A Visit to the Serpukhov 76-GeV Synchrotron

The world's largest particle accelerator, the 76-GeV synchrotron at Serpukhov, is now producing 2×10^{11} protons/pulse and is expected to be doing experiments shortly. Groups from CERN and France are collaborating with Serpukhov scientists, and there is some hope for American participation, too. (Such international coöperation may, of course, be influenced by the Czechoslovakian situation.)

When we recently visited the High-Energy Physics Institute at Serpukhov we were overwhelmed by the great size of the machine: its huge magnets, vacuum chamber, tunnel (there is plenty of space for a few people to chat alongside a test rack) and experimental hall.

The machine. It seems clear that there was a tremendous need that the Serpukhov machine work well and work on schedule. The beam was turned on (PHYSICS TODAY, December 1967, page 59) in time to celebrate the 50th anniversary of the Russian revolution; the event was one of several scientific spectaculars apparently timed for the festivities.

The beam is still being tuned, but Yuri Ado, who heads the Serpukhov accelerator department, feels the synchrotron will eventually reach the space-charge limit on intensity, roughly 2×10^{12} protons/pulse at an energy of 80 GeV.

The strong-focusing synchrotron, like most Russian accelerators, was built by E. G. Komar's group in Leningrad, the Institute for Electrophysical Apparatus. The engineering of the Serpukhov accelerator apparently surpasses that of earlier Komar-built machines, such as the 10-GeV synchrophasotron at Dubna.

Ado took us on the long stroll required to circle the 470-meter-diameter ring. Acceleration is in three stages. The preinjector makes 700-keV protons; a linear accelerator boosts them to 100 MeV, and then the synchrotron takes over.

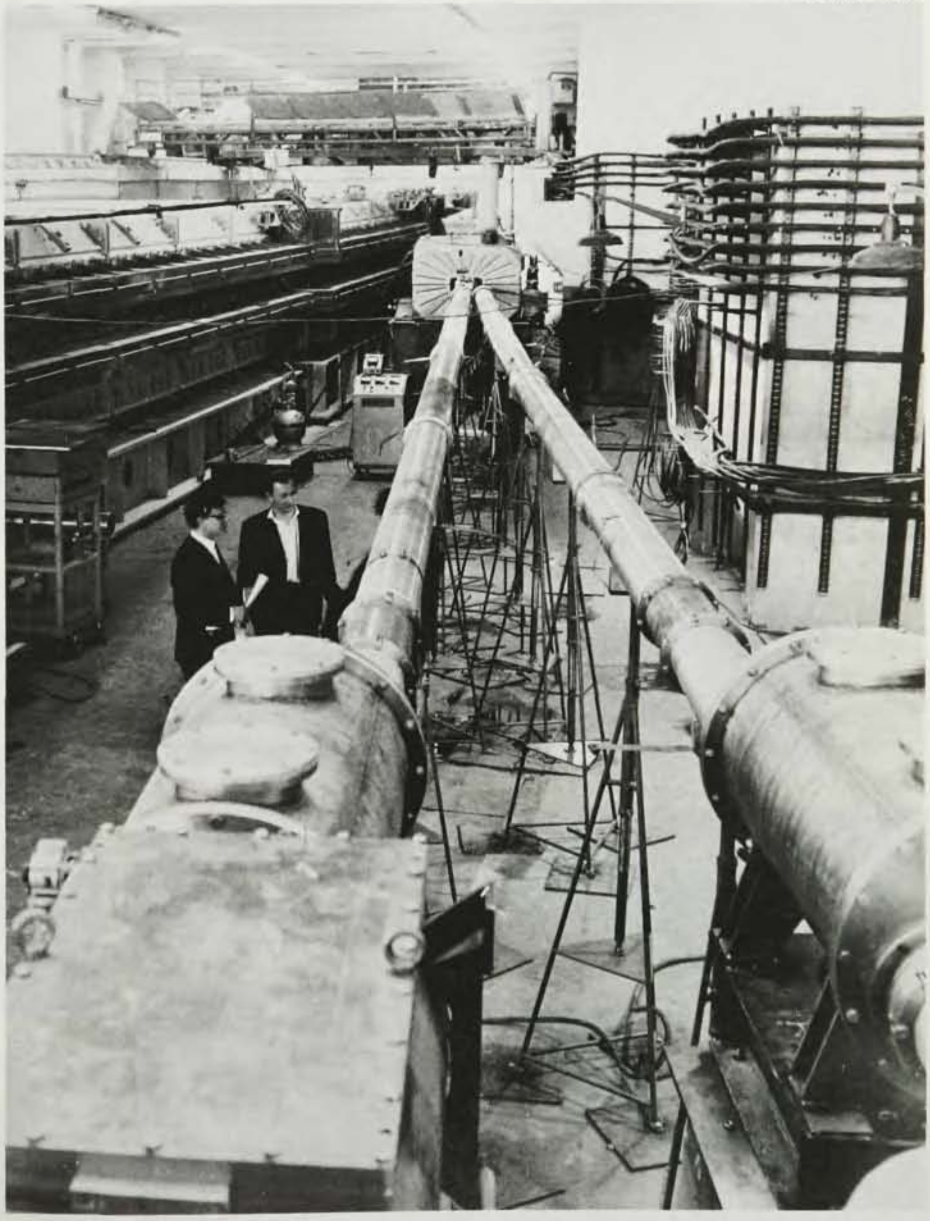
The linac operates at 148 MHz, unlike the injectors for the Brookhaven, CERN and Berkeley synchrotrons (which operate at 200 MHz). The linac has lived up to expectations for injection currents as high as 30 milliamps: the beam momentum spread is 0.3% and the beam emittance is 2.2 milliradian-cm.

