

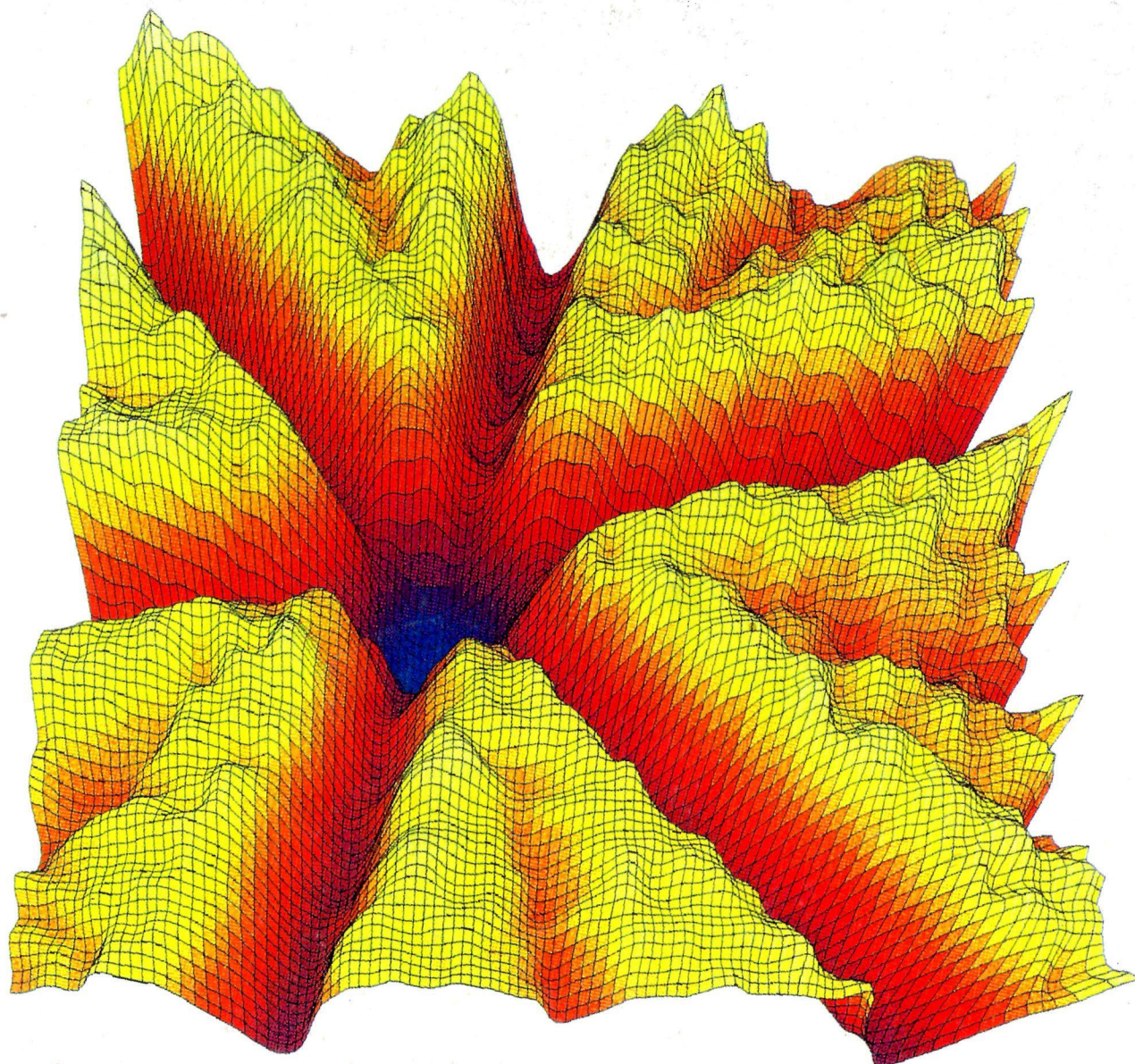
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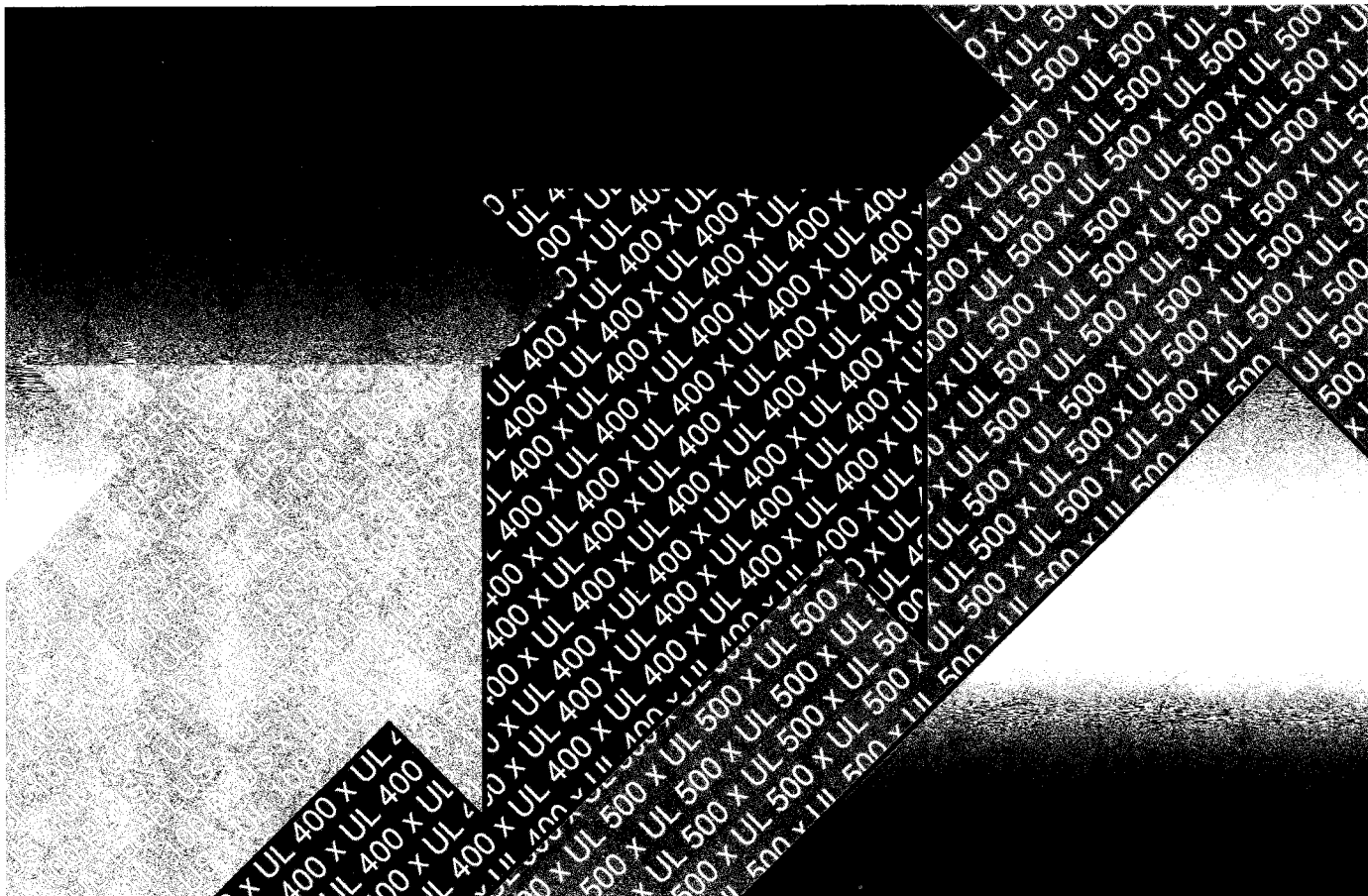


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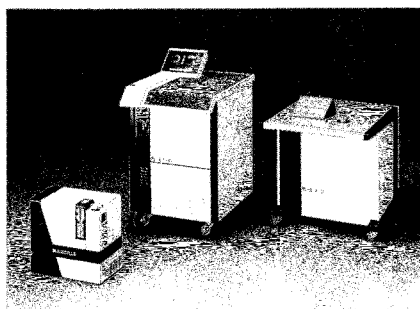
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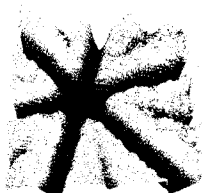
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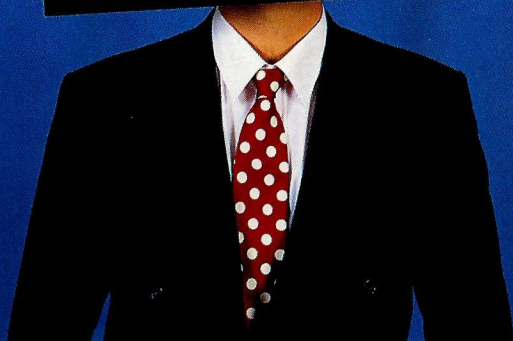
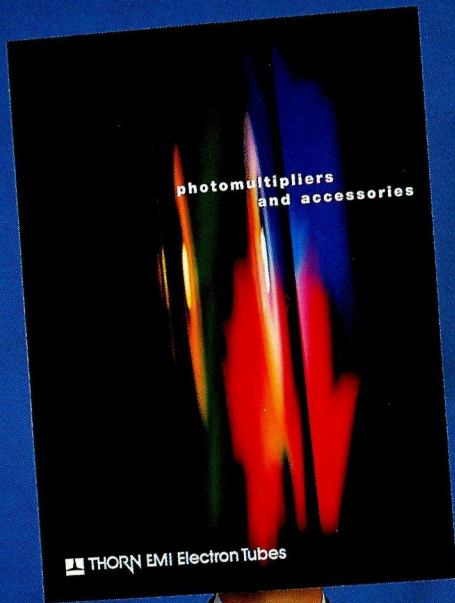
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Cover photograph: The vivid channeling of emitted alpha particles in diamond shows the location of an implanted lithium-8 nucleus. A recent workshop at CERN (see page 6) demonstrated the benefits that on-line isotope sources like CERN's ISOLDE can bring for solid state science.



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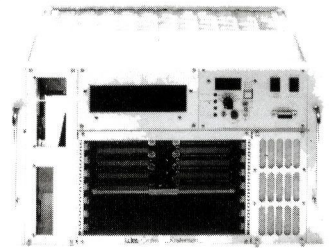
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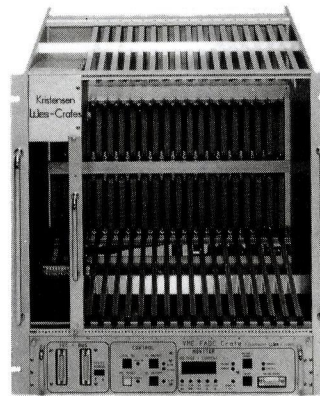
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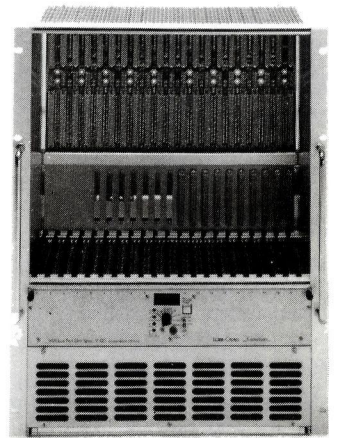
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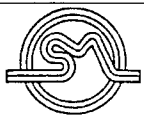
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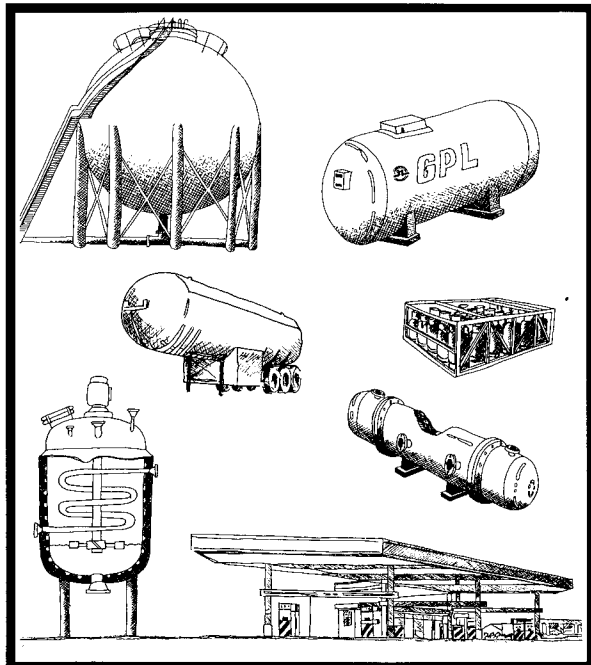
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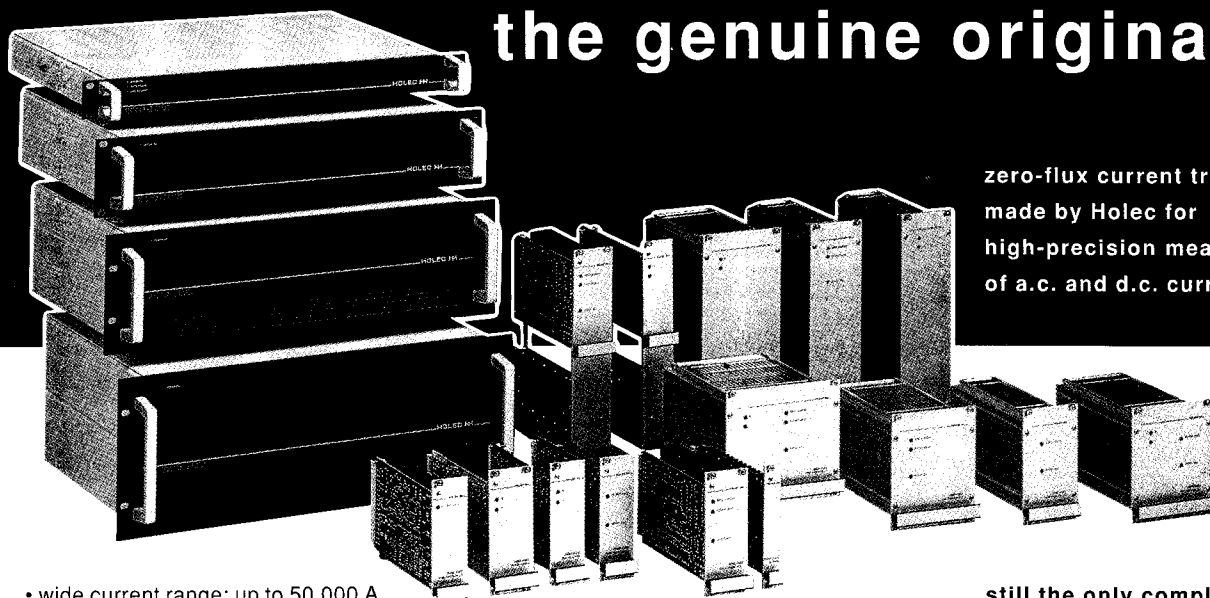
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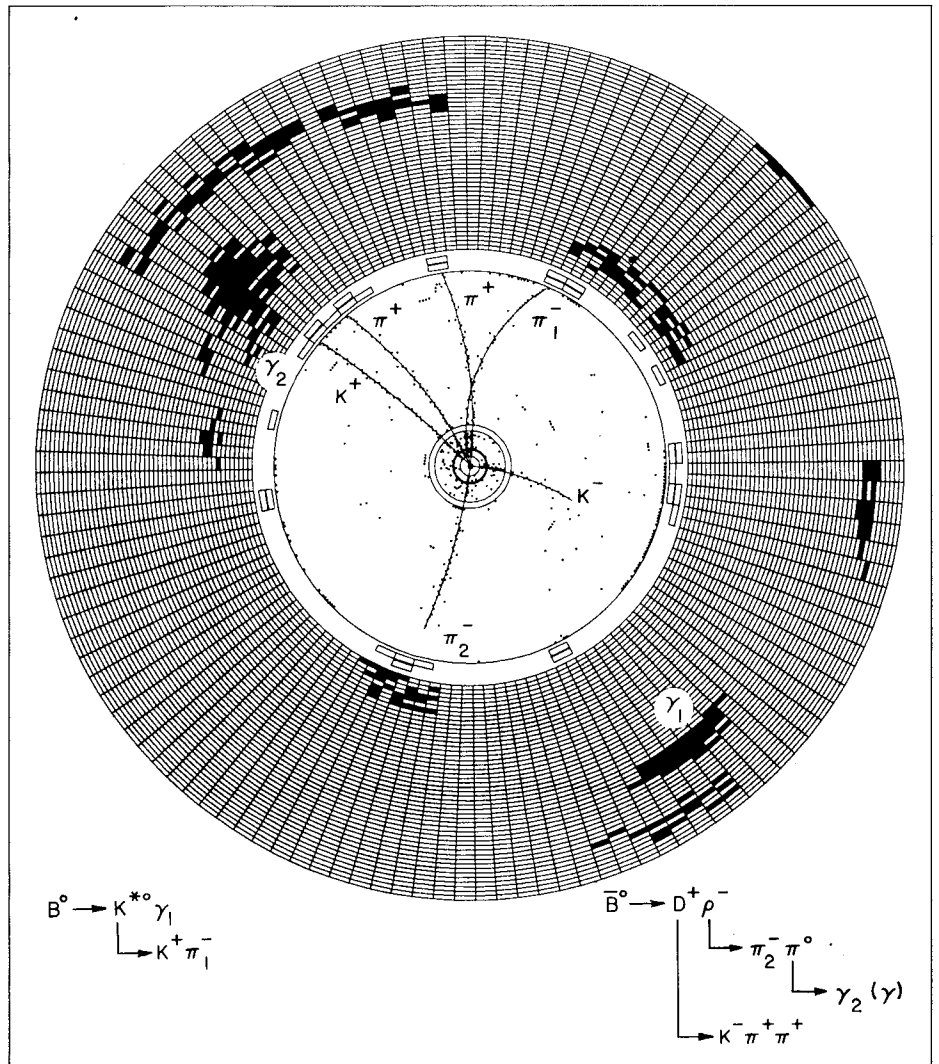
CORNELL CLEO discovers B meson penguins

