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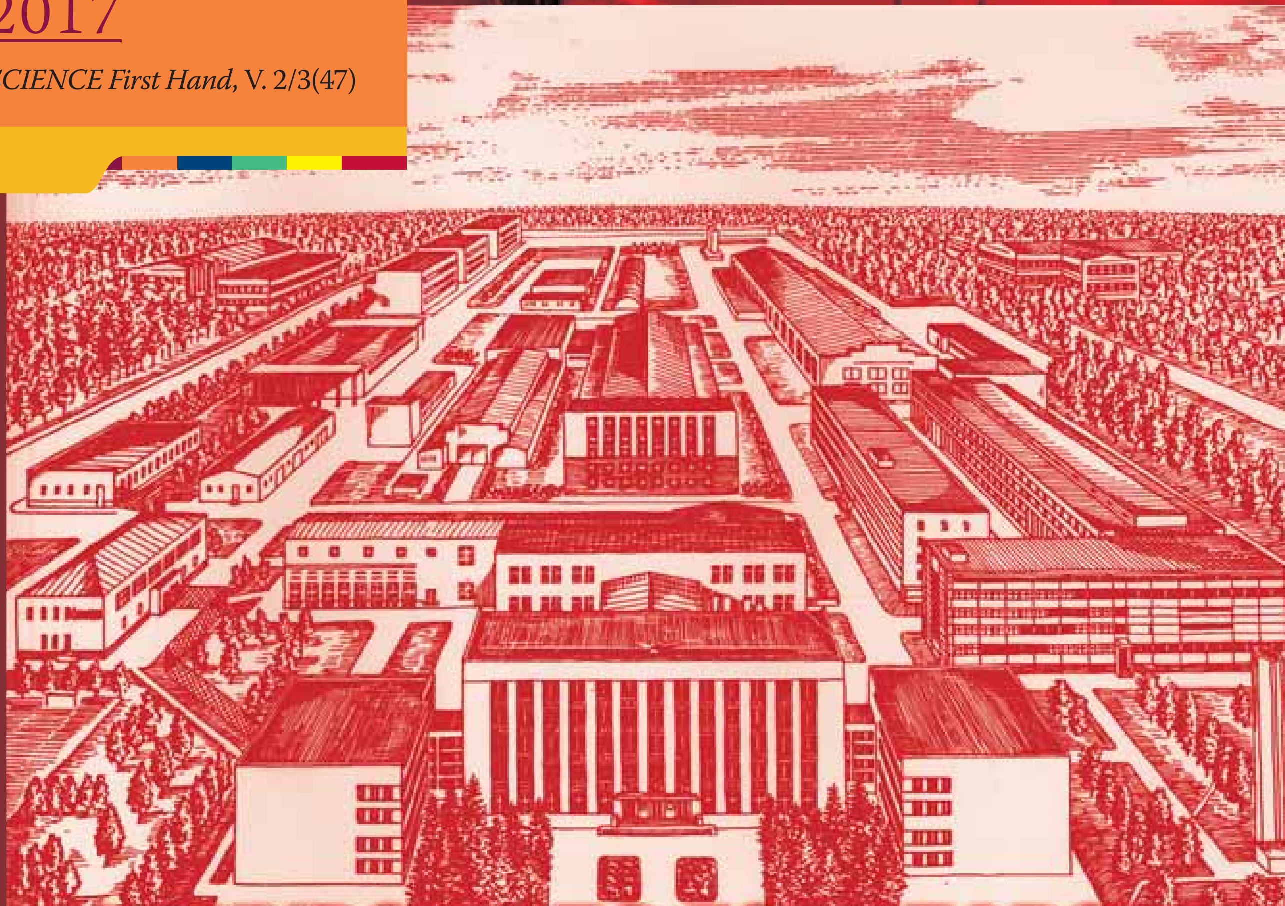


BINP grew in a forest, like a mushroom

In the mid-20th century, physicists began to talk about the colliding-beam accelerator. Back then, a sweeping majority of scientists around the globe saw it as a fantasy and remained skeptical. However, Andrei Mikhailovich Budker, then a researcher at the Institute of Atomic Energy in Moscow, got inspired by the colliding beams idea after the Geneva high-energy physics conference in 1956. A team of young scientists was put together to devise the VEP-1 electron–electron collider. The construction works on the collider began in Moscow, but VEP-1 delivered its first colliding electron beams later, when Budker and his team had moved to Siberia and established the Institute of Nuclear Physics in Novosibirsk

