Physics – Uspekhi **53** (7) 753 – 754 (2010)

PACS number: **01.90.+g**

Physics news on the Internet (based on electronic preprints)

DOI: 10.3367/UFNe.0180.201007f.0758

1. Neutrino oscillations

A number of experiments studying neutrino oscillations observed a reduction in the number of muon neutrinos along neutrino beams; this, however, was only an indirect indication that a different type of the neutrino appeared in the beam. A qualitatively new result is now reported in the OPERA experiment, where the first appearance of tau neutrinos in a beam of muon neutrinos was recorded. The OPERA detector at the Gran Sasso National Laboratory (Italy) sits in a tunnel under a massive mountain. The working substances of the detector are emulsion films alternating with plates of low-background-noise lead. In 2008 and 2009, the facility monitored a ν_μ beam with an energy of about 17 GeV, sent into the OPERA detector from the CERN accelerator at a distance of 730 km through the body of Earth. The candidate event involving ν_τ was identified by the characteristic topology of the decay of the τ lepton which was created in the interaction between the ν_τ and a lead nucleus. The detection of the first candidate event featuring ν_τ with a probability of 98% points to the appreciable effect of neutrino oscillations ($\nu_\mu \to \nu_\tau$). Confidence in the reality of neutrino oscillations will be achieved only after several such events have been recorded. Neutrino oscillations assume that neutrinos have mass, which means going beyond the tenets of the Standard Model of elementary particles. The OPERA experiment is being conducted by an international team of researchers from 12 countries, which includes scientists from five research institutions in Russia. In another experiment MINOS (being run since 2005 at the Fermi National Accelerator Laboratory), a very accurate comparison of the effects of neutrino and antineutrino oscillations is being conducted. The MINOS detector is located at a distance of 735 km from the accelerator which produces the ν_μ and ν_τ beams. The process occurring in the detector is the magnetic separation and recording of muons and antimuons generated by the interaction of ν_μ and ν_τ with the material of the detector. An unexpected result was obtained: the mass difference squared of neutrinos, $(\Delta m)^2$, is 40% smaller than for the corresponding types of antineutrinos. However, the statistical significance of this result reaches only about 2σ, which means that further testing is necessary. New theoretical approaches will have to be worked out in order to explain this fundamental difference between the neutrino and the antineutrino, provided its reality is confirmed.

Sources: http://arXiv.org/abs/1006.1623
http://www.physorg.com/newsl95733444.html

Uspekhi Fizicheskikh Nauk **180** (7) 758 (2010)
DOI: 10.3367/UFNr.0180.201007f.0758
Translated by V I Kisin

2. Quantum teleportation over a free-space distance of 16 km

X-M Jin and his coworkers in China performed an experiment on quantum teleportation of photon states through air at a distance of 16 km. In the past, it was only possible to implement teleportation over a distance of several dozen meters for photons transmitted through an optical fiber. Quantum teleportation assumes that a change in the state of one particle of a pair instantaneously changes the state of the second remote particle which resides in an entangled quantum state with the partner particle, i.e., the quantum state has been teleported. Quantum entanglement of the state of motion of one photon and the state of polarization of the second photon was produced here in a nonlinear BBO crystal, after which one of the photons of the pair was sent into the detector located at a distance of 16 km. The two photons remained entangled with an average fidelity of 89%, which is considerably higher than the classical limit equal to 2/3. The experiment implemented all the main components of the scheme of quantum teleportation, with the exception of the local unitary operation. Successful quantum teleportation at Earth's surface over a distance of 16 km [exceeding the effective atmosphere thickness ($\approx$ 10 km)] has demonstrated the possibility of employing this effect in optical communication channels between ground stations and satellites.

Source: *Nature Photonics* **4** 376 (2010)
http://dx.doi.org/10.1038/nphoton.2010.87

3. Organic compound with the properties of a metal

Researchers from the RAS Institute of Problems of Chemical Physics and the Institute of Solid State Physics (Chernogolovka), together with their colleagues in Japan (Kyoto, and Nagoya), have succeeded in synthesizing N-methyl-ethyldiazobicyclooctane-triptycene-C_{60}, a fullerene-containing organic material which contains no metal atoms but possesses metallic properties. The new crystalline material was obtained by the diffusion method and its structure was studied by X-ray diffraction. The material consisted of planar layers in which C_{60} anions are arranged in a honeycomb pattern, fullerene layers alternating with layers of molecules containing only atoms of light elements: hydrogen, carbon, and nitrogen. The close-packed structure in the arrangement of fullerene molecules is supported by ring molecules of the aromatic hydrocarbon triptycene $C_{20}H_{14}$. Direct measurements using electrical contacts fixed to specimens revealed that at temperatures above 1.9 K electric conductivity of the material is at the level of metallic conductivity.

Source: *Angewandte Chemie* **49** 4829 (2010)
http://dx.doi.org/10.1002/anie.201001463

4. Instantaneous velocity of a Brownian particle

T Li (University of Texas at Austin, USA) and colleagues studied the Brownian motion of silica (SiO_2) beads about 3 μm in size in air and for the first time measured their instantaneous velocity. Typically, experiments follow the diffusive regime of Brownian motion over relatively long stretches of time, when $\langle(\Delta x)^2\rangle \propto t$. However, over very short intervals of time, shorter than the relaxation time of particle momentum, the particle moves by inertia, in the ballistic regime. A particle of SiO_2 was trapped in an optical tweezer formed by two focused laser beams. The motion of the particle, which is described by the Langevin equation in harmonic potential, was observed in the reflected laser light at high time resolution. As expected, over short time intervals the relation is $\langle(\Delta x)^2\rangle \propto t^2$. Furthermore, it has been established that the distribution of Brownian particles corresponds to the Maxwell–Boltzmann distribution and that the particle energy conforms with the energy equipartition theorem.

Source: *Science* **328** 1673 (2010)
http://dx.doi.org/10.1126/science.1189403

5. Anisotropy of cosmic rays in the southern hemisphere

A number of experiments conducted in the northern hemisphere detected a slight anisotropy (of about 10^{-4}–10^{-3}) in the arrival direction of cosmic rays with energies of up to several TeV. Similar measurements of anisotropy in the TeV region in the southern hemisphere were first carried out in the international IceCube experiment conducted in Antarctica at the South Pole. The main purpose of the IceCube experiment was to record neutrino events, but it can also measure the flux of cosmic rays. IceCube is to reach an effective volume of 1 cubic km and total functionality in 2011, by which time 5160 optical modules are expected to be installed on 86 strings in the ice at depths from 1450 to 2450 m. The described measurements were conducted in 2007–2008 using the partially deployed IceCube detector operated in a configuration with 1320 digital optical sensors distributed over 22 strings. Among the recorded data, 4.3×10^9 reliable events of detecting cosmic-ray particles with energies of up to 20 TeV were selected, and the directions were measured with an angular resolution of 3°. Careful work was carried out to remove from the experimental data the effects of asymmetric geometry of the detector, seasonal variations, and other factors that could distort the result. The distribution of the measured intensity of cosmic rays in the southern sky smoothly matches the distribution which was previously obtained in the northern hemisphere. One possible explanation of the anisotropy lies in the peculiarities in the distribution of interstellar magnetic fields in the vicinity of the Sun on a scale of less than one parsec. The nature of this anisotropy will probably be clarified after the planned IceCube measurements of anisotropy as a function of the particle energy.

Source: http://arXiv.org/abs/1005.2960

Compiled by *Yu N Eroshenko*
(e-mail: erosh@ufn.ru)