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1. Toponium

In the framework of nonrelativistic quantum chromodynamics, the quarks t and $\bar{t}$ are predicted to be able to form a quasi-bound state (toponium) near the $t\bar{t}$ pair production threshold, when the quark velocities are close to zero. An excess of $t\bar{t}$ pairs near the threshold compared to the expected value has already been observed in the ATLAS and CMS experiments at the Large Hadron Collider at CERN. The CMS collaboration has presented a new analysis of $t\bar{t}$ pair production at a center-of-mass energy of 13 TeV on the basis of a data array thrice as extensive as the previous one [1]. Final states with two charged leptons and at least two quark jets were selected, and spin correlations were traced. As a result, an excessive yield of $t\bar{t}$ pairs in the vicinity of the kinematic threshold of their production was confirmed. This enhancement can be explained by the formation of toponium, although alternative interpretations cannot be ruled out, including effects beyond the Standard Model, e.g., those with additional Higgs bosons. In addition, the new study confirmed the small divergence, revealed earlier, between the expected and measured values of spin correlations in $t\bar{t}$ pairs.

2. Superradiant transition in a magnon system

The effect of superradiation predicted by R.H. Dicke has recently attracted attention as applied to the interaction of atoms with an electromagnetic field in cavities, and the question of superradiant phase transitions upon matter-radiation coupling strengthening has been discussed. Such a transition is impossible for an electromagnetic resonator because of the presence of a diamagnetic term in the Hamiltonian of the system. But, as has been shown, the role of photons in magnon systems can be played by the magnon oscillation mode, and the diamagnetic term is absent. D. Kim (Rice University and Ames National Laboratory, USA) et al. have become the first to demonstrate experimentally a magnon superradiant phase transition in an $ErFeO_3$ crystal [2]. Terahertz and gigahertz magnetospectroscopy experiments showed the presence of a quantum phase transition. At the boundary between superradiation and the normal phase, the branch of electron paramagnetic resonance of Er^{3+} approaches zero, while the Fe^{3+} magnon branch demonstrates a kink. The authors developed an extended Dicke model demonstrating the observed properties.

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3. Axion quasiparticle

In 2024, M.N.Y. Lhachemi and I. Garate predicted that a magnetoelectric coupling α (the derivative of magnetization with respect to the electric field) in magnon systems can be an analogue of the field θ in quantum chromodynamics, and coherent oscillations of α can be quasiparticles similar to axions. An experiment conducted by J.-X. Qiu (Harvard University, USA) and his co-authors have demonstrated for the first time the occurrence of such dynamic axion quasiparticles in two-dimensional layers of $MnBi_2Te_4$ in a magnetic field with laser-pumped magnons [3]. The quantity $\alpha(t)$ was measured by the Kerr rotation effect with femtosecond resolution. Coherent oscillations of $\alpha(t)$ representing axion quasiparticles were observed. In cosmology, axions (coherent oscillations of the field θ) are thought of as probable candidates for the role of dark matter particles, and some experiments are being performed to search for them. As the authors have shown, a detector of cosmic axions can be designed on the basis of materials with axion quasiparticles, which will have a sensitivity exceeding that of existing detectors in some ranges of axion masses.

4. Runaway electrons (REs) in capacitive discharge plasma

In their theoretical work, A.V. Gurevich, K.P. Zybin, Yu.V. Medvedev, and other authors have shown that the formation of high-altitude atmospheric electric discharges are greatly influenced by REs. An RE-caused breakdown in the atmosphere occurs in an electric field approximately an order of magnitude lower than the field of an ordinary breakdown [4]. A direct study of high-altitude discharges, such as columnar red sprites, is very difficult and, therefore, it is important to reproduce similar phenomena in laboratory conditions. REs have already been recorded in experiments in plasma contacting a metal cathode (see [5, 6]). In a new experiment carried out at the Institute of High-Current Electronics SB RAS (Tomsk), plasma diffusion jets have been obtained for the first time and REs have been recorded in plasma without contact with metal electrodes [7]. E.Kh. Baksht, V.F. Tarasenko, and N.P. Vinogradov created capacitive pulse-periodic discharges in a quartz tube at a temperature of $\sim 25\,^{\circ}C$ and pressures of 0.4 or 1 Torr. The electrodes were located outside the tube and had no contact with the plasma. The discharge was photographed, and its spectrum and time characteristics were measured with a resolution of 0.9 ns. In the experiment, the RE beams were ahead of the plasma diffusion jet front and were recorded by the collector before its arrival.

5. Observation of jets

The Event Horizon Telescope is a network of radio telescopes operating together in the interferometer mode. J. Roder (Max

Planck Institute for Radio Astronomy, Germany and the Institute of Astrophysics of Andalusia-CSIC, Spain) and his colleagues have used the Event Horizon Telescope to study jets (jet ejections) from galactic centers at a distance of less than 1 pc from the sources at a frequency of 230 GHz [8]. To interpret the obtained data, the results of previous observations at lower frequencies (2–86 GHz) were used, in particular, the observations of the RadioAstron telescope [9, 10]. One of the main goals was to trace the frequency dependence of the properties of jets and cores (central regions of radiation). Their radiance temperature, size, polarizations, etc. were measured. Noticeable deviations from the standard Blandford-Königl model with a conical jet and a constant Lorentz factor turned out to exist on scales smaller than 1 pc. A sharp lowering of the magnetic field with radius has been revealed, which is indicative of jet acceleration. It has also been noticed that, in observations at a frequency of 230 GHz, the core sizes are larger by an order of magnitude than those following from the preceding RadioAstron data at low frequencies, and the radiance temperature is much lower.

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