Numerical simulations for ICRF wave fields in a linear plasma device

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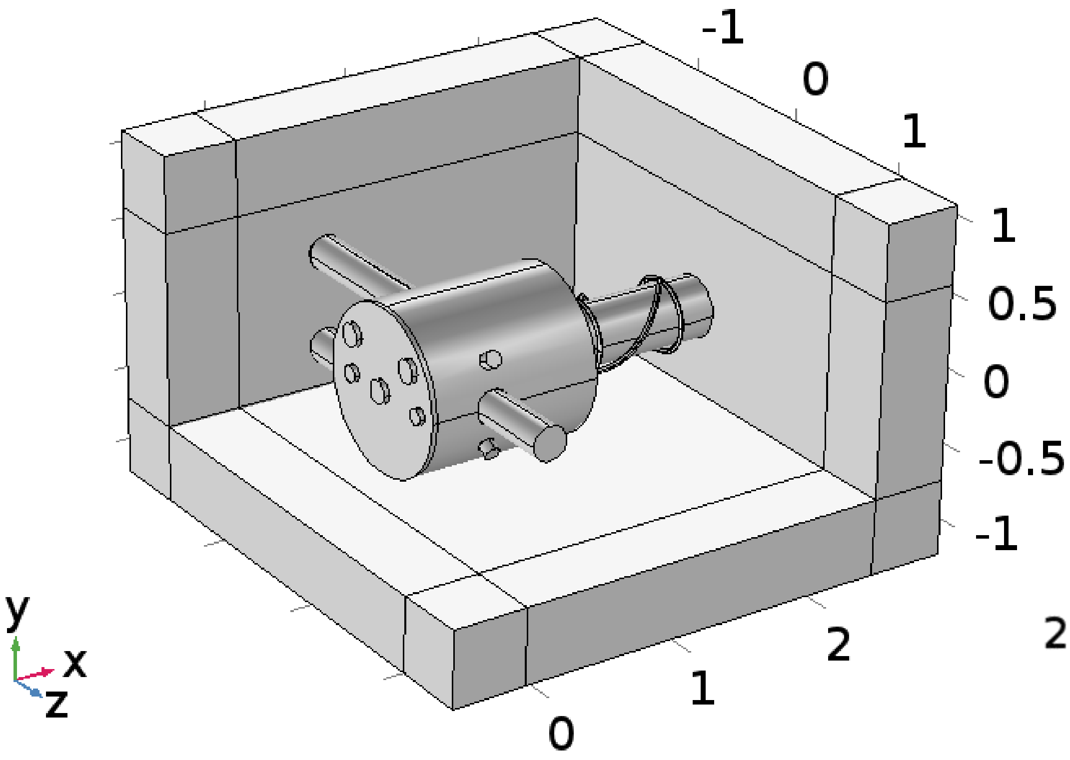
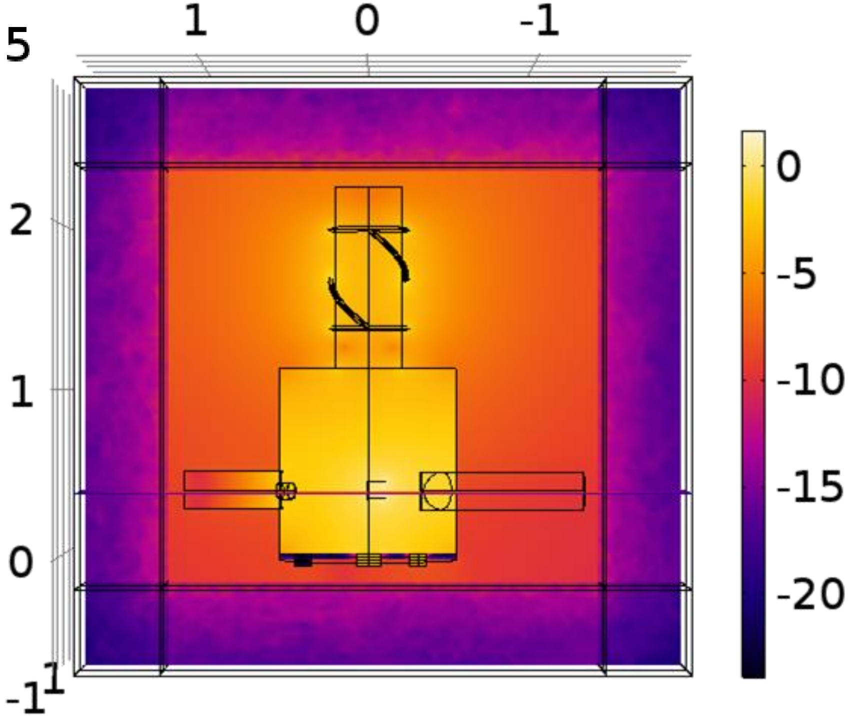
Linear plasma device

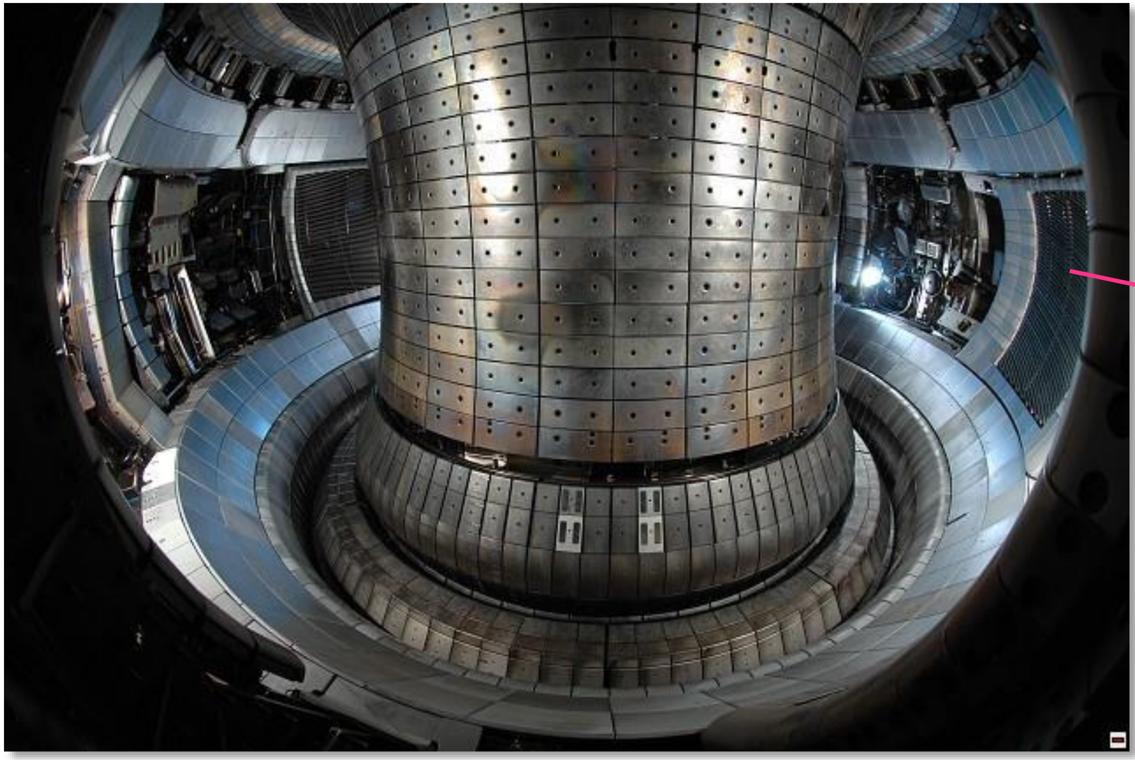


No plasma yet!
Only vacuum.

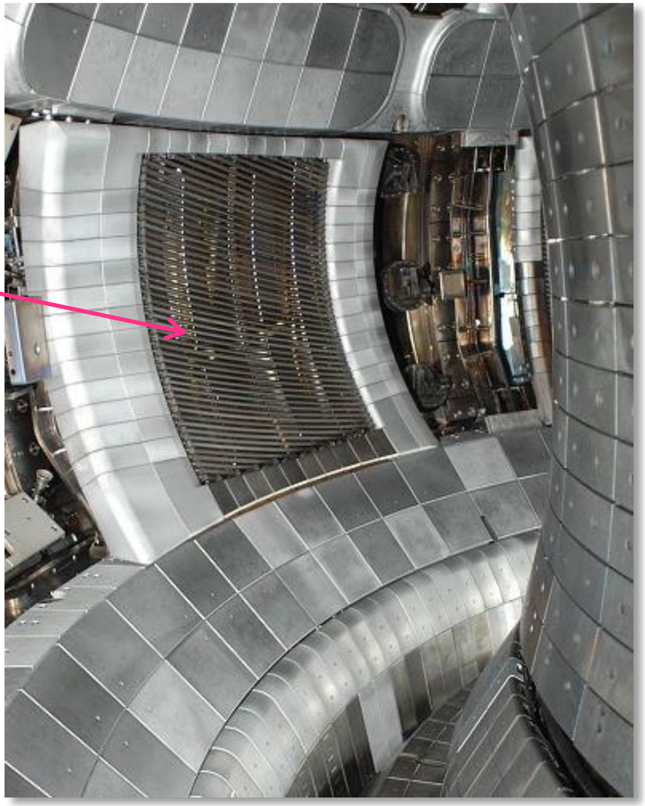


Example of magnetic field distribution
(logarithmic scale)

