Vacuum system for the CLIC two-beam modules

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CERN/TE/VSC

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Outline

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- Vacuum dynamics for a non-baked system
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- Vacuum in the accelerating structures
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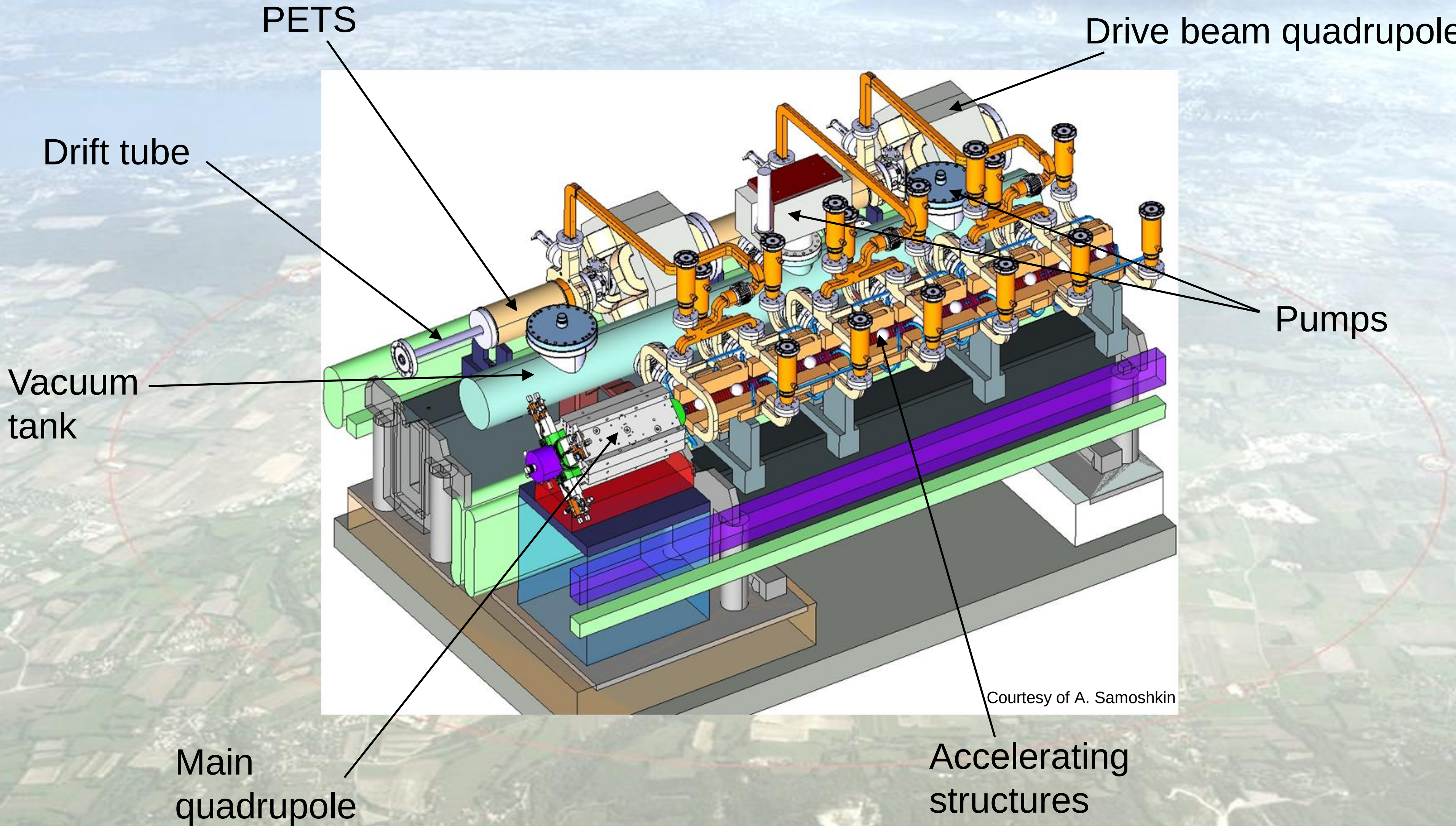
Vacuum system in the CLIC module

