CERN

The real “life” of operation

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The CERN Accelerator School

LABORATORY

Introduction

- Your beautiful and expensive vacuum system was well designed and prototypes deeply tested …

… so what can happen?

First turns of LHC: 10 Sept 2008

The real life of operation …

Roger Bailey
Operation SL

C. Llewellyn Smith
CERN DG
1994-1998

L. Maiani
CERN DG
1999-2003

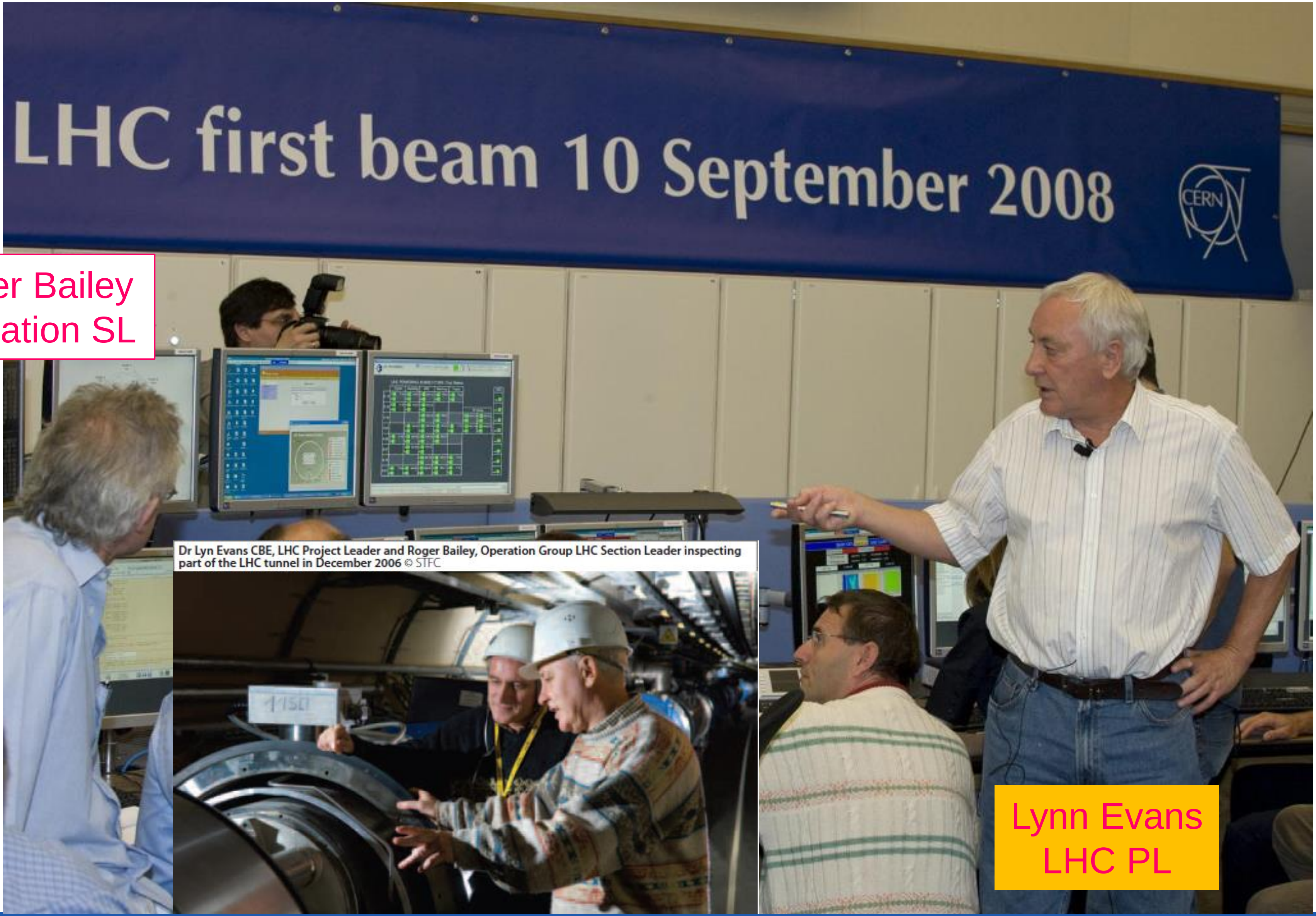
R. Aymar
CERN DG
2004-2008

E. Schopper
CERN DG
1981-1988

Roger Bailey
Operation GL

C. Rubbia
CERN DG
1989-1993

The real life of operation …

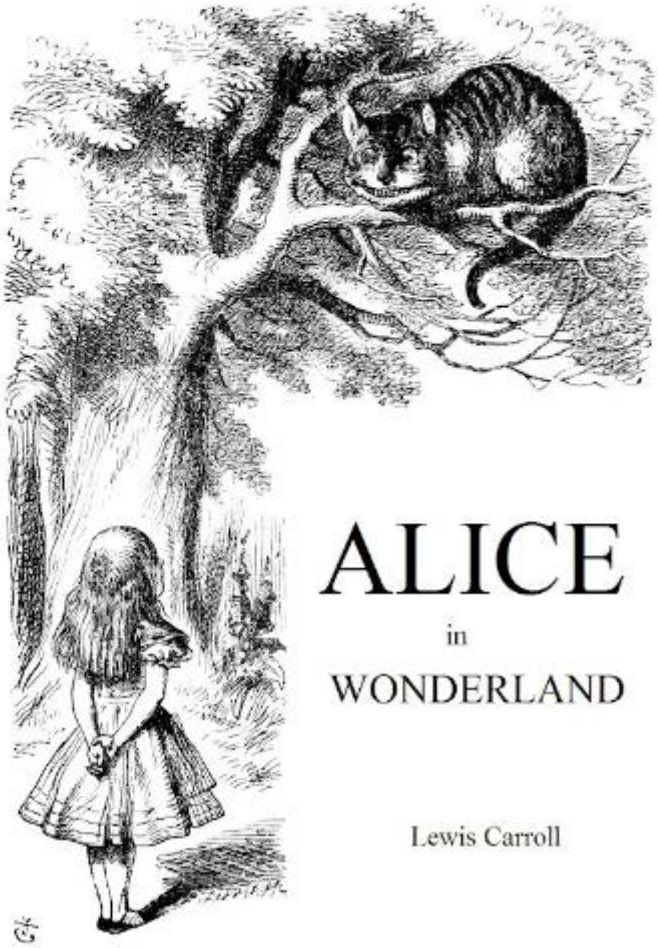


Dr Lyn Evans CBE, LHC Project Leader and Roger Bailey, Operation Group LHC Section Leader inspecting part of the LHC tunnel in December 2006 © STFC

Roger Bailey
Operation SL

Lynn Evans
LHC PL

What about the real life through the looking glass?



ALICE

in

WONDERLAND

Lewis Carroll

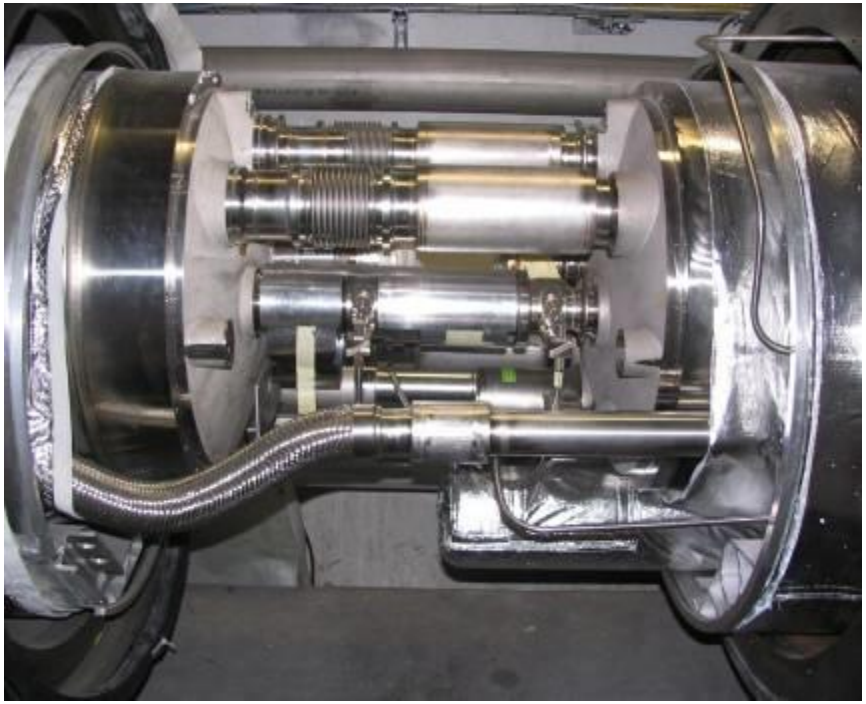
The Sector 3-4 incident (just before the 1st ramp)

19th September 2008 at 11:18.36

last test of the last sector: 7kA (4TeV) towards 9.3 kA (5TeV)

Electrical arc at 8.7 kA in the interconnection

Rupture of bellows, expansion of liquid Helium with superinsulation debris



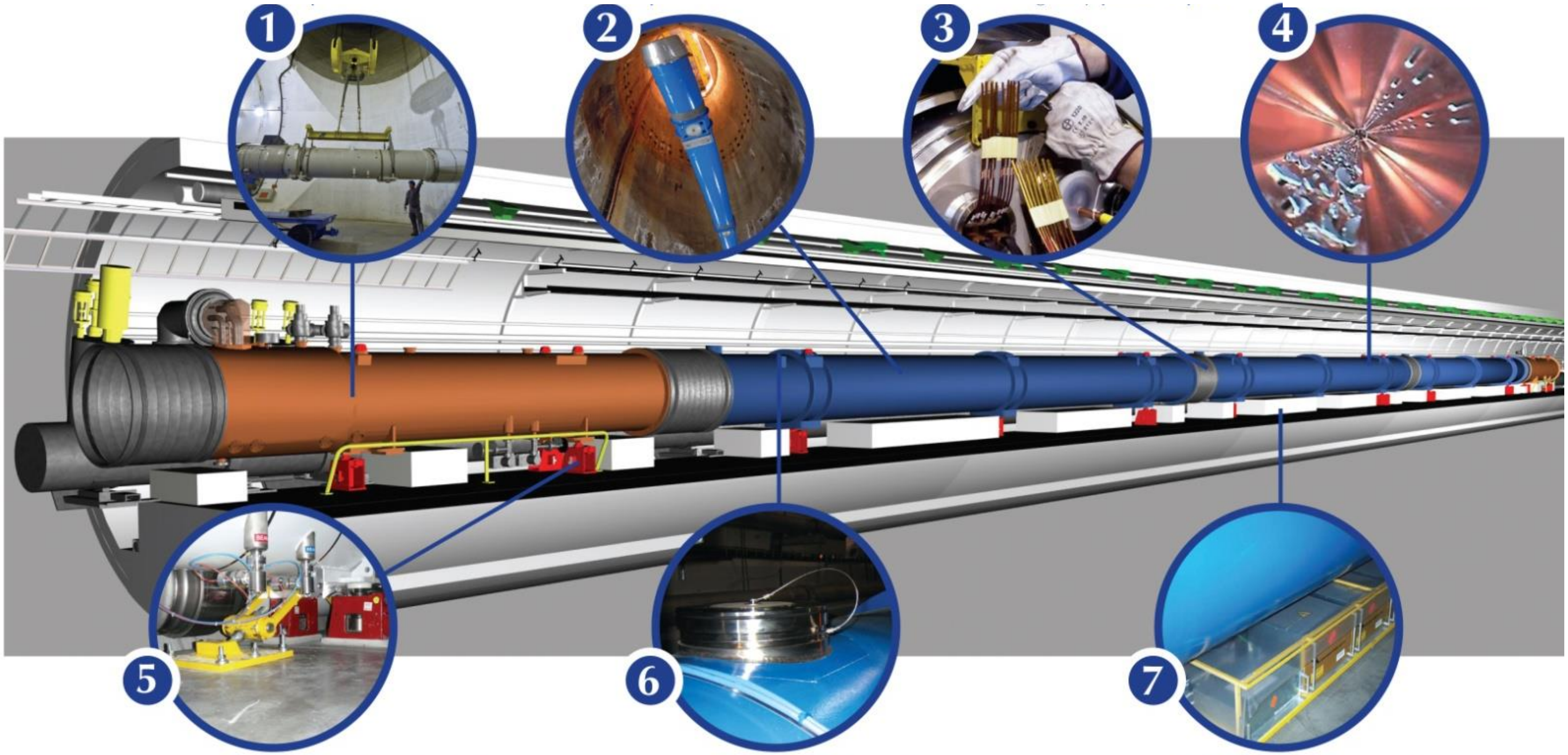
2009 - overall repair and consolidation

14 quadrupole magnets replaced

39 dipole magnets replaced

204 interconnections repaired

5km beam-tube cleaned



longitudinal restraining system quadrupoles

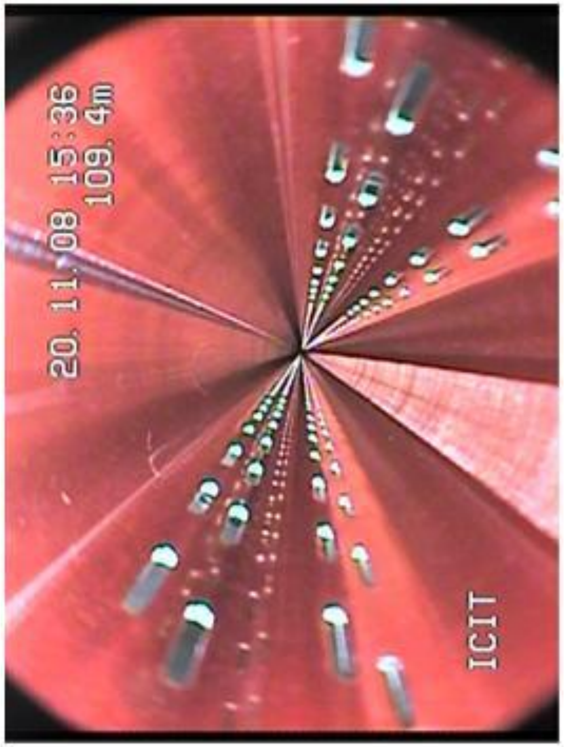
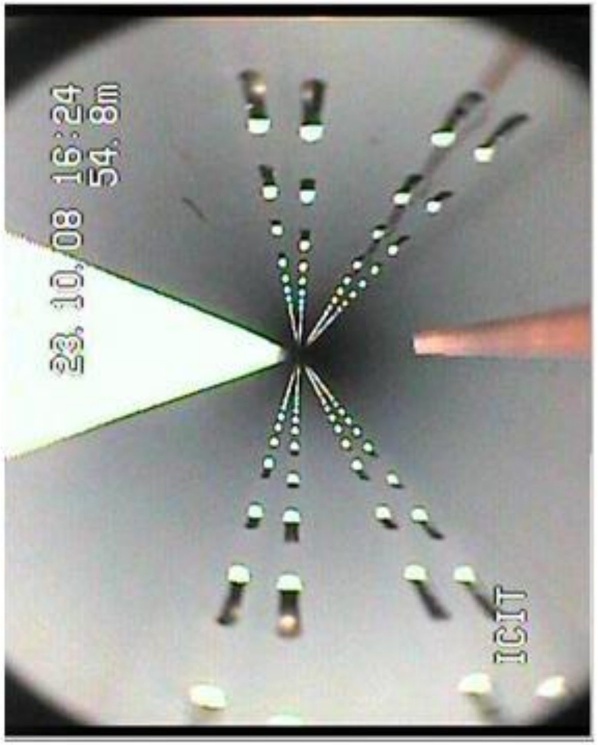
900 ports for helium pressure release

6500 new detectors and 250km cables for new Interconnect Protection System

collateral damage mitigation

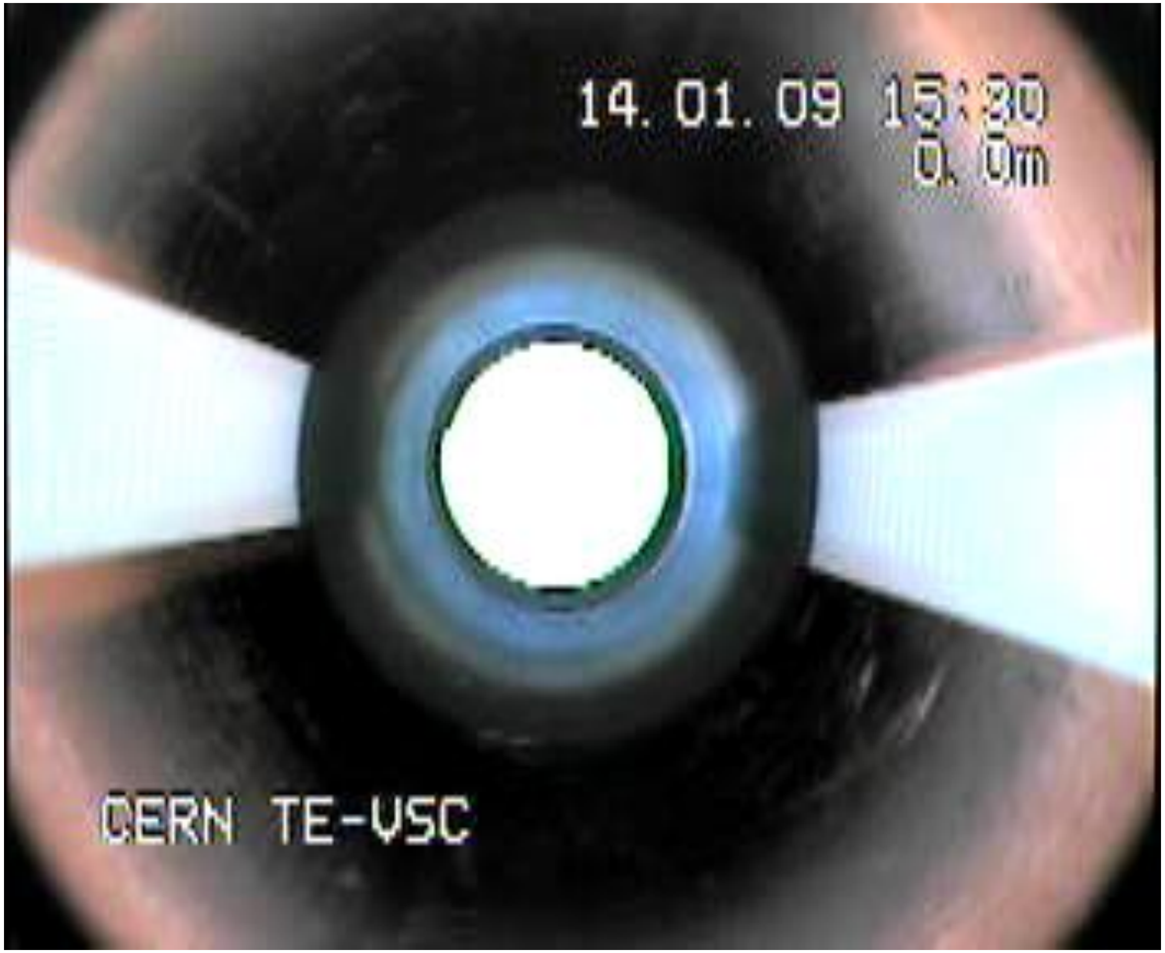
Impact on beam tube …

- 2x 2.8 km damaged

Clean Copper surface.	Contamination with multi-layer magnet insulation debris.	Contamination with soot.
		

≈ 60% of the chambers **≈ 20% of the chambers**

TE-VSC Vacuum Cleaner



Credits: E. Mahner, B. Jenninger, B. Henrist

Beams back: 20 Nov 2009

Roger still here!
Happier than ever!

1. What can happen?

Disclaimer

- What I will show is not an exhaustive list of the events which can happen …
- I really trust the creativity of nature and humanity to complete the list!

1.1 Vacuum loss

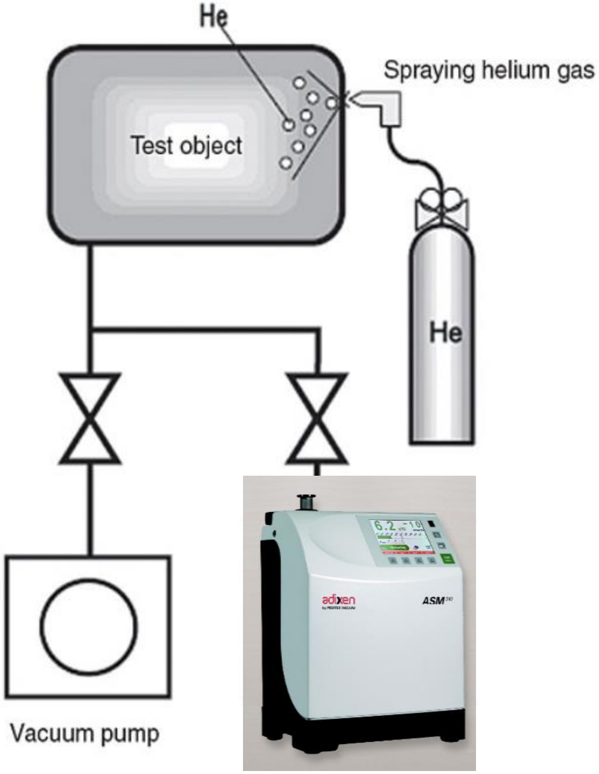
Leaks

- This is the first demon faced by the vacuum expert

- Leaks can be due to:
    - installations non conformity
    - bad design / material
    - mechanical or thermal fatigue of a component
    - corrosion
    - …

- One great thing, if you don't look for them, you might not find them yourself ….

… but something else might find it for you!



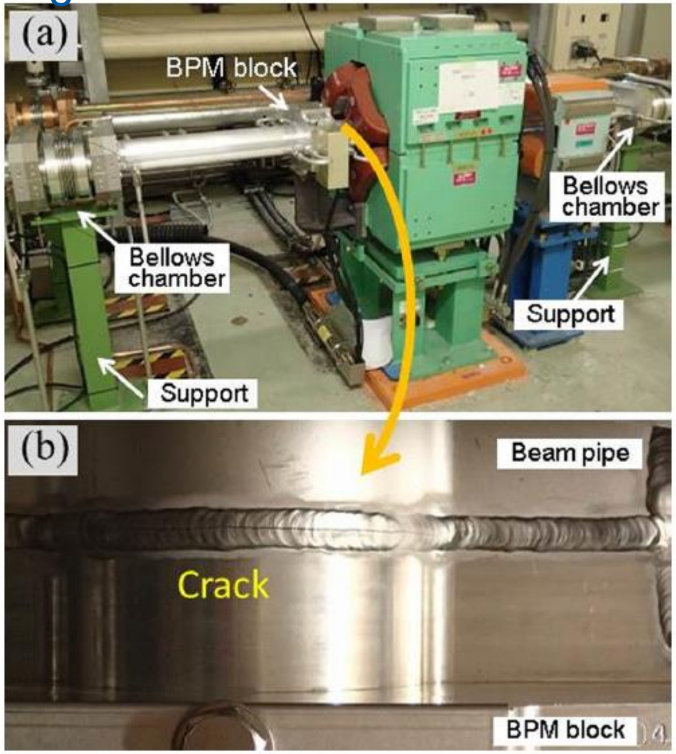
He leak detector

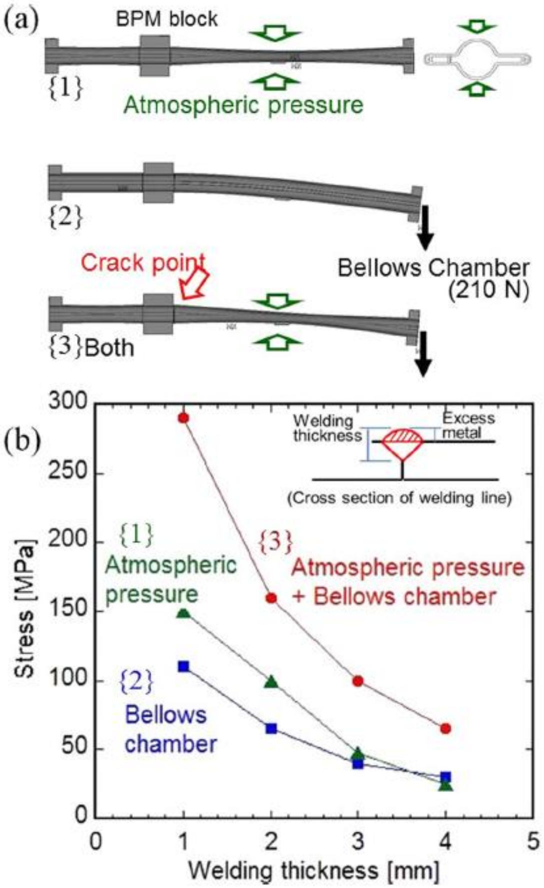
See tutorial P. Cruikshank, G. Bregliozzi

Leak at welds: mechanical analysis

- The stress at the level of the weld increases under vacuum and weight (and thermal stress)

- Example of SuperKEKB:
  - Supporting of below before evacuation
  - Rewelding if too thin thickness





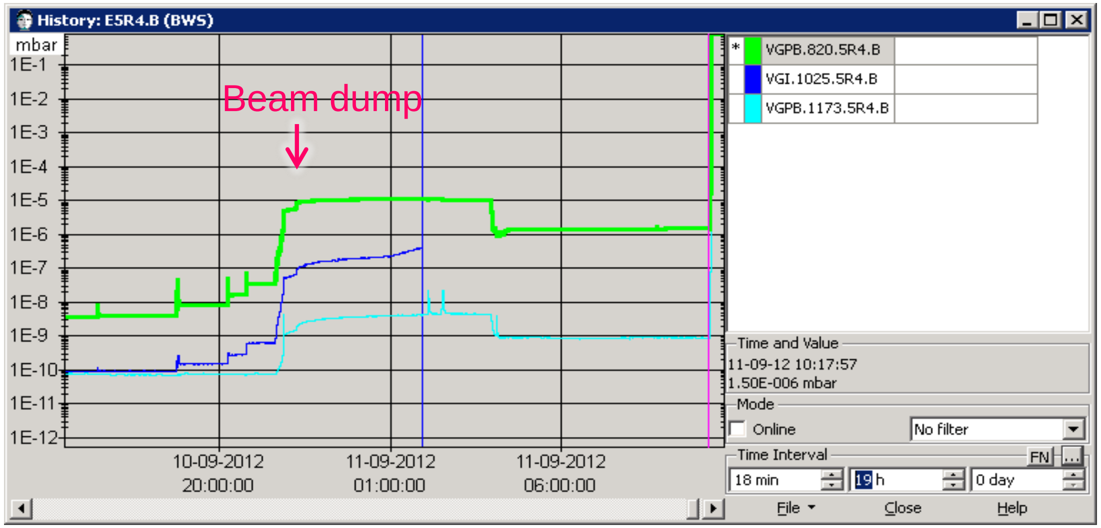
Y. Suetsugu *et al.* J. Vac. Sci. Technol. A 34, 021605 (2016)

LHC: 1^{st} Leak triggering a beam dump

- During operation, the bellow of a wire scanner broke, creating a leak
  - The total amount of bellow's cycle was not recorded since the start of LHC and overpassed by far the acceptable limit ;-)

- Varnished was applied without success

- The emergency procedure which consist in Ne venting allowed to replace the faulty component and resume beam operation after 2 days



* 🟩 VGPB.820.5R4.B
🟦 VGI.1025.5R4.B
🟦 VGPB.1173.5R4.B

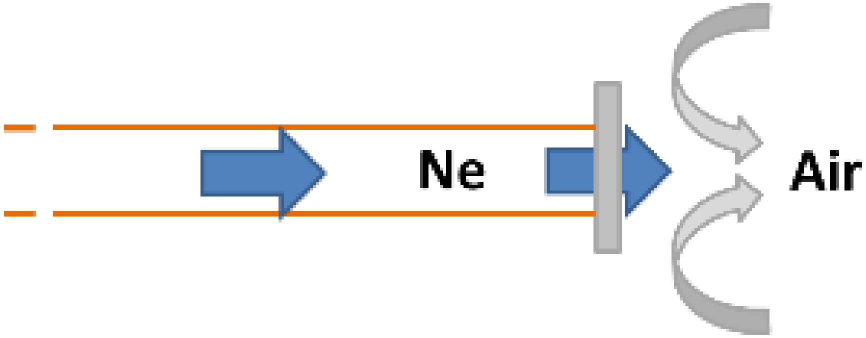
Time and Value
11-09-12 10:17:57
1.50E-006 mbar

Mode
☐ Online
No filter

Time Interval
18 min
19 h
0 day

Fast Repair: Ne venting

- 5 days intervention
- Ne flow to reduce air back streaming
- This method avoids the NEG saturation (remember Ne is an inert gas)
- Avoid major NEG saturation but possible local saturation close to the exchanged piece
- Zone that can stand **over pressurization** +100mbar



Neon trolley

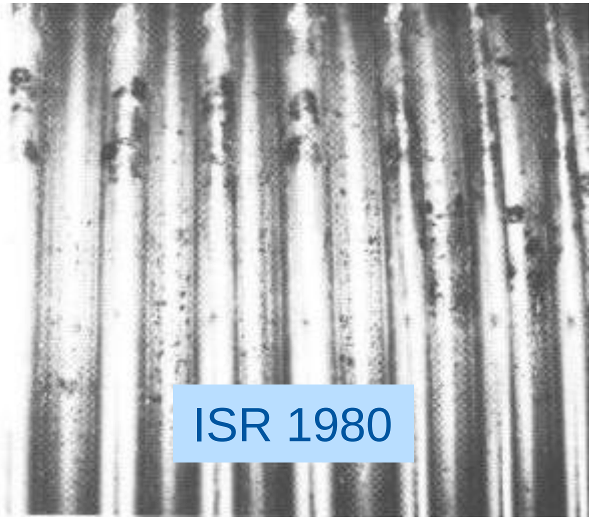
Corrosion

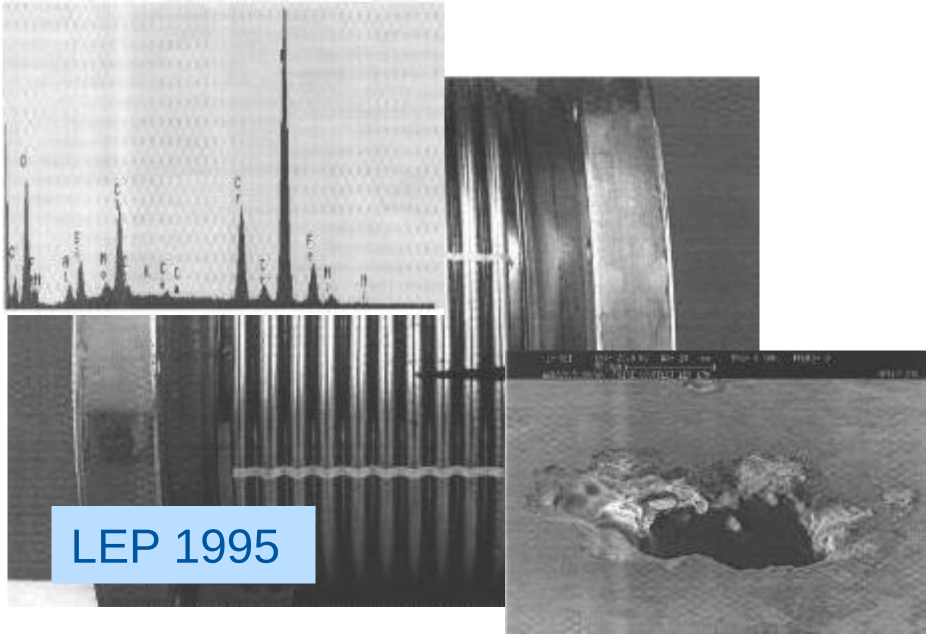
- Originates from chlorine pitting

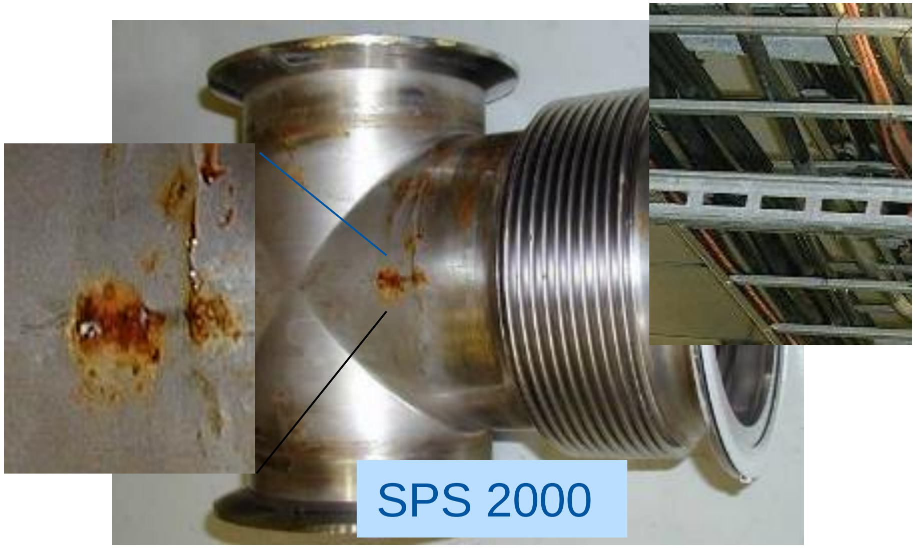
- ISR: Brazing flux ! ($ZnCl_2$)

- SPS: fire detection PVC pipes subjected to radiation in a wet environment and located above the vacuum system

- LEP: PVC based tape wrapped around photomultipliers


ISR 1980

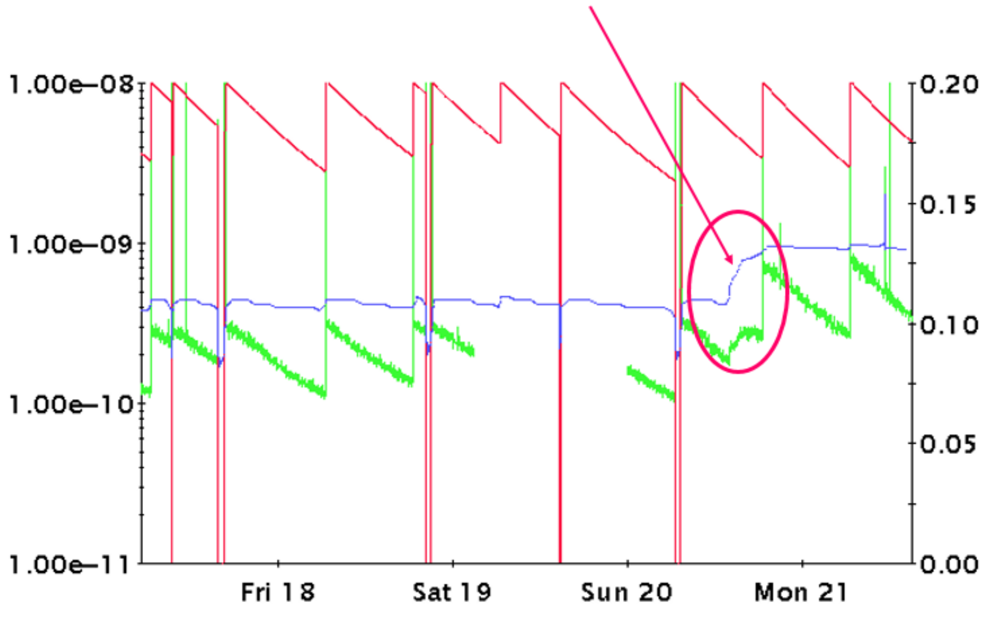

LEP 1995

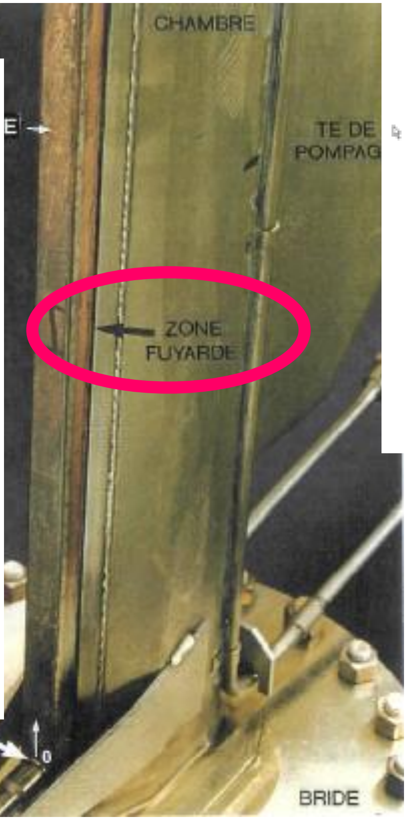

SPS 2000

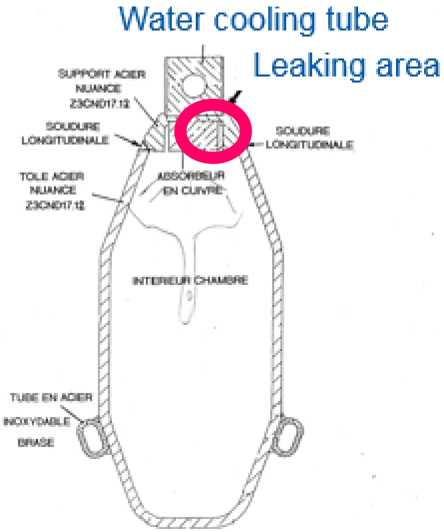
See S. Sgobba, F. Cerutti, M. Brugger lectures

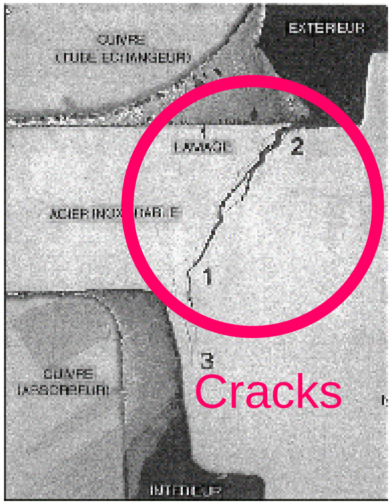
Corrosion

- Brazing flux containing chlorine leads to corrosion.
- Example, ESRF


What typically happens ? A pressure rise due to an air leak …







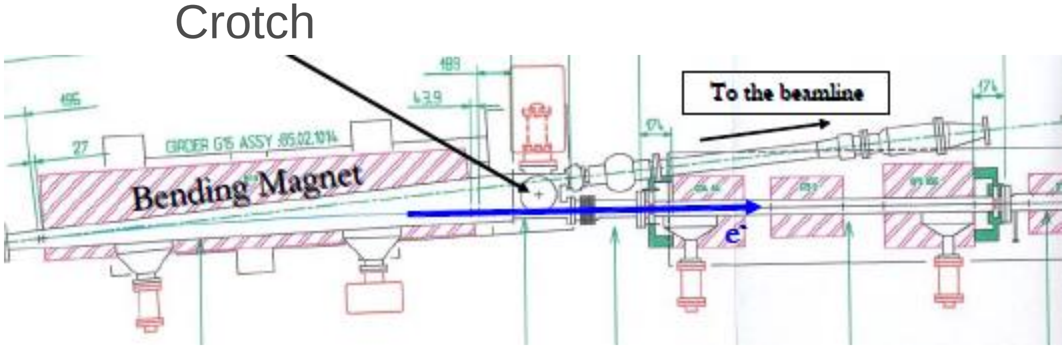
The chlorine cannot be cleaned being trapped in small interstices! Brazing flux forbidden!

