Mechanical design considerations for beta=1 cavities

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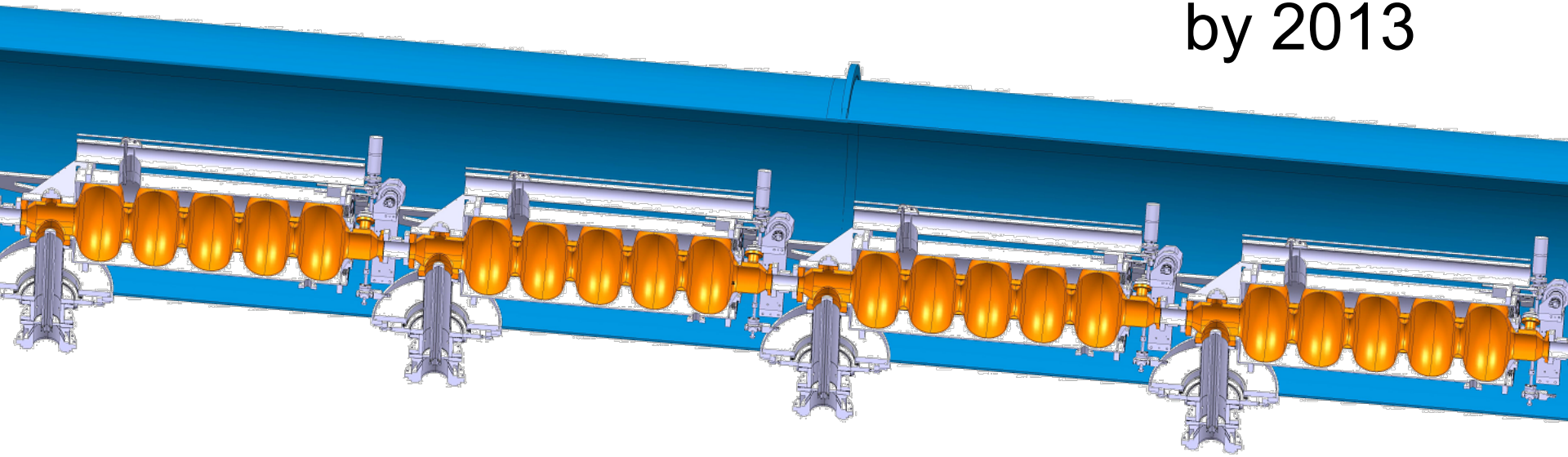
Introduction

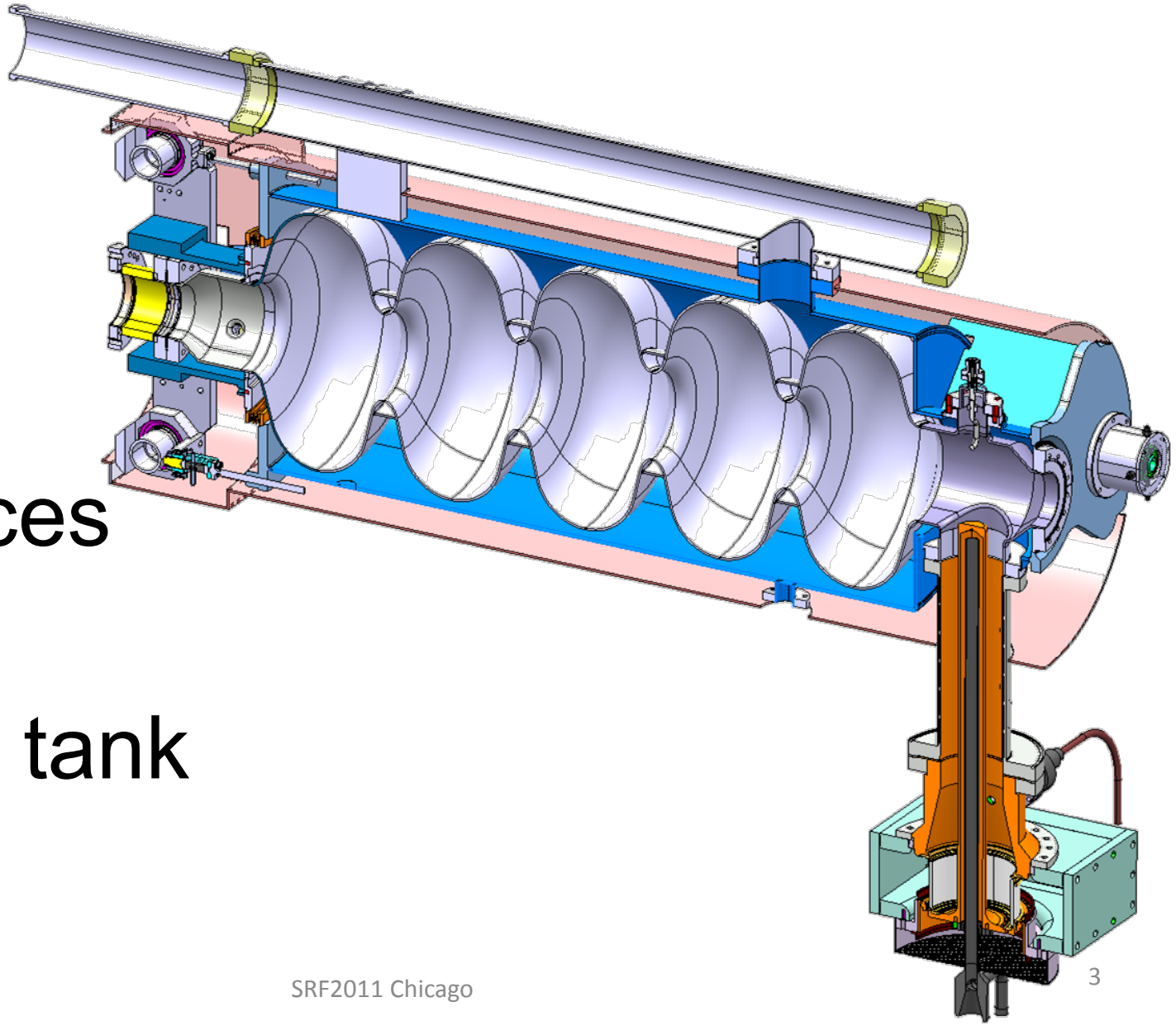
- Talk illustrated by SPL cavities development
- A string of 4 equipped beta=1 bulk niobium cavities to be installed into a short cryo-module by 2013



- G. Olry talk today on *"SPL Cavity Development"*
- J. Plouin poster on Monday *"Optimized RF design of 704 MHz beta=1 cavity for pulsed proton drivers"*

