Simulation of a plasmoid penetrating a magnetic barrier

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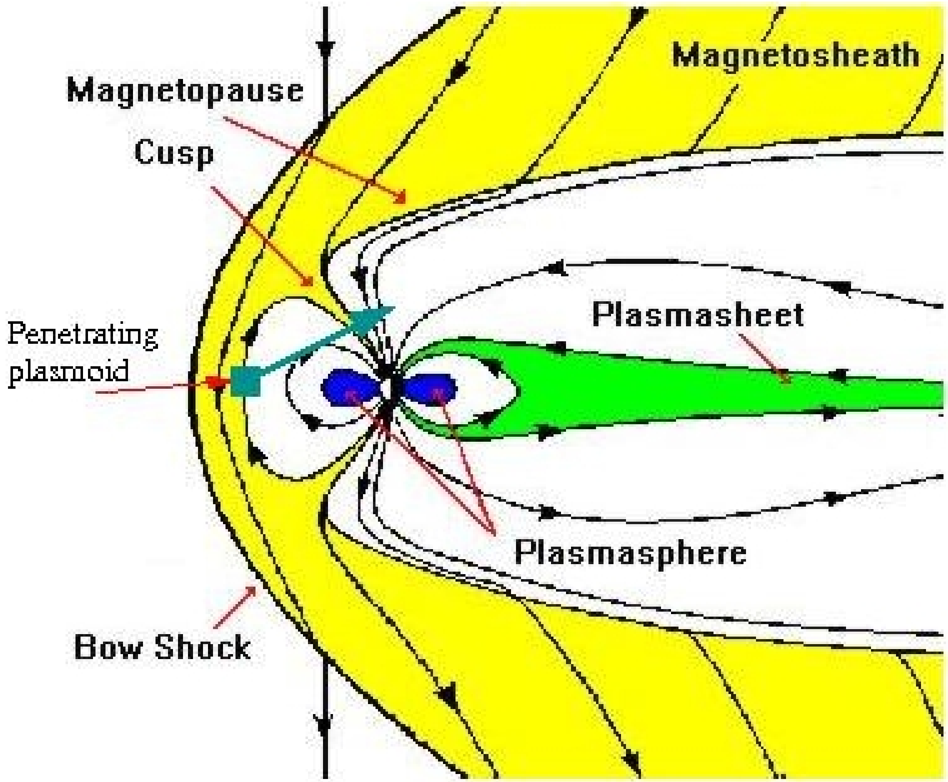
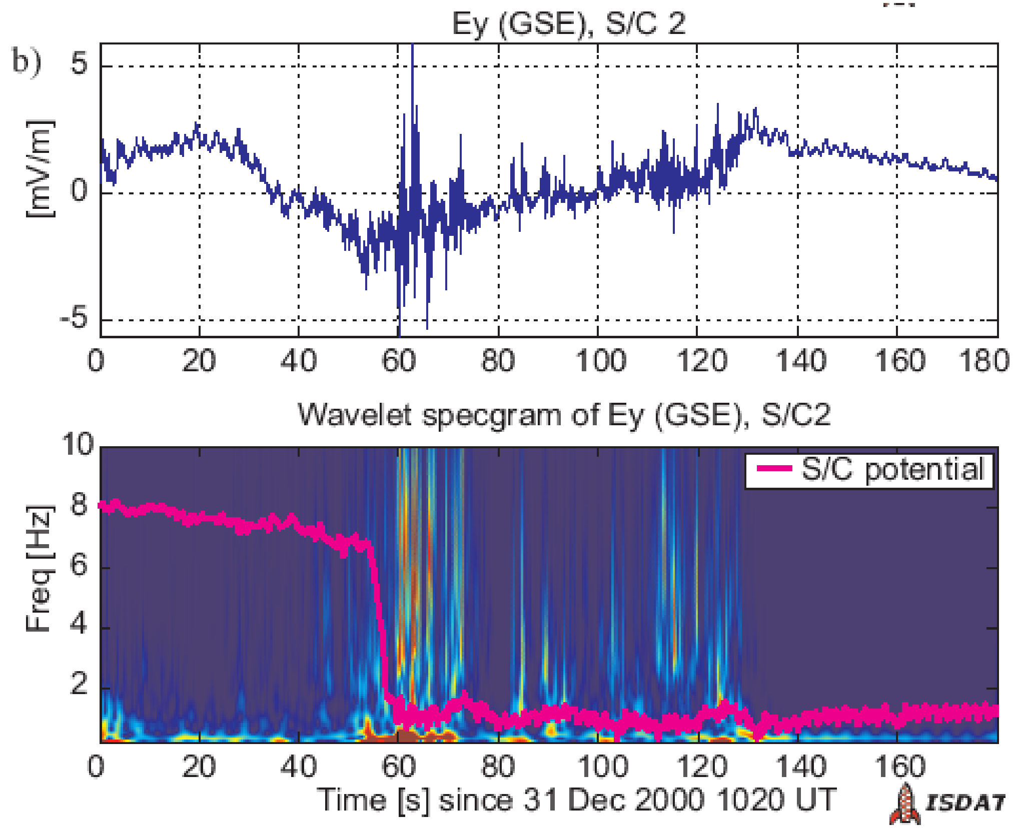
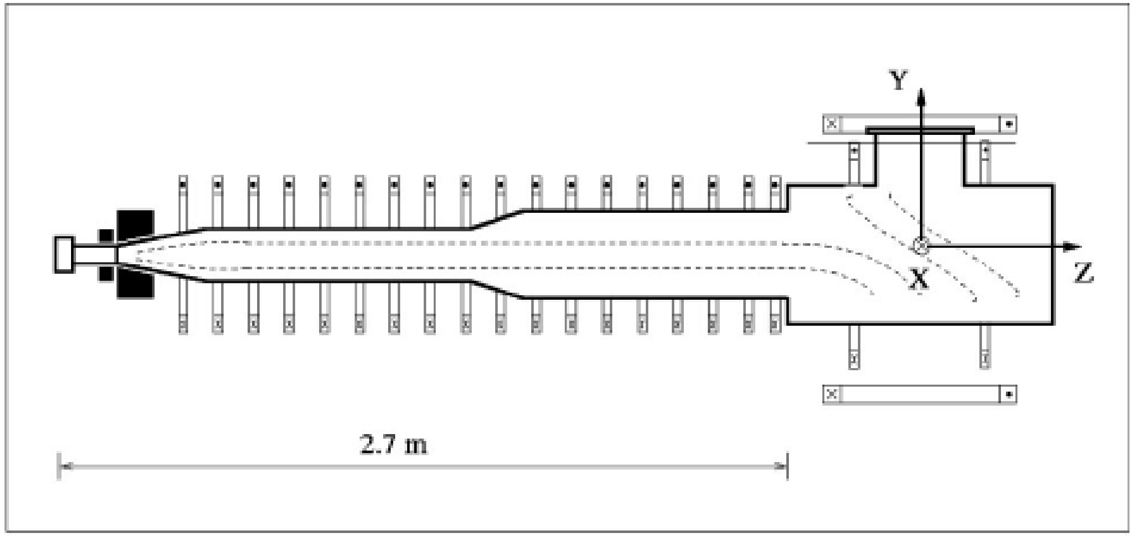
Introduction – space





