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

- Vacuum requirements
- Sectorisation & Pumping Scheme
- Vacuum Simulations
- Integration study
- Mechanical design
- Production
- Surface Coating
- Layout drawings

- Technical Documentation
- ECRs
- Installation

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Machine layout before Crab Cavities

2015

TPSG

MST

Enlarged Quad
Vacuum level before Crab Cavities

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

Pressure gauge 61736

Gauge 61775

Gauge 61778

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Vacuum layout – Early stage concept

Vacuum/mechanical requirements:
Early stage concept:
- Y-chamber design to allow for bypass + experiment configuration
- Dedicated sector with two high capacity ion pumps.
## Vacuum layout – Early stage concept

<table>
<thead>
<tr>
<th>a-C Coating</th>
<th>NEG coating</th>
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### Coating
- **a-C Coating**
- **NEG coating**

### Cloud Suppression
- Dynamic pressure 
- Mitigation
- Saturation

### Bake-Out & NEG Activation
- No

### Mechanical Integration
- SPS
- Conical flanges
- UHV
- Conflat flanges

### Thermal Outgassing
- X 5 higher than stainless steel

### Linear Pumping

### Intervention time (vacuum)
- ≈ 30 h
- ≈ 1 week

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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

- Ion pump 500 l/s
- VPIB 500 l/s
- Gauge
- Gauge
- Gauge
- Gauge
- BPM
- BPM
- BPM
- DQW/RFD - cryomodule
- aC Coating
- L = 11.1m
Integration

**Upstream**
- Fixed pumping group
- Sector valve + compressed air
- Vacuum gauges

**Downstream**
- Y-chamber + bypass supports
- Sector valve + Compressed air
- 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).

- $\alpha = 11^\circ$ – 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 $\sim 10^{-9}$ mbar.
- Bake-out at 150°C 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).

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.

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

Coating process – powered cathode and plasma.
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 > $1 \times 10^{-6}$ mbar.
Vacuum performance 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.
New updates of the crab cavities cryomodule are implying an upgrade of the document already released (EDMS 1864637).

- New vacuum layout inside of the cryostat;
- New solution for the RF continuity at the cryostat extremities;
- New vacuum integration of the vacuum instrumentation;
- New solution for the cryostat interconnect: vacuum modules with deformable RF bridge (DRF).

Possible new solution for the cryomodule extremities.
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 + …
- Successful 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!

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