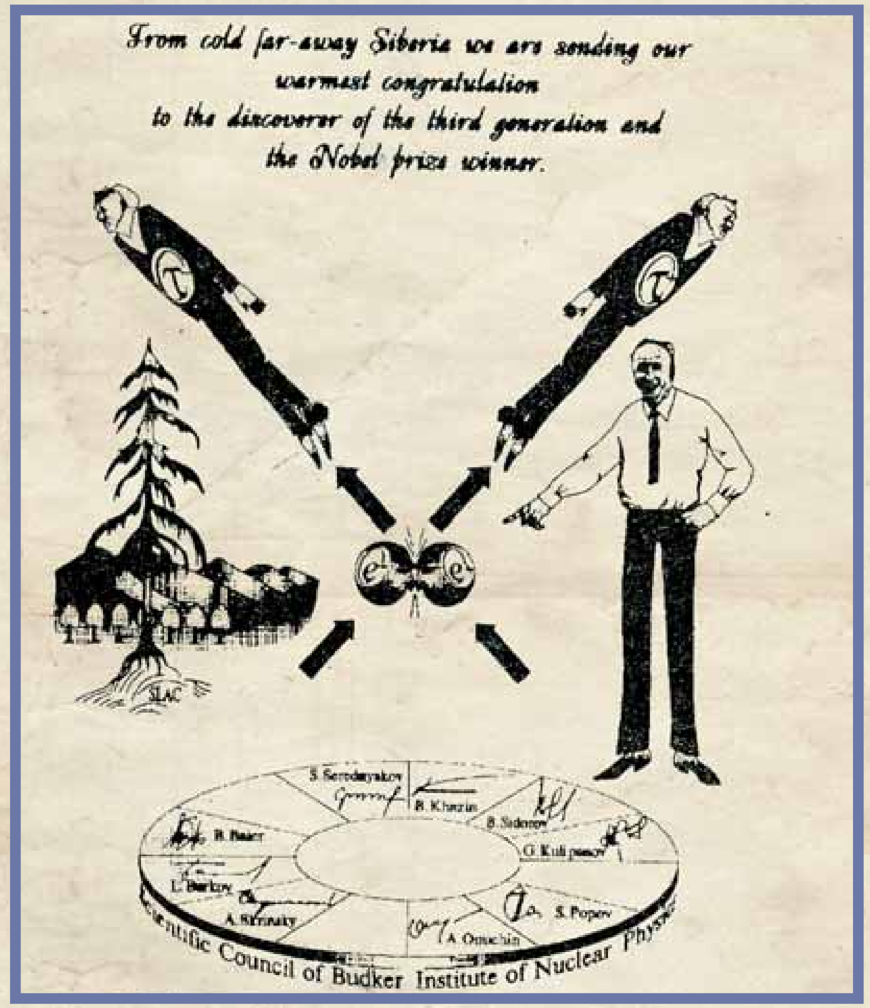
Key words: Institute of Nuclear Physics, Budker, particle accelerators, VEP-1, VEPP-2, Large Hadron Collider, CERN

A.N. SKRINSKY

I first heard about Andrei Mikhailovich* Budker and his lab – the Laboratory of New Acceleration Methods at the Institute of Atomic Energy in Moscow – when I was finishing my fourth year at the Physics Department of Moscow State University. It was time to decide where to apply for pre-graduation practical training. The parents of a girl in my study group were on friendly terms with Prof. I. I. Gurevich, who advised me to choose Budker as a supervisor of my degree thesis.

Academician A.N. Skrinsky

* Budker's real first name and patronymic were Gersh Itskovich, but his close friends and colleagues called him Andrei Mikhailovich



"From cold far-away Siberia we are sending our warmest congratulations to the discoverer of the third generation of leptons and the Nobel prize winner," the Scientific Council of the Institute of Nuclear Physics sent their congratulations together with a drawing by Efim Bender to an American physicist Martin Perl, who discovered several elementary particles, including quarks

I decided I would go to an interview with Budker at his lab at the end of the summer and went on a hike with friends to Lake Baikal. The hike was very demanding, lasting three weeks, so I barely made it to the interview on time. But they accepted me to the lab as a trainee.

I'd worked with Boris Chirikov as my mentor for three months when Budker invited me to join a microgroup that investigated colliding electron beams. At that time he was recruiting young scientists to design the world's first colliding beam accelerator. So, I and a few others flung ourselves into all kinds of scientific tasks associated with colliding beams.

Back then, a dozen labs around the world attempted to develop a colliding beam accelerator, but only two of them – we and Stanford University – reached the finish line.

Alexander N. SKRINSKY, Member of the Russian Academy of Sciences; Doctor of Physics and Mathematics; Scientific supervisor of the Budker Institute of Nuclear Physics, SB RAS (Novosibirsk). Fellow of American Physical Society and invited member of Royal Academy of Sciences (Sweden). Prizes awarded include the Lenin Prize (1967), the State Prize of the USSR (1989), the State Prize of Russia (2001 and 2006), the Demidov Prize (1997), the R.R. Wilson Prize of the American Physical Society, and the A.P. Karpinsky Prize of the Toepfer Foundation (Germany). Medals and orders conferred on A. Skrinsky are the V.I. Veksler Gold Medal of RAS (1991), the P.L. Kapitza Gold Medal of RAS (2004), the Red Banner Order (1975), the October Revolution Order (1982), the Order for Services to Motherland, IVth degree (1996), the Order for Services to Motherland, IIIrd degree (2000), the Order for Services to Motherland, IInd degree (2007). Author and co-author of over 300 works on accelerator physics and high energy physics. Likes classical music and ski races

Academician G.I. BUDKER, outstanding physicist, founder and first director of the Institute of Nuclear Physics of the Siberian Branch of the USSR Academy of Sciences

