Proposed layout and mechanics

C. Garion on behalf of TE/VSC

Outline:

- Motivation and requirements
- Layout
- Mechanics
- Interfaces

Motivation

During an unexpected gas inrush in a vacuum chamber, a pressure wave develops with a velocity of ~ 1000 m/s for room temperature system or 35 m/s for a cold system (this value is based on observations done during the 3-4 incident). The pressure wave carries small particles [P. Lebrun, LHC project report 1168] that can compromise the functioning of sensitive machine systems.

After 3-4 incident, it has been proposed to install fast shutter to protect sensitive system such as the RF cavities.

Reference:

1. J.M. Jimenez: Means to limit the collateral damages in the beam vacuum chamber, Chamonix 2010
2. V. Baglin, VACUUM – MUCH ADO ABOUT NOTHING, Chamonix 2011
3. J.M. Jimenez, lhc vacuum upgrade during ls1, Chamonix 2012
4. R. Veness et al., Development of fast shutters for the LHC, EDMS 1093346

Requirements

Main requirements for the valve:

- Fast closure in the 20 ms range;
- Bake able;
- Minimum aperture: 80 mm;
- Local/remote control;
- Small and smooth aperture changes;

Main requirements for the blade:

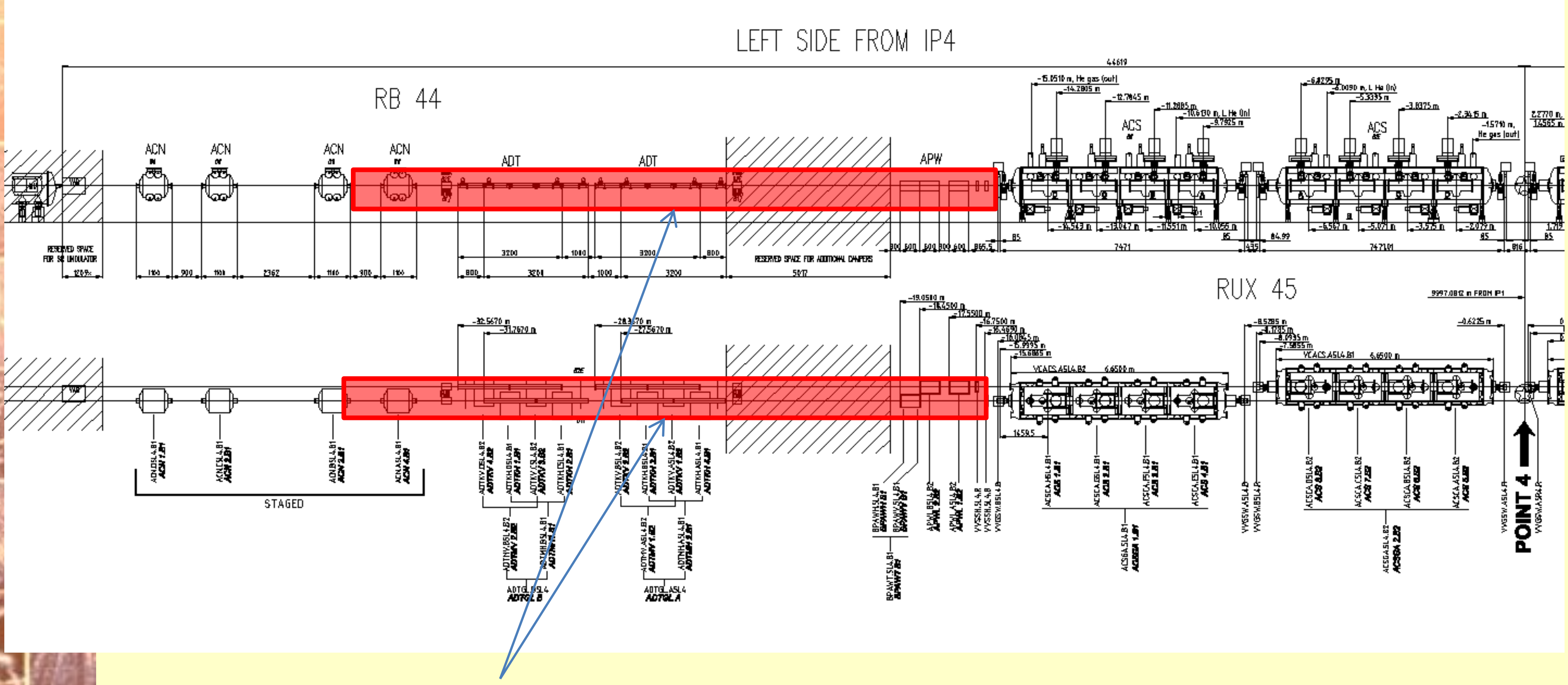
- Fast closure in the 20 ms range;
- Dust free to not contaminate sensitive adjacent elements;
- Vacuum compatibility and leak tightness (in the range 1 mbar.l/s).
- Transparency and high fusion temperature in case of closure with beam;

Layout

Minimal non-protected length due to time response of the fast shutter:

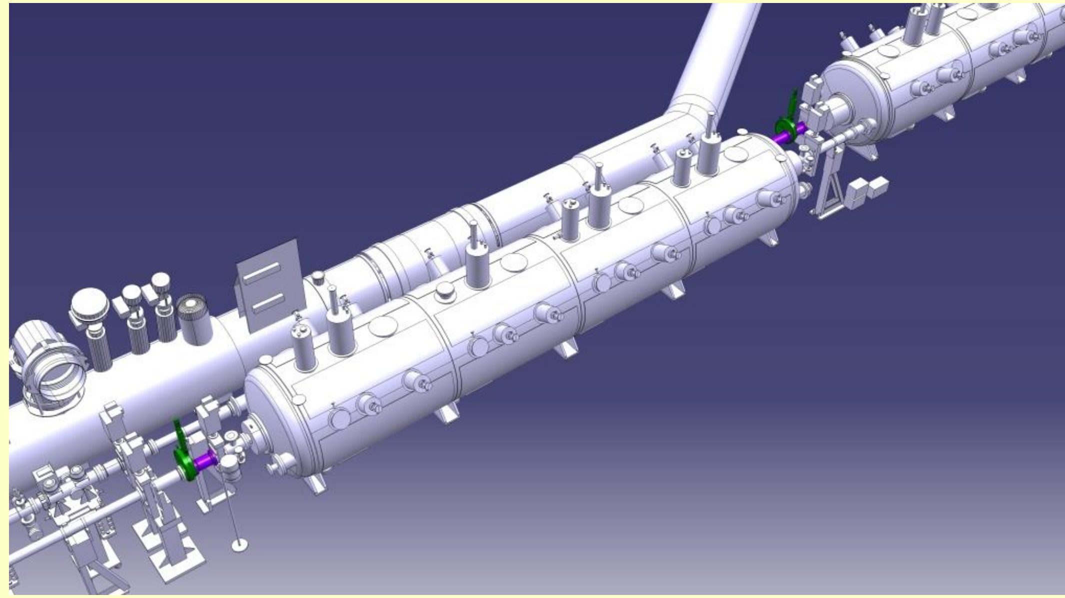
- ~ 20 m, if room temperature sector,
- 0.7 m, if cold temperature sector

