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Physics news on the Internet (based on electronic preprints)

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1. New particles containing b-quarks

The Belle Collaboration at the KEKB asymmetric energy electron–positron collider in Japan has for the first time observed resonant states of bottomonium-like particles $Z_b(1P)$ and $Z_b(2P)$ with masses of 10,610 MeV and 10,650 MeV, respectively, created in decays of bottomonium $\Upsilon(5S)$. The observed particles, whose detection confidence was about 10σ, belong to the family of so-called exotic hadrons consisting of more than three quarks. Like bottomonium, the new particles include b- and $\bar{b}$-quarks as component particles, but are electrically charged. This means that they contain at least two more quarks, perhaps u- and $\bar{d}$-quarks. The ATLAS experiment running on the Large Hadron Collider has discovered also for the first time the bottomonium $\chi_b(3P)$ comprising a $b\bar{b}$ pair in the triplet state. Earlier experiments revealed only the $\chi_b(1P, 2P)$ states, while the existence of $\chi_b(3P)$ was predicted theoretically. The $\chi_b(3P)$ particle with a mass of 10.54 GeV was evidenced through its radiative decay to $\Upsilon(1S, 2S)\gamma$ and $\Upsilon \to \mu^+\mu^-$. Quarkonium $\chi_b(3P)$ became the first new particle which was detected at the Large Hadron Collider with a sufficient confidence (at the 6σ level).

Sources: http://arXiv.org/abs/1110.2251
http://arXiv.org/abs/1112.5154

2. Thermodynamics of phase transition to the superfluid state

M W Zwierlein (Massachusetts Institute of Technology, USA) and his colleagues have studied the thermodynamic characteristics of substance in the transition to the superfluid state. The gas of ^{6}Li fermionic atoms was a mixture of atoms residing at the two lower levels of the hyperfine-splitted state in a magnetic field near the Feshbach resonance. The atoms were confined and cooled in a magneto-optical trap. Optical absorption observations have shown that a cloud of superfluid gas builds up at the center of the trap, formed of atoms joined together into bosonic pairs and surrounded by unpaired atoms in the normal state. In this experiment, there was no need to independently measure the temperature, since it was obtained in terms of gas density in the areas of traps with different confinement potential. Compressibility, density, and pressure of gas were measured with high accuracy using the same approach, which resulted in finding the equation of state of the gas, including that at the phase transition point. The transition occurred at $T_c = 0.167(13)T_F$, where T_F is the Fermi temperature. A sharp rise in gas compressibility was found in the vicinity of T_c, and a Λ-shaped feature appeared in the curve of heat capacity as a function of temperature, which is a characteristic feature of the second-order phase transitions.

Source: *Science* **335** 563 (2011)
http://dx.doi.org/10.1126/science.1214987

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Translated by V I Kisin

3. Transfer of electrons along the surface of superfluid helium

Researchers from Princeton University and Sandia National Laboratories have developed an efficient technique for achieving controlled transfer of electrons along a surface. An array of 120 parallel microchannels, 3 microns in thickness each, filled with superfluid helium at 1.6 K, were fabricated lithographically. An array of control electrodes and sensor electrodes which detected the position of electrons with an accuracy of the distance between channels were arranged underneath the channels at right angles to them. Packages of 1 to 20 electrons were transferred along the channels on the helium surface by means of a running potential created at the electrodes. The structure thus created resembled a CCD matrix: the intersections of channels and control electrodes play the role of 'pixels'. The feature noted specially was the exceptionally high reliability of electron displacements: there was no loss of electrons from the packets, even when the distance covered was $\sim 10^9$ pixels (or 9 km), which stems from high electron mobility on the surface of superfluid helium. One additional channel was arranged at right angles to the rest of the channels for electron transfer between the channels, demonstrating the feasibility of 2D displacements. This method may prove useful in creating and governing qubits (quantum bits).

Source: *Phys. Rev. Lett.* **107** 266803 (2011)
http://dx.doi.org/10.1103/PhysRevLett.107.266803

4. Resonant-tunnelling-diode oscillators operating in THz range

M Feiginov (Technological University of Darmstadt, Germany) and his colleagues have created a tunneling diode capable of generating radiation at a record frequency of 1.1 THz at room temperature. At the heart of the device is a semiconductor heterostructure with two AlAs barriers and a quantum wall separating them. Each layer is about 1 nm thick. The operating frequency is limited by electron tunneling time and the time of Coulomb relaxation, which is the decisive factor at this stage. However, it was possible to weaken the restriction on the relaxation by using special doping. Attached to the diode is a resonance antenna; the total size of the device does not exceed 1 mm^2. Terahertz-range emission promises important practical applications, such as nondestructive medical diagnostics or the search for and detection of dangerous substances in protection and security systems. According to the calculations of the authors, their technology is likely to gradually raise the generated frequency to 3 THz as the parameters of the tunneling diode and the oscillator go through the optimization process.

Source: *Appl. Phys. Lett.* **99** 233506 (2011)
http://dx.doi.org/10.1063/1.3667191

5. Gamma-rays from the Tycho's supernova remnant

Gamma-ray emission from the remnant of the Tycho Brahe supernova, whose explosion was observed in 1572, has now been recorded at the 5σ confidence level using the LAT gamma-ray telescope aboard the Fermi Space Observatory after almost three years of data taking in sky survey mode. The supernova SN 1572 belongs a type Ia; it was created by the thermonuclear explosion of a white dwarf. According to observations, the explosion front continues to freely expand in one direction, and a reverse shock wave is developing, while the front propagating in the opposite direction is beginning to slow down as it enters the region of high-density interstellar gas. The spectrum of radiation in the range 0.4–100 GeV fits quite well the models of radiation generation by cosmic rays accelerated on shock waves. According to this model, accelerated protons collide with nuclei of the surrounding gas and produce neutral pions whose decays create gamma photons. The measured integral flux of gamma radiation in the specified interval amounts approximately to 3.5×10^{-9} cm^{-2} s^{-1}.

Source: *Astrophys. J. Lett.* **744** 2 (2012)
http://arXiv.org/abs/1108.0265

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