Plasmoid penetration across a magnetic barrier:
Scaling from laboratory experiments to impulsive penetration into the Earth's magnstosphere..

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…and propagation, based on ionospheric experiments.

Part 1: penetration

comparison to lab experiments

- Establish limits between magnetic expulsion, self polarization and rejection

Part 2: propagation

comparison to ionospheric injection experiments

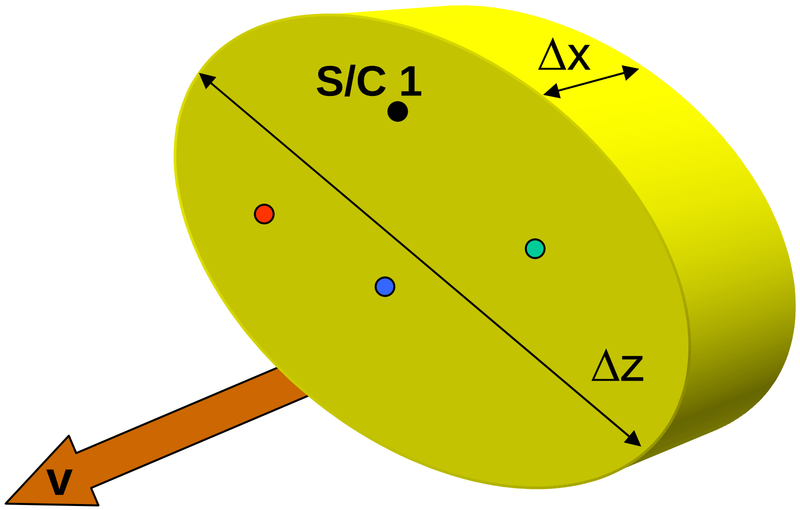
- Coupling along **B**: momentum exchange, **E** fields, and **B**-parallell currents

Now: Part 1, penetration

CLUSTER DATA: Determination of scale sizes

1. Along *x*-direction: width of half maximum of Δn_e

2. *y* and *z*: in effect only four measurement points

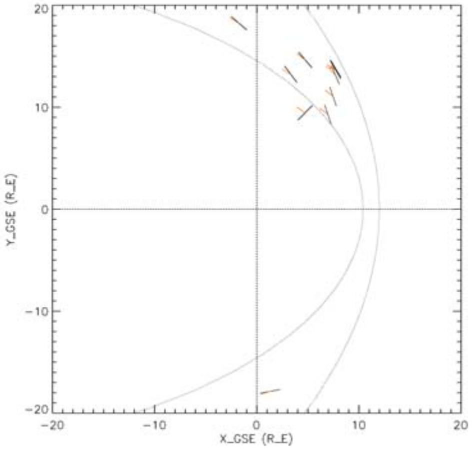


NOTICE: Selected events for zero relative motion compared to the near surroundings.

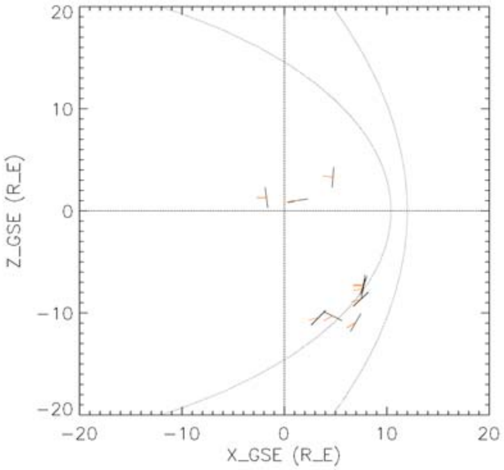
Orientation in the Earth’s magnetosheath:

mainly along the magnetopause.

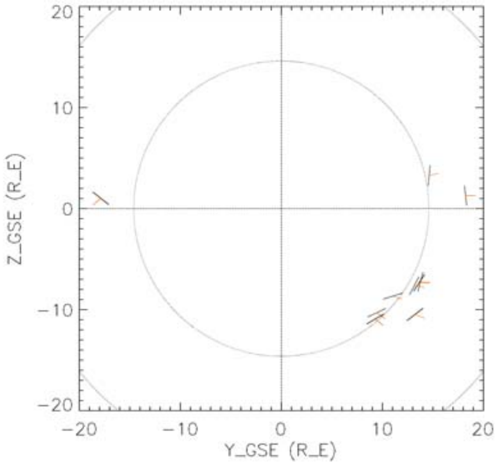
Orientation x-y



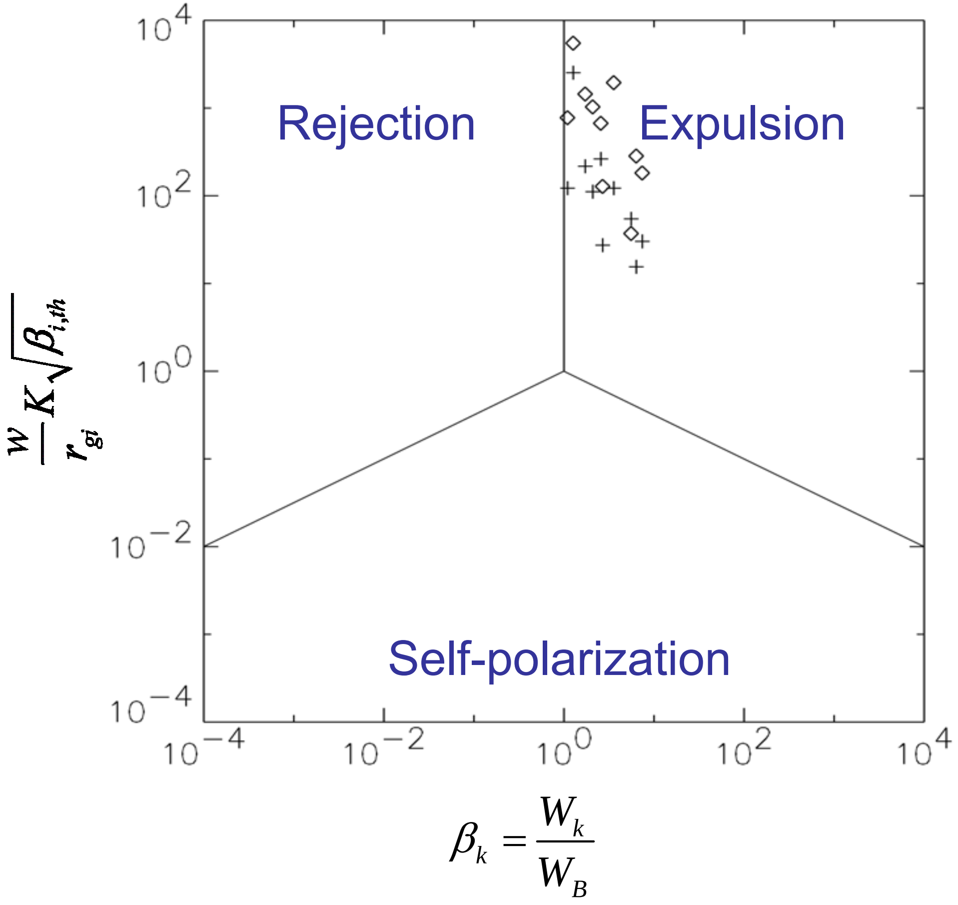
Orientation x-z



Orientation y-z



Penetration parameters



$$W_k = \frac{m_i n_e v_d^2}{2}$$

$$W_{i,th} = \frac{m_i n_e v_{i,th}^2}{2}, \quad T = 200\ \text{eV}$$

$$W_B = \frac{B_0^{\ 2}}{2\mu_0}, \quad B_0 = 50\ \text{nT}$$

$$\beta_k = \frac{W_k}{W_B}$$

$$\beta_{i,th} = \frac{W_{i,th}}{W_B}$$

$$w = l_x$$

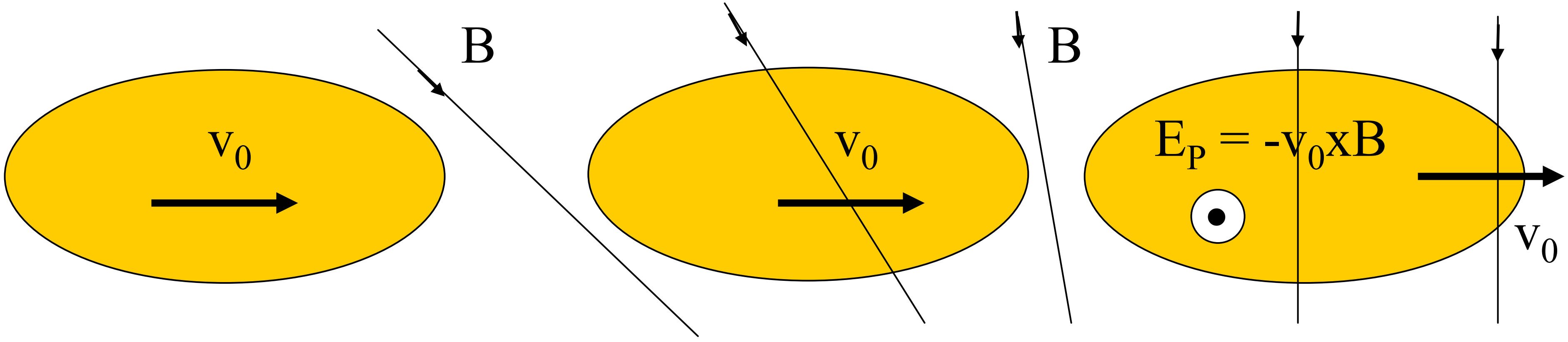
$$r_{gi} = \frac{m_i v_d}{eB_0}$$

$$K = 2.3$$

PENETRATION

Laboratory and simulations

Co-workers here: Tomas Hurtig, and Michael Raadu



PENETRATION PROPAGATION

(1) Phys. Plasmas 10, no 11, 4291, 2003 (2) Phys. Plasmas 11, L33, 1, 2004, (3) http:hal.ccsd.cnrs.fr/ccsd-00001839/en/, 2004 (4) Phys Plasmas 12 012308, 2005, (5) Phys Plasmas 12 012309, 2005.

Three possibilities

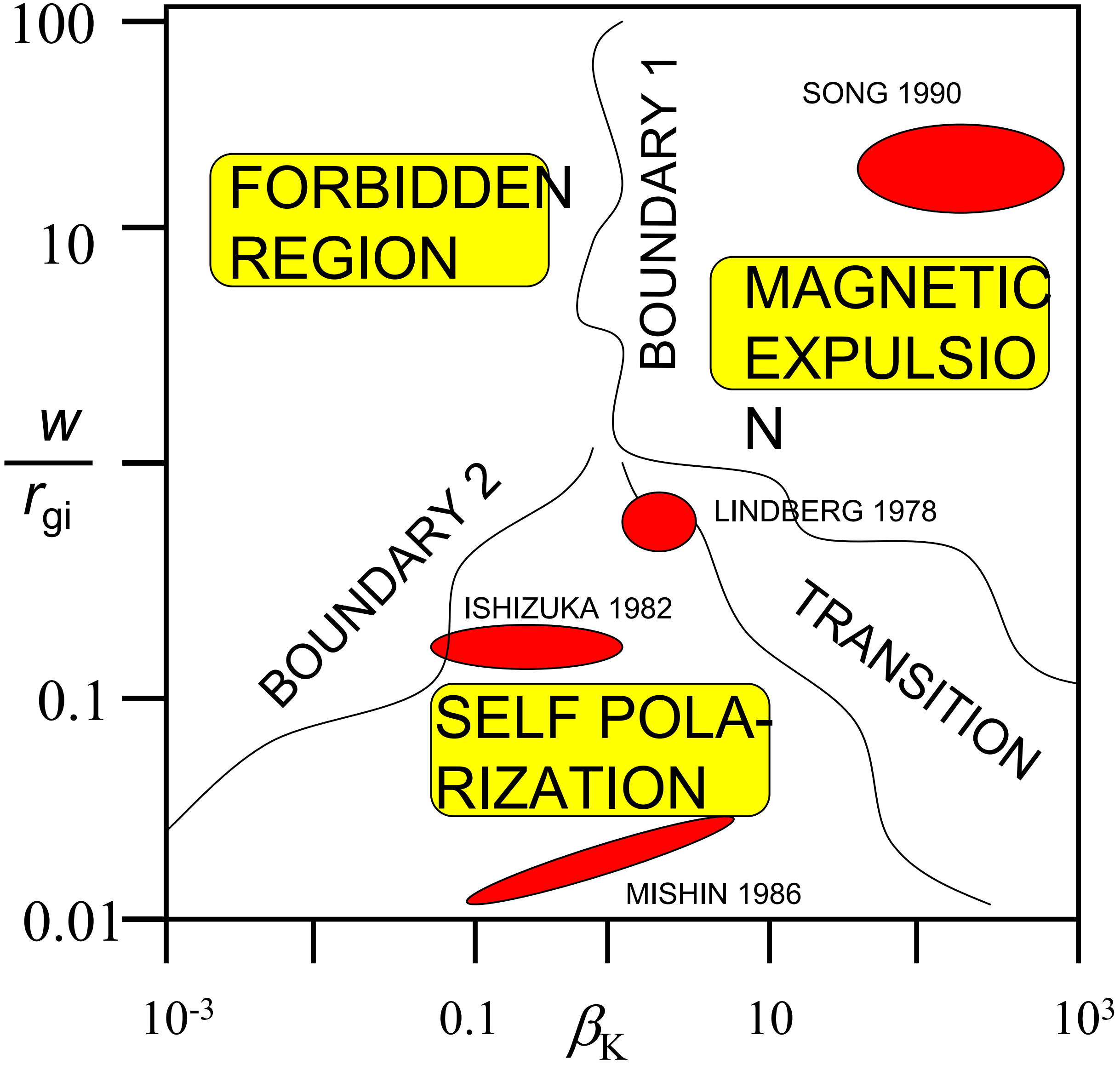
- **B** expulsion

  $\Delta B/B = 100\%$

- Polarization

  $\mathbf{E_P} = -\mathbf{v_0} x \mathbf{B}$

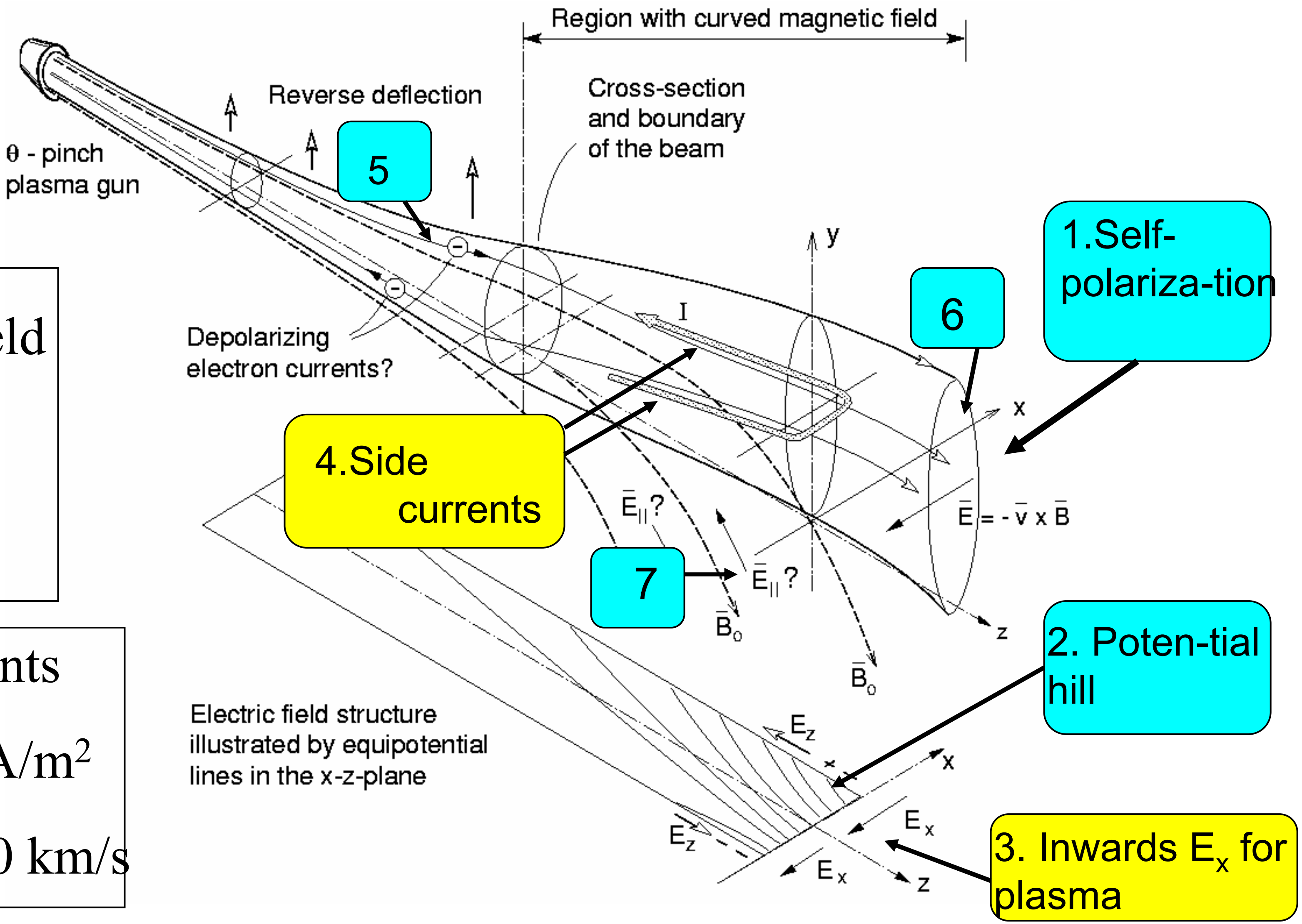
- Rejection



Experiment. Remember (1) equipotentials, (2) side currents

v_0=300 km/s

n_e=10^{18}-10^{19} m^{-3}



5

6

1.Self-polariza-tion

4.Side currents

7

2. Poten-tial hill

3. Inwards E_x for plasma

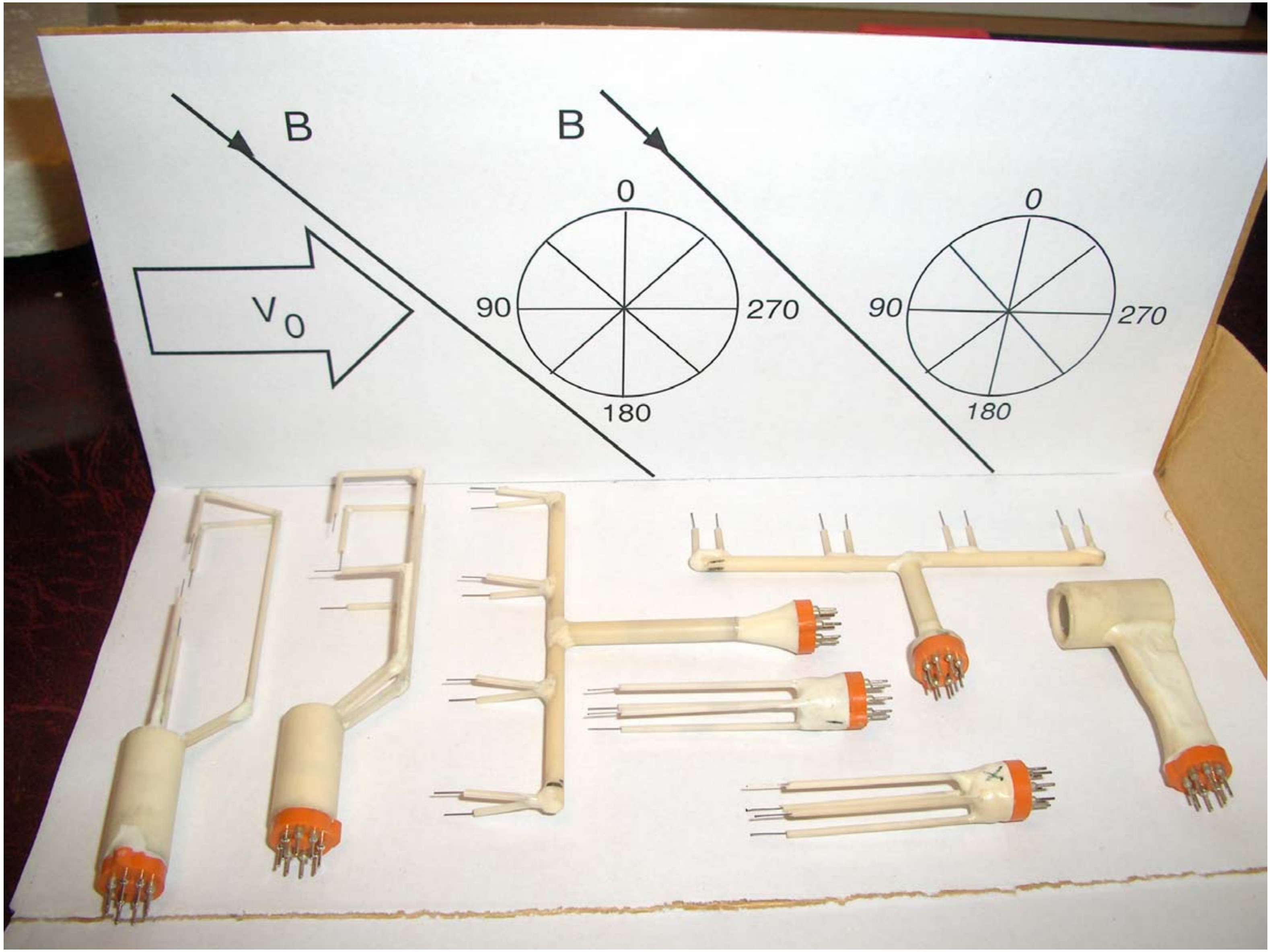
Plasma field ($\mathbf{E}_x$ - $\mathbf{E}_P$)

Side currents

> 10 kA/m^2

v_e-v_i ≈ 100 km/s

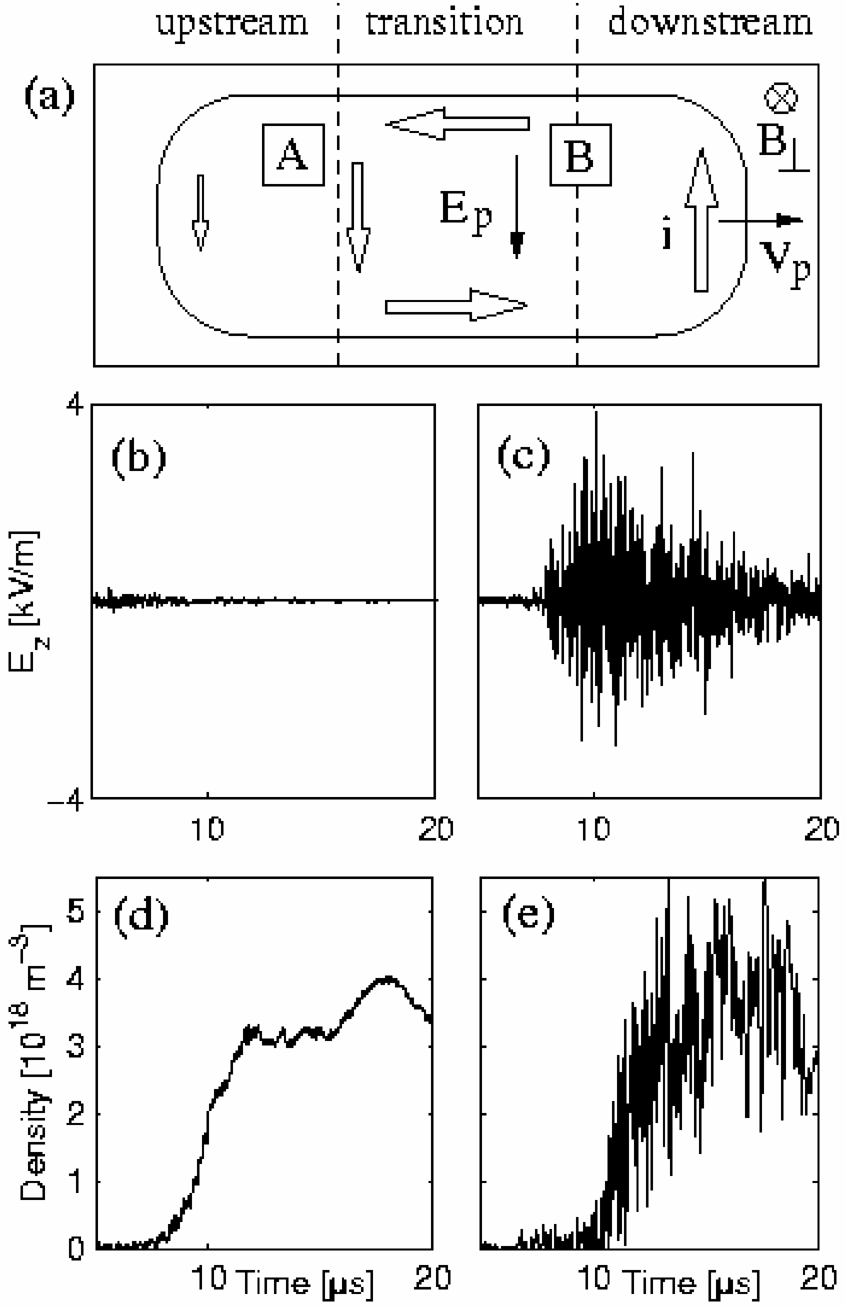
PROBES TO STUDY THE E FIELD IN THE WAVES



OSCILLATIONS ARISE IN THE TRANSITION

At B there are oscillations in:

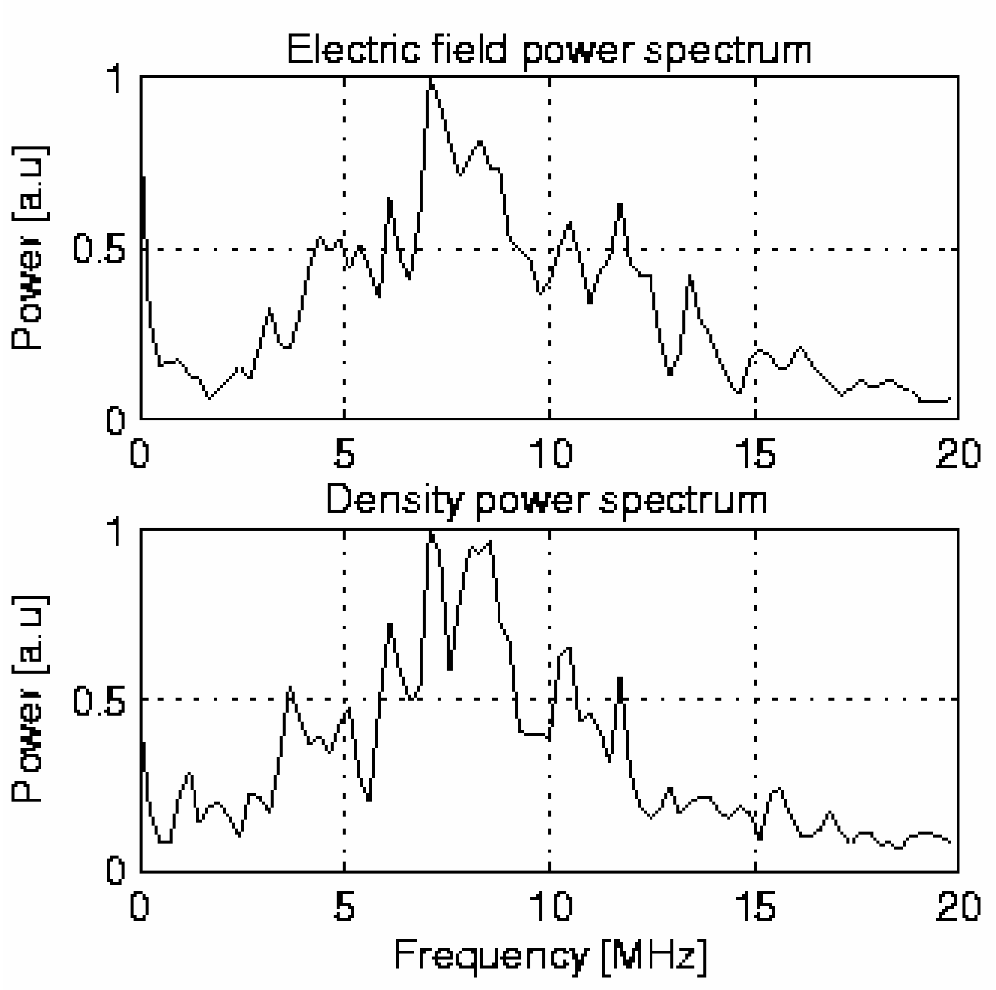
- E_z (up to 5 kV/m)
- n_e (up to 100%)



POWER SPECTRUM: 5 - 10 MHz.