The CLEO collaboration at Cornell's CESR electron-positron storage ring has discovered a rare type of B meson decay in which only a high energy photon and a K^* meson are produced. These decays provide the first unambiguous evidence for an alternative route for heavy quark decay that has been given the whimsical name "penguin diagram".

In the mid-1970s penguin diagrams were proposed to explain the puzzling strangeness quantum number selection rules in the decay of K mesons. At the same time it was realized that penguin diagrams could also be important in the CP violation seen in neutral K meson decay. CP violation, an asymmetry between matter and antimatter, is an essential ingredient in understanding why there is much more matter than antimatter in the universe. CP violation introduces a definite direction to the arrow of time, which could otherwise point equally forwards or backwards. In addition, penguin decays are very sensitive to some extensions of the Standard Model of weak decay.

Although penguin diagrams were first proposed to explain an effect in K meson decay, the K system gives no unique signature for them, and verification of penguin processes meant looking elsewhere.

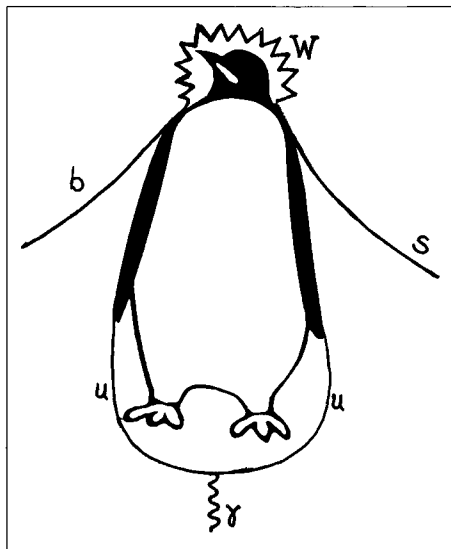
In the Standard Model, quarks decay under the influence of the weak force, emitting a W boson. Since the W is charged, the charge of the initial quark differs from that of the final quark, so the charge of the quark changes as well as its flavour.



B mesons contain beauty (b) quarks, with charge $-1/3$, which ordinarily decay to charm (c) or up (u) quarks with charge $+2/3$. So far there has been no evidence for "flavour changing neutral currents" which would result in quark transformations without changing electric charge. In a penguin process, a b quark can also decay to an s quark via a one-loop process (2nd order effect) in which a W boson is emitted and then reabsorbed. Since the b and s quarks have the same charge, this process is an effective flavour

Computer display of a CLEO event in which all of the particles produced in the decays a B meson pair have either been observed or inferred. One B decayed in an electromagnetic penguin mode; the other decayed conventionally. The curved tracks in the large inner circle are the tracks of the charged particles in a drift chamber in the 1.5 T magnetic field. The outer region with its radial-angular segments is the "barrel" portion of the CLEO II cesium iodide electromagnetic calorimeter. Each segment represents a counter as it would appear in perspective if one were looking down the barrel. The photons in the event are indicated; the other black segments are due to charged particles in the counter or usual background signals from stray particles from other sources.

Penguins at work. When a quark transforms under the influence of the weak force, it necessarily changes its electric charge as well as its quark 'flavour'. In so-called 'penguin' processes, two such quark transformations couple back-to-back, providing an additional, but very rare route for quark transformation. In the process seen at Cornell an emitted photon is seen accompanied by a K^ meson, formed by the strange quark emerging from the penguin mechanism combining with a spectator up or down quark.*

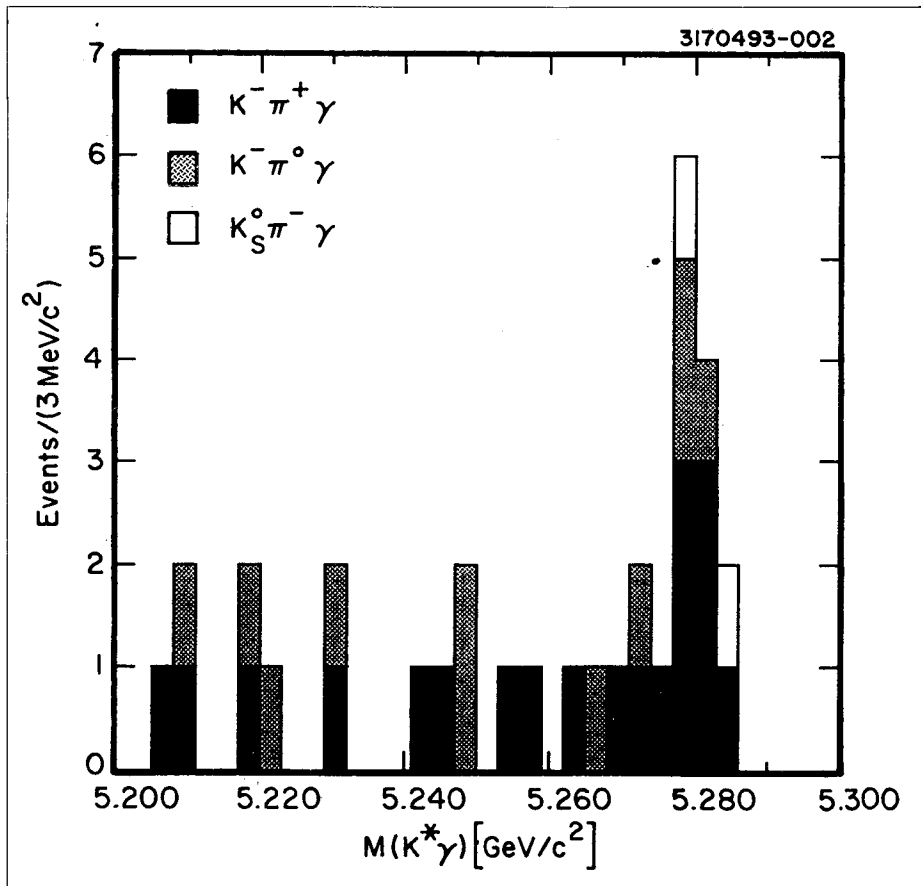


changing neutral current. Accompanied by the emission of a high energy photon, the decay is known as an electromagnetic penguin decay. B meson decays which result in only a K^* meson and a high energy photon are a striking and unambiguous signature for this type of process.

Events in which a B meson decays to only a K^* and a photon are rare - approximately one per 20,000 decays. Taking into account the inefficiencies of even the best detector, more than a million B mesons are needed to obtain an unambiguous signal. During the last two years, over 3 million B mesons were recorded in CLEO. At CESR, B mesons are produced in pairs without additional particles, so the events are very clean and the energy of the B mesons is fixed - a good environment for studying rare B decays.

Both the B and K^* mesons decay much too quickly to be observed directly in the CLEO detector, so they must be reconstructed from their decay products. The search for these penguin decays starts with identification of a high energy photon in the detector in coincidence with a

The distribution of masses reconstructed from K, pi, and photon candidates for 'penguin' decay of B mesons seen by the CLEO detector at Cornell's CESR electron-positron collider. The 13 events in the peak between 5.274 and 5.286 GeV is the signal for the decay. Events at lower mass are due to random combinations of particles from other processes.



K and pi meson. If a number of other selection criteria are satisfied, the K and pi are checked to see if they are consistent with their being the products of the decay of a K^* . If so, the reconstructed K^* is combined with the high energy photon, and the total energy of these particles is compared to the energy of the CESR electron and positron beams. This constraint on the energy of the decay products eliminates nearly all background due to random combinations of K mesons, pi mesons, and photons that come from other processes.

Once these three candidate particles have been selected, the mass of the parent particle that might have produced them can be calculated. The peak in the mass spectrum at

the B meson mass, 5.280 GeV, shows that many of the candidates actually resulted from the decay of a B meson. Of the 13 events in the peak, only about two are attributable to background.

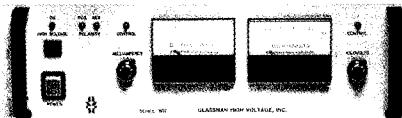
These decays establish the existence of the electromagnetic penguin decay process, but theoretical understanding is not yet sufficient to make accurate calculations of specific processes. However reliable calculations can be made for the total rate including all electromagnetic penguin decays, and these calculations are sensitive to the existence and masses of the sixth (top) quark and a hypothetical charged Higgs boson, neither of which have been observed. Now that the existence of



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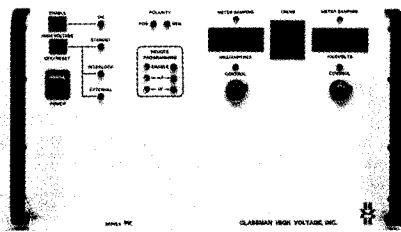


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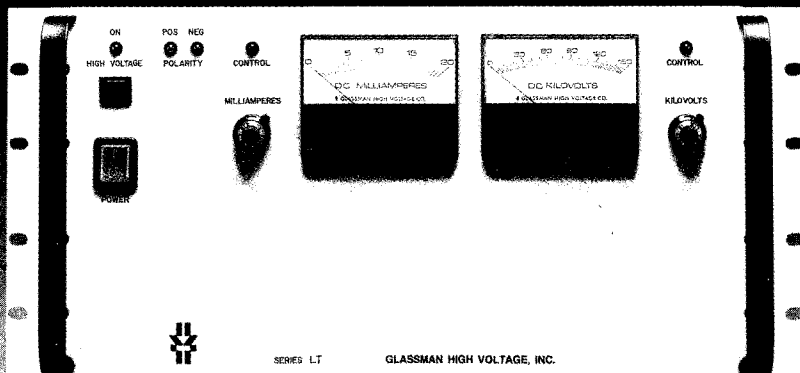
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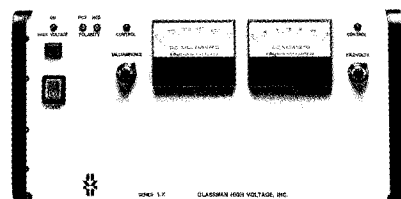
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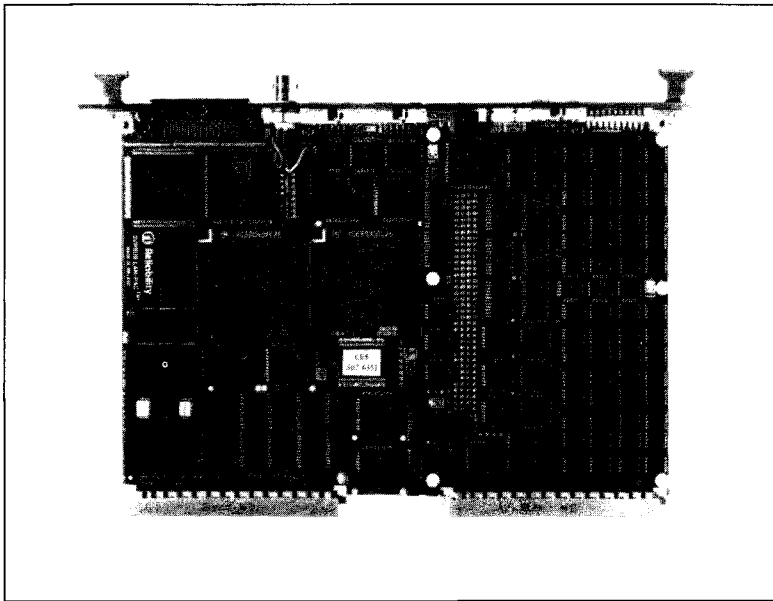
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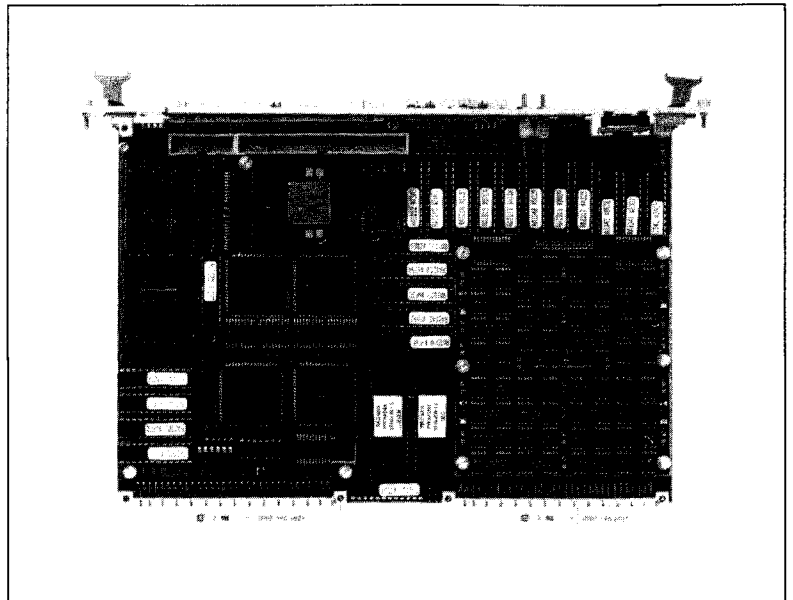
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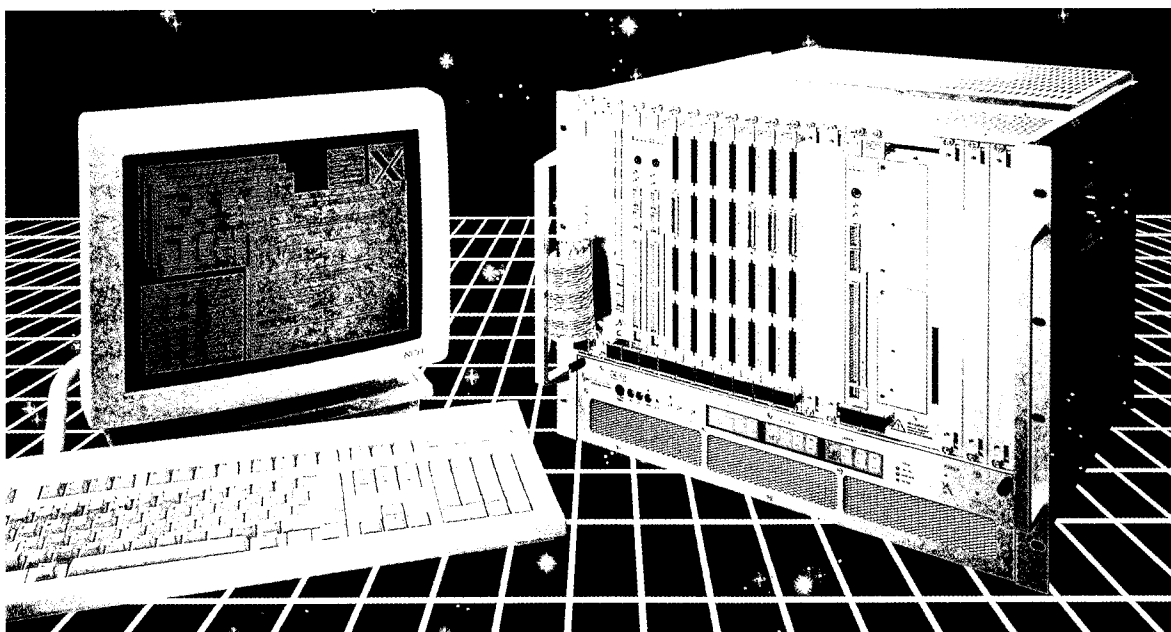


