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Influences of Beam Parameters on the Interaction Between Ion and Electron Beams

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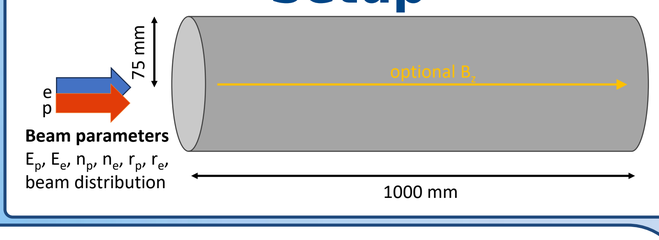
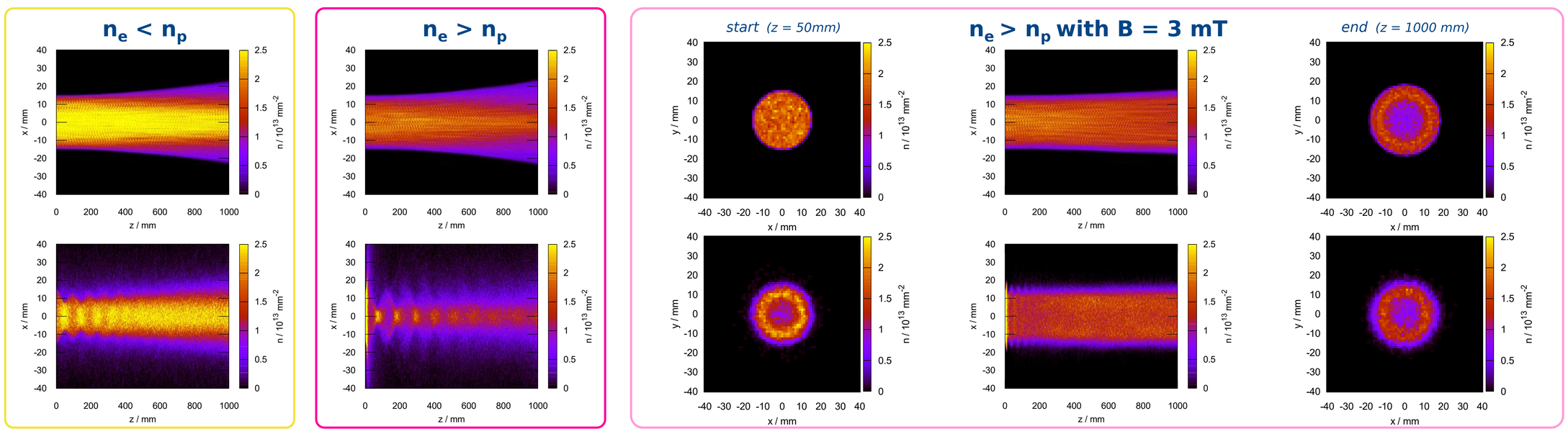
Abstract

Electrons can be confined as a static column or as a comoving beam for applications in accelerator physics. Depending on the configuration of the electrons, they can cool, compensate or even focus the ion beam. In the case of an electron beam, the parameters must be chosen correctly to obtain the desired effects. The influences of these beam parameters on the interaction between the ion and electron beam are investigated in numerical simulations by using a particle-in-cell code. The understanding of the different interaction mechanisms will allow an even better matching of the beams to each other for the intended application. With additional suitable beam diagnostics, it will be possible to draw conclusions about the interaction of the superimposed beams in order to evaluate the quality of the settings and, if necessary, to correct them.

