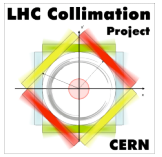


LHC Collimators for Phase 1

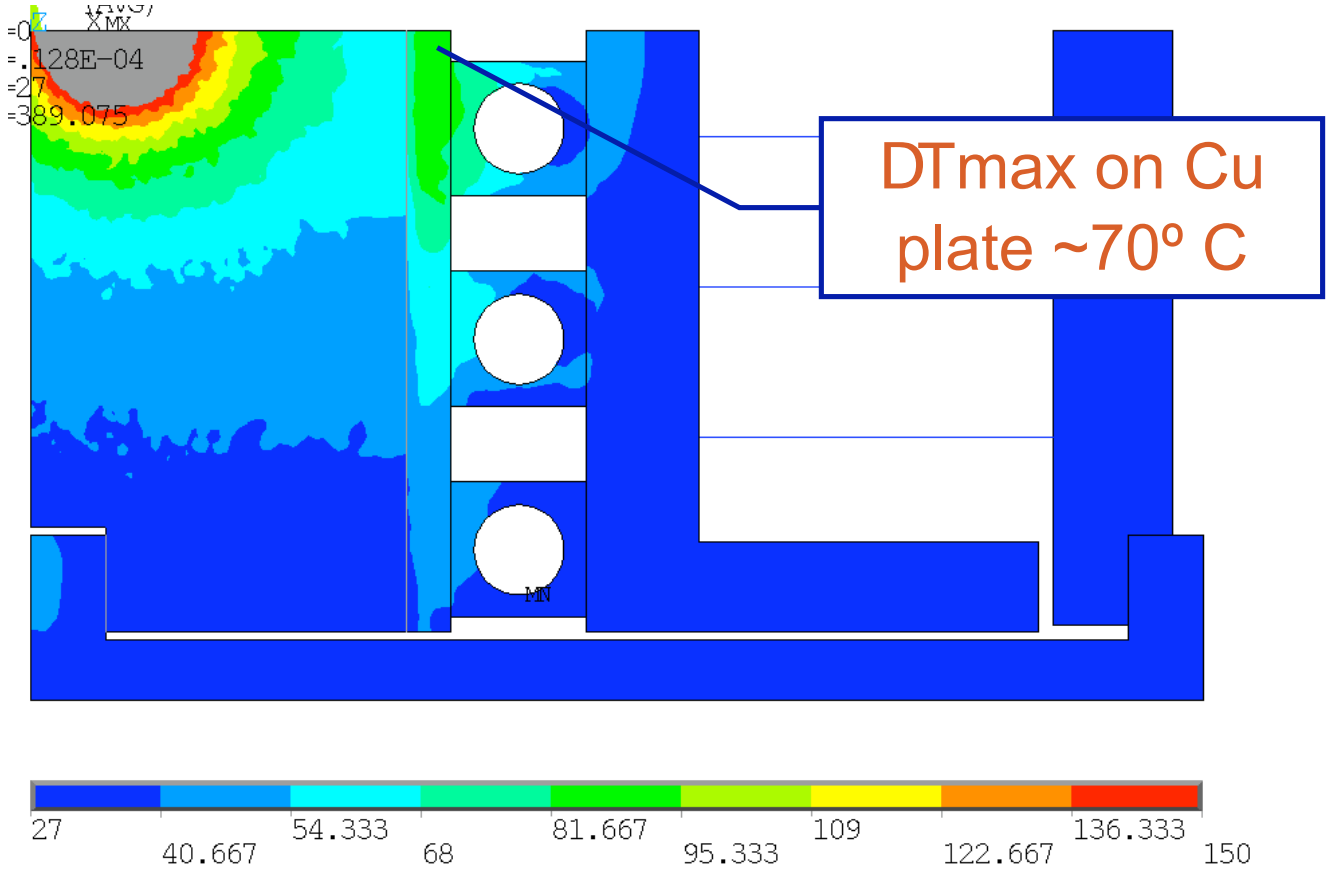
450 GeV injection accident – from numerical simulation to experimental measurements

CWG 02/10/2006

Alessandro Bertarelli TS-MME
Alessandro Dallocchio TS-MME

Thermo-mechanical analysis

Injection error accident -Temperature profile after 7.2 ms (5 mm offset) "hottest" cross-section (z=1000 mm)



