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# An estimate of collisional beam scattering during final focus in NDCX-II

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The final focus of NDCX-II contains a region with quite high plasma density. We estimate here how much collisional scatter we expect from transit through this plasma. A separate question, not explored here, is how much scatter there might be off of collective fluctuations in the neutralizing plasma, including those driven by the passage of the beam.

From the NRL tables the rate of perpendicular scatter is given by:

$$\frac{d}{dt}\left(v_\perp - \overline{v}_\perp\right)^2 = \nu_\perp v^2 \tag{1}$$

where the relevant scattering process is fast beam ions scattering off of the ions and electrons in the background plasma. For MeV-plus-energy beam ions and a few eV plasma electrons (and plasma ions), we are in the limit of fast test particles scattering on a slow background, so that

$$\nu_\perp = 1.8 \times 10^{-7}(n_e\lambda_{ie} + n_i\lambda_{ii}Z_i^2)Z_b^2\mu_b^{-1/2}\epsilon_b^{-3/2} \tag{2}$$

Taking $v^2 = \text{constant} = 4v_b^2$ in the final focus region, the net integrated r.m.s. scattering angle $\theta_s$ is then given by

$$\theta_s = \left(v_b^{-1}\int \nu_\perp dz\right)^{1/2} \tag{3}$$

and we would like the integrated spread of spot size resulting from this scattering to be small compared to the beam size; hence we compare

$$\Delta r_s = \int dz v_r/v_z \approx \int dz\theta_s \approx v_b^{-1/2}\int dz\left(\int^z \nu_\perp dz'\right)^{1/2} \tag{4}$$

to the spot size neglecting scattering effects. The details, as expected, depend on the distribution of plasma density, which, because of the planned injection location and magnetic-field design, will be high near the target and fall off upstream.

To obtain an estimate, we approximate the plasma density as uniform, with value $n_{ep}$ over a length $L_s$, and present expressions relative to reference values of $n_{ep} = 10^{15}$ cm$^{-3}$ and $L_s = 50$ cm. For fast beam ions, the electron and ion plasma temperatures and the plasma ion atomic mass enter only very weakly via the Coulomb logarithm, which we evaluate here for plasma temperatures $T_e = T_i = 3$ eV and ion mass $A_i = 27$ (Aluminum), and beam energy 2 MeV, beam ion mass 7 (Lithium), and charge 1. For these parameters we obtain $\log\lambda_{ei} = 23$ and $\log\lambda_{ii} = 22$, and hence take simply 23 for the coulomb log. Then we obtain

$$\Delta r_s \approx \frac{2}{3}\left(\nu_\perp/v_b\right)^{1/2} L_s^{3/2} =$$

$$3\times 10^{-3}\text{cm} \times \left(\frac{n_e\lambda_{ie} + n_i\lambda_{ii}Z_i^2}{2\times 23\times 10^{14}\ \text{cm}^{-3}}\right)^{1/2} \times \frac{2\ \text{MeV}}{\epsilon_b} \times \left(\frac{L_s}{50\ \text{cm}}\right)^{3/2} \tag{5}$$

Since the desired focussed spot size is around 0.1 cm, we conclude that collisional scattering is a negligible concern for the likely range of plasma densities and scale lengths.

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