Thermo-mechanical studies of collimator robustness

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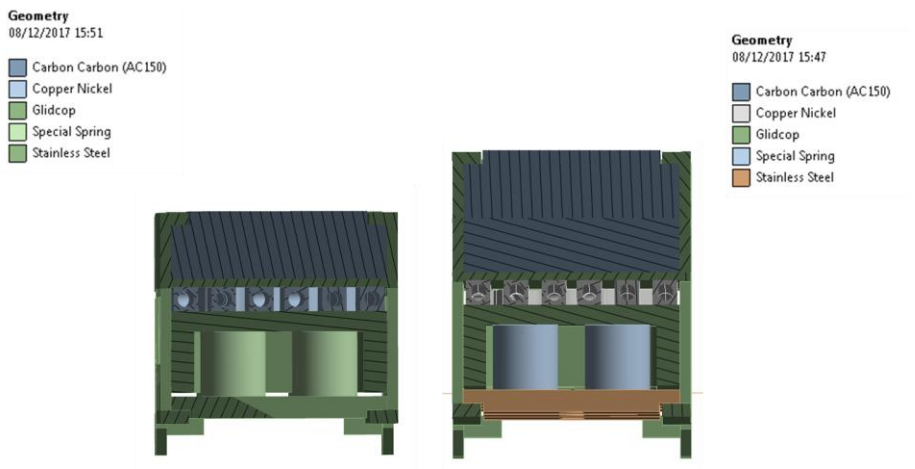
FCC Week 2019

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:

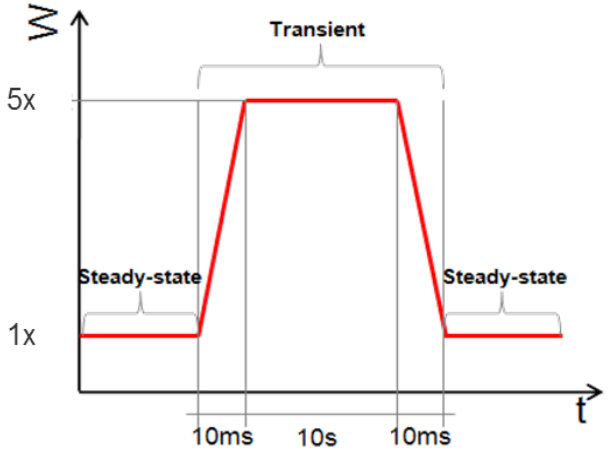
  Primary collimator

  → Accidental case: 0.2h BLT (10s)

  Secondary collimator

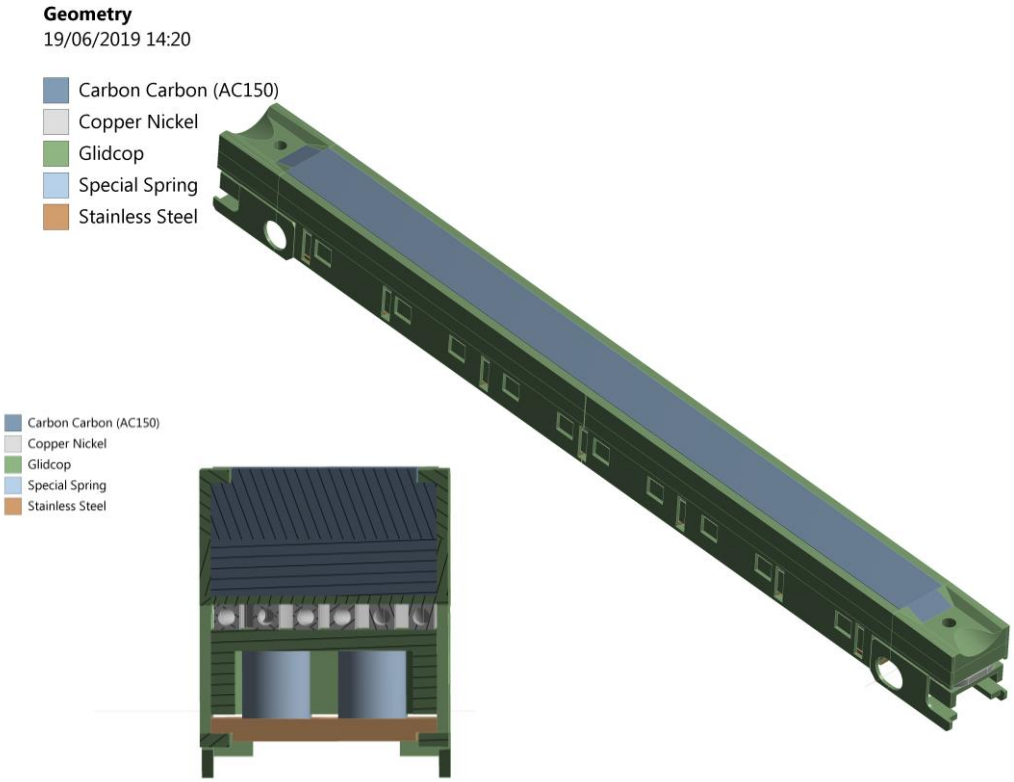
  → Nominal operation: 1h BLT

  → Accidental case: 0.2h BLT (10s)