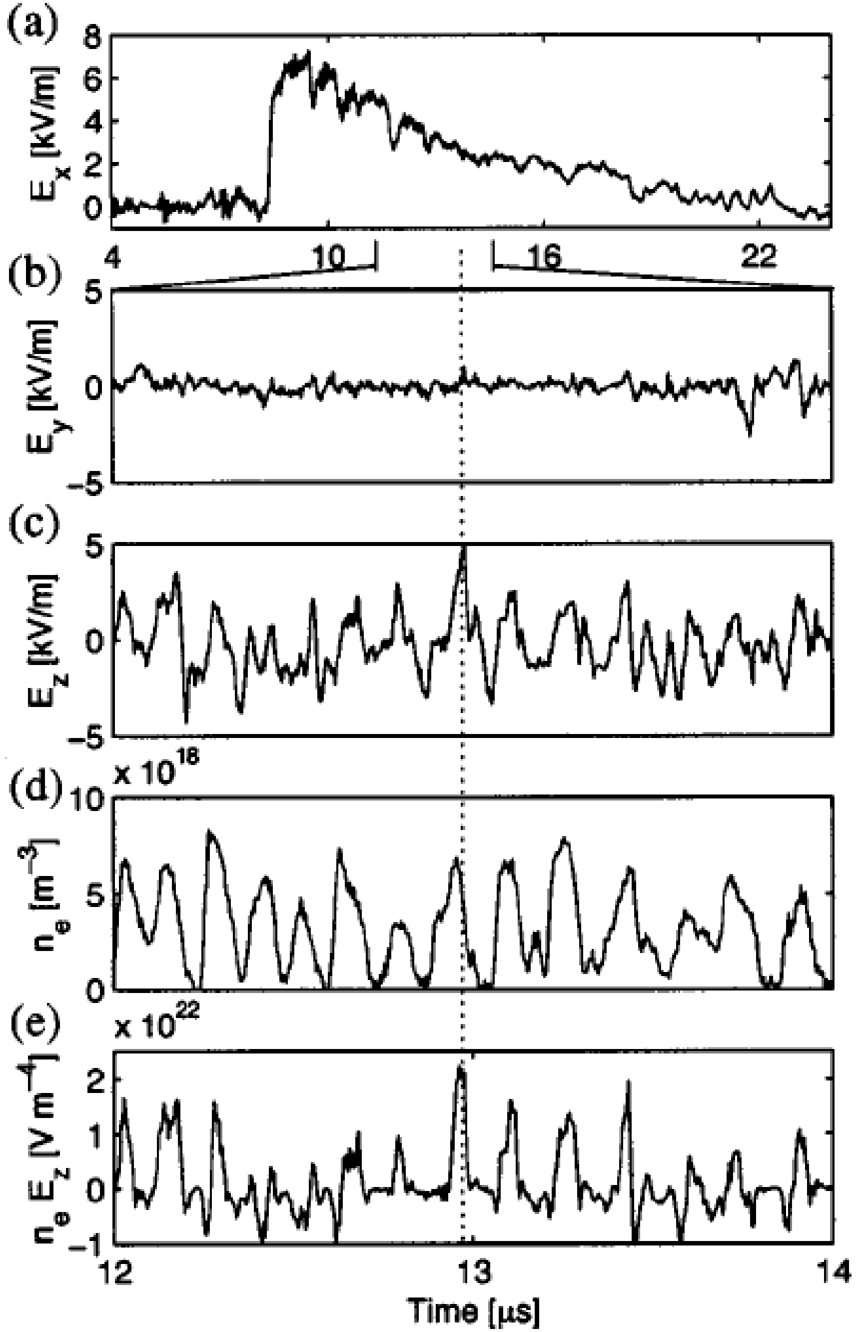
Left: Impulsive penetration at the magnetopause.
Right: Electric field measured by Cluster showing waves in the lower hybrid frequency range (*André, et al. 2001*).

