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1. Production of single t quarks together with photons

As distinct from $t\bar{t}$ quark pairs, production of a single t quark together with a photon in one process has never been observed because of the low probability of such an event and its difficult identification against the background of more numerous events with $t\bar{t}$. The production of a single t quark together with a photon has been reliably revealed for the first time by the ATLAS detector at the Large Hadron Collider [1]. In the examined process, the initial state is represented by a gluon and a quark q in colliding protons. The gluon splits into a $b\bar{b}$ pair, and the quark b interacts with q, forming one t quark and a quark of some other type. The quark t emits γ before its decay into a b quark and a W boson, which decays into e or μ and ν. When recording charged leptons, the ATLAS collaboration used machine learning algorithms to identify single t quarks produced together with photons at a 9.8σ confidence level. The measured cross section of this process turned out to be a little larger than the Standard Model theoretical prediction (divergence at the level of 2σ). Processes related to single-t quark production are fairly sensitive to electroweak interactions of t quarks, and their analysis may lead to the discovery of new particles and interactions beyond the Standard Model.

2. New approach to constructing the quantum theory of gravity

The fundamentals of the quantum theory of gravity uniting quantum mechanics and the General Relativity Theory were laid in the 1935 paper by M P Bronshtein [2], but this theory is still far from being completed because of essential difficulties in gravitational field quantization. It is typically assumed that, like fields of matter, a gravitational field (the space-time geometry) must have a quantum origin. One of the arguments is the necessity of quantum superposition of gravitational fields generated by a particle in the state of superposition of different spatial positions. Nevertheless, in his new study, J Oppenheim (University College of London, Great Britain) [3] has made an attempt to construct a consistent theory, where the gravitational field is purely classical (not quantum), and quantum fields evolve against the background of the classical space-time. To agree with the above arguments, the interaction between quantum fields and geometry is assumed to have a stochastic nature and to be described by the density matrix. The decoherence process in this theory is due to the interaction of quantum fields with a classical gravitational field. Promising as this approach looks, serious difficulties remain that should be overcome.

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3. Nonfocal Mie scattering

In 1908, G Mie developed the theory of light scattering by spherical particles. Although the Mie theory operates with plane light waves, it describes well a majority of phenomena. Y-L Tang (National Taiwan University) and their co-authors showed in their experiment [4] that the use of nonplanar wave fronts and nonfocal configurations changes radically the scattering process. Investigated was the scattering of focused laser light by rectangular silicon bars, the center of the light spot shifting relative to the bar center. When the light wavelength is close to the bar size, nonfocal positions exist in which the scattering is maximum. The results obtained can be explained by excitation of scattering modes with higher multipoles, which are absent in the case of plane waves.

4. Electric discharge under contact electrification

Contact electrification, that is, an electric charge transfer between adjoining surfaces, has been studied for centuries. If the surfaces are separated, air comes into the gap with the electric field, and an electrical breakdown occurs, followed by a partial discharge. However, the details of the process remained unclear because of the complexity of measurements without interfering with the system (without additional electrodes). The American researchers H Tao and J Gilbert have become the first to examine contact electrification using an electrode-free technique to measure electric voltage [5]. In the chamber, two dielectric discs were brought into contact and separated, and the charge-dependent force of their Coulomb attraction was measured. Measurements at different distances between the discs and at different gas pressures in the chamber confirmed the averaged Paschen's law, but in individual measurements the corresponding graphs turned out to be stepwise due to the discrete nature of the discharge process. An electrical discharge is a very common phenomenon, and it can also lead to fires and explosions. On the contrary, the absence of gas discharge in space leads to the destruction of satellite parts due to accumulation of a large surface charge. Such phenomena demonstrate the importance of studies on electrification mechanisms.

5. Parity conservation in relic radiation

It is a known fact that electroweak interactions violate P parity, that is, symmetry of processes related to mirror reflection. As predicted by the cosmological inflation theory, one of whose main founders was the outstanding Russian scientist A A Starobinsky, the entire visible region of the Universe arose as a result of inflation of one of the causally connected microscopic volume. Since models exist of parity-violation under inflation, and inflation has led to the occurrence of inhomogeneities, parity violation can be expected in the distribution of galaxies and the cosmic microwave background (CMB). And, indeed, a weak indication (at the 2σ level) of the parity violation effect in galaxy surveys was obtained in 2022 [6]. To verify parity conservation in the CMB, O H E Philcox (Columbia University, USA) has carried out a new analysis of Planck telescope data [7]. Parity violation could have appeared in the trispectrum of CMB fluctuations, but, at the available accuracy, the violation has not been detected. In the case of the inflationary origin of the inhomogeneities, this result cast doubt on the indicated violation in galaxy surveys, since it would have led to a much larger parity violation in the CMB, which is ruled out by O H E Philcox's work. Observing the CMB provides valuable information about the early Universe's evolution. It is expected that in the near future it will be possible to reliably single out CMB polarization generated by gravitational waves (the tensor mode of perturbations) and thus verify various inflation theories. In particular, A A Starobinsky's inflation theory predicts a certain magnitude of the tensor mode. As distinct from alternative models, the inflation paradigm explains many observed properties of the Universe. If the theory of early Universe inflation is ultimately proven, it will become, along with A A Friedman's cosmological expansion model, one of the greatest achievements of humankind in understanding the structure of our Universe.

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