Contribution ID: **30** Type: **Oral**

Overview of XPR experiments and gaps in extrapolating to future devices

Wednesday 29 October 2025 09:05 (40 minutes)

The exhaust of power as well as the He particles produced by the fusion reactions in a nuclear fusion reactor remains one of the key challenges. As a possible solution for this problem Alternative Divertor Configurations (ADCs) have been studied in many tokamaks worldwide, like TCV \citep{Reimerdes_2017,Theiler_2017}, DIII-D \citep{Soukhanovskii_2018}, NSTX \citep{Soukhanovskii_2016} and MAST-U \citep{Soukhanovskii_2022}, but only at low or moderate heating powers. An outstanding feature of ASDEX Upgrade (AUG) is its high heating power ($\geq$\ 20 MW) compared to its size ($R = 1.65$\ m). In order to study a variety of ADCs \citep{Lunt_2017} at these high power conditions AUG has installed a pair of in-vessel divertor coils, a charcoal coated cryo-pump capable of capturing He, new divertor targets as well as an outstanding set of diagnostics in its upper divertor. During the two-year long opening enormous technical challenges were solved, like the in-vessel winding of the continuous conductor or the installation of the divertor tiles with an alignment accuracy of 0.2 mm. Since April 2025 the new advanced upper divertor is now fully operational and the experimental campaign in full-swing. In a first step several ADCs like the X-divertor (XD, \citep{Lunt_2019b}), the Low-Field-Side Snowflake minus (LFS SF$^-$, \citep{Pan_2018,Pan_2020}) or an extreme form of the Compact Radiative Divertor \citep{Lunt_2023} have been established. As an example Fig.\ \ref{fig:LFSSFm} shows an infrared thermography image recorded during the LFS SF$^-$ phase of a high power discharge. The overplotted magnetic equilibrium shows the primary (red) and secondary (purple) separatrices. The example clearly shows the SOL power splitting between the primary and secondary outer strike lines. In a second step, power, fueling and impurity seeding scans were performed to study the exhaust and detachment behavior of the different configurations. We present the first results of these experiments with heating powers of up to 20 MW, interpret them by means of SOLPS and/or EMC3-EIRENE modelling and give an outlook to further studies.

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Session Classification: X-point and other Radiator Regimes

Track Classification: X-point and other Radiator Regimes