

Nobel 1995

Clyde Cowan (left) and Frederick Reines (right) at their original 1953 experiment at the Hanford reactor which saw promising indications of neutrino interactions.
(Photo Los Alamos)

The theme of the 1995 Nobel Prize for Physics is leptons, the particles which feel the weak nuclear force, best known in nuclear beta decay. The prestigious award is shared by Frederick Reines of the University of California, Irvine, and by Martin Perl of the Stanford Linear Accelerator Center.

Professor Reines' award is in recognition of his epic 1956 discovery, made with Clyde Cowan at the Savannah River reactor in South Carolina, that the neutrino, predicted by Wolfgang Pauli in 1930, is a physically observable particle. Unfortunately Clyde Cowan died in 1974. Professor Perl's discovery of the tau lepton at the SPEAR electron-positron collider in 1976 was less expected, but no less important for today's Standard Model of particle physics.

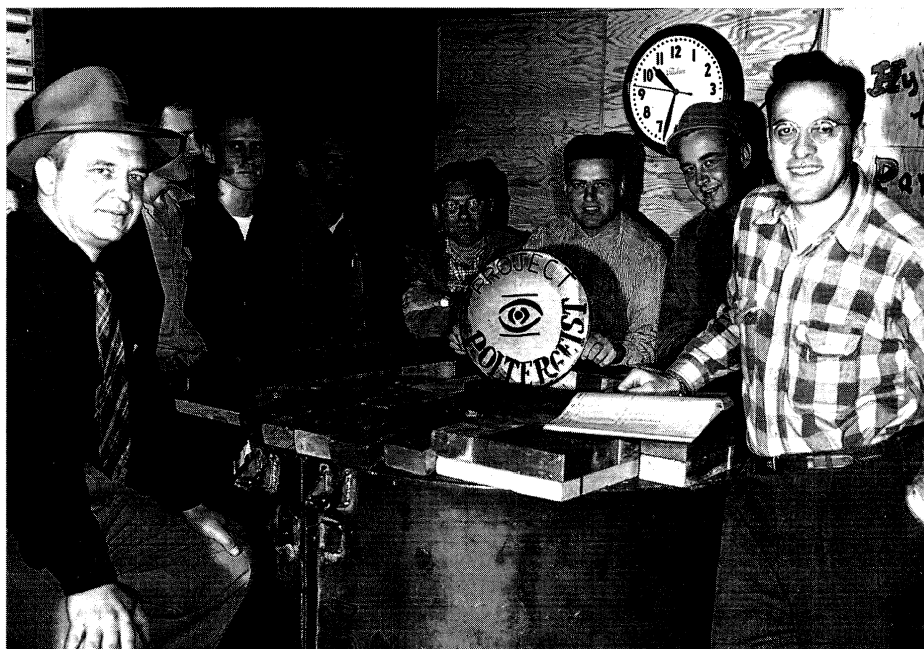
The discovery of the neutrino

The discovery of the neutrino is traditionally described as an experimental verification of a bold theoretical prediction by Wolfgang Pauli. However Leon Lederman has pointed out that it should be the experimentalists who get the lion's share of the credit. Experiments provided the data which 'made it perfectly obvious' that Pauli had to invent the neutrino!

Looking at the same data, Niels Bohr was led to suggest that conservation of energy inside the atom would not be absolute.

Pauli only made his suggestion out of desperation, says Lederman, adding 'driving a theorist as good as Pauli to desperation has been the goal of red-blooded experimentalists ever since'.

With beta decay experiments



reporting a tiny energy imbalance, Pauli was driven in 1930 to suggest that an otherwise invisible particle was emitted along with an electron when a neutron decayed into a proton. At first, he was reluctant to talk about a particle which could not be detected, but by 1934 the neutrino had been incorporated into Enrico Fermi's theory of weak interactions.

Hans Bethe and Rudolf Peierls calculated the expected absorption rate of neutrinos by nuclei and concluded such particles would be undetectable. However Bethe and Peierls had not known about the enormous numbers of neutrinos emitted in fission reactions.

