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1. Longitudinally polarized W boson

The prediction of the Standard Model of elementary particles concerning the possibility of production of longitudinally polarized W bosons has been confirmed in an LHC experiment [1]. W bosons may have a longitudinal polarization with spin along momentum owing to a nonzero mass occurring by the Higgs mechanism. Particles were born in proton-proton collisions at a center-of-mass energy of 13 TeV, and the ATLAS detector was used to examine effects with two same-sign leptons and two jets in the final state. Same-sign $W^{\pm}$ boson pairs, one of which was longitudinally polarized, were discovered for the first time. The significance of recording such events is 3.3σ, and the cross section of the process, 0.88 ± 0.30 fbn, agrees with calculations within the Standard Model. Observation of this process paves the way for searching for effects beyond the Standard Model. The described experiment also gave the most stringent constraint on the possibility of the production of two single-signed longitudinally polarized W bosons.

2. Investigation of islands of inversion of atomic nuclei

In the nuclide table, there are regions — 'islands of inversion' — where the shape of the nucleus in the ground and excited states differs strongly. Experiments have revealed four such islands near nuclides with filled neutron shells. A spin in the ground state and magnetic dipole moment of ^{61}Cr nuclei having $N = 37$ neutrons were measured for the first time using laser spectroscopy at the CERN-ISOLDE installation [2]. Spin-parity of ^{61}Cr nuclei in the ground state was considered earlier to be $I^{\pi} = 5/2$, but the measurement showed that actually $I^{\pi} = 1/2$. Such a refinement made it possible to improve the scheme of ^{61}Cr levels and to determine the boundary of the island of inversion near $N = 40$. The results of measurements were interpreted in the framework of the new LSSM and DNO-SM theoretical models. According to these calculations, the ground state of ^{61}Cr nuclei has a triaxial shape with prevalence of the neutron configuration $2p - 2h$ connected with an unpaired neutron, and the change in the neutron shape is due to wavefunction reconstruction upon quantum phase transition.

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3. Neutrino laser

In 1954, R. Dikke predicted the possibility of superradiation, i.e., a collective spontaneous radiation of an ensemble of atoms [3–5], and for photons, this effect had already been realized in experiments. In their theoretical work [6], B.J.P. Jones (University of Texas at Arlington, USA) and J.A. Formaggio (Massachusetts Institute of Technology, USA) have shown that it is, in principle, possible to use superradiation to create a powerful directed neutrino beam. Although, in the case of neutrinos, the laser effect of stimulated radiation is missing, the coherent properties of the beam allow calling the device under discussion a 'neutrino laser.' Neutrino superradiation must take place in collective spontaneous beta decays with an electron trapped in a Bose–Einstein condensate of radioactive atoms. Atoms in a condensate have a common wavefunction, and therefore, in decays, quantum probability amplitudes are summed, and decays accelerate proportionally to the number of particles squared. According to calculations, a condensate of $\sim 10^6$ atoms of ^{83}Rb already suffices to create a neutrino laser, and the ^{83}Rb half-decay time will decrease from 86.2 days to 2.5 minutes. If neutrino lasers appear, they may find application in fundamental studies and for neutrino communication. Furthermore, the inverse effect of neutrino capture in a Bose–Einstein condensate can be used to register relic (cosmological) neutrinos.

4. Testing area law for black holes (BHs)

On January 14, 2025, two gravitational-wave LIGO detectors recorded gravitational-wave burst GW250114 with a record signal-to-noise ratio, equal to 80, which has made it possible to reach the level of BH spectroscopy and investigate various horizon oscillation modes [7]. Two BHs with masses of $33.6^{+1.2}_{-0.8} M_{\odot}$ and $32.2^{+0.8}_{-1.3} M_{\odot}$ and small spins merged in this event. Observed was a gravitational wave emission upon BH approach, radiation during coalescence, as well as radiation upon oscillations of the BH, which was formed upon coalescence (the ringdown phase). In the analysis, several of the strongest oscillations upon coalescence were excluded, and so, for the remaining time interval, the linear perturbation theory was applicable. The resultant BH had a dominant oscillation mode and its first overtone. The frequencies and times of damping are indicative of the formation of a rotating BH described by a perturbed Kerr solution. It also appeared possible to test Stephen Hawking's prediction of a nondecrease in the horizon area when BHs merge more precisely than before (at a 4.4σ credibility level).

5. Unusual cosmological objects

Recent J. Webb space telescope observations have revealed a new class of compact (with a radius of ~ 150 pc) bright red shaded galaxies within the first billion years of the Universe's life ($z \geqslant 6$). Such objects were called 'little red dots' (LRDs). LRD radiation is generated either by stars or by active galactic nuclei. In the latter case, central supermassive black holes (SMBHs) must have masses larger by 2–3 orders of magnitude than follows from the known relations in the modern Universe. It is still unknown what the nature of LRDs is, how they formed, and what they later transformed into. New J. Webb observations revealed an LRD at a record-high $z = 9.288$ [8]. This galaxy has a broad Balmer emission line and a stellar mass $\leqslant 10^9 M_{\odot}$, and the SMBH mass makes up $> 5\%$ of the star masses. Observations of another LRD revealed a large amount of hot dust [9]. An object resembling an LRD was also discovered at $z = 3.55$ [10]. It may be not a star galaxy but rather an SMBH immersed in a dense gas cloud and accreting in the super-Eddington regime. In paper [11], LRDs were hypothesized to be rare galaxies with a small angular momentum L. The small L simultaneously explains the compactness of LRDs (a high concentrations of stars) and their observed number.

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