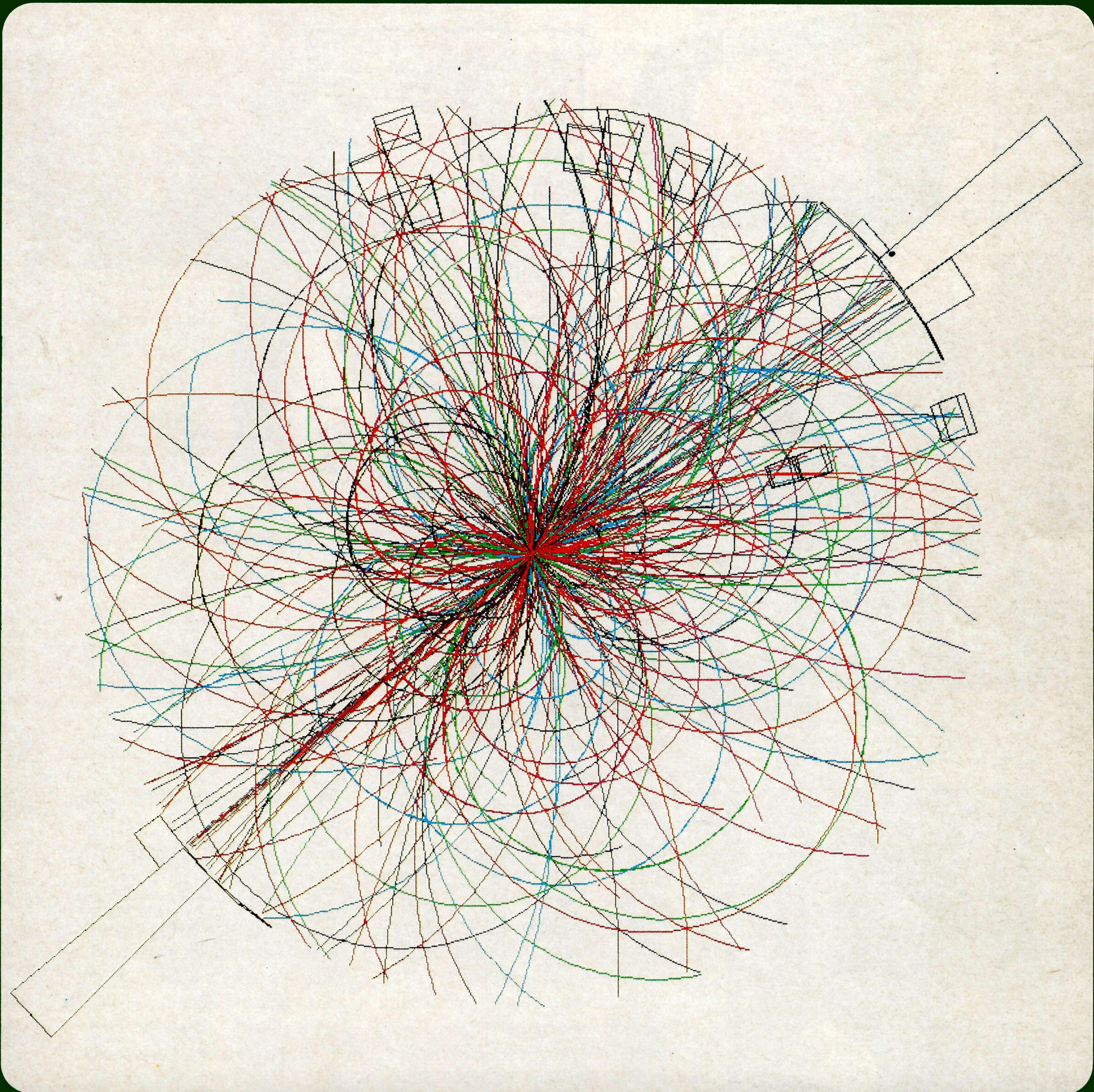
CERN COURIER

International Journal of High Energy Physics



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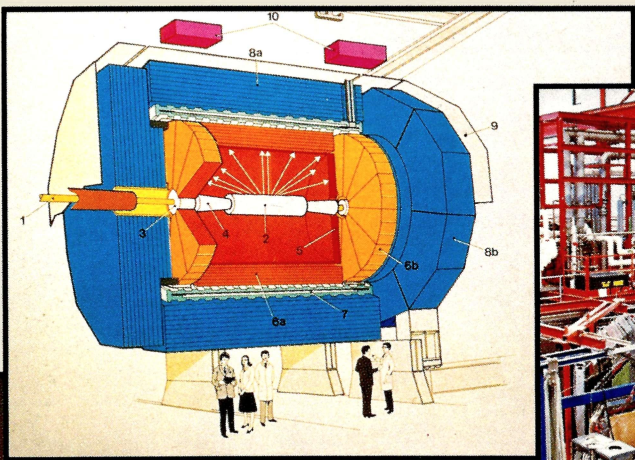