Overview

- Cavity
- Interfaces
- Helium tank

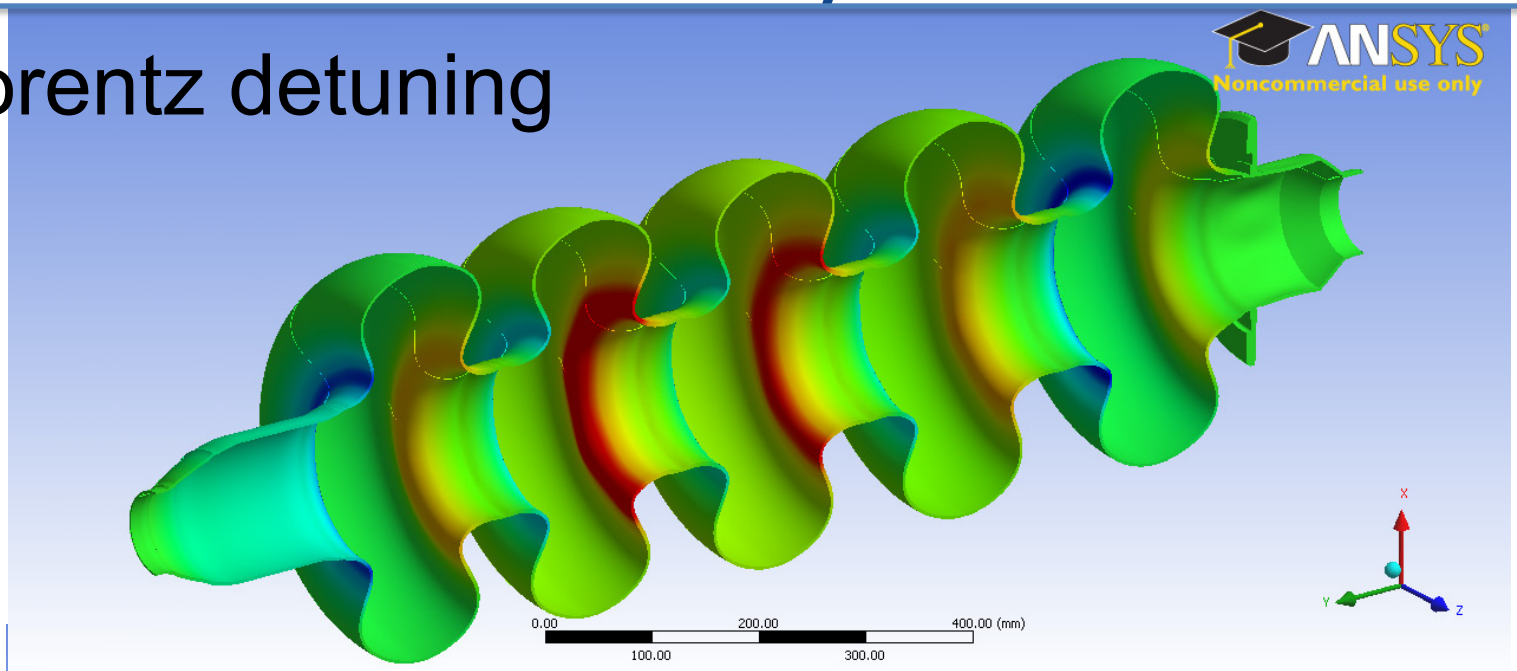


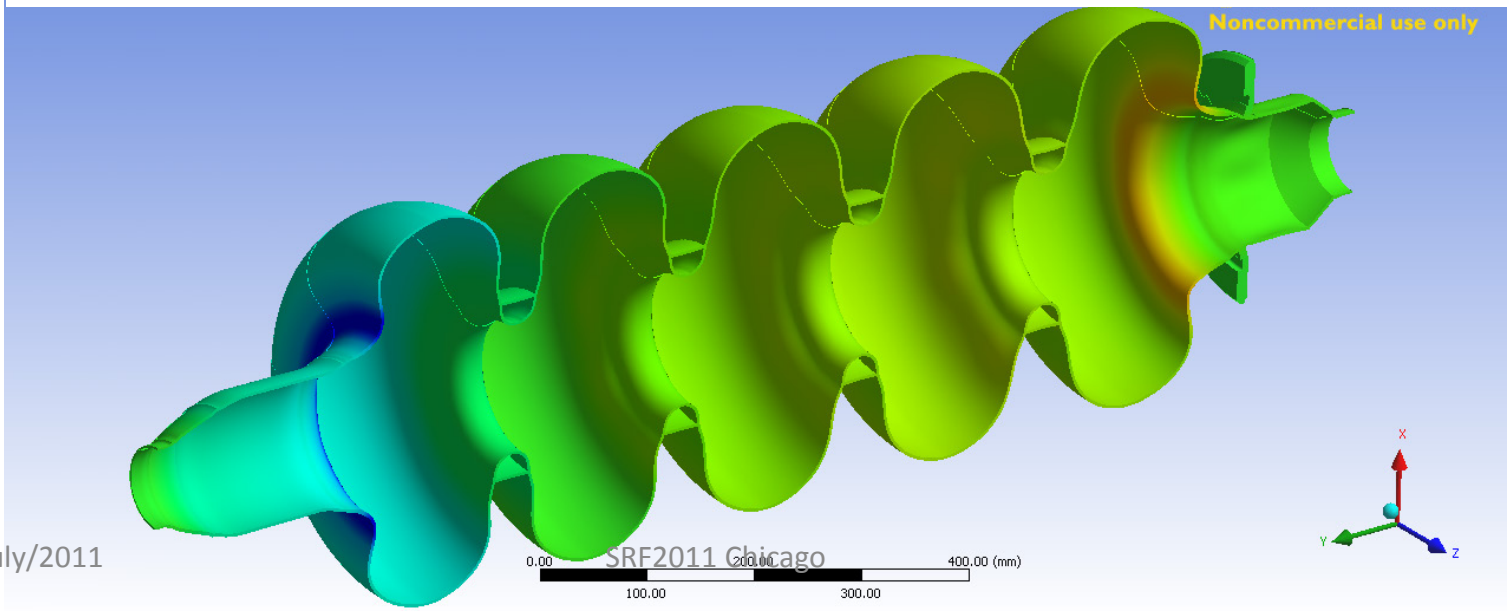
Cavity

- Mechanical dimensioning
  - Static (quasi-static)
    - Lorentz detuning
    - Maximum pressure / sensitivity to fluctuation
    - Deformation for tuning
    - Handling configurations
  - Natural vibration modes
  - Bucking

