ESS NEUTRINO SUPER BEAM

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Summary of WP4: simulation results for the horn and the target spheres

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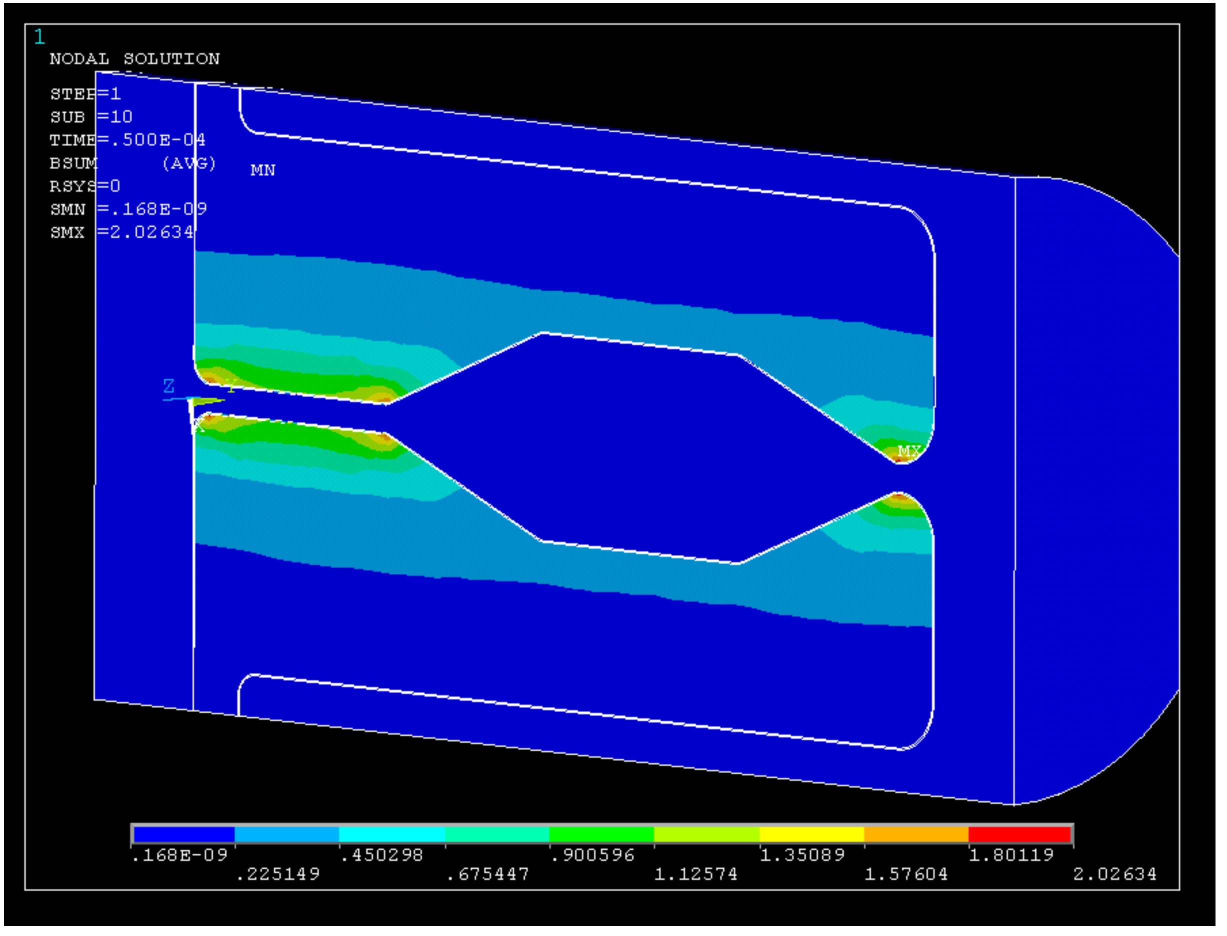
Strasbourg, 08.11.2018

