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1. X17 particle

In 2016, A J Krasznahorkay (Institute of Nuclear Research, Debrecen, Hungary) and co-authors reported in their experiment an anomaly in angular correlations of electrons and positrons born in intranuclear transitions in ^{8}Be nuclei (see [1]). This anomaly was interpreted as the birth and decay of a new particle, called the X17 particle, of mass $\simeq 17$ MeV. This result attracted much attention, as X17 might explain, for example, dark matter or discrepancy between measurements of the muon anomalous magnetic moment, or else it might be a boson-carrier of a new force. In an updated experiment with new detectors, A J Krasznahorkay and co-authors [2] have verified and specified the former results with ^{8}Be and performed new measurements with ^{4}He nuclei. They examined an electromagnetically forbidden transition $0^- \to 0^+$ in the nuclei of ^{4}He produced in the bombardment of a hydrogen target by a proton beam. The background, mostly due to cosmic rays, was measured a fortnight before and a fortnight after the experiment and was subtracted from the results of measurements. The additional peak corresponding to the production of the new particle of the same mass, $\simeq 17$ MeV, as that of ^{8}Be nuclei was observed both in the energy spectrum with 7.1σ statistical significance and in e^+e^- angular correlations with 7.2σ significance. Particles with presupposed properties of X17 have recently been sought in the CERN experiment NA64. No new particles were registered, but the range of their interaction with electrons was substantially limited. Nevertheless, a wide allowed region still remains. The hypothesis concerning the birth of the X17 particle can be verified in several independent experiments to be performed in the near future.

2. Spin heat engine

The investigation of microscopic and quantum heat engines is of great interest for nanotechnologies. A thermodynamic cycle has recently been realized with a unit ion in a trap. However, the heat energy greatly exceeded the distances between quantum energy levels, which made this heat engine very largely classical. In the new experiment, J P S Peterson (University of Waterloo, Canada) and colleagues [3] have managed to attain a regime in which the heat engine requires a quantum description. The NMR spectroscopy method was used to investigate the quantum version of the Otto cycle in a $CHCl_3$ solution in acetone. Spins $1/2$ of ^{13}C nuclei served as a working substance of heat engines and the nuclear spins of ^{1}H were used as heat carriers. The hot and cold reservoirs were represented by, respectively, high- and low-frequency radio waves. The Otto cycle stages were also initiated by radio pulses. Although the working substance of heat engines consisted of 10^{17} molecules, they behaved independently because of their weak interaction, and therefore only averaged characteristics were studied in the experiment. The measurements showed that the heat engine does operate at a quantum level with the determining role of quantum fluctuations. Its efficiency equals 42%, which is close to the upper limit of 44% for the Otto cycle, and the work done in one cycle at a unit spin amounted to several peV.

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3. Quantum analog of the Penrose inequality

In the gravitation theory, several important theorems are known for whose validity a light-like (isotropic) null energy condition (NEC) (see [4]) is needed but violated by some types of so-called exotic matter. One of these theorems is the Penrose inequality relating the minimum body mass to the area covering its trapped surface. Researchers from the USA and Spain (R Bousso, A Shahbazi-Moghaddam, and M Tomasevic) have clearly shown [5] that the Penrose inequality is also violated in the presence of exotic quantum matter and extended it to the quantum case. The main idea of their approach lies in the substitution of the generalized entropy on a light sheet for the trapped surface area. Since the generalized entropy can be expressed in terms of quantum degrees of freedom, this method may appear to be useful in formulating the theory of quantum gravity. In the new work, the authors also introduced a quantum analog of surface expansion and gave a new definition of the trapped surface. These definitions were used to formulate the quantum analog of the Penrose inequality and to demonstrate its application in simple examples.

4. Electric waveguide in graphene

The feasibility for the information contained in quantum states of electrons to be transmitted through nanowires is limited to a small electron free path length in nanowires. In graphene (a carbon layer one atom thick), charges behave like Dirac massless quasi-particles and can be carried over large distances, but the creation of a strictly directed beam of these particles remained problematic. A Cheng (Harvard University, USA) and co-authors [6] have used a carbon nanotube as a guiding device. Graphene was placed between the insulator layers with a nanotube above one of the layers. Between the nanotube and graphene, the potential difference was maintained, creating a potential well along the nanotube. Dirac fermions could move in graphene along this tube in the waveguide single-mode regime. This configuration is conceptually similar to the optical fiber through which photons are transported. The experiment demonstrated fermion transport at a distance of 500 nm bounded by the device size. The nanotube simultaneously served as a charge sensor used for measurements that confirmed the device operation as a waveguide. For graphene electronics, see the review [7].

5. Torsional Alfven waves

Researchers from Norway, Great Britain, and France have become the first to directly observe torsional Alfven waves in a solar flare [8]. Torsional Alfven waves were theoretically predicted to participate in energy transfer between different layers of the solar atmosphere; however, earlier observations provided only indirect evidence of their existence. These waves are difficult to observe because the plasma density and, accordingly, its luminosity in torsional oscillations are homogeneous. P Kohutova, E Verwichte, and C Froment investigated the flare of December 9, 2015 with plasma stream ejection in the solar corona (for coronal processes, see [9, 10]). Energy release in a magnetic tube in the course of magnetic field line reconnection generated torsional motion in the plasma. The IRIS data with Doppler shift measurements in silicon and magnesium lines were used, which made it possible to observe both the time evolution of plasma velocity and the velocity distribution across the stream. The data obtained corresponded to the torsional Alfven waves propagating at a velocity of 140 km s^{-1}.

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