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Yu N Eroshenko

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1. Triple W boson production

Rare events of three W-boson production in one process have been registered for the first time at the Large Hadron Collider at CERN [1]. Collisions of protons at a center-of-mass energy of 13TeV were recorded by the ATLAS detector. WWW events were singled out with a statistical significance of 8σ using 139 fb^{-1} of the database. Such events have never been reliably revealed before because of the small cross section of inclusive production $pp \to WWW$. The measured cross section turned out to be 2.6σ larger than predicted by theoretical calculations. At the given stage, this divergency may be thought of insignificant. The $pp \to WWW$ process is sensitive to self-interaction of intermediate bosons and to other effects, and therefore considerable deviations from Standard Model predictions might testify to a contribution from the 'new physics' [2, 3]. This shows the importance of studies in this area. Russian researchers from several scientific institutions are affiliated with the ATLAS Collaboration.

2. Spin noise spectroscopy

Magnetization fluctuation (spin noise) spectra contain important information about the properties of different materials [4, 5]. One of the spin noise detection methods is measuring noises from Faraday rotation — the polarization twist of a probing beam crossing a sample. This approach was earlier considered to be inapplicable to optically anisotropic crystals because of polarization distortion. V S Zapasskii (St. Petersburg State University) and his colleagues have shown [6] both theoretically and experimentally that the problem only concerns homogeneous crystals, whereas in media with random uncorrelated inhomogeneities (spin fluctuations) the Faraday rotation noises are not suppressed, and the spin noise spectroscopy remains an efficient research method. This conclusion was experimentally verified with $CaWO_4$ and $LiYF_4$ crystals activated by Nd^{3+} ions. Crystals were put into a cryostat at a temperature of 3 K in a magnetic field, and lasing-induced transitions between Nd^{3+} levels were examined. The experiment has confirmed that anisotropy does not seriously affect the spin noise measurement. The physical 'spin noise spectroscopy' research method was developed by E B Aleksandrov and V S Zapasskii in 1981 [7]. The results obtained open new possibilities for its application in optically anisotropic and inhomogeneous media.

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

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3. Angle-resolved photoemission spectroscopy and the Fermi surface

Angle-resolved photoemission spectroscopy (ARPES) appeared exactly 100 years ago and became one of the basic research methods in solid state physics [8]. S Borisenko (G W Leibniz Institute for Solid State and Materials Research and Fermiologics Company, Germany) and his co-authors have updated the ARPES methods within a short time period to obtain high-resolution 3D images of the Fermi surface [9]. An electron lens was placed between a sample and detector, which heightened the angular resolution. The second key point was a negative cutoff potential a bit lower than the threshold photoelectron energy. This allowed measuring their spectrum with high accuracy. Experiments realizing these ideas have demonstrated measurement of the 3D Fermi surface in the $TiTe_2$ compound and detailed 2D Fermi surface measurements in several superconductors, topological insulators, and other substances.

4. Josephson effect at the atomic scale

In 1966, I Kuluk showed in [10] that the presence of spin states in a tunnel junction between superconductors can reverse the Josephson current flow by a phase shift by π. This effect was observed in mesoscopic systems, but, at the atomic scale, a similar effect, known as the 'Yu–Shiba–Rusinov state,' had not been realized before. S Karan (Max Planck Institute for Solid State Research) et al. have performed a new experiment [11] to observe the Yu–Shiba–Rusinov State for the first time. A magnetic impurity was placed at the endpoint of a superconducting vanadium needle drawn near a superconducting sample. This device differs from the conventional SQUID by the absence of a loop. Instead, the phase shift is realized through a quantum phase transition inducing destructive interference of two transport channels and reversing supercurrent between the needle and the sample, which is indicative of the Yu–Shiba–Rusinov state. The Josephson effect at the atomic scale may find application in quantum sensors and in investigations of superconductivity mechanisms.

5. Periodicity in the fast radio burst FRB 20191221A

The generation mechanism of fast radio bursts, i.e., millisecond radio signals from space, has not yet been clarified. One of the hypotheses suggests bursts on neutron stars — magnetars [12]. B C Andersen (McGill University, Canada) and her co-authors from the CHIME/FRB Collaboration have detected a fast radio burst, FRB 20191221A, with a total duration of about 3 s, and which contains nine components separated by time intervals of multiples of 217 ms [13]. The statistical significance of the discovered periodicity is 6.5σ, and the large measure of burst dispersion points to its extragalactic origin. Although sources of repeated bursts with nonrigorous periodicity are already known, such a fast periodicity as that of FRB 20191221A has not yet been observed. This testifies in favor of the model [14] of burst generation directly in the magnetosphere of a rotating neutron star (like galactic radio pulsar bursts, but much more powerful) and restricts models where bursts are generated in more distant regions.

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