CERN COURIER

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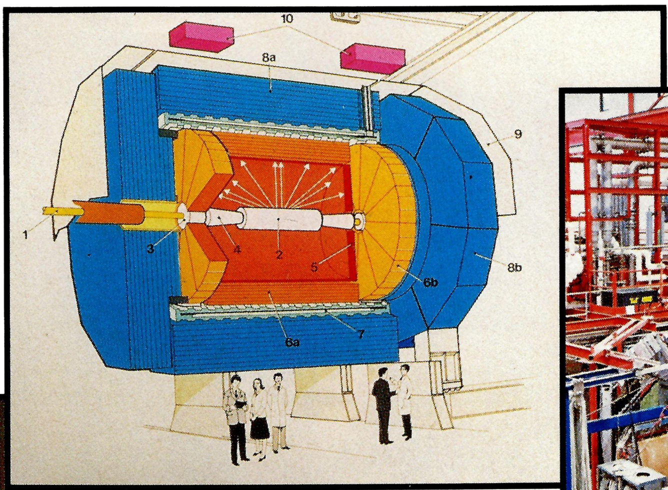

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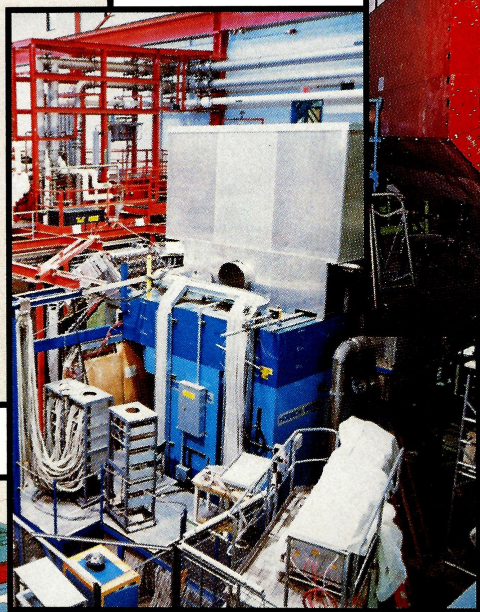

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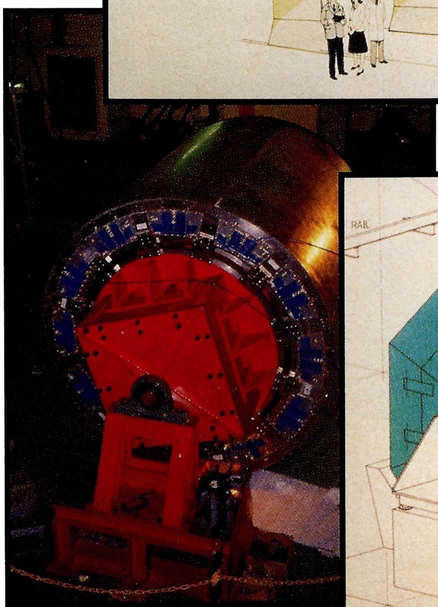

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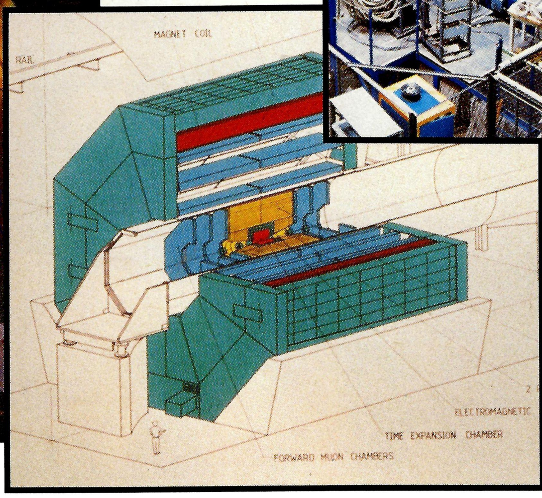

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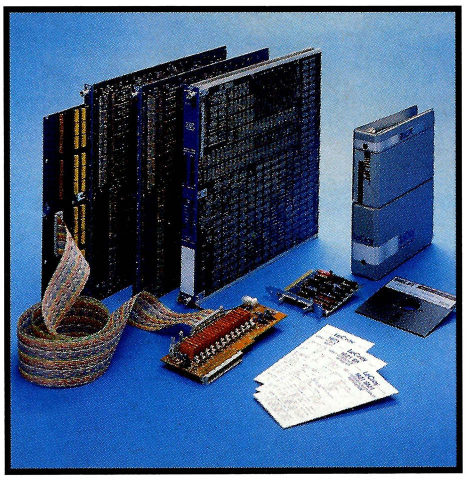

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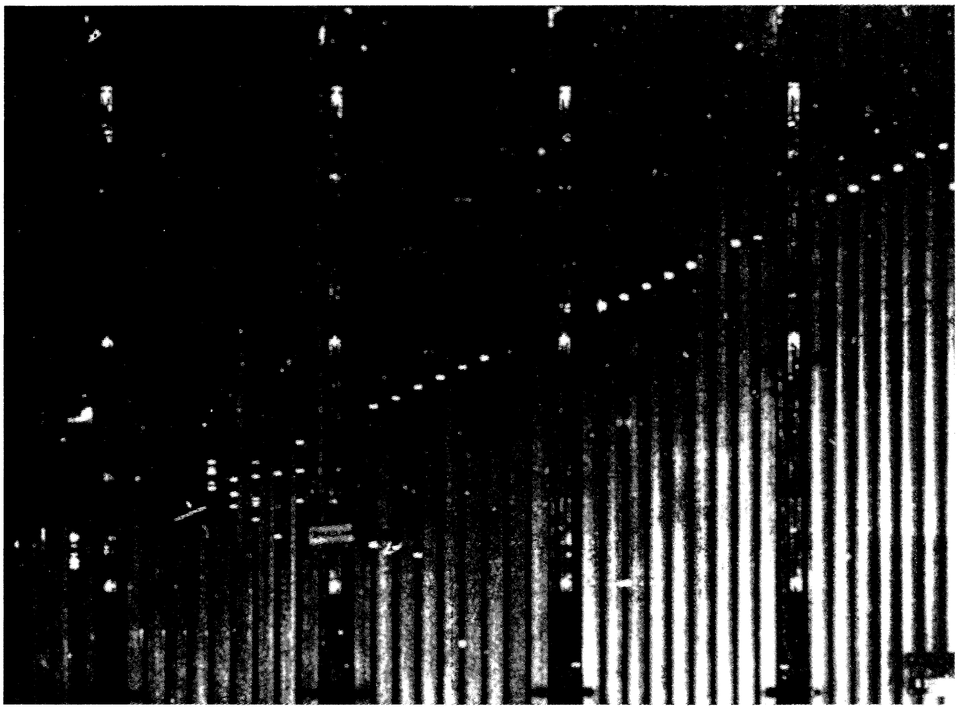
Cover photograph:
The sparks fly at L3. Installation work for the experiments at CERN's 27-kilometre LEP electron-positron collider pushes ahead – see page 38 (Photo François Julliard, CERN).

Nobel Prize 1988



A 1962 neutrino makes its mark – the long tell-tale track of a muon shows up clearly in the ten-ton spark chamber of the world's first experiment using high energy laboratory neutrinos.

At the beginning of the 1960s, new proton synchrotrons were getting into their stride at Brookhaven and at CERN. What physics questions could be answered using these high energy machines?

At about the same time, physicists intrigued by the subtleties of the weak nuclear interaction were asking whether the decays of the pions and kaons copiously produced by high energy proton beams could give a secondary neutrino beam for physics experiments. Neutrino experiments were not new – in the 1950s F. Reines and C.L. Cowan had detected free neutrinos produced from the beta decay of fission products in a nuclear reactor – but the idea of making a neutrino beam in a Laboratory was. As neutrinos interact only through the weak nuclear force, perhaps such experiments would reveal vital new information about this force.

Physicists suspected that neutrinos come in two types – those associated with electrons, and those produced along with muons, heavier cousins of the electrons. The clue was that nobody had seen a muon decay into an electron and a gamma ray (photon), a process which otherwise should be commonplace. (Jack Steinberger, for one, had spent a lot of time looking for just this decay.) Theorists also pointed out that even the flimsy understanding they then had of weak interactions would be in trouble unless there were two types of neutrinos, one for electrons, one for muons.

Neutrino physics needed a lot of shielding to screen off other particles, and with low energy neutrinos able to pass virtually unhindered through millions of miles of lead, it also called for a big detector and lots of neutrinos to maximize the chances of catching any. A detector looking for different types of neutrinos also had to be able to distinguish between muons and electrons.

Jack Steinberger and Leon Lederman first met at Columbia University's Nevis Laboratory in New York in 1951 when its 385 MeV synchrocyclotron was just coming on-line – then the highest energy machine in the world. Attending undergraduate courses at Columbia at the time was Mel Schwartz, who went on to become Steinberger's student. When Schwartz returned to Columbia in 1958 after a stint at Brookhaven, the talented trio became intrigued by the possibility of a neutrino experiment at the new Brookhaven Alternating Gradient Synchrotron.

Muons travel long distances without doing much, while electrons quickly dissipate their energy into characteristic showers of particles. Just appearing on the scene at the time was a new kind of detector – the spark chamber. When a high voltage pulse was applied to a series of thin plates, after a charged particle had ionized the gas between the plates, the chamber lit up with a nice track. This seemed to be the way to go, however for neutrinos it meant building a spark chamber bigger than anyone had ever done before.

At Brookhaven the stage was being set for this first physics production using beams of artificial neutrinos. As well as Lederman, Schwartz and Steinberger, the Columbia/Brookhaven team also included Gordon Danby, Jean-Marc Gaillard, Dino Goulianos and Nari Mistry.

Mel Schwartz relates: 'in planning for experiments, I tend to be an optimist, and when we first sat down to do the figures, we said "well, we ought to get one event per ton per day". That was the number we worked with. Actually it turned out to be smaller than that, but fortunately we built a 10-ton detector'.

The massive spark chamber was

Neutrino experiment group at Brookhaven in 1962 – left to right; Jack Steinberger, now head of the Aleph experiment at CERN; Konstantin Goulianos, now at Rockefeller; Jean-Marc Gaillard, now working at CERN; Nariman Mistry, now at Cornell; Gordon Danby, now at Brookhaven; Brookhaven technician Warner Hayes; Leon Lederman, now Director of Fermilab; and Mel Schwartz, now with Digital Pathways.

completed in the summer of 1961 and worked extremely well. As the experiment got underway later that year, the neutrino shielding (armour plate from a naval scrapyard) was gradually increased to a thickness of 13.5 metres – and after several months the first tell-tale sign of physics appeared – a neutrino had hit the spark chamber, producing a long muon track going all the way out of the detector.

In the end the pioneer experiment caught about fifty examples of muon production by neutrinos, corresponding to about one event per day in the ten-ton detector – only a tenth of what had been anticipated, but nevertheless the first examples of high energy neutrinos interacting with matter. The dominant muon signal showed clearly that the neutrino comes in two kinds – electron-like and muon-like. (A single type of neutrino would produce equal numbers of electrons and muons.)

The results emerged in a classic 1962 paper, and neutrino beams went on to become one of the standard tools of particle physics. 26 years later Lederman (now Director of Fermilab), Schwartz (now with his company, Digital Pathways, in California) and Steinberger (now head of the Aleph experiment being installed at CERN's LEP electron-positron collider) received the Nobel accolade. On hearing the news, Steinberger, 67, said, 'if you want to get that prize, do your work early!'.

Supercollider site

On 10 November US Energy Secretary John S. Herrington announced the 'preferred' site for the proposed US Superconducting Supercollider – SSC. After evaluation of seven initially selected sites (March issue, page 13), the preferred location for the 84-kilometre ring to collide 20,000 GeV proton beams is an area of gently rolling prairie some 40 kilometres south of Dallas, Texas. The final decision is scheduled for January after an environmental review. Construction funding has yet to be voted.

Gearing up for UNK

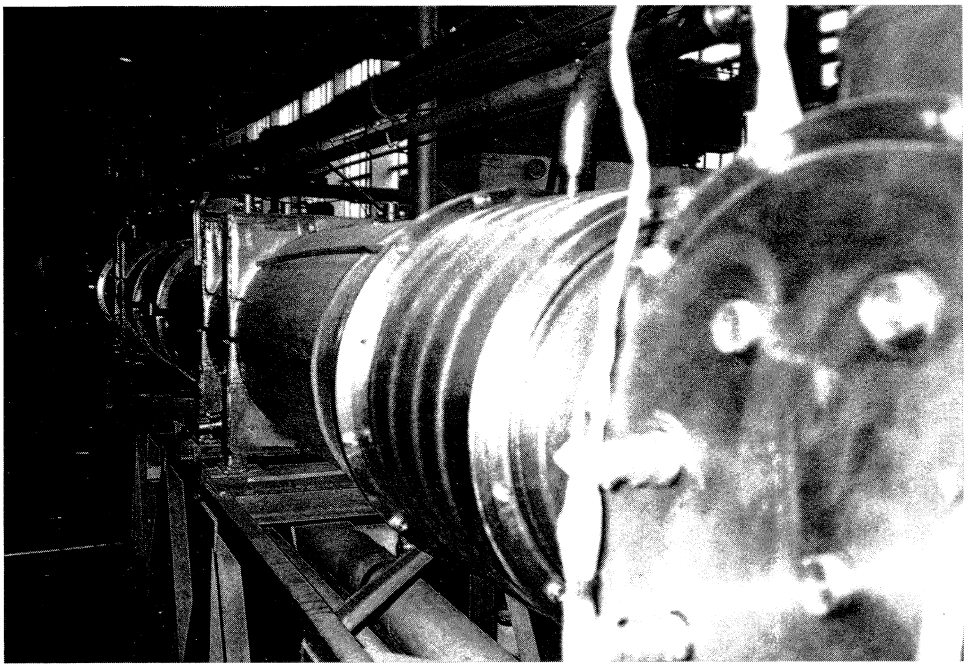
Going by its announced goals, the Soviet Institute for High Energy Physics (IHEP) at Protvino, near Serpukhov in the Moscow region, and celebrating its 25th anniversary this year, should in the next five to six years become one of the major world centres for particle physics research.

The road is marked UNK, a 21 kilometre tunnel eventually to house three proton rings. Construction work began modestly in 1984, however a top level Moscow decision last year promoted UNK to priority status (January/February issue, page 3). The plan now is to have a 400 GeV ring of conventional magnets (UNK-1) injecting into the UNK-2 superconducting ring attaining 3 TeV (3000 GeV) feeding fixed target experiments. If all goes well, the UNK fixed target programme should be underway by 1994.

A second superconducting ring (UNK-3) would add 6 TeV proton-proton collisions to the experimental programme several years later. Another result of last year's top level decision is the plan to construct a big linear electron-positron collider alongside UNK, eventually to attain multi-TeV energies. The Novosibirsk Laboratory is acting as scientific coordinator for this part of the project, and the first contingent from Novosibirsk is getting installed at IHEP.

Conventional magnets for UNK-1 are now arriving in quantity from Leningrad. Development work for the superconducting magnets to steer the higher energy beams in UNK-2 and UNK-3 began with warm iron (Fermilab-type) magnets. Fields attained 6.2 tesla, well above the design figure of 5 tesla, but tests revealed substantial heat leaks, unwelcome in a 21 kilometre ring.

Prototype six-metre cold iron superconducting dipole magnet under test for the UNK machine being built at the Soviet Institute for High Energy Physics (IHEP), Protvino, near Serpukhov. Supplying 3 TeV (3000 GeV) proton beams, the 21 kilometre UNK ring, scheduled to come into operation by 1994, should then be the world's highest energy machine.



Attention turned to a cold iron (HERA-type) design, with a simpler cryostat. With increased superconductor current-carrying capacity and using 16 wires per cable instead of 23, the amount of superconductor could be reduced by 30 per cent. After 30 short model cold iron magnets were put through their paces, two full length six-metre cold iron dipoles performed well.

By any standards, building the thousands of magnets to equip two 21 kilometre superconducting rings is a considerable technological and logistical challenge. Niobium-titanium wire, supplied by Soviet industry, is wound at IHEP into cable and insulated. Cryostats are also supplied by industry, but IHEP is taking on the bulk of the mammoth task of assembly work.

The first 100 six-metre cold iron magnets should be completed in IHEP's existing assembly shops next year. For the main assembly task, a vast 20,000 square metre hall has been built, and the on-site manpower will be considerably increased. When work is in full swing, each of the three main production lines should deliver one magnet per day.

