Vacuum system in the main Linacs

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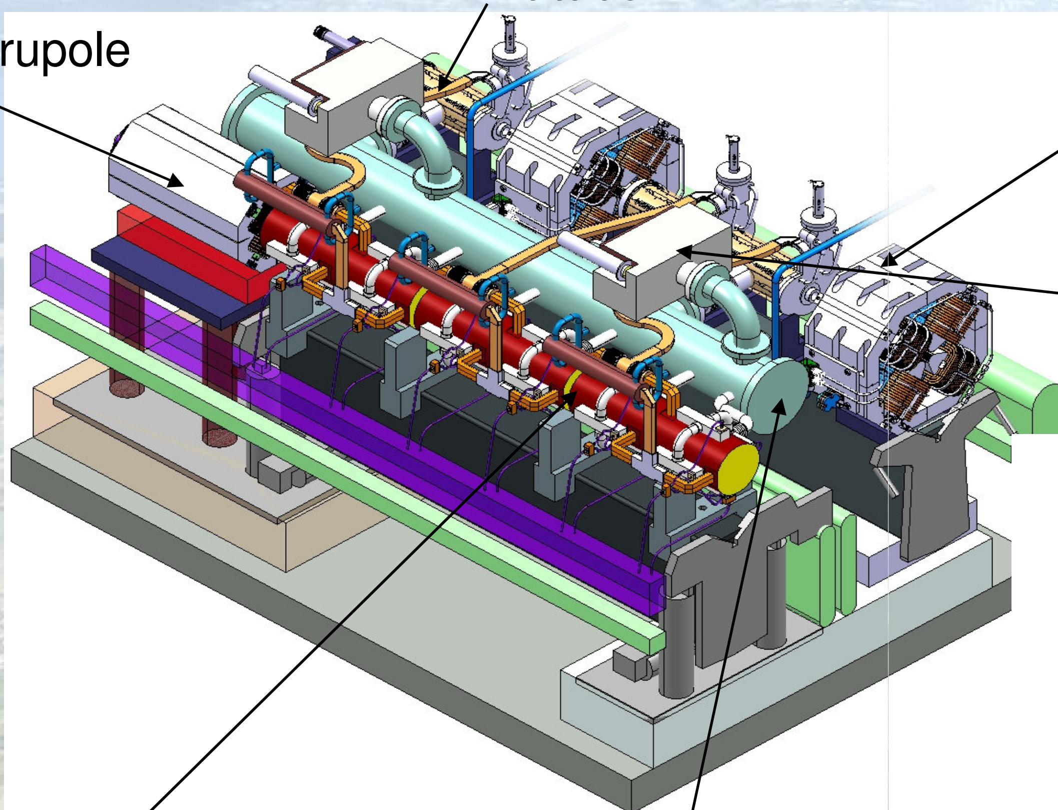
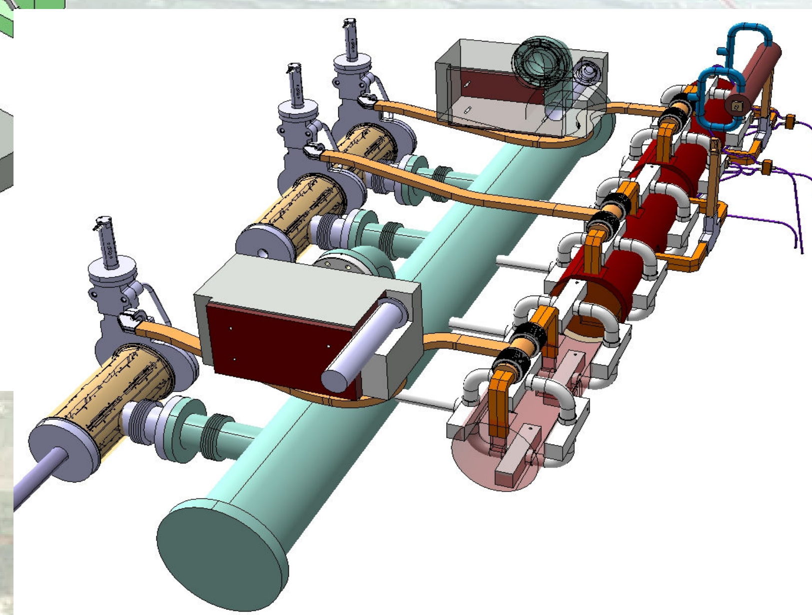
- Vacuum in the accelerating structures
  - Different vacuums
  - Static vacuum
  - Study of vacuum during breakdown
- Interconnections
- Conclusions

