Chaotic long orbits of energetic positrons in a dipole magnetic field configuration

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In a toroidal dipole magnetic field configuration, one can realize simultaneous trapping of positively and negatively charged particles. Investigations on antimatter non-neutral plasmas [1] and fusion-oriented high temperature plasmas [2,3] are being conducted or planned in levitated dipole field experiments. In the limit of a small gyro radius, charged particle behavior in the dipole field is an integrable system consisting of three periodic motions. However, in general, because there are only two constants of motion, namely the canonical angular momentum P_θ and the total energy H, the particle motion is non-integrable in the dipole geometry [4]. This means that particles are not always trapped permanently on magnetic surfaces. A remarkable example of transport phenomena across the closed dipole field lines is the inward diffusion and acceleration of charged particles [5] driven by slow (~ toroidal precession frequency of particles) fluctuations. These phenomena, realized through breakdown of the conservation of the third adiabatic invariant Ψ, are widely observed in planetary magnetospheres and laboratory experiments [2,3,5]. Here spontaneous formation of peaked density profiles is one of the key characteristics. By focusing on phenomena with shorter time scales, on the other hand, there is another non-adiabatic effect related to the first and second adiabatic invariants μ and J. In a strongly inhomogeneous dipole field, μ and J are often not conserved because of the resonance between gyro and bounce motions [4]. This enables chaotic long orbit lengths of particles. When high energy positrons are directly injected from an isotope source located at the edge confinement region of the dipole trap, the injected positrons make multiple toroidal circulations with chaotic motions before the recombination at the source. In this contribution, we numerically and experimentally study the behavior of energetic positrons from a ^{22}Na source in the RT-1 device [6]. Numerical orbit analysis showed that considerable ratio of these high-energy positrons has chaotic long orbits in the confinement region of RT-1. Experimental results with a 1 MBq (27 μCi) ^{22}Na source were consistent with the numerical calculations. Assuming the use of a more intense positron source, one can steadily create toroidal positron cloud in a dipole field trap with this method.

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