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1. Production of t-quarks in proton–nucleus collisions

The production of t-quarks, the heaviest particles in the Standard Model, was observed earlier at the Tevatron in pp collisions only, where the t-quark had been first discovered, and also in pp collisions at the CERN Large Hadron Collider. In the CMS experiment carried out with the LHC, t-quark production was first registered in the collisions between protons and lead nuclei with the nucleon–nucleon center-of-mass energy of $\sqrt{s} = 8.16$ TeV. Earlier, in analogous experiments, $\sqrt{s}$ and the intensity of ion beams were insufficient for recording t-quarks. In the CMS experiment, $t\bar{t}$ pairs were most often produced in the interaction of two gluons $gg \rightarrow t\bar{t} + \ldots$, and then t-quarks decayed rapidly into W bosons. Events were chosen in which one of the W bosons decayed along the lepton channel, and the other along the hadron channel, which led to the formation of four jets and a high-energy single lepton. Seven hundred ten events satisfying the criteria of t-quark production were registered, and the statistical significance of the result was 5σ. The measured t-quark production cross section $\sigma_{tt} = 45 \pm 8$ nb is highly consistent with predictions from perturbative quantum chromodynamics.

Source: *Phys. Rev. Lett.* **119** 242001 (2017)
https://doi.org/10.1103/PhysRevLett.119.242001

2. Verification of the Jarzynski relation for a single ion

Much attention is now being paid to the study of thermodynamic relationships at the quantum level. As distinct from most relations, which in the case of nonequilibrium processes are quantified only by inequalities, the Jarzynski relation is written as an equality relating the mean work done under an arbitrary nonequilibrium change in the state of the system to the difference among equilibrium free energies in its final states. Similar relations were earlier derived by G N Bochkov and Yu E Kuzovlev (for the history of the issue, see *Usp. Fiz. Nauk* **181** 647 (2011) [*Phys. Usp.* **54** 625 (2011)] and *Usp. Fiz. Nauk* **183** 617 (2013) [*Phys. Usp.* **56** 590 (2013)]). In their experiment, T P Xiong (Wuhan Institute of Physics and Mathematics, Chinese Academy of Sciences) and his colleagues have confirmed the Jarzynski relation for a single ultracold $^{40}Ca^{+}$ ion in a Paul trap. The ion spin states prepared and measured with the aid of laser pulses coded the quantum bit. Examined was the relationship between nonequilibrium processes and the information transferred during measurements, and the Jarzynski relation was confirmed successfully for the evolution of the system between two projective measurements.

Source: *Phys. Rev. Lett.* **120** 010601 (2018)
https://doi.org/10.1103/PhysRevLett.120.010601

3. Properties of supercooled water

Water has some interesting physical properties that distinguish it from the majority of other liquids. The growth of the thermodynamic functions of water, such as isothermal compressibility, under deep cooling gives evidence that two phases of liquid supercooled water with different densities may exist and fluctuate into each other, and at a high pressure a critical point must exist where these phases coexist. It is, however, difficult to analyze this region of the phase diagram directly, because water crystallization is spontaneous in this region even without the participation of impurities. A Nilsson (Stockholm University, Sweden) and colleagues have applied the method of femtosecond X-ray laser pulse scattering by drops to investigate the properties of supercooled water at a temperature of ~ 228 K and at an almost zero pressure. Drops ~ 14 μm in diameter were ejected into a vacuum and underwent evaporative cooling. Their temperature was determined by the duration of cooling at different distances from the nozzle. The isothermal compressibility, as well as the correlation length found from the character of X-ray diffraction on liquid drops that did not have enough time to crystallize, turned out to have maxima at 227.2 ± 1 K for ordinary H_2O, and at 233.0 ± 1 K for heavy water, D_2O. These measurements confirm the hypothesis about the existence of two phases of deeply supercooled water and testify indirectly to the presence of a critical point at high pressure.

Source: *Science* **358** 1589 (2017)
https://doi.org/10.1126/science.aap8269

4. 'Quantum radio'

Ordinary radio waves employed in radio communication attenuate rapidly in dense media, but very low-frequency (VLF) waves with $f = 3-30$ kHz can penetrate through very large depths. The development of atomic magnetometers capable of measuring superlow magnetic fields has paved the way for the application of VLF waves for the purpose of communication and positioning in buildings, in tunnels, underground, and in water, although the transmission capacity of the communication channel is rather poor because of the low carrier frequency. Researchers from the National Institute of Standards and Technology (NIST, USA), V Gerginov, F C S da Silva, and D Howe, have used an atomic magnetometer to detect modulated magnetic signals of binary phase manipulation. An inductance coil served as a transmitter. In an optically pumped magnetometer serving as a sensor, ^{87}Rb atoms were used in a glass

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vessel in the magnetic field. The magnetic signal was registered by its effect on the atomic precession frequency and, thus, on the polarization of a laser beam transmitted through the vessel. The use of binary phase manipulation allowed singling out this signal over the external noise level and, first and foremost, over the background of alternating current of 60 Hz and its harmonics, as well as the geomagnetic background. Magnetic signals of order 10^{-12} T were registered at frequencies of less than 1 kHz from a distance of dozens of meters.

Source: *Rev. Sci. Instrum.* **88** 125005 (2017)
https://doi.org/10.1063/1.5003821

5. GW 170817 gravitational burst and β-decays of nuclei

In a laboratory experiment carried out by a group of researchers from several American universities, an unexpected signal was registered coincident in time with the GW 170817 gravity wave burst generated by the coalescence of two neutron stars. Measured was the rate of beta decay of Si-32 and Cl-36 nuclei, whose samples were put in succession into one and the same plastic scintillation detector every half an hour. Before the GW 170817 burst and for some time after, the rates of nuclear decay randomly fluctuated by the usual law $\sqrt{N}$ without mutual correlation. But the decays turned out to be strongly correlated (at a level of 95%) during the five-hour interval following at once the burst. Namely, the rates of Si-32 and Cl-36 decays during five successive series of half-hour measurements simultaneously decreased and then increased again, the probability of accidental coincidence being no higher than $\approx 6.7 \times 10^{-3}$. If these correlations are interpreted as the effect of neutrinos or other particles emitted under binary neutron star inspiral, then from the time delay the masses of these particles $m_x \leqslant 16$ eV can be restricted at the energy of 10 MeV. This interval includes admissible neutrino mass region $m_\nu \lesssim 2$ eV. Correlations of radioactive decays with the season or with the level of solar activity have already been observed in some experiments; however, at the current level of knowledge, the process which might affect the decay of nuclei is unknown, because the neutrino fluxes that reach Earth are too small for this purpose. E Fischbach and his colleagues suggest seeking such correlations in the data of other experiments carried out during the registration of GW 170817 inspiral. See also the discussion in *Usp. Fiz. Nauk* **168** 1129 (1998) [*Phys. Usp.* **41** 1025 (1998)], *Usp. Fiz. Nauk* **170** 213 (2000) [*Phys. Usp.* **43** 203 (2000)], and *Usp. Fiz. Nauk* **170** 214 (2000) [*Phys. Usp.* **43** 205 (2000)].

Source: https://arXiv.org/abs/1801.03585

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