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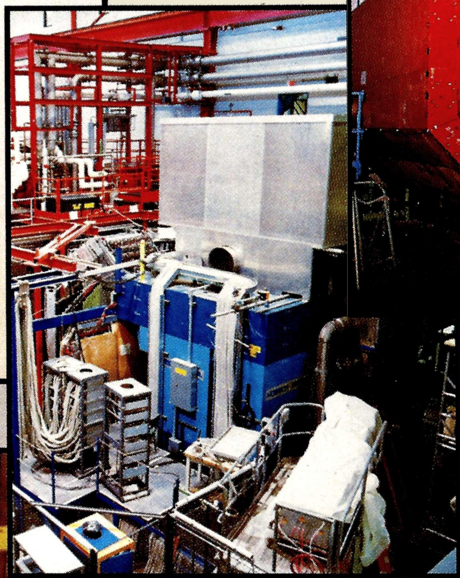

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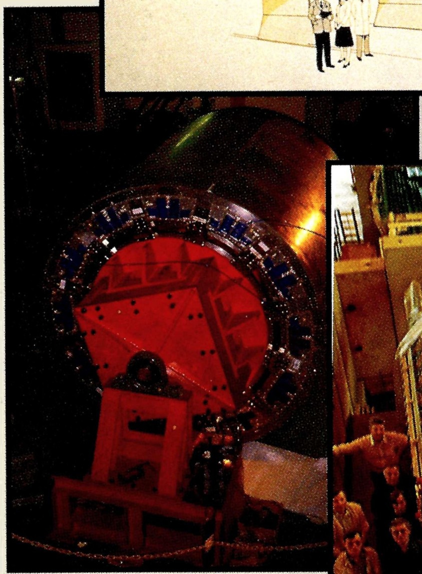

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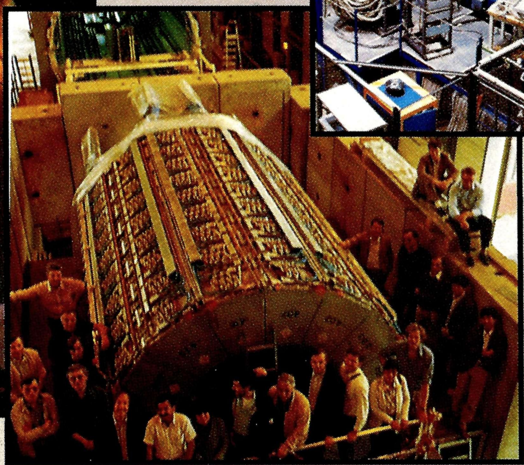

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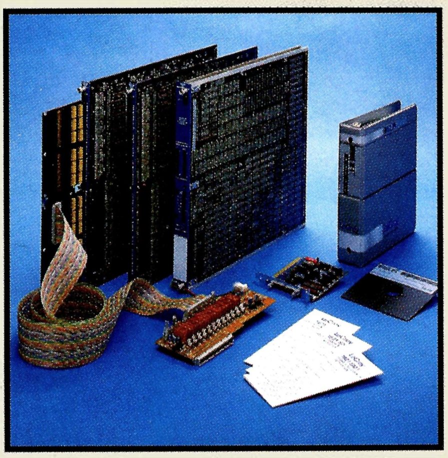

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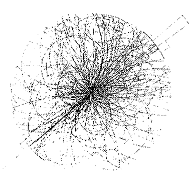
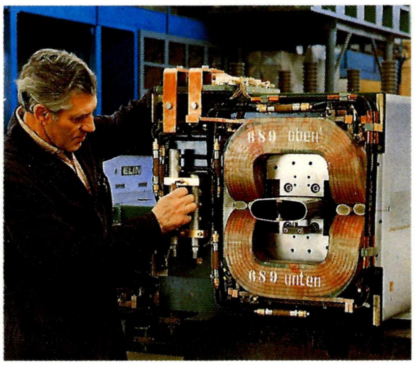


Cover photograph:
This computer simulation of the result of a high energy proton-proton collision was used on the poster of the ICFA School of Instrumentation being held at the International Centre for Theoretical Physics, Trieste, this month.