The vast refrigeration system, supplied by the 'Cryogenmash' agency, will use six main liquifiers (two of which will normally be held in reserve) with satellite liquifiers around the ring, Fermilab-style, to provide 60,000 watts of cooling power for a maximum of 10,000 litres of liquid helium per hour.

With additional manpower now available after last year's high level decision, about half the tunnelling work is complete, and good progress is being made. A full face boring machine is soon to make an appearance, driving out from the ring towards the experimental area for fixed target experiments. A second such machine is also on the cards. Tunnelling should be complete late next year.

Meanwhile the experimental programme at the existing IHEP 70 GeV 1.5 kilometre synchrotron continues to develop. Physicists foresee about five years before the

▼ IHEP will assemble the thousands of superconducting magnets for the high energy UNK-2 and UNK-3 rings (both fixed target and collider physics are foreseen). Here is one wing of the new 20,000 square metre magnet assembly hall at IHEP, showing some of the first conventional magnets (manufactured in Leningrad) for the 400 GeV UNK-1 ring.

(Photos G. Fraser)

machine has to undergo a major shutdown to adapt to its new role as the UNK injector, supplying 5 x 10^{13} protons per pulse.

In the meantime an internal target and four extracted beam zones cater for a range of studies, including the GAMS multi-photon detector (May issue, page 21), and a new multiparticle spectrometer.

Neutrino physics uses a new complement of detectors, including a big counter experiment in the wide-band beam and two 20 metre tanks of liquid argon with aluminium targets for exposure to a tagged beam. The SKAT heavy liquid bubble chamber, the world's last big detector of this type, is still available.

Following an international workshop on UNK experiments last year (see May issue, page 1), ideas for the future experimental programme began to take shape (see July/August issue, page 6). A study of spin effects using a gas jet target will be the first experiment to get underway, using the UNK-1 ring, but will be subsequently transferred to UNK-2. Other proposals for fixed target work include studies with hyperon beams and polarized beams, and several experiments using new spectrometers. For the collider, a big calorimetric detector and a streamer chamber study are being put forward.

However the situation is still fairly fluid, and more proposals would be welcomed, especially if these bring in outside collaboration. These should appear soon, before civil engineering plans are finalized for the start of experimental hall construction in 1990. It is hoped to have the experimental programme decided by the end of 1989.

A further workshop on the UNK experimental programme is to be held at Protvino from 20-24 March.

25 years

The Soviet Institute for High Energy Physics (IHEP) at Protvino, near Serpukhov in the Moscow region, this year proudly celebrated its 25th anniversary. While awaiting completion of the 21 kilometre UNK ring, the world's largest proton machine, the Laboratory continues to be centred around the 70 GeV proton synchrotron.

When it came into operation in 1967, this machine supplied the world's highest particle energies, a position it held until the arrival of CERN's Intersecting Storage Rings and Fermilab's 500 GeV machine in the early 1970s. This first look at an unexplored physics terrain naturally led to several early important results.

Under an agreement between CERN and the USSR State Committee for Atomic Energy signed in 1967, joint CERN/IHEP experiments soon got underway at the 70 GeV machine. One early result was the interesting 'scaling' behaviour of the production rates of different particles. With the kinematics appropriately scaled, measurements using different particle beams fell into line, suggesting that effects due to the quark constituents (in those days known as partons) of nucleons were becoming important at these higher energies. Landmark studies at the Stanford linac discovered these effects using electron beams in 1968, but the IHEP results were the first time such behaviour had been seen using beams of hadrons (strongly interacting particles).

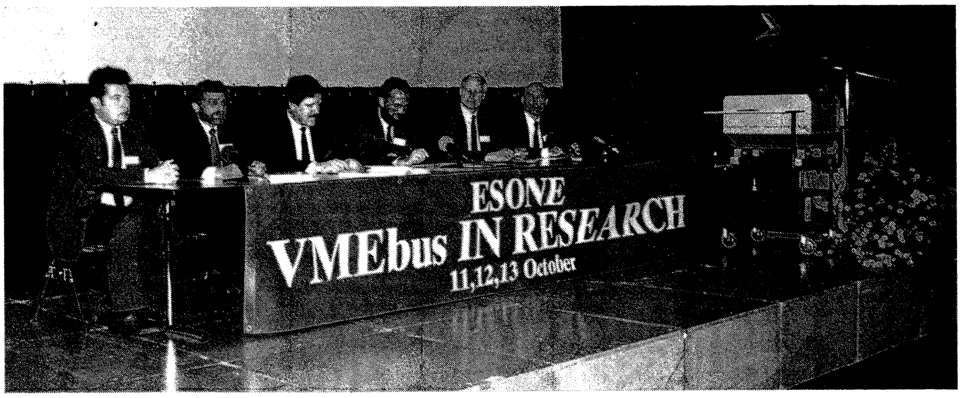
Before the CERN Intersecting Storage Rings (ISR) opened up new energy horizons in the early 70s, experiments with the IHEP machine provided the first indications of particle affinities (total cross-sections) beyond the energies previously surveyed at CERN and Brookhaven. Instead of falling with increasing energy (as had been observed previously), these cross-sections were seen to flatten out, and, with positive kaons, even rise, heralding what was to come at the ISR.

Other physics highlights have included the sighting of the antitriton (the antinucleus of helium-3) in 1971 and the discovery in the mid-70s of high spin mesons which provided valuable fuel for the quark model of particles. A decade of painstaking studies has provided valuable new insights into the behaviour of light mesons, with many rare decay modes having been seen, while spectrometers (including the GAMS photon spectrometer developed under the CERN/USSR agreement) have evidence for exotic mesons outside the simple quark model (see page 25).

VMEbus in research

*** *On 18 November, first protons were accelerated to 50 MeV in the new proton linac at the German DESY Laboratory, Hamburg.***

At a panel discussion on software at the 'VMEbus in Research' meeting held in Zurich in October – left to right – Martin Timmerman (VITA Benelux User Group), Shlomo Pri-Tal (VITA Technical Committee Chairman), Kim Kempf (Microware), Chris Eck (CERN), Hugh Maaskant (Philips), John Rynearson (Mizar).



More than 500 participants, more than 40 exhibitors, the largest ever ESONE conference, the largest ever VMEbus-only event: these were some of the superlatives coming from the ESONE 'VMEbus in Research' conference held in Zurich from 11-13 October.

Associated with ESONE (the European Standards on Nuclear Electronics committee of European Laboratories) in the organization of the conference were CERN, the European CAMAC Association (ECA), the International Federation for Information Processing (IFIP), the Paul Scherrer Institute (PSI, formerly SIN, Switzerland), the Swiss Automation Pool and the VMEbus International Trade Association (VITA).

The Swiss Institute of Technology (ETH) generously allowed the use of their magnificent building overlooking the city of Zurich, as well as providing the technical support for the presentations and exhibition. The conference was a sequel to 'VMEbus in Physics' sponsored by, and held at CERN in October 1985, where the development and application of the standard, as well as problems specific to its use in high energy physics, were explored.

VMEbus, 'the most popular microprocessor backplane bus ever', to quote one speaker at the conference, was introduced at CERN in 1982 in response to the requirement for a platform for the then newly introduced Motorola M68000 family of 16/32 bit microprocessors.

In simple terms, VMEbus can be considered as the basis of a modular computer, allowing elements such as processors, memories and communications links to be combined into the desired system, and which may be reconfigured and enlarged almost at will. Coming from the adaptation of Motorola's proprietary 'VERSAbus' onto 'Euromechanics', the VMEbus ('VERSA Module Europa') was jointly developed as an 'open' bus by Motorola, Mostek and Philips/Signetics.

In this context its 'openness' is very important since the VMEbus specification was placed in the public domain and has, subsequently, been standardized by the IEEE and the IEC. There are no copyrights, no royalties and no ties to any one manufacturer, in fact there are now several hundreds of companies producing VMEbus boards world-wide. The standard is now under the guardianship of VITA, a non-profitmaking association of manufacturers and users.

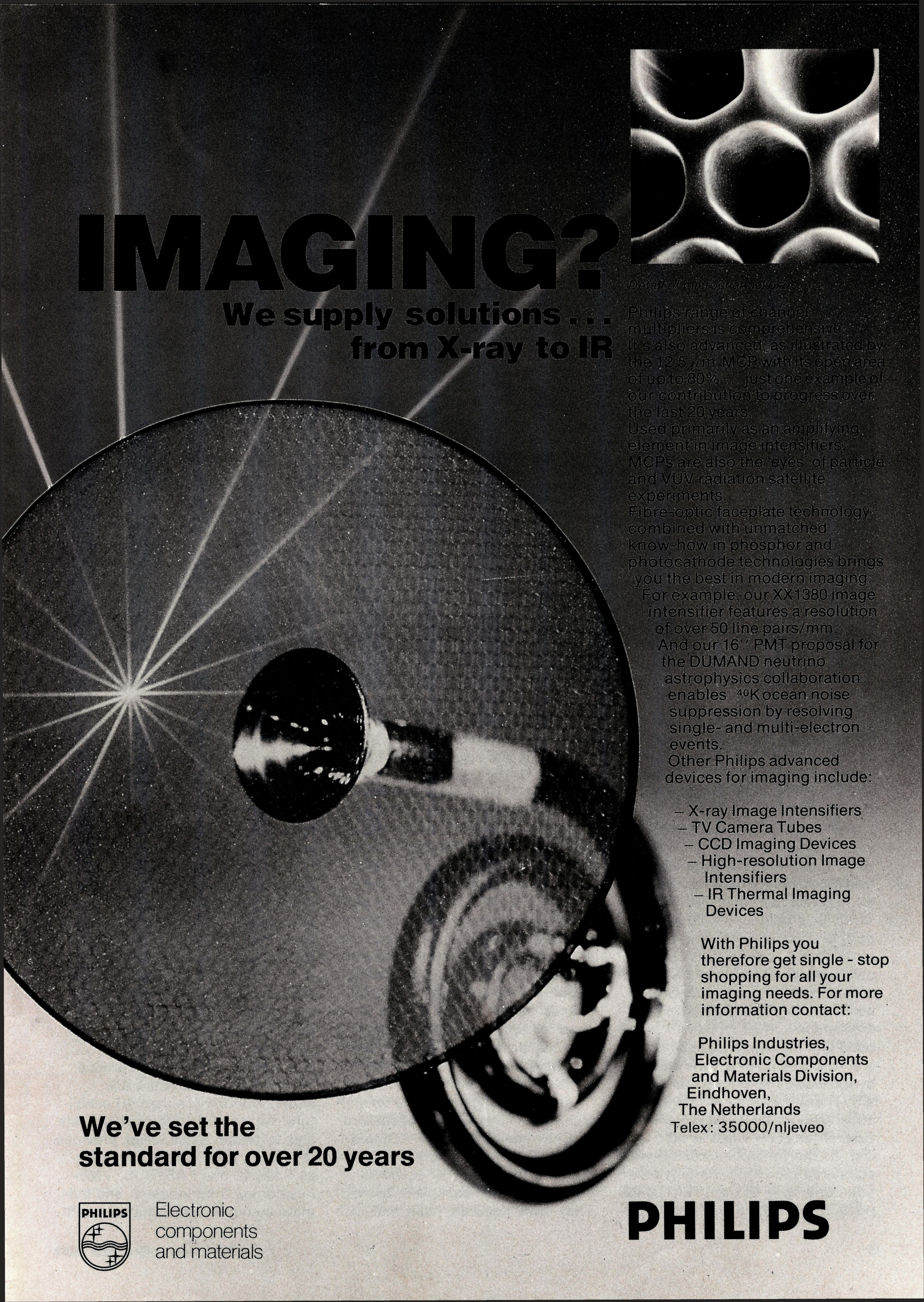
Since its introduction to CERN, VMEbus has had considerable success in control systems, test equipment and experimental data acquisition. The pioneers of the latter application, the big UA1 experiment at the proton-antiproton collider, first installed VMEbus in their updated detector in 1984. Since then several other experiments have based their data acquisition in whole or in part on VMEbus; notably OPAL, one of the four experiments currently being installed at CERN's new LEP electron-positron collider, and several of the experiments at the LEAR low energy antiproton ring.

The control system for LEP itself is based on multi-microprocessor systems using VMEbus, and the control systems for both the PS and SPS proton synchrotrons are being rebuilt with VMEbus replacing their previously used minicomputers.

VMEbus also plays an important role in test systems, for the development of hardware in VMEbus itself as well as in other standards such as CAMAC and FASTBUS, and for checking out detector subsystems. It has also recently been applied to the calibration of the magnets for the OPAL and ALEPH experiments at LEP.

Other high energy physics laboratories are also using VMEbus extensively; the H1 and Zeus experiments on the HERA ring at DESY and the Advanced Computer Program (ACP) at Fermilab are some notable examples. However industry at large provides the major market for VMEbus. It is heavily used in test, control and data acquisition in all branches of industry and research, the consequent economies of scale enabling all users to benefit from the available choice of equipment and the cost savings.

The conference participants were welcomed by Alex Zehnder of PSI, which hosted the conference as an associate organization



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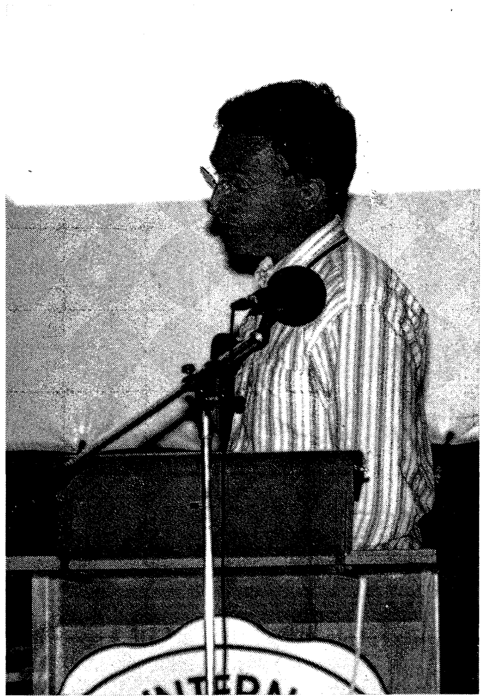
At the VMEbus in Research welcome party hosted by the city and canton of Zurich – left to right – Marc-Rene Jung (University of Zurich), Wilfried Schoeps (Paul Scherrer Institute and Chairman of the Organizing Committee), Chris Eck (CERN and Chairman of the Paper Selection Committee).

Bob Dobinson of CERN sums up the VMEbus in Research meeting.



of the ETH, by Organizing Committee Chairman Wilfried Schoeps also of PSI, and by Ted Owen of Daresbury Laboratory, UK, as Chairman of ESONE, the conference's principal sponsor.

Many topics and developments were discussed during the three days, but one of the important messages to emerge was the need to 'improve the breed'. Although VMEbus is by now a mature standard as modern backplane bus systems go, its specification covers only the lowest levels of hardware transactions. System level concepts such as interprocessor communication in multiprocessor systems and multicrate installations are each treated in different ways by individual manufacturers and users. These aspects are now being addressed by the VITA Technical Committee (TC), which is also tackling the thorny problem of software standardization, and the Software Sub-committee of the VITA TC expects to publish its first results for comment next Spring. The current thinking was explored during a stimulating panel discussion on the first day of the meeting.

Other hot topics included the 'VXIbus' (VMEbus Extensions for Instrumentation). Although VMEbus is a successful microprocessor backplane bus, it is not well suited to the construction of front-end electronics. It has a relatively small board size and lacks support for ECL and analog signals. VXIbus, recently developed from the basic VMEbus by a consortium of instrumentation manufacturers, attacks all these problems, as well as the need for systems level concepts, and may provide a future platform for integrating VMEbus into the front-end of experiments.

An insight into the future was given by Shlomo Pri-Tal of Motorola, Chairman of the VITA TC, and by Paul Borrill of National Semiconductor Corporation, an acknowledged expert on backplane buses. They both made the point that with the advent of very high performance microprocessors (above 100mips), the need for corresponding bus systems is becoming essential.

The VITA TC is discussing what form the 'Next Generation Architecture' should take, and how to marry it to VMEbus, which will nevertheless continue to play an increasingly important role in its own right well into the '90s. There was some crystal gazing from Ernst Kristiansen of Norsk Data who reported the work of the IEEE P1596 committee on a Gigabyte/second throughput 'Scalable Coherent Interface' (previously known as 'Superbus').

In parallel with the conference, VITA held a successful trade show, where more than 40 exhibitors displayed their latest hardware and software. Since unlike previous standards used in research, such as CAMAC and FASTBUS, VMEbus comes from industry, and intimate contacts between users and manufacturers are essential. Thus the third day of the conference was devoted to presentations from industry.

