§10. A Sutdy of the Neutralization Efficiency for a Diagnostic He^0 Beam

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Alpha-particle measurement using a high-energy neutral beam seems to be feasible on the D-^{3}He experiment of LHD and on the DT experiment of ITER. In this scheme, alpha particles are neutralized by beam particles through two-electron transfer processes,

$$^4He^{++} + A^q \text{-------}> {}^4He^0 + A^{q+2} ,$$

escape from a plasma, and are detected in the high energy neutral particle analyzer. In order to measure alpha-particles over the energy range of 0.5 - 3.5 MeV, the required beam energy is approximately 1 MeV for a $^3He^0$ beam.

There are several methods to produce such a high-energy He^0 beam; (1) the gas neutralization of a He^+ beam of the MeV region, (2) the gas neutralization of a high energy He^- beam, (3) the time of flight neutralization of a He^- beam, and (4) the gas neutralization of a high energy HeH^+ beam. In general, a certain fraction of a long-life metastable state He^*, which is easily ionized in a gas cell or in a plasma, is contaminated in a He^0 beam.

Taking in the most of the possible charge transfer and excitation/deexcitation processes, the beam fractions of $He^-(I^-)$, $He^0(I^0)$, $He^*(I^*)$, $He^+(I^+)$, $HeH^+(I_{HeH}{}^+)$, and $He^{++}(I^{++})$ are calculated when a beam of He^+, He^-, or HeH^+ enters in an helium gas cell by solving the rate equations, as the following,

$$dI^-/dx = -(\sigma_{-,0}+\sigma_{-,*}+\sigma_{-,+}+\sigma_{-,++})I^-$$

$$dI^0/dx = \sigma_{-,0}I^- +\sigma_{*,0}I^* +\sigma_{+,0}I^+ +\sigma_{++,0}I^{++} -(\sigma_{0,*}+\sigma_{0,+}+\sigma_{0,++})I^0$$

$$dI^*/dx = \sigma_{-,*}I^- +\sigma_{0,*}I^0 +\sigma_{+,*}I^+ +\sigma_{++,*}I^{++} -(\sigma_{*,0}+\sigma_{*,+}+\sigma_{*,++})I^*$$

$$dI^+/dx = \sigma_{-,+}I^- +\sigma_{0,+}I^0 +\sigma_{*,+}I^* +\sigma_{++,+}I^{++} -(\sigma_{+,0}+\sigma_{+,*}+\sigma_{+,++})I^+$$

$$dI^{++}/dx = \sigma_{-,++}I^- +\sigma_{0,++}I^0 +\sigma_{*,++}I^* +\sigma_{+,++}I^+ -(\sigma_{++,0}+\sigma_{++,*}+\sigma_{++,+})I^{++}$$

The charge fractions when a He^- beam of 600 keV is injected into a helium gas are shown in Fig. 1 as a function of the target gas thickness. The optimum neutralization efficiencies for various beams thus obtained are shown in Fig.2.

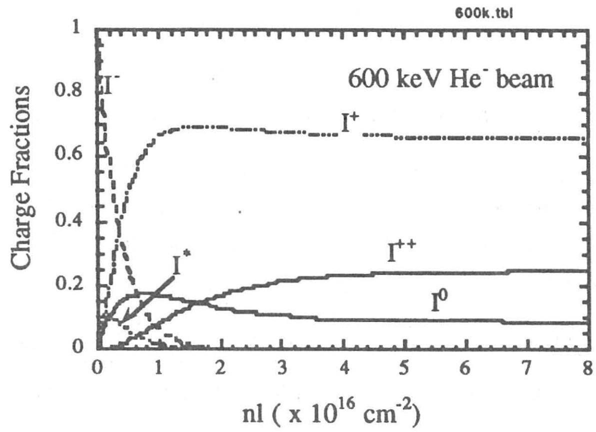

Fig. 1 The charge fractions of a He^- in He

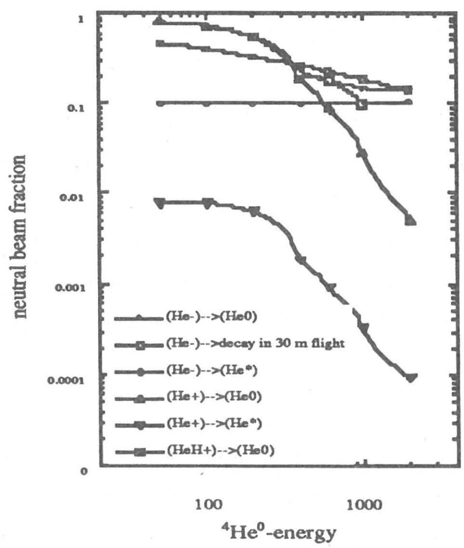

Fig. 2 Neutralization efficeincies: energy is in keV