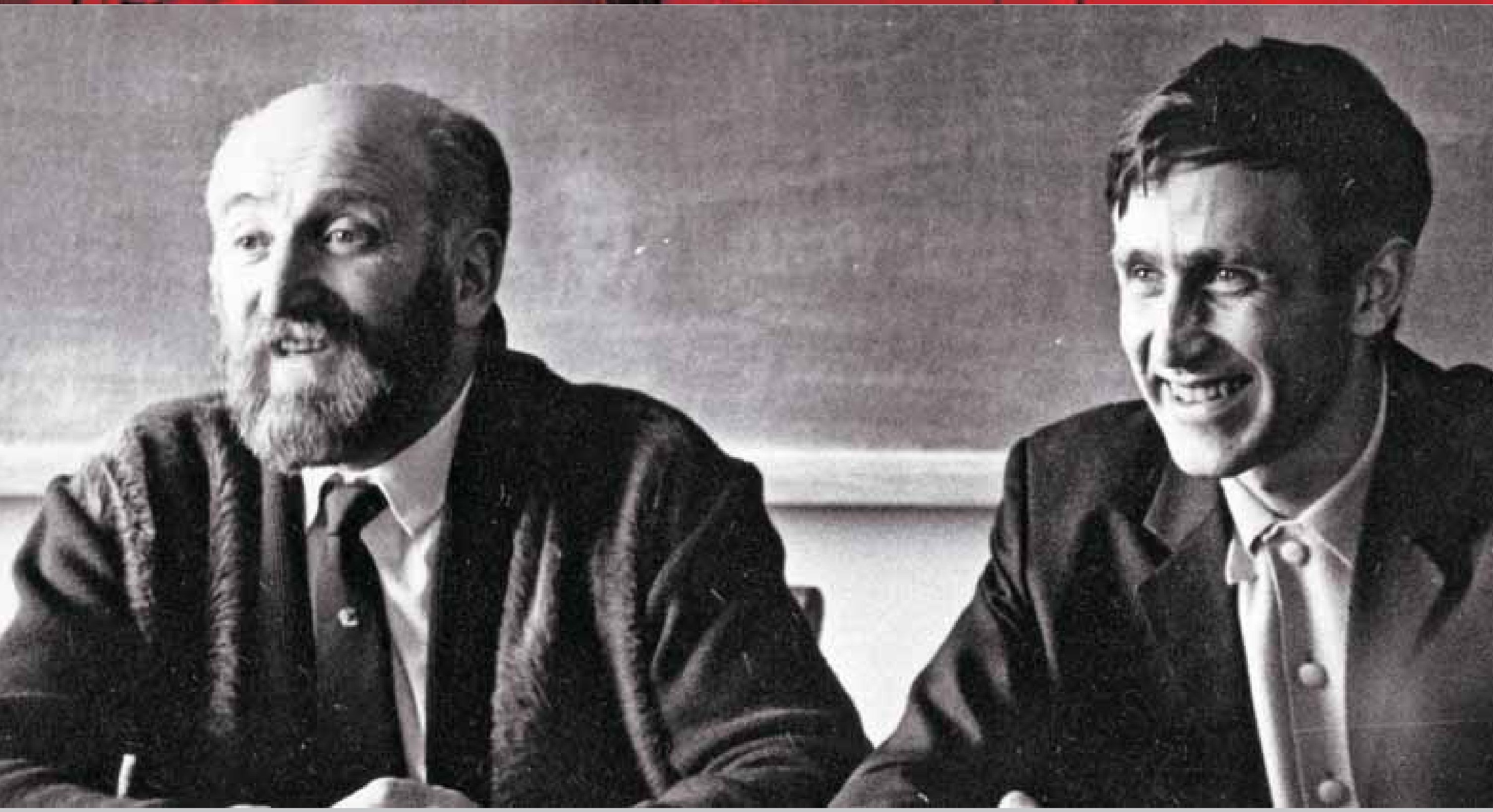
One of the major tendencies in the development of modern physics is the obtaining of higher and higher energies in charged particle accelerators to increase the energy of the interaction reaction of particles. Since the times of Rutherford, the scheme of such experiments has not changed; a fixed target is bombarded by a bunch of fast particles. This scheme, however, is not efficient at high energies when particles are accelerated to near light speeds. At such a speed, the mass of "particles-projectiles" abruptly increases and becomes much greater than the mass of target particles. When a heavy "projectile" hits a light particle of the target, only an insignificant part of its energy obtained with such difficulty is used by the reaction itself. The "lion's share" is merely spent for the motion of both particles.