ICRH



ASDEX Upgrade tokamak at Max Planck Institute of Plasma Physics

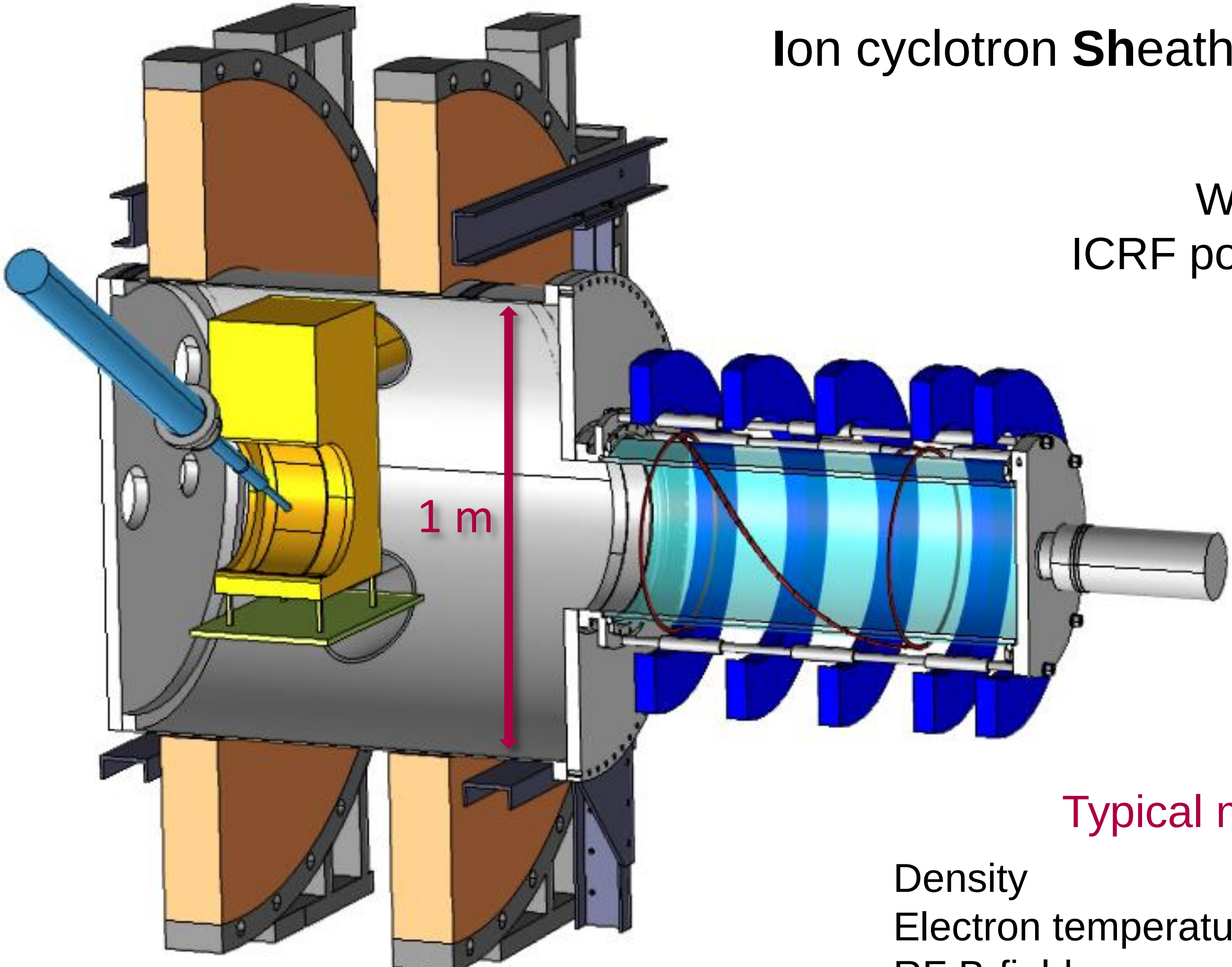


ICRH antenna of AUG

ICRH – **I**on **C**yclotron **R**esonance **H**eating

ICRH – **I**on **C**yclotron **R**ange of **F**requency (30-120 MHz)

IShTAR



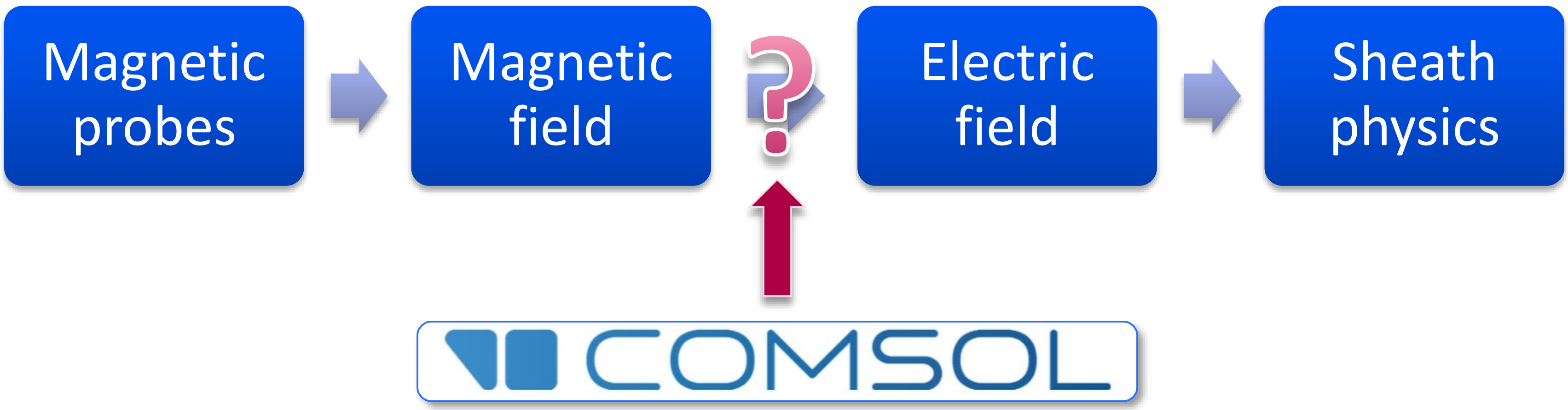
Ion cyclotron **Sh**eath **T**est **AR**rangement

RF Sheath
Wave propagation
ICRF power – edge interaction

Typical measured parameters:

Density	10^{16}-10^{18} m^{-3}
Electron temperature	1-10 eV
RF B-fields power	100 mW

Motivation



Tasks addressed:

- power losses through the use of a perfectly matched layer (PML)
- disturbance caused by a metallic probe presence
- probe calibration
- fields distribution in realistic IShTAR geometry

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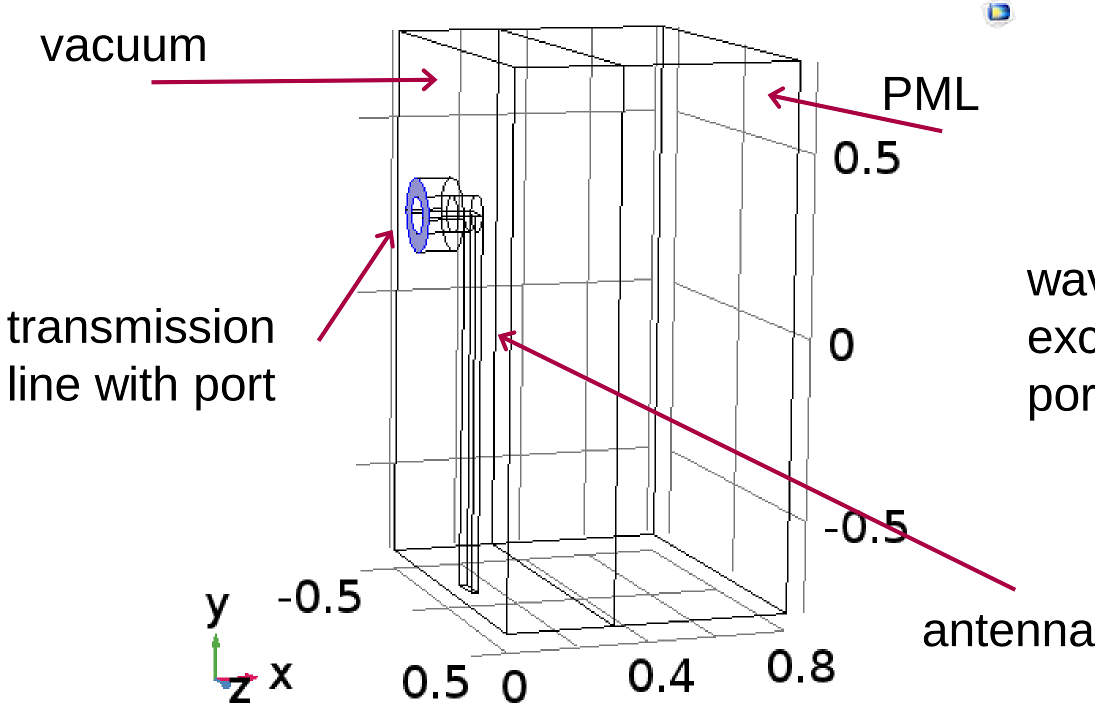
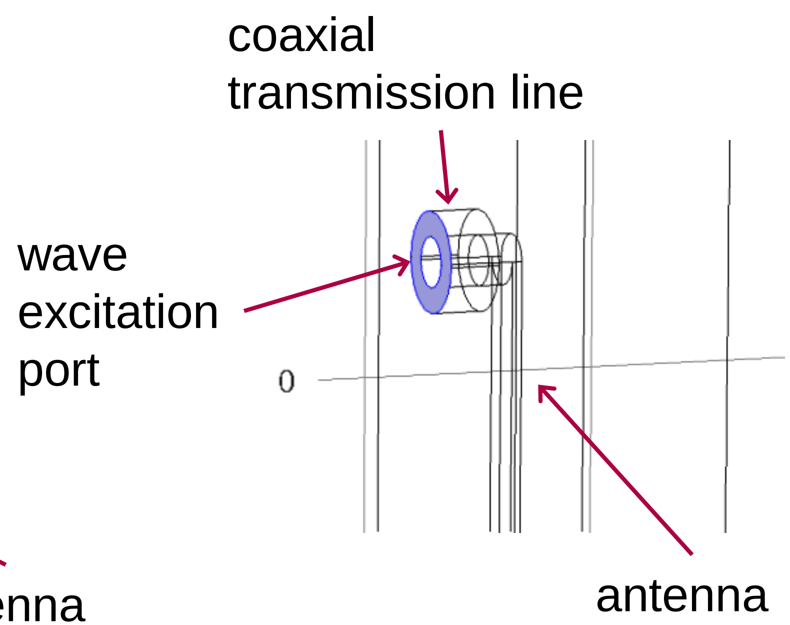
Power losses

