Vacuum experience from SPS-DQW & HL-LHC outlook

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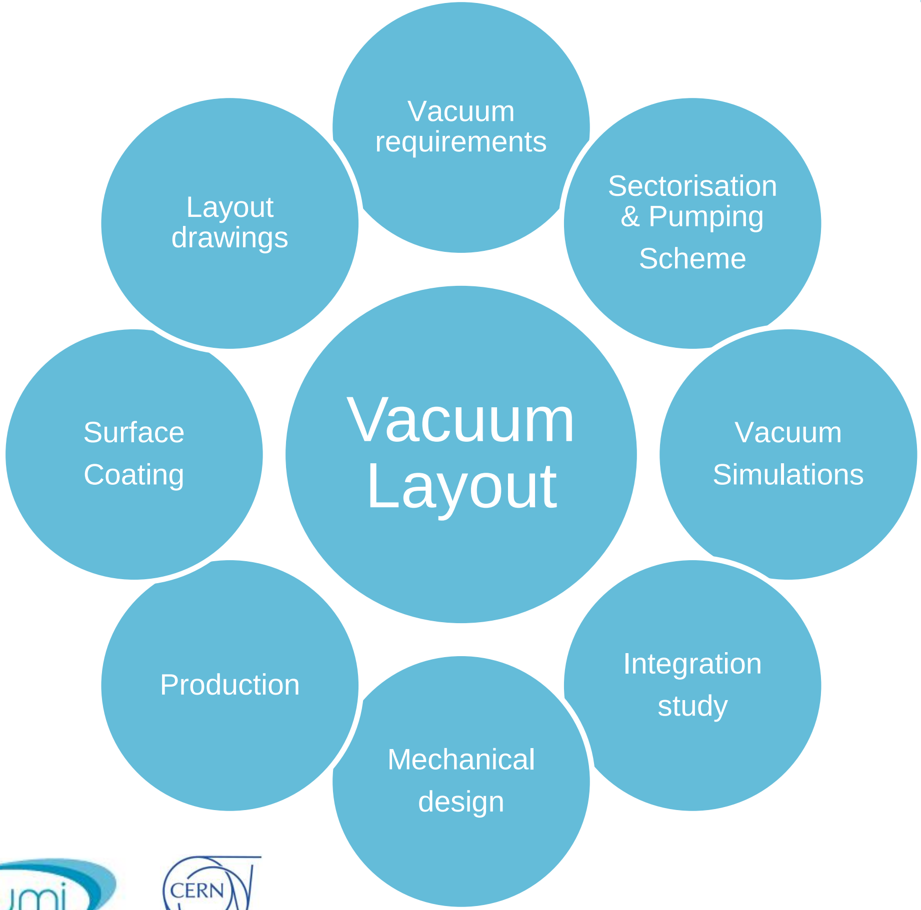
Outline

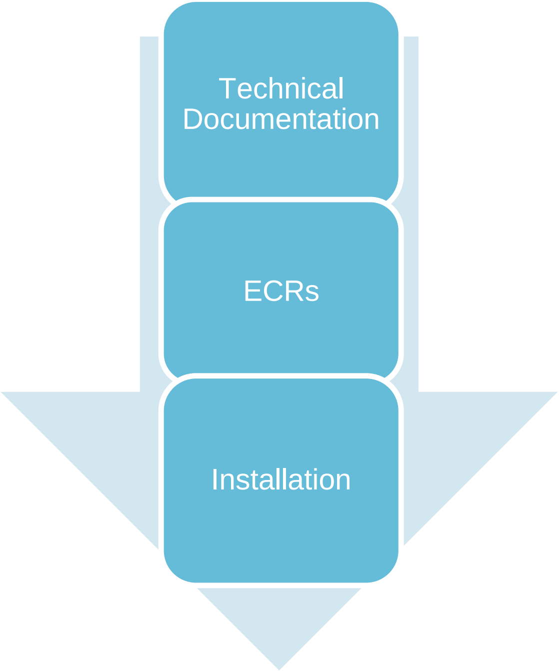
- Introduction
- Vacuum layout
- Installation
- Vacuum performance
- Crab cavities LHC
- Summary

Introduction

- The Crab Cavity project aims at installing 4 cavities per interaction point side in CMS and ATLAS during LS3.
- Tests concerning the interaction of the RF with high intensity beam are required to validate the technology prior to LHC installation.
- SPS was seen as an ideal place, in view of the enlarged tunnel in the LSSs and the ability to test with high intensity beam.
- A first sectorisation in SPS LSS6 took place during EYETS 16/17, followed by the final installation in YETS 17/18.
- Conceptual studies are ongoing regarding the new vacuum layout for the crab cavities in LHC.

