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PERSONALIA

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In memory of Leonid Ivanovich Ponomarev

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February 12, 2020 would have been the 83d birthday of the outstanding Russian theoretical physicist, academician of the Russian Academy of Sciences (RAS) Leonid Ivanovich Ponomarev, who passed away unexpectedly on January 3, 2019.

Leonid Ivanovich was born in 1937 in the town of Druzhkovka in the Donetsk region, where he spent his childhood and youth. Having finished secondary school in 1954, he entered the Mendeleev Moscow Institute of Chemical Technology, and in 1958 he transferred to the Physical Faculty of Lomonosov Moscow State University (MSU). In 1963, Leonid Ivanovich graduated from this University and began working at the Laboratory of Theoretical Physics of the Joint Institute for Nuclear Research (LTP JINR) in the town of Dubna, where Semen Solomonovich Gershtein became his tutor, colleague, and friend for the rest of his life. Under his guidance, Leonid Ivanovich defended in 1965 his Cand. Sci. thesis "Mesoatomic processes in chemical compounds" and, in 1971, his Dr. Sci. (Phys. and Math.) thesis "Mesoatomic and mesomolecular processes in matter".

Leonid Ivanovich obtained brilliant scientific results. He made a great contribution to the solution to fundamental problems of contemporary physics. He proposed the model of large mesic molecules, which was the starting point of a new line of research, namely, "mesonic chemistry" (see the review by S S Gershtein, V I Petrukhin, L I Ponomarev, Yu D Prokoshkin *Sov. Phys. Usp.* **12** (1) 1 (1969) [*Usp. Fiz. Nauk* **97** (1) 3 (1969)]).

Leonid Ivanovich showed his outstanding personal qualities in the organization of research of the muon catalized fusion phenomenon and, on its basis, nuclear breeding. At JINR, he formed an informal group of young scientists from LTP, the Laboratory of Nuclear Problems (LNP), and the Laboratory of Computing Techniques and Automation (LCTA), who developed efficient methods to solve the quantum-mechanical three-body problem with Coulomb interaction. On the basis of these methods and with LCTA limited computational facilities, they not only confirmed within a short time and with high accuracy the previous estimates of probabilities of muon catalyzed fusion processes, but also calculated with sufficient reliability the unknown rates of other basic reactions.

Leonid Ivanovich promoted carrying out an exclusive muon catalyzed fusion experiment, the first in the world, with a deuterium-tritium target on a muon beam from the LNP accelerator. As a result of his activity, in 1979, LNP physicists had experimentally confirmed the high efficiency of muon catalysis in a deuterium-tritium mixture predicted by L I Ponomarev's group together with S S Gershtein.

Leonid Ivanovich Ponomarev
(12.02.1937 – 03.01.2019)

Muon catalyzed fusion is the unique possibility of nuclear synthesis reactions in cold deuterium and tritium mixtures. Its idea dates back to the work of Ch Frank, A D Sakharov, and Ya B Zel'dovich (see the review by Ya B Zel'dovich and S S Gershtein in *Sov. Phys. Usp.* **3** (4) 593 (1961) [*Usp. Fiz. Nauk* **71** (4) 581 (1960)]). A muon lives only about two microseconds, but within this interval it has time to catalyze in the deuterium-tritium mixture over a hundred reactions of deuterium-tritium nuclear fusion with a neutron yield and about a 2-GeV energy release, which is 20 times higher than the rest energy of the muon itself. The released energy is insufficient to compensate the energy spent on a negative muon production (5 to 10 GeV for a deuteron beam) in the accelerator. However, $\sim$ 14-MeV neutrons released during muon catalysis of dt-reactions can be used not for heat generation, but for an efficient reproduction of nuclear fuel in nuclear breeding reactions (see S S Gershtein, Yu V Petrov, L I Ponomarev *Sov. Phys. Usp.* **33** (8) 591 (1990) [*Usp. Fiz. Nauk* **160** (8) 3 (1990)]). A high-intensity source of 14-MeV neutrons for application in different fields of science and

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technology (materials science, radiation resistance, etc.) can also be designed on the basis of muon catalyzed fusion.

The discovery of a new way of obtaining nuclear energy and neutrons initiated an intense experimental and theoretical study of muon catalyzed fusion at many leading Russian and foreign research centers: in Petersburg Nuclear Physics Institute (PNPI), Paul Scherrer Institute (PSI, Switzerland), Los Alamos National Laboratory (LANL, USA), the accelerator centers TRIUMF (Canada) and KEK (Japan), and others.

Leonid Ivanovich's works on muon catalysis brought him world fame. Owing to his exceptional capacity for work, inexhaustible energy, and great erudition, he became a world-renowned leader in this area of science. The uncommon personality of Leonid Ivanovich and his great talent fostered the foundation of the autonomous nonprofit organization Research Coordinative Center on the Problem of Muon Catalyzed Fusion and Exotic Quantum Systems (MUCATEX) and his successful guidance of the large-scale program of research on muon catalyzed fusion under the difficult economic conditions in Russia in the 1990s. This program coordinated the work of various research centers in our country (JINR, All-Union (now All-Russian) Research Institute of Experimental Physics (VNIIEF), PNPI, Kurchatov Institute of Atomic Energy (IAE), etc.), in collaboration with scientists from Poland, Switzerland, Holland, Italy, Great Britain, the USA, and Japan.

