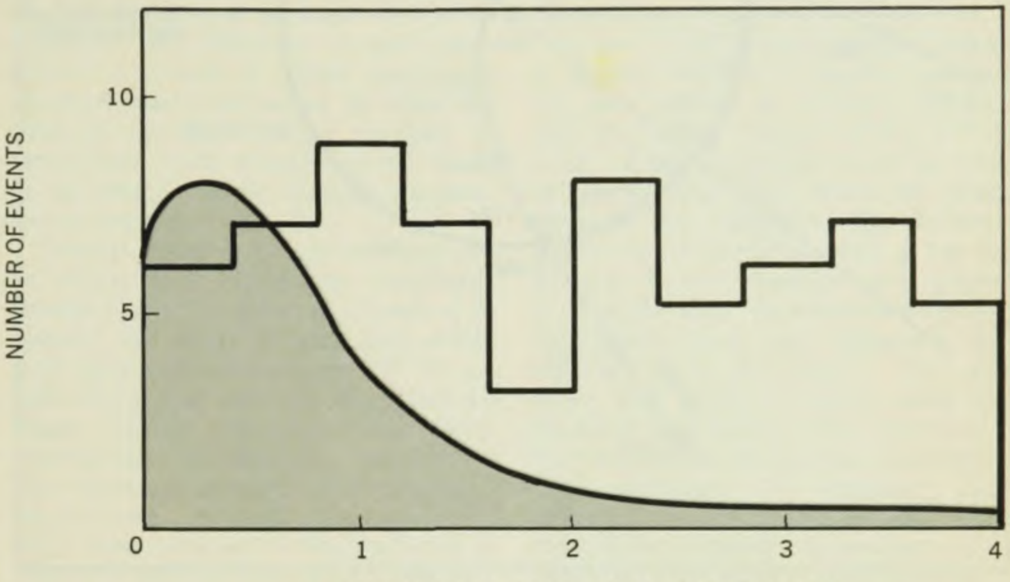
search & discovery

CERN and NAL groups claim evidence for neutral currents

Two experiments, one at CERN and the other at the National Accelerator Laboratory, are showing evidence for the existence of neutral currents. They are finding events in which a neutrino interacts with a nucleon and, instead of producing a muon or an electron, yields hadrons without a charged lepton. Because of the recent interest in theories that attempt to unify the weak and electromagnetic interactions, such as those proposed by Steven Weinberg (PHYSICS TODAY, April 1972, page 17) and by Abdus Salam, the new observations are exciting great interest. These theories generally require the existence of neutral currents.

Both experiments were discussed at the Berkeley meeting of the American Physical Society in August, at the International Symposium on Electron and Photon Interactions at High Energies held in Bonn in August and at the 2nd International Conference on Elementary Particles, held in Aix-en-Provence in September. Although both groups suggest that they may be seeing neutral currents, they also offer alternative explanations. And many experimenters are skeptical that either group has demonstrated the existence of neutral currents.



Neutral current events observed at CERN using an antineutrino beam. The histogram shows the observed distribution of such events. The colored curve is obtained from a Monte Carlo calculation assuming that the events were caused by neutrons.

Experiment. The CERN experiment, done by a collaboration from Aachen, Brussels, CERN, École Polytechnique, Milan, Orsay and University of London, uses a neutrino beam and an antineutrino beam from the Proton Synchrotron. The beam is incident on the huge Gargamelle bubble chamber ($10\ m^3$), which is filled with Freon. The group looks for events whose visible energy caused by any neutral particle is bigger than 1 GeV. Then they look for those events in which all the particles resemble hadrons.

By switching the sign of a focusing device, the experimenters can change their incoming beam from neutrinos to antineutrinos (which are produced by π^- decays instead of π^+ decays). Neutrino energies range from 0.5–5 GeV.

For the ratio of non-muon-producing decays to muon-producing decays, the CERN team finds for the neutrino beam the value is $(21 \pm 3)\%$ and for the antineutrino beam, $(45 \pm 9)\%$.

The NAL experiment, done by a collaboration from Harvard, University of Pennsylvania, University of Wisconsin and NAL, consists of a large bath of liquid scintillator interspersed with optical spark chambers; these are followed by a large iron magnet, which is also interspersed with counters and optical spark chambers. The neutrinos interact with the liquid. The secondary particles produced that interact in the detectors are hadrons. The secondary particles that go through a lot of iron, on the other hand, are muons. The experimenters make sure there is no charged particle entering the liquid scintillator. Their trigger is to look at events with an energy release in the scintillator of about 10 GeV, we were told by A. K. Mann of the NAL team.

