# LHC Collimators

## Conceptual Mechanical Design

Test Case #1 - *Preliminary results*

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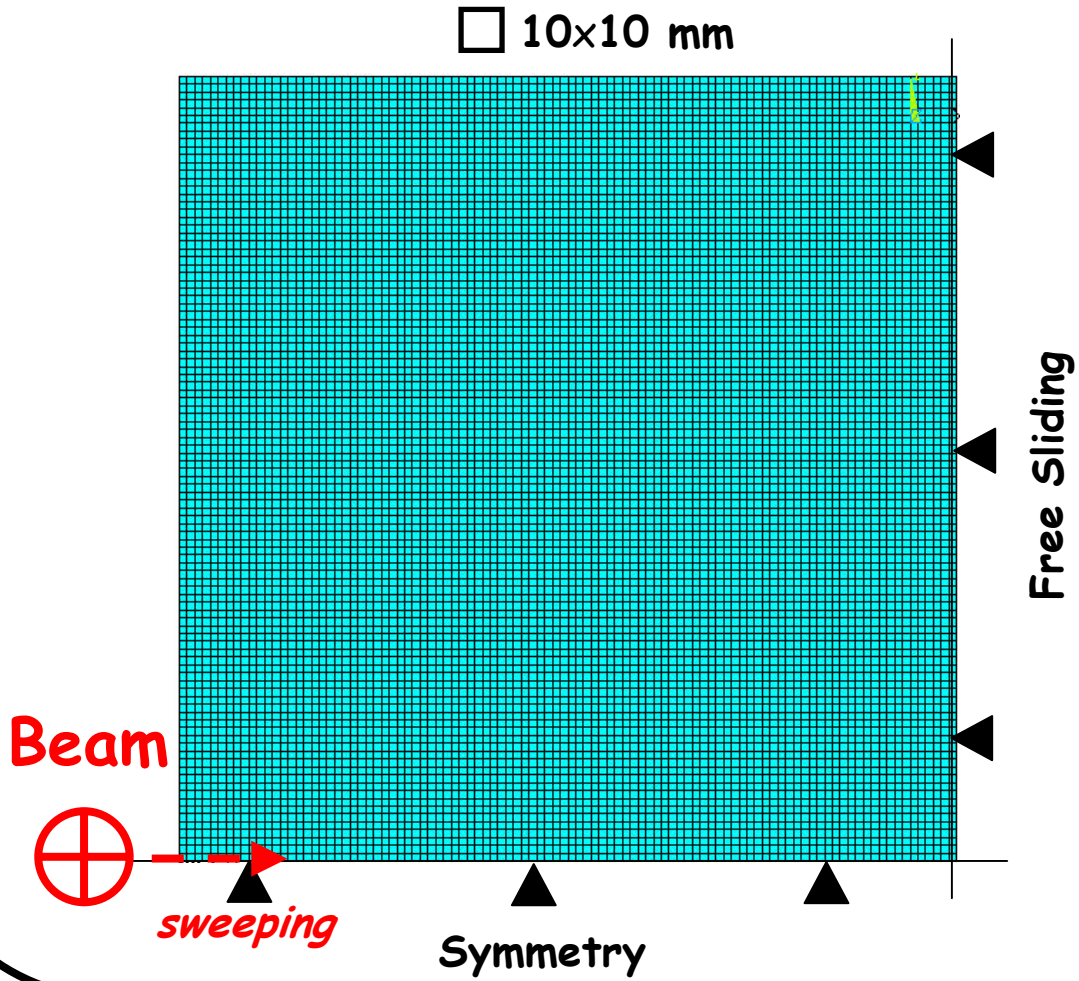
Target & Dumps Section

# Test Study #1 - Finite Element Model




**2D MESH**

$10^4$ parabolic elements

3 $10^4$ nodes

0.1×0.1 mm mesh size

**MATERIAL**

Graphite "standard"

Homogeneous isotropic

Elastic linear law

Small deformations

# Test Study #1 - Out-of-plane Boundary Conditions

1. Plane stress
2. Generalized Plane Strain with bending
3. Generalized Plane Strain without bending
4. Plane strain

Less conservative
(stress underestimate)