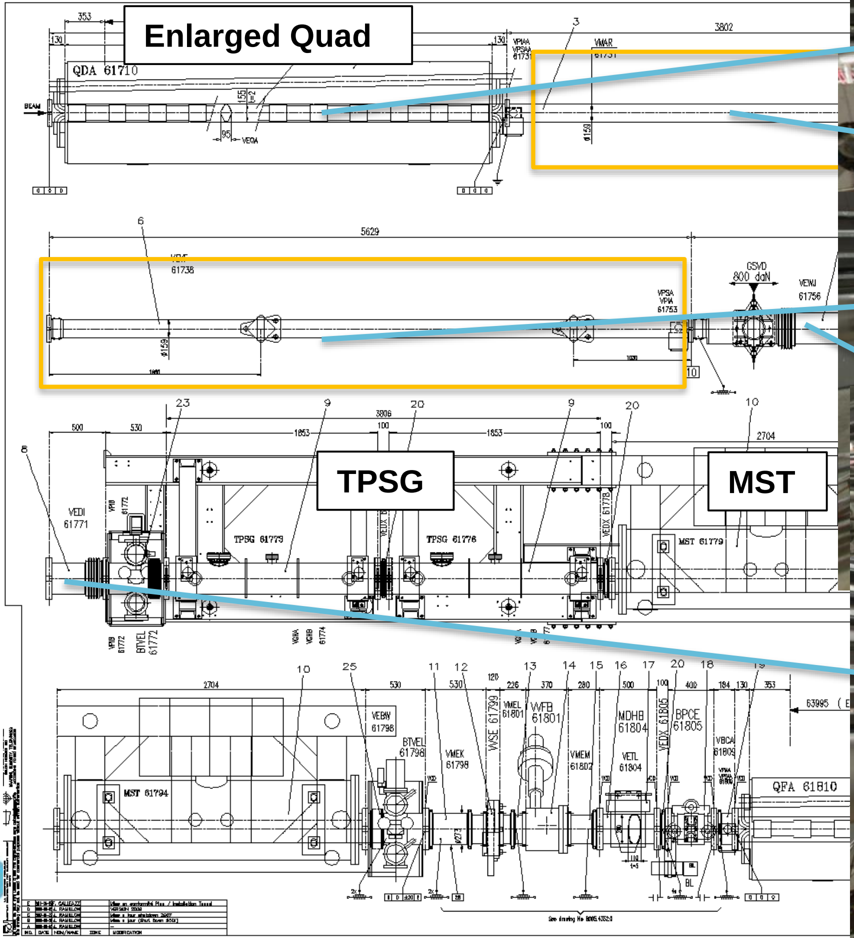
Vacuum layout

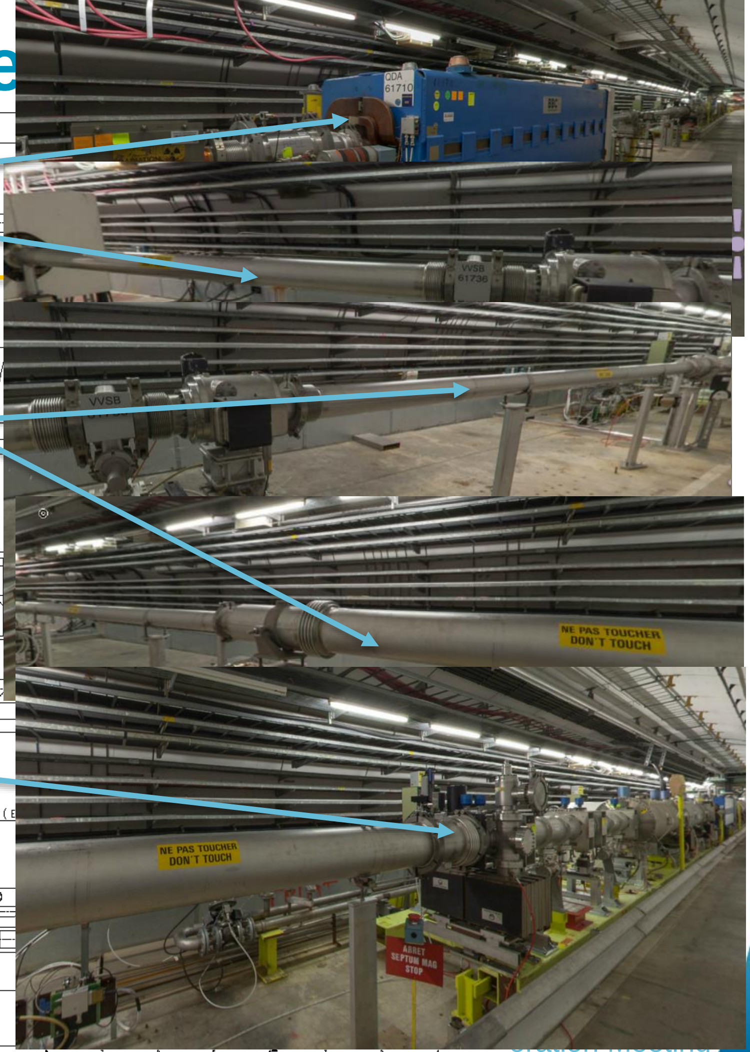




Machine layout before

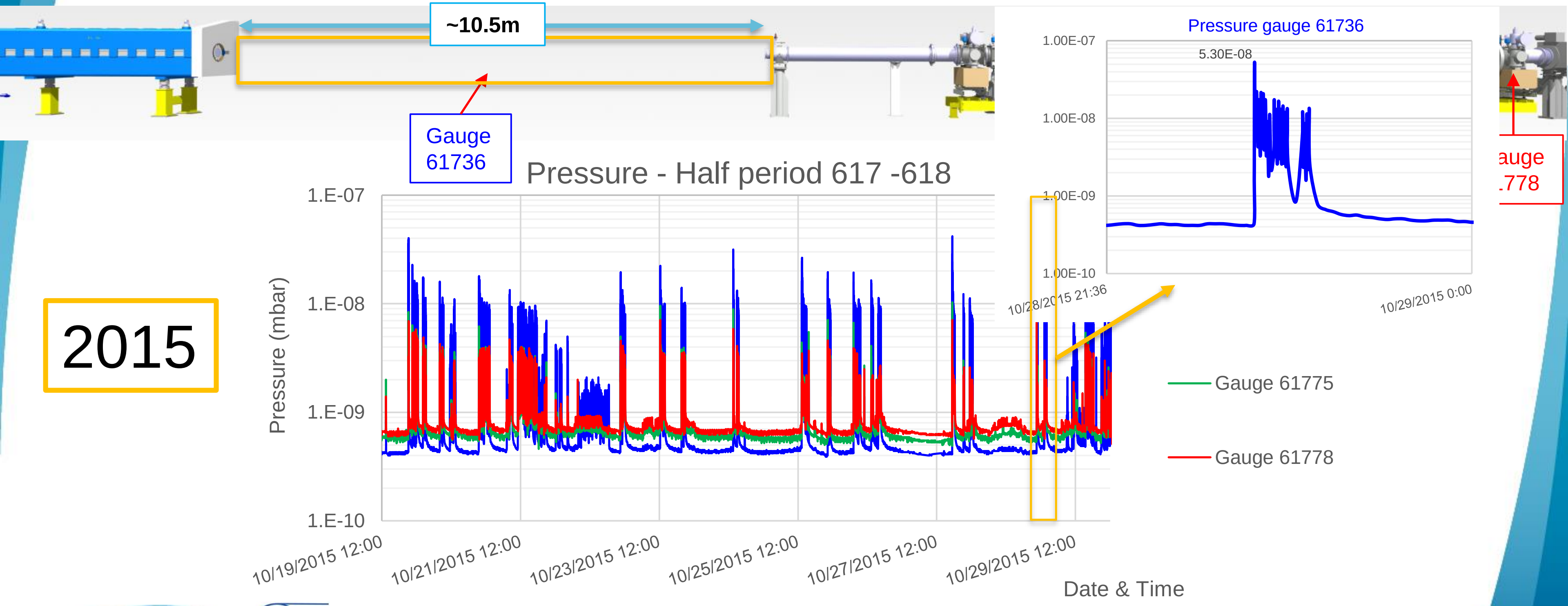
2015





Vacuum level before Crab Cavities

Crab cavity target pressure: 10^{-10} mbar range @ 2K -> vacuum opened to neighbour sectors below 10^{-8} mbar.