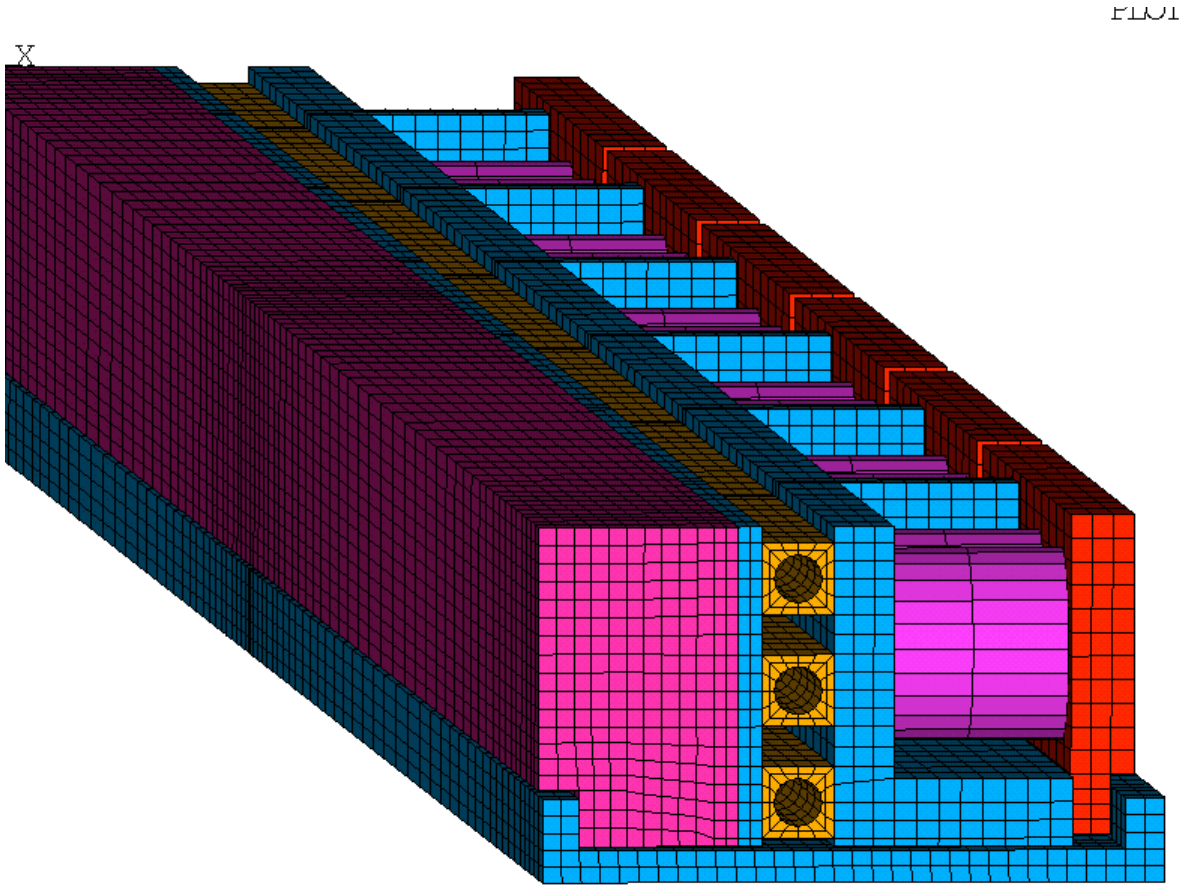
Beam Parameters for numerical simulation

- 3.2×10^{13} protons (i.e. $4 \times 72 \times 1.1 \times 10^{11}$)
- 450 GeV
- Uniform power deposition over 7.2 ms
- 5 mm impact parameter
- FLUKA input from M. Magistris' (Sep. 2005)

Thermo-mechanical Analysis

3-D full model of the series TCSG (Glidcop Plate – CuNi pipes)

