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RENdtI

Renato De Prisco

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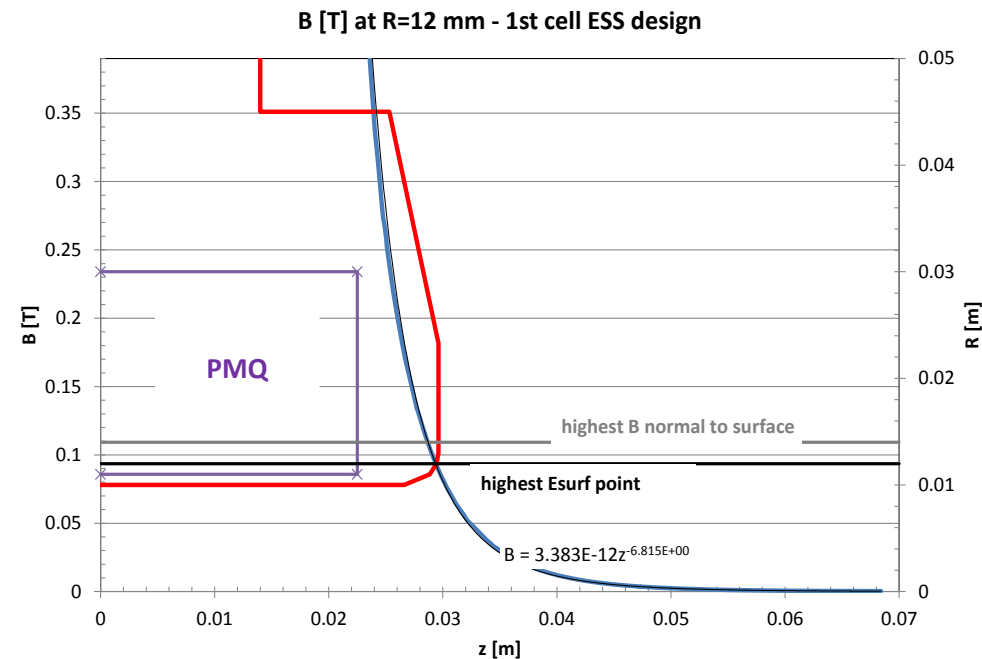
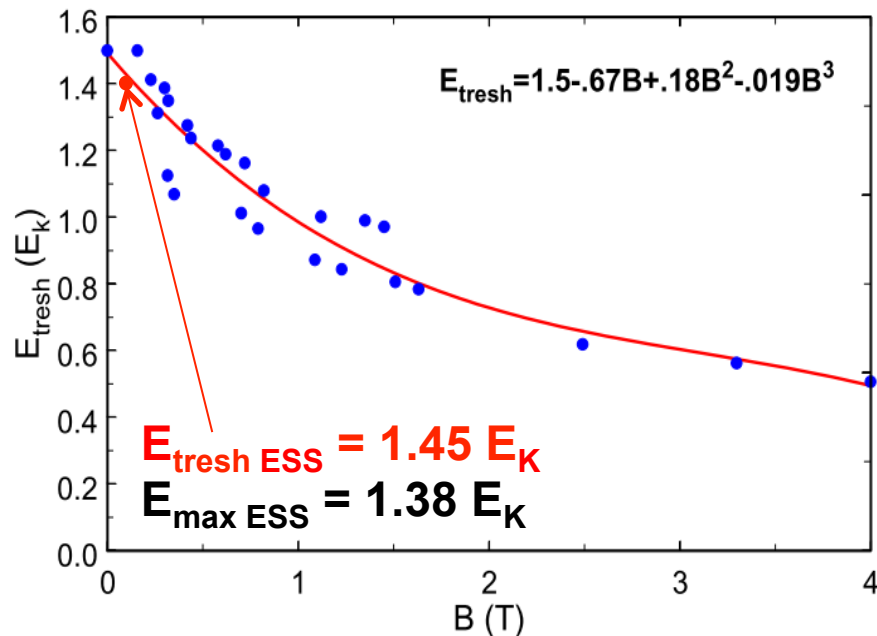




- DTL General Parameters
- Peak electric field
- DTL Geometric Parameters
- Tank Field Tuning Software
- DTL Tank Properties
- Post Couplers
- RENdtl

- 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)
 - $2.15 \text{ MW} > P_{\text{copper}} \times 1.25 + P_{\text{beam}}$ ($I_{\text{beam}} = 50 \text{ mA}$, 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
- $E_0 = 3.16 \text{ MV/m}$ in Tank 2-3-4
- PMQ: diameter=60mm, lengths = 45mm and 80mm
- $E_{\text{surface}} < 1.4 E_k (E_k = 18.4 \text{ MV/m @ } 352.20 \text{ MHz})$

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

DT diameter = 90mm

$R_c = 5 \text{ mm}$

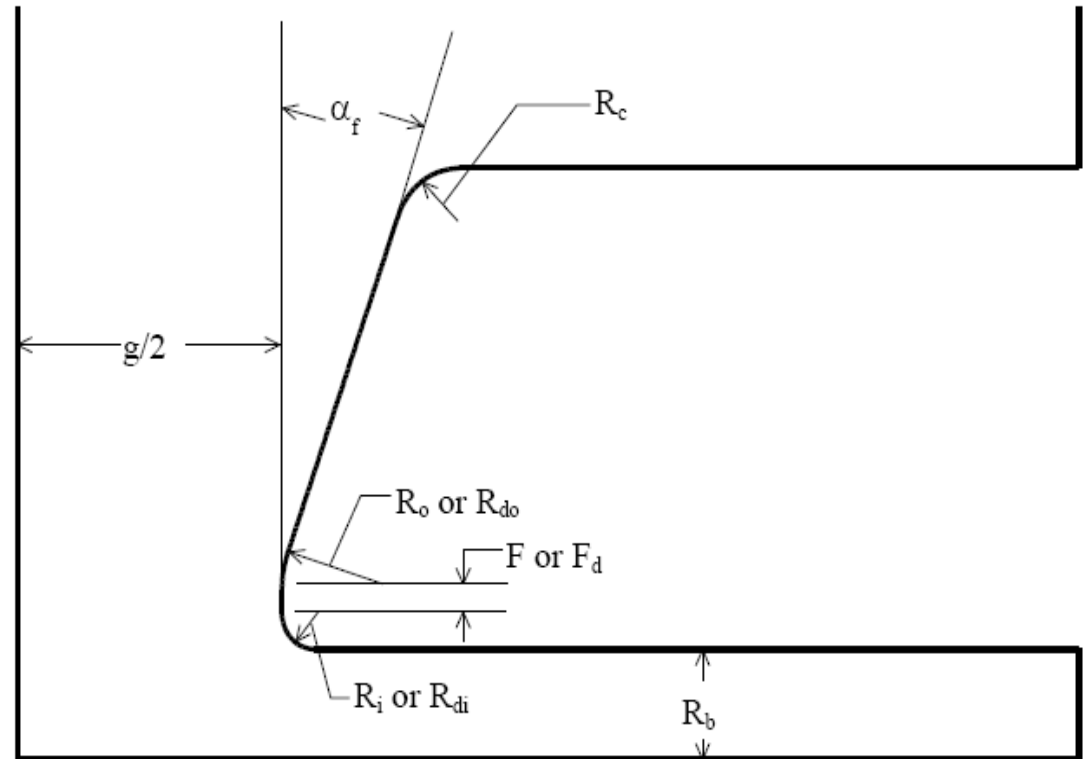
$R_o = 8 \text{ mm}$

$R_i = 3 \text{ mm}$

$R_b = 10, 10, 11, 12 \text{ mm}$

$F = 7, 5, 5, 4 \text{ mm}$

Tank diameter = 520mm

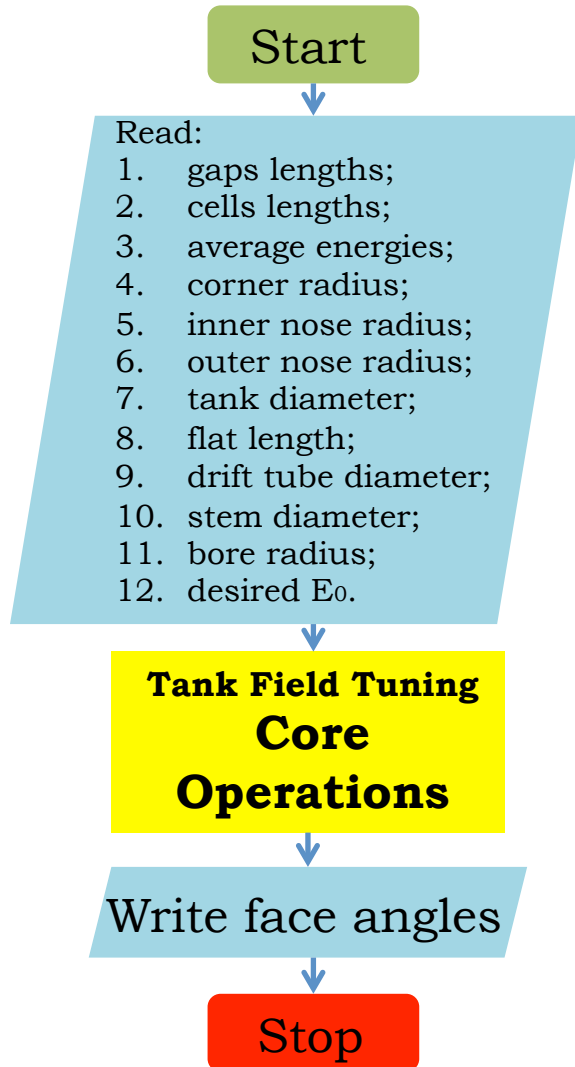


Gap and cell length from beam dynamics.

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



Tank Field Tuning Software



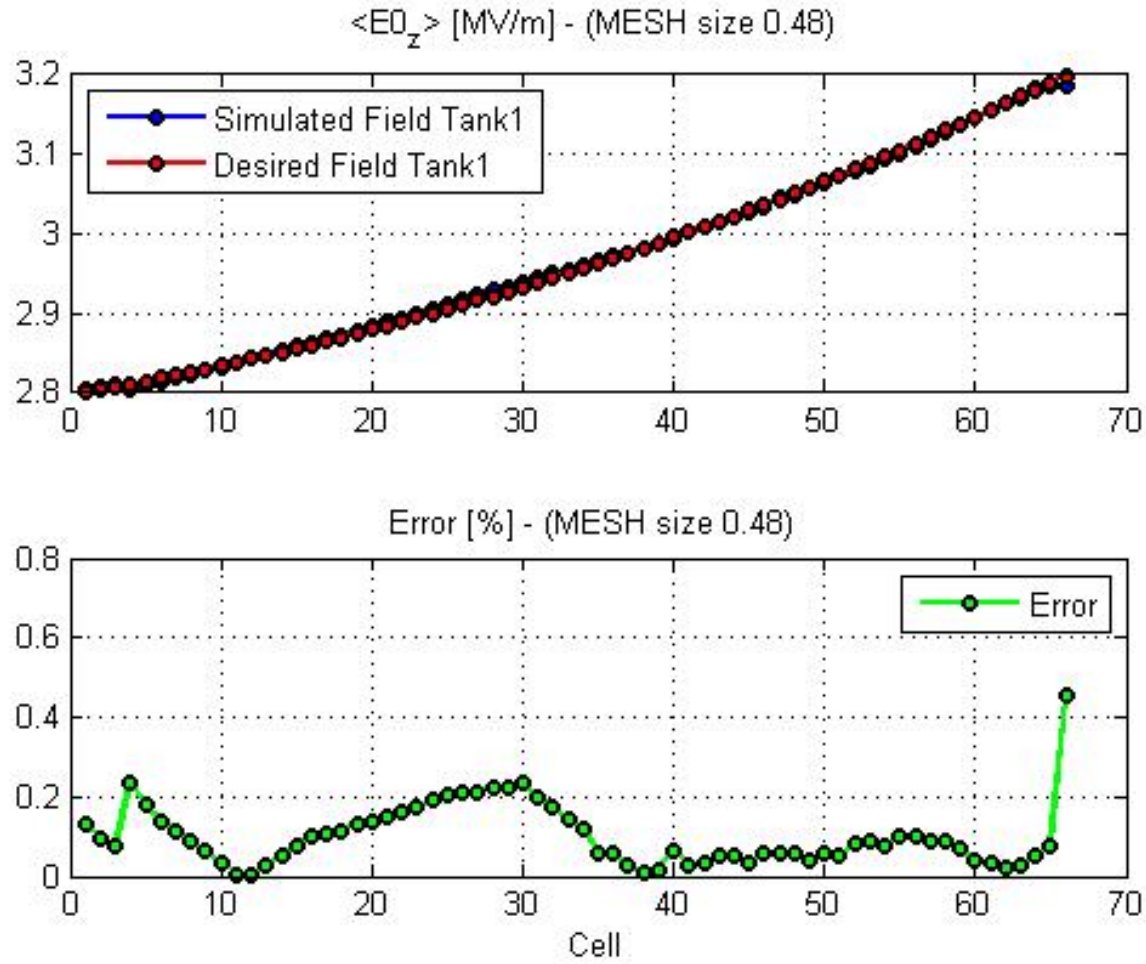
Tank Field Tuning Software is useful to find face angles which:

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

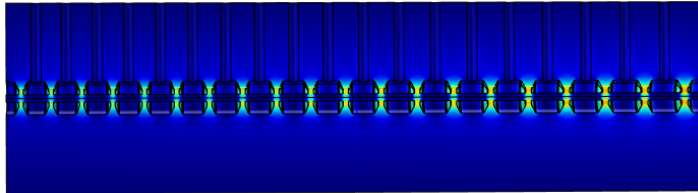
Tank Field Tuning Software is useful also to:

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

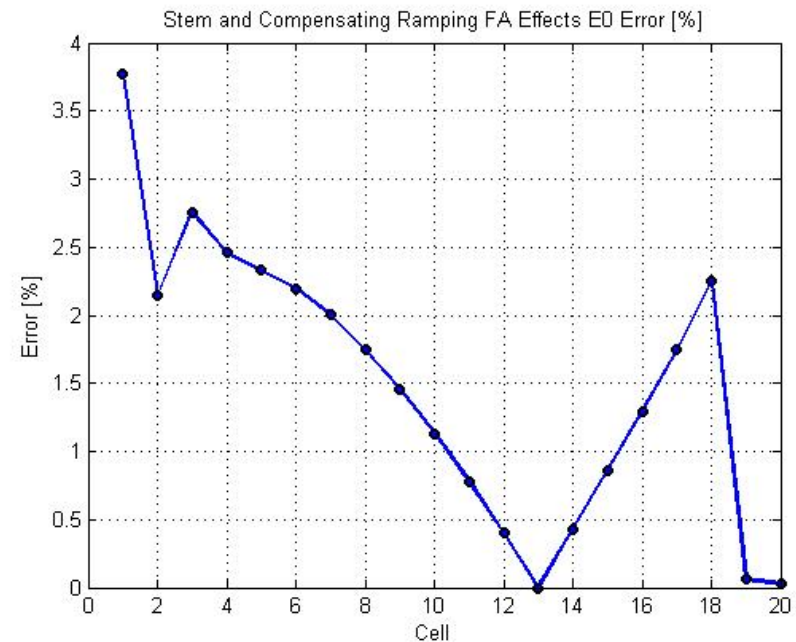
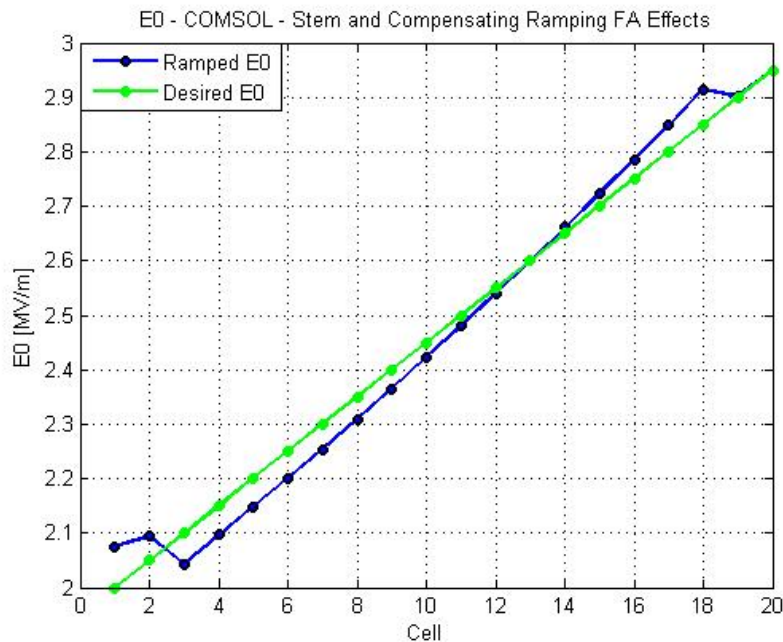
Accelerating field



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 (9.3 λ)	7.62 (8.9 λ)	7.76 (9.1 λ)	7.72 (9.0 λ)
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

- 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	± 0.100	0.010	± 0.045	0.005
D_{DT}	0.6	± 0.025	0.020	± 0.015	0.012
Gap	5.6	± 0.025	0.007	± 0.140	0.039
Face Angle	5.8	± 0.025	0.003	± 0.145	0.017
D_{Stem}	-0.136	± 0.025	0.010	± 0.003	0.001
Sum				± 0.348	0.075
Total					0.405



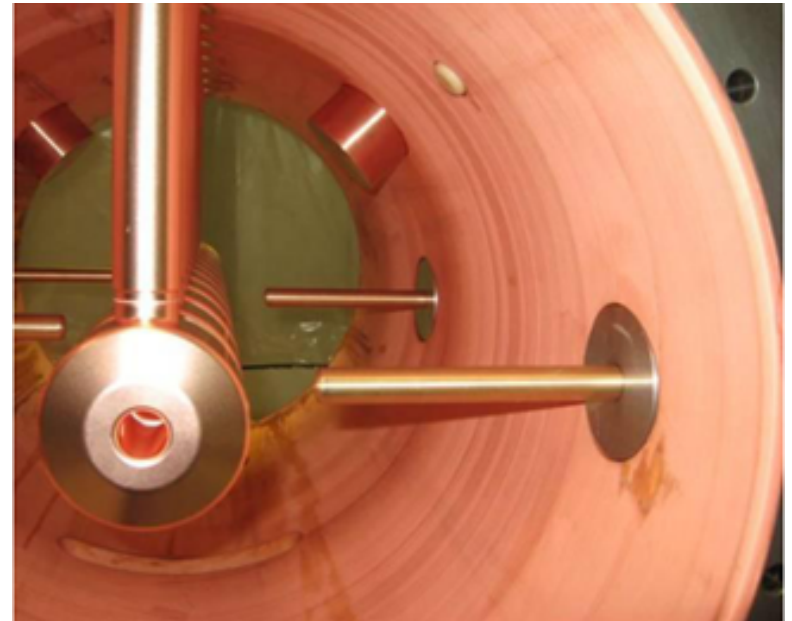
Post Coupler

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

Post Couplers must keep E_0 within specifications ($\pm 1\%$) in case of a reasonable perturbation of the end-cells.

Cell1 of Tank 1 is the most sensitive to perturbation.

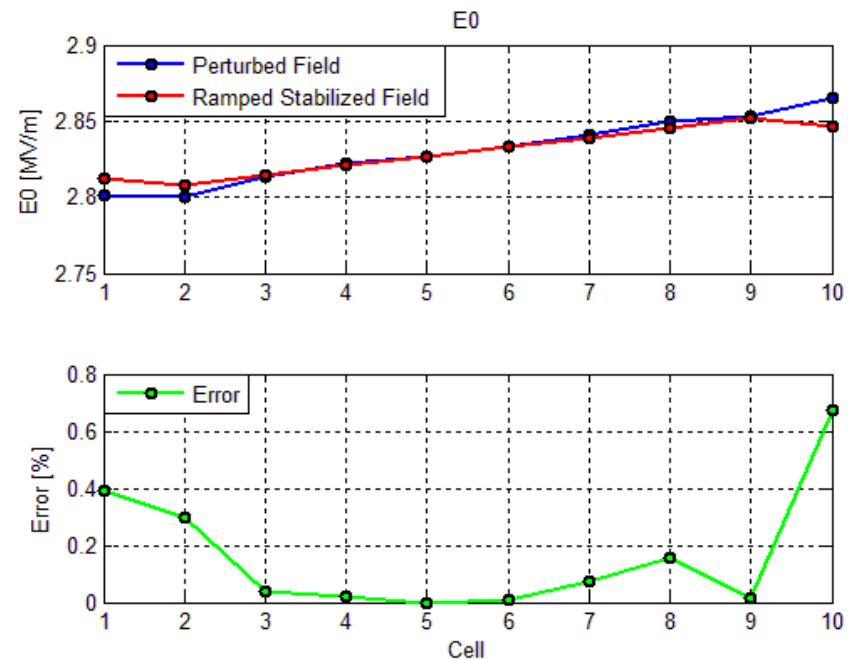
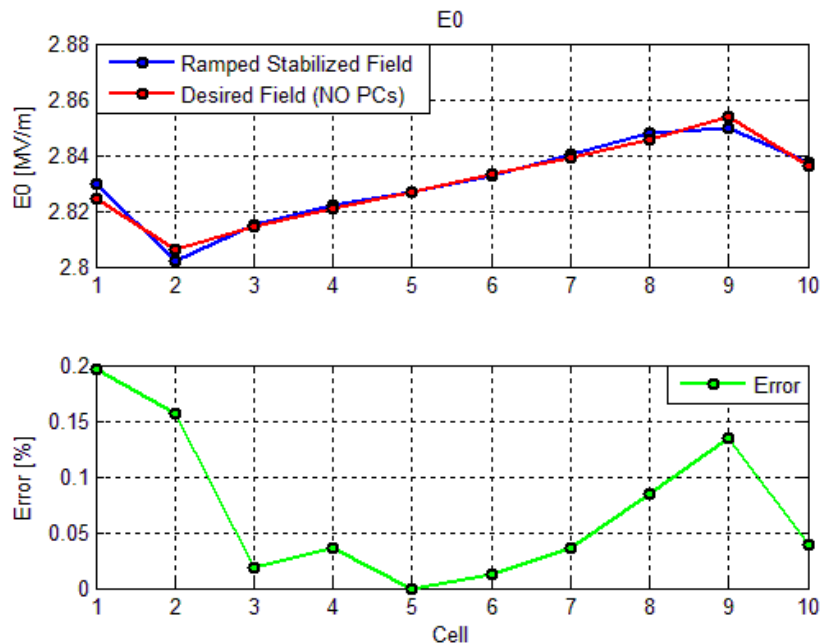
Electric field of the post mode and the magnetic field of the accelerating mode produce a non-zero Poynting vector longitudinal component.



Post Couplers (case 1)

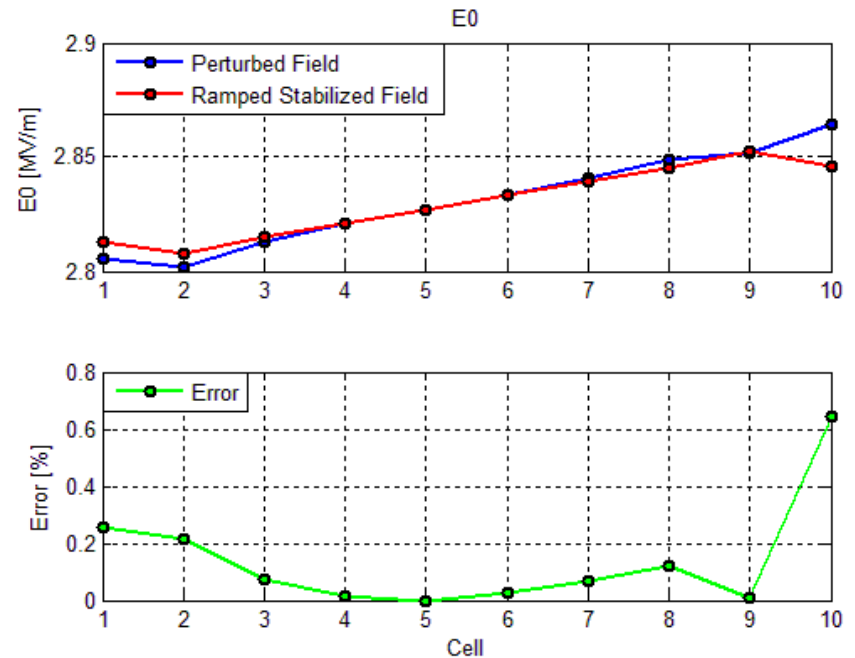
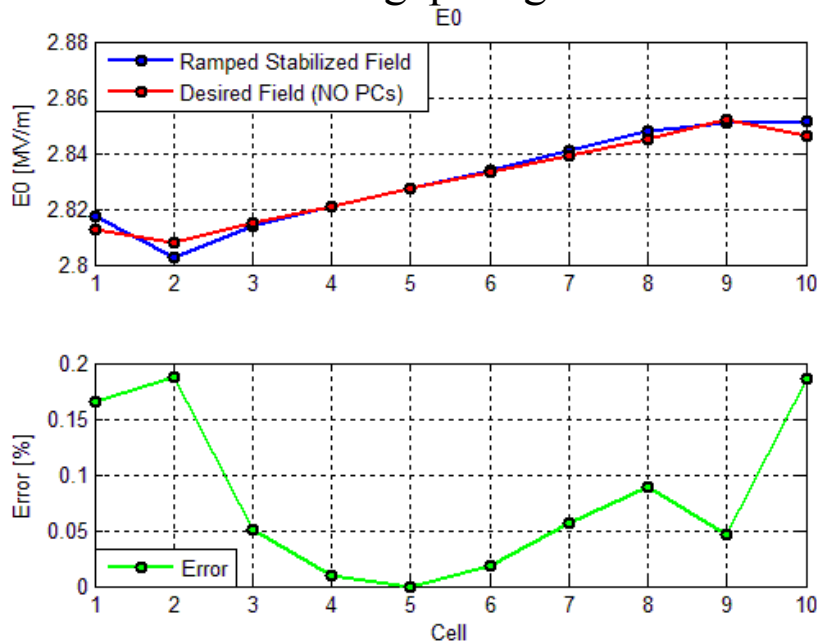
On the left figure, is plotted the accelerating field in a sample tank (case1) in which are present unexcited post couplers (left figure).

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



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

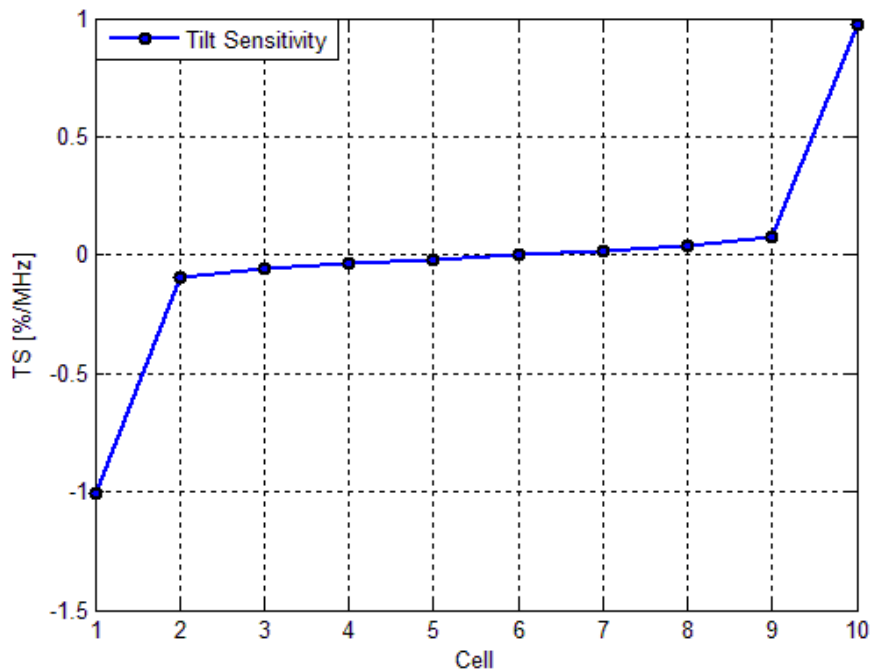
The face angles perturbation of the end cell on the frequency (to have a flat field), is the same perturbation on the frequency given by an error in the order of tenths of a millimeter on the gap length.



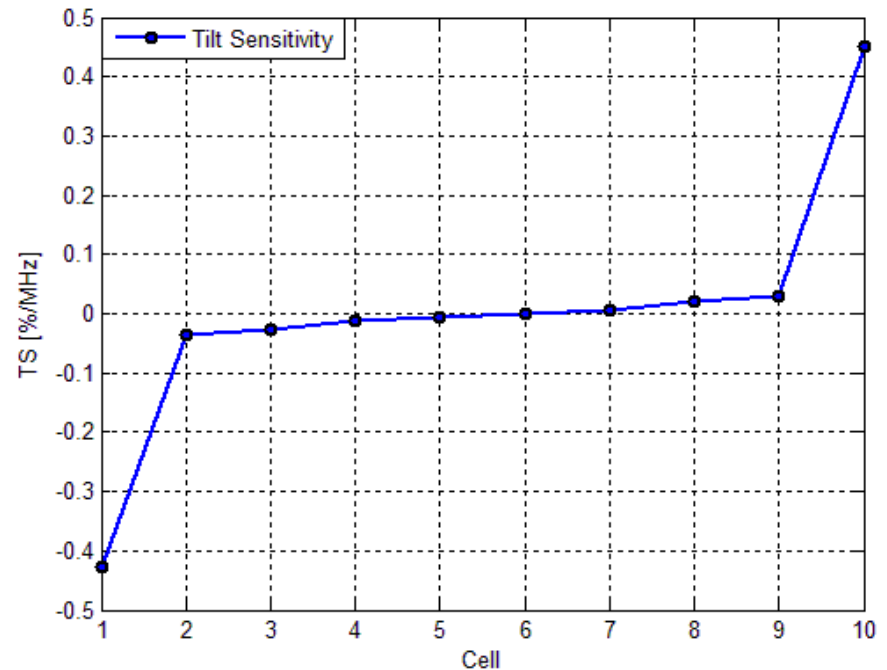
Tilt Sensitivity

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 [<i>m</i>]	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 [<i>MHz</i>]	0.17	0.17	0.20	0.17
Power [<i>MW</i>]	0.031	0.036	0.044	0.031





EXECUTION Time



DATA

Import

PMQ

Length	Height	Safe Dist.	<input type="checkbox"/> Tuners
0.00	0.00	0.00	

Save

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] 0.00 Corr. Fact. 0.00

TUNING

Ramp

- Cells Cell Numb. 0
- Wall Err MAX [%] 0.00
- Mix Err MAX [%] 0.00
- Auto

Fine TUNING

- Yes
- No
- Err MAX [%] 0.00

Post Coupler

Active

Diameter [cm] 0.00

Analysis

- 2D 3D
- Mesh Size AUTO
-

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

OPERATION

24%

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RENdtl - Data Import


The interface is divided into several functional areas:

- EXECUTION Time:** A circular progress indicator showing the current execution status.
- DATA:** A yellow-highlighted section for data import. It includes an 'Import' field with a 'Browse' button, 'PMQ' settings for Length (0.00), Height (0.00), and Safe Dist. (0.00), a 'Tuners' checkbox, and a 'Save' field with a 'Browse' button.
- RESULT:** A section for result visualization. It includes a 'Plot' area with checkboxes for Cell Length, Face Angle, TTF, ZTT, Sync Phase, and E0. A 'Power' section has a checkbox for 'Active', a 'Power MAX [KW]' field set to 0, checkboxes for 'Power Calculation' and 'Power Optimization', and 'Current [mA]' and 'Corr. Fact.' fields both set to 0.00.
- TUNING:** A section for parameter tuning. It includes a 'Ramp' area with checkboxes for Cells, Wall, Mix, and Auto, and corresponding 'Cell Numb.', 'Err MAX [%]', and '0.00' fields. A 'Fine TUNING' area has checkboxes for 'Yes' and 'No', and an 'Err MAX [%]' field set to 0.00.
- Post Coupler:** A section with an 'Active' checkbox, a 'Diameter [cm]' field set to 0.00, an 'Analysis' area with checkboxes for 2D and 3D, a 'Mesh Size' slider set to AUTO, and a 'MAX' label. It also includes checkboxes for 'Number' and 'Position' with an 'Err MAX [%]' field set to 0.00.
- Stem:** A section with an 'Active' checkbox, a 'Diameter [cm]' field set to 0.00, a 'SubTanks' area with an 'Active' checkbox, and an 'LMAX [cm]' field set to 0.00.
- 3D Layout:** A section with checkboxes for HFSS and COMSOL, a 'Tank' field set to 0, a 'Cell' field, checkboxes for Post Coupler, Stem, and Use Symmetry, and a 'Create 3D' button.
- OPERATION:** A section with 'RUN', 'STOP', and 'PAUSE' buttons, a progress bar at 24%, and a 'Contact' button.
- Contact:** A button labeled 'Contact RENATO DE PRISCO' with a green arrow icon.




RENdtl - Plot Result





EXECUTION Time



DATA

Import

PMQ

Length Height Safe Dist. Tuners

Save

RESULT

Plot

Cell Length

Face Angle

TTF

ZTT

Sync Phase

E0

Power Active

Power MAX [KW]

Power Calculation

Power Optimization

Current [mA] Corr. Fact.

TUNING

Ramp

Cells Cell Numb.

Wall

Mix Err MAX [%]

Auto

Fine TUNING

Yes

No

Err MAX [%]

Post Coupler

Active

Diameter [cm]

Analysis

2D 3D

Mesh Size AUTO

Number Err MAX [%]

Position

Stem

Active

Diameter [cm]

SubTanks

Active

LMAX [cm]

3D Layout

HFSS COMSOL

Tank

Cell

Post Coupler

Stem

Use Symmetry

OPERATION

24%

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RENdtl - Tuning



DATA

Import

PMQ

Length Height Safe Dist. Tuners

Save

RESULT

Plot

Cell Length
 Face Angle
 TTF
 ZTT
 Sync Phase
 E0

Power Active

Power MAX [KW]

Power Calculation
 Power Optimization

Current [mA] Corr. Fact.

TUNING

Ramp

Cells Cell Numb.
 Wall
 Mix Err MAX [%]
 Auto

Fine TUNING

Yes
 No
Err MAX [%]

OPERATION

Post Coupler

Active

Diameter [cm]

Analysis

2D 3D

Mesh Size AUTO

Number Err MAX [%]
 Position

Stem

Active

Diameter [cm]

SubTanks

Active

LMAX [cm]

3D Layout

HFSS COMSOL

Tank
 Cell
 Post Coupler
 Stem
 Use Symmetry

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RENdtl - Post Couplers



The screenshot displays the RENdtl software interface with several configuration panels:

- EXECUTION Time:** A circular progress indicator showing the current execution status.
- DATA:** Includes an 'Import' field with a 'Browse' button, 'PMQ' settings for Length (0.00), Height (0.00), and Safe Dist. (0.00), a 'Tuners' checkbox, and a 'Save' field with a 'Browse' button.
- RESULT:** Contains a 'Plot' section with checkboxes for Cell Length, Face Angle, TTF, ZTT, Sync Phase, and E0. The 'Power' section has an 'Active' checkbox, 'Power MAX [KW]' set to 0, 'Power Calculation' and 'Power Optimization' checkboxes, 'Current [mA]' set to 0.00, and 'Corr. Fact.' set to 0.00.
- TUNING:** Features a 'Ramp' section with checkboxes for Cells, Wall, Mix, and Auto, and corresponding numerical inputs for Cell Numb., Err MAX [%], and Auto. The 'Fine TUNING' section has 'Yes' and 'No' checkboxes and an 'Err MAX [%]' input set to 0.00.
- Post Coupler (highlighted):** Includes an 'Active' checkbox, 'Diameter [cm]' set to 0.00, an 'Analysis' section with '2D' and '3D' checkboxes and a 'Mesh Size' slider set to 'MAX', and 'Number' and 'Position' settings.
- Stem:** Has an 'Active' checkbox, 'Diameter [cm]' set to 0.00, and a 'SubTanks' section with an 'Active' checkbox and 'LMAX [cm]' set to 0.00.
- 3D Layout:** Includes checkboxes for HFSS, COMSOL, Tank (set to 0), Cell, Post Coupler, Stem, and Use Symmetry, along with a 'Create 3D' button.
- OPERATION:** Contains 'RUN', 'STOP', and 'PAUSE' buttons, a progress bar at 24%, and a 'Contact RENATO DE PRISCO' button.



RENdtl - Stem

The image shows the RENdtl - Stem software interface. It features several panels for configuration and execution:

- EXECUTION Time:** A circular progress indicator showing the current execution status.
- DATA:** Includes an 'Import' field with a 'Browse' button, 'PMQ' settings for Length, Height, and Safe Dist. (all set to 0.00), a 'Tuners' checkbox, and a 'Save' field with a 'Browse' button.
- RESULT:** Includes a 'Plot' section with checkboxes for Cell Length, Face Angle, TTF, ZTT, Sync Phase, and E0. A 'Power' section has a 'Power' checkbox (Active), 'Power MAX [KW]' (0), 'Power Calculation' and 'Power Optimization' checkboxes, 'Current [mA]' (0.00), and 'Corr. Fact.' (0.00).
- TUNING:** Includes a 'Ramp' section with checkboxes for Cells, Wall, Mix, and Auto, and 'Cell Numb.' (0) and 'Err MAX [%]' (0.00) fields. A 'Fine TUNING' section has 'Yes' and 'No' checkboxes and an 'Err MAX [%]' field (0.00).
- Post Coupler:** Includes an 'Active' checkbox, 'Diameter [cm]' (0.00), 'Analysis' options (2D, 3D), 'Mesh Size' (AUTO), a slider to 'MAX', and 'Number' and 'Position' fields (0.00).
- Stem:** This panel is highlighted in yellow and includes an 'Active' checkbox, 'Diameter [cm]' (0.00), 'SubTanks' section with an 'Active' checkbox, and 'LMAX [cm]' (0.00).
- 3D Layout:** Includes checkboxes for HFSS, COMSOL, Tank (0), Cell, Post Coupler, Stem, and Use Symmetry, and a 'Create 3D' button.
- OPERATION:** Includes 'RUN', 'STOP', and 'PAUSE' buttons, a progress bar at 24%, and a 'Contact' button.

At the bottom right, there is a 'Contact' button and the name 'RENATO DE PRISCO'.



RENdtl - Power



The image shows the RENdtl - Power software interface. It features several panels for configuration and execution:

- EXECUTION Time:** A circular progress indicator showing the current execution status.
- DATA:** Includes an 'Import' field with a 'Browse' button, 'PMQ' settings for Length, Height, and Safe Dist. (all set to 0.00), a 'Tuners' checkbox, and a 'Save' field with a 'Browse' button.
- RESULT:** A 'Plot' section with checkboxes for Cell Length, Face Angle, TTF, ZTT, Sync Phase, and E0. A highlighted 'Power' section includes a 'Power' checkbox (unchecked), 'Power MAX [KW]' set to 0, 'Power Calculation' and 'Power Optimization' checkboxes (unchecked), and 'Current [mA]' and 'Corr. Fact.' both set to 0.00.
- TUNING:** A 'Ramp' section with checkboxes for Cells, Wall, Mix, and Auto, and input fields for Cell Numb. (0), Err MAX [%] (0.00), and Auto (0.00). A 'Fine TUNING' section has 'Yes' and 'No' checkboxes (unchecked), and an 'Err MAX [%]' input field (0.00).
- Post Coupler:** An 'Active' checkbox (unchecked), a 'Diameter [cm]' input field (0.00), an 'Analysis' section with '2D' and '3D' checkboxes (unchecked), a 'Mesh Size' set to 'AUTO', and a slider for 'MAX'. Below are 'Number' and 'Position' checkboxes (unchecked) and an 'Err MAX [%]' input field (0.00).
- Stem:** An 'Active' checkbox (unchecked), a 'Diameter [cm]' input field (0.00), and a 'SubTanks' section with an 'Active' checkbox (unchecked) and an 'LMAX [cm]' input field (0.00).
- 3D Layout:** Checkboxes for HFSS and COMSOL (unchecked), a 'Tank' input field (0), a 'Cell' input field, checkboxes for Post Coupler, Stem, and Use Symmetry (unchecked), and a 'Create 3D' button.
- OPERATION:** 'RUN', 'STOP', and 'PAUSE' buttons, and a progress bar showing 24% completion.

At the bottom right, there is a 'Contact' button with a green arrow and the name 'RENATO DE PRISCO'.



RENdtl - 3D Analysis



The interface is divided into several functional areas:

- EXECUTION Time:** A circular progress indicator showing the current status of the simulation.
- DATA:** Includes an 'Import' field with a 'Browse' button, 'PMQ' settings for Length, Height, and Safe Dist. (all set to 0.00), a 'Tuners' checkbox, and a 'Save' field with a 'Browse' button.
- RESULT:** Contains a 'Plot' section with checkboxes for Cell Length, Face Angle, TTF, ZTT, Sync Phase, and E0. The 'Power' section has an 'Active' checkbox, 'Power MAX [KW]' set to 0, 'Power Calculation' and 'Power Optimization' checkboxes, and 'Current [mA]' and 'Corr. Fact.' both set to 0.00.
- TUNING:** Features a 'Ramp' section with checkboxes for Cells, Wall, Mix, and Auto, and corresponding numerical inputs for Cell Numb., Err MAX [%], and Auto. The 'Fine TUNING' section has 'Yes' and 'No' checkboxes and an 'Err MAX [%]' input set to 0.00.
- Post Coupler:** Includes an 'Active' checkbox, 'Diameter [cm]' set to 0.00, an 'Analysis' section with '2D' and '3D' checkboxes and a 'Mesh Size' slider set to 'MAX', and 'Number' and 'Position' checkboxes with an 'Err MAX [%]' input set to 0.00.
- Stem:** Includes an 'Active' checkbox, 'Diameter [cm]' set to 0.00, and a 'SubTanks' section with an 'Active' checkbox and 'LMAX [cm]' set to 0.00.
- 3D Layout:** A highlighted yellow box containing checkboxes for HFSS, COMSOL, Tank (set to 0), Cell, Post Coupler, Stem, and Use Symmetry, with a 'Create 3D' button.
- OPERATION:** Features 'RUN', 'STOP', and 'PAUSE' buttons, a progress bar at 24%, and a 'Contact' button.

At the bottom right, there is a 'Contact' button with an arrow and the name 'RENATO DE PRISCO'.



RENdtl - Contact

The image shows the RENdtl - Contact software interface. It features several panels for configuration and execution:

- EXECUTION Time:** A circular progress indicator showing the current execution status.
- DATA:** Includes an 'Import' field with a 'Browse' button, 'PMQ' settings for Length, Height, and Safe Dist. (all set to 0.00), a 'Tuners' checkbox, and a 'Save' field with a 'Browse' button.
- RESULT:** Includes a 'Plot' section with checkboxes for Cell Length, Face Angle, TTF, ZTT, Sync Phase, and E0. A 'Power' section has a 'Power' checkbox (Active), 'Power MAX [KW]' set to 0, 'Power Calculation' and 'Power Optimization' checkboxes, 'Current [mA]' set to 0.00, and 'Corr. Fact.' set to 0.00.
- TUNING:** Includes a 'Ramp' section with checkboxes for Cells, Wall, Mix, and Auto, and 'Cell Numb.' and 'Err MAX [%]' fields. A 'Fine TUNING' section has 'Yes' and 'No' checkboxes and an 'Err MAX [%]' field.
- Post Coupler:** Includes an 'Active' checkbox, 'Diameter [cm]' set to 0.00, an 'Analysis' section with '2D' and '3D' checkboxes and a 'Mesh Size' slider (set to AUTO), and 'Number' and 'Position' fields.
- Stem:** Includes an 'Active' checkbox, 'Diameter [cm]' set to 0.00, a 'SubTanks' section with an 'Active' checkbox, and 'LMAX [cm]' set to 0.00.
- 3D Layout:** Includes checkboxes for HFSS and COMSOL, 'Tank' set to 0, 'Cell' field, 'Post Coupler', 'Stem', and 'Use Simmetry' checkboxes, and a 'Create 3D' button.
- OPERATION:** Includes 'RUN', 'STOP', and 'PAUSE' buttons, a progress bar at 24%, and a large yellow button labeled 'Contact RENATO DE PRISCO'.



Thanks ESS
Happy birthday Steve!