High Luminosity LHC

Engineering guidelines & issues

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The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404.

Outline:

- Vacuum system layout
  - Sectorization
  - Instrumentation
  - Supporting system
- Vacuum system components
  - General requirements
  - Vacuum chamber
  - Compensation system
  - C/W transition
- Assembly techniques
  - Flanges
  - Weld
  - Vacuum brazing
  - Trapped volume
- Insulation vacuum
- Quality assurance
  - Documentation
  - MTF
- Conclusion

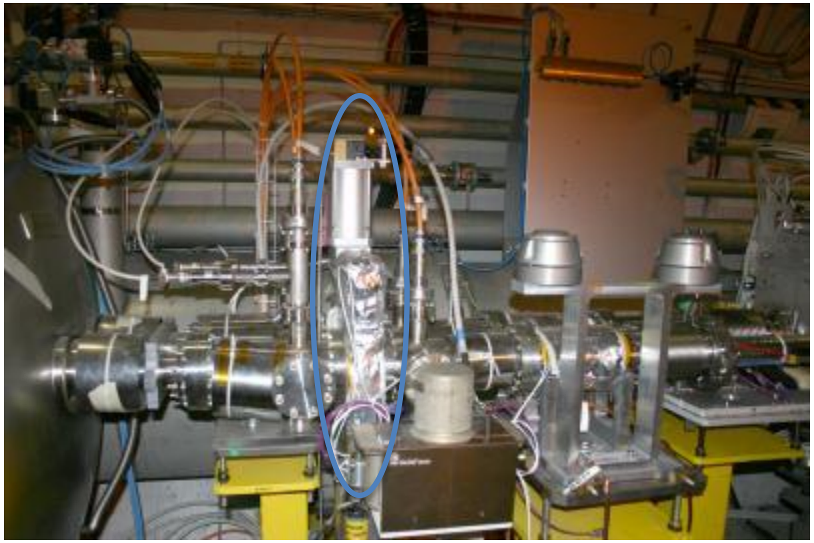
Vacuum system layout

Sectorisation:

To avoid contamination, to ease the replacement of an element or the commissioning, a sector valve shall be installed on each line at both element extremities.

They are installed in case of warm vacuum sector/cold magnet(s) transition, collimators, cavities, …

Typical closure time is 1 s.



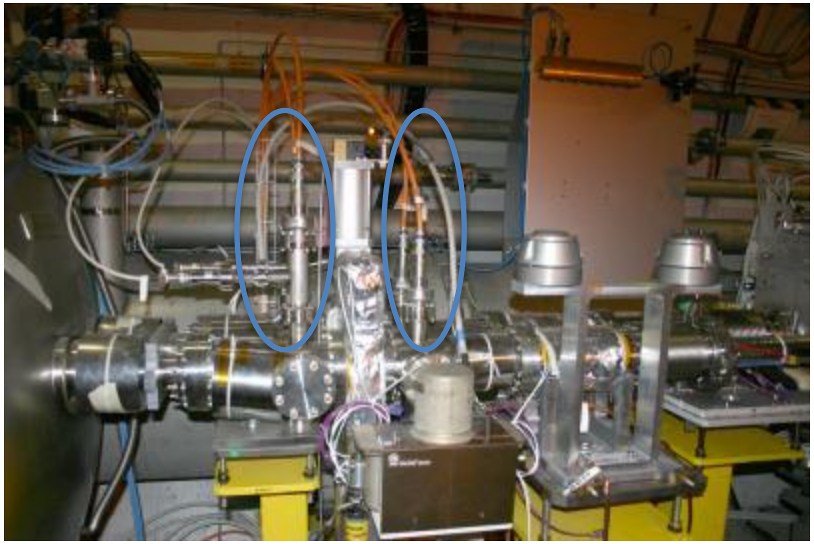
Vacuum system layout

Instrumentation:

