

Thermo-mechanical studies of collimator robustness

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FCC Week 2019

25/6/2019



Case studies

- Most loaded **primary** and **secondary collimators**: TCP and TCSP
- Design as those currently installed in LHC but with **thicker jaw**

- Slow losses:

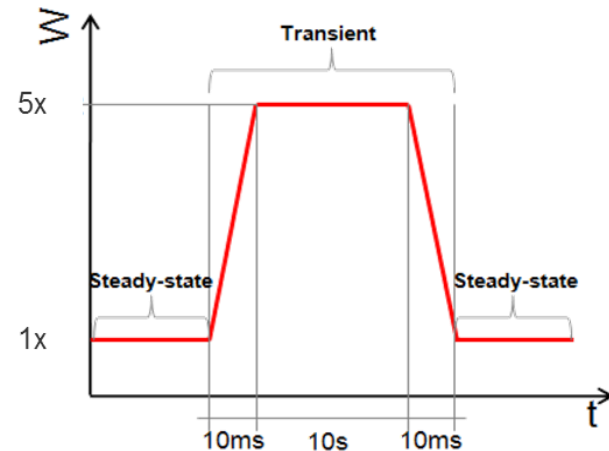
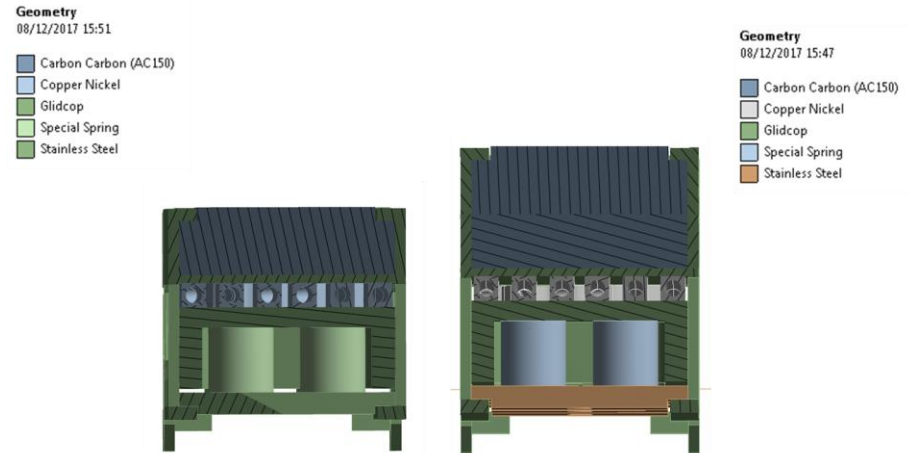
Primary collimator

→ Accidental case: 0.2h BLT (10s)

Secondary collimator

→ Nominal operation: 1h BLT

→ Accidental case: 0.2h BLT (10s)



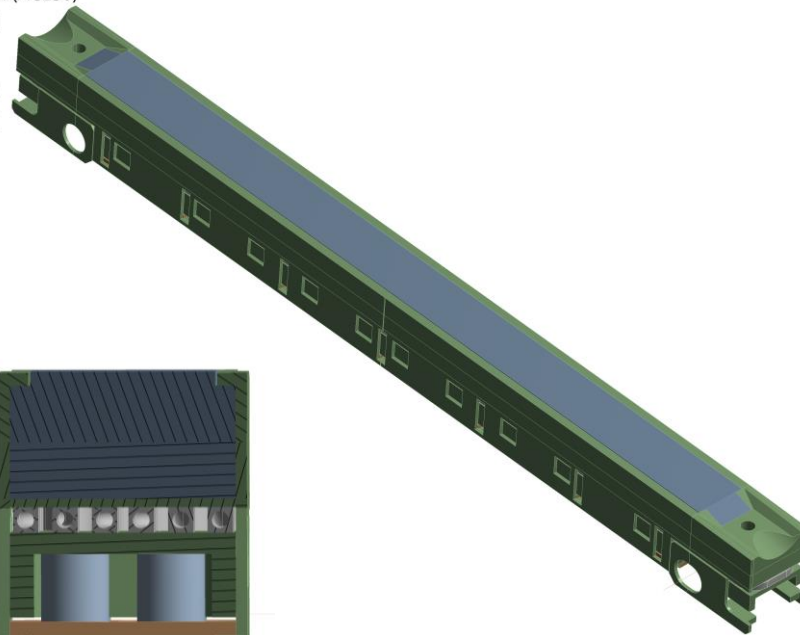
Method



Geometry

19/06/2019 14:20

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



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



Assumption

Stiffer structure than the current one (LHC), simulated with **bonded contacts** between **CFC** and **Glidcop** housing

Secondary collimator

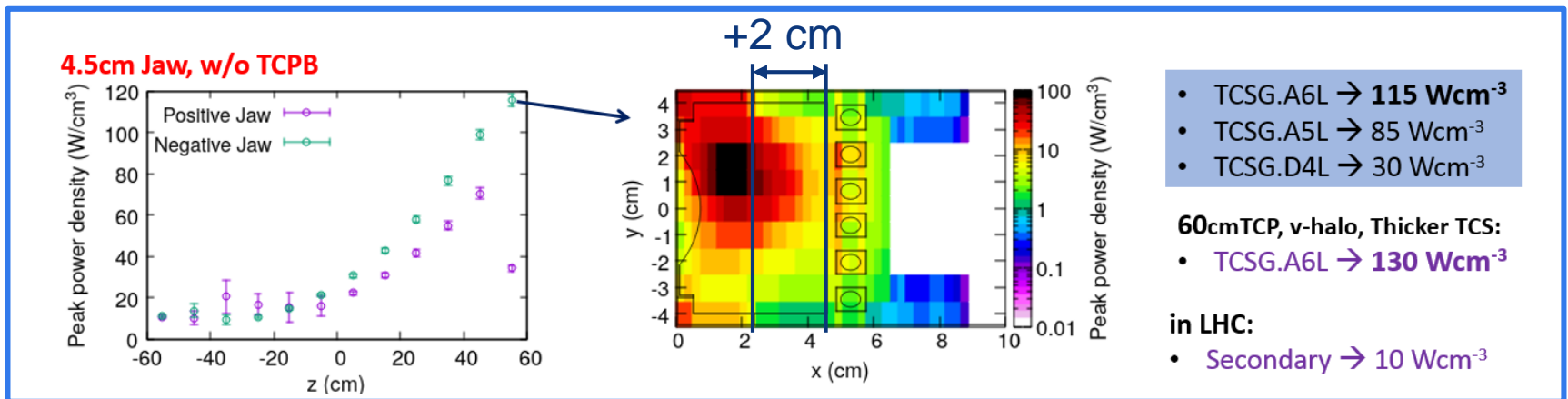
- TCSP most loaded jaw of the first secondary collimator (**TCSGA6L**)
- Thicker jaw: 4.5 cm** instead of 2.5 cm
- Skew TCP removed and thickness of primary collimator jaws (30 cm long) increased from 2.5 cm to 3.5 cm

