with the exception of channels with formation of one π^0 meson[1], were determined by starting from the different cross sections of the corresponding (with respect to multiplicity) reactions with charged pions and statistical isospin coefficients [10].

To estimate the upper limit of the production cross section of the predicted resonance, the experimental spectrum was approximated by a sum of a background curve and a Gaussian curve. The unknown parameters were the relative contribution of the resonance N and its mass. The width of the Gaussian distribution was fixed and amounted to 16 MeV (the experimental resolution in the given mass interval). The value obtained for the contribution of the resonance N' turned out to be close to zero. At the 90% confidence level, the number of $N' \to p + \gamma$ decays is less than 1.7% of the total number of events in the spectrum, corresponding to 10 events.

To determine the cross section for the production of the resonance N', we used the total cross section of the reaction $\pi^- p \to \pi^- p$ + "neutral particles," which amounts to 3860 ± 160 μb[2] at $P_{\pi^-} = 5$ GeV/c. At the 90% confidence level, the upper limit of the cross section for the production of the resonance N', $\sigma(\pi^- p \to N'(N' \to p\gamma)\pi^- + k\pi^0,\ k \geq 1)$, is equal to 70 μb.

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EXPERIMENTAL INVESTIGATIONS OF CONTAINMENT OF A HOT-ELECTRON PLASMA IN THE "URAGAN" STELLARATOR

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Theoretical and experimental investigations carried out recently have led to considerable progress in the study of plasma transport in stellarators. In

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[1] The cross sections of the reactions $\pi^- p \to \pi^- p \pi^0$, $\pi^- p \to p\rho^-$, and $\pi^- p \to \Delta^+(1236)\pi^-$ at 5 GeV/c were obtained by interpolating the data for 4 GeV/c [6 - 7] and 6 GeV/c [11].

[2] This quantity was determined from the data of [7, 11, 12].

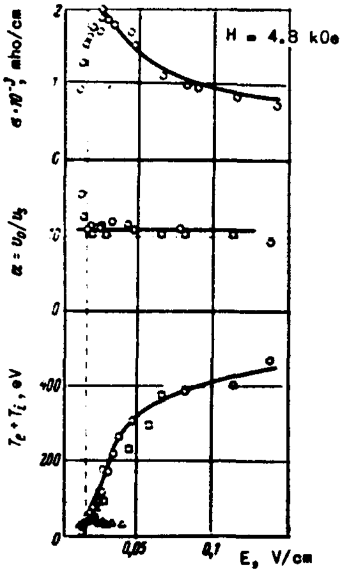

Fig. 1. Dependence of the electric conductivity of the plasma, the relative velocity of the current drift, and the "diamagnetic" temperature (circles) on the electric field intensity in the plasma. For comparison, the figure shows the electron temperature determined from the microwave radiation (squares), from light scattering (diamond) and from the Coulomb electric conductivity of the plasma (triangles).

a number of model experiments with low-density and cold plasma [1 - 3], satisfactory agreement was obtained for the particle lifetimes with calculations performed in [4, 5].

We present here the results of an investigation of containment of an electron-hot collisionless plasma in the "Uragan" stellarator, with a steep helical winding [6]. The shear was 0.1, and the angle of twist of the force line on the outer magnetic surface with average radius 6.8 cm was 1.7π.

1. Heating and anomalous electric conductivity of the plasma. A high electron temperature was ensured in the described experiment by turbulent heating with longitudinal current in the regime of ion-acoustic anomaly of the electric conductivity of the plasma [7, 8]. The experiments were performed in the longitudinal electric field range $0.1 < E/E_0 < 1.0$ and at a magnetic field $\omega_{He}/\omega_{0e} \approx 1$. Here $E_0 = 1.3 \times 10^{-12} n/T_e$, ω_{0e} is the electron plasma frequency, and ω_{He} is the gyrofrequency of the electrons. Under these conditions, the velocity of the current drift of the electrons was stabilized at the level $v_0 \approx 10 v_s = 10\sqrt{ZT_e/M_i}$ (see Fig. 1), and intense heating of the electrons was observed, up to a temperature on the order of 0.5 keV and above. The electron temperature of the plasma was determined from the Thompson scattering of laser light and from the diamagnetic signal. The ion temperature, determined from Doppler broadening of the He II line, was of the order of 10 - 20 eV and depended little on the discharge parameters, so that we always have $T_e \gg T_i$. Investigations of the microwave radiation at the frequency ω_{0e} have shown that the spectrum, level, and time behavior of this radiation corresponds to thermal radiation. This probably indicates that there are no "runaway electrons."

