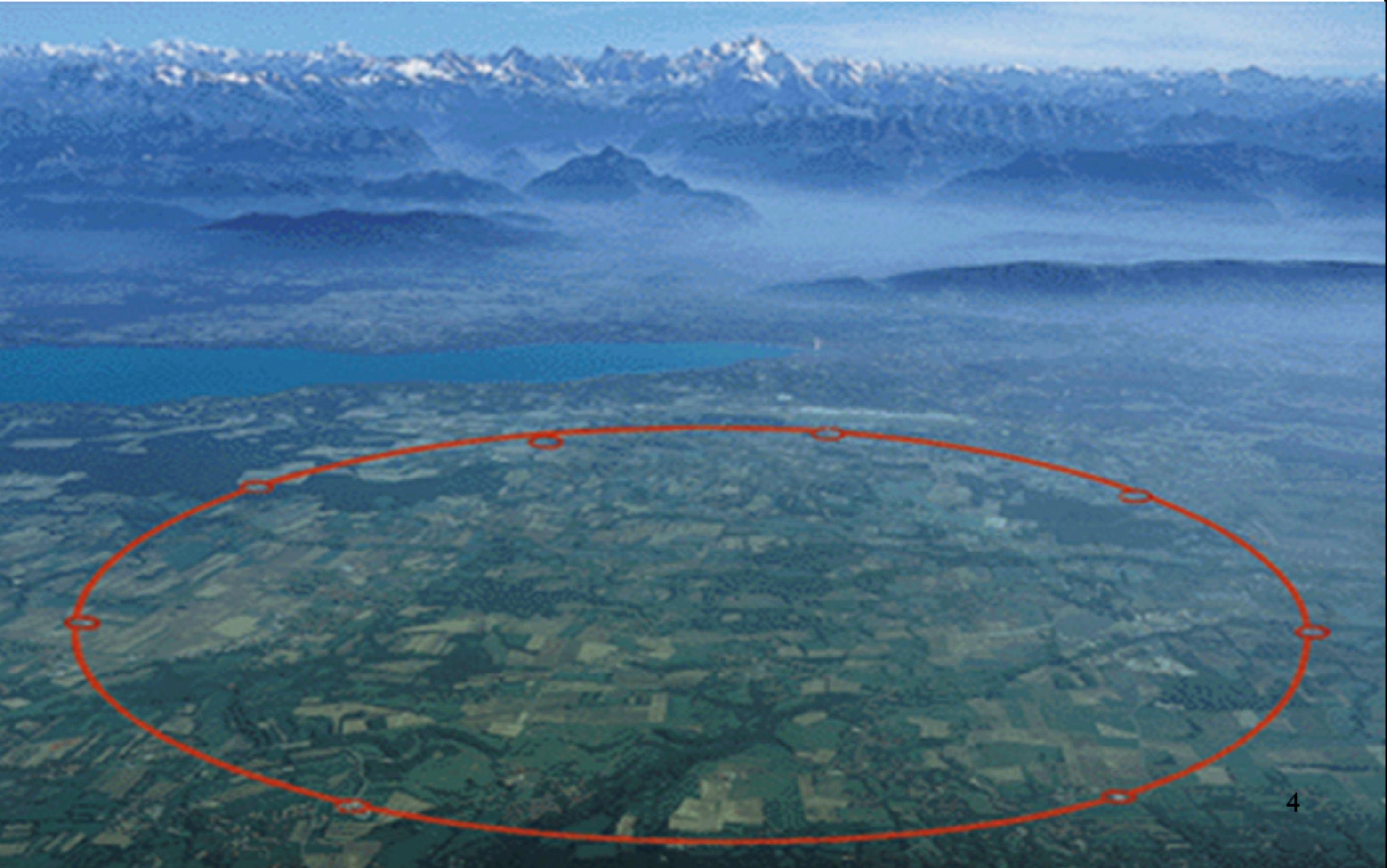
Content

- Review of the LHC magnet system
- Performance during construction
- Performance during Hardware commissioning
- The incident
  - Cause and collateral damage
  - Consolidation and repairs
- Conclusions

Content

- Review of the LHC magnet system
- Performance during construction
- Performance during Hardware commissioning
- The incident
  - Cause and collateral damage
  - Consolidation and repairs
- Conclusions

LHC, the push for energy: a gigantic magnet system



LHC, the push for energy: a gigantic magnet system

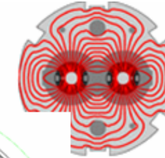
$B_{dip} \cong 8.3$ T
$R_{dip} \cong 3$ km
$L_{dip} \cong 15$ m $\times$ 1232
$L_{tunnel} = 27$ km

1500 tonnes of top quality SC cables

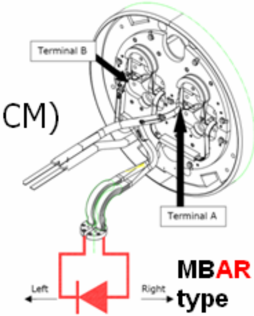
15'000 MJ of magnetic energy

Type	Number	Function
MB	1232	Main dipoles
MQ	392	Arc quadrupoles
MBX/MBR	16	Separation & recombination dipoles
MSCB	376	Combined chromaticity & closed orbit correctors
MCS	2464	Sextupole correctors for persistent currents at injection
MCDO	1232	Octupole/decapole correctors for persistent currents at injection
MO	336	Landau damping octupoles
MQT/MQTL	248	Tuning quadrupoles
MCB	190	Orbit correction dipoles
MQM	86	Dispersion suppressor & matching section quadrupoles
MQY	24	Enlarged-aperture quadrupoles in insertions
MQX	32	Low-beta insertion quadrupoles

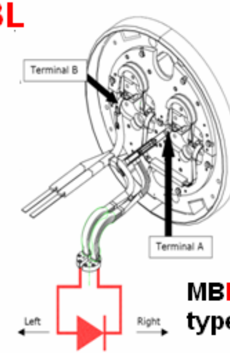
LHC Magnets: main dipoles



- **1232 units** in total (arcs+DS)
- Cold Mass assembly types: **2 main variants** (change needs opening CM)
  - **MBA**: MB with 2 Sextupoles and 2 Octupoles/decapoles – busbars routing "type A"
  - **MBB**: MB with 2 Sextupoles – busbars routing "type B"
- Diode Installation types: **2 variants** (easy to swap)
  - **R**: "Anode on the Right"
  - **L**: "Anode on the Left"
- **4** Cold Mass types delivered by Industry: **MBAR, MBAL, MBBR, MBBL**
- Final customization (just before installation): **32 variants**
  - **Ancillaries** (depending of interconnection type, machine topology) : easy changes
  - **Beam screen orientation (2 variants): swap means scrap of valuable BS**



MBAR type



MBBL type

Equip. code	Total	DS R1	Sec 1-2	DS L2	DS R2	Sec 2-3	DS L3	DS R3	Sec 3-4	DS L4	DS R4	Sec 4-5	DS L5	DS R5	Sec 5-6	DS L6	DS R6	Sec 6-7	DS L7	DS R7	Sec 7-8	DS L8	DS R8	Sec 8-1	DS L1
LBALA	198				1	46	4	4	46	1	1	46	1										1	46	1
LBALB	92					23			23			23												23	
LBALE	18				3					3	3		3												
LBARA	198	1	46	1																					
LBARB	92		23																						
LBARE	15	3		3																					
LBARJ	1																								
LBARL	2																								
LBBLA	188				1	46		1	46		1	46													
LBBLB	4						2	2																	
LBBLC	30								7			23													
LBBLD	64					23	1	1	16																
LBBLF	9				2					1	2		1												
LBBLG	3				1																				
LBBLI	3									2			1												
LBBRA	188	1	46																						
LBBRB	5																								
LBBRC	64																								
LBBRD	30		23																						
LBBRF	8	2		1																					
LBBRG	3	1		1																					
LBBRI	1																								
LBBRK	1																								
LBBRM	1																								
LBBRN	1																								
LBBLP	3									1			1												
LBBRP	2			1																					
LBBLQ	3										1		1												
LBBRQ	2			1																					
LBBLR	1						1																		
LBBRR	1																								
LBBRS	1																1								

LHC Magnets: quads and correctors

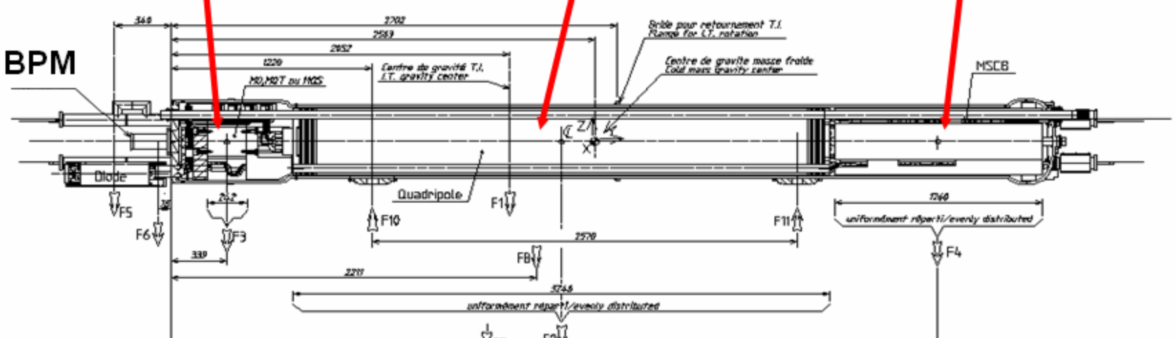
474 cold masses (CM) housed in cryostats → **Short Straight Sections (SSS)**

- **360 CM** in the **arcs** containing:
  - 1 **Main Quadrupole** (MQ)
  - 1 **Lattice Correction Element** (i.e. Tuning or skew **quadrupole** or **octupole**)
  - 1 **Orbit Corrector dipole** and 1 Lattice **Sextupole**
- **64+50 CM** in the **Dispersion Suppressors** (DS) and **Matching Sections** (MS):
  - **MQM** or **MQY quads**
  - **Orbit corrector dipoles** (MCB) , ...
- Every CM is equipped with **BPMs**

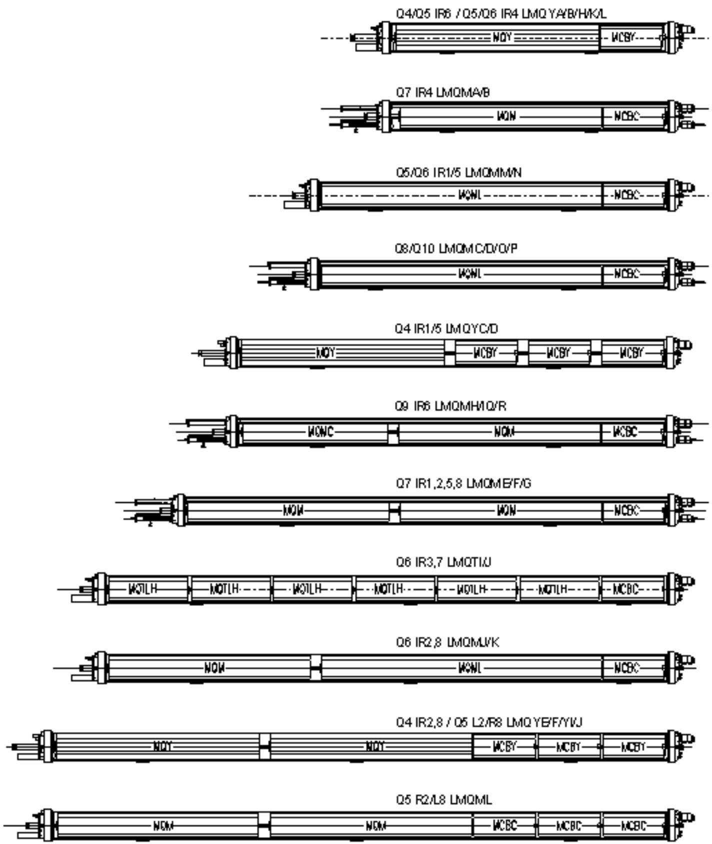
MO Octupole
MQT Tuning quadrupole
MQS Skew quadrupole