E_z

n_e

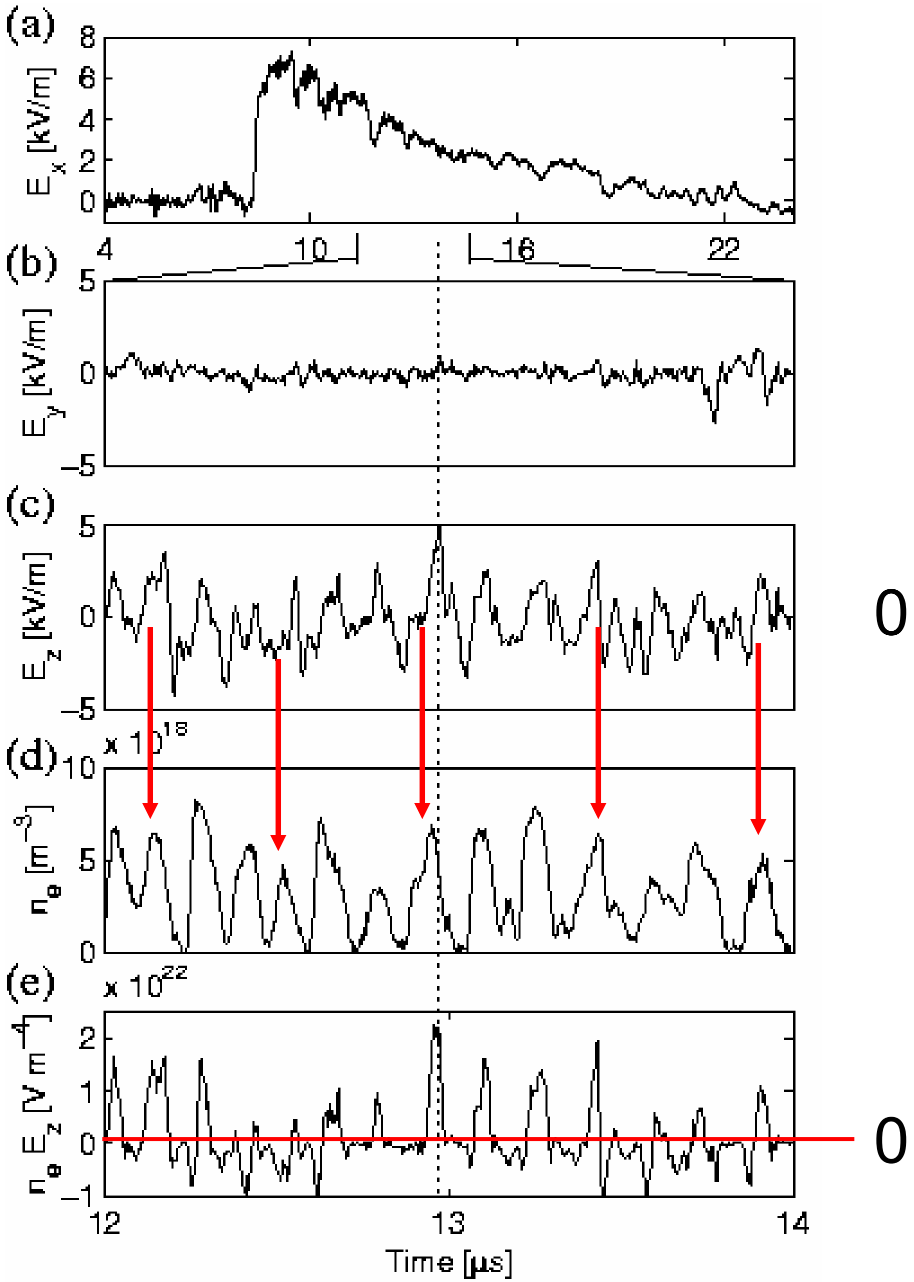


f_{gi} = 0.25 MHz

f_{LH} = 10 MHz

f_{ge} = 400 MHz

Correlations



SELF-POLARIZATION E_P

E_X

WEAK

E_Y

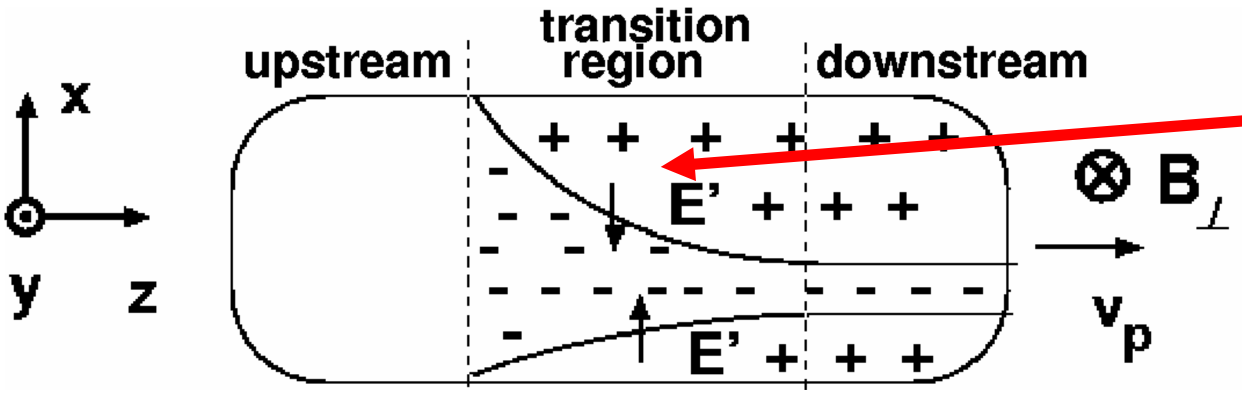
ALONG FLOW DIRECTION

E_Z

DENSITY $\Delta n_e/n_e$: 100%

PRODUCT $E_z n_e$

Electron transport rate across beam



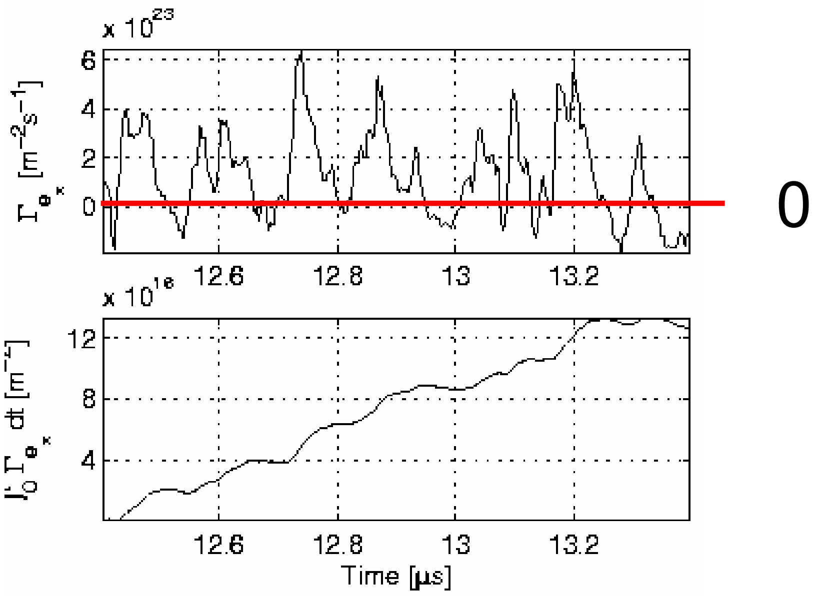
(x,y,z) =

(0, 0, 0.03)

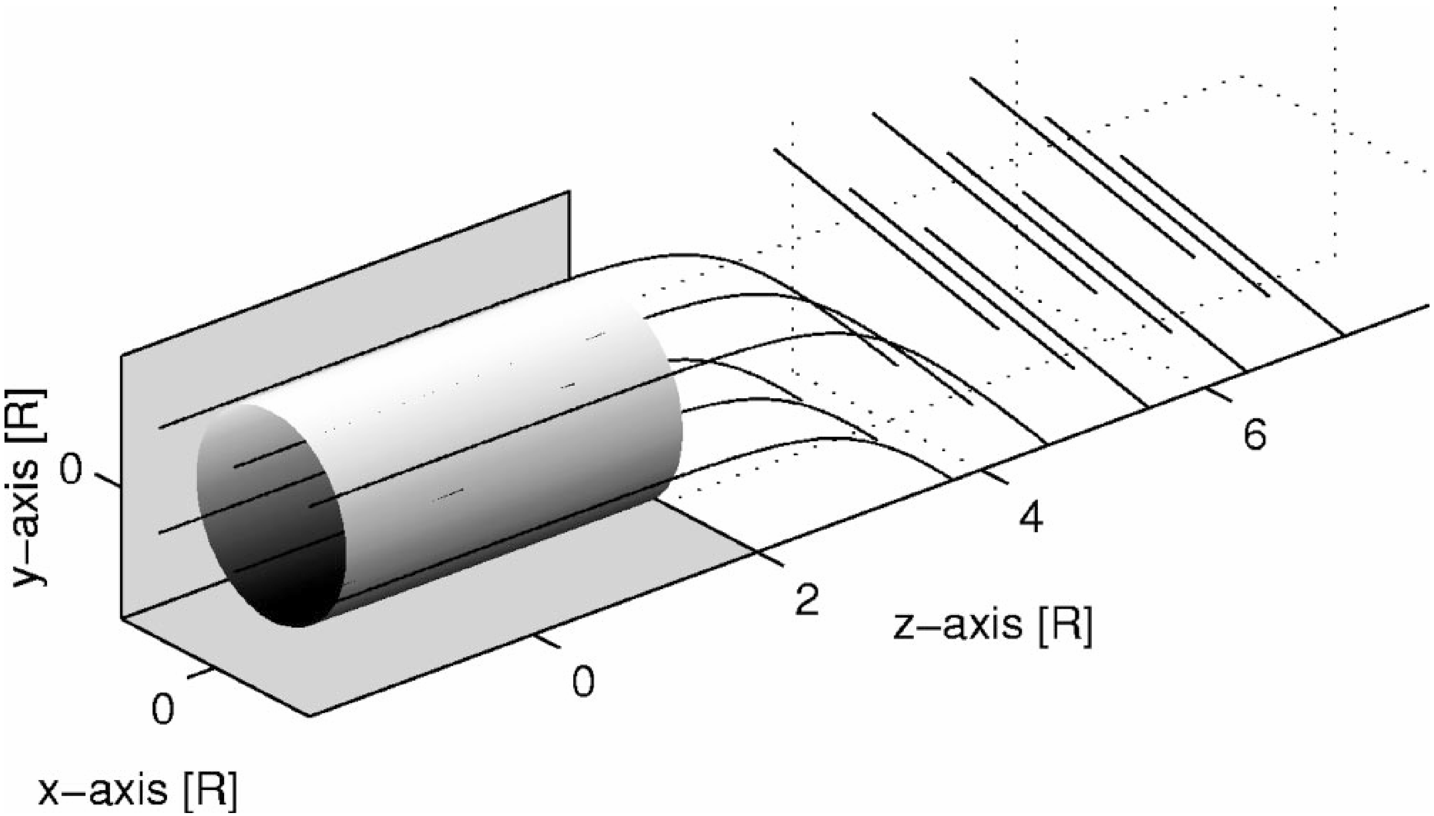
v_0 = 300 km/s

$$\Gamma_x = n_e E_Z / B$$

$\langle v_x \rangle$ = 50 km/s

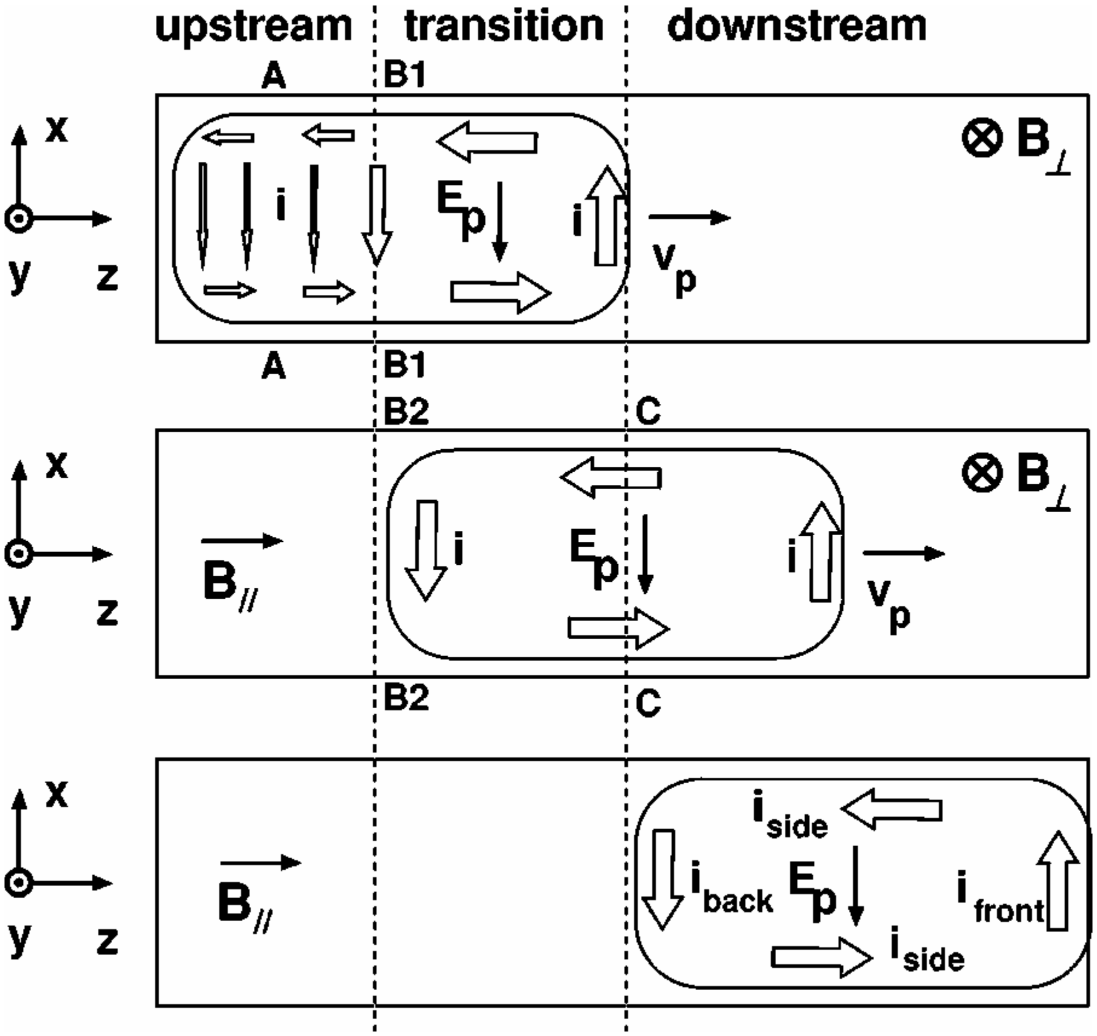


3D Simulation



PIC simulation with a moving grid, Open boundary conditions: the potential on the walls is, for each step, calculated as it would be for a system extended to infinity. Less than 1% of the particles are lost to the walls. Size: < 10^5 grid points, < 10^7 particles.

CARTOONS



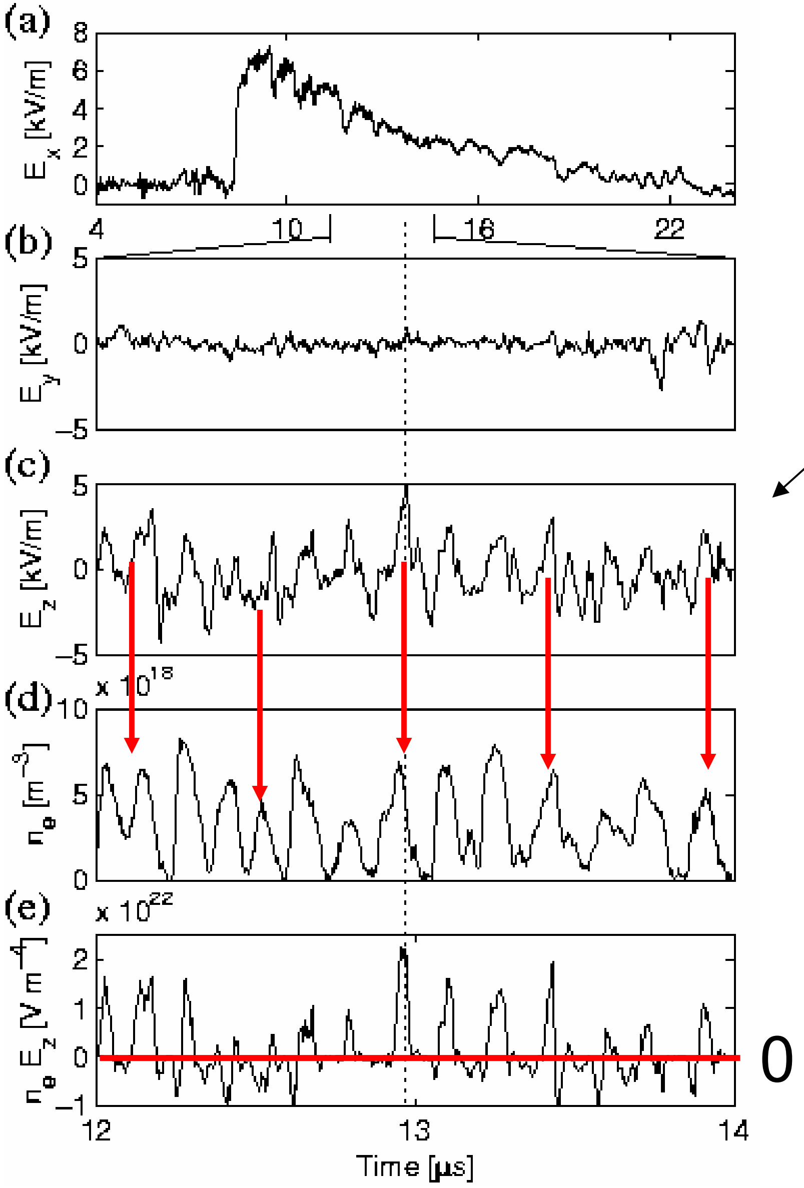
The transition region acts as a generator of a strong diamagnetic current.

Only a little current is driven upstream, but the current becomes frozen into the plasma downstream

The current density is large enough to drive instabilities, which however cannot be resolved in the 3D simulation

WHICH INSTABILITY? 2 1/2-D simulation

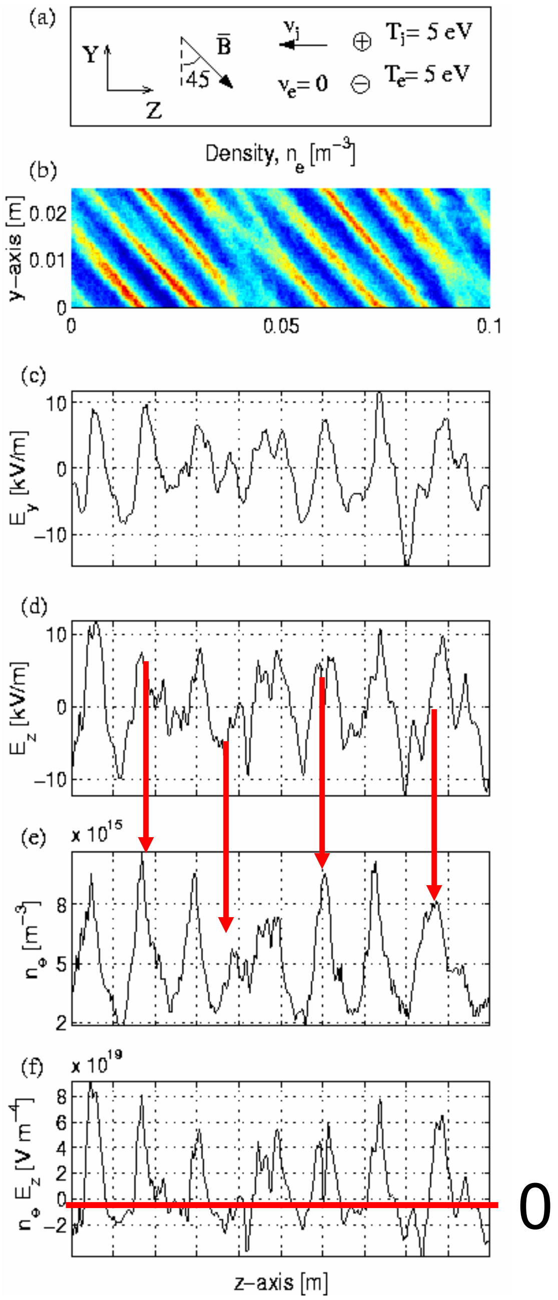
EXPERIMENT



E_z

n_e

$n_e E_z$



Threshold, linear theory

$$j_{\mathrm{MIN}} \approx e n_e v_{\mathrm{ith}} \,,$$

ION THERMAL CURRENT DENSITY, where v_{ith} is the speed at the average ion thermal energy

$v_{\mathrm{ith}} = (3\mathrm{k}T_{\mathrm{i}}/m_{\mathrm{i}})^{1/2}$

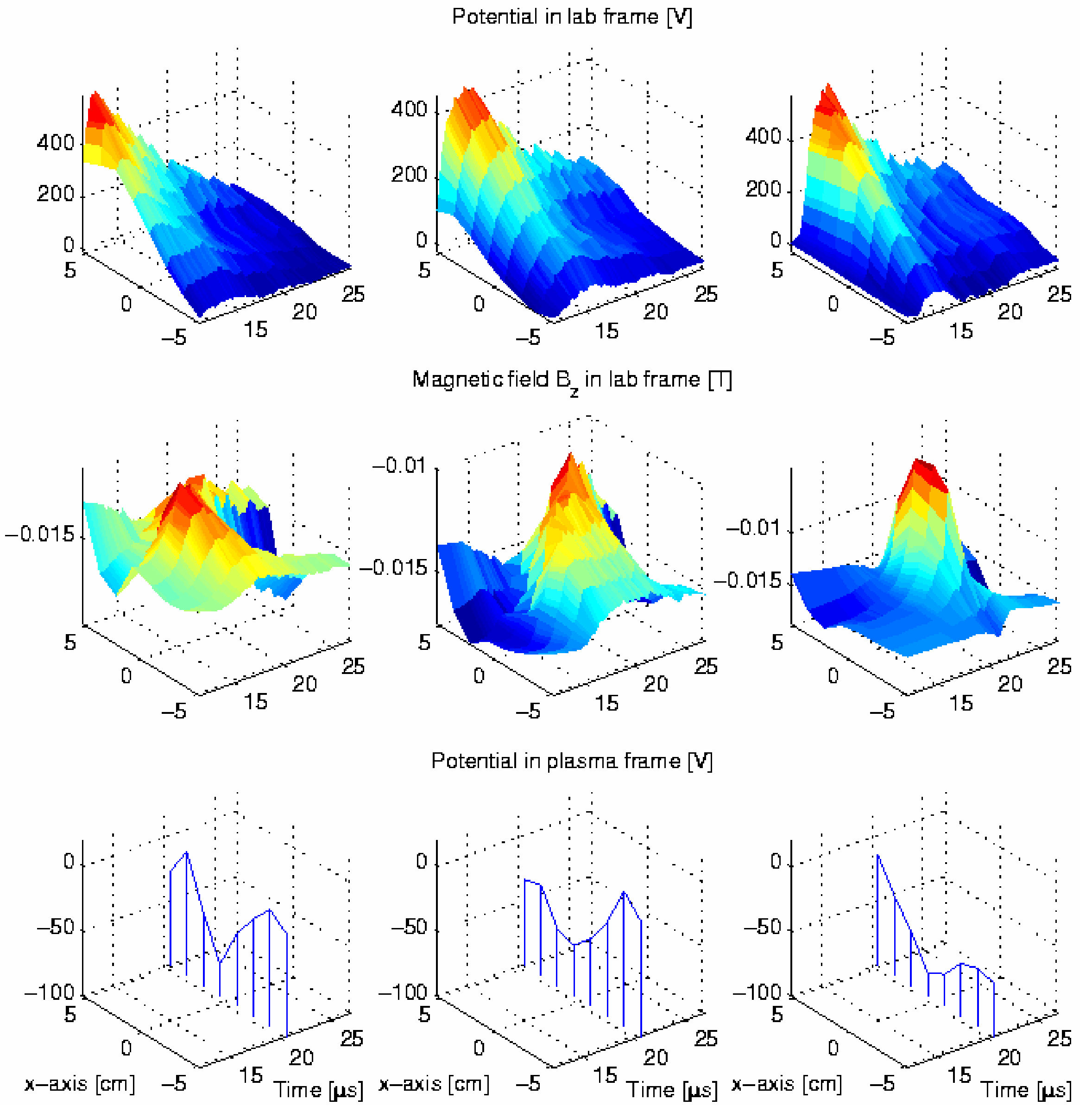
Is the current density in different experiment normalized by the threshold j_{MIN} ?

Three streams with different density

$\Delta B/B_0 = 10\%$

30%, 70%

$j_{\text{side}} \approx 2{,}3\ e n_e v_{ith}$



Potential in lab frame [V]

Magnetic field B_z in lab frame [T]

Potential in plasma frame [V]

This is probably the fastest and most efficient anomalous transport that is ever demonstrated (but not only here).

Re-calculated into anomalous transverse resistivity it is more than 100 times The Spitzer value.