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% ▼

↓

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

Power density on the First Secondary



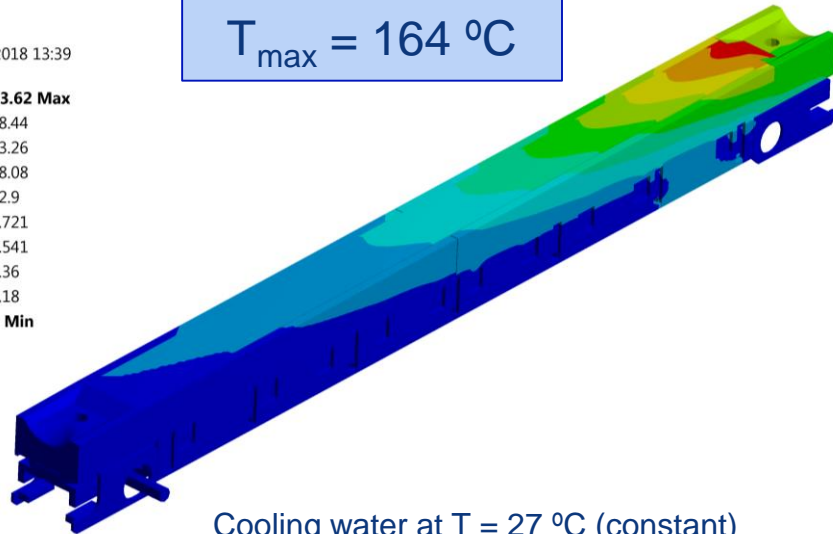
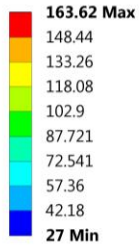
M. Varasteh Energy deposition studies: 30cm TCPs with thicker jaws and no skew
CERN - FCC collimation design meeting #14

20.11.2017 8

Results - 1h BLT

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

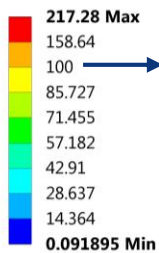
$T_{max} = 164 \text{ } ^\circ\text{C}$



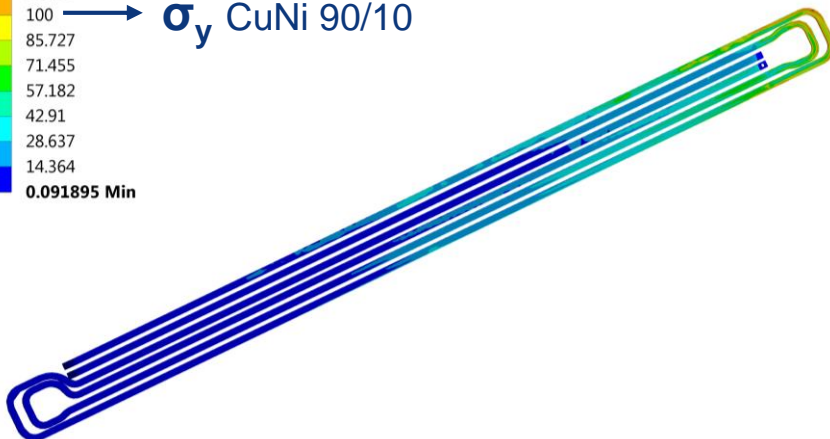
Cooling water at $T = 27 \text{ } ^\circ\text{C}$ (constant)

Type: Stress Intensity
Unit: MPa
Time: 1
17/06/2019 15:37

Plasticity downstream

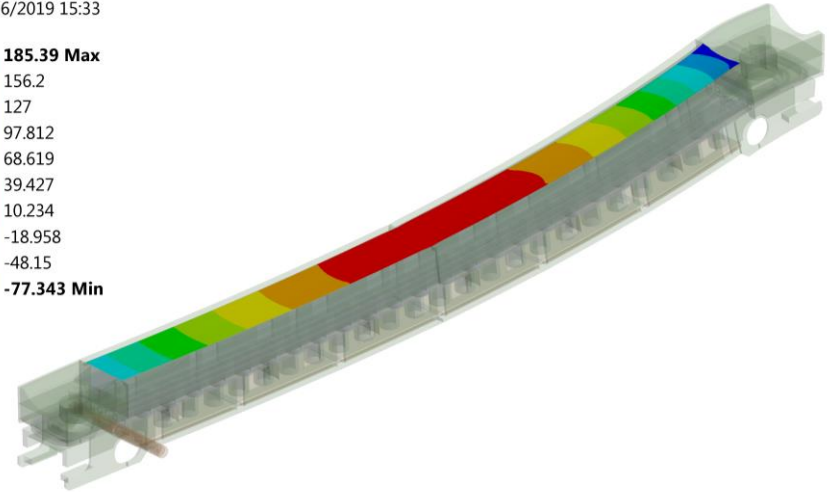
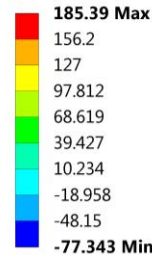


