

PACS number: **01.90.+g**

Physics news on the Internet (based on electronic preprints)

DOI: 10.1070/PU2003v046n08ABEH001617

1. A pentaquark particle is discovered

Until very recently, only hadrons consisting of two or three quarks had been observed. The existence of the pentaquark particle $uudd\bar{s}$ was predicted theoretically by D Diakonov, V Petrov, and M Polyakov in 1997. Last year T Nakano and his colleagues in Japan have for the first time detected this particle in an experiment on collisions between high-energy gamma rays and neutrons in a carbon nucleus. The gamma radiation was produced by scattering laser light from a beam of accelerated electrons. The photons flew through a plastic scintillator and interacted with neutrons composing the carbon nuclei. Pentaquark particles Θ^+ with a mass of 1.54 GeV were created in the reaction $\gamma n \to K^- \Theta^+ \to K^- K^+ n$ and were identified through a resonance in the energy spectrum of K^+-mesons. Subsequent experiments at the Institute of Theoretical and Experimental Physics (ITEF) in Russia and the T Jefferson National Accelerator Facility in the US also detected the five-quark state, thus confirming the results of the Japanese scientists. In the ITEF experiment, which involved collisions of K^+-mesons with liquid xenon, $K^+ Xe \to K^0 pXe'$, a resonance corresponding to a pentaquark was discovered in the energy spectrum of the reaction products. There remains the probability, however, that the five-quark state detected in the above experiments is in fact not a hadron resonance but a molecular meson – baryon one.

Source: *Phys. Rev. Lett.* **91** 012002 (2003);
http://prl.aps.org;
http://arXiv.org/abs/hep-ex/0304040

2. A superconductor with a large upper critical field

H J Niu and D P Hampshire (both of the University of Durham in the UK) have developed a method for fabricating superconducting materials with a very large upper critical field B_{c2}. This is the external magnetic field at which the superconductivity of a material disappears completely due to the entire volume of the superconductor being filled with magnetic vortices. According to the Ginzburg – Landau theory, B_{c2} grows with decreasing coherence length or the electron mean-free path, which is due to the decrease in the vortex size. Niu and Hampshire reduced the electron mean-free path considerably in the superconductor $PbMo_6S_8$ by mechanically milling it into a very fine powder and then using hot isostatic pressing at high temperatures and pressures. The resulting sample has a granular structure with crystalline grains about 20 nm in size. Electrons in the superconductor undergo strong scattering from the disordered grain boundaries, the coherence length $\xi \sim 2$ nm turning out to be much less than the characteristic grain size. The value of B_{c2} in a granulated sample is about 100 T, twice the value for a bulk superconductor $PbMo_6S_8$. It is as yet technologically impossible to make the windings of superconducting magnets from a brittle granulated material.

Source: *Phys. Rev. Lett.* **91** 027002 (2003);
http://prl.aps.org

3. Formation of molecules in a degenerate Fermi gas

D Jin and her colleagues at the National Institute of Standards and Technology (NIST), JILA and the University of Colorado in Boulder have for the first time made ultracold molecules from atoms of a degenerate Fermi gas. Weakly bound molecular states of the atoms of potassium-40 appeared due to accessing the Feshbach resonance at a magnetic field of about 224 G and temperature $T < 150$ nK. The number of separate atoms in the optical trap was controlled by spectroscopic methods. Using the Zeeman effect, the energy of atoms near the resonance could be changed smoothly by varying the magnetic field. On assessing the resonance, the number of separate atoms decreased almost by half in a jump, indicating that some of the atoms joined together to form molecules. About 250,000 $^{40}K_2$ molecules were trapped in the experiment. Away from the resonance, the molecules decompose and the number of atoms returned to its original value. The binding energy of the molecules as measured using radio frequency spectroscopy turned out to be in consistent agreement with the theoretical value. Further experiments are planned to see if superfluidity is possible in the molecular gas produced.

Source: *Nature* **424** 47 (2003), www.nature.com;
http://arXiv.org/abs/cond-mat/0305028

4. Experimental study of the Landau – Pomeranchuk effect

In 1953, L D Landau and I Ya Pomeranchuk showed theoretically that at high energies the radiative energy loss of electrons in material decreases and their penetrating power increases. This phenomenon, described formally as an increase in the radiation length, is due to the fact that high-energy electrons interact with many atoms simultaneously. Earlier, however, the Landau – Pomeranchuk effect had been studied experimentally only for electrons with energies below 25 GeV, and the dependence of radiation length on electron energy had not been revealed. Now H D Hansen and his colleagues at CERN have conducted a new experiment for electron energies of 149, 207, and 287 GeV and have for the first time seen an increase in radiation length with increasing electron energy. A beam of electrons from an accelerator was directed into an iridium target, and the spectrum of bremsstrahlung photons was measured. The results of the experiments are in good agreement with A B Migdal's 1956 calculations of the effect. The Landau – Pomeranchuk effect

Uspekhi Fizicheskikh Nauk **173** (8) 904 (2003)
Translated by E G Strel'chenko

may have a major role in the development of cosmic-ray-produced high-energy electromagnetic showers near the Greisen – Zatsepin – Kuz'min cutoff of high-energy photons.

Source: *Phys. Rev. Lett.* **91** 014801 (2003);
http://prl.aps.org

5. Evolution of galaxies and of supermassive black holes

Experimental observations of recent years have shown that almost all elliptical and spiral galaxies harbor black holes $10^6 - 10^9$ the mass of the Sun at their cores. However, the formation mechanism of the supermassive black holes is not yet reliably established. The black holes might have formed in the 'dark ages' of the universe (and then increased their mass through the accretion process) or at a later time from the material of destroyed stars in the central regions of galaxies. Observations made by astronomers at Johns Hopkins University in Baltimore made it possible to establish that the mass growth of black holes in distant galaxies and the formation of star systems took place synchronously. Data on 120,000 nearby galaxies from the Sloan Digital Sky Survey were employed. Statistical analysis showed that star formation processes and the activity of galaxy cores are time correlated and possibly interrelated.

Source: www.nature.com

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