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1. Search for new physics at LHC

Rare processes proceeding beyond the Standard Model of elementary particles are being sought in the experiments performed with the CMS and ATLAS detectors at the Large Hadron Collider (LHC). Events in which hadron jets and lepton–antilepton pairs $l\bar{l}$ (e^+e^- or $\mu^+\mu^-$) are involved and the 'missing' transverse momentum, i.e., the imbalance between the resultant measured momentum of reaction products and the pp initial momentum is fixed, were selected among the products of pp collisions (with the center-of-mass energy of 8 TeV) and investigated. The additional momentum could be carried away by weakly interacting particles not registered in the experiment. In particular, supersymmetry models with Z-boson production in squark and gluino decays were verified. For the channel of $l\bar{l}$ pair production in the decay of an on-shell Z-bozon, ATLAS Collaboration obtained a small deviation (at the level of 3σ) from calculations within the Standard Model. This deviation, if it does exist, may be thought of as a manifestation of the supersymmetry effects. In the independent production of l and $\bar{l}$ leptons, no deviations were observed. In the CMS experiment, on the contrary, no deviations were registered for the $Z \to l\bar{l}$ process, and the excess of the signal over the background was found in the second case at the level of 2.6σ. Since the deviations from the Standard Model have a little statistical significance and the data of the two experiments differ, it is untimely to speak of the new physics, and further studies are needed.

Source: http://arXiv.org/abs/1502.06031,
http://arXiv.org/abs/1503.03290

2. Quantum teleportation of two properties of a particle

The quantum teleportation effect has already been demonstrated in a number of experiments; however, the state of only one quantum degree of freedom inherent in the particle was transferred. Researchers from the University of Science and Technology (Heifei, China) have become the first to realize quantum teleportation of two degrees of freedom of a sole photon simultaneously, namely, its spin state and orbital angular momentum. Three pairs of photons in quantum-entangled states were utilized in the experiment. One of the pairs was 'hyperentangled', i.e., entangled in both the polarization states and the states of the orbital angular momentum of photons. This pair served as the quantum channel of teleportation, while the other pairs were used for measurement and preparation of quantum states. The results of measurements taken on the initial photon (whose state was subjected to teleportation) together with the measurement of the state of one of the two photons from the hyperentangled pair were transported to the recipient through the classical channel. Making use of this information, the recipient could bring the second photon of the hyperentangled pair to the quantum state of the initial photon, i.e., teleportation took place. The quantum fidelity confidently exceeded the classical level, which testifies to successful teleportation. Quantum teleportation of several properties simultaneously will possibly find practical applications in quantum communication and quantum calculations.

Source: *Nature* **518** 516 (2015)
http://dx.doi.org/10.1038/nature14246

3. Observation of corpuscular-wave dualism of quasiparticles

L Piazza (Federal Polytechnic School of Lausanne, Switzerland) and colleagues have observed wave and corpuscular properties of quasiparticles in one and the same experiment. Surface polaritons (SPs) in a metallic nanowire placed on a graphite substrate that served for heat removal was investigated. SPs comprise electromagnetic surface waves associated with charge oscillations. Like ordinary particles, these quasiparticles possess corpuscular-wave dualism. A nanowire was exposed to a laser beam which generated itinerant SPs. When reflected from the tips of the nanowire, SPs formed a standing wave along the wire. The structure of this standing wave was observed by electron beam scattering. At the same time, in each individual event the electron interacted with an SP as with a particle, and the electron received an additional discrete energy increment $\Delta E = \pm n\hbar\omega$. As a result, a flux of scattered electrons both carried information on the spatial wave structure of SPs and contained electrons with discrete energy increments corresponding to corpuscular SP properties.

Source: *Nature Communications* **6** 6407 (2015)
http://dx.doi.org/10.1038/ncomms7407

4. Pressure-induced superconductivity of MnP

J-G Cheng (Institute of Physics, Chinese Academy of Sciences, China) and colleagues have revealed for the first time that manganese phosphide (MnP) becomes a superconductor at a temperature below ~ 1 K and a pressure of about 8 GPa. At low pressures, the magnetic field destroys Cooper pairs, but with increasing pressure the magnetic properties weaken, which results in the emergence of superconductivity in a narrow region of the phase diagram near ~ 8 GPa, where a quantum critical point exists. A similar effect of the superconductivity occurrence was discovered earlier in the CrAs compound which, just like MnP, possesses a spiral magnetic structure. MnP became the first known manganese-based superconductor. Its superconductivity was registered by a decrease in the electrical resistance and a change in the magnetic susceptibility. The close proximity of the magnetic and superconducting states in MnP may be

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indicative of a nonstandard mechanism of electron pairing due to quantum spin fluctuations.

Source: *Phys. Rev. Lett.* **114** 117001 (2015)
http://arXiv.org/abs/1412.7883

5. Search for signals from dark matter annihilation

Dwarf spheroidal galaxies are promising objects in the search for signals from dark matter particle annihilation, because the relative content of dark matter in them is large and the background radiation is small. The cosmic gamma-ray telescope Fermi-LAT was exploited for six years to investigate 15 dwarf spheroids — satellites of our Galaxy in the energy range of 500 MeV to 500 GeV. No statistically significant excess of gamma-ray signals from dwarf spheroids above the background was found. This implies that for dark matter particles of mass less than 100 GeV and with the annihilation channel to pairs of $b\bar{b}$ quarks or $\tau^+\tau^-$ leptons, the annihilation cross section is below the value of $\langle\sigma v\rangle \approx 2.2\times10^{-26}$ cm^2 s^{-1} needed for thermal production of these particles in the early Universe. Such a restriction presents some difficulties for the most popular dark-matter model in the form of weakly interacting massive particles (WIMPs). However, models comprising annihilation channels directed to light leptons are not also excluded, for in these cases the restrictions on gamma-ray emission prove to be substantially weaker.

Source: http://arXiv.org/abs/1503.02641

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