Method

Tracking code → Energy deposition Fluka → Thermo-mechanical simulations Ansys



Assumption

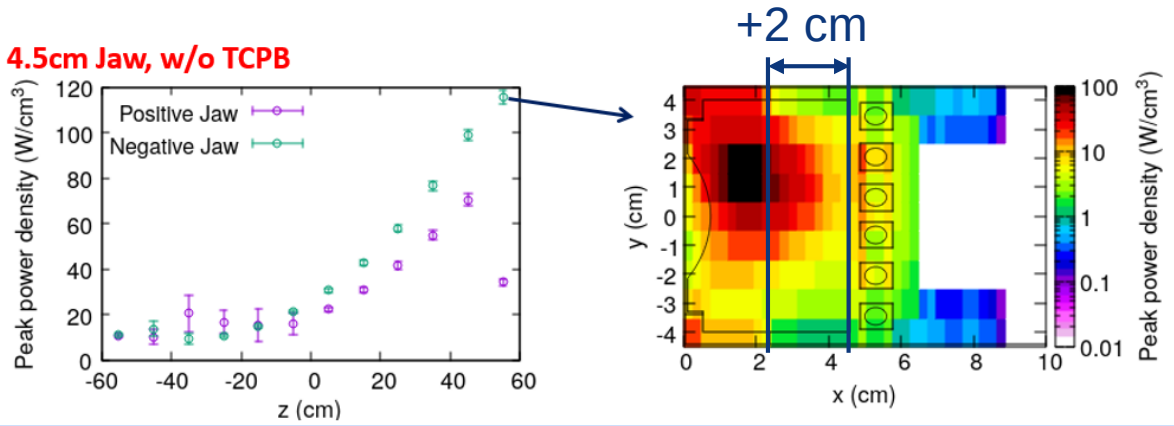
Stiffer structure than the current one (LHC), simulated with **bonded contacts** between **CFC** and **Glidcop** housing

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%▼

Power density on the First Secondary



- TCSG.A6L → **115 Wcm^{-3}**
- TCSG.A5L → 85 Wcm^{-3}
- TCSG.D4L → 30 Wcm^{-3}

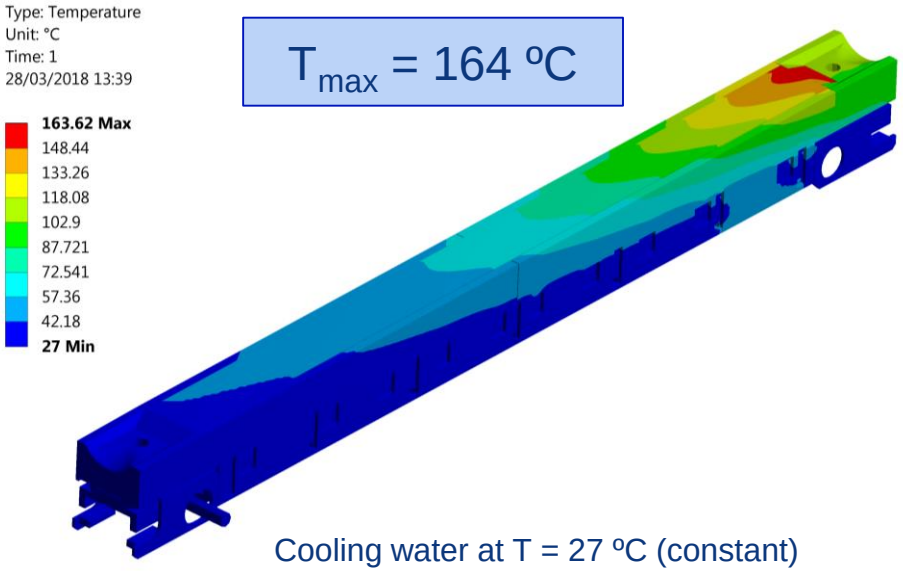
60cmTCP, v-halo, Thicker TCS:

- TCSG.A6L → **130 Wcm^{-3}**

in LHC:

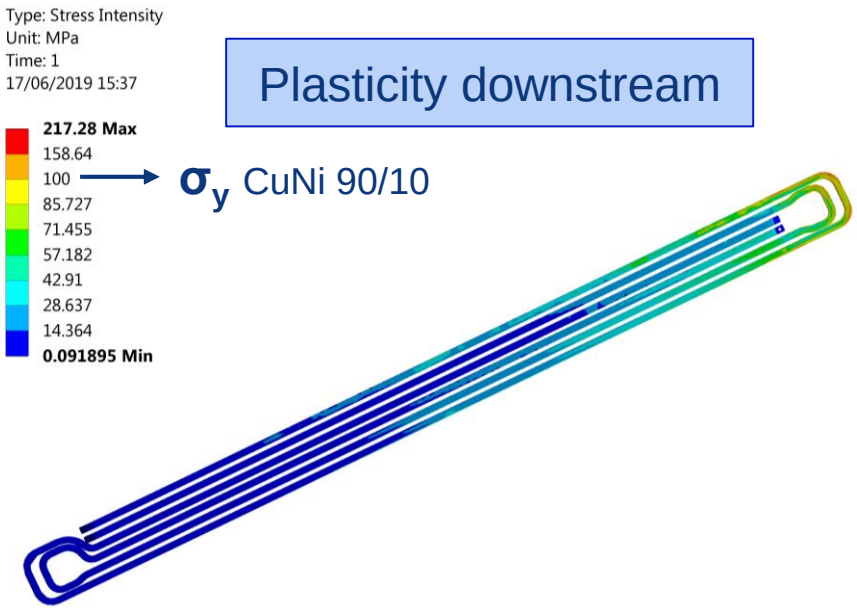
- Secondary → 10 Wcm^{-3}

Results - 1h BLT



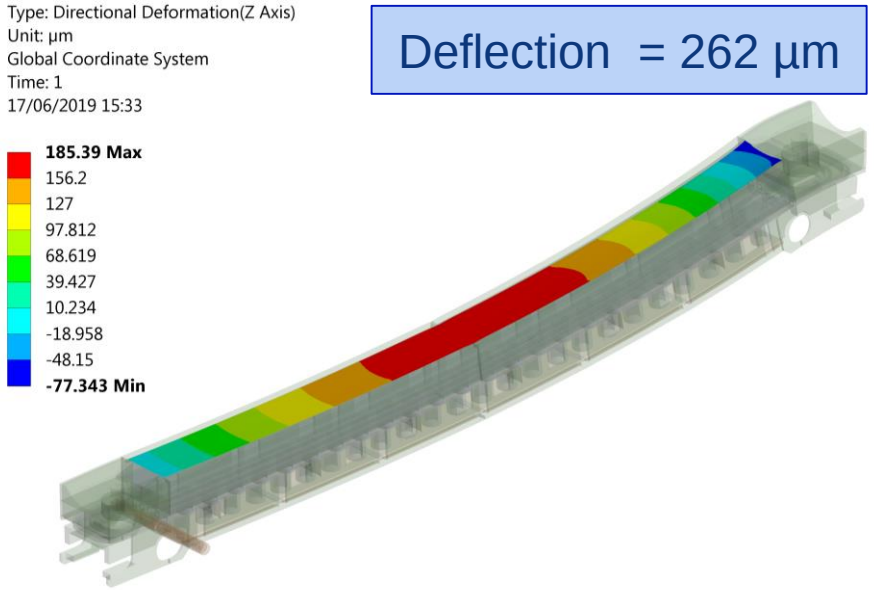
T_{max} = 164 ºC

Cooling water at T = 27 ºC (constant)



