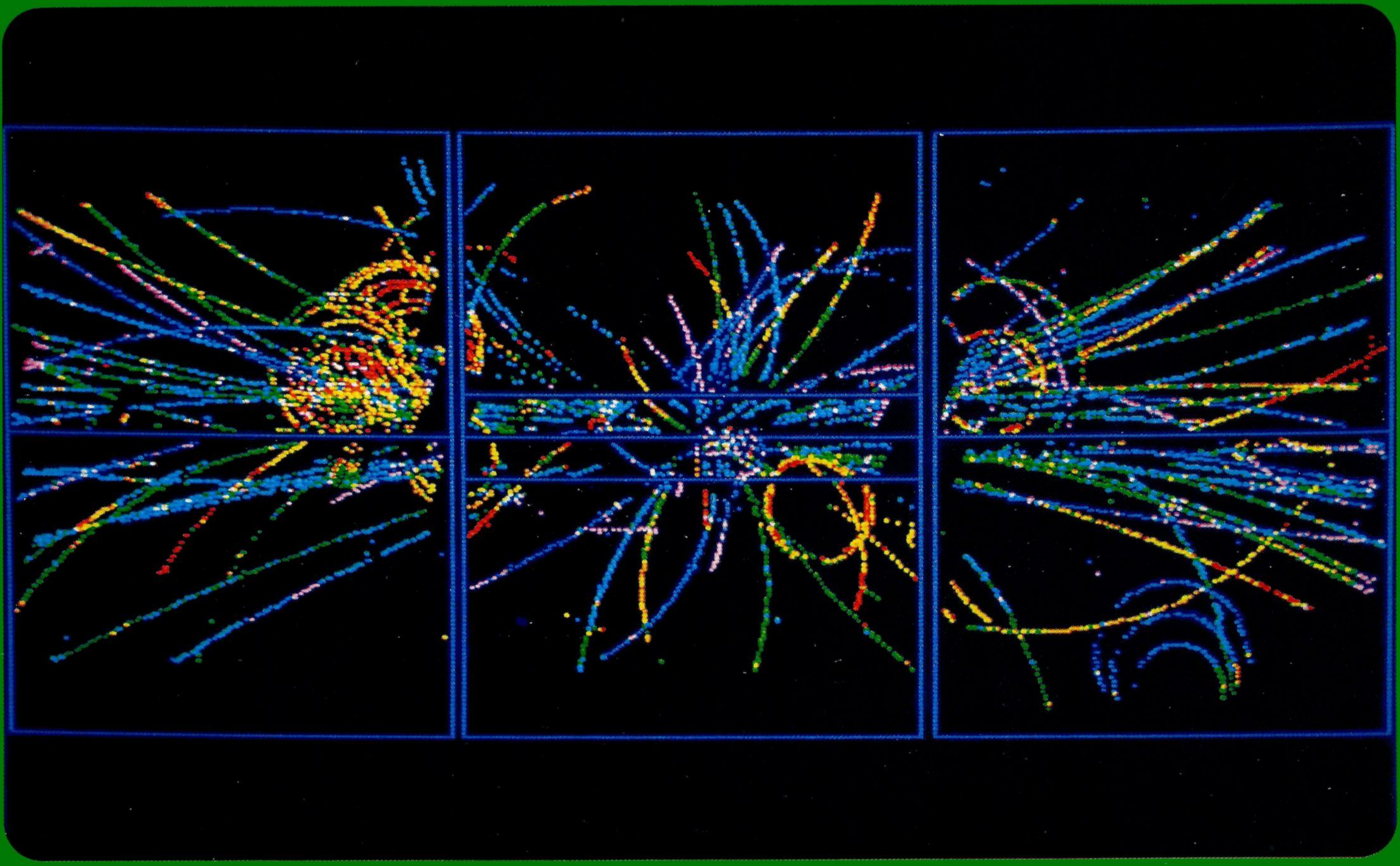
# CERN COURIER

International Journal of High Energy Physics



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# CERN COURIER

**International Journal of the High Energy Physics Community**

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Around the Laboratories

Physics monitor

*Cover photograph: a 540 GeV proton-antiproton collision in the CERN SPS ring as seen in the on-line monitoring display of the UA1 experiment. The colours indicate the depth, the track colours changing from the red end of the spectrum towards the violet as the particles move away. The end of last year saw a highly successful period of proton-antiproton collisions in the SPS — see page 6 (Photo CERN X511.11.82).*

# Around the Laboratories

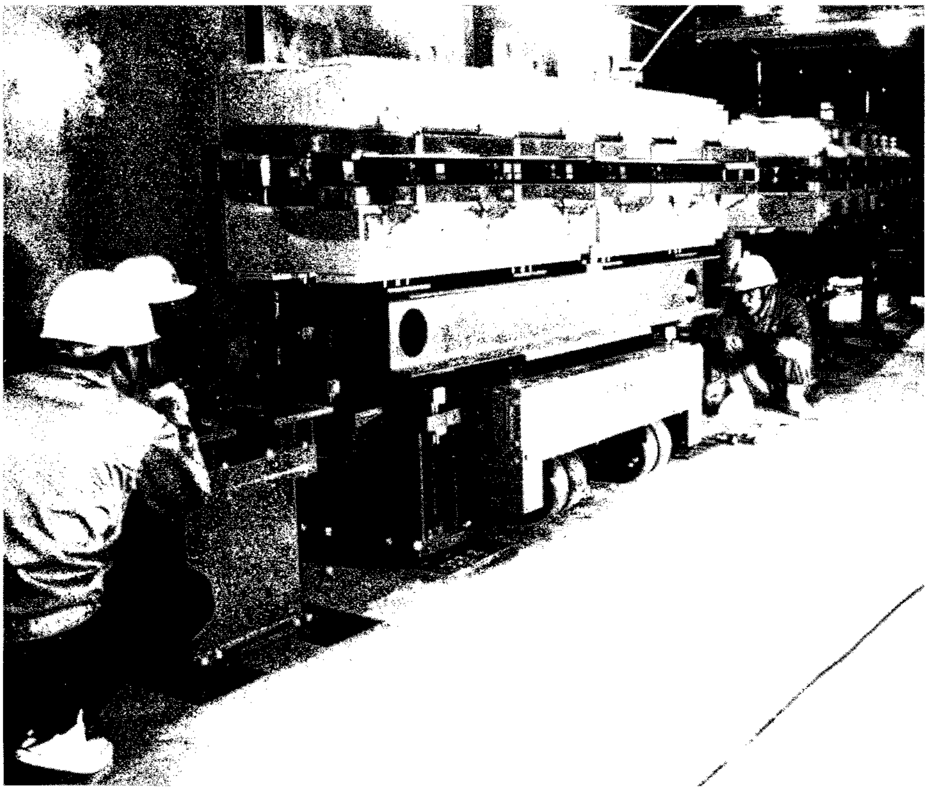
## KEK
## TRISTAN progress

The Japanese National Laboratory for High Energy Physics has asked for proposals (or letters of intent) for further experiments at its TRISTAN electron-positron collider, which is to begin operation in 1986. This call is for its third and fourth experimental halls. Of the four halls which are to be built on the main ring, two are already assigned to the TOPAZ and VENUS projects (see next page).

TRISTAN is open to the whole international community and KEK is eagerly looking for active participation by overseas groups at the new collider.

The TRISTAN project to build a 60 GeV electron-positron collider on the KEK site in the 'Science City' of Tsukuba is making a steady progress. An army of earth-moving equipment and steam hammers rushed in the day after the groundbreaking ceremony on 19 October 1981. Now, the 377 m-long tunnel for the accumulating ring is ready and two experimental halls on this ring are nearing completion. The components for the accumulating ring have been delivered and tested. Installation and alignment of the magnets took place in December, with a target date for electron acceleration in the fall of 1983.

The accumulating ring is a separate synchrotron and is designed to take the electrons from the 2.5 GeV linear accelerator of the KEK Photon Factory, which began operation last March. It will accelerate the electrons to 8 GeV for injection into the main ring. The positrons will also be handled in this ring with a 200 MeV high current linear accelerator for positron generation. The accumulation rate is expected to be about 60 mA/s for electrons and 0.3 mA/s for positrons with the hope that the 2.5 GeV linear accelerator will have a peak current of 1 A for electrons and 5 mA for positrons. This accumulating ring will have two beam collision areas, each with an experimental hall, so that it also can be operated at a centre-of-mass energy of about 12 GeV with optimum luminosity of about $2 \times 10^{31}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$ for studying electron-positron collisions.



*Installing magnets in the TRISTAN Accumulation Ring at KEK, Japan. This ring will take electrons and positrons from 2.5 GeV to 8 GeV, ready for injection into the main ring. It will also be equipped with its own experimental areas.*

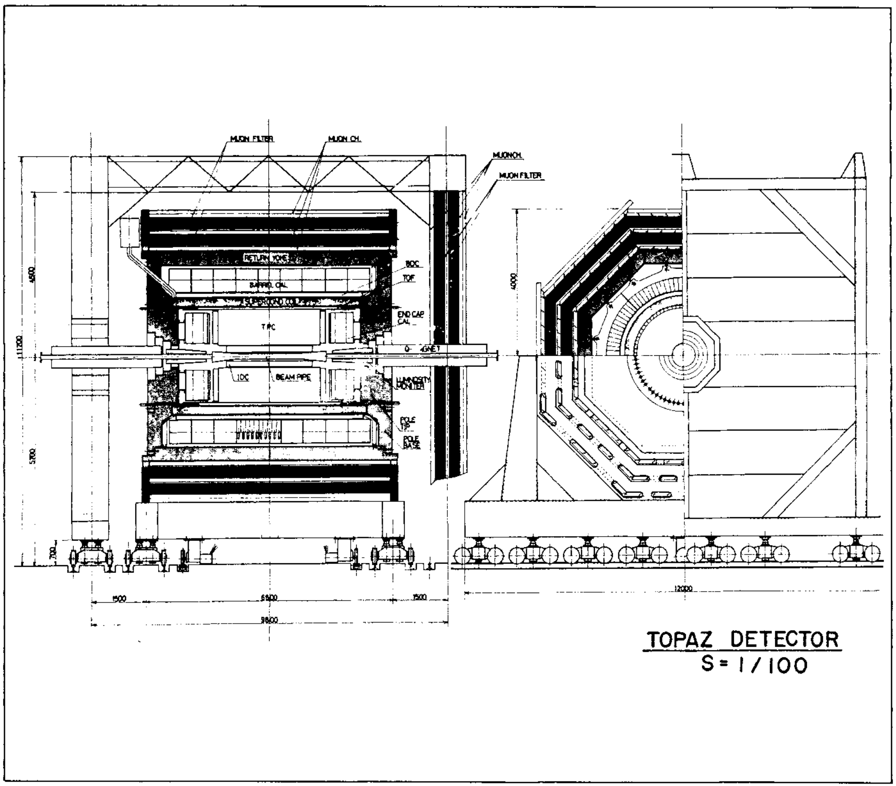
*(Photo KEK)*

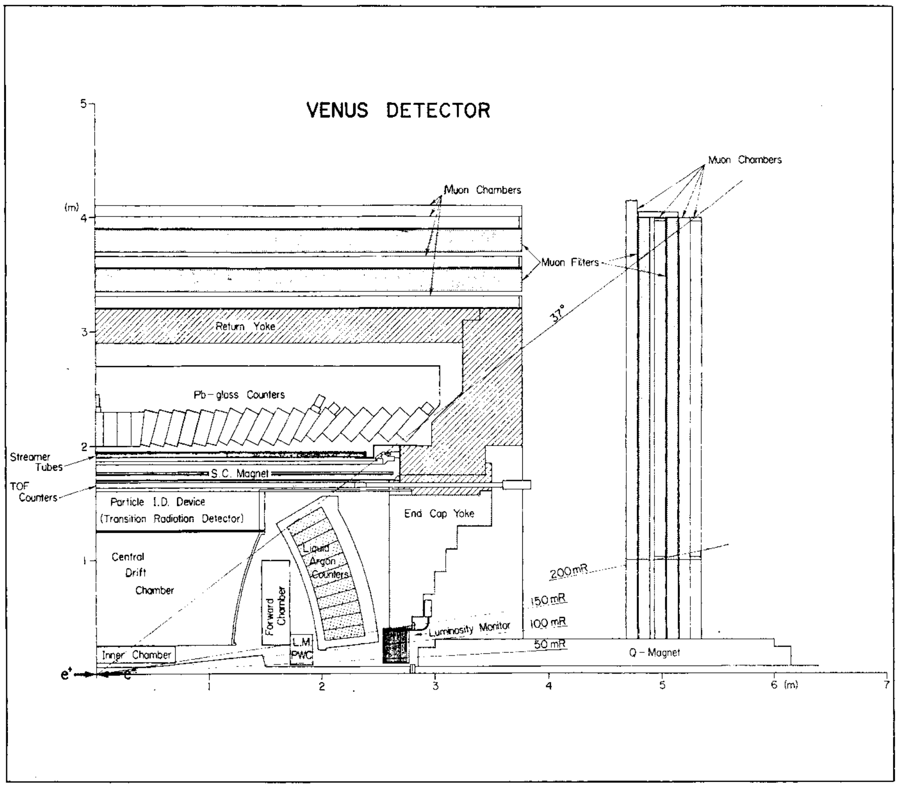
The construction of the 3 km-long tunnel for the main colliding ring and of its four experimental halls began in December. The tunnel, about 11 m below ground, is 6 m in width and 4 m in height, large enough to allow future expansion. The main ring has a fourfold symmetry with four long straight sections of 194 m for the r.f. acceleration equipment and a 6 m-long experimental insertion, connected together with four arcs of 347 m average radius of curvature. The energy and intensity attainable with the electron accelerator are ultimately limited by the accelerating voltage and power available to compensate for synchrotron radiation loss. The TRISTAN main ring will employ a series of cavities of total length 320 m. With 25 MeV of power into the room temperature r.f. cavities, a luminosity of $10^{31}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$ at 60 GeV is anticipated. With superconducting cavities, which are being developed at KEK and elsewhere, the collision energy can be increased to 80 or 90 GeV. The accelerator magnets are designed to handle this energy. Since the r.f. equipment is the key element of this collider, an intensive design study is in progress for its optimization. Meanwhile the design of all other accelerator components has been fixed and production is under way, with target date for the assembly of the entire main ring early in 1986.

