CERN COURIER

International Journal of High Energy Physics

VOLUME 29 2 MARCH 1989

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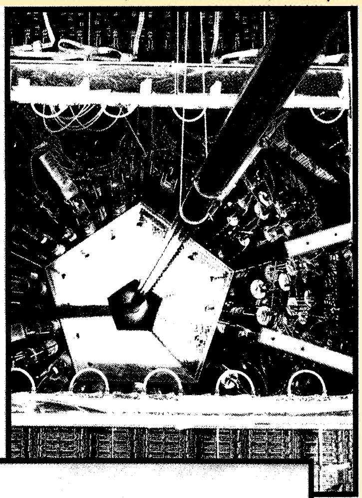
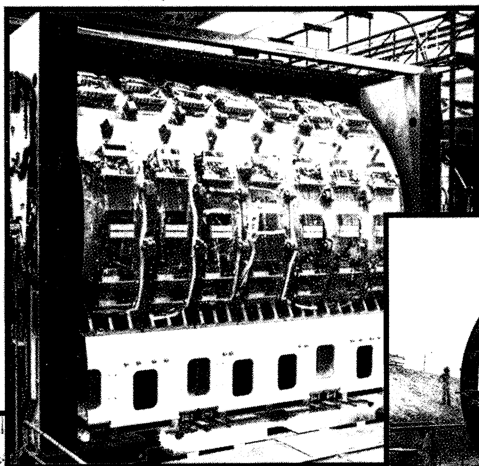


Plastic Ball, WA80 CERN, Europe



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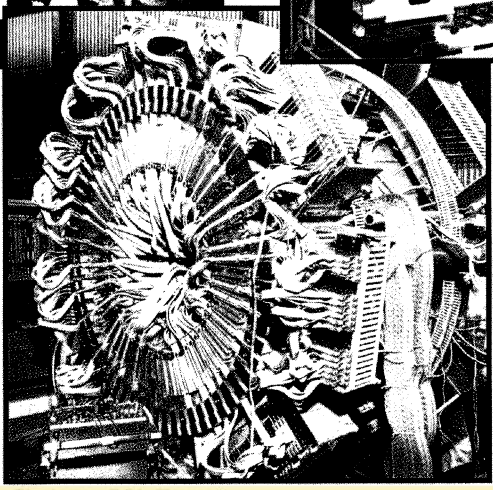
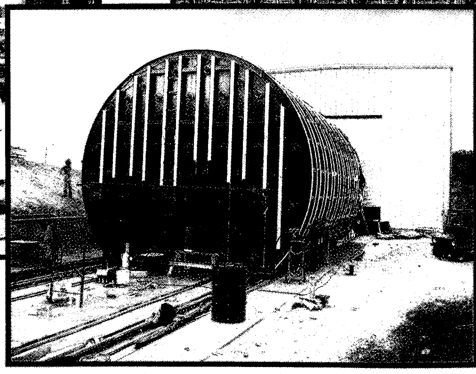


Sindrum, PSI, Europe



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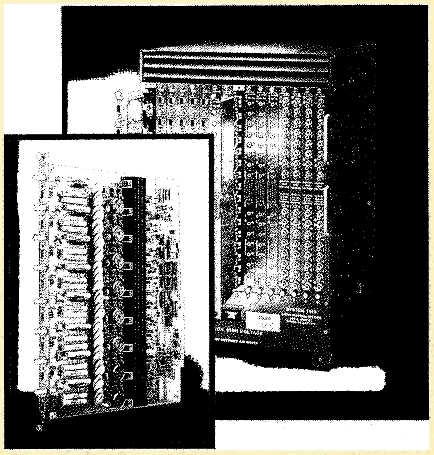

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Volume 29
No. 2
March 1989

CERN COURIER

Covering current developments in high energy physics and related fields worldwide

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Illinois 60510

CERN COURIER is published ten times yearly in English and French editions. The views expressed in the Journal are not necessarily those of the CERN management

Printed by: Presses Centrales S.A.
1002 Lausanne, Switzerland

Published by:
European Laboratory for Particle Physics
CERN, 1211 Geneva 23, Switzerland
Tel. (022) 83 61 11 (767 61 11 from 22 April), Telex 419 000 CERN CH
[CERN COURIER only
Tel. (022) 83 41 03 (767 41 03 from 22 April), Telefax (022) 82 19 06 (782 19 06 from 22 April)]

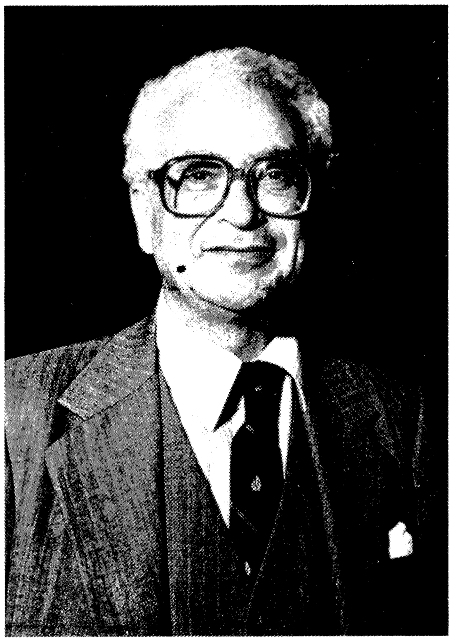
USA: Controlled Circulation
Postage paid at Batavia, Illinois

Cover photograph:
For CERN, 1989 is LEP year, with the 27-kilometre electron-positron collider's switchon scheduled this summer. Much of the ring is already complete, while in the remaining sectors and the four vast underground experimental halls final installation work pushes ahead (Photo CERN 142.1.89).

Omega-minus plus 25 years

Authors of the 'Eightfold Way' – Murray Gell-Mann (right) and Yuval Ne'eman.

(Photos Kathleen Blumenfeld)



A quarter of a century ago, in February 1964, the world learned that particle physicists had found the omega-minus particle, setting the stage for a new era in our understanding of the components of the atomic nucleus.

Particle physics had hit the headlines before and has done so many times since, but the dramatic discovery by a Brookhaven bubble chamber team of a particle whose exact properties had been predicted by seemingly simple chalk-and-blackboard arguments was especially romantic.

In the 1920s, physicists had strived to explain all the underlying structure of matter in terms of just two particles, the proton – the heavy constituent of the atomic nucleus – and the light electrons orbiting round the nucleus or given off in beta decay. When the neutron – the electrically neutral component of the nucleus – was discovered by James Chadwick at Cambridge in 1932, understanding took a step backwards.

Then Werner Heisenberg pointed out that the proton and the neutron, apart from their electric charge, were otherwise quite similar – both lived inside nuclei and both weighed about 900 MeV.

Perhaps, suggested Heisenberg, they were the two possible quantum states of a single entity – the nucleon – inhabiting some abstract two-dimensional 'isospace'. A new quantity – 'isospin' – was introduced to describe quantum symmetries in this space, analogous to spin, the label that emerged from quantum physics in ordinary space and time.

The nucleon is an isospin doublet, while the pion, with three electrical charge options (positive, negative and neutral), is classified as an isospin triplet.

The underlying mathematical ideas were further developed in the mid-50s by C.N. Yang and R. Mills (and independently by R. Shaw) who explored how the formalism of abstract isospaces depended also on space and time (gauge theory).

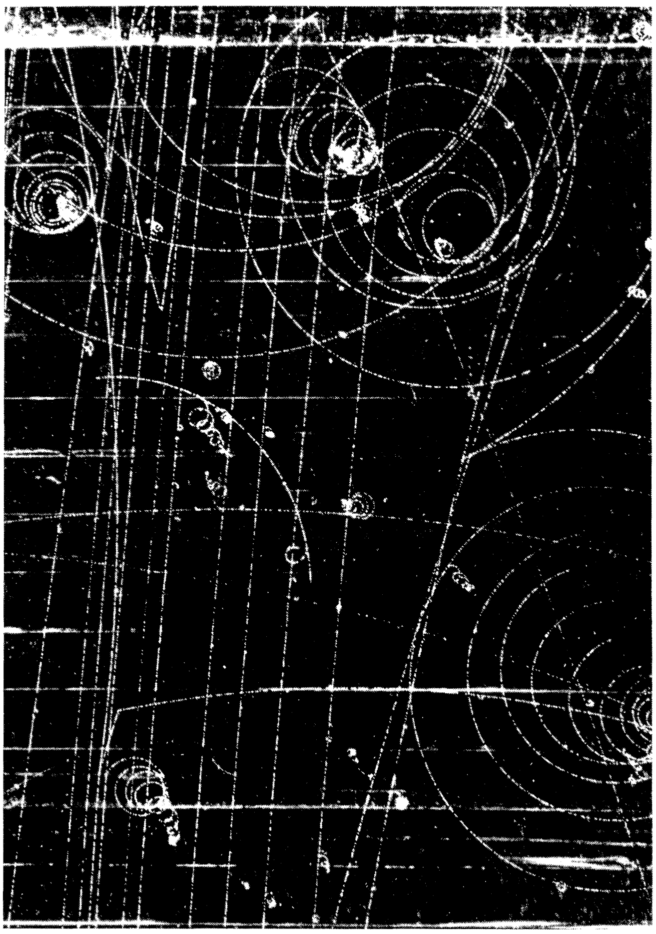
At around this time, it was becoming clear that the subnuclear world had many other denizens – particles created in high energy collisions but which did not normally live inside the nucleus. Why were there so many particles? To make some order out of the chaos, Murray Gell-Mann and Kazuhiko Nishijima proposed a new quantum number – 'strangeness'. Some of the particles with approximately equal masses appeared to fall into neat multiplets. These could be grouped in turn into larger families, hinting at some deeper symmetry hidden underneath.