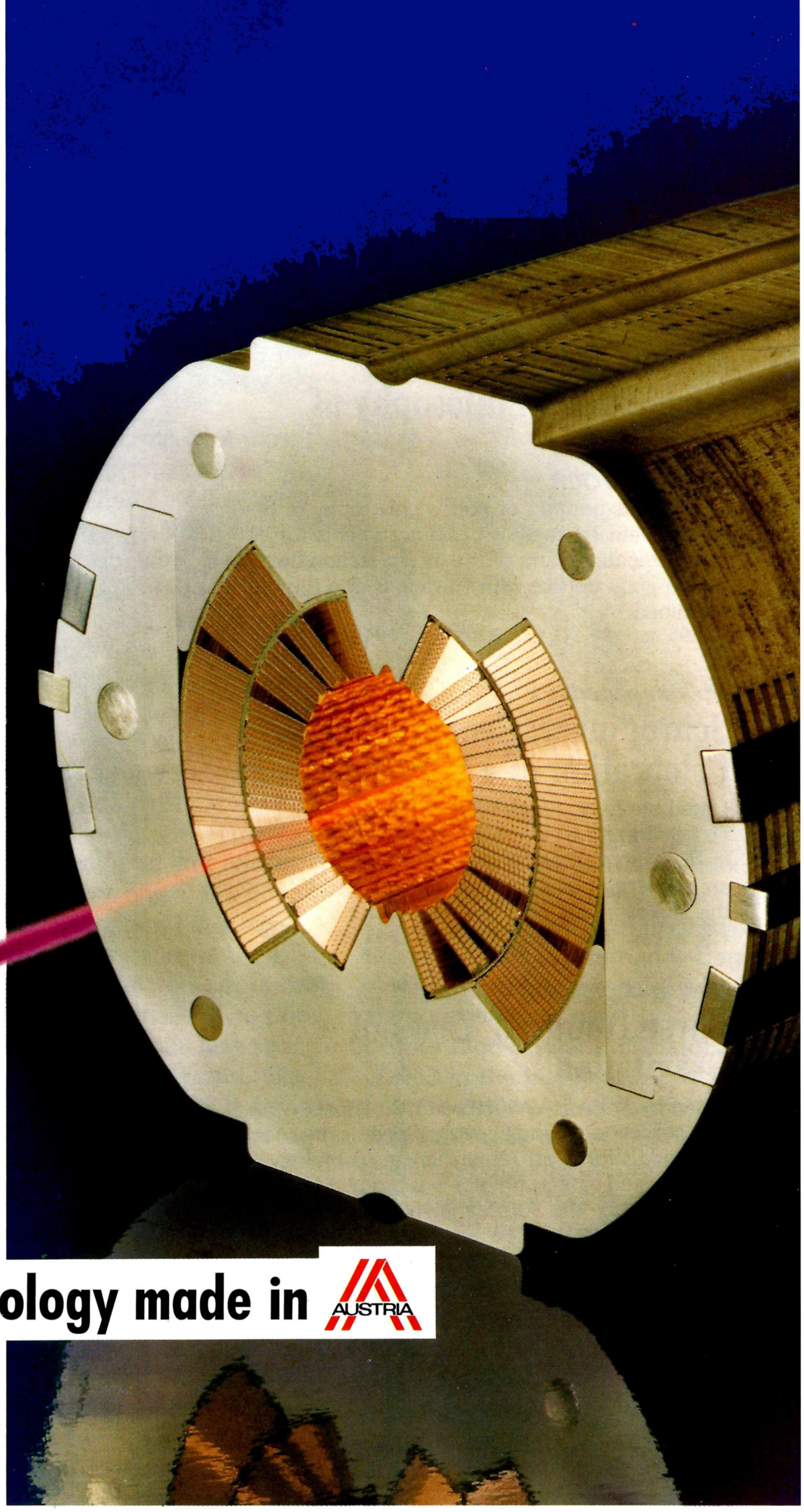
ELIN

Magnet Technology

In delivering magnets for CERN since 1980 Elin has proven itself as a capable partner with regard to design, engineering and manufacture of high field precision magnets for subnuclear-particle experiments.



Superconducting Magnet Technology followed by Elin is based on Nb3Sn as SC material allowing for conventional helium cooling (4,2 K). Recently an Elin coil successfully achieved a stable field of 10.2 T, marking a „world record". Thereby Elin has initiated a breakthrough to fields beyond 10 T, offering new opportunities to high energy physics.