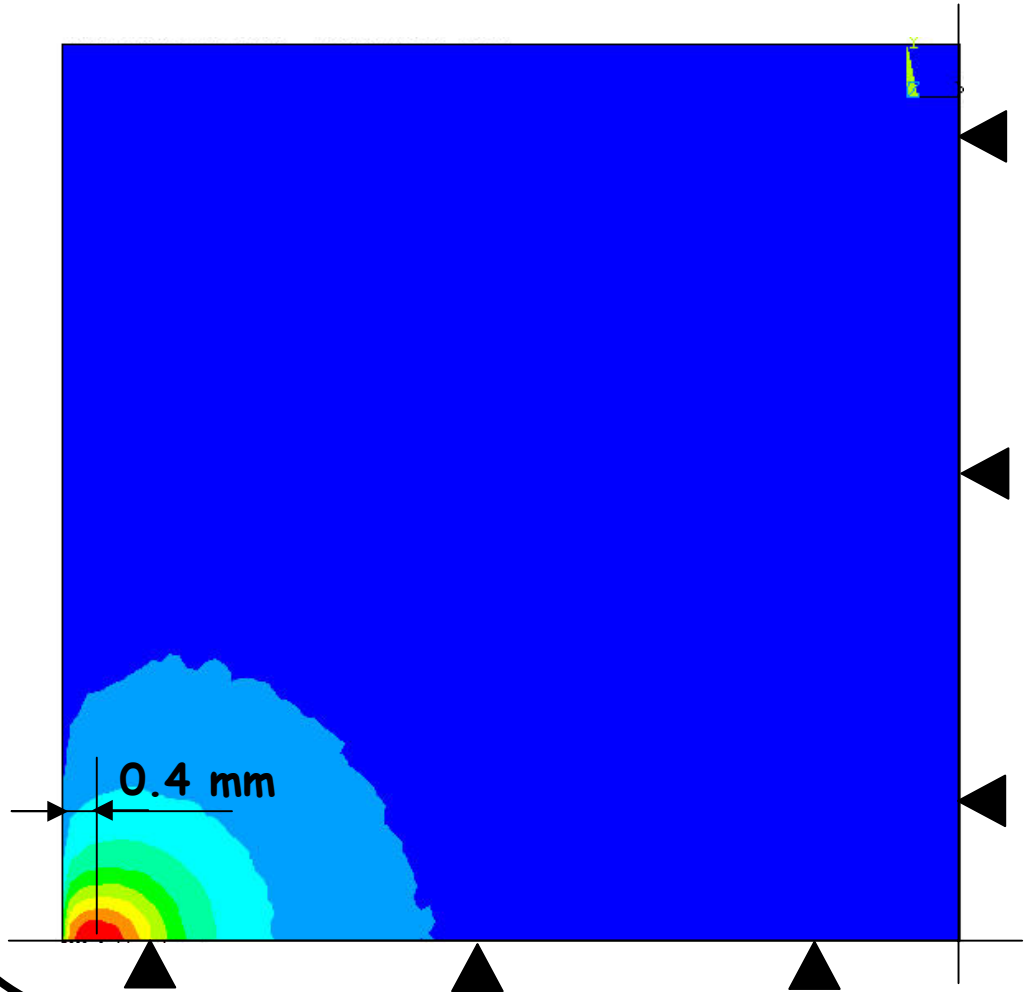
More conservative
(stress overestimate)

# Test Study #1 - Stress field studied (Analysis type )

1. Static stress
2. Dynamic stress
3. Initial stress
4. Eigenstress

Less conservative
(stress underestimate)

