

FCC secondary collimator – 1hBLT FEA

G. Gobbi, F. Carra

FCC collimation design meeting #19






ENGINEERING
DEPARTMENT

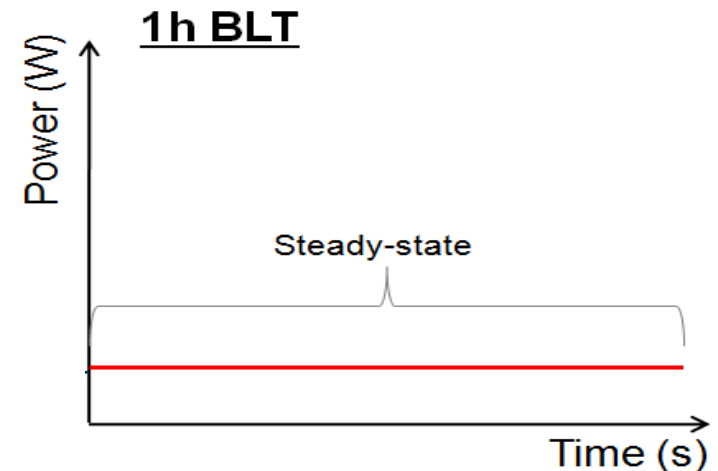
25/6/2018

TCSP case study

- TCSP most loaded jaw of the first secondary collimator (**TCSGA6L**)
- Thicker jaw (4.5 cm instead of 2.5 cm)**
- Skew TCP removed and thickness of primary collimator jaws (30cm long) increased from 2.5 cm to 3.5 cm
- Slow losses
 - Nominal operation: 1h BLT
 - Accidental case: 0.2h BLT (10s)
Already presented at FCC meeting #15 on 08/12/2017
- TCSP design with stiffer structure than the current one, simulated with bonded contacts between CFC and Glidcop housing

Collimator Jaws	TCP 60cm	TCP 30cm	TCP 30cm Thicker Jaw, w/o TCPB	
Primaries (kW)				
TCP.D6L	14.7	7.7	6.5	-16% ▼
TCP.C6L	158.7	99.2	79.7	-20% ▼
TCP.B6L	260.8	153.7	NA	
Secondaries (kW)				
TCSG.A6L	220.9	226.6	92.4	-59% ▼
TCSG.B5L	10.6	13.9	9.8	-29% ▼

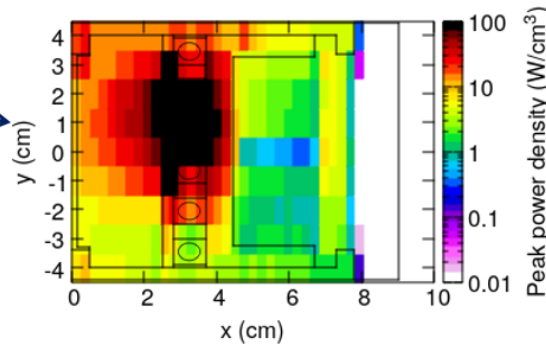
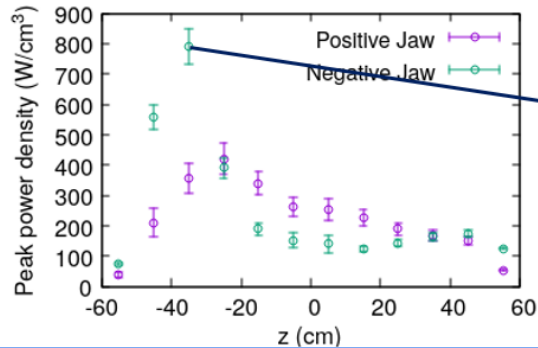



 Energy deposition studies: 30cm TCPs with thicker jaws and no skew
 CERN - FCC collimation design meeting #14



TCSP – FCC thermal load

Power density on the First Secondary

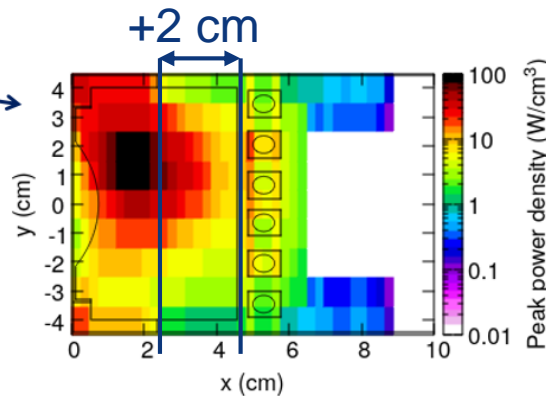
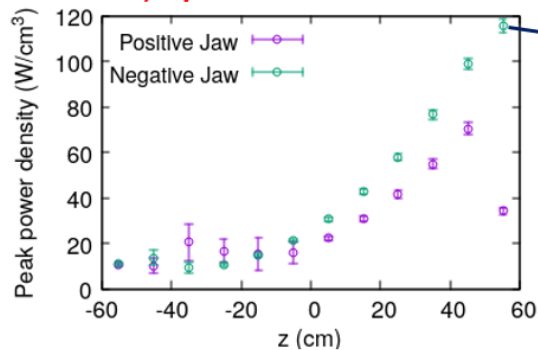
2.5cm Jaw



x-y-z resolution: **0.24cm, 1cm, 10cm**

- TCSG.A6L → **800 Wcm⁻³**
- TCSG.A5L → 90 Wcm⁻³
- TCSG.D4L → 33 Wcm⁻³

4.5cm Jaw, w/o TCPB



- TCSG.A6L → **115 Wcm⁻³**
- TCSG.A5L → 85 Wcm⁻³
- TCSG.D4L → 30 Wcm⁻³

60cmTCP, v-halo, Thicker TCS:

- TCSG.A6L → **130 Wcm⁻³**

in LHC:

- Secondary → 10 Wcm⁻³



M. Varasteh



Energy deposition studies: 30cm TCPs with thicker jaws and no skew
CERN - FCC collimation design meeting #14

20.11.2017

8



25/06/2018

G. Gobbi, M. Pasquali - CERN

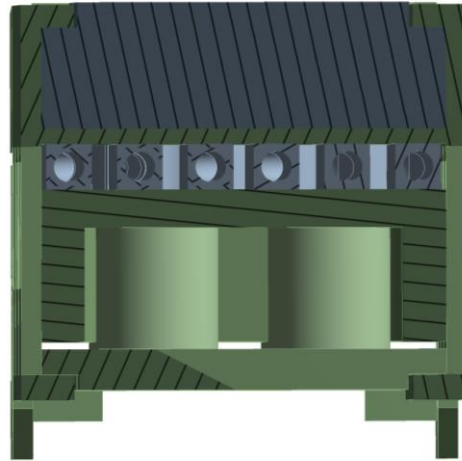
3

TSCP case study

Geometry

08/12/2017 15:51

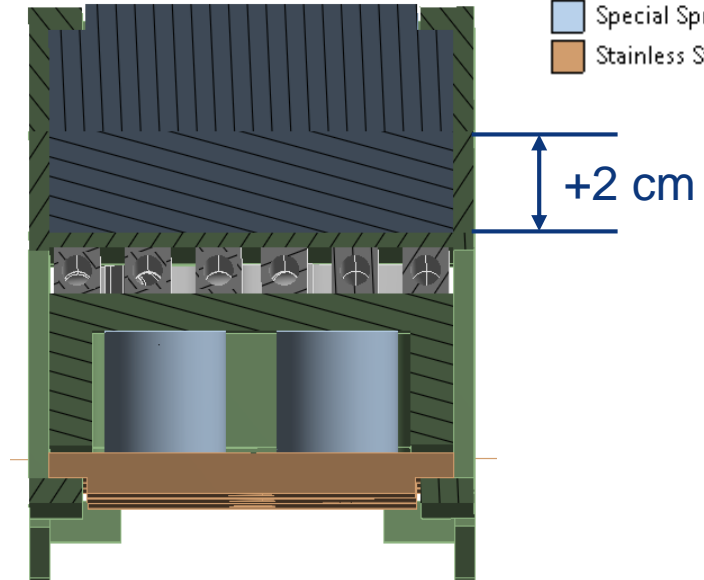
- Carbon Carbon (AC150)
- Copper Nickel
- Glidcop
- Special Spring
- Stainless Steel



