Traineeship activities for Radiation effect on Materials in Space and Vibration tests for Terzina space experiment

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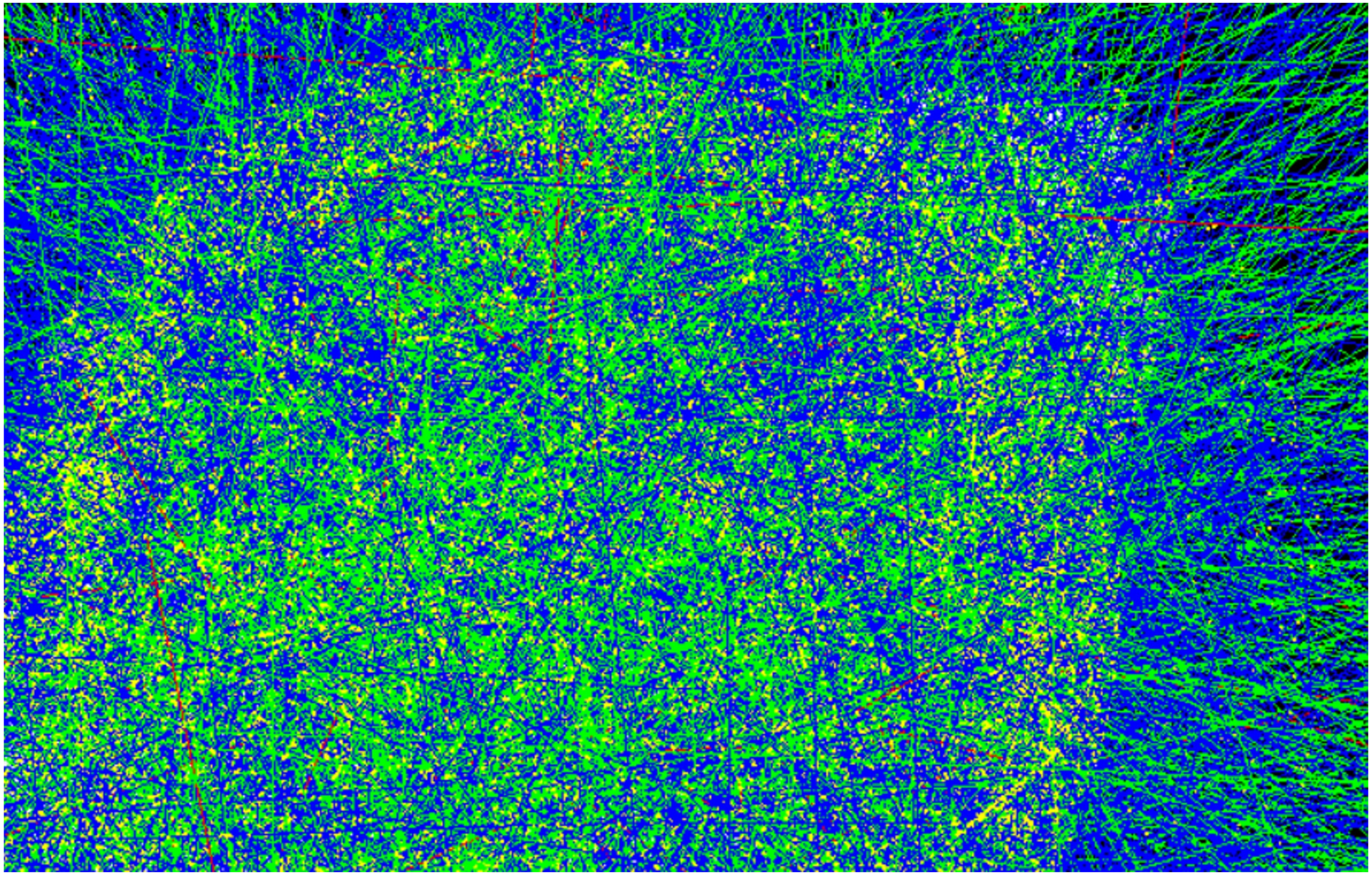
Simulation on Geant4



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June – August 2023

Introduction and purpose of the study

Today, we want to go further into space but one of the major setbacks is the deadly amount of ra

In this study, we will work on Geant4, a software to make radiation simulation.

Aim of the study :
Know if there is a link between the precision of the model (number of solid angles) and the accu
Later, the second aim will be to compare this result with the one obtained with another model wh

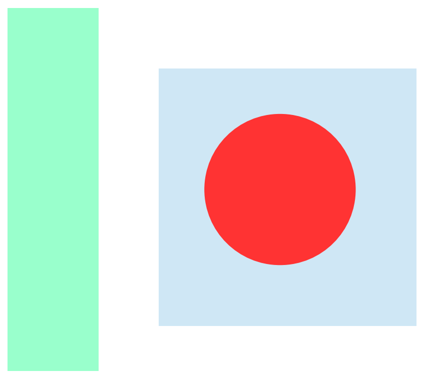
First step → define the geometry and the particule to be shot