# Test Study #1 - Beam Heat Load

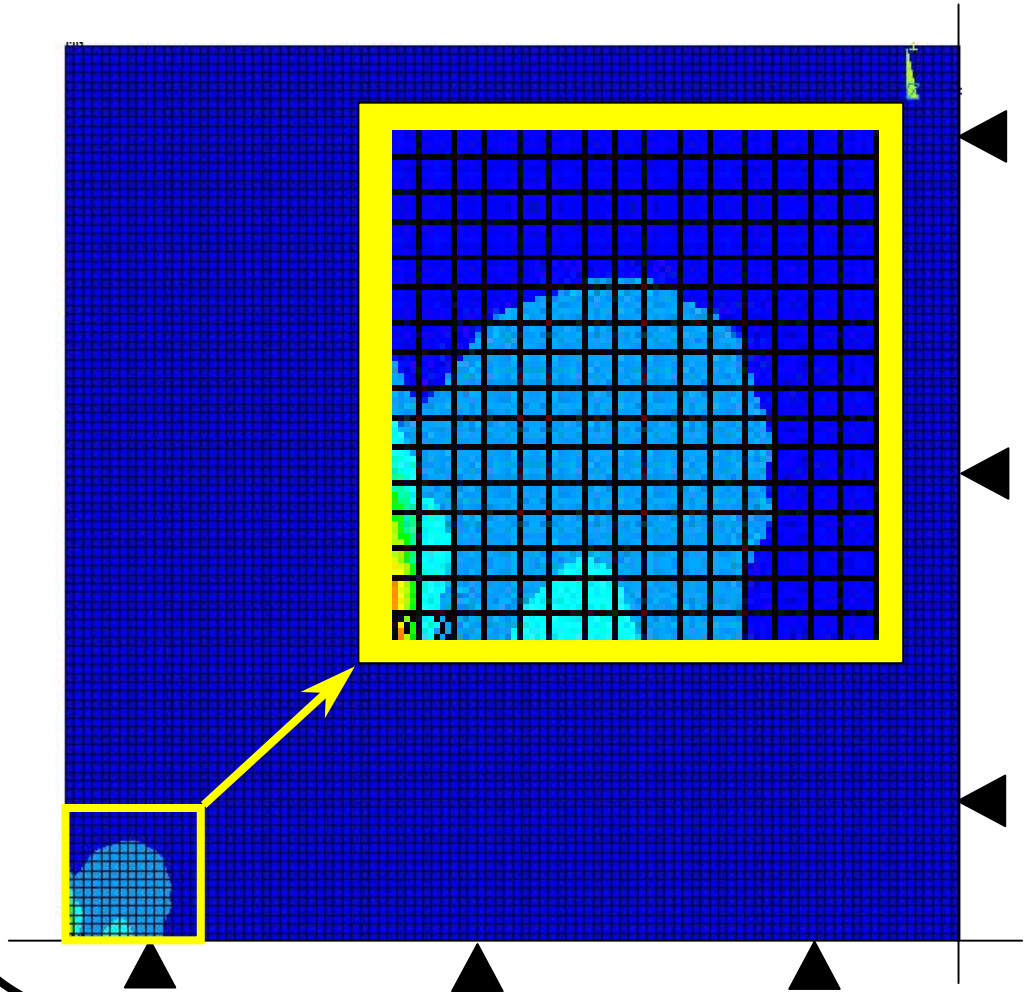



Absolute Temp. [°C]
Graphite jaw
Z = 1400 mm
2 $10^{12}$ protons

20
186.407
352.814
519.221
685.628
852.035
1018
1185
1351
1518

$T_{max}$

# Test Study #1 - Von Mises Stress



$\sigma_{VM}$ [Pa]