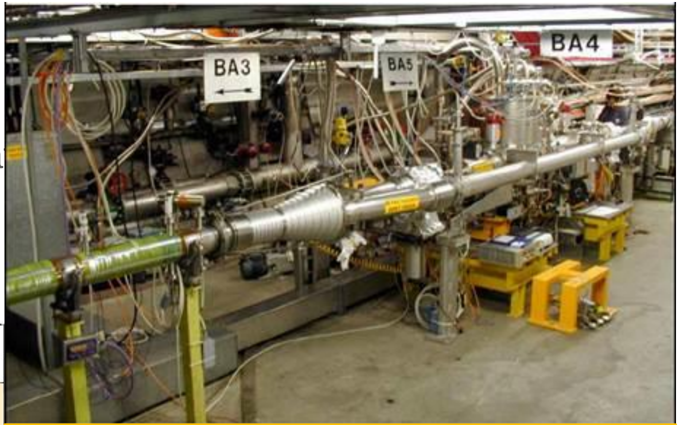
2015

Vacuum layout – Early stage concept

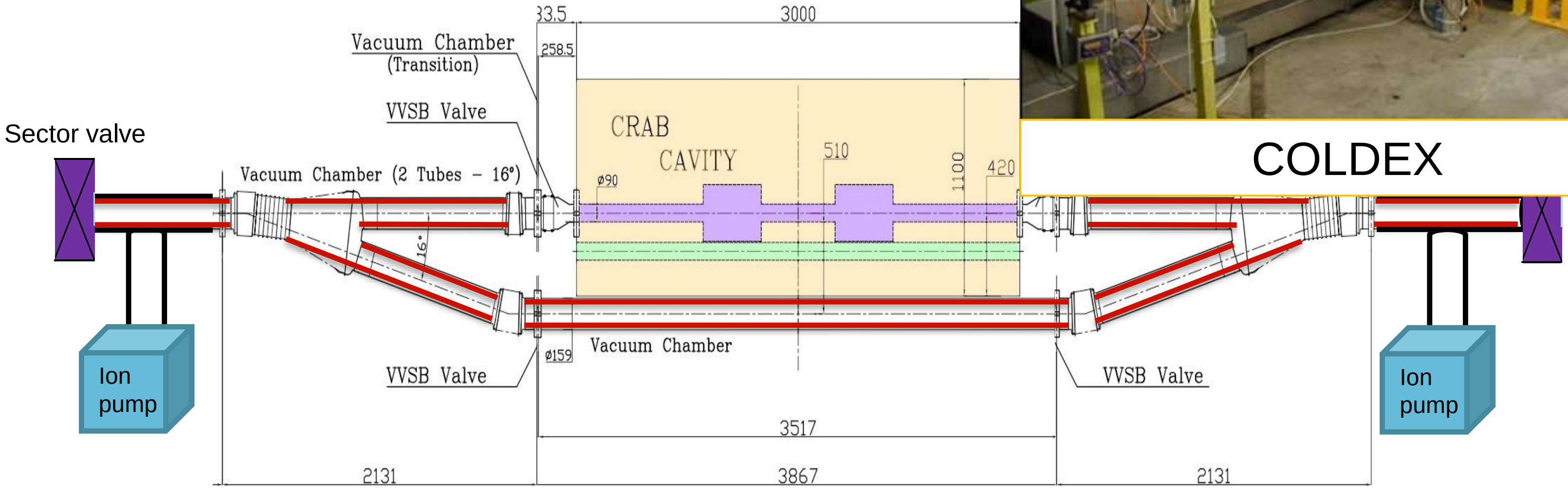
Vacuum/mechanical requirements:

Early stage concept:

- Y-chamber design to allow for bypass + experiment configura
- Dedicated sector with two high capacity ion pumps.