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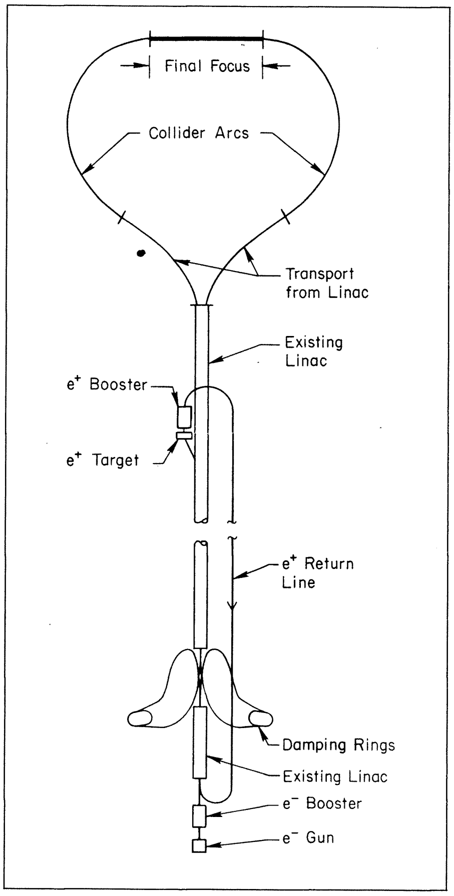
New Stanford collider starts at Z

Schematic of the SLC Stanford Linear Collider. Beams of electrons and positrons accelerated in the main two-mile linac are separated into two arcs, bringing the beams round to the final collision point.



On 11 April the new SLC Stanford Linear Collider created its first Z particle, inaugurating high energy physics research at this novel machine based on the two-mile linac at the Stanford Linear Accelerator Centre, SLAC.

The much-awaited event was identified early the next day (during offline analysis of the data) by Barrett Milliken of the California Institute of Technology – a member of the collaboration operating the 1800-ton Mark II detector at the SLC interaction point. By noon word of the find had spread around the globe, and electronic mail messages were pouring into the offices of SLAC Director Burton Richter, including one from CERN Director General Carlo Rubbia. 'Congratulations,' it read, 'And welcome to the club.'

(The Z, the electrically neutral carrier of the weak nuclear force, was discovered at CERN in 1983, leading to the award of the Nobel Physics Prize the following year to Carlo Rubbia and Simon van der Meer. Several hundred Zs have now been accumulated by the experiments at the big proton-antiproton colliders at CERN and at Fermilab. Stanford's Zs are the first to be found in electron-positron annihilations.)

Over the following weekend the SLC produced another four Z particles. In the first four events the Z gave a pair of narrow, back-to-back jets of hadrons, the characteristic fingerprint of a pair of quarks. This is the first time such decays have been seen unambiguously. In the fifth (colour photo, page 2), one of the two quarks also emitted a gluon, producing a three-jet pattern.

Produced in collisions of point-like electrons and positrons at an energy close to the Z mass (near 92 GeV), these Zs are very clean. To find Zs in the mass of particles produced in their proton-antiproton collisions, experimenters at CERN and Fermilab usually have to look for decays into pairs of electrons or muons.

The commissioning of the SLC started two years ago with high hopes of producing Zs by the end of 1987. But a series of technical problems (October 1987 page 23, and December 1988 page 12) delayed the onset of high energy physics research.

With the production of Z particles now routine, physics has clearly begun. The Mark II collaboration, including physicists from Caltech, Johns Hopkins, Berkeley, SLAC, and the Universities of Colorado, Hawaii, Indiana, Michigan and California (Santa Cruz), now has its first shot at studying hadronic decays.