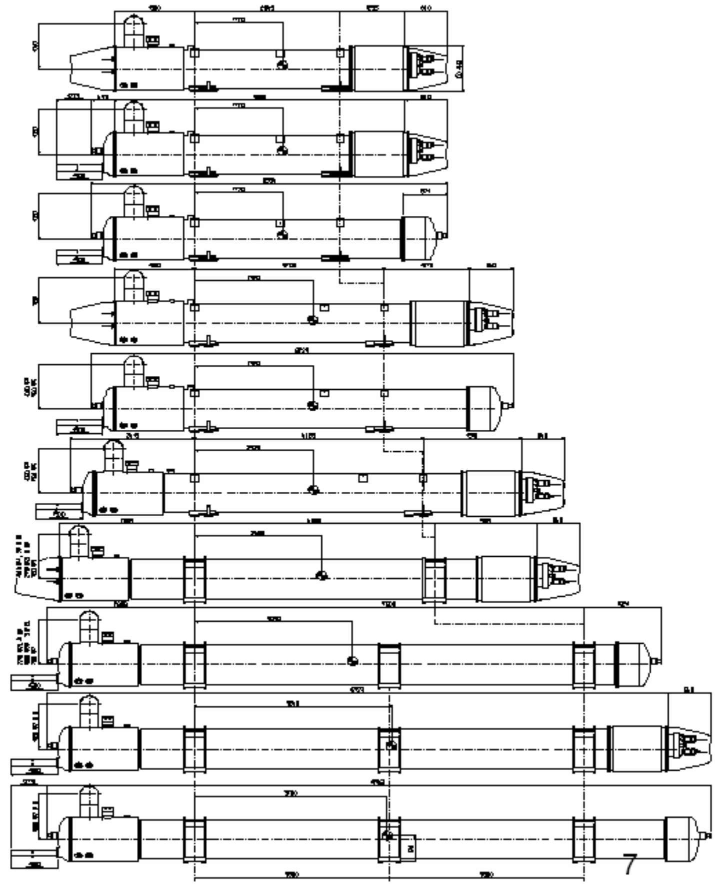
MQ (F,D) Main quadrupole

MSCB (A,B,C,D) Sextupole-dipole corrector

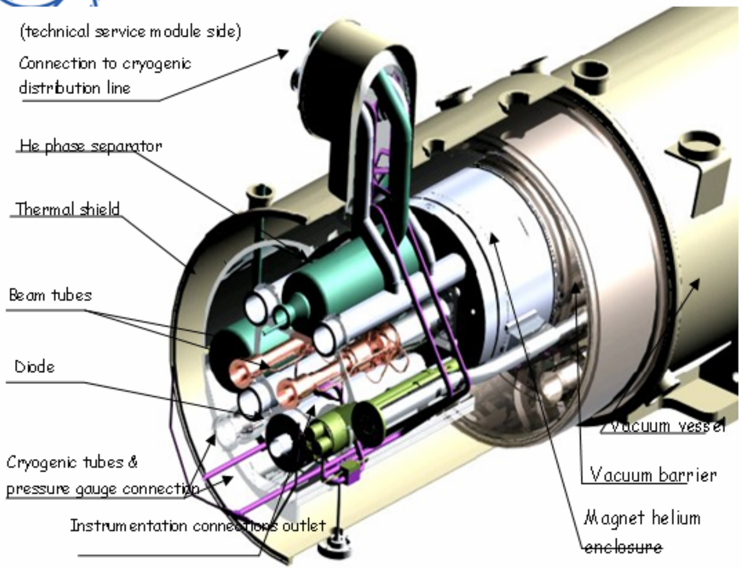


SSS (arc, DS and MS): variety in CM and cryostat



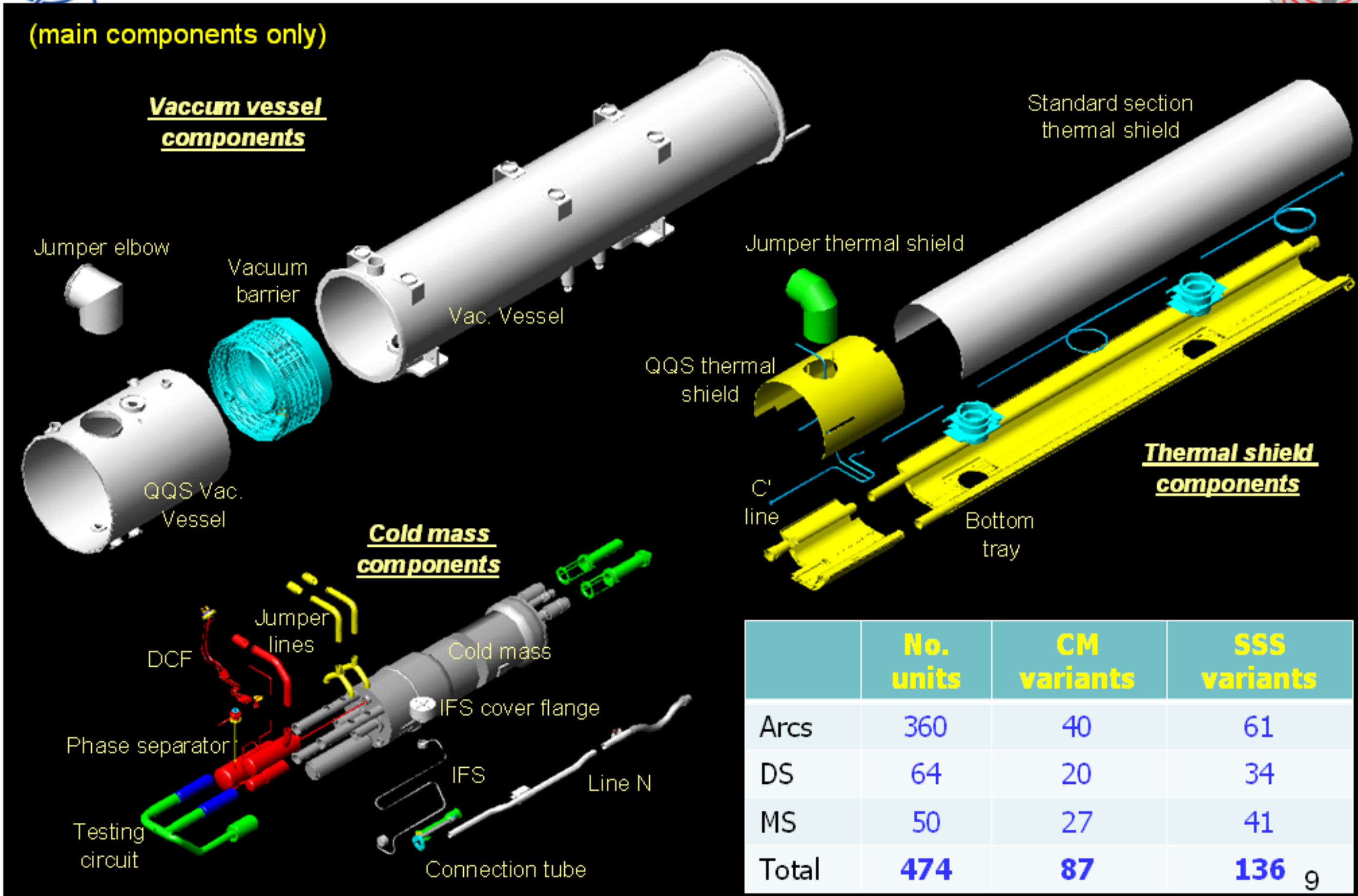


SSS: integrates key items



- BPM and instrumentation feed-throughs
- Resistive current leads for orbit corrector dipoles
- Link to cryo distribution line
- Cryogenic ancillaries and diagnostics (He phase separator, He level gauges, P transducers, ...)
- Vacuum Barriers
- ...

SSS: complex in variants and assembly

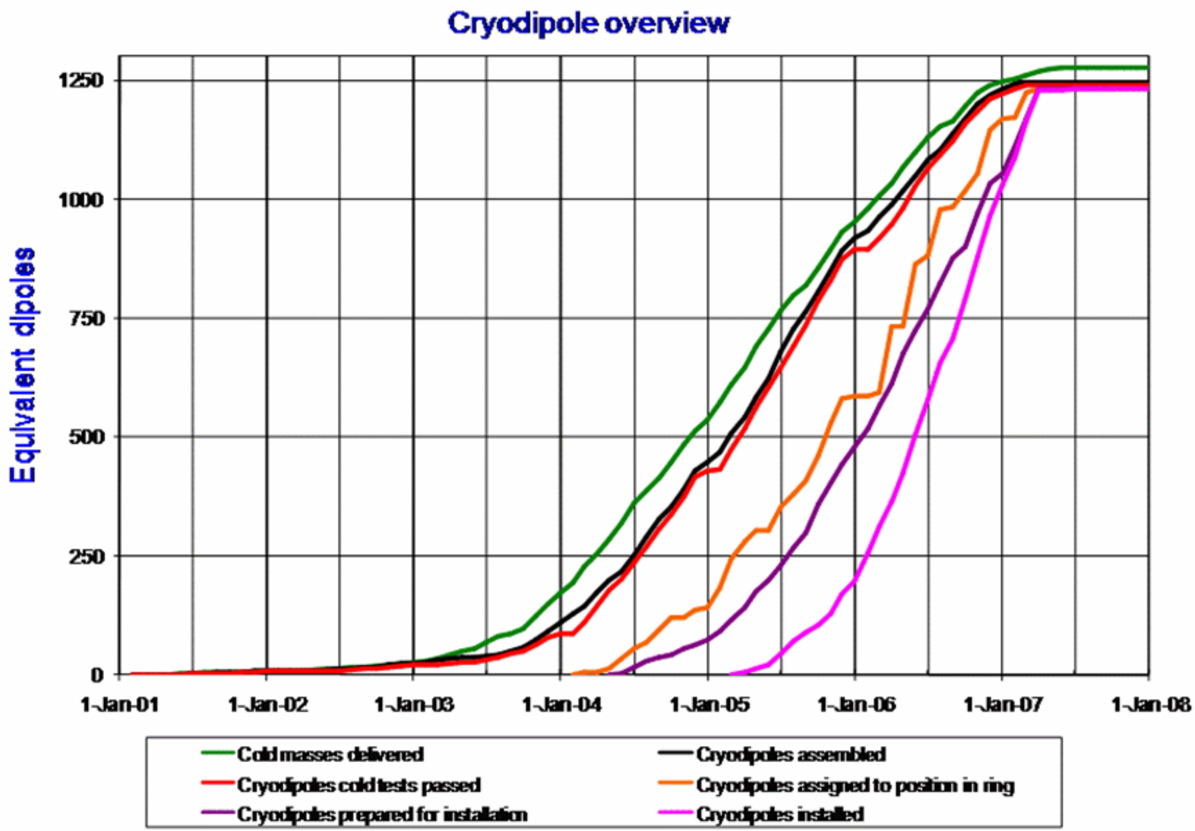


	No. units	CM variants	SSS variants
Arcs	360	40	61
DS	64	20	34
MS	50	27	41
Total	**474**	**87**	**136**

Content

- Review of the LHC magnet system
- **Performance during construction**
- Performance during Hardware commissioning
- The incident
  - Cause and collateral damage
  - Consolidation and repairs
- Conclusions