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electromagnetic penguin processes has been established, conclusions derived from measurements of the rate of inclusive decays are substantially more significant.

The CLEO collaboration has also searched for electromagnetic penguin decays by looking for photons in an energy region where these decays should dominate. The number of photons observed is not significantly larger than the number expected from background electron-positron annihilation processes in which no B mesons are produced. The resulting upper limit, 5.4×10^{-4} , for the rate of inclusive electromagnetic penguin decays rules out a large class of models that include charged Higgs bosons with masses in the 100 GeV range. This result sharpens the focus of ongoing Higgs searches.

Further elucidation of the role of penguin diagrams in heavy quark decay requires much larger samples of B mesons. Cornell is currently upgrading the luminosity of CESR by at least a factor of five (December 1992, page 17). Cornell also has an asymmetric B Factory proposed as a further CESR upgrade (July/August 1991, page 8).

CERN Materials science with radioactive isotopes from ISOLDE

Among the major physics objectives at CERN's ISOLDE on-line isotope separator is the growth field of nuclear solid state physics, where the goals are both technological and scientific. ISOLDE research entered

a new era when the facility began operations last year in its new home at the 1 GeV Booster synchrotron (July 1992, page 5). Nuclear solid state physics accounts for about 30% of ISOLDE beam time, other research highlights being nuclear physics, atomic physics, nuclear astrophysics, and biophysics.

The achievements so far and ongoing goals of nuclear solid state research were covered in a recent workshop - 'Materials Science with Radioactive Isotopes' - held at CERN from 5-7 April. This carried on from where the 'Radioactive Implants in Materials Science' meeting in Bad Honnef left off in January 1992.

The main aims of the CERN meeting were:

- to show the outstanding possibilities offered by ISOLDE for solid state experiments using short-lived isotopes;
- to stimulate discussion between physicists using nuclear techniques and those employing other methods; and
- to look for collaboration opportunities between present ISOLDE users and other researchers: small teams could be strengthened to provide a very cost-effective way of exploiting ISOLDE beams.

Nuclear solid state physics at ISOLDE is mainly focused on the investigation of defects and impurities in semiconductors, but will also be used for metals, surfaces and interfaces, using nuclear techniques such as radiotracer diffusion, emission channeling, and Mössbauer or Perturbed Angular Correlation Spectroscopy (PACS).

The hitherto serious limitation of many nuclear methods due to a restricted range of chemically different suitable radioactive probe atoms can be easily overcome by ISOLDE's

lengthy isotope menu.

Thus whole new classes of semiconductors become accessible for PACS, yielding information on the annealing of radiation damage after heavy ion implantation and on the hydrogen passivation of acceptor dopants. Emission channeling has been used to investigate the lattice site location of implanted lithium-8 (see front cover).

Radioactive isotopes also open up new techniques, for example the Conversion Electron Spectroscopy of Valence Electron Configurations (CESVEC), where the detection of conversion electrons by a high resolution beta spectrometer gives the energy state density of the probe atom's valence electrons.

Participants at meeting also heard how combining standard techniques like Deep Level Transient Spectroscopy (DLTS) with radioactive isotopes can overcome otherwise inherent 'chemical blindness' - the decay rate of the radioactive implant identifies the chemical species and gives the energy levels of chemical impurities. This trick can also be applied to optical techniques like photoluminescence or electric methods like the Hall Effect.

Summarizing at the end of the CERN workshop, R.C. Newman of the Interdisciplinary Centre for Semiconductor Materials Research at London's Imperial College pointed out that more collaboration between the nuclear and conventional technique communities would be useful, while non-nuclear techniques should exploit the advantages of radioactive isotopes to get additional information. 'The conference has made us aware of new possibilities,' he concluded.

(See front cover illustration)

*• The next issue will include a description of the GEM proposal for a second major detector at the SSC.

SSC Laboratory physics research staff and some of the GEM collaborators who are using the big 'Texas Test Rig' to study prototype muon chambers.

SUPERCOLLIDER Testing muon chambers Texas style

Encouraging performance is being achieved for large muon chambers at the Superconducting Supercollider Laboratory (SSCL) in Ellis County, Texas. As part of the R&D effort for the muon system of the GEM detector*, a cosmic ray test stand known as the Texas Test Rig (TTR) has been built for studying chamber response.

The triggerable volume of the TTR is large, with a surface area of 1.2 m x 5 m and a height of 3 m, allowing performance studies of as many as six different chambers simultaneously. All chamber types tested to date have shown excellent performance, with resolutions better than the 75-micron GEM design goal.

Comprehensive testing has yielded unanticipated and important knowledge on chamber operation. The TTR has become the first user facility at the SSCL, with more than 100 participating physicists from 19 universities and national laboratories in China, Mexico, Russia, and the United States.

At the TTR, a metre of steel absorbs cosmic rays with less than about 1.3 GeV momentum. Removing this "soft" component makes resolution studies less susceptible to misleading multiple scattering effects, and reduces the trigger rate to about 60 Hz. Scintillator hodoscopes with timing resolution of about 300 ps above and below the steel provide the fast trigger. The steel can be magnetized to 15 kG by solenoidal coils. With the magnet on, a finer position measurement with four



planes of 1-cm pitch larocci chambers can be used to select the higher momentum component of the muon spectrum, effectively raising the threshold to 10 GeV/c.

The state-of-the-art data acquisition (DAQ) system developed at the SSCL accommodates a wide variety of contributions from visiting groups.

Four types of detectors have been tested. Pressurized drift tubes (PDT), limited-streamer drift tubes (LSDT), and cathode strip chambers (CSC) were candidates for position measuring detectors, with resistive plate chambers (RPC) for triggering and bunch tagging.

Two separate PDT systems were built at Dubna and Michigan State using staggered layers of tubes 3-4 cm in diameter, 4 m long, stacked

32 tubes wide. Using gas pressures up to 5 atmospheres, the PDTs give 50-90 micron resolution. An LSDT from MIT, operating at atmospheric pressure, gave similar results.

CSC systems were developed independently by Brookhaven, Dubna, and Houston. In a CSC, image charge induced on the cathode strips is typically shared among several adjacent strips, and the hit position is estimated from the pulse heights. Different mechanical designs addressed issues of construction, alignment (GEM tolerances are tight), and manufacturability. Several chambers were tested, the largest approximately 1 m x 2 m. The three systems have shown 50-80 micron resolution.

A 1.2 m x 2.4 m RPC from a

Livermore-MIT group uses plastic doped with conducting polymer as a low-cost alternative to scintillator for large area counting. Tests with a radioactive source indicate rate capability to 1 kHz/cm², substantially higher than bakelite RPCs currently in use. GEM groups working with PDTs and CSCs had been concerned that their chambers would pick up spurious signals from the RPCs, but TTR tests show clearly this is not the case.

Such excellent and rapid results were possible because of advances in chamber design, a sophisticated DAQ system, and the TTR's size and flexibility, despite its being limited to cosmic rays.

Advanced Light Source (ALS) management and staff met with Lawrence Berkeley Director Charles Shank to discuss successful storage-ring commissioning. Left to right are (seated) accelerator physicists Hiroshi Nishimura and Malika Meddahi, operator Cheryl Hauck, and Jay Marx, who guided the ALS construction project until last October;

(standing) ALS Director Brian Kincaid, LBL Director Shank, Accelerator Group Leader Alan Jackson, Electrical Group Leader Henry Lancaster, Head of Operations Ben Feinberg, and Accelerator-physics Section Leader Rod Keller. ALS Project Manager, Ron Yourd, was not present.



BERKELEY ALS ring

Everybody at Lawrence Berkeley Laboratory's Center for Beam Physics is pleased with the rapid progress in commissioning LBL's Advanced Light Source (ALS) electron storage ring, the foundation for this third-generation synchrotron-radiation facility. Designed for a maximum current of 400 mA, the ALS storage ring reached 407 mA just 24 days after storing the first beam on 16 March.

ALS construction as a US Department of Energy (DOE) national user facility to provide high-brightness vacuum ultra-violet and soft x-ray radiation began in October 1987. One technical requirement marking project completion was to accumulate a 50-mA current in the storage ring. The ALS passed this milestone on 24 March, a week ahead of the official deadline.

Once injected, the electron beam decays quasi-exponentially primarily because of interactions with residual gas molecules in the storage-ring vacuum chamber. Eventually, when the pressure in the vacuum chamber with beam decreases toward the expected operating level of 1 nanoTorr, it will only be necessary to refill the storage ring at intervals of four to eight hours. At present the vacuum is improving rapidly as surfaces are irradiated (scrubbed) by the synchrotron radiation itself. At 100 mA, beam lifetime was about one hour (9 April).

To generate high-brightness VUV and soft x-ray synchrotron radiation, the ALS electron storage ring is designed to have very low emittance. The calculated natural emittance of the ring is 3.5 nm-rad at the normal operating energy of 1.5 GeV. However, the ring is capable of operating over the range 1-1.9 GeV.

The triple-bend achromat (TBA) magnet lattice contains 12

superperiods with a total of 36 gradient magnets, 72 focusing quadrupoles, and 48 sextupoles, with horizontal and vertical orbit correction by auxiliary windings on the sextupoles and by 46 dedicated corrector magnets.

The first successful attempt to inject beam into the storage ring came on 19 January when, just before midnight, a jubilant accelerator crew successfully guided an electron beam around the storage ring for the first time. In subsequent days, the number of turns was gradually raised beyond 400, nearly the maximum possible without the radiofrequency system to replenish energy lost to synchrotron radiation.

By mid-March, the 500-MHz storage-ring rf system was ready. On 16 March, with a little fine tuning, the ALS crew was gratified to see the number of turns on the beam-position monitors increasing dramatically from several hundred to several million. Beam started to accumulate immedi-

ately. The dc current transformer reported a stored current of 6 mA in four bunches, and the vacuum gauges shot up from about 10 nanoTorr to 1 microTorr as a result of desorption induced by synchrotron radiation.

After carefully tuning the rf cavities and optimizing rf power and phase, another try on 19 March resulted in a current of 42 mA in four bunches. This exceeded a performance goal of 7.6 mA in a single bunch, a specification that will be useful when operating in a single- or few-bunch mode for time-resolved experiments. March 24 saw the passing of the milestone known as the "DOE Project Plan Technical Baseline" requirement of 50 mA, a figure well below the maximum current of 400 mA but chosen in recognition that accelerators seldom reach full design performance levels without extensive commissioning and extended operating time. To surpass the 50-mA figure, the ALS accelerator crew further optimized the rf power, phase, and cavity tunes, adjusted the vertical closed orbit, and shifted to a more uniform multi-bunch filling pattern. These improvements took the current to 67 mA and brought a congratulatory letter from Secretary of Energy Hazel O'Leary.

The accelerator crew kept pushing and boosted the stored current to 90 mA the next day after carefully adjusting most of the available corrector magnets and a subset (QFA) of the horizontally focusing quadrupole magnets in the storage-ring TBA lattice. At this point, the beam decayed from 90 to 20 mA in 16 minutes.

A week later, the peak current reached 290 mA, and the accelerator crew decided to limit the current temporarily to 200 mA for further

machine studies until they were sure that no ring component could be overheated by spilled photons or beam-induced effects. Occasional attempts to raise the current were permitted during continuing machine refinements, and the maximum current at the time of writing was 407 mA.

As a third-generation source of VUV and soft x-ray synchrotron radiation, the ALS emphasizes insertion devices in the straight sections between the 12 arcs of the ring. Ten sections are available for undulators and wigglers up to 4.5 m in length. Of the two remaining, one is occupied by injection hardware and the other by two rf cavities. In addition, each arc of the storage ring is fitted with four ports for access to bend-magnet radiation.

Completion of the initial accelerator studies early in May is followed by a three-month shutdown for installation of the first two undulators and front-end hardware for the two undulators, as well as one undulator and three bend-magnet photon beamlines. One of the bend-magnet beamlines is designated for machine diagnostics. It is hoped that completed beamlines for synchrotron-radiation research will gradually become

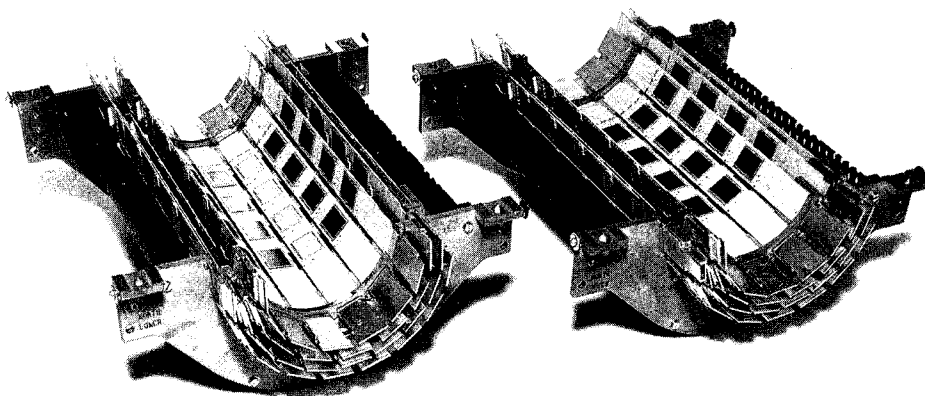
available beginning around August. Over the summer, the ALS accelerator crew will attack the problem of operating with first one and then multiple undulators in the storage ring with their gaps closed to the maximum magnetic-field value.

