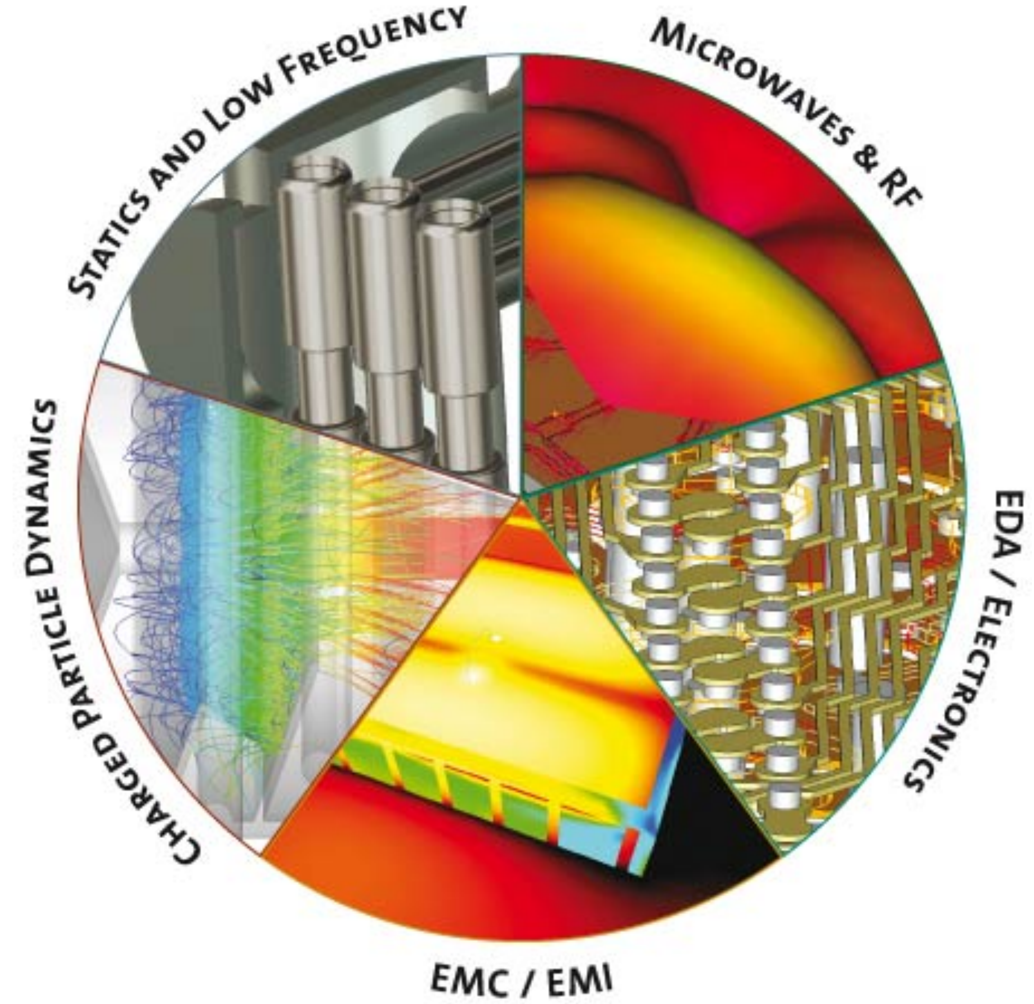
Simulation of a Resisitive Wall Pipe with CST



Simulation of a Resistive Wall Pipe

Let's review the theory:

Under some assumptions we wrote the longitudinal impedance as:

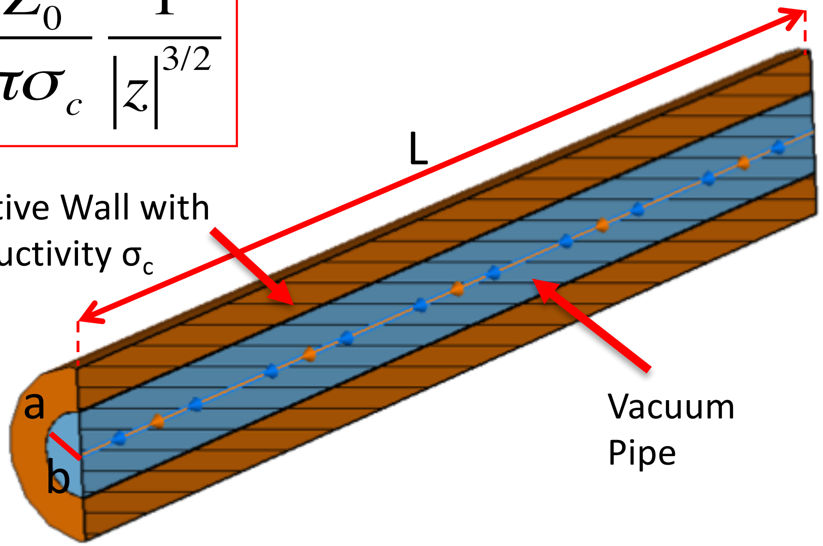
$$Z_{//}(\omega) = [1 - i\,\mathrm{sgn}(\omega)]\frac{L}{2\pi b}\sqrt{\frac{Z_0|\omega|}{2c\sigma_c}}$$

The wake field was given by:

$$w_{//}(z) = \frac{Lc}{4\pi b}\sqrt{\frac{Z_0}{\pi\sigma_c}}\frac{1}{|z|^{3/2}}$$

We have also defined the wake potential of a bunch as

$$W_{//}(z) = \frac{1}{q}\int_{-\infty}^{\infty} w_{//}(z'-z)\lambda(z')dz'$$



If we consider a Gaussian bunch, the above integral can be done, giving

$$W_{//}(z) = \frac{cL}{4\pi b\sigma_z^{3/2}}\sqrt{\frac{Z_0}{\sigma_c}}|x|^{3/2}e^{-x^2}\{I_{-3/4}(x^2) - I_{1/4}(x^2) + \mathrm{sgn}(z)[I_{3/4}(x^2) - I_{-1/4}(x^2)]\}$$

with $x = z/2\sigma_z$

Simulation of a Resistive Wall Pipe

WHY CST?

CST Studio Suite is a software used for the study of electromagnetic fields. It comprises tools for the design and optimization of accelerator devices operating in a wide range of frequencies, from static to optical. Analysis may also include thermal and mechanical effects, as well as circuit simulations.

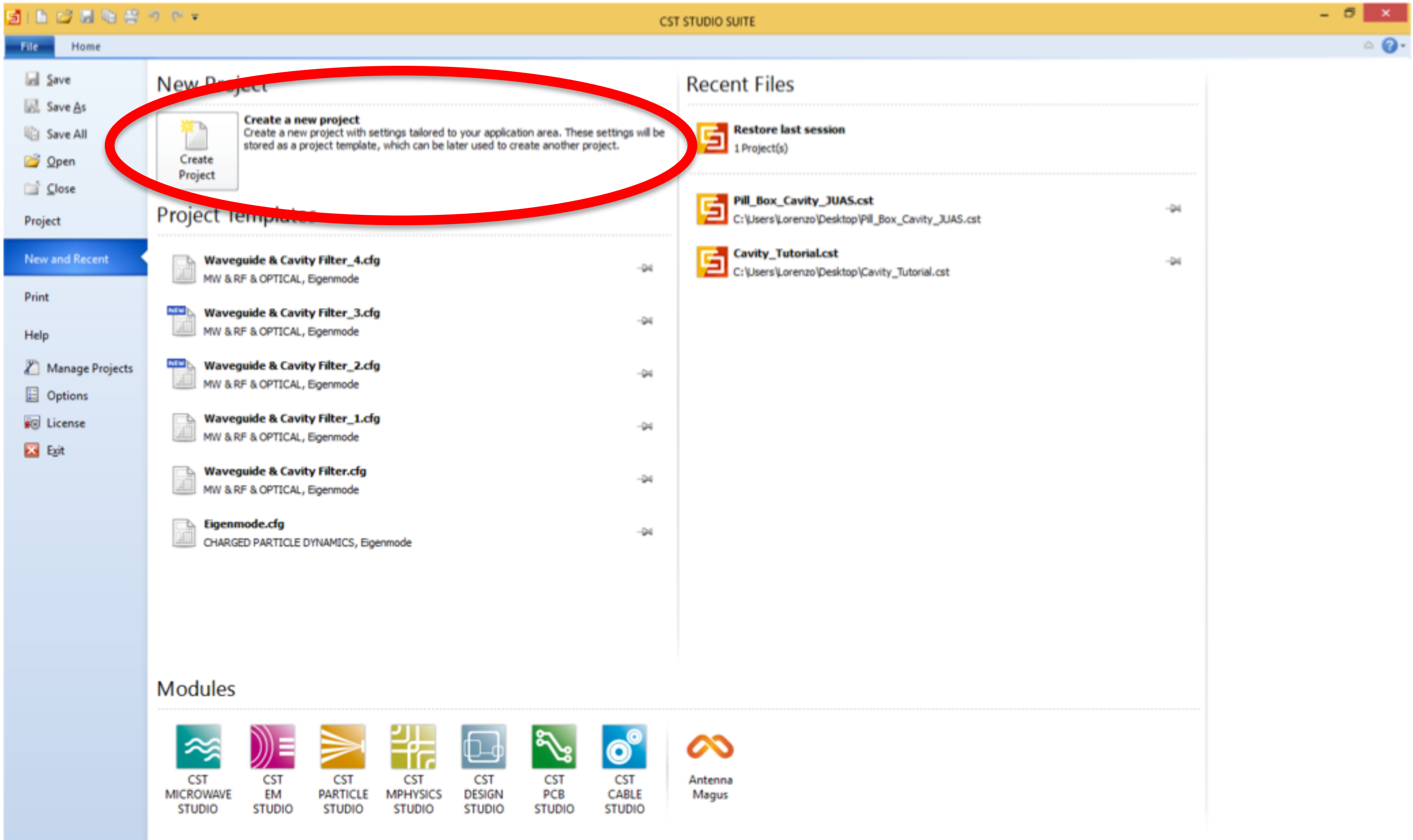
WHAT ARE WE GOING TO DO?

In this tutorial we are going to show, step by step, how to use CST in order to design a resistive wall pipe and determine wake potential and impedance.

Simulation of a Resistive Wall Pipe

READY TO GO!

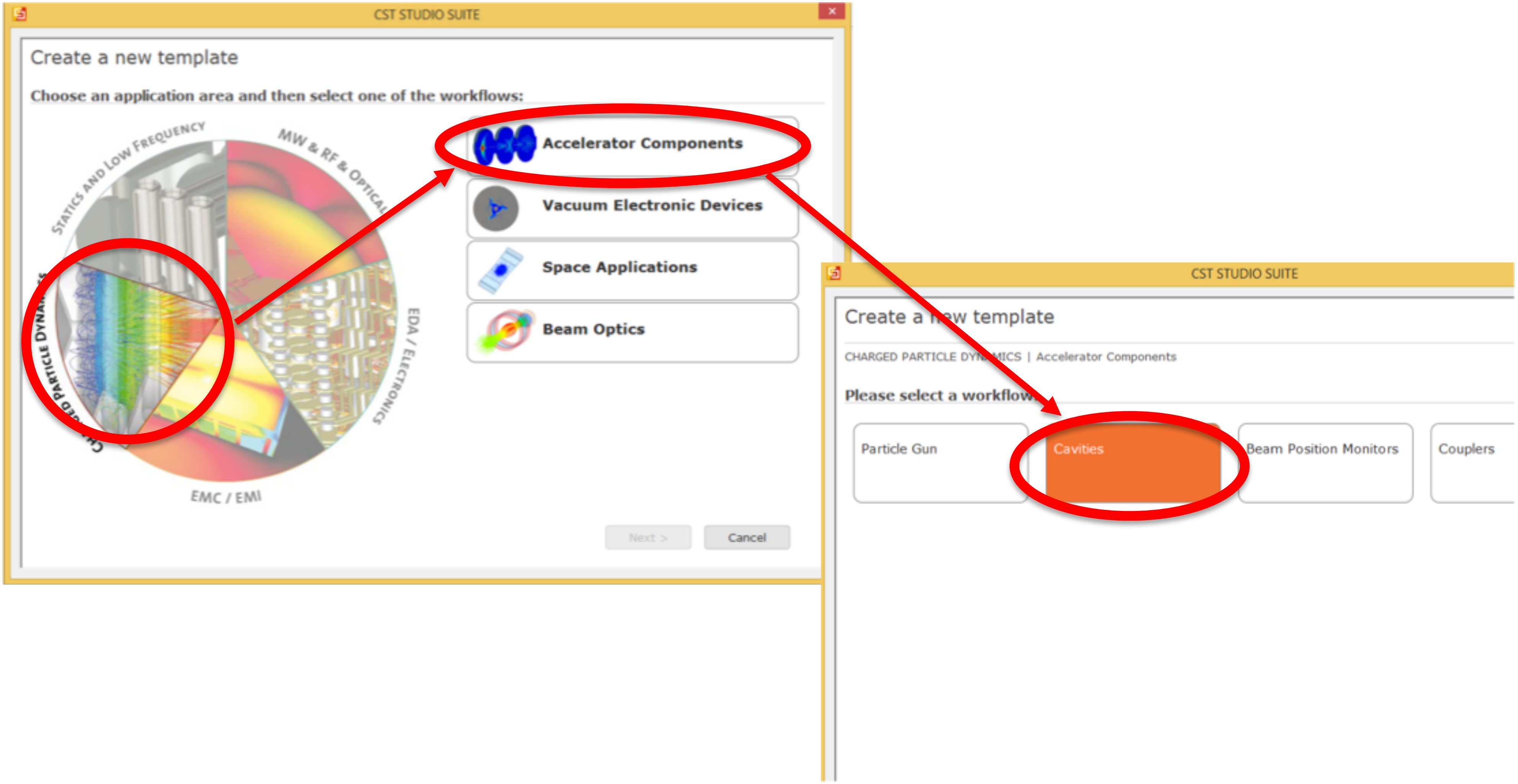
Open CST studio suite and select "Create a new Project"



Simulation of a Resistive Wall Pipe

READY TO GO!

