The Village Crier
fermi national accelerator laboratory
Operated by Universities Research Association Inc.
Under Contract with the Energy Research & Development Administration
Vol. 8 No. 6
February 12, 1976

THE SEARCH FOR HIGH MASSES

(A Columbia University-Fermilab-Stony Brook team [Experiment #288] presented evidence for a new particle at the New York meeting of the American Physical Society February 2. The experimental group has prepared the following report about their work for The Village Crier. Leon Lederman is spokesman for E-288.)

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The data obtained at Fermilab by E-288 places the mass of the new particle at 6 GeV, the most massive one yet found - weighing more than 6 times the proton. The research was carried out at the U.S. Energy Research and Development Administration's Fermi National Accelerator Laboratory Facility based upon the 400 GeV Proton Accelerator at Batavia, Illinois. The research was carried out in the Proton Center and was installed by P-lab starting in 1971.

...Double arm spectrometer used by E-288 on the P-Center experimental line at Fermilab...

MOTIVATION

E-288 was designed to probe for structures inside normal matter (protons and neutrons), structures characterized by "smallness" (exploration of "inner space"). It has often been noted that in this function, a large accelerator can be compared to a microscope of great magnification. It is however true that the actual "magnification" depends on the experimental instruments that are brought to the accelerator by the research teams. In this case, the experimenters were pursuing a line of effort that can be traced to an earlier Columbia experiment carried out at Brookhaven Lab in 1968 and which first detected the emission of what could be called "heavy light" from strong nuclear collisions. In that research, as in the present Fermilab experiment, photons (units of electromagnetic radiation) are generated in the nuclear collision - these photons live so short a time that they are permitted, by the laws of Quantum Theory, to carry a mass (normal photons from light bulbs and suns carry zero mass). The more massive the photon, the more indicative is the process of the nature of the source of the emission. The generally understood correlation is that massive photons can only come from small structures in the proton.

The Fermilab experiment was designed to extend the study of massive photons from the highest masses seen at Brookhaven, ~5 billion volts, (abbr: GeV) to the limit available at Fermilab (~25 GeV!). Already many theorists had interpreted the massive photon yield previously observed in terms of "quarks" or basic (and small) constituents of the proton and neutron.

EXPERIMENTAL DETAILS

The search for massive photons involved four experimental components: i) the bombardment of a small target made of beryllium by 400 GeV protons, ii) The detection of a positive and negative electron emerging symmetrically from the collision, iii) the precise measurement of the energies of the electrons, and iv) the careful study of all processes that could simulate the effect being sought.

A simple calculation based on the measured properties of the detected electrons gives the mass of the parent object which gave rise to the positive and negative electron. The

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presumption that the parent is a virtual photon comes from the familiar fact that normal photons readily convert to electron pairs.

E-288 experiment was especially designed to look at very high masses - extending close to the maximum mass that the law of conservation of energy permits with the 400 GeV protons of Fermilab. The general expectation was that the emission of low masses is "easy" and there should be lots of them - however, the distribution of high masses is much less probable - one theory estimating that only one 10 GeV virtual photon would be emitted for every 10,000 2 GeV photons, and this in turn happens only once in every million nuclear collisions. Thus, the Columbia-Fermilab experiment had to be extremely sensitive to these rare processes hidden in the vastly more frequent but mundane nuclear debris.

RESULTS

The experiment was proposed to the Fermilab in 1970 but did not set up the present phase of the experiment until the summer of 1975. Good data taking began in the fall and it soon became clear that the yield of electron pairs corresponding to high mass - the physicists call "high" anything above 5 GeV - was considerably lower than theoretical expectations. Interesting events came in at a rate of about 1 per day of perfect operation of the accelerator. The Researchers noticed a suspicious accumulation of events near 6 billion volts and, at first, attributed this to a statistical accident - fully expecting the data to smooth out into a more natural distribution of masses. Much to their surprise and excitement, the clustering near 6 billion volts continued to build until, by January 26, a total of 12 events had been recorded - all between 5.9 and 6.1 GeV. This, statistically, was considered very strong evidence for a unique mass, i.e., a particle of this mass which is born in the 400 GeV collision and disintegrates rapidly into a positive and negative electron.