Thus, the values of the electron temperature, obtained by three independent methods, turned out to be in good agreement with one another (see Fig. 1).

At discharge currents $I_{dis} \leq I_{cr}$, the measured values of the total kinetic energy of the plasma satisfy the empirical relation

$$nT_e \approx 4{,}5\cdot 10^{12}\, I_{dis}\, \mathcal{H}_0 \left(a_0^2 \frac{i}{2\pi}\right)^{1/2}.$$

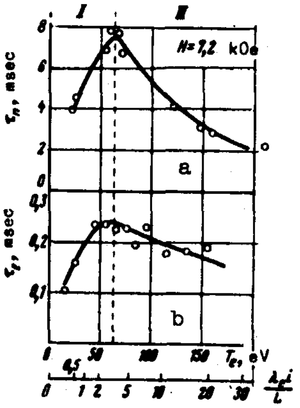

Fig. 2

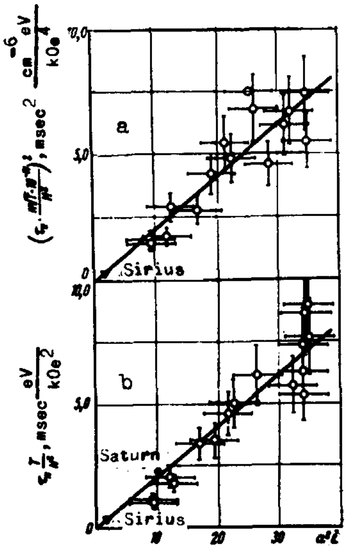

Fig. 3

Fig. 2. Dependence of the energy lifetime of the plasma and the lifetime of the particles on the electron temperature of the plasma. Here λ_e is the mean free path of the electrons as determined from the Coulomb conditions, L the total length of the plasma column, and i is the twist angle of the force line (plasma density 6×10^{12} cm^{-3}, $a_0 = 6.8$ cm, $i = 1.5\pi$).

Fig. 3. Dependence of the normalized particle lifetime and of the energy of the parameter $(a^2 i/2\pi)$. For comparison, we show data obtained with the stellarators "Saturn" [11] and "Sirius" [12].

Here and throughout the plasma density n was in the range $(0.2 - 0.8) \times 10^{13}$ cm^{-3}, the plasma electron temperature T_e varied from 50 to 500 eV, the discharge current I_{dis} changed from 0.5 to 10 kA, the radius of the outer magnetic surface a_0 changed from 8 to 5 cm, the twist angle on the outer magnetic surface i ranged from 0.2 to 1.7π radians, and the longitudinal field $\mathcal{H}_0$ ranged from 5 to 10 kOe. The values of a_0 and i were determined experimentally during the adjustment of the magnetic system with the aid of an electron beam [9]. The critical current I_{cr} depends on the magnetic field: $I_{cr} = 0.7\mathcal{H}_0$ (at $a_0 = 6.8$ cm and $i = 1.5\pi$).

2. Energy lifetime. The energy lifetime of the plasma (disregarding loss to radiation) was determined from measurements of the total plasma energy (by diamagnetism) and the input power. The dependence of the energy lifetime on the electron temperature is shown in Fig. 2b. τ_E increases with increasing temperature in region I and decreases approximately in proportion to $T_e^{-1/2}$ in region II. In this region, the measured values of the energy lifetime in milliseconds agree well with the empirical formula (see Fig. 3a)

$$\tau_E \approx (3 - 5)\cdot 10^{10} \frac{\mathcal{H}_0^2 (a_0^2 i/2\pi)^{1/2}}{n_e T_e^{1/2}} .$$

The absolute value of τ_E reached $(5 - 6)\tau_B$.

3. Particle lifetime. The particle lifetime was determined from the balance equation of the charged particles by measuring the electron density

and the contribution of the ionization of the atoms and singly-charged ions of helium. A plot of τ_n obtained in this manner is shown in Fig. 2a. The decrease of τ_n in region II is proportional to T_e^{-1} and is independent of the electron density. All the results of measurements of τ_n in region II can be represented by the empirical relation (see Fig. 3b)

$$\tau_n \approx (0.2 - 0.3)\frac{\mathcal{H}_0^2}{T_e}\left(a_0^2 \frac{i}{2\pi}\right) .$$

The absolute value of τ_n lies in the range $(50 - 60)\tau_B$.

