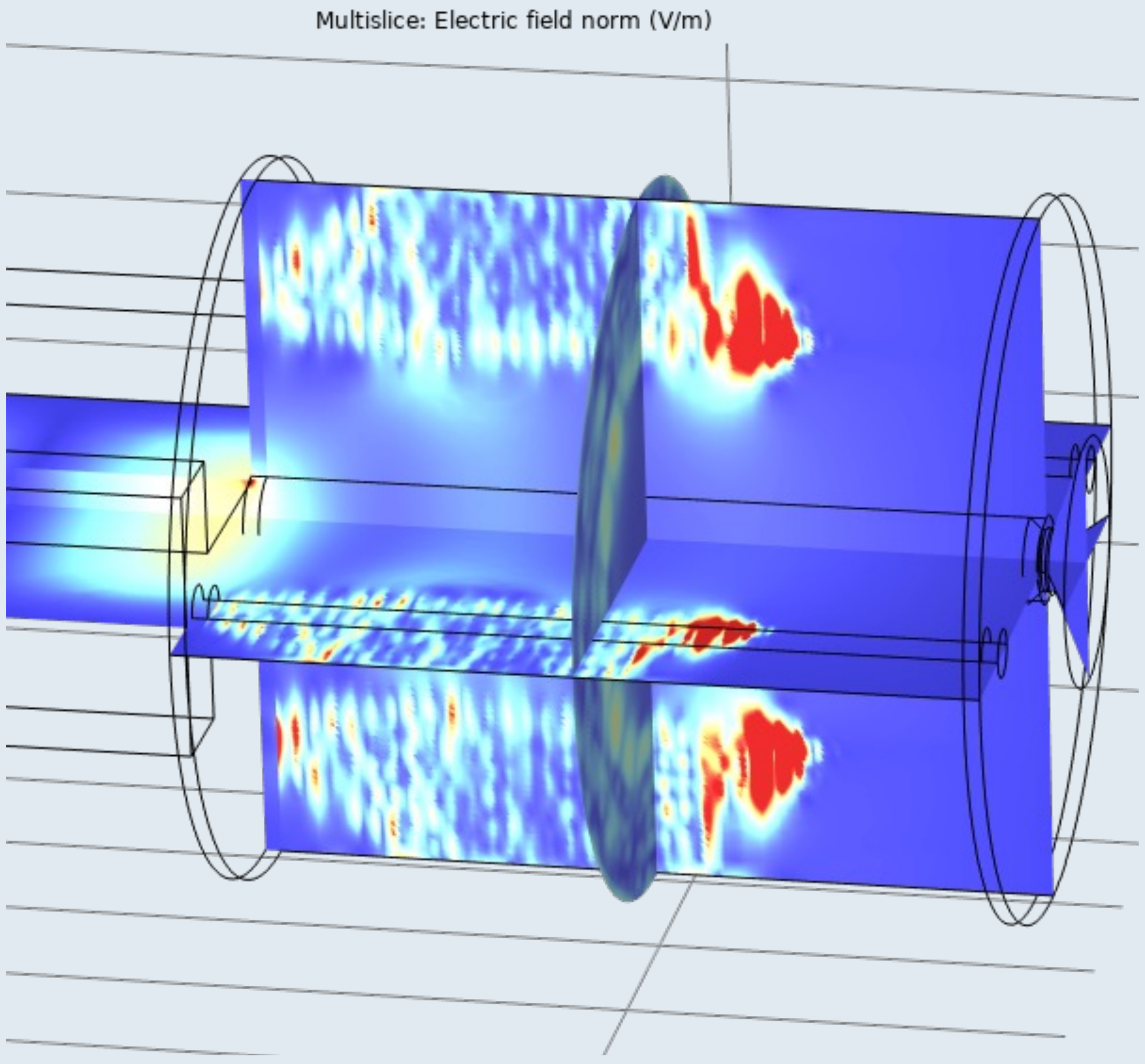

PIC Simulation of a 2.45 GHz ECR Ion Source Using COMSOL® Tensorial Permittivity RF Capability

Electromagnetic field propagation in a non-homogeneous and magnetized plasma was computed, using tensorial permittivity and cold approximation, to be integrated into a Particle In Cell (PIC) code.

L. Neri
INFN – Laboratori Nazionali del Sud, Catania, Italy.

Abstract

The development of the Ion Source based on the Electron Cyclotron Resonance (ECRIS) was primarily based on technological upgrades. Many different experimental setups are continuously identified, and the performance measured to be selected as improvement or discharged. Modern simulation techniques and rising computer capability make the simulation of such complex systems possible. Through simulation and experimentation, the evolution is improving fast and efficiently.The magnetic configuration of the ECR ion source under study and the plasma density evolution intercept different resonances: Electron Cyclotron Resonance, Critical Electron Density, Upper Hybrid Resonance, R-cutoff, and L-cutoff. The result was fascinating because it shows the conversion of electromagnetic waves depending on their position in the CMA diagram and their capability to ignite electrostatic waves. With this software, we intend to disclose why the HSMDIS [1] magnetic configuration produces higher beam stability than the standard magnetic configuration used in this type of ion source.

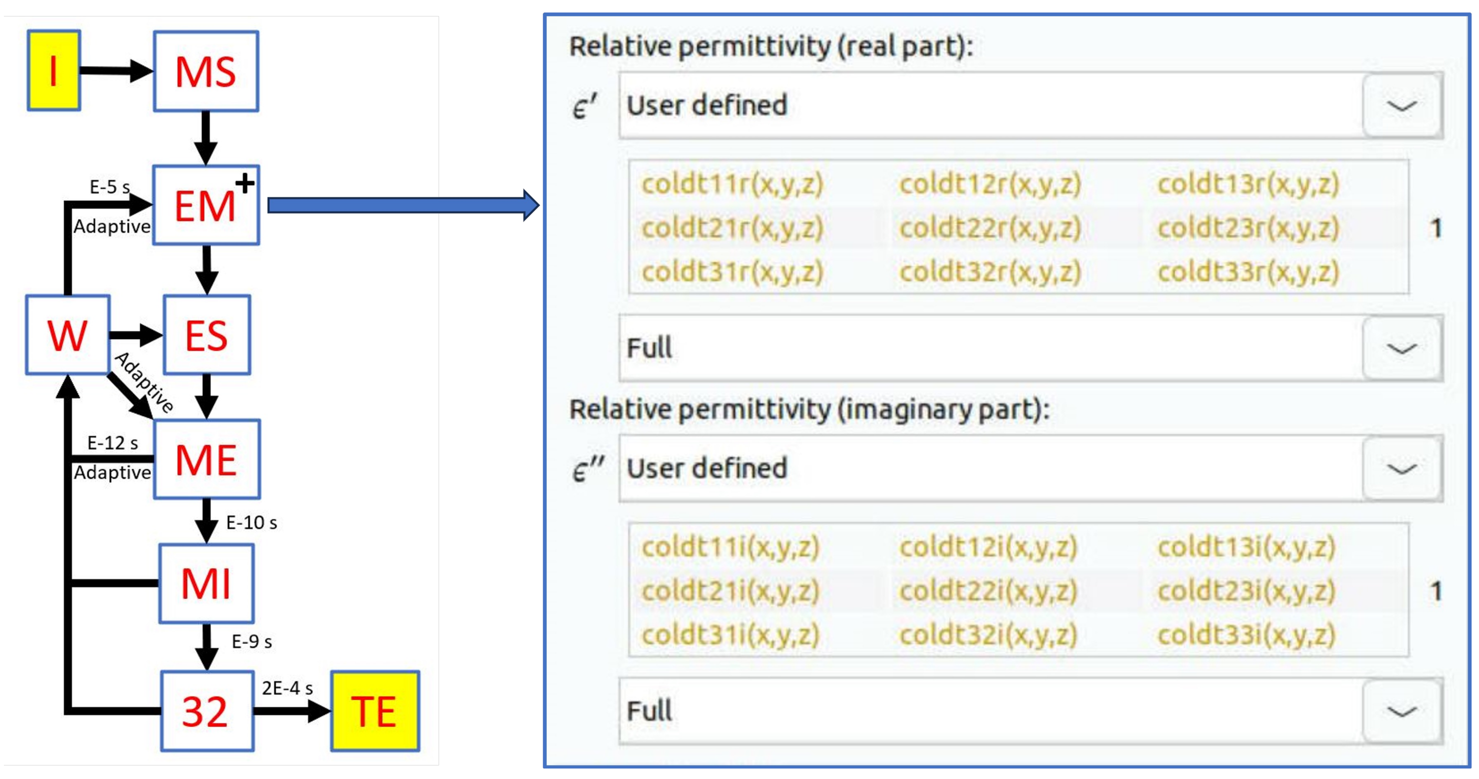

FIGURE 1. PIC code schema with the computational blocks and the different execution orders used for adaptive optimization.

Methodology

The PIC simulation tool is developed using MATLAB®, parallelized functions written in C and LiveLink™ *for* MATLAB® module to export the tensorial permittivity map from MATLAB® to COMSOL® and import in MATLAB® the electromagnetic field computed in COMSOL. The design of the PIC code actually consist of: 3D Initialization of 1E7 particles; 3D MagnetoStatic simulation; 3D (2.45GHz) ElectroMagnetic simulation with tensorial complex permittivity + special treatment of resonances; 2D Axial Symmetric ElectroStatic simulation with adaptive time step up to 4E-12 s; 3D Motion of Electrons (Boris mover); 3D Motion of Ions (Boris mover); Different Adaptive techniques to speed up the computation; 3D 32 Plasma reactions (e-, H+, H2+, H3+, H2, H, H2v, Hn); 3D Interaction with Walls: particle loss, secondary electrons, reflection; The End

Results

The output produced by the PIC code is a video showing many plasma parameters: electron and ion spatial and temperature distribution and evolution, electromagnetic field, species fraction evolution, plasma potential, and extracted current. The actual validation phase, where simulation results are compared to experimental data, is ongoing, and fine-tuning of the code is in progress. The commissioning of the PS-ESS source shows a region where the source does not produce a beam, even if powered by 600W of RF power. This behavior was fully disclosed by simulation. The role of the different resonances acting on the standard high current configuration (MDIS) and super stable configuration (HSMDIS [1]) is now clear. Simulation are now close to reproduce experimental observed behavior.

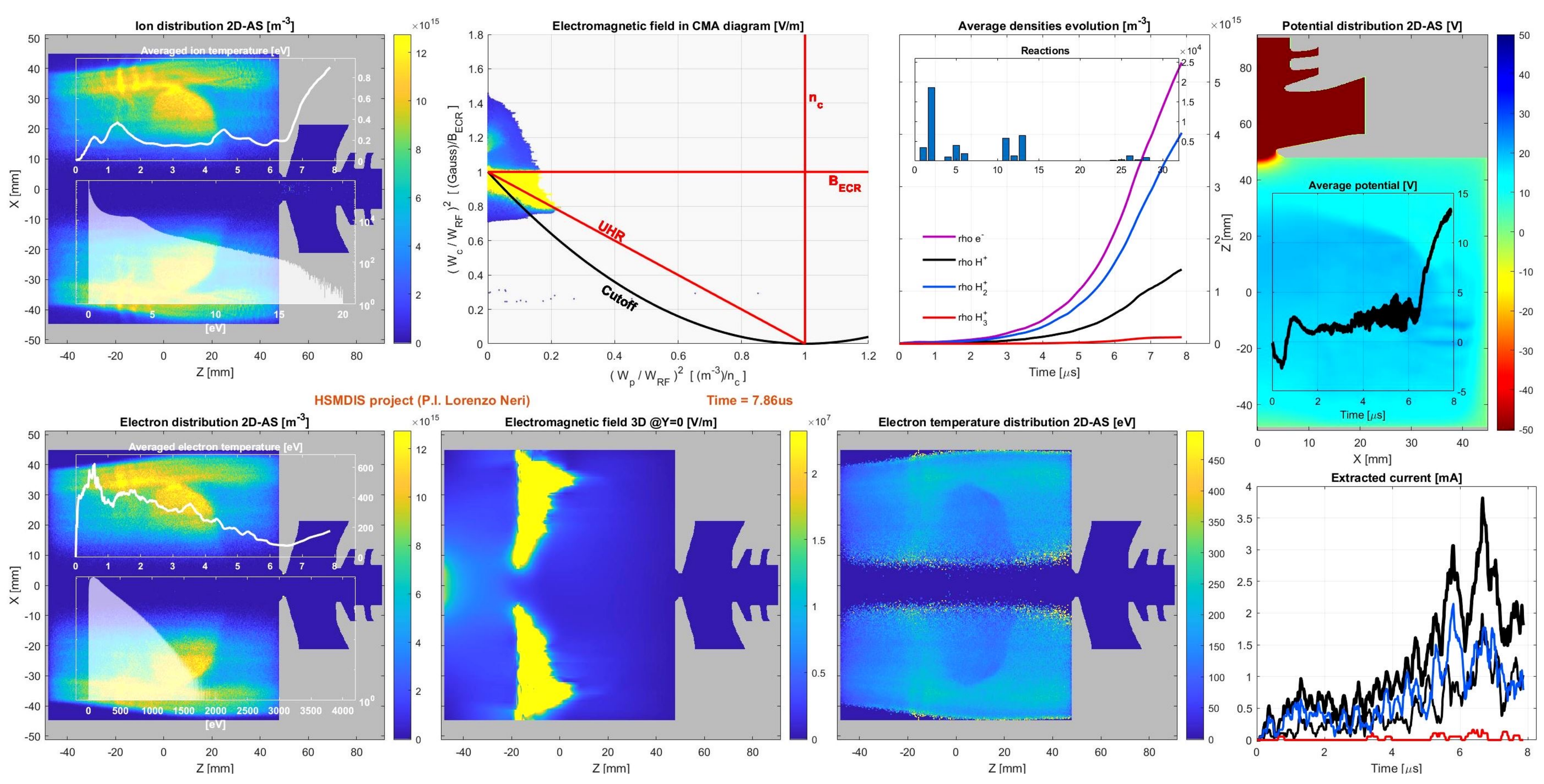

FIGURE 2. This is an interface used for visualizing the plasma evolution computed with the PIC code.

REFERENCES

1. L. Neri, L. Celona, "High Stability Microwave Discharge Ion Sources", Nature Scientific Reports 12, 3064 (2022) https://doi.org/10.1038/s41598-022-06937-7

INFN LNS