COLDEX

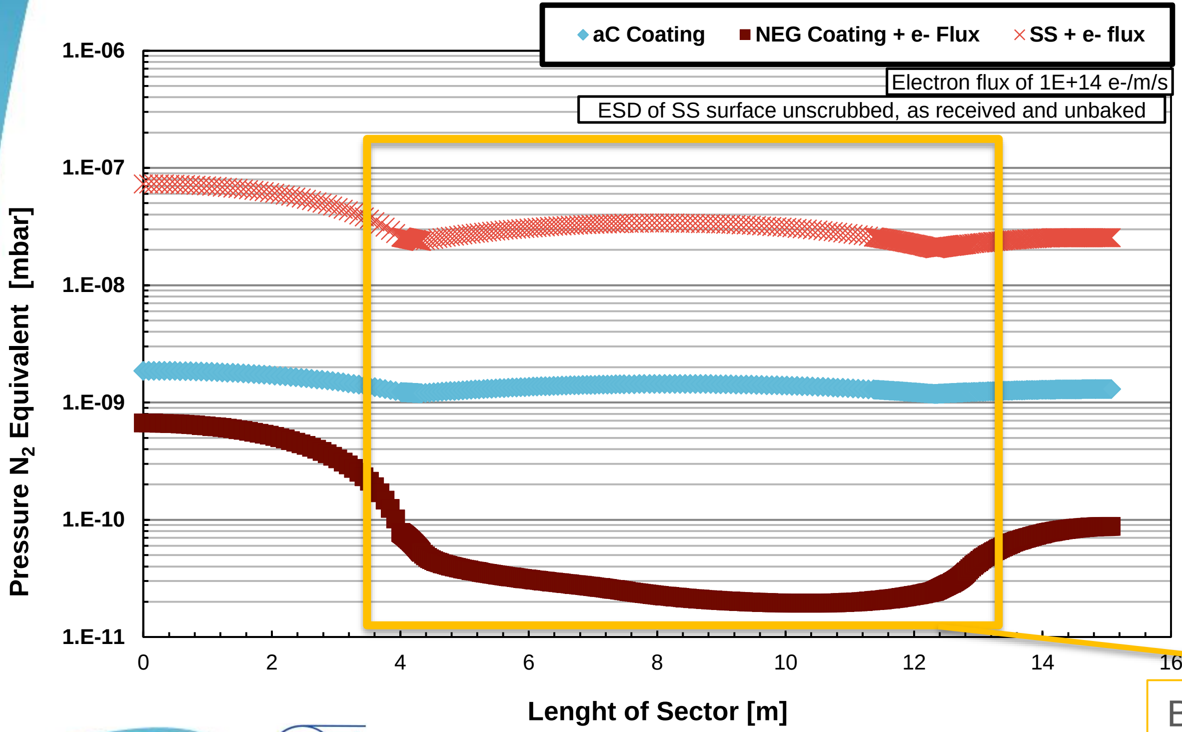


Vacuum layout – Early stage concept

	a-C Coating	NEG coating

Vacuum Simulations

Vacuum performance simulations @ VASCO & Molflow+:



Stainless steel uncoated is dominated by electron cloud effects

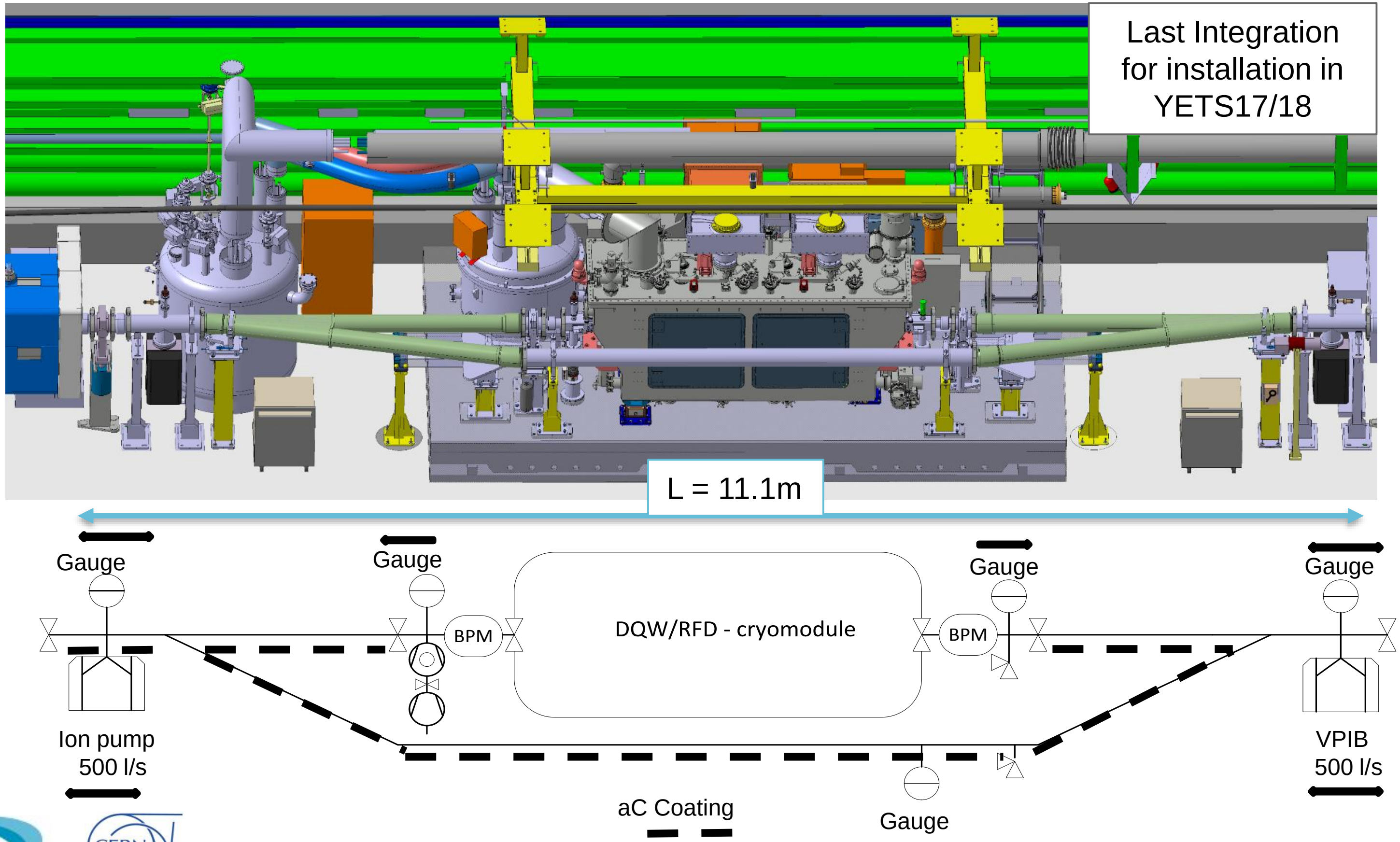
Acceptable performance of a-C coating.