Compared to ”Bohm diffussion equivalents” it is a factor of 10 higher. The collisionality corresponds to

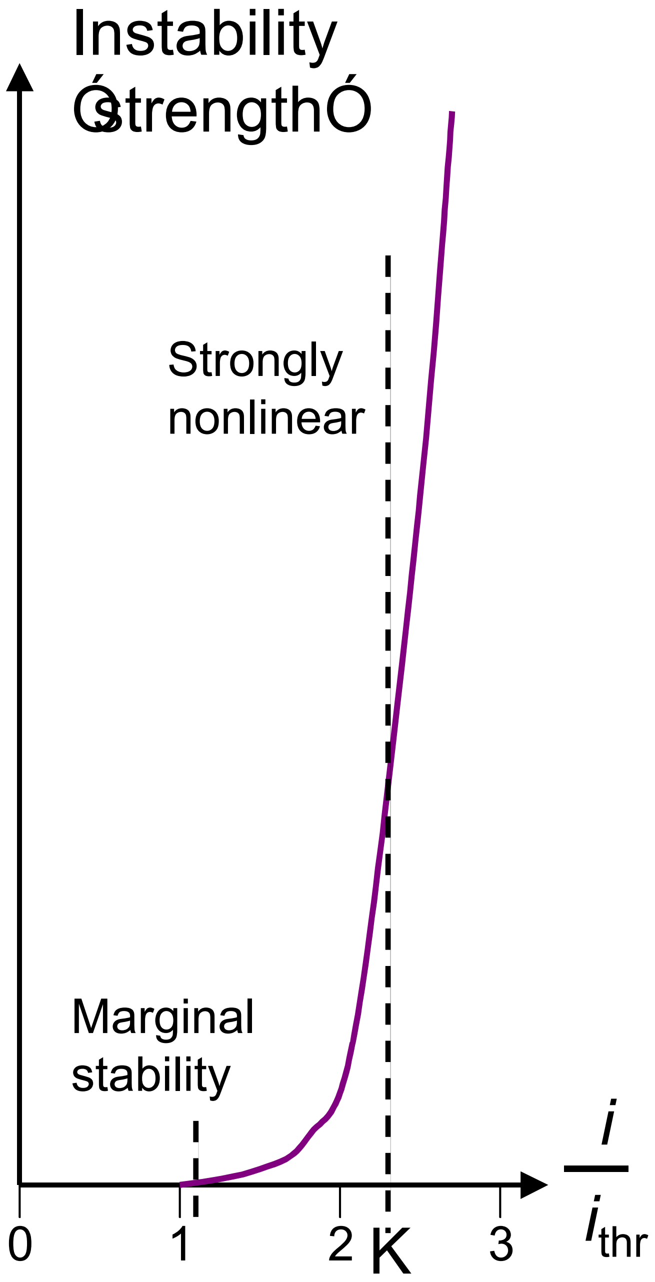
$$(\omega_{ge}\tau_e)_{eff} \approx 2$$

Similar values are only seen in other extreme cases:

- theta pinches with opposite magnetic bias
- high power industrial magnetrons, HIPIMS.

INTERPRETATION

- ion separation from electrons give secondary inwards fields E_2.
- the electrons react by a diamagnetic Hall current
- the current grows until the MTSI has grown strong enough to enable the electrons to follow the ions.
- because the system is driven abruptly (B field changes faster than on the ion gyro time), the instability has to be so far above the threshold that it can grow to large amplitude in the short time available
- this happents at current densities 2-3 times the ion thermal current density.



Our critical current density ($K \approx 2.3$) tested in other exp:s

NEW VARIABLE
FOR BEAM WIDTH

Ion thermal β

Instability parameter K

Limits defined

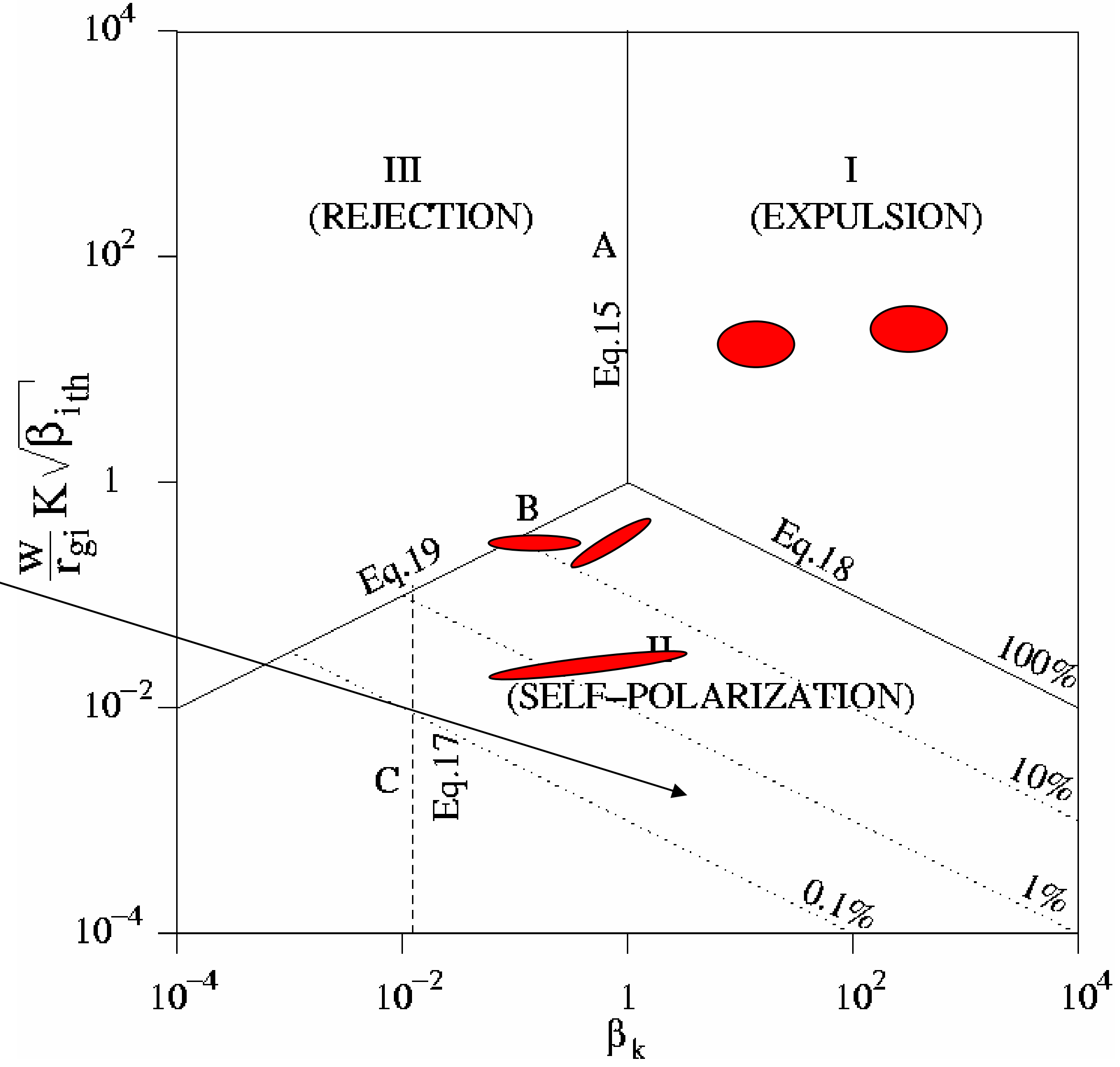
Fractions $\Delta B/B$

PROCEDURE

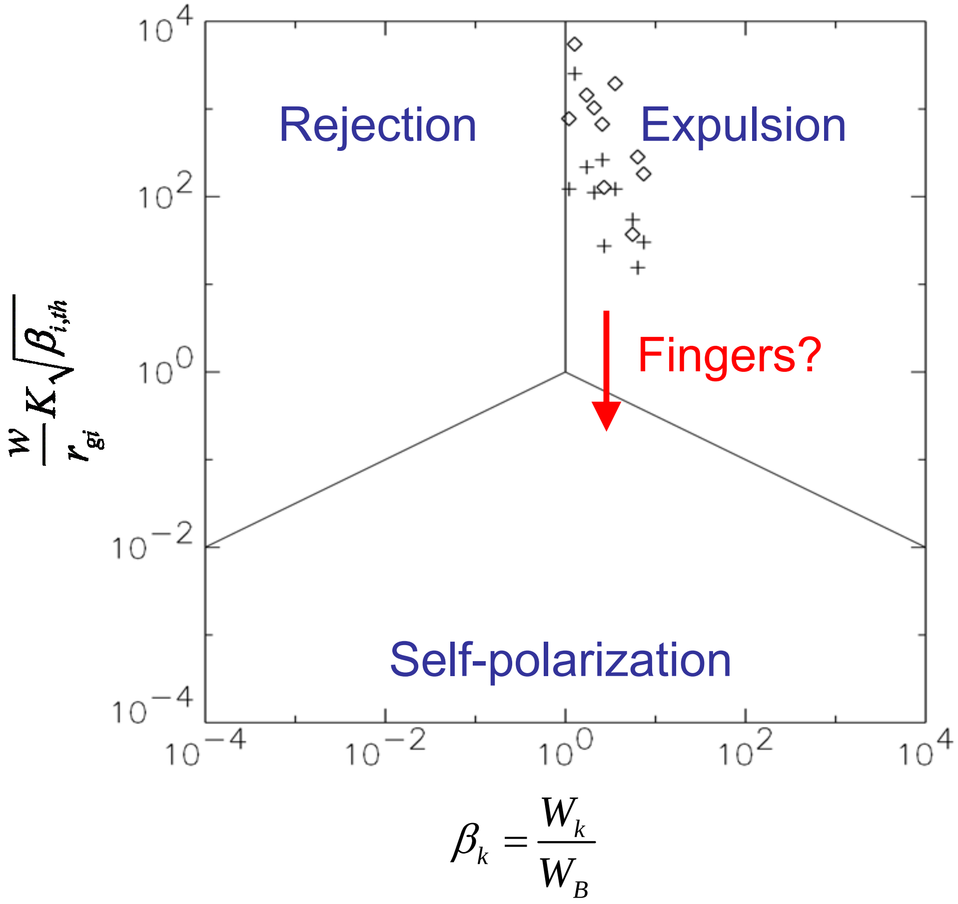
Experiments 🟥

Simulation

Generalization



The CLUSTER data again



Conclusions, Penetration

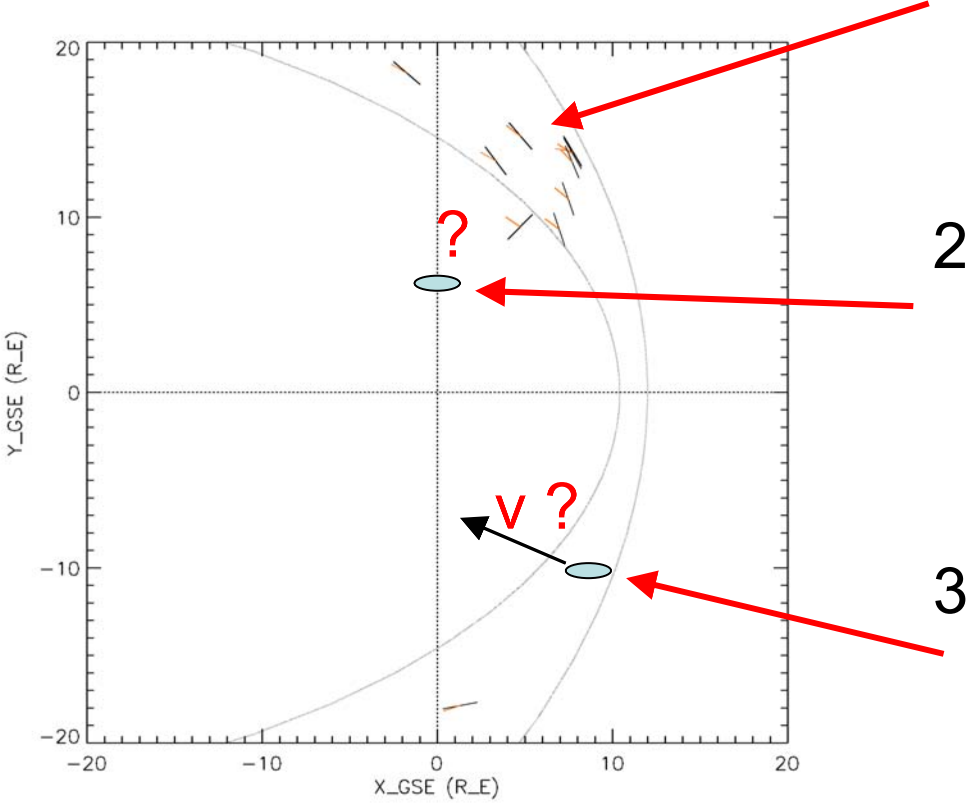
1. The clouds are too wide for anomalous mobility to play a role. Finger formation?

2. The beta value is high enough for penetration but this requires two things:

- velocity perpendicular to boundary - here excluded by the selection of events.

- no large momentum coupling along the B field.

Propagation: POINTS OF INTEREST



1. The observed plasma blobs' interaction // **B**. Features to look for?
2. Looking for blobs that might have penetated: internal features and Alfven wings?
3. Looking for blobs in the plasma sheet that don't follow the stream (as those selected so far do).

Part 2: propagation

comparison to CRIT ionospheric injection experiments

Co-workers here: C. Swensson, G. Haerenndel, M. Kelley, R. Pfaff, G. Marklund, O. Bolin, H. Stenbaek-Nielsen etc. A series of publications in JGR.

- Topic: coupling along **B**: momentum exchange, **E** fields, and parallell currents

- 1. Standard model: Alfven wave coupling,

$$E_{//} = 0$$

- 2. Parallel **E** field due to current limitation

CRIT I and CRIT II rockets

- 2 rockets, 2 fast clouds each
- Main payload in beam, sub payload along **B**
- **E** and **B** fields, density, electron and ion data with energy and angle resolution:

LOTS OF DATA!

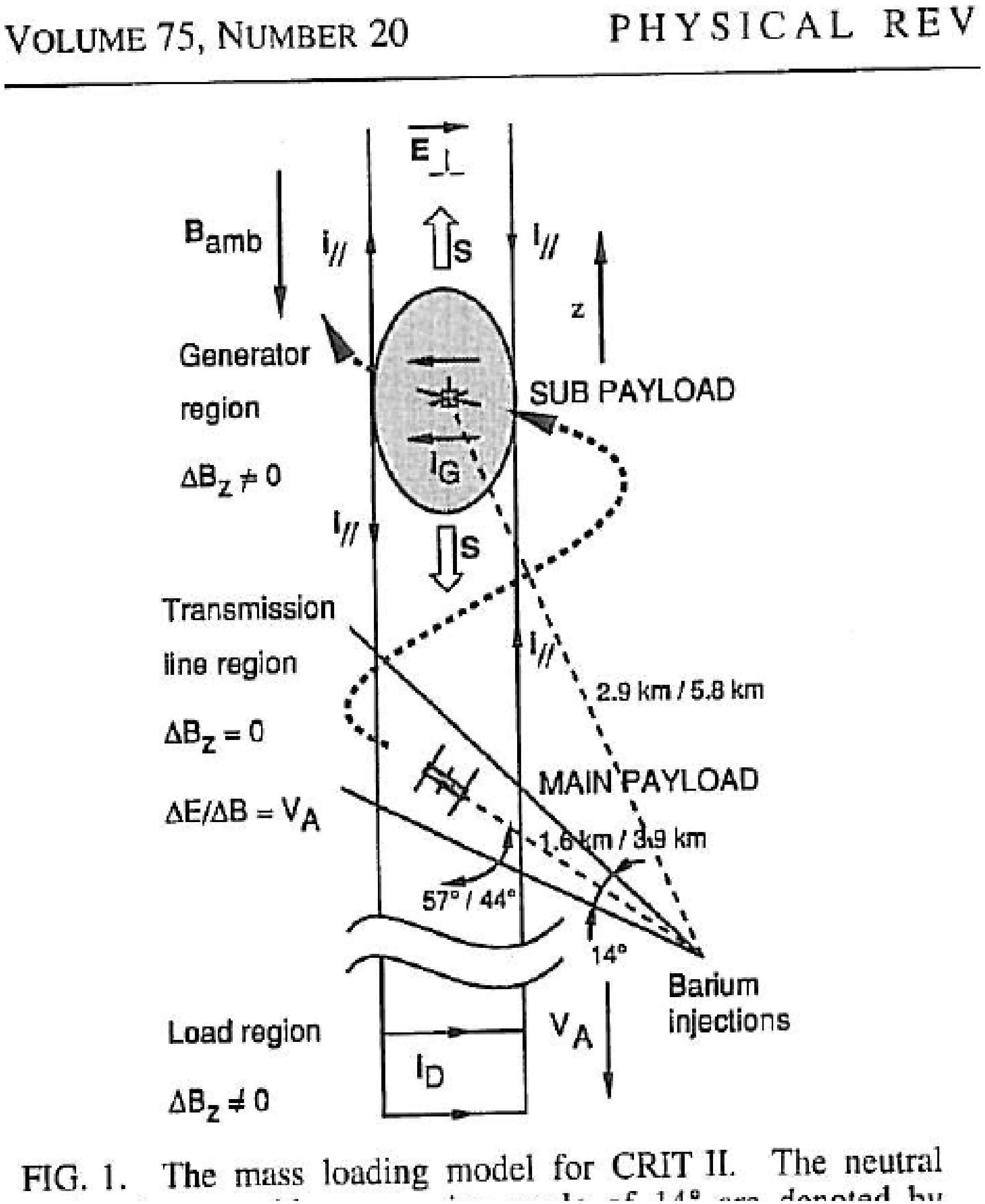

VOLUME 75, NUMBER 20 PHYSICAL REV

FIG. 1. The mass loading model for CRIT II. The neutral

(lett. 1995)

STANDARD coupling along B: Alfven waves.

Wave front

Field-aligned currents

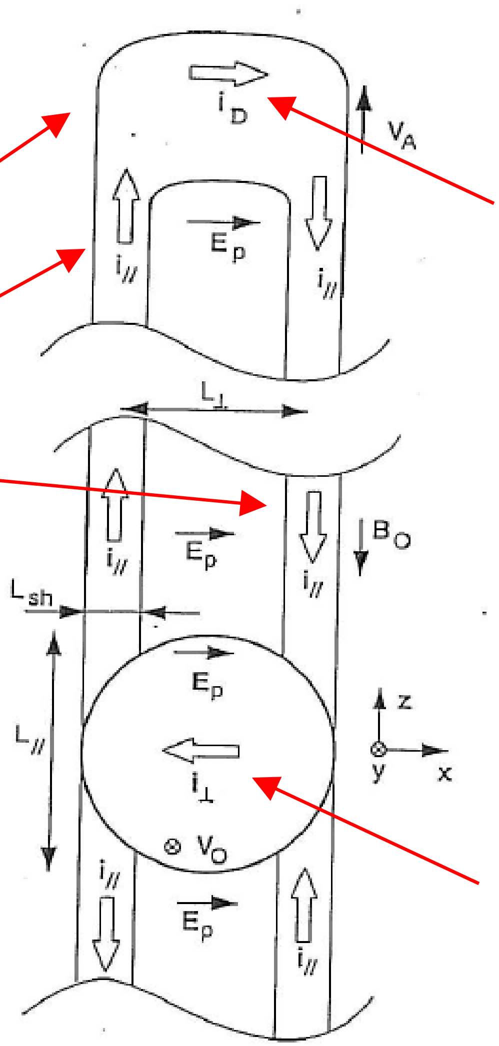


FIG. 1. The electrodynamical coupling between the ambient ionosphere and a plasma cloud which is injected with a velocity v_0 across the magnetic field. A plasma displacement current i_D flows across B_0 in the Alfvén wave front.

LOAD

Plasma displacement current

TRANSMISSION LINE

GENERATOR

Mix of current types:

- electron Hall,
- ion flow,
- anomalous transverse resistivity.

Model #1. The generator region was modelled as a cylinder in the first approximation, and being copled to the load by FAC:s.

BRENNING ET AL.: BARIUM SWARM

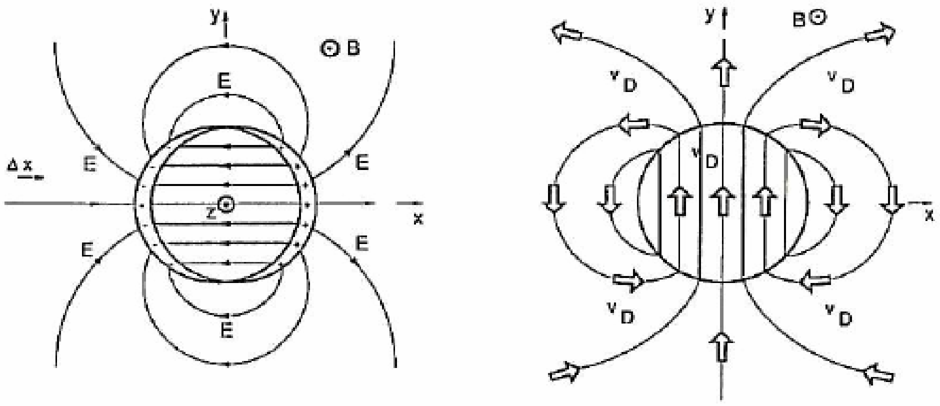
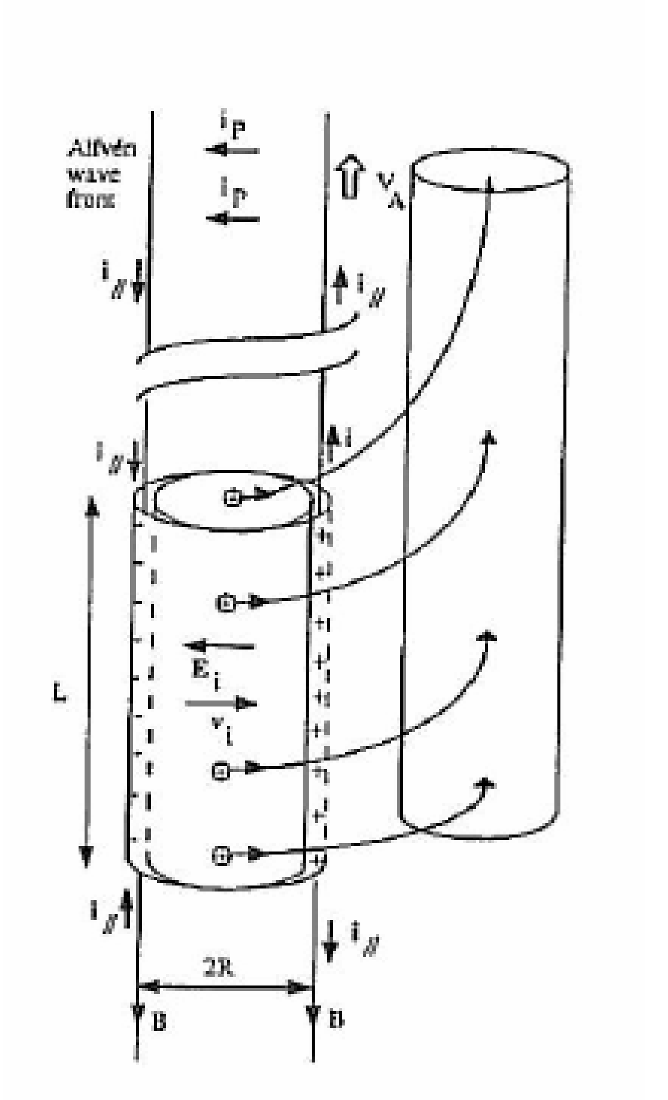
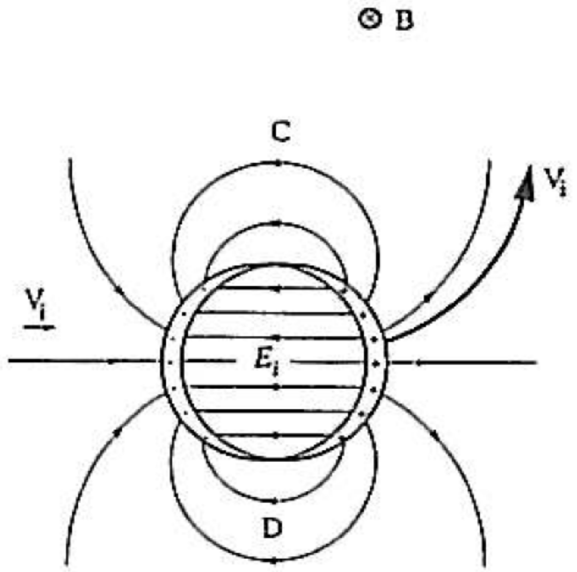


Fig. 3. The electric field of equations (2) and (3), and the associated plasma drift pattern.

