CERN

Installation of fast shutter valves in IR4 during LS1

MPP, A.Lechner et al

LHC project report 1168 – P.Lebrun et al

"Closure of the sector valves (typical closure time ~1 s) at end of the continuous cryostat and on either side of cold stand-alone quadrupole Q6, triggered by the increase in pressure measured by Penning gauges and ion pumps in the warm sections, occurred early enough to avoid transport of debris in the warm sections and to protect the superconducting cavities at Point 4 from contamination."

"***5.2. Recommendations aiming at mitigation of the consequences of an electrical arc:***

5.2.4. The closure logic of the sector valves on the beam vacuum systems must be reviewed, with the aim of containing propagation of contamination due to in-rush of gas. The Task Force recommends that these sector valves be normally closed during powering of the sectors in absence of beam."

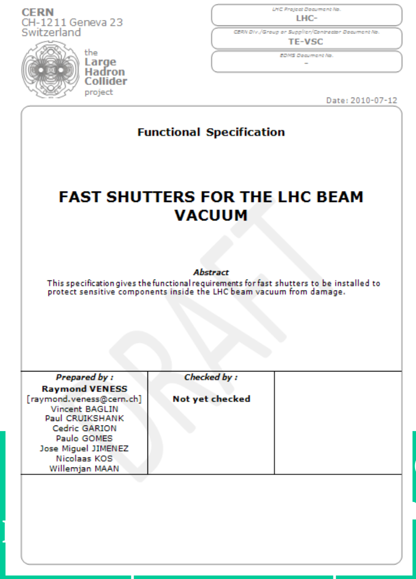
Means to limit the collateral damages in the beam vacuum chamber, Chamonix 2010 – J.M.Jimenez

Fast-closing valves

- Shall not be necessarily leak tight
- Shall close within 20-50 ms
- Shall use a low-Z material for the sealing plate
  - Transparent to the beam in case the valve closes while beams are still circulating
  - Faster since lighter
  - Spring or pyrotechnic actuator
- Requires reliable interlock signals + means to trigger their closure
  - Beam loss monitors
  - Pressure gauges or nQPS in the absence of circulating beams
- Needs a complete development and validation tests

Vacuum, much ado about nothing
Chamonix 2011 – V.Baglin

- Functional specification in work (R. Veness)



Activity	Area	Motivatio	Affected	otential ...nflict with splice consolidation
Install NEG and electron cloud pilot sectors	LSS (1,2,5,8)	Diagnostic instrumentation	EL	no
Inspection X-ray VM modules	LSS	Identify rf finger problems	Access restriction	yes
Exchange VM modules as required	LSS	Reduce impedance		no
Install fast shutters and modify pneumatic valves	LSS 4 + other LSS	Protect sensitive LHC equipment	EL, TE/MPE	no

Vacuum Upgrades (during LS1), Chamonix 2012 – J.M.Jimenez

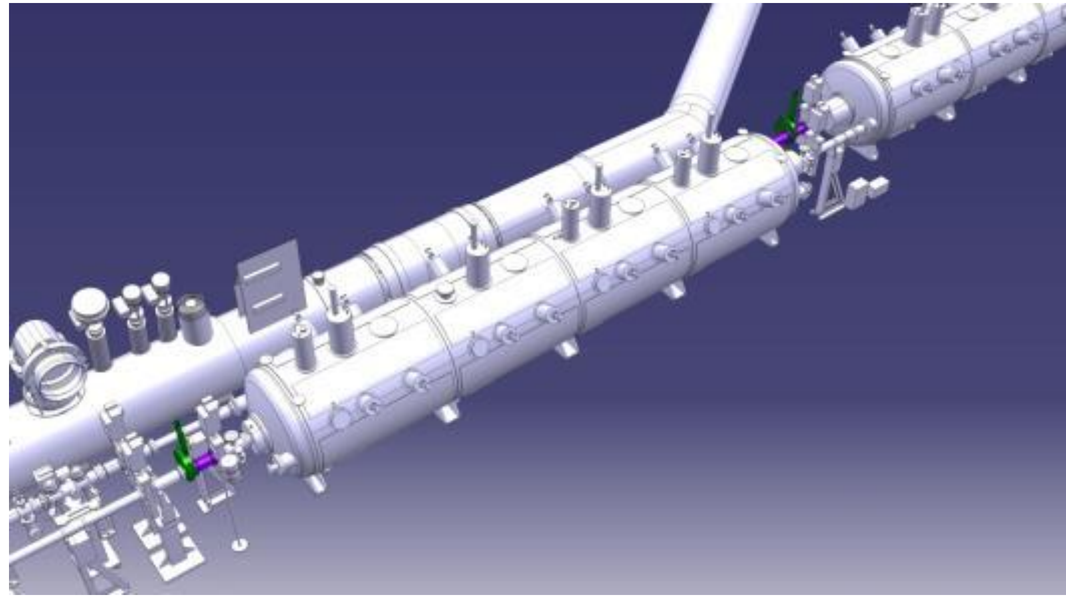
Only found in appendix, not in presentation….