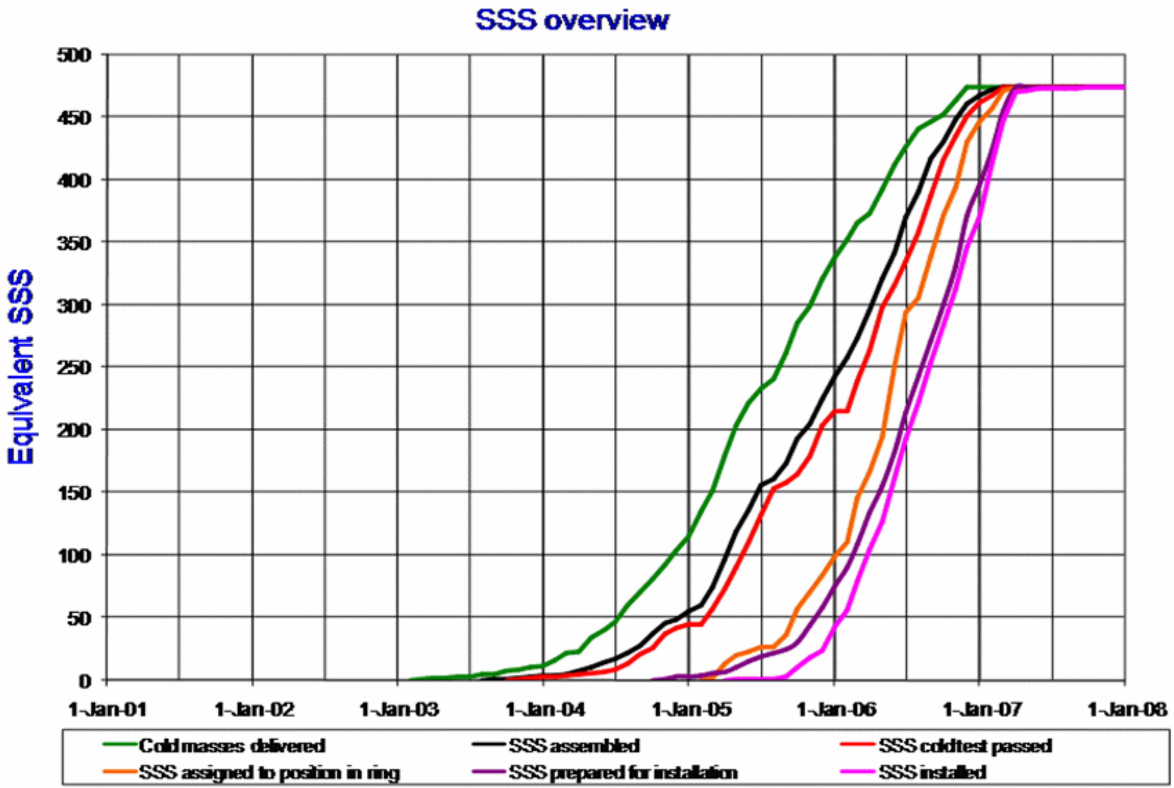
Production dashboards



Updated 31 December 2007

Data provided by D. Tommasini AT-MCS, L. Bottura AT-MTM

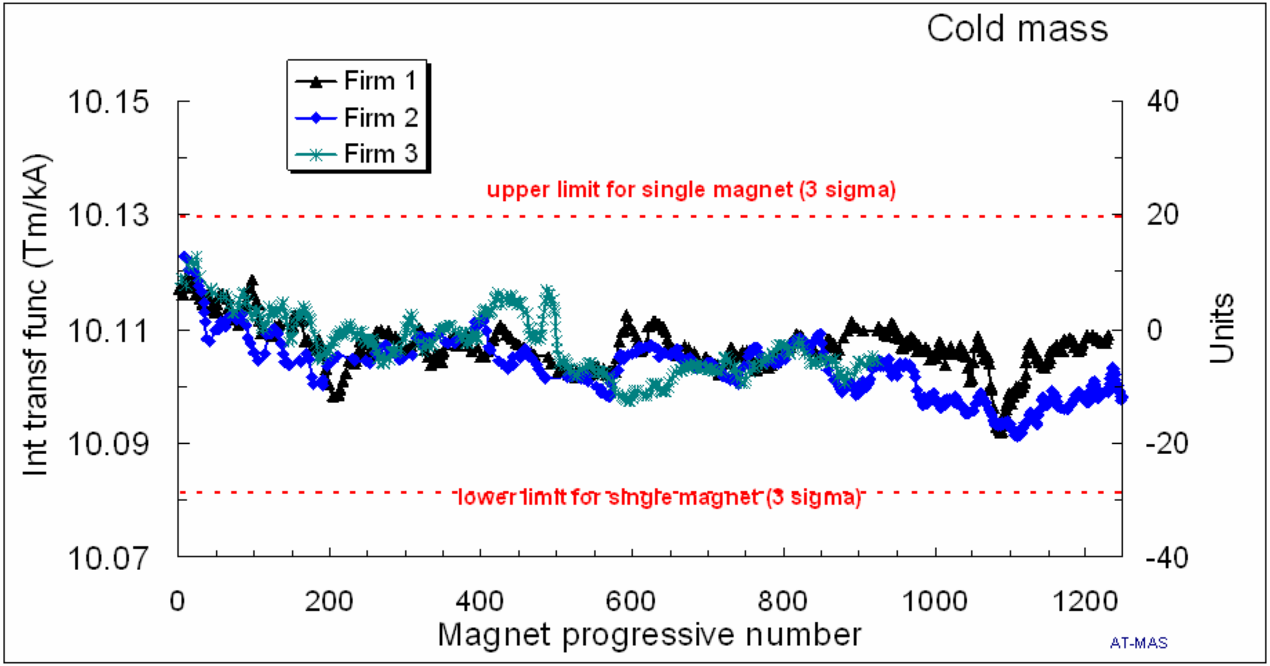
Production dashboards



Updated 31 December 2007

Data provided by M. Modena AT-MCS, L. Bottura AT-MTM

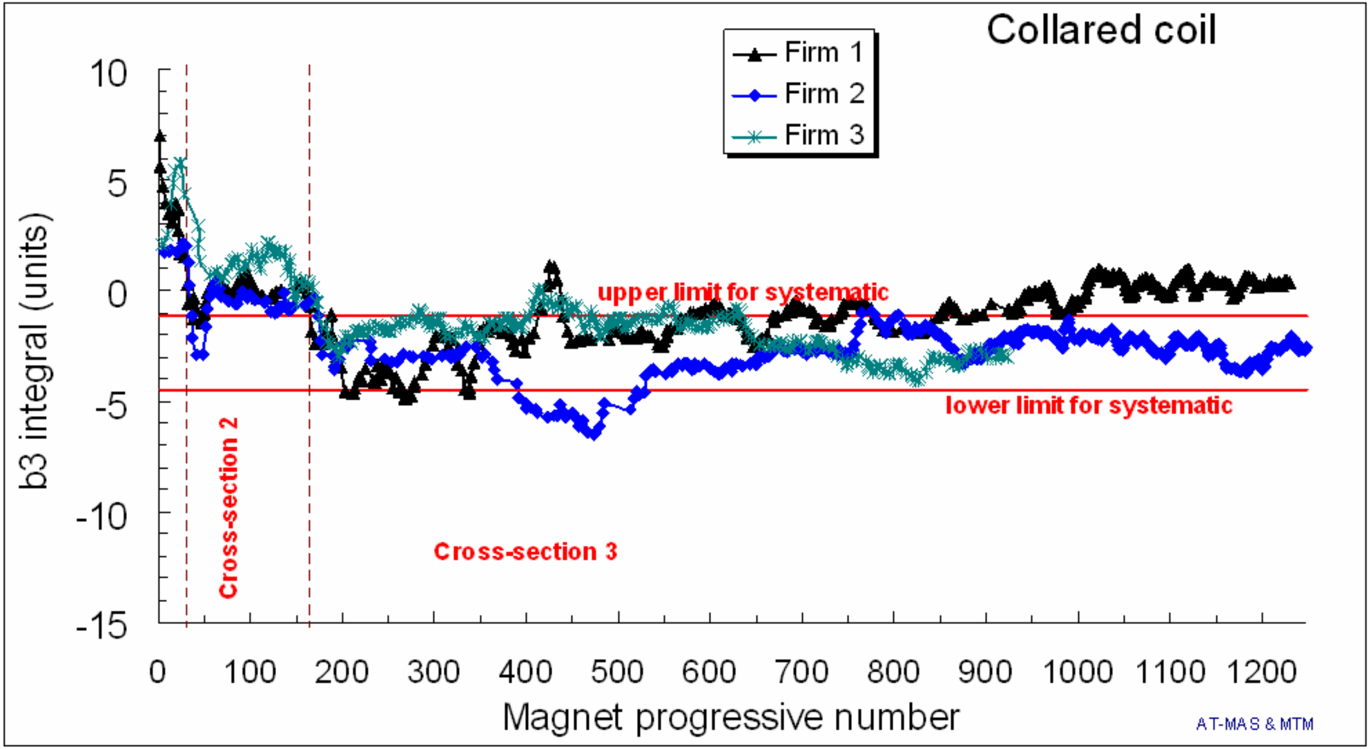
Dipoles: bending strenght



(each dot is the average of 5 consecutive magnets of the same Firm).

Courtesy of Ezio Todesco, (CERN TE-MSC)

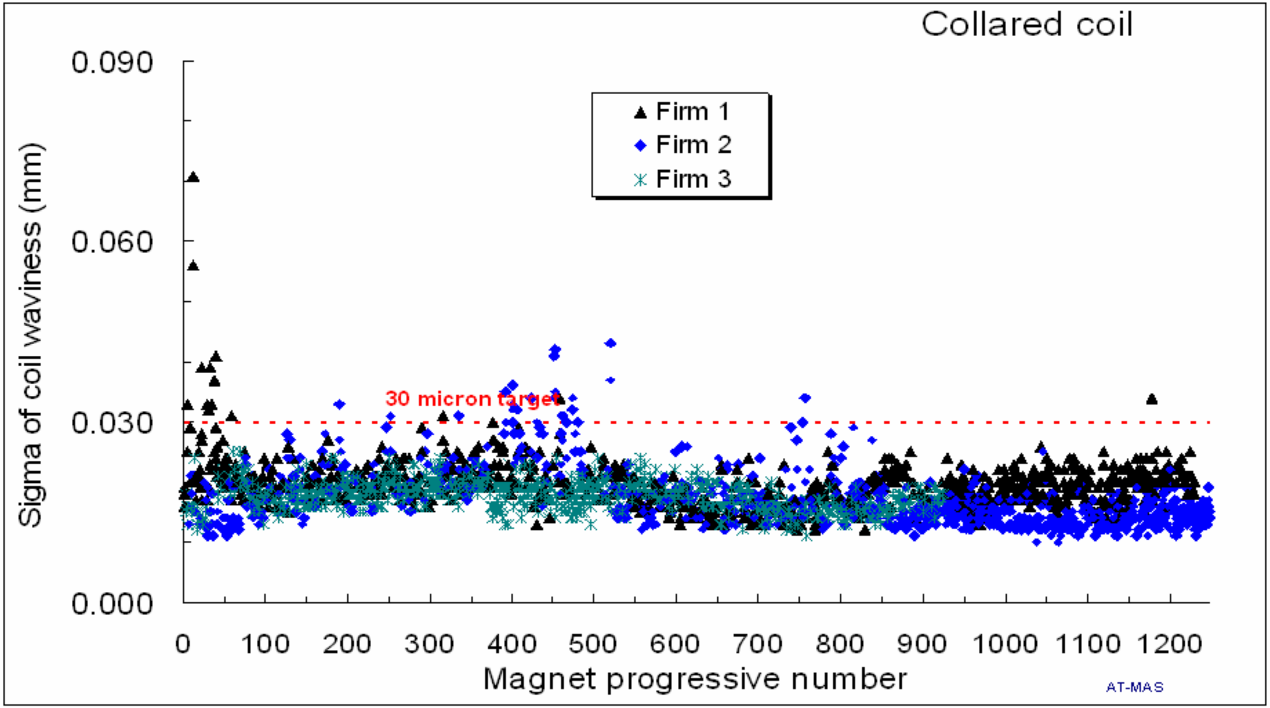
Dipoles field quality: b3



(each dot is the average of 5 consecutive magnets of the same Firm; beam dynamics targets for the systematic (red lines) based on correlations with 198.5 cryodipoles).

Courtesy of Ezio Todesco, (CERN TE-MSC)

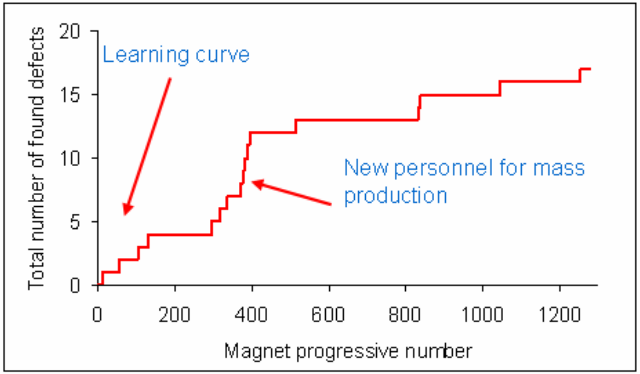
Dipoles: coil waviness



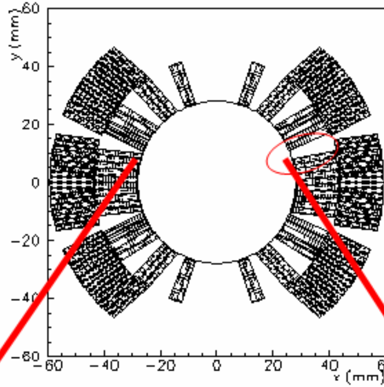
Estimated coil waviness in the straight part of the measured collared coils (black dots: aperture 1, blue dots: aperture 2).

Courtesy of Ezio Todesco, (CERN TE-MSC)

Warm magnetic measurements, also effective for QA

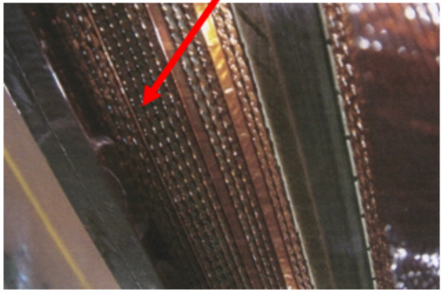


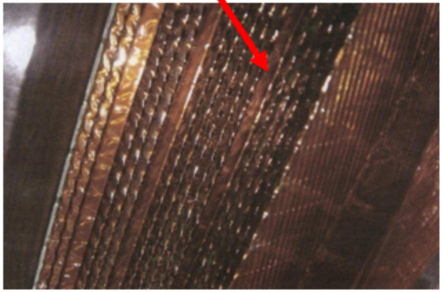
Total number of defects found with room temperature magnetic measurements versus magnet progressive number.



Wrong wedge detected

All defects detected and repaired in Industry, no scrap



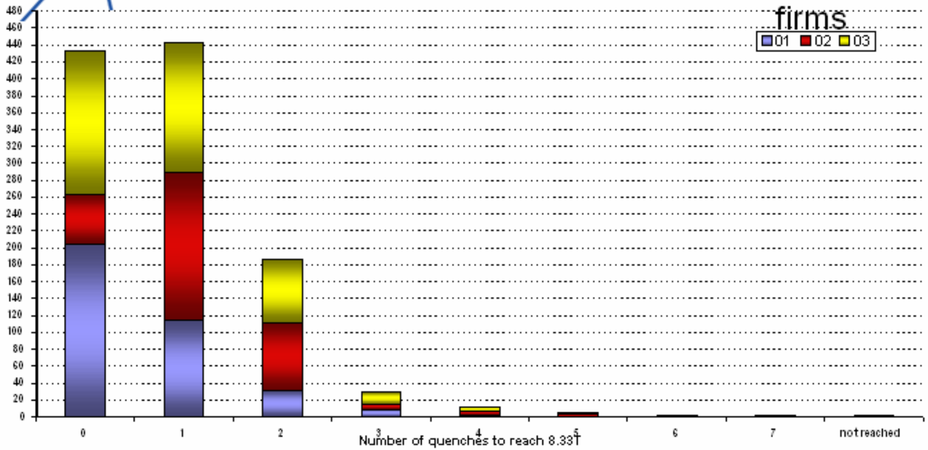


Detected as -13 units of b2, -5 units of b3, 16 units of a2, 12 units of a3, 7 of a4

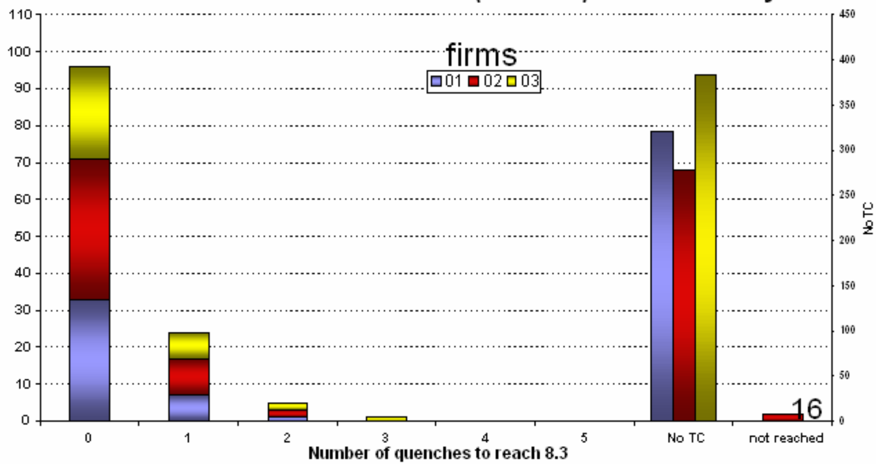
Courtesy of Ezio Todesco, (CERN TE-MSC)

Dipoles: single quench performance

No. Of Quenches to reach 8.33 T (11'860 A)



No. Of Quenches to reach 8.33 T (11'860 A) after thermal cycle

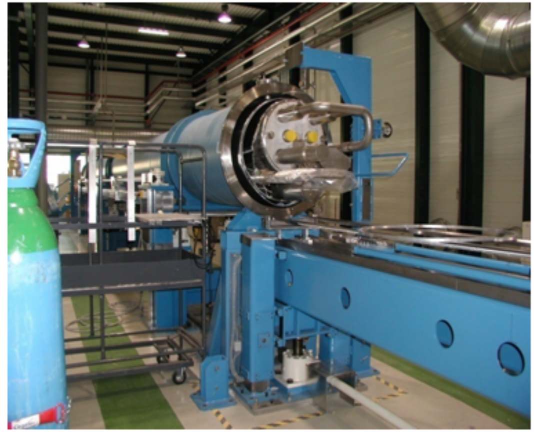


Only 2.5% rejected

Half for quench half for electrical NCs (QH)

