



**High  
Luminosity  
LHC**

# **Crab Cavities: Vacuum Considerations for SPS and HL-LHC**

**V. Baglin (TE-VSC)  
on behalf of WP12**

**5<sup>th</sup> Joint HiLumi LHC-LARP Annual Meeting  
CERN – 26-30 October 2015**

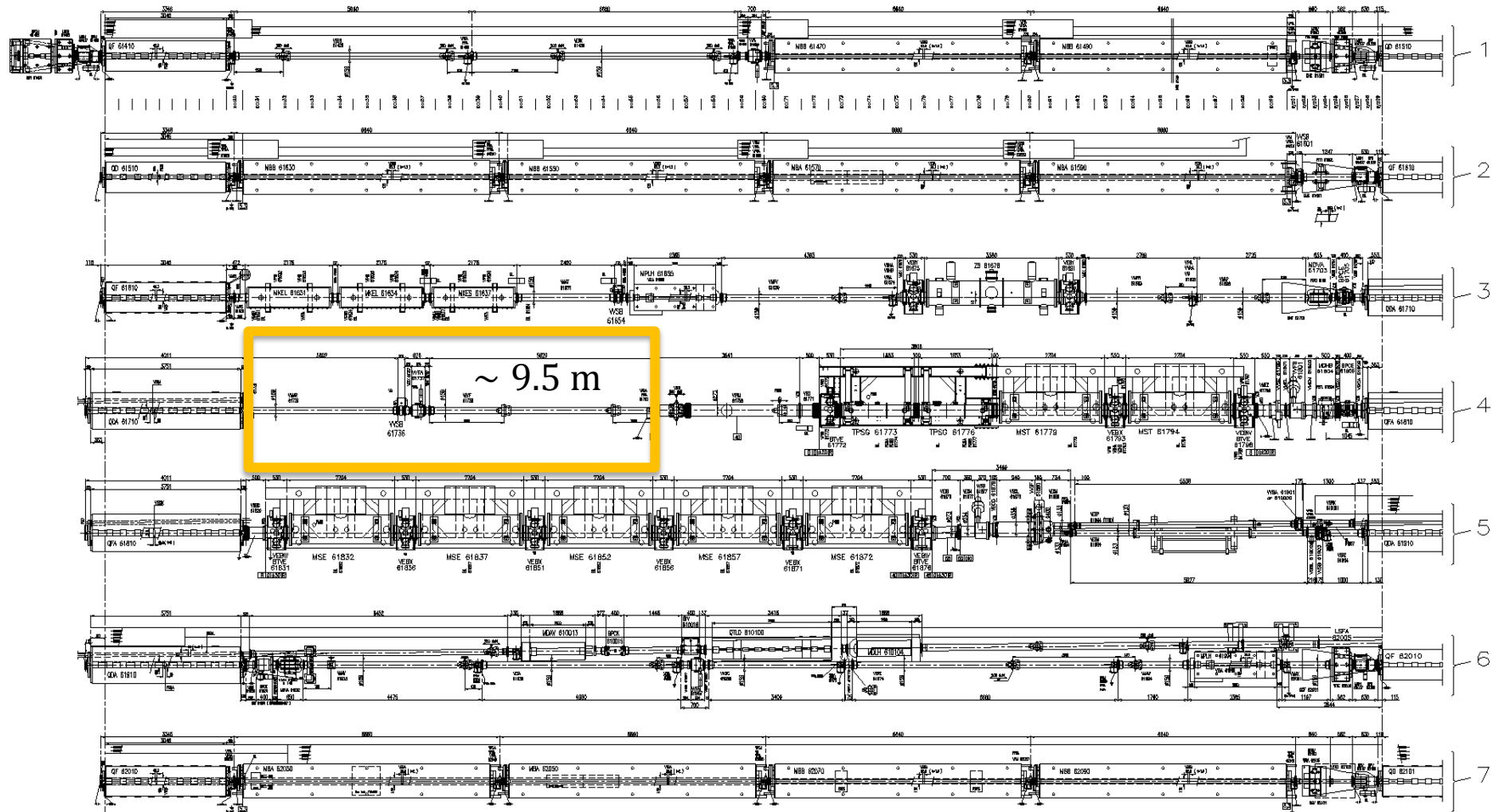


The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404.