Geometry

08/12/2017 15:47

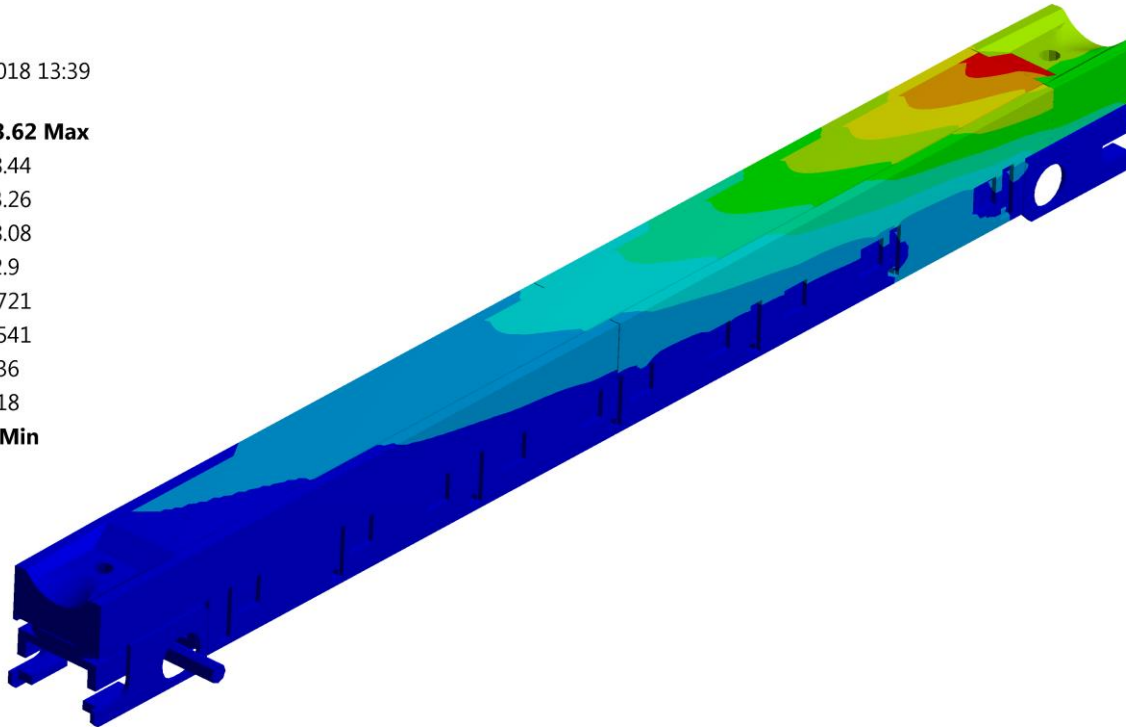
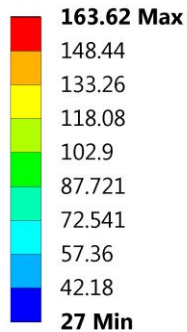
- Carbon Carbon (AC150)
- Copper Nickel
- Glidcop
- Special Spring
- Stainless Steel



Thermal analysis – results 1hBLT

E: FCC map 1h + 0.2h BLT with support_jaw_4.5cm_BondedContacts

Temperature
Type: Temperature
Unit: °C
Time: 1
28/03/2018 13:39



Cooling water at $T = 27 \text{ }^{\circ}\text{C}$ (constant)

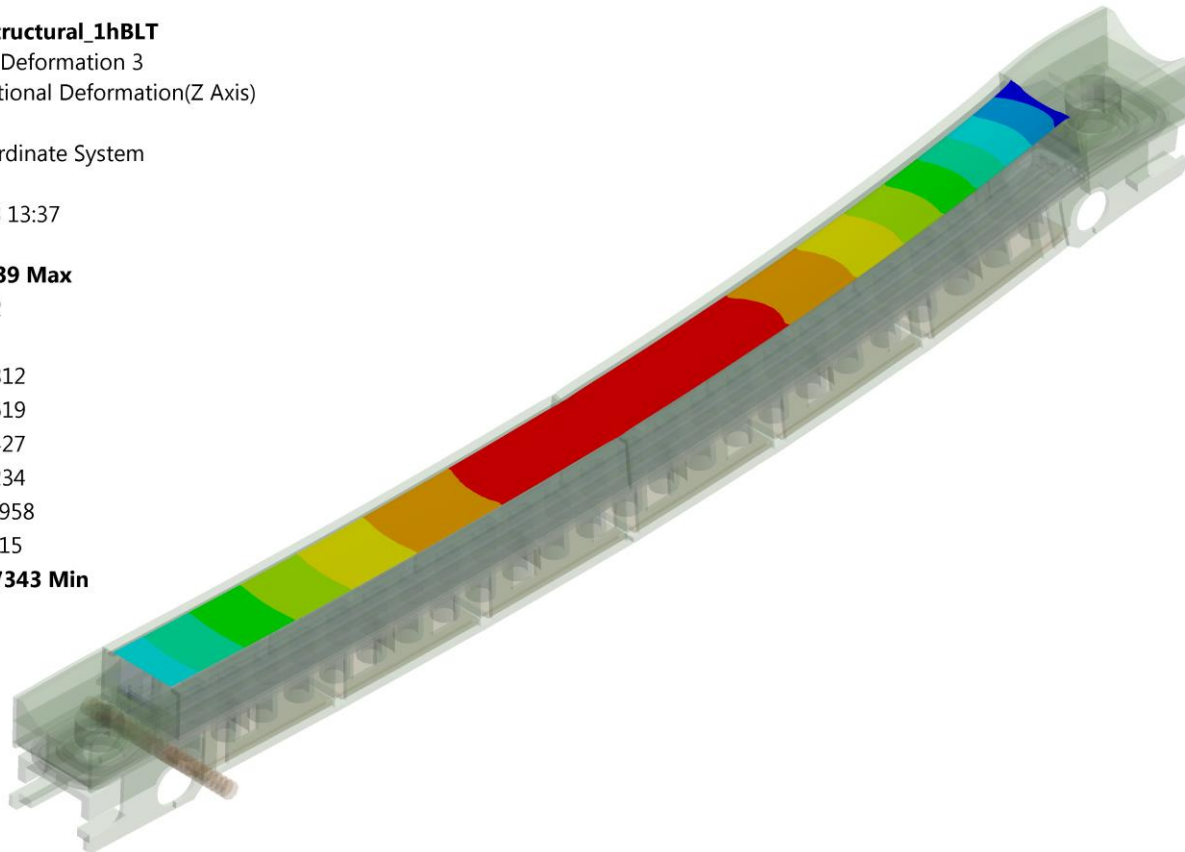
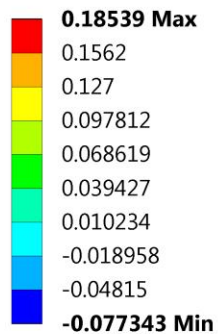
$T_{\text{max}} = 164 \text{ }^{\circ}\text{C}$ (4.5 cm jaw)

$T_{\text{max}} = 330 \text{ }^{\circ}\text{C}$ for **0.2hBLT**

Structural analysis - results

G: Static Structural_1hBLT

Directional Deformation 3
Type: Directional Deformation(Z Axis)
Unit: mm
Global Coordinate System
Time: 1
28/03/2018 13:37



Bonded contacts (stiff structure)

