§11. Particle Confinement due to Adiabaticity and Mirror Effect in D-^{3}He/FRC Plasmas

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In collisionless FRC (Field-Reversed Configuration) plasmas, we often regard the condition of particle loss that particles have negative canonical angular momentum (P_θ) in the case magnetic flux inside the separatrix is positive. However, particles will not always be lost because of adiabaticity and mirror field effect. We study particle loss for the equilibrium configuration as mentioned below. Along the guiding center for negative $P_{//}$ -particles, the point of minimum magnetic field (B_{min}) is located near the x-point and the maximum one (B_{max}) is assumed at the edge of an FRC device. Particles with negative $P_{//}$ can be gyrating in the neighborhood of the separatrix and nearly conserving the magnetic moment. These adiabatic particles are confined around the field minimum. A criterion of such confinement is described as

$$\sin \Theta_0 \geqq (B_{min}/B_{max})^{1/2} = (1/R)^{1/2} \qquad (1)$$

$R \equiv B_{max}/B_{min}$: mirror ratio

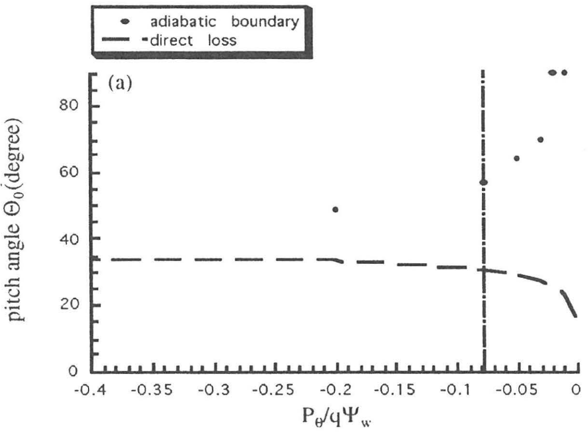
Θ_0 : pitch angle at the minimum field.

As shown by R.J.Hastie *et al.* [1], however, abrupt step-like changes in the particle's magnetic moment are observed in the vicinity of the field minima. This jump sometimes causes to change the average value of magnetic moment. We call these changes "nonadiabaticity". Due to nonadiabatic effect, the average magnetic moment or pitch angle decrease.Therefore, there is some possibility that particles with large pitch angle are lost passing through the loss cone.

The investigation of the boundary between adiabaticity and nonadiabaticity shows the confinement region on the P_θ and Θ_0 plane. In order to find this boundary ,we solve the exact equation of motion. A behavior of magnetic moment is shown from this calculation and serve us a knowledge of this boundary.

Figure shows the confinement region for 14.7 MeV protons (a) and for 100 keV bulk ions (b) with negative $P_{//}$. The symbols • are adiabatic boundary, above which particle plays adiabatic behavior, and dashed lines mean Θ_0 from eq.(1). Vertical dotted lines indicate that the accessible domain grazes the separatrix critically. From these figures one can obtain bulk ions are confined better than fusion proton.

From our result, particles can be confined even if they have no confinement region closed within a definite region. Collisional effects, however, should modified the condition of adiabatic confinement.



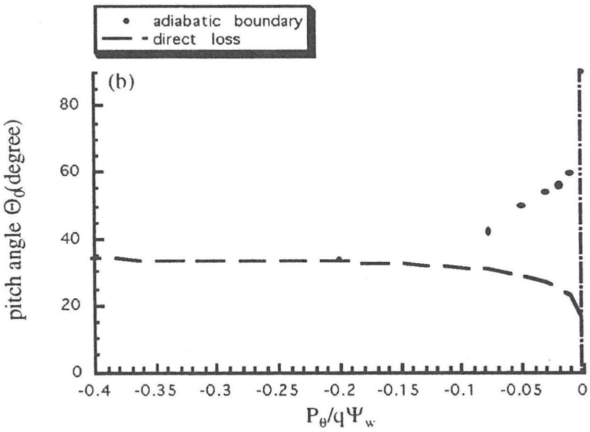


Figure adiabatic boundary
(a)14.7MeV (b)100keV
Ψ_w: magnetic flux on the conducting wall

References

1) Hastie, R.J., Hobbs, G.D. and Taylor, J.B., Proc.3rd Int.Conf.on Plasma Physics and Controlled Nuclear Fusion Research, vol.1, Vienna, (1968) 389.