NEG has the best performance, as expected.

Bypass + Crab cavities sector

Integration

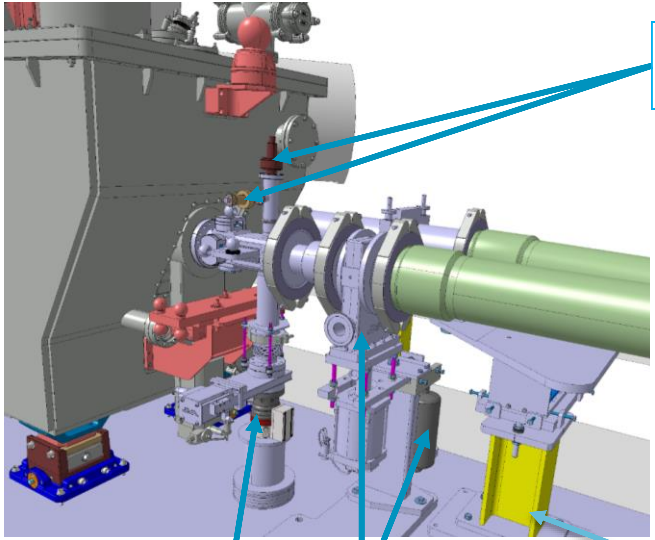
Last Integration for installation in YETS17/18