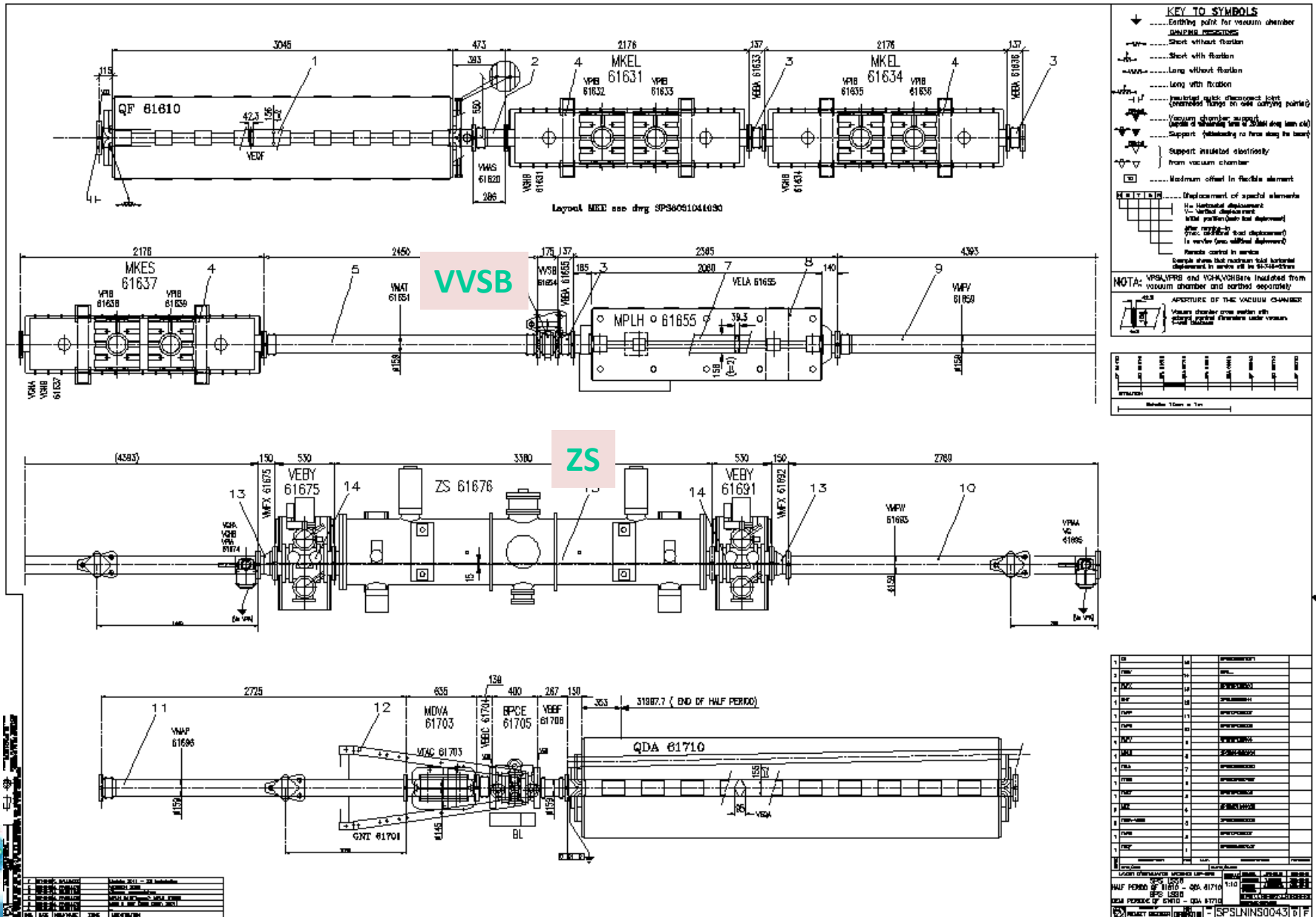


# 1. Crab Cavities in SPS

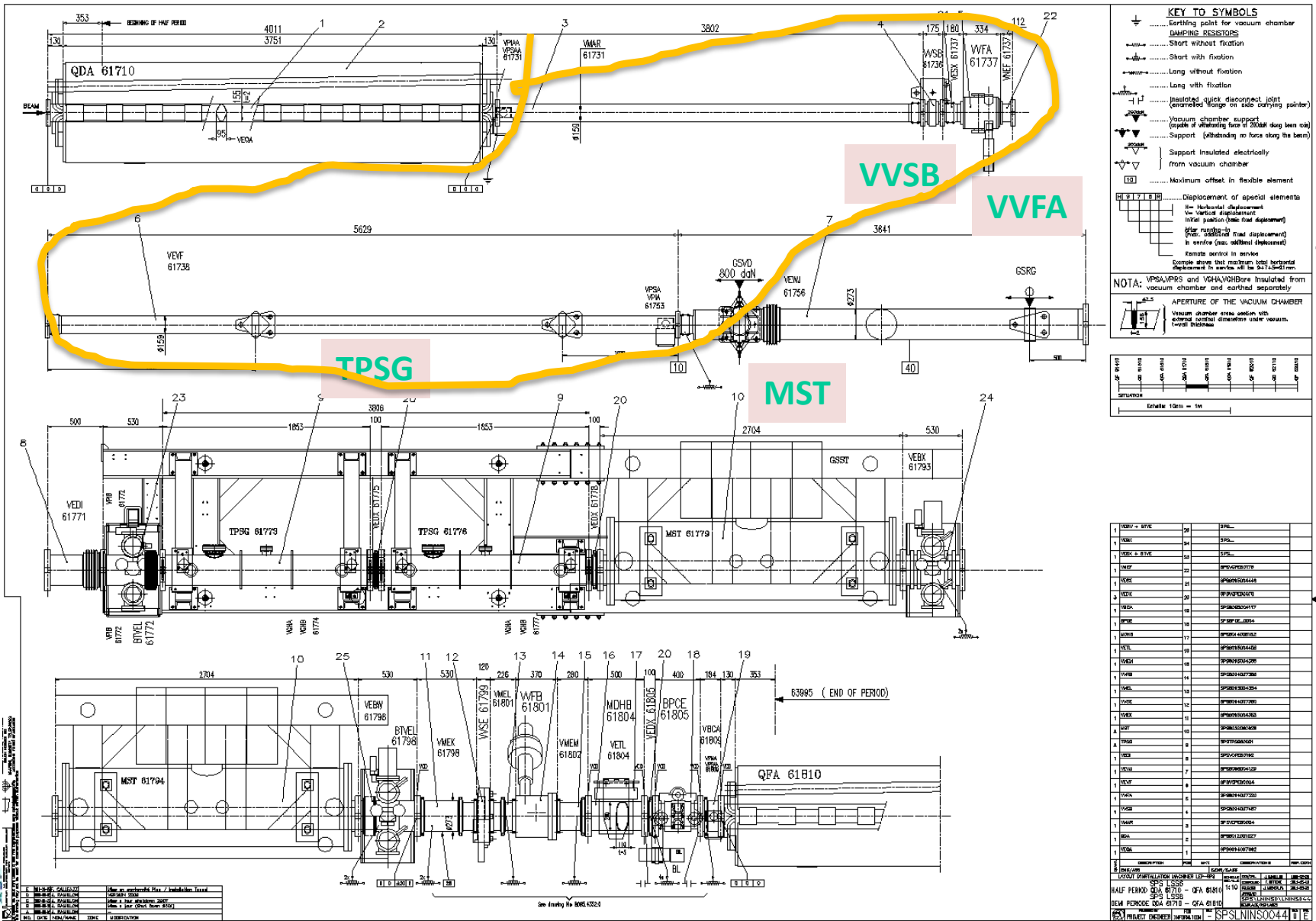
# SPS Long Straight Section 6



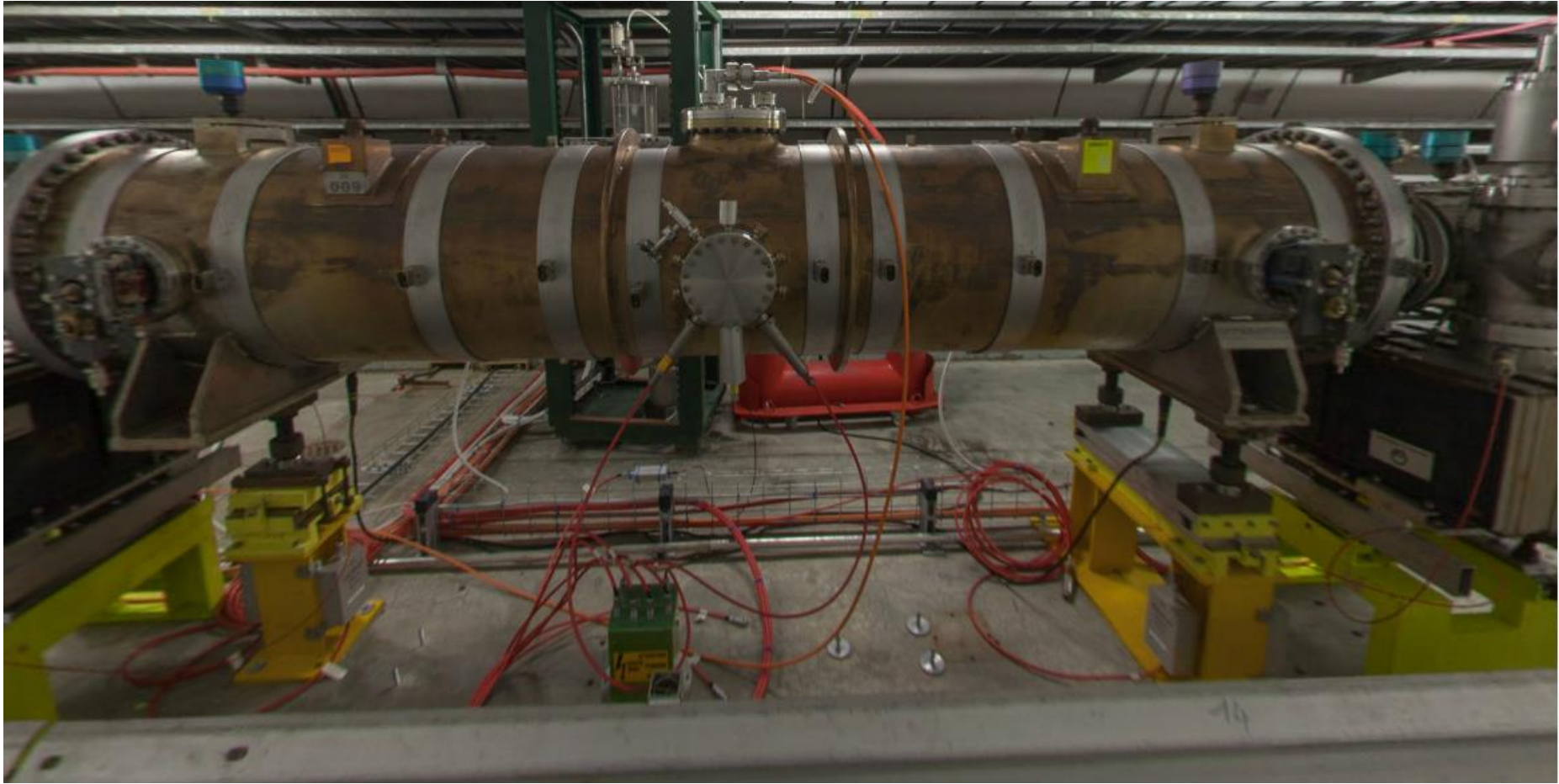
# SPS LSS6 – Half period QF 61610 – QDA 61710



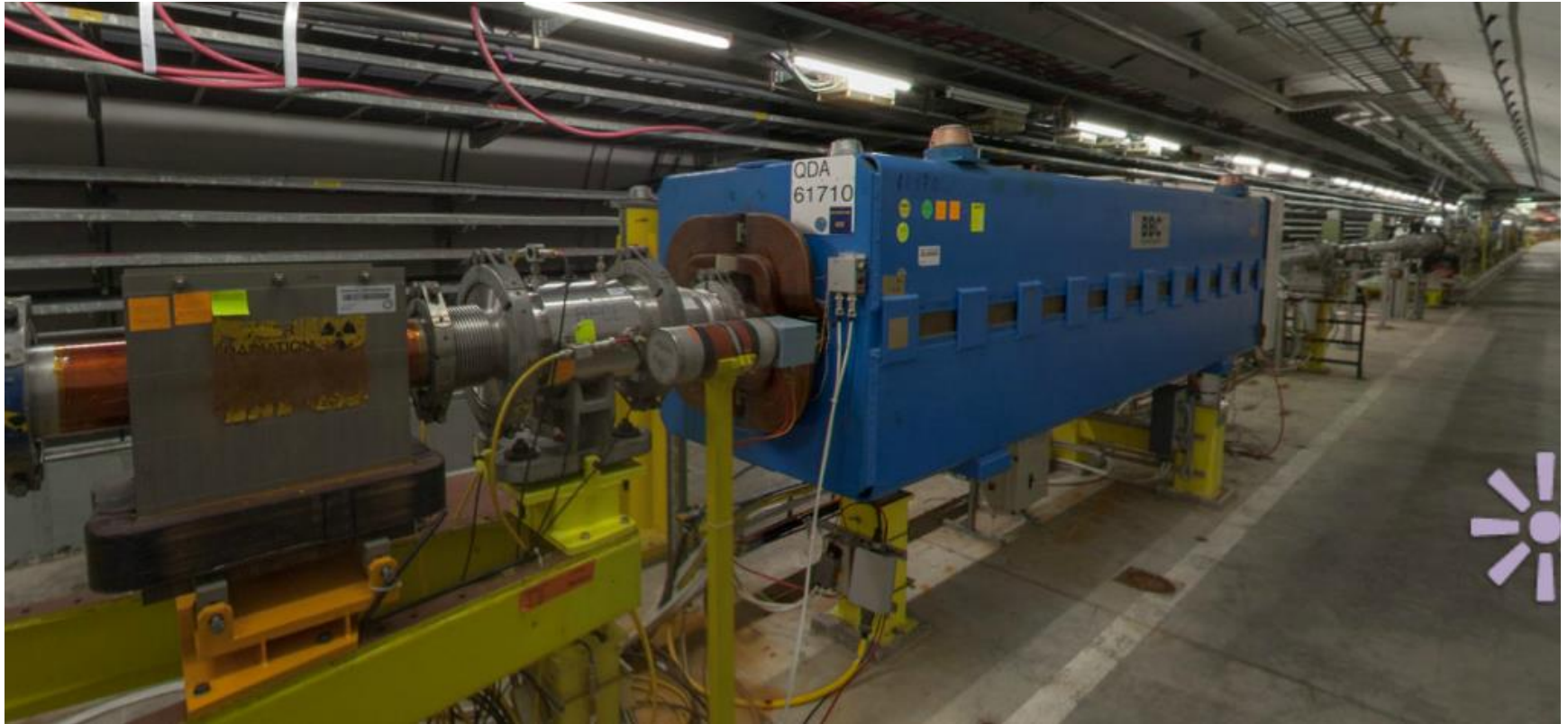
# SPS LSS6 – Half period QDA 61710 – QFA 61810