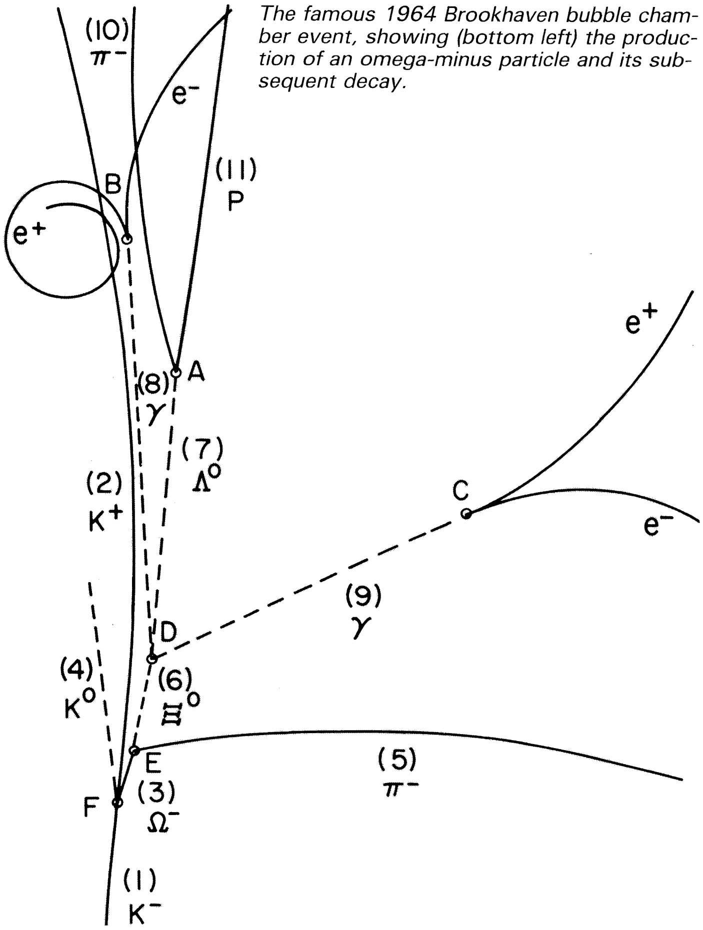
Many attempts were made. In the late 50s Shoichi Sakata toyed with the idea of explaining the rash of particles in terms of just three – the proton, the neutron and the strange lambda. No real physics followed, but the seeds of an idea had been sown.

In 1961 Murray Gell-Mann at Caltech and Yuval Ne'eman at London's Imperial College realized that many particles could be grouped into octets – 'the eightfold way' – characteristic of a special form of symmetry under three-dimensional rotations (SU3). The symmetry also had other multiplets but at the time these could not be filled up with particles.

The usefulness of the SU3 octet pattern had been noticed before in attempts to find write down the algebra of carrier particles transmitting the nuclear forces, but Gell-Mann and Ne'eman saw that the neat octets fitted other particles too.

(By this time Gell-Mann was well known in the field, having developed with Nishijima the idea of strangeness, and with Richard Feynman some important links in our understanding of the weak





The famous 1964 Brookhaven bubble chamber event, showing (bottom left) the production of an omega-minus particle and its subsequent decay.

nuclear force. Ne'eman, a prominent Israeli army officer, had come to London in a diplomatic role, and put his multifarious talents to additional use in Abdus Salam's school, where Salam, with J.C. Ward, was working on particle classification schemes.)

At an international conference at CERN in 1962, Bernard Gregory of France's Ecole Polytechnique and George Snow of Maryland summarized the status of the physics of the new strange particles. After Snow's talk, Murray Gell-Mann went to the blackboard and pointed out the appealing regularities inside a then hypothetical decuplet of heavier cousins of the nucleon.

The decuplet was in the form of a triangle drawn in a grid of isospin and strangeness quantum numbers. Nine of the grid points could be filled by known particles – a quartet at the base, with a triplet and a doublet above, but the apex of the triangle was empty. Gell-Mann predicted a new negatively-charged particle carrying three units of strangeness, and even gave it a name, the omega-minus. Extrapolating from the mass patterns in the triangle, he wrote down its mass, heavier than any particle ever seen before.

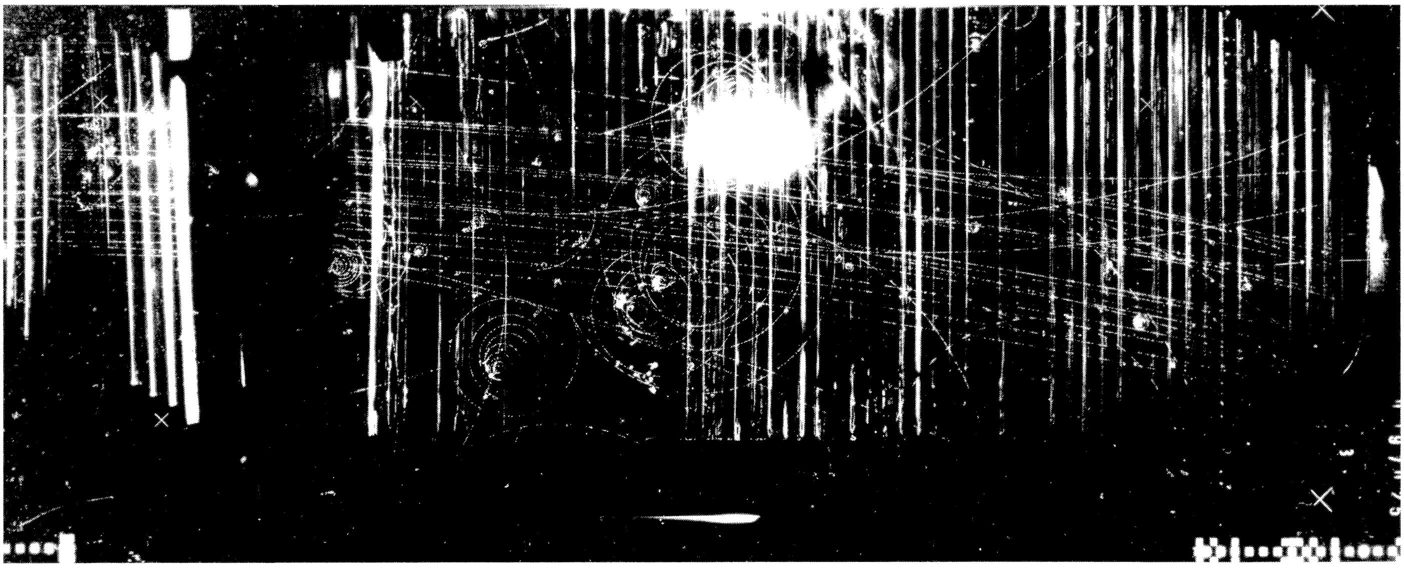
At Brookhaven, a new 80-inch bubble chamber was being readied at the Alternating Gradient Synchrotron (AGS). This was the highest energy accelerator in the world at the time and Leon Lederman, Jack Steinberger and Mel Schwartz had just used it to provide the world's first beam of neutrinos. However when it came to finding new particles, the physicists using Luis Alvarez' bubble chambers at Berkeley were still the acknowledged experts.

In December 1963, Brookhaven's new bubble chamber came into action, and a team of more than thirty physicists took up Gell-Mann's challenge. In January 1964, after looking at 50,000 photographs, they stumbled on a shot showing a pion carrying a lot of transverse momentum, with a strange particle produced some distance away from the primary collision. Looking closer, they spotted the spirals of not one, but two of the characteristic electron-positron pairs of a high energy gamma ray (photon). Moreover these two gammas pointed back to a common origin. By careful measurement and calculation, the team unravelled the complex series of decays, finally backtracking to a particle carrying minus three units of strangeness, and with a mass of 1686 MeV, almost right on top of Gell-Mann's blackboard prediction!

The commissioning of the bubble chamber had not been plain sailing. As it had only one window, special reflectors had to be used so that the tracks could be both illuminated and photographed from the same side. Early in the run, some of these reflective 'coat hangers' had come adrift and fallen on the window. As well as obscuring some of the field of view, these could have damaged the window, and with 1,000 explosive litres of liquid hydrogen inside, the future of the experiment hung in the balance. After gingerly testing the chamber with a few expansions, team leader Ralph Shutt decided to continue.

The omega-minus showed that SU3 symmetry was behind the neat particle families. But why SU3? What parentage was behind such large families of eight and ten? Even before the omega-minus

The complete Brookhaven 1964 bubble chamber picture. About a quarter of the chamber was invisible due to an illumination problem.



appeared, Gell-Mann, and independently George Zweig, working at CERN, showed how the eights and tens followed naturally from triplets of more basic entities – termed 'quarks' by Gell-Mann.

In the same way that the Periodic Table of elements paved the way for our present picture of the atom, so Gell-Mann and Ne'eman's octets had hinted that subnuclear particles had some internal mechanism, at least on paper.