Activity	Area	Motivation	Other Groups Affected	Co-activities with splice consolidation
Reconfiguration of permanent bake-out	IR3, IR7	Reduce the dose received by personnel		No
Install new cabling & instrumentation	LSS	Improve controls logic for sector valves – Impact of NEG coatings	EL	No
Install fast shutters	LSS 4 + MKIs	Protect sensitive LHC equipment (studies still ongoing)	EL, ABT, RF	No

Vincent BAGLIN

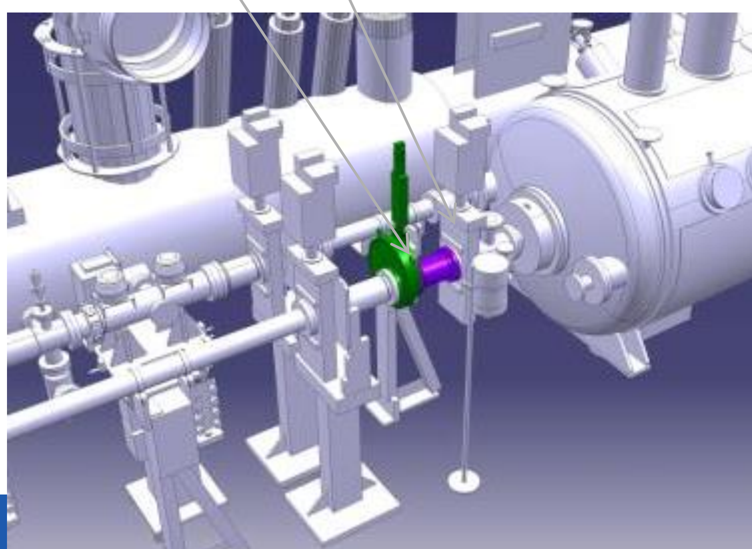
Layout

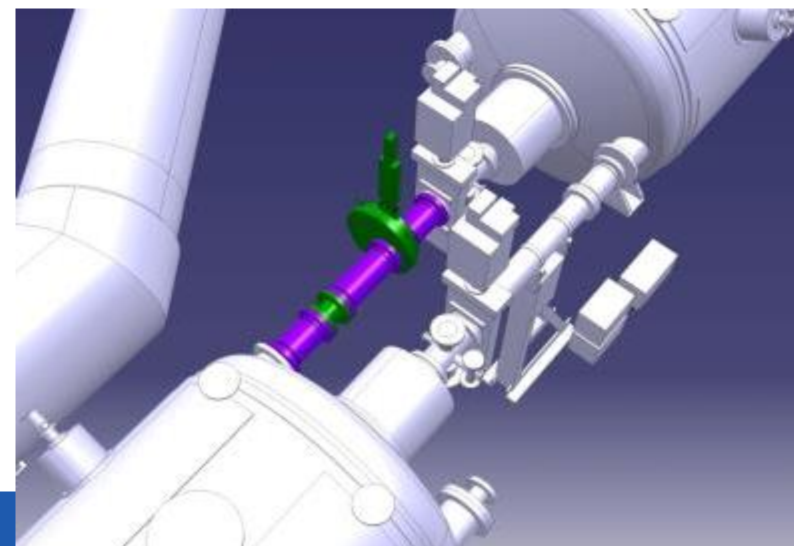
C5L4:



Sector valves

Fast valves





Mechanics

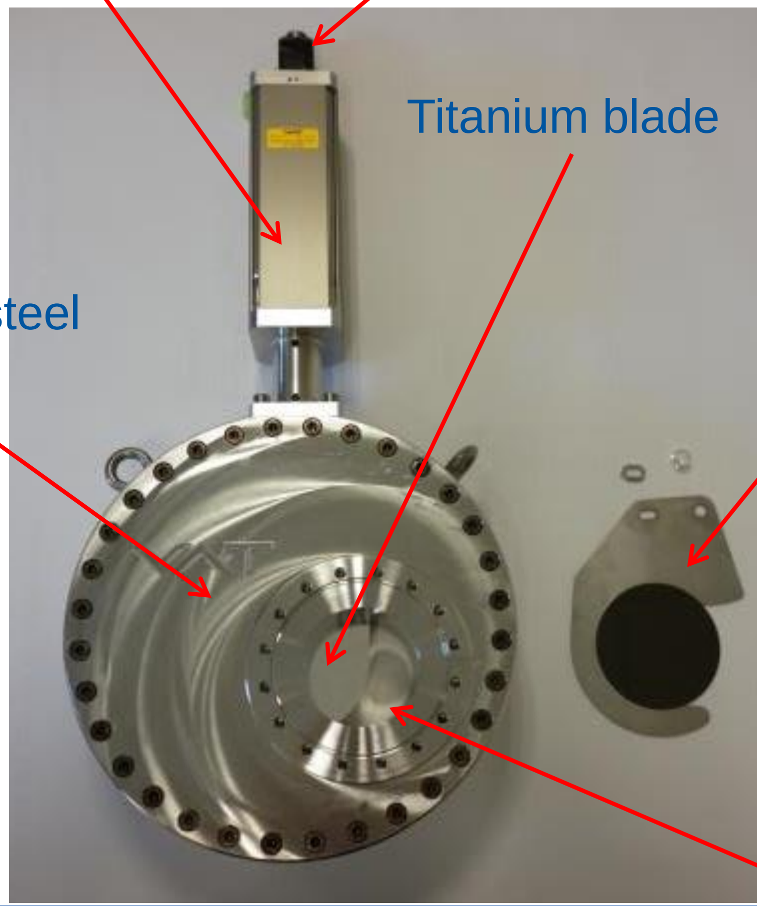
Connector

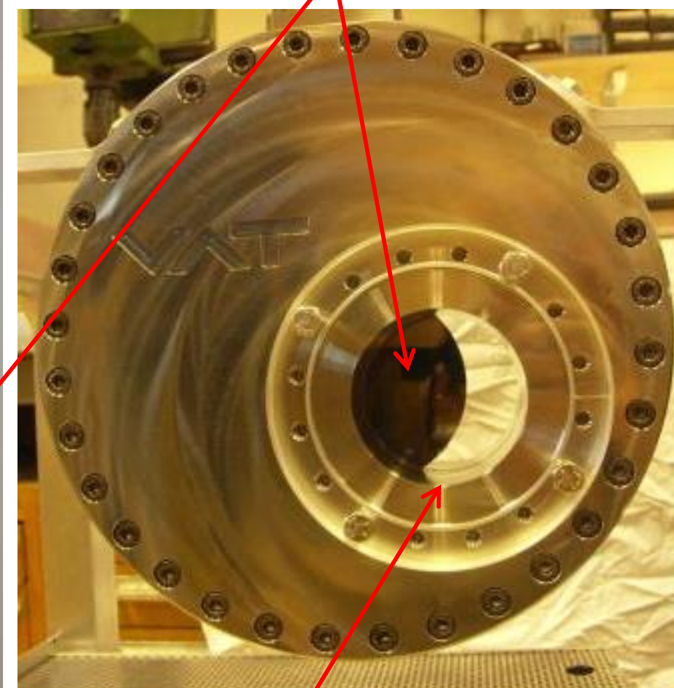
Pneumatic actuator

Titanium/glassy carbon blade

Titanium blade

Stainless steel body





Aperture 80 mm

Time closure: 16 ms (manufacturer data)