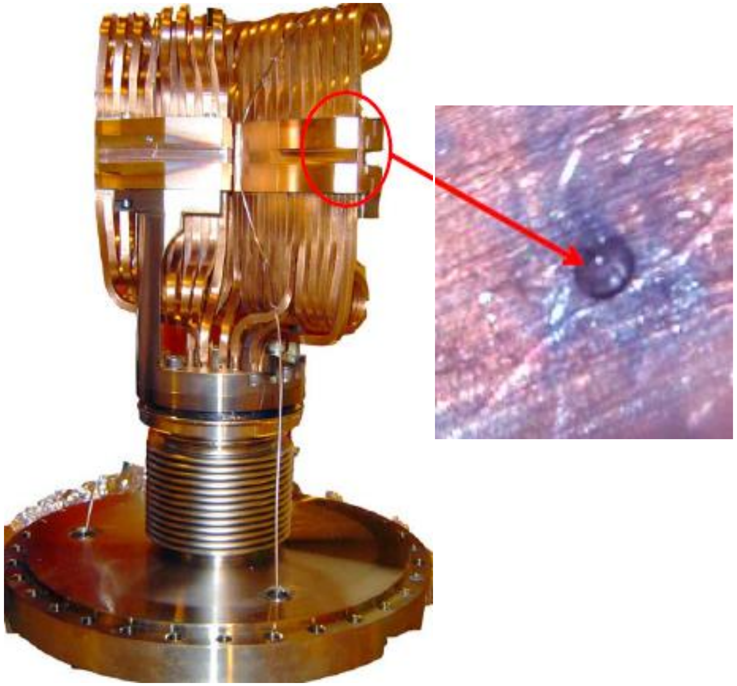
L. Hardy, ARW 2009

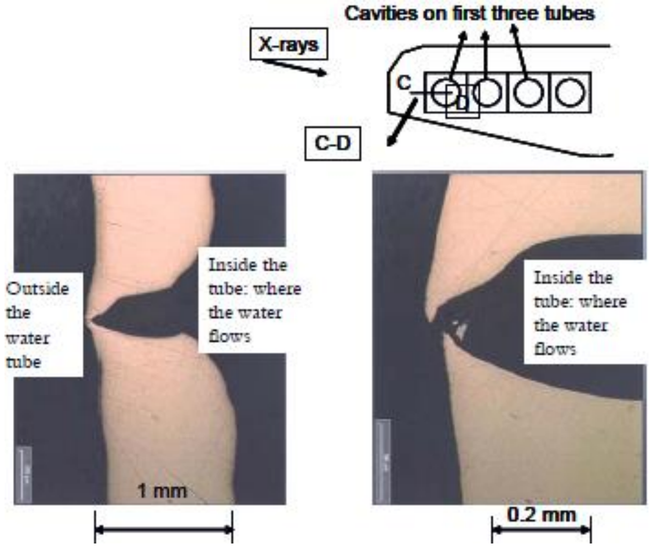
Water leak in cooled devices

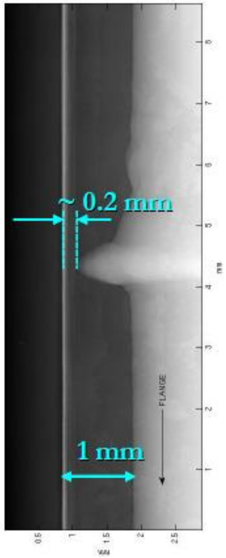
- The crotch is a photon absorber (~ kw), used in SR machines. It need to be water cooled …
- Example ESRF crotch, March 2005

- Water leak:
    - 50 m vented
    - water inside the vacuum system!
    - 5 days lost







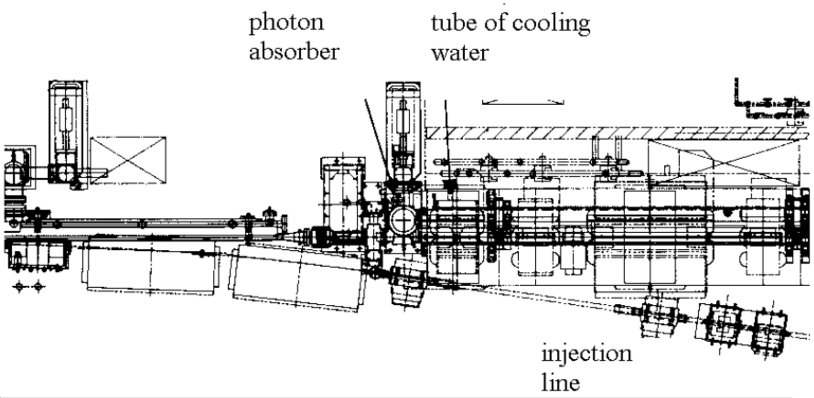


L. Hardy, ARW 2009

Origin: de-ionised water+ Copper + radiations

Water – cooled devices: another example

- Example Spring 8 photon absorber, June 2001
  ➔ New design with cooling tube out of the SR fan



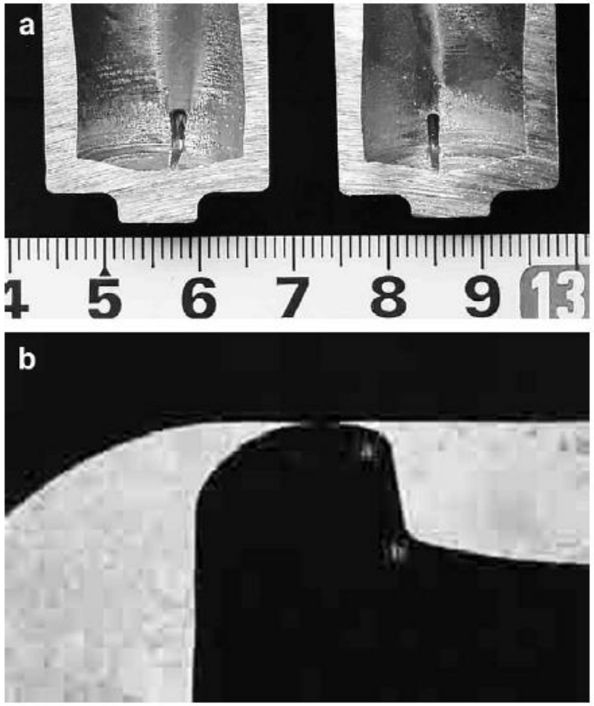
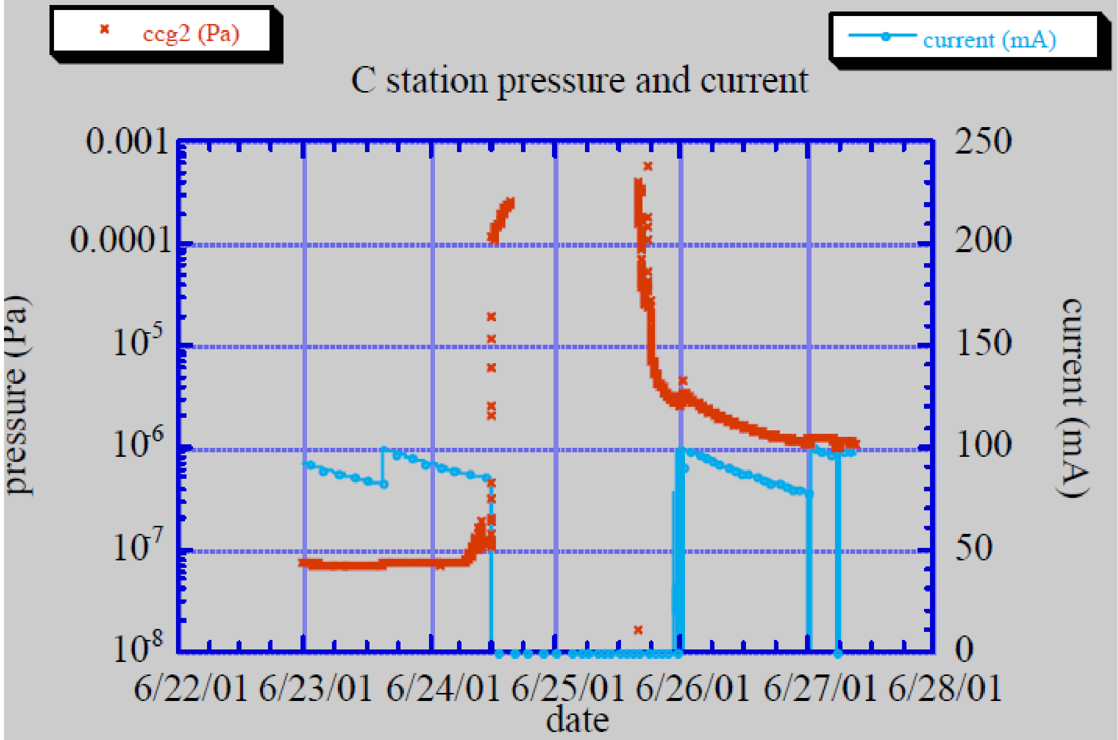


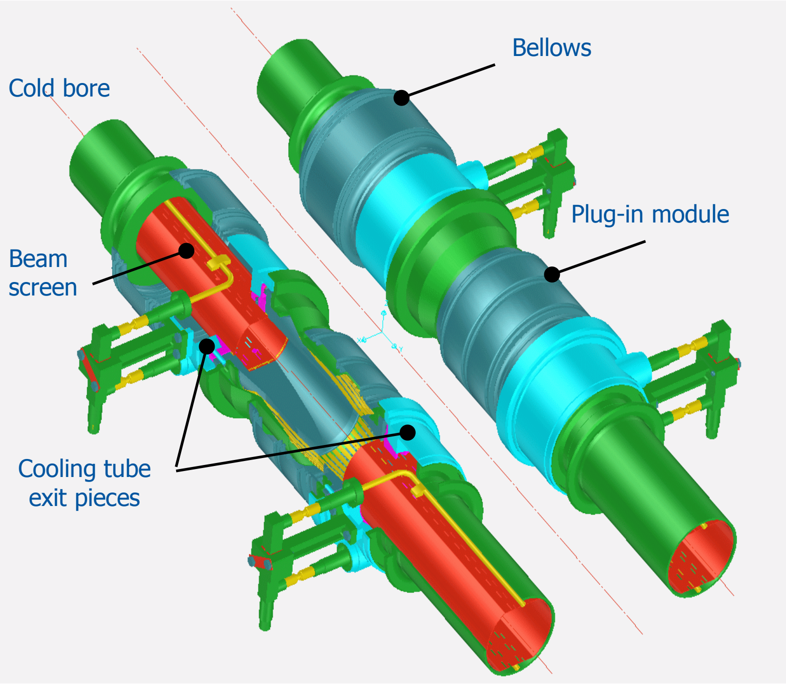
Fig. 5. Photographs of the cross section of the photon absorber removed from the RF cavity (a) and the cross section of the eroded part (b). Corrosion was found only inside the water pipe where the synchrotron radiation hits.

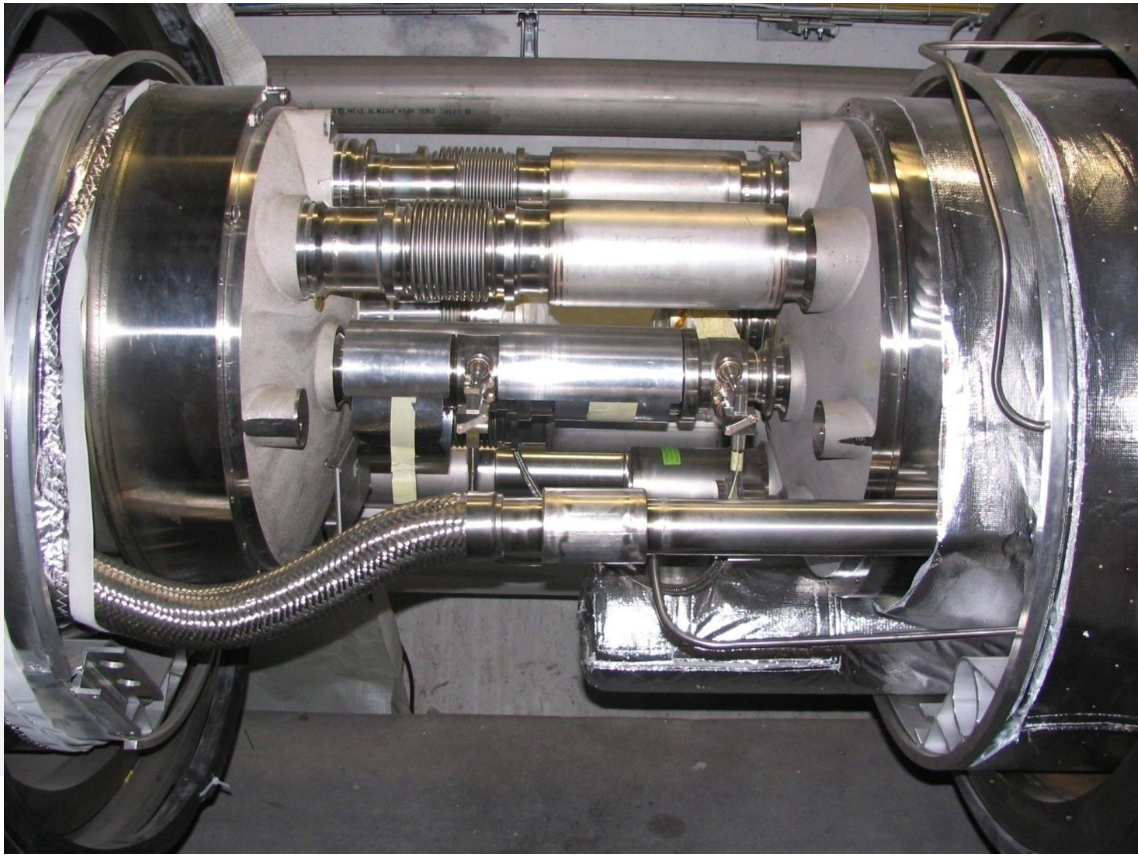


M. Shoji *et al.*
Vacuum 84 (2010) 738–742

1.2 Non conformities

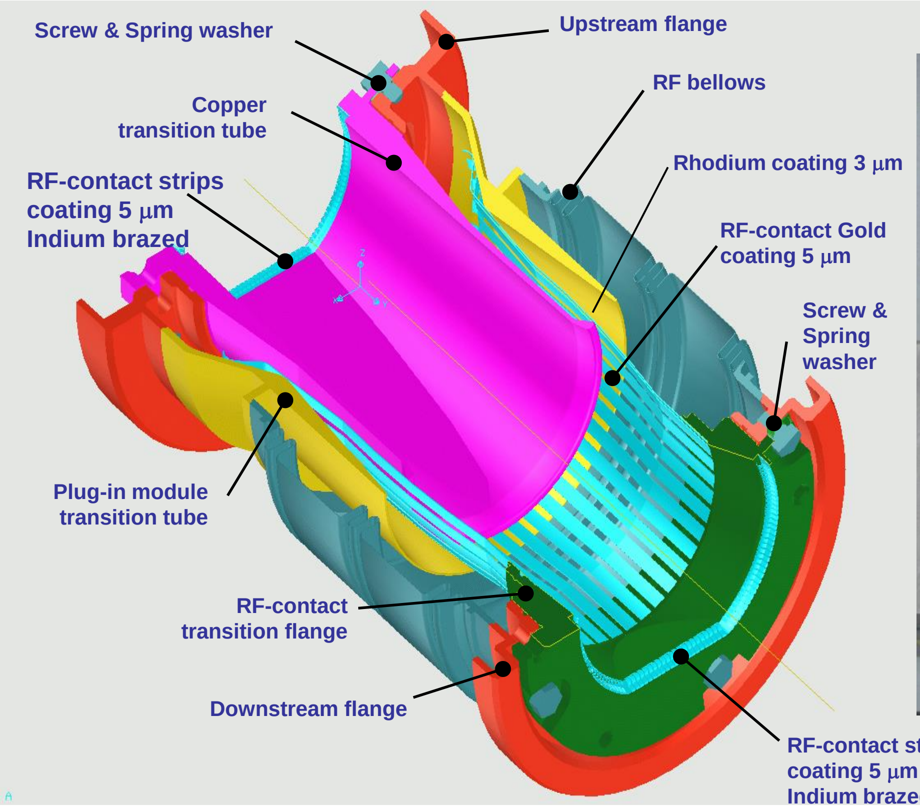
LHC Dipole-Dipole Interconnection



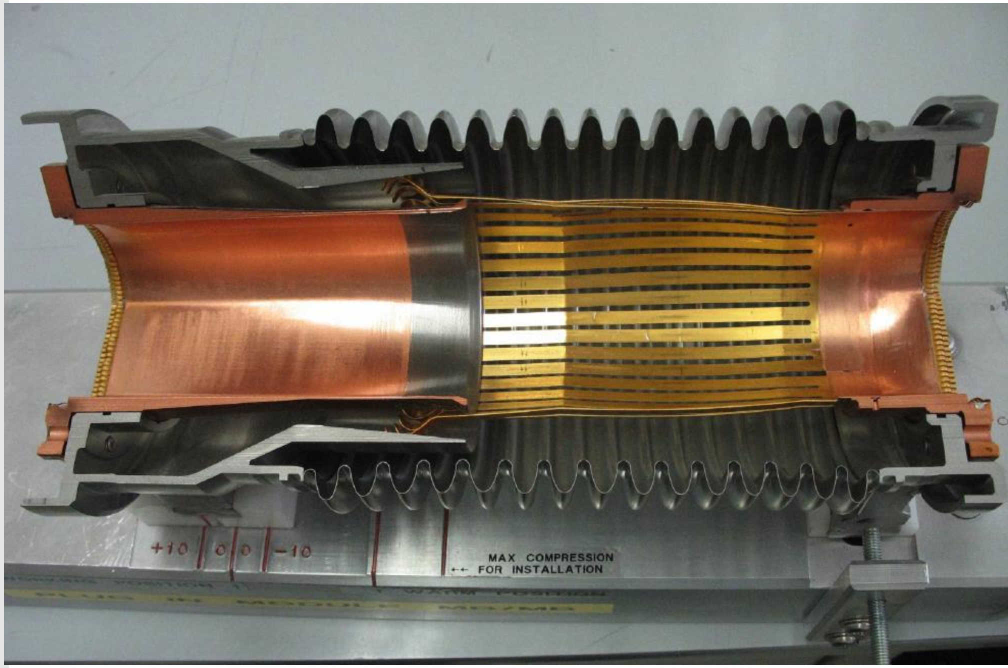


Plug-in Modules with RF Fingers

- Last installed component to interconnect superconducting magnets (~ 1 700 PIM)
- RF bridge made of sliding RF fingers (Au coated to avoid cold welding)
- < 0.1 mOhm contact resistance, Rh coating (i.e. 3 mOhm/RF finger)



Room temperature position



Courtesy R. Veness

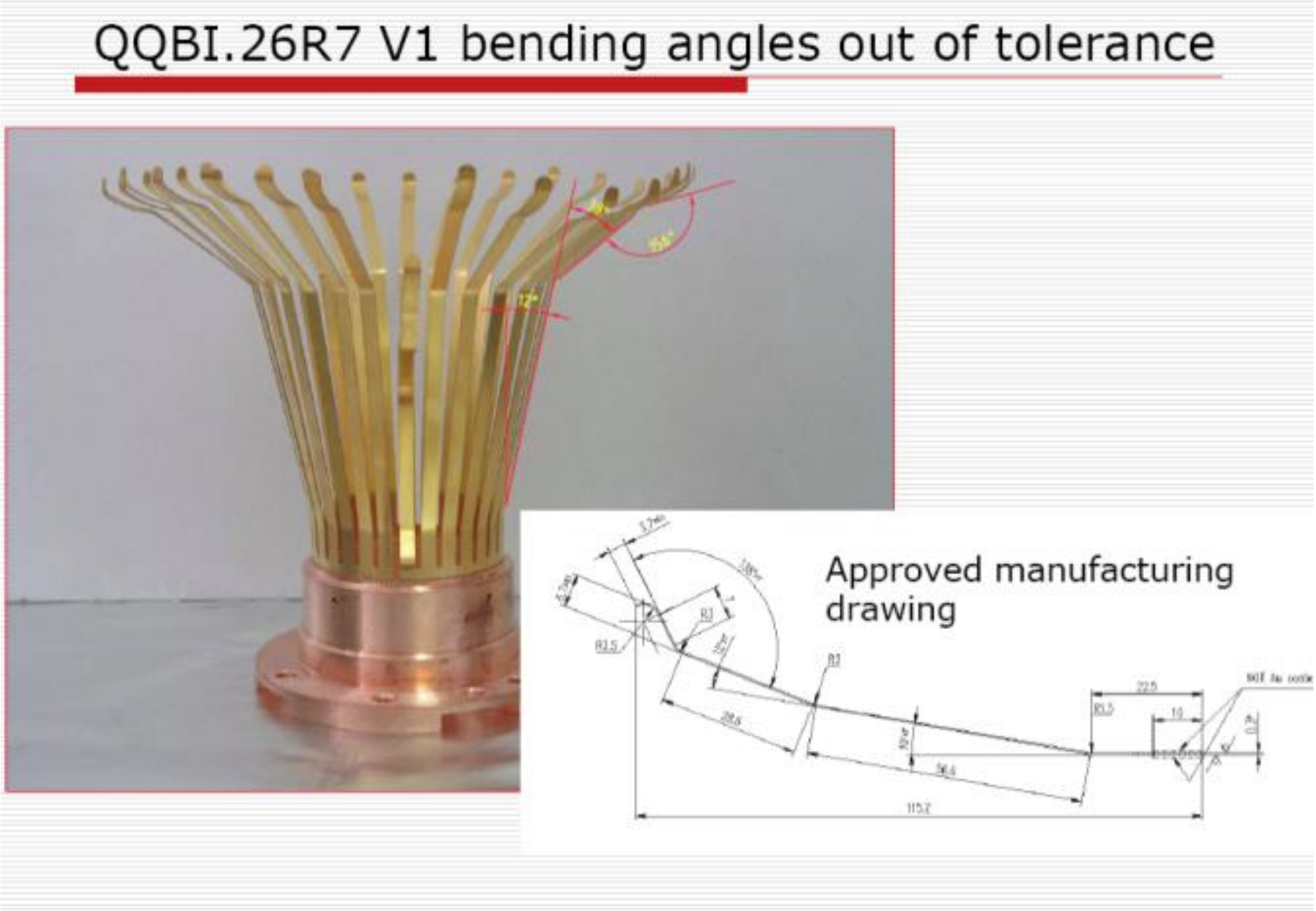
Working position at cryogenic temperature

August 2007

- After warm-up of sector 7-8
  - A buckled PIM was discovered in interconnect QQBI.26.R7
  - Was really found by chance!

Why buckling ?

- Non conformity during manufacturing
- Not properly documented => Lesson: respect of Quality Assurance is a MUST

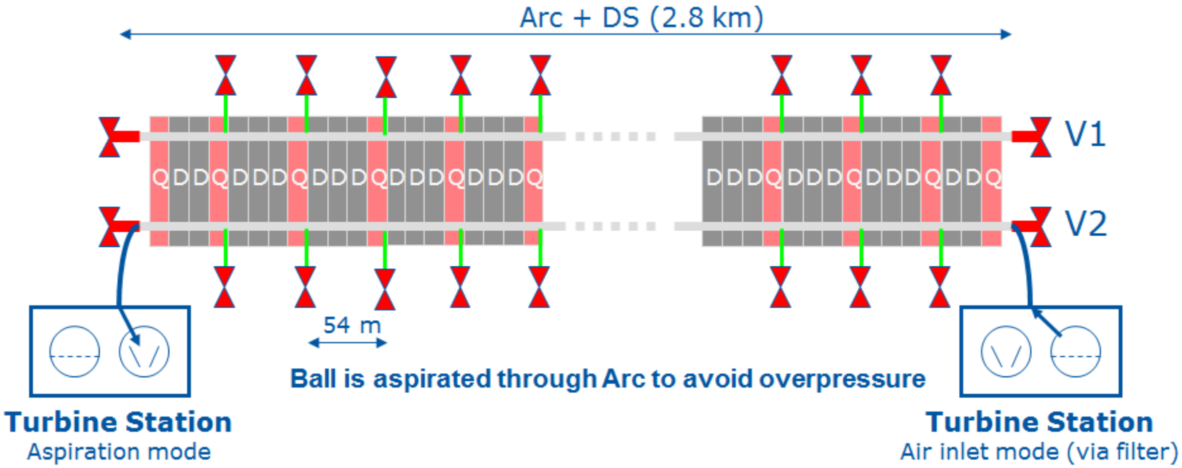


QQBI.26R7 V1 bending angles out of tolerance

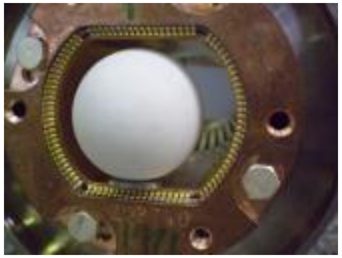
Approved manufacturing drawing

The consequence: RF ball emitter

- Identification of critical PIM :
  - Repair / consolidation when possible
  - ~ 1 mm longitudinal shift of quadrupole to gain margin
- Maintain arc below 130 K during stand-by period
- Recurrent observation after each warm up of arc with:
  - RF ball
  - Tomography
  - Endoscopes



RF ball



RF ball inside PIM

A buckled PIM

Deformation of bellow

- Production of bellows for the LHC QRL:
    - design: convolution height “at the limit”
    - non-conform production
    - not traced !

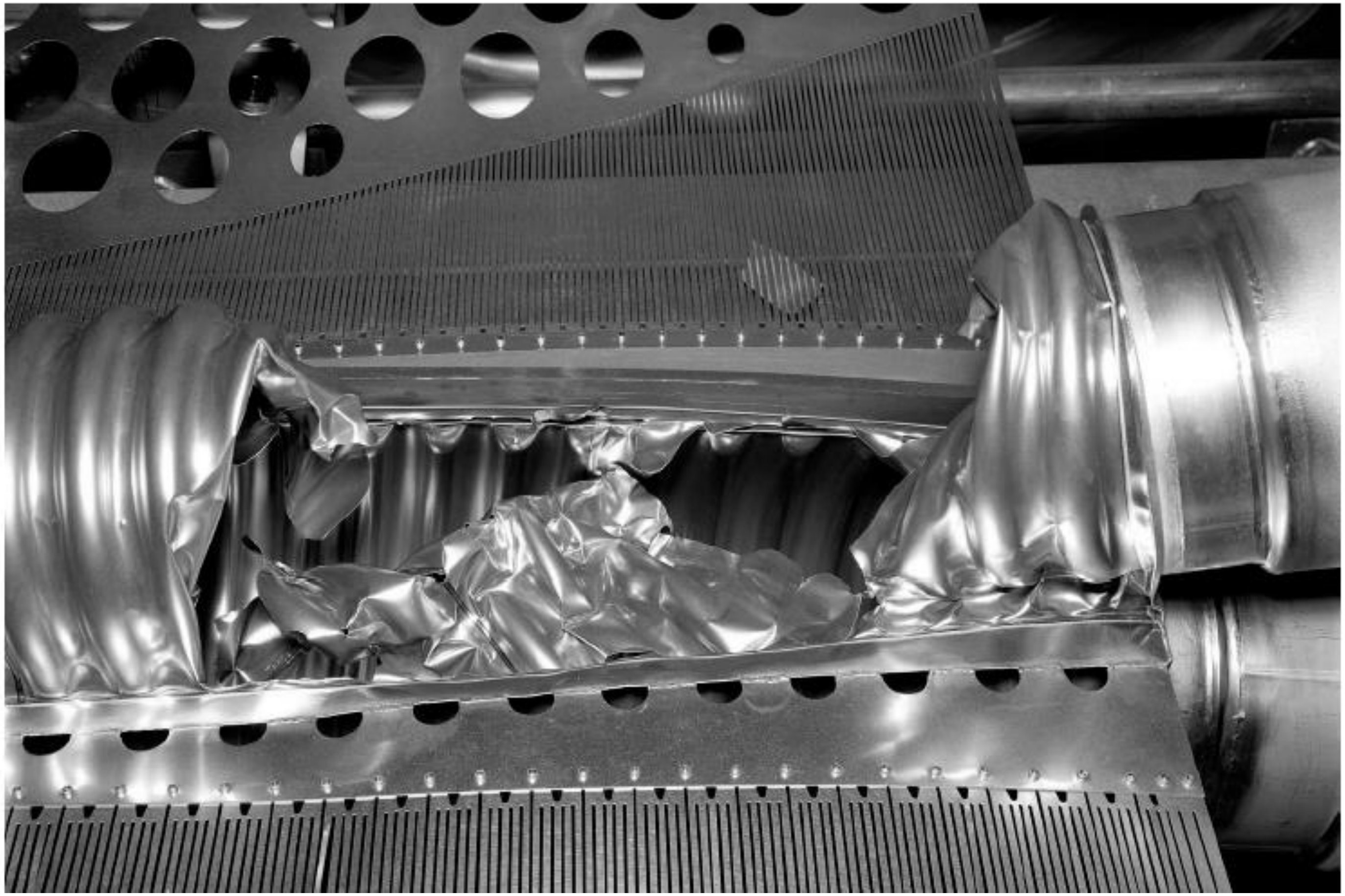
- Cured by mechanical consolidation
- Production follow-up shall be appropriate !

See C. Garion lecture and tutorial

It can always be worse ..

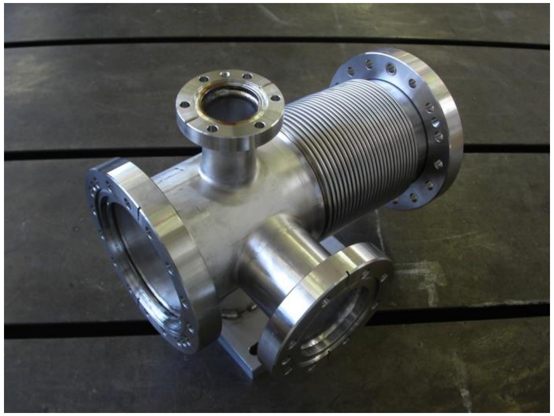
- CERN ISR vacuum chamber located at the interaction point

Imploded Thin Walled Vacuum Chamber

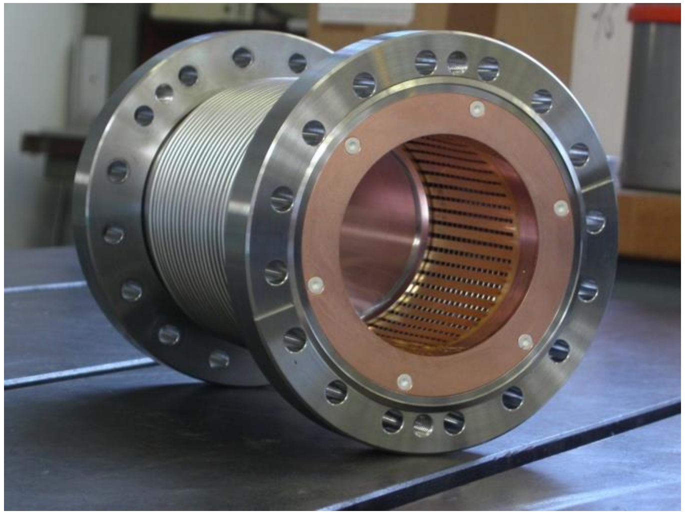


1.3 Aperture losses

Warm Modules for Interconnection



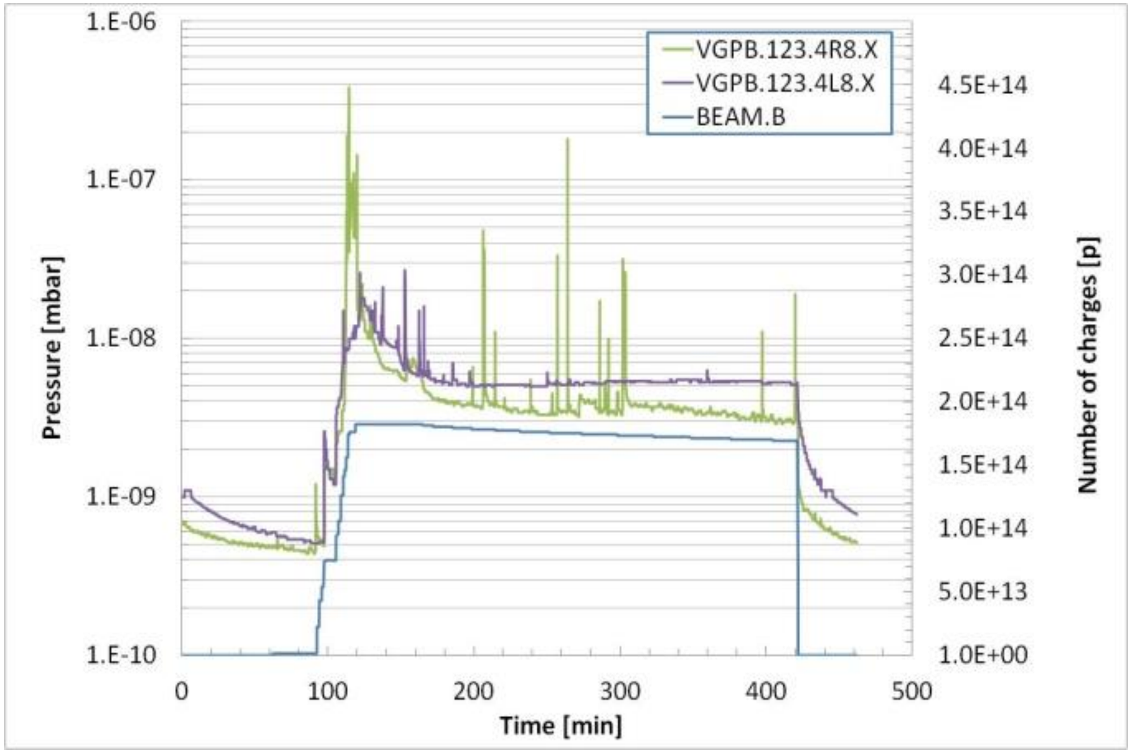
- Modular system
- ~ 1 800 in the LHC ring
- Bellow shielding to optimise beam impedance
- RF bridge with several shapes (circular/elliptical)
- Ag coated CuBe fingers
- Rh coated insert
- Allow thermal expansion during bakeout (+/- 20 mm stroke)
- Can accommodate instrumentation ports



See R. Wanzenberg, B. Salvant, S. Calatroni lecture and tutorial

Summer 2011 : Vacuum Modules - VMTSA

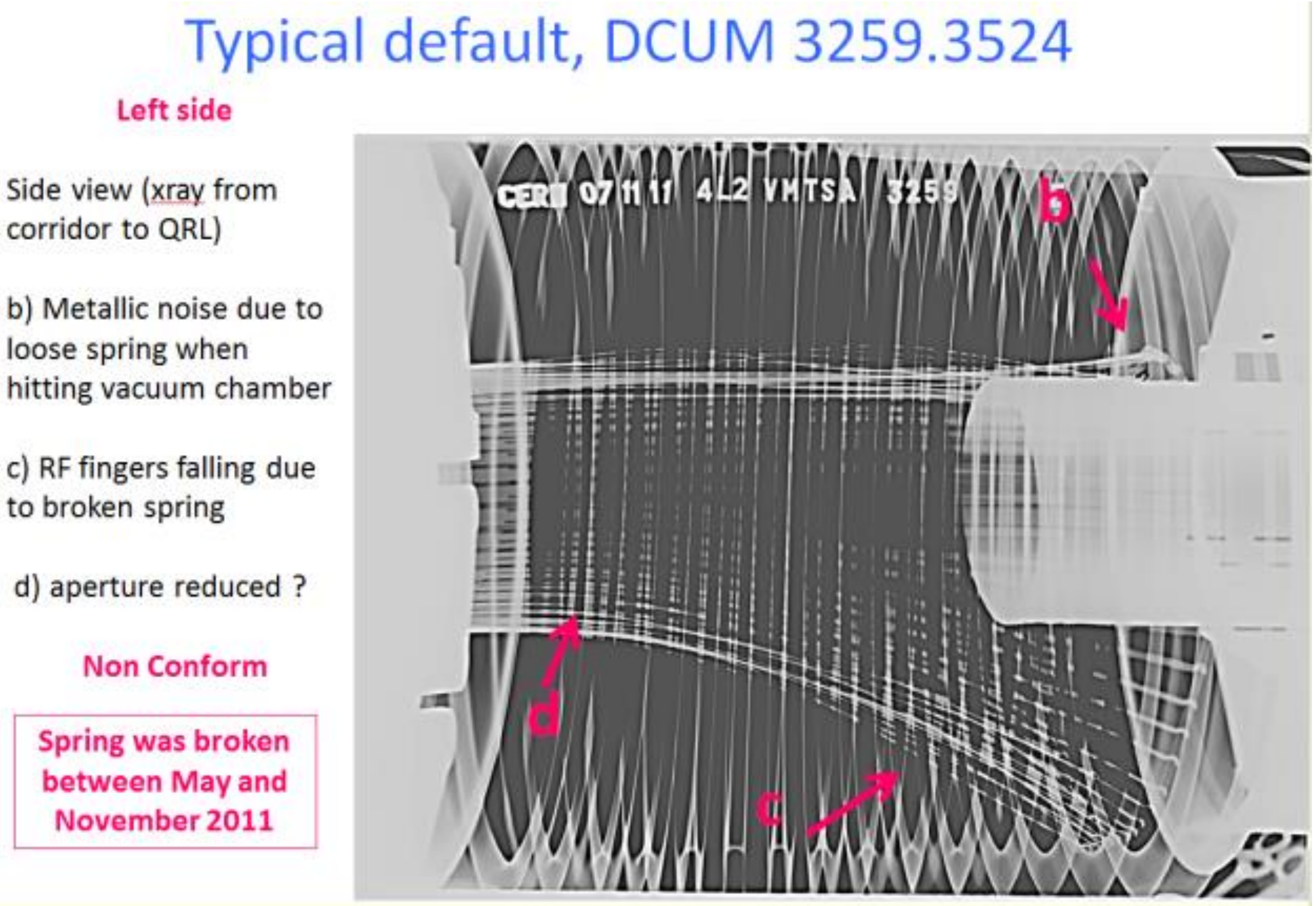
- Design extrapolated and not mechanically validated before installation in the ring
- Pressure spikes located beside inner triplets generated interlocks and background



Observed Pressure spikes during a physics fill

Vacuum Modules : VMTSA - 2011

- X-rays done in May showed a conform module, in November the module was broken
- The RF bridge was destroyed by the beam !
- 8 out of a total of 20 in LHC were damaged i.e. 40 %



Typical default, DCUM 3259.3524

Left side

Side view (xray from corridor to QRL)

b) Metallic noise due to loose spring when hitting vacuum chamber

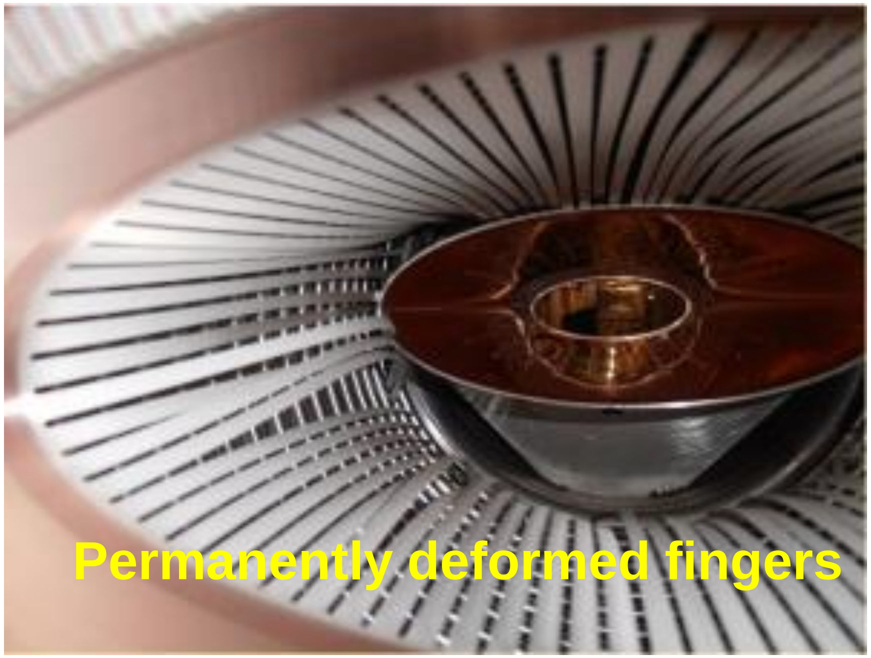
c) RF fingers falling due to broken spring

d) aperture reduced ?

