§6. Calibration of Tandem Energy Analyzer of Heavy Ion Beam Probe on LHD

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By using a high gain current detector, a micro channel plate (MCP), the secondary beam was successively detected on the Heavy Ion Beam Probe of LHD. By analyzing obtained signals, we checked the beam orbit and calibrated the tandem-energy analyzer. We report the experimental result for the calibration of the tandem-energy analyzer.

Usually for a heavy ion beam probe, a Proca-Green type parallel energy analyzer is used. However, if we apply this type of analyzer to HIBP on LHD, the required voltage to analyze the energy of 6MeV Au^+ beam reaches to 500 keV~1 MeV. The power supply to generate this range of voltage is very expensive. Therefore, in order to reduce the required voltage, the tandem type of energy analyzer 1) has been developed.

In Fig.1, a schematic view of the tandem energy analyzer is shown. The beam injection angle to the first electrodes of the analyzer is 6 degrees, and to the second is 10 degrees, these are smaller than that of conventional type of energy analyzer, 30 degrees. Due to this small injection angle, the required voltage can be reduced to 56.5 kV for the first parallel electrodes and 113.6 kV for the second parallel electrodes to analyze 6 MeV beam.

For the calibration of the tandem analyzer, the secondary beam originating in the neutral gas scattering is used because the potential in the neutral gas is zero. The total secondary ion beam current obtained by using the high gain detector, MCP, is about a few tenths of pA. This current level is very small to achieve a good signal-to-noise ratio. In order to reduce noise level, the signal of the secondary beam current is filtered by averaging in the each duration of 100 ms. In the calibration experiment, we change the voltage of beam accelerator, and the change in the beam energy is measured by the tandem analyzer. In Fig.2, the temporal evolution of measured beam energy with the tandem analyzer is shown. In this figure, the 3 cases of the accelerator voltages that we set are shown: 5.042 MeV, 5.045 MeV and 5.046 MeV. The vertical axis is the change in the beam energy measured by the tandem analyzer, and the offset level is determined by averaging the case of 5.042 MeV. The horizontal lines show the averaged values of each case in the temporal duration from -2 to -1 sec. In the case of 5.042 MeV, the variation level of the signal is larger than other two cases, because the secondary ion beam current is smaller than others: ~0.05 pA in the case of 5.042 MeV, ~0.15 pA in 5.045 and 5.046 MeV.

In Fig.3, the beam energy measured with the tandem-analyzer as a function of the accelerator voltage is shown. Here, for error bars, the standard deviations calculated from signals in Fig.2 are used. The magnitude of error is a few keV. The secondary beam current originating in the plasma is larger than in the neutral gas-scattering, therefore, the less error level is expected in measuring the plasma potential. However, for realizing more high temporal resolution (<10ms), larger current is required for the probing beam.

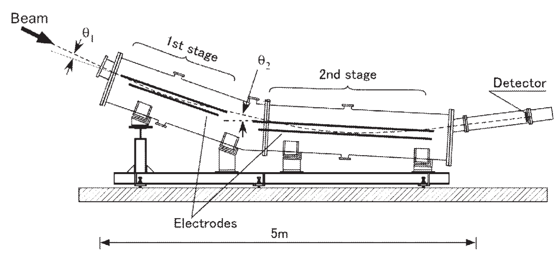

Fig.1. A schematic view of the tandem energy analyzer.

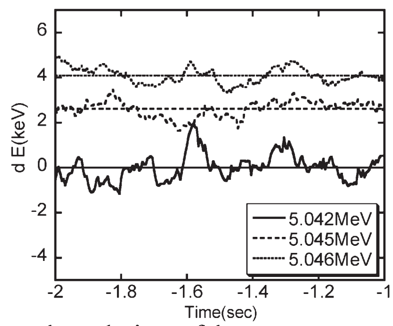

Fig.2. Temporal evolution of beam energy measured by the tandem analyzer. The 3 cases of acceleration voltages are shown.

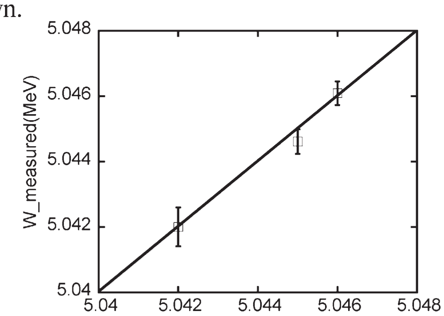

Fig.3. The beam energy measured with the tandem-analyzer as a function of the accelerator voltage

Reference

1) Y. Hamada, et al., Rev. Sci. Instrm. **68**, (1997) 2020