Thermal induced deflection (4.5 cm jaw) = 262 μm

Thermal induced deflection = 375 μm for **0.2hBLT**

Structural analysis - results

G: Static Structural_1hBLT

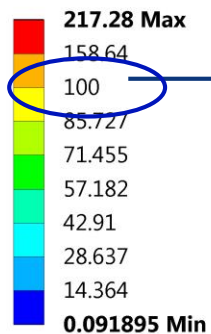
Stress Intensity

Type: Stress Intensity

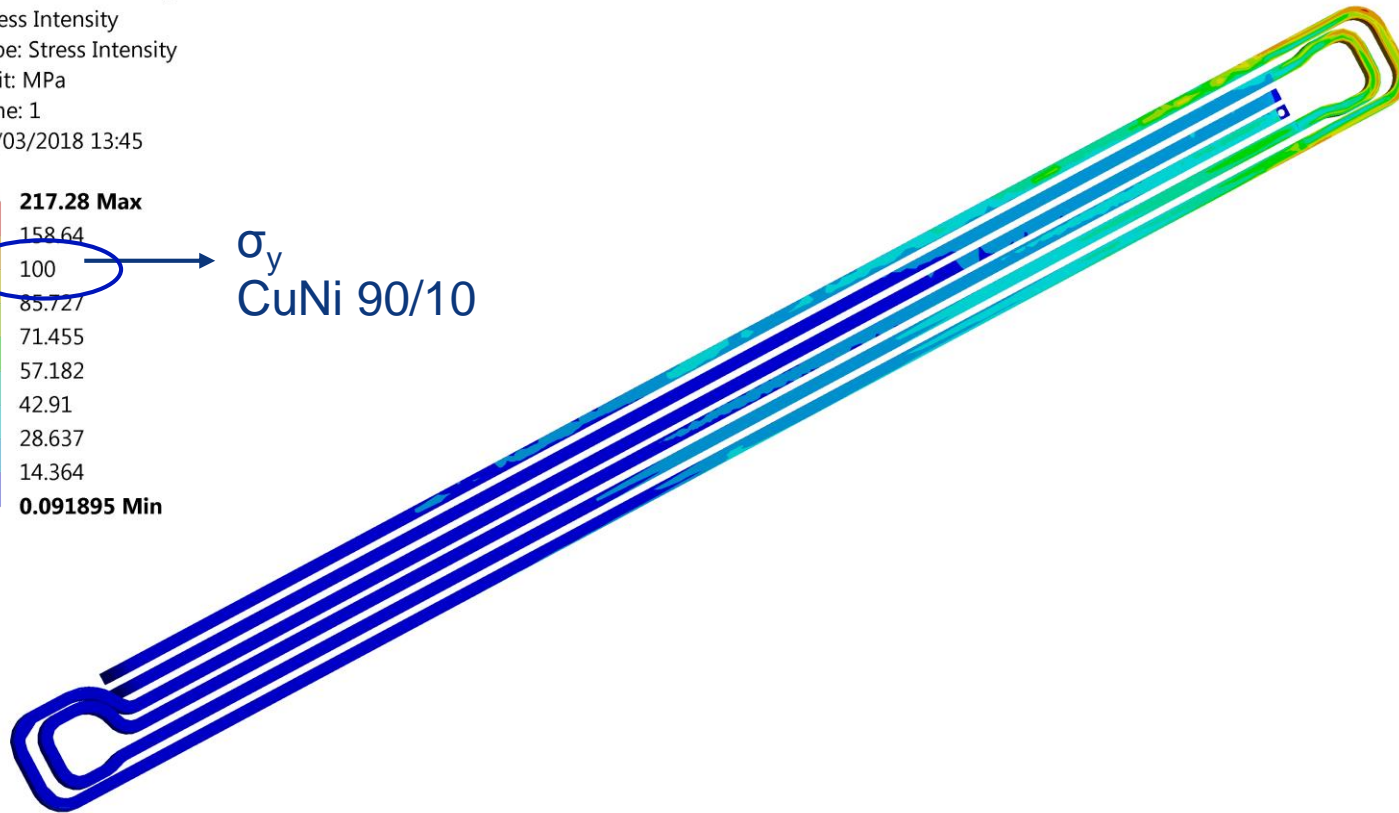
Unit: MPa

Time: 1

28/03/2018 13:45



σ_y
CuNi 90/10



Plasticity on downstream region of cooling pipes

Summary

- 1h BLT scenario was simulated for a thicker TCSP collimator jaw (4.5 cm) with FCC load → conceptual study
- Maximum $T = 164^{\circ}\text{C}$ → 1/2 with respect to 0.2h BLT (330°C)
- Thermal induced deflection $262\ \mu\text{m}$ vs $375\ \mu\text{m}$ of 0.2h BLT, obtained with bonded contacts between CFC and housing (structure much stiffer than the current one)
- Plasticity on the cooling pipes still present even if in a smaller region → can be addressed with different cooling pipes material

FCC primary collimator – 0.2hBLT FEA

M. Pasquali, G. Gobbi, F. Carra and A. Bertarelli

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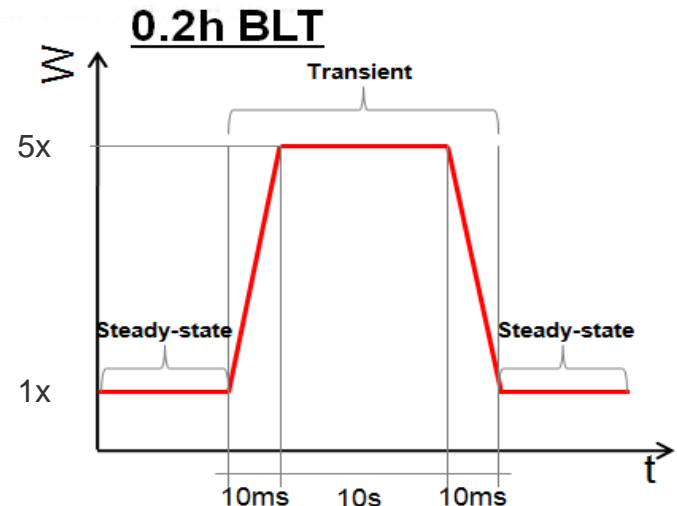
TCP case study

- Vertical primary collimator (**TCPD6L**)
- Thicker jaw** → **3.5 cm** instead of 2.5 cm
- Active length 30 cm**
- Slow losses
 - Nominal operation: 1h BLT
 - Accidental case: 0.2h BLT (10s)
- TCP design with stiffer structure than the current one, simulated with bonded contacts between CFC and Glidcop housing

Collimator Jaws	TCP 60cm	TCP 30cm	TCP 30cm Thicker Jaw, w/o TCPB	
Primaries (kW)				
TCP.D6L	14.7	7.7	6.5	-16% ▼
TCP.C6L	158.7	99.2	79.7	-20% ▼
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Secondaries (kW)				
TCSG.A6L	220.9	226.6	92.4	-59% ▼
TCSG.B5L	10.6	13.9	9.8	-29% ▼

Note: A red arrow points to the TCP 30cm column in the table.

CERN M. Varasteh Energy deposition studies: 30cm TCPs with thicker jaws and no skew CERN - FCC collimation design meeting #14



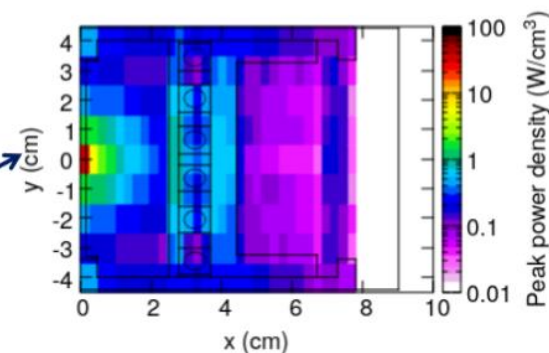
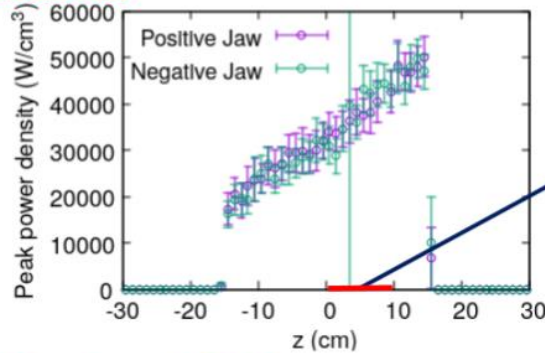
TCP – FCC thermal load

Peak power density on Vertical Primary

x-y-z resolution: **5 μ m, 5 μ m, and 1cm**

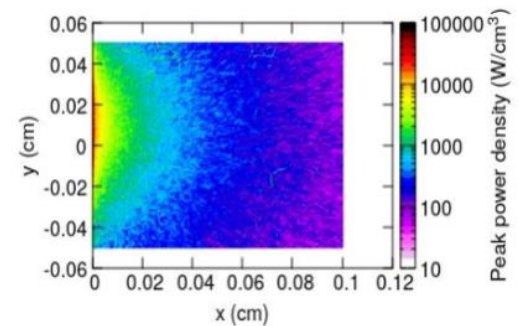
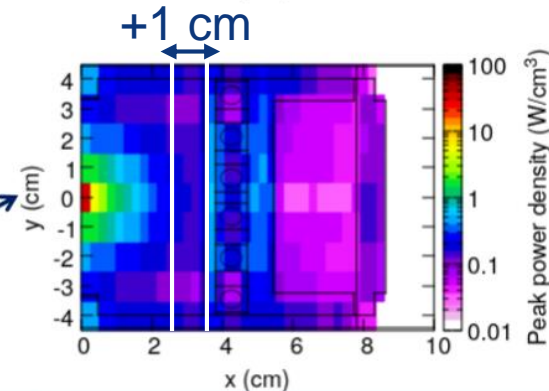
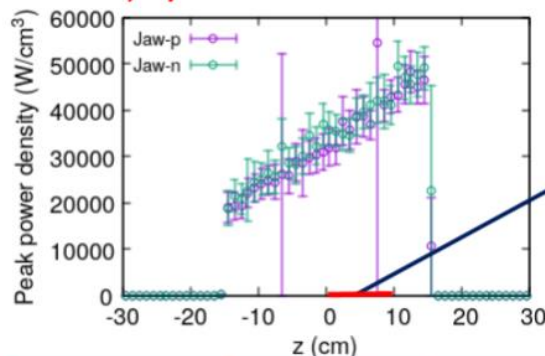
x-y-z resolution: **0.24cm, 1cm, and 10cm**

2.5cm Jaw



The most exposed collimator in terms of peak power density:
Vertical TCP with a total power which is more than a factor of 10 less than the Horizontal Primary

