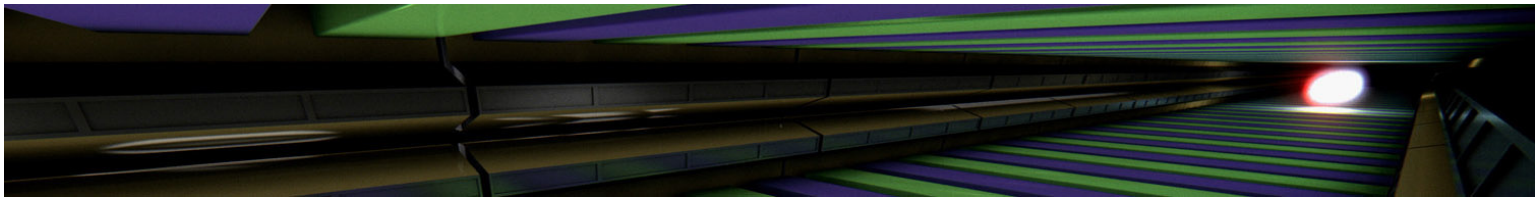


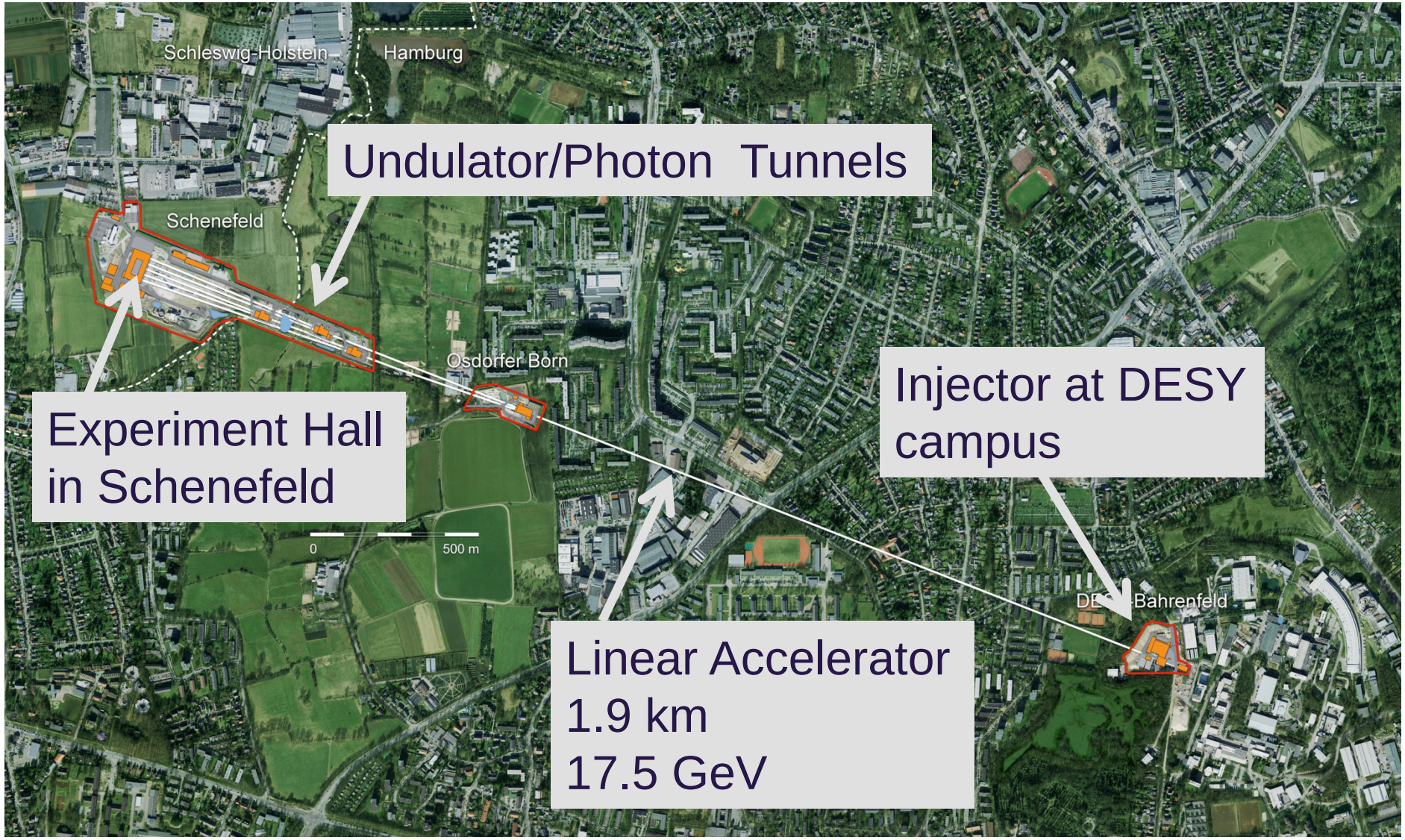
Damage limitations to scientific experiments at the European XFEL

Viktor Lyamayev (European XFEL, Hamburg)

Damage to VUV, EUV, and X-ray Optics V
Prague,15-16 April 2015

European XFEL

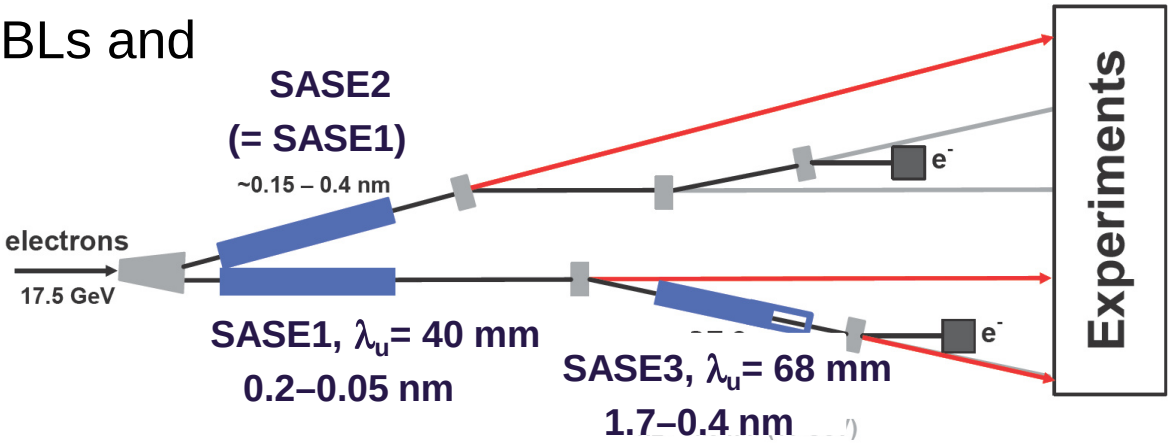
European XFEL layout



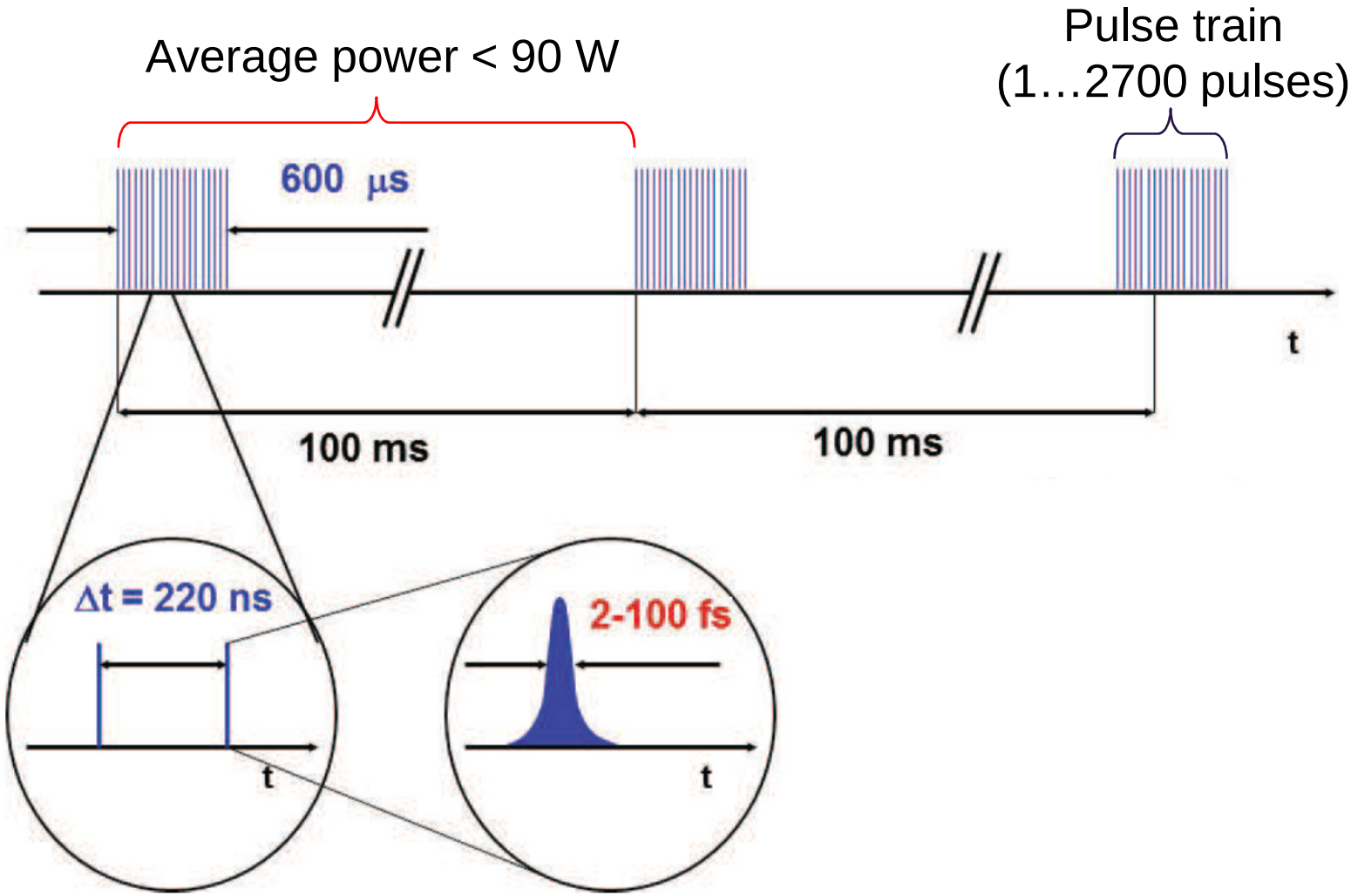
European XFEL

Some specifications

- Photon energy 0.24–24 keV
- Pulse duration ~ 10–100 fs
- Pulse energy few mJ
- Superconducting linac. 17.5 GeV
- 10 Hz (27 000 b/s)
- 5 beamlines / 10 instruments
  - Start version with 3 BLs and 6 instruments