Magnetic analysis

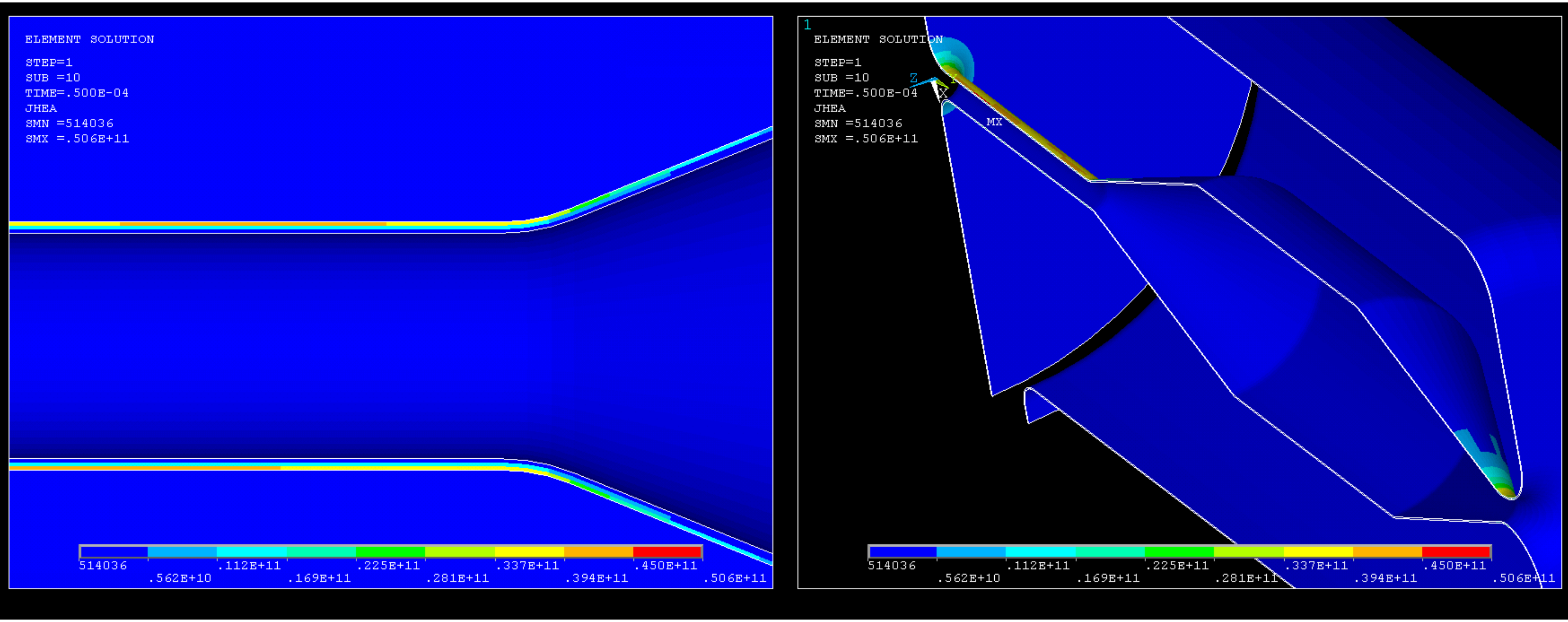
Magnetic flux *B* at *t* = 50μs



Magnetic analysis

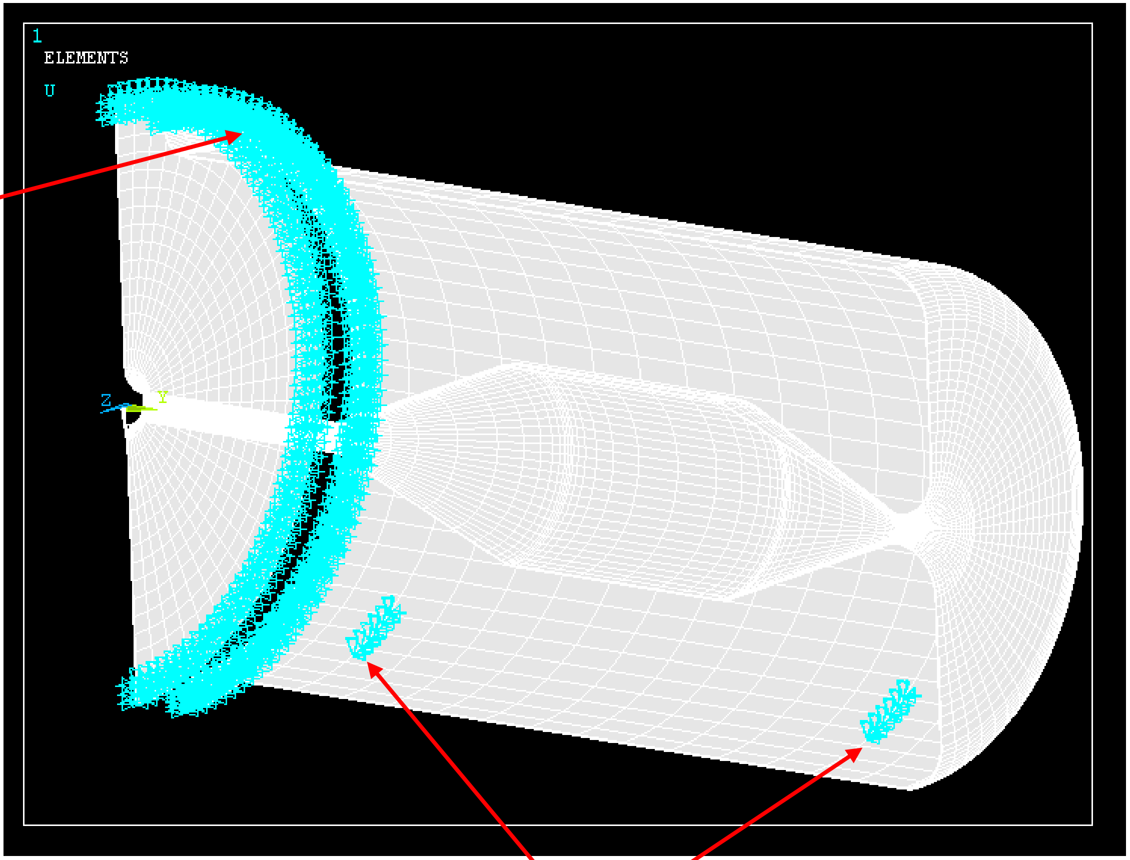
Joule heating at t = 50µs

Skin effect



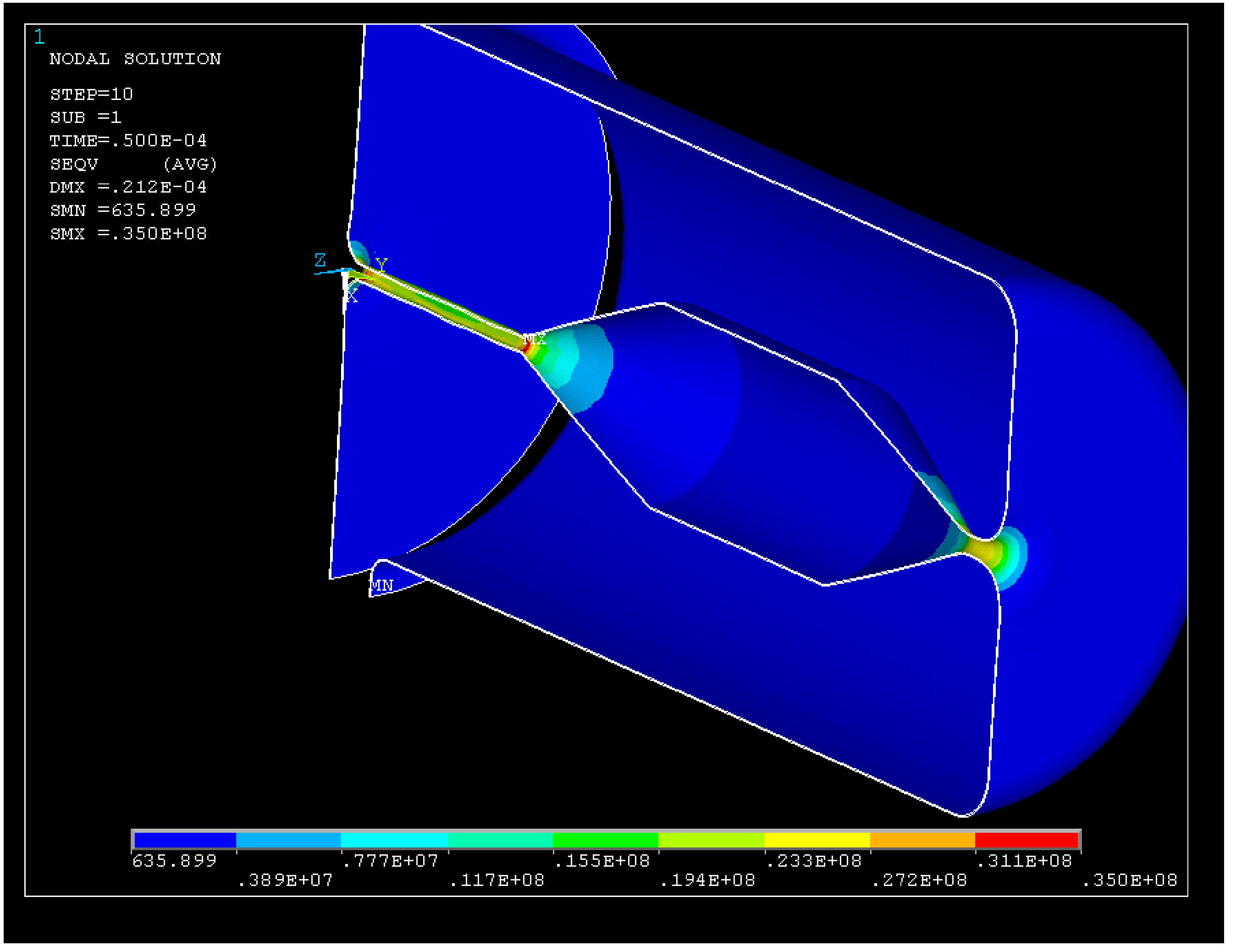
