§56. A Design Study of Heavy Ion Beam on a Spherical Tokamak

Shimizu, A., Fujisawa, A. (Kyushu Univ.),
Hasegawa, M. (Kyushu Univ.)

The heavy ion beam probe (HIBP) is a very useful tool to study confinement physics related to the radial electric field in magnetically confined plasmas. This system is generally expensive because the high voltage accelerator is needed to generate the probe beam to inject the beam ion into the plasma core on the condition of strong magnetic field strength (> 1T). However, for the device of which the magnetic field strength is weak (< 0.2 T), the required energy for probe beam is low and costs may be reasonable.

We consider a HIBP system on the spherical tokamak, QUEST, because the magnetic field strength of this device is low. The major/minor radius of the device is 0.68 / 0.4 m, and its maximum toroidal magnetic field strength is 0.25 T. Here, we assume that the magnetic field strength in the operation is 0.1 T, and the probe beam orbit for a HIBP is calculated in this condition. The vacuum magnetic field produced by 8 discrete toroidal coils are used in this calculation, and effects of plasma beta and the plasma current are ignored. In Fig.1, an example of beam orbit calculation results is shown. The primary probe beam is injected from the upper port, and the secondary beam is extracted from the outer port. Solid/dotted lines of beam correspond to primary/secondary beam. Orbits for three different injection angles are seen in the figure. The electrostatic deflector is located in the outside of outer port (1.77 < R < 2.07), where electric field to the positive direction of z-axis is applied, therefore, the probe beam is deflected to upward direction in this region. Magnetic surfaces of a standard configuration are displayed as reference. For this configuration, observation points are restricted to peripheral region of plasma due to the limitation of diagnostic ports. The size of injection port is narrow, therefore a special method such as double deflectors in the Madison Symmetric Torus (MST[1)]) may be required. The beam acceleration energy is 45 keV for sodium (Na) beam and 19 keV for cesium beam (Cs). The acceleration energy is not large and costs will be reasonable price.

To observe the central region of plasma, another orbit can be adopted. In Fig.2, this orbit for probe beam is shown. The primary beam is injected from the outer diagnostic port, and the secondary beam is ejected from the lower oblique diagnostic port. In this case, the beam energy is 55 keV for Na beam and 23 keV for Cs beam, that is a little bit larger than that in Fig.1. Due to the limitation of the size of the lower oblique diagnostic port and the vacuum wall of the center pole, it is difficult to obtain the wide observation region.

The ratio of secondary beam current to primary beam current roughly estimated from these beam orbits in Fig.1 and Fig.2 is about 4×10^{-4} in the case of $n_e \sim 10^{19}$ m^{-3}, $T_e \sim$ 100 eV. In this case, the sufficient secondary current will be detected for measurements, however the density is an important to increase up to the order of 10^{19} m^{-3} because the rf heating tends to be low density discharge. The detail design for electric deflector and arrangement of energy analyzer are future issues.

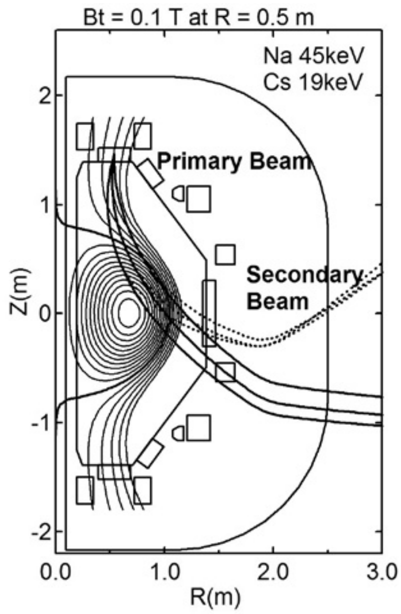

Fig. 1. Beam orbits for probe beam in QUEST is shown. Solid / dotted lines are primary / secondary beam orbits.

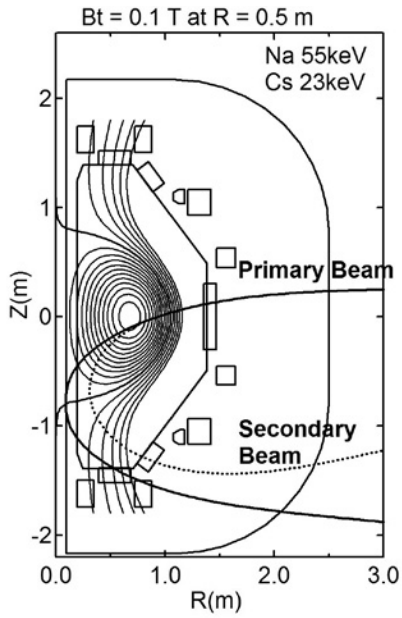

Fig. 2. A beam orbit to observe the central region of plasma is shown.

1) Demers, D. R., Fimognari, P. J.: Rev. of Sci. Instrum. **83** (2012) 10D711.