Overview



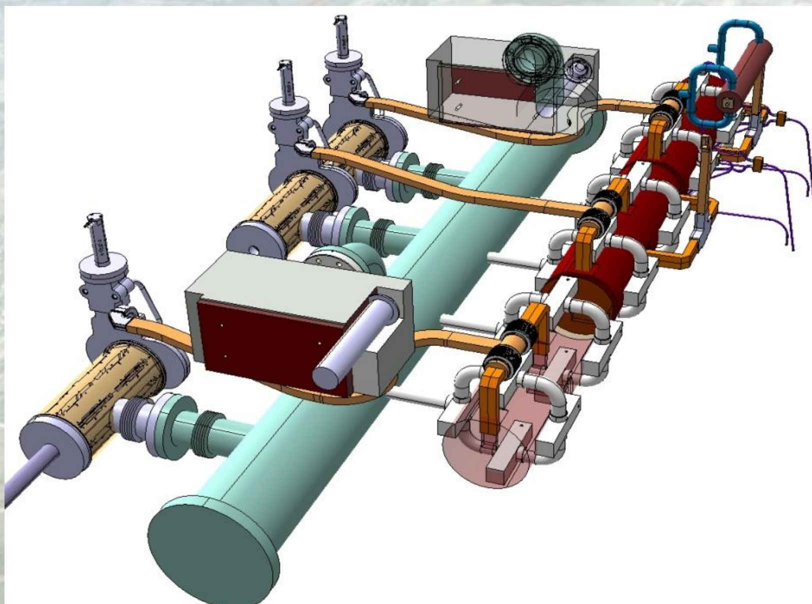
Vacuum system in the CLIC module

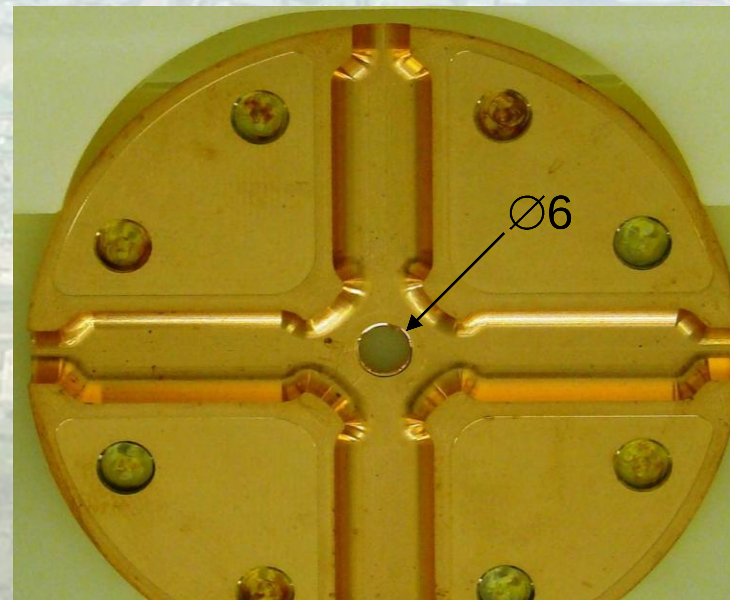
Requirements

Field ionization studies resulted in a lowering of the vacuum threshold for fast ion beam instability to: pressure < 1 nTorr [G. Rumulo]

Specificities

1. Non-baked system → vacuum is driven by water
2. Low conductance (beam pipe diameter ~ 10 mm) and large areas (~3000 cm^2/AS)