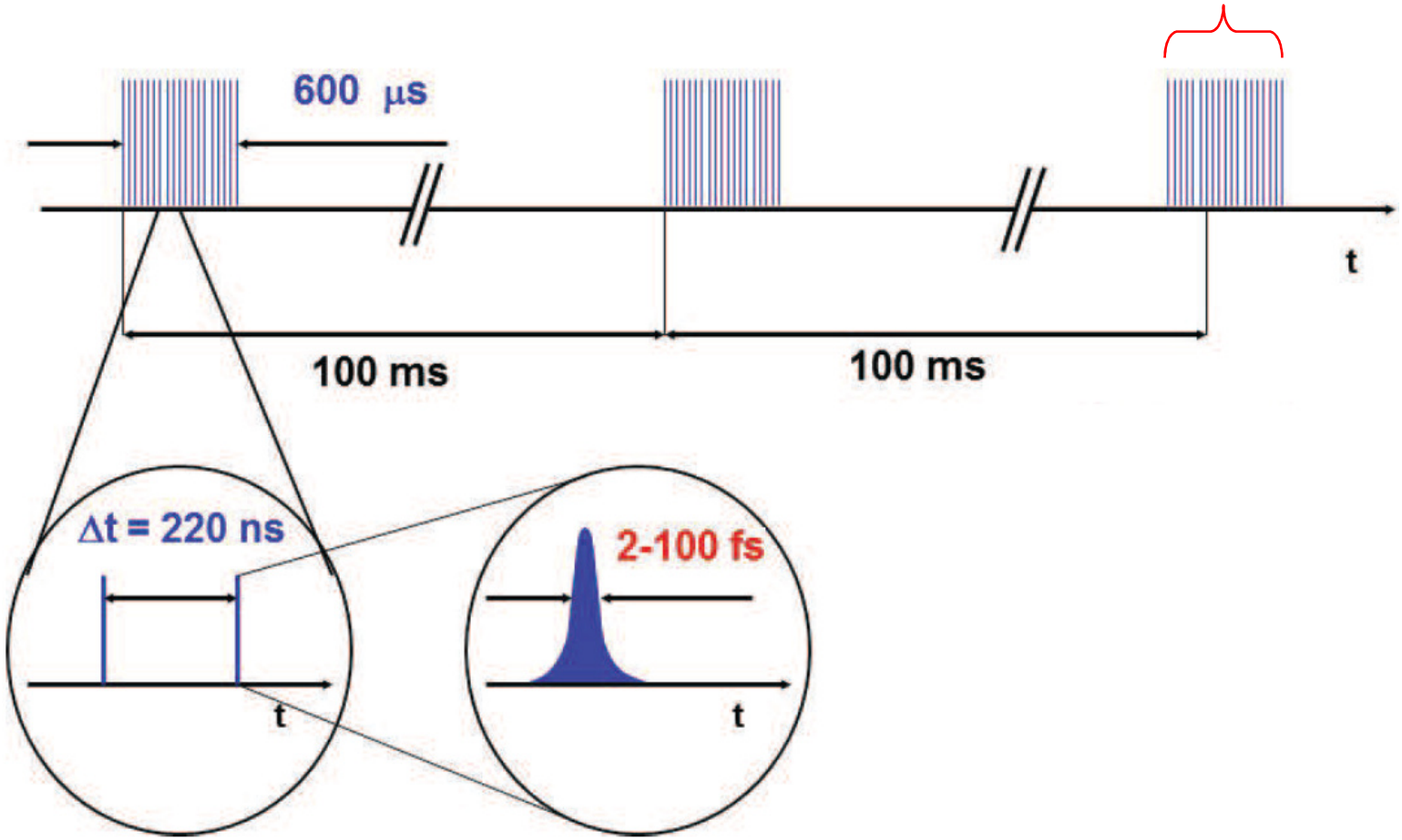
X-ray pulse structure



X-ray pulse structure of the European XFEL

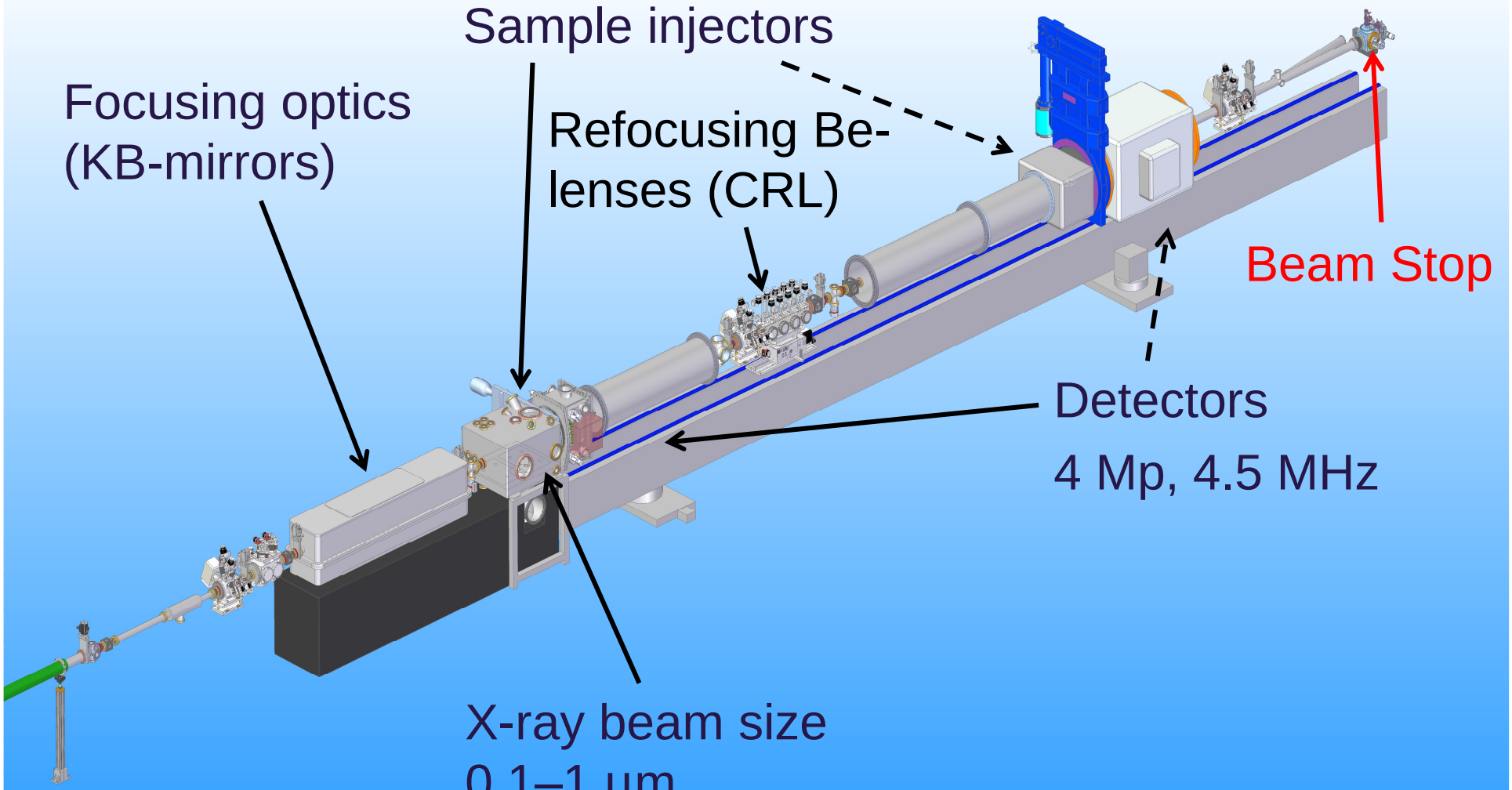
X-ray pulse structure

Power of each pulse train: 3 mJ * 2700 pulses / 0.6 ms = **13 kW** !!!



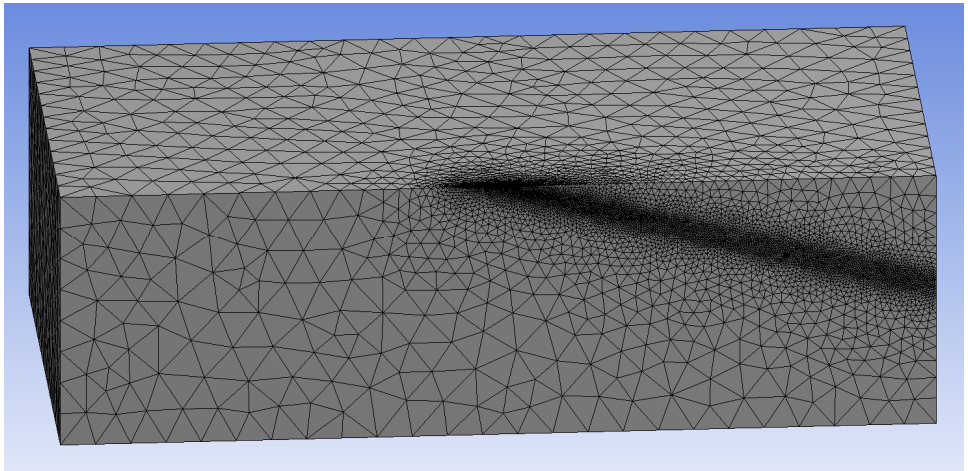
X-ray pulse structure of the European XFEL