The three days of 'VMEbus in Research' provided a most stimulating atmosphere: a mixture of interests from the user, manufacturer and those attempting to promote the standards – a melting pot for ideas from all sides. At the end of this hectic activity, Bob Dobinson of CERN was able to summarize the 60 sessions, 20 posters and the exhibition in just 30 minutes. Finally Chris Eck of CERN and Chairman of the Paper Selection Committee proposed a vote of thanks to all concerned, including the City and Canton of Zurich, and looked forward to the next, as yet unspecified, venue for the conference.

By Chris Parkman (On-line Computing Group, DD Division, CERN)

CERN/FERMILAB Collider records smashed

The second half of 1988 has seen world record production of antiprotons, with both CERN and Fermilab displaying impressive prowess at manipulating antimatter.

Although CERN's new Antiproton Accumulator Complex (AAC) came into action for the first time last year, it is only this year that the real benefits are being reaped. With improved antiproton production techniques and with the new AC Antiproton Collector ring complementing the AA Antiproton Accumulator, the goal was to boost considerably the rate of proton-antiproton collisions for experiments.

(In the original version, the AA collected, cooled and stacked the antiprotons. Now the new AC ring collects and precools before passing the antiparticles to the AA for more cooling and final stacking.)

With the AAC benefiting from a run earlier this year for the LEAR low energy antiproton ring, an interim world record store of antiprotons got this year's proton-antiproton collider run in September off to a flying start.

Once the collider was back in its stride with six bunches each of protons and antiprotons, the records started to tumble, with luminosity (a measure of the collision rate) regularly exceeding $10^{30}cm^{-2} sec^{-1}$, eclipsing CERN's previous record of a few 10^{29}.

Then resourceful groups all along the long antiproton production chain added something extra. The Booster did some spectacular radiofrequency gymnastics to increase the number of protons available for producing antiprotons. Some delicate radiofrequency manoeuvres ('ion shakers') in the AA overcame troublesome ion effects which had been limiting the size of the antiproton stack, pushing the stack to a new record figure of 8.5 x 10^{11}.

As well as lots of antiprotons, long coasts in the collider ensured that physicists were clocking up plenty of collisions. In less than one month of running, the accumulated number of proton-antiproton collisions sailed past the inverse picobarn (1000 inverse nanobarn) milestone. About a day later, the collider cruised past the total collision score amassed in the seven years 1981-7, including the historic Nobel-earning 1983 run which discovered the W and Z particles! The accumulated collision score continued to grow steadily, passing two inverse picobarns on 8 November.

The muon detection capacity of the UA1 experiment has been substantially improved for the 1988 Collider run. Additional iron shielding has been installed between the main magnet and the outer muon chambers and is fully equipped with planes of Iarocci gas tubes.The data acquisition system has been redesigned, using VME and multi-event buffering, to provide a flexible second level trigger system. Events are recorded on IBM 3480 cartridge drives at a rate in excess of 1 Mbyte per second. The central detector has been equipped with a laser calibration system so that potential distortions at high luminosity can be carefully monitored. The faithful 'gondola' and 'bouchon' electromagnetic calorimeters have been removed in preparation for later installation of the new uranium/TMP (room tem-

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A corner of CERN's Antiproton Accumulator Complex, with the new Antiproton Collector (AC) ring (outside) which stores and precools the particles before passing them on to the concentric Antiproton Accumulator (AA).

(Photo CERN 202.5.87)

perature liquid) calorimeter.

Fortunately the hadron calorimeter is able to measure the medium energy jets associated with heavy quark production. A sophisticated new trigger processor, destined for use with the new calorimeter, is already installed and will be commissioned during the present run.

The first level muon trigger identifies a pattern of struck tubes forming a vertex pointing cone with a precision of about 200 mrad, and the decision is available after about 2.5 microsecs. A second level trigger in VME processors uses the drift time information to apply a stricter pointing cut. Using a carefully optimised algorithm, a decision time of about 5 msec is achieved and the trigger rate is typically reduced by about a factor of four. A third level trigger uses a battery of up to twelve 3081 emulators, running standard offline software, to reconstruct the muon candidates in the central detector. A few percent of events, containing a good muon candidate with high transverse momentum, are written in parallel to an 'express' output stream, also on IBM 3480 cartridge, for fast offline analysis.

For the high interaction rate, the UA2 experiment activated all the three levels of its trigger system. The first level is based on home-built electronics which sums of calorimeter cell energies and calculates the total 'missing' transverse momentum needed to balance each event. This introduces no dead time, the decision being taken well within consecutive bunch crossings.

At these luminosity levels, the typical 80 Hz rate from the first level trigger is reduced tenfold at the second level by a dedicated fast processor (XOP) using a fast digitization of the calorimeter signals to construct energy clusters and calculate multi-jet masses. It also runs algorithms of electron identification. Dead time is less than 0.1%. For events selected at this level, the detector is fully read out only for electron and missing transverse momentum triggers. For jet triggers, previous experience has shown that only selected information needs to be read out. Overall dead time, due to both trigger and read-out, is of the order of 15%.

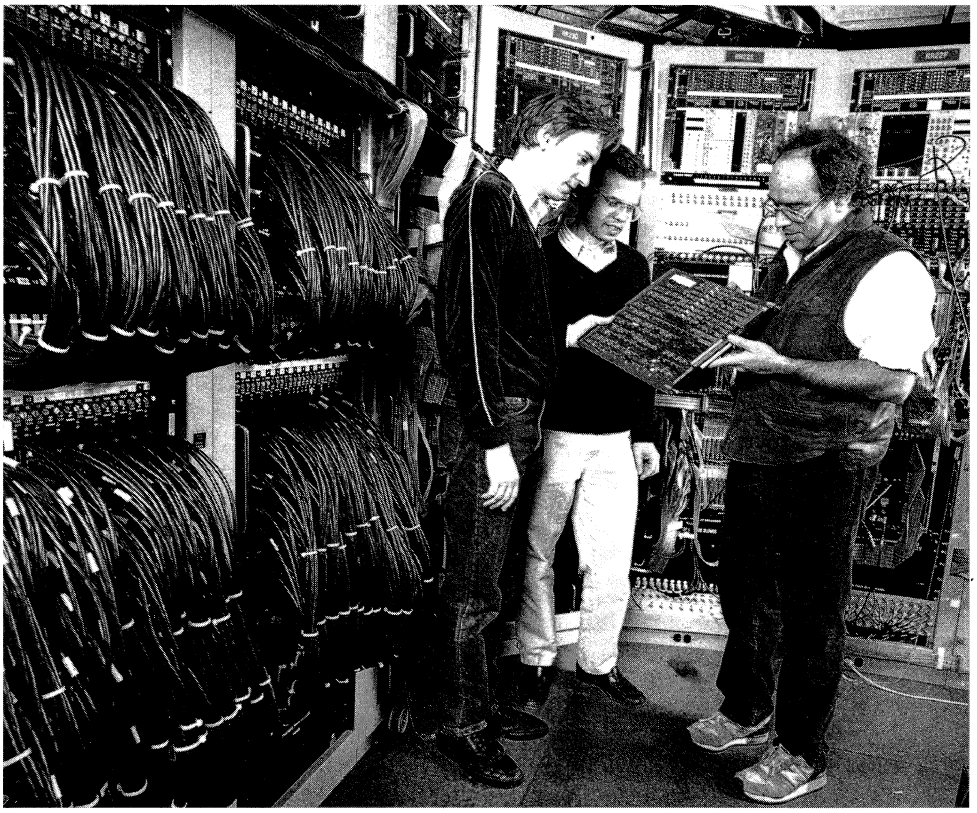
A further 50% reduction comes from the third level trigger, a set of four FASTBUS processors (Aleph Event Builders) running in parallel the full off-line filter program, thereby reducing the off-line processing load. No dead time is introduced here and the resulting 150 kByte/sec of data are recorded on cartridges for off-line analysis.

At Fermilab, the number of proton-antiproton collisions recorded on tape up to last year was only about a tenth of the levels achieved by the big experiments at CERN, however the increased collision energy (1800 GeV compared to the routine 630 GeV at CERN) had begun to pay dividends (September issue, page 4).

This year the big CDF detector has had proton-antiproton collisions galore. Since it began running during the first week of July, the Tevatron collider's performance has been spectacular, with the design luminosity of 10^{30} being reached on September 7. In the weeks that followed, the Tevatron achieved a new record initial luminosity of 1.59×10^{30}. The largest antiproton stack was 8.13×10^{11} with the peak stacking rate attaining 1.9×10^{10} in a single hour. By mid-November the collider had delivered over 2300 inverse nanobarns of collisions (compared with 30 before this year's run!).

In the previous run, CDF had

Left to right, Jay Hauser, Melvin Shochet and Henry Frisch (Chicago) with a Fastbus module for the second level trigger system of the CDF experiment at the Fermilab Tevatron proton-antiproton collider. With the high data rates now being supplied, powerful trigger systems to filter the incoming data are vital.



only used its first level of triggering to filter the incoming collision information. The addition of extra levels for this run helped the detector make fast on-line decisions to dig out the rare events of real physics interest.

With about 40,000 collisions per second each time the beams cross, the first two levels (zero and one) reduce the trigger rate to 1000 per second, allowing the next level (two) to search for clusters of energy, 'stiff' tracks, electrons and muons, forwarding up to ten events per second to the next level (three). After the final selection, even a casual observer can watch interesting physics arriving on-line.

The level two trigger can be set to look for different kinds of physics, including the missing sixth ('top') quark.

Because CDF had not bargained for so many collisions so quickly, the final trigger was going to be held in reserve. However the need was soon clear for this level, using about 50 Fermilab Advanced Computer Program (ACP) nodes with all event information in digital form and using software programs, and good progress is being made.

Presently, on a good shift CDF can write as much as 70% of the incoming collision rate to tape. Before the run, the stated goal had been to accumulate an inverse picobarn (1000 inverse nanobarns), but with the increased Tevatron performance, the CDF data acquisition system could not much more than this by the end of the run.

It will take time before all the physics potential of this data has been exploited, but with wagers having been placed on the sighting of the sixth (top) quark, many physicists will cut short their Christmas holidays this year.

STANFORD
Linear collider progress

Despite its difficulty in making Z particles, the electrically neutral carriers of the weak nuclear force, the Stanford Linear Collider (SLC) made major advances in accelerator physics during its recent run.

Not only were micron-size electron and positron beams held in collision for hours at a stretch, but precision methods have been developed to aim the beams to a fraction of their diameters. And a beam stabilization technique known as 'BNS damping' has led to marked improvements in collider operations.

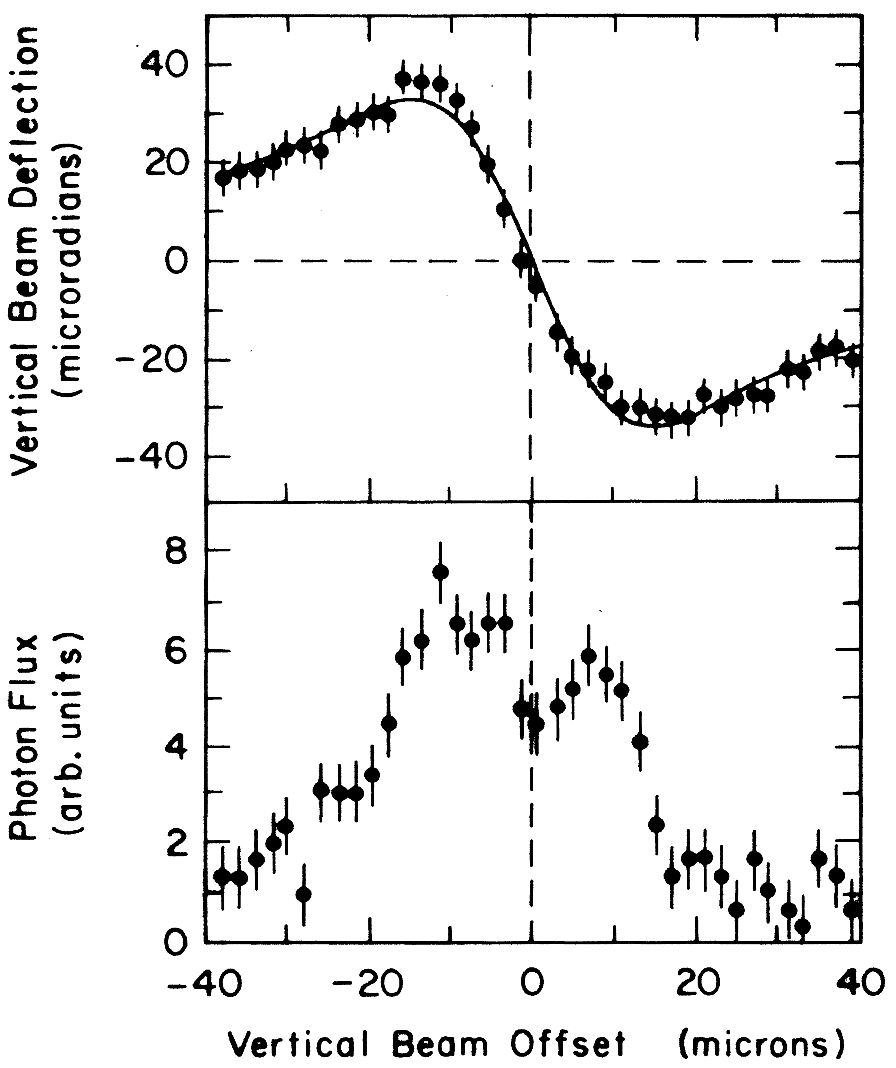
First witnessed in June, beam-beam deflections (caused by the mutual attraction of the two beams when not aimed exactly head-on) are now employed routinely to steer the beams to a relative accuracy of 1 micron at the interaction point. Using computer-controlled scans, operators can accomplish this and resteer the beams in less than a minute. Slow drifts of the beams, typically a few microns per hour, are easily corrected.

In early September, clear signals were observed for another phenomenon of special importance to linear colliders called 'beamstrahlung'. These bursts of photons, with energies up to tens of MeV, are emitted forward by compact electron and positron bunches as they intersect. A small fraction of the photons convert in a thin metal plate, and the resulting electron-positron pairs are detected by a Cherenkov counter.

As one beam is scanned across the other, a characteristic peak

Top: at the new SLC Stanford Linear Collider, beam-beam deflections (caused by the mutual attraction of the electron and positron beams when not aimed exactly head-on) are now employed routinely to steer the beams to a relative accuracy of 1 micron at the interaction point. The diagram shows the vertical deflection of the positron beam as it is scanned across the electron beam.

Below: exploiting 'beamstrahlung' – the bursts of photons, with energies up to tens of MeV, emitted forward by compact electron and positron bunches as they intersect. As one SLC beam is scanned across the other, a characteristic peak emerges in this photon flux, with a dip at its centre corresponding to exact alignment. These data were recorded at beam sizes of about 6 microns and intensities of about 7 x 10^{9} electrons and positrons per bunch.



emerges in the photon flux, with a dip at its centre corresponding to exact alignment. This flux peaks with the beams at maximum deflection, which occurs when they are offset by about 1.6 radii. SLC physicists plan to employ a combination of beam-beam deflections and beamstrahlung signals to optimize the luminosity without interrupting data-taking.

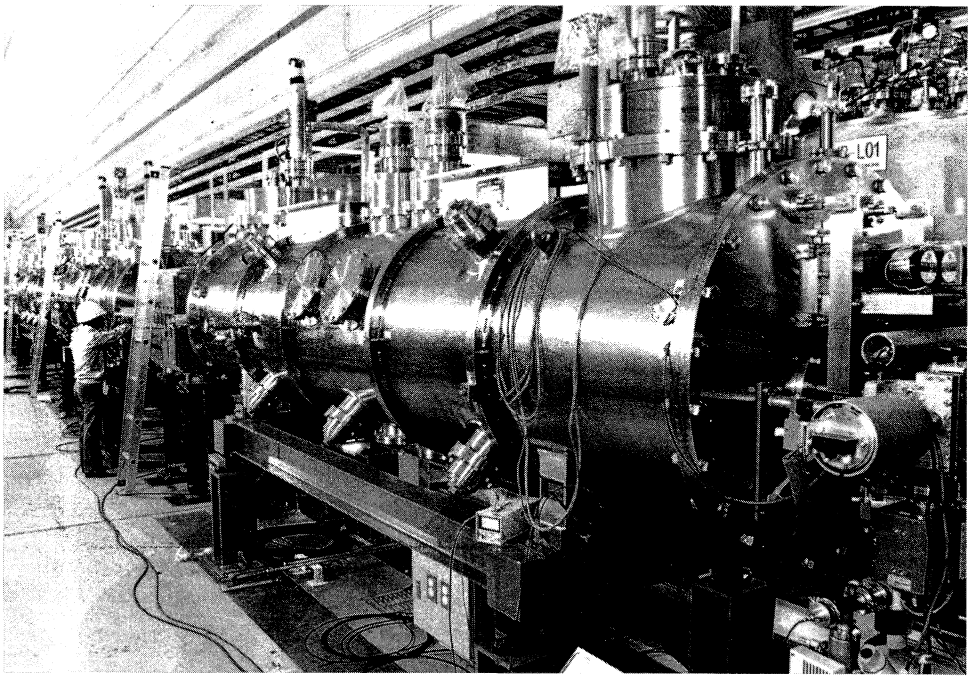
First proposed in 1983 by V. E. Balakin, A. V. Novokhatsky and V. P. Smirnov of the Soviet Novosibirsk Laboratory, BNS damping was successfully implemented on the SLC during August – the first time this technique has ever been used in practice. By selectively rephasing the klystrons along the two-mile linear accelerator, the growth of transverse wake-field effects can be suppressed markedly. The tails on the electron and positron bunches, which can cause serious backgrounds at the interaction point (April issue, page 12) are much smaller with BNS damping in effect. The SLC also appears to operate more stably under these conditions.

