Stellarator Fast Ion Physics in Wendelstein 7-X

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Demonstration of improved fast ion confinement at finite plasma beta in Wendelstein 7-X (W7-X) directly addresses a key criticism of stellarators, namely that of poor fast ion confinement[1]. The conversion of kinetic energy from the fusion reactions to thermal energy of a sustained burning plasma requires that energetic helium ions (alphas) be confined. Additionally, unacceptably high wall loads can result from lost fast ions. Such confinement is guaranteed in axisymmetric systems but must be engineering into stellarators through careful tailoring of the magnetic field spectrum[2]. The W7-X stellarator seeks to explore the confinement of such particles via neutral beam injection[3], ion cyclotron resonance heating[4], and eventual deuterium operation[5] (producing D-D fusion products). These methods of generating fast ions probe different aspects of reactor relevant fast ions. Recently the neutral beam injection system began operation on W7-X providing preliminary data for such studies[6]. Such experiments demonstrated up to 5s of continuous NBI operation and densities reaching $2x10^{20}$ m^{-3}. This talk reviews the theoretical physics of stellarator fast ion confinement, fast ion modeling efforts for W7-X, and experimental systems which will become available in the coming experimental campaign. This includes the challenges in validating our predictive capability for fusion born fast ion confinement and extrapolation from W7-X to a D-T fueled reactor[7].

References:

[1] D. Gates et al., Journal of Fusion Energy **37**, 51-94 (2018)
[2] S. A. Henneberg *et al.*, Plasma Phys. Control. Fusion **62**, 014023 (2019)
[3] P. McNeely et al., Fusion Eng. and Design **161**, 111997 (2020)
[4] J. Ongena et al., AIP Conf Proceedings **2254**, 1 (2020)
[5] J. Kontula et al., Plasma Phys. Control. Fusion **63**, 03
[6] S. A. Lazerson *et al.*, Nucl. Fusion **61**, 096008 (2021)
[7] S. A. Lazerson *et al.*, Plamsa Phys. Control. Fusion **63**, 125033 (2021)