Cavity

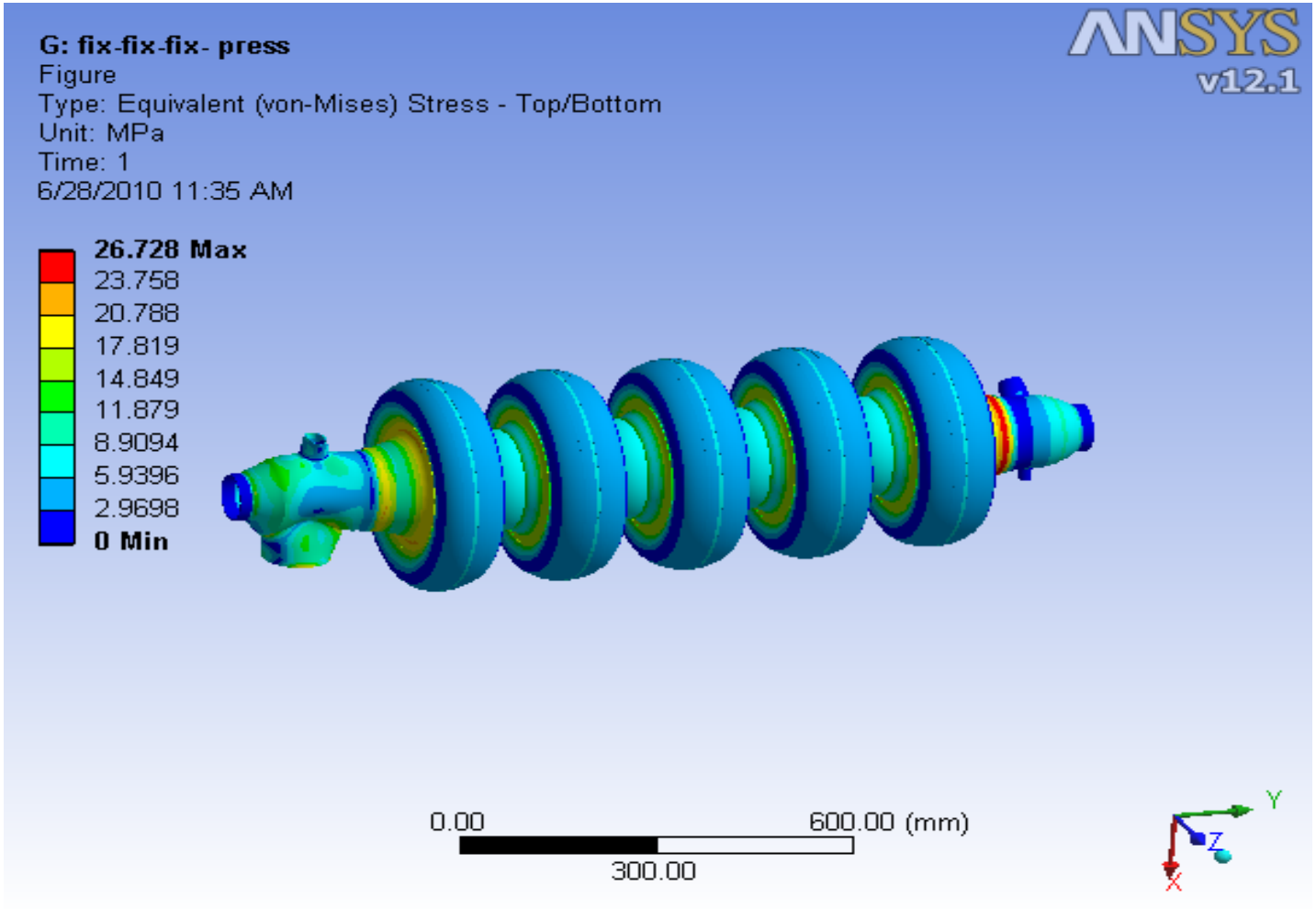
- Lorentz detuning





Cavity

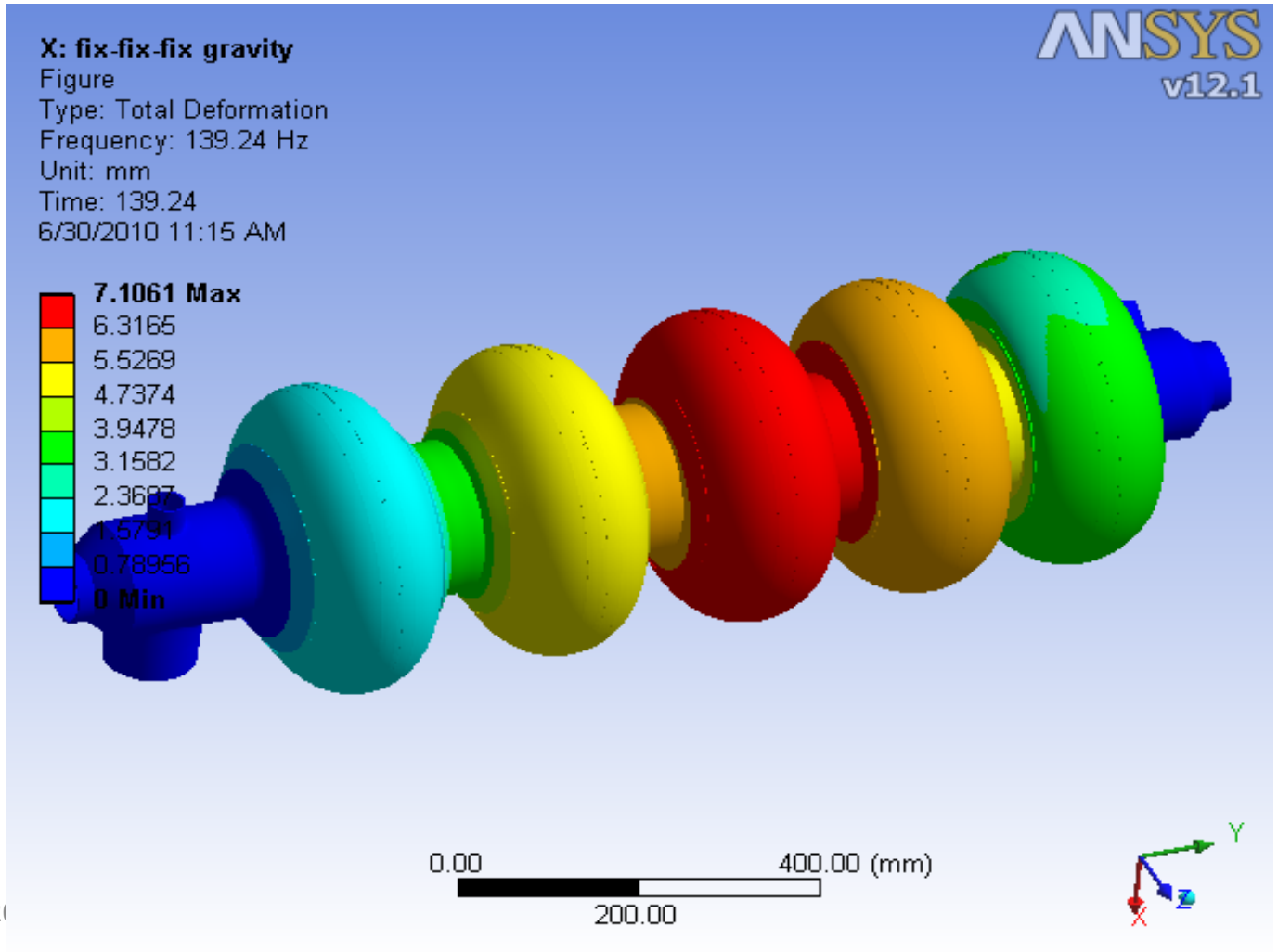
- External pressure of 2 bars – fix-fix boundary condition



- Sensitivity to pressure fluctuations => one order of magnitude lower that the frequency bandwidth

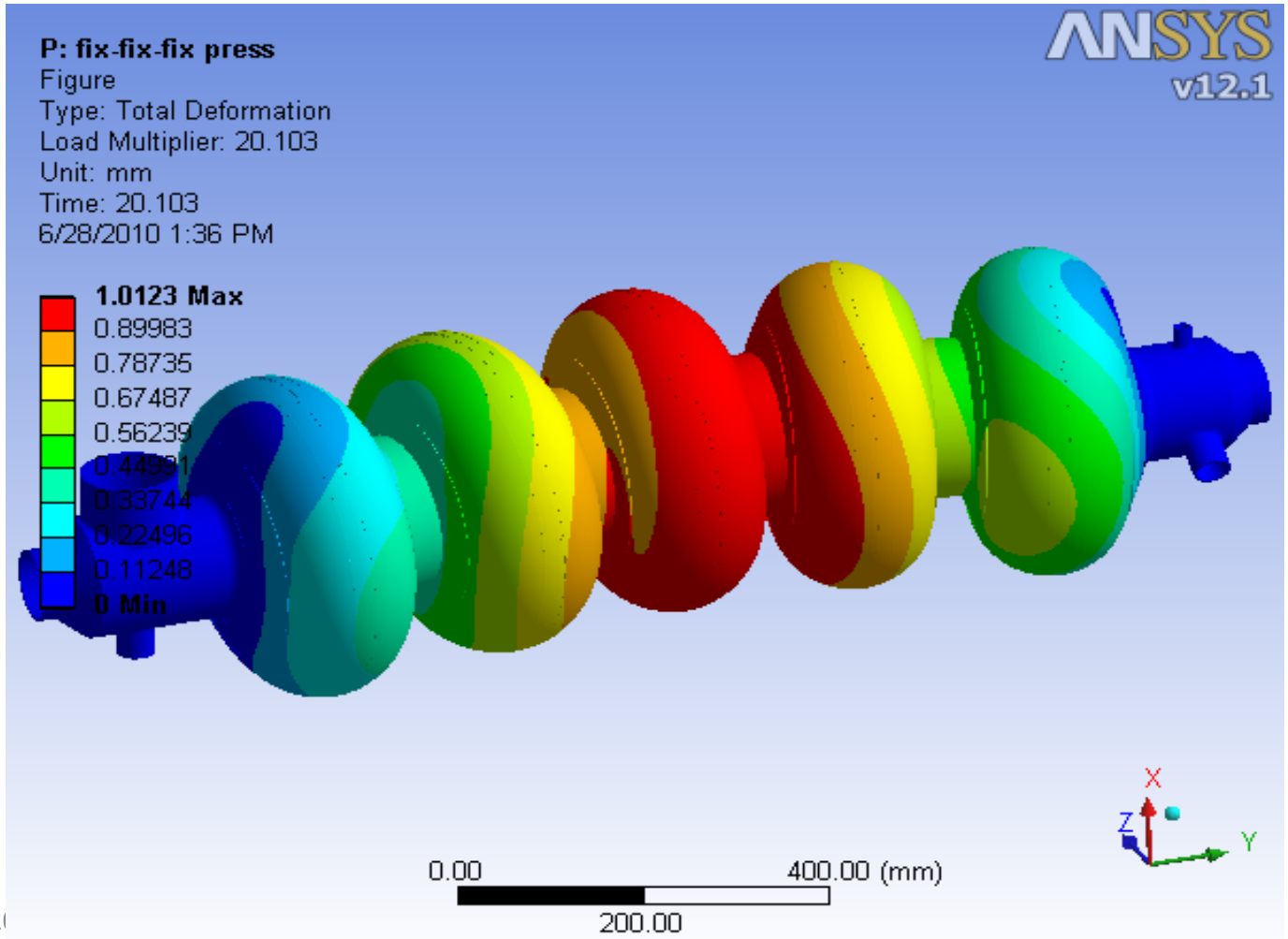
Mechanical behaviour for real dimensions

