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PERSONALIA

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Semen Solomonovich Gershtein (on his 90th birthday)

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July 13, 2019 was the 90th birthday of the outstanding theoretical physicist, Academician Semen Solomonovich Gershtein, whose research work has made a fundamental contribution to atomic physics, particle physics, and astrophysics.

S S was born in Harbin (Manchuria) to a family of Soviet citizens. In 1936, he moved to Moscow together with his family. In 1937–1938, his parents were subjected to repression (in 1955–1956, they were completely rehabilitated). From the age of 8, S S was brought up by his grandmother A I Mendelevich, who worked as a medical assistant at a factory medical clinic.

In 1946, S S finished secondary school with a gold medal and entered the Physical Faculty of Lomonosov Moscow State University (MSU). In 1951, he graduated from the university and was sent to work as a teacher at a secondary school in the village of Belousovo in the Kaluga region, although the advisor for his diploma work, Professor A A Vlasov, had done his best to keep S S in the postgraduate course or to send him to a scientific institution. He worked three years in Belousovo. In spite of the fact that he worked over 40 hours a weak, it took him little more than a year to take the exams of the theoretical minimum with L D Landau. He was the last person whom L D Landau oversaw personally. After S S passed the theoretical minimum, L D Landau recommended him to Ya B Zeldovich who, according to a 'special subject topic', was then engaged in the β-decay theory. Together with Ya B Zeldovich, S S considered the question of what changes in β-decay constants are due to the fact that a 'bare' nucleon is surrounded by a pion 'coat'. The authors did not limit themselves to the analysis of only the scalar (S) and tensor (T) versions of β-decay, which were considered at that time to be established experimentally, but also examined the vector (V) and axial-vector (A) versions. Using the results of the Ya B Zeldovich's previous work on pion β-decay, which is only possible in the vector version, the authors came to the conclusion that the constant of the β-decay vector version remains unchanged under strong nucleon–pion interaction. They were so amazed at the analogy that arose between weak and electromagnetic interactions that they decided to publish this result in a letter to *ZhETF*, where they wrote: "It is of no practical value, but is of methodical interest that in the case of the vector (V) version of interaction, one should expect the identity $g_{F(V)} = g'_{F'(V)}$, i.e., equality of the value of the vector constant of Fermi interaction to its value for a 'bare' nucleon referring to the interaction of charged particles with the electromagnetic field: in this case, the virtual processes happening with particles... do not lead to renormalization of the particle electric charge"

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Semen Solomonovich Gershtein

(*ZhETF* **29** 698 (1955)). This was the first published paper by S S.

Three years later, after the formulation of the $(V-A)$ theory of a universal weak interaction by R Feynman–M Gell-Mann and R Marshak–E Sudarshan, this conclusion acquired fundamental significance. R Feynman and M Gell-Mann rediscovered the result of S S and Ya B Zeldovich. They proceeded from the fact that the muon lifetime calculated using the constant of the vector interaction of neutron β-decay coincides to an accuracy of 2% with the experimentally measured one. They called the independence of the weak interaction vector constant of the nucleons' strong interaction the hypothesis of vector current conservation (VCC). To realize this hypothesis, they had to assume the existence of pion β-decay, considered earlier by Ya B Zeldovich on the basis of weak interaction universality and the compound structure of the isotopic pion triplet. According to R Feynman, he and M Gell-Mann had been unacquainted with the study by S S and Ya B Zeldovich. Later on, M Gell-Mann always referred to it as the priority publication. The fundamental law of nature — the vector current conservation — and the analogy between weak and electromagnetic interactions played an exceedingly important role in creating the modern microworld picture. It was, in fact, VCC that caused physicists to turn to the theory of Yang and Mills, who suggested that the interactions should be described on the basis of gauge fields whose sources are conserved charges. This idea paved the way not only for the formulation of a unified theory of electroweak interactions (where VCC is one of the basic points) but also for quantum chromodynamics. The VCC law was also the starting point of such a fruitful area in the theory, current algebra.