RUTHERFORD/ STANFORD

First physics from novel detector

Pixel-based tracking detectors are making their mark. The first such detector used for high energy physics was a twin charge coupled device (CCD) assembly at the front end of the CERN fixed target experiment NA32, completed in 1986. Measuring space points on the particle tracks with five-micron precision and having unprecedented track resolu-

The vertex detector for the SLD experiment at Stanford's SLC linear collider, prior to assembly round the beam pipe. The innermost of the four concentric barrels has a radius of 29 mm. The detector consists of 60 ladders, each fitted with 8 CCDs. Each CCD comprises 250,000 independently digitized pixels.



tion, this detector enabled a large variety of charm particle lifetimes to be measured accurately, including the only determination to date of the lifetime of the neutral charmed χ , which lives for only 0.8×10^{-13} seconds.

Following that experiment, the group from the Rutherford Appleton Laboratory and Brunel University in the UK, joined by several Stanford-based physicists, extended this technology to a collider environment (the SLD detector at Stanford's SLC linear collider).

Achieving good solid angle coverage round a 25mm-radius beam-pipe meant increasing the number of CCDs from two to 480. The detector, consisting of 120 million independent elements, started running in May 1992, giving tracking quality as precise as in the earlier fixed target experiment.

The combination of the very small and stable SLC beam spot (just 2 microns across), the small beam pipe, the precise measurement of space points from the vertex detector, and a high quality central drift chamber, is now bringing SLD some clean physics for Z decays into heavy flavour quarks.

One advantage of CCDs for tracking detectors is that since they are widely used, new developments are continually being made. Since the design phase of the SLD vertex detector, the technology has advanced to the point where one of the 'ladders' of eight CCDs could be constructed with a single device, which furthermore could be read out ten times faster.

Such developments will allow even more powerful vertex detectors to be constructed in the future. The main areas of possible application in high energy physics will continue to be in



Environmental work ('wetlands mitigation') for Fermilab's planned Main Injector.

fixed target experiments and in linear colliders.

For the high luminosity conditions of the next generation of hadron colliders, a number of groups are developing 'smart pixel' devices with a micrologic controlled silicon matrix array (January 1990, page 19).

These have demonstrated detector feasibility over small surfaces (half a square centimetre) en route to the much larger areas needed for actual experiments.

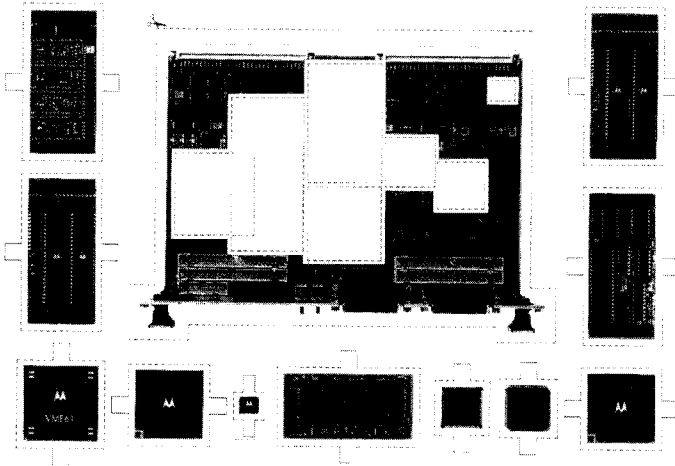
FERMILAB Main Injector

The Fermilab Main Injector (FMI) project is the centerpiece of the Laboratory's Fermilab III programme for the 1990s. Designed to support a luminosity of at least $5 \times 10^{31} \text{ cm}^{-2} \text{ s}^{-1}$ in the Tevatron collider, it will also provide new capabilities for rare neutral kaon decay and neutrino oscillation studies.

The Fermilab Main Injector 8-150 GeV synchrotron is designed to replace the existing Main Ring which seriously limits beam intensities for the Tevatron and the antiproton

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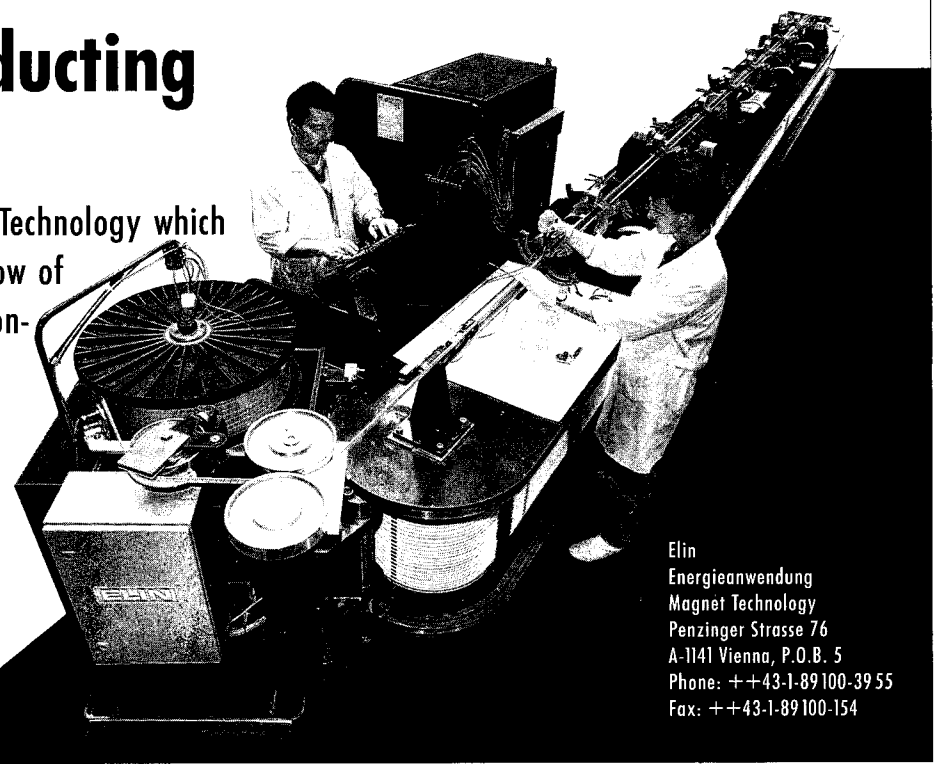
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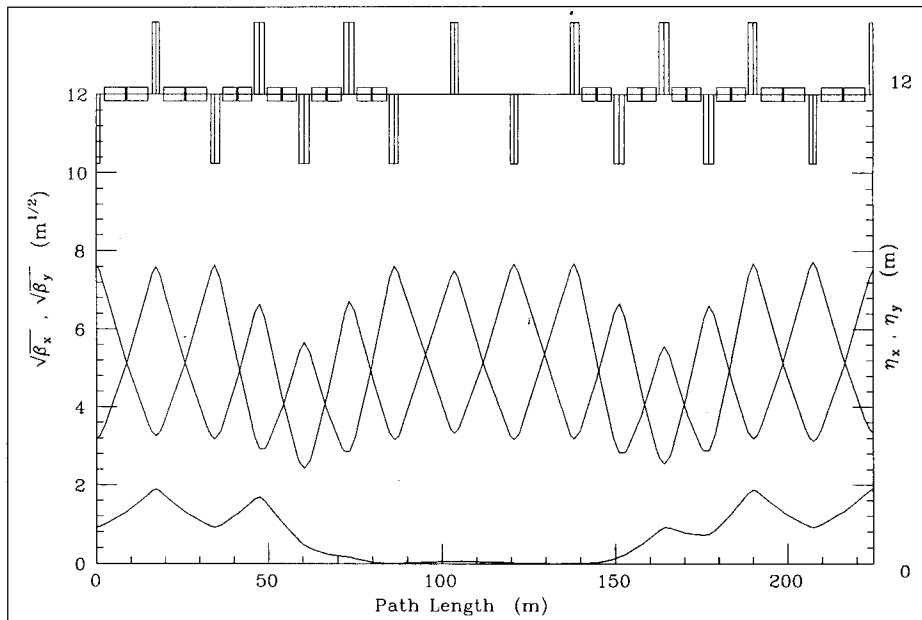
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Characteristics (beta and dispersion functions) for a portion of the Fermilab Main Injector cell design. Shown here (left to right) are a normal cell, a dispersion suppressing cell, a dispersion-free straight cell, a dispersion suppressing cell and a normal cell. The horizontal blocks represent bending magnets while the vertical blocks signify focussing or correction magnets.



production target.

The project has passed several significant milestones and is now proceeding rapidly towards construction. The project received a \$11.65M appropriation in 1992 and has been given \$15M for the current fiscal year. Through the Energy Systems Acquisition Advisory Board (ESAAB) process, the US Department of Energy (DoE) has authorized funds for construction of the underground enclosure and service building where the Main Injector will touch the Tevatron, and to the preparation of bids for remaining project construction.

Last year, work began on filling some six acres of wetlands. Permission had been granted by the US Army Corps of Engineers contingent upon the creation of nine acres of new wetlands close by. Earth moving is complete.

The new accelerator will use 344 new conventional dipole magnets, together with quadrupoles, accelerating radiofrequency cavities and instrumentation from the Main Ring.

The lattice features two types of cells: normal (34.6 m) cells in the arcs and straight sections, and dispersion-suppressor (25.9 m) cells adjacent to the straight sections to reduce the dispersion to zero in the straight.

Tighter focussing and smaller dispersion give smaller beams than in the Main Ring, and over three times the acceptance. The standard cell consists of a FODO lattice containing two 6-metre dipoles in each half-cell. Straight section cells are the same length as normal ones. The dispersion suppressor cells require special length quadrupoles and dipoles; again, the lattice is a simple FODO array with two 4-m dipoles between quadrupoles.

The dipole magnet has been designed and two prototypes constructed and measured. Both magnets give field quality well described by computer models and within the performance specification. The magnets have four 2.54 cm x 10.16 cm turns per pole of conductor (for rapid ramping), with a peak

current of 9375 A, and peak power of 75 kW. The poletip gap is 5 cm, and the good-field region exceeds ± 4.4 cm at injection. At the peak field (1.72 T) there is significant saturation producing a sextupole field which determines the required strength of the chromaticity-controlling sextupole magnets. Twelve production prototype dipoles are to be built in this year before magnet production gets underway.

Four new beamlines will link the FMI to Fermilab's accelerator complex: a 760-m 8 GeV line from the Booster injector, two 260-m beamlines to connect to the Tevatron (one for protons and one for antiprotons), and a beamline to transport 120 GeV protons to the antiproton production target or to the experimental areas. This latter beamline will utilize a remnant of the Main Ring.

The two 150 GeV lines to transfer beams to the Tevatron will be almost mirror images of one another, utilizing Main Ring magnets for all of the dipoles and quadrupoles. Beam transfers to the Main Ring remnant will utilize the same beamline as proton transfers to the Tevatron. The Lambertson magnets at the Tevatron will be turned off, allowing the beam to continue upwards.

R&D work in support of the project is also well advanced. In addition to the dipole effort, R&D for the twelve 1000V/10,000A supplies required to power the dipoles has also begun. Finally, significant progress has been made on the project's 200 kW radiofrequency power amplifier. Eighteen such units will be required.

Much work has been accomplished in technical design, in project management and in permit applications. Fermilab was awarded a State of Illinois grant, with which the architect/

engineering firm Fluor-Daniel provided advance conceptual design work for the civil construction and site mitigation. The state money was also used for environmental impact studies. All other construction permits have been secured construction of the MI-60 underground enclosure began in March.

DUBNA Update

At the annual session of the Plenipotentiaries Committee of the Joint Institute for Nuclear Research (JINR), Dubna, near Moscow in March, Institute Director Vladimir G. Kadyshevsky reported on important recent achievements.

The Nuklotron superconducting accelerator has now been completed and is in operation. (A report will feature in a forthcoming edition of the CERN Courier.)

The FOBOS multiple event spectrometer mounted in the heavy ion beam of the U-400M cyclotron is designed to record the products of nuclear reactions in the high mass and charge region with high efficiency. New experiments are envisaged.

At the IBR research reactor a cryogenic moderator has been put into operation. Physics goals include generation of an impulse flux of cold neutrons. The neutron Fourier high resolution diffractometer was commissioned for polycrystal studies.

Meanwhile an imaginative scheme to establish an International University using JINR research facilities and highly qualified personnel is being implemented.

New appointments include Alexei Sissakian and Tzvetan Vylov as Vice-Directors, Nikolai Russakovitch as Chief Scientific Secretary, Vladislav Sarentzev as Chief Engineer and Alexandre Lebedev as Administrative Director.

Western physicists elected mem-

bers of JINR Scientific council include Ugo Amaldi and Lucien Montanet from CERN, Claude Detraz (IN2P3, Paris), Friedrich Dydak (Munich), Guido Piragino (Italy), George Trilling (Berkeley), Herwig Schopper (Germany) and Norbert Kroo (Hungary).

Earlier this year saw the 80th birthday of Venedikt Dzheleпов, Honorary Director of JINR's Laboratory of Nuclear Problems.



At the annual session of the Plenipotentiaries Committee of the Joint Institute for Nuclear Research (JINR), Dubna, near Moscow in March.

Physics monitor

Neutrinos, atoms and gravity

A interesting overview of ongoing developments in neutrino physics and recent advances in atomic and optical physics and in gravitation emerged from the recent 'Moriond' Workshop on Perspectives in Neutrinos, Atomic Physics and Gravitation Theory, held from January 30 to February 6 at Villars sur Ollon in the Swiss Alps.

Neutrino physics is a Moriond tradition, and the Workshop began with presentations of new measurements of the tritium beta spectrum by the Livermore and Mainz groups, setting limits on the mass of electron (anti)neutrino of 8 eV and 7.2 eV respectively.

It is puzzling that the five most advanced experiments setting upper limits on the electron (anti)neutrino mass (Livermore, Los Alamos, Mainz, Tokyo and Zurich) report negative best-fit values for the square of the neutrino mass, with a weighted average of $-59 \pm 177 \pm 26 \text{ eV}^2$. This corresponds to an excess of counts near the tritium endpoint, rather than a deficit which would indicate a nonzero neutrino mass.

Gerry Stephenson presented a possible explanation, invoking a very light (or massless) scalar boson coupled only to neutrinos. Perhaps more plausibly, a systematic effect may be the cause, and further studies are underway. Nonetheless, the limits are unlikely to change significantly, and the results exclude electron neutrinos as the possible dominant component of dark matter.

The solar neutrino problem persists. The event rate in the Kamiokande experiment is now 0.49 ± 0.04 (stat)

± 0.06 (syst) of the Bahcall-Pinsonneault Standard Solar Model (SSM) prediction. For the new gallium-based experiments, GALLEX, from the first 15 runs, gives $82 \pm 17 \pm 8$ solar neutrino units (SNU), while SAGE sees $58 \pm 17/-24 \pm 14$ SNU, to be compared with the SSM predictions of 125-132 SNU.

