Vacuum layout and experience from SPS

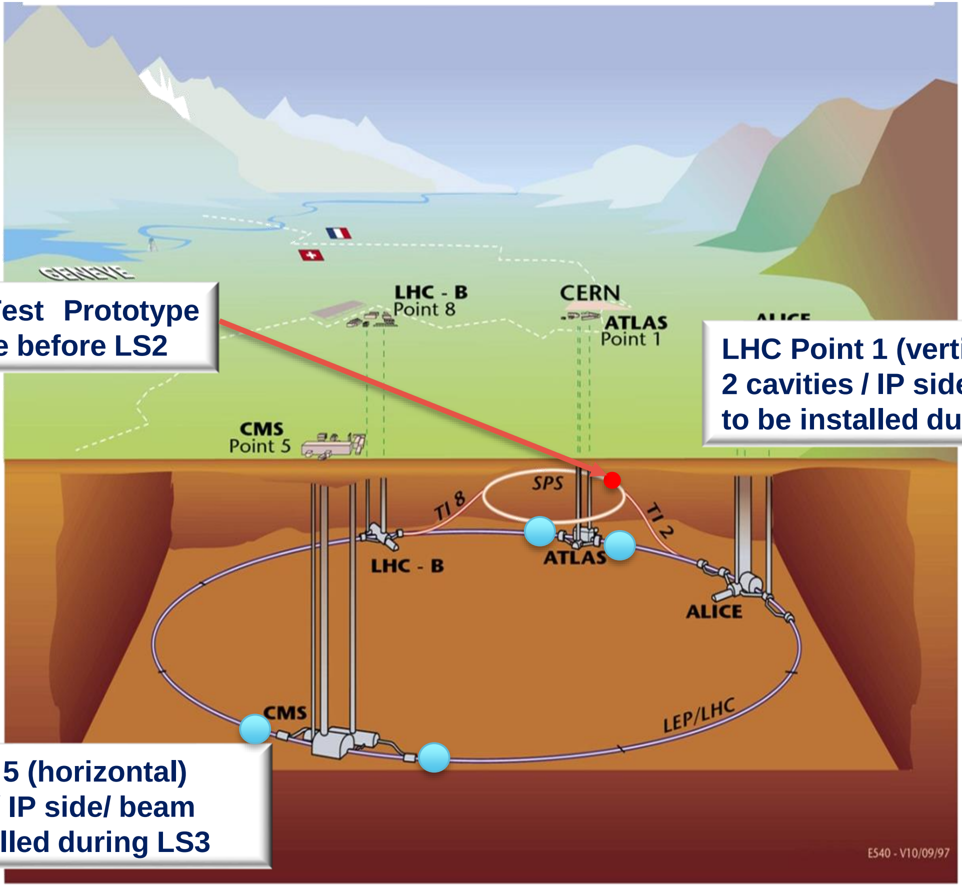
Chiara Pasquino (**V**acuum, **S**urfaces & **C**oatings Group)

International Review of the Crab Cavity system design and production plan for the HL-LHC

Outline

- Introduction;
- Vacuum layout and integration in SPS – Long Straight Section 6 (LSS6);
- TE-VSC contribution to the Double Quarter Wave (DQW) installation in SPS;
- Vacuum behavior analysis;
- Outlook: RF Dipole (RFD) – LHC type integration in SPS;
- Conclusions.

Introduction



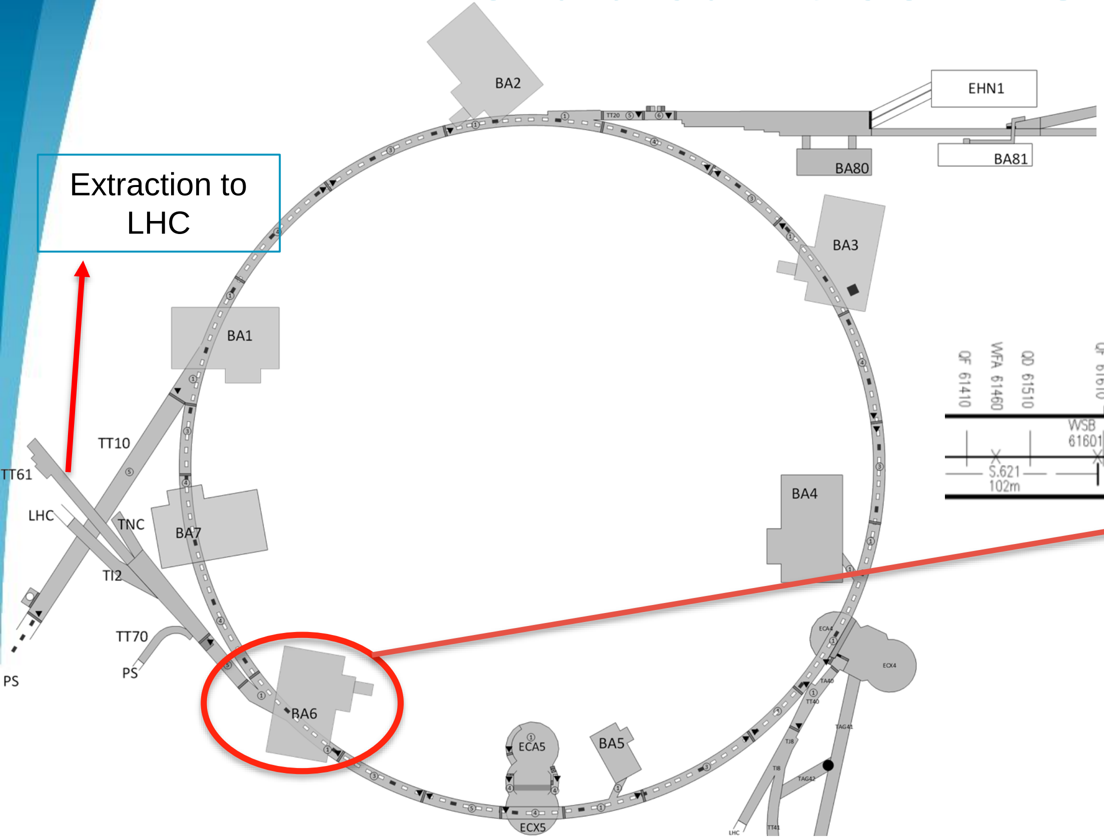
SPS Test Prototype Module before LS2

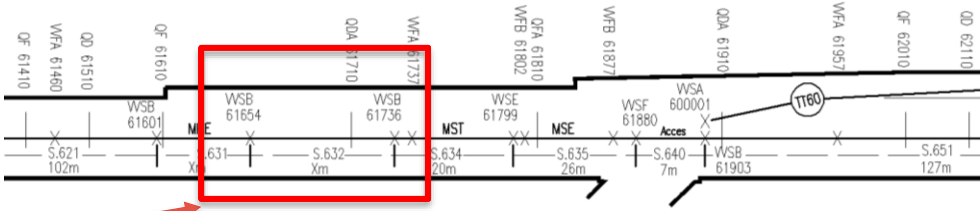
LHC Point 1 (vertical)
2 cavities / IP side/ beam
to be installed during LS3

LHC Point 5 (horizontal)
2 cavities / IP side/ beam
to be installed during LS3

Crab cavities in SPS – LSS6

Extraction to LHC

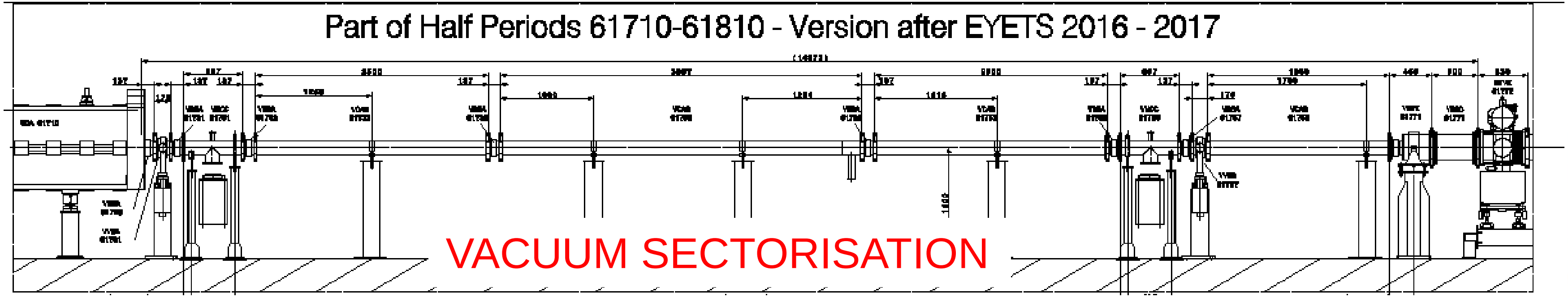




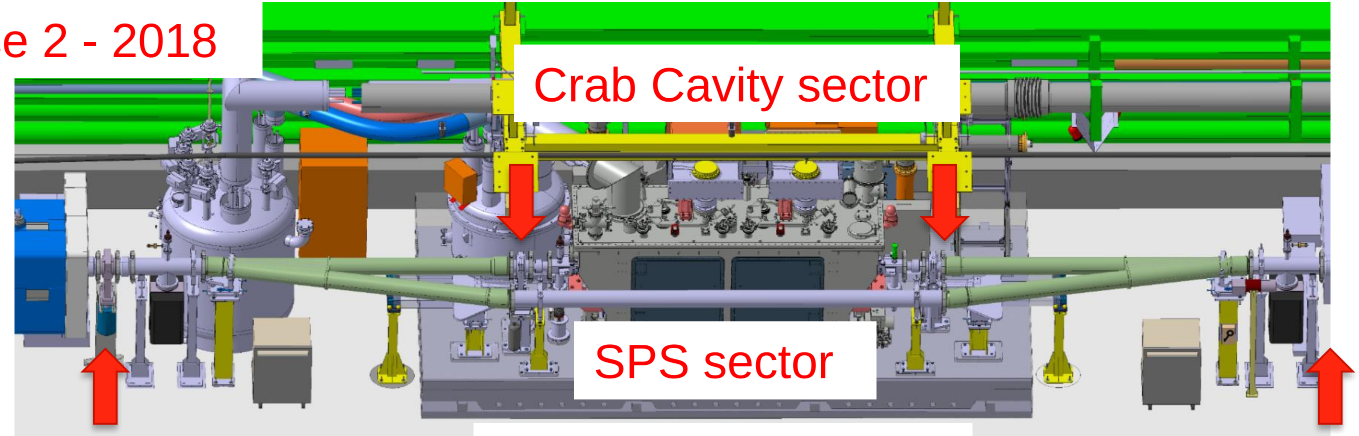
Pressure requirement:
$<1*10^{-9}$ mbar @ 2K
EDMS #2043014