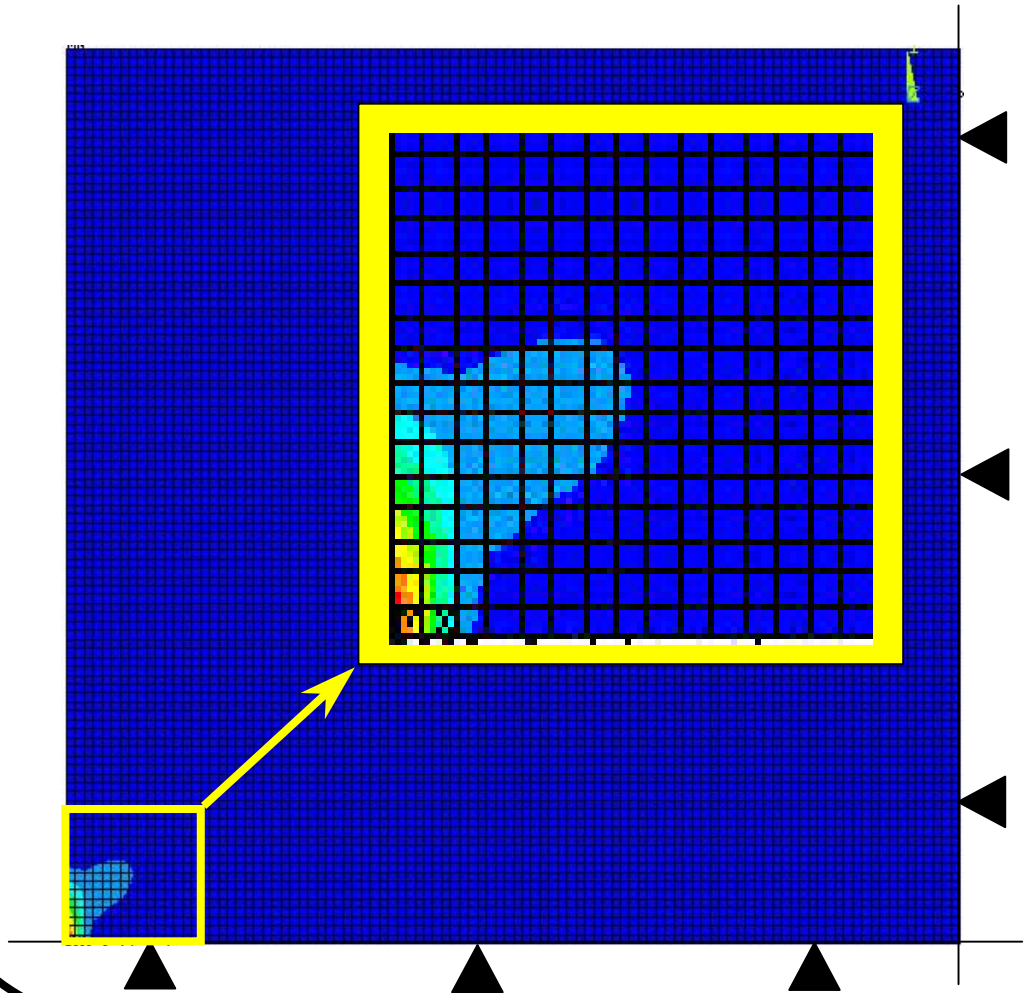
740.841
.709E+07
.142E+08
.213E+08
.284E+08
.355E+08
.426E+08
.497E+08
.567E+08
.638E+08

**For reference:**

**Allowable: 18 Mpa**

**Safety factor 2/3**

# Test Study #1 - Stassi Stress



$\sigma_s$ [Pa]

| |
|---|
| .002205 |
| 4.328 |
| 8.653 |
| 12.979 |
| 17.305 |
| 21.63 |
| 25.956 |
| 30.281 |
| 34.607 |
| 38.932 |

**For reference:**

**Allowable: 18 Mpa**

**Safety factor 2/3**

# *Test Study #1 - Further work*

*What is still to be done ?*

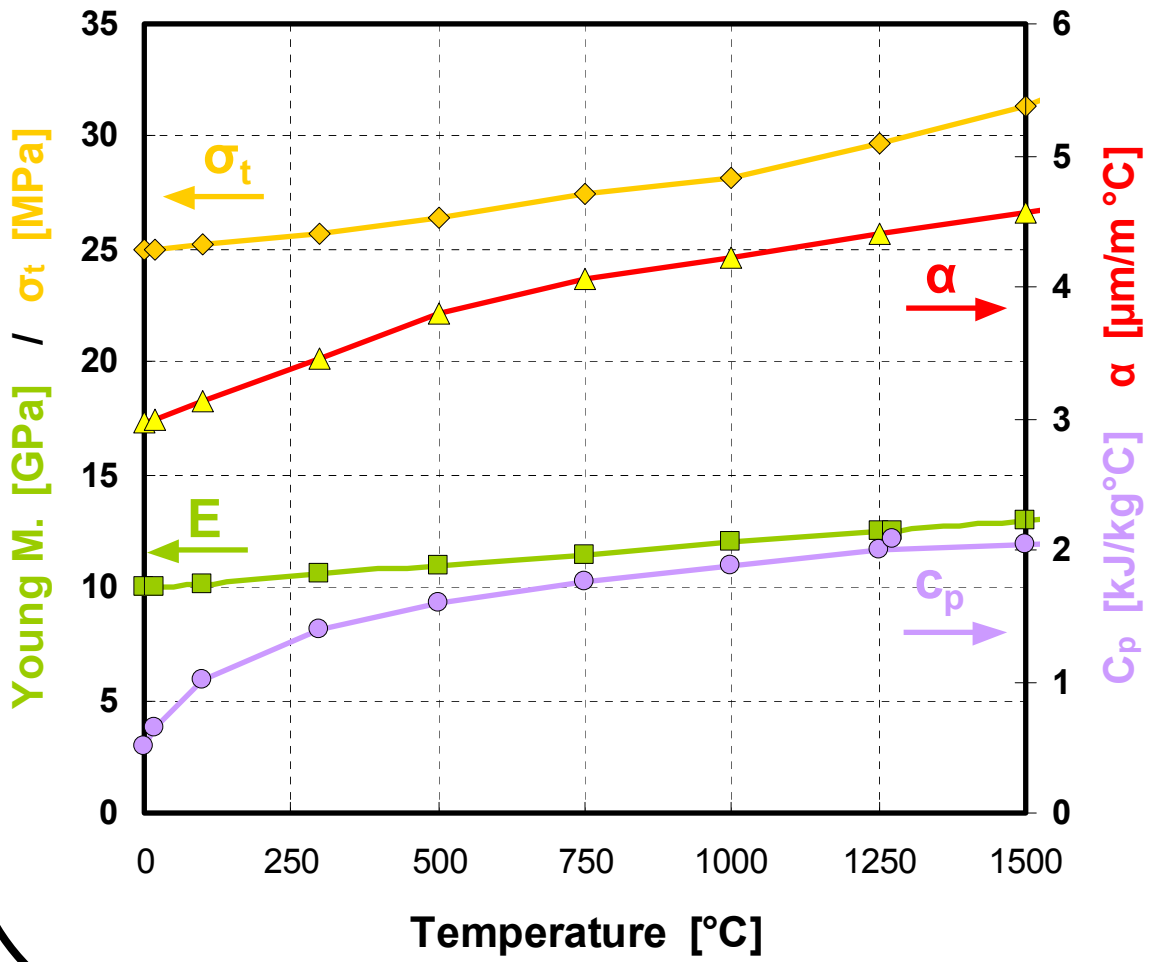
- **Check sensitivity to model and mesh size;**
- **Study stress components;**
- **Compare boundary conditions;**
- **Investigate load at different cross-sections;**
- **Perform dynamic analysis ;**
- **Choose material models.**

