Vacuum & interconnections of the CLIC main linac modules

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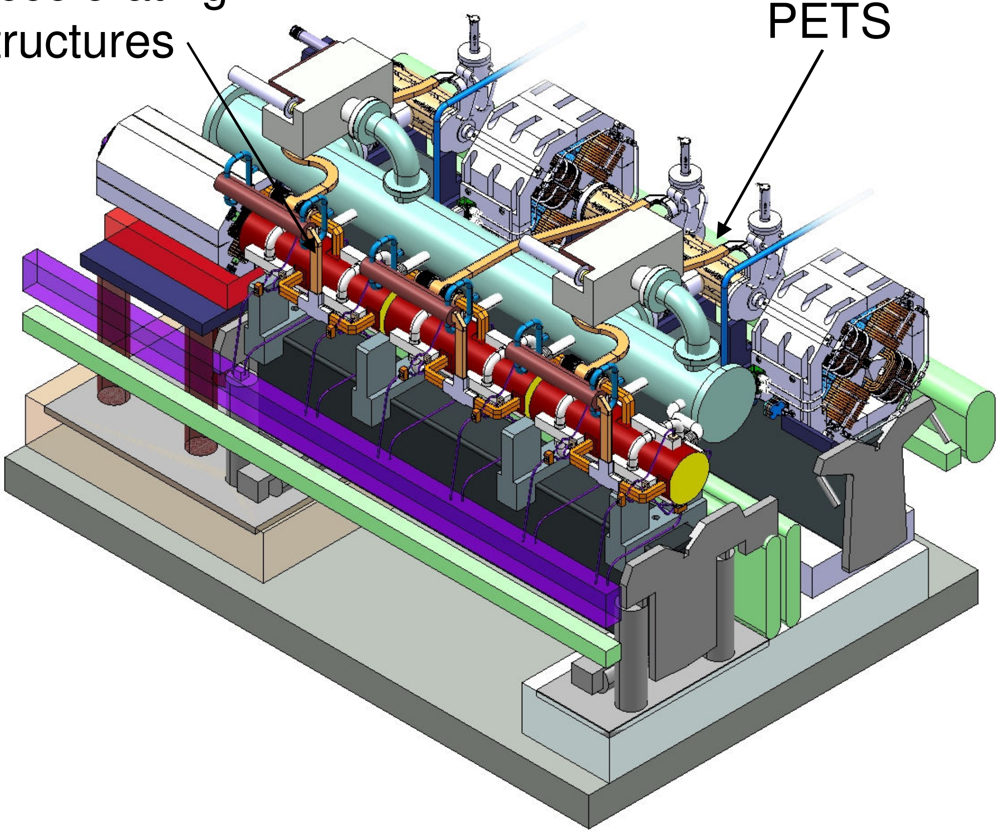
Review, 15-16th September 2009

Outline

- Vacuum system for the modules
  - vacuum chambers
  - pumping system
  - general layout
- Interconnections
  - drive beam
  - main beam
  - wave guides
- Conclusions

Vacuum system of the module

Vacuum chambers



Spec: EDMS 992778, 954081

→P_{MB} ~ 10nTorr

→$Ri_{MB}P$ 3 mm (now baseline is 4 mm)

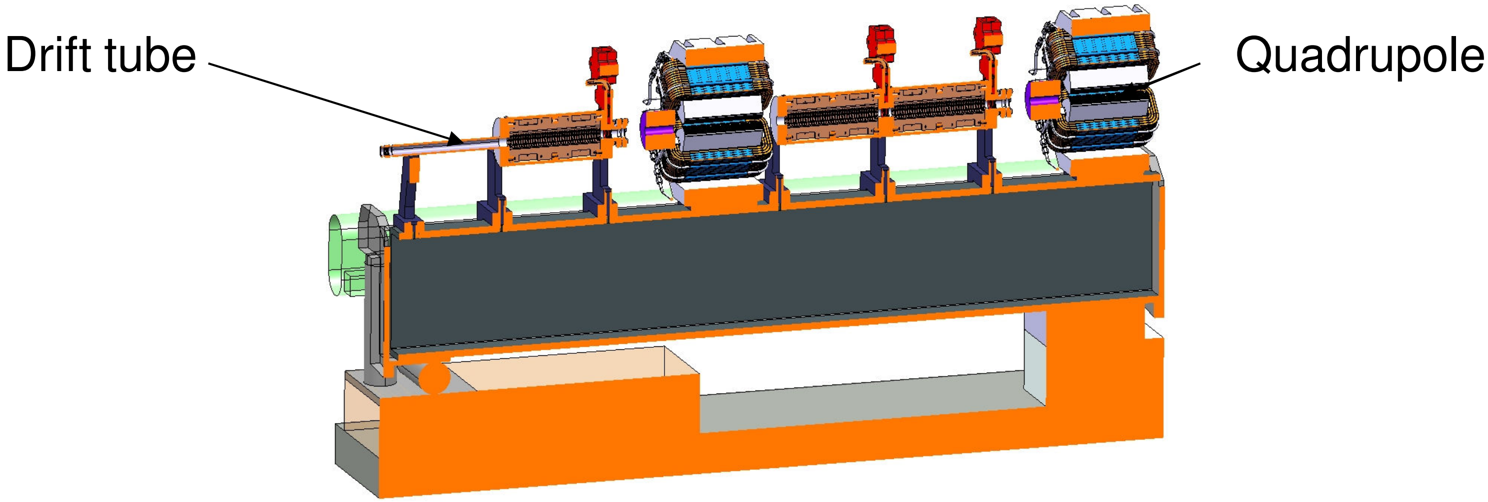
→ material: copper (or Cu coated)

Spec: EDMS 992790

→ $Ri_{DB}P$ 11.5 mm

Vacuum chambers are mainly PETS or AS

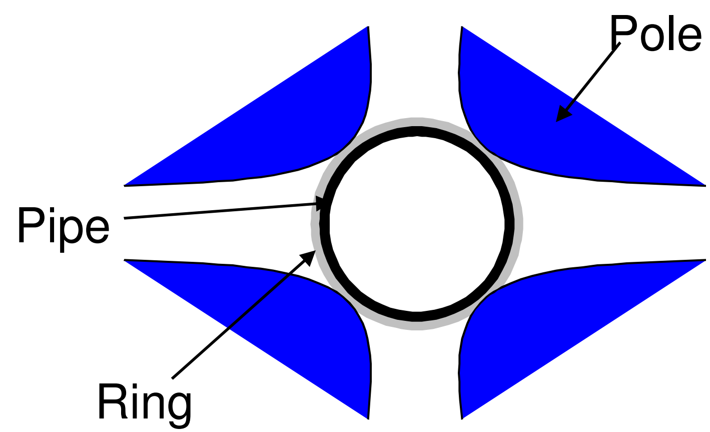
Vacuum chambers of the drive beam



Space limited by an aperture of 23 mm in diameter and a pole diameter of 26 mm for the quads.

For both cases, precision tubes in stainless steel can be used (∅23 *1 in 316L)

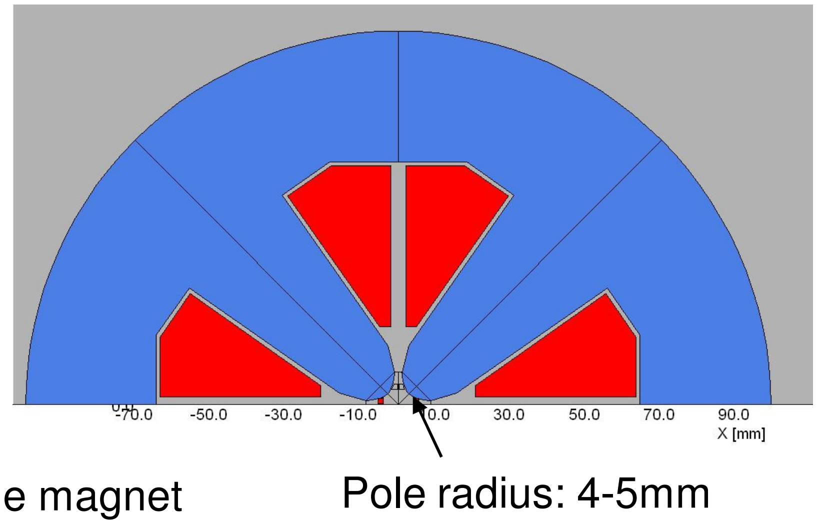
Quadrupole chambers can be centered with 2 “soft” rings (PEHMW)



Vacuum chambers of the main beam quad

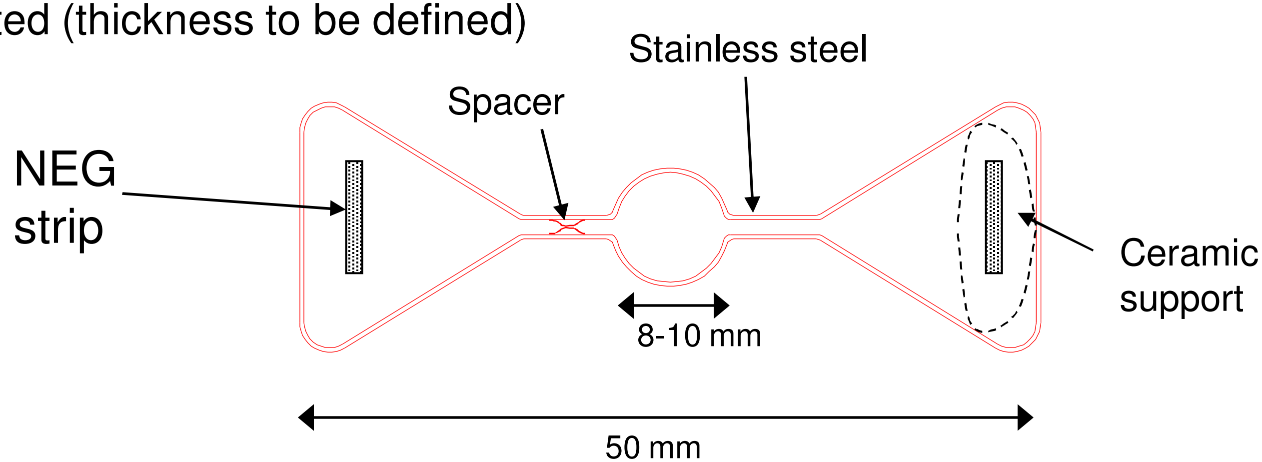
Constraints

- Very tight space available → low conductance→ distributed pumping is mandatory
- Unbaked system → vacuum is driven by water pumping



