Fedor L'vovich Shapiro. A brief biography

S. M. Shapiro and A. V. Strelkov
Joint Institute for Nuclear Research

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This article is a brief biography of the eminent Soviet physicist Professor F. L. Shapiro, who was a Corresponding Member of the USSR Academy of Sciences. © *1995 American Institute of Physics.*

On April 6, 1915 a boy was born into the family of the commercial traveller Lev Borisovich Shapiro from the town of Gomel'. He was given the name Faĭvish.

Lev Borisovich's wife, Lyubov' L'vovna, went to her mother's in Vitebsk for the birth, where Faĭvish was then born. Subsequently, so that the boy's life should be more peaceful, his name was changed to Fedor and thus, outside the family, he was known as Fedey, but at home he was Faya. At that time, the family was living in Gomel', but in 1928 they moved to Moscow. There were also two daughters in the Shapiro family: Zhenya, who was four years younger than Fedor L'vovich, and Tamara, who was born when the family were already in Moscow and who was 14 years younger than Fedor L'vovich.

Fedor L'vovich's father was an educated man, and he knew quite a lot about ancient history and Jewish and Russian literature. He had mastered elementary mathematics and was good at chess. He played a big role in his son's upbringing, devoting a lot of attention to him. He loved setting his son various mathematical riddles and puzzles.

At the same time, Fedor L'vovich's father had a patriarchal character which was expressed in a striving to observe the ancient Jewish customs. He was also a Jewish nationalist. In his everyday life he was not a practical or able man, and he was egoistic and vain.

Fedor L'vovich's mother, Lyubov' L'vovna, was from a very intelligent family. She was a beautiful, well-built woman with a good and gentle nature, completely devoid of egoism and eternally devoted to her husband and children. At home, she cultivated an atmosphere of love, goodness, and mutual respect.

A definite influence on Fedor L'vovich's *weltanschauung* at that time was his Leningrad uncle on his mother's side, S. L. Shapiro, a scholarly psychologist. Whenever he came to Moscow, he would have conversations with Fedor L'vovich and would bring him interesting and thought-provoking books.

At school, Fedor L'vovich was top of the class. On his father's insistence, he skipped a few years (he went from the third to the fifth year, and from the eighth to the tenth). He finished school when he was 15 and could not get into higher education because of his age. Moreover, in the thirties it was very difficult for the children of white collar workers to get any kind of higher education.

On the advice of his uncle, who was an electrical engineer, Fedor L'vovich went to the G. M. Krzhizhanovskiĭ Moscow Power Technical School. Fedor L'vovich found the work very easy; he enjoyed helping his fellow students and sometimes even stood in for teachers who were ill. While studying at the technical school, the 19 year old Fedor L'vovich proposed an original method for the transformation of thermal energy into electrical energy by means of a change in the magnetic flux, brought about by a periodically repeated heating and subsequent cooling of the ferromagnetic core in the region of the Curie point. For this invention, Fedor L'vovich received his first author's (inventor's) certificate (No. 48752).

In 1935, Fedor L'vovich left the Technical School, where his special subject had been "Electrically Equipped Industrial Businesses," and started work for the design organization "Tsentroélektromontazh" as an engineer and later as a senior engineer. He worked on developing complex electricity drives and automation. At this time in his life, Fedor L'vovich began to get interested in physics, in particular in nuclear physics. Fedor L'vovich immersed himself in a large number of popular books, and he particularly enjoyed the books by M. N. Bronshteĭn and G. S. Gorelik.

Fedor L'vovich decided to go to university, and in 1936, a year after finishing at the Technical School, he passed the entrance examination and enrolled at the Physics Faculty of Moscow University. At that time, Fedor L'vovich was already 21 and was three or four years older than most of the students, who had only just finished school. Throughout the five years Fedor L'vovich studied, he continued to work for electrotechnical organizations because he was the main breadwinner in the family. His father had grown old and earned very little, and his mother worked at home, knitting underwear. Fedor L'vovich's family lived in a wooden house on Malaya Kalitnikovskaya Street, without running water, drains, or central heating. While working and studying, Fedor L'vovich also helped a lot around the house; he did all the hard work. As well as this, he was involved in the upbringing of his younger sister. Family life was close and loving. At home, Fedor L'vovich was seen as a saint; they were proud of him and adored him. That was understandable: He was clever, good, not at all selfish, and patient where the faults of his loved ones were concerned. These qualities also gave him great authority amongst his friends and fellow students. Their group of friends would get together for parties on holidays, and they went for walks along the frozen rivers Chusovaya and Belaya. In the summer of 1940, Fedor L'vovich took part in a climbing expedition in the Caucasus.

At the university, Fedor L'vovich was a brilliant student. He was attracted to nuclear physics, but at that time there was no Nuclear Physics Faculty at Moscow State University. As far as subject matter was concerned, the faculty closest to

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nuclear physics seemed to Fedor L'vovich to be the Gas Discharge Faculty, led by Professor N. A. Kaptsov. Fedor L'vovich's thesis subject was a design for an x-ray tube with special parameters. His supervisor was the senior lecturer É. M. Reĭkhrudel'.