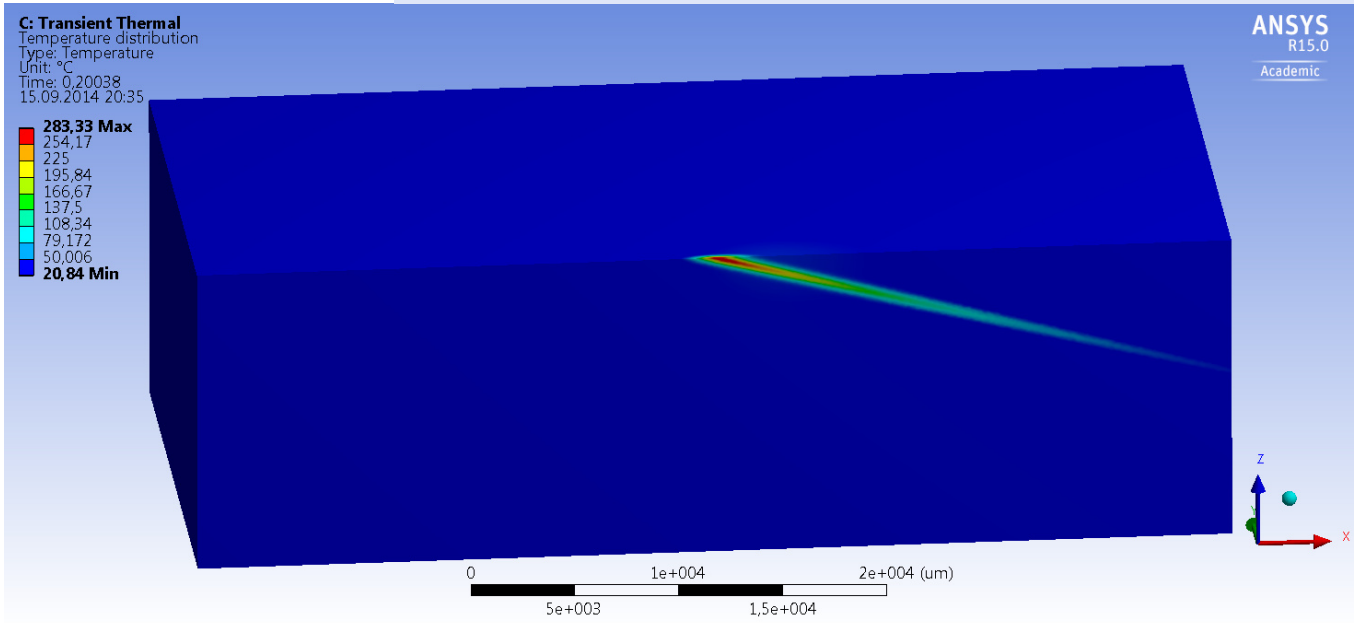
Single Particles, Clusters, and Biomolecules (SPB) Instrument



FEM-analysis of the heat load

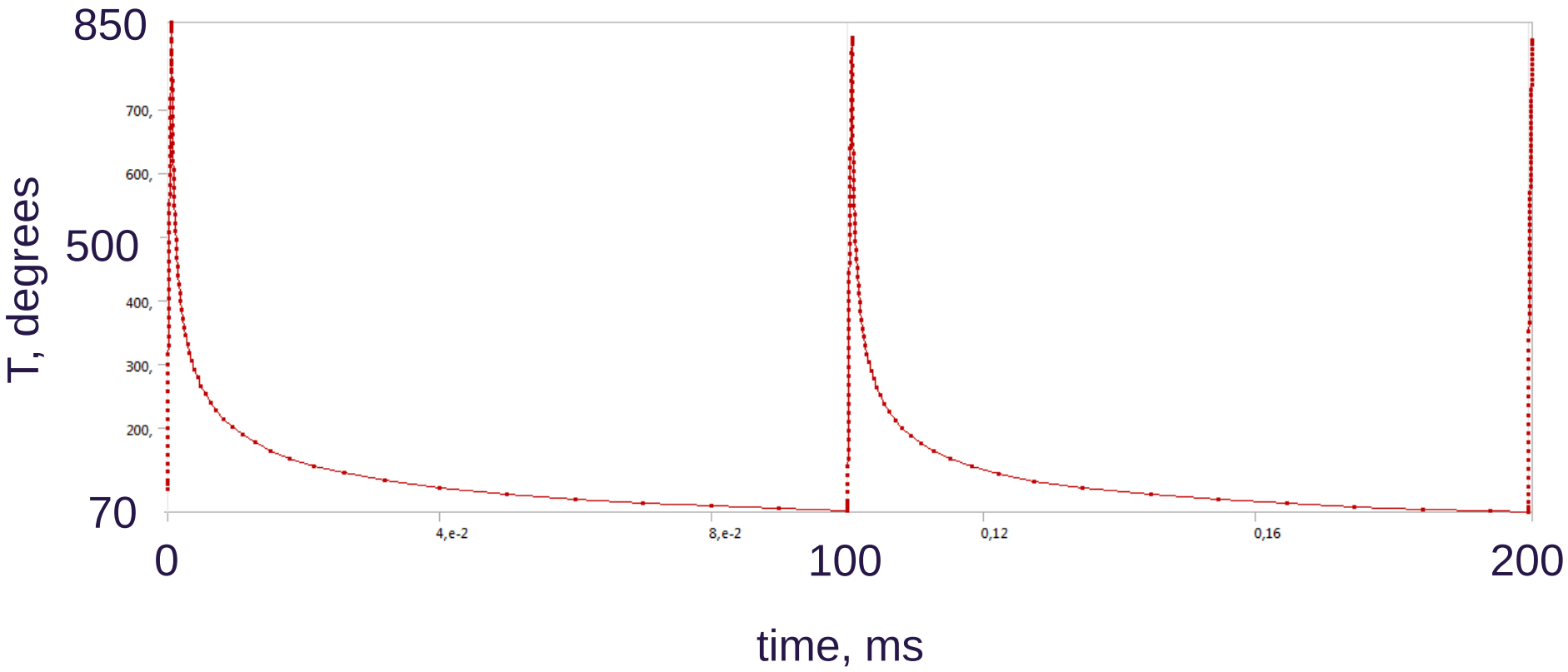
The main problem is to combine fine meshing of a small interaction volume (e.g. FWHM = 20 µm) with meshing of much bigger absorbing body (e.g. 50×50×50 mm³).





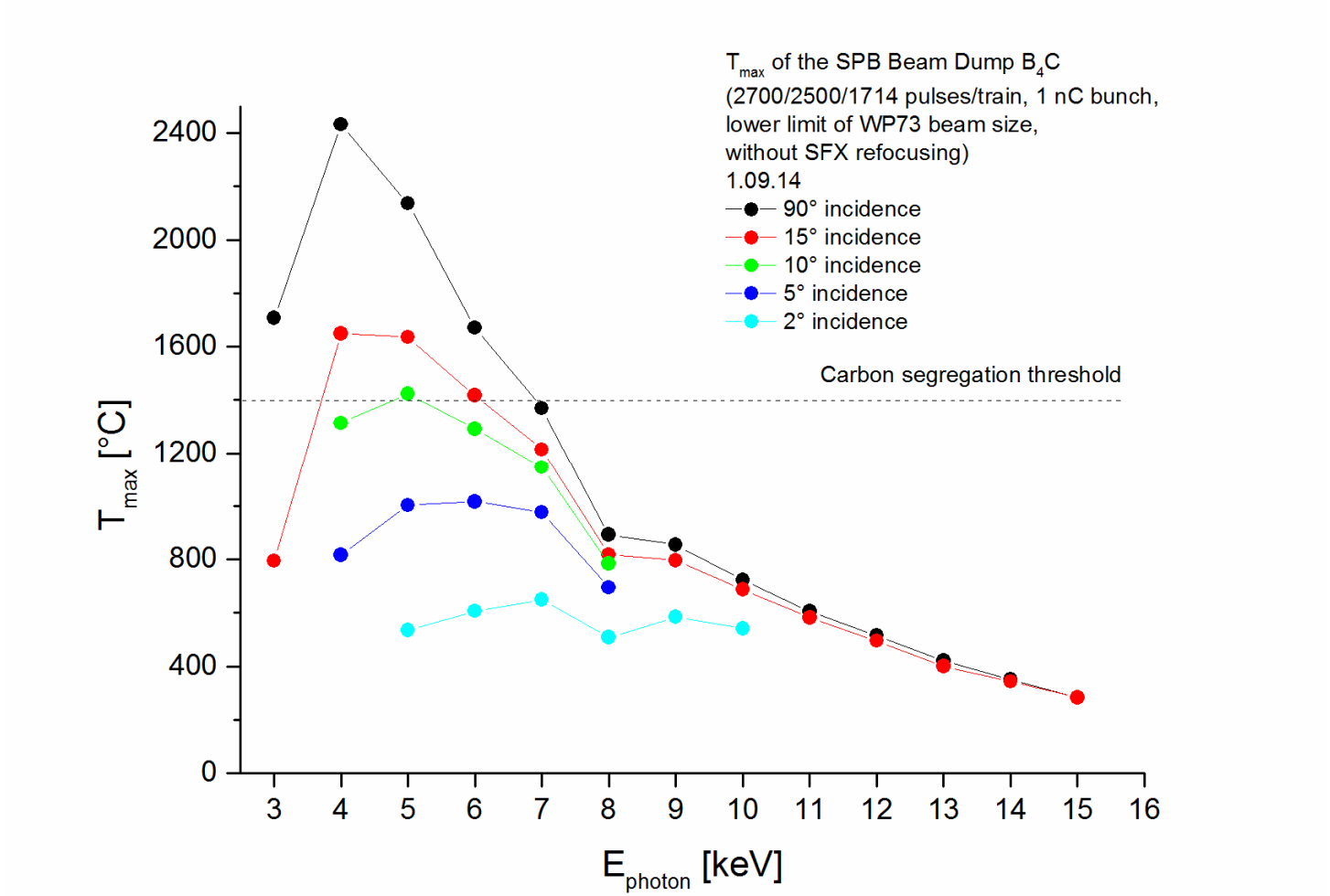
FEM-analysis of the heat load

Heat load on the B_4C absorber of the Beam Stop (3 consecutive pulse-trains):