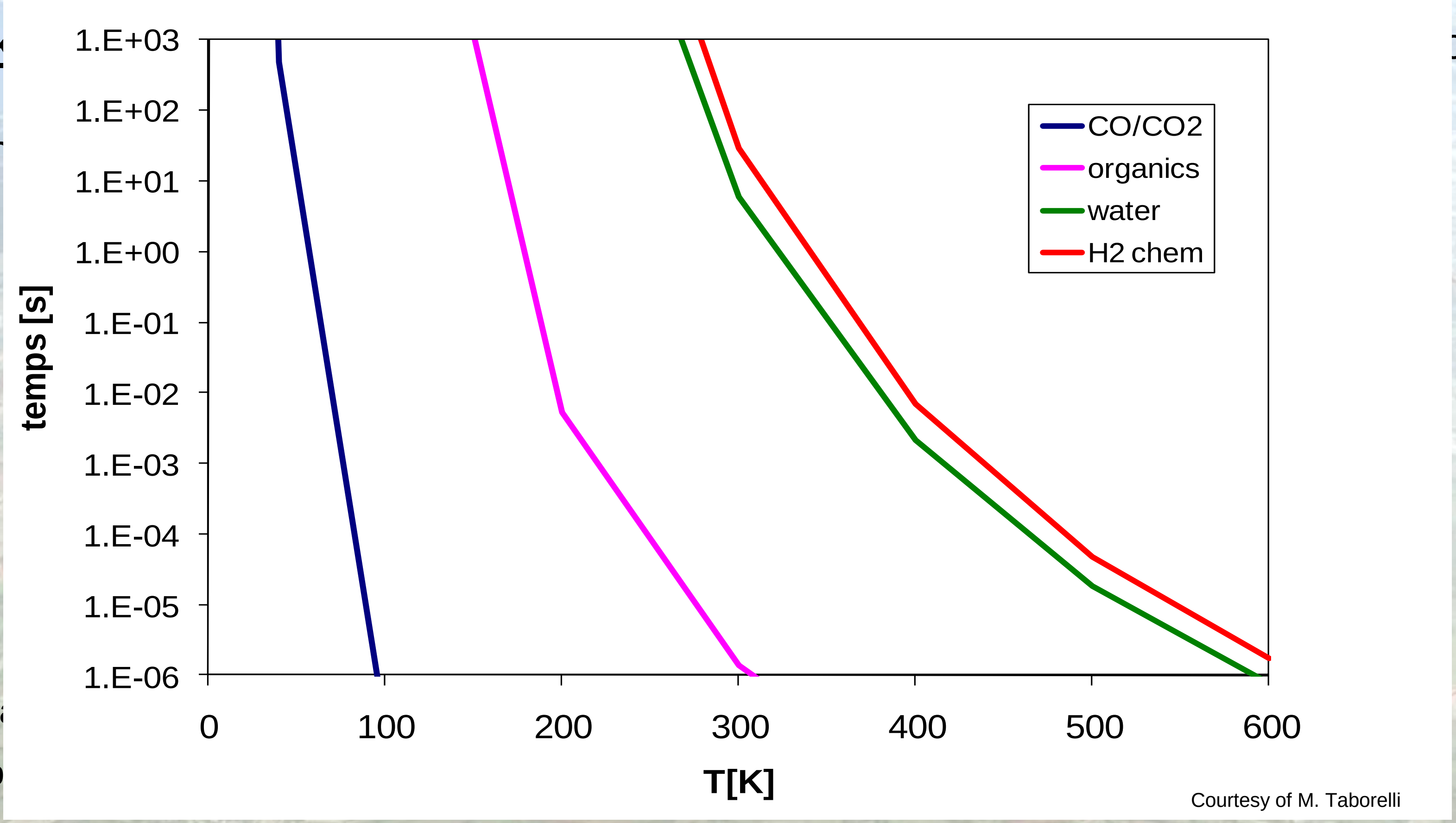


Typical shape and dimensions of an accelerating structure disk

Vacuum dynamics for a non-baked system

Elements of theory

Non bak ... urn
time are
importar



Courtesy of M. Taborelli

Usually, v

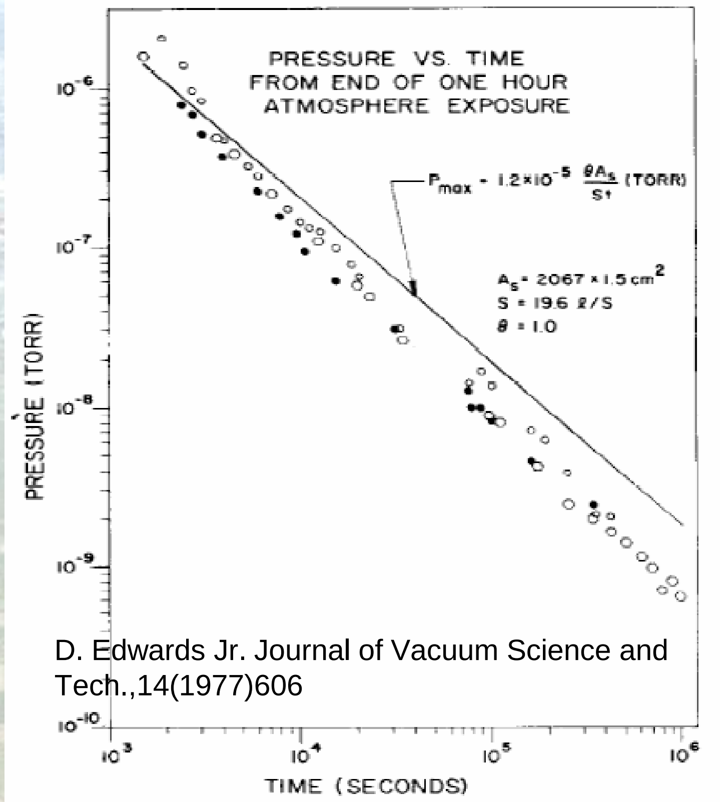
Sticking p

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:

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

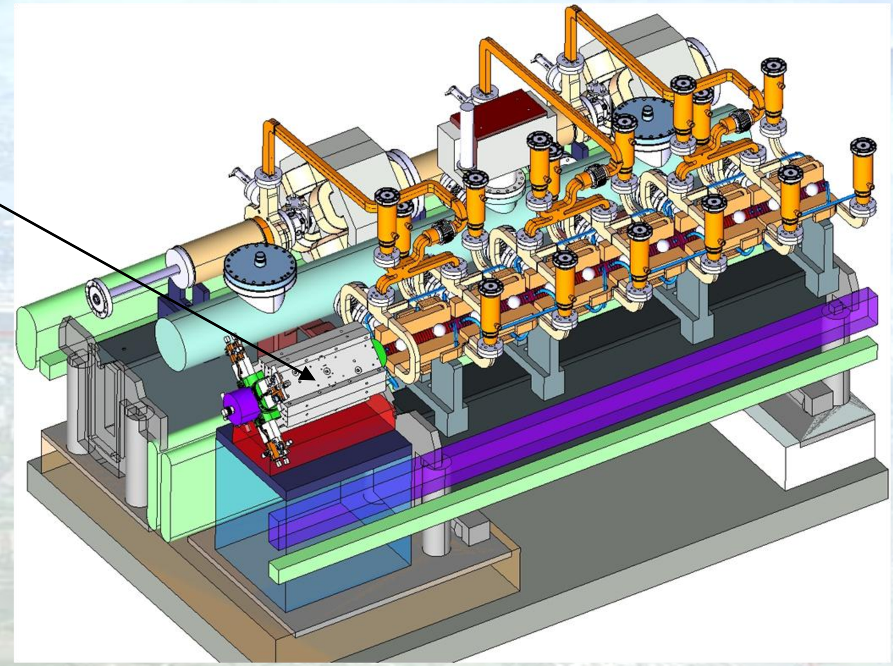


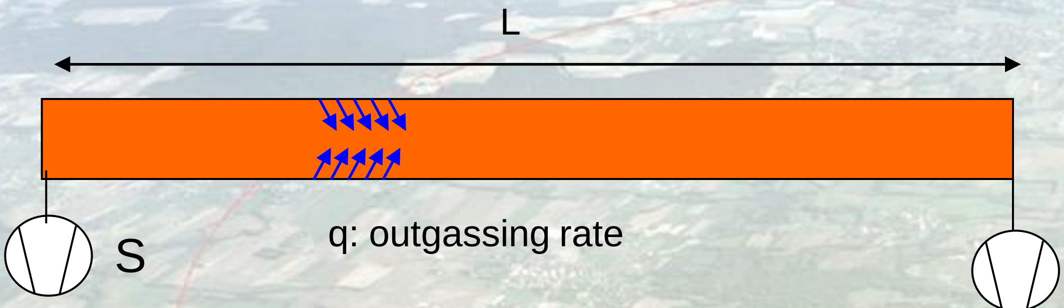
D. Edwards Jr. Journal of Vacuum Science and Tech.,14(1977)606