Interlock valve

Pirani/Penning

Each side of the valve → interlock for the valve

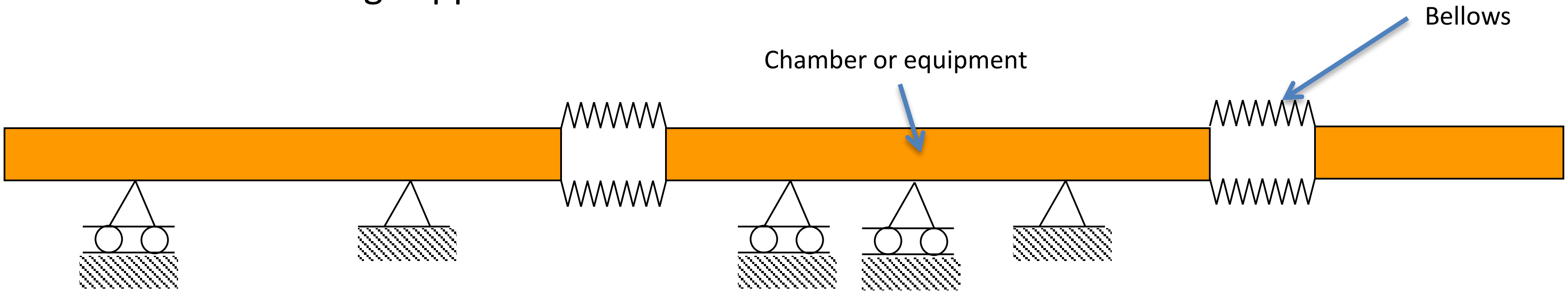


Vacuum system layout

Supporting system:

Principle:

- 1 fixed point per assembly between two bellows
- Other sliding supports



Under vacuum/atmospheric differential pressure, the fixed support has to withstand a longitudinal force induced by the difference of bellows cross-sections. Commissioning or maintenance scenario has to be taken into account (blank flange).

$$\boldsymbol{F}_{\rightarrow Support} = P_{atm} \cdot \sum \overline{\boldsymbol{S}}_{bellows}$$

Vacuum system components

Vacuum chambers:

Material:

- No polymer material (high outgassing rate, radiation damage) in the vacuum system.
- Temperature resistance: nominal 230 °C for NEG coated chambers, uncoated stainless steel: 250-300 °C.

Materials commonly used:

→ Stainless steel with low carbon and inclusion contents: 316L, 316LN
→ Copper OFS
→ Aluminium alloy: 2219

→ Aluminium should be preferable used from radioprotection point of view. Assessment of other aluminium grades to be done for UHV applications: mechanical, vacuum and radioprotection aspects (collaboration with KEK, ActiWiz code).

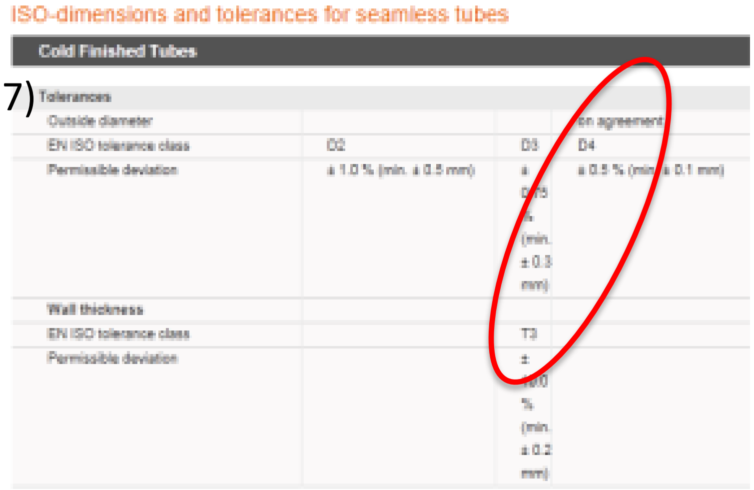
Design:

- For buckling resistance, the minimum thickness is around D/100 (stainless steel) to D/80 (aluminium)

Vacuum system components

Vacuum chambers:

Tolerances:



ISO-dimensions and tolerances for seamless tubes

Cold Finished Tubes			
Tolerances			
Outside diameter			on agreement
EN ISO tolerance class	D2	D3	D4
Permissible deviation	± 1.0 % (min. ± 0.5 mm)	± 0.75 % (min. ± 0.3 mm)	± 0.5 % (min. ± 0.1 mm)
Wall thickness			
EN ISO tolerance class		T3	
Permissible deviation		± 10.0 % (min. ± 0.2 mm)	

- Standard high precision seamless tubes: D4 T3 (ISO 1127)
    - Class D4: OD: +/- 0.5 %
    - Class T3: Thickness: +/- 10 % (class T4: +/- 7.5%)

For info:

- Tube OD 147 +/- .74, t: 4 +/- 0.3

→ ID 139 +/- 1

- Arc cold bore tube:
    - OD: 53 +/- 0.15
    - Thickness: 1.5 +/- 0.1
    - Straightness: 0.5 mm/m

- Machined long circular tube: (Input's from Manufacture de forage, tbc)
    - ID : 139 0/+0.1
    - Thickness: 4 +/- 0.5
    - Straightness: 0.3 mm/m

Straightness will be an important tolerance for the cold bore an the "stiff" beam screen.

