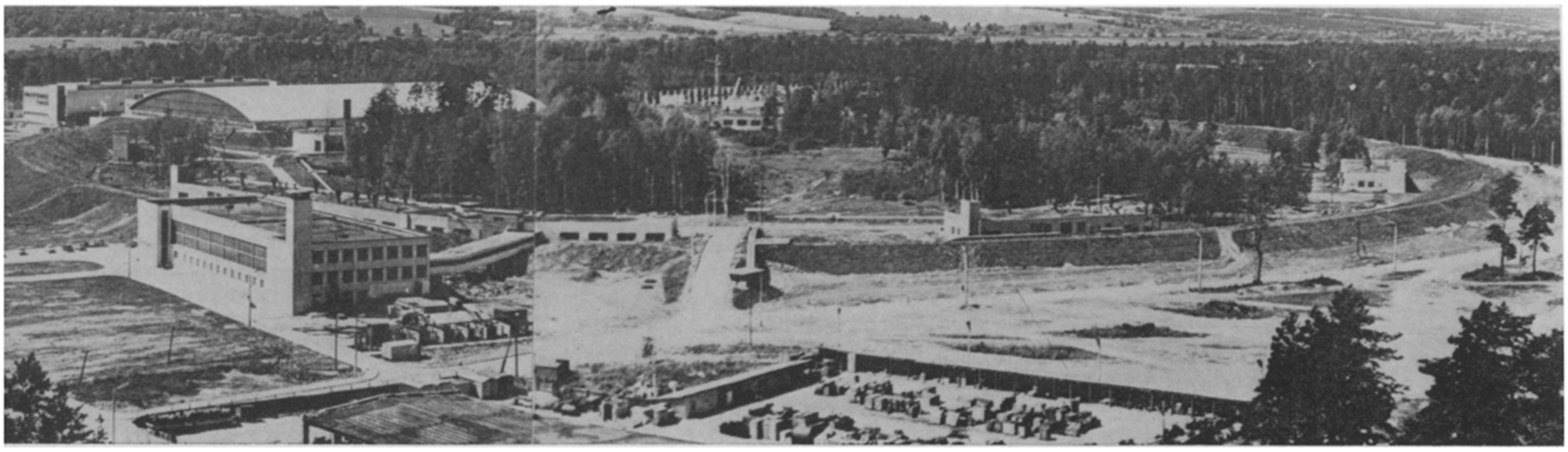

HIGH-ENERGY PHYSICS

Surprises at Serpukhov

Results that contradict present theory are intriguing Russian and United States physicists

by Dietrick E. Thomsen

Physicists construct ever more energetic particle accelerators in order to probe ever finer details of natural structures. As the energy of the probing particles has gone up, the center of attention has progressed from atoms to nuclei to the structure of such particles as protons and neutrons themselves.

With each major increase in energy have come surprises, new classes of objects, new kinds of physical properties, that have forced radical changes in theory. But now, at the level of probing the structure of the so-called elementary particles themselves, some physicists have thought there ought to be a limit. Other physicists are not so sure.

The latest step in the parade of energy increases is the 76-billion-electron-volt (GeV) synchrotron at Serpukhov in the Soviet Union. It is more than twice as energetic as anything that operated before it, and when it began experiments about two years ago, the question in physicists' minds was whether experimentation in this range would bring surprises or whether it would merely confirm and extend information already gathered at lower energies.

The first Serpukhov experiments have already shown enough surprises to have theorists shaking their heads. Further results are now eagerly awaited.

Among the first experiments were so-called total cross-section experiments intended to find out in a general way where things are at this energy range. The cross section reveals the probability that anything at all will happen when an accelerated particle is shot at a target. It depends on a wave that is associated with each particle, the so-called de Broglie wave named for Prince Louis de Broglie, who first suggested its existence in the early 1920's.

The de Broglie wave is a way of measuring the probability of a particle's being somewhere in a given volume at a given time; its wavelength determines the area over which a particle's influence is felt, and the probability of some interaction with a target depends on this.

At low energies the de Broglie wavelength is larger than the physical size of the particle, but as the energy goes up the wavelength decreases. Eventually a point should come where the wavelength becomes less than the physical size of the particle. At this point the total cross section becomes dependent on the size of the particle and should remain constant if the energy is further increased. But the Serpukhov results are showing that the total cross sections do not approach constant values as fast as current theory indicates they should.

A related surprise is that the total cross sections for a particle and that for its antiparticle do not come together at high energies as theory says they should. At low energies the total cross sections for particle and antiparticle differ, since there are natural rules that prohibit antimatter from doing some of the things matter can do. At high energy these rules should lose their effect, and theory says the two cross sections should come to the same value, but experimentally they are not exhibiting the expected behavior.