(As often happens in physics, ideas born in one context can lead to useful spinoff in another. The gauge theory groundwork developed in parallel with isospin and the eightfold way went on to pay handsome dividends in the formulation of the 'electroweak' unification of the 1960s, showing how the weak nuclear force and electromagnetism have a common origin.)

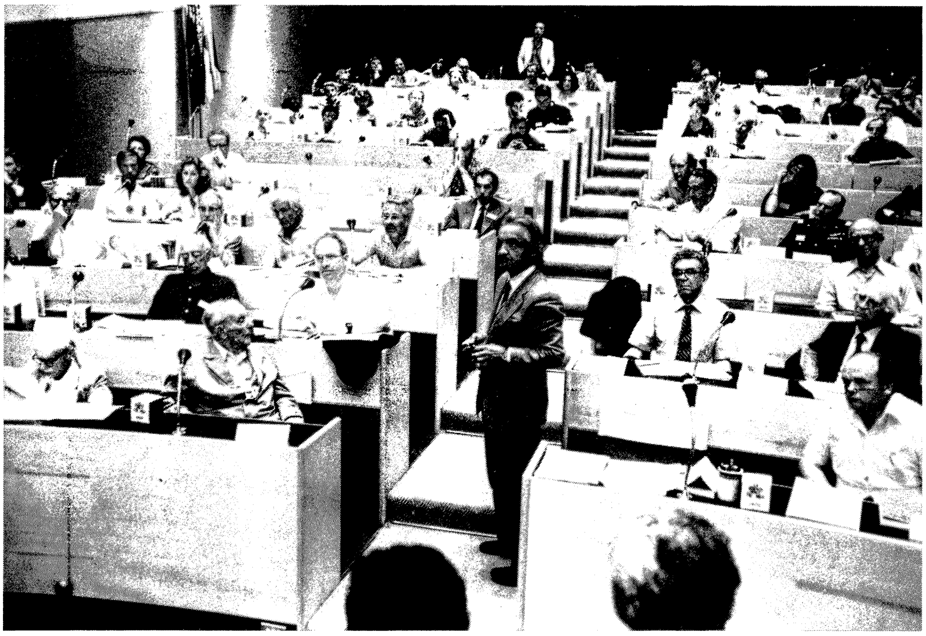
It took another ten years of painstaking work to find the tiny grains of matter hidden deep inside the nucleon and show that they behaved like quarks. However they steadfastly refuse to come out into the open, staying locked inside their nucleon prisons. To see free quarks, physicists probably need to recreate the conditions of the Big Bang which started it all off.

World science

The World Laboratory and the Third World Academy of Sciences are examples of ambitious new global ventures using the established broad base of science and technology in the industrialized nations as a springboard for important projects in and among developing countries.

Established in 1986, the World Laboratory aims to promote truly global, open cooperation in technical and scientific research, with free circulation of information and researchers. The bottom line is an impressive list of ongoing multidisciplinary projects, with a wide geographical spread.

Under its president Antonino Zichichi, and with its main coordination centre in Geneva and with regional coordination centres in Moscow and Beijing, World Lab's ongoing programme is grouped into four main areas. The Archimedes programme covers geological (seismology, volcanology, ...) and environmental (climate, pollution,.....) monitoring and modelling, together with computer projects in the education and health areas. The Eloisatron basic physics programme includes the Eloisatron project for a multithousand GeV proton collider, ongoing plans at CERN's LEP electron-positron collider, and the establishment in China of Advanced Centres for Science and Technology and for



At the second Seminar on Nuclear War held at the Centre for Scientific Culture at Erice, Sicily, in 1982, Paul Dirac and Piotr Kapitza (front row, left) and Antonino Zichichi (standing) drafted the 'Erice statement', a declaration of awareness and intent for scientists to influence ongoing nuclear policy and safeguard the future of the planet. Recipients of the new Erice Prize will be nominated by the signatories of this statement.

Erice Statement

- It is *unprecedented* in human history that mankind has accumulated such a military power to destroy, at once, all centres of civilization in the world and to affect some vital properties of the planet.

The *danger* of a nuclear holocaust is not the unavoidable consequence of the great development of pure science.

In fact, *Science* is the study of the fundamental laws of Nature.

Technology is the study of how the power of mankind can be increased.

Technology can be for peace and for war. The choice between peace and war is not a scientific choice. It is a cultural one: the *culture of love* produces peaceful technology. The *culture of hatred* produces instruments of war. Love and hatred have existed forever. In the bronze and iron ages, notoriously pre-scientific, mankind invented and built tools for peace and instruments of war. In the so called « modern era » it is imperative that *culture of love* wins.

An enormous number of scientists share their time between pure science research and military applications. This is a fundamental source for the arms race.

It is necessary that a *new trend* develops, inside the scientific community and on an international basis.

It is of vital importance to identify the basic factors needed to start an effective process to protect human life and culture from a third and unprecedented catastrophic war. To accomplish this it is necessary to change the peace movement from a unilateral action to a truly international one involving proposals based on mutual and true understanding.

- **Here are our proposals:**

1. Scientists who wish to devote all of their time, fully, to study theoretically or experimentally the basic laws of nature, should in no case suffer for this free choice, to do only pure science.
2. All Governments should make every effort to reduce or eliminate restrictions on the free flow of information, ideas and people. Such restrictions add to suspicion and animosity in the world.
3. All Governments should make every effort to reduce secrecy in the technology of defense. The practice of secrecy generates hatred and distrust. To start a ban for military secrecy will create greater stability than offered by deterrence alone.
4. All Governments should continue their action to prevent the acquisition of nuclear weapons by additional nations or non-national groups.
5. All Governments should make every effort to reduce their nuclear weapons stockpiles.
6. All Governments should make every effort to reduce the causes of insecurity of non-nuclear powers.
7. All Governments should make every effort to ban all types of nuclear tests in war technology.

- **Conclusion**

Those scientists — in the East and in the West — who agree with this « Erice Statement », engage morally themselves to do everything possible in order to make the *new trend*, outlined in the present document, to become effective all the world over and as soon as possible.

Erice prize

The regional government of Sicily has decided to finance an annual international award recognizing eminent work in scientific culture. Worth a thousand million lire (more than a million Swiss francs), the award will be known as the Erice Prize, underlining the important role played by the Centre for Scientific Culture at Erice, near Trapani on the north-west corner of the island, established by Antonino Zichichi 25 years ago.

Named after the famous Italian theoretical physicist Ettore Majorana, this centre is now home to over seventy regular schools in all branches of science, including the Seminar on Nuclear War, where concerned scientists from all over the world gather to discuss the catastrophic implications of the global nuclear arsenal. At the second of these nuclear war seminars in 1982, Paul Dirac and Piotr Kapitza (both since deceased), together with Zichichi drafted the 'Erice statement', a declaration of awareness and intent for scientists to influence ongoing nuclear policy and safeguard the future of the planet.

This statement, which now has well over 10,000 signatories, also led to the establishment of the World Laboratory (see accompanying article).

The new prize will be attributed from nominations proposed by the Erice Statement signatories.

The recently completed China Centre of Advanced Science and Technology (World Laboratory) in Beijing. Second from the left is Ambassador Qian, who represents China at the United Nations in Geneva.

Astrophysics, together with neutrino and cosmic ray studies at the new Italian Gran Sasso underground Laboratory and elsewhere, detector research and development, and basic theory. Under the heading 'Improvement of Modern Life' comes a series of projects aiming for advances in food technology (production, processing and storage), medicine (15 projects), and progress in environmental and ecological sectors; three projects deal with advanced technologies such as coal slurrying and new clean energy sources. The final development area is the field of controlled nuclear fusion.

Each of these four areas is grouped into well defined projects, each with its own clearly defined objectives and one or more directors.

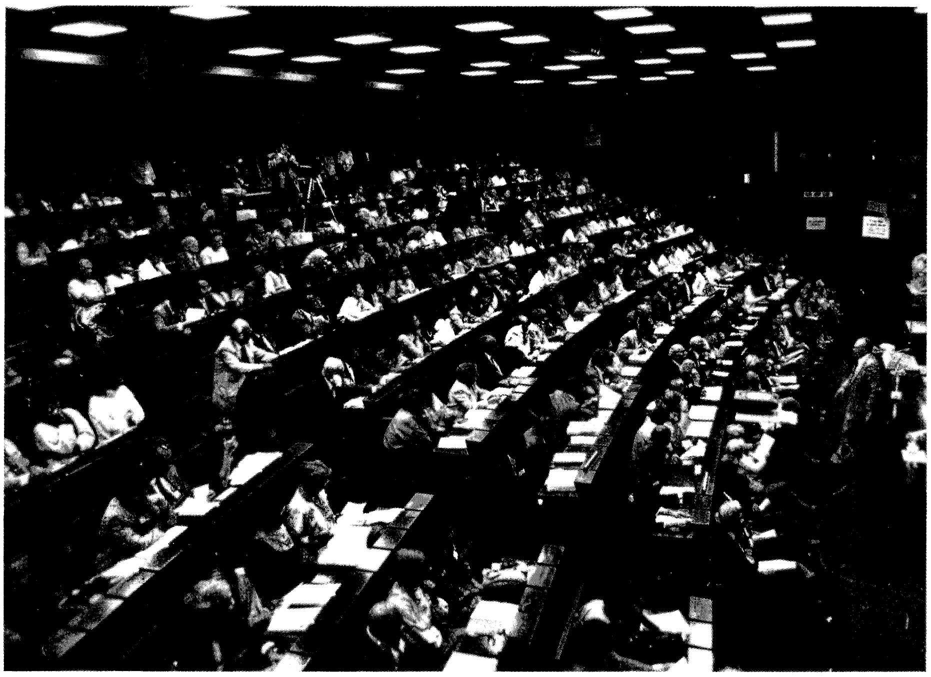
One major success is the establishment of the China Centre for Advanced Science and Technology under T.D. Lee, who has been very influential in getting this project off the ground. The aim is to provide qualified Chinese students with hands-on experience in new technologies, bridging the gap between university education and the modern research environment. The first World Lab building has recently been completed in Beijing.