Typical timeline for non-standard material procurement: ~ 1 year.

Vacuum system components

<u>Compensation system:</u>
Bellows expansion joints

Material:

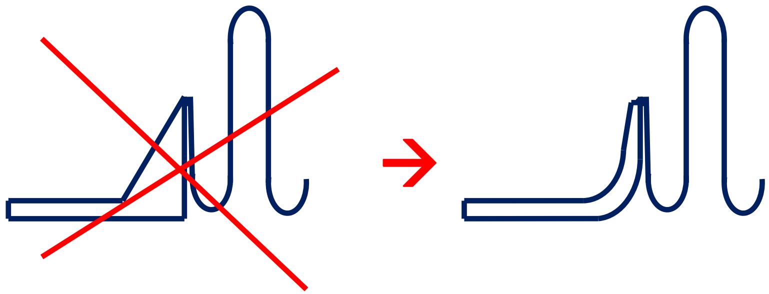
- convolutions: 316L, CERN specification 525
- End fittings in stainless steel: 316L or 316LN

Design:

- Hydroformed convolutions, baseline at cryogenic temperatures
- Bellows should conform to EJMA (formed bellows)
- Rule of thumb for low fatigue regime: convolution length = 2 * stroke

Manufacturing of the end fittings:

- no machining perpendicular to the fibers in “standard” material
  → Flanged tube
- Machining from a 3D forged block



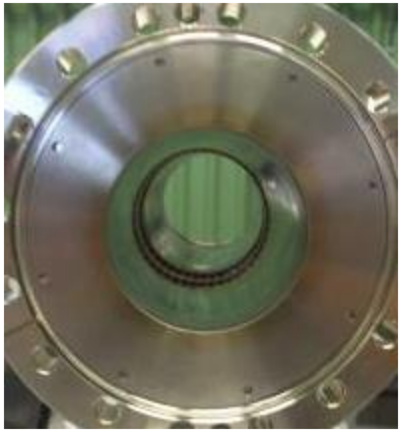
Vacuum system components

<u>Compensation system:</u>

RF fingers

PIM with sliding RF fingers

Deformable RF finger prototype



Concept:

- Sliding fingers (baseline)
- Deformable fingers under study

Material:

- Contact strips in gold plated (cryogenic temperature) or silver plated (room temperature) copper beryllium alloy
- OFE copper inserts coated by electroplated Rh

Interface:

- Preferably circular aperture,
- No geometrical transition (shape or offset) in the compensation system

Vacuum system components

Cold/Warm transition:

Cold/warm transitions are installed between cold masses and warm vacuum sectors (sector valve).

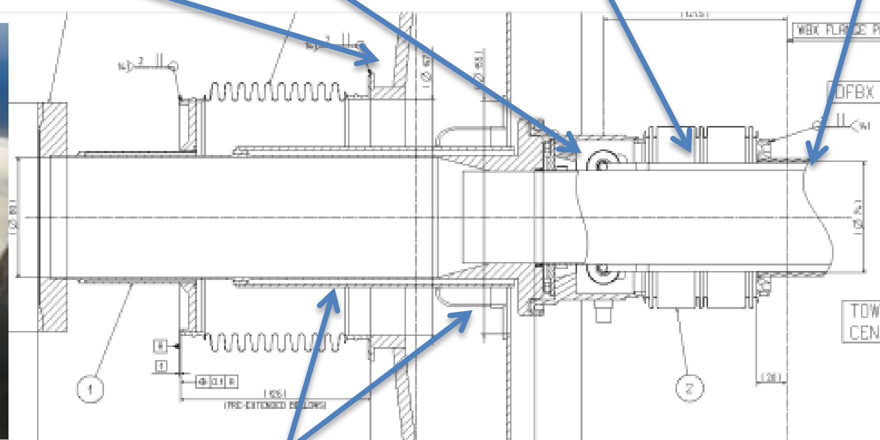
Temperature profile has to be well controlled (thermal load, condensation on warm module).