Vacuum layout in LSS6

Phase 1 - 2017

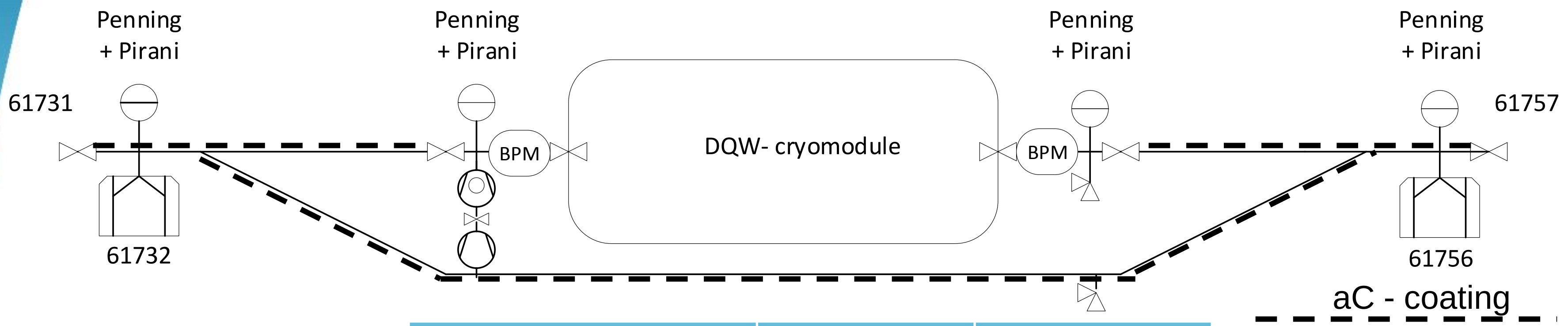


Phase 2 - 2018



DQW INTEGRATION

Crab Cavities teststand in SPS:Integration



	aC coating	NEG coating
e- cloud suppression	✓	✓
Final static pressure (mbar)	≈ $1*10^{-9}$	≈ $1*10^{-10}$
Saturation	X	✓
Bake –out (activation)	X	✓
Mechanical integration	Conical flanges	CF
Pumping speed (**l/s/cm2**)	-	1-10
Intervention time (vacuum)	≈ 24 h	≈ a week

CRAB in LHC : NEG coated

TE-VSC scope

Design	Procurement	Assembly at surface	Acceptance tests	Installation in the tunnel
• Integration of vacuum components and instrumentation • Specifications for vacuum components • Cabling request (DIC)	• Vacuum components and instrumentation (e.g. pumping groups, gauges) • Safety valves • PLCs and crates • SCADA • Surface treatment of vacuum components		• Leak tightness test of the assembled module • RGA measurements of the assembled module	• Cabling • Installation of vacuum components and instrumentation/ vacuum sectorization

See Germana's presentation

Crab cavities in SPS –LSS6: TE-VSC contributions

Vacuum layout modifications

Vacuum Integration & design of vacuum components

Production and procurement

aC coating

Mechanical Installation
Beam and Insulation vacuum commissioning
Interlock tests

	Phase 1: Vacuum sectorisation	**Phase 2: DQW integration**
Vacuum Integration & design of vacuum components	January 2016 – April 2016	April 2016 – October 2016
Production and procurement	June – December 2016	October 2016 - December 2017
aC coating	November 2016	December 2017
Mechanical Installation, Beam and Insulation vacuum commissioning, Interlock tests	EYETS 2016-17: 16 weeks of access - 2 weeks of vacuum installation	YETS 2017-18: 8 weeks of access – 3 weeks of vacuum installation

Crab cavities in SPS –LSS6: TE-VSC contributions

Phase2:
Surface activities

SM18

Summer 2017

November 2017-
January 2018

DQW – cryomodule SPS prototype

RGA analysis of bare cavities + cavity string & support for procurement of vacuum components

DQW vacuum acceptance test – RGA analysis before and after cooldown

Installation - phase 1 (EYETS16-17)

Sectorisation of vacuum sector 633

Installation - phase 2 (YETS17-18)

Installation of the bypass, Y chambers, and BPM sections upstream and downstream the cryomodule.

Interlock & vacuum controls integration

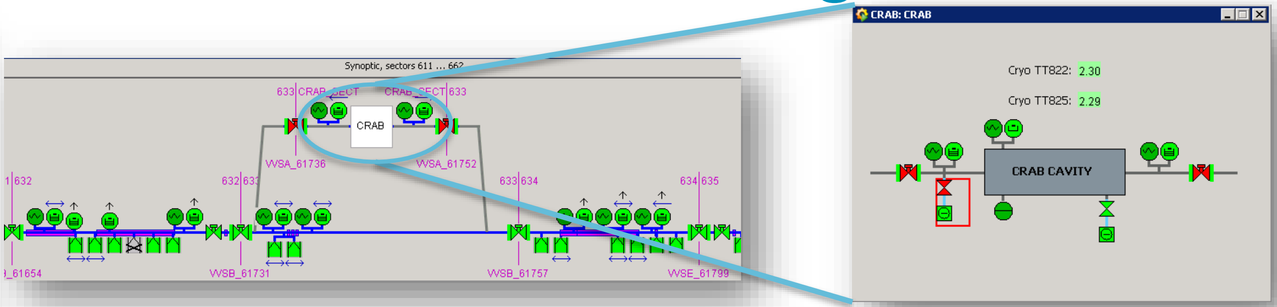


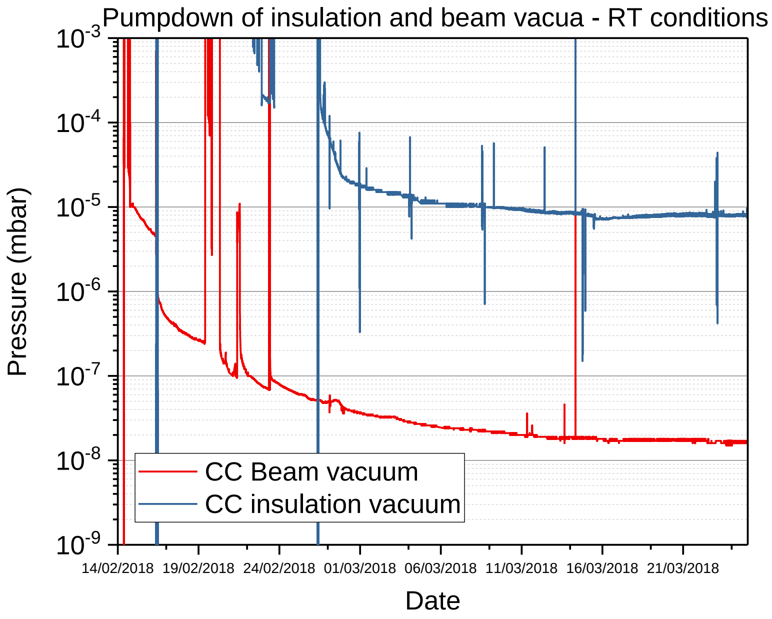
Table position and vacuum valve interlock logic:

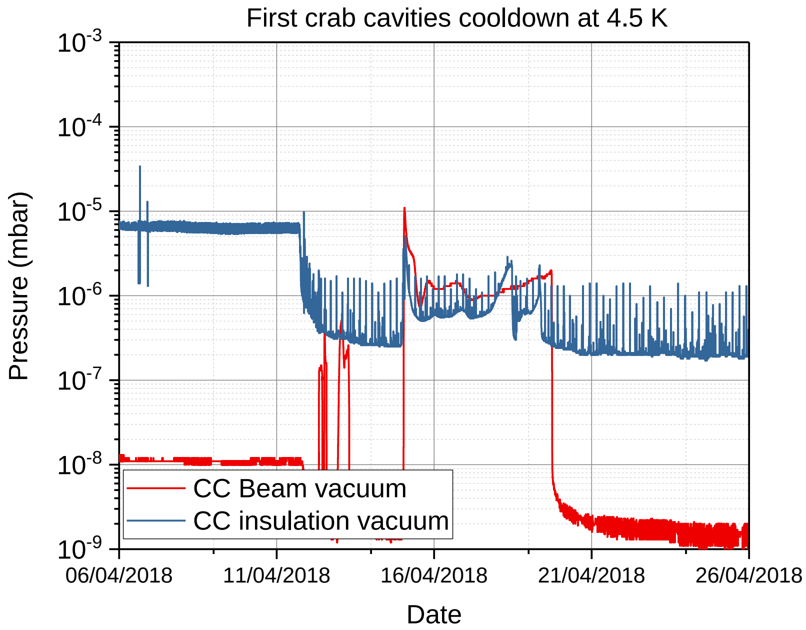
- Table moves **ONLY** if SPS bypass & CC sector valves are **closed**;
- If table is in **IN BEAM** position, valves can be opened;
- If the table is in middle position, the valves **ARE NOT** allowed to be open;
- Gauges on both sides of the cryomodule **INTERLOCK** the valves for pressure > $1*10^{-5}$ mbar.

TE-VSC contributions:

- Vacuum SCADA application update;
- Procurement of the gauges and pumps power supplies;
- Cables connections and interlock testing.
- 2w1 Staff, 4w 1 FSU.