In addition to field work, World Lab progress is regularly reviewed at international meetings and seminars.

The aim of the Third World Network of Scientific Organizations (TWNSO), established last year with its headquarters in Trieste, Italy, is to promote the role of science and technology in developing countries. TWNSO, under the presidency of Abdus Salam, is an offshoot of the Third World Academy of Sciences, which has pushed the cause of international scientific collaboration since its establishment in 1983.

With support from industrialized nations pledged and with more prospects in the pipeline, TWNSO's membership includes 80 organizations drawn from 60 countries. Aims are to promote the development and application of science and technology both within the Third World and through Third World participation in international schemes. Areas such as space science, controlled thermonuclear fusion, biotechnology and high technology in general are seen as having a potentially strong impact on economic and social development in Third World countries. As well as welcoming with enthusiasm the TWNSO cause, ministers attending the inaugural meeting in Trieste also pledged to produce results in their home countries.

In addition to a strongly regional structure, with Asian, Arab, African and Latin vice-presidents, TWNSO has three project-oriented standing committees dealing with global projects, hazards and programmes.



Cesar Lattes of the Centro Brasiliero de Pesquisas Fisicas, Rio de Janeiro, addresses a meeting of the Third World Academy of Sciences in Trieste.

Around the Laboratories

WORKSHOP
Crystalline beams

Following pioneer work by specialists at the Soviet Novosibirsk Laboratory some ten years ago, interest developed in the possibility of 'freezing' ion beams in storage rings by pushing cooling (to smooth out beam behaviour) to its limits, the final goal being to lock the ions into a neat crystal pattern.

After advances by groups working on laser cooled ions in traps, and with several cooling rings now in operation, a workshop on crystalline ion beams was organized recently by the GSI (Darmstadt) Laboratory and held at Wertheim in Germany.

Participants at the recent workshop on crystalline beams organized by the GSI (Darmstadt) Laboratory and held at Wertheim, West Germany.

Some remarkable progress was reported on the understanding of the structure and dynamical behaviour of crystalline beams by molecular dynamics (J.P.Schiffer and R.W.Hasse) and analytical calculations (D.Habs). This work finds no sharp ion energy where ordering should start, the finite width of the beam playing a special role.

Important effects to be taken into account are 'shear' due to the ring radius (particles on the outside tend to be slowed down) and the efficient control of space charge by the focusing force. F.Mills advocated that a ring using modified betatron operation could be better suited to the task than one using alternating gradient focusing.

In the meantime, advances have been made using ion traps with laser cooling. Pioneer studies with Paul and Penning traps (H.Walther, R.Bluemel and J.J.Bollinger, W.M.Itano) have succeeded in making crystals containing a up to a hundred ions (Paul trap) or up to 2000 ions in cylindrical layers (Penning trap – see also following article).

Encouraging from the Paul trap studies is the apparent absence of ordered state heating by the alternating radiofrequency potential. However in a disordered 'cloud' system a Munich group has found strong heating due to chaotic motion.

In the field of cooling techniques, O.Poulsen pointed out the advantage of lasers over electrons in attaining temperatures of a fraction of a degree millikelvin. By coupling longitudinal and transverse optical modes, even three-dimensional cooling is possible. Both methods promise high longitudinal cooling rates, and the challenge is to accelerate transverse cooling and make it equally fast. P.E.Toschek looked at the possibilities of using nonlinear light forces to penetrate the microkelvin degree region.

Recent achievements of cooling rings were surveyed by R.E.Pollock, H.Poth and E.Jaeschke, while D. Moehl of CERN looked at density limitations achieved in practice. Conditions are still five to six orders of magnitude away from spatial ordering in three dimensions.

Unfortunately nobody from Novosibirsk was at the meeting to comment on Schottky signal measurements at the NAP ring which hint at longitudinal ordering. Earlier results had suggested that cooling had succeeded in destroying virtually all momentum spread in a proton beam, so that the stored particles look like a string of beads (with a separation of a few microns).

Although immediate prospects are dim, insights can still come from simulation studies of storage ring lattices with discrete quadrupoles and dipoles (I.Hofmann). These calculations show that rings with a low number of superperiods are handicapped (due to coherent resonances), and that a cooling device must follow each dipole, unless a shear-free ring can be designed. However a longitudinal chain of ions looks to be possible

with existing lattices.

Another problem is how to recognize any onset of crystal beam behaviour once it happens. One promising method is coherent Rayleigh scattering (R.Neumann). Coherent Thomson scattering might work in principle (though technically very difficult), if the cooling electron beam carries a signature of the ion ordering (G.Dodel). The need to continue theoretical work on correlations was also stressed (C.Toepffer). 'Conventional' diagnostics via the Schottky noise spectrum are problematic due to signal distortion and suppression for correlated particles, and it is questionable whether any ordering can be detected this way (S.Baird). New ideas using narrow-band pickups for 1000-3000 GHz working as confocal optical resonators (F.Caspers) placed many wavelengths away from the beam could be useful.

In summary, the meeting showed that ultra high frequency diagnostics and extensive cooling experiments at existing storage rings need to be pushed before longitudinal ordering can be demonstrated. New rings with high symmetry, little shear and lots of cooling are needed to grow crystalline beams and open up this area of accelerator and condensed matter physics.

From Ingo Hofmann

CERN
Low energy frontier

While CERN and other big particle physics Laboratories look toward higher energies to probe deeper inside the structure of matter (the TeV – 1000 GeV, or a million million electronvolts is now a commonly used unit), three teams working at CERN's LEAR low energy antiproton ring have another objective – to look at the behaviour of very slow antiprotons, comparing the results with protons to check the basic principles of the laws of physics.

LEAR takes GeV-scale antiprotons down to energies of just a few MeV. A Harvard/Mainz/Washington (PS 196) team uses the electric and magnetic fields of a Penning trap as supplementary particle brakes. Also playing a vital role in this 'cooling' process are electrons, slowed down to a fraction of an electronvolt in the trap. These act in turn on the antiprotons, cooling many of them to below one electronvolt.

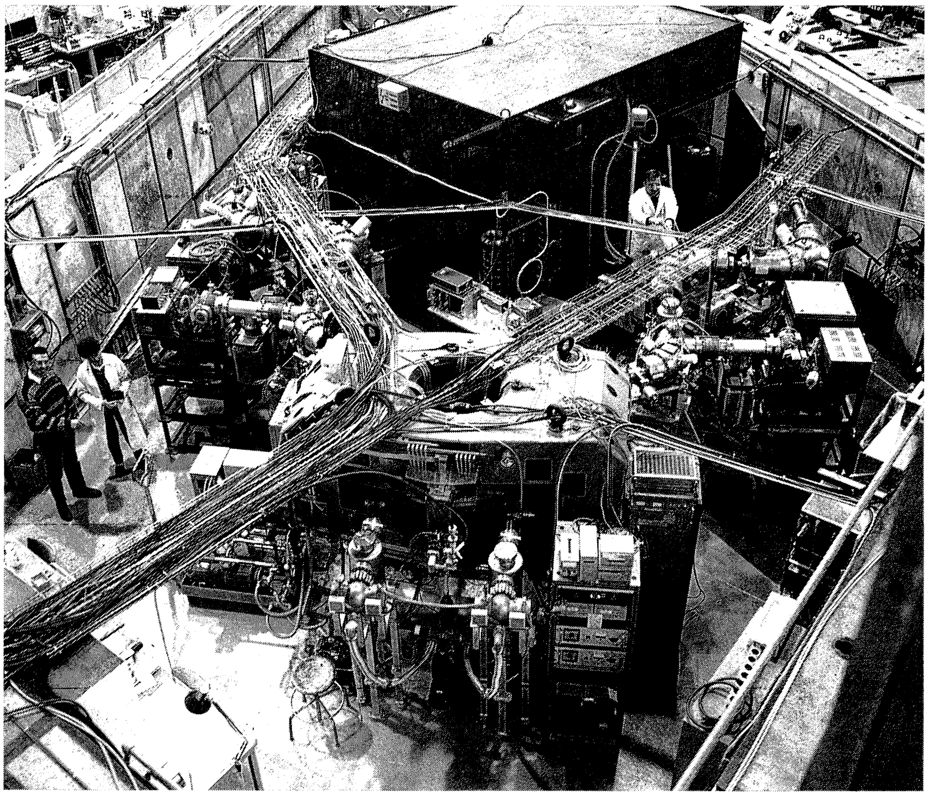
At high energies, CERN's antiprotons are regularly held for days at a time, however the risks of annihilation with atoms of residual gas increase quickly at lower energies. Nevertheless the PS 196 team manages to trap antiprotons for up to several days – much shorter than the ten-month world record for a single electron, but a great advance on the experiment's previous antiproton performance.