Introduction – lab

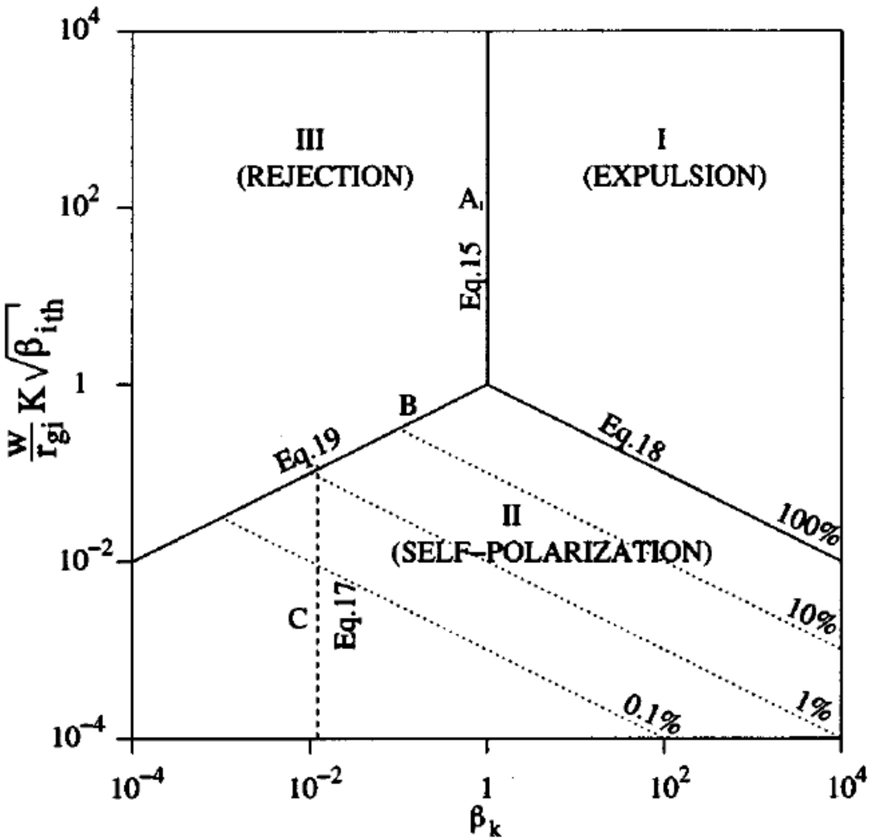


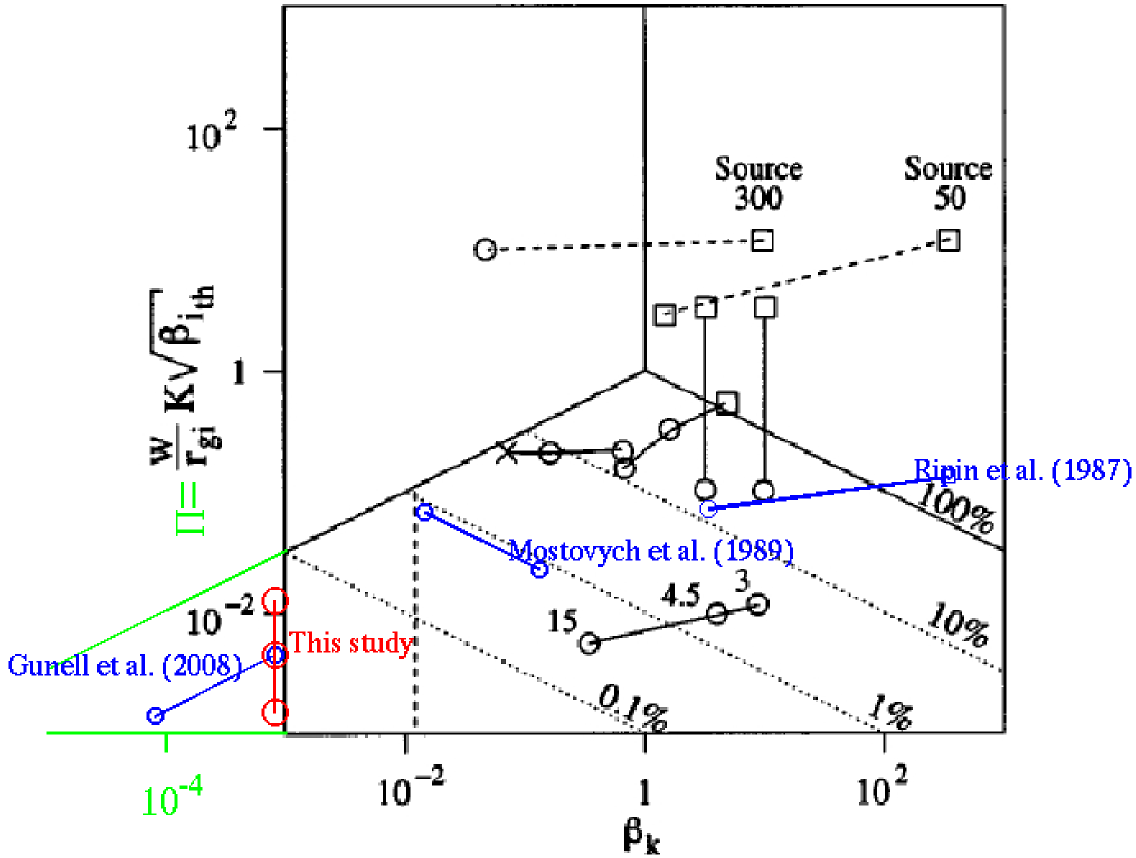
Above: A plasma cannon.

Right: a) Polarisation field E_x; b) vertical electric field E_y; c) E-field in flow direction E_z; d) plasma density; e) $n_e E_z$.



Introduction – parameter regimes



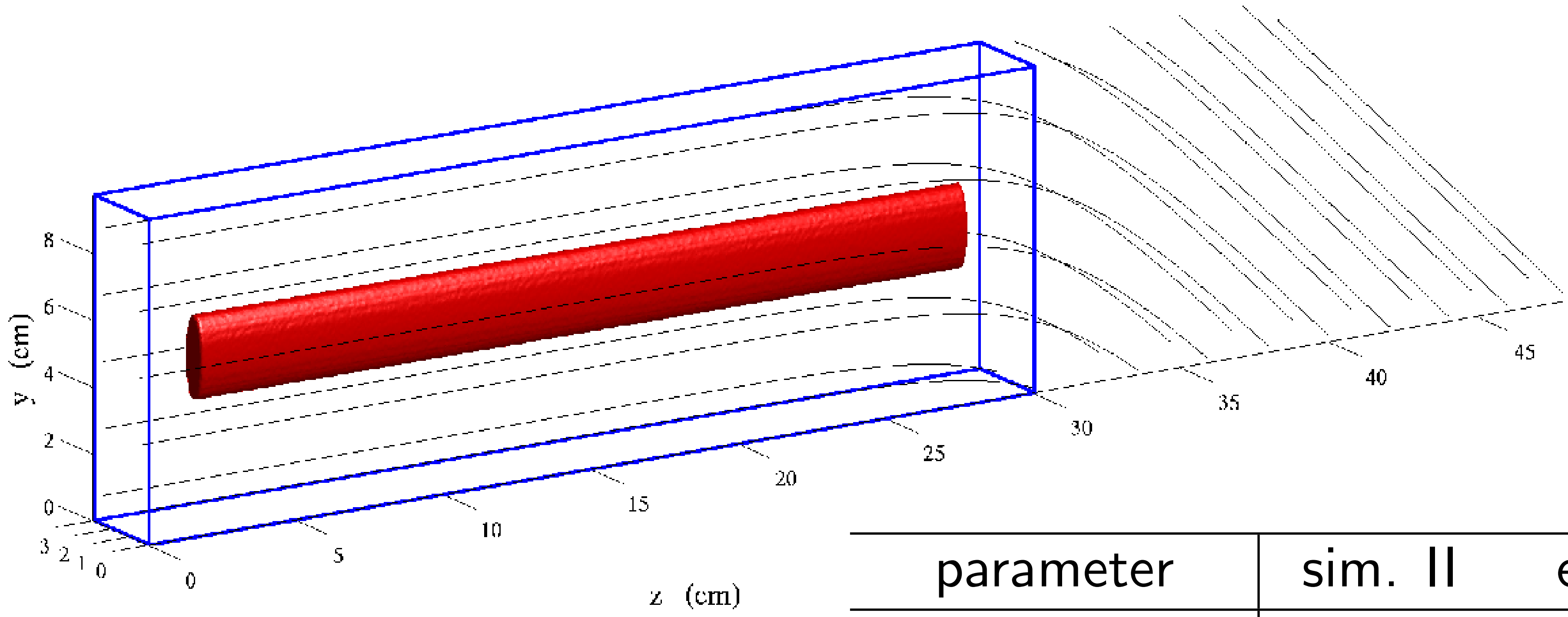


1. **Expulsion.** A plasma structure can penetrate a magnetic barrier by expelling the magnetic field if $\beta_k > 1$ and $\Pi > 1/\sqrt{\beta_k}$.

2. **Self-polarisation.** A plasma structure can penetrate a magnetic barrier by convection in a polarisation electric field if $\Pi < \sqrt{\beta_k}$ for $\beta_k < 1$ and $\Pi < 1/\sqrt{\beta_k}$ for $\beta_k > 1$.

3. **Rejection.** The plasma cannot penetrate the magnetic barrier if $\beta_k < 1$ and $\Pi > \sqrt{\beta_k}$.