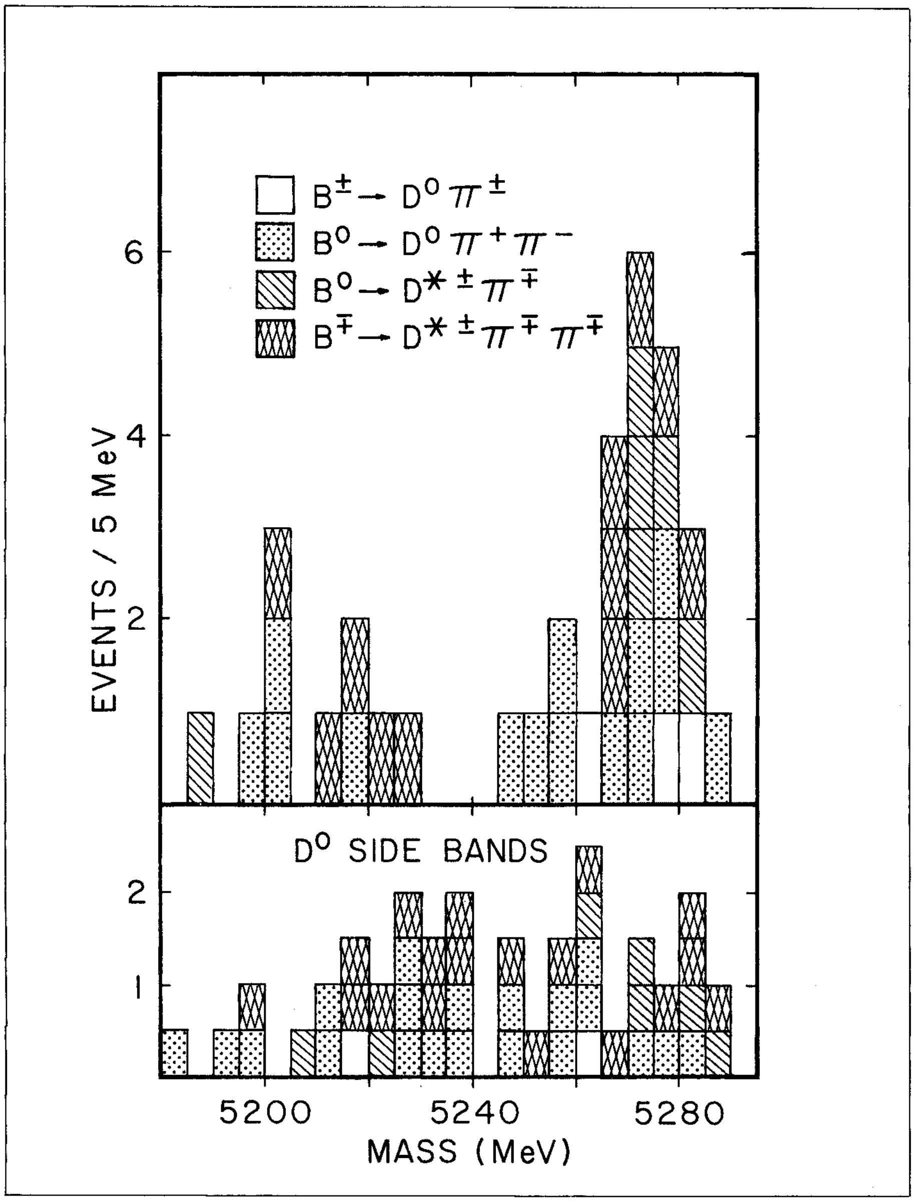
In order to evaluate the experimental proposals for this collider, TRISTAN Physics Program Advisory Committee (or TPAC) was established at KEK last May. Reflecting the fact that this collider is open to international collaboration, this nine-member committee includes two eminent physicists from abroad — one from the European community and one from the US. In April 1982, three predominantly Japanese collaborations expressed their intent to propose a detector for the collider. After a careful review, first stage approval has been issued to two of these collaborations, TOPAZ and VENUS, with an understanding that a detailed full proposal on their detectors shall be submitted by the end of January. Although the third proposal from the WATER BALL collaboration was unique and of interest, the Laboratory did not issue a go-ahead, hoping that the collaboration could be expanded and the proposal resubmitted at a later date. These steps were taken with a view that the first two detectors at TRISTAN could be built more or less as a national project.

Both TOPAZ and VENUS have as basic configuration the standard collider detector of cylindrical geometry, equipped with various detector components. A small cylindrical internal chamber, a large cylindrical central tracking chamber and a set of time-of-flight counters occupy the space inside the solenoid coil, 2.7 m in diameter and 5.0 m in length for TOPAZ and 3.4 m in diameter and 5.8 m in length for VENUS. In both cases, the magnetic field is generated by a thin cell superconducting solenoid, taking advantage of the advanced superconducting technology in Japan. Several thousand lead glass blocks will be used for the barrel electromagnetic shower detector outside the solenoid in both detectors but in rather different configura-

*Diagrams of the TOPAZ and VENUS detectors as initially proposed for the first two of the four collision areas at the new Japanese TRISTAN ring.*







*Top, mass plot of beauty meson candidates from the CLEO group at the CESR electron-positron collider at Cornell. The decay channel for each event is shade-coded. The lower plot is for background events where the observed kaon-pion signals are slightly off the mass of the D⁰ meson. No structure is seen.*

tions. The usual muon identifier of iron slab and drift tube detector sandwich covers the magnet return yoke. The end-cap calorimeters (with forward drift chamber in the case of VENUS) covers the forward and backward solid angle to as small an angle as practical. In these designs, the specific detectors for two-photon physics are not included. However the intention is not to pass by this interesting physics.

Although TOPAZ and VENUS detectors are similar in their basic configuration, each of them emphasize a certain aspect of physics with a corresponding choice of the detector components. The TOPAZ emphasis is in the identification of the produced particle with the ionization loss measurements, as reflected in its choice of the Time Projection Chamber as its central tracking chamber. TOPAZ-TPC, according to the current design, will have an eight-sector configuration with radial sensitive path length of 80 to 85 cm, depending on the azimuthal angle, and will be operated at a few atmospheres pressure. With an energy loss resolution of some three per cent estimated for the TOPAZ-TPC, and helped by an increase in the relativistic rise at lower pressure, this device should give particle identification over a wide range of momentum.

The VENUS collaboration takes a more conservative approach to their central tracking detector, with the intention of having a device which will work well on Day One. A conventional cylindrical drift chamber has been chosen only to measure the trajectory of the particle with good precision. The emphasis in VENUS is rather directed towards its good capability to detect the electromagnetic shower with an improved segmentation and with an improved resolution over the largest possible solid angle. For the segmentation, each block of lead glass will be mounted so as to point roughly toward the interaction point, thus reducing the probability of overlap. For the improved resolution this collaboration has elected to use a pair of liquid argon detectors with lead converter as end-cap calorimeters. In addition, an effort is being made to reduce the radiation length of the material in front of the barrel lead-glass shower detector by a use of the carbon fibre epoxy board for the structural material of the chambers and cryostat.

## CORNELL
## Beauty mesons

After accumulating much indirect evidence for beauty (B) mesons, the CLEO group at Cornell's CESR electron-positron ring has now reconstructed explicit signals for these mesons from their decay products.

The key to this reconstruction is the study of the weak decays of different types of quark. Earlier work on the D mesons at the SPEAR ring at Stanford had shown that charmed quarks prefer to decay into strange quarks, while studies with CESR tuned around the fourth upsilon resonance had shown that the beauty quark prefers to decay into a charm quark.

The first three (narrow) upsilon states consist of a beauty quark and antiquark tightly bound together. However the fourth upsilon is less strongly bound and can decay into two beauty mesons. The beauty hunt therefore concentrates on the energy range near this fourth upsilon. Since the installation of a mini beta magnet system to squeeze the colliding beams, the excellent luminosity available at CESR during 1982 produced a sample containing some 40 000 events.

The first sign that beauty meson reconstruction might be possible was the observation that various different charmed mesons were being produced (see December 1982 issue, page 418). With these charmed particles reconstructed, the next step was to try to work back to the original beauty mesons from the data around the fourth upsilon. The search concentrated on allowed combinations of charmed mesons plus one or two pions, rather than more frequent (but more complicated) decays producing more particles.

After careful selection, a clear peak of 18 events showed up in the mass region between 5265 and 5285 MeV, where the scale is adjusted to agree with the precision measurement of the upsilon mass in the VEPP-4 ring at Novosibirsk (see October 1982 issue, page 325). Background effects were carefully allowed for in order to detect any mechanism which could fake the observed peak.

This important observation at CESR will be reported in more detail in the next issue. It is a significant milestone in new particle spectroscopy, and the hope is that increased data samples will soon open up this field for more detailed study.

Champagne at the CERN SPS. Research Director Erwin Gabathuler (second from left) had promised a crate of champagne if the maximum proton-antiproton collision luminosity achieved in the SPS during the initial operations in 1981 could be increased tenfold. Enjoying his generous offer with him are (left to right) André Faugier, Lyndon Evans, Jacques Gareyte and Robin Lauckner.

(Photo CERN 209.11.82)

## CERN
## When antimatter mattered

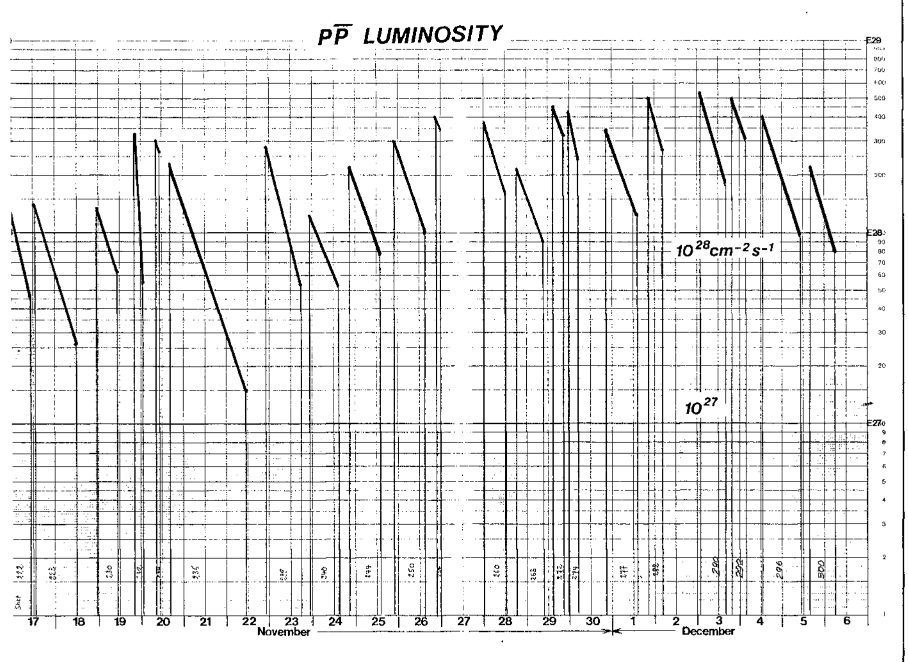
On 6 December, the highly successful 1982 period for proton-antiproton collisions in the SPS ring came to an end. For almost two months, the big UA1 and UA2 experiments were able to log particle collisions at the highest man-made energies (540 GeV) ever achieved, and at a substantial rate.

The SPS collider experiments had their first taste of physics at these record energies in 1981, and interesting first results emerged from the meagre samples of data which were collected. Now the experiments have been able to accumulate about five hundred times as much data as before, and the new physics results are eagerly waited.

Proton-antiproton operation had been scheduled earlier last year, but a mishap at the UA1 experiment meant that it had to be postponed. This proved to be something of a blessing in disguise. Two periods of collider operation were merged into an almost continuous block, which made for considerable savings in setting-up and running-in. In this way the experiments were able to have the continuous supply of collisions which they need.

The 'low beta' insertions to squeeze the beams together in the collision areas came into action for the first time in the latest period. Another major factor which made for higher luminosity (collision rate) was that several circulating antiproton bunches became available for collision with proton bunches moving in the opposite direction. In addition, the Antiproton Accumulator Ring and the PS complex which together supply the precious antiprotons were able to boost the supply of antimatter available.

The period began modestly enough early in October, when there were teething troubles. After several days the linac ion source went out of action, which meant that the Antiproton Accumulator was left with a substantial stack of antiprotons, but there were no protons to collide them with. The decision was made to try for antiproton injection into the LEAR low energy antiproton ring. After some trepidation at such short notice, the resourceful PS operations



*The second half of the latest period of proton-antiproton collisions in the CERN SPS. For each injection, initial luminosity regularly surpassed $10^{28} cm^{-2} s^{-1}$. Total integrated luminosity over the whole period (which began in October) was more than 25 inverse nanobarns, good news for the big experiments.*

team successfully decelerated the 3.5 GeV/c antiprotons from the AA down to 600 MeV/c, and the beam circulated happily in the 80 m perimeter LEAR ring.

With the proton supply reestablished, the proton-antiproton luminosity gradually built up, briefly reaching a new record level of $10^{28}$ $cm^{-2}$ $s^{-1}$ on 12 October. In mid-October, first trials began with three bunches each of circulating protons and antiprotons. This proved tricky to master, but by the end of October, three bunches on three became the standard pattern, injection luminosities around the $10^{28}$ level were the norm, and the experimenters acknowledged that they were confidently logging lots of data with low backgrounds.

At the beginning of November, there was a brief pause before the period was continued, initially in 'high beta' configuration so that the UA4 experiment could take valuable data on elastic scattering.

Then there were a few hitches, but everything came back with a bang at the middle of November with a new luminosity record of over $3 \times 10^{28}$, and champagne was called for. Towards the end of the period, this level was surpassed several times. The final record luminosity was $5 \times 10^{28}$. Typical beam coasting time was 15-20 hours, although one antiproton shot lasted for 42 hours.

At the end of the run, the total number of interactions — the integrated luminosity — exceeded 25 inverse nanobarns, most of which was recorded by the experiments. According to the theory, this should be sufficient for the production of some intermediate bosons of the charged kind. While waiting for the next run in April, there are many bright eyes scouring the data.*

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**** Preliminary proton-antiproton data was reported at January's Topical Workshop on Collider Physics, held in Rome.***

# Fixed Target Workshop

With the first generation of fixed target experiments at the 400 GeV SPS proton synchrotron completed or nearing completion, with SPS proton-antiproton collider operation well established, with LEP construction imminent, and with the closure of the Intersecting Storage Rings planned, it is a propitious time to review the programme of fixed target experiments at the SPS and to look ahead.