Non Conform

Spring was broken between May and November 2011

Heating due to Re[Z]



Permanently deformed fingers

LHC: the most expansive brazing machine

- Origin of the systematic default was identified to be due to a poor contact between the RF finger and the transition tube.

- Lesson : always validate the design of your components (**even** under schedule pressure)

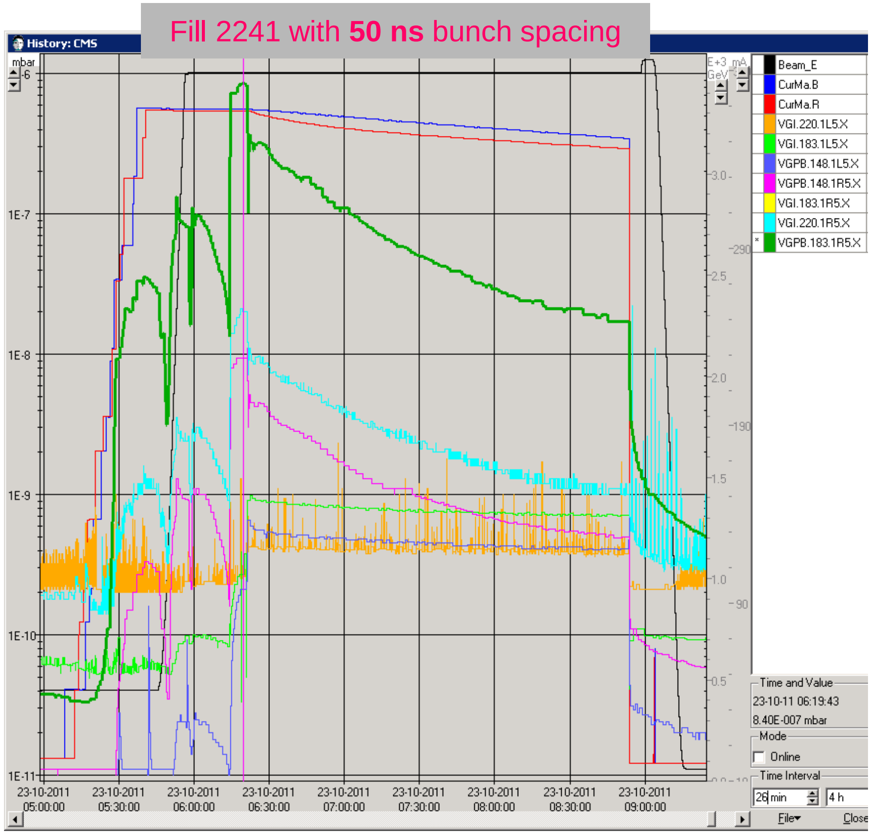
See R. Wanzenberg, B. Salvant and S. Calatroni lecture and tutorial

2011: Pressure spikes in right side of CMS

- In 2011, frequent pressure spikes, some up to 10^{-6} mbar, were observed at CMS, 18 m, right side.

- When the local pressure was above 10^{-8} mbar, CMS background was larger than 100 % thereby reducing the detector capability

Fill 2241 with **50 ns** bunch spacing



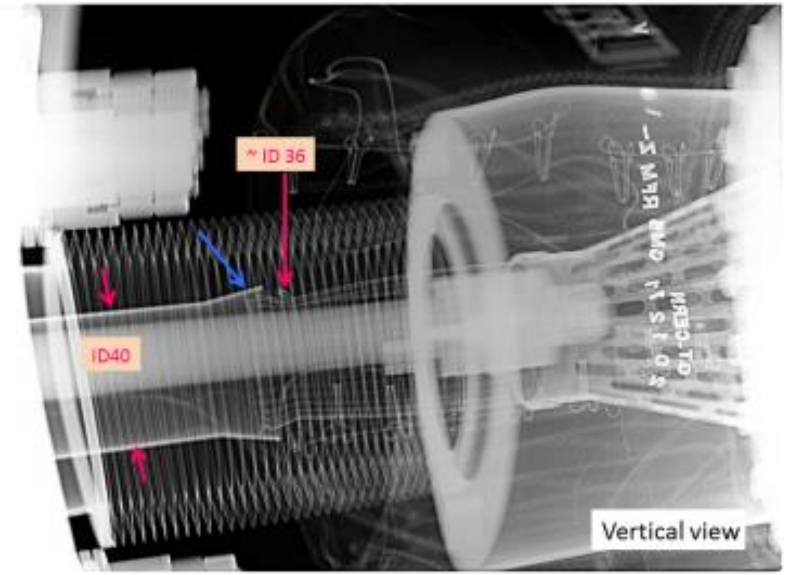
■	Beam_E
🟦	CurMa.B
🟥	CurMa.R
🟧	VGI.220.1L5.X
🟩	VGI.183.1L5.X
🟦	VGPB.148.1L5.X
🟪	VGPB.148.1R5.X
🟨	VGI.183.1R5.X
🟦	VGI.220.1R5.X
* 🟩	VGPB.183.1R5.X

Time and Value
23-10-11 06:19:43
8.40E-007 mbar

Mode
☐ Online

Time Interval
26 min
4 h

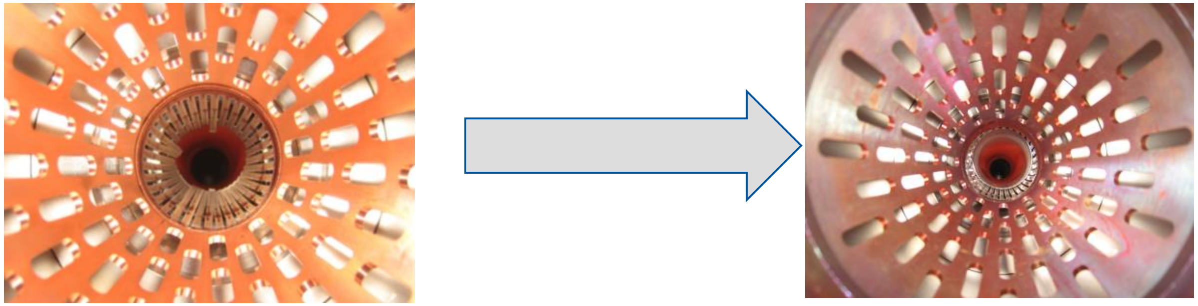
Typical Observation

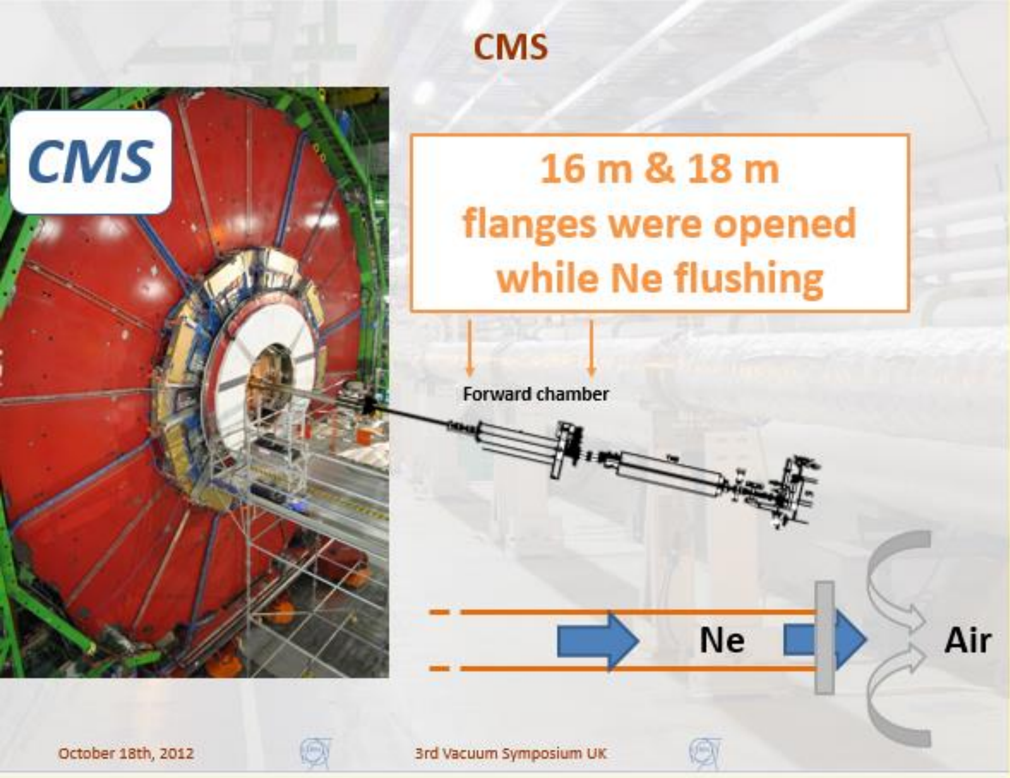


Courtesy J-M. Dalin EN-MME

Ne venting to save the 2012 CMS Run !

- Vacuum system performance recovered even following the dismounting of 2 m long vacuum chambers





CMS

16 m & 18 m
flanges were opened
while Ne flushing

Forward chamber

Ne

Air

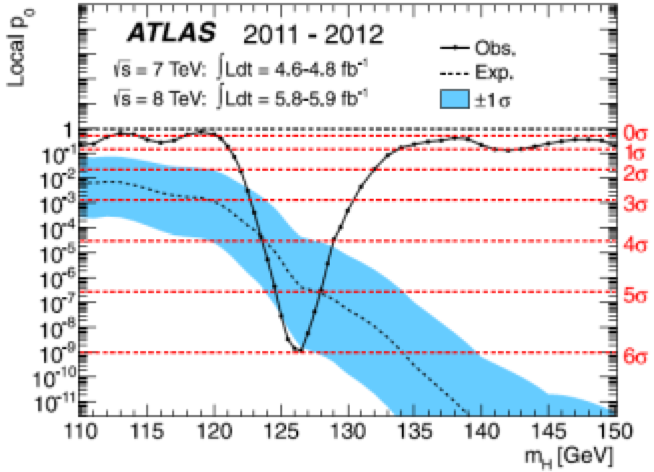
October 18th, 2012

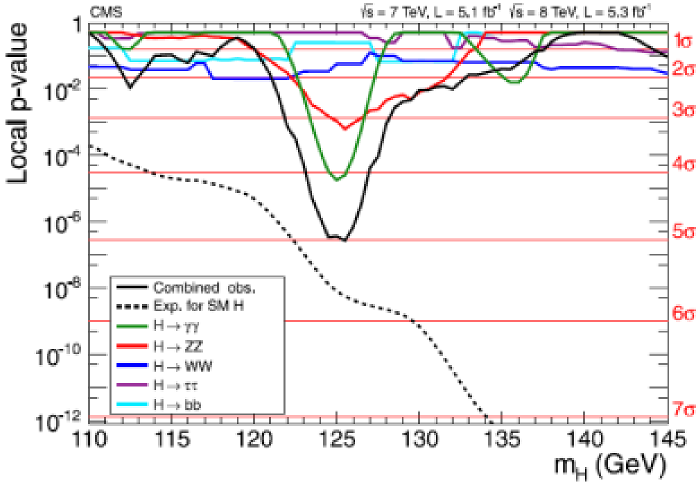
3rd Vacuum Symposium UK

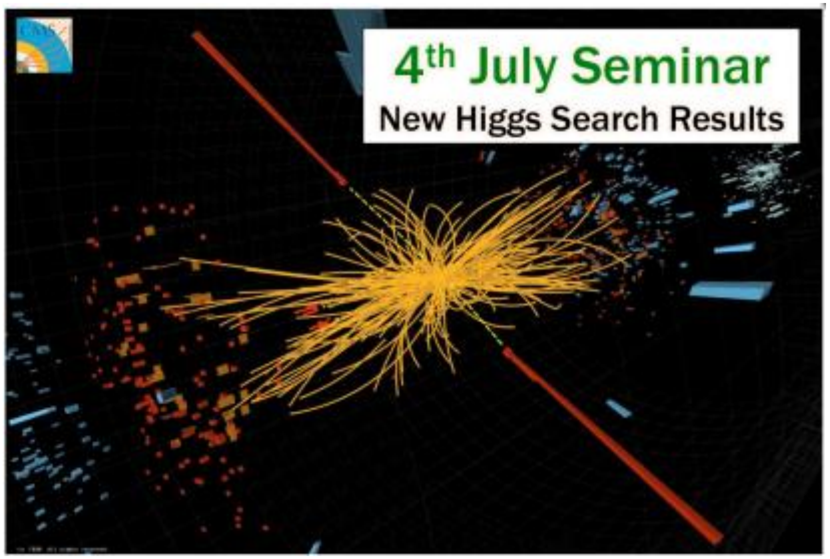
January 2012

4th July 2012: SM BEH Boson Discovery

ATLAS and CMS discovered a new boson in the mass region ~ 125-126 GeV/c^2





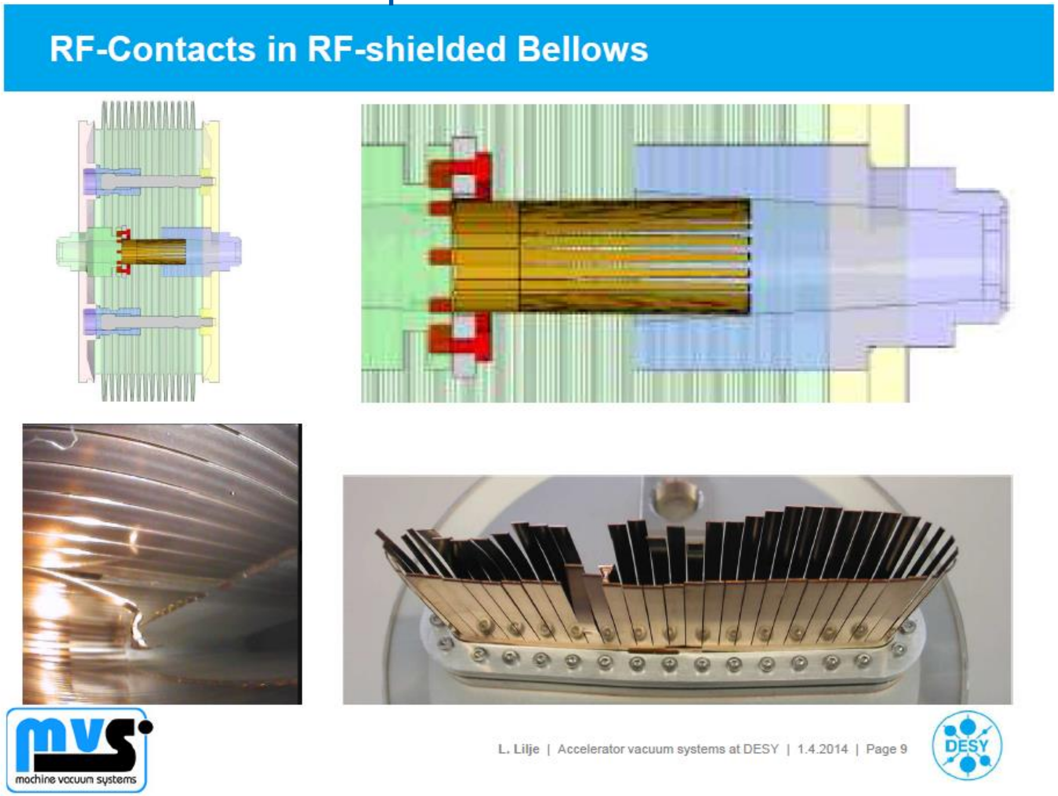


RF bridge: PETRA III

- PETRA III RF contact are placed inside the transition tube when the bellow are over-extended

  => beam intensity limited in 40 bunch modes to 80 mA till 2012 (design 100 mA)

- Define specification
- Check at surface mechanical and electrical specification



RF-Contacts in RF-shielded Bellows

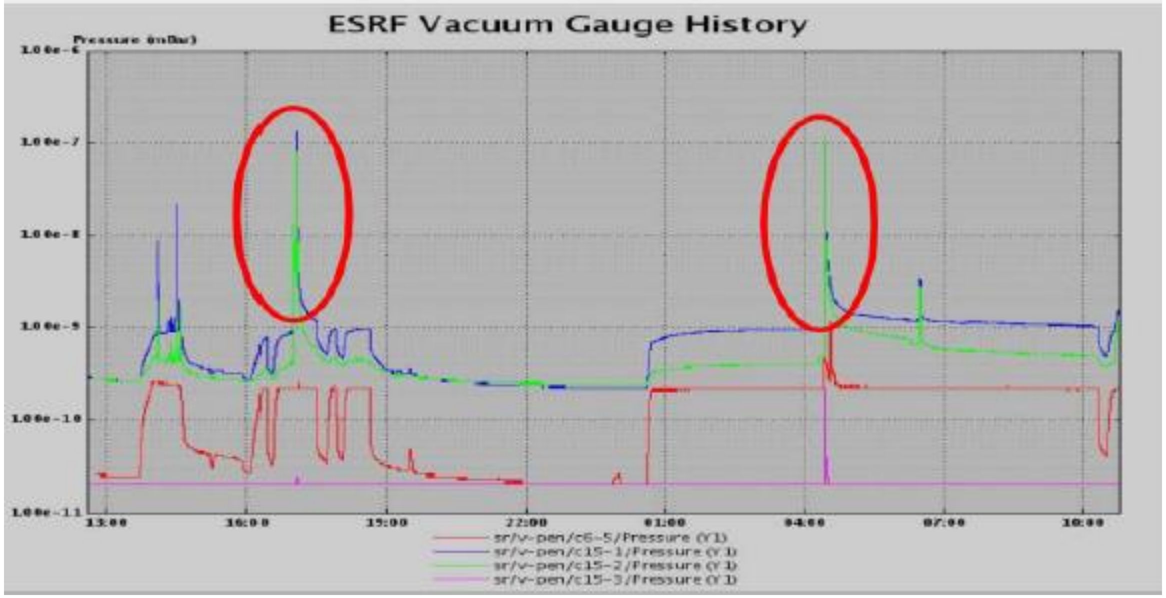
L. Lilje | Accelerator vacuum systems at DESY | 1.4.2014 | Page 9

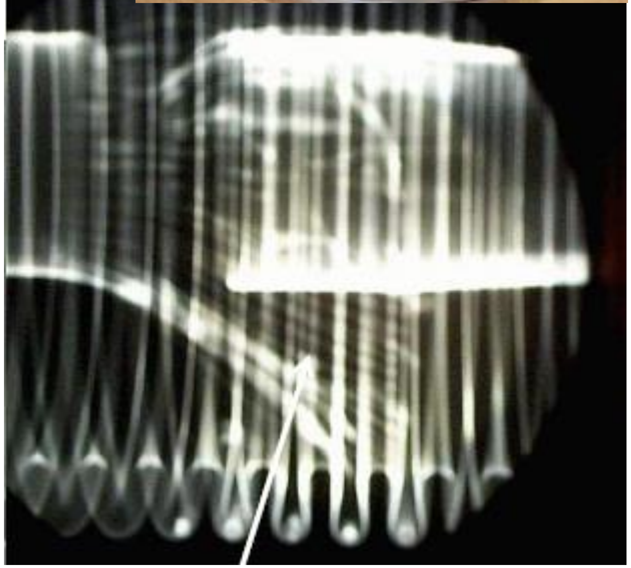
Courtesy L. Lilje

RF bridge: ESRF

- Vacuum levels and gamma-graphy are great tools to avoid disaster.

- X-rays before machine closure and pressure follow up helps!



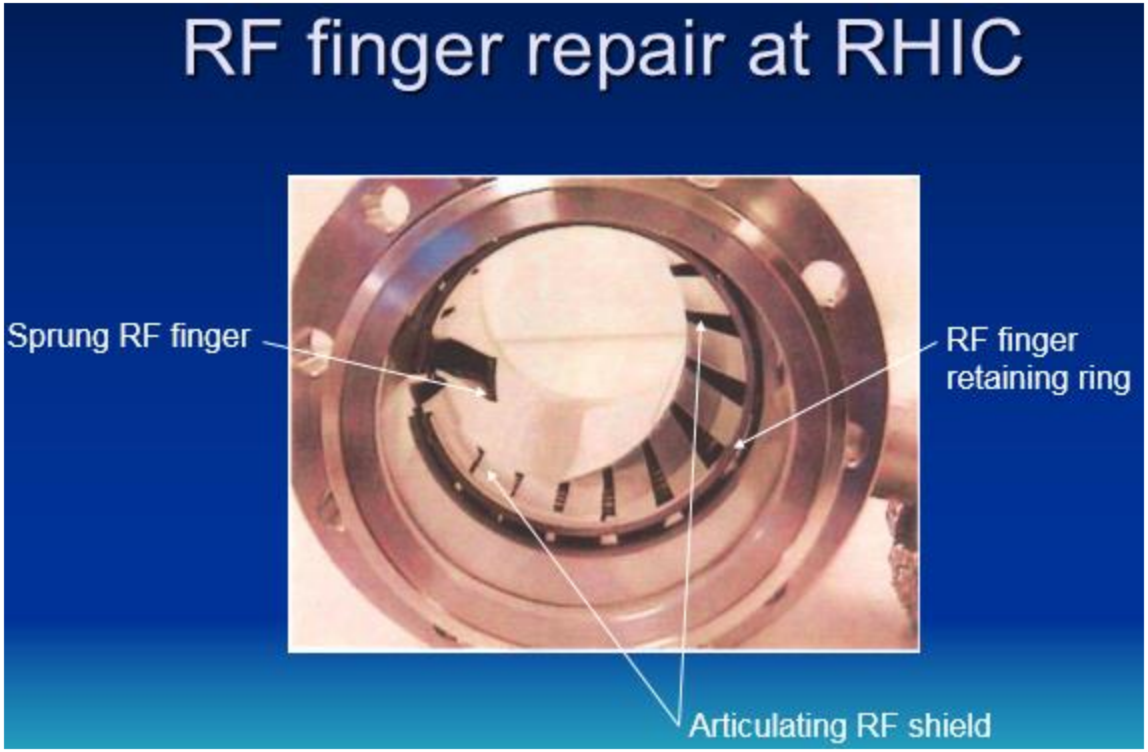


RF Contact: SOLEIL

- Misplaced RF contact are producing arcing

N. Bechu, OLOAV 2014

RF bridge: RHIC



RF finger repair at RHIC

P. Sampson, ARW2009

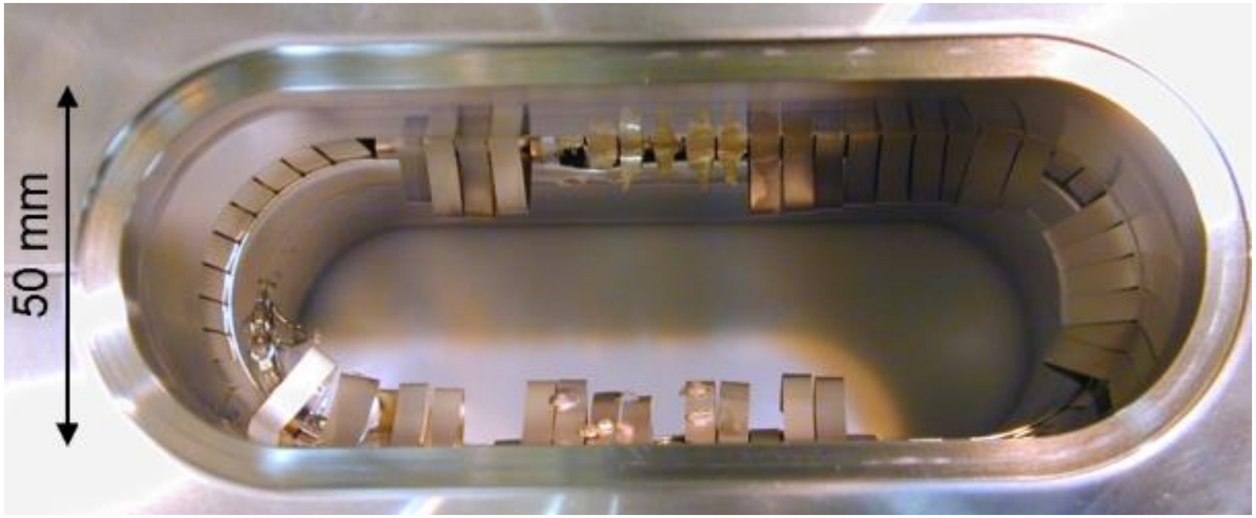
RF bridge: BEPC II

Bellow damaged downstream

of R21-AMB

J, Cao, ARW2013

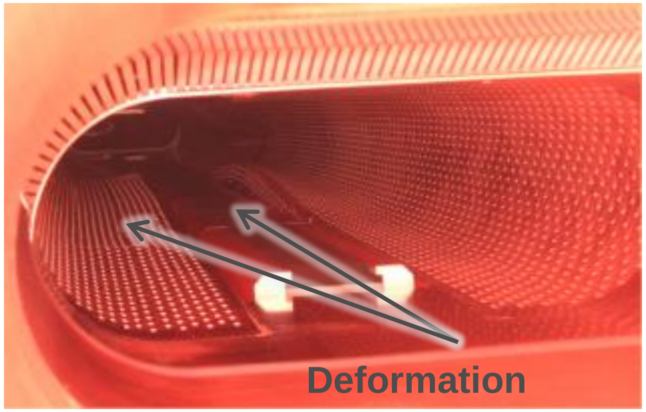
RF Bridge: KEKB



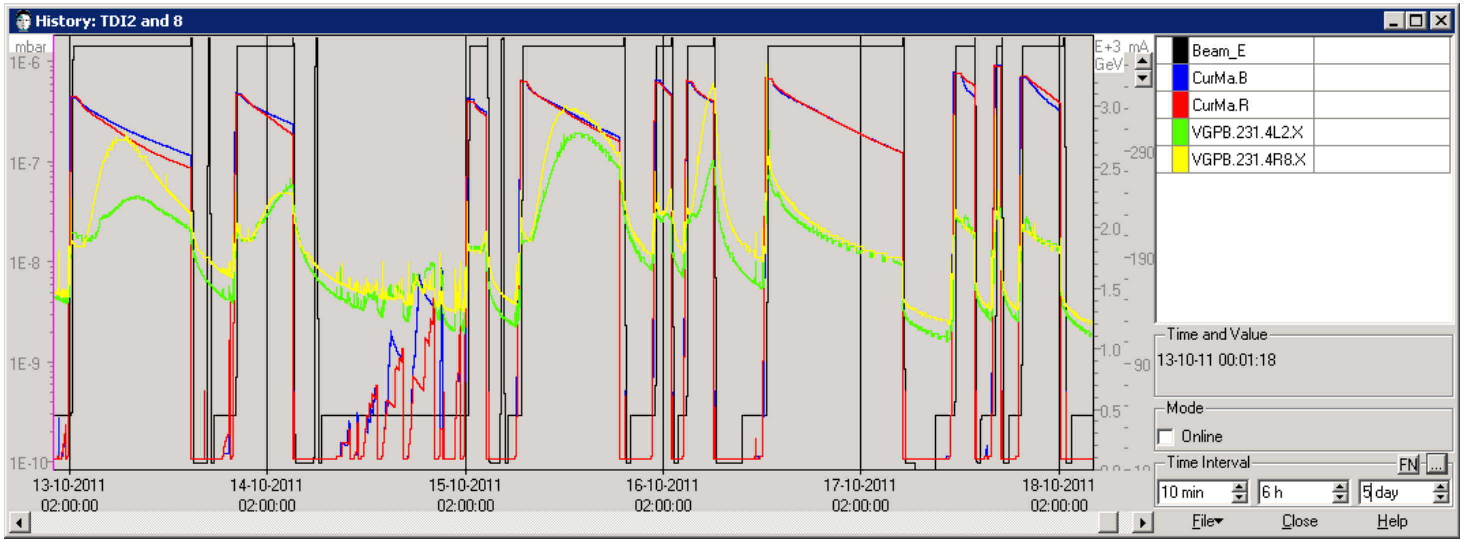
M. Mazuzawa, 2004

Beam induced outgassing

- A movable mask to protect ALICE during injection (Boron nitride jaw)
- Deformed beam screen observed during winter technical stop 2011-12
    - Suspected origin is a bad sliding point
    - Cu beam screen was deformed during bakeout at 300 deg



- Beam induced, via impedance, thermal outgassing
    - ~ 10^{-7} mbar



Time and Value: 13-10-11 00:01:18

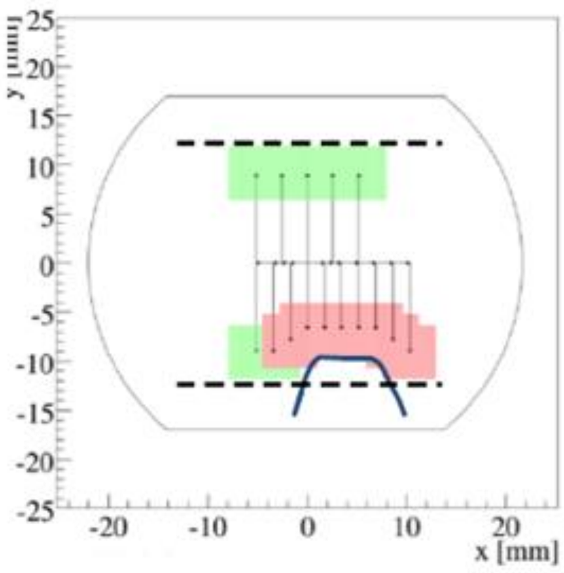
Mode: ☐ Online

Time Interval: 10 min | 6 h | 5 day

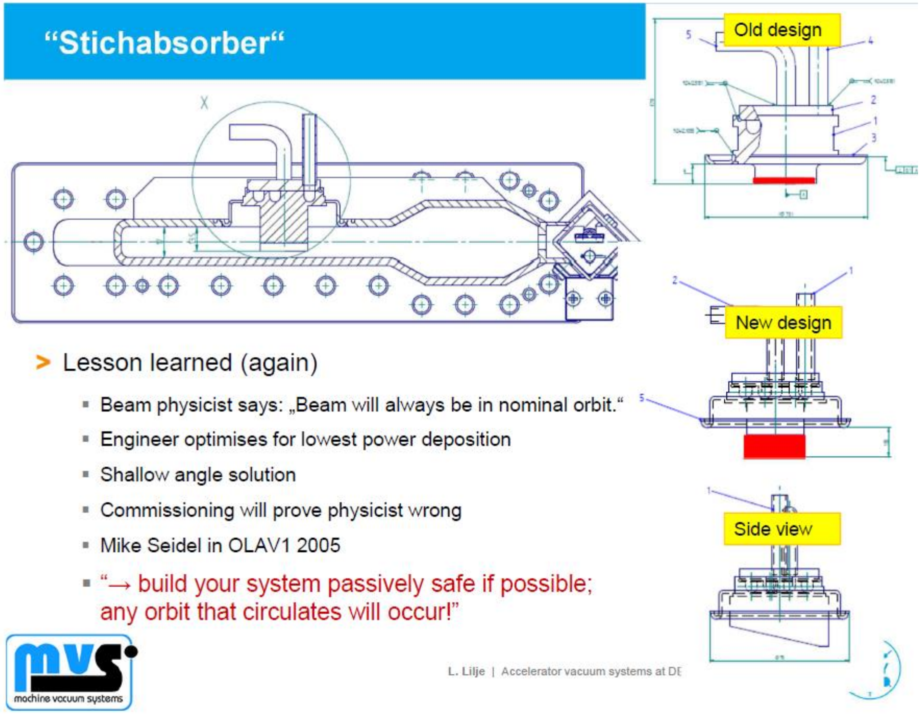
Benefit of a large aperture

- Allows many optics to be deployed, in particular new ones not foreseen at the stage of the design *e.g.*
  - CERN Achromatic Telescope Squeeze to be used for HL-LHC
  - PETRA III

- Solving ULO (unidentified lying object) issue by applying a bump



CERN ULO 15R8



“Stichabsorber“

> Lesson learned (again)
- Beam physicist says: „Beam will always be in nominal orbit.“
- Engineer optimises for lowest power deposition
- Shallow angle solution
- Commissioning will prove physicist wrong
- Mike Seidel in OLAV1 2005
- “→ build your system passively safe if possible; any orbit that circulates will occur!”

