§2. High Power and Stable Injection

Tsumori, K., Osakabe, M., Kaneko, O., Takeiri, Y.,
Nagaoka, K., Ikeda, K., Nakano, H., Shibuya, M.,
Asano, E., Sato, M., Kondo, T., Komada, S.

It has past 12 years since the first beam injection started in LHD. The problems of LHD-NBIs have been solved and the systems have been continuously improved. The nominal injection power of LHD-NBI of more than 15 MW has been attained with three negative-ion-based NBIs since 2007. Stable beam injections are, however, required to change widely the parameters of target plasma with the same condition and to confirm the reproducibility. Esppecially, the success rate, defined here as the ratio of the actual beam length to setting one, decreases due to arcings and voltage breakdowns in the accelerator in high-power beam injections. Thus, we survey what is effective to satisfy the high power and stable injection simultaneously.

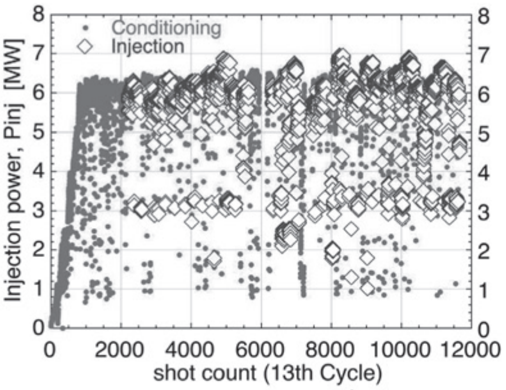

Fig. 1. Trend of injection power in the 13th LHD experimental campaign (FY2009). The closed circles and open diamonds indicate the conditioning and injection beam powers, respectively.

Figure 1 shows the trend of injection power of beamline 1 in the 13th LHD-experimental campaign in FY2009. The open diamonds indicates the port-through (injection) powers, and the powers are estimated from the shine-through power measured with thermocouple array in the beam armor on the LHD inner wall. The solid circles show the estimated injection power during beam conditionings. The increasing power from shot count of 0 to 800 is the start up phase of the conditioning before conditioning, and the power reaches to 6 MW within 5 days. The injection powers have been kept ~6 MW during the LHD-experiment except for the experimental conditions to reduce the power or those with the pulse length of 5 – 10 sec. The maximum injection power reaches 7 MW at 190 keV for 1.6 sec. The distribution of the injection power and beam energy is shown in Fig. 2(a) and 2(b), respectively. The beam power shown in Fig. 2a has a peak near 6.2 MW and longer tail distributes on the higher energy side. In this power range, the control of cesium seeding, arc-power and bias voltage setting becomes difficult to avoid voltage breakdown in the accelerator, and we were careful to increase the power. The peak of the beam power near 3.2 MW shows the injection with one of two ion sources installed the beamline. The peak position of the energy distribution is ~190 keV as shown in Fig. 2b. The energy range is rather narrow, about 186 – 193 keV, and the injection power changes from 5.6 to 7 MW in that beam energy range due to the cesium and bias-voltage conditions. The success ratio to the injection power is shown in Fig. 3. The ratio is averaged within the range of every 0.2 MW form 2 to 7 MW. The peak regions of single and full ion sources of the beam line are indicated with hashed area, and the success ratio is more than 80 % in those regions.

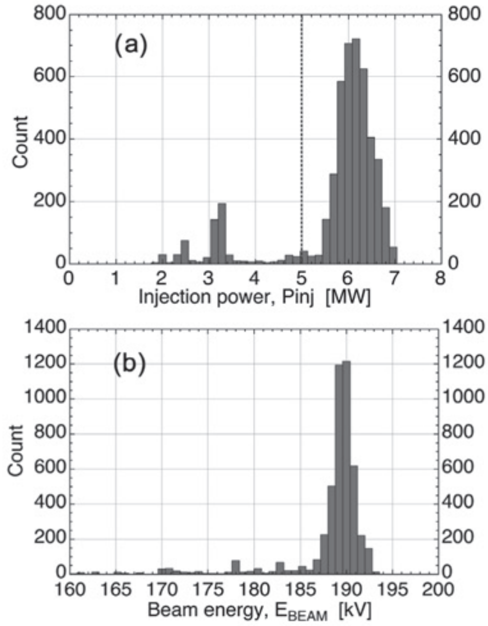

Fig. 2. (a) Injection-powers distribution and (b) beam energy of LHD beamline 1 in FY2009.

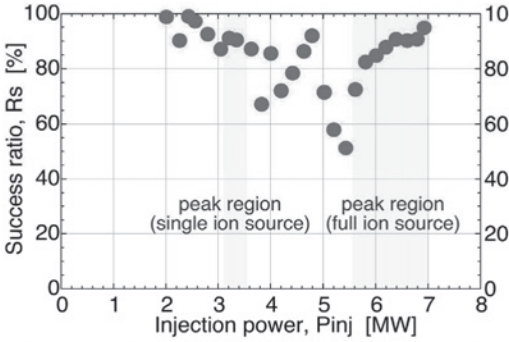

Fig. 3. Success ratio to injection power. The power is divided by 0.2 MW from 2 to 7 MW.

In FY2009, the success ratio of 80 – 90 % is obtained in high-power injection of more than 6 MW. The dominant factor of high success ratio is suitable cesium supply. In FY2009, the LHD beamline 1 had no trouble, such as water leakage. In such a situation, the total cesium consumption is about 10 g, which is less than 0.1 mg / shot, per ion source for 3 months operation.