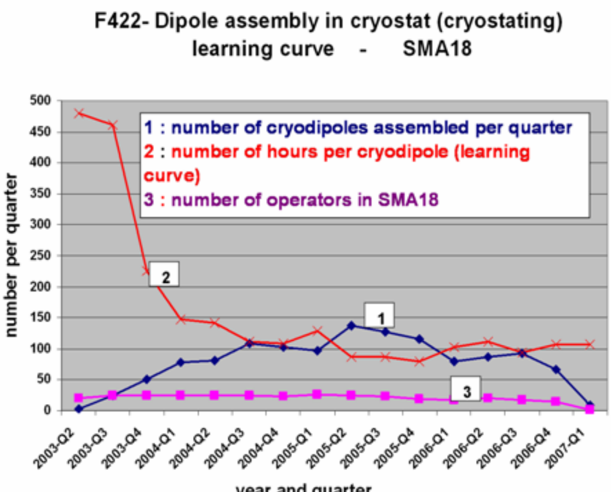
Except 1, all repaired successfully

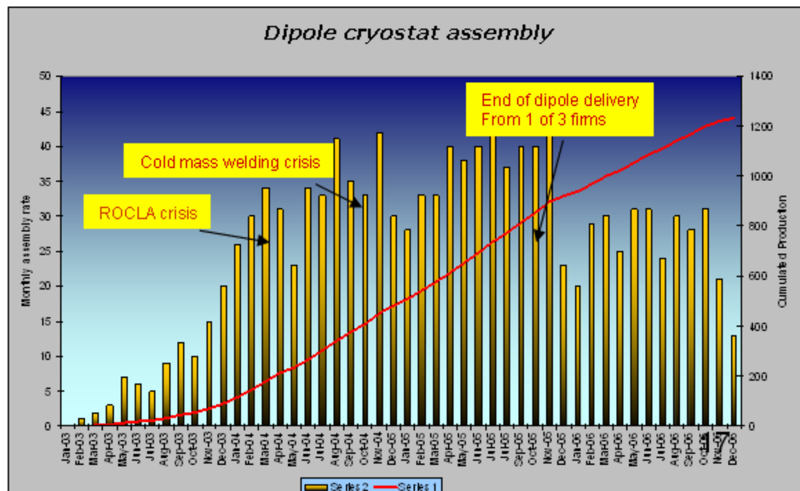
Assembly of dipole cryostats at CERN



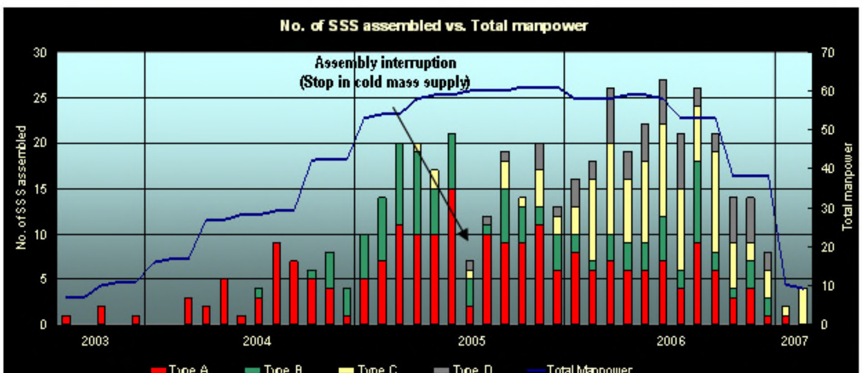
Key Figures:

- 1232 units in 4 yrs
- 30 FTE workers
- Peak rate: 45 units/month (2 shifts)





Assembly of the SSS: a factory at CERN



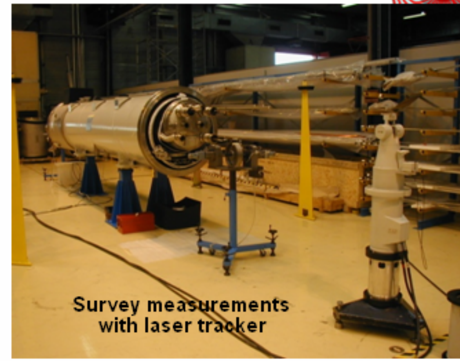
Key figures:

- 474 units and 136 variants
- ~ 400 main type of components
- 60 FTE workers at peak production
- > 6 km of leak-tight welds
- 3300 leak detection tests
- 3.5 yrs of production

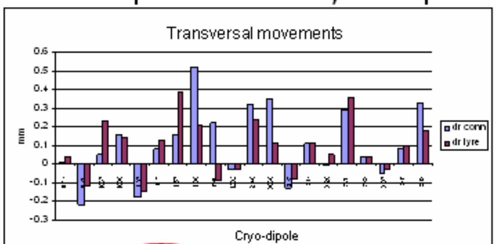
Geometrical Stability: survey measurements

- SSS CM position stability and reproducibility after ther.cyle

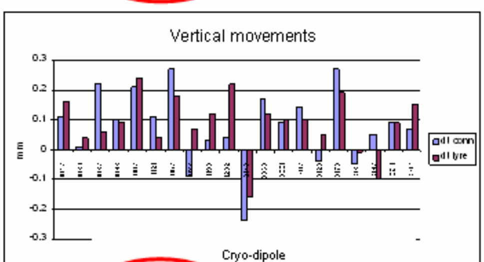
Arc SSS (392 units)	Horizontal		Vertical	
	Mean [mm]	St.Dev. [mm]	Mean [mm]	St.Dev. [mm]
Positional reproducibility after 1 cool-down/warm-up cycle	-0.08	0.42	0.04	0.43
Cool-down movements	-0.17	0.22	-1.3	0.36



- Dipole position stability in cryostat (after transport to tunnel, 20 dipoles)



Mean: +0.1mm; St.dev.: 0.17mm



Mean: +0.08mm; St.dev.: 0.11mm

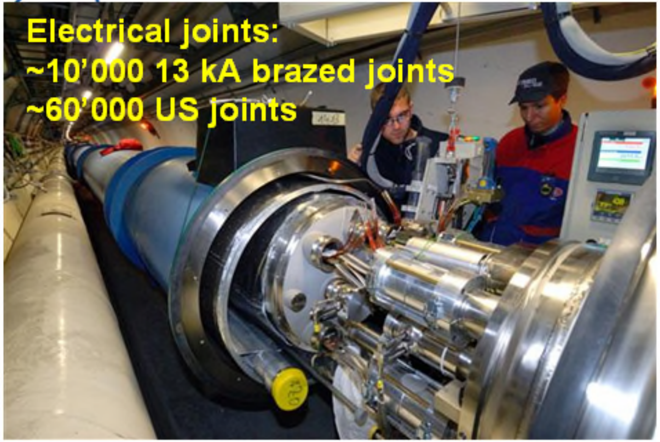
Courtesy of CERN Survey (TS-SU)

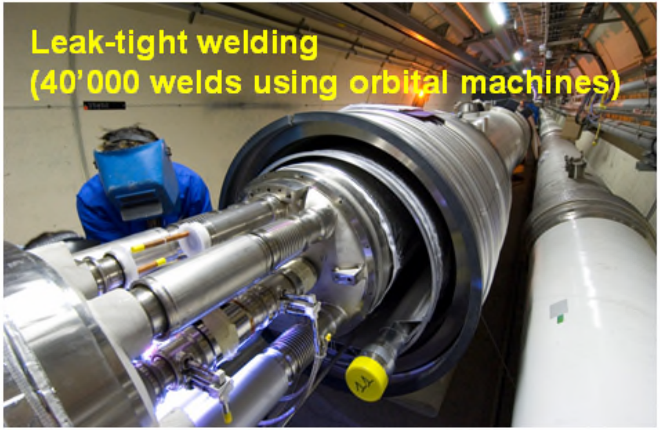
The LHC tunnel

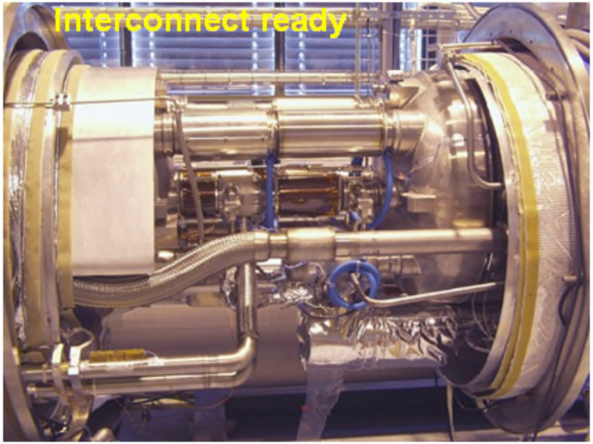
a hostile working environment

Tunnel transport: narrow and delicate

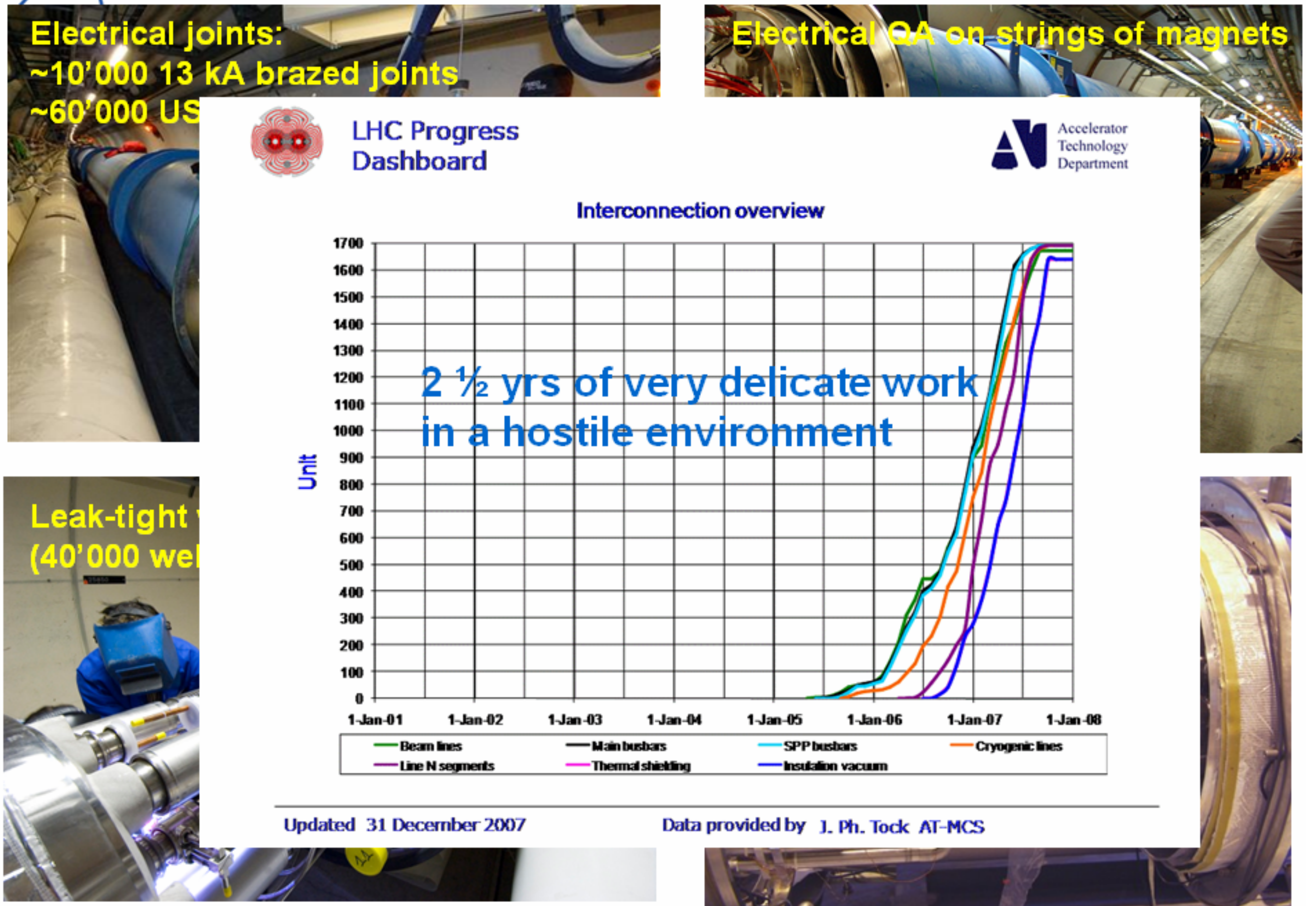
Magnet interconnections







Magnet interconnections

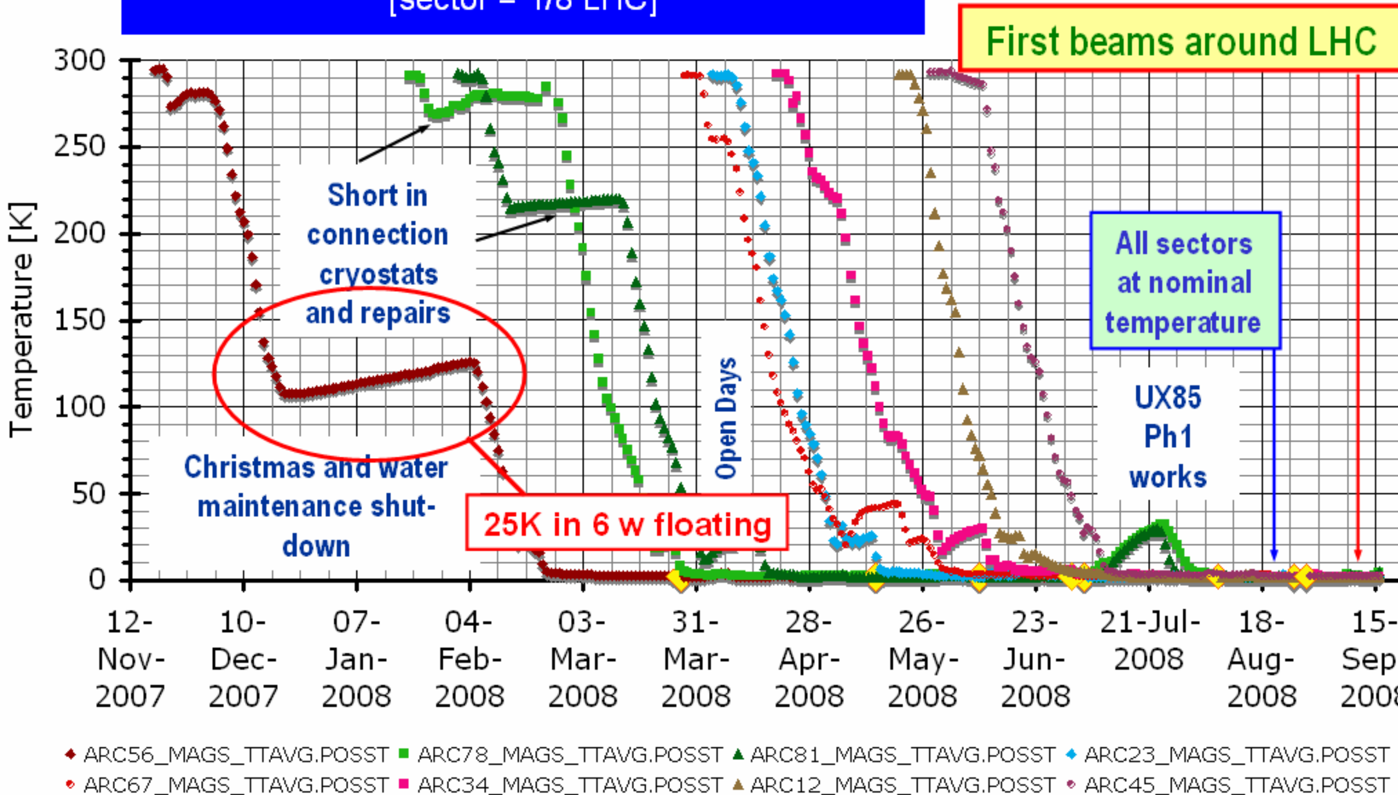


Content

- Review of the LHC magnet system
- Performance during construction
- Performance during Hardware commissioning
- The incident
  - Cause and collateral damage
  - Consolidation and repairs
- Conclusions