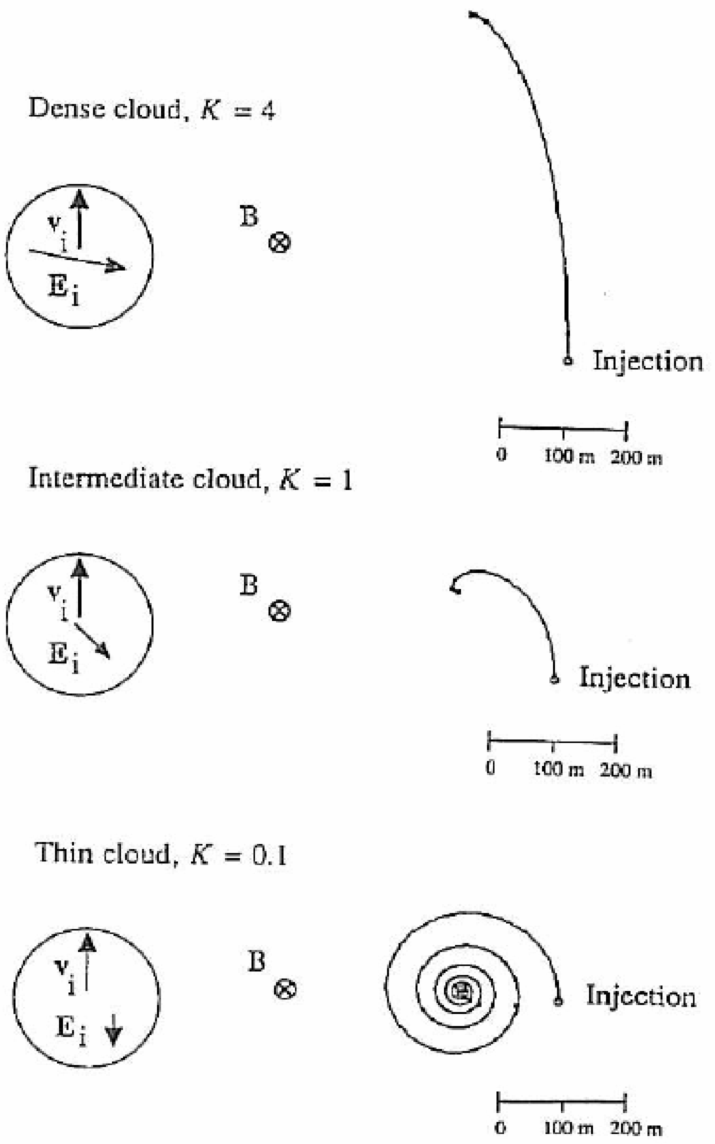
The ”mass loading factor” K value pops up in the model





$$K = \frac{\Delta n\, e\, \mu_0\, V_A\, L_{//}}{4\,B}$$

$$K = \frac{\Delta n \, e \, \mu_0 \, V_A \, L_{//}}{4B}$$



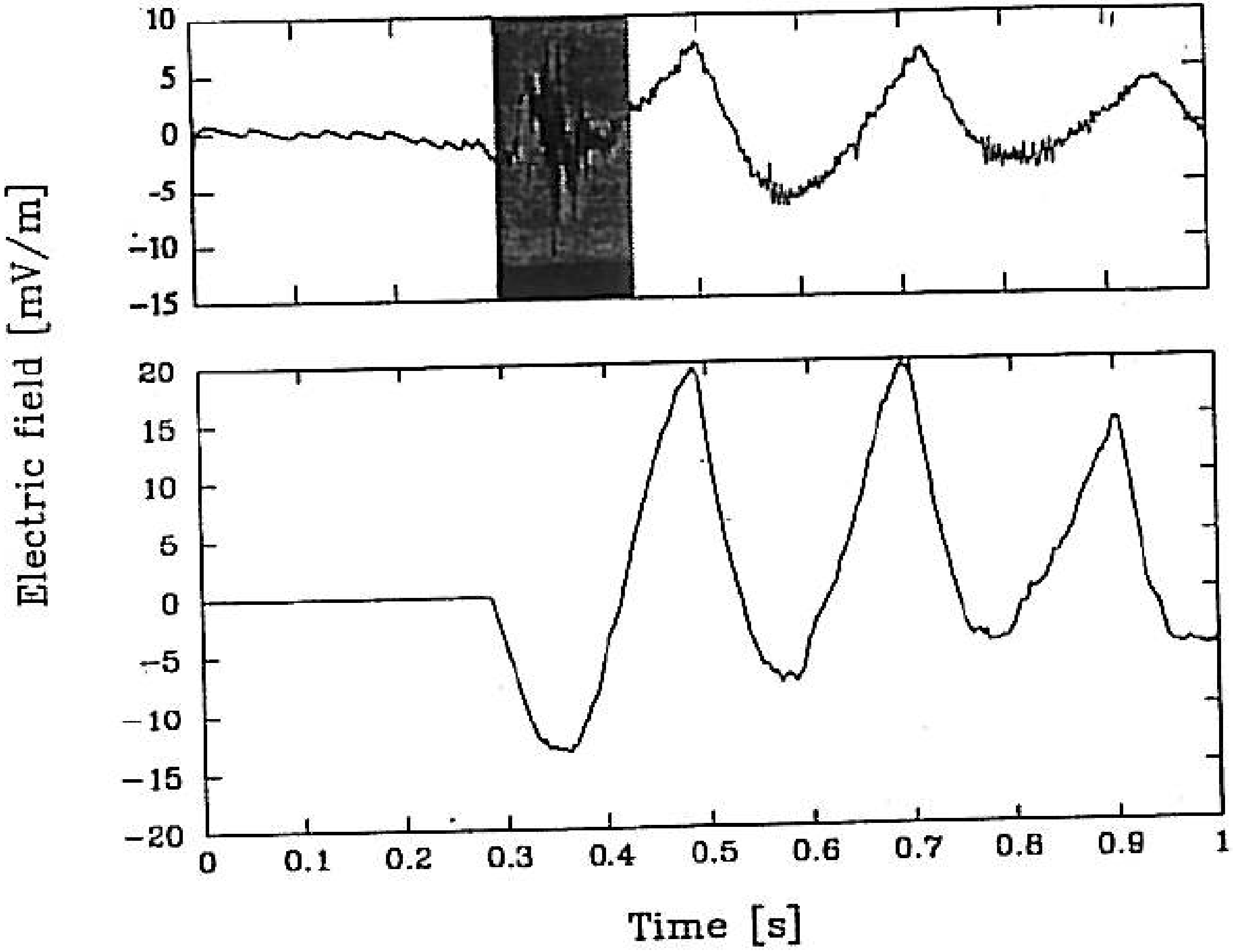
LONG
SKIDDING

FAST STOP

The CRIT
cases here

GYRATION
LOCALLY

Model #2. Same physics, but used in a 2-d pic simulation, with parallell currents from Alfven waves



MEASURED DATA. CRIT II, (lowest K value)

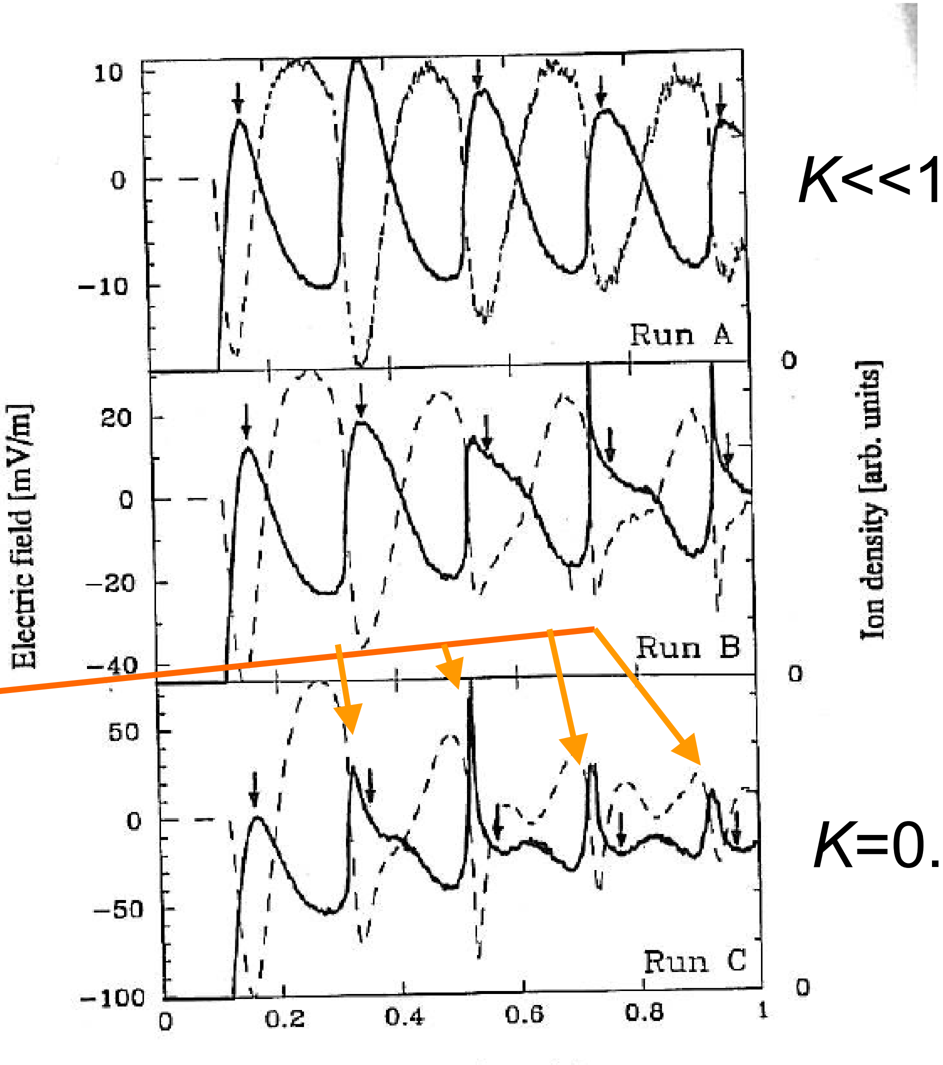
PARTICLE SIMULATION

Model #2. Deformation of the cloud with time (still based on standard model for coupling along B)

HIGHER K values give internal deformation

Notice

Sharp peaks at the front of the wave

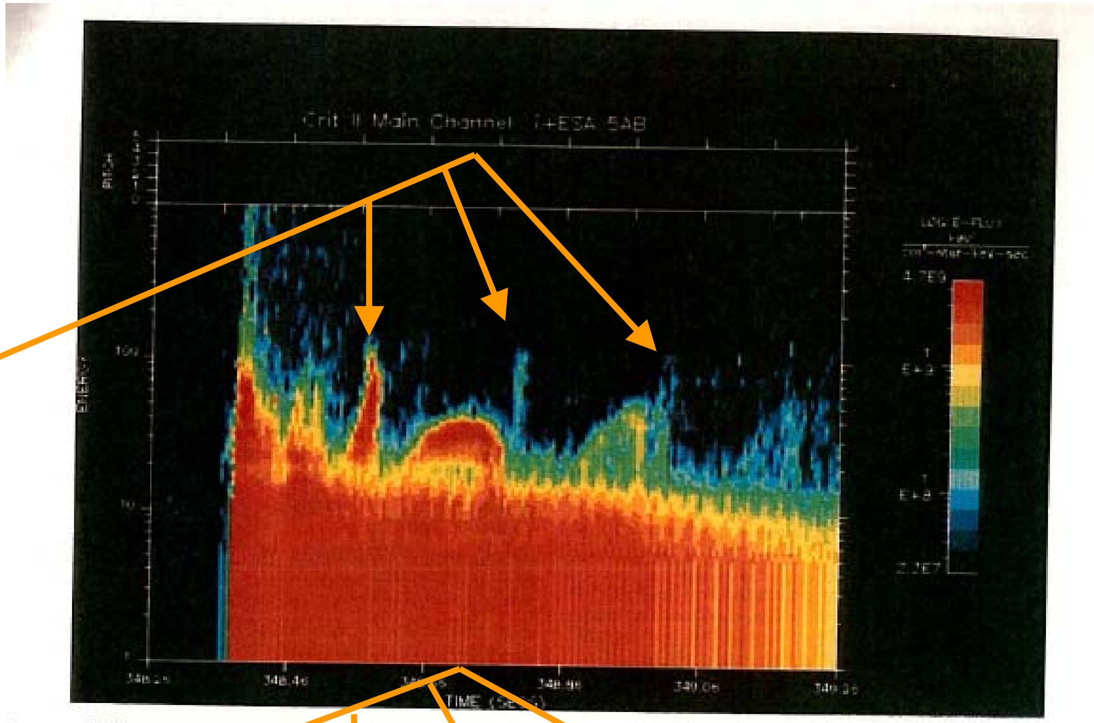


K<<1

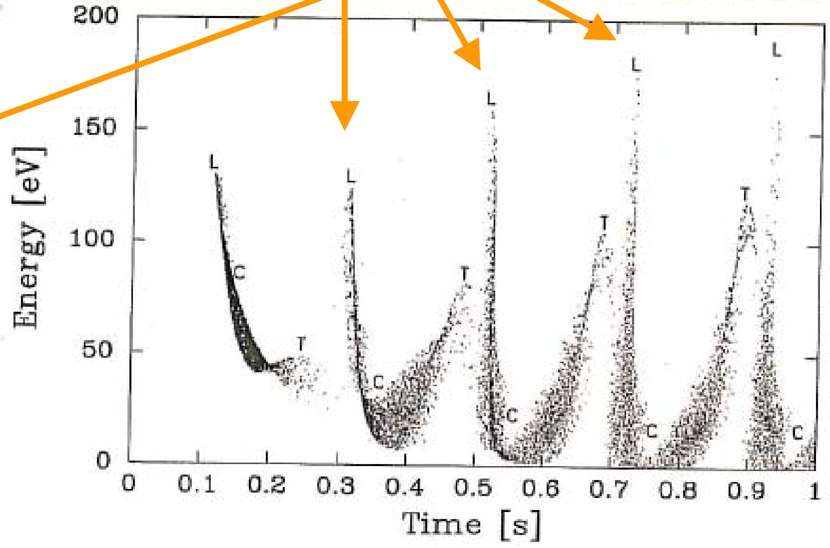
K=0.3

The ”sharp front peaks” are seen also in the ion energy data

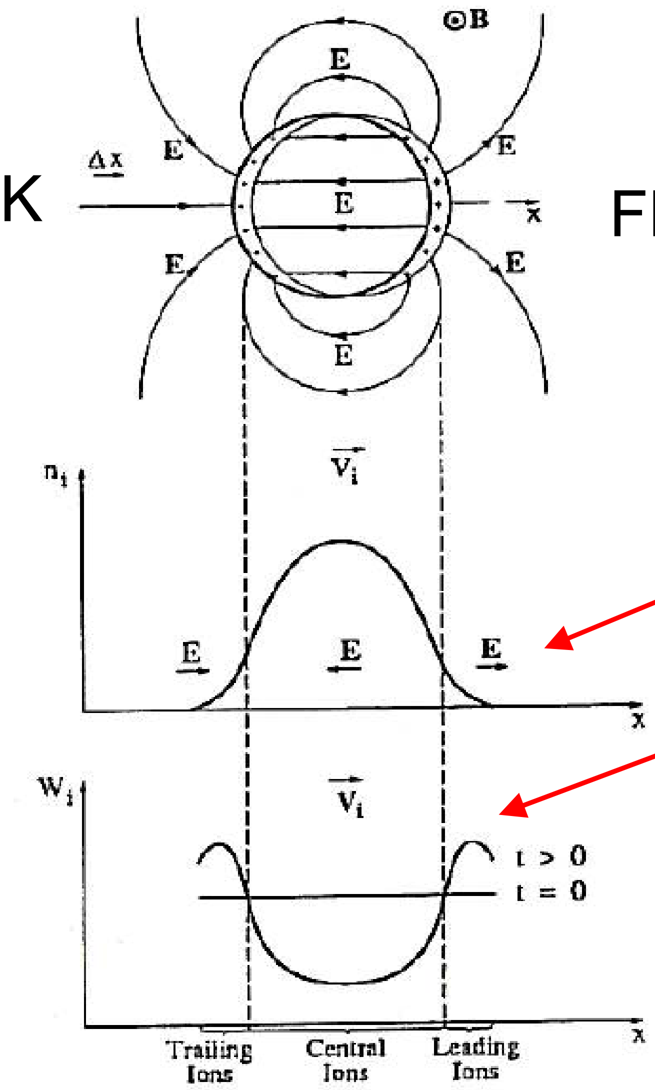
Measured



Simulated



A careful look into the simulations give a simple explanation.



BACK

FRONT

Leading ions get an extra kick

FIG. 6. A simplified model of the deformation of the cloud.

CONCLUSIONS for the STANDARD MODEL

Inside the plasmoid it gives quantiative results, including deformation of the cloud shape and rearrangement of energy and momentum in space and between particle populations.

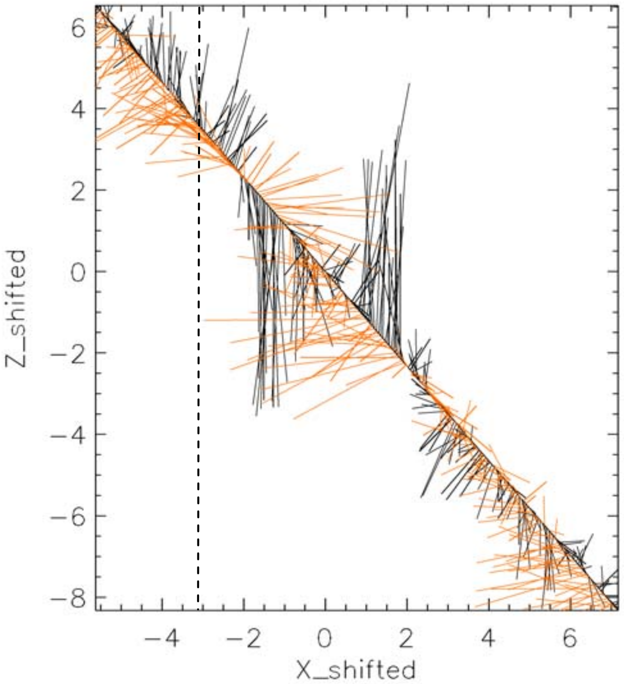
Outside the plasmiod is a load region where the Δ**E** and Δ**B** fields are perpendicular, with the ratio

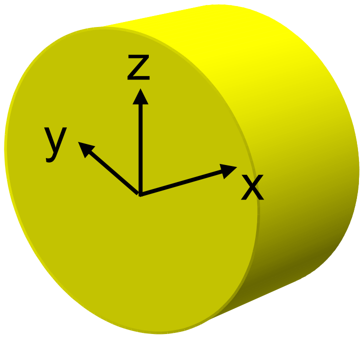
$$\frac{\Delta\mathbf{E}}{\Delta\mathbf{B}} = V_A$$

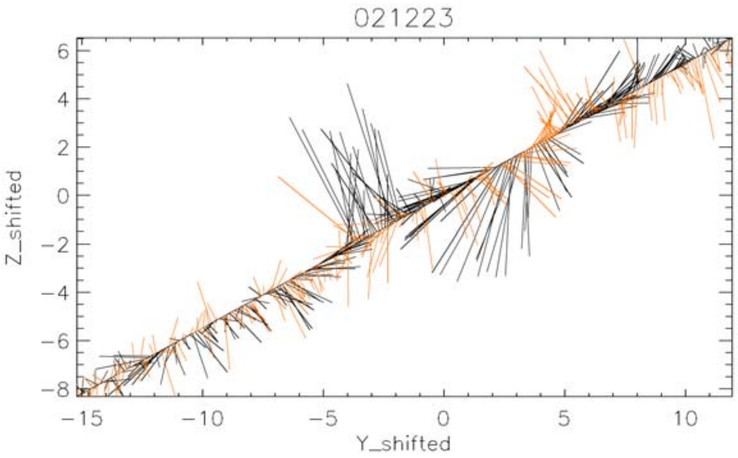
and with Poynting flux along **B** and away from the cloud

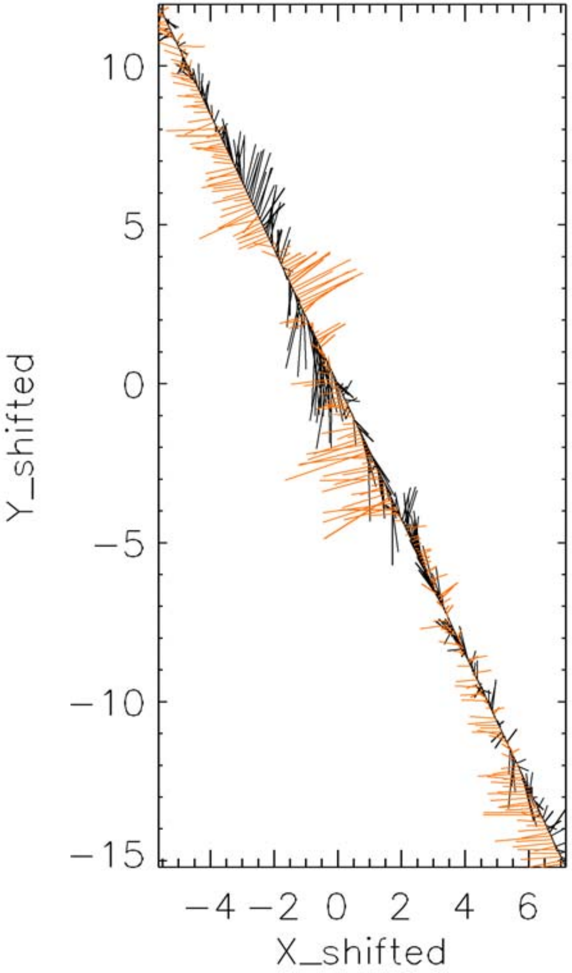
CLUSTER data: E and B

2002-12-23 (36 040 s)









Limitations of the standard model:

1. It assumes homogeneous surrounding medium, otherwise the Alfven waves will be partially reflected

2. It assumes

$$E_{//} = 0$$

Counter-examples could be found already in the CRIT experiments:

From the ”standard model” follows a given FAC (current density)

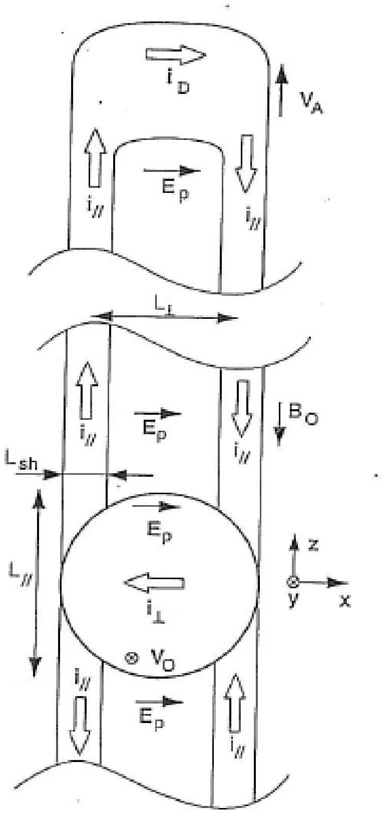
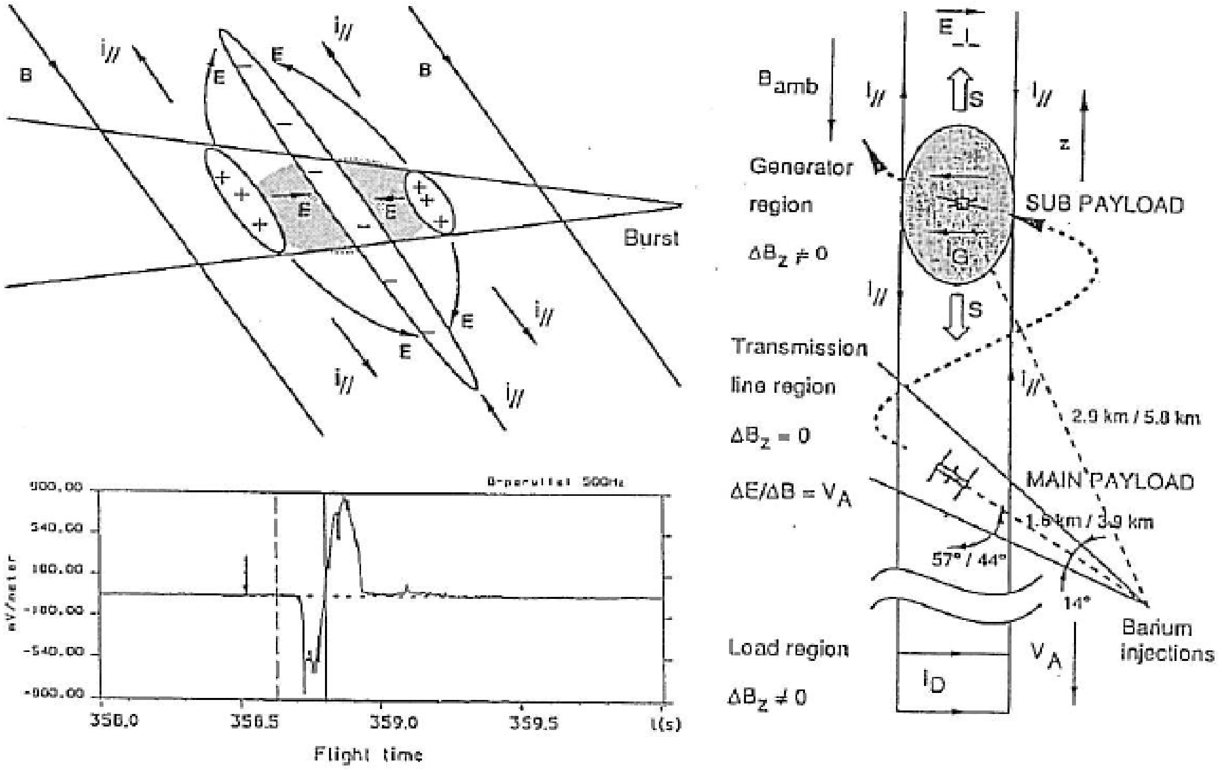


FIG. 1. The electrodynamical coupling between the ambient ionosphere and a plasma cloud which is injected with a velocity v_0 across the magnetic field. A plasma displacement current i_D flows across B_0 in the Alfvén wave front.



$$\mathrm{div}\, i_{\perp} = i_{//} = \frac{\mathrm{div} E_{\perp}}{\mu_0 V_A}.$$

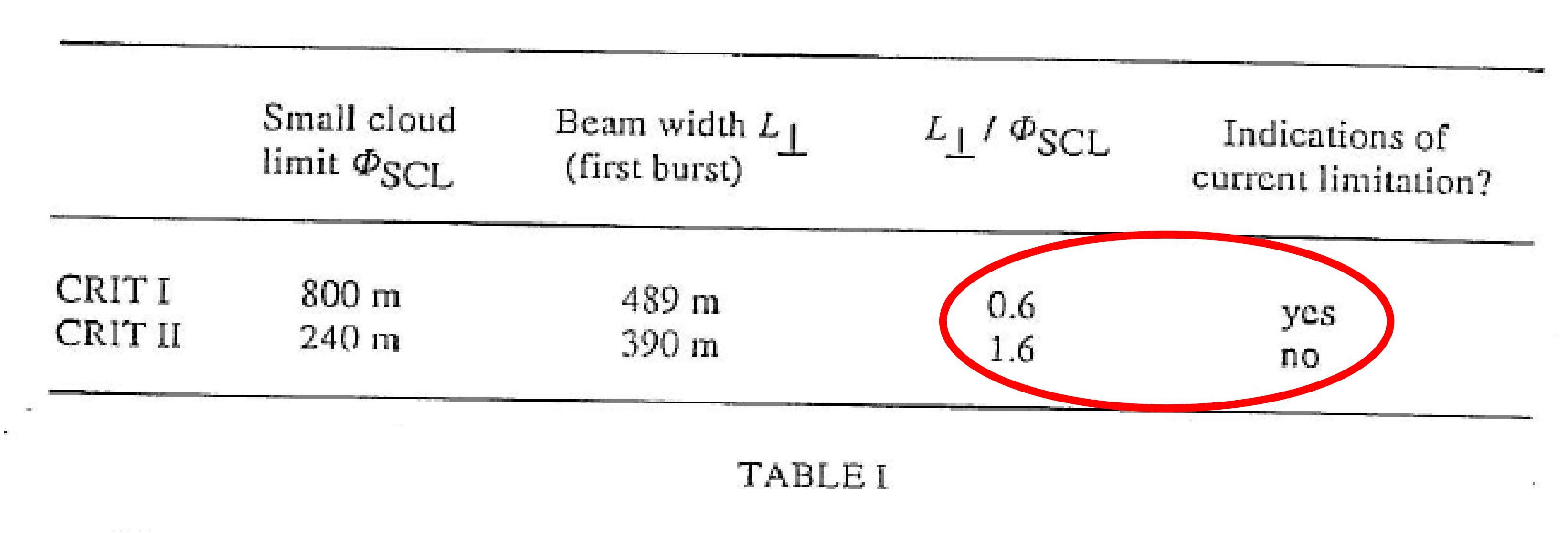
We use the measured field in the generator region

$$F = i_{//}/i_{\mathrm{sat}} = \frac{4v_{\mathrm{D}}}{v_{\mathrm{e,th}}} = \frac{4V_{\mathrm{A}}r_{E/B}}{v_{\mathrm{e,th}}L_{\mathrm{sh}}} .$$

$$\Phi_{\mathrm{SCL}} = \frac{8\,r_{E/B}\,V_{\mathrm{A}}}{v_{\mathrm{e,th}}} .$$

Fraction of saturation current.