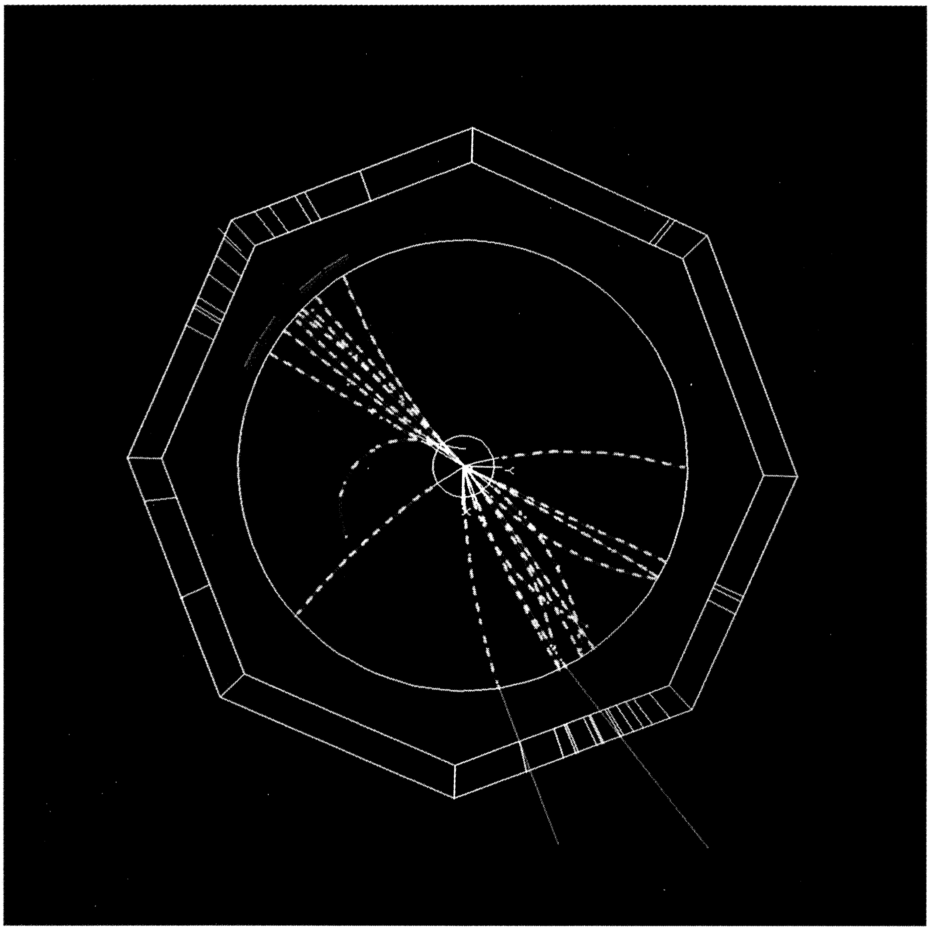
During the initial week, the SLC proved capable of producing one or two Zs per day with its electron and positron beams operating at 30 pulses per second and about 10^{10} particles per pulse. Bunch sizes at the clashpoint have routinely measured 4 microns by 4 microns, with three-micron spots being attained occasionally. The principal improvement since last year has come in the stability and reliability of the SLC; the Mark II detector has frequently been able to log data for more than 30 percent of the time – a factor of 10 improvement over last summer.

SLC architect Richter was pleased but cautioned physicists working on the machine that 'many months of hard work lie ahead before we can bring this first-of-its-kind accelerator to its design performance.' A few Zs are enough to demonstrate that linear colliders work in principle, but dozens a day are needed if the SLC is to make important contributions to physics.

The long process of upgrading the machine's performance began in April. The first of many additional improvements went in – a series of four high-power collimators installed in the last sector of the linac. These are used to trim off any wayward tails of the electron and positron bunches before injection into the arcs. Stray particles in these tails have been clipping other collimators in the SLC final focus, sending streams of troublesome penetrating muons into the Mark II detector. With the new collimators these muon backgrounds are markedly lower, with consequent benefits for Mark II.

Over the last weekend in April, the SLC showed the positive ef-

End-on view of the decay of one of the first Z particles seen by the Mark II detector in electron-positron annihilations at the new SLC Stanford Linear Collider. The decay is dominated by two back-to-back sprays ('jets') of strongly interacting particles (hadrons). 'Hits' in the central drift chamber are shown in pink while those in the outer barrel of the electromagnetic calorimeter are in yellow. The blue-and-maroon sandwiches are hits in the time-of-flight scintillation counters just inside the barrel. Red reconstructed tracks are identified as charged hadrons, and green as electrons or positrons. The two blue tracks are probably pions that punched through the calorimeter, rather than muons. The particle identifications are preliminary.



fects of this upgrade. A peak luminosity of 3 x 10^{27} cm^{-2} s^{-1} has been achieved, equivalent to 3 Zs per day given current operating efficiencies (and assuming the 92.2 GeV tuned collision energy is spot-on).

