

PARTICLE DYNAMICS IN FRC

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In this work we consider dynamics of particles in FRC in order to search influence of various phenomena on collisionless losses of protons out of trap .

Two important facts of FRC systems point out the necessity of numerical analysis of particles dynamics in FRC plasma . Firstly, it is well-known that particles and energy transport in FRC plasma is convective and one is determined with collisionless processes. Consequently, investigation of influence of different phenomena on particles dynamics and particles losses is necessary . Such investigation allows to connect directly possible processes inside FRC plasma and particles losses. Secondly, both FRC magnetic field and plasma density are strongly inhomogeneous . Consequently, it is in general impossible to obtain simple formulas for charged particles and to estimate particles losses .

The main cause of particles and energy losses out of FRC plasma is collisionless losses connected with different features of FRC plasma . They are : type of magnetic system , presents of electrostatic and electromagnetic waves etc.

Consequently analysis of collisionless dynamics of particles in FRC plasma is important problem . A number of authors investigated motion of particles inside FRC magnetic system [1, 2] . In [1] theoretical analysis of particles dynamics is carried out and condition of stochastization for particles are obtained . In [2] for Hill's vortex magnetic configuration confinement conditions are obtained .

In this work we present some numerical results taking into account the influence of other factors : initial dynamics conditions for particles , given azimuthal electrostatic field , given electromagnetic field propagating inside FRC plasma.

In contrast with [2], we use L. Steinhauer magnetic field model [3] . The following expression for flux function ψ inside separatrix [3] :

$$\psi(r, z) = \left(\frac{3}{2}\right)^{1/2} \frac{x_s B_w r^2}{2} \left(1 - \frac{r^2}{a^2} - \frac{z^4}{b^4}\right) \quad (1)$$

Let's consider some results .

1. Motion of particles in FRC . Fig. 1a shows the adiabatic motion of low energy proton. Such motion is restricted inside a narrow closed band . Thus collisionless particles is

remained inside magnetic trap endlessly . Fig. 1b shows the motion of high energy particles . They move through the whole internal space of traps . The important feature of such particles is finite time of stay of particles inside FRC . Thus time is more less then relaxation time for typical conditions of FRC plasma . Naturally for considered samples canonical angular momentum and energy of particles are conserved .

2. Influence of azimuthal electrostatic field (Fig. 2a) . It is shown that P_θ and E_θ are varied (Fig.3,4) i.e. motion is non-adiabatic . This results in losses of particles .
3. Influence of oscillations in FRC plasma (Fig. 2b).

Therefore it shows an essential influence of azimuthal electric field and electromagnetic waves on particles dynamics in FRC system . Taking into account of electric field results in change P_θ . But particles confinement in FRC system is improved for $E \neq 0$ in comparison with $E = 0$.

Taking into account electromagnetic waves inside plasma also results in change of P_θ and confinement particles is also deteriorate.

It is shown essential influence of mentioned fields on particles dynamics and particles losses .

References

- [1] J.M. Finn: Plasma Phys. **21**, 405 (1979)
- [2] M.Y. Wang, G.H. Miley: Nuclear Fusion **19**, 39 (1979)
- [3] Loren C. Steinhauer: Phys. Fluids **B2**, 3081, (1990)

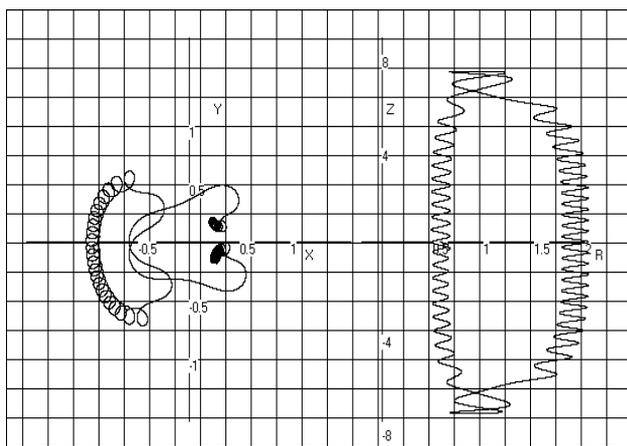


Fig. 1a. X-Y and R-Z plane for the 140eV protons.

