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Enhanced collective focusing of intense neutralized ion beam pulses in the presence of weak solenoidal magnetic fields

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The design of ion drivers for warm dense matter and high energy density physics applications and heavy ion fusion involves transverse focusing and longitudinal compression of intense ion beams to a small spot size on the target. To facilitate the process, the compression occurs in a long drift section filled with a dense background plasma, which neutralizes the intense beam self-fields. Typically, the ion bunch charge is better neutralized than its current, and as a result a net self-pinching (magnetic) force is produced. The self-pinching effect is of particular practical importance, and is used in various ion driver designs in order to control the transverse beam envelope. In the present work we demonstrate that this radial self-focusing force can be significantly enhanced if a weak ($\sim$100 G) solenoidal magnetic field is applied inside the neutralized drift section, thus allowing for substantially improved transport. It is shown that in contrast to the magnetic self-pinching, the enhanced collective self-focusing has a radial electric field component and occurs as a result of the overcompensation of the beam charge by plasma electrons, whereas the beam current becomes well-neutralized. As the beam leaves the neutralizing drift section, additional transverse focusing can be applied. For instance, in the Neutralized Drift Compression Experiments (NDCX) a strong (several Tesla) final focus solenoid is used for this purpose. In the present analysis we propose that the tight final focus in the NDCX experiments can possibly be achieved by using a much weaker (few hundred Gauss) magnetic lens, provided the ion beam carries an equal amount of co-moving neutralizing electrons from the preceding drift section into the lens. In this case the enhanced focusing is provided by the collective electron dynamics strongly affected by a weak applied magnetic field.