Horn support in the structural analyses

fixed displacement in all directions

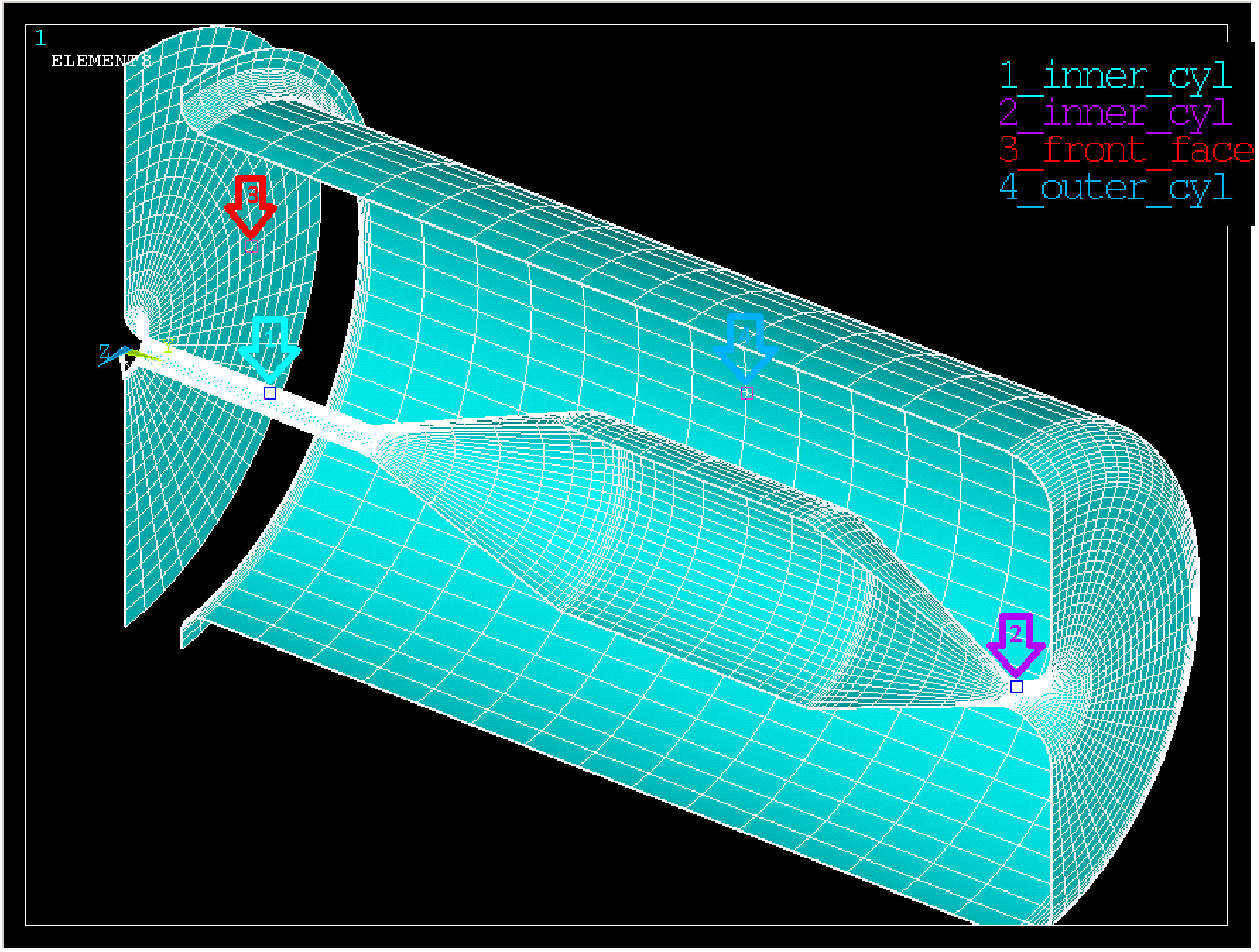


lateral displacements fixed

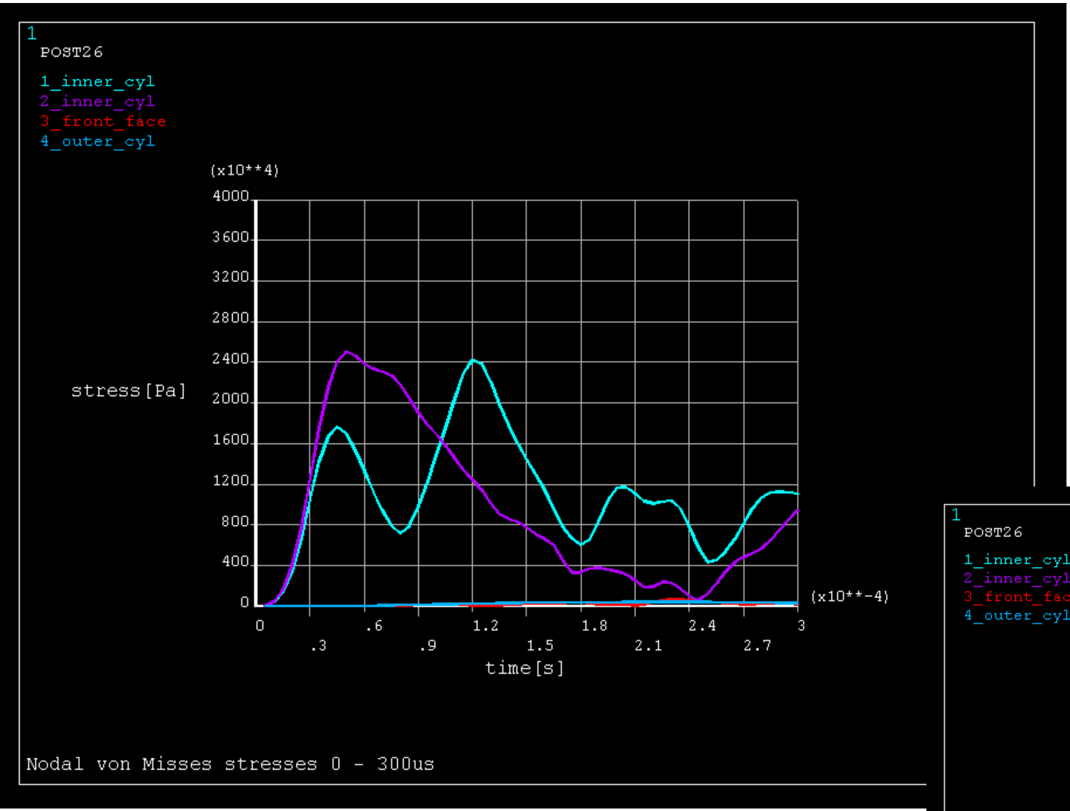
von Misses stress

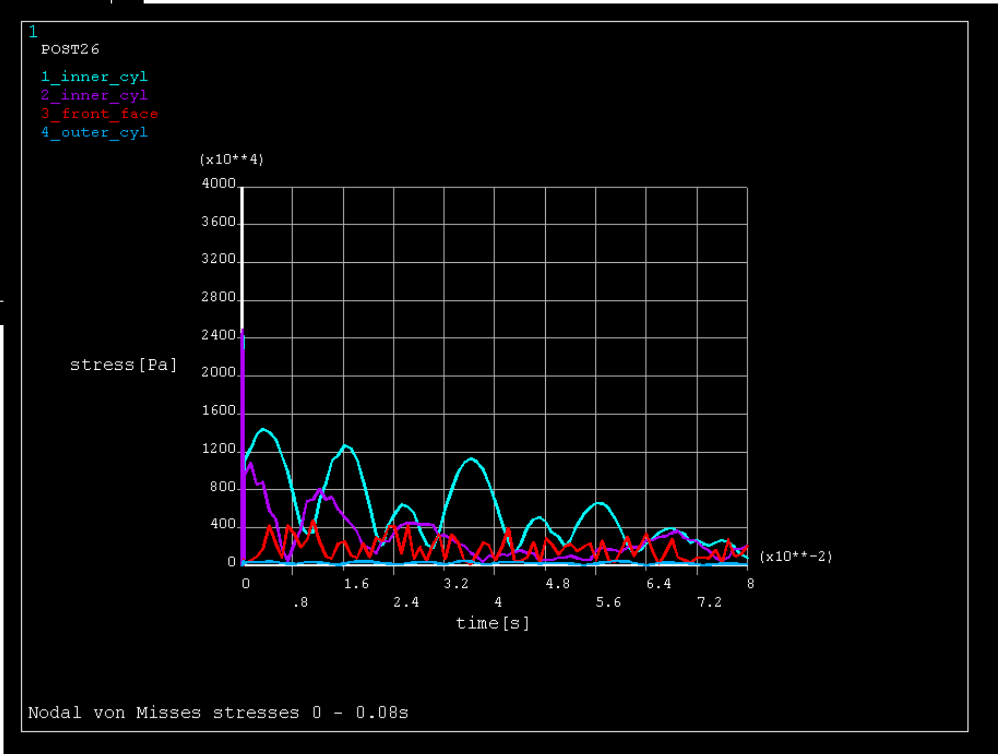


