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Investigations on symmetrizing the plasma properties in the expansion region of large RF ion source via magnetic fields

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The ITER NBI system will rely on the neutralization of accelerated hydrogen/deuterium negative ion beams, extracted from a plasma ion. A radio-frequency (RF) current with 1 MHz excites cylindrical coils, which generate the discharge in eight quartz cylinders, called drivers, and it expands into a bigger metallic chamber equipped with an extraction system. The negative ions are extracted inevitably with electrons. A magnetic filter field applied for cooling down the plasma to ≈1 eV reduces the co-extracted electrons. Side-effect of the filter are ×B drifts, resulting in a vertical plasma inhomogeneity which can affect the co-extracted electrons and limit the source performance.
Inspired by the experimental investigations at the test Facility ROBIN [1] the influence of the magnetic field configuration on the vertical plasma uniformity is modelled by a fluid model on the similar ion source BATMAN Upgrade. The model is fully time-dependent 2D with self-consistent coupling of the coil's RF electromagnetic fields with the plasma. The study aims to investigate the effect of different profiles of the magnetic filter field on the plasma parameters in the expansion and the collected currents on the first grid of the extraction system –the plasma grid (PG). Different topologies of the magnetic field are studied: profile similar to standard BUG operation, created by high current flowing through the PG (IPG), profiles with different configurations of permanent magnets attached to the ion source side walls and superposition of IPG with permanent magnets. The results show the plasma properties in vertical direction can be symmetrize as a superposition of IPG filter field with permanent magnets acting as weakening magnetic field in the region of the higher plasma density. In this case the collected electron current on the PG has the lowest value, which could benefit on lower co-extracted electrons.
[1] K. Pandya et al Rev. Sci. Instrum. 96, 043309 (2025)

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