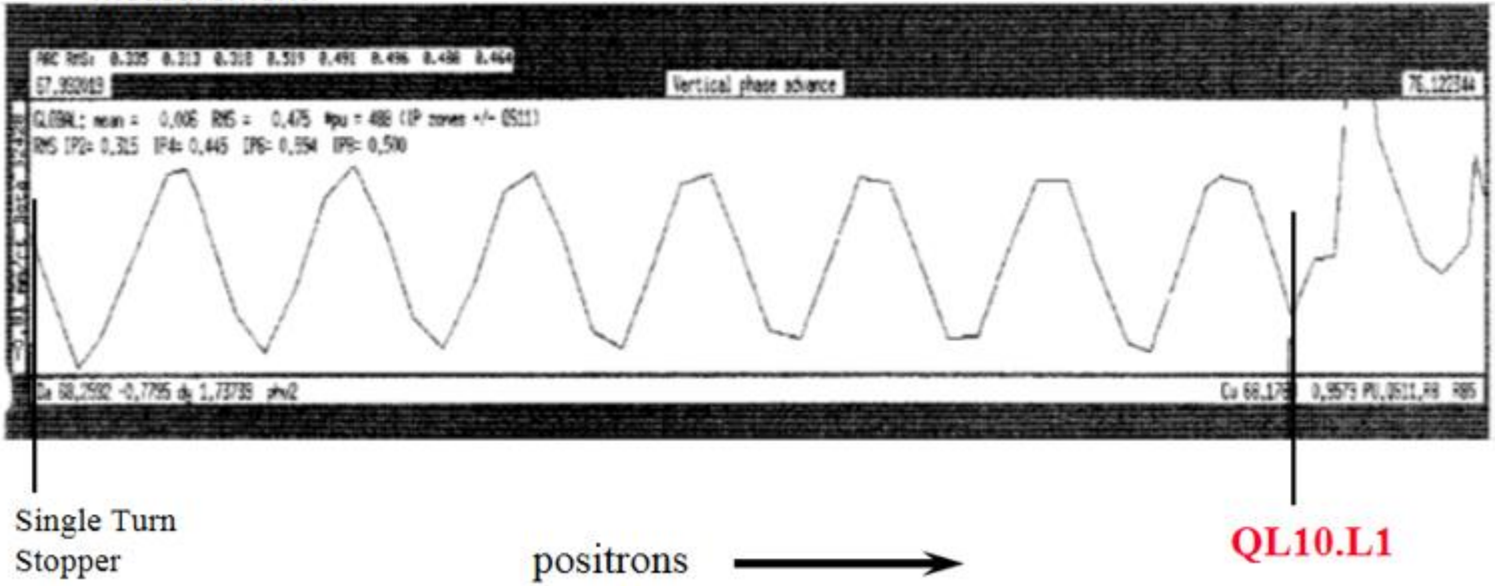
machine vacuum systems

L. Lilje | Accelerator vacuum systems at DE

L. Lutz, Olav 2014

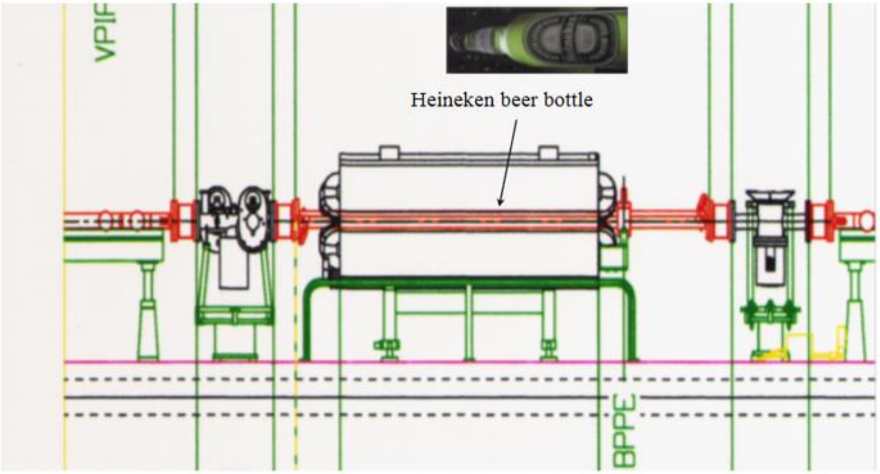
Unexpected beam aperture restriction in LEP around IP1 22 June 1996

Could not get the beam to circulate more than 15 turns even with large bumps all around the ring. Use single turn orbit system and normalised the measurement.

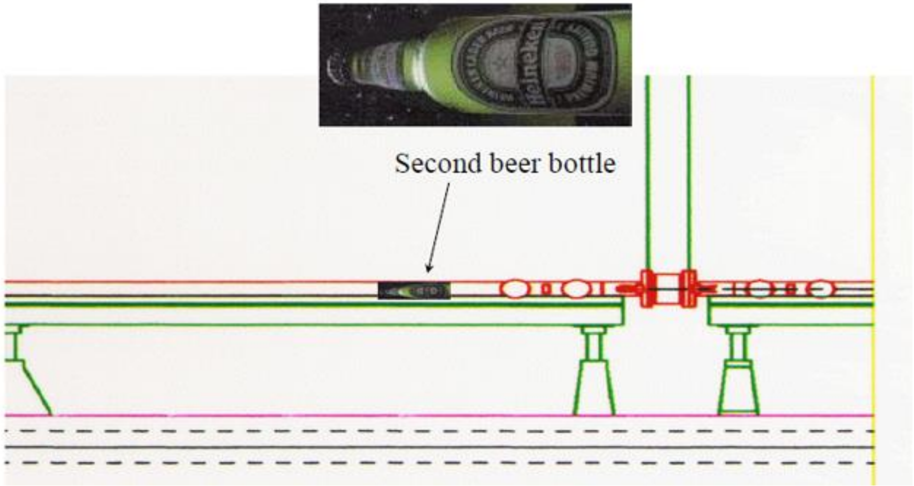


S. Myers

Unexpected beam aperture restriction in LEP around IP1 22 June 1996



Zoom in on Quadrupole



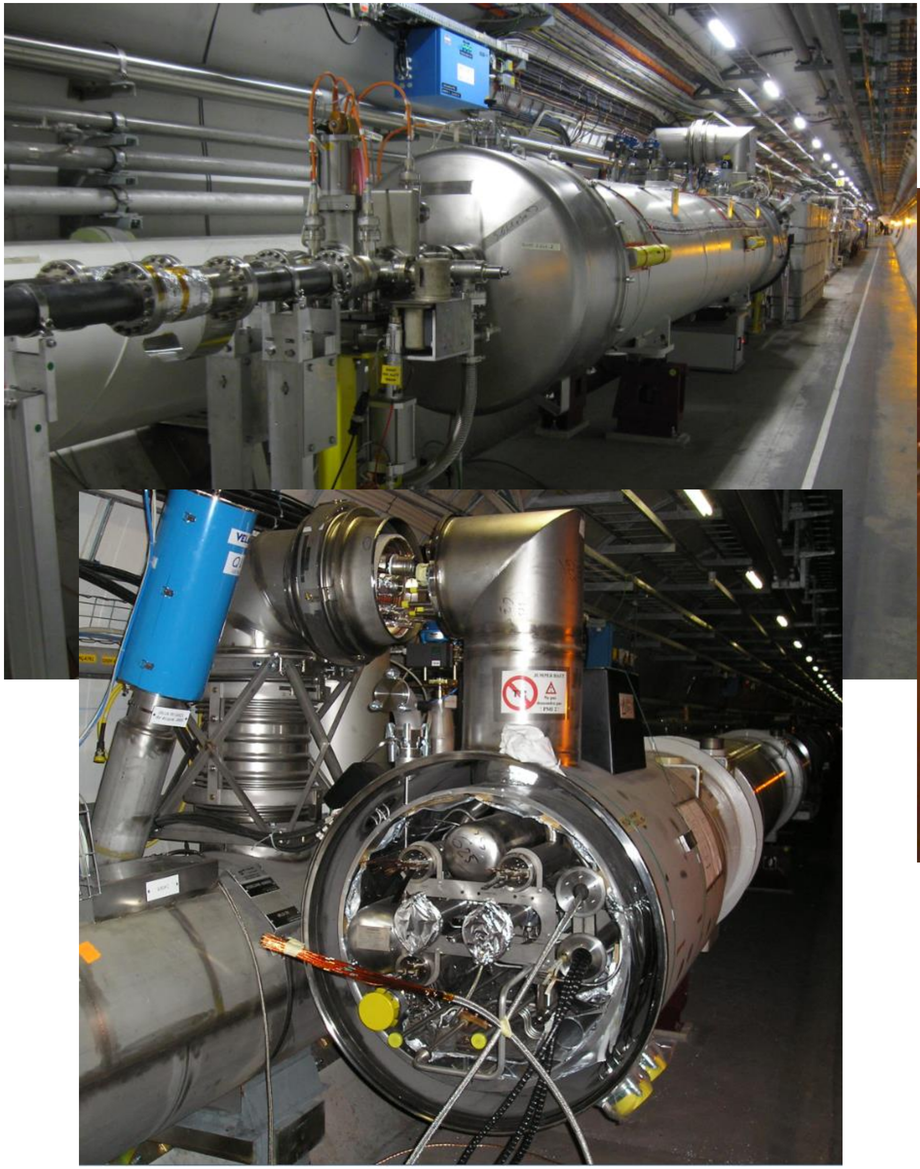
10 metres to the right

- Qualified by of the CERN accelerator director, S. Myers, of:

Unsociable sabotage: both bottles were empty!!

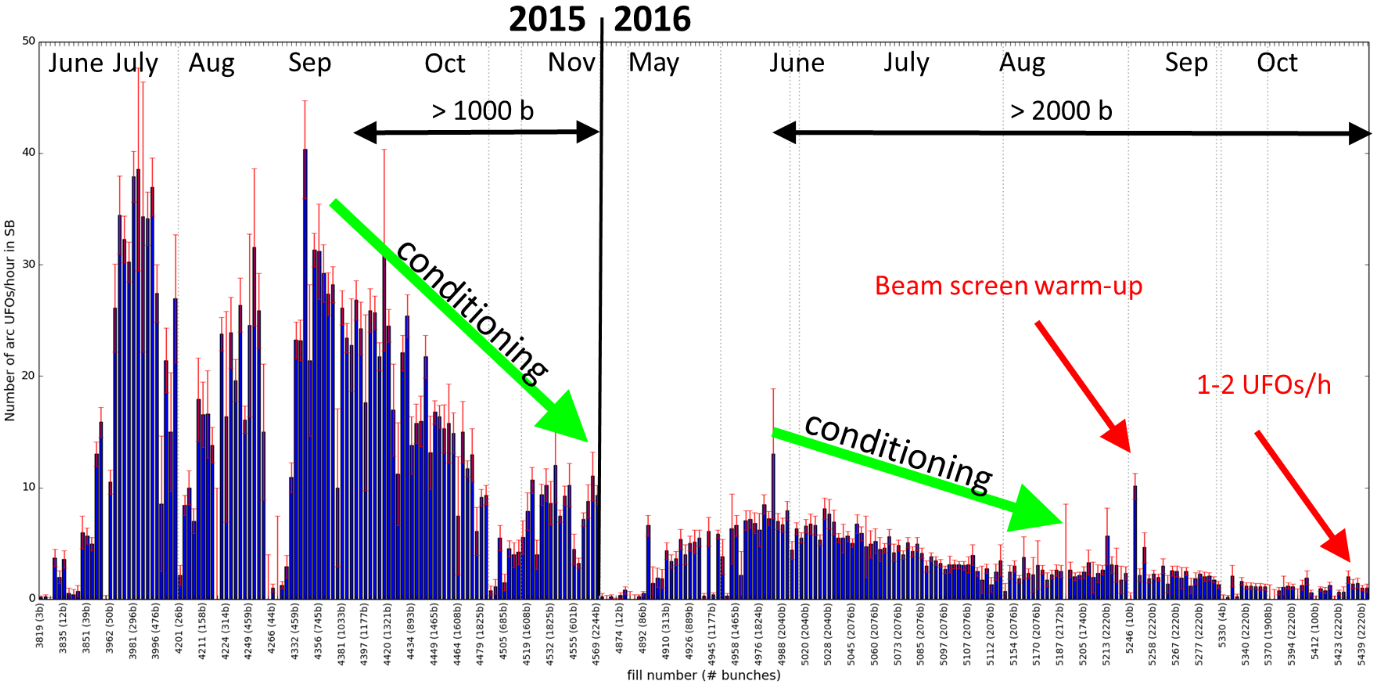
1.4 Energy losses

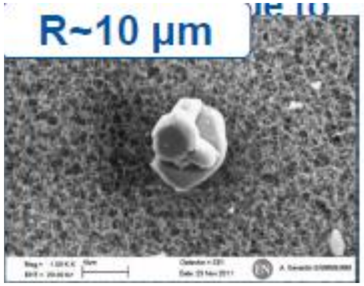
Tunnel environment and cleanliness …



UFO Particulates

- They originate from the construction / installation and may latter interact with the beams
- Most of the particulates have a positive charge (shall be less sensitive to positive beams)
- HERA
  - pumping system upgraded to NEG strip and positron operation preferred
- LHC
  - Most of them are very small, a few leads to beam dump triggered by BLM system
  - Rate reduce with time thanks to gravity and vibrations.

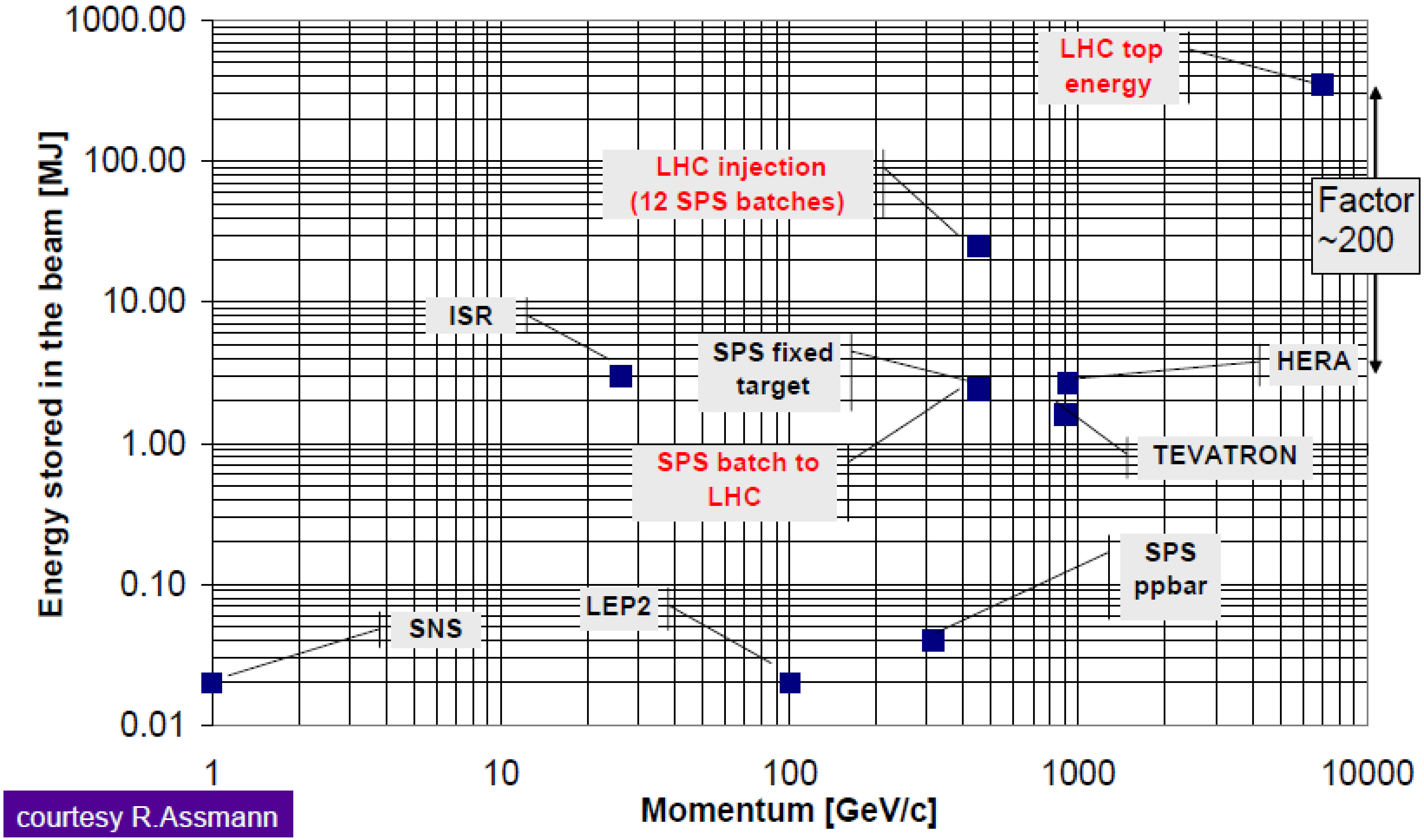




See lecture L. Lilje

Stored Energy

- Modern machines have a few MJ of energy … what can you do with that apart from collision ?



courtesy R.Assmann

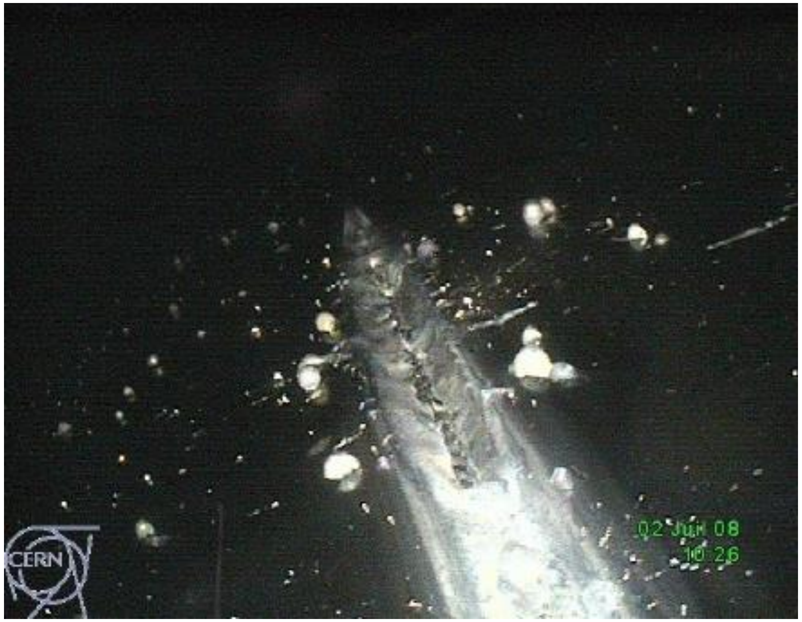
See F. Cerutti, M. Brugger lectures

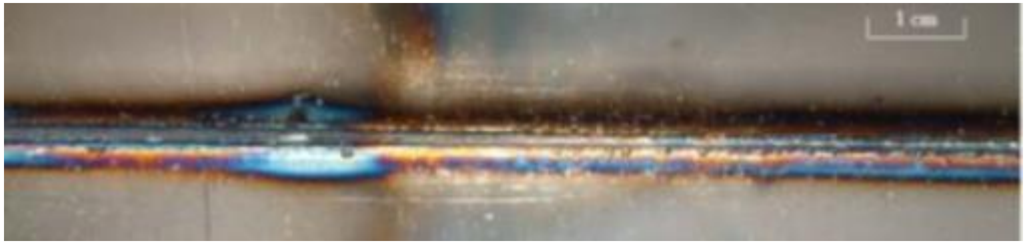
Beam extraction from SPS: 10/2004

- 450 GeV beam, 3.4 10^{13} p on stainless steel (3 MJ) miskicked, result:

➔ A 1 m long groove along a SPS vacuum chamber after the impact of ~1% of a nominal LHC beam during an ‘incident’: ~ 3 days repair

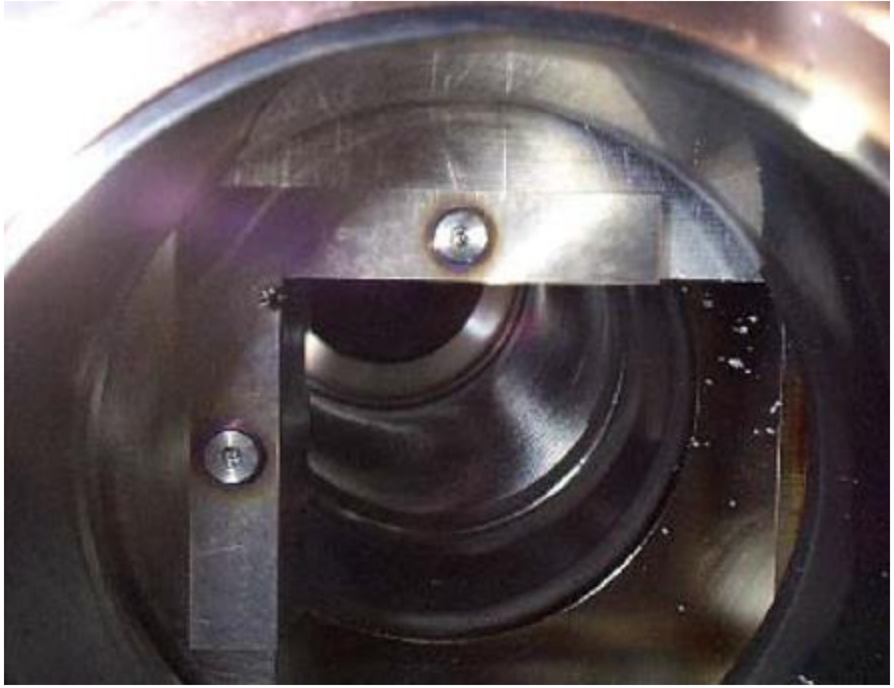
- **In a superconducting machine, it would cost several months of work!**



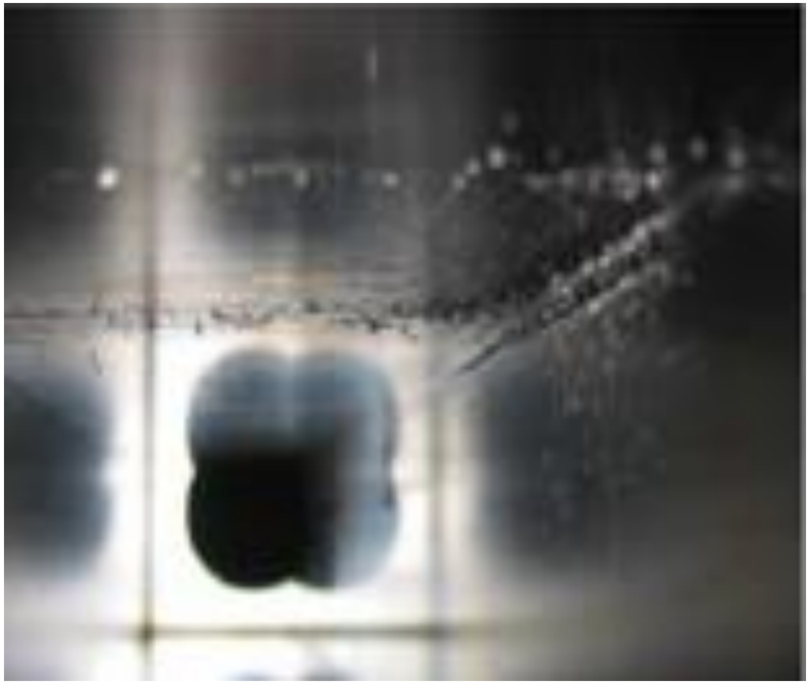


TEVATRON Accident: 5 December 2003

- A roman pot moved into the beam
  - ➔ the particle showers quenched 16 superconducting magnets
- The beam moved by 0.005 mm/turn and touched a collimator jaw surface after ~ 300 turns
  - ➔ the entire beam was lost, mostly at the collimator
- Beam loss monitor where switched off!
- 10 days repair



5 mm hole in a vertical W jaw



25 cm groove in stainless steel

Also with electrons machine

- Example of an air leak in SPRING 8:
  - 8 GeV electron beam with 15 micron vertical beam size on a 0.7 mm thick stainless steel wall

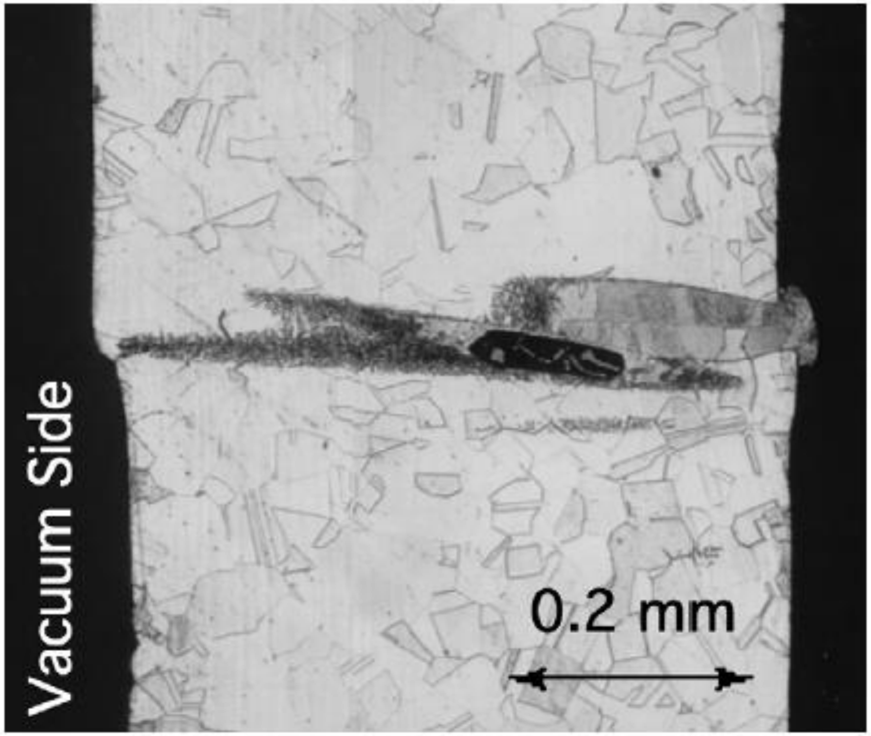


Fig. 6. Cross section of the injection chamber wall at the broken part. It seems that the electron beam hits the thin wall several times, since many traces of electron beam bombardment were found.

M. Shoji *et al.*
Vacuum 84 (2010) 738–742

Also with photons from SR machine

- Example of melted gate valve at SSRF, Shangai:
  - The photon shutter was opened while the gate valve was closed, the synchrotron radiation produced by 3.5 GeV electron beam at 200 mA melted the stainless steel.

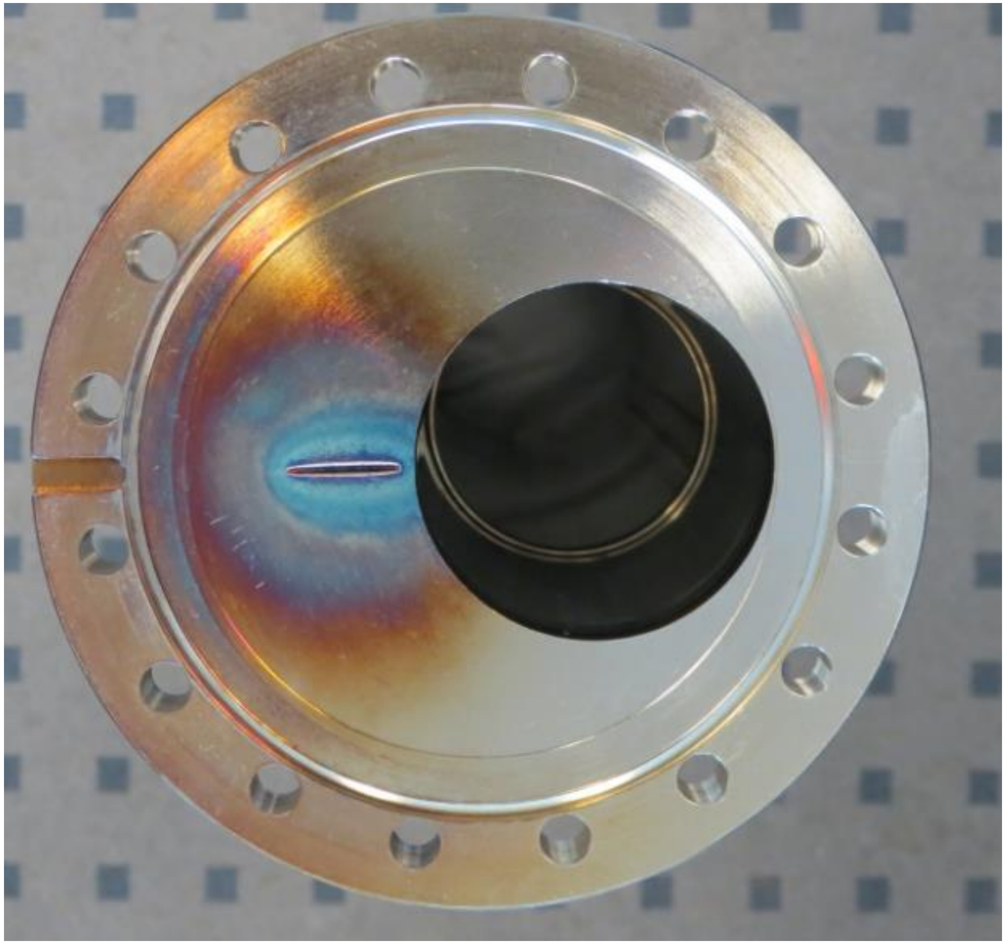
L. Yin, ARW2013

Also with photons from SR machine

- Example of SOLEIL, france

Metal melted by SR

heat load

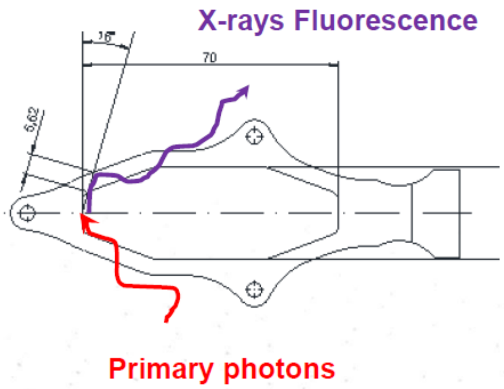


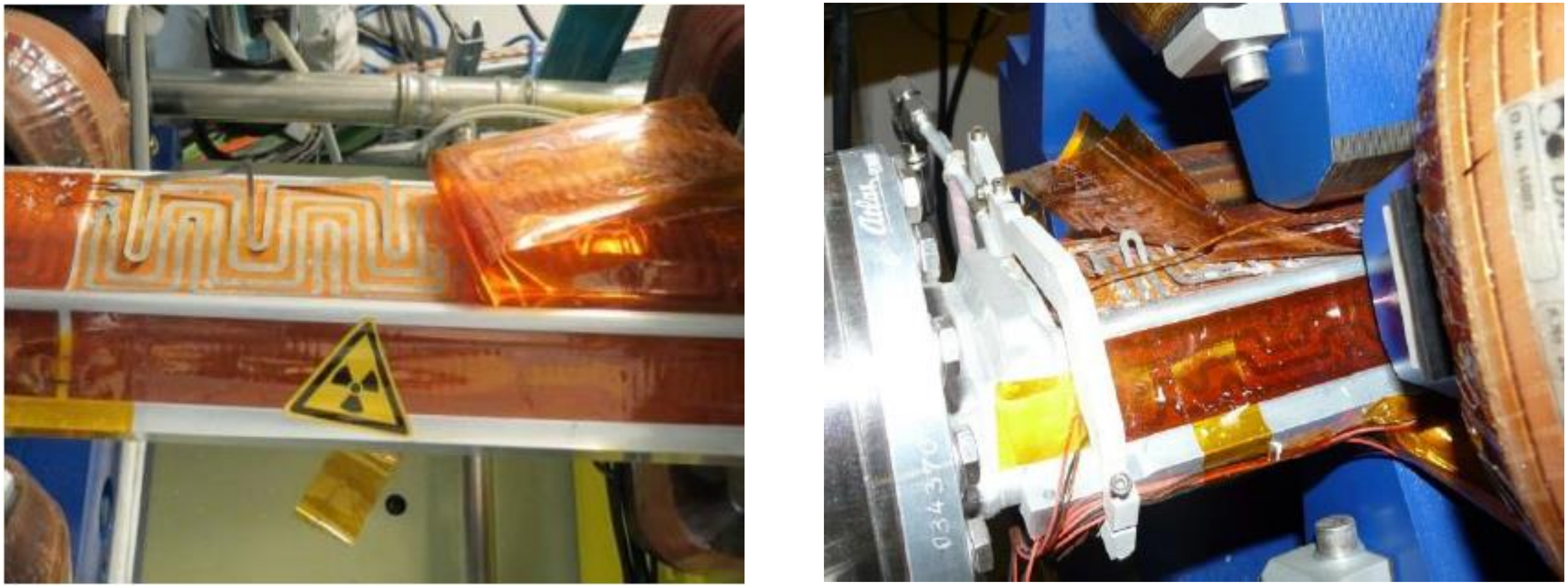
Courtesy N. Bechu

SR induced fluorescence

- Observed at SOLEIL, france

- The X-ray fluorescence of Zr at 16 and 18 keV can destroy the Kapton bakeout foil if the Al or Cu vacuum chamber is thick enough





C. Herbeaux, OLAV 2014

The read pressure is not always a true pressure

- Photons produce photoelectrons, stray particles can ionised the cable or magnetic field can modified significantly the reading of pressure

The apparent absence of beam conditioning is due to scattered particles on the gauge collector and cable

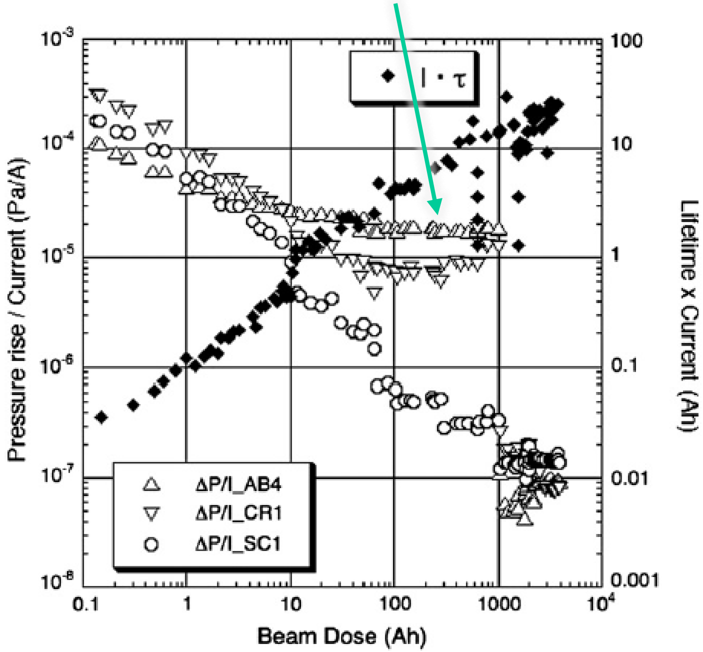
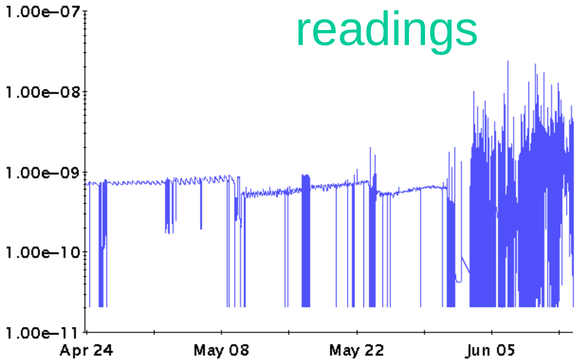
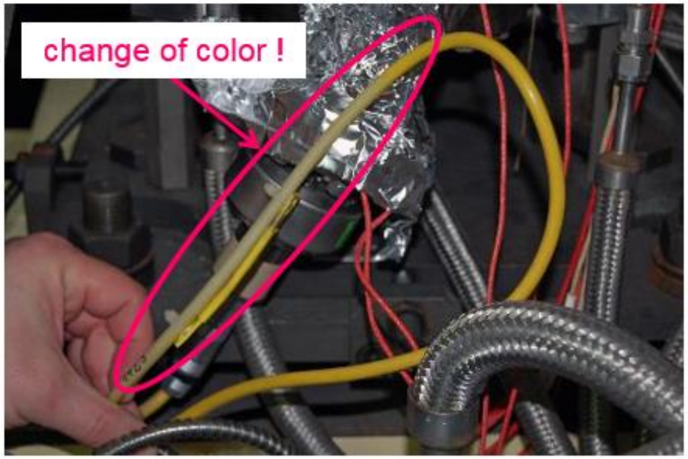


Fig. 2. Normalized pressure rise and beam lifetime as a function of beam dose. Pressure rise is the difference between beam-on and beam-off pressure.

M. Shoji *et al.*
Vacuum 84 (2010) 738–742

Erratic pressure readings





L. Hardy, ARW 2009

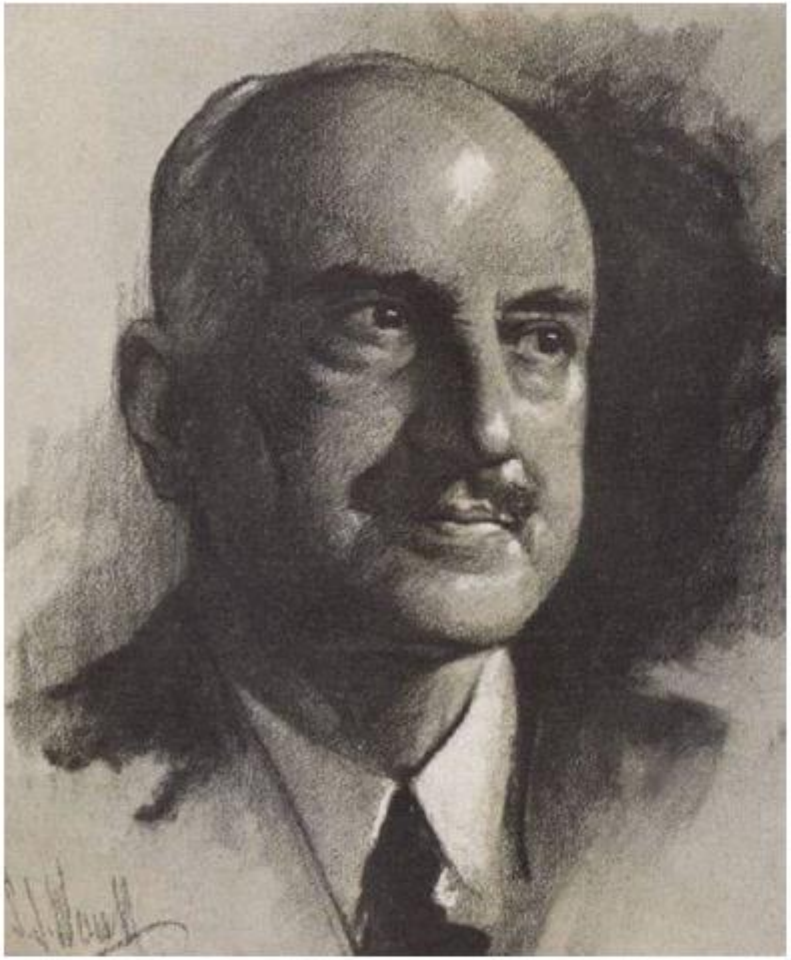
See F. Cerutti and M. Brugger lectures

1.5 Summary

Summary

- The vacuum group people have always the impression of being firemen !!!!!