Results - location of the points



von Misses stress vs. time





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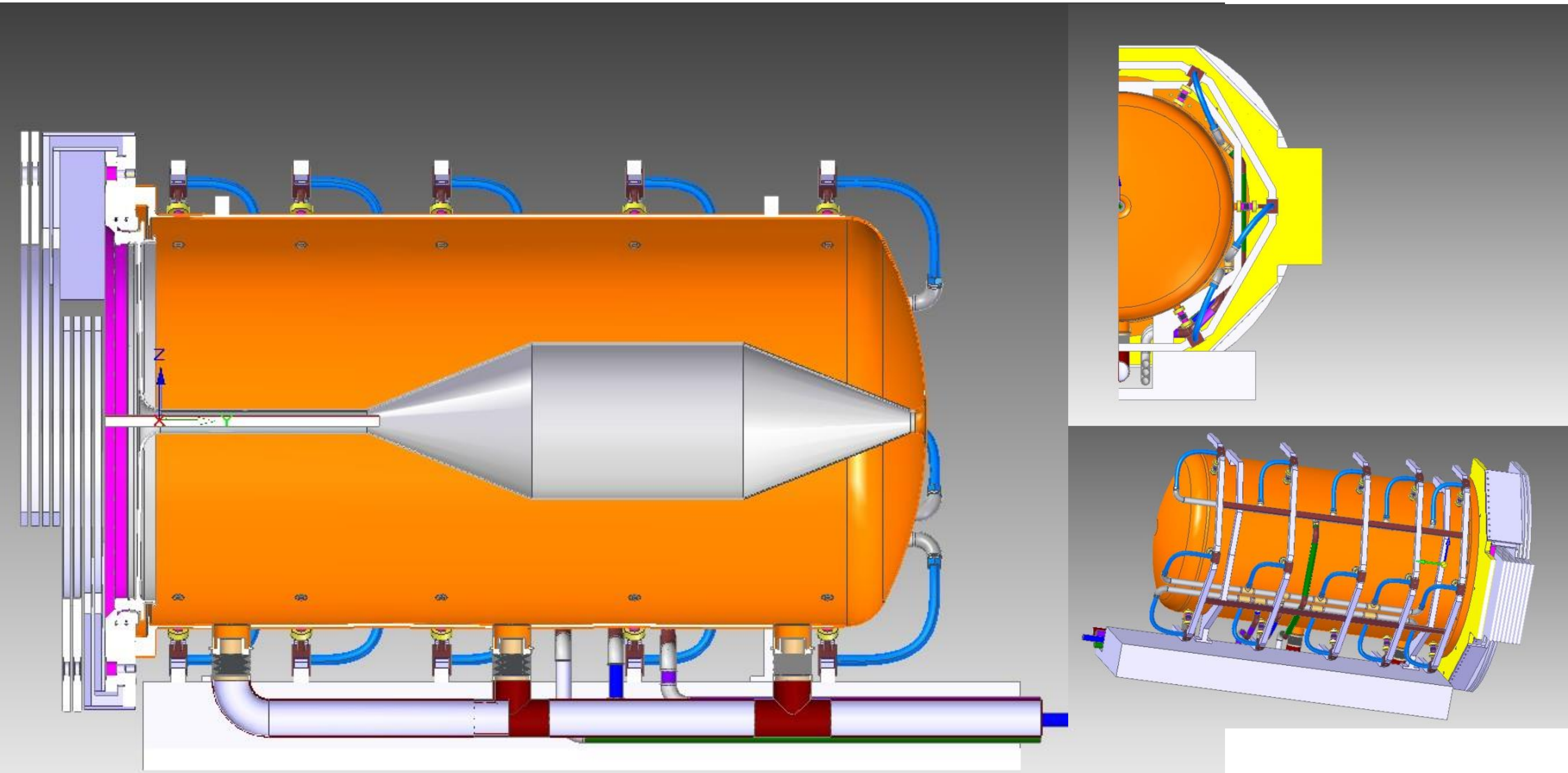
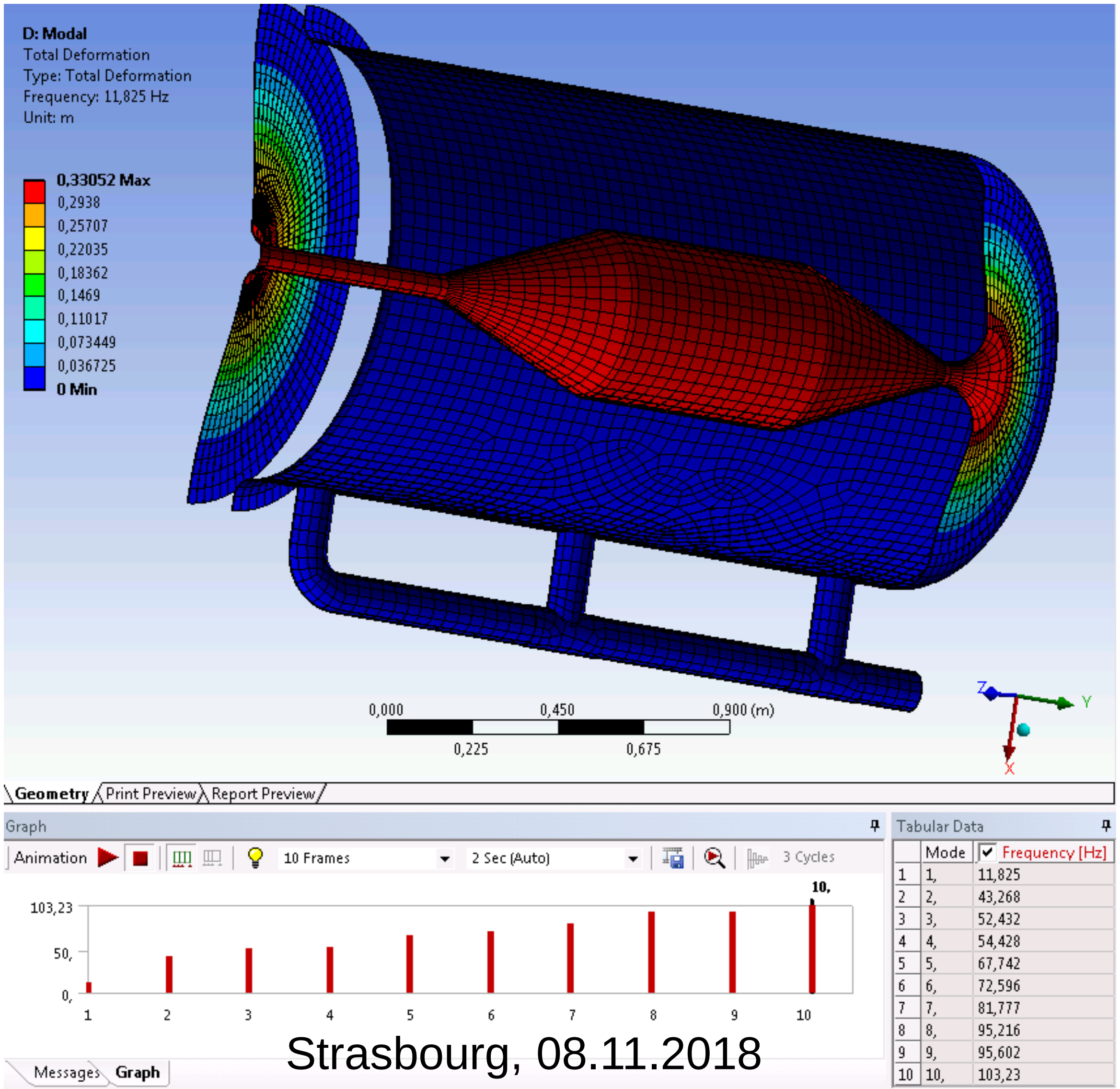
Horn with auxiliary equipment – EUROnu geometry