Vacuum dynamics at 4.5K: first pumpdown and cooldown in the tunnel

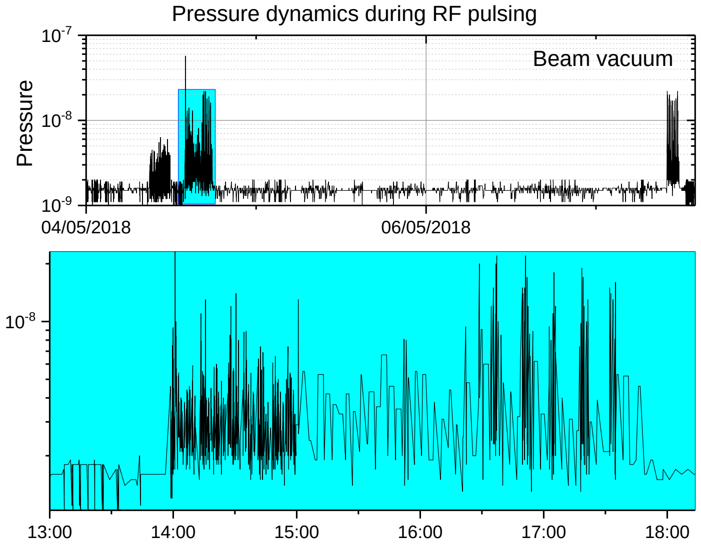


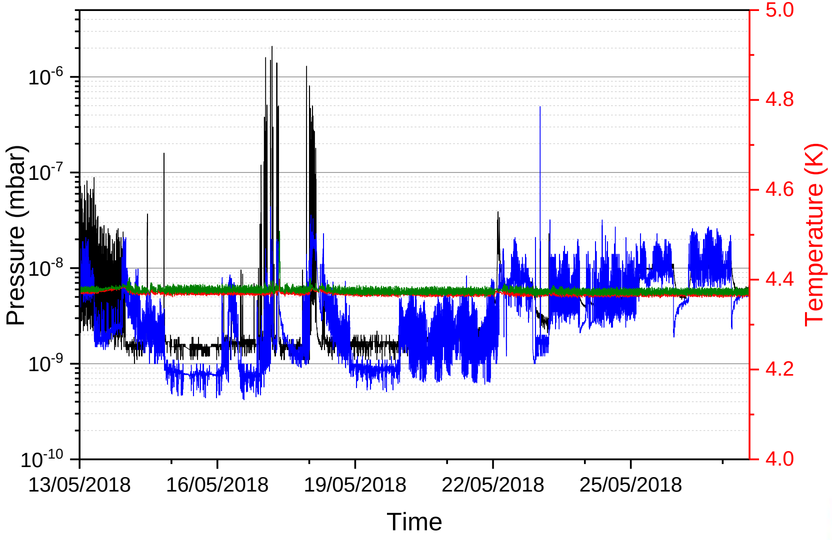


≈ 1 week of downtime in case an intervention on the cryomodule;
≈ 30 h of downtime in case of intervention on the bypass;

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

Vacuum dynamics and cryogenics at 4.5K

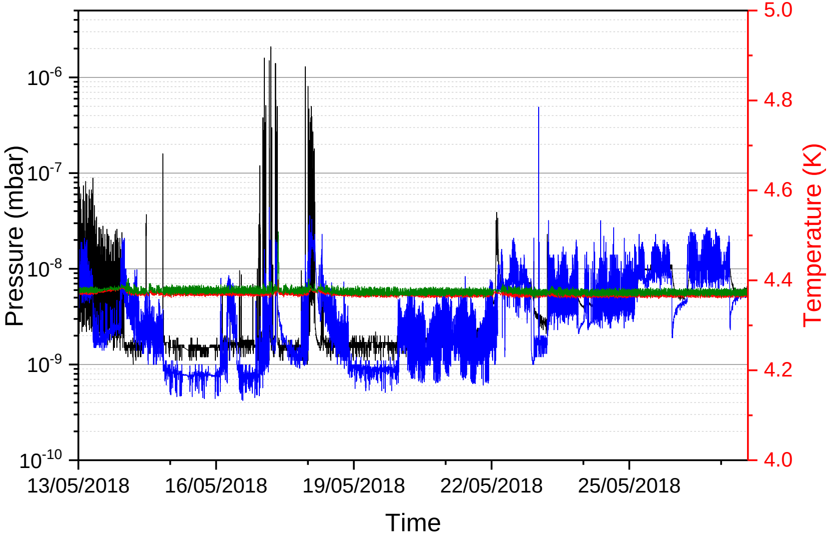


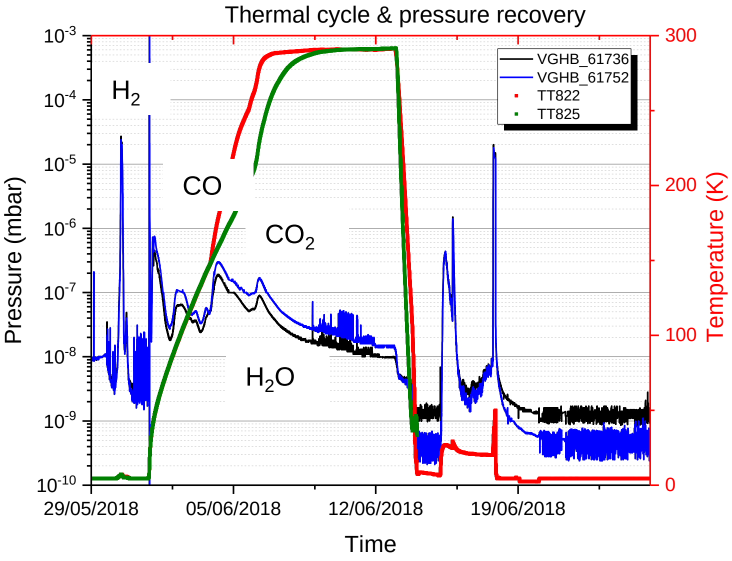


Pressure dynamics during RF pulsing (8kW) at 4.5 K of the cavities, seen by the vacuum gauges on beam vacuum.

Pressure build-up at 4.5 K + pressure dynamics during RF pulsing (5kW on cavity 1 and 1kW on cavity 2)

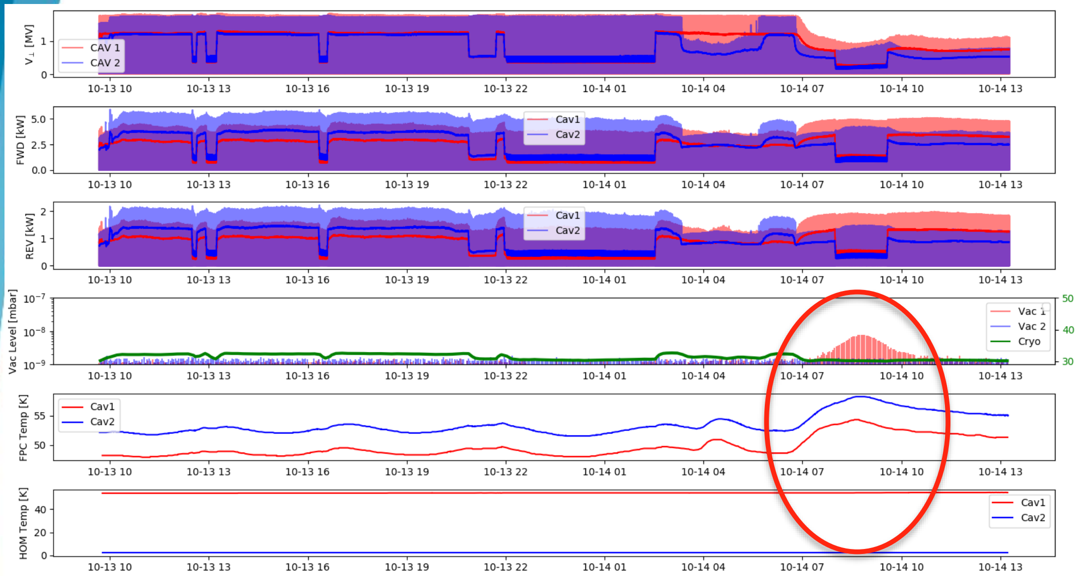
Vacuum dynamics and cryogenics at 4.5 K

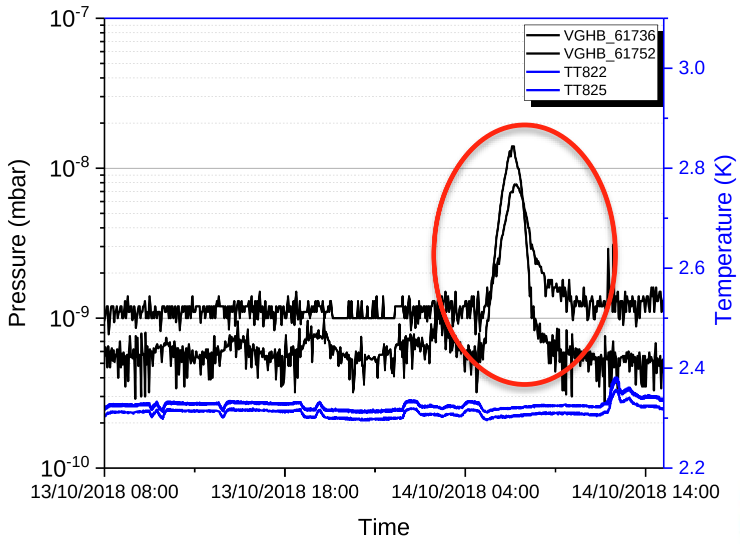




Aiming at removing hydrogen, the warm up could be stopped at 20-30K. For future cryomodules, it could be part of the conditioning procedure at surface or part of the LHC cold check-out.