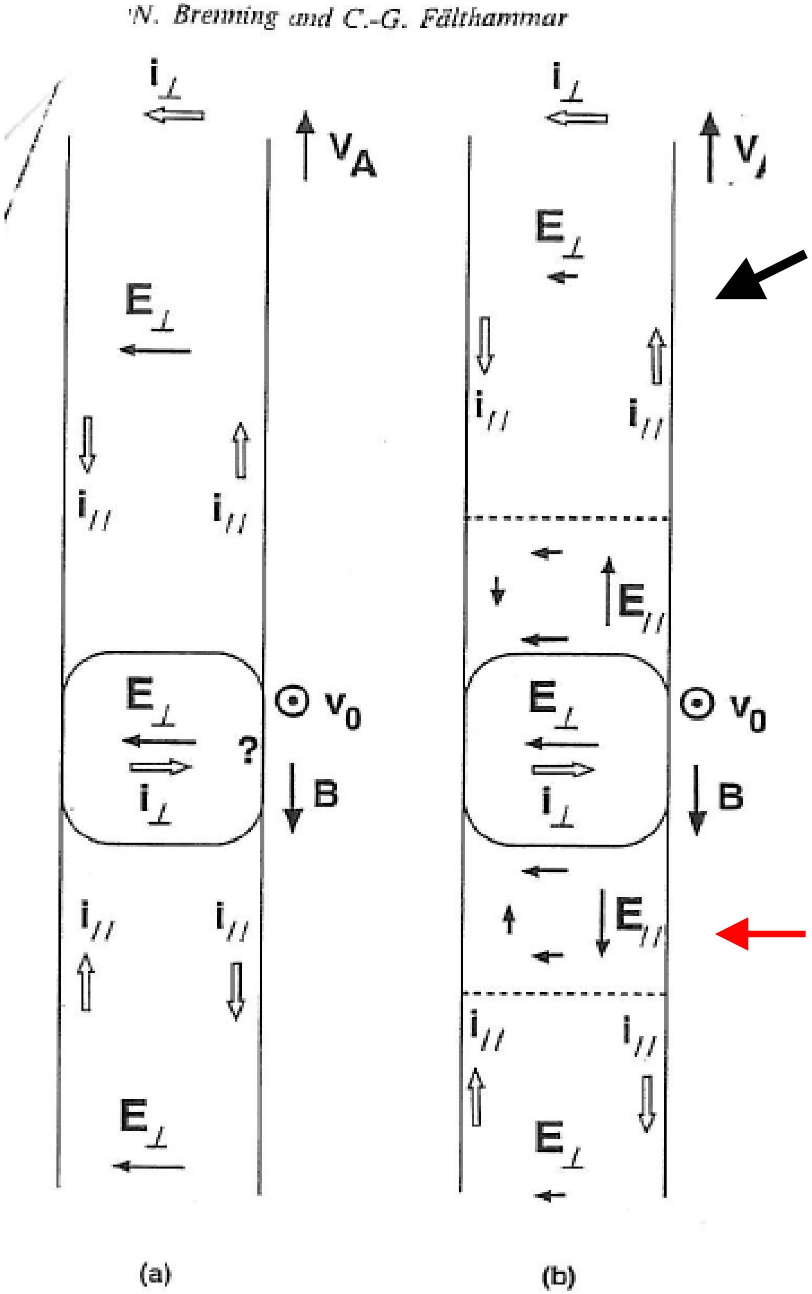
Formula for cloud size and strong current limit – ”small cloud limit”.



	Small cloud limit Φ_{SCL}	Beam width $L_{\perp}$ (first burst)	$L_{\perp} / \Phi_{\mathrm{SCL}}$	Indications of current limitation?
CRIT I	800 m	489 m	0.6	yes
CRIT II	240 m	390 m	1.6	no

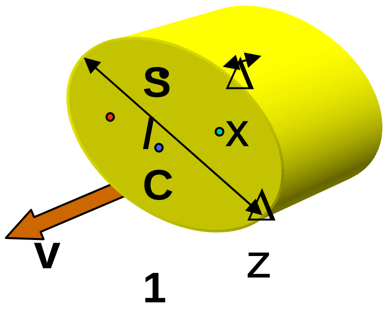
TABLE I

STANDARD MODEL

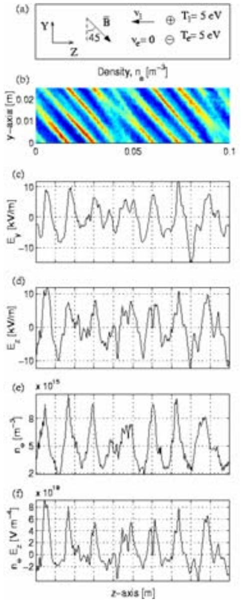


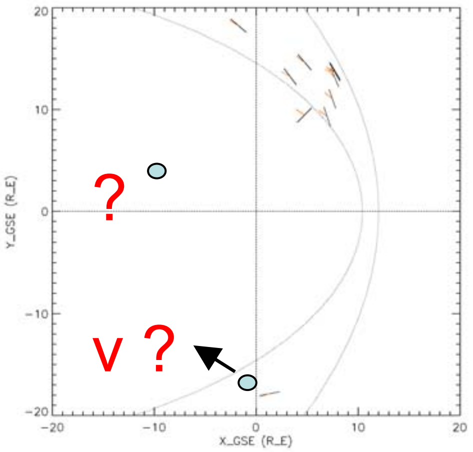
STANDARD MODEL OUTSIDE A CENTRAL REGION WITH PARALLELL E FIELDS

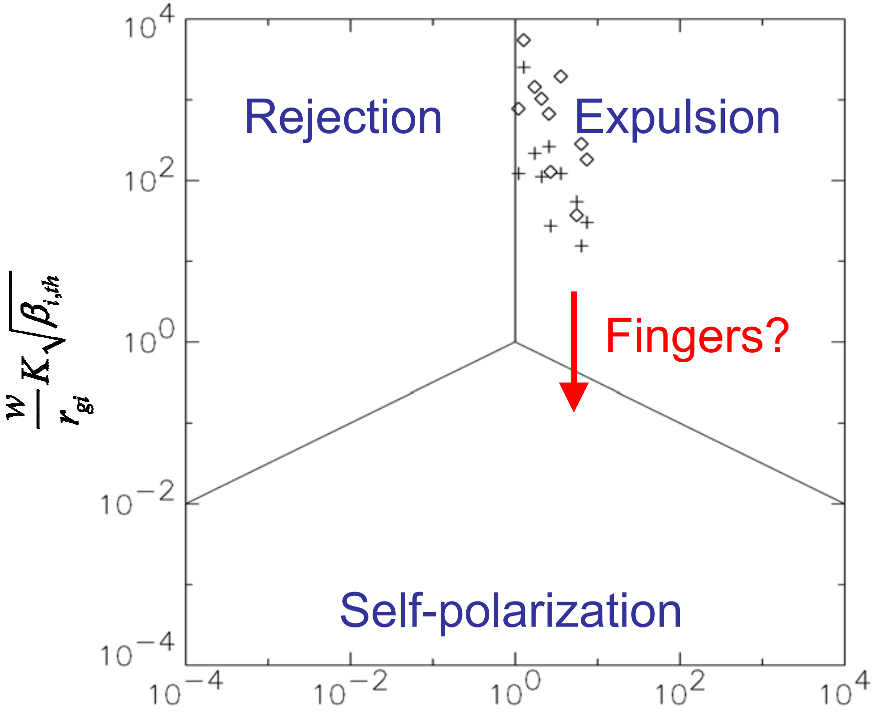
Here, no measurements were made in the CRIT experiments.

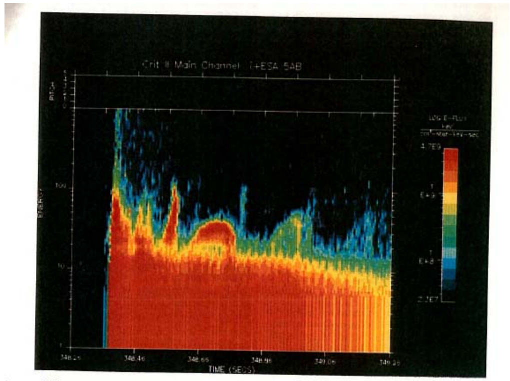


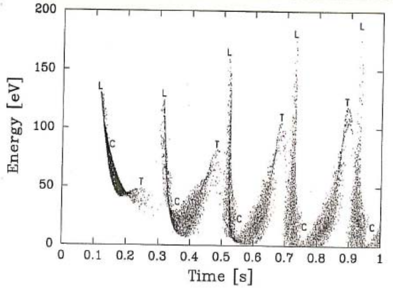
Thank you for your attention











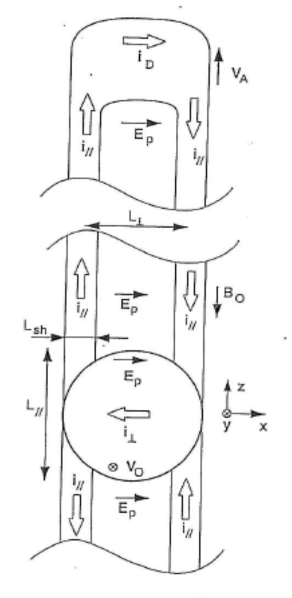


FIG. 1. The electrodynamical coupling between the ambient ionosphere and a plasma cloud which is injected with a velocity v_0 across the magnetic field. A plasma displacement current i_D flows across B_0 in the Alfvén wave front.

$$\beta_k = \frac{W_k}{W_B}$$

$$(\omega_{ge}\tau_e)_{eff} \approx 2$$

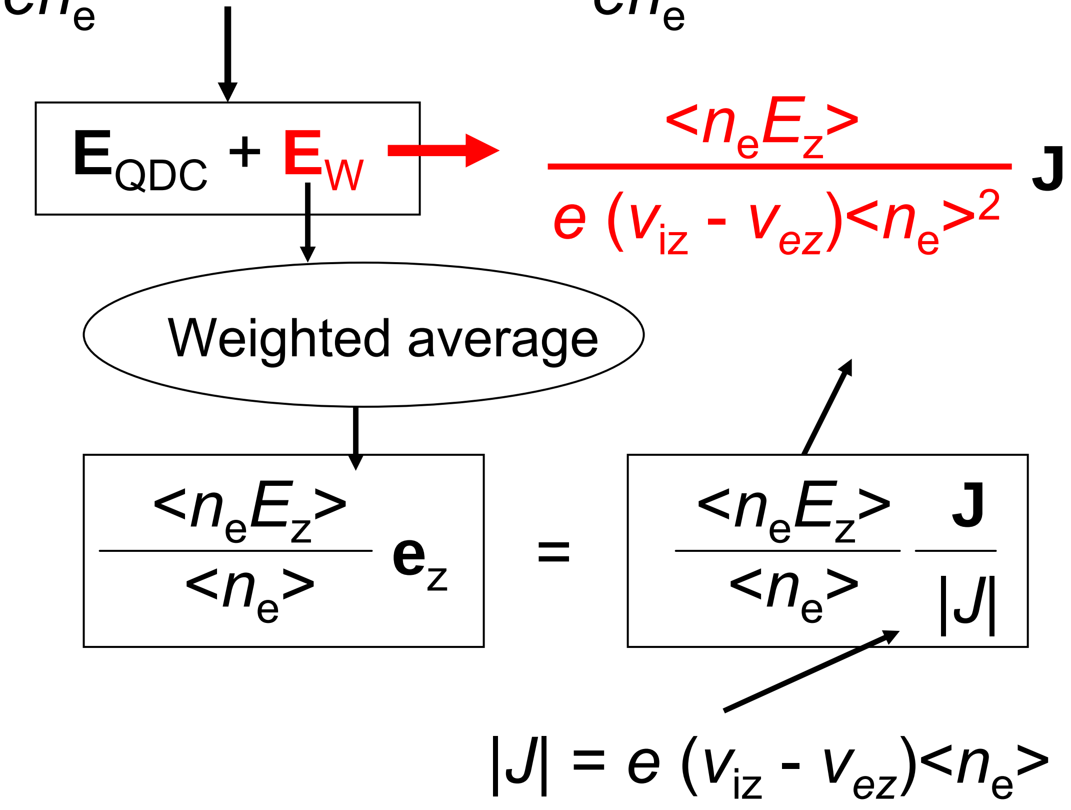
$$E_{//} \neq 0??$$

FIXED ORDER ABOVE THIS

2007-07-11

We only look here at two terms; $\eta_c\mathbf{J}$ and $\mathbf{E}_W$

$$\frac{m_e}{e^2 n_e}\frac{d\mathbf{J}}{dt} + \eta_c\mathbf{J} + \frac{\mathbf{J}\mathrm{x}\mathbf{B}}{e n_e} = \mathbf{E} + \mathbf{v}\mathrm{x}\mathbf{B} + \frac{\nabla p}{e n_e}$$



$$\mathbf{E}_{QDC} + \mathbf{E}_W \rightarrow \frac{<n_e E_z>}{e\,(v_{iz} - v_{ez})<n_e>^2}\,\mathbf{J}$$

Weighted average

$$\boxed{\frac{<n_e E_z>}{<n_e>}\,\mathbf{e}_z} = \boxed{\frac{<n_e E_z>}{<n_e>}\,\frac{\mathbf{J}}{|J|}}$$

$$|J| = e\,(v_{iz} - v_{ez})<n_e>$$

Both these terms are // **J**.

The $\mathbf{E}_W$ term can be calculated from data.

The wave $\mathbf{E}_w$ field at x = 0.03 has the macroscopic effect of an anomalous transverse resistivity

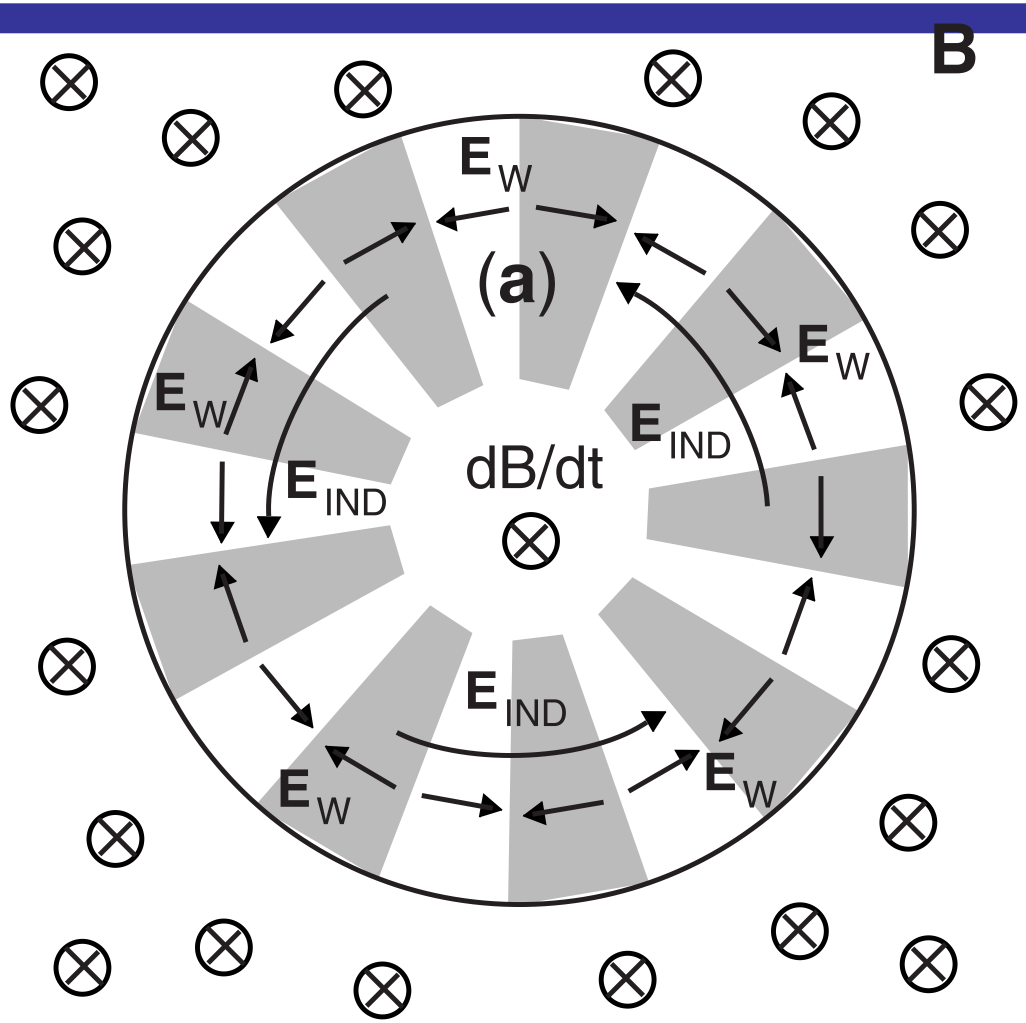
$$\eta_{EFF} = \eta_c + \frac{\langle n_e E_z \rangle}{e\,(v_{iz} - v_{ez})\langle n_e \rangle^2}$$

The value of η_{EFF} is typically 200-300 times the Spitzer η_c.

It corresponds to an effective collision frequency about ten times the observed wave (lower hybrid) frequency.

1. Assuming a costant η_{EFF} in the whole plasma, at this value, gives:

Symmetric magnetic diffusion into a plasma



PROPOSITION: ”strong instability”

A strongly driven system will tend to be on the steep part of some kind of instability curve

Such an instability curve can represent, for example, be the wave amplitude after some ”driving time constant”.

In our experiment (abrupt transition $t_{\mathrm{DRIVE}} = t_{\mathrm{TRANS}}$ Å t_{GI}), we find it relates to the ion thermal current:

$$i = 2.3 \ \mathrm{e} \ n_{\mathrm{e}} \ v_{\mathrm{ith}} \pm 34\%$$

EXAMPLE.

Lots of detail,

here, B field data at succeeding passages of the ”rest cloud”, at the Barium ion gyro frequency.

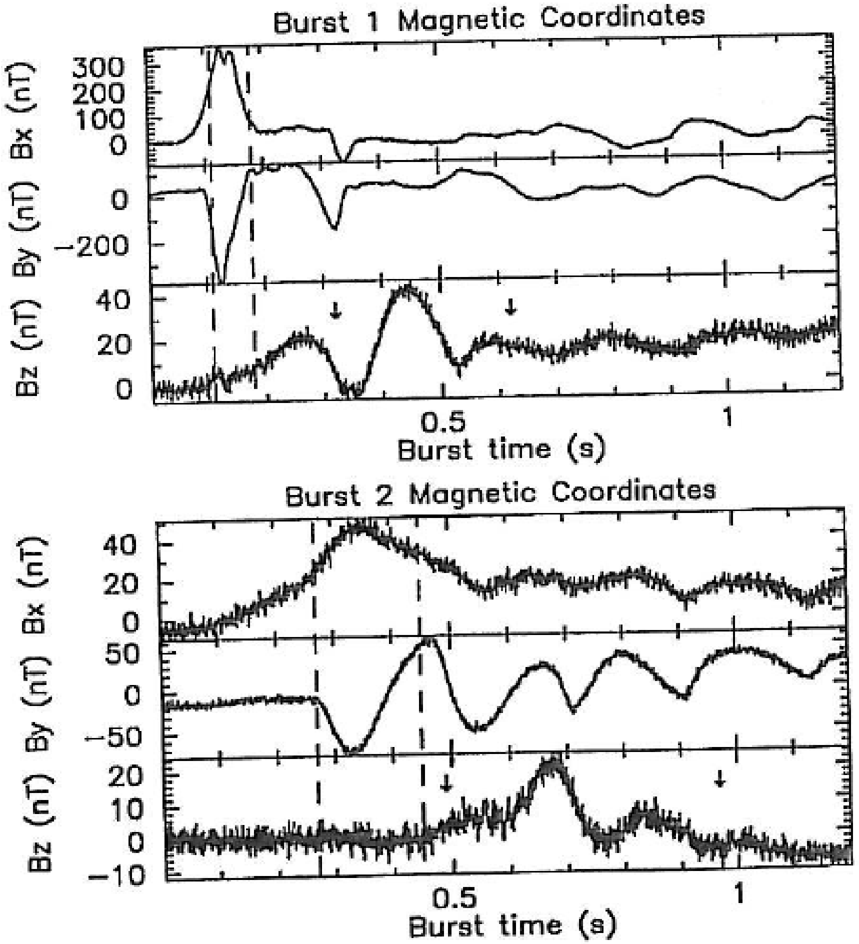


FIG. 2. The subpayload **B** field data in the magnetic coordinate system.

Track #2: propagation

comparison to ionospheric injection experiments

- Topic: coupling along **B**: momentum exchange, **E** fields, and parallell currents
- 1. Standard model: Alfven wave coupling,

  $$E_{//} = 0$$

- 2. Parallel **E** field due to current limitation
- 3. Parallel **E** fields due to dynamic trapping

PIC simulation: ions are pushed onto a **B** flux tube.

Electrons try to neutralize by motion along **B**.

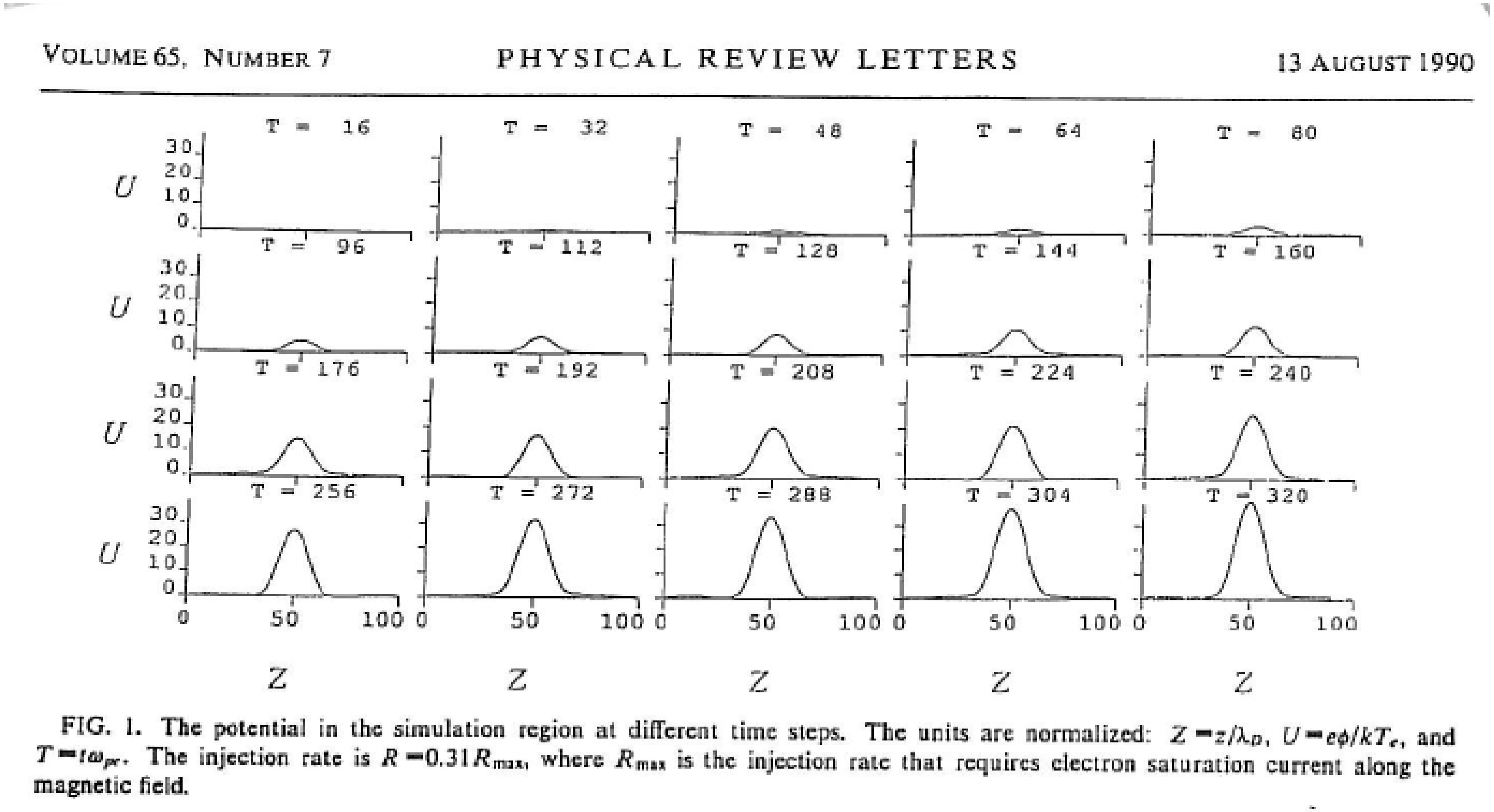


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FIG. 1. The potential in the simulation region at different time steps. The units are normalized: $Z = z/\lambda_D$, $U = e\phi/kT_e$, and $T = t\omega_{pe}$. The injection rate is $R = 0.31 R_{max}$, where R_{max} is the injection rate that requires electron saturation current along the magnetic field.

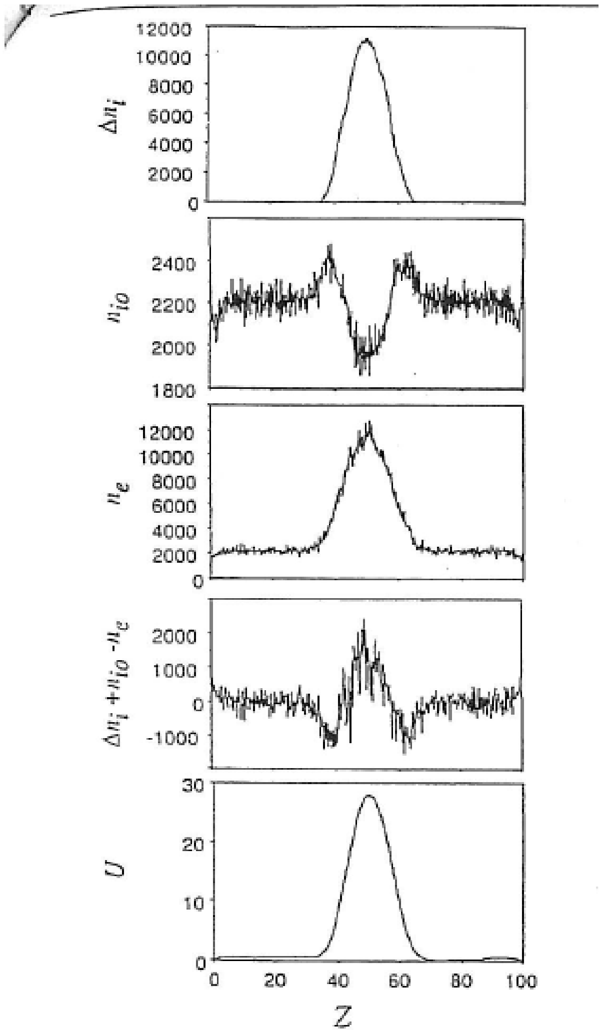


FIG. 2. From top to bottom: The injected ion density, the ambient ion density, the electron density, the net charge density, and the potential at time $T = 256$ of Fig. 1.

The new ions (Ba) are heavy and stay put

Background ions (O) begin to be pushed out

Electrons are trapped for quasineutrality, out of the field-aligned flux. KEY POINT!!

However a net space charge

gives the quite strong potential hill needed to trap the electrons in the first place.

