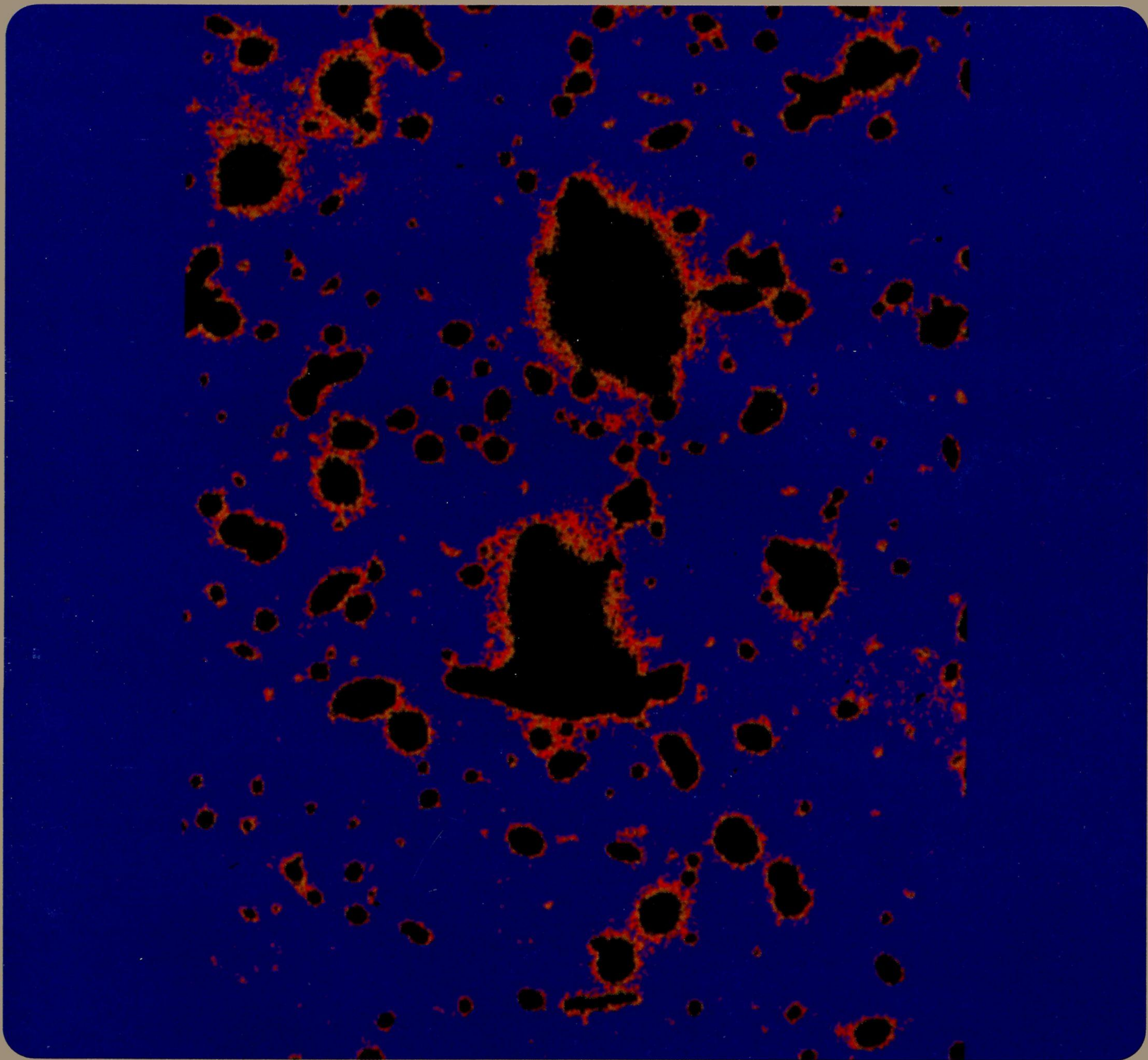
CERN COURIER

International Journal of High Energy Physics



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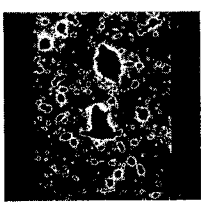

Cover photograph:
The recent discovery of a giant arc in the galaxy cluster Abell 370 (lower centre, superimposed with a large central 'blob') suggests that the central cluster acts as a 'gravitational lens' amplifying and imaging the signals from fainter, more distant objects. This was discussed at a recent particle physics/cosmology/astrophysics meeting in Bologna (see page 1). This photograph is a further look at the cluster, using a CCD (charge-coupled device) camera at the 3.6 metre Canada/France/Hawaii telescope, bringing hints of even more distant galaxies (Bernard Fort – European Southern Observatory).

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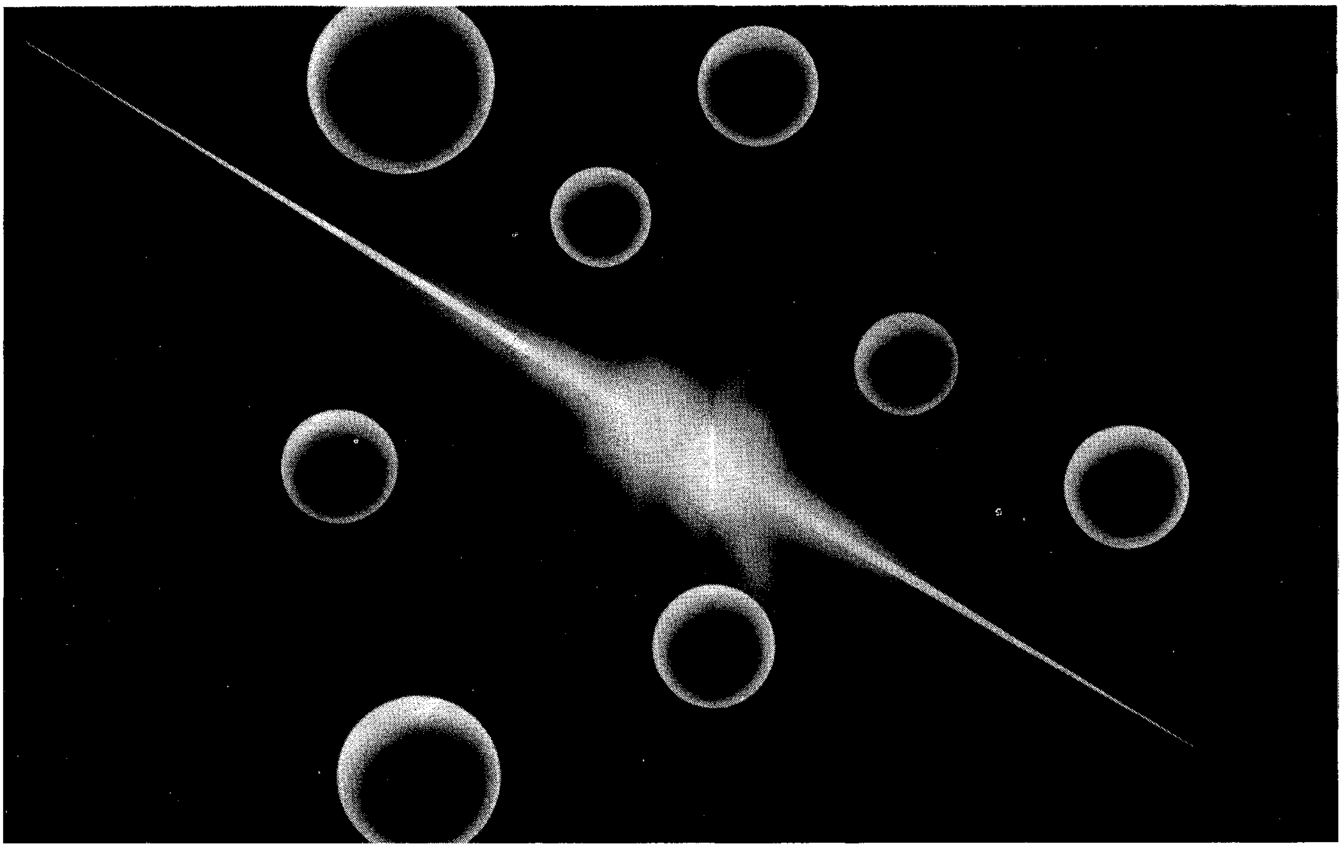

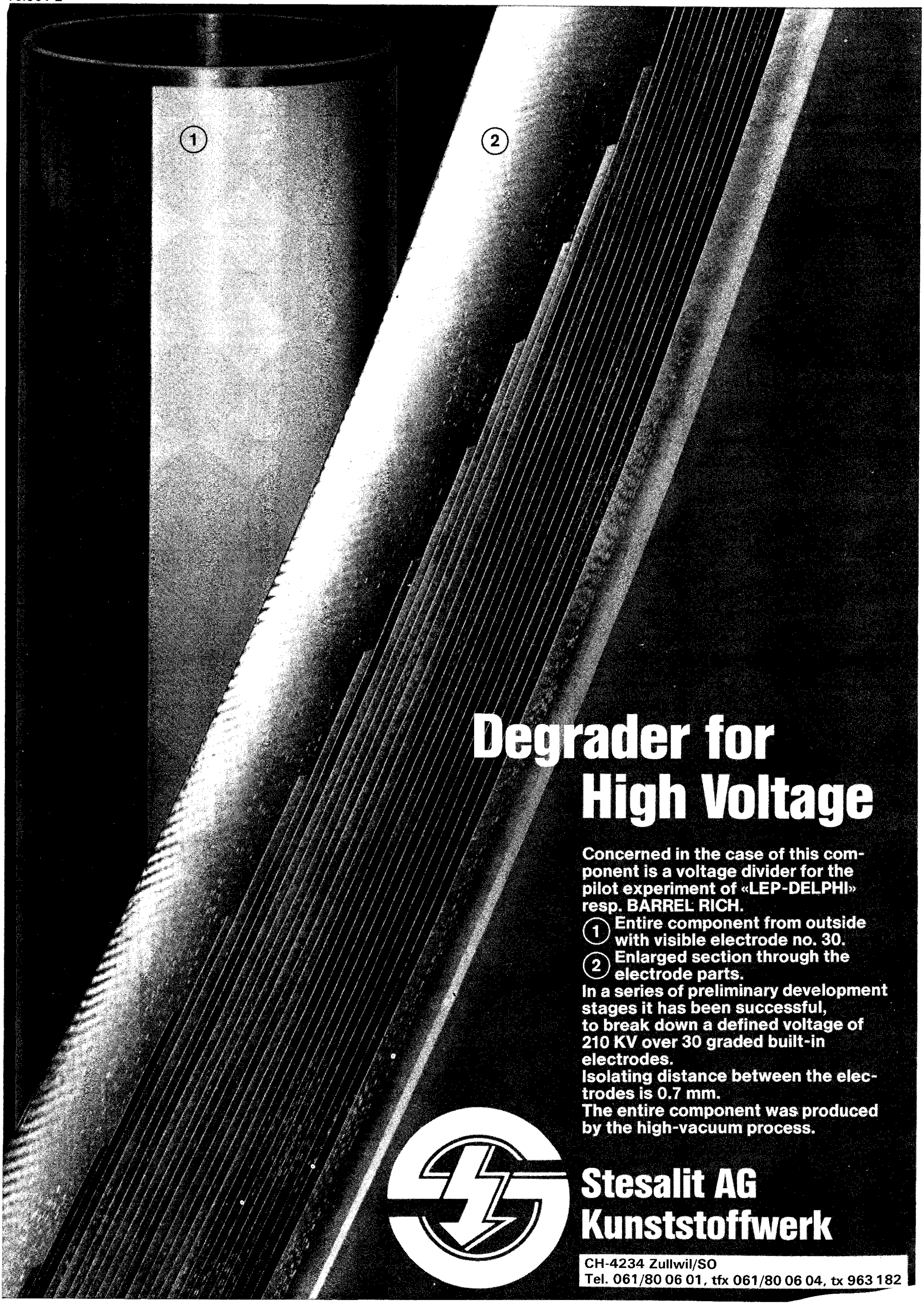
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Making physics more fundamental

Bologna's Palazzo Re Enzo was the historic setting for this year's CERN/European Southern Observatory (ESO) Symposium on Astronomy, Cosmology and Fundamental Physics.