Michel Spiro presented simulation results (performed in collaboration with Jim Rich) which show that the three radiochemical experiments' data (Davis et al., GALLEX, and SAGE) are statistically selfconsistent.

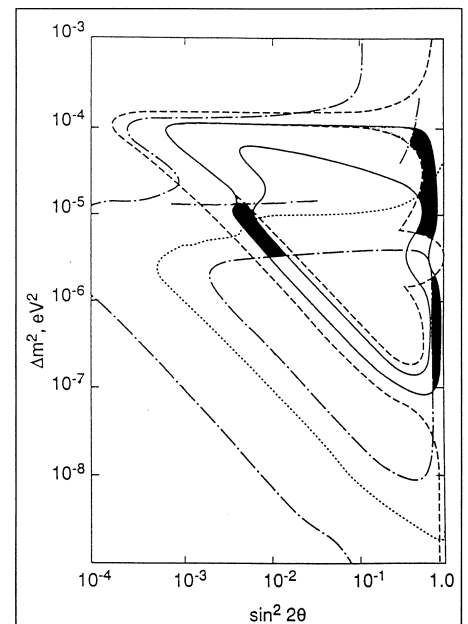
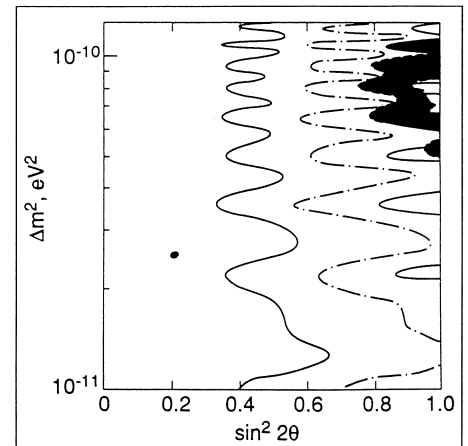
Moreover, given the few events registered so far by the SAGE and GALLEX collaborations (25 and 75, respectively), the results of these two gallium experiments, although different, are still statistically compatible. Thus, Spiro felt justified in combining the two gallium results to yield a weighted average of $72 \pm 17 \pm 14$ SNU.

Marc Pinsonneault showed that the SSMs generally reproduce measured solar parameters quite well, an exception being the abundances of lithium, beryllium, and CNO isotopes at the Sun's surface. Inclusion of rotational mixing may resolve these differences, and initial calculations in this framework show lower rates in the chlorine experiments by 7% at most and in the gallium experiments by less than 1%.

Pinsonneault also looked at possible astrophysical solutions of the solar neutrino problem proposed so far and concluded that all of them have problems (either not self-consistent or incompatible with the observations). This reinforces the case for an elementary particle solution.

While many possible mechanisms are not ruled out (as vacuum oscillations and spin-flavour precession of

Neutrino oscillations at work. Shown in black are the regions of the two parameters (difference of squares of neutrino masses, vertical axis, and lepton mixing angle, horizontal axis) required to fit solar neutrino observations. The top diagram is for vacuum oscillations, the lower for resonant neutrino mixing (the 'MSW Effect'). The figures are from P.I. Krastev and S.T. Petcov.



solar neutrinos, and solar neutrino transitions induced by neutrino flavour changing neutral current interaction), as discussed by Serguey Petcov, the nonadiabatic MSW (Mikheyev-Smirnov-Wolfenstein) transitions provide an especially attractive particle physics solution. Given the gallium results midway between the SSM predictions and a clear signature for a particle physics solution, only the next generation of solar neutrino detectors (SNO, SuperKamiokande, Borexino, and ICARUS) will allow the problem to be

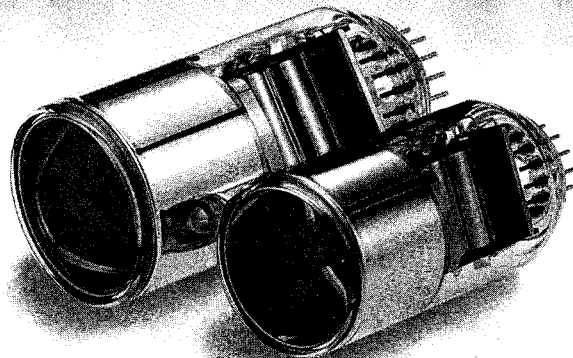
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resolved definitively.

The relative deficit of muon to electron atmospheric neutrinos observed by the Kamiokande and IMB collaborations is confirmed by recent data from Soudan II experiment, albeit with large uncertainties. While the Kamiokande results are consistent with neutrino oscillations, IMB collaboration does not make such a claim, due to much larger systematic uncertainties (attributed mostly to simulations).

An experiment at a test beam at the Japanese KEK Laboratory is being set up in a joint IMB-Kamiokande effort using a 1-kiloton water Cherenkov detector. This should provide important information about electron-muon separation at low energies, crucial for correct interpretation of the Kamiokande and IMB data.

The Moscow-Heidelberg group searching for neutrinoless double beta decay of germanium-76 using an enriched sample detector now has, as reported by Piepke, a lower limit on the isotope lifetime of 1.6×10^{24} yrs, implying an upper limit on a Majorana mass of the electron neutrino of 1.2-1.4 eV (a Majorana particle is its own antiparticle - a Dirac particle has a distinct antiparticle).

Although an excess of events below the endpoint is seen, the shape of the electron spectrum rules out Majoron emission for a Majoron-neutrino coupling greater than 1.8×10^{-4} . This makes it rather unlikely that the excess of events in other experiments is due to Majorons.

Dark matter was covered by Larry Krauss and David Caldwell. The COBE and IRAS satellite data is best fitted by a mix of hot and cold dark matter containing 30% of 7 eV (tau?) neutrinos. Two groups searching for

MACHOs (MASSive Compact Halo Objects) have seen nothing so far, but only a small fraction of the data has been analysed. A new generation of cryogenic detectors should soon be able to probe the region predicted for a supersymmetric dark matter candidate - the lightest neutralino.

Gravitation sessions concentrated mainly on current tests of the equivalence principle, and the theoretical significance of this effort. A special section reviewed the development of the STEP project for a satellite test of the principle. Theoretical talks underlined the challenge of measuring the extremely small effects of any such violation.

Covering such a wide range of different but interrelated areas of physics was a challenge. However in the informal Moriond atmosphere participants could ask even 'elementary' questions, increasing the scope, as well as the depth, of their physics knowledge.

The workshop was organized by J. Tran Thanh Van and his colleagues with the financial support from CNRS, CEA, NSF and the Observatoire de Paris.

Information from T.J. Bowles and P.S. Joshi

Mass-producing B mesons

Since the discovery of the upsilon resonances in 1977 the physics of the fifth quark - beauty - has played a vital role in establishing and consolidating today's Standard Model of particle physics.

In recent years, a wealth of data on B particle (containing the beauty

quark) has emerged from the detectors ARGUS (at the DORIS ring, DESY, Hamburg) and CLEO (at the Cornell CESR ring) as well as from CERN's LEP electron-positron collider and the proton-antiproton colliders at CERN and Fermilab.

But the most challenging goal of this physics is to explore the mystery of CP violation, so far only seen in neutral kaon decays. This subtle mechanism - a disregard for the combined symmetry of particle-antiparticle switching and left-right reflection - possibly moulded the evolution of the Universe after the Big Bang, providing a world dominated by matter, rather than one where matter and antimatter play comparable roles.

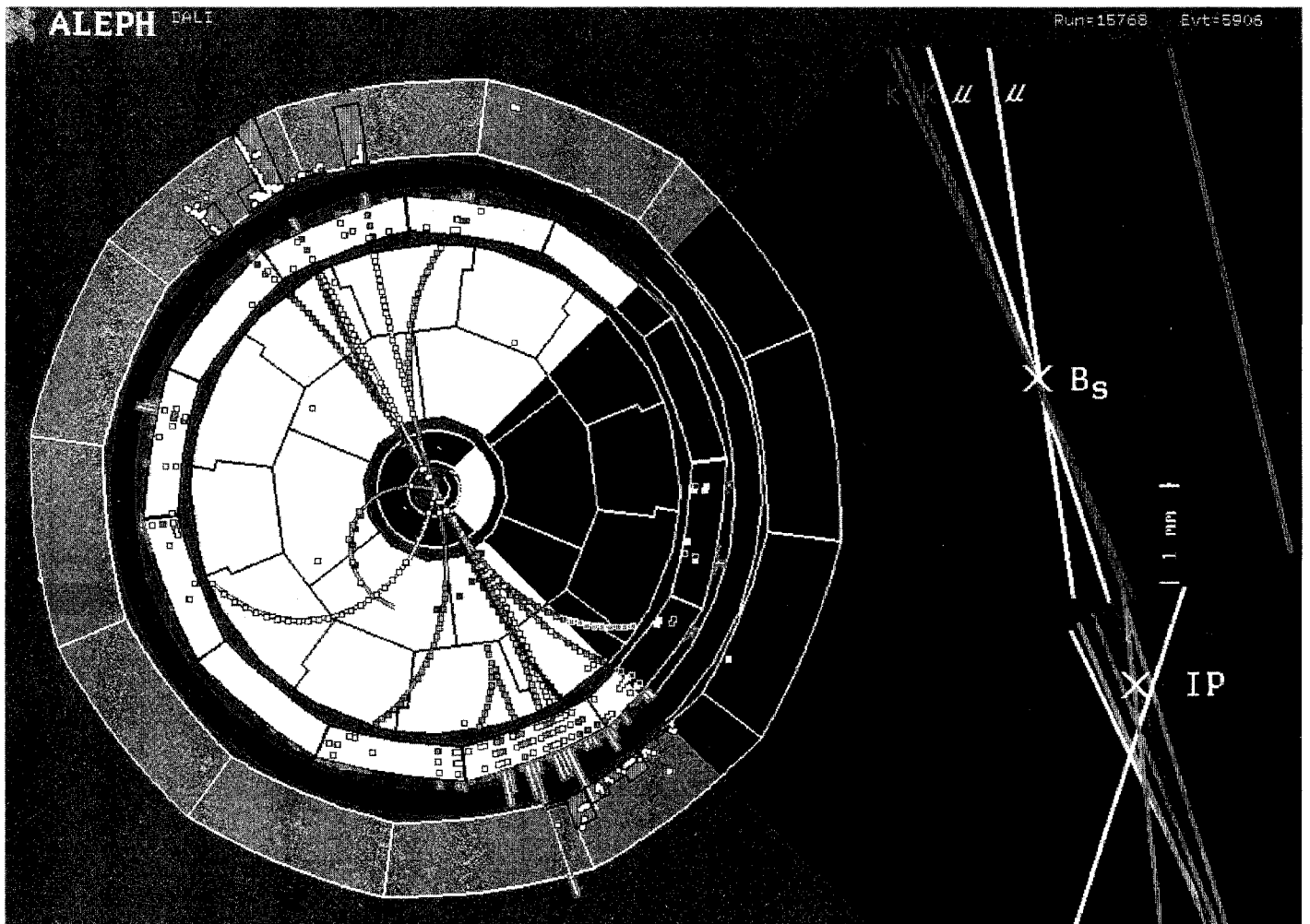
To fully explore CP violation in the laboratory needs a dedicated machine - a particle 'factory' - to mass produce B mesons. Only when this full picture of CP violation has been revealed will physicists finally be able to solve its mysteries.

As well as major proposals in the US and Japan, several ideas have been launched in Europe. Over the years, many working groups have accumulated an impressive amount of data and knowledge on the physics as well as on the machine and detectors.

The spearheads of experimental B physics are the ARGUS and CLEO collaborations. Highlights include the determination of the parameters of the (Cabibbo-Kobayashi-Maskawa, CKM) quark mixing matrix, testing the consistency of the Standard Model with six quarks and three leptons, and giving the first indirect hint that the as yet unseen sixth ('top') quark is very heavy, together with initial indications of how it should decay.

Valuable complementary informa-

A recent sighting at the Aleph experiment at CERN's LEP electron-positron collider was this beautiful fully reconstructed formation of a B_s meson and its subsequent decay into a ψ' meson (subsequently giving a muon pair) and a ϕ meson (giving a kaon pair). The B_s mass is 5.3746 GeV, in accord with theoretical predictions.



tion has come from proton-antiproton collider data and particularly from the LEP experiments at the Z resonance. Experiments at LEP have measured average and individual lifetimes of the various B hadron species as well as the weak neutral current properties of the b quark, while both electron-positron and proton-antiproton studies have been able to establish a significant signal for neutral B mixing. The B_s -meson (containing a strange antiquark and a b quark) and lambda-b baryon have been seen by experiments at CERN.

B physics information can be combined with results from CP

violation in kaon decays to constrain the Standard Model. However, there are still large uncertainties, especially the top quark mass, which to the best of our knowledge is somewhere between 91 and 180 GeV.

Top quark particles will hopefully soon be found at Fermilab's Tevatron collider. However determination of the various quark couplings and form factors needs a reliable theoretical framework. Here lattice gauge theory calculations are promising. Although the present lattice-volumes are not sufficient to simulate B physics directly, reliable methods have been developed in extrapolating the results

on charmed particles, and in the limiting case of an infinitely heavy quark system, both of which have been studied by lattice techniques. These methods are well on their way to providing fully quantitative predictions for many aspects of B decays.

Awaiting experimental determination of several important quark couplings, recent measurements of the D_s meson (strange antiquark and charmed quark) by the WA75 collaboration at CERN provide a useful check on a number of theoretical models and strengthen confidence in lattice results.

To match the precision and reach of

experiments at a B factory needs further development of theoretical tools. A particular goal is to perfect the lattice techniques needed to compute B decays with a precision of 10% or better.

In the same vein, the discovery of heavy quark symmetry by Isgur and Wise in 1989 and its subsequent consolidation has opened up reliable predictions for B decays. This approach exploits the big difference between quark masses, revealing powerful symmetries in heavy quark systems which facilitate computations. The approach has already paid handsome dividends, but data from B factory experiments would increase its usefulness.

Flavour changing neutral current transitions in B decays creep in as higher order (rare) processes and are dominated by virtual top quark contributions. Measurements would provide valuable constraints on the top quark mass and its inter-quark couplings. The recent observation by the CLEO collaboration at Cornell's CESR electron-positron collider of the decay of a B meson into a K^* and a photon provides a good check of the strength of so-called 'penguin' processes (see page 1) and opens a new chapter in the study of weak decays. However exploiting the full potential of the B sector with its many rare decay possibilities requires a B factory. Precision measurements on all these B decays would provide full and stringent tests of the quark mixing matrix and probe any loopholes indicative of new physics.

CP violation in B decays is expected to happen through three mechanisms. The interference of two Feynman diagrams with different weak and strong phases gives so-called direct CP violation. The unequal probabilities for neutral B-

mesons to transform into each other provide another possibility, while the interference of this effect with direct B decay gives a third. In the Standard Model, this latter class might exhibit large CP violating effects, much larger than those seen in kaon decays.

While the bulk of analysis so far uses a Standard Model context, B decays also provide a scenario for physics beyond the Standard Model. With high production rates for tau leptons, a B factory will allow searches for many decays at levels at least two orders of magnitude more sensitive than present limits.

