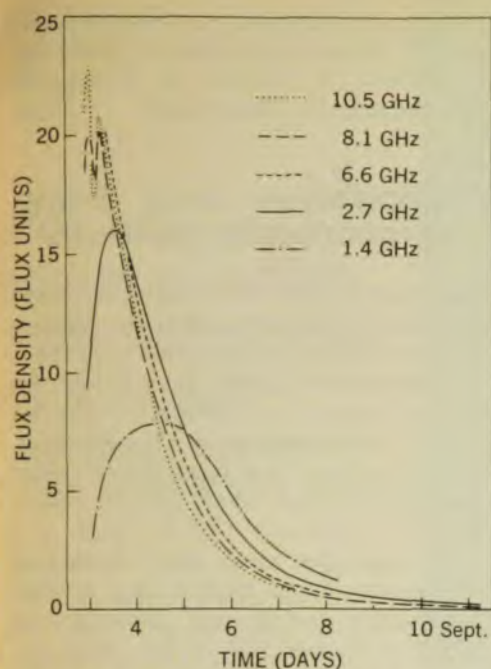




Flux density of Cygnus X-3 as a function of time for five different frequencies.

put Cygnus X-3 behind a large amount of interstellar dust, which could explain why it has not been detected optically, Gregory remarks.

Theory. What caused the peculiar behavior of Cygnus X-3? The Canadian and NRAO groups say that it is caused by an expanding cloud of relativistic electrons. In their picture the radio emission comes from synchrotron radiation produced by the interaction of the relativistic electrons with the magnetic field. Hjellming told us that the radio emission agrees well with this picture—the power law, the polarization, and the way the frequency evolves as a function of time agree well with simple theories of what happens when you have initial injection of cosmic-ray electrons with a relatively flat energy spectrum. The first outburst, in particular, fits the theory nicely.

Hugh D. Aller (University of Michigan) and William A. Dent (University of Massachusetts) think the Cygnus X-3 outburst looks like solar centimeter-wavelength bursts. They suggest that the radio emission is produced by synchrotron radiation, but they say that the exponential decay of the flux density comes from bremsstrahlung caused by Coulomb collisions between the relativistic particles and an ambient thermal plasma.

Speaking at the Sixth Texas Symposium on Relativistic Astrophysics in December, Remo Ruffini (Princeton) said that Cygnus X-3 is a black hole. He and Robert W. Leach (Princeton) argue that all x-ray sources can be separated into pulsating sources, which are neutron stars, and nonpulsating sources, most of which are black holes. (By pulsations one means sharp, well-defined and regular pulses much

like the optical and radio signals from pulsars.) Ruffini and Clifford Rhoades (now at Kirtland Air Force Base) had shown that a neutron star can never have a mass larger than 3.2 solar masses if you don't want to violate causality or general relativity. Black holes are more massive than neutron stars and are always axially symmetric, unlike neutron stars. Thus it appears extremely unlikely that one can obtain long-lasting periodic phenomena from black holes; rather they might emit short bursts distributed randomly.

Because x-ray binaries are so common, Ruffini told us, we can now determine limits on the masses of many neutron stars and black holes with a precision of two or three decimal places—from the orbital period and the velocity (from the Doppler shift) of the x-ray source. The mass can be determined making various assumptions on the inclination of the binary system. This ability to measure masses of collapsed objects is the most important new factor in distinguishing between black holes and neutron stars, he feels.

For Cygnus X-1 Ruffini and Leach obtain a mass of eight solar masses. Because of its mass and the fact that it doesn't pulsate, they conclude that it is a black hole. Cygnus X-3, Ruffini explains, must be in the same family because it is nonpulsating and there is evidence for a binary period of 4.8 hours. He argues that it is a binary which, because of its period has to be extremely massive—or else the masses would be very close together and the system would have a very short lifetime, making it highly improbable that one would observe it. He therefore concludes that Cygnus X-3 is a black hole.

The Princeton work does not disagree with a synchrotron model, which refers to the shell, whereas the Princeton model talks about the collapsed object itself, Ruffini explained. Work related to the Princeton effort has been done by R. A. Sunyaev (Institute for Applied Mathematics in Moscow), who has done a detailed analysis of the structure of the disk accreting material around an x-ray source.

—GBL

Multihadron production greater than expected

The cross section for the annihilation of an electron and a positron into hadrons is much higher than many had expected, according to new experiments performed with the electron-positron colliding beam devices at the Cambridge Electron Accelerator and at Adone in Frascati, Italy. Although the error bars are large, the multihadron production cross section is, for example, much higher than a simple quark model would predict.