Fedor L'vovich graduated with distinction. His last state examination was on June 21, 1941, and the next day war broke out. Of course, Fedor L'vovich and all the men—the students of yesterday—enthusiastically signed up for the army and the front, while the girls went to hospitals, clinics, and even the M. Raskovaya Air Navigation College. Fedor L'vovich and two of his closest friends, Petya Zhukovskiĭ and Vanya Panchenko, left for the Moscow Homeguard. However, after a few days, Fedor L'vovich returned home, having been told "Specialists such as yourself are needed at the rear!" Fedor L'vovich never saw those two friends of his again. They were killed in their first few days of battle. Fedor L'vovich stayed in Moscow with his father; his mother and sisters were evacuated to the Ufa region. He continued to work at Élektroprom and searched for an opportunity that would take him to the front, which was rapidly getting closer to Moscow. Finally, on October 16, Fedor L'vovich got called up to the front. He joined the Communist Battalion as the commanding officer of a section of the Independent Motorized Infantry of the Reconnaissance Company in the Moscow Workers' Division and immediately took part in the battles raging outside Moscow. "During his time of service, Comrade Shapiro was one of the best commanding officers. In fighting situations, he was courageous and used his initiative." These words come from a reference given to Fedor L'vovich by the political instructor of the company Fedor L'vovich served with. Fedor L'vovich was presented with the "For Courage" medal by Kalinin himself. Later, after the war, Fedor L'vovich received other orders and awards as well, but it was precisely this medal that he was proud of all his life. During the seige of Moscow, Fedor L'vovich was seriously injured during reconnaissance. His jawbone was shattered, shrapnel in his chest reached his heart, and he also had numerous shrapnel wounds to both legs. In December 1941, Fedor L'vovich was evacuated to a hospital (No. 1665) in Kazan', where he stayed until April 1942. The doctors decided not to remove the shrapnel in his chest, and it was in fact never removed. In the hospital, Fedor L'vovich learned English. Wanting to help the effort at the front in some way, he solved a mathematical problem concerning guns in fighter planes and sent this result to the Peoples' Commissariat for Defense.

When he was discharged from the hospital, Fedor L'vovich visited his mother and sisters in Ufa and then returned to his father in Moscow. Fedor L'vovich was no longer fit for active service, and, in December 1942, he started work at Glavsevermorput', a design group, and in the middle of 1943 he transferred to the Special Design Project No. 42 Tsentroélektromontazh, where he worked on the electrical equipment of airplanes.

Surviving in the starving Moscow of that time was extremely difficult, and, as well as this, he contrived to help his evacuated mother and sisters.

To a certain degree, the whole of Fedor L'vovich's future fate was decided by a chance meeting with É. L. Fabelinskiĭ in a streetcar at the end of the war. Fabelinskiĭ was working at the P. N. Lebedev Physics Institute of the USSR Academy of Sciences and was conducting optical experiments at the Physics Faculty in Moscow State University. He remembered Fedor L'vovich as a capable student, and, after questioning him, he advised him to return to physics. Discovering that Fedor L'vovich was passionate about nuclear physics, he promised to introduce him to D. V. Skobel'tsin as a possible post-graduate student. The prospect of being a post-graduate student in nuclear physics was tempting, but it did not promise the sufficient material resources that Fedor L'vovich needed to support his large family. In addition, Fedor L'vovich had already heard about intensive studies in nuclear physics being carried out at the Laboratory of Measuring Instruments of the Academy of Sciences (or Laboratory No. 2), and the pay was better there. Fedor L'vovich managed to get a meeting with I. V. Kurchatov, who suggested that Fedor L'vovich prepare a paper on the subject "The Neutron." Having prepared it, Fedor L'vovich delivered a long talk on this subject at a seminar and made a good impression on Kurchatov's team. However G. N. Flerov's brother, N. N. Flerov, was taken on instead of him.

Some time later, Fedor L'vovich repeated his talk at a seminar at the Lebedev Physics Institute, after which he was taken on as a post-graduate by I. M. Frank, with whom the rest of his life was connected. Fedor L'vovich left the Aviation Design Office and returned to Élektroprom, where he was received with open arms. He was able to work there for money, and, simultaneously, he could work at the Lebedev Physics Institute, which was what he really loved.

Shapiro's first task as a post-graduate was to investigate some hints of the existence of strange positively charged particles in β decay, which Skobel'tsin had observed in a Wilson chamber. The same task was given to a friend of his who went by the same name, I. S. Shapiro, who was at the Institute of Physics-2 (now the Institute of Nuclear Physics at Moscow State University), and who was taken out of the army along with several others to be retrained as nuclear specialists. (At that time, the government had already decided to build the atomic bomb and had taken specialists out of the army to investigate this problem.) Fedor L'vovich compiled a list of these specialists and students, and he found out their army addresses from their parents. Both Shapiros worked enthusiastically on the creation of a Wilson chamber: They built electromagnets and got hold of flash-bulbs and lots of other things.