The initial idea of Reines and Cowan was to catch neutrinos from an underground atomic bomb explosion. Any detector near an exploding bomb would not survive, but perhaps a detector could be dropped down the shaft. Such an experiment was difficult to repeat, and in the immediate post-war years there were powerful new reactors offering

alternative sources of neutrinos.

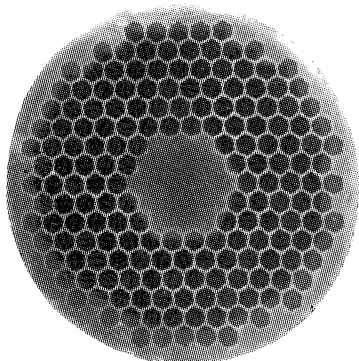
Rather than seeing neutrino emission in beta decay, the aim of Reines and Cowan's detector was to see inverse beta decay, where a neutrino hits a proton, producing a neutron and a positron. The latter would soon annihilate, releasing an electron-positron pair. In addition, Reines and Cowan also wanted to detect the neutron, through the gamma rays emitted in its eventual nuclear capture after it had slowed down. These gamma rays would be seen a few microseconds after the annihilating positron. This 'delayed coincidence' was the key to neutrino discovery.

In 1953, they started work with a 300-litre drum of liquid scintillator at Hanford, Washington, and saw a slight increase in the delayed coincidence signal. This was encouraging, but not enough to claim any discovery.

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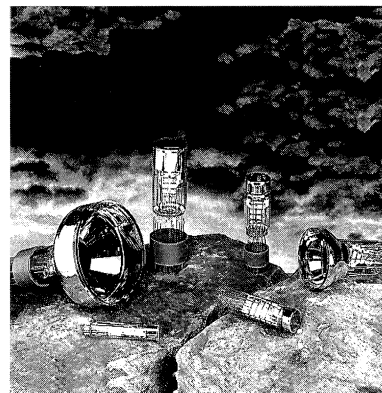
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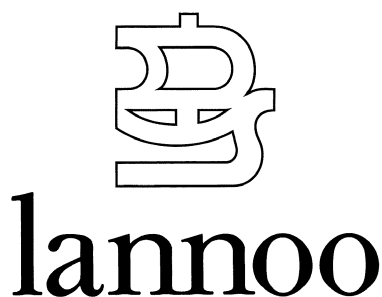
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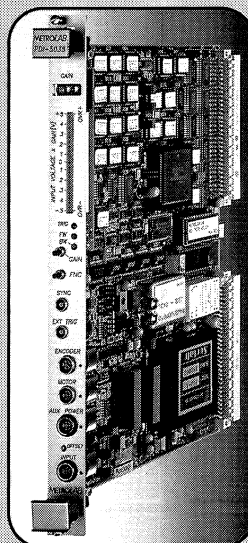


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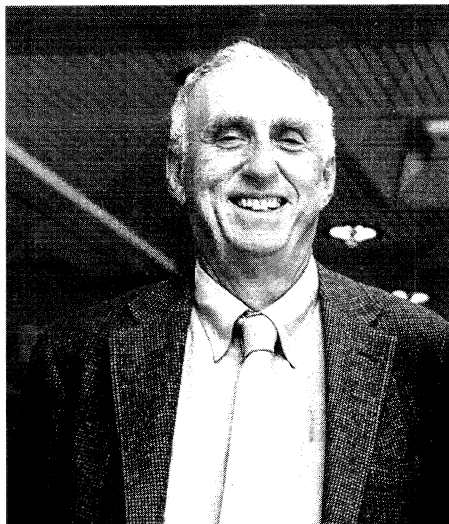
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Discoverer of the tau lepton, Martin Perl of the Stanford Linear Accelerator Center shares the 1995 Nobel Physics Prize.



Carolina. Over 100 days of running, they averaged three tell-tale delayed coincidences per hour. Neutrinos were not just symbols in equations. They were for real. On 14 June 1956 Reines and Cowan triumphantly sent a telegram to Pauli in Zurich. Unfortunately the telegram was sent to the University, not the ETH institute where Pauli worked, but the error was dutifully corrected.

More neutrinos

Neutrinos are not only produced in nuclear beta decay. They are also found, with muons, in the weak decays of pions and kaons. Were the neutrinos produced with muons from pion decay identical to those seen in nuclear beta decay?