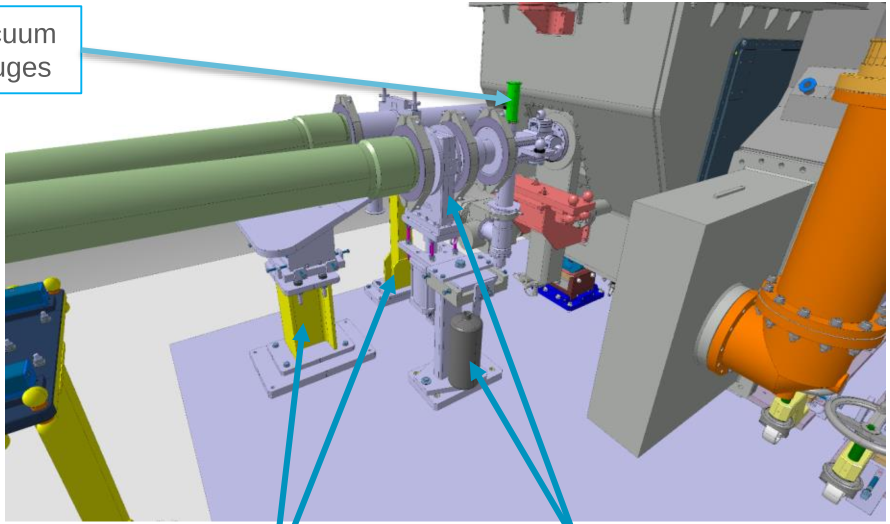


Integration

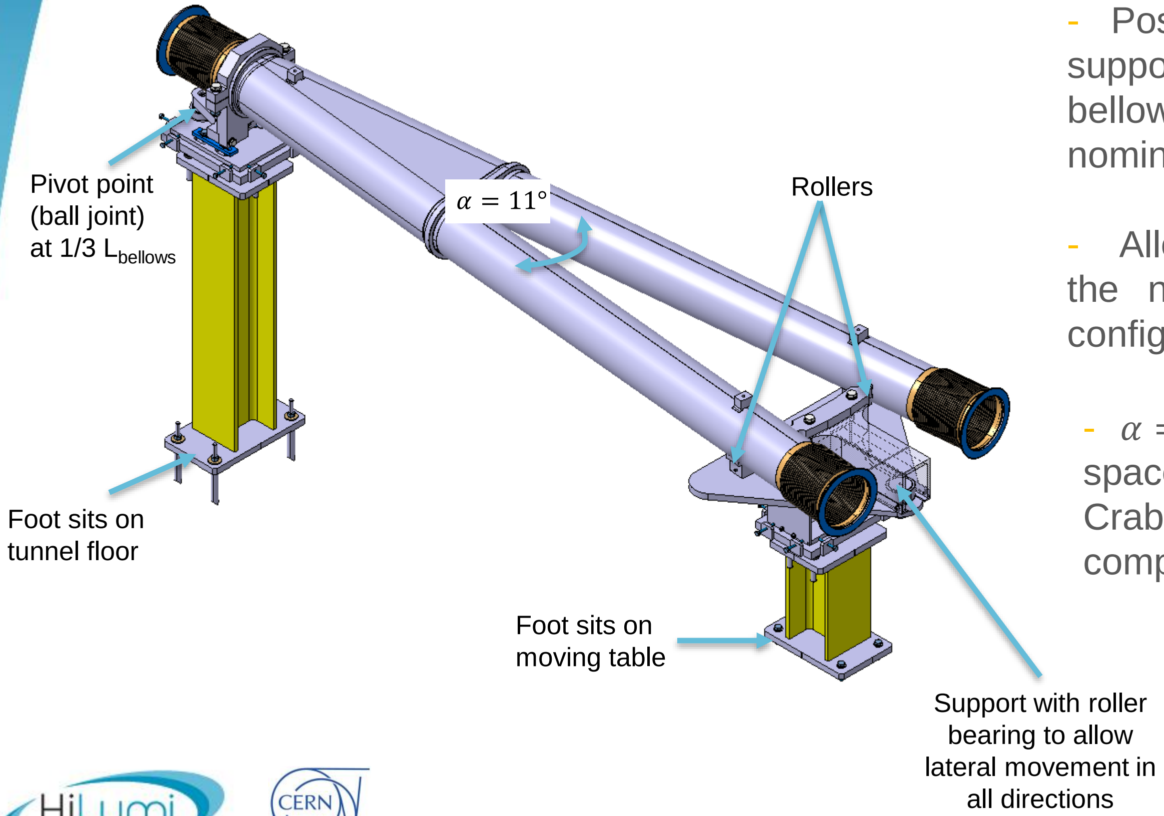
Upstream

Downstream





Mechanical Design & Production



- Positioning of pivot point and table support optimized to minimize efforts in bellows and ensure they are working within nominal length.

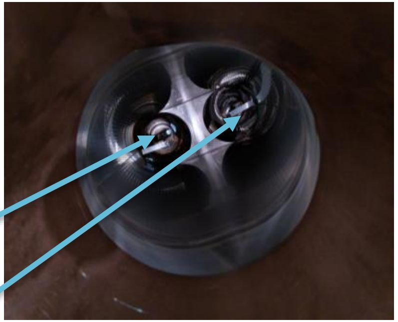
- Allow movement of the Y-chamber up to the nominal operating position in both configurations (Crab Cavities & bypass).

- $\alpha = 11°$ – to guarantee the minimum space necessary for the integration of the Crab Cavities and all the other components on top of the moving table.

a-C coating

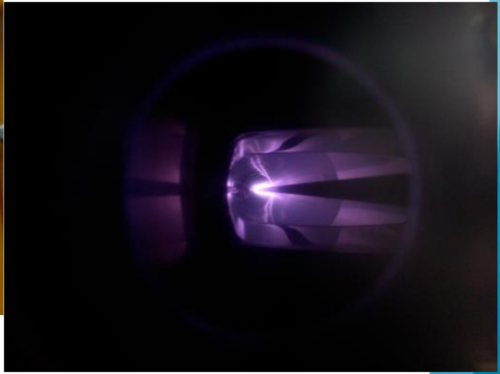
a-Coating of vacuum chambers:

- Pump-down to ~10^{-9} mbar.
- Bake-out at 150℃ for 24h to pump water and hydrogen more effectively.
- Ar injection up to low 10^{-2} mbar.
- Carbon cathode powered up to -500V & chamber grounded .
- Assembly in the center of a solenoid magnetic field of up to 200 Gauss.
- Coating by sputtering of cathode, until the best quality layer is achieved (typically 400nm).



Individual cathodes along mechanical axis of each of the 3 segments.

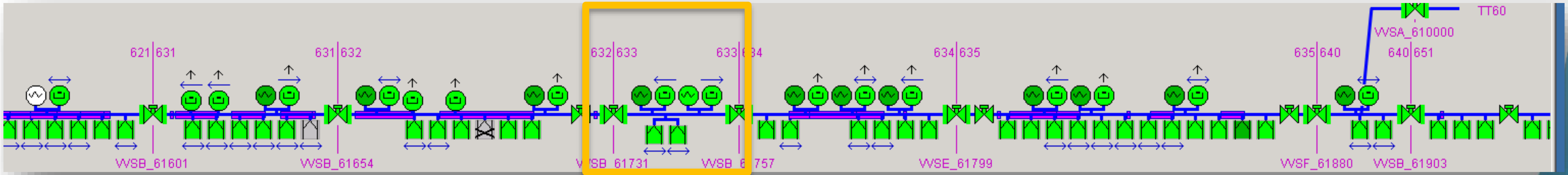
Lower part inside solenoid vessel & 2 separate solenoid wrappings around Y-segments – best way to proper distribute the magnetic field along all chamber segments and lead to homogeneous coating quality.



Coating process – powered cathode and plasma.

Installation

EYETS 2016/2017 - Creation of dedicated vacuum sector for Crab Cavities, with some chambers that were included in the final layout.



