Target stress Analysis at DESY

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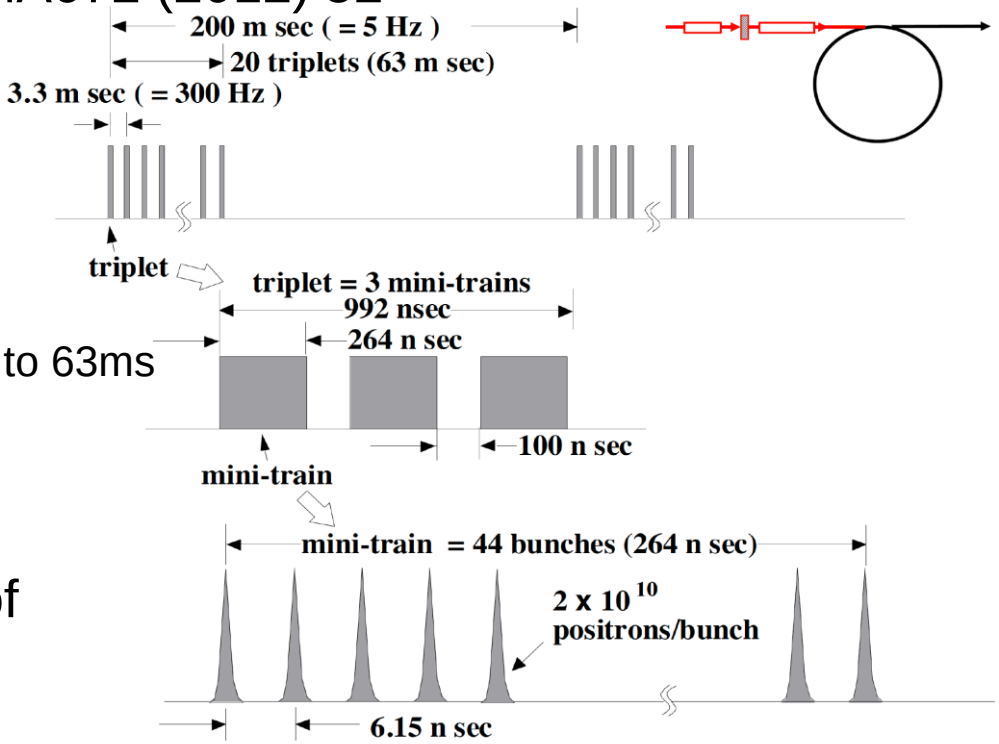
outline

- alternative source
- the models
- implementation in ANSYS
- temperature calculation
- time structure 1 – fine resolution
- time structure 2 – optimal resolution
- result
  - comparison of both time structures
  - comparison of both models
  - short time – normal stress in x-direction
  - short time – normal stress in z-direction
  - long time – normal stress
  - SLC vs. Convetional Source
  - Preliminary results – surface movement
  - Velocity (preliminary)
  - Deformation (preliminary)
- conclusion
- outlook

‘conventional’ ILC positron source

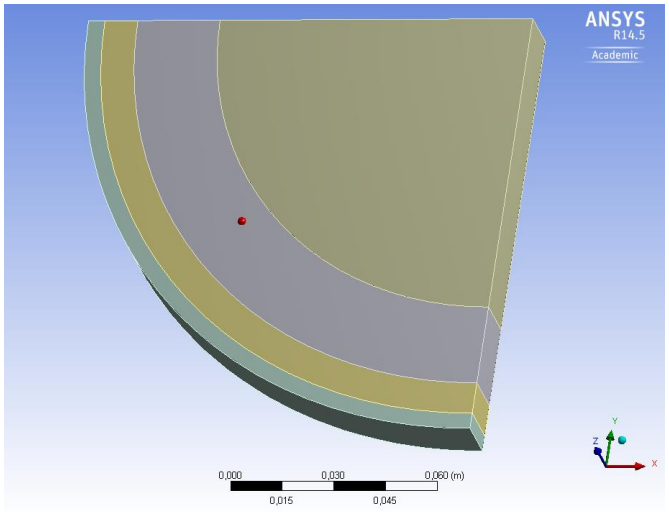
- suggestion of T. Omori et al. NIMA672 (2012) 52
- uses e^- beam E=6 GeV
- Target: tungsten t=1,4 cm
- 300 Hz-scheme
  - stretches ILC bunch train (~1ms) up to 63ms → less heat load
  - rotation is still needed v=5 $\frac{m}{s}$
- ILC time structure at extraction of e^+ from damping ring

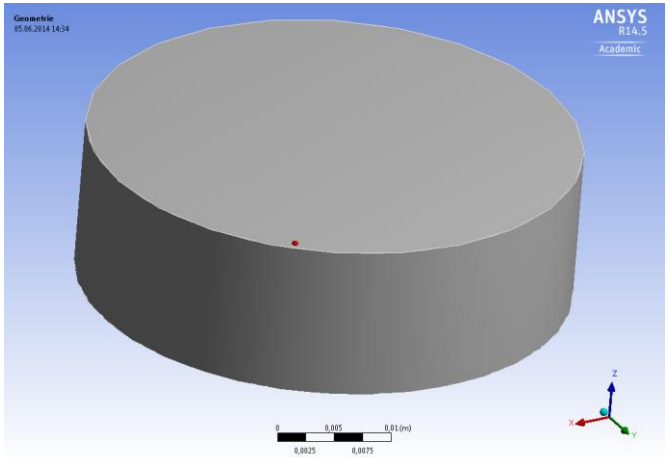


- average energy deposition in target: 35 kW
- Benchmark for max. load: SLC Target

the target models

- model 1– full target
  - Fe – ring (r_a=135mm)
  - Ag – ring (r_a=130mm)
  - W-26% – core (r_a=120mm)
  - distance to center of the beam= 10,75 cm
- model 2– beam spot only
  - W-26%
  - radius of the model r = 2,2cm
  - beam radius r_b= 0,8 cm $= 2\sigma$
- parameter for the models
  - particle shower has been calculated in FLUKA
  - $\Delta T(\text{per Bunch}) \approx 1{,}4K$

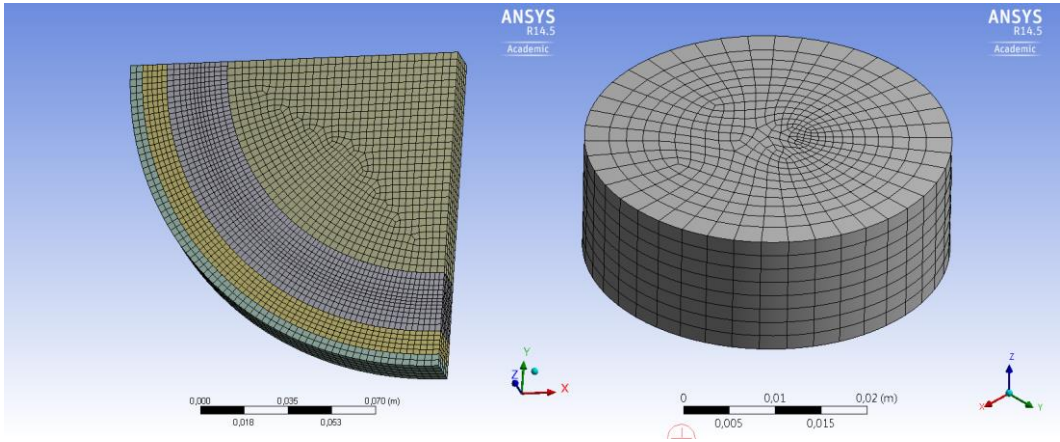




implementation in ANSYS

> Mesh of the FEM

- is linked to time structure
- $\Delta t = \frac{l}{c_S} \Leftrightarrow \Delta t$ is given → $l \approx 1.5 \mu m$
  c_S = speed of sound = 5174 $\frac{m}{s}$
- model 1 : 22124 elements
- model 2 : 9419 elements
- cubic elements



