EUROPEAN SPALLATION SOURCE

LUNDS UNIVERSITET

RENdtl

Renato De Prisco

ADR - 29/11/ 2012

Content

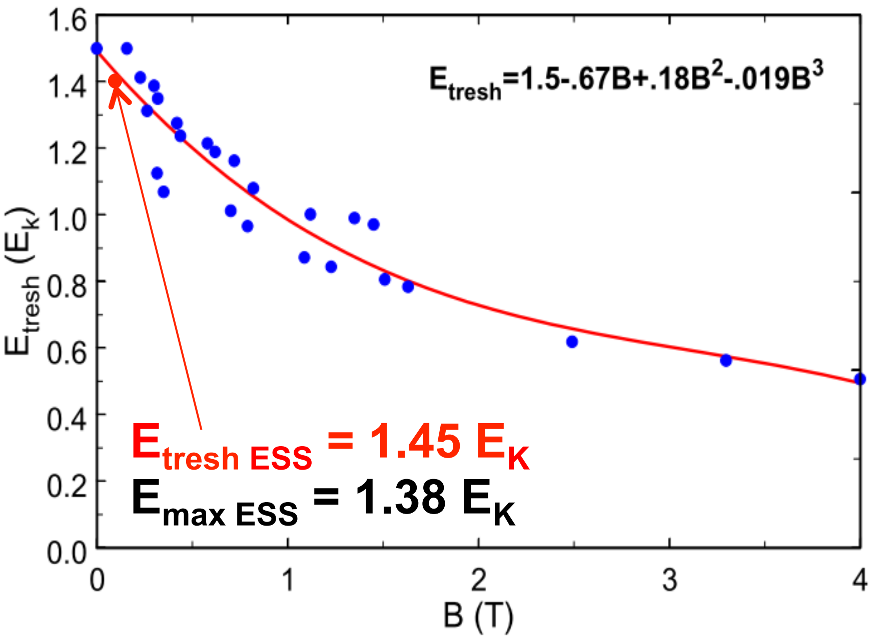
- DTL General Parameters
- Peak electric field
- DTL Geometric Parameters
- Tank Field Tuning Software
- DTL Tank Properties
- Post Couplers
- RENdtl

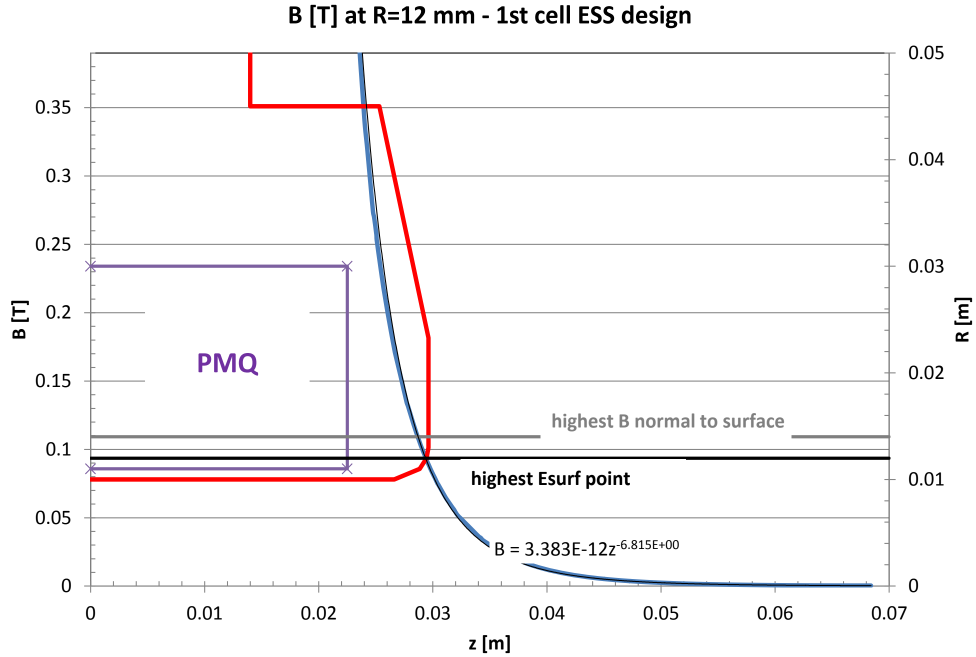
Parameters and Constraints

- Energy: 3 to 77 MeV in 4 tanks, total tanks length = 32m
- Power:
  - 1 klystron of 2.8 MW per tank, duty cycle = 4%
  - Power at RF tank input = 2.15 MW (30% margin for WG losses)
  - 2.15 MW > $P_{copper} \times 1.25 + P_{beam}$ (I_{beam} = 50 mA, 1.25 margin on Superfish computation)
  - 2 power couplers per tank (each peak power = 1 MW)
- E_0 linearly ramped in Tank1 from 2.8 MV/m to 3.2 MV/m
- E_0 = 3.16 MV/m in Tank 2-3-4
- PMQ: diameter=60mm, lengths = 45mm and 80mm
- $E_{surface} < 1.4\ E_k$(E_k=18.4MV/m @ 352.20MHz)

Peak Electric Field

Moretti and others, have made extensive measurements of RF breakdown thresholds in the presence of a DC magnetic field. The result of their measurements are reproduced in the left-hand figure.





- Maximum surface electric field is at R = 12mm.
- At that point, for the 1st cell, B = 0.092 T.
- E_K = 18.43 MV/m at 352.2MHz.