Vacuum system in the CLIC module

Presentation



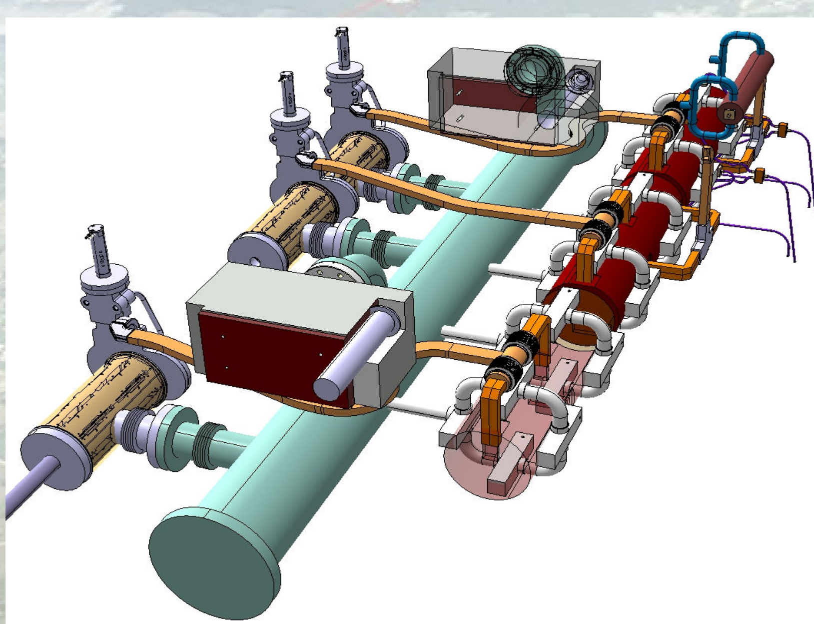


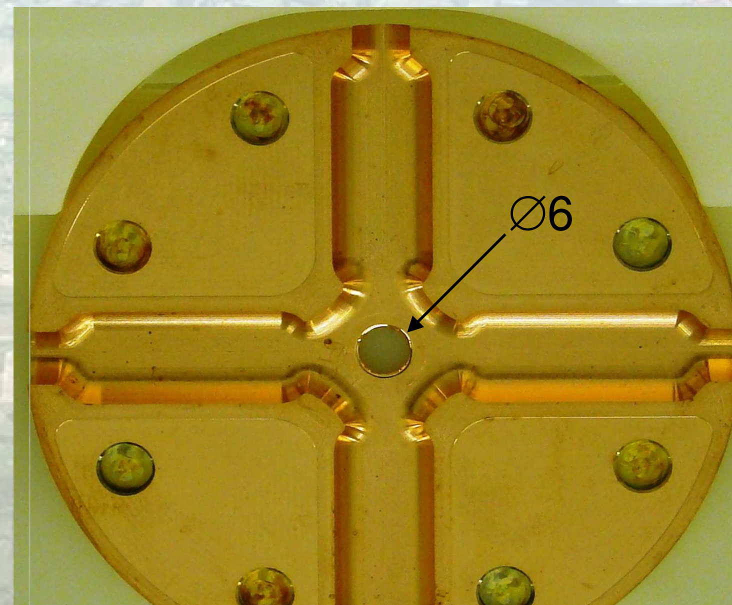
Baseline: 10^{-8} mbar

Vacuum system in the CLIC module

Specificities

1. Non-baked system → vacuum is driven by water
2. Low conductance (beam pipe diameter ~ 10 mm) (and large areas)





Typical shape and dimensions of an accelerating structure disk

Vacuum dynamics for a non-baked system

Elements of theory

Non baked system: Main molecular specie is water→ sticking probability and sojourn time are not negligible (whereas for a baked system the time of flight is the most important parameter)

$$\tau = \tau_0 \exp\left(\frac{E}{RT}\right)$$

- τ_0: 10^{-13} s
- E: Activation energy of desorption
- T: Temperature

Usually, vacuum technical surfaces exhibits a wide range of binding energy (distribution density).

Sticking probability depends also the sticking factor and also on the coverage.

Vacuum dynamics for a non-baked system

Elements of theory

For the design of a vacuum system the outgassing rate is usually used. For an non baked system, a simplified evolution law is used:

$$q_h = \frac{q_1}{h} + q_{\lim}$$

In the literature, q_1 varies from 10^{-9} to ~ 10^{-8} mbar.l.h/s.cm2

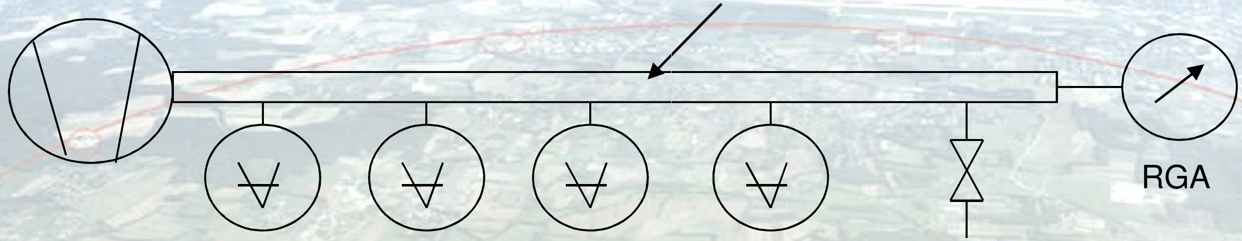
This is not surprising because of the dependence of the adsorption/desorption with the surface coverage and properties (porosities,…)

→ Measurement of outgassing rate has to be done on representative samples and conditions.

