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Self-Consistent and Investigation of Density Fueling Needs on Future Devices Utilizing the New Pellet Ablation Module

J. McClenaghan, T. Slendebroek[2], A.M. Garofalo[1], L.L. Lao[1], S.Y. Ding[1], V. Chan[3,4]
[1]General Atomics, PO Box 85608, San Diego, CA 92186–5608, USA
[2]Oak Ridge Associated Universities, Oak Ridge, Tennessee, USA
[3]Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, Anhui, China
[4]University of Science and Technology of China, Hefei, Anhui, China
Email (speaker): mcclenaghanj@fusion.gat.com

Self-consistent modeling using the stability, transport, equilibrium, and pedestal STEP [1] workflow in the OMFIT [2] integrated modeling framework (predicting pedestal with EPED [3], core profiles with TGYRO [4], current profile with ONETWO [5], and EFIT [6] for equilibrium) suggests ITER [7] and future devices such as BEST and CFETR [8] will benefit from high-density operation (Greenwald density fraction f_{Gw}≈0.7-1.3). Regimes with operational f_{Gw} above 1 will likely need peaked density profiles so that the pedestal density remains below the Greenwald limit. Peaked density profiles can be achieved with the help of pellet injection. A flexible Pellet Ablation Module (PAM), which predicts the density source based on a comprehensive analytical pellet ablation model, has been developed for predicting pellet fueling for transport studies, and has been incorporated into the STEP workflow for predictive modeling. This workflow is applied to DIII-D and finds good agreement with the experiments. On ITER the effect of pellet fueling is examined on an advanced inductive scenario. A fusion gain of up to Q=9 is predicted with strong central pellet fueling. On CFETR, with a mid-radius density source, an average of 1.5×10^{22} electrons/sec are required to achieve density and temperature profiles necessary for the 1000 MW advanced scenario with a tritium burn-up fraction of ~5%. Shown in Figure 1, a Q=5 inductive scenario is predicted for the BEST tokamak when a deep pellet fueling source is added to the simulations. Performance of this scenario is found to be directly related to the pellet fueling depth. Additionally, a pellet-like localized external particle source at ρ~0.6 is found to facilitate a strong ITB in the density channel of a high Shafranov shift scenario, predicting high line-averaged density f_{Gw}=0.8-1.2 while keeping pedestal density at low f_{Gw}=0.5-0.7, and is show in Figure 2. High core density is favorable to high fusion power and high bootstrap current fraction (~80%), which are keys to realize Q>1 in steady-state.

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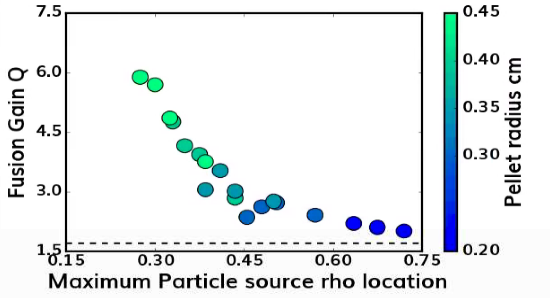

Figure 1: STEP predicted fusion gain for BEST is plotted vs. radial location of peak particle source.

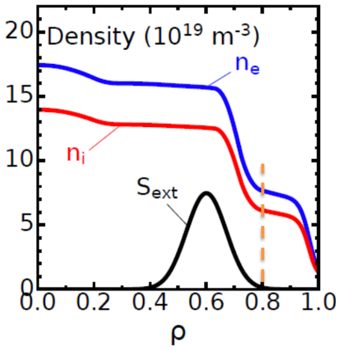

Figure 2: STEP predicted density and particle source for non-inductive ITB scenario