4. Conclusion. The main result of this paper is the experimental investigation of the functional dependence of the containment time of a hot-electron collisionless plasma on the discharge parameters and on the magnetic field intensity. Two regions were observed, with different functional dependences of the lifetime on the electron temperature of the plasma. The first region (T_e < 50 eV) probably corresponds to the Pfirsch-Schluter region [10], while the second region (T_e > 50 eV) corresponds to the Galeev-Sagdeev "plateau" [4].

In this region, we investigated experimentally for the first time the energy lifetime of a collisionless hot-electron plasma. The results show that in spite of the fact that the energy loss is determined here principally by the electronic component of the plasma, the energy lifetime differs noticeably from the particle containment lifetime both in absolute magnitude and in the discharge parameters

$$\frac{\tau_n}{\tau_E} \approx 10^{-11}\frac{n a_0 (i/2\pi)^{1/2}}{T_e^{1/2}} \approx 5 - 10.$$

The results of experiments on plasma containment in the stellarators "Saturn" [11] and "Sirius" [12] are in good agreement with the empirical relations obtained in the present paper.

In conclusion, the authors are deeply grateful to B.B. Kadomtsev, K.N. Stepanov, and S.S. Moiseev for interest in the work and for a fruitful participation in the discussion of the experiment.

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EXCITATION OF SPONTANEOUSLY FISSIONING ISOMER STATES ^{239}Pu AND ^{243}Am IN INELASTIC SCATTERING OF γ QUANTA

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An investigation of the mechanism of excitation of spontaneously fissioning isomer levels in different nuclear reactions is one of the principal methods of studying the nature of these states [1 - 4].

As shown in a number of papers [5, 6], the fission barrier has a complicated structure and the spontaneously fissioning isomer states are interpreted as the lower levels in the second potential well. Such a form of the barrier leads to the existence of two independent systems of levels and therefore the population of the states in the second well can result either from transitions from highly excited states of the nucleus, or from tunneling through the first barrier.

The energy of the quasistationary states in the second well usually lies in the 3 - 5 MeV range, and therefore to excite these levels it is tempting to use γ quanta whose energy can be regulated within any range. In the case of neutrons, the energy introduced by them always exceeds the binding energy ($\sim$6 MeV), and in (d, p) reactions the investigation is made complicated by the need for measuring the energy of the emerging particle.

We have investigated the inelastic scattering of γ quanta by the isotopes ^{239}Pu and ^{243}Am; this scattering leads to the formation of known spontaneously fissioning isomers with half-lives 8 and 6.5 msec, respectively [7]. The measurements were performed with the extracted beam from the microtron of the Institute of Physics Problems of the USSR Academy of Sciences, with 17 orbits, at electron energies from 7 to 11 MeV and an average current 20 - 25 μA.

The experimental procedure was described in our preceding paper [3]. The fission-fragment detector was a multifilament spark counter [8] surrounded by cadmium to protect it against thermal neutrons.

The targets weighed 2 mg each, with 95% enrichment.

The delayed-fission fragments were registered between the current pulses of the microtron with a delay of 2 - 3 μsec. To reduce the neutron background, the decelerating target was of aluminum 3 cm thick, and the γ-quantum beam was absorbed in a thick aluminum block after passing through the counter.

Control background measurements outside the γ-quantum beam have demonstrated the

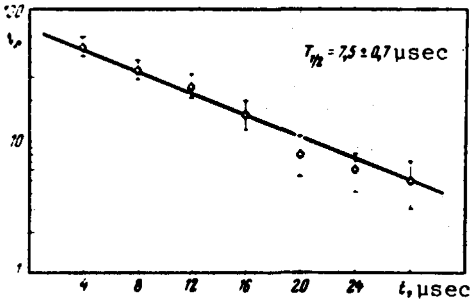

Fig. 1. Dependence of the number of fragments of the delayed fission (N_f) on the time (t) in the reaction ^{239}Pu(γ, γ')^{239mf}Pu at a γ-quantum end-point energy 11 MeV.

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