From an engineering point of view: q [mbar.l/s/cm^2] ~ 2.10^{-9} / t[h] (valid for all metals)

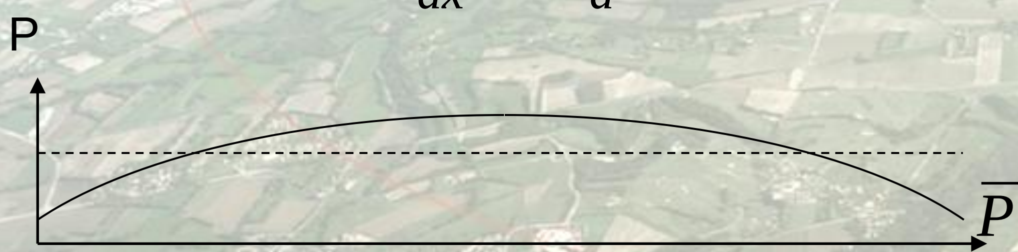
Vacuum chambers for the MB quadrupoles

- 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 = 2.10^{-11} mbar.l/s.cm^2

(after 100 hours of pumping)

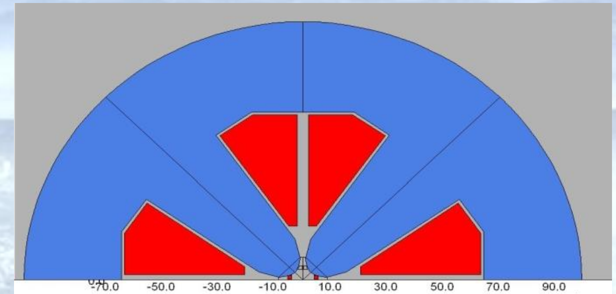
L = 2 m

$$\bar{P}_{(S\to\infty)} \sim q\left(\frac{L}{r}\right)^2$$

~2.10^{-8} mbar

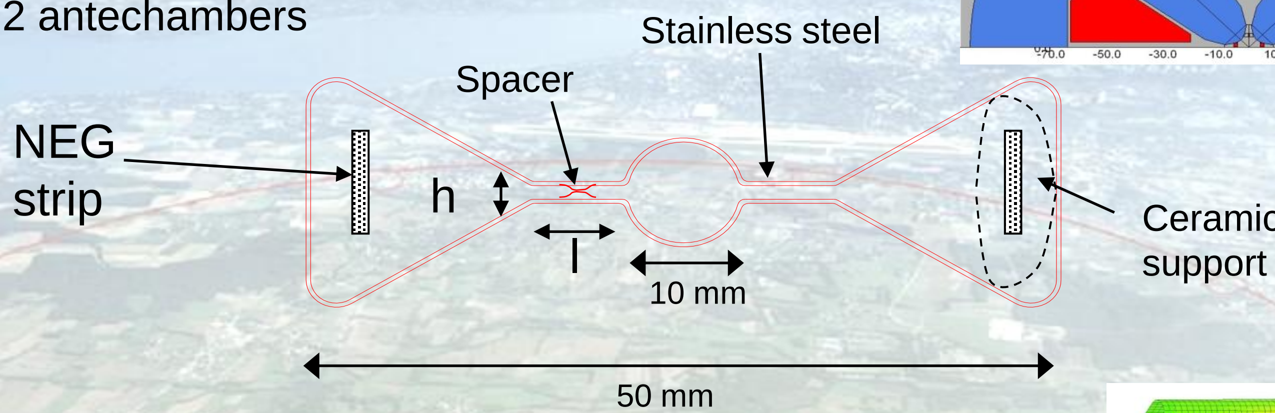
→ Distributed pumping is mandatory

Vacuum chambers for the MB quadrupoles



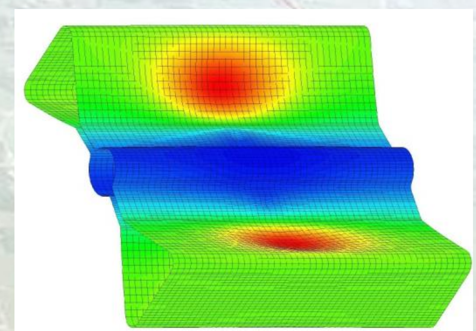
Present design:

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



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

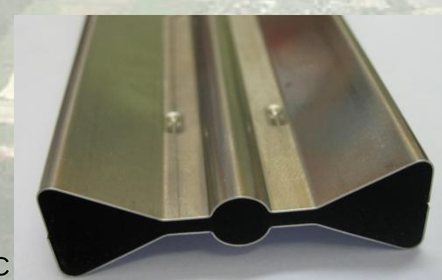
Pressure in the central part is determined by the gap → reduce the sheet thickness → stability becomes an issue (0.3 mm for the prototype)



Buckling mode

$q = 2.10^{-11}$ mbar.l/s.cm^2 → P ~ 8.10^{-10} mbar

Prototype has been manufactured and is being tested.