→ Place the fast shutter as close as possible to the RF cavities



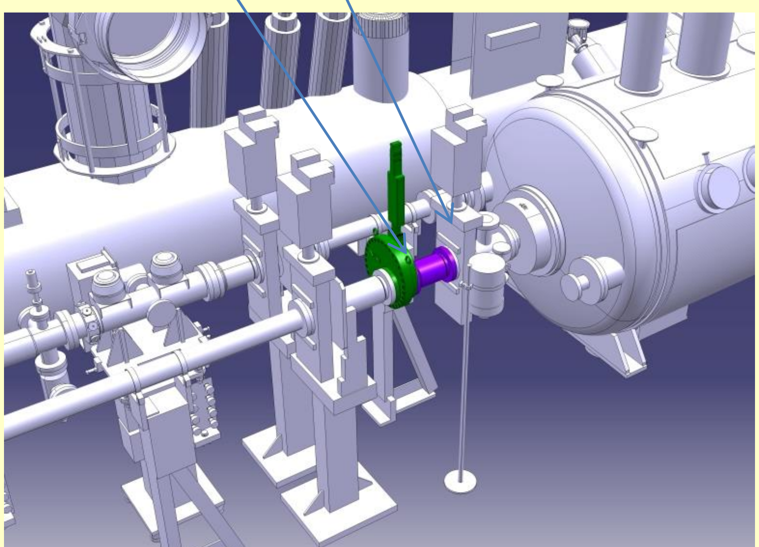
Layout

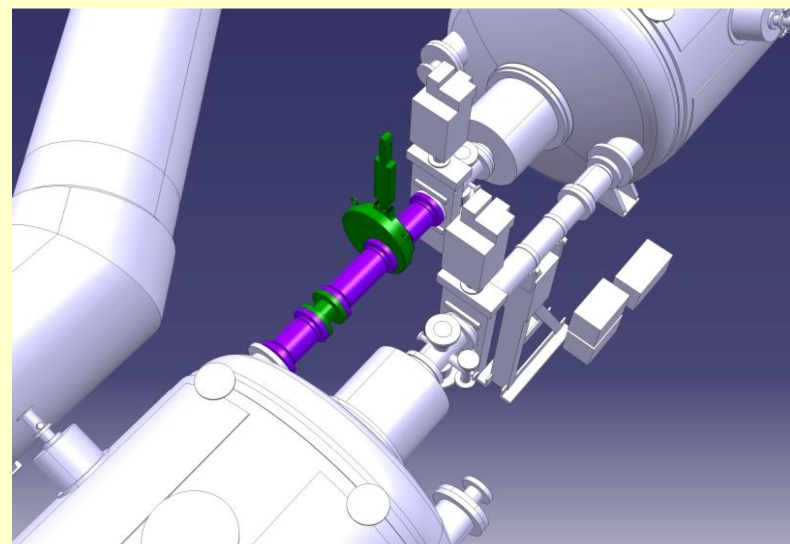
C5L4:



Sector valves

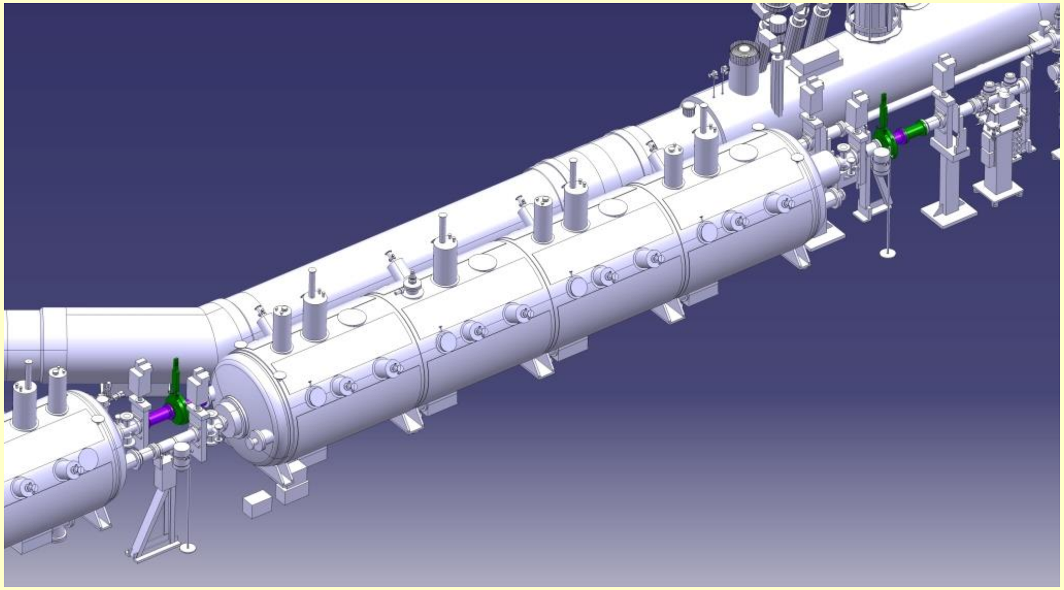
Fast valves

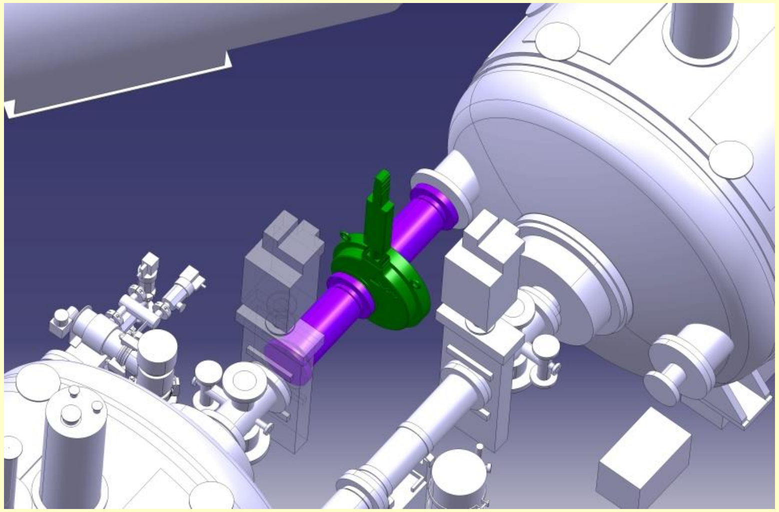


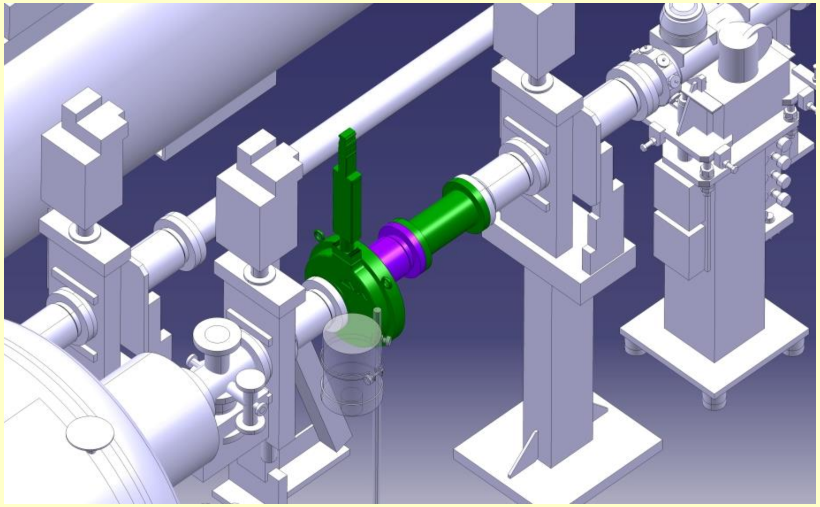


Layout

C5R4:







Mechanics

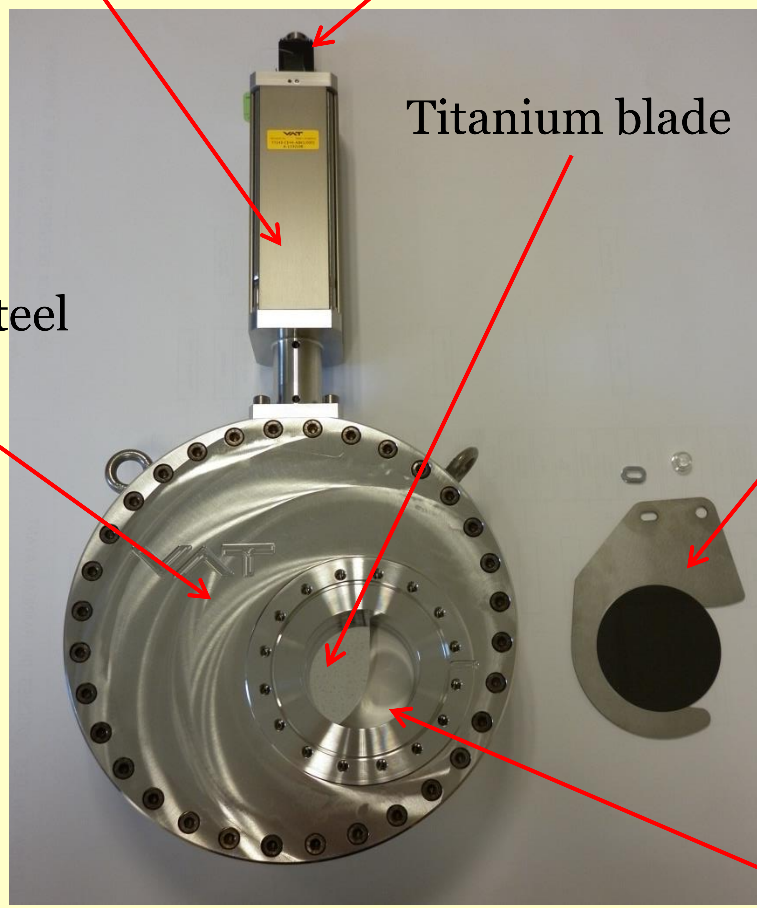
Connector

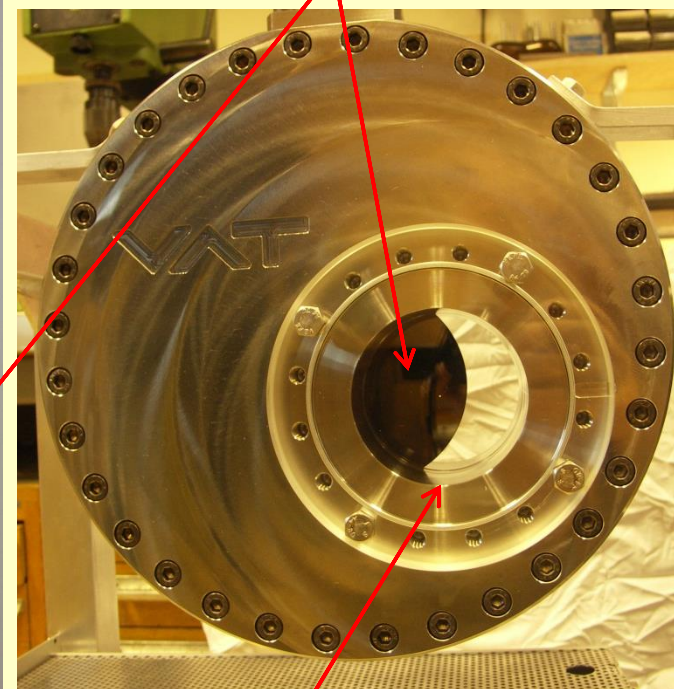
Pneumatic actuator

Titanium/glassy carbon blade

Titanium blade

Stainless steel body



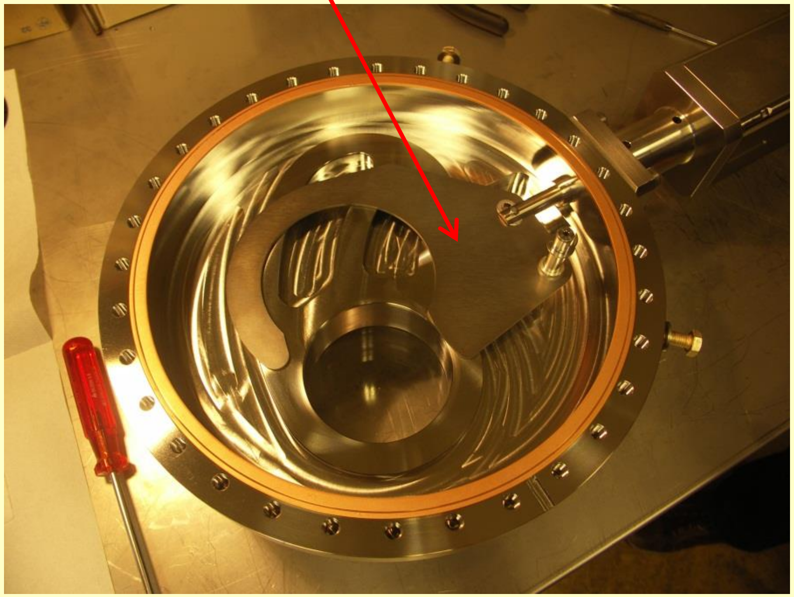


Aperture 80 mm

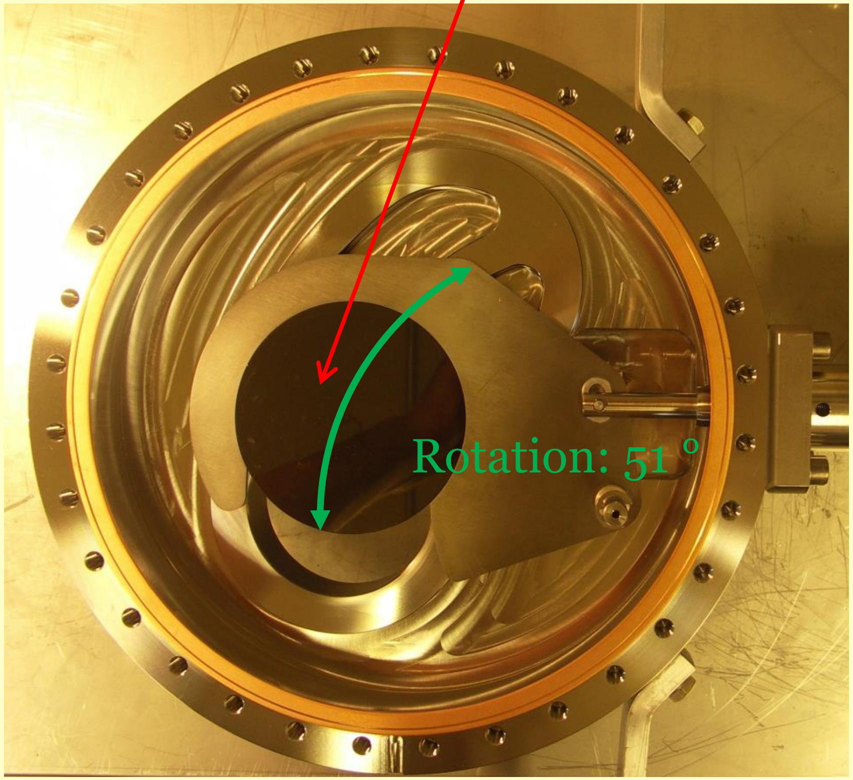
Time closure: 16 ms (manufacturer data)

Mechanics

Disc support:
- Titanium
- 2 mm thick



Disc :
- Titanium or glassy carbon
- 100 mm in diameter
- 2 mm thick



The disc and its support are guided between two planes.