Proposal:

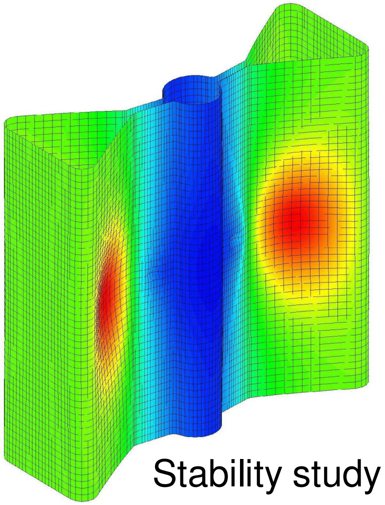
- Stainless steel vacuum chamber, squeezed in the magnet
- NEG strips sited in 2 antechambers
- Copper coated (thickness to be defined)



Vacuum chambers of the main beam quad

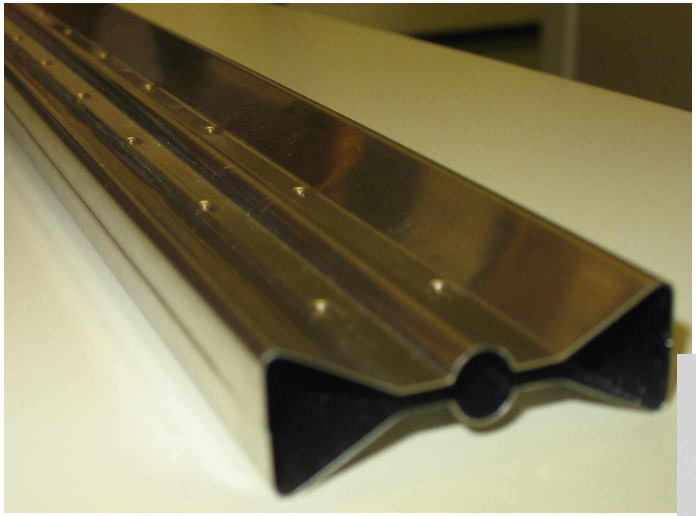
Present design

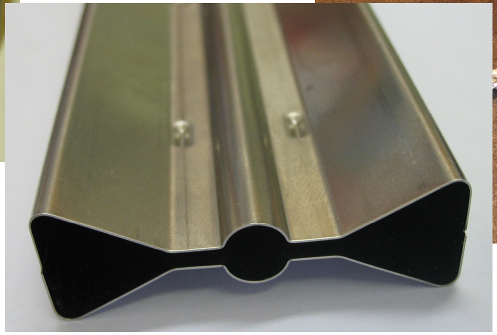
Pressure in the central part is determined by the gap ($S_{eff} \sim h^2/L$)
→ reduce the sheet thickness (0.3 mm for the prototype)



Stability study

Spacers stamped in the shell (has to be improved)

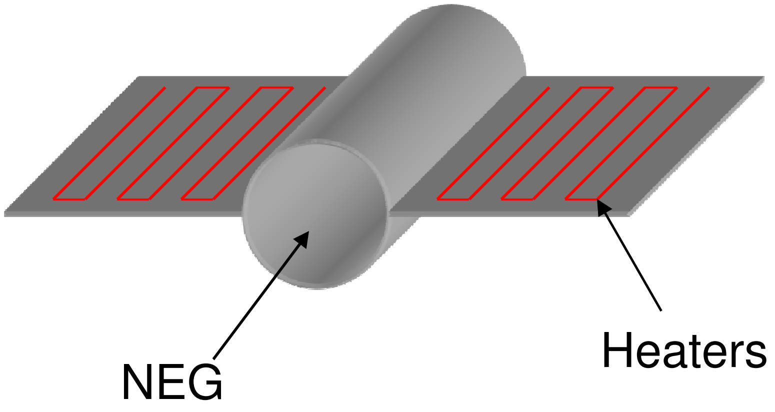




Vacuum chambers of the main beam quad

Concept under study

Two half shells coated with low activation temperature NEG



Main advantages:

Pressure not limited by conductance

No electrical feedthrough

Pumping system

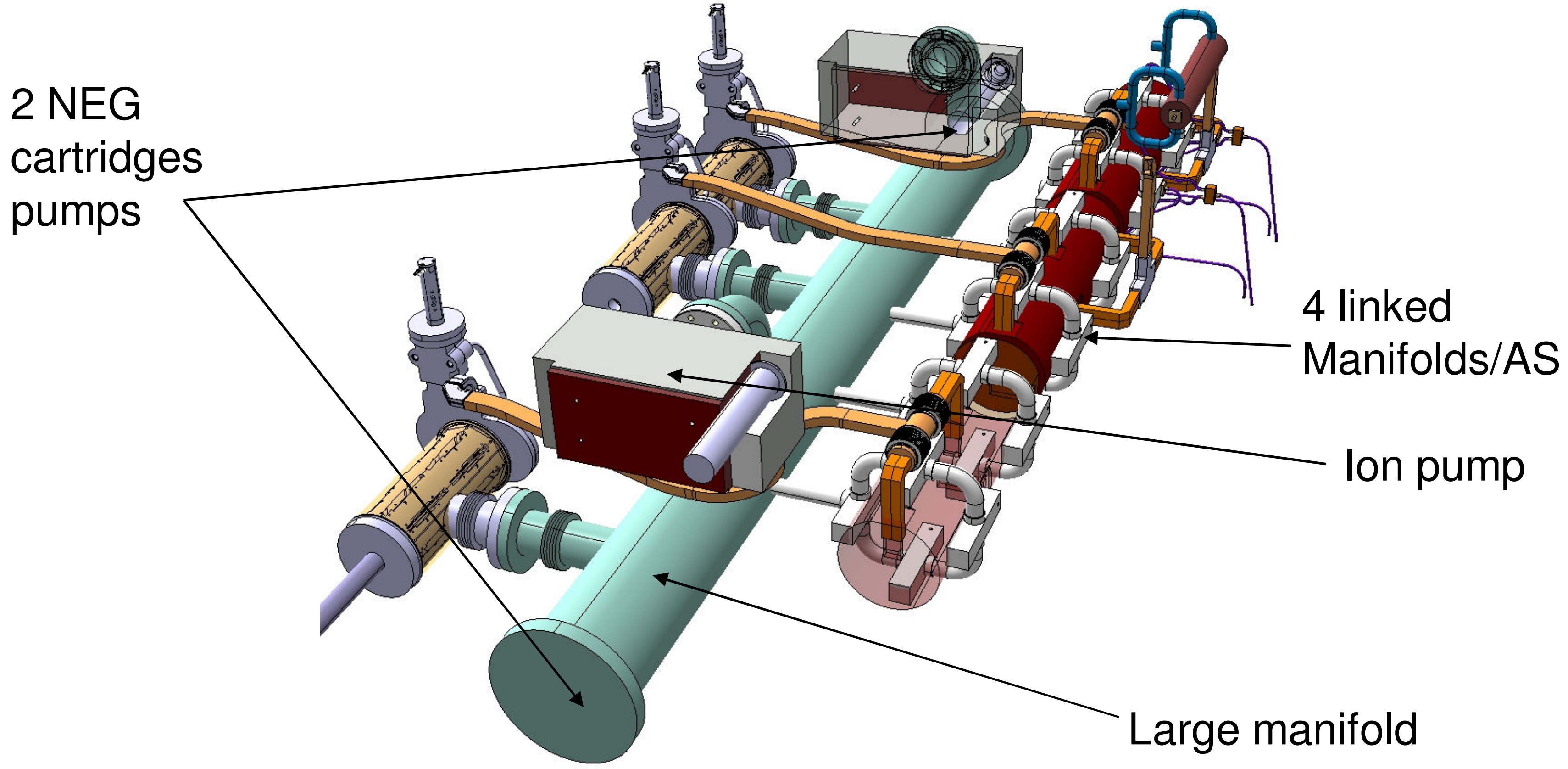
Vacuum equipment (version sealed disk):