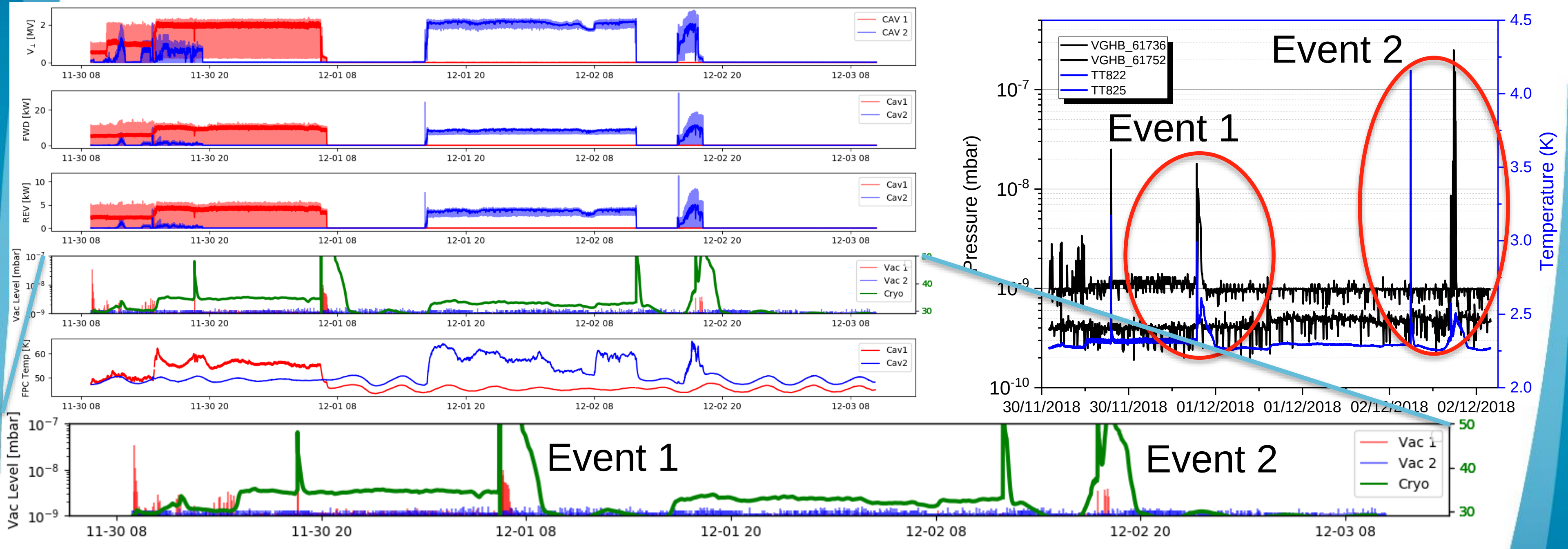
Vacuum dynamics and cryogenics at 2K





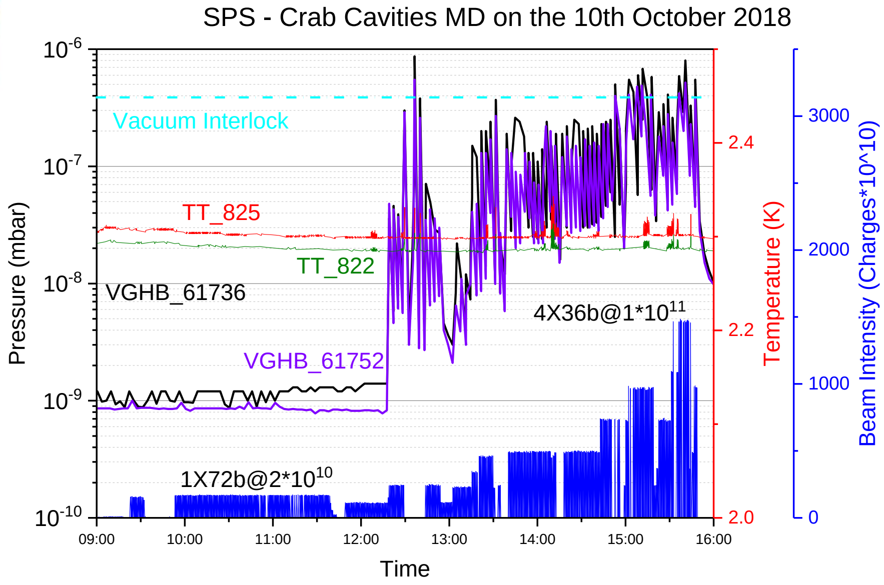
Vacuum dynamics corresponding to an increase of temperature on the Fundamental Power Couplers