The long plasmoid



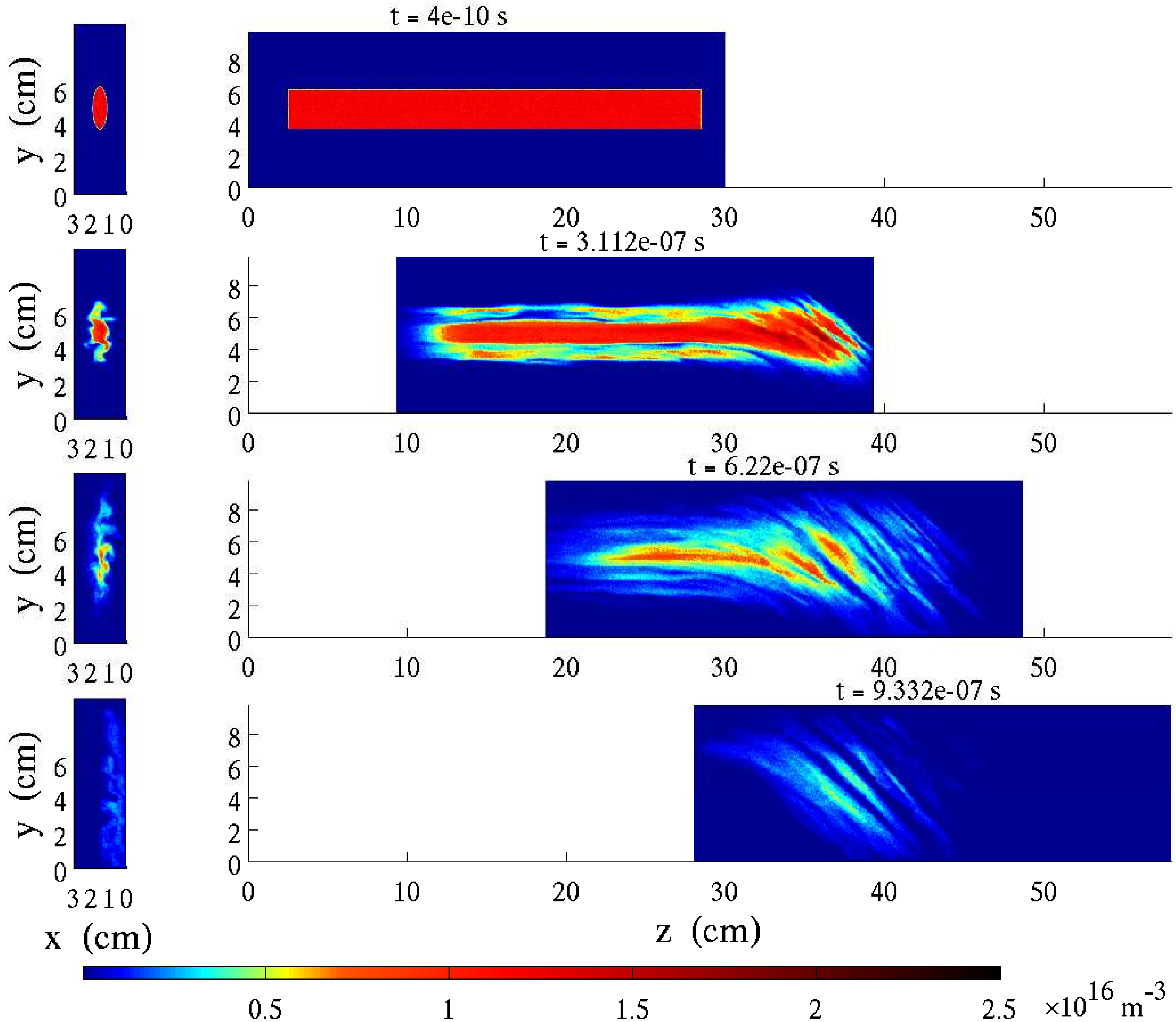
$$W_K = \frac{1}{2} n_0 m_i v_0^2$$

$$W_E = \frac{1}{2} \epsilon_0 \left(v_0 B_\perp\right)^2$$

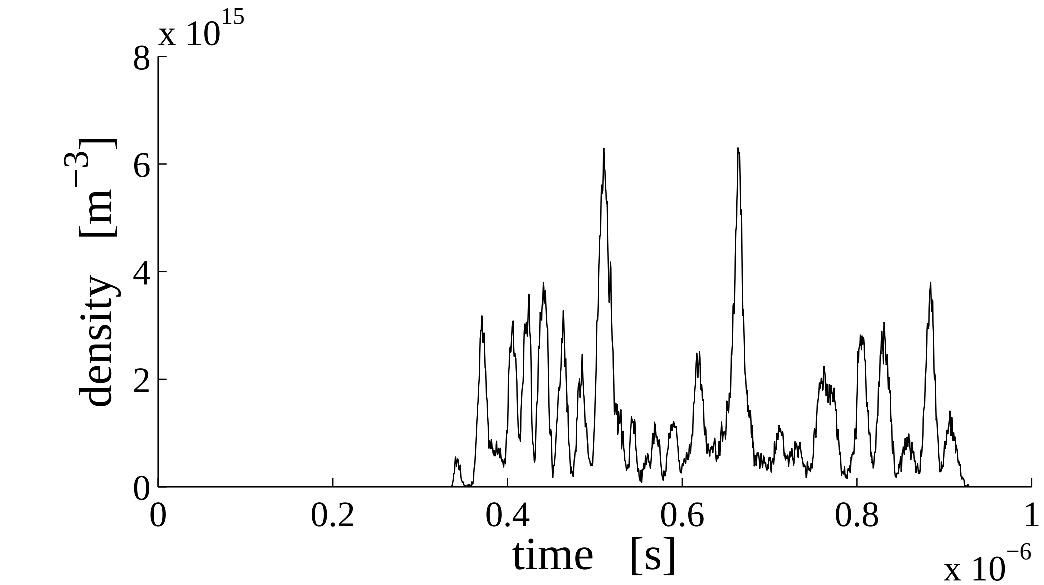
$$W_B = \frac{B_\perp^2}{2\mu_0}$$

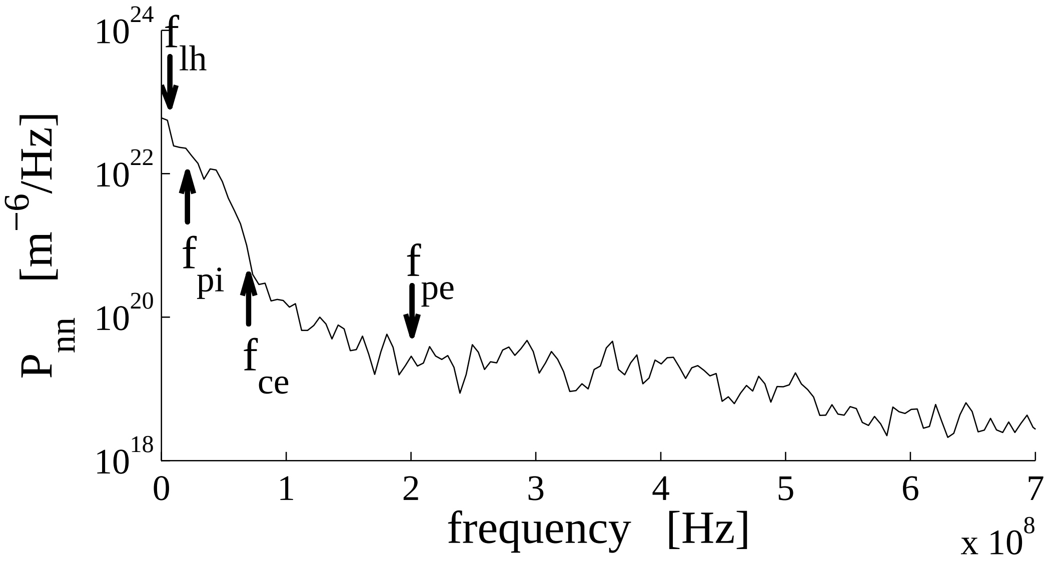
parameter	sim. II	exp.
$v_0/(\mathrm{km/s})$	300	300
$B_\perp/\mathrm{T}$	0.05	0.015
n_0/m^{-3}	10^{16}	10^{18}
m_i/m_e	92	1836
W_K/W_E	756	$8 \cdot 10^5$
$\frac{1}{10}\frac{W_K}{W_E}\sqrt{\frac{m_e}{m_i}}$	7.9	$2 \cdot 10^3$
$\beta_k = W_K/W_B$	$8 \cdot 10^{-4}$	0.8