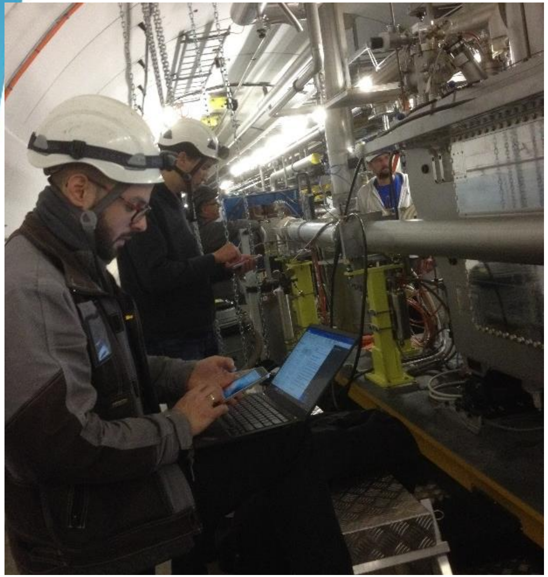
Installation

EYETS 2017/2018 – Installation of all remaining components of vacuum layout after moving table and Cryomodule were put in place.

-All vacuum equipment successfully installed on schedule.

-Minor delays due to large periods of unavoidable co-activity (VSC, cryo, transport, RF, …).

Interlock & SCADA integration



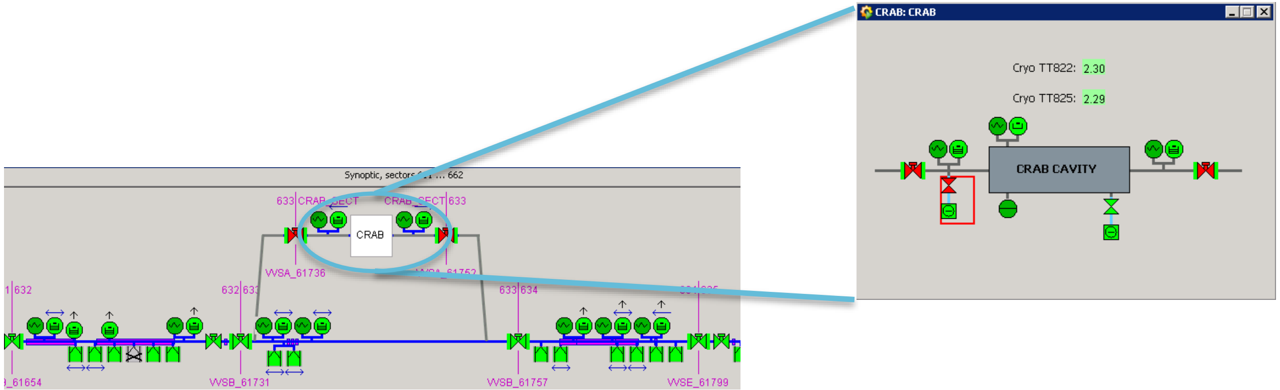
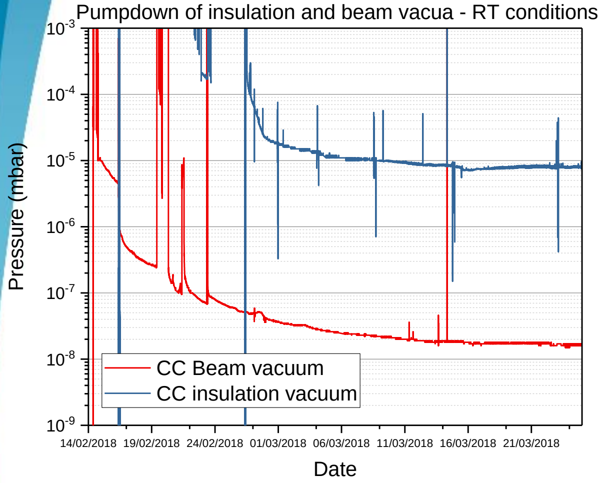
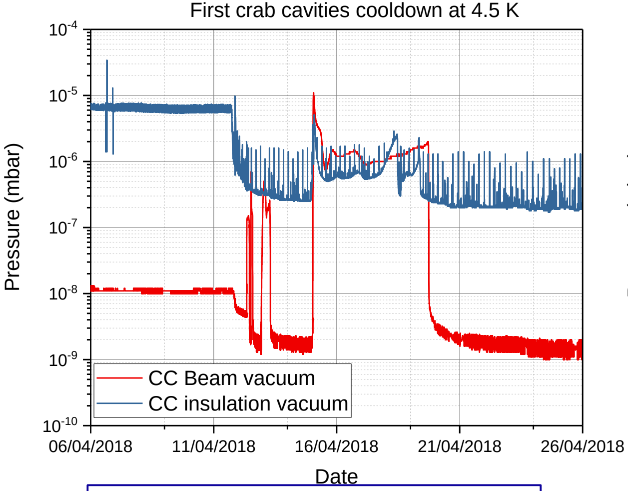