Main components of IShTAR:

- vacuum chamber
- ICRF antenna
- coaxial transmission line
- quartz windows causing power losses

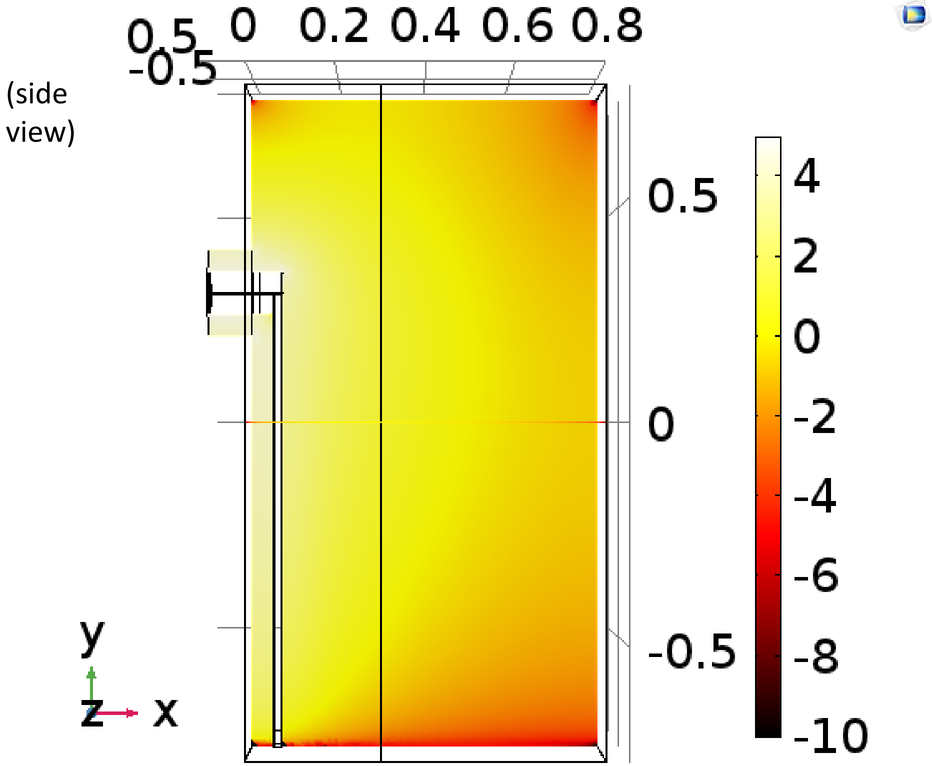
Simplified geometry (sizes in m) with realistic characteristic dimensions:



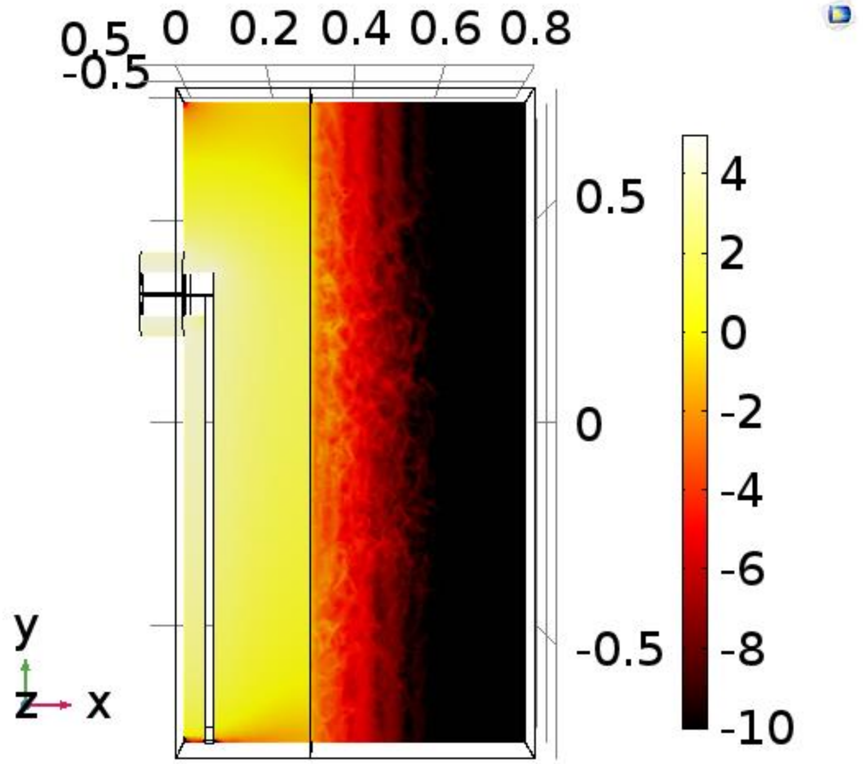


PML

E-field distribution without PML (log scale)



E-field distribution with PML (log scale)



Power flow through the PML edge surface, time average, x-component (f_0 = 5 MHz):