→ generate a text file with the materials crossed by each particule and the coo

```
Position (0,0,0) Material G4_C
Position (0,10,10) Material G4_Ar
Position (0,21.2132,21.2132) Material G4_WATER
Position (0,100,100) Material G4_AIR
Position (0,0,0) Material G4_C
Position (0,-10,0) Material G4_Ar
Position (0,-30,0) Material G4_WATER
Position (0,-100,0) Material G4_AIR
Position (0,0,0) Material G4_C
Position (0,0,-10) Material G4_Ar
Position (0,0,-30) Material G4_WATER
Position (0,0,-150) Material G4_AIR
Position (0,0,0) Material G4_C
Position (10,0,-10) Material G4_Ar
Position (21.2132,0,-21.2132) Material G4_WATER
Position (35,0,-35) Material G4_A-150_TISSUE
Position (55,0,-55) Material G4_WATER
Position (100,0,-100) Material G4_AIR
Position (0,0,0) Material G4_C
Position (-10,0,0) Material G4_Ar
Position (-30,0,0) Material G4_WATER
Position (-100,0,0) Material G4_AIR
Position (0,0,0) Material G4_C
Position (0,0,10) Material G4_Ar
Position (0,0,30) Material G4_WATER
Position (0,0,150) Material G4_AIR
Position (0,0,0) Material G4_C
Position (-10,-10,0) Material G4_Ar
Position (-21.2132,-21.2132,0) Material G4_WATER
Position (-100,-100,0) Material G4_AIR
Position (0,0,0) Material G4_C
Position (0,10,0) Material G4_Ar
Position (0,30,0) Material G4_WATER
Position (0,100,0) Material G4_AIR
Position (0,0,0) Material G4_C
Position (10,0,0) Material G4_Ar
Position (30,0,0) Material G4_WATER
Position (35,0,0) Material G4_A-150_TISSUE
Position (55,0,0) Material G4_WATER
Position (100,0,0) Material G4_AIR
```

Text file obtained for 9 geantinos shot from the center of the sphere

Second step → write a python script to find the number o



Geometry for the first study

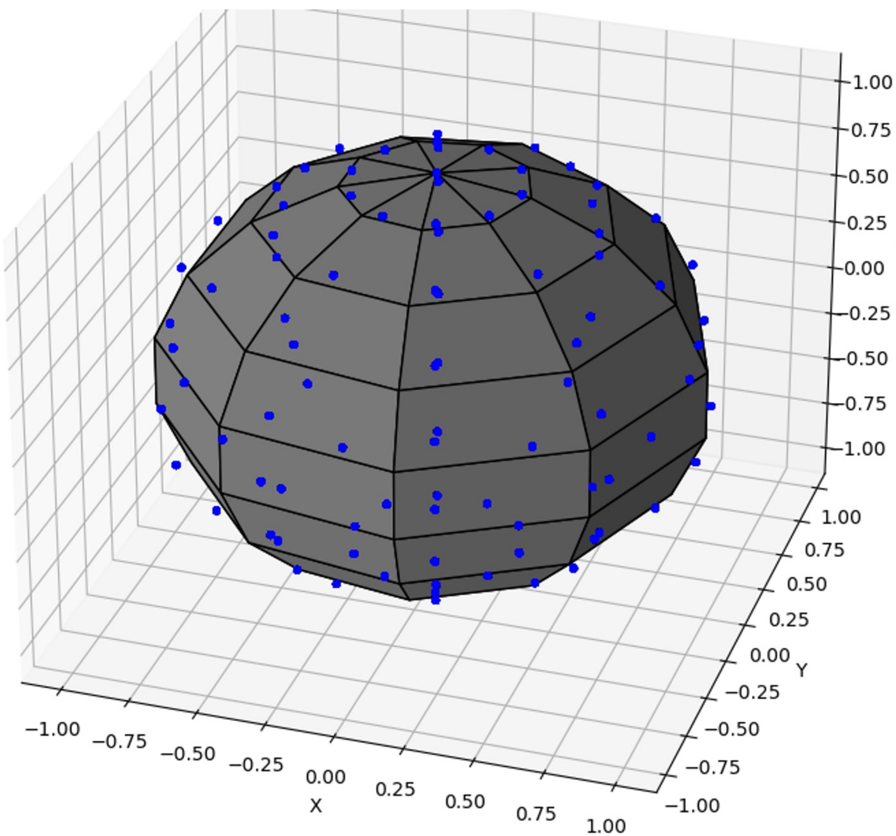
Third step : write a python file

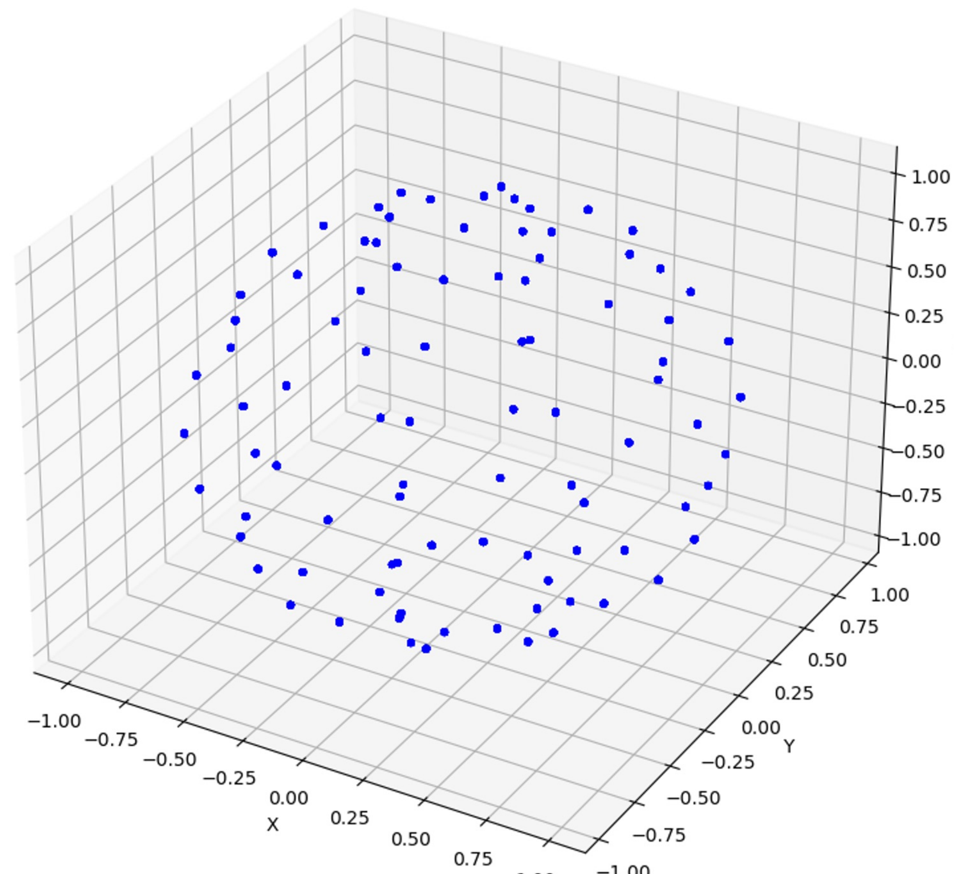
→ Create a 100 solid angles, we divide φ = [0, 2π] and θ = [0, π] in ten and put the values in a ta