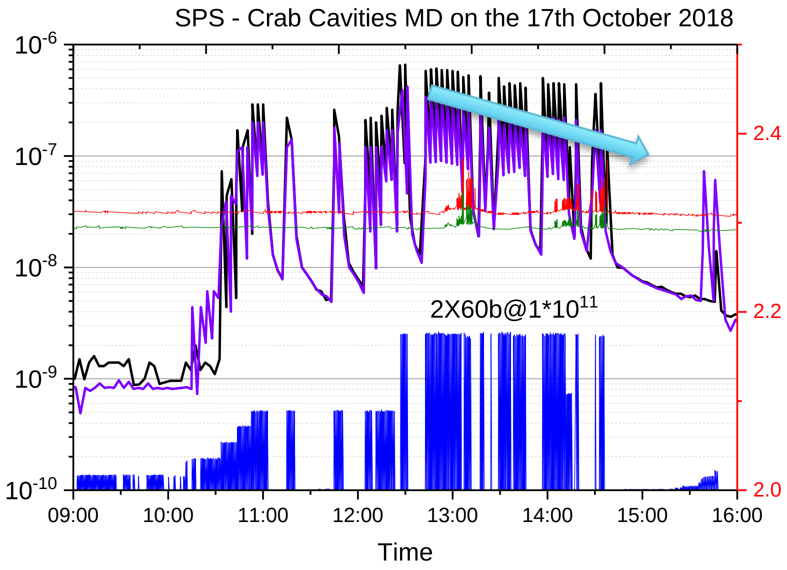
Vacuum dynamics and cryogenics at 2K



Sudden increase in cryo power demand → limited effects on vacuum

Vacuum dynamics vs beam intensity

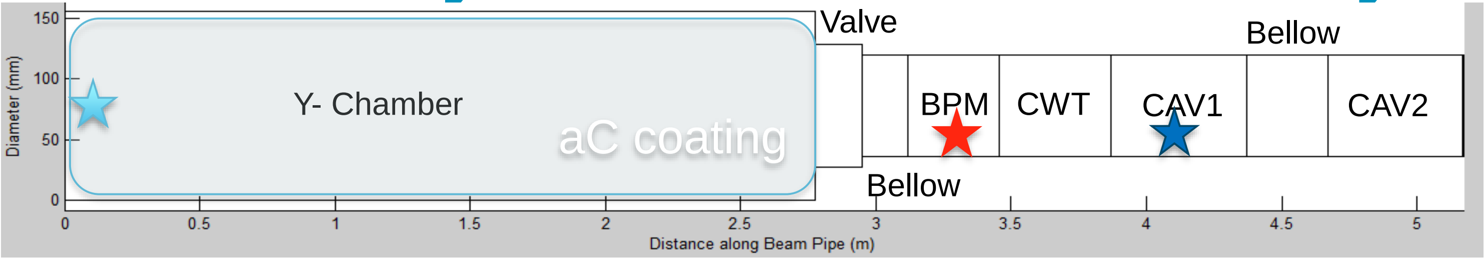


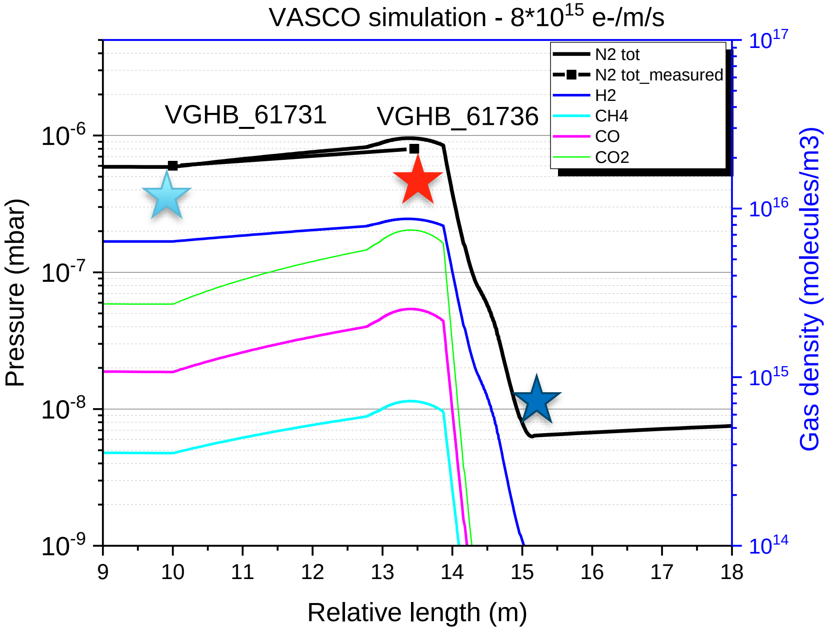


Pressure dynamics with higher intensity beams at 25ns

Pressure dynamics: beginning of scrubbing effects

Vacuum dynamics Vs beam intensity

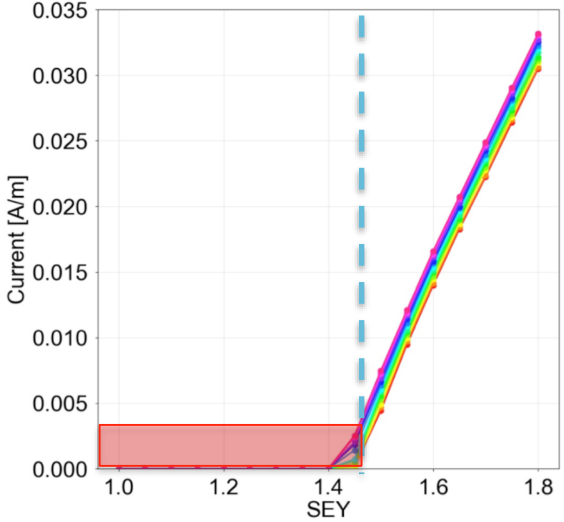




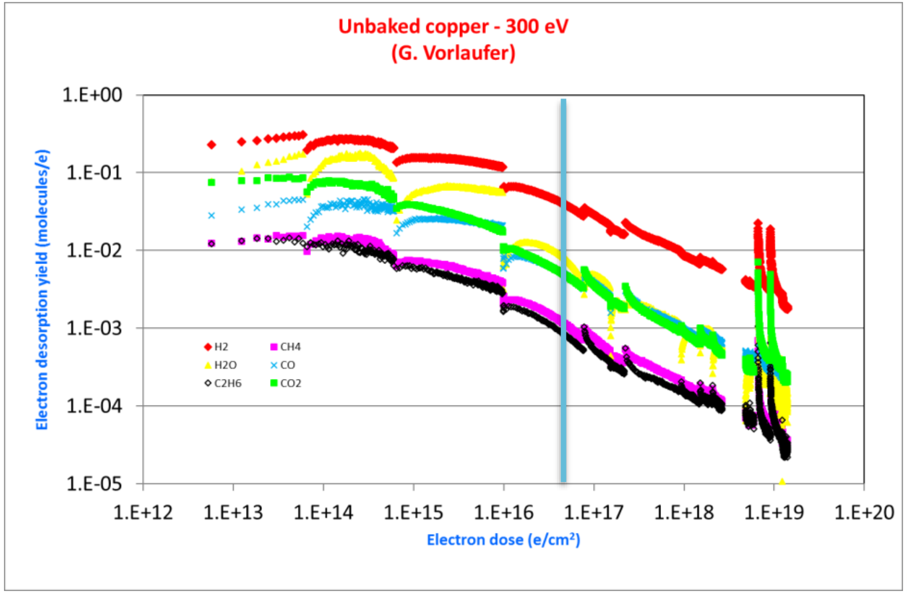
$8*10^{15}$ e-/m/s = $1.28*10^{-3}$ A/m = $5.38*10^{-9}$ A/mm^2

Vacuum dynamics Vs beam intensity

Ø 80mm,
1*10^{11} ppb, field free, 25ns



Courtesy of G. Iadarola

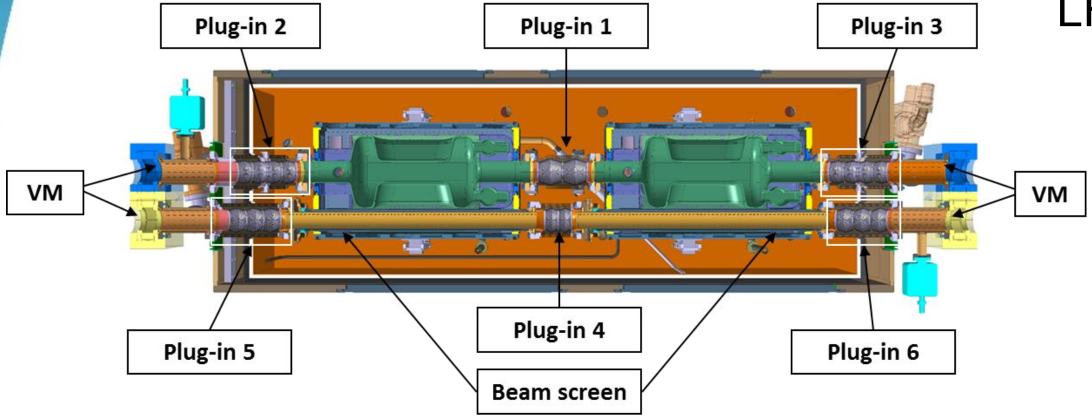


$1*10^{-4}$ C/mm^2 = $6.25*10^{16}$ e-/cm^2

About 10 h needed to scrub with beam (SEY<1.4)

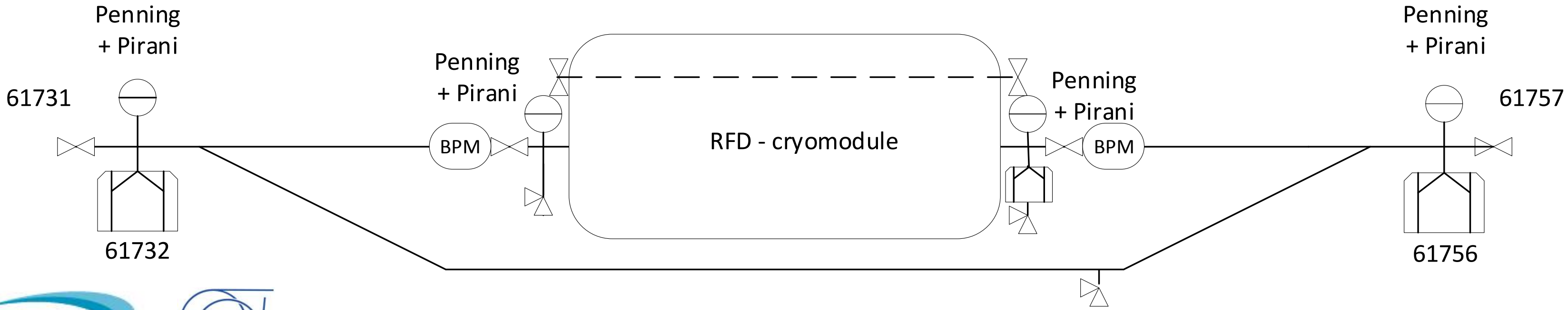
Scrubbing of the Cold – Warm transition will be needed in LHC too.

RFD – ‘LHC like’ integration in SPS



LHC – like configuration:

- 2 beam lines;
- New vacuum modules (VM) equipped with gauges and ion pumps (interlocking the neighbouring sector valves)



TE-VSC organization and link persons

SPS

Coordination
V. Baglin, G. Riddone, A. Carvalho

Design (Q4/2019)
C. Pasquino
J. Perez Espinos
TE-VSC-ICM

Procurement (Q2/2020)
C. Pasquino
A. Carvalho
L. Ferreira
TE-VSC-ICM

Acceptance tests (Q2/2021)
TE-VSC-BVO

Installation in the tunnel (Q1/2022)
BVO, ICM

RFD integration in SPS

- Detailed integration to be studied;
- Vacuum modules, interconnections, vacuum equipment and safety equipment will be supplied by VSC;
- New cables needed for ion pumps → SCADA layout modification;
- VSC contribution:
  - RGA analysis of the cavities and strip cavities;
  - RGA analysis for the final validation of the cryomodule;
  - Support to installation;
  - Vacuum controls development and hardware procurement;

See Germana's presentation

Conclusions

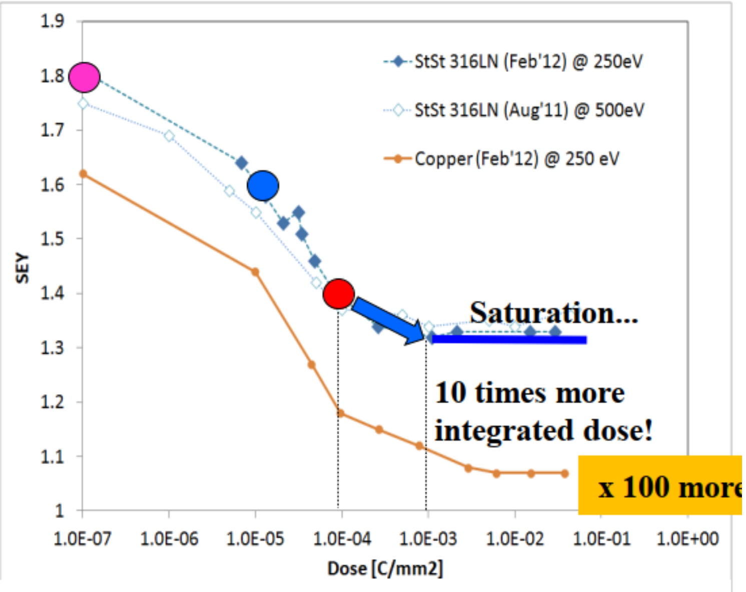
- DQW integration within the SPS vacuum system has been performed on time and with no major issues to highlight;
- Dynamic pressure rises due to the e- cloud could be solved by scrubbing;
- Procedure for the preparation of the cryomodule can be re-discussed and optimised in view of the RFD – SPS and LHC cryomodules;

Documentation

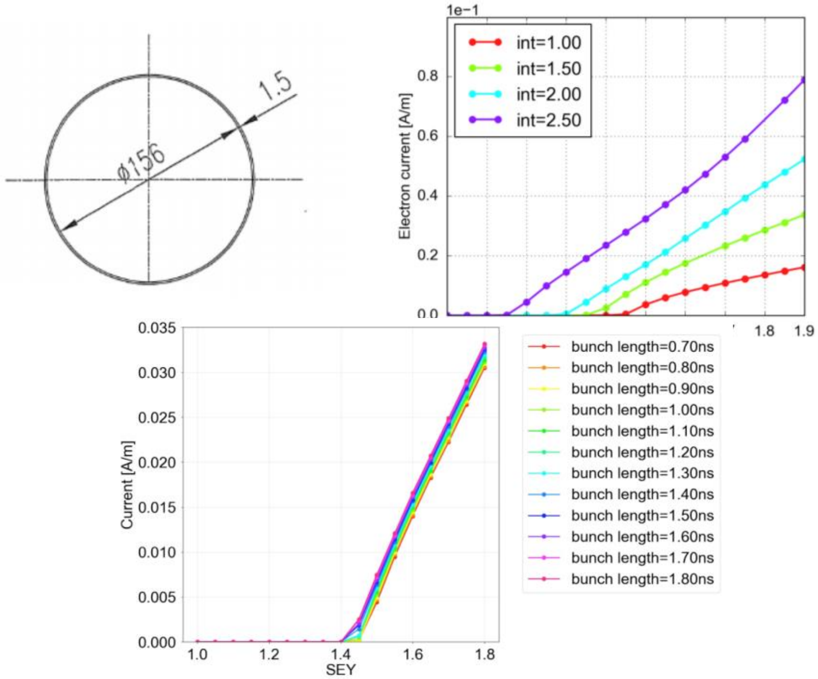
- TE-VSC contribution to the HL-LHC WP4: EDMS#1754567
- Conceptual design of the Crab Cavities vacuum system – EDMS#1864637
- TE-VSC mandate for insulation vacuum of RF equipment in the SPS tunnel – EDMS#1953501
- TE-VSC mandate for insulation vacuum of RF equipment in the LHC tunnel - EDMS#2143391
- Planning: vacuum equipment for WP4 – EDMS#2155574
- Criteria for vacuum acceptance tests - EDMS#1752123
- Codification of surface cleanliness levels – EDMS#347564

THANKS FOR YOUR ATTENTION!