The war came to a close; his mother and sisters returned from evacuation, but life was still not straightforward. Victory came, and everyone rejoiced. There were tears of joy and hopes for the future. Fedor L'vovich now started his own family—on December 15, 1945, he married Sofya Matveevna Dubina, a former student at the university whom Shapiro had known since before the war. She came from Rostov-on-Don, had graduated from the Physics Faculty in 1942, and had worked at the All-Union Power Institute when she was evacuated to Ashkhabad. The young family moved into a small room, only 6.5 m^2, which Sofya Matveevna got in a communal apartment on the second floor of the apart-

ment house No. 17 on Rozhdestvenskiĭ Boulevard. A year later, on October 5, Fedor L'vovich became a father. Their son, Boris, was born in Rostov-on-Don, where Sofya Matveevna had gone to her parents for the birth. Fedor L'vovich had dreamed of a son and was tremendously happy. He immediately flew to Rostov and appeared at Sofya's room in the hospital with a huge bouquet of white chrysanthemums.

Fedor L'vovich would remain all day at the Laboratory, and his nights were spent in the little room, where the family would huddle together. He worked on reports, writing his own and editing those of others. These reports and the continuous work at Élektroprom made it possible to feed his family, and he also sent part of his income to his parents.

In 1946, Fedor L'vovich became an assistant at the Department of Nuclear Physics at Moscow State University, the director of which was I. M. Frank. Experimental nuclear physics was being organized in the department, and Fedor L'vovich was put in charge of this. Almost everything had to be done by hand, and, after a very short amount of time, working instruments and installations were in place.

On January 9, 1949, Lev Borisovich died of tuberculosis. Fedor L'vovich found it very hard to get over his father's death and was deeply depressed. At the same time, his son was often ill as well.

In summer 1947, Fedor L'vovich finished his time as a post-graduate student. His investigations into the hypothetical "Skobel'tsin particles" did not confirm their existence. The tracks that were observed in the Wilson chamber appeared as a consequence of multiple scattering of electrons, and Shapiro showed clearly that by using the method that had been proposed to him it was impossible to interpret unambiguously the tracks observed in the Wilson chamber. Despite the fact that Fedor L'vovich's work was a completely worthy dissertation, his supervisor Frank considered it awkward in relation to Skobel'tsin to allow the defense of a dissertation with a negative result.

Frank, wanting to let Fedor L'vovich stay on at his laboratory after his time as a post-graduate student, "borrowed" from V. I. Veksler a permanent position for a junior scientific research worker and quickly put Fedor L'vovich down for it. It carried a handsome salary for that time. This allowed Fedor L'vovich to leave Élektroprom, and he shifted the emphasis of his investigations to neutron physics. At that time, almost half a year had gone by since the first Soviet atomic reactor, a uranium–graphite one, had started working on the territory of the Laboratory of Measuring Instruments of the USSR Academy of Sciences. Part of the research into the uranium–graphite systems was assigned by Kurchatov to Frank's Laboratory.

Research into subcritical uranium–graphite systems using the prism method was conducted at the old Lebedev Physics Institute building on Miusskaya Square. Because of the conditions of the time, this research was highly secret, for it was linked to the problems of creating atomic weapons. As well as Frank, E. L. Feĭnberg, L. E. Lazareva, L. V. Groshev, K. D. Tolstov, and I. V. Shtranikh were already conducting this research before Fedor L'vovich joined them. In just two years, Shapiro measured with high accuracy the coefficient of neutron multiplication per fission event, the probability of resonance capture, and the neutron utilization coefficient. The temperature dependences of these quantities were also measured. The uranium–graphite installations were deeply subcritical, and their admissible multiplication coefficient was very small; this required experimental elegance and automation of the measurements. In the course of the research, Shapiro was forced to develop the prism theory further and to establish the behavior of neutron resonance capture in different energy regions. This research made up the contents of his candidate's dissertation, which he successfully defended in 1949. The defense was conducted in secret at the Laboratory of Measuring Instruments, and the official opponent was I. I. Gurevich.

Immediately after his defense, Fedor L'vovich was made a senior scientific research worker and his material well-being improved. However, the family continued to squeeze into the little room. So Fedor L'vovich and his wife were delighted when they found out that S. I. Vavilov, the director of the Lebedev Physics Institute, had arranged for their family to get a two-roomed apartment in an apartment house built by the Lebedev Physics Institute from its own resources for its researchers. In fall 1949, the Shapiro family moved into the new apartment. Their neighbors were the families of physicists who were already well known: the Markovs, the Ginzburgs, the Fabelinskiĭs, the Balabanovs, the Podgoretskiĭs, etc. The apartments were behind the new building of the Lebedev Physics Institute, on First Academic Drive. Soon afterwards, Frank's Laboratory moved to the new Lebedev Physics Institute building as well. Fedor L'vovich already had his own group. The subject was still the same—neutron physics—but the directions of the research were different, ranging from purely practical to exclusively fundamental. All the research continued to be highly secret.