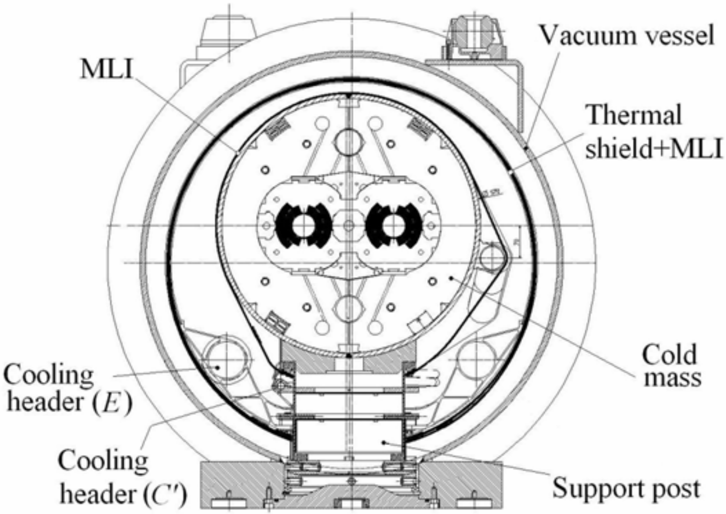
First cool-down of LHC sectors

Cool-down time to 1.9 K ~ 4-6 weeks/sector
[sector = 1/8 LHC]

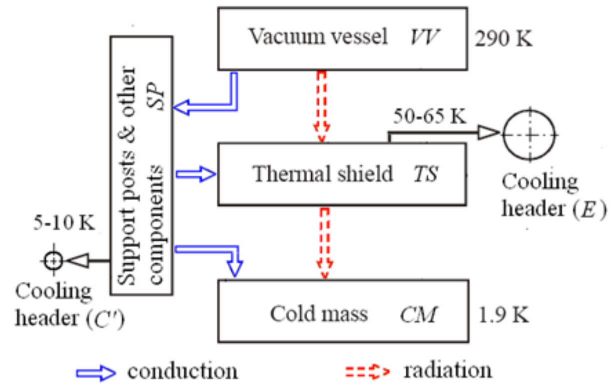


Cooling sectors + Cryo tuning + Powering activities

Cryostat performance: static heat loads

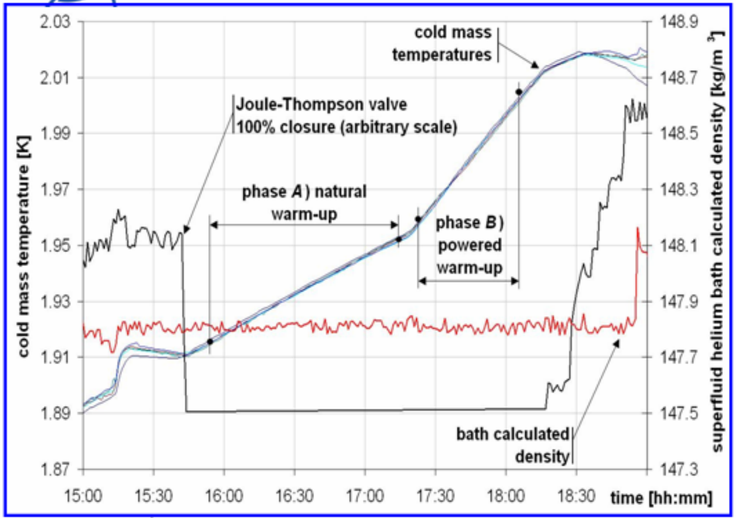


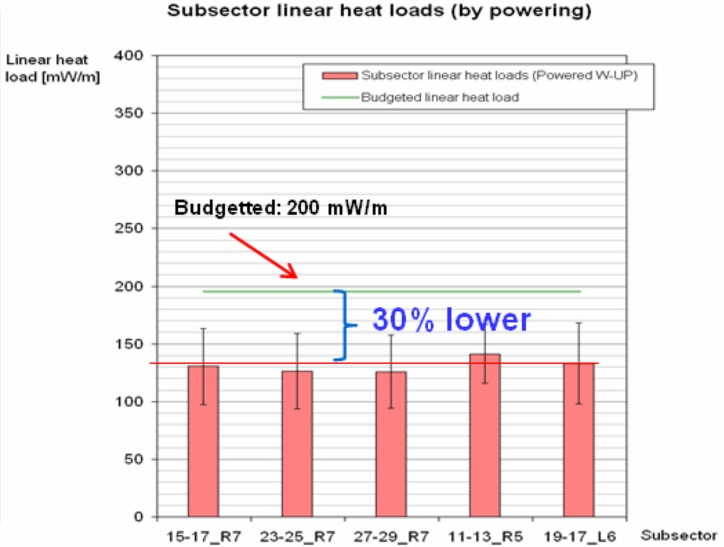
Cross section of a dipole cryostat

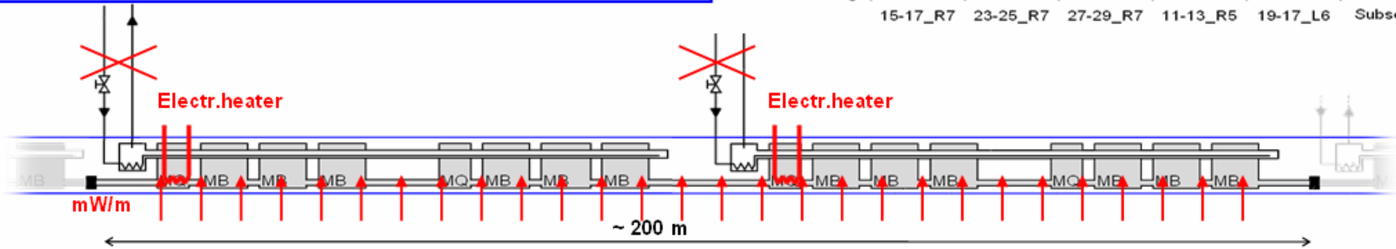


Schematic of heat flows and heat sink temp.

Static heat loads to magnets by precision calorimetry in superfluid He

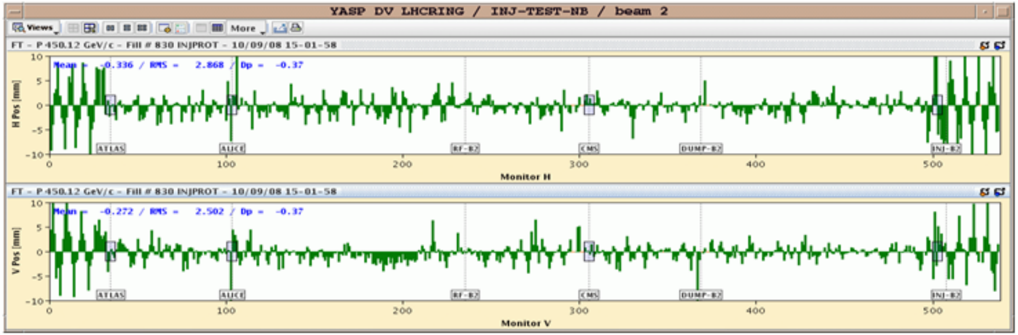






- Heat loads @ 1.9K: **130 mW/m**. 30% lower than budgetted
- Natural warm-up: ~ 0.6 K/day!

First LHC beams



Beam 2

Ease in injecting and circulating first beams at Injection Energy (450 GeV) indicates, amongst others:

- **Homogeneity** in magnet quality
- Good magnet **alignment** (through cryostats)
- Well prepared **current settings** and **correction of higher order field errors**, resulting from good predictions of the main field integral transfer functions and field errors through the **Field Description of the LHC (*FiDeL*)**

see Poster WE6PFP023

...yet much still to be learned from **energy ramping** to 5 TeV!

(Re)training during commissioning

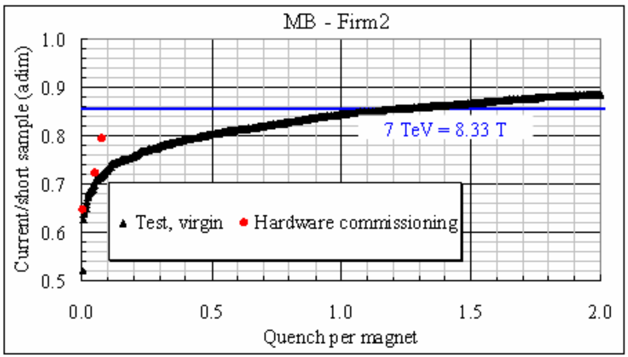
of estimated training quenches in machine

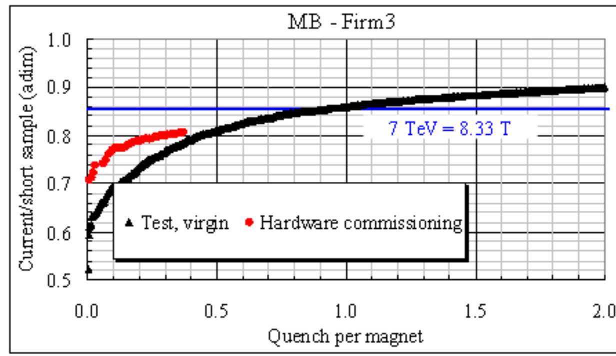
based on commissioning (main dipole and quads only) :

- @ 5 TeV (7 sect. tested): no training
- @ 6.5 TeV (1 sect. (5-6) tested): 84 dipoles, 4 quads (<1 week/sector, assuming 3 quenches/day)
- @ 7 TeV: no commissioning data so far

6.5 TeV estimate

Magnet	Current (kA) at 6.5 TeV	#	Quench/magnet	Magnets trained to 6.5 TeV	Tot. quenches estimated
MB	11.00	1232	0.068	13%	**84**
MQ	11.00	392	0.010	25%	**4**
MQM 1.9 K	5.01	66	0.02	100%	**1**
MQM 4.5 K	4.00	20	0.40	100%	**8**
MQY 4.5 K	3.35	24	0.21	100%	**5**
MQXA	6.64	16	0.00	88%	**0**
MQXB	11.10	16	0.00	88%	**0**
MBX	5.34	4	0.00	100%	**0**
MBRC IP1-5	4.09	4	0.00	100%	**0**
MBRC IP2-8	5.62	4	0.33	75%	**1**
MBRS	5.13	4	2.33	75%	**9**
MBRB	5.13	4	0.00	100%	**0**





Only sect.5-6 extensively tested (up to 95% of nominal, i.e. 7.9 T)

- Firm 2 is good (firm 1 even better)
- Tests in virgin state: **1.2 quench/magnet**
- During HC: **good memory**

- Firm 3. In virgin state: **1 quench/magnet**
- During HC: starts with **good memory of initial training...then curve flattens**
- **Loss of memory for firm 3** after thermal cycling.

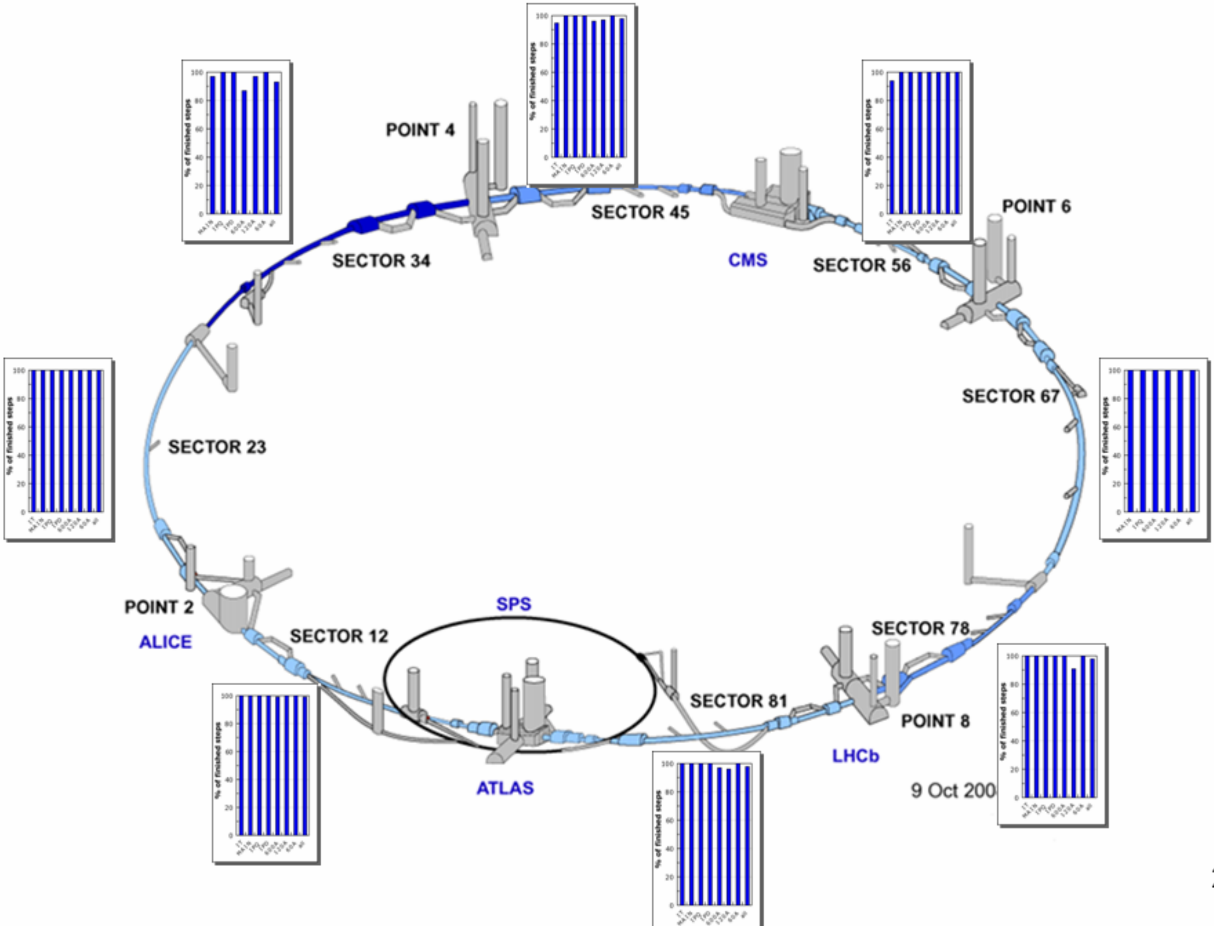
→ **Today still unexplained**

Courtesy of E.Todesco (TE-MCS)