Plasticity downstream

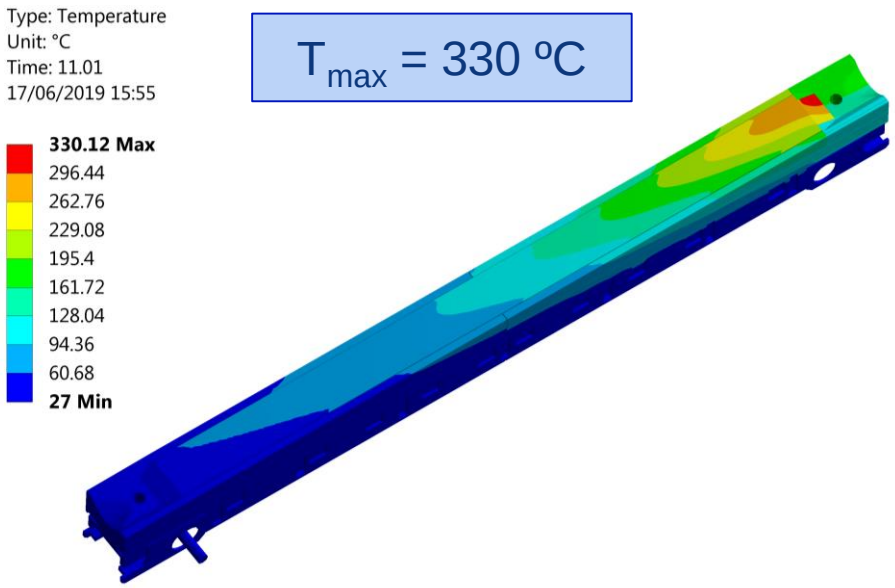
σ_y CuNi 90/10



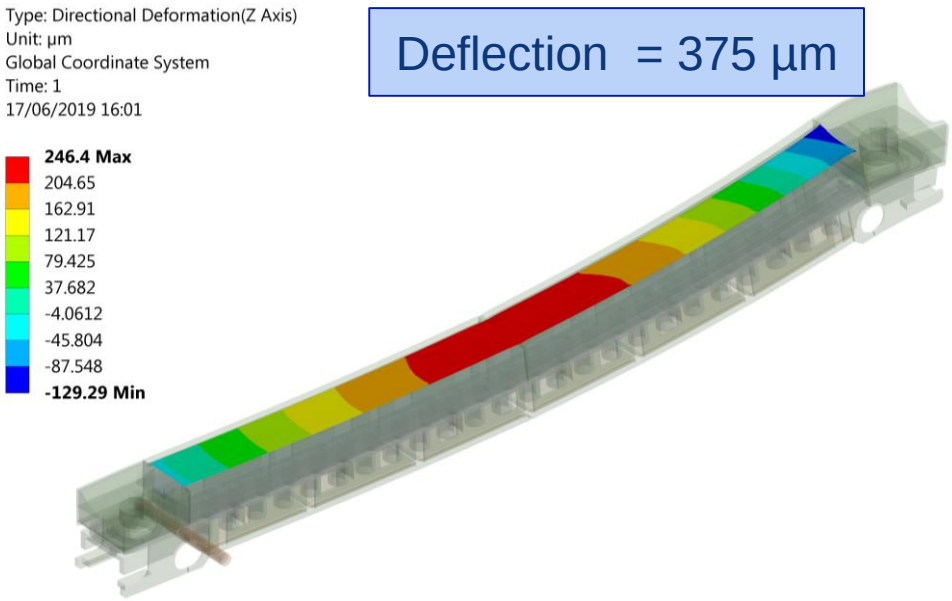
Deflection = 262 µm

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

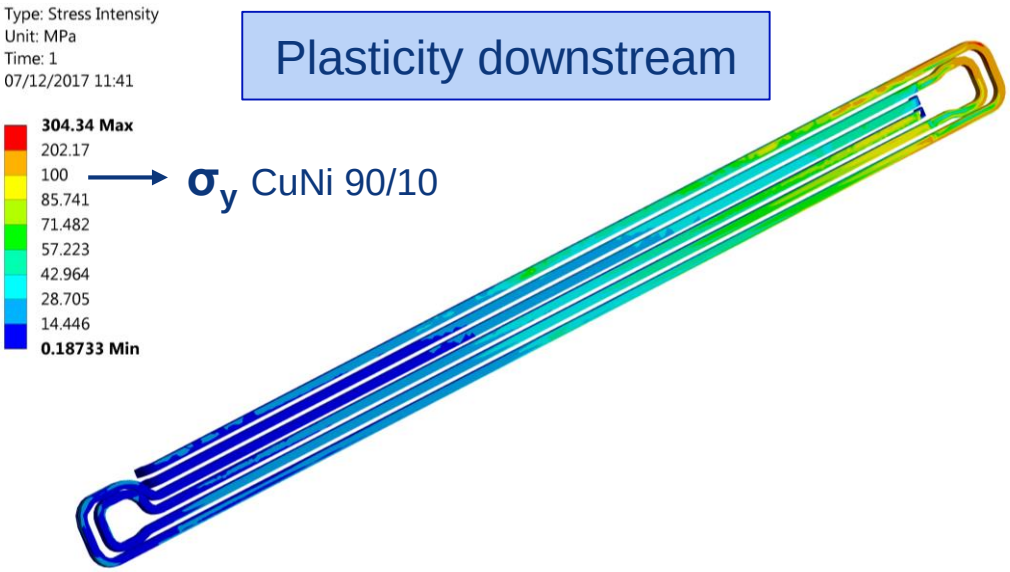
Results - 0.2h BLT



T_{max} = 330 ºC



