

Visit to Serpukhov

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At its Meeting in December 1965, the Council approved the initiative of Professor Weisskopf in pursuing the possibility of collaboration with the Russian accelerator Laboratory at Serpukhov. This article conveys more information about the new Laboratory, together with some of the impressions received during a recent visit by a group of physicists from CERN.

At the end of last year, five physicists from CERN visited the Institute for High Energy Physics at Serpukhov, where the Soviet 70 GeV proton accelerator is under construction. Soon afterwards, the Director of the Laboratory, A. A. Logunov, and several of his colleagues spent a week in CERN*. Thus contacts with the new Laboratory have been renewed opening up possibilities of future collaboration.

Leaving Moscow early on a November morning, our small bus shared the main road to Kharkov with the usual heavy commercial traffic. The countryside is now flat, now gently undulating with small hills. A grey sky covered large pastures and fields, forests of birch and spruce, and occasional groups of traditional houses decorated in bright colours. Leaving the main road at the entrance of the industrial city of Serpukhov, a smaller road first follows the wide valley of the Oka river, then enters a forest of high spruce.

After a total of two and a half hours driving, the headquarters of the Laboratory appeared in a clearing. This functional building, recently taken over from the builder, houses the directorate offices and a number of laboratories. We were welcomed by the Director and his staff and were first reminded of the general characteristics of the accelerator (see Table) and briefed on the present and future activities.

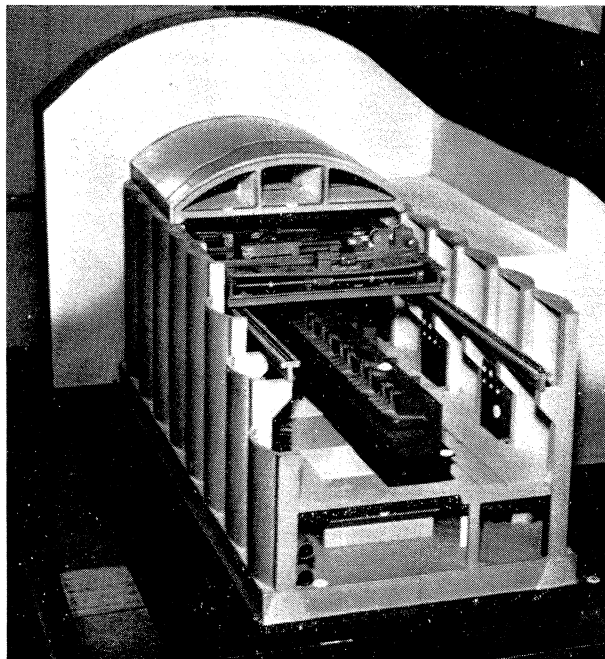
The Serpukhov project started several years ago, under the guidance of physicists from the Moscow Institute of Experimental and Theoretical Physics. Preliminary work on the site began in 1960. The project recently became more autonomous under the

name 'Serpukhov Institute for High Energy Physics'. Construction work received new impetus and a programme for the preparation of beams and experiments was launched. Part of the work takes place on the site itself and part is done by teams temporarily stationed at Dubna. The experimental physics staff now numbers about 70, and is expected to grow to a size comparable to CERN's in about two years. The accelerator design is done at the Research Institute for Electro-Physical Equipment in Leningrad, which centralizes this type of work for the entire Soviet Union. The parts are built by industry.

On site, some limited workshops facilities are available to help with the minor modifications and repair always connected with the assembly work. A large engineering firm is responsible for the construction of the machine. Their representatives asked us not to take photographs on the spot but we were given, later, a picture of magnet units in the accelerator ring*. We attempted to capture some of the atmosphere by photographing, under the amused eyes of our hosts, a model of a section of the accelerator (figure 1), the hosts and guests themselves (figure 2), and an artist's view of the experimental hall (figure 3).

The artist, indeed, gives a good impression of this huge and elegant hall. Its symmetrical external shape fits nicely with the rounded mounds of the shielding banks, where bulldozers seemed to be giving the finishing touches while we were there. Inside the hall, the huge arch is constructed from a light aluminium frame and a large overhead crane is installed. Also sheltering in the hall, are a few birds taking refuge from the forest, begging the warden for crumbs. The vast floor, 150 x 90 m², is at present used to store and test the magnet units and coils. The magnetic properties of the magnet blocks and units are measured on an automated test bench with the help of a small on-line computer. We saw some of the final stages of this work and carried

Figure 1. A model of a section of the magnet ring tunnel of the 70 GeV accelerator. Most of the magnets are now in position and installation of the magnet coils is underway.



