Physics – Uspekhi **68** (1) 105 – 106 (2025)

PHYSICS NEWS PACS numbers: **01.10. – m**, **01.30. – y**, **01.90. + g**

Physics news on the Internet: January 2025

Yu.N. Eroshenko

DOI: https://doi.org/10.3367/UFNe.2024.12.039824

1. B-meson decays

Interesting anomalies in B-meson decays have been observed already for many years [1]. In particular, according to the general principles of the theory, the channels of $B \to PP$ decay into different types of pseudoscalar particles (K or π) must be related to each other by a flavor $SU(3)_F$ symmetry, but the measured parameters of different decays do not agree with each other. Previously, because of the lack of experimental data, it was necessary to make some dynamic assumptions in the analysis to rule out some of the Feynman diagrams, but now the amount of data is sufficient for a comprehensive analysis without additional hypotheses. R. Berthiaume (University of Montreal, Canada) and his co-authors have performed a new analysis of $B \to PP$ decays caused by quark transitions $\bar{b} \to \bar{u}u\bar{q}$ and $\bar{b} \to \bar{q}$, where $q = d, s$ [2]. A discrepancy at the level of 3.6σ with the $SU(3)_F$ approximation in the Standard Model of elementary particles was found. However, if we assume QCD factorization, the discrepancy increases to 4.4σ. This fact may be indicative of a strong violation of $SU(3)_F$ symmetry in B-meson decays. A possible cause of the violation may be the new physics beyond the Standard Model (see [3, 4]).

2. Toroidal electric dipole moment of the nucleus

Different types of toroidal modes occur in many physical systems. Models of the atomic nucleus predict that toroidal electric modes, called modes of toroidal dipole resonance, may also occur in nuclei. As distinct from spherical Hill vortices, where fluid undergoes complete circulation, nucleons in these modes only experience small oscillations. P. von Neumann-Cosel (Technical University of Darmstadt, Germany) et al. may have become the first to obtain indications of toroidal modes with energies of 6–11 MeV in spherical ^{58}Ni nuclei in the state $J^{\pi} = 1^{-}$ [5]. A combination of inelastic scattering of photons, protons, and electrons by nuclei was used. To single out toroidal modes, it was necessary to solve the complex problem of eliminating the dominant contribution of E1 transitions. A comparison of the measurement results and calculations by the density functional method made it possible to identify low-energy states — candidates for a toroidal electric dipole. Russian researchers from the Laboratory of Theoretical Physics of JINR (Dubna) and the Dubna State University took part in the work.

Yu.N. Eroshenko Institute for Nuclear Research,
Russian Academy of Sciences,
prosp. 60-letiya Oktyabrya 7a, 117312 Moscow, Russian Federation
E-mail: erosh@ufn.ru

Uspekhi Fizicheskikh Nauk **195** (1) 112 (2025)
Translated by N.A. Tsaplin

3. Proton conductivity of porous titanium

Materials that allow hydrogen (or positive hydrogen ions — protons) to pass through them but retain all other gases are very important for technical applications. To date, graphene and hexagonal boron nitride (hBN) have possessed record-breaking measured proton conductivity. However, the use of these substances encounters some difficulties, and it is also highly desirable to obtain an even higher value of proton conductivity. Yu. J (University of Macau, China) and their co-authors have discovered that a titanium monolayer, produced by a special multistage exfoliation procedure, has an unexpectedly high proton conductivity, two orders of magnitude higher than that of a graphene monolayer and an order of magnitude higher than that of hBN at room temperature [6], the monolayer not allowing a helium flow through itself. Samples ~ 1.1 nm thick and several μm in size were examined. As shown by the study with the help of a high-resolution transition electron microscope, from 7.5 to 13.5% of all positions of atoms are occupied by vacancies (missing titanium nuclei). The authors of the work believe that it is precisely this porosity at the nanoscale that is responsible for the high proton conductivity. The tendency of conductivity growth under heating shows that it is much higher at high temperatures. Such materials with a high proton conductivity may find application in hydrogen fuel cells, membranes, and other devices.

4. Phonon qubit

The quantum properties of mechanical systems have already been demonstrated in some experiments. Yu. Yang (Swiss Federal Institute of Technology Zürich) and their co-authors have taken the next step by creating a controllable, fully mechanical phonon-based qubit [7]. Their experiment used a bulk solid-state acoustic resonator (a piezoelectric disc on a sapphire substrate) coupled to a transmonic superconducting circuit. The qubit was implemented at the two lowest quantum levels of mechanical oscillations (on phonons), and the electromagnetic device only served to control the level of oscillation anharmonicity. The single-phonon anharmonicity in the system exceeded its decoherence rate by a factor of 7. A strong nonlinear interaction of phonons made it possible to bring the mechanical qubit to a given initial state during decoherence and then read out the final state, i.e., create single-qubit quantum gates. The advantage of mechanical qubits is their compactness and long lifetime of mechanical quantum states. Based on such mechanical qubits, it may be possible to construct practically useful devices to work with quantum information. For another type of qubit — superconducting qubits — see [8].

5. Record-long-period cosmic radio transient

To date, only a few periodic radio transients (variable radio signals) with periods from several minutes to $\sim$ two hours have been detected, and in most cases, it was impossible to reliably register their optical radiation. It is only in the case of the radio transient ILT J1101 + 5521 that the source (a low-mass star paired with a white dwarf) is observed in the optical range. Analyzing the observational data from the Murchison Widefield Array and MeerKAT radio telescopes, N. Hurley-Walker (Curtin University, Australia) and her co-authors have discovered a new radio transient GLEAM-X J070437 with a record large period of 2.9 hours and predominantly linear polarization and then revealed its optical radiation in the archive data of ground-based optical telescopes and Gaia telescope [9]. After the indicated period, radio pulses with a duration of 30–60 s follow. A probable interpretation is a dwarf star of spectral class M3 at 1.5 ± 0.5 kpc, whose stellar wind interacts with the magnetosphere of the other object of a binary system. The neighboring object, invisible in the optical range, is most likely a white dwarf with a strong ordered magnetic field. It is not ruled out that the second object is a neutron star, but this model encounters some difficulties. The period of 2.9 hours may be either the period of revolution of the white dwarf around its axis or the orbital period of the pair. Moreover, the radio emission shows modulation with a period of ~ 6 years, which has not yet been reliably explained.

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