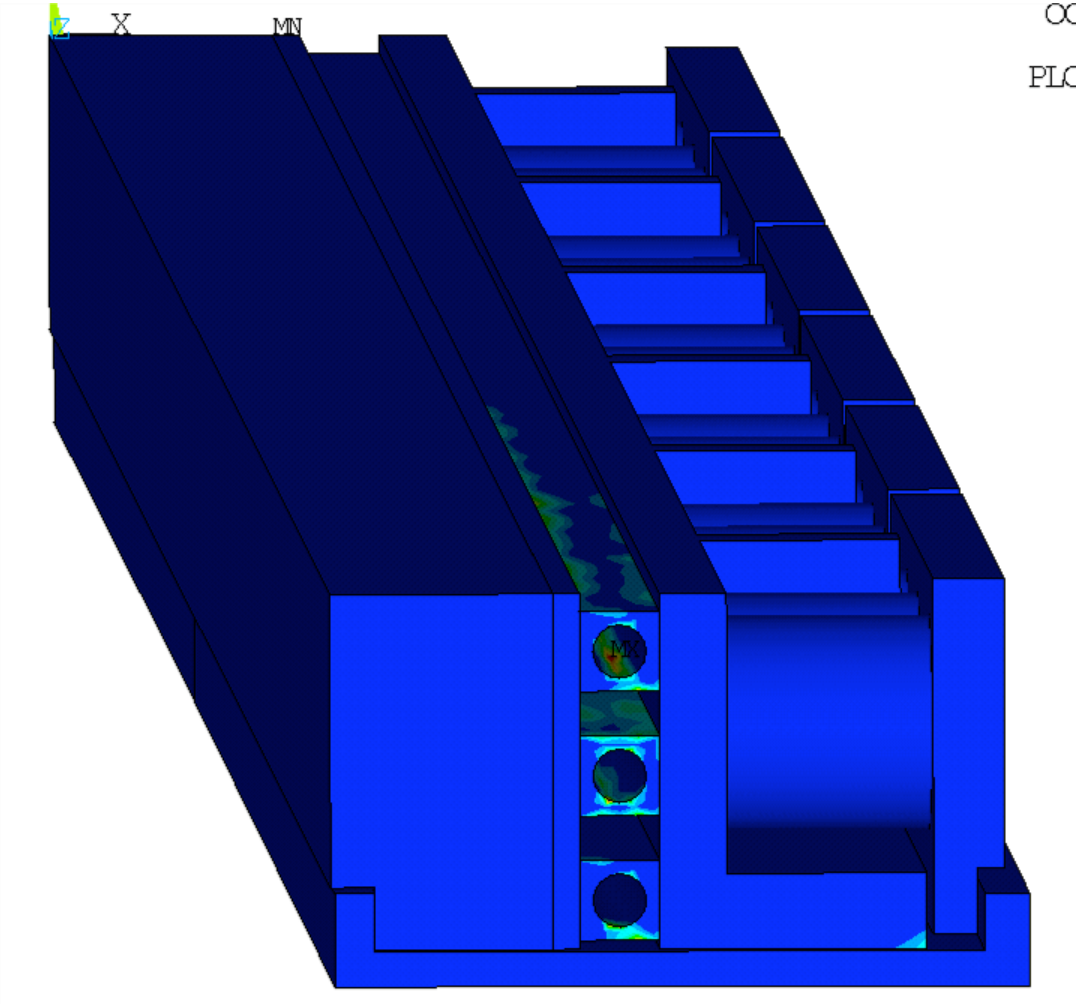
- Full TCS model (1 m long; no tapering). Infinitely rigid axle supports
- Actual energy distribution from FLUKA (linearly increasing during 7.2ms)
- Elasto-plastic behavior for metals
- Fast transient, coupled-field analysis (time-step 0.1 ms) ⇨ huge CPU time – several