FEM-analysis of the heat load

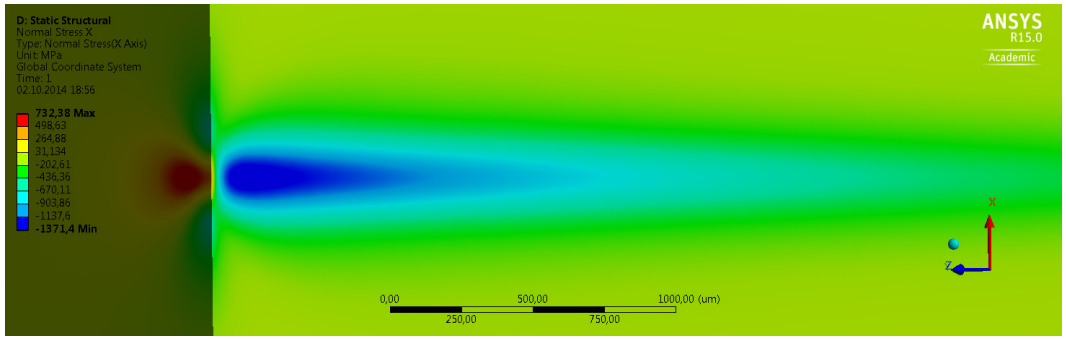
Heat load on the B_4C absorber of the Beam Stop



FEM-analysis of the heat load

Thermomechanical stresses in B_4C absorber of the Beam Stop

X



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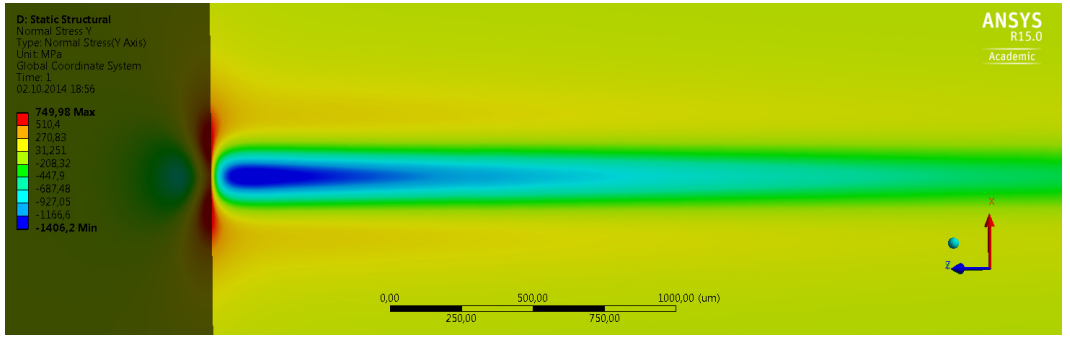

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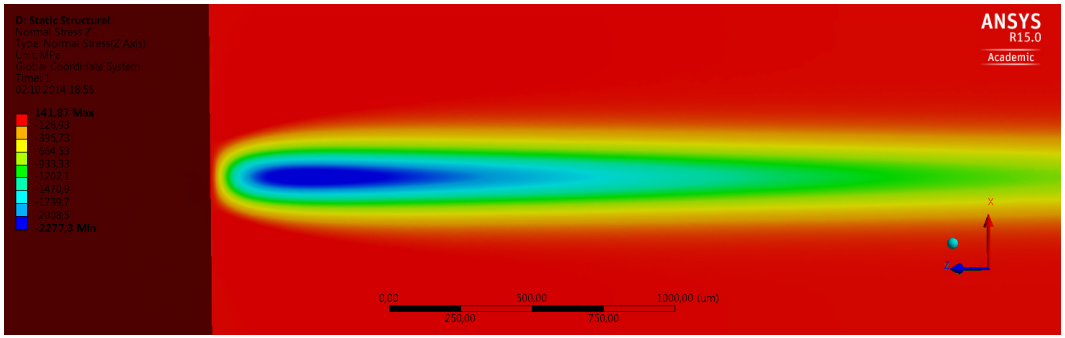
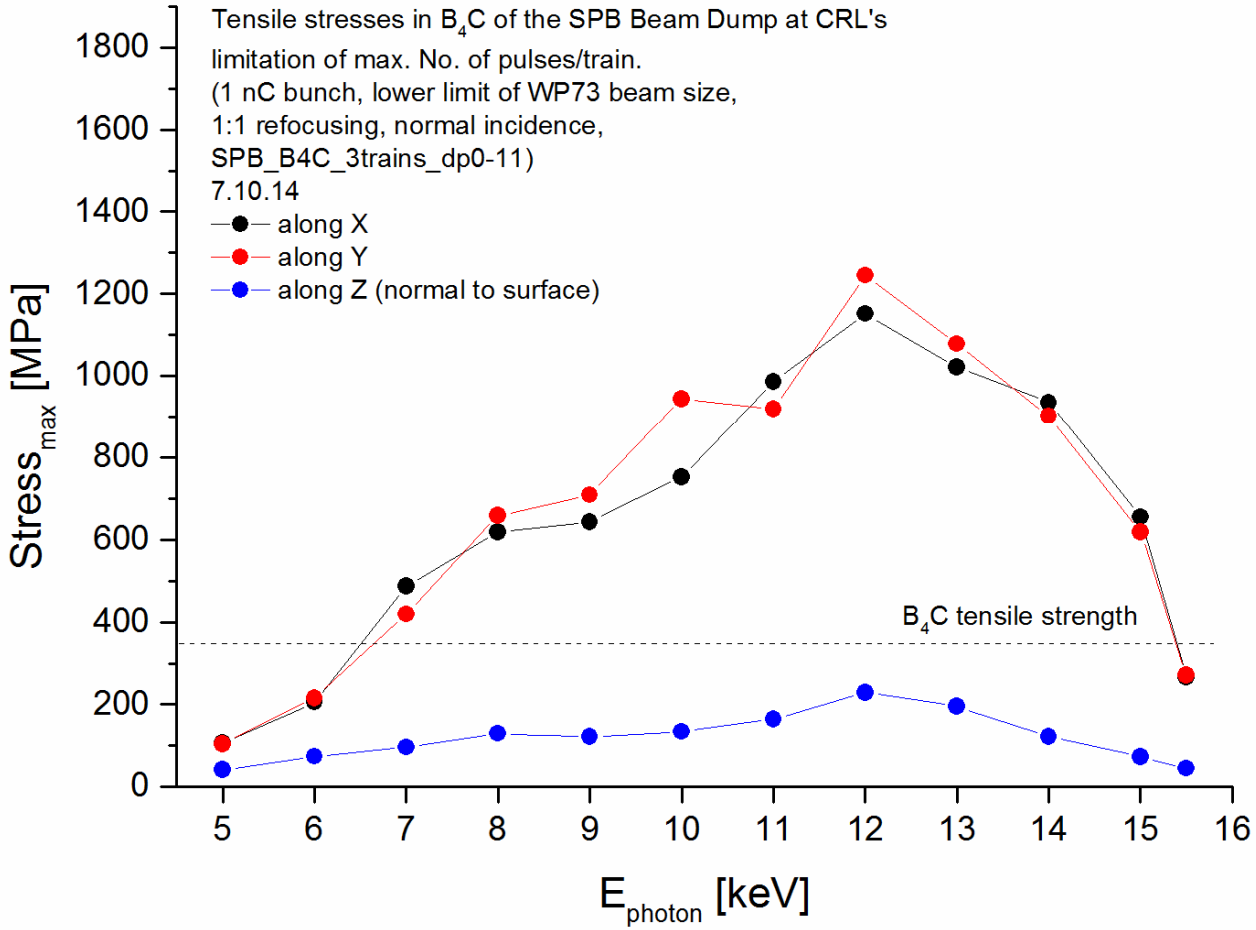
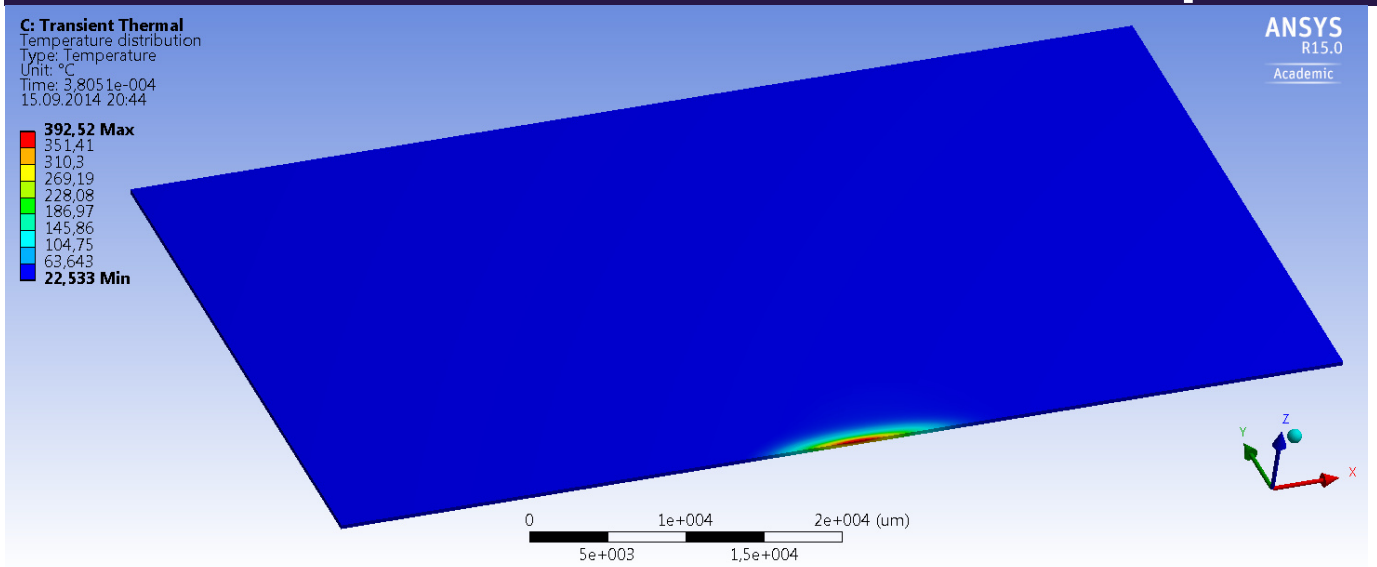


