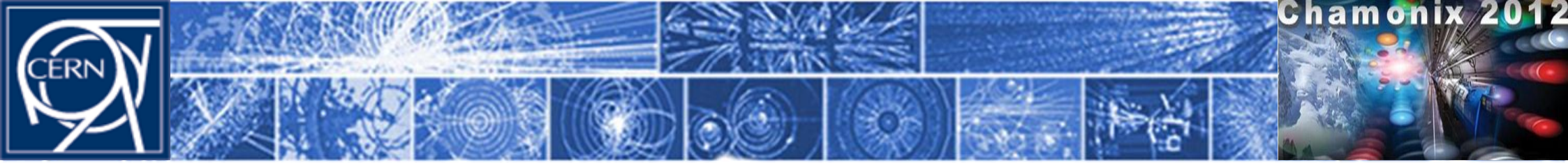


Vacuum upgrade

José Miguel JIMENEZ

On behalf of the Vacuum, Surfaces and Coatings Group

Main Topics

- **Introduction**
- **What has been learnt so far?**
- **Major consolidations**
- **Challenges**
- **Operation at nominal LHC performances**
- **Conclusions**

What has been learnt so far?

Beam Vacuum & Dynamic effects

- **NO DESIGN ISSUE, pumping layout and instrumentation behaved as expected**
  - Vacuum "activity" enhanced by the fast increase of luminosity
  - BS cooling loop successfully optimised ⇨ Heavy gas coverage is more sensitive to ΔT
  - Non NEG coated areas dominated by far the pressure rises ⇨ all equipment groups are concerned
- **Vacuum instrumentation insufficient in few places where unexpected pressure rise were taking place ⇨ difficult to make accurate diagnostics**
- **Operation with 50 ns beams should go smoothly for beam vacuum even if the bunch population is slightly increased**
- **Operation with ions is "transparent" for the beam vacuum**

What has been learnt so far?

Insulation Vacuum & Leaks

- **Air leaks could generate collateral damages ⇨ Ice plug like in the QRL bellows**
  - Large leaks to be fixed, is part of the baseline, time has to be allocated
  - Problem appears during fast warm-up ⇨ avoid thermal runaway by preventive pumping capacity adapted to the amount of gas release
  - ☞ Is not a limitation during operation, no systematic leak problems seen
- **Helium (gas or liquid) leaks can only be partly cured by adding additional turbo pumps ⇨ Limited to a factor 2-4 maximum contingency**
  - Cryo leaks tend to open and increase by orders of magnitude
    - Temperature cycles above 120 K must be avoided
  - 2 critical leaks in magnet cryostat S34 and in QRL S45

Major consolidations: SAFETY

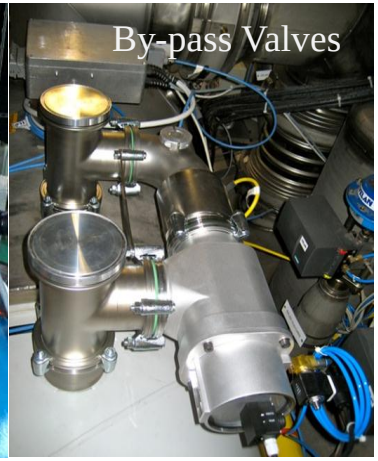
See Annex A for details

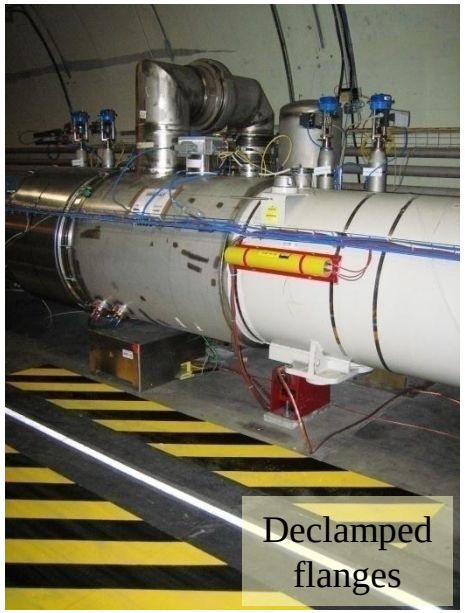
- **Pressure relief valves, flap valves and half shells are in co-activities with the splice consolidation**
- **Reclamping of quadrupole flanges to be made in collaboration with BE-BI**
- **Pressure triggering at Q10 instead of Q7, fast shutters requires cabling by EN-EL**