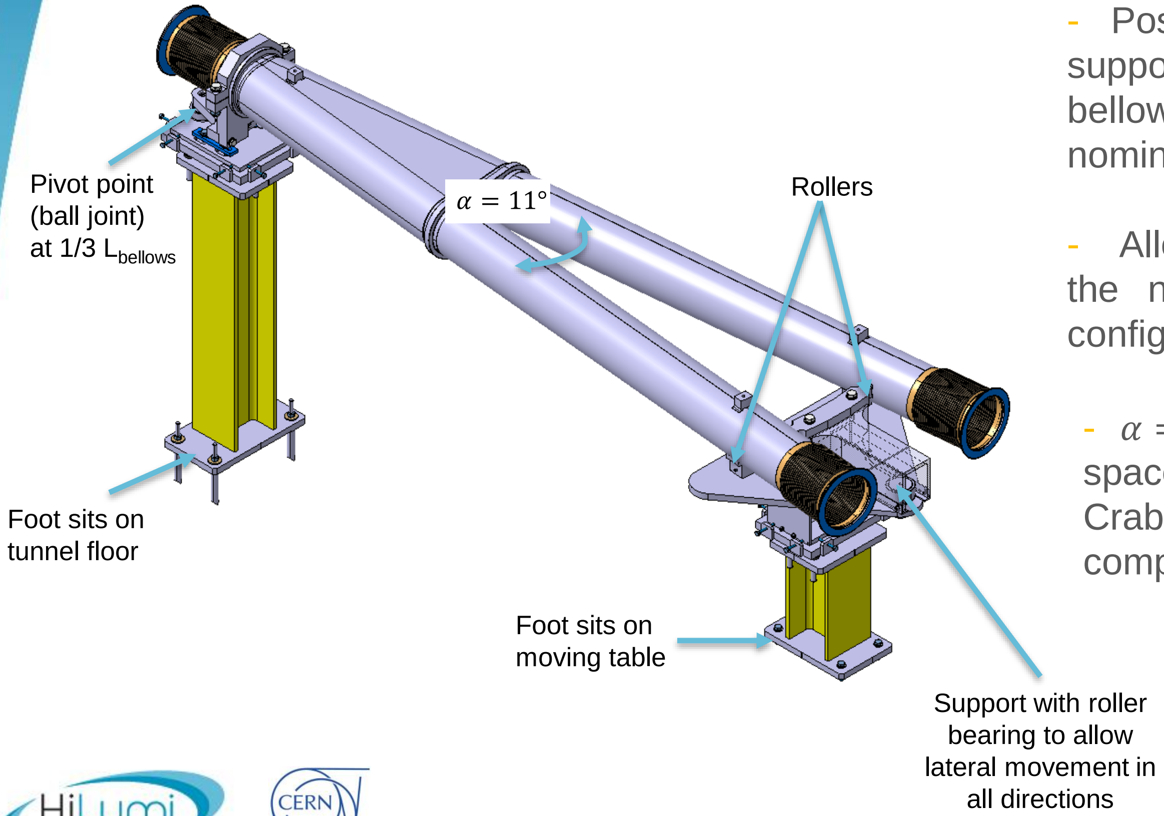
SPARE SLIDES



Simulation results: 156-mm drift chamber



Mechanical Design & Production



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

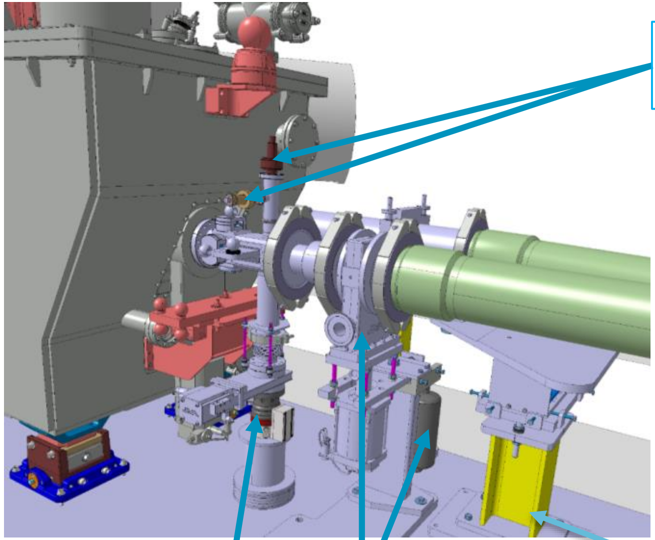
- Allow movement of the Y-chamber up to the nominal operating position in both configurations (Crab Cavities & bypass).

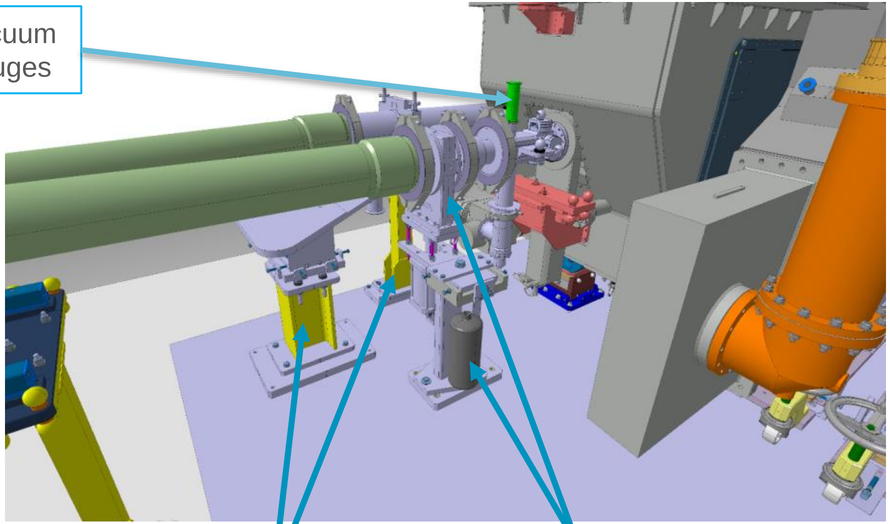
- $\alpha = 11°$ – to guarantee the minimum space necessary for the integration of the Crab Cavities and all the other components on top of the moving table.

