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Beam Divergence of RF Negative Ion Sources for Fusion

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Neutral beam injectors (NBI) for fusion facilities have strict requirements on the beam divergence (7 mrad for the ITER NBI at 1 MeV). Measurements of the single beamlet divergence of RF negative ion sources (at lower beam energy < 100 keV) show significantly higher values (12-15 mrad), also larger than filament arc sources at similar beam energies. This opened up questions whether the higher divergence is a problem at all after full acceleration, whether it is caused by different measurement or evaluation techniques, or whether it is a direct cause of the RF source, e.g. due to a higher temperature of negative ions. In a joint effort modeling and diagnostic capabilities at NNBI test facilities have been massively extended and evaluation methods benchmarked. Particularly challenging is the strong increase in beamlet divergence at a lower filling pressure, seen both in filament arc and RF sources. More energetic negative ions in the source at lower filling pressure might be the reason, hints given by beam simulations [1].

Beside the source and beam investigations carried out in SPIDER (with selected, isolated apertures rather than the total of 1280 apertures) at Consorzio RFX [2], the IPP test facilities ELISE (640 apertures) and BATMAN Upgrade (70 apertures) contribute to the physics understanding of the beam optics in RF sources. ELISE is capable to determine beam properties and uniformity on a global scale. BATMAN Upgrade offers an extended set of diagnostics for measuring and correlating the single beamlet divergence to fluxes and energy distributions of the parent particles atomic hydrogen and positive ions in the source plasma.

This contribution summarizes the present beam divergence understanding gained from experimental measurements and beam optics simulations. The views and opinions expressed herein do not necessarily reflect those of the ITER Organization.

[1] N. den Harder et al., contribution to the IAEA FEC 2023
[2] E. Sartori et al., this conference

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Yes

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