Deflection = 375 µm



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	
Primaries (kW)				
TCP.D6L	14.7	7.7	6.5	-16% ▼
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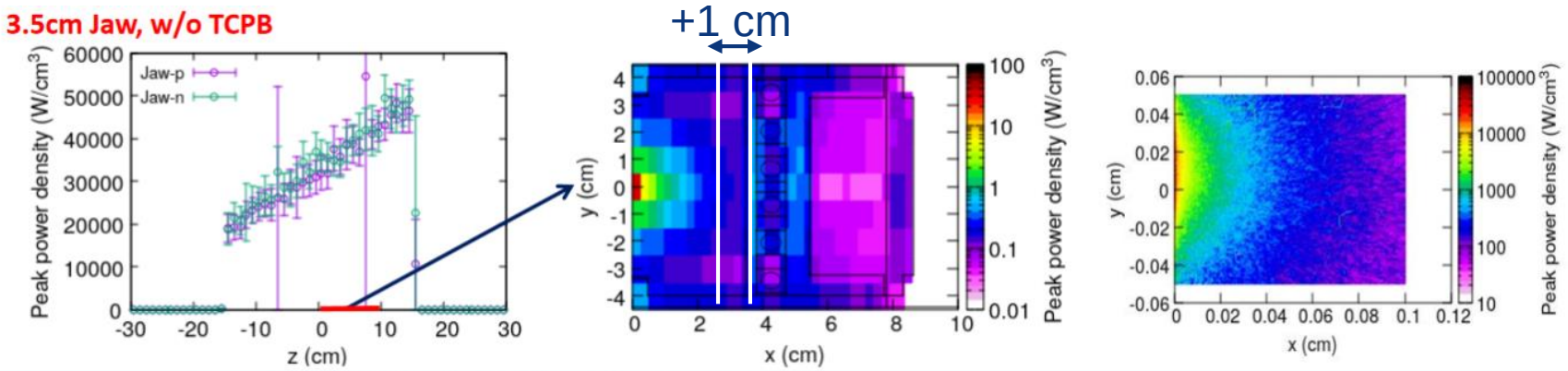
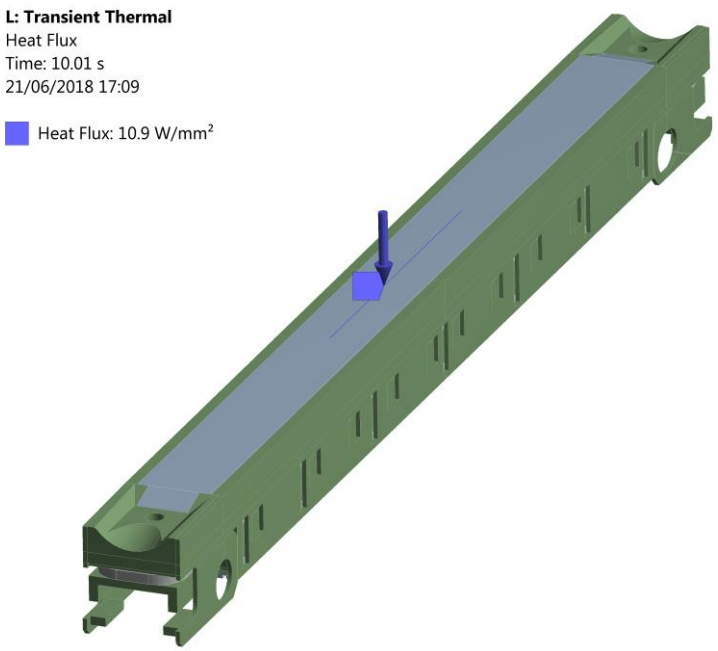
Peak power density on Vertical Primary