☞ **All consolidations decided after S3-4 incident will be completed in LS1**


Protective half shells


Flap Valves


By-pass Valves


Declamped flanges

Major consolidations: SAFETY

Activity	Area	Motivation	Other Groups Affected	Potential conflict with splice consolidation
Splice consolidation				
Cryomagnet replacement				
Connection cryostat consolidation				
Y-Lines repair				
New DN200 & Reclamping of instrumentation flanges				
SAM helium gauge consolidation				
Triplet braid				

See Talk of Jean-Philippe TOCK

- **These activities will require VSC support**
  - Beam Screen installation and leak testing in SMA18
  - Extensive leak testing and pump down support in the tunnel (10'000 welds, 8'000 o-rings)
  - As for LHC installation, leaks will be found during critical path activities

☞ **Activities in sequence mode so limit VSC flexibility and availability for other tasks**

Major consolidations: PERFORMANCE

See Annex B for details

- **Mitigation of electron cloud on non-NEG coated components ⇨ Vacuum, BI, ABT, RF and ATB components**
  - NEG or a-C coatings (liners as an alternative) or solenoids
- **Optimisation of cold warm transitions ⇨ getting far from gas adsorption isotherms**
- **New beryllium beampipes for ATLAS, CMS and LHCb**
  - New forward beampipes for ATLAS

☞ **Pressure rise observed (2010-11) have been understood and mitigations are integrated in the approved consolidations**

☞ **Consolidations allows performing at 7 TeV / beam and ultimate intensities**

- **Consolidation of equipment from ABT, BI, RF, ATB and VSC groups are needed**

Major consolidations: RELIABILITY

See Annex C for details

- **RF ball aperture tests to be executed after warm-up and before cool down ⇨ to be organised with CRG group**
- **PIMs exchange (114 in total) to be synchronised with magnet exchange and splice consolidation**
- **Leak test envelopes, localization and repair of known leaks (x 21) to be synchronised with CRG and splice consolidation ⇨ Decisions will be taken if leak not found on time**
- **Replacement of non conforming RF inserts in bellow modules ⇨ manufacturing work could be required**

☞ **All known reliability problems will be fixed**

- Leak testing of cyomagnets is not always straightforward due to accessibility problems
- Must be prepared to allocate more time **or** accept to leave with the leak...

Major consolidations: OPERATION MARGIN

- **Modification of 50% of DN200 flanges to adapt for DN100 pumping ports (2 per Sector) ⇨ in collaboration with EN-MME**
- **Additional pumping around injection kickers and collimators (IR1, 2, 5 and 8) ⇨ cabling will be required**
- **Additional instrumentation (P and T) around collimators ⇨ cabling will be required**
- **Modification of the layout of the vacuum instrumentation modules to avoid artefacts induced by electrons and photons ⇨ limit wrong pressure reading**

Challenges: Impact of the Injectors' activities

See Annex E for details

- **PS Complex & TLs**
  - LINAC 2&3: Maintenance
  - LINAC 4: Acceptance tests and start of the installation
  - PSB & TLs & ISOLDE: Maintenance and modification of TLs
  - PS & TLs: Maintenance and Upgrade of vacuum controls
  - AD: Maintenance

- **SPS Complex & TLs**
  - TE-VSC: Maintenance, new vacuum sectorisation and pumping layout
  - Needs expressed by other equipment owners: ABT, BI, RF, ATB, MSC
  - Project's related studies: LIU-SPS Electron Cloud preparatory work, COLDEX studies