On September 12 the SLC was shut down for modifications while preparations for high energy physics research began at the PEP and SPEAR electron-positron storage rings. In the last run before this shutdown, the Mark II detector recorded its first high energy collision – a two-photon event (photon-photon collision) – at the SLC. Plans call for full time Z research at the SLC to resume in February.

KEK Superconducting acceleration power

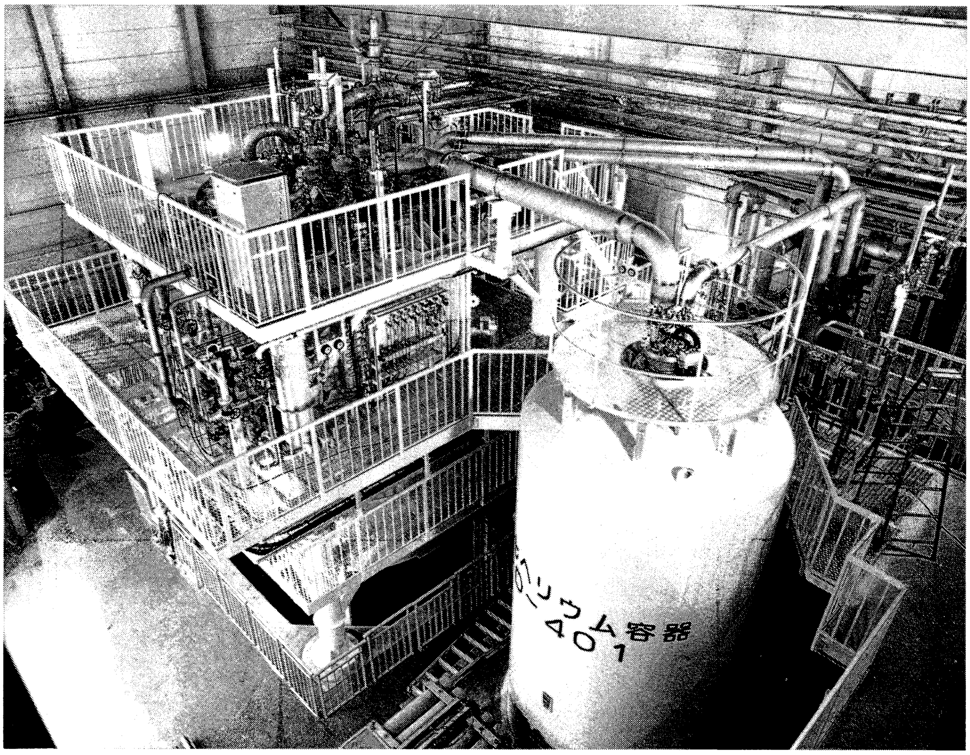
At the three kilometre TRISTAN ring at the Japanese KEK Laboratory, now supplying the world's highest energy electron-positron collisions for physics, one of the four 200 metre straight sections had been left free for subsequent installation of superconducting radiofrequency cavities to boost the beam energies above 30 GeV.

This straight section is now equipped with 16 of the planned 32 five-cell niobium cavities. With two five-cell units per cryostat, the newly installed units add about 24 metres of radiofrequency acceleration, at about four times the field gradient of the machine's conventional cavities. This is the first major installation of superconducting radiofrequency acceleration power in a large storage ring.



▲ *Superconducting radiofrequency accelerating power newly installed in the TRISTAN electron-positron collider at the Japanese KEK Laboratory.*

▼ *4.2 kilowatts of cooling power for the KEK superconducting cavities.*



The TRISTAN team hopes to provide 30 GeV colliding beams this year, and installation of the remaining 16 cavities is scheduled for the middle of next year, pushing the beam energy to 32-33 GeV.

Prior to installation, average accelerating field gradient attained in tests of individual cavities was 9.3 MV/m at 508 MHz, with a quality factor (Q) of 2.8 x 10^9 at 5 MV/m, while further tests after reassembly with frequency tuners as well as input and higher mode couplers yielded an average field gradient of 6.9 MV/m, comfortably above the 5 MV/m level required to provide 30 GeV beams.

The large helium refrigerator tested this summer provides 4.2 kilowatts of cooling power at liquid helium temperatures, and could be upgraded to handle 6.5 kW.

CERN
Probing big molecules

Molecular biology, using X-ray diffraction to open up the structure of large molecules, was one of the early scientific spinoffs from what went on to become particle physics. X-ray diffraction studies continue using the intense beams of synchrotron radiation from electron storage rings.

The genetic information stored in the chromosomal DNA of a biological cell is exported into the surrounding cytoplasm as messenger RNA, serving as a template for the subsequent production of proteins.

Also playing a vital role in this synthesis are the ribosomes which coordinate the translation of the genetic code, interacting with messenger RNA to provide the correct

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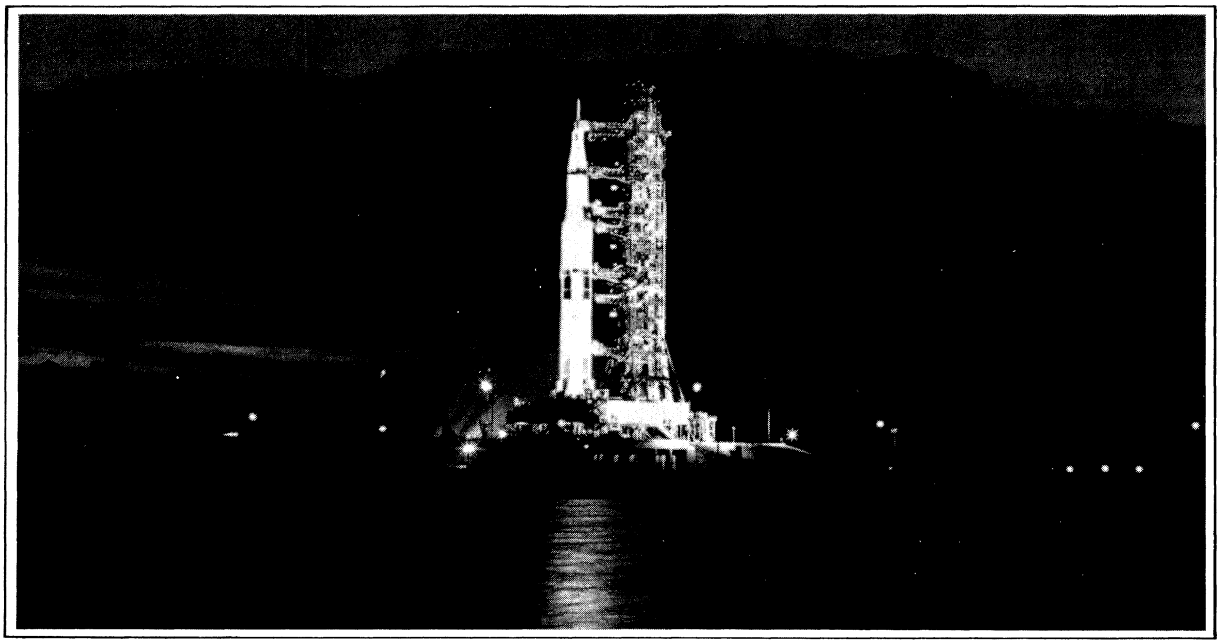
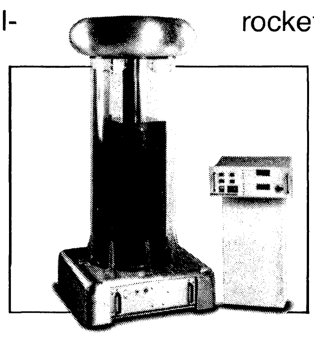


Missile and rocket fuel must be sheltered from unintentional ignition.



A major manufacturer of solid rocket motors subjects its fuel containers and their protective devices to exhaustive testing to ensure maximum freedom from such risk. Their testing facility incorporates Spellman RHP 200kV 1kW power supplies. These Spellman power supplies repeatedly generate simulated lightning aimed at the rocket fuel containers to check the safety limits to static charge.

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molecules to elongate the protein chain.

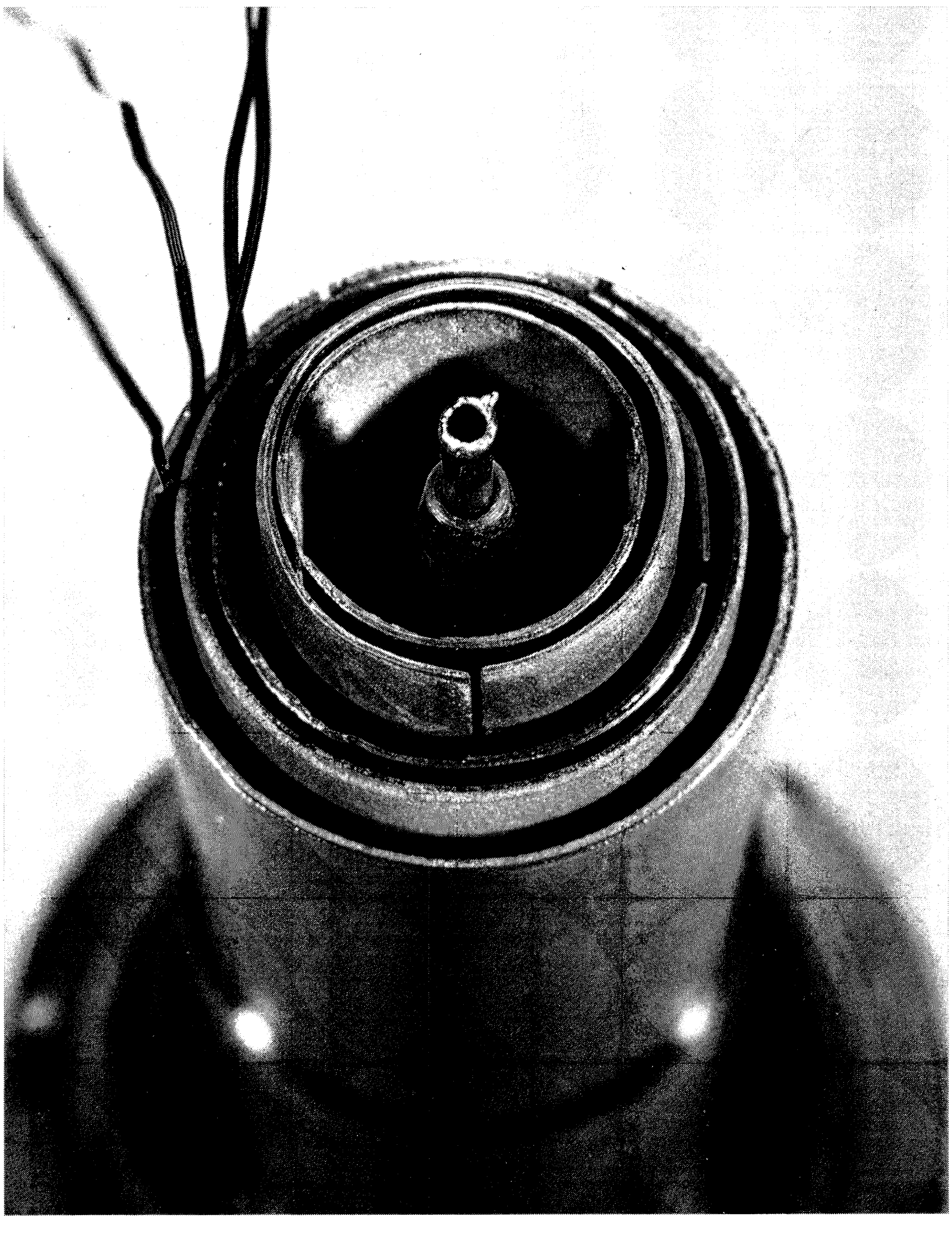
However scientists have yet only a rudimentary idea of how the ribosome works. X-ray diffraction studies could go on to provide important information, but the ribosomal protein structure is so fine that the increased resolution of neutron scattering is called for, and a pioneer 15-year study by D.M. Engelmann and P.B. Moore using neutron beams at Brookhaven has revealed the complex structure of certain ribosomes. This work is continuing at several neutron scattering research centres.

Deeper analysis to probe the inner ribosomal structure and the mechanics of protein synthesis by neutron scattering calls for special techniques such as the substitution of protons by deuterons to boost scattering effects. However these substitutions are tricky in such large molecules.

The neutron scattering power of a nucleus also depends on its spin state, and in some cases the spin effects are more marked than deuteron substitution. After the first successful polarization (orientation) of nuclear spins in a protein (lysozyme) at CERN in 1985, samples of spin polarized proteins, transfer-RNA and ribosomes were prepared for analysis by polarized neutron scattering at the GKSS Laboratory, Geesthacht, Germany.

The results tie in with parallel studies using nuclear magnetic resonance, however not enough information came through to build up a detailed picture. Thus the reactor's neutron yield has been boosted, a beryllium reflector installed, and another dilution refrigerator for the polarized target specially modified by CERN. (This was developed at CERN in the 70s for use in 'frozen' spin polarized targets for particle physics.) With these and other improvements, proton spin polarizations of 96 per cent have been achieved – a good starting point for a new series of investigations to study the way the genetic code is put into action.

The long association between particle physics and molecular biology thus continues. Moreover similar equipment could go on to be useful in reactor laboratories, particularly for fast neutron instrumentation.



The business end of the special 25 mm diameter heat exchanger developed by the Low Temperature Detectors and Instrumentation Group of CERN's Experimental Physics Division to cool biological samples to 0.2 K using superfluid helium-4. The use of polarized (spin oriented) nuclei in neutron scattering experiments promises to yield important new insights into the intricate mechanisms of molecular biology.

Picking up short wavelength gamma rays – a clear Cherenkov ring from a single 5 GeV high energy electron.

DETECTORS
Cherenkov telescope for gamma rays

A new high energy gamma ray telescope idea proposed by Ioanis Giomataris and Georges Charpak at CERN promises efficient detection with good energy and angular resolution, with potential applications in many areas of physics research.

The (Cherenkov) light emitted by charged particles passing through a medium has long been used for particle identification. The light comes out at an angle which depends on the particle velocity, and if the particle momentum is measured separately from the way the track is bent in a magnetic field, the particle mass can be calculated over a range of velocities, giving the particle's identity.

In the increasingly popular Ring Imaging Cherenkov (RICH) counters, the emitted Cherenkov photons are focussed by a mirror into a ring whose radius identifies emerging particles.

Conventional RICH counters produce rings containing only a few detected photons (tens at the most), and it was not clear whether the huge sprays of electrons produced by high energy gamma rays would produce a discernable Cherenkov ring at all. Now this has been demonstrated and the difficulties of handling thousands of photoelectrons have been mastered by the Charpak group, using a technique which picks up the light emitted by atoms excited in ionization avalanches, and which looks promising for a wide variety of applications.

The shape and position of the produced rings helps tell which direction an incoming photon has come from, opening the door to new particle physics applications and, with its high aperture, for astronomical gamma ray telescopes.

Following earlier simulation studies which suggested the feasibility of the approach, this summer I. Giomataris, A. Gougas and W. Dominik looked at the electromagnetic showers produced by a 10 GeV electron beam in lead-glass, using a liquid freon Cherenkov radiator with a multistep avalanche chamber as the photosensitive detector and a CCD camera for the readout. Clear rings were seen, from which the parent high energy electron (or photon) can be pinpointed to within about a milliradian.

Like its conventional RICH cousins, the technique can also be used for particle identification, distinguishing between pions and kaons up to 4 GeV.