Unfortunately, at that time at the Lebedev Physics Institute, like everywhere else, the party nomenclature reigned supreme: Many matters were decided by the KGB representative, who was from the First Section and was Deputy Director representing the regime. A miasma of suspiciousness, informing, and anti-Semitism penetrated the Institute. One day, a distraught Shapiro returned home with the words: "There are people in our Institute who say that Frank's Laboratory has been taken over by three Jews—Barit, Belovitskiĭ, and Shapiro—and there's even something not quite right about Frank." At that time, rumors were rife in Moscow about the resettlement of Jews in Siberia, and the Doctors' Affair was publicly spoken about. Fedor L'vovich did not panic, but said to his wife: "We have four hands and two heads—we will surely be able to feed our children."

Their daughter Anna was born at the beginning of 1951. At home, she was called Asya. She was a very restless baby to begin with, and Fedor L'vovich often had to take his turn at spending sleepless nights, walking around with his daughter in his arms.

Fedor L'vovich found it hard to get over his mother's death, when she died on February 19, 1955. He was very close to his mother; he inherited her goodness and gentleness in his relationship with other people.

At the beginning of the fifties, Shapiro's group turned to

the practical realization of moderation-time neutron spectrometry. The idea for this method had been put forward by Feĭnberg in 1944. At the Laboratory, a 100-ton cube of extremely pure lead was assembled; in its center, a tritium target, which was irradiated with short pulses of a deuterium beam from an accelerating tube, was placed. The fast neutrons produced in small batches in the target gradually slow down with every collision with a lead nucleus and are grouped in energy around a certain mean value, which decreases monotonically with time. This spectrometer made it possible to measure the previously unknown cross sections of radiative capture for more than ten nuclei and also to observe a number of new effects, which caused a scientific sensation. The observation that the neutron capture cross section deviated from a certain well-known law, which at that time appeared to be universal for all nuclei, achieved the most fame. Specialists greeted these results with hostility. Landau too came down violently against them at the Moscow Conference on Nuclear Reactions in 1958, and it was only subsequently that these results were generally accepted and found their way into the textbooks. During work on the lead cube, Fedor L'vovich proposed the method of nonstationary neutron diffusion in the many-group approximation and developed this method with the theoretician in his group, M. V. Kazarnovskiĭ.

This research achieved wide recognition, and it was decided that it would be presented at the International Conference on the Peaceful Uses of Atomic Energy at Geneva in 1955. "Competent organs" had to choose people who could appear at Geneva and, of course, people with the "wrong" ethnicity were not desirable. A first exception was made for V. I. Veksler; he was too well known abroad, and anyway he was a party member. The "organs" decided that Veksler should present Fedor L'vovich's work at Geneva; however, Vladimir Iosifovich was categorically against this, for it was not his field, and moreover, as he put it to Skobel'tsin, the director of the Lebedev Physics Institute, "Let Shapiro go and present his own work." It is hard to imagine how Skobel'tsin managed to achieve the impossible. At that time, practically no one was allowed to leave the country, let alone someone with a "defective file."

At the conference in Geneva, Fedor L'vovich, as well as delivering his talk, took part in discussions. During one of these, he put forward his original idea for "inverted neutron spectrometry"—not to regulate and control the velocity of neutrons incident on the target nuclei, but to fire the investigated nuclei, contained in the accelerated ions, from an accelerator at a neutron target—a cloud of thermal neutrons in a channel running through the reactor. This idea literally stunned the delegates at the conference. A lively debate developed. Everyone commented how original and unusual Fedor L'vovich's idea was. He returned from Geneva very excited and full of all the things he had heard and seen. He had met some foreign physicists whose names he already knew well. From there, he also brought the idea for the pulsed fast reactor.

Fedor L'vovich once again started work at the Lebedev Physics Institute and started lecturing on neutron physics at the Physics Faculty—the students called the lectures "Shapiro's special course." His lectures stood out because of their great clarity and precision, which enabled him to explain the problems of physics to his students simply and clearly. It was this clarity and precision that distinguished all his talks and reports at seminars at the Institute, and during discussions he was always polite and always "hit the nail on the head." Fedor L'vovich also had to give closed seminars in the presence of Kurchatov at his Institute.

A few months after his return from Geneva, the "regime" reminded Fedor L'vovich of a few of his deviations from their "rules of behavior" when abroad. One day, Fedor L'vovich did not return home from work. He was gone all night. His wife went mad, phoning the police and the morgues. Fedor L'vovich came home in the morning, exhausted, and said, with a kind of tortured smile, that he had had to do some experiments at night, and, for some reason, he had not been able to phone home. That was so unlike him. It was only later that he told how he had been taken to the Lubyanka and kept there all night, where they had in turn tried to bring him round and threaten him. "They" had discovered (someone close to him had informed) that while Fedor L'vovich had been in Geneva at the conference he had promised one of the foreign physicists that he would visit his grandmother, who lived in Moscow. At the Lubyanka, they threatened Fedor L'vovich with taking away his "permit" (which at that time would have meant losing his job) and tried to force him to work for them. They promised trips to conferences abroad and in return asked Fedor L'vovich to inform for them. However, they did not realize that they were not dealing with a terrified Jew or a man without principles. Having got a firm "no" in response to their promises, and silence in response to their threats, they let him go home.

