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Computationally studying H- extraction and beamlet formation: the impact of the plasma model

The ITER NBI requires H-/D-beamlets with a low divergence, in view of the beamline transmission. Ion extraction and beamlet formation are typically studied with gun-type codes such as IBSimu, which do not treat the plasma explicitly. The beamlet particles are tracked through the full grid system; the compensating charge density in the plasma region is given by an analytical function. As a result, many physical processes are neglected, such as the surface production of negative ions, particle drifts in the plasma as result of magnetic fields, and sheath formation at surfaces. The 3D PIC MCC code ONIX does include these processes, but the computational domain ends after the extraction region to limit the computational cost. ONIX was coupled with IBSimu to extend the computational domain so that the accelerated beamlet properties could be studied and compared to standalone IBSimu simulations. As already known from standalone ONIX simulations, the surface produced particles are very divergent. Since the IBSimu simulations do not include surface production, only the volume produced particles are studied. The angular distribution of the accelerated particles was fitted with a double Gaussian to evaluate the core and halo components. The core divergence and the average angle are very similar for both simulation approaches. The ONIX-IBSimu calculations have a less pronounced halo component compared to the IBSimu standalone calculations. This is a consequence of the Debye sheath, which forms between the plasma and the grid, and is included in ONIX but not in IBSimu. Particles coming from the plasma are repelled by the sheath and thus the extracted current density profile decreases near the edge of the aperture. Particles that are extracted near the edge tend to have a large angle in the accelerated beamlet, and thus fewer of these particles leads to a less pronounced halo. An attempt is made to include this effect ad-hoc in the IBSimu plasma model, so that the impact can be assessed over a wide range of parameter variations.

Primary author: DEN HARDER, Niek (Max-Planck Institute for Plasma Physics)

Co-authors: REVEL, Adrien (LPGP); MIMO, Alessandro; WÜNDERLICH , Dirk; Mr LINDQVIST, Max (IPP); Dr NOCENTINI, Riccardo (IPP); Dr MOCHALSKYY, Serhiy (Max Planck Institute for Plasma Physics (IPP)); Prof. MINEA, Teofil (Université Paris-Saclay); FANTZ, Ursel

Presenter: DEN HARDER, Niek (Max-Planck Institute for Plasma Physics)

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