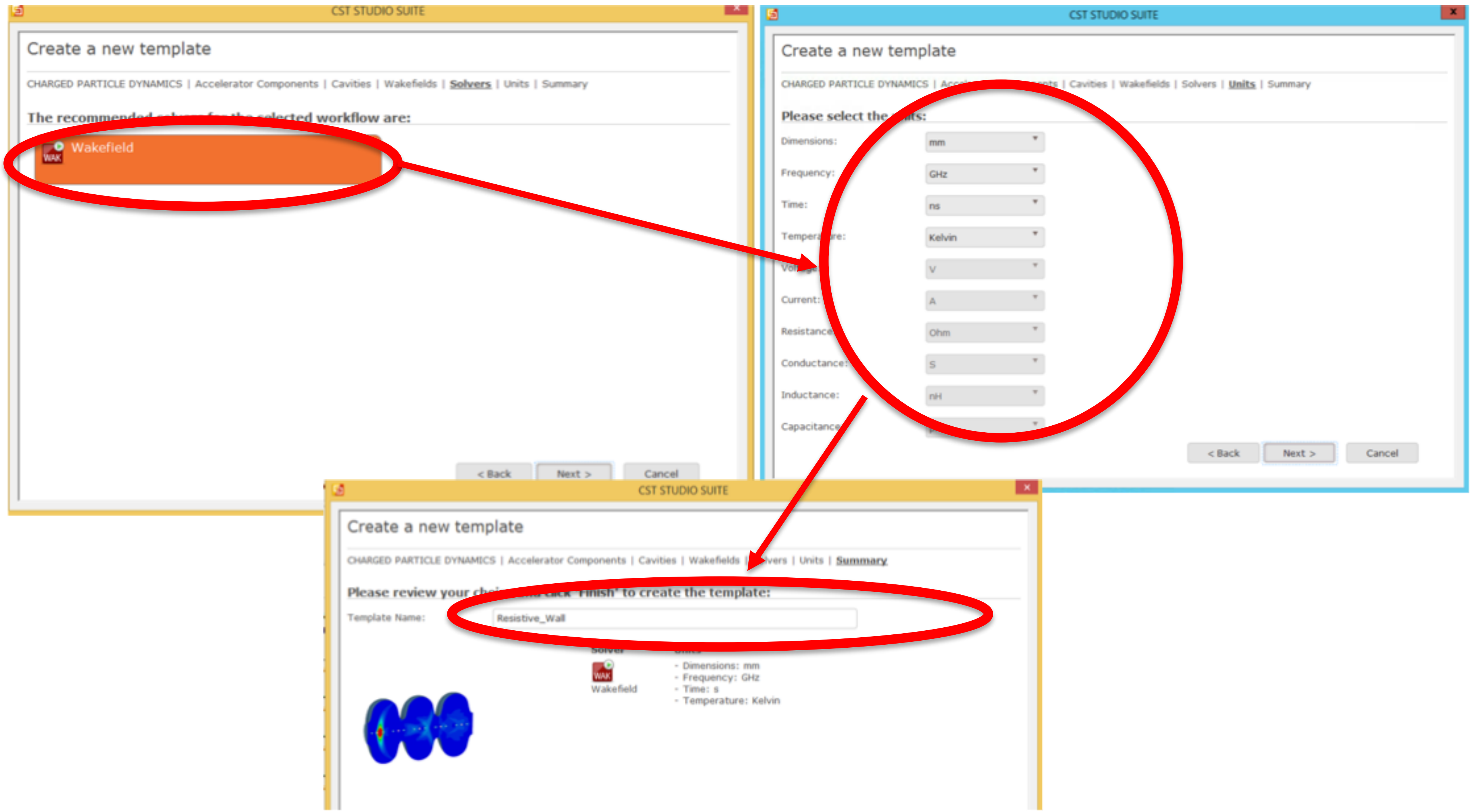
Now we need to select the correct Solver, Wakefield. Thus let's select Charged Particle Dynamics-> Accelerator Components -> Cavities



Simulation of a Resistive Wall Pipe

READY TO GO!

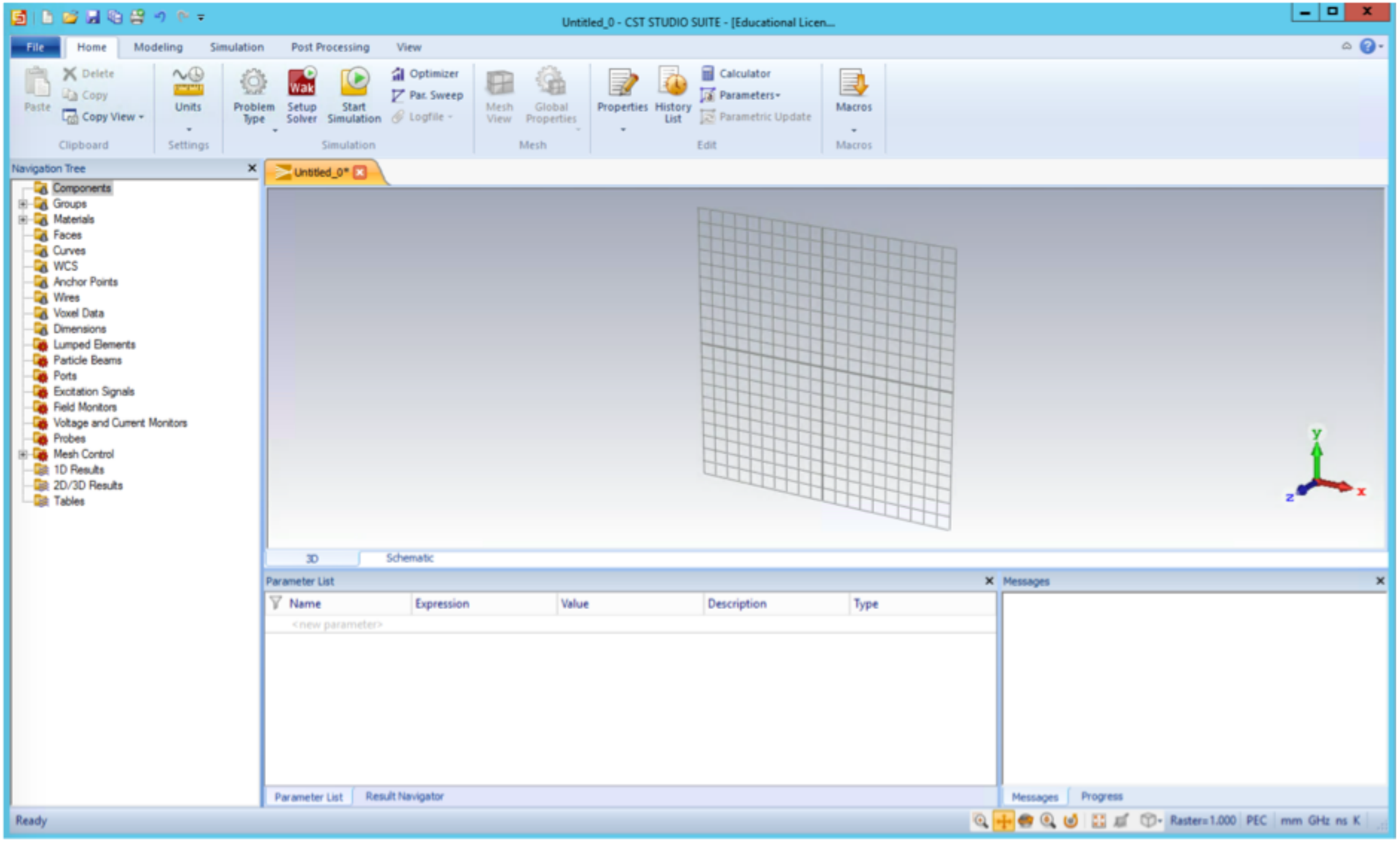
Then “Wakefield”. After that, we select the working dimensional units (mm, GHz, s,…) and call the file as : Resistive_Wall



Simulation of a Resistive Wall Pipe

READY TO GO!

You should now see a screen like this one.