- Dynamic (natural frequencies):
  - First longitudinal mode at ~140 Hz



Mechanical behaviour for real dimensions

- Bucking under external pressure for fix-fix boundary conditions: security factor 20



Cavity

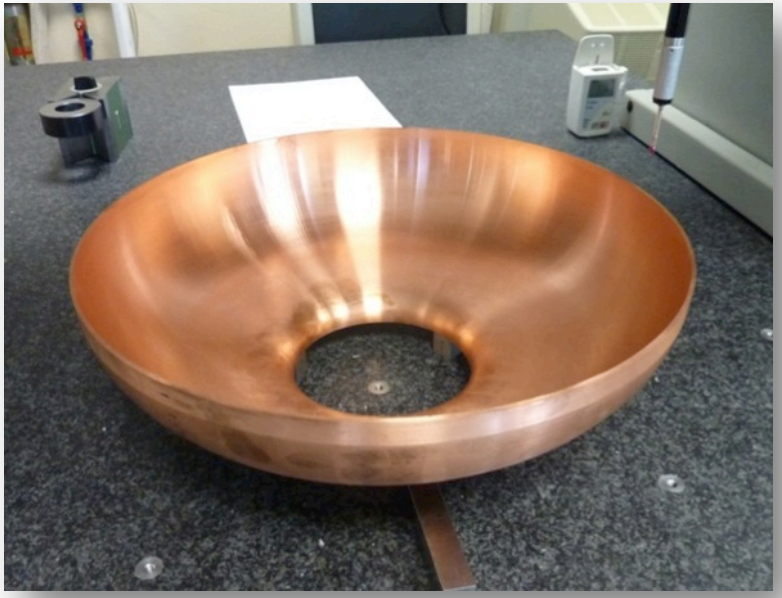
- Manufacture technology chosen: spinning + EB welding
- First manufacturing tests results
  - Spinning => loss in thickness non uniform up to 0.6 mm