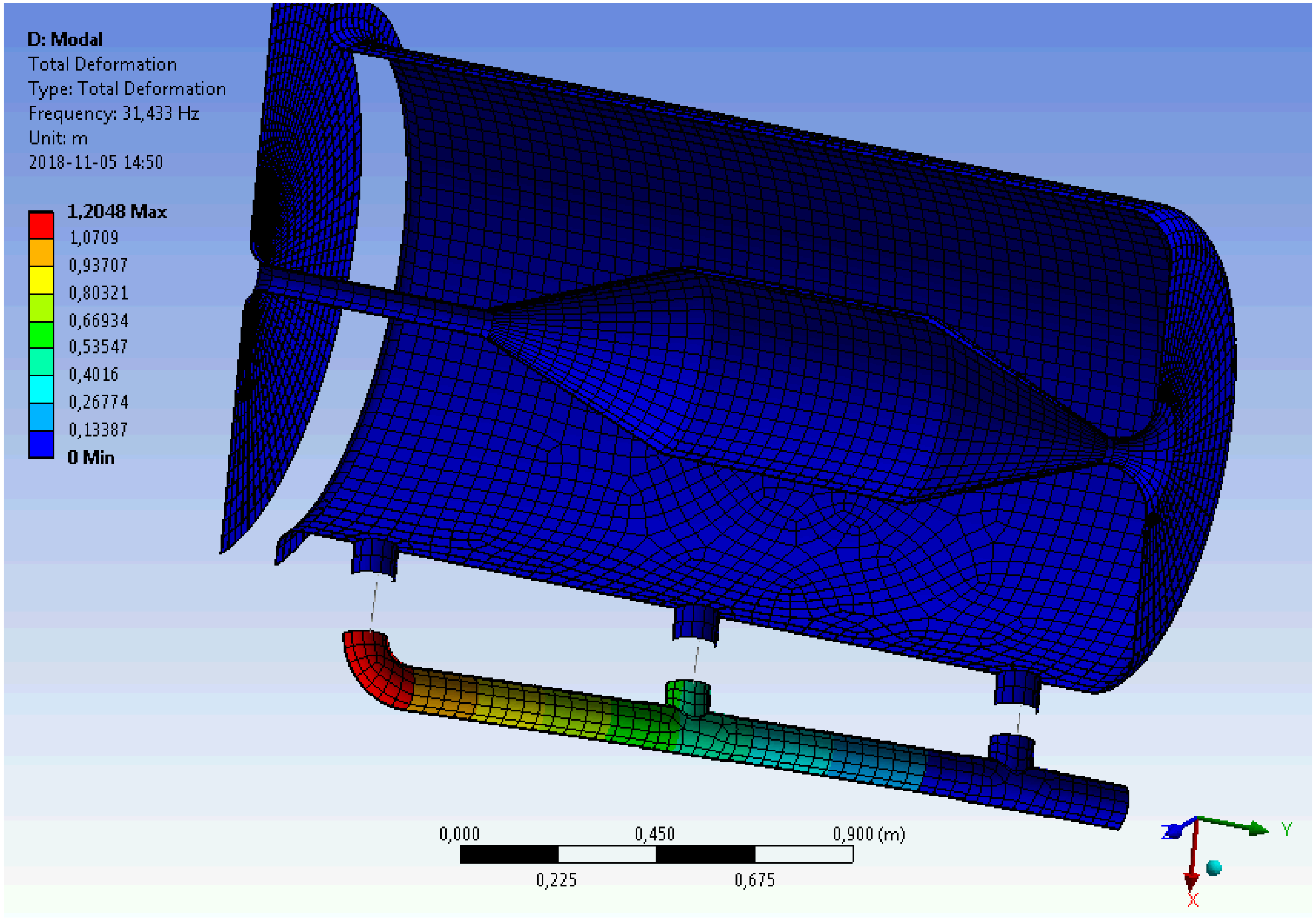


Horn with drainpipe



	Mode	Frequency [Hz]
1	1,	11,825
2	2,	43,268
3	3,	52,432
4	4,	54,428
5	5,	67,742
6	6,	72,596
7	7,	81,777
8	8,	95,216
9	9,	95,602
10	10,	103,23

Modal analysis



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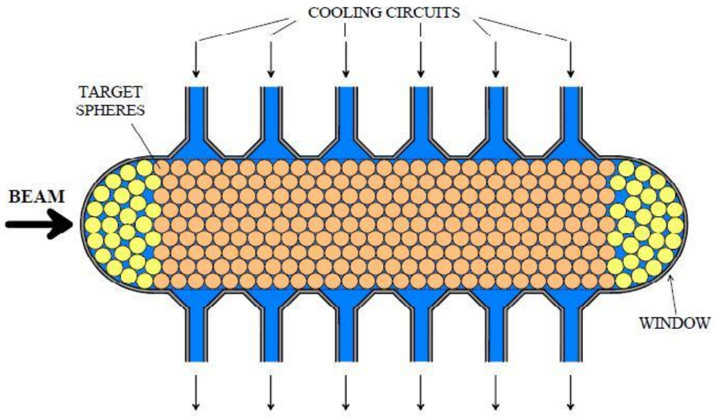
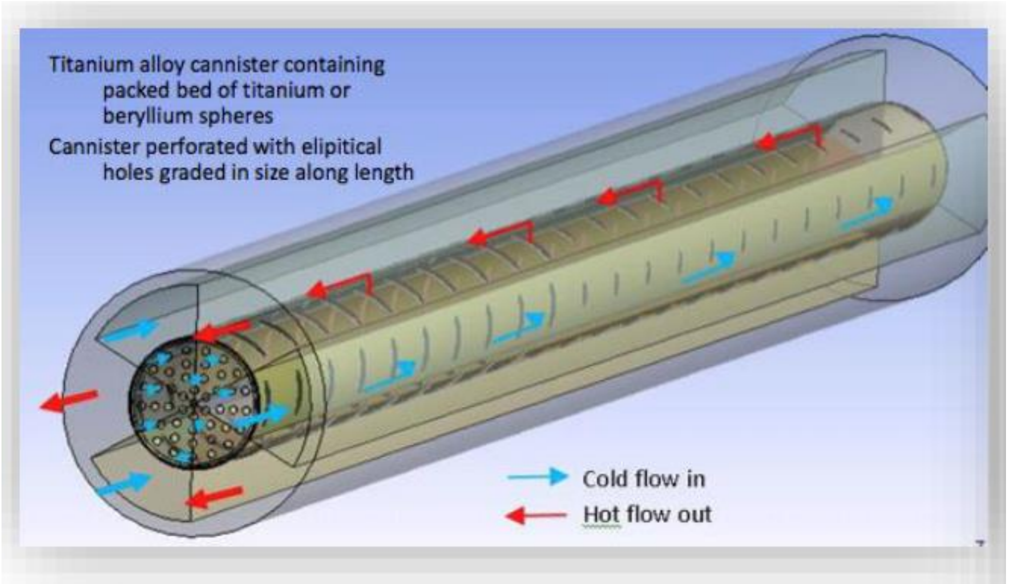
Motivation – granular (packed bed) target