Drift Tube Geometric Parameters

DT diameter = 90mm

R_c = 5 mm

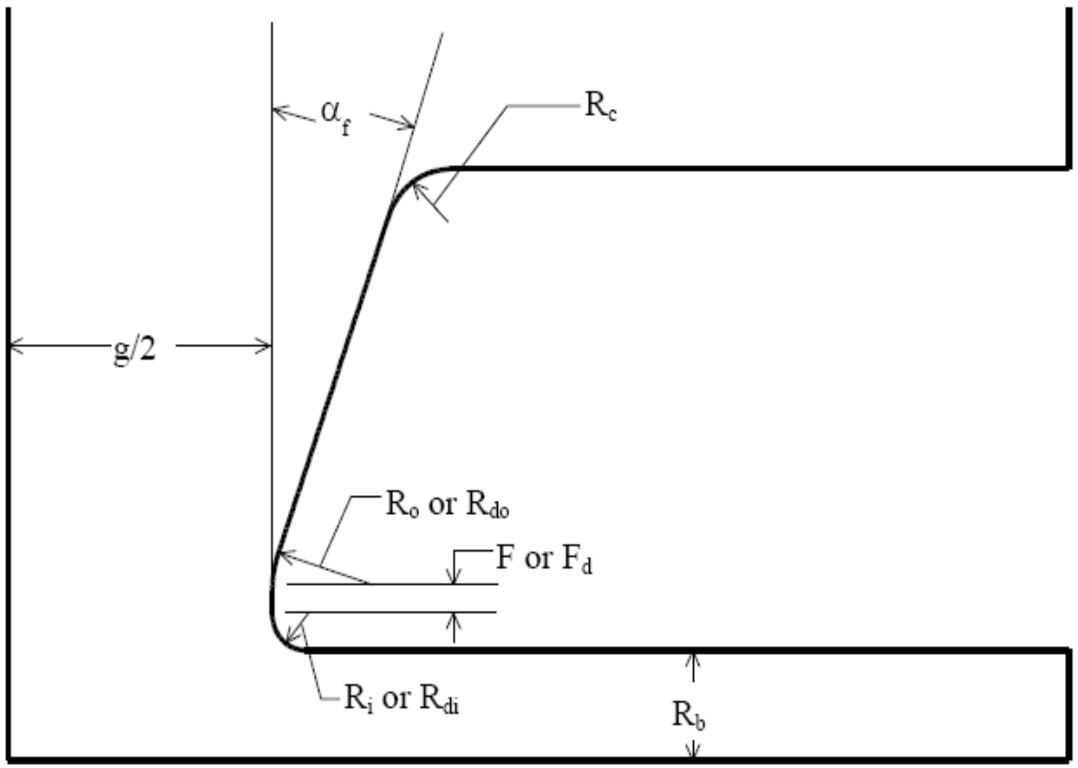
R_o = 8 mm

R_i = 3 mm

R_b = 10, 10, 11, 12 mm

F = 7, 5, 5, 4 mm

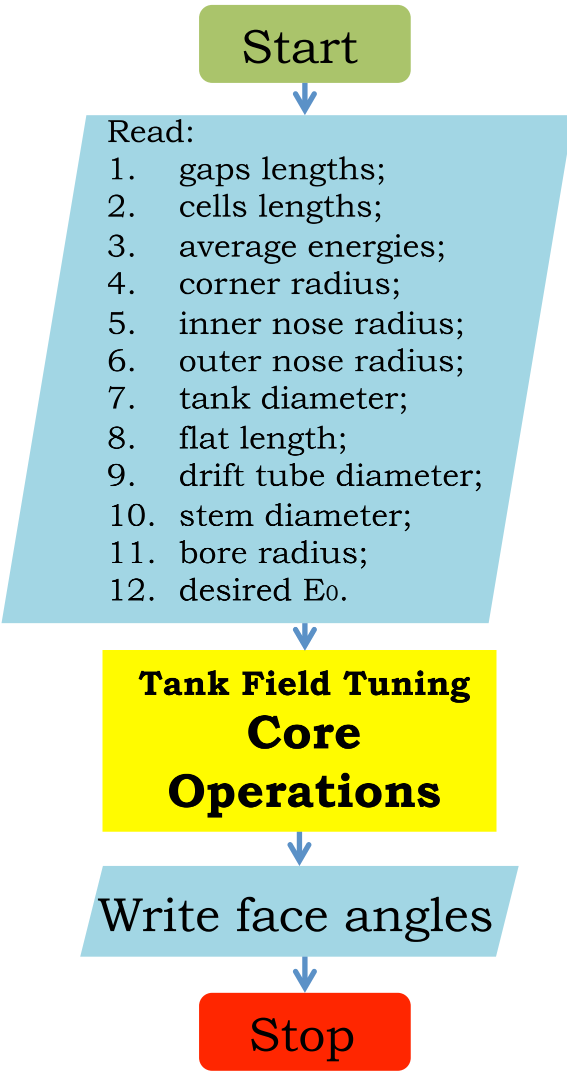
Tank diameter = 520mm



Gap and cell length from beam dynamics.

A = A1, A2, A3, A4 means that A1 is referred to Tank1, A2 to Tank2, etc.

Tank Field Tuning Software



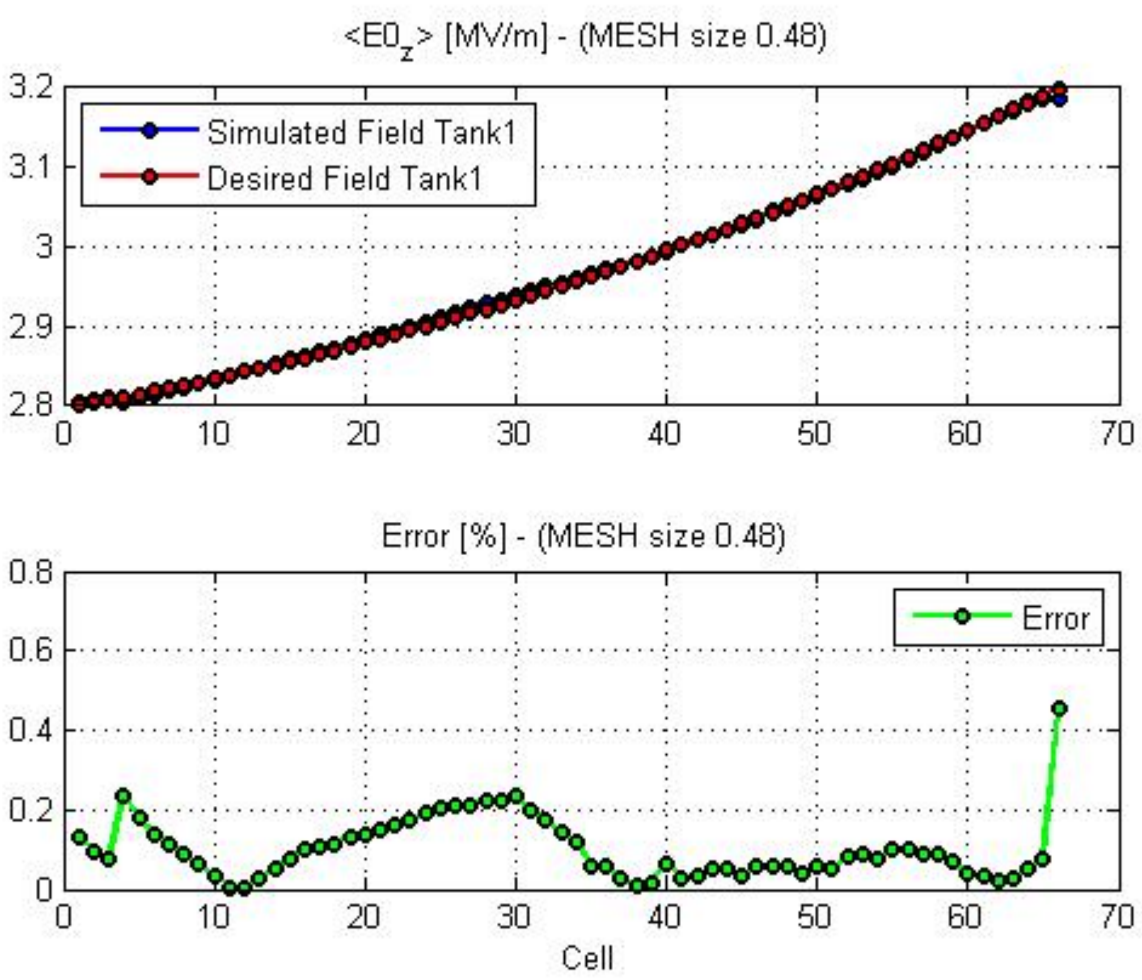
Tank Field Tuning Software is useful to find face angles which:

- take into account the frequency shifts of stems;
- take in account frequency shifts of post coupler;
- give desired E0 (not only constant or ramped).

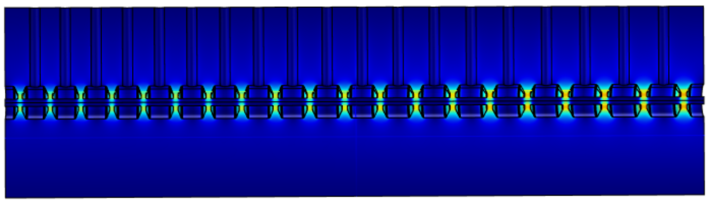
Tank Field Tuning Software is useful also to:

- take in account the maximum power dissipation;
- determine the number of post couplers and their positions;
- interact with the most popular 3D software.

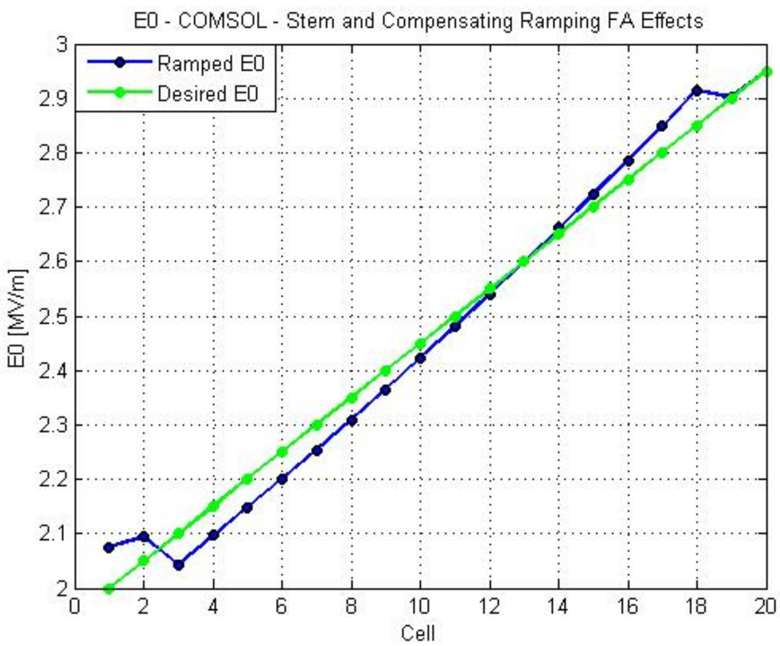
Accelerating field

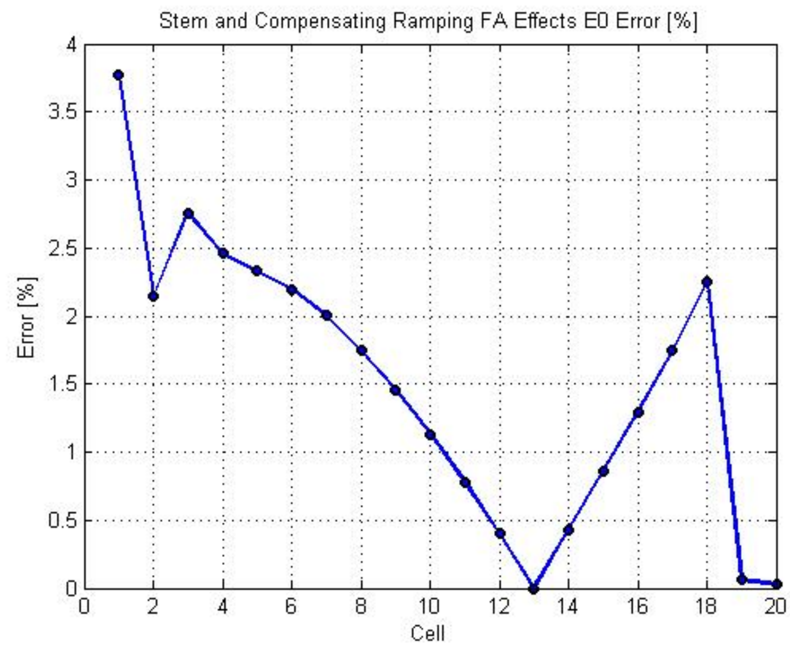


3D Validation



- Design procedure validated in a representative tank (20 cells) with aggressively ramped field
- 1 100 000 tetrahedra (revolution swept, similar to Superfish)