Although these energies are miniscule by high energy standards, they are still equivalent to about the temperature of the sun's surface. Initial measurements hope to compare the proton and antiproton masses to one part in a million, improving on the best result so far, eventually going down lower.

Elsewhere (see previous article), other experiments using these techniques have cooled protons down to a fraction of an meV (millielectron volt), equivalent to cryogenic temperatures, while laser

Foreground, the spectrometer of the CERN/Orsay experiment at CERN's LEAR low energy antiproton ring preparing to compare the masses of the proton and the antiproton.

(Photo CERN 285.1.89).



cooling methods have attained particle temperatures of just a few millidegrees above absolute zero.

Also at LEAR, a CERN/Orsay team is preparing to compare proton and antiproton masses down to one part per thousand million using a radiofrequency mass spectrometer and benefiting from lower energy LEAR antiprotons.

A CERN/Italy/US team will look at the effect of gravity on an antiproton beam cooled to thermal levels by a series of traps, to see whether antiprotons 'fall' upwards! This study opens up a new field of study. Gravitation is universally attractive – no example has yet been found of a gravitational repulsion – however the interaction of gravity with antimatter is unexplored of territory.

Stanford Linear Accelerator Centre (SLAC) Director Burt Richter (hard hat No. 60) explains the new SLC Stanford Linear Collider to Texas Senator Lloyd Bentsen (hard hat No. 1, who was last year's Democrat Vice Presidential candidate) and former astronaut Sally Ride.

(Photo Edward W. Souza, Stanford News and Publications Service)

STANFORD Record PEP collision rates

With the new Stanford Linear Collider SLC temporarily on hold (December 1988, page 12) for the past few months, physics at the Stanford Linear Accelerator Center (SLAC) reverted to the PEP and SPEAR electron-positron storage rings.

With only one major experiment (the TPC time projection chamber) running at PEP, the six (three electron, three positron) bunches were colliding at one point only, and the quadrupoles used to squeeze the colliding beams were pushed closer together.

In early December, the peak luminosity (a measure of the particle collision rate) attained 6×10^{31} cm^{-2} s^{-1}, a PEP record. For electrons and positrons, only the CESR ring at Cornell has exceeded these levels. With reliable beams, PEP's accumulated daily collision score reached new heights.

After tests and further installation work, the SLC resumed operation in February, with the goal of supplying the Mark II detector with the first SLC Z particles – the heavy (93 GeV) carriers of the electrically neutral component of the weak nuclear force. Work is also progressing on switching techniques to enable SLC and the storage rings to run in parallel.

DUBNA/SERPUKHOV Ultrarelativistic atoms

The ultrarelativistic region where physics has to be seen in the framework of special relativity is commonplace in particle physics where beams of charged particles are regularly accelerated to velocities approaching that of light.

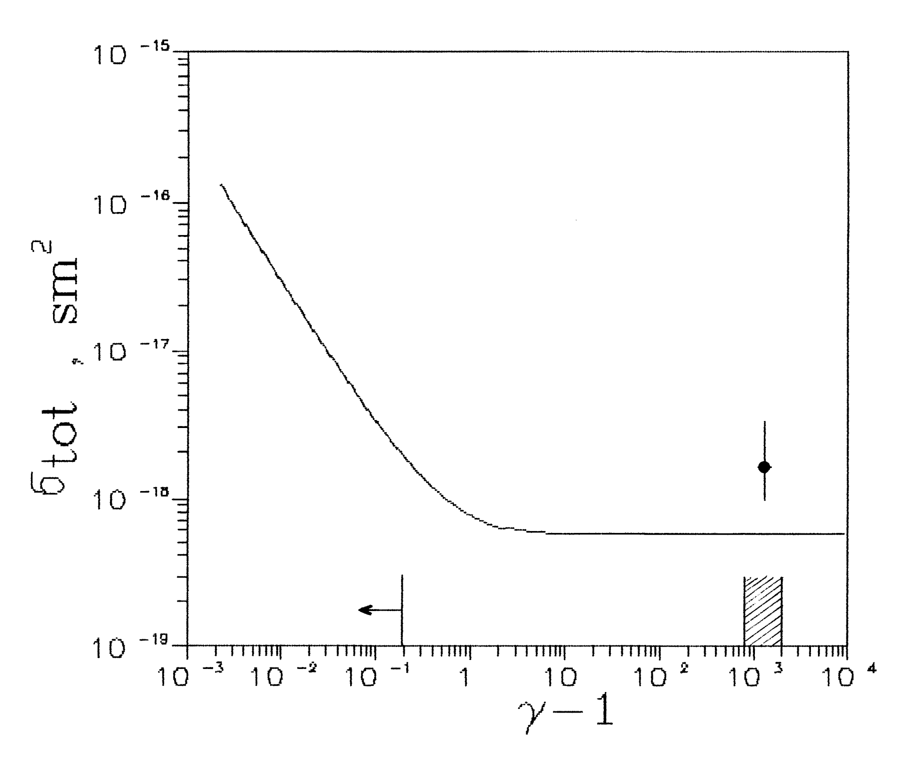
In other areas of physics, such as the interactions of neutral atoms

(with their full complement of orbital electrons), these conditions can be more difficult to explore.

The importance of relativity is measured by the mass increase (gamma) factor, which approaches infinity as the velocity nears that of light. Theoretical ideas say that the collision rate between atoms would reach a plateau starting from gamma values of about 10, but even this modest level has been difficult to reach with beams of neutral atoms.

One of the simplest atoms is positronium – an artificial concoction of an electron and a positron circling round each other. In an experiment at the 70 GeV proton machine at the Soviet Institute for High Energy Physics at Serpukhov, near Moscow, one neutral pion decay per billion yielded a fast moving positronium atom, with a gamma factor between 800 and 2000.

The interaction rate of these synthetic atoms was measured by passing them through a carbon foil a fraction of a micron thick. Taking all relativistic effects into account (under these conditions any intra-atomic positronium clock runs much slower than the actual flight time through the foil), the reaction cross-section of positronium atoms with carbon is found to be 16(+16-6).10^{-19} cm^2/atom. This does not contradict the theoretically expected value, but also does not rule out ultrarelativistic ionization or excitations which could considerably increase the reaction rate.



Variation of total reaction rate (cross-section) with kinetic energy (expressed in terms of the relativistic gamma factor) for the interaction of positronium atoms with carbon, showing the theoretical expectation (solid line) and the data point from a Dubna/Serpukhov experiment investigating an ultrarelativistic region (shaded). Previous experiments using hydrogen atoms were confined to much lower velocities (arrow).

FERMILAB 20 years on

Its twentieth anniversary celebrations last December gave Fermilab an opportunity to look back to its beginnings, look over its accomplishments, and look ahead to the next two decades.

In 1963, the Ramsey Panel had recommended the United States Atomic Energy Commission (AEC) to build a 200 GeV accelerator. These were early days for particle physics (the discovery of the muon neutrino at Brookhaven by Leon Lederman, Jack Steinberger, and Melvin Schwartz was then only one year old) but physicists were becoming aware of the new horizons that higher energies could bring, and US researchers applauded the Ramsey Panel's idea.

Four years later, the National Accelerator Laboratory/AEC Design Study Contract was signed, appointing Robert Wilson as Director of the new Laboratory. With the 1967 selection of the Batavia site near Chicago, and a construction authorization of $250 million, ground was broken the following year.

Under the able leadership of Robert Wilson, it took just four years to complete the four-mile Main Ring and ramp it to its 200 GeV design energy. With an eye to the future, ambitious R&D work also began on magnets for a possible new superconducting accelerator. After returning $6.5 million dollars to the United States Government, the Laboratory was dedicated as the Fermi National Accelerator Laboratory, routinely providing 400 GeV beams.

A new laboratory energy scale

Twenty years ago, a pristine shovel for groundbreaking at the future Fermi National Accelerator Laboratory was wielded by (left) Laboratory Director Robert Wilson, and by US Atomic Energy Commission Chairman Glenn Seaborg.

