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1. Mixing of D^0-mesons

The transformations of D^0-mesons to their $\bar{D}^0$ antiparticles were observed with the *BABAR* detector at the PEP-II storage rings at the Stanford Linear Accelerator Center (SLAC). The mesons were created when electron and positron beams collided in the storage ring and were recorded in decay products in the channel $D^0 \to K^+\pi^-$. The effect of mixing D^0- and $\overline{D}^0$-mesons, which is responsible for the transformation of particles into antiparticles, is predicted by the Standard Model of elementary particles, while mixing-free models are excluded by this experiment at the level of 3.9 standard deviations. The Standard Model also predicts an asymmetry (a small difference in decay rates) in the decays of $\overline{D}^0$- and $\overline{D}^0$-mesons due to the violation of the CP invariance; however, the experiment is so far insufficiently sensitive to register this asymmetry. A similar effect was earlier observed with B- and K-mesons [see, e.g., *Phys.-Usp.* **49** 536 (2006)]. The group of experimenters included some Russian scientists from the G I Budker Institute of Nuclear Physics, SB RAS (Novosibirsk).

Sources: http://arxiv.org/abs/hep-ex/0703020

2. Quantum critical point in an antiferromagnet

P Gegenwart and co-workers in Germany (Max Planck Institute for Chemical Physics of Solids, Dresden) and their colleagues in the USA studied low-temperature phase transitions in an antiferromagnetic compound $YbRh_2Si_2$ in a magnetic field. The measured characteristics were the isothermal magnetostriction — an expansion of a specimen as a function of magnetic field at various fixed temperatures — and the electrical properties of specimens. The growth of the bubbles of a new phase at the initial stage is characterized by fluctuations, such that at sufficiently low temperatures the zero quantum fluctuations dominate the thermal ones. A transition was found at temperatures below 0.8 K, which does not sit well with the conventional scenario of 'universal classes' of phase transitions that works nicely in the case of thermal fluctuations. At the moment, no detailed theoretical description exists of the mechanism of the new phase transition but it was suggested that the emergence of entangled quantum states between conduction electrons and the magnetic moments of valence electrons play the key role. This produces quasiparticles whose properties resemble those of heavy electrons. According to this model, the appearance of a 'liquid of heavy electrons' is the factor that is responsible for the observed phase transition.

Sources: http://physicsweb.org/articles/news/1 1/2/18/1

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Translated by V I Kisin

3. Observation of photons in a cavity

S Gleyzes and co-workers in France carried out an experiment in which for the first time single photons were observed in a microwave cavity by a quantum nondemolition (QND) method. The tool that served to carry out the measurements was a beam of rubidium atoms in Rydberg states, sent across the cavity. The cavity consisted of two superconducting niobium mirrors facing each other and placed in a protection shield that cancelled the effects of thermal radiation and external electromagnetic fields. Before crossing the cavity, Rb atoms were transferred to a superposition of quantum states with the principal quantum numbers $N = 50$ and $N = 51$. The microwave cavity resonance frequency was somewhat different from the frequency of transitions between atomic levels, so a photon was not absorbed in the interaction with an atom and only a phase shift occurred in the dipole oscillations of the atom. Hence, the observation of the photon was nondestructive. The phase shift increased the probability of the subsequent transition of the atom to a level with the principal quantum number $N = 51$. Atoms emerging from the cavity were detected using an atomic interferometer. The presence of a photon in the cavity was established by measuring the relative number of Rydberg atoms in the state $N = 51$ emerging from the cavity. Time and again a photon was spontaneously created in the cavity. Hundreds of atoms had time to cross the cavity during the life of the photon. The atomic beam, thus, made it possible to monitor the entire 'lifetime' of a photon in the cavity from its creation until its disappearance.

Sources: *Nature* **446** 297 (2007); www.nature.com

4. Vortices in the Bose – Einstein condensate

Vortex formation was observed by D R Scherer and colleagues at the University of Arizona when independent clouds of Bose – Einstein condensate of ^{87}Rb atoms were allowed to merge together in a confining potential. Laser beams created potential barriers inside a cylindrical atomic trap, which partitioned the trap into three identical circular segments. An independent Bose – Einstein condensate cloud formed in each segment in the course of evaporative cooling. When the potential barriers were turned off, the condensate clouds merged and one or several vortices were seen to form. The number of vortices depends on the rate of merging of the clouds, which is controlled by the rate at which the barrier is removed. This phenomenon is a result of phase differences between the wave functions of the independent condensate clouds and, therefore, of the nonzero net angular momentum possessed by the condensate.

Source: *Phys. Rev. Lett.* **98** 110402 (2007); prl.aps.org

5. The Greisen – Zatsepin – Kuzmin effect (the GZK Cutoff)

In 1966, K Greisen and independently G T Zatsepin and V A Kuz'min made a theoretical prediction that, owing to the interaction between particles of cosmic rays and microwave background photons, the spectrum of cosmic rays should have a cutoff energy of about 6×10^{19} GeV. A number of experiments have been carried out since that time to observe 'extensive air showers' — that is, cascades of particles that are created in the interaction between cosmic rays and atoms in the atmosphere. In several cases, particles were encountered with energies above the cutoff threshold but these results were ambiguous and had large errors. Cosmic ray particles with superhigh energies are probably a product of acceleration at shockwave fronts in other galaxies or galaxy clusters. Reports on the detection of particles with energies above the cutoff threshold led to the creation of alternative 'top-down' models of the origin of cosmic rays in decays of hypothetical supermassive particles in our Galaxy. The situation may get clearer through the use of new detectors that have already started measurements. At the moment, one of the latest experiments, the High Resolution Fly's Eye (HiRes), which collected data from 1997 to 2006, has built the best statistics of observations of superhigh-energy cosmic rays. The HiRes consists of two telescopes that measure the UV radiation of nitrogen molecules in the earth's atmosphere excited by extensive air showers. According to the data of this experiment, the spectrum does indeed manifest a cutoff at the confidence level of about 5σ at an energy of 5.6×10^{19} eV. One can thus conclude with a sufficient measure of confidence that the Greisen – Zatsepin – Kuzmin effect has been observed in the HiRes experiment. HiRes also confirmed a feature in the cosmic-ray spectrum known as the 'ankle', which was predicted by V S Berezinsky and S I Grigor'eva in 1988.

Sources: http://arxiv.org/abs/astro-ph/0703099

Compiled by Yu N Eroshenko