9th Asia-Pacific Conference on Plasma Physics, 21-26 Sep, 2025 at Fukuoka

Primary Results of Multi-filter Soft X-Ray Tomography during Counter-Helicity Spheromak Merging

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We developed soft X-ray tomography to investigate the generation and spatial distribution of high-energy electrons across multiple energy ranges during counter-helicity spheromak merging in the TS-6 device.

In this study, bremsstrahlung emissions captured by energy-resolved soft X-ray imaging were analyzed, enabling detailed examination of localized electron acceleration during magnetic reconnection. Multi-filter soft X-ray tomography was utilized to simultaneously measure emissions ranging from 10 eV to over 200 eV in the mid-plane of the UTokyo TS-6 device [1]. The diagnostic system includes four pinholes, four filters, four built-in microchannel plates, fiber optics, and a high-speed camera. Although the captured images represent line-integrated signals through the plasma, soft X-ray emissions in the R-Z plane were reconstructed using the maximum entropy method and the minimum generalized cross validation criterion [2].

Figure 1 illustrates the two possible cases of counter-helicity spheromak merging: case-I and case-O, each defined by opposing toroidal field polarities. These configurations exhibit different reconnection dynamics, with the X-point moving inward in case-I and outward in case-O due to the bending of the magnetic field influenced by the polarity difference of the reconnection electric field.

Figure 2 presents reconstructed image of the soft X-ray emission for both case-I (left) and case-O (right), using three filters (columns) and three different reconnecting magnetic field strengths, B_{rec}[T] (rows), at 475us. At the onset of magnetic reconnection, emissions from the 1um aluminum filter peaked in the inward downstream region for both cases. In contrast, the 2.5um aluminum and 1um mylar filters did not exhibit such peaks, indicating an electron energy of approximately 10 eV to 80 eV. This energy range suggests the presence of downstream acceleration driven by reconnection outflow [3].

Additionally, while case-I consistently exhibited high emission levels across varying B_{rec} values in the 1um aluminum filter, case-O displayed weaker discharges corresponding to the decreasing in B_{rec}. This difference is attributed to the direction of the reconnection outflow: case-I, with a strong toroidal component, triggers electron trapping in the pile-up region, while case-O's dominant radial outflow leads to electron dispersion.

References
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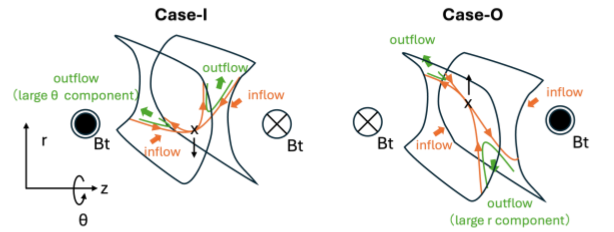

Figure 1. Counter-helicity spheromak merging for both Case-I and Case-O. Colored lines are magnetic field lines (orange: inflow, green: outflow) and black lines are a section of spheromak torus.

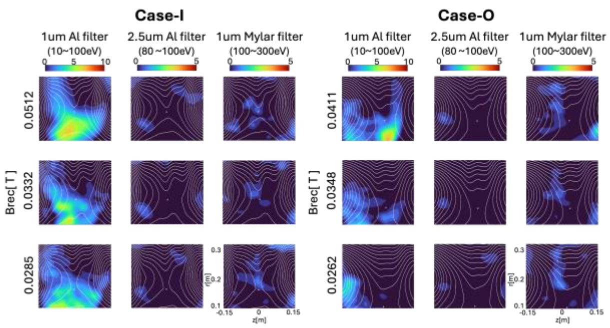

Figure 2. R-Z contours of 2D soft X-ray emission (color) with poloidal flux surfaces (white lines) for 1um Aluminum, 2.5ul Aluminum, and 1um Mylar filter each with 3 different B_{rec} [T] for both Case-I and Case-O at 475us