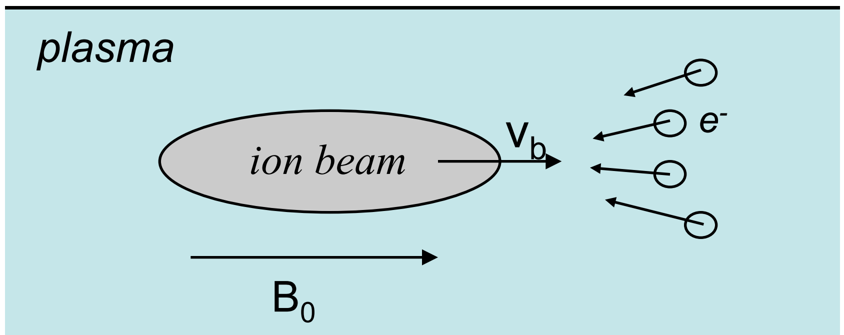
Use of a weak solenoidal magnetic field for collective beam focusing and diagnostic purposes



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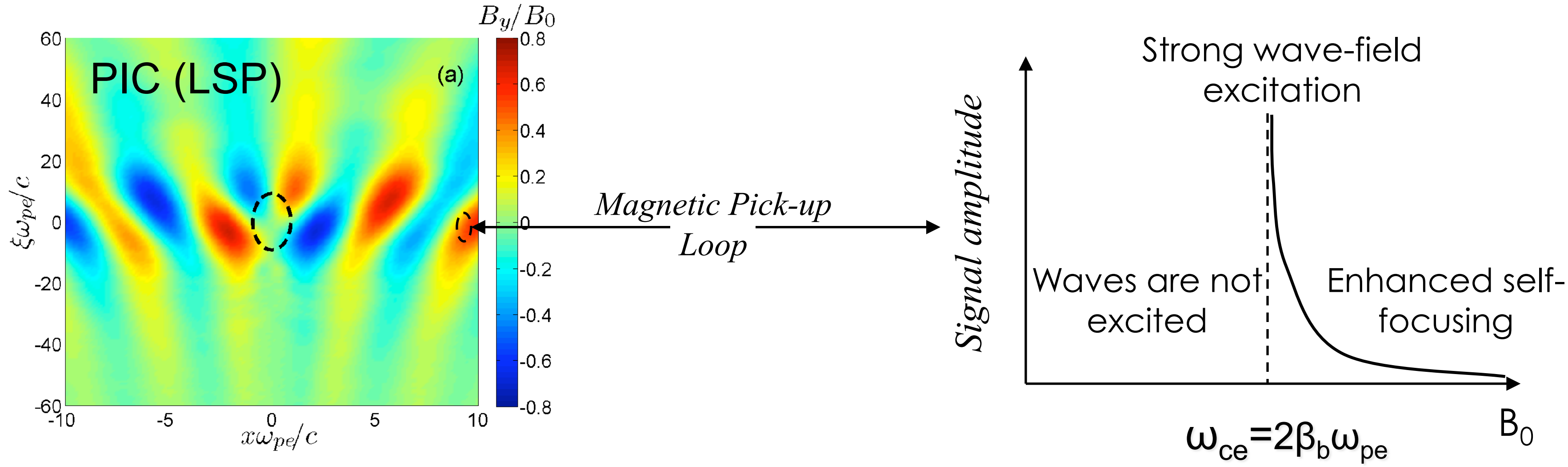
Wave-Field Excitation Can Be Used for Diagnostic Purposes

