§35. Bootstrap Current Profile Calculations with the SPBSC and the VENUS+δf Codes for the LHD

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Total bootstrap current calculations with the updated VENUS+δf code that incorporates energy convolution and the momentum correction technique have been performed for the experimental Large Helical Device configurations with different magnetic axis positions. The VENUS+δf results have been compared with the corresponding SPBSC code [1] numerical predictions and with the LHD experimental tendency [2].

The essential contribution in the VENUS+δf code development includes the transition from monoenergetic [3] to Maxwellian distribution of particles; an ion momentum conservation procedure in the collision operator for like-particles; plasma temperature and density gradient effects. This contribution provides the next step towards an accurate calculation of the bootstrap current profile in non-axisymmetric magnetic configurations [4].

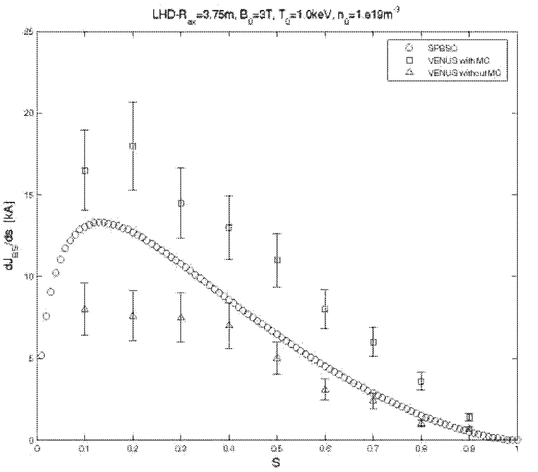

Figure 1. The LHD $R_{ax} = 3.75m$ bootstrap current derivative dJ_{BS}/ds versus the flux label s with linear plasma density profile $n=n_0(1-s)$, $n_0=10^{19}\,m^{-3}$, $T_0 = 1.0\,keV$ calculated with the SPBSC code (circles) and with the VENUS+δf code (squares with momentum conservation, triangles without momentum conservation).

The main experimental effect of the outward shifted magnetic axis on the bootstrap current has been confirmed in the simulations. For the LHD configurations with the magnetic axis positions of $R_{ax} = 3.75m$ and $R_{ax} = 3.90m$ the calculated bootstrap current J_{BS} lies in the limits 15-30 kA (Fig.1), while for the $R_{ax} = 4.00m$ we get $J_{BS} \approx$ 5kA and for $R_{ax} = 4.05m$ the bootstrap current is small and can be negative up to - 5kA (Fig.2). Calculations have been performed with linear temperature and density profiles. In addition a flattened density profile has also been used to approach the experimentally measured results. We assumed that both ions and electrons have the same temperature and density profiles, while radial electric fields and islands were neglected.

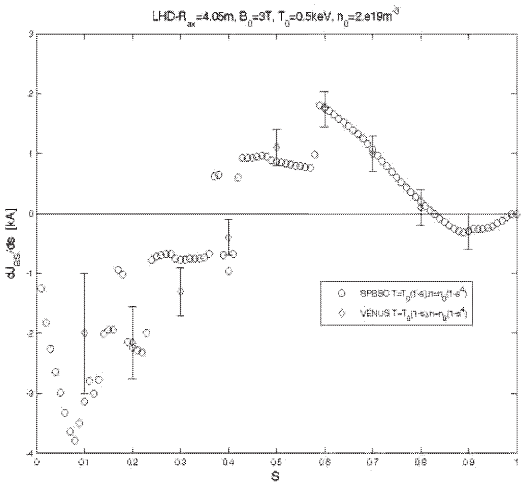

Figure 2. The LHD $R_{ax} = 4.05m$ bootstrap current derivative dJ_{BS}/ds versus the flux label s with the flattened plasma density profile $n=n_0(1-s^4)$, $n_0=2.0 \times 10^{19}\,m^{-3}$, $T_0 = 0.5\,keV$ calculated with the SPBSC code (circles) and with the VENUS+δf code (diamonds).

The difference between the SPBSC and the VENUS+δf codes has been observed near the resonances, since the VENUS+δf code uses the magnetic spectrum from the TERPSICHORE code with resonance detuning. Another difference in the results should be visible for the low collisionality regime due to the different models implemented into the SPBSC and VENUS+δf codes. For the complicated magnetic field spectrum of the LHD configurations, the VENUS+δf code requires significant CPU resources. The calculations were performed for several collisional times, the steady-state solution were obtained with error bars on the level 10-15%.

In order to compare our neoclassical simulations with the LHD experimental results, we will use in the near future experimentally obtained density and temperature profiles for ions and electrons and more accurate collisional operator, which conserves both the particle energy and momentum [5].

[1] K.Y.Watanabe et al., *Nucl Fusion*, **44**, 1499(1992).

[2] K.Y.Watanabe et al., *J. Plasma Fusion Res. SERIES*, **5**, 124(2002).

[3] M.Yu. Isaev et al., *Plasma Fusion Res.*, **3**, 036(2008).

[4] M.Yu. Isaev et al., *Nucl. Fusion*, **49**, 075013(2009).

[5] S.Satake et al., *Nucl Fusion*, **47**, 1258(2007).