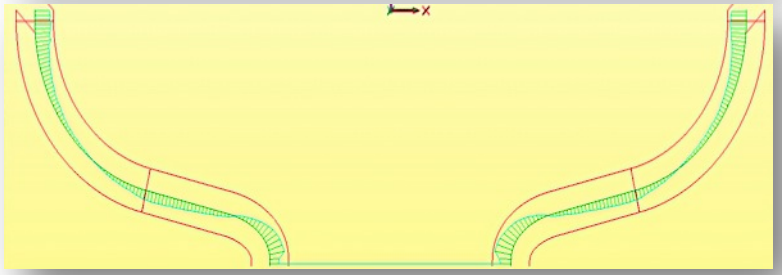


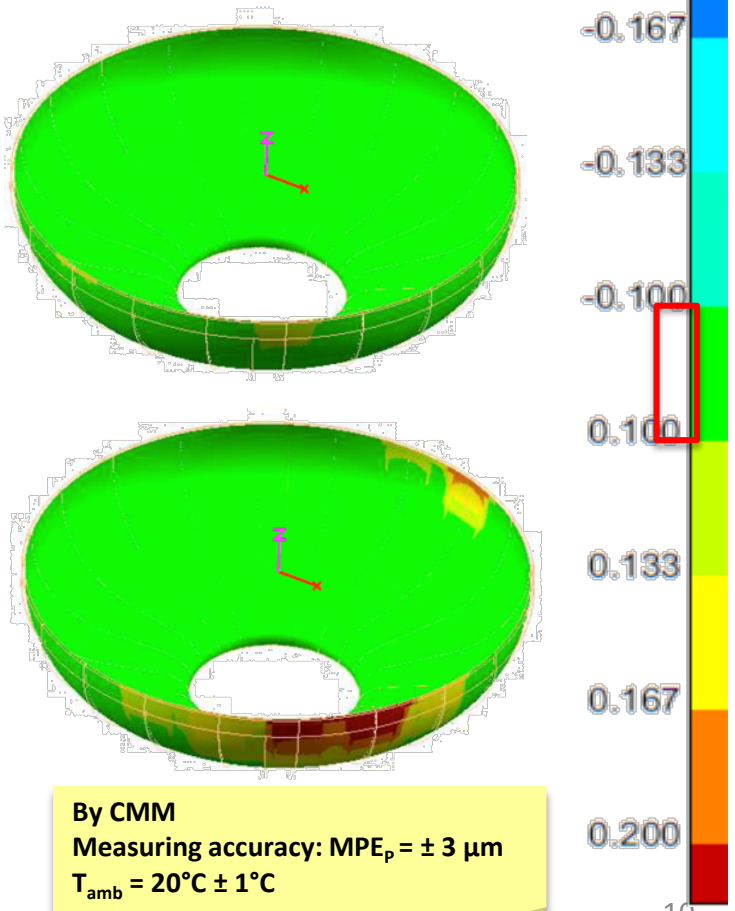
Cavity

The average shape accuracy achieved is 0.150 mm

The best half cell: shape accuracy 0.100 mm

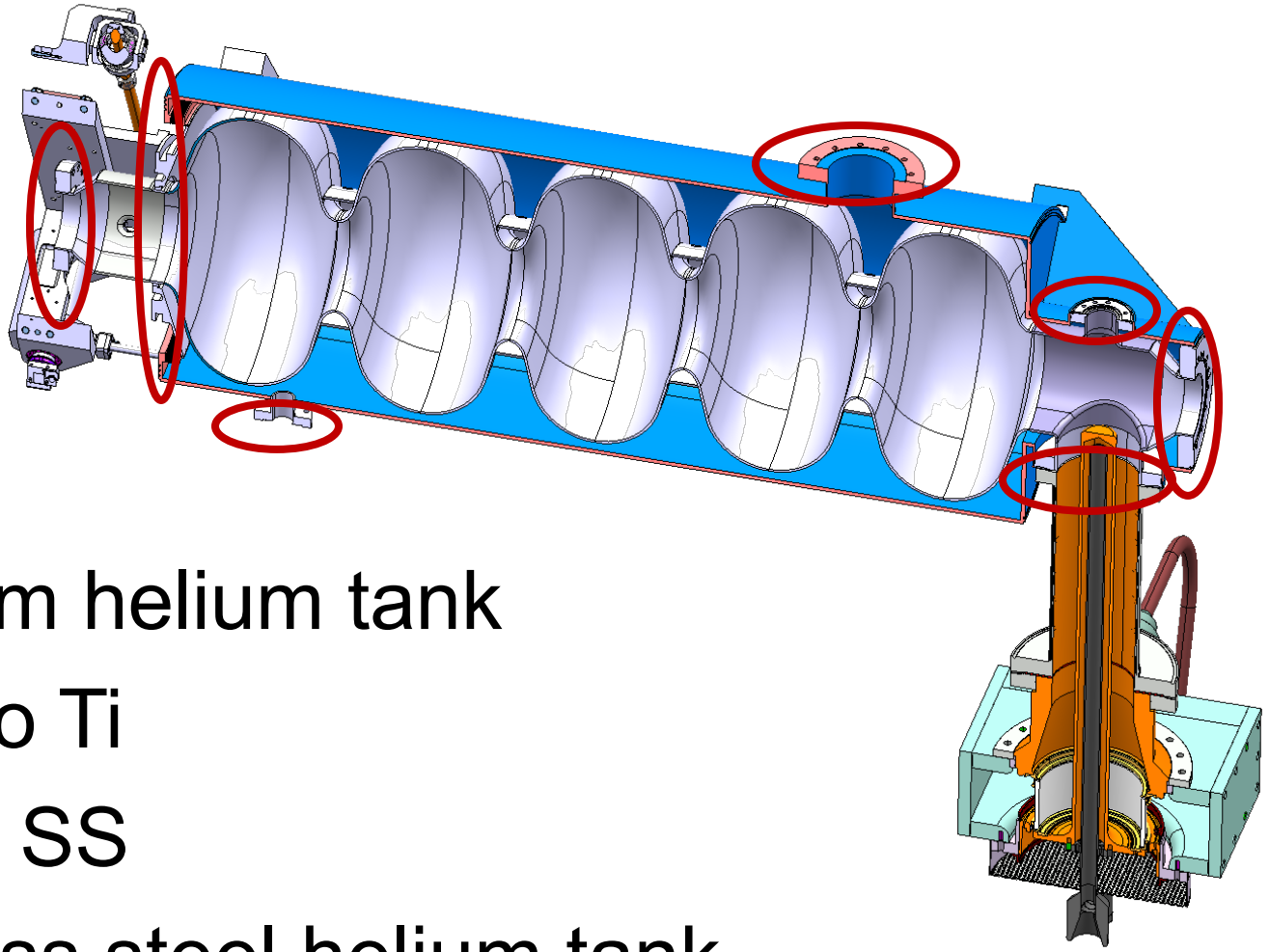






By CMM
Measuring accuracy: MPE_p = ± 3 µm
T_{amb} = 20°C ± 1°C

Interfaces



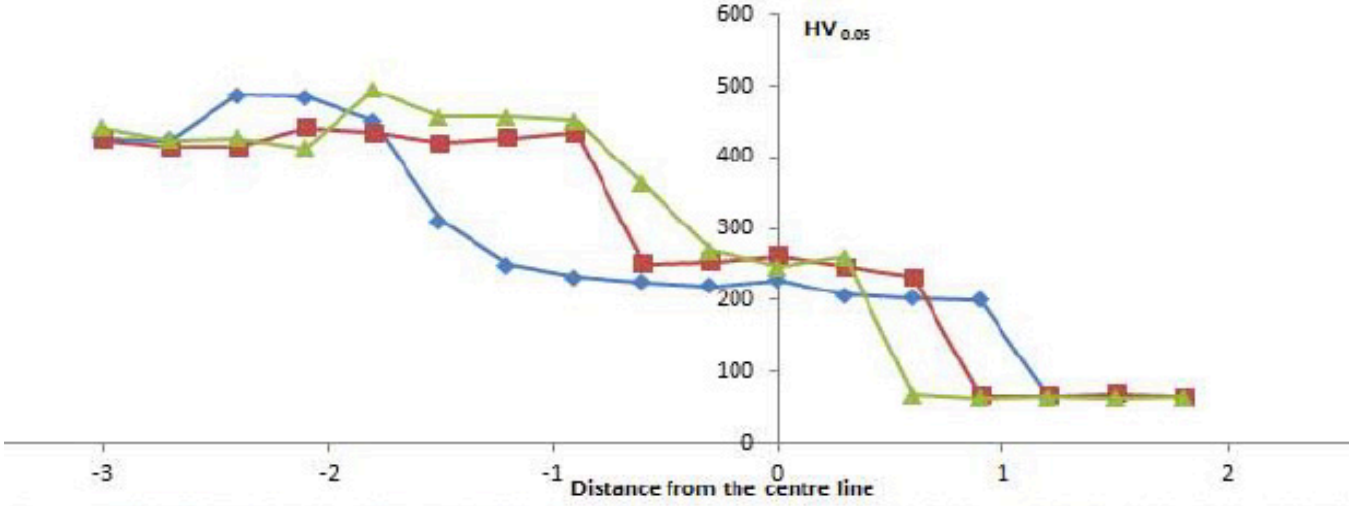
- Titanium helium tank
  - Nb to Ti
  - Ti to SS
- Stainless steel helium tank
  - Nb to SS

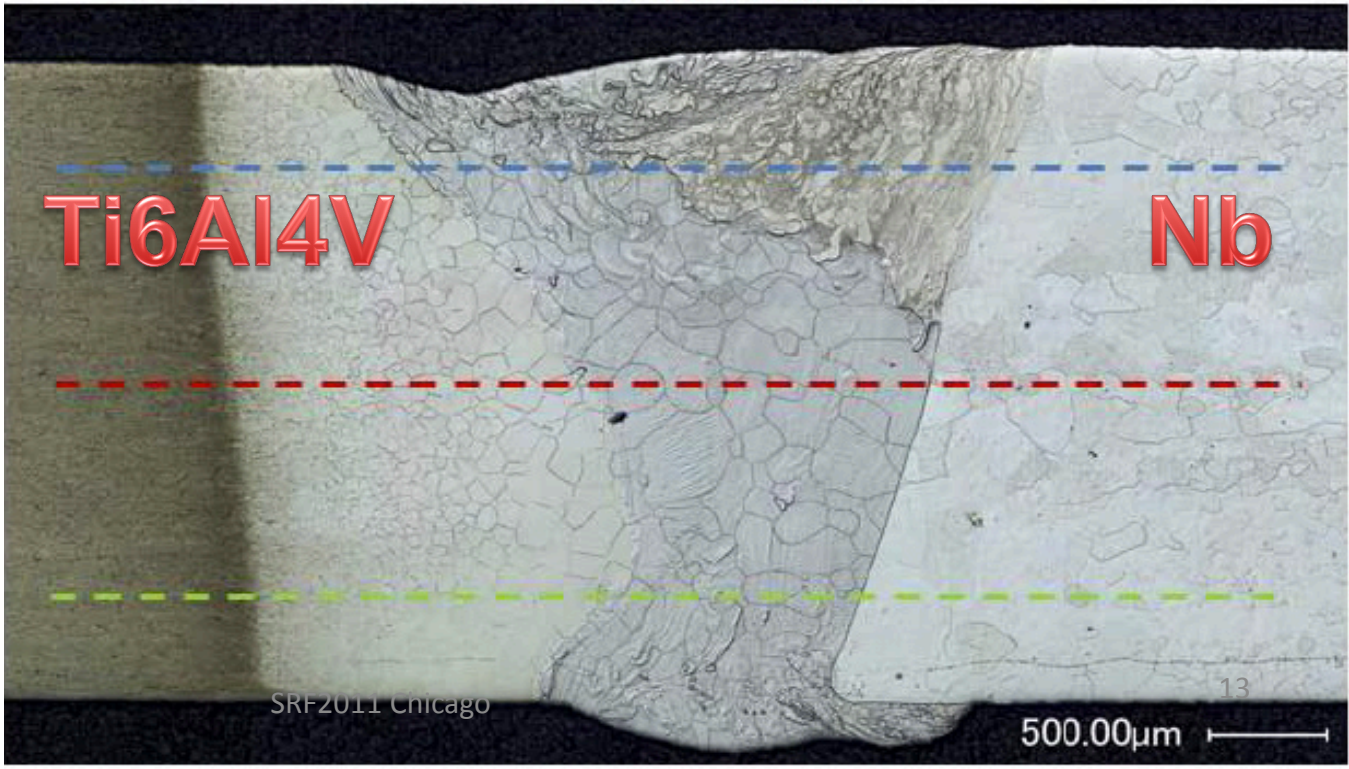
Interfaces

- Niobium to titanium
  - DESY XFEL choice:
    - EB welding Nb to NbTi and NbTi to Ti grade 2
    - NbTi flanges
  - Choice motivated by the stability of the mechanical properties after HT at 1400ºC
  - Heat treatment no longer at 1400ºC but at 800ºC
    A properly selected Titanium (cheaper) could be then a valid option (instead of NbTi)
    - The grade 5 Titanium Ti6Al4V (alloy) for flanges and transition to helium tank