EDMS doc 1093346 – R.Veness

The fast shutter shall be triggered if any of the following threshold levels are measured:

Pressure Rise: The shutter control system shall monitor the following instruments, W,X,Y,Z. If any 2 of these instruments show a pressure of more than X mbar for a duration of more than Y mSec, then a trigger shall be generated.

QPS signal: If a signal X is received from the quench protection system for a duration of more than Y mSec then a trigger shall be generated.

Shutter Transparency:

The object which moves across the beam (shutter) shall represent no more than X radiation lengths to minimise damage due to a circulating beam.

Controller

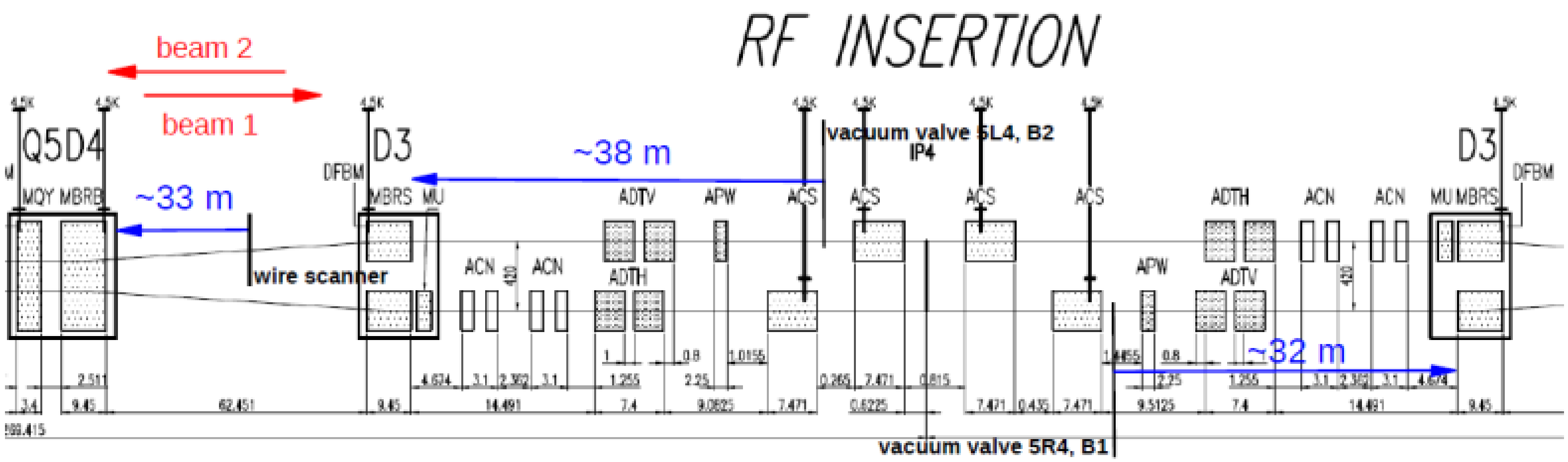
A control unit which ensures the proper sequencing for the operation of the shutter shall be provided. This unit shall be used both as the manual control unit and as the interface to the main control system.

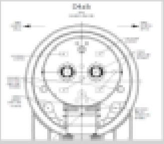
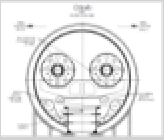
It shall be possible to control the shutter locally and remotely.