Tank Properties

Parameter/Tank	1	2	3	4
Cells Number	66	36	29	25
E_0 $\left[\frac{MV}{m}\right]$	2.8 to 3.2	3.16	3.16	3.16
Synchronous Phase [°]	-35 to -24	-24	-24	-24
End tank phase matching [°]	-8	-8	-8	-6
Tank length $[m]$	7.95 (9.3λ)	7.62 (8.9λ)	7.76 (9.1λ)	7.72 (9.0λ)
Q_0 (Super Fish)	53000	56000	55000	55000
Modules Number	4	4	4	4
Peak Power in Copper $[MW]$	0.91	0.91	0.92	0.95
Beam output energy $[MeV]$	21.4	41.0	60.0	77.7
Peak RF Power (1.25 margin) $[MW]$	2.06	2.12	2.10	2.07

Errors and Frequency Budget

- Tuners compensate construction errors.
- Evaluation with realistic tolerances on important dimensions. (tank diameter, drift-tube lengths, drift tube diameter and face angles).
- Movable tuners compensate thermal deformations in operation.
- Evaluation with thermo-mechanical simulations.
- 1st cell of Tank 1 is the most sensitive. It is taken for all cells as a margin.

Cell$_1$ (Tank$_1$)	Sensitivity $[\frac{MHz}{mm}]$	Machining Error $[mm]$	Dynamic Error $[mm]$	Static Error $[MHz]$	Dynamic Error $[MHz]$
D_{Tank}	-045	$\pm$0.100	0.010	$\pm$0.045	0.005
D_{DT}	0.6	$\pm$0.025	0.020	$\pm$0.015	0.012
Gap	5.6	$\pm$0.025	0.007	$\pm$0.140	0.039
Face Angle	5.8	$\pm$0.025	0.003	$\pm$0.145	0.017
D_{Stem}	-0.136	$\pm$0.025	0.010	$\pm$0.003	0.001
Sum				$\pm$0.348	0.075
Total				0.405	

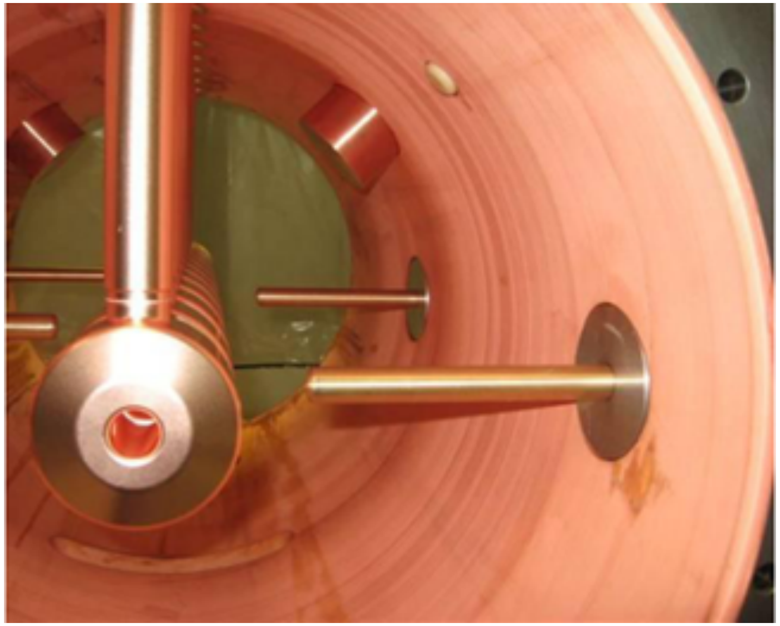
Post Coupler

DTL *stabilisation* or *compensation* against geometric errors (manufacturing, deformation) is done by Post Couplers.

Post Couplers must keep E0 within specifications (±1%) in case of a reasonable perturbation of the end-cells.

Cell1 of Tank 1 is the most sensitive to perturbation.

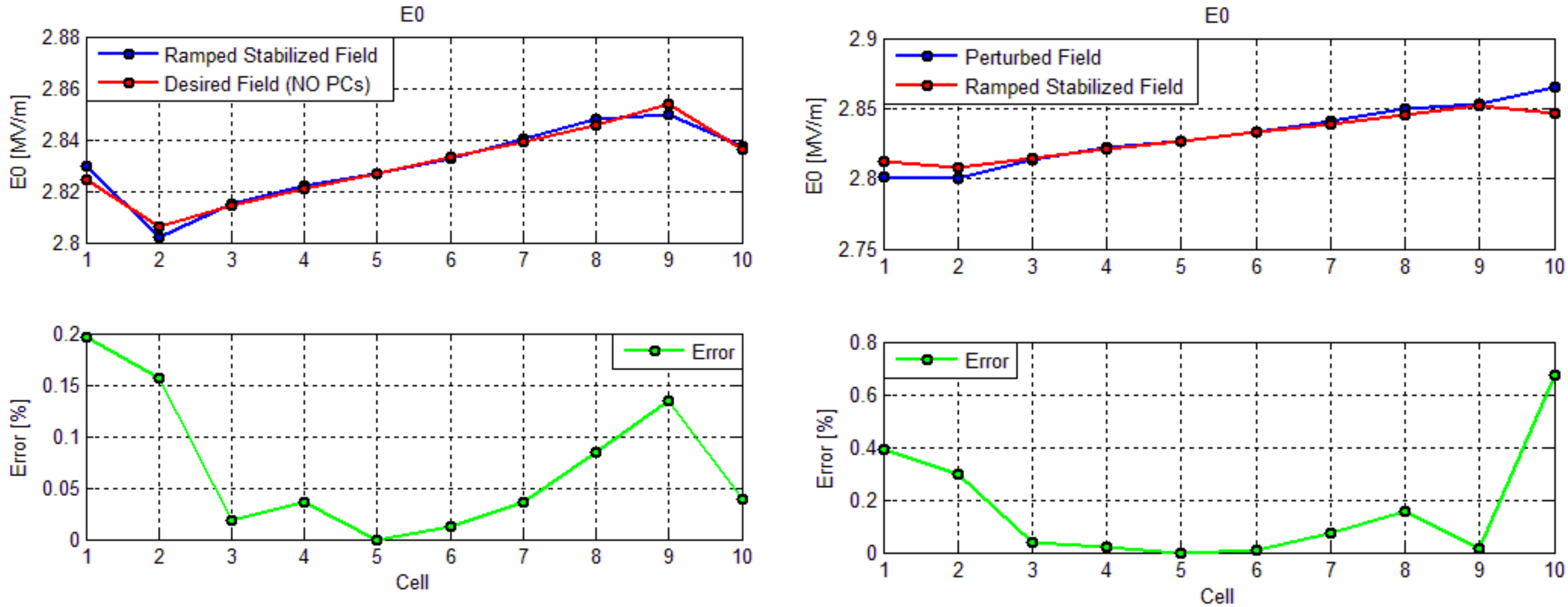
Electric field of the post mode and the magnetic field of the accelerating mode produce a non-zero Poynting vector longitudinal component.



Post Couplers (case 1)

On the left figure, is plotted the accelerating field in a sample tank (case1) in which are present unexcited post couplers (left figure).

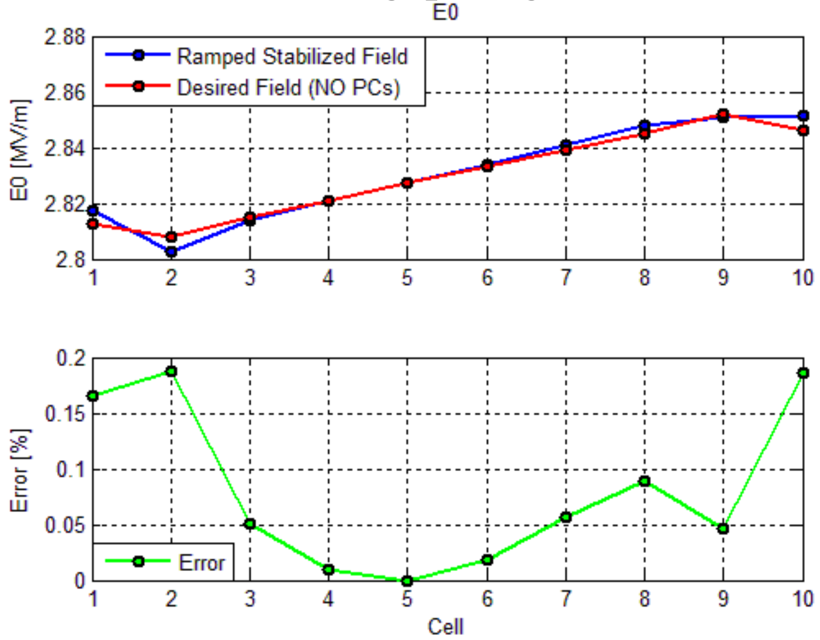
To study the effectiveness of post couplers in stabilising the field, the face angles are those that allow a flat field (right figure).