At the recent "Rochester" conference (held at the University of Chicago and the National Accelerator Laboratory) Corrado Mencuccini reported on Frascati measurements with a total center-of-mass energy between 1.2 and 3.0 GeV. These were done by the " $\gamma\gamma$ " group and the " $\mu\pi$ " group. They find that the multihadron production cross section is two to three times as large as the cross section for muon pair production. Two years ago, shortly after Adone first went into operation, preliminary measurements at center-of-mass energies of 1.5 to 2.2 GeV had indicated a multihadron production cross section of one to two times the muon pair production. In the future, Adone experimenters want to modify their apparatus to better analyze the abundant multihadron production they have found. Multihadron results from two other groups were reported to the conference by Vittorio Silvestrini; these were from the "boson" group and the Bologna-CERN-Frascati group.

The Frascati experimenters also find evidence for a peak in the multihadron cross section at a total energy of 1.6 GeV that suggests a resonance behavior that can be interpreted as a ρ' meson which decays into 4π ; this particle would have spin one and negative parity, similar to the ρ meson, which has a lower mass. Earlier evidence for a ρ' has been reported from photoproduction experiments at DESY and by Robert Mozley and his collaborators at SLAC.

Also at the Rochester conference CEA experimenters reported on multihadron production at a center-of-mass energy of 4 GeV. Their preliminary analysis of the data shows the ratio of the multihadron production cross section to the two-muon production cross section is within the following limits: 2.4 and 6.0.

It is difficult to make a general statement about the behavior of the multihadron production as a function of energy from the CEA and Frascati data. Theoretical predictions are all made for the asymptotic region—a place that always appears to be just beyond the horizon of the high-energy experiments. Many people are surprised at how high the cross section is compared to the "pointlike" muon-pair cross section. In asymptopia, if you have either pointlike particles or partons inside the proton (if you want to use parton language), or if you have canonical dimensions (if you want to use light-cone language), then the multihadron cross section should go as a constant over s , the square of the collision energy. From CEA and Frascati data one could draw a curve that goes as $1/s$ or a curve that is a constant independent of the collision energy.

What one can say is that the multi-

hadron cross section is much larger than the two-muon cross section. The Gell-Mann-Zweig quark model predicts for the ratio of multihadron production to muon-pair production a value of 2/3. The newer quark model, involving current quarks with para-Fermi statistics, which Richard Feynman has called "red, white and blue quarks," predicts a value for the ratio three times as big, namely two. In the Han-Nambu scheme, which involves three triplets of quarks with integer charges, the ratio is four. All these predictions apply, however, only in the asymptotic region, when you would see a $1/s$ fall-off, and in

process will produce hadrons predominantly along the electron and positron beam direction but Brodsky told us that neither Adone nor CEA data tells definitely whether any of the events seen were due to this two-photon process. Another process that may obscure any attempt at present energies to find an asymptotic fall-off is resonance production. There may be a ρ'' and a ρ''' hidden in the Adone and CEA data. Elucidation requires the higher luminosity expected from newer storage rings coming into action. High-energy workers will be eagerly awaiting the results that will eventually come out of

Pordes, J. Sisterson, K. Strauch, G.-A. Voss, H. Winick, A. Litke, R. Madaras, R. Wilson, G. Hanson, J. Leong, H. Newman and G. Tarnopolsky. —GBL

Westinghouse tests 5-MW superconducting generator

Researchers at Westinghouse have developed a superconducting electric generator, which is expected to produce five megawatts at 60 Hz. Except for its small size it is believed suitable for use as a utility generator. The Westinghouse generator has been tested under open-circuit and short-circuit conditions.