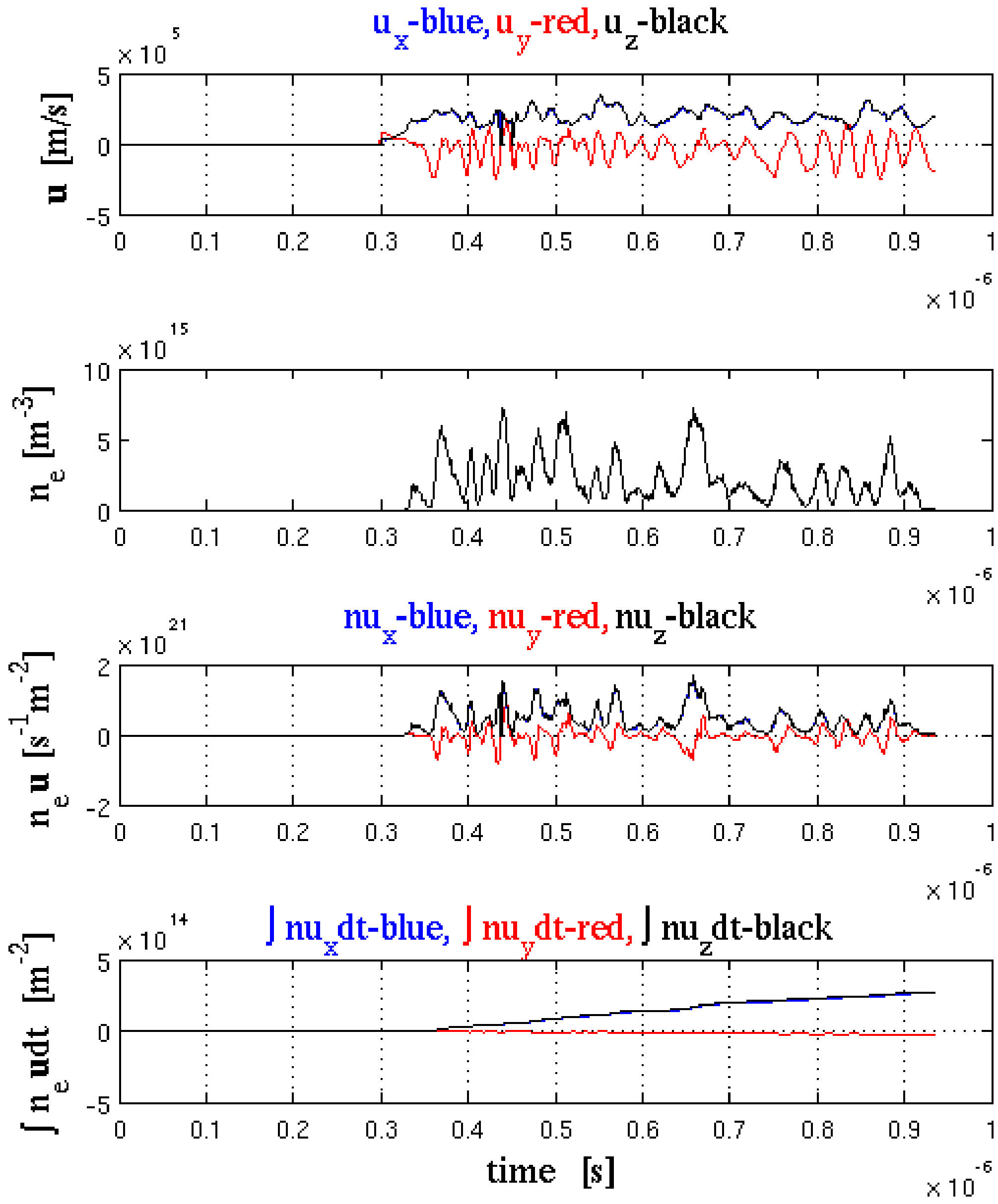
The long plasmoid – density



The long plasmoid – waves