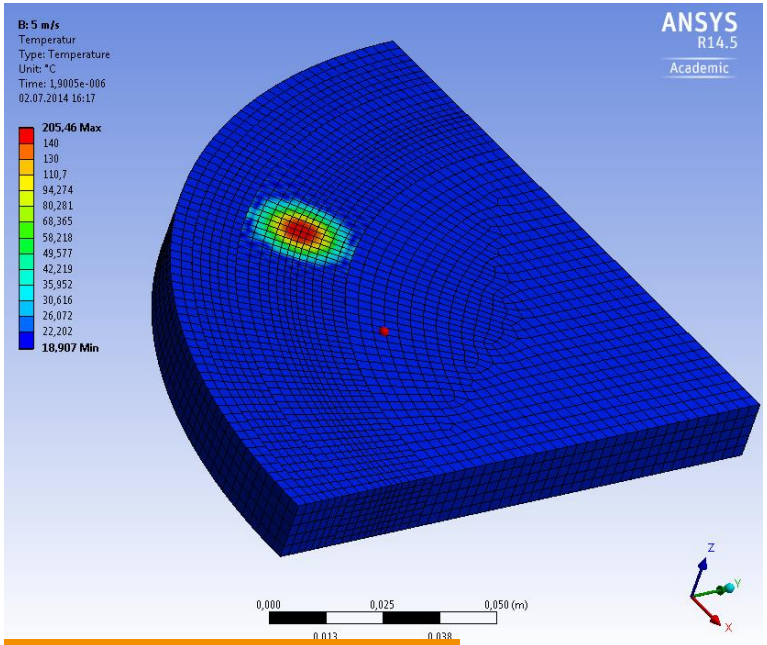
> time structure of the FEM

- linear rise of the temperature during one mini train → less computing time

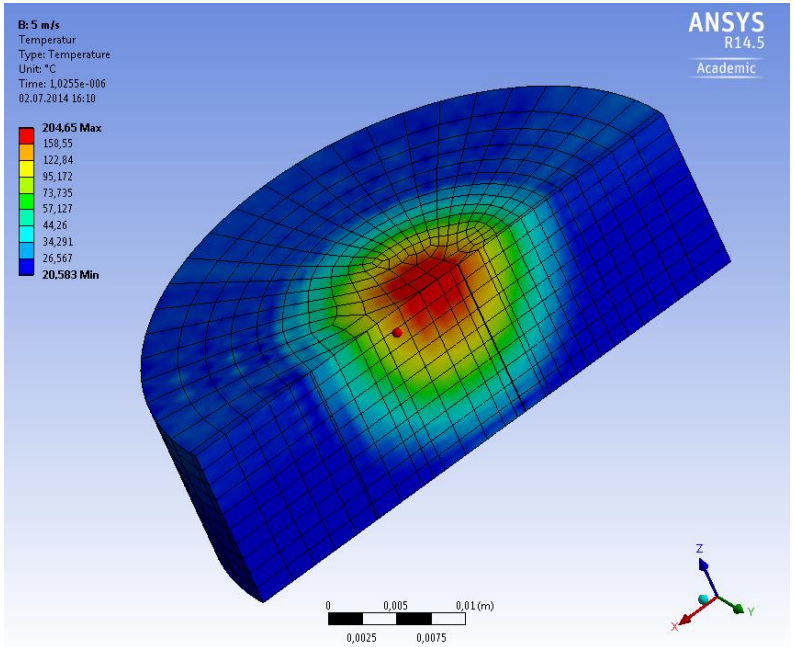
> calculation & results

- model 1 – full target : long time analysis, no sufficient resolution in the beam spot
- model 2 – beam spot only : short time analysis, but detail simulation of the beam zone

temperature distribution



Model 1 (full target)

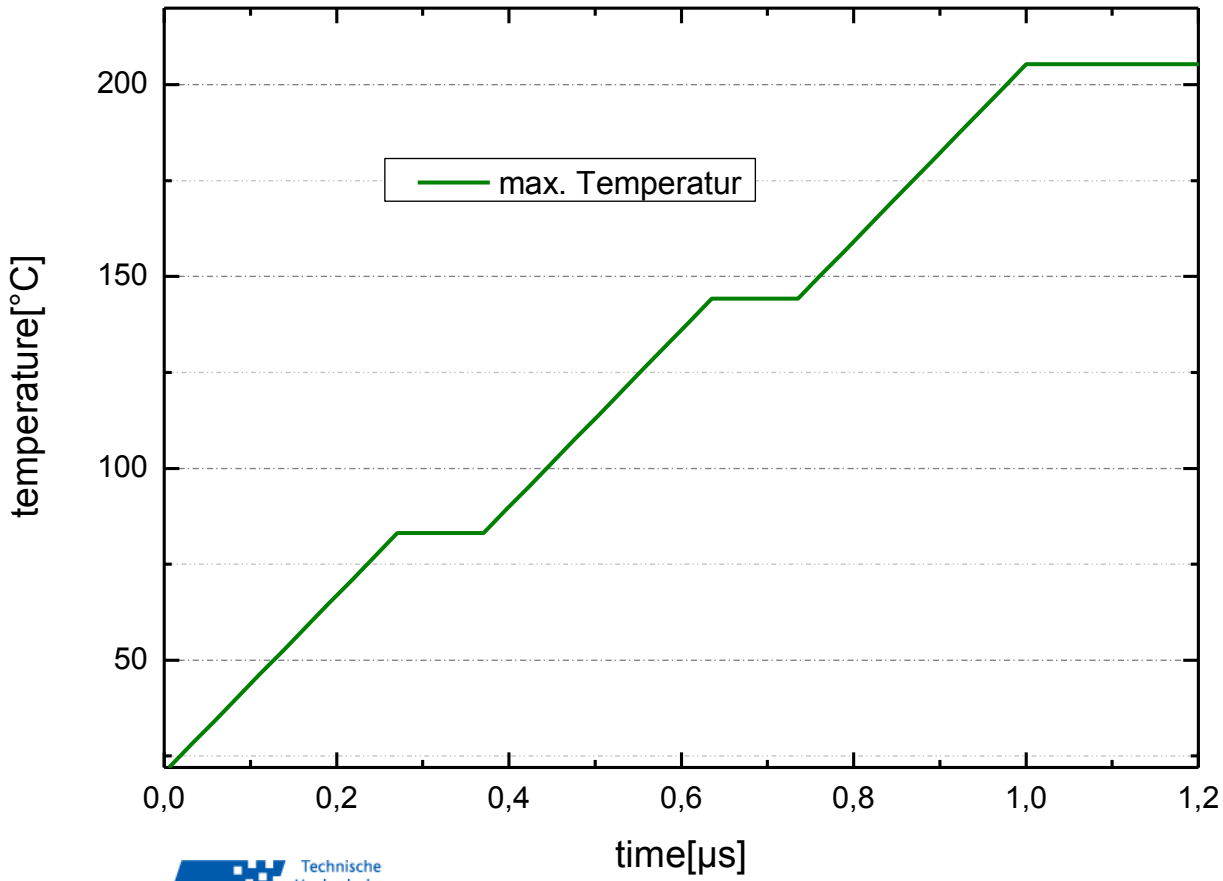


Model 2 (beam spot)

- FLUKA output describes the energy deposition and is used to calculate the temperature distribution
- good mesh→ regular and correct temperature rise

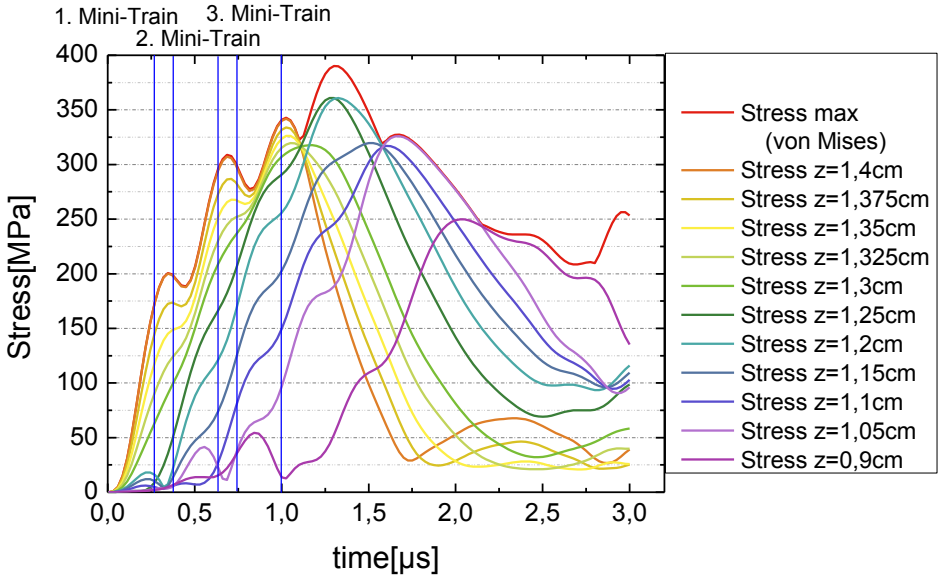
time structure – optimal resolution

- temperature rises per Mini - Train by 61,6 K → T_{max}=206 °C
- temperature rise for the first triplet (3 Mini-Trains) :

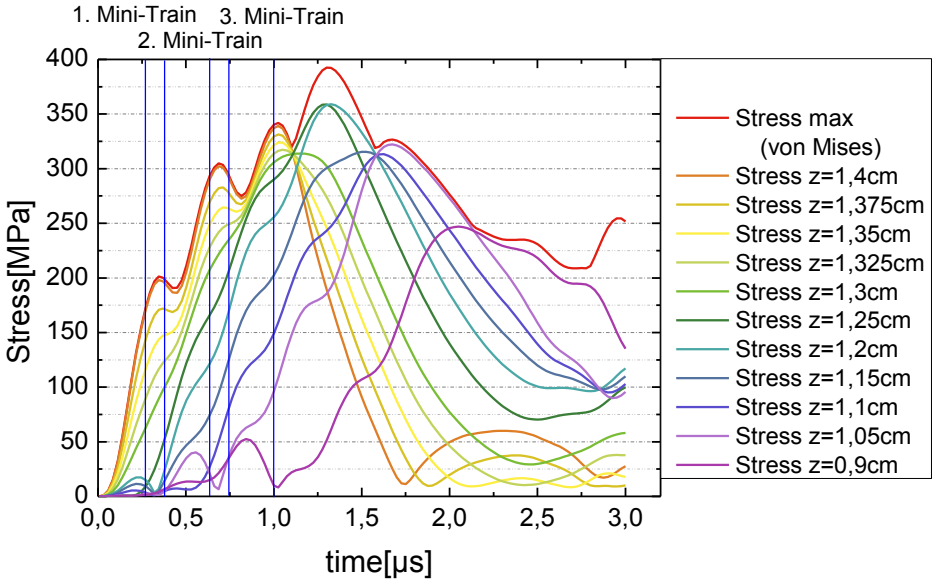


result – short time – comparison of the models

- model 1 (full target)