The question was answered in 1962 by an experiment by Leon Lederman, Mel Schwartz and Jack Steinberger at Brookhaven, which showed that neutrinos come in different kinds. Lederman, Steinberger and Schwartz were awarded the Nobel Prize for Physics in 1988.

The discovery of the tau

In 1974, attention at the SPEAR electron-positron collider at the Stanford Linear Accelerator Center, was focused on the famous J/psi particles. These had been discovered independently by teams led by Burton Richter at SPEAR and by Sam Ting at Brookhaven. These particles had heralded a fourth quark, which carried a special quantum number 'charm'.

Such a fourth quark had been predicted in 1970 by Sheldon Glashow, John Iliopoulos and Luciano Maiani to explain the behaviour of the electrically neutral current of the weak interaction when the quark quantum number called strangeness was involved.

For a while, it looked as though the 'Standard Model' (the term had not yet been invented) of particle physics was complete with four types of quarks grouped as two pairs - up/down and strange/charm - together with two leptons - the electron and the muon, each with its own kind of neutrino.

One of those eager to understand why leptons come in distinct varieties was Martin Perl. Before coming to SLAC, Perl had been Sam Ting's thesis adviser at Michigan. Always on the lookout for signs of new leptons, he did a long search using the two-mile linac, without success. Undeterred, he joined Richter's team at the new SPEAR ring: in his pocket were predictions by J.J. Sakurai and by Y.S. Tsai about what the decays of heavy leptons could look like.

To avoid making it a visible budget item, the 200-metre Stanford Positron-Electron Asymmetric Ring had been built by Richter on a parking lot at SLAC out of the laboratory's operating budget for \$5 million in less

than two years. By the summer of 1973 it was logging data. One of the experiments lined up for SPEAR was a search for new leptons, but in November 1974 had come the bonanza J/psi discovery and attention focused on getting the most out of SPEAR's Mark I detector.

Earlier, the ADONE electron-positron collider at the Italian Frascati Laboratory and the unconventional CEA Cambridge (Massachusetts) machine had shown how spectacular electron-positron annihilations could be, even at lower energies, producing a surprising number of pions and other hadrons as well as weakly interacting particles. However searches for heavy leptons had been fruitless in the energy region covered by ADONE.

After the J/psi discovery, the SPEAR energy was inched higher in the search for more new particles. Perl noticed a few events which produced an electron and a muon but no other visible particles. At 1975 conferences, Perl was referring to his interesting haul of 24 events as 'U' (for unknown) states.

However most other physicists were obsessed with charm. The J/psi particles, composed of a charmed quark and its antiquark, had only 'hidden' charm. Somewhere there had to be particles with 'open' charm, containing only one charmed quark, and at a mass suspiciously close to Perl's U states. Were Perl's Us due to open charm?

However open charm was soon seen, while Perl, working with Gary Feldman, had accumulated over a hundred events which, he said, defied conventional description. Others were not convinced, alleging the U events to be background noise, spurious effects which mimicked a particle. The mass was suspiciously

close to the charm threshold. At the DORIS electron-positron ring at DESY, Hamburg, no U events were seen initially.

Undeterred, Perl kept talking about his Us and was still seeing more them. Boldly he claimed the discovery of a new lepton, the tau, from the initial letter of the Greek word triton - 'third' - weighing in at 1777 MeV, much heavier than the electron at 0.5 MeV and the muon at 105 MeV.

By 1977, independent evidence for the tau came in from the PLUTO detector at the DORIS ring, and by the time of the 1977 Lepton-Photon meeting in Hamburg this had been joined by DASP at DORIS and the DELCO experiment now installed at SPEAR.

Although SPEAR's Mark I detector received several improvements, notably muon shielding to protect the

muon signal against hadronic intrusion, the tau was discovered by the same detector which revealed the J/psi. It is probably the first example of separate Nobel Physics Prizes having been earned by the same apparatus.

The Standard Model

If there was a third lepton, then there had to be another pair of quarks. Both were discovered at Fermilab. The fifth quark, beauty, was revealed in 1977, and its partner, top, in 1995. These particles completed today's Standard Model of three quark pairs linked to three leptons and their corresponding neutrinos.

