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In memory of Lev Borisovich Okun

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The outstanding scientist and teacher Lev Borisovich Okun, a world renowned physicist and full member of the Russian Academy of Sciences (RAS) passed away after a long and serious illness on 23 November 2015 in the 87th year of his life.

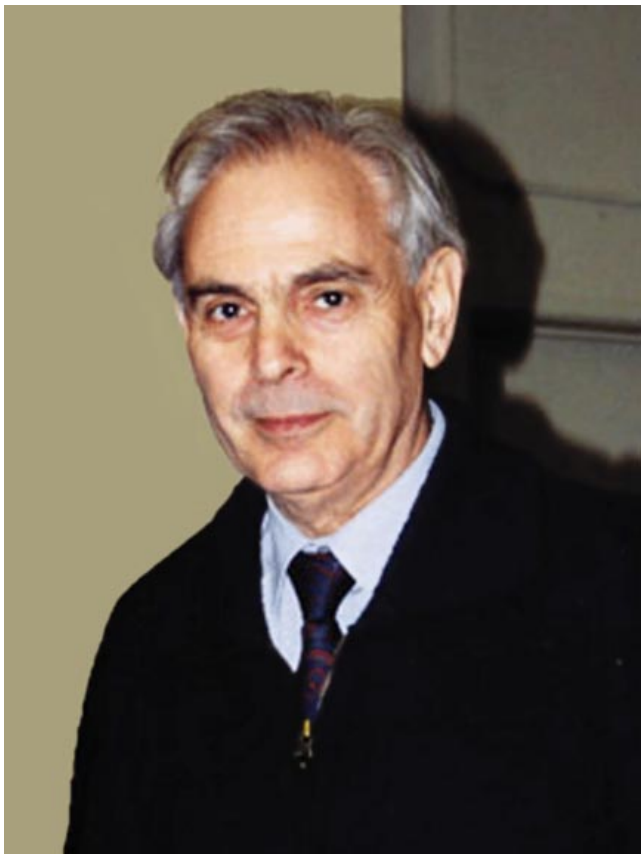
Lev Borisovich was born on 7 July 1929 in the town of Sukhinichi, Kaluzhskaya region. After finishing secondary school with a gold medal, he entered the Moscow Engineering Physical Institute, from which he graduated in 1953 (he worked on his diploma under the tutorship of V I Kogan and A B Migdal).

In 1954, Lev Borisovich entered as a postgraduate student the Institute of Theoretical and Experimental Physics (ITEP), with which all his further scientific work was connected. In 1956, Lev Borisovich defended his candidate thesis at ITEP under the tutorship of I Ya Pomeranchuk (L D Landau, Pomeranchuk's teacher, once called Lev Borisovich his 'grandson'), and in 1961 he defended his doctor's thesis. In 1966, he was elected a corresponding member and in 1990 a full member of the USSR Academy of Sciences. Lev Borisovich taught students at the Moscow Institute of Physics and Technology (MIPT), where he was a professor beginning in 1967.

At ITEP he organized and headed for over 30 years the laboratory of elementary particle theory. The center of 'Okun's school', i.e., his collaborators, disciples, and disciples of his disciples, worked at ITEP. Many Russian and foreign scientists came to the institute to discuss physics with Lev Borisovich. He invariably tried to reach full insight into the most sophisticated physical phenomena. His deep intuition and the ability to formulate fundamental problems exerted influence on the development of elementary particle physics for more than fifty years.

His concluding talk at the Leptons and Photons conference in the distant 1981 was devoted to the importance of the search for the Higgs boson, i.e., a scalar particle responsible for renormalizability of the electroweak theory; he called it the number one task in elementary particle physics. Note that this had been said two years before the discovery of intermediate vector W- and Z-bosons. The Higgs boson was only discovered thirty years after that at the Large Hadron Collider (LHC). In the same talk, he spoke of the possible existence of a whole 'country of scalar particles', i.e., a large number of new fundamental particles with different masses and charges. These discoveries may lie ahead for LHC, which in 2015 started operating at the total energy 13 TeV.

Some time ago, Lev Borisovich asked himself questions such as why only two charged leptons (e and μ) exist and a third one does not (the τ lepton was discovered only in 1975); and why spin 1/2 mesons are missing (they may occur in the supersymmetric theories formulated later).