→ manifolds around the accelerating structures linked to a common tube

→ Tanks around the PETS linked to a common tube

→ MB and DB vacuum coupled via the common manifold and the waveguides

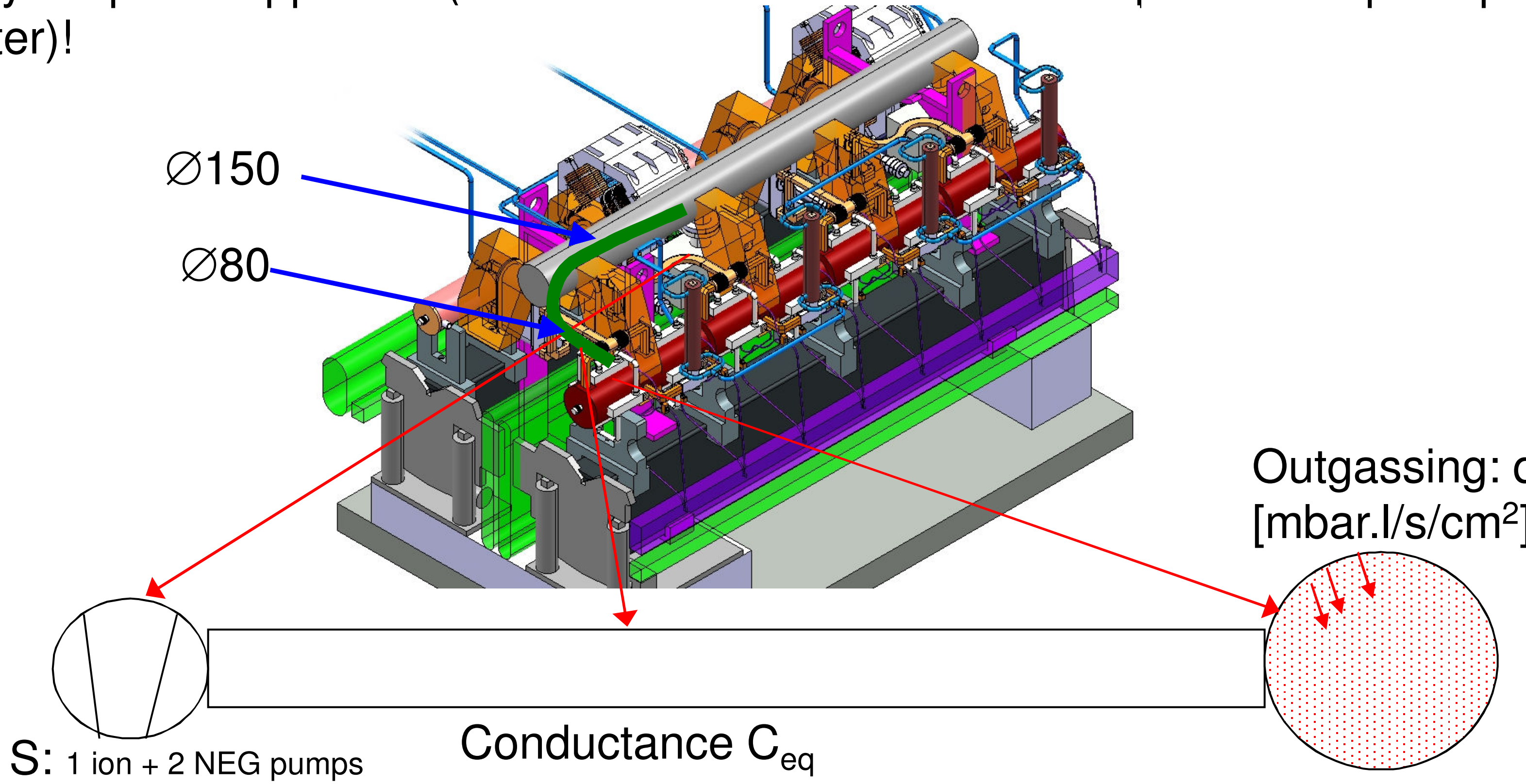
→ pumping system: mobile turbomolecular station + holding ion and cartridge pumps



Pumping system performances: static vacuum

Non standard system with small conductances

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~10^{-10}mbar.l/s/cm^2 (after 100 hours of pumping), area~2800cm^2/AS

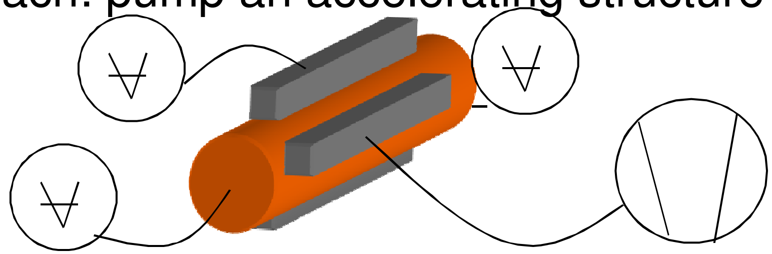
→ P_{100h}~6E-9 mbar

Pumping system performances: static vacuum

Program of study

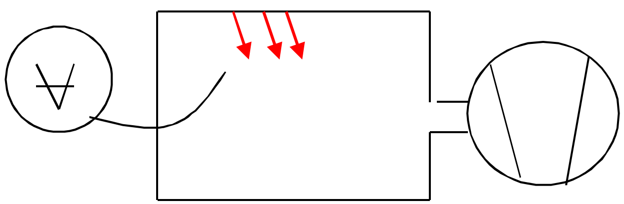
Study at 3 different levels:

- global approach: pump an accelerating structure



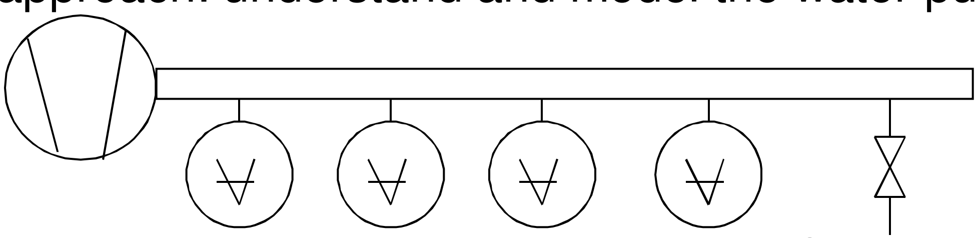
P=f(t,S,geometry)

- semi global: measure of the apparent outgassing rate



q(t)=P.S/surface

- Local approach: understand and model the water pumping process



Desorption/adsorption phenomenon including coverage, residence time study

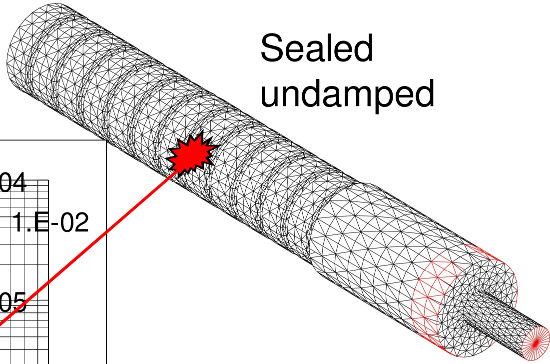
Dynamic vacuum in the accelerating structures

Assumptions:

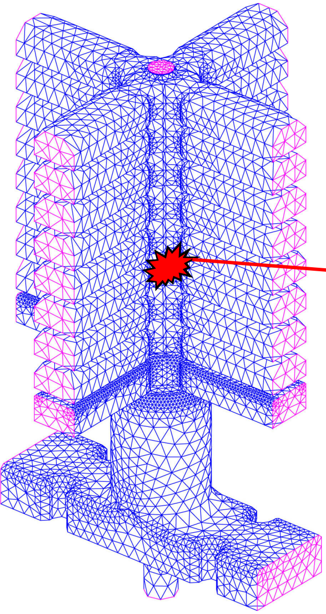
- 10^{12} H_2 molecules released during a breakdown
- Gas is at room temperature (conservative)

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

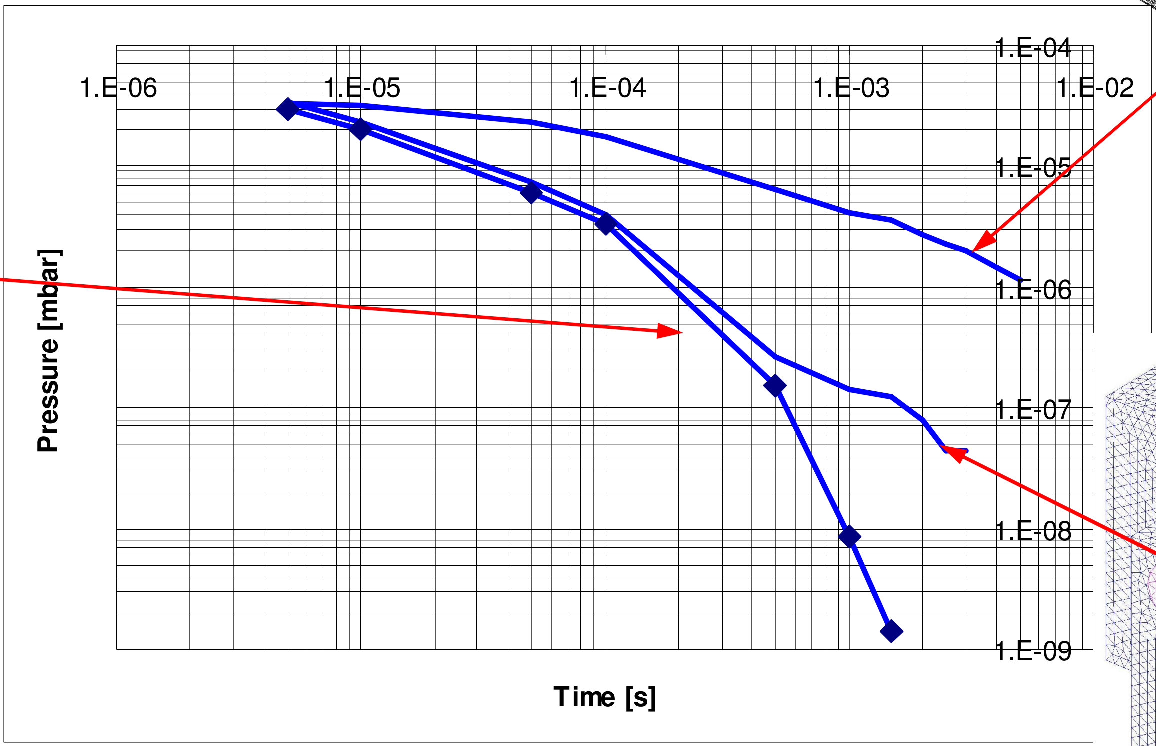
Monte Carlo simulation implemented in a FE code (Castem)

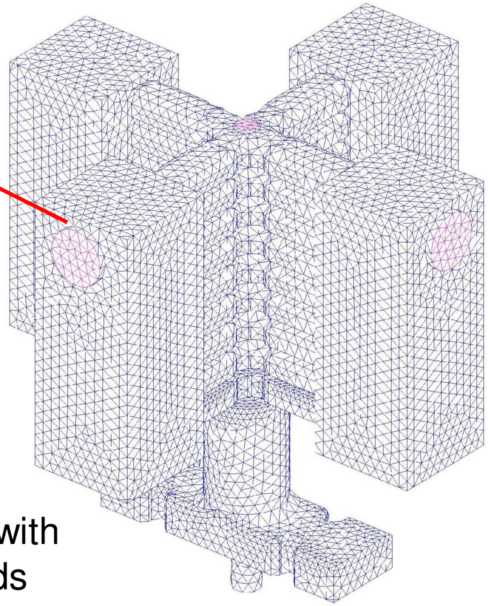


Sealed undamped



Sealed in tank





Sealed with manifolds

Pumping system – General layout

Vacuum system sectorisation

Why a sectorisation?

