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1. Charge radius of muonic deuterium

In the 2010 CREMA experiment, the proton charge radius in muonic hydrogen was found to be 4% smaller than in ordinary hydrogen. This discrepancy has not yet been explained. As distinct from ordinary hydrogen, it is a muon rather than an electron that revolves around the proton in muonic hydrogen. R Pohl (Max Planck Institute of Quantum Optics, Germany) and colleagues from the same CREMA Collaboration took new measurements, but this time with muonic deuterium (μd) — the exotic atom formed by a deuteron and a negative muon (μ^-). A muon beam was directed to a vessel with gaseous deuterium where muons were trapped in μd atoms and the Lamb shift very sensitive to the nuclear charge radius was measured by the spectroscopic method. The measured root-mean-square charge radius $r_d = 2.12562(78)$ fm was 7.5 standard deviations smaller than the CODATA-2010 value, and 3.5σ less than the CREMA collaboration value obtained for ed. This discrepancy is analogous to that obtained earlier in the comparison of electronic and muonic hydrogen. To explain the revealed discrepancies, one should possibly refine the theoretical calculations, but the contribution of effects beyond the Standard Model is not ruled out as well.

Source: *Science* **353** 669 (2016)
http://dx.doi.org/10.1126/science.aaf2468

2. Neutrino studies

New data on the properties of neutrinos have been obtained in three experiments. Studied in the T2K experiment were ν_μ and $\bar{\nu}_\mu$ oscillations in a beam that had passed from the J-PARC accelerator in Tokai (Japan) to the underground Super-Kamiokande detector at a distance of 295 km. 32 ν_e and 4 $\bar{\nu}_e$ were registered, whereas 23 and 7, respectively, were expected, provided that CP invariance was not violated. Thus, indications of the maximum CP invariance violation in neutrino oscillations were obtained for the first time, although the probability of statistical fluctuation now remains yet high, $\simeq 1/20$. In another experiment, NOvA, ν oscillations are also being studied in a beam propagating from the Fermilab accelerator to the detector located at a distance of 810 km. The measurements showed for the first time that unequal contributions from muon and tau flavors are possibly present in the third mass state. This effect is called 'nonmaximal mixing'. However, a larger set of statistics is needed for its reliable confirmation. The IceCube detector located in the ice of the South Pole is deployed to seek oscillations of atmospheric ν_μ and $\bar{\nu}_\mu$ to sterile neutrinos. No signals corresponding to sterile neutrinos were detected, which narrows the domain of possible parameters for such neutrinos. Russian researchers from a number of scientific organizations are taking part in the international T2K, NOvA and IceCube Collaborations.

Sources: http://t2k-experiment.org/2016/07/t2k-presents-first-cp-violation-search-result/
http://news.fnal.gov/2016/08/nova-shines-new-light-neutrinos-behave/
http://dx.doi.org/10.1103/PhysRevLett.117.071801

3. Programmable quantum computer

Prototypes of quantum computers consisting of several connected qubits have already been demonstrated earlier, but they have been configured only to implement particular planned programs. C Monroe (University of Maryland in College Park, USA) and colleagues have become the first to design a quantum computer that can be reprogrammed for working with different algorithms. The computer consists of a chain of five ytterbium ions $^{171}Yb^+$ trapped in a radio-frequency Paul trap. The zero and unity states were coded by sublevels of a hyperfine-splitted $^2S_{1/2}$ level. Using sequences of laser pulses, one can change the ion states by setting required sequences of quantum operations, and the states (the results of quantum computations) were read by exciting cyclic $^2S_{1/2} - {}^2P_{1/2}$ transitions and registering fluorescent radiation. The pair interaction of ions was realized through their spin–spin interaction and transverse collective movements of ions in the chain. On this computer, the Deutsch–Jozsa and Bernstein–Vazirani algorithms were implemented and the quantum Fourier expansion was demonstrated for the first time, which plays an important role in quantum computations. On account of quantum superposition of states, future quantum computers will be able to solve some problems with an exponentially higher operation speed than conventional classical computers.

Source: *Nature* **536** 63 (2016)
http://dx.doi.org/10.1038/nature18648

4. Room-temperature magnon supercurrent

B Hillebrands (Kaiserslautern University of Technology, Germany) and his colleagues have carried out an experiment in which supercurrent was observed, perhaps for the first time, in room-temperature Bose–Einstein condensate of magnons (quasiparticles — spin wave quanta). Supercurrent was observed earlier only at superlow temperatures in the case of superconductivity and superfluidity. The Bose–Einstein magnon condensate was obtained in a room-temperature ferromagnetic $Y_3Fe_5O_{12}$ film through parametric pumping. Laser pulses created a local temperature gradient in the film, thus inducing the phase shift of the condensate wave function and the divergent magnon flux registered with the aid of Brillouin spectroscopy. The flux characteristics turned out to be quite consistent with the theoretical predictions for a magnon supercurrent. However, the existence of supercur-

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rent is called yet into question, and the demonstration of a dissipationless magnon flow might become decisive confirmation.

Source: *Nature Physics*, online publication of 1 August 2016 http://dx.doi.org/10.1038/nphys3838

5. Search for dark matter particles

The origin of dark matter (DM), which makes up approximately 27% of the Universe's mass, is not yet disclosed. According to one of the basic hypotheses, dark matter consists of spin-independent weakly interacting massive particles (WIMPs), and they are directly or indirectly being sought in a number of experiments. Presented are the new results of investigations on one of the most sensitive underground detectors, Large Underground Xenon (LUX), trying to register the interaction events between WIMPs propagating through Earth and ^{127}Xe nuclei. No excess of signals over the background was revealed, which imposed new constraints on the interaction cross section. Also presented are new results of the search for the annihilation of DM particles using gamma-ray emission by the array of ground-based Cherenkov detectors H.E.S.S (High Energy Stereoscopic System). The inner region of the Galaxy with a radius of 300 pc was observed where the dark matter density is expected to be high and, accordingly, the annihilation must be effective. The H.E.S.S data do not show a statistically significant excess of signal over background either, which imposes constraints on the annihilation cross section. Near a mass of 1.5 TeV for annihilation to W^+W^- pairs, the inequality $\langle \sigma_{\rm ann} v \rangle < 6 \times 10^{-26}$ cm^3 s^{-1} was obtained. Thus, according to the data of ground-based measurements, the constraints approached for the first time the $\langle \sigma_{\rm ann} v \rangle$ value corresponding to thermal relic WIMP production in the early Universe.

Sources: http://arXiv.org/abs/1608.07648 http://arXiv.org/abs/1607.08142

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