§1. Operation Summary of Neutral Beam Injection System in the 18th Campaign

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The neutral beam (NB) injection system in the LHD consists of three negative-ion-based NB injectors (NBI), namely NBI#1, NBI#2 and NBI#3, and two positive-ion-based NB injectors, namely NBI#4 and NBI#5. The total injection power is achieved to 25MW. The NB injection system has greatly contributed to the extension of the LHD plasma parameter regime as a main heating system and especially contributed to the simultaneous achievement of the high ion temperature of 6keV and of the high electron temperature of 7keV in the 18th 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 maximum injection power was 14MW.

The shot evolutions of the injection power for individual negative-NBIs are shown in Fig. 2. In NBI#1, 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 195keV. In NBI#2, at the middle 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 about one month to recover its injection power after the replacement of the segment. After that, reliable injection of around 4MW was carried out. However, at the end of the campaign, an air leak occurred at the top plate of the ion-source arc chamber. As a result, the injection power was reduced to a half due to the operation with one ion source out of two. In NBI#3, an air leak at the back plate of the arc chamber was also occurred for the single ion-source at the middle of the campaign. After that, the operation of the ion-source with the air leak was limited for special case where the mission oriented experiments were performed. The injection power was limited to around 2MW without the operation of the damaged ion-source. The highest injection power of NBI#3 was 4.5MW. At the end of the campaign, a water leak also occurred at the one segment of the ground grids of the non-damaged ion-source of NBI#3. After that, the operation of the injector was stopped.

A positive-NBI of NBI#4, in which low-energy beams are perpendicularly injected at 40keV, is utilized for the Ti-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 5.2MW in many cases due to a high-frequency beam modulation, as shown in Fig. 3. In a normal unmodulated injection, 5.9MW of the injection power was achieved.

NBI#5 is also a low energy perpendicular injector based on positive ion-source. The operation of NBI#5 was the most stable among the all of NBIs. The maximum injection power during 18th campaign was 5.8MW and its regular injection power was around 5.7MW.

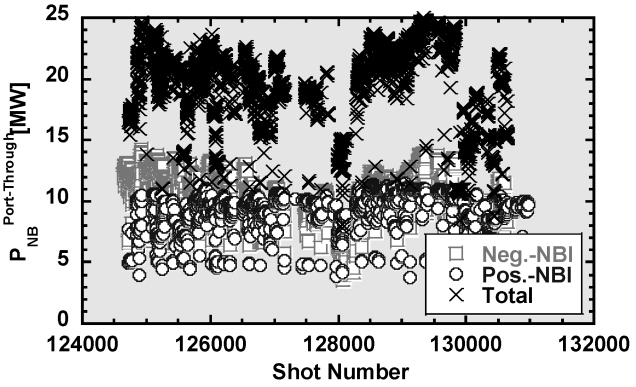

Fig.1 History of total injected powers by negative-ion basesd NBIs(□), positive-ion based NBI(○) and sum of them(×).

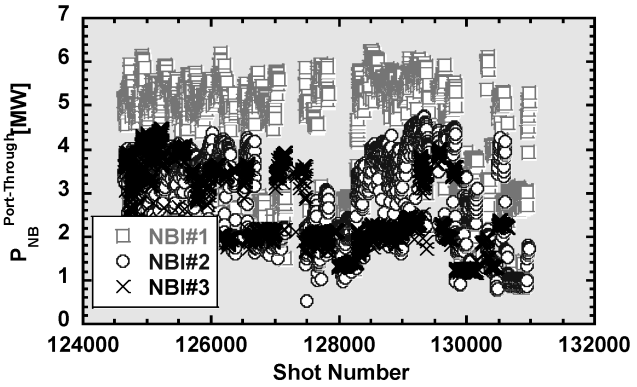

Fig.2 History of injected powers by negative-ion based NBIs. The injection powers of NBI#1 are shown by squares (□), those of NBI#2 are shown by circles(○), and those of NBI#3 are shown by crosses(×).

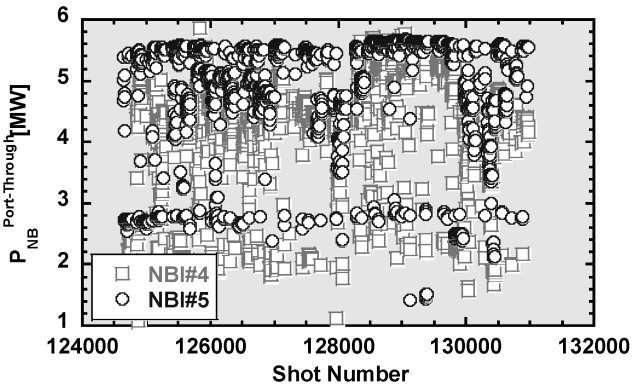

Fig.3 History of injected powers by positive-ion based NBIs. The injection powers of NBI#4 are shown by squares (□) and those of NBI#5 are shown by circles(○)