σ_y CuNi 90/10



Type: Directional Deformation(Z Axis)
Unit: μm
Global Coordinate System
Time: 1
17/06/2019 15:33

Deflection = $262 \text{ } \mu\text{m}$

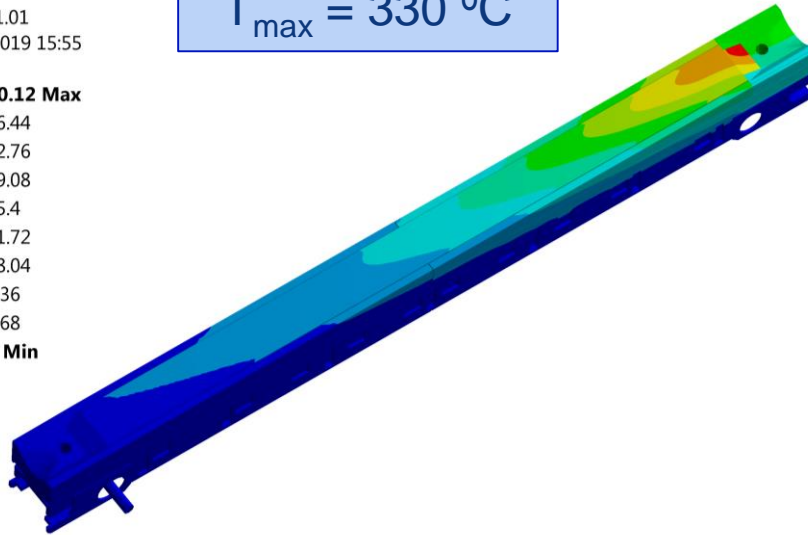
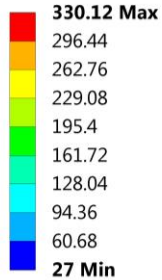


- Moderate temperature on the overall collimator, with local peak \rightarrow improved pumping system could be beneficial
- Jaw assembly survives without plasticity (except pipes)
- Deflection away from the beam
- Low stresses on the CFC absorber

Results - 0.2h BLT

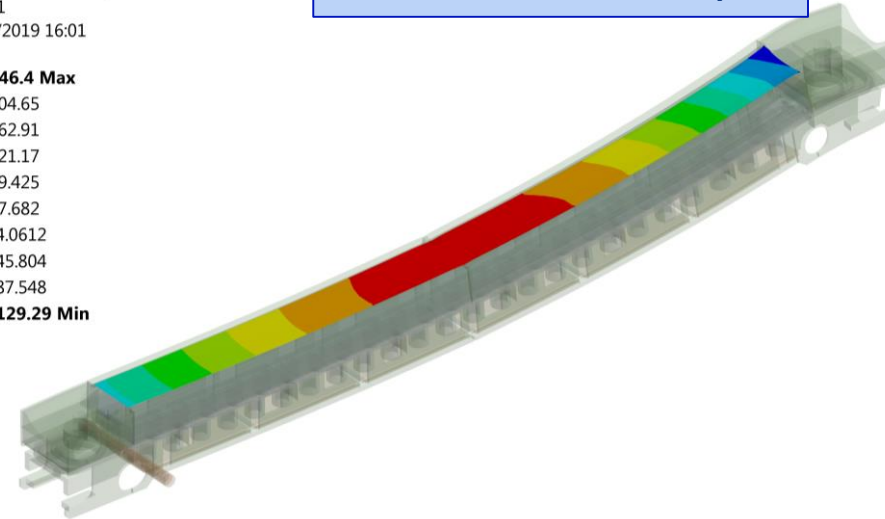
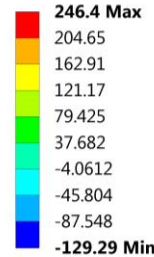
Type: Temperature
Unit: °C
Time: 11.01
17/06/2019 15:55

$T_{max} = 330 \text{ °C}$



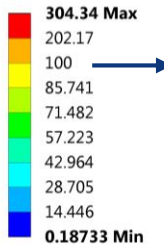
Type: Directional Deformation(Z Axis)
Unit: μm
Global Coordinate System
Time: 1
17/06/2019 16:01

Deflection = 375 μm

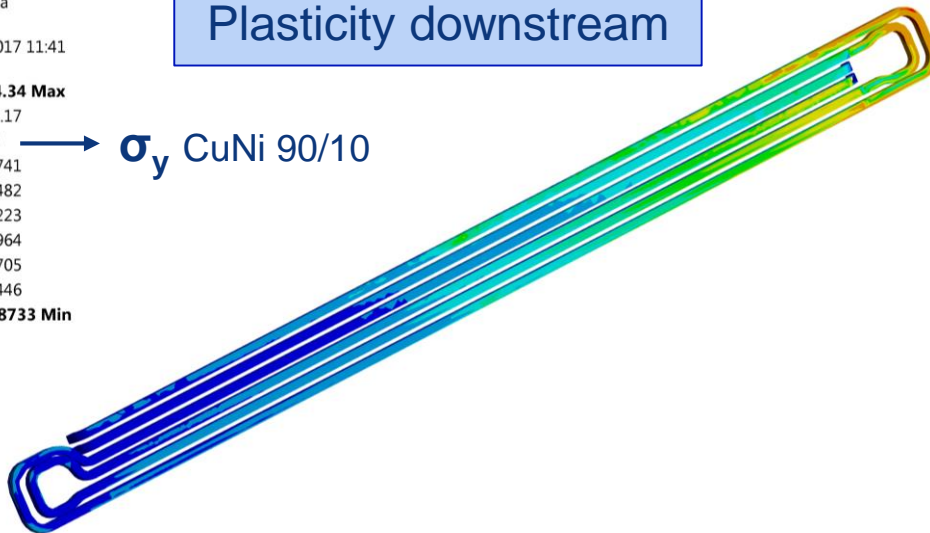


Type: Stress Intensity
Unit: MPa
Time: 1
07/12/2017 11:41

Plasticity downstream



σ_y CuNi 90/10



- High temperature → but for 10 s
- Jaw assembly survives without plasticity (except pipes)
- Onset of plasticity on cooling pipes could be addressed by using different material