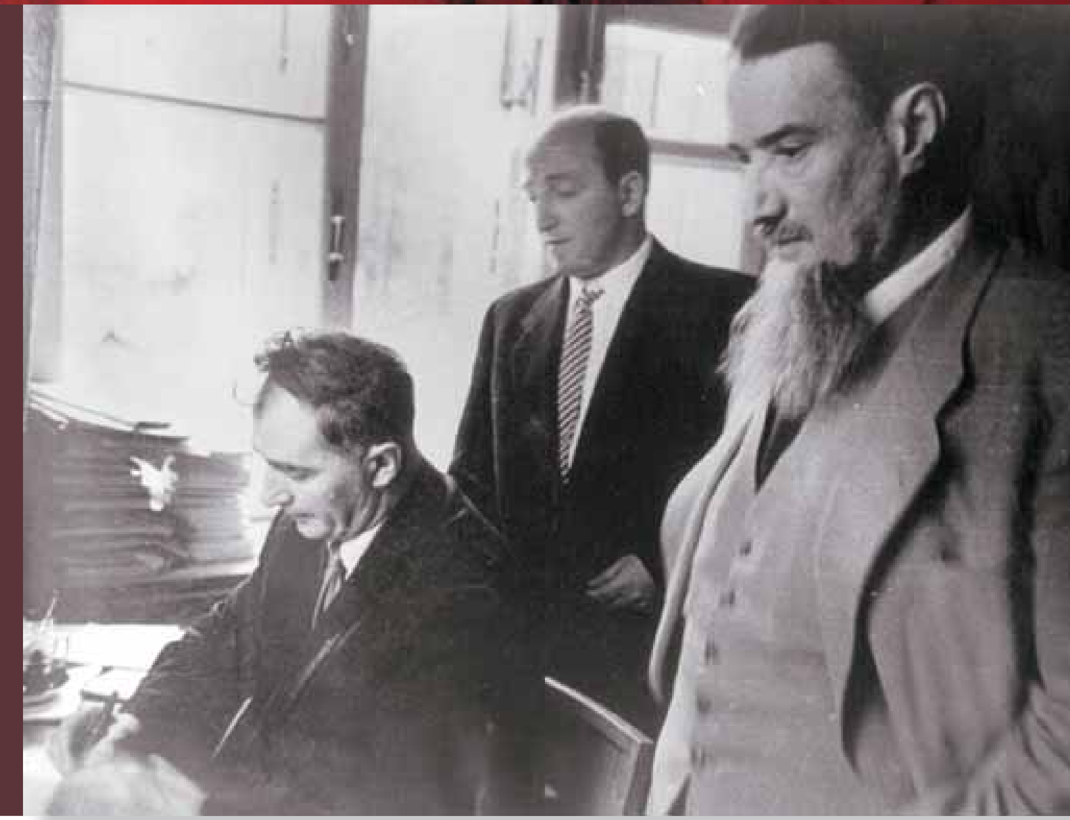
We followed another path, making the target mobile and colliding two particle beams accelerated to the same energy. In this case, the masses of the "projectile" and target remain equal, and they can turn all their energy into the energy of interaction.

It is very important that at particle velocities close to the light velocity, the effect of interaction of colliding particles increases much more than by a factor of four (in accordance with Newtonian mechanics). For instance, at the collision of two electrons moving towards each other with an energy of a billion of eV, the effect of interaction is the same as that of a conventional accelerator with an energy of 4000 GeV. The very idea of colliders is not new; it is not a scientific discovery. This is a mere consequence of Einstein's relativity theory. This idea was expressed earlier but, as a rule, the possibility of its realization was viewed pessimistically. This is understandable. After all, the density of a mobile target, i.e., a beam of particles in conventional accelerators, is by a factor of hundreds of trillions (number with 17 zeros) less than that of a fixed target. The problem of colliding two particles is about as complex as that of "arranging" a meeting of two arrows, one of which is shot by Robin Hood from the Earth and the other one by Wilhelm Tell from the planet revolving around Sirius. However, the advantages of colliding beams in comparison with conventional methods are great, so that we decided to overcome the difficulties. This required increasing the density of beams and making them pass many times through each other.

Newspaper "Za nauku v Sibiri", January 14, 1970

VEP-1, now a relic. Participants of the launch (*from left to right*): G.N. Kulipanov, S.G. Popov, A.N. Skrinsky and G.M. Tumaikin





Gersh I. Budker and Igor V. Kurchatov (*standing, left to right*) at the signing of important documents in Moscow in 1957. *SB RAS Photo Archive*

Andrei Mikhailovich burned with the desire to embark immediately on the realization of all these ideas. However, the ideas were too complicated, almost fantastic, and he himself was only a theoretician. At this time he took probably the most important step in his life, a very bold and unusual one, not a step, but rather a jump into the unknown – he decided to place himself at the head of a group of enthusiasts, experimenters and engineers, who were prepared to transform his ideas into reality. Andrei Mikhailovich did not take this step without internal hesitation and even dread, but nevertheless he made up his mind, made up his mind in the face of insistent advice and exhortations of many close friends. Having no experience in organization of experimental research, but also unfettered by tradition, Andrei Mikhailovich advanced his original ideas also in this area: how a creative scientific group should live and develop. Thus was born the Budker school. At first, in 1953, this was a small group of only eight men. However, the results were not long in coming – in the first few years he built an accelerator of the betatron type with a current up to 100 A, which exceeded by two orders of magnitude the currents of the best accelerators of that time. Andrei Mikhailovich's small group grew into one of the largest laboratories (The Laboratory of New Acceleration Methods) of the Atomic Energy Institute, and in 1958 it was converted into the independent Nuclear Physics Institute of the young Siberian Division of the Academy of Sciences of the USSR. Nevertheless, it turned out to be impossible to produce a stabilized beam – the technical difficulties turned out to be insurmountable. This problem still awaits its solution in the future. Andrei Mikhailovich understood this, probably, sooner than others did. What should be done? Quite a large group had been working intensively with total devotion. Where should this flux of creative energy be directed? He found the solution – colliding beams!