$B_w=6.7T$, $a=1m$, $b=8m$, $X_s=0.25m$

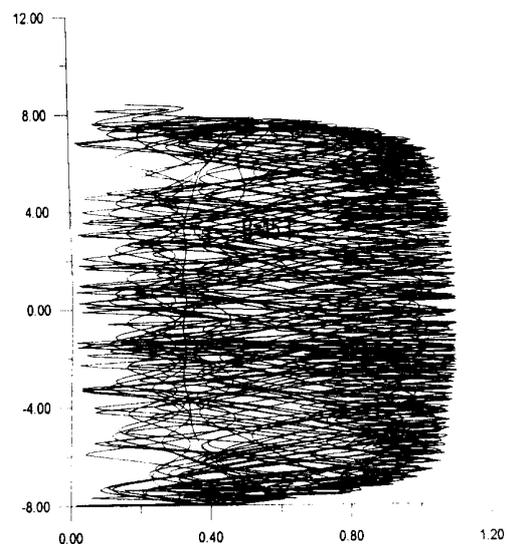


Fig. 1b. Stochastization occurs.

14 MeV proton in Artemis-L magnetic field (R-Z plane)

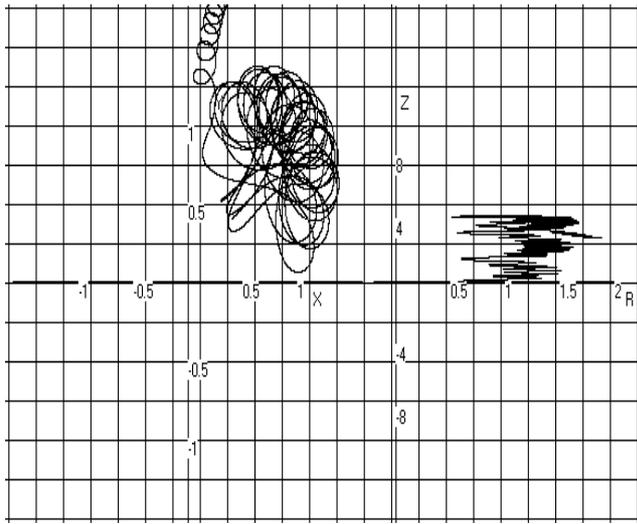


Fig. 2a. X-Y and R-Z plane for the 140eV protons.
 ($E=1e4$ V/m), $B_w=6.7T$, $a=1m$, $b=8m$, $X_s=0.25m$

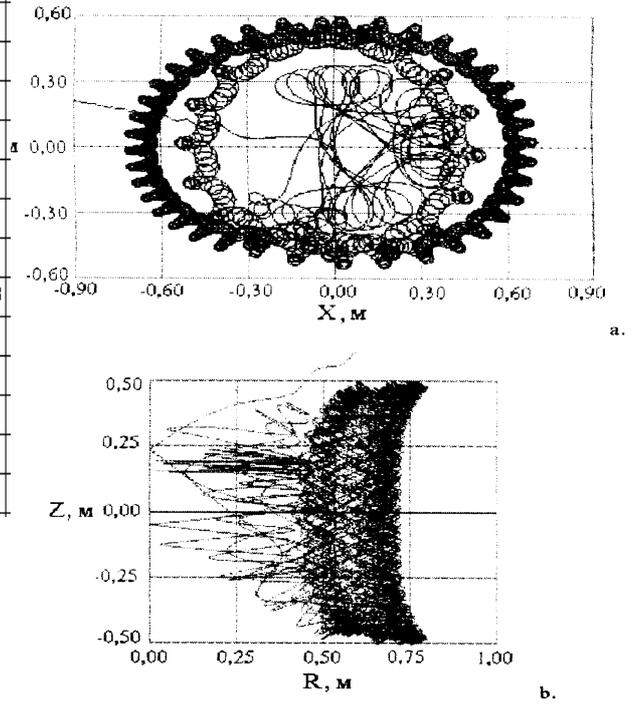


Fig. 2b. Fig.3a X-Y and R-Z plane for the 140keV proton. $B_w=2T$, $E_{mx}=0.6e6V/m$, $\omega_x=1e7H$, $a=0.5m$, $b=0.7m$

