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Experimental Plan for Measuring Fluctuations in the Velocity Distribution Function of Relativistic Electrons Using Electron Cyclotron Emission Spectra in the Spherical Tokamak FIRST

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Experimental attempts have been made to diagnose the electron velocity distribution function (EVDF), $f(v)$, from electron cyclotron emission (ECE) by utilizing relativistic frequency shifts [1, 2]. These methods allow for the determination of the EVDF of mildly relativistic electrons using the second and third harmonic ECE intensities observed vertically in a tokamak, where the magnetic field strength remains constant along the line of sight. However, these approaches face limitations, such as relying on ad hoc assumptions about the pitch-angle distribution of the EVDF and being applicable only to steady-state conditions.

The MEM–HT (Maximum Entropy Method with the Hankel Transform) is a novel approach developed to reconstruct the fluctuation components of the EVDF, $\delta f(v)$, and the associated electron entropy from ECE harmonic spectra in optically thin plasmas [3]. It can diagnose relativistic electron populations, except in scenarios involving harmonic overlap or optically thick conditions. Notably, the method avoids ambiguous assumptions and does not require radiometer calibration for EVDF measurements.

Furthermore, the measurement of relativistic frequency shifts can be incorporated with the MEM–HT method to derive the dependence of $\delta f(u)$ on the relativistic parallel velocity amplitude $|u_{//}|$. Accurate knowledge of the local electron cyclotron frequency Ω_{ce} is crucial for the success of this reconstruction technique. A particularly effective configuration to meet this requirement involves vertical observation of the tokamak plasma from the top of the device, thereby isolating a region with a uniform magnetic field—similar to the configuration used in the Hutchinson–Kato method [1, 2]. In this setup, the reconstructed EVDF is line-integrated along the viewing path.

We plan to apply the MEM–HT method in the Formosa Integrated Research Spherical Tokamak (FIRST) experiment in Taiwan. The FIRST tokamak, under planning and construction since 2023, features a designed aspect ratio of 0.45 m / 0.3 m, a toroidal field strength of 0.5 T, and a plasma current of 100 kA. The experimental campaign is scheduled to begin in early 2026. Details of the ECE-based measurement plan for the relativistic EVDF in the FIRST experiment will be presented in this talk.

References

[1] Hutchinson I H and Kato K 1986 *Nuclear Fusion* **26** 179
[2] Kato K and Hutchinson I H 1986 *Phys. Rev. Lett.* **56** 340
[3] Kawamori E 2025 *Nuclear Fusion* **65** 026024