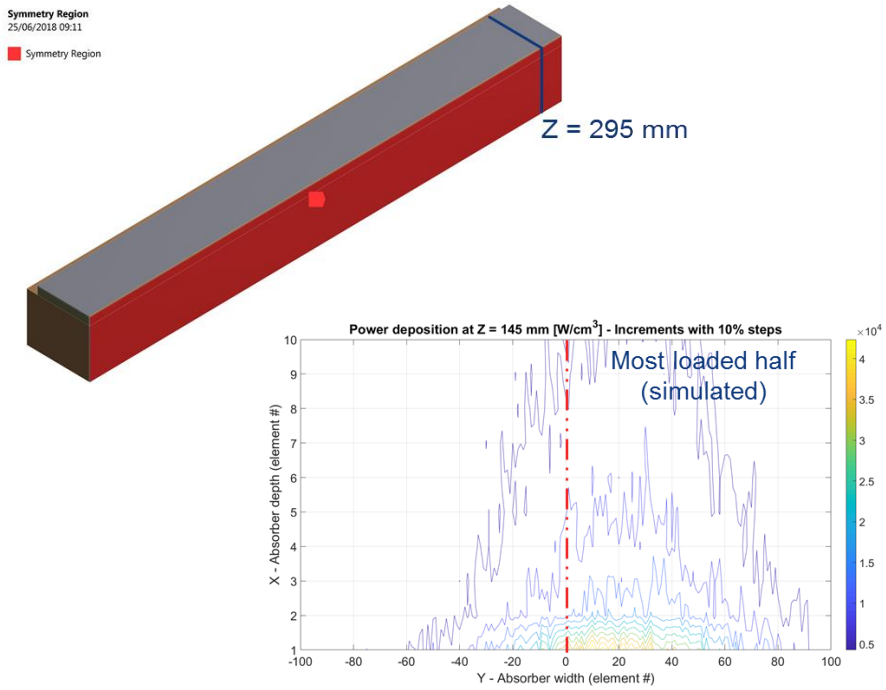
Approach

COLLIMATOR STRUCTURE



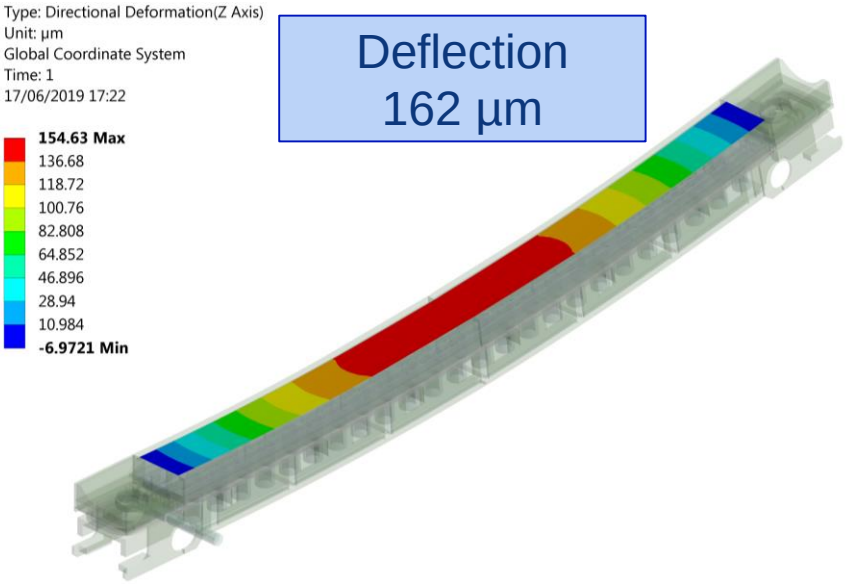
- Surface 300 x 1 mm
- Heat flux equivalent to 3.27 kW (total thermal load on the absorber)
- t = 10 s

CFC ABSORBER

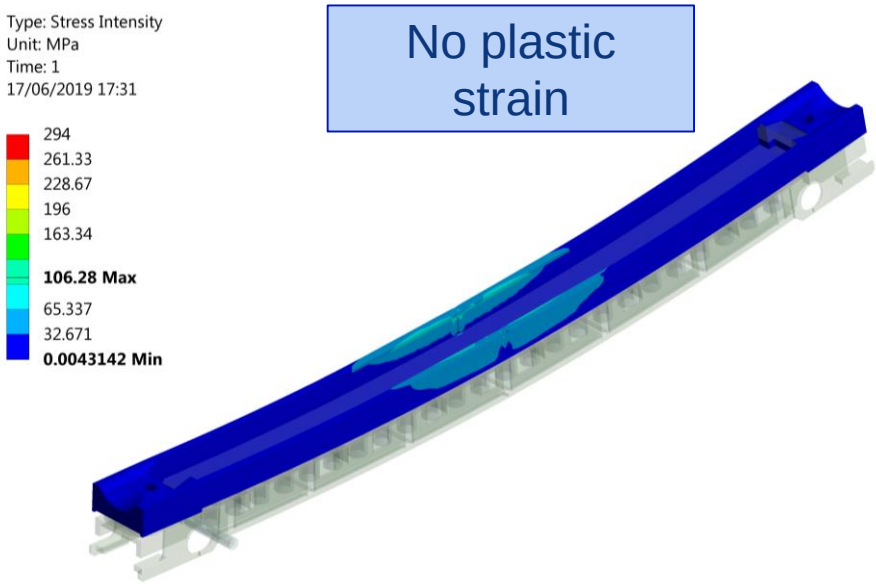


- Half absorber, the most loaded one
- Biased mesh down to 2.5 x 2.5 x 1000 µm
- 44400 W/cm^3 max thermal load