Ion beam pulse can effectively excite whistler waves

Azimuthal magnetic field — *Schematic of the detected signal*

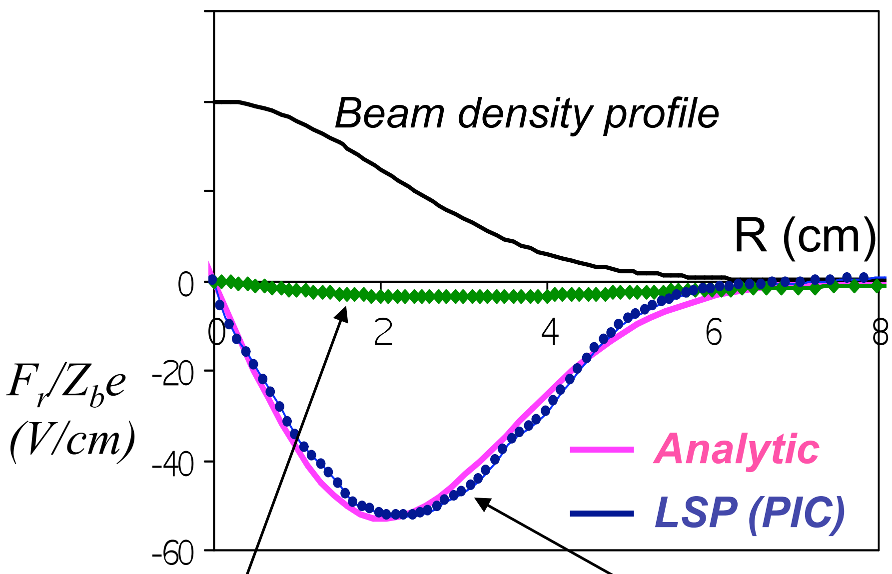


β_b=0.33, l_b=10r_b, r_b=0.9·ω_{pe}/c, n_b=0.05n_p,
B_{ext}=1600G, n_p=2.4·10^{11}cm^{-3}

- *Wave frequency is given by the Cherenkov condition $\omega \sim k_z V_b \sim V_b/L_b \sim 1/t_p$*
- *Strong wave excitation occurs at $\omega_{ce}/2\beta_b\omega_{pe}$ (supported by PIC simulations)*
- *$\omega_{ce}=2\beta_b\omega_{pe}$ peak can be used, for plasma density measurements*

A Weak Solenoidal Magnetic Field Can Enhance the Ion Beam Self-Focusing

Radial focusing force



$B_{ext}=0$

Magnetic self-pinching

⇓

The focusing is provided by an azimuthal self-magnetic field

$B_{ext}=300$ G

Collective self-focusing

⇓

The focusing is provided by a strong radial self-electric field

Enhanced self-focusing force

$(\omega_{ce} >> \beta_b \omega_{pe})$

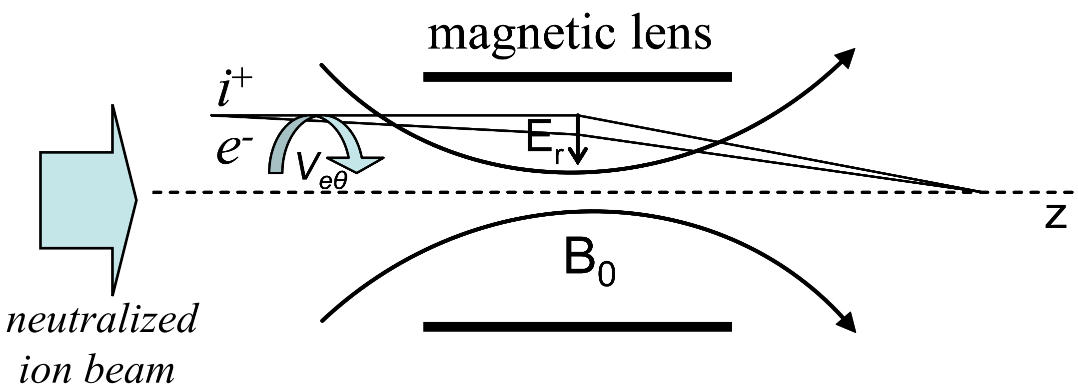
$$F_{sf} = Z_b^2 m_e V_b^2 \frac{1}{n_p}\frac{dn_b}{dr} \qquad \frac{V_b}{\omega_{ce}}\sqrt{1+\frac{\omega_{ce}^2}{\omega_{pe}^2}} << r_b << \frac{c}{\omega_{pe}}$$

- *The force is nonlinear in radius, but can effective compensate beam thermal spreading, ~$T_b dn_b/dr$*

Gaussian beam: $\mathbf{r_b=0.55c/\omega_{pe}}$, $l_b=3.4r_b$, $\beta=0.05$, $n_b=0.14n_p$, $n_p=10^{10}$ cm^{-3}

Collective Focusing Lens for a Heavy Ion Driver Final Focus

Collective focusing lens (S. Robertson, 1982)



Strong focusing electric field

$$E_r = -m_e \Omega_e^2 \frac{r}{4e}$$

Conditions for collective focusing

$$\omega_{pe} \geq \Omega_e / \sqrt{2}$$

To maintain quasi-neutrality

$$r_b \leq 2c/\omega_{pe}$$

To assure small magnetic field perturbations

NDCX-I

- Numerical simulations with the LSP code demonstrate the feasibility of tight collective focusing (M. Dorf et al, IPAC 2010)
- However, beam prepulse can provide secondary electrons from the target, thus suppressing the collective focusing effect

NDCX-II

- The entire beam pulse undergoes simultaneous compression (no prepulse)
- Strong magnetic lens (B_0~10 T) can be replaced by ~900 G for Li^+ ion beam, provided the pre-compressed beam density at the exit of the drift section is $n_b > 4 \times 10^{10}$ cm^{-3}