Temperature distribution in the target for the undulator based ILC positron source

Subtitle of Presentation

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HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY

Outline

01 ILC-Positron Source

- Setup
- Functional principal

02 ILC- Positron Source Target

- Challenges
- Magnetic bearings
- Cooling by thermal radiation

03 Simulation of the target temperature

- Simulation in ANSYS
- Solution for some challenges
- Preliminary simulation for a sliced Target

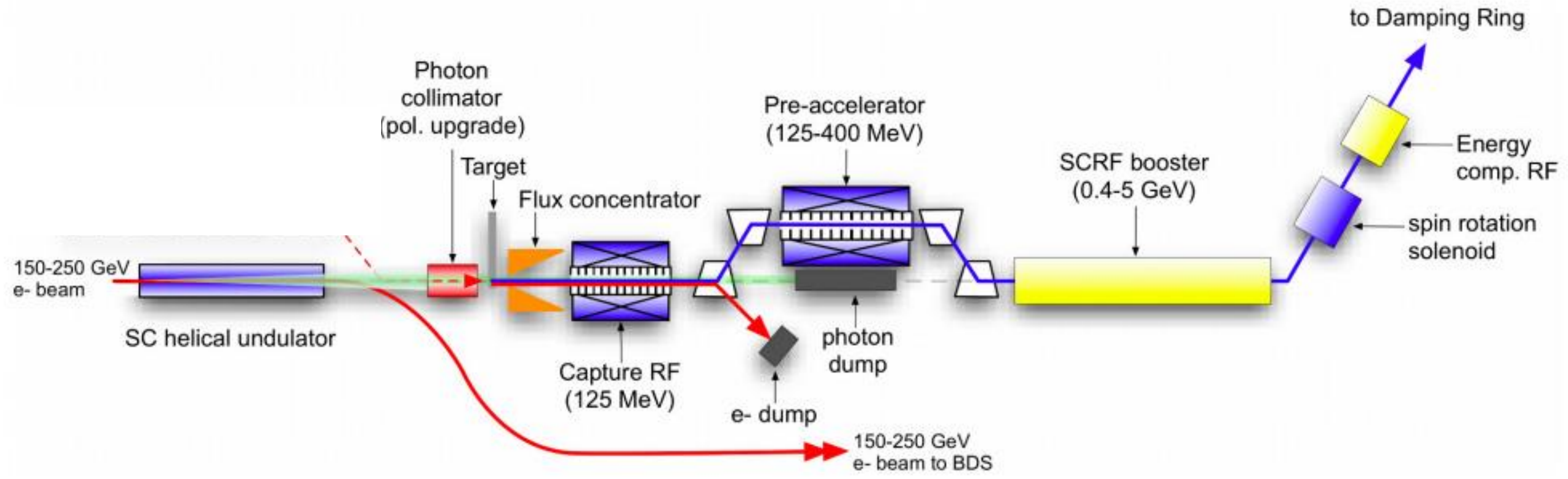
04 Summery

ILC-Positron Source

ILC-Positron Source

Setup

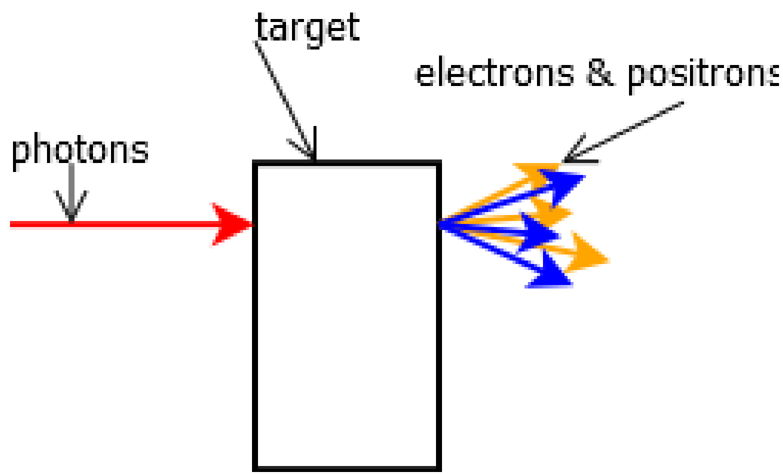
- Source needs three major parts to create positrons
  - Helical Undulator (max total length: 264 m [see also talk from Khaled Alharbi])
  - Target wheel r = 510 mm, at 250 GeV thickness = 7 mm
    - Target Material: Ti6Al4V
  - Positron capture: Flux concentrator/Quarter-Wave-Transformer
- Focus of this talk: e+ target