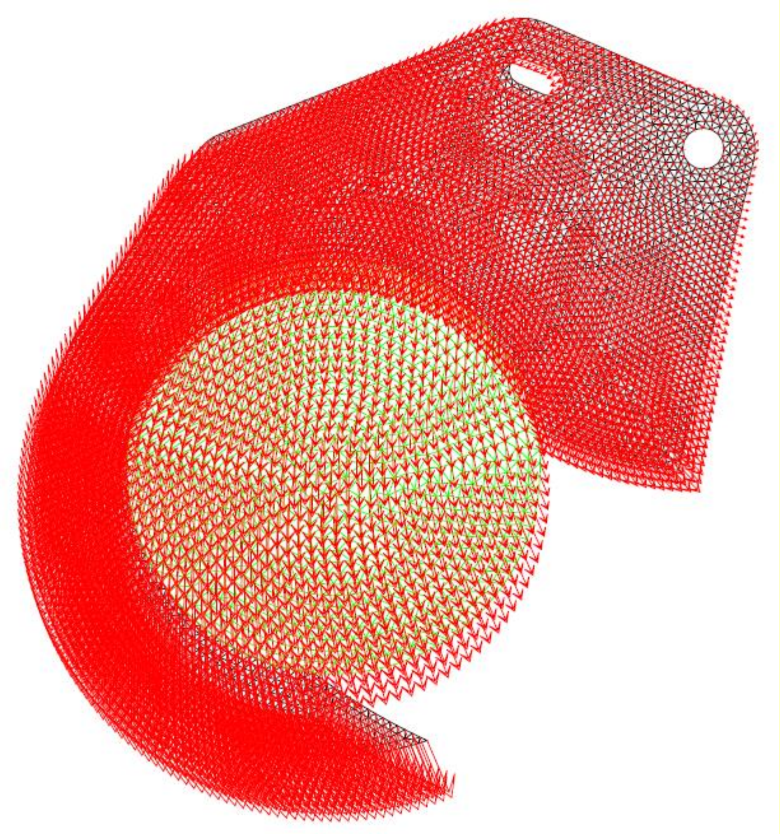
Material properties

	Titanium Grade 5	Glassy carbon Grade G
Radiation length [cm]	3.7	30
Density [g/cm³]	4.5	1.42
Young modulus [GPa]	110	35
Yield strength [MPa]	910	-
Ultimate strength [MPa]	1000	260 (flexural) 460 (compression)
Toughness [MPa.m$^{1/2}$]	90-100	1
Thermal expansion [10^{-6}/K]	9	3-4
Melting temperature [°C]	1650	> 3000
Thermal conductivity [W/K/m]	22	6.3
Heat capacity [J/kg/K]	520	810

Dynamics

Dynamic specific forces:

$$\vec{f} = \rho\omega^2 R\overrightarrow{e_r} - \rho\frac{d\omega}{dt}R\overrightarrow{e_\theta}$$



The analysis has been done for a titanium or glassy carbon disc in the acceleration of deceleration phases (based on assumptions for the motion parameters).

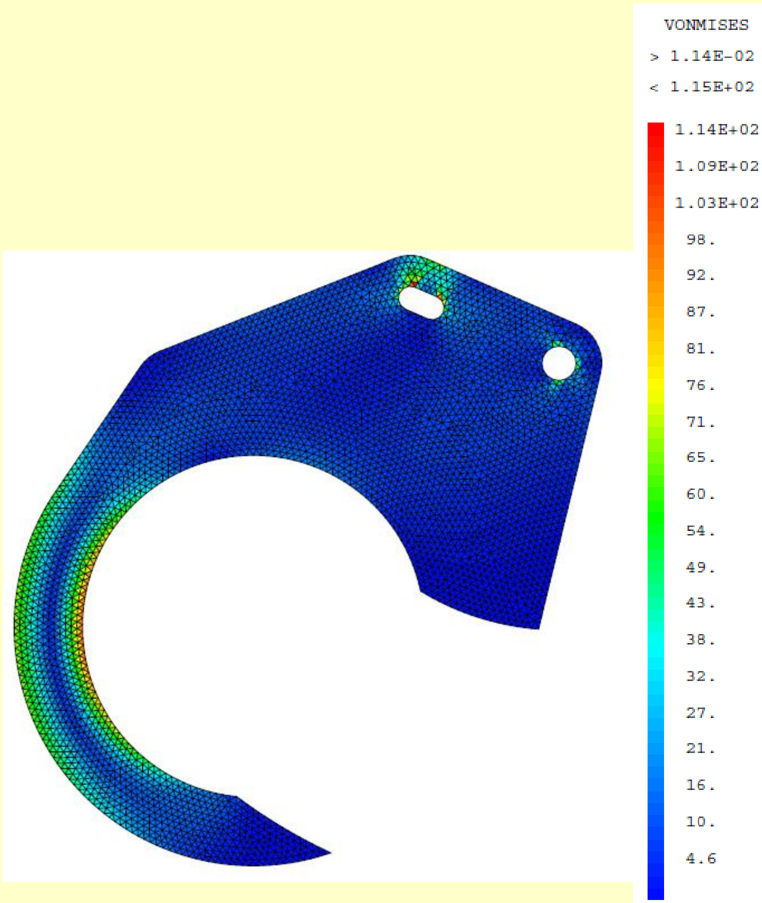
W ~ 180 rad/s

Dw/dt ~ 36000 rad/s2

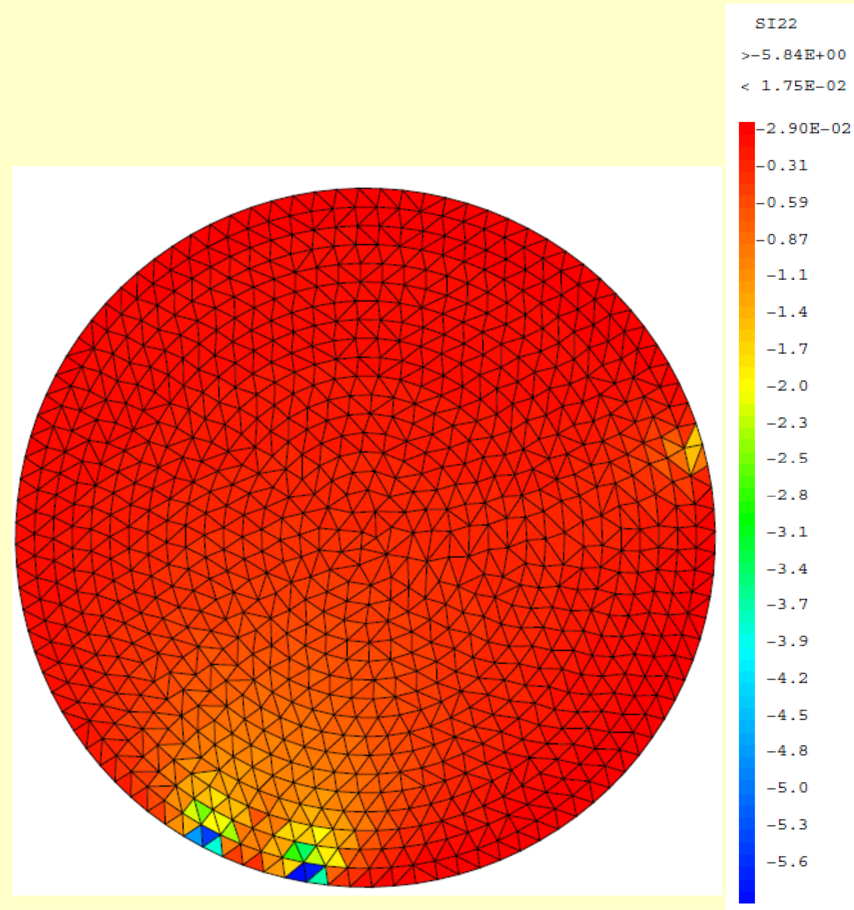
$\gamma_r \sim \gamma_\theta \sim 4500\ m/s^2$