Fedor L'vovich devoted a lot of attention to his family and children. Aware of their father's good nature, the children often asked to go shopping with him, knowing that he would buy lots of tasty things. Fedor L'vovich also made sure the family was cared for when they went to the dacha for summer; he would travel between Moscow and the dacha every day, bringing food and everything that was needed. Sometimes Sofya Matveevna would invite her husband to a concert at the conservatoire. Fedor L'vovich would refuse and tell her "not to waste good tickets on him." Fedor L'vovich preferred choral music to symphonies, and he would buy records of long Russian songs; he particularly liked the Ural Choir.

In spring 1958, Il'ya Mikhaĭlovich Frank suggested that Fedor L'vovich take on an additional post at the Joint Institute for Nuclear Research at Dubna. At that time, Frank was running the Laboratory of Neutron Physics at this newly-opened Institute, where they were already constructing a fast-neutron pulsed reactor (Pulsed Fast Reactor). Frank decided to try to tempt Fedor L'vovich to studies on this working reactor, by promising him complete freedom in choosing his scientific subject. Fedor L'vovich agreed and began to travel regularly to Dubna. At first, he had a room in a hotel, but by summer he had already been offered a cottage on the Chernaya River, in the wooded area of Dubna. The cottages had only just been built, and Fedor L'vovich was even offered a choice; he chose the one at the very end of the street,

next to the wood. His comrade from the Lebedev Physics Institute, M. I. Podgoretskiĭ, got a cottage nearby. In the summer, Fedor L'vovich moved the family to Dubna from Moscow, and everyone liked it there: It was peaceful, and there was the wood and the river. They got a motor boat and went on trips up the Volga.

Fedor L'vovich was absorbed by his work at the Laboratory, which he had, essentially, set up. It was where the center of all his scientific interests lay. After a while, his main work was at Dubna, and although he still had a post at the Lebedev Physics Institute he went there quite rarely.

As well as his work on neutron physics, Fedor L'vovich was also very interested in the effect that had just been discovered by the German physicist Mössbauer: the resonant scattering of γ rays without recoil of the nuclei that emit them. In effect, Fedor L'vovich became the first advocate in the Soviet Union of this new method of gamma spectroscopy. He created a classical theory of the Mössbauer effect, and, working with Barit and Podgoretskiĭ, was the first to point out the possibility of setting up an experiment, with the help of the Mössbauer effect, to check a prediction of the general theory of relativity in the laboratory—to observe the frequency shift of photons in gravitational or inertial fields. Fedor L'vovich set up a group at the Laboratory, led by V. P. Alfimenkov, to prepare for this experiment. For this experiment, Fedor L'vovich suggested using the narrowest gamma line of the zinc-67 nucleus as a photon source. The group obtained for the first time a velocity scan of this line with a relative energy resolution that even today is a record, of the order of 10^{-15}. However, the observed effect proved to be too small and insufficient for use in a gravitational experiment; therefore, Fedor L'vovich suggested trying a variety of methods to increase the effect. Unfortunately, the American physicists Pound and Rebka did a similar experiment first. Discovering this, Fedor L'vovich recognized the superiority of the experimental setup of his rivals and called upon his colleagues "to learn from them and also from their own mistakes." Subsequently, the group was given a new direction—research in the field of solid-state physics.

In 1960, the Pulsed Fast Reactor began working, and research started immediately, using its beams, to study the total and partial cross sections of neutron interaction with nuclei. In 1964, one of the beams of the Pulsed Fast Reactor was successfully used to try out a method, suggested by Fedor L'vovich, for the separation of a definite neutron polarization from an unpolarized beam, by means of its transmission through a polarized proton target. This method made it possible to obtain polarized neutrons in the range of energies up to 10 keV, which had previously been inaccessible for research. This method was used to measure the spins of neutron resonances of several nuclei, and it also proved possible to determine a set of neutron–deuteron scattering amplitudes at low energies, and subsequently the magnetic moments of neutron resonances were measured.

In 1961, Fedor L'vovich suggested using slow neutrons from the Pulsed Fast Reactor to study the physics of condensed media. He suggested using the high-luminosity method of inverted geometry, allowing the thermal vibrations of atoms in solid bodies to be studied. This same method was successfully used in measurements of the self-diffusion coefficient at the critical liquid–vapor point, which did not confirm the results of the numerous macroscopic attempts that indicated a cessation of diffusion at the critical point. Fedor L'vovich and the Polish physicist B. Buras demonstrated that the time-of-flight method could be used for diffraction studies of the structure of matter. With the direct participation of Fedor L'vovich at the Laboratory, a method of neutron diffraction on magnetic structures in strong pulsed fields was realized. This work made him well known also among specialists of condensed-matter physics.

The director of the Laboratory, I. M. Frank, loved to repeat that he was director of everything and that all the science at the Laboratory was managed by him. However, this was not strictly true. Frank, who was an Academician and a Nobel Laureate, was also a very shrewd and farsighted leader; when he saw that Fedor L'vovich was a powerful generator of ideas, he gave him freedom and set up opportunities for these ideas to be realized. It was very fortunate that two such people were to meet and complement each other well.