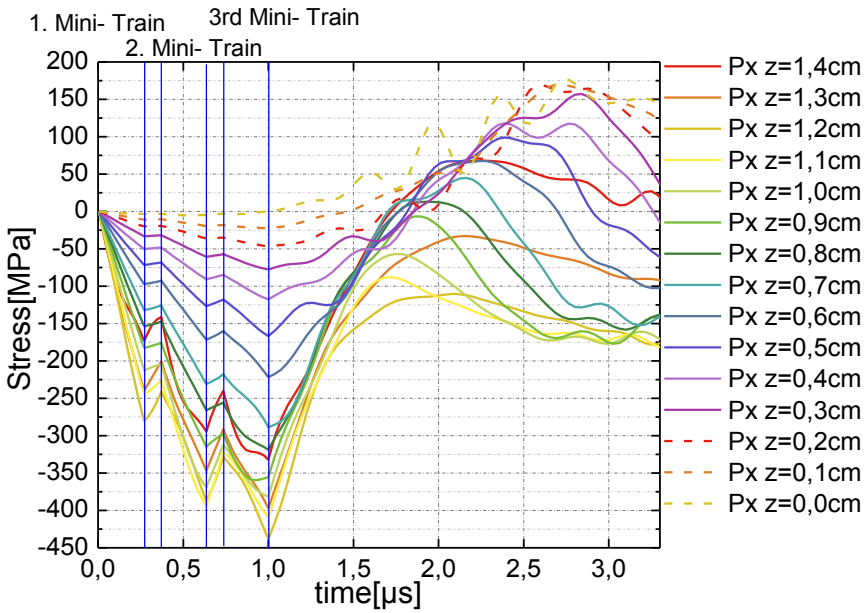
- model 2 (beam spot only)



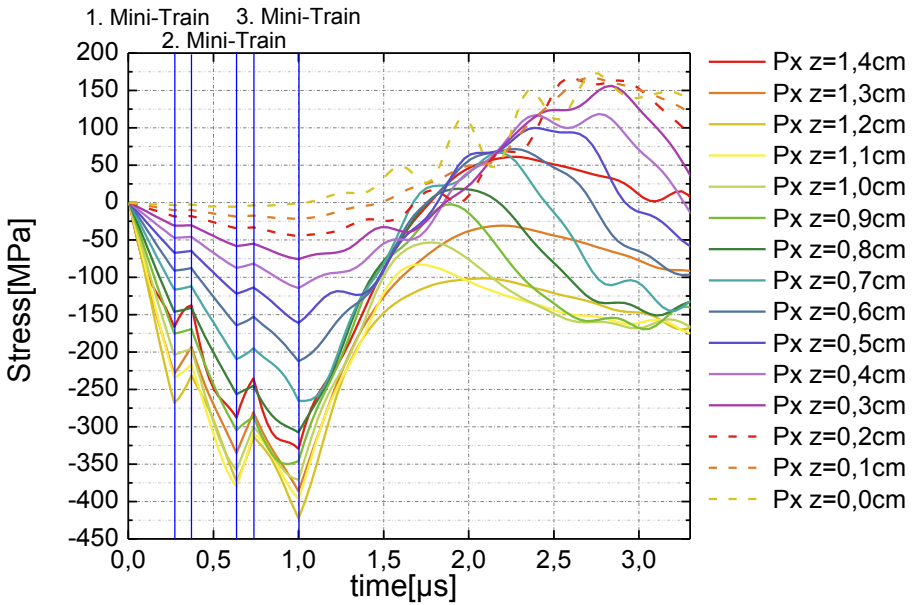
- von Mises stress for model 1 (full target) & model 2 (beam spot only)
- both graphs seem to agree well
- model 2 (beam spot only) can be used only for short time analysis; model 1 (full target) has to be used for long-term studies

result – short time – normal stress in x-direction

- model 1 (full target)



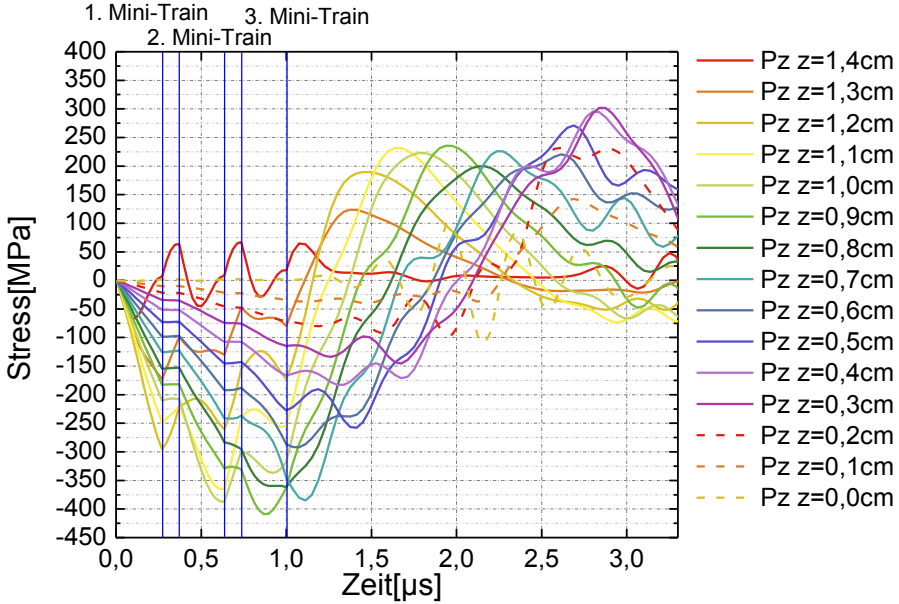
- model 2 (beam spot only)



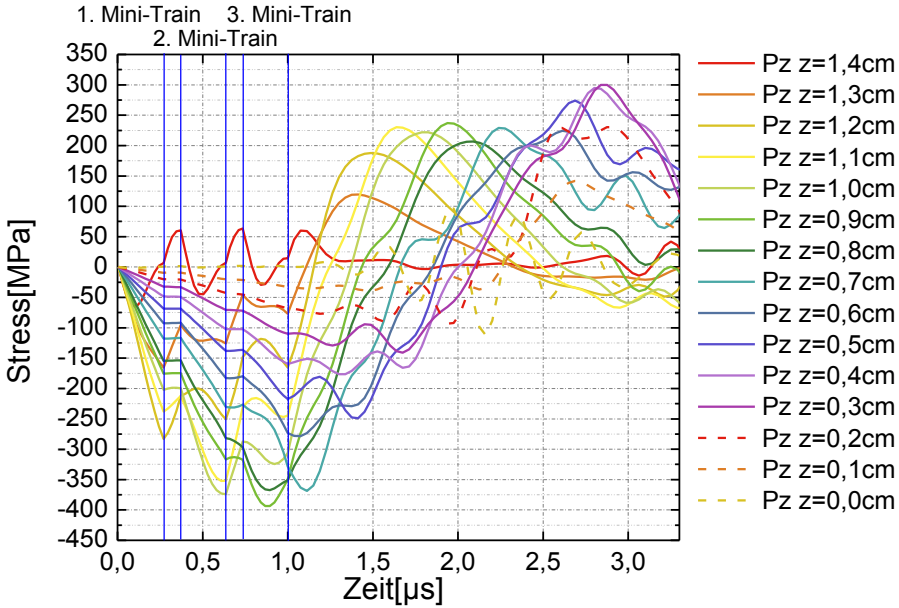
- short time analysis for both models → equivalent results
- stress is given at the center of the beam at different z-positions
- maximum stress : 438 MPa at the end of the last Mini-Train
- maximum stress not at the surface, at z=1,2 cm
- load changes of 549 MPa

result – short time – normal stress in z-direction

- model 1 (full target)



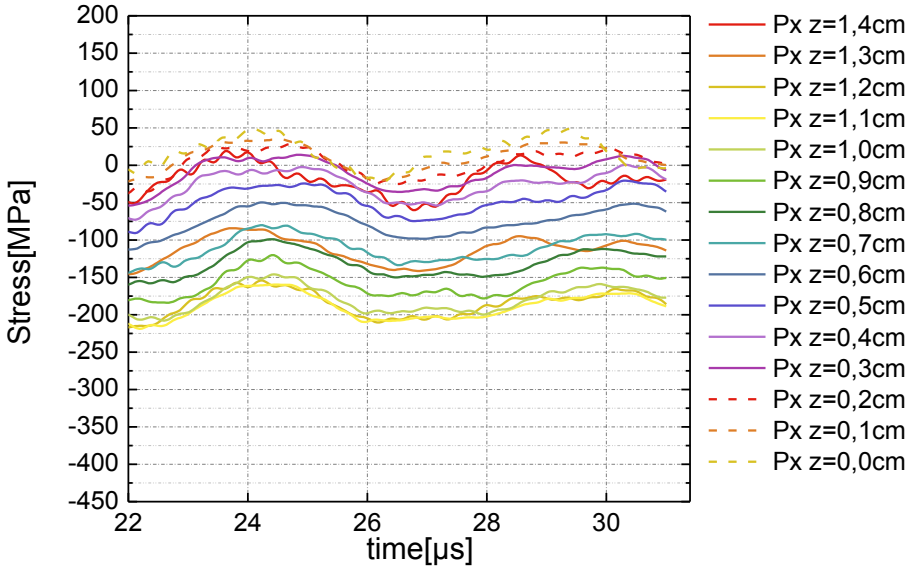
- model 2 (beam spot only)