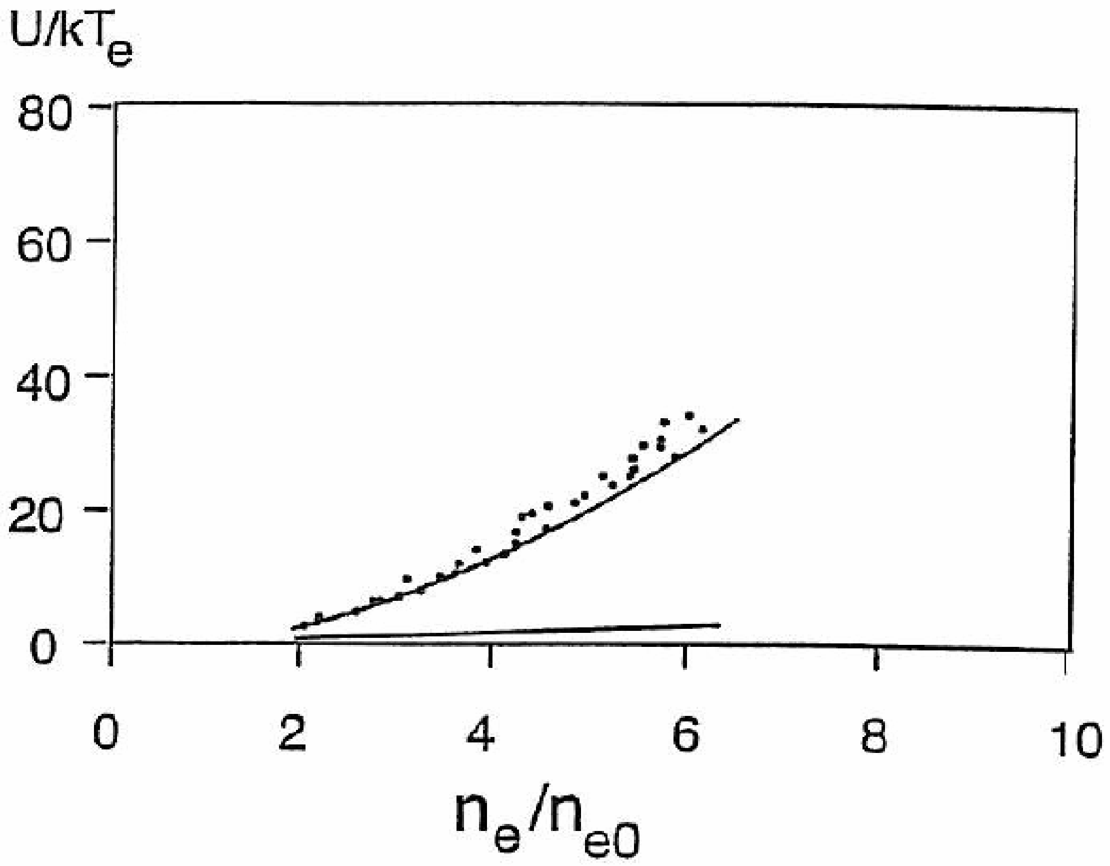
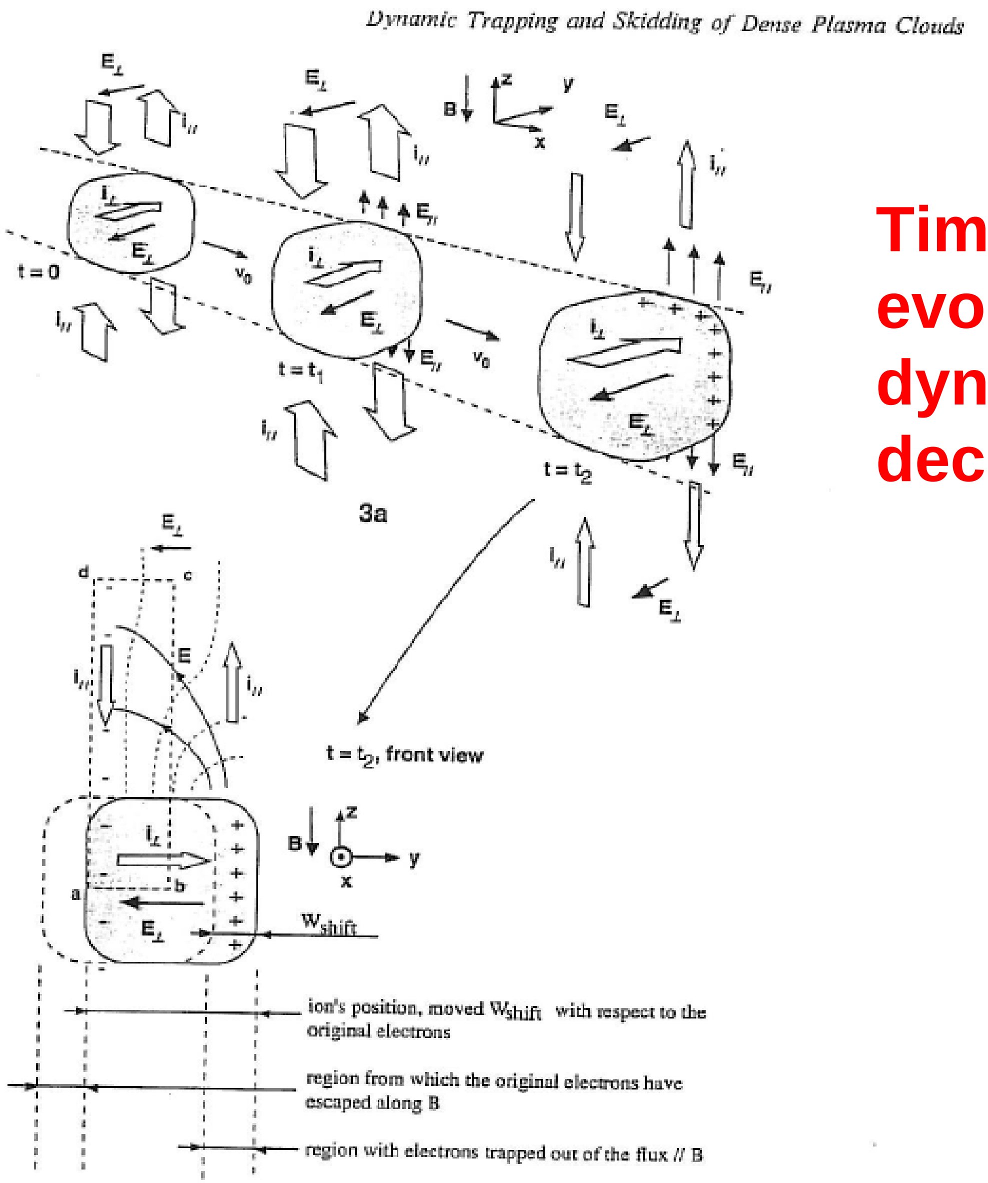
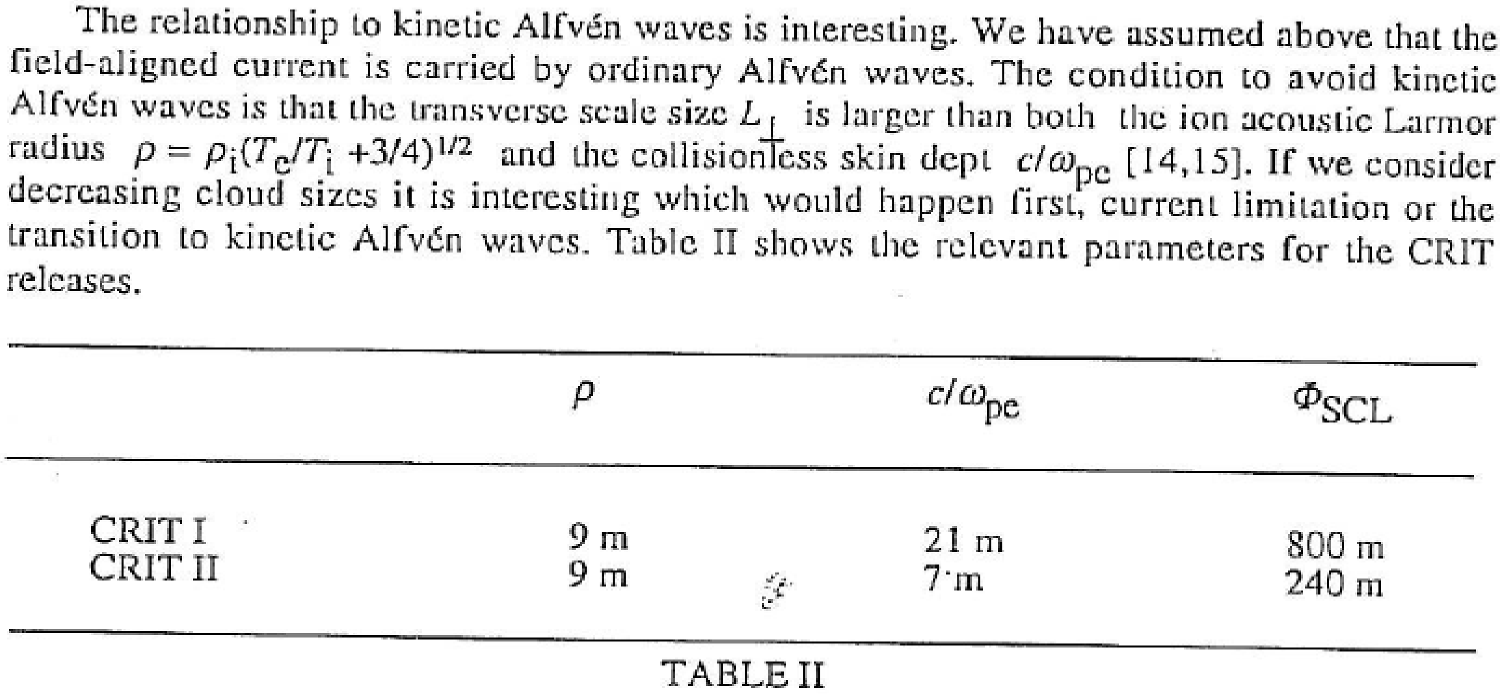


Fig. 2. The relation between density increase and normalized electric potential U/kT_e due to dynamic trapping. The dots are obtained from a computer simulation [4], made with barium ion mass and a typical ionospheric ambient electron temperature of 0.1 eV. The upper solid line is the analytical relation, and the lower solid line shows, for reference, the Boltzmann relation $n_e/n_{e0} = \exp(eU/kT_e)$.



Time and space evolution of a dynamically decoupled cloud.



The relationship to kinetic Alfvén waves is interesting. We have assumed above that the field-aligned current is carried by ordinary Alfvén waves. The condition to avoid kinetic Alfvén waves is that the transverse scale size $L_\perp$ is larger than both the ion acoustic Larmor radius $\rho = \rho_i(T_e/T_i + 3/4)^{1/2}$ and the collisionless skin dept c/ω_{pe} [14,15]. If we consider decreasing cloud sizes it is interesting which would happen first, current limitation or the transition to kinetic Alfvén waves. Table II shows the relevant parameters for the CRIT releases.

	ρ	c/ω_{pe}	Φ_{SCL}
CRIT I	9 m	21 m	800 m
CRIT II	9 m	7 m	240 m

TABLE II

The generalized Ohm's law

$$\frac{m_e}{e^2 n_e}\frac{d\mathbf{J}}{dt} + \eta\mathbf{J} + \frac{\mathbf{J}\text{x}\mathbf{B}}{en_e} = \mathbf{E} + \mathbf{v}\text{x}\mathbf{B} + \frac{\nabla p}{en_e}$$

Definition of η: $\mathbf{P}_{ei} = \eta e n_e \mathbf{J}$

This includes both quasi-dc $\mathbf{E}_{QDC}$ and hf wave field $\mathbf{E}_W$.

In our special case, $\mathbf{E}_W$ is parallel to $\mathbf{J}$

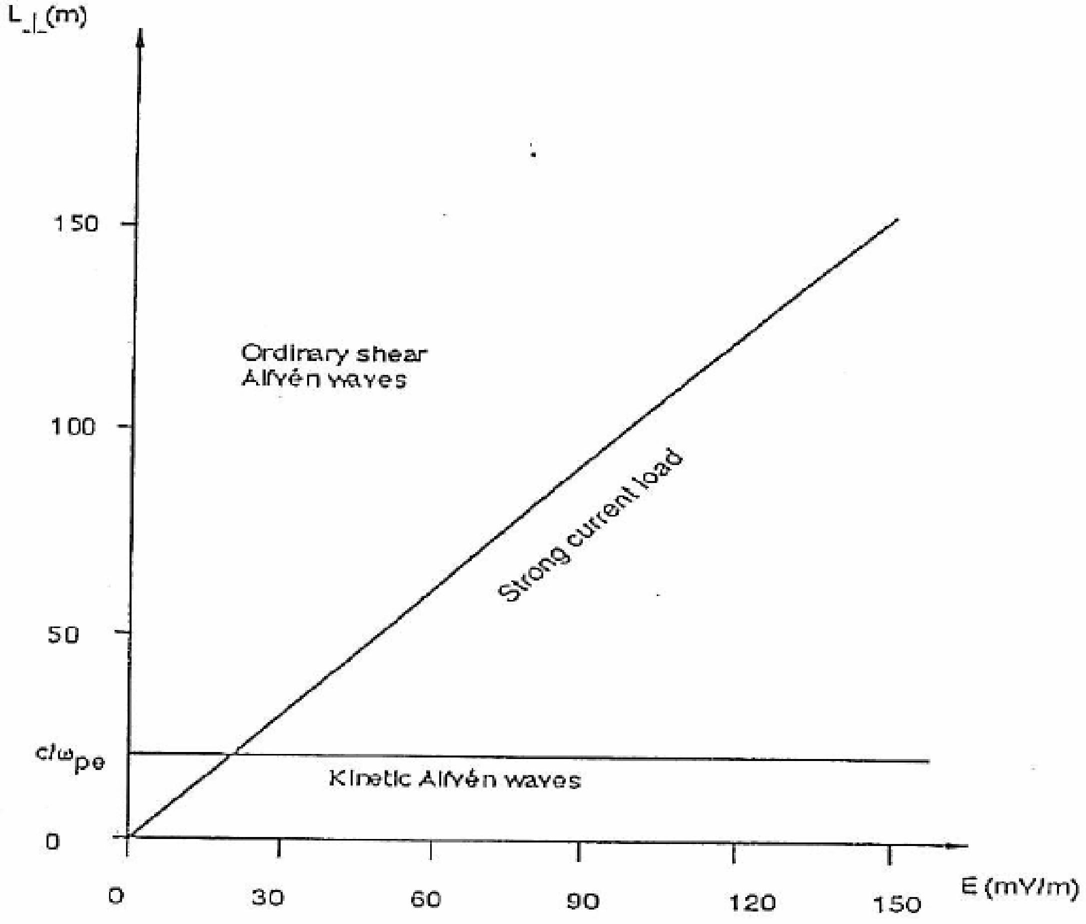


Fig. 3. A comparision between the strong current load condition and the parameter range within which Alfvén waves become kinetic, exemplified by the CRIT I release.

For a plasma stream where $\Delta B/B = 30\%$, 1 μs fter entering the transition region:

Diffusion time for the magnetic field into the plasma:

$\tau_B = \mu_0 L/4\eta_{EFF} = 0.5\ \mu\text{s}$. 30% after 1 μs is reasonable

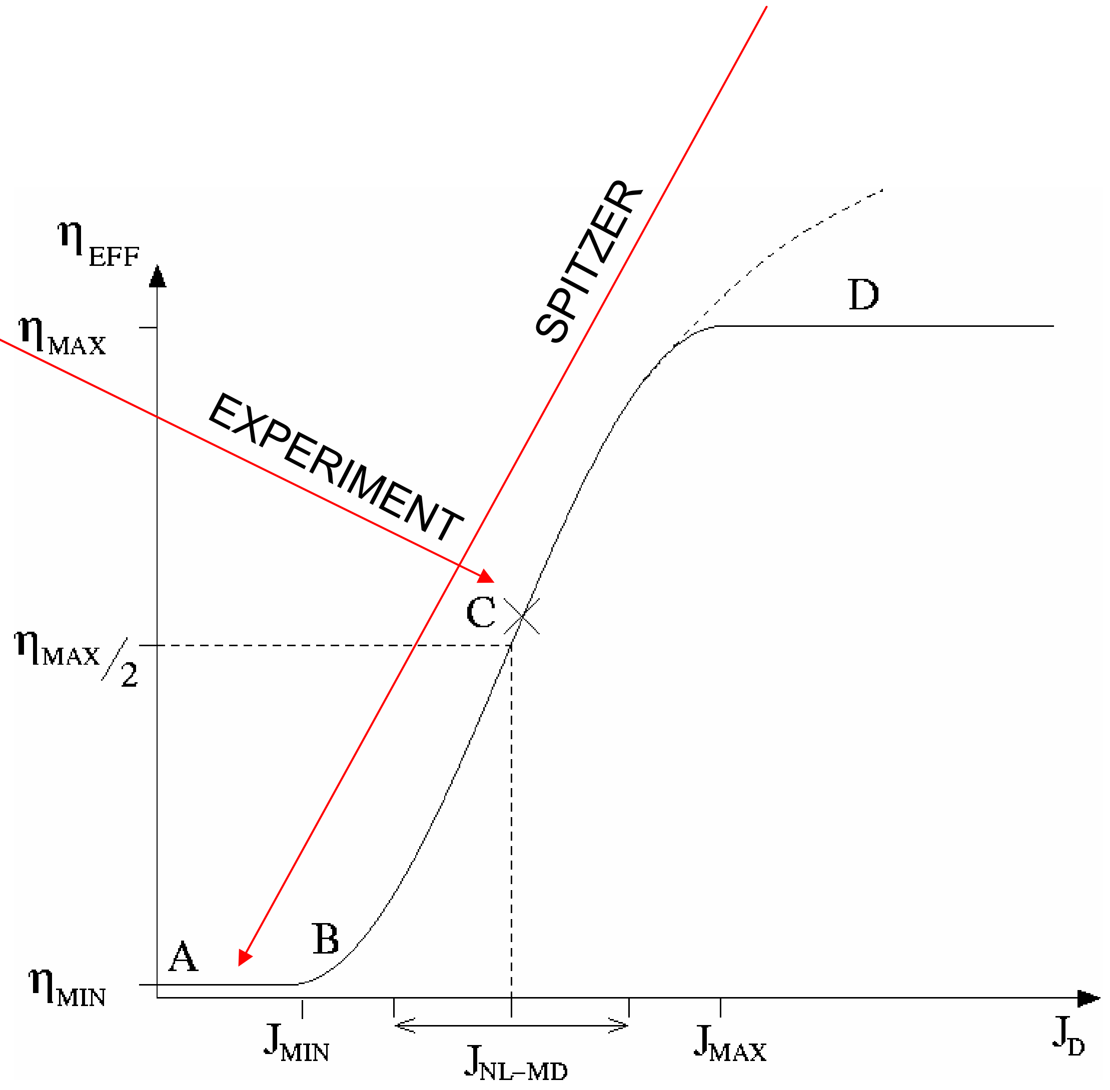
Both classical (Spitzer) and Bohm diffusion are about two orders of magnitude too slow.

Assuming a relationship $\eta_{EFF}(i/i_{thr})$ we can calculate the B diffusion during 1 μs into stationary clouds

ASSUMED RELATION MOTIVATED IN POINT A-B, AND AT C. THE CURVE BETWEEN IS A HYPOTESIS

$$D_B = \eta_{EFF}/\mu_0$$

Solving the diffusion equation in one dimension, with the external field ramped during 1 μs gives



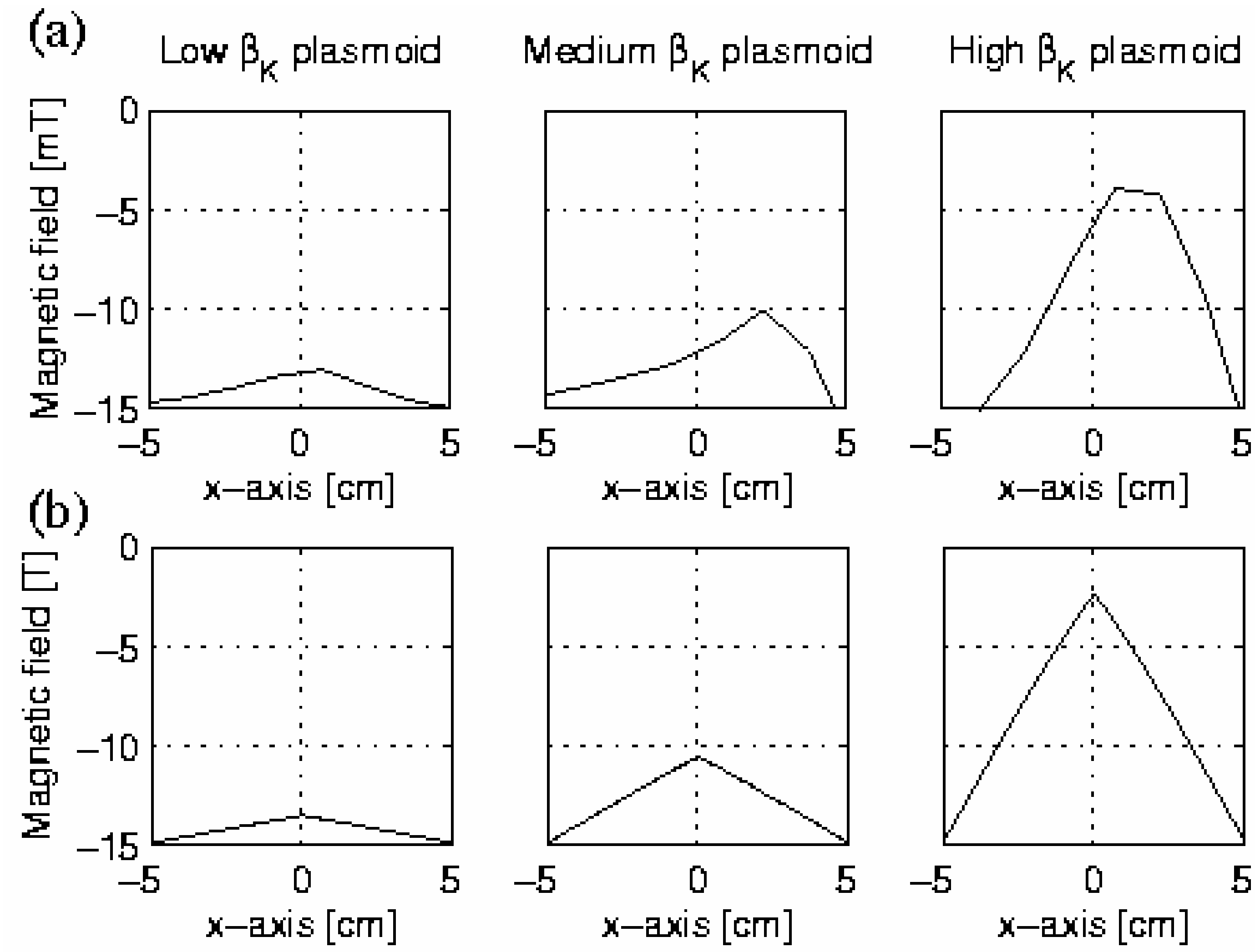
The magnetic expulsion agrees with observations, but the assymetry in the experiment is lost.

ΔB from

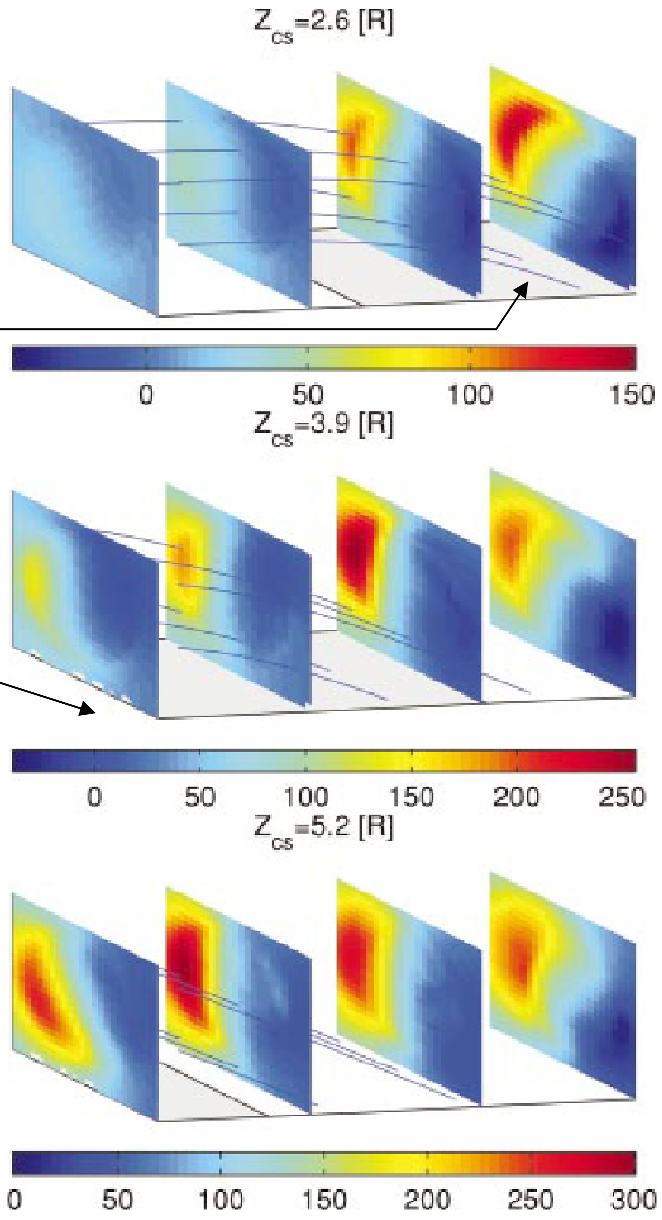
Experi-
ment

ΔB from

Diffusion
model



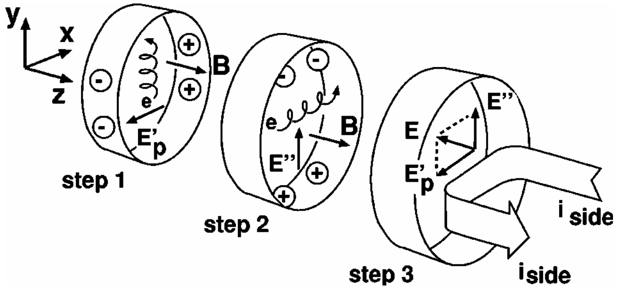
FIRST order potential: *U* in the lab frame.