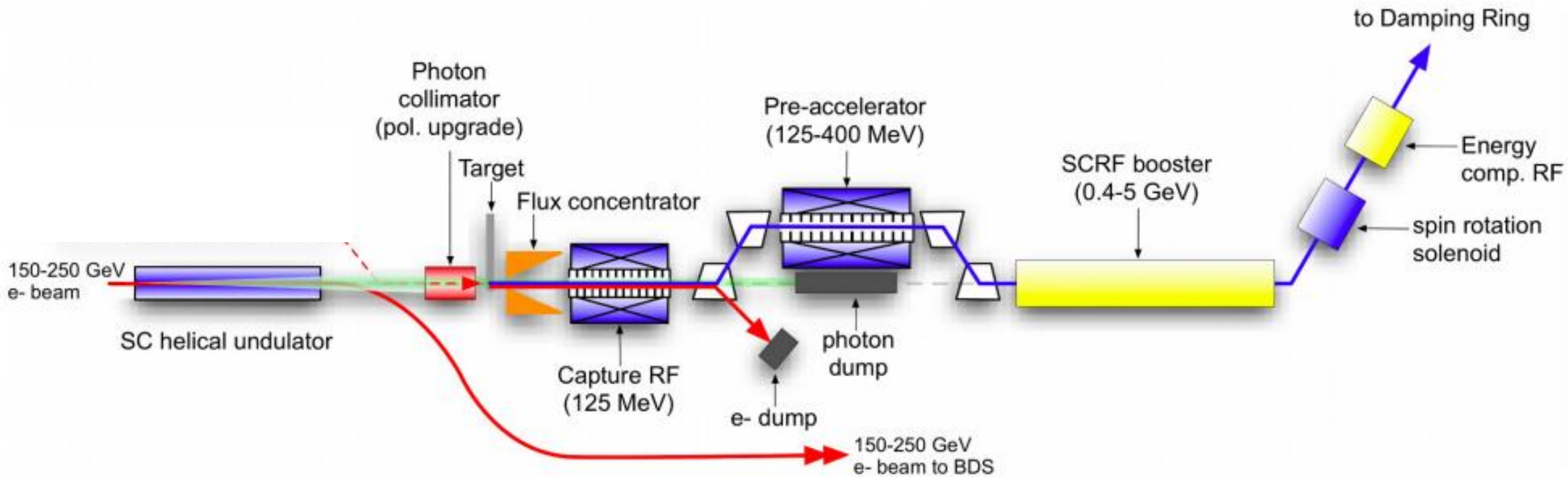


ILC-Positron Source

Positron Production / Functional Principal

- Electrons pass the helical Undulator
- Polarized Photon beam hits the Target
- Pair production of Positrons and Electrons
  - Positrons are accelerated
  - Electrons are separated and dumped



