§7. Study of Secondary Particles in Multi-aperture Accelerator

Kisaki, M., Tsumori, K., Ikeda, K., Nakano, H., Osakabe, M., Nagaoka, K., Takeiri, Y., Kaneko, O., Veltri, P., Agostinetti, P., Serianni, G. (Consorzio RFX)

An injection power of a neutral hydrogen beam has reached to more than 15 MW by three N-NBIs on LHD. It is indispensable for further extension of the beam power and pulse length to reduce the heat loadings on acceleration grids and beamline components, which are mainly caused by secondary particles produced in the accelerator.

Negative ion sources for fusion experiments produce the ion beam of several tens of amperes with large-sized and multi-aperture grids. In previous studies, the trajectory of the secondary particles was calculated assuming that the negative ions are extracted with the same current density in each aperture and the magnetic field is uniformly distributed in whole area. As a result, a large discrepancy between experiments and simulations has been observed. In this study, we focused on the influence of non-uniformity in the magnetic field on trajectories of H^- and the secondary particles.

In the accelerator, several kinds of particles (i.e., electrons, positive ions, and neutrals) are created by particle-particle and particle-wall interactions. In addition, charged particles are accelerated and deflected by the electromagnetic field. To simulate these processes, Electrostatic Accelerator Monte Carlo Code (EAMCC)[1] is applied to the N-NBI on LHD. The electric and magnetic fields for EAMCC are obtained by OPERA-3d. As shown in Fig. 1, a row of 14 horizontal apertures is modeled to investigate the multi-aperture effects. The aperture displacements in the SG and GG are taken into account and the magnetic field produced by filter magnets and electron deflection magnets is also included. In the accelerator, the magnetic field is formed non-uniformly in horizontal direction and becomes stronger by closing to the grid edge.

Secondary particle trajectories in non-uniform magnetic field were calculated with the uniform plasma condition, where 14 beamlets with the current density of 30 mA/cm^2 are extracted at the extraction voltage of

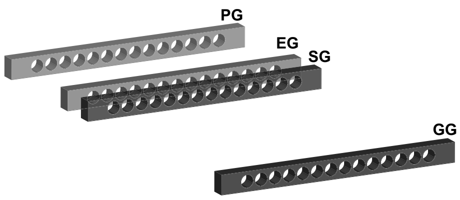

Fig. 1: Multi-aperture accelerator of N-NBI on LHD modeled for particle trajectory calculation

9.6 kV and the acceleration voltage of 178 kV. Fig. 2 shows the power loss of the H^- and secondary particle on the grounded grid (GG) in each aperture for uniform and non-uniform magnetic field cases. Note that in the uniform field case, the magnetic field map in the central aperture was used for other apertures. The power loss on the GG increases by closing to the grid edge in non-uniform magnetic field. Fig. 3 shows the number of electrons incident on the GG as a function of the electron energy. There are two peaks at the low energy region (< 5 keV) and the high energy region (=178 keV), which correspond to the stripped electron produced near the GG and the secondary electron ejected from the EG and the SG, respectively. Most of incident electrons is the low energy stripped electron, but the heat loading on the GG becomes high due to high energy secondary electron. In Fig. 3, the number of secondary electrons increases near the outmost aperture, resulting in higher power loss. This indicates that the secondary electrons are more likely to be intercepted by the GG due to the stronger magnetic field.

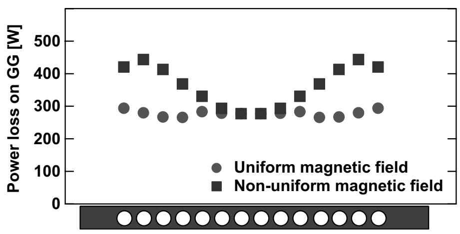

Fig. 2: Power loss of particles on acceleration grids in uniform and non-uniform magnetic field.

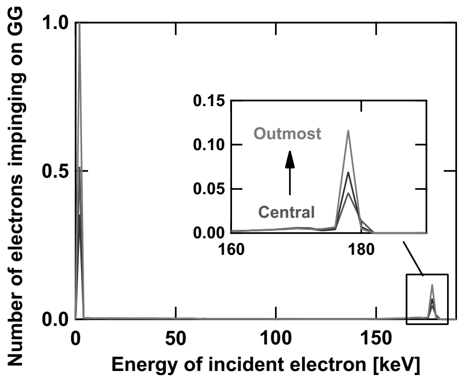

Fig. 3: Number of electrons impinging on GG as a function of electron energy in non-uniform magnetic field.

1) G. Fubiani, et al., Phys. Rev. ST Accel. Beams **11**, 014202 (2008).