So at the end of last year CERN decided to sponsor a comprehensive workshop, which was organized by I. Mannelli, to review the physics which could be covered with the machine during the second half of the current decade. This physics potential has to take particular account of the different conditions which can be studied at the SPS proton-antiproton collider, and of the start of operations at the Fermilab Tevatron.

The field was divided into five main areas — neutrino physics (convener D. Haidt), muon physics and structure functions (J.-J. Aubert), new particles (L. Foa), hadron physics (D. Treille) and nuclear beams and targets (W. Willis). Working groups were set up and met periodically during the autumn, but the workshop was concentrated mainly into a week of parallel and plenary sessions at CERN at the beginning of December.

The plenary sessions presented a condensed version of what had been discussed earlier in the various working groups and parallel sessions, but this compression of material continued on the final day of the workshop, when the five conveners summarized what had been discussed under each heading.

As well as paving the way for specific future studies at the SPS, it was also clear that the workshop provided a good chance to review the current status of particle physics, indicating interesting new results or controversial topics.

In muon physics and structure function studies, in neutrino work, in new particle studies and in hadron physics, the trail has already been blazed, and the initial work with the SPS has clearly pointed the way ahead. But there are still many questions to be resolved and there is no shortage of areas for study in the years ahead.

In muon physics and structure functions, initial data has provided important information and new clues, but the measurements need to be refined and extended. Of particular interest are the systematic differences between structure functions as measured in iron and deuterium by the European Muon Collaboration experiment (see November 1982 issue, page 362). Muon physics is also beginning to probe weak/electromagnetic interference (see January/February 1982 issue, page 5), and associated jet studies could usefully complement the information from colliders.

Neutrinos have always been a strong point of the SPS programme, and there is still a lot to explore. The search for tau neutrinos and neutrino oscillations, precision measurements of neutrino scattering off electrons and of semileptonic neutral current interactions, and the further study of associated hadrons are all potentially rich fields. The technique of holography could be exploited and pay considerable dividends.

The production and decay of new particles is a field which is still developing, and there is continual progress with new techniques to study the short particle lifetimes involved. Pioneering work for several of these new techniques (silicon targets, silicon microstrip detectors and holographic high repetition rate bubble chambers) has been carried out at CERN. New theoretical developments such as supersymmetry have shown that it is important to continue the search for new particles.

Hadronic physics still provides a fruitful field of study. High energy secondary beams (antiprotons, photons, etc.) could support a healthy physics programme. In addition, many of the basic features of hadron interactions (e.g. elastic scattering) continue to merit further investigation. Associated lepton production provides a deep probe of the underlying particle mechanisms. There is new interest in spin physics since novel possibilities exist for the use of polarized proton beams and targets. The decision to close the Intersecting Storage Rings (see December 1982 issue, page 412) is felt to be a serious loss for hadron physics.

As yet less well explored, especially at higher energies, is the subject of nuclear beams and targets, a relatively new and fast developing field of study. There is obviously a great deal of interest in the possible use of nuclear beams and targets, both at the SPS and the 26 GeV PS proton synchrotron, to search for evidence of a new state of matter — the so-called 'quagma', or quark-gluon plasma — which is expected to have very different properties to those of conventional nuclear matter. At CERN, a decision whether to attack this is expected soon. Many theorists are confident that there is a lot of new ground to cover, and there are some indications from studies at other machines that new results might be well within reach.

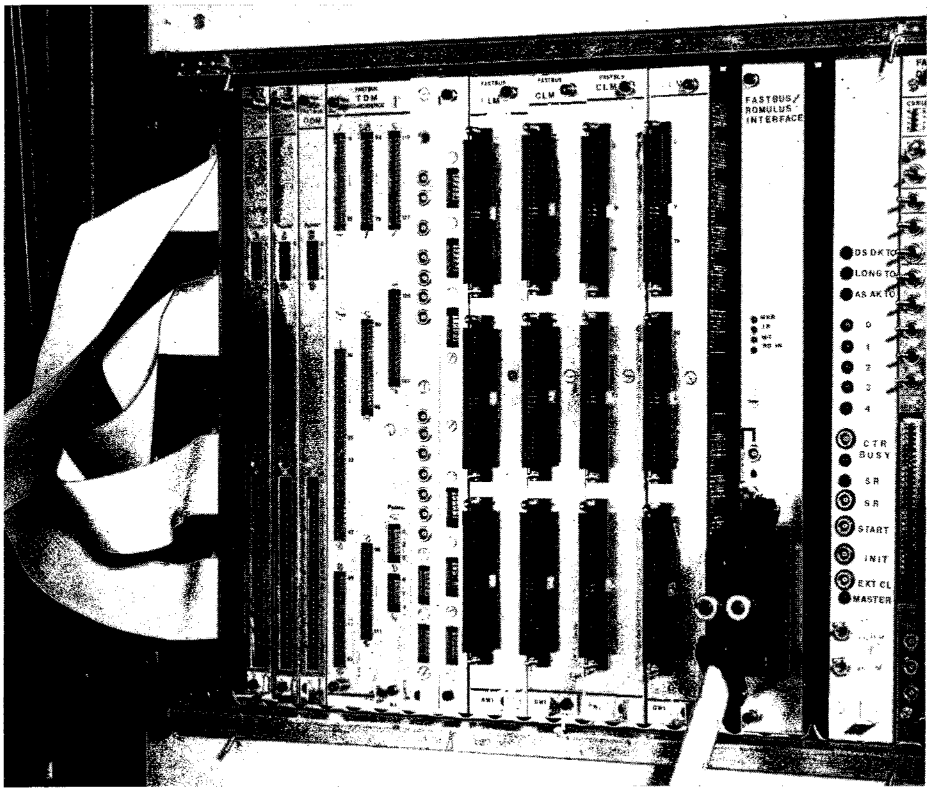
Summing up the workshop, Alvaro de Rujula was in characteristically ebullient mood and tried to cover a wide field. Many of his remarks ap-

*The CERN Auditorium was packed for the summary talks during the recent SPS Fixed Target Workshop.*

*(Photo CERN 157.12.82)*

*The Fastbus system installed at CERN in the European Muon Collaboration Experiment.*

*(Photo 231.9.82)*



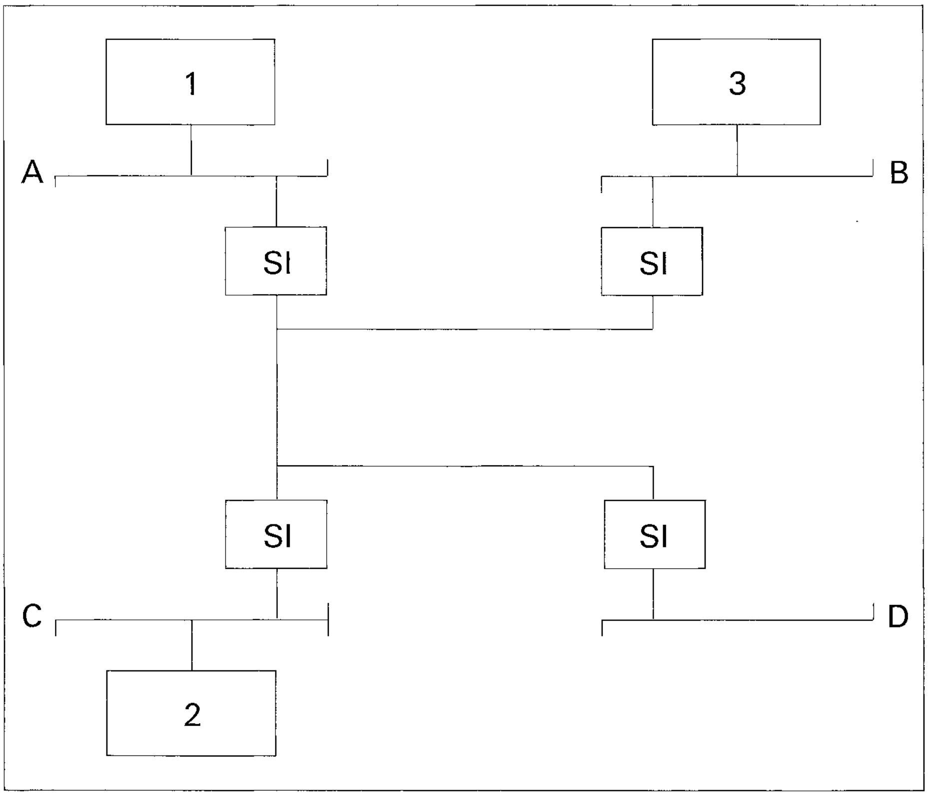
plied equally well to high energy physics as a whole rather than the future programme at the SPS. However his talk, just as the workshop overall, provided a lot of food for thought.

As well as the formal presentations, the workshop provided a fruitful opportunity for contact and interaction between physicists working on common problems, where they could step aside from their current research problems and try to imagine their requirements several years or more in the future.

## Fastbus progress

1982 was a successful year for the CERN Fastbus pilot project, led by Bob Dobinson. Fastbus is the new physics data acquisition system designed with the next generation of experiments very much in mind. A single-crate system was brought into operation last summer in the European Muon Collaboration experiment in the North Area of the CERN SPS 400 GeV proton synchrotron. The trigger processor together with its associated readout and control (see March 1982 issue, page 54) ran very reliably during both setting up and eventual data-taking. Once commissioned, its reliability has been in fact somewhat superior to that of CAMAC and other 'mature' data processing equipment used in the experiment.

In the latter half of the year, significant progress has also been made in the area of multi-segment Fastbus. At the University of Illinois last June, two Fastbus crates were successfully linked via two segment interconnect modules. The segment interconnect was designed by Bob Downing, assisted by Jim Kohlmeier



*Configuration of the four-crate (A, B, C, D), three-computer (1, 2, 3) Fastbus set-up recently tested. It employs four segment interconnect modules (SI) linked by three pieces of cable, each 30 m long.*

***Just before Christmas, the PETRA electron-positron collider at DESY attained a collision energy of over 40 GeV. More news soon.***

and Mike Haney. Dave Lesney wrote the software to test the system.

CERN made two copies of the Illinois segment interconnects, and got them running with the help of Bob Downing during a visit to CERN. The CERN modules have recently travelled to the US, where they were put together with the two original segment interconnects to form a four-crate, three-computer system interconnected by almost 100 m of cable. The three computers were hooked into the set-up at various points and shared access to the overall system. Tests were made with all computers operating simultaneously, generating large amounts of competing traffic. Multi-processor access proceeded in an orderly fashion, with essentially no errors, even with artificially introduced electrical noise.

With this encouraging recent progress and the increasing interest of commercial suppliers, the stage now seems set for Fastbus to appear in a wide range of high energy physics and other roles (a medical application is now under way).

## DESY Theory Workshop

The subject of last year's traditional DESY theory workshop was 'weak interactions at high energies'. Several presentations concentrated on tests of the standard (Glashow / Salam / Weinberg) electroweak model. Data from lepton-neutrino scattering and from muon pair production in electron-positron annihilation give a handle on the electroweak mixing parameter ('Weinberg angle') and the couplings of the weak neutral current. These are consistent with the standard model, as are the observed asymmetries in muon pair production in electron-positron annihilation.

Although at first sight the standard model therefore appears to be in good shape, some of its deeper implications have yet to be tested. These include the existence and properties of the intermediate bosons as the weak force carriers. In addition, the standard model has a number of unattractive features — the mixing angle is an arbitrary parameter, not fixed by the theory, and Higgs bosons are required.

In recent years, there has been an enormous effort to construct alternative models to remedy one or other of these shortcomings. But it now appears clear that models which attempt to extend the basic symmetry and the assignment of particles of the electroweak model can be ruled out from recent electron-positron annihilation data. However more sophisticated ideas could still help. Among these, supersymmetry has to be mentioned. This demands an additional level of particle symmetry with new particles. No signs of these particles have been seen yet, but P. Fayet reported on limits imposed by PETRA data and argued that the 'photino' (the supersymmetric counterpart of the photon) may be detectable at the PETRA and PEP electron-positron rings.

Another promising attempt is based on the idea of a deeper substructure of particles yet to be discovered. This was covered at the DESY meeting by Haim Harari. These composite models can reproduce the standard electroweak features at energies up to 100 GeV without recourse to elementary Higgs particles. However the models also predict heavier intermediate weak bosons and a whole spectrum of additional excited particle states.

Several talks covered the idea of grand unified theories, including a report on the status of proton decay experiments. Last but not least, the link between weak interactions and astrophysics was discussed.

Electron-positron annihilation in the existing PETRA and PEP rings could provide important tests of new ideas in electroweak interactions.

*(We are grateful to K. Decker and T. Walsh for providing us with this information.)*

*Left to right, Paul Söding, Haim Harari and Günter Wolf at the recent DESY theory workshop.*

*(Photo DESY)*

# Physics monitor

## Monopole Workshop

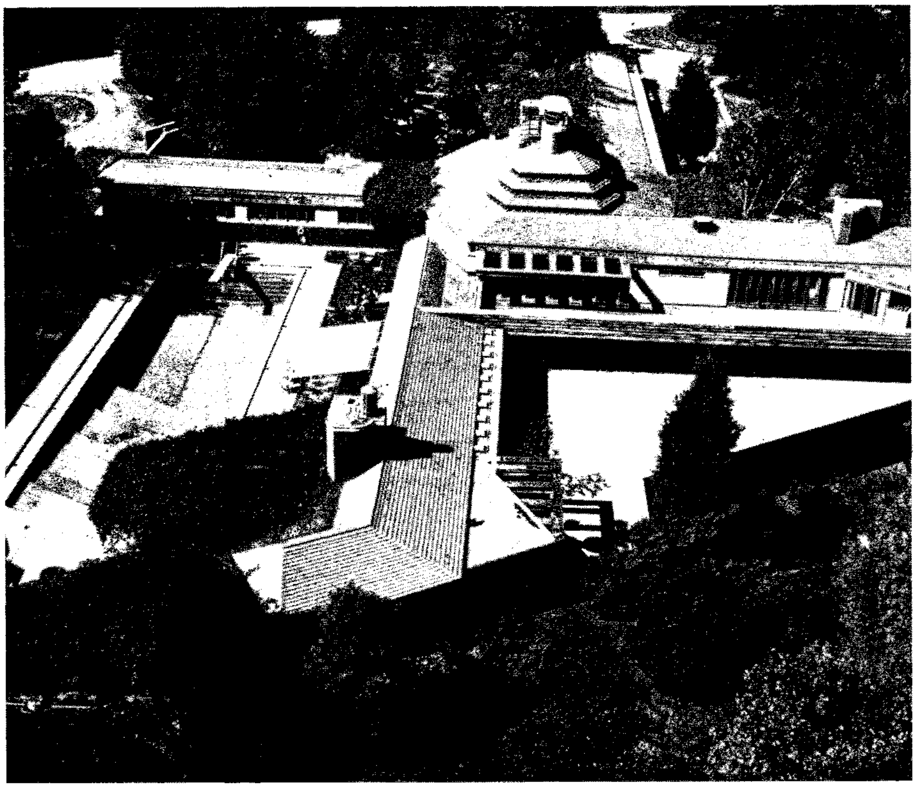
Some 90 physicists from 13 countries gathered in October to examine new evidence and theories concerning the magnetic monopole. The venue was Wingspread, the last, but by no means least, of architect Frank Lloyd Wright's marvellous prairie houses, located in Racine, Wisconsin.