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* See CERN COURIER, vol. 6, no. 1 (January 1966) p. 14.



Figure 2. The CERN visitors and their hosts photographed in front of the Laboratory headquarters at Serpukhov. From left to right: B. Montague (CERN), A.A. Filippov (Dubna), A. Rousset (Ecole Polytechnique and CERN), A. A. Logunov (Serpukhov), M. Ferro-Luzzi (CERN), J. M. Perreau (CERN), Y. D. Prokoshkin (Serpukhov) and R. M. Sulaev (Serpukhov).

away as souvenirs, a few punched cards, exactly the same as our familiar western counterparts, except for a few printed cyrillic characters. The coils are tested hydraulically and electrically, and most of the repairs are done on the spot. On both sides of the hall, inside and outside the ring, laboratory buildings are planned. Slightly further out are the generator buildings, workshops and other facilities. It is planned to extend the hall by a long gallery, containing particle separator equipment, leading to a bubble chamber building to be situated several hundred meters away.

We passed over the scar of mud and dust that the construction work has made in the forest, to visit the building housing the injector, a three-stage linear accelerator (40 - 70 - 100 MeV) with a Cockcroft-Walton generator as input and with quadrupole focusing. The generator is already there, together with a spare, and so are two of the linear accelerator vacuum tanks. The copper resonators are ready to be mounted in the first tank. We were told that the titanium pump and r.f. generators were ready at a Moscow factory. Some of the electrical installation was under way, but it was obvious that first priority was being given to completion of the building. Concrete dust was still flying around and we met many men and women workers — carpenters and masons.

The accelerator ring tunnel is relatively spacious. On both sides, room is available for the installation of equipment and for storage (see figure 1). Most of the magnet units were in position in the ring and the job on hand was the installation of the magnet coils. We noticed the use of aluminium conductors, both to feed the coils and for the coils themselves, and a systematic use of aluminium welding.

The straight sections in the magnet ring are relatively short, creating some problems for beam injection and ejection. Designs are in progress for a fast ejected beam for protons up to 40 GeV/c, and for slow extraction up to 60 or 65 GeV/c, with target dates of

18 months to a year after the first accelerated beam has been obtained (see below). To our eyes, more familiar with the CERN and Brookhaven machines, the Serpukhov magnets and their supports appeared large and massive, the tunnel endless. Alice in Wonderland's mushroom that makes everything bigger is in this case partly the Russian engineering tradition and partly the factor of almost three in accelerator energy.

The question on all our lips was, of course, 'When do you expect the first accelerated beam?' The best estimate our hosts gave us was two years (end of 1967), with a margin of error of minus two months, plus one year. They asked us, in turn, to make an estimate on the basis of what we had seen. But we saw only a point on a curve, and not its slope. Instead of a wild guess, we wished our friends the best of luck in reaching this date which must be dear to all their hearts.

The first ray of sunshine of the day accompanied our return to the laboratory buildings. The barks of the birches were shining and the Serpukhov spruces, which are also three times larger than their Brookhaven counterparts, stood out prominently. We broke into smaller groups to talk shop about our respective fields. Everywhere we found a high level of competence, and the fire of questions and answers showed the keen knowledge and understanding that our hosts had of all the works published by other Laboratories. From these conversations we learned the proposals for beams and the experimental programme.

Design is in progress on the following:

- a high energy unseparated negative beam (30 to 60 GeV/c) from an internal target for π^- (and $\bar{p}$) to go diagonally across the experimental hall;
- a high energy unseparated positive beam, from an internal target, with momenta up to 40 or 50 GeV/c;
- two electrostatically separated beams, going towards the inside of the ring: one fully separated (up to 7 or 8 GeV/c), the other with one-stage partial separation and high flux, reaching 15 GeV/c;