Another joint result of S S and Ya B Zeldovich, which gained wide distinction, was the establishment from cosmological data of the upper limit on the rest mass of all stable neutrinos in 1966. This limit strengthened several orders of magnitude the experimentally obtained constraints on the masses of the muon neutrino and τ-neutrino, discovered later in laboratory experiments. The very possibility of such estimations stimulated the merging of cosmology and elementary particle physics that took place in our time.

In the spring of 1955, when P L Kapitza returned to the post of director of the Institute for Physical Problems, L D Landau could take S S as his postgraduate student. After S S defended his candidate thesis in 1958, he worked two years at the Leningrad Institute of Physics and Technology, where his intimate friends were V N Gribov, Yu V Petrov, and others. In the early 1960s, he moved to the town of Dubna at the invitation of A A Logunov and N N Bogoliubov to work at the Laboratory of Theoretical Physics of JINR. This was largely due to the fact that several experiments at the Laboratory of Nuclear Problems directly related to his studies were being prepared. Continuing the research started by A D Sakharov and Ya B Zeldovich, S S developed the theory of mesomolecular processes and muon-induced nuclear reactions of hydrogen isotope synthesis. He calculated the levels of mesomolecules and isotopic exchange processes with allowance for corrections to the adiabatic approximation (in the first order in the muon-to-nucleus mass ratio) and found the main mechanism of formation of mesomolecules with the same nuclei. He noticed that the deuterium mesomolecule (ddμ) has a rotational-vibrational level with a low binding energy (below 7 eV) and assumed that the resonant formation of mesomolecules in this state could account for the considerable increase in the μ-catalysis rate in gaseous deuterium that was found experimentally by V P Dzhelepov's group at the Laboratory of Nuclear Processes (LNP) of JINR. The concrete mechanism of the resonant ddμ mesomolecule formation was found by S S's postgraduate student from Estonia, E Vesman, after S S drew his attention to the fact that the binding energy released in $(\mathrm{dd}\mu)^+$ mesomolecule production can be transferred to oscillation excitation in a usual molecule with the mesomolecular $(\mathrm{dd}\mu)^+$ ion as one of its nuclei. This result initiated the search for an analogous weakly bound level in the dtμ mesomolecule consisting of deuterium and tritium nuclei. Such a level was actually revealed by a group of physicists and mathematicians guided by a disciple of S S's, academician of RAS L I Ponomarev. Using this result, S S and L I Ponomarev predicted that in the mixture of deuterium and tritium one muon can induce more than 100 nuclear fusion reactions. This aroused great interest in μ catalysis all over the world. The experimental studies undertaken in Dubna, of PNPI, and in many meson plants abroad confirmed those predictions. Several international conferences on μ catalysis were held, and even a special journal, *Muon Catalyzed Fusion*, was issued.

One of most interesting mesoatomic processes considered by S S was the fast transition between levels of the hyperfine mesoatomic structure, which is due to muon exchange in collisions between mesoatoms and nuclei of the same hydrogen isotope. In hydrogen mesoatoms (pμ), such a transition, as was noted by S S and Ya B Zeldovich, increased the probability of muon capture by a proton fourfold, which seemed to be very important for an experimental verification of the $(V-A)$ version of the weak interaction for muons. According to the S S's calculations, the velocity of a pμ atom transition to the lower state turns out to be so high that the experiment could be performed in a gas without the production of mesomolecules (ppμ) complicating the interpretation. Such an experiment was performed in 2008, 50 years after it was proposed. A strong effect was revealed of mesoatom transition to the lower state of the hyperfine structure in the μ-catalysis probability (Gershtein–Wolfenstein effect). The predicted effect was also observed in a large number of experiments for different isotope mixtures. S S pointed out that a large cross section of muon transition from hydrogen isotopes to nuclei of other elements with charge $Z \geqslant 3$ is due to the intersection of molecular terms. This mechanism, as has become clear, is valid in atomic physics and proves to be substantial in conditions of a plasma of controlled thermonuclear fusion (CTF).

Mesomolecular processes and μ-capture were the subject of S S's doctoral thesis. The panel members at the defense were Academicians A D Sakharov, B M Pontecorvo, and A M Baldin.