☞ **Would like to get informed of new demands as soon as known**

Challenges

Resources for Vacuum activities in tunnel and support in Labs

- **Difficult to allocate the Injectors' Experts to the LHC LS1 activities in 2013**
  - Exception of NEG activation teams ☞ Impact on Injectors' activities to be expected
- **Start quickly in 2013 on Injectors' activities**
  - Must avoid creating a bottleneck in Oct'13-March'14
  - Radiation issues to get priority in planning i.e. push them to the end (SPS-ZS and NA)
- **Injectors' Experts (50%) will be redeployed in LHC LS1 activities as from 2014 Run**
  - Priority on LINAC 4 will be kept
  - Other activities will suffer: AD consolidation studies, support to equipment owners, CTF3
- **Industrial Support has to be significantly increased ⇨ up to 34 vacuum Experts required**

☞ **New demand will go through the "priority" filtering**

Challenges: Risks & Schedule Issues

- **Risks**
  - Avoid damaging nested bellows during the Splice's consolidation
    - Appropriate training of teams, strong supervision in-situ...
  - Not being able to eliminate all leaks due to tight schedule (cryomagnets and QRL)
  - Need to redeploy compensatory measures if equipment from other groups cannot be optimised on time (HOM, Electron Cloud)
- **Schedule**
  - Delays with leak detections of existing and new leaks (splice consolidation / new magnets)
  - Ensuring timely arrival of beryllium beampipes for CMS and ATLAS – close contract follow up to detect and mitigate schedule risks ⇨ 2 months contingency (enough?)
  - Keeping on track the reinstallation schedule of equipment from other groups in the tunnel

Operation at nominal LHC performances

25 ns, 2808 bunches, 7 TeV

- **Vacuum dynamic effects will be seen on all non-NEG coated components of arcs and LSS**
  - Pressure rise to be seen in LSS
  - Heat loads in arcs
    - Arc gauges "should not see" pressure rise

  ☞ No pressure rise does not means necessarily no electron cloud

- **Will "discover" the synchrotron radiation induced effects**
  - Heat loads
  - Photo-electrons

  ☞ Effect on the electron cloud build-up will need some beam time to compare predictions with observations

Conclusions

- **Safety**
  - All consolidations related to Safety of personnel and of the accelerator will be completed
- **Performances**
  - Vacuum system will be prepared for 7 TeV operation with high bunch populations up to ultimate
    - Electron Cloud will be mitigated whenever feasible (at reasonable cost: resources & budgets)
    - Sources of background to Experiments is a priority: HOM, RF inserts, ferrite heating…
- **Reliability**
  - Vacuum systems and instrumentation reliability will be increased: target is 100% but…
- **Operation margin**
  - Will give room for mitigation solutions if needed

Conclusions

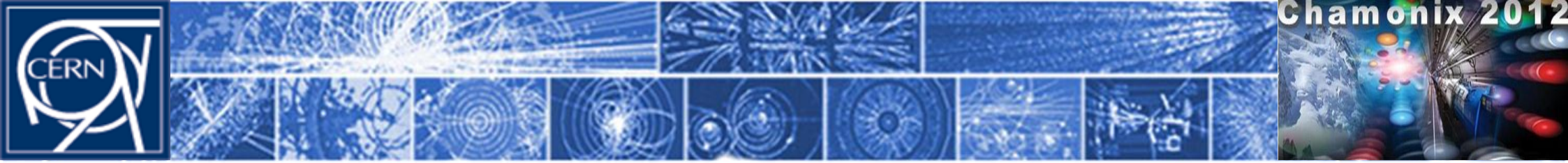
- **Challenges**
  - No showstopper but some concerns which will get clarified during the 2012 Run
    - How many more equipment to be removed from the tunnel?
- **Operation at nominal LHC performances**
  - All benefits from 2010-2012 Runs will not be lost
    - Scrubbing of arcs is expected to be partly kept
      - Scrubbing will then goes faster (memory effect)
    - OP Crew, Equipment Owners and Vacuum will know better the machine behavior and meaning of signals (vacuum, BLM)
  - 2011 was the year of electron stimulated desorption in LSS

☞ 2014-15 will be dominated by:

- Heat load induced in the arcs
- Photon stimulated desorption and photo-electrons

Acknowledgements

- **Many thanks to:**
  - TE-VSC Teams for their commitment on performance and for their availability
  - To the Engineers in charge and Operators for their helpful and proactive feedbacks
  - To our Colleagues, Equipment Owners, for the open-minded discussions and interesting brainstorming
  - To Experts (Cryo, impedance, RF, Survey, Design & Mechanics, Materials...) for their technical support
  - To Steve for "**keeping Pressure on Vacuum Experts**"
    - Quench limit at 2 bars so no problem for operation...