The stellar death throes of supernovae have been seen and admired since time immemorial. However last year's (1987A, May 1987 issue, page 1) was the first to come under the combined scrutiny of space-borne radiation detectors and underground neutrino monitors as well as terrestrial optical telescopes and even gravity wave antennae. The remarkable results underline the power of modern physics to explain and interrelate processes in the furthest reaches of the cosmos and the deep interior of nuclear particles.

In recent years this common ground between 'Big Bang' cosmology and particle physics has been regularly trodden and retrodden in the light of fresh new insights and new experimental results, and thinking has steadily converged. In 1983, the first Symposium on Astronomy, Cosmology and Fundamental Physics, organized by CERN and the European Southern Observatory (ESO), was full of optimism, with new ideas ('inflation') to explain how the relatively small variations in the structure of the Universe could have arisen through the quantum structure of the initial cataclysm.

In 1986, the second Symposium paused for reflection in the light of new results from satellite-borne experiments, showing new evidence for large-scale asymmetries in the universal distribution of galaxies, tying in with a curious directional effect in the microwave background radiation (the fossil relic of the Big Bang).

The third Symposium, held in Bologna in May to coincide with the celebrations of the university's 900th anniversary, hinted at a further new threshold in understanding. Fundamental theorists, looking at physics on the widest scale, need theories encompassing all the forces of Nature.

Although the confirmation of the 'electroweak' unification of electromagnetism with the weak nuclear force by experiments at CERN in 1983 was a major step forward, fundamental theorists also need to bring in the strong nuclear force – inter-quark attractions – into the picture, not to mention the classic enigma of gravity, the dominating factor in the large-scale structure of the Universe.

After many years of ups and downs, with fundamental theorists often more concerned with detailed mathematics than with reality, Dimitri Nanopoulos of Madison (Wisconsin) came to Bologna with 'stunning' developments to report.

Universal theories first have to synthesize electroweak and quark effects, not conceptually difficult as the electroweak picture has shown the way, but an awesome dimensional gap has somehow to be bridged. To sugar this bitter pill and to open the door to gravity, theorists turned to new ideas. 'Superstrings' use one-dimensional strings rather than infinitesimal points as the pawns of the game. The other unorthodox step involves abandoning the 'classical' view of particles as either 'fermions' – carrying half units of spin angular momentum and obeying the famous Pauli Exclusion Principle – and 'bosons' – integer spins with no quantum occupancy restrictions. In supersymmetry, each fermion is allocated a boson partner and vice versa. Doubling the number of particles in this way opens new mathematical avenues, and although no supersymmetric particle partners have been seen so far, this flexibility gives physics scope too.

Hitherto devoid of predictive

Dimitri Nanopoulos – 'stunning' new results.

power, this superstring approach has been dogged by problems of too many dimensions, requiring all sorts of 'compactification' dodges to somehow map ultra-dimensional worlds onto the modest four dimensions that we know. However new approaches to invariance and consistency have shown how to build four-dimensional superstring pictures, and using an alternative method of embedding the unification of electroweak and quark forces, real results seem to follow.

Nanopoulos startled his Bologna audience with theorists' predictions of the mass of the unseen sixth ('top') quark in the range 70-90 GeV (in line with experiments so far), while the 'heavy' tau- and muon-type neutrinos are attributed with masses of a few electronvolts, and the light electron-type version could weigh as little as 10^{-8} electronvolts, small to be detected directly but still full of cosmological import.

Ten years ago, before the electroweak unification had even been confirmed, bold theorists were toying with the unification of the electroweak and quark sectors, predicting that the proton would be unstable. At some 10^{32} years, this lifetime dwarfed even the estimated age of the Universe (conventionally measured in Giga – 10^9 – years), but no problem to accommodate with so many protons available.

In three continents, new underground experiments were built or existing ones modified to provide the intense shielding from random cosmic rays to search for nucleon (proton) decay. However no convincing evidence for proton decay has been seen in many years of patient search, and the proton has been given a new lease of life.

The new formulation of unified theory now predicts a proton lifetime of some 10^{35} years, holding out new hope for the next generation of bigger underground detectors. With no positive evidence to report, Nucleon Decay (ND) searches had reconfigured as Neutrino Detectors, and the neutrino sighting from last year's supernova was cynically heralded as one of the greatest success of the old theory of electroweak/quark force unification. With the unstable proton now back on the theoretical map, and with big new underground detectors being prepared or proposed, the ND label could revert to nucleons.

However these stimulating new ideas are still highly speculative and could yet evaporate as quickly as their predecessors. The front line of established physics is still the 'Standard Model' – a loose combination of the electroweak picture with the field theory of inter-quark forces (quantum chromodynamics – QCD). Roberto Peccei of DESY reviewed the latest experimental results, where evidence for just three types of neutrinos continues to accumulate, and where insights from experiments at the CERN proton-antiproton collider firmly put the mass of the top quark at above 70 GeV.

Impressive, according to Peccei, is the way detailed (radiative) electroweak effects can now hone results, showing excellent agreement between the electroweak parameters measured in fixed target and colliding beam experiments. Consistency arguments based on these calculations show the top quark to be lighter than about 200 GeV, providing a useful upper limit.

Although the sixth quark remains aloof, there is 'excellent indirect evidence', Peccei assured. The subtle asymmetries seen in electron-positron annihilation show that the fifth ('beauty' or 'bottom' – b) quark must have a partner.

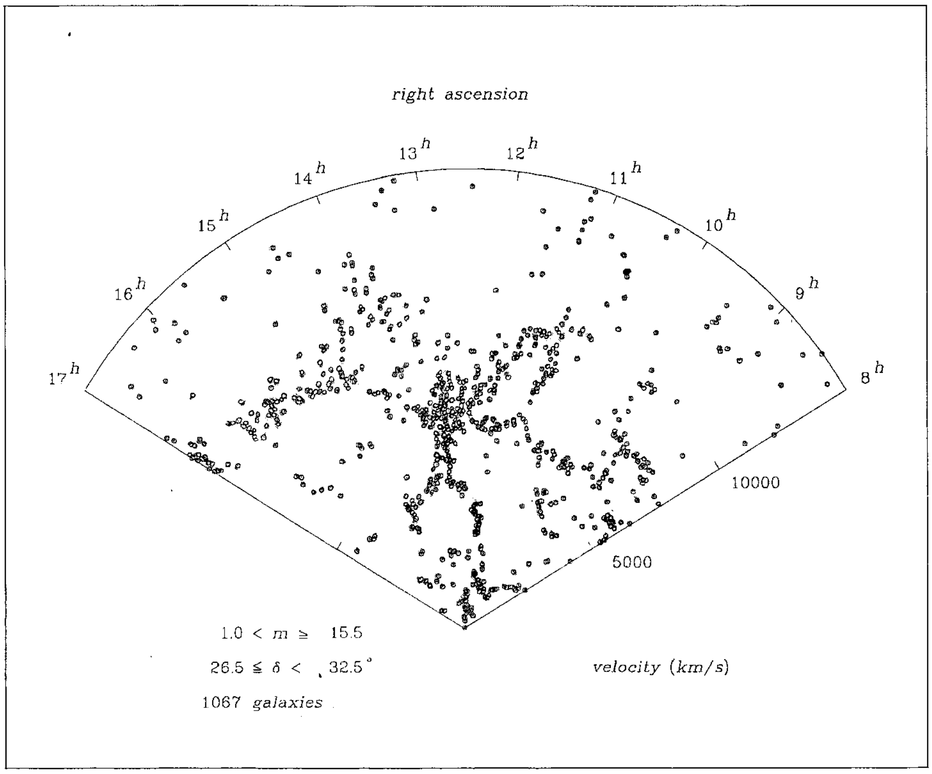
Peccei explored the (Cabibbo-Kobayashi-Maskawa) matrix relating quark and weak nuclear interaction parameters (see page 7), showing how some parameters are in good shape, others less certain.

Supernova

After the initial formation (primordial nucleosynthesis) of light elements in the Big Bang, heavier material is believed to have been cooked in the fiery interior of supernova explosions. A special session at the Bologna symposium was given over to the 1987A supernova, now well over a year old. Former ESO Director L. Woltjer showed how the progressive dimming of the supernova reflects the

Close analysis of slices of the sky shows how clusters of galaxies seem to lie in 'sheets' and 'filaments'.

(Margaret Geller)



radioactive processes at work in the core, with nickel, then cobalt being produced. About 6-7 per cent of a solar mass of iron looks to be the outcome, and when multiplied by the estimated number of such supernovas to have occurred in the history of the Universe, ties in well with the natural abundance of iron, the most stable nucleus, providing a startling bridge between nuclear physics and cosmology.

Complementing the optical tracking of the supernova were results from neutrino (M. Koshiba) and X-ray (Y. Tanaka, J. Trumper) sightings. The neutrino results provide a good test of basic neutrino parameters, while a marked two-fold X-ray spectrum (hard and soft components) needs explanation.

Wolfgang Hillebrandt of Garching showed how theoretical understanding of the 1987A supernova is assisted as this time the progenitor star of the explosion is known, although the picture is still far from complete ('weather forecasts are always difficult').

Another intriguing supernova effect is the report by the Rome group operating a 2300 kilogram gravity wave detector of correlations between impulses recorded in their apparatus (and in the Maryland, US, instrument) and neutrino signals from the detector in the Mont Blanc tunnel.

Astrophysics

In contrast with Peccei's rich harvest of particle physics data, Alan Dressler of California's Mount Wilson Observatory added the latest chapter in the painfully slow determination of basic cosmological parameters. In the late 1920s, Edwin Hubble opened a new era in cosmology with his discovery that stars recede at a rate proportional to their distance.

The proportionality (the Hubble constant) has moved over the years as observational astronomy has improved, but with star brightness and distances difficult to quantify, stubbornly refuses to be fixed. However when local variations are added to the main Hubble flow, Dressler showed how the picture looks tidier, with less scatter between different observations.

With an expanding Universe, one question is whether it can continue to expand, or whether there is enough gravitational interattraction between matter for it one day to reach some critical limit and become 'flat'. While there is lots of prejudice supporting this idea, 'there is lots of evidence against it,' remarked Dressler.

Margaret Geller showed remarkable large-scale structure in the distribution of luminous matter. Looking at slices of the sky ('red-shift surveys'), the clusters and 'superclusters' of visible galaxies seem to lie in 'filaments' or 'sheets', with intervening voids, themselves expanding at thousands of kilometres per second. Analysis of neighbouring slices shows clearly that these structures are real, and not just some statistical accident. Explaining such marked effects by gravity alone is not straightforward, leaving loopholes for additional 'explosive' forces.

Bruce Partridge of Haverford College took a hard look at the microwave background radiation, the thermal vestige of the Big Bang. Dipole asymmetries in the observed pattern of radiation point to local motion, with no comparable quadrupole effect to suggest directional matter expansion as the culprit.

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The remaining signal is uniform to less than one part in a thousand over a wide range of wavelengths, but Alexei Starobinsky of Moscow's Landau Institute preferred to wait for measurements from new Soviet space studies probing down to one part per million. In his talk, Starobinsky pointed out the range of 'inflation' theories now on the market.

Recent rocket-borne studies looking at sub-millimetre wavelengths see a marked effect, which could be a distortion in the microwave radiation itself or the onset of a new signal from rapidly receding intergalactic dust, nothing directly to do with the Big Bang.