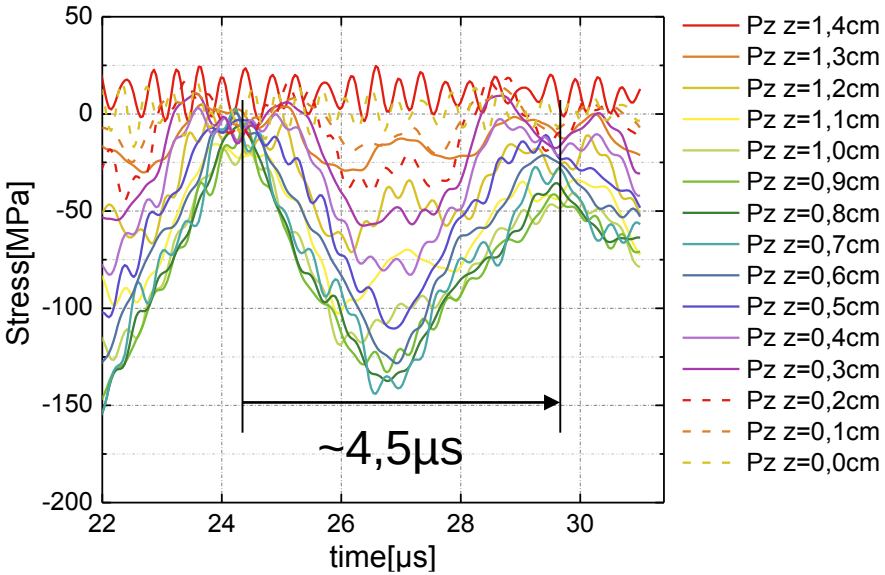
- short time analysis for both models → equivalent results
- stress is given at the center of the beam at different z-positions
- maximum stress 408 MPa during the last Mini-Train
- maximum stress not at the surface, at z=0,9 cm
- maximum load change : 644 MPa

result – long time – normal stress at z-axis

- x-direction



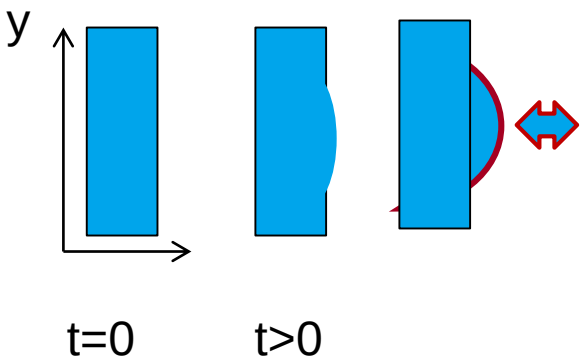
- z-direction



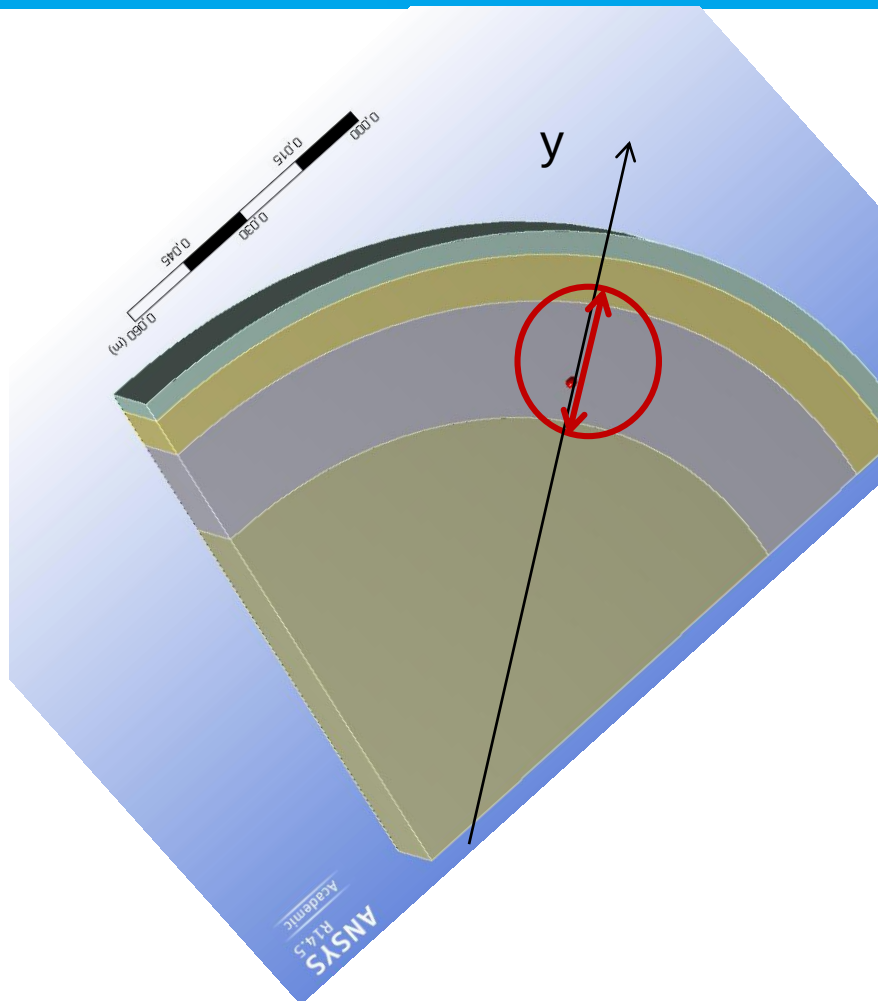
- only model 1 (full target) is suitable
- small amplitude in x-direction→ but high static stress
- Stress amplitudes in z-direction depend strongly on z-positions
- Basic frequency in z-direction: ≈4,5 µs (corresponds to doubled target thickness

Preliminary results – surface movement

- evaluate displacement and velocity at the exit side

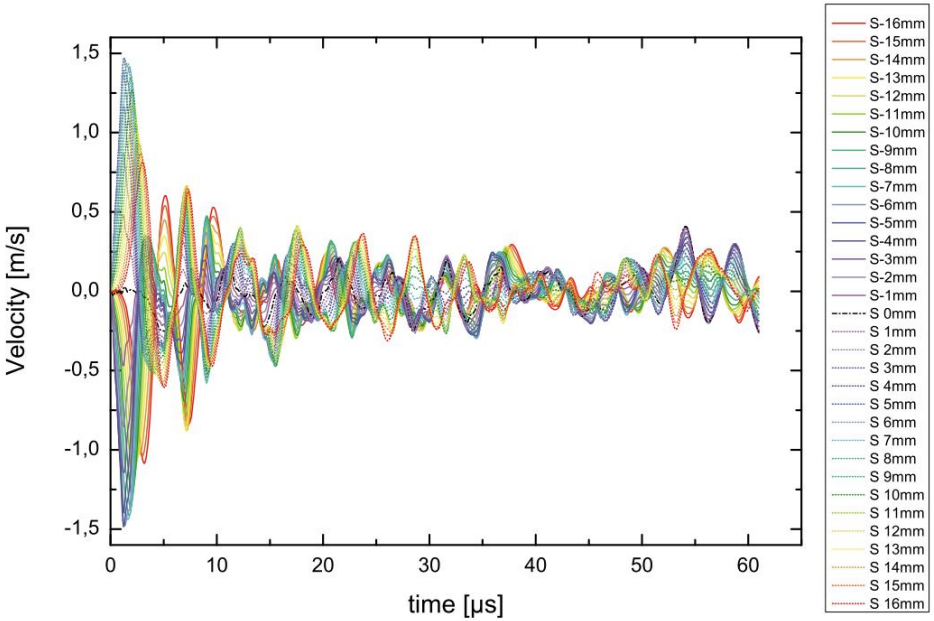


- data is collected at a line through the center of the beam spot up to +/-16 mm away from the beam spot center

