ELECTROSTATIC POTENTIAL FORMATION DUE TO A LARGE DIP IN THE MAGNETIC FIELD WITH APPLICATION TO FRC CONFINEMENT

by

S. E. Parker

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Electrostatic Potential Formation Due to a Large Dip in the Magnetic Field with Application to FRC Confinement

S. E. Parker

I. Introduction

Electrostatic effects may explain the enhanced plasma confinement observed in the open field line region of field-reversed configurations.[1] We are studying the formation of electrostatic potentials due to nonuniform magnetic fields. This type of phenomenon is being modeled using particle simulation. Our two dimensional (x,y) electrostatic particle code, ES2 has been used to study the formation of electrostatic potentials due to magnetic wells and peaks with an injected flux of well magnetized electrons and weakly magnetized ions. These results are being used to help interpret the electrostatic potential contours outside the separatrix of a FRC, which are really cylindrical, (r,z). These potentials may explain the anomalously high ion confinement in the FRC edge layer. Our work naturally follows from the qualitative description of electrostatic effects on FRC confinement given by L. C. Steinhauer.[1]

II. Review of FRC Edge Layer Characteristics

Plasma confinement outside the separatrix of FRC's as observed by experiment is not consistent with what is expected from fluid models.[1,2] These discrepancies are as follows:

1) The thickness of the edge layer is a few times larger than the ion gyroradius and sheath confinement times are a few times larger then the predicted ion thermal transit time from free streaming along the open field lines.

2) The overall confinement time, τ_E, with FRC length does not scale as predicted by fluid models. The MHD model predicts $\tau_E \propto l$, where l is the length of the FRC. The experimental results show scaling like $\tau_E \propto (l)^a$, where $a \sim 0.5 - 0.7$.

3) The magnetic flux of the escaping plasma is greater in the sheath region than in the jet region: $\langle \phi \rangle_{sheath} > \langle \phi \rangle_{jet}$

4) The velocity in the jet region is larger then the bulk thermal speed (greater than a factor of two).

III. Steinhauer's Hypothesis

Steinhauer has suggested that an electrostatic potential structure is the most likely candidate to explain the anomalous confinement in the FRC Edge Layer.[1] The potential structure that he proposes is sketched in Figure 2, along with the magnetic field in the z-direction along the edge layer. In the minimum B region outside the separatrix, ions are weakly magnetized, but electrons are still strongly magnetized. The ions then can diffuse across the field lines. The electrons are confined to the field lines, but have much higher mobility parallel to B. This situation is similar to the magnetic configuration and potential formation in a cusp.[3] The potential structure is symmetric about the z-axis. The ions that flow across B cause formation of a potential peak that confines ions axially in the sheath. Then there is an inner negative potential channel formed by the electrons well confined to the field lines. This potential well accelerates ions out axially that are in the inner part of the sheath. This acceleration gives rise to the fast jet velocity and smaller magnetic flux in the jet.

IV. Computer Simulation

We are working to develop a simulation model that gives us better understanding of this mode of confinement in the FRC edge layer. A 2d electrostatic particle code has been developed,[4] which can be used to study electrostatic potentials formed by nonuniform magnetic fields. The simulation experiment is sketched in Figure 1. Ions and electrons are injected from a portion of the left boundary with a half Maxwellian velocity distribution. The right wall is at the floating potential. There are two current carrying rods in the center to cause a dip in the magnetic field. The rods are permeable and have no other effect on the plasma. The magnetic field is external and fixed. The electrons are well magnetized and the ions are weakly magnetized.

The results are show in Figures 3 through 6. These snapshots are taken at $t = 200$. Note that the ions have large gyroradii, $r_{gi} \sim 1-5$. Whereas, the electrons have relatively small gyroradii, $r_{ge} = \frac{1}{10} r_{gi}$. Figure 4 shows overall confinement of ions. Figure 6 shows the positive potential peaks formed by the higher mobility of the weakly magnetized ions. The simulation parameters are listed in the following table.

Simulation Parameters

Initially Empty	Electron Thermal Velocity=1.
Size=64X64	Ion Thermal Velocity=0.1
$\Delta t = 0.2$	$m_e = e = 0.060$
$\Delta x = 1.$	$m_i = 100\ m_e$
$\vec{B}_0 = 8.0\ \hat{x}$	$\epsilon_0 = 1.$
$\vec{B}(32,32) = 2.0\ \hat{x}$	Open External Cicuit
Injection Region Width=6.	