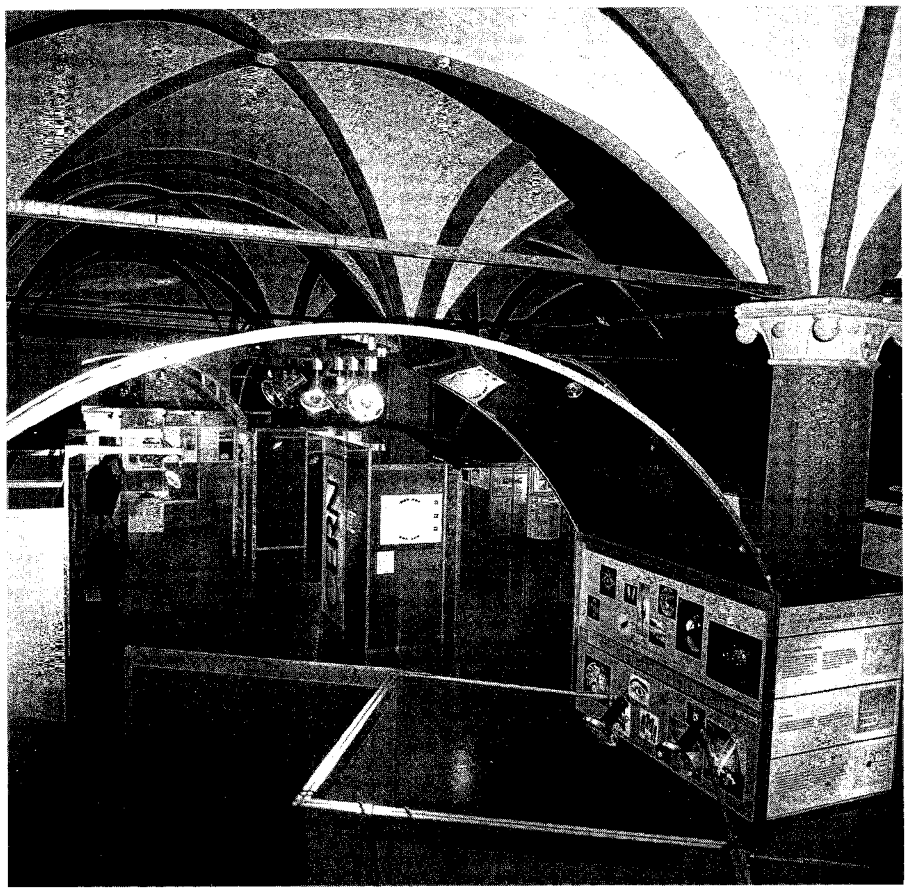
Nostalgia came from Fred Hoyle, once an advocate of the 'Steady State' picture of the Universe, now abandoned in favour of the Big Bang idea. Had this never happened, he pointed out that the new information gathered in the meantime might have made it more difficult to revoke the Steady State idea!.

More light on dark matter

More than half a century ago, analysis of stellar motion and the visible distribution of galactic matter first showed a basic incompatibility – more matter is required than meets the eye. The concept of invisible 'dark matter' was born. More support came from Big Bang calculations of nuclear synthesis.

New ideas (April issue, page 25) have provided a new scenario which lessened the need for 90 per cent of the Universe to be invisible,

The CERN portion of the public exhibition held in parallel with the Symposium.



Former CERN Director-General Leon Van Hove received an honorary doctorate from the 900-year old Bologna University at a ceremony marking the end of the ESO/CERN Symposium. Former ESO Director L. Woltjer was also honoured.

Participants at the ESO/CERN Symposium pose in front of the CERN bubble chamber mosaic, part of the exhibition organized in parallel with the meeting.

but at Bologna Paris astrophysicist Hubert Reeves pointed out incompatibilities with the observed levels of lithium-7.

Cambridge astronomer D. Lynden-Bell was 'sceptical' of measured light element levels. He also underlined differences in the matter distributions measured optically and through the IRAS infra-red astronomy satellite. While the optical results need dark matter support, the infra-red data taken at face value might not. Rather than using this as evidence against dark matter, Lynden-Bell pointed out the inherent difficulties ('underclustering') in infra-red source counting.

Chicago astrophysicist Michael Turner surveyed the candidate list for the missing 90 per cent of the Universe. 'Even if you buy the idea of all baryons, where do you put them?' he challenged. Neutrinos figured high on Turner's list, an alternative not viewed as too exotic by symposium summarizer Leon Van Hove of CERN.

New hope for revealing matter in the outlying regions of the Universe came from B. Fort of ESO, showing how rich clusters of galaxies can act as natural 'gravitational telescopes' to amplify and image the faint light from more distant objects. After initial investigations, further careful analysis has picked out extremely faint contributions due to additional star-forming galaxies far beyond the usual range of vision.

For particle physics, Fermilab Director Leon Lederman sketched the range of experiments in progress or in preparation at his Laboratory, while Enrico Bellotti outlined the physics studies being readied at the new Italian Gran Sasso underground Laboratory.

The cosmic scope of particle physics ideas was indicated by Abdus Salam in his introduction, chaired by Bruno Pontecorvo, and underlined by summarizer Leon Van Hove, who also drew attention to other recent particle physics and astrophysics results, such as the new data from CERN on the distribution of intrinsic angular momentum (spin) deep inside the proton (June issue, page 9), and the information learned from satellite monitoring of Halley's Comet in 1986.

With the same laws of physics holding good over some fifty powers of ten of distance, and with new breakthroughs in understanding on the horizon, the frontiers of physics seem to be converging.

Report by Gordon Fraser

SERPUKHOV
Experiments for UNK

With half the 21 kilometre tunnel for the UNK accelerator at Serpukhov, near Moscow, now excavated and with completion expected some time early in 1990, attention is now turning to the experiments to exploit this latest addition to the front rank of the world particle physics scene.

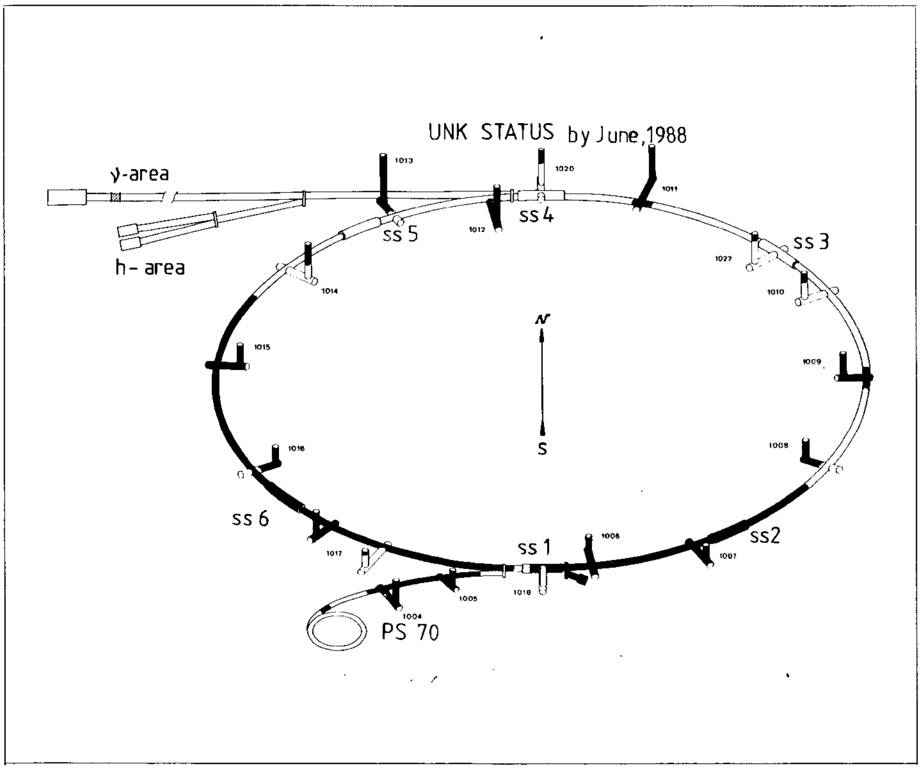
While work on UNK has been underway for some time, construction was given a boost last year by a top-level Moscow decision (January/February issue, page 3). With Soviet accomplishments in other areas of technology so impressive, such a move should considerably benefit high energy physics.

The 400 GeV UNK booster ring (maximum energy 600 GeV) of conventional magnets could be ready as early as 1990, with the 3 TeV beams from the superconducting ring following 3 years later. The addition of a second ring will provide 3 TeV colliding proton beams (6 TeV collisions) in the middle 1990s.

An international meeting at Protvino last year highlighted the physics opportunities that the new machine would offer (May issue, page 1).

Some initial UNK experiments have now been approved, although in some cases further details remain to be fixed, while the green light for further experiments could follow later this year. Already playing a significant role in experiments at other world centres (in particular the Delphi and L3 experiments at CERN's LEP electron-positron collider have Soviet contributions), Soviet scientists are keen to have international collaboration at UNK.

About half the 21 kilometre tunnel for the UNK accelerator at Serpukhov, near Moscow, has now been excavated (in black). Particles will be injected from the existing 70 GeV proton ring (below).



No details have yet been fixed, but there have been several indications of interest from groups in Europe and the US.

The first experiment to run at UNK will be the 'Neptun' gas jet target, which should get underway in 1991. Sited 60 m underground, this study will probe spin effects with high energy proton beams.

Other UNK experiments already approved include a Multiparticle Spectrometer to exploit the expected high production rate of particles carrying the 'beauty' quantum number, and in particular look for the first signs of the violation of CP symmetry (physics invariance under combined particle/antiparticle switching and mirror reflection) outside the neutral kaon sector.

A 'Gluon' experiment, with the goal of searching for 'glueballs' (particles composed of the gluon carriers of the inter-quark force, rather than the quarks themselves) would follow broadly along the lines of a Soviet/European/US collaboration now working at CERN and Serpukhov (May issue, page 21).

The Leningrad nuclear physics institute will play a major role in a study of hyperons (heavy baryons), carrying on from where the recent Fermilab hyperon experiment (June issue, page 25) left off.

One UNK experimental area will be given over to neutrino beams, and initial proposals, including a liquid argon calorimeter, will be considered at Serpukhov later this year.

Although UNK operation as a 6 TeV proton-proton collider is still some years away, the big configurations needed to exploit these conditions take a long time to design and engineer. Two projects are emerging – a large Universal Calorimeter Detector (UCD) experiment for precision tests of the current Standard Model of particle physics together with searches for new behaviour, and a streamer chamber to give visual records of the complex effects expected at these record collision energies.

CERN New effects with neutral kaons

After preliminary indications last year (November 1987 issue, page 20), a CERN experiment has confirmed important new behaviour in the decays of neutral kaons.

In 1964, a historic experiment by J.H. Christenson, J.W. Cronin, V.L. Fitch and R. Turlay at Brookhaven discovered that the neutral kaon behaved oddly. Previously, the neutral kaon was thought to come in two kinds, a long-lived variety decaying into three pions, and a short-lived cousin producing pion pairs.

This was in line with so-called CP symmetry – physics was thought to be unchanged if particles and antiparticles were switched (C) at the same time as left and right were interchanged (P). But the Brookhaven experiment found about one long-lived kaon in five hundred giving two pions instead of three, and CP symmetry fell.

Nearly a quarter of a century later, this is still a mystery, although the effects can be conveniently described in terms of the possible permutations of the six quark 'flavours' due to the weak nuclear force (Cabibbo-Kobayashi-Maskawa matrix). However prediction is limited as almost all the input

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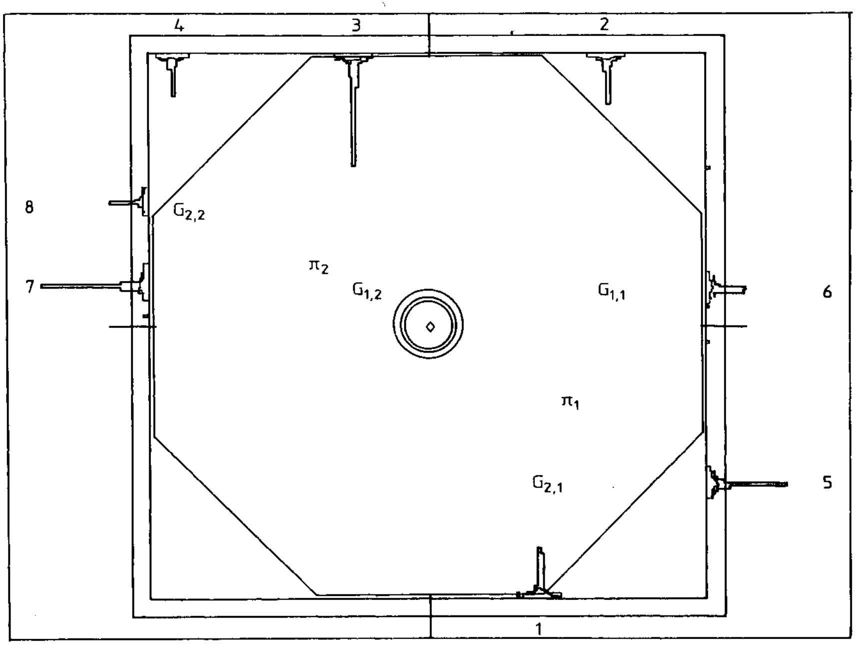
Comprehensive axial view of the decay of a neutral kaon into two neutral pions, each of which then produces a pair of photons, as seen by the NA31 experiment at CERN, with the reconstructed positions of the incoming kaon and the two outgoing pions.



comes from laboratory measurements.