2.6E-13 W

3E-3 W

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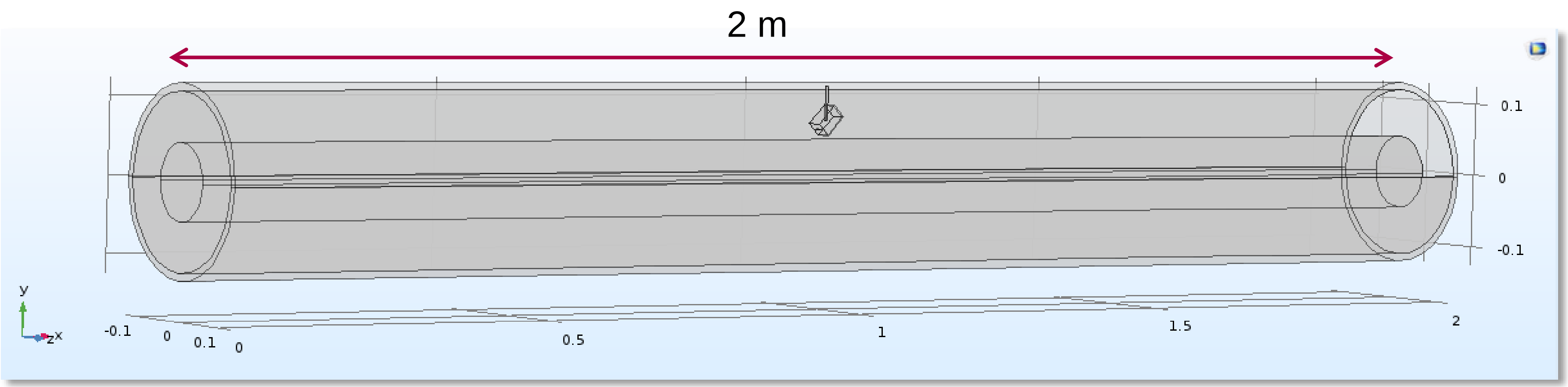
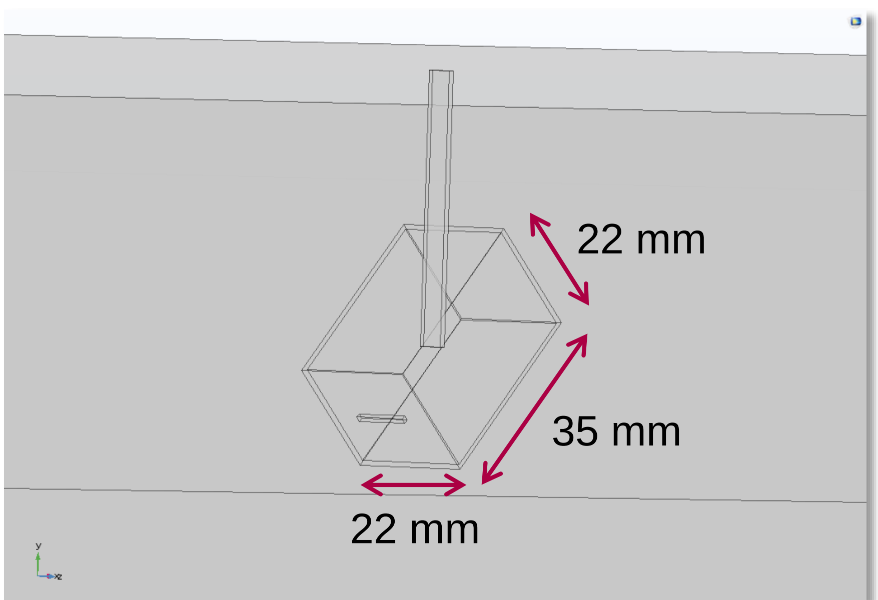
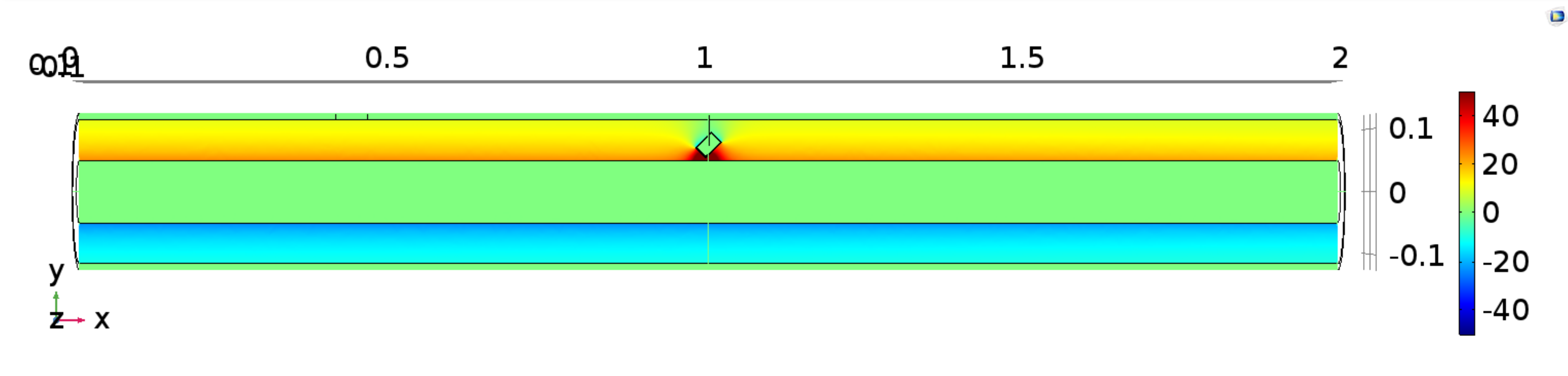
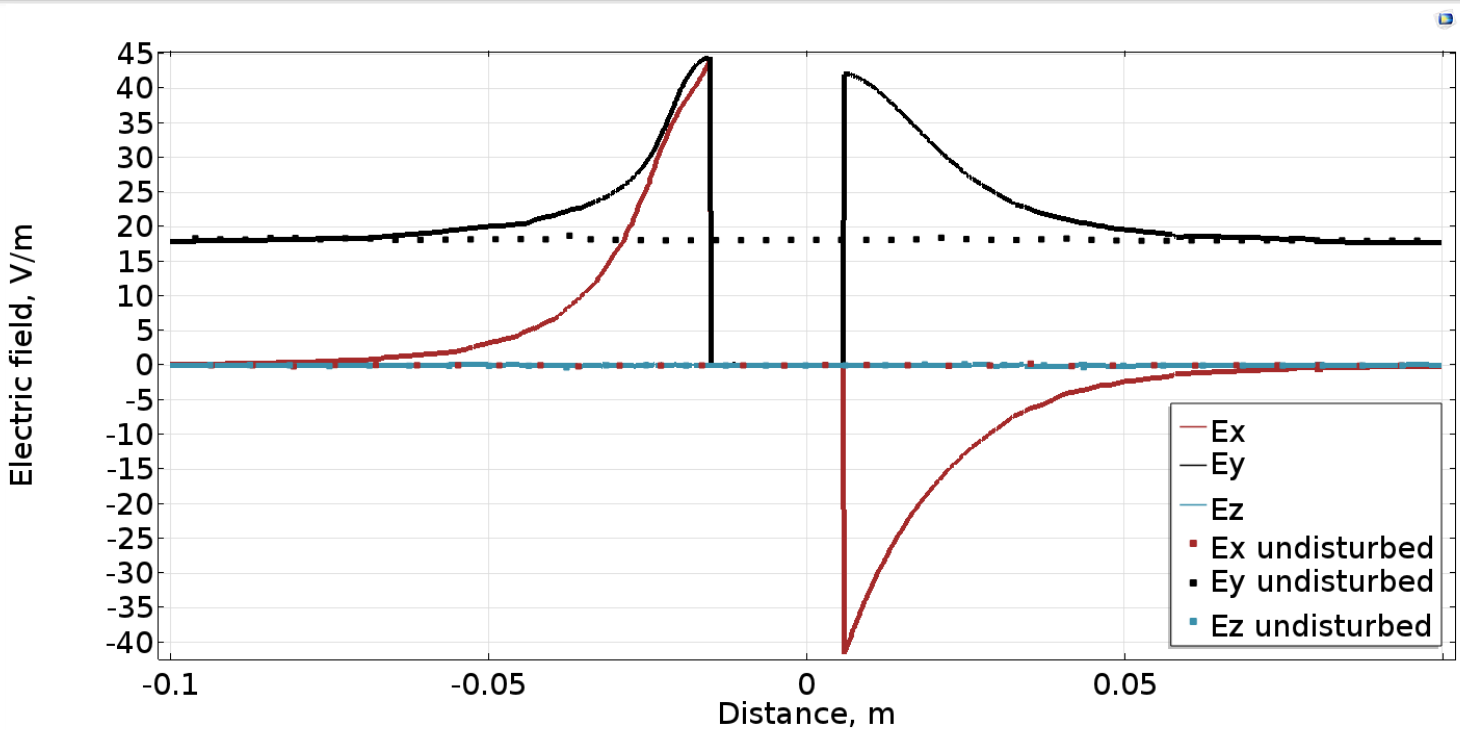
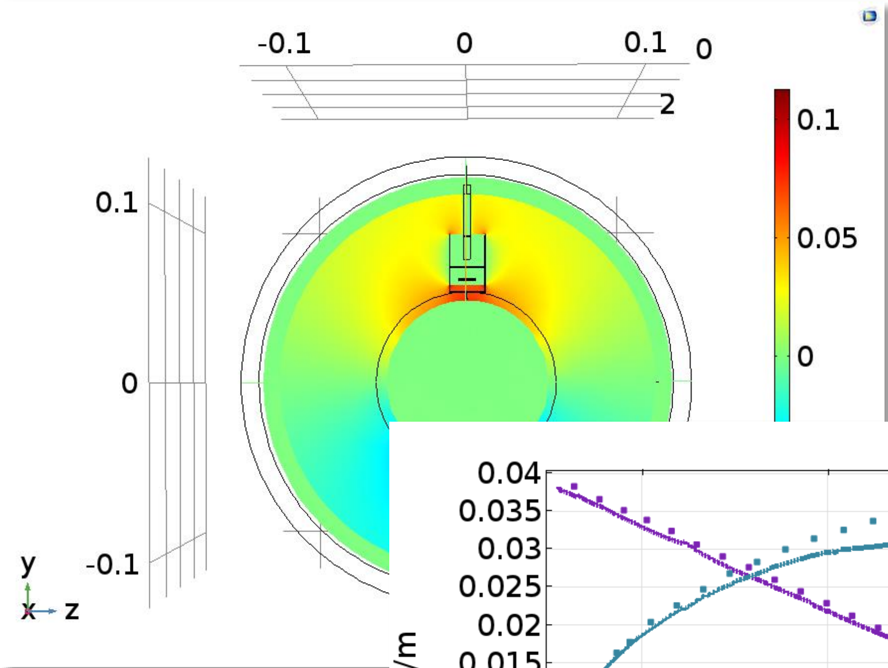