In the NAL experiment, the beam is a mixture of roughly two-thirds neu-

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Observers prepare for Comet Kohoutek

The brilliance of the newly discovered Comet Kohoutek and its relatively early observation, nearly a year before the predicted 28 December perihelion, have stimulated astronomers to an abundance of experimental efforts. Results of the studies, which will take place from ground-based telescopes, from airplanes, from orbiting satellites and balloons and probably from Skylab, could provide some answers to long-standing questions about the origins of comets, the forces that operate within them and the origin of the solar system itself.

Lubos Kohoutek discovered the comet, also known as Comet 1973f, on plates taken 7 March at the Hamburg Observatory. He found the 16-mag. object in Hydra while using the 80-cm. Schmidt telescope to search for a minor planet he had discovered in 1971. By 21 March the comet had reached a magnitude of 15 (less positive numbers indicate brighter objects) and at perihelion the magnitude is predicted to be between −3 and −10, perhaps bright enough to be seen in daylight. The comet will then be only 0.14 astronomical units from the sun (1 a.u. = 150×10^6 km). This is four times closer than Comet Bennett, which was studied with great success when it appeared in 1970—it was during these studies that the presence of an enormous hydrogen cloud surrounding a comet was first discovered.

Comet Kohoutek will be closest to Earth (0.80 a.u.) on 15 January. Brian Marsden, director of the Central Bureau for Astronomical Telegrams, Smithsonian Astrophysical Observatonew 36-inch infrared telescope of NASA-Ames, which is mounted in a C-141 airplane.

Mariner 10, scheduled for launching on 3 November, will transmit video pictures of the comet in January and February. These images, combined with photos taken at different angles from ground-based equipment, could show the true comet shape and the trajectories of transient structures moving through the tail.

Helium. Some observers will be looking for atomic species never before discovered in comets—such as helium. A spectrograph on Skylab (S082A) is believed sensitive enough in the extreme ultraviolet range to find ionized helium; Richard Tousey of the Naval Research Laboratory is the principal investigator for this experiment. Deuterium will also be sought. Maran explains that Ernst Öpik of the Armagh Observatory, UK, believes helium could be stored as an ice, whereas a more widely held view (introduced by Delsemne and Pol Swings in 1952) is that clathrates (chemical compounds trapped in water snow) in comets may also trap the helium, which leaks out slowly. If the helium cloud exists, it would be larger than the visible head of the comet (less than 5×10^4–1×10^6 km) and smaller than the hydrogen cloud (greater than 10^6 km) in extent, estimates Maran.

Still another group of observations will be made from five sounding rockets to be launched in January from White Sands, New Mexico. Among those sending up experimental packages will be William Fastie (Johns Hopkins), George Lawrence (University of Colorado) and Theodore Stecher (Goddard). —*Marian S. Rothenberg*

Argonne ZGS yields polarized proton beam

A collaboration of physicists and engineers at the Argonne National Laboratory has produced polarized proton beams of 6 GeV, the first polarized beam to be achieved in a synchrotron, says Alan Krisch (University of Michigan). The beam, with a polarization of (62 ± 15)% was achieved by using a polarized proton source in conjunction with the Zero Gradient Synchrotron (ZGS).

Krisch and his university colleagues have cooperated with Argonne accelerator staff to install on the ZGS a $225 000 polarized-proton source (acquired from the Auckland Nuclear Accessory Company Ltd, Auckland, New Zealand). The source was installed in June and successfully operated with the ZGS-linac injector to produce a 50-MeV beam having 70% polarization. The beam current was 3–4 microamps. Acceleration to 6 GeV in the ZGS was achieved during July; a beam of 12 GeV is anticipated later this year.

A potential problem in accelerating the polarized beam is the existence of energies where strong depolarizing resonances occur. The strongest resonances between 50 MeV and 6 GeV are believed to be at 3.7 and 4.6 GeV; four more depolarizing resonances are expected between 6 and 12 GeV. To overcome this difficulty, at least up to 6 GeV, a system of pulsed quadrupole magnets was constructed to allow the tune of the ZGS to be changed 12 times each cycle permitting the beam to be passed rapidly through the resonance energies.