The two neutral kaons, a particle-antiparticle pair, are distinguished only by their quark label (strangeness) conserved in strong nuclear interactions. When the weak nuclear force is at work, strangeness is no longer conserved and the neutral kaon particle and antiparticle get mixed up.

Such 'particle mixing' has also been seen in the neutral B mesons (carrying the 'beauty' quark) by the UA1 experiment at CERN's proton-antiproton collider, and by the ARGUS experiment at the DORIS electron-positron collider at the German DESY Laboratory (June 1987 issue, page 16).

Mixing also results in CP violation, seen so far only in the neutral kaon sector. Projects for copious supplies of B particles hope to extend the CP violation arena to a new breed of particles.

In the quark picture, mixing is explained by transient quark effects inside the particles, and observed mixing rates provide new fixes on quark parameters and transition rates. However such quark transitions should also contribute to the decays of the particles, giving additional CP violating effects.

The CERN/Dortmund/Edinburgh/Mainz/Orsay/Pisa/Siegen collaboration built and operated an ingenious detector to pick up the decays of both short- and long-lived kaons simultaneously. From a total sample of about a million charged and neutral pion pairs from short-lived kaons and ten times as many from long-lived kaons, the experiment finds a two per cent difference between the ratio of long-lived kaons decaying into neutral and into charged pion pairs and the corresponding ratio for short-lived kaons.

This is the first time that 'direct' CP violation, not due to particle mixing, has been seen. As well as helping to understand the origin of this delicate physics effect, it provides important new input to the quark picture.

CLICing into place

Spurred by ambitious plans for physics research around the end of the century and the beginning of the next, long-range accelerator research and development is coming back onto the scene at CERN after the years when resources were heavily committed to LEP. This year a budget line for this work has reappeared.

Development never stopped – witness the mastery of superconducting radiofrequency cavities, and the rapid success with high field superconducting magnets (see June issue, page 13) with a view to a 'Large Hadron Collider' (LHC) in the LEP tunnel.

However other Laboratories with less ambitious short-term commitments, particularly in the USA, were giving more attention to the challenge of new acceleration techniques for the next century. At CERN, more emphasis on this work was strongly advocated by the CERN Long Range Planning Committee led by Carlo Rubbia, and, in addition to the more immediately feasible LHC, the Committee considered the next generation of electron colliders under the name CLIC.

Present CERN ideas on electron linacs in the 1 TeV region have some formidable parameters. New electron sources are needed to provide very intense, short bunches to excite superconducting linac cavities. Laser stimulated photo-cathode sources are looking promising and these are being studied. A superconducting drive linac follows fairly naturally from the work on the LEP cavities. Power has then to be transferred to the 'real' linac requiring special transfer cavities.

The final focus of colliding

An example of the relatively modest investment needed for long-range accelerator research and development is the Advanced Accelerator Test Facility at Argonne studying the production of wakefields in structures and plasmas (June issue, page 16).

beams from such linacs is another topic requiring new ideas and experimental development – the beam dimension at the crossing point for CLIC should be about 12 nanometres, a thousand times thinner than a human hair. (The new SLC Stanford Linear Collider is struggling to collide beams of a few microns.) Among the possibilities is a plasma lens where the neutralized electric self-field leaves the self-focusing magnetic field intact. In principle a focal length of a few centimetres is feasible at 1 TeV which would work for CLIC. Imperial College London is working with CERN on another idea, developed for example at Los Alamos, where a laser beam pre-ionizes plasma in the beam channel. This could also yield a focal length of about 5 cm.

There is work on power sources to concentrate high power into short intervals of time. The old radar technique of 'chirping' is back in vogue. This works by crowding power at different frequencies together. CERN is looking at chirping in superconducting waveguides. Power switching techniques are already highly developed but need to be taken further to switch high currents at high voltage in nanoseconds.

There are novel concepts under study also. One, prompted by the idea of a switched power linac, envisages a radial transformer structure where photocathodes on the outer rim of the accelerator provide the power to be amplified into the central bore. Another idea which has been tested in the same structure is to combine different resonant modes in one coherent moment of acceleration. This will soon be tested in a superconducting structure at Wuppertal. Ferroelectric crystals can develop huge charges on their surfaces and the possibility of using the associated fields for acceleration is being studied in collaboration with Thessalonika University in Greece and Katowice University in Poland. There is a recent proposal to build both the drive and main linacs of CLIC into a single accelerator with an appropriate structure (voltage multiplying r.f. structure) to allow a drive beam to be sent down the bore followed by the 'real' beam, which then sees high fields because of the amplification taking place in the structure.

Although the goals still look formidable, there is no shortage of original ideas.

BROOKHAVEN Polarized protons

Polarized (spin oriented) protons were accelerated to 18.5 GeV last winter for a one-month physics run at the Brookhaven Alternating Gradient Synchrotron (AGS) in the third round of a programme which has been spaced over the past four years. In this latest run three experiments took data, each studying large effects seen earlier and still unexplained. (Two were seen much earlier and provided the impetus for polarized protons at the AGS.)

One 'old' effect investigated was the large polarization of hyperons (heavier cousins of nucleons and carrying the strangeness quantum number) first seen at Fermilab (without polarized beams). With polarized protons, the AGS studies test the transfer of spin from the initial proton to the produced hyperon. Naively, one expects the lambda, where the spin is carried by the component strange (s) quark, not to remember the parent proton's spin, as there is no s-quark in the proton (made of 'up' and 'down' quarks). This was confirmed by a

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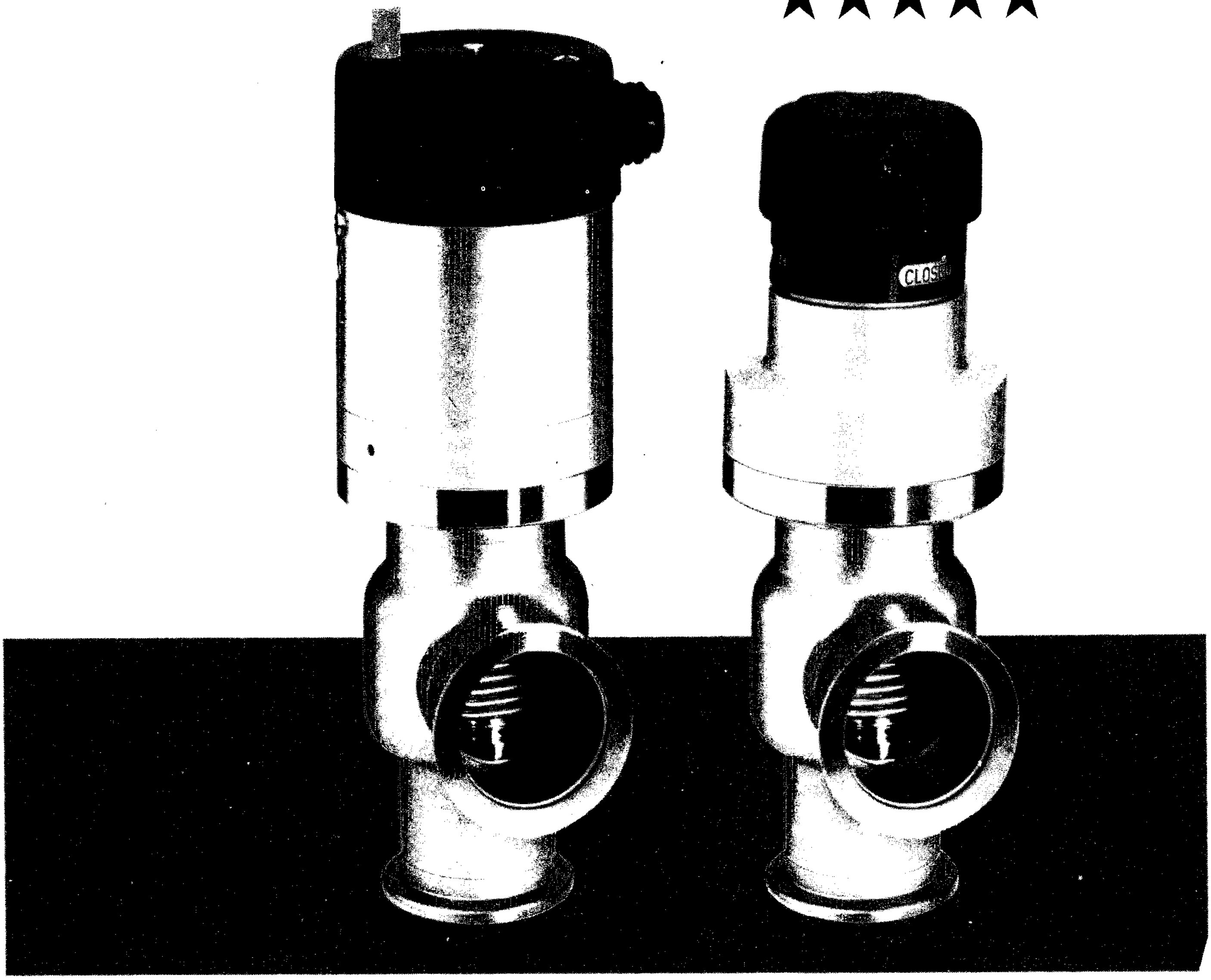

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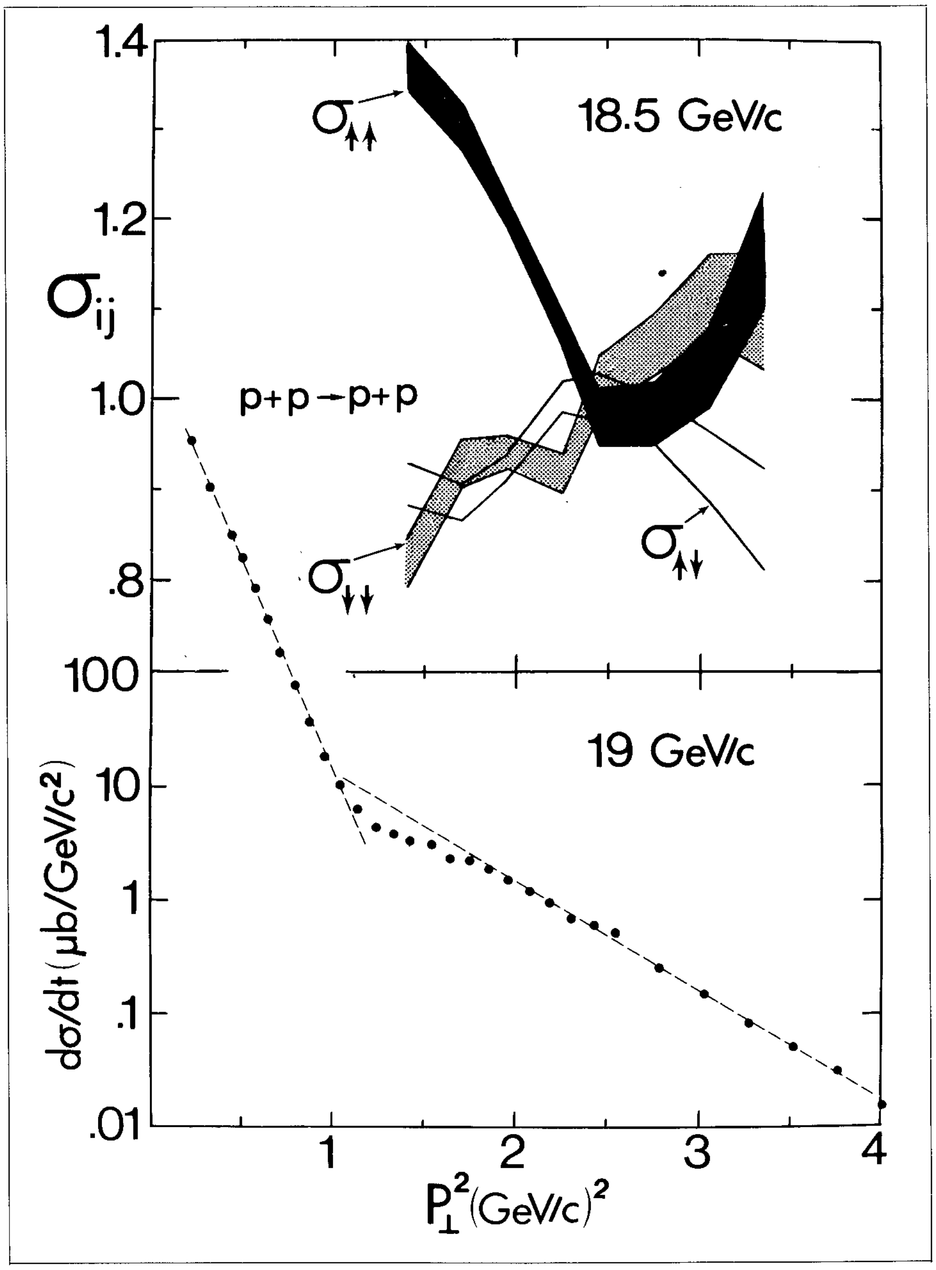
Top, measurements at the Brookhaven Alternating Gradient Synchrotron of the way spinning protons bounce off each other contrast with spin-averaged behaviour (bottom). The arrows indicate the three combinations of proton spin orientations: up-up, down-down, and up-down.