Primary collimator

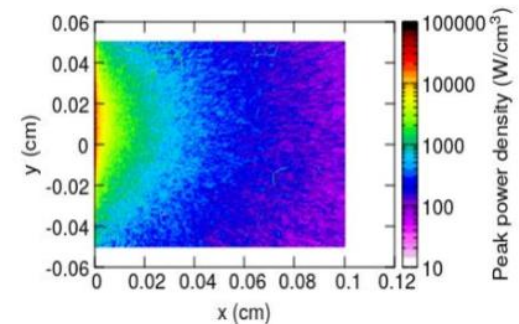
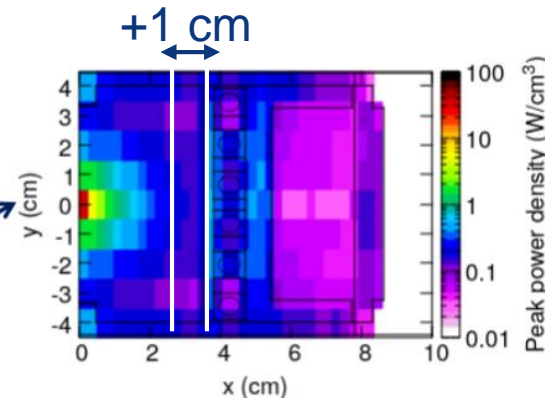
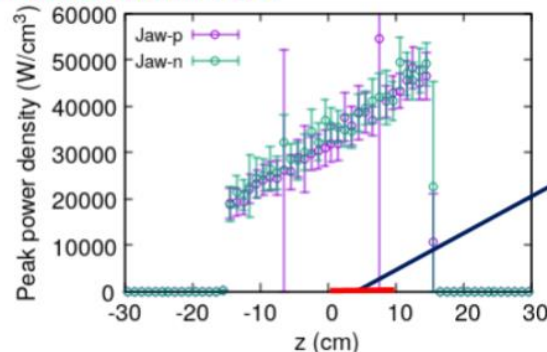
- Vertical primary collimator (TCPD6L)
- The most exposed collimator in terms of peak power density
- Thicker jaw: 3.5 cm instead of 2.5 cm
- Active length 30 cm

Collimator Jaws	TCP 60cm	TCP 30cm	TCP 30cm Thicker Jaw, w/o TCPB	
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*Energy deposition studies: 30cm TCPs with thicker jaws and no skew
CERN - FCC collimation design meeting #14*

Peak power density on Vertical Primary

3.5cm Jaw, w/o TCPB



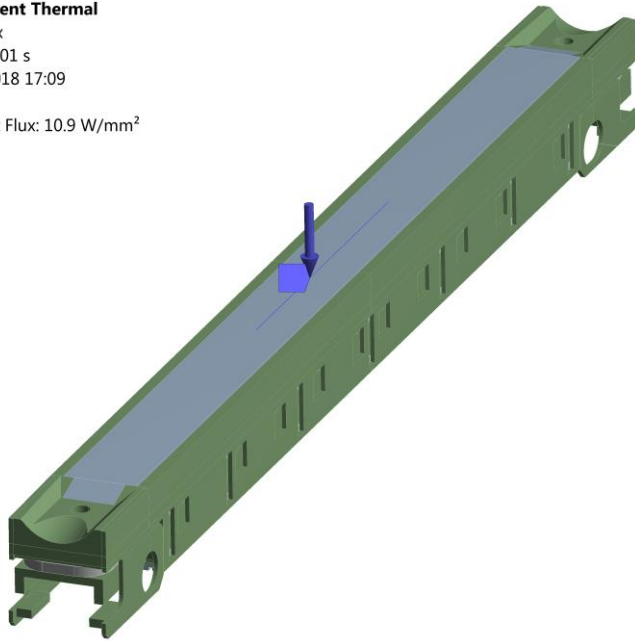
Approach

COLLIMATOR STRUCTURE

L: Transient Thermal

Heat Flux
Time: 10.01 s
21/06/2018 17:09

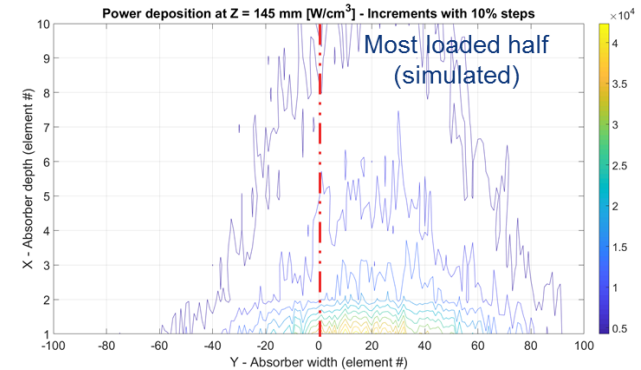
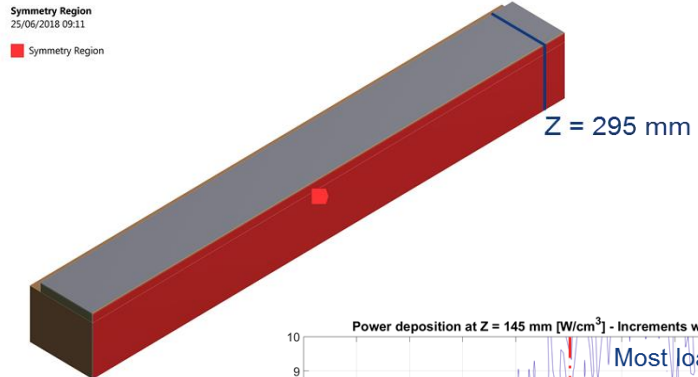
Heat Flux: 10.9 W/mm²



- Surface 300 x 1 mm
- Heat flux equivalent to 3.27 kW (total thermal load on the absorber)
- $t = 10$ s

