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1. Higgs boson decay to a Z boson and a photon

After the discovery in 2012 of the Higgs boson in the ATLAS and CMS experiments performed at the Large Hadron Collider, this boson has been actively examined, and some of its properties predicted by the Standard Model have already been tested [1]. In the Standard Model, the Higgs boson is of fundamental importance as being responsible for the appearance of mass in other elementary particles. The combination of data of the same ATLAS and CMS experiments for the period of 2015–2018 made it possible to register for the first time with a rather high fidelity of 3.4σ another predicted rare process of Higgs boson decay to a Z boson and a photon, proceeding with a probability of only 1.5×10^{-3} for the Higgs boson mass near 125 GeV [2]. Data on pp-collisions with an energy of 13 TeV in the center-of-mass system were used. The Z boson was registered by its decay into e^+e^- and $\mu^+\mu^-$ pairs. The measured Z boson decay probability $(3.4 \pm 1.1) \times 10^{-3}$ is consistent with the theoretical expectation within 1.9σ. The analysis of the $H \to Z\gamma$ decay channel is important, in particular, because the intermediate virtual states of the indicated channel may contain a contribution of new particles and interactions [3].

2. Test of quantum electrodynamics with exotic atoms

A test of strong-field quantum electrodynamic theory is of interest for the search for new effects and, perhaps, manifestations of new physics beyond the Standard Model. An alternative to multicharged ions is the study of muon atoms, in which one of the electrons is replaced by a muon (for exotic atoms, see [4]). Because of its large mass, the muon orbital is 207 times closer to the nucleus, where the field is 40,000 times stronger. T Okumura (Physical and Chemical Research Institute RIKEN, Japan) and their co-authors have examined the X-ray spectra of muon neon — a system of a neon nucleus and a muon [5], occurring upon a low-pressure collision of a muon beam with gaseous neon. The $5g \to 4f$ and $5f \to 4d$ transition energy was measured using superconducting X-ray detectors (transition edge sensors — TESs). The choice of these levels is explained by the rather large distance from the nucleus, which reduces correction for the nucleus size. This gave perfect agreement with the theoretical predictions. In particular, the strong-field vacuum polarization effect was verified to within 5.8%. The precision of the results obtained is comparable with that of the test of strong-field quantum electrodynamics with multicharged uranium ions.

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3. Monopole transition in α particles

In many cases, the complex structure of strong interactions fails to give complete theoretical predictions of phenomena in nuclear physics. Studies by S Kegel (Johannes Gutenberg University Mainz, Germany) and his co-authors of helium nuclei (α-particle) excitations confirm that, in this case, the theoretical calculations are not consistent with experiment [6]. Transitions between the ground level O_1^+ of a α particle and the first excited level O_2^+ (monopole transitions) were examined on the Mainz microtron (MAMI), where an electron beam collided with cold helium nuclei, and the spectrum of the scattered electrons with momenta $Q^2 = 0.5 - 5\ \mathrm{fm}^{-2}$ was measured. The calculations in the framework of the chiral effective field theory fail to reproduce the obtained monopole transition formfactor. This discrepancy has already been known for 10 years, but the accuracy of new measurements exceeds significantly the accuracy of the preceding measurements, which only covered some portions of the indicated interval Q^2. The authors suppose that the difference can be explained by inaccuracies in the structure of the nuclear Hamiltonian. The resonance level O_2^+ is interesting in its location only a little higher than the nucleus decay energy, and it is not yet clear now whether the helium nucleus at the O_2^+ level is a predominantly collective four-nucleon excitation or a molecular state of a proton and a tritium nucleus.

4. Spiral spin liquid

Unusual spin structures (skyrmions, etc.) are important both from the fundamental viewpoint and for their potential application in new technologies [7–9]. A spiral spin liquid, i.e., a correlated paramagnetic state formed by fluctuating spin spirals, remains a poorly investigated structure. It was theoretically predicted in Heisenberg's models $J_1 - J_2$ but has not yet been experimentally observed. The difficulty in its registration lies in the fact that substances have many more chances to transfer to other more typical magnetic states. J N Graham (University of Birmingham, Great Britain and Laue–Langevin Institute, France) and her co-authors used neutron scattering by a polycrystalline sample to find for the first time the spiral spin liquid in the compound $LiYbO_2$ [10]. Spiral contours corresponding to the spiral spin liquid were revealed on diffusion scattering maps. The existence of this state was also evidenced by the measured spin-spin correlation functions.

5. Ring-like structures in the center of galaxy M87

The Event Horizon Telescope observations of 2017 at a wavelength of 1.3 mm revealed a ring-like structure around the black hole (BH) in the center of the galaxy M87. This structure is assumed to be formed by gravitationally lensed radiation from the central region. R-S Lu (Shanghai Astronomical Observatory, China and Max Planck Institute for Radio Astronomy, Germany) and their co-authors published the data of interferometric observations of the same region, carried out with several radio telescopes at a wavelength of 3.5 mm [11]. Thanks to an improved data processing technique, the achieved resolution was 4 times higher than that in previous observations. At the wavelength of 3.5 mm, one can see a ring-like structure with a diameter of $8.4^{+0.5}_{-1.1}$ Schwarzschild radii of the BH, which is 50% larger than that on a wave of 1.3 mm. The new ring-like structure is interpreted as synchrotron radiation of accreted matter with absorption. Furthermore, a transition region from a ring-like structure to a relativistic jet was observed for the first time. Near the BH, the jet was somewhat wider than expected, which is indicative of a possible effect of wind from an accretion flow. For the BH silhouette in M87, see [12].

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