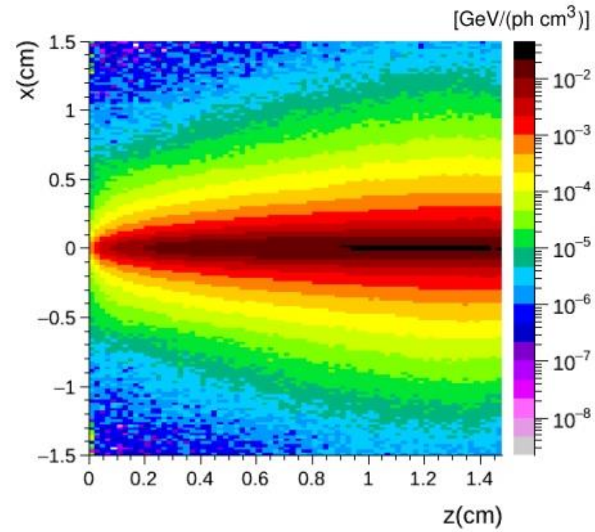


ILC-Positron Source Target

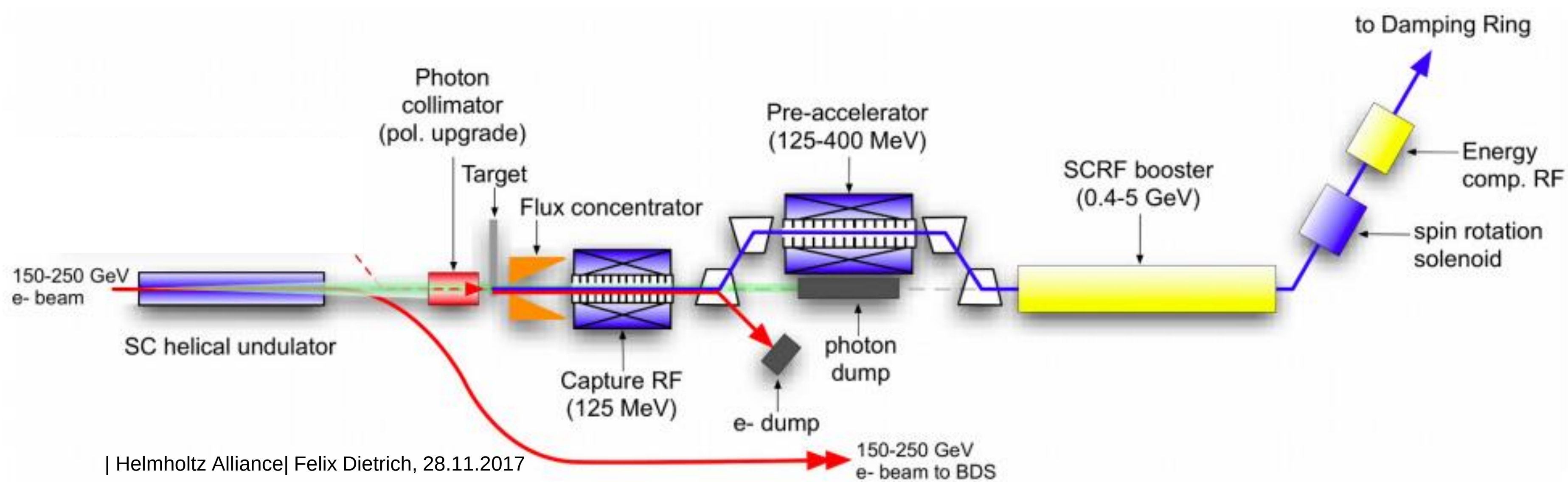
ILC-Positron Source Target

Challenge

- Energy deposition in target ~few kW, 2kW at E_{cm}=250GeV
  - Photon beam size ~2mm
- To avoid damage: the Target wheel rotates at 2000 rpm
- Photon beam hits target at a radius of 500 mm → speed of target 100 m/s
- Without rotation →Target would melt
- Focused photon beam is smeared over ~7.5cm
- Target heats up locally → heat gets distributed slowly due to low thermal conductivity of Ti6Al4V