C. Garion, IWLC

Dynamic vacuum in the accelerating structures

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

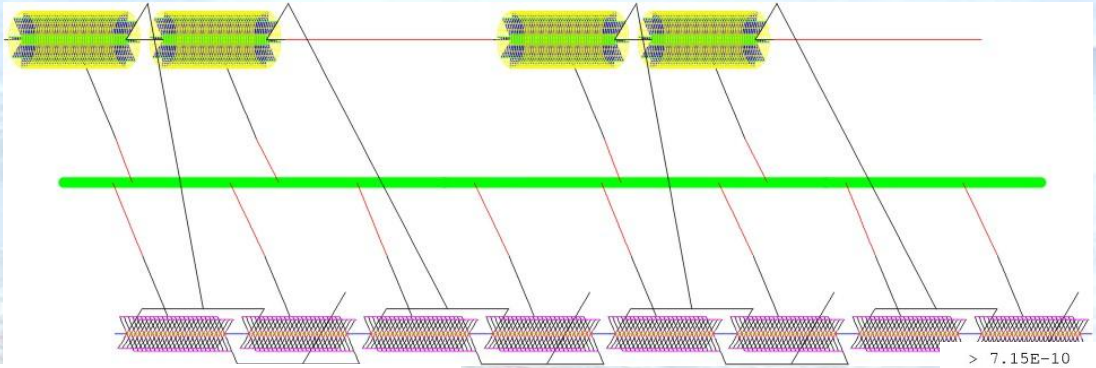
- Static: pressure after pump down without RF power and beams
- Dynamic: during breakdown
- Dynamic: during RF pulses without breakdown

Vacuum analysis based on thermal/vacuum analogy

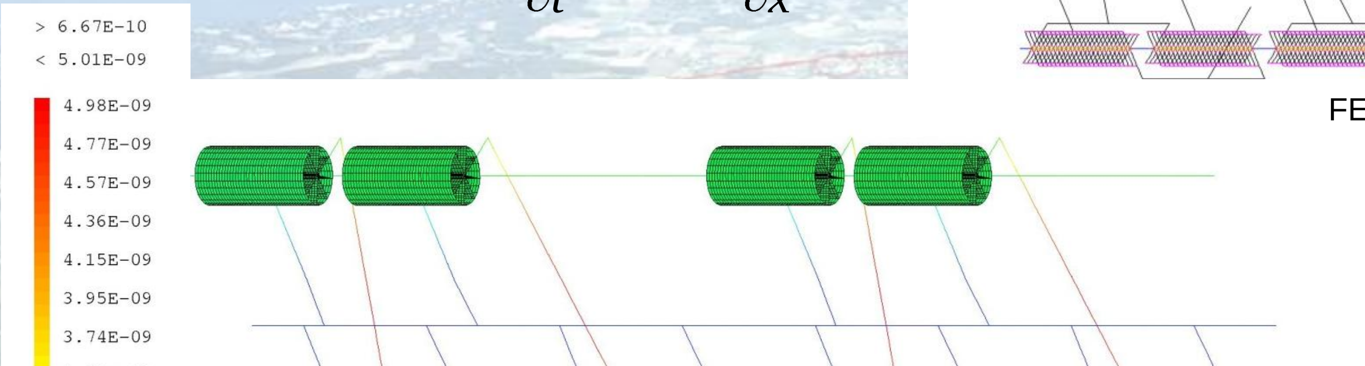
Implementation in a FE code and application to the CLIC module

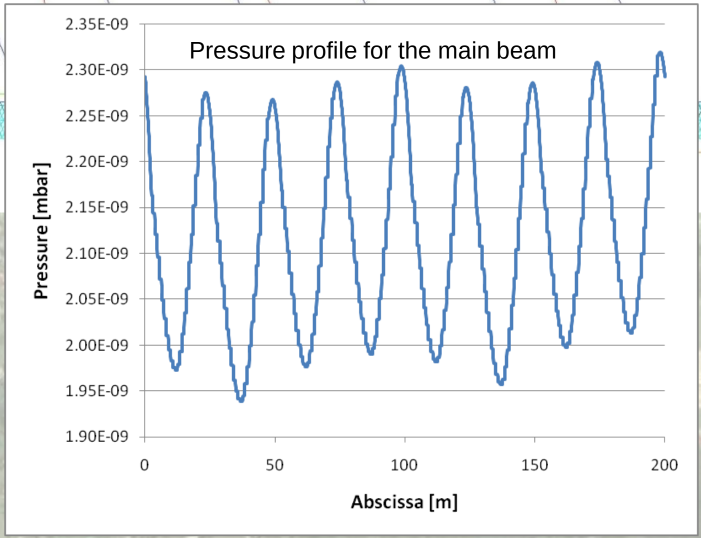
Heat transfer equation: $$\rho c_p \frac{\partial T}{\partial t} = q + k\Delta T$$

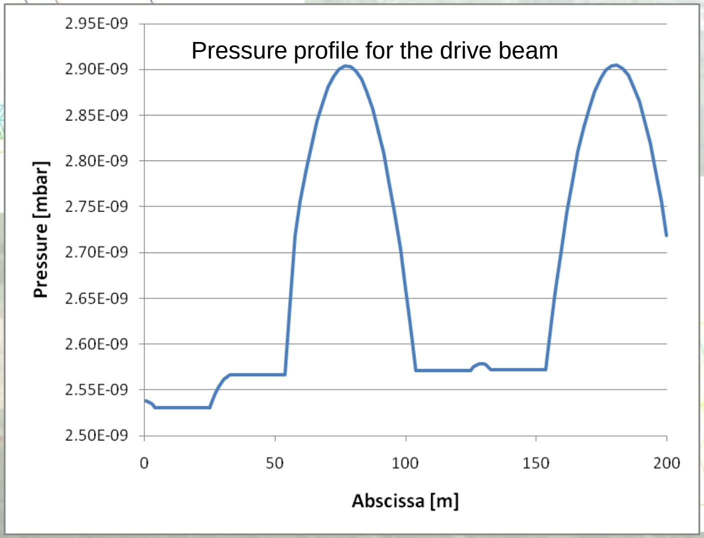
Gas flow equation (1D): $$S\frac{\partial P}{\partial t} = a + c\frac{\partial^2 P}{\partial x^2}$$