# SPS LSS6 -ZS



# SPS LSS6 –QDA 61710



# SPS LSS6 – RF testbed area





# SPS LSS6 – Sector and Fast Valves located in RF test bed area



# SPS LSS6 – New Position of Sector and Fast Valves



# SPS LSS6 – TPSG and MST



# SPS LSS6 – TPSG



# SPS LSS6 – MST

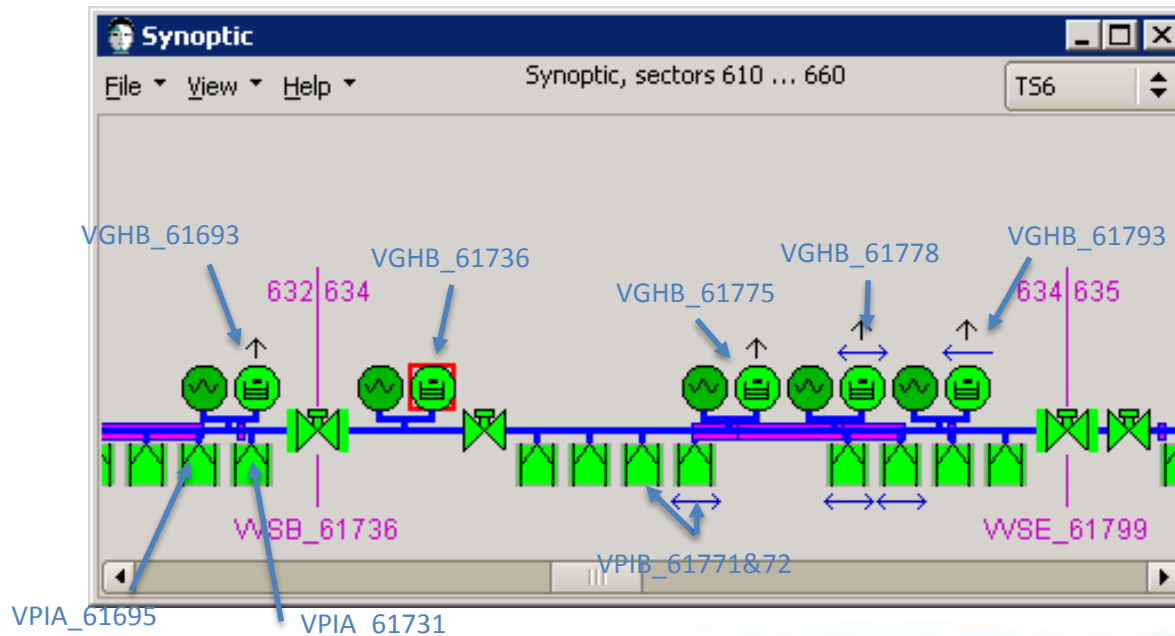
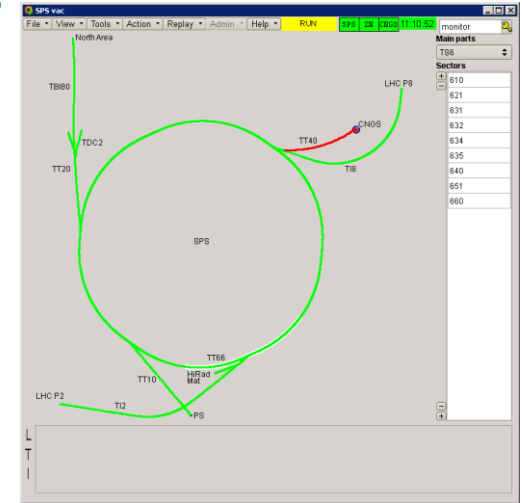


# Description

- QDA 61710
  - A defocussing quadrupole, length 4011 mm
  - Vacuum chamber VEQA, elliptical
- VVSB
  - Aperture 150 mm
  - A sector valve
  - It must be displaced and moved on the right side by at least xx meters
- VVFA
  - Aperture 150 mm
  - A fast valve which protects the ??
  - It must be displaced and placed to at least xx meters upstream to the protect equipment
- TPSG
  - A graphite mask which protects the downstream septum
  - Must be vented, isolated with a new sector valve, and pump down for at least 3-4 weeks before beam
- Pumping system
  - On the right side of QDA 61710: a 20 l/s ion pump, VPIAA
  - At 61753, another a 20 l/s ion pump, VPIAA
  - At the level of the TPSG, 61772, 2 ions pumps of 400 l/s each, VPIB

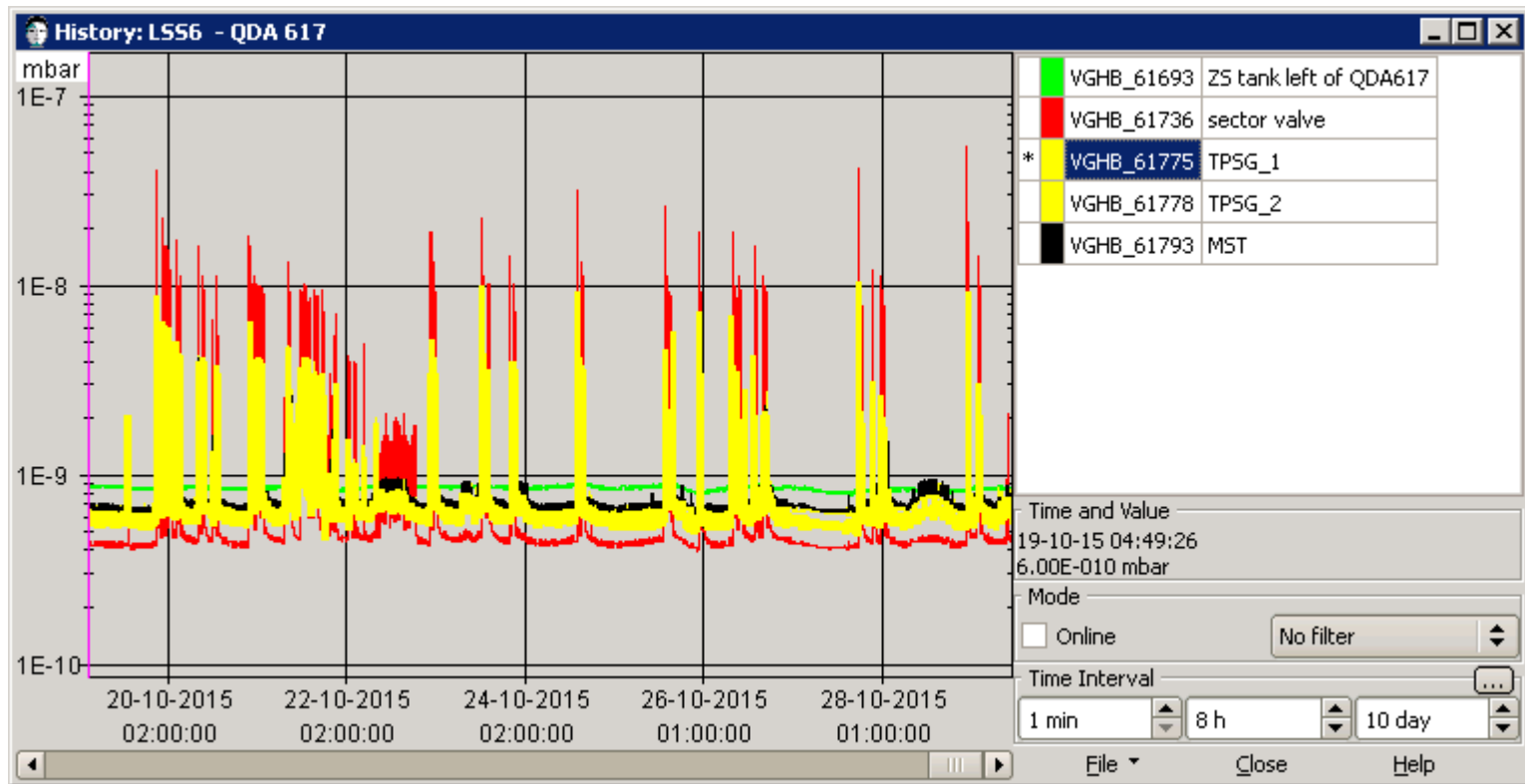
# Pressure profile

- VGHB\_61693: ZS tank left of QDA 61710
- VPIA\_61731: right of QDA 61710
- VGHB\_61736: on VVSB\_6173 sector valve
- VVFA\_61737: fast valve
- VPIA\_61737:
- VPIA\_61753
- VPIB\_61771: on left side of TPSG 61773
- VPIB\_61772: on left side of TPSG 61773
- VGHB\_61775: TPSG 61773
- VGHB\_61778: TPSG 61776
- VPIB\_61792: on right side of MST 61779
- VPIB\_61793: on right side of MST 61779
- VGHB\_61793: on right side of MST 61779



