

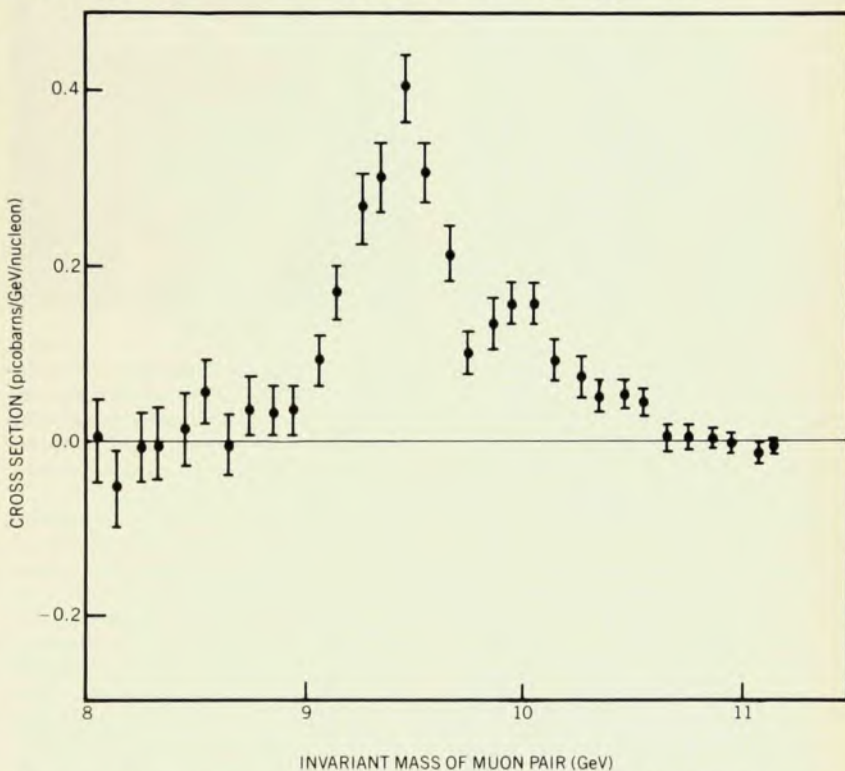
search & discovery

Upsilon particles at 9.4 and 10 GeV suggest new quark

Possible evidence for a new kind of quark has been reported by a group working at Fermilab. The team of experimenters from Columbia University, Fermilab and the State University of New York at Stony Brook observed a dimuon resonance, which they called Υ , at 9.4 GeV, by far the most massive resonance ever found. They reported their results at the European Physical Society Particle-Physics Conference held in Budapest in July. Since then the group reported evidence for Υ' at 10.0 GeV and preliminary indications for a third resonance at about 10.4 GeV. Both Υ and Υ' have widths less than or equal to 200 MeV. These latest results were announced at the International Symposium on Lepton-Photon Interactions held in Hamburg late in August.

One promising interpretation of the Υ is that it is a bound state of a new quark and its antiquark. This new quark, proposed by a number of theorists over the past couple of years, would join the ranks of the up, down, strange and charmed quarks.

The experiment was done by Steven W. Herb, David C. Hom, Leon M. Lederman, Johann C. Sens, H. David Snyder and John K. Yoh (Columbia), Jeffrey A. Appel, Bruce C. Brown, Charles N. Brown, Walter R. Innes, Koji Ueno and Taiji Yamanoichi (Fermilab), Al S. Ito, *continued on page 19*



Muon-pair production cross section as a function of the invariant mass of the muon pair. The smooth exponential continuum fit to the data has been subtracted to reveal the 9–10-GeV region in more detail. Note the peak at 9.4 corresponding to Υ , 10.0 to Υ' and a preliminary indication of a bump at 10.4 GeV. The data were presented at the Hamburg meeting.

NAS panel is concerned over atmospheric CO₂ buildup

A major buildup in atmospheric carbon dioxide could increase average global temperatures by as much as 6°C over the next century or two; this is the chief problem associated with continued worldwide dependence on fossil fuels, according to a panel on energy and climate convened by the National Academy of Sciences. The effects of such a climatic change, throwing the Earth's habitable surface back to conditions that prevailed in the Mesozoic Era, probably would include a shift of the agricultural and fishing zones toward the poles and destabilization of those semi-arid regions now considered marginal for human occupancy. The panel has recommended extensive further study of the energy-climate relationship,

a tremendous interdisciplinary research effort and new institutions to deal with the problem. Physicists may be able to contribute to meeting the CO₂ threat through development of improved theoretical models and more precise determination of numerous measurements needed for accurate climatic predictions.