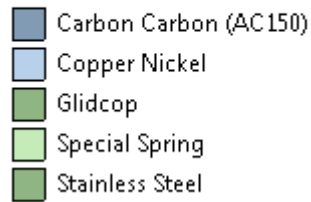
3.5cm Jaw, w/o TCPB



TCP case study

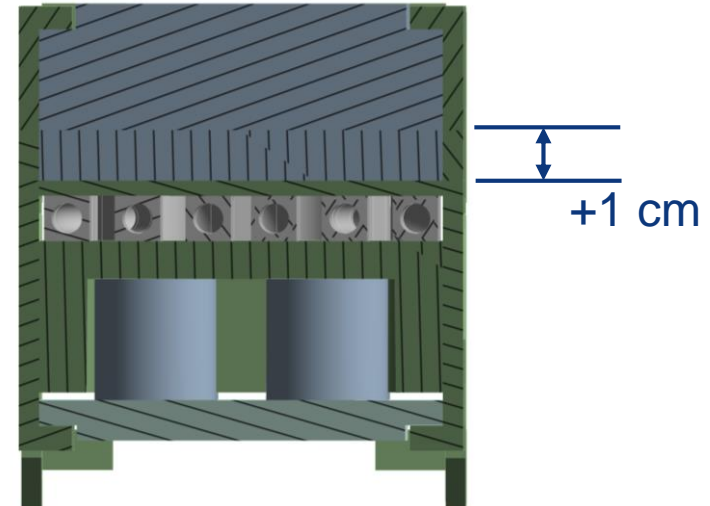
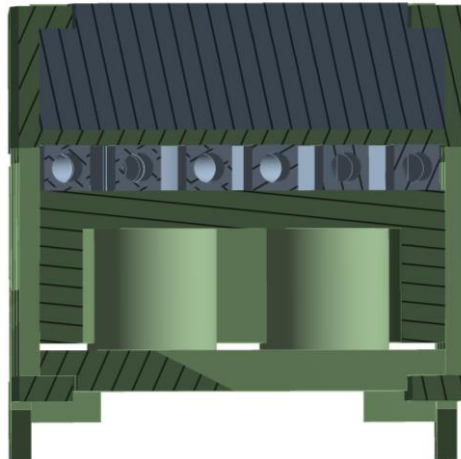
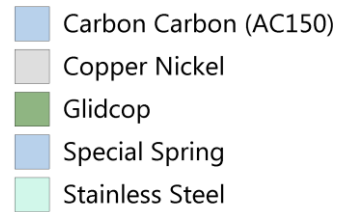
Geometry

08/12/2017 15:51



Geometry

21/06/2018 17:05



2 approaches:

1. Check collimator structure
2. Focus on CFC absorber

Thermal load – Approach 1

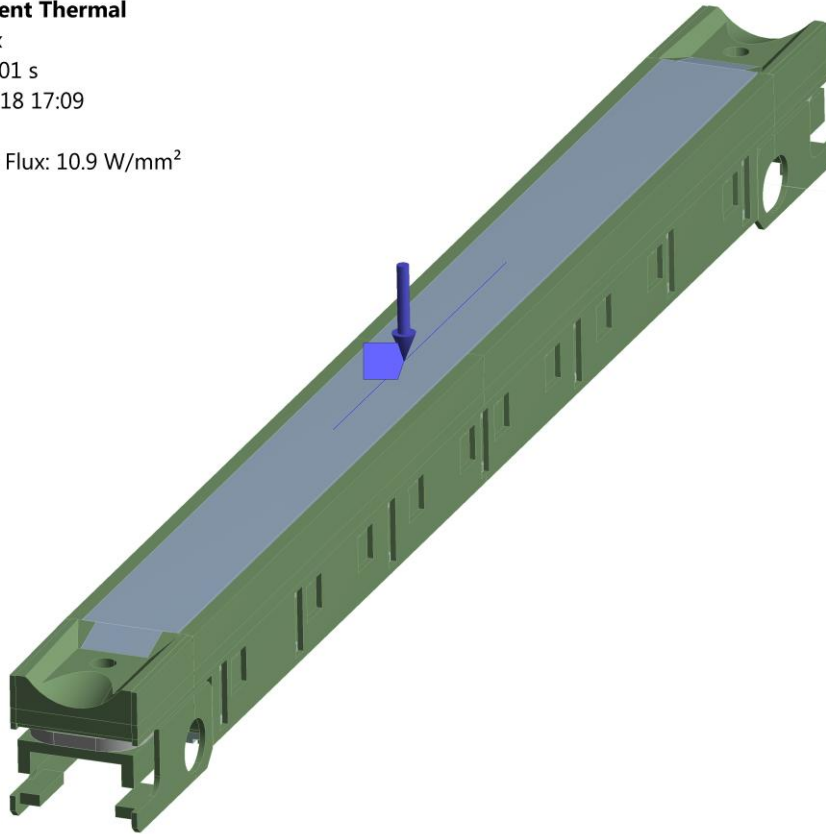
L: Transient Thermal

Heat Flux

Time: 10.01 s

21/06/2018 17:09

■ Heat Flux: 10.9 W/mm²



- Surface 300x1 mm
- Heat flux equivalent to 3.27 kW (total thermal load on the absorber)
- $t = 10$ s

Structural analysis - results

M: Static Structural

Directional Deformation

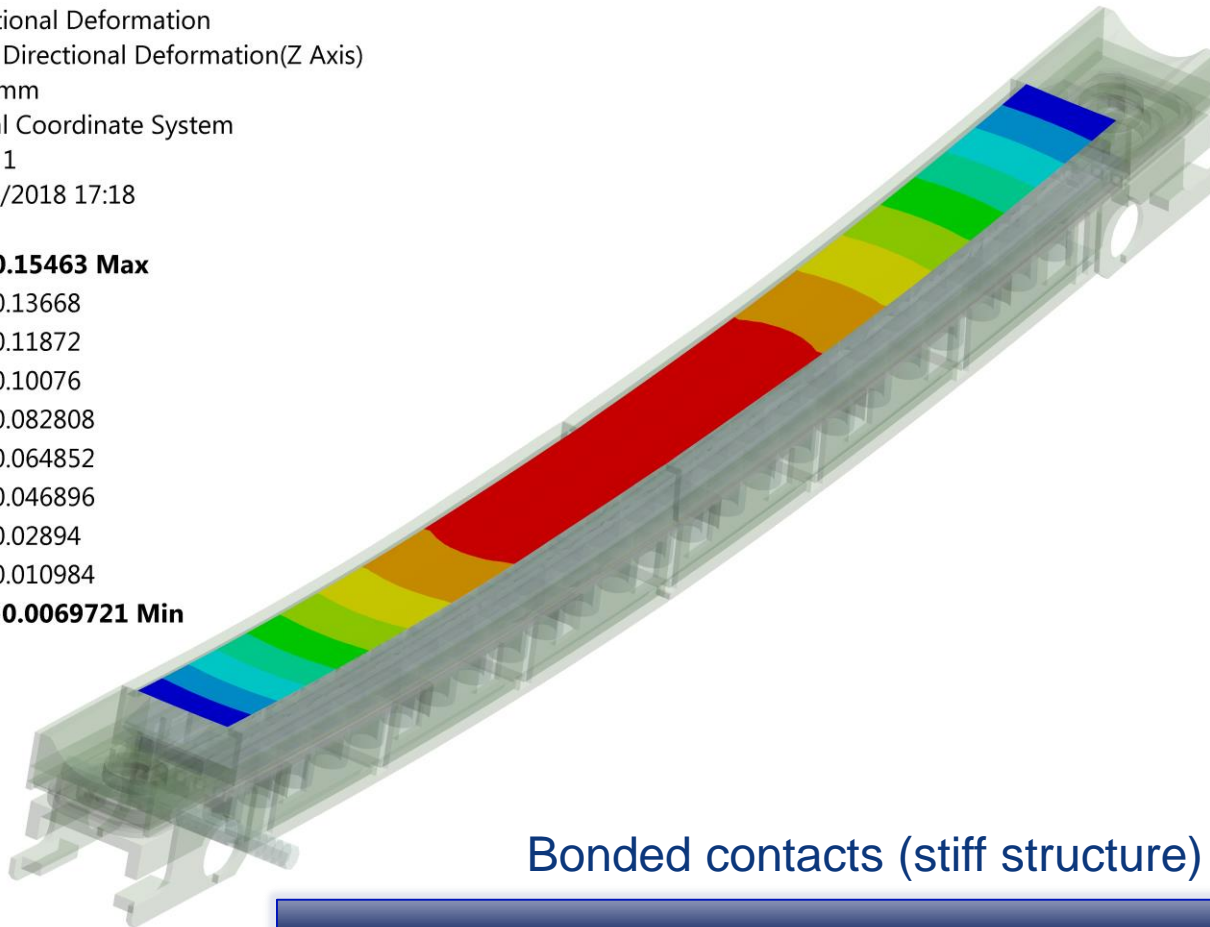
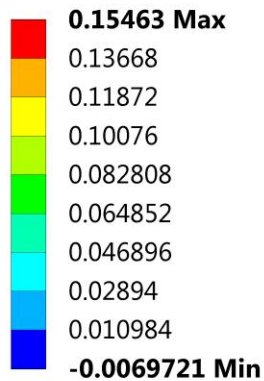
Type: Directional Deformation(Z Axis)

Unit: mm

Global Coordinate System

Time: 1

21/06/2018 17:18



Bonded contacts (stiff structure)