Content

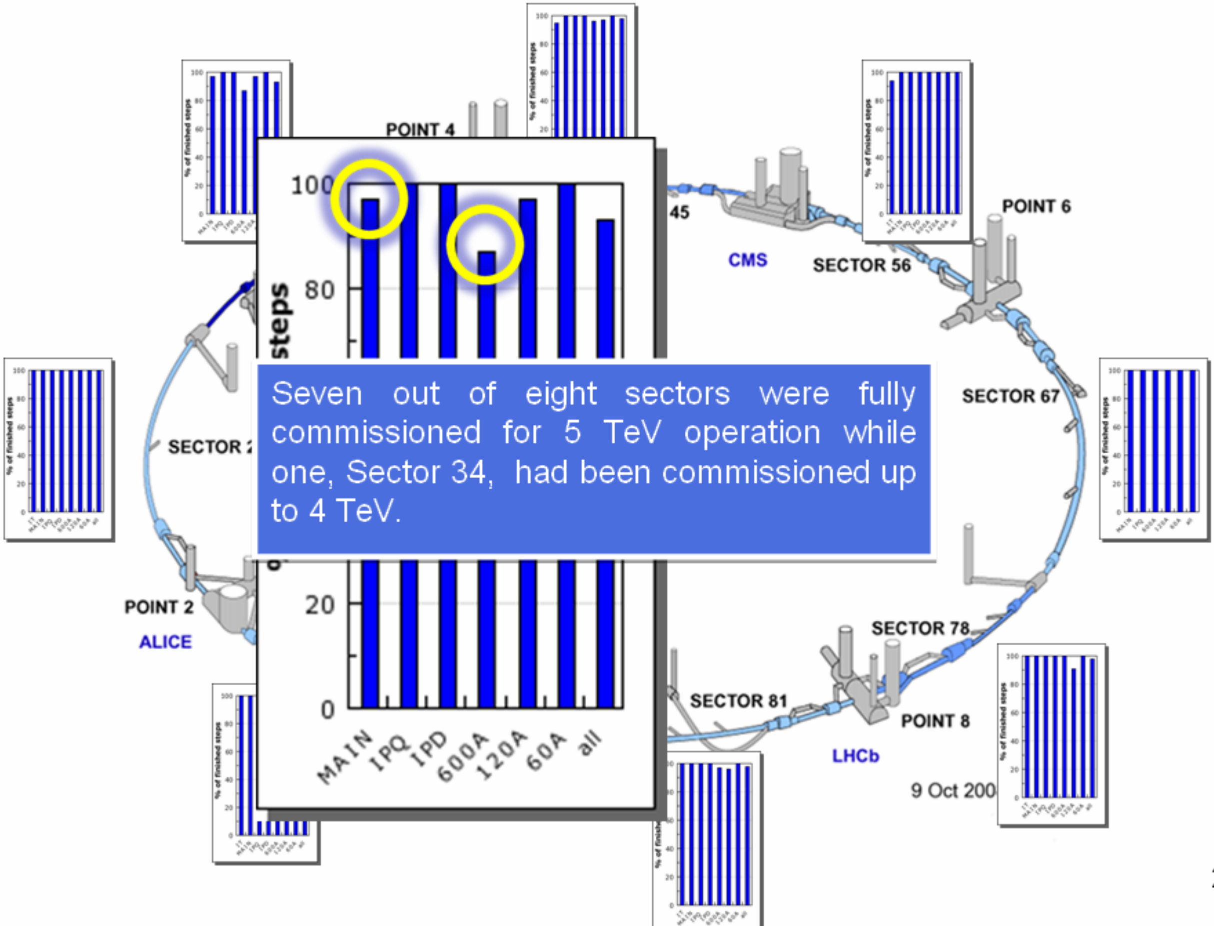
- Review of the LHC magnet system
- Performance during construction
- Performance during Hardware commissioning
- The incident
  - Cause and collateral damage
  - Consolidation and repairs
- Conclusions

Status of the commissioning, Sept. 19th



9 Oct 200

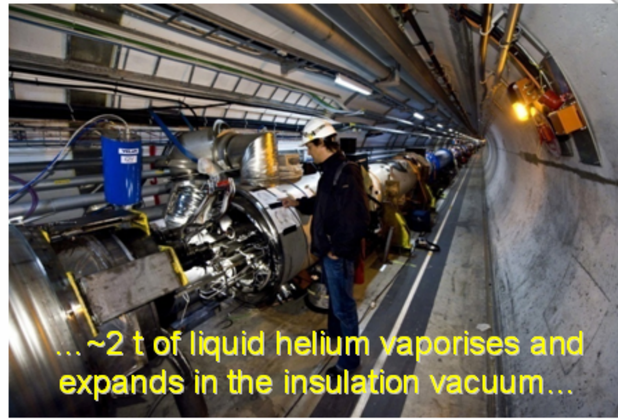
Status of the commissioning, Sept. 19th



Seven out of eight sectors were fully commissioned for 5 TeV operation while one, Sector 34, had been commissioned up to 4 TeV.

19th September 2008:
…an electrical arc in sect.3-4…

…punctures He envelope and beam lines

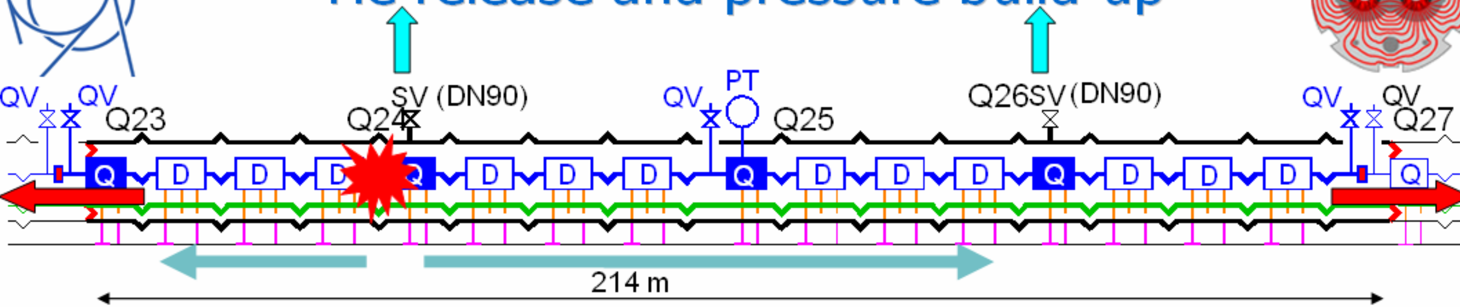


…~2 t of liquid helium vaporises and expands in the insulation vacuum…

…exerting ~50 t longitudinal forces on SSS with vacuum barriers…

…supports uprooted floor breaks

He release and pressure build-up



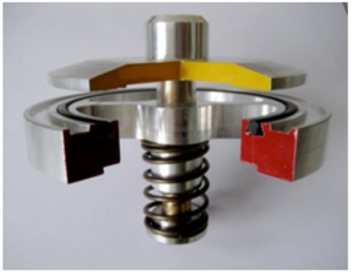
Cryostats protection:

Insulation vacuum **pressure relief devices** (SV):

- Limit internal pressure **≤ 1.5 bars**, for a helium release with **mass flow ≤ 2 kg/s** *(helium release from cold mass to insulation vacuum without electrical arc)*
- **2 spring-loaded valve devices**, ID90 each, 100m spaced

Sect.3-4 incident:

- Cryostat internal **pressure estimate: 8 bar**
- **He mass flow estimate ~20 kg/s !** *(helium on electrical arc)*



Spring loaded relief device

Collateral damage from pressure & He flow

Primary damage (direct effect of pressure/flow):
- 3 SSS with vac. barrier uprooted and longitudinally displaced
- Floor break at jack fixations
- MLI damage, soot
- Bellows damage (CM and beam vacuum lines)

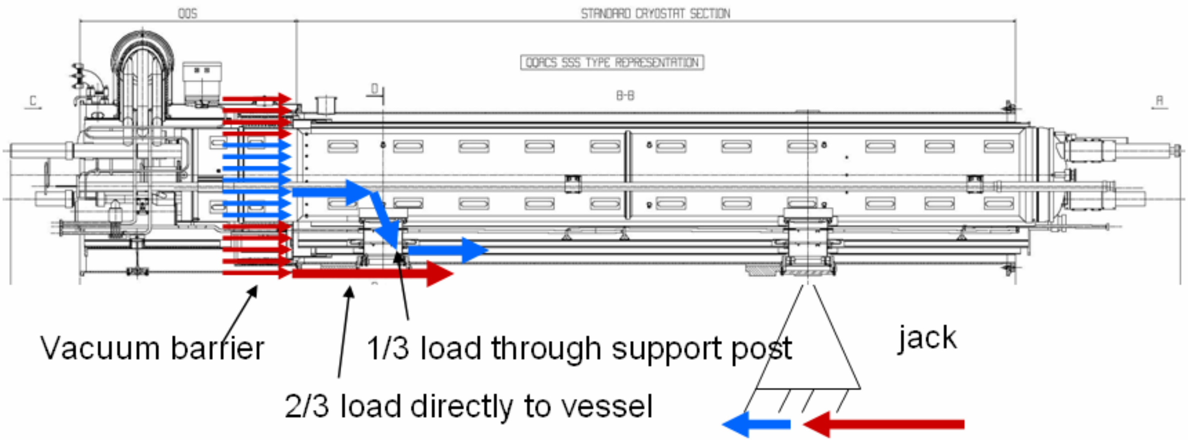
→ Can be mitigated (not eliminated!) by **limiting pressure rise** and **reinforcing jack fixations to ground**

Secondary damage (consequence of SSS displacements):
- **Domino effect** . Damage to chain of interconnects/dipoles
- Break of dipole support posts and cold masses longitudinal displacement in vessel
- Secondary arcs in damaged interconnects
- Additional MLI damage and soot propagation to adjacent vacuum subsectors

→ **Avoidable if primary damage avoided**

Summary of collateral damage:
- About ¼ sector (~ 700 m, 60 magnets) involved
- 39 dipoles and 14 SSS removed for repair
- Floor break in 4 locations

Pressure forces on SSS with vacuum barrier



Vacuum design forces:

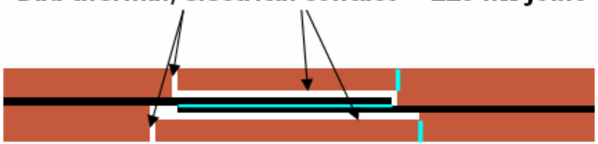
- **Δp = 1.5 bars** across vac. Barrier → **120 kN** (40 kN through support post, 80 kN through Vacuum Barrier)

- 120 kN **taken by 1 jack** fixed to ground

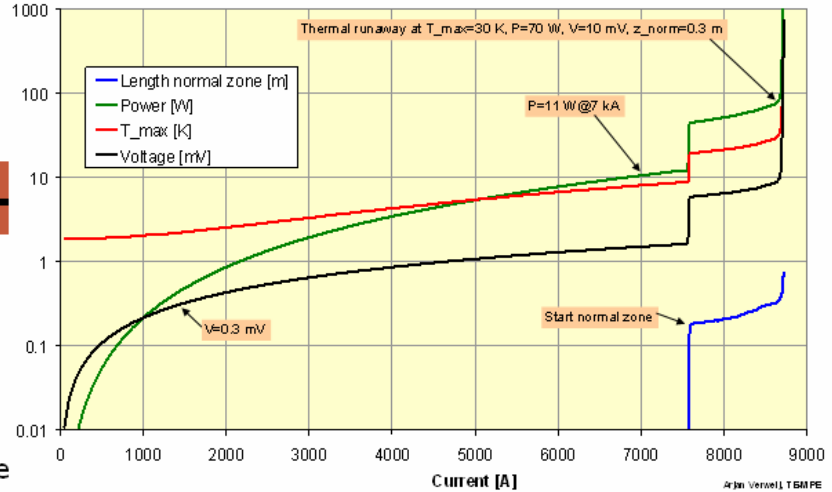
A resistive joint of about 220 nΩ with bad electrical and thermal contacts with the stabilizer

One possible scenario (other exist)

Bad thermal/electrical contact + 220 nΩ joint



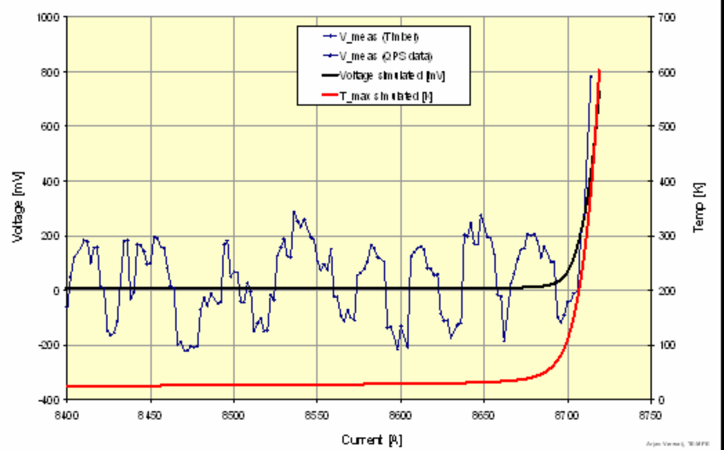
(For example: a non-soldered joint)