→ Create the 100 points (table2) with a φ and θ value from the table and a radius value fixed

→ Convert this spherical coordinates into carthesian coordinates

→ Plot to see if the points are correctly placed





→ Obtain the point in the middle of the square made by four points (table2).
Define the middle point of each square area defined by four points of the table 2. In order to do t

→ Obtain a text file with the carthesian coordinates of the point in the table 3 using these formula

$$\begin{cases} x &= \rho \sin\theta \cos\varphi \\ y &= \rho \sin\theta \sin\varphi \\ z &= \rho \cos\theta \end{cases}$$

, where ρ is the radius

Each point is going to be a direction to shoot a geantino later in the study.

→ Write the GDML file to define the 100 solid angles which is a part on a sphere define with a

```
    <sphere name="SolidAngle0" rmin="200" rmax="233.63129629629628" startphi="0.0" deltaphi="0.06283185307179587" starttheta="0.0" deltatheta="
    0.031415926535897934" aunit="rad" lunit="mm"/>
<sphere name="SolidAngle1" rmin="200" rmax="233.63129629629628" startphi="0.06283185307179587" deltaphi="0.06283185307179587" starttheta="0.0"
deltatheta="0.031415926535897934" aunit="rad" lunit="mm"/>
<sphere name="SolidAngle2" rmin="200" rmax="233.63129629629628" startphi="0.12566370614359174" deltaphi="0.06283185307179587" starttheta="0.0"
deltatheta="0.031415926535897934" aunit="rad" lunit="mm"/>
```

Fifth step : creating the GDML file for testing the shielding distribution

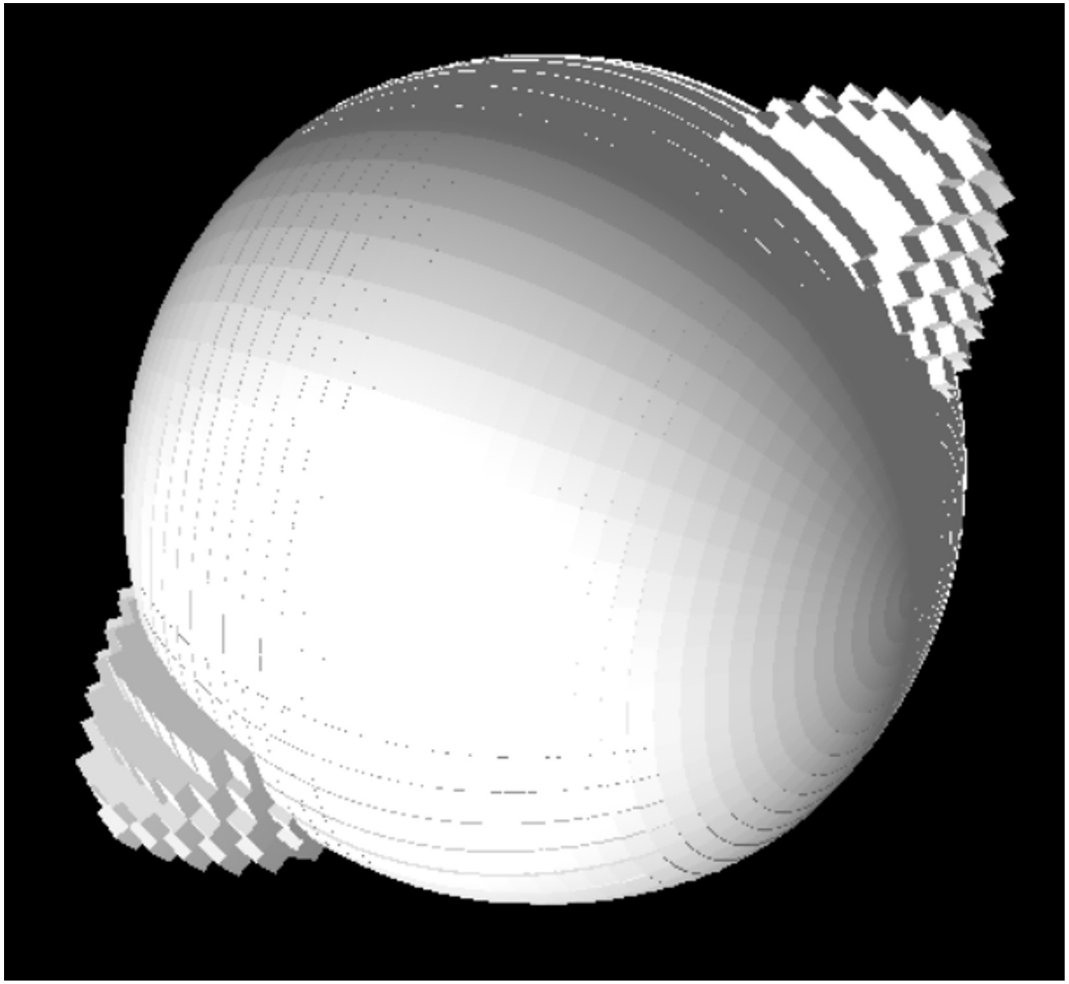
→ retrieve the text file with every value of shielding and normalize the values