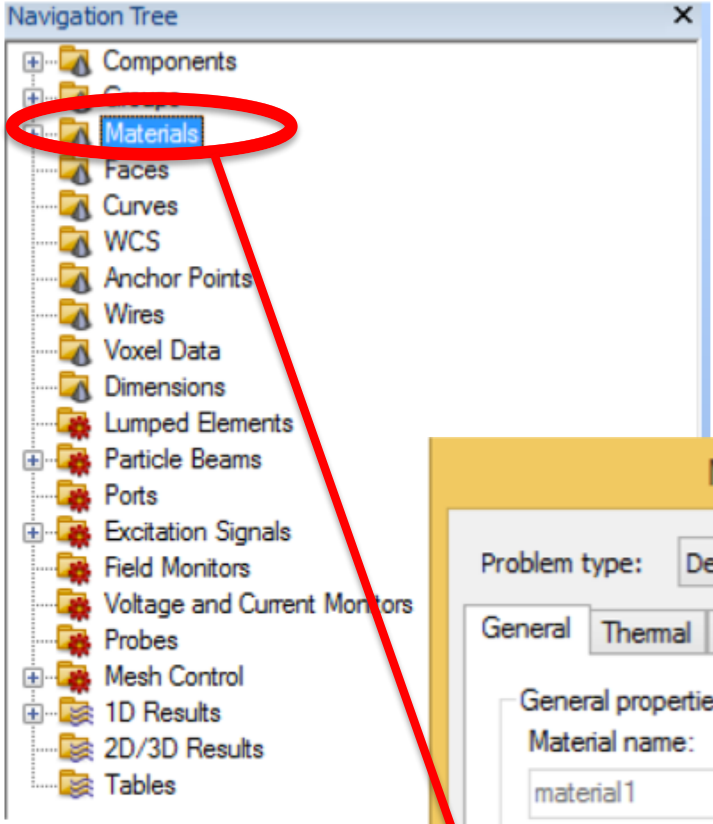


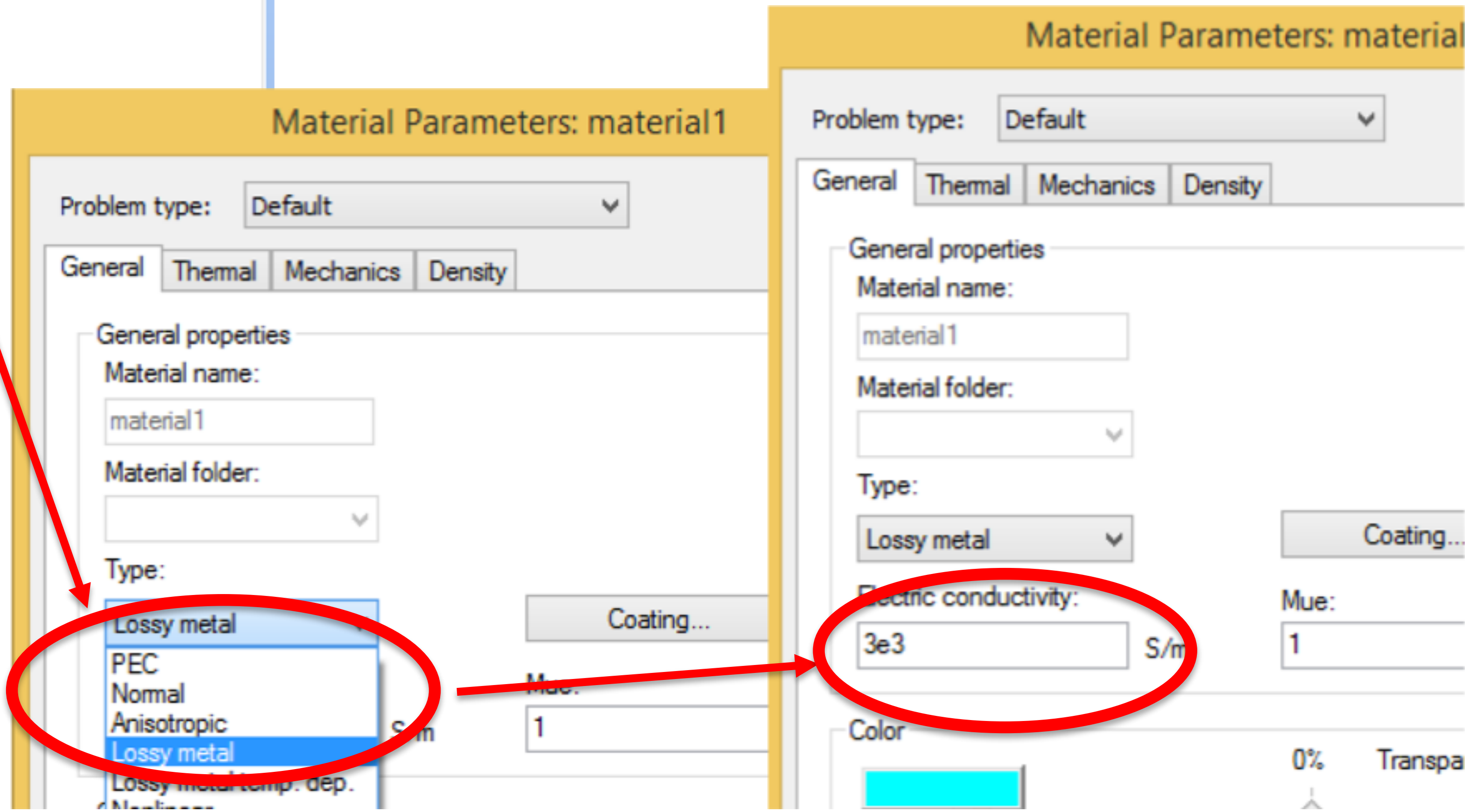
The working window is divided into 5 sub-windows (but it depends on the chosen preferences). The largest one shows the figure of the device you are designing.

Simulation of a Resistive Wall Pipe

MODELING

Let's now define a new material with a given conductivity. Let's select "materials" on the navigation tree on the left of the working window. Then, right-click on the folder and select "New Material..." from the menu. Select "Lossy metal" as "Type" in the General menu and then set the conductivity value at 3e3 S/m.

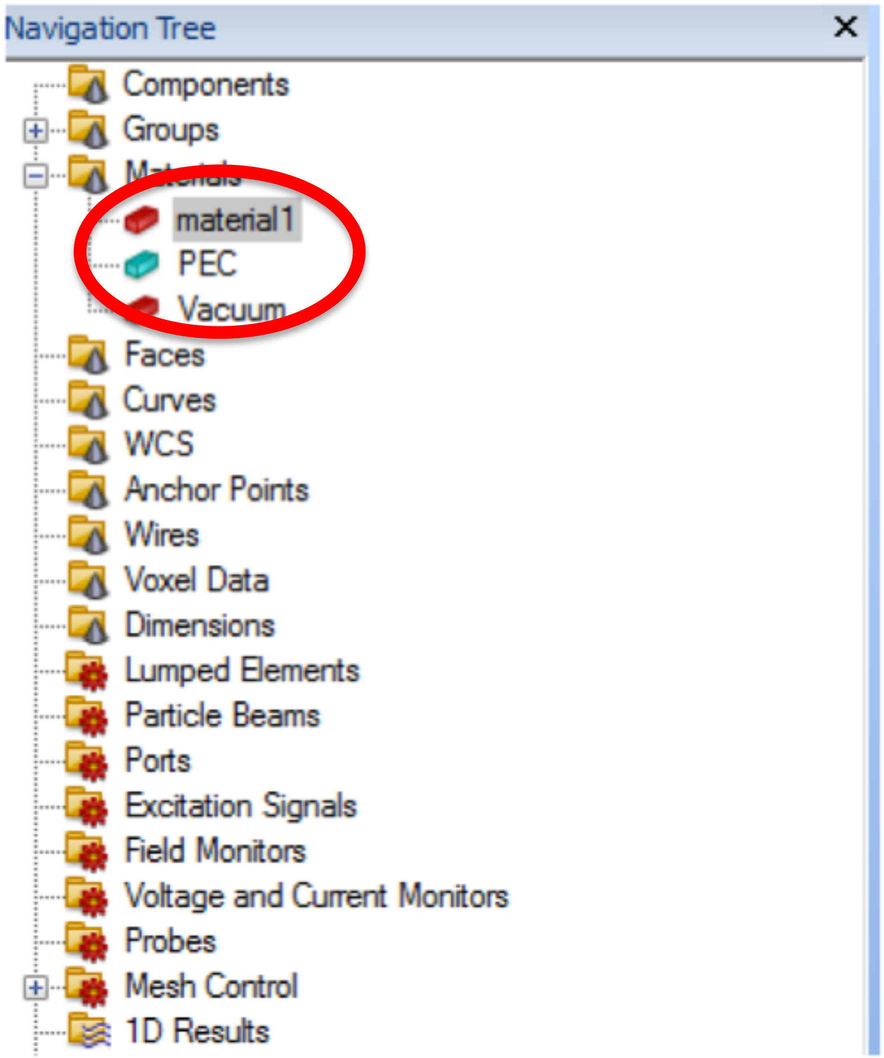




Simulation of a Resistive Wall Pipe

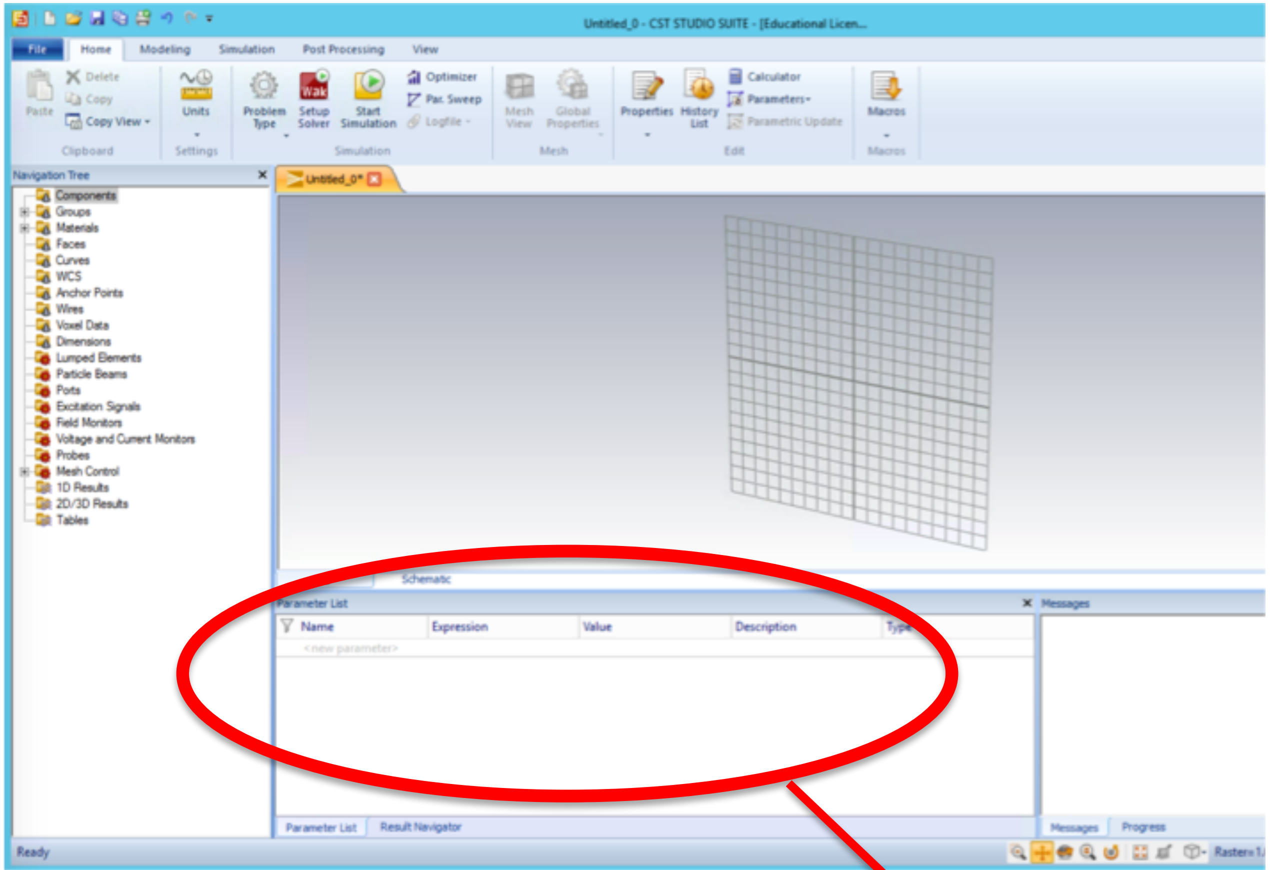
MODELING

Now you should be able to see your new material in the materials list as shown.

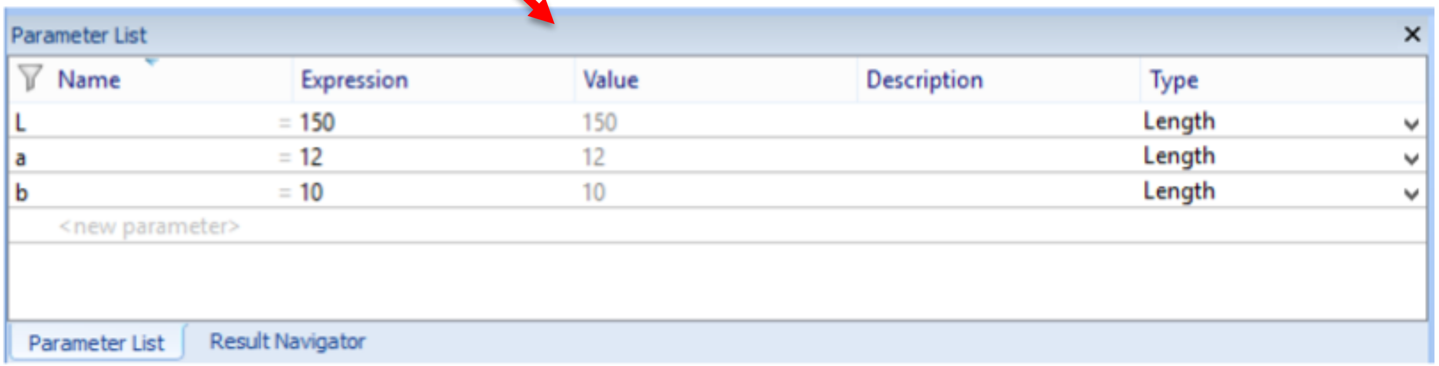


Simulation of a Resistive Wall Pipe

MODELING



Let's now introduce the geometrical dimensions of the beam pipe as parameters. This will allow easily to modify the entire model in future. It is possible to enter the parameter name, its expression (it could be a value, according to the dimensional units previously selected, or a combination of other parameters), its description and its type.