Thermal induced deflection = 162 μm

Structural analysis - results

M: Static Structural

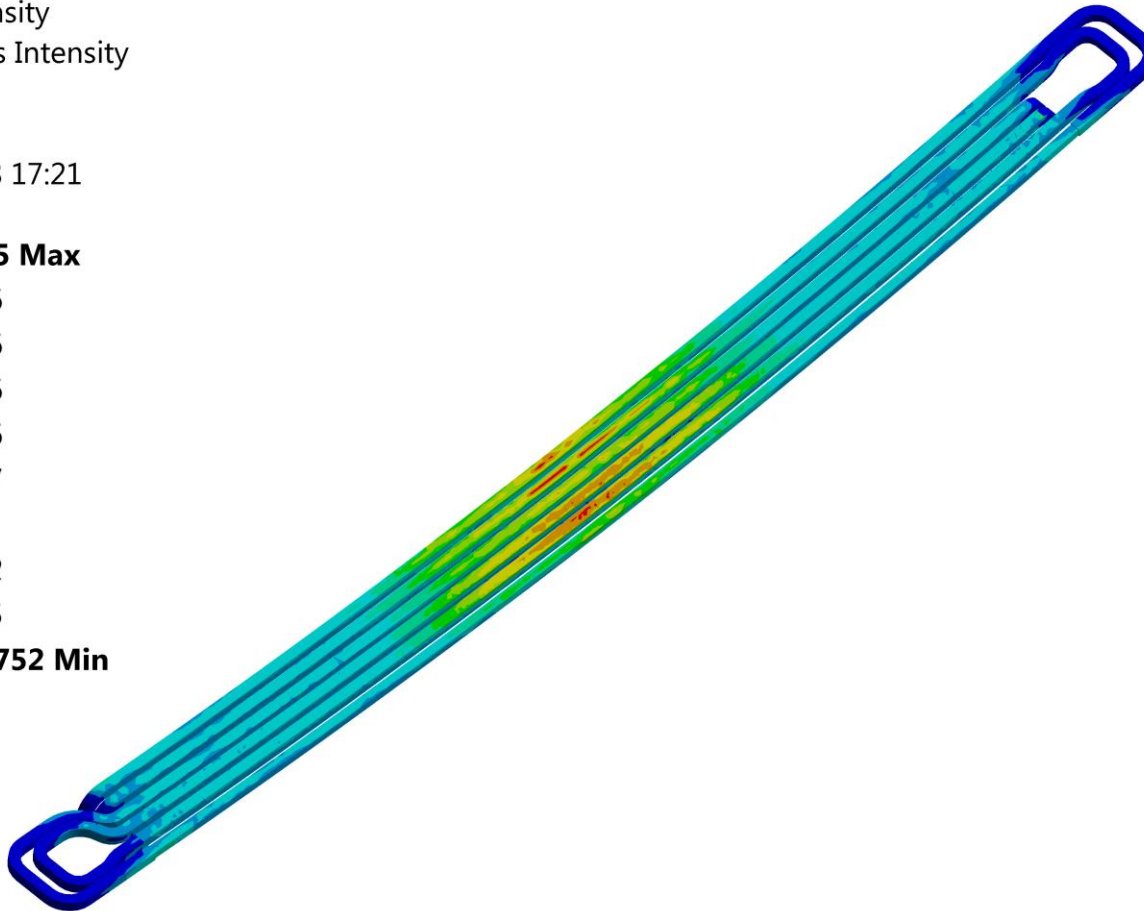
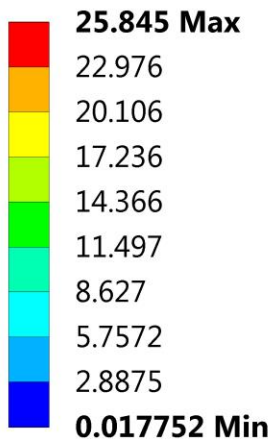
Stress Intensity

Type: Stress Intensity

Unit: MPa

Time: 1

21/06/2018 17:21



$\sigma_{yCuNi} = 100 \text{ MPa} \rightarrow$ no plastic strain

Structural analysis - results

M: Static Structural

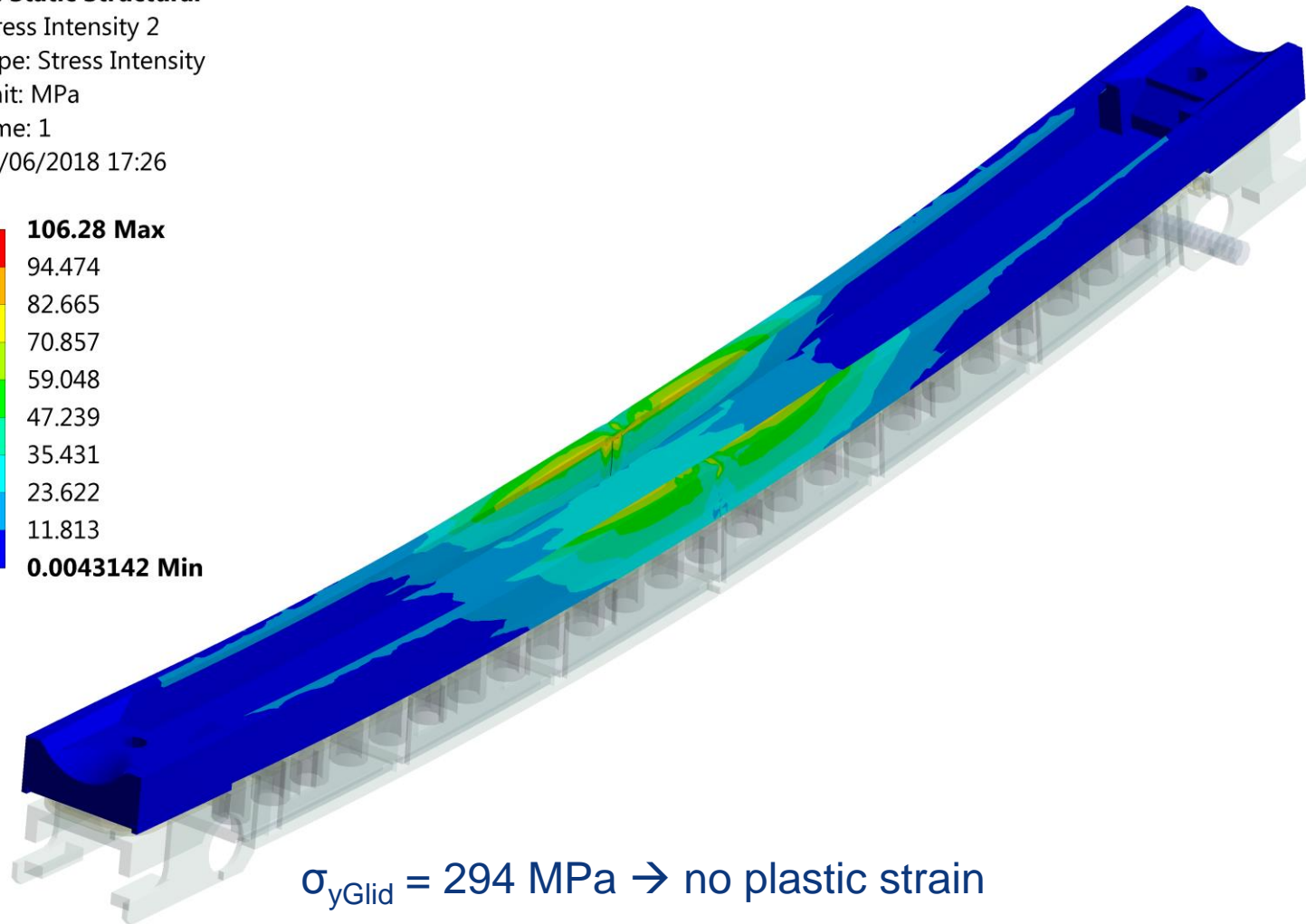
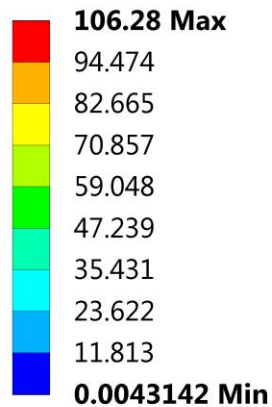
Stress Intensity 2