- Piece wise installation/commisionning
- Ease local intervention for machine maintenance
- Ease localisation of leak
- Containment of accidental vacuum degradation

A manageable sector of 200m for the main linac. Sectors valves have to be installed on both beams at the same locations.

Interconnections

General considerations

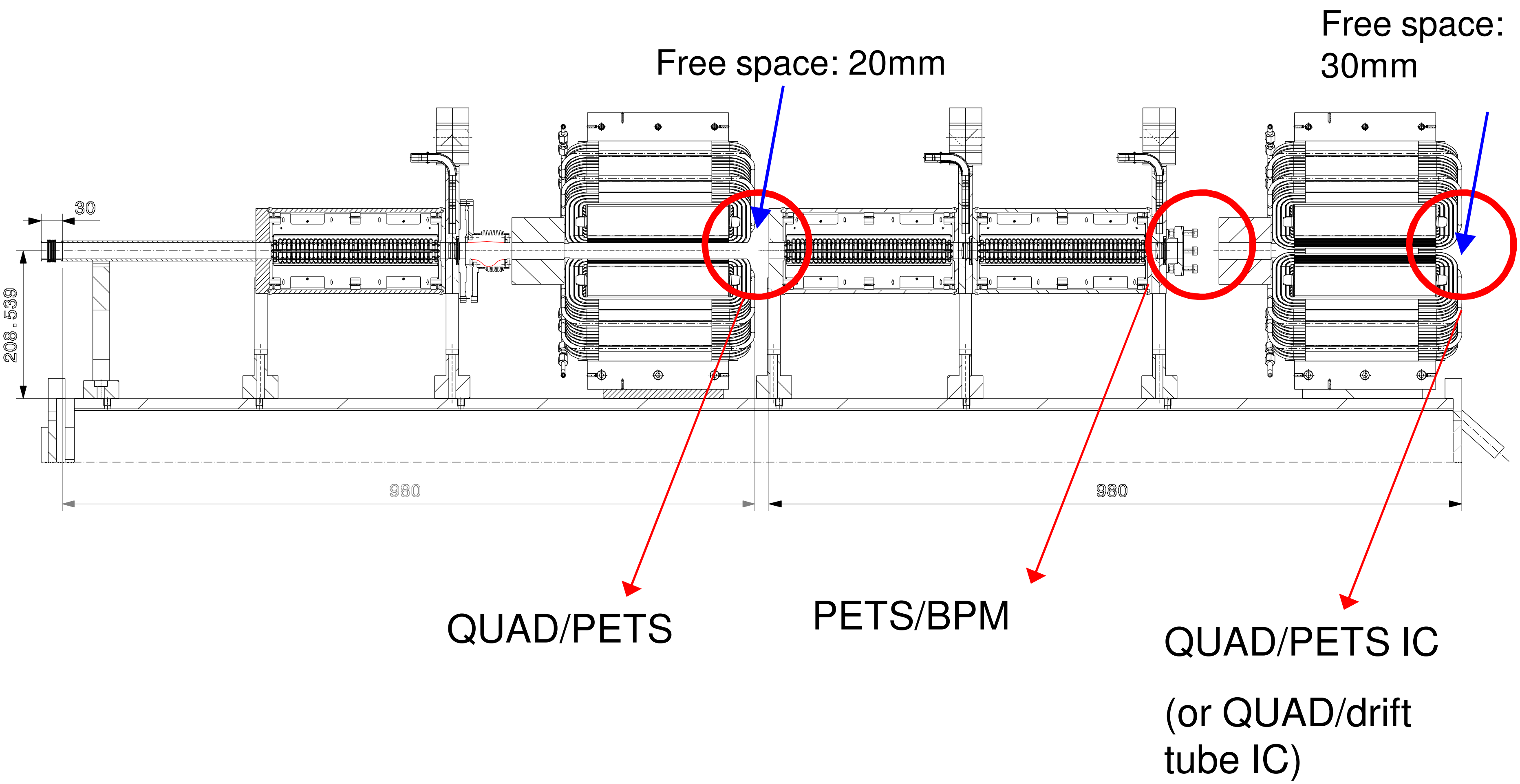
Spec: 975234

- adjustment capability (maximum stroke for intermodule interconnections): ~0.27mm longitudinally, ~0.36 mm transversally
- lifetime: 1000 cycles for main beam, 10000 cycles for drive beam (TBMWG 20/7/09)

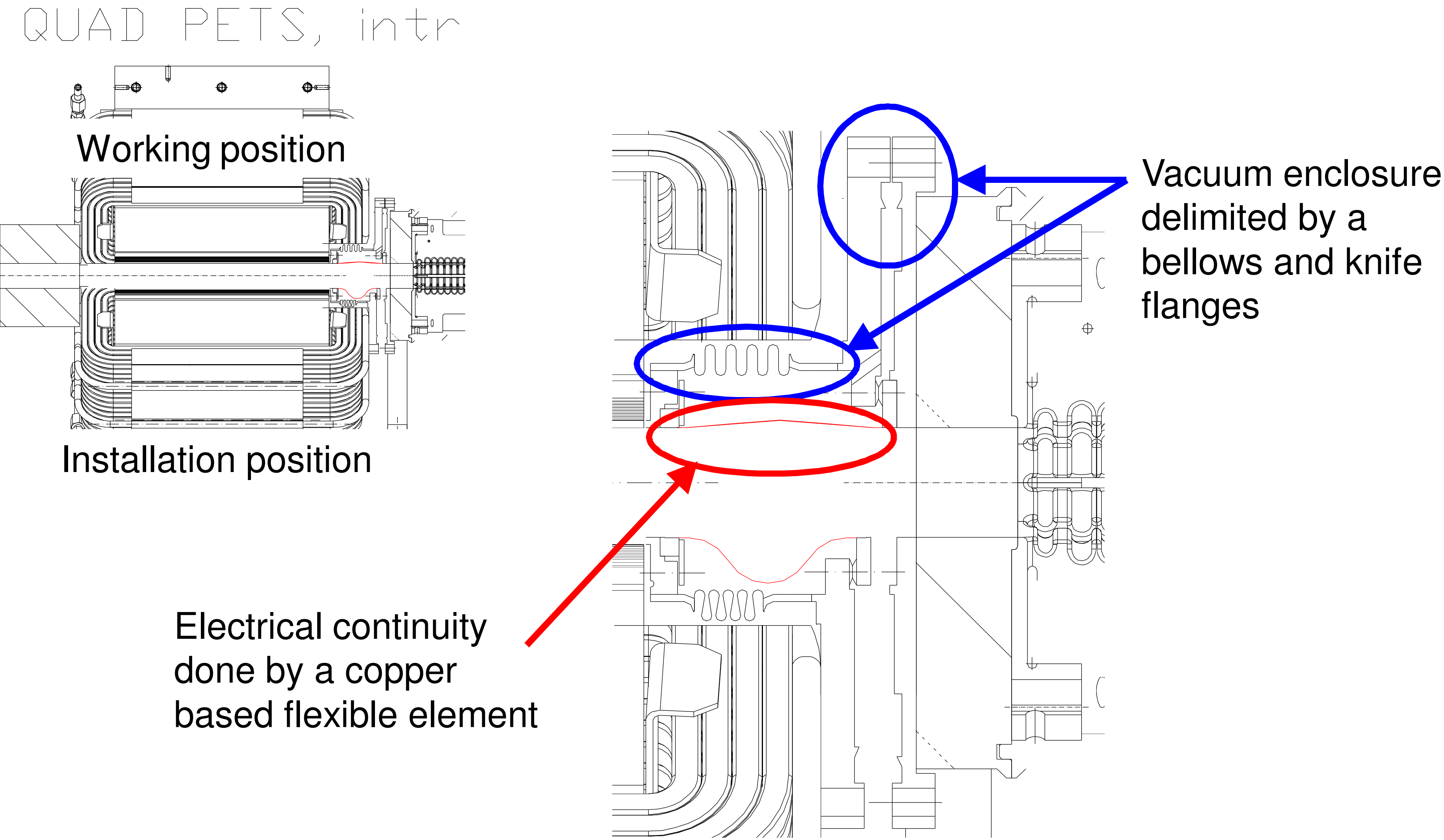
Non-exhaustive list of points to be considered:

- leak tightness
- RF/electrical continuity
- flexibility/uncoupling (w.r.t. which displacements)
- accessibility
- in-situ or pre-assembly
- dismounting possibility? How many time? Cleanness?
- reliability