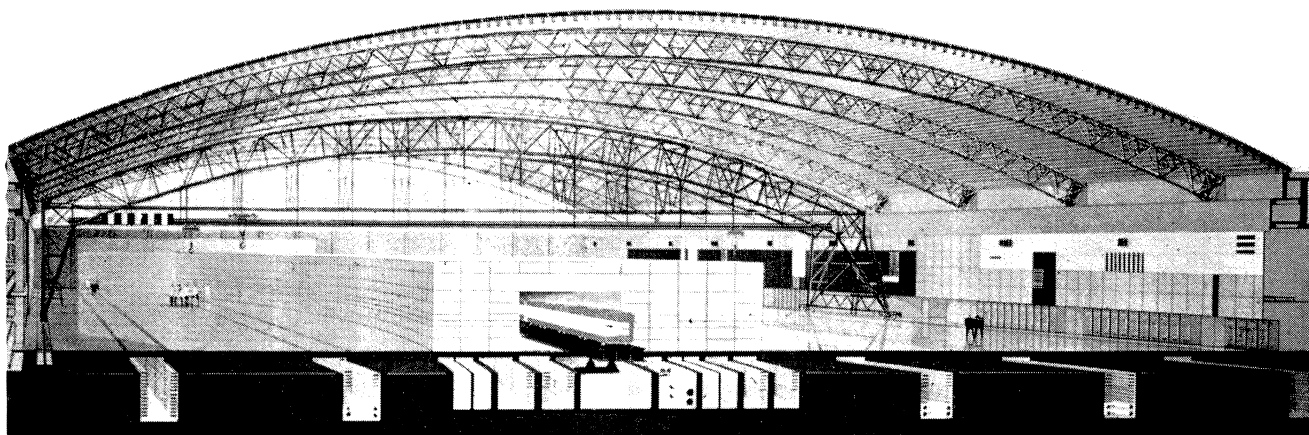


Figure 3. An artist's impression of the large experimental hall. As can be seen, the building has no internal supports to interfere with the positioning of beam lines. The accelerator itself and its surrounding shielding are in the centre of the picture. The tunnels for the various ancillary supplies can be seen under the floor level of the hall.

TABLE : Design parameters of the Serpukhov accelerator*

Type — strong focusing, alternating gradient	
Orbit length	1483.64 m
Effective radius of the orbit inside the magnet blocks	194.12 m
Length of normal block measured along its iron core	10.42 m
Length of shortened block	9.3 m
Number of blocks	120
Number of superperiods	12
Number of normal blocks in a superperiod	$3 F + 3 D = 6$
Number of shortened blocks in a superperiod	$2 F' + 2 D' = 4$
Length of short straight section	1.27 m
Length of medium straight section	2.62 m
Length of long straight section	4.86 m
Maximum field at equilibrium orbit	1.0 to 1.2 T
Number of betatron oscillations per turn	9.7
Kinetic energy at injection	100 MeV
Transition energy (total)	8.9 GeV
Maximum proton energy	58 to 70 GeV
Field at injection	0.0076 T
Chamber half-height	57.5 mm
Chamber half-width (effective)	85.0 mm
Maximum orbit displacement at a unit momentum deflection $\Delta p/p = 1$	3.53 m
Maximum amplitude of forced oscillations	34 mm
Maximum amplitude of free oscillations	22.8 mm
Total weight of silicon steel in magnet	20 000 t
Total weight of aluminium in the windings	700 t
Energy stored in magnetic field	120 MJ
Peak supply power	100 MW
Number of cycles per minute	5—10
Rectified voltage at the beginning of the cycle	9230 V
Maximum rectified current	2×5750 A
Current rise time	3.5 s
Duration of pulse flat top	1.5 s
Expected intensity for first beam	10^{11} protons/pulse
Maximum intensity	2 to $3 \cdot 10^{12}$ protons/pulse

* Vladimirov V. V., Goldin L. L., Koshkarev D. G., Tarasov E. K., Yakovlev B. M., Komar E. G., Monoszon N. A., Strelzov N. S., Stolov A. M., Titov V. A., Malyshev I. F., Popkovitch A. V., Gustov G. K., Kulikov V. V., Minz A. L., Rubchinski S. M., Vodopjanov F. A., Kuzmin A. A., Uvarov V. A., Kuzmin V. F., Shirjajev F. Z., Filaretov S. G., Zhadanov V. M.:

Proceedings of the International Conference on High Energy Accelerators, Dubna, August 21—27, 1963

Atomizdat, Moscow 1964 pp. 197—201

Transl. AEC, Conf. 114, TID-4500, 43rd Ed., pp. 233—239

Small changes and additions after visit to Serpukhov.

— a r.f. separated beam not yet fully defined, to operate probably with an external target, leading through the outside gallery to the bubble chamber building.