In the synchrotron itself, there are 120 magnet units, three kinds of straight sections (short, medium and long) and 54 rf stations. The resonators operate at the 30th harmonic of the revolution frequency, and their frequency ranges from 2.6 to 6.1 MHz.

Magnetic field rises from 76 to 13 000 oersteds in 2.6 sec; once the protons are at full energy there is a 0.5-sec flat top; then magnetic field decreases for 2.5 sec, followed by a 2-sec pause. Repetition rate is about 8 cycles/min.

Although 2×10^{12} protons are injected, only about 20% of them are trapped. Out of these, half are lost in the first 30 millisec; so only about 2×10^{11} particles are successfully accelerated. Ado expects trapping efficiency will improve after the build-

TASS FROM SOVFOTO



SERPUKHOV BEAM LINES are being prepared to transport secondary particles. Machine has yielded 2×10^{11} protons/pulse; 2×10^{12} protons/pulse are expected.

ers finish their studies of loss mechanisms later this year and install prebunching.

In installing the synchrotron magnets, accelerator people paid special attention to their alignment and achieved a relative accuracy of 100 microns. As a result, the field error above 300 gauss was 0.05%; so no correction was required. Below 300 G errors were three or four times as great, but corrections have now been made.

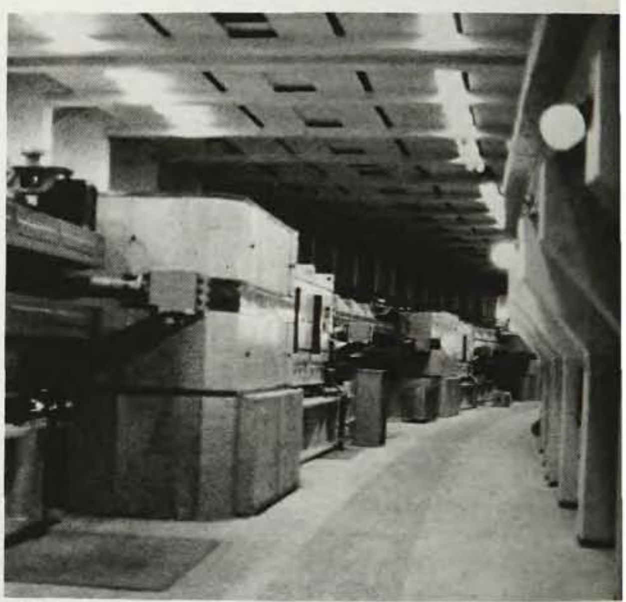
Bringing out beams. Ado took us through the main experimental hall, where we saw two beam lines. One beam produces 5–6 GeV/*c* positive particles, and it is directed toward the inside of the ring. The other beam produces negative particles, whose momenta can be varied from 40 to 60 GeV/*c* by selecting one of three internal targets (only one had been installed). Beam optics are now being adjusted.