Interfaces

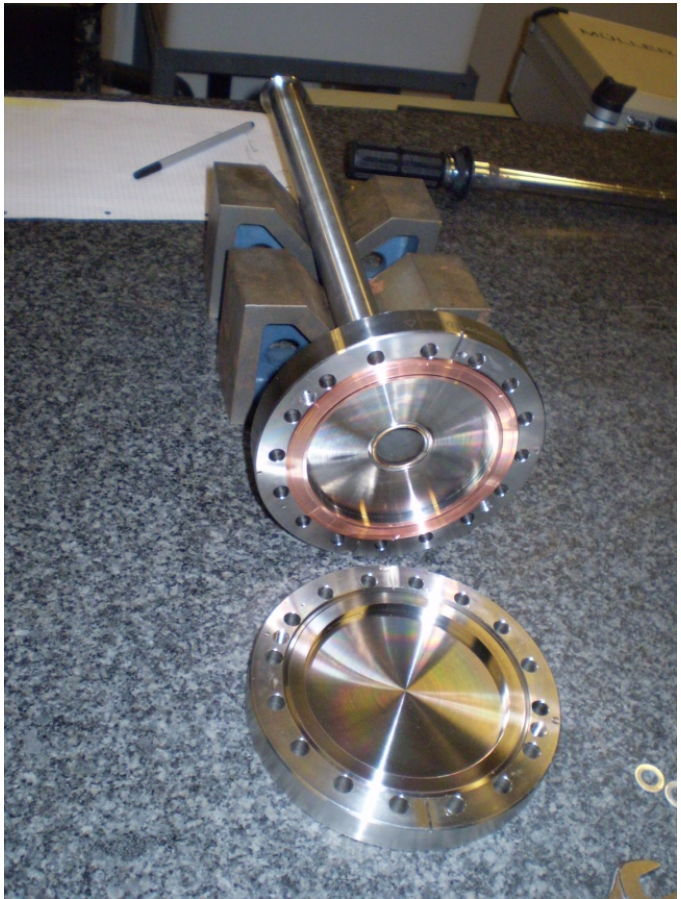
- Niobium to titanium grade 5 (Ti6Al4V) EB welding successfully tested before and after heat treatment at 800 C





Interfaces

- Titanium to stainless steel
  - By flange connection



CF flange SS 316LN + OFE copper + CF flange Ti6Al4V, liquid nitrogen tests

Interfaces

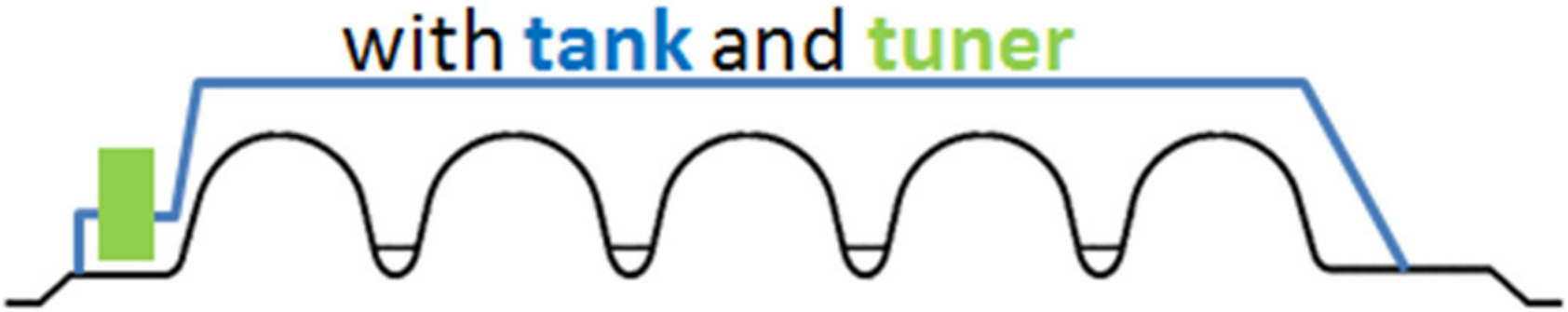
- Niobium to stainless steel
  - Vacuum brazing
  - Electron beam welding tests ongoing

Helium tank

- Material choice => interfaces => cavity
- Stiffness => Lorentz detuning
- Heat load to superfluid helium extraction

Helium tank

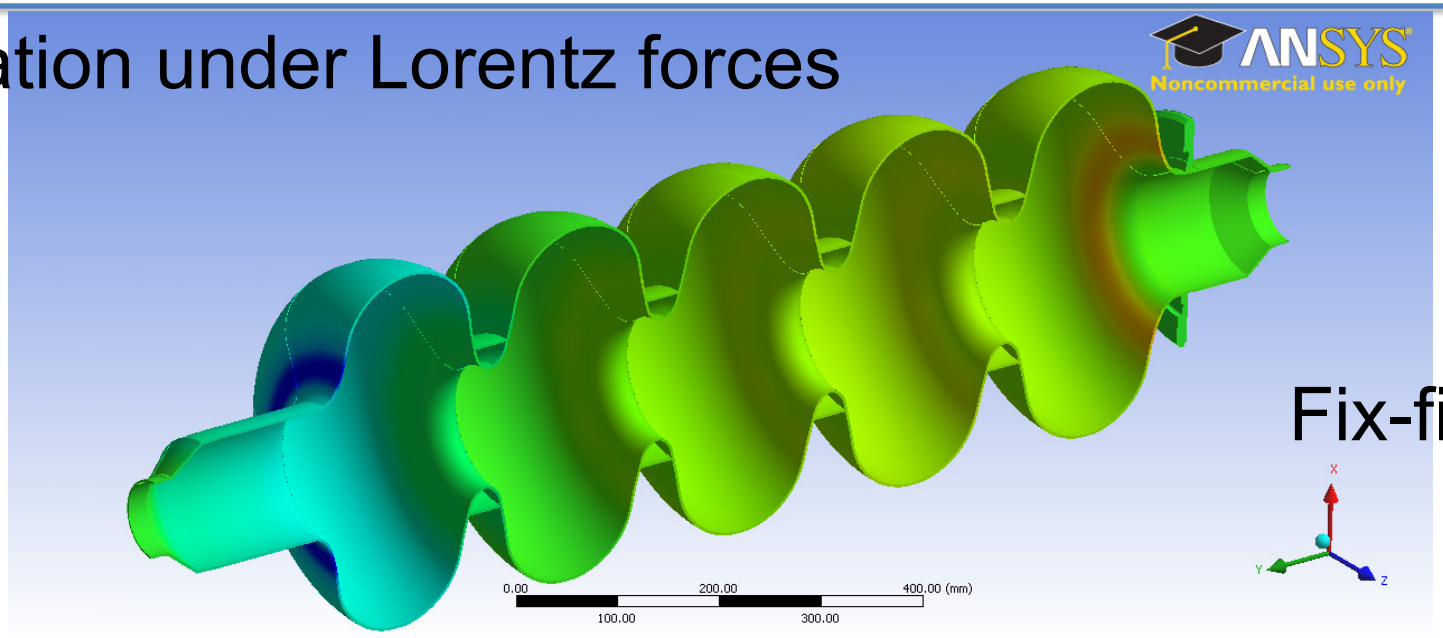
- Helium tank + tuner act as boundary conditions to cavity => different stiffness gives different deformation of cavity due to Lorentz forces