With CERN's mighty LEP electron-positron collider now readying to make its entrance, the contribution that the SLC makes to our knowledge of the Z, and to high energy physics in general, remains to be seen. But whatever the physics may bring, with the SLC a new kind of particle collider has made a successful debut on the high energy research stage.

Chicago particle accelerator conference

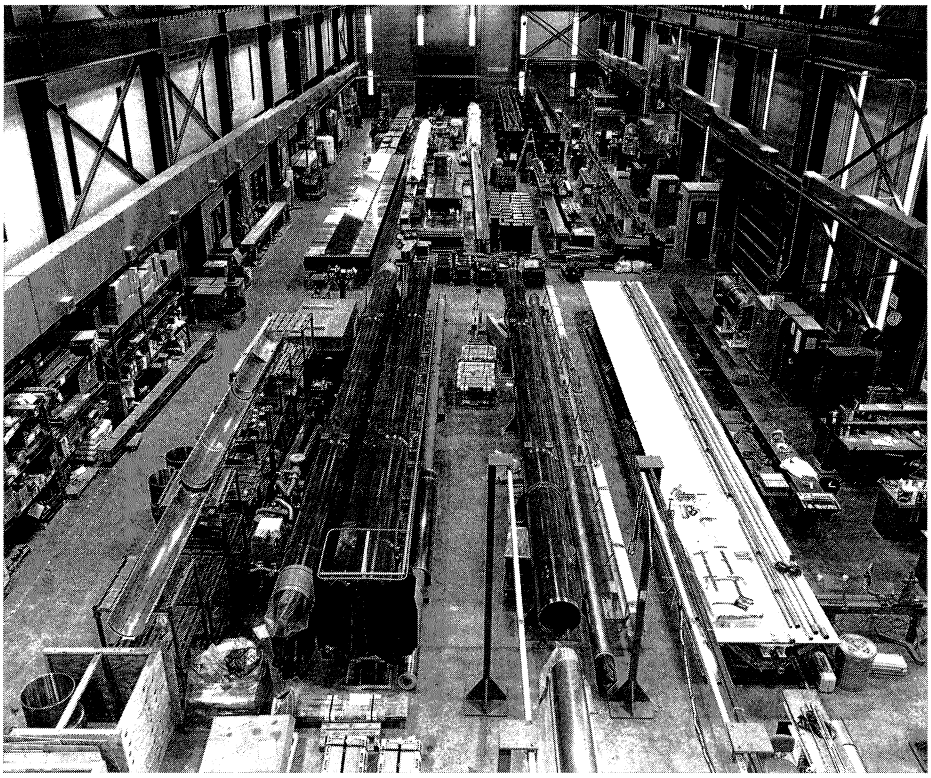
Naturally, emphasis at the Particle Accelerator Conference in Chicago in March was on work in the US, just as the newly instituted European Particle Accelerator Conference places emphasis on work in the 'old continent' (September 1988, page 7). All will come together at the international conference in Japan in August.

The proposed US Superconducting Supercollider (SSC) was highlighted in the opening talk at Chicago. Progress on this inchoate project to explore the TeV (1000 GeV) energy region by colliding 20 TeV proton beams was reported by the recently-appointed Director of the SSC Laboratory, Roy Schwitters. He reviewed the physics challenges and described progress and plans towards full authorization of construction.

This year, the SSC conceptual design will be transformed into a 'site specific' report, now that the location at Waxahachie in Ellis County, Texas, has been selected. The Central Design Group, based in Berkeley for the past few years, will soon move to the Waxahachie region. The top management structure is taking shape and an International Advisory Committee is being formed.

The project is receiving very strong local support. A Commission has been set up in Texas to organize a billion dollars of State

Final assembly of the 17 m superconducting magnet prototypes for the SSC. Some aspects of the crucial magnet development programme are going well. Others need more attention before magnet production can be passed to industry.



funds for the project. This will include about a hundred million dollars to strengthen the research and development phase, presently underway in Laboratories elsewhere in the US. Given the enormous scale of the project, with about ninety kilometres of twin storage rings, major collaborations with industry are essential and the SSC is already teaming up with several industrial partners (November 1988, page 28).

It is hoped that government authorization will enable construction to start next year, when the big collaborations to design and build the detectors can also be formed.

