Pseudoclassical and Anomalous Containment in FM-1

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Abstract: Particle confinement times well in excess of one second are observed on FM-1. Below about 1 eV the confinement time scales as T_e^m ($m \sim 3/4$), while above 1 eV the confinement time scales as T_e^n ($n \sim -1$).

The parameter dependence of the particle containment time in the FM-1 spherator on plasma density, electron temperature and toroidal magnetic field has been determined. FM-1 is operated with a superconducting, levitated, internal ring giving a magnetic configuration similar to the first levitated spherator (LSP). [1] Comparable poloidal and toroidal fields strengths in FM-1 produce high magnetic shear giving a stable plasma equilibrium. Measurements were made for plasma densities between $2.5 \times 10^{10} \text{ cm}^{-3}$ and $2.0 \times 10^{11} \text{ cm}^{-3}$, and electron temperatures between 0.1 eV and 5 eV. The results can be compared to those obtained on LSP for similar plasma parameters.

The plasma is produced with electron cyclotron resonance heating (ECRH) from a helium filling pressure of 4×10^{-6} Torr with an electron temperature of about 5 eV. The electron temperature in the afterglow of the ECRH plasma is controlled by the use of nonresonant resistive microwave heating (above resonant). The electron cooling in the afterglow is dominated by electron-ion coupling along with ion-neutral interactions. The electron temperature is measured above 2 eV with excitation light, between 0.1 and 5 eV with Langmuir probes and below 0.2 eV with recombination light.

The particle confinement times were determined from the density decay rates measured with 4 mm and 8 mm microwave interferometers. Above 2 eV ionization became important and was corrected for by measuring the ionization light. To exclude the possibility of ionizations by high energy electrons

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produced during the ECRH plasma formation a 6 mm pellet was dropped through the plasma with a transit time long enough to allow collection of any high energy electrons present. The pellet had no observable effect on the plasma decay rate.

The results of the confinement time measurements on FM-1 are plotted in Fig. 1 as a function of electron temperature for various plasma densities. Also shown in Fig. 1 are confinement times measured in LSP [1] at a density of $2 \times 10^{11} \text{ cm}^{-3}$. At electron temperatures below 1 eV the confinement time improves with increasing

electron temperature as T_e^m with $m \sim 3/4$. In this temperature

range the confinement time decreases with increasing plasma density approximately as n_e^{-1} . This result suggests classical collisional diffusion however the diffusion rate exceeds the classical rate by about a factor of 5 (pseudoclassical diffusion). [2] At electron temperatures above about 1 eV the confinement time decreases with increasing electron temperature as approximately T_e^{-1} . In this temperature region the confinement appears to be independent of plasma density. This temperature and density dependence of the confinement at higher electron temperatures suggests the so-called Bohm diffusion; however, the diffusion rate falls short of the Bohm diffusion rate by about a factor of 300.

The confinement time on FM-1 at a density of $2 \times 10^{11} \text{ cm}^{-3}$ can be compared to the results obtained on LSP at the same density. LSP was a smaller device than FM-1 with a magnetic field magnitude of about one-half that used

Fig. 1. Particle confinement time as a function of electron temperature with density as a parameter for FM-1 and LSP

on FM-1. The lines shown on the graph for this density, scale between the two devices approximately as $a^2 B$ and $a^2 B^2$ for the T_e^{-1} and $T_e^{3/4}$ curves respectively; where a is the density scale length and B the magnetic field magnitude.

Recombination light measurements were used to determine the electron-ion recombination rate. Recombinations were found to be important only below 0.15 eV. The recombination rate at 0.1 eV represented 30% of the total particle decay rate.

Experiments on LSP demonstrated that impurities can have a detrimental effect on plasma containment. [3] Results on FM-1 corroborate the findings on LSP; however, when FM-1 was operated with good background pressure

(2×10^{-8} Torr) the effect of impurities on containment was unimportant.

To determine the effect of varying the toroidal magnetic field the confinement time was measured as a function of electron temperature for two magnitudes of the toroidal field.

The results of this measurement are shown in Fig. 2. The confinement

time was measured for a reduced tor-

oidal field ($I_T/I_P = 1/4$) and compared to the result obtained for

the standard running condition ($I_T/I_P = 1$), where I_T is the axial current producing the toroidal field and I_P is the poloidal ring current. The variation in the toroidal field had little effect (30%) on the pseudoclassical confinement but had a strong effect (350%) on the T_e^{-1} confinement.

The most important question concerning the containment in FM-1 is the loss mechanism responsible for the T_e^{-1} dependence of confinement time at

Fig. 2. Particle confinement time as a function of electron temperature for two magnitudes of the toroidal field.

higher electron temperatures. Fluctuations and/or field asymmetries are likely to be responsible for the loss at higher temperatures. Field asymmetries were shown to produce enhanced loss on LSP at higher electron temperatures. Studies are underway to determine the extent to which asymmetries are responsible for the observed loss in FM-1.

Density fluctuations are observed at higher temperatures in FM-1, and correlations between density and electric field are being measured to determine the importance of these fluctuations.

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