§6. Operation Summary of Neutral Beam Injection System in the 15th Campaign

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The neutral beam injection (NBI) system in the LHD consists of three negative-ion-based NB injectors (BL1, BL2 and BL3) and two positive-ion-based NB injectors (BL4 and BL5). The total injection power is achieved to 27MW. The NBI system has greatly contributed to the extension of the LHD plasma parameter regime as a main heating system, and 7keV of the ion temperature was achieved by the NBI heating in the 15th campaign.

In the negative-NBIs, the total injection power with three injectors is summarized in Fig. 1. High-energy hydrogen beams with the nominal injection energy of 180keV are tangentially injected. The nominal injection power of 15MW was available during the campaign, and the maximum injection power was 15.7MW.

The shot evolutions of the injection power for individual negative-NB injectors of BL1, BL2 and BL3 are shown in Fig. 2. In BL1, stable and reliable operation was demonstrated, and 5 to 6MW of the neutral beams were constantly injected for 2sec throughout the campaign. The injection energy was tried to be raised, and achieved to 194keV. In BL2, at the start of the campaign, a water leak occurred at one segment of the grounded grid consisting of five segments in one negative ion source. It took two weeks to replace the grid segment and to recover the injection. After that, reliable injection of around 4.5MW was carried out. However, at the end of the campaign, another water leak occurred at the other grid segment. As a result, the injection power was reduced to a half due to the operation with one ion source out of two. In BL3, stable and reliable injection was maintained with the injection power of around 5MW throughout the campaign. The highest injection power of 5.4MW was achieved due to successful optimization of the operation.

A positive-NBI of BL4, in which low-energy beams are perpendicularly injected at 40keV, is utilized for the T_i-profile measurement with the CXS, in addition to the contribution mainly to the ion heating experiments. Thus, pulse-modulated injection was usually carried out, and the injection power was suppressed to around 5.6MW in many cases due to a high-frequency beam modulation, as shown in Fig. 3. In a normal unmodulated injection, 6.3MW of the injection power was achieved.

BL5 is also a perpendicular injector, and was operational in the 14th campaign to inject 45keV-5.8MW of hydrogen beams. In the 15th campaign, the injection energy was tried to be raised to 50keV, and the hydrogen beams were constantly injected with the energy of 40 to 50keV throughout the campaign. However, due to a reduction of the neutralization efficiency at higher energies, the injection power was not increased, no more than 5.6MW, with an increase in the energy, as shown in Fig. 4.

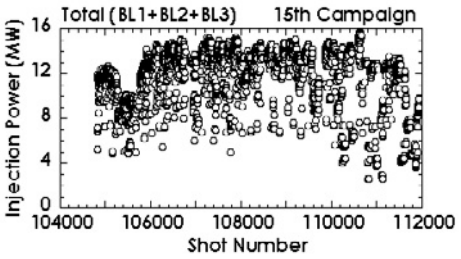

Fig. 1. Shot evolutions of the total injection power for the negative-NB injectors.

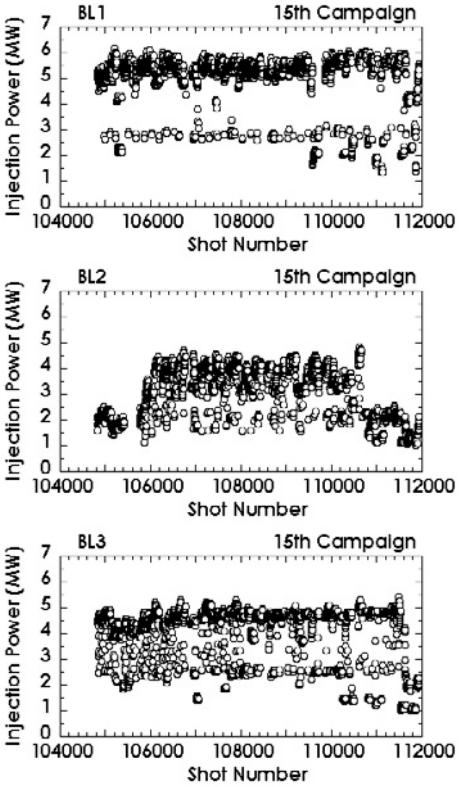

Fig. 2. Shot evolutions of the injection power for BL1, BL2, and BL3.

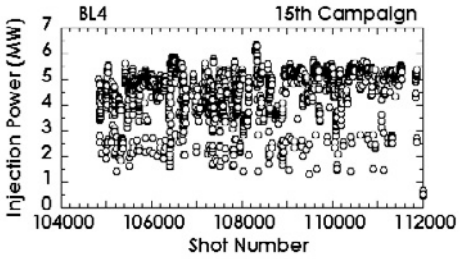

Fig. 3. Shot evolution of the injection power for BL4.

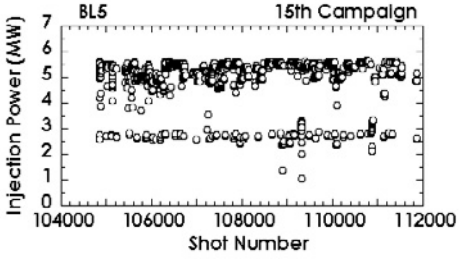

Fig. 4. Shot evolution of the injection power for BL5.