Superconducting magnets

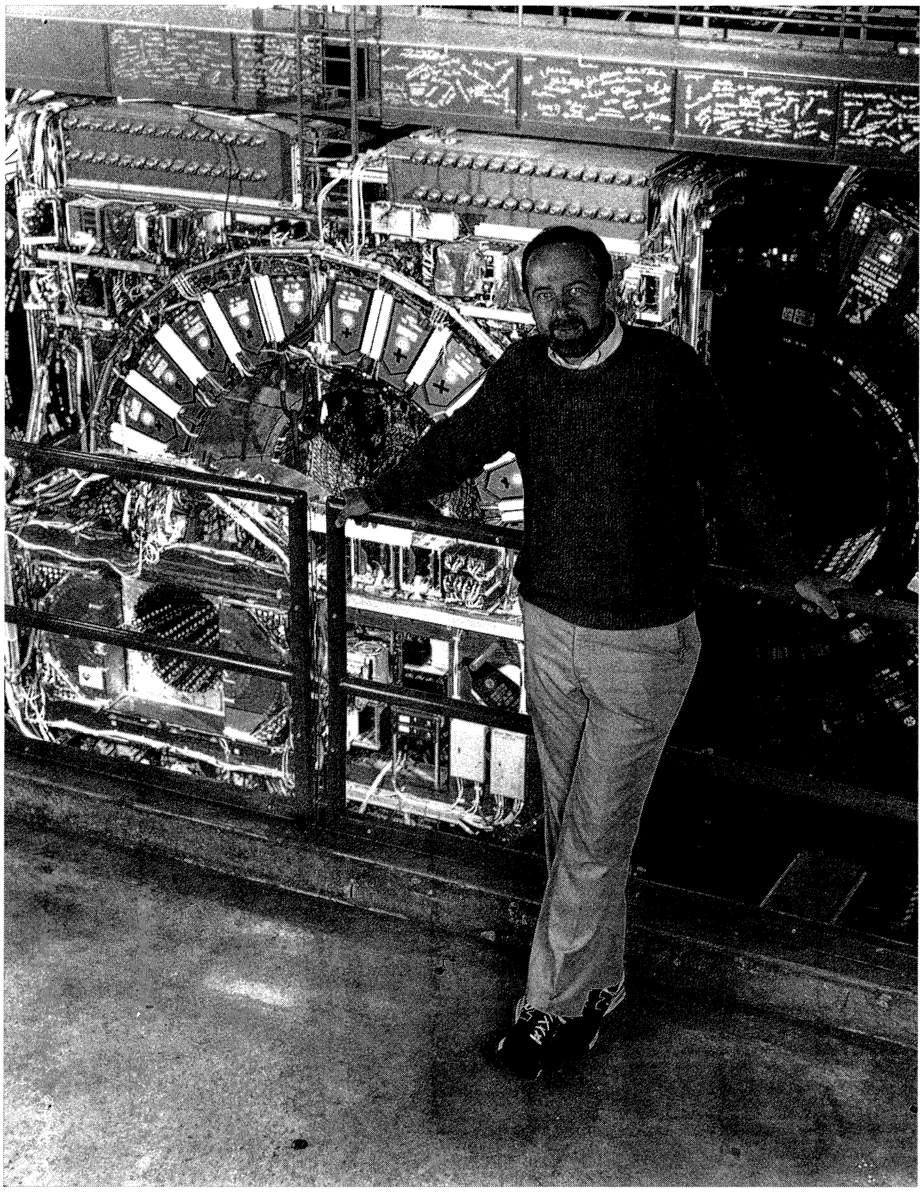
Crucial to the SSC machine design are the superconducting magnets to bend the particle beams. Their manufacture and installation will dominate the construction schedule and their cost (over a billion dollars) will be about a third of the total outlay. Some twenty thousand kilometres of superconductor will be required, compared to some 1.5 thousand for the Tevatron at Fermilab and one thousand for the HERA collider now being built at the German DESY Laboratory in Hamburg. Conductor quality has been improving remarkably in recent years. The SSC provisional specification called for a critical current of the superconductor of 2.4 kA per square millimetre. This was upgraded to 2.75 kA in the conceptional design report and the manufacturers are now aiming for 3 kA.

The SSC magnet research and development programme was covered by Tom Kirk. It involves Berkeley for the development of the superconductor itself, Brookhaven for the winding of the coils and their assembly in the cold mass, and Fermilab for the installation in cryostats and magnet testing. Fermilab has recently put together the necessary tooling for full magnet construction; this could increase the prototype magnet production rate and will also prepare for industrial production. So far sixteen firms have expressed interest.