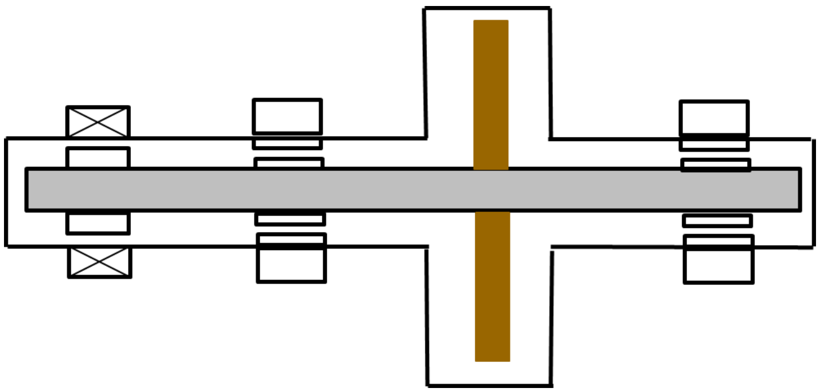
Quelle [Ushakov 2015]

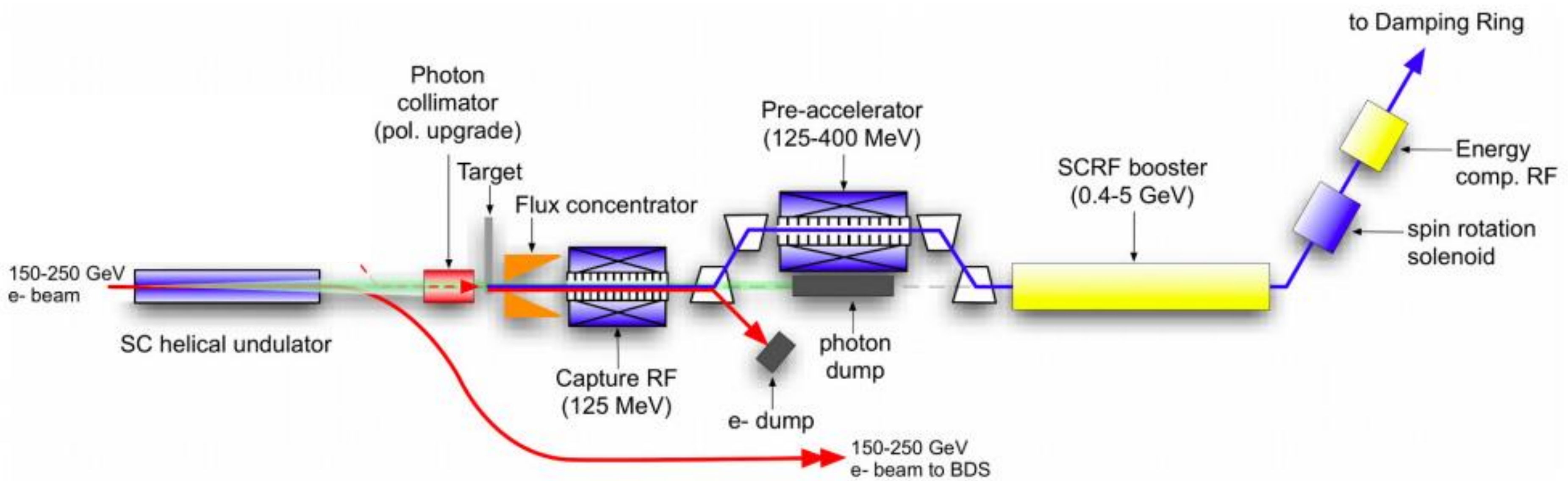


ILC-Positron Source Target

Magnetic Bearings

- Target must be in vacuum (stationary windows would melt)
- Target is mounted horizontally
- Target wheel is loaded on Magnetic Bearings → weight of wheel is an issue
- Every effect like unbalanced masses or vibrations has to be studied carefully