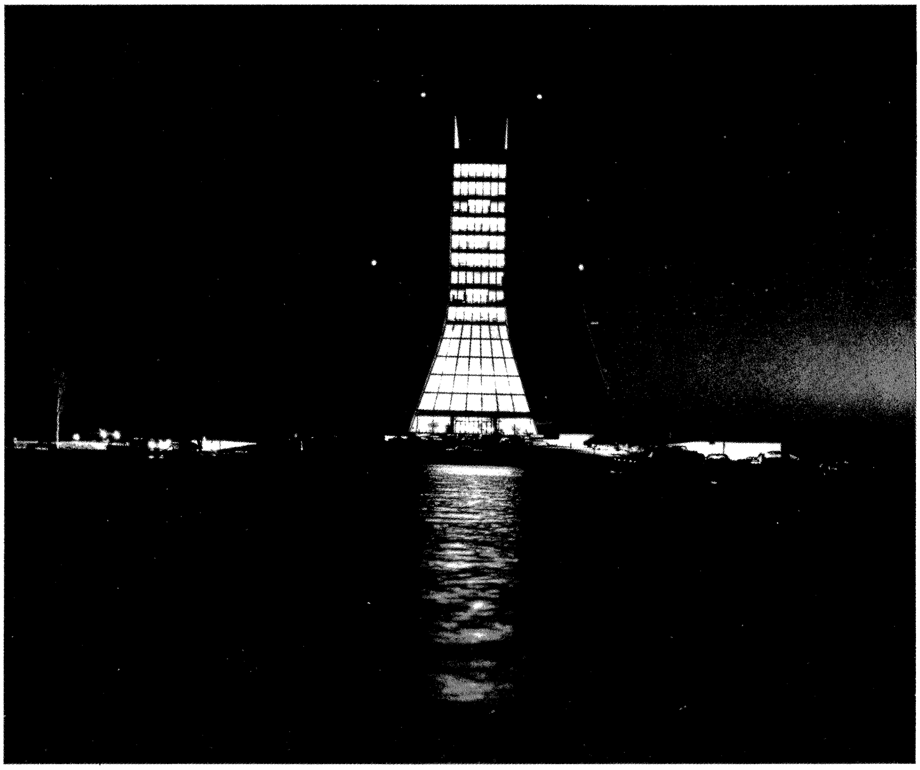
was born when the 1000 GeV 'Tevatron' was formally proposed by Wilson in 1975, but in the environmentalist climate of the time, the name 'Energy Saver' was adopted for the 1977 proposal to the Department of Energy (DOE). That same year, Leon Lederman was named Director following Wilson's dramatic resignation, and the discovery of the upsilon particle by Lederman's Columbia/Fermilab/Stony Brook team showed that quarks come in at least five varieties.

Construction of the Energy Saver began in 1979, and work was well advanced when preparations to exploit the higher energy beams were launched with the Tevatron I scheme in 1981 and Tevatron II the following year.

The new Energy Saver broke the Main Ring's 500 GeV record in 1983 when protons were accelerated to 512 GeV. In the same year, construction of the Antiproton Source began as part of the Tevatron I plan to provide the US with a proton-antiproton collider to rival CERN's, which had begun operations in 1981.

1984 brought Fermilab and the world into a new higher energy domain with protons being accelerated to 800 GeV. Less than a year later, the new Antiproton Source provided antiparticles for the Tevatron to supply 1.6 TeV collisions for the new CDF detector. A comprehensive programme of fixed-target physics with the upgraded Tevatron II facilities and an 800 GeV proton beam rounded out the physics programme.

A prolific amount of fixed target data (May 1988, page 16) and re-



The Wilson Hall high-rise – centrepiece of Fermilab's striking architecture.

cord antiproton production rates (December 1988, page 9) were early dividends from the Tevatron investment.

But Fermilab is more than a world centre for high energy physics. Thanks to the vision of founding director Robert Wilson, its idyllic site and imaginative architecture continually thrill and inspire visitors, whether scientists or the curious public. New buildings like the Muon Laboratory and the Feynman Computing Center have continued the tradition. The unfenced 6,800 acre site is a paradise of natural beauty and a haven of environmental interest, the scene of ambitious projects to restore the Mid-West prairie to its former state, and home to a large herd of buffalo.

The vision behind Fermilab was captured in Director Lederman's testimony before a Congressional Science and Technology Sub-Committee on Energy Development in 1984. 'High energy physics pays back because it enhances our culture, contributes to human dignity, broadens our view of the evolution of the universe and our own position in it. Some will tell you that society profits because we set standards for applied science, we recruit young people into science by the seduction of neutrinos and quarks and black holes. All this is true, but what is also true is that the predecessors of today's high energy physicists changed the world, and there is no reason to believe that what we do now, abstract and remote as it may seem, will not have major effects on the lives of our children's children.'

Upgrading

With its Tevatron collider and fixed target programmes well into their stride, Fermilab could raise its sights and aim for higher collision rates and more intense fixed target beams.

Initial work is already underway to revamp the linac injector (September 1988, page 16) to provide more protons. To further boost the collision rate, measures include improvements to the antiproton source and beam cooling, stronger quadrupoles to squeeze the colliding beams closer together, more stored bunches, and electrostatic beam separation. In addition, improved Tevatron cryogenics could push operating levels higher and make the machine live up to its name.

To push collider performance still higher calls for more ambitious schemes. A 20 GeV proton superbooster injecting into the existing main ring, and a new antiproton 'depository' have been looked at in some detail. Even higher energies could be reached by replacing both the existing main ring and the superconducting Tevatron with higher field superconducting magnets, similar to those piling up for the HERA electron-proton collider at the German DESY Laboratory in Hamburg.

The big advantage of a proton-antiproton (or any particle-antiparticle) collider is that the contrarotating beams can be held in the same ring. However proton antimatter is not easy to handle, and in any push for higher collision rates there comes a stage when it is more cost effective to aim instead for a two ring solution providing proton-proton collisions. The original main ring could be replaced by a smaller 150 GeV ring nearby, leaving space above the Tevatron for a second superconducting ring.

Apart from particle physics, the Fermilab site boasts other attractions.

MEETING
Lattice 88

The forty-year dream of understanding the properties of the strongly interacting particles from first principles is now approaching reality. Quantum chromodynamics (QCD – the field theory of the quark and gluon constituents of strongly interacting particles) was initially handicapped by the severe limitations of the conventional (perturbation) approach in this picture, but Ken Wilson's inventions of lattice gauge theory and renormalization group methods opened new doors, making calculations of masses and other particle properties possible.

Lattice gauge theory became a major industry around 1980, when Monte Carlo methods were introduced, and the first prototype calculations yielded qualitatively reasonable results. The promising developments over the past year were highlighted at the 1988 Symposium on Lattice Field Theory – Lattice 88 – held at Fermilab.

Peter Hasenfratz of Bern summarized recent lattice work on the mass limits of the so-far unseen Higgs particle (responsible for mass in the standard electroweak model). It has long been known that simple Higgs theory breaks down if the Higgs is heavier than about 1 TeV. Recent lattice work has even brought the limit down to about 600 – 700 GeV and made it more general. According to these calculations, no Higgs below this level means some new physics beyond the standard model.

Julius Kuti of San Diego outlined further lattice applications in the electroweak sector, including bounds on the mass of the missing sixth ('top') quark. Ideas of a new strongly coupled phase of quantum electrodynamics were aired by John Kogut of Illinois.

The calculation of particle masses is one of the main lattice theory goals, the contribution of itinerant 'sea' quarks being the most difficult to include. A 'quenched' approximation with valence quarks only, ignoring sea effects, is not expected to give the right answer, but it is still important to see what happens before embarking on the full calculation.

Progress with the quenched approximation was covered by Enzo Marinari of Rome. High statistics calculations by a special-purpose computer using improved calculational methods say the proton is about 1.4 times heavier than the rho meson, compared to the actual value of 1.22.

New improved algorithms were reviewed by Don Weingarten of IBM, Yorktown Heights, and Stephen Adler of the Institute for Advanced Study, Princeton. Progress has been most spectacular in gauging the effects of sea quarks, with new Monte Carlo algorithms being about 10,000 times faster than their predecessors.

Hardware too has seen comparable improvements. The special purpose machines under construction at various institutions around the world are roughly 10,000 times more powerful than the VAXes used for the original calculations seven years ago. Norman Christ of Columbia described machines existing or under construction at Columbia, IBM, Rome, Fermilab, Caltech, and Tsukuba, and in industry. Some of these borrow ideas from the approach pioneered by the Columbia group and now in widespread use for lattice calculations – fast floating point chips on a massive parallel array of nodes.

Peter Hasenfratz – mass limits for the long-awaited but still unseen Higgs particle.

The better understanding of glueballs (particles containing gluons rather than quarks) was pointed out by Andreas Kronfeld of Fermilab. Two years ago, confusion reigned in this area and there was no unanimity even on basic questions. Improved methods of calculating glueball masses have helped to clarify the situation, the consensus being that the spin 2, positive parity glueball is about 1.5 times heavier than its spin zero counterpart.

Pierre van Baal of CERN summarized recent analytic work on the spectrum of a pure glue theory. In addition to being very beautiful, this work has been accurately verified by Monte Carlo methods, so increasing confidence in the numerical approach.

The physics of QCD at high temperatures and densities – interesting for heavy ion physics, astrophysics, and cosmology – has provided the first accurate, reliable simulation result – the transition temperature at which quarks are unlocked from their conventional

A.A. Migdal – putting strings on the lattice.

nucleon imprisonment. Masataka Fukagita of Kyoto concluded that this calculation is still in good shape. The phase transition seems to be much weaker than originally thought, and there is some controversy as to its type (weak first order or second order). Preliminary calculations in full QCD hint that the transition temperature may be around 150 MeV (about 10^{12} degrees!). Frithjof Karsch of CERN claimed that the simple picture of the hot QCD plasma as an ideal gas of quarks and gluons interacting through small perturbations looks good so far, though much room remains for nonperturbative effects.

Input from lattice calculations provides a useful complement to new data, giving theorists additional room to manoeuvre. These difficult calculations were described by Claude Bernard of Santa Barbara. The kinematic behaviour of quark content (structure functions) and of particle form factors was one of the earliest successes of perturbative QCD, but prediction of the quantities themselves requires lattice calculations, reviewed by Guido Martinelli of CERN. Chris Sachrajda of Southampton described the painstaking analytic work behind the lattice treatment of the standard model.