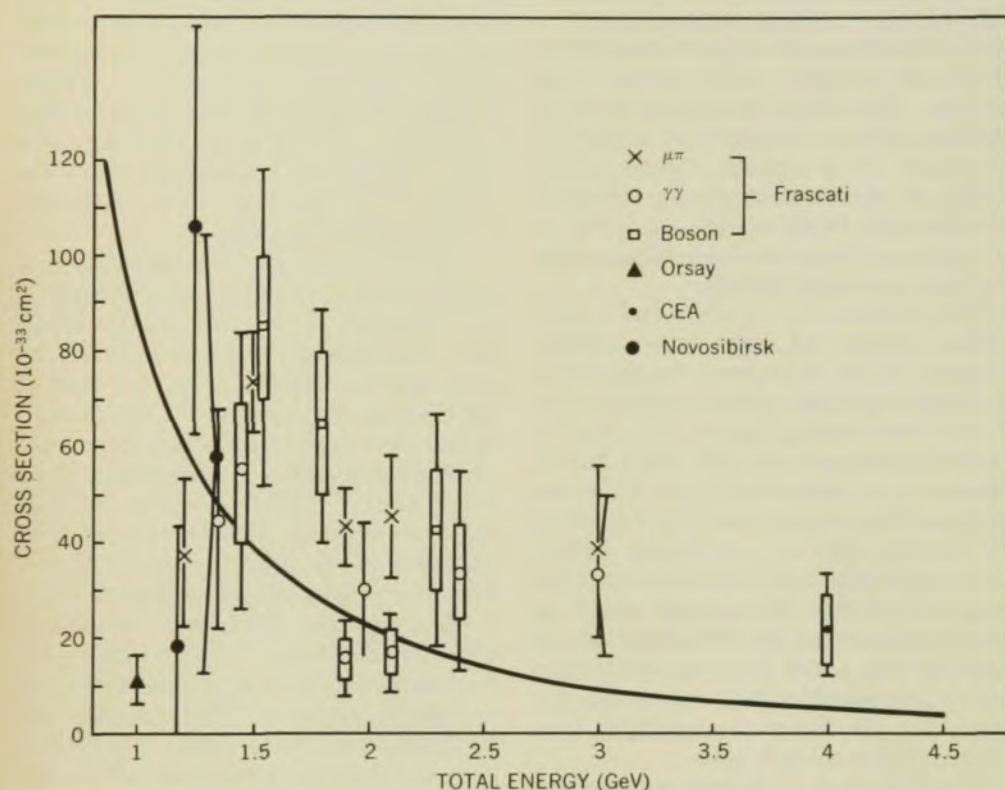
The generator has a superconducting rotor made of a niobium-titanium alloy and copper and is kept between four and five degrees Kelvin by liquid helium. The rotor is contained in what is essentially a rotating Dewar vessel that turns at 3600 rpm. The stator is similar to those in conventional generators except that the high magnetic field in the generator—40 to 50 kilogauss—requires that it be built of more finely divided copper.

The work on the generator was initiated in late 1969 by George Wiener, research director at Power Systems, and John Hulm, research director at Westinghouse Research Laboratories. John Mole, the chief engineer, has had about 40 people working on the project.

Hulm told us about some of the problems that were encountered in designing the generator. The only way to get liquid helium into the rotor is through the rotating generator shaft, and so special rotating seals had to be developed. Furthermore, the generator shaft turned out to be a major source of heat loss to the rotor, yet it had to be strong enough to withstand the torque applied to the generator by the prime mover. The researchers designed a tube with thin walls to minimize heat loss, yet maintain adequate strength.

The first power application of the superconducting generator is expected to be as a peaking power generator. This type of generator usually has an output between 50 and 100 MW and is used by utilities to supply power during periods of high demand. Eventually, says Hulm, they expect to have superconducting generators that will produce up to 1000 MW and higher. These could be used as main generators in a power station.

Superconducting generators have higher efficiencies than conventional generators; in the higher power models it is expected that energy losses will be reduced by a factor of two. In the long run superconducting generators will also be cheaper to build, Hulm says. —SMH



Cross section for electron-positron annihilation into hadrons as measured at various colliding-beam devices. Colored curve is cross section for muon-pair production as computed from quantum electrodynamics. Hadron production is higher than expected.

the absence of asymptotic behavior, all bets are off. So it is too soon to make any general statements about one or another model being vindicated or thrown out the window.

Two years ago Stanley Brodsky (SLAC), Toichiro Kinoshita and Hidezumi Terazawa (Cornell), V. M. Budnev and I. F. Ginzburg (Novosibirsk), and Paul Kessler and his colleagues at College de France argued that there would be a competing process to multihadron production through e^+e^- annihilation. They proposed that for beam energies higher than 1 GeV the cross section for producing two photons in the intermediate state in reactions of the type $e^+ + e^- \rightarrow e^+ + e^- + 2\gamma \rightarrow e^+ + e^- + \text{hadrons}$ becomes increasingly more important than for one photon, increasing as a power of $\log E$. This "two-photon"

SPEAR in Stanford (3.0 GeV in each beam) and DESY in Germany (3.5 GeV in each beam).

The members of the $\gamma\gamma$ group are C. Bacci, R. Baldini-Celio, G. Capon, Muccicini, G. P. Murtas, G. Penso, G. Salvini, M. Spinetti, B. Stella and A. Zallo.

Those in the $\mu\pi$ group are G. Barbarino, B. Borgia, F. Ceradini, M. Conversi, S. D'Angelo, K. Ekstrand, M. Grilli, E. Iarocci, M. Nigro, L. Paoluzzi, R. Santonico, P. Spillantini, L. Trasatti, V. Valente, R. Visentin and G. T. Zorn.

The boson group members are B. Bartoli, F. Felicetti, G. Martini, A. Nigro, H. Ogren, Silvestrini and F. Vanoli.

The CEA experimenters are R. Averill, A. Hofmann, J. Koch, L. Law, R. Little, H. Mieras, J. M. Paterson, R.