- Can we do better?



Those who cannot remember the past are condemned to repeat it.

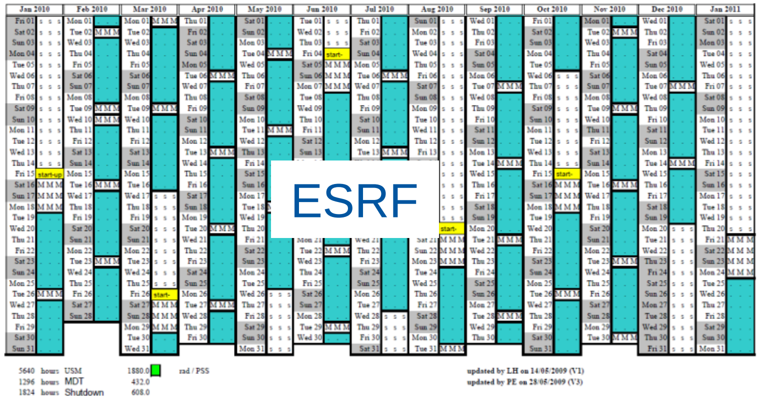
George Santayana

2. Quest towards availability

Availability: Vad fan är det här?
(what the hell is this?)

Availability: The percentage of time an equipment is in operable state

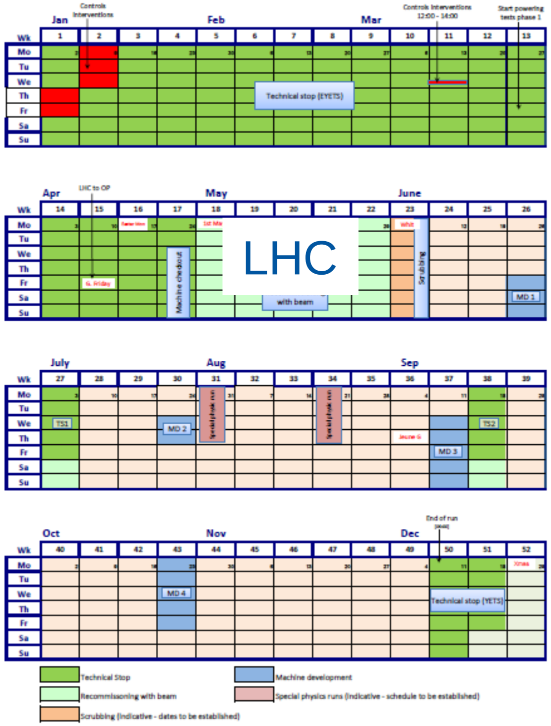
Accelerator schedule: objective beam time!



ESRF

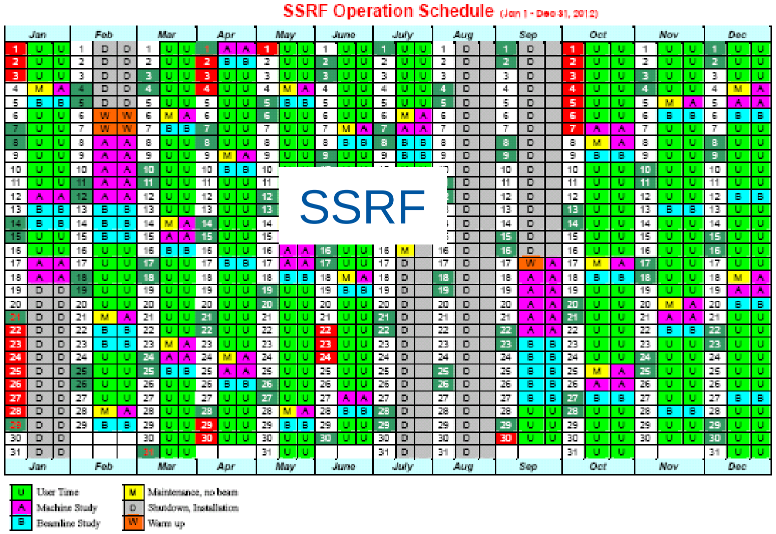
5640 hours USM 1880.0 🟩 rad / PSS
1296 hours MDT 432.0
1824 hours Shutdown 608.0

updated by LH on 14/05/2009 (V1)
updated by PE on 28/05/2009 (V3)



LHC

🟩 Technical Stop
🟦 Machine development
🟩 Recommissioning with beam
🟥 Special physics runs (Indicative - schedule to be established)
🟧 Scrubbing (Indicative - dates to be established)



SSRF Operation Schedule (Jan 1 - Dec 31, 2012)

SSRF

U	User Time	M	Maintenance, no beam
A	Machine Study	D	Shutdown, Installation
B	Beamline Study	W	Warm up

2.1 Study, Design, Procurement & Installation

Design reports

- Communication & release of Official documents and books is mandatory to share pertinent information across the project

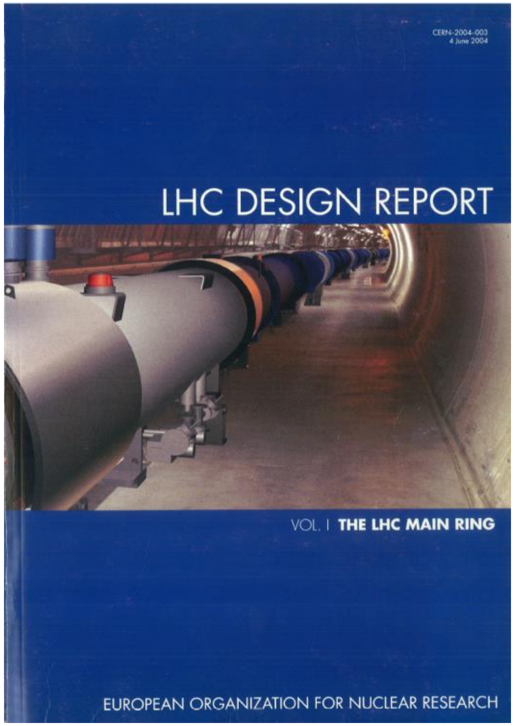
MAX IV design report

Detailed Design Report

MAX IV Facility

2010

LHC design report



CERN-2004-003
4 June 2004

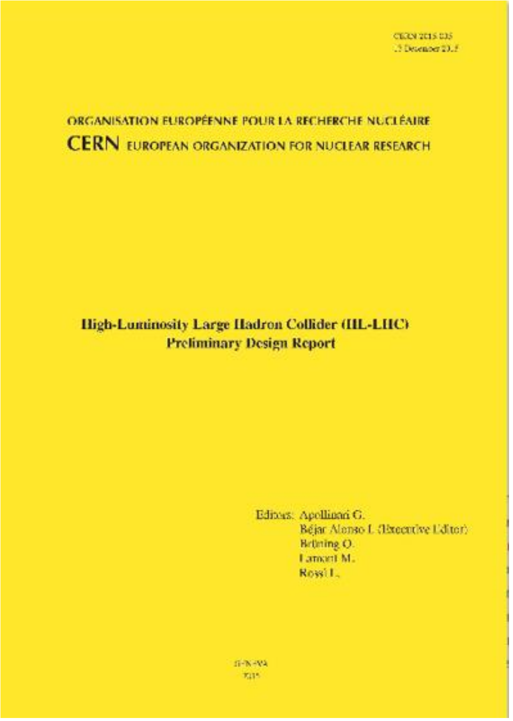
LHC DESIGN REPORT

VOL. I THE LHC MAIN RING

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

2004

HL-LHC
Preliminary design



ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

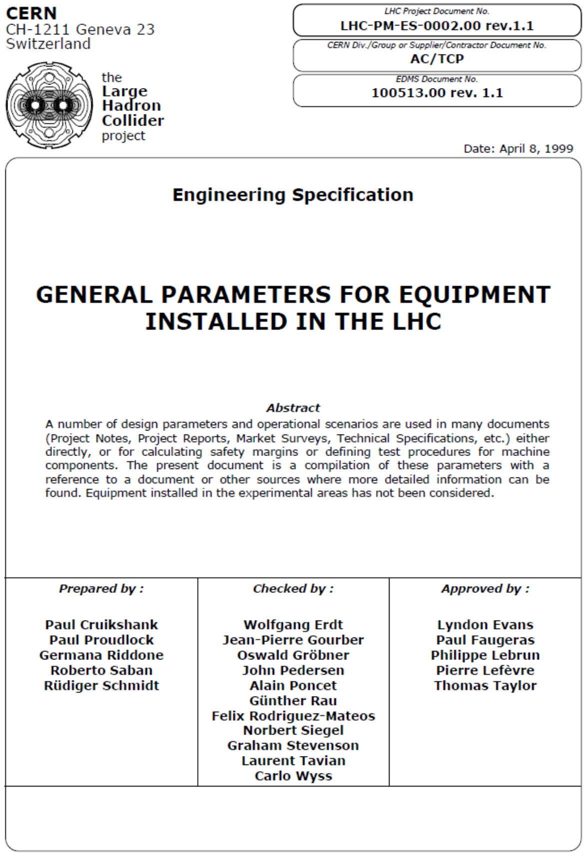
High-Luminosity Large Hadron Collider (HL-LHC)
Preliminary Design Report

Editors: Apollinari G.
Béjar Alonso I. (Executive Editor)
Brüning O.
Lamont M.
Rossi L.

2015

LHC Project

- Defining and understanding the machine parameters impacting the vacuum system was a crucial part of the project



CERN
CH-1211 Geneva 23
Switzerland

the
Large
Hadron
Collider
project

LHC Project Document No.
LHC-PM-ES-0002.00 rev.1.1

CERN Div./Group or Supplier/Contractor Document No.
AC/TCP

EDMS Document No.
100513.00 rev. 1.1

Date: April 8, 1999

Engineering Specification

GENERAL PARAMETERS FOR EQUIPMENT INSTALLED IN THE LHC

Abstract

A number of design parameters and operational scenarios are used in many documents (Project Notes, Project Reports, Market Surveys, Technical Specifications, etc.) either directly, or for calculating safety margins or defining test procedures for machine components. The present document is a compilation of these parameters with a reference to a document or other sources where more detailed information can be found. Equipment installed in the experimental areas has not been considered.

Prepared by :	*Checked by :*	*Approved by :*
Paul Cruikshank **Paul Proudlock** **Germana Riddone** **Roberto Saban** **Rüdiger Schmidt**	**Wolfgang Erdt** **Jean-Pierre Gourber** **Oswald Gröbner** **John Pedersen** **Alain Poncet** **Günther Rau** **Felix Rodriguez-Mateos** **Norbert Siegel** **Graham Stevenson** **Laurent Tavian** **Carlo Wyss**	**Lyndon Evans** **Paul Faugeras** **Philippe Lebrun** **Pierre Lefèvre** **Thomas Taylor**

	Design	
	Nominal	Ultimate
Energy [TeV]	7	
Luminosity [x10^{34} $cm^{-2}.s^{-1}$]	1.0	2.3
Current [mA]	584	860
Proton per bunch [x10^{11}]	1.15	1.7
Number of bunches	2808	
Bunch spacing [ns]	25	
Normalised emittance [μm.rad]	3.75	
β * [m]	0.55	
Total crossing angle [μrad]	285	
Critical energy [eV]	44.1	
Photon flux [ph/m/s]	1 10^{17}	1.5 10^{17}
SR power [W/m]	0.22	0.33
Photon dose [ph/m/year]	1 10^{24}	1.5 10^{24}

Allow provisions for upgrades!

- There might be always good reasons to upgrade the performance of the machine that you ignore at the time of the design of your project …

ISR Luminosity Evolution

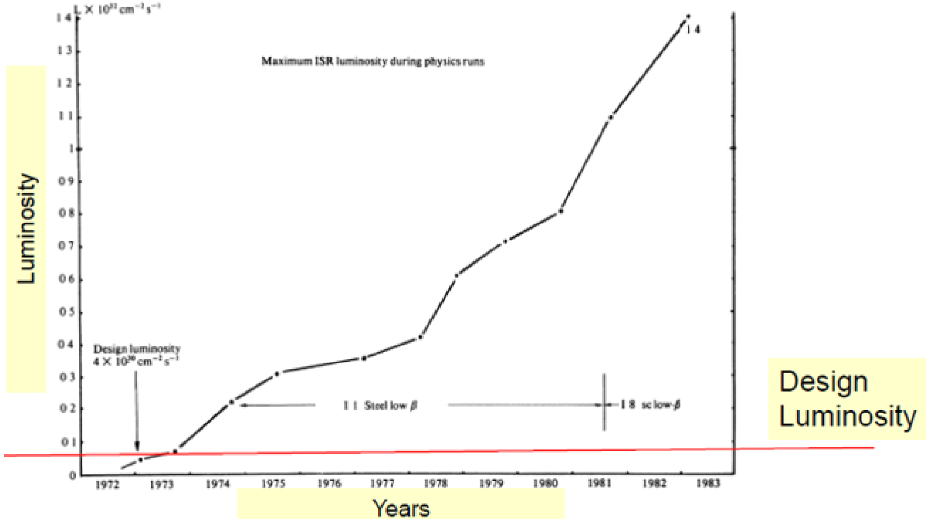
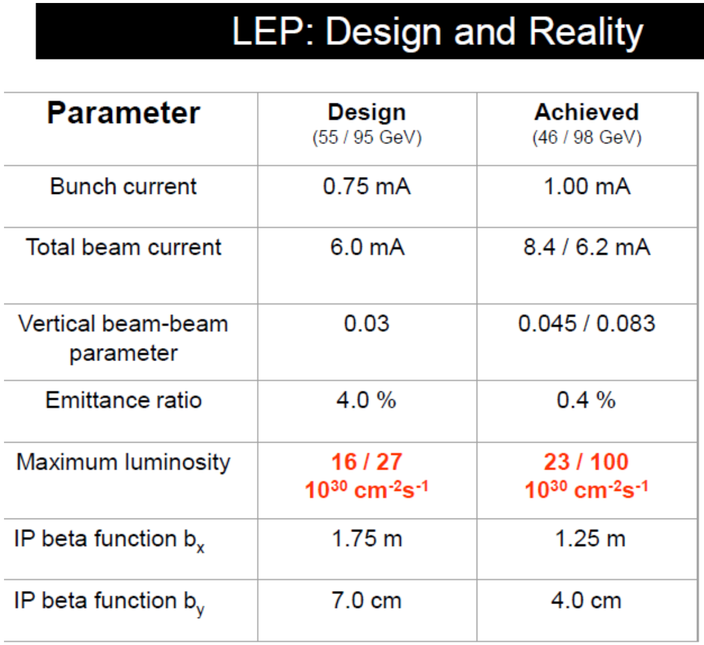


Fig 9 ISR luminosity [illegible] first ISR experiment to be completed, R101; maximum luminosity = 1 3 × 10^{29} cm^{-2} s^{-1} December 1982 -- Highest luminosity achieved for physics (R807) = 1 4 × 10^{32} cm^{-2} s^{-1}



LEP: Design and Reality

Parameter	**Design** (55 / 95 GeV)	**Achieved** (46 / 98 GeV)
Bunch current	0.75 mA	1.00 mA
Total beam current	6.0 mA	8.4 / 6.2 mA
Vertical beam-beam parameter	0.03	0.045 / 0.083
Emittance ratio	4.0 %	0.4 %
Maximum luminosity	**16 / 27** **10^{30} $cm^{-2}s^{-1}$**	**23 / 100** **10^{30} $cm^{-2}s^{-1}$**
IP beta function b_x	1.75 m	1.25 m
IP beta function b_y	7.0 cm	4.0 cm

x 10

x 1.4 / 3.7

Reality better than design (result of many years work)!

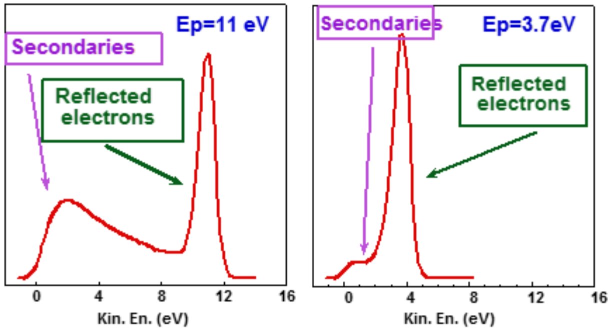
S. Myers

- LEP becomes LEP2
- LHC becomes HL-LHC
- ESRF upgrades
- KEKB becomes SuperKEKB
- …

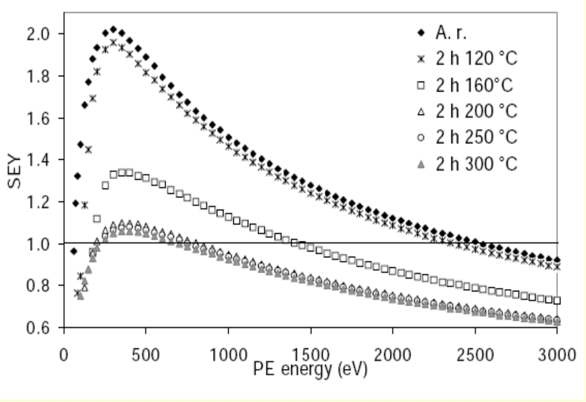
Base Line Validation

- Many studies conducted over ~ a decade with experts all around the world, some examples:

Material performance qualification



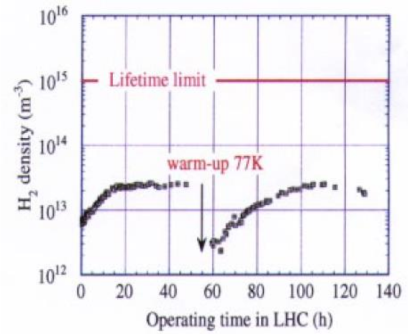
R. Cimino , I.R. Collins, App. Surf. Sci. 235, 231-235, (2004)



C. Scheuerlein *et al.* Appl.Surf.Sci 172(2001)

See O. Malyshev and R. Cimino lectures

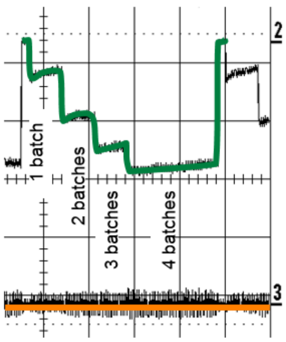
System performance qualification



V. Anashin *et al.*, J. Vac. Sci. Technol. A 14(4) (1996) 2618

Reference unbaked Stainless Steel

ID 156mm - **5V PU**



NEG - activated 250°Cx2h + saturated

rectangular - **100 mV PU**

A. Rossi, Proc. Ecloud'04

Design of components / assemblies

- Design review (conceptual, detailed, production readiness …)
- During LHC procurement, the LHC-VAC group internally reviewed all technical specifications and drawings :
  - ensure compatibility across the vacuum system
  - allows optimisation across components and performance (standardisation)
  - use quality class (class A, approval circuit after control 1&2)

- GOLDEN Rule: reject components, including in-kind, which do not meet VACUUM DESIGN APPROVAL
  - Do's and don'ts (just a few important ones from LHC design and experience)
    - No halogenated fluxes
    - No cold demountable joints
    - Helium envelopes are all-metal
    - Joining techniques need to be validated (materials, welding, DT)
    - No dye penetrant testing
    - Minimise thin wall components.
    - Combine RT leak and pressure test of components
    - Decide a policy for cold testing of critical components
    - Keep non-vacuum group manufacturing under control – assign a vac link person
    - Don't allow deliveries until tightness certification is approved
    - Minimise number of welds to be tested in the tunnel
    - Many, many more
    - …

➔ Technical specification & drawing validation

➔ State of the art material, cleaning methods, procedures

Spares

- a spare policy / strategy shall be defined based on:
  - cost
  - time to recover including building of components
  - failure rate
  - failure probability
  - complexity of the component
  - long term storage of spare
  - In case of accident, does the repair can be done in the shadow of another faulty component ?
  - …

- Driven by major items and possible events (rupture, beam loss …)

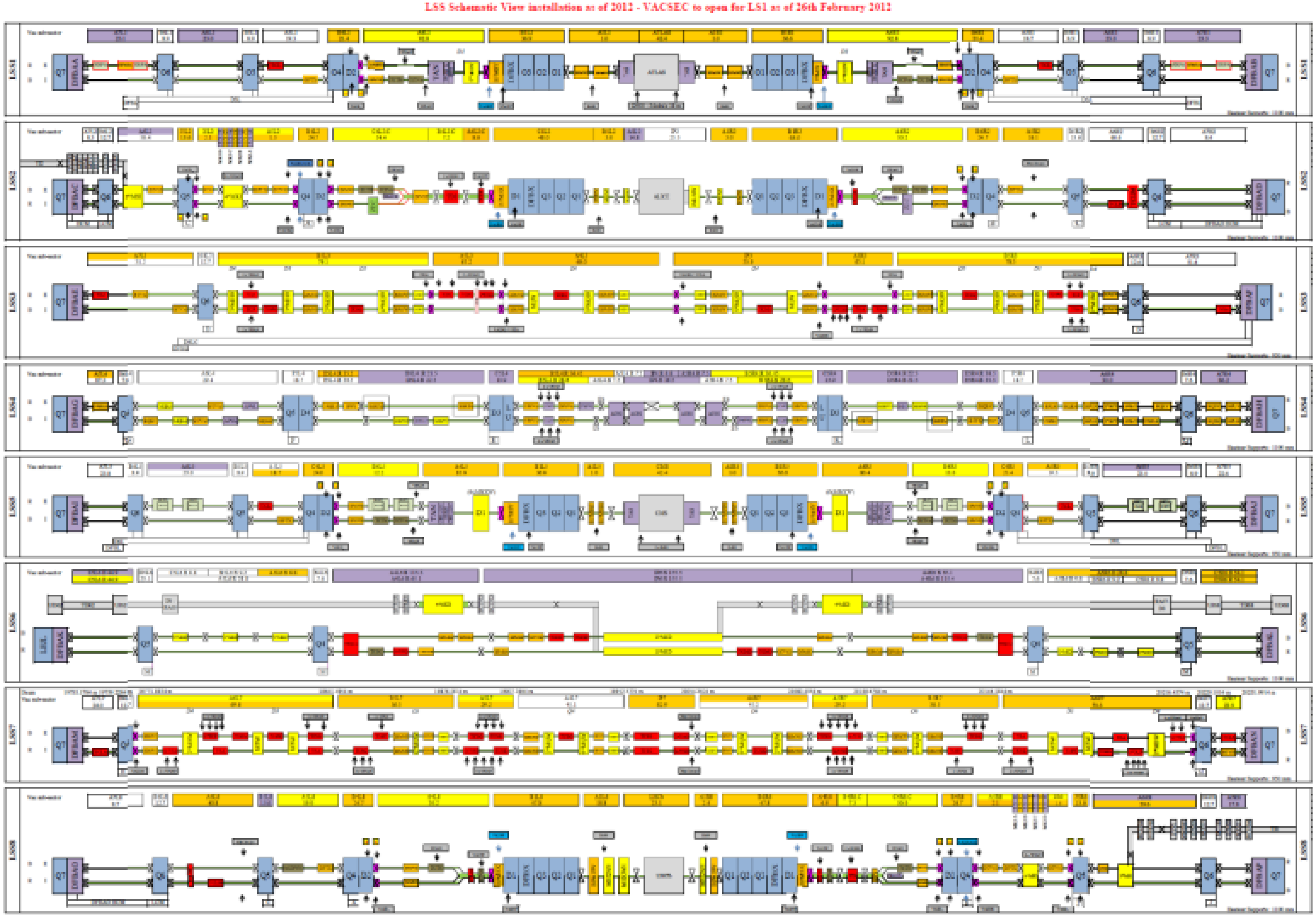
Long Shutdown 1 (LS1)

- Main aim : consolidate the splice interconnection between superconducting magnets to allow operation at 7 TeV/beam

- Started Feb 2013, Physics resumed April 2015

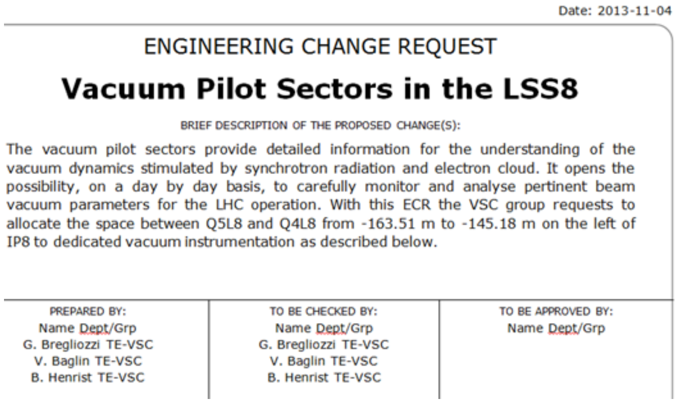
Overview of LSS Beam Vacuum Activities

- 148 vacuum sector to re-commission *i.e.* 5.1 km of vacuum system (80 % of the LSS)


LSS Schematic View installation as of 2012 - VACSEC to open for LS1 as of 26th February 2012

Quality Assurance Plan

- Allows to share information in a global way producing the right component



Date: 2013-11-04

ENGINEERING CHANGE REQUEST

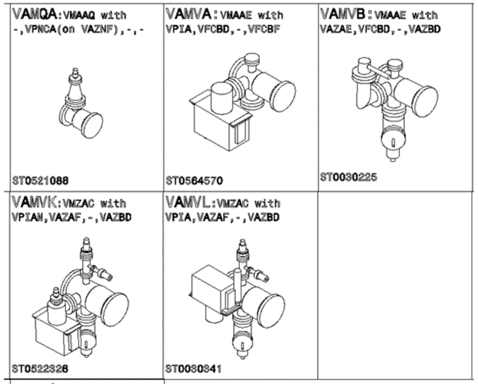
Vacuum Pilot Sectors in the LSS8

BRIEF DESCRIPTION OF THE PROPOSED CHANGE(S):

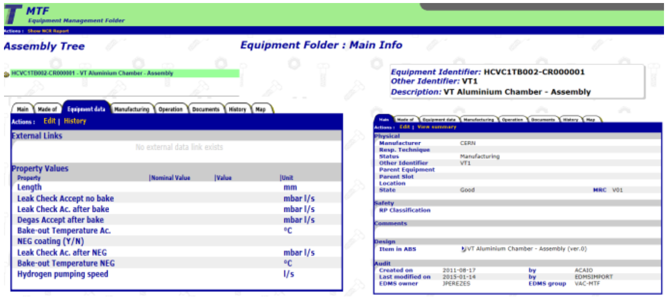
The vacuum pilot sectors provide detailed information for the understanding of the vacuum dynamics stimulated by synchrotron radiation and electron cloud. It opens the possibility, on a day by day basis, to carefully monitor and analyse pertinent beam vacuum parameters for the LHC operation. With this ECR the VSC group requests to allocate the space between Q5L8 and Q4L8 from -163.51 m to -145.18 m on the left of IP8 to dedicated vacuum instrumentation as described below.

PREPARED BY:	TO BE CHECKED BY:	TO BE APPROVED BY:
Name Dept/Grp	Name Dept/Grp	Name Dept/Grp
G. Bregliozzi TE-VSC	G. Bregliozzi TE-VSC	
V. Baglin TE-VSC	V. Baglin TE-VSC	
B. Henrist TE-VSC	B. Henrist TE-VSC	

Engineering Change Request



Standard components Libraries



Assembly Tree

HCVC1TB002-CR000001 - VT Aluminium Chamber - Assembly

Equipment Folder : Main Info

Equipment Identifier: HCVC1TB002-CR000001
Other Identifier: VT1
Description: VT Aluminium Chamber - Assembly

External Links

No external data link exists

Property Values

Property	Nominal Value	Value	Unit
Length			mm
Leak Check Accept no bake			mbar l/s
Leak Check Ac. after bake			mbar l/s
Degas Accept after bake			mbar l/s
Bake-out Temperature Ac.			°C
NEG coating (Y/N)			
Leak Check Ac. after NEG			mbar l/s
Bake-out Temperature NEG			°C
Hydrogen pumping speed			l/s

Physical
Manufacturer: CERN
Resp. Technique:
Status: Manufacturing
Other Identifier: VT1
Parent Equipment:
Parent Slot:
Location:
State: Good MRC V01

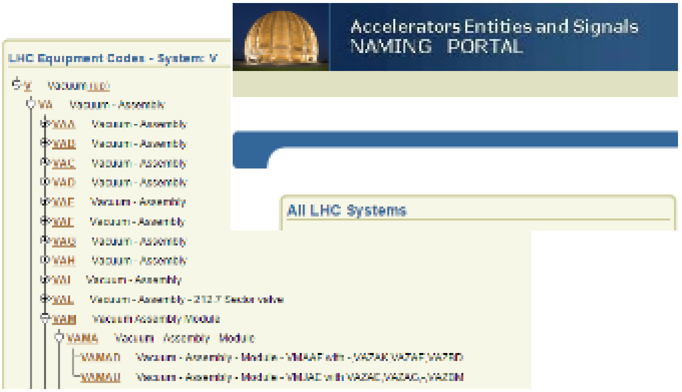
Safety
RP Classification:

Comments

Design
Item in ABS: VT Aluminium Chamber - Assembly (ver.0)

Audit
Created on: 2011-08-17 by ACAIO
Last modified on: 2015-01-14 by EDMSIMPORT
EDMS owner: JPEREZES EDMS group VAC-MTF

Equipment Management Folder



LHC Equipment Codes - System: V

V Vacuum (LHC)
VA Vacuum - Assembly
VAA Vacuum - Assembly
VAB Vacuum - Assembly
VAC Vacuum - Assembly
VAD Vacuum - Assembly
VAE Vacuum - Assembly
VAF Vacuum - Assembly
VAG Vacuum - Assembly
VAH Vacuum - Assembly
VAI Vacuum - Assembly
VAL Vacuum - Assembly - 212.7 Sector valve
VAM Vacuum Assembly Module
VAMA Vacuum Assembly Module
VAMAD Vacuum - Assembly - Module - VMAAF with -,VAZAK,VAZAF,VAZBD
VAMAU Vacuum - Assembly - Module - VMJAC with VAZAE,VAZAG,-,VAZBM

Naming Convention

Version: STUDY

IDENTIFICATION

ID: 272538
Machine: LHC Ring
Type: VABBG (Type ID : 571137, naming convention : HC)
Description: Vacuum - Assembly - 63 Sector Valves, 194 Separation - DFBA - Instrumentation G
Layout Name: VABBG.7L1.C
Expert Name: VABBG.235.7L1.C
Vacuum Name: VABBG.235.7L1.C
Beam: This slot is on both beams (B1, Blue ; B2, Red) [IE]
Function: This vacuum slot is for both beams [C]
Links to other databases
Classification
Log

DIMENSIONS

Length	Width	Height
0.655 m	0 m	0 m

LOCALISATION

Vacuum Sector: VACSEC.ARC8-1.B
Vacuum Sector: VACSEC.ARC8-1.R

		Positions (S/U/V)							Rotations			
Location	From	S Start	S Middle	S End	U Start	U End	V Start	V End	B	A	C	Magnetic Length
7L1	IP1	26402.2742 m	26402.6017 m	26402.9292 m	0 m	0 m	0 m	0 m	0 °	0 °	0 °	
7L1	IP1.L1	-256.609 m	-256.2815 m	-255.954 m	0 m	0 m	0 m	0 m	0 °	0 °	0 °	

Location: **RR13**

MECHANICAL APERTURES

Aperture	Function	S	U	V	Offset S	Shape	Inner Diameter u / v	Ellipse Parameters a/b/c/d
E	B2	26402.2742	-0.097	0	0	CIRCLE	0.063 / 0.063	0.0315 / 0.0315 / 0.0315 / 0.0315
E	B2	26402.9292	-0.097	0	0.6550	CIRCLE	0.08 / 0.08	0.04 / 0.04 / 0.04 / 0.04
I	B1	26402.2742	0.097	0	0	CIRCLE	0.063 / 0.063	0.0315 / 0.0315 / 0.0315 / 0.0315
I	B1	26402.9292	0.097	0	0.6550	CIRCLE	0.08 / 0.08	0.04 / 0.04 / 0.04 / 0.04

OTHER PROPERTIES

Radiation Zoning Tag: 🟥
Status: An equipment is installed in this slot
Responsible: PAUL CRUIKSHANK (TE-VSC)
Comment: VGR, VGP :: VPIA, VGP
Downstream flange: DN100
Upstream flange: DN63
SMARTEAM References

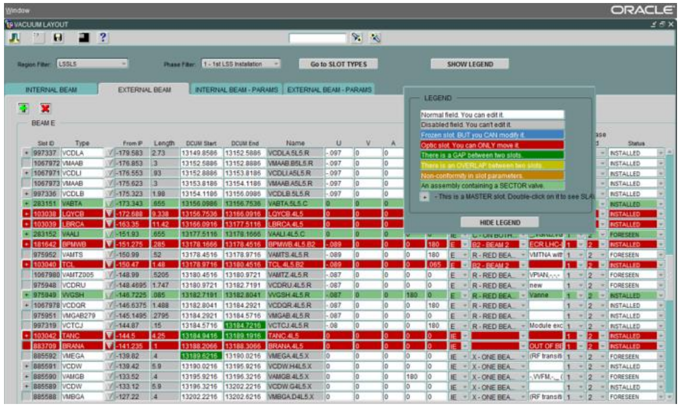
Detail	TRSF	Doc number - Doc revision
MODELE SIMPLIFIE	IDENTITY	ST0029104_03 - a.00
VACUUM TOP VIEW	IDENTITY	ST0029104_02 - a.00

Pins & Pinouts

LHC layout database

Vacuum Layout

- Define components, produce data based drawings and SCADA systems, ease installation and optimise future intervention (e.g. in radioactive areas)



Window

VACUUM LAYOUT

Region Filter: LSSL5

Phase Filter: 1 - 1st LSS Installation

Go to SLOT TYPES

SHOW LEGEND

INTERNAL BEAM | EXTERNAL BEAM | INTERNAL BEAM - PARAMS | EXTERNAL BEAM - PARAMS

BEAM E

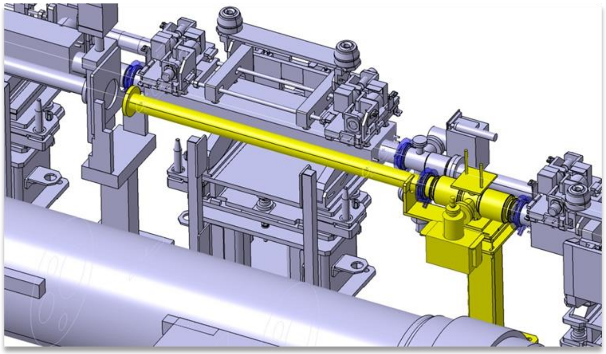
Slot ID	Type	From IP	Length	DCUM Start	DCUM End	Name	U	V	A								Status
997337	VCDLA	-179.583	2.73	13149.8586	13152.5886	VCDLA.5L5.R	-.097	0	0								INSTALLED
1067972	VMAAB	-176.853	.3	13152.5886	13152.8886	VMAAB.B5L5.R	-.097	0	0								INSTALLED
1067971	VCDLI	-176.553	.93	13152.8886	13153.8186	VCDLI.A5L5.R	-.097	0	0								INSTALLED
1067973	VMAAB	-175.623	.3	13153.8186	13154.1186	VMAAB.A5L5.R	-.097	0	0								INSTALLED
997336	VCDLB	-175.323	1.98	13154.1186	13156.0986	VCDLB.5L5.R	-.097	0	0								INSTALLED
283151	VABTA	-173.343	.655	13156.0986	13156.7536	VABTA.5L5.C	0	0	0								INSTALLED
103038	LQYCB	-172.688	9.338	13156.7536	13166.0916	LQYCB.4L5	0	0	0								INSTALLED
103039	LBRCA	-163.35	11.42	13166.0916	13177.5116	LBRCA.4L5	0	0	0								INSTALLED
283152	VAALI	-151.93	.655	13177.5116	13178.1666	VAALI.4L5.C	0	0	0			IE	C - ON BOTH...	_VGNB.VG	1	2	FORESEEN
181642	BPMWB	-151.275	.285	13178.1666	13178.4516	BPMWB.4L5.B2	-.089	0	0	0	180	E	B2 - BEAM 2	ECR LHC-	1	2	INSTALLED
975952	VAMTS	-150.99	.52	13178.4516	13178.9716	VAMTS.4L5.R	-.089	0	0	0	180	E	R - RED BEA...	VMTNA with	1	2	FORESEEN
103040	TCL	-150.47	1.48	13178.9716	13180.4516	TCL.4L5.B2	-.089	0	0	0	.065	E	B2 - BEAM 2		1	2	INSTALLED
1067980	VAMTZ005	-148.99	.5205	13180.4516	13180.9721	VAMTZ.4L5.R	-.087	0	0	0	0	E	R - RED BEA...	VPIAN,-,-,-	1	2	FORESEEN
975948	VCDRU	-148.4695	1.747	13180.9721	13182.7191	VCDRU.4L5.R	-.087	0	0	0	0	E	R - RED BEA...	new	1	2	FORESEEN
975949	VVGSH	-146.7225	.085	13182.7191	13182.8041	VVGSH.4L5.R	-.087	0	0	180	0	E	R - RED BEA...	Vanne	1	2	INSTALLED
1067978	VCDQR	-146.6375	1.488	13182.8041	13184.2921	VCDQR.4L5.R	-.087	0	0	0	180	E	R - RED BEA...		1	2	INSTALLED
975951	VMGAB279	-145.1495	.2795	13184.2921	13184.5716	VMGAB.4L5.R	-.087	0	0	0	0	E	R - RED BEA...		1	2	INSTALLED
997319	VCTCJ	-144.87	.15	13184.5716	13184.7216	VCTCJ.4L5.R	-.08	0	0	0	180	E	R - RED BEA...	Module exc	1	2	INSTALLED
103042	TANC	-144.5	4.25	13184.9416	13189.1916	TANC.4L5	0	0	0	0	0	IE			1	2	INSTALLED
883709	BRANA	-141.235	1	13188.2066	13188.3066	BRANA.4L5	0	0	0	0	0	IE		OUT OF BE	1	2	INSTALLED
885592	VMEGA	-139.82	.4	13189.6216	13190.0216	VMEGA.4L5.X	0	0	0	0	0	IE	X - ONE BEA...	(RF transit	1	2	FORESEEN
885591	VCDW	-139.42	5.9	13190.0216	13195.9216	VCDW.H4L5.X	0	0	0	0	0	IE	X - ONE BEA...		1	2	INSTALLED
885590	VAMGB	-133.52	.4	13195.9216	13196.3216	VAMGB.4L5.X	0	0	0	180	0	IE	X - ONE BEA...	-,VVFM,-,_(	1	2	FORESEEN
885589	VCDW	-133.12	5.9	13196.3216	13202.2216	VCDW.G4L5.X	0	0	0	0	0	IE	X - ONE BEA...		1	2	INSTALLED
885588	VMBGA	-127.22	.4	13202.2216	13202.6216	VMBGA.D4L5.X	0	0	0	0	0	IE	X - ONE BEA...	(RF transit	1	2	FORESEEN