Parameter List

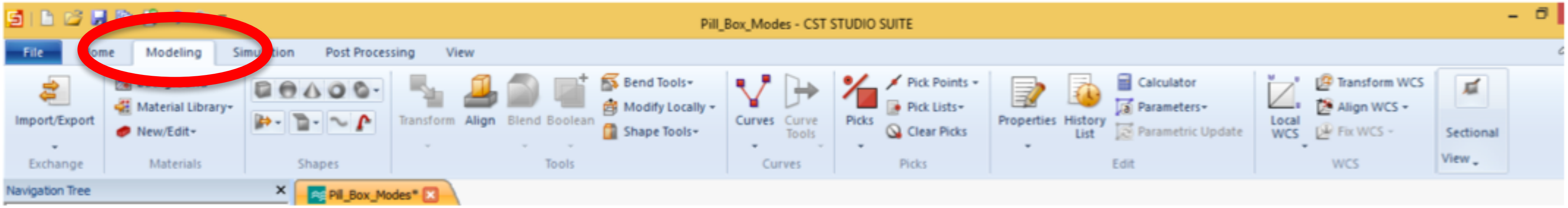
Name	Expression	Value	Description	Type
L	= 150	150		Length
a	= 12	12		Length
b	= 10	10		Length
<new parameter>				

Parameter List | Result Navigator

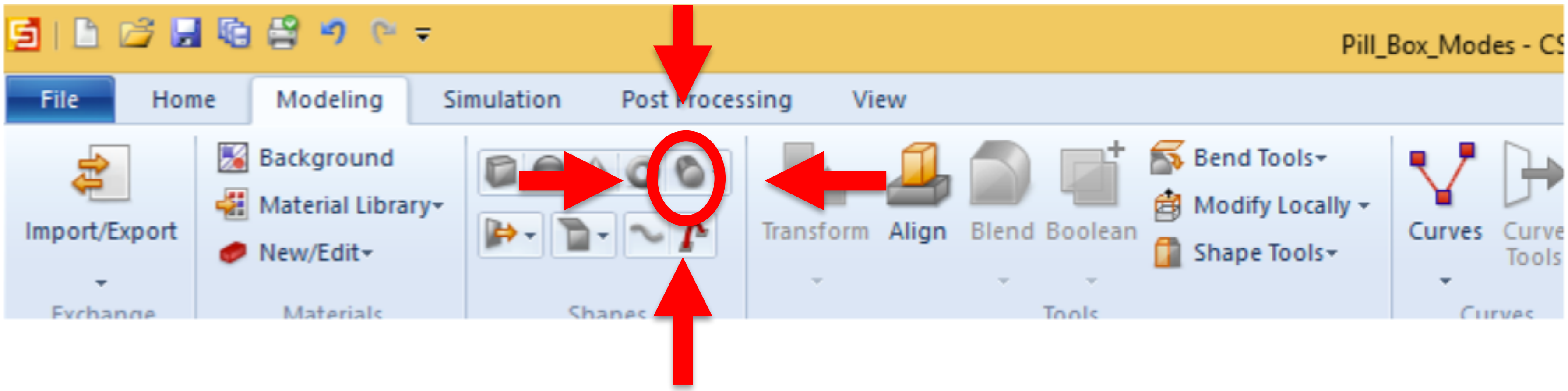
Simulation of a Resistive Wall Pipe

MODELING

Now click on “Modeling” item on the top menu



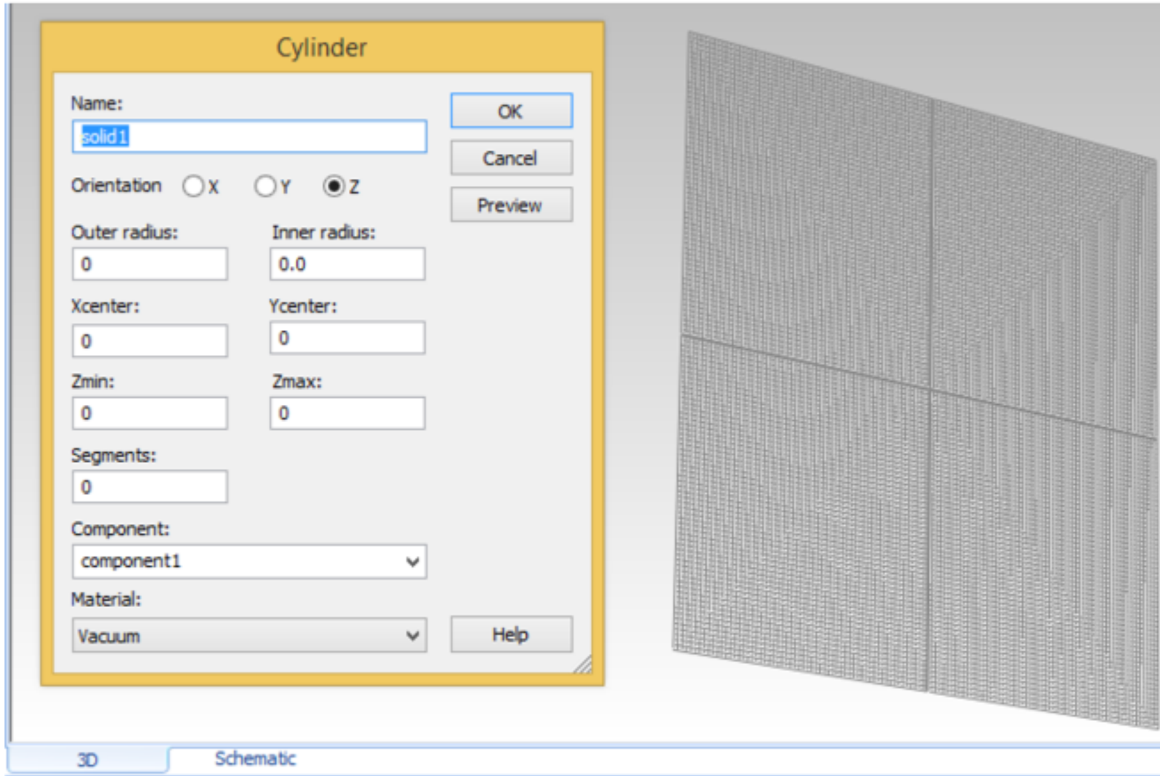
Then select the cylinder

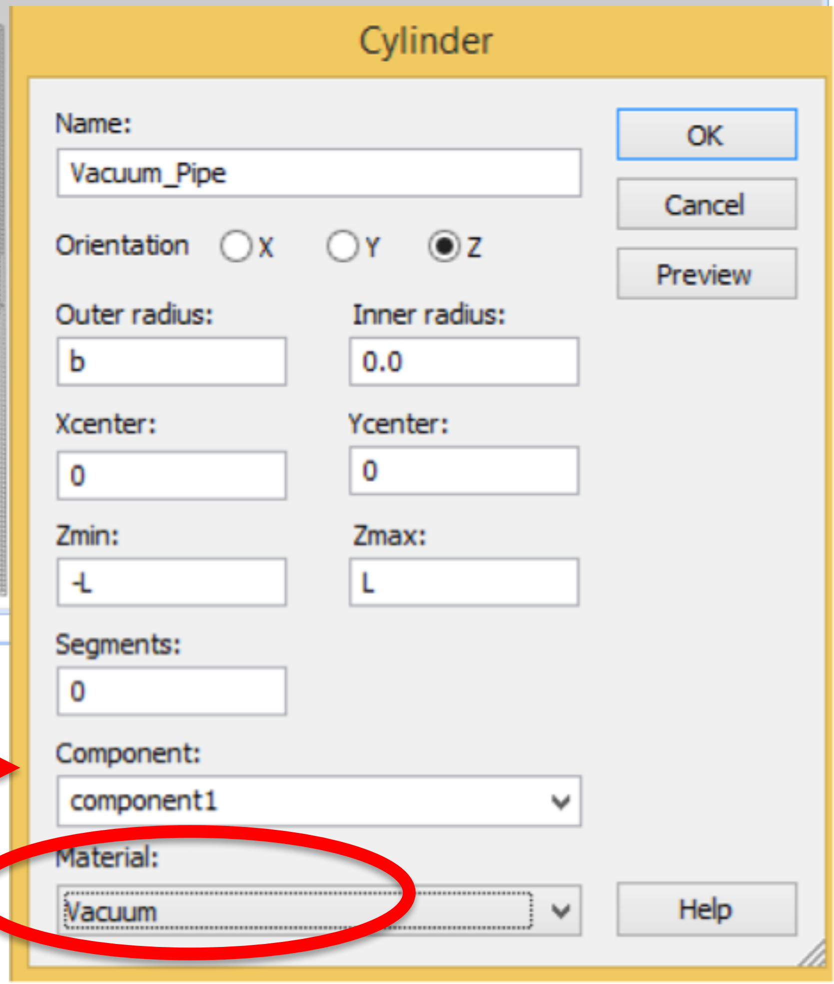


Simulation of a Resistive Wall Pipe

MODELING

Press esc. You should visualize the following window.



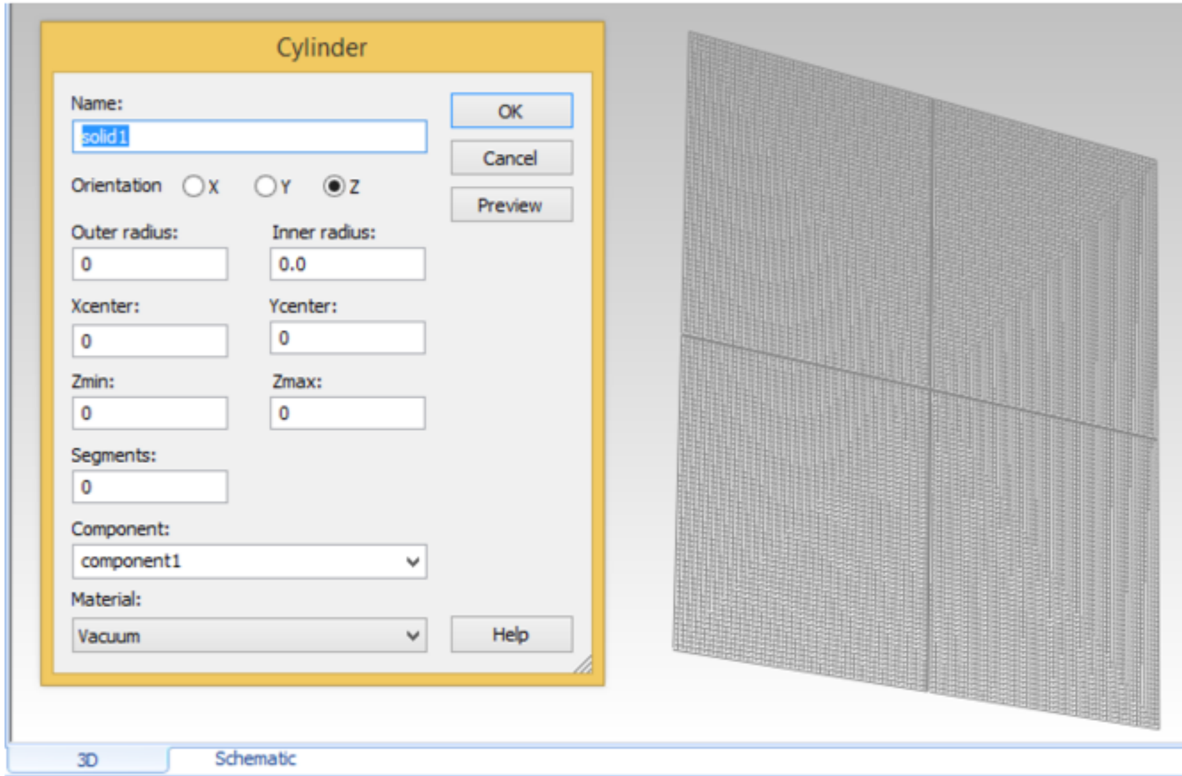


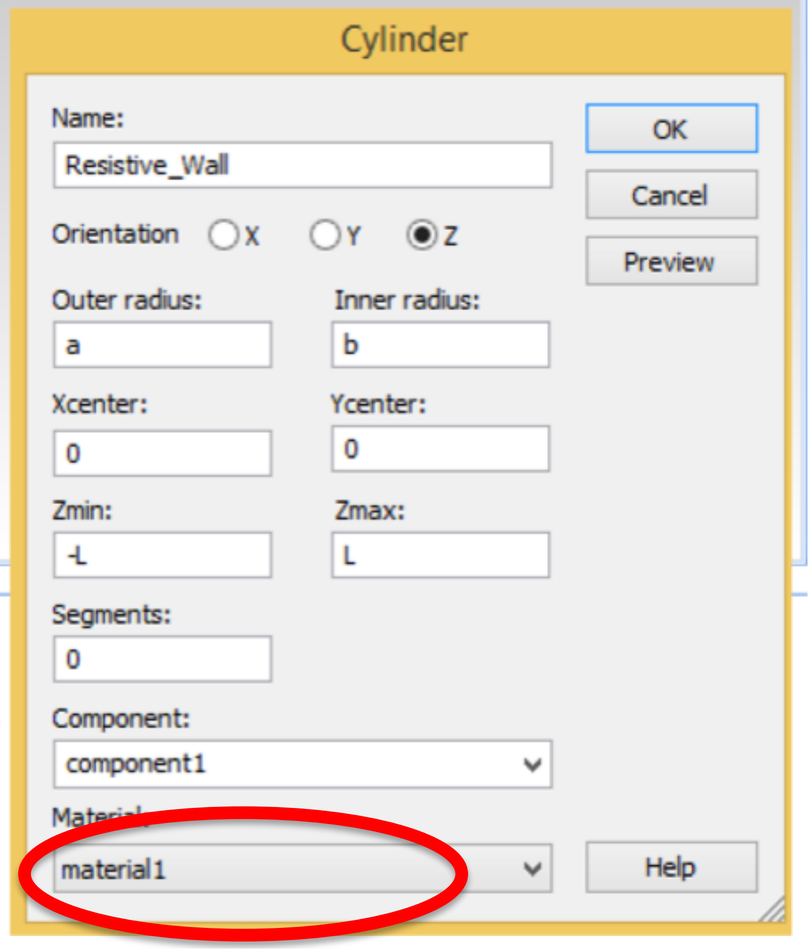
Fill the windows as shown and press OK. Remember to select "Vacuum" as material. You have now the vacuum pipe.