Several research groups are expected to utilize this high-energy polarized-proton beam. In general, according to Krisch, the study of pure spin states and spin–spin correlations will be expedited because both the beam and the target can be polarized. Heretofore, information on spin–spin correlations was obtained through triple-scattering experiments. Krisch's group measured total cross sections for the scattering of polarized protons from a polarized proton target at 3.5 GeV. This was accomplished by using 10% of a circulating beam of 3×10^8 protons per pulse. The Argonne and Michigan group in collaboration with St. Louis University physicists will continue work this fall to get a comprehensive set of elastic-scattering differential cross-section measurements.

Another group at Argonne will use an Effective Mass Spectrometer to study baryon resonance production with the polarized beam. A University of Pennsylvania experiment will deal with the asymmetries in inclusive processes, and a University of Chicago group is interested in the polarized-proton beam as a possible good source of polarized hyperons. Such a source could lead to significant new weak-interaction experiments on hyperon decay. —RAS

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trinos and one-third antineutrinos, with the peak of the spectrum at about 25 GeV. They find that the ratio of non-muon-producing interactions to muon-producing interactions is (29 ± 9)%, a value consistent with the CERN results.

The NAL experimenters say that the simplest explanation of their result is that neutral currents exist. However, they note that other causes of the effects are possible: there may be contamination of the muon-type neutrinos with electron-type neutrinos; a new particle may be produced, substantially affecting the correction for undetected muons; there may be some novel process resulting from a new type of lepton.

Sources of error. Commenting on the CERN experiment, C. N. Yang (Stony Brook) said that he was convinced that the group has found neutral currents. Leon Lederman (Columbia), on the other hand, felt that neither experiment is yet completely convincing; he is worried about the dangers of the so-called "bandwagon effect."

In the CERN experiment the events, if they are not due to neutral currents, can only be due to neutrons, we were told by Robert Palmer of the CERN team. If these neutrons enter the front of the chamber they would be attenuated as they pass down the chamber. Many events would be seen at the beginning of the chamber and almost none at the end. In contrast with this, the events seen are uniformly distributed down the length. The only other way neutrons could enter the chamber and produce the events is if they were made by neutrinos in the steel that surrounds the chamber. The neutrons so made could then leak in the sides of the chamber and produce events distributed uniformly along the length, as observed. The CERN group estimates the number of events from this source by counting how often they observe a neutrino event making a neutron in the chamber and observe the subsequent interaction of that neutron. From these events they calculate that at most only 20% of their observed events could come from this source. Some experimenters are still worried, however, because the CERN group had to employ a Monte Carlo calculation to obtain this result.

Some experimenters have criticized the NAL experiment because of the difficulty of knowing how to correct for certain muon-producing events that do not go through the muon detector, which is at the end of the array and subtends only a limited solid angle. One way to calculate this number is to assume scaling, that is, to take the low-energy results, and scale them to high energy to find out the angular distribution. A second way to get this number is to use neutrino interactions in part of the iron magnet to determine the muon efficiency.

Theoretical significance. As long as ten years ago, T. D. Lee and C. N. Yang had suggested in their paper on neutrino reactions that one should look for neutral currents. A neutral current occurs in a process where a lepton scatters off another particle, does not change its charge, and a heavy neutral particle is exchanged between the lepton and the particle it scatters from. (An exception to this definition is that you can get a neutral current when electron-type neutrinos strike electrons and scatter elastically. But in this case there are also contributions from charged currents because the electron neutrino can annihilate the electron, produce a charged intermediate vector meson, which then turns back into an electron neutrino and an electron.)

Since the Lee-Yang paper, various experiments have searched for neutral currents. Frederick Reines and his collaborators, using the Savannah River pile, have determined an upper limit on the cross section for an electron-type neutrino or antineutrino scattering off an electron. The results were consistent with no neutral currents within that limit. An experiment at Gargamelle has used muon-type antineutrinos scattering off electrons. Recently one event was found that could have been a neutral-current process, but it is difficult to distinguish it from background.

Weinberg feels that the new experiments from CERN and NAL provide an enormous shot in the arm for the whole idea of spontaneously broken gauge theories of the weak and electromagnetic interaction. He notes that it is hard to imagine such theories unless there were also neutral currents, although Sheldon Glashow and Howard Georgi actually did discuss such a theory about a year ago. A lot of physicists were beginning to feel, Weinberg told us, that if neutral currents were not found, perhaps something was wrong with the whole idea. Weinberg feels that if one takes the reported accuracy of the CERN and NAL experiments at face value, there is already significant quantitative agreement between theory and experiment.