From: Academician Gersh Itskovich Budker (Obituary) by Aleksandrov A.P. et al., 1978

After hot science – to cold Siberia

Soon afterwards, Andrei Mikhailovich insisted that we all should move to Novosibirsk. In Moscow, authorities kept scientists on a short leash while Siberia promised more scientific freedom and autonomy. Still, the most part of the lab chose to stay in Moscow – very few dared to leave for Siberia.

At that time, a young physicist Veniamin Sidorov returned to Moscow after a year at the Nielson Bohr Institute. Andrei Mikhailovich offered him the position of the head of the Moscow laboratory while he himself would set off with a small team to Novosibirsk for yet unknown prospects. Sidorov retorted, however, that he had no desire to get stuck in Moscow doing old stuff while Budker's team was doing real science in Siberia. Eventually, Sidorov became head of laboratory at the future Institute of Nuclear Physics, and I became his deputy.

However, most of our colleagues didn't side with us: they thought that moving to Siberia was utter stupidity – Moscow was a city of opportunity and we were about to leave "for woods." One very good physicist with an acid tongue told me, "You're going to Novosibirsk? That's just nuts. Okay, give it a try, and in two or three years, when all of you go under, we'll take you back." In 3 years we obtained the first colliding beams, and in 15 more years this physicist came to Novosibirsk to defend his doctor-of-science dissertation. I didn't gibe.

Our institute soon became the leading center of elementary particle physics in the Soviet Union. So, we grew in a forest, like a mushroom.

As early as during the construction of VEP-1, Budker contrived an idea of a facility with electron–positron colliding beams, a far more complex and exciting project. Budker went to Moscow to meet with Igor Kurchatov and showed him a "project description" on a few sheets of paper. Kurchatov sent those papers to the three leading physicists of the Soviet Union for a review. One of these physicists was Vladimir Veksler, an Academician of the USSR Academy of Sciences. All the three sent back their very similar opinions: an electron–positron collider was a brilliant idea, but impossible to implement – neither now, nor in the future. Budker drooped his head, but Kurchatov stroke his famous beard and said: "Well, let's now draft a resolution for the Central Committee and the Council of Ministers." He thought it more important that the reviewers considered the idea interesting, and implementation was, in his view, a secondary issue. Kurchatov dared to bet not on high-class physicists but on a team of vealy enthusiasts (the oldest guys in our group were recent university graduates, and Budker himself was only 37 years old).

So, the Laboratory of New Methods of Acceleration transformed into the Institute of Nuclear Physics, Siberian Branch, USSR Academy of Sciences. By the way, only one of the three reviewers later admitted that he was wrong. Veksler came to Novosibirsk when VEP-1 had generated the first beams and VEPP-2 was under construction. He saw, with his own eyes, the synchrotron radiation from the beams; he saw the beams accumulate, shrink crosswise,

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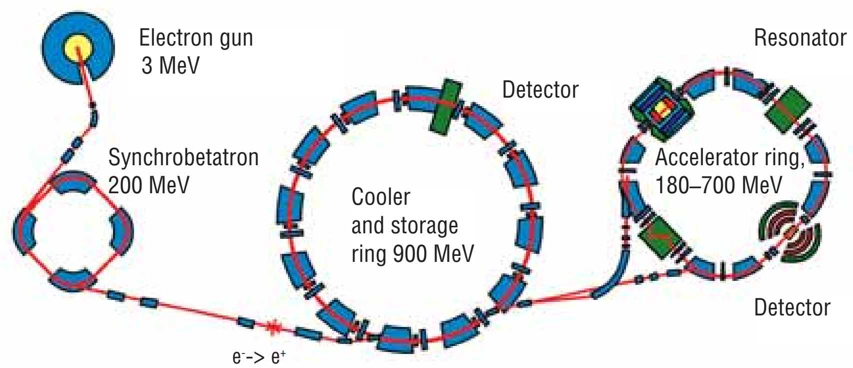
1964 Launch of VEP-1, the first colliding beam accelerator

The first colliding beam accelerator VEP-1

1965 Launch of the VEPP-2 electron–positron collider

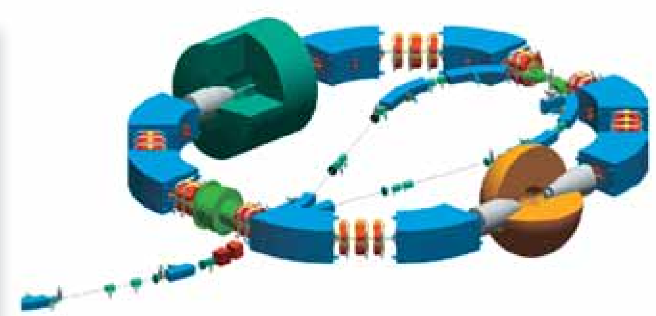


The VEPP-2 facility operated in the energy range 0.4–1.4 GeV. The maximum luminosity achieved at VEPP-2 was $5{\times}10^{30}$ cm$^{-2}{\times}$s^{-1} at 510 MeV. In 1972, the institute launched a new VEPP-2M accelerator. *Below:* the VEPP-2 rotating magnet, now a museum exhibit

1971 Development of the VEPP-3 electron–positron storage ring

The B-4 booster synchrotron in which there occurs initial acceleration of electron (positron) beams to the injection energy (360 MeV) into the VEPP-3 storage ring

1999 Modernization of VEPP-2M—development of VEPP-2000



SND (Spherical Neutral Detector), a detector of elementary particles, in the experimental gap of the VEPP-2000 booster ring

shine brighter and brighter... With increasing energy, the beams changed their color from orange to blue, and they lived long! Veksler came to a roundtable meeting at the institute and said: "I gave a negative review on the project, and I was wrong. My congratulations on your success!"