Dynamics

Maximum stresses:



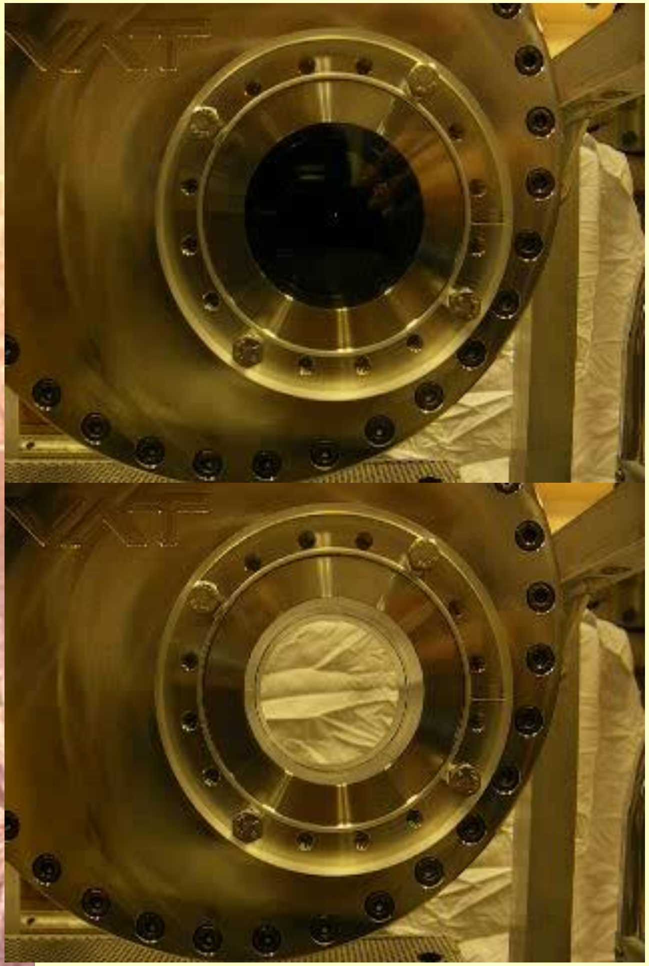
Titanium support with a titanium disc in deceleration:
σ ~ 100 MPa



Glassy carbon disc in deceleration:
σ ~ 6 MPa

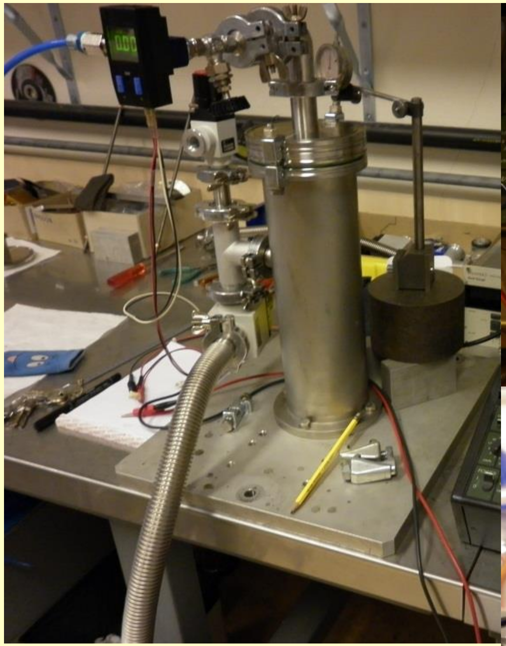
Mechanical tests

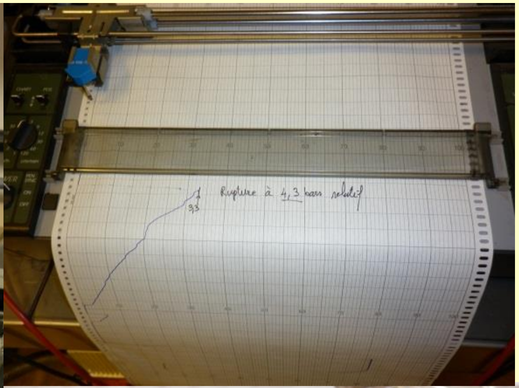
Fatigue tests:
opening/closure cycles

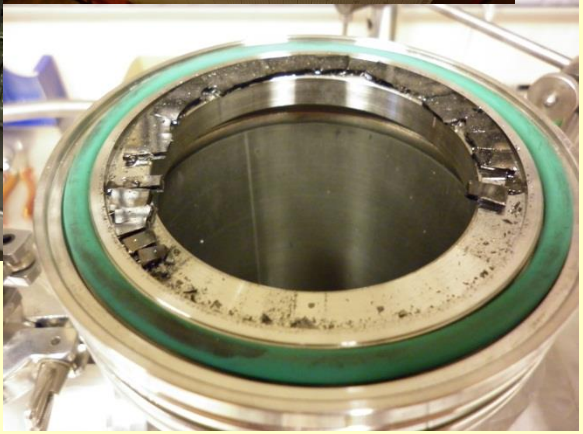


> 200 cycles

Rupture tests (on glassy carbon)







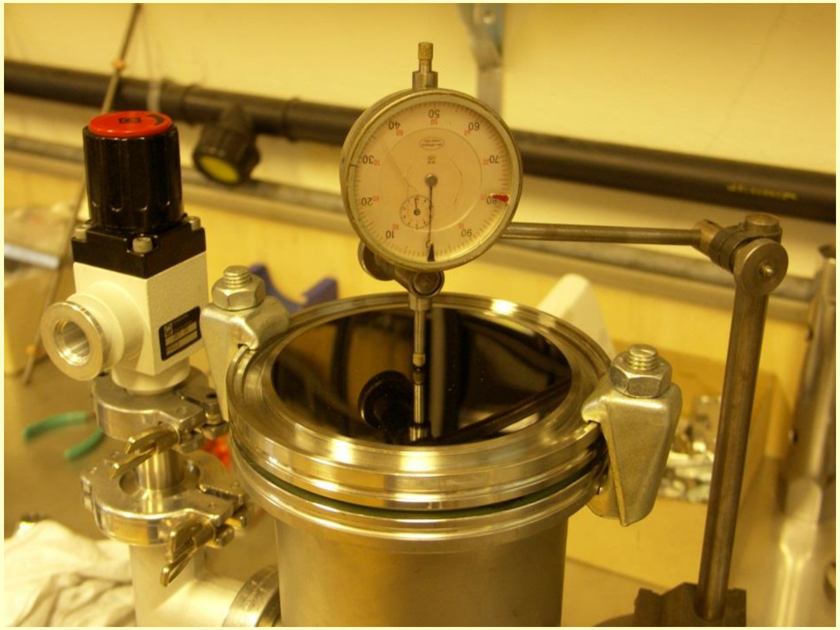
Pressure to failure: 4.3 bars (relative)

Leak tests

Deflection under vacuum ~ 1.3 mm.