The remaining 14 events are distributed from 5 to 10 GeV and the team is most eager to increase the data in order to see if more "pearls" are hidden in this totally unexplored domain. Obviously, more data is urgently needed!

Physicists are excited by this discovery because the new particle (dubbed Upsilon: Υ) seems to have a property which sets it apart from the hundred or so, so-called elementary particles. This is the narrowness of the mass interval into which the events crowded. Such a narrow band of mass implies, by quantum principles, relatively long lifetime. Now a particle as massive as the Υ has an enormous number of states into which it could disintegrate - states containing pions, kaons, protons, antiprotons, etc. - all of which have relatively negligible mass. The fact that it refuses to do so indicates a new law of nature is acting to forbid this transition and new laws of nature are the name of the game.

The fact that the new object appears under precise conditions in which virtual photons also appear is a very significant fact - the complete implications of which are not yet clear. It would appear as if the tiny virtual photon sources inside the proton resonate strongly at precisely 6 GeV.

WHAT DOES IT ALL MEAN?

Physicists use accelerators like the Fermilab giant in order to find the "key" to the structure of matter. The best known example of such a concern was the onslaught on the nature of the atom - a program which began to make progress around 1900 (with the discovery of the electron) and could be said to have culminated about 1930 with the theoretical formula derived by P.A.M. Dirac and which included all the necessary ingredients to a complete accounting for atoms. From that time on, the subject of atomic physics - concerned with the properties and connections between atoms - became the concern of chemists and none of the great advances of our civilization which is based upon the vast expansion of our chemical technology - from petrochemicals to medical biochemistry, from semiconductors to protein chemistry - none of this could have taken place without the scientific research which included the discovery of the electron in 1897, the nucleus with its protons and neutrons, in 1911, and the detailed measurements which were the frontier concerns of physicists in the 1920's and 1930's.

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SEARCH FOR HIGH MASSES (Continued)

Physicists after 1930 turned their attention to the nucleus of the atom and, increasingly since 1950, to a concern with the bewildering array of transient new particles that kept being discovered in the period 1950 to the present. These findings were made possible by the construction of increasingly more powerful accelerators, capable of launching deep probes down into the core of the nucleus. Today, there is a feeling of unusual excitement - many clues suggest that a new synthesis is "in the air" - that a simple and beautiful key may soon make possible the explanation and accounting for what would otherwise be a zoo of strange and seemingly unrelated elementary particles. It is expected that this key will provide the analogue to the atomic case - in which 3 objects: protons, neutrons and electrons - are combined to produce the infinite variety of things which make up the macroscopic world.

Last November, the physics world was made ecstatic by the discovery of the so-called J or Ψ particle, announced simultaneously at Brookhaven and Stanford. The subsequent discovery of closely associated objects, all in the mass range 2 to 4 GeV gave a great impetus to the idea that a simple 4-quark system could form the basis for all particles and also account for the variety of forces under which they move and interact.

The Upsilon particle, if confirmed, and the new explorations at even higher mass may indicate an unexpected complication or that the 4-quark structure is too simple or perhaps that totally new phenomena "undreamed in our philosophies" are being observed. An important corollary is that the experiment has established the fact that proton collisions can generate very high masses, so far, events as high as 10 times the proton mass have been observed. This leads to the very strong presumption that very small (almost "point-like") substructures exist in protons and perform in observable ways. The implication is that proton accelerators like Fermilab and its European sibling, the SPS, will continue to play a crucial role since only these accelerators have the combination of energy and intensity to explore this new domain.

THE FUTURE

The team expects to soon switch over to detection of muon pairs in the hopes of speeding up the data collection. This involves both opportunities and risks. Estimates based on some experience indicate about 5-10 times the data rate. This is good. However, experience also indicates that muons bring with them a subtle background which could require a time consuming effort to understand. The decision on when to take the "muon gamble" will be made in the near future. Ultimately, after a reconfiguration of the Proton Center Laboratory, in which the proton beam dump will be moved to the rear of the PC pit (instead of its current location 7 ft. downstream of the target), the group hopes to pursue the study of the high mass region with more than 100 times the intensity. On the way to this goal, it is hoped to do a study of massive hadron pairs (pions, kaons and protons) in collaboration with SUNY, Stony Brook.