Simulation of a Resistive Wall Pipe

MODELING

Repeat the instructions to create a resistive beam pipe, filling the window as shown below



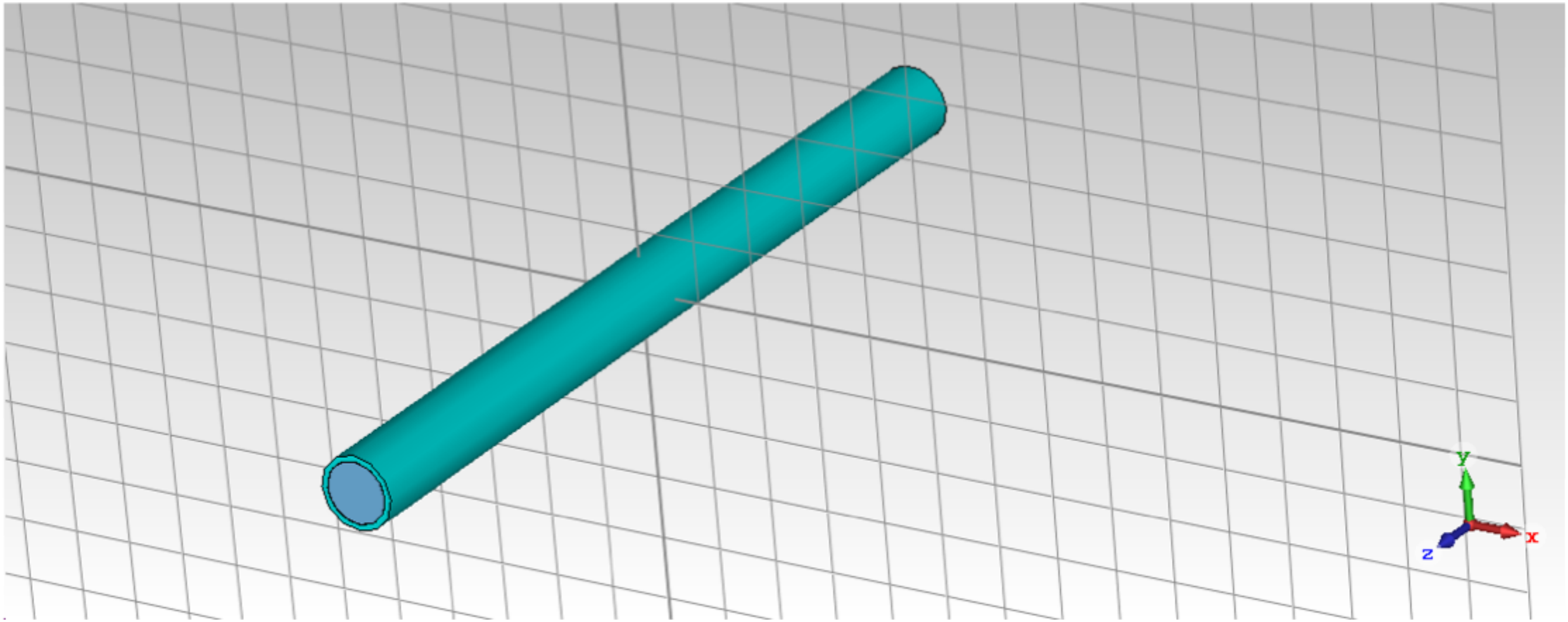


Fill the windows as shown and press OK. <u>Remember to select "material1" as material.</u> Here it is the resistive pipe!

Simulation of a Resistive Wall Pipe

MODELING

This is our Resistive Beam Pipe!



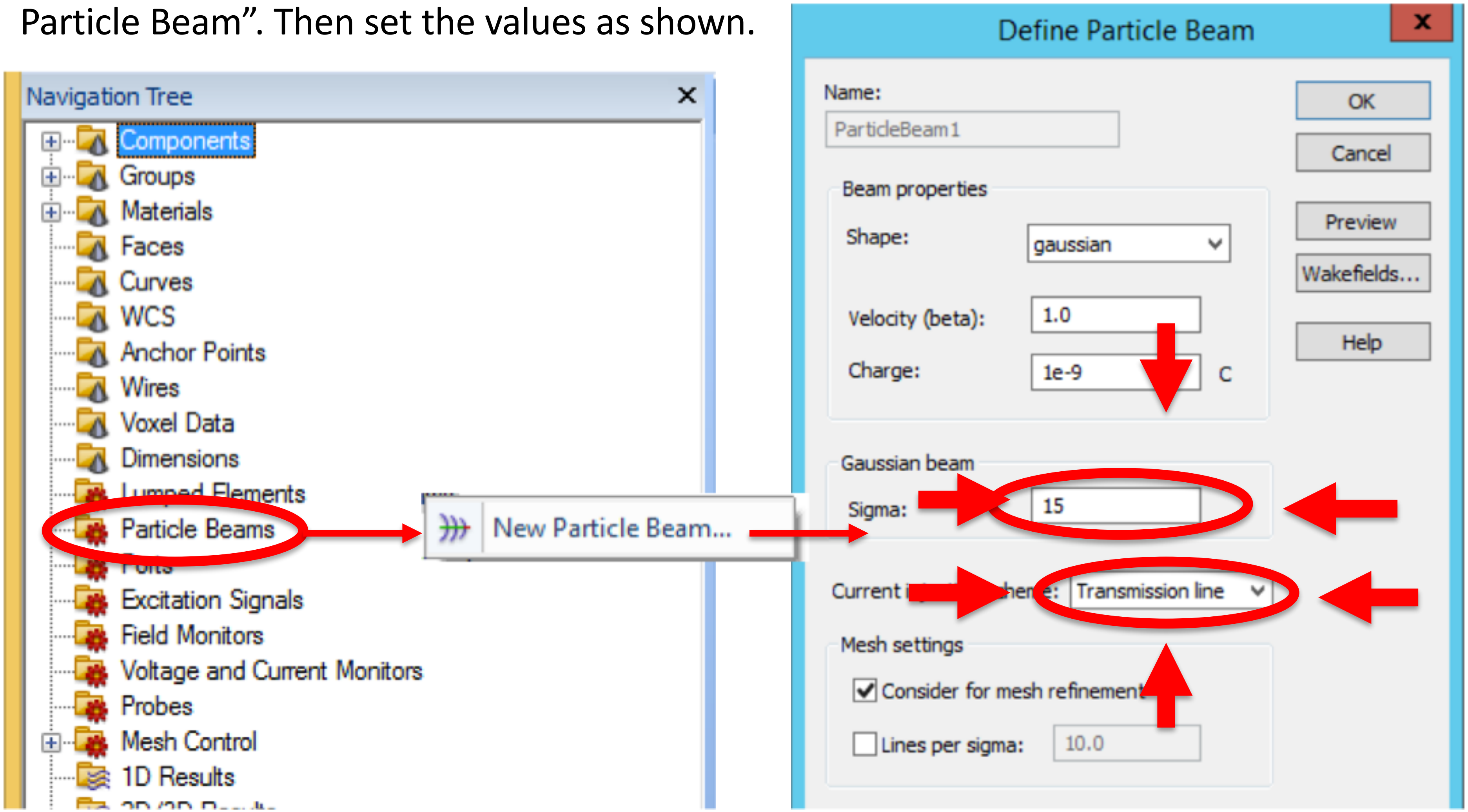
The geometry is done!

Simulation of a Resistive Wall Pipe

ANALYSIS

We are almost ready for simulations, but we first need to define the particle beam, that is the source of the wakefield.

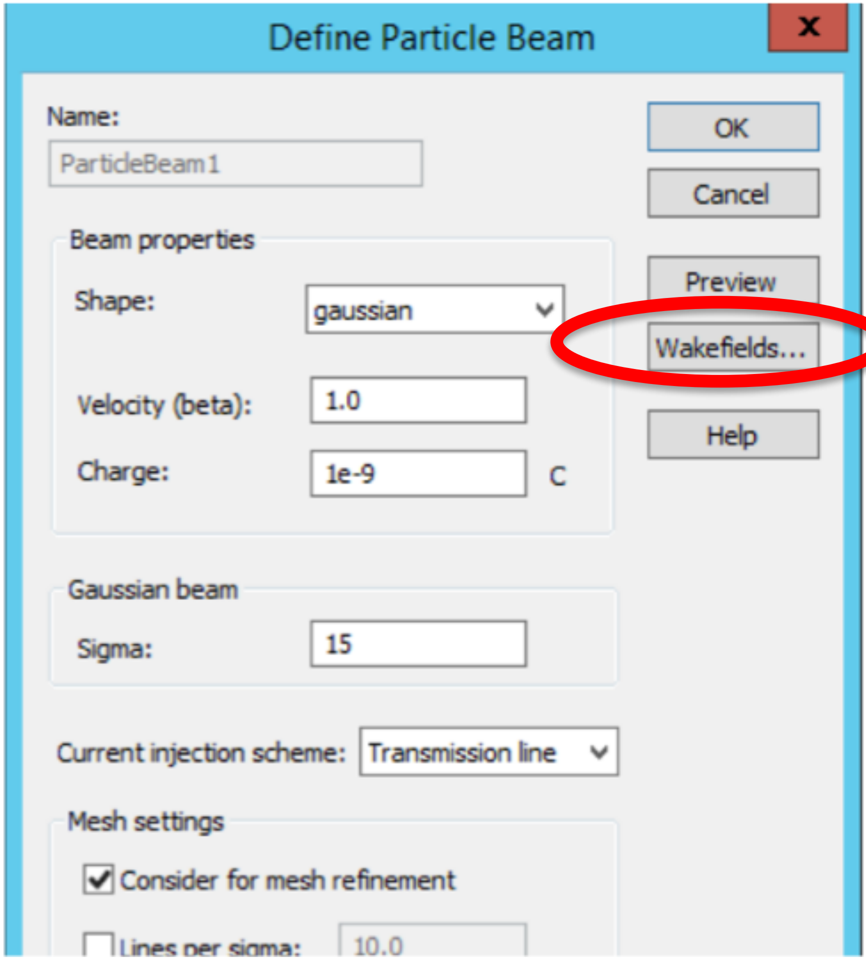
Let's right-click on "Particle Beams" in the "Navigation Tree" window and select "New Particle Beam". Then set the values as shown.