LEGEND

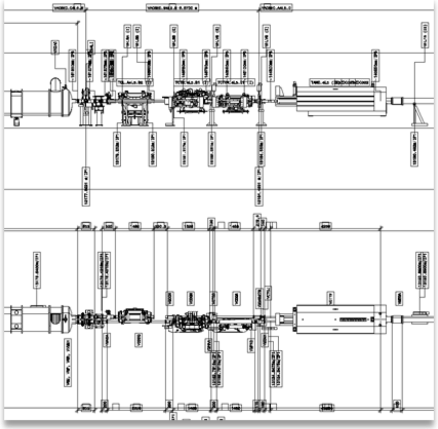
- ⬜ Normal field. You can edit it.
- Disabled field. You can't edit it.
- 🟦 Frozen slot. BUT you CAN modify it.
- 🟥 Optic slot. You can ONLY move it.
- 🟩 There is a GAP between two slots.
- 🟨 There is an OVERLAP between two slots.
- 🟧 Non-conformity in slot parameters.
- 🟩 An assembly containing a SECTOR valve.
- + - This is a MASTER slot. Double-click on it to see SLA

HIDE LEGEND

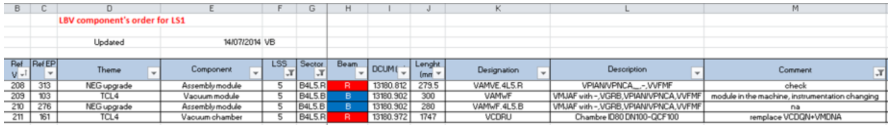
Vacuum layout database



Integration studies



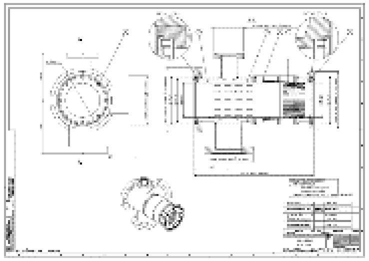
Installation drawings



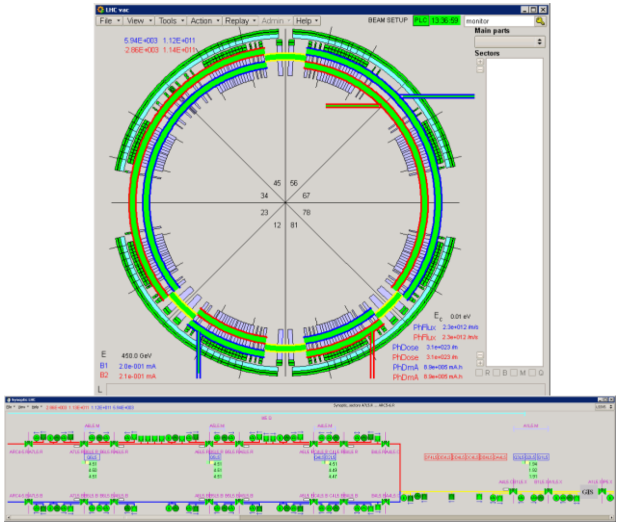
LBV component's order for LS1

Updated 14/07/2014 VB

Ref V	Ref EP	Theme	Component	LSS	Sector	Beam	DCUM (	Lenght (mm	Designation	Description	Comment
208	313	NEG upgrade	Assembly module	5	B4L5.R	R	13180.812	279.5	VAMVE.4L5.R	VPIAN/VPNCA_,-,VVFMF	check
209	103	TCL4	Vacuum module	5	B4L5.B	B	13180.902	300	VAMWF	VMJAF with -,VGRB,VPIAN/VPNCA,VVFMF	module in the machine, instrumentation changing
210	276	NEG upgrade	Assembly module	5	B4L5.B	B	13180.902	280	VAMWF.4L5.B	VMJAF with -,VGRB,VPIAN/VPNCA,VVFMF	na
211	161	TCL4	Vacuum chamber	5	B4L5.R	R	13180.972	1747	VCDRU	Chambre ID80 DN100-QCF100	remplace VCDQN+VMDNA



New components
Production & follow up



SCADA

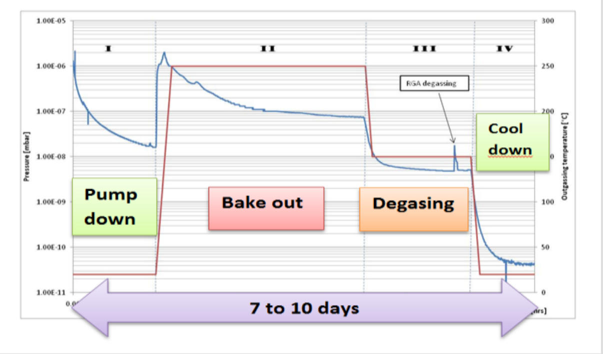
Infrastructure and Material

- Adapted stores, components, tools and storage management are mandatory

Vacuum Acceptance Tests

- Prior installation all (several thousands) equipment have been baked and validated at the surface before installation in the tunnel:
  - functional test
  - leak detection
  - residual gas composition
  - total outgassing rate

➔ Logistics, scheduling, coordinating & official reporting



2 ALFA Roman pot stations (XRPA) connected to TB1 in B113

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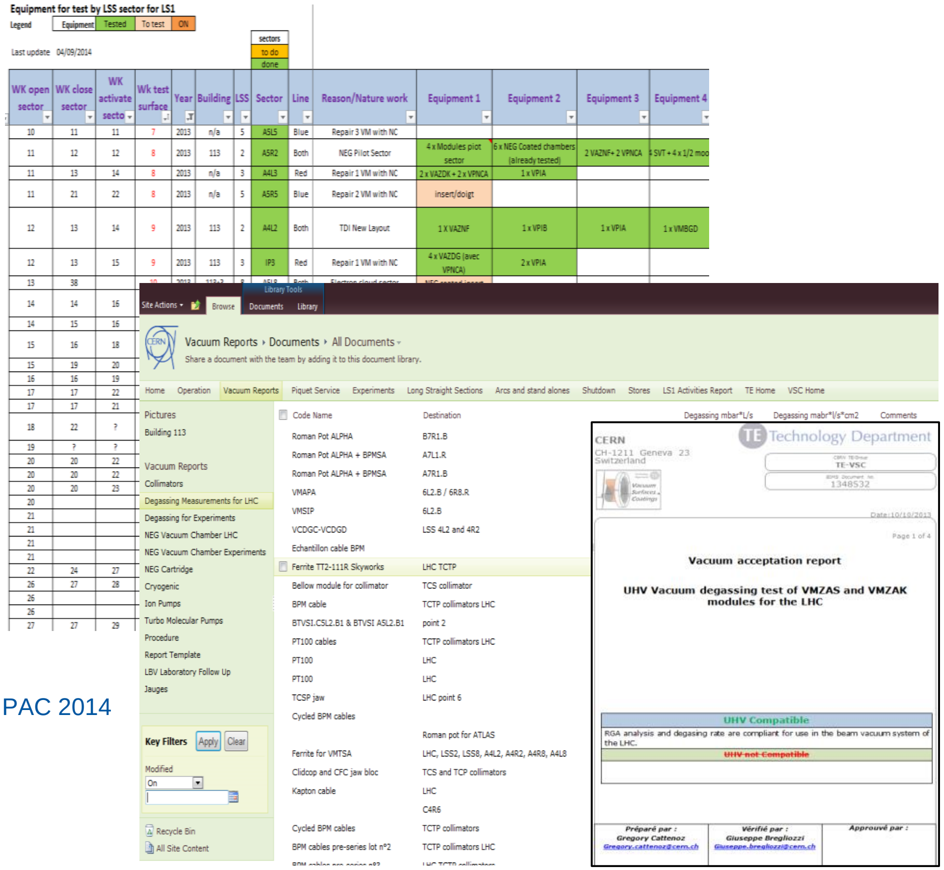

Equipment for test by LSS sector for LS1

Legend: Equipment | 🟩 Tested | To test | ON

Last update 04/09/2014

sectors: to do | done

WK open sector	WK close sector	WK activate secto	Wk test surface	Year	Building	LSS	Sector	Line	Reason/Nature work	Equipment 1	Equipment 2	Equipment 3	Equipment 4
10	11	11	7	2013	n/a	5	A5L5	Blue	Repair 3 VM with NC				
11	12	12	8	2013	113	2	A5R2	Both	NEG Pilot Sector	4 x Modules piot sector	6 x NEG Coated chambers (already tested)	2 VAZNF+ 2 VPNCA	4 SVT + 4 x 1/2 moo
11	13	14	8	2013	n/a	3	A4L3	Red	Repair 1 VM with NC	2 x VAZDK + 2 x VPNCA	1 x VPIA		
11	21	22	8	2013	n/a	5	A5R5	Blue	Repair 2 VM with NC	insert/doigt			
12	13	14	9	2013	113	2	A4L2	Both	TDI New Layout	1 X VAZNF	1 x VPIB	1 x VPIA	1 x VMBGD
12	13	15	9	2013	113	3	IP3	Red	Repair 1 VM with NC	4 x VAZDG (avec VPNCA)	2 x VPIA		
13	38												
14	14	16											
14	15	16											
15	16	18											
15	19	20											
16	16	19											
17	17	22											
17	17	21											
18	22	?											
19	?	?											
20	20	22											
20	20	22											
20	20	23											
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21													
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21													
21													
22	24	27											
26	27	28											
26													
26													
27	27	29											

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Pictures
Building 113

Vacuum Reports
Collimators
Degassing Measurements for LHC
Degassing for Experiments
NEG Vacuum Chamber LHC
NEG Vacuum Chamber Experiments
NEG Cartridge
Cryogenic
Ion Pumps
Turbo Molecular Pumps
Procedure
Report Template
LBV Laboratory Follow Up
Jauges

Key Filters [Apply] [Clear]
Modified: On ▾

Recycle Bin
All Site Content

☐ Code Name	Destination	Degassing mbar*L/s	Degassing mabr*l/s*cm2	Comments
Roman Pot ALPHA	B7R1.B			
Roman Pot ALPHA + BPMSA	A7L1.R			
Roman Pot ALPHA + BPMSA	A7R1.B			
VMAPA	6L2.B / 6R8.R			
VMSIP	6L2.B			
VCDGC-VCDGD	LSS 4L2 and 4R2			
Echantillon cable BPM				
☐ Ferrite TT2-111R Skyworks	LHC TCTP			
Bellow module for collimator	TCS collimator			
BPM cable	TCTP collimators LHC			
BTVSI.C5L2.B1 & BTVSI A5L2.B1	point 2			
PT100 cables	TCTP collimators LHC			
PT100	LHC			
PT100	LHC			
TCSP jaw	LHC point 6			
Cycled BPM cables				
	Roman pot for ATLAS			
Ferrite for VMTSA	LHC, LSS2, LSS8, A4L2, A4R2, A4R8, A4L8			
Clidcop and CFC jaw bloc	TCS and TCP collimators			
Kapton cable	LHC			
	C4R6			
Cycled BPM cables	TCTP collimators			
BPM cables pre-series lot n°2	TCTP collimators LHC			

CERN
CH-1211 Geneva 23
Switzerland

TE Technology Department

TE-VSC

1348532

Date:10/10/2013

Page 1 of 4

Vacuum acceptation report

UHV Vacuum degassing test of VMZAS and VMZAK modules for the LHC

UHV Compatible

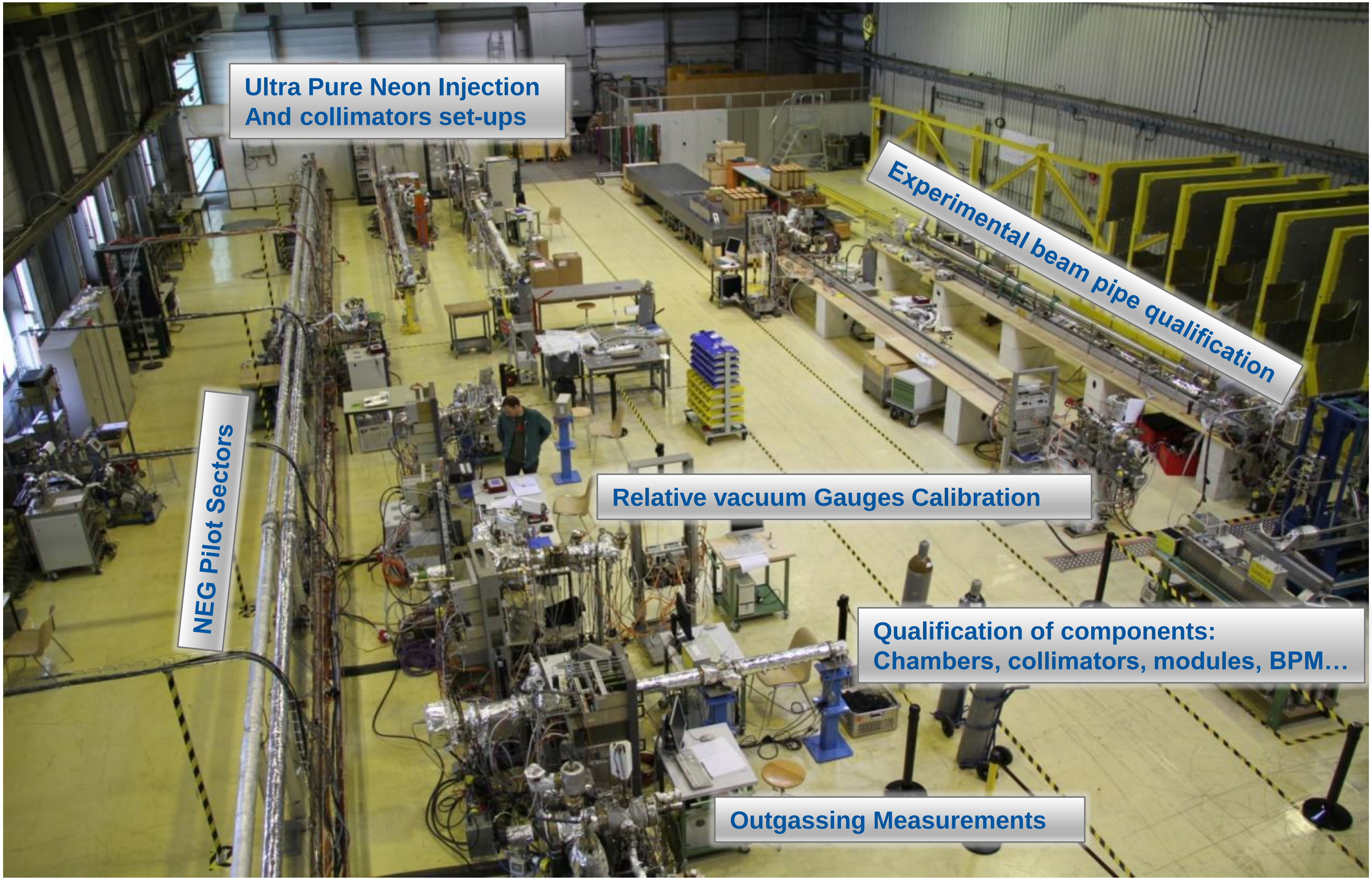
RGA analysis and degasing rate are compliant for use in the beam vacuum system of the LHC.

~~UHV not Compatible~~

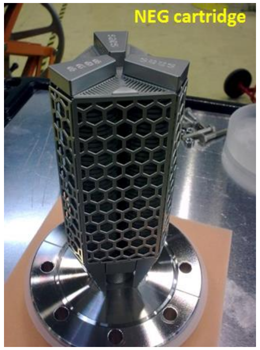
Préparé par :	Vérifié par :	Approuvé par :
Gregory Cattenoz Gregory.cattenoz@cern.ch	Giuseppe Bregliozzi Giuseppe.bregliozzi@cern.ch	

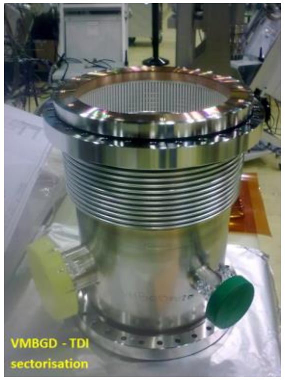
See G. Bregliozzi lecture

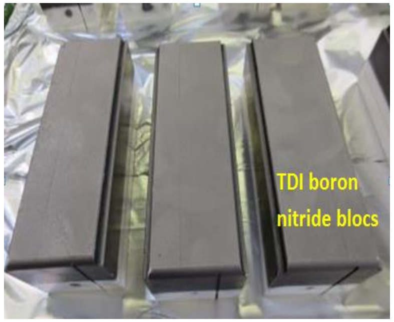
The LHC beam Vacuum Laboratory in 2012

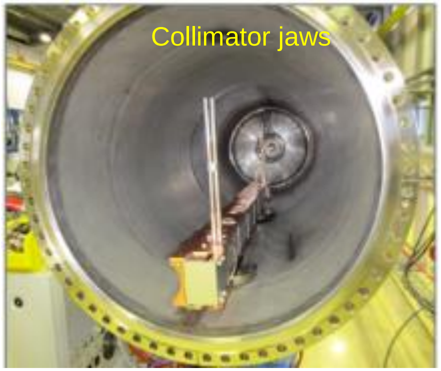


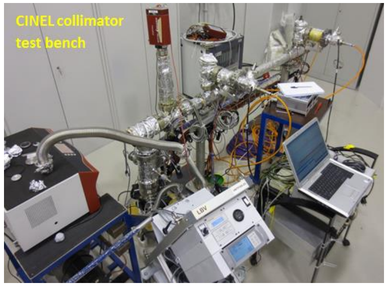
Examples of tested parts

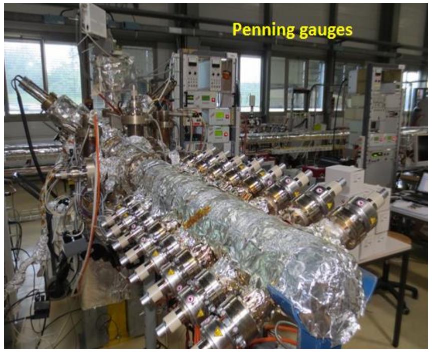


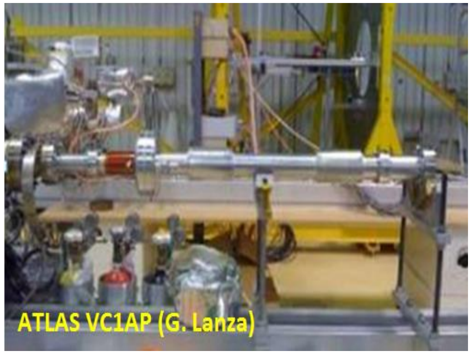






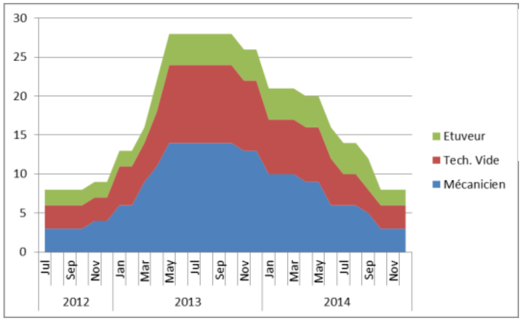


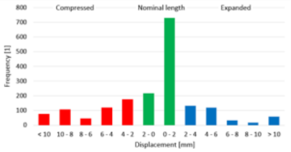


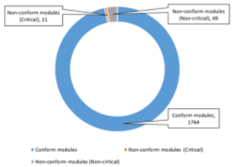


Installation and Quality Control

- Expert teams dedicated to specific tasks, logistic included
- Industrial support coordinated by CERN staff







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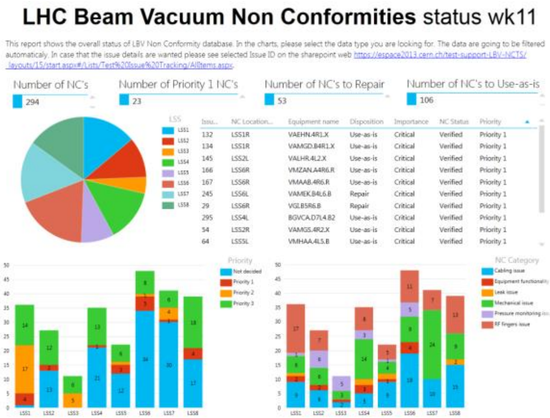


LHC Beam Vacuum Non Conformities status wk11

This report shows the overall status of LBV Non Conformity database. In the charts, please select the data type you are looking for. The data are going to be filtered automaticaly. In case that the issue details are wanted please see selected Issue ID on the sharepoint web https://espace2013.cern.ch/test-support-LBV-NCTS/_layouts/15/start.aspx#/Lists/Test%20Issue%20Tracking/AllItems.aspx.

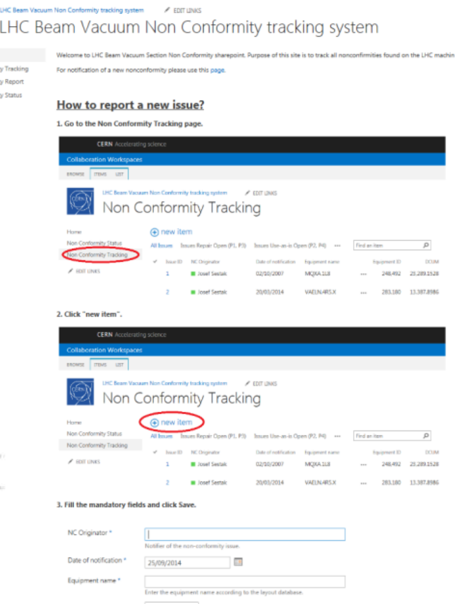
Number of NC's 294

Number of Priority 1 NC's 23

Number of NC's to Repair 53

Number of NC's to Use-as-is 106

Issu...	NC Location...	Equipment name	Disposition	Importance	NC Status	Priority
132	LSS1R	VAEHN.4R1.X	Use-as-is	Critical	Verified	Priority 1
134	LSS1R	VAMGD.B4R1.X	Use-as-is	Critical	Verified	Priority 1
145	LSS2L	VALHR.4L2.X	Use-as-is	Critical	Verified	Priority 1
166	LSS6R	VMZAN.A4R6.R	Use-as-is	Critical	Verified	Priority 1
167	LSS6R	VMAAB.4R6.R	Use-as-is	Critical	Verified	Priority 1
245	LSS6L	VAMEK.B4L6.B	Repair	Critical	Verified	Priority 1
29	LSS6R	VGI.B5R6.B	Repair	Critical	Verified	Priority 1
295	LSS4L	BGVCA.D7L4.B2	Use-as-is	Critical	Verified	Priority 1
54	LSS2R	VAMGS.4R2.X	Use-as-is	Critical	Verified	Priority 1
64	LSS5L	VMHAA.4L5.B	Use-as-is	Critical	Verified	Priority 1



LHC Beam Vacuum Non Conformity tracking system

Welcome to LHC Beam Vacuum Section Non Conformity sharepoint. Purpose of this site is to track all nonconfirmities found on the LHC machin

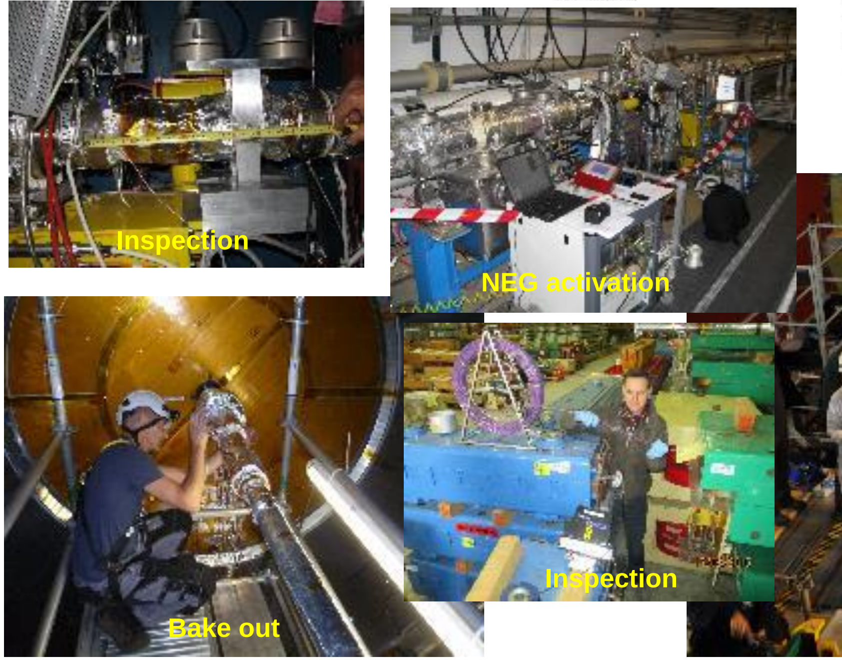
For notification of a new nonconformity please use this page.

How to report a new issue?

1. Go to the Non Conformity Tracking page.

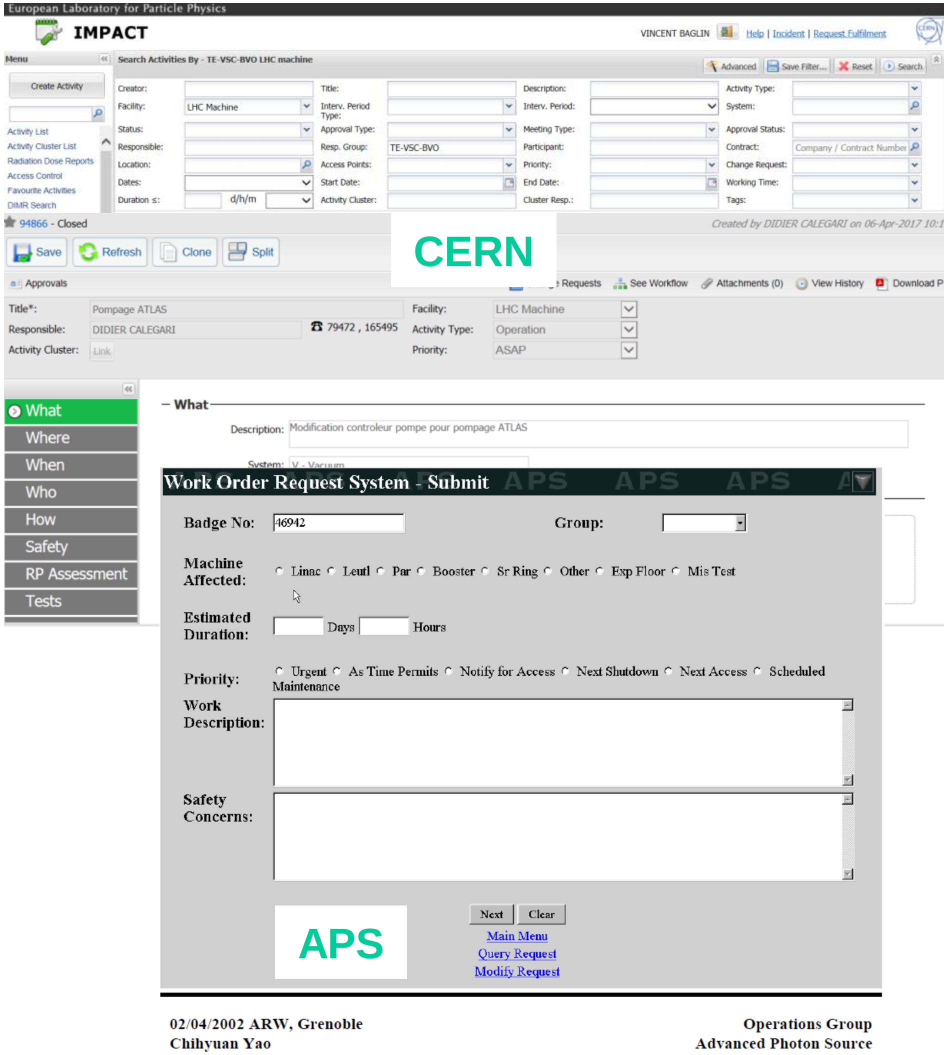
2. Click "new item".

3. Fill the mandatory fields and click Save.



Work Orders

- Allows, scheduling, coordination, identification of tunnel activities, control of equipment and fulfil safety aspects: electrical lock-out, radiation



European Laboratory for Particle Physics

IMPACT

Search Activities By - TE-VSC-BVO LHC machine

Facility: LHC Machine

Resp. Group: TE-VSC-BVO

94866 - Closed

Created by DIDIER CALEGARI on 06-Apr-2017 10:1

Title*: Pompage ATLAS

Responsible: DIDIER CALEGARI ☎ 79472 , 165495

Facility: LHC Machine

Activity Type: Operation

Priority: ASAP

What

Description: Modification controleur pompe pour pompage ATLAS

System: V - Vacuum

Work Order Request System - Submit

Badge No: 46942

Group:

Machine Affected: ○ Linac ○ Leutl ○ Par ○ Booster ○ Sr Ring ○ Other ○ Exp Floor ○ Mis Test

Estimated Duration: Days Hours

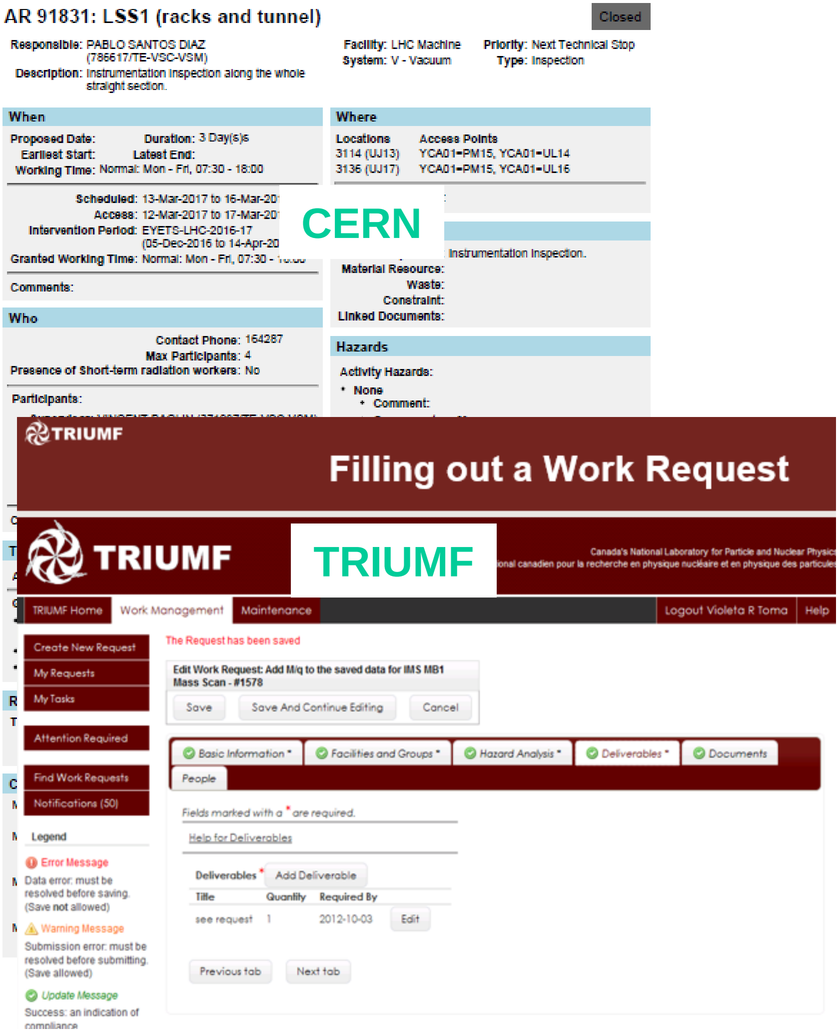
Priority: ○ Urgent ○ As Time Permits ○ Notify for Access ○ Next Shutdown ○ Next Access ○ Scheduled Maintenance

Work Description:

Safety Concerns:

02/04/2002 ARW, Grenoble
Chihyuan Yao

Operations Group
Advanced Photon Source



AR 91831: LSS1 (racks and tunnel)

Closed

Responsible: PABLO SANTOS DIAZ (786617/TE-VSC-VSM)

Description: Instrumentation inspection along the whole straight section.

Facility: LHC Machine

System: V - Vacuum

Priority: Next Technical Stop

Type: Inspection

When

Proposed Date: Duration: 3 Day(s)s

Earliest Start: Latest End:

Working Time: Normal: Mon - Fri, 07:30 - 18:00

Scheduled: 13-Mar-2017 to 16-Mar-201

Access: 12-Mar-2017 to 17-Mar-201

Intervention Period: EYETS-LHC-2016-17 (05-Dec-2016 to 14-Apr-20

Granted Working Time: Normal: Mon - Fri, 07:30 -

Comments:

Where

Locations	Access Points
3114 (UJ13)	YCA01=PM15, YCA01=UL14
3136 (UJ17)	YCA01=PM15, YCA01=UL16

Instrumentation Inspection.

Material Resource:

Waste:

Constraint:

Linked Documents:

Who

Contact Phone: 164287

Max Participants: 4

Presence of Short-term radiation workers: No

Participants:

Hazards

Activity Hazards:

- None
  - Comment:

The Request has been saved

Edit Work Request: Add M/q to the saved data for IMS MB1 Mass Scan - #1578

Fields marked with a * are required.

Deliverables *

Title	Quantity	Required By
see request	1	2012-10-03

Legend

Error Message
Data error: must be resolved before saving. (Save not allowed)

Warning Message
Submission error: must be resolved before submitting. (Save allowed)

Update Message
Success: an indication of compliance

Commissioning of a vacuum sector

Usually a **3 weeks** intervention (typical of any baked vacuum system) depending on the sector complexity:

- Venting the sector to air
- Mechanical intervention
- Pumping and leak detection
- Bakeout installation
- Bakeout and NEG activation
- Bakeout removal

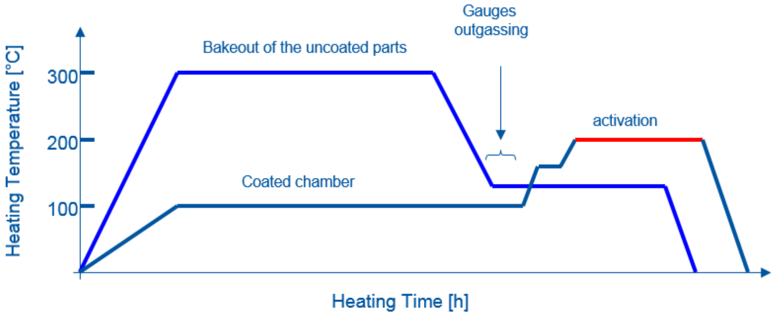
Mechanical installation

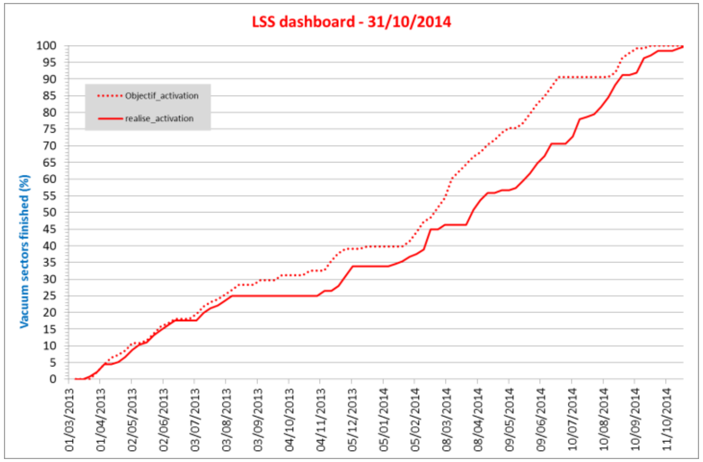
Bake out installation

NEG activation

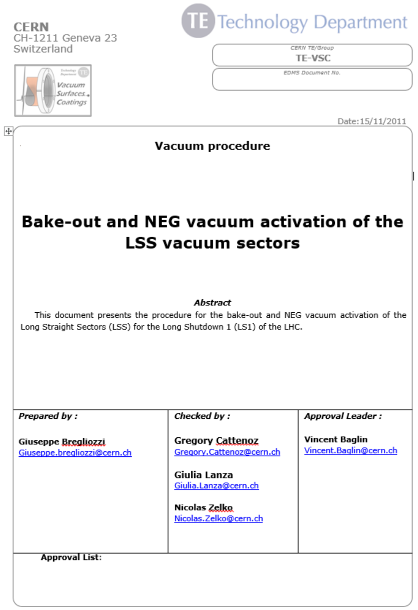
Commissioning of the NEG coated vacuum system

- Bake out of stainless steel part first
- Followed by NEG activation





→ Specific procedure for NEG activation
→ Activity reports
→ Progress & performance charts



CERN
CH-1211 Geneva 23
Switzerland

Technology Department

CERN TE/Group
TE-VSC

EDMS Document No.