# Pressure profile

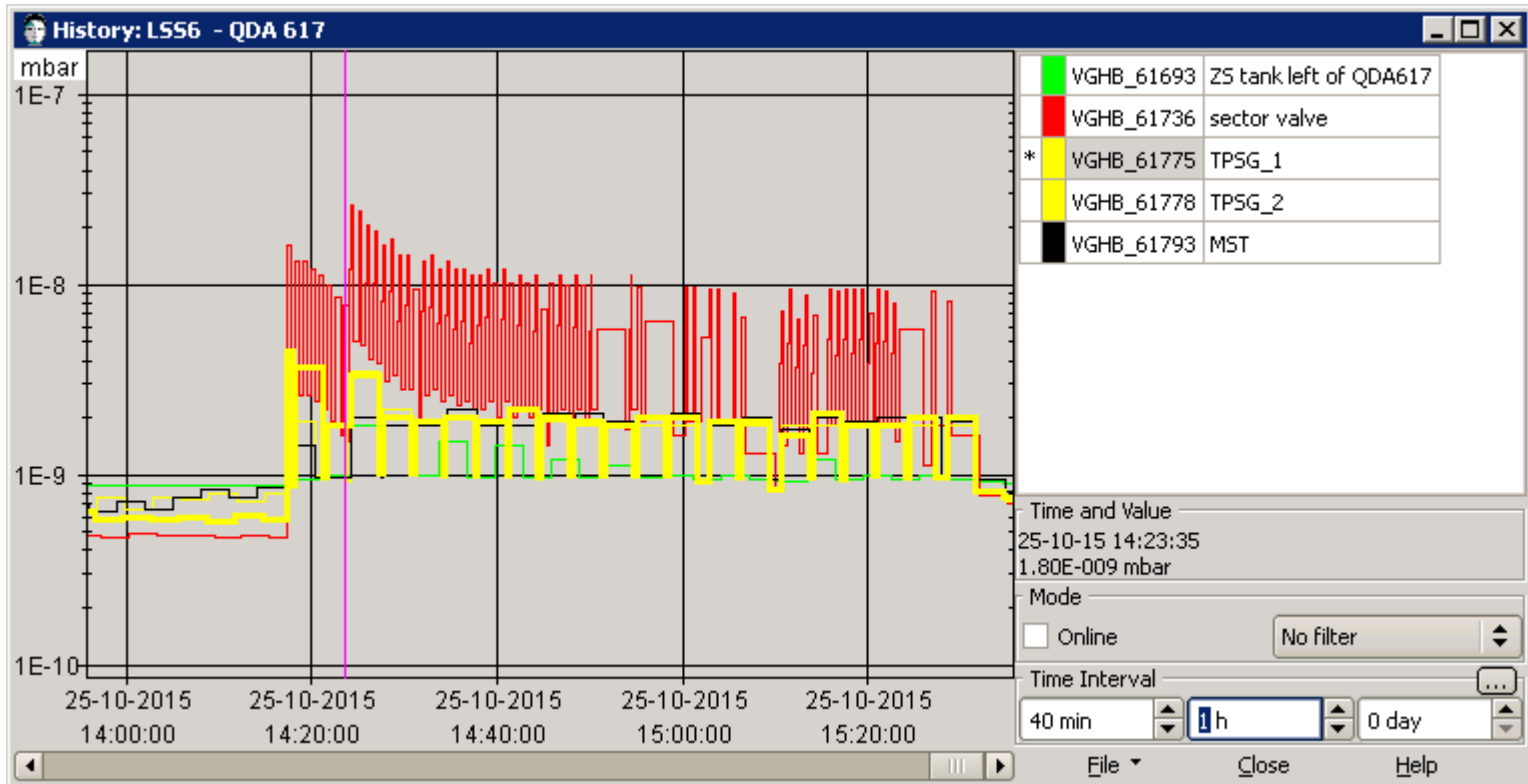
- Actual pressure in the sector  $\sim 2 \cdot 10^{-8}$  mbar: dominated by pressure at sector valve





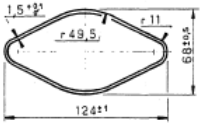
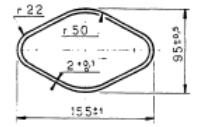
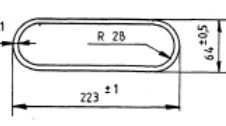
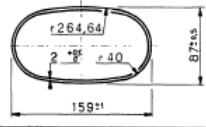
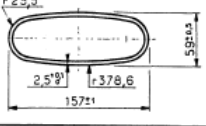
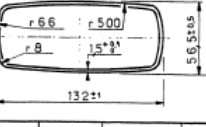
# Pressure profile

- Actual pressure in the sector  $\sim 2 \cdot 10^{-8}$  mbar: dominated by pressure at sector valve
- ZS =  $2 \cdot 10^{-9}$  mbar
- TPSG =  $3 \cdot 10^{-9}$  mbar
- MST =  $2 \cdot 10^{-9}$  mbar



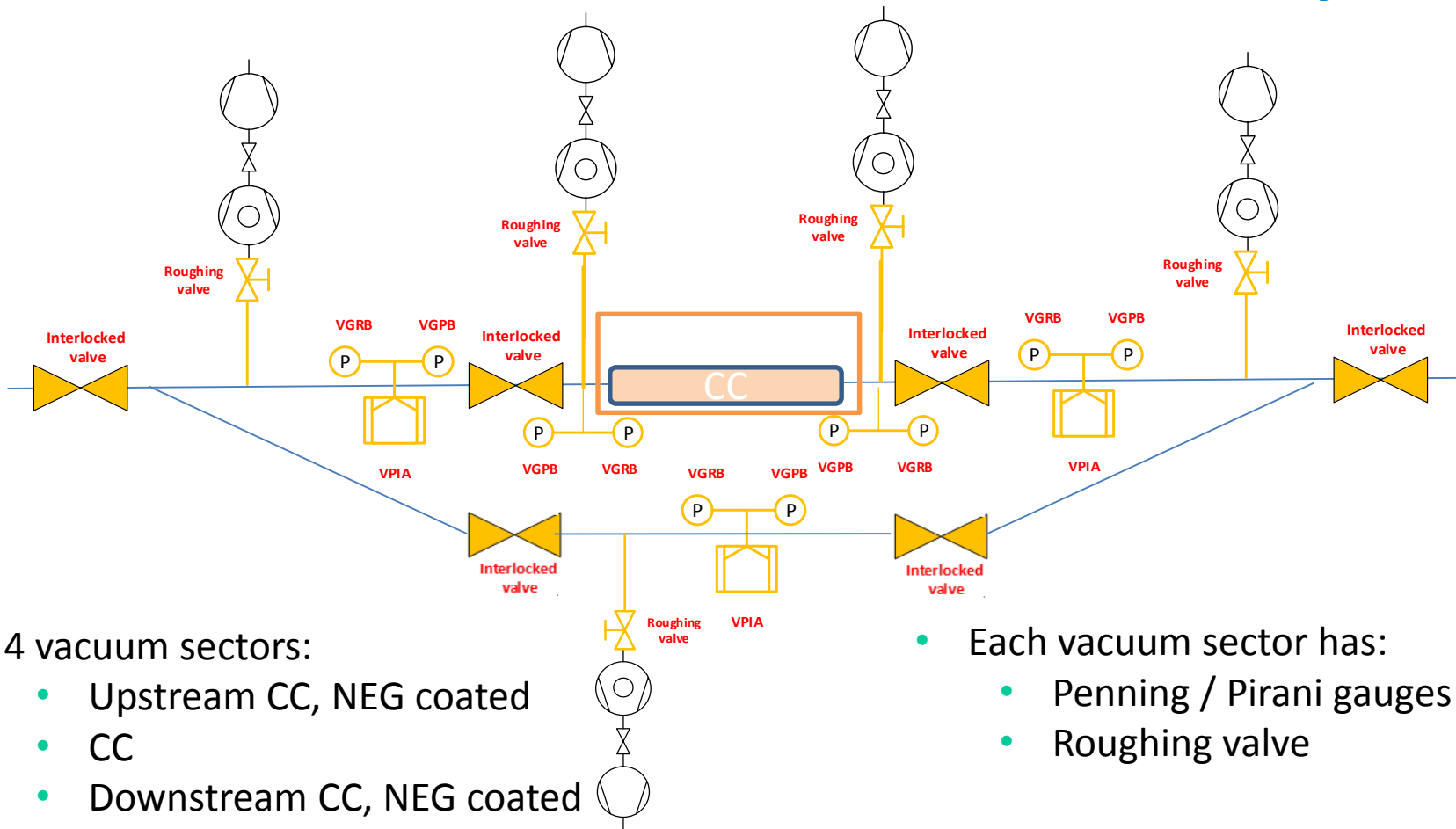
→ One order of magnitude must be gained to reach the specs :  $10^{-10}$  mbar in CC

# SPS vacuum chambers: QDA

REFERENCES :	CONSIGNES DE CONSTRUCTION SPS / SME.DD TUBES A VIDE ELLIPTIQUES ET OVALES STANDARD SPS	N° DE CLASSEMENT :	
		13.10.06	
DIMENSIONS	LONGUEUR	UTILISATION	NO DESSIN
	1152 1892 1900 3400	IT 60	8097-0006-3
	3995	QFA QDA	8095-0386-3
	3554	MOV2	8097-0168-2  Masse = 15,90 Kg/a
	3000	NDHD NDPH	8095-0605-3
	2500	Expérience DAL Calorimètre 07	8095-2141-3
	6428	MBB	8095-0042-3
DATE DESSIN : 81.12.22	EDITEUR : R. CUENOT	MODIFICATION :	DATE : 01.01.03
REVISÉ PAR :	VISA :		8091-5185-3
			2/3