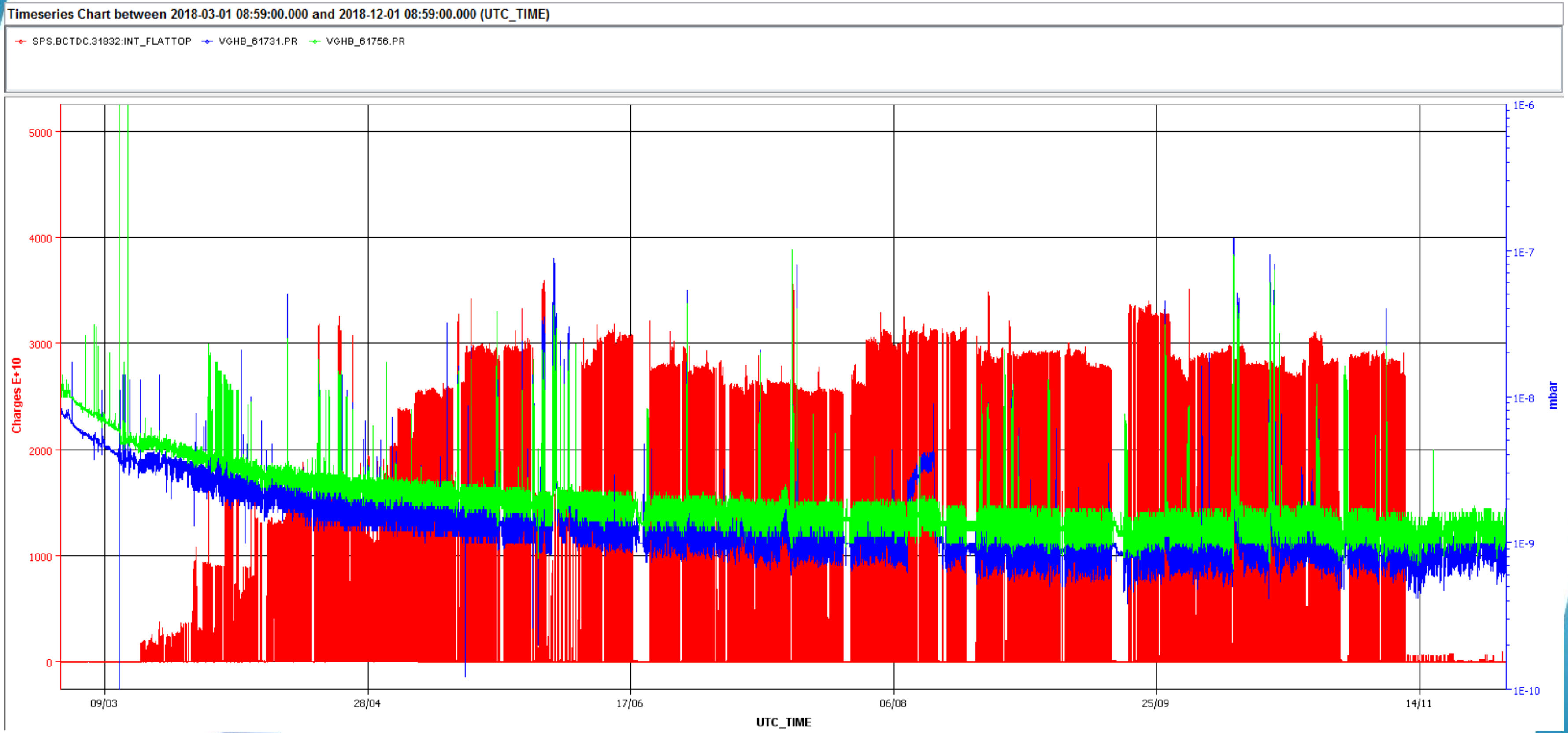
Integration

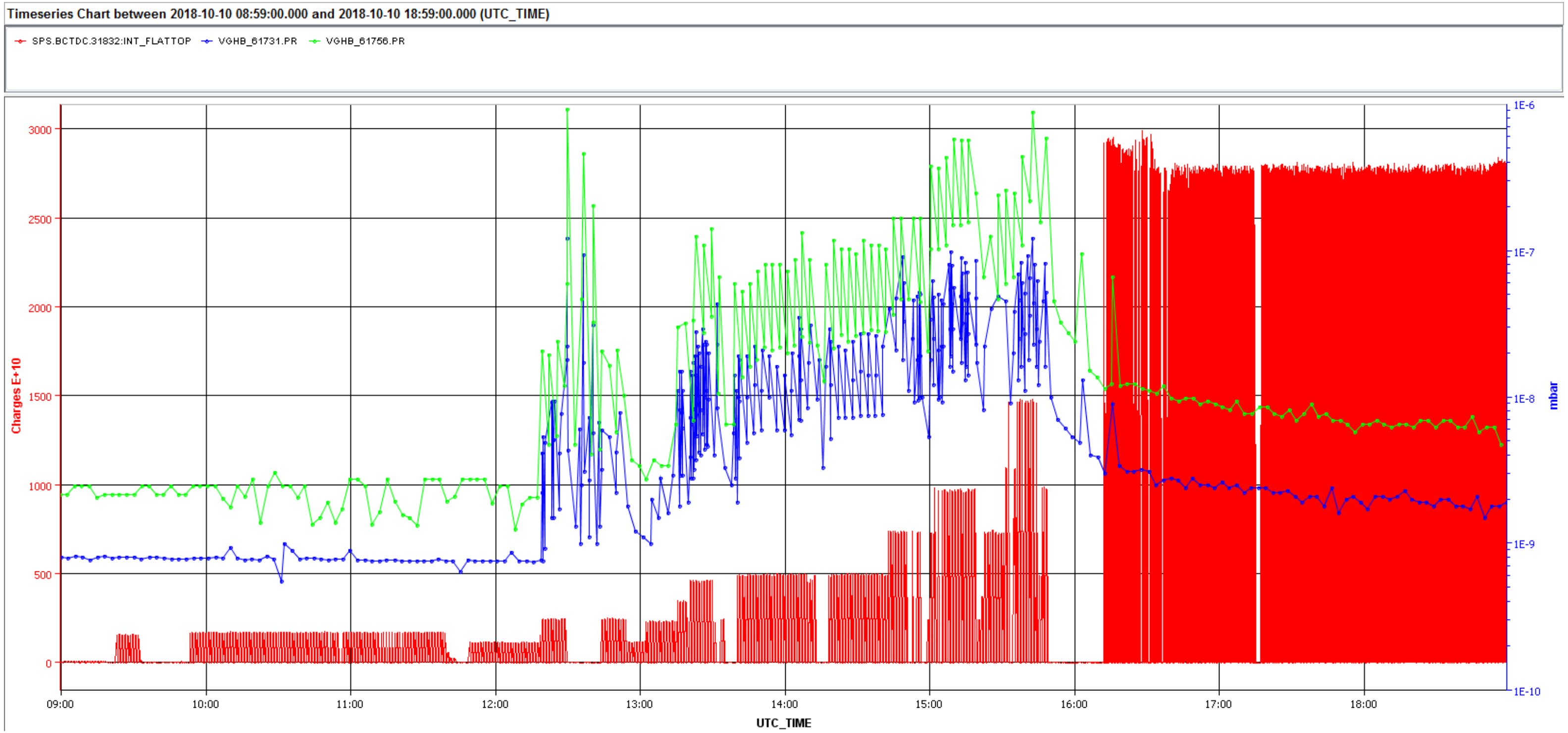
Upstream

Downstream





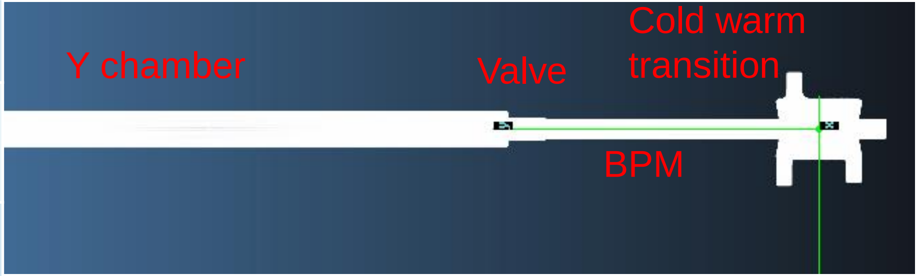

Timeseries Chart between 2018-03-01 08:59:00.000 and 2018-12-01 08:59:00.000 (UTC_TIME)
SPS.BCTDC.31832:INT_FLATTOP
VGHB_61731.PR
VGHB_61756.PR
Charges E+10
5000
4000
3000
2000
1000
0
1E-6
1E-7
1E-8
1E-9
1E-10
mbar
09/03
28/04
17/06
06/08
25/09
14/11
UTC_TIME

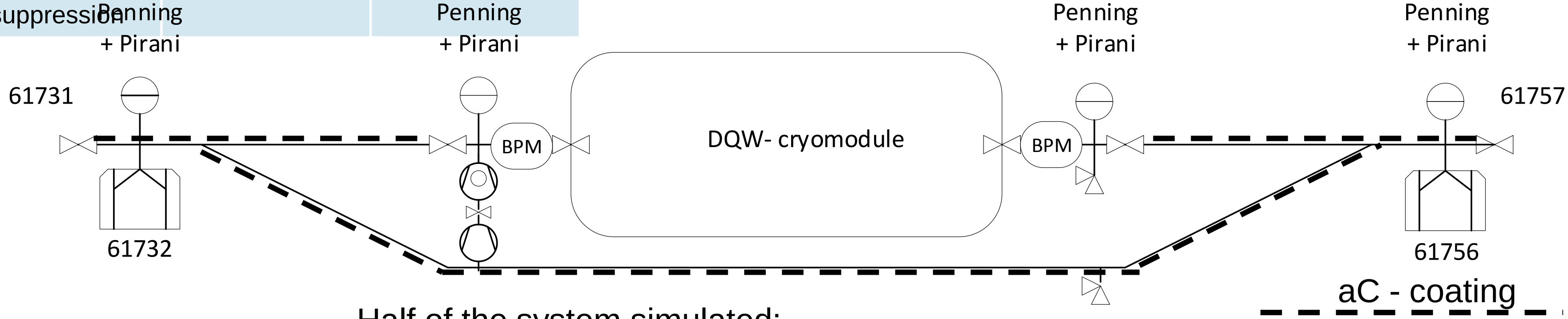


Timeseries Chart between 2018-10-10 08:59:00.000 and 2018-10-10 18:59:00.000 (UTC_TIME)
SPS.BCTDC.31832:INT_FLATTOP
VGHB_61731.PR
VGHB_61756.PR
Charges E+10
mbar
UTC_TIME

rmance Vs beam intensity

Boundary conditions	Pressure – Y chamber	Pressure on the BPM
Actual configuration	$3*10^{-8}$	$1*10^{-6}$
Bellows+BPM e- cloud suppressed	$1*10^{-8}$	$2*10^{-7}$
Valve+Bellows +BPM e- cloud suppression	$2.5*10^{-9}$	$1.6*10^{-7}$