Leak rate in the range 1-10^{-3} mbar.l/s, depending on the surface state of the glassy carbon disc.

No influence of the fillet radius (~0.2, 1, 1.5, 2, 2.5).

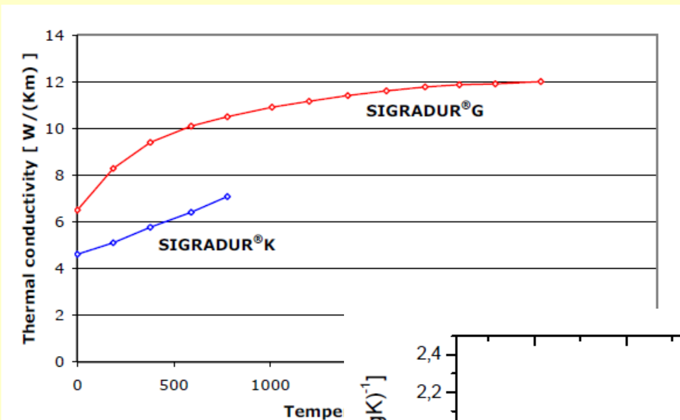


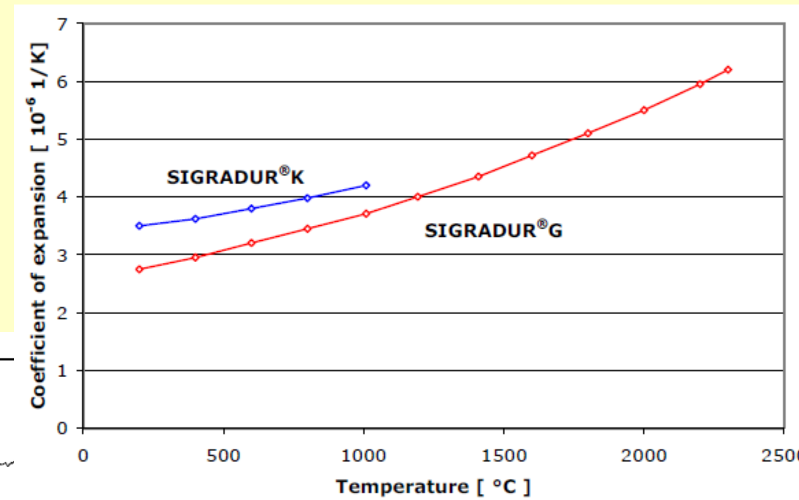
Thermo-mechanical study

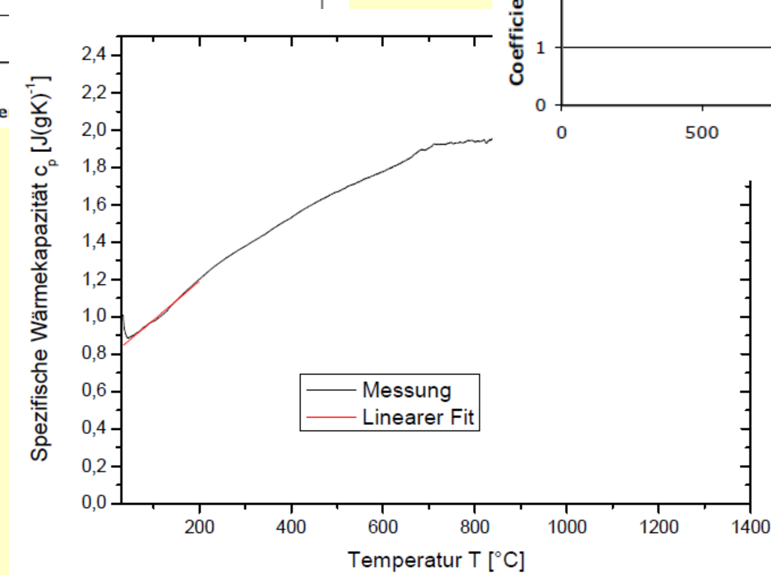
Preliminary study with beam in

Assumptions:

- Temperature dependent thermo-mechanical properties of the glassy carbon (thermal conductivity, specific heat capacity, thermal expansion)





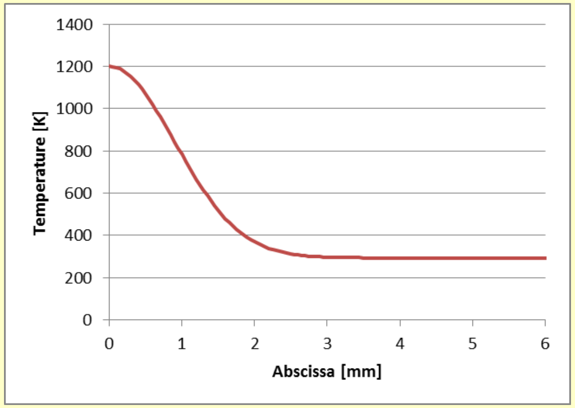


Thermo-mechanical study

Preliminary study with beam in

Rough and conservatives assumptions:

- Temperature profile (→heat deposition), similar to the dump window (in C/C) without beam dilution.