While many physicists remain sceptical about magnetic monopoles, a growing number are speculating that they may have been made in the first blaze of creation. If found, monopoles would provide a profound clue as to the origin and nature of the universe.

In the last decade, scientific interest has focused on the possibility of extremely heavy monopoles. In the middle seventies, A. Polyakov and G.'t Hooft independently noted that such monopoles were a characteristic feature of a large class of gauge theories which now are most commonly used to perform the so-called Grand Unification of forces. The masses of monopoles associated with the standard Grand Unification model are very large indeed, about $10^{16}$ times larger than the proton. Such monopoles defy ordinary expectations — they are finite in size and reluctantly accelerated. Even in passing through the magnetic field of the entire galaxy they attain at most a speed a thousandth that of light. Stopping them is correspondingly difficult because of their enormous momentum.

Several years ago, J. Preskill (Harvard) examined monopole production in the early universe and discovered a puzzle. Monopoles should have been created with about the same abundance as protons and, therefore, should dominate the mass of the universe. On the other hand, conventional arguments about the measured rate of expansion of the universe limit their number to something like one monopole per $10^{18}$ protons. Nonobservation of monopoles further suggests that suppression is clearly needed to reduce the monopole population. One of the favorite approaches discussed at Wingspread was Guth's (MIT) inflationary universe, which although curing this and some other outstanding cosmological problems, introduces a few of its own.

Wingspread, Racine, Wisconsin, scene of the recent Magnetic Monopole Workshop.



In 1981, Lazarides, Shafi and Walsh (CERN) questioned lower limits on monopole abundances and argued that it was difficult to force the flux of monopoles much below $10^{-16}$ per square centimetre per second. Their flux limit was not very far below the now famous 'Parker bound', which notes that the measured galactic magnetic field places a limit on the monopole abundance — on the earth about one monopole per football field per year is to be expected.

By late 1981, theoretical interest in monopoles had reached the point where a meeting was organized at the International Centre for Theoretical Physics in Trieste. Those proceedings, now published, chronicle many curious mathematical conjectures about the properties of monopoles but contain just one solitary contribution which describes experimental efforts.

1982 was a year where the concrete problems of monopoles were confronted. These challenges have included Cabrera's (Stanford) tantalizing monopole candidate event (see July/August 1982 issue, page 220); the conjecture that monopoles might catalyze proton decay; a searching, but as yet inconclusive, struggle to predict energy loss for slow monopoles; a Grand Unification study of 'monium' with its cosmological con-

*One of the speakers at the Wingspread workshop was Blas Cabrera of Stanford, one of the few people to have seen possible evidence for magnetic monopoles.*

sequences; and an explosive growth in the number of monopole search experiments. The Wingspread workshop, convened as a clearing house for these activities, has produced a status report which provides guidance as to how to proceed.

There is no doubt that Cabrera's candidate event set the stage for the hectic and confused scene that led to the Wingspread workshop. Early in 1982, Cabrera, a Stanford low-temperature physicist, found a striking monopole-like signal in his superconducting detector — a two-inch diameter, four-strand loop of wire devoid of ambient magnetic field down to a very low billion level. Cabrera's detector works by induction and thus is only sensitive to the monopole's magnetic charge.

Suddenly, the tables were turned. This small detector suggested too large a flux and thus motivated scenarios which contrived to remove the Parker bound. Cabrera's limit was increasingly in conflict with those of ionization detector experiments. However, some questioned whether slow moving monopoles would ionize at all. An interesting diversion to this central theme at Wingspread was the unusual sight of a number of puzzled theorists trying to decide whether the recent idea of monopole catalysis of proton decay was valid. By the time of the Wingspread meeting, Cabrera, bereft of further monopole candidates despite the continuous running of his original detector and the inauguration of a new three-loop detector whose coverage was seven times larger, lowered his earlier flux limit by almost a factor of ten.

Representatives of more than 25 different inductive and ionization experiments in various stages of development were a major faction at Wingspread. Other inductive experiments generally paralleled Cabrera's technique but aimed toward larger detectors by expediently using less sophisticated shielding.

Investigations of ionization loss expected from slow moving monopoles remain inconclusive. S. Ahlen (Berkeley) was quick to point out that there is much concrete information on the energy loss for electrically charged particles moving at velocities expected for monopoles. Several current ionization experiment using sensitive detectors of about a square metre running for a year are reporting no candidates. The largest detector attacking the monopole problem is the gigantic Baksan cosmic ray detector in the Soviet Union.

At Wingspread, Curtis Callan argued persuasively for monopole catalysis, where a monopole passes through ordinary matter, converting protons to electrons, mimicking 'ordinary' proton decay and leaving a trail of detectable debris along its path. Arguments continue to evolve on the rate of the process; strong, weak, or never.

Another interesting aspect to the whole picture has been C. Hill's (Fermilab) study of the pole-antipole pair system, originally called monopolonium but sensibly shortened to monium. The unique aspect of monium is its incredibly slow de-excitation — if created in the Big Bang with a separation of an angstrom, it would still not have fallen to the ground state! However, monium decay products may be observable and plentiful. Because monium is magnetically neutral, it is exempt from the Parker bound.

After the Wingspread meeting it is still not possible to conclude whether magnetic monopoles do or do not exist. If anything, it was learnt that it will be harder to see monopoles than earlier results suggested. However, even if monopoles are not part of Nature's plan, the impact of the Wingspread workshop was no less important as it has helped to clarify some very critical and fundamental issues.

The Wingspread workshop was organized by P. Trower (Virginia

## Soviet detector in action

*A recent search at the big underground detector at the Baksan Neutrino Observatory in the North Caucasus revealed no magnetic monopoles. This four storey construction measures 16 metres by 16 by 11 and is beneath some 2000 metres of rock. It contains 3132 liquid scintillators each 70 x 70 x 30 cm and viewed by a photomultiplier.*

Tech) and R. Carrigan (Fermilab), acting on the advice of G. Giacomelli (Bologna), D. Schramm (Chicago), Q. Shafi (Trieste) and F. Wilczek (Santa Barbara) with the support of the North Atlantic Treaty Organization, the US Department of Energy, the US National Science Foundation and the Johnson Foundation.

## Continuing the hunt for the axion

While prediction is considered by some to be too strong a word, theoretical arguments certainly do not exclude the existence of 'axions' — very light, highly penetrating particles.

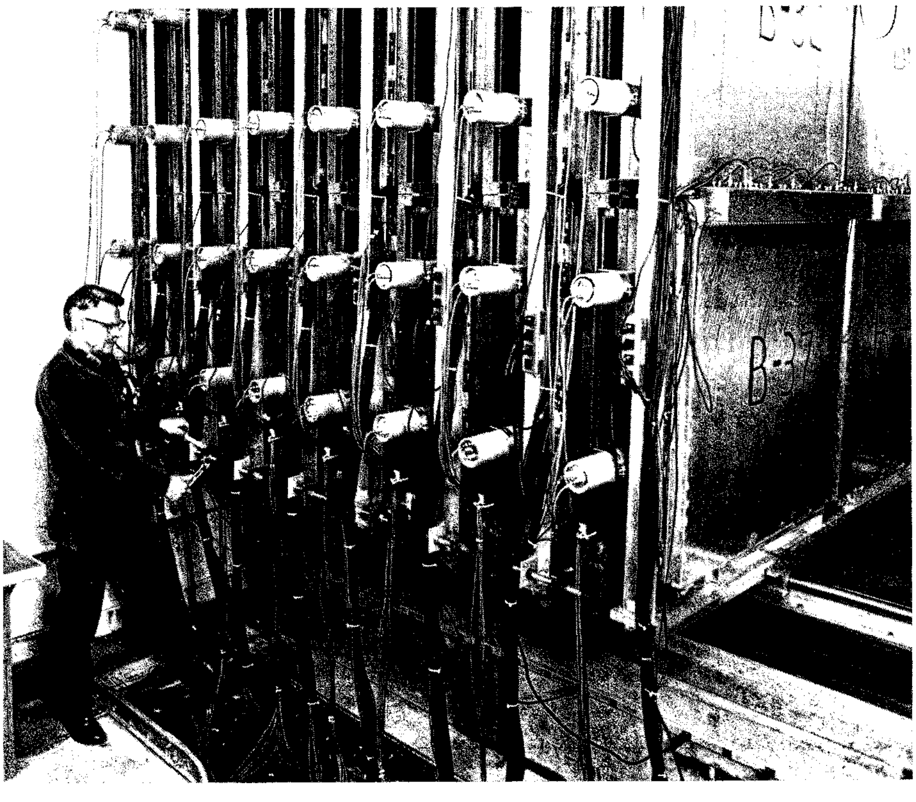
The most common light, penetrating particle is the neutrino, obtained in the laboratory from the weak decay of pions and kaons. In beam-dump experiments, the pions and kaons are first removed (usually by a thick metal block), so that the conventional copious supply of neutrinos is severely reduced. But the beam dump might not necessarily remove other light, penetrating particles, such as axions, which will have a better chance of showing up when they are not swamped by neutrinos.

A study at the far end of the electron beam from the SLAC linac has joined the ranks of these beam-dump experiments. The particles which survive after passing through the beam dump itself then have to pass through a 200-metre thick hill, and a distant downstream shower counter has been set up to catch any signs of photons coming from the decay of rare particles. An initial run early last year revealed no surprises.

The experimental team includes James D. Bjorken of Fermilab, generally considered to be a theoretician, but showing that now, just as in Fermi's day, theory and experiment are by no means mutually exclusive physics careers.

One experiment which has seen an unexplained effect in a beam dump is by an Aachen team, working at the Swiss SIN machine, which detected an excess of forward photon pairs in the particles emerging from the metal shielding (see May 1981 issue, page 161). After more extensive examination of the data and further consistency tests, the effect remains.

Some signals have also been reported in experiments studying the particles produced in nuclear reactors, but confirmation has not been possible. In the absence of a definite answer to the axion question, the experimenters (and theoreticians) keep looking for possible new particles.



Finn Halbo adds a few final touches to the apparatus designed to look for signs of exotic new particles in a beam dump experiment at the Stanford linac.

(Photo Joe Faust)

## The highest energy cosmic rays

A paper entitled 'Research into primary cosmic radiation at ultra-high energy' won a Lenin prize last year for the Soviet scientists Nikodim Efimov, Dmitri Skobeltsyn, Georgi Zatsepin, Sergei Nikolski, Dmitri Krassilnikov and Georgi Christiansen. Here Sergei Nikolski describes the scope of these studies.

The study of elementary particles and the proof of a hypothesis of the origin of cosmic rays requires a knowledge of the number and energy of the particles reaching Earth from cosmic 'accelerators', the composition of these 'beams' and the part of the galaxy with which they are linked. The study of these problems is made difficult by the low intensity of primary cosmic radiation at ultra-high energies. The primary cosmic particles, with an energy up to $10^{18}$ electronvolts (millions of times higher than the energy of the particles obtained in the world's largest accelerators) arrive in the Earth's vicinity at a frequency of one particle per year per square kilometre. It is hard to build a particle detector with a big enough sensitive area and it is impossible to set it up outside the atmosphere. Particles with an energy 1000 times lower are less rare: their rate of arrival is greater by a millionfold. However recording them in satellite-borne equipment is restricted: an instrument with a sensitive area of about 1 $m^2$ weighs several tons.

Fortunately it has been possible to overcome some of the difficulties in studying such particles because when they enter the atmosphere and interact with the nuclei of air atoms, the primary cosmic radiation particles at ultra-high energy produce an avalanche of secondary particles. These secondary particles, essentially electrons, photons and muons, are scattered hundreds of metres around the avalanche's axis.

These atmospheric showers were discovered in 1938. At the same period it was found that they largely consist of electrons and photons. The explanation for such rays was initially based, therefore, on the photo-electronic cascade theory.

The Soviet scientist Dmitri Skobeltsyn, however, observed differences between the theoretical predictions and experimental results and assumed that the penetrating particles played a considerable part in the formation of the atmospheric showers. Subsequent studies enabled Georgi Zatsepin and Dmitri Skobeltsyn to draw up, in about 1950, a nuclear cascade diagram for the development of these showers. According to this diagram, the shower starts with an inelastic collision between the proton or the primary cosmic radiation nucleus and the nucleus of the air atom. The secondary particles — hadrons in contemporary parlance — produced at that moment collide with the atoms of the air and produce new generations of hadrons. These, therefore, constitute what might be called the nuclear cascade skeleton of the atmospheric shower.

This concept completely reoriented the study of the atmospheric showers. However there are at present considerable obstacles in determining the energy and nature of the primary particle. The study of the spectra of the showers in relation to the number of electrons and muons has enabled Sergei Vernov, Georgi Christiansen and other research workers to establish that, in the energy range of about $10^{15}$ electronvolts, the energy spectrum of primary cosmic radiation cannot be expressed in one single way, but is characterised by a 'split' in the diagram.