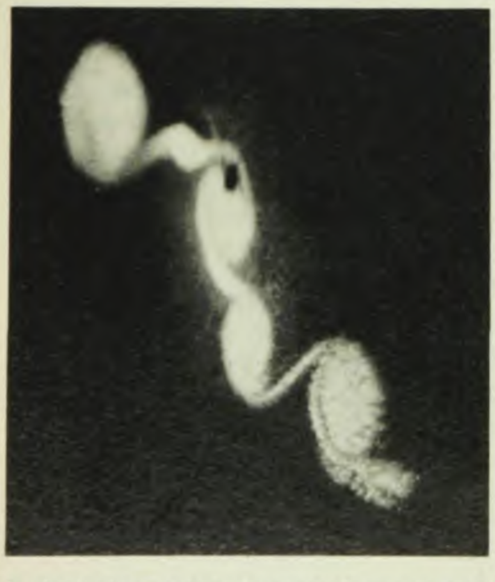
Several experiments, which unlike the CERN and NAL experiments, are designed especially to look for neutral currents, will be running this fall and winter at Brookhaven. Both the CERN and NAL experiments are continuing.

Meanwhile, even if neutral currents are indeed found, no one is claiming that Weinberg–Salam theories must be right. Even Weinberg believes that the model he proposed in 1967 is probably not the final answer because it is not sufficiently pleasing from an aesthetic point of view. He feels that his model may be part of a larger theory in which there are intermediate vector mesons that are so heavy that they produce weak interactions weaker than the ordinary weak interactions—so weak that they have not yet been experimentally observed. —GBL

Auroral effects seen in laboratory vortexes

An explanation of the aurora's undulating folds and rays may come from models of instabilities, some of which were developed to explain effects seen in the laboratory. The folds and rays appear to be vortexes of charge density that occur when the aurora charge sheet becomes unstable above a certain charge density. Work reported by Harold F. Webster (General Electric) and Thomas J. Hallinan (University of Alaska)[1] has centered on the analysis of charge distribution in current sheets and charge sheets in the presence of a magnetic field and its possible usefulness as an auroral model.

Laboratory experiments have shown that vortexes occur in electron beams when the charge density exceeds a certain threshold. Charge concentrations cause the sheet beam to ripple. In turn, there is electron flow toward these curves that serves to reinforce the charge concentration.



A clockwise vortex structure forms in a laboratory electron sheet beam (left). A model developed by Webster and Hallinan may serve to explain this pattern and one of similar appearance in aurorae (right). This example was recorded by a low-light TV camera.

In addition to the more widely known charge-sheet instability, a current-sheet instability should exist that will produce geometrically similar instability patterns. In place of the drift velocity of charge caused by asymmetry in the charge sheet, is the transverse velocity of current caused by a perpendicular component of the magnetic field B generated by the current. This form of instability has not, however, been directly confirmed by laboratory experiments.

The rate of instability growth for both the charge sheet and current sheet is dependent on several factors. The growth time of the charge-sheet instability t_K is

$$t_K = (2B\epsilon_0/\rho)(\lambda/d)$$

where ρ is the charge density, λ is the wavelength of the disturbance and d is the sheet thickness. The growth time t_j for current-sheet instability is

$$t_j = 2\pi(2B/V\mu_0 j)$$

where V is the charge velocity and j is the current density. Both expressions show that a higher magnetic field suppresses the instability and a higher charge or current density promotes instability.

Photographic evidence appears to indicate that both types of instabilities contribute to auroral morphology. Auroral rays often appear as vortexes. Those that are about two kilometers across and spiral in a counterclockwise fashion when viewed antiparallel to B are of the charge-sheet instability type, caused by an excess of electrons in a sheet of precipitating particles.

These particle sheets occur in groups and in some ways can act in unison and, therefore, be treated as a single thicker sheet. The thicker sheet forms clockwise spirals with a diameter of 30 to 1400 km. These spirals appear to be characteristic of current-sheet instability—electron flow in both hemispheres appears to be the cause of the particular rotational sense.

Another phenomenon is the occurrence of less complex auroral folds, folds whose development has been arrested in an early stage. These may be kink instabilities that, unlike a current-sheet instability, are dependent on a finite current-sheet width. Typically, current-sheet widths are too large for kink instabilities; hence it is expected that current instabilities dominate in aurora. —RAS

Reference

1. H. F. Webster, T. J. Hallinan, Radio Science 8, 475 (1973).