When we obtained the first electron–positron beams, it was unbelievable! No words would describe our emotion. Now it all seems to have happened fast, but back then we worked day and night and didn't see any progress. Things were always breaking down; we had to repair them again and again.

In 1967, we got the Lenin Prize for our experiments with colliding beams. A year earlier, in 1966, Budker and I made a tour of the United States, where we visited all the institutes and labs studying elementary particle physics. We toured the country for a month, talking about the behavior of particle beams at collisions.

This marked the beginning of a new chapter in our life: our institute became a world center of nuclear physics, and we began to teach vigorously at Novosibirsk State University and Novosibirsk State Technical University. Since then, 90% of our staff have been graduates of these two universities.

1979 Launch of the VEPP-4 electron–positron collider

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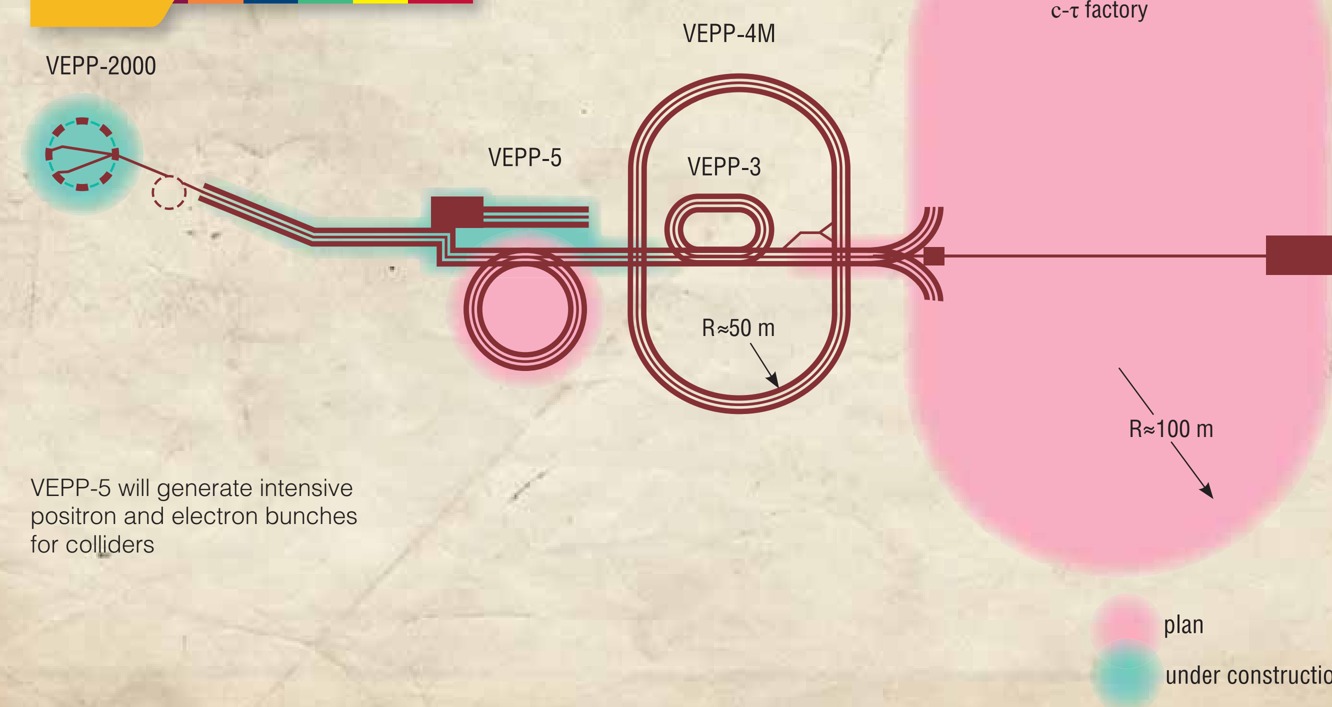
Celebrating the birth of epsilon-mesons at VEPP-4. April 30, 1982

SR AT THE BINP

It is known that synchrotron radiation (SR) is the daily bread for many users; for accelerator physicists, it is a parasite because it takes away a large part of energy pumped with great effort into the beam of charged particles accelerated nearly to the speed of light. Now the SR sources at the Institute of Nuclear Physics (INP) are VEPP-3 (created in 1972) and VEPP-4M (put in operation in the early 1980s and later modernized), on which studies in the field of elementary particle physics are conducted. Consequently, SR experiments take only 15% of the total time of accelerator operation. Thus, although SR experiments have been carried out at the INP ever since 1973, they still use not sufficiently bright first-generation SR sources.