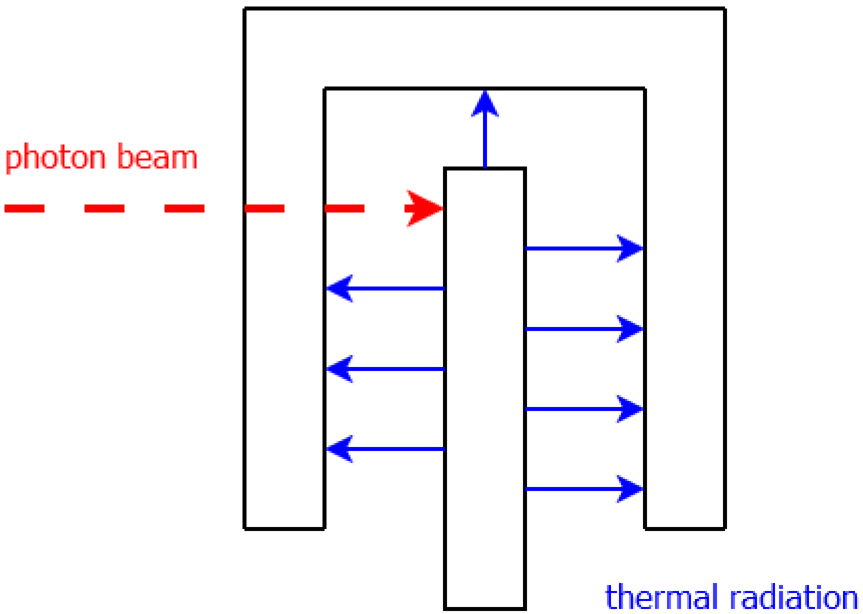




ILC-Positron Source Target

Cooling the target by thermal radiation

- Each Pulse yields instantaneous temperature rise by ~80K (E_{cm} = 250GeV)
- Water cooling of the target wheel is challenging
- good cooling is needed applicable for the wheel spinning in vacuum
- Option: radiation cooling
  - Contactless cooling
  - No water is needed in the rotating Target
  - The heat is radiated from the spinning wheel to a stationary water-cooled cooler
  - Surfaces have to be cooled
    - QWT might be a problem (Surface reduction)



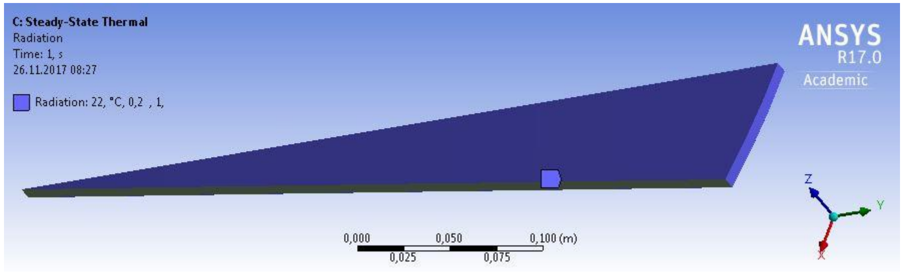
$$P \sim \sigma \varepsilon A\left(T_{target}^{4} - T_{cooler}^{4}\right)$$

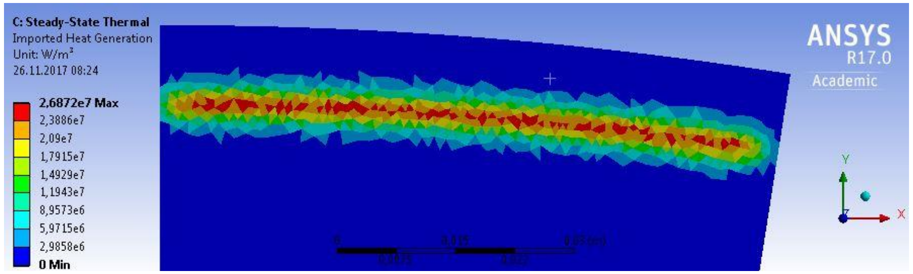
Simulation of the target temperature

Simulation of the target temperature

Simulation in ANSYS / Setup

- Evaluation of Temperature Profile
  - Input: FLUKA simulation of energy deposition from Dr. Andriy Ushakov
- To reduce calculation time only one slice of the wheel is simulated
- Emission coefficients of the surfaces:
  - Ti = 0.2
  - Cu = 0.8
- Material data is heat dependent (density, heat capacity, thermal conductivity, mechanical parameters)