Lev Borisovich Okun
(07.07.1929 – 23.11.2015)

Weak interactions were Lev Borisovich's favorite subject of research from the very beginning and over all the time of his scientific activities. The success of this choice was exceptional in that within the past few years the gauge electroweak theory was formulated, which is one of the vertices of theoretical physics. Already in the early work in this area he obtained fundamental results such as the conclusion that P parity violation in beta decays also implies violation of C parity (together with B L Ioffe and A P Rudik, 1957) and the estimation of the neutral K meson mass difference (together with B M Pontecorvo, 1957). In 1963, a remarkable book by Lev Borisovich, *Weak Interaction of Elementary Particles*, appeared, which became a textbook and a handbook for many students and research workers. This book, which was published before the appearance of the quark model, was based on one of the first successful composite hadron models (the term introduced by him), the so-called Sakata–Okun model, which he had been developing since 1958. In this model, all the particles known by that time consisted of three

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praparticles — predecessors of quarks. The existence of η and η' mesons was predicted and the selection rule $\Delta Q = \Delta S$ formulated for semileptonic decays of strange particles.

A series of his papers in the early 1970s with V N Gribov, A D Dolgov, and V I Zakharov was devoted to the study of the behavior of weak interactions at asymptotically high energies in the framework of the four-fermion theory. Lev Borisovich began to study with enthusiasm the new gauge theory of electroweak interactions which appeared at that time and was described in his book *Leptons and Quarks*, published in 1981 and reissued in 1990. A special issue of this book devoted to the discovery of the Higgs boson appeared in 2014. A new scheme of account of loop radiative corrections to electroweak observables, in particular, to the probabilities of Z-boson decays, was proposed in the 1990s in a series of papers (with co-authors M I Vysotsky, V A Novikov, and A N Rozanov), where the results of precision measurements at the LEP I, LEP II, Tevatron, and SLC accelerators were also analyzed.

Very important results that became classic in the theory of strong interactions belong to him. The study of the behavior of strong interactions at asymptotically high energies led, notably, to the well-known 1956 Okun–Pomeranchuk theorem of isospin independence of scattering cross sections in the limit of such energies. In the second half of the 1970s, in collaboration with A I Vainshtein, M B Voloshin, V I Zakharov, V A Novikov, and M A Shifman, he proposed and developed the QCD sum rule method for charmonia, which in the literature is referred to as the 'ITEP sum rules'. At the same time he wrote with co-authors the fundamental review "Charmonium and gluons", which has up to the present day served as one of the standard texts on the physics of heavy quark systems.

Lev Borisovich was one of the founders of the study of the interrelation between the properties of elementary particles and cosmology and astrophysics. The study of the dovetailing of particle physics and the evolution of the Universe, galaxies, and stars has now become, in fact, a separate area in natural science. Such a 'synthesis' of cosmology and elementary particle physics was first considered in the 1965 paper (written together with Ya B Zel'dovich and S B Pikelner), where the method was proposed of calculating relic concentrations of elementary particles in the course of the Universe's expansion. In this work, the authors calculated the concentration of free fractionally charged quarks in our Universe. Their absence in observations is one of the proofs of quark confinement. At the present time, this method is used to examine the abundance of existing and hypothetical particles, in particular, dark matter particles in space.

One dark matter model that is still topical was in fact proposed by Lev Borisovich, I Yu Kobzarev, and I Ya Pomeranchuk in the mid-1960s. In connection with the discovery of *CP* symmetry breaking, they suggested the hypothesis of the existence of a 'mirror world' of particles (with the opposite sign of symmetry breaking) interacting with 'our' world only gravitationally.

In 1974, he turned to the study of quasi-classical configurations of quantum fields and their possible manifestations in cosmology. In a paper co-authored with I Yu Kobzarev and Ya B Zel'dovich, he considered for the first time the influence of vacuum domains and domain walls occurring upon spontaneous violation of discrete field symmetry on the expansion dynamics of the Universe. In the same year, in collaboration with M B Voloshin and I Yu Kobzarev, he constructed the theory of spontaneous decay of a metastable vacuum. Each of these studies evolved into an independent branch in the physics of fields and particles and in cosmology. In particular, the problem of metastable vacuum decay, which seemed to be rather abstract, became practically topical with the discovery and measurement of the Higgs boson mass. With today's values of this mass and the t-quark mass, 'our' physical vacuum must be metastable only provided its stabilization is not attained thanks to 'new physics'.

