§1. Injection Summary of Neutral Beam Injection System in the 12th Campaign

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Neutral beam injection (NBI) system is a main heating system in the LHD, and the LHD has extended the plasma operation regime in accordance with the improvement of the NBI system. The LHD is equipped with three negative-ion-based NB injectors of BL1, BL2 and BL3, and one positive-ion-based NB injector of BL4. In the negative-NBI high-energy hydrogen beams are tangentially injected at 180keV while low-energy beams are perpendicularly injected at 40keV in the positive-NBI.

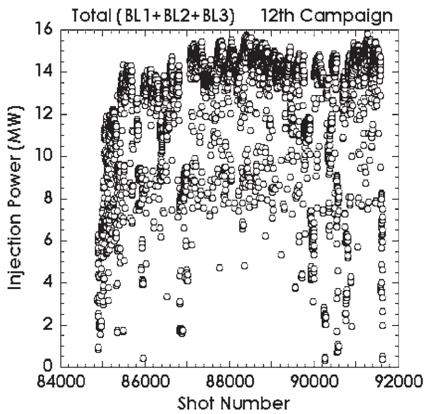

Fig. 1. Shot evolution of the total injection power for the negative-NB injectors in the 12th campaign.

Figure 1 shows the shot evolution of the total injection power with three negative-NB injectors. The maximum power is 16MW, which exceeds the designed value of 15MW. Although it is the same value as that in the 11th campaign, high-power injection of more than 14MW is constantly achieved throughout the campaign. This reliable operation provided a wide range of the LHD experiments, i.e., mission-oriented subjects such as high-T_i, high-n_e, and high-β, and physics subjects such as transport and MHD.

The shot evolutions of the injection power for individual negative-NB injectors are shown in Fig. 2. In BL1, where the multi-slotted grounded grid (GG) is employed for the accelerator of the negative ion source, high-power injection of around 6MW is stably carried out. The maximum injection power is 6.8MW for 1.5s with the energy of 189keV. In the multi-slotted GG, the GG heat load is as small as around 7% of the drain current of the acceleration power supply, which leads to extension of the injection duration to 8s with high power injection of 4MW.

In BL2, the multi-round aperture GG is utilized for the ion source accelerator. The GG heat load is around 10%, which would restrict the injection power, compared with BL1. The maximum injection power is 5.6MW for 1s with the energy of 189keV.

In BL3, the accelerator with the multi-round aperture GG was modified, so that the secondary electrons generated inside the extraction grid (EG) aperture would not be accelerated downstream. The effectiveness of this modification was confirmed in BL2 in the 11th campaign. The GG heat load was reduced as expected. However, the voltage holding ability was not sufficiently improved, the cause of which is unclear, and the achieved injection power is remained at 4.9MW for 1.6s with the energy of 183keV.

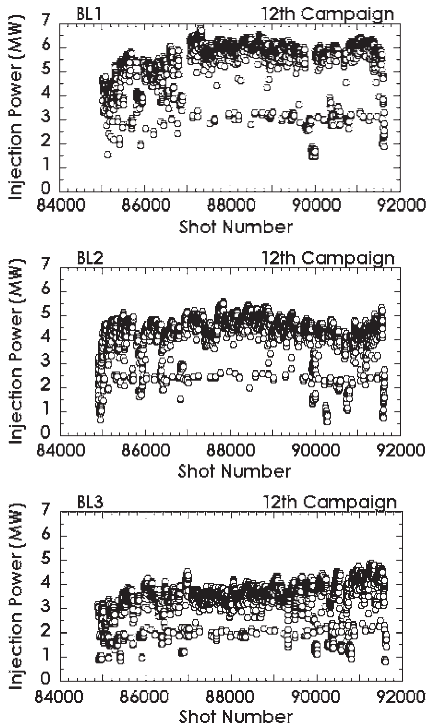

Fig. 2. Shot evolutions of the injection power for individual negative-NB injectors of BL1, BL2, and BL3.

The positive-NBI of BL4 was mainly utilized for the high-T_i experiments and the experiments for the high-energy particle behavior. With the pulse-modulated injection, BL4 is also utilized for the T_i-profile measurement with the CXS method. The injection power is reliably more than 6MW with the energy of 40keV, and, however, the injection duration is limited below 0.5s to avoid an excess heat load on the residual beamdump due to the unexpected beam focusing. For the reduced power of 4MW the injection duration was extended over 2s.

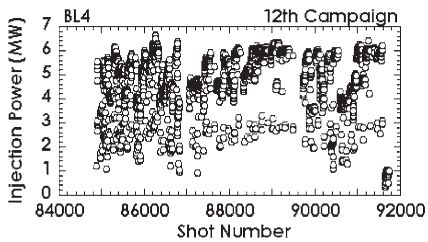

Fig. 3. Shot evolution of the injection power for the positive-NB injector of BL4 in the 12th campaign.