→ generate another GDML file like the first one except for the thickness of the sphere that is repl

→ we add a small detector in the center of the sphere

→ we change the way particule are shot, we define a sphere a little larger than the the larger sec

→ we collect the amount of radiation received

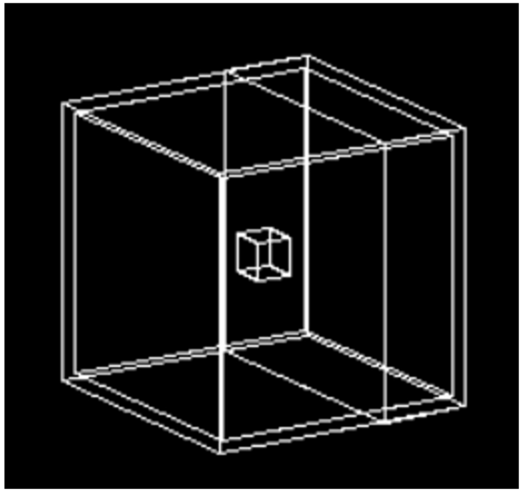


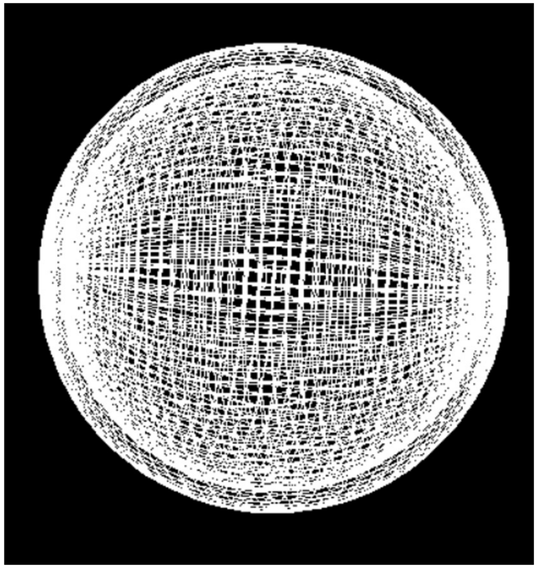
We now do all the process again from the third step but we change the factor by which we devic

number of points	amount of radiation (nanoGy)	difference to the model
100	33,6635	0,2510871106
2500	33,771	0,2518889245
4900	33,8809	0,2527086395
7396	33,7056	0,2514011233
10000	34,1321	0,2545822736
model value	134,071	

We can see that increasing the number of solid angles doesn't make the value more accurate
Also, we can see that the values we obtain equal a quarter of the model value.

Finally, we want to test if we obtain the same kind of trend with another geometry, espacially one





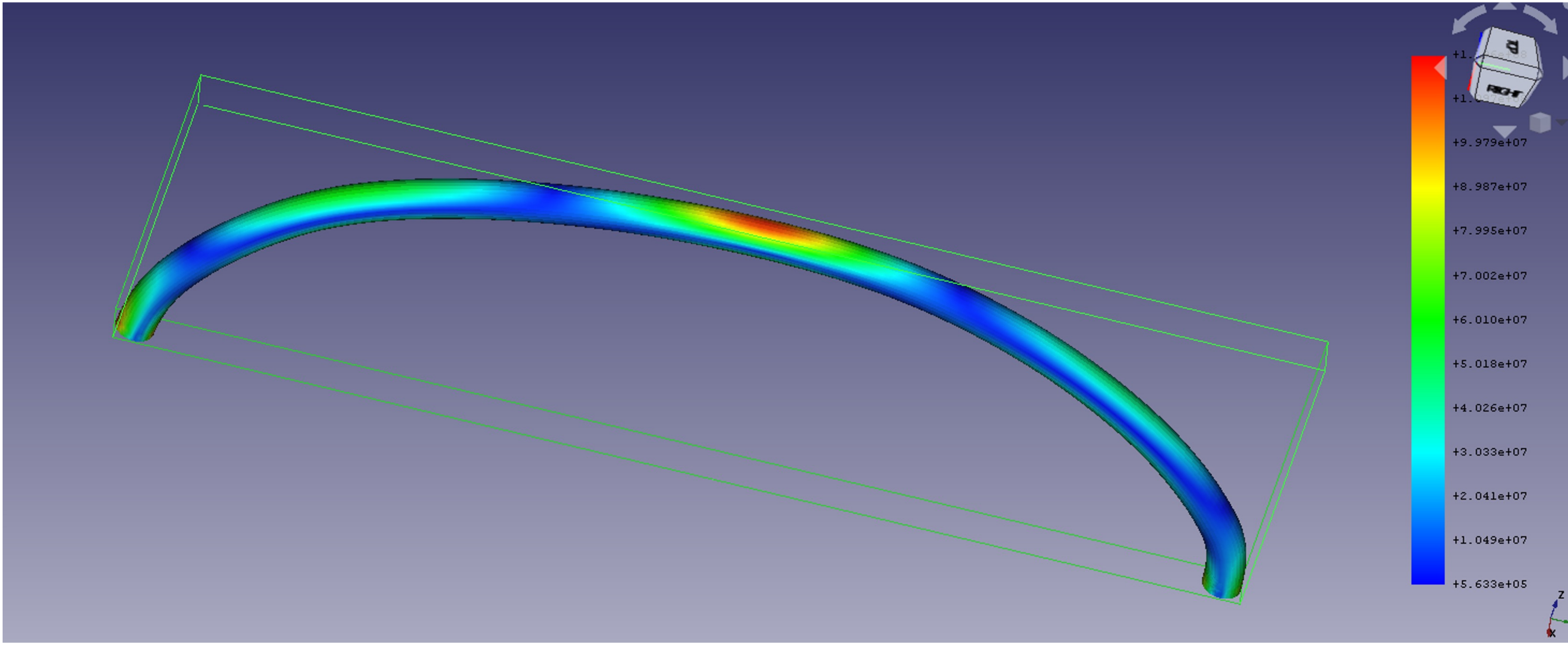
This time we obtain these results :