Lev Borisovich long contemplated profoundly the applicability limits of 'unshakeable' fundamental principles of physics, such as the Pauli principle, *CPT* invariance, electric charge conservation, the absence or the existence of 'other photons', atom electroneutrality, and the photon masslessness. With each of these issues, he tried to attain a quantitative formulation of accuracy to which the fulfillment of these principles is known and analyzed practical ways to improve this accuracy.

Scientific discussions with Lev Borisovich played an invaluable role for his colleagues. His inexorable desire to reach the clearest understanding often exhausted his interlocutor, but was always fruitful. Many people appreciated his ability to put forth 'correct' questions. A well-known example is a remark during the talk by A M Polyakov in 1975 that the solution of Yang–Mills equations found by the speaker is nothing but a magnetic monopole.

Lev Borisovich spent much time and did everything in his power for the journal *Uspekhi Fizicheskikh Nauk* (*UFN*). Becoming a *UFN* author in 1957 and a *UFN* editor in 1967, he largely determined the image of our journal over half a century. For example, immediately after the well-known burst of a supernova in the Large Magellanic Cloud in 1987, for which a neutrino signal was registered, he became the main initiator of publication of a detailed review of this event in *UFN*. Owing to his very important critical remarks and unprecedented persistence, this review (by the ITEP astrophysicists V S Imshennik and D K Nadezhin) was successfully published very soon — at the end of 1988. This review turned out to be the first in the world scientific literature, even in the English translation. (The next review — by American astrophysicists — appeared approximately half a year later.) After that, Lev Borisovich was immutably interested in the development of neutrino astronomy, which may be thought of as rooted in precisely the registration and interpretation of the neutrino signal from SN1987A.

Lev Borisovich taught at the MIPT sub-faculty Elementary Particle Physics for 50 years. The lectures on weak interactions he delivered were legendary. More than 20 candidate dissertations were defended under his supervision. Most of his disciples became well-known theoreticians. Lev Borisovich invariably delivered lectures at all Winter Physics Schools at ITEP.

Lev Borisovich was a prominent popularizer of physics. He wrote brilliant books for the general public, namely, α, β, γ,... *Z*, *Elementary Particle Physics*, *Elements of Physics — a Very Short Guidebook*, which were issued and many times reissued all over the world. In his last years, Lev Borisovich fought fearlessly and untiringly with the archaic and partly incorrect interpretation of Special and General Theories of Relativity that took root in the world literature. The results of this fight were presented in several papers in *UFN*, the *American Journal of Physics*, and the collection *Energy and Mass in Relativity Theory* (2009).

Lev Borisovich's public activity in the years after Perestroika was of paramount importance for the successful existence of science in Russia and other countries of the CIS. He was one of the organizers of the International Scientific Foundation (Soros Foundation) and the International Association for the Promotion of Cooperation with Scientists from the Independent States of the Former Soviet Union (INTAS).

The international scientific community highly valued the scientific results obtained by Lev Borisovich. He was member of the European Academy of Sciences, an honorary member of the New York Academy of Sciences, and a full member of the Institute of Physics (IOP, Great Britain), and he delivered honorary lectures at the world's leading scientific centers. He received numerous scientific awards and prizes.

For his exceedingly high level of scientific results, Lev Borisovich was decorated with the Badge of Honor.

News of the demise of Lev Borisovich led to a flow of condolences from scientists who knew him well and those of the younger generation who learned physics through his books. People write of him as a man embodying the drive towards the truth that underlies physics and as an outstanding physicist.

Lev Borisovich not only professed physics, but also taught to always be honest in everything and to have a conscience. Cultured, educated, and considerate, he never raised his voice and spoke very quietly. He always spoke of the main things, the essentials. He was an absolute authority for all of us. A very clever, kind, honest, and respectable man has passed away. Those who associated with him will never forget this man.

Lev Borisovich will live on in his children, grandchildren, and great-grandchildren, in his classic work, and in the work of his disciples.

M B Voloshin, M I Vysotsky, S S Gershtein,
S I Godunov, M V Danilov, A D Dolgov,
B L Ioffe, A Yu Morozov, V A Novikov,
L P Pitaevskii, V A Rubakov, V E Fortov