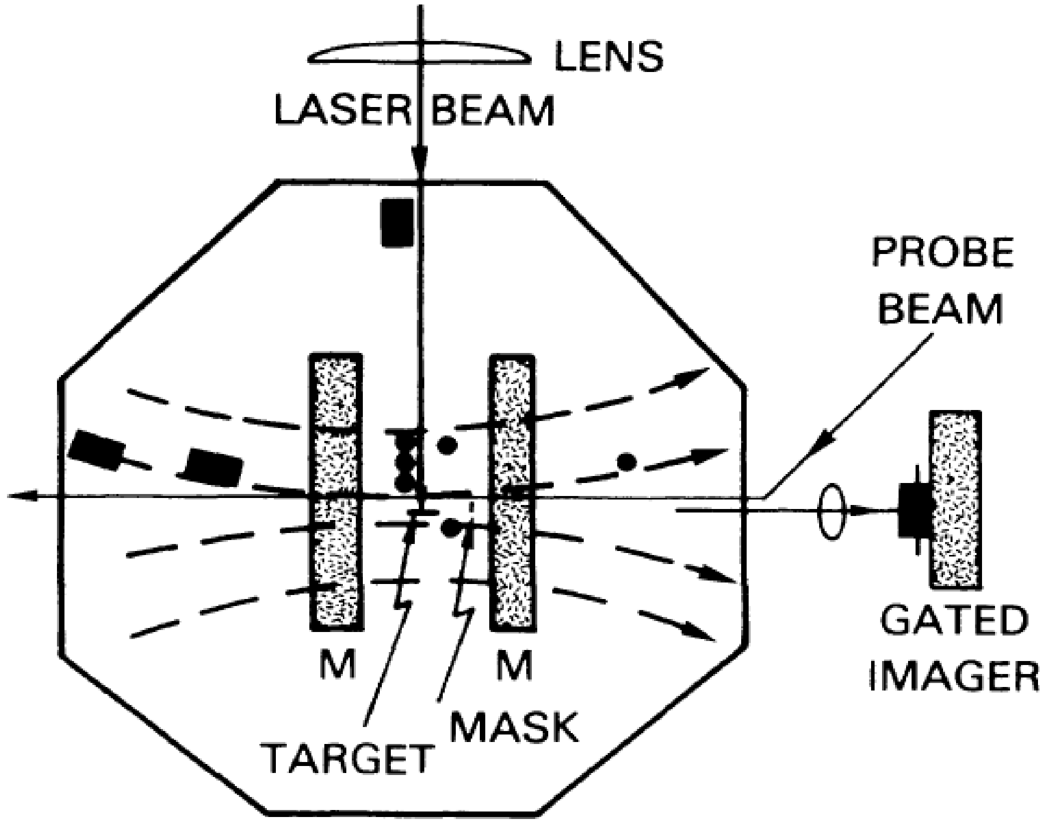


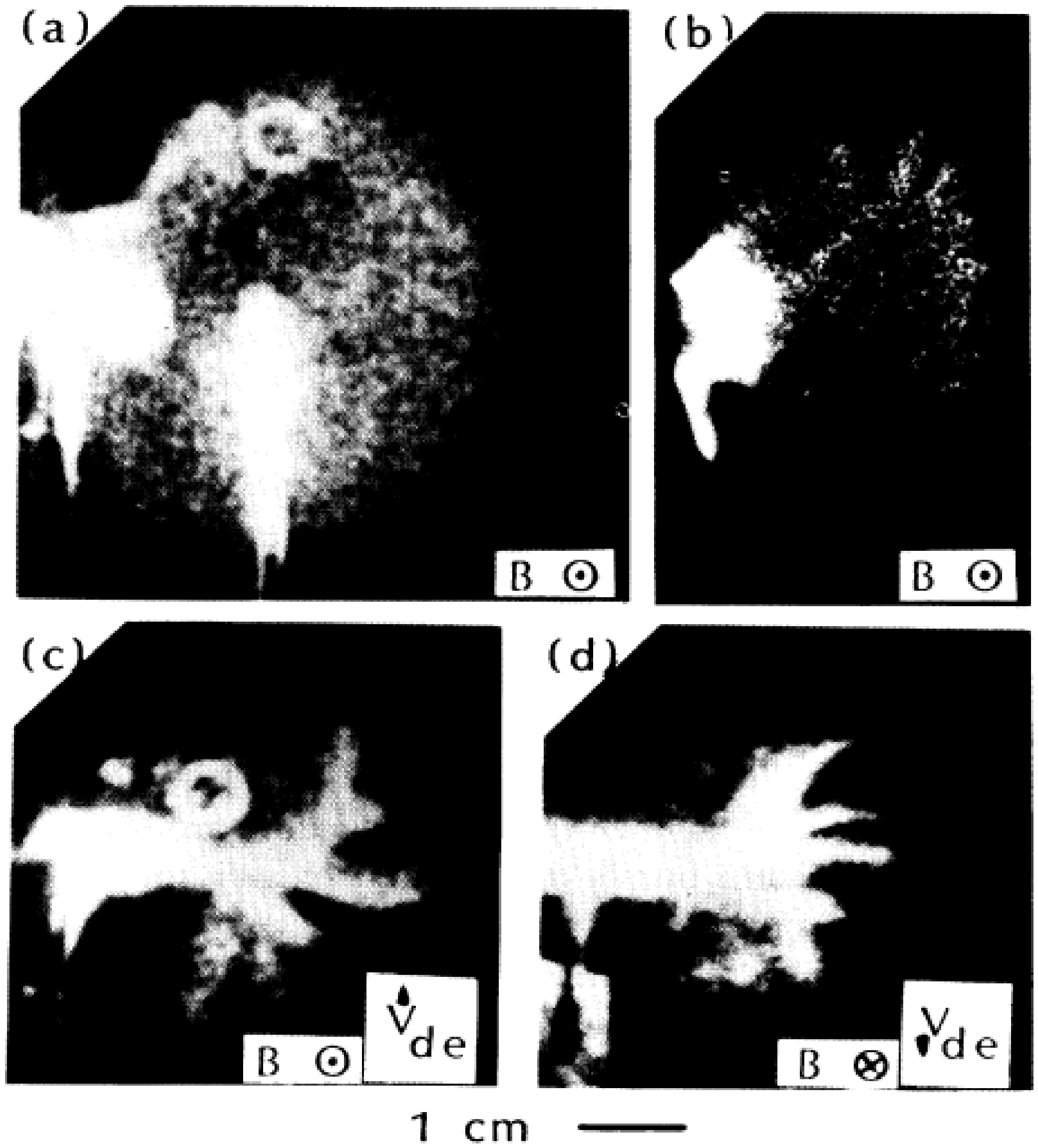




Density probe at $z = 0.39$ m.