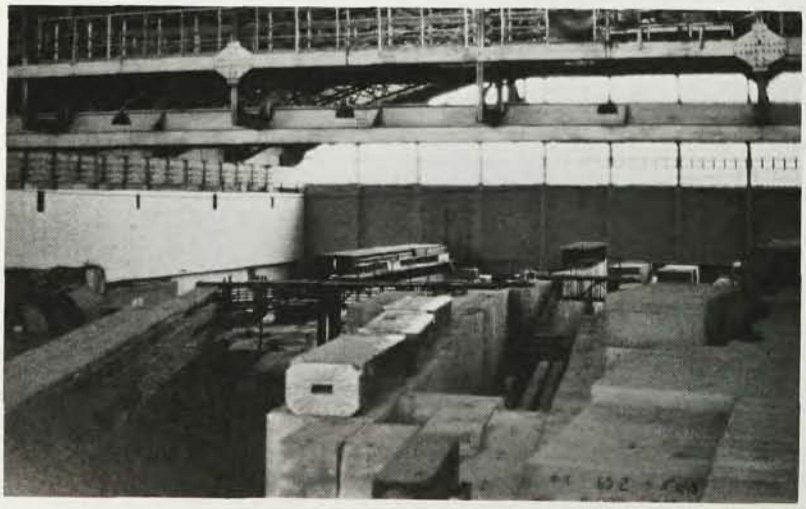
Two fast-ejection systems are being built and should be ready in a couple of years. One is under construction at Komar's institute. The other system is part of a tripartite arrangement, in which a CERN group is building the ejection system plus an external beam-transport system that will feed a French-built bubble chamber. The 4.5-meter hydrogen chamber, known as Mirabelle, will be the largest bubble chamber in the world when Saclay scientists finish it next year.

In one of the first experiments, physicists from CERN and Serpukhov will do a counter measurement of production cross sections. In this "yield experiment" they can get a rough idea of particle production as a function of momentum. The next thing planned is to add a hydrogen target and measure total cross sections. Another early experiment, which the Soviet scientists will do alone, is a search for quarks.

American participation. Although

PHOTOS BY GLORIA LUBKIN





SERPUKHOV SYNCHROTRON (clockwise from bottom). Experimental hall contains two beam lines, one for 5–6 GeV/*c* positive particles, the other for 40–60 GeV/*c* negative particles. Linear accelerator injects 100-MeV protons into the 470-meter-diameter ring. Gloria Lubkin of PHYSICS TODAY sits at the synchrotron control panel. Synchrotron tunnel houses 120 magnet units and 54 rf stations to make 76-GeV protons. Yuri Ado, who heads the accelerator department, points to large magnet aperture.

international coöperation is obviously working at Serpukhov, no American physicists have managed to get their equipment through the door yet. Discussions have been going on from time to time over the past few years, and at least three informal proposals have been made by groups headed by S. J. Lindenbaum of Brookhaven, Jay Orear of Cornell and Luke C. L. Yuan of Brookhaven.

The day before our visit, US Atomic Energy Commissioner Gerald Tape and Igor Morokhov, first deputy chairman of the Soviet State Committee for the Utilization of Atomic Energy, had signed a memorandum of agreement for the exchange of scientists at various laboratories of their respective organizations. Serpukhov is one of the laboratories.

The following day Tape and Anatoly Alexeivich Logunov, director of the Serpukhov institute, discussed the possibility of American physicists doing experiments at Serpukhov.

Since Soviet progress in computers is not as great as that in the US, one lively prospect is the Lindenbaum proposal. He would like to bring an array of scintillation-counter hodoscopes, electronics and a part of the Brookhaven on-line data facility, complete with a PDP-6 computer, to Serpukhov. The apparatus has already been successfully used to measure pion-proton and proton-proton scattering at small angles for incident momenta from 8 to 26 GeV/c (PHYSICS TODAY, May 1967, page 63). At Serpukhov one could easily extend these measurements beyond 60 GeV/c.

One not-so-obvious problem raised by international coöperation is, what do you do with all the foreign newcomers? When 100 French scientists and technicians arrive next year to operate Mirabelle, the laboratory town of Protvino will have to provide housing for 400 additional people.