Fedor L'vovich did not strive for either titles or respect. He was in charge of the scientific direction of two major laboratories, one in Dubna and one in Moscow, but still went by the modest title of Candidate of Physics. Frank had to use considerable effort and even resort to cunning in order to force Fedor L'vovich to defend his doctoral thesis. This he did by having made this one of the conditions of socialist emulation of the Laboratory of Nuclear Physics at the Lebedev Physics Institute.

Fedor L'vovich's scientific authority grew remarkably quickly. He took part at meetings and conferences as an invited speaker, traveling to Czechoslovakia, Poland, and India.

In 1962, the well-known American neutron physicist H. Palevsky from Brookhaven visited the laboratories in Dubna and Moscow. He delivered several lectures on neutron physics, which were simultaneously interpreted from the English by Fedor L'vovich. At the beginning of these lectures, Palevsky was a little confused because Fedor L'vovich did not seem to be talking for as long as he was himself. It was only later that he realized that Fedor L'vovich was able to translate what he was saying more compactly. Palevsky made Fedor L'vovich a compliment on this, which Fedor L'vovich declined to translate.

In 1964, Fedor L'vovich became a member of the Editorial Board of the most prestigious journal *Uspekhi Fizicheskikh Nauk*.

The Pulsed Fast Reactor continued to work steadily, but Fedor L'vovich was already considering a way in which to increase its power and gave his colleague E. P. Shabalin, who was a reactor specialist, the task of examining the physics of the principal limitations on power growth in a reactor of this type. The development of this work led to the creation of a new section of a second Pulsed Fast Reactor, and then to the construction of the new reactor itself: IBR-2.

Running the laboratories was a lot like being a grandmaster playing on many different chess boards. The majority of the research done was into ideas of Fedor L'vovich, not

because he was in charge, but because his were the best that were put forward. Fedor L'vovich would infect the person he was talking to with his ideas; he would demonstrate them with chalk on the blackboard, talk about them in the corridors and in the canteen, on the way home, and on the commuter train. Every seminar in the laboratories would usually be made up of two parts: The first part was the long part, when the speaker would give his talk, and the second part was the short part, when Fedor L'vovich would say something on the subject at the end. And the second part would always give much more to the listener than the first part. Often, not wanting to fill the room in which he was talking to someone with cigarette smoke, he would conduct conversations walking up and down the corridor with a slight shuffle, one hand stuffed into his jacket pocket and the other one holding a cigarette up high, almost vertically, so that the little column of accumulated ash on top of the cigarette would not fall on the floor. Holding his cigarette, he would ask questions, discuss things, give advice, and think. He was a thorough and tidy person, both inwardly and outwardly, and was particularly attentive and good-natured. Whenever he met someone, he would always ask how they were, and whether they had any problems. He was concerned for everybody. Fedor L'vovich carried out any requests exceptionally attentively and was quick to help in any way he could, never putting anything off. He made himself accessible to everybody and was not guarded by his secretaries. The door to his study opened directly into the corridor, and it was enough just to pop your head round the door and ask: "When would it be possible to come and talk to you, Fedor L'vovich?" This was always greeted with the response: "What's it about? About physics? Then come in and let's talk about it now!"

Of course, he did make the odd mistake. His behavior in such situations too could be a lesson to us all. Once, when Fedor L'vovich was summing up an unsuccessful experiment involving a rather complex mechanism, he said to his colleagues: "Hide this monument to our inability to think things out in the cupboard, away from the people in the workshop. It is not their fault at all that we have to throw out their mechanism."

The whole Laboratory loved Fedor L'vovich. They all celebrated his 50th birthday in a wonderfully joyful, warm, and happy way. In the entrance hall they hung a huge poster, wishing him a happy birthday. Well-wishers crammed into the conference hall, standing in the aisles and spilling out into the corridor. On stage, a smiling, deeply touched Fedor L'vovich received his present. People played jokes on him and performed little sketches. It showed just how charming he was that he came joint first with L. Bulavin, a graduate student from Kiev and universally recognized as a very handsome man, in a poll of the women conducted on the eve of March 8 by The Neutron. If Fedor L'vovich chanced upon a little get-together in one of the laboratories, he would sit himself down and drink whatever was being drunk, laugh, and tell funny stories. He treated everyone the same and was never over-familiar.

Fedor L'vovich spent numerous holidays with his family and friends on walking tours in the Caucasus, Karelia, along the rivers Belaya and Tuva. Everywhere he would show the necessary quality of a born natural scientist—a curiosity about every phenomenon in the surrounding world and a desire to understand it. One day, while on a walking tour, Fedor L'vovich gave his children a task and then explained to them the paradox that they had observed. He asked them why twigs would collect in the center of the powerful whirlpools found in rivers just below waterfalls, when one would expect them to go to the edge of the vortices because of the centrifugal force. To explain this, he used the analogy of tea leaves in a cup. Because of the amazing precision with which he expressed the essence of the phenomenon, Fedor L'vovich was also able to answer the question, put to him by a five-year-old boy: "Why doesn't the sand fall out of my bucket when I spin it around above my head?" Fedor L'vovich replied in language that the boy could understand: "Because it doesn't have time!"