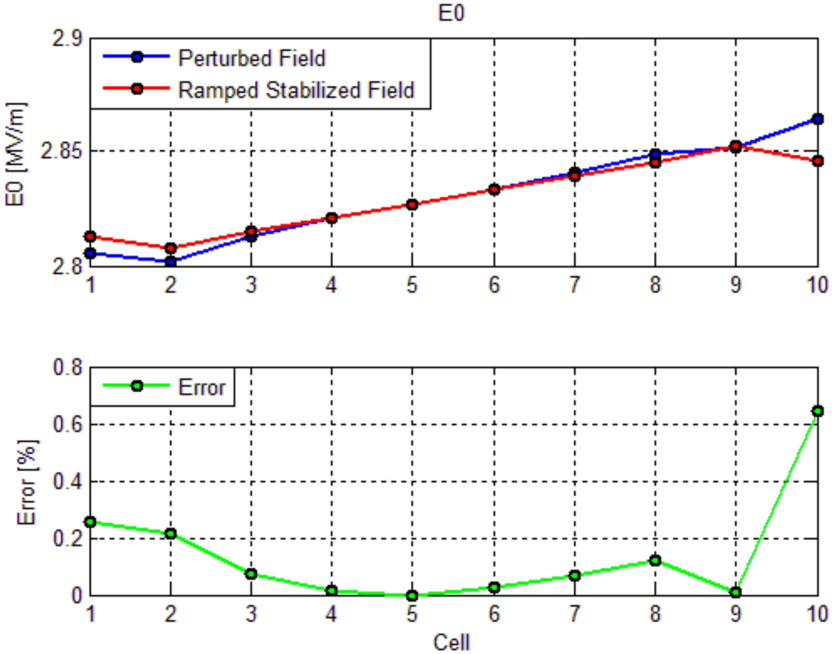


Post Couplers (case 2)

It is possible to get a very good result: the error on the field in a **perturbed** case is less than 0.7%.

The face angles perturbation of the end cell on the frequency (to have a flat field), is the same perturbation on the frequency given by an error in the order of tenths of a millimeter on the gap length.

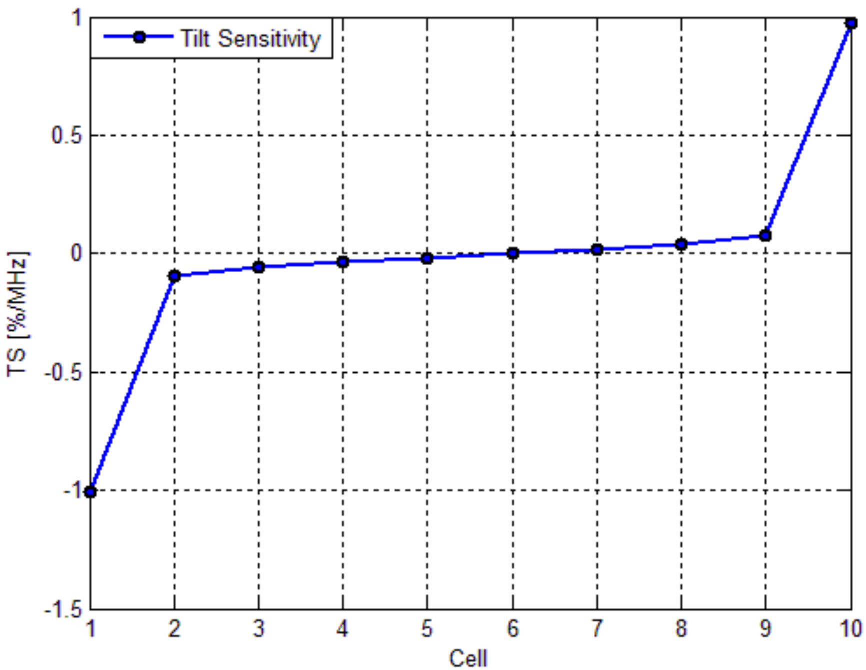




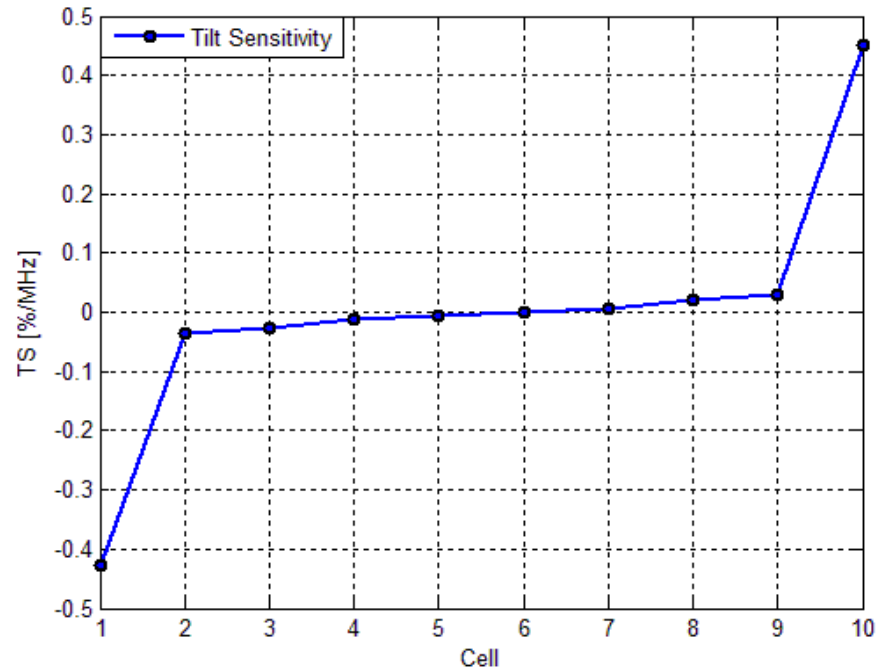
Tilt Sensitivity

A Tilt Sensitivity (TS) indicates the effectiveness of post couplers in stabilising the field.

$$TS = \left(\frac{E_{0,pert} - E_{0,unpert}}{E_{0,unpert}} \right) \frac{1}{\Delta f}$$



10 cells tank: cell equal to cell 10 of tank1



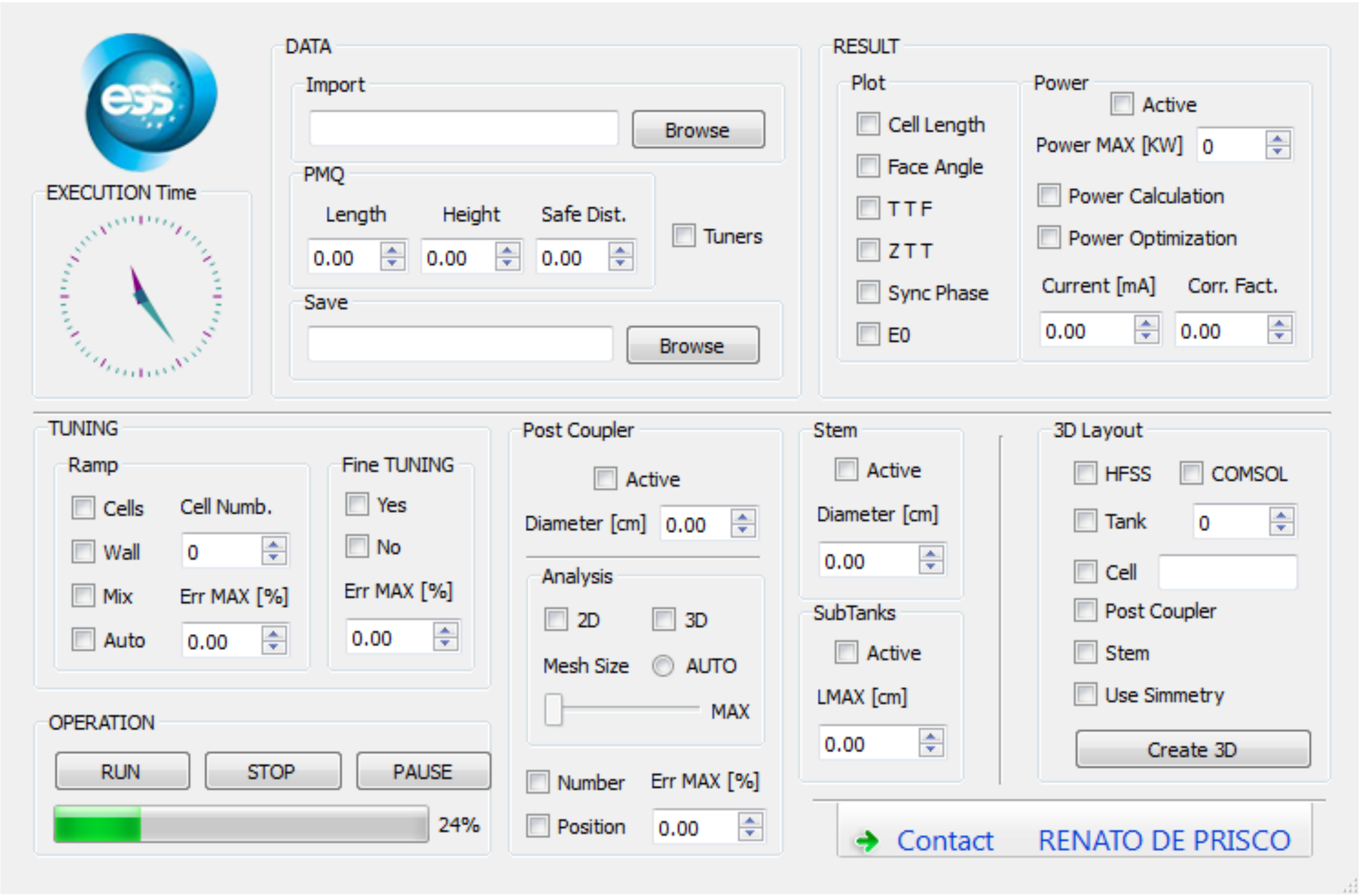
10 cells tank: cell equal to cell 30 of tank1

