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Physics news on the Internet (based on electronic preprints)

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1. LHC experiment does not confirm the existence of tetraquark X(5568)

It was reported earlier that a new particle — tetraquark X(5568), all of whose four quarks having different flavors (b, s, u, d), and its identification significance being estimated at a level of 5.1σ — was discovered in a D0 experiment at the Tevatron accelerator. However, the search for this particle in the LHCb experiment failed to yield the result, in spite of the fact that a much larger data volume than that involved in the D0 experiment was processed. Exotic X(5568) hadrons were sought by examining the spectrum of decaying B_s^0 and $\pi^{\pm}$ particles that could be born by themselves upon X(5568) decays. No statistically significant excess of the number of events over the background testifying to X(5568) production was revealed, and restrictions from above on the X(5568) production rate were found.

Source: http://cds.cern.ch/record/2140095/

2. Verification of the law of gravitation at submillimeter distances

W-H Tan (Huazhong University of Science and Technology, China) and colleagues have conducted a new experiment testing the Newtonian law of gravitation (inverse-square law) at distances down to 295 μm. The deviation from this law was predicted in some versions of string theory and in M theory. Oscillations of a torsion pendulum hanging on a thread and attracted by eight masses fixed on a rotating disc were measured. Calibration was reached through dual compensation, i.e., an addition of mass on both the pendulum and the attractor, which reduced the role of errors in the determination of distances. The setup was located in a vacuum chamber and was thoroughly screened from electrostatic fields. The inverse-square law was checked on the assumption that the corrections to it have the form of the Yukawa potential $V(r) = -Gm_1m_2(1 + \alpha \exp[-r/\lambda])/r$. The validity of the Newtonian law written as the inequality $|\alpha| \leqslant 1$ was confirmed down to $\lambda = 59$ μm at a confidence level of 95%. The upper bounds on the value of α, which are the best as of today, were obtained in the range of $\lambda \simeq 70-300$ μm.

Source: *Phys. Rev. Lett.* **116** 131101 (2016)
http://dx.doi.org/10.1103/PhysRevLett.116.131101

3. Test of the quantum 'free will theorem'

In 2006, J H Conway and S B Kochen formulated the 'free will theorem' in quantum mechanics [see *Foundations of Physics* **36** 1441 (2006) and a stronger version of the theorem in *Notices of the AMS* **56** 226 (2009)]. The crucial points of the theorem are quantum nonlocality, quantum contextuality, and the possibility of their combination in one experiment. Free will is understood in the sense that, if the experimentalist has the freedom of choosing the measurement technique, the result of measurements on a particle does not depend under certain conditions on the whole previous history. B-H Liu (University of Science and Technology of China, Hefei, China) and colleagues have become the first to test this theorem experimentally. Pairs of photons residing in hyperentangled states appeared, i.e., entangled in two degrees of freedom, namely, in spatial paths and polarizations. One of the photons of the pair was sent to the first laboratory, where it underwent three successive measurements, and the second photon was sent to the second laboratory, where it was subjected to one measurement. On the basis of the data obtained, it was possible to calculate the correlations between successive measurements taken at the first laboratory or between one of the measurements in the first laboratory and the similar measurement in the second laboratory. This was the way to check Einstein–Podolsky–Rosen correlations between the states of particles at different laboratories, and the violation of the Peres–Mermin inequalities describing noncontextuality. The results of measurements agree with high reliability with the free will theorem. From the practical point of view, this proves the possibility of designing devices that simultaneously perform quantum calculations and provide guarded quantum communications.

Source: http://arXiv.org/abs/1603.08254

4. Heat capacity of photon gas under Bose–Einstein condensation

A team of researchers from the University of Bonn (Germany) has measured for the first time the change in the heat capacity of a photon gas under its Bose–Einstein condensation. W Weitz and his colleagues studied the photon gas between two mirrors spaced at a distance on the order of the photon wavelength. The cavity between them was filled with dye whose particles scattered and reemitted photons, which led to photon gas thermalization. In such a system, the photon gas was quasi-two-dimensional and was effectively described by the equations for an almost ideal gas of massive boson particles. By varying the setup parameters, one could change the Bose–Einstein condensation temperature within some limits around room temperature, at which the experiment was carried out. This is how the set of experimental points above and below the condensation temperature was obtained. Photons were pumped into the medium by a laser, and the photon gas temperature was found through measuring the photon wavelength distribution. As expected, at a temperature near the Bose–Einstein condensation temperature the curve of specific heat exhibited a cusp singularity similar to the one near the λ-point in liquid helium.

Source: *Nature Communications* **7** 11340 (2016)
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5. Gamma-ray emission from young galaxies

Gamma-ray emission from the young radio galaxy PKS 1718-649 was registered by the Fermi-LAT gamma-ray telescope in the range of 0.1–100 GeV. It had been predicted before that charged particle fluxes of emerging radio bursts into galaxies must generate gamma-ray emission in the course of inverse Compton scattering. It was registered for the first time at a confidence level of $> 5\sigma$ through processing the Fermi-LAT data. Thus, young radio galaxies form a separate class of cosmic gamma-ray sources, and observations in the gamma-ray range will help to find the physical conditions in their compact radio bursts interacting with the galactic medium. The Fermi-LAT also registered gamma-ray emission from the ultrabright IR galaxy Arp 220 located at a distance of 77 Mpc. The Arp 220 spectrum testifies to a high rate of star formation and, accordingly, to a large cosmic-ray charged particle flux accelerated in supernova remnants. For this reason, the Arp 220 galaxy was *a priori* expected to be the source of gamma-ray emission generated through the interaction of cosmic rays with the interstellar medium. This gamma-ray emission with an energy above 200 MeV was registered at a confidence level of 6.3σ. Recording the gamma-ray luminosity of Arp 220, the efficiency of energy transfer from supernova remnants to cosmic rays — $4.2 \pm 2.6\%$ — was found for the first time for cosmic rays with energies above 1 GeV.

Sources: http://arXiv.org/abs/1604.01987
http://arXiv.org/abs/1603.06355

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