- Computing electron cloud levels in QDA type chambers would be beneficial to evaluate the pumping scheme

# A Possible Instrumentation Layout

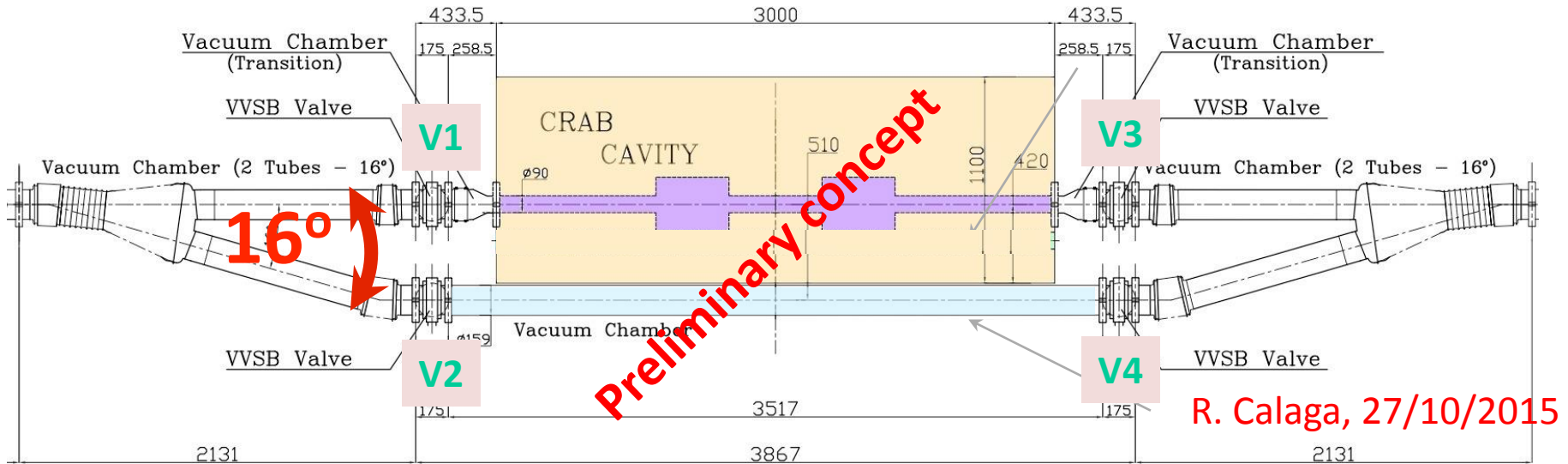


- 4 vacuum sectors:
  - Upstream CC, NEG coated
  - CC
  - Downstream CC, NEG coated
  - Bypass, NEG coated
- Each vacuum sector has:
  - Penning / Pirani gauges
  - Roughing valve
- NEG coated sectors have:
  - Ion pumps

➔ Detailed study is needed to optimise the pumping scheme

➔ More instruments could be added

# Conceptual Hardware Layout around CC

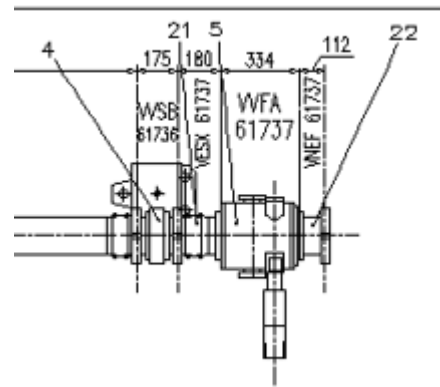


- Y chamber
  - Impedance free
  - NEG coated
  - Number of cycles for the bellows ?
- Bypass chamber
  - Distance between mechanical axis of bypass and CC ?
- Crab cavity volume
  - $L = 3000$  mm
  - $W = 1100$  mm
  - Interface flange: CF ? DN100 ?
- Sector valves, V1,2,3,4
  - Fixed to the movable table

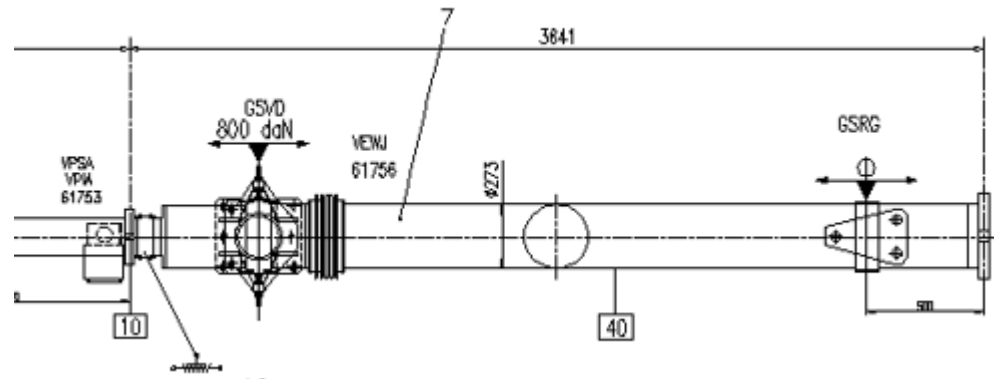
➔ Is available longitudinal space of  $\sim 9.5$  m enough ?

# New Sectorisation

- The assembly sector valve plus fast valve must be moved towards the right side by  $\sim 5.5 - 6$  m
  - ECR needed
  - Fast valve might be completely removed from the layout if needed



- The chamber VEWJ can be reduced in length (pending aperture checks) if needed



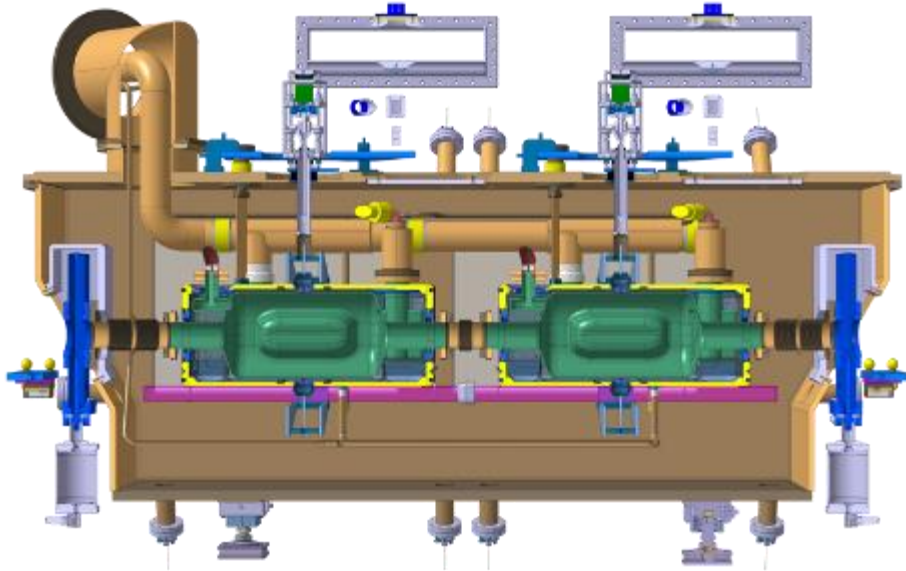
# Installation

- Planned for EYETS 2016-17
- Definition needed by **Dec 2015** for :
  - Vacuum sectorisation & instrumentation layout
  - Y chambers → need frozen specification for design
  - Procurement of main components : sector valves (6+1), pumps, gauges etc..
- Intervention planning to be detailed:
  - Venting the 2 adjacent sectors with N2
  - **Immediate** installation of the external sector valves to allow pump down of the adjacent vacuum sectors (ZS tank , Graphite TPSG, Septum ...)
  - Installation of the movable sectors
  - Installation and closure of the CC bypass system with a **replacement chamber**

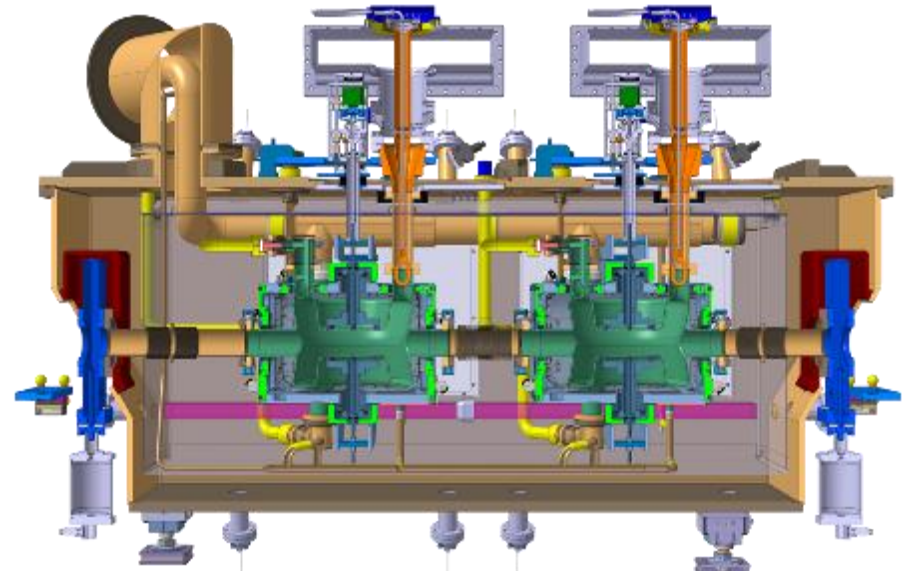
## 2. Crab Cavities in HL-LHC

# Crab Cavities

- Operating pressure  $\sim 10^{-10}$  mbar with beams
- 2 designs with bulk Nb operating at 2 K
- Vacuum instrumentation on the modules is under definition