Vacuum dynamics for a non-baked system

Possible measurements

Another test set-up used to understand the dynamics of water pumping



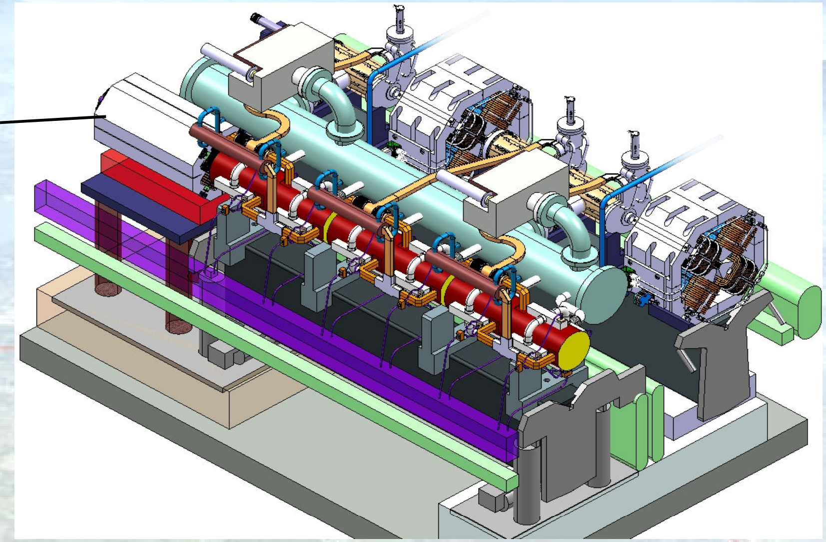
Desorption/adsorption phenomenon including coverage, residence time study

First measurements showed before stopping [Costa Pinto]:

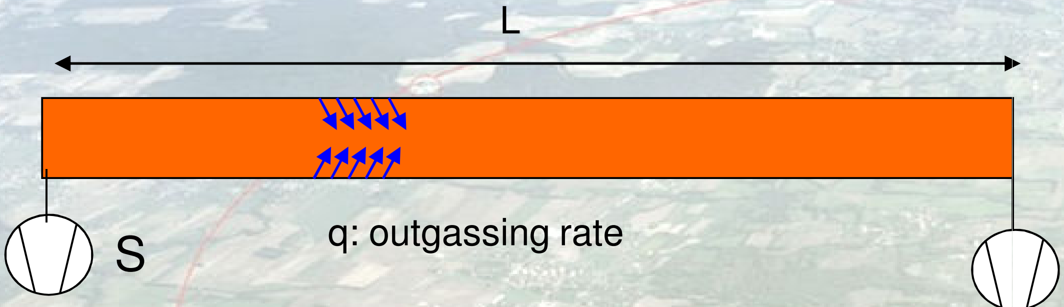
- An evidence of sticking factor at least higher than 10^{-3}.
- Sticking probability varies along the tube and in time

Should the measurements and simulations restart?

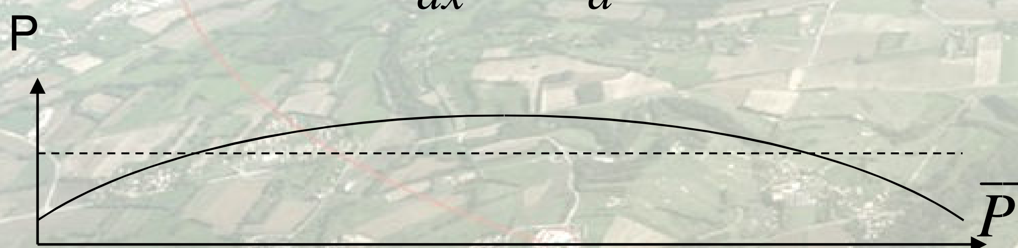
Vacuum chambers for the MB quadrupoles



- Length L of the magnet is comprised between ~50cm and 2 m
- The aperture diameter is around 10 mm



In steady state: $$\frac{d^2P}{dx^2} = -\frac{c}{a}$$ with c the unit conductance of the tube and a the gas desorption per unit length

