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Investigation of collisionless charged particle motion near the X-point of the two-wire model

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This research numerically investigates collisionless charged particle motion and transport phenomenon in the magnetic configuration of the two-wire model (TWM), which encompasses a magnetic X-point[1]. The TWM is of research interest as it resembles the magnetic configurations of single-null diverted tokamaks and those of the magnetic reconnections[2].

Single particle trajectories are governed by two conserved quantities: total kinetic energy and base field line value (derived from axial canonical momentum). As particles gyrate along the field lines, their proximity to the X-point can cause shifts of the magnetic moment, $\mu = W_\perp/B$, due to the large field gradient. Consequently, particles with large magnetic moments and Larmor radii probabilistically cross the separatrix to transport to the other side of the TWM configuration. Cross-field transport of particles near the X-point is referred to as 'migration' in this work.

The statistical behavior of magnetic moment shift is decided by the two aforementioned conserved quantities. despite the apparent chaotic nature of the shift. Additionally, there exists the migration threshold energy, that depends on the base field line value. The time between consecutive migrations follows an exponential distribution. The average time, denoted as the migration confinement time, is shorter for particles with the base field line closer to the separatrix and with higher energy. An empirical expression derived from the single particle simulations is provided for the estimation of the collisionless migration confinement time.

The effect of the additional axial field in the TWM is investigated as well. With smaller field gradient near the X-point, the magnetic moment is preserved, and there exists four distinct orbits near the separatrix, with the strong drift near the X-point playing a significant role.

References
[1] S.P. Auerbach *et al*, Phys. Fluids. **23** (1980)
[2] B. Ahn *et al*, J. Plasma Phys. **90** (2024

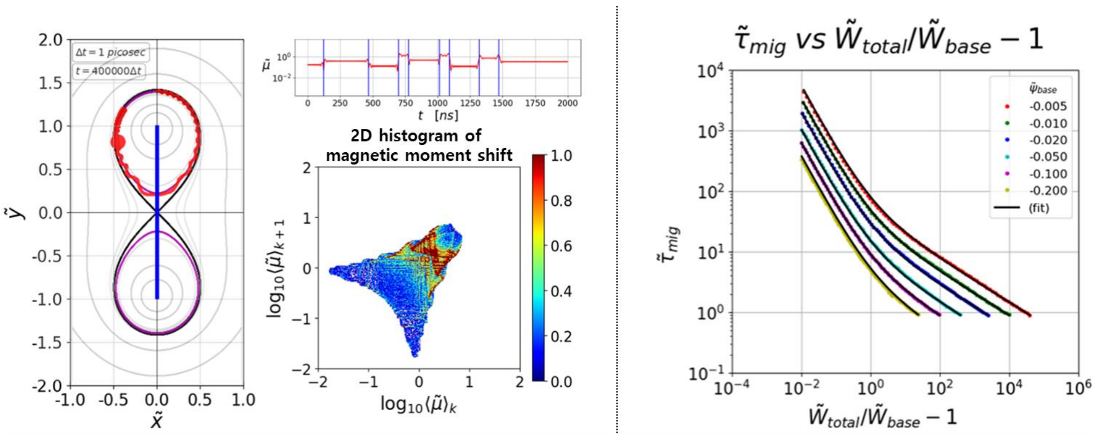

Figure 1. The trajectory of a particle, the temporal evolution of its magnetic moment, and 2D histogram showing magnetic moment shift distribution (left). The migration confinement times of various pairs of base field line value and kinetic energy, calculated from the simulation data (right).