Rice/Brookhaven/Johns Hopkins/Houston/SE Massachusetts collaboration two years ago.

Now the same group has investigated neutral sigma particle production, where the sigma's up quark does carry some of the spin, and therefore one expects the produced particle to remember the proton spin direction some of the time.

While the spin transfer analysis is still underway, the simpler measurement of a different parameter, the scattering asymmetry, has been done. This reflects the overall upwards-downwards mix of the protons' spin axes. The scattering asymmetry for neutral sigmas – expected to be the same as the polarization of inclusively produced lambdas – was found to be surprisingly small, making researchers eager to see what the spin transfer analysis will yield.

A second experiment investigated a large 'new' spin effect observed previously at the AGS by the Michigan polarized target group with an unpolarized beam on a polarized target. That group found a large asymmetry at large angles when protons 'bounce' off polarized protons (elastic scattering). The present experiment, by a Brookhaven/ Minnesota/Penn State/Southeastern Massachusetts group, reversed the roles of beam and target, using the polarized proton beam on an unpolarized hydrogen target, and collected elastic scattering data at larger transverse momentum (squared – 7 GeV^2).

Over ten years ago at the old Argonne ZGS, pioneer studies found that protons were four times more likely to bounce elastically from other protons at large angles if their spins were aligned. This effect was not and is not understood, although intriguing new ideas have been put forward. This spin-spin result led to polarized proton physics at the AGS, and the first run above the 12 GeV available at the ZGS took place in 1986. The successful polarized proton run this year gave the Michigan polarized target group a more detailed look at spin-spin effects. Using a polarized proton beam and a polarized proton target, studies concentrated on a high precision angular distribution measurement in the medium transverse momentum region where the event rate is hundreds of times larger than that at higher transverse momenta. The three possible spin orientations ('up' proton spins bouncing off 'up', 'down' off 'down' and 'up' off 'down') contrast with the behaviour seen in unpolarized (spin averaged) proton-proton scattering (data first obtained about 20 years ago at CERN).

This suggests some large effect at medium transverse momentum, invisible in the unpolarized experiments, but showing up clearly when spin is labelled. Spinning protons have not yet finished yielding their secrets.

BROOKHAVEN More light

In February 1987, the X-ray ring of the US National Synchrotron Light Source (NSLS) at Brookhaven was shut down for major improvements to double (from 30 to 60) the possible number of experiments and to boost machine performance.

New equipment in the ring includes high brightness insertion chambers, replacing six of the sixteen dipole vacuum chambers, and the Laser Electron Gamma Source (LEGS) experiment.

In an impressive series of pre-recommissioning tests in April the revamped machine circulated, stored and stacked electron beam in seventeen hours, boding well for the restart of research this summer using 2.5 GeV beams. This follows an earlier upgrade of the NSLS ultra-violet ring.

Keeping protons polarized

Brookhaven's latest polarized proton physics run was preceded by a three-week commissioning effort. Keeping the proton spins lined up during the acceleration cycle is a complicated business due to both horizontal focusing fields and to magnet imperfections which also give rise to horizontal fields.

These horizontal fields typically cancel in their effect on the polarization, but resonances occur at certain energies when the effect of the fields becomes cumulative. 'Imperfection' resonances are avoided by changing the orbit of the circulating beam using small magnetic fields while 'intrinsic' resonances are avoided by changing the tune of the machine.

An added complication presented itself when the Siemens motor generator set powering the AGS ring magnets developed a short. A vintage backup generator (Westinghouse), unused for 20 years, could only provide enough power for an 18.5 GeV run.

The commissioning successfully negotiated the 30 imperfection depolarizing resonances and the five intrinsic resonances which must be crossed to achieve 18.5 GeV. The physics run had 2 x 10^{10} protons every 2.8 seconds, with an average polarization of 42 per cent (80 per cent being supplied by the linac). The ramp of the backup power supply was necessarily slower and increased the time spent at resonance energies, making tuning even more tricky. One resonance was extremely sensitive and required frequent retuning – until it was decided to mistune the resonance sufficiently to completely reverse the polarization at that point! This did the trick, and three other resonances were also flipped for the physics run.

As a result of a considerable alignment effort for main ring magnets and ferrite quadrupoles (used to jump intrinsics) which took place over last summer, beam problems (emittance growth when intrinsic resonances are jumped) were minimized.

INDIANA Electron cooling ring in action

A new proton storage ring with electron cooling is being commissioned at Indiana University in the US. The cooling system came into action on April 16, and already the next day interaction of the cooled beam with an internal jet target was being studied.

Initial off-line tests of the electron beam on March 30 gave electron beam currents to 1 Ampere (cathode diameter 25 mm), energies from 50 to 125 keV, and very good current collection (to 99.98%). The system was so well-behaved that further off-line testing was halted and the cooling device rolled into the ring during an eight day break between test runs.

Cooling (smoother beam properties) was observed as soon as the electron and stored proton beam positions and angles were measured and shifted to coincide. Although the ring has stored 10^9 protons, the first cooling tests were carried out with 10^7 to 10^8 particles stored at the injection energy of 45 MeV, and electron beam currents from 0.05 to 0.7 A.

With no radiofrequency, Schottky signals showed the injected frequency spread of 0.06% narrowing

in a fraction of a second to 0.003%. With r.f. at 6 MHz, the time spread of the beam was quickly reduced to less than 2 ns, and the beam lifetime increased from a second or two to over 40 seconds.

The new Cooler is injected with beams from the 2 Tesla-metre isochronous cyclotron at the Indiana University Cyclotron Facility (IUCF). It heralds a second generation of small cooled storage rings for research in atomic, nuclear, and particle physics. Several other rings at Heidelberg, Uppsala, Tokyo, and Aarhus are scheduled to come into operation soon.

The 86.82 m circumference is similar to that of the LEAR ring at CERN, but has a smaller magnetic rigidity of 3.6 Tesla-metres (corresponding to a momentum of 1.08 GeV/c for singly-charged particles). This means that an unusually large fraction of the ring is left open for internal target experiments.

The Cooler can be filled by stripping light ions, or kickers can be used to inject beams without stripping. A first look at this process was obtained on May 8 and 9 with storage and cooling of unpolarized and then polarized protons of 148 MeV from the cyclotron. This gave essentially the same 3 keV energy spread as at 45 MeV, time spreads below 1.2 ns and beam lifetimes of 3 to 4 minutes. These tests were carried out at low intensity with single turn injection. Longitudinal stacking of polarized protons and deuterons, heavily used by the IUCF research community, is planned for the autumn.

Acceleration in the Cooler will extend the energy range of all ions, and the electron cooling system has been designed to match any of the stored beams (requiring electron kinetic energies up to 270 keV).

Although proton beams of IUCF energies have been available from accelerators for nearly forty years, the superior beam quality of the isochronous cyclotron has made possible a number of new results from IUCF and the other large cyclotrons that began operation in the mid 70s.

According to Robert E. Pollock, one of the Cooler's designers and its project manager during the construction years, plans for electron-cooled antiproton beams in LEAR, with markedly better phase space density than the proton beams from IUCF, were a revelation (January/February issue, page 10).

Internal target experiments can exploit this beam quality, and the Cooler concept was born. Of course the Novosibirsk (USSR) originators of the electron cooling had anticipated applications such as those planned for the Cooler, but the Indiana group was the first to go for cooling with internal targetry.

One Cooler straight section has an experiment with a jet target operating at densities up to 10^{15} atoms per square cm, and detectors covering the forward cone, designed for a pion threshold measurement. The second straight section is used by a Michigan group preparing a 'Siberian snake' to further control the beam. A third target location in the ring has a 6 degree bend to separate reaction products for an experiment by a Pittsburgh-Illinois collaboration.

The experimental programme approved so far includes seven experiments, with five more to be considered. Future plans include a polarized target, spectrometers in the ring, and experiments with recoil ions and tagged secondaries.

The Cooler project was funded by the US National Science Foundation ($7.7 million) and by the State of Indiana ($4 million).

MEETING
Warsaw 1938-1988

Each year the University of Warsaw organizes a one-week meeting on theoretical particle physics in the charming little town of Kasimierz on the Vistula, 150 km south of Warsaw. These meetings are a lively testimony to the important work on theoretical physics in Poland.

The latest meeting, in May, brought together about 120 participants, about half from abroad, and marked the 50th anniversary of a milestone meeting in Warsaw on new theories in physics, with contributions from Niels Bohr, Louis de Broglie, Louis-Marcel Brillouin, Sir Arthur Eddington, Hendrik Kramers, Oskar Klein and Paul Langevin.

The 1938 proceedings were widely reread this time, and 1988 summarizer David Gross preferred to summarize instead the 1938 meeting. Besides much discussion about the interpretation of quantum mechanics, in those days people were trying to reconcile the strong nuclear force and the Fermi theory, formulated for weak nuclear forces (beta decay), but the only tractable picture available at the time and the object of much speculation.