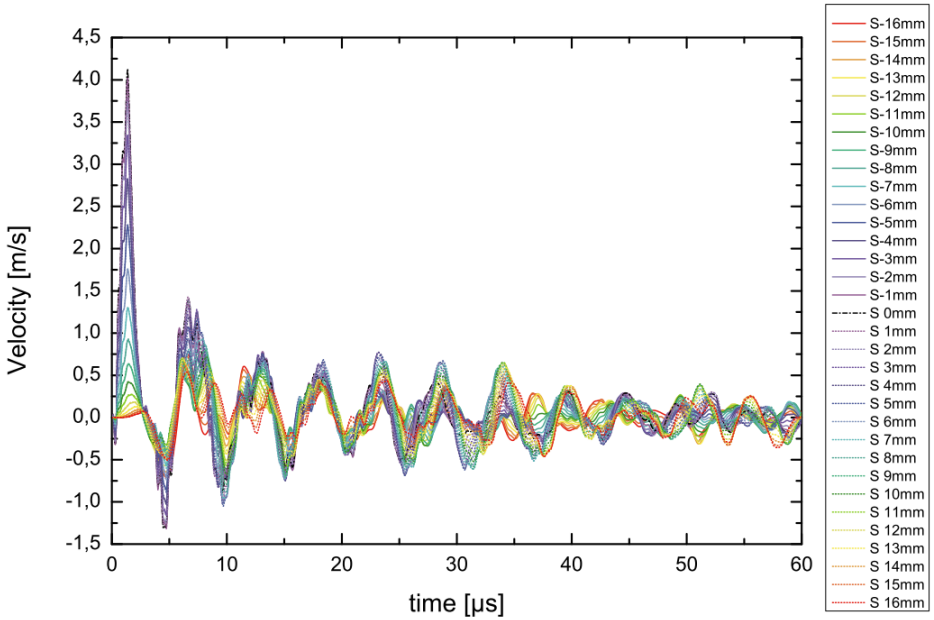


Result – velocity (preliminary)

x-direction



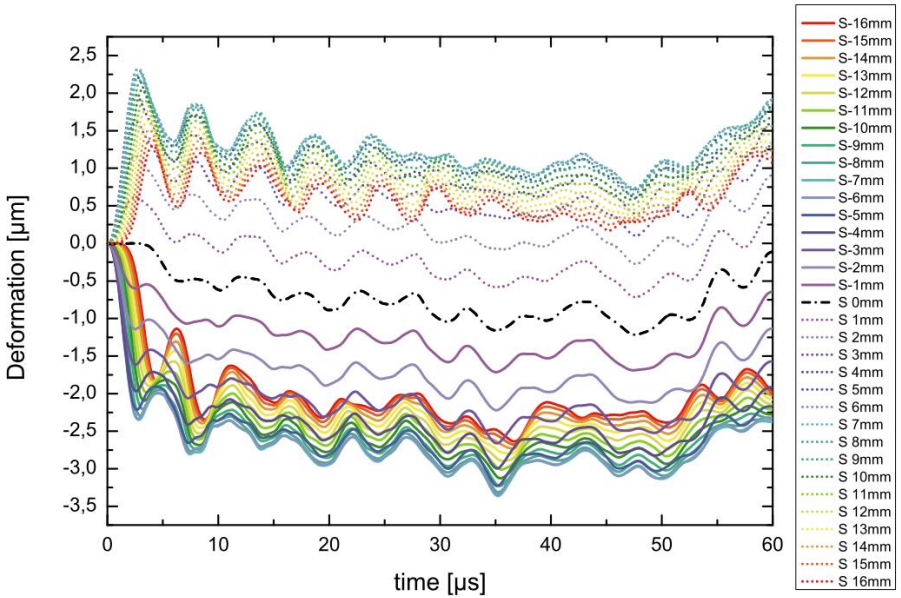
z-direction



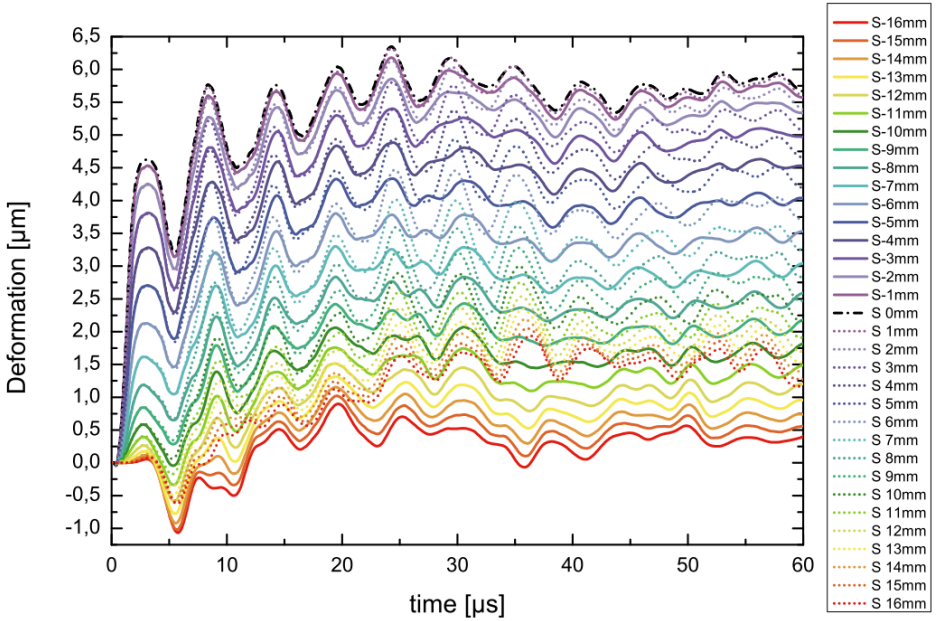
- shows velocity at the exit side at the center and +/-16 mm from the center with a stepping of 1mm
- max. elongation while heating
- highest speed obtained in z – direction in the center
- lowest speed obtained in x – direction in the center

Result – Deformation (preliminary)

x-direction

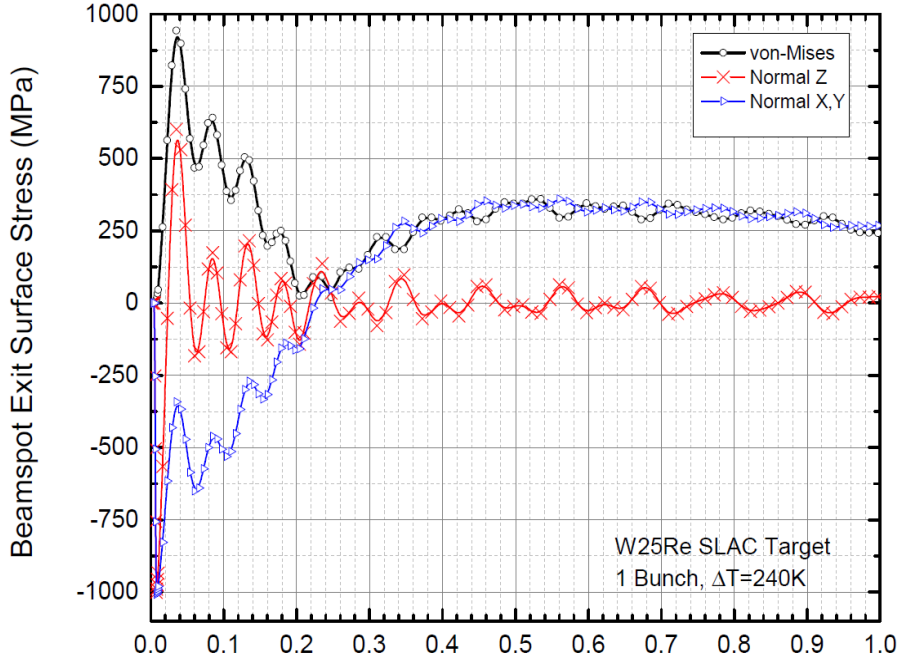


z-direction



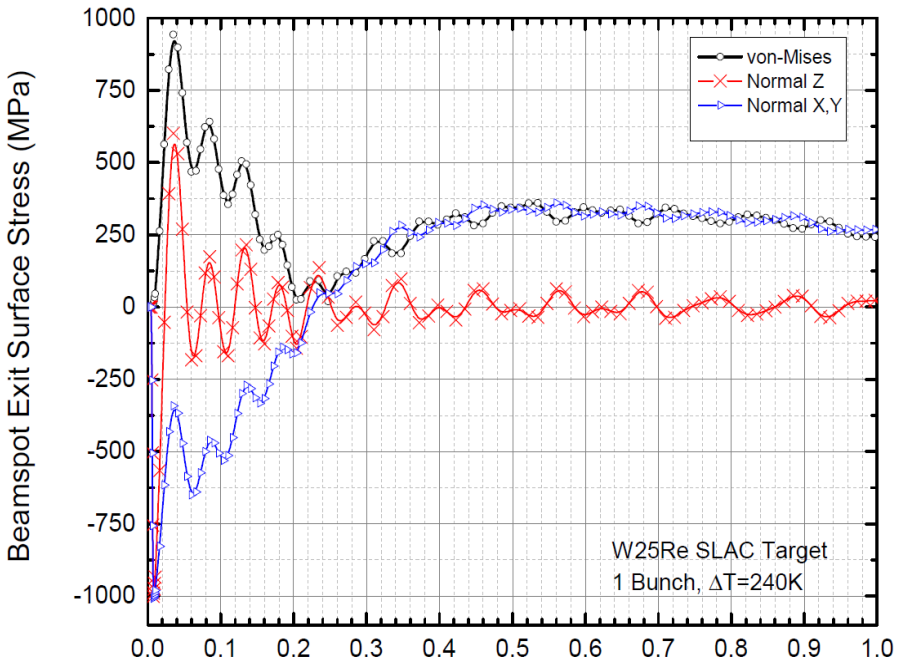
- shows deformation at the exit side at the center and +/-16 mm from the center with a stepping of 1mm
- max. elongation while heating
- highest deformation obtained in z – direction in the center; ~6.5 µm
- highest deformation obtained in x – direction at 8mm; ~3 µm
- Deformation amplitudes ~few µm