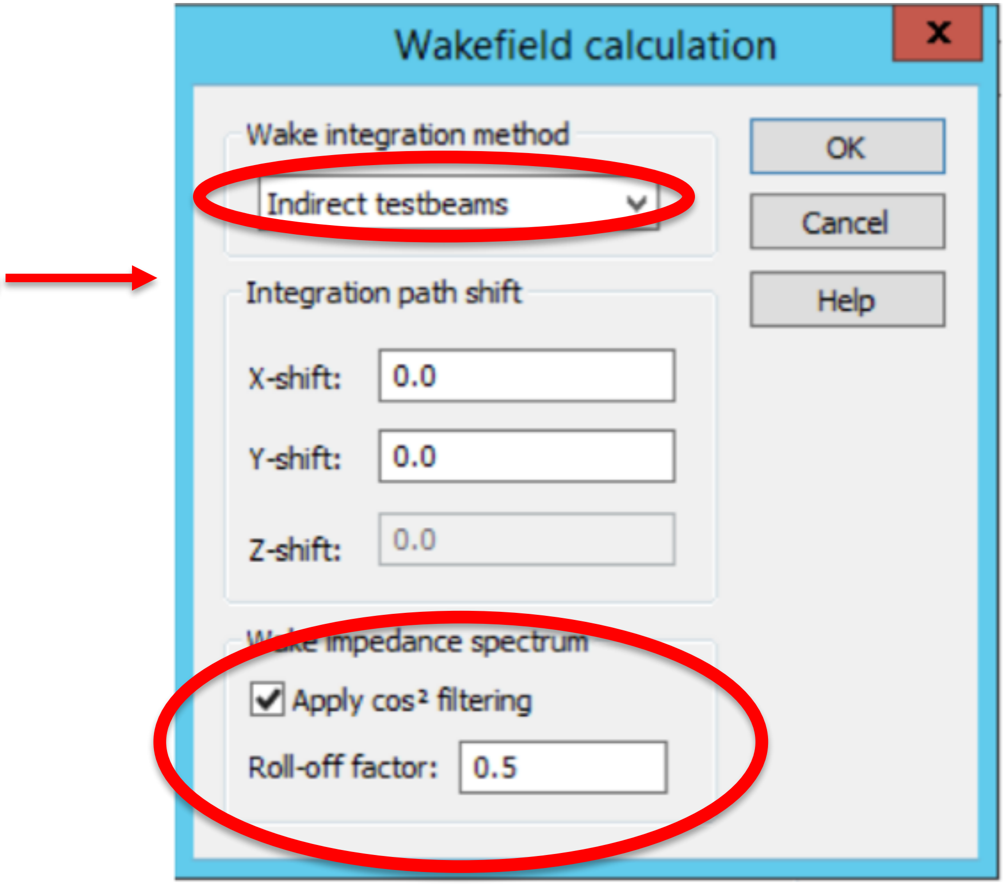


Simulation of a Resistive Wall Pipe

ANALYSIS

Click now on "Wakefields…" and change the "Wake integration method" from "Direct" to "Indirect testbeams" (if possible, you should always use it). In addition to that, let's apply a roll-off parameter of 0.5 (this will lead to a smoother solution, removing numerical noise in the results).

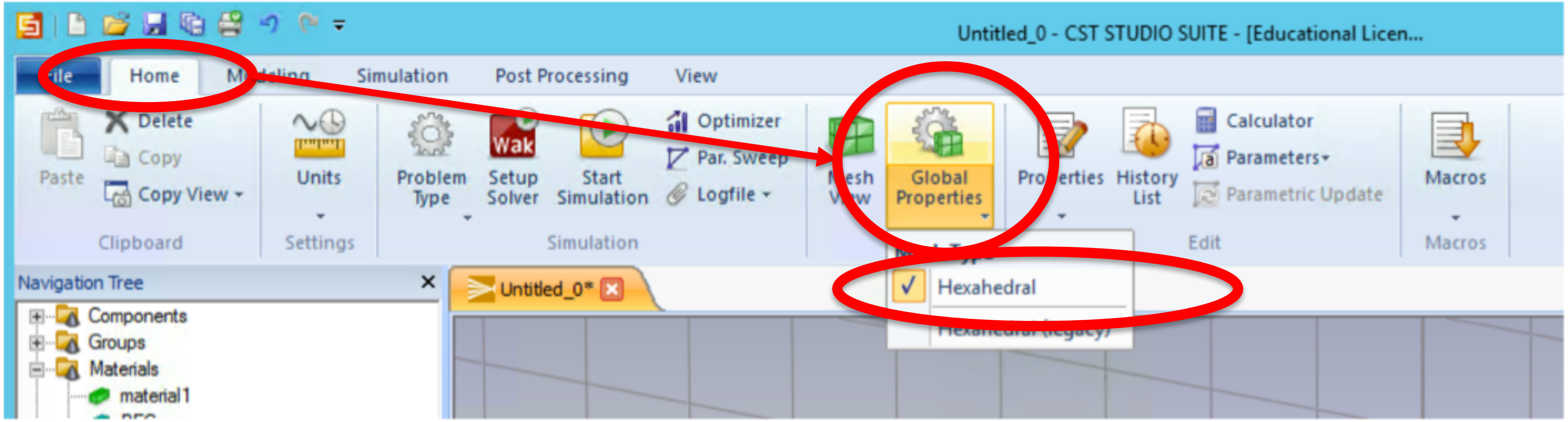


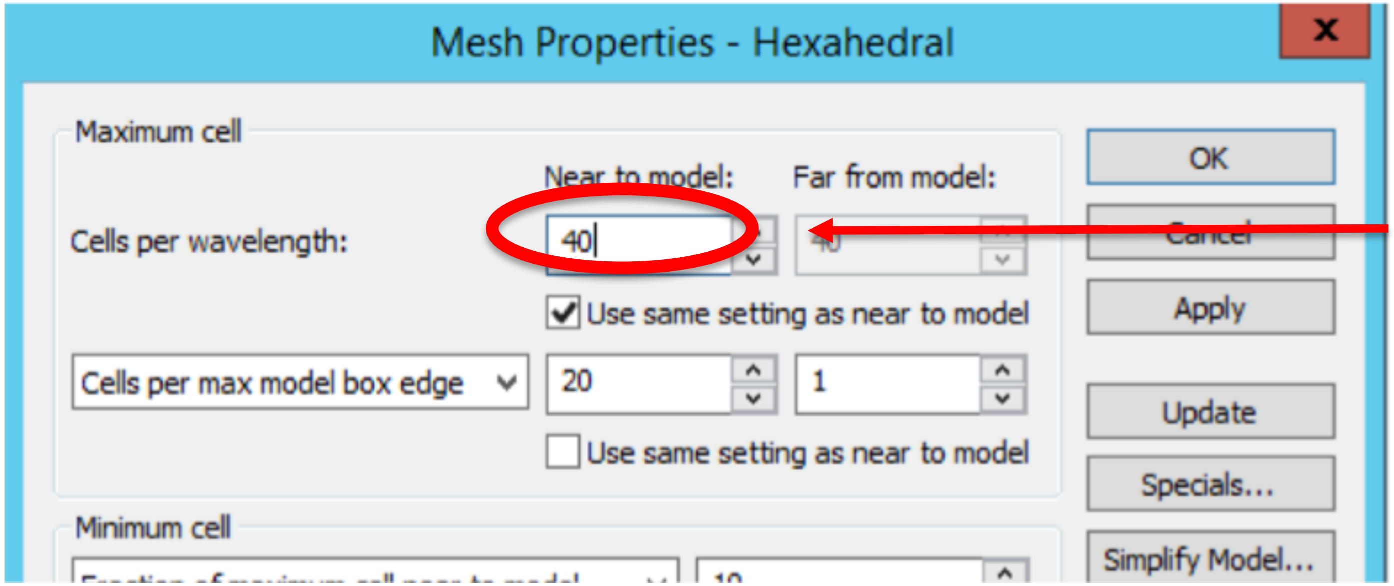


Simulation of a Resistive Wall Pipe

ANALYSIS

Let's now adjust the mesh. Select, from the top menu, Home -> Global Properties -> Hexahedral





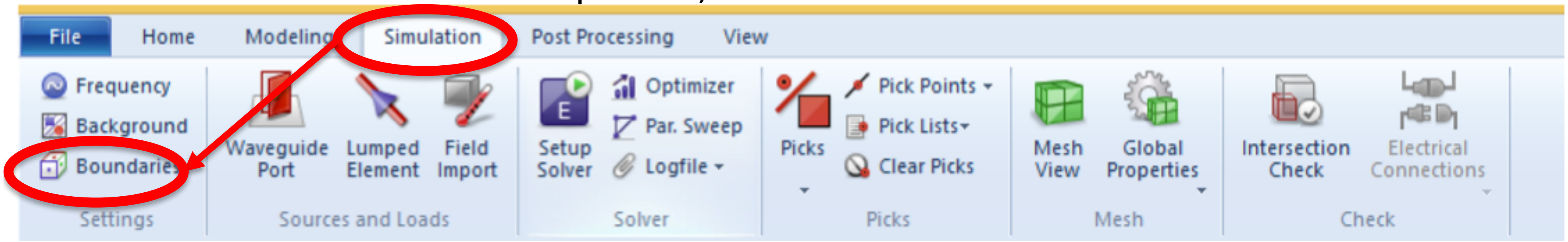
Then, in the window that appears, set the value as shown.

Simulation of a Resistive Wall Pipe

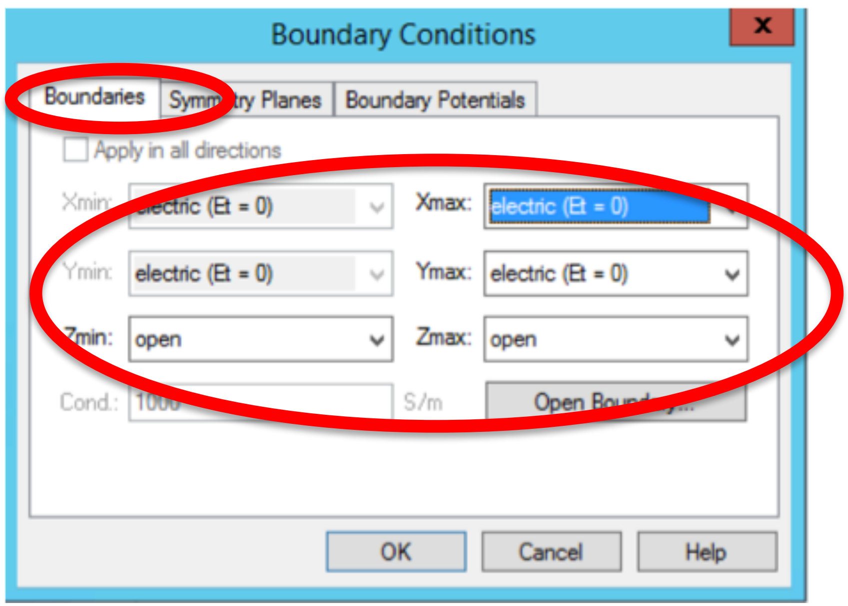
ANALYSIS

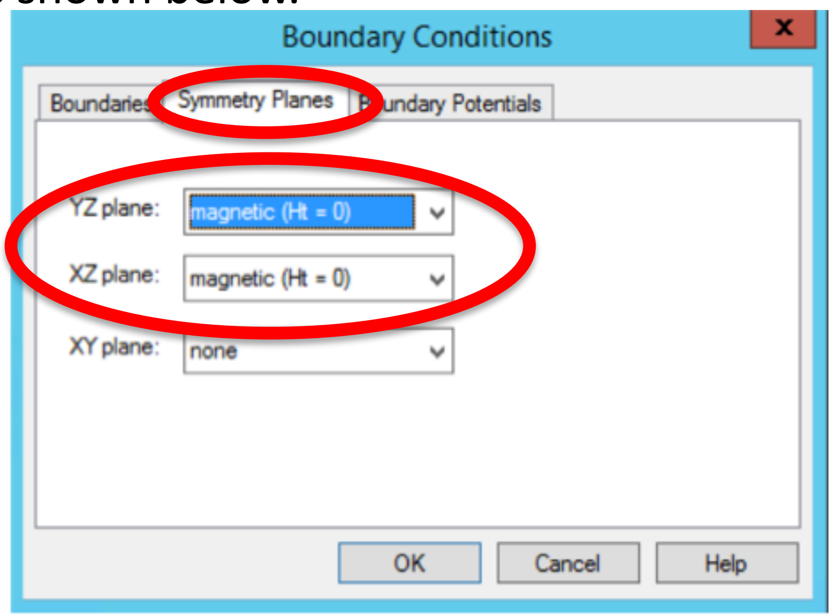
Almost done.

Click on “Simulations” on the top menu, then “Boundaries”



Let’s now select the simmetry planes of our geometry from the “Symmetry Planes” window (YZ Ht=0 and XZ Ht=0) and the boundaries as shown below.