The heavy particle postulated by Yukawa as the origin of strong nuclear forces was then widely believed to have spin (intrinsic angular momentum) of one unit (the pion, the first nuclear meson to be discovered, has zero spin). Meanwhile the photon ('a daring abstraction') was being associated with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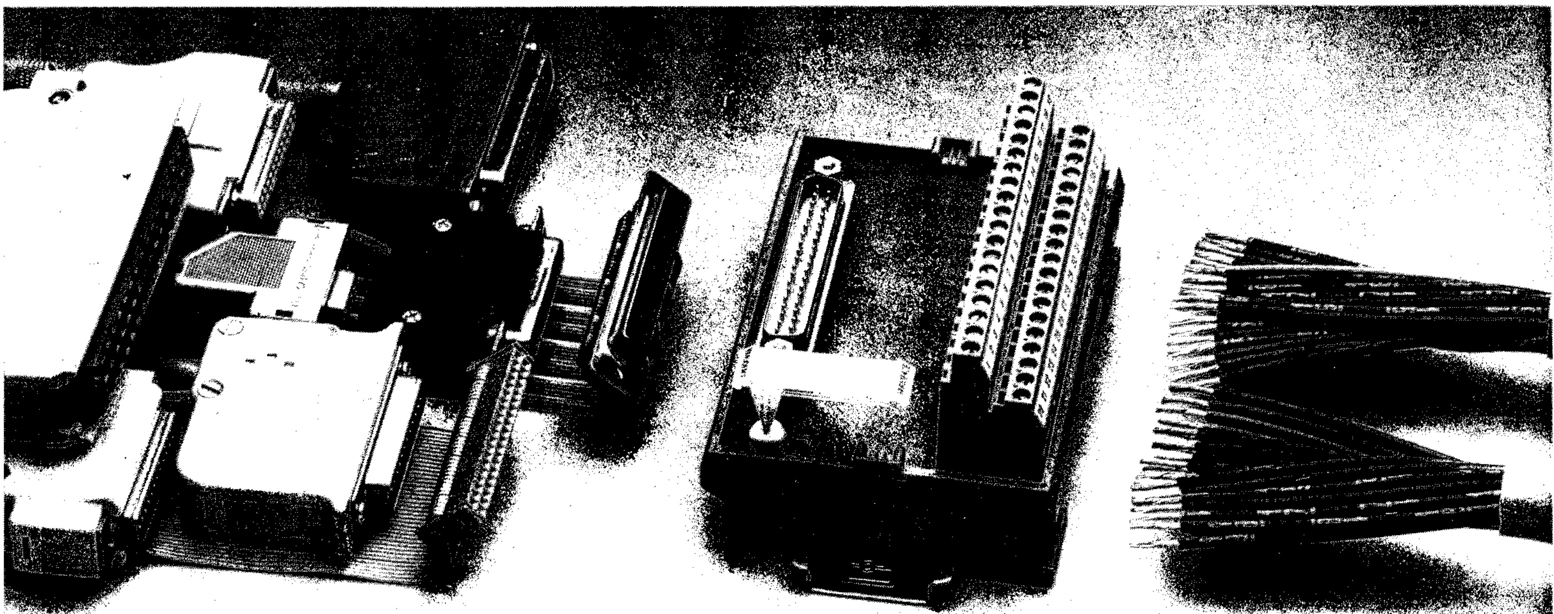


At the Kasimierz meeting, Lev Okun (left) with David Gross.

(Photo M. Jacob)

zero spin (it has spin one).

Oskar Klein had proposed a far-reaching unification scheme encompassing the photon (the carrier of electromagnetism) with the two electrically charged nuclear mesons, but changed it rapidly when informed that there were also nuclear forces which did not permute electric charges.

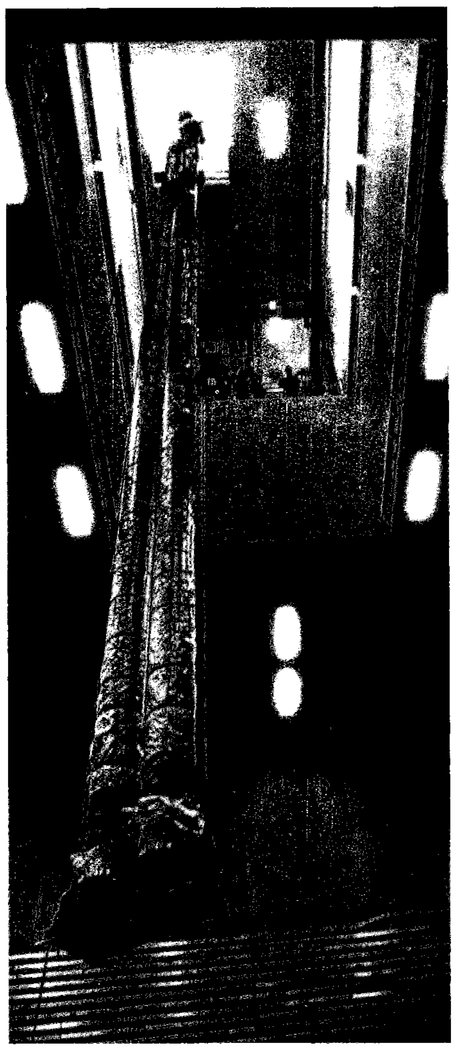
The 1988 Kasimierz meeting was convened by S. Pokorski and A. Trautman of Warsaw, and organized by Z. Ajduk.

From Maurice Jacob

DESY
HERA progress

At the end of May, finishing touches were put to the last of the 400 standard magnet modules for the 30 GeV electron ring of the HERA electron-proton collider being built at the German DESY Laboratory in Hamburg. With its copper vacuum pipe, this 14 metre module includes a 9 metre dipole, a quadrupole, a sextupole and a correction magnet.

At the beginning of June major components of a 52 MHz radiofrequency system arrived from Chalk River, Canada, for installation in the PETRA ring where protons destined for HERA will be accelerated from 7 to 40 GeV. Chalk River is also supplying the corresponding 52MHz system (two cavities) for the HERA ring itself, where four 208 MHz cavities will reduce the bunches from 2 metres to 60 cm.



▶ A 24 metre section of helium transfer line for the 6.3 km superconducting proton ring of the HERA electron proton collider being built at the DESY Laboratory in Hamburg is eased down ten storeys before being put in position.

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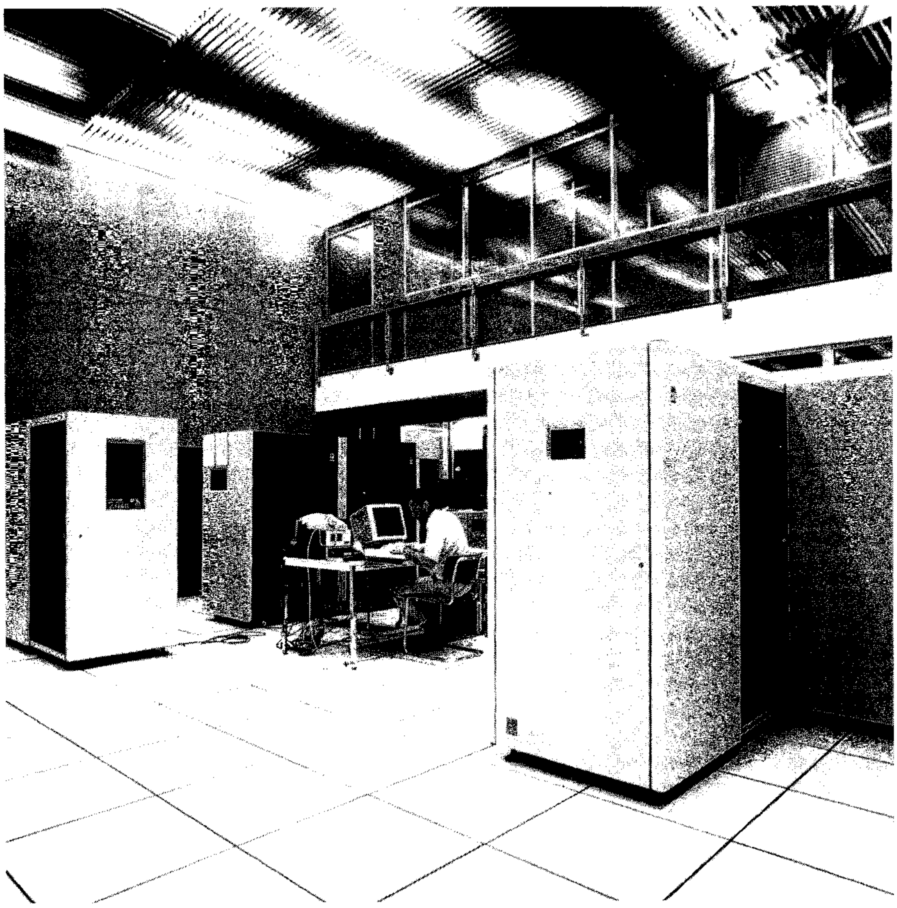
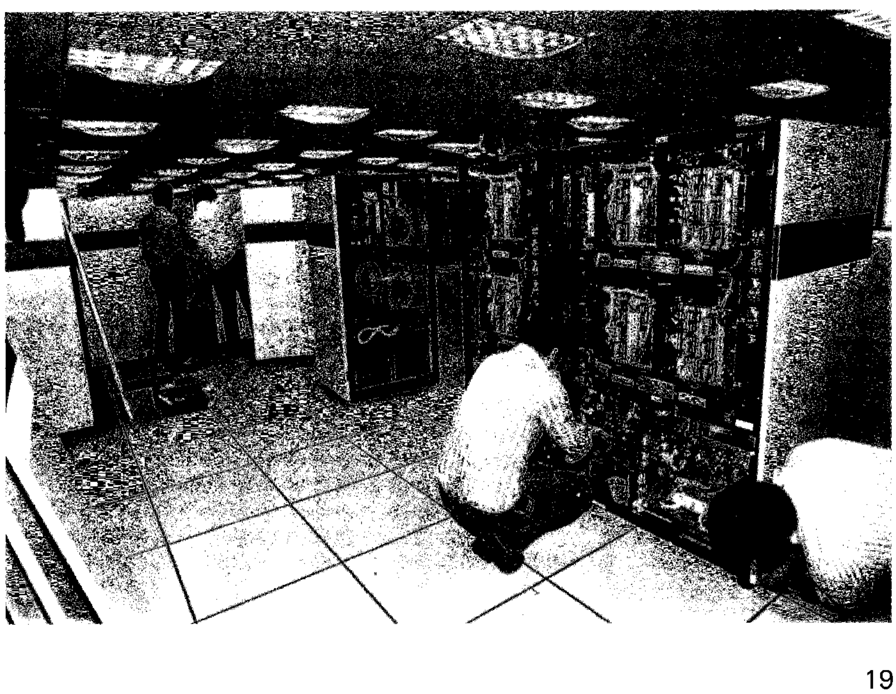
New computers arrive. Top, an IBM 3090-400E for CERN (Photo CERN 297.5.1988), and (below) an Amdahl 5890 600E for Fermilab.





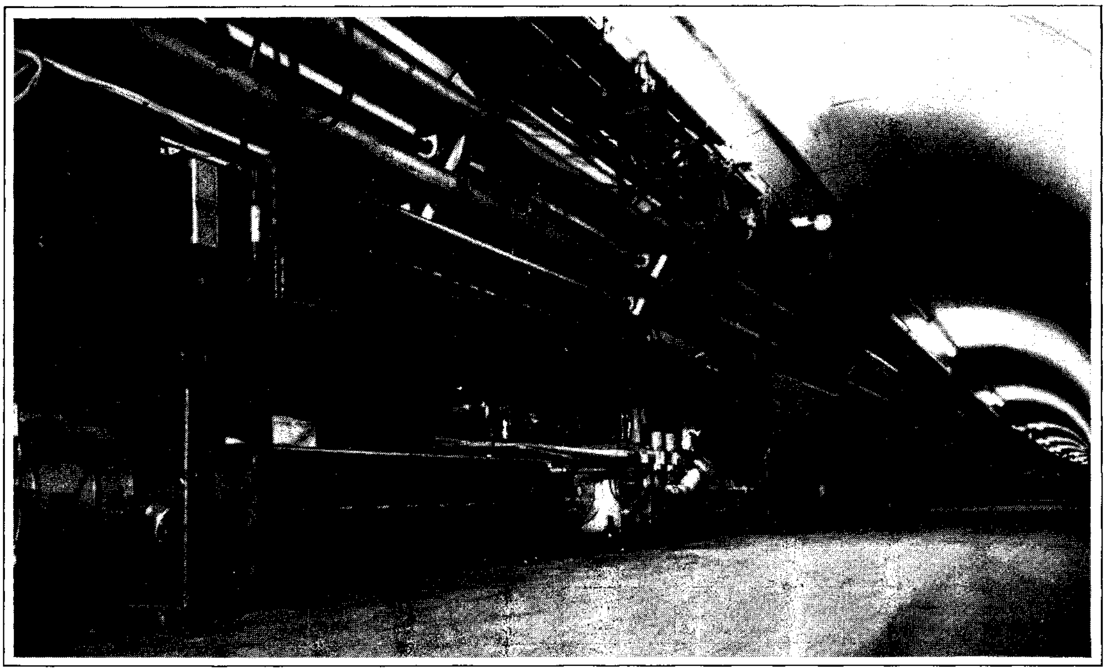
FERMILAB Looking for new particles

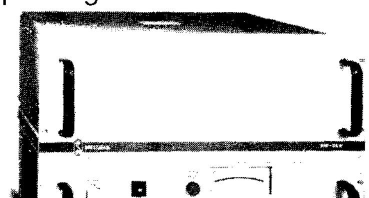
Experiment 774 is a new Fermilab fixed-target search for short-lived neutral particles that couple to the electron. The observation of narrow electron and positron peaks in heavy ion collisions (March issue, page 13) suggests the existence of such objects and has focussed attention on a region of mass and lifetime where they could exist and yet would not have been seen.