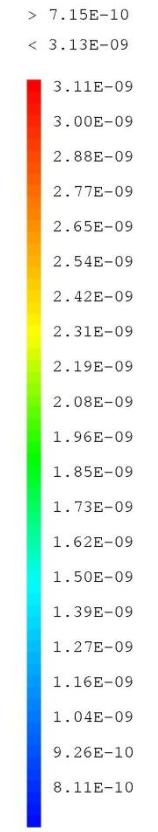


FE vacuum model

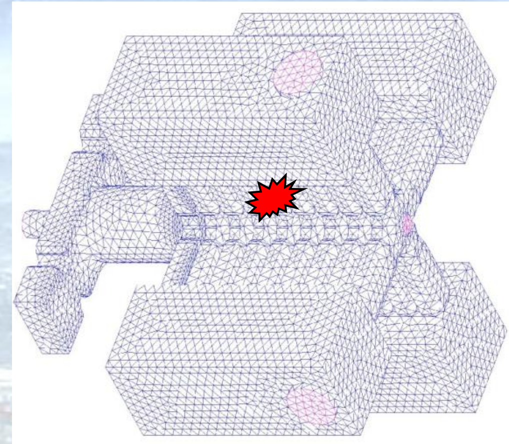








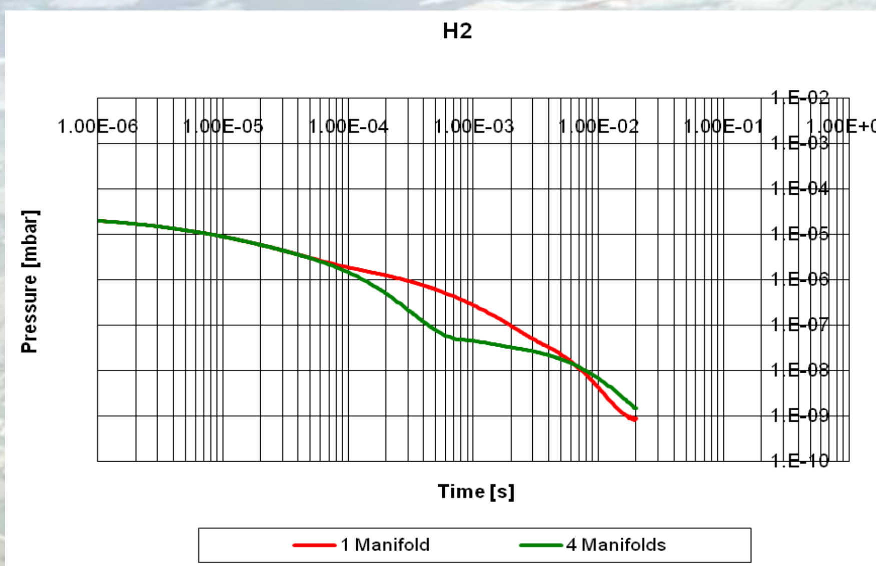
Dynamic vacuum in the accelerating structures



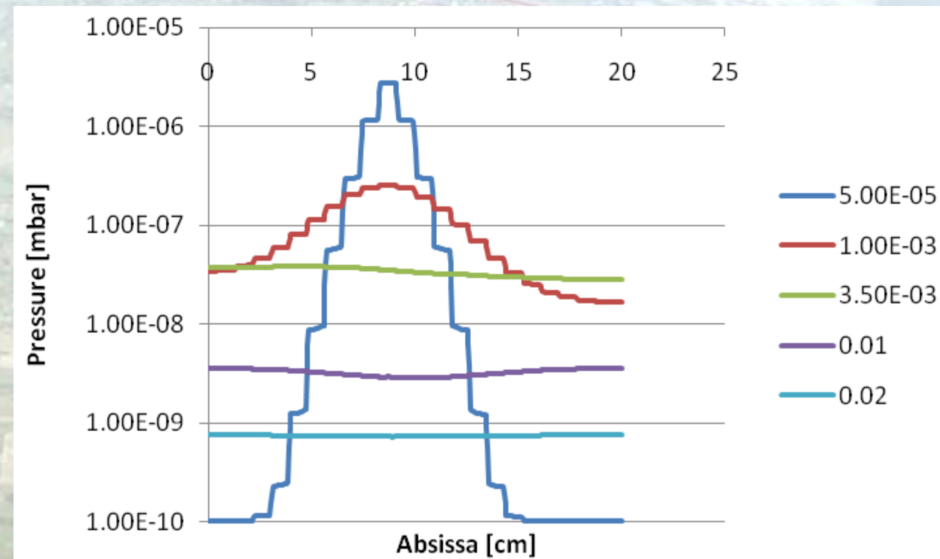
Assumptions:

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

Requirement: Pressure$<10^{-9}$ mbar 20ms after breakdown
Monte Carlo simulation or thermal analogy



Maximum pressure during time



Longitudinal distribution as a function of time

Vacuum degradation remains localized close to the breakdown and seems not to be an issue.