Date:15/11/2011

Vacuum procedure

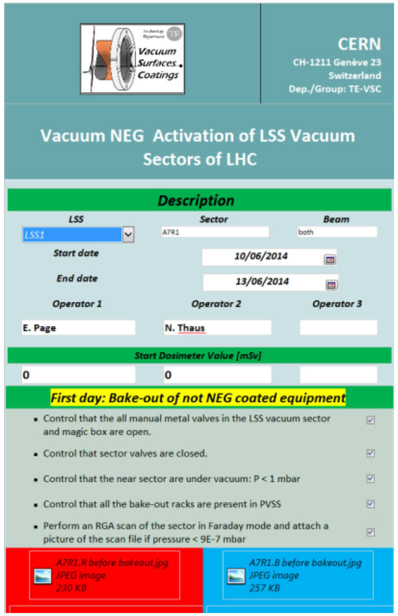
Bake-out and NEG vacuum activation of the LSS vacuum sectors

Abstract

This document presents the procedure for the bake-out and NEG vacuum activation of the Long Straight Sectors (LSS) for the Long Shutdown 1 (LS1) of the LHC.

Prepared by :	***Checked by :***	***Approval Leader :***
Giuseppe Bregliozzi Giuseppe.bregliozzi@cern.ch	**Gregory Cattenoz** Gregory.Cattenoz@cern.ch **Giulia Lanza** Giulia.Lanza@cern.ch **Nicolas Zelko** Nicolas.Zelko@cern.ch	**Vincent Baglin** Vincent.Baglin@cern.ch

Approval List:



CERN
CH-1211 Genève 23
Switzerland
Dep./Group: TE-VSC

Vacuum NEG Activation of LSS Vacuum Sectors of LHC

Description

LSS	*Sector*	*Beam*
LSS1	A7R1	both

Start date 10/06/2014
End date 13/06/2014

Operator 1	*Operator 2*	*Operator 3*
E. Page	N. Thaus	

Start Dosimeter Value [mSv]

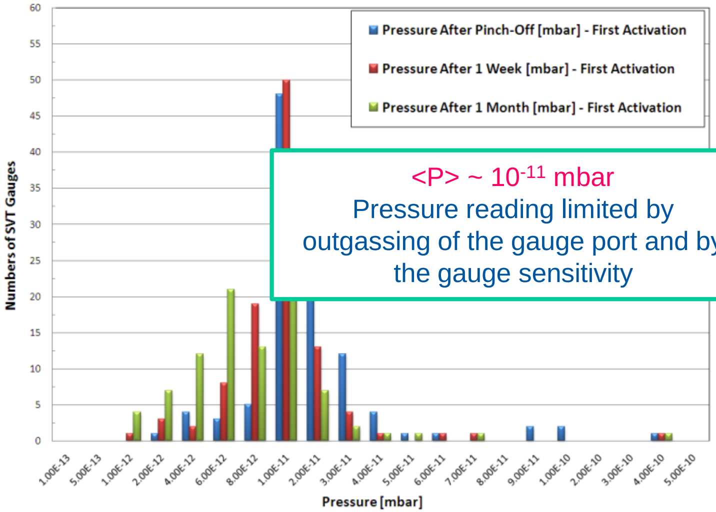
0	0	

First day: Bake-out of not NEG coated equipment

- Control that the all manual metal valves in the LSS vacuum sector and magic box are open. ☑
- Control that sector valves are closed. ☑
- Control that the near sector are under vacuum: P < 1 mbar ☑
- Control that all the bake-out racks are present in PVSS ☑
- Perform an RGA scan of the sector in Faraday mode and attach a picture of the scan file if pressure < 9E-7 mbar ☑

A7R1.R before bakeout.jpg
JPEG image
230 KB

A7R1.B before bakeout.jpg
JPEG image
257 KB



<P> ~ 10^{-11} mbar
Pressure reading limited by outgassing of the gauge port and by the gauge sensitivity

G. Bregliozzi *et al.*, EPAC Genoa, 2008

Human error

- Controls are necessary because of human fallibility, not incompetence
- Would you take this plane if there were no check list?

Airbus A380 cockpit

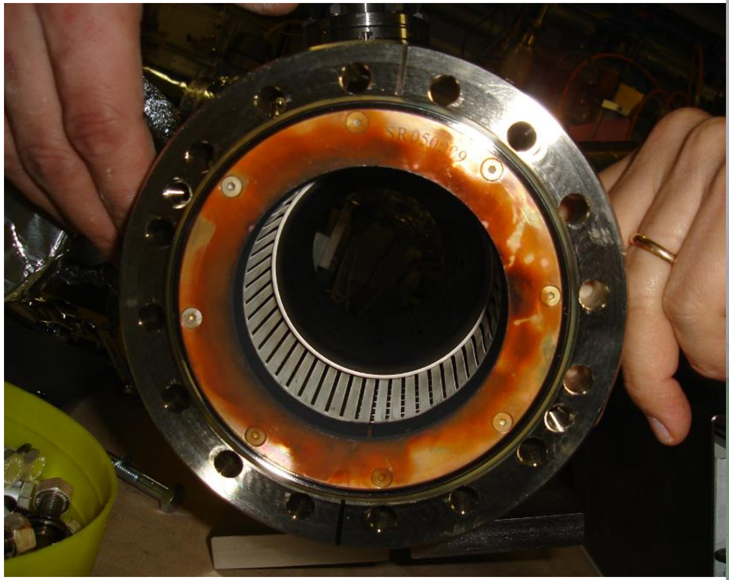
Some examples

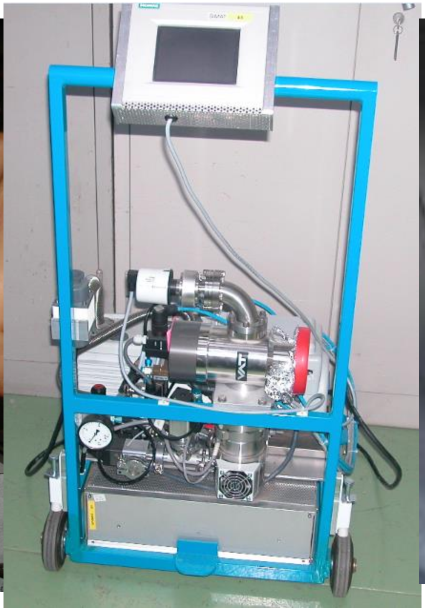
- A classic: venting or commissioning the wrong vacuum sector!

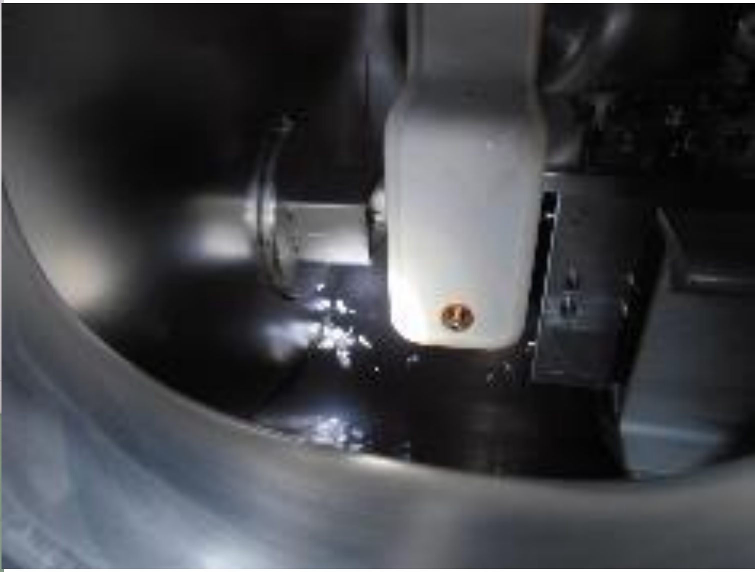
- Exchanging the of a turbomolecular pump without closing the sector valves while the pump is connected to the beam vacuum venting several vacuum sectors!

- Activating / baking a vacuum sector under atmospheric pressure!

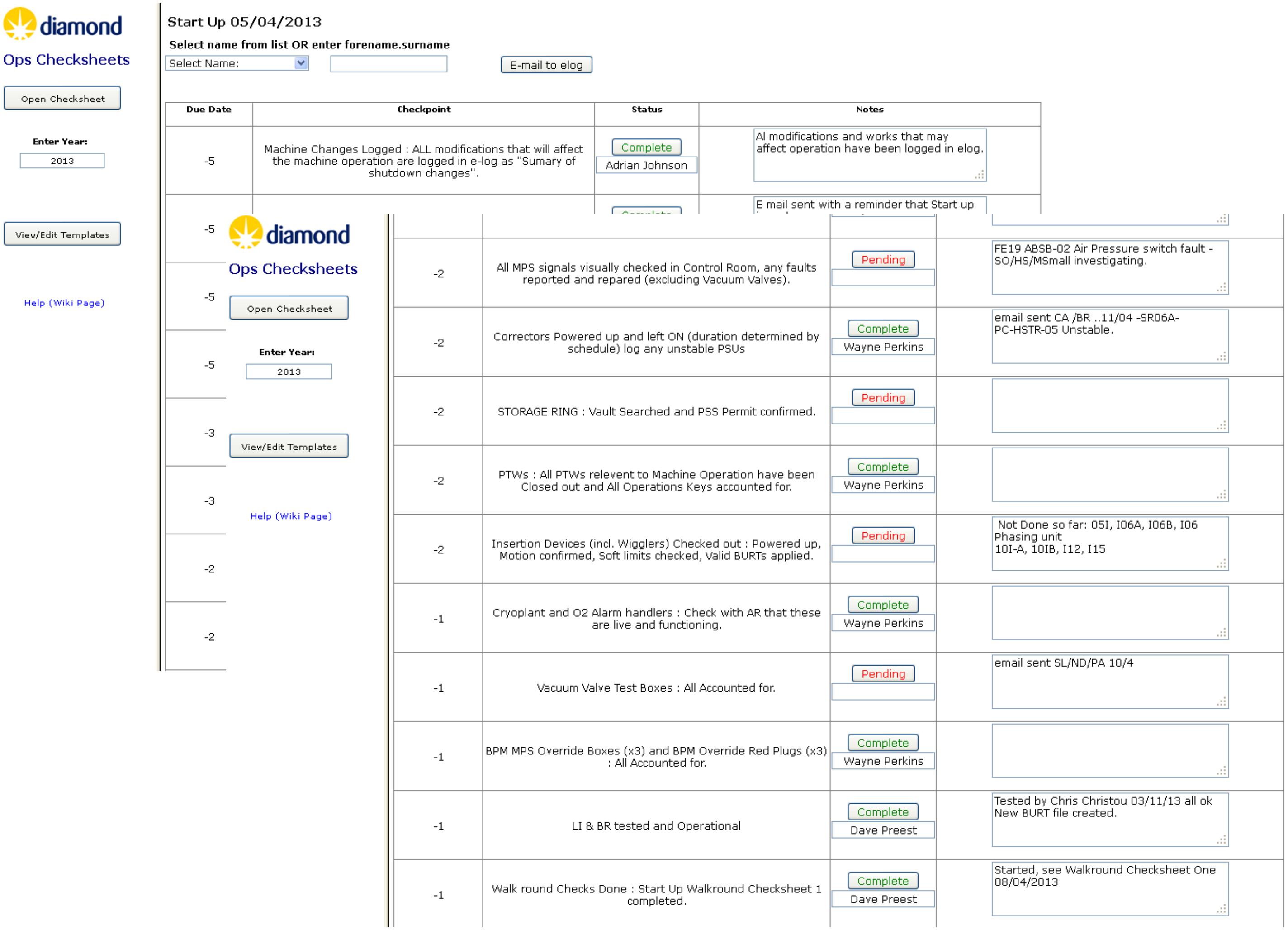
- Pumping down a vacuum sector with aluminium foils used at blank flange!







Check lists



diamond

Ops Checksheets

Open Checksheet

Enter Year:

2013

View/Edit Templates

Help (Wiki Page)

Start Up 05/04/2013

Select name from list OR enter forename.surname

Select Name:

E-mail to elog

Due Date	Checkpoint	Status	Notes
-5	Machine Changes Logged : ALL modifications that will affect the machine operation are logged in e-log as "Sumary of shutdown changes".	Complete Adrian Johnson	Al modifications and works that may affect operation have been logged in elog.
-5			E mail sent with a reminder that Start up
-5			
-5			
-3			
-3			
-2			
-2			

diamond

Ops Checksheets

Open Checksheet

Enter Year:

2013

View/Edit Templates

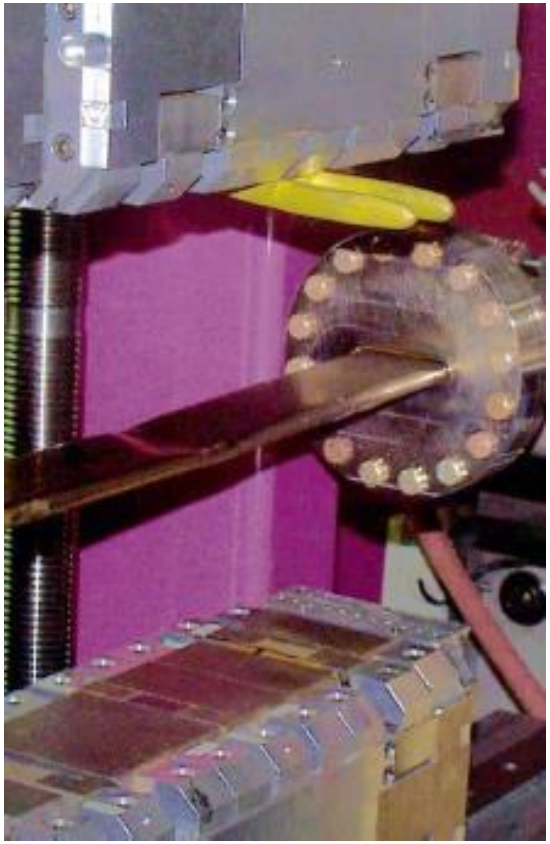
Help (Wiki Page)

-2	All MPS signals visually checked in Control Room, any faults reported and repared (excluding Vacuum Valves).	Pending	FE19 ABSB-02 Air Pressure switch fault - SO/HS/MSmall investigating.
-2	Correctors Powered up and left ON (duration determined by schedule) log any unstable PSUs	Complete Wayne Perkins	email sent CA /BR ..11/04 -SR06A-PC-HSTR-05 Unstable.
-2	STORAGE RING : Vault Searched and PSS Permit confirmed.	Pending	
-2	PTWs : All PTWs relevent to Machine Operation have been Closed out and All Operations Keys accounted for.	Complete Wayne Perkins	
-2	Insertion Devices (incl. Wigglers) Checked out : Powered up, Motion confirmed, Soft limits checked, Valid BURTs applied.	Pending	Not Done so far: 05I, I06A, I06B, I06 Phasing unit 10I-A, 10IB, I12, I15
-1	Cryoplant and O2 Alarm handlers : Check with AR that these are live and functioning.	Complete Wayne Perkins	
-1	Vacuum Valve Test Boxes : All Accounted for.	Pending	email sent SL/ND/PA 10/4
-1	BPM MPS Override Boxes (x3) and BPM Override Red Plugs (x3) : All Accounted for.	Complete Wayne Perkins	
-1	LI & BR tested and Operational	Complete Dave Preest	Tested by Chris Christou 03/11/13 all ok New BURT file created.
-1	Walk round Checks Done : Start Up Walkround Checksheet 1 completed.	Complete Dave Preest	Started, see Walkround Checksheet One 08/04/2013

V. Kempson, ARW 2013

Visual inspection

- Documented inspection tours are needed and avoids potential failures

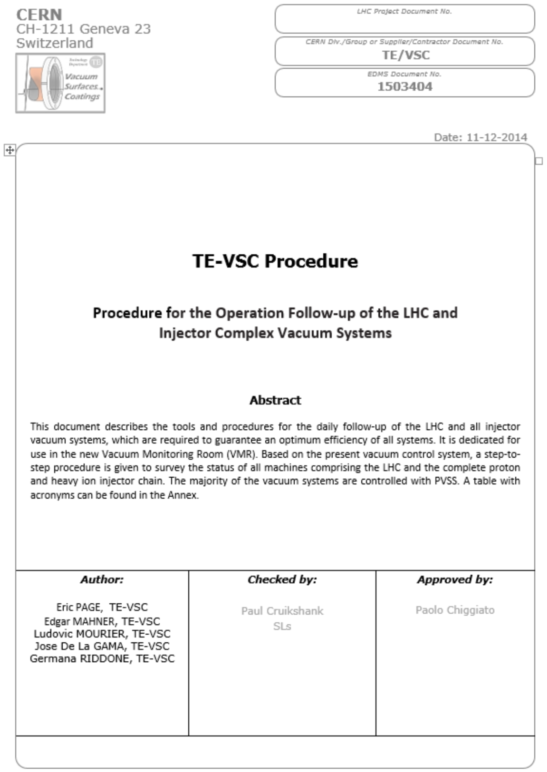


Someone forgot a tool on an undulator:
The imprint of it is visible on the Al vacuum chamber!

2.2 Operation

Vacuum Monitoring – Stand-By

- General monitoring : check status of components, record of machine status
- Stand-by with specific duties: answer to control room request, act on simple intervention, assist expert teams during complicate / delicate interventions
- Stand-by must be trained !



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Switzerland

LHC Project Document No.

CERN Div./Group or Supplier/Contractor Document No.
TE/VSC

EDMS Document No.
1503404

Date: 11-12-2014

TE-VSC Procedure

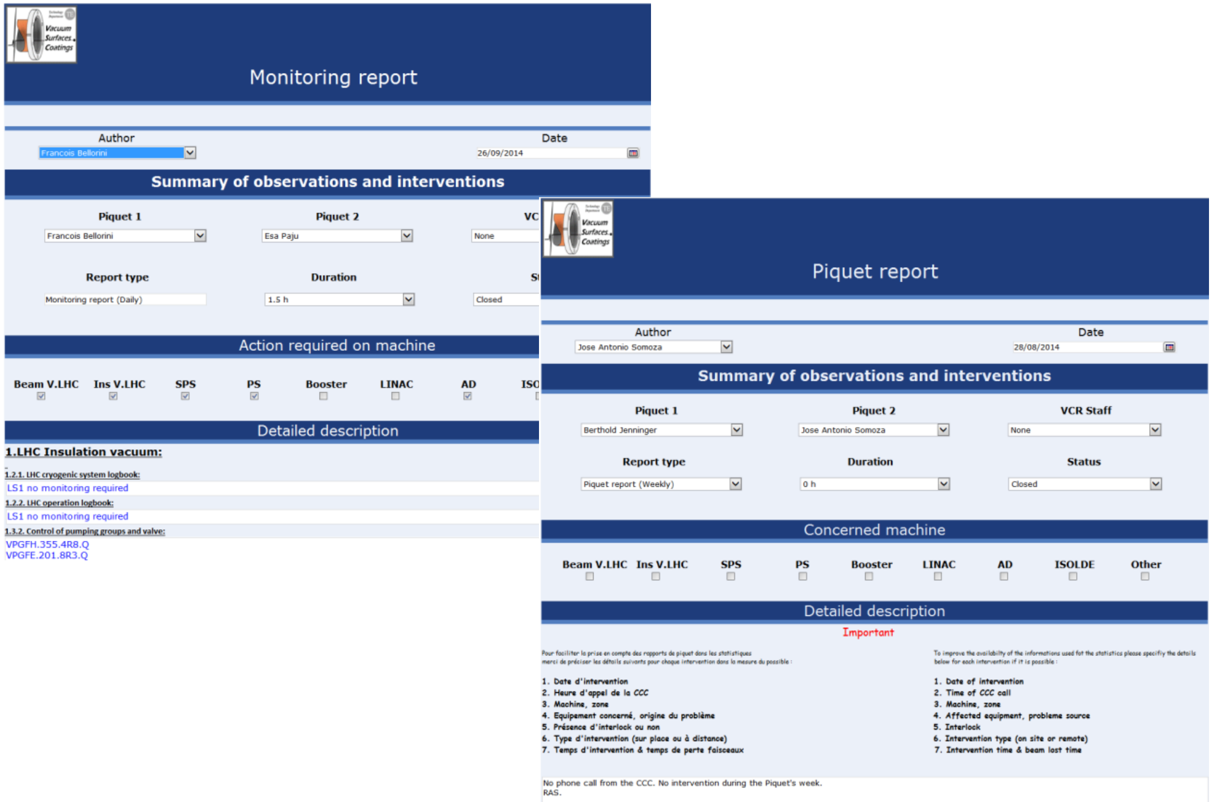
Procedure for the Operation Follow-up of the LHC and Injector Complex Vacuum Systems

Abstract

This document describes the tools and procedures for the daily follow-up of the LHC and all injector vacuum systems, which are required to guarantee an optimum efficiency of all systems. It is dedicated for use in the new Vacuum Monitoring Room (VMR). Based on the present vacuum control system, a step-to-step procedure is given to survey the status of all machines comprising the LHC and the complete proton and heavy ion injector chain. The majority of the vacuum systems are controlled with PVSS. A table with acronyms can be found in the Annex.

Author:	***Checked by:***	***Approved by:***
Eric PAGE, TE-VSC Edgar MAHNER, TE-VSC Ludovic MOURIER, TE-VSC Jose De La GAMA, TE-VSC Germana RIDDONE, TE-VSC	Paul Cruikshank SLs	Paolo Chiggiato

Procedures



Monitoring report

Author: Francois Bellorini
Date: 26/09/2014

Summary of observations and interventions

Piquet 1: Francois Bellorini
Piquet 2: Esa Paju
VC: None
Report type: Monitoring report (Daily)
Duration: 1.5 h
St: Closed

Action required on machine

Beam V.LHC ☑ Ins V.LHC ☑ SPS ☑ PS ☑ Booster ☐ LINAC ☐ AD ☑ ISO ☐

Detailed description

1.LHC Insulation vacuum:

1.2.1. LHC cryogenic system logbook:
LS1 no monitoring required

1.2.2. LHC operation logbook:
LS1 no monitoring required

1.3.2. Control of pumping groups and valve:
VPGFH.355.4R8.Q
VPGFE.201.8R3.Q

Piquet report

Author: Jose Antonio Somoza
Date: 28/08/2014

Summary of observations and interventions

Piquet 1: Berthold Jenninger
Piquet 2: Jose Antonio Somoza
VCR Staff: None
Report type: Piquet report (Weekly)
Duration: 0 h
Status: Closed

Concerned machine

Beam V.LHC ☐ Ins V.LHC ☐ SPS ☐ PS ☐ Booster ☐ LINAC ☐ AD ☐ ISOLDE ☐ Other ☐

Detailed description

Important

Pour faciliter la prise en compte des rapports de piquet dans les statistiques merci de préciser les détails suivants pour chaque intervention dans la mesure du possible :

1. Date d'intervention
2. Heure d'appel de la CCC
3. Machine, zone
4. Equipement concerné, origine du problème
5. Présence d'interlock ou non
6. Type d'intervention (sur place ou à distance)
7. Temps d'intervention & temps de perte faisceaux

To improve the availabilty of the informations used fot the statistics please specifiy the details below for each intervention if it is possible :

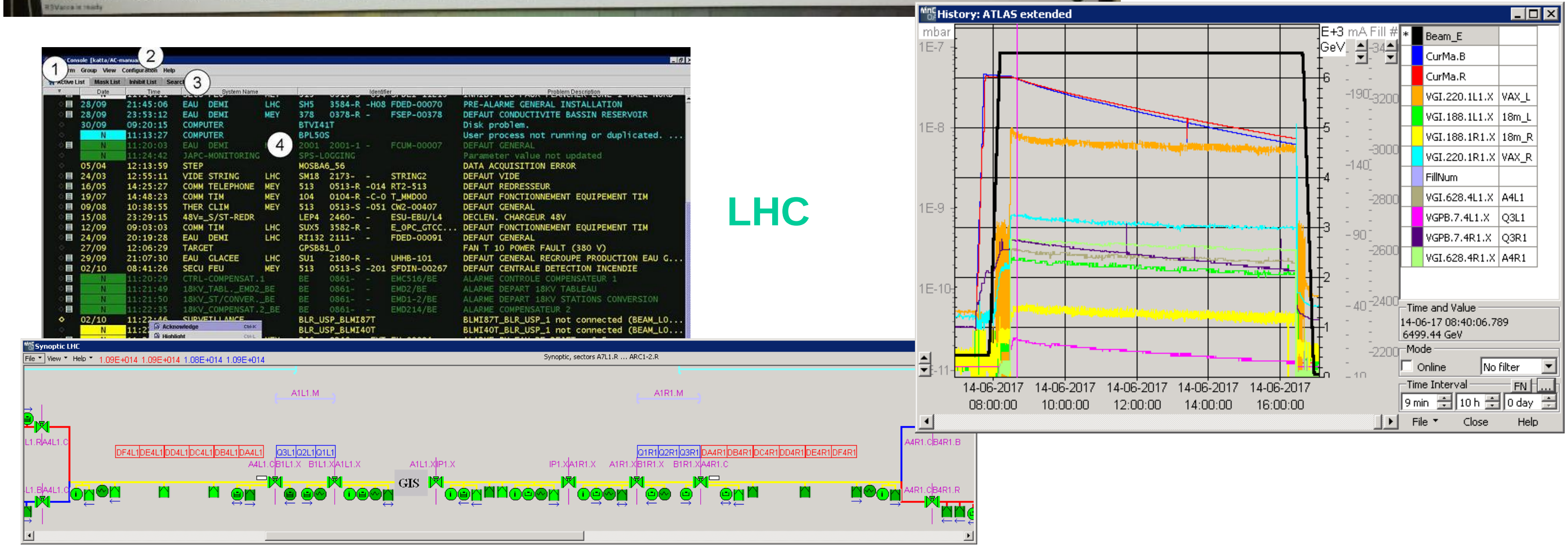
1. Date of intervention
2. Time of CCC call
3. Machine, zone
4. Affected equipment, probleme source
5. Interlock
6. Intervention type (on site or remote)
7. Intervention time & beam lost time

No phone call from the CCC. No intervention during the Piquet's week.
RAS.

Daily and weekly Reports

SCADA & Alarms

- Software tools are available to help & alert the vacuum expert
- Next generation will integrate predictive behaviour of pressure levels!



```
28/09  21:45:06  EAU  DEMI           LHC  SH5    3584-R -H08 FDED-00070     PRE-ALARME GENERAL INSTALLATION
28/09  23:53:12  EAU  DEMI           MEY  378    0378-R -    FSEP-00378     DEFAUT CONDUCTIVITE BASSIN RESERVOIR
30/09  09:20:15  COMPUTER                 BTVI41T                           Disk problem.
  N    11:13:27  COMPUTER                 BPL50S                            User process not running or duplicated. ...
  N    11:20:03  EAU  DEMI                2001   2001-1 -    FCUM-00007     DEFAUT GENERAL
  N    11:24:42  JAPC-MONITORING          SPS-LOGGING                       Parameter value not updated
05/04  12:13:59  STEP                     MOSBA6_56                         DATA ACQUISITION ERROR
24/03  12:55:11  VIDE STRING         LHC  SM18   2173-  -    STRING2        DEFAUT VIDE
16/05  14:25:27  COMM TELEPHONE      MEY  513    0513-R -014 RT2-513        DEFAUT REDRESSEUR
19/07  14:48:23  COMM TIM            MEY  104    0104-R -C-0 T_MMD00        DEFAUT FONCTIONNEMENT EQUIPEMENT TIM
09/08  10:38:55  THER CLIM           MEY  513    0513-S -051 CW2-00407      DEFAUT GENERAL
15/08  23:29:15  48V=_S/ST-REDR           LEP4   2460-  -    ESU-EBU/L4     DECLEN. CHARGEUR 48V
12/09  09:03:03  COMM TIM            LHC  SUX5   3582-R -    E_OPC_GTCC...  DEFAUT FONCTIONNEMENT EQUIPEMENT TIM
24/09  20:19:28  EAU  DEMI           LHC  RI132  2111-  -    FDED-00091     DEFAUT GENERAL
27/09  12:06:29  TARGET                   GPSB81_0                          FAN T 10 POWER FAULT (380 V)
29/09  21:07:30  EAU  GLACEE         LHC  SU1    2180-R -    UHHB-101       DEFAUT GENERAL REGROUPE PRODUCTION EAU G...
02/10  08:41:26  SECU FEU            MEY  513    0513-S -201 SFDIN-00267    DEFAUT CENTRALE DETECTION INCENDIE
  N    11:20:29  CTRL-COMPENSAT.1         BE     0861-  -    EMC516/BE      ALARME CONTROLE COMPENSATEUR 1
  N    11:21:49  18KV_TABL._EMD2_BE       BE     0861-  -    EMD2/BE        ALARME DEPART 18KV TABLEAU
  N    11:21:50  18KV_ST/CONVER._BE       BE     0861-  -    EMD1-2/BE      ALARME DEPART 18KV STATIONS CONVERSION
  N    11:22:35  18KV_COMPENSAT.2_BE      BE     0861-  -    EMD214/BE      ALARME COMPENSATEUR 2
02/10  11:22:46  SURVEILLANCE             BLR_USP_BLMI87T                   BLMI87T_BLR_USP_1 not connected (BEAM_LO...
  N    11:2                               BLR_USP_BLMI40T                   BLMI40T_BLR_USP_1 not connected (BEAM_LO...
```

Synoptic LHC: 1.09E+014 1.09E+014 1.08E+014 1.09E+014

Synoptic, sectors A7L1.R ... ARC1-2.R

	Beam_E	
	CurMa.B	
	CurMa.R	
	VGI.220.1L1.X	VAX_L
	VGI.188.1L1.X	18m_L
	VGI.188.1R1.X	18m_R
	VGI.220.1R1.X	VAX_R
	FillNum	
	VGI.628.4L1.X	A4L1
	VGPB.7.4L1.X	Q3L1
	VGPB.7.4R1.X	Q3R1
	VGI.628.4R1.X	A4R1

Time and Value
14-06-17 08:40:06.789
6499.44 GeV

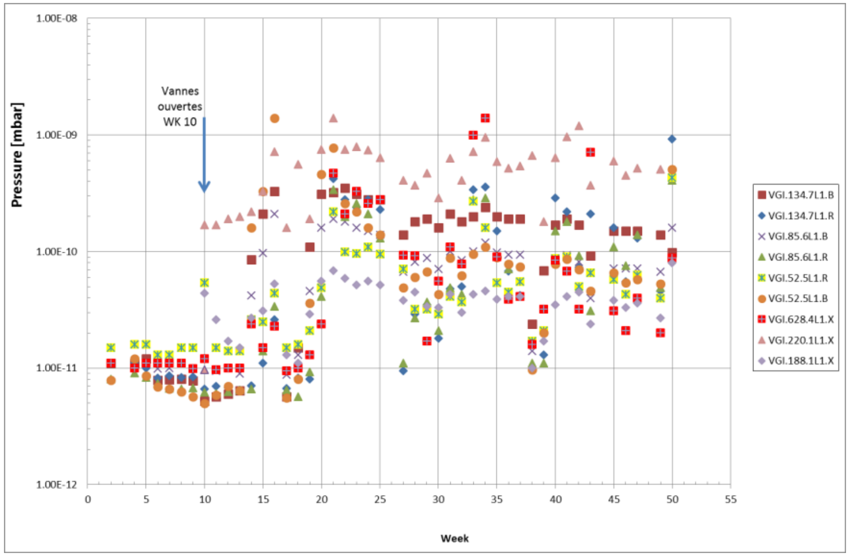
Mode
☐ Online
No filter

Time Interval
9 min
10 h
0 day

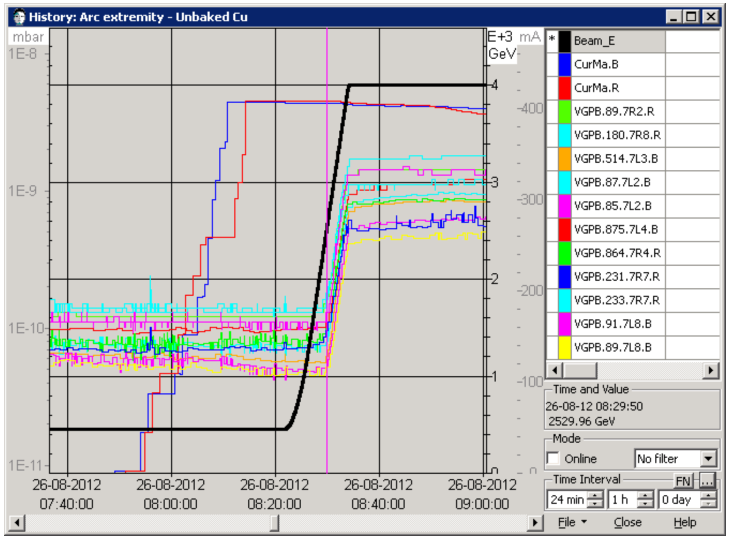
File Close Help

Pressure Follow-Up

- Expert monitoring: check general trends and track / resolve specific issues, follow daily and detailed machine operation

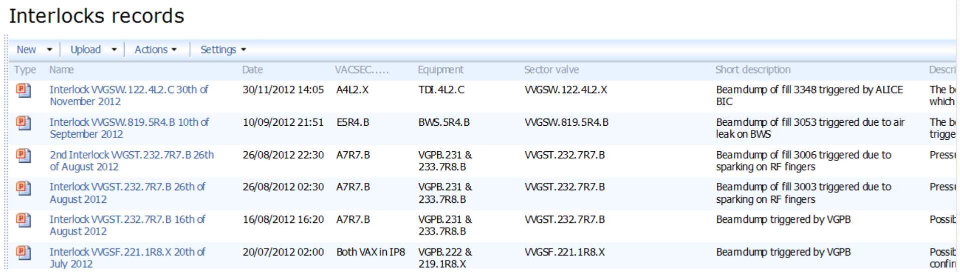


General trends



Time and Value: 26-08-12 08:29:50 2529.96 GeV

Time Interval: 24 min, 1 h, 0 day

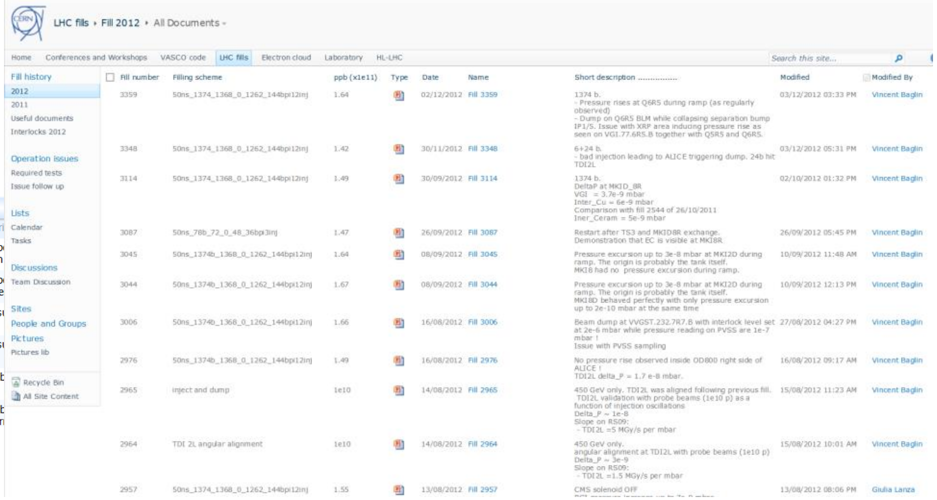


Interlocks records

New ▾ | Upload ▾ | Actions ▾ | Settings ▾

Type	Name	Date	VACSEC.....	Equipment	Sector valve	Short description	Descri
	Interlock VVGSW.122.4L2.C 30th of November 2012	30/11/2012 14:05	A4L2.X	TDI.4L2.C	VVGSW.122.4L2.X	Beamdump of fill 3348 triggered by ALICE BIC	The b which
	Interlock VVGSW.819.5R4.B 10th of September 2012	10/09/2012 21:51	E5R4.B	BWS.5R4.B	VVGSW.819.5R4.B	Beamdump of fill 3053 triggered due to air leak on BWS	The b trigge
	2nd Interlock VVGST.232.7R7.B 26th of August 2012	26/08/2012 22:30	A7R7.B	VGPB.231 & 233.7R8.B	VVGST.232.7R7.B	Beamdump of fill 3006 triggered due to sparking on RF fingers	Pressu
	Interlock VVGST.232.7R7.B 26th of August 2012	26/08/2012 02:30	A7R7.B	VGPB.231 & 233.7R8.B	VVGST.232.7R7.B	Beamdump of fill 3003 triggered due to sparking on RF fingers	Pressu
	Interlock VVGST.232.7R7.B 16th of August 2012	16/08/2012 16:20	A7R7.B	VGPB.231 & 233.7R8.B	VVGST.232.7R7.B	Beamdump triggered by VGPB	Possib
	Interlock VVGSF.221.1R8.X 20th of July 2012	20/07/2012 02:00	Both VAX in IP8	VGPB.222 & 219.1R8.X	VVGSF.221.1R8.X	Beamdump triggered by VGPB	Possib confir

Tracking interlocks



LHC fills › Fill 2012 › All Documents

Home | Conferences and Workshops | VASCO code | LHC fills | Electron cloud | Laboratory | HL-LHC | Search this site...