It is worth mentioning that the 2003 commissioning of the first line of a free electron laser system (a source of powerful terahertz radiation beams) principally expanded the INP's research potential; however, it is still necessary to develop a more powerful new generation SR source that will operate in the X-ray range.

2015 Launch of the first part of the VEPP-5 accelerator complex



VEPP-5 will generate intensive positron and electron bunches for colliders

Nonetheless, our sources have been heavily exploited for both research and routine technological aims. For instance, the researchers from the Institute of Catalysis SB RAS (Novosibirsk) are constantly analyzing samples of novel catalysts intended for industrial applications. Our main advantage is that SR at the INP has largely maintained its initially unrestricted status of a research tool; so, practically any scientist can use it to verify his/her idea (however crazy it may be). In this respect, it is very important that our SR sources are located in such an unusual infrastructure as Novosibirsk Akademgorodok, i.e. in a vast multidisciplinary environment. For instance, archaeologists, who work in the same neighborhood, can ask physicists to analyze any artifact they are interested in.

Moreover, we elaborate the procedures which in principle are difficult to develop at large SR centers, which, to some extent, is due to administrative restrictions. A good example is the study of detonation processes with a submillisecond time resolution in a special explosion chamber located at the SR output channel. The first experimental station, named Detonation, was set on the VEPP-3 storage ring, and later a second station started its work on the VEPP-4 storage ring: the new chamber made it possible to investigate the detonation of charges weighing up to 200 g. Here, we plan to study the effect of powerful laser plasma pulses on construction materials. The knowledge of these processes will be necessary for designing future thermonuclear reactors.

The COSMOS synchrotron radiation station – a little "piece of cosmos" enclosed in a vacuum chamber where synchrotron radiation comes from the VEPP-4 storage ring. The combination of high vacuum and strong radiation fluxes creates volumes (in the experimental station conditions) that are similar to conditions in the near-earth space. COSMOS is now the only synchrotron radiation station in Russia that works for metrology needs in the soft X-ray and EUV ranges and can perform satellite equipment calibration.

(Zolotarev, Piminov, 2015; Nikolenko, 2015)

The Large Hadron Collider constructed at CERN has a circumference of the main tunnel of 27 km, and its name is fully justified. Connected to LHC will be a whole family of accelerators in which particles are successively accelerated to velocities maximally close to the speed of light

SKRINSKY'S PLAN

In the beginning of the 1990s, it became clear to me as well as to all my colleagues working in the field of high energy physics that the only chance for Russia to remain in the vanguard in this area was to become an equal member of the LHC project. No need to say, our government could not afford to invest over 100 million dollars of its budget in CERN, as other countries did. Then I came up with an unconventional plan of Russia's participation in the project, which was sure to satisfy all the parties interested.

The gist of this plan is as follows: Russia supplies high-tech research equipment whose cost, in world prices, is 150 million dollars. Russia's research institutes – contractors agree to make it for 100 million dollars, which they obtain, in equal parts, from the budgets of CERN and Russia. In this plan everybody wins: CERN gets the equipment for $100 million "net" as Russia's contribution in the project; Russia pays only $50 million for its participation in the most ambitious research project of our days and supports, with the same money, its own research institutes; and the Institutes get good money and guaranteed participation in the future experiments to be carried out at LHC. Despite the obvious pluses, virtually nobody believed that the plan would work. It seemed impossible that in 1994 we could agree about what we would do in Russia in the following ten years, at the beginning of the 2000s and, what's more, using such a sophisticated financial structure.

It took me two years to explain that the plan was beneficial for them, for us, and for the whole research community. The Ministry of Science gave us its support. We organized a Russia-CERN Committee consisting of CERN's five top executives and five members from Russia: director of the Ministry of Atomic Energy, three representatives of research community, and the Minister of Science as chairman. As a result, the CERN Council made a special resolution to finance our work. (European colleagues asked reasonable questions: why cannot their centers, their institutes, and industries do this work?).