CHALK RIVER
Tandem cyclotron upgrade

The first half of the final construction phase is complete for the Tandem Accelerator Superconducting Cyclotron (TASCC) at the Canadian Chalk River Laboratory (January/February 1987 issue, page 29), and experiments are in full swing.

TASCC was shut down at the beginning of the year to remove experimental equipment on temporary beamlines, to reinstall it in permanent positions, and to construct 50 metres of new beam transport line. The goal was to have beam available to four target stations in the summer, and this was achieved on schedule. The three major TASCC facilities can now operate with beam from the tandem or from the cyclotron (with tandem injection). Five more target positions will follow.

In August, a workshop on heavy ion physics attracted researchers

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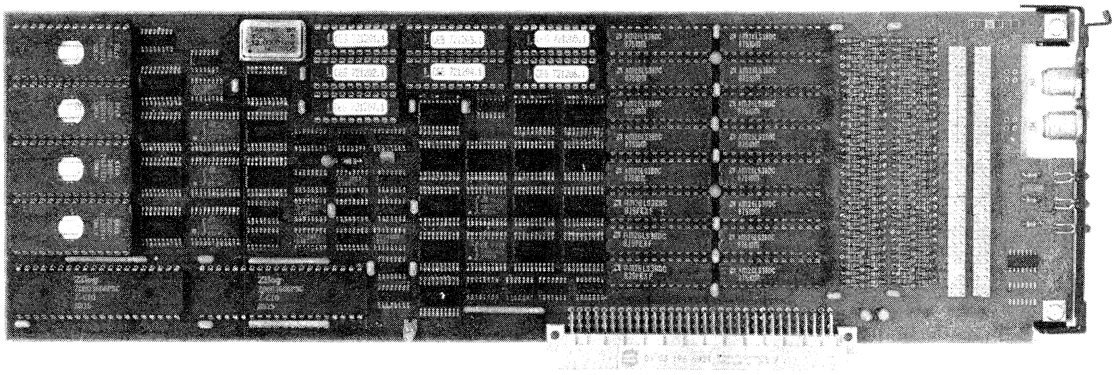

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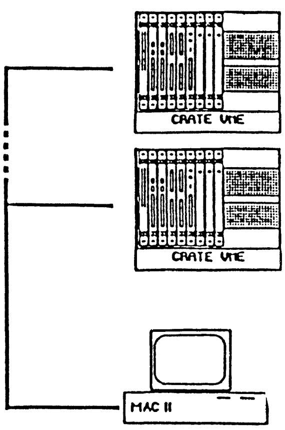

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CREATIVE ELECTRONIC SYSTEMS

A good turnout for the CERN Accelerator School's 1988 General Accelerator Physics Course, held at Salamanca in Spain.

(Photo S. Turner)

from abroad, looking at the three major areas of TASCC research – heavy ion reaction mechanisms, fundamental beta decay and nuclear structure at high spin, – discussions on the latter leading to a gamma ray spectrometer experiment immediately following the workshop.

ACCELERATORS
Spanish steps

In September, the CERN Accelerator School (CAS) held its third General Accelerator Physics Course, the venue this time being Salamanca, the oldest university in Spain.

Spain, which rejoined CERN in 1982, now has a vigorous and steadily growing high energy physics community making substantial contributions to physics detector development and successfully involving Spanish industry. However the embryonic accelerator community cannot yet generate an equivalent level of activity, and this important channel for introducing new high technology into industry has yet to be fully exploited.

However interest in accelerators and the concomitant spinoff technology is growing rapidly, as demonstrated by the decision of the Centre for Industrial Development to award ten scholarships for Spanish students attending the course. Hopefully this initial Spanish enthusiasm for accelerators will continue.

The intense lecture course, supplemented by seminars on accelerators and on industrial spinoff, was attended by over a hundred students, including for the first time participants from Iraq and Saudi Arabia. The School was organized by CAS in collaboration with the 'Comisión interministerial de Ciencia y Tecnológia, the Centro de Investigaciones Energéticas, Mediambientales y Tecnológicas, the Centro para el Desarollo Tecnológico e Industrial, and the University of Salamanca.

Industrial collaboration

The special November issue of the CERN Courier was given over to the increasing collaboration between particle physics and industry. Several contributions arrived too late for inclusion in that issue.

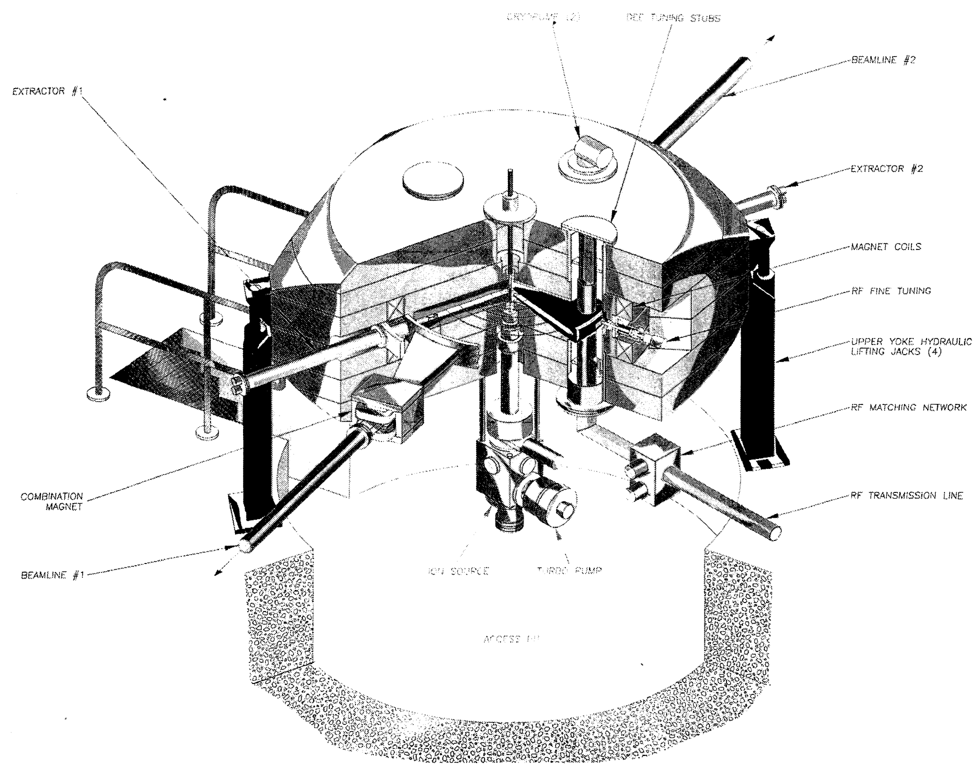
TRIUMF
Medical applications

TRIUMF, Canada's national subatomic research laboratory in Vancouver, is based on a 520 MeV cyclotron providing 150 microamp proton beams. While most researchers are interested in pure particle and nuclear physics research, TRIUMF's Applied Programme Division has other objectives.

The Applied Programme has traditionally concentrated on medical areas. There is an active positron emission tomography (PET) programme; radioisotopes are produced both for PET and for use as tracers or standards; an intense beam of negative pions is used for cancer therapy; and a small commercial cyclotron (suitable for isotope production at hospitals) is being designed and built in conjunction with local industry.

Non-medical applications include neutron activation analysis of mineral samples by an industrial assaying company, and an electronics laboratory developing new kinds of gallium arsenide charge-coupled devices (eventually to be manufactured commercially).

30 MeV cyclotron for radioisotope production at hospitals under development by EBCO Industries of Vancouver in collaboration with the Canadian TRIUMF Laboratory.



TRIUMF's tomography group has developed rapid automated methods for the synthesis of many new radiopharmaceuticals for medical imaging, especially those containing fluorine-18. This group also explores new 'camera' techniques, and has recently begun testing the prototype for a new kind of scanner for positron emission tomography (PET). Based on a gamma-ray detector developed at TRIUMF during the past three years, it has outstanding sensitivity. The group believes that this model, when perfected, could be manufactured commercially at a fraction of the cost of present machines, thus making the advantages of PET more widely available to hospitals in the future.

Accelerator beams can produce many positron-emitting isotopes. With the demand for these steadily increasing, a second cyclotron (40 MeV) was installed to enhance radioisotope production. Most of this production is handled by the Radiochemical Co., a subsidiary of Atomic Energy of Canada Ltd., which has laboratory facilities at TRIUMF.

Domestic and international sales of material produced at TRIUMF (especially the ultra-pure iodine-123 from enriched xenon-124) are now in the $(US) 4 million range – a considerable fraction of the accelerator-based radioisotopes sold in North America.

Recently the Applied Programme has entered new fields of industrial collaboration, including a small cyclotron designed for high current operation with multiple beam extraction, using a negative hydrogen ion source and other technology developed at TRIUMF. A Vancouver-area company, EBCO Industries, has agreed to build and market the 30 MeV version of this design. Its first order, for Atomic Energy of Canada Ltd., includes both the cyclotron and its facility in a turnkey contract. EBCO is thus developing expertise not only in small accelerators but also in plant for isotope production operations.

Besides the production of small accelerators, this firm is also studying camera systems for positron emission tomography, hoping to find ways of making these scanning techniques more widely available.

For the future, TRIUMF's proposal for upgrading the Laboratory to a high intensity 'KAON Factory'(September issue, page 1), presently under consideration by Canada's federal government, includes a detailed plan for pushing applied research. A 'TRIUMF KAON Ventures Office' would provide the financial expertise and business contacts to assure the rapid exploitation of useful spinoff technology.

PSI
Industrial collaboration

The Swiss Paul Scherrer Institute (formerly SIN) has several collaboration projects which illustrate the close links between particle physics research and industry.

The electronics group has worked with industry on the development of a system for on-line inspection of fast-moving sheet material for microscopic defects, optical and colour variations, holes, scratches and inclusions.

Using 32 opto-electronic sensors interfaced to a personal computer, it can detect defects as small as five microns in material up to 10 m wide, moving at speeds up to 1000 m/min.

Physics monitor

Since 1980, systems for laser resonance experiments in light muonic atoms have been under development at the Laboratory. This work involved the building first of a 50 nS, 1J Nd:glass slab geometry laser, later of a Nd:YAG laser capable of 2J in 15 nS. Based on this experience, and in collaboration with two firms in the context of a multinational industry-scientific research collaboration scheme (Kommission für wissenschaftliche Forschung), slab lasers are under further development, with the goal of building a 1kW Nd:YAG laser; this represents an order of magnitude improvement over today's devices.

One problem now being given high priority worldwide is the safe management of radioactive waste from power plants, medicine, industry and research. PSI, together with the Swiss Federal Institute for Reactor Research, EIR, is working with NAGRA, the Swiss organization with overall responsibility in this field. In 1988, the collaboration amounted to some 40 man years.

PSI's contribution is in the study of the possible release of material from a repository and its subsequent transport into the human environment. This involves the detailed study of the properties of the repository itself, together with its geological environment; possible nuclide release from the repository, the performance of any barriers, transport of nuclides within the repository, through the geosphere and biosphere, and, finally of doses to humans.

CONFERENCE
Quark matter 88

The 'Quark Matter' Conference caters for physicists studying nuclear matter under extreme conditions. The hope is that relativistic (high energy) heavy ion collisions allow formation of the long-awaited quark-gluon plasma, where the inter-quark 'colour' force is no longer confined inside nucleon-like dimensions.

Exploratory programmes got underway at CERN and Brookhaven in 1986 using beams of oxygen-16 nuclei with 60 and 200 GeV per nucleon at CERN and 15 GeV per nucleon at the US Laboratory. Studies at CERN continued in 1987 with the higher energy densities available from sulphur-32 at 200 GeV per nucleon, and with a proton control run this year. This has involved six major experiments and several emulsion studies. At Brookhaven, the heavy ion programme at the Alternating Gradient Synchrotron will eventually involve three major experiments, with ions up to gold at 14.5 GeV per nucleon in 1992. At this energy, interesting data have been taken with oxygen and silicon ion beams.

The 1987 Quark Matter Conference at Nordkirchen, Germany (November 1987 issue, page 5) was the first in the series where extensive data from CERN and Brookhaven were presented. This included detailed information on energy and secondary multiplicity distributions, hinting that the energy density of a few GeV per cubic fermi needed to produce the quark-gluon plasma could be reached in head-on collisions.

The first batch of interesting results included pion interferometry from the NA35 streamer chamber experiment at CERN, showing that pion freezeout in the central region occurs on the surface of a blob nearly three times the size of the incident oxygen ion. There was a hint of strangeness enhancement from the Brookhaven E802 study, and the first real 'smoking gun' –

Left, S. Nagamiya of Columbia, Chairman of the Organizing Committee of the Quark Matter meeting at Lenox, with R. Bock of GSI Darmstadt.

How to visit CERN

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Quark Matter discussions – H. Gutbrod of the CERN WA80 experiment (left) with E. Feinberg of Moscow.

(Photos M. Jacob)

synthesis in the early Universe or the cooling of neutron stars.

New developments in the pipeline are the proposed source of lead ions at CERN, and Brookhaven's idea for the RHIC Relativistic Heavy Ion Collider to provide beams of 100 GeV per nucleon.

Organized by G. Baym (Urbana), P. Braun-Muniziger (Stony Brook) and S. Nagamiya (Columbia, Chairman), Quark Matter 88 brought together over 250 participants, equally split between particle physics and nuclear physics. The next meeting in the series will be held in France in 1990.

From Maurice Jacob

the suppression of J/psi production seen by the NA38 experiment at CERN.

At the Quark Matter 1988 meeting, held recently in Lenox, Massachusetts, the input from the sulphur-32 run at CERN consolidated the results and conclusions drawn from the earlier oxygen run. The reasons for apparent J/psi suppression were closely examined, and while the quark-gluon plasma hypothesis withstood all experimental tests presently possible, other scenarios, based on more conventional physics, presented valid viewpoints. Whatever its cause, the clear experimental effect implies a system of high energy density (a few GeV per cubic fermi) and an appreciable lifetime (enough for light to travel a few fermis).

Main new result was evidence for an anomalously high production of strange particles – another possible quark-gluon plasma signal. With a good set of results on charged kaon production, E802 from Brookhaven puts the strangeness enhancement (a kaon to pion ratio of about 20 per cent) first hinted by the 1987 results on very firm ground. At CERN, NA35 repeated a high yield of lambdas, 2.5 times more than expected and increasing with secondary multiplicity. WA85 (using the Omega spectrometer at CERN) has looked at the production of lambdas and the corresponding antiparticles, finding an antiparticle/particle ratio twice that of antiproton/proton formation in proton-proton collisions at the same energy.

Again, while not proving conclusively that quark-gluon plasma is being produced, these strangeness enhancements call for a system of high density and appreciable lifetime.

Seldom has particle physics produced such interesting results from such short experimental runs. Enthusiasm to continue these studies on the boundary between particle physics and nuclear physics runs high. As well as probing fundamental questions in quark field theory, the issues are also of great interest to astrophysicists studying nuclear

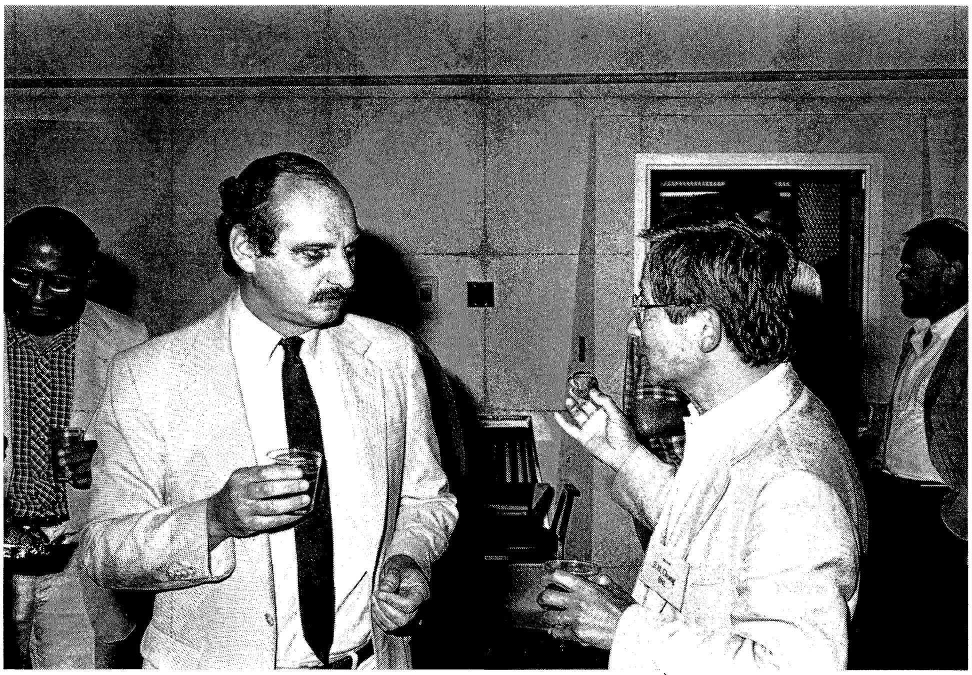
BROOKHAVEN
Glueballs, hybrids and exotics

A workshop at Brookhaven from August 29 to September 1 looked at the current status of hadron spectroscopy beyond the realm of states conventionally built up from quarks and discussed future experimental effort to explore such exotic states.

