NAL: The protons go round and round, and come out behind the high-rise.

Norman Ramsey and E. M. McMillan.

Physicists on the road to Asymptopia

The high-rise building that will house the offices of the National Accelerator Laboratory still lacks a few stories. The auditorium next to it was barely roofed in time. When the 900 or so high-energy physicists attending the 16th International Conference on High Energy Physics moved to the laboratory from the University of Chicago, they found themselves in an ambience highly suggestive of unfinished business and new beginnings that matched the nature of the scientific reports that they had been hearing. (The original plan had been to hold the entire meeting at NAL, but the unfinished condition of the buildings made it impractical, so the University of Chicago offered its facilities for parallel sessions the first four days.)

It was in a way the inauguration of the laboratory, the first real opportunity to show it in working order to a large number of specialists in high-energy physics, and the laboratory put on a real gala. As in ancient times, there was even an animal sacrifice: One of the laboratory's buffalo was slaughtered and roasted (along with other animals gotten from the butcher) to provide a feast for the guests.

Beside the buffalo, the meeting had two big stars: The NAL itself and the Intersecting Storage Rings at the CERN laboratory in Geneva. It was the first time these two installations had really been heard from at an international gathering, and the question in many minds was: Will they, or won't they? The answer is that they do. The two machines had been designed in the belief that the energy range they inhabit would open an entirely new domain in particle physics, and the reports amply support that supposition.

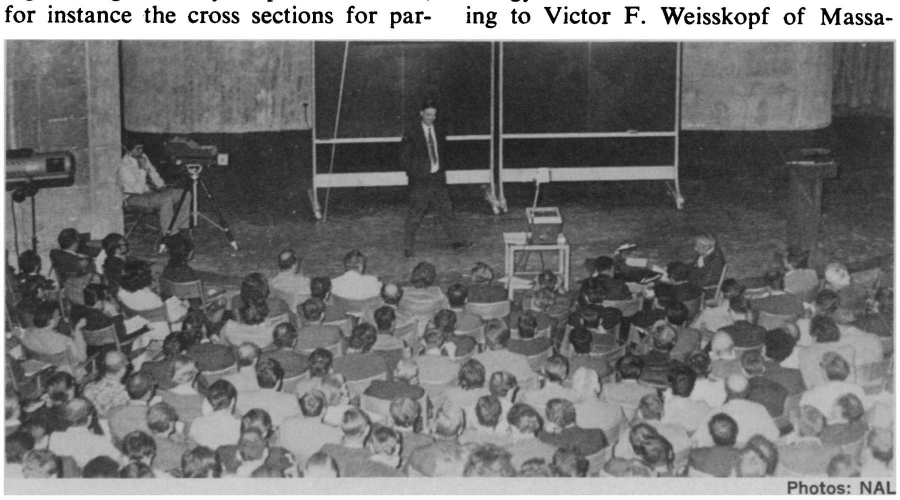
The NAL can now drive beams of protons accelerated to 300 billion electron-volts (300 GeV) against stationary targets. The ISR takes proton beams of 30 GeV from the CERN proton synchrotron and clashes them together head on. This makes available for the formation of new particles and other effects almost the entire 60 GeV. It would take a stationary-target accelerator of 2,000 GeV (or 2 tera-electron-volts) to do the same. The two machines are not rivals, but complements. The NAL can do many experiments that the ISR cannot—or at least it will be able to when its intensity becomes high enough to make practical beams of secondary particles, mesons and neutrinos. The ISR can do only one experiment, proton against proton, but it does it at extremely high energy.

The atmosphere in the sessions where experimental data on high-energy collisions were reported was hectic. In one morning session of three and a half hours, at least 20 persons tried to communicate their results, speaking as fast as possible and begging and fighting the chairman for extra minutes. Many of the data were preliminary and are subject to refinement in future reports; experimenters had rushed themselves to get at least something to say to this meeting.

The data give, not so much a picture, as an outline. It is an outline of a region sometimes called Asymptopia. At these high energies many important results, for instance the cross sections for particular interactions or for the production of new particles, no longer seem to depend on the energy brought into the collision, as they do at lower energies. Instead they seem to be asymptotically approaching constant values. Another striking thing is the production of many secondary particles in these ultrahigh-energy proton-proton collisions. Physicists were not used to this before. Suddenly "multiplicity," the number of particles produced per collision, becomes an important physical datum.

There is as yet no clear theoretical picture of what is going on. There are several models of what happens in the collisions, but some of the data seem to support one and some another. Most of the people at the meeting seemed to agree that more and better-refined data are necessary before a clear choice can be made among the models.

The fading out of energy dependence is likewise ambiguous for the moment. As Robert G. Sachs of the University of Chicago puts it: "It can mean that things are very simple in this high-energy domain, or it can mean that things are so complicated and depend on so many factors that changing the energy makes little difference." According to Victor F. Weisskopf of Massa-



The SRO signs were out as NAL Director R. R. Wilson welcomed conference.

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Russian physicists came to the feast.

chusetts Institute of Technology, the new high-energy domain is so strange that physicists are still trying to devise a language to use in speaking of the phenomena found there. In his view the points where data disagree with the models are most interesting because this kind of antithesis can lead to the synthesis of better theory.