The wide diversity of B decay channels needs to be exploited to improve our understanding of weak decays. Present measurements and theoretical analyses support the Standard Model, but consistency is not yet complete. Experiments at a B meson factory will pin this down.

In particular, the possibility of observing CP violation in B decays is an outstanding opportunity to finally get to grips with a fundamental physical phenomenon vital to our understanding of the evolution of universe.

Last but not least, there is the general dissatisfaction with the Standard Model, where masses and mixing patterns have to be put in by hand. Understanding this is one of the major challenges facing physicists today, and a B factory could provide the long-sought clue to what makes the Standard Model tick.

From Roy Aleksan (Saclay) and Ahmed Ali (DESY)

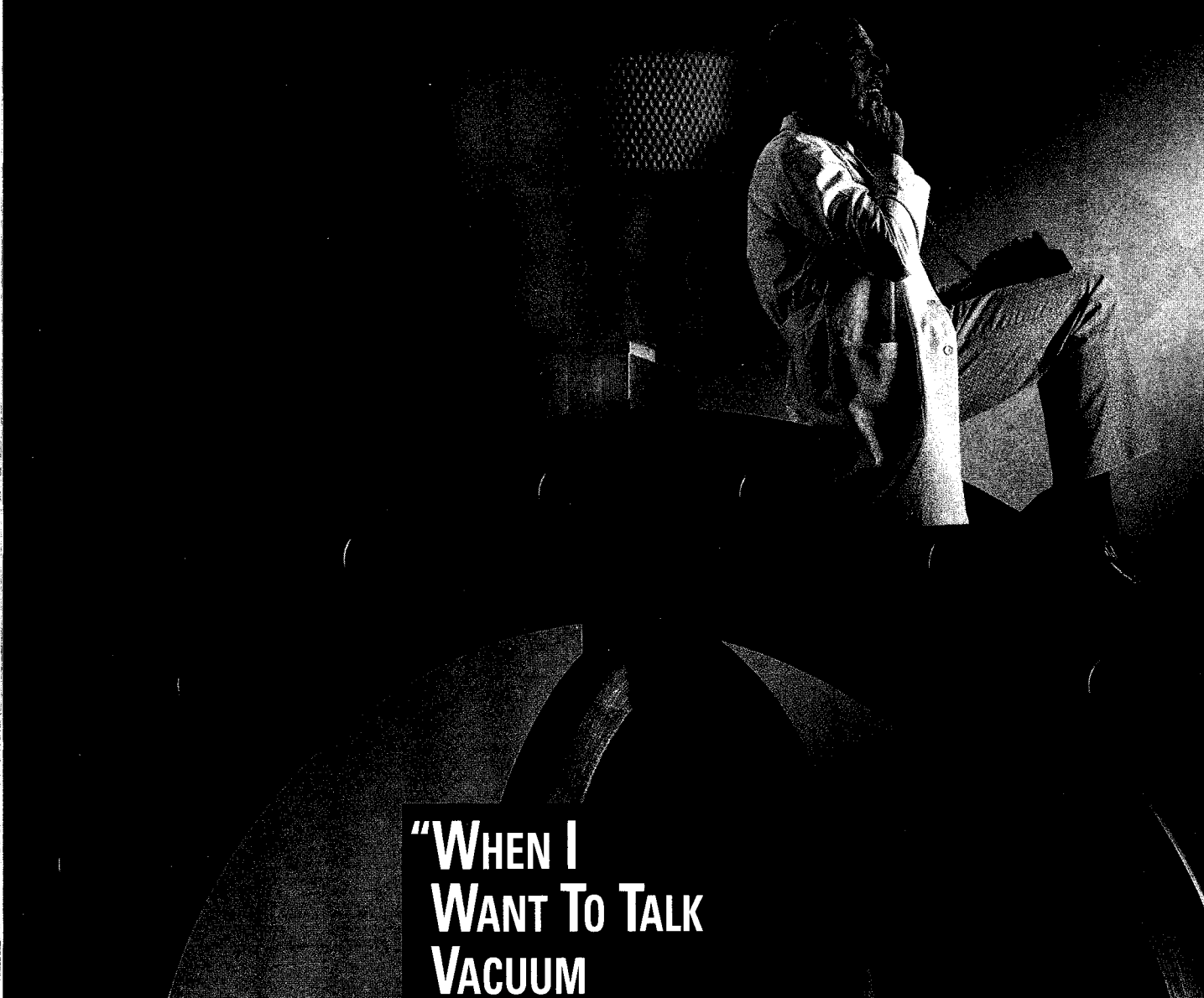
Physics and astrophysics of quark-gluon plasma

The quark gluon plasma - matter too hot or dense for quarks to crystallize into particles - played a vital role in the formation of the Universe. Efforts to recreate and understand this type of matter are forefront physics and astrophysics, and progress was highlighted in the Second International Conference on Physics and Astrophysics of Quark Gluon Plasma (ICPA-QGP 93), held in Calcutta from 19-23 January. (The first conference in the series was held in Bombay in February 1988).

Although primarily motivated towards enlightening the Indian physics community in this new and rapidly evolving area, in which India now plays an important role, the conference also catered for an international audience. Particular emphasis was placed on the role of quark gluon plasma in astrophysics and cosmology.

While Charles Alcock of Lawrence Livermore looked at a less conventional picture giving inhomogeneous ('clumpy') nucleosynthesis, David Schramm (Chicago) covered standard big bang nucleosynthesis. The abundances of very light elements do not differ appreciably for these contrasting scenarios; the crucial difference between them shows up for heavier elements like lithium-7 and -8 and boron-11.

Richard Boyd (Ohio State) highlighted the importance of accurate measurements of the primordial abundances of these elements for clues to the cosmic quark hadron phase transition. B. Banerjee (Bom-



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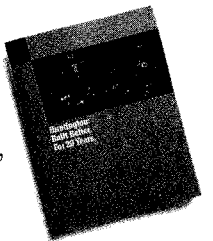
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Participants at the recent Calcutta International Conference on the Physics and Astrophysics of Quark-Gluon Plasma.



bay) argued, on the basis of lattice calculations, for only slight supercooling in the cosmic quark phase transition - an assertion which runs counter to the inhomogeneous nucleosynthesis scenario.

Jes Madsen of Aarhus reviewed the role of (meta)stable strange quark matter in astrophysics and cosmology, discussing the prospects for distinguishing between neutron stars and quark stars (where the neutron matter is compressed into a cold version of quark-gluon plasma).

P. Bhattacharya (now at Bangalore) reported the results of recent calculations by the Calcutta group with a colour flux tube model giving evaporation from quark nuggets formed in the cosmic phase transition. With conservative estimates of baryon number above which such nuggets would be stable, they are a viable candidate for dark matter. However self-consistency conditions require these nuggets to be of supernuclear density, in contrast to those of normal density postulated by Ed Witten some time ago.

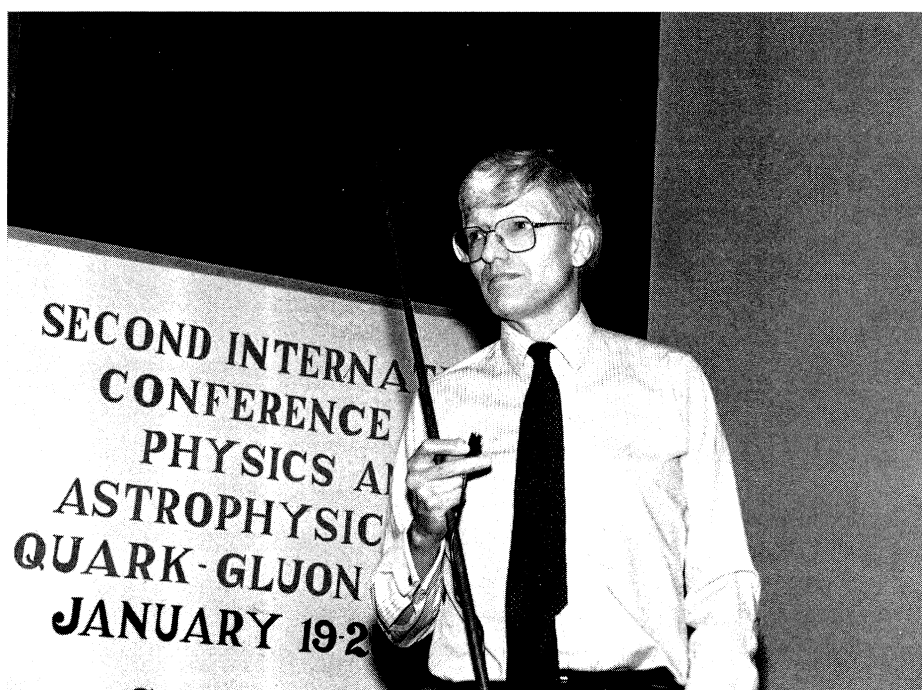
On the experimental side, Albert Romana (Palaiseau) reported the recent analysis of dimuon data by

NA38 at CERN. Hans-Ake Gustafsson (Lund) discussed WA80 (CERN) data on charged particle distributions for sulphur-32 beams. Karl-Heinz Kampert (Munster) focussed on WA80 data on thermal photon and neutral meson production for oxygen and sulphur projectiles

while Thomas Peitzmann (also WA80) presented results on pion-pion interferometry, claiming a two component structure of the pion source, with one component substantially bigger than the original target. Preliminary proton-proton correlation measurements, he reported, show no such effect.

Chris Voltolini (Strasbourg) gave the strangeness measurements of the NA36 collaboration. J. Dodd (Columbia) showed preliminary NA44 data on two-particle correlations in proton and sulphur beam experiments. Johanna Stachel (Stony Brook) reviewed the results from the Brookhaven AGS experiments. Soren Sorensen (Knoxville and Oak Ridge) discussed measurements of

CERN Director General designate Chris Llewellyn Smith at the Calcutta quark-gluon plasma meeting.



transverse and forward energies.

The consensus was that although SPS (CERN) and AGS experiments clearly indicate the formation of hot dense nuclear matter, on the other hand one does not necessarily need to invoke QGP formation to explain any of the observations, including the key suppression of J/psi or strangeness enhancement.

What then happened to the confident predictions of some years ago that at energy densities of a few GeV/fm³, QGP must be formed? This is closely linked to the estimation of stopping in nuclear collisions, as pointed out by Franz Plasil (Oak Ridge) in his experimental overview. We do not as yet have an universally accepted criterion for estimating stopping, and the evaluation of initial energy density depends, noted Plasil, quite sensitively on this estimate.

Many experimental talks looked forward to new experimental possibilities and new machines - new beams at CERN's SPS, new energy domains from RHIC at Brookhaven and LHC at CERN.

In the theory talks, Sibaji Raha (Calcutta) reviewed the status of electroweak probes for possible QGP signals. Summarizing the work of the Calcutta group, he showed that photons can indeed be a viable QGP signal, contrary to the apprehension resulting from recent work which suggested that massive resonances make a hadron gas 'shine' as brightly as QGP.

The other important Calcutta result, reported by Raha and J. Alam, is the transverse expansion in nuclear collisions at SPS, RHIC and LHC energies. They showed that with transverse expansion, the importance of including higher mass resonances in the hadronic phase 'pales' with increasing energy, and at

LHC energies, the lifetime of the reaction seems unaffected by whether the hadronic phase is treated as only massless pions, or pions and massive resonances. It thus seems that photons continue to be viable QGP signals, assuming preequilibrium photon production is neglected. It was however pointed out that preequilibrium photon production could indeed play havoc with the electroweak signals, an observation made by the same group over two years ago. Detailed analysis of photon and dilepton signals, taking into account all these effects at all energies, are eagerly awaited.

Rajiv Gavai (Bombay) and Sean Gavin (Brookhaven) discussed J/psi production and related matters. J.Y. Ollitrault (Saclay) proposed anisotropy in transverse momentum distributions as a signature of transverse collective flow. Klaus Werner (Heidelberg) reviewed the status of various event generators in the market for the simulation of ultrarelativistic nucleus-nucleus collisions. There were no talks on lattice calculations due to a couple of last minute cancellations. Arthur Poskanzer (Berkeley) and Bikash Sinha (Calcutta) respectively summarized experiment and theory.

The conference was inaugurated by P.K. Iyengar, then Chairman of the Atomic Energy Commission of India, who pointed out that with ICPA-QGP 1988 having initiated the younger generation of Indian physicists, there was now a responsibility to nurture them. He noted with satisfaction that Indian participation in experimental QGP studies had matured remarkably in the intervening five years and urged scientists to broaden their horizons through these and other collaborative efforts. This was underlined by C.H. Llewellyn Smith's talk

on the future directions of CERN activities, where he welcomed greater involvement of Indian scientists.

In all it was a stimulating week for the 220-odd participants. Civil unrest in India at the time made the organizers' work difficult, but those who did attend could vouch for excellent organization by Santanu Pal and his team. Several participants felt it should not be as long as five years before the next conference in the series.

The genesis of unified gauge theories

by Tom Kibble

Abdus Salam in Munich, 1947.



states of a single fundamental entity, the nucleon. The symmetry was generalized to include Yukawa's mesons in an important paper by Nick Kemmer in 1938, which is incidentally perhaps one of the first papers to suggest the need for a neutral current.

Kemmer was very influential in British theoretical physics in the immediate post-war period. He was Paul Matthews' supervisor in Cambridge and when I was a student in Edinburgh he was my Head of Department, having succeeded Max Born in 1953.

In the forties and fifties, as new particles proliferated, it was natural to try to bring some order into this chaos by enlarging the symmetry group beyond the SU(2) of isospin, especially after the discovery of the new quantum number, strangeness.

Salam had students working on every conceivable symmetry group. One of those students was Yuval Ne'eman, who had the good fortune and/or prescience to work on SU(3). From that work, and of course from

From 8-12 March, at a 'Salamfest' at the International Centre for Theoretical Physics in Trieste, Italy, friends, colleagues, admirers and former students paid tribute to the Institute's founder and director Abdus Salam, and his contributions to science. Presentations centred around the development of today's Standard Model of particle physics and attempts to go beyond it, and the parallels between the physics of condensed matter and elementary particles.

During the week, Salam was awarded the honorary degree of Doctor of Science by the Rector of St. Petersburg University, Academician S. Merkuriev.

While in recent years Salam has mainly been identified with the Centre which he established in 1964, many of his important contributions to physics came when he resided permanently at London's Imperial College. At the Trieste Salamfest, Tom Kibble, formerly Head of Physics at Imperial and a longtime colleague of Salam, described Salam's role at Imperial in the quest for a unification of electromagnetism and the weak force. In 1979 Salam, Sheldon Glashow and Steven Weinberg shared the Nobel Physics Prize for the new synthesis, one of the major achievements of 20th-century physics.

(This is an abridged version of the talk, the complete version being available on request from Tom Kibble at the Blackett Laboratory, Imperial College, London, SW7).

The theoretical physics group at London's Imperial College in 1959 had three permanent faculty: Abdus Salam, his erstwhile thesis supervisor Paul Matthews, and John C. Taylor. I joined as a lecturer the following year.

In those early days we had lots of visitors, both long- and short-term - Murray Gell-Mann, Ken Johnson, John Ward, Lowell Brown, Gordon Feldman and Steven Weinberg.

About a year after I arrived we were transferred from the Mathematics to the Physics Department under the formidable Patrick (P.M.S.) Blackett. Having been brought up in the Cavendish Laboratory tradition under Lord Rutherford, Blackett was rather scornful of theoretical physicists, but he knew a good thing when he saw one and had persuaded Salam to join the rapidly expanding Physics Department.