Stress at the SLC target

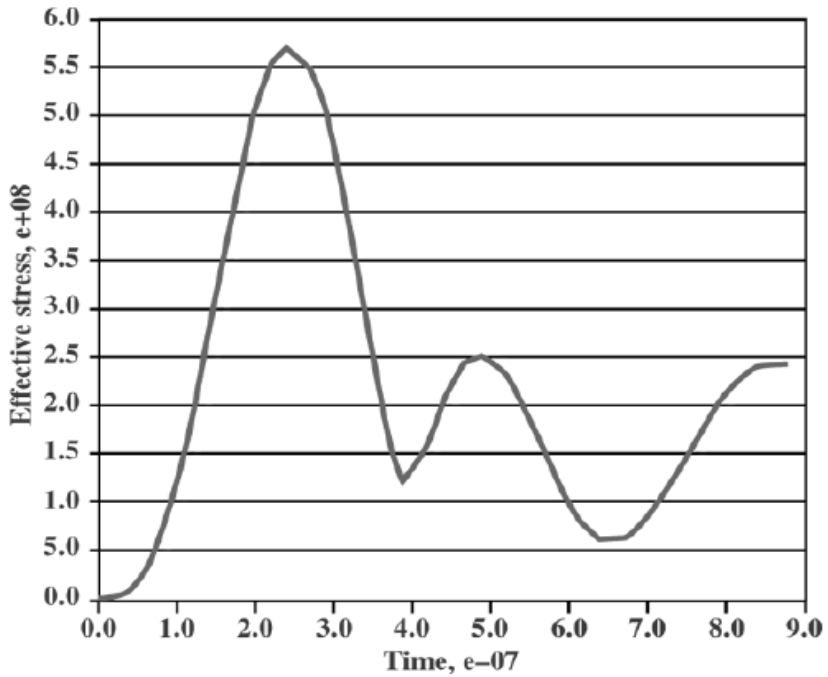


- SLC-Target stress analysis re-done by J. Howarth
  - Oscillations probably due to non-optimal time steps; will be reconsidered
- At t ≈ 0: Max normal stress ≈1GPa, but von Mises stress is zero

Stress at the SLC target

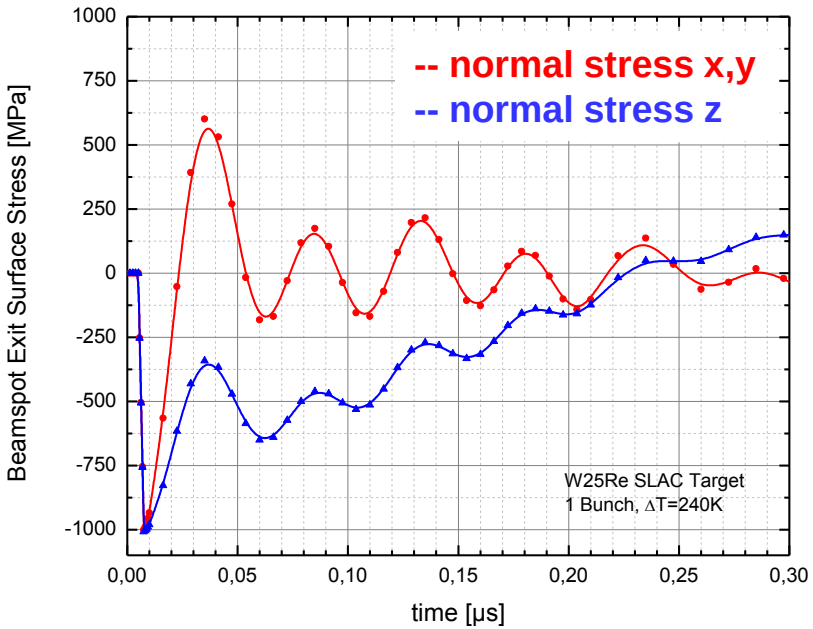


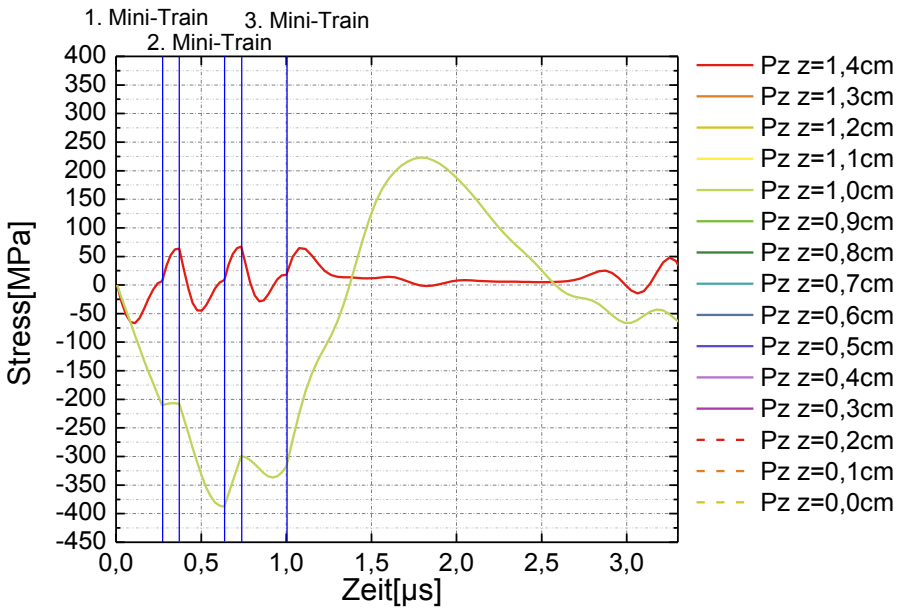
SLC-PUB-9437, Stein et al.;
$\Delta\sigma_{max,vM} \approx 550MPa$



- Normal stress load cycle values of ~1000MPa (Howarth et al.) compared to von Mises stress load cycles of 550MPa (W. Stein)
- J. Howarth could reproduce the result of W. Stein et al. using larger time steps and mesh size
- Dynamic peak stress values in SLC target probably higher than in 300Hz target

SLC vs. 300Hz conventional Source





- SLC-Target stress analysis done by J. Howard
  - Oscillations probably due to non-optimal time steps; will be reconsidered
- SLC: one bunch/train, $\Delta T \sim 200K$ within few tens ps
  300Hz scheme: energy deposition per mini-train → $\Delta T \sim 200K$ within 1µs
- SLC target stress shows probably substantially higher peak values than stress in the 300Hz target
- Further studies needed

conclusions

- 300Hz target: maximum Mises stress : 392 MPa
  - Von Mises stress is always positive→ not suitable for load change evaluation
- 300Hz target: maximum normal stress in z direction 437MPa, maximum is about 3mm - 4mm beneath the surface
- max load change in z direction is 643MPa; higher than the limit of 589 MPa → early material dysfunction possible
- 300Hz target: deformation and speed of deformation (preliminary):
  - z-direction = highest speed/deformation in the center
  - x-direction = highest speed/deformation at 8 mm from the center
  - max displacement values are below 10μm
- Dynamic stress in SLC target probably higher than in 300Hz target due to the energy deposition in much shorter time (studies will be continued)
- Considering the target stress, the 300 Hz-scheme should work

outlook

- simulation for a longer period:
  - more triplets
  - with target rotation
  - Detailed comparison with stress in SLC target
- degradation of the target material
  - new stress simulation with modified material parameters