Nb points	dose (en nanoGy)	difference to the model
100		
2500	47,4358	0,3870003998
4900	47,0363	0,3837411175
7396	46,8493	0,3822154961
10000	46,9237	0,3828224813
model value	122,573	

Due to technical problems, the simulation could not be run for 100 solid angles.
With these new simulations, we arrive at the same conclusion, excepted the fact that the values

→ Difference between the model and the other simulations due to the fact that this model was ma

Strength and stress of a wire



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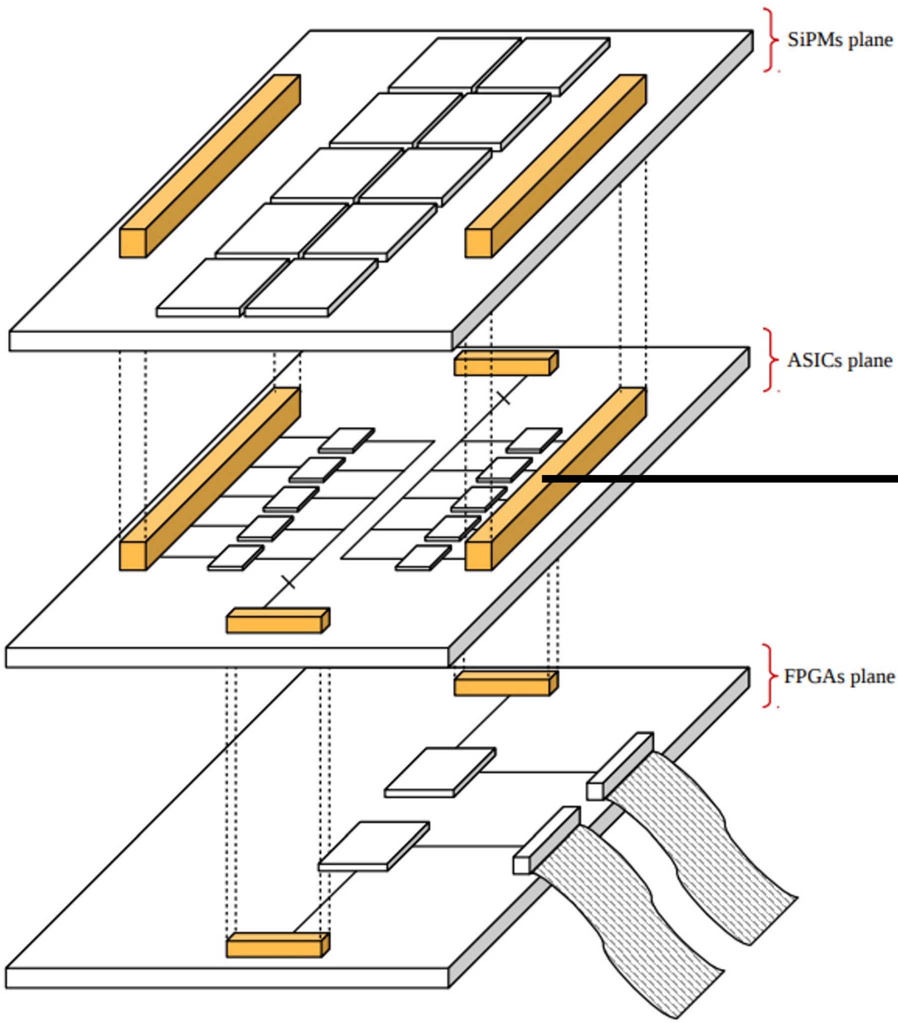
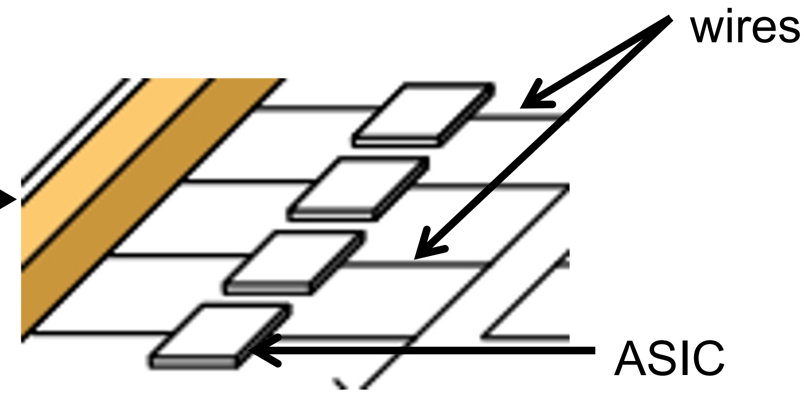
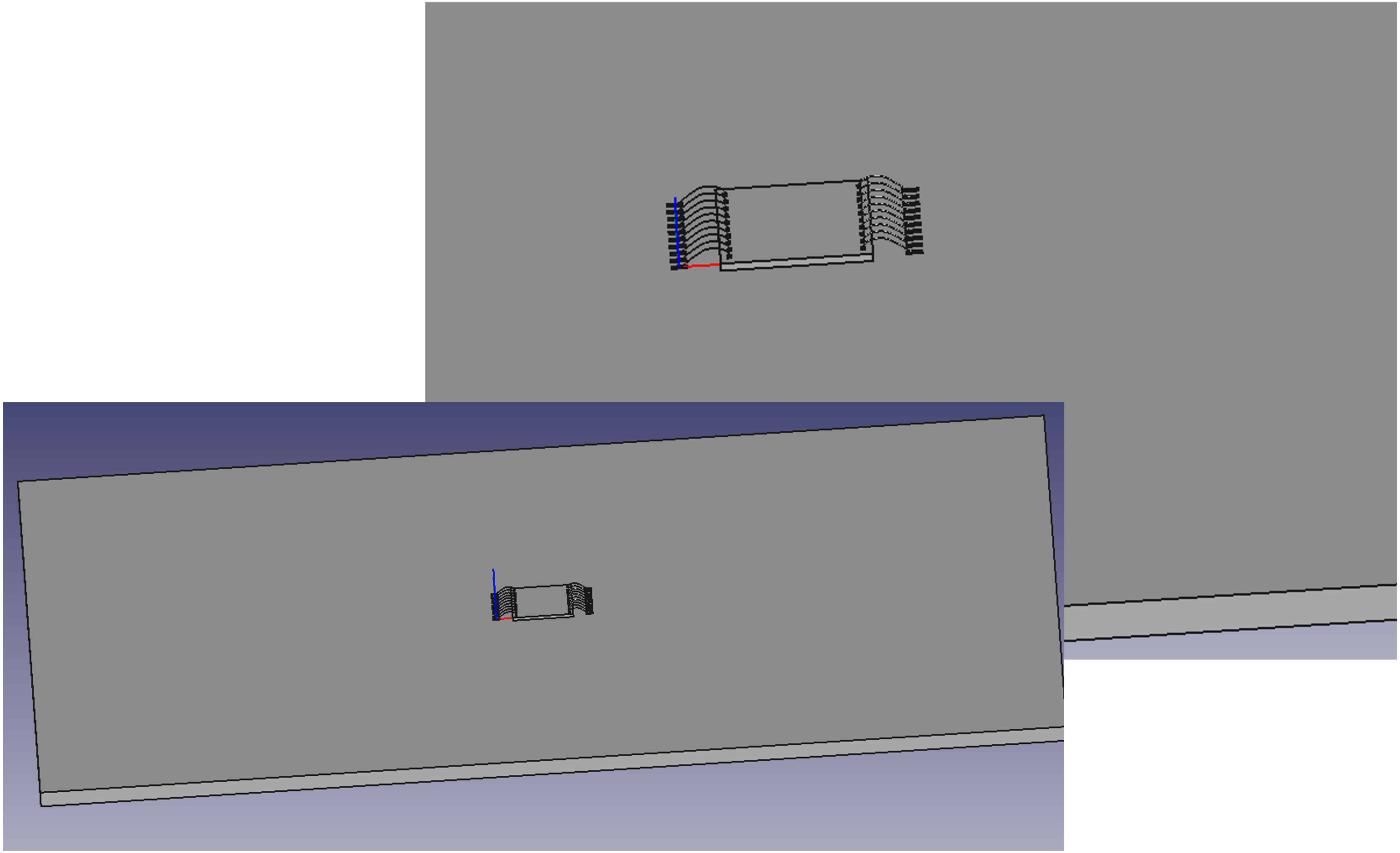
Terzina project → send a satellite in low earth orbit
One of the component of the satellite is a tower (as drawn below) that will be put in a solid box