- **Simulations** confirm this as possible cause
  - Initially slow, then fast thermal runaway
  - QPS threshold of **1V is too high**

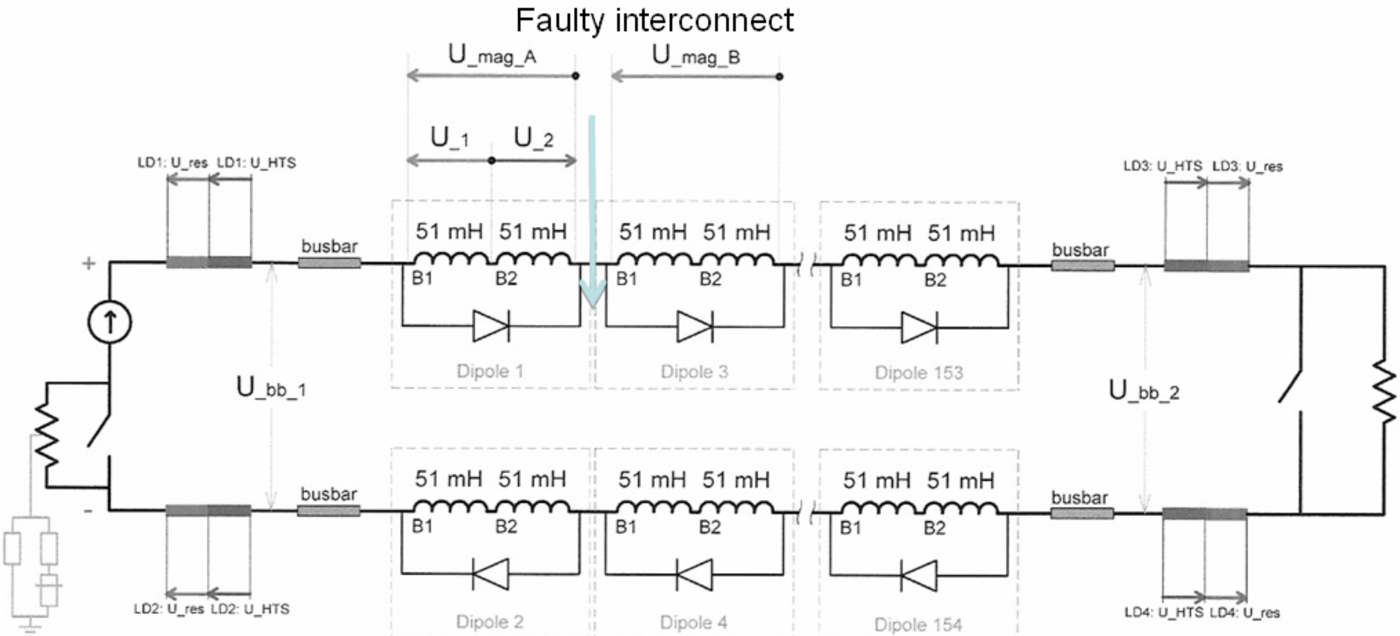
→ **sect.3-4 data fit reasonably well**

→ **Confirms that discontinuities in joint stabilizer are critical**



Courtesy of A. Verweij (TE-MSC)

Protection of the dipole circuit in a sector



Bus

$U_{\_res} = U_{\_bb\_1} + U_{\_bb\_2} - N\ (U_{\_mag\_A} + U_{\_mag\_B})/2$

Threshold is **1V during 1 s**

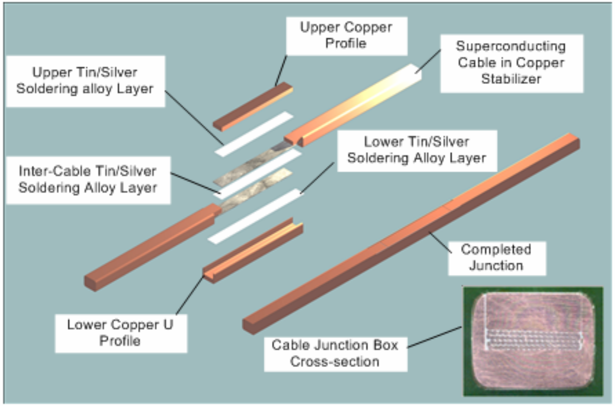
Magnets

$U_{\_res} = U_{\_1} + U_{\_2}$

Threshold is **100 mV during 10 ms**

New threshold of 0.3 mV being implemented in QPS consolidation

Electrical joints on 12 kA bus bars



- Soldered (SnAg9604): 230 °C melting point
- Induction heating machines
  - automatic heating cycle
  - Interlocked recordings of soldering parameters
- Joint resistance (at cold):
  - Requirement **< 0.6 nΩ**
  - Achieved (witness samples): average< 0.2 nΩ, **peak < 0.3 nΩ**
- Many unsuccessful attempts to reproduce 200 nΩ splices
- For 1 sample, in **absence of soldering** (no solder+no heating): **5000 nΩ!**

→ **Confirms lack of solder could be the possible cause**

Content

- Review of the LHC magnet system
- Performance during construction
- Performance during Hardware commissioning
- The incident
  - Cause and collateral damage
  - Consolidation and repairs
- Conclusions

New diagnostics for splice measurements

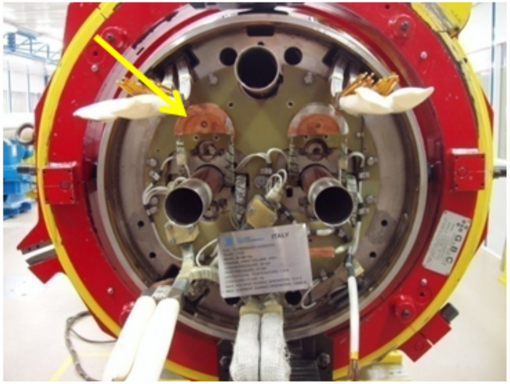
- **Colorimetric measurement** in supefluid helium can detect down to: **~ 40 nΩ**
  - Post analysis on sect.3-4 data a few days before the incident confirmed evidence of a resistive heating (~10 W,~200 nΩ)
  - Systematic diagnostics of cold sectors made

see Poster WE6RFP003

- **In-situ high precision voltage measurements** on suspected interconnects to measure down to: **<1 nΩ**
- High statistics on voltage data of the QPS (**"snap-shots"**) at various current levels to localise magnets with internal defective splices

The result of investigations on available cold sectors:

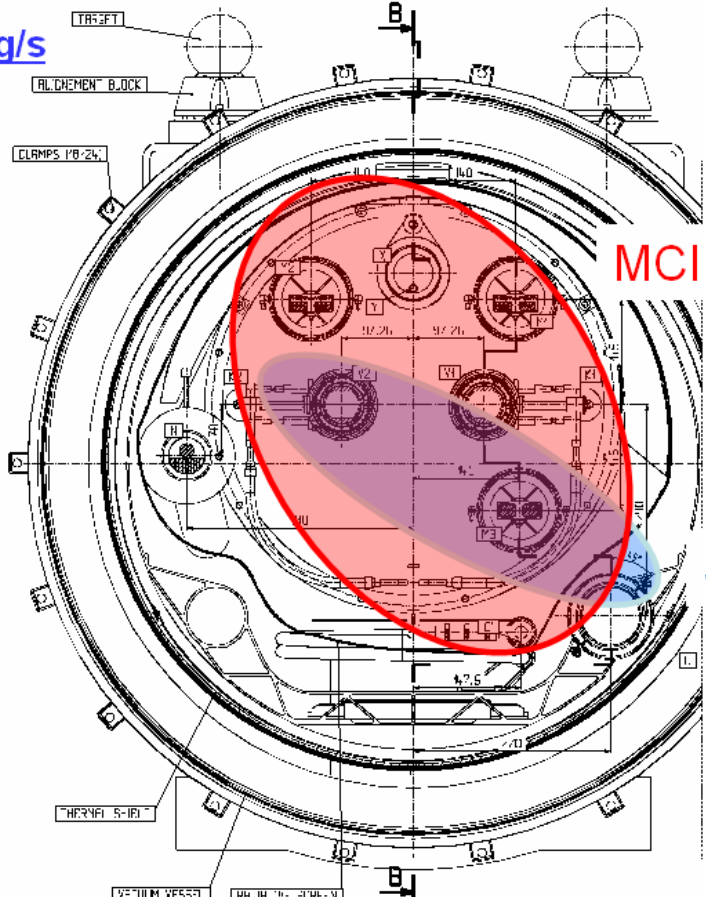
- **No other suspicious interconnect** splices found
- **2 dipoles** found with **defective splices** (50 and 100 nΩ) in 2 other sectors
- Dipoles have been replaced



→ **Testing of remaining splices mandatory during new commissioning**

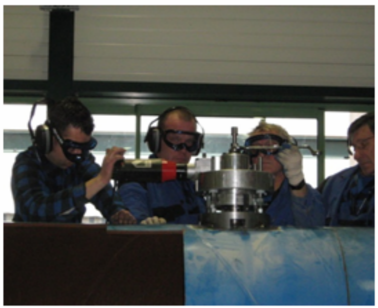
Revision of Maximum Credible Incident (MCI) in case of electrical arc

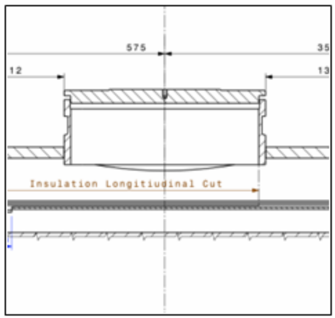
Helium mass flow: <u>40 kg/s</u>
(originally: 2 kg/s!)

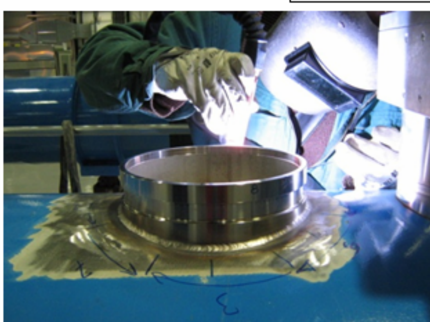


Consolidation: new pressure relief system

- **Warm sectors (1/2 machine)**
  - Add new ID200 relief device on every dipole (drill/weld in-situ!)
  - Exhaust area: **x 33**
  - Max. Pressure for MCI: **<1.5 bar**
  - ***Installation now completed***





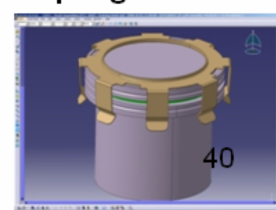


- **Cold sectors (1/2 machine)**

  (mitigating option until warm up)
  - Use existing ports as relief devices
  - replace clamps on existing flanges with new "pressure relief spring" under vacuum
  - Exhaust area: **x 10**
  - Max. pressure for MCI: **~3 bar**
  - Max pressure forces: **24 kN**

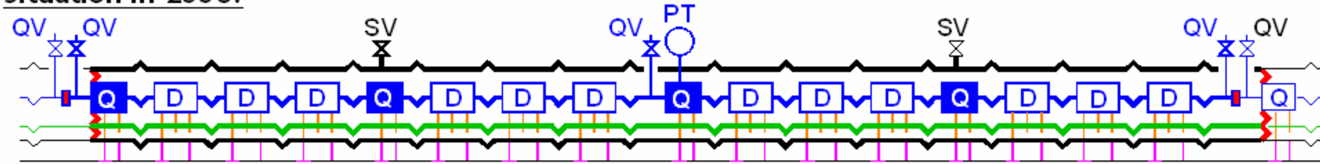
  → **Requires reinforcement of jack's anchoring** (*next slides*)

pressure relief springs

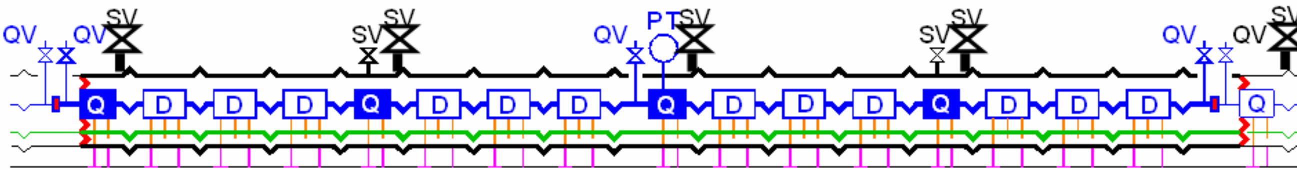


Updated pressure relief schemes

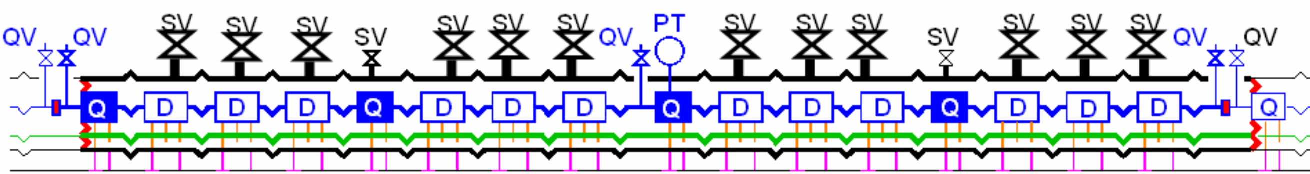
Situation in 2008:



Mitigating option for cold sectors, ½ machine: x10

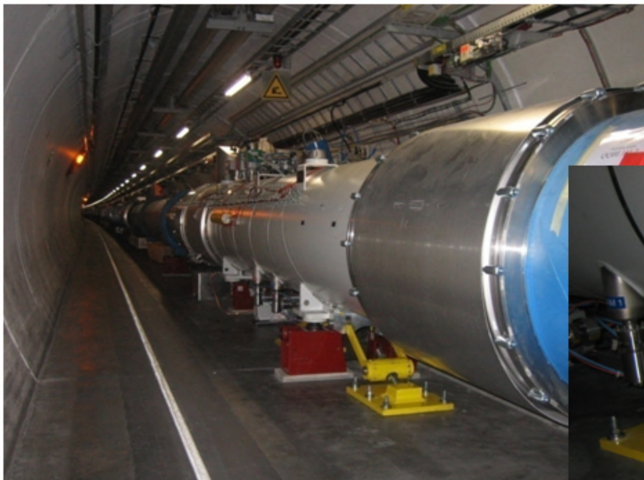


Consolidation for warm sectors, ½ machine: x33



Reinforced anchoring of SSS with vacuum barrier

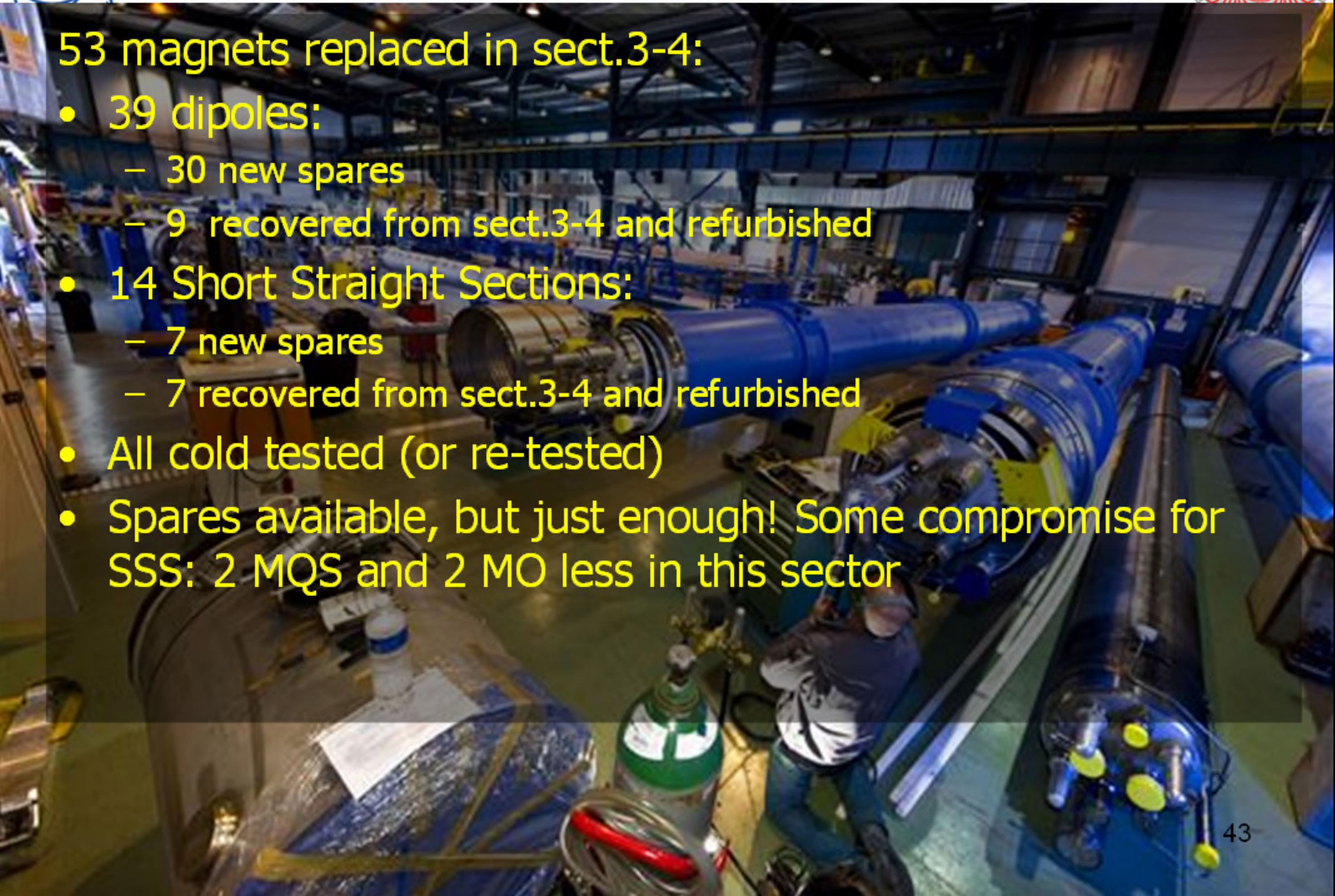
- Withstand longitudinal load of 240 kN (3 bar inner pressure)
- Implemented on 104 SSS with vacuum barriers in 8 sectors



Preparation of spare magnets

(started on 22nd Sept., 3 days after incident)

Preparation of spare magnets
(started on 22nd Sept., 3 days after incident)



53 magnets replaced in sect.3-4:

- 39 dipoles:
  - 30 new spares
  - 9 recovered from sect.3-4 and refurbished
- 14 Short Straight Sections:
  - 7 new spares
  - 7 recovered from sect.3-4 and refurbished
- All cold tested (or re-tested)
- Spares available, but just enough! Some compromise for SSS: 2 MQS and 2 MO less in this sector

30th April 2009: last magnet for sect.3-4

SSS279 lowered into the tunnel

Last open slot waiting for the last SSS279.

Interconnection work under high QA surveillance

Improvements in sect.3-4:

- In-situ adaptation of joint stabiliser for tight fit (improve continuity)
- Tighter quality control
- RT measurement of stabiliser resistance

Sequence of QC steps for main bus bar splices

Control of cables and stabiliser prior to connection by ICIT team

↓

Temperature control during soldering,
visual inspection of the finished splice by operators

↓

QC visual and geometric inspection according to IEG-C-BR-001 rev C

↓

QC US test

↓

Splice resistance measurement whenever possible

↓

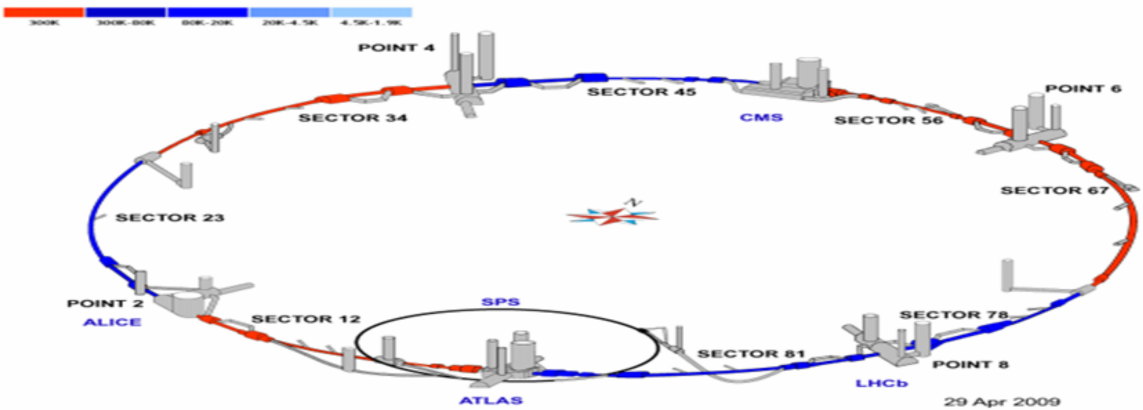
In case of doubts (e.g. previous NCRs on cable or bus bar stabiliser)
⇒Gamma ray

1

In other sectors (warm and cold):

- Continuity of joint stabilizer under investigation:
  - RT measurement of stabiliser resistance without opening interconnect
  - Resistance correlation between RT and cold (but >Tc) for cold sectors

The LHC on 2nd May



- **Sect.1-2**: Sector warm (T=300K). Warmed up to replace dipole with faulty splice found with calorimetric measurements. Done.
- **Sect.2-3:** Cool-down started (Tav=80K)
- **Sect.3-4:** Sector warm (T=300K)
- **Sect.4-5:** Sector left floating during Shut Down (Tav~80K)
- **Sect.5-6**: Sector warm (T=300K). Warmed up for other repairs
- **Sect.6-7**: Sector warm (T=300K). Warmed up to replace dipole magnet with a faulty splice found with calorimetric measurements. Done.
- **Sect.7-8:** Sector left floating during Shut Down (Tav~50K)
- **Sect.8-1:** Sector left floating during Shut Down (Tav~50K)

Commissioning foreseen to resume end of May

Conclusions (1 of 3)

Production:

- The successful industrial production of the magnet system is the result of careful preparation in the years of R&D and pre-industrialization
- The last dipole has been delivered in November 2006, 1.5 year later than the schedule of 1996 however on time with the 2001 schedule at contract signature
- In the production period major industry's insolvency events has to be tackled and solved: 1 contract of main dipoles cold mass and 1 contract of SSS cryostat assembly (in sourced at CERN)

Conclusions (1 of 3)

Production:

- The successful industrial production of the magnet system is the result of careful preparation in the years of R&D and pre-industrialization
- The last dipole has been delivered in November 2006, 1.5 year later than the schedule of 1996 however on time with the 2001 schedule at contract signature
- In the production period major industry's insolvency events has to be tackled and solved: 1 contract of main dipoles cold mass and 1 contract of SSS cryostat assembly (in sourced at CERN)

Performance:

- The field quality has been closely monitored and steered and is according to design.
- Dynamic effect still have to be tested with energy ramping
- Excellent understanding of field quality and the precise field model, as well as the very fine alignments of the magnet system have allowed such an "easy operation" in the first beam of LHC.
- The cryostats have proven to have an excellent thermal performance and mechanical stability

Conclusions (2 of 3)

The incident of Sep.19th. Lessons learned, "the tough way"

- The primary cause is most probably a faulty interconnection splice, revealing a weakness in the QA and an insufficiently assessment of the related risk for the machine.
- Electrical discontinuities in the joint stabilizer may hinder the machine's reliability and is being deeply investigated
- A better integration of the electrical magnet interconnect in the whole magnet powering circuit (and namely in the bus bar system) would have helped to avoid it
- The Quench Detection System was inadequate to protect the bus bars splices
- The cryostats overpressure relief system was largely underestimated
- The ground anchoring of the SSS with vacuum barriers was also marginal in strength

Conclusions (2 of 3)

The incident of Sep.19th. Lessons learned, "the tough way"

- The primary cause is most probably a faulty interconnection splice, revealing a weakness in the QA and an insufficiently assessment of the related risk for the machine.
- Electrical discontinuities in the joint stabilizer may hinder the machine's reliability and is being deeply investigated
- A better integration of the electrical magnet interconnect in the whole magnet powering circuit (and namely in the bus bar system) would have helped to avoid it
- The Quench Detection System was inadequate to protect the bus bars splices
- The cryostats overpressure relief system was largely underestimated
- The ground anchoring of the SSS with vacuum barriers was also marginal in strength

How bad we are!

Conclusions (3)

Consolidation and repairs:

- The consolidation of the cryostats overpressure relief system is well advanced. 4 warm sectors are equipped with new relief devices, the remaining 4 cold sectors will be equipped at the next shut down
- The reinforced anchoring of the SSS with vacuum barriers is being implemented
- The QPS system is being upgraded to cover, amongst others, the detection of 0.3 mV voltages along sector electrical circuits
- Newly developed diagnostic tools allowing precise resistance measurements detected faulty splices in 2 dipoles which were replaced
- All spare magnets for sect.3-4 are in the tunnel and interconnection work under high QA surveillance is in progress
- Special measures are being implemented to detect possible discontinuity in the joint stabilizer in all machine. The maintain of the tight schedule for 2009 may depend on these results

Conclusions (3)

Consolidation and repairs:

- The consolidation of the cryostats overpressure relief system is well advanced. 4 warm sectors are equipped with new relief devices, the remaining 4 cold sectors will be equipped at the next shut down
- The reinforced anchoring of the SSS with vacuum barriers is being implemented
- The QPS system is being upgraded to cover, amongst others, the detection of 0.3 mV voltages along sector electrical circuits
- Newly developed diagnostic tools allowing precise resistance measurements detected faulty splices in 2 dipoles which were replaced
- All spare magnets for sect.3-4 are in the tunnel and interconnection work under high QA surveillance is in progress
- Special measures are being implemented to detect possible discontinuity in the joint stabilizer in all machine. The maintain of the tight schedule for 2009 may depend on these results

Caution is our Guiding principle

SUPPORTING SLIDES

Sector 3-4 Event Findings and Observations Summary

← Point 3 — (Based on investigation and measurements by AT-MCS, AT-MEI, AT-VAC, TS-MME and TS-SU) — Point 4 →

	A18	B18	C18	Q18	A19	B19	C19	Q19	A20	B20	C20	Q20	A21	B21	C21	Q21
SSS type								J,VB,Plugs								J
Δ Cryostat	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Δ CM Longit.								<5	<5	<5	<5	<5	<5	<5	<5	<5
MLI&Cleannes Status																
CM Status																

	A22	B22	C22	Q22	A23	B23	C23	Q23	A24	B24	C24	Q24	A25	B25	C25	Q25
SSS type								J,VB,Plugs								J
Δ Cryostat (➡ +)	<2	<2	<2	-7	<2	<2	<2	-187	<2	<2	<2	<2	<2	<2	<2	<2
Δ CM Longit. (➡ +)	<5	<2	<2	-20	-67	-102	-144	<5	-190	-130	-60	<5	<2	<2	<2	<5
MLI&Cleannes Status																
CM Status																

	A26	B26	C26	Q26	A27	B27	C27	Q27	A28	B28	C28	Q28	A29	B29	C29	Q29
SSS type								J,VB,Plugs								J
Δ Cryostat	<2	<2	<2	<2	<2	<2	<2	474	-4	<2	<2	11	<2	<2	<2	<2
Δ CM Longit.	<2	<2	<2	<5	57	114	150	-45	230	189	144	85	50	35	<5	<5
MLI&Cleannes Status																
CM Status																

	A30	B30	C30	Q30	A31	B31	C31	Q31	A32	B32	C32	Q32	A33	B33	C33	Q33	A34
SSS type								J,VB,Plugs								J,VB	
Δ Cryostat	<2	<2	<2	<2	<2	<2	<2	188	<2	<2	<2	5	<2	<2	<2	<2	<2
Δ CM Longit.	<5	<5	<5	<5	19	77	148	<5	140	105	62	18	<5	<5	<5	<2	<2
MLI&Cleannes Status																	
CM Status																	

J,VB,Plugs	SSS type	Cryostat displacement		Primary Electrical Fault	
Zone with magnets removed		Holes in LHe enclosure		Electrical interruptions	
Cold mass displacement		Jumper (to QRL) damaged		Dipole in short circuit	

(* Note: damages on Beam pipes Vacuum (PIMs, BS bellows, and CBT/BS pollution) also OUTSIDE zone Q19-Q33 (up to Q7.R3 and Q7.L4))

M.Modena, TE-MSC — 23-Apr-09

Planning for the coming months