RF Dipole,  
Horizontal Deflection (CMS)



Double Quarter Wave,  
Vertical Deflection (ATLAS)

R. Calaga, O. Capatina, 27/10/2015



# Crab Cavities

- Impact of the electron cloud in the CC modules must be evaluated:

- Nb cavity itself
- Inter-cavity tube
- Module cold warm transition



Samples needed for qualification

1.1 < Nb film SEY < 1.7

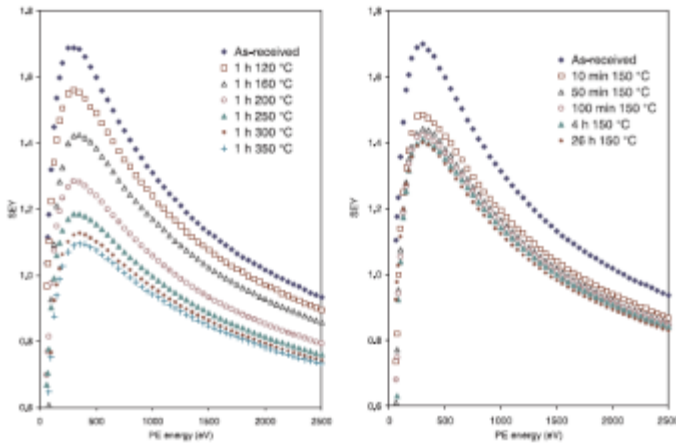
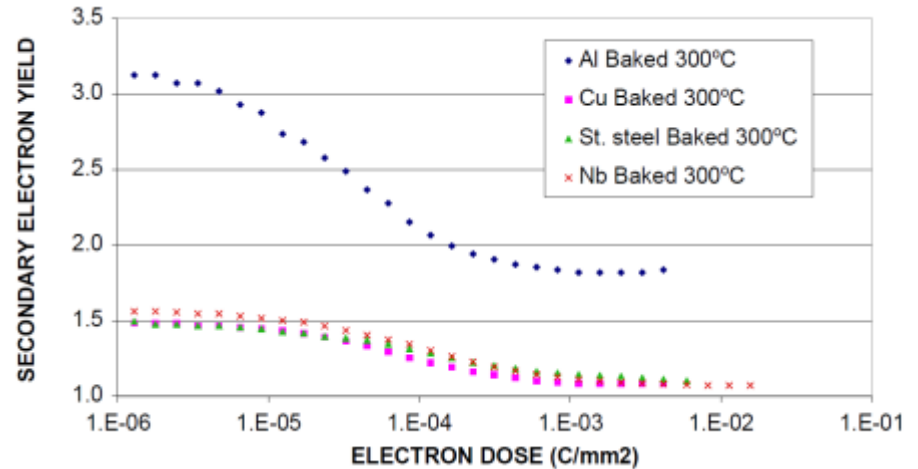


FIGURE 2 SEY vs PE energy of a Nb thin film as a function of heating temperature at 1 h heating time (left plot) and as a function of heating time at 150 °C (right plot)

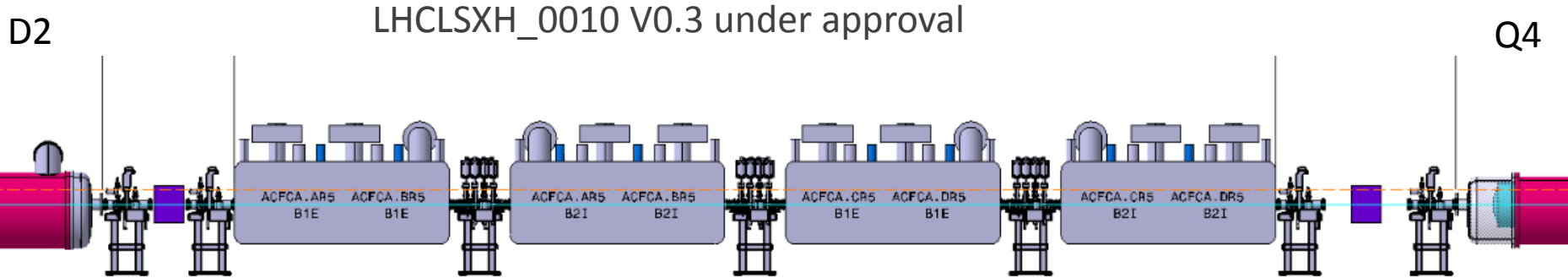
N. Hilleret *et al.*, Appl. Phys. A 79, 1085-1091 (2003)

Electron conditioning



N. Hilleret *et al.* EPAC 2000, Vienna, Austria

# Layout –D2-Q4

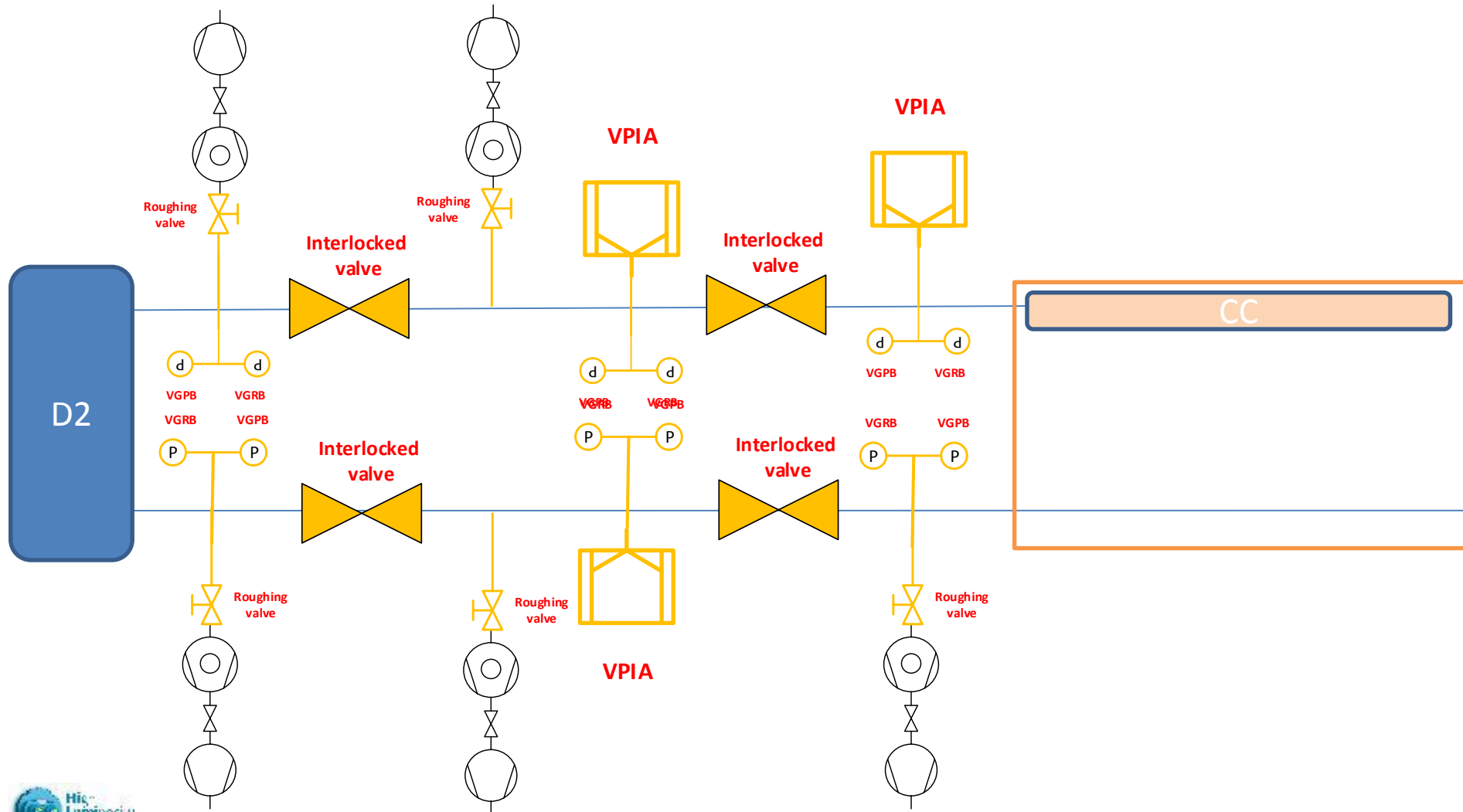


Courtesy B. Vasquez de Prada

- 5 x 4 sector valves between D2 and Q4 !
- 9 x 2 vacuum sectors !
- Room temperature sectors (except CC modules): bakeable and **NEG coated**
- 4 sectorised CC modules: unbaked, operating at **cryogenic temperature**
- 3 types of sector valves assemblies (VAB)