Aim of the study : Know if the board and the c



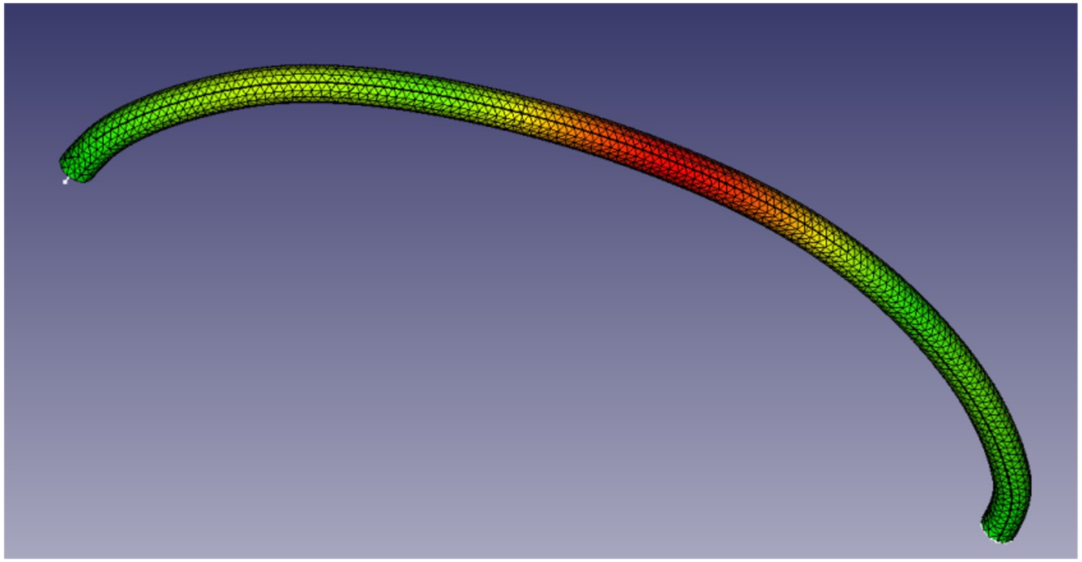


→ 3D model of the object on Freecad

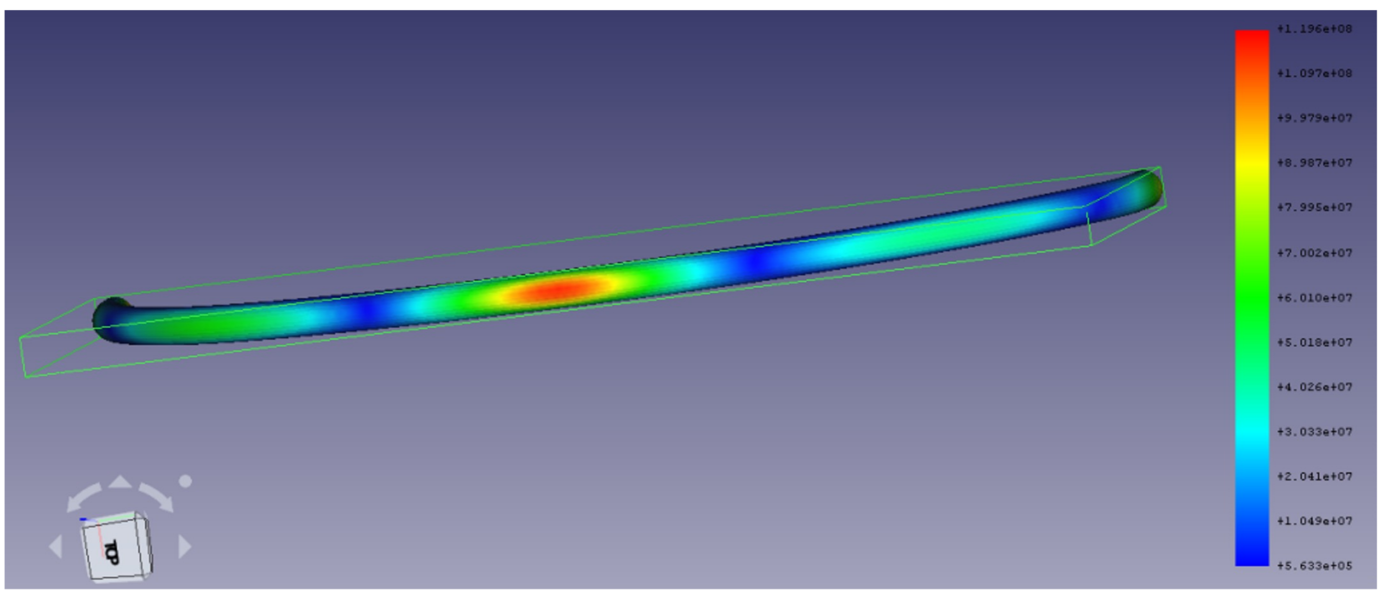


Considering all the model is too complex → Focus on what seems the weakest part : the wire

I. First, simulation on a simple wire of generic aluminium



As we can see, on the displacement fie



Maximum stress at the middle of the wire is 120 MPa for a vertical force of 0.01N

- For 0.05N, the maximum displacement is 6.41 µm and the maximum stress is 590 MPa.

- For 0.1N, the maximum displacement is 12.81 µm and the maximum stress is 1196 MPa.

- For 0.15N, the maximum displacement is 19.22 µm and the maximum stress is 1795 MPa.

Ultimate stress resistance for pure aluminium = 90 MPa → wire would break for 0,01N

Ultimate stress resistance for an alloy = 600 MPa → wire would break for 0,05N but unlikely beca

Experiment → Breaking force = 0,07N

II. So we have difference between the experiment and the simulation but we have some tra

A. Considering the wire is an alloy → 99% Al + 1% Silicon

→ ultimate stress resistance between 296 MPa and 310 Mpa → breaking force between 0,02 anc