The powerful simulation methods of lattice theory are useful in other areas of physics. Jorge Hirsch of San Diego ('What should a lattice gauge theorist be doing in his/her spare time?') reviewed current theoretical ideas on high temperature superconductivity. Sasha Migdal of the Cybernetics Council in Moscow described progress towards a lattice formulation of bosonic string theory, complementing analytic work based on Polyakov's conformal field theory approach. The agreement between analytic and numerical calculations is as important in this field as for QCD.

The past year has been the most active ever for lattice gauge theory, but the vast increase in algorithmic and hardware computing power of the past seven years is not the end of the line. Approximation schemes show promising results, and full calculations will not be far behind. With unrestricted predictive power, a full exploration of the wide open physics territory both in and beyond the standard model will then begin in earnest.

From Paul Mackenzie

DESY
Theory with flavour

Last year, the annual Theory Workshop at the German DESY Laboratory in Hamburg had 'Flavour Physics' as its main theme. The sighting by the UA1 experiment at CERN's proton-antiproton collider and by the ARGUS team at DESY of 'oscillations' in the electrically neutral B mesons carrying the beauty quantum number, and the measurement at CERN of a new parameter in the delicate violation of combined particle-antiparticle and left-right symmetry (CP) in the decays of neutral kaons (July/August 1988, page 7) have made this subject particularly topical.

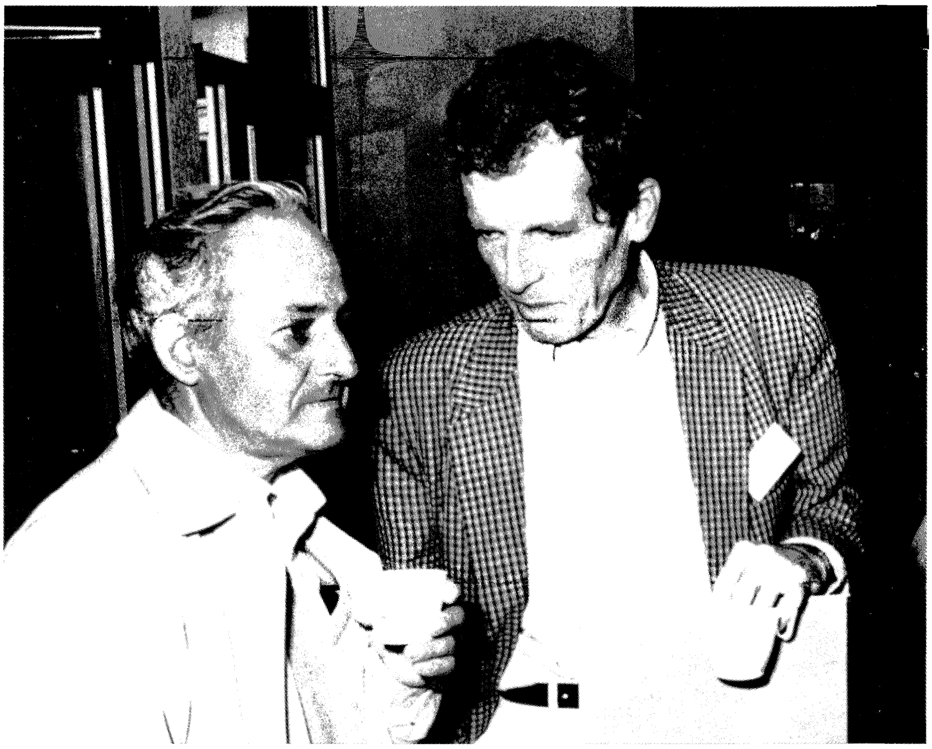
Setting the tone for the meeting, W. Schmidt-Parzefall (DESY) described the current evidence for neutral B mixing, looking also at the possibilities for a B meson 'factory' at DESY to search for additional signs of CP violation.

In the production, spectroscopy and decay of charm particles (R.J. Morrison – Santa Barbara), significant advances have been made by new high-statistics experiments. B. Stech (Heidelberg) showed how B and charm decay theory was in line with the data. Less conventionally, his explanation of isospin selection rules for weak kaon and hyperon decays based on 'diquarks' provoked some lively discussion.

Mass limits for the so-far unseen sixth ('top') and other heavy quarks (J. Kuehn, MPI Munich) turned the discussion towards an outlook for the future. Kuehn assessed the chances of finding the top up to 80 GeV at the CERN proton-antiproton collider and up to 100 GeV at the Fermilab Tevatron, going on to look at the implications of top physics for the new electron-positron colliders – LEP at CERN and SLC at Stanford.

A. Ali (DESY) examined the physics of heavy quarks at the HERA electron-proton collider being built at DESY and underlined the potential of HERA in the search for top and for a detailed study of B meson oscillations. Open questions

At the DESY Theory Workshop – top, R. Rueckl (left) with R. Peccei; below, E. Lohrmann (left) with C.A. Heusch.



in B physics were also taken up by K.R. Schubert (Karlsruhe), concluding that B factories would be very useful, and in the case of CP violating B decays even necessary, using as an illustration the project proposed at the Swiss Paul Scherrer Institute (PSI – July/August 1987, page 21).

M.P. Schmidt (Yale) imagined the detectors needed to exploit the enormous production rate of B particles in hadron colliders, in particular at the proposed US SSC Superconducting Supercollider.

Looking to the other extreme of the particle mass scale, the meeting turned to the neutrinos. A survey of the numerous delicate experimental studies, particularly in the mass and oscillation sectors by K. Winter (CERN), was followed by the theory viewpoint from R. Mohapatra (Maryland), illustrating the possible connection between neutrino mass and very high energy physics with the help of several models.

In a series of talks on CP violation, quark masses and flavour mixing, M. Holder (Siegen) covered new CP violation parameter measurements of neutral kaons at CERN and Fermilab and looked at future experiments, such as a study at CERN's LEAR low energy antiproton ring. I. Bigi (Notre Dame) turned to CP violation in both B and charm meson decays, estimating the chances of seeing such effects. Finally C. Jarlskog (Stockholm) painted scenarios for CP violation in the electroweak picture using three or four quark families.

Subsequent talks concentrated on calculating the input for a theoretical description of weak decays, mass mixing and CP violation. G. Martinelli (CERN) summarized the status of lattice calculations, while A. J. Buras (Munich) advo-

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University of Cambridge
Department of Physics

University Assistant Lecturer in
Experimental Particle Physics

Applications are invited for the post of University Assistant Lecturer in the High Energy Physics Group of the Cavendish Laboratory. The research programme of the group is currently centred upon the OPAL experiment at LEP, the UA2 experiment at the CERN proton-antiproton collider and the development of electronic detectors for particle physics.

It is hoped that the successful candidate will take up appointment by 1st October 1989, or as soon as possible thereafter. The appointment is for three years, with the possibility of reappointment for a further two years. The statutory limit of tenure of a University Assistant Lectureship is five years, but all holders of the office of University Assistant Lecturer are considered for possible appointment to the office of University Lecturer during the course of their tenure.

The pensionable scale of stipends for a University Assistant Lecturer, not ordinarily resident in College, is £10,460, rising by seven annual increments to £14,500.

Further information may be obtained from the Secretary of the Appointments Committee for the Faculty of Physics and Chemistry, Institute of Astronomy, Madingley Road, Cambridge CB3 OHA, England, to whom applications (ten copies), including a curriculum vitae and the names of three referees, should be sent so as to reach him not later than **31st March 1989.**

People and things

cated an alternative perturbation expansion approach, and A. Pich (CERN) covered duality and quark field theory sum rules. The isospin 1/2 selection rule was a yardstick for reliability of the different results.

H. Harari (Weizmann Institute) investigated the hierarchy of quark and lepton masses, paying particular attention to the neutrinos and looking at relationships between masses and mixing angles.

The final day of the workshop was given over to speculations beyond the standard model and possible experimental tests. H.K. Walter (PSI) surveyed worldwide efforts to detect rare decays of muons, pions, kaons and heavy particles. A. Masiero (Padua) showed how rare decays of B mesons could be used as a litmus test for a fourth quark family, further Higgs bosons, left-right symmetry and supersymmetry.

Flavour dynamics in the standard model is intimately connected with spontaneous symmetry breaking and the concomitant Higgs bosons, which have so far eluded observation. However renormalization group and lattice studies can give limits for Higgs and other masses, as demonstrated by R. Petronzio (Rome). The results all say that the standard Higgs boson should be lighter than 1 TeV.

R. Peccei (DESY) speculated on an exotic zoo of spin zero particles, including leptoquarks, majorons and cosmons.

Superstrings are a long way from flavour physics, however these ambitious ideas could shine new light on many open questions. The concepts of string theories were introduced by H. Nicolai (Hamburg), while H. P. Nilles (Munich) looked at the possible links between strings and conventional physics.

Summarizing, H. Fritzsch (Munich) singled out the question of particle masses in the standard model, claiming the potential for answering this problem to be a good measure of theoretical physics progress.

(The Workshop organizing committee consisted of J. Bartels of Hamburg, W. Buchmueller of Hannover, J. Koerner of Mainz, R. Rueckl of DESY, B. Stech of Heidelberg, and P. Zerwas of Aachen as chairman.)