Post Coupler Properties

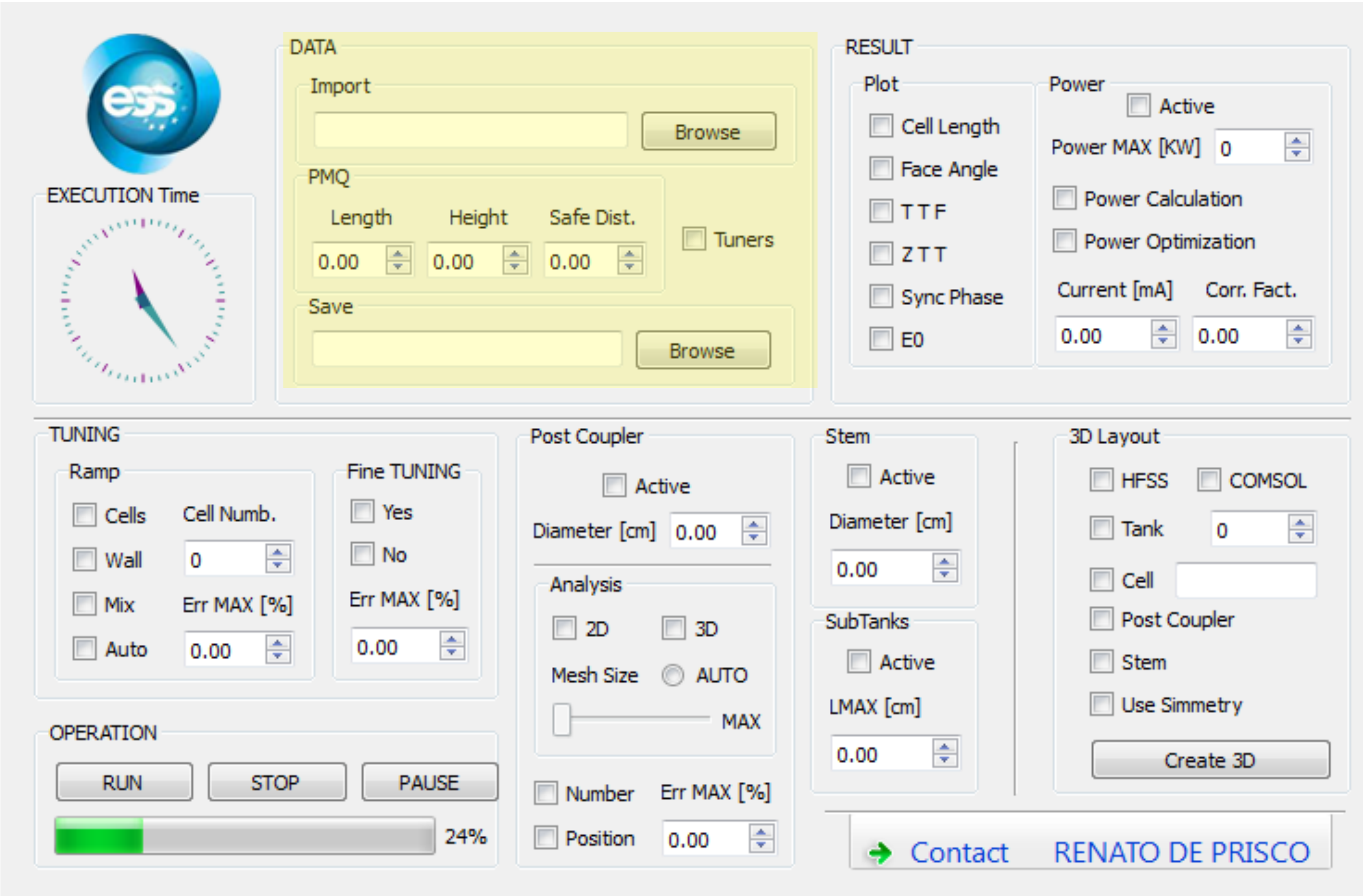
These nominally unexcited bent post couplers stabilise the **natural ramp** in the field produced by perturbations of the end cells. Other perturbations that tend to disturb the natural distributions, excite the post couplers as necessary to prevent the field disturbance.

Parameter/Tank	1	2	3	4
Num cells	66	36	29	25
PCs distance $[m]$	0.35	0.33	0.35	0.32
Num PCs	22	23	28	24
Num PCs / Num cells	1/3	first 1/2	1/1	1/1
Detuning $[MHz]$	0.17	0.17	0.20	0.17
Power $[MW]$	0.031	0.036	0.044	0.031

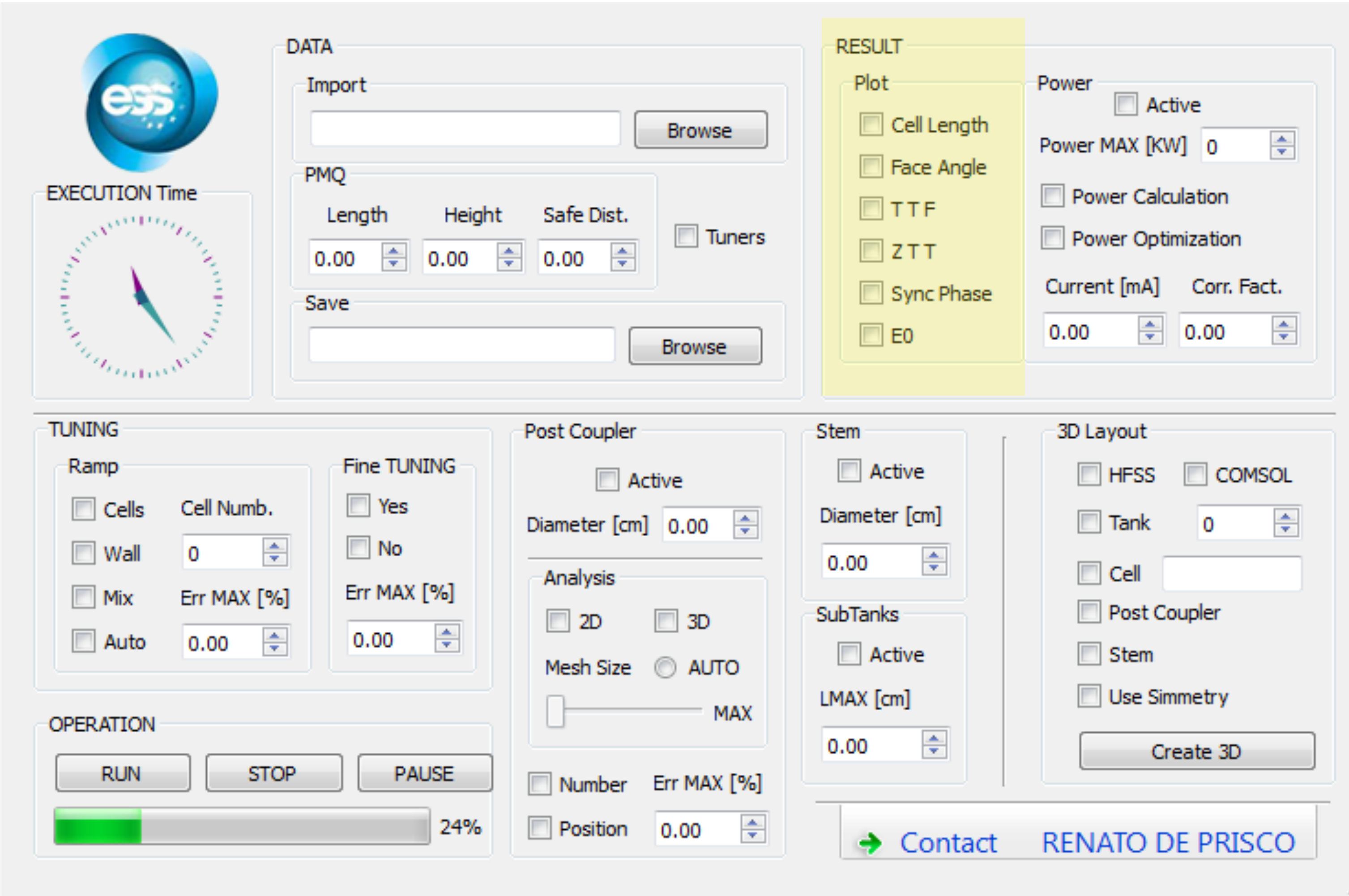
RENdtl


DATA
Import
Browse
PMQ
Length
Height
Safe Dist.
0.00
0.00
0.00
Tuners
Save
Browse
EXECUTION Time
RESULT
Plot
Cell Length
Face Angle
T T F
Z T T
Sync Phase
E0
Power
Active
Power MAX [KW]
0
Power Calculation
Power Optimization
Current [mA]
Corr. Fact.
0.00
0.00
TUNING
Ramp
Cells
Cell Numb.
Wall
0
Mix
Err MAX [%]
Auto
0.00
Fine TUNING
Yes
No
Err MAX [%]
0.00
Post Coupler
Active
Diameter [cm]
0.00
Analysis
2D
3D
Mesh Size
AUTO
MAX
Number
Err MAX [%]
Position
0.00
Stem
Active
Diameter [cm]
0.00
SubTanks
Active
LMAX [cm]
0.00
3D Layout
HFSS
COMSOL
Tank
0
Cell
Post Coupler
Stem
Use Simmetry
Create 3D
OPERATION
RUN
STOP
PAUSE
24%
Contact
RENATO DE PRISCO

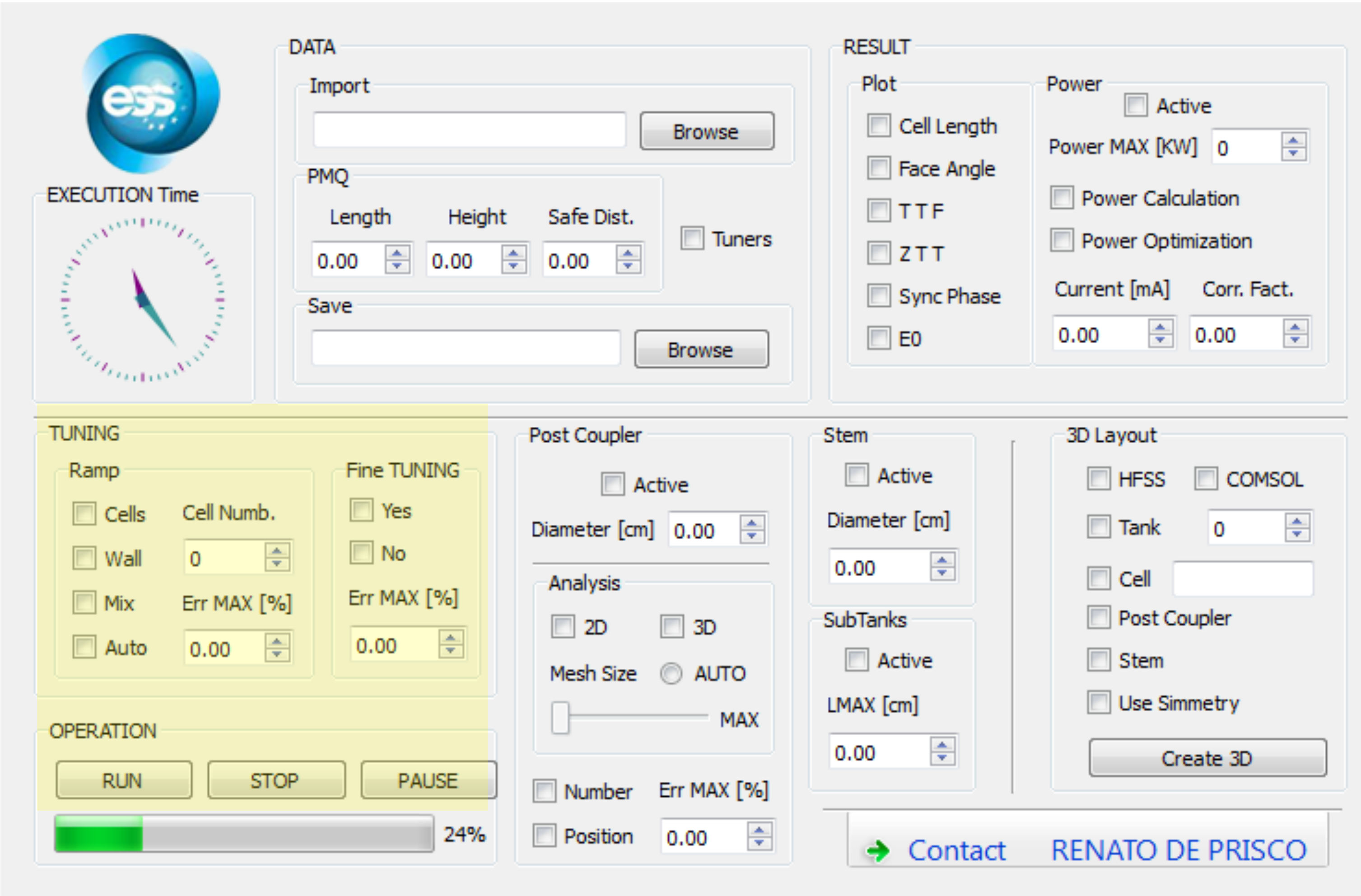
RENdtl - Data Import



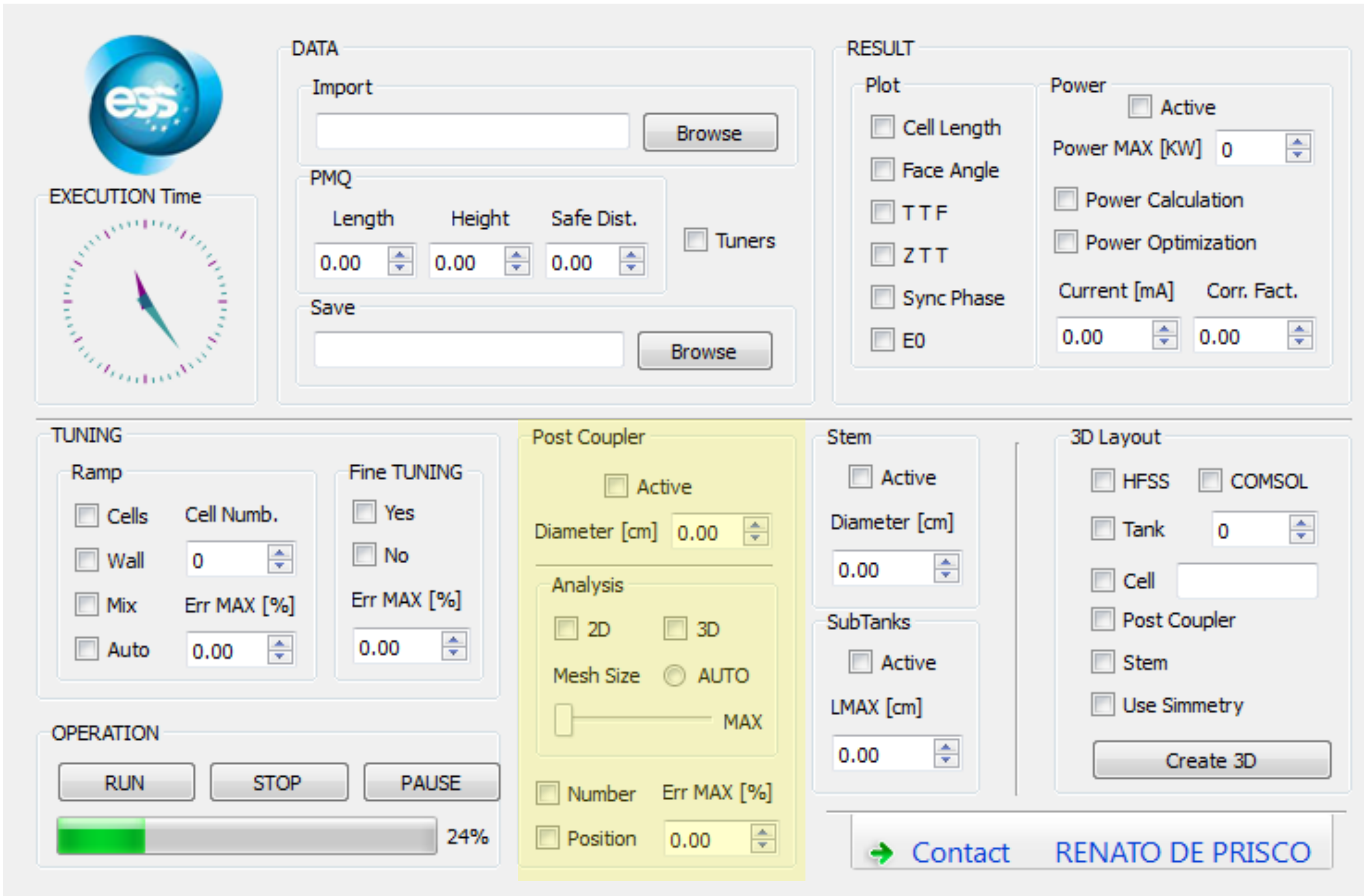
RENdtl - Plot Result



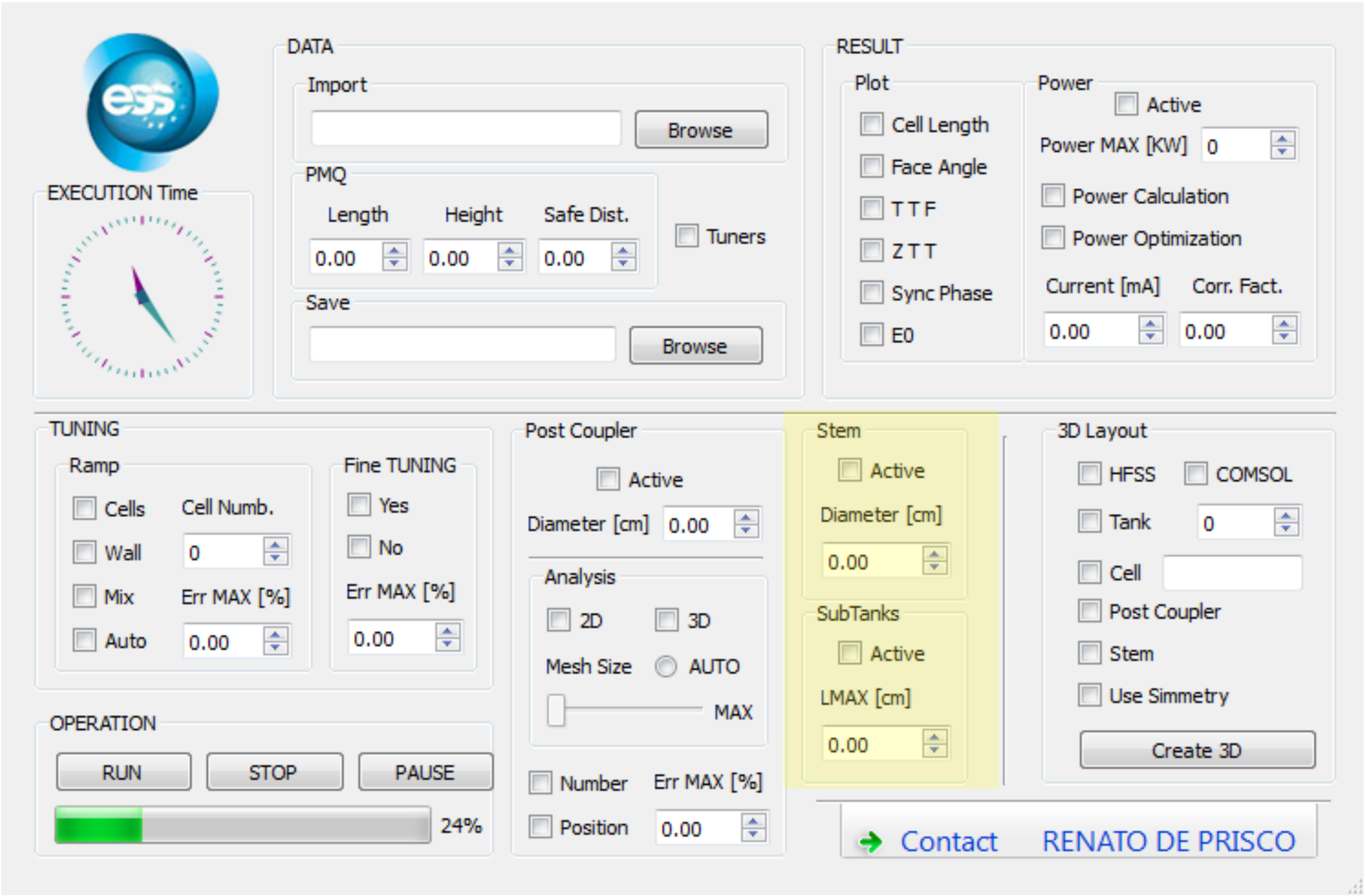
RENdtl - Tuning



RENdtl - Post Couplers



RENdtl - Stem



DATA
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Browse
PMQ
Length
Height
Safe Dist.
0.00
0.00
0.00
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Power Calculation
Power Optimization
Current [mA]
Corr. Fact.
0.00
0.00
EXECUTION Time
TUNING
Ramp
Cells
Cell Numb.
Wall
0
Mix
Err MAX [%]
Auto
0.00
Fine TUNING
Yes
No
Err MAX [%]
0.00
Post Coupler
Active
Diameter [cm]
0.00
Analysis
2D
3D
Mesh Size
AUTO
MAX
Number
Err MAX [%]
Position
0.00
Stem
Active
Diameter [cm]
0.00
SubTanks
Active
LMAX [cm]
0.00
3D Layout
HFSS
COMSOL
Tank
0
Cell
Post Coupler
Stem
Use Simmetry
Create 3D
OPERATION
RUN
STOP
PAUSE
24%
Contact
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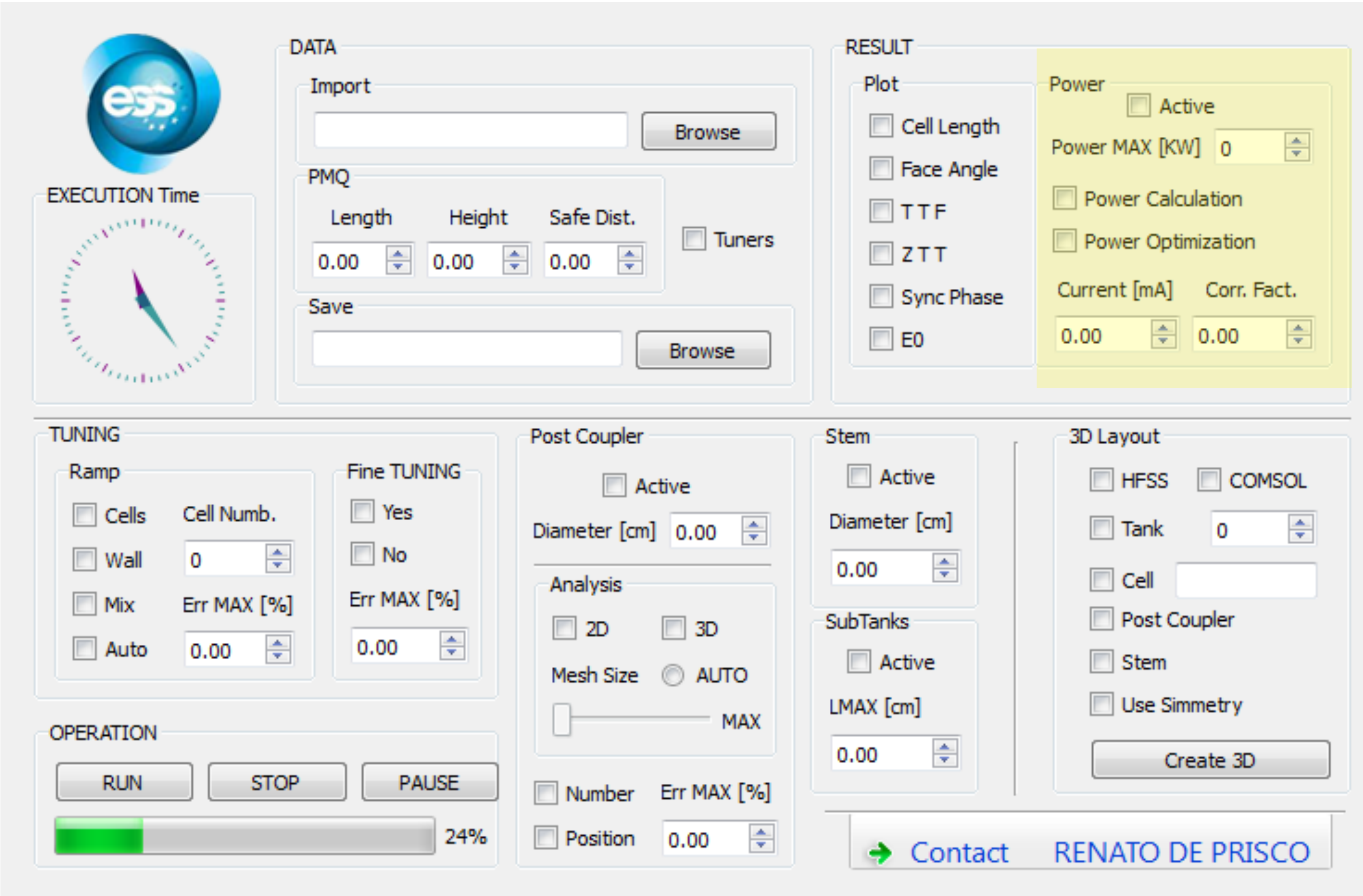
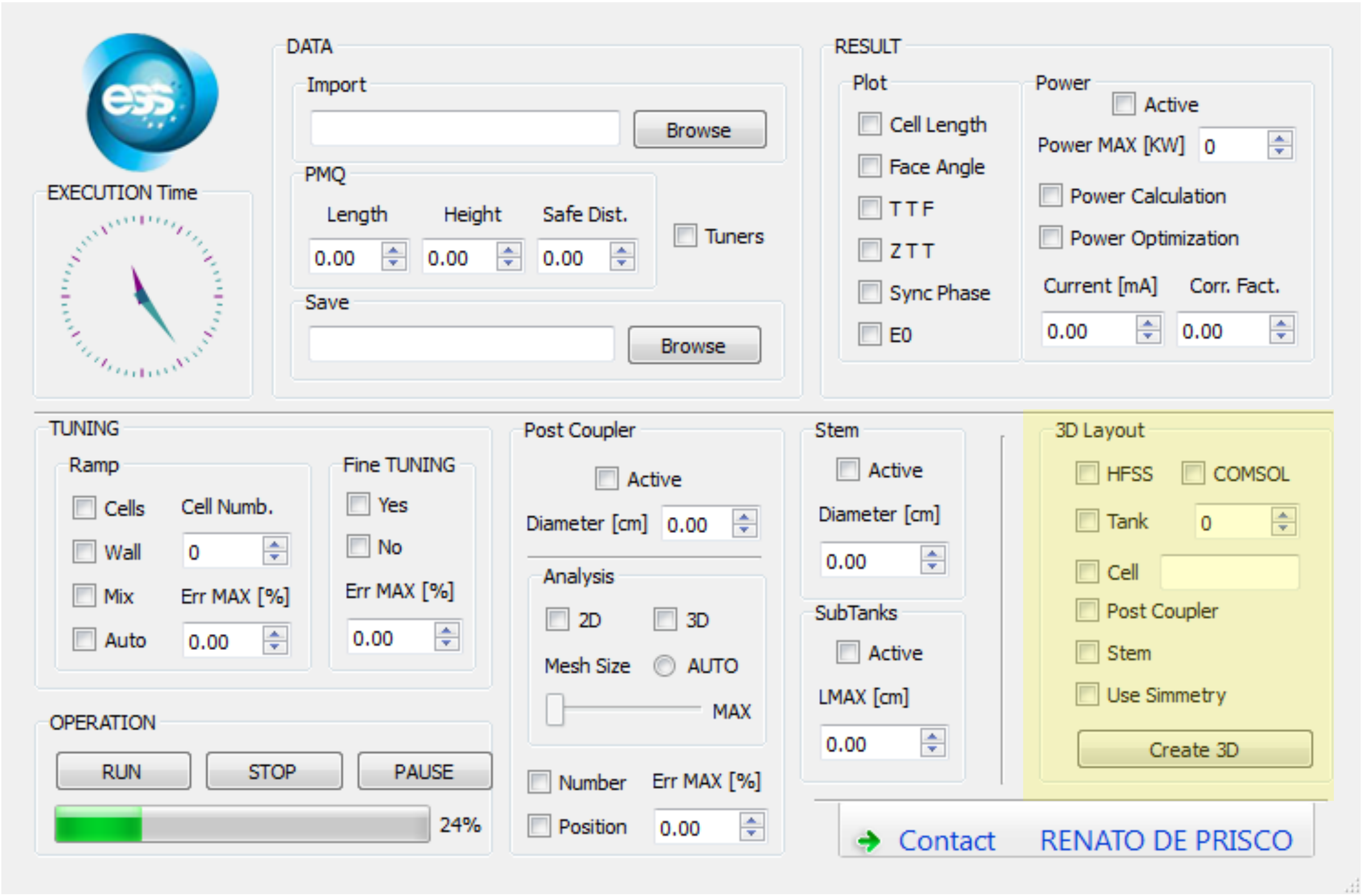
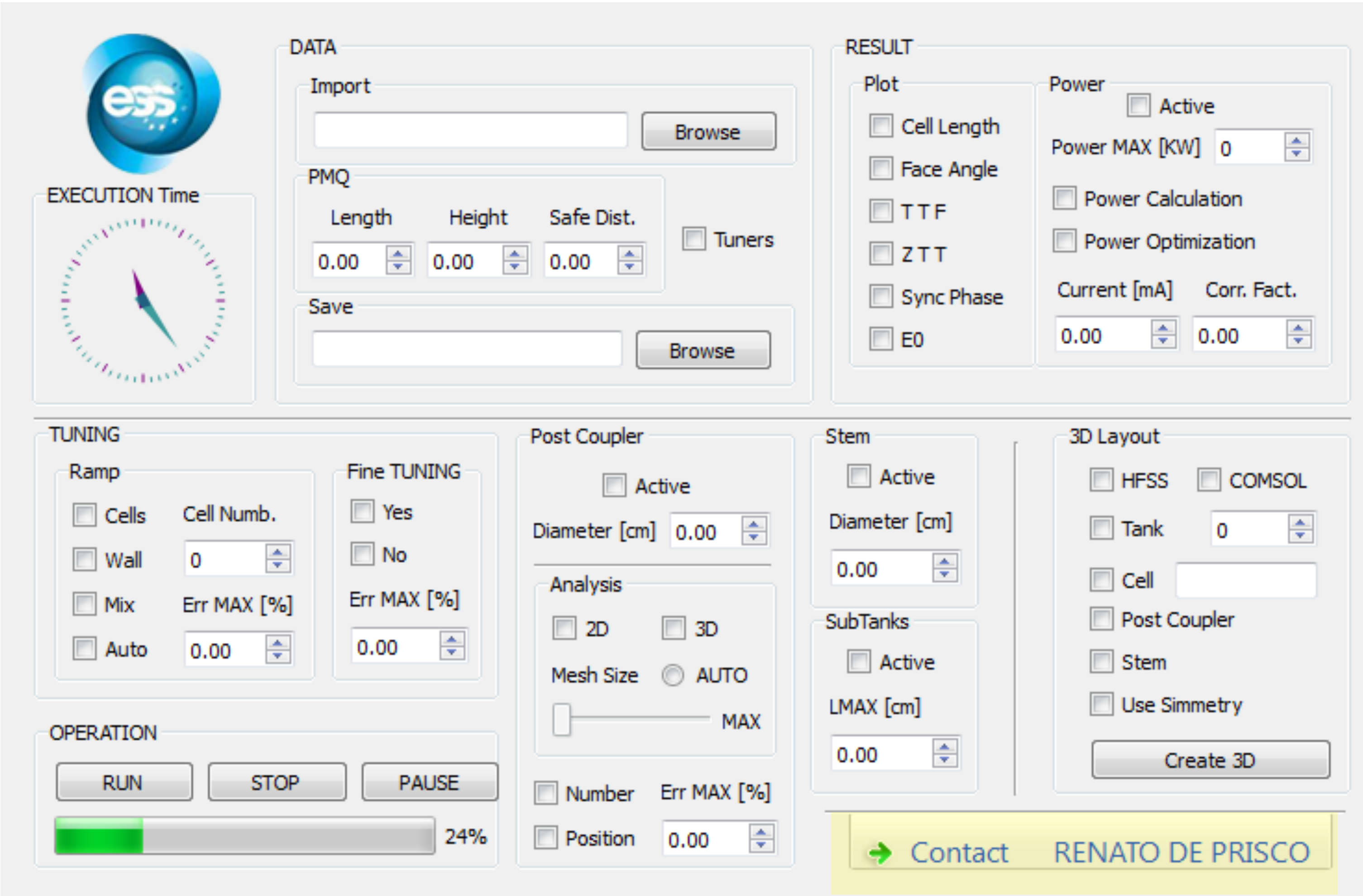
RENdtl - Power



RENdtl - 3D Analisys



RENdtl - Contact



Thanks ESS

Happy birthday Steve!