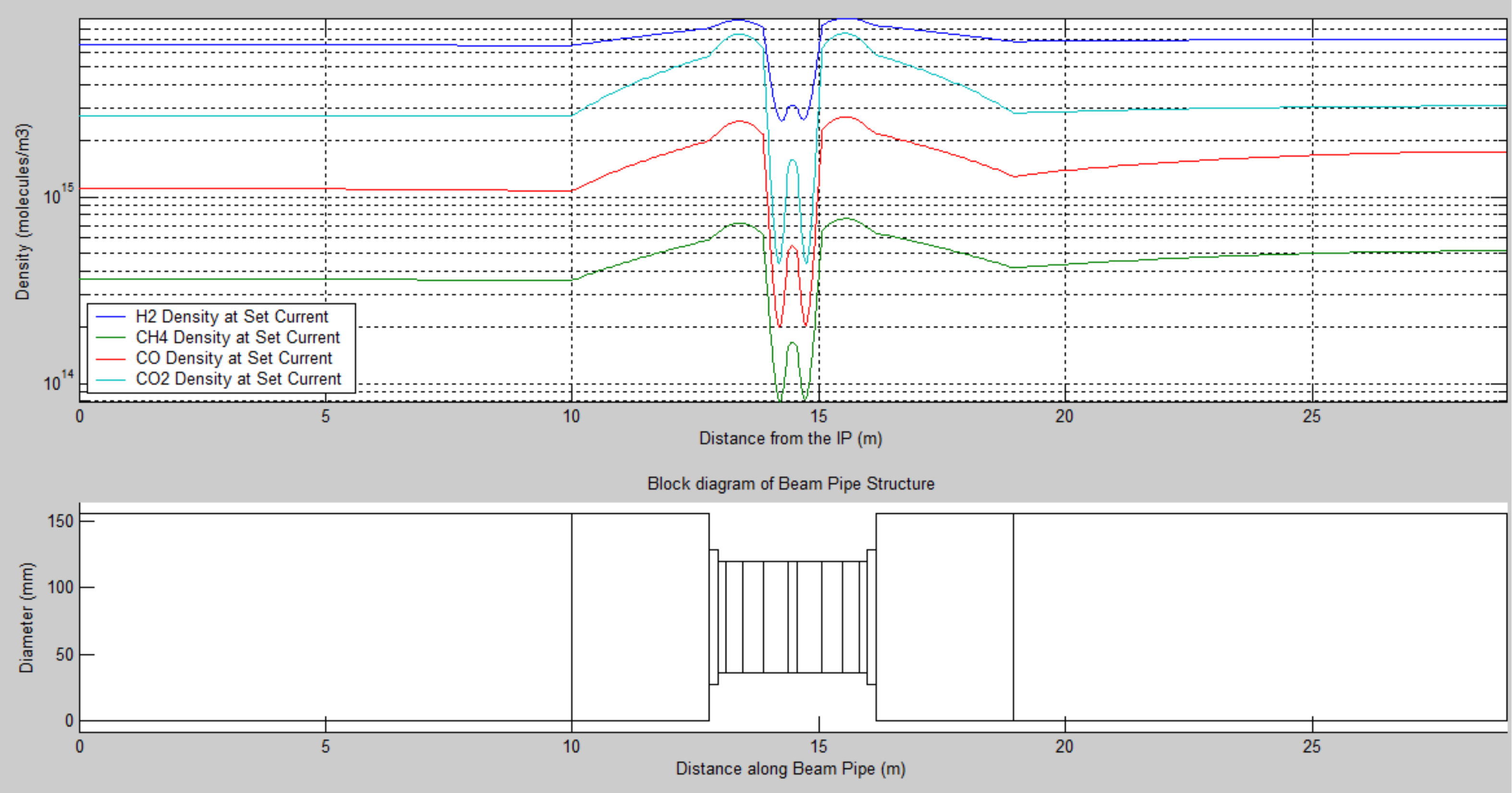




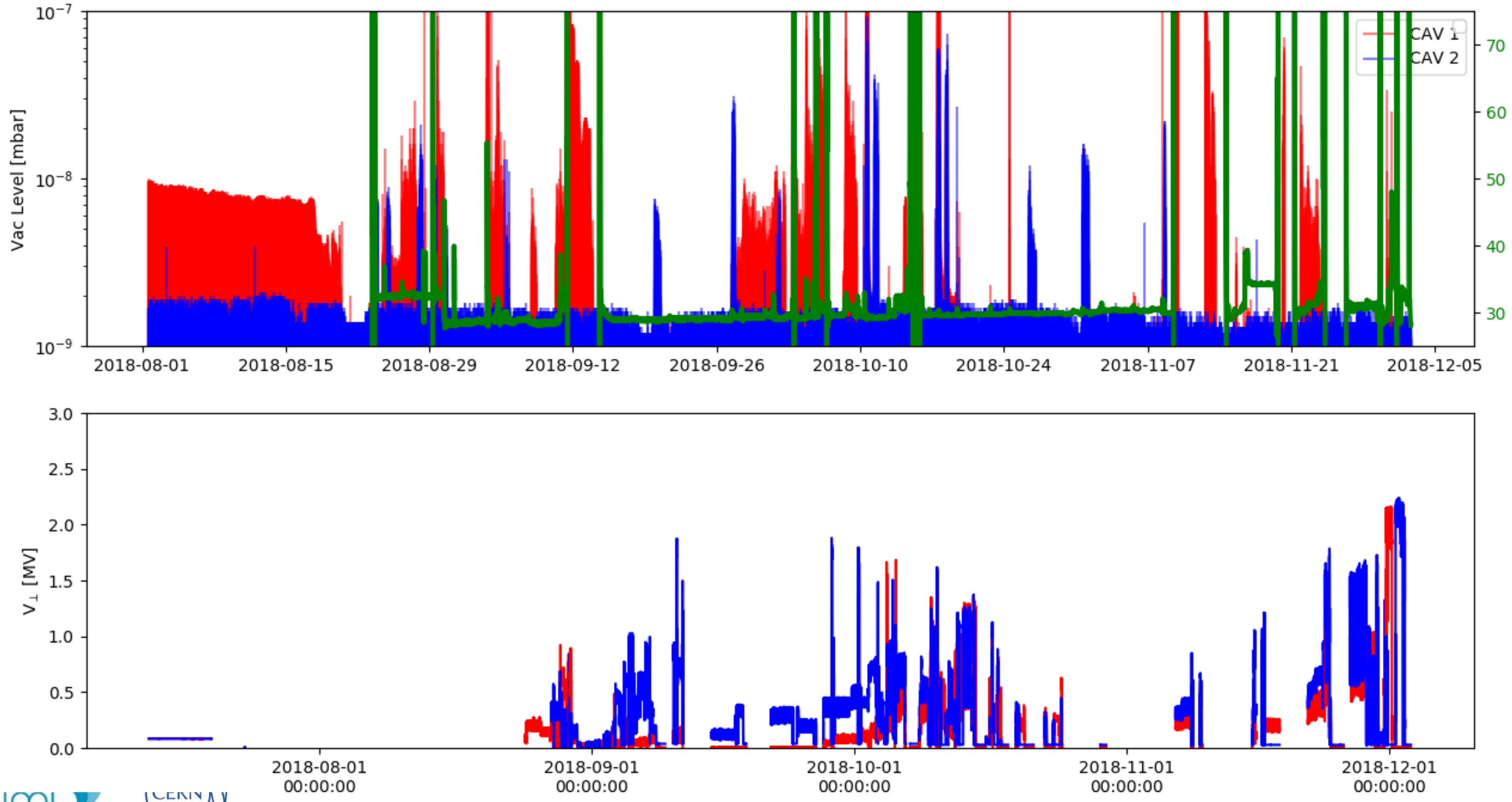
Half of the system simulated:

- Gas load added to the non coated components;
- Cavity at 2K;
- Pressures in N_2 equivalent;
- Minor differences if the sector valve' e-cloud is suppressed

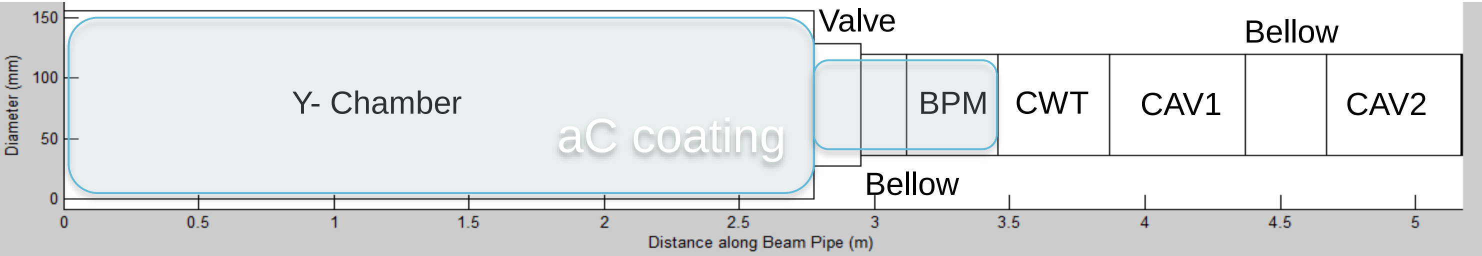
Vacuum dynamics Vs beam intensity

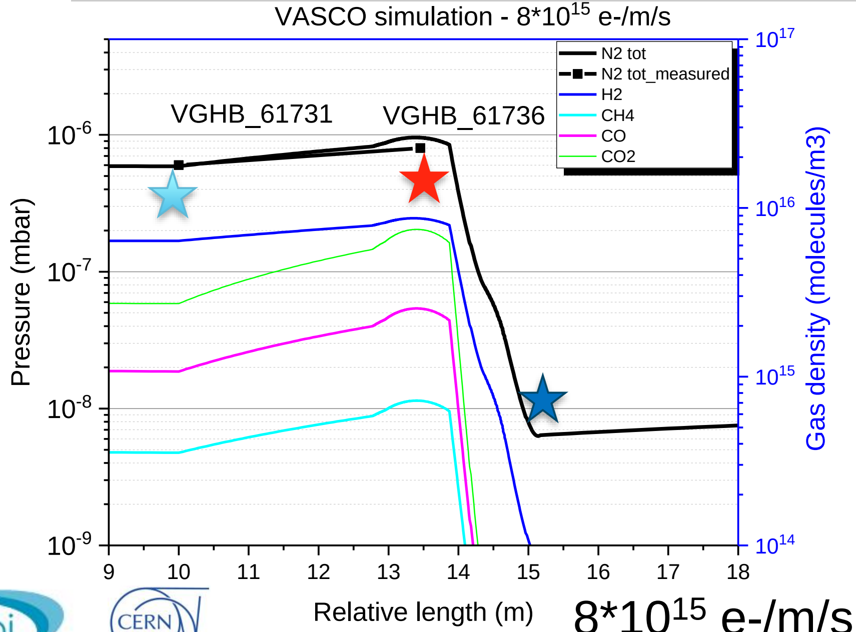


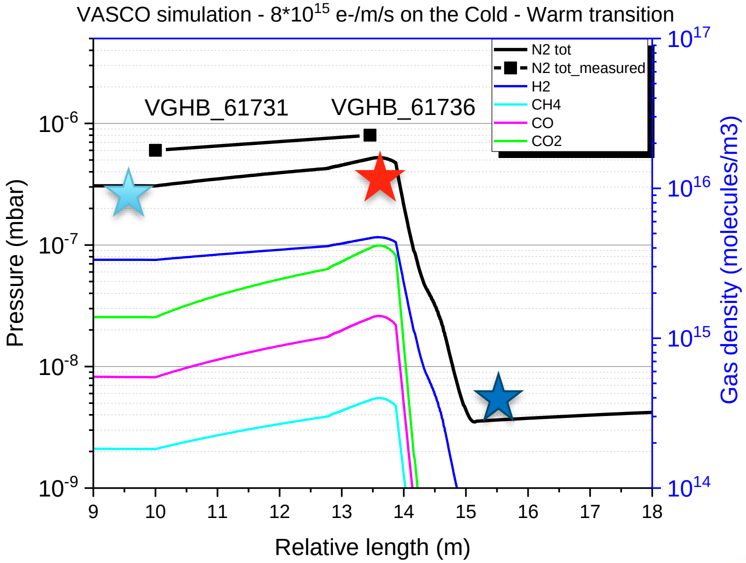
Pressure VS voltage



Vacuum dynamics Vs beam intensity







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