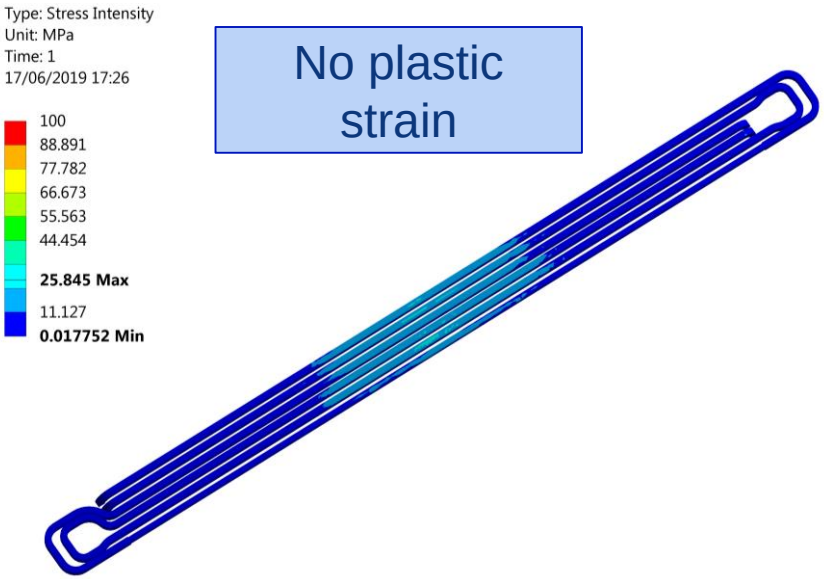
Results – Collimator structure



Deflection 162 µm



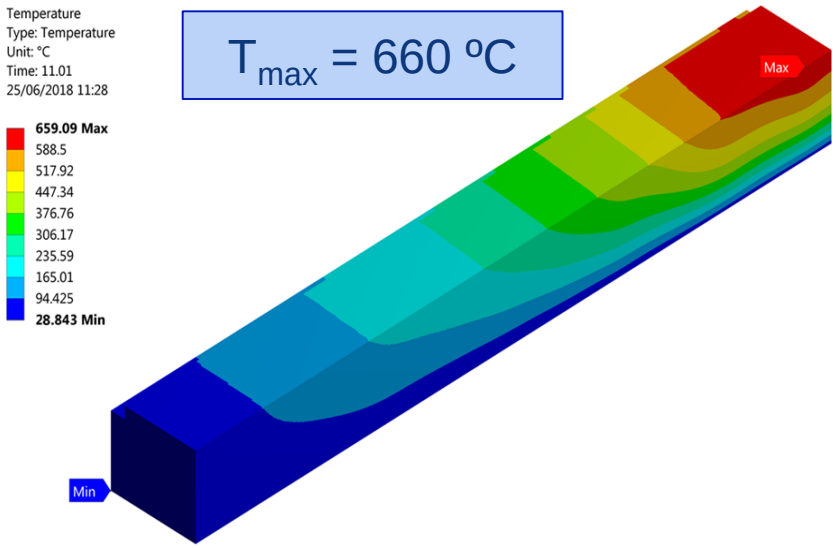
No plastic strain



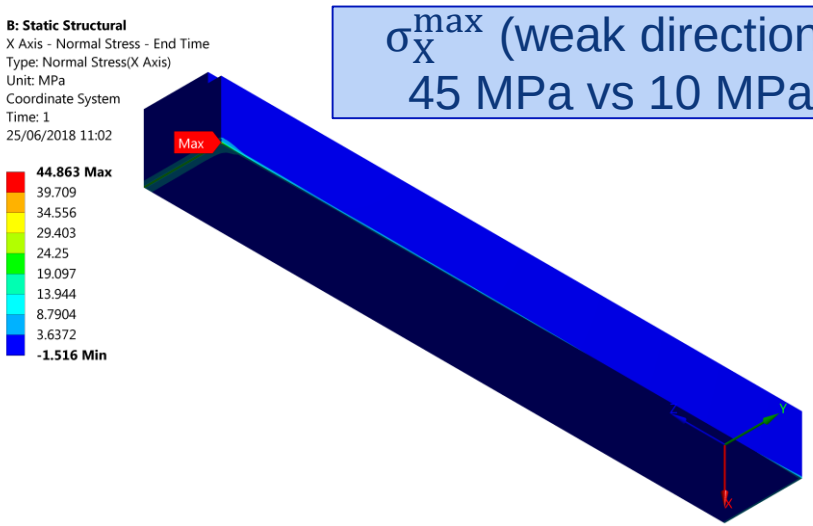
No plastic strain

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

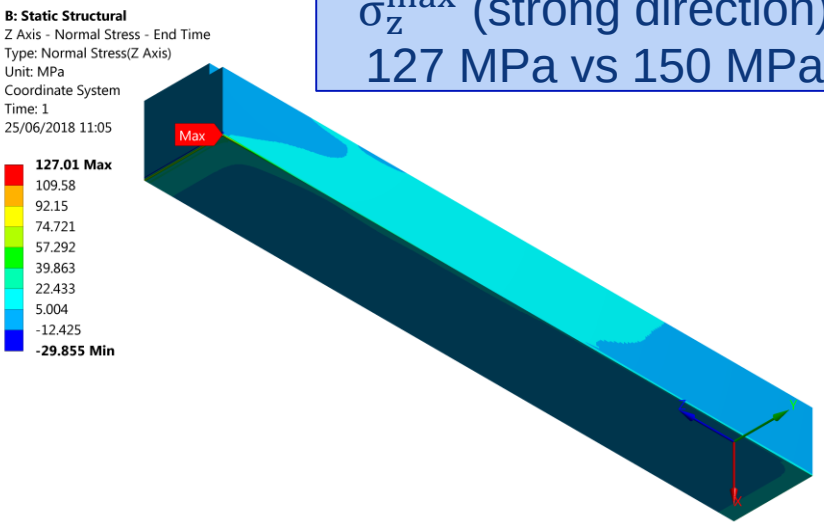
Results - CFC absorber



T_{max} = 660 ºC



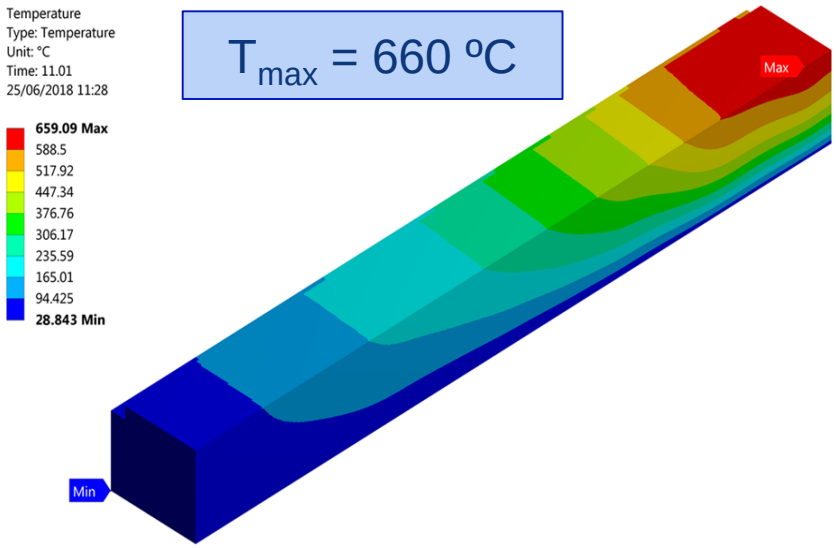
σ_X^{max} (weak direction)
45 MPa vs 10 MPa



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

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

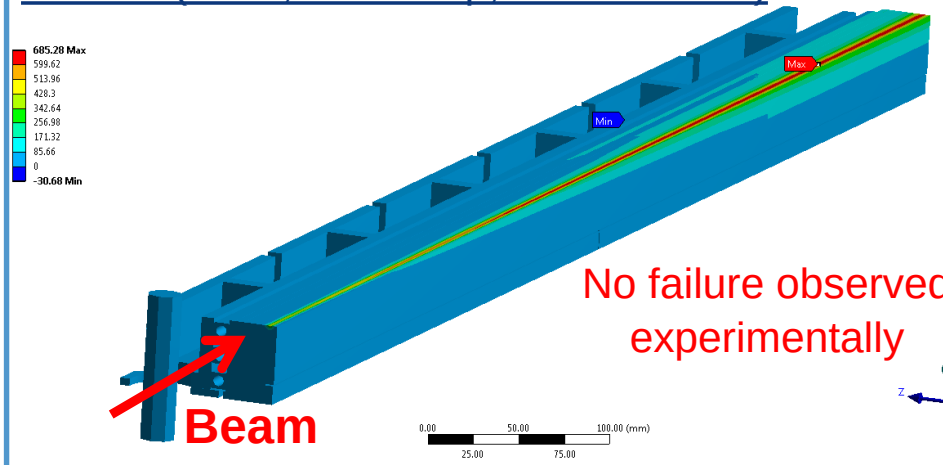
Results - CFC absorber



T_{max} = 660 ºC

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

The HRMT-23 case: max simulated T on CFC jaw: **685 ˚C** (288b, 3.79E13p, σ = 0.35 mm)