Vacuum in the accelerating structures with RF

See S. Calatroni, Accelerator session: WG 4

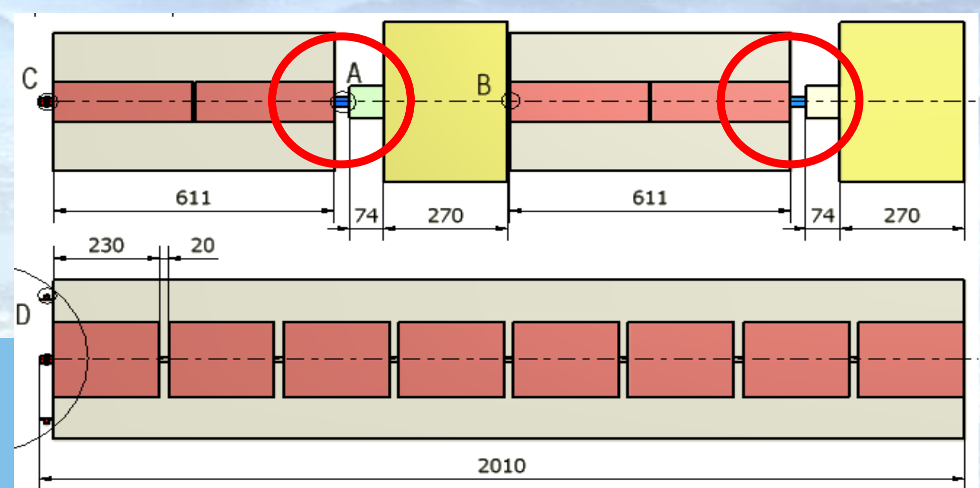
Qualitatively:

- Thermal effect related to the power dissipation leading to thermal outgassing (conditioning)
- Field emission leading to electron stimulated desorption and/or to local heating
    1. Dark current simulations from SLAC
    2. ESD data on unbaked copper at high e^- energy from CERN [Pasquino, Calatroni]
    3. Introduce these into MC models and get gas distribution, with reasonable assumptions on molecule's speed.

Direct measurements seem not to be feasible due to timescale

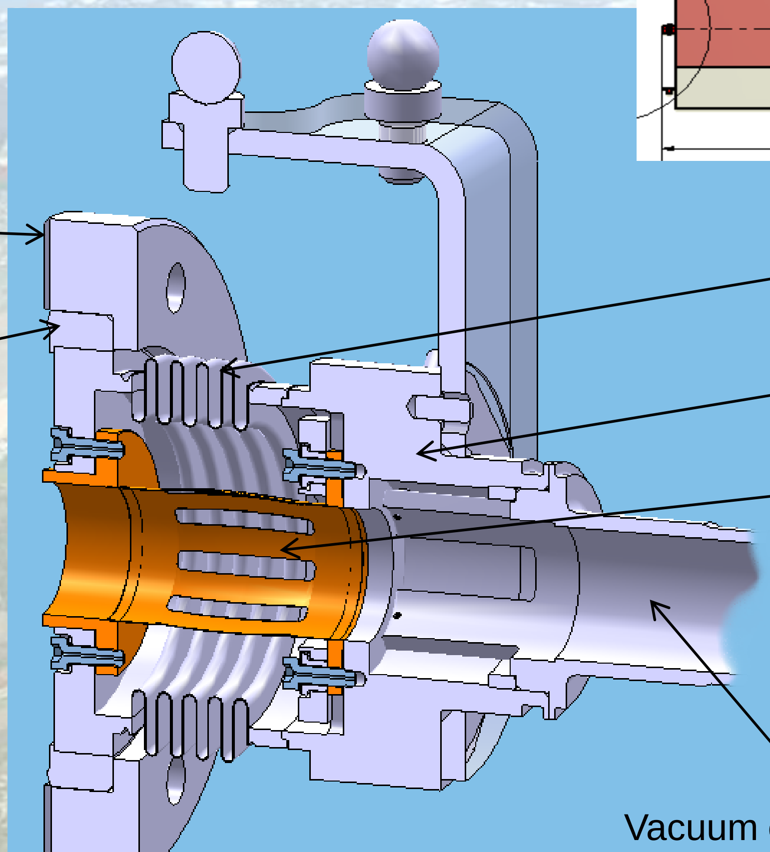
Drive beam interconnections

Intramodule: Standard module / drive beam PETS/BPM



Rotatable flange

Conflat Flange DN63



Courtesy of A. Samoshkin, D Gudkov

Bellows

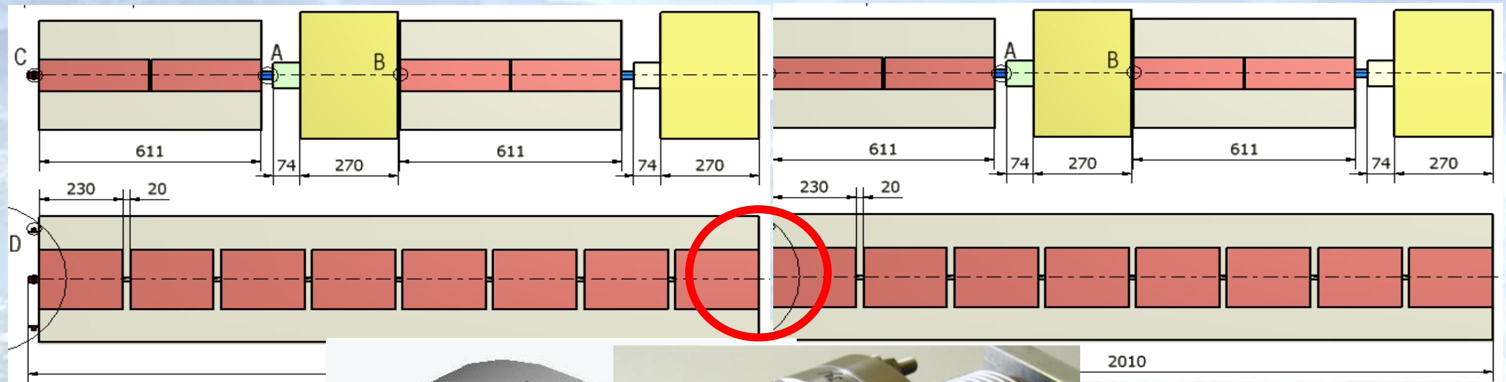
Part of the BPM is installed in the magnet