→ Update/confirmation of target parameters

thank you for your attention

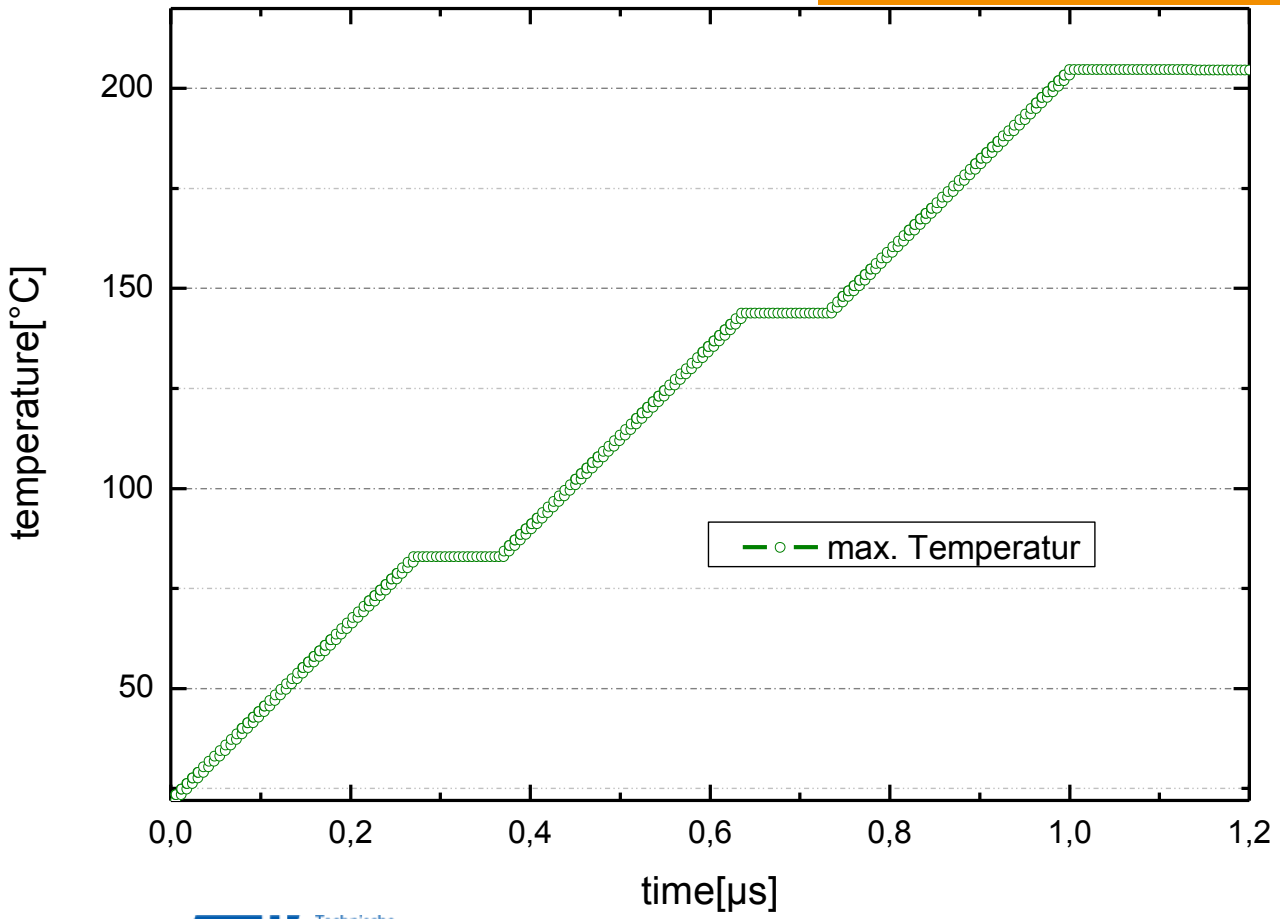
Back up

- Zeitliche Grenzen des model 2
- $t_{Modell\,2} = \frac{2*r}{c_s} = \frac{4{,}4*10^{-2}\,m}{1574\,\frac{m}{s}} = 28\,\mu s$
  - r → Radius
  - c_s → Schallgeschwindigkeit

time structure 1 – fine resolution

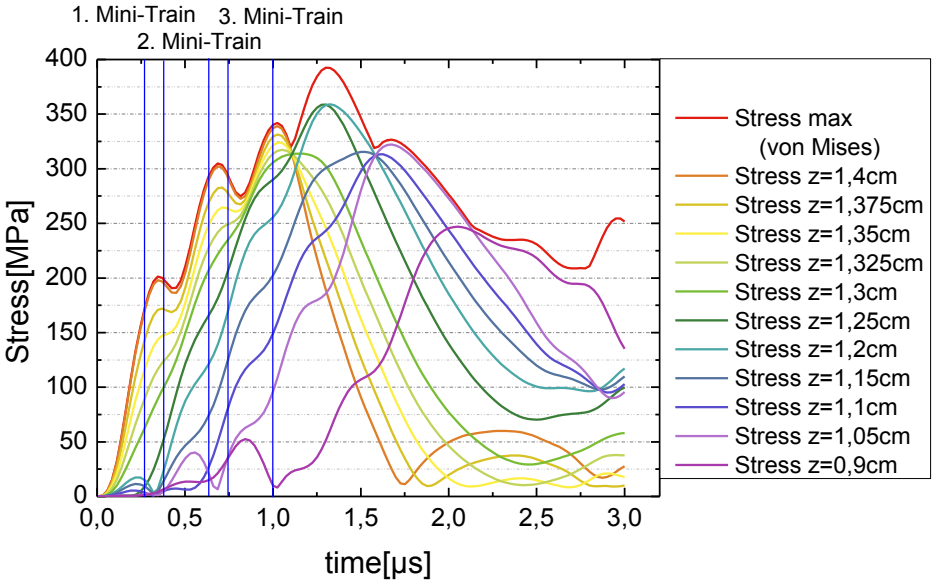
- temperature rise per bunch by 1,4 K → T_{max}=206 °C
- temperature rise for the first Triplet:

Slide weglassen – ggf ins backup

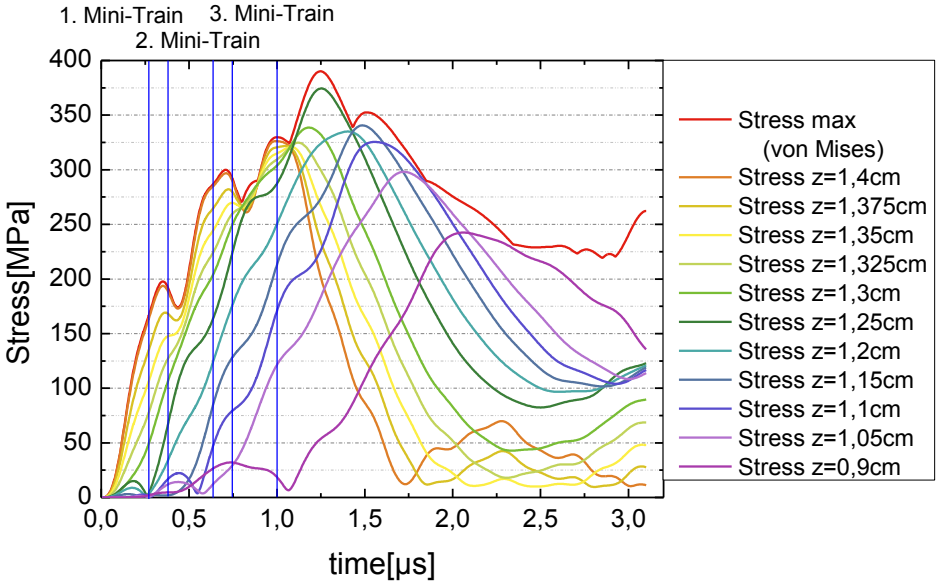


results – short time– comparison of the time structures

- time structure 1 (fine resolution)

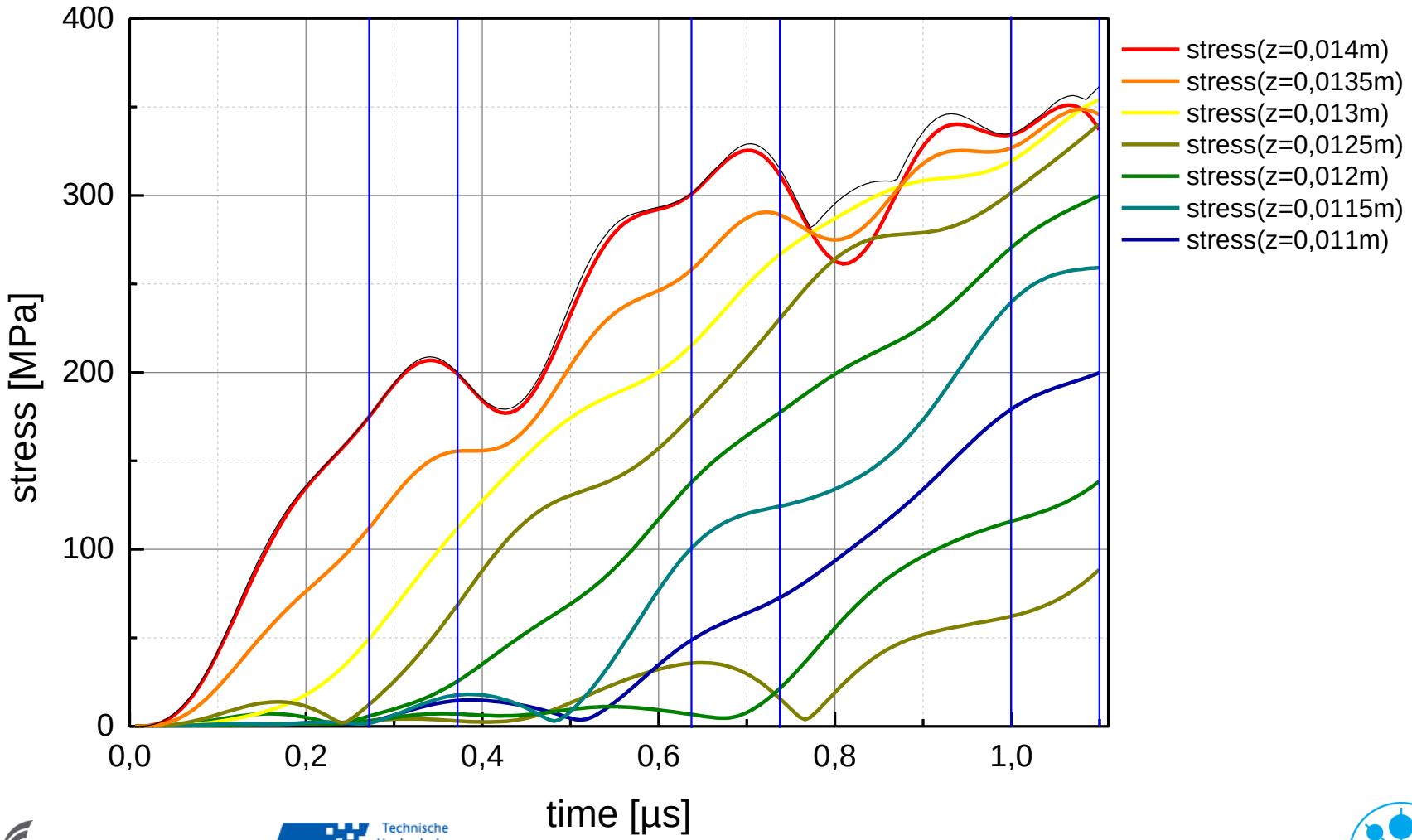


- time structure 2 (optimal resolution)