In 1989, the arrival of higher energy electron-positron collisions at

Stanford's SLC Linear Collider and CERN's LEP electron-positron collider showed that Nature has no room for more than three kinds of neutrinos, and looking for leptons suddenly dropped out of fashion.

Precision tau physics, probing the third generation of the Standard Model, has become a minor industry at LEP, while precision measurements of the tau mass were made at the Beijing electron-positron collider. The Workshop on Tau Lepton Physics now a major feature in the international physics calendar. Martin Perl is always guest of honour. He has been a member of CERN's Scientific Policy Committee since 1991.

With tau-charm factories planned (October, page 8) tau physics is assured of a bright future.

RESEARCH ASSOCIATE THEORETICAL PARTICLE PHYSICS INDIANA UNIVERSITY

Applications are invited for the position of postdoctoral research associate in theoretical particle physics, available September 1, 1996. Initial appointment is for one year, with probable renewal for a second year. We seek outstanding candidates in theoretical particle physics who have overlapping interests with our group. Each application should include a curriculum vitae, a description of research interests and accomplishments, and a list of publications. Candidates should also have at least three letters of reference sent to: Particle Theory Group, Physics Department, Indiana University, Bloomington, IN 47405, USA. Applications received before January 15, 1996 may receive preference. Indiana University is an Equal Opportunity/Affirmative Action Employer.



Post Doctoral Position

The Deutsche Elektronen-Synchrotron, DESY, in Hamburg, performs basic research in the field of elementary particle physics by means of a High Energy Storage Ring. It is a research institute of international repute which collaborates with similar research centres throughout the world.

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As a study for possible future e⁺/e⁻ colliders, test accelerators are being constructed and will shortly go into operation. Thus participation in and realisation of technical designs and theoretical analysis in the areas of superconductivity, high frequency and accelerator physics are required.

Applicants should have a Ph.D. in physics or in an allied field and be not more than 32 years old. The contract will be limited to 3 years. The salary will be according to the "MTV Angestellte" Group 11a. Handicapped applicants with equal qualifications will be preferred. DESY is interested in advancing the professional development of women and would encourage women to apply for this position. Written applications complete with certificates and references should be sent to our Personnel Department before 27.11.1995.

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School of Physics and Chemistry

RESEARCH ASSOCIATE POSITION

Applications are invited for a postdoctoral Research Associate Position in the Particle Physics Group. The successful candidate will work in one of the following activities of the group.

1. Studies of electroweak interactions in ALEPH AT LEP at CERN.
2. Deep Inelastic Scattering in the H1 group at HRA at DESY.
3. Detector development for the inner tracking detector for the ATLAS collaboration at the LHC at CERN.
4. BaBar Collaboration at SLAC.

The post is supported by the PPARC in the UK.

For further details and application forms please contact Personnel Services quoting reference number L401, Bowland College, Lancaster University, Lancaster LA1 4YT, UK (Telephone (44) 1524 846549). Application forms should be returned to Personnel by 10 December 1995.

Further information about this post can be obtained from Professor T. Sloan (e-mail T.Sloan@Lancaster.ac.uk).

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Assistant Research Astrophysicist

Center for Particle Astrophysics

UNIVERSITY OF CALIFORNIA AT BERKELEY

The Center for Particle Astrophysics, an NSF Science and Technology Center, invites applications for the position of Center Fellow.

The Center is investigating the dark matter problem through four lines of experimental attack: using conventional and cryogenic detectors to detect the interaction of dark matter particles in the laboratory; studying the diffuse radiation from the early universe (particularly the 3K microwave background); using distant supernovae to determine how much dark matter exists; and studying the role of dark matter in the evolution of large-scale structure. The Center Fellowship is intended to provide a young experimentalist with the opportunity to bring fresh insight (particularly from other fields of physics) to bear on the dark matter problem and take a leading role in developing new initiatives. This two-year position will start in October, 1996, with a possible extension for a third year.

