was certain that evidence of the sixth quark would be found in the energy range now open, but many hoped that it might be, and the negative result is a disappointment for those hopes.

The negatives come from four experiments set up at the same installation, the PETRA colliding beam facility of the Deutsches Elektronen-Synchrotron Laboratory in Hamburg. The colliding beam operation takes highly energetic electrons and positrons (antielectrons) and bangs them together head-on. In the collision there is an annihilation reaction between matter (electron) and antimatter (positron), and the energy brought by the two is then available for the formation of a large variety of particles. Among such things may be a previously unknown variety of particle.

At the moment, PETRA is the world's most energetic facility for this kind of collision. Its energy can be tuned between 5 billion and 17 billion electron-volts for the electron and for the positron. The experiments consist of filling the space around the place where electron and positron meet with complicated arrays of particle detectors that try to get a complete picture of what comes out of the collision. PETRA's four experiments are called MARK J, PLUTO, TASSO and JADE. They were represented at the Fermilab meeting by, in respective order, Harvey Newman of DESY, Christoph Berger of the Technical University of Aachen, G. Wolf of DESY and Shuji Orito of the University of Tokyo. These physicists reported a variety of interesting information about a number of topics — any of these experiments sees all sorts of things at once — and some of that will be dealt with in later stories. But on the subject of the sixth quark, familiarly known as the top quark, each man got up and delivered a negative in similar words.

The first piece of evidence considered in such a case is the quantity called r, which is the ratio of the cross section or probability of producing quark-made particles (hadrons) to that of producing quarkless particles (leptons, here specifically muons) in the electron-positron collision. In the past, new quarks have been found as the energy of the interactions went up. This is presumably because the new quarks are more massive than the ones previously known and therefore require more energy for their production or the production of particles made with them. When the energy domain where a new quark appeared has been reached in the past, the value of r has taken a stepwise upward move. All four DESY experiments are consistent with each other in not finding such a step.

Another possible evidence is the discovery of a new kind of particle, one made with the new quark. In the past the psi particle was the first evidence for the charm quark, the upsilon particle for the bottom quark. A particle of this kind (it should be a top-antitop combination) would make a sharp upward spike in the graph of r when the energy range required to produce its mass was reached. *A fortiori,* no such spike appeared. Nor in analyses of what did happen in numerous electron-positron collisions was there any evidence of a sixth quark.

There was some question whether the four DESY experiments were entirely independent of one another, but as one finding of four, the result is an unhappy one. Many had hoped that evidence of the top quark would appear in this energy range. The theory does not specify what the masses of the quarks should be. Anyone who wanted to speculate had to put in extra assumptions, and many chose the most hopeful assumptions for the top quark. However, its nonappearance is not causing any panic. Its mass (or rather the masses of its particular particles) may lie beyond the energy range now available.

The next step is to repeat these observations and to parallel them with new ones in a different place when the PEP colliding beam facility at Stanford University (which will have the same energy range as PETRA) goes into operation early next year. If the top quark continues to refuse to appear, it will be necessary to search at higher energies if ever they become available. If the top quark has a much higher mass than hopeful theorists thought, it could prove an expensive thing to find. □

Resources for the Future reports

The second group of scholars to put forth its predictions this summer on U.S. energy supplies for the next 20 years presented its findings last week. In a 555-page tome, the group, sponsored by the nonprofit Washington organization Resources for the Future, echoed many of the conclusions arrived at more than a month earlier by the Harvard Business School in its report, *Energy Future.* Both agreed that two major conflicting factions, environmentalists and economic expansionists, must resolve their differences before the energy problem can be solved; that market forces must be brought to bear on energy pricing, including price decontrols for oil, but that tax breaks, subsidies, federal market guarantees and other forms of economic inducement are essential to get synthetic fuel, solar energy and energy conservation programs off the ground. This would be especially effective in substantially reducing the energy used in transportation, industry and residential heating, which consumed almost half of the total energy used in the United States during 1977.

But while the Harvard report promoted energy conservation and solar energy as the top priority energy sources for the future, the RFF report, entitled *Energy in America's Future,* refused to pinpoint any one energy solution. The RFF report did conclude, however, that energy consumption could be sustained without endangering the economy. Even if the price of oil were to double, energy use could increase at a rate of 1.8 percent and sustain a gross national product rise of 3.2 percent, said Joel Darmstadter, senior RFF fellow. It would amount to 115 quads (quadrillion Btus) of energy available in the year 2000 (57.5 million barrels of oil a day) — 20 percent less than had been predicted in 1973. In 1978 the United States consumed 78 quads.

The report estimated that the price of synthetic fuel would range from $15 to $35 a barrel, depending on whether the United States embarks on an immediate crash program to develop synthetic fuels or does extensive preliminary testing to learn how to minimize the risks and reduce costs, said project member Harry Perry. Prices for synthetic gas and fuel should be twice the current prices, at about $5.20 per million Btu for high Btu gas, and perhaps more than $35 a barrel for synthetic liquids, the report said, although Perry added that estimates could be as much as 40 percent off, due to uncertainty about existing records and about future policy. Coal and nuclear power will probably remain cost-competitive for the next few years, the report said. It should hover at a price of 2 cents per kilowatt-hour and eventually becoming cheaper as the technology is improved. Other decentralized energy sources, such as solar, "do not appear to be the wave of the future," the report said. □

Water reveals arteries

A viewing technique that allows surgeons to follow the flow of blood through the coronary arteries during open heart surgery has been developed by doctors and engineers at the University of Edinburgh and the Edinburgh Royal Infirmary in Scotland. It uses an infrared camera and a small injection of cooled saline to record body heat. The camera picks up the cool solution among the warm organs exposed during surgery, and doctors are able to follow the network of fine dark lines as the saline wends its way through the coronary arteries. The technique has proved particularly useful in checking that grafted arteries intended to bypass blocked coronary arteries are actually working properly and that blood is indeed reaching previously starved areas. The only other way of viewing the arteries is a cumbersome X-ray technique that cannot be used as a regular operating room routine. The Scottish surgeons are so pleased with the technique that they plan to expand its use to a routine assessment of the extent of coronary blockage as an aid to designing appropriate surgery. □