V. Conclusions and future work

We have been able to simulate the formation of positive potential peaks similar to those proposed by Steinhauer to help explain ion confinement in the edge layer of FRC's. We are looking for possible improvements in our model. Plans are under way to model the magnetic field and boundary conditions of the edge layer more accurately.

References

[1] L. E. Steinhauer, "Electrostatic Confinement in the Edge Layer of Field-Reversed Configurations", Phys. Fluids **29**, 3379 (1986).

[2] W. T. Armstrong *et al*,"Field-Reversed Experiments on Compact Toroids", Phys. Fluids **24**, 2068 (1981).

[3] N. Hershkowitz, J. R. Smith, and H. Kozima, "Electrostatic Self-Plugging of a Picket Fence Cusped Magnetic Field", Phys. Fluids **22**, 122 (1979).

[4] 2d "ES2 User's Manual - Version 1", K. Theilhaber, E.R.L. Report, Univ. of Calif., Berkeley, May 1987.

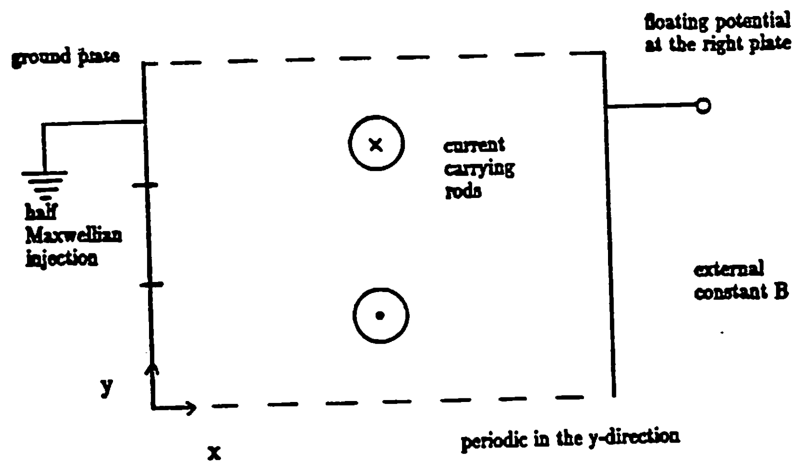

Figure 1. Simulation model

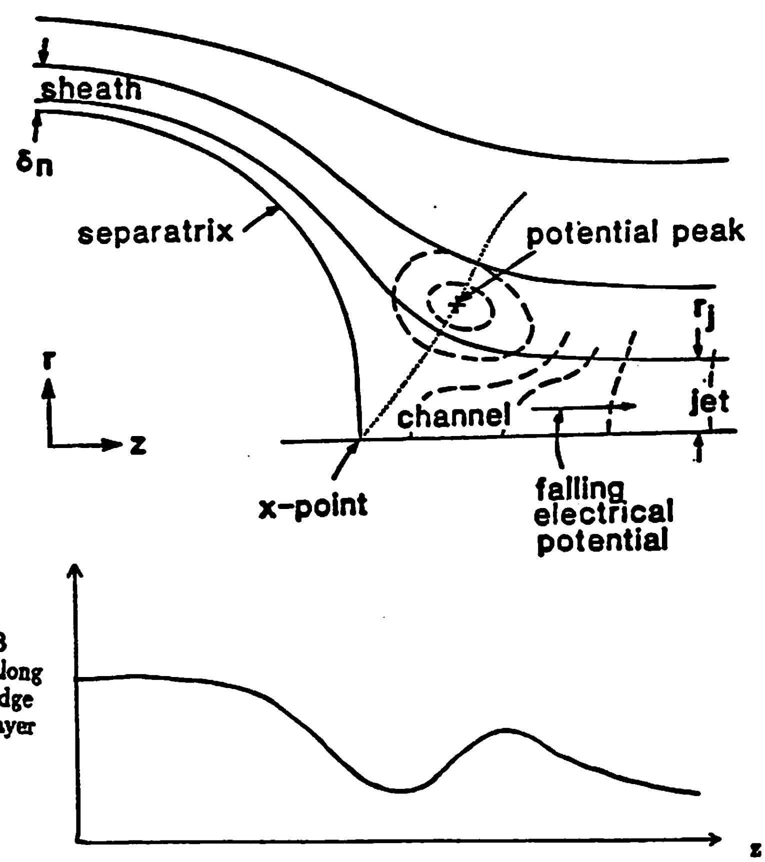

Figure 2. Field-Reversed Configuration
taken from Stienhauer reference 1.