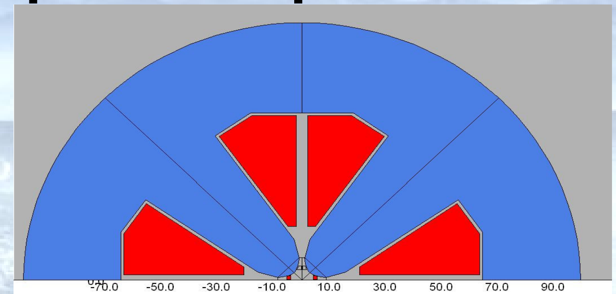


q = 10^{-10} mbar.l/s.cm^2
(after 100 hours of pumping)
L = 1 m

$$\overline{P}_{(S\to\infty)} \propto a\left(\frac{L}{r}\right)^2 \sim 2.10^{-8}$$ mbar

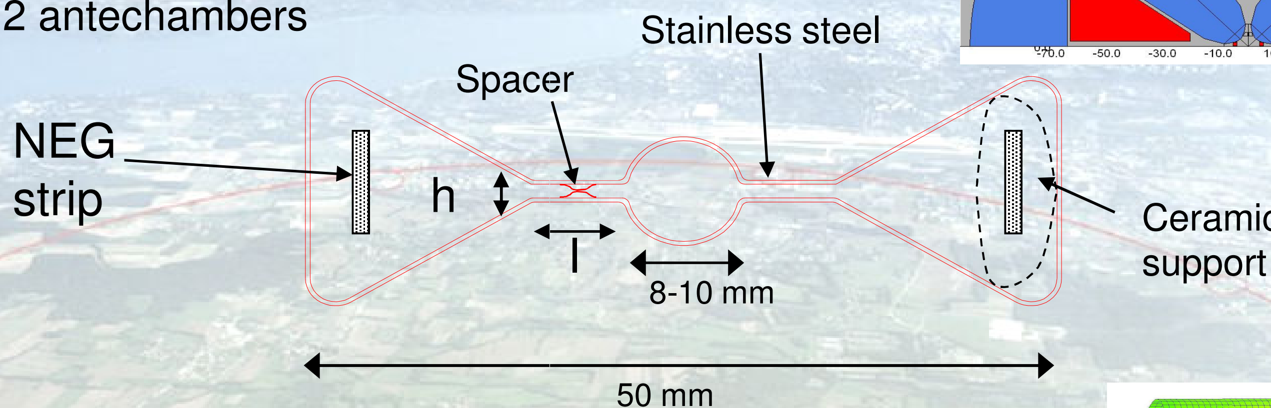
→ Distributed pumping is mandatory

Vacuum chambers for the MB quadrupoles



Present design:

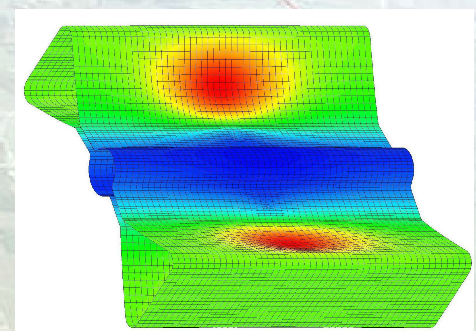
- Stainless steel vacuum chamber, squeezed in the magnet
- NEG strips sited in 2 antechambers
- Copper coated



Effective pumping speed per unit length: $S_{eff} \propto h^2/l$

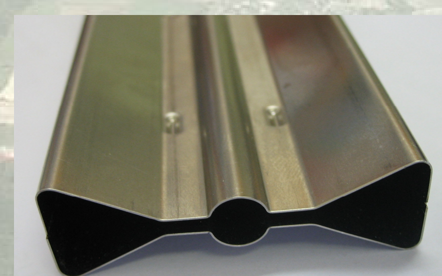
Pressure in the central part is determined by the gap → reduce the sheet thickness → stability becomes an issue (0.3 mm for the prototype)

$q = 10^{-10}$ mbar.l/s.cm^2 → P ~ 4.10^{-9} mbar



Buckling mode

Prototype has been manufactured and is being tested.