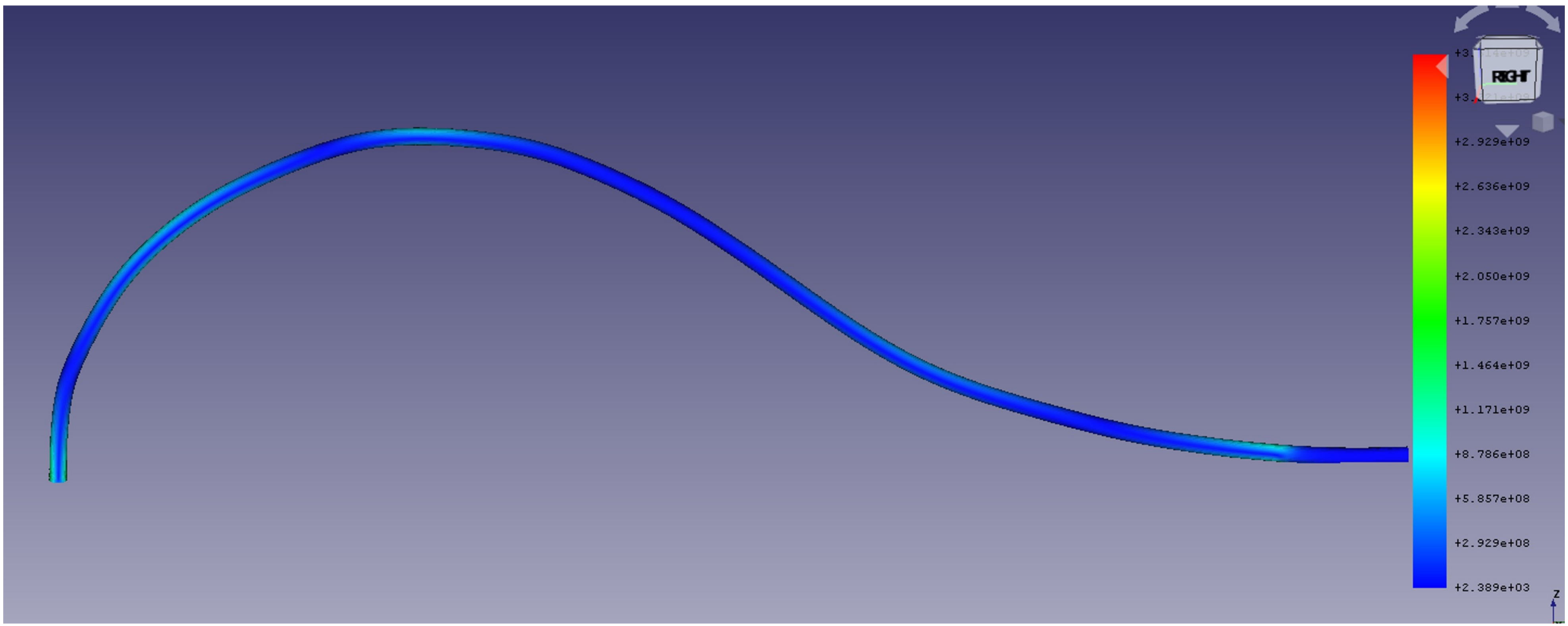
→ changing the Young Modulus for the simulation → between 67 and 87 GPa → small impact →

For the rest of the study, we will keep the Young Modulus and Poisson Ratio of generic aluminiun

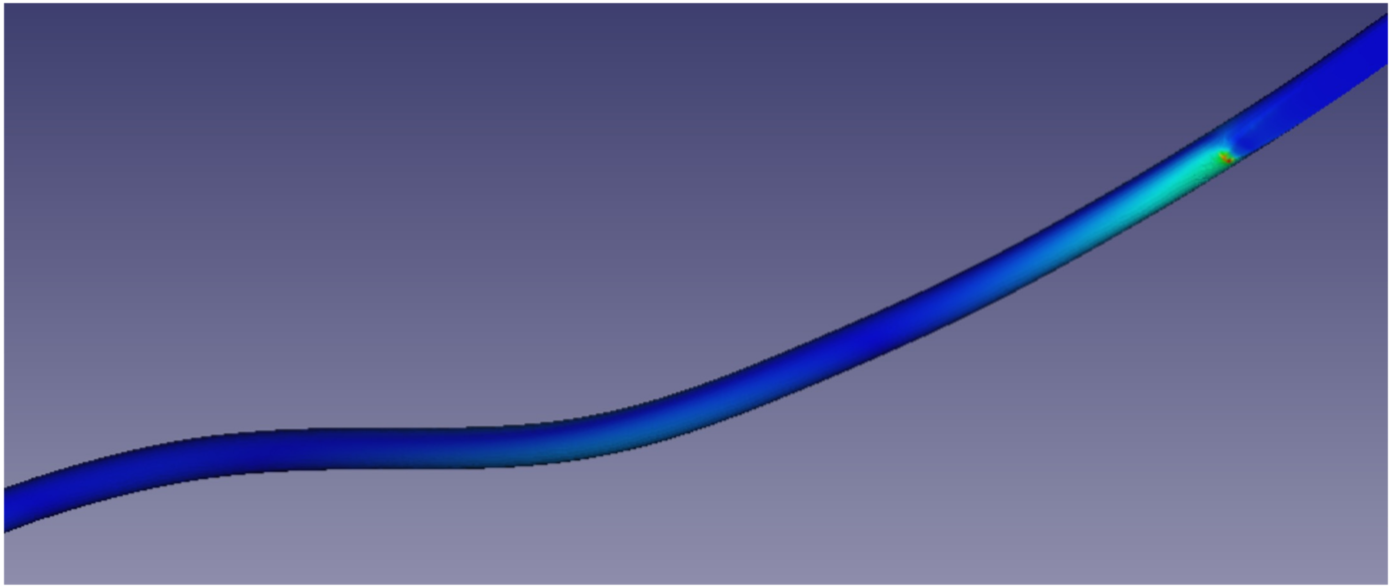
B. Use a shape closer to the experimental one

→ use the real dimension → distance between the two fixed points = 1,8 mm and maximum heig

→ changing the shape for a non-symetrical one



With the pure aluminium value, we obtain : 175 MPa for a 0,01N force and 880 MPa for a 0,05 N
But difficult to read because of the focus of stress



Stress concentration
Numerical artefact

→ Breaking force between 0,02 and 0,03 N

C. The plasticity

Because we go to the breaking point and we go out of the elastic area we need to take into acco

D. Other studies

→ studies can be done on Abaqus and it can help for the plastic study