At the end of the sixties, Fedor L'vovich's son became seriously ill. The diagnosis was hopeless—multiple sclerosis. Borya was already studying at the University then; he showed a talent for exact sciences and was a gifted student. Soon he was confined to his bed. This affected Fedor L'vovich very deeply. He just had to live with it and continue working. "He needs us, Asya needs us, we've got to be strong," he said to his wife, to try to reassure her. Fedor L'vovich continued to go to work, never betraying his grief to people. The "competent organs" were causing a lot of unpleasantness for him; they stopped allowing him to go abroad, for which they had their own reasons. Fedor L'vovich would try to pacify colleagues, who were also banned from traveling abroad, by saying: "Look on this as you do the weather!" Fedor L'vovich was not a party member; neither did he express dissident opinions. He kept himself away from politics. But he was not forgiven for taking on at the Laboratory a talented young physicist, Dr. A. V. Voronel', who, as it turned out, was a friend of the writer Yuri Daniél'. After the "angry condemnation" of the writers Daniél' and Sinyavskiĭ and the court case brought against them, the directors of the Joint Institute for Nuclear Research expelled Voronel', saying that he had broken the rules concerning secret documents. Fedor L'vovich was also not forgiven for the fact that he invited Sakharov, who was already greatly annoying the country's leaders with his behavior at that time, to give a talk at a seminar at the Laboratory. Fedor L'vovich categorically refused when the KGB told him very firmly that he should speak in favor of the government's policies at an anti-Zionist meeting in 1967 at the House of Friendship of Peoples in Moscow, which was broadcast on television. Fedor L'vovich continued to receive invitations to take part in conferences abroad. Sometimes the authorities would give the impression that they were ready to let him go, even filling out the documents for his journey. However, at the last minute he would be refused permission and informed very nicely: "We did not manage to complete your documents!" That is what happened the last time as well when, in August 1971, Fedor L'vovich should have flown to America, to Albany, where he had been invited to give a talk at a conference on the statistical properties of nuclei. He had also been asked to chair one of the meetings. That summer, Fedor L'vovich and his family had arranged all their plans around

the fact that he would be going to America; however, at the very last moment they told him that they had not managed to complete his documents. They asked his closest colleague, V. I. Lushchikov, who was to go to the conference with Fedor L'vovich, to tell him the news. "It was really awkward for me, I felt terrible for Fedor L'vovich," Lushchikov said to his colleagues later, "I was allowed to go although, unlike Fedor L'vovich, I was not giving a talk and had no ideas on the subject matter."

In April 1968, Fedor L'vovich wrote an article in the journal *Uspekhi Fizicheskikh Nauk* describing a method of experimentally checking the law of conservation of time-reversal parity—one of the fundamental laws of contemporary natural science. Fedor L'vovich suggested setting up an experiment to observe the electric dipole moment of the neutron. Fedor L'vovich also showed that the desired effect should be brought about by a remarkably weak influence on the neutron and could be observed only for neutrons that moved very slowly—so-called ultracold neutrons. Until then, no one had yet observed ultracold neutrons, though the unusual behavior of these neutrons (which are more like a rarefied gas than a particle beam) had already been predicted in publications. However, all "sensible" physicists would smile when they talked about ultracold neutrons; they did not believe that it would ever be possible to work with them after they had been extracted from a reactor beam by means of screening, since their fraction constituted less than one hundred billionth of the total number of neutrons in the beam. Of course, the beams in the IBR were very weak indeed, but there were other reactors which had more powerful neutron beams, where there should be more ultracold neutrons. However, in the summer of 1968 (at the very height of the summer holidays), Fedor L'vovich and his colleagues managed to conduct the experiment successfully and observe ultracold neutrons for the first time. The experiment was very simple and transparent, clearly demonstrating the peculiarities in the behavior of ultracold neutrons. Like gaseous atoms, they collided repeatedly with the walls and escaped out of the bent tube coming from the reactor. Fedor L'vovich was telephoned one morning and told that the first ultracold neutrons had definitely been detected in the night. He soon appeared at the control desk of the facility, smiling and carrying a huge Astrakhan water melon. "Hurray!" he said, "we deserve this. Come on, let's eat this big neutron!" Within a few years the result of this experiment was recognized as a discovery. This might not have been the case, since a similar experiment had been performed abroad six months later and the credit could have gone there. Of course, it was not a race for priority that had determined the speed and fervor assigned to this experiment by Fedor L'vovich, but pure scientific curiosity. The path of this experiment had been full of difficulties; the main one had been to convince the director of the Laboratory, Frank, to put off the beginning of work on modernizing the reactor, which meant putting off his own work until the ultracold-neutron experiment was completed. Completing the experiment was very difficult, because the majority of the people who worked at the reactor had gone away for the summer, and the people who were left were preparing to pull down the old reactor. In the course of the discussions and attempts at persuasion, Fedor L'vovich even suggested that he replace the engineer at the reactor, who was away. After the first experiment, the research into ultracold neutrons was transferred to more powerful stationary reactors at the Kurchatov Institute, Alma-Ata, and Melekessa, where the fluxes of ultracold neutrons became much greater. Quite often, Fedor L'vovich had to travel to these places and convince the local scientists of the topicality and expediency of the research into ultracold neutrons. The work done on ultracold neutrons achieved wide recognition in the scientific community. When Fedor L'vovich delivered a talk on ultracold neutrons at the Presidium of the USSR Academy of Sciences, the hall echoed with applause at the part of his lecture in which he described the bend in the neutron guide that formed a gravitational spectrometer of ultracold neutrons. The "old regulars" at the presidium meeting could only remember one other time when the speaker had been applauded, and that was when news was given of the successful explosion of the atomic bomb.