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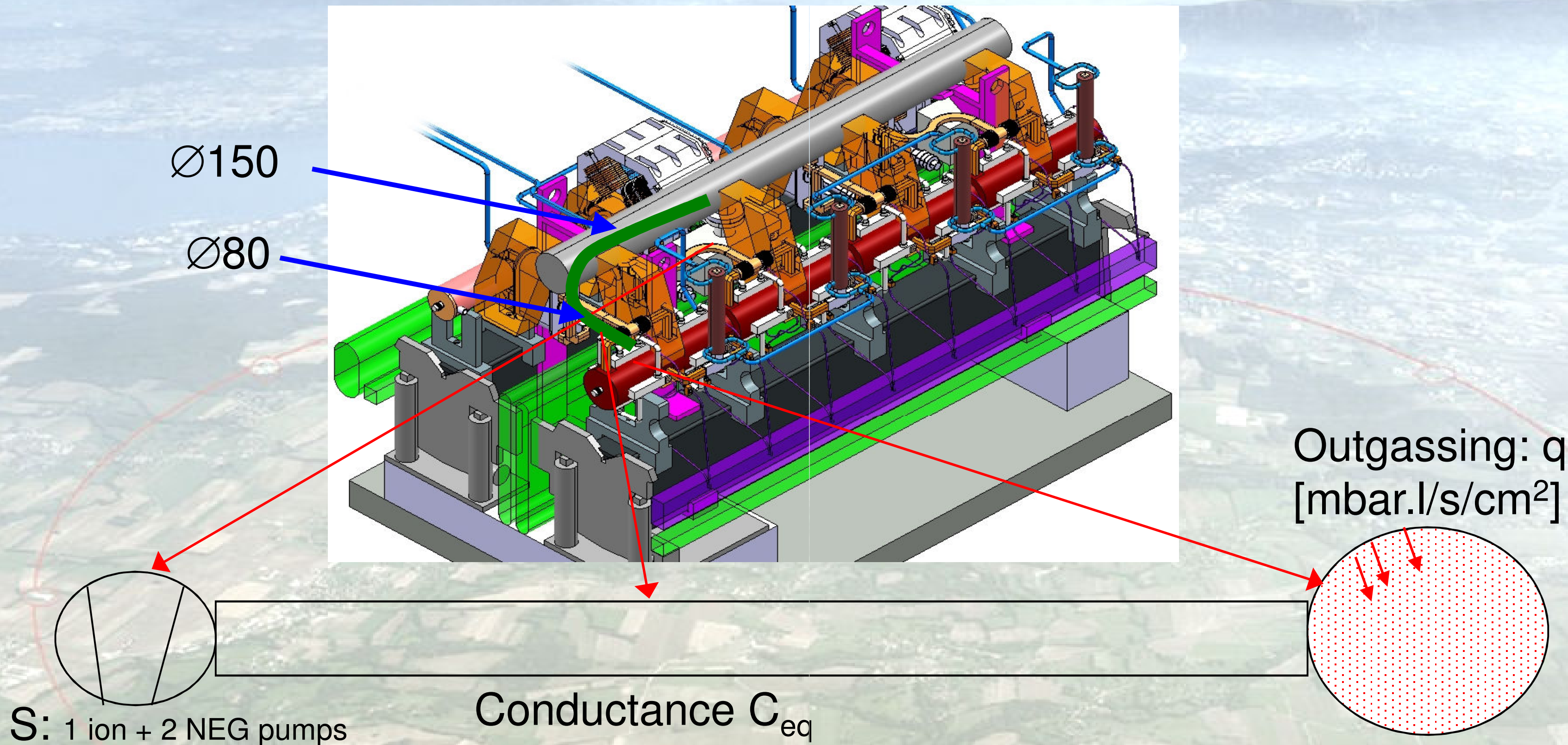
Vacuum in the accelerating structures

Different vacuum inside the PETS and the accelerating structures can be considered:

- Static: pressure after pump down without RF power and beams
- Dynamic: during rf pulse with no breakdown
- Dynamic: during breakdown

Vacuum in the accelerating structures

Very simplistic approach (does not take into account adsorption desorption physics of water)!



Effective pumping speed: Seff with: 1/Seff=1/S+1/Ceq

P=Q/Seff=q*area/Seff

$q \sim 10^{-10}$ mbar.l/s/cm^2 (after 100 hours of pumping), area~2800cm^2/AS (damping material is not taken into account!!)

→ P_{100h}~6E-9 mbar (to be updated with the last module layout)

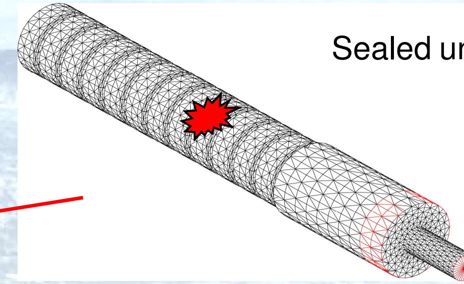
Dynamic vacuum in the accelerating structures

Assumptions:

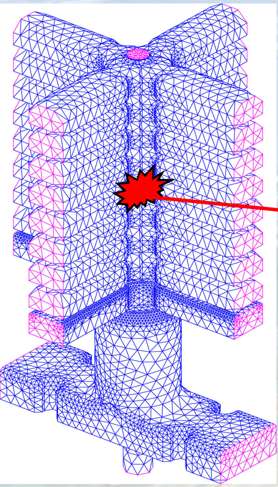
- 10^{12} H_2 molecules released during a breakdown [Calatroni et al.]
- Gas is at room temperature (conservative)