Type: Stress Intensity

Unit: MPa

Time: 1

21/06/2018 17:26

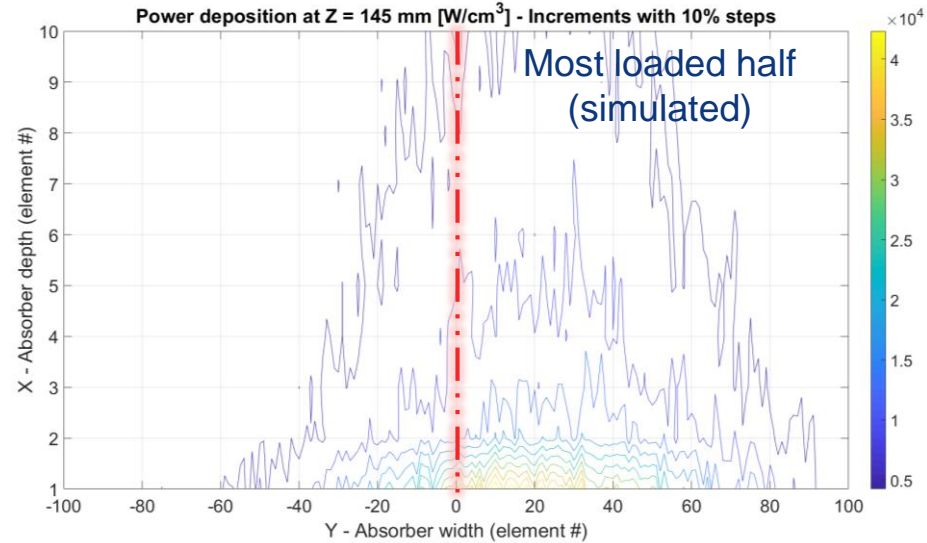
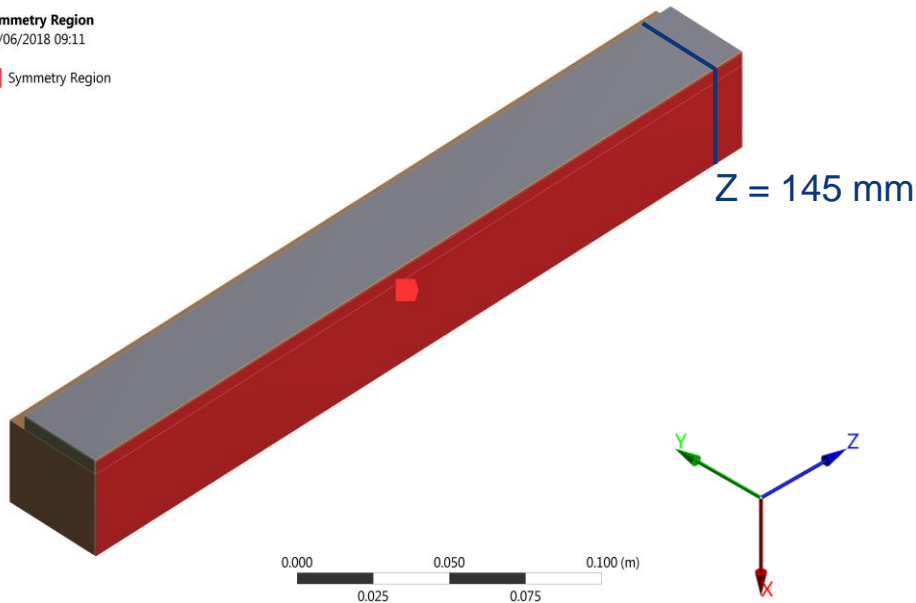


$\sigma_{y\text{Glid}} = 294 \text{ MPa} \rightarrow$ no plastic strain

Thermal load – Approach 2

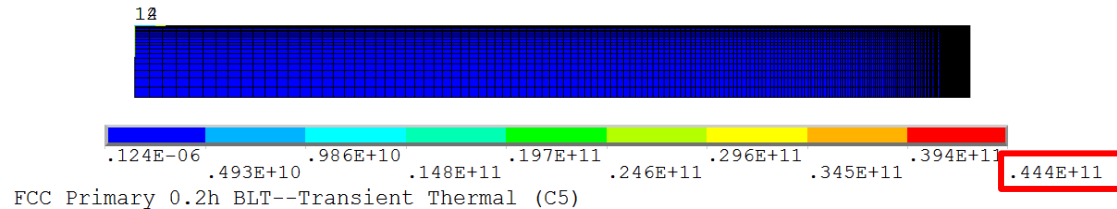
Symmetry Region
25/06/2018 09:11

■ Symmetry Region



- Simulation of half absorber (most loaded one)
- Biased mesh (5 x 5 x 5 μm at highest refinement point)
- 44400 W/cm³ as max resolved thermal load

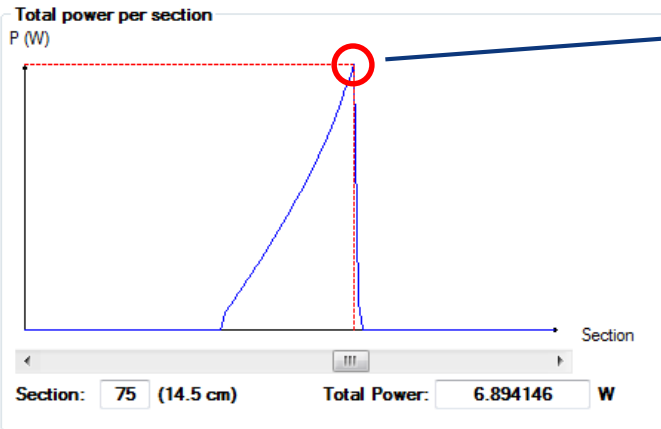
ELEMENTS
HGEN RATES
QMIN=.124E-06
QMAX=.444E+11



ANSYS
R18.2
Academic

JUN 25 2018
10:46:35

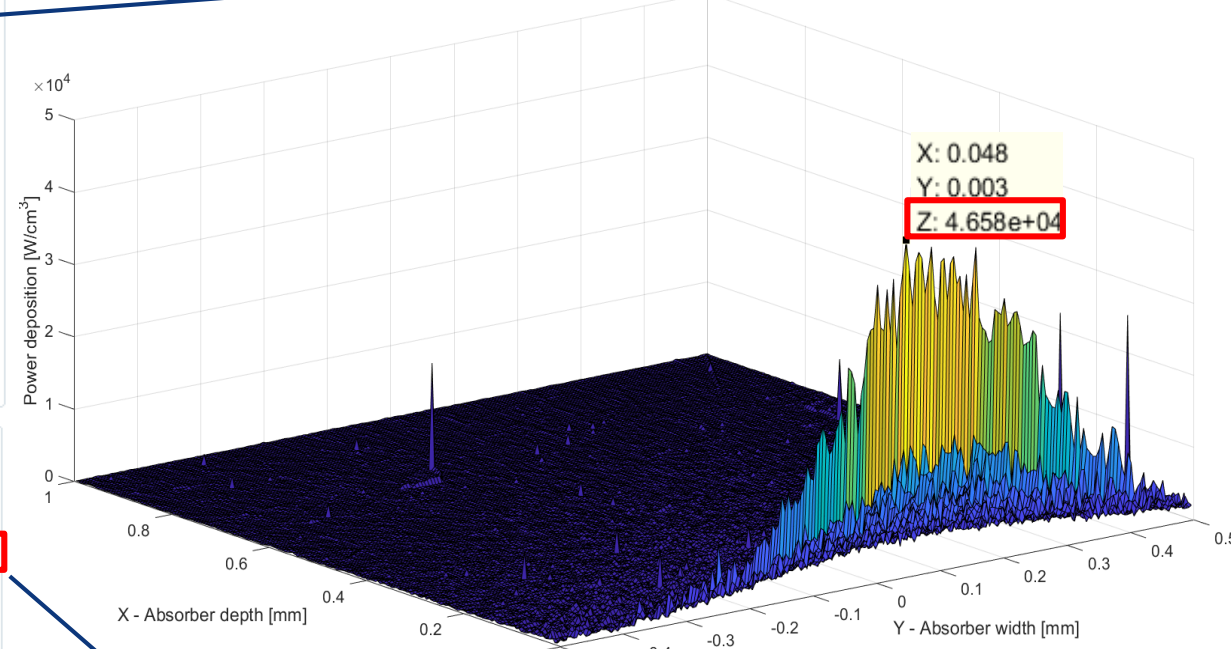
TCP – FCC thermal load



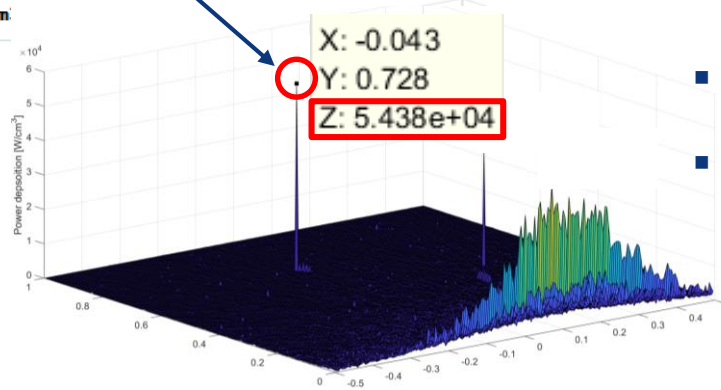
Power Values

Total Deposited Power per m3:	3.95443606	x 10 ¹⁴	14	W/m3
Total Deposited Power:	9.88609016	x 10 ¹	1	W
Maximum Deposited Power per m3:	5.43841996	x 10 ¹⁰	10	W/m3
Maximum Deposited Power:	1.35960499	x 10 ⁻²	2	W
Maximum Deposited Energy:	3.91566237	x 10 ⁷	7	J/cm3
Element Volume:	2.5	x 10 ⁻¹³	13	m3
Total Volume:	1.2	x 10 ⁻⁶	6	m