Earlier searches (for example Fermilab Experiment 605 and Experiment 141 at the Stanford Linear Accelerator Center) found no trace of any new particles in the mass and lifetime range available to them.

E-774 (a Fermilab/ Illinois/Krakow/Northeastern/Stanford (SLAC) collaboration) exploits the exceptionally high energy and flux of Fermilab's Wide Band Electron Beam to probe an unexplored region. During the recent fixed-target run, tests ensured that E-774 could run simultaneously with the E-687 photoproduction experiment which is the primary user of the beam, and logged 48 hours of data, which should already provide new limits.

It is a 'beam dump' experiment, with the electron beam hitting a totally absorbing target calorimeter (the 'dump'), looking for electrons interacting in the dump to produce a light neutral particle, decaying into an electron-positron pair some distance downstream. If a decay is to be seen, the unstable neutral particle must first emerge unscathed from the target calorimeter. Here the large relativistic time dilatation at high energy helps –





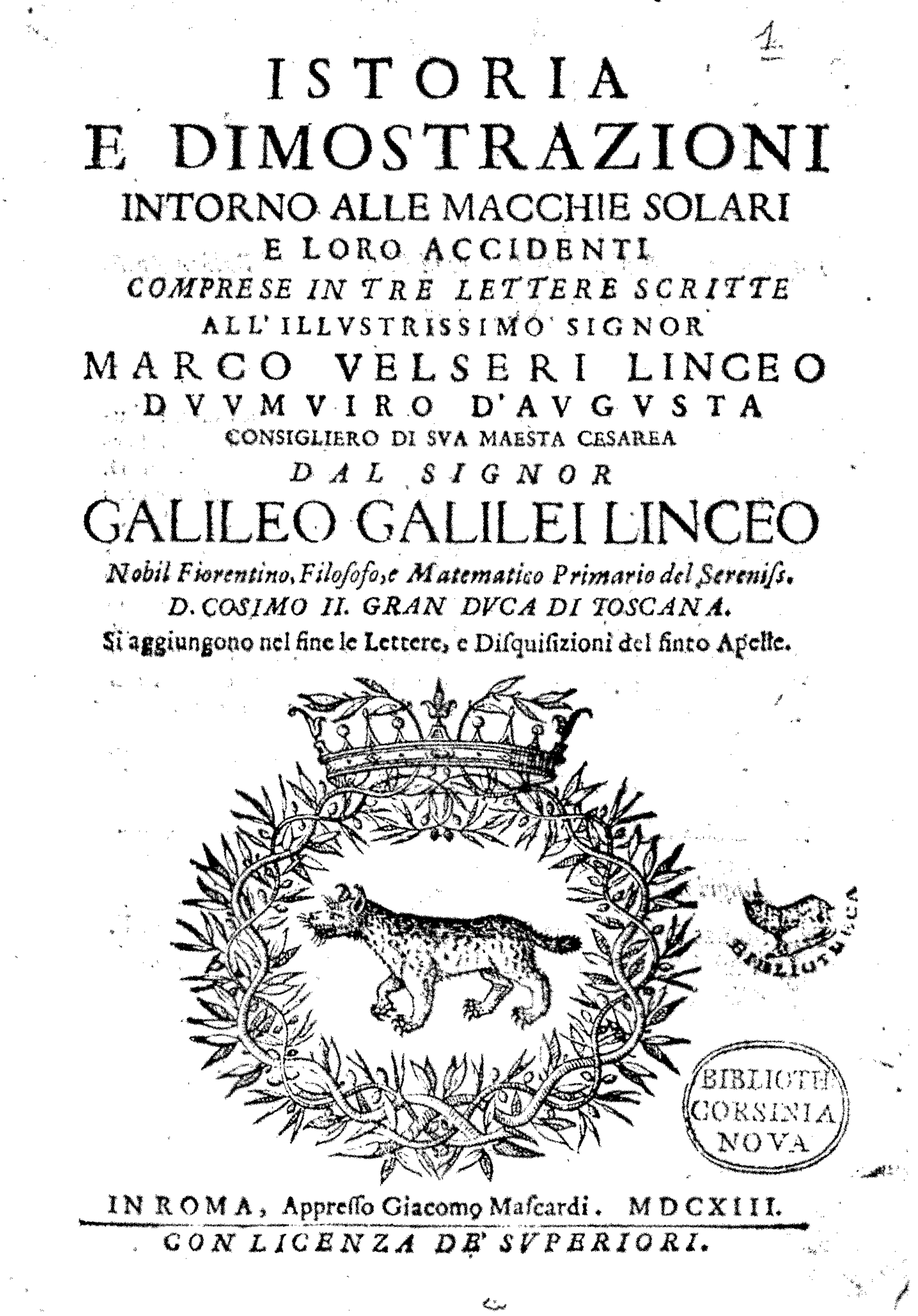
the lifetime of a 2 MeV mass, 200 GeV energy particle is increased 100,000-fold.

The target calorimeter also has to be as short as possible. It uses tungsten plates instrumented with scintillating fibre ribbons, 200 microns thick (May issue, page 29) for frequent sampling, but with the sampling material comprising only 6% of the total thickness. Downstream, a simple neutral decay spectrometer is followed by a trigger calorimeter. The target and trigger calorimeters were in place for the test run, but not the spectrometer.

Science and the humanities

In August 1603, Federico Cesi, from a wealthy Umbrian family, and three companions founded 'l'Accademia dei Lincei' (lynx) to discover and investigate the 'great theatre of Nature'. After a demise in 1651, the present National Academy was set up in 1874, and has gone on to play an important role in fostering philosophy and philology in Italy, work which has gone on to leave its mark further afield.

After having been on view at several venues in Italy, an exhibition 'Federico Cesi and the Foundation of the Accademia dei Lincei',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Galileo's first paper for the Accademia dei Lincei (1613).

Robert Wilson – 'where there is beauty, there is humanness'.

was mounted, for the first time outside Italy, at CERN in May. Reflecting the basic inspiration common to all human endeavour to extend knowledge, the exhibition was marked also by a Symposium on the Unity and Internationalism of the Sciences and the Humanities, sponsored by the CERN Science and Society Seminar and the Istituto Italiano per gli Studi Filosofici, and in cooperation with the CERN Staff Association.

Speakers, drawn from a wide cross-section of disciplines, paused for a moment from their everyday researches and gave their views on the basic unity of the quest for knowledge, and its consequences, intellectual internationalism and the resultant worldwide relationships of understanding and cooperation.

Lincei Vice-President Edoardo Amaldi chaired and first day's proceedings, and Giovanni Pugliese Carratelli, Director of the Istituto Italiano.per gli Studi Filosofici, Naples, introduced the session by pointing out the common roots of intellectual disciplines – the 'search for truth' – characterized by different research techniques.

Sculptor, architect and former Fermilab Director Robert Wilson stressed the human qualities that top flight science brings. Although 'no flower blooms and no birds sing' in physics, the research brings a whole emotional spectrum 'passion, heartbreak, jealousy, ecstasy,...'. Beauty is embodied in the laws of physics – 'like poems' – while symmetry has equal appeal for scientist and artist alike.

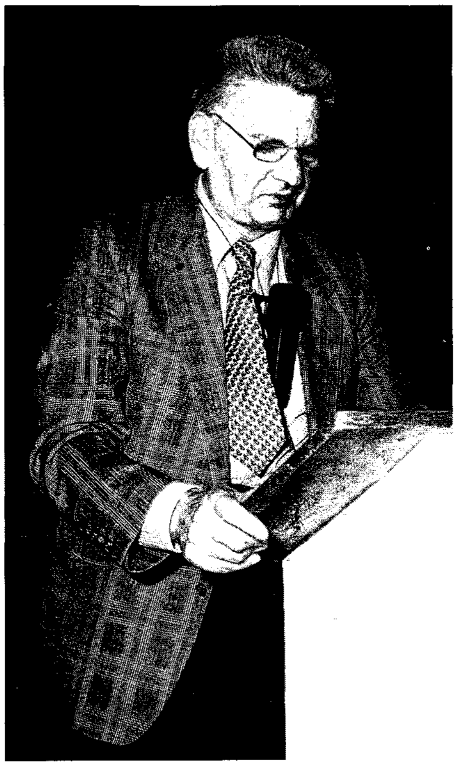
Wilson emphasized the usefulness of popular science for bridging the gap between the initiated and the profane, and advocated increased cross-disciplinary contact in universities.

Former CERN Research Director General Leon Van Hove ('From Cosmology to Particle Physics') showed how the laws of physics hold good from the largest scales (10^{36}cm) to the smallest (10^{-17}cm), the span having been extended by a factor of 10^{14} on either side in the last century from the classical 'beautifully austere' Newtonian picture of gravity.

Van Hove showed how the observations of last year's supernova dramatically illustrated the interplay of gravitation with the weak and strong nuclear forces, demonstrating the complementarity of the different forces at work in Nature, and providing a new astronomical window on bulk nuclear effects.

The second day's session, chaired by Olivier Reverdin of the University of Geneva, began with Remo Bodei of Pisa examining the contemporary philosophical view of cross-disciplinary reasoning. 'Philosophy is no longer queen of the sciences,' he claimed. While inheriting much 'moribund' knowledge, philosophical approaches can still help clarify concepts, adding cohesion and bite.

René Thom – 'hard' and 'soft' sciences

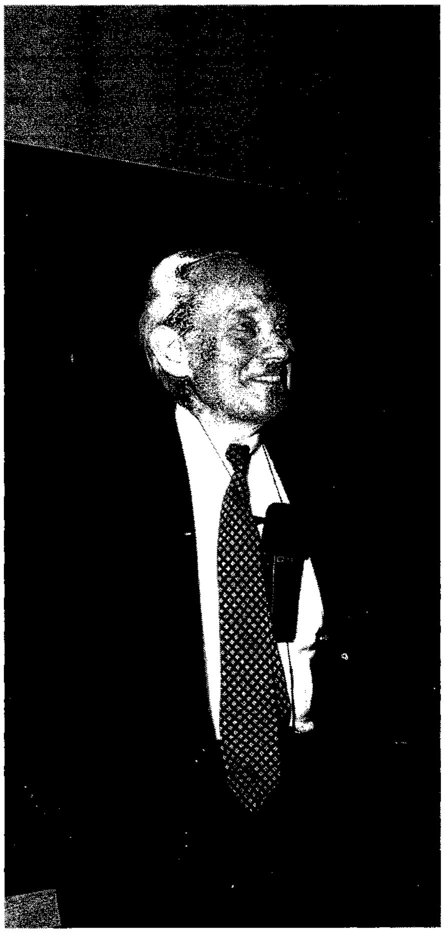


René Thom, pioneer of catastrophy theory, illustrated the inherent differences between 'hard' sciences with exact laws and 'soft' descriptive sciences. The rift between mathematics and everyday language is a corollary, and ways of bridging this descriptive gap would help in the drive to make the world more intelligible.

Girolamo Controneo of Messina ('The relation between philosophy and human sciences') looked at the sociological prerequisites for new theories, and examined the dichotomy between the speculative and scientific approaches which seems to characterize modern culture.