CFC ABSORBER

Symmetry Region
25/06/2018 09:11



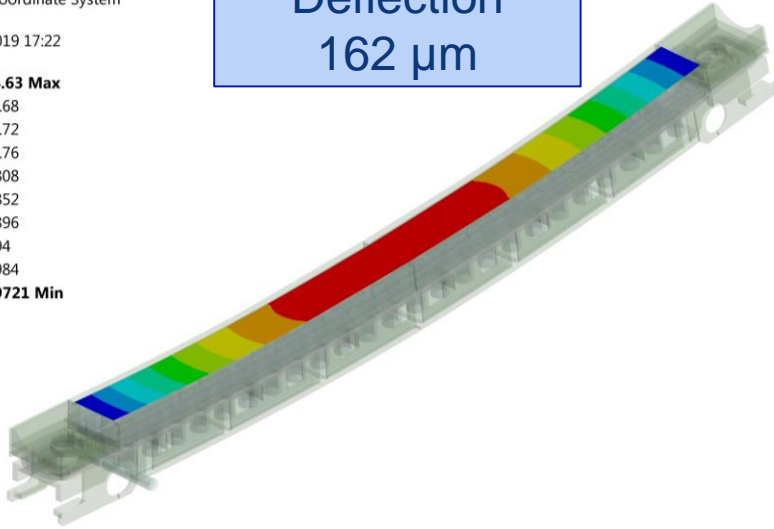
- Half absorber, the most loaded one
- Biased mesh down to 2.5 x 2.5 x 1000 μ m
- 44400 W/cm³ max thermal load

Results – Collimator structure

Type: Directional Deformation(Z Axis)
Unit: μm
Global Coordinate System
Time: 1
17/06/2019 17:22

Deflection
162 μm

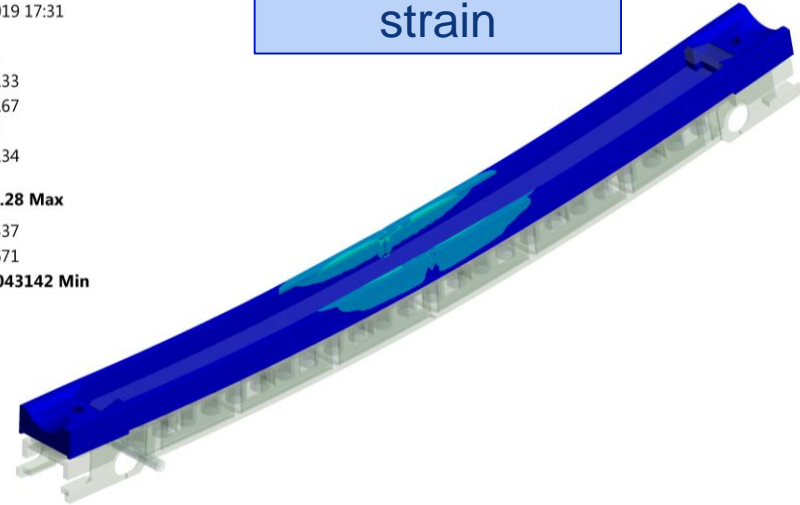
154.63 Max
136.68
118.72
100.76
82.808
64.852
46.896
28.94
10.984
-6.9721 Min



Type: Stress Intensity
Unit: MPa
Time: 1
17/06/2019 17:31

No plastic strain

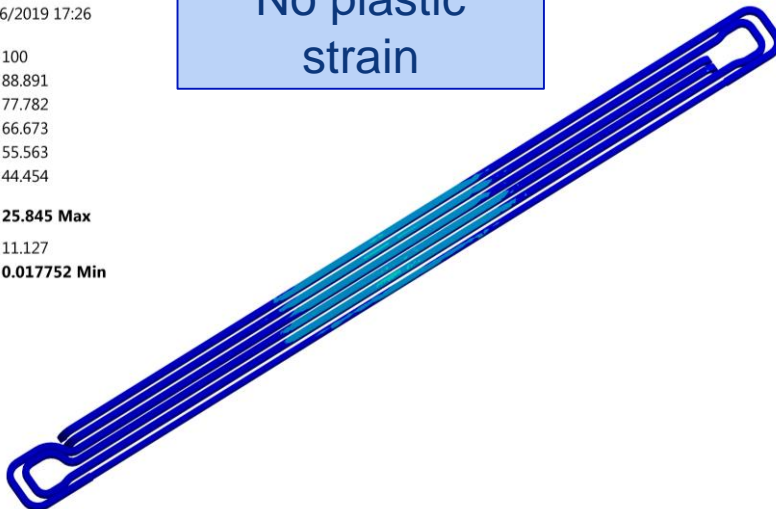
294
261.33
228.67
196
163.34
106.28 Max
65.337
32.671
0.0043142 Min



Type: Stress Intensity
Unit: MPa
Time: 1
17/06/2019 17:26

No plastic strain

100
88.891
77.782
66.673
55.563
44.454
25.845 Max
11.127
0.017752 Min



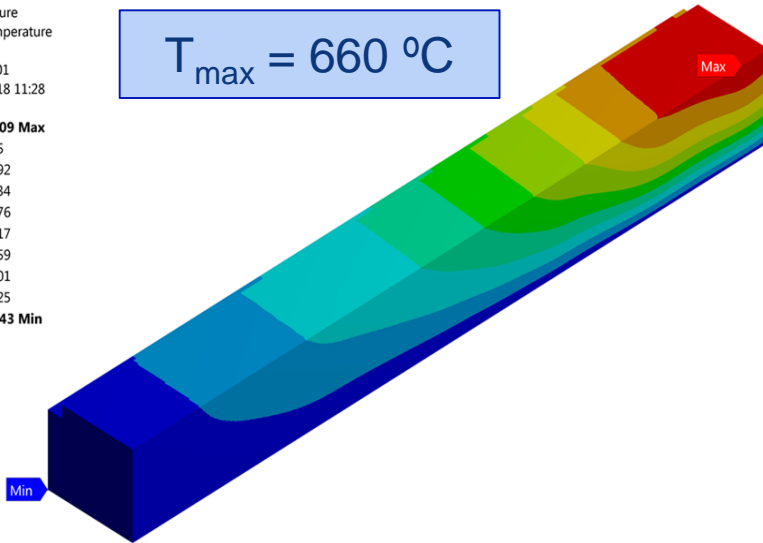
- No relevant issues for the jaw structure → load concentrated on the absorber