2 m
0.1
0
-0.1
y
z x
-0.1
0
0.1
0
0.5
1
1.5
2


22 mm
35 mm
22 mm

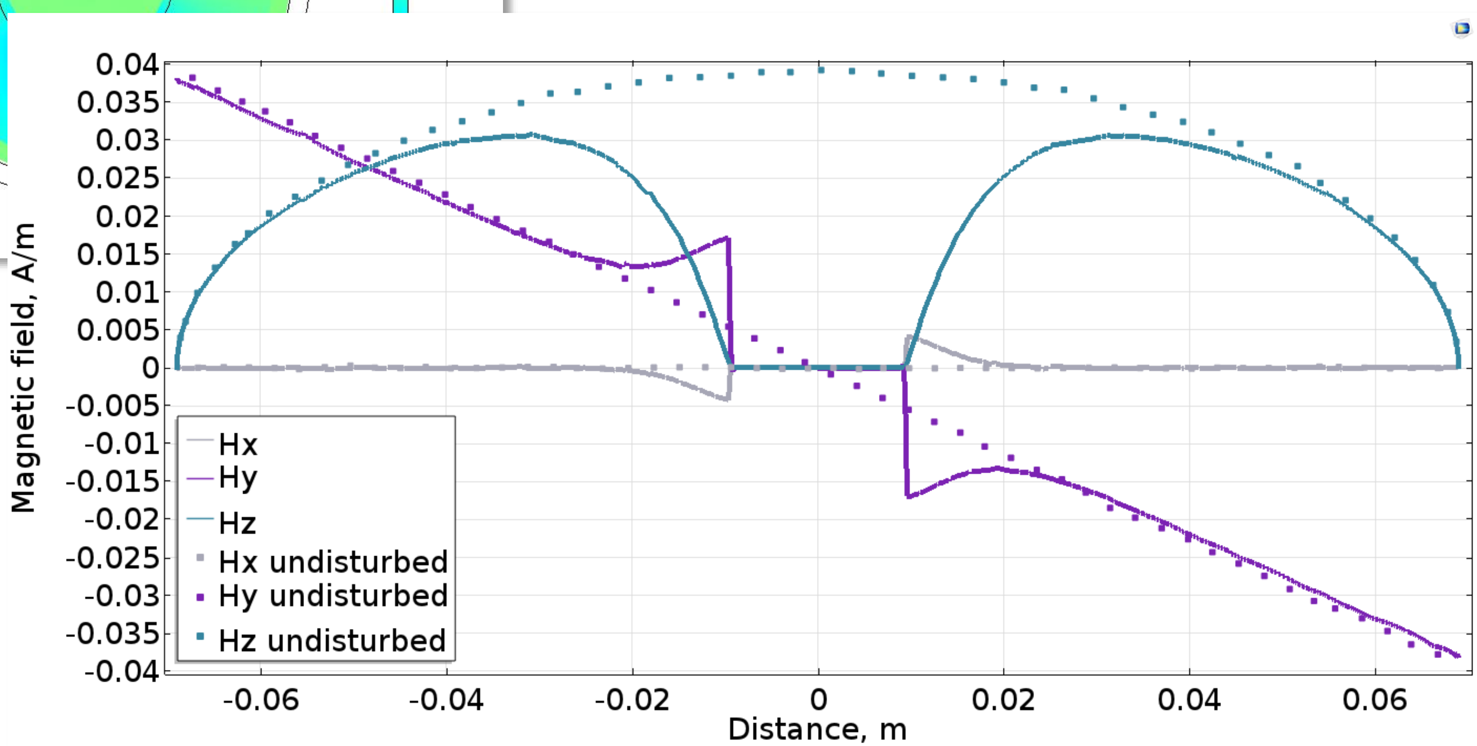
Fields disturbance by probe







Distance of disturbance:
5 cm for electric field and
3 cm for magnetic field



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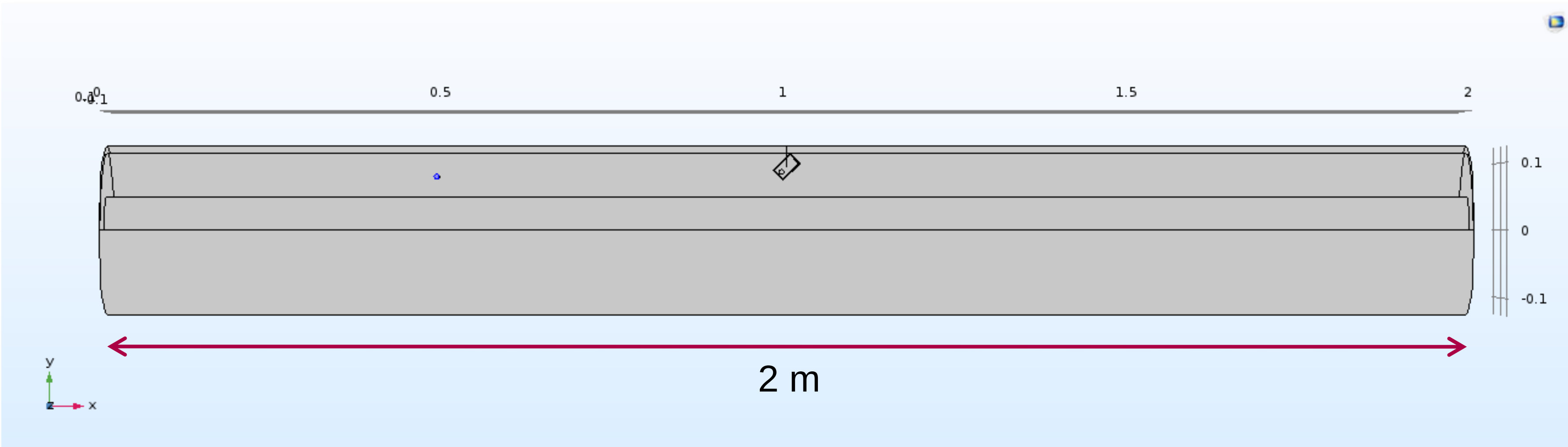
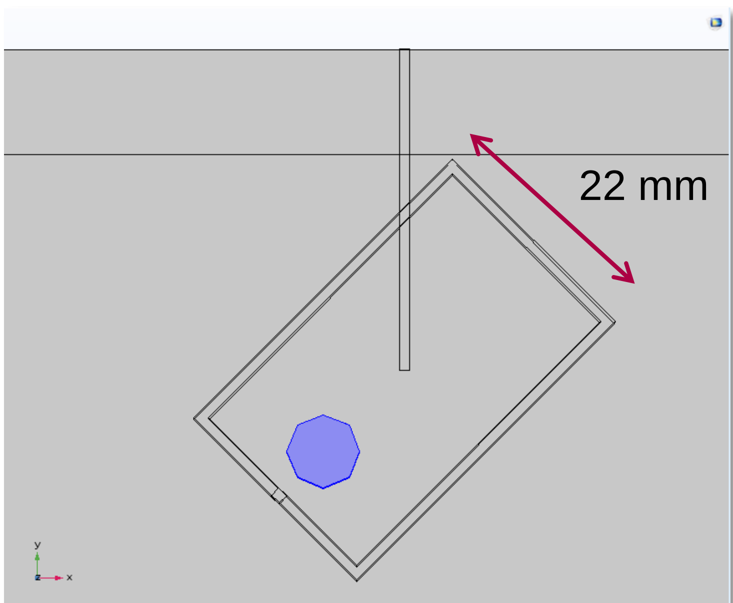
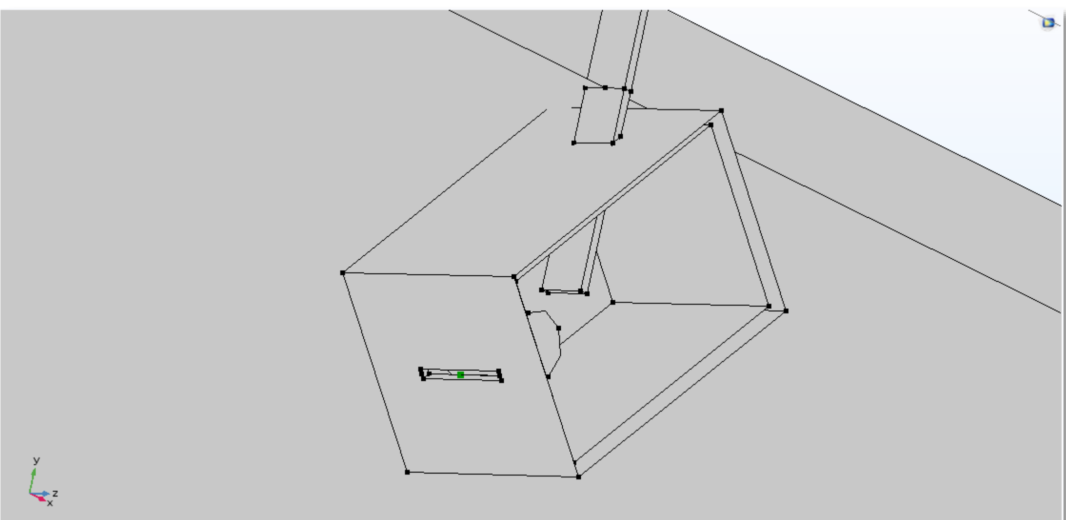
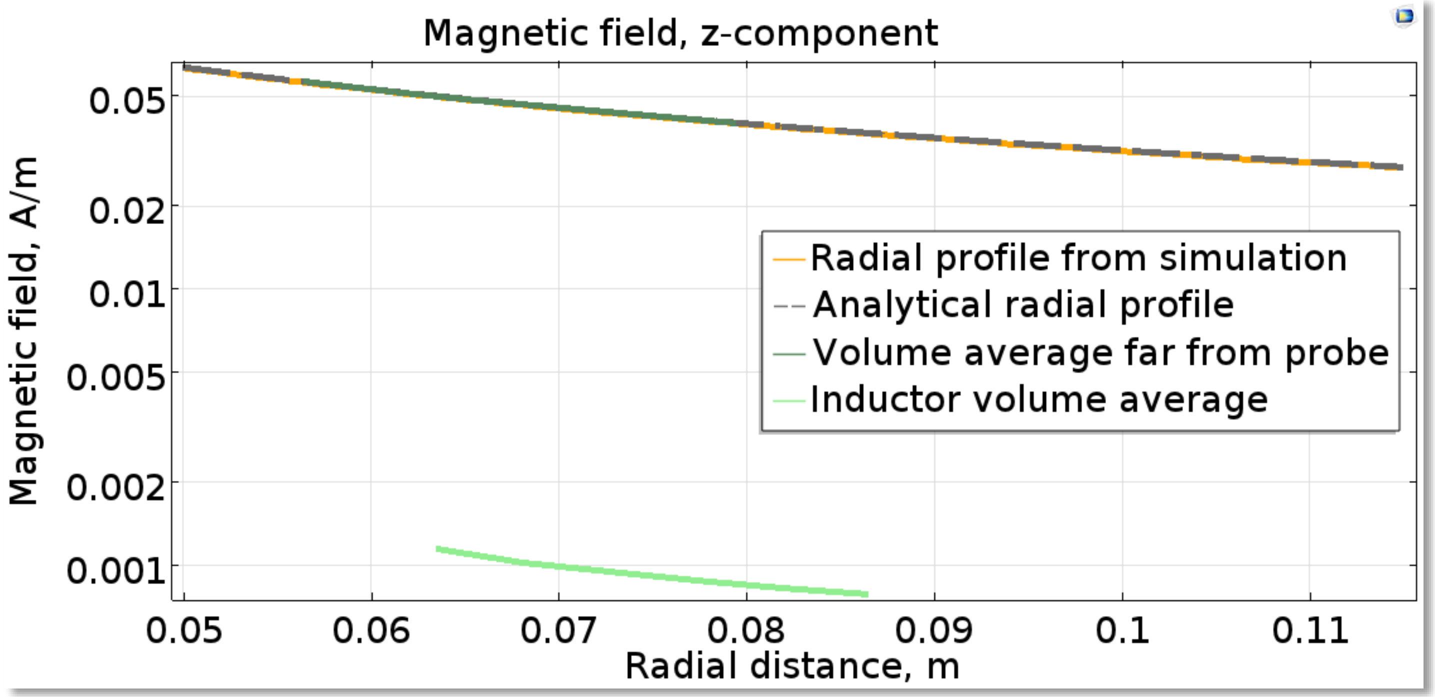
Probe calibration



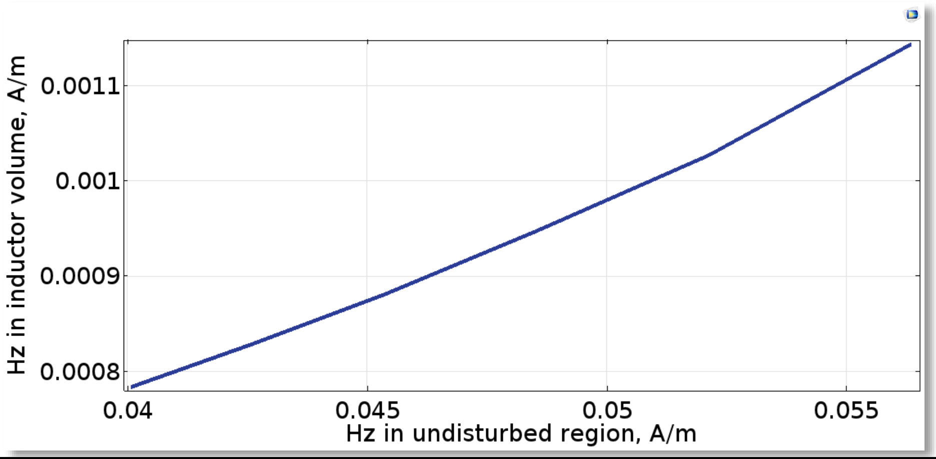


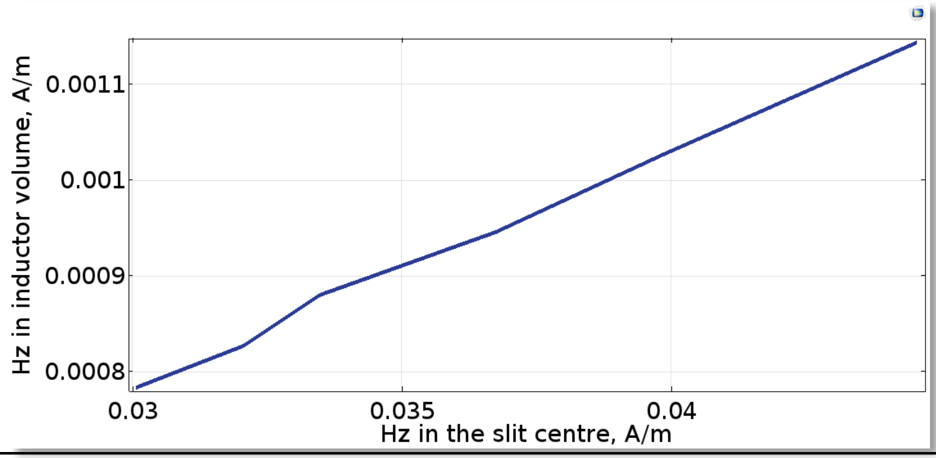


Probe calibration



$$H(r) = \frac{U}{2\pi r R}$$





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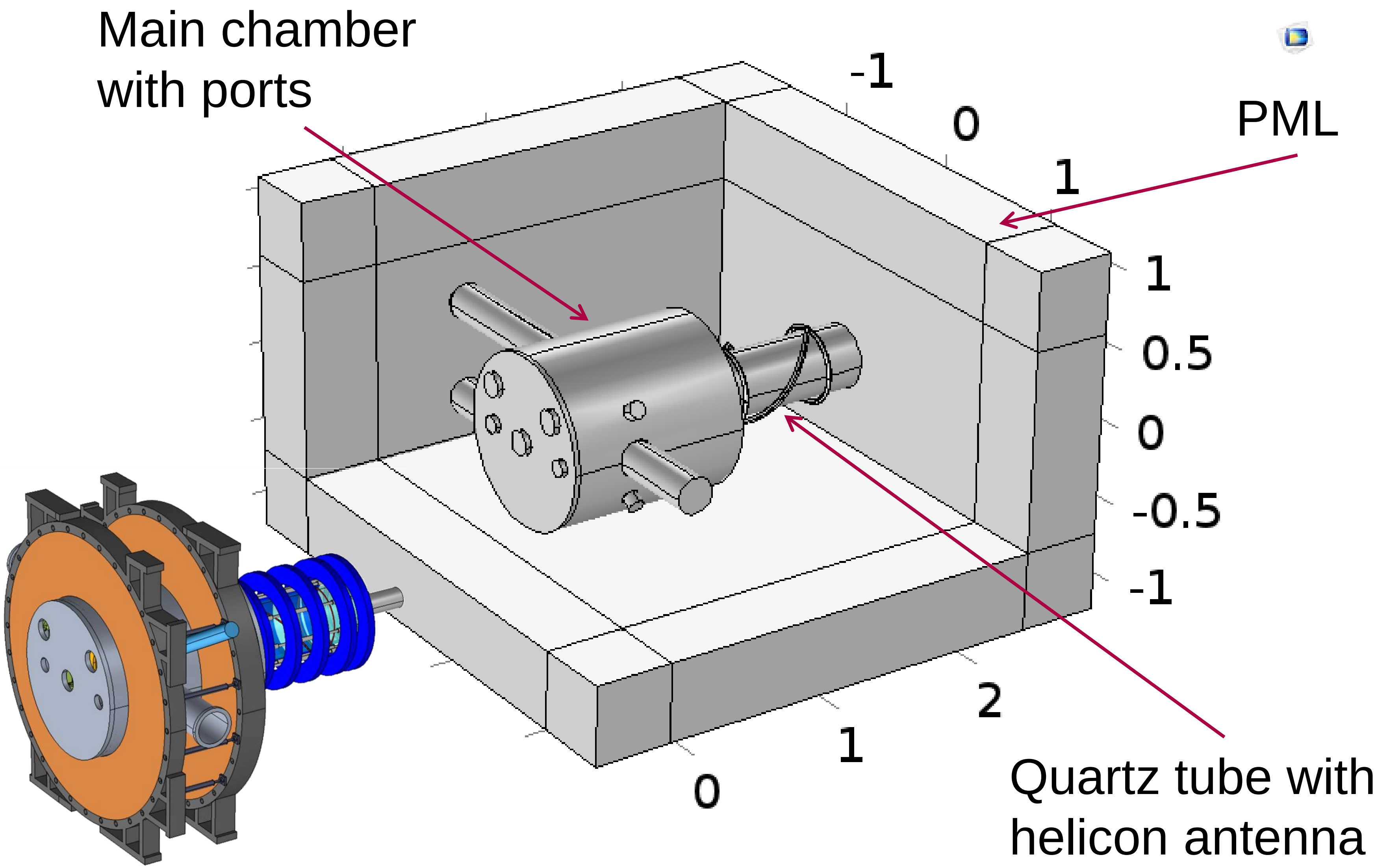
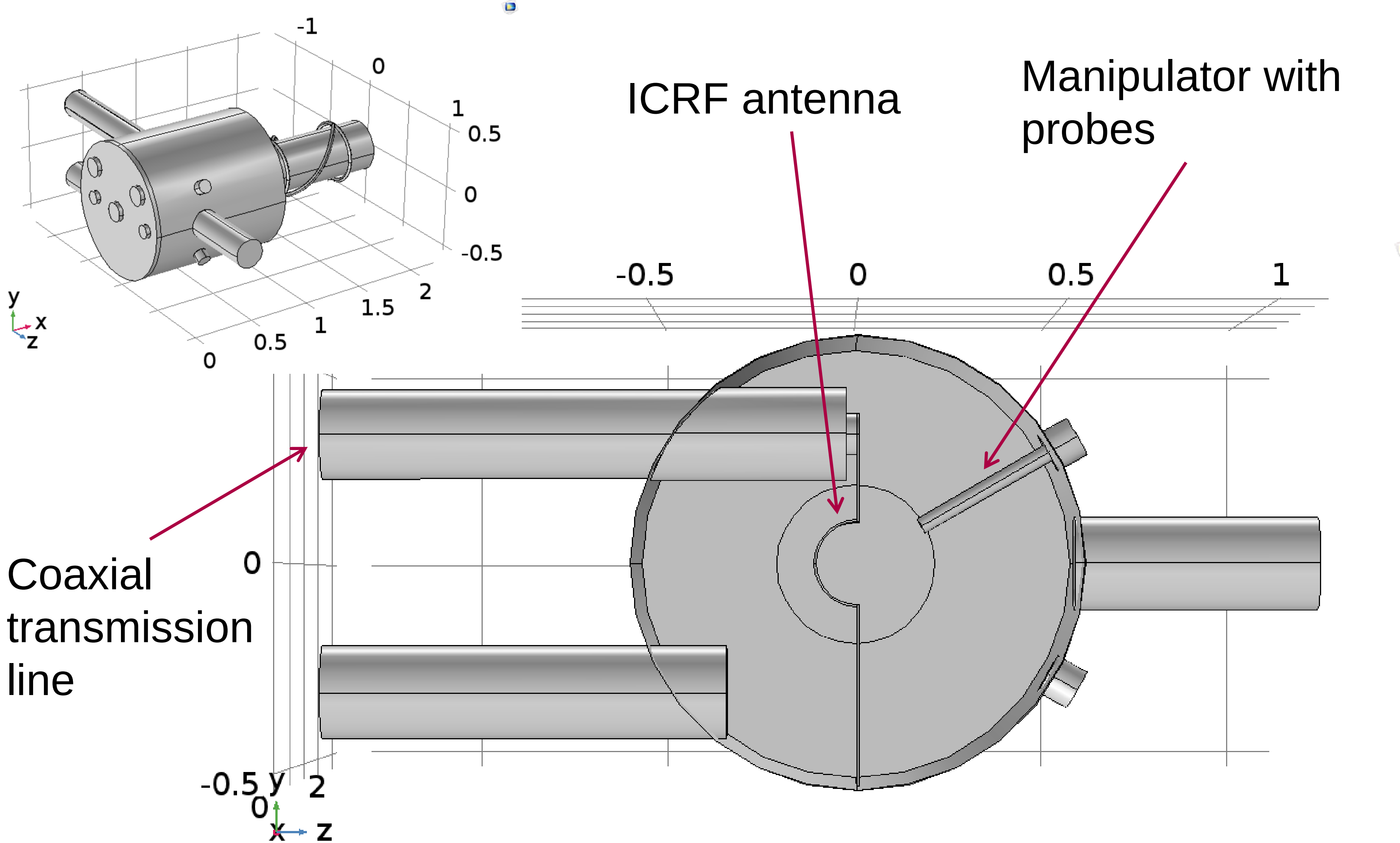
IShTAR model



IShTAR model



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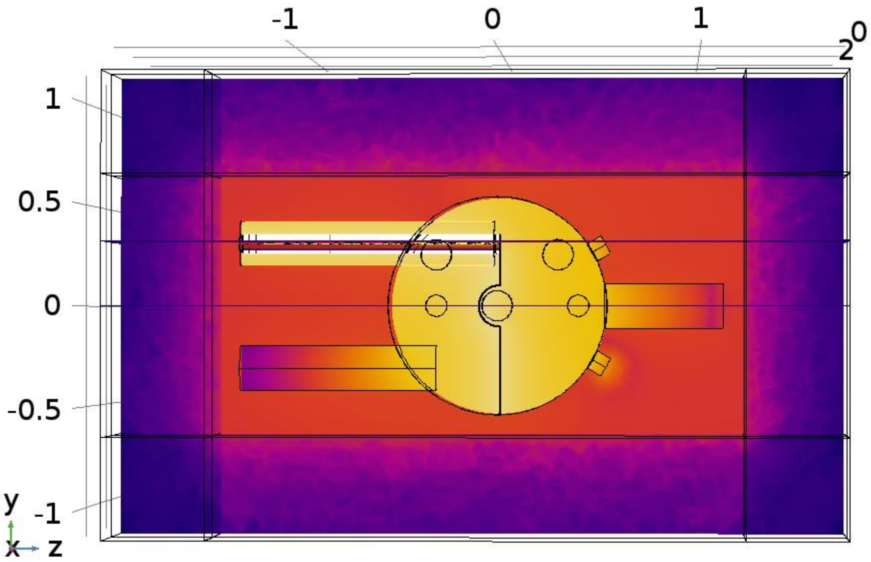
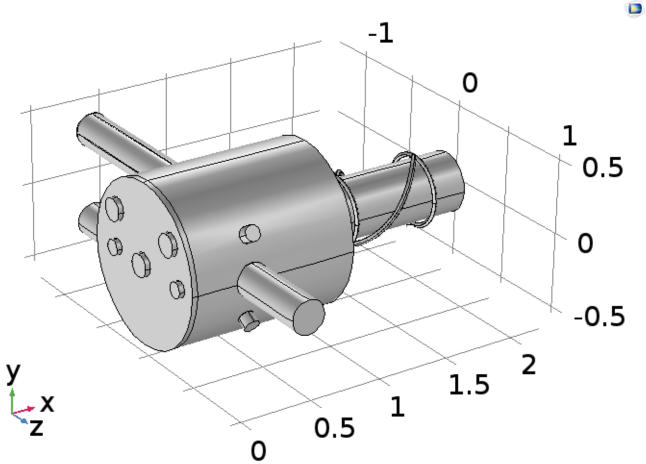
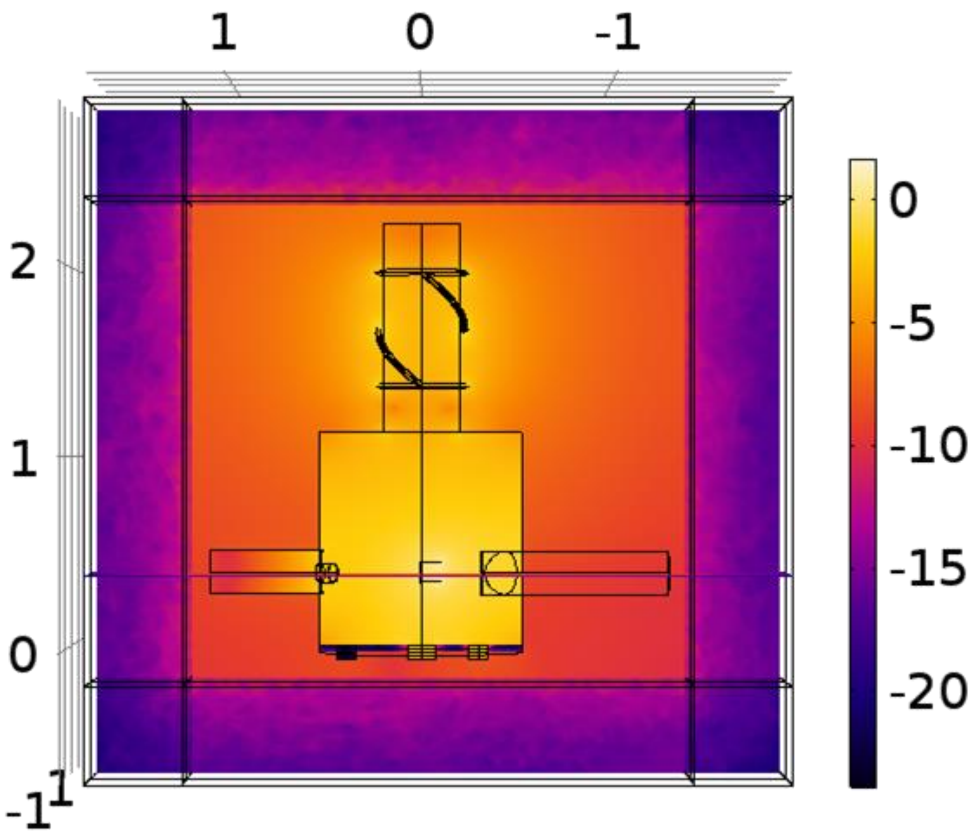
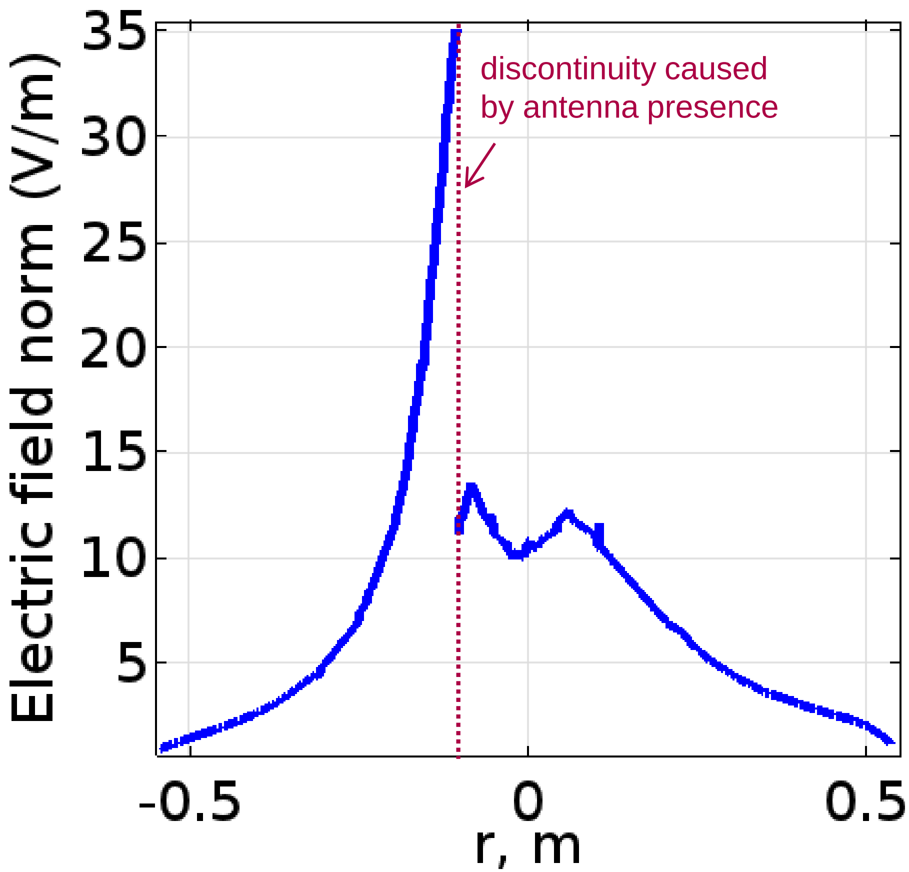
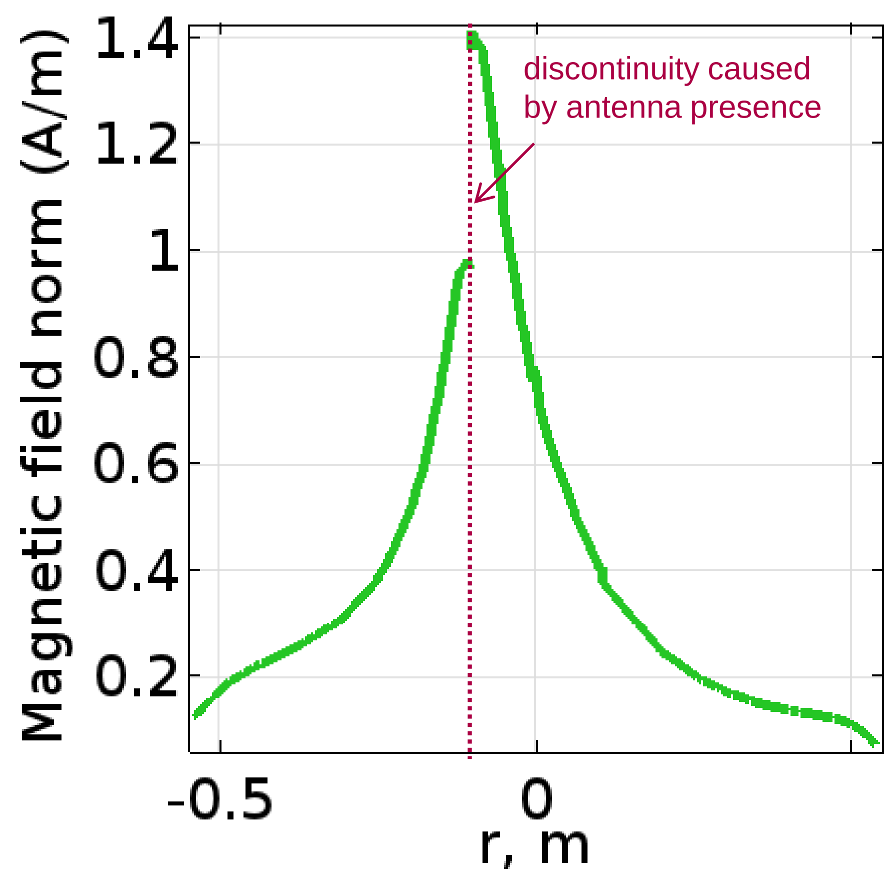






Log of the H norm (in A/m)





Input power: 1 W from the ICRF antenna and 1 V from the helicon antenna (50 Ω impedance)

Summary

COMSOL simulations provide necessary support for RF sheath studies on IShTAR and complement experimental results from diagnostics.

Several tasks are completed in an attempt to approach the realistic IShTAR conditions.

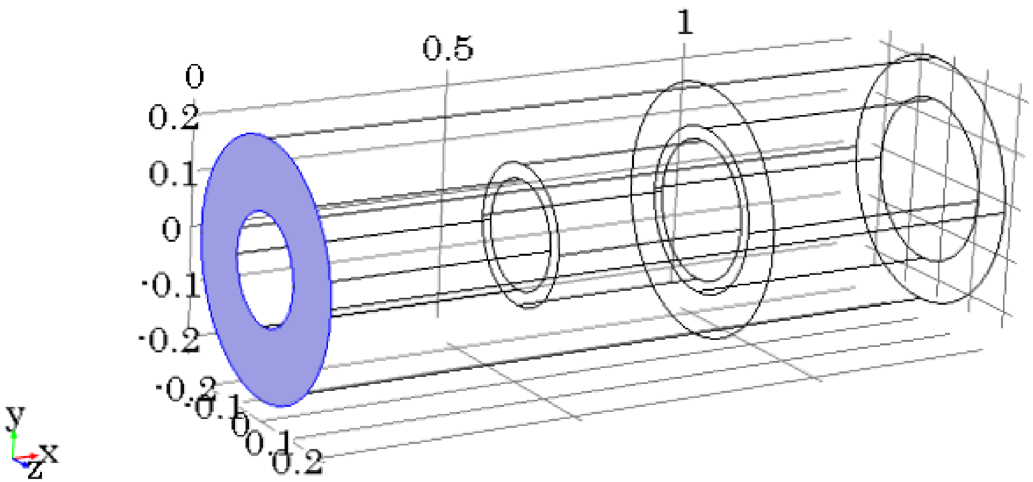
Modeling results are ahead of the experiments at the moment.

Future steps:

- Experimental data processing by using results from simulations.
- New antenna geometry implementation.
- Simulations in plasma instead of vacuum.

Appendix

Middle coaxial cable 2 performs impedance matching for cables 1 and 3.

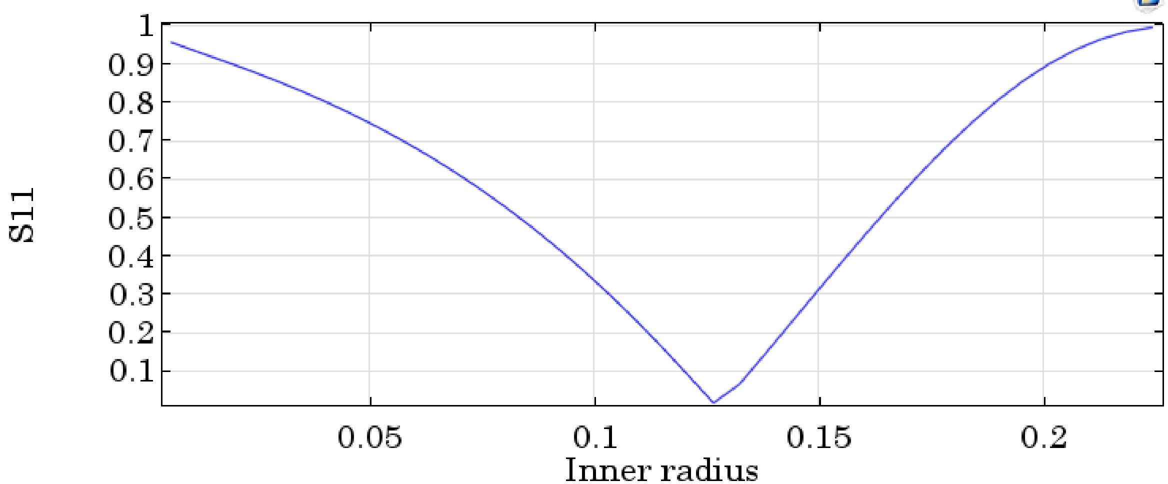


Conditions:

- $l_{in2} = c/4f_0$
- $Z_1/Z_2 = Z_2/Z_3$

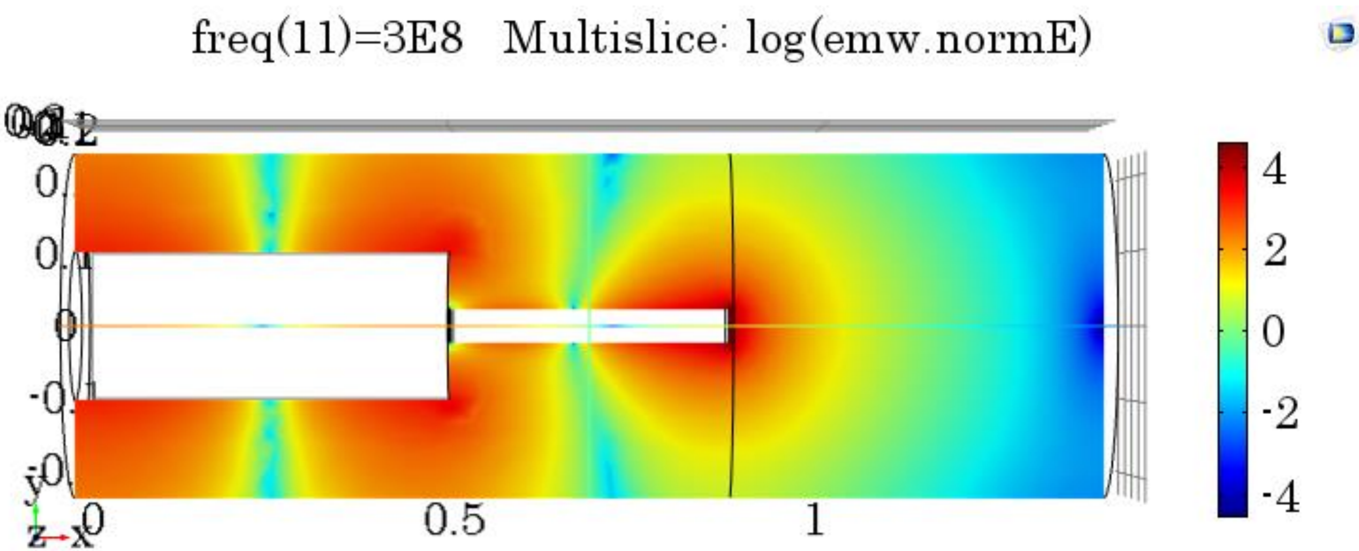
Parameters:

- f_0 = 200 MHz → l_{in2} = 0.38 m
- Z_1 = 50 Ω, Z_3 = 25 Ω
- r_{in2} = range(r_{out}*0.025,r_{out}/40,r_{out}*0.975
  Z_2 = range(221.18 Ω, 1.518 Ω)



S11 should reach minimum at Z_2 = 35.3 Ω, i.e. r_{in2} = 0.128 m

Impedance matching to vacuum



ICRH

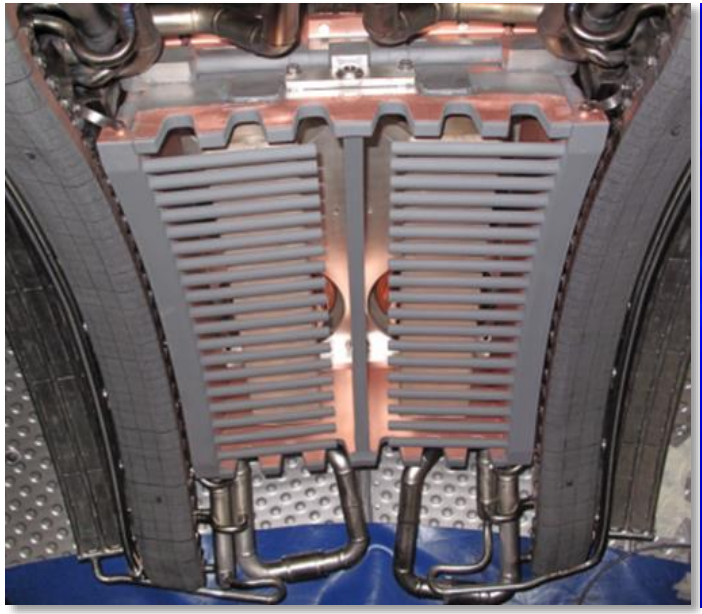
Ion

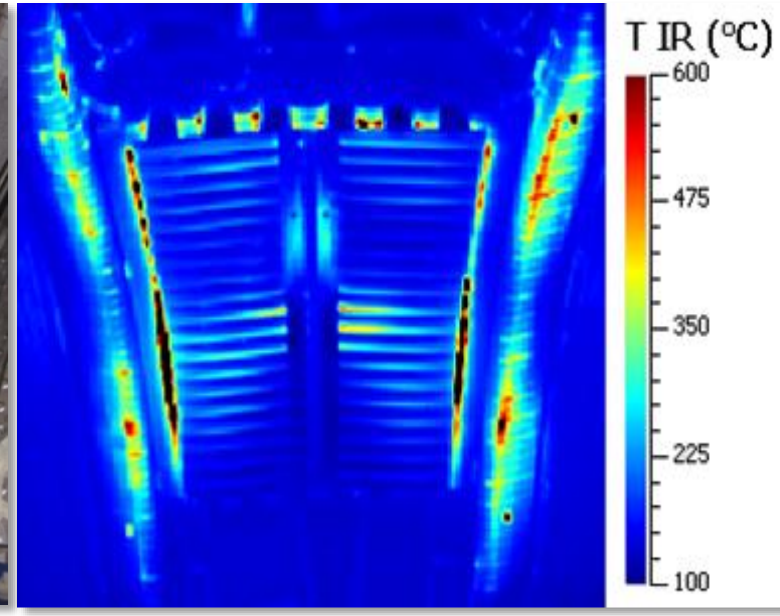
Cyclotron

Resonance

Heating

(30-120 MHz)





IR image - front face of the Tore Supra ICRH antenna
[J. Jacquot et al, PoP 21, 061509 (2014)]

Hot spots on antenna structures:

- Increased impurity concentration in plasma
- Power losses, reduced heating
- Can damage the antenna