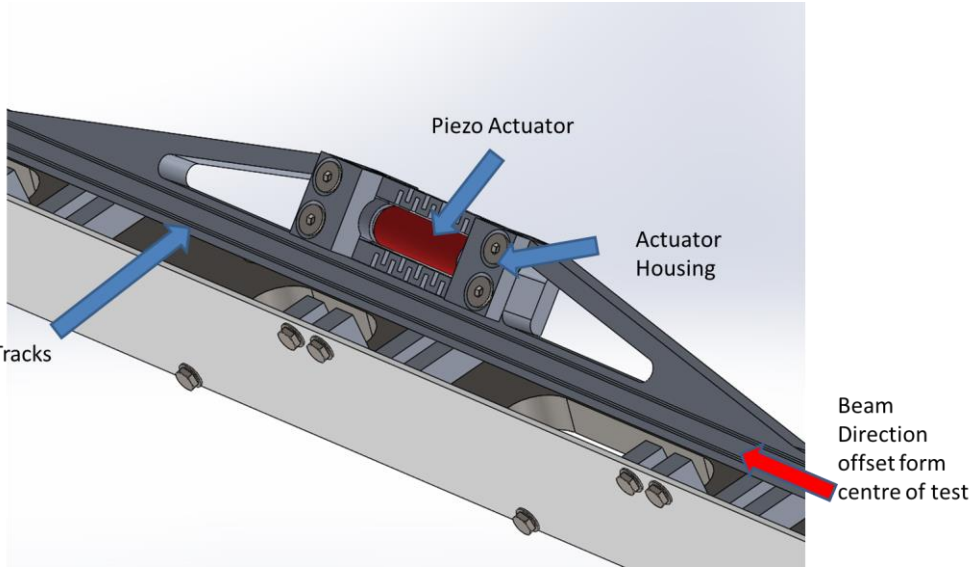


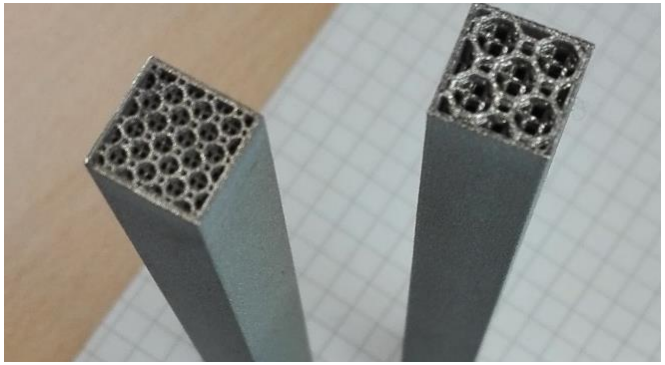
The HRMT-36 case: **>1500 ˚C** (grazing shot at 288b, 3.72E13p, σ = 0.25 mm) →No failure observed

Conclusions

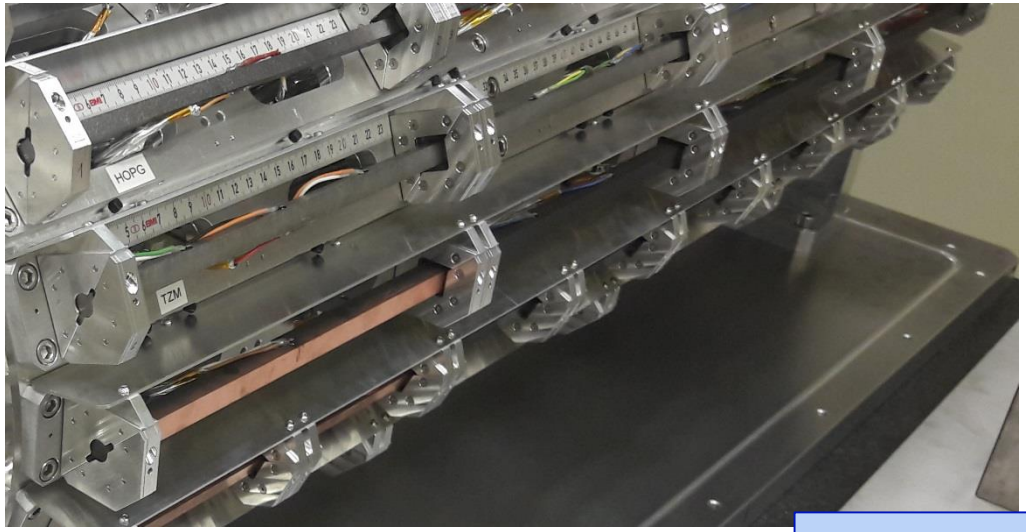
- Thermo-structural studies of **most loaded primary** (TCP) and **secondary** (TCS) collimators of the FCC performed for **1h** and **0.2h BLT**
- Stiff structure considered for the conceptual design→ **bonded assembly**
- **Highest** value of jaw **deflection** for the most loaded **secondary** collimator, **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 ?

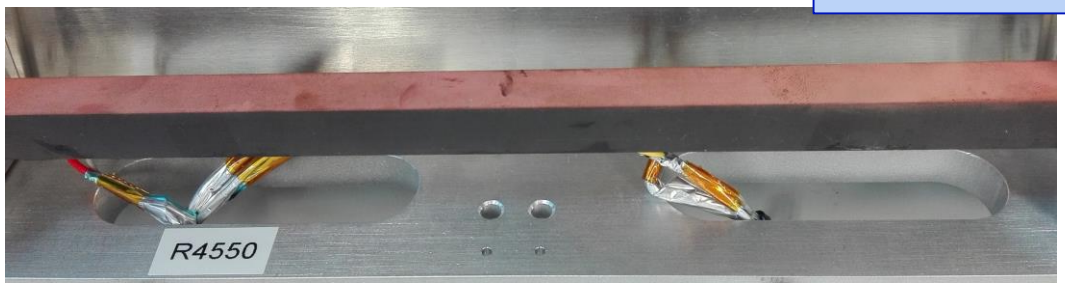

Piezo Actuator
Actuator Housing
Fibre Tracks
Beam Direction offset form centre of test