Candidates should have a Ph.D. in Physics or Astronomy. Research experience at the post-doctoral level is preferred. Salary will be commensurate with experience. Interested applicants should submit a statement of their research interests, a curriculum vitae, and arrange for letters of support from three referees who are familiar with their work. These items and a letter of application should be sent to:

Professor Bernard Sadoulet
Center for Particle Astrophysics
301 LeConte Hall
University of California
Berkeley, CA 94720, USA

The closing date for applications will be January 1, 1996. The University of California is an Affirmative Action/Equal Opportunity Employer. We especially encourage applications from female and minority candidates.

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Sweden has vigorous activities in both experimental and theoretical astroparticle physics. There are strong experimental groups involved in experiments such as AMANDA and CAPRICE.

The Swedish Natural Science Research Council now expands these activities by inviting applications for a tenure track type Council Researcher position at the assistant/associate professor level. Initially the position is for 3+3 years. The successful applicant is expected to join one of the Swedish research groups. The salary range will correspond to that of an associate professor (SEK 255 000-350 000 per year, i.e. USD 36 000-49 000 per year).

Applications should include a detailed curriculum vitae and bibliography, summary of past research, a short research plan, names of three references who can be contacted and, at most, 10 scientific papers. The applicant is kindly asked to state which Swedish research group he/she would like to join. Four copies of the application and reprints, also in quadruplicate, should reach the Swedish Natural Science Research Council, Box 7142, S-103 87 Stockholm, Sweden, by December 1, 1995.

Further information can be obtained from Ms Natalie Lunin, at the Secretariat of NFR, Telephone: +46-8-454 42 32, fax: +46-8-454 42 50, or email: finn@nfr.se

RESEARCH ASSOCIATE Experimental High Energy Physics

The Department of Physics at Stanford University is inviting applications for a post-doctoral research associate to participate in a rare K^0 decay experiment at Brookhaven National Laboratory and in a long baseline neutrino experiment, MINOS, at Fermilab.

The K^0 decay experiment, BNL E871, looks for rare decay modes with a single event sensitivity of 10^{-12} . The emphasis is on two body decays, $\mu^+\mu^-$, e^+e^- and μ^+e^- . Initial five month long data taking run was concluded in June 1995 and has met its planned goals. It is expected that the experiment will run again starting in February 1996 and possibly also in 1997.

The MINOS experiment is designed to be sensitive to $\nu_\mu \rightarrow \nu_e$ and $\nu_\mu \rightarrow \nu_\tau$ oscillations down to $\sin^2 2\theta = 0.01$ and to Δm^2 values below 10^{-2} . This experiment was recently endorsed by HEPAP as an important element of the future US high energy physics program. The neutrino beam will be produced by the protons extracted from the Fermilab Main Injector, currently under construction and scheduled to be completed by 1999. The far detector will be a multi-kiloton magnetic spectrometer in the Soudan mine in Minnesota, some 730 km away. The existing Soudan 2 detector will also form part of the detector apparatus. It is hoped that data taking can begin in 2001.

The successful applicant will be expected to spend the first year at BNL, participating in E871 data taking and MINOS test beam work. Subsequently it is anticipated that the majority of his or her time will be spent in residence at Stanford, working mainly on MINOS simulation, design, and construction but also participating in the analysis of E871. The initial appointment will be for three years with the possibility of an extension.

Interested applicants are requested to send three letters of reference and a resumé to:

Professor Stanley Wojcicki
SLAC
PO Box 4349, MS 63
Stanford, CA 94309, USA

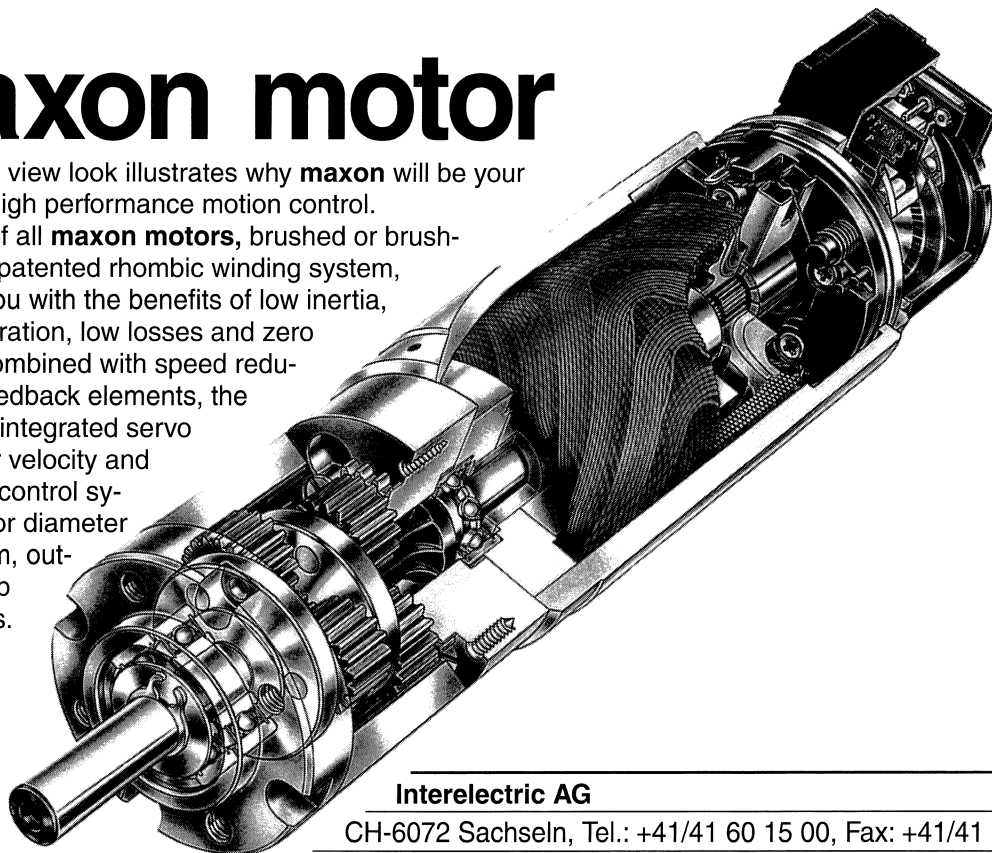
The applications will be accepted until December 15, 1995 or until the position is filled.

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The Continuous Electron Beam Accelerator Facility (CEBAF), located in Newport News, Virginia, USA, is a world class facility for nuclear physics research. With a 4 GeV high intensity, continuous wave electron accelerator, CEBAF will explore the fundamental nature of nuclear matter with particular emphasis on quark-gluon degrees of freedom. The physics program of the High Resolution Spectrometer Group focuses on precision studies of electromagnetic and weak-neutral current form factors of the nucleon and bound nucleon properties in few body systems. The experimental equipment in Hall A, namely, a pair of identical 4 GeV/c High Resolution Spectrometers equipped with a focal plane polarimeter, are expected to be operational in 1996.

Applications are being invited for a post-doctoral research associate position for the High Resolution Spectrometer Group. The position requires a recent Ph.D. in Experimental Subatomic Physics. The successful candidate will participate in the commissioning of the experimental equipment in Hall A and analyze initial experiments. Demonstrated experience in the implementation and analysis of lepton-nucleus physics experiments is preferred. Interested candidates should send curriculum vitae and three letters of reference to: CEBAF, ATTN: Employment Manager, 12000 Jefferson Avenue, Newport News, Virginia 23606, USA. Please specify position #PT2104 and job title when applying. CEBAF is an equal opportunity, affirmative action employer.

POSTDOCTORAL POSITION EXPERIMENTAL HIGH ENERGY PHYSICS University of California, San Diego

The Department of Physics at the University of California, San Diego invites applications from outstanding candidates for a Postdoctoral Researcher position to work in the field of Experimental High Energy Physics.

UCSD is a member of the CLEO Collaboration at the Cornell Electron Storage Ring and is committed to a strong b-physics program with the CLEO detector. The CLEO detector has recently been equipped with a three layer, three-dimensional Silicon Vertex Detector to significantly enhance its charged particle tracking capability. The successful candidate is expected to play a major role in the commissioning of the silicon detector and in the integration of the silicon detector data with that from pre-existing tracking devices. The candidate is also expected to play a leading role in physics analysis using data obtained with this upgraded detector. To this end, the candidate's prior experience with charged particle tracking in general and silicon vertex detectors in particular shall be very useful.