Thermo-mechanical Analysis

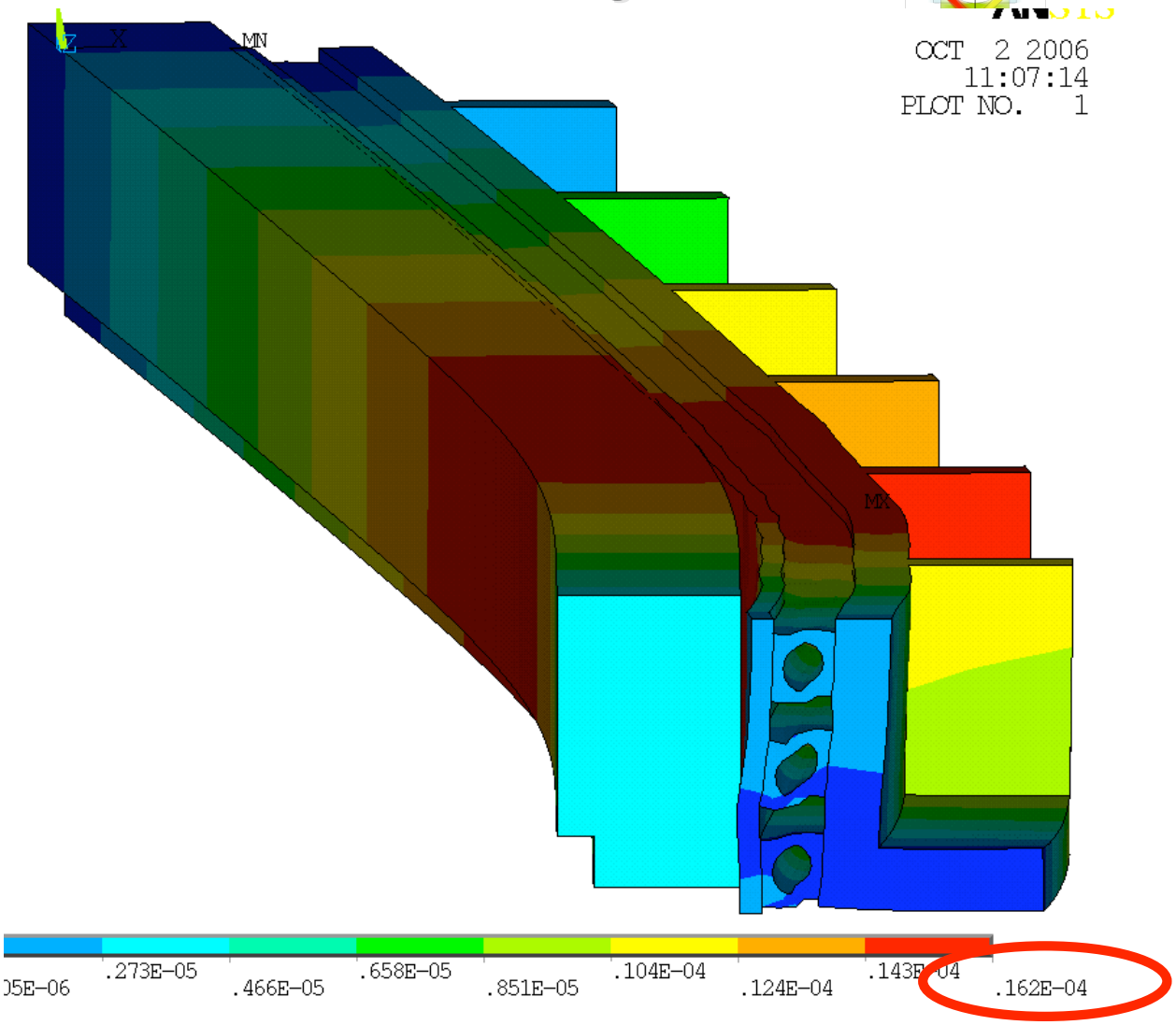
Results for the full TCS model – Plastic strains

Plastic strains only appear in the CuNi pipes – Glidcop plate does not present sign of plastic behaviour (as opposed to 2004 prototype Copper plate)