In an introductory talk on the current status of the quark model, N. Isgur of Toronto emphasized that this is now a mature picture, successfully describing almost all the gross features of the observed hadron spectrum. A flux-tube model, with quarks bound inside hadrons by 'colour' flux and the gluonic degrees of freedom naturally realized by its excitations, leads to specific predictions for hybrid states.

In quark field theory, the carriers of the inter-quark force - the gluons

Dave Hitlin of Caltech (left) discusses exotic hadron spectroscopy with Suh-Urk Chung of Brookhaven.



– are themselves sources of the force, so that gluons, as well as quarks, should be able to stick together to form particles. S. Sharpe of Stanford reviewed progress in lattice gauge theory. Though reliable predictions are difficult for the masses of such 'glueballs', certain mass ratios are better determined.

At a special workshop, there were many speculations about which candidate would claim the prize for being the first definitive glueball, with enlightening exchanges, sometimes heated, between the competing camps.

This glueball workshop covered hadronic production of glueball candidates by both single- and double-particle exchanges, together with the traditional glue-rich J/psi radiative decays from electron-positron production. The workshop underlined the importance of all three production processes and their inter-relationship for glueball searches.

M. Pennington (Brookhaven/Durham) presented evidence for light non-standard S states (January/February 1987 issue, page 16) at 991 and 988 MeV. Four-quark 'molecules' such as the S(988) may show up only in neutral kaon pair channels, while zero-spin, positive parity quark-antiquark bound states would be heavier, in the range of 1.3 to 1.5 GeV. Then the S(991) may well be the lightest glueball.

F. Binon of Brussels discussed another candidate, the G(1590) seen in eta decay modes by the GAMS group.

The three spin-two positive parity phi-phi states observed in negative-pion/proton interactions are considered by many to be glueball candidates, as is the theta(1720) seen in J/psi radiative decays. At the meeting, there was a discussion of the theta spin-parity assignment. Though spin two is still favoured, a significant spin zero component is not yet ruled out.

The iota(1440) was long claimed to be a prime spin zero, negative parity glueball candidate because of its copious production in J/psi radiative decays. Since it is also observed in conventional hadronic production channels at Brookhaven and at the Japanese KEK Laboratory, in addition to proton-antiproton annihilation channels at CERN, it is likely to be quarks mixed with a glueball, or perhaps a hybrid quark/gluon state. Brookhaven data from a high statistics experiment for hadroproduction of E(1420)/iota(1440) show evidence of complex structure in the 1400-1450 region. States may exist with slightly different masses and decay patterns.

The hybrid workshop focused on the study of mesons with quantum number assignments defying classification as conventional quark states, such as the M(1406) and the U(3100), and those with decays that do not correspond to simple quark-pair creation, such as the C(1480), supplemented by other exotic states, such as the E(1420), produced by more complex mechanisms. The longest discussions were on the exotic M(1406) following reports by the GAMS group (May issue, page 21).

Despite the lack of conclusive evidence, all agreed that the results so far underline the importance of neutral particle detection in unravelling the hadron spectra. More experiments in this area are needed, and several proposed studies at KEK and Brookhaven to confirm the GAMS results were described.

In a special joint glueball and hybrid session covering two-photon physics, recent experimental data were confronted with the predictions of some favourite four-quark models by N. Achasov and by K. F. Liu.

I. Shipsey of Syracuse covered the status and future of the physics of B mesons (containing the heavy

'beauty' quark) using the CLEO detector at Cornell's CESR electron-positron ring, where 'charmless' B decays are not seen, in contrast to last year's results from the ARGUS experiment at the German DESY Laboratory (October issue, page 3).

The B physics potential of the Relativistic Heavy Ion Collider (RHIC) proposed at Brookhaven was discussed by W. Morse, highlighting the crucial role fresh insights would play in our understanding of weak decays.

The need for a 'B-factory' was universally accepted but the type of machine needed was (and will be) a topic of continuing debate.

The detectors and facilities workshop explored the next generation of these devices and how they could make an impact on the unanswered questions in hadron spectroscopy. It was emphasized that a continued worldwide effort was necessary. Overall, the meeting highlighted hadron spectroscopy as a crucial testing ground for current particle physics ideas, and looked forward to a detailed confrontation of lattice calculations with experiments. The participants left with a feeling that real progress had been made in the past few year, and a resolve to continue to explore unconventional quark states – a subject at the very heart of matter.

From S.-U. Chung

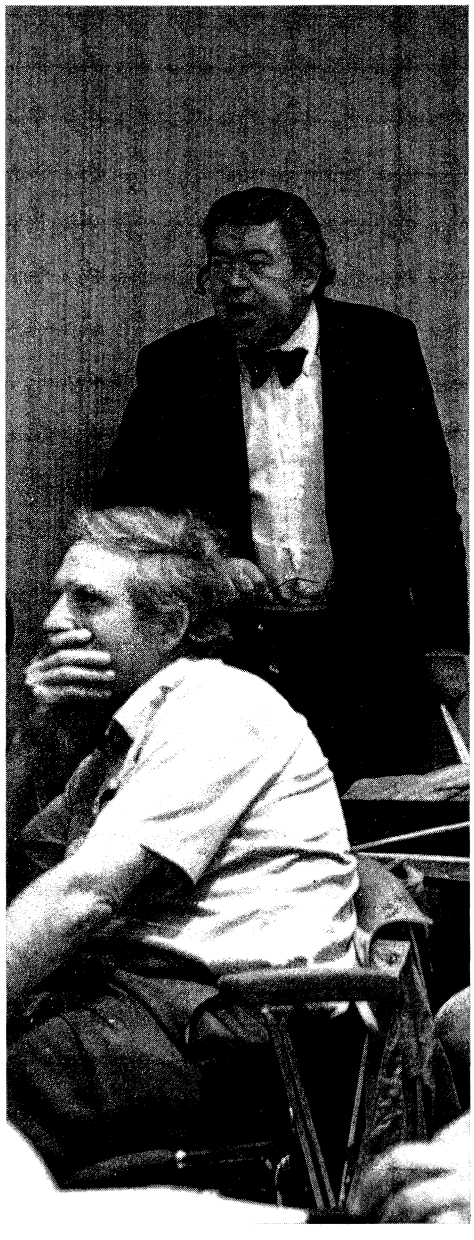
WORKSHOP
Let's twist again...

In the quantum chromodynamics (QCD) candidate theory of inter-quark forces, calculations involve summing the effects from many different possible quark/gluon interactions. In addition to the 'leading term' frequently used as the basis for QCD calculations, additional contributions - so-called 'higher twists' – are modulated by powers of kinematical factors. An illuminating international workshop to discuss higher twist QCD was held at the College de France, Paris, from 21-23 September.

Evidence for higher twist effects is accumulating from many quarters. Impressive new data from an experiment by a Chicago/Iowa/Princeton collaboration at Fermilab were presented by Kirk McDonald of Princeton. This experiment measures the quark structure (structure function) of the pion under conditions where a participating quark carries a high proportion of the momentum. Characteristic evidence for higher twist is seen, showing that the incident pion interacts coherently with a target quark. Ed Berger of Argonne reviewed higher twist in lepton pair production and forward jet suppression.

The theory of direct production was covered by Reinhard Ruckl and Maurice Benayoun for heavy and light quarkonia (bound states of a quark and an antiquark) respectively. Particularly interesting was the development of the relativistic treatment of the light quarkonia to include mesons where the constituent quarks have orbital angular momentum, the result of a recent study by Benayoun and Marcel Froissart.

Evidence for the direct lepto- and hadroproduction of mesons was reported from CERN experiments WA59 and WA77 respectively. The latter is analysing new data to look at energy dependence. In addition, the related time-reversed process – forward jet suppression through a coherent interaction of the incident meson – has been seen by Fermilab experiment E609. Paulo Nason of ETH Zurich explained why production of heavy quarks unpaired with their corresponding antiquarks is well understood qualitatively. There are still problems with the absolute predictions for J/psi production, with further input to come from the European Muon Collaboration.



Theory and experiment at the College de France's 'higher twist' workshop. Standing, theorist Marcel Froissart of the host institution, one of the organizers of the meeting. Seated, Terry Sloan of the European Muon Collaboration experiment.

People and things

The extraction of the effects due to higher twist terms in processes where the incident quarks probe deep inside the target particles is known to be difficult. The theoretical aspects of analysing the resultant structure functions were presented by Joaquin Sanchez Guillez of Santiago de Compostela. Careful comparison of different structure function results was illuminating. A different approach is taken by the Stanford experiment using high energy electron beams, which presented copious new data on the relative contributions of different photon polarization states over a range of kinematics. This particularly clear test finds that higher twist is not needed in the kinematical range covered. The experiment wants to extend the kinematics to cover regions more sensitive to higher twist. The description of mesons, particularly relevant to many higher twist phenomena, was tackled by T. Huang of Beijing and V.L. Chernyak of Novosibirsk.

Summarizer Keith Ellis of Fermilab reminded the audience of the origins of higher twist in QCD formalism, while the meeting benefited from the presence of Ed Berger, a leading proponent of higher twist.

The College de France meeting was organized by a team from the host institution (Maurice Benayoun, Marcel Froissart, Philippe Leruste and Jean-Louis Narjoux), together with Michel Fontannaz (Orsay), Michel Denegri (Saclay), Emanuel Quercigh (CERN) and Ed Berger (Argonne).

From Orlando Villalobos Baillie.

Edoardo Amaldi 80

The 80th birthday of Edoardo Amaldi was celebrated at CERN on 10 October following a special session of the Scientific Policy Committee attended by previous committee members. SPC Chairman Italo Mannelli introduced two talks in honour of Amaldi. Gian Carlo Wick covered contributions to physics and described Amaldi as one of the leaders of the scientific renaissance in Italy after the Second World War. Wolfgang Paul described Amaldi's crucial role in the creation of CERN and the advancement of its scientific programme.

Amaldi was Secretary General of CERN in its fledgling years. He chaired the European Committee for Future Accelerators when it was set up in the 1960s and his name is associated with the report which launched the Intersecting Storage Rings and the 300 GeV machines, which have been vital to CERN's scientific progress. He was President of CERN Council when approval for the construction of the 300 GeV machine (now the SPS Super Proton Synchrotron) was finally achieved.

Amaldi is widely recognized as one of CERN's great personalities, who has always believed deeply in the Organization and has given much of his life and his abilities to promoting the good of CERN.

Director General Herwig Schopper concluded by expressing the congratulations and the appreciation of the CERN staff and the CERN user community. Edoardo Amaldi replied simply 'it has always been a joy to work for CERN'.

Edoardo Amaldi (right), 80 this year, with CERN Director-General Herwig Schopper.

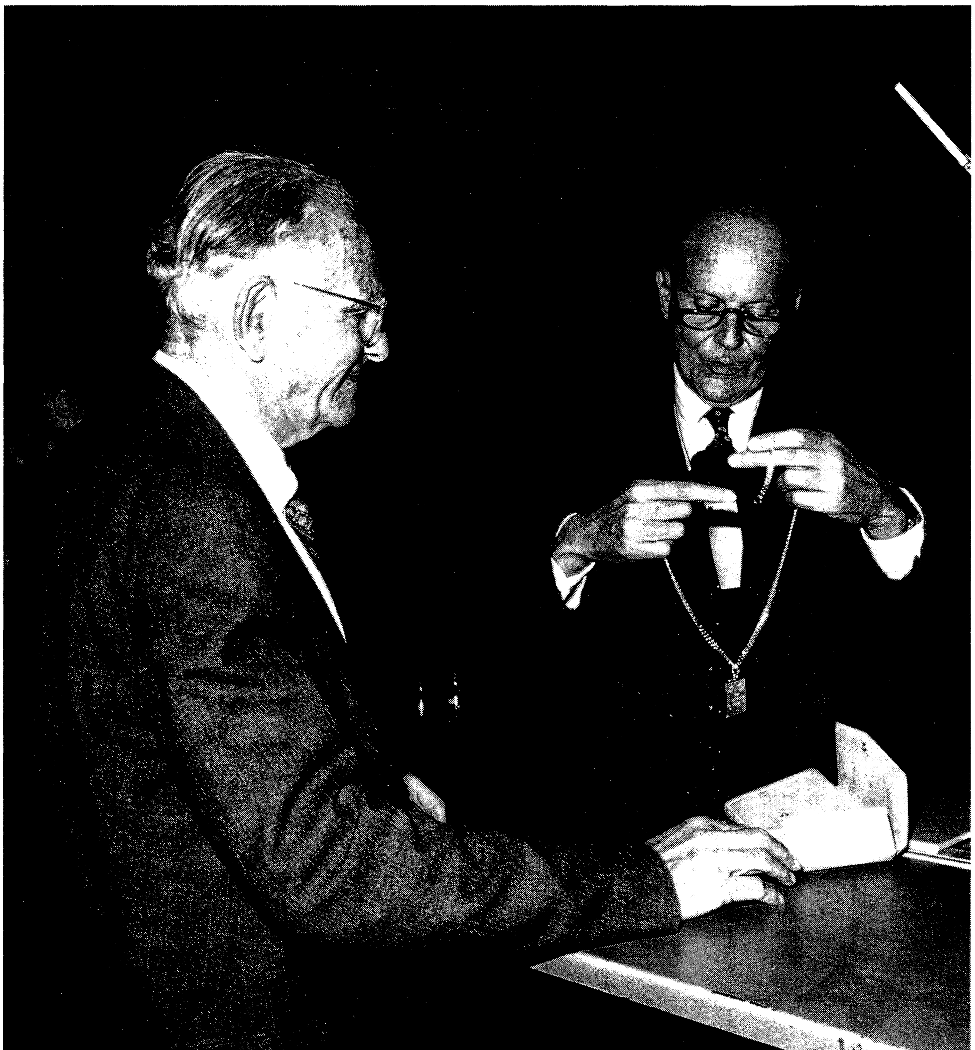
(Photo CERN 143..10.88)

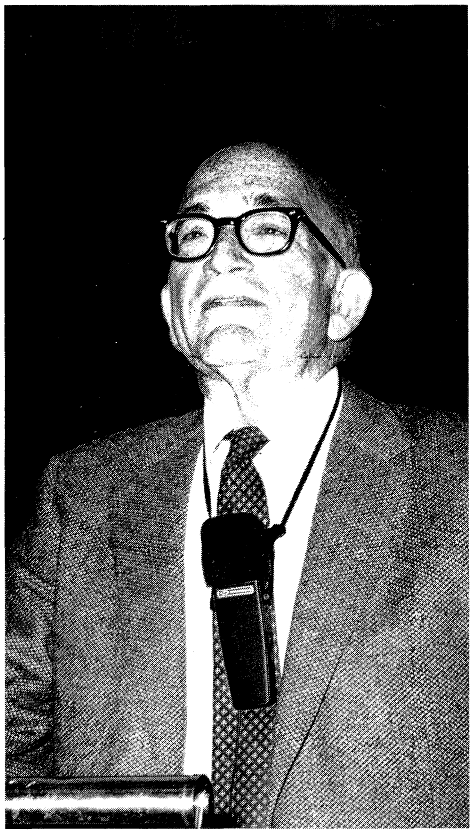
Happy Birthday Viki

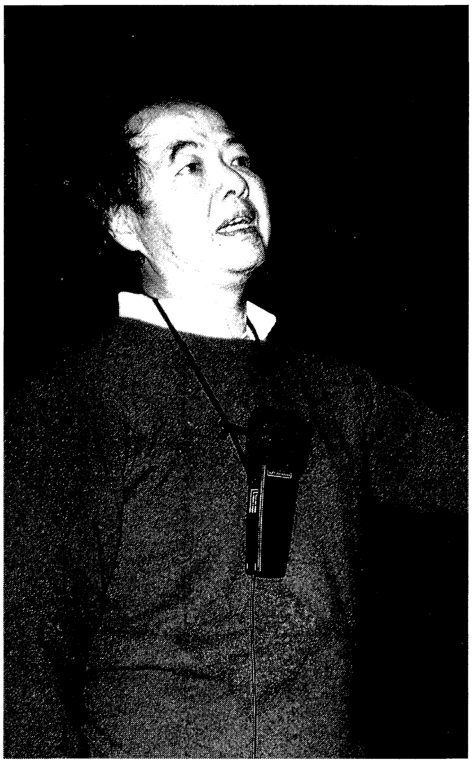
The CERN auditorium was packed on the 19th and 20th of September when friends and colleagues of Viktor Weisskopf gathered to celebrate the 80th birthday one of the best known and most admired personalities in the particle physics community. A galaxy of scientists was lined up to speak at an international colloquium on 'Science, Culture and Peace', organized by CERN and the Ettore Majorana Centre for Scientific Culture.

