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Physics news on the Internet (based on electronic preprints)

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1. Long-range particle correlations in pp collisions at the Large Hadron Collider

A new type of two-particle angular correlations for charged particles created in collisions was observed in an experiment carried out by the CMS Collaboration to study pp collisions at the Large Hadron Collider. The distribution over azimuthal angles ϕ of particles' emission from the point of reaction and pseudorapidities $\eta(\theta)$ (function of polar angle θ relative to the beam axis) were studied, and correlation functions $R(\Delta\eta, \Delta\phi)$ were constructed for particle pairs. A ridge-shaped elevation of the two-dimensional surface $R(\Delta\eta, \Delta\phi)$ was observed for $2.0 < |\Delta\eta| < 4.8$ at energies of about 7 TeV in the case of high-multiplicity events, with a maximum near the point $\Delta\phi \approx 0$. This means there is a kind of coupling (correlation) between the particles emitted at close azimuthal angles ϕ, despite a large difference in the values of η. Previously, no such angular correlations of particles in pp and $p\bar{p}$ collisions were observed. So far, mathematical modeling of the interaction between particles has not been able to reproduce this feature of the two-particle correlation function: the difficulty lies in the fact that, according to the theory, particles with large $\Delta(\eta)$ should be independent of each other. It is possible that the detected long-range correlations are the result of collective interactions between particles at very high densities of matter.

Source: http://arXiv.org/abs/1009.4122

2. Relativistic time dilation measured in the laboratory

Predictions of the theory of relativity on the slowing down of clocks in a gravitational field and in the case of their motion with respect to the inertial reference frame have been confirmed at Time and Frequency Division of NIST (the National Institute of Standards and Technology, USA). The optical clocks worked on individual trapped $^{27}Al^+$ ions interacting with auxiliary 'logic' $^{9}Be^+$ or $^{25}Mg^+$ ions used to detect changes in the internal state of $^{27}Al^+$ in optical transitions $^1S_0 \leftrightarrow {}^3P_0$. The high Q of the system, $f_0/\Delta f = 1.4 \times 10^{17}$, allowed measuring relative frequency shifts of about 10^{-16}. Two copies of the clocks were placed 75 m apart and were connected by optical fibers to compare how they kept time. In the first experiment, the ion in a trap executed harmonic oscillations at a typical speed of ≈ 10 m s^{-1} relative to the stationary ion in a second trap. The measured relativistic dilation of time in the first clock as a function of ion velocity exactly coincided with the theoretical predictions. In the second experiment, one of the clocks was lifted by 33 cm, which led to acceleration of its 'ticking' due to the variation of the gravitational field. The measured relative frequency shift $(4.1 \pm 1.6) \times 10^{-17}$ was also in good agreement with the calculated value. These effects of time dilation have previously been measured in a number of experiments at high speeds and large altitude differences; the resulting corrections are taken into account, even in satellite navigation systems. The method of measuring small time dilations using a pair of optical clocks may find practical application in geodesy and high-precision experiments searching for changes in fundamental physical constants with time.

Source: *Science* **329** 1630 (2010)
http://dx.doi.org/10.1126/science.1192720

3. New measurement of the gravitational constant

Laboratory experiments with a torsion balance have achieved a relative accuracy of $\approx 10^{-5}$ in measurements of the gravitational constant G. H V Parks (University of Colorado and NIST, USA) and J E Faller (Sandia National Laboratories, USA) improved an alternative interferometric technique of G measurements using pendulums, making it possible to achieve comparable accuracy. Laser interferometric measurements detected a change in the distance between pendulums suspended from strings and oscillating relative to four tungsten cylinders — sources of the gravitational field — with masses of 120 kg each. The second arm of the interferometer, which served as the standard of distance, was fixed between the pivots of the pendulums. The value obtained in measuring G [$G = (6.67234 \pm 0.00014) \times 10^{-8}$ cm^3 g^{-1} s^{-2}] is three standard deviations below the value of G recommended in 2008 by the Committee on Data for Science and Technology (CODATA), but is consistent with the earlier value supported by CODATA in 1986. The difference with the results of the currently best-accuracy experiment with a torsion balance reaches 10σ. The revision of the magnitude of G that occurred between 1986 and 2008 was due to the study of inelasticity in suspension strings in torsion balances. The causes of the observed discrepancies between the results of the new experiment of H V Parks and J E Faller and those of previous measurements are not yet clear.

Source: *Phys. Rev. Lett.* **105** 110801 (2010)
http://arXiv.org/abs/1008.3203v3

4. Quantum random number generator

C Gabriel (Max Planck Institute for the Science of Light and Institute of Optics, Information and Photonics of the University of Erlangen-Nuremberg, Germany) and his colleagues from Germany and Denmark created a random number generator which operates by using the random nature of the zero-point vacuum fluctuations of an electromagnetic field. In contrast to classical algorithms of the generation of random numbers, in the quantum case it is in principle impossible to predict a sequence of numbers. The new

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generator operates on laser splitters with two optical inputs and synchronous photon detectors at the outputs. Even in the absence of a signal in one of the inputs, the total signal contains a random contribution from quantum fluctuations, and this property is utilized to generate random numbers. The calculated probability distribution function for the number of responses was divided into segments with equal cumulative probability, corresponding to different random numbers. Random numbers are generated at a rate of 12 Mbit s^{-1} but certain improvements can greatly increase the rate. The new quantum random number generator is of the fairly simple design and can be used, for example, in cryptography and for numerical Monte Carlo simulations.

Source: *Nature Photonics* **4** 711 (2010)
http://dx.doi.org/10.1038/nphoton.2010.197

5. Sources of ultrahigh-energy cosmic rays

Three years ago, the correlation of arrival directions of ultrahigh-energy cosmic rays with directions toward active galactic nuclei was found by processing the data of the Pierre Auger detector consisting of an array of surface and Cherenkov detectors (see *Usp. Fiz. Nauk* **177** 1318 (2007) [*Phys. Usp.* **50** 1289 (2007)]). The galaxies were not farther than 75 Mpc, which is admissible as a distance to sources in terms of the Greisen–Zatsepin–Kuz'min effect. The coincidence of arrival directions is defined as the direction of the axis of an extensive air shower (the cascade of particles) pointing to an area with a radius of 3.1° around the active nucleus. According to information obtained prior to 31 August 2007, this correlation was obeyed by $69^{+11}_{-13}\%$ of the reported events. The volume of statistical data more than doubled between 31 August 2007 and 31 December 2009; according to revised data, the fraction of events whose arrival directions correlate with the positions of active galactic nuclei reaches $38^{+7}_{-6}\%$, while the fraction of random coincidences in the case of isotropic distribution of sources is evaluated at the level of 21%. The strongest concentration of events detected by Pierre Auger was observed in the direction of the nearest radiogalaxy Centaur A (NGC 5128), and no correlations were found for the nearest large cluster of Virgo galaxies and the giant radiogalaxy M87. Even though ultrahigh-energy cosmic rays ($E \approx 10^{17}$–10^{20} eV) have been recorded for several decades now, the mechanism of their origin and the nature of the sources are not yet understood. It proved possible to establish from the behavior of the events observed in the detectors that the primary particles of highest-energy cosmic rays are protons or atomic nuclei, and that photons can cause only a small fraction of events.

Source: http://arXiv.org/abs/1009.1855

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