Granular target proposed by P. Sievers at CERN (2001)



The pebble bed target studied at RAL (T.Davenne)

Transient temperature in a solid sphere

A sphere with radius a=1 mm is considered, with the following material properties (aluminium for test purposes, to be replaced by the constants of titanium):

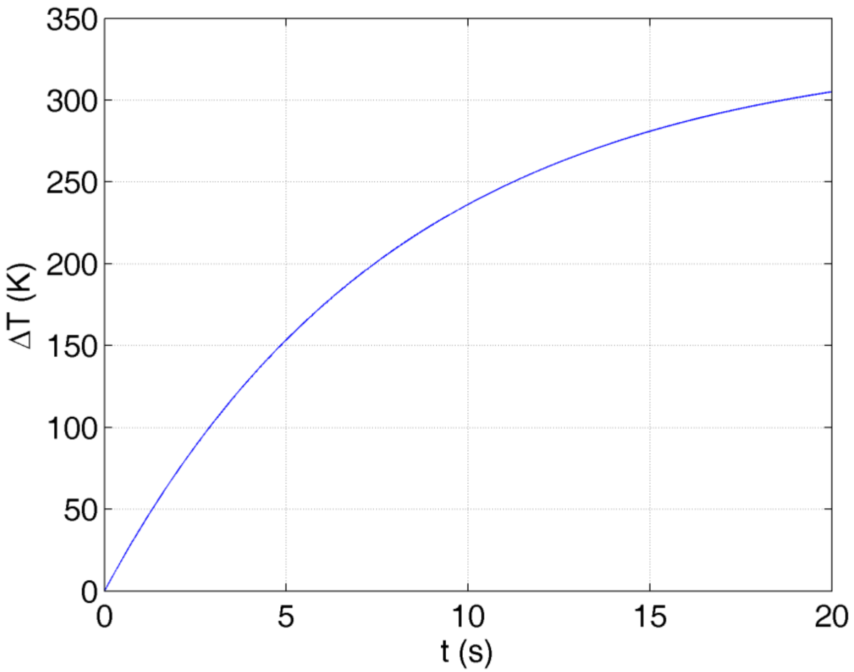
$K = 220$ W/mK thermal conductivity

$c = 900$ J/kgK specific heat

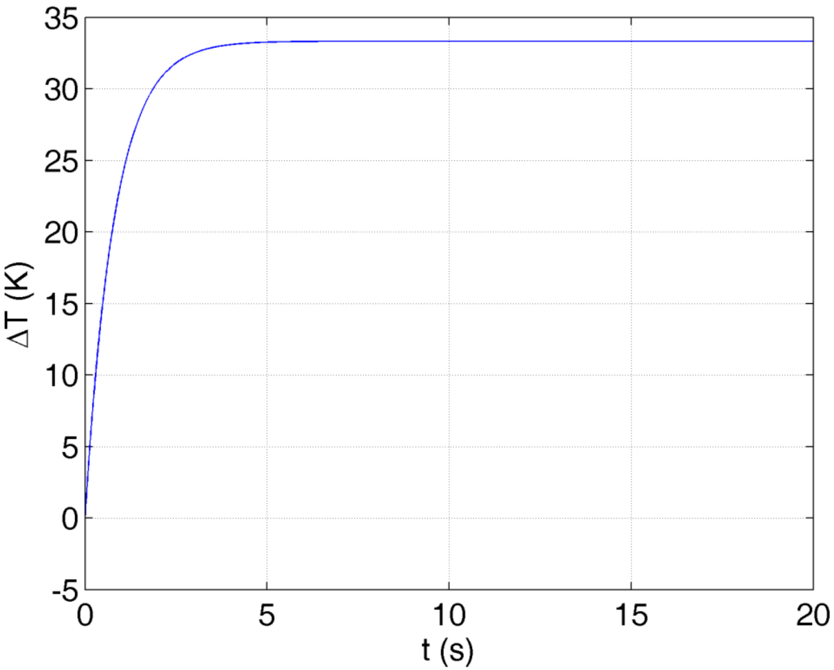
$\rho = 2.7 \cdot 10^3$ kg/m^3 mass density