The talks tuned in to the many facets of Viki's character. Sid Drell had as his title 'Scientist, Humanist, Accompanist and Friend'. T. D. Lee communicated Viki's concern with world problems, talking about the World Lab and the remarkable work that has been accomplished in China. Herwig Schopper said that it is largely thanks to Viki's early influence that CERN is an organization that makes international collaboration an end in itself. Many speakers referred to his humane actions, his concern to promote understanding of science and the influence of his example as a teacher and a friend. Others talked about physics where Viki had made many important contributions and had drawn so much pleasure.

Nino Zichichi introduced Italian Ambassador Roberto Franceschi (right) who presented the Gold Medal of the International Science for Peace Committee to Viktor Weisskopf (left). Viki replied rejoicing that this event had taken place at CERN, 'symbol of the United States of Europe', and of international collaboration in science.







Tributes to Viki

Viktor Weisskopf and his wife (top left) listen to tributes from Sid Drell (top right) – 'Viki as Scientist, Humanist, Accompanist and Friend', CERN Director General Herwig Schopper (bottom right) underlining Viki's influence on CERN, and T.D. Lee describing Viki's concern with world problems.

Abdus Salam, Director of the International Centre for Theoretical Physics (ICTP), Trieste, presents J.N. Onuchic of Sao Paulo, Brazil, with the ICTP 1988 Heisenberg Prize for his work on the theory of electron transfer reactions applied to biological and chemical systems.

On people

Italian industrialist Francesco Somaini's triennial award for physics research achievement went this year to Carlo Castagnoli, eminent Turin cosmic physicist, underlining his work in the search for proton decay and for his role in the Mont-Blanc cosmic particle detector which among other things picked up neutrino signals from last year's supernova. A Somaini study fellowship went to Decio Pietro Cocolicchio, enabling him to spend some time at CERN.

Oxford mathematician Sir Michael Atiyah, well known for his work in geometry, topology, analysis and theoretical physics, receives the Copley Medal of the UK Royal Society.

Books

Festi-val – a 65th birthday festschrift for Val Telegdi – edited by K. Winter of CERN, is published by Elsevier/North Holland. The 300 page volume includes physics essays by friends and former students, including the presentations by Murray Gell-Mann, Louis Michel and Bruce Winstein made at the special event at CERN in July 1987 (September 1987 issue, page 46).

A function at the Tata Institute of Fundamental Research, Bombay, India, on 30 August marked the 60th birthday of distinguished Indian physicist M.G.K. Menon (right) now Scientific Adviser to the Indian Prime Minister. Here he is greeted by Indian industrialist J.R.D. Tata (left), Chairman of the Council of Management of the Tata Institute.

(Photo Tata Institute)

The 1988 CERN School of Physics, held in Lefkada, Greece, attracted about a hundred students from CERN and its Member States.

(Photo N. Tracas)

1989 CERN-JINR School of Physics

The 1989 CERN-JINR School of Physics will be organized jointly by the Joint Institute for Nuclear Research (JINR), Dubna, USSR, the Dutch National Instituut voor Kernfysica en Hoge-energiefysica (NIKHEF), Amsterdam, and CERN. Its basic aim is to teach various aspects of high energy physics, especially theoretical physics, to young experimenters, mainly from the Member States of JINR and CERN.

It will be held in Egmond-aan-Zee, Netherlands, from 25 June to 8 July 1989. Further information from the JINR Organizing Secretary, Mrs. T.S. Donskova, USSR, 101 000 Moscow, Head Post Office, PO Box 79, JINR; or from the CERN Organizing Secretary, Ms. S.M. Tracy, CERN School of Physics, CERN, 1211 Geneva 23, Switzerland, bitnet TRACY at CERNVM.

CERN School of Computing

The 1988 CERN School of Computing, held at Queen's College, Oxford, UK, from 14-27 August, was attended by 62 students from 12 countries.

The 1989 School will be held from 20 August to 2 September 1989 at the Kulm Hotel, overlooking the village of Bad Herrenalb in the German Black Forest, and

Distinguished Soviet theoretician I.S. Shapiro (right), well known for his contributions to group theory methods, to nuclear physics and to antiproton physics connected to the work at CERN's LEAR Low Energy Antiproton Ring, celebrated his 70th birthday in November. On a visit to CERN earlier this year, he discussed matters of interest with André Martin.

(Photo CERN 253.9.88)

The 20th Maria Laach Autumn School for High Energy Physics took place this year in the Benedictine Abbey of Maria Laach, near Bonn. Over the years, this school has played an important role in training a whole generation of German high energy physicists. Here school director Hans Dahmen of Siegen is with P. Athanasius, the monastic community's host for the school.

(Photo M. Jacob)

organized in collaboration with the Institut für Hochenergiephysik der Universität Heidelberg. The programme has yet to be fixed definitively, however mainstream courses will cover parallel processing, high speed networks, high performance computing, pattern recognition in detectors, data acquisition and triggers. Lectures on operating systems, expert systems, the evolution of high energy physics computing, and ciphering algorithms, among other topics, are also planned.

Participants should have a few years' experience in computing, particle physics or related fields. Application forms are available from the School Secretary, Mrs. Ingrid Barnett, CERN, 1211 Geneva 23, Switzerland. Deadline for applications is 31 March.

Meetings

The 21st International Cosmic Ray Conference, organized through the International Union of Pure and Applied Physics (IUPAP), will be held in Adelaide, Australia, from 6-19 January 1990. Further information from the Secretariat, XXI International Cosmic Ray Conference, Dept. of Physics and Mathematical Physics, University of Adelaide, Adelaide, South Australia 5001, Australia.

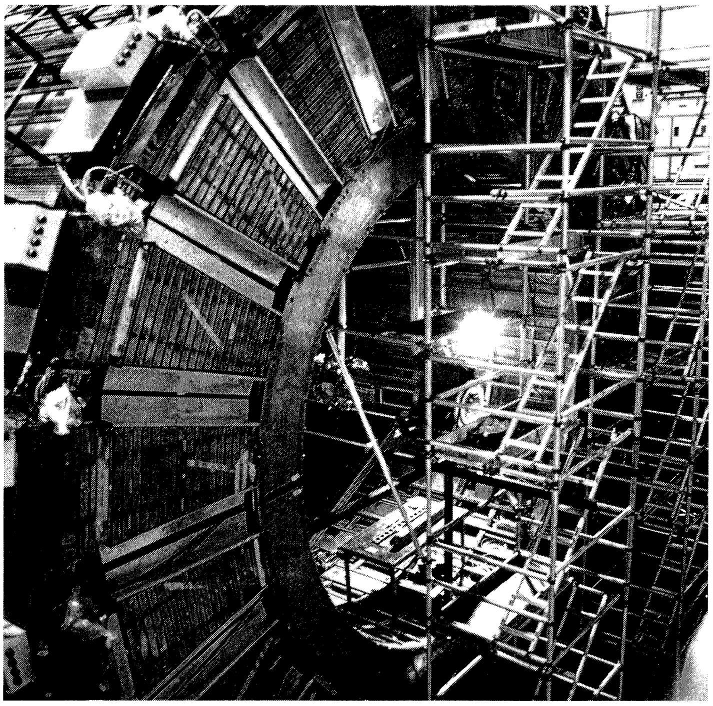
The second ICFA (International Committee for Future Accelerators) School on Instrumentation in Elementary Particle Physics will be held at the International Centre for Theoretical Physics (ICTP), Trieste, Italy, from 12-23 June 1989. Covering the physics of particle detectors and their applications, the school, including laboratory sessions, is aimed at advanced graduate students or recent post-doctoral scientists. Participants from developing countries will receive financial support from ICTP. Application forms from Prof. L. Bertocchi, ICTP, PO Box 586, I-34100 Trieste, Italy.

The tenth Biennial Meeting on Nuclear Physics, at Aussois, near Modane, Savoy, organized by the Nuclear Physics Institute of Lyon, will be held from 6-10 March. These meetings aim to underline progress over the past two years in the region where low energy nuclear physics blends into particle physics. Short communications for inclusion in the pre-session proceedings are welcome. Further information from Jaques Meyer, IPN Lyon, 43 Boulevard du 11 novembre 1918, 69622 Villeurbanne, Cedex, France, bitnet meyerj at frcpn11.

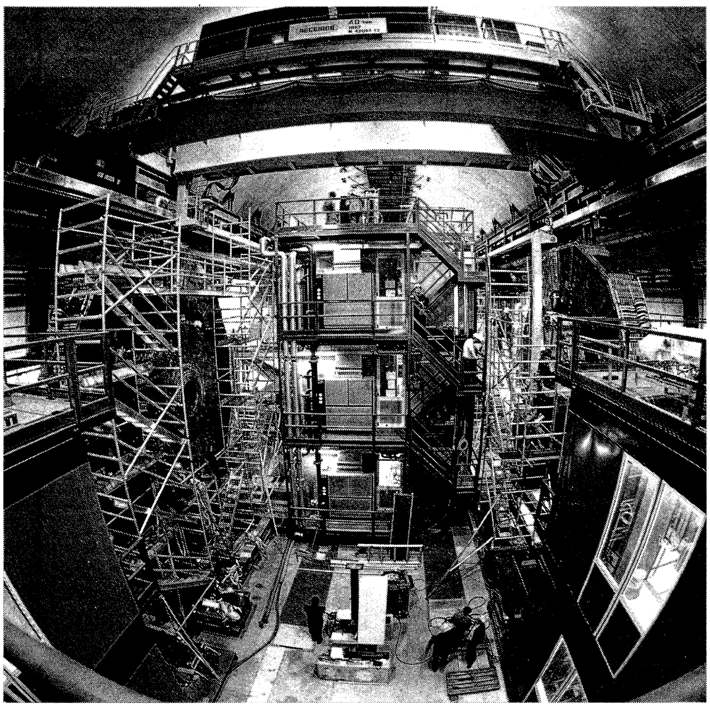
The fourth Lake Louise Winter Institute will be held from 19-25 February at the Chateau Lake Louise, Canada. This year the topic for the first three days of pedagogical lectures is 'Frontiers of Physics – from Colliders to Cosmology', followed by a short topical conference. Further information from LLWI Secretary, Department of Physics, University of Alberta, Edmonton, Canada T6G 2JI.

The XII International Workshop on Weak Interactions and Neutrinos will be held in Kibbutz Ginosar, Israel, from 9-14 April, sponsored by the Technion-Israel Institute of Technology. The programme includes invited lectures and discussion sessions. Further information from Organizing Committee Chairman Paul Singer, Department of Physics, Technion-Israel Institute of Technology, Haifa, Israel. Bitnet phr26w1 at technion.

DELPHI – mapping the field inside the world's largest superconducting magnet prior to installation of electromagnetic calorimeter modules. Outside the magnet solenoid is the segmented yoke of the hadron calorimeter followed by the first layers of muon chambers (Photo CERN 880.9.88).



ALEPH – this unusual view shows the electronic barracks with the 40-ton installation crane towering overhead. To the right, shrouded in scaffolding, is the first end-cap from the Rutherford and Glasgow groups; the second end-cap (left) is due in the Spring (Photo CERN 676.9.88).

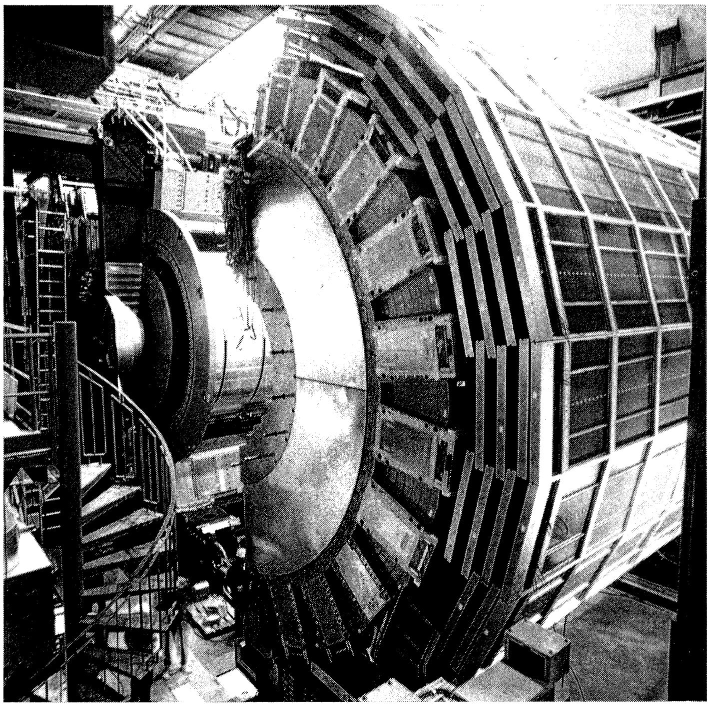


LEP experiments take shape

With first beams in CERN's 27-kilometre LEP electron-positron collider scheduled for next summer, installation work for the four big experiments pushes ahead.

L3 – construction of the 7800-ton octagonal magnet is complete and the magnet has been operated at nominal field for 100 hours. Here the doors at one end of the detector are open, giving an excellent view inside the 14 metre-diameter magnet installed with millimetre precision. From mid-November, this fine view became obscured by the arrival of the interior 32-metre support tube (Photo CERN 605.9.88).

OPAL – here the magnet is open with the pole piece (left) withdrawn to give access to the central detector. OPAL's four-layer muon barrel detector (Manchester) now surrounds the outside of the detector with 10-metre drift chambers. Towards the centre are the electronics boxes for the hadron barrel detector (Maryland, Bologna and Riverside) (Photo CERN 861.9.88).



CERN ''Yellow'' Reports

In order to release scarce resources at CERN, the ordering and distribution by the Scientific Information Service of reprints of CERN papers had to be brought to an end last year. As a consequence, the well-known monthly 'List of CERN publications' card was also discontinued.

However new publications in the CERN 'Yellow' report series, as well as the less frequent CERN-HERA reports, will now be listed in the CERN Courier. The first titles in 1988 are listed below. Copies may be obtained by writing to: CERN Scientific Information Service, CH-1211 Geneva 23, Switzerland, or by sending a bitnet electronic mail message to LIBDESK at CERNVM.

CERN 88-01, Evans, L., The proton-antiproton collider CERN, 11 Mar 1988. – 17 p.

CERN 88-02, Mulvey, J.H. (ed), The feasibility of experiments at high luminosity at the Large Hadron Collider: report of the High-Luminosity Study Group to the CERN Long-Range Planning Committee, CERN, 22 Apr 1988. – 93 p.

CERN 88-03, Verkerk, C. (ed), 1987 CERN School of Computing, Troia, 13 – 26 Sep 1987, CERN, 8 Jun 1988. – 436 p.

CERN 88-04, Hagel, J.; Keil, E. (eds), 2nd Advanced ICFA beam dynamics workshop, Lugano, 11 – 16 Apr 1988, CERN, 29 Jul 1988. – 236 p.

CERN 88-05, Bengtsson, J., Non-linear transverse dynamics for storage rings with applications to the low-energy antiproton ring (LEAR) at CERN, CERN, 1 Aug 1988. – 142 p.

CERN 88-06 v 1, Alexander, G.; Altarelli, G.; Blondel, A.; Coignet, G.; Keil, E.; Plane, D.E.; Treille, D. (eds), Polarization at LEP, v 1, CERN, 1 Sep 1988. – 357 p.

CERN 88-06 v 2, Alexander, G.; Altarelli, G.; Blondel, A.; Coignet, G.; Keil, E.; Plane, D.E.; Treille, D. (eds), Polarization at LEP, v 2, CERN, 1 Sep 1988. – 266 p.

APS Committee

For 1989, the Executive Committee of the Division of Particles and Fields of the American Physical Society will consist of: Fred Gilman (SLAC, Chairman), Ed Berger (Argonne, Vice-Chairman), Barry Barish (Caltech, Past Chairman), Adrian Melissinos (Rochester, Divisional Councillor), Bill Bardeen (Fermilab), Lowell Brown (Washington), Paul Langacker (Pennsylvania), Juliet Lee-Franzini (Stony Brook), Greg Loew (SLAC), Mike Witherell (Santa Barbara), and Bruce Barnett (Johns Hopkins, Secretary/Treasurer).