CERN
Chamonix 2012

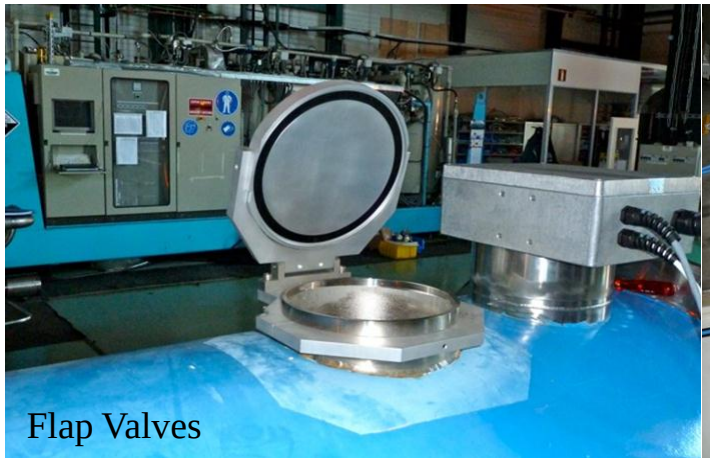
Annex A
Major consolidations: SAFETY

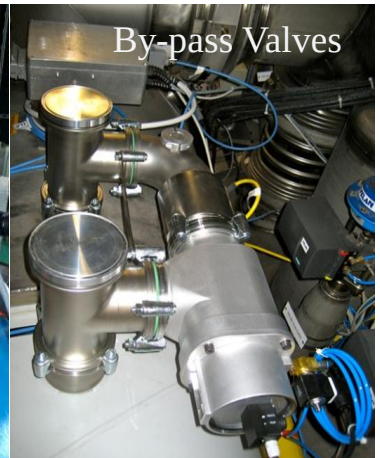
Activity	Area	Motivation	Other Groups Affected	Co-activities with splice consolidation
Resume installation of DN200 Pressure Relief Valves	2-3, 7-8, 8-1 and half of 4-5	Self closing over pressure valves	MSC	Yes
Reclamping of Quadrupole DN100 flanges	2-3, 7-8, 8-1 and half of 4-5	No longer required after installation of DN200	BI	No
Install Flap Valves on DN200/DN160	arcs, LSS SAMs	Self closing over pressure valves		No
Install Pressure Relief Valves (2 per sector) - replaces unclamped configuration	QRL	Spring based closing over pressure valves		No
Install protective half shells in interconnections	arcs	Protect bellows (mechanical/arcs), increase buckling limit, limit contamination by MLI	MSC	Yes
Pressure triggering at Q10 instead of Q7 (present situation)	Arcs Q10	Provide Δt needed to trigger the closure of sector valves		No
Install additional rupture disc	Arcs SSS, LSS	Protect beam vac. against overpressure		No

Paul CRUIKSHANK

Cédric GARION

Vincent BAGLIN





Annex A
Major consolidations: SAFETY

Activity	Area	Motivation	Other Groups Affected	Co-activities with splice consolidation
Reconfiguration of permanent bake-out	IR3, IR7	Reduce the dose received by personnel		No
Install new cabling & instrumentation	LSS	Improve controls logic for sector valves – Impact of NEG coatings	Vincent BAGLIN	No
Install fast shutters	LSS 4 + MKIs	Protect sensitive LHC equipment (studies still ongoing)	EL, ABT, RF	No