Transient temperature in a solid sphere

Film coefficient H=100 W/m^2K

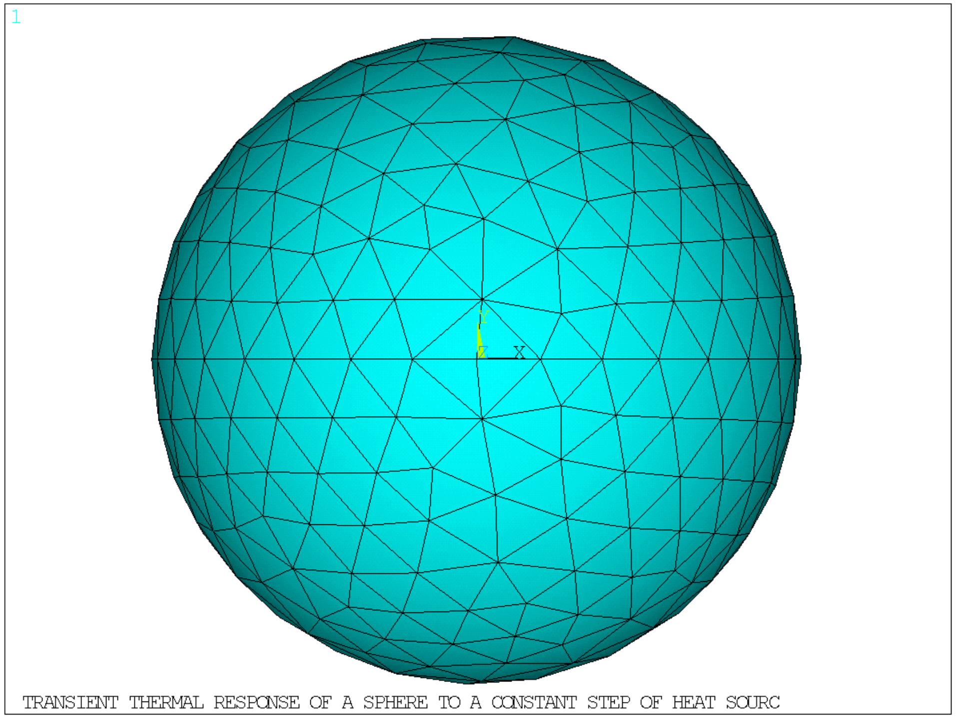


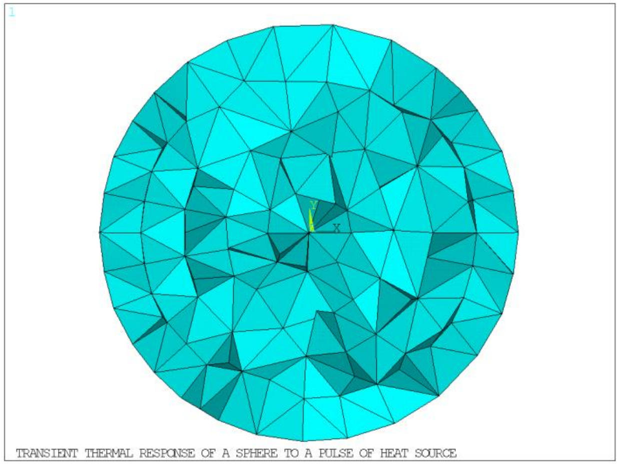
Film coefficient H=1000 W/m^2K

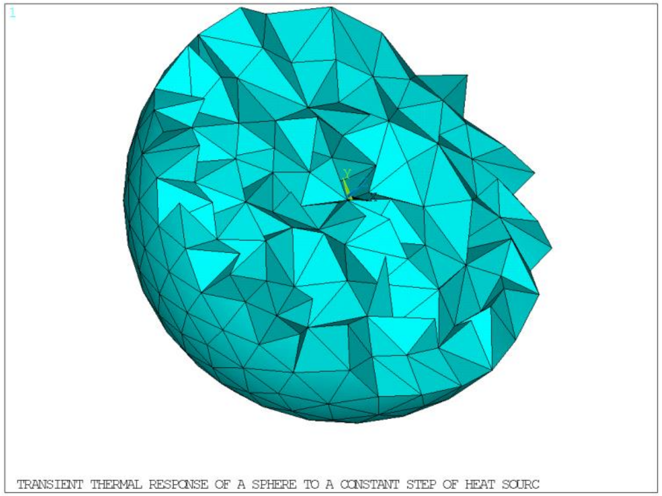


Finite element model of a sphere

Free meshing with tetrahedral elements





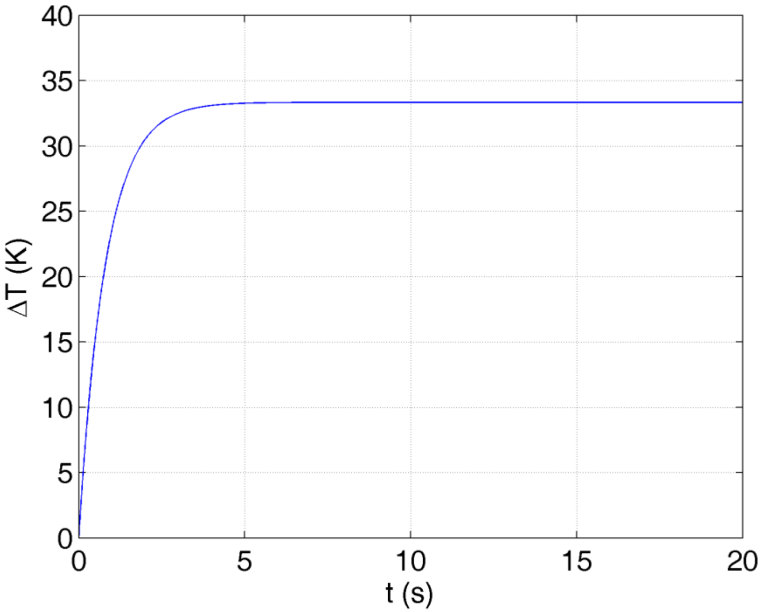


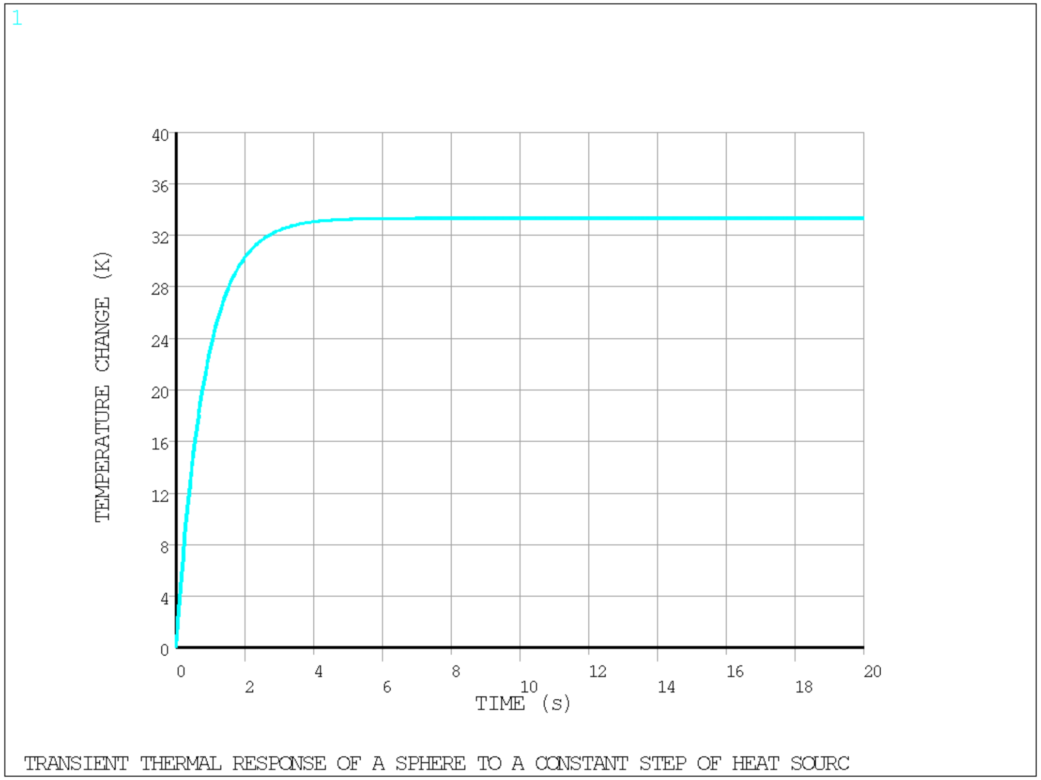
Finite element vs. analtytical solution

Film coefficient H=1000 W/m^{2}K

Ansys

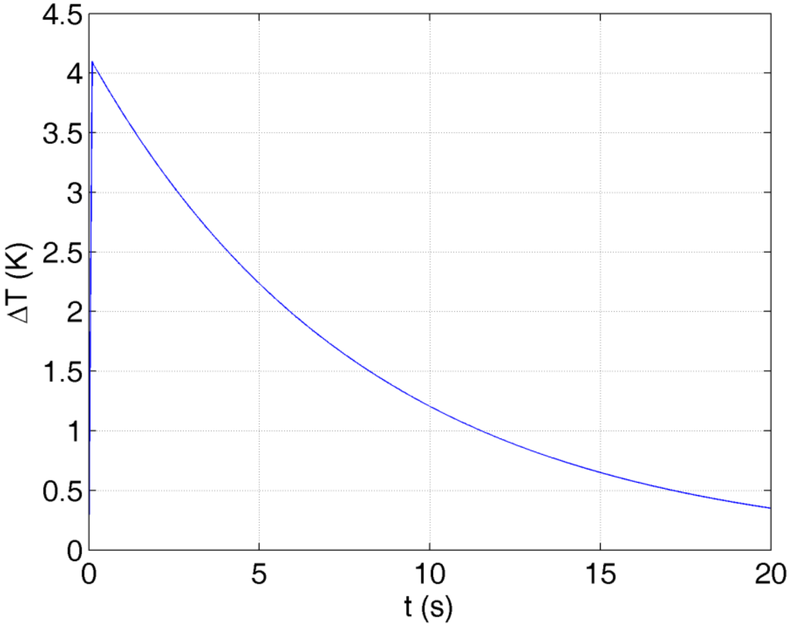
Analytical



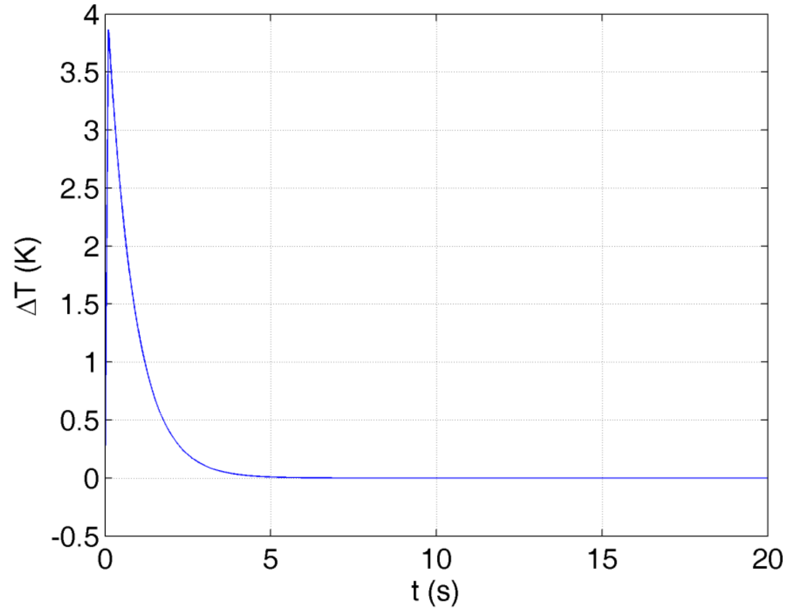


Temperature in a sphere due to a heat pulse

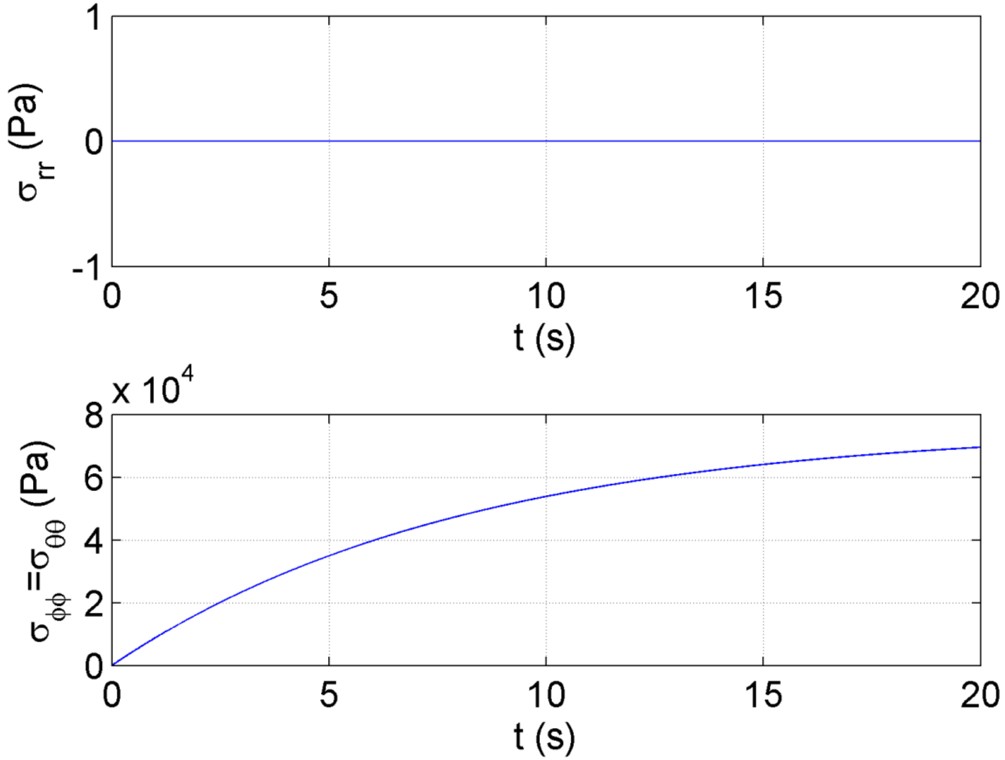
Film coefficient H=100 W/m²K



Film coefficient H=1000 W/m²K



Termal stress in a sphere due to a heat source applied step-wise



Termal stress in a sphere – analytical vs. finite element solution

The values of thermal stress on the surface of a sphere with radius a=1 mm, at time t=20 s (the value of the film coefficient used was assumed to be H=100 W/m^2K)

Analytical	ANSYS	Relative error (ANSYS-analytical)/analytical
69549 (Pa)	69054 (Pa)	-0.7%

Natural frequencies of axisymmetric vibration of an elastic sphere – analytical solution

The frequency equation of axisymmetric vibration modes:

$$(\lambda+2\mu)\left[(2-k^2a^2)\sin(ka)-2ka\cos(ka)\right]+2\lambda\left[ka\cos(ka)-\sin(ka)\right]=0$$