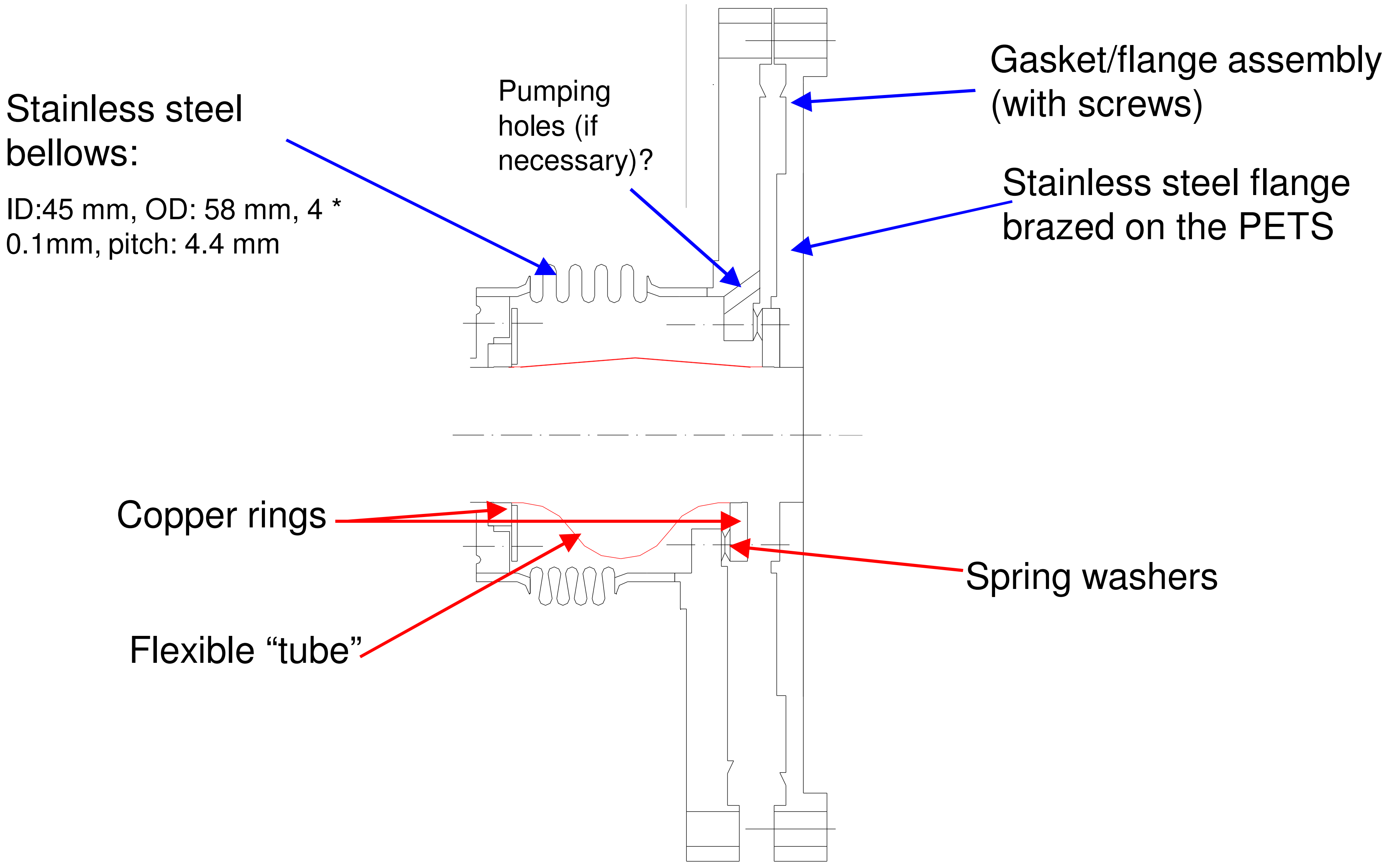
Interconnections - Drive beam



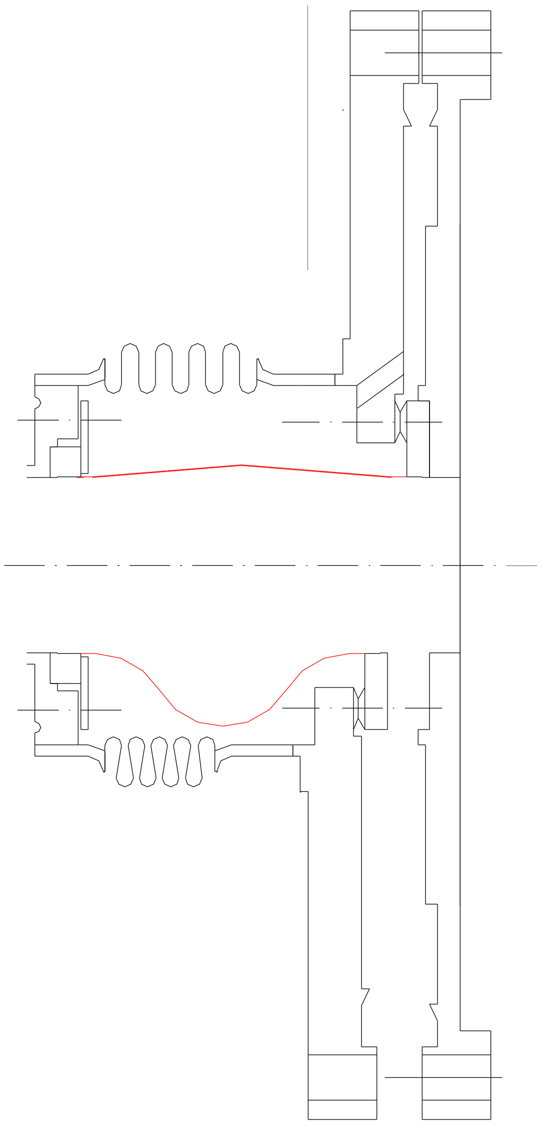
Drive beam – QUAD/PETS intramodule interconnections