The bubble chamber programme includes a project for a 4 to 5 m heavy liquid chamber, to be constructed at Serpukhov, a 5 m x 1.5 m hydrogen bubble chamber, under study by a group in Dubna, and a 2 m hydrogen bubble chamber with horizontal window, which will be initially assembled and operated in Dubna, where parts have already arrived. Active work is under way to prepare analysis programmes, designed for the future large digital computer, BECM 6a (10⁶ operations per second, 16 magnetic drums, 54 magnetic tapes, Algol, Fortran).

Several experiments are being prepared using electronic and spark chamber techniques: for instance, hodoscope type experiments with computer on-line to measure total cross-sections and elastic scattering; a large 6 m magnetic spark chamber. Development work is in progress on total absorption spectrometer sandwiches for gamma ray detection, and on digitized spark chambers.

A neutrino experiment will not be attempted before obtaining the extracted proton beam. A 100 m decay path and the necessary shielding will probably be

placed next to the r.f. gallery. Multi-ton spark chambers and the heavy liquid chamber will be used for detection.

As dusk settled on the forest, we walked to the new, elegant cafeteria, where our hunger, aroused by a long and exciting day, was soon appeased by delicacies matching the refinement of the setting. Toasts were exchanged to the future of a commencing collaboration.

Serpukhov is in the heart of a countryside which attracted many artists, painters and poets, and thus belongs to the Russian cultural tradition. Nearby, many kinds of sport can be practised, from fishing to aviation. Within easy reach also are other scientific Institutes, for instance in the field of astrophysics. On our walk back to the laboratory buildings, we had noticed between the trees the small laboratory town, with its school and apartment houses, lit up by the windows of its shops. The people in the few streets seem young, alert and confident, and the atmosphere is homely. Serpukhov will soon be contributing to the cultural tradition as one of the outposts of scientific thought and achievement. In the words of the Serpukhov Scientific Director, Y. D. Prokoshkin, it will be a place where physicists from all over the world will, also, feel at home.

BOOKS

Nuclear techniques in analytical chemistry, by Alfred J. Moses (Oxford, Pergamon Press Ltd., 1964; 45 s.); is intended to guide the analytical chemist in the use of nuclear methods. As an introduction it contains general information about the handling of radioactivity and the measurement of radioactive nuclides. Then follow a number of chapters describing the application of nuclear techniques to various fields of analytical chemistry, including activation analysis, tracer methods, dating methods, etc.

The general impression of this little book is that the introductory part is rather weak. The author has tried to lighten the text with a large number of illustrations, but many of these are quite uninteresting (the first two chapters contain, for instance, six photographs of counters and spectrometers). He would have been better advised to give more space to textual matter instead.

The chapters concerning the applications of the techniques are of greater value, however. The larger number of examples giving procedures for the analysis of specific elements will give the reader, not already familiar with the use of these methods, a feeling for the amount of work involved, the instrumentation needed, and the sensitivity and accuracy of the analytical methods. He will then be in a better position to make comparisons with more conventional methods. He might even make direct use of the procedures described.

There are a few typographical errors, such as the interchange of figure captions. More confusing, however, is a statement that cobalt can be extracted in 2-nitroso-1-naphthol.

This would certainly be quite difficult, as the latter compound is a solid (it forms a complex with cobalt which can be extracted with a solvent such as chloroform).

In spite of its shortcomings the monograph gives a fair survey of the place of nuclear techniques in analytical chemistry. It can certainly serve as an introduction to this field and can therefore be said to answer to its purpose.

G. R.

Quantum optics and electronics, edited by C. DeWitt, A. Blandin and C. Cohen-Tannoudji (New York, Gordon and Breach Science Publishers Inc., 1965; paper \$ 8.50, cloth \$ 10.50) is a record of the lectures on these subjects at the Les Houches Summer School in 1964. Although the title could be taken to cover a wide range of subjects, the emphasis is clearly on those fields which are most affected by the recent spectacular development of maser and laser technology.

The introductory lectures by N. M. Kroll on 'Quantum theory of radiation' and R. J. Glauber on 'Optical coherence and photon statistics' presuppose no special knowledge beyond, say, what may be found in Messiah's *Quantum mechanics*. These lectures, especially the ones by Glauber, are of a high pedagogical standard and their contents should form part of the basic knowledge of every physicist. Subsequent lecturers include those who have been most directly responsible for the great progress in the field of masers and lasers. Lectures by W. E. Lamb (with an introduction which reminds physicists that they are citizens in