For reasons of efficiency, the selected candidate shall be posted onsite at Cornell University in Ithaca, New York. The salary is commensurate with the candidate's qualifications and will be based on the University of California pay scale.

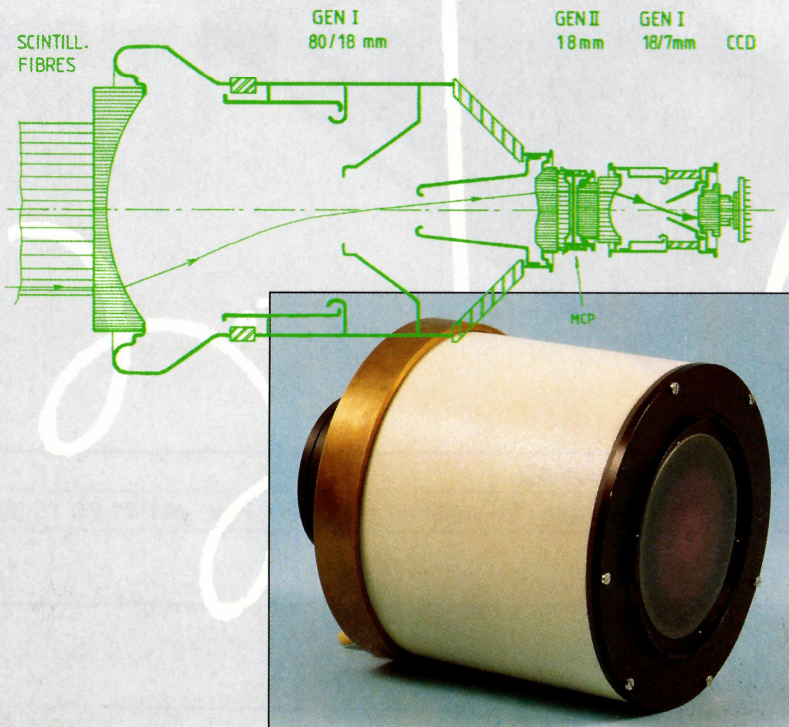
Interested candidates should send a copy of their CV, three letters of recommendation and a statement of physics interests to: **Prof. Vivek Sharma, Physics Department 0319, University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0319, USA. Email: vsharma@ucsd.edu.**

The deadline for applications is **1 December 1995**.

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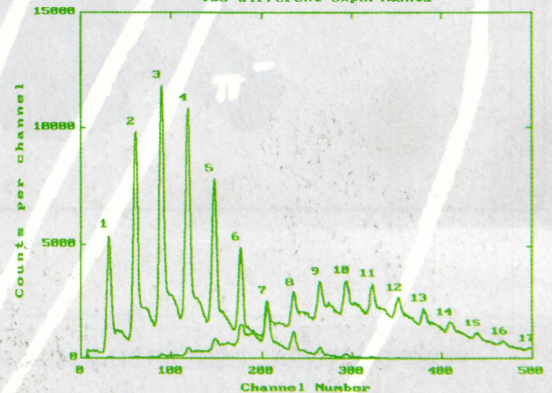
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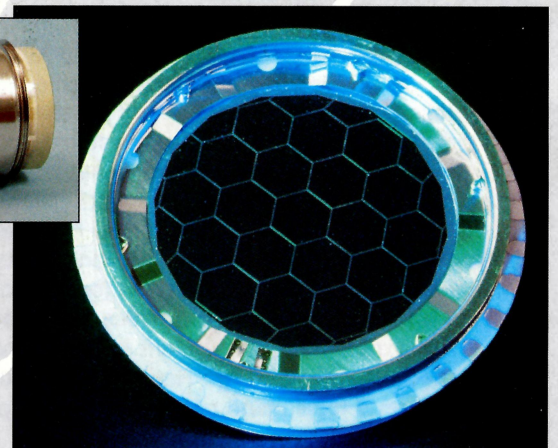
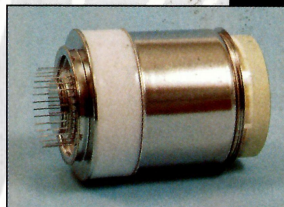
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