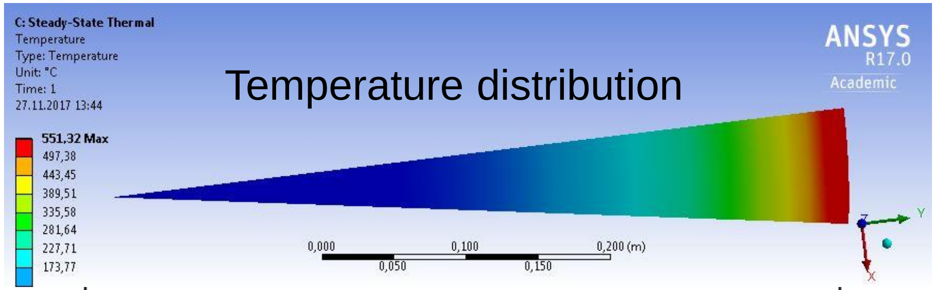


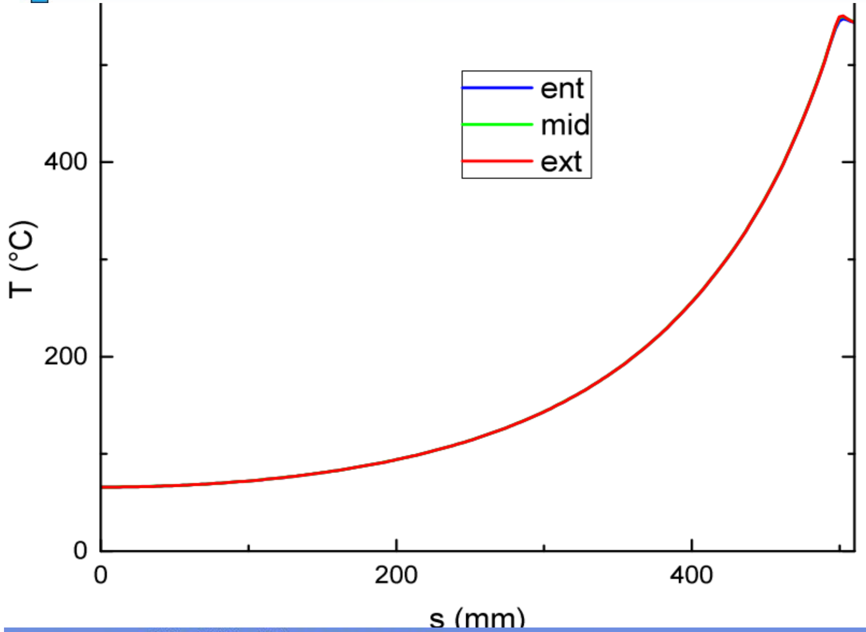


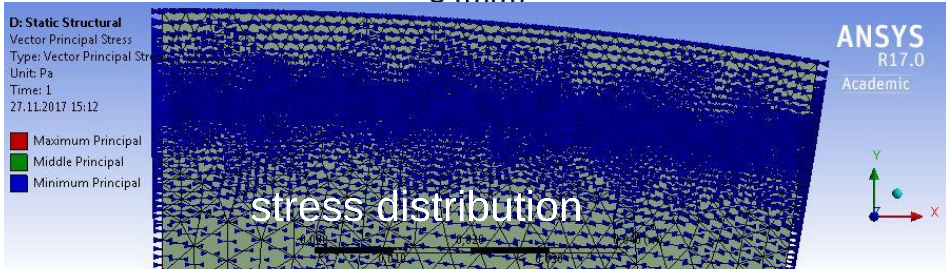
Simulation of the target temperature

Simulation in ANSYS / results

- Different approaches showed: Easiest working solution is a Titan Disk (250 GeV)
- Findings from test beam experiments with Ti6Al4V show that maximum temperatures until 700°C are acceptable
    - design must ensure that maximum temperature does not exceed 700°C
    - currently at a maximum of ~550 °C
- Heat distribution shows high temperatures on the rim and lower temperatures at lower radius
- That means: although the surface of the hot outer parts is relatively small it is very important for cooling
- This heat distribution creates hoop stress in the outer Target ring which exceeds the fatigue limit