$$\lambda=\frac{\nu E}{(1+\nu)(1-2\nu)},\quad \mu=\frac{E}{2(1+\nu)}$$

$$\omega=\sqrt{\frac{\lambda+2\mu}{\rho}}k$$

Natural frequencies of axisymmetric vibration of an elastic sphere – analytical solution

All natural vibration results are for a steel sphere with radius a=1 mm, with the following material properties: $E=2.1\cdot10^{11}$ N/m^2, $\nu=0.3$, $\rho=7.8\cdot10^3$ kg/m^3.

Roots of the frequency equation of the symmetric modes:

$$ka : 2.6702,\ 6.0920,\ 9.3009,\ 12.4743$$

The natural frequencies in Hz:

$$f : 2.5584\cdot10^6 \text{ Hz},\ 5.8370\cdot10^6 \text{ Hz},\ 8.9116\cdot10^6 \text{ Hz},\ 11.952\cdot10^6 \text{ Hz}$$

Natural frequencies – finite element vs. analytical solution

Lowest two natural frequencies of a steel sphere of radius a=1 mm (the sphere is unrestrained on its surface)

Analytical	ANSYS	Relative error
$f_1 = 2.5584 \cdot 10^6$ Hz	$f_1 = 2.5559 \cdot 10^6$ Hz	-0.1%
$f_2 = 5.8370 \cdot 10^6$ Hz	$f_2 = 5.8424 \cdot 10^6$ Hz	0.1%

Fot the discussion of the non-radial vibration see the presentation during WP4

Some future work

- Vibration transmission from the horn to the cooling piping
- The performance of the horn cooling system
- Fatigue life estimate of the horn and the spheres
- Thermal stress and wave propagation in a pebble bed target using composite material and numerical approach
- Target cooling issues
- Environmental effects (radiation damage, cavitation, etc.)