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Towards low divergence beams for the ITER neutral beam injection system

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The beam divergence is the figure of merit applied to quantify the width of the particle angular distribution as they travel along the beamlines of neutral beam injection (NBI) systems. In the case of the high power neutral beam planned for the ITER experiment, a divergence of less than 7 mrad is mandatory to assure the power level needed for plasma heating in ITER.
In the last decades, the R&D around radiofrequency driven (RF) negative ions sources for fusion focused mainly on solving the fundamental challenges related to increasing the negative ion current density while keeping the co-extracted electron current low, and on increasing the pulse length from few seconds to hundreds of seconds. Only recently, it was pointed out that the divergence of beams produces by this type of sources were higher than the above requirements (more than 20 mrad). Since then several activities were started to tackle this issue, involving several laboratories and including upgrades to the existing ion sources, dedicated investigation of the particle properties inside the plasma, modelling and improvements in the diagnostics systems.
This contribution reviews the recent developments on this topics in the last years, and includes the result of a benchmark activity carried out recently, aimed at comparing the divergence measured on 5 different ion sources, arc- and RF-driven. As a results of this coordinated effort several hypotheses about the root cause of the divergence increase could be tested. The common analysis of results from different diagnostic methods and input parameter studies gave insights into the sensitivity to input parameters with the conclusion that the RF source is characterized by about 12 mrad.
The more recent results seem to link the elevated divergence measured with the presence of high energy positive ions inside the RF plasma.

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