The study of these atmospheric showers is like trying to reconstruct the outside of a building which has been destroyed, after the resulting stones have been used to pave a road. The task seems impossible. Nevertheless, once the volume of stone has been calculated, it is easy to imagine the size of the destroyed building. If all the particles of the showers (including the photons) can be 'collected', and their energy determined, and if the energy used by the shower to ionize the atmosphere is taken into account, the sum should be equivalent to the energy of the primary particle which produced the shower. The absolute calibration of the energy spectrum of primary cosmic radiation at an energy of about $10^{15}$ electronvolts has been time-tested over twenty years.

The study of the nuclear composition of primary cosmic radiation is a more complex problem. The experiments performed at the Tian-Shan high altitude station of the Physics Institute of the USSR Academy of Sciences, with the participation of a group of Bulgarian physicists under Jordan Stamenov, have shown that the composition of primary cosmic radiation at an energy of $10^{15}$ or $10^{16}$ electronvolts differs little from that of primary radiation with energies tens of thousands of times lower. Protons represent 40 per cent of the total flux of the particles at the given energy; 12 to 15 per cent consists of helium nuclei and about 15 per cent of iron nuclei. The rest is made up of nuclei of elements of intermediate atomic number: carbon, nitrogen, oxygen, magnesium, etc.

Such a result is also interesting in the attempt to understand the origin and distribution of cosmic rays in the galaxy. The flux of highest energy cosmic rays and of the corresponding great atmospheric showers is very small. As the showers are large, the mesh of the net of shower particle detectors can also be large. One of the largest installations in the world for such research has been built in the Yakut Republic, involving some forty stations for observing large atmospheric showers located over an area of 20 $km^2$. The distance between neighbouring observation stations varies between 0.5 and 1 km. The simultaneous measurement of a great atmospheric shower by three stations or even more and the measurement of the density of the shower particle flux at each one makes it possible to find the centre of the shower and the total number of particles in it.

The Soviet scientists have pursued their studies of primary cosmic radiation to the maximum energies which, today, represent about $10^{20}$ electronvolts.

The discovery of the relation between the intensity of primary cosmic radiation at an energy of more than $10^{18}$ or $10^{19}$ electronvolts and the direction in which the particles arrive has produced an important new result. Lower energy cosmic rays are diffused in virtually every direction in the galaxy, which may be explained by the confusion of the trajectories of the charged particles in the galactic magnetic fields. The analysis of the experimental data obtained on cosmic rays at the highest energies demanded the combination of measurements made by several large installations in the world.

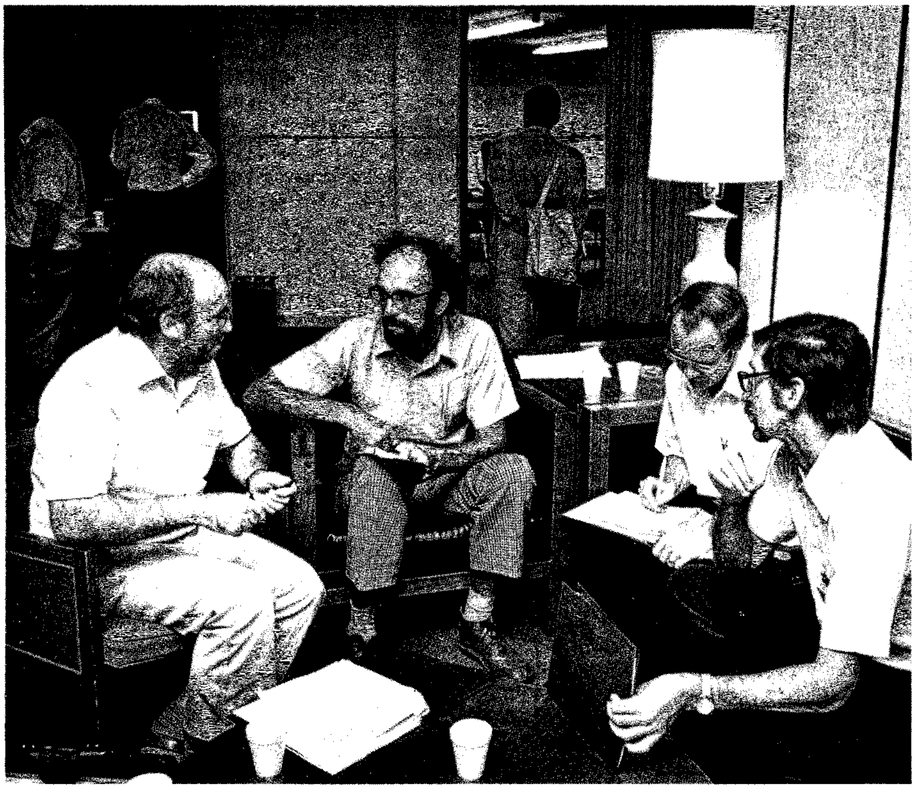
The first convincing communication concerning the heterogenous nature of the diffusion of cosmic rays at ultra-high energies was published in the joint paper by the Soviet physicist Dmitri Krassilnikov and his Scottish colleague A. Watson. The flux of cosmic rays in the extreme high energy range arising from the central sector of the galaxy is twice as small as that from the opposite direction. There are excess particles in the flow from the centre of the mass of galaxies closest to our planet. It could be that the high energies of the cosmic rays so far observed are truly limited in the galactic cosmic rays.

(NPA)

# Spin Conference

The 5th International Symposium on High Energy Spin Physics met in September at Brookhaven under the leadership of G.M. Bunce and the sponsorship of the International Spin Committee, chaired by A.D. Krisch of Michigan. The symposium has evolved to include a number of diverse specialities: theory, including parity violations and proposed quantum chromodynamics (QCD) tests with polarized beams; experiment, including the large spin effects discovered in high transverse momentum elastic scattering and hyperon production, dibaryons, and magnetic moments; acceleration and storage of polarized protons and electrons; and development of polarized sources and targets. Over 200 physicists from throughout the world discussed the many large, unusual, and unexplained spin effects which have been discovered in various experiments. The symposium brought together people who prepare polarized beams and targets with people who do high energy spin experiments and with people who predict what will happen or, with hindsight, explain what happened. Studying spin has been a rewarding but often difficult program, where it is often necessary to know something about many fields besides high energy physics.

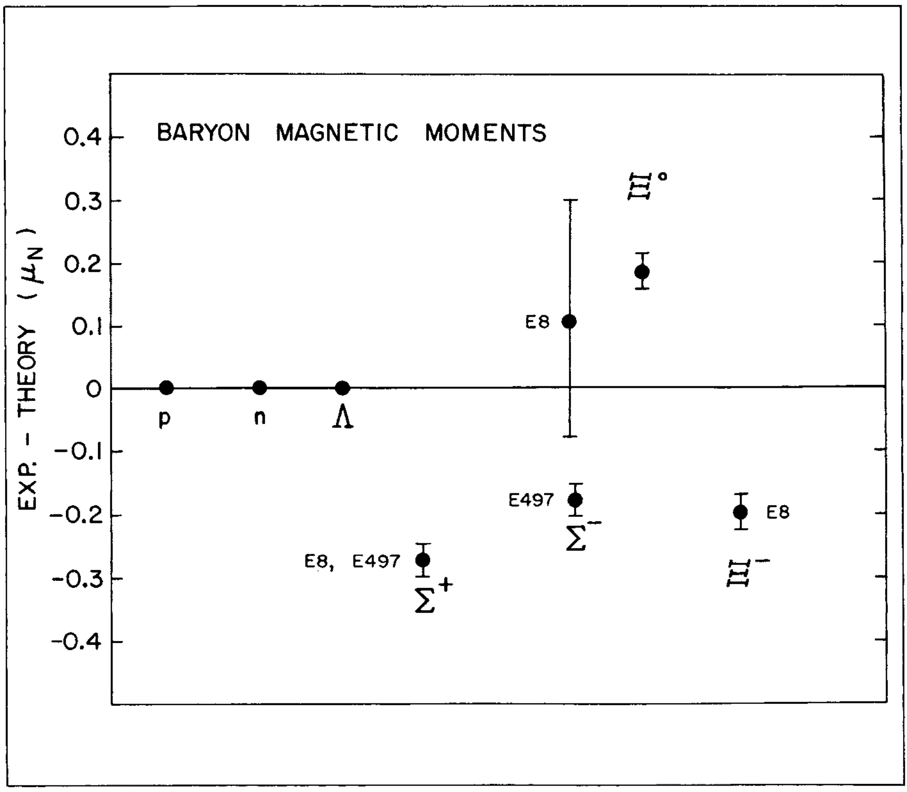
The symposium opened with a welcome by Brookhaven Director Nick Samios, who remarked on the appropriateness of holding the conference at Brookhaven, where spin effects will soon be studied in depth with the AGS polarized proton beam. Other early remarks were made by C.N. Yang of Stony Brook, who chaired the first session, and L.H. Thomas, Professor emeritus at North Carolina State University, who offered his recollections of a weekend's work in 1925 that led to his



*Several participants at the polarized target workshop at the recent International Spin Symposium held at Brookhaven: left to right, Geoff Court of Liverpool, Don Crabb of Michigan, Dan Hill of Argonne and Rick Fernow of Brookhaven.*

*(Photos Brookhaven)*

*The baryon magnetic moment puzzle. Using the observed proton, neutron and lambda moments as input, the predictions for other hyperons do not agree with the observed values. The vertical scale is in nuclear magnetons and E8 and E497 refer to Fermilab experiments.*



discovery of the Thomas precessional frequency. Yang commented: 'We know something about the effects of spin and we know how to use spin as a tool; but... what is (intrinsic) spin? The whole story isn't in yet'.

The conference included 60 invited talks for both plenary and parallel sessions, and three workshops on theory, on polarized proton acceleration, and on polarized targets. The workshops featured considerable give and take and many contributed papers were presented within the informality of the workshops.

The many new results presented included three measurements of the negative sigma hyperon's magnetic moment, two of the positive sigma's moment, and one of the negative ksi's moment. With many of the experimenters and theorists who have studied baryon moments present, there was a very lively parallel session. L. Pondrom of Wisconsin summarized the situation by applying the quark model to predict the hyperon moments using the proton, neutron, and lambda moments as input. The hyperon moments are typically a quarter of a nuclear magneton away from simple calculations. Few patches are available that don't end up with more parameters than data. In any case, experiments are now much better than theory and Pondrom stressed that many experimenters would like to understand the relationship between the quark mass and the quark moments obtained from these baryon moments. For the future, C. Rebbi of Brookhaven mentioned recent attempts by theorists to predict moments using lattice gauge calculations. Results have so far come within a factor of two.

There were several new results on hyperon polarization, and theoretical discussion centred on how to explain this with QCD. The effect, first reported in 1976 for lambdas at Fermilab, has how been seen with other hyperons at CERN (ISR and PS), Brookhaven, Fermilab and now KEK. It is remarkably independent of energy, and now apparently transverse momentum as well. B. Lundberg of the Wisconsin / Michigan / Rutgers / Minnesota group reported a large lambda polarization at 3.5 GeV transverse momentum, the same as seen at 1 GeV. This is not predicted by QCD and is difficult to explain, particularly as it persists to large transverse momentum.

One of the highlights of the symposium was a talk by R.D. Kulsrud of the Princeton Plasma Physics Laboratory. He described the possibility of improving fusion in a Tokamak by polarizing the deuterium and tritium nucleii. The idea was recently suggested by M. Goldhaber of Brookhaven and looks very promising. By polarizing the nucleii the fusion rate may be enhanced by about 50 per cent and the neutron background reduced by perhaps a factor of ten. Many of the techniques developed by the symposium participants might be applicable, and there was pleasure and considerable surprise that spin might help to produce energy.

New dibaryon results came from Saturne, SIN, Los Alamos, Argonne, and Dubna. This exciting topic, which started with the early Argonne experiment, has become one of the liveliest areas of intermediate energy physics. A session on parity violation discussed a new Los Alamos result for the total cross-section of longitudinally polarized protons incident on a water target, a Zurich measurement of parity violation in nuclear physics, and atomic parity violation. The earlier large result at 6 GeV from an experiment at Argonne is a factor of ten higher than both lower energy data and theoreti-

*International Spin Committee members Gus Voss (left) and Alan Krisch enjoy some lighter spin moments.*

cal estimates and may imply an energy dependence of parity violation.

A number of theoretical suggestions for testing quantum chromodynamics were put forward, as discussed in the theory workshop chaired by K. Heller of Minnesota and J. Soffer of Marseille. Polarization in hyperon production is still a topical subject and, according to the Lund picture, its underlying mechanism is caused by colour confinement. The large and still unexplained spin-dependent asymmetries in high transverse momentum proton-proton elastic scattering was another very active topic of discussion. The importance of producing phases in perturbative QCD was reaffirmed with the new 'Coulomb-Chromo-Phase Model' which generates a natural energy dependent phase for Drell-Yan processes and for proton-proton elastic scattering. Spin experiments can reveal the existence of such a phase, which is calculable. A vast list of QCD predictions for the large transverse momentum production of various particles now shows the importance of using polarized beams at high energies to learn about spin properties of hadron constituents and to test the electroweak theory.

There was also considerable interest in colliding polarized electrons on polarized protons to study the spin structure of the proton. J.D. Bjorken of Fermilab stressed that the polarization carried by the quarks, antiquarks and gluons could be studied at the proposed HERA machine at DESY using polarized protons, while polarized electrons allow searches for right-handed currents. There are plans at Stanford to use the proposed SLC linear collider with polarized electrons to produce polarized $Z^0$ intermediate bosons, which should show increased charge asymmetries. Spin tests would be highly sensitive to any heavier such bosons. Polarized electrons also offer the most sensitive measurement of the electroweak mixing parameter (the Weinberg angle).

These experiments require intense polarized lepton beams and the polarization must be maintained at high energy. G.A. Voss of DESY discussed the electron polarization workshop at DESY last spring. He also described the polarized colliding electron-positron beams at PETRA where polarization of about 80 per cent has recently been achieved with good luminosity at the maximum energy. For protons, a device called a Siberian snake should maintain the polarization within a storage ring up to about 1 TeV, according to E.D. Courant of Brookhaven. High intensity and high energy are both important, and a polarized atomic hydrogen source discussed in an elegant lecture by D. Kleppner of MIT is a strong candidate to provide polarized intensities equivalent to unpolarized proton sources. T.O. Niinikoski of CERN in summarizing the technical side said 'It looks very promising that polarized luminosities will be the same as for unpolarized beams.'