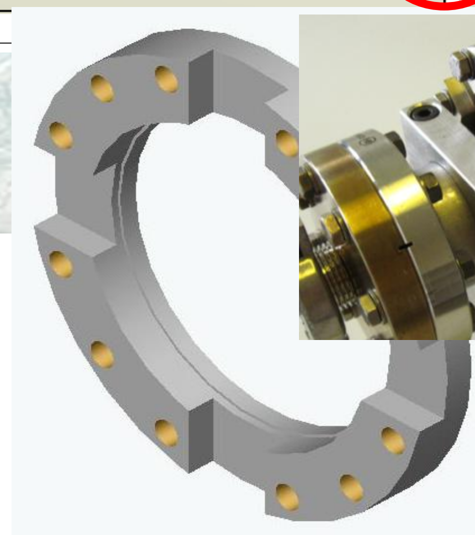
RF fingers: 0.1 copper alloy

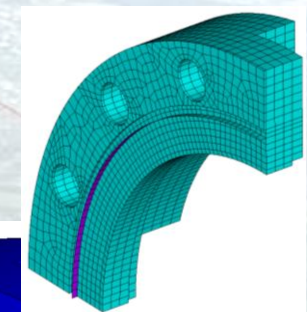
Vacuum chamber

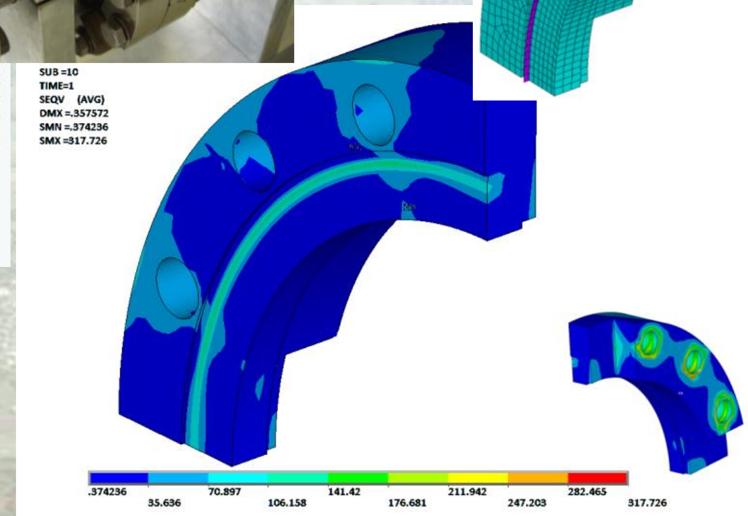
Main beam interconnections

Intermodule:
T0T0/ main beam

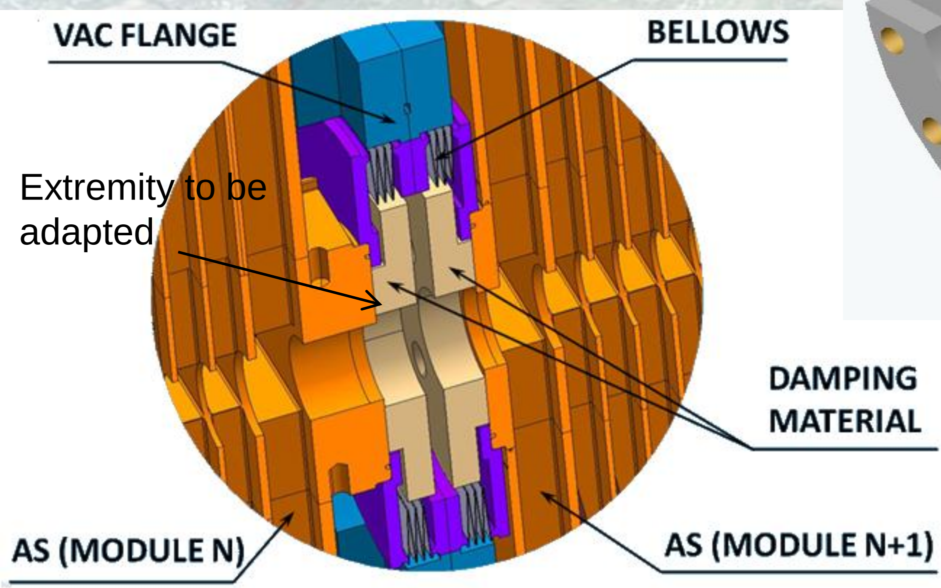








Non standard flange study



Conclusions

The vacuum system of the CLIC main linac is non-standard:

- non-baked system with low pressure requirements, low conductances and large surface areas:
  - Static vacuum seems to be achieved only marginally with present design
  - Dynamic vacuum due to breakdowns seems to be under control
  - Dynamic vacuum due to field emission: the problems seems to be real
- extremely limited space for vacuum system and interconnections