Results - CFC absorber

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

$T_{\max} = 660 \text{ }^{\circ}\text{C}$

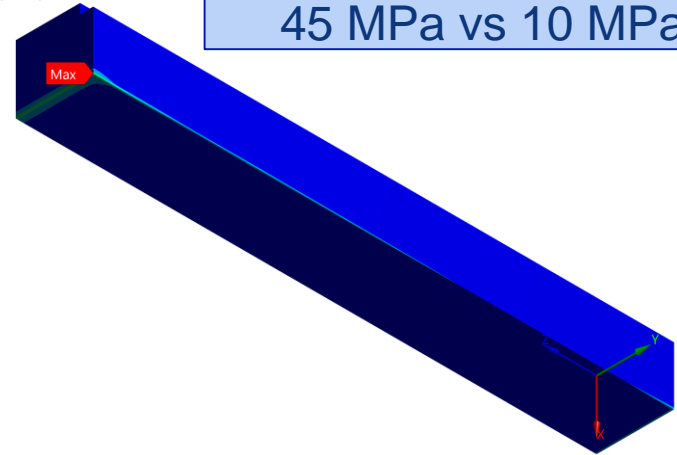
659.09 Max
588.5
517.92
447.34
376.76
306.17
235.59
165.01
94.425
28.843 Min



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

σ_X^{\max} (weak direction)
45 MPa vs 10 MPa

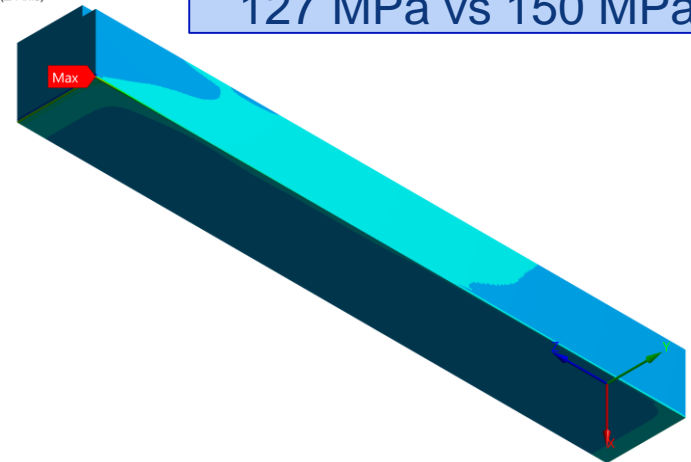
44.863 Max
39.709
34.556
29.403
24.25
19.097
13.944
8.7904
3.6372
-1.516 Min



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

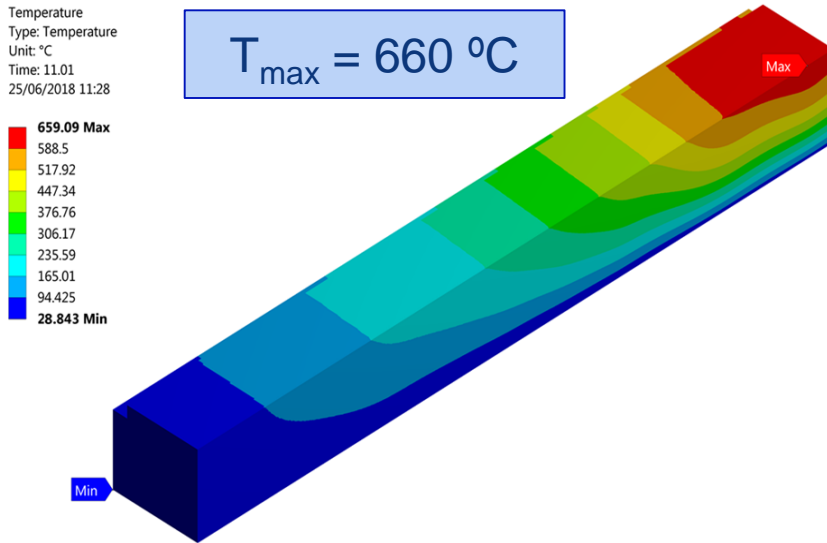
σ_Z^{\max} (strong direction)
127 MPa vs 150 MPa

127.01 Max
109.58
92.15
74.721
57.292
39.863
22.433
5.004
-12.425
-29.855 Min

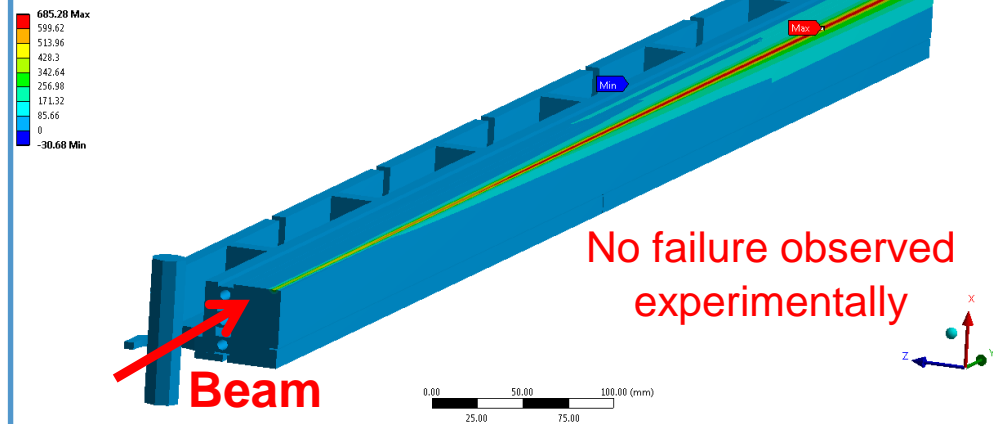


- Temperature high (smooth gradient)
- Vacuum issue? (t = 10 s)
- Numerical stresses higher than material limit → failure?