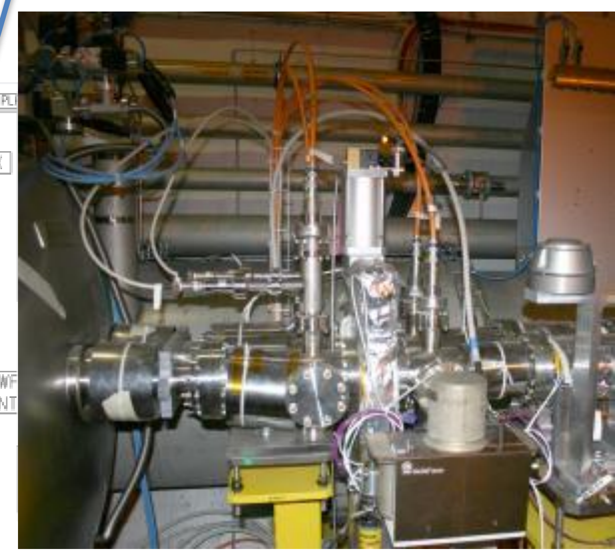
Cryostat end cover

Capilaries exit tubes

Beam screen bellows

Cold bore



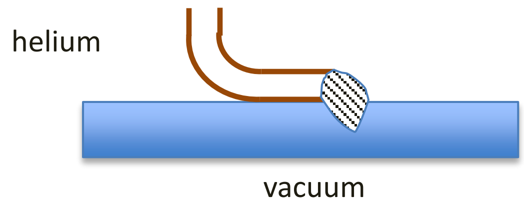


Thermalisation to the thermal screen: Copper braid and tube

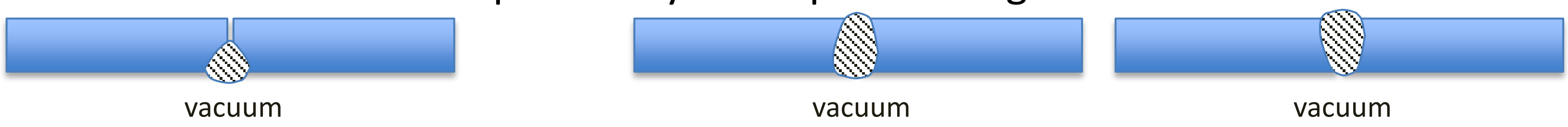
Assembly technics

Welds:

No weld between helium and vacuum
→ Non penetrating weld onto the vacuum chamber



Welds on vacuum side or preferably 100% penetrating



Brazing:

Vacuum brazing shall be used for vacuum components.

Assembly techniques

Flanges:

ConFlat flanges is the baseline for stainless steel and copper vacuum chambers.
Quick conical CF flanges have to be used in high radioactive areas.

Helicoflex are used in case of aluminium components.
Alternative to helicoflex gasket has to be developed for aluminium flanges.

Screws:

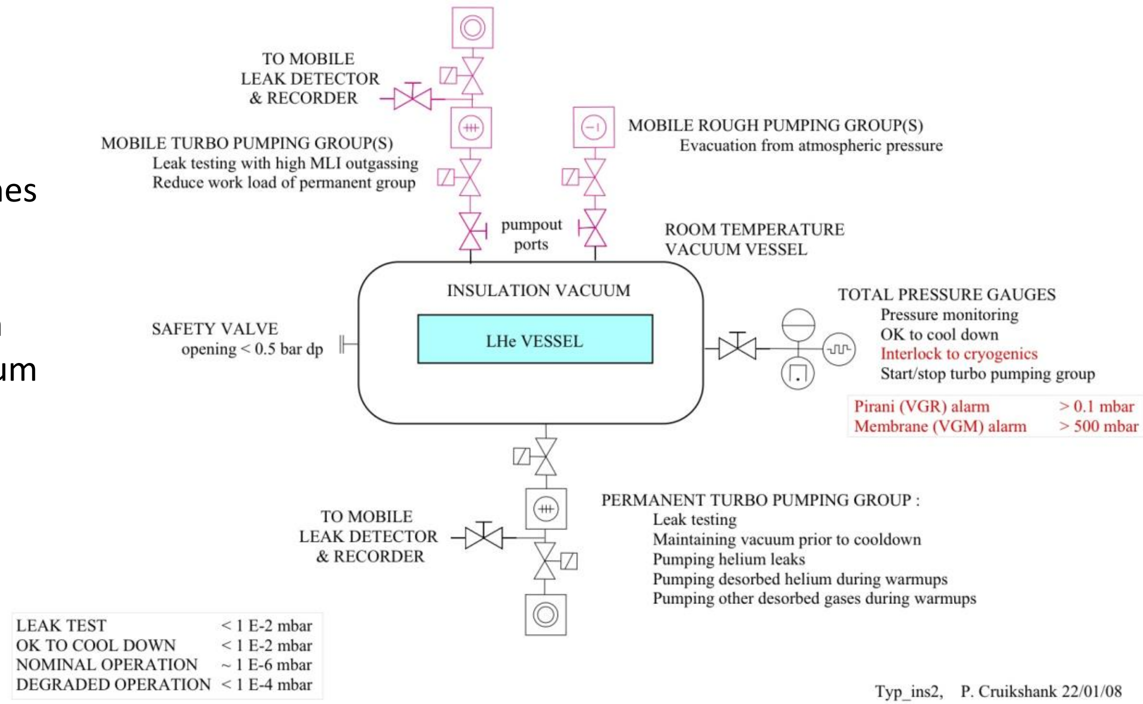
Silver coated bolts (or screws if no bolts) have to be used for UHV assemblies in stainless steel.

No trapped volume in vacuum (virtual leak): venting holes have to be done (either in the screw or at the bottom of the drilled hole).

Insulation vacuum

Concept:

- Sectorization of large vacuum volumes
- Decoupling cryogenic distribution line/magnet cryostat,
- Permanent turbo pumping group on each insulation vacuum sector (helium pumping),
- Additional pumping ports (leak detection, rough pumping),
- Pressure relief valve.



Potential issues for HL-LHC:

- Radiation resistance of electronics,
- Radiation resistance of elastomers

Quality assurance

Methodology:

Documentation sequence:

1. Conceptual specification
2. Functional specification
3. Engineering specification and technical drawings
4. Integration
5. ECR

Non VSC equipment (related to vacuum)

Steps where VSC group has to be involved.

All drawings of systems/components exposed to vacuum has to be checked and validated by TE/VSC.

Quality assurance

MTF:

VSC equipment will be recorded in MTF:

Top Assembly Identifier: **HCVC1AX002-CR000001**
Other Identifier: **VA1**
Description: **VA Aluminium Chamber Subassembly**

Main | Made of | **Equipment data** | Manufacturing | Operation | Documents | History | Map

Actions : Edit | History

External Links

No external data link exists

Property Values

Property	Nominal Value
Length	
Leak Check Accept no bake	
Leak Check Ac. after bake	
Degas Accept after bake	
Bake-out Temperature Ac.	
NEG coating (Y/N)	
Leak Check Ac. after NEG	
Bake-out Temperature NEG	
Hydrogen pumping speed	

Main | Made of | Equipment data | **Manufacturing** | Operation | Documents | History | Map

Actions : Add extra step

Workflow Diagram

No workflow diagram is defined for this top assembly

Workflow Steps — Last Repeated

Step	R/E	Other name	Description	Status	Result	NC
10		()	Reception Check	Pending		
20		()	Metrology I	Pending		
30		()	Cleaning	Pending		
40		()	Vacuum Acceptance Test	Pending		
50		()	Metrology II (after bake-out)	Pending		
60		()	Coating other than NEG	Pending		
70		()	Wrapping for permanent bake-out jacket	Pending		
80		()	NEG Coating	Pending		
90		()	NEG Qualification Test	Pending		
100		()	Acceptance for storage	Pending		
110		()	Acceptance for installation	Pending		

Vacuum acceptance tests are mandatory for VSC and non-VSC equipment.

Conclusion

Development of vacuum engineering for HL-LHC:

Design and integration of the beam screen (Roberto's talk):

- Properties of Inermet at cold
- Reliability of the interface Inermet/beam screen

Vacuum system in high radioactive environment:

- Aluminium alloy qualification for vacuum chambers and flanges
- Design compatible with remote tooling and/or handling
- Increase reliability of sensitive elements:
  - Sector valves
  - RF fingers

Insulation vacuum has not to be forgotten.

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