The Workshop on Polarized Proton Targets was organized by D.G. Crabb of Michigan and D.A. Hill of Argonne. One active topic of discussion was the increasing use of dilution refrigerators in polarized targets. There was also a very lively discussion on chemically undoped ammonia beads which become polarizable when irradiated. These are now widely used and have high hydrogen content and can be used in high intensity beams. The Workshop participants recalled that this concept was first suggested at the 1978 workshop at Argonne in response to the battering that polarized targets were getting from high intensity beams.

There was also a workshop on polarized proton acceleration organized by Y.Y. Lee of Brookhaven and K.M. Terwilliger of Michigan. This concentrated on spin precession and depolarizing resonances in proton synchrotrons. There were new and surprising data from Saturne II at Saclay which has successfully crossed both imperfection and intrinsic resonances using adiabatic spin flipping (see July/August 1982 issue, page 231). The data were inconsistent with the conventional understanding of spin flip phenomena. When polarized protons were accelerated through strong resonances, the spin of the particles reversed as theory predicted; however, when the resonance strength was increased, they observed depolarization, contradicting simple accelerator theory. The Workshop concluded with a recommendation to the Saturne administration:

'The initial very exciting Saturne II results on resonance crossing with polarized protons have raised questions about our understanding of the process. We believe it is extremely important that further studies be undertaken at Saturne to investigate the phenomena in considerable depth. As well as being of general interest, the results of such studies certainly will be important for the imminent KEK and AGS polarized proton resonance crossing programmes.'

The symposium summary for theory and experiment was given by C. Y. Prescott of SLAC. The future of spin physics looks exciting at high energies and large effects are expected. Both proton-antiproton and proton-proton colliders with polarized protons provide excellent laboratories for QCD studies. Polarized electron-proton and electron-positron colliders are excellent laboratories for electroweak or other gauge models. Thus, the participants were given the charge of convincing their local machine builder to polarize all beams in time for the 6th High Energy Spin Physics Symposium which will be held in Marseille in fall 1984.

*(We are grateful to G. Bunce of Brookhaven for this extensive report.)*

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# Supersymmetry and supergravity

## by Bruno Zumino

> *Editor's Note*
> *This article, specially written by one of the foremost authorities in the field, goes somewhat beyond the degree of technicality normally encountered in the CERN COURIER. However its broad sweep and penetrating insight make it eminently worthy of publication. We urge the reader to persevere.*

Considering that there is no experimental evidence whatsoever that supersymmetry is relevant to the world of elementary particles, it is remarkable that there is so much interest in the idea. One is almost led to suspect that many theorists are working in this field because of a basic lack of other new ideas. I shall try to explain the reasons for thinking that supersymmetry will become directly relevant and shall trace the progress of the work so far.

There is an impressive amount of experimental evidence supporting the theoretical description of the strong, weak and electromagnetic interactions in terms of renormalizable gauge theories. In spite of their remarkable success, these theories have some basic shortcomings. The standard model, combining the quantum chromodynamics theory of inter-quark forces with the unified electroweak model, has more than twenty arbitrary parameters which cannot be predicted theoretically. The so-called Grand Unified Theories (GUTs), which try to encompass and unify the standard model, do not significantly reduce the number of parameters. In GUTs there is an additional theoretical problem, because there are two widely different mass scales: the mass of the intermediate boson which mediates the weak interactions, which is of the order of 100 GeV, and the grand unification [redacted] which electroweak and eractions become comparable, $10^{15}$ GeV. The great difference between these two masses is hard to understand theoretically (Hierarchy Problem) and raises technical questions because in a quantum field theory it is unstable under renormalization. This problem is related to that of the small masses of certain Higgs particles. Neither the standard model nor GUTs give an understanding of the spectrum of elementary particles, and in particular of the existence of three (or more) families of quarks and leptons. While GUTs make a brave attempt at unification of all interactions, they still omit gravity, which must become relevant for elementary particles at the so-called Planck mass, about $10^{19}$ GeV, only just beyond the grand unification mass.

The large number of arbitrary parameters, the hierarchy of mass scales and its stability, the structure of the particle spectrum, the unification with gravity: these are theoretical problems stemming from physicists' attempts to develop a simple unified picture; there is no known contradiction of the orthodox picture with experiment.

Another seldom mentioned theoretical problem is that of Einstein's cosmological constant. Observationally its value is very small, compatible with being exactly zero, but in quantum field theory there is a highly divergent induced cosmological constant and in a gauge theory with spontaneous symmetry breaking even the finite part is unacceptably large, in complete disagreement with the present cosmological picture. Of course, one can start with a non-vanishing cosmological constant, adjusted so as to cancel exactly that generated by spontaneous symmetry breaking and radiative corrections. One could then argue that there is no real problem provided one finds no difficulty through the various phase transitions the universe undergoes according to our present cosmological picture. However it is exactly this 'fine tuning' of parameters, similar to that needed for the mass scales in GUTs, that theorists would like to avoid. A truly predictive theory should explain these very small numbers. Supersymmetry promises a possible cure for all these diseases.

Supersymmetry (SUSY) is a symmetry which connects fermions with bosons. Fermions carry half-integer spin and obey the Pauli Exclusion Principle so that not more than one particle can occupy each available energy state. Bosons carry integer spin and have no such restrictions. Considering the basic differences between fermions and bosons, it is a very remarkable fact that such a symmetry can be formulated at all without breaking any of the rules of quantum field theory, and in particular that there exist supersymmetric gauge theories. In a SUSY theory there are one or more conserved spinorial quantities which are the analogues of the conserved charges of an internal symmetry, such as isospin. Just as the isospin charges transform the members of a multiplet (e.g. the three different charge states of the pion) among themselves, so the SUSY charges transform a boson into a fermion and vice versa. Particles of different spin and statistics arrange themselves into so-called supermultiplets. Rather than being an internal symmetry, SUSY is intimately connected with space-time symmetries.

How can SUSY help with the gauge theory problems described above? First, as an additional symmetry, one can hope that it will put some order in the particle spectrum and restrict the number of independent couplings. Actually this hope has not been realized, at least in the N=1 SUSY theories (theories with only one supersymmetric spinorial charge). Secondly, SUSY provides a natural place for scalar fields (Higgs fields etc.), as partners of spinors, and justifies the smallness of scalar masses by relating them to the smallness of spinor masses, which in turn can be understood as a consequence of chiral symmetry. It can further help towards a solution of the Hierarchy Problem because SUSY theories are of a very special type. The special relations among couplings of fermions and bosons cancel divergences. Mass-like parameters are usually not renormalized, so the smallness of a mass is stable or 'natural' (this property of SUSY theories is sometimes referred to as 'supernaturalness'). Third, in a rigorous SUSY theory there is no induced cosmological constant. Unfortunately this is no longer true when SUSY is broken, even spontaneously, but we shall come back to this question later. Finally, there is a SUSY theory of gravity, called supergravity, and its coupling to SUSY matter has been studied in great detail. This theory has some remarkable properties.

In SUSY theories each known particle must have one or more partners of different spin and statistics. For N=1 SUSY one expects that there must be scalar counterparts of the conventional quarks and leptons (squarks and sleptons) and spin one-half partners of the weak intermediate bosons W and Z, the photon, and the gluon (Wino, Zino, photino and gluino). None of these new 'sparticles' are yet known to exist. If SUSY were exact, a sparticle would have the same mass as the corresponding particle, which is clearly not the case. For instance, it is known from experiments at PETRA and SLAC that scalar electrons and muons (selectrons and smuons) must weigh more than 16 GeV. In a rigorous SUSY theory the anomalous magnetic moment of the electron and of the muon would vanish; from this one can infer a lower bound on the mass of the smuon comparable to that given above. So SUSY is a broken symmetry and the breaking is characterized by a mass scale which is at least 15-20 GeV. Fortunately we are used to broken symmetries in theoretical physics, but the breaking must not spoil completely the desired relations among the particle masses and couplings. This can be achieved, just as for internal symmetries, by breaking SUSY either spontaneously or explicitly, but softly. Another way, which is the object of many investigations these days, is to break the supersymmetry of a SUSY gauge theory through its interaction with supergravity.

The mass scale of SUSY breaking is sometimes called the SUSY Gap, and we have seen that is at least 15-20 GeV; but how big is it actually? It may be natural and economic to assume that it is comparable to one of the other mass scales in the theory, 100 GeV, $10^{15}$ GeV or $10^{19}$ GeV, and models have been suggested which agree with any one of these hypotheses. But other values have been argued as well (the reader would be perfectly justified in thinking that the SUSY Gap is infinite). All the SUSY GUT models suggested so far have the unappealing feature that they require not only their sparticles but entire new supermultiplets of still more particles and sparticles. The particle spectrum becomes even more chaotic than that of ordinary GUTs and no understanding of the family problem is obtained. All this is the price one has to pay for a softening of the hierarchy problem. The smallness of the number is not predicted but at least the fine tuning has a certain stability due to SUSY. The problem of the cosmological constant remains unsolved.

Before discussing supergravity let me mention that SUSY theories, because they are less divergent than other quantum field theories, are of interest irrespective of their relevance to the real world. A fascinating example is the N=4 (four spinor charges) SUSY 'Yang-Mills' theory, which is a four dimensional gauge theory with one vector, four spinors and six scalars and involves a single coupling constant. It has been conjectured that this theory is well-behaved in perturbation theory, to all orders. Recent work by Stanley Mandelstam confirms this. One is tempted to argue that a theory with such unique properties must have some relevance somewhere for Nature.

In supergravity (SUGRA), supersymmetry becomes a local space-time dependent symmetry. It involves a spin three-half field and the associated particle, which is the SUSY partner of the graviton, is called the gravitino (neither particle is known experimentally, but just as the existence of the graviton is the unavoidable consequence of quantum theory applied to the gravitational field, SUSY then requires the existence of the gravitino). There are various forms of SUGRA, depending upon the number N of supersymmetric charges. All these forms have been explored, the largest being N=8 SUGRA. For N larger than eight, the theory would have to contain fundamental fields corresponding to particles of spin larger than two, for which it seems impossible to construct a consistent interaction formalism. The consistency of smaller SUGRAs, with their fields ranging in spin from two down (for N greater than 3 all the way to spin zero), is in itself remarkable. SUGRA theories also have special convergence properties in perturbation theory. There have been numerous attempts to base a phenomenological picture on extended (which means with supersymmetries having N greater than one) SUGRAs, but none of these attempts can be considered successful so far. For this reason, and also because it would take another article to describe them, I shall restrict myself in what follows to some remarks on N=1 SUGRA interacting with N=1 SUSY matter. At any rate, a theory with more than one supersymmetry is expected to reduce to an N=1 theory when the energy is below some threshold and only one SUSY is still effective, the remaining ones being broken.

When SUSY is spontaneously broken, there must be a massless spin one-half particle in the theory, which is the supersymmetric analogue of the Goldstone bosons of spontaneously broken internal symmetries. It is therefore called a 'Goldstino'. If the SUSY matter is coupled to SUGRA the Goldstino is absorbed by the initially massless gravitino which thereby acquires a mass; the graviton remains massless. This is the Super-Higgs effect, perfectly analogous to the Higgs effect of ordinary gauge theories. The spontaneous breaking of SUSY generates an induced cosmological constant but the SUGRA theory can be arranged so that is has the opposite cosmological constant and the resulting value can be made arbitrarily small or zero if one wishes. This, of course, is fine tuning, but it is quite different from the ad hoc fine tuning in ordinary gravity which only achieves a vanishing cosmological constant and has no other consequences.

First of all, the algebra satisfied by the SUSY charge implies that the induced cosmological constant from spontaneously broken SUSY always has a well defined sign. It turns out that in SUGRA with local SUSY the cosmological constant also has always a specific sign (that corresponding to the so-called Anti-De Sitter universe). These two signs are opposite. This permits the desired cancellation and also provides relations among the masses of the gravitino and other particles, and certain Yukawa and scalar couplings.

Does the cosmological constant really have to be vanishingly small? Hawking and collaborators, developing an earlier picture by Wheeler, have argued that space-time has a foamy structure and that the observed cosmological constant will be vanishingly small, provided the cosmological constant which enters in the basic equations, and which can be quite large, has the right sign. This line of argument, if correct, would remove a strong constraint on our theories and in particular on the formulation of the Super-Higgs effect.

Where does all this leave us? Experimental discovery of sparticles, the SUSY partners of known particles, would vindicate all this recent theoretical work. However if the SUSY Gap is sufficiently large, no SUSY partners will be found for quite a while. The appeal of supersymmetry is in its theoretical beauty and elegance, but supersymmetry is a general framework rather than a specific theory. What we need is an equally appealing specific model whose consequences could be tested experimentally, even if the supersymmetry gap is very large. At this moment the only possibility of this kind I see is in the further study of extended supersymmetry theories and especially the N=4 supersymmetric Yang-Mills theory and the N=8 extended supergravity.

# Advising the CERN COURIER

## by Maurice Jacob
## (retiring Chairman of the CERN COURIER Advisory Panel)

As an experiment, a 'CERN COURIER Advisory Panel' was set up two years ago by the then Research Director General, Leon Van Hove. The Panel Members were Ugo Amaldi, Kurt Hübner, Maurice Jacob (Chairman) and Egil Lillestøl. This Panel has now been granted continuing status. Jacques Prentki replaces Maurice Jacob as Chairman, Jim Allaby replaces Ugo Amaldi, and visitor Jim Cronin comes in during his extended stay at CERN.

CERN COURIER is unique. It is now an international journal serving the whole high energy physics community, having moved far from its initial conception as the CERN 'house journal'. This international role emerged at the New Orleans meeting of Laboratory Directors in 1975, when it was decided 'to expand the COURIER coverage to give a balanced view of global activities in the high energy physics field'.

The COURIER is widely read. The latest survey indicated that it is consulted regularly by about 60 000 people, a large number of whom read the magazine from cover to cover. Its aim is to promote high enery physics while looking at the field in a rather broad context, mentioning also technological achievements originating from, or relevant to, particle physics, and presenting interesting associated developments from other fields of physics. A special effort is made to cover milestone events such as major conferences and anniversaries, which provide good opportunities to survey progress and development in this frontier field of research.

In 1982, each issue contained on average 44 pages, half of which carried advertisements. Ten issues are published each year, and the journal is unusual in that it is published in parallel English (12 000 copies), and French (6 000 copies) editions. The English edition caters generally for the international readership while the French translation is followed by the large staff of non-physicists at CERN, most of whom are French speaking, and in the French speaking region which hosts the CERN Laboratory.