Wide plasmoids



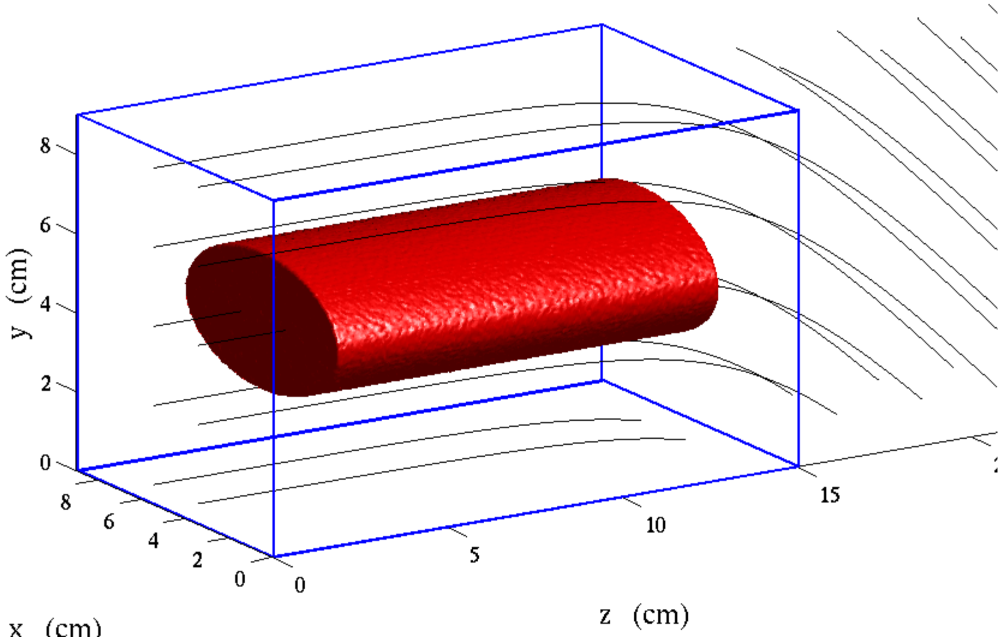


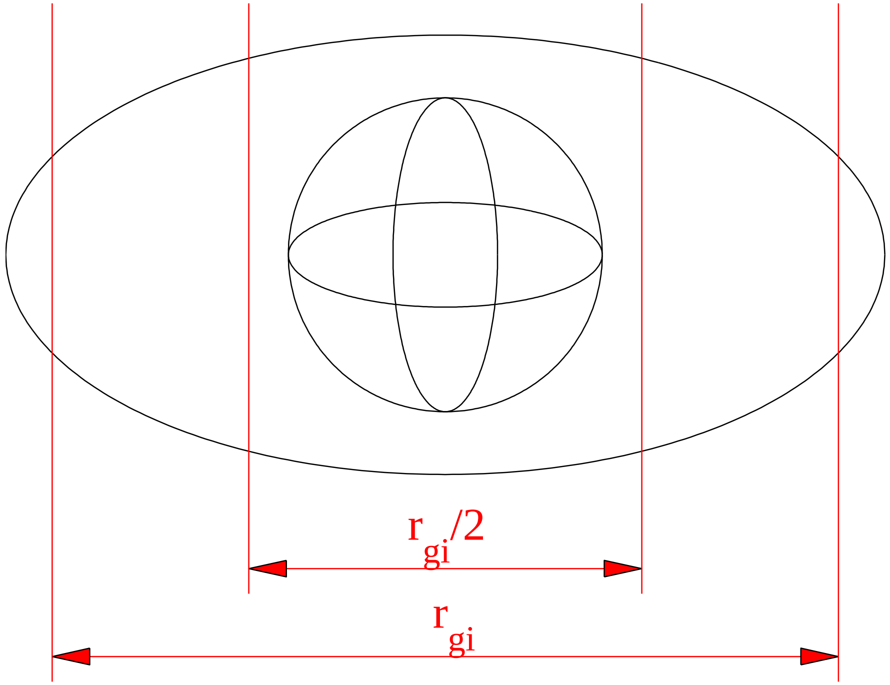
Pictures from *Ripin et al. (1987)*.

The wide plasmoid

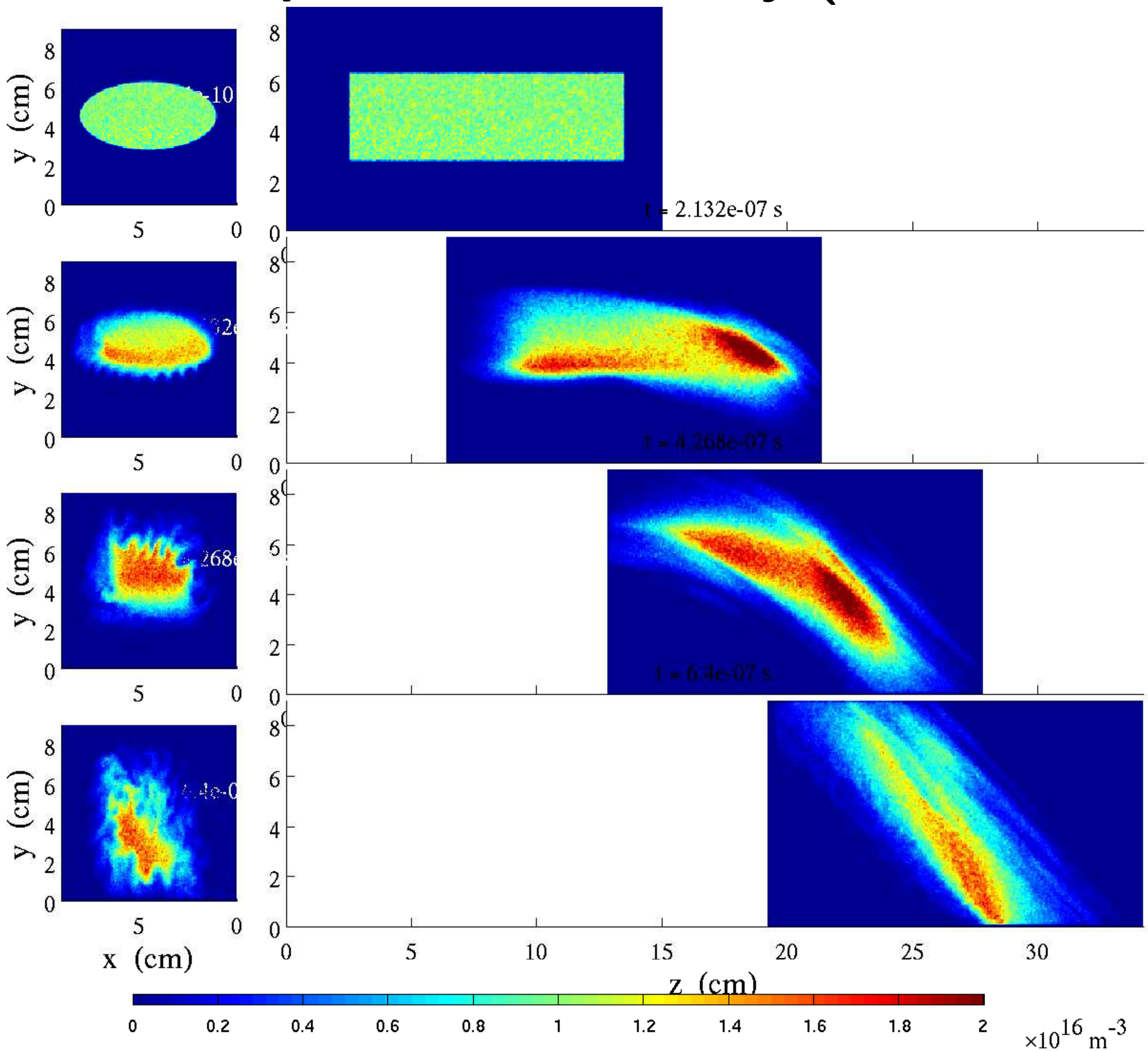
The limit estimated by *Lindberg (1978)*:

$$ewv_0B_\perp \le \frac{1}{2}m_iv_0^2 \qquad \Rightarrow \qquad w \le \frac{1}{2}\frac{m_iv_0}{eB_\perp} = \frac{1}{2}r_{gi}$$