As experimental devices, the two large machines have already shown scientific justification for their construction, and the results have heartened those working on similar projects. CERN is building a 300-GeV accelerator, which is expected to come into operation in 1976. The project is crowded into a suburb of Geneva and will be built 60 meters underground to allow other uses of the surface. "It's like digging a mine," says G. Giacomelli of the University of Bologna. In contrast he says of the NAL site, "you have so much room here." Land acquisition at CERN is a slow procedure. It is much more difficult to expropriate landowners in France and Switzerland than it is in the United States. So far the laboratory owns only the locations of the six shafts that are being dug down from the surface, but public authorities promise to obtain the rest. There is also a border-crossing problem. The ring will straddle the French-Swiss border. Placing customs posts in a particle accelerator tunnel would be a diplomatic first (and a high-order absurdity). Yet, if totally free access is permitted, Giacomelli warns that "in any large group there will be a few guys who will take advantage."

In the United States the meeting results gave increased enthusiasm to proponents of project Isabelle, which would provide storage rings for the Alternating Gradient Synchrotron at Brookhaven National Laboratory. And there is already talk of building a bypass at the National Accelerator Laboratory so that the main beam could collide with its own 8-GeV booster. □

The drama of Cygnus X-3: Fits the model perfectly

The drama of Cygnus X-3 continues. "Rarely in astronomy is the answer so nice and clear-cut," says Robert Hjellming of the U.S. National Radio Astronomy Observatory at Greenbank, W. Va. He was speaking of the cataclysmic radio outburst in Cygnus X-3 discovered by Philip C. Gregory of Canada and co-workers. The outburst must have begun roughly at 7 a.m. Sept. 2. It continued at unusually high levels for three days (SN: 9/9/72, p. 164). Hjellming and Bruce Balick, also of NRAO, as well as astronomers around the world continued to observe the source as it began dying. It hit the peak level of 22 flux units at one frequency the first day. By Sept. 11 it had returned to the normal level of 0.1 flux units. The total radio energy has been calculated to be 10^{40} ergs, assuming a distance of 10 kiloparsecs.

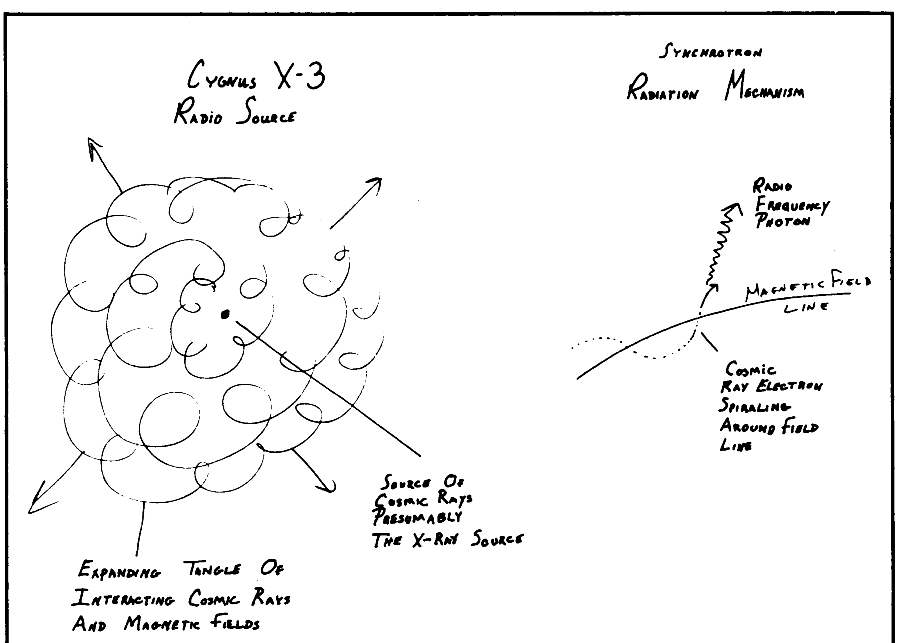
"Anyone looking at the data would come to the same conclusion: It fits perfectly the model for synchrotron or magnetic bremsstrahlung radiation," says Hjellming. Synchrotron radiation is the result of the interaction between electrically charged particles and a magnetic field. It is especially strong at radio wavelengths. Radio emissions from quasars, supernovas and radio galaxies are believed caused by this mechanism.

Kenneth I. Kellermann, also of NRAO, has been studying extragalactic sources of synchrotron radiation (such as quasars and radio galaxies) for several years now. "The Cygnus X-3 phenomenon is very similar to what we see in the quasars," says Kellermann. "But it usually takes months to several years for it to happen. Cygnus X-3 happened in just a few days. Just change the time scale from days to months or years and it fits nicely."

The Cygnus X-3 event makes Kellermann a little happier about his work—and, he admits, a little envious. The theoretical prediction of synchrotron radiation in quasars and radio galaxies has been difficult to confirm precisely. What he sees from quasars and radio galaxies looks similar to what is seen from the Cygnus X-3 event, "but it has never been so nice." Instead of one clear burst and then death, Kellermann sees from his sources a burst, and then another burst before the first one dies. Also, the sources are much farther away, and the energies emitted are much greater. "They have been able to do with Cygnus X-3 in a couple of days what we've been trying to do for years." The fact that Hjellming can interpret the observation so neatly as synchrotron radiation gives support to the theory that synchrotron radiation is the source for radio emissions from quasars and radio galaxies.

There are some puzzles about the Cygnus X-3 event, however. The theoretical model for synchrotron radiation predicts that X-ray synchrotron emissions should also have been present. Cygnus X-3 has been known as an X-ray source, although it has not been determined whether they were synchrotron X-rays. But X-ray observations by the Uhuru satellite show no anomalous behavior during the period of the radio outburst.

Another problem is the source of the cosmic rays. In the emissions of the Crab nebula, it is thought that the



Robert Hjellming

Hjellming's informal schematic of what was probably happening in Cyg X-3.