Luis Alvarez – a personal approach to physics

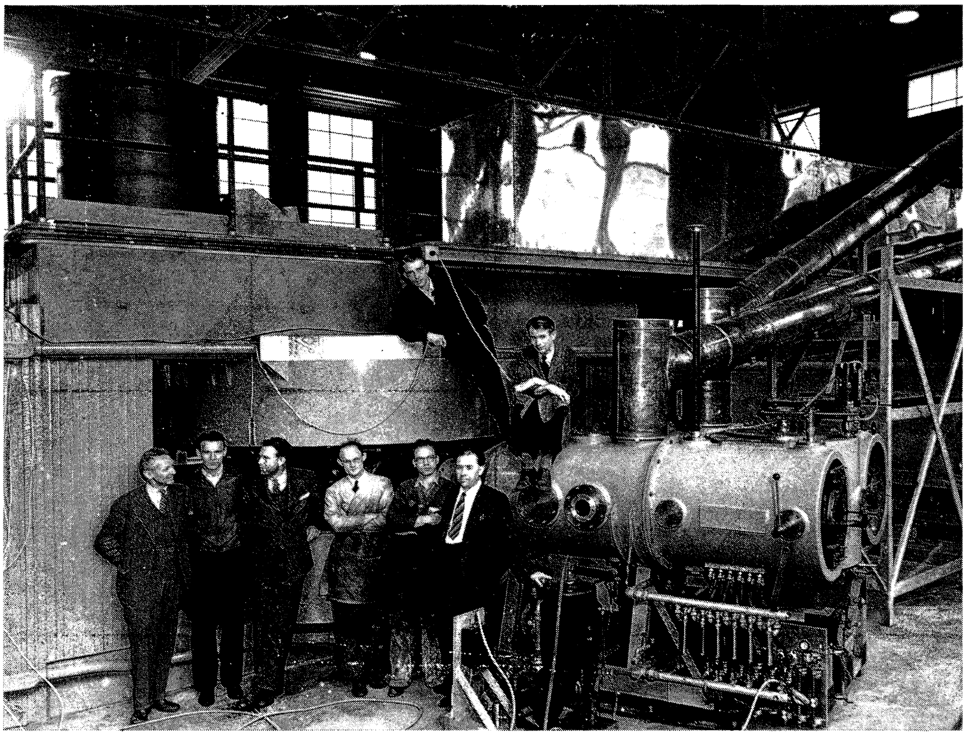
One of the major pioneer figures and outstanding personalities of particle physics, Luis Alvarez, died on 1 September. In addition to his numerous particle physics achievements, he became famous for his ventures in archaeology, palaeontology, and astronomy, and for his inventions. As a tribute to this remarkable man, we publish here some extracts from 'Adventures in Nuclear Physics', given as the 1962 University of California Faculty Research Lecture. According to custom, this presentation is a personalized account rather than an impersonal scientific discourse.

(Some of this material is also included in his 1987 autobiography 'Adventures of a Physicist', published by Basic Books, New York.)

As an undergraduate research projetct at Chicago my advisor suggested that I build one of the new fangled Geiger-Müller counters that he had recently read about in the German literature. He assigned me a room of my own on the first floor of the famous Ryerson Laboratory, which I soon learned had been Millikan's laboratory when he had made his historic measurement of the charge on the electron, using the oil drop technique. Of course, I had to build the metallic parts of the counters in the student shop, and then seal them into glass envelopes myself, and evacuate them on a vacuum system I had put together, while learning the art of glass blowing. The most difficult part was the amplifier, because the laboratory didn't own a cathode ray oscilloscope, a signal generator or a vacuum tube voltmeter. For the first two months, when things didn't work, I had no way of telling whether the trouble was in the counter or in the amplifier. But finally, after making every kind of mistake you can imagine, and some that I'm sure my friends who are electronic experts would absolutely refuse to believe could be made, the counter did work. No one in the department had seen such a device before, and I was invited to demonstrate it, and talk about it at the weekly Physics Department colloquium. Actually, I was only allotted half of the hour, because it wasn't thought proper for a mere undergraduate to take up a full hour of the department's time. This was my first scientific talk, and I can remember rehearsing it several times in one of the basement rooms.

About this time, Arthur Compton took an interest in my work, and I became one of his graduate students. In my first year as a graduate student, Professor Vallarta of MIT gave a talk at Chicago in which he showed how one could tell the

In 1939 at the Berkeley 60-inch cyclotron, Luis Alvarez showed that helium-3 was a stable constituent of ordinary helium. This 1944 picture of the cyclotron shows, left to right, Alvarez with Edwin McMillan above, with Donald Cooksey, D. Corson, Ernest Lawrence, Robert Thornton, John Backus and Winfield Salisbury below.



sign of the electric charge of the cosmic rays, by using an arrangement of Geiger counters.

Several physicists had looked for an effect, and not found it. Vallarta pointed out with great excitement that they had all done their looking in temperate latitudes, where the magnetic field of the earth had no measurable effect on the rays. He predicted that in his native Mexico City there would be a large effect.

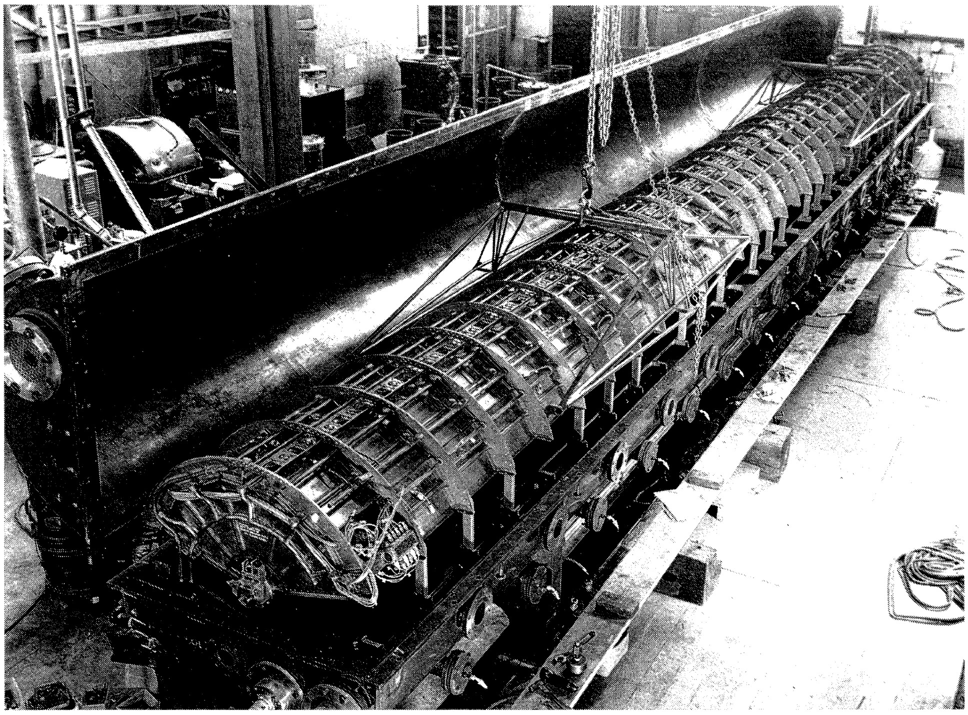
Arthur Compton realized at once that he had no apparatus that was directionally sensitive, so he asked me if I would like to take my Geiger counters to Mexico City. He said that Tom Johnson, a well-known cosmic ray physicist from Swarthmore had heard Vallarta's talk and planned to have a look for himself. Vallarta said he would take leave from MIT, and be our host in Mexico City. I worked feverishly to get my apparatus in shape – it had to be converted to battery operation, because the Mexican AC voltage was notoriously variable, and stabilized power supplies hadn't been invented yet.

Johnson and I arrived in Mexico City on the same day, and set our apparatus up on the roof of a small hotel. We started measuring cosmic ray intensities a few days later, and, within a few hours of each other, had found the so-called East-West effect. We both concluded that the rays were positively charged. We published our data independently in the same issue of the Physical Review, and it was with pride that I saw my first serious paper signed "Alvarez and Compton".

Berkeley

The second stage of my scientific life was the four and a half year period I spent in Professor Lawrence's old wooden laboratory at Berkeley. It was the most stimulating experience in my career. Everyone worked long hours in the wonderful spirit of cooperation that Ernest Lawrence instilled in his coworkers by the example he set, and by the strength of his personality. As I look back through the collected reprints of the prewar Radiation Laboratory, it is hard for me to convince myself that we really did do that much scientific work, because we had none of the luxuries that are available to physicists today. Today's machines are operated and serviced by professional crews. We serviced the cyclotron ourselves, and when the tank was removed from the magnet for repairs, which was frequently, we did the repair work on a 24-hour basis. We took turns operating the cyclotron, while other members of the laboratory staff made measurements on their individual pieces of apparatus. We built our own apparatus, both mechanical and electronic. The reason I find it hard to believe that I turned out a substantial amount of physics in those days is that any time my mind flashes back to that period, I see myself standing at a lathe, hunting for vacuum leaks in the cyclotron system, cleaning out a tar-filled heat exchanger, or wiring up an electronic chassis.

When Felix Bloch and I made the first measurement of the magnetic moment of the neutron in 1938 and 1939, we ran on the 37-inch cyclotron for weeks at a time, with time off only when the machine was used to treat cancer patients, or to prepare radioactive samples for the experiments of other members of the laboratory staff. The recording counters, and the control mechanisms for that experiment were set up close to the cyclotron control desk, so that I could operate the cyclotron myself, and take



The 40-foot radiofrequency cavity of the Alvarez proton linac, built in less than two years after Alvarez returned to Berkeley in 1945.

experimental data at the same time.

Soon after I came to Berkeley, Lawrence raised $ 50,000 to build a 60-inch cyclotron. He told me one day, that he wanted me to design the best magnet to fit into that budget. When I said that I didn't know anything about magnets, he merely said, "You'll learn".

The shielding for the 60-inch cyclotron couldn't be designed until the machine was finished and operating, because no one could predict how penetrating the radiation from such a machine would be. Until the shielding was fabricated, the machine couldn't be used for most of its normal purposes, which required high intensity beams. During this period of enforced idleness as an operating cyclotron, one of my graduate students, Robert Cornog, and I converted the machine into a sensitive mass spectrometer, and discovered helium-3.

Until 1932, hydrogen was believed to consist of a single isotope of atomic mass one, and helium was believed to consist of a single isotope weighing 4 atomic units. Then Harold Urey, acting on a suggestion of our own Professor Birge, found the rare isotope of hydrogen, with mass two, now known as deuterium. A year later, Rutherford and his co-workers in Cambridge discovered the famous fusion reactions. The British group found that when two deuterons reacted, the final products of the reactions contained either a helium nucleus of mass three, or a hydrogen nucleus of mass three. These newly discovered nuclei could only be observed when they were moving at high speed, so no one knew what happened after they slowed down and picked up the one or two electrons they needed to turn themselves into atomic systems.

Two independent arguments convinced everyone that helium-3 was radioactive, and that hydrogen-3, or tritium as it is now called, was stable. Stable tritium should therefore occur naturally in water, along with ordinary hydrogen and deuterium. We went on to show that these arguments were wrong.

Lord Rutherford's last published paper, just before his death, dealt with a search for stable tritium in a highly concentrated sample of heavy water. He searched the sample for tritium, using the most sensitive mass spectrometer then available, and found none present. Had there been the slightest question in his mind about the possible radioactivity of tritium he would have put the sample near a Geiger counter, and seen it go wild. Professor Libby found the old concentrated sample in the Cavendish Laboratory museum in Cambridge after the war, and even then, ten years after Rutherford's death, it made a counter rattle with its radioactivity!

I made one major goof, because I didn't realize how important a certain observation would be. As soon as fission was discovered, (and Ken Green and I verified it the day it was announced in the daily papers), everyone guessed that neutrons would be emitted at the same time, and these would make the chain reaction possible. My neutron time-of-flight apparatus seemed an obvious way to find these neutrons, if they existed, because it could yield a flux of pure thermal neutrons; something that no one else in the world had available at that time. I went over to the

Alvarez (second from right) and colleagues with bubble chambers built over the years.

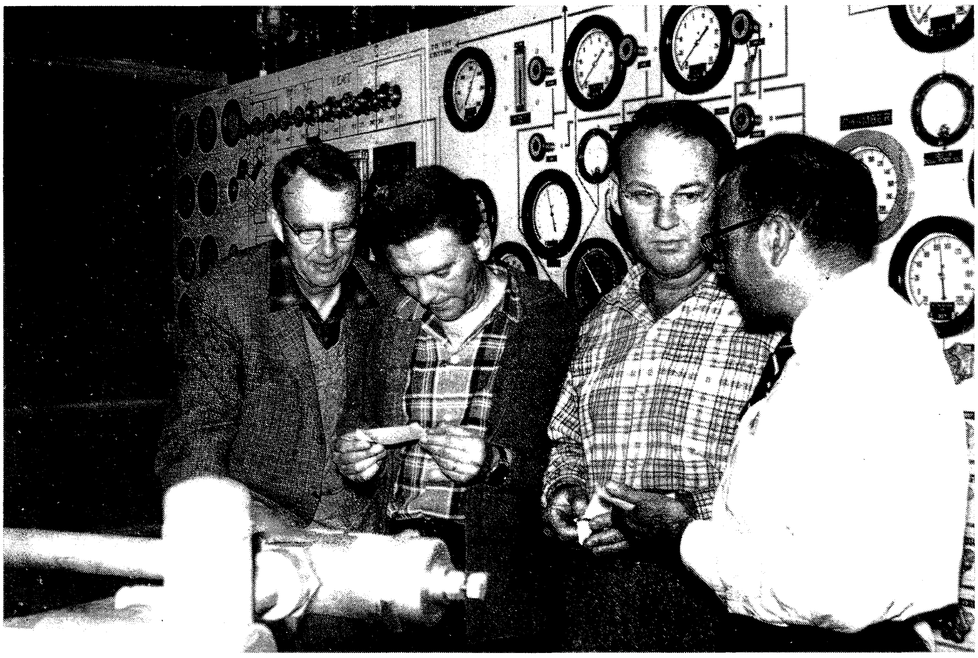
chemistry storeroom, and signed out for a few pounds of uranium oxide. I put this near my big counter, and looked for the secondary neutrons. When I didn't see any effect in a couple of minutes, I merely said, "Too bad", and went back to what I was interested in at the time. There is no doubt that had I taken an hour off to move the counter closer to the cyclotron, and to collect some more uranium, the counts would have been there.

After five years of wartime science and engineering, I returned to Berkeley in 1945, to begin another phase of my career. While at Los Alamos, I had decided that when I returned to Berkeley, I would build a high energy linear electron accelerator, employing the techniques I had learned in my radar work, and using the huge store of surplus radar equipment that would be flooding the peacetime market. My tentative plans were well along, when Ed McMillan told me of the synchrotron, which he had invented the day before. It was so obviously better than what I had in mind, that I immediately dropped all plan's for accelerating electrons and decided to do a similar job on protons. General Groves gave the laboratory a blank cheque to rebuild its facilities after the war, so the only problems were technical. I assembled a hard working team of former colleagues, and in just under two years, we had a beam from the 32 million volt proton linear accelerator. In this period of time, we learned how to solve some new and difficult technical problems in the field of radiofrequency engineering, and put together the highest energy Van de Graaff generator then attempted. Our 32 million volt protons held the high energy record in their field for over a year, until the 184-inch cyclotron was converted to accelerate protons to 350 million volts.

Bubble chambers

I met Don Glaser at a meeting of the Physical Society, and heard about his wonderful invention of the bubble chamber. I went away with a resolve to try liquid hydrogen as soon as I got back to Berkeley, and to try to build large chambers to use at the Bevatron. The story of our progress from very small hydrogen chambers is *physics history (ed).*

I am naturally much prouder of the important physics that has come from our family of hydrogen bubble chambers than I am of the chambers themselves. If I had to single out one discovery that was made possible by the chambers, I would talk about the catalysis of fusion reactions by mu mesons. I had the pleasure of being a working physicist on the ten-inch bubble chamber experiment at the time this quite unexpected reaction showed up. The fact that it was quite unexpected, and that it took our keenest powers of observation to find it, are the qualitites that put it in the adventure class, as far as I am concerned. However this has to do with my personal taste in physics.



March 24, 1959, first operation of the Berkeley 72-inch hydrogen bubble chamber at Berkeley. With Alvarez (left) are Bob Gow, Bob Watt and Paul Hernandez.

(Photos LBL)

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