Fill history
2012
2011
Useful documents
Interlocks 2012

Operation issues
Required tests
Issue follow up

Lists
Calendar
Tasks

Discussions
Team Discussion

Sites
People and Groups
Pictures
Pictures lib

Recycle Bin
All Site Content

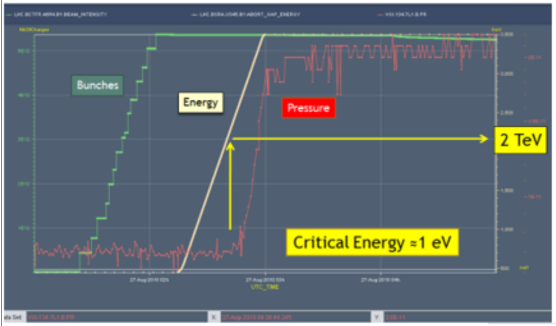
Fill number	Filling scheme	ppb (x1e11)	Type	Date	Name	Short description	Modified	Modified By
3359	50ns_1374_1368_0_1262_144bpi12inj	1.64		02/12/2012	Fill 3359	1374 b. - Pressure rises at Q6R5 during ramp (as regularly observed) - Dump on Q6R5 BLM while collapsing separation bump IP1/5. Issue with XRP area inducing pressure rise as seen on VGI.77.6R5.B together with Q5R5 and Q6R5.	03/12/2012 03:33 PM	Vincent Baglin
3348	50ns_1374_1368_0_1262_144bpi12inj	1.42		30/11/2012	Fill 3348	6+24 b. - bad injection leading to ALICE triggering dump. 24b hit TDI2L	03/12/2012 05:31 PM	Vincent Baglin
3114	50ns_1374_1368_0_1262_144bpi12inj	1.49		30/09/2012	Fill 3114	1374 b. DeltaP at MKID_8R VGI = 3.7e-9 mbar Inter_Cu = 6e-9 mbar Comparison with fill 2544 of 26/10/2011 Iner_Ceram = 5e-9 mbar	02/10/2012 01:32 PM	Vincent Baglin
3087	50ns_78b_72_0_48_36bpi3inj	1.47		26/09/2012	Fill 3087	Restart after TS3 and MKID8R exchange. Demonstration that EC is visible at MKI8R	26/09/2012 05:45 PM	Vincent Baglin
3045	50ns_1374b_1368_0_1262_144bpi12inj	1.64		08/09/2012	Fill 3045	Pressure excursion up to 3e-8 mbar at MKI2D during ramp. The origin is probably the tank itself. MKI8 had no pressure excursion during ramp.	10/09/2012 11:48 AM	Vincent Baglin
3044	50ns_1374b_1368_0_1262_144bpi12inj	1.67		08/09/2012	Fill 3044	Pressure excursion up to 3e-8 mbar at MKI2D during ramp. The origin is probably the tank itself. MKI8D behaved perfectly with only pressure excursion up to 2e-10 mbar at the same time	10/09/2012 12:13 PM	Vincent Baglin
3006	50ns_1374b_1368_0_1262_144bpi12inj	1.66		16/08/2012	Fill 3006	Beam dump at VVGST.232.7R7.B with interlock level set at 2e-6 mbar while pressure reading on PVSS are 1e-7 mbar ! Issue with PVSS sampling	27/08/2012 04:27 PM	Vincent Baglin
2976	50ns_1374b_1368_0_1262_144bpi12inj	1.49		16/08/2012	Fill 2976	No pressure rise observed inside OD800 right side of ALICE ! TDI2L delta_P = 1.7 e-8 mbar.	16/08/2012 09:17 AM	Vincent Baglin
2965	inject and dump	1e10		14/08/2012	Fill 2965	450 GeV only. TDI2L was aligned following previous fill. TDI2L validation with probe beams (1e10 p) as a function of injection oscillations Delta_P ~ 1e-8 Slope on RS09: - TDI2L =5 MGy/s per mbar	15/08/2012 11:23 AM	Vincent Baglin
2964	TDI 2L angular alignment	1e10		14/08/2012	Fill 2964	450 GeV only. angular alignment at TDI2L with probe beams (1e10 p) Delta_P ~ 3e-9 Slope on RS09: - TDI2L =1.5 MGy/s per mbar	15/08/2012 10:01 AM	Vincent Baglin
2957	50ns_1374_1368_0_1262_144bpi12inj	1.55		13/08/2012	Fill 2957	CMS solenoid OFF	13/08/2012 08:06 PM	Giulia Lanza

Fill by fill monitoring

Operation Follow-Up: Checking Design

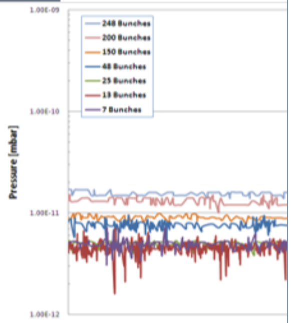
- Checking that the system behave as expected: example synchrotron radiation induced gas desorption

First Observation of Synchrotron Radiation: Aug-2010



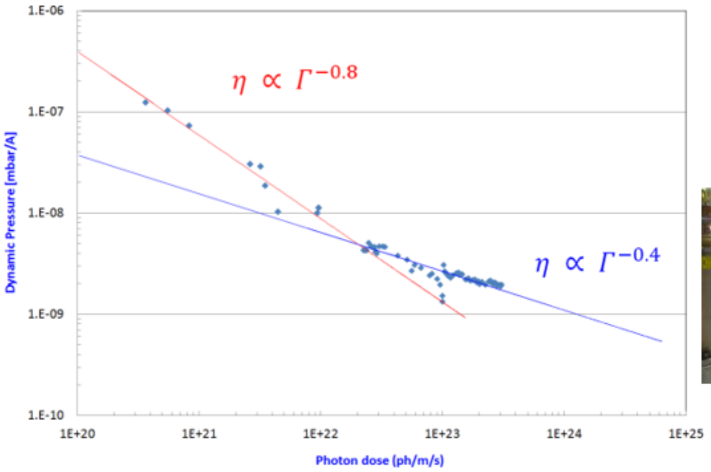
- Pressure rise during the beam energy ramp

- Dynamic pressure increases with beam current
- DeltaP = 2 10^{-10} mbar



Cleaning Effect under SR

- Arc extremity's vacuum gauges : unbaked Cu and cryogenic beam screen
- Reduction by 2 orders of magnitude since October 2010

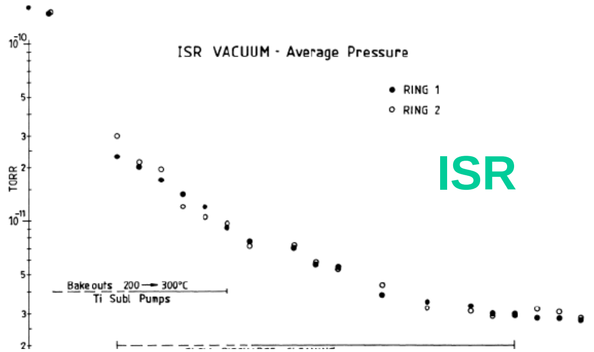


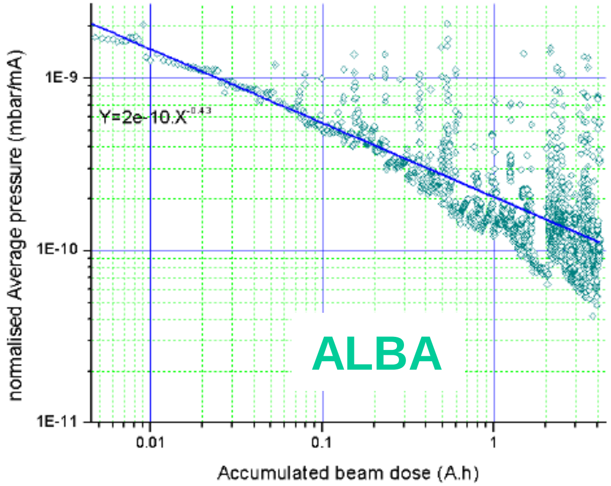
- 2 trends :
  - Room temperature
  - Cryogenic temperature

- Inside the arc, at 5-20 K, deltaP < 10^{-10} mbar (i.e. below detection limit)
- The photodesorption yield at cryogenic temperature is estimated to be < 10^{-4} molecules/photon

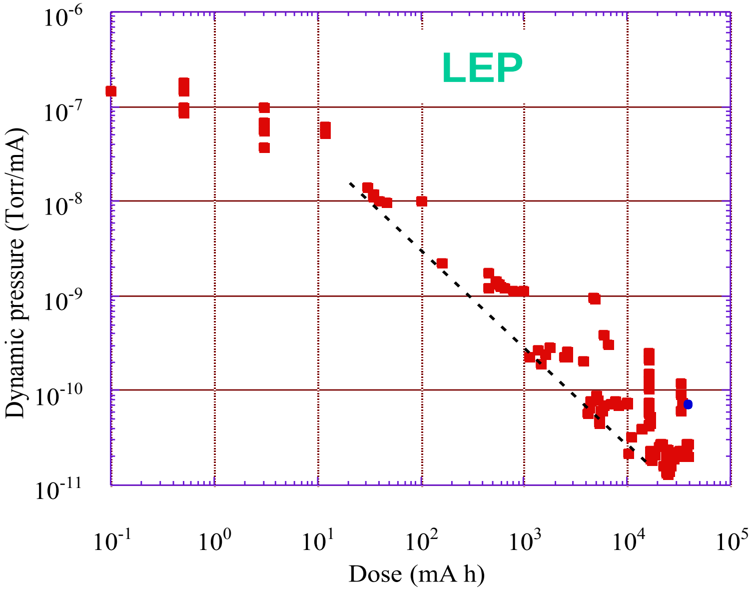
Beam conditioning

- This is not a myth and it is observed in many machines across the world!
- **Your machine** shall behave the same way



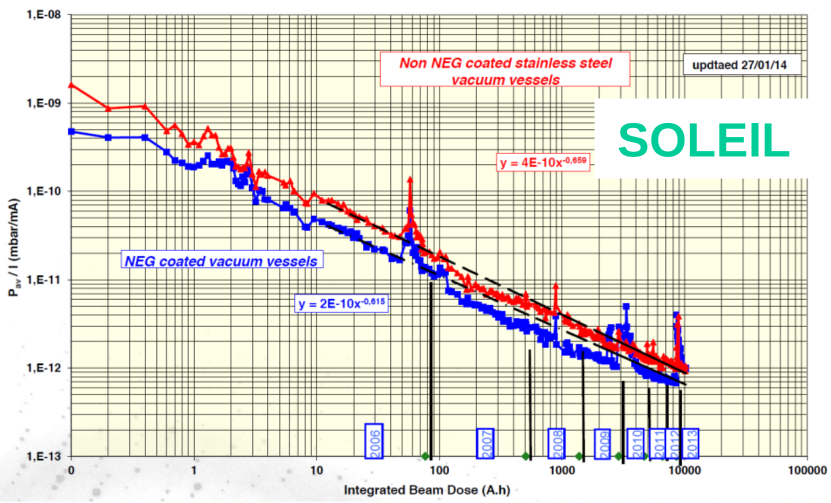


E. Al-Dmour, D. Einfeld, IPAC 2011



O. Gröbner. Vacuum 43 (1992) 27-30

Average pressure rise in cell C07 normalized to current Vs. beam dose

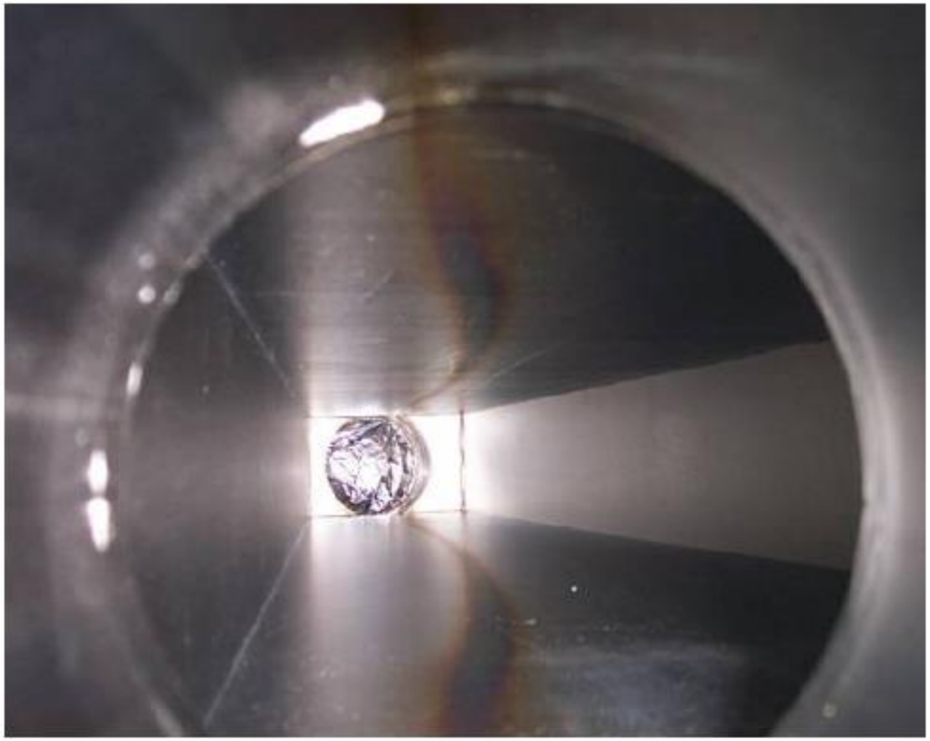


C. Herbeaux, Journée thématiques RTVide, décembre 2014

Beam scrubbing

- Graphitization is clearly visible!

LANL



dipole chamber (SRBM11, 6/20/07)

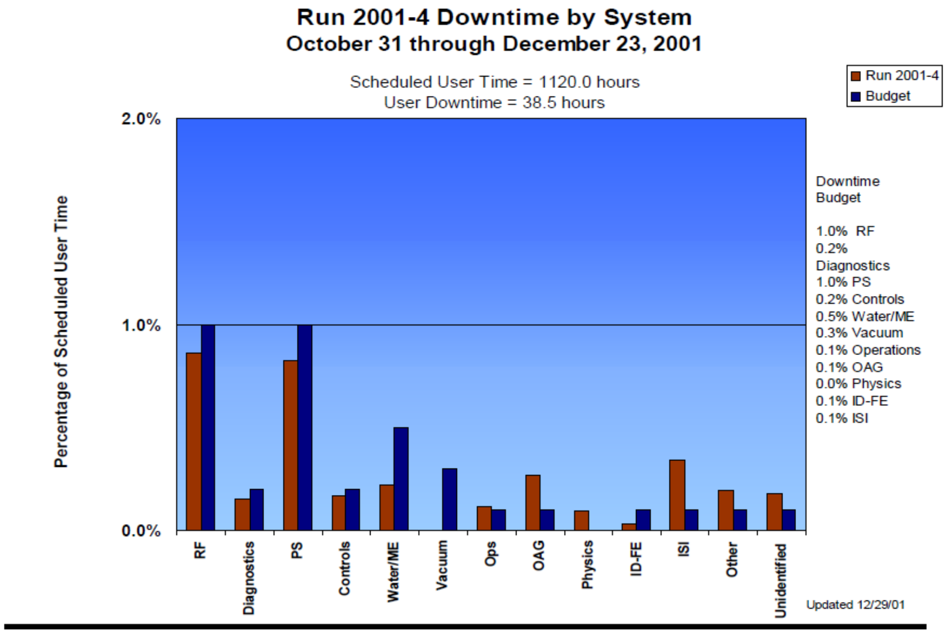
quadrupole chamber (SRQF11)

Courtesy R. Macek

Accelerator Fault Tracker

- Big brother is watching you … for your system health!

- **it Pays:**
  - **Machine availability > 96%**
  - **X-ray availability > 91 %**

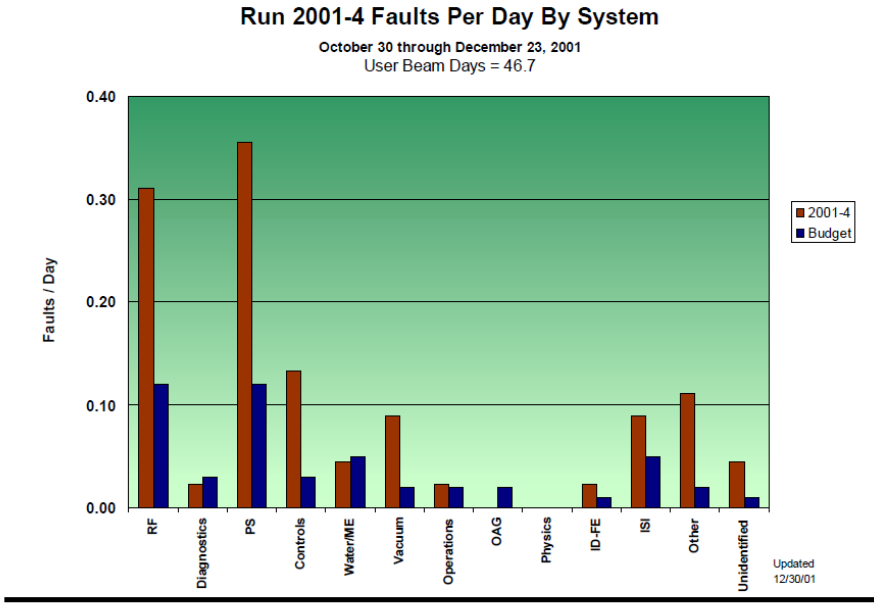


Run 2001-4 Downtime by System
October 31 through December 23, 2001

Scheduled User Time = 1120.0 hours
User Downtime = 38.5 hours

02/04/2002 ARW, Grenoble
Chihyuan Yao

Operations Group
Advanced Photon Source

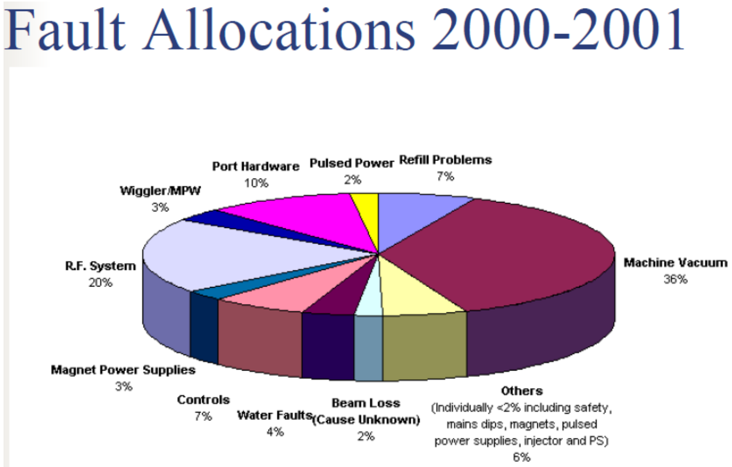


Run 2001-4 Faults Per Day By System
October 30 through December 23, 2001
User Beam Days = 46.7

02/04/2002 ARW, Grenoble
Chihyuan Yao

Operations Group
Advanced Photon Source

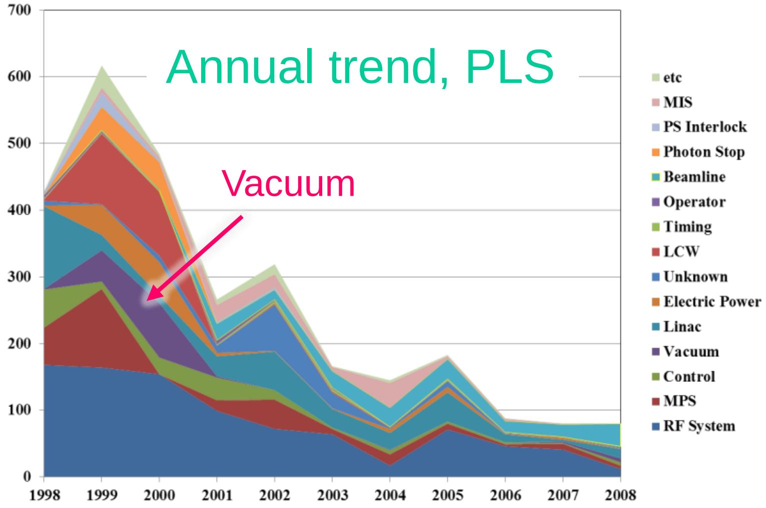
Fault allocation



SRS, Daresbury

	PS	RF	CONT ROLS	VAC	Cooling	other	BL	refill
APS	>15%	>15%	>10%	>35%	<5%	>10%	>5%	
ELETTRA	>15%	>5%	>10%	<5%	>10%	> 5%	>5%	>10%
ESRF	> 5%	>20%	**> 5%**	>25%	>15%	<5%	>5%	

E. Karantzoulis, 2002

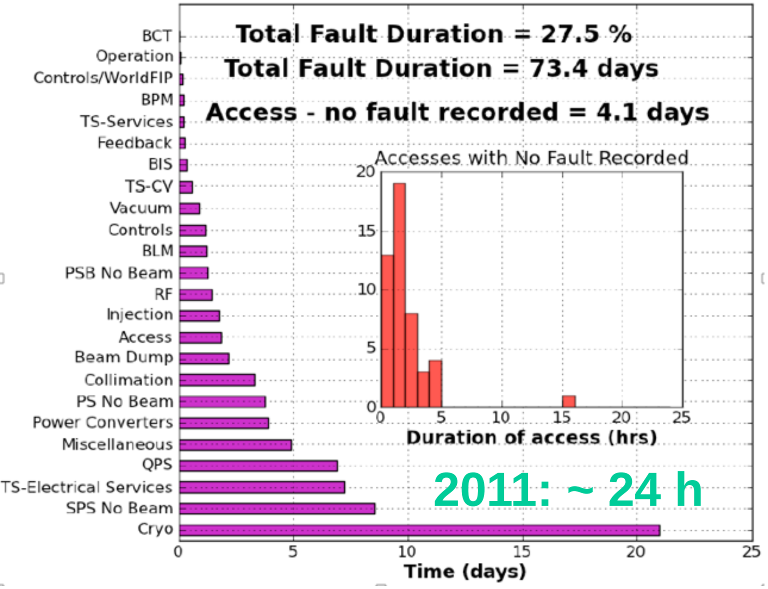


E. Park, ARW2013

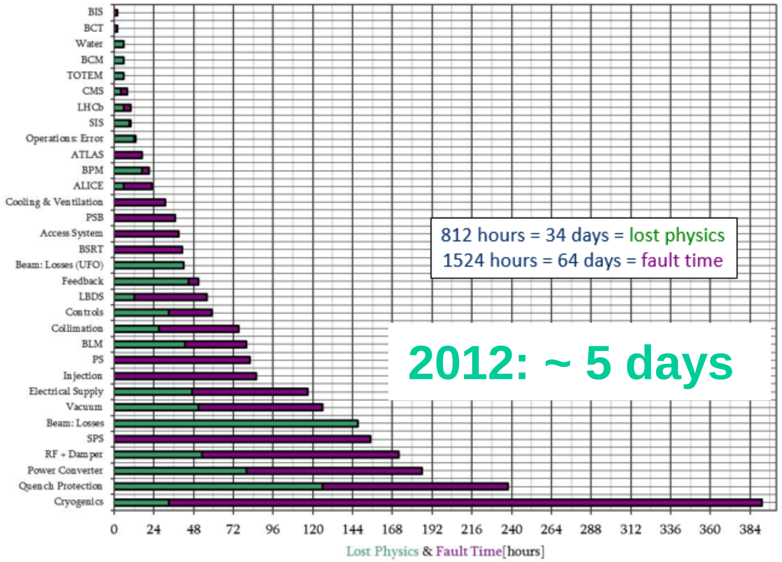
The vacuum system is always a good candidate for fault generator, in particular at the beginning of a project

LHC Vacuum: Lost Physics and Fault Time

- A thorough consolidation of the vacuum system during LS1 paid!

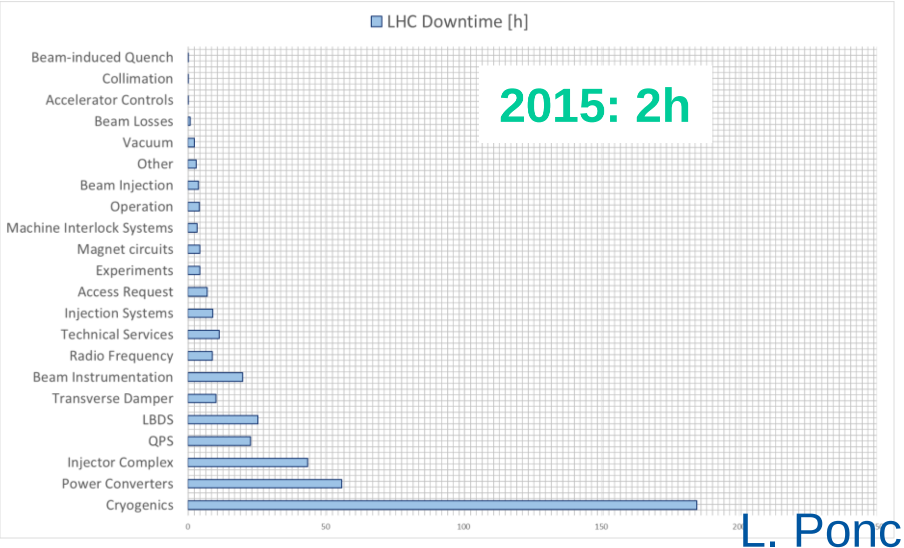


2011: ~ 24 h

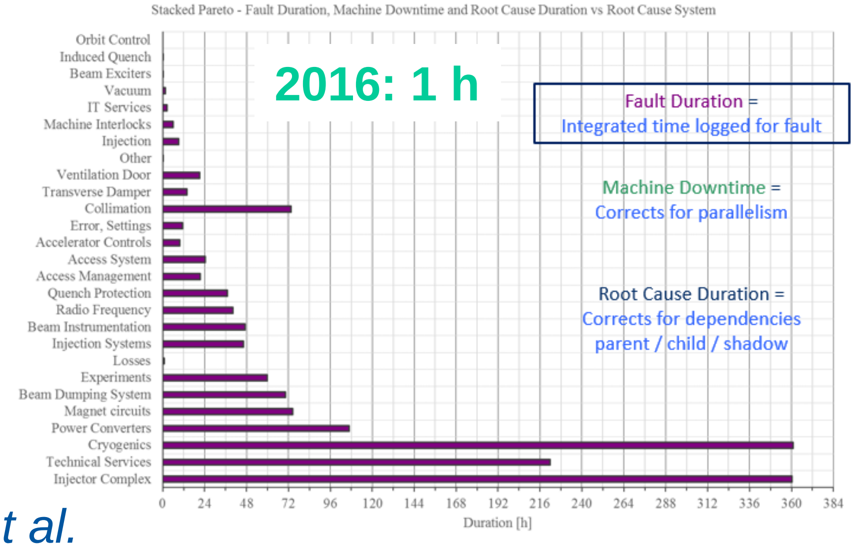


812 hours = 34 days = lost physics
1524 hours = 64 days = fault time

2012: ~ 5 days



2015: 2h



2016: 1 h

Fault Duration = Integrated time logged for fault

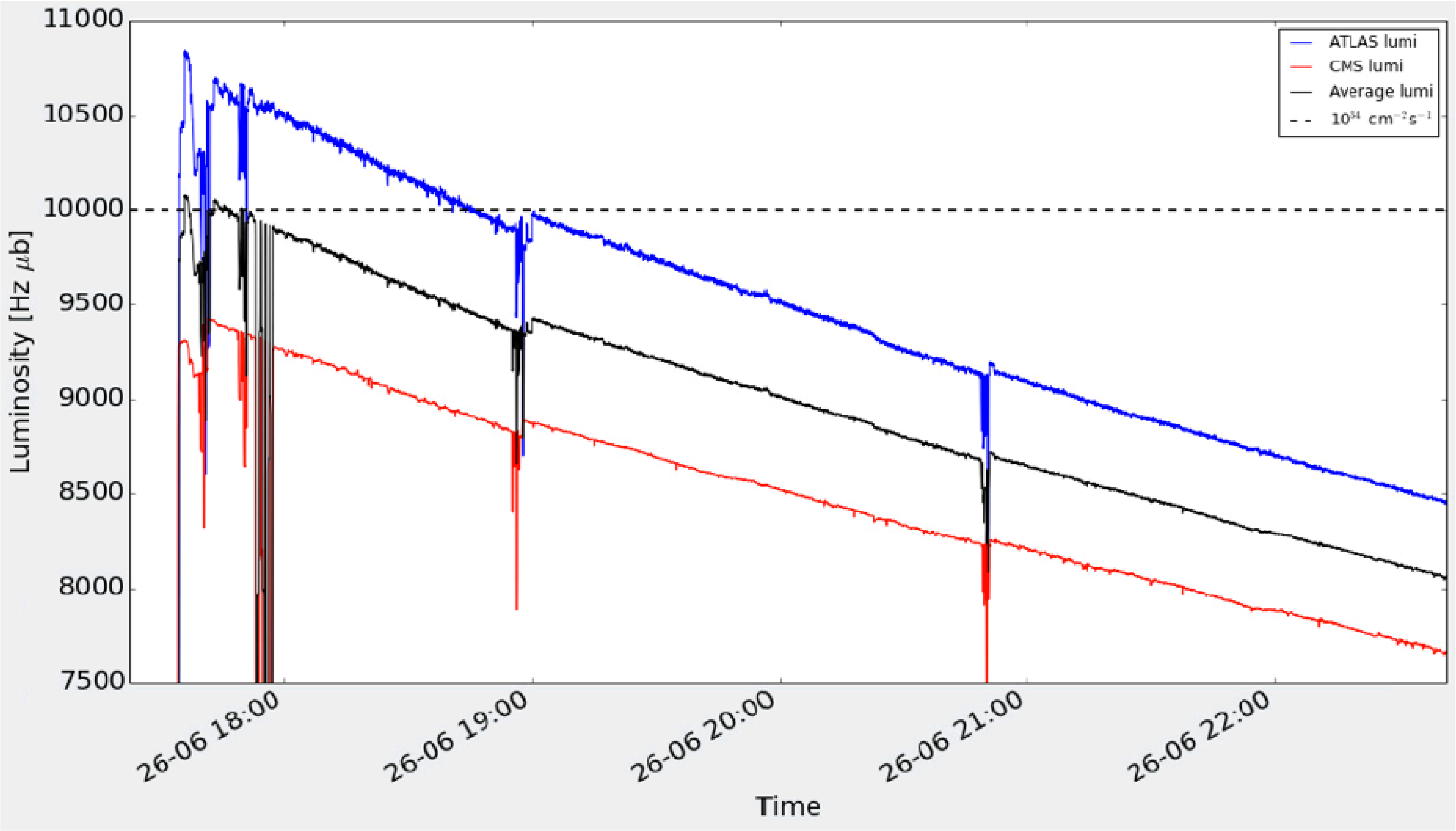
Machine Downtime = Corrects for parallelism

Root Cause Duration = Corrects for dependencies parent / child / shadow

L. Ponce *et al.*

LHC Design Luminosity: 26th June 2016

We reached design luminosity!



Celebration at the CCC!

Summary

- The real life of operation relies on availability.

- Availability is a constant concern during the life of a system.

- Availability of vacuum system relies on :

  - Group Expertise (which must be maintained and continued to be developed)
  - New concepts
  - Studies
  - Design
  - Production & installation follow up: Quality Assurance Plan is a must
  - General monitoring / support by stand-by
  - Fill by fill and daily monitoring / support by experts
  - Repair, consolidation and upgrade of the system

- All these activities are based on many technical, engineering and scientific skills which must be available for the project to ensure availability!

Some References

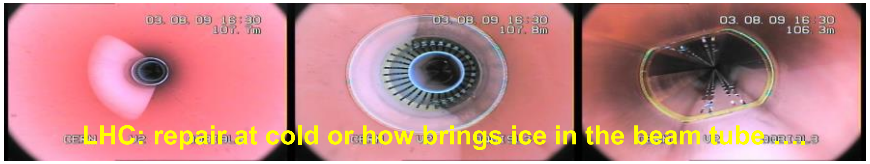
- Cern Accelerator School, Vacuum technology, CERN 99-05
- Cern Accelerator School, Vacuum in accelerators, CERN 2007-03
- This school !

Workshops & conference

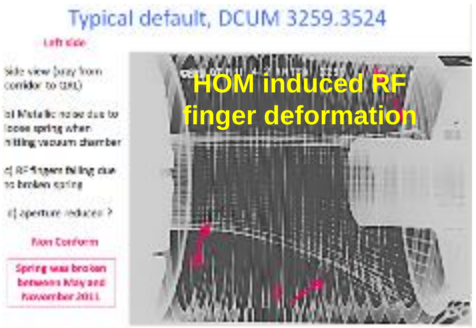
- PAC, EPAC, IPAC series available on JACOW web site
- OLAV: Operation of Large Vacuum Systems Workshops
- ARW: Accelerator Reliability Workshops
- WAO: Workshops on Accelerator Operation

Thank you for your attention !!!

Superinsulation harvest



LHC: repair at cold or how brings ice in the beam tube…



Typical default, DCUM 3259.3524

Left side

Side view (tray from corridor to (IR))

b) Metallic noise due to loose spring when [illegible]ing vacuum chamber

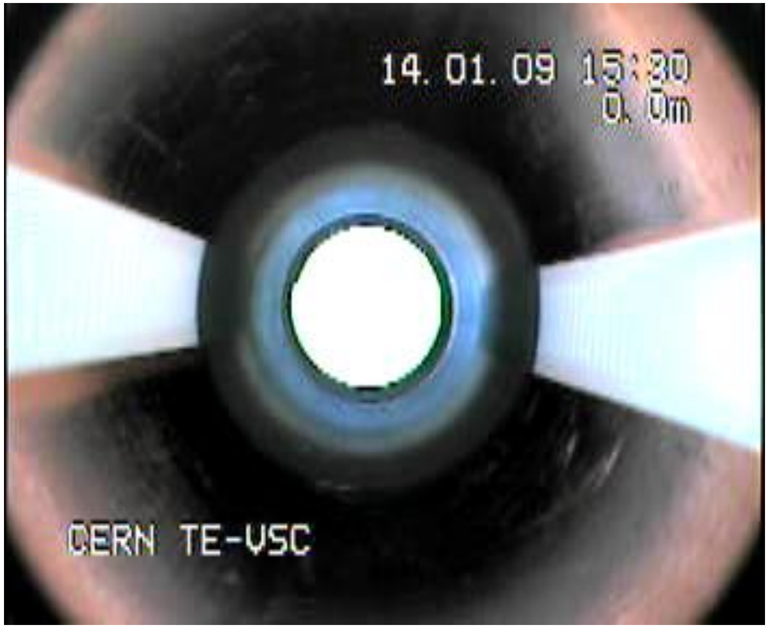
c) RF fingers falling due to broken spring

d) aperture reduced ?

Non Conform

Spring was broken between May and November 2011

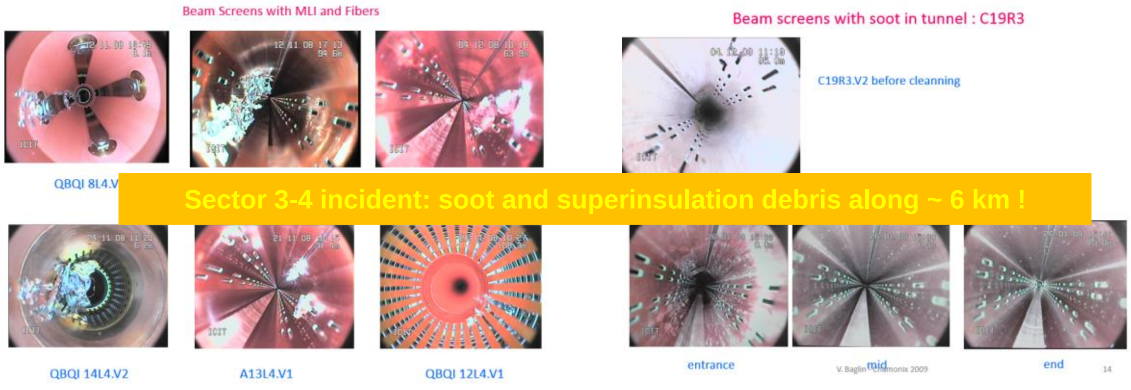
HOM induced RF finger deformation



QQBI.26R7 line V2

Increasing contact impedance at the price of buckling

LHC: the most expansive brazing machine



Beam Screens with MLI and Fibers

QBQI 8L4.V

QBQI 14L4.V2

A13L4.V1

QBQI 12L4.V1

Beam screens with soot in tunnel : C19R3

C19R3.V2 before cleanning

entrance

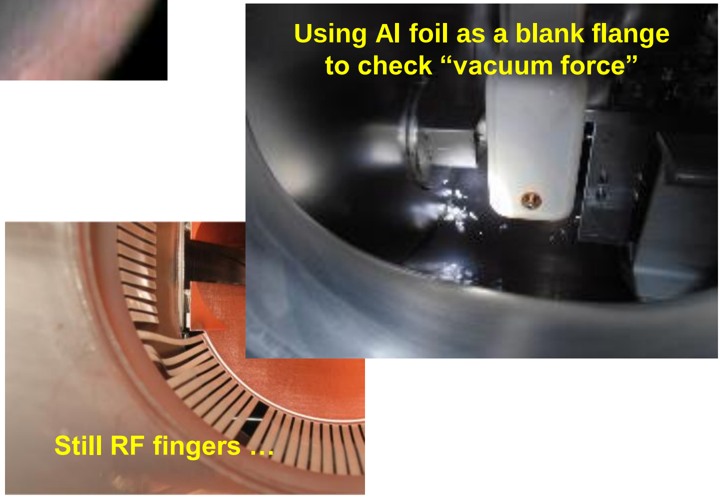
mid

end

V. Baglin Chamonix 2009

14

Sector 3-4 incident: soot and superinsulation debris along ~ 6 km !



Using Al foil as a blank flange to check “vacuum force”

Still RF fingers …

CERN