

# Physics news on the Internet (based on electronic preprints)

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## 1. $D^0 - \bar{D}^0$ oscillations

The LHCb experiment being carried out on the Large Hadron Collider (and involving some Russian researchers) has recorded flipping (oscillations) of the  $D^0$  meson (with  $c\bar{u}$  quark composition) into its antiparticle  $\bar{D}^0$ , predicted by the Standard Model. These oscillations are caused by neutral weak currents through charm mixing. Similar oscillations of  $K^0$ ,  $B^0$ , and  $B_s^0$  mesons have already been observed in the past.  $D^0 \rightarrow \bar{D}^0$  oscillations were also recognized earlier in the aggregate of BaBar, Belle, and CDF data arrays, but their statistical significance was low. In the fresh LHCb experiment, the type of a particle ( $D^0$  or  $\bar{D}^0$ ) was first detected from the presence of  $\pi^+$  in  $D^{*+} \rightarrow D^0 \pi^+$  decays and then from the ratio of the rates  $R$  of the Cabibbo-allowed decay  $D^0 \rightarrow K^- \pi^+$  to Cabibbo-suppressed decay  $D^0 \rightarrow K^+ \pi^-$ . Notice that the same decay products  $K^+ \pi^-$  were produced in the  $D^0 \rightarrow \bar{D}^0$  oscillations followed by the  $\bar{D}^0 \rightarrow K^+ \pi^-$  decays. The measured form of  $R$  as a function of time confirms the actuality of the  $D^0 \rightarrow \bar{D}^0$  oscillations, while the hypothesis of their absence (viz.  $R = \text{const}$ ) is ruled out at a  $9.1\sigma$  confidence level.

Source: *Phys. Rev. Lett.* **110** 101802 (2013)<http://dx.doi.org/10.1103/PhysRevLett.110.101802>

## 2. Computation of unknown eigenvalues with a quantum algorithm

Until recently, quantum computations were carried out in quantum bits (qubits) but the devices for reading out the results (the measurements) had to be specially configured using known classical (nonquantum) solutions of the same problems. A team of researchers (Xiao-Qi Zhou et al.) from the University of Bristol (United Kingdom) and the University of Queensland (Australia) have implemented a protonic experiment of a new type, without simplifying the circuits of the quantum read-out, with the result of quantum computations unknown in advance. The phase of the states of photon polarization was determined iteratively (using the phase estimation algorithm). The method of finding the phase  $\phi$  in the eigenstate of the unitary operator  $U\psi = \exp(i2\pi\phi)\psi$  is widely used in quantum algorithms and makes it possible to exponentially speed up calculations in comparison with the classical case. Eigenstates defining the polarization of photons transmitted through splitters were constructed, and consecutive bits were calculated in the binary phase representation in the measurement chain, beginning with less significant bits which were later used to refine the more significant ones. Quantum computations without predeter-

mined knowledge of the result are an important step on the way to creating practical quantum computers.

Source: *Nature Photonics* **7** 223 (2013)<http://dx.doi.org/10.1038/nphoton.2012.360>

## 3. Collapse of the wave function in graphene

Y Wang et al. (University of California and Berkeley National Laboratory, USA) have utilized clusters of calcium ions immersed in the graphene lattice to implement an effect analogous to the collapse of an electron wave function in the vicinity of a superheavy nucleus. This effect was predicted by I Ya Pomeranchuk and Ya A Smorodinskii (*J. Phys. USSR* **9** 97 (1945)) but has so far remained unobserved. According to QED calculations (see the review by Ya B Zel'dovich and V S Popov, *Physics Uspekhi* **105** 403 (1971)), the atom becomes unstable when its charge  $Z$  increases above  $Z_c \sim 170$ . The wave function of the electron collapses—the electron falls onto the nucleus, resulting in the creation and ejection of positrons. Using a scanning tunneling microscope, clusters about 5 nm in diameter were formed from pairs of ions (calcium dimers) in the lattice of graphene, with up to five dimers in each cluster. The dimers were produced spontaneously under heating and then moved by a microscope needle into clusters. The same microscope was utilized for monitoring the electron cloud by measuring the  $dI/dV$  spectrum at different distances from the cluster. Electrons in graphene have a high coupling constant and relativistic type dispersion curve, which creates favorable conditions for wave function collapse already at the cluster charge  $Z_c \sim 1$ . The interaction between an electron and a cluster of 3–5 dimers indeed resulted in wave function collapsing, which manifested itself in the formation of a resonance state of electrons with an energy below the Dirac point within distances from clusters slightly exceeding 10 nm. In accordance with the prediction in the version with individual nuclei, electron vacancies—holes—were ejected instead of positrons in the experiment with graphene. The results of the experiment are in good agreement with the theoretical evaluations of wavefunction collapse. Alternative explanations, such as multiple scattering of electrons between dimers, are incapable of reproducing the observed pattern.

Source: *Science*, online publication of 7 March, 2013<http://dx.doi.org/10.1126/science.1234320>

## 4. Polymer capacitor

Researchers at Nanyang Technological University (Singapore) have created a prototype capacitor with a polymer insulator between plates, whose characteristics are much better than those of conventional capacitors; they can find important applications in microelectronics. Polymer capacitors were used previously as well, but had a serious drawback: a low field of electric breakdown due to defects in polymer structure, which led to destruction of the insulator. Singapor-

ean researchers synthesized a new multilayer insulator with a much higher breakdown threshold field than is typical of ordinary capacitors. The insulator is based on a chemically, thermally, and electrically very stable polymer.

Source: <http://physicsworld.com/cws/article/news/2013/feb/26/polymer-capacitor-dazzles-flash-manufacturer>

## 5. Black hole with large angular momentum

It has been established using NASA's NuSTAR and XMM-Newton X-ray space telescopes that the supermassive black hole at the center of the galaxy NGC 1365 possesses angular momentum  $L$  close to the maximum allowed by general relativity. This result was obtained by recording the variable X-ray emission reflected off the inner edge of the accretion disk around the black hole. The faster the rotation of the black hole, the smaller the radius of the inner part of the disk, thus producing a very specific modification of the emission spectrum. The interaction of radiation with the gas along the line of sight can also distort the spectrum, so it was necessary to separate this contribution from relativistic effects. This problem has been solved by G Risaliti (at the Arcetri Observatory in Florence) and his colleagues with the NuSTAR telescope, whose working wavelength ranges from 3 to 80 keV, which is somewhat higher than in other X-ray telescopes. Observations in the high-energy segment of the X-ray spectrum made it possible to identify unambiguously the effect of broadening of the iron spectral line and the excess of Compton radiation produced by the gravitational field of the black hole. These measurements gave the parameter of the angular momentum of the black hole as  $a = Lc/(GM^2) \geq 0.84$ , against the maximum possible  $a = 1$ . The black hole could attain this large angular momentum either during its formation or at a later stage, under strongly nonspherical accretion of matter onto it, or in merging with other black holes.

Source: *Nature* **494** 449 (2013)  
<http://arXiv.org/abs/1302.7002>

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