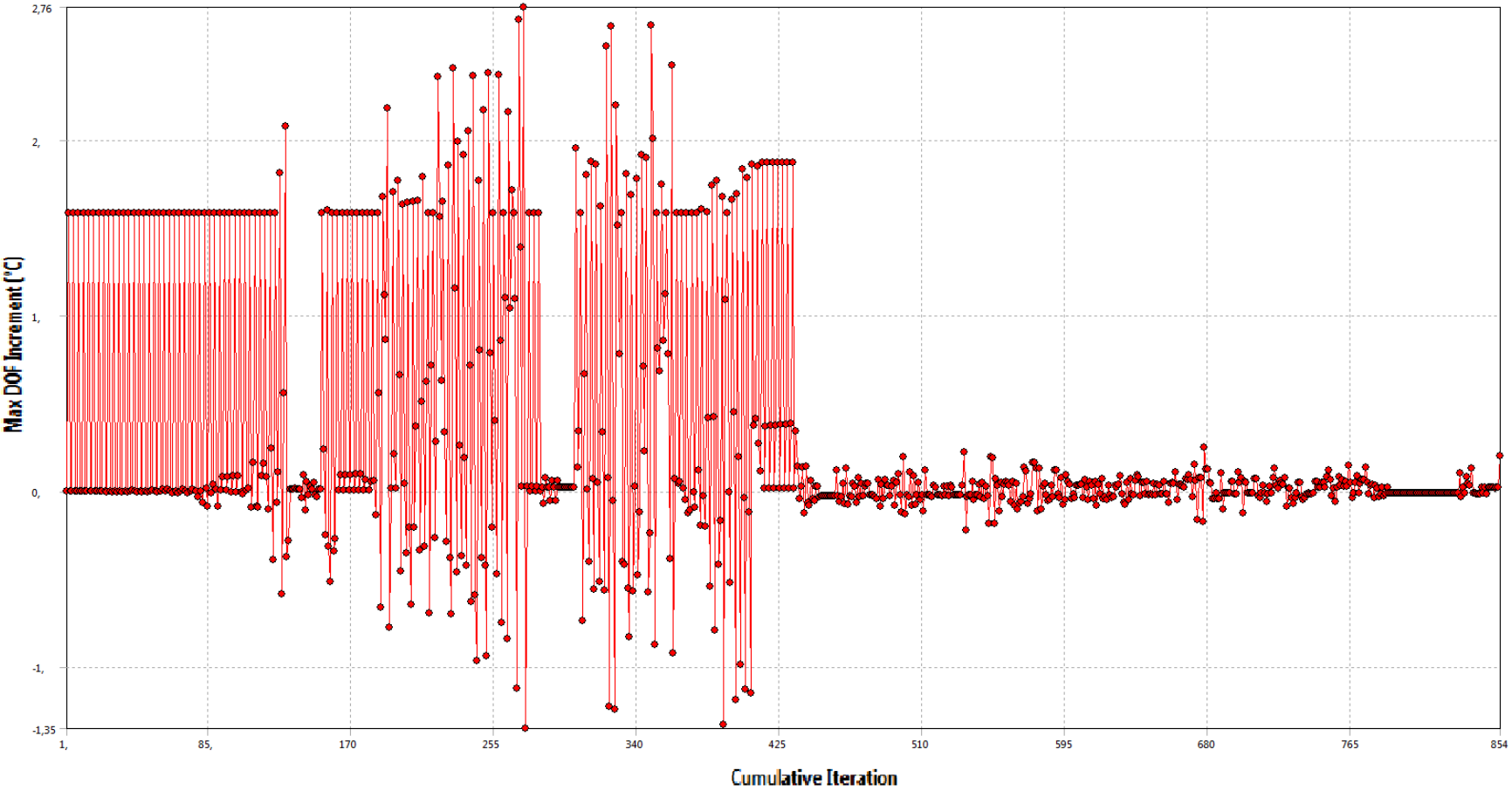
- Von Mises stress of model 2 (beam spot only) with time structure1 (fine resolution) & time structure 2 (optimal resolution)
- both graphs are equally sufficient → time structure 2 (optimal resolution) can be used instead of time structure 1 (fine resolution) → less computing time

Addition

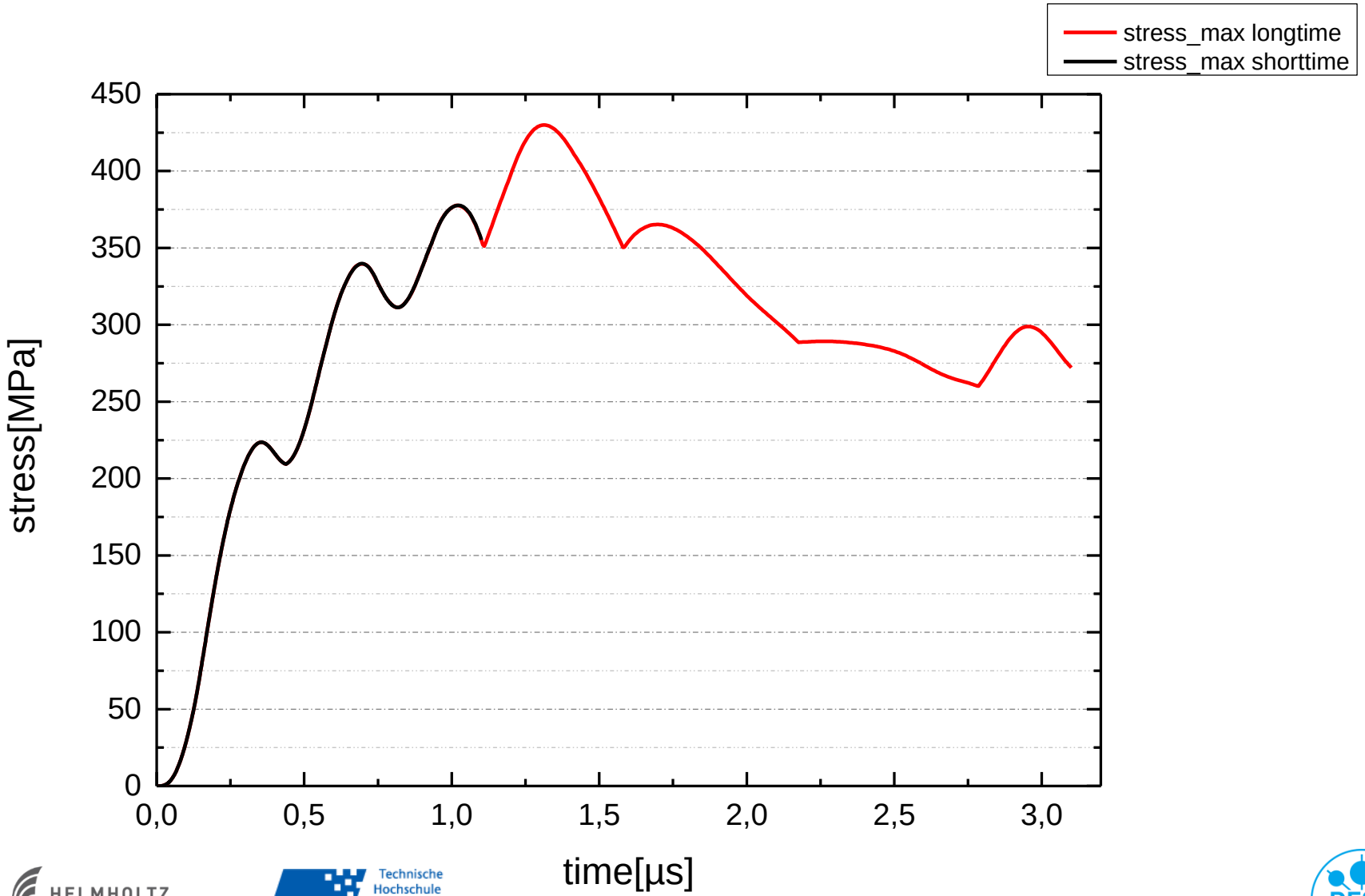

400
300
200
100
0
stress [MPa]
0,0
0,2
0,4
0,6
0,8
1,0
time [µs]
stress(z=0,014m)
stress(z=0,0135m)
stress(z=0,013m)
stress(z=0,0125m)
stress(z=0,012m)
stress(z=0,0115m)
stress(z=0,011m)

Addition

- 0,3


2,76
2,
1,
0,
-1,
-1,35
Max DOF Increment (°C)
1,
85,
170
255
340
425
510
595
680
765
854
Cumulative Iteration

Addition


stress_max longtime
stress_max shorttime
stress[MPa]
450
400
350
300
250
200
150
100
50
0
0,0
0,5
1,0
1,5
2,0
2,5
3,0
time[µs]

time structure 1 – fine resolution

- temperature rise per bunch by 1,4 K → T_{max}=206 °C
- temperature rise for the first Triplet:

Slide weglassen – ggf ins backup