Contribution ID: **27** Type: **Oral**

Status of Divertor Operation in Stellarators

Thursday 30 October 2025 14:00 (20 minutes)

The Wendelstein 7-X (W7-X) experiment has shown remarkable success in core plasma performance, achieving record triple product values in a stellarator geometry. This success has placed the stellarator as a top-contender in the race for fusion energy. However, heat and particle exhaust remains one of the outstanding topics to be addressed prior to the design of any future stellarator reactor. The divertor performance metrics are the same for tokamaks and stellarators: heatfluxes to the divertor within engineering limits <10 MWm^{-2}, T_{div}<5 eV to minimize W sputtering, impurity screening, and sufficient pumping of Helium ash to avoid core dilution/sufficient pumping of fuel particles to maintain density control. Thus far, experiments on W7-X, utilizing the island divertor with open divertor geometry, show deficiencies both in heat exhaust at higher input powers (in at least one main configuration) [1] and in density build-up at the target for fuel/Helium pumping. This contribution summarizes the latest developments and work towards advancing the physics basis of the stellarator divertor. The stellarator scrape-off layer (SOL) is significantly more complex than that of a tokamak: the magnetic connection lengths are generally much longer due to the lower field line pitch, increasing the weight of perpendicular transport [2]. Additionally, the inherent 3D shape of the flux tubes and discontinuous divertors result in complicated relationships of the plasma parameters along the field lines [3]. Both of these aspects of the 3D SOL make it impossible to use either simplified models or sophisticated modeling capabilities developed for tokamaks in their present form. Of particular importance is understanding the effects of drifts and anomalous cross-field transport processes in determining divertor performance: measurements in W7-X indicate that the poloidal flow velocities between the X-points, largely thought to be attributable to drifts, are faster than the poloidal contribution from parallel flow velocities [4]. Such measurements indicate that drifts could be the dominant transport mechanism in the stellarator SOL.
With respect to heat exhaust, a simplified model has been developed that provides a qualitative understanding of how the drifts impact the heatflux pattern observed on W7-X [5]. Additionally, advancements have been made in understanding the relationship between scrape-off layer (SOL) geometry and radiation behavior – finding new kinds of geometries associated with detachment instability [6,7]. Additionally, work is starting on first closed divertor designs for the stellarator island divertor [8]. Studies of how the open and closed divertor performance extrapolate to reactor-size are in progress. Finally, there have been recent advancements in comparisons of simulated heatfluxes of non-resonant divertor configurations with experiment [9].
[1] V. Perseo et al, this conference
[2] Y. Feng et al, Plasma Phys. Control. Fusion 53 (2011) 024009
[3] F. Sardei et al, J. Nuc. Mat. 241-243 (1997) 135-148
[4] C. Killer et al, Plasma Phys. Control. Fusion (2020)
[5] A. Kharwandikar, 29th IAEA Fusion Energy Conference (2023) London, UK
[6] V. R. Winters et al, Nucl. Fusion 64 (2024) 126047
[7] Y. Feng et al, Nucl. Fusion 64 (2024) 086027
[8] A. Menzel-Barbara et al, DPG Frühjahrstagung 2025, Göttingen, DE (Invited)
[9] N. Allen et al, APS Division of Plasma Physics 2024, Atlanta, GA (Poster)

Speaker's title

Ms

Speaker's Affiliation

Max-Planck-Institut für Plasmaphysik

Member State or IGO

Germany

Author: WINTERS, Victoria (Max Planck Institute for Plasma Physics)

Co-authors: Mr KHARWANDIKAR, Amit (Max Planck Institute for Plasma Physics); Mr MENZEL-BARBARA, Antara (Max-Planck-Institut für Plasmaphysik); BOEYAERT, D. (University of Wisconsin-Madison); ZHANG, Daihong; Dr BOLD, David (Max-Planck-Institut für Plasmaphysik); KRIETE, David Matthew (Auburn University); REIMOLD, Felix (Max Planck Institute for Plasma Physics, Greifswald, Germany); Ms GARCIA, Kelly (University of Wisconsin - Madison); Mr NASSIM, Maaziz (Max-Planck-Institut für Plasmaphysik); Dr DAVIES, Robert (Max-Planck-Institut für Plasmaphysik); Dr DE WOLF, Ruben (KU Leuven); Mr TORK, Tobias (Universität Greifswald); PERSEO, Valeria (Max-Planck-Institute für Plasmaphysik); FENG, Yuhe (Max-Planck-Institute for Plasma Physics)

Presenter: WINTERS, Victoria (Max Planck Institute for Plasma Physics)

Session Classification: Scrape-off-Layer and Divertor Physics

Track Classification: Divertors for Next-Generation Devices