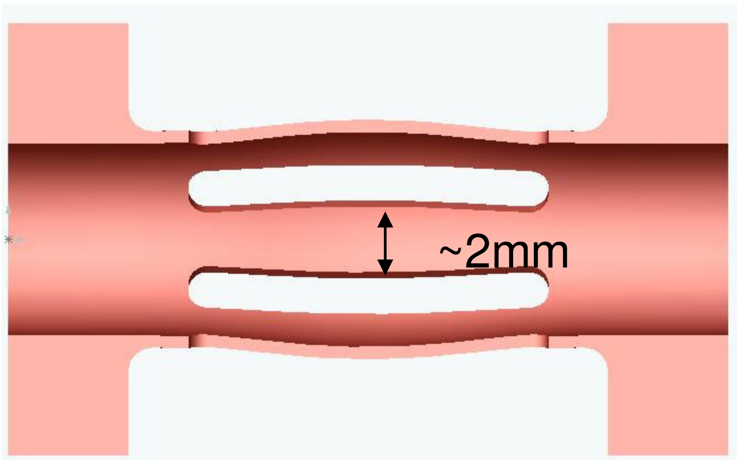


Drive beam – QUAD/PETS intramodule interconnections



Drive beam – QUAD/PETS intramodule interconnections

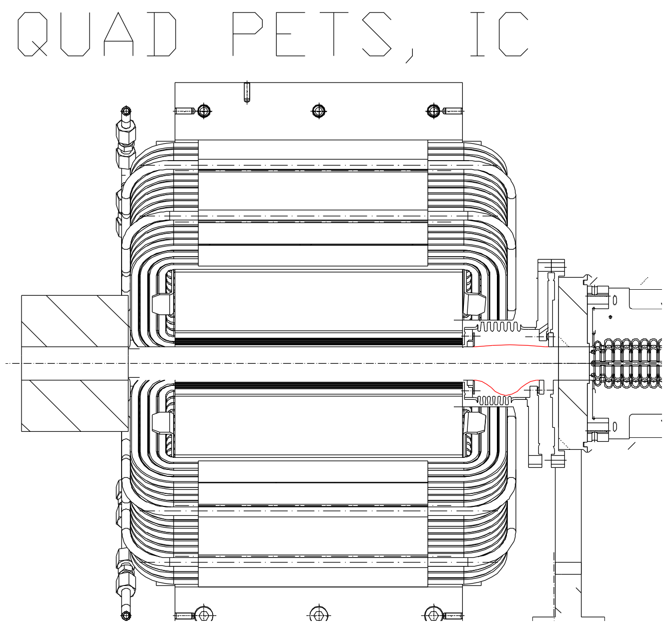


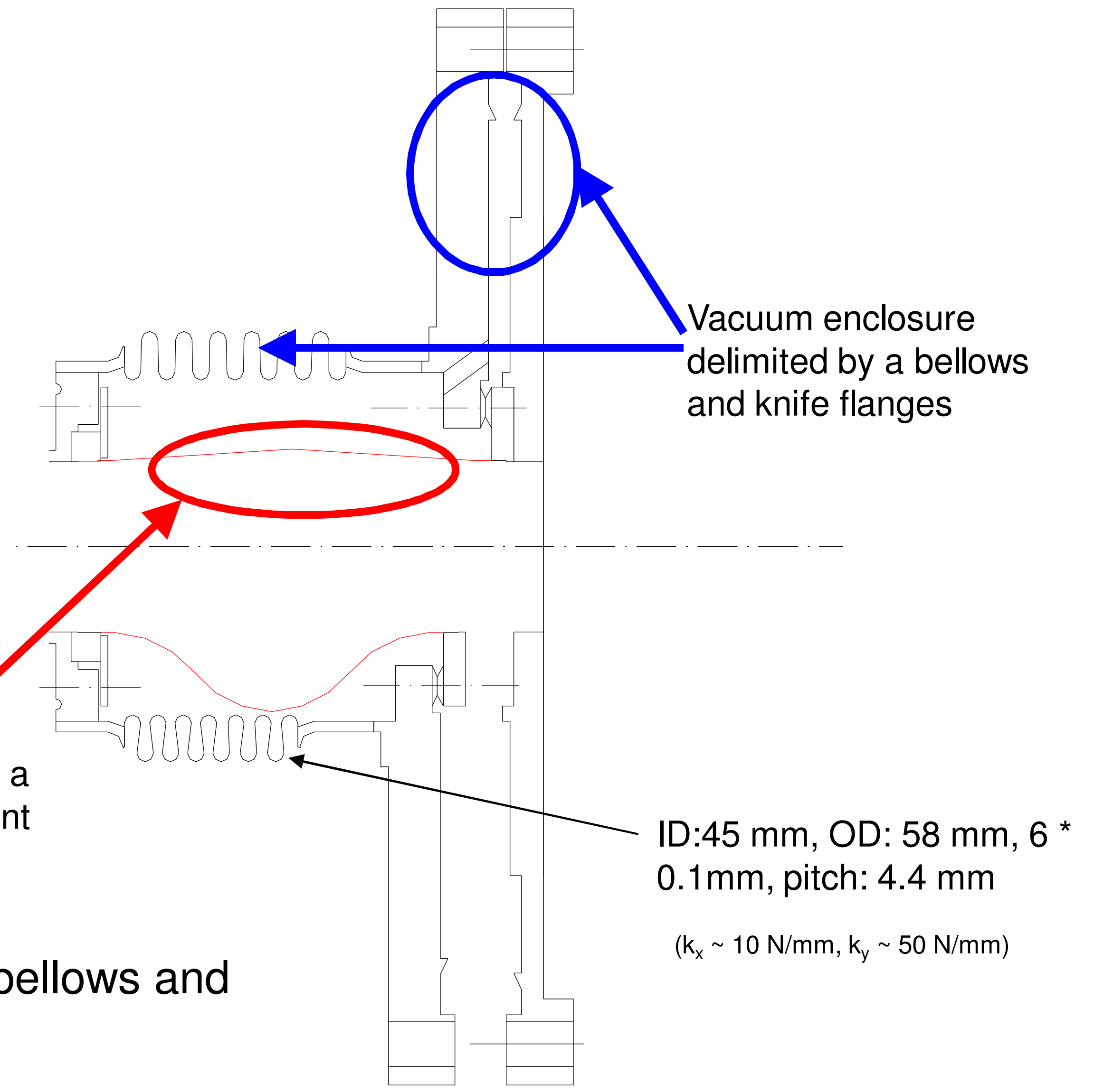


Schematic artistic view of the flexible element

Thin foil (0.1mm) in copper based material

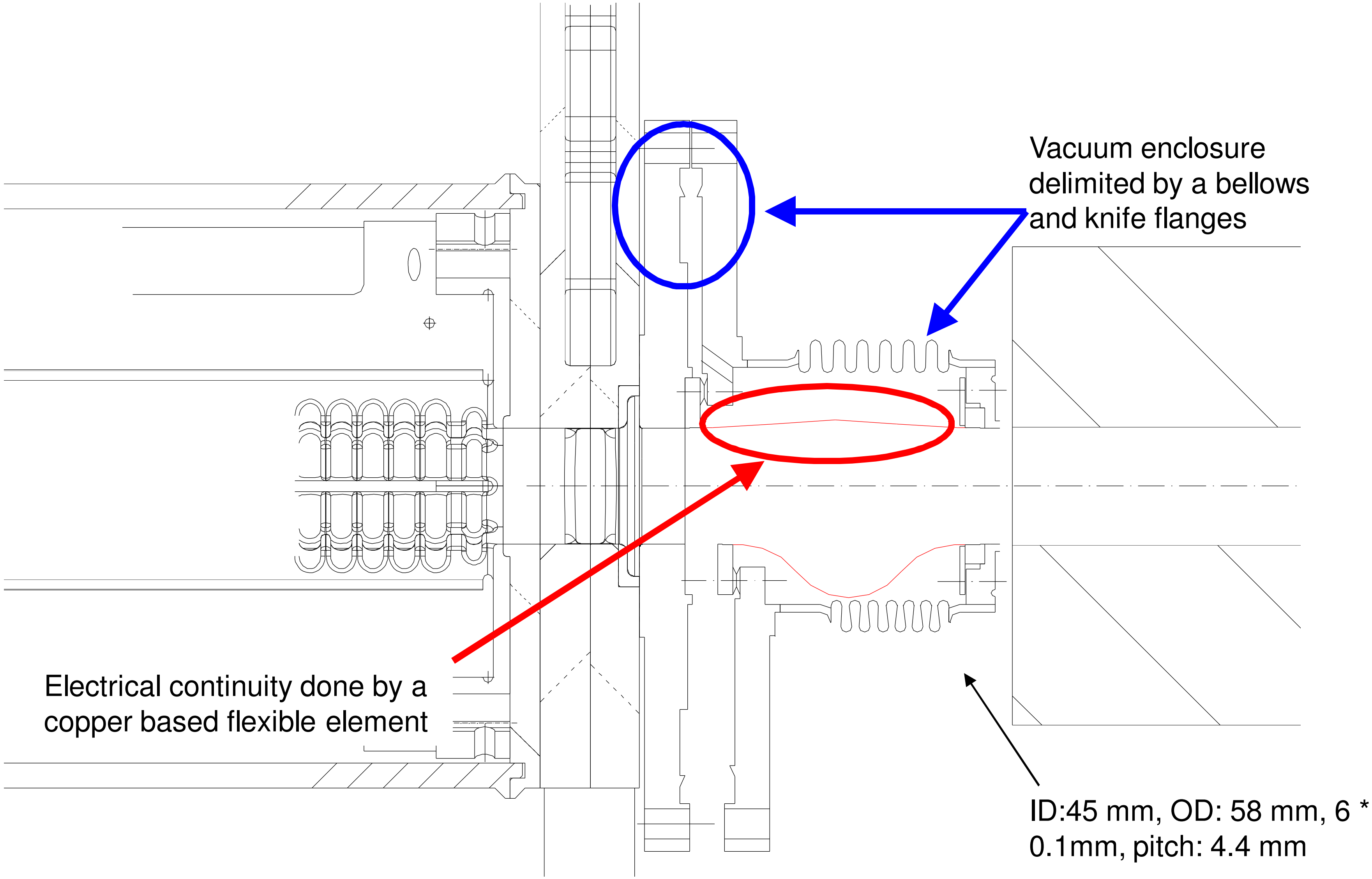
Drive beam – QUAD/PETS intermodule interconnections





Same components with longer bellows and flexible element

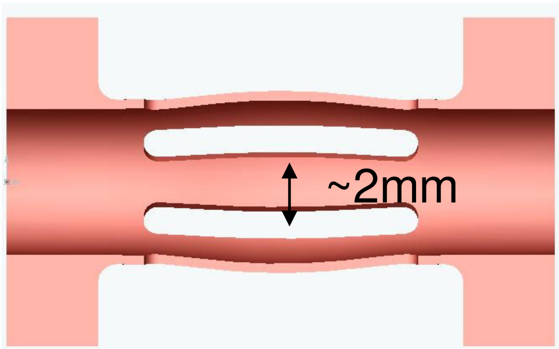
Drive beam –PETS/BPM intramodule interconnections



Same components as QUAD/PETS intermodule interconnections except flange on PETS side

Drive beam interconnections

Fatigue life of flexible elements and material choice



Schematic artistic view of the flexible element

Rough estimations of strains:

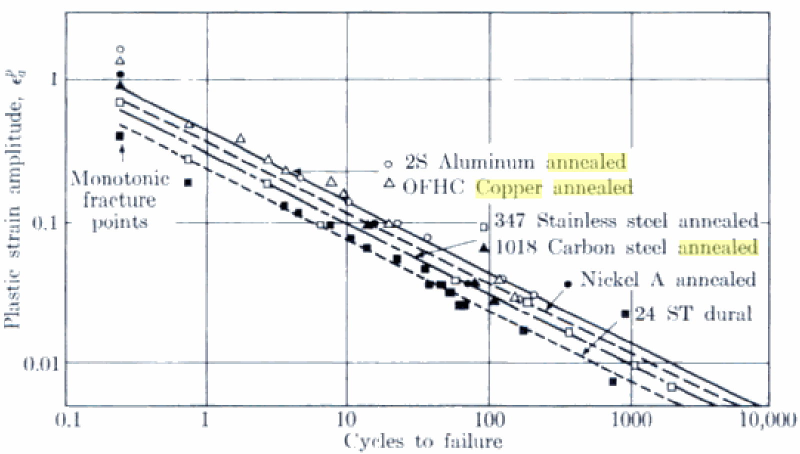
•Installation cycle: ~1%

•Axial cycle (thermal cycle): ~0.1%

•Transverse cycle (0.36 mm): ~0.3%

Simple Manson Coffin law:

$$\Delta\varepsilon^{P} N_f^{\beta} = cst$$



0.14. Courbes de Manson-Coffin pour divers alliages métalliques.

<u>Assumptions:</u>

10 “installation” cycles

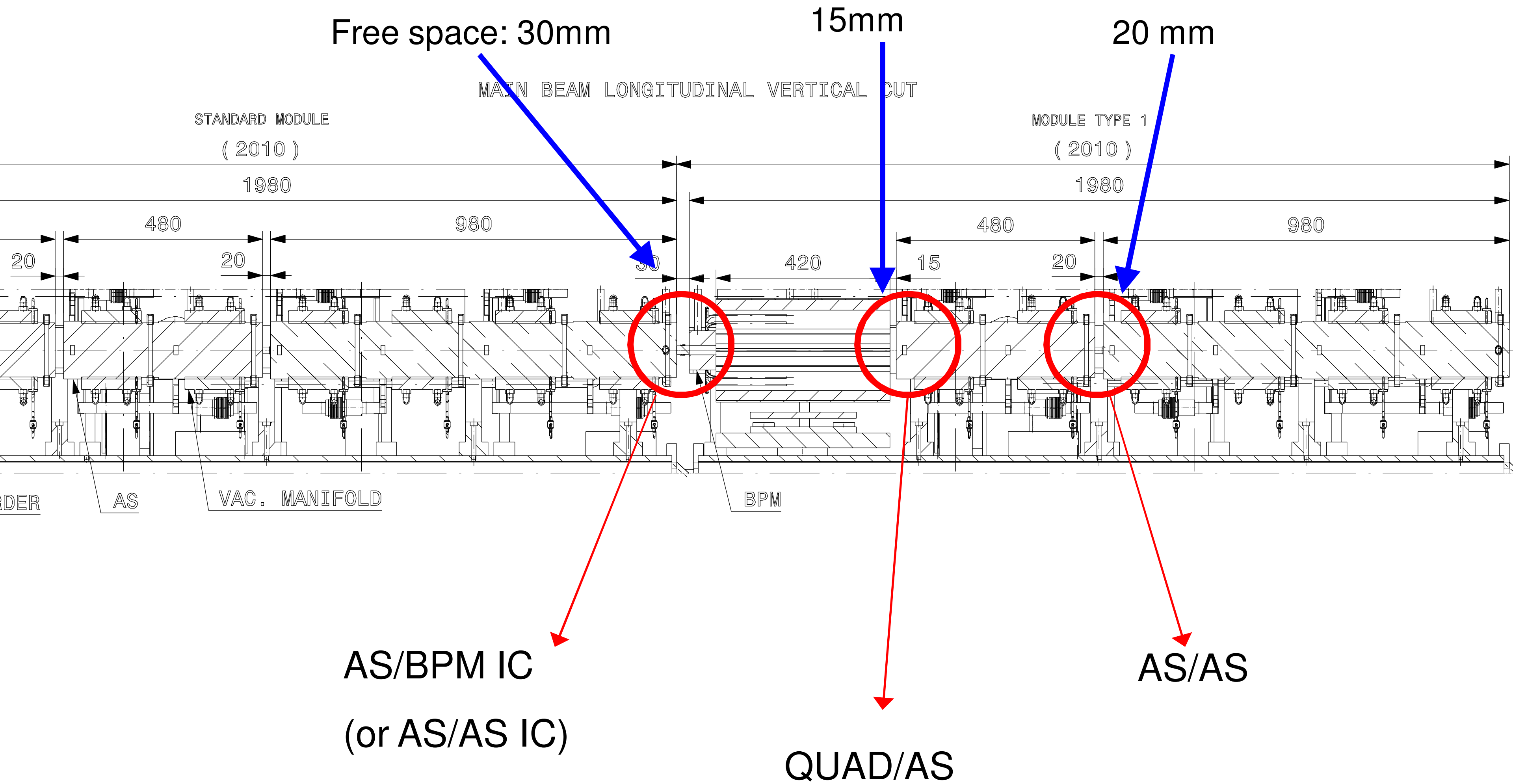
Miner Law (linear cumulative damage)

→Number of cycles to failure: ~9800

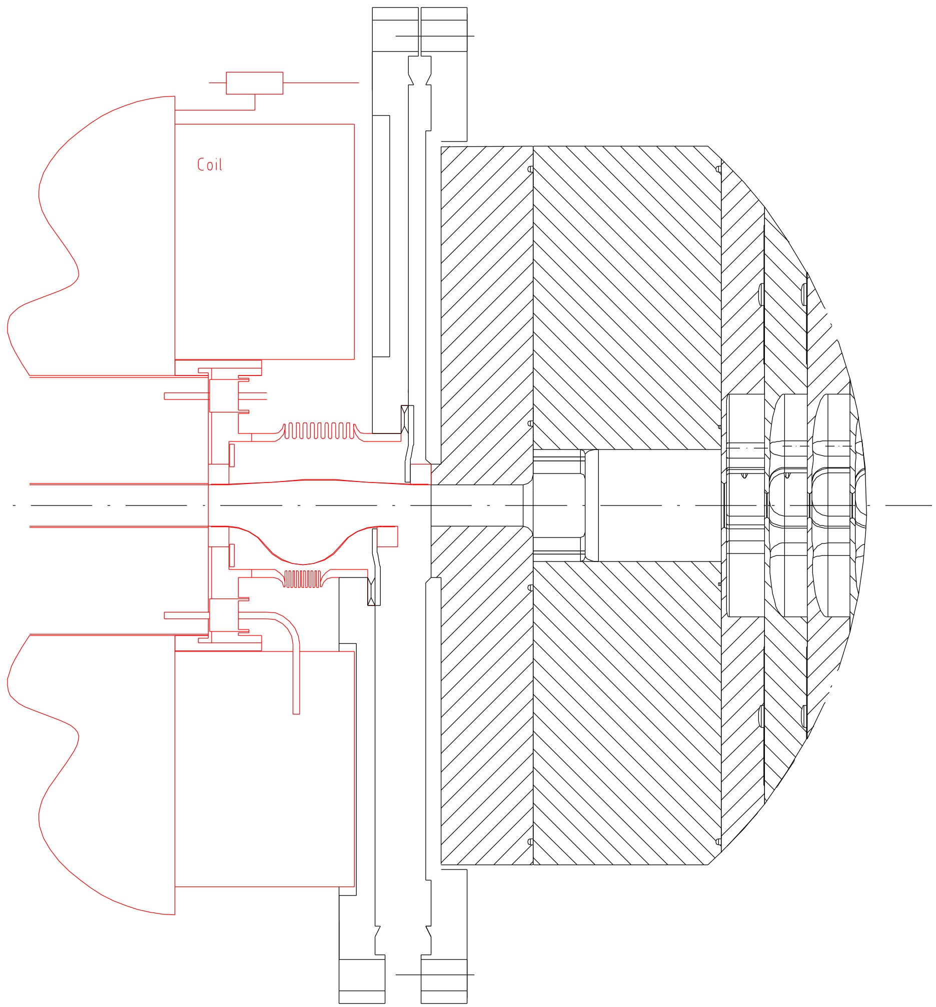
Numbers of cycles in the range of the specification (10000 cycles) for OF copper but structural ratcheting is not studied.

Superellastic alloy (CuAlBe) could improve the behavior (to be discussed)