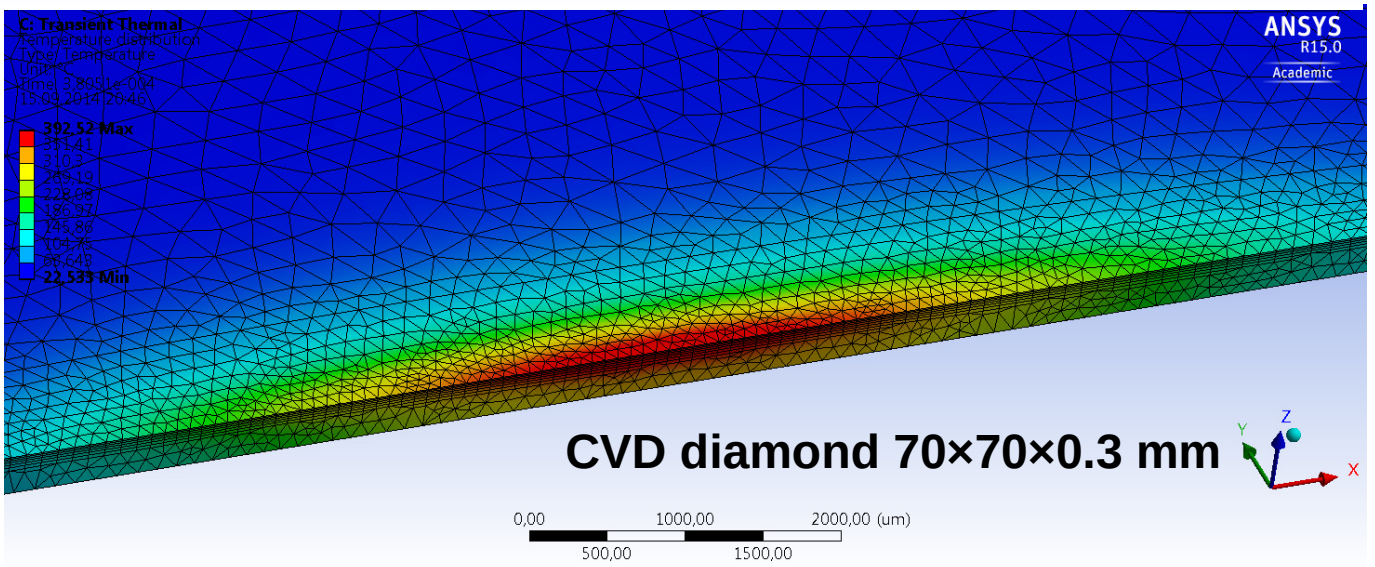
FEM-analysis of the heat load

Tensile stress in B_4C absorber of the Beam Stop



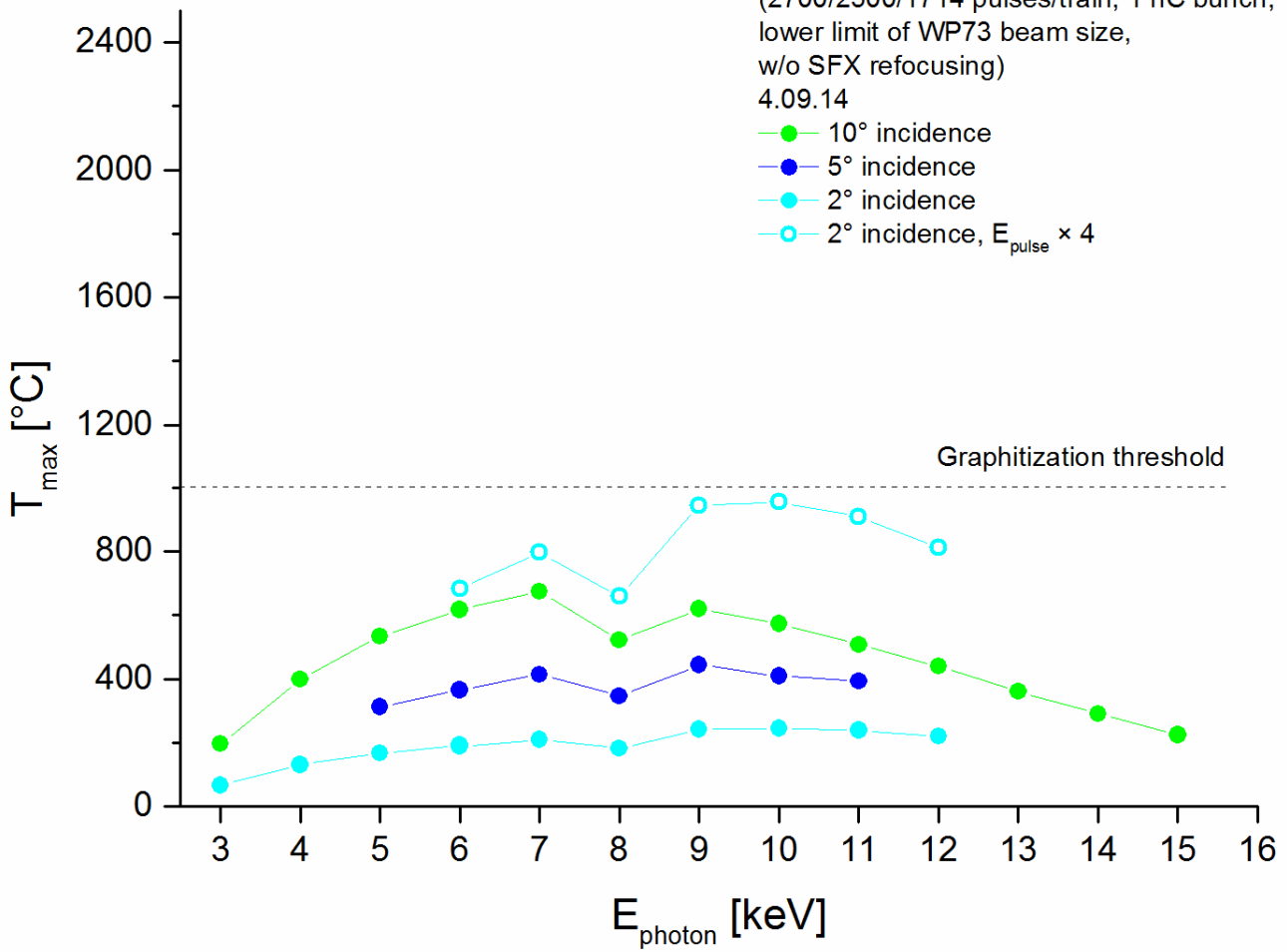
Alternative materials for the Beam Stop





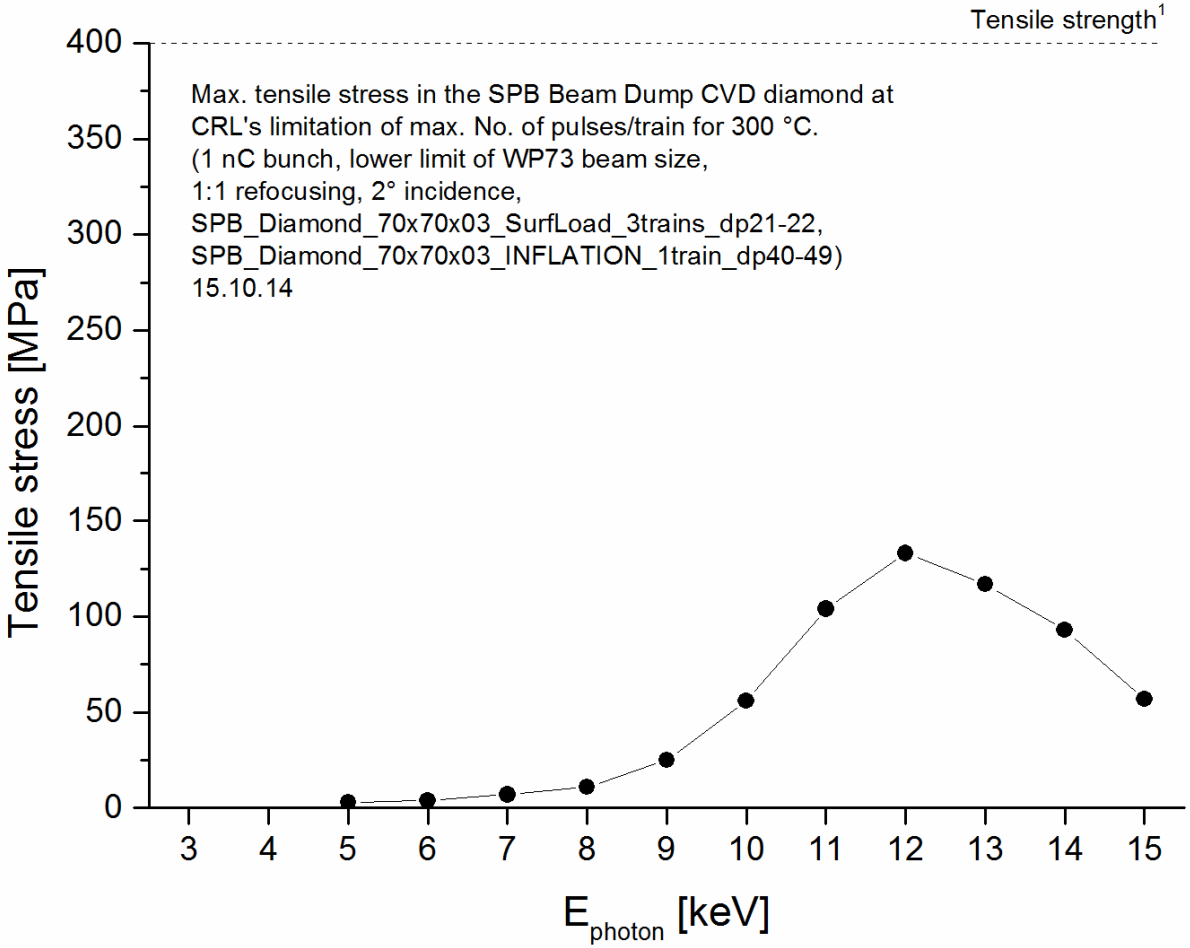
Alternative materials for the Beam Stop

CVD diamond 70×70×0.3 mm



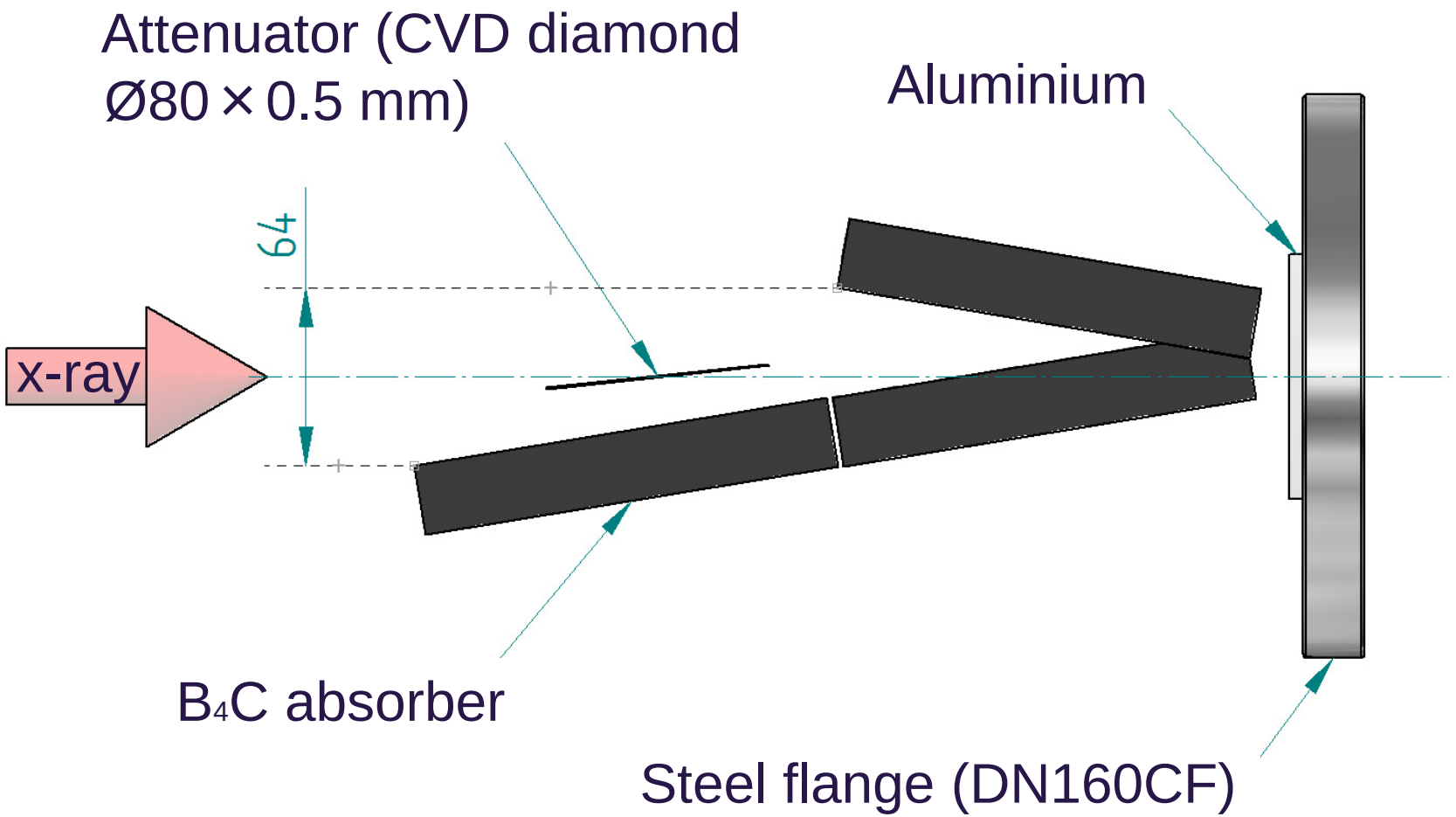
Alternative materials for the Beam Stop

Tensile stress in the Beam Stop (CVD diamond)