Results - CFC absorber



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



- **No failure** demonstrated experimentally
- Numerical model overestimates stresses

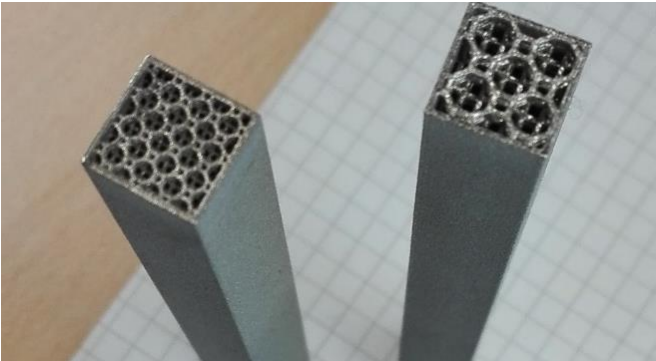
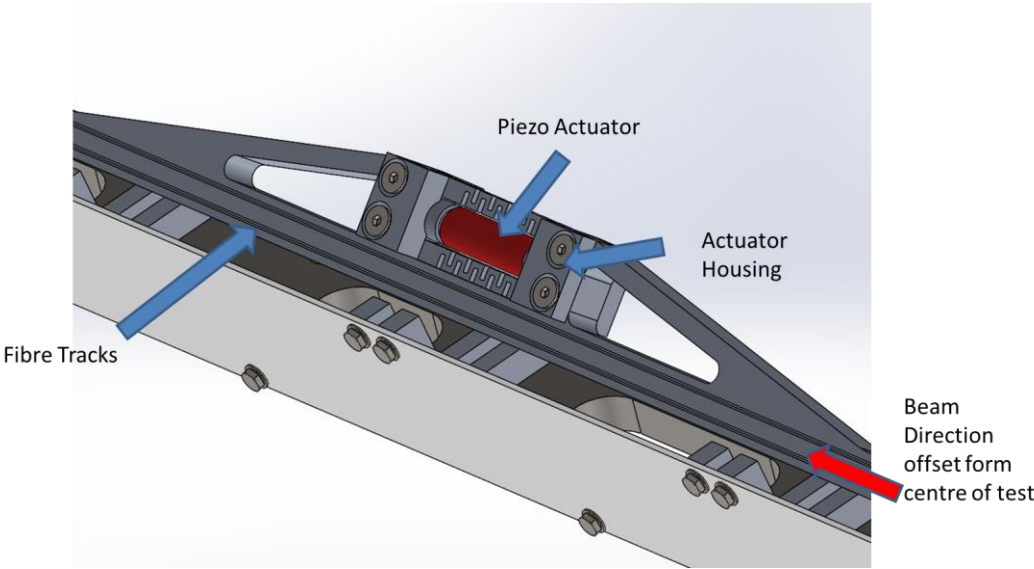
The HRMT-36 case: **>1500 °C** (grazing shot at 288b, 3.72E13p, $\sigma = 0.25 \text{ mm}$) → **No failure observed**



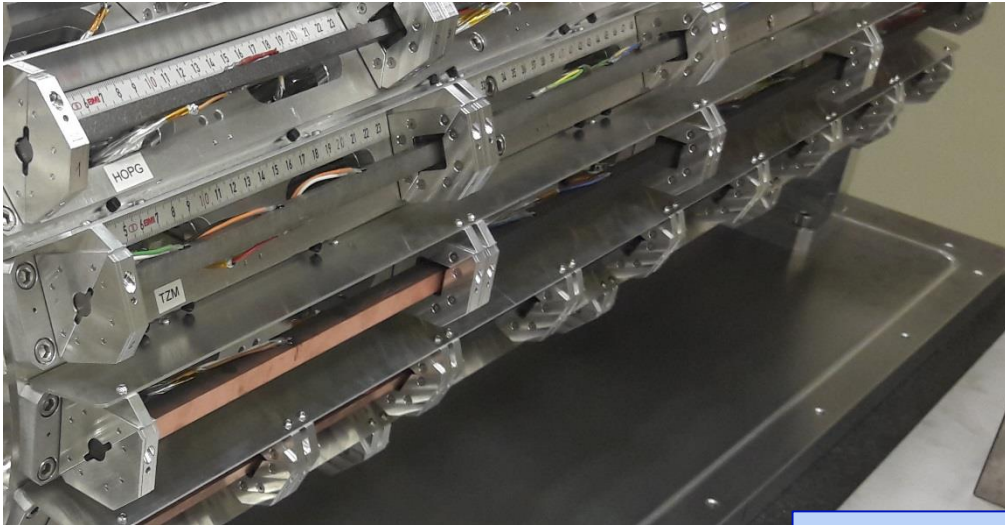
Conclusions

- Thermo-structural studies of **most loaded primary** (TCP) and **secondary** (TCS) collimators of the FCC performed for **1h** and **0.2h BLT**
- Stiff structure considered for the conceptual design → **bonded assembly**
- **Highest** value of jaw **deflection** for the most loaded **secondary** collimator, **0.2h BLT**, around 370 μm away from the beam
- **Highest temperature**, 660 °C, on **primary** collimator for **0.2h BLT** scenario without CFC failure
- **Collimators survive** without permanent damage in spite of extreme loss conditions
 - **Onset of plasticity** on the cooling pipes could be cured with **alternative materials** or geometry
- Overall, **high temperatures** may lead to **high outgassing** ...

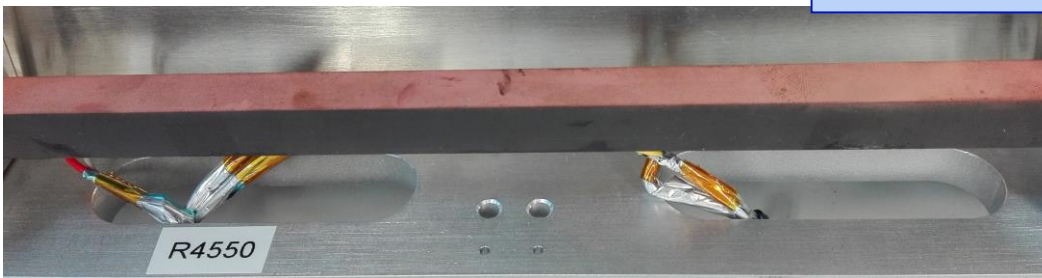
What's next ?



