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1. Unusual elementary particle

The CDF collaboration detected an unusual particle in an experiment at the DOE's FNAL Tevatron accelerator; so far this particle cannot be classified in terms of the accepted quark recipe of building mesons and baryons. The researchers selected $B^+ \to J/\phi\psi K^+$ decays. It was found in specific cases that the intermediate state of the decays is new particles Y(4140) with a measured mass of about 4140 MeV. The CDF experimenters recorded 14 ± 5 such events at a statistical significance of 3.8 standard deviations. The assumption that Y(4140) is one of the states of the system of $c\bar{c}$ quarks met with serious difficulties in describing the observed characteristics of the decays; the structure of the new particle is still unclear. There is a possibility that Y(4140) constitutes a hadronic molecule, a hybrid particle that includes gluons as its components, or that Y(4140) is a new four-quark state. The Y(4140) particle is another in a series of exotic particles discovered in recent years (see *Usp. Fiz. Nauk* **177** 1318 (2007) [*Phys. Usp.* **50** 1289 (2007)]).

Source: http://arXiv.org/abs/0903.2229

2. The Efimov effect for four particles

In 2006, H-C Nagerl and colleagues of Insbruck University in Austria observed for the first time bound quantum states of three caesium atoms (see *Usp. Fiz. Nauk* **176** 440 (2006) [*Phys. Usp.* **49** 438 (2006)]). The object of study was the Bose–Einstein condensate in which the intensity of interaction between atoms was controlled by the magnetic field and the bound states were identified by determining recombination losses. The effect of formation of bound trimers, predicted by V I Efimov in a theoretical paper in 1970, can arise even in the absence of bound paired states of atoms. After this discovery, in 2007–2008 two groups of researchers made a theoretical prediction that a similar effect is possible for four particles too; furthermore, some observational evidence of the formation of bound quartets was found among the data of the first experiment. Now Nagerl and his colleagues carried out a new experiment using a technique completely reproducing that of the earlier experiment. The presence of bound quantum states of four particles was demonstrated unambiguously. The range of applicability of the Efimov effect was thus extended to quartets of atoms. In contrast to trimers, bound atomic quartets form only a pair of universal states and not an infinite sequence. The data obtained in this work will be used to test principally important aspects of quantum mechanics.

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3. Doubly magic ^{24}O nucleus

Nuclei of the unstable oxygen isotope ^{24}O having a large excess of neutrons were studied at the GSI laboratory (Darmstadt, Germany) by an international team of physicists. It was found that these nuclei are doubly magic, i.e., their proton and neutron shells are completely filled, despite a strong distortion of the level structure at the nucleus stability boundary. A beam of ^{24}O nuclei was generated at the accelerator by sending ^{48}Ca nuclei into a target. This process created three ^{24}O nuclei per second, which then collided with a carbon target, losing one neutron each. The form of the momentum distribution of the resulting ^{23}O nuclei made it possible to determine the structure of nucleon shells in ^{24}O nuclei. It was confirmed that ^{24}O nuclei are indeed doubly magic, with spherically symmetric shells. The study of ^{24}O isotopes is highly important for nuclear astrophysics because they may be created in supernova explosions; these nuclei may also be present in the crust of neutron stars.

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4. Optical version of Maxwell's demon

J J Thorn and his colleagues at the University of Oregon (USA) created an optical barrier that allows ultracold ^{87}Rb atoms to transmit through when incident on one side of the barrier but reflect from the other, i.e. in one direction only. Two almost parallel laser beams separating a dipole atomic trap into two parts were focused near its center. The frequency of one of the beams differed from the resonance frequency of transition between sublevels of hyperfine splitting in ^{87}Rb. This beam created a potential barrier whose penetrability for an atom depends on its state: atoms at the lower sublevel pass through the beam unobstructed, while the potential created by the barrier for the excited atoms is repulsive. The frequency of the second laser equals the frequency of transition between the sublevels. If an atom in the ground state crosses the second beam and passes from one side of the trap to the other, it absorbs a photon from the second beam and after this is unable to pass through the barrier in the opposite direction. As a result, atoms accumulate on one side of the barrier only. This system of beams, which operates as an atomic diode, is an analog of Maxwell's demon. By analogy to Maxwell's thought experiment, it is possible to experimentally check how entropy is transferred between the parts of the system in the case of the optical barrier. The reduction in entropy caused by the displacement of atoms to one side of the trap is compensated for by the production of entropy when photons are scattered. Furthermore, this technique is of interest for developing new ways of laser cooling of atoms.

Source: http://arXiv.org/abs/0903.3635v1

5. Superconductivity in $SrFe_2As_2$

Scientists at the Tokyo Institute of Technology (Japan) discovered that, after the compound $SrFe_2As_2$ was treated with water vapor, it became a superconductor with the temperature of superconducting transition $T_c \approx 25$ K. The compound $SrFe_2As_2$ belongs to a class of new layered iron-based superconductors. Its intense study began in 2007 (see *Usp. Fiz. Nauk* **178** 1243 (2008) [*Phys. Usp.* **51** 1201 (2008)]). However, superconductivity arises in these compounds only when they are doped with certain impurities or under high pressures. H Hosono and his coworkers exposed an epitaxial thin film of pure (undoped) $SrFe_2As_2$ to humid atmospheric air for more than four hours, which resulted in the samples becoming superconducting. Tests demonstrated that exposure to individual components of air (nitrogen, oxygen, or carbon dioxide) without H_2O did not produce such changes. So far, the exact mechanism of the H_2O effect remains unclear. It is suggested that either oxygen atoms from water molecules penetrate the structure of the crystal $SrFe_2As_2$, or strontium atoms bind to the OH group and form atomic vacancies. Superconductivity arises in response to the application of water in some other (not iron-based) layered compounds too, but neutron diffraction studies have established that interlayer spacings in $SrFe_2As_2$ do not grow (as is the case in other compounds) in response to water treatment, but are reduced. It was also found that the superconductivity of $SrFe_2As_2$ caused by water vapor is strongly anisotropic in a magnetic field (T_c depends on the field orientation) — in contrast to the almost isotropic superconductivity of $SrFe_2As_2$ doped with cobalt atoms.

Source: http://arXiv.org/abs/0903.3710

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