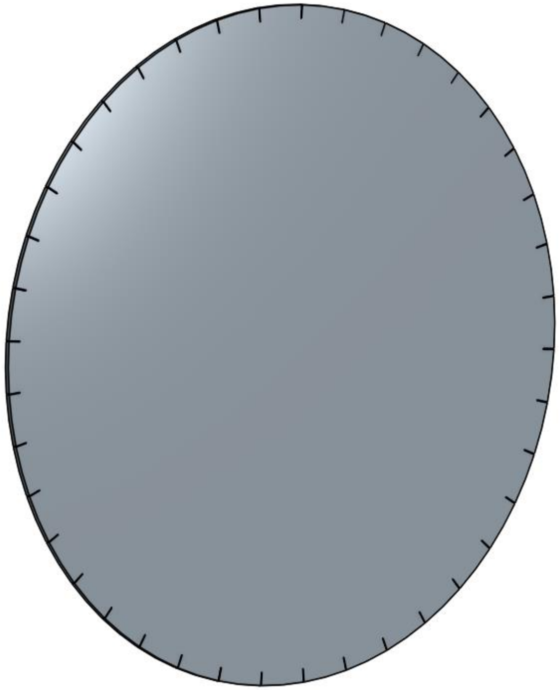


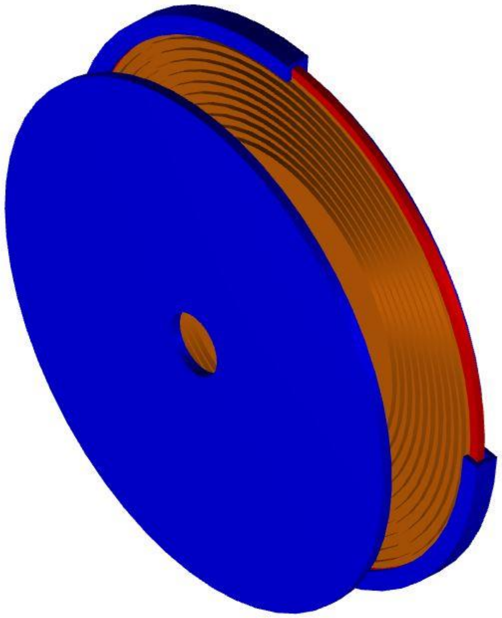


Simulation of the target temperature

Solution for some challenges

- To reduce hoop stress
  - Create a sliced Target
  - Rotation frequency has to be designed accordingly
- To improve thermal radiation efficiency and to reduce temperatures in Target
  - Cooling Fins can be used (radiating surface is increased)
  - Partially substitution of Target-material by material with high thermal conductivity, i.e. Copper (Heat gets distributed more evenly to a larger surface)
    - A connection between target rim and radiator material has to be designed and tested