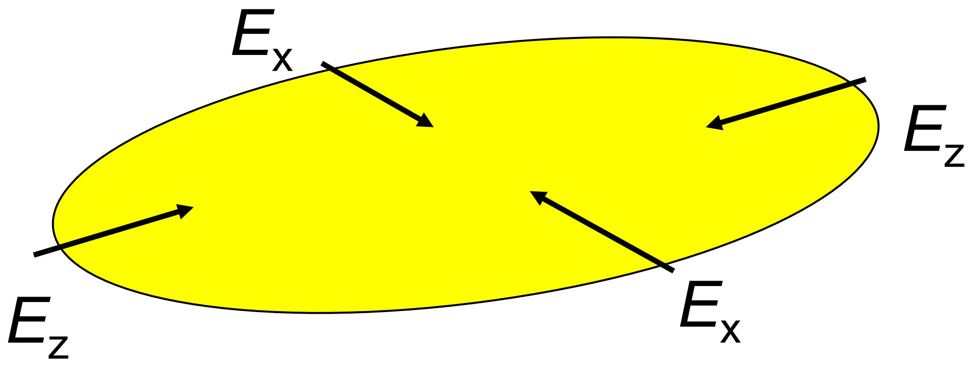
The grey areas show the magnetic transition

Blue is ground = the upstream potential

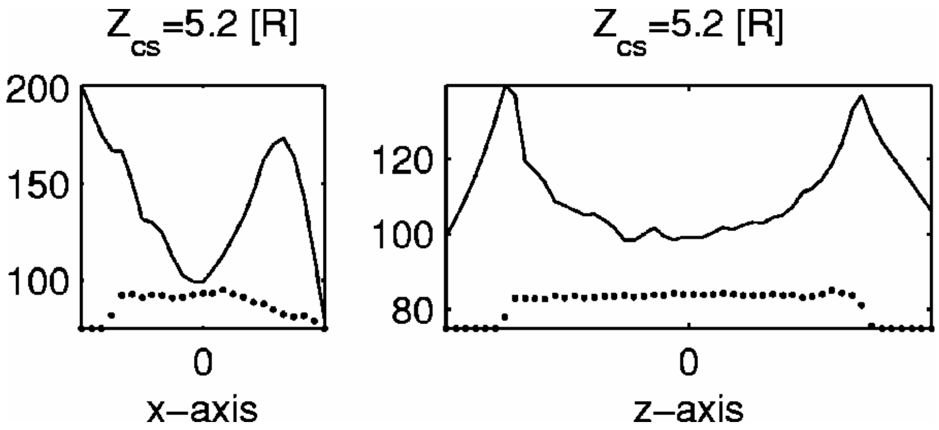
Red is positive: the ions have to climb a hill

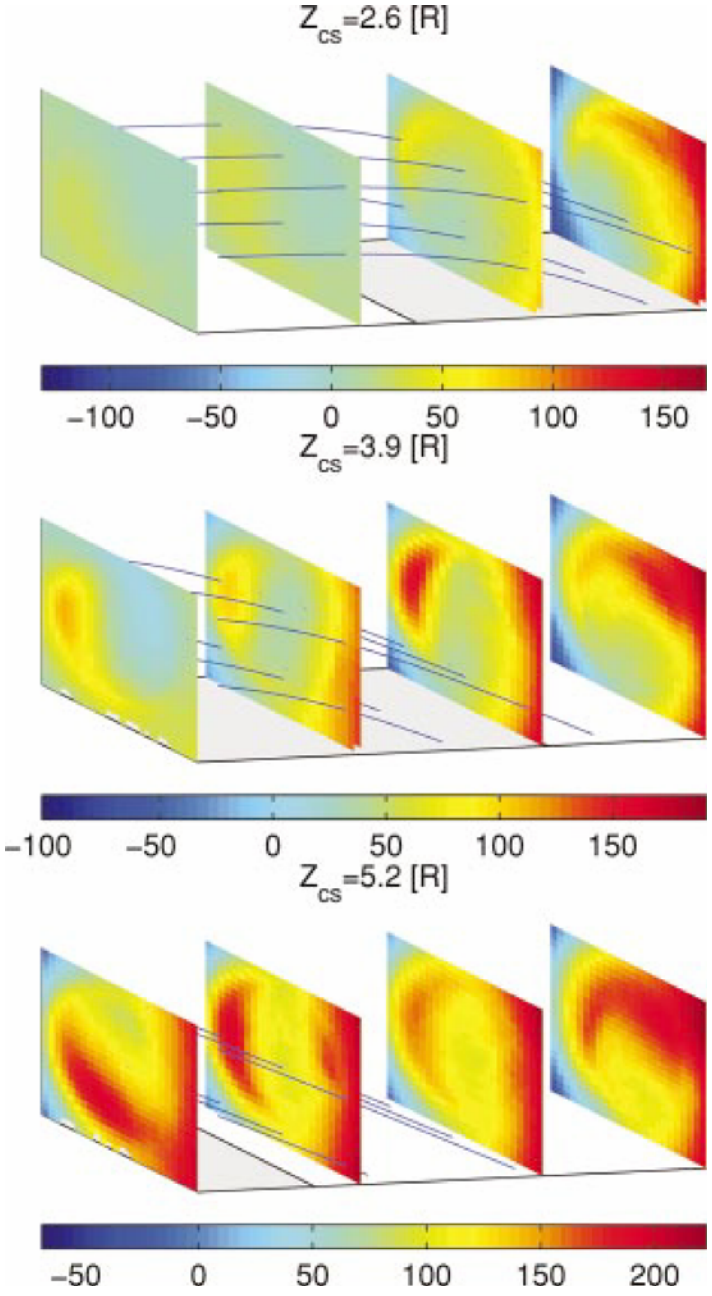


SECOND order potential: *U* in the plasma rest frame.

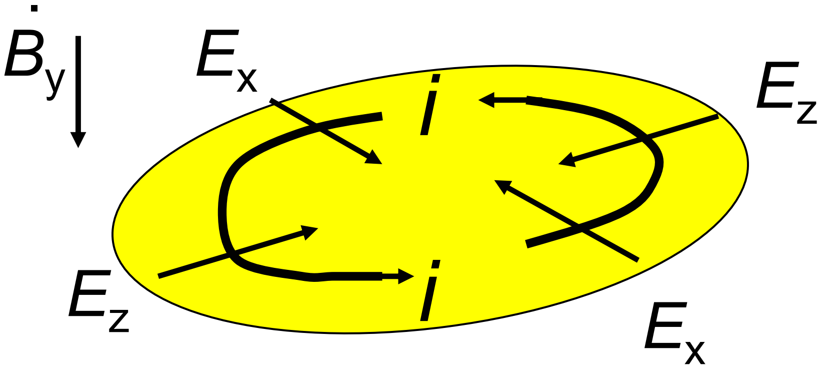


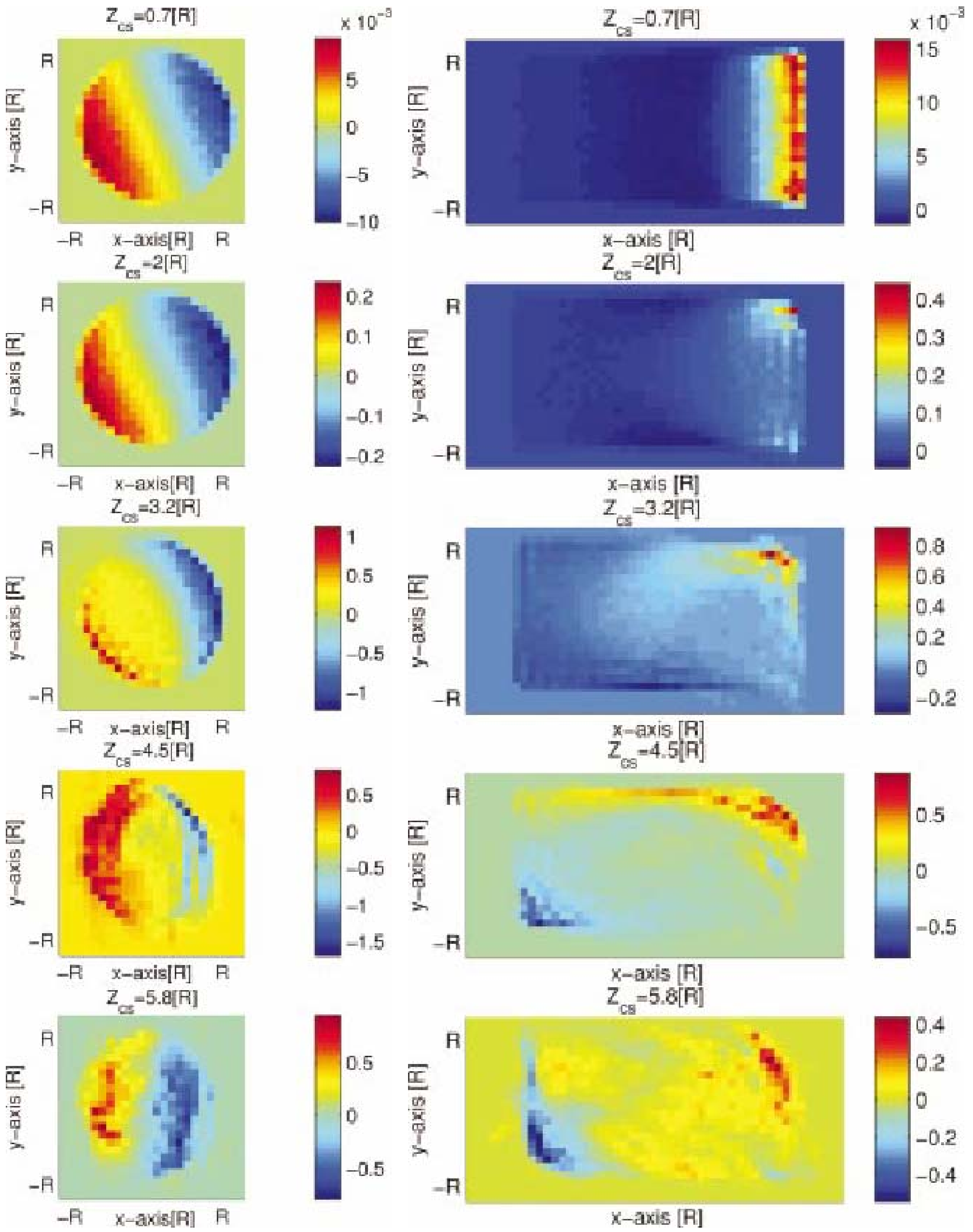
INWARDS **E** FROM ALL DIRECTIONS





CURRENT: ELECTRON HALL **EXB**/B^2 DRIFT IN THE INWARDS E_X AND E_Z FIELDS





LEFT HAND PANELS:

CURRENTS ALONG THE SIDES OF THE PLASMA STREAM

RIGHT HAND PANELS:

CLOSURE OF THE CURRENTS IN THE FRONT AND BACK OF THE STREAM.

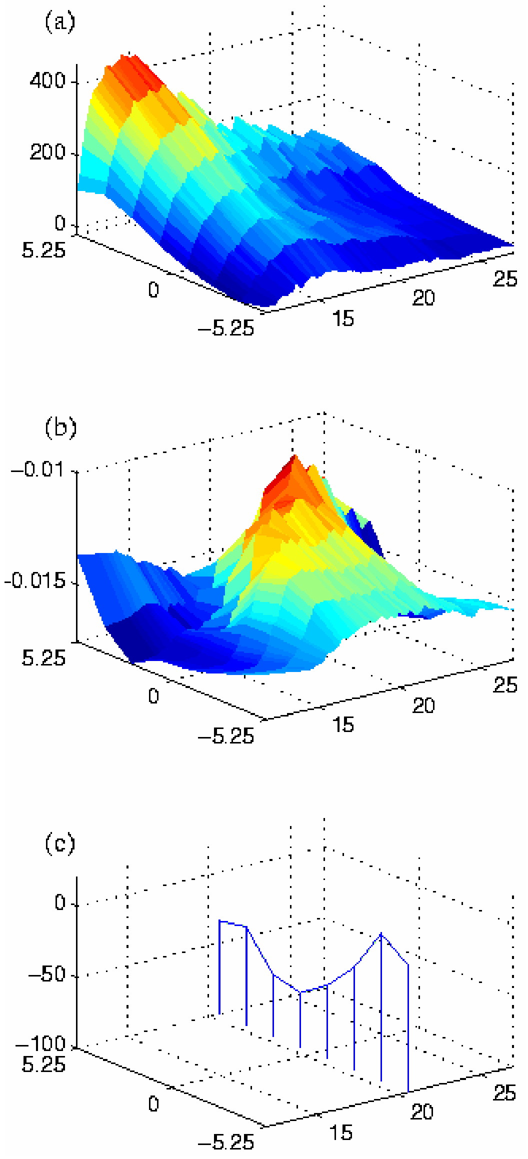
Careful study of one experiment with $\beta_K \approx 1.5$, with:

Self-polarization to 70% of $\mathbf{E}_P = -\mathbf{v}_0 \mathrm{x} \mathbf{B}_0$.

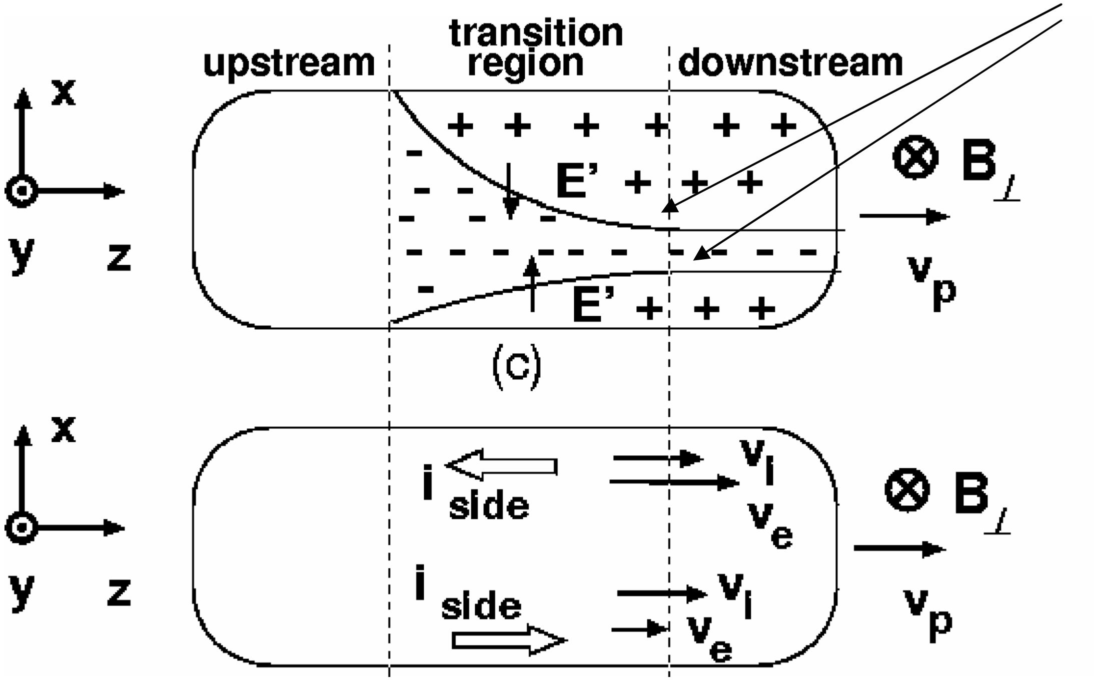
Partial magnetic expulsion, $\Delta B/B_0 = 30\%$.

(notice that the zero level is upwards)

Inwards electric field



CARTOONS



Equipotential surfaces from the potential U in the lab frame

Charge separation grows until **THE FIRST OF THESE HAPPEN**:

(1) ions are stopped or compressed to be where the electrons go,

(2) The magnetic field is deformed so that the electrons can follow

(3) Anomalous transport of the electrons across **B** is enabled.

TWO KEY PARAMETERS

$$\beta_k = \frac{W_{\mathrm{K}}}{W_{\mathrm{B}}} = \frac{m_{\mathrm{i}}\, n_{\mathrm{e}}\, v_0^{\,2}/2}{B^2/2\,\mu_0}$$

KINETIC

BETA

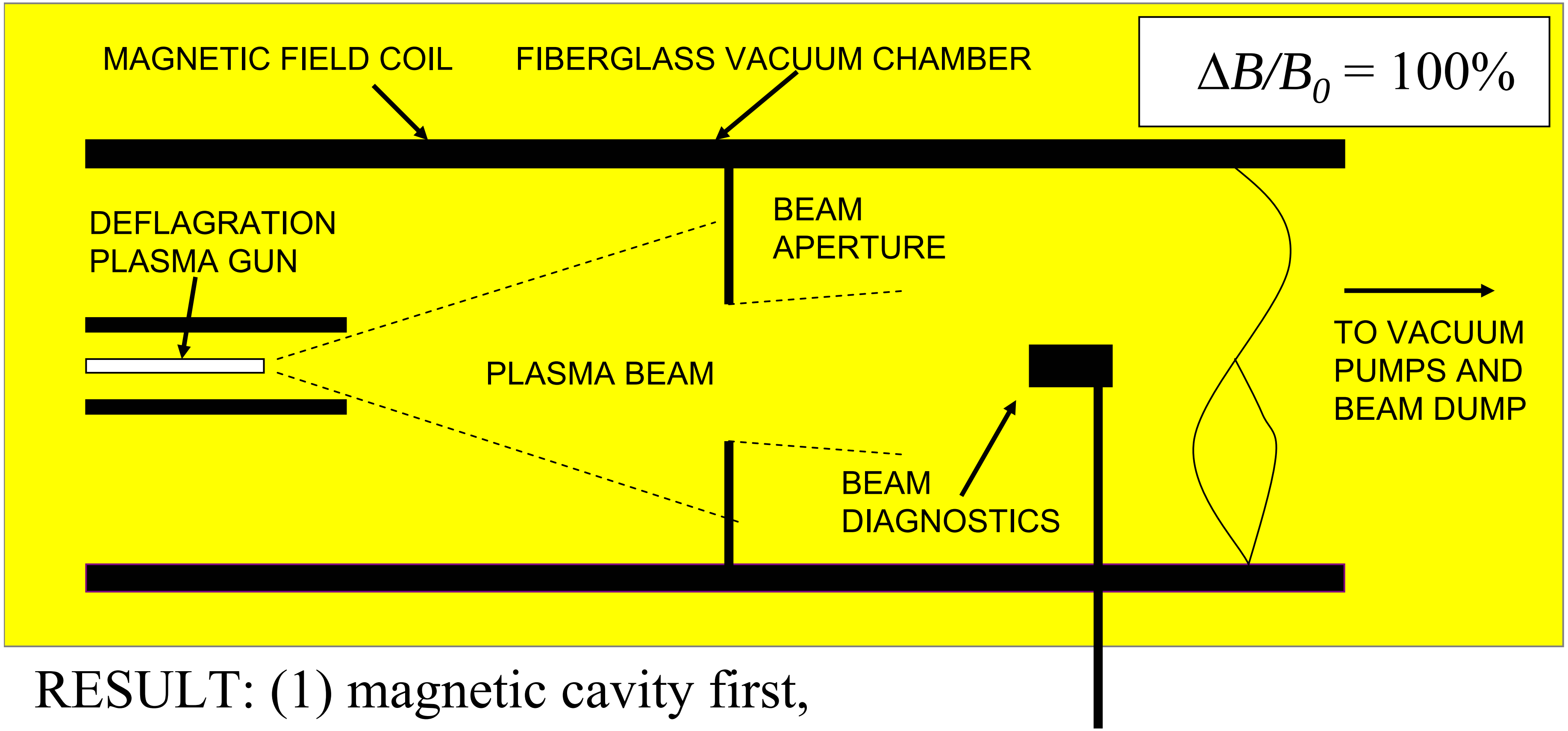
$$\frac{w}{r_{\mathrm{gi}}} = \frac{\text{plasma stream width}}{\text{ion gyro radius at } v_0}$$

BEAM

WIDTH

Experiments have been made over 3-4 orders of magnitude in both

EXTREME EXAMPLE #1: wide beam (*w/r* up to 24, high β_K (up to 300). Song *et al*, 1990.



MAGNETIC FIELD COIL

FIBERGLASS VACUUM CHAMBER

$\Delta B/B_0 = 100\%$

DEFLAGRATION PLASMA GUN

BEAM APERTURE

PLASMA BEAM

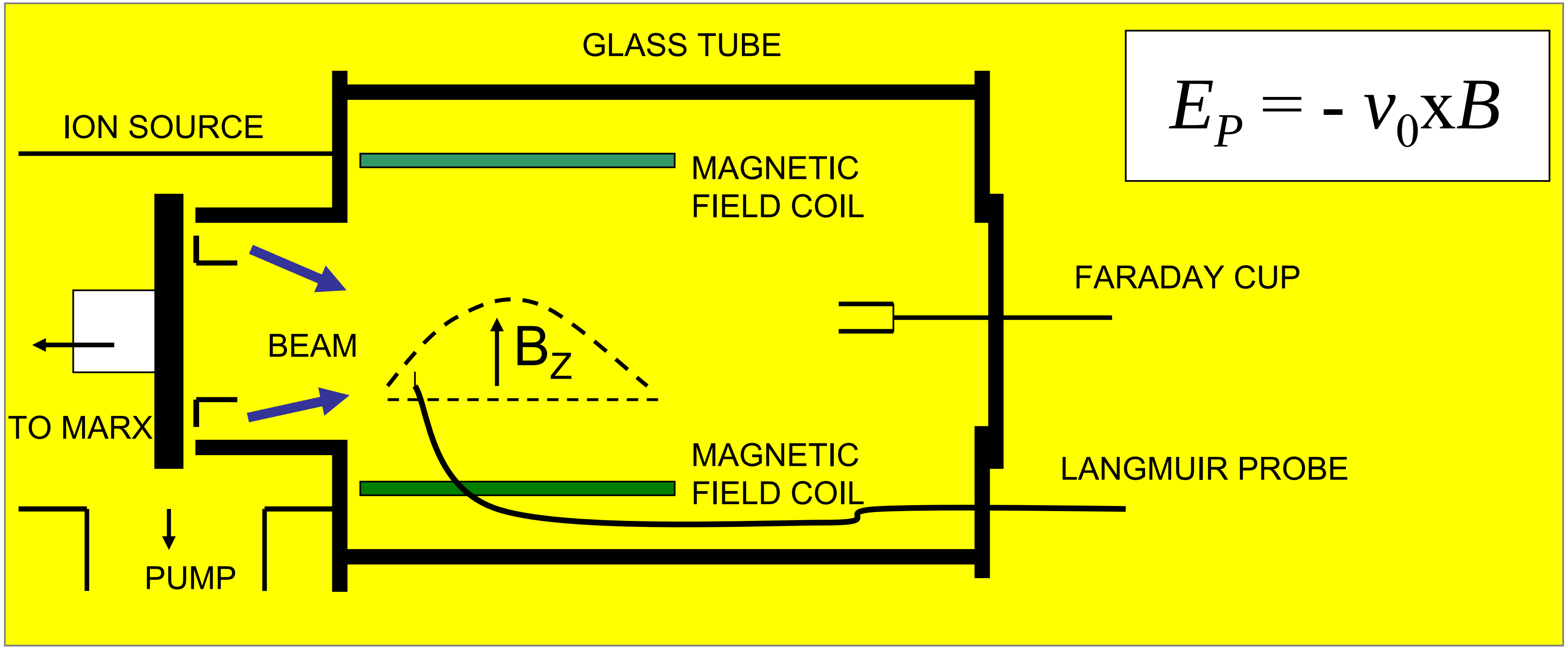
TO VACUUM PUMPS AND BEAM DUMP

BEAM DIAGNOSTICS

RESULT: (1) magnetic cavity first,

(2) then gradual magnetic diffusion into the plasma

EXTREME EXAMPLE #2: narrow beam (*w/r* down to 0.3, low β_K (down to 0.1). Ishizuka and Robertson, 1982.



RESULT: (1) self-polarization

(2) for lowest β_K: rejection from barrier

Narrowing of focus, #2. Only self polarization.

Three possibilities:

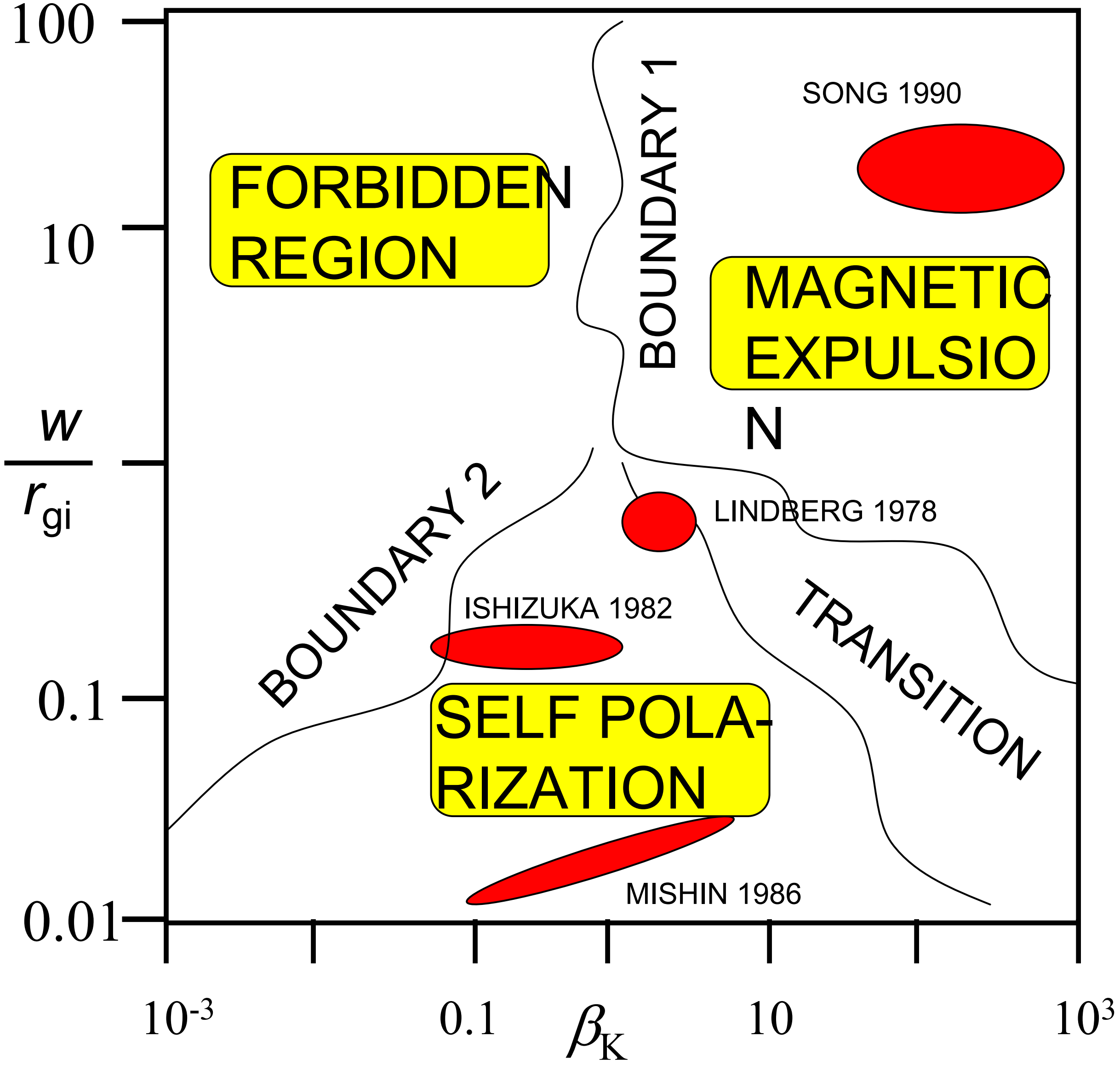
- **B** expulsion

  $\Delta B/B = 100\%$

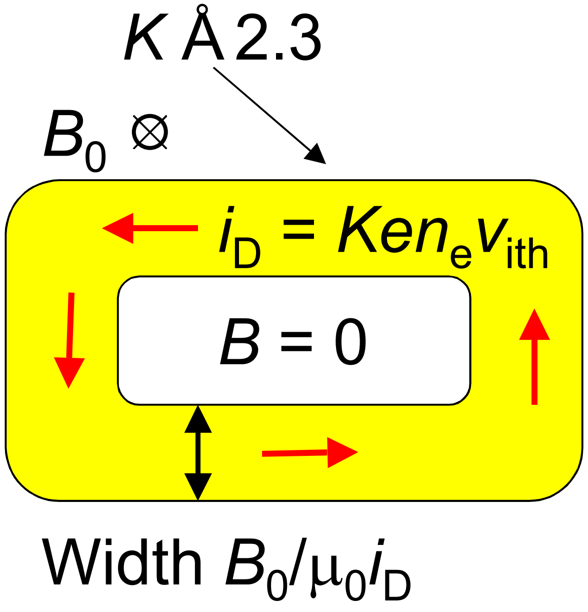
- Polarization

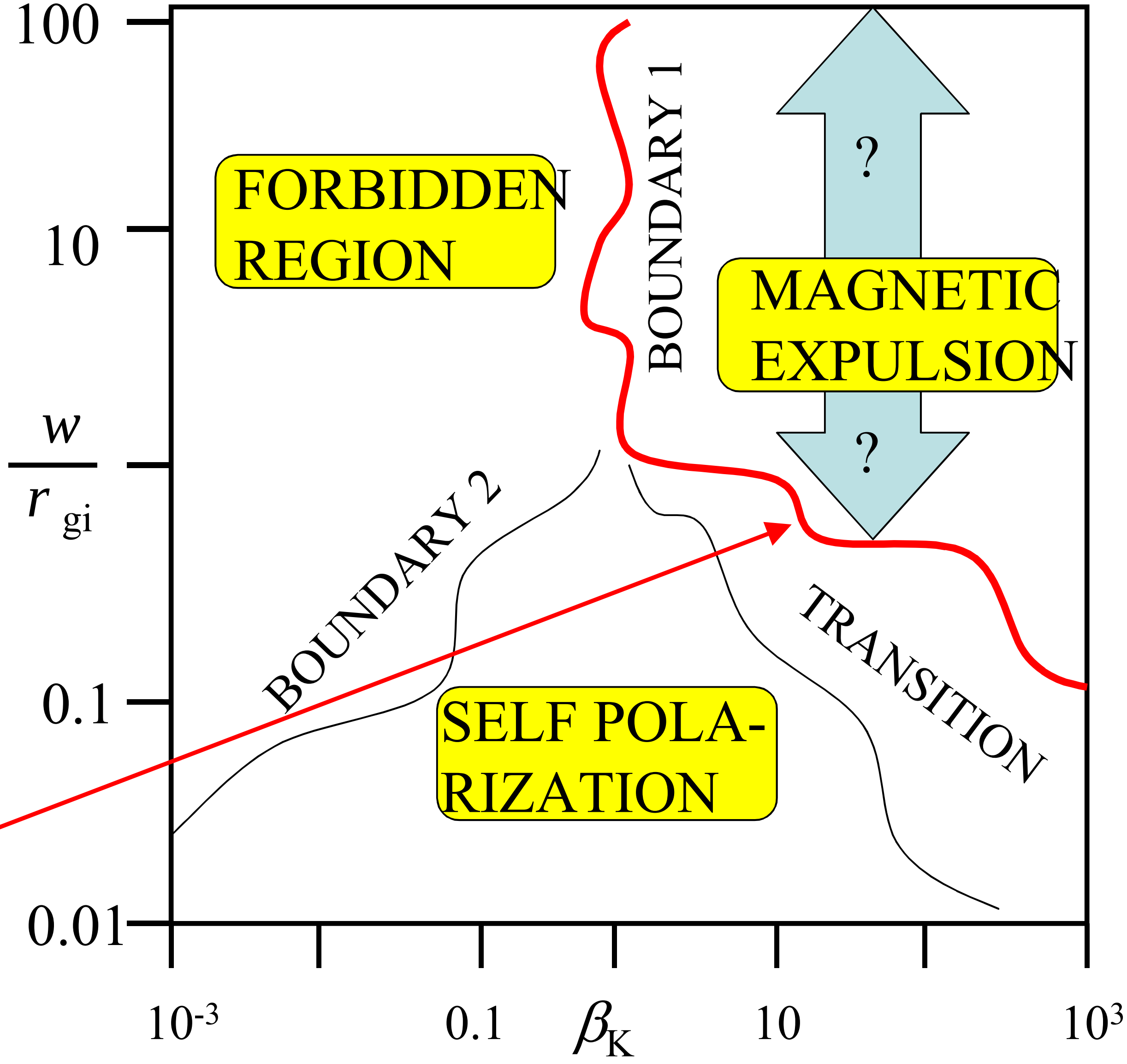
  $\mathbf{E}_P = -\mathbf{v}_0 \times \mathbf{B}$