# Material Choice

| Graphites and hBN - Material Properties at 20 °C | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Property** | **Unit** | **Carbone-Lorraine** | | | **SGL** | | | | **POCO** | **h-BN** |
| | | 1940 | 2020 | 2333 | R7500 | CZ3 | CZ5 | CZ7 | ZXF-5Q | AX05 |
| Apparent Density | g $cm^{-3}$ | 1.76 | 1.77 | 1.86 | 1.77 | 1.73 | 1.84 | 1.88 | 1.78 | 1.91 |
| Open Porosity | % | 16 | 9 | 10 | 13 | 14 | 10 | 10 | 16 | |
| Avg. Grain size | µm | 12 | 16 | 5 | 10 | 20 | 10 | 3 | 1 | |
| Young Modulus | Gpa | 10 | 9.2 | 10 | 10.5 | 10 | 11.5 | 14 | 14.5 | 30 |
| Thermal exp. Coeff. | µm/m °C | 4.7 | 3.5 | 6 | 3.9 | 3.8 | 5.1 | 5.8 | 8.1 | 0.5 |
| Thermal Conductivity | W/m°C | 81 | 75 | 90 | 80 | 65 | 100 | 100 | | 71/121 |
| Electrical resistivity | µΩ m | | 16.5 | | 14 | 18 | 13 | 13 | 19.5 | > $10^{14}$ |
| Specific heat | J/kg °C | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 800 |
| Flexural strength | MPa | 45 | 41 | 76 | 50 | 40 | 60 | 85 | 115 | 22 |
| Compressive Strength | MPa | 91 | 100 | 167 | 120 | 90 | 125 | 240 | 195 | 23 |
| Tensile strength | MPa | 30 | 27 | 50 | 33 | 26 | 40 | 56 | 76 | 15 |
| | | | | | | | | | | |
| Ratio $\sigma_c/\sigma_t$ | - | 3.1 | 3.7 | 3.3 | 3.6 | 3.4 | 3.2 | 4.3 | 2.6 | 1.5 |
| K ~ $(\sigma_t C_p)/(E \alpha)$ | - | 0.45 | 0.60 | 0.59 | 0.57 | 0.49 | 0.48 | 0.49 | 0.46 | 0.80 |

**A wide range of materials is nowaday available. The table shows a selection of graphite grades as compared to hexagonal boron nitride.**

# Graphite Properties




**Thermo-mechanical Efficiency**

$$K \propto \frac{\sigma_t \, c_{p,avg}}{E \, \alpha}$$

The change of properties with temperature is to be considered in the comparison between the different materials.