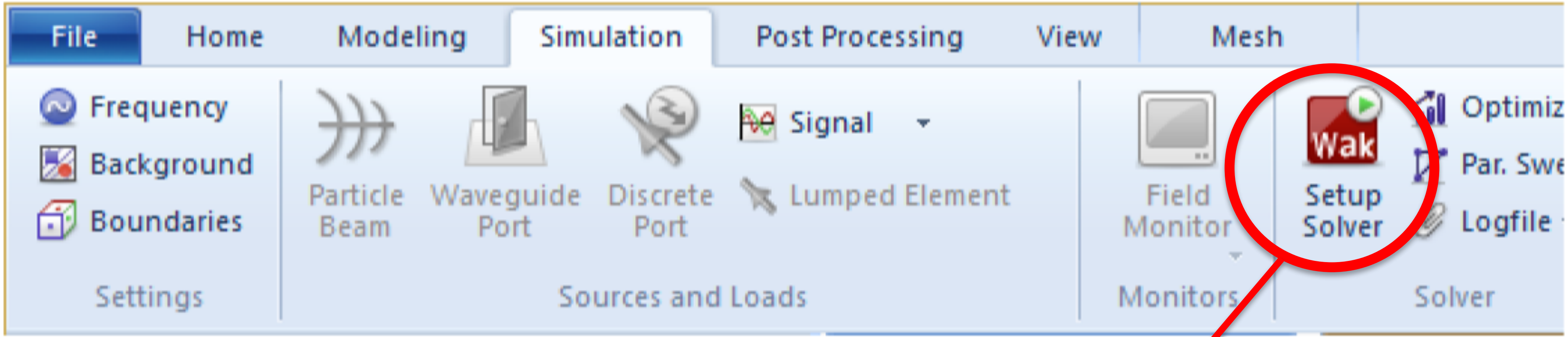


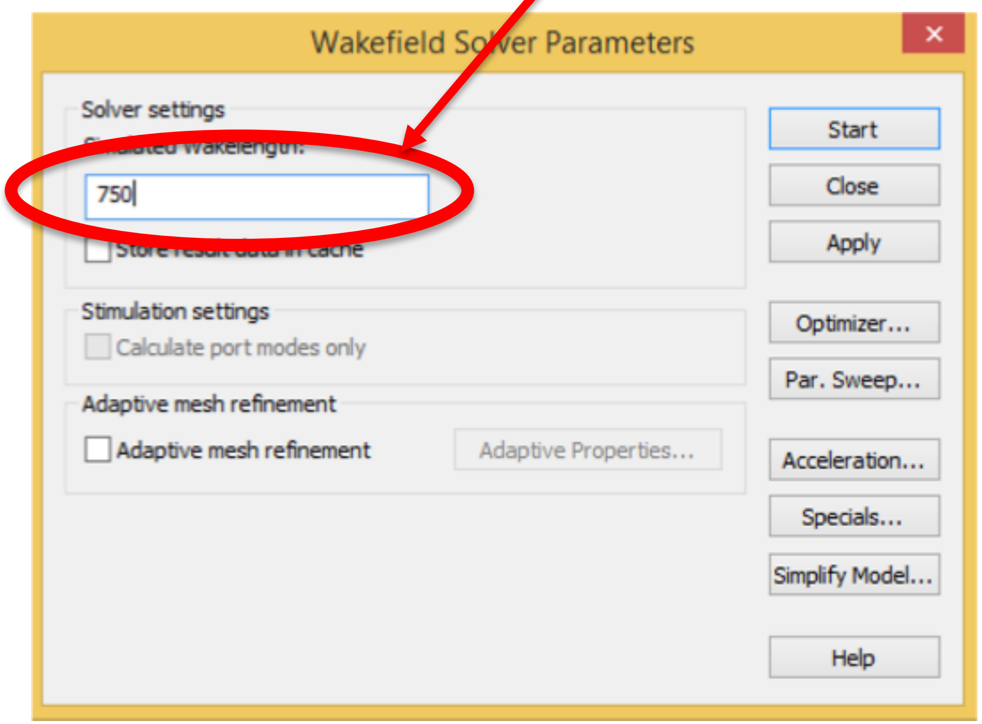


Simulation of a Resistive Wall Pipe

ANALYSIS

Now we are ready. From the Simulation bar click on “Setup Solver”





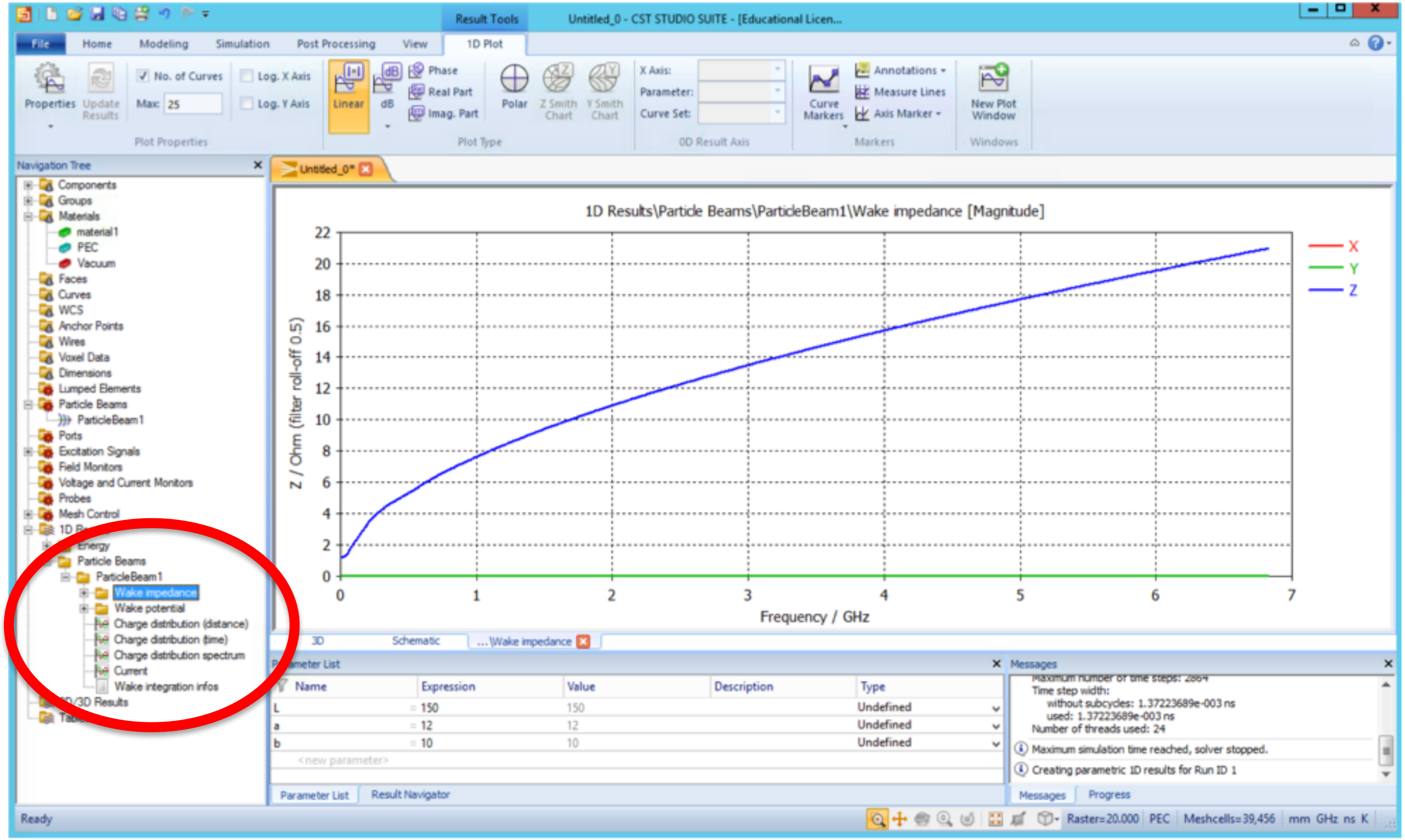
Set the “Simulated Wakelenght” to 750 mm (several bunch lengths) and click on start.

This is the maximum distance from the centre of the bunch where the wake potential is evaluated.

Simulation of a Resistive Wall Pipe

ANALYSIS

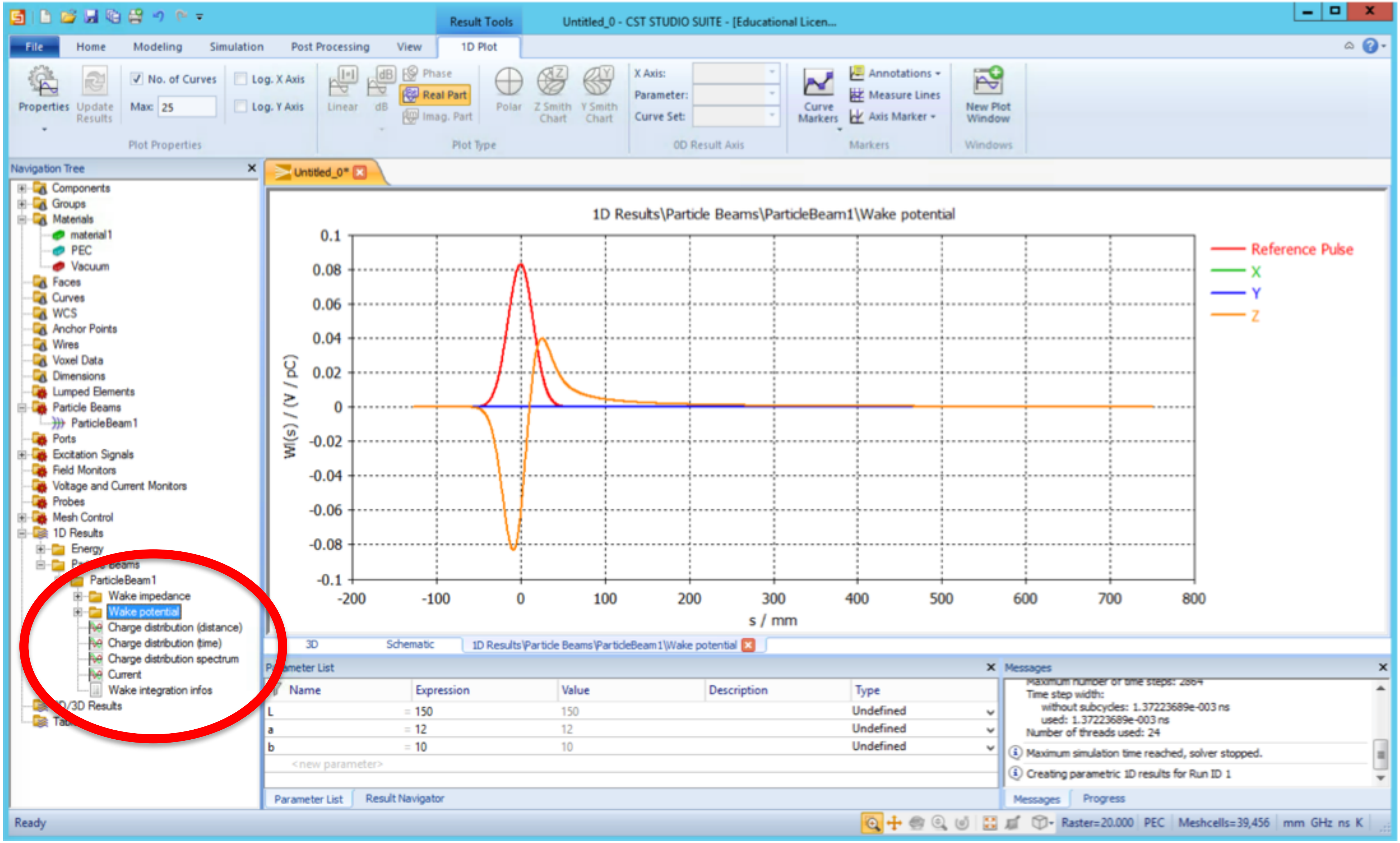
After a while we have our results on the navigation tree. Clicking on the folder 1D Results -> Particle Beams -> ParticleBeam1, we can plot the impedance and the wake potential. This is the impedance (absolute value).