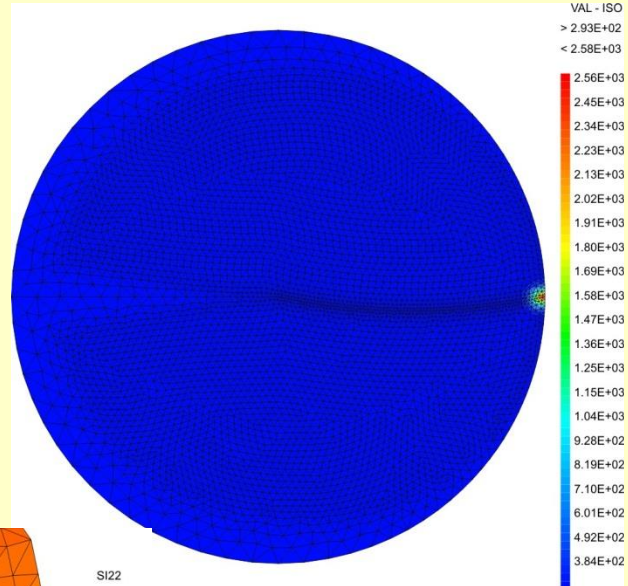
σ=0.9 mm

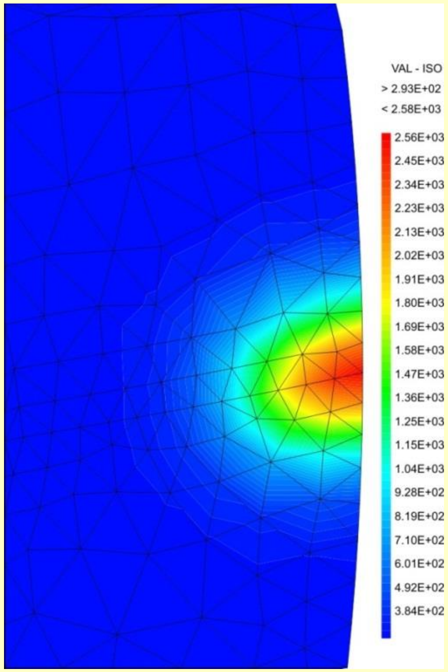
- The disc reaches the aperture center after a rotation of 25 ° with a constant rotation speed (80 rad/s) and reaches the BLM threshold.
- The delay for the extraction of the full beam is 320 μs and split in:
  - Time for the BLM to initiate the trigger: 1 turn: 90 μs (from the position of the disc tangent to the aperture center),
  - Travel time from the BLM to the beam dump system: 50 μs,
  - Synchronisation of the extraction kicker: 1 turn: 90 μs,
  - Extraction of the beam: 1 turn: 90 μs,

Thermo-mechanical study

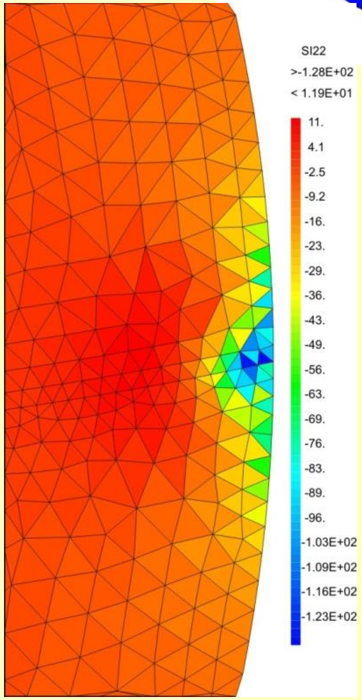
Temperature profile:

Maximum temperature ~ 2580 K





Stress level:



Maximum stresses:

- 128 MPa in compression
- 12 MPa in tension

Hints for titanium

Heat deposition in titanium ~ 7.9 times the heat deposition in carbon.

Thermal inertia for titanium ~ 2 thermal inertia for carbon

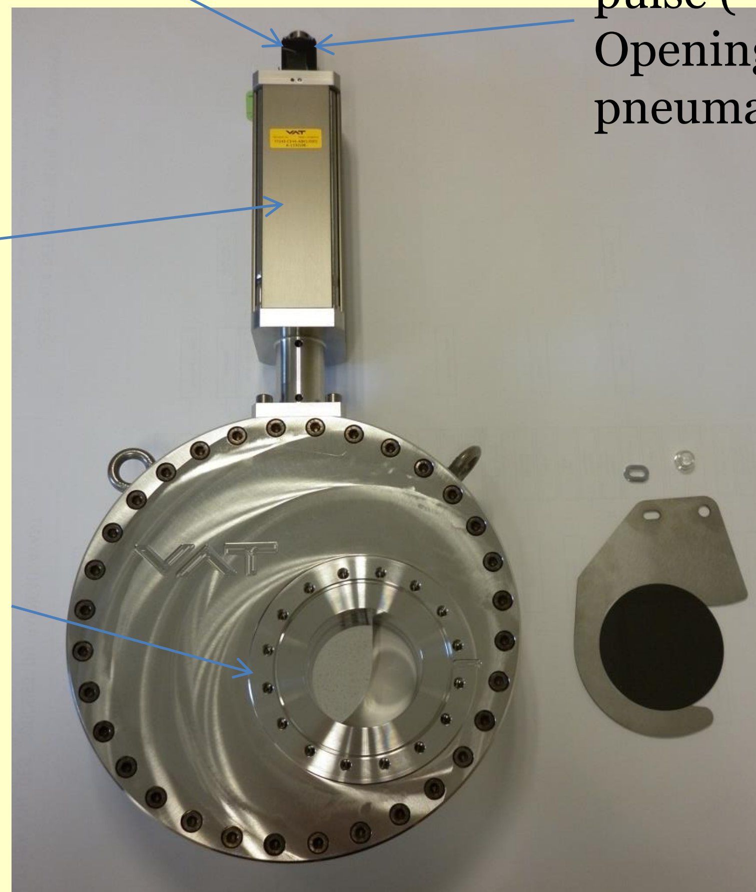
→ Temperature increase for titanium ~ 4 times for carbon!!

Interface

Position indicator: Single Switch (Open, Closed)

Closure (trigger): tension pulse (~110V)
Opening (command): 24V pneumatic distributor

Fast actuation source: compressed air charge



DN 100 CF flange

Next steps

Measurements of the closure motion parameters. Tests foreseen early 2013.

If required, study of titanium disc based on realistic heat deposition (heat field, time).

Control to be finalized.