In 1960 field theory was widely regarded as very *passé*. It had had its triumphs: renormalization theory had made sense of divergences, and quantum electrodynamics had been magnificently vindicated.

But field theory didn't seem to work for anything else, particularly not for the strong interactions, and was definitely out of fashion. There were, however, a few places in the world where field theory was still studied unashamedly. Imperial College was one. Harvard was certainly another; many of our visitors over the next few years were Julian Schwinger's students.

At Imperial there were two dominant theory themes: symmetries and gauge theories. Both had their origins in the concept of isospin.

The isospin symmetry between protons and neutrons had shown how two apparently disparate particles might be regarded as different

The International Centre for Theoretical Physics, Trieste, Italy was founded by Abdus Salam in 1964.

the independent work of Murray Gell-Mann, stemmed the Eightfold Way, with its triumphant vindication in the discovery of the omega-minus in 1964.

Salam himself made many important contributions to these symmetries, but I believe this was not his first love. His real goal was to find the ultimate theory to describe the weak, electromagnetic and strong interactions, and even gravity - what we would now call a Theory of Everything.

From an early stage, certainly well before I joined Imperial, Salam was convinced that the ultimate theory would be a gauge theory.

The starting point was the epoch-making paper of Yang and Mills in 1954. There may be others who deserve some of the credit - Weyl, Klein, Shaw, Utiyama - but Yang and Mills articulated very clearly the 'gauge principle' - sometimes paraphrased as 'Nature abhors a rigid symmetry'.

Yang and Mills argued that a rigid, global isospin symmetry is incompatible with relativistic field theory. Their point was that once isospin symmetry has been accepted, it is arbitrary which component is identified with the proton and which with the neutron. But it then seems odd that making this choice should automatically fix the convention throughout all space for ever. So they looked at what needed to be done to make isospin a local symmetry.

The gauge principle provided a natural basis for electromagnetic interactions, and after the work of Yang and Mills people began to look for gauge theories of the strong and weak interactions.

The first goal was strong interactions; that is what Yang and Mills themselves were after. But it was



hard to make progress because calculations were difficult. With such a strong coupling, perturbation theory would not work, and the asymptotic freedom of quarks was unknown.

So the weak interactions emerged as a better bet. There were certainly tantalizing hints of a structure very similar to electrodynamics. While Fermi's classic recipe with four particles interacting at a point was obviously non-renormalizable, it was probably a shorthand way of writing an effective interaction due to the exchange of a heavy boson.

Progress was held up while people searched for the correct space-time symmetry of the weak interaction. The breakthrough came with another suggestion of Yang's, working this time with T.D. Lee, that mirror symmetry (parity) is not conserved in weak interactions. After the fall of parity in 1957, Salam was one of the first to point out the connection between left-handedness and a zero mass neutrino.

Meanwhile Marshak and Sudarshan

and Feynman and Gell-Mann showed how the weak interaction should be written down. This suggested that weak interactions could be mediated by a charged vector boson, the W.

The seemingly insuperable difficulty was the large W mass. If the interaction were of the same strength as electromagnetism, the W mass would have to be about 40 GeV. But putting a mass term in the Lagrangian would destroy the gauge invariance, and the heavy vector particle would make the formalism blow up and become unrenormalizable.

As early as 1958, Salam and John Ward proposed a unified gauge theory of weak and electromagnetic interactions, involving a charge triplet of vector mesons, with the neutral component identified with the photon. They placed the electron, neutrino and positron too in a triplet. This was ingenious, but of course they could only obtain the parity-conserving part of the weak interaction. Parity

Abdus Salam at Stockholm in 1979 - the first Pakistani to receive the Nobel Award.

violation was artificially imposed, and the W mass put in by hand.

Two years later they proposed a unified theory of weak, electromagnetic and strong interactions, based on the gauge group $SO(8)$, a paper well ahead of its time, foreshadowing later ideas of grand unification.

But these theories did not really work; nor did similar ones proposed by Glashow and others. The major obstacle remained the vector meson mass. This was essential to make the interaction weak and short-range, but apparently incompatible with both gauge invariance and renormalizability. The only way anyone knew to make a vector-meson theory renormalizable was to use zero-mass gauge bosons.

As often happens, progress was delayed by a 'folk theorem'. Theoretical physicists sometimes quote 'theorems' that everyone believes but eventually turn out not to be true.

One such folk theorem was that the photon is massless because of gauge invariance, considered one of the predictive successes of the gauge principle. In 1961 Julian Schwinger said this theorem might be false, although he was thinking more about strong interactions at the time.

Another folk theorem came in when people began edging towards spontaneous symmetry breaking to explain the heavy gauge mesons. Here the Goldstone theorem apparently predicted unobserved massless spin-zero particles.

When Steven Weinberg came to Imperial College in 1961-62, he and Salam, collaborating at long range with Jeffrey Goldstone, spent a lot of time confirming this theorem. In condensed-matter physics, counterexamples to the Goldstone theorem were known for long-range



forces. But the theorem seemed to rule out this mechanism for relativistic theories.

An important 1963 paper by Phil Anderson showed how Schwinger's suggestion of a heavy gauge field could work. One example was the plasmon: in a high-density plasma the photon acquires a non-zero 'mass' - the plasma frequency. But Anderson also pointed out, using the example of superconductivity, how Goldstone bosons could 'become tangled up with Yang-Mills gauge bosons and, thus, do not in any true sense have zero mass'. He concluded 'the Goldstone zero-mass difficulty is not a serious one, because we can probably cancel it off against an equal Yang-Mills zero-mass problem'. This is exactly what is now known as the Higgs mechanism.

This should have cleared everything up, but these new ideas were difficult to understand. By the time Gerry

Guralnik and Dick Hagen, both at Imperial that year, and I had also realized the Goldstone theorem doesn't apply to gauge symmetries, others were there too. The result was published independently in 1964 by Englert and Brout and by Peter Higgs.

So by 1963-64 the problem of the origin of mass was solved, at least in principle. But there was still another major hurdle, to unify weak interactions, which are parity-violating, with electromagnetism, which is not. It took another three years to realize that for the photon to coexist with the parity violation of weak interactions, the gauge group had to be extended from $SU(2)$ to $SU(2) \times U(1)$, with two neutral particles rather than one.

Actually the solution, or something very like it, was already there in Sheldon Glashow's 1961 paper which had proposed $SU(2) \times U(1)$ with mixing between the neutral particles, but this was before the key concepts of spontaneous symmetry breaking and the Higgs mechanism had been developed.

At Imperial, Salam kept plugging away at the problem, especially in collaboration with John Ward. In autumn 1967, Salam gave a series of lectures at Imperial in which he described the $SU(2) \times U(1)$ theory. Meanwhile the same model had been found independently by Steven Weinberg.

When Weinberg's paper appeared I was at Rochester, where Bob Marshak asked me to give a talk to his weekly discussion group.

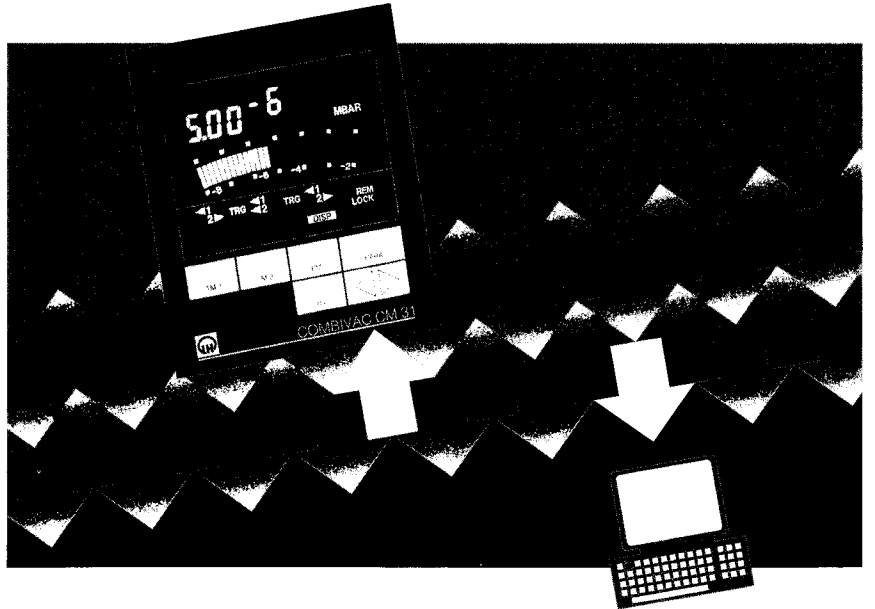
I mentioned that Salam and Ward had been working on very similar ideas, and focused on the problems in constructing a unified theory of weak and electromagnetic interactions and how ingeniously the new model avoided them. However I

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While I was myopic, in a sense I was right. The whole thing seemed much too ad hoc and ugly, with its curious built-in asymmetry between the left- and right-handed fermions and its large number of independent parameters. If it is part of the final theory, it is ugly; surely the Creator was having an off day! But that is not the right way to look at it. Seen merely as one step towards a still undiscovered final theory, the intricate way the electroweak picture fits together does have a remarkable beauty.

It is sad that Paul Matthews, who died tragically six years ago, could not have given this tribute. For many years, Imperial was Salam and Matthews. They made a superb team, exactly complementing each other's strengths and abilities.

Paul Matthews (1919-1987). Abdus Salam's first mentor.



First crumb of research

In 1964, Abdus Salam introduced Paul Matthews' inaugural lecture at London's Imperial College. It was a poignant moment. Salam, who had taken his first steps in theoretical physics at Cambridge under Matthews' watchful eye, had become Imperial's first professor in Theoretical Physics. Now he was overseeing the promotion of his former supervisor.

Salam recalled his 1949 research debut at Cambridge, where, because of impressive examination results, he had initially been directed towards the laboratory.

'Soon, I knew the craft of experimental physics was beyond me,' wrote Salam later. 'It was the sublime quality of patience which I lacked.' Looking towards theory, he had gone to Nicholas Kemmer (in the front row at Matthews' inaugural). Kemmer had said he had enough students already and did not want another. Salam had pleaded, and fortunately Kemmer had relented.

'All theoretical problems in quantum electrodynamics have been solved by Schwinger, Feynman and Dyson,' Kemmer had told Salam. 'Paul Matthews has applied their methods to meson theories. He is finishing his PhD. Ask him.'

At Imperial in 1964, Salam recalled that first meeting with Matthews in 1950.

'What are you reading?' Matthews had asked.

'Heitler's Quantum Theory of Radiation,' had come the reply. It was the only standard text at the time.

Matthews quickly recommended instead the new work by Schwinger, Feynman and Dyson, then known

only to a privileged few.

Later, his PhD complete, Matthews left a research 'crumb', as Salam put it. The agreement was that Salam would look at a continuing problem in meson field renormalization while Matthews took a few months off before starting work at Princeton in the fall. If Salam had made no progress, Matthews would repossess the problem.

Characteristically, Salam's first act as a research student was to phone Freeman Dyson (his 'hero'), then visiting Birmingham, and ask for an interview. The discussion continued on the train to Southampton, where Dyson was to embark for the US. The seeds of the solution were sown and soon the 'crumb' problem was solved. It was the start of a meteoric career.

People and things

This model twin-aperture superconducting magnet from the research and development programme for CERN's LHC proton-proton collider recently achieved a magnetic field of 10.25 tesla at 2K.

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Elisabeth Locci
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Yu. Ryabov
- Stanford Linear Accelerator Center, (USA)
M. Riordan
- Superconducting Super Collider, (USA)
N. V. Baggett
- TRIUMF Laboratory, (Canada)
M. K. Craddock

LHC magnets

In the research and development programme for CERN's LHC high energy proton-proton collider to be built in the 27-kilometre LEP tunnel, a model twin-aperture superconducting magnet recently achieved a magnetic field of 10.25 tesla after being cooled to 2K.

The magnet used new wide-cable niobium-titanium conductor, with up to 27,000 5-micron filaments.

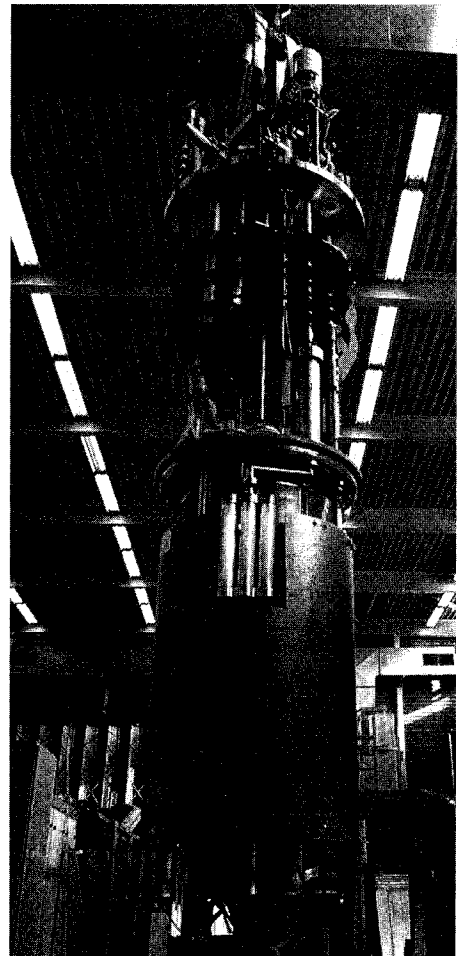
Meanwhile on 23 April an agreement was signed between CERN, Helsinki University of Technology and Uppsala University for the development of prototype LHC superconducting magnets. CERN LHC superconducting magnet development work already involves collaborations with partners in Austria, France, Germany, Holland, Italy, Spain and the UK.

Physics cinema

Physics cineast Lynn Silverman's 53-minute film 'Anatomy of an Experiment' about the Aleph collaboration at CERN's LEP electron-positron collider had peak time showing on the Franco-German 'Arte' channel in May.

Oxford accelerators

Oxford Instruments are combining skills from their Synchrotron and Cyclotron groups into an Accelerator Technology Group under Martin Wilson. Principal activities are manufacture of compact superconducting synchrotrons and cyclotrons, together with development and design work for new accelerator applications and research equipment.



Gerhard 'Gerry' Fischer 1929-93

Gerhard 'Gerry' Fischer of the Stanford Linear Accelerator Center (SLAC) died on 7 February. After research at Columbia and Harvard, he became convinced of the importance of electron-positron colliders. He moved to SLAC for the design and construction of the SPEAR ring. As well as being responsible for SPEAR's injection system, he also designed the solenoid magnet for the famous Mark I experiment. Subsequently he went on to assume a major role in the development of Stanford's SLC Linear Collider.

University of Lancaster
School of Physics and Materials

TWO RESEARCH ASSOCIATE POSITIONS

Applications are invited for two postdoctoral Research Associate Positions in the Particle Physics Group. The successful candidates 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 HERA at DESY.
3. Detector development for the inner tracking detector for the ATLAS collaboration at the LHC at CERN.

Both posts are supported by the SERC in the UK. Applications consisting of a CV together with the names of two referees should be sent to:

Professor T Sloan
School of Physics and Materials
University of Lancaster
Lancaster LA1 4YB
UK

(e-mail: TS@UK.AC.LANCS.PH.V1).

from whom further details can be obtained. The closing date for applications is 30 June 1993.