Requirement: Pressure<10^{-8} mbar 20ms after breakdown

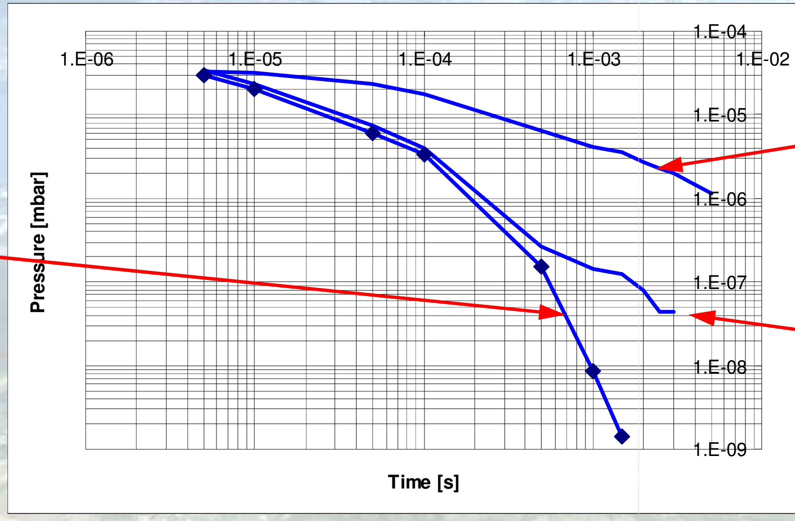
Monte Carlo simulation implemented in a FE code (Castem)



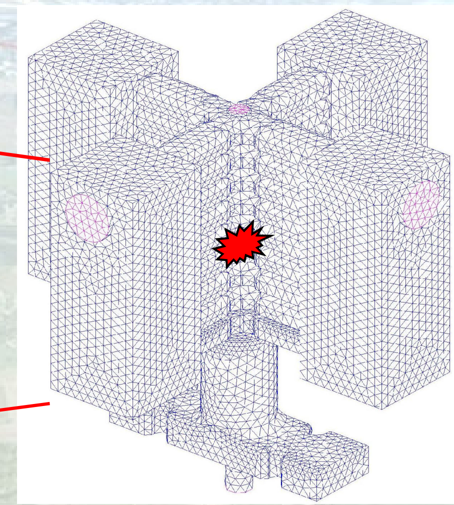
Sealed undamped



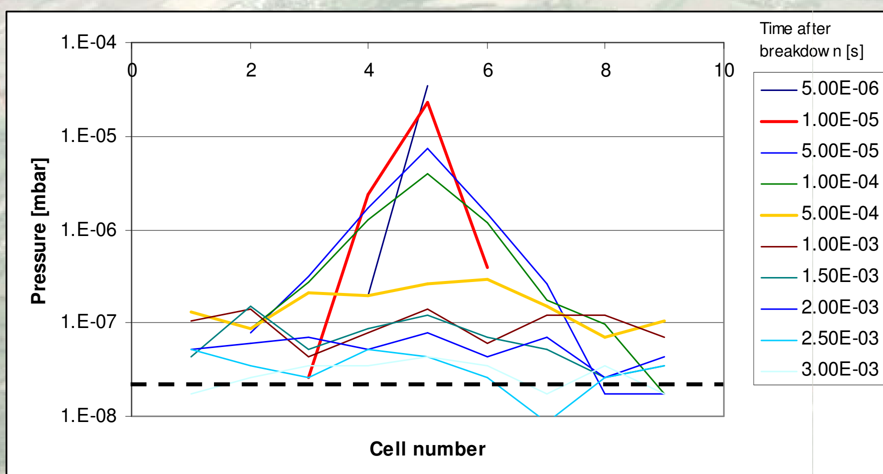
Sealed in tank



Pressure in the cell where breakdown occurs as a function of time



Sealed with manifolds



Vacuum degradation remains localized close to the breakdown

Longitudinal distribution as a function of time

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Vacuum in the accelerating structures with RF

Qualitatively:

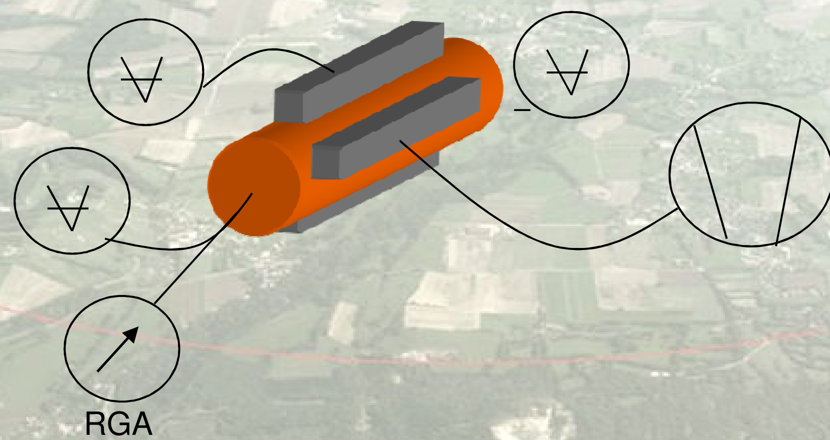
1. Thermal effect related to the power dissipation leading to thermal outgassing (conditioning)
2. Multipactor effect leading to electron stimulated desorption and/or to local heating