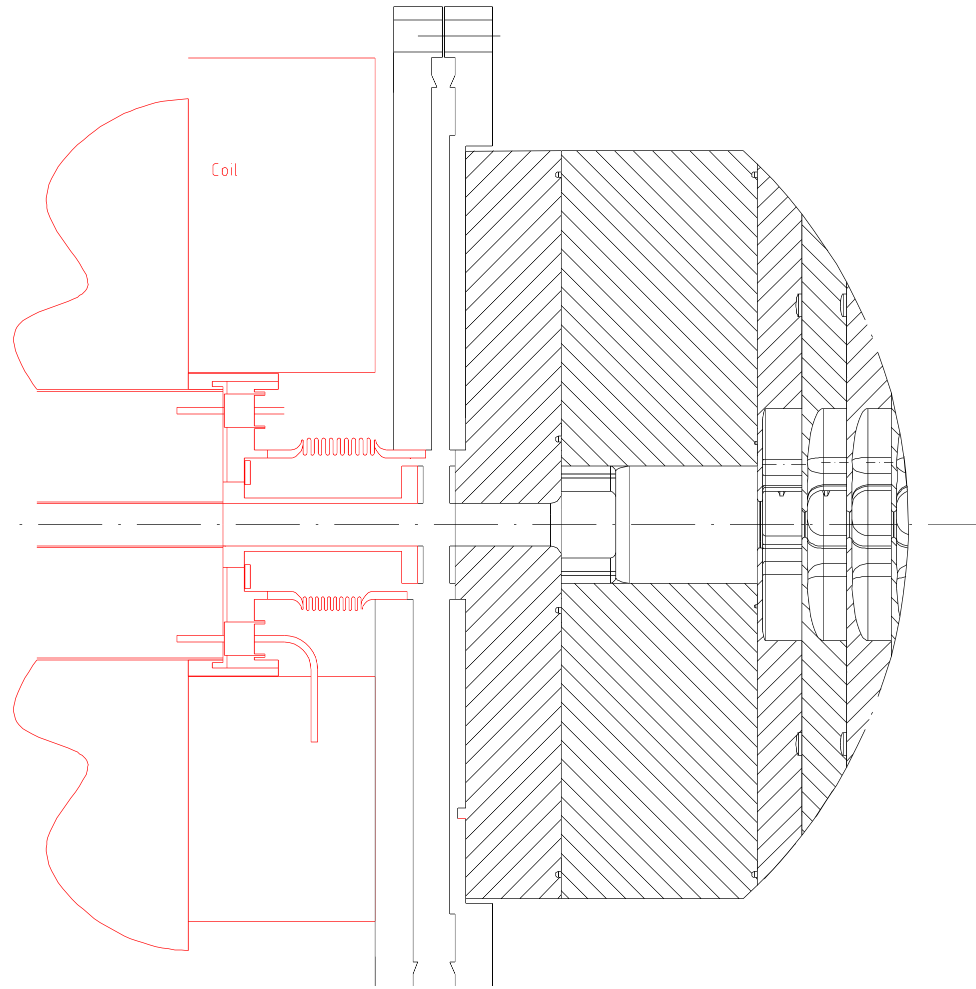
Interconnections - Main beam



Main beam – QUAD/AS intramodule (intermodule) interconnections



Continuous solution

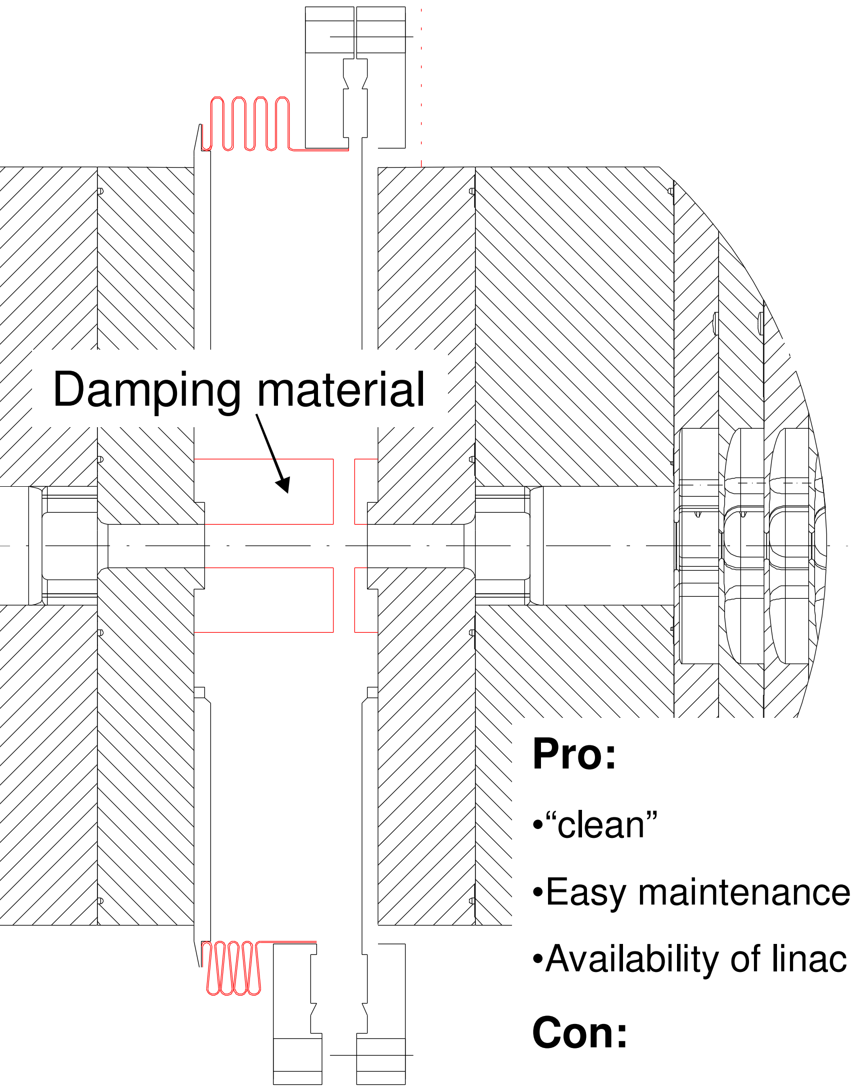


Solution with a gap and damping material (under study)

QUAD/AS intermodule is the same with longer bellows and flexible element

Main beam – AS/AS intermodule interconnections

Sealed version with gap



Pro:

•“clean”

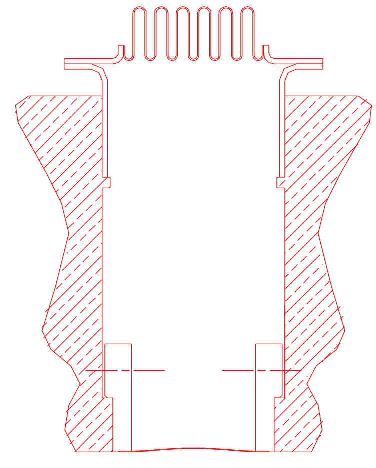
•Easy maintenance

•Availability of linac (procedure tbs)

Con:

RF properties (to be checked)

Welded version with flexible element



Pro:

Good RF continuity

Con:

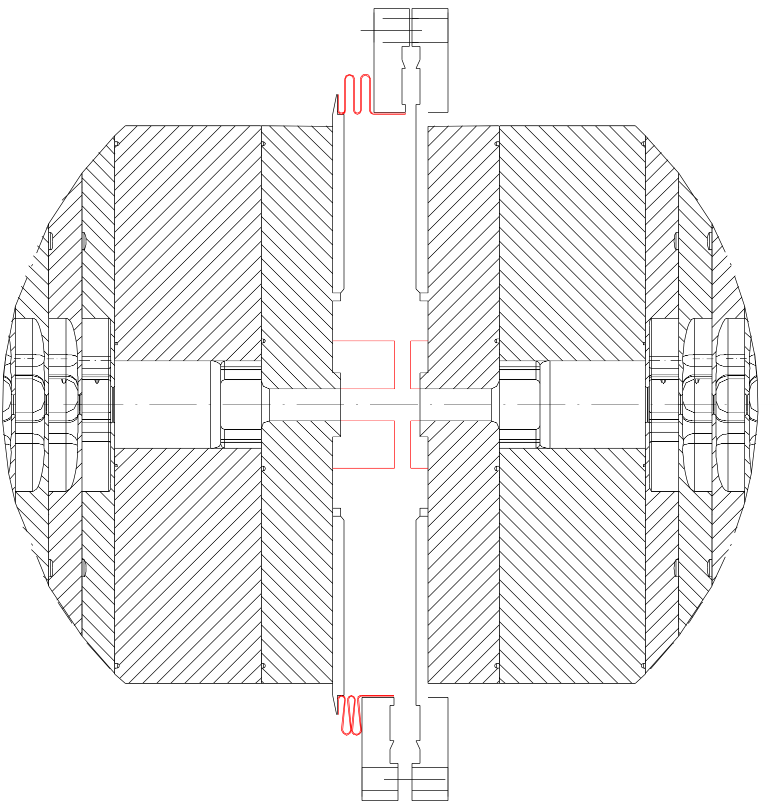
•“dirty”

•Specific tooling (welding and cutting machine)

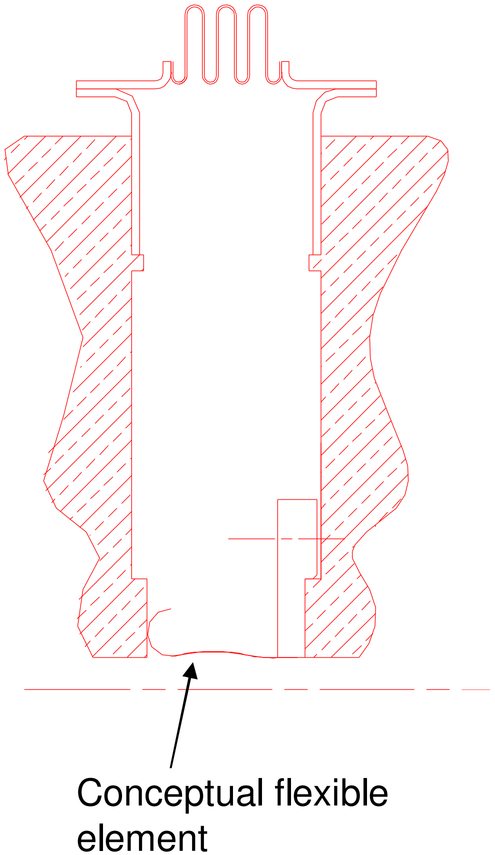
•Axial and radial space needed

Main beam – AS/AS intramodule interconnections

Sealed version



Welded version

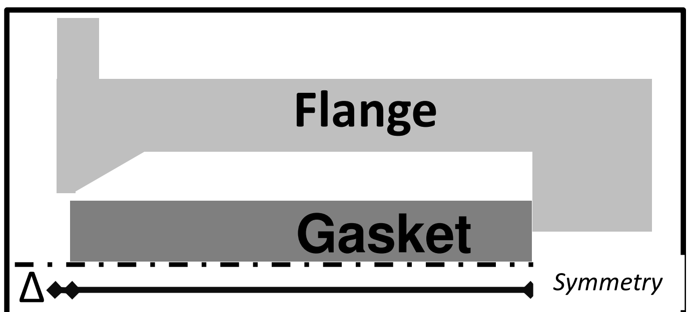


Interconnections – inter beam waveguide flanges

Existing SLAC design:

- non symmetric gasket cross section
- Two different flanges
- sealing mechanism by shearing

A new design has been proposed to reduce the RF attenuation (smooth transition) and the cost



New CLIC design concept

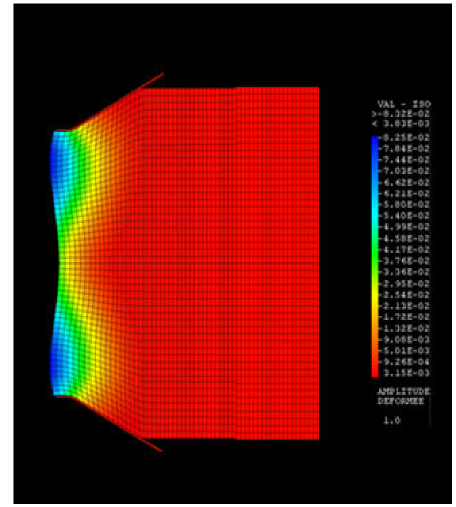
- Optimization has been done
- Prototypes have been manufactured

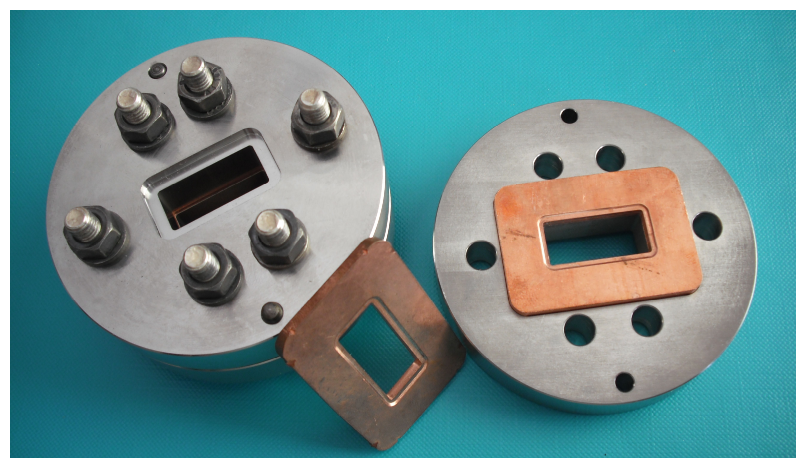
- FE model

→Gasket deformation

→Plastic strain field

→Contact pressure





Interconnections – inter beam waveguide flanges

Qualification tests are on going:

- Leak tightness tests

  3 standard leak tightness tests: OK

  3 severe leak tightness tests with thermal shocks: OK

- Geometrical tests

  On going

- RF tests

  3 samples in preparation

  Tests at CERN (low power) and at SLAC

Conclusion

Concepts for the vacuum system and the interconnections exist. Few questions are pending.

Mock up for the pumping of the accelerating structures is being prepared.

Alternatives for the main beam interconnections have been showed. Sealed version could be preferred for this application. Welded solutions seems risky.

Copper based shape memory alloys could be used for interconnection components and have to be studied.

Prototypes for interconnections elements have to be done.

Concepts are ready for implementation in 104 modules. Vacuum quality could be validated in the 104 modules (Integration of instrumentation to foresee).