The 15-member Energy and Climate Panel, headed by Roger R. Revelle (University of California, San Diego, and Harvard University), was established after the NAS's Geophysics Research Board finished planning in 1974 for a series of studies on topics of geophysical interest. A Geophysics Study Committee, led by co-chairmen Philip H. Abelson

(Carnegie Institution, Washington) and Thomas F. Malone (Holcomb Research Institute), supported Revelle's panel in its work.

Approaching the CO₂ problem. The panel began by considering three by-products of energy production and consumption—heat, particulate matter and gases—as potential sources for a significant degree of inadvertent modification of the Earth's over-all climate. The first two they soon dismissed as not irrevocably harmful on a global scale: Direct-heat release may be an important factor in local-climate determination, but for the foreseeable future manmade heat output will remain a tiny fraction of the heat produced by incoming solar radiation; the venting of particulate

Upsilon particles

continued from page 17

Hans Jostlein, Dan M. Kaplan and Robert D. Kephart (Stony Brook) and reported in the 1 August issue of *Phys. Rev. Letters*. In his Budapest talk, the leader of the experimental group, Lederman, took the unusual step of singling out four of his collaborators for special mention: Herb, Yoh, Innes and Kaplan.

Experiment. Lederman told us that he and his collaborators have been looking at the production of lepton pairs since 1968, when, at Brookhaven, they found a so-called "shoulder" at 3 GeV but were unable to identify it as the resonance later known as the J/ψ . A continuation of the search for e^+e^- pairs at the CERN ISR in 1972 was frustrated by an unexpectedly large amount of hadron production at high transverse momentum. In 1974 Samuel C. C. Ting (MIT) and his collaborators found the J particle at 3.1 GeV in an electron-pair production experiment at Brookhaven. Meanwhile at SLAC, Burton Richter and his collaborators had found the ψ particle at 3.1 GeV in the inverse experiment, electron-pair annihilation. All of these experiments, Lederman noted, can be interpreted in terms of quark constituents of the proton.

In 1975 Lederman and his collaborators set up a double-arm spectrometer experiment at Fermilab, bombarding a target of platinum or beryllium with 400-MeV protons, and looking for production of lepton pairs plus anything else. In their first runs, they looked at electron pairs, and after four or five months obtained 30 events with mass greater than 5 GeV showing above background. At that time, the experimenters thought they had found a resonance at 6 GeV because they had 13 events clustered in a small mass range. At that time they suggested the name υ "if the particle were confirmed."

To improve the event rate beyond one in three or four days, the experimenters turned to detecting muon pairs instead. They installed a filter to screen out the pions and succeeded in obtaining 150 events with a mass greater than 5 GeV. However, the resolution had worsened from 1% for e^+e^- to 4% for $\mu^+\mu^-$. At that time, they did not see anything at 6 GeV. The experience with muons proved more valuable than the results, and the group began designing an improved muon experiment.

While building new equipment, the experimenters repeated the electron-pair production experiment and obtained an additional 30 events. Lederman says the combined enhancement at 6 GeV was still significant (1 chance in 50 of a fluctuation) but no more so than the original data. The group did notice a small clustering way out at 9.5 GeV, which when taken together with a similar bump in the muon data created some internal excite-

ment. Yoh put a bottle of champagne in the refrigerator labeled 9.5. It has since been consumed.

In February this year they started installing the present experiment at Fermilab, began taking data in May and sent in a paper to *Phys. Rev. Letters* in June. At that time they had 9000 events above 5 GeV with a resolution of 2%. At this writing, the team has 27 000 events. As soon as data taking began, the experimenters immediately noticed an enhancement in the 9.5-GeV region. Unfortunately, the following week a fire broke out in the experimental area; the electronics had to be removed because chlorine fumes from cable insulation combined with humidity to deposit HCl everywhere. A European salvage expert was called in. Under his direction the group washed 900 affected wire-chamber amplifier cards in secret solutions. And then, the Columbia-Fermilab-Stony Brook experiment could proceed.

In their paper, mailed in June and discussed at the Budapest meeting, the group said they saw a single resonance at 9.5 GeV whose structure was wider than the apparatus resolution. Now, Lederman told us, they clearly see two peaks (at 9.4 GeV and at 10.0 GeV) and the suggestion of a third at about 10.4 GeV. The location of each of the two resonances is known to about four parts in 1000. The resolution has an rms width of 200 MeV, but Lederman feels that the resonances must be narrower than that. The 9.4-GeV peak, called Υ , has a production cross section of (0.19 ± 0.01) picobarns. The 10.0-GeV peak, called Υ' , has a production cross section of (0.07 ± 0.008) picobarns.