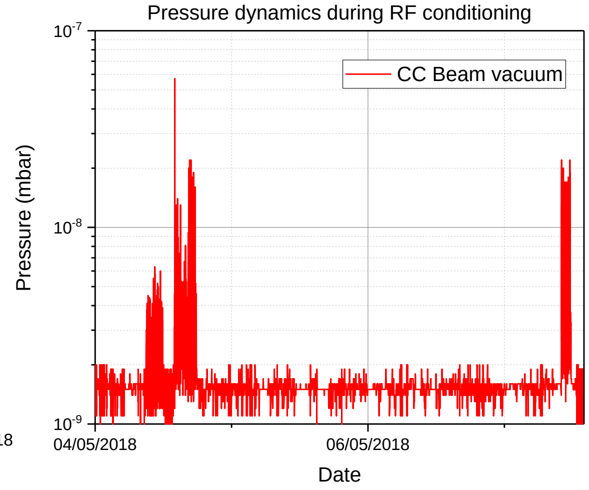
Table position – vacuum valves interlock interfaces:

- Table moves **ONLY** if SPS bypass & CC sector valves are **closed**;
- If table is in **IN BEAM** position, valves can be opened;
- If the table is in middle position, the valves **ARE NOT** allowed to be open;
- Gauges on both sides **INTERLOCK** the valves for pressure > $1*10^{-6}$ mbar.

Vacuum perfomance after installation







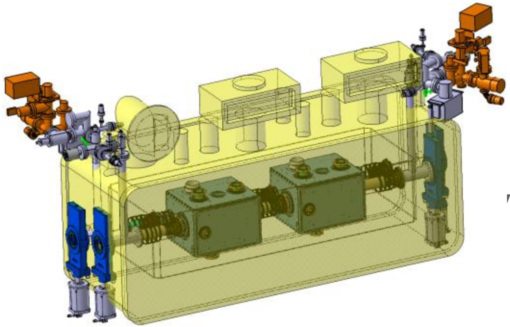
Static pressure on the bypass and neighboring sectors = 1-2*10^{-9} mbar

Same procedure as in SM18:
- Cooldown at 150K with turbo pumping;
- Isolation of the turbo at 150K;
- Cooldown at 4.5 K;

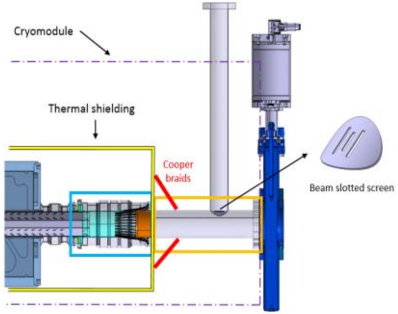
Pressure dynamics during RF conditioning at 4.5 K of the cavities, seen by the vacuum gauges on beam vacuum.

Crab cavities LHC

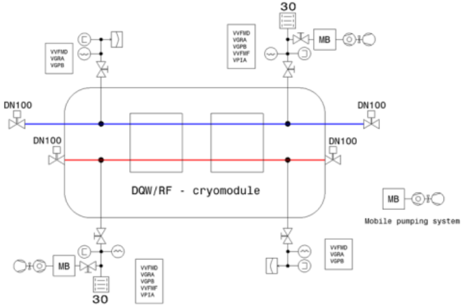
Previous version



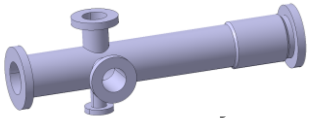
3D model of cryomodule and vacuum instrumentation



RF continuity solution



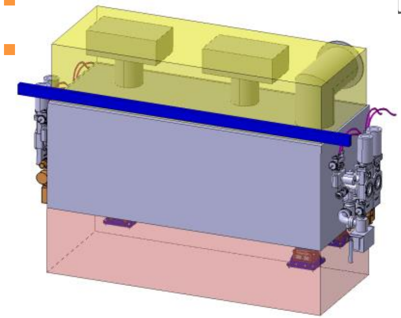
Vacuum instrumentation schematics

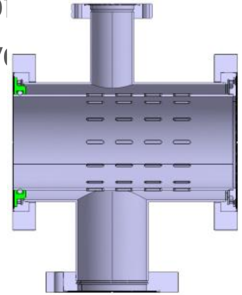


Vacuum module with RF fingers for interconnect

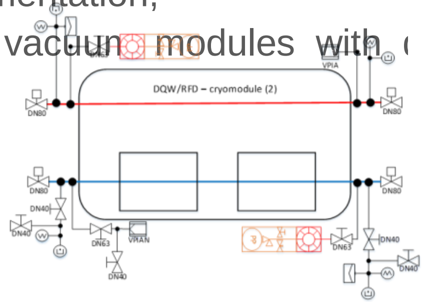
- New vacuum layout inside of the cryostat;
- New solution for the RF continuity at the cryostat extremities;
- New vacuum integration of the vacuum instrumentation;
- … e cry… …nect: vacuum modules with … ormable RF bridge

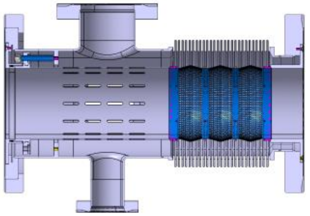
New version under study





Possible new solution for the cryomodule extremities





Vacuum module with DRF for interconnect

Summary

Vacuum group is strongly involved in the Crab cavities project, from the surface treatment of both DQW and RFD cavities to the final installation and controls/interlock system commissioning.

Crab cavities SPS:

- Vacuum layout extensively studied : simulation + design + …
- Succesful installation in two steps : EYETS 16/17 & YETS 17/18.
- Good performance achieved in beamline and insulation vacuum.
- Demonstrated controls and interlocks reliability.

LHC outlook:

- Dedicated studies are ongoing to:

  - Analyze the impact of electron cloud on dynamic pressure rise.

  - Define the vacuum layout where the future cavities will be installed, featuring newly designed vacuum equipment integrating a linear pumping solution on each side of the crab cavities (NEG).

Thank you!

Acknowlegments:

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