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Effects of Magnetic Helicity on 3D Equilibria and Self-Organized States in KTX Reversed Field Pinch

Ke Liu[1], Guodong Yu[1], Yuhua Huang[1], Wenzhe Mao[1], Caoxiang Zhu[1] and KTX Team[1]
[1] School of Nuclear Science and Technology, University of Science and Technology of China
e-mail (speaker): lk2020@mail.ustc.edu.cn

The reversed field pinch (RFP) is a toroidal magnetic configuration in which plasmas can spontaneously transform into different self-organized states. Among various states, the quasi-single-helical (QSH) state significantly improves confinement [1]. Many theoretical and experimental efforts have investigated the transitions among different states. This study employs the multi-region relaxed magnetohydrodynamic (MRxMHD) model to study the properties of QSH and other states. The stepped-pressure equilibrium code (SPEC) is used to compute MHD equilibrium for the Keda Torus eXperiment (KTX) [2,3]. The toroidal volume of KTX is partitioned into two subvolumes by an internal transport barrier. The geometry of this barrier is adjusted to achieve force balance across the interface, ensuring that the plasma in each subvolume is force-free and that magnetic helicity is conserved. By varying the parameters, we generate distinct self-organized states in KTX. Our findings highlight the crucial role of magnetic helicity in shaping these states. In states with low magnetic helicity in both subvolumes, plasma exhibits axisymmetric behavior. With increasing core helicity, the plasma gradually transforms from an axisymmetric state to a double-axis helical (DAx) state and finally to a single-helical-axis (SHAx) state [4]. Elevated core magnetic helicity leads to a more pronounced dominant mode of the boundary magnetic field and a reduced core magnetic shear. This is consistent with previous experimental and numerical results in other RFP devices [1,5]. We find a linear relationship between the plasma current and helicity in different self-organized states. Our findings suggest that KTX may enter the QSH state when the toroidal current reaches 0.72 MA. This study demonstrates that the stellarator equilibrium code SPEC unveils crucial RFP equilibrium properties, rendering it applicable to a broad range of RFP devices and other toroidal configurations.

References
[1] R. Lorenzini *et al.* Nature Phys. 5, 570–574 (2009).
[2] W. Liu *et al.* Nucl. Fusion 57, 116038 (2017).
[3] S. R. Hudson *et al*. Phys. Plasmas 19, 112502 (2012).
[4] K. Liu *et al.* Nucl. Fusion 64, 056037 (2024).
[5] M. Gobbin *et al.* Phys. Rev. Lett. 106, 025001 (2011).

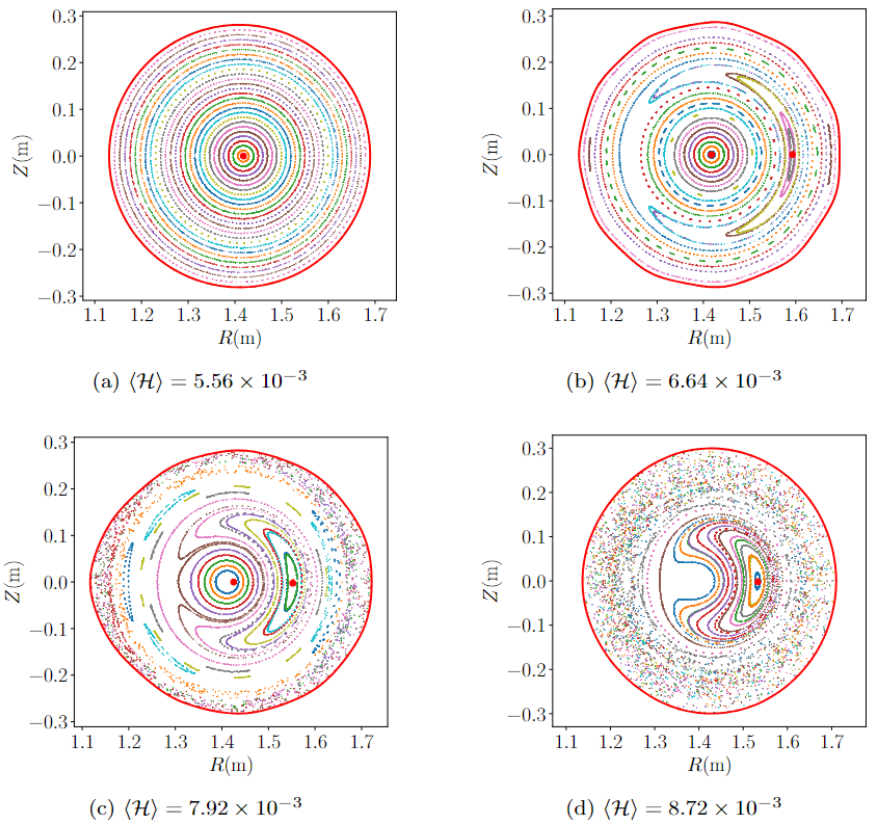

Figure: Poincaré plot of the inner subvolume with different magnetic helicity density $\langle\mathcal{H}\rangle$[4].