The equipment does not take advantage of the total Fermilab intensity; it can only take 3×10^{11} protons/pulse (100 times less) because it is limited by the background rates of the wire detectors. The usable proton intensity is limited by the requirement that the counting rate at any detector plane (singles rate) not exceed 10^7 counts/sec. The group obtained a higher singles rate than expected; the rate did not appear to depend on the separation between target and counter. Because of that, in the new arrangement the group moved their detectors as close to the target as possible, improving the solid angle by a factor of six.

In the early experiments, Lederman and his collaborators used a filter made of uranium and steel to absorb pions and transmit muons. A low- Z material is preferable, he says; so the latest set-up used a 20-foot-long (2 metric tons) beryllium filter. Unfortunately, this makes the pions take a long time to be absorbed, thus contributing to the singles rate. Nevertheless the sensitivity achieved is more than 100 times any previous experiment and has better resolution than most, Lederman said.

Theory. Presumably the υ is a

Oak Ridge Heavy-Ion Facility



The first section of the pressure vessel for a Pelletron-type 25-MV accelerator is shown being lifted into place on 3 August at the Holifield Heavy-Ion Research Facility in Oak Ridge. The tower reached its present height of 140 feet in mid-July. All eleven sections of the pressure vessel are now in place; welding and testing are to be finished by early January. Meanwhile construction of the Pelletron itself is nearly complete at the National Electrostatics Corp in Middleton, Wisconsin.

The heavy-ion facility will combine the existing Oak Ridge Isochronous Cyclotron with the Pelletron; the combination will allow acceleration of heavy ions with masses as high as 150 with energies sufficient to overcome the Coulomb barrier. The \$18-million facility is scheduled for completion in Fall, 1979. James B. Ball is director.

vector meson, that is with spin one and odd parity, because so far all particles decaying into muon pairs have been. Other vector mesons are the rho, omega, phi and J/ψ , for example. The J/ψ is believed to be a bound state of a charmed quark and its antiquark. Until the introduction of the charmed quark, the conventional quark picture was of three spin- $1/2$ particles, the up, down and strange quarks. On symmetry arguments that one should have the same number of quarks as leptons (electron, muon, electron neutrino and muon neutrino), Sheldon Glashow (Harvard University) and J. D. Bjorken (SLAC) and others in 1964 introduced a fourth quark, the charmed quark. Evidence has mounted since the discovery of the J/ψ for a whole spectrum of psi particles called charmonium, all bound states of a charmed quark and its antiquark. And evidence has been found for naked charm, that is, a single charmed

quark bound to an ordinary antiquark (charged meson) or to two ordinary quarks (charged baryon).

Meanwhile, two experimental observations suggested the existence of a fifth and sixth quark. At SLAC Martin Perl and his collaborators found evidence for a heavy lepton, the tau, with a mass of about 2 GeV. Subsequent experiments at DESY in Hamburg, by the Pluto and DASP groups, have tended to confirm the indications of a heavy lepton. The tau would presumably have a neutrino associated with it, making six leptons. By symmetry arguments, a fifth and sixth quark would be in order.

The second observation was of the so-called "high- γ anomaly," found in neutrino scattering by a Harvard-Penn-Wisconsin-Fermilab group and a Caltech-Fermilab group. To explain the anomalous energy distribution, in 1974 Michael Barnett (SLAC) suggested the existence of new right-handed quarks, to be contrasted with the left-handed quarks (up, down, strange and charmed). But recent experiments at CERN by an Aachen-Bonn-CERN-London-Oxford-Saclay group and by a CERN-Dortmund-Heidelberg-Saclay group and at Fermilab by a Caltech-Fermilab group have reported seeing no rapid energy variation of the cross section. So perhaps one no longer needs additional right-handed quarks to explain a high- γ anomaly. The absence of a high- γ anomaly does not rule out new left-handed quarks.

Nevertheless, several groups of theorists have talked about adding pairs of quarks to the standard model. Feza Gursey (Yale University), Pierre Sikivie (University of Maryland) and Pierre Ramond (Caltech) and Barnett proposed a total of six quarks, the new ones both having charge $-\frac{1}{3}$. Groups from places such as Harvard, Princeton, University of Hawaii and Caltech have suggested adding to the standard model pairs of quarks, one with charge $+\frac{2}{3}$, and one with charge $-\frac{1}{3}$. More than one pair is also a possibility. The new quarks have been called top (charge $+\frac{2}{3}$, like the up and charmed quark) and bottom (charge $-\frac{1}{3}$, like the down and strange quark) or truth and beauty. In January Estia Eichten (now at Harvard) and Kurt Gottfried (Cornell) predicted that for a quark of mass greater than 4 GeV, three bound states (analogous to J/ψ and ψ') should be seen in electron-positron collisions. In a fixed-target experiment this would be seen as very narrow peaks in a $\mu^+\mu^-$ spectrum.