Power Deposition at Z = 145 mm



Power Deposition at Z = 75 mm

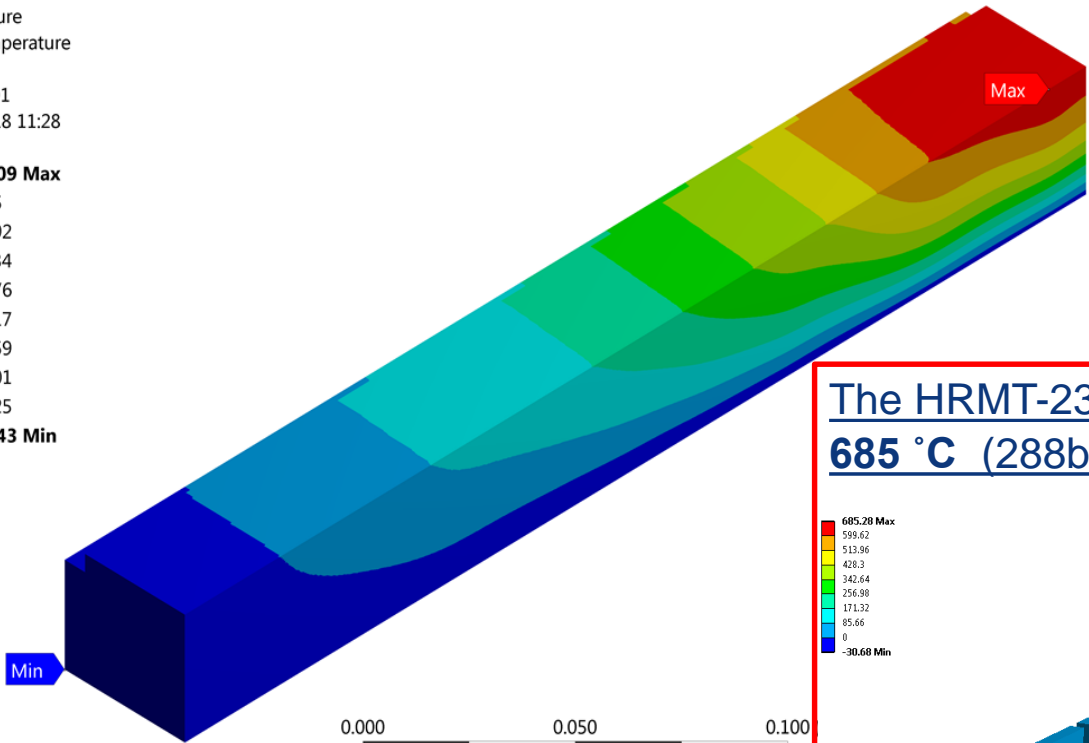


- Isolated max = 54380 W/cm³
- Max on most loaded section = 46580 W/cm³ (it was 44400 W/cm³ resolved by the mesh)

Thermal analysis – results 0.2hBLT

A: Transient Thermal
 Temperature
 Type: Temperature
 Unit: °C
 Time: 11.01
 25/06/2018 11:28

659.09 Max
 588.5
 517.92
 447.34
 376.76
 306.17
 235.59
 165.01
 94.425
 28.843 Min



$$T_{\text{water}} = 27 \text{ °C (constant)}$$

$$h_{\text{eq}} = \frac{k_{\text{Glid}}}{l_{\text{Glid}}} + \frac{k_{\text{CuNi}}}{l_{\text{CuNi}}}$$

The HRMT-23 case: max simulated T on CFC jaw:
685 °C (288b, 3.79E13p, $\sigma = 0.35 \text{ mm}$)

Beam

No failure observed experimentally

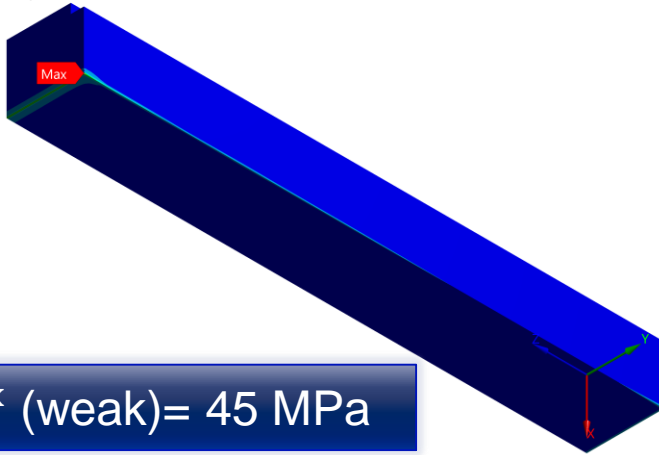
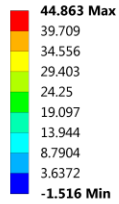
$T_{\text{max}} = 659 \text{ °C}$

The HRMT-36 case: grazing shot at 288b,
3.72E13p, $\sigma = 0.25 \text{ mm}$ => **No failure observed**

Structural analysis - results

B: Static Structural

X Axis - Normal Stress - End Time
 Type: Normal Stress(X Axis)
 Unit: MPa
 Coordinate System
 Time: 1
 25/06/2018 11:02

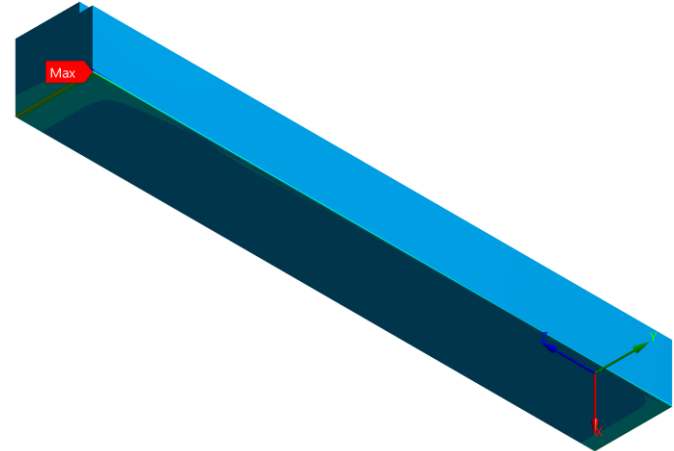
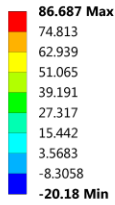


$$\sigma_X^{\max} \text{ (weak)} = 45 \text{ MPa}$$



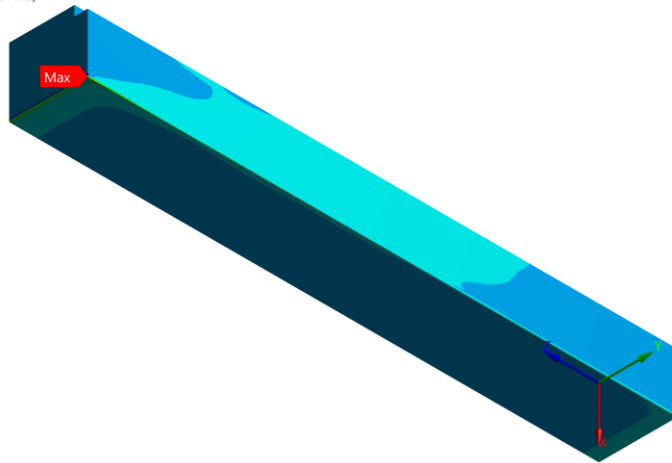
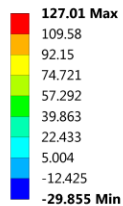
B: Static Structural

Y Axis - Normal Stress - End Time
 Type: Normal Stress(Y Axis)
 Unit: MPa
 Coordinate System
 Time: 1
 25/06/2018 11:04



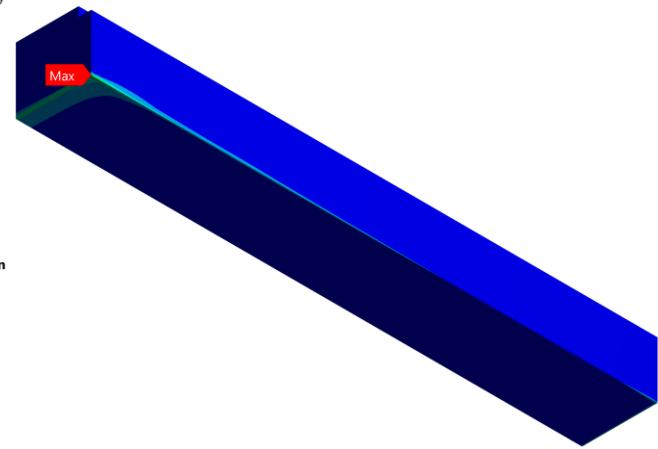
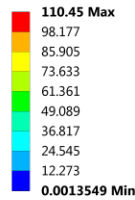
B: Static Structural

Z Axis - Normal Stress - End Time
 Type: Normal Stress(Z Axis)
 Unit: MPa
 Coordinate System
 Time: 1
 25/06/2018 11:05