The magnets will be 17 m long with a 3.3 cm aperture for the beam. The design field is 6.6 T produced by a current of 6.5 kA in the coils. Operating lifetime is set at ten years without maintenance. A series of short (1.8 m) and full-scale magnets have been built, and recent magnets have a mixed history. Number 13 performed exceptionally well, with only two quenches at 4.3 K and reaching a field of 8 T at 3.35 K. Tests showed excellent mechanical stability of the coil package. However number 16 did not top 5 kA in the coil, well below the design requirement, despite also showing excellent mechanical properties. The problem has been traced to bad superconductor and more stringent quality control is now being implemented. The latest full-scale prototype (number 17) had only one quench before reaching design field and has operated with over 7 kA. Number 18 is almost ready for cooldown. Equipment for measuring field quality in these long magnets will soon be operational at Fermilab. Mass production of the magnets in industry should start in 1992.

Industrial production of superconducting magnets, a feature of the HERA project at DESY, was reported by Bjorn Wiik. The proton ring of this proton-electron collider needs over four hundred supercon-

Roy Schwitters, newly appointed Director of the SSC Laboratory, gave the opening talk at the Chicago accelerator conference covering progress on this proposed huge US project. He is photographed in front of the Collider Detector Facility at Fermilab where he led the collaboration which built the detector.



ducting magnets to provide a field of 4.7 T. More than a hundred have been measured; they exhibit essentially no training and achieve fields above design level. The first superconducting quadrupoles were installed in the HERA tunnel in March and the proton ring is scheduled for completion next year.

The main concern in the operation of the HERA bending magnets is the effect of persistent currents at low fields during injection. Fortunately the variation of these currents from magnet to magnet is proving to be small and it is expected that compensation will be straightforward. Overall, the HERA project is going well (see page 19).

The world's first big superconducting accelerator, the Fermilab Tevatron, has now several years of operating experience. Gerry Dugan described the great success of recent runs. The fixed target programme receives 800 GeV beams of 1.7 x 10^{13} protons per pulse. The proton-antiproton collider is operating at luminosities of 2 x 10^{30} (twice the design goal). The integrated luminosity goal was initially set last year for 1000 inverse nanobarns, but had already reached 7000 with two months still to go!

There were dozens of papers at the conference on the performance of the Tevatron and its antiproton source. In the next few years it is hoped to take the luminosity to 10^{31} with a new 400 MeV linac to reduce Booster space charge problems at injection, a more powerful low beta section, and the installation of electrostatic separators to keep the proton and antiproton beams apart except at the two big detectors. By operating at a lower temperature than 4.2 K, the collision energy will inch up (see page 15).

This higher energy performance is overtaking the similarly impressive achievements following the improvements at the CERN proton-antiproton collider (described by Eifion Jones). Peak luminosity so far was 2.4 x 10^{30} and a new run is well underway (Luminosity at CERN's proton-antiproton collider has since exceeded 3 x 10^{30}).

The European project to add a Large Hadron Collider (LHC) in the LEP tunnel for multi-TeV proton-proton physics was not reported at the conference but there has been promising work at CERN in collaboration with industry to produce high field superconducting magnets. Both niobium-titanium and niobium-tin magnets are under development.

A celebration in honour of Georges Charpak (second from left) was organized during the 5th Vienna Wire Chamber Conference (April issue, page 1). Charpak has been a major influence on the evolution of this conference to international status – 260 participants from 22 countries attended this latest event. With him in the newly-built conference centre of the University of Vienna are the conference organizers, left to right, Meinhard Regler, W. Bartl and Gunther Neuhofer.

Superconducting radiofrequency

Impressive was the report by Y. Kojima from the Japanese KEK Laboratory on the upgrading of TRISTAN to higher energies using superconducting radiofrequency cavities. The electron-positron ring has 104 conventional copper cavities producing a peak energy of 28.5 GeV, and sixteen niobium superconducting cavities were added last November (December 1988, page 13).

The good performance is put down to improved quality niobium, and careful preparation and checking at all stages of cavity construction. Procedures include titanium-wrapped annealing after the first electropolishing, to remove hydrogen from the niobium, and a final ample rinse in water with hydrogen peroxide in an ultrasonic bath. There have been problems with leaks at the input-coupler windows (now modified), heating of higher-order mode cables, some degradation in performance when changing from vertical to horizontal cryostats, and strong X-ray emission when operated in the machine (due to poor machine synchrotron radiation shielding rather than excessive electron activity in the cavities).

The latest cavities show almost no electron emission from the cell surfaces and there are now many cavities giving accelerating field gradients in excess of 10 MeV per metre under test in vertical cryostats. A further sixