

Full-wave simulation of mode-converted electron Bernstein waves at very low magnetic field in the SCR-1

TEC | Tecnológico de Costa Rica

R. Solano-Piedra^{1*}, A. Köhn², V.I. Vargas¹, E. Meneses^{3,4}, D. Jiménez³, A. Garro-Vargas³, E. Zamora¹, L.D. Chavarría⁴, F. Coto-Vílchez¹, L.A. Araya-Solano¹, M.A. Rojas-Quesada¹, D. López-Rodríguez¹, J. Sánchez-Castro¹, J. Asenjo¹ and J. Mora¹
*Corresponding author: risolano@tec.ac.cr



¹Plasma Laboratory for Fusion Energy and Applications, Instituto Tecnológico de Costa Rica, Cartago, Costa Rica.

²IGVP, University of Stuttgart, Germany.

³Advanced Computing Laboratory, Costa Rica National High Technology Center, CeNAT, San José, Costa Rica.

⁴School of Computing, Instituto Tecnológico de Costa Rica, Cartago, Costa Rica.

MOTIVATION

The Stellarator of Costa Rica 1 (SCR-1) was designed, constructed and implemented at TEC, with the main goal to carry out engineering and physics research in small magnetic confinement devices [1]. Other aims are:

- To identify problems related to the design and construction of small modular stellarators.
- To train human resources in fusion technology and physics.
- To collaborate with international research centers in the pursuit of nuclear fusion energy.
- To strengthen the participation of Latin America in fusion research.

This work presents new computational results related with single O-X pass conversion with microwave heating scenarios. The BS-SOLCTRA (Biot-Savart Solver for Computing and Tracing magnetic fields) code also has been improved with a better visualization quality and parallel execution that turns into an easy, high performance computing platform. Vacuum magnetic flux surfaces measurements are compared with the BS-SOLCTRA code calculations to verify the design and correct position of the coils.

SCR-1 parameters

- 2-field period modular Stellarator
- Major radius $R = 247.7$ mm
- Aspect ratio = 6.2
- Low shear configuration
- $\iota_o = 0.312$ and $\iota_a = 0.264$
- 6061-T6 aluminum vacuum vessel
- ECH power 5 kW (2.45 GHz), second harmonic ($B = 43.8$ mT), $\langle B \rangle = 41.99$ mT
- 12 modular coils with 6 turns each
- 725 A per turn, providing a total toroidal field (TF) current of 4.35 kA-turn per coil
- The coils will be supplied by a bank of cell batteries of 120 V
- Plasma pulse between 4 s to 10 s

SCR-1 plasma parameters

- Minor plasma radius: 39.95 mm
- Line averaged electron density: $5 \times 10^{16} \text{ m}^{-3}$
- Plasma density cut-off value of $7.45 \times 10^{16} \text{ m}^{-3}$
- Estimated energy confinement time: 5.70×10^{-4} ms (of ISS04 [Ref.2])
- Plasma volume: 7.8 liters (0.0078 m^3)
- $\beta_{\text{Total}} = 0.01\%$
- Electron temperature: 6 - 14 eV

Conclusions

- Microwave heating scenarios proves the existence of UHR layer with a O-X conversion between 12% - 14% (previous results).
- The BS-SOLCTRA code took its first steps to turn into a full-scale simulation-visualization infrastructure with the option of to generate better visualization quality of magnetic flux surfaces and it was parallelized to enhance performance demands,
- The magnetic mapping experiment confirms the correct positioning of the modular coils in SCR-1.

SCR-1 Stellarator

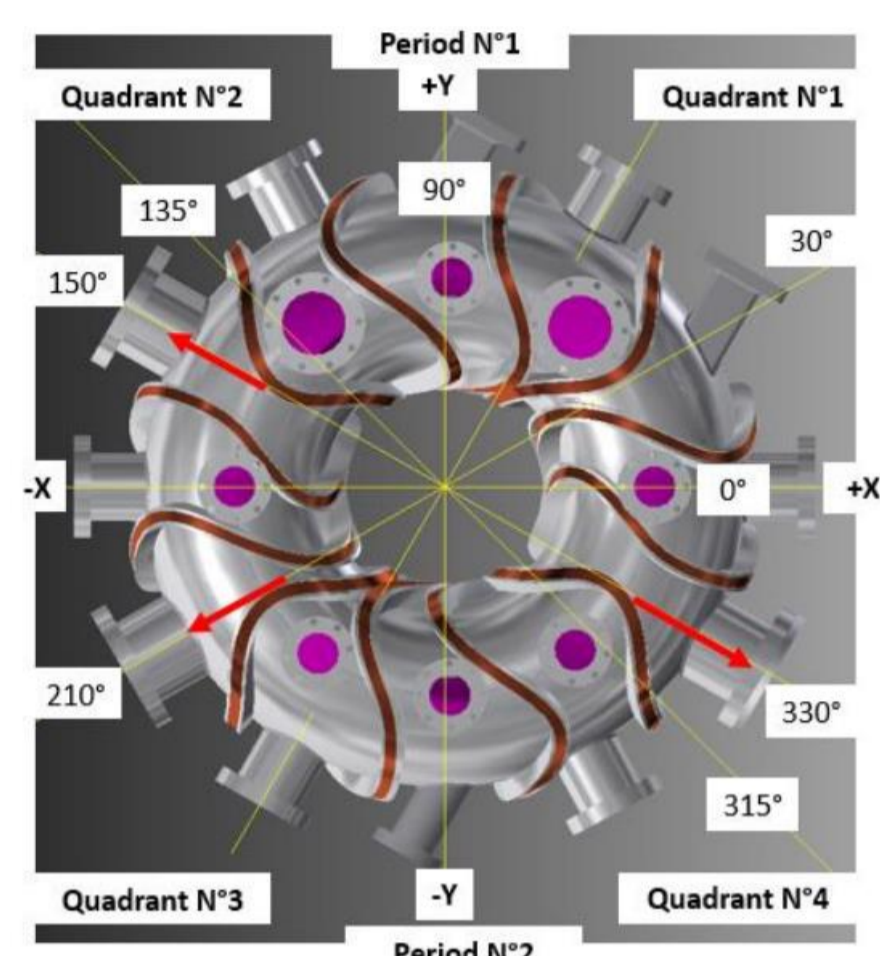


Figure 1. Schematic upper view of SCR-1 Stellarator

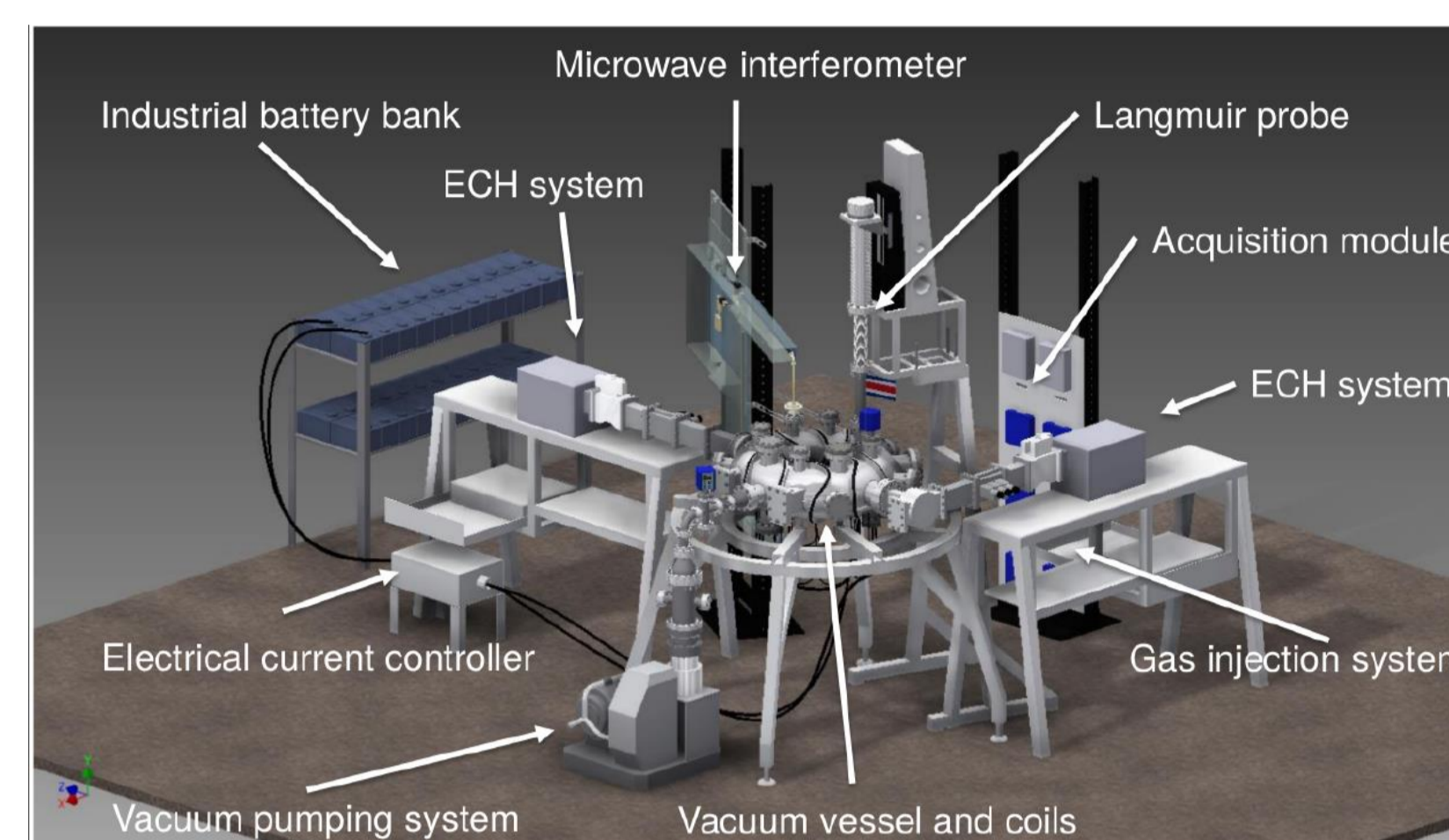


Figure 2. SCR-1 Main Components

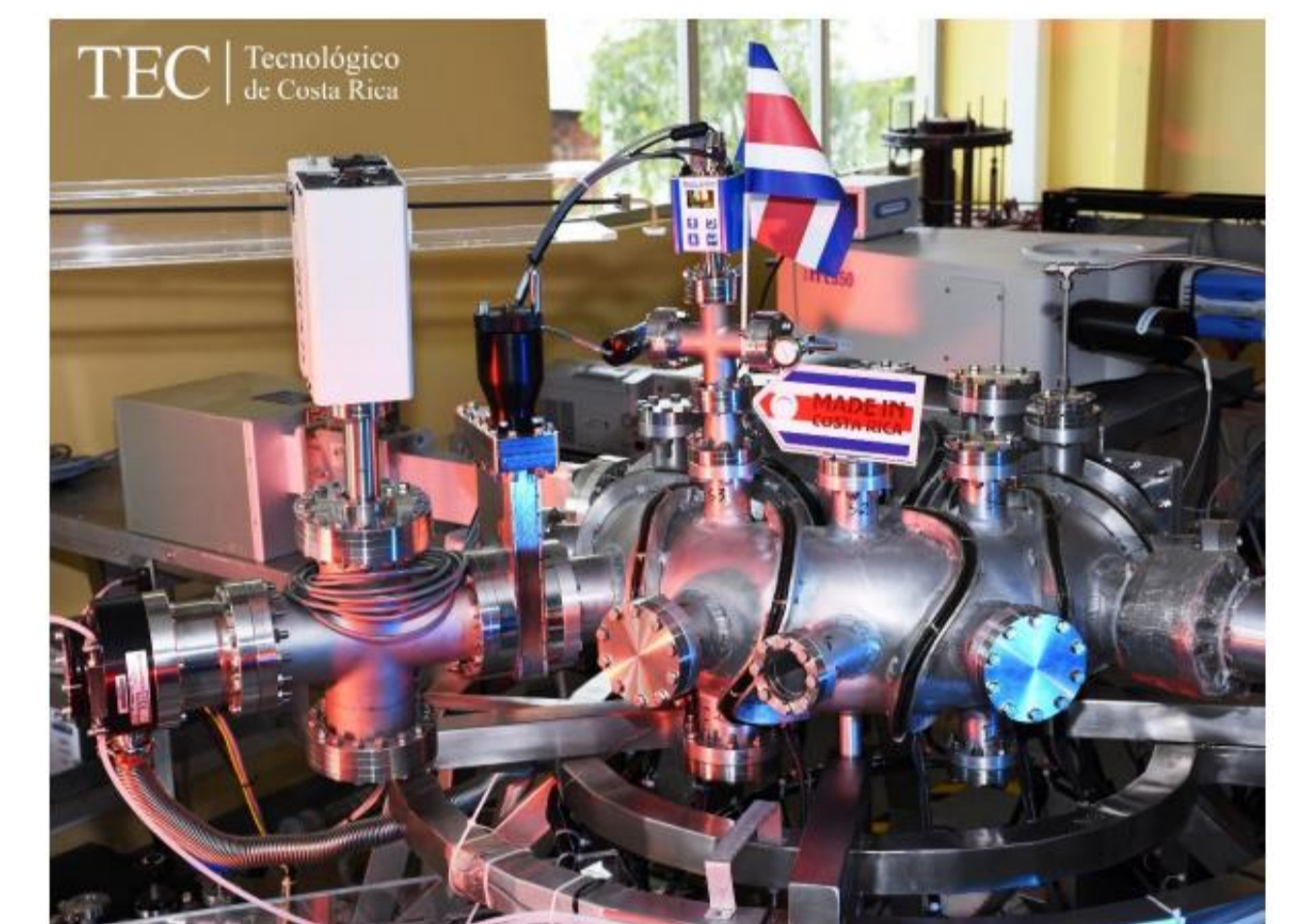


Figure 3. SCR-1 at Instituto Tecnológico de Costa Rica.

Microwave Heating Scenarios

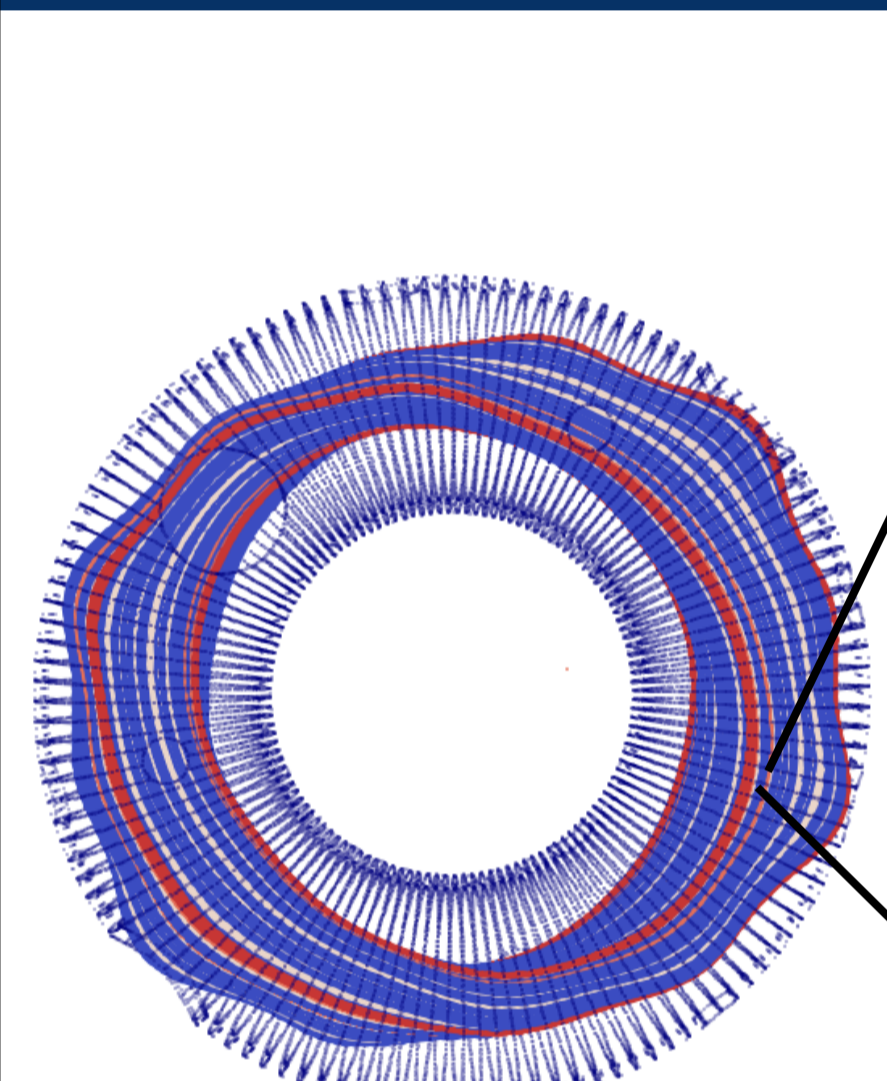


Figure 5. Last closed magnetic flux Surface in 3 Dimension generated by BS-SOLCTRA code.

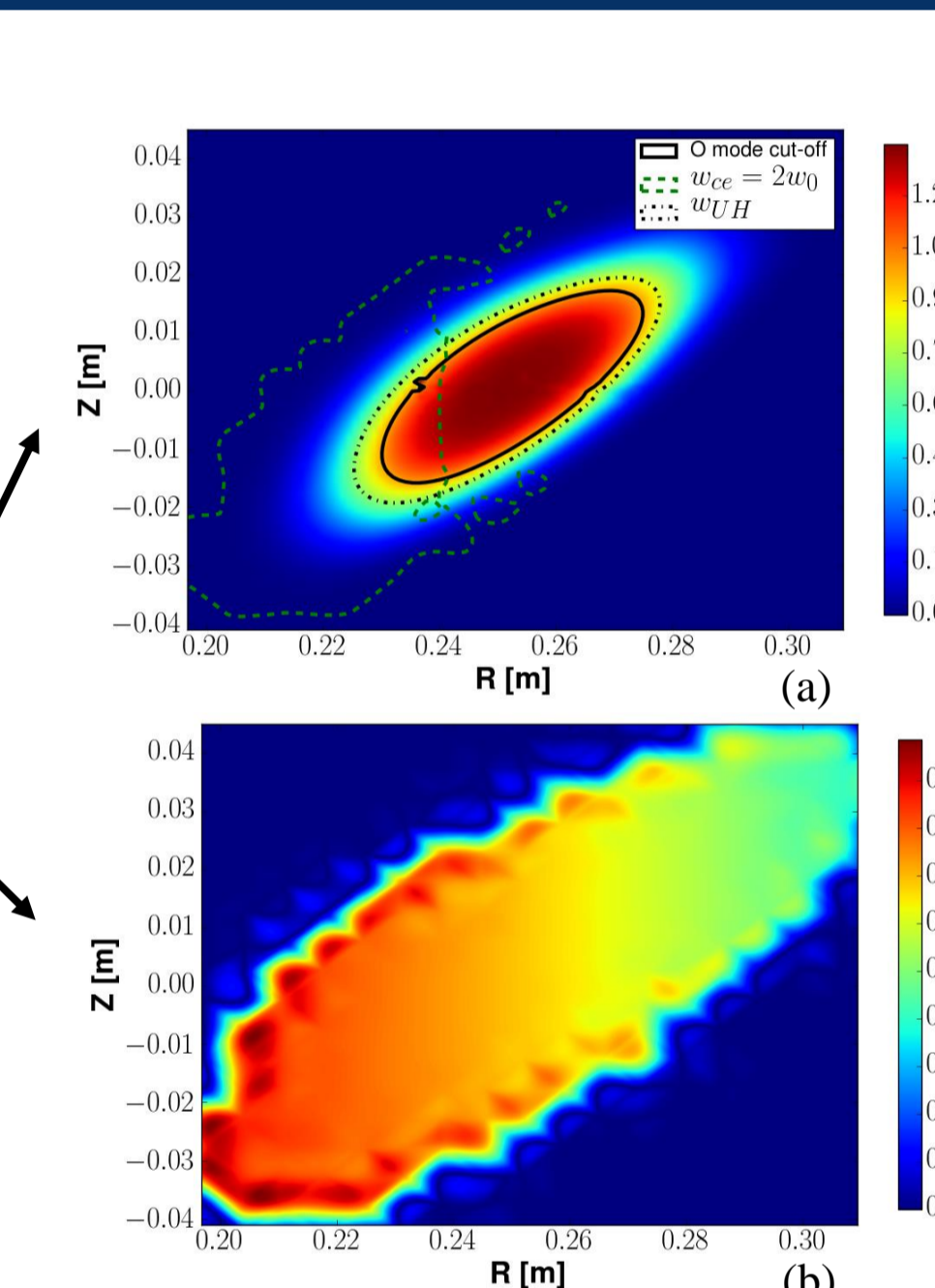


Figure 6. (a) Electron density and (b) magnetic field strength contour map for the toroidal position of 330°.

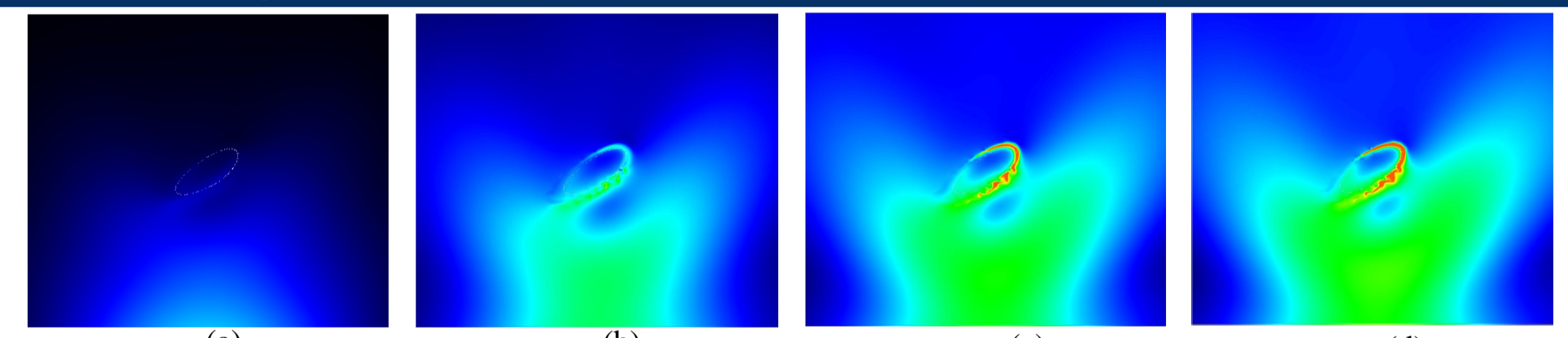


Figure 7. Full wave simulation at the toroidal position of 330° for the injection angle of 58° for: (a) 5 periods, (b) 10 periods, (c) 15 periods and (d) 20 periods.

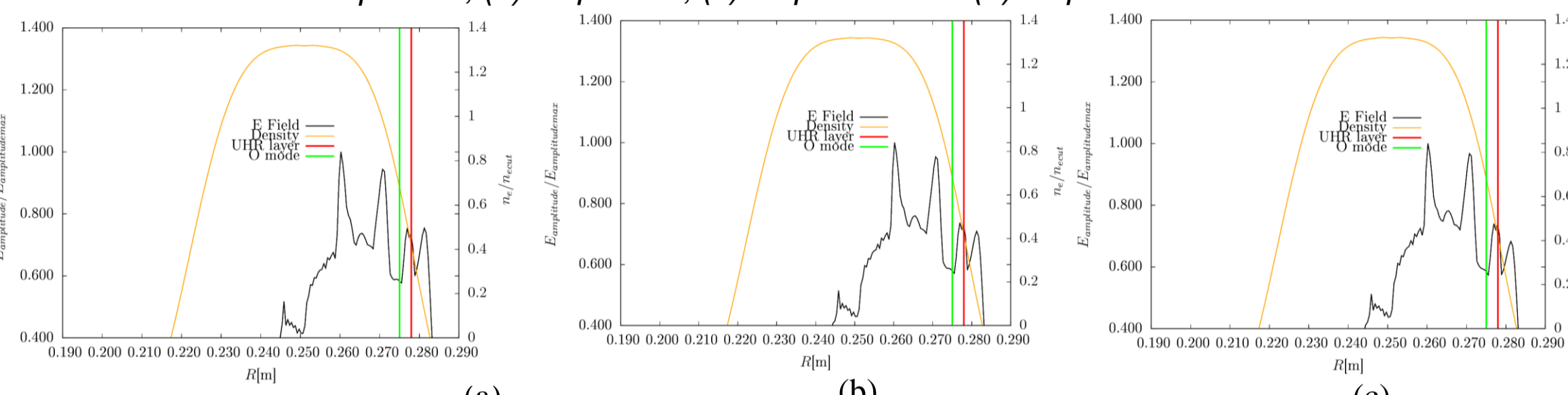


Figure 8. Amplitude variations of the electric field of the electromagnetic wave for (a) $1.1w_0$, (b) $1.5w_0$ and (c) $1.9w_0$.

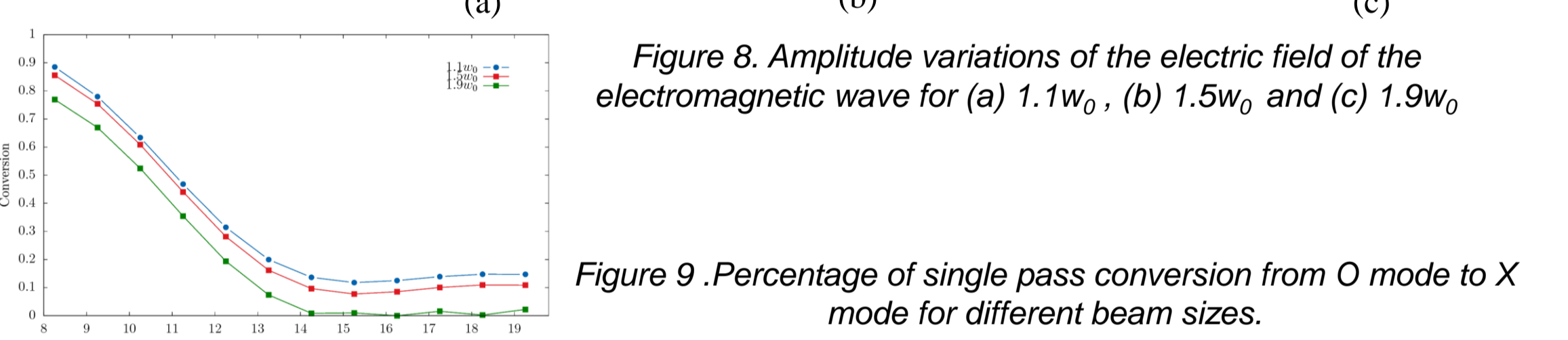


Figure 9. Percentage of single pass conversion from O mode to X mode for different beam sizes.

BS-Solctra code

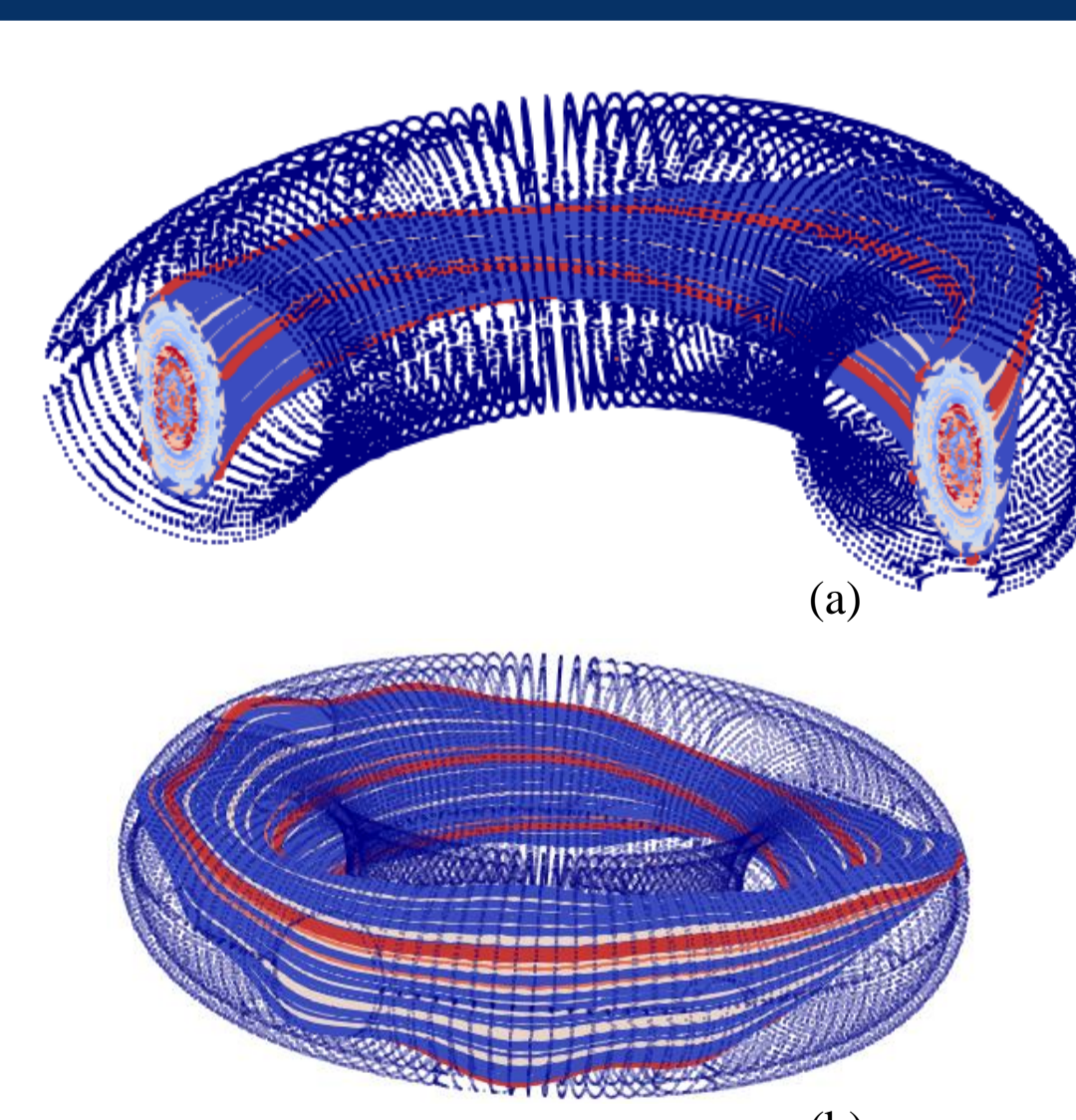


Figure 6. Last closed magnetic flux Surface in 3 Dimension generated by BS-SOLCTRA code for (a) a half cut and (b) lateral view

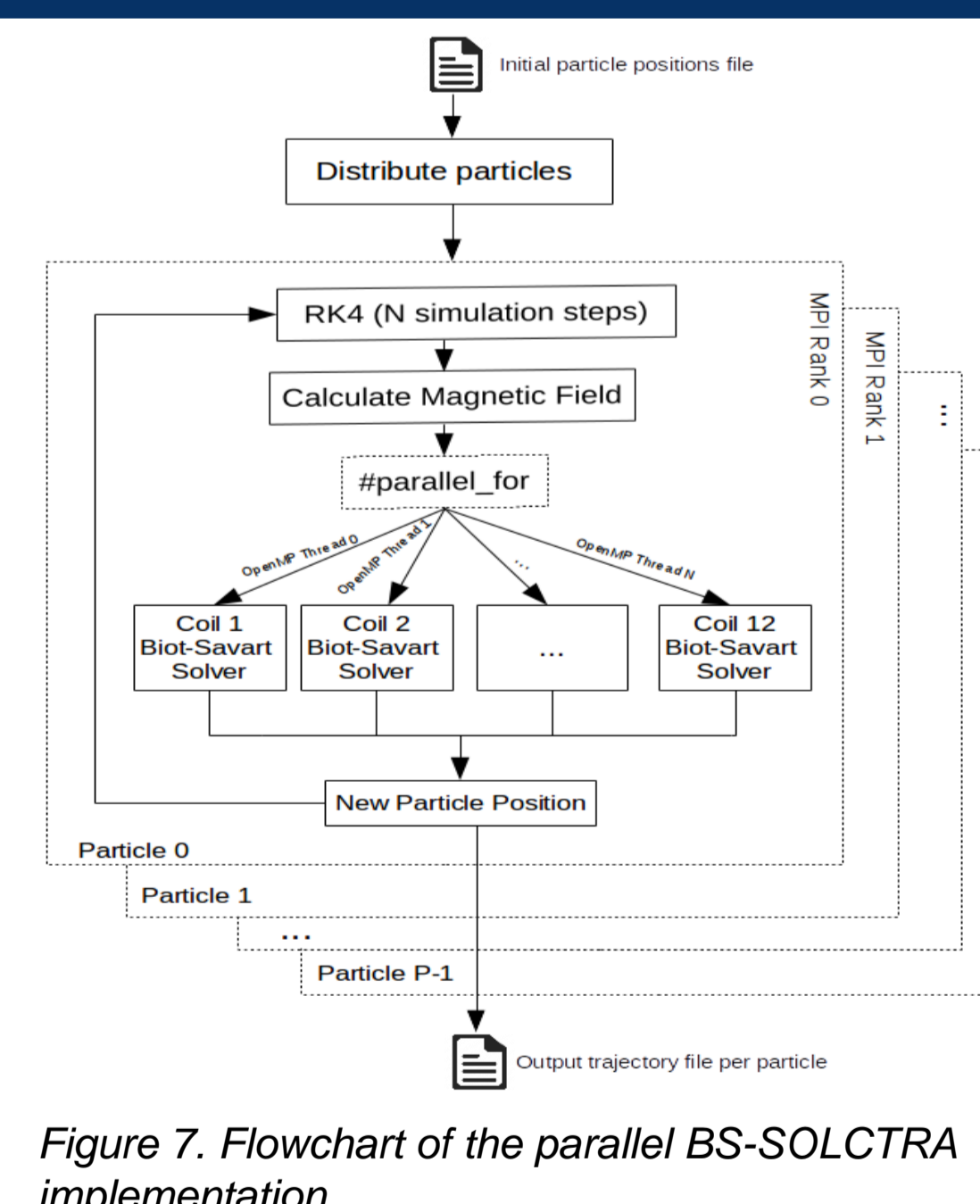


Figure 7. Flowchart of the parallel BS-SOLCTRA implementation

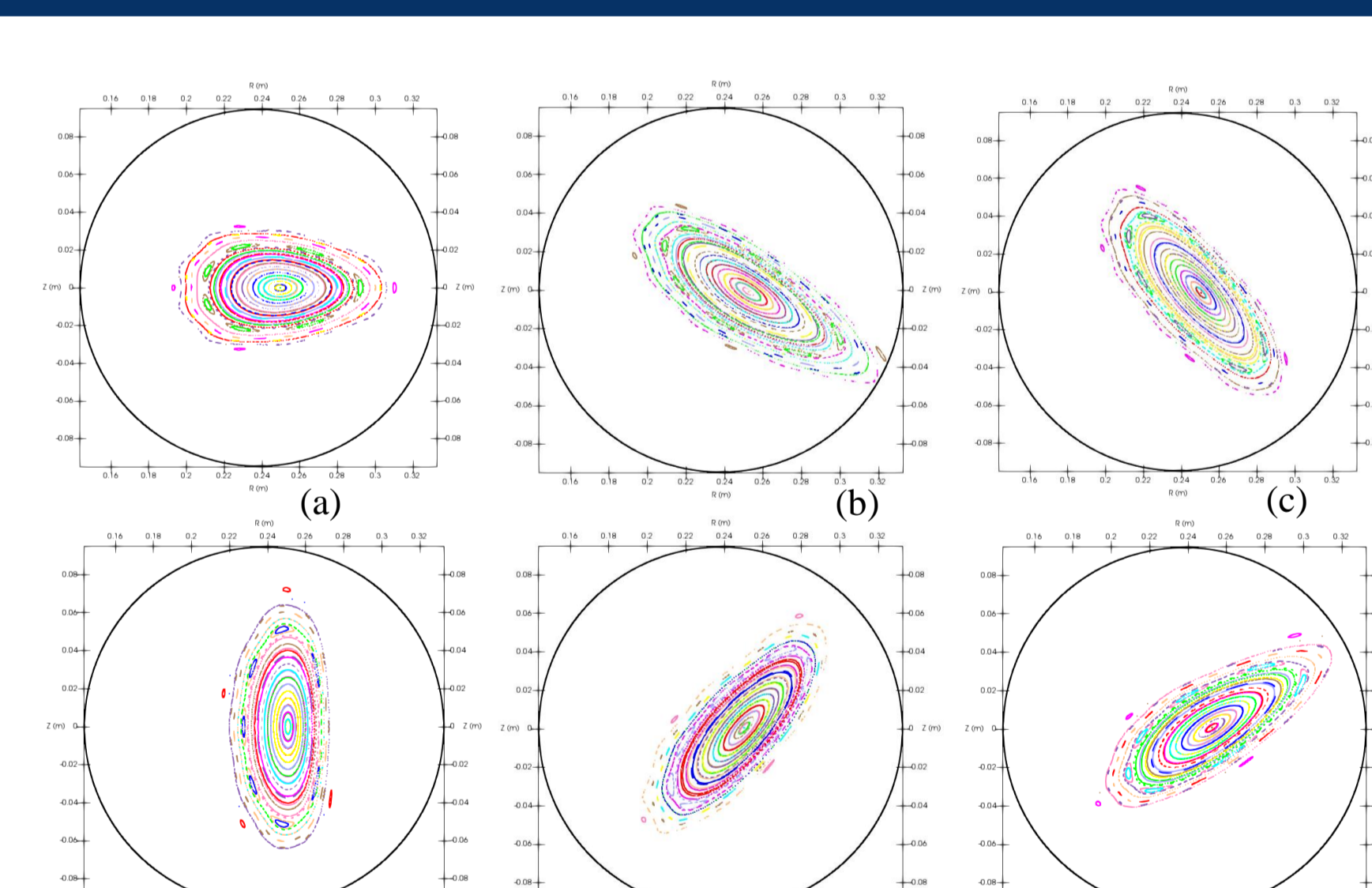


Figure 8. Vacuum magnetic flux surfaces at toroidal positions of: (a) 0° , (b) 30° , (c) 45° , (d) 90° , (e) 135° and (f) 150°

Magnetic Mapping

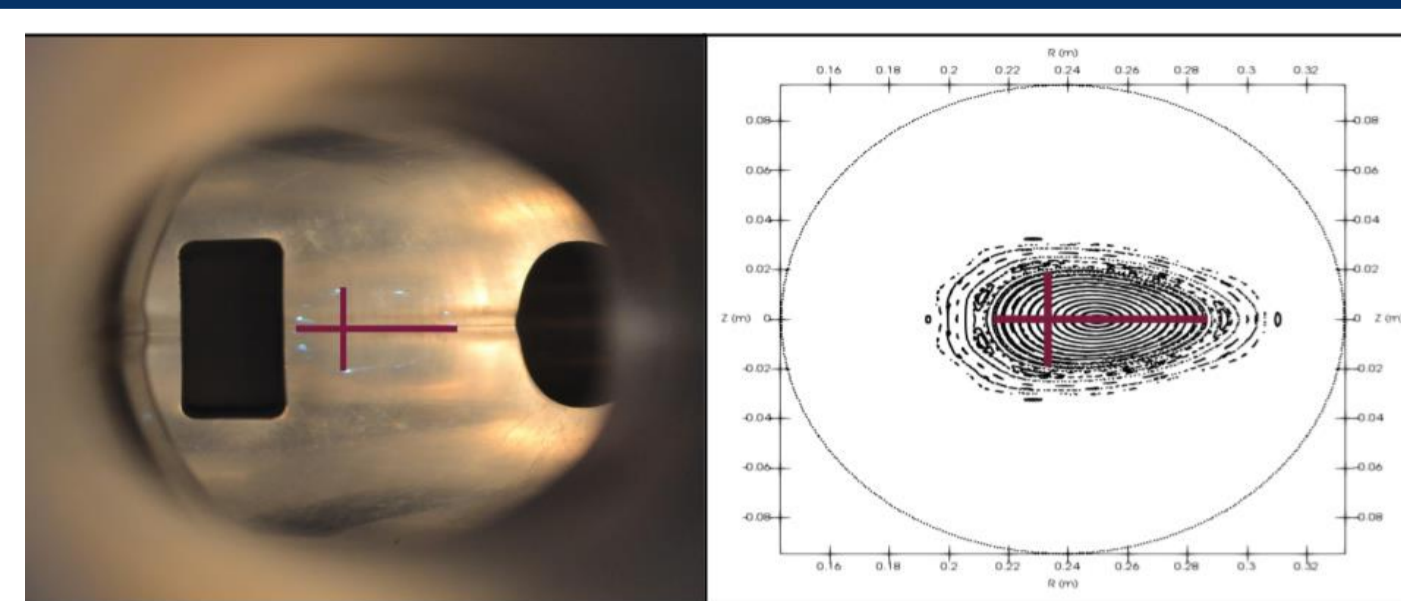


Figure 9. Comparison between (a) points where the hits on the oscillating rod, obtained using a high speed camera and (b) Poincare diagram at the toroidal position of 0° using modified version of BS-SOLCTRA code.

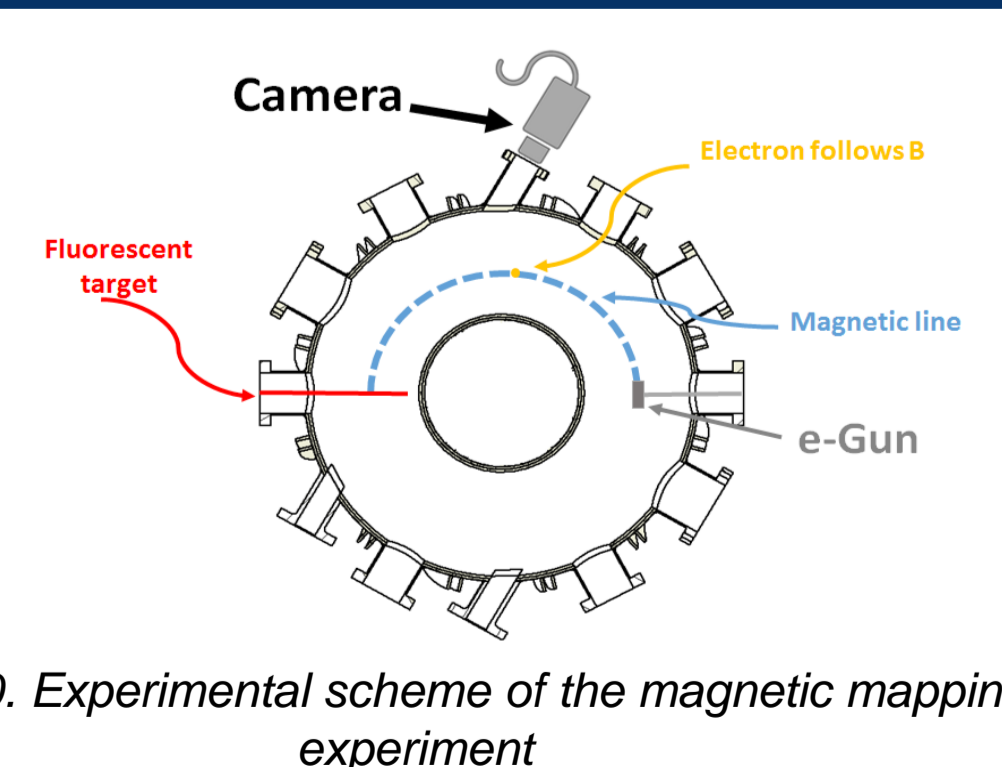


Figure 10. Experimental scheme of the magnetic mapping experiment

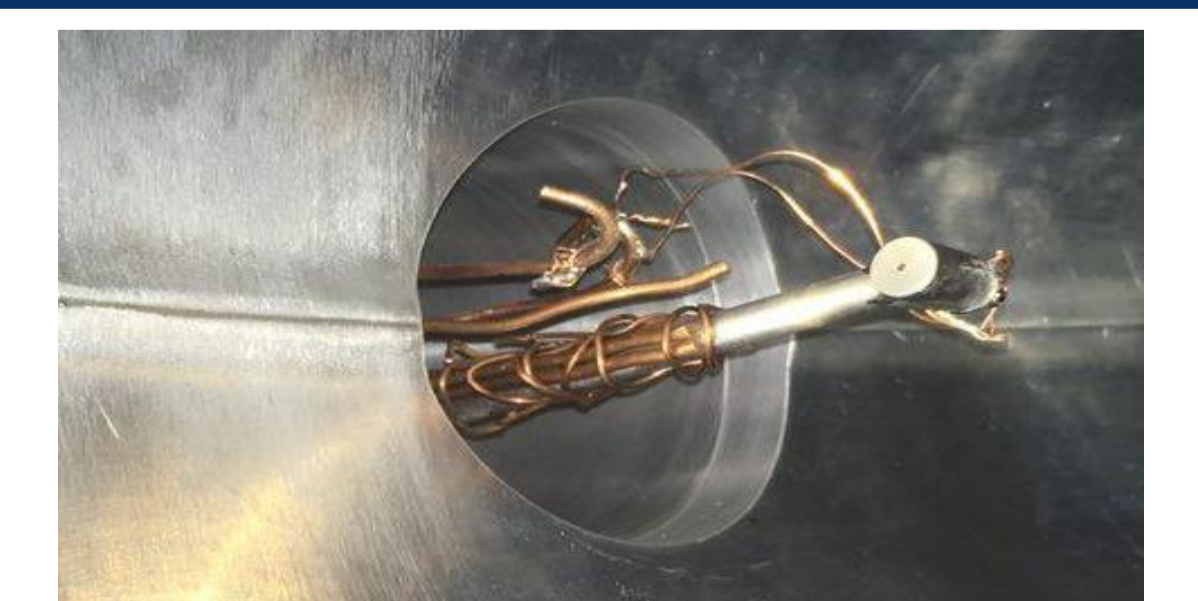


Figure 11. e-gun installed at SCR-1 stellarator vacuum vessel

References

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