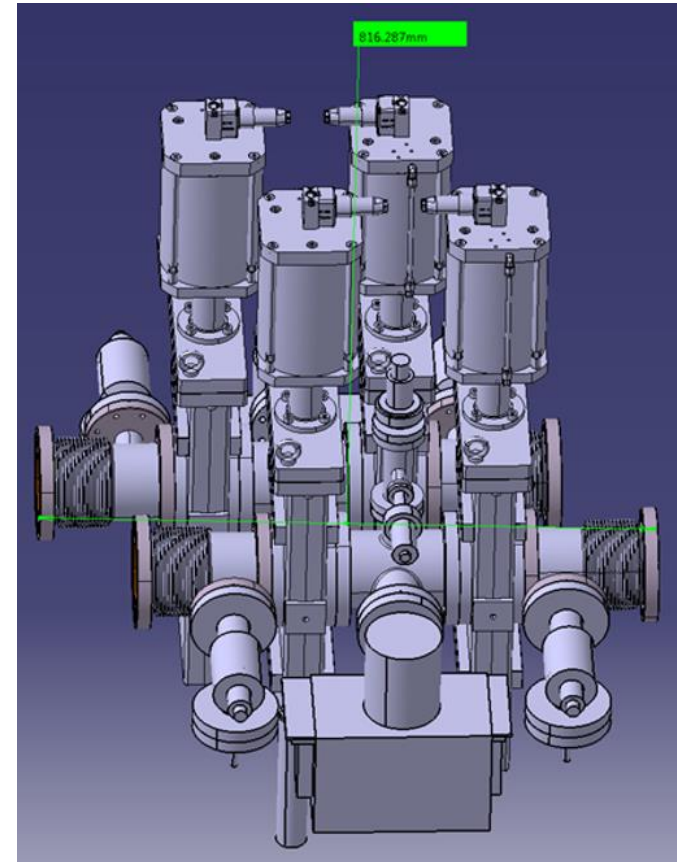
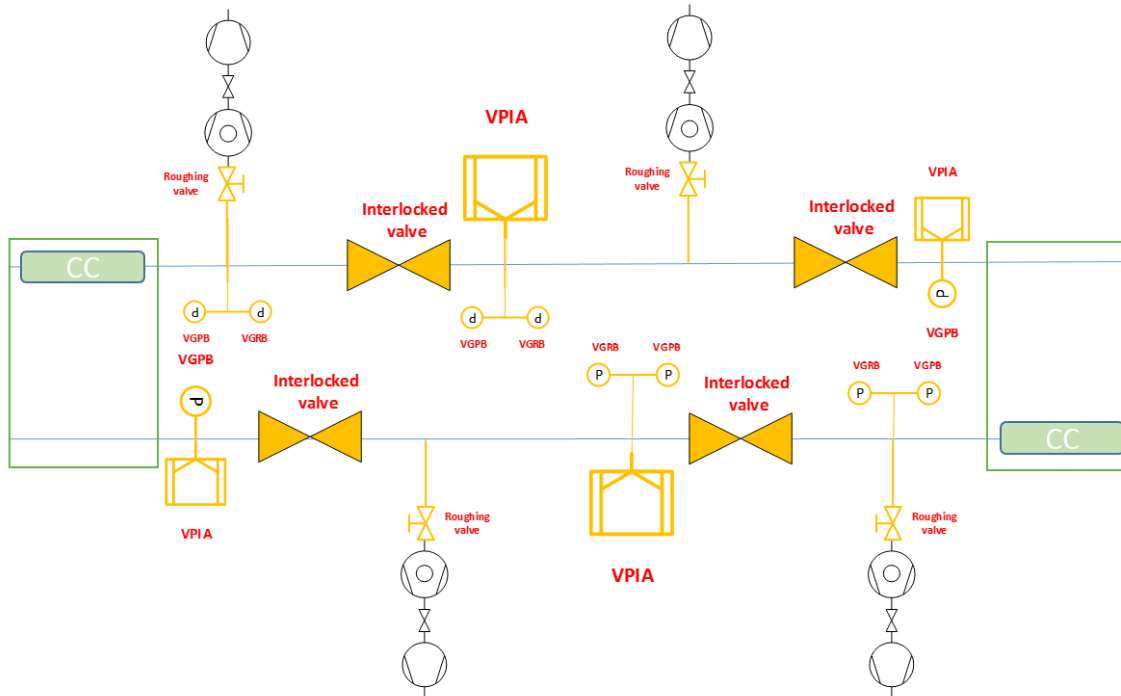
# D2 -1<sup>st</sup> Module Interconnection

- A new vacuum sector is needed following the shift of the module due to DSL link
- Detailed integration study is needed (sector valves side by side ?)



# Crab Cavities Modules Interconnection

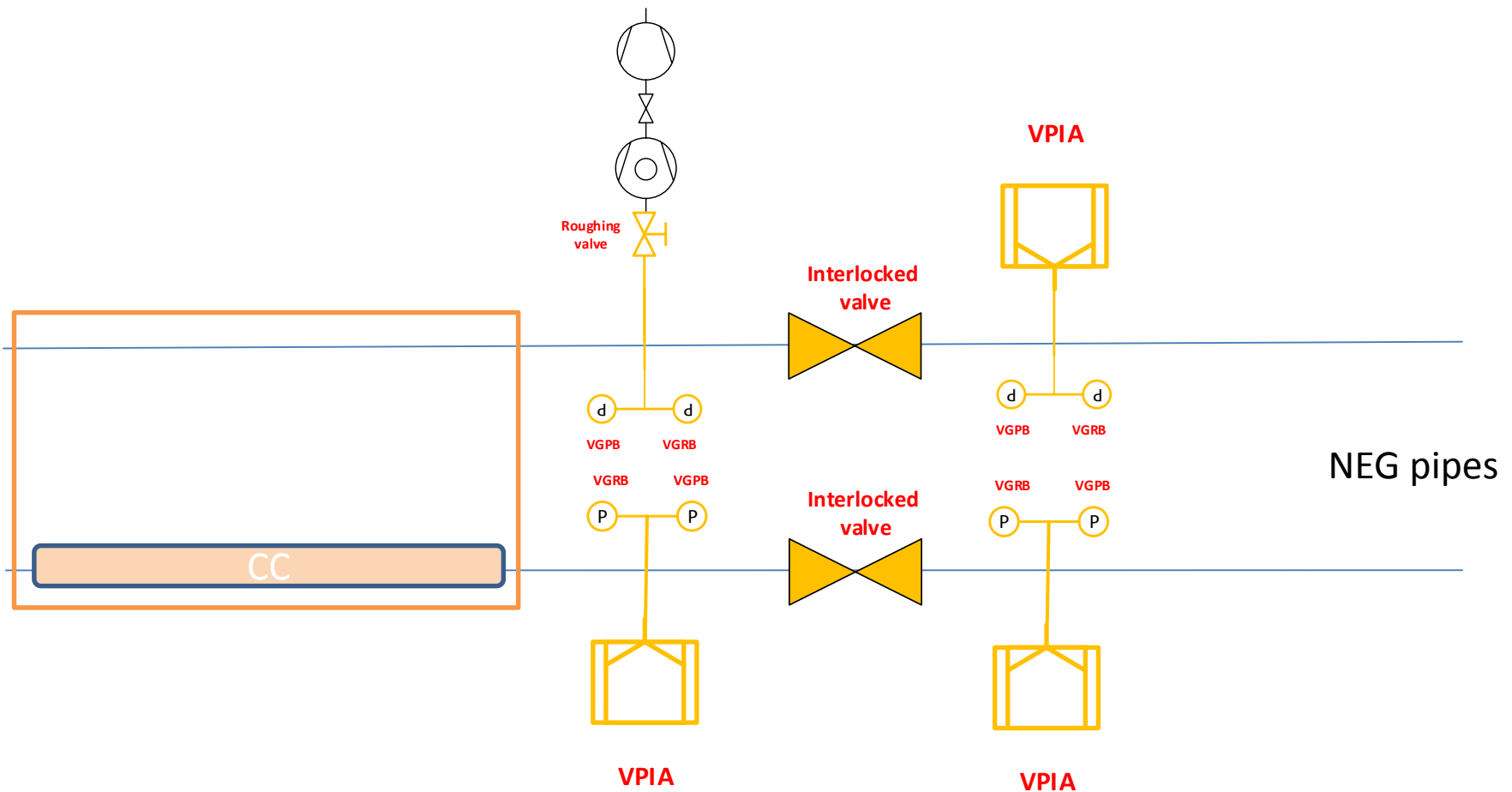
- Progress in the definition of the inter-module: allocated length **increased** to 820 mm



Courtesy R. F. Gomez

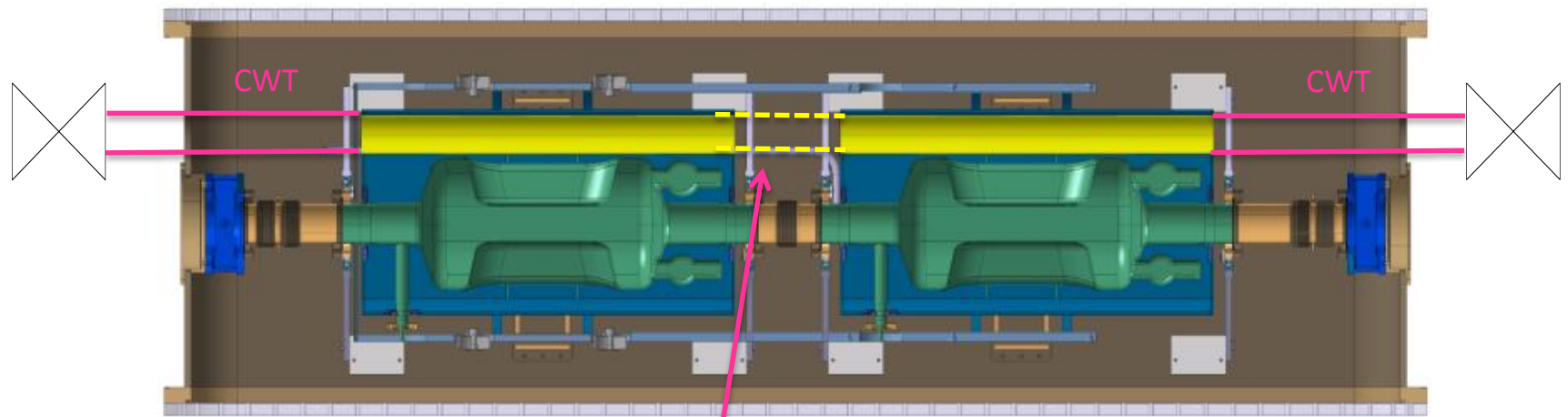
# 4<sup>th</sup> Module – NEG sector Interconnection

- Detailed integration study is needed (sector valves side by side ?)