From R. Rueckl

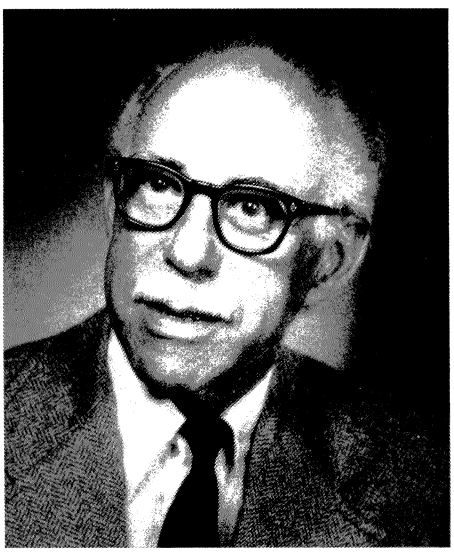
Fermi Award

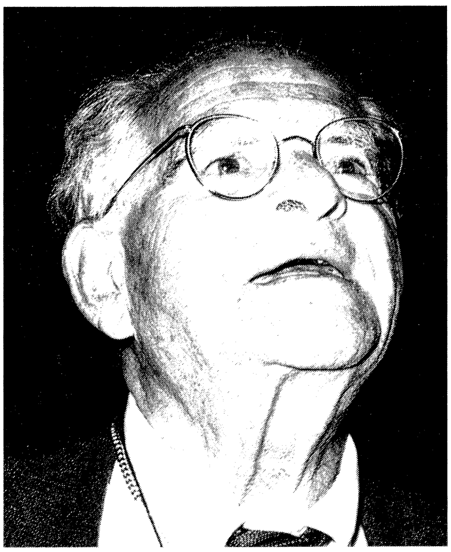
The 1988 Enrico Fermi Award, the highest scientific award of the US Department of Energy, goes to Viktor Weisskopf, doyen of the particle physics community, and to Richard B. Setlow, a biophysicist at Brookhaven.

The career of Weisskopf, who celebrated his 80th birthday last year (December 1988, page 32), spans the entire history of particle physics, beginning in the golden age of quantum mechanics in Europe in the 1920s. He was Director General of CERN from 1961-5, has been very influential in the development of modern US particle physics policy, and has remained a steadfast proponent of international collaboration.

Richard Setlow is honoured 'for his pioneering and far-reaching contributions to the fields of radiation biophysics and molecular biology, beginning with the discovery and conceptualization of the processes of DNA repair that have had an impact on research in genetics, recombination, mutation and carcinogenesis'.

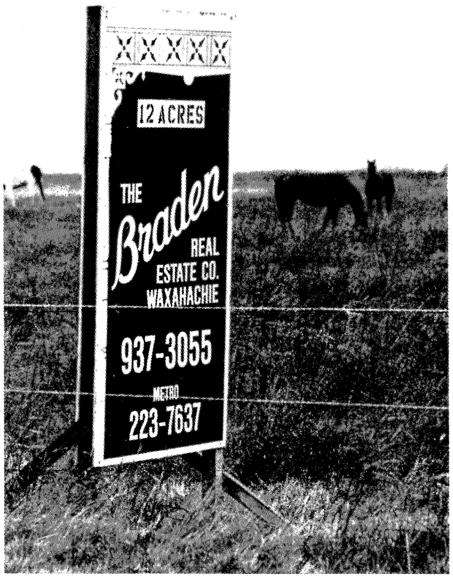
The 1988 Enrico Fermi Award of the US Department of Energy goes to Richard B. Setlow of Brookhaven (left) and Viktor Weisskopf (right).





Waxahachie walkabout

On a recent North American trip, CERN's E.J.N. ('Ted') Wilson took his camera to Waxahachie, Texas, preferred site for the proposed 84-kilometre US Superconducting Supercollider ring to collide 20,000 GeV proton beams.



Directors old and new at the Joint Institute for Nuclear Research, Dubna, near Moscow. Left to right, new Vice-Director Alexei Sissakian (USSR), former Director and now Honorary Director N.N. Bogolubov, new Director Dezso Kiss (Hungary) and new Vice-Director Ditmar Ebert (East Germany).

Dubna Directorate changes

Following the recent senior staff reshuffle at the Joint Institute for Nuclear Research (JINR), Dubna, near Moscow (January/February, page 29), the Committee of Plenipotentiaries of the JINR Member States at its January meeting elected a new Directorate.

Academician Dezso Kiss (Hungary) was elected JINR Director for three years from 1 March, with Alexei Sissakian (USSR) and Ditmar Ebert (East Germany) as Vice-Directors for three years from 1 April.

Former Director N.N. Bogolubov was named Honorary Director in recognition of his outstanding role in the development of the Institute, which has eleven Member States.

On people

Francis Cole, well known in the accelerator field and who has played a major role in Fermilab documentation, has left Fermilab to work on the Loma Linda University Medical Center proton therapy accelerator.

W.P.Swanson 1931-1988

William P. Swanson of Berkeley's Occupational Health Division died in December. After twenty years as a particle physicist, he turned his attention to radiation physics and radiological protection. His work at Stanford and Berkeley created a wealth of expertise on the radiation environments of large accelerators, and he was the author of the definitive work 'Radiological Aspects of the Operation of Electron Linear Accelerators'.

Meetings

The new Summer Nuclear Institute at the Canadian TRIUMF Laboratory aims to provide short nuclear physics courses at the first or second year graduate level. This year's Institute will be held from 31 July – 11 August with core courses covering multiple scattering and the optical potential, hypernuclear physics, relativistic nuclear physics, and hadronic symmetries. Short seminars will cover other topics. Further information from Byron Jennings, TRIUMF, 4004 Wesbrook Mall, Vancouver BC, Canada V6T 2A3.

Instrumentation technology

The European Committee for Future Accelerators (ECFA) is organizing a study week on the new instrumentation technology needed to exploit the high luminosity hadron colliders – such as the LHC hadron collider in the 27 kilometre LEP ring at CERN – now being proposed for the next generation of particle physics research. The meeting will be held from 14-21 September in Barcelona, Spain.

For the LHC machine itself, R and D partnerships between CERN and European industry are already underway, and the physics community is now eager to stimulate industrial interest in the technology for big new detectors, with possibilities for significant spin-off.

Key technical areas to be covered at the meeting include semiconductor technology, optical fibres, optoelectronics, fast electronics, and computing.

Further information from Oscar Barbalat, Industry and Technology Liaison Office, CERN, 1211 Geneva 23, Switzerland, or Markus Nordberg, University of Helsinki, Otaniemi Science Park, 02150 Espoo, Finland.

CERN's phone number

From 22 April, CERN's general telephone number will change from Geneva 836111 to Geneva 767 6111. For direct dialling, use 767 followed by the four-digit internal number. Thus the CERN Courier's new number will be Geneva 767 4103. (The international dialling code for Geneva ends with 4122.)

The 12th International IUPAP Conference on Few Body Problems in Physics will be held in Vancouver, Canada, from 2-8 July. Topics will cover nuclear, medium energy, particle and atomic physics. Further information from Terry Murphy (local arrangements, bitnet fewbody at triumfcl) or Harold W. Fearing (conference organizer, bitnet fearing at triumfcl), TRIUMF, 4004 Wesbrook Mall, Vancouver, British Columbia, Canada V6T 2A3.

20 years of the Triangle Seminar

Last year saw the 20th anniversary of the 'Triangle Seminar', founded by H. Pietschmann of Vienna to stimulate particle physics contact between the universities of Vienna, Budapest and Bratislava, building on a previous tradition of joint Vienna/Bratislava seminars. From its modest beginnings, it has become an important east-west bridge, attracting physicists also from Prague, Trieste, Crakow and Zagreb.

ACCU-rate

Following the recommendations of the CERN Review Committee under Anatole Abragam, the role of the Advisory Committee of CERN Users (ACCU), established in 1978, has been redefined, making it more representative and improving its efficiency as a mutual consultation channel between CERN and its user communities.

ACCU's task is to advise CERN on the practical measures and administrative arrangements needed to complement the research facilities, in particular as regards working conditions and technical support for outside researchers working at CERN. Each Member State is represented by one or two users recognized by their appropriate scientific organizations. In addition, there are two representatives each for users from outside the Member States (a growing community at CERN) and for CERN research staff. While contacts between established users and CERN are being strengthened in the respective countries, individual users (particularly those from outside the Member States) are encouraged to channel their requirements through their ACCU representative(s):

***Austria** – W. Bartl;*
***Belgium** – C. Bricman;*
***Denmark** – P. Hansen;*
***France** – A. Roussarie, G. Sauvage;*
***Germany** – M. Holder, H. Siebert;*
***Greece** – G. Theodosiou;*
***Italy** – G. Conforto, P. Laurelli;*
***Netherlands** – D. Toet;*
***Norway** – E. Lillestol (Chairman);*
***Portugal** – P. Bordalo;*
***Spain** – J. Hernandez;*
***Sweden** – P.O. Hulth;*
***Switzerland** – J. Schacher;*
***United Kingdom** – P. Booth, P. Norton;*
***Non-Member States** – I. Galaktionov, S.L. Wu;*
***CERN** – C. Fabjan, P. Jenni.*

H. Pietschmann (left) and W. Thirring (right) of Vienna celebrate the 20th anniversary of the Vienna/Budapest/Bratislava 'Triangle Seminar' with organizer R.A. Bertlmann.

(Photo Renate Bertlmann)