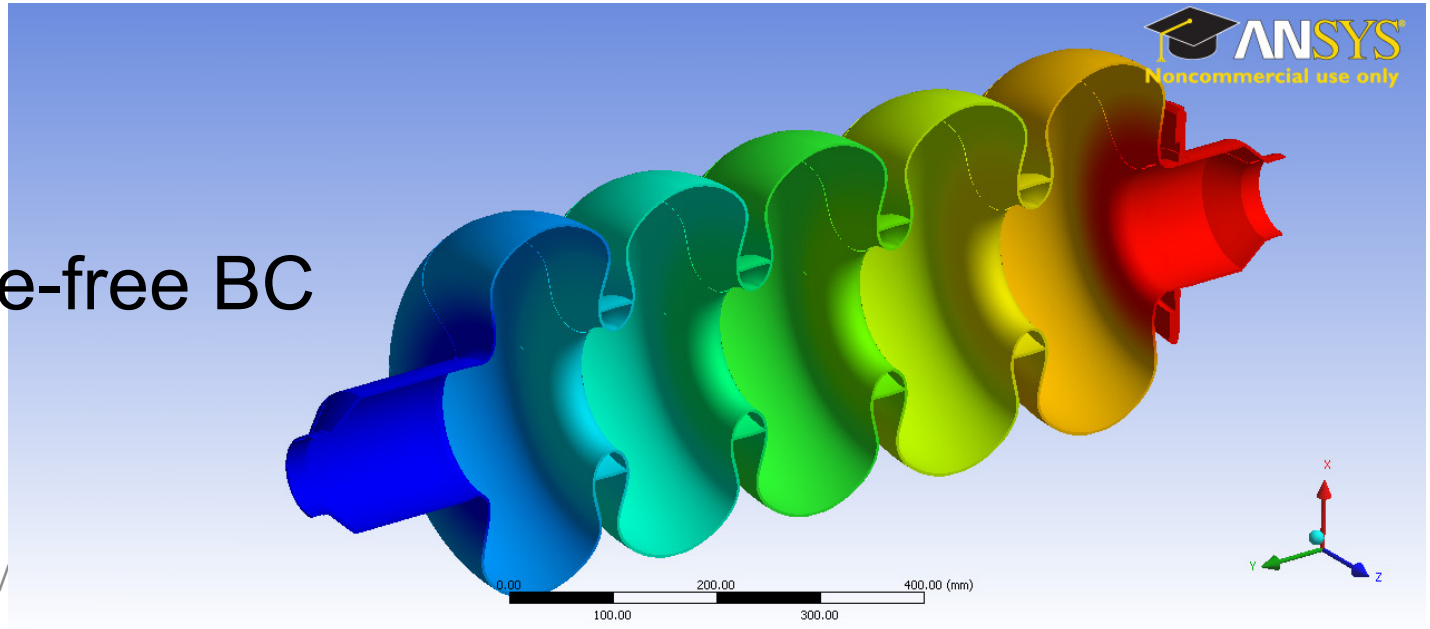
  - Zero tank + tuner stiffness equivalent to free-free BC for cavity
  - Infinite tank + tuner stiffness equivalent to fix-fix BC for cavity