Protvino and the High-Energy Physics Institute are actually 20 km away from Serpukhov, which is about 100 km south of Moscow. The 2500 scientists and technicans of the institute live in Protvino. Support workers and families also live there; population is about 20 000.

Competition. Despite their obvious desire for international coöperation, the Serpukhov physicists we met seemed to feel the same sort of competition with American high-energy physicists that is so apparent between Russian and American space scientists.

At lunch we chatted with Serpukhov physicists including Logunov, Ado, Alexei Naumov, deputy director, and Yuri Prokoshkin, chief of the experimental department. One American suggested a joint effort to build a 1000-GeV accelerator. A Russian rejoined, "We are grateful to you for building the 30-GeV Brookhaven machine because that meant that we could build our 70-GeV machine. And we are grateful that you are building the 200-GeV machine at Weston because that means that we can build a 1000-GeV machine here—by ourselves. Of course that's my personal point of view." —GBL

Stanford Group Builds Visible CW Parametric Oscillator

A continuously operating visible optical parametric oscillator was recently reported by Bob Byer, Kenneth Oshman, Jim Young and Stephen Harris of Stanford (*Appl. Phys. Letters*, 1 August). The oscillator uses the cw output of an argon laser at 0.5145 micron as pump and lithium niobate as the nonlinear crystal. The signal wavelength is tunable from 0.6800 to 0.7050 micron with the idler in the corresponding range 2.11 to 1.90 microns in the infrared.

Besides operating in the visible region of the spectrum, Harris explained, his oscillator differs from the earlier cw oscillator of Richard Smith and his collaborators (PHYSICS TODAY, June 1968, page 60) in two respects. First, since the frequency spacing of the idler modes is equal to the frequency spacing of the modes of the pumping laser, the oscillator uses the total multimode pumping power of the driving laser. Although the pump modes may be randomly phased and erratic in amplitude, corresponding behavior of the idler modes compensates to allow continuous pumping of a single signal mode.

Second, since the Stanford oscillator operates relatively far from degeneracy and also uses a relatively long crystal (1.65 cm), the measured bandwidth of the parametric oscillator is about ten times less than that of previous oscillators. Total oscillation bandwidths of about three wave numbers are observed.

A maximum average output power of 1.5 mW is observed when the pumping power is 2.8 times the threshold value. The output mirror of the oscillator has a transmission of 0.04%; it is expected that larger powers will be obtained with optimum output coupling. The parametric output consists of pulses that are typically 0.1–1.0 millisec long. The oscillator wavelength may be continuously tuned by changing the temperature of the crystal, and the oscillator maintains nearly constant power output during the tuning process.

Fast Chemical Kinetics Studied with Laser Light

Scattering of laser light off molecules in solution can yield previously unknown information on the kinetics of ionic chemical reactions. Yin Yeh and Norris Keeler (Lawrence Radiation Laboratory) have studied solutions of simple salts in chemical equilibrium. Ionic reactions occur spontaneously in such solutions, dissociation of molecules and association of ions causing continuous local variations from equilibrium; the relaxation time for return to equilibrium gives the rate of the ionic reaction. These reactions are too fast and involve too few molecules for standard chemical-kinetic methods to work.

Yeh and Keeler shone a 63.28-micron-wavelength helium–neon laser beam into salt solutions and looked for Doppler broadening of the scattered light; the degree of observed broadening was a measure of the reaction rate. So far in their work they have looked at zinc-sulfate and sodium-sulfate solutions, obtaining reaction times of about 10^{-9} sec for fluctuations of a few thousand molecules.

The method does not itself disturb the reaction under investigation, so Yeh and Keeler hope to collaborate with colleagues in the Livermore biomedical department to study rapid reactions in biochemical systems, such as those involving enzymes.

Columbia Builds Meson Factory From Nevis Synchrocyclotron

Columbia University is converting the 18-year-old 384-MeV synchrocyclotron at its Nevis Laboratories to raise the energy to between 500 and 600 MeV and increase the internal beam current from about 1 microampere to 10–50 microamperes. A new long-duty-factor external beam of 5–40 microamperes is expected to be used for most experiments and will produce