These things seem to be saying that there is something in the nature of the particles that exhibits itself at Serpukhov energies that was not taken into account in present theory, but theorists have so far not come up with an explanation.

Other experiments have looked for more surprises. Serpukhov has looked for quarks, the theoretically predicted building blocks out of which the particles are supposed to be made, but has not found them.

For several months the accelerator has been shut down for a rearrangement of the experimental hall and beams. When it reopens one of the first experiments will be less direct check of the quark theory than a search for quarks themselves: an investigation of negative mesons. This experiment will be done in collaboration with the CERN laboratory in Geneva as was some of the cross-section work.

The quark theory says that all particles are built of either two or three subparticles called quarks, and on this basis makes predictions about their masses and other properties. Previous experiments at CERN have found a series of negatively charged mesons that fit the predictions of the quark theory especially well. The forthcoming

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experiment at Serpukhov will try to produce heavier negative mesons than the CERN proton synchrotron can make to see if they fit the theory equally well or if some discrepancy shows up.

The experiment will also look for a possible doubly charged negative meson. All the known particles that have electric charge have the same amount as an electron has. There seems to be no natural reason against the existence of a particle with twice as much charge, but the quark theory forbids mesons, though not other classes, from having it.

Mesons, says the theory, are made of two quarks. The theory also says that quarks have either one-third or two-thirds the charge of an electron, and there is no way to add two of these and get two. If a doubly charged meson should turn up, it would be a disaster for the quark theory as it is now formulated.

In addition to the collaboration agreement with CERN, Serpukhov has one with French physicists. In both of these cases the Russians demanded the delivery of hardware items as a price for admission to the facility, and both partners agreed. The French have built a bubble chamber for Serpukhov, and CERN has sent spark chambers, computers and other gear.

The United States Government is trying to negotiate an agreement that would allow teams of experimenters to be exchanged between American laboratories and Serpukhov, but it balks at the Russian demand for hardware since this is contrary to existing custom among Western countries. In the West foreign scientists are welcome at national accelerators if they can convince the laboratory management that their experiment needs that accelerator. They may be asked to make financial arrangements for the cost of the experiment, but an admission price is never charged.

Instead, the United States is offering the Russians access to the 200/400-GeV National Accelerator Laboratory at Batavia, Ill., after it is completed in about 1972. The Russians are insisting on their hardware, and the negotiations are stalled for the moment.

Another protocol, which has been agreed to, permits individuals to go as guests of Soviet institutions. Under this, an American, Dr. Zaven Guiragossián of the Stanford Linear Accelerator Center, wishes to go to Serpukhov to test a proposal for "making a proton machine more universal," as he puts it, by making it produce beams of electrons.

Serpukhov's proton beam produces a copious flow of pi mesons when it strikes a target. These pi mesons striking another target will produce the beam of electrons. Once electrons have been prepared, they can be used with yet another target to produce high-energy photons.

Thus one machine could be used to produce four basic probe particles of high-energy physics—protons, mesons, photons and electrons—and there would be less need to build both proton and electron accelerators at very high energies where they are very expensive.

If the scheme works at Serpukhov, Dr. Guiragossián will suggest trying it at the National Accelerator Laboratory, when that institution's 200/400-GeV machine is completed. Serpukhov's 76-GeV protons could produce electrons up to 45 GeV with a good flux; NAL's 200-GeV protons could yield 100-GeV electrons.

If he can get support money from the Atomic Energy Commission, Dr. Guiragossián will go to the Soviet Union as the guest of the Yerevan Physics Institute in Armenia. Equipment for the experiment has been under development at Yerevan, especially a new kind of particle detector that directly measures the energy rather than the velocity of particles, which was invented by Dr. Artemii Isaakovich Alikhanian. A Yerevan team including Dr. Guiragossián will go to Serpukhov to do the experiment.

If the setup works they will study the interactions of a photon beam with atomic nuclei from hydrogen to uranium. Specifically, they want to see whether, in colliding with nuclear matter, a photon turns into either a positron-electron pair or into a kind of particle called a vector meson (SN: 8/30, p. 164). Whatever it does is of great importance to theories of subatomic forces.

In addition there are two subexperiments, which, says Dr. Guiragossián, "could be of greater scientific value than the primary one, but are not the sort of thing you propose as a primary experiment because of their speculative nature." One is an attempt to see if the velocity of light ever varies. If it does, physical theories of space and time will have to be recast completely. The second subexperiment is to see if there is a fundamental length in nature below which present theories of physics, and especially of electrodynamics, no longer apply. This has been searched for at lower energies and does not appear down to a 10-million-billionth of a centimeter. Serpukhov can look at smaller stretches.

The experiment has been approved by the Serpukhov Scientific Council and could be on the machine by summer if Dr. Guiragossián's support from the AEC is forthcoming. □