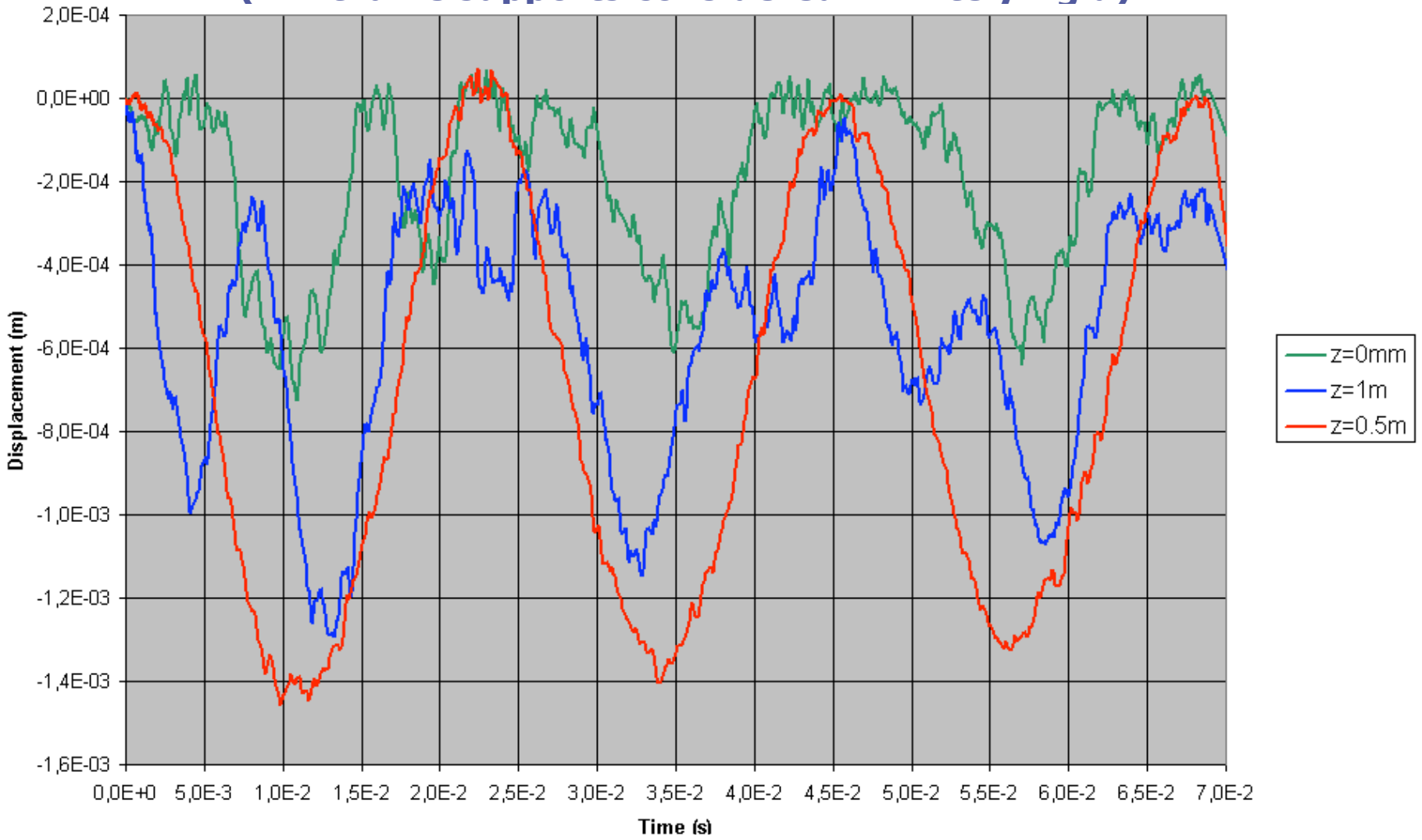
Thermo-mechanical Analysis

Calculated Transverse residual displacement: 16 mm



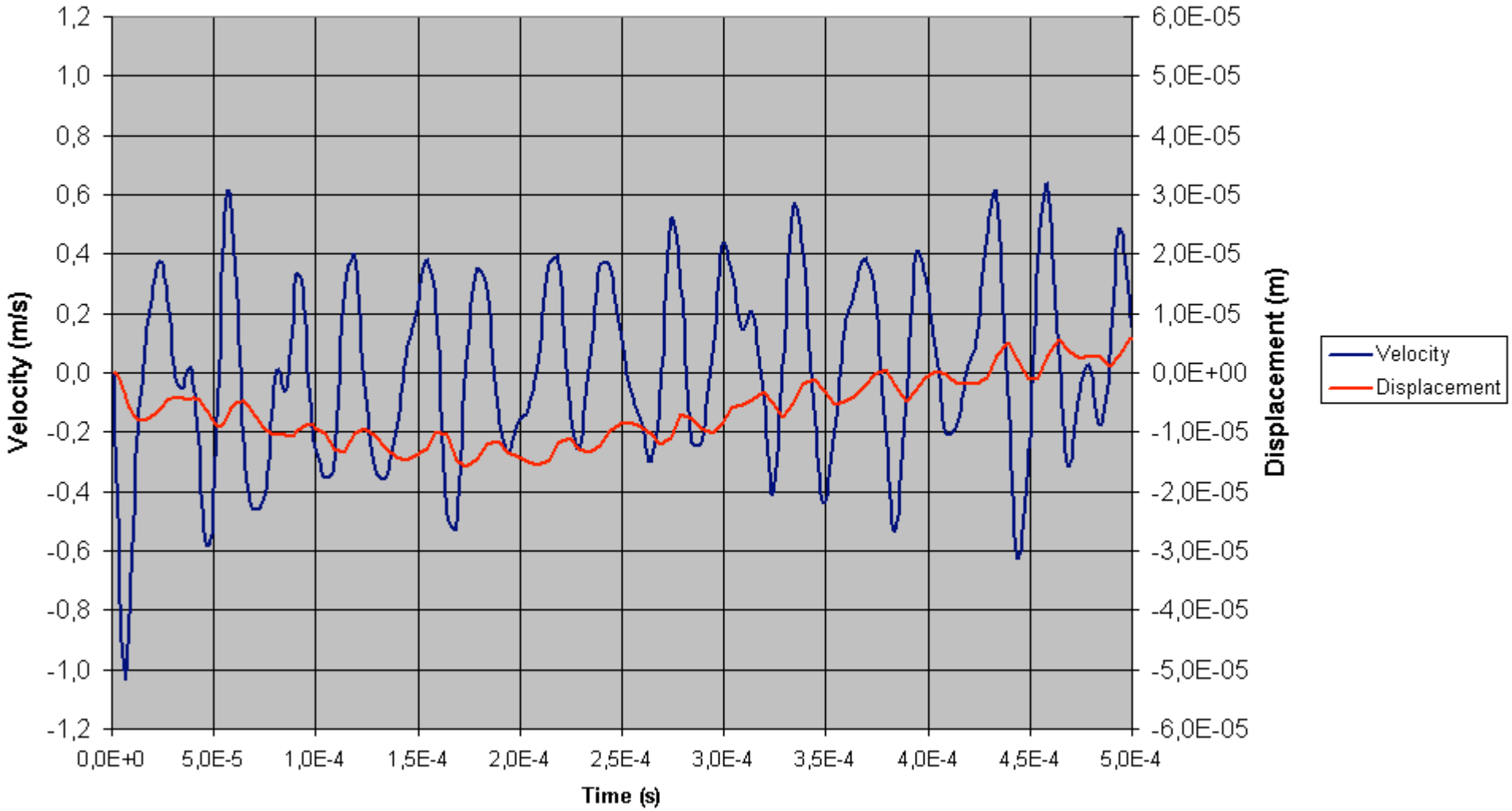
Thermo-mechanical Analysis

Jaw Transverse displacement versus time
(w.r.t. axle supports considered infinitely rigid)



Thermo-mechanical Analysis

Jaw Transverse velocity versus time at jaw centre



Indications for TT40 measurements (1/2)

- Maximum transverse displacement is found at jaw centre; displacement at jaw ends are also considerable.
- Highest mode of interest is at ~30÷35 kHz (max. velocity ~ 1m/s): to capture this mode 128ms recording time should be enough (Bandwidth 100 kHz)
- Low frequency bending oscillations (~40 Hz – 1.5 mm) can also be found with 128 ms recording, but final permanent deformation may not, as it might not be fully damped yet: slow recording is also necessary (12.8 s?)

Indications for TT40 measurements (2/2)

- Transverse jaw displacements should be taken at 100 mm (end of 1st tapering), 600 mm (jaw centre) and 1100 (start of 2nd tapering). Measurements on support axles as well?
- Relevant measurements should be taken at 5mm impact parameter; measurements can be scaled to numerical results for lower intensity shots.
- Assuming 4 shots are hitting the jaw at 5mm offset (intensity growing from 1 to 4 batches), measurements could be taken at high frequency for the low intensity shots (1 and 2 batches) and at low frequency for the high intensity shots, to capture the residual deformation.

Limitations of the numerical model

In setting up and calibrating the measuring system, one should bear in mind the following limitations:

- Several jaw assembly components were ignored, including the end tapered parts, bolts, etc. The mass is underestimated by ~15÷20% ⇨ Natural frequencies may be lower than predicted.
- Internal damping was completely ignored.
- Elastic-plastic behavior of materials is theoretical.
- Calculated displacements are relative to jaw axles. Absolute displacements of jaw supports are ignored.
- Mesh could only be rather coarse.
- The usual error band on Fluka simulation applies.