Vacuum in the accelerating structures

Tests on a representative structure will be done to determine:

- The static pressure and the influence of manifold dimensions, pumping speeds, air exposition (commissioning and operation)
- The gas analysis during time
- The influence of RF power on the vacuum
- …

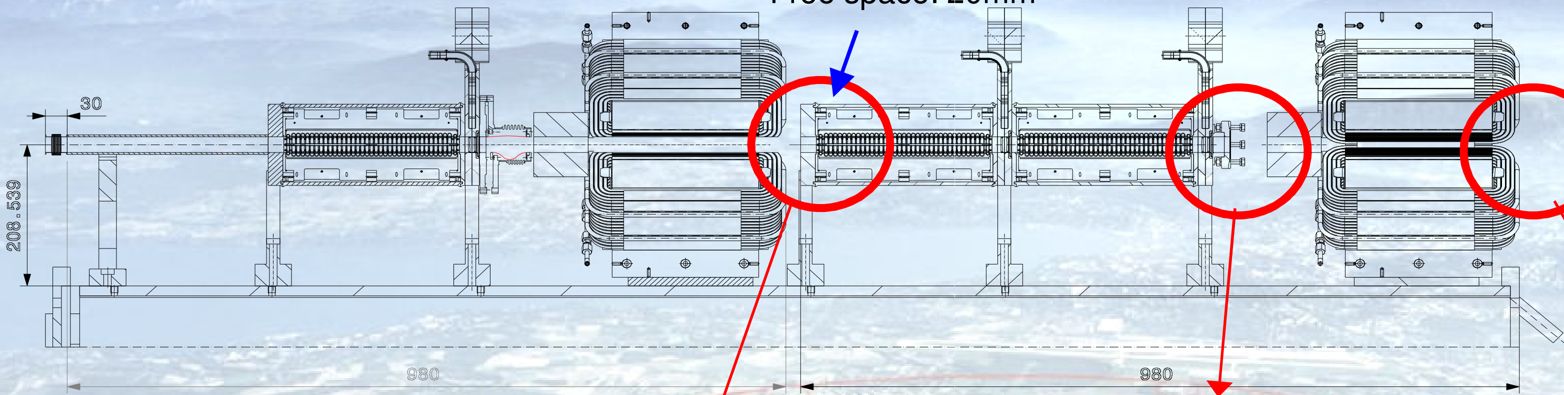
Mock up is planned to be ready beginning of next year for static conditions and probably mid year with RF.



Drive beam interconnections

Free space: 20mm

Free space: 30mm



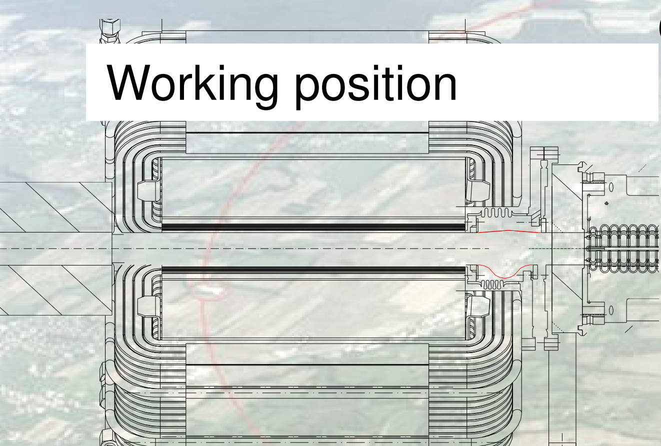
QUAD/PETS IC

(or QUAD/drift tube IC)