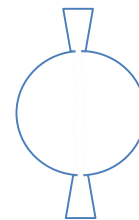


# Layout –D2-Q4: 2<sup>nd</sup> beam pipe

- The 2<sup>nd</sup> beam pipe is held at 2 K and has cold warm transitions (CWT) !
- Current material is Ti, diameter limited by space
- In LHC, maximum length without beam screen is < 1 m (to be revised for HL-LHC)
- Detailed studies are needed to comply with vacuum stability and pressure level (electron cloud !)



A beam screen between  
2 cryogenic pipes ?



A beam pipe with  
Antechamber ?

# 3. Summary

# Summary

- SPS layout with crab cavities:
  - The bypass layout has to be **frozen by end 2015** to start Y chamber design and procurement of main components
  - Detailed computation of pressure profile is needed to **optimise** the pumping scheme
  - An installation planning has to be drafted
- HL-LHC:
  - Crab cavities area **vacuum layout is** under definition
  - **Dedicated studies** are needed to:
    - understand the impact of electron cloud
    - design the 2<sup>nd</sup> (non-crabbed) beam pipe integrating a distributing pumping scheme





**High  
Luminosity  
LHC**

**Thank you for  
your attention**



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.





# High Luminosity LHC



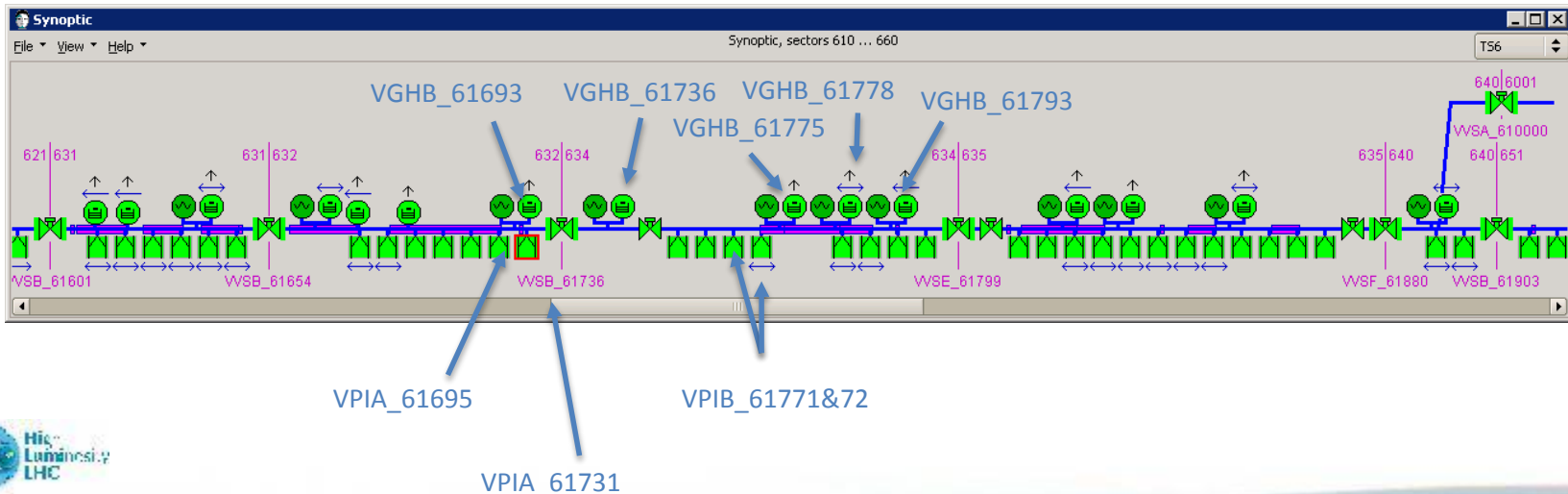
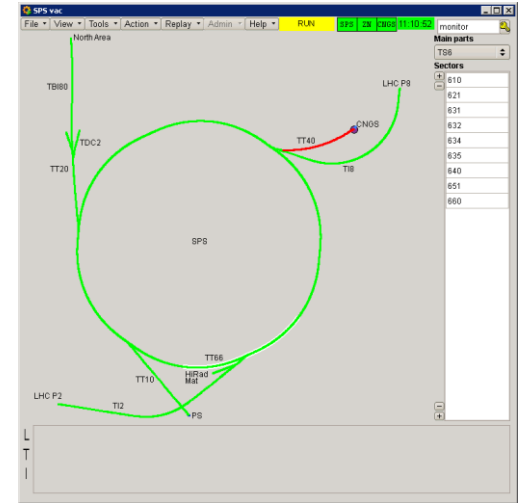
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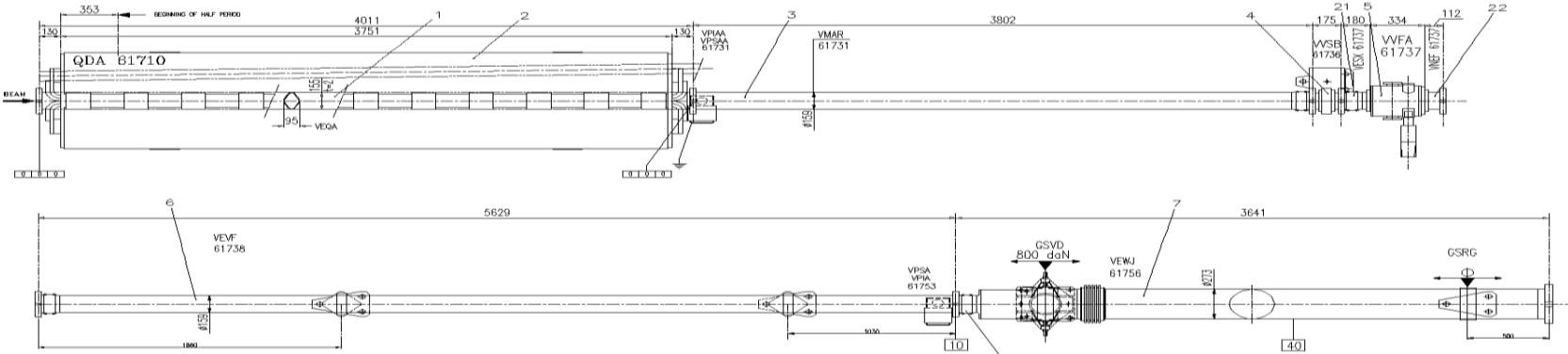
# Backup Slides

# Pressure profile

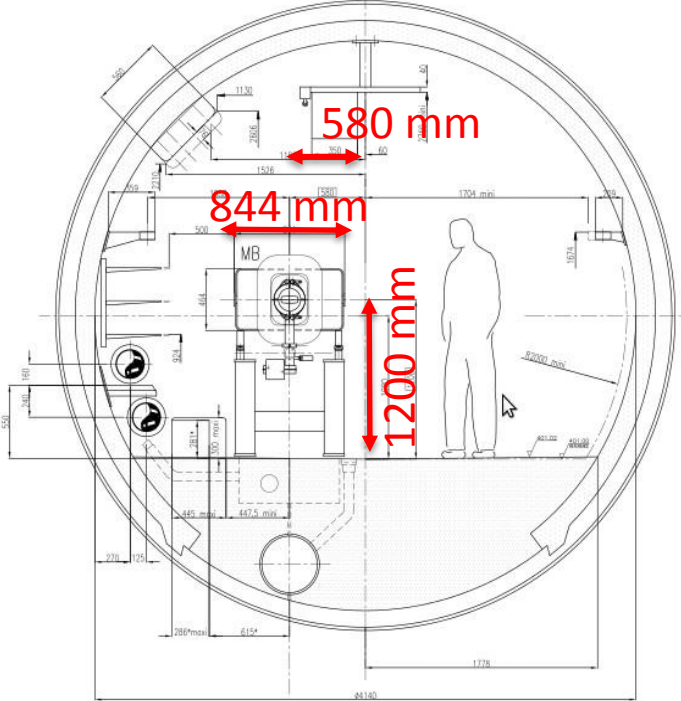
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# SPS QDA617 – QFA618



Standard SPS Cross Section



Present LSS6, Crab Zone