- Rejection



The condition for 100% B - expulsion in the centre

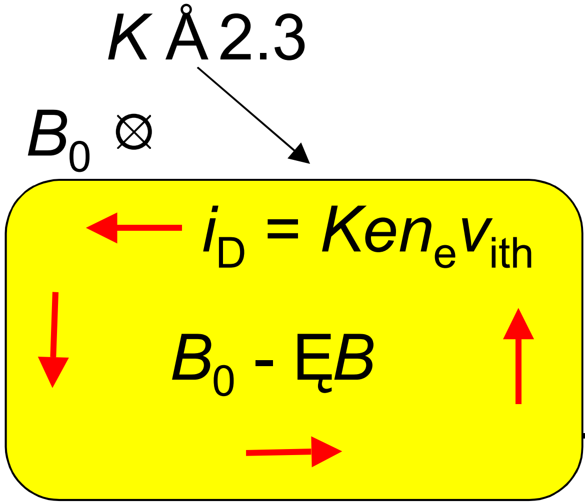


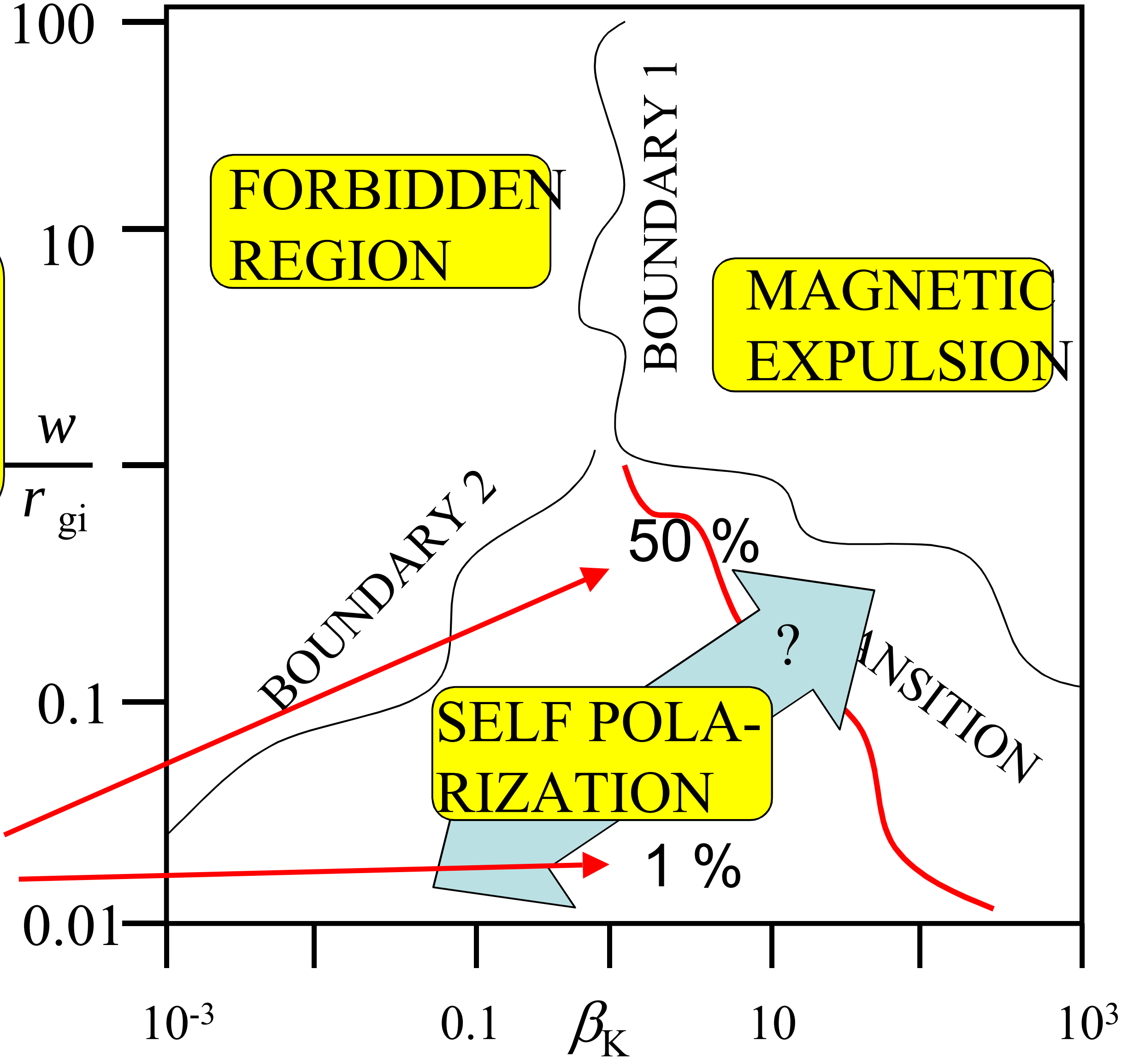


$$\frac{w}{r_{gi}} K \sqrt{\beta_{ith}} = \frac{1}{\sqrt{\beta_K}}$$

Equation (1)

The degree of self-polarization (the remaining ĘB/B$_o$)





$$\frac{ĘB}{B_0} = K\sqrt{\beta_{ith}\beta_K}\,\frac{w}{r_{gi}}$$

Equation (2)

The Òelectrostatic limitÓ, physical reason

Wessel, Ishuzika, Robertson

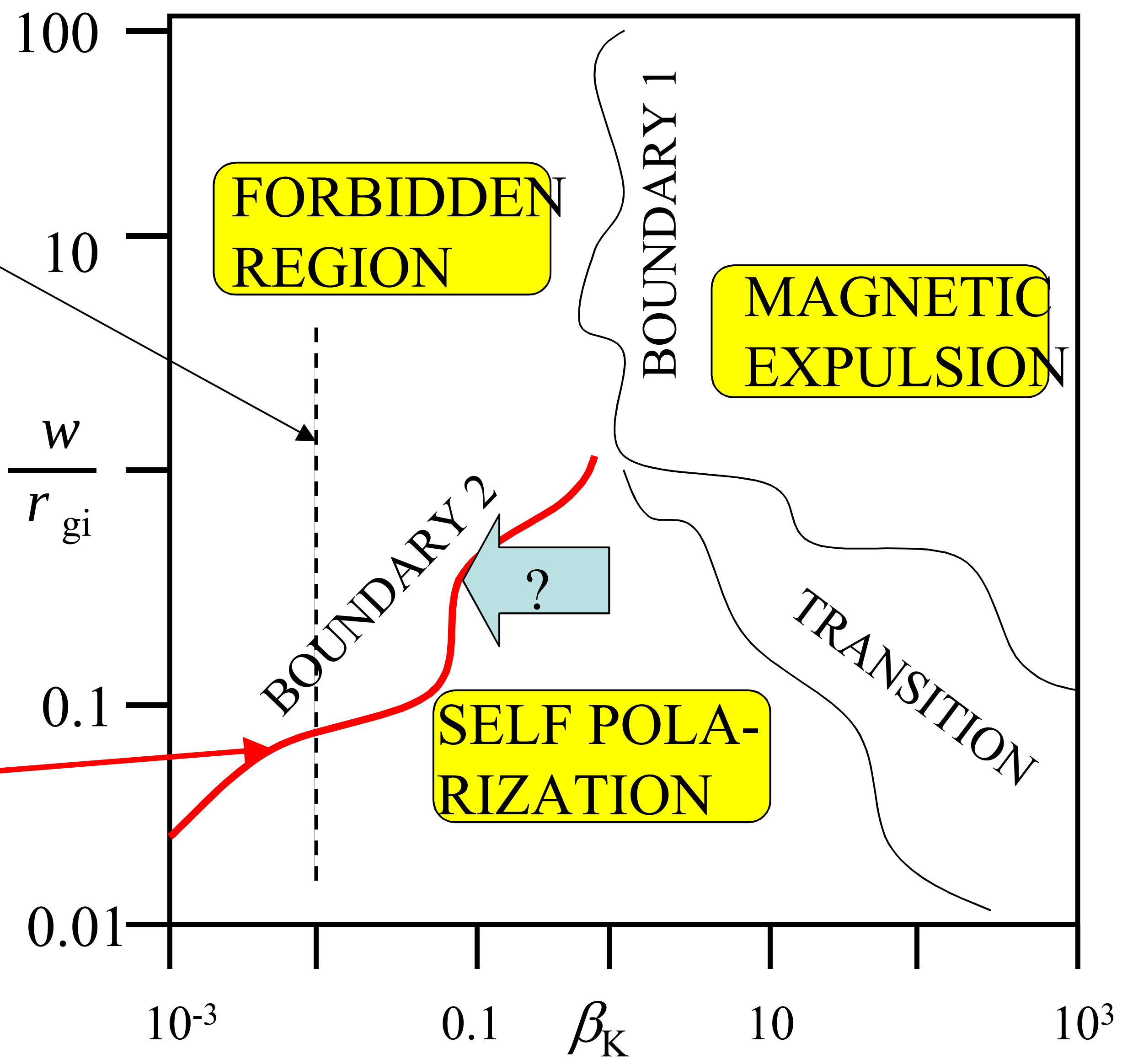
The condition

Ę$W_B < W_K$

gives:

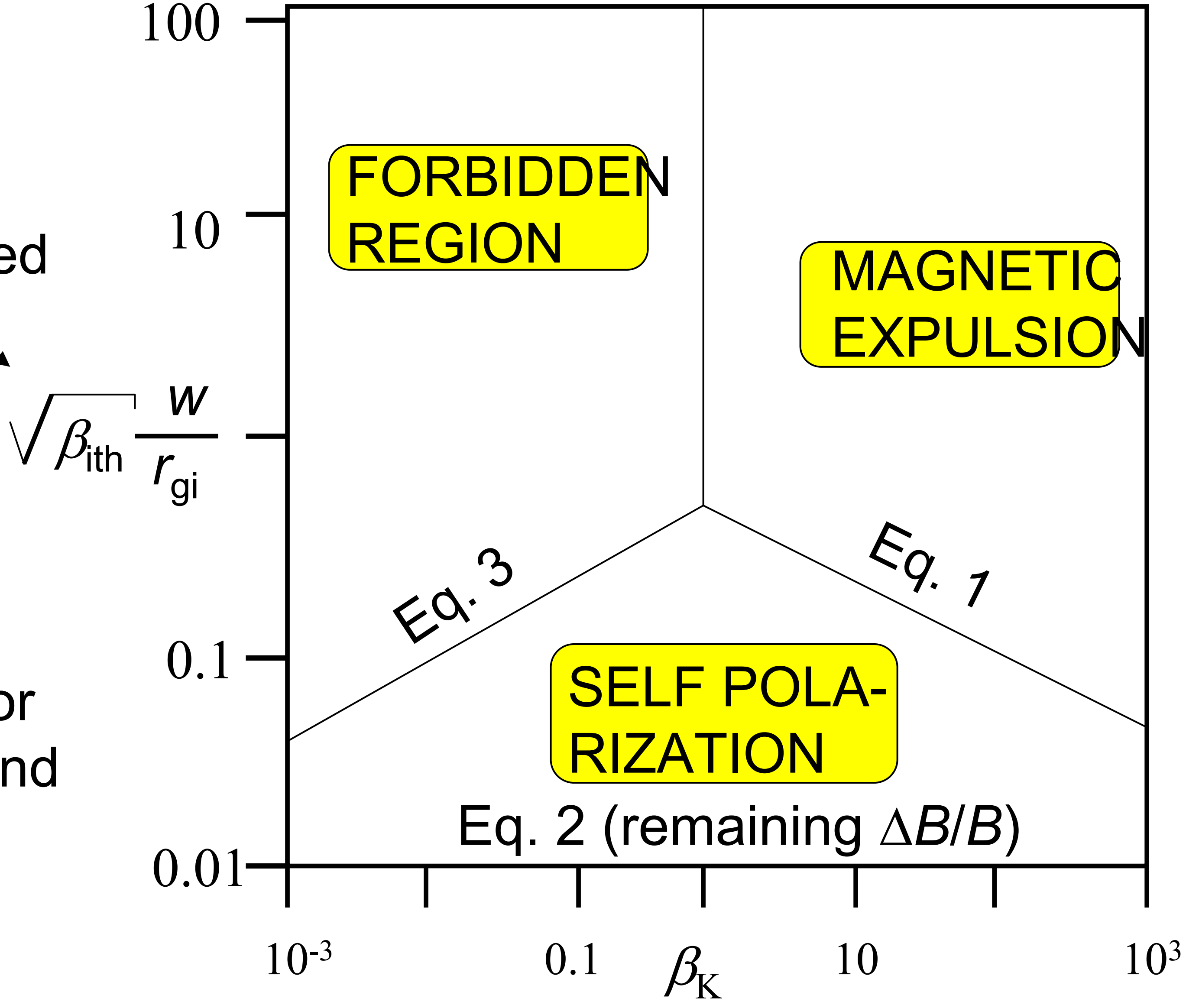
$$\frac{w}{r_{gi}} < \frac{1}{K}\frac{v_0}{v_{ith}}$$

Equation (3)



NEW OVERWIEW PLOT, borders here plotted with $K = 2.3$

NEW normalized width



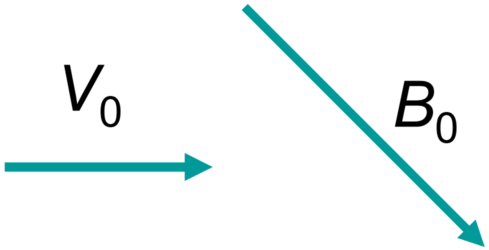
Equations for boundries and degrees of expulsion

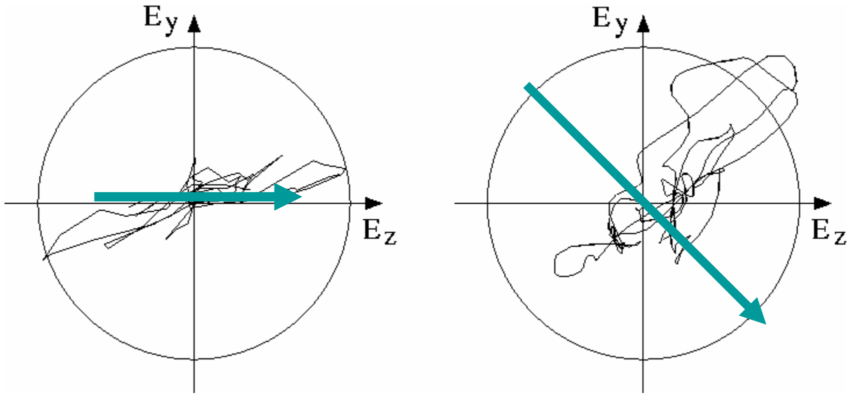
SLIDES NOT USED IN THE TALK BELOW THIS POINT

X

The Modified Two-stream Instability MTSI

- Frequency (lower hybrid)
- Wavelength (2-3 cm)
- Growth rate (1 ms to 100% amplitude)
- Electron tail heating (earlier known)
- Wave structure (E_w, n_e)as experiment
- only difference:



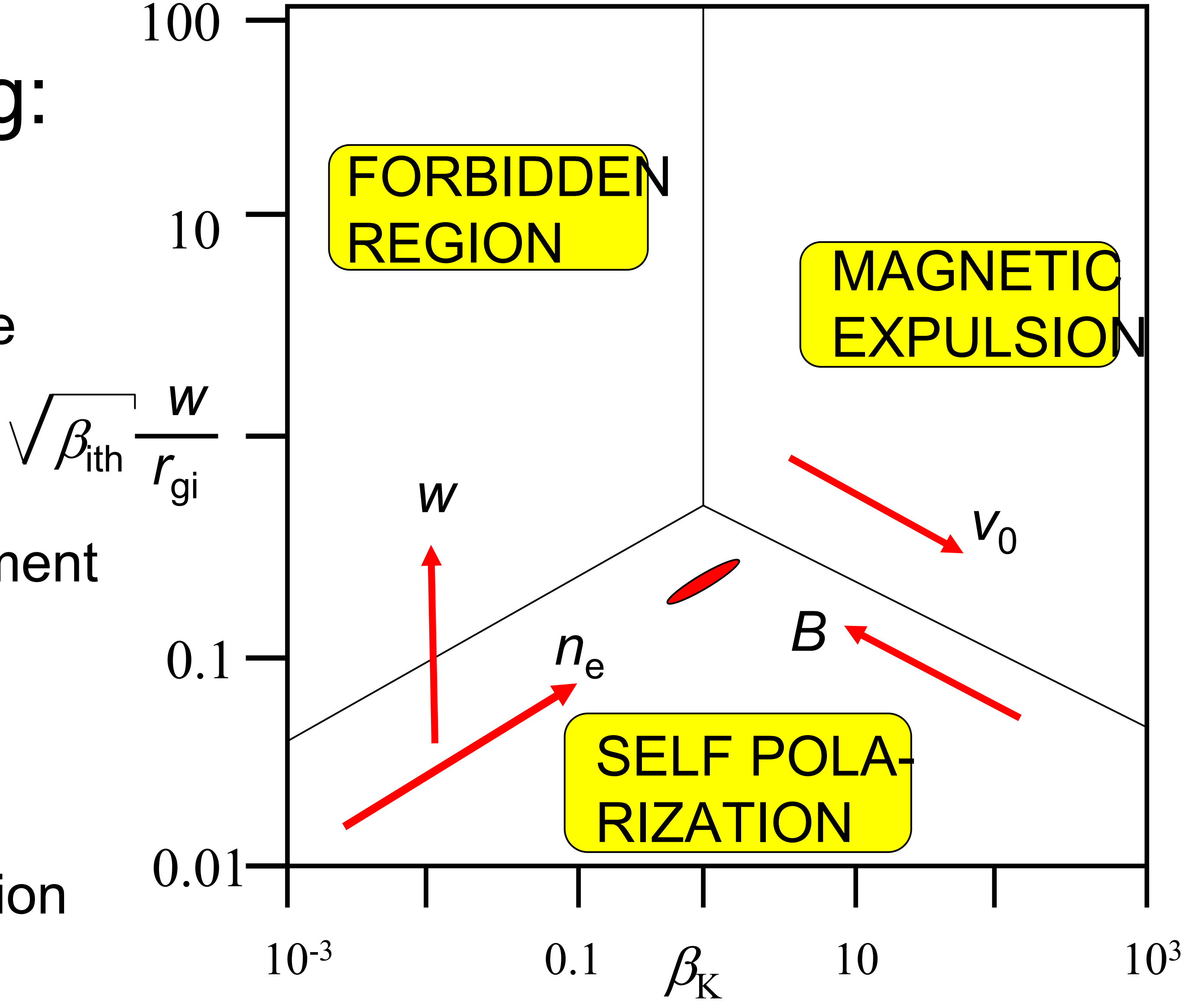


EXP. SIM.

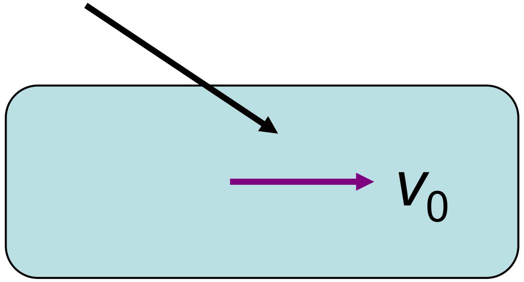
INCREASING THE PARAMETERS? (one at a time, still K=2.3)

Surprising: no lower limit on n_e

In our experiment we could increase B or reduce v_0 to approach the forbidden region



Towards a fluid description. This is hampered by the fact that we only have measurements in one small region, 3 cm beside the middle of the stream. However, we believe them to be representative for the whole upper part of the stream



We can

(1) Estimate the local parameters in this position

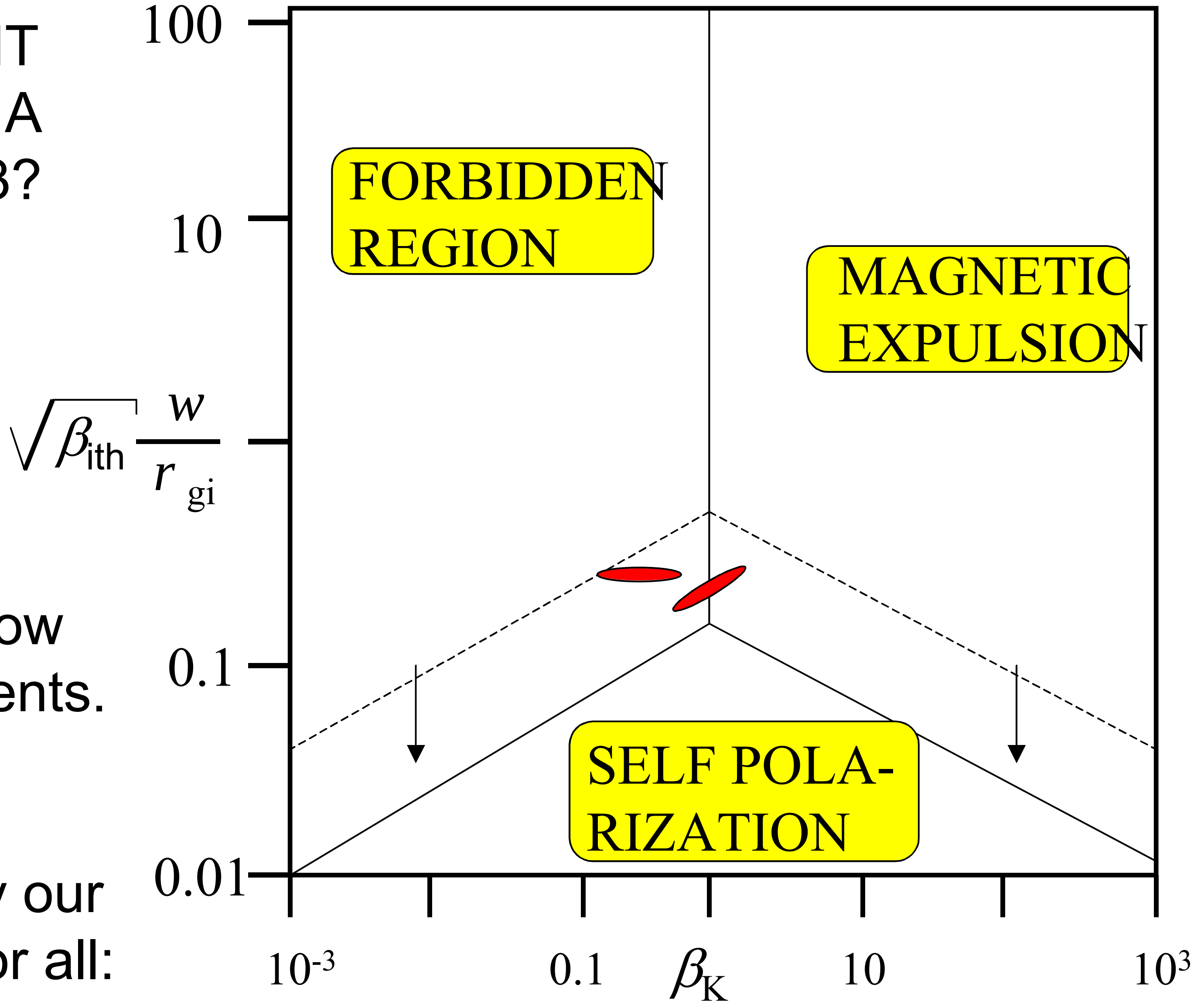
$(\eta_{\mathrm{EFF}}, D_{\mathrm{B}}, \nu_{\mathrm{EFF}})$

(2) Test the assumption: ”these parameters are global” against data (magnetic Reynolds number R_{M}, magnetic diffusion time τ_{B})

(3) Postuate a relation $\eta_{\mathrm{EFF}}(i/i_{\mathrm{thr}})$, calculate magnetic profiles, and compare to measurements.

QuickTime och en
YUV420 codec-dekomprimerare
krävs för att kunna se bilden.

REDUCING ANOMALOUS TRANSPORT TROUGH INCREASING CRITICAL CURRENT DENSITY BY A FACTOR OF 3? (K = 9))



This would show up in experiments.

Next: let us try our value K=2.3 for all:

THE ONE FLUID DESCRIPTION CONTAINS AD HOC ASSUMPTIONS, BUT:

The experiment corresponds to extremely high effective collision frequencies (10 times lower hybrid) and magnetic diffusion times (much higher even than Bohm diffusion)

Altough wave measurements are only made in on position, extrapolations (assuming the same mechanisms in the whole plasma) agree with observations.