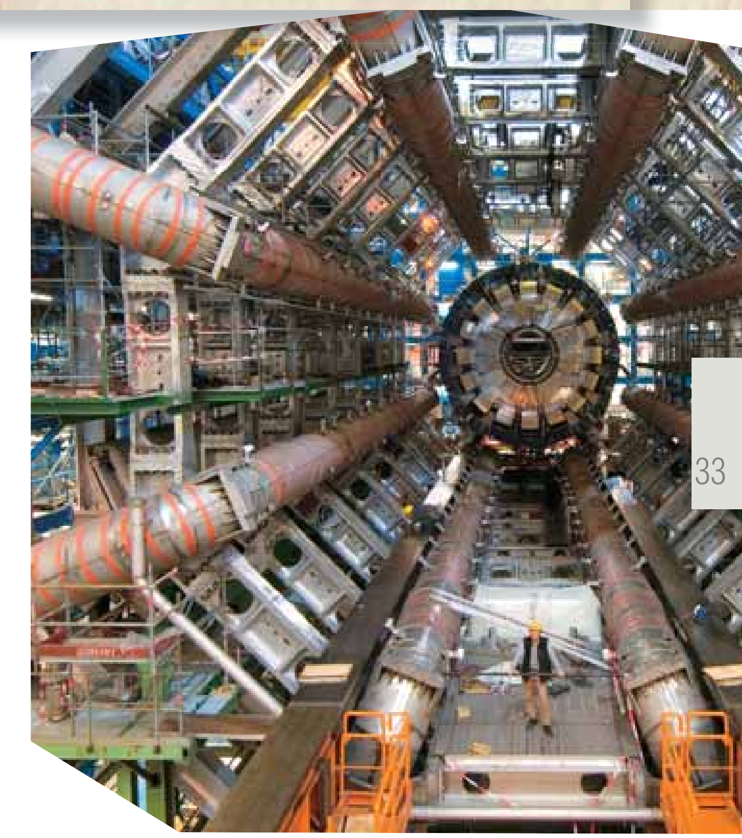
The plan (referred to as "Skrinsky's plan") proved workable. By the way, in all these years the Ministry of Science has received no similar proposal from other research fields.

Skrinsky, 2006

… INP SB RAS researchers have developed, manufactured, installed, and adjusted 360 dipole magnets and 180 quadrupole magnets for the collider injection channels, ultrahigh-vacuum facilities, an electronic cooler of heavy ions, and numerous other high-technology facilities with a total weight of about 5 000 tons!

The CERN management has repeatedly emphasized that the contribution of Russian scientists, specialists, institutes, and enterprises to the elaboration and execution of the Large Hadron Collider Project is invaluable. It covers not only the logistic support of some key positions, but also the use of the advanced ideas and achievements in particle physics and accelerator engineering presented and developed by our scientists earlier. Naturally, two streets in CERN are named after the Russian physicists V. I. Veksler and G. I. Budker, who made fundamental contributions to the world accelerator science

Bondar, 2009



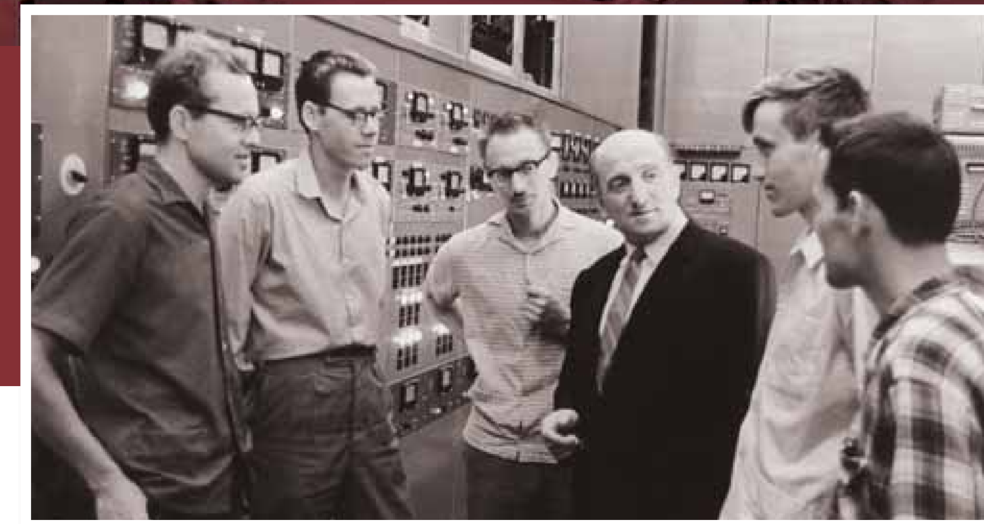
Made in the BINP

Andrei Mikhailovich Budker was designing an institute different from others. Everything was different – from career hierarchy to financing schemes. Just imagine: I became head of laboratory three years after graduating from university. In 1966, Budker negotiated a personal agreement with Alexei Kosygin that the government would issue a resolution allowing the Institute of Nuclear Physics, Siberian Branch, USSR Academy of Sciences, as an exception, to sign contracts not based on a preset cost calculation. At first we were an object of ridicule: "What an idea – to make money in Russia!" Then broke a storm of outrage: "They are allowed to make money, and we aren't?!"

However, a legal opportunity to make money isn't enough; one has to deliver a product that no one else can. We lived and worked in Novosibirsk yet built CERN in Switzerland and Brookhaven in the United States; we produced facilities for Japan and China. If we mark on the world map all the spots where our physicists and facilities have worked and are now working, we'll cover all the cities and countries, from Australia to Canada.

We go on living like this today – we participate in most diverse international projects. For instance, a considerable part of hardware in CERN's projects is made in the BINP.

Andrei Mikhailovich, who was very fond of sports and did some boxing and volleyball when he was young, always said that we were a team, rather than a lab, and our team should have a good captain. The institute was indeed a solid team and remained one even in the hardest of times – when Andrei Mikhailovich passed away and when the Soviet Union broke apart. We managed to save science and our place in it.



At VEPP-2 control terminal.
From left to right:
V. Sidorov,
I. Protopopov,
S. Popov,
G. I. Budker,
A. Skrinsky,
V. Petrov

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This article includes drawings by E. Bender