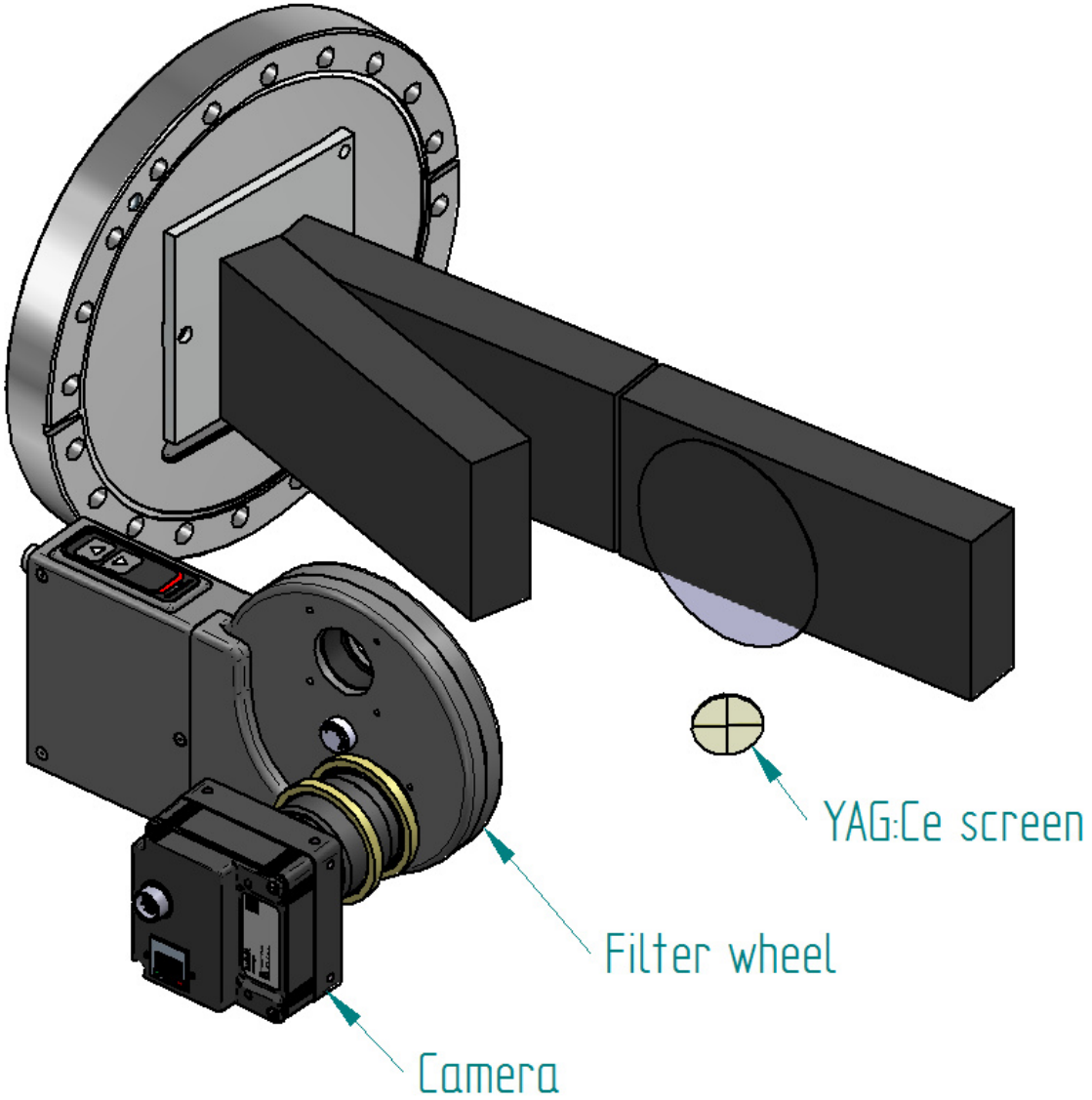


[1] http://www.e6cvd.com/cvd/page.jsp?pageid=349#2

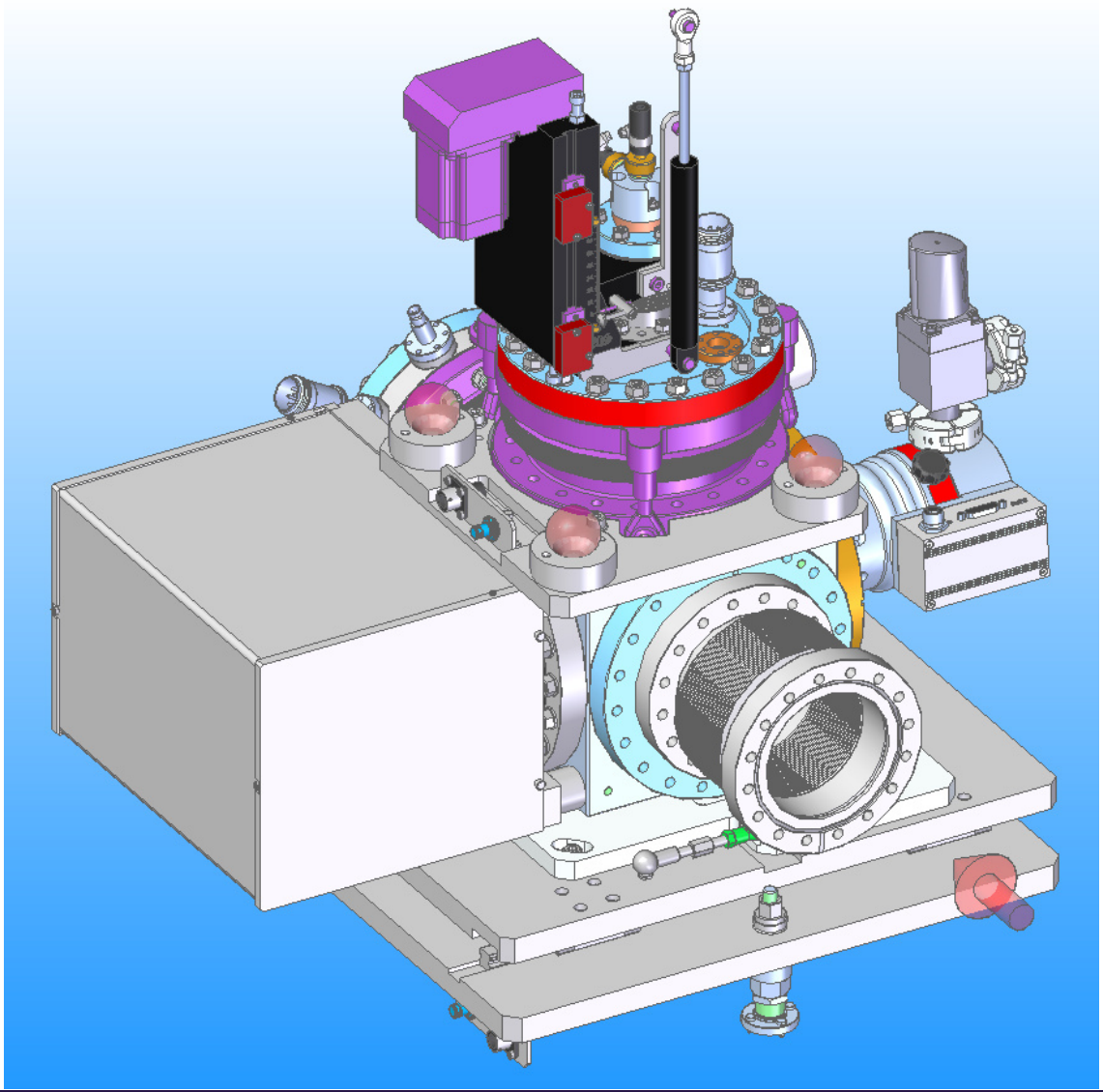
Beam Stop concept



Beam diagnostics

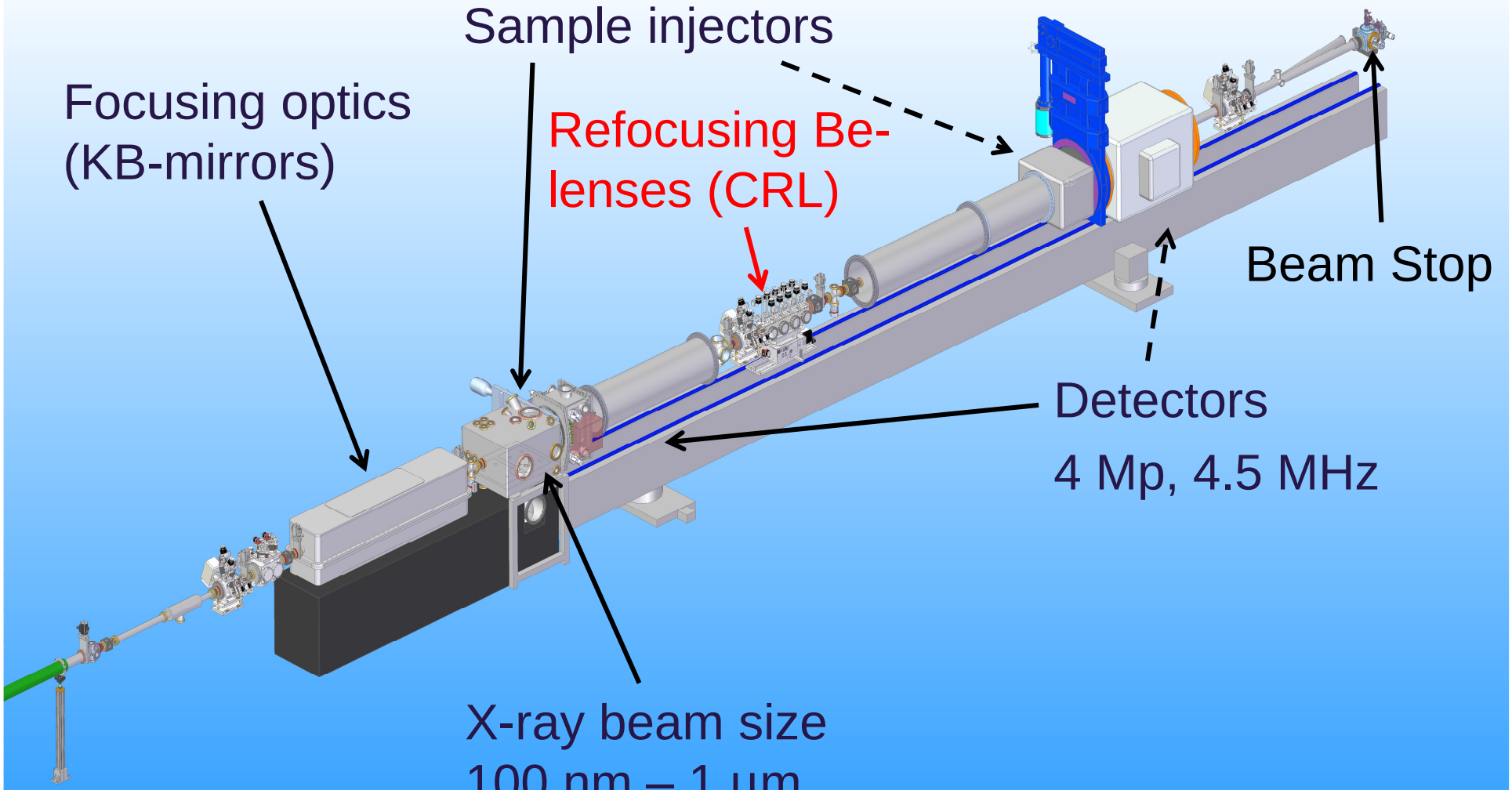


Beam Stop of the SPB Instrument



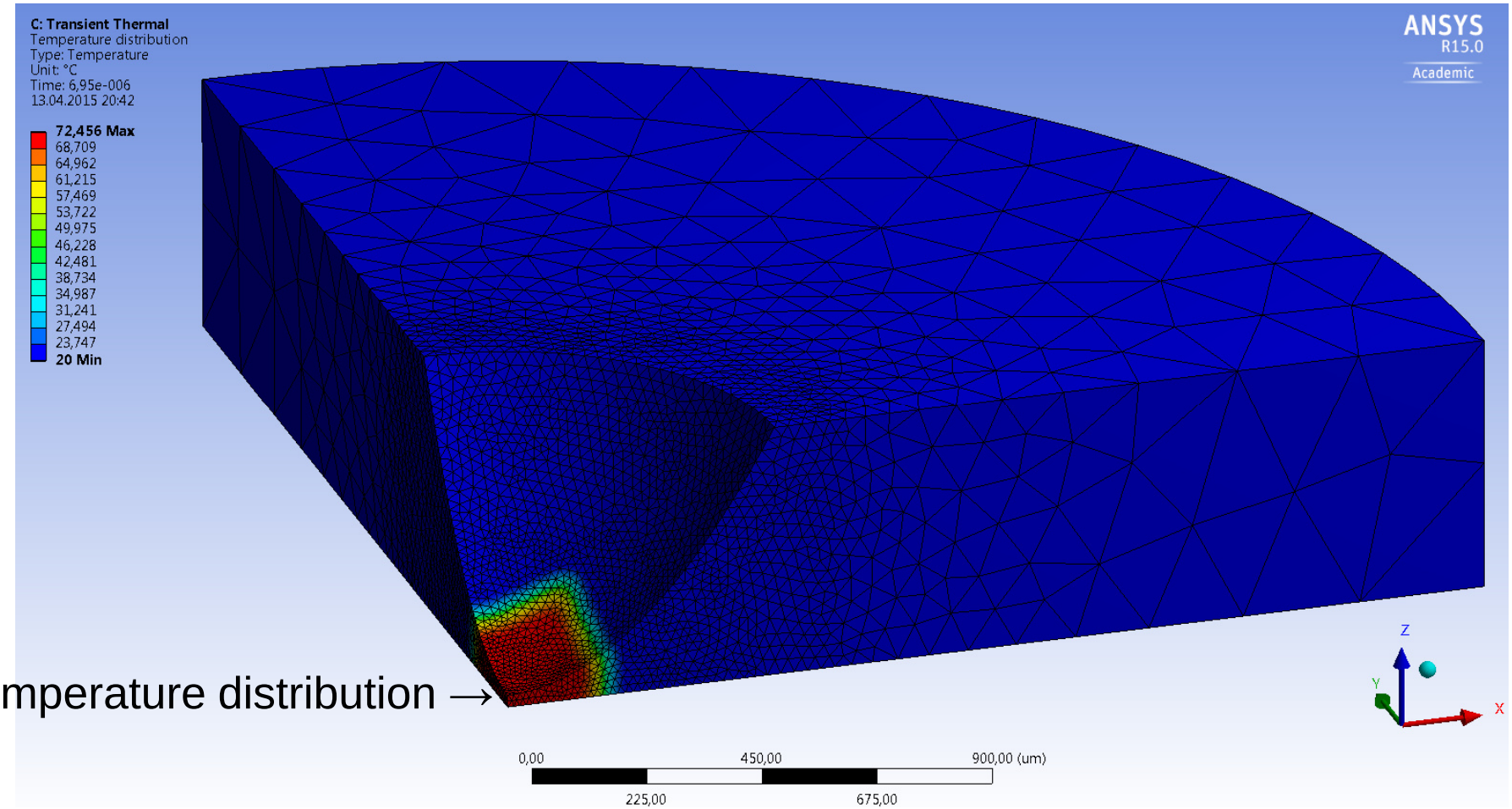
European XFEL

SPB Instrument



Heat load on other instrument components

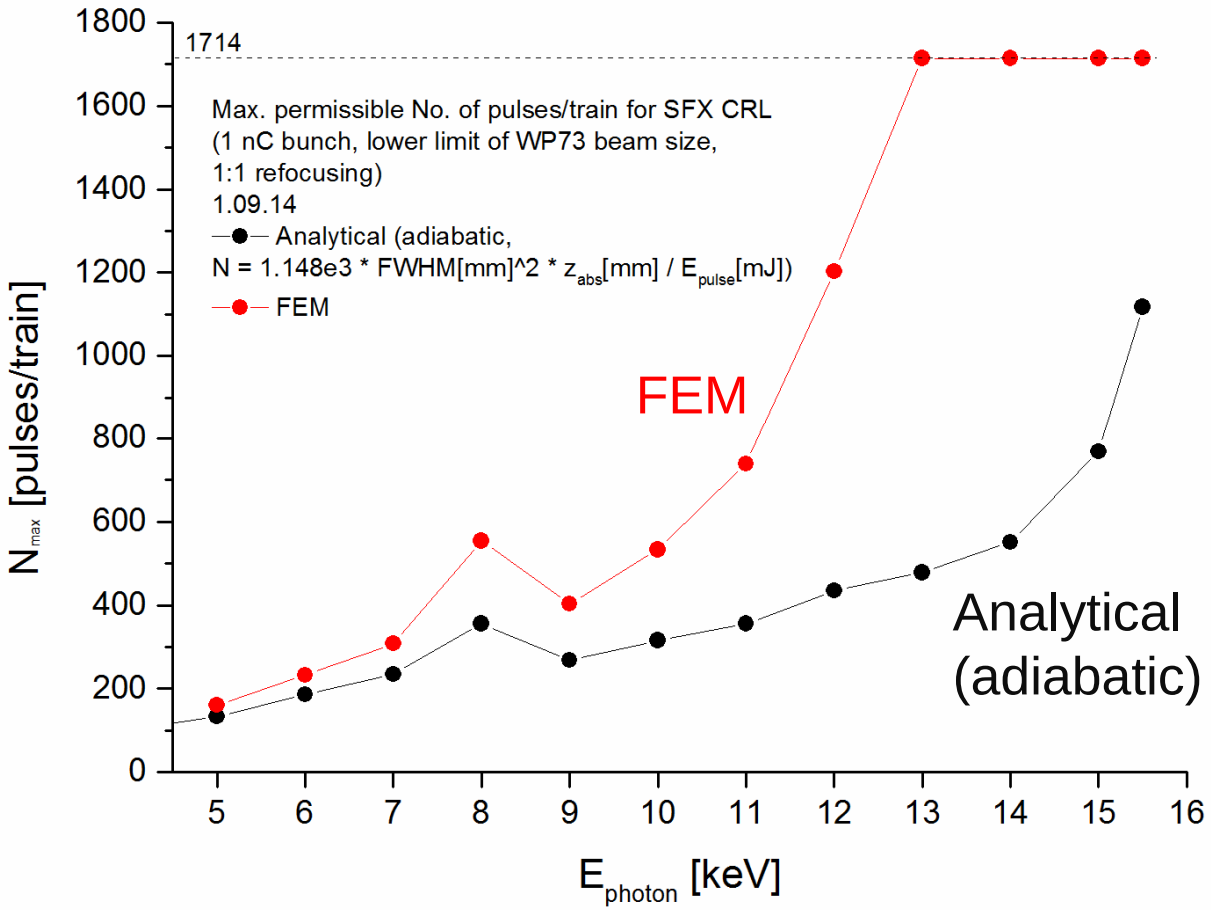
Compound Refractive Lenses (CRL)



Temperature distribution →

Heat load on other instrument components