The printing and distribution costs of the journal are covered by income from the advertisements. Requests to receive CERN COURIER therefore can be accepted free of charge. (For details, see inside front cover.)

Following the New Orleans meeting, several Laboratories have been acting as distribution centres. The distribution of each edition of the journal is a complex, but smoothly running affair, involving a series of interlocking consignments outwards from CERN to regional distribution centres and the readers. An effort is being made to tighten this up so that readers will receive their copies with a minimum of delay.

An extensive network of correspondents in Laboratories all over the world (see inside front cover) helps to keep the editors abreast of the news. However the editors have considerable independence and responsibility in judging the balance and tone of the coverage. Frequently this involves broad decisions on the overall presentation of the field, and on the mix of information coming from different sources. The publication of an article in the COURIER does not imply any approval of its content by the CERN Management.

A considerable effort is made to achieve a reasonable balance in the news coming from different Laboratories, despite an uneven stream of incoming information. This is largely reflected in the 'Around the Laboratories' section, although bigger articles about specific Laboratories are sometimes elevated to feature status. Of the major Laboratories, CERN is the most prominent, but there is still extensive coverage of the major US Laboratories, and of Europe's other large Laboratory at DESY, Hamburg, thanks to active correspondents.

The reader will rarely find a representative balance in any one particular issue — indeed some issues may even appear 'polarized'. But averaged over several months, the balance is apparent.

During the first two years of its existence, the Advisory Panel understood its major task as improving the contact between the editors and the physics community, and helping to maintain a good balance of information. The Panel provided advice and comment but did not act at all as a refereeing body, leaving the editors with the journalistic freedom which should be theirs.

The Panel has also commissioned contributions from personalities, and the number of such signed articles has increased over the past two years. Hopefully this will continue. In close contact with different sectors of the community, the Panel Members extended the news-gathering network, providing some useful help with topical conferences.

The collaboration between editors and Panel has been successful, but there is more which can be done. The Panel members wish to thank their many colleagues for the generous help given, and we look forward to an ever more fruitful association between the COURIER and the high energy physics community in the years to come.

# People and things

*At a ceremony on 24 September last year, former Brookhaven Laboratory Director Maurice Goldhaber received the degree of Doctor Honoris Causa from the Catholic University of Louvain, Belgium.*

*J. J. Sakurai*

## *J. J. Sakurai*

*Japanese theoretician J. J. Sakurai died suddenly at the end of October at the age of 49. He was visiting CERN at the time, and a memorial meeting, attended by his family and friends, was held at CERN on 8 November. He is perhaps best known for his work on vector mesons, and for his two classic books 'Invariance Principles and Elementary Particles' and 'Advanced Quantum Mechanics'. At the time of his death he was nearing completion of a book on non-relativistic quantum mechanics, which will be published posthumously.*

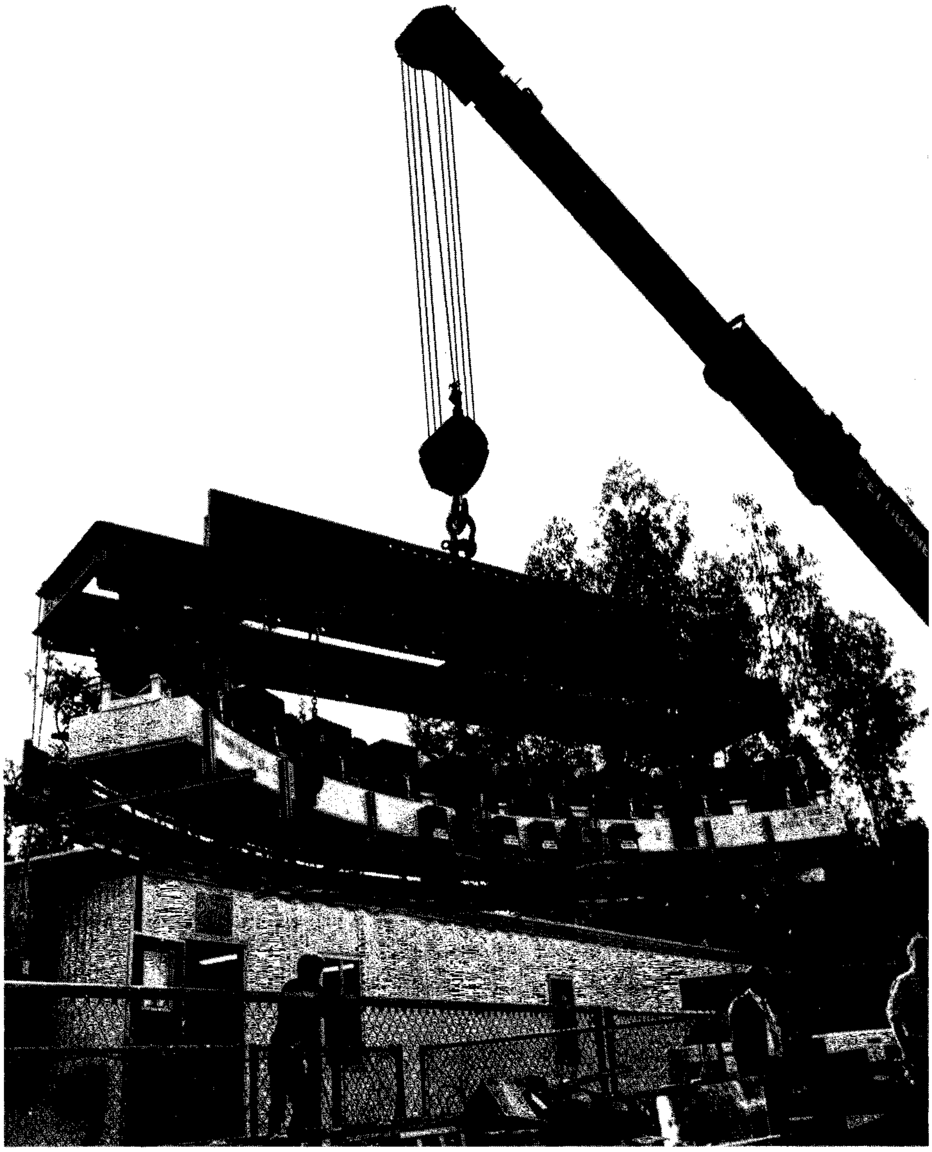
*A memorial fund has been established, and contributions can be sent to account C7-103.853.0 at the Société de Banque Suisse at CERN, 1211 Geneva 23, Switzerland.*

## *CERN Council*

*At its meeting in December, the CERN Council approved the establishment of a LEP Main Ring Division for the proposed new electron-positron collider. Under the leadership of Gunther Plass, the division formally came into existence on 1 January. Ian Butterworth of Imperial College London was appointed Research Director, with effect from 1 July, to succeed Erwin Gabathuler.*

## *LEP Experiments*

*Four experiments for the LEP electron-positron ring to be built at CERN have been approved conditionally by the CERN Research Board. They are ALEPH, DELPHI, OPAL and the as yet unnamed L3*



*Construction work for the damping ring for the proposed SLC linear collider at SLAC has been proceeding even with the main linac in operation. Here a raft of magnets is seen being lowered into the damping ring vault. Beam has been carried through the linac-to-ring transport system. (Photo Joe Faust)*

*proposal. For a brief description see October 1982 issue, page 322.*

## On people

*For a period of three years from 1 January, Val Telegdi succeeds Sir John Adams as Chairman of the International Committee for Future Accelerators, ICFA.*

*Heinz Pagels of Rockefeller received the 1982 American Institute of Physics/US Steel Science Writing Award for his book 'This Cosmic Code: Quantum Physics as the Language of Nature'.*

## First beams at GANIL

*On 19 November, the first beam of heavy ions was accelerated and extracted from the new French GANIL (Grand Accélérateur National d'Ions Lourds) machine at Caen. It consists of three cyclotrons operating in series. The beam of argon ions attained 1.8 GeV, and experiments involving 300 scientists are scheduled.*

## Mark II for SLAC linear collider

*The Mark II detector letter of intent has been selected as the basis for the first experiment for the proposed SLC linear collider at SLAC. This would be the third machine at which this detector will have operated. Initially a Berkeley / SLAC collaboration, Mark II was first mounted in the West Pit at the SPEAR ring, where it carried out sterling work. Then it was moved in 1979 to interaction region 12 at the PEP ring. The detector has a cylindrical drift chamber inside a solenoid 3 m in diameter and 4 m long. A lead/liquid argon calorimeter, lepton counters and end caps surround the target region.*

*The SLAC Experimental Program Advisory Committee is scheduled to meet in May to consider the final form of the Mark II proposal, and to select a second SLC experiment from the other submitted letters of intent.*

## CERN COURIER Index 1982

*As an experiment, the Index to the 1982 editions of the CERN COURIER is not distributed along with the copies of the journal. Instead, copies (English or French versions) are available on demand from Monika Wilson, CERN, 1211 Geneva 23, Switzerland. Please specify whether you want the English or French version of the Index.*

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## Physicist

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# Opportunities for B-QUARK PHYSICS with ARGUS

The Canadian group participating in the ARGUS experiment at DESY has two openings for RESEARCH ASSOCIATES to be resident in Hamburg. ARGUS is a new detector which has just started to take its first data at the DORIS-II storage ring.

The Canadian group is composed of physicists from McGill University, University of Toronto, York University and Carleton University. We have provided a VAX-11/780 computer which is used as an on-line monitoring system for the ARGUS experiment. In addition, a high precision cylindrical vertex detector is being built in Canada, with installation planned for the spring.

There are opportunities in on-line software, hardware associated with the vertex detector and/or physics analysis. Interested applicants should submit a curriculum vitae and two letters of reference to:

**Dr. B. Orr or Dr. M. Goddard, DESY - F15, Notkestrasse 85,**
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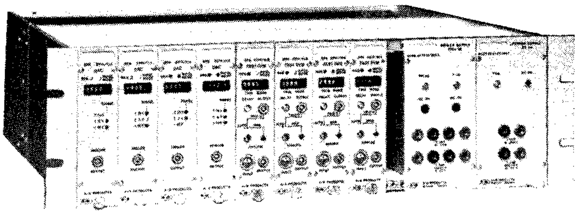

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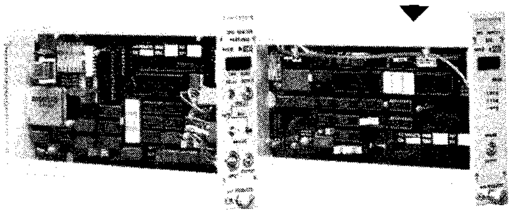

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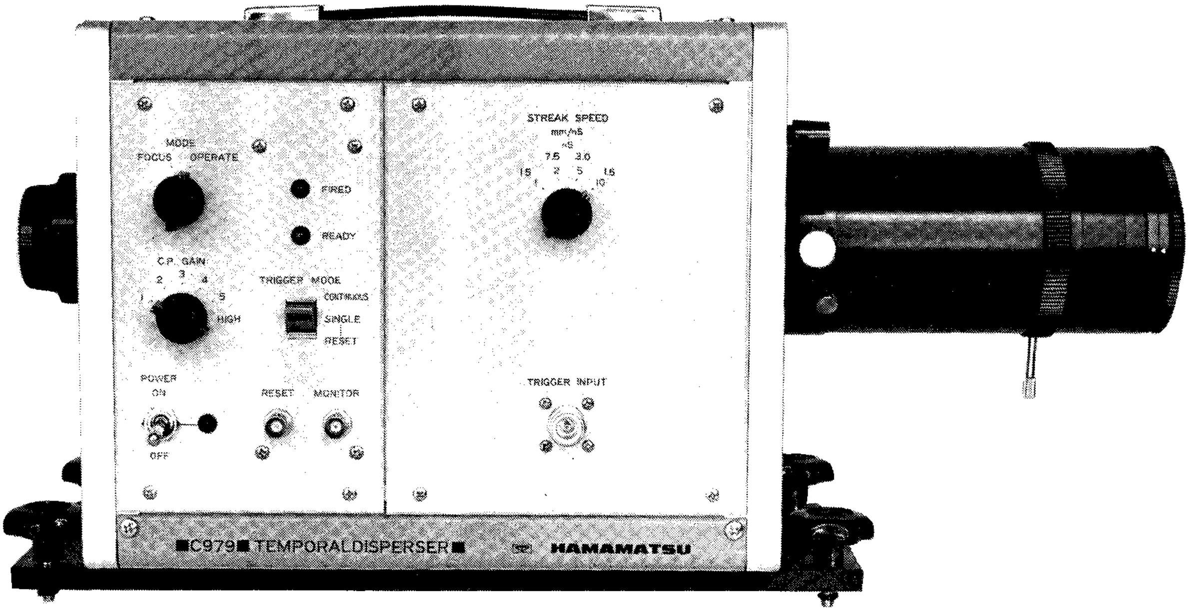

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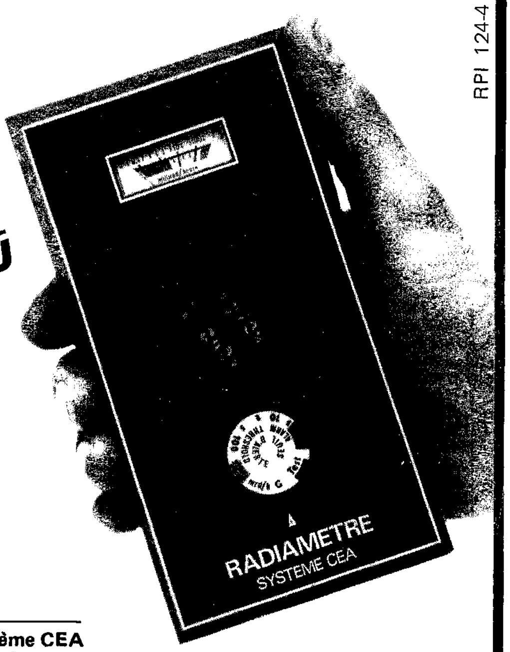
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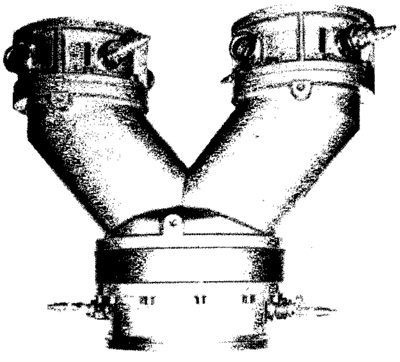