HEAD OF FACILITIES DEPARTMENT NATIONAL SUPERCONDUCTING CYCLOTRON LABORATORY MICHIGAN STATE UNIVERSITY

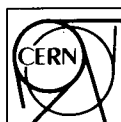
The National Superconducting Cyclotron Laboratory at Michigan State University is seeking to fill the position of Head of the Facilities Department. The NSCL has a staff of approximately 130 people and it is funded by the National Science Foundation for research in basic nuclear physics, accelerator physics, and related instrumentation R&D. The Head of the Facilities Department will be responsible for directing approximately 10 technical professional staff in the disciplines of ion source operation and related R&D superconducting magnet design and fabrication, and cryogenic and mechanical engineering. The department is responsible for the continued reliable operation of the experimental facilities including the ion sources, K1200 superconducting cyclotron, and associated beam transport systems. The department is also expected to initiate and/or participate in R&D projects aimed at improving present operations.

The candidate must have a demonstrated ability to manage in a technical research environment. Previous experience in accelerator laboratories is highly desirable. A bachelor's degree or equivalent in mechanical engineering, electrical engineering, or physics with at least five years professional experience is required.

Positions in the NSCL Continuing Appointment system parallel tenure system ranks at MSU. Applicants should send resume to Ms. Chris Townsend, Laboratory Administrator, Cyclotron Laboratory, Michigan State University, East Lansing, MI 48824-1321 by July 12, 1993. Michigan State University is an affirmative action/equal opportunity institution. Women and minorities are especially encouraged to apply.

University of South Carolina Faculty Position in High Energy Physics

The Department of Physics at the University of South Carolina invites applications for a tenure-track position in the area of experimental high energy physics to begin on January 1, 1994. The position is at the assistant professor level although appointment at a higher level may be considered for an exceptionally qualified candidate. The South Carolina high energy group currently pursues e^+e^- collider physics at KEK's TRISTAN ring using the AMY detector and two experiments at Fermilab, E789 on two-body B^0 decays and E687 on charm photoproduction. The ongoing programs would welcome new members, but candidates with other research interests will also be considered. Applicants should submit a curriculum vitae and publications list, a statement of research interests, and the names of professional references to **Prof. Frank T. Avignone, III, Chairman, Department of Physics and Astronomy, University of South Carolina, Columbia, SC 29208**. The University of South Carolina is an Affirmative Action / Equal Opportunity employer and solicits applications especially from qualified women and minorities.



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1992 Physics Nobel Georges Charpak (right) tours the successful 'La France au CERN' trade expo held at CERN from 30 March to 2 April.



Alexander S. Davydov (1912-1993)

A.S. Davydov died in February of a disease induced by a heart attack. In the early 1940s simultaneously and independently of Rarita and Schwinger he proposed a relativistic equation for spin $3/2$ particles. Later he shifted towards solid state theory, nuclear physics, nonlinear phenomena and biophysics. Such notions as "Davydov splitting", "Davydov-Filippov model of nonaxial nuclei", "Davydov solitons" became widespread. A popular author of brilliant books and manuals, his "Quantum Mechanics" is used worldwide as a basic text. He worked in Moscow, Kiev, Obninsk and Ufa. From 1973-88 he headed the Institute for Theoretical Physics of the Ukrainian Academy of Science in Kiev, and remained as Honorary Director of the Institute.

From L. Jenkovszky and V. Loktev (Institute for Theoretical Physics, Kiev)

On 29 March CERN Research Director Walter Hoogland formally opened CERN's travelling exhibition in Prague, organized in collaboration with the Czech Academy of Sciences, with Czech Deputy Ministers P. Bratinka (left, Foreign Affairs) and V. Ludvik (right, Industry and Trade).

A Guide to Radiation and Radioactivity Levels Near High Energy Particle Accelerators, by Anthony H. Sullivan, Nuclear Technology Publishing, Ashford TN231JW UK (ISBN 1-870965-18-3)

The design of shielding and the prediction of the induced radioactivity for high energy accelerators have usually been considered by most accelerator builders as a somewhat mysterious subject for which they were largely dependent on the wisdom of a few specialists.

This has changed dramatically for people with a do-it-yourself mentality after the publication of this delightful book by Tony Sullivan of CERN, which will stand as his 'scientific testament', condensing the knowledge from a lifetime's work as a radiation protection physicist.

For each subject Sullivan gives a short description of the physics involved, after which he uses his extensive experience around CERN accelerators to condense a diversity

of physics processes into a wealth of handy formulae and tables as well as almost 100 graphs.

This data enables those with minimal knowledge in this field to find their own answers to many of the radiation protection questions which arise in accelerator design, such as the dose rate as a function of shielding thickness, the shape and dimensions of access chicanes, skyshine from weak spots in roof shielding, the level and decay rate of induced radioactivity during a machine shut-down, etc.

There was clearly a strong need for such a handbook, and I am convinced Sullivan's book will save a lot of time for people involved in radiation protection around accelerators.

Bastiaan de Raad

European Physical Society

After two years in office, Maurice Jacob of CERN steps down as President of the European Physical Society. His successor is Budapest



**Physics Faculty Position
Theoretical Accelerator Physics
University of Houston**

The Department of Physics invites applications for a tenured, or tenure-track position which it expects to be open for Fall 1993, at a rank appropriate to the qualifications of the candidate. Applicants for the position are expected to have extensive experience in theoretical research on high energy accelerators and storage rings. Involvement in operation of accelerators, and beam studies, are considered important. The candidate is expected to have demonstrated outstanding excellence in research, and to have interest and ability in teaching. Topics of research interest at UH include: beam dynamics in linacs, space charge effects in low energy proton synchrotrons, optimization of synchrotron tunes in the presence of nonlinear multipole fields, self-consistent treatment of beam-beam interaction in hadron colliders, emittance dilution due to periodic crossings of nonlinear resonances, and the optimum arrangement of magnets in superconducting rings. The group maintains active collaborations with Argonne, Brookhaven, Fermilab and SSCL. Students participate in theoretical investigations as well as various beam studies during residence at laboratories. Applicants should send a full resume and the names of at least references as early as possible, to Prof. Roy Weinstein, Chairman of Search Comm., IBPD, Room 632 SR1, University of Houston, Houston, Texas 77204-5506. The University of Houston is an equal opportunity/Affirmative Action Employer.

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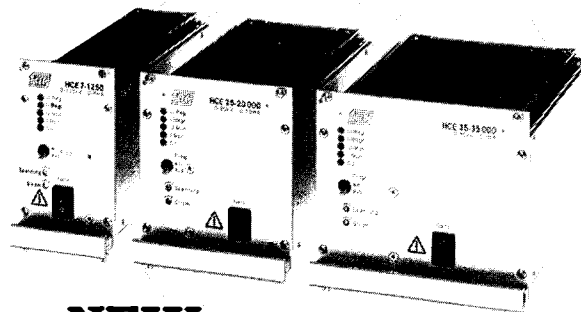
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condensed matter physicist Norbert Kroo. Former CERN Director General Herwig Schopper was reelected to the Executive Committee.

The Society's recent Council meeting in Nice also underlined the importance of EPS involvement in physics education.

Meetings

This year's DESY Theory Workshop on "Quantum Chromodynamics" will be held in Hamburg (Germany) from Sept.29 - Oct.1, 1993. Further information from O.Nachtmann (Chairman), Inst. Theor. Physik, Universitaet Heidelberg, D-6900 Heidelberg (Germany); e-Mail: C12 at vm.urz.uni-heidelberg.de



Neutrino 94 - the XVI International Conference on Neutrino Physics and Astrophysics - will be held from 29 May - 3 June 1994 in Eilat, Israel. Contact Arnon Dar, Dept. of Physics, Technion, Haifa 32000 Israel. Fax +972.4.221514, e-mail phr19ad@technion

The second biennial workshop on nucleon-antinucleon physics will be held at the Institute of Theoretical and Experimental Physics (ITEP), Moscow, from 13-18 September. Further information from Naja Smorodinskaya, ITEP, B. Cheremushkinskaya ul. 25, 117259 Moscow, Russia, fax +7(095) 123 6584, e-mail nan93@vxitep.itep.msk.su. Or Silvia Giromini (fax +39 6 9403 243) or Donatella Pierluigi (fax +39 6 9403

European Physical Society and physics education. At the recent EPS Council meeting in Nice, Uppsala particle physicist G. Tibell (left), responsible with G. Marx of Budapest for the new EPS Forum on Education, talks with C.M. Ferreira of Lisbon, who oversees education matters on the EPS Executive Committee.

559), INFN-Laboratori Nazionali di Frascati, cp 13, 00044 Frascati, Italy, decnet vaxInf::nan93 bitnet nan93@irmlnf

Internal targets at HERA

At DESY an international workshop on 'Physics at HERA with internal targets' from September 21-23 will discuss the physics accessible with both the 30 GeV electron and the 820 GeV proton beam of HERA. Special emphasis will be given to: the physics accessible through scattering experiments with polarized/unpolarized electrons and polarized/unpolarized targets; Beauty Physics and CP violation using the HERA proton beams; and the implications for proposed and planned experiments and the accelerators. Participation is open to anybody interested. For further details from e-Mail WIT93@VXDESY.DESY.DE or fax: ++49 40 8994 4304.

Polarized beams at Stanford

A marked increase in beam polarization and a recent doubling of the luminosity at Stanford's SLC linear collider have considerably increased physics potential. Story in the next issue.

L. Jackson Laslett

Prominent Berkeley machine physicist L. Jackson Laslett died on 7 May. A full tribute will appear in the next issue.

C. de Witt (left), founder of the Les Houches Summer School over 40 years ago, and A. Nemoz, President of the University of Grenoble, at les Houches in April to discuss future les Houches programmes. During the meeting, the main auditorium was dedicated to the late Y. Rocard who served on the Les Houches Board for many years. C. de Witt was recently awarded the 'Prix du Rayonnement français'. (Photo M. Jacob)

Elementary Particle Physics

The Particle Physics Department of the Rutherford Appleton Laboratory has a vacancy for an Elementary Particle Physicist to work on its experimental programme. The Department is engaged in research at CERN and DESY and other Institutes abroad. The programme also includes non-accelerator experiments.

The successful applicant will be expected to participate in one of the current projects and to plan future experiments for the next generation of accelerators. He or she will be required to work closely with other members of the Department and to collaborate with physicists from Universities and other Institutes in the UK and abroad. Communication skills and the ability to contribute effectively as a member of a team are therefore essential. He/she should be prepared to spend a significant fraction of his /her time working overseas, if required.

The appointment will be made in the Higher Scientific Officer or Senior Scientific Officer grade, according to ability and experience. The salary ranges are:

Higher Scientific Officer	£12,833 to £22,669 pa
Senior Scientific Officer	£15,929 to £28,687 pa

Formal minimum entry qualifications required for the Higher Scientific Officer grade are a degree, HNC/HND or equivalent in a relevant subject together with at least 2 years Post Graduate experience with a first or second class honours degree or 5 years relevant experience with an ordinary degree, HNC/HND or equivalent. For the Senior Scientific Officer grade a first or second class honours degree plus at least four years post graduate experience is required. It is expected that the successful candidate should have several years of post-doctoral experience in the field of Elementary Particle Physics. We offer excellent working conditions and benefits include a non-contributory pension scheme and generous holidays.

For an application form please contact the Recruitment Office, Personnel and Training Division, Science and Engineering Research Council, Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, OX11 0QX. Tel: 0235-445435 for an application form, quoting reference number VN 1114.

All applications must be returned by 25th June 1993

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Rutherford Appleton Laboratory

Physicist – Silicon Detector Systems

The LBL Physics Division is participating in the design and construction of several major silicon detector systems. The most demanding is the SDC Silicon Tracker, which requires a variety of novel techniques in front-end electronics and electro-mechanical integration.

LBL is seeking a technically oriented physicist to assume responsibility for the development of Silicon Tracker detector modules, which combine detectors, integrated front-end electronics and cabling. Low-mass hybrid and cabling technologies are critical components of this work, which requires close interaction with commercial vendors. Overall electronic and mechanical characteristics of modules will be measured and analyzed in detail to tailor the design to the experimental environment. With a total of 6.5 million channels, the Silicon Tracker requires carefully developed procedures for quality control, reliability testing, installation, maintenance, and operation.

LBL offers a wide range of technical expertise, including semiconductor device design and fabrication utilizing the LBL Microsystems Laboratory. Our IC

design group has extensive experience in conventional and radiation-hard technologies.

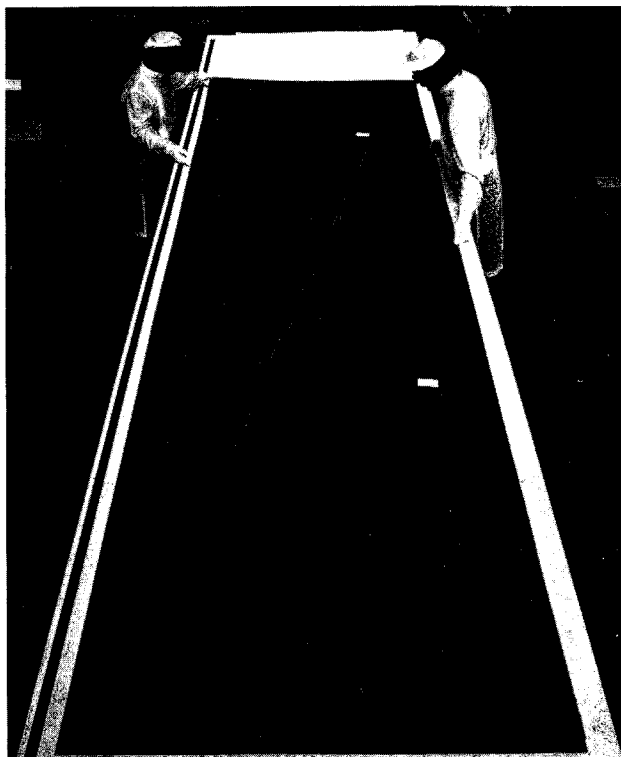
Applicants must have participated in the technical design, installation, and use of complex particle detector systems in high-energy or nuclear physics experiments (not limited to silicon technology). The tasks require a thorough understanding of electronic detectors and measurement techniques, coupled with experience in the conceptual design of small mechanical systems. The ability to carry out research independently and interact with a diverse group of scientists and engineers is essential. Ph.D. in experimental physics preferred.

This is a term appointment, with the possibility of becoming a career appointment. Please send your resume, with references and salary history to: **Lawrence Berkeley Laboratory, Staffing Office, Job #A/1305, One Cyclotron Road, Bldg. 90/1042, Berkeley, CA 94720.** We are an equal opportunity employer.



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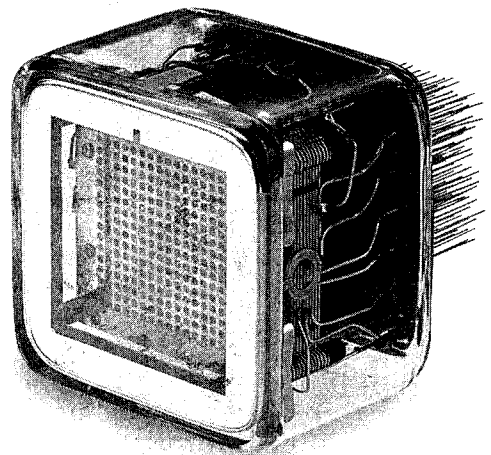
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