In 1967, Fedor L'vovich became a professor, and on November 28, 1968 he was chosen as a Corresponding Member of the USSR Academy of Sciences. This was in recognition of his services to atomic nuclear physics and his research into the structure of matter.

In summer 1971, Fedor L'vovich began to complain at home about headaches. The doctors, having examined him, diagnosed overwork and recommended that he take a good long holiday. Fedor L'vovich went to Lake Issyk-Kul', where he spent his holiday at a tourist center with his former postgraduate student, V. Konskiĭ. He returned a little refreshed, but his face was pale and drawn, and he had lost still more weight. At the very end of 1971, some of his colleagues began to notice, much to their surprise, something that had never happened before: When Fedor L'vovich was talking he would repeat himself, and his judgments were sometimes inconsistent. His outward appearance changed also; he began to droop and rapidly went grey. In the course of January 1972, Fedor L'vovich's condition deteriorated catastrophically. The doctors' diagnosis was awful: He had a malignant brain tumor. With the help of his connections, Frank managed to have Fedor L'vovich hospitalized urgently at the Burdenko Institute for Neurosurgery, where he was operated upon on the very next day. The operation lasted several hours. During his operation, his family, friends, and colleagues stood outside the operating theater, waiting for the operation to be over and ready to help in whatever way they could. After a long stay in intensive care, Fedor L'vovich was moved to a general ward, and his doctors were stunned to see him reading a book (*A Theatrical Novel* by M. Bulgakov). The fact is that the surgeons were in no way sure before the operation that Fedor L'vovich would not suffer brain damage. On his birthday, April 6, 1972, Fedor L'vovich was already at home again. It was a warm sunny day. Friends and colleagues visited him, and he was jolly and joking. He told them about the intelligence test that the doctors had set for him before he was allowed to leave hospital: They asked him to keep taking 13 away from 100. After his rapid answers, the doctors began whispering to each other and decided that the patient had given the correct answers at first, but had then

started making mistakes. But in fact Fedor L'vovich had been giving his answers so quickly that he had already had to use negative numbers, which the doctors had not understood.

Fedor L'vovich started to feel better and longed to return to the Laboratory in Dubna. He spent May at the Uzkoe Health Farm outside Moscow, where he grew a bit stronger. Finally, at the very beginning of summer, he phoned the Laboratory from his home in Dubna and asked for a car to be sent to pick him up. This news quickly spread around the Laboratory, and soon everyone was looking out of the windows as Yura Taran brought Fedor L'vovich to the Laboratory in his white Moskvich car (it had not been possible to find an official car at such short notice).

There was his study again. There was work to be done, conversations to be had, and physics to be discussed. His colleagues knew all about his condition, and, watching him intensely, they realized to their delight that there was no trace left of his illness. He was just as clever, good-natured, and attentive as he had been before. The faint hope of a miracle was born; that his powerful brain would cope with this illness.

Fedor L'vovich continued to work intensively. He was working on a long review talk about ultracold neutrons, to be given at the International Conference on the Study of Nuclear Structure by Means of Neutrons in Budapest. (That talk remains to this day the best description of the properties and problems of ultracold neutrons.) The talk was delivered at Budapest for Fedor L'vovich by V. I. Lushchikov.

In the fall, Fedor L'vovich began to get weaker, and the miracle, sadly, did not happen. His headaches got worse. At the end of November 1972, the doctors at the same clinic performed a second operation on Fedor L'vovich in the hope of somehow improving his condition; however, this was not achieved. Overcoming the pain, Fedor L'vovich was present for a while at his daughter's wedding on December 25, 1972. At the beginning of January, Frank visited him for the last time, and Fedor L'vovich could not get up to greet him.

Throughout all this difficult time, his loyal friend Izrail' Yakovlevich Barit, a man of rare goodness and devotion, stayed by him.

Early in the morning, at about 4 a.m., on January 30, 1973, Fedor L'vovich died.

For more than 20 years now, his family, friends, and colleagues have gathered twice a year, on his birthday and on the anniversary of his death, at his grave in the Donskaya Cemetery in Moscow. His son Borya, who died four years after his father, is also buried there. Two bright red carnations are placed on the black granite of the grave, and, on the wintry last day of January, the snow on the grave is covered with fir branches laden with cones, brought there from Dubna.

The more time goes by, the clearer it becomes that Fedor L'vovich's life was a wonderful gift to all those who knew him.

Translated by Julian B. Barbour