Experimental mapping and benchmarking of magnetic field codes on the LHD Ion Accelerator

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A test-bed facility comprising a RF-driven Negative Ion Source with 100 kV Accelerator (SPIDER) and a complete 1 MV Neutral Beam System (MITICA) is presently under construction in Padova, as a support to the realization of the Heating Neutral Beam (HNB) system for the ITER experimental Fusion Reactor [1].
A considerable effort has been addressed to the final design optimization of SPIDER and MITICA in order to assure the achievement of the ITER HNB target performances in all operating conditions.
This activity has necessarily included the improvement of the beam optics by optimization of three magnetic field sources:

- "Filter" field, produced by current flowing in the Plasma Grid and in suitable busbars, reduces the number of co-extracted electrons and also affects the Negative Ion production efficiency;
- "Suppression" field, produced by permanent magnets in the Extraction grid, deflects the co-extracted and secondary electrons;
- "Compensation" field, produced by permanent magnets and ferromagnetic material in the Grounded Grid , compensates the deflection of the accelerated ions due to the electron Suppression field;

The optimization has required the use of particle tracking codes combined with numerical magnetic field models (SLACCAD, EAMCC, OPERA and ANSYS). A "mixed potential" formulation has been adopted for magnetic modelling of the accelerator, in order to describe both the details of the single beamlet apertures on the grids and the 3D edge effects on the global scale.
For the validation of the models, an experimental benchmark against a full-size device has been sought. The LHD BL2 injector {2] has been chosen as a first important validation step, because its negative ion source and beam accelerator are similar to SPIDER, even though BL2 does not include current bars and ferromagnetic materials.
An accurate experimental mapping has been carried out on the LHD BL2 ion source and accelerator, using a suitably designed 3D adjustable structure for the fine positioning of the magnetic field sensors on several thousands of points along the beamlet trajectories. The data have been compared against the values calculated on the same points using a detailed model of the LHD BL2 device.
The work has confirmed the quality of the numerical model, and has also provided a tolerance criteria for permanent magnet positioning and residual magnetic field in order to ensure sufficient uniformity of the magnetic field in the SPIDER Accelerator.
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[1] P. Sonato et al. Fusion Engineering and Design, Vol. 84, 269-274 (2009)
[2] H. Yamada et al, Fusion Engineering and Design, Vol 84, 186–193 (2009)