Members of the E-288 collaboration are:

Columbia University*	Fermilab	Stony Brook*
David Hom	Jeffrey A. Appel	Dan M. Kaplan
Leon M. Lederman	Bruce C. Brown	
Hans P. Paar	Charles N. Brown	
H. David Snyder	Walter I. Innes	
Jeffrey M. Weiss	Taiji Yamanouchi	
John K. Yoh		

*Work supported by the National Science Foundation.

These scientists have emphasized that these new results are only possible through the efforts of a large number of people throughout the Laboratory. They particularly mention P. Bury, K. Gray, P. Lucey, F. Pearsal, B. Tews, and S. J. Upton who helped with apparatus. The Proton Department and the Alignment group have also given valuable assistance and the steady operation of the machine by the Accelerator Division was instrumental in this success.

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INTERNATIONAL FILM SOCIETY PRESENTS

"Weekend"

France 1967

Friday, February 13 - 8 p.m. - Auditorium

Jean-Luc Godard's view of man as both creator and victim of chaos is shown most explicity in this film which explores the effects of civilization on man's primitive drives, accentuating violence and greed. A middle class couple go off on a drive through the country, but find that their attempts to get away from it all bring them full circle into a nightmare of destruction. The horrors they encounter are symbolic of all that is wrong in our society.

Godard points the moral with a razor edge, reinforcing it with his incisive, unsettling wit. He has since taken himself too seriously as an enfant terrible among directors. "Weekend" stands as his most meaningful, perhaps his best, effort before his lapse into mannerism.

Admission: $1.50 adults, 75¢ children.

MORE ABOUT DOGS...

Individuals (employees and visitors) may walk dogs in open areas of the Fermilab site provided the dogs are the private property of the individual, not part of a commercial enterprise, are not functioning as hunters or pointers, and no dog packs are included. Times for this activity are limited to open hours in any open area.

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GET YOUR TICKETS EARLY - Music Club Dance - Saturday, February 21 - Village Barn - $4.00 per person. See Jesse Guerra, Larry Jackson, Ed Stitts, Larry Tate.

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ICE SKATING PARTY - postponed from Sunday, February 8 - re-scheduled for Sunday, February 15 - 2-5 p.m.

THIRD LECTURE

BICENTENNIAL LECTURE SERIES

presents

Dr. William E. Powers

"The Physical and Biological Basis of Cancer Therapy"

Friday, February 20 - 8:30 p.m.
No charge - tickets necessary

Call Guest Office - Ext. 3440 - CL-1W

CLASSIFIED ADS

FLEA MARKET - Old fashioned, Feb. 15, 9-5, Ramada Inn, Aurora. Crafts, coins, jewelry, candles, stained glass, C.B. radios, wholesalers, and more.

FOR SALE - '73 Merc. Montego Brghm., 2-dr., hrd.-top, full pwr., AC, AM-FM stereo, 56,000 mi., good cond. Contact Ron Cudzewicz, Ext. 4068.

WANTED - Babysitter to watch 3 yr. old and infant, occasional evenings, preferable in Aurora. Call Shirley, Ext. 3370 or 851-5128.

FOR RENT - House, 5 bedroom brick farm home near Sugar Grove w/15 acres pasture and barn. $450/month. Call Bob Pearson, 630-6000.

FOR SALE - Kenmore Foot Whirlpool, offer. Like new Kenmore bathtub type whirlpool, perfect cond., offer. Harold Minster, Ext. 3233.

FOR SALE - Kimball "500" swinger early American spinet organ, perf. cond. & priced to sell. 1975 Datsun B-210, 2-dr. hatchback, AM/FM radio, electric clock, new radial tires. 1974 Datsun "610" 4 dr. sedan AC, AM/FM stereo w/8 track tape built-in, radial tires, electric clock. George Clever, Ext. 3360.