Lederman notes that the consensus of theoretical argument he has received is that the upson is a bound state of a bottom quark and its antiquark but says that "confirmation of this hypothesis will depend on a clearer delineation of the mass distribution. This is in progress at Fermilab. Conclusive proof will require the observation of 'naked bottom,' that is, particles containing only one bottom

quark." However, he notes that other interpretations are tenable.

Another possibility would be a bound state of a top quark and its antiquark. However, some very recent theoretical work suggests that the production estimates fit a bottom quark better.

Some theorists have calculated (on the basis of Zweig's rule) that the upson should have an extremely narrow width, just as the J/ψ does.

Still other explanations of the upson are possible, of course. For example the Υ' could be a bound state of yet another quark. It will be interesting to watch the results coming from other lepton-production experiments now under way at Fermilab (four of them), CERN (six of them), and Serpukhov and an electron-positron annihilation experiment at DESY. And the new electron-positron storage rings at Cornell, SLAC and DESY should probably see a spectrum of excited states much richer than charmonium. —GBL

Hawaiian observatory starts lunar ranging

The Lunar Ranging Observatory of the University of Hawaii recently began ranging measurements from its site atop the mountain of Haleakala on the island of Maui. The data will support the existing program at McDonald Observatory at the University of Texas and will be useful for a wide variety of geophysical observations.

The neodymium-YAG laser produces infrared pulses that are frequency doubled before transmission; the pulse length is about 0.2 nanosec. The beam is aimed at the Moon by a movable mirror placed in front of a fixed telescope with a 16-inch aperture. This system enlarges the laser beam and collimates it to provide a divergence of about 2 arcseconds under optimum conditions (about 2 miles on the Moon). The beam is reflected from the Moon by five arrays of retroreflecting prisms placed there by the Apollo astronauts and by the unmanned Soviet landers. Each array has many high-quality prisms slightly deformed from a perfect corner cube to compensate for the small movement of the Earth that occurs while the pulse makes its round-trip.

The returning light pulse is received with a telescope consisting of 80 small refracting telescopes whose lenses are mounted in a single faceplate; the whole assembly is set on an altitude-azimuth mount. Timing is done to about 200 picosec, corresponding to a range uncertainty of 2-3 inches in the raw data. By measuring the distance several hundred times in quick succession, the Earth-Moon distance can be determined with even greater accuracy.

A program is underway to determine if the Observatory is really fixed on the surface of the Earth, or if it is moving up,

down, or sideways, and by how much. Several tide gauges are to measure differential changes in sea level; tiltmeters will measure changes in the direction of gravity; strain meters are to detect uplift or subsidence; geodetic surveys will establish the amount and direction of shifts relative to the rest of the island. From the aforementioned measurements, the observers hope to learn more about the motions of the Moon about the Earth, the Earth's rotation, the wobble in this rotation, and, in conjunction with the McDonald Observatory, the displacement of the Hawaiian Islands relative to the continental United States due to continental drift. Eventually, the Observatory hopes that other ranging stations in Australia, Japan, France and Germany will be able to join the program.

Out-of-ecliptic mission planned by US and Europe

NASA and the European Space Agency are planning a joint 1983 mission outside the plane that contains the Sun and planets. Although the out-of-ecliptic mission has not yet been approved by Congress, NASA and ESA are inviting scientists to propose experiments now.

Two unmanned spacecraft, one supplied by NASA and one by ESA, would be launched simultaneously on looping trajectories that would bring them out to 748 million km from the Sun. The spacecraft would pass over both of the Sun's poles during its five-year mission. Instruments aboard the two spacecraft would investigate, as a function of solar latitude, the properties of the solar corona, the solar wind, the structure of the Sun-wind interface, the solar magnetic field, solar and nonsolar cosmic rays, and the interstellar and interplanetary neutral gas and dust.

Interested US scientists should write to Adrienne F. Timothy, OOE Study Scientist, Code ST, NASA Headquarters, Washington, DC 20546. ESA will solicit European candidates separately; its member nations are Belgium, Denmark, France, Germany, Ireland, Italy, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom. All others should write to the Office of International Affairs, NASA Headquarters.

in brief

Princeton University has signed a five-year contract for about \$100 million with Ebasco Services, Inc to provide engineering, design and management for the Tokamak Fusion Test Reactor, now under construction at the Plasma Physics Laboratory. Ebasco's major subcontractor is the Grumman Aerospace Corp. □