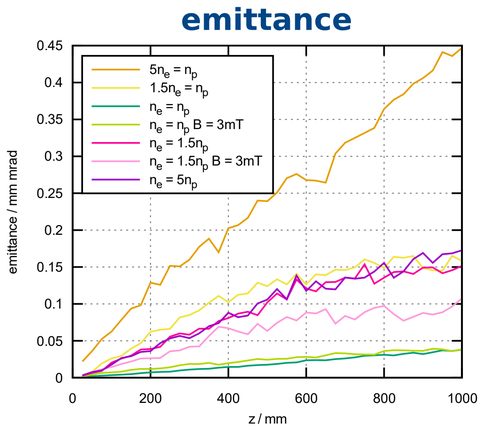
Setup



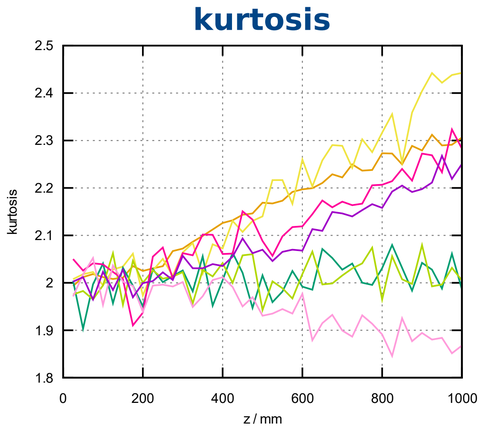
Density Influence



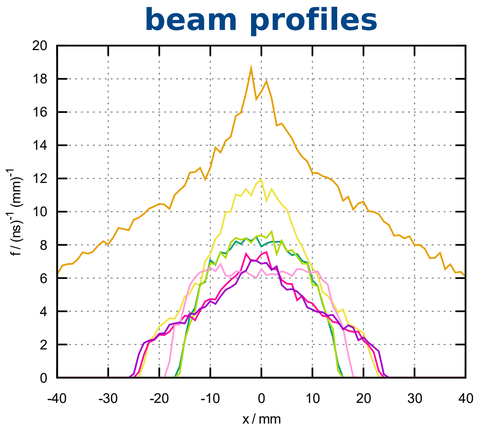
emittance



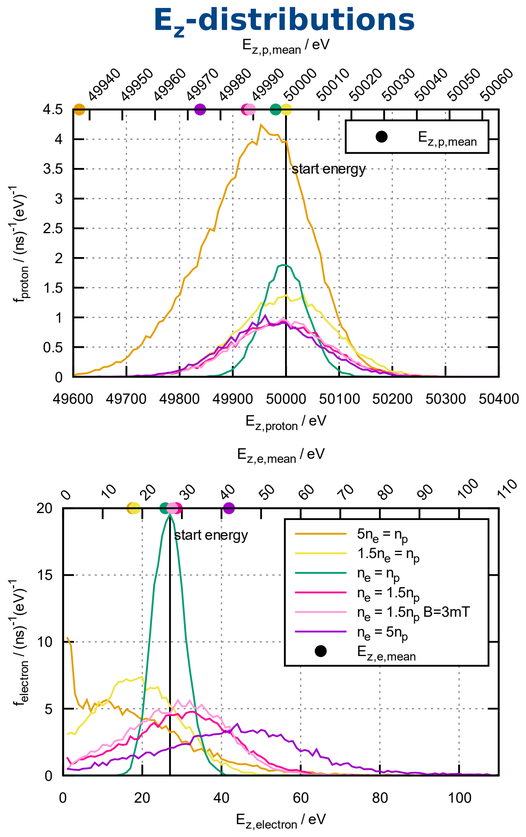
kurtosis



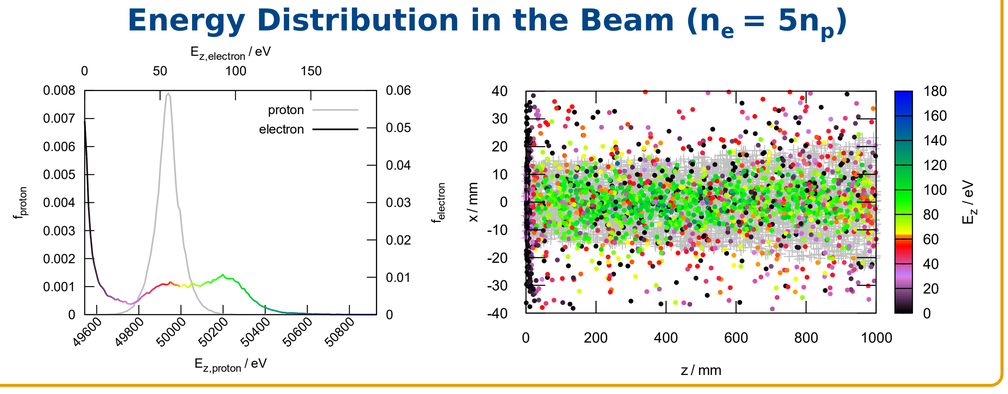
beam profiles



E_z-distributions



Energy Distribution in the Beam ($n_e = 5n_p$)



The initial parameters are chosen the same in each of the cases, while the density of the beams is varied.

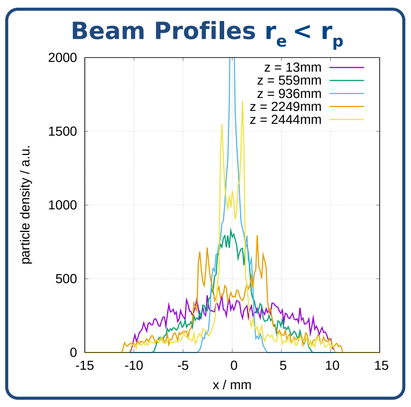
Without a magnetic field:
All cases with initial $n_e > n_p$ result in $n_e < n_p$, because the space charge forces and the strong mobility of the electrons at the beginning of the simulation volume leads to a strong divergence and accumulation of the electrons in an electron slice ($E_z = 0$), which reduces the following density of the electrons. Due to their high mobility, the electron density adapts to the protons.

With a magnetic field:
A longitudinal magnetic field is needed to avoid radial losses of electrons and to keep the electron density. The mobility of the electrons decreases, so that the protons are more mobile than the electrons. The proton density adapts to the electrons to reach a state of equilibrium.

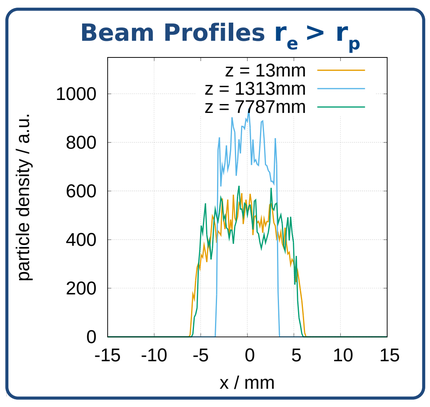
Consequences of $n_e \neq n_p$:
- emittance growth
- distribution change (due to non-linear fields)
- energy shift

Radius Influence

Beam Profiles $r_e < r_p$



Beam Profiles $r_e > r_p$



The radii of the beams are varied. In the case that $r_e < r_p$, non-linear fields arise, which leads to a periodic change of the distribution and possible losses**. In the case that $r_e > r_p$, the distribution is preserved.** If the density difference of the beams is small, then only a periodic compression and decompression occur.

Distribution Influence

initial start distributions:
electron beam kv
proton beam gauß

The beams have the same initial parameters as in the density influence simulations except that the distributions differ. The proton beam starts with a Gaussian distribution and the electron beam with a KV distribution. A simulation was performed without and with a longitudinal magnetic field. With a magnetic field, the electron beam is kept approximately in its initial distribution, so that the proton beam reaches the KV distribution faster than without a magnetic field.

Consequences of different distributions
- emittance growth
- desired distribution of the ion beam can be predefined