Limitations of Compound Refractive Lenses

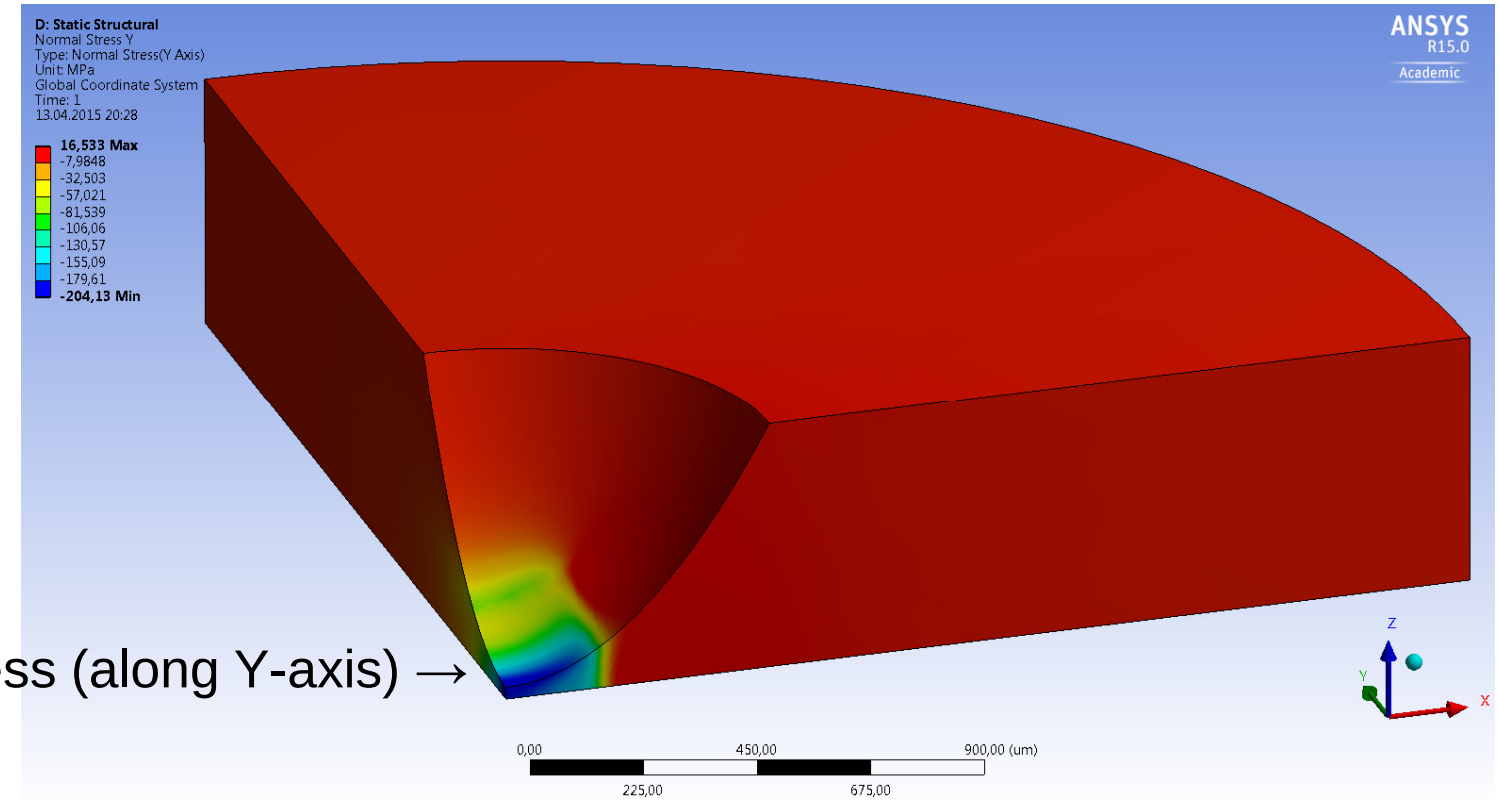


Thermomechanical stresses in CRL

D.D.Ryutov, *Thermal stresses in the reflective x-ray optics for the LCLS*, Rev.Sci.Instrum. 74, 3722 (2003):

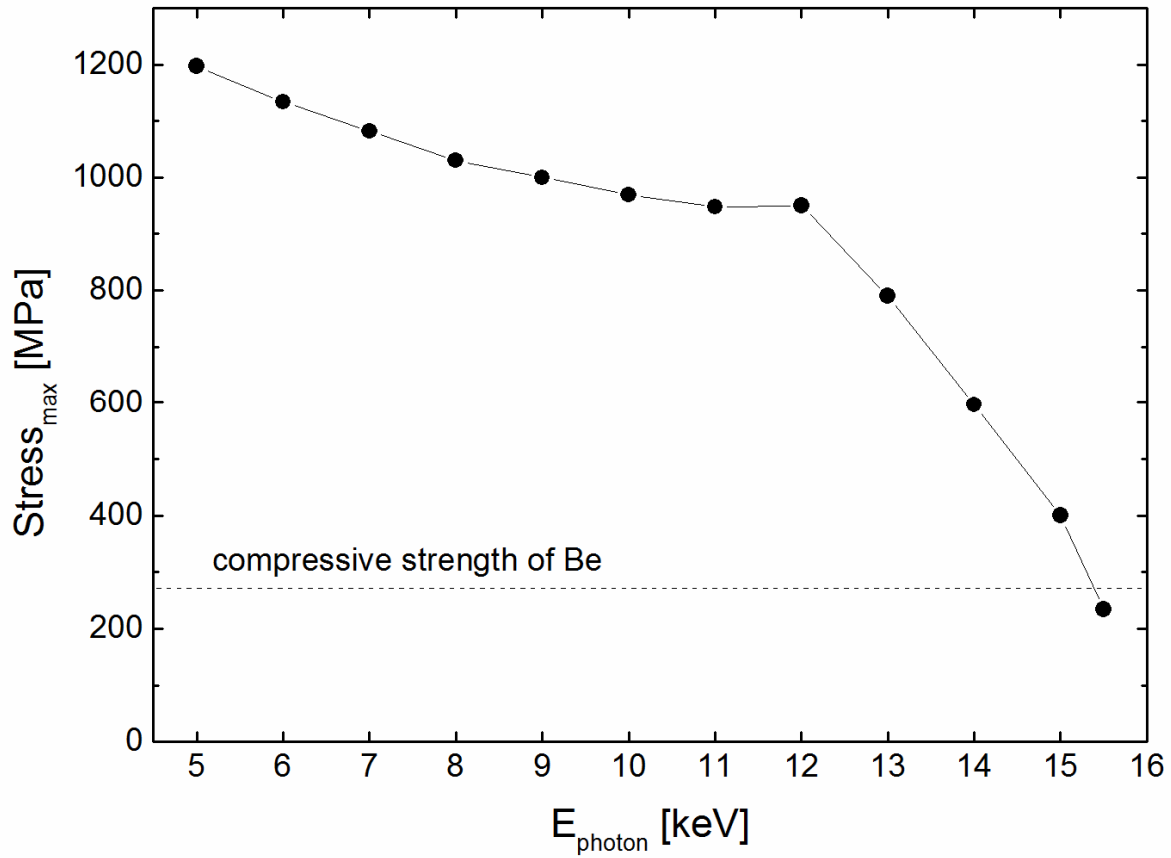
- stresses shouldn't exceed yield strength (for metals)
- otherwise cycling at 10 Hz will lead to cracking

Stress (along Y-axis) →



Thermomechanical stresses in CRL

At heat load leading to T~300 °C compressive stress exceeds yield strength of Be by several times!:



European XFEL

Summary

- X-ray optics and other components of the instruments (CRL, windows, Beam Stop) can potentially limit the science
- Based on comprehensive FEM-simulations optimized Beam Stop design was developed that can withstand full pulse train (2700 pulses)
- Some components show limitation also due to thermomechanical stresses
- 10 Hz cycling should also be taken into account for definition of permissible stresses