Manfred Eigen of the Max Planck Institute for Biophysical Chemistry in Gottingen focused on the inter-

Manfred Eigen – the physics of biology

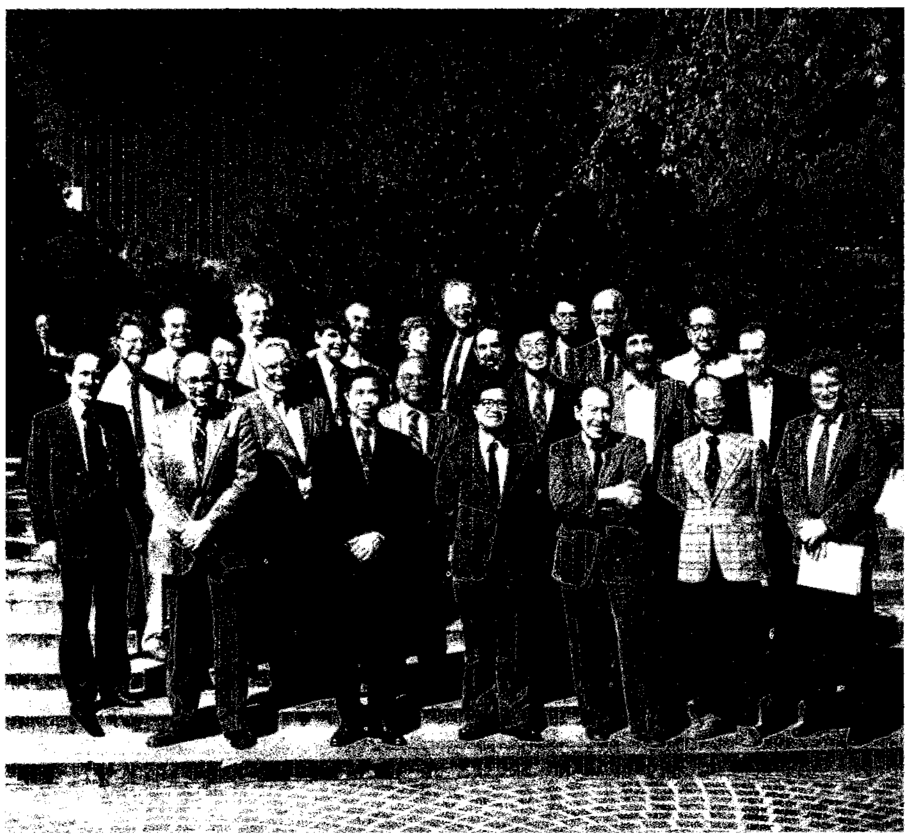


face between chemistry and biology, showing how certain hydrogen bonding (complementary base pairing) marks the threshold where molecules can be regarded as truly 'biological' rather than inertly chemical.

He described vivid simulations of cell reproduction which show how the 'error rate' of cell mutation compounds to produce new effects – evolution – in a way very reminiscent of phase changes in physical chemistry. At a certain stage, the information held in the cells 'melts', and new mutants emerge ('survival of the fittest').

During the two days of the symposium, many deep and thought-provoking ideas were aired, and will be available to a wider audience with the publication of the proceedings. 'We have planted some trees,' said Ugo Amaldi, one of the prime movers behind the symposium, 'others will have to be added to make a real forest.'

A recent symposium at the University of California at Los Angeles marked the 70th birthday of Julian Schwinger (third from right, front row).



People and things

On people

On 15 May, Carlo Rubbia, Physics Nobel Prizewinner with Simon van der Meer in 1984, Director-General-Designate of CERN and Higgins Professor of Physics at Harvard, received the degree of Doctor of Science, honoris causa, from Boston University.

On 12 April Dubna's scientific community celebrated the 75th birthday of eminent Soviet scientist Venedikt Petrovich Dzhelepov. He was among the leading organizers of the Soviet national high energy physics centre which grew into Dubna's International Joint Institute for Nuclear Research, where he has been Director of the Laboratory of Nuclear Problems since 1956.

Faculty Position

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The Department of Physics at the University of Oregon invites applications for a tenure track faculty position in experimental particle physics. The appointment will be at the Assistant Professor level, although an outstanding candidate may be considered at the Associate Professor level. The appointment will begin in September 1989, adding a second member of the program in experimental particle physics that has been started this year. The new group is working on the construction of the SLD detector at SLAC and on SSC R & D projects. We expect the new faculty member to join research efforts on SLD. The applicant is expected to have a solid record of research accomplishments. The Department already has an active research group in theoretical particle physics, has experimental programs in several other areas and has good experimental shop facilities.

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V.P. Dzhelepov, Director of the Dubna Laboratory for Nuclear Problems, celebrated his 75th birthday in April.

Erich Vogt (left), Director of the Canadian TRIUMF Laboratory in Vancouver, shows a model of the proposed TRIUMF KAON particle 'factory' to British Columbia Premier W. Vander Zalm (centre) and Advanced Education Minister S. Hagen.

Awards

The 1988 American Physical Society Prizes included: the Tom W. Bonner Prize to Raymond Davis of Pennsylvania for his use of nuclear reactions to detect neutrinos; the Dannie Heineman Mathematical Physics Prize to Julius Wess of Karlsruhe and Bruno Zumino of Berkeley for their work on supersymmetry (April issue, page 31); the W.K.H. Panofsky Prize to Charles Prescott of the Stanford Linear Accelerator Center for his role in the experiment demonstrating the interference between weak and electromagnetic interactions; the J.J. Sakurai Prize to Stephen Adler of the Institute for Advanced Study for his work in chiral symmetry; and the Robert R. Wilson Prize to

CERN Director General Designate Carlo Rubbia (right) with Italian Minister for Scientific Research and Universities Antonio Ruberti at the opening of the 'Italy at CERN' trade exhibition at CERN on 31 May.

(Photo CERN 544.5.88)

Donald Kerst of Wisconsin for his many contributions to accelerator physics.

Books

The proceedings of the international conference marking the 40th anniversary of the discoveries of the pi- and V-particles, held at Bristol last July (October 1987 issue, page 11) have been published by Adam Hilger (Bristol and Philadelphia). The invited papers provide a fascinating glimpse into the particle physics techniques, and life, of yesteryear. Entitled '40 Years of Particle Physics', the book is edited by B. Foster and P.H. Fowler.

Meetings

The 8th International Symposium on High Energy Spin Physics will be held at the University of Minnesota, Minneapolis, from 12-17 September. Topics will include Symmetries and Spin, Static Properties of Leptons and Hadrons, Weak Decays, Hadron and Lepton Interactions, Electron Accelerators, Hadron Beams, Hadron Sources, Hadron Polarimeters, and Targets. Workshops on Theory (6-10 September), Polarized Electron Sources and Polarimeters (8-9), Depolarizing Corrections in Future Accelerators (10-11) and Polarized Gas Targets for Storage Rings (10-11) will also be held in Minneapolis preceding the Symposium. Further information from Sandy Smith, Conference Secretary, School of Physics and Astronomy, University of Minnesota, Minneapolis, Minnesota 55455, USA, telephone (612) 624-7886, bitnet SPIN88 at UMNACVX.

Electronic Mail

The CERN Courier editorial desk can be contacted through electronic mail using the EARN/BITNET communications network. The Editor's address is

COURIER@CERNVM

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For subscriptions (free!), changes of address, etc. the contact is

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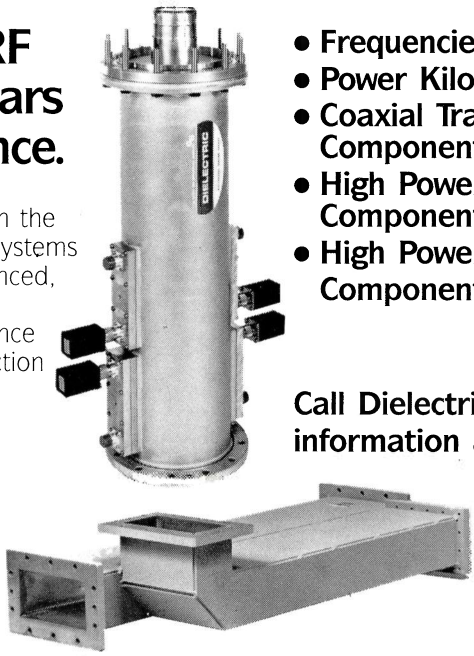
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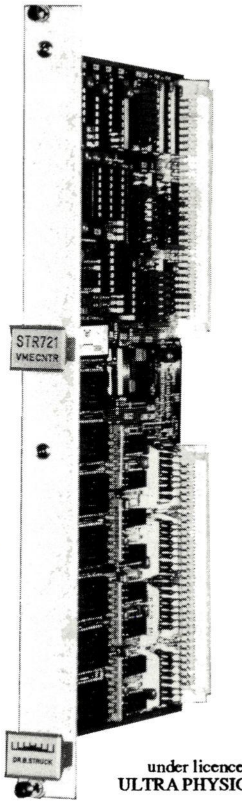
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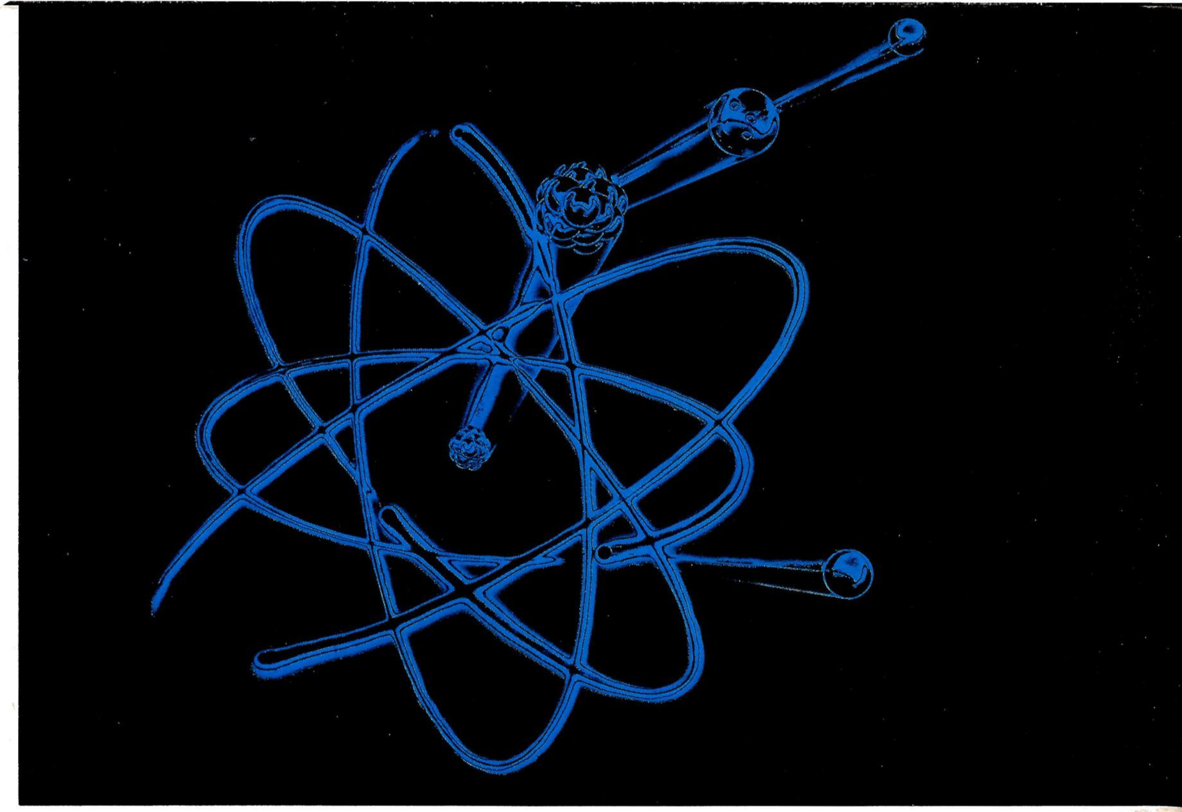

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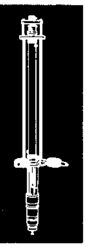

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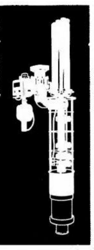

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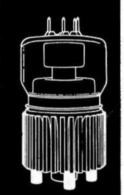

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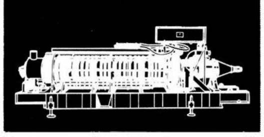

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