What's next

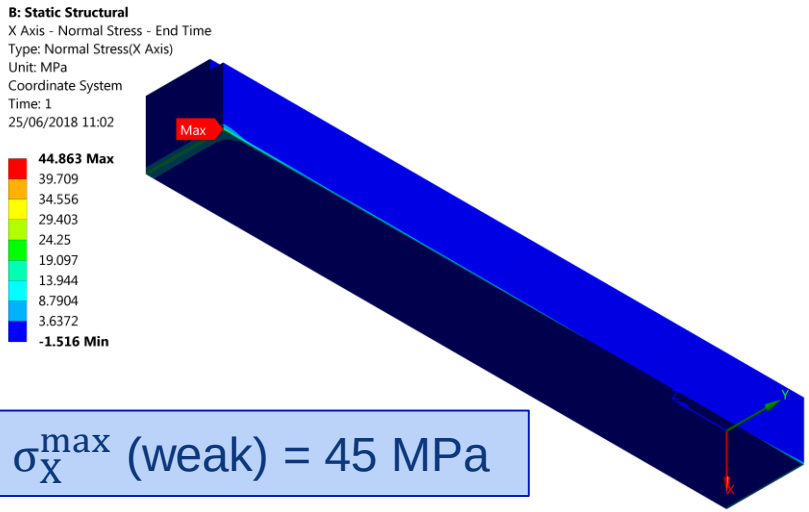


HRMT-36
MultiMat

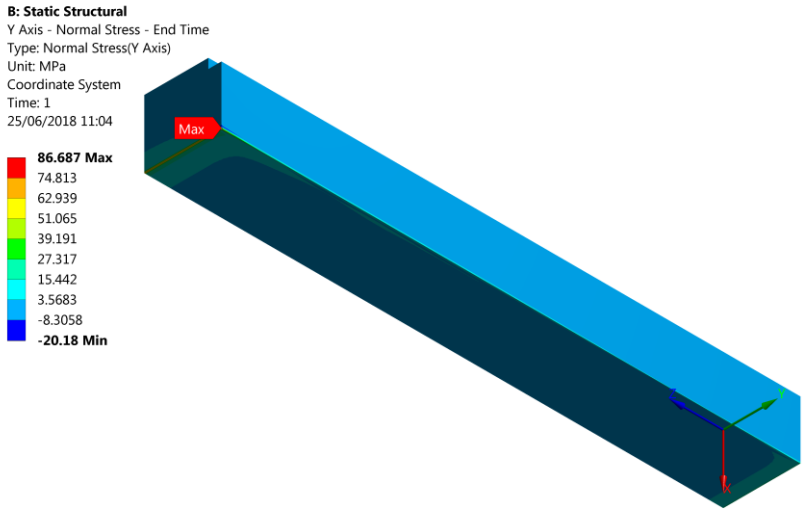


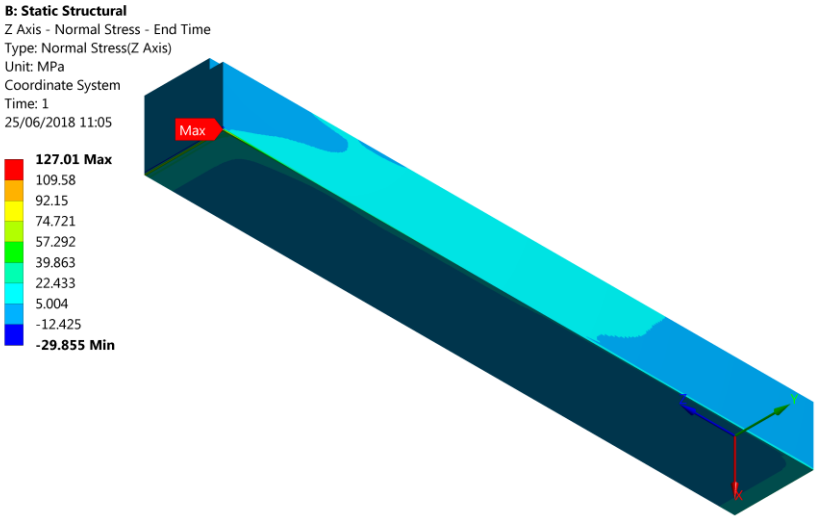
Thanks for your attention

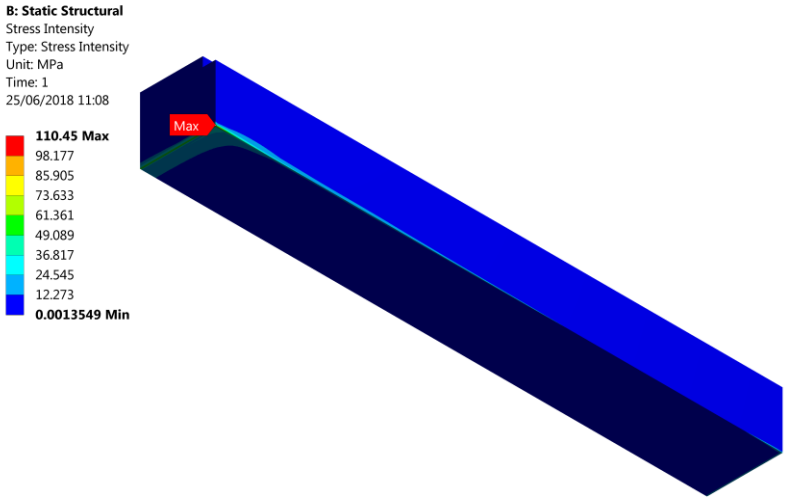
Results - CFC absorber



σ_X^{max} (weak) = 45 MPa







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)*
Most loaded jaw	2	5	8.9	10	25	44.5
Absorber of most loaded jaw	0.4	1.1	4	2	5.5	20
Total on collimator	**4.5**	**12.6**	**20.7**	**22.5**	**63**	**103.5**