Helium tank

deformation under Lorentz forces



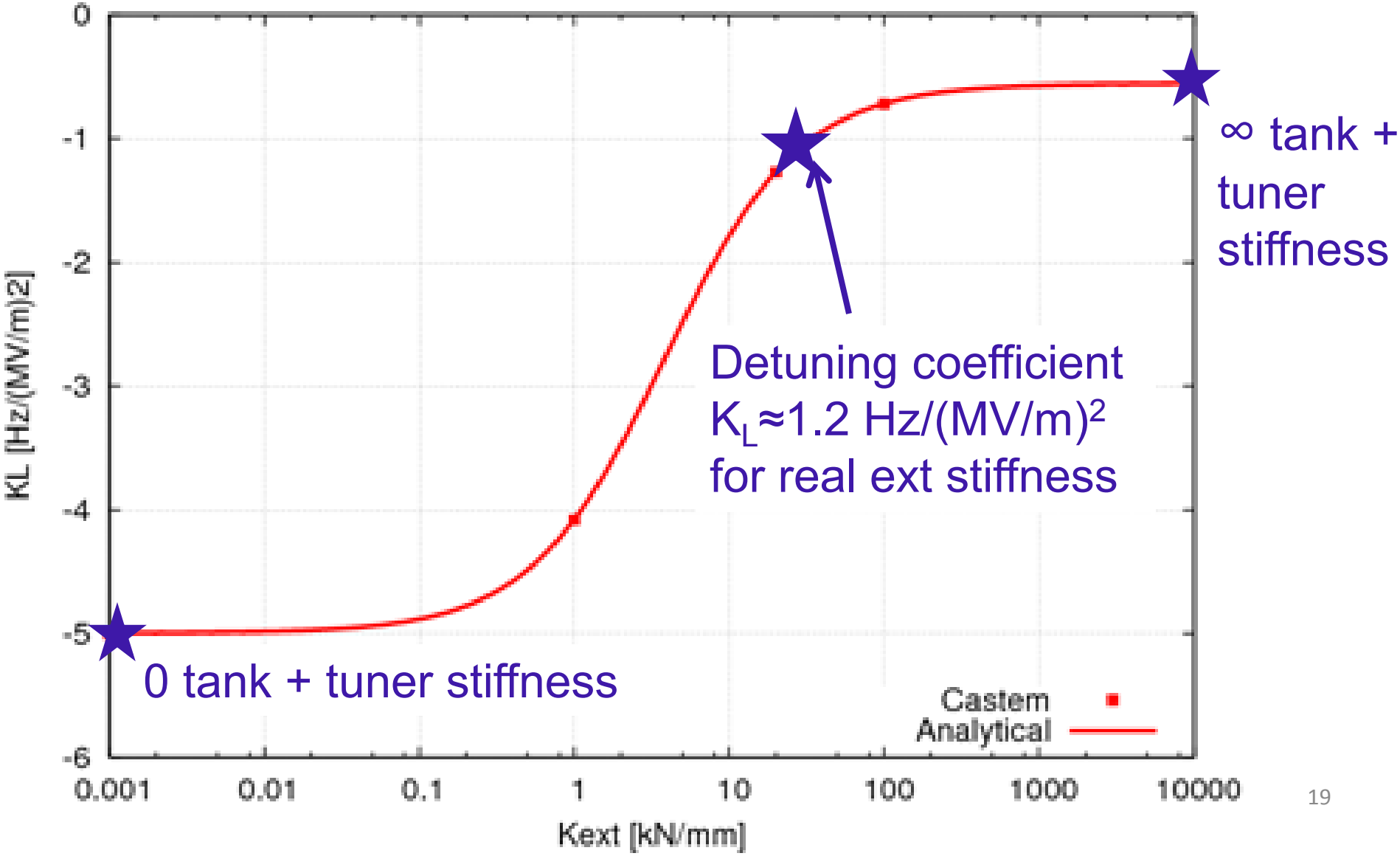
Fix-fix BC



Free-free BC

Helium tank

- Lorentz detuning => min helium tank stiffness 100 kN/mm



Helium tank

- Operation point: saturated He II at 2 K

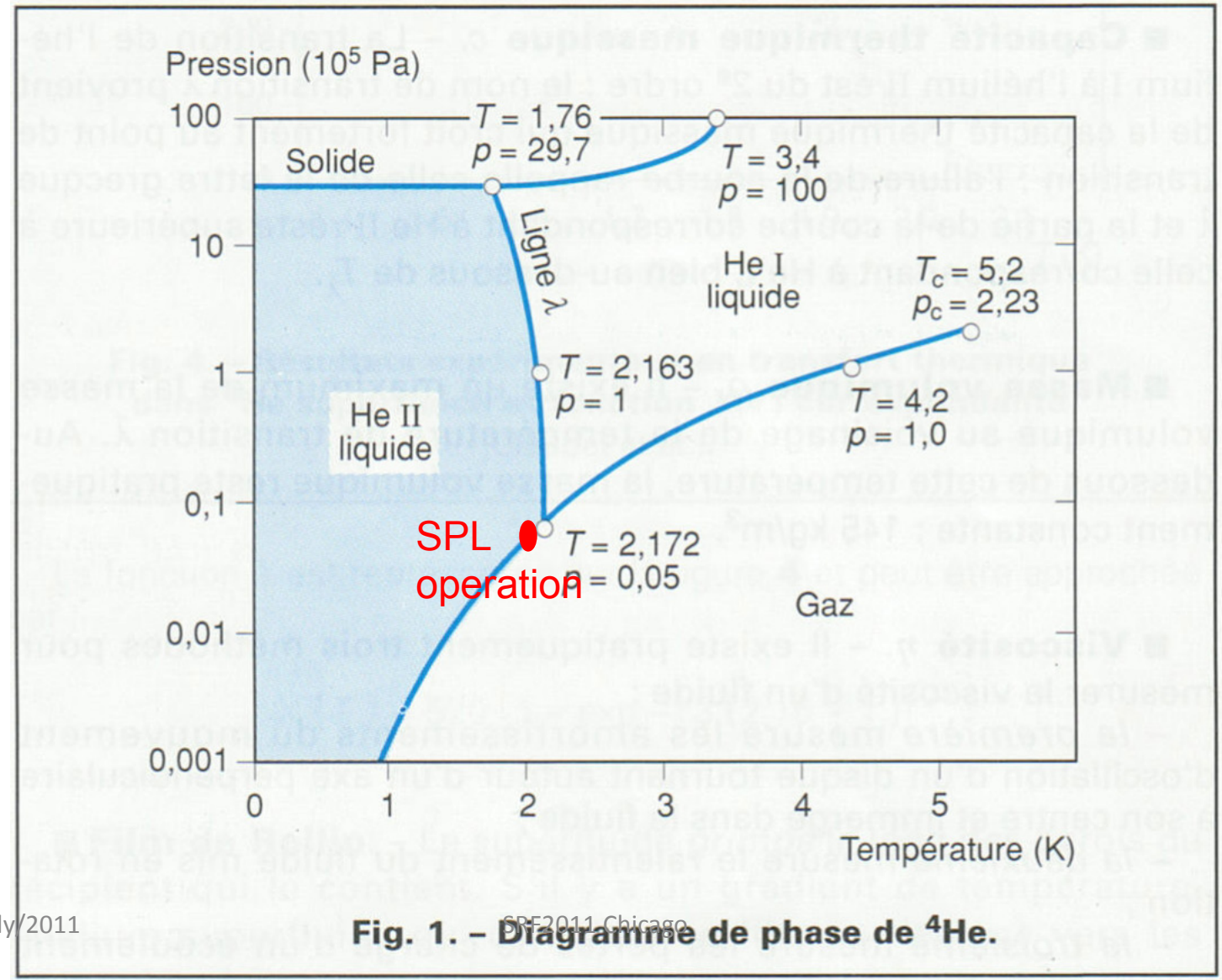
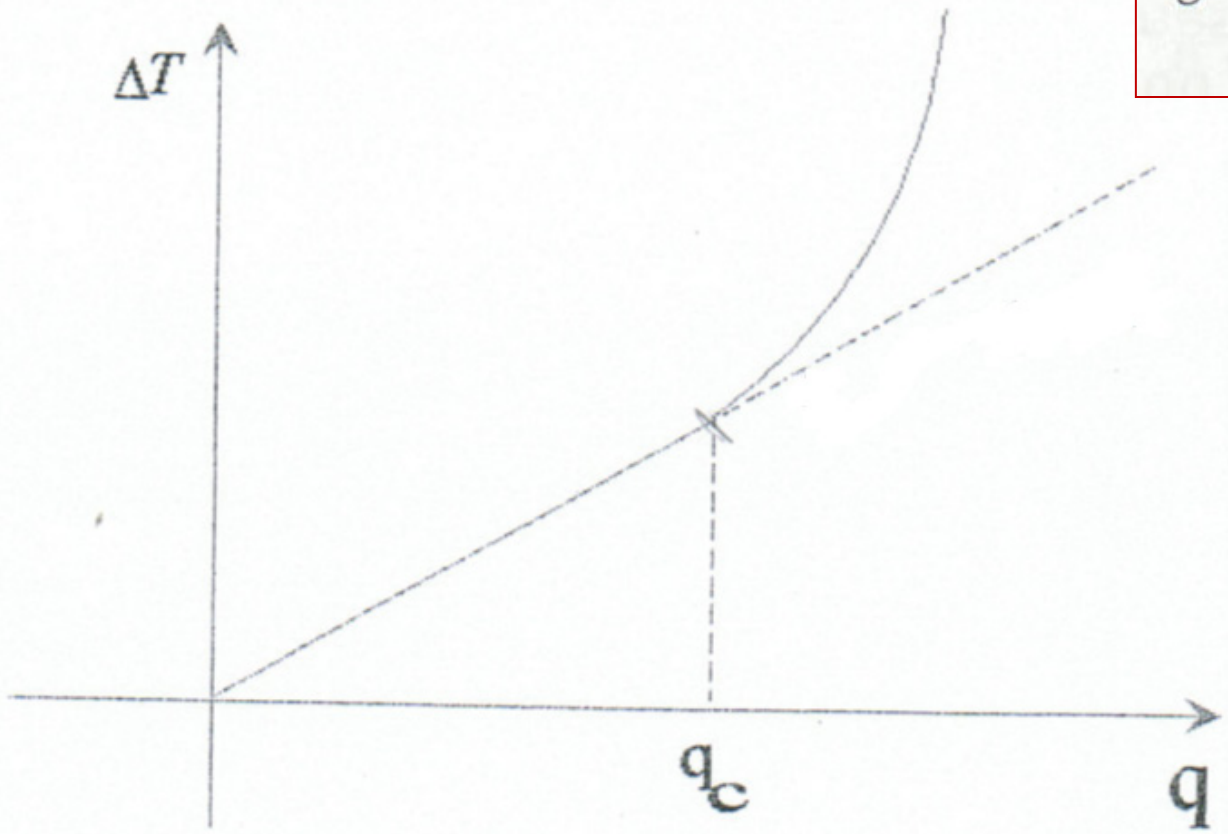


Fig. 1. – Diagramme de phase de ^{4}He.

Helium tank

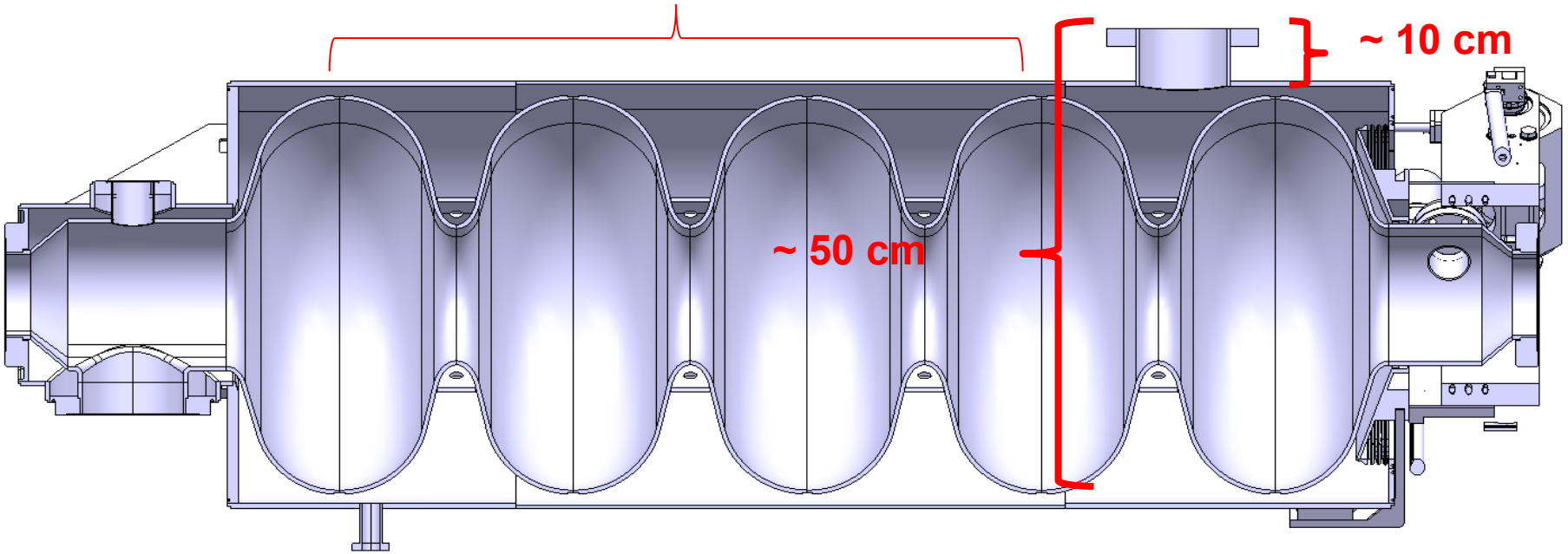
- Heat flux in He II depend on bath temp. and channel dimension

$$\frac{\dot{Q}}{S} = \left[\frac{X(T_f) - X(T_c)}{l'}\right]^{0,29}$$



Helium tank

- Heat load from 0.8 – 1.5 W/cm^2 => Tank dimensions accordingly to extract dynamic heat load 20 W



Conclusions

- After RF design finalized, still some work to do
- RF design, mechanical design, material, manufacturing, processing are very closely inter-linked
- During the cavity development, the mechanical considerations should be taken into account from the beginning
- Sometimes useful to have a critical view to existing solutions