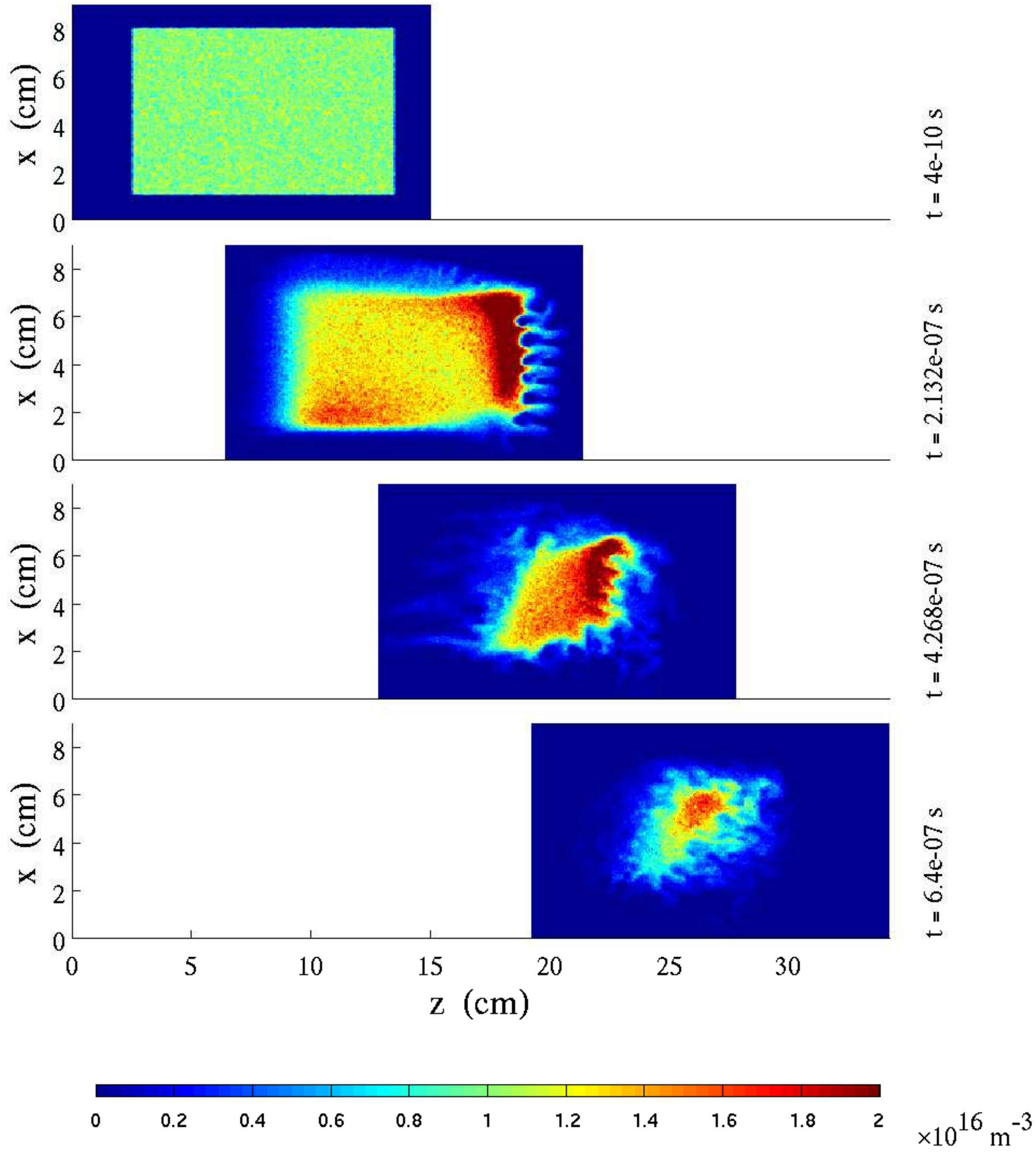




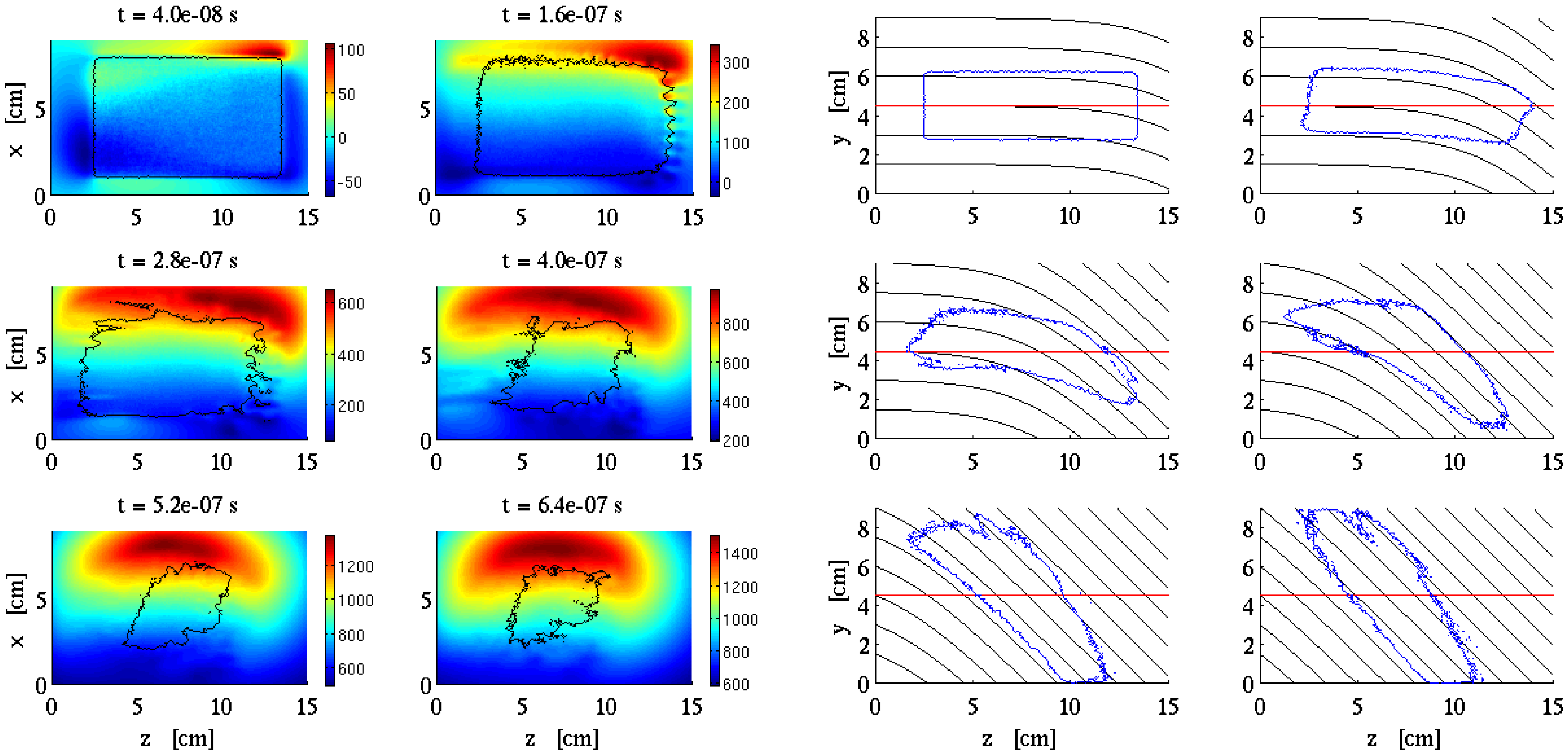
The wide plasmoid – density (vertical slice)



The wide plasmoid – density (horizontal slice)



The wide plasmoid – penetration



Conclusions

- Lower hybrid frequency waves are seen at the magnetopause, in laboratory experiments and in simulations.

- For $w < r_{gi}/2$ all cross sectional shapes are compressed into vertically aligned structures.

- Plasmoids with $w \approx r_{gi}$ can penetrate with the aid of a backward propagating potential and through compression to smaller widths.

- The finger-like structures that develop at an early stage for $w \approx r_{gi}$ plasmoids are a result of the same instability that gives rise to the lower hybrid frequency waves along the flanks.

- Next step: $w \gg r_{gi}$