Leonid Ivanovich was an initiator of and a brilliant speaker at international conferences on muon catalyzed fusion, and was one of the founders and editors of the international journal *Muon Catalyzed Fusion* elucidating these studies.

In 1983, Leonid Ivanovich moved to work at the Kurchatov IAE (now Nuclear Research Center 'Kurchatov Institute'), where he was head of the Theoretical Department for 20 years. From 2013 he was a chief expert at the A A Bochvar High-Technology Scientific Research Institute of Inorganic Materials (VNIINM). However, his relations with JINR continued up to his last days. Leonid Ivanovich was always interested in and supported experimental work on muon physics at LNP JINR, taking part in the discussions and developments of research programs and in the work of dissertation councils and seminars at JINR.

Large-scale investigations of muon catalyzed fusion using the TRITON experimental facility were carried out at LNP JINR on the initiative and with the extensive support of Leonid Ivanovich. As a result, the main characteristics of muon catalyzed fusion were measured within a wide temperature range for dense deuterium-tritium mixtures (V R Bohm et al. *JETP* **100** (4) 663 (2005) [*Zh. Eksp. Teor. Fiz.* **127** (4) 752 (2005)]), for pure tritium (L N Bogdanova et al. *JETP* **108** (2) 218 (2009) [*Zh. Eksp. Teor. Fiz.* **135** (2) 242 (2009)]), and for hydrogen-tritium mixtures, where three new nuclear fusion channels were observed for the first time (A Adamczak et al. "Experimental Search of Nuclear Fusion Reactions in a ptμ System" Proc. NTIHEP-18, 24–30 Sept. 2018, Budva, Montenegro).

In his last years, Leonid Ivanovich focused on research in a field associated with the development of molten-salt fast neutron reactors. His studies of that period are of exceptional scientific significance for solving the problems of nuclear energy and its future development. A homogeneous nuclear reactor was considered for the first time by Ya B Zel'dovich and Yu B Khariton as far back as 1939–1940 (see the paper by Ya B Zel'dovich and Yu B Khariton in *Usp. Fiz. Nauk* **23** (4) 329 (1940)). Since then, this idea has waxed and waned, and it has again been revived but now with the knowledge and experience of past years. In his review in the *Usp. Fiz. Nauk* issue devoted to the centenary of Y B Zel'dovich, Leonid Ivanovich presented one of the modern versions of the development of the idea of the homogeneous reactor — a molten salt reactor with a uranium-plutonium fuel cycle (see L I Ponomarev *Phys. Usp.* **57** (3) 215 (2014) [*Usp. Fiz. Nauk* **184** (3) 227 (2014)]).

Leonid Ivanovich Ponomarev was the author of more than 180 scientific papers, three monographs, and many discoveries and inventions. For his scientific merits Leonid Ivanovich was awarded the I V Kurchatov Prize of the Russian Academy of Sciences (RAS, 1986), JINR Prizes, and the V P Dzhelepov Prize. In 1994, he was elected a corresponding member and in 2016 a full member of RAS. He took an active part in the work of RAS as a member of the committees for awarding RAS Gold Medals, prizes to young scientists, on fighting against pseudo-science and falsification of scientific research, and he was also a member of the editorial board of the newsletter *V zashchitu nauki* (*In Defense of Science*). Leonid Ivanovich was a member of academic councils of V P Dzhelepov LNP at JINR, NRC "Kurchatov Institute" and A A Bochvar VNIINM.

For many years, Leonid Ivanovich taught at Moscow Institute of Physics and Technology and National Research Nuclear University MEPhI. He trained a brilliant corps of disciples — Doctors and Candidates in Physics and Mathematics working in leading Russian and foreign scientific research centers.

The next generations of physicists will remember Leonid Ivanovich not only for his scientific studies and professionally delivered lectures on quantum mechanics and nuclear physics, meson chemistry, muon catalyzed fusion and nuclear breeding, molten salt reactors and fast neutron reactors, but also for publication of his wonderful popular scientific books *The Quantum Dice* (1993) [*Pod znakom kvanta* (1989)], in the first edition — *In Quest of the Quantum* (1971) [*Po tu storonu kvanta* (1971)]. These brilliant books on the foundations of quantum mechanics and nuclear physics were written in a beautiful expressive literary language that can rightful be called 'highly artistic'. The books underwent many editions, were translated into 16 languages and are used in some countries as textbooks on the basic elements of quantum mechanics and nuclear physics. In 2009, for the book *The Quantum Dice*, Leonid Ivanovich was awarded the Prosvetitel (Enlightener) Prize instituted by the Dynasty Foundation.

Leonid Ivanovich was a brilliant and multi-faceted person. His outstanding talent of theoretical physicist, his astounding erudition, and his great organizational and personal qualities won the sincere respect of students and colleagues. The vivid memory of Leonid Ivanovich, this remarkable man and scientist, will live in our hearts.

L N Bogdanova, S I Vinitsky, S S Gershtein,
D L Demin, D I Kazakov, V I Korobov,
V A Matveev, V S Melezhik, Yu Ts Oganessian,
V A Rubakov, A A Yukhimchuk, M P Faifman