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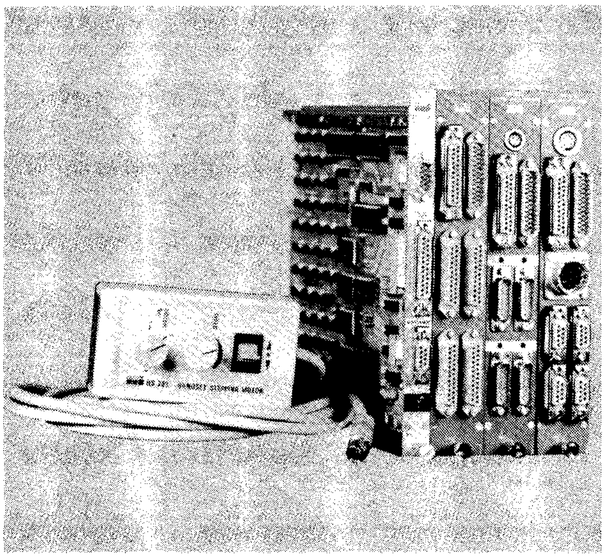

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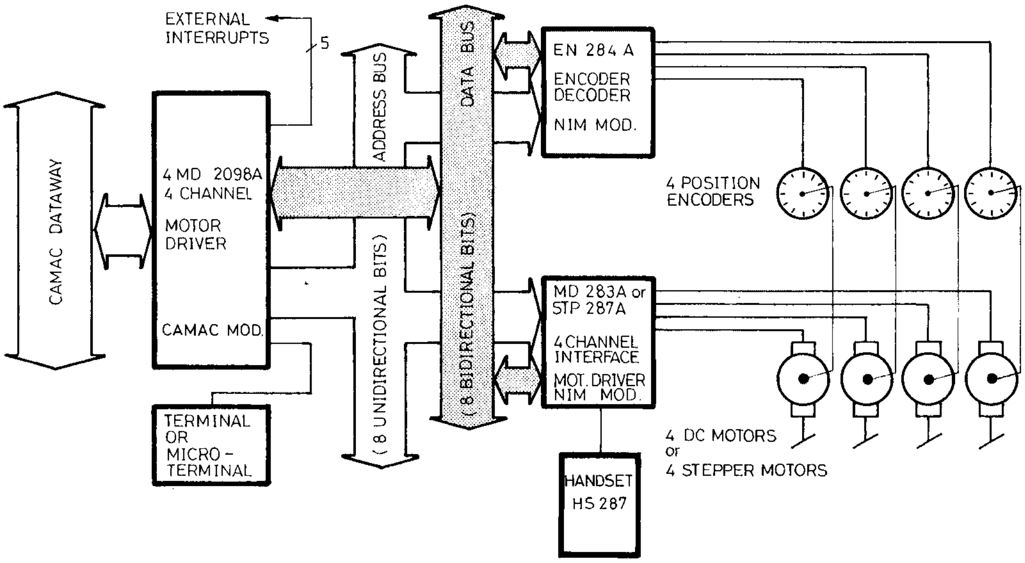

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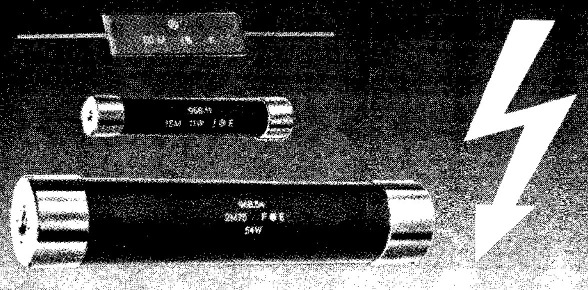

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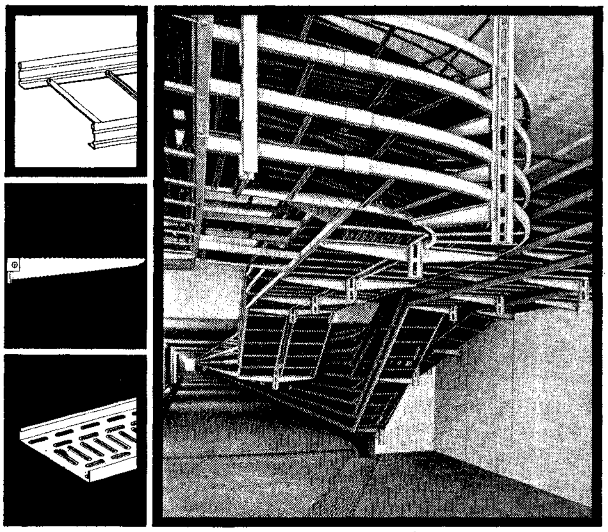

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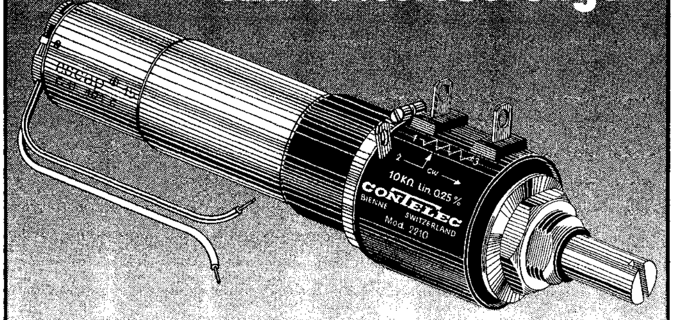

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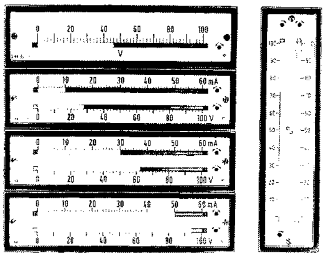

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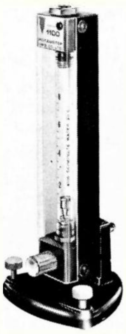
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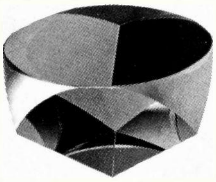
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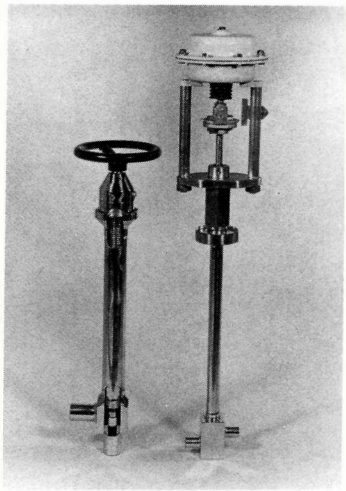

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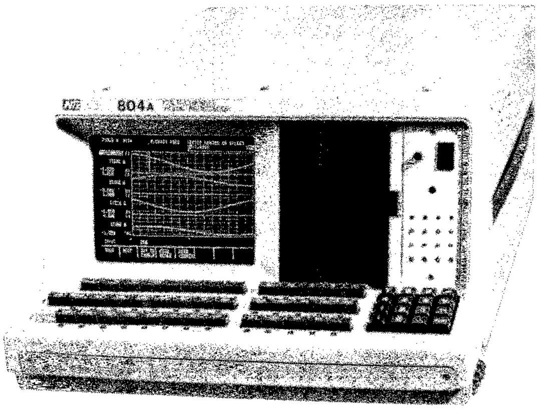
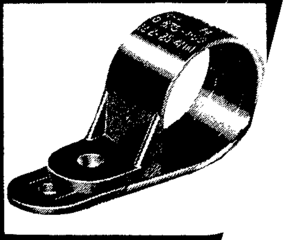


## Summerer – partie intégrante de la technique



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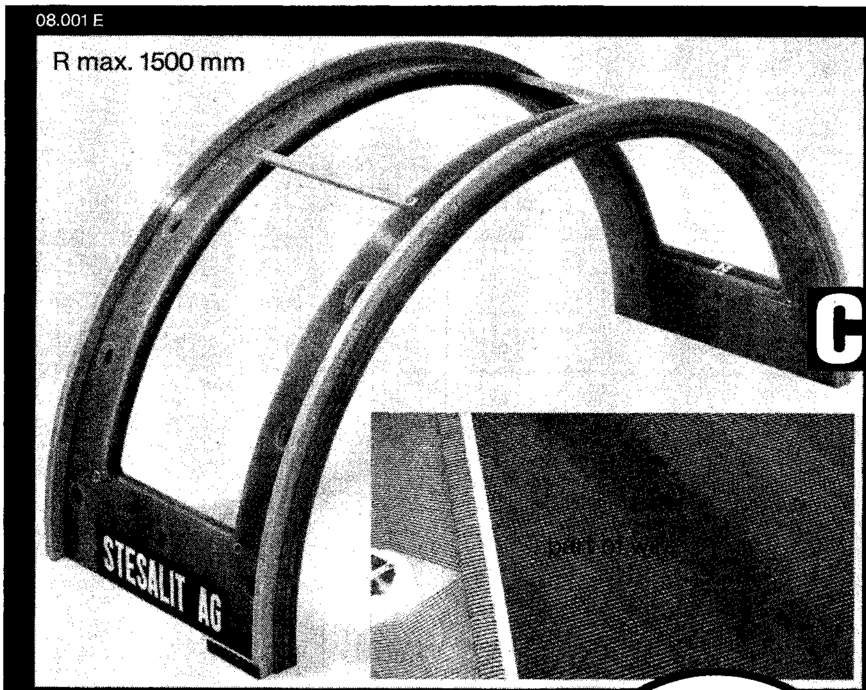
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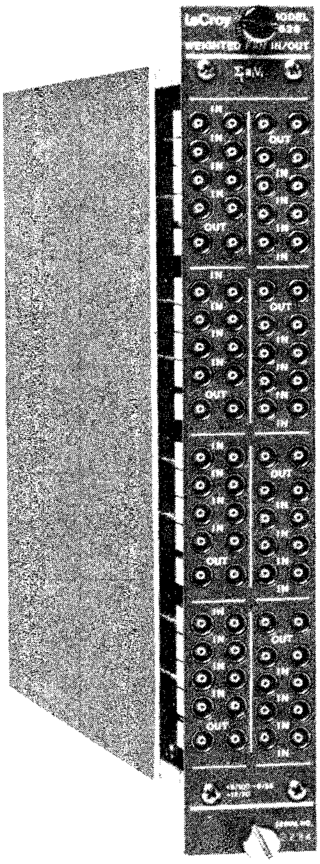

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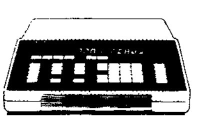
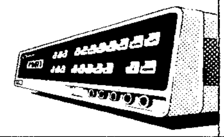


DMM's



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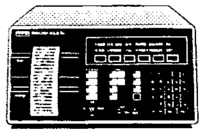

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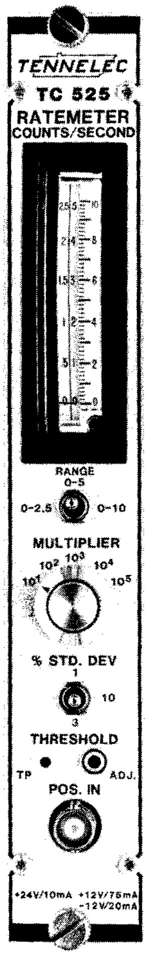
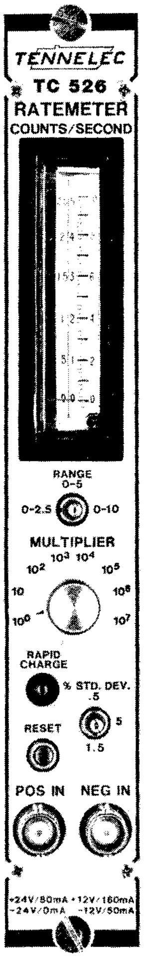


TENNELEC
TC 525
RATEMETER
COUNTS/SECOND
RANGE
0-5
0-2.5
0-10
MULTIPLIER
% STD. DEV
THRESHOLD
TP
ADJ.
POS. IN
+24V/10mA +12V/75mA -12V/20mA



TENNELEC
TC 526
RATEMETER
COUNTS/SECOND
RANGE
0-5
0-2.5
0-10
MULTIPLIER
RAPID CHARGE
% STD. DEV.
RESET
POS IN
NEG IN
+24V/80mA +12V/160mA -24V/0mA -12V/50mA

# Gould Hiflex

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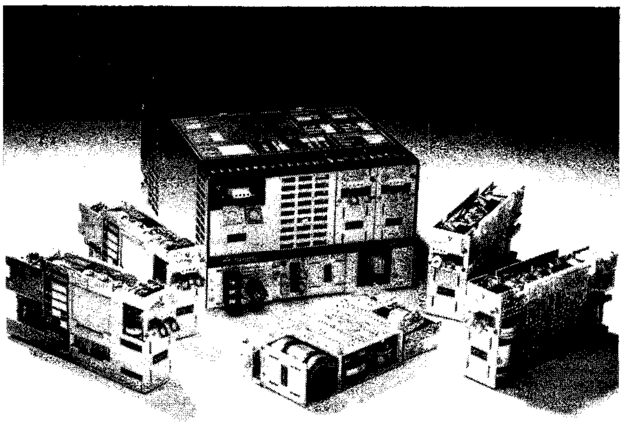

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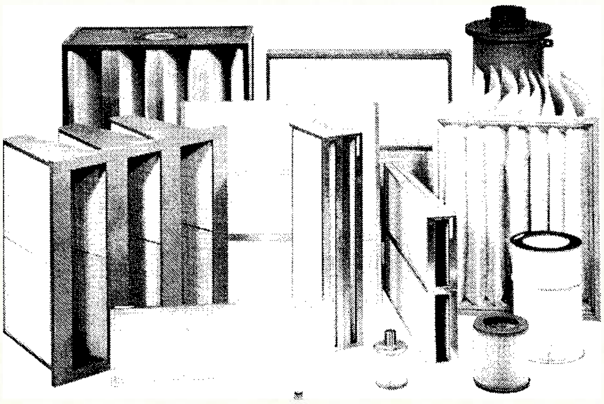

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