Annex B
Major consolidations: PERFORMANCE

Activity	Area	Motivation	Other Groups Affected	Potential conflict with splice consolidation
Install/remove mobile pumping groups	Arcs, LSS	Remove desorbed gas/recondition		No
NEG Coatings (use of liners?) on BPMs and other components (ADT, BPT, BGI) not NEG coated	LSS	Decrease the Electron Cloud induced pressure rise	BI, ABT, RF	No
Improvement of pumping performances	LSS	Decrease the pressure rise when Electron Cloud mitigation are not feasible		No
Install NEG and electron cloud pilot sectors	LSS (1,2,5,8)	Diagnostic instrumentation	EL	No
Install beam stoppers to protect Q4 in IR6 L&R	IR6	Protection of Q6	ABT, ATB	No
Exchange of Beryllium beampipes	ATLAS, CMS	New aperture		No
New aluminum based forward VI, VA, VT chambers	ATLAS	Improve transparency & activation, IBL detector	ATLAS coordination	No
New aluminum based ion pumps	ATLAS	Beampipe transparency and lower activation as compared to steel	ATLAS coordination	No
"Hambourg" experimental beampipes	IR1 L&R	ATLAS Experiment	ATLAS coordination	No
Change support UX85/2 & /3	LHC-b	Improve transparency of supports	LHCb coordination	No
Change supports in end cap/forward region	CMS	Improve access, reduce intervention risk	CMS coordination	No

Vincent BAGLIN

Annex B
Major consolidations: PERFORMANCE

Activity	Area	Motivation	Other Groups Affected	Potential conflict with splice consolidation
Additional NEG cartridge pumps on ALL Inner Triplets and ALL SAMs with dipoles	SAMs	Decrease sensitivity to BS temperature oscillations		No
Heaters on Cold/Warm transitions to decrease the gas coverage	SAMs	Decrease sensitivity to BS temperature oscillations		No
(a-C coating of D1 magnets in IR2 and IR8)	SAMs	Decrease sensitivity to BS temperature oscillations		No
NEG Coatings in sectorisation modules	SAMs	Mitigate Electron Cloud induced pressure rise		No

Vincent BAGLIN

Annex C
Major consolidations: RELIABILITY

Activity	Area	Motivation	Other Groups Affected	Potential conflict with splice consolidation
RF ball test	Arcs	Aperture checks: after warm-up AND before cool down	Vincent BAGLIN	No
Exchange PIMS	Arcs, LSS	Eliminate critical PIMs	Cédric GARION	Yes
Leak test envelopes (global)	arcs, LSS, QRL	Check tightness integrity	CRG	Yes
Localise and repair known leaks	all arcs	Eliminate helium leaks	MSC, CRG	Yes
Inspect beam screen capillary	arc 8-1	Understand helium leak origin	Paul CRUIKSHANK	
Install additional turbos (& cables)	QRL extremities	Create pumping redundancy	EL	No
Maintain turbo pumping groups	arcs, LSS	Maintenance - preventive and corrective		No

Motivation	Quantity
Preventive actions (Q7/B, B/Q7)	18
Damage bellows	~10
Fingers buckled during warm-up	~14
Magnet replacement	72
Total	**~114**

Annex C
Major consolidations: RELIABILITY

Activity	Area	Motivation	Other Groups Affected	Potential conflict with splice consolidation
Repair gauge cabling in mid arcs	arcs	Eliminate faulty gauge reading	Vincent BAGLIN	No
Install additional gauges in arcs	Arcs	Consolidate instrumentation	EL	No
Replace UX85/3 chamber	LHC-B	Eliminate NC chamber	LHC-B Coordination	No
Inspection X-ray VM modules	LSS	Identify RF finger problems	Access restriction	yes
Exchange VM modules as required	LSS	Reduce impedance	Vincent BAGLIN	No
Review of the RF screen inserts in bellows	LSS, Experimental Areas	Improve HOM screening	ABP, MME	No
Modification of vacuum layout near cold D1	IR2 L&R, IR8 L&R	Decrease non-baked length		No