In 1962, before neutral currents were discovered and neutrino experiments were performed, S S, together with R A Eramjan and Nguyen Van Hieu, showed that the process of excitation of nuclei in neutrino scattering can be used to seek neutral currents at average energies. The authors choice of an interaction which allowed nuclear transitions with spin variation proved to be completely coincident with the results given further by the electroweak theory. This result fostered the work of Yu V Gaponov and I V Tyutin on the calculation of the cross section of neutrino splitting of deuteron. This process later became the most convincing proof of solar neutrino oscillations and validity of the Standard Model of the Sun.

In 1964, S S began working at the Institute for High Energy Physics (IHEP) and took an active part in developing the program of studies on the accelerator that was under construction at that time. Together with a team of experimentalists, he participated in working out the program of neutrino experiments, including experiments with photoemulsions for finding short-lived particles. On his initiative and using his calculations, an intense 46-GeV electron beam was created on the proton accelerator for the first time in the world. It was inaccessible for the then available electron accelerators. S S took part in photoscattering experiments conducted by the joint group FIAN–Erevan Physics Institute–IHEP.

Later, Semen Solomonovich and his disciples carried out a series of studies of charmed quark production in neutrino experiments. Estimates of the hadron cross section of the Υ-meson and its radial excitations allowed the authors to find the preferred b-quark charge.

In a series of studies undertaken after the discovery of the b-quark, S S Gershtein and a group of young scientists calculated the mass spectrum, lifetime, and $B_c(b\bar{c})$-meson production cross section and its excitations, confirmed later in experiments on the FNAL and LHC colliders. In the latest 2019 LHC measurements, the CNS, LHC_b, and ATLAS groups discovered radial excitations of B_c-meson $B_c^*(2S)$. The analysis of the production of hadrons consisting of heavy quarks allowed the estimation of the characteristics of another object, namely, a baryon with two heavy quarks. The theoretical predictions were confirmed in 2018 when a baryon with two charmed quarks was observed for the first time.

Together with V S Imshennik and others, S S investigated the role of neutrino emission in a thermonuclear explosion of SNIA-type supernovae. He proposed an original mechanism of collective acceleration of solar cosmic rays and suggested the idea that gamma-ray bursts are associated with specific flares of massive stars.

In recent years, S S has considered several consequences of gravitation field theory developed by A A Logunov. In particular, in his work with A A Logunov and M A Mestvirishvili, he received from data on relic radiation anisotropy a possible graviton mass upper limit lower than the previous limit by three orders of magnitude.

For many years, S S has taught physics: in 1958–1959 at the Leningrad Polytechnical Institute, and in 1961–1962 at the Dubna branch of the Physical Faculty of MSU, and since 1963, he has delivered general courses of theoretical physics at MIPT. Among his former students are prominent scientists, who think of him with gratitude. S S is rightfully proud of the fact that, among his former pupils at school in the village of Belousovo, four became doctors of sciences and about ten graduated from the MIPT branch and then worked at the Obninsk Institute for Physics and Power Engineering. S S always upholds actively young talented scientists and generally gifted people. He is an initiator and participant of a series of new scientific trends, not only in theoretical but also in experimental physics.

S S is much engaged in popularizing science. As a member of the editorial board of the encyclopedia *Fizika Mikromira* (*Physics of the Microworld*) and a consulting editor of the *Great Soviet Encyclopedia*, he wrote over a dozen papers for these editions. At the present time, S S is a member of the editorial boards of the journals *Priroda* (*Nature*), *Yadernaya Fizika* (*Nuclear Physics*), and *Teoreticheskaya i Matematicheskaya Fizika* (*Theoretical and Mathematical Physics*). He is member of the Bureau of the Division of Physical Sciences of RAS.

S S is known as a benevolent person and at the same time is irreconcilable to all possible manifestations of grubbiness in science and in human relations. He has always been devoid of a clannish approach in solving controversial questions, and he never tires of saying that a "principled position is the most correct one."

His colleagues, disciples, and friends heartily wish him all the best on this jubilee and wish him good health and new creative achievements.

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S V Ivanov, A K Likhoded, V A Matveev,
V A Petrov, V A Rubakov,
A N Skrinsky, N E Tyurin