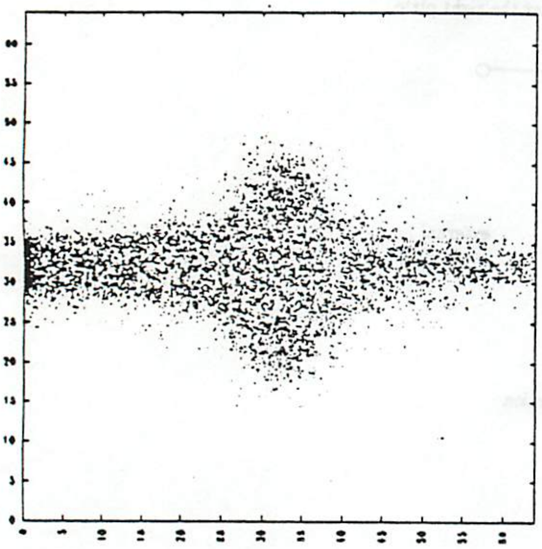

Figure 3. Position of ions (x,y)

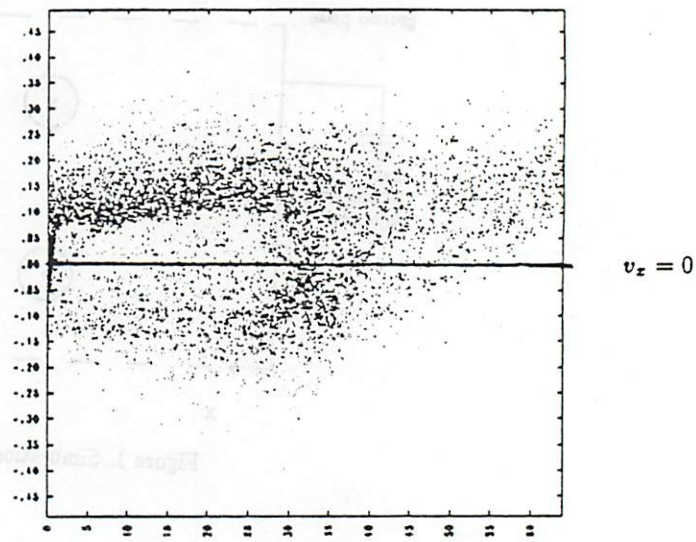

Figure 4. Phase space for ions (x, v_x)

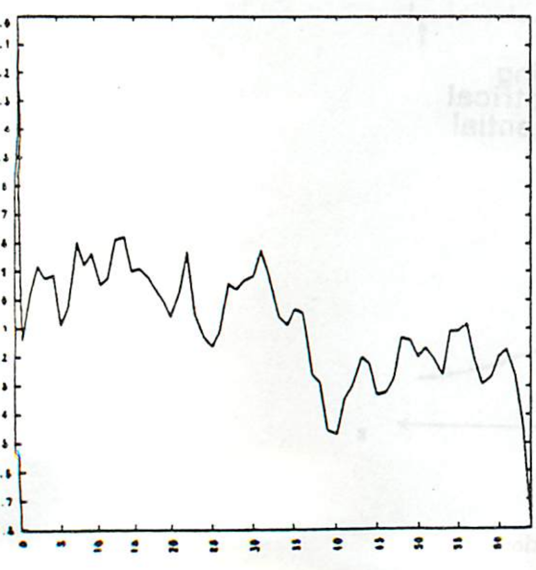

Figure 5. Electrostatic potential $\phi(x, y = 32)$

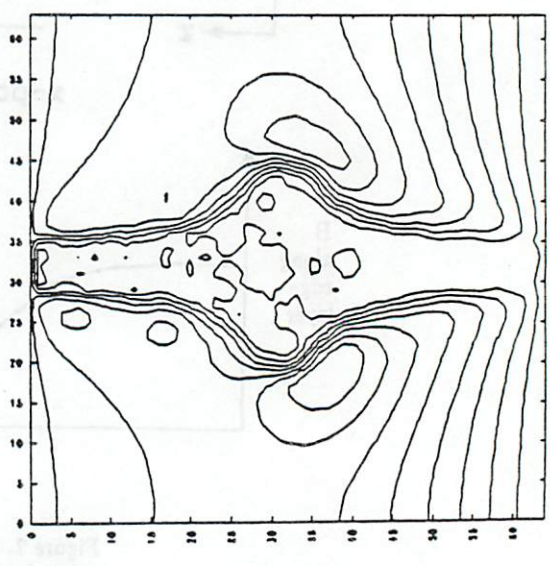

Figure 6. Contour plot of $\phi(x, y)$