Damage potential for downstream superconducting magnets (D3)

Strategy:

- To estimate peak energy density in D3 separation dipoles, past FLUKA simulations of wire scanner quench test are considered
- In both cases, we have an almost point-like source of secondary particles (beam impact on obstacle)
- Both cases involve similar distances (see illustration) and magnet types (same coils, same magnetic length and field strength), however different beam energies (wire scanner test was done at 3.5 TeV)



	Wire scanner test	Fast vacuum valves
Material/thickness	0.03 mm diameter carbon fibre (2 g/cm^3)	2 mm glassy carbon (1.42 g/cm^3) or titanium (4.54 g/cm^3) blade
Downstream magnet	MBRB (~33 m from wire scanner) 	MBRS (~32/38 m from valve) 
Beam momentum	3.5 TeV/c	7 TeV/c

Damage potential for downstream superconducting magnets (D3)

Wire scanner simulation:

- Peak dose (and energy density) in MBRB coils per inelastic interaction of a proton in the wire: 1.48×10^{-12} J/g (=9.1×10^{-12} J/cm^3)

Titanium blade:

- Inelastic scattering length (@7TeV) = 25.05 cm
- Interaction probability per particle impacting = 0.2 cm / 25.05 cm = 0.00798
- Estimated peak dose (and energy density) in MBRS coil (per bunch)
  = 1.48×10^{-12} J/g (=wire scanner result per inel. interaction)
  · 2 (=energy factor from 3.5 to 7 TeV)
  · 1.15×10^{11} (=nominal bunch intensity)
  · 0.00798 (=interaction probability)
  = 2.7 mJ/g (=16.7 mJ/cm^3)

Glassy carbon blade:

- Inelastic scattering length (@7TeV) = 59.30 cm
- Interaction probability per particle impacting = 0.2 cm / 59.30 cm = 0.00337
- Estimated peak dose (and energy density) in MBRS coil (per bunch)
  = 1.48×10^{-12} J/g (=wire scanner result per inel. interaction)
  · 2 (=energy factor from 3.5 to 7 TeV)
  · 1.15×10^{11} (=nominal bunch intensity)
  · 0.00337 (=interaction probability)
  = 1.1 mJ/g (=7.0 mJ/cm^3)

Remark:

- The above values are only an estimate and one should clearly account for a safety factor
- In particular, the bold assumption of a factor 2 increase of the energy density from 3.5 to 7 TeV should be considered with caution

Damage potential:

- Evidently, the actual energy density in D3 coils depends on the number of inelastic interactions in the blade
- Determining the number of interactions is not trivial and requires accurate simulations accounting for different effects (time evolution):
  - In case of titanium, of the order of 100 bunches[a] (impacting on the same spot) are sufficient to reach melting temperature in the blade in the proximity of the beam center (probably explosive spread of material and hence less material to interact with for following bunches)
  - On the other hand, the blade moves and impact locations are hence diluted (assuming a speed of 10 m/s, the blade moves by about 25μm during the impact of 100 bunches, meaning that dilution is rather "slow")
- Instantaneous damage limit for superconducting elements is specified as 87 J/cm^3 (if all bunches over 1 turn would have the chance to interact in 2 mm of titanium, we would reach - according to the above estimate - about half of this value ...)

[a] In adiabatic limit, and assuming a beam size (@7TeV) of $200 \times 250 \mu m^2$ (at position of valve 5L2,B2, ϵ_n=2μm)

MPP proposal?!

Today in a situation where mechanical solution is close to finalization, developments for the interlocking and controls part of the device have not yet started and are (following a discussion with P.Gomes) not foreseen and to be expected for the end of LS1.

In absence of a full integration and validation of the system (along with the required dependability analysis) impact on machine protection is – if any – detrimental, hence we would propose you to:

-) Perform needed preparations during LS1 for a later installation of the device, however not to install the devices at present (even not in locked out and disconnected state)
-) Re-assess the requirements for such fast vacuum valves in view of the performed LS1 consolidations and additional protection systems (nQPS)
-) Start and finalise the design of the controls, interlocking and triggering part along with the provision of a dependability analysis of the chosen solution