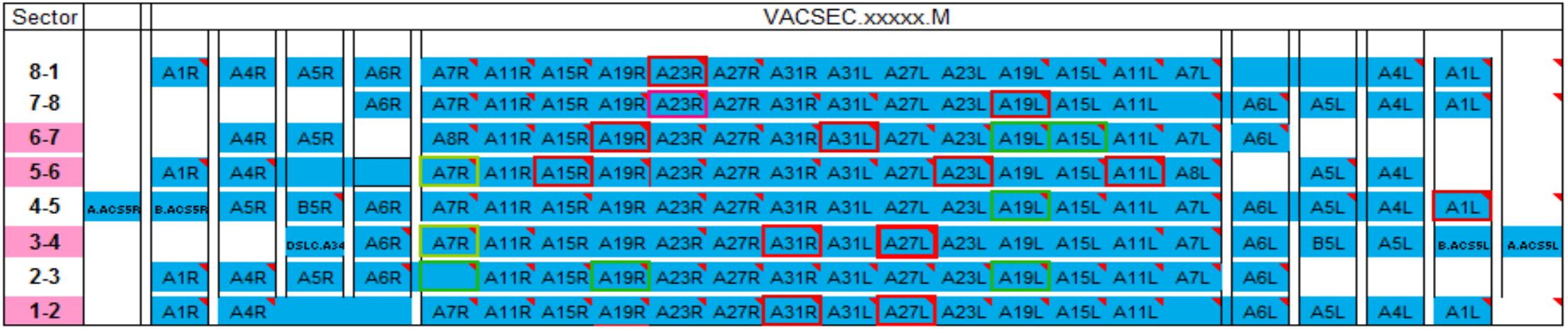
Annex C

Major consolidations: RELIABILITY

Status of LHC insulation vacuum - helium leaks January 2012

Internal helium leak - with turbo on, equilibrium pressure at 1.9K > 1 e-6 mbar

Internal helium leak - with turbo on, vacuum pressure fluctuations during temp transients



QRL: internal helium leak in S45 subsector B

Secteur	Sous secteur	Valeur de fuite calculée (à l'air) suite aux remontées de pression 2010	Valeur de fuite (He) obtenue lors du test	Element	Réparation
4-5	Sous secteur B	0.1 mbar.l/s	Pas de fuite détectée, pas de remonté de pression		
7-8	Sous secteur A	3.10-2 mbar.l/s	3.2.10-2 mbar.l/s	Fuite sur soudure	Mastic (provisoire)
7-8	A6L8.M	4.10-2 mbar.l/s	4.10-3 mbar.l/s	Fuite sur pied gauche aimant	Mastic (provisoire)
7-8	A19L8.M	10-3 mbar.l/s	Pas de fuite détectée		
7-8	A23L8.M	10-3 mbar.l/s	Pas de fuite détectée		
3-4	A15L4.M	5.10-4 mbar.l/s	3.3.10-4 mbar.l/s	Fuite sur joint manchette	LS1
3-4	A19L4.M	5.10-4 mbar.l/s	1.10-4 mbar.l/s	Fuite sur pied central aimant	LS1
8-1	QRL SS.G	3.8.10-4 mbar.l/s	Pas de fuite détectée		
3-4	A15R3.M	3.1.10-4 mbar.l/s	Pas de fuite détectée mais communicant avec A19R3.M		
3-4	A19R3.M	2.10-4 mbar.l/s	4.1.10-4 mbar.l/s	Fuite sur soudure jumper	En cours
3-4	A23R3.M	2.25.10-4 mar.l/s	Pas de fuite détectée		
3-4	A27R3.M	2.2.10-4 mar.l/s	Fuite non détectée (detection d'une seconde fuite a 2.10-6 mbar.l/s)	Fuite sur O-ring BLM	LS1
4-5	A31L5.M	5.7.10-5 mbar.l/s	Pas de fuite détectée		
4-5	A27L5.M	1.10-4 mbar.l/s	1.10-4 mbar.l/s	Fuite sur pied droit aimant	Mastic (provisoire)

Annex C
Major consolidations: RELIABILITY

Leak Testing at t_0 (recall from Chamonix 2011)

- **Some leak testing activities must be made before splice consolidation can start i.e. the systems are still under vacuum.**
  - Important to have status of all vacuum subsectors before major interventions

- **Localize the known helium leaks before venting:**
  - Under vacuum, temperature > 20 K, He pressure constant
  - Two 8 hour days per known leak with above conditions.
  - Need support from CRG to pump or pressurise circuits.
  - Leaks in the same arc can be partially treated in parallel
  - After venting, MSC will be asked to open priority interconnects ~ 1 day.
  - VSC will need pressure (~ 5 bar) in coldmass or c'k circuit for ~ 2 days.

- **Leak test all vacuum subsectors before venting:**
  - Under vacuum, temperature > 80 K, He pressure constant
  - Two 8 hr days per arc – LSS can be made in parallel.

Annex D
Major consolidations: OPERATION MARGIN

Activity	Area	Motivation	Other Groups Affected	Potential conflict with splice consolidation
Install 2 DN200 flanges with DN100 pumping port/Sector	arcs	Provide more ports for additional turbo pumping	MME	No
Preparation of 10 mobile pumps with offset electronics	arcs	Be able to install quickly additional pumping	EL	No
Exchange S3-4 beam screens with reversed saw teeth	Arc 3-4	Dynamic vacuum effects	MSC,EL,SU	Yes
CMS carbon support to be replaced if not fulfilling the LS1.5 constraints	IP5	Be sure that existing support is compatible with future work	CMS Coordination	No
Additional vacuum instrumentation in ALICE at the centre (close to IP)	IP2	Provide local measurement of pressure	EL	No
Exchange of bellows between Q1 and VAX Requires new BPMs	All Q1/VAX	Allow more displacement margin for the ITs	BI	No
Vacuum performances of injection kickers intermodules	IR2L, IR8R	Improve the pumping and ultimate vacuum	ABT	No
Integration & Layout changes at MSD	LSS6	Reduce vacuum sector length	EL, ABT	No
Install thermocouples near collimators	LSS 3 and 7	Monitor effect of collimators	EL	No
Vacuum instrumentation modification to limit artifacts induced by electron cloud	LSS	Avoid the part of electron cloud is collected by gauges		No

Paul CRUIKSHANK

Mark GALLILEE

Vincent BAGLIN

Annex E
Challenges: Impact of the Injectors' activities

PS Complex & TLs

- **LINAC 2&3**
  - Maintenance of the ion pumps and primary pumps.
- **LINAC 4**
  - Start installation in the tunnel as from Oct'12, activities all along 2013 including validation tests of
- **PSB & TLs & ISOLDE**
  - Layout modification of the TLs (except injection to be done in 2015)
    - Includes major modification of the vacuum instrumentation, cabling and racks
  - Exchange of the PSB beam dump; upgrade of beam stoppers and slits
  - Installation of RF cavities (Fin-Met)
  - Intervention in most of the vacuum sectors for replacement or maintenance of BPM, BCT, MTV, etc.
  - Pumps' maintenance and refurbishing of GPS separators.
- **PS & TLs**
  - Upgrade of the vacuum instrumentation and control system
  - Installation of RF cavities (Fin-Met), several beam instrumentation monitors, magnets and spoiler
  - Replacement of septum 23
  - Possible replacement of BFA 9 and 21 (beam dumpers)
  - Interventions in the whole TT2 line for maintenance and replacement of BCT and magnets.
  - East-Hall: pumps' maintenance and intervention for the replacement of 2 magnets
- **AD**
  - Consolidation of the vacuum instrumentation and controls
  - Replacement of septum in sector 1A, intervention for beam monitors, beam stoppers and removal of magnets (in preparation of ELENA)
  - Bakeout system's rejuvenation and bakeout of vented sectors.
  - Exchange of ion pumps with corroded feedthroughs (30 % of the pumps)
    - Installation of heaters to limit corrosion

Annex E
Challenges: Impact of the Injectors' activities

SPS Complex & TLs

- **TE-VSC driven**
  - Ion pumps to be exchanged (about 40)
  - New vacuum sectorisation of bending sections and kickers
  - Consolidation of SPS pumping and venting valves
  - Consolidation of the North Area
  - Consolidation of TI2 & TI8: SPS to LHC TLs
- **Needs expressed by other equipment owners**
  - Exchange of kickers in BA1 and BA4, new vacuum sectorisation and removal of old turbo pumps
  - Interventions on extractions in BA2 (ZS) and BA6 (MSE)
  - Interventions in RF cavities in BA3 (BPWA, insertion of new pickups, wideband kickers)
  - Interventions on beam instrumentation: fast BCT, pickups, wire scanners, BCRT.
  - Installation of a pump and instrumentation in the new TBID of the North Area
  - Installation and bakeout of a graphite collimator in BA5 (UA9)
  - Magnet exchanges (less than 50)
- **Project's related studies**
  - Electron Cloud preparatory work
  - COLDEX studies