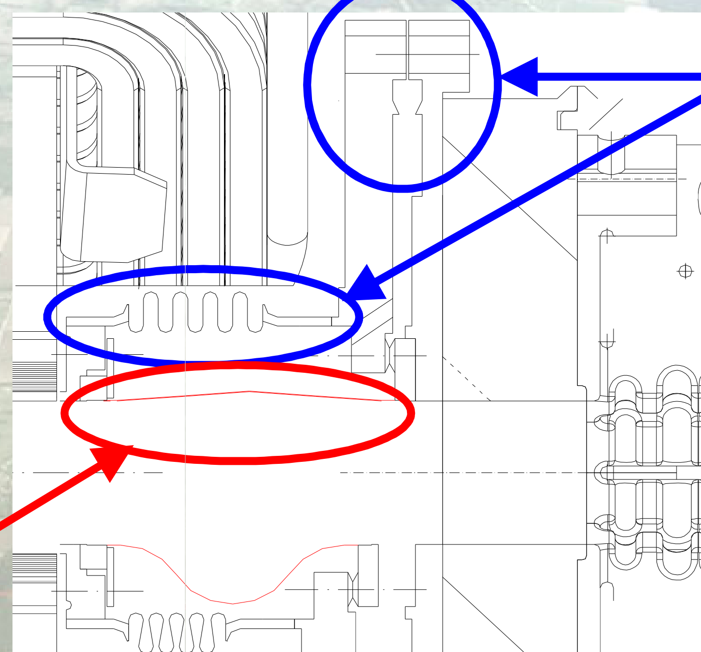
PETS/BPM

QUAD/PETS

Working position



Installation position



Vacuum enclosure delimited by a bellows and knife flanges

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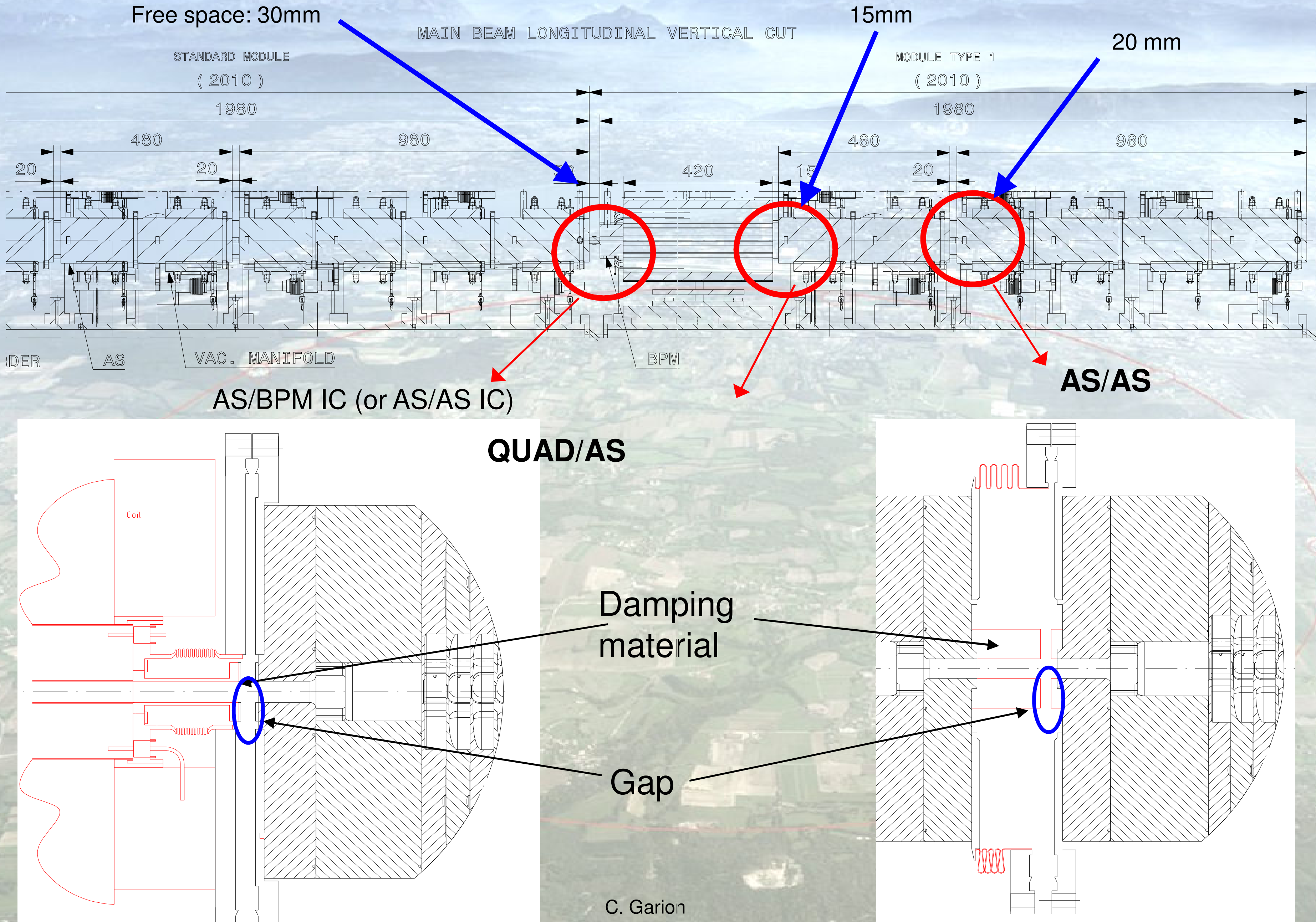
Electrical continuity done by a copper based flexible element

Other drive beam interconnections are based on the same concept

Main beam interconnections



Conclusions

The vacuum system of the CLIC main linac is non-standard: non-baked system with low pressure requirements and with low conductances.

The vacuum system has been designed on simple approach with inputs found in the literature.

More detailed experiments are in preparation to qualify and validate the vacuum system.