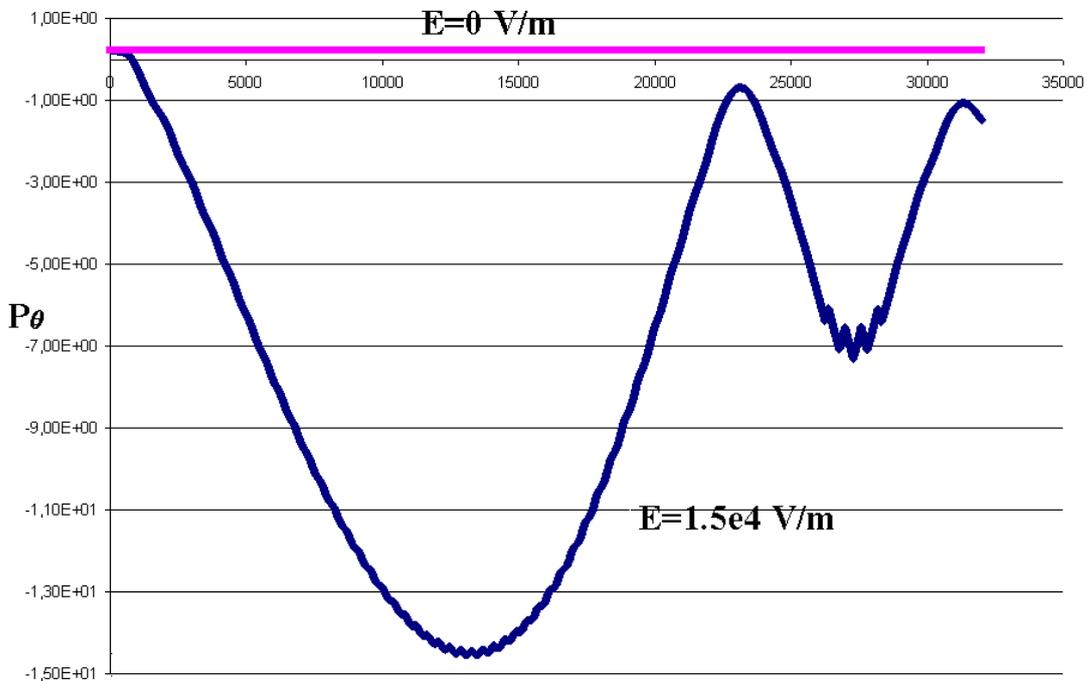


Fig. 3. Canonical angular momentum $P_\theta(t)$ for $E=0$ and $E=1.5 \cdot 10^4$ V/m.
 $B_w=6.7T$, $a=1m$, $b=8m$, $X_s=0.25m$

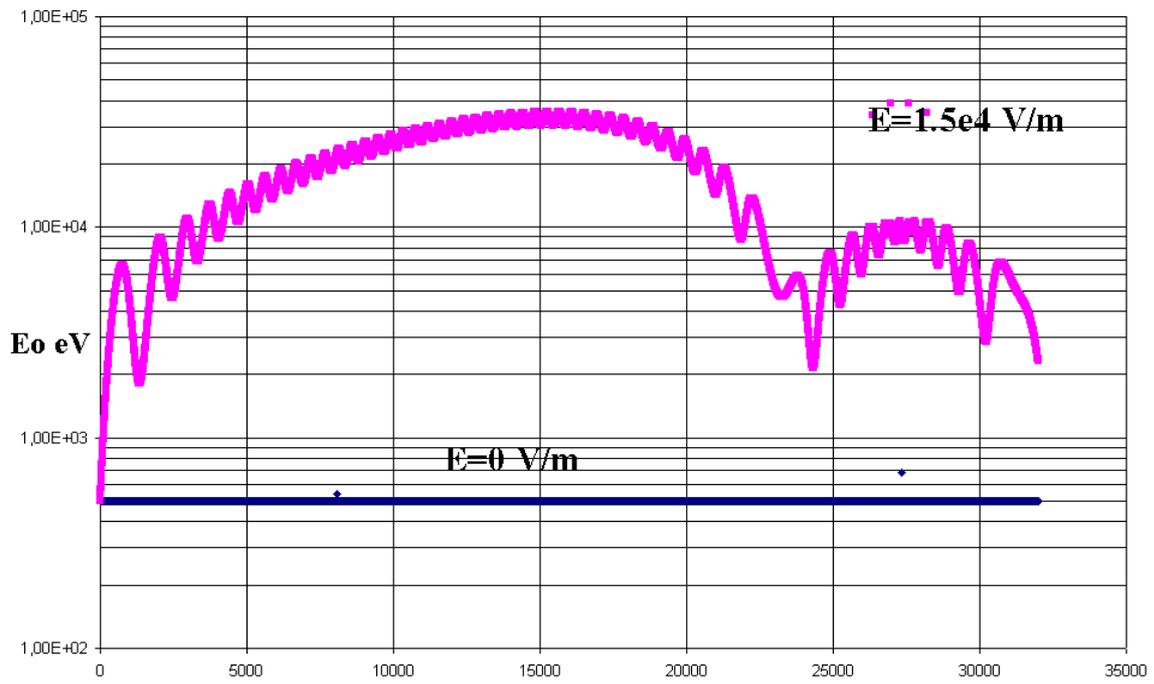


Fig. 4. Energy proton $E_o(t)$ for $E=0$ and $E=1.5 \cdot 10^4$ V/m.
 $B_w=6.7T$, $a=1m$, $b=8m$, $X_s=0.25m$