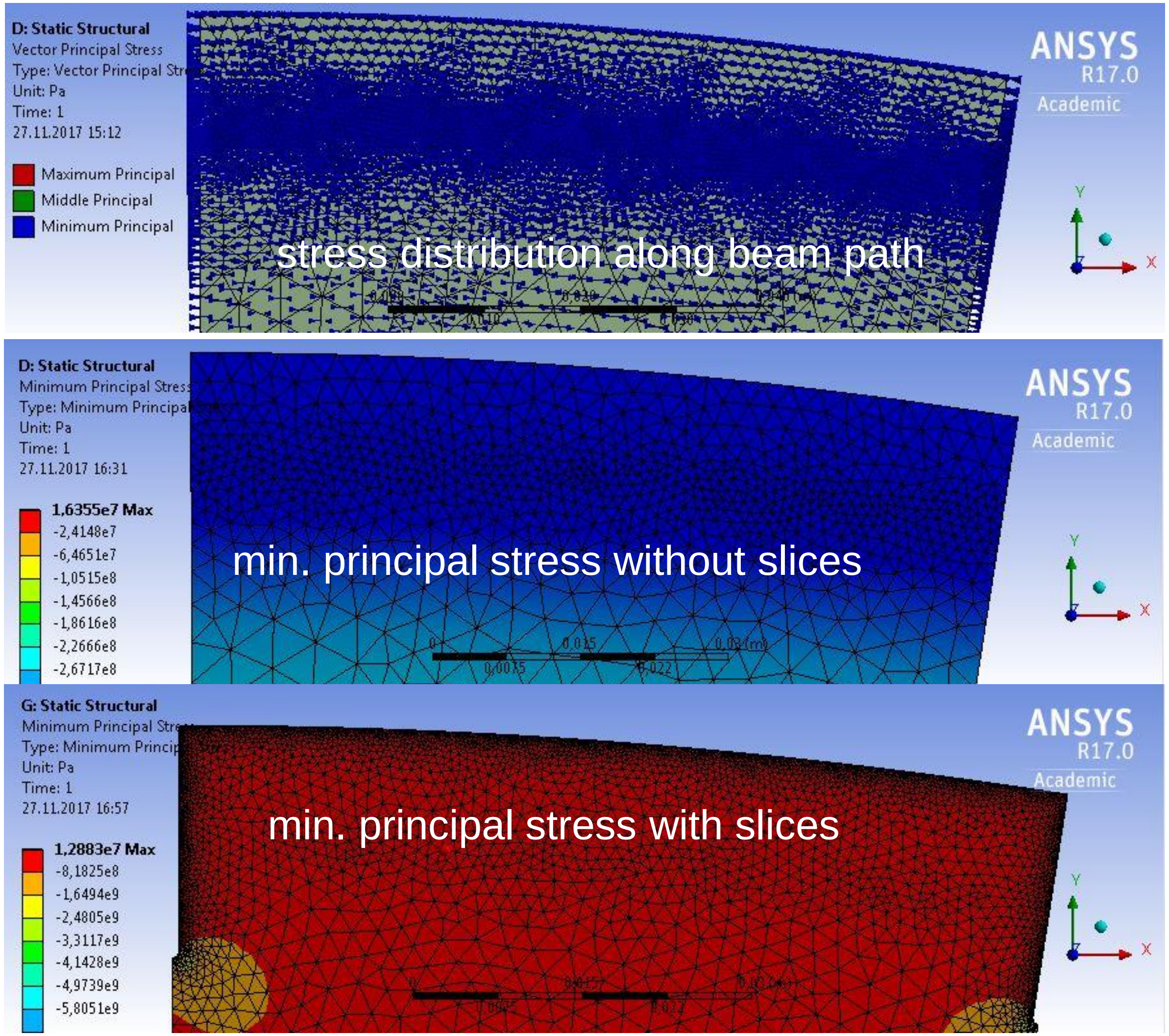




Simulation of the target temperature

Preliminary simulation for a sliced Target

- Slices can drastically reduce hoop stress
- The stress at the ‘bottom’ at the gap has still to be analyzed
- Results shown here are preliminary



Summary

- Target faces large heat issues
- But cooling by thermal radiation works
- It still needs optimization and construction work
- Prototype to test the cooling efficiency is highly desired, in particular to optimize the cooling in case of higher energy deposition in the target (polarization upgrade); a design is in work
- Elements like magnetic bearings still have to be designed
- Positron beam produced by the undulator based source is polarized
  - benefit for physics analysis is under study: - 25% higher effective luminosity can be achieved for s-channel processes with P = (80;30)