What's next



**HRMT-36
MultiMat**





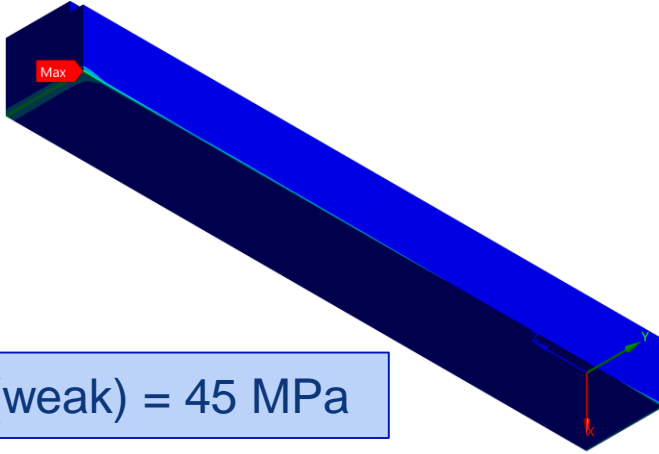
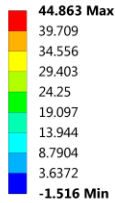
ENGINEERING
DEPARTMENT

Thanks for your attention

Results - CFC absorber

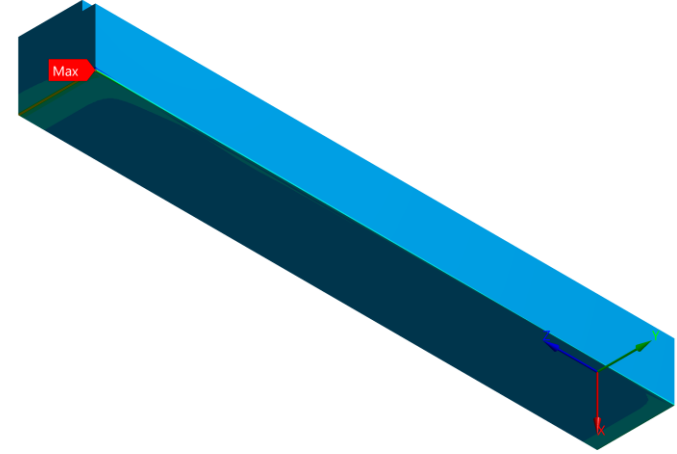
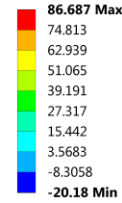
B: Static Structural

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



B: Static Structural

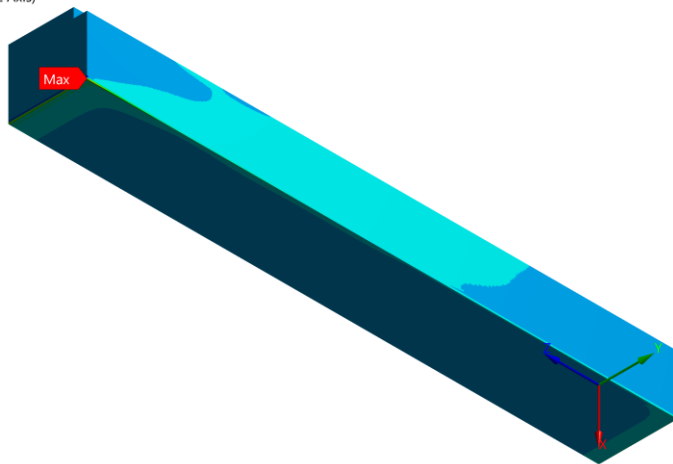
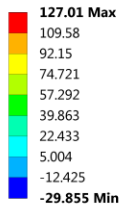
Y Axis - Normal Stress - End Time
 Type: Normal Stress(Y Axis)
 Unit: MPa
 Coordinate System
 Time: 1
 25/06/2018 11:04



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

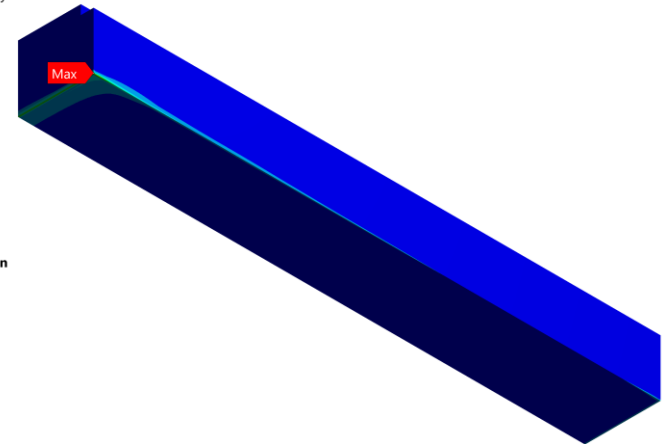
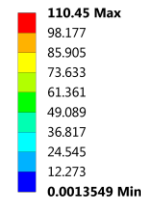
B: Static Structural

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



Slow losses

	Power deposition (kW)					
	1h BLT			0.2h BLT		
	$TCSP_{CFC}$ (LHC)	$TCSPM_{CFC}$ (HL-LHC)	$TCSPM_{MoGr}$ (HL-LHC)	$TCSP_{CFC}$ (LHC)	$TCSPM_{CFC}$ (HL-LHC)	$TCSPM_{MoGr}$ (HL-LHC)
<i>Most loaded jaw</i>	2	5	8.9	10	25	44.5
<i>Absorber of most loaded jaw</i>	0.4	1.1	4	2	5.5	20
<i>Total on collimator</i>	4.5	12.6	20.7	22.5	63	103.5