Simulation of a Resistive Wall Pipe

ANALYSIS

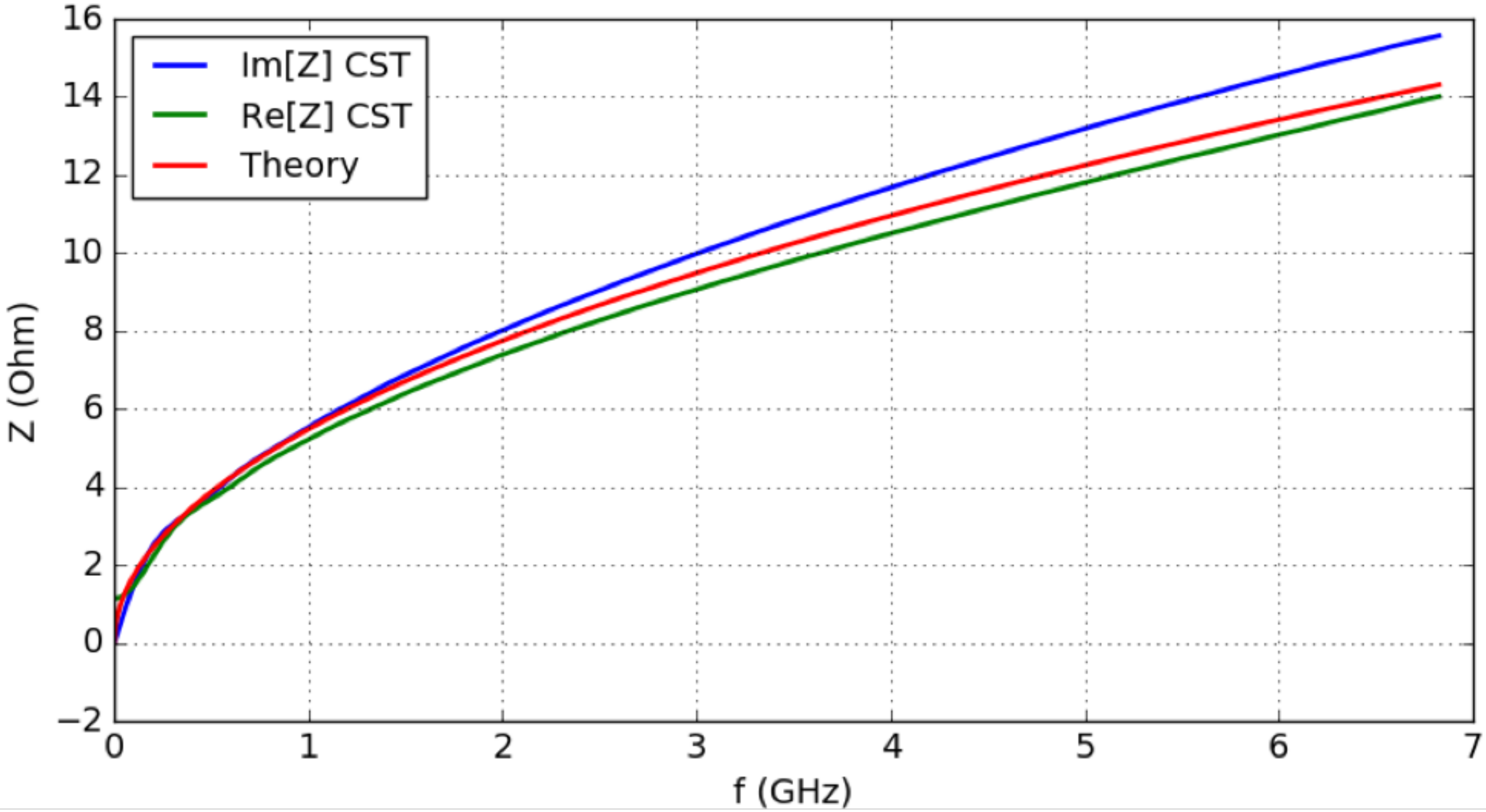
And this is the wake potential.



Simulation of a Resistive Wall Pipe

Comparison with theory

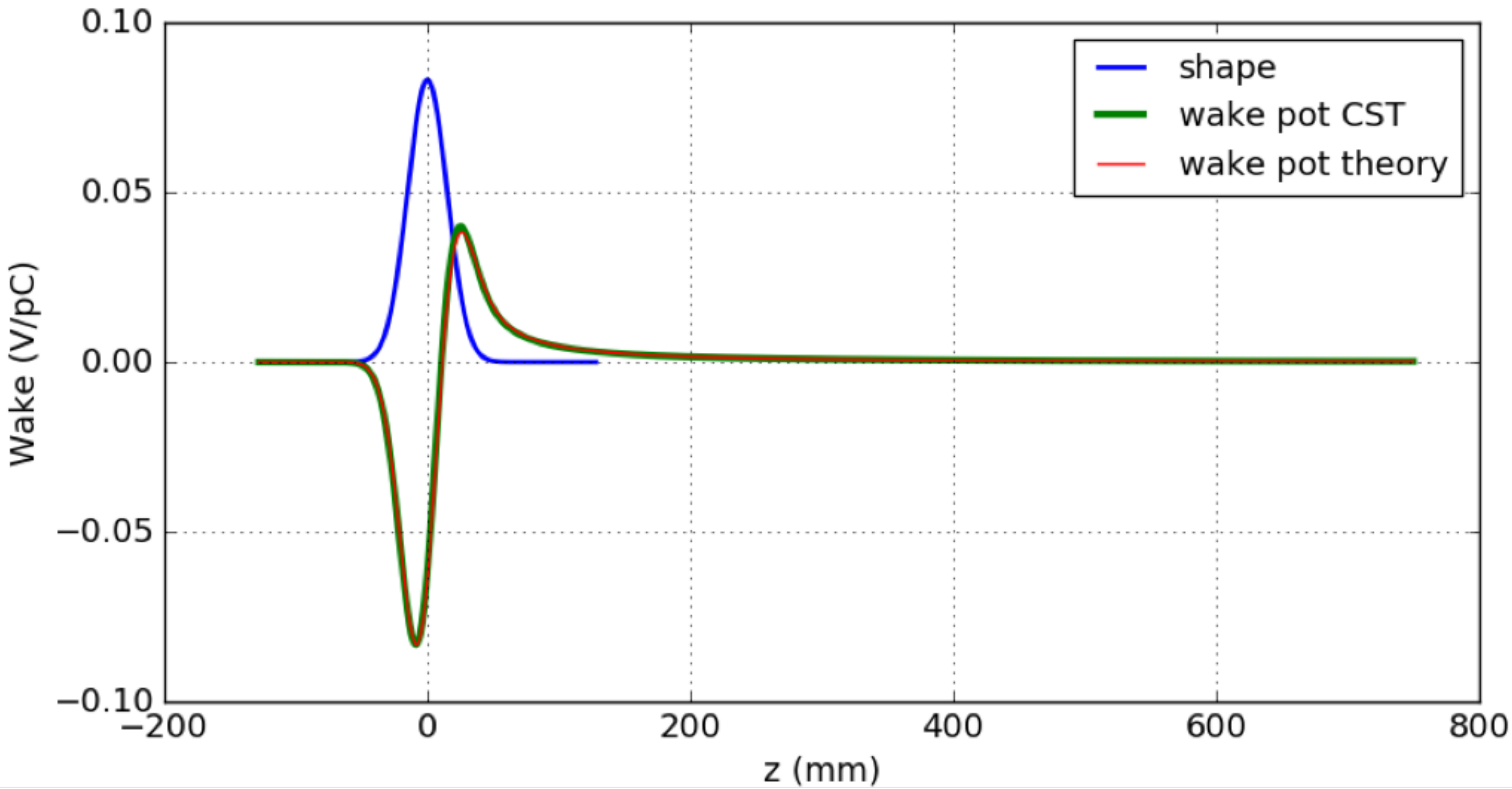
$$Z_{//}(\omega) = \left[1 - i\,\mathrm{sgn}(\omega)\right] \frac{L}{2\pi b} \sqrt{\frac{Z_0 |\omega|}{2c\sigma_c}}$$



Simulation of a Resistive Wall Pipe

Comparison with theory

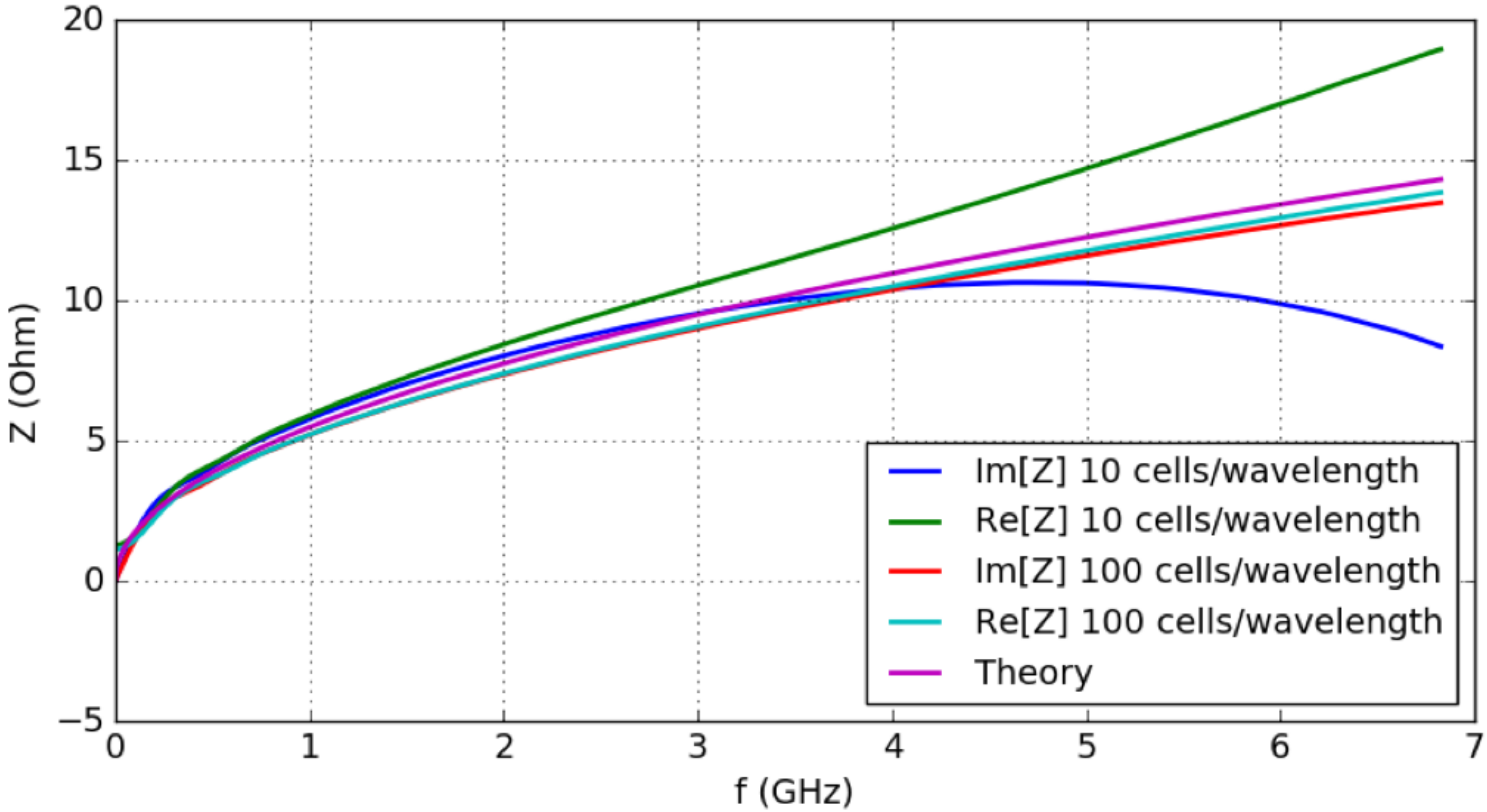
$$W_{//}(z) = \frac{cL}{4\pi b \sigma_z^{3/2}} \sqrt{\frac{Z_0}{\sigma_c}} |x|^{3/2} e^{-x^2} \{ I_{-3/4}(x^2) - I_{1/4}(x^2) + \mathrm{sgn}(z) [I_{3/4}(x^2) - I_{-1/4}(x^2)] \}$$



Simulation of a Resistive Wall Pipe

LAST BUT NOT LEAST

CST, as other codes which use Finite Difference Method, is particularly sensitive to the mesh accuracy. In order to better understand this point, let's change the "cells per wavelenght" from 40 to 10 or 100 …



Simulation of a Resistive Wall Pipe

LAST BUT NOT LEAST

Try a simulation with:

1) Load from material library: pure copper
2) Pipe in copper
3) Bunch length 25 mm
4) Cells per wavelength 10 … 60
5) Simulated wavelength 3000 mm
6) Look at the real and imaginary part of the impedance