B: Static Structural

Stress Intensity
 Type: Stress Intensity
 Unit: MPa
 Time: 1
 25/06/2018 11:08



Structural analysis - results

B: Static Structural

X Axis - Normal Elastic Strain - End Time

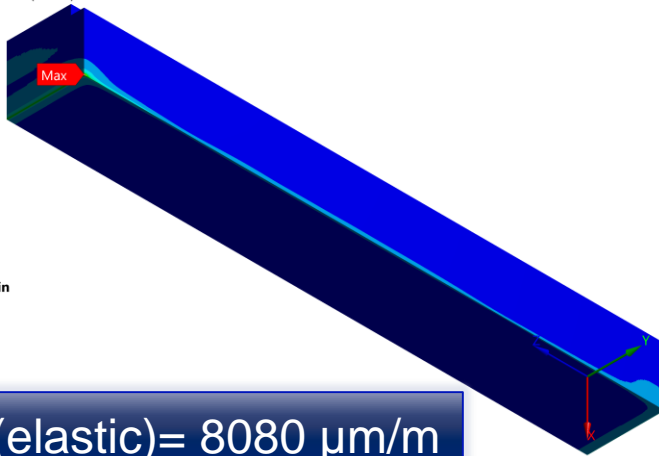
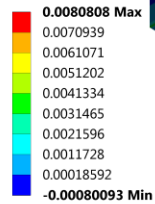
Type: Normal Elastic Strain(X Axis)

Unit: m/m

Coordinate System

Time: 1

25/06/2018 11:14



$$\epsilon_X^{\max} \text{ (elastic)} = 8080 \mu\text{m/m}$$



B: Static Structural

Y Axis - Normal Elastic Strain - End Time

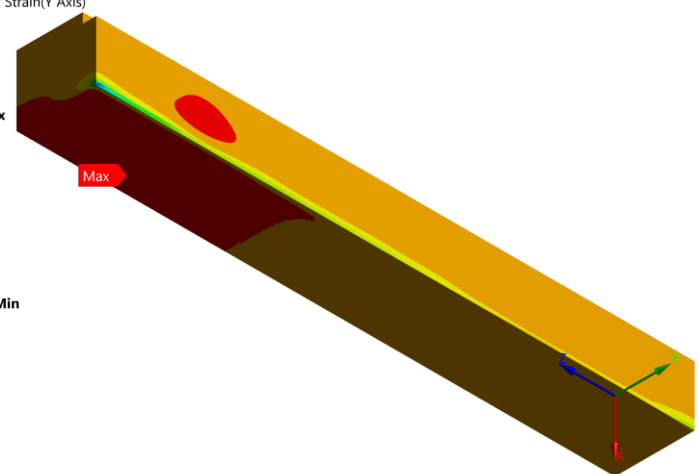
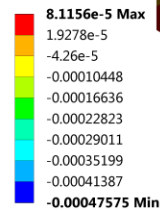
Type: Normal Elastic Strain(Y Axis)

Unit: m/m

Coordinate System

Time: 1

25/06/2018 11:17



B: Static Structural

Z Axis - Normal Elastic Strain - End Time

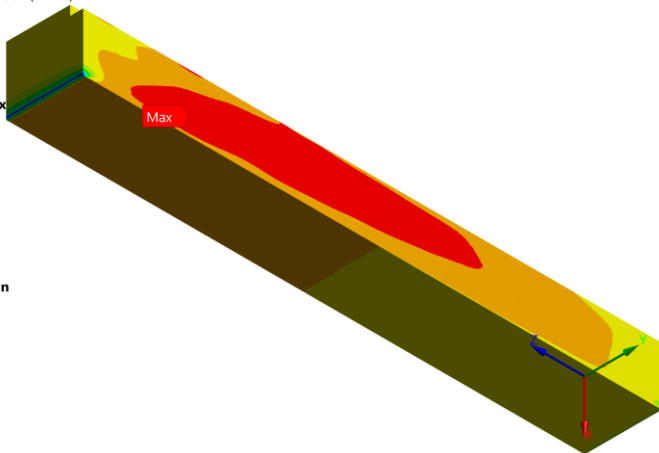
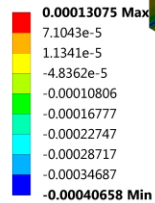
Type: Normal Elastic Strain(Z Axis)

Unit: m/m

Coordinate System

Time: 1

25/06/2018 11:18



B: Static Structural

Directional Deformation

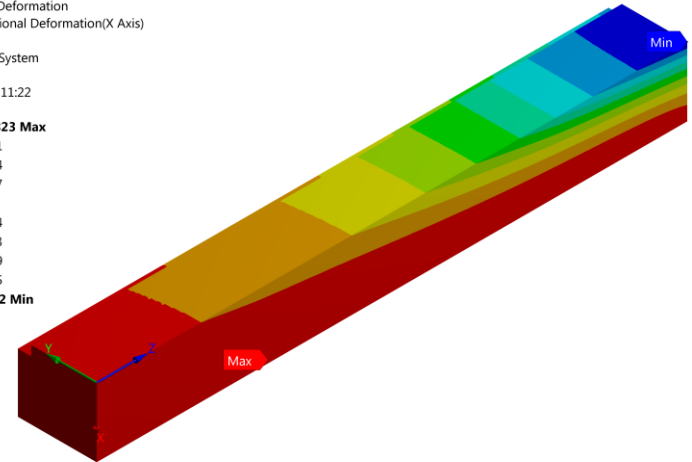
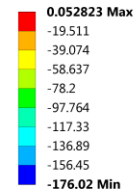
Type: Directional Deformation(X Axis)

Unit: μm

Coordinate System

Time: 1

25/06/2018 11:22



Summary

- 0.2 h BLT scenario was simulated for a thicker TCSP collimator jaw (3.5 cm) with FCC load → conceptual study
- Global structure: thermal induced deflection of 162 μm
- No plasticity arising on the housing or the cooling pipes
- Maximum $T = 659\text{ }^{\circ}\text{C}$ on CFC absorber. Previous experimental tests featuring similar peak temperatures showed no failure on CFC absorbers
- Max thermal induced stress along X (weak direction) 45 MPa corresponding to 8000 $\mu\text{m}/\text{m}$ (elastic equivalent) →
 - Glidcop-CFC bonding simulated as an infinitely rigid fixed bc
 - Numerical analyses have shown to over predict stress/strain values (e.g. HRMT-23, HRMT-36);



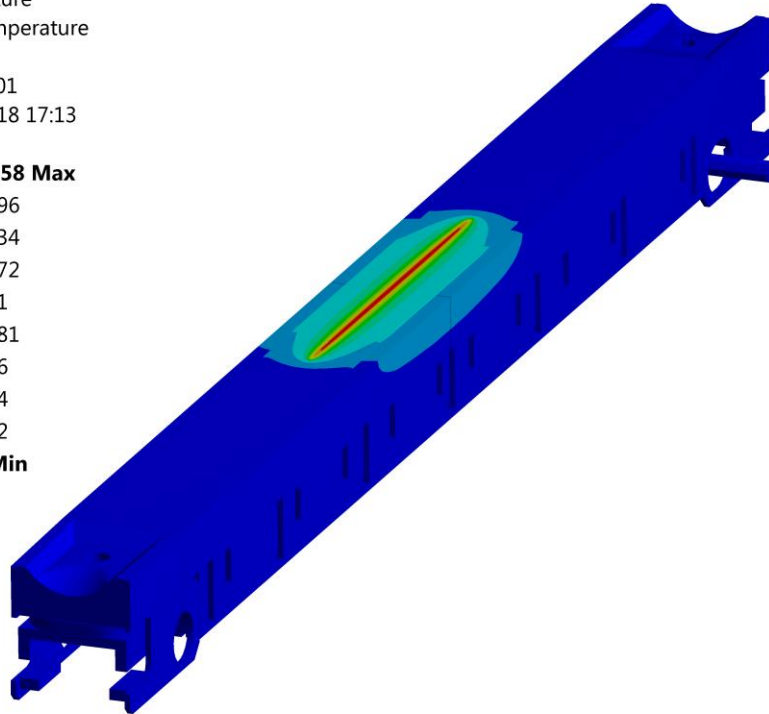
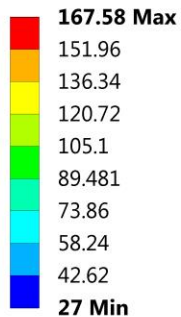
ENGINEERING
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Thanks for your attention

Thermal analysis – results 0.2hBLT

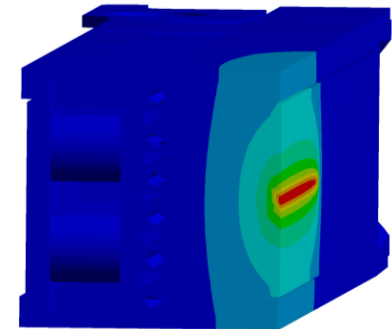
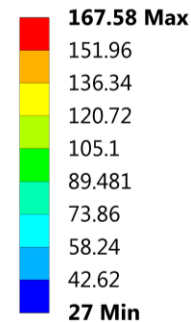
L: Transient Thermal

Temperature
Type: Temperature
Unit: °C
Time: 10.01
21/06/2018 17:13



L: Transient Thermal

Temperature
Type: Temperature
Unit: °C
Time: 10.01
21/06/2018 17:16



Cooling water at $T = 27\text{ °C}$ (constant)

$$T_{\max} = 167\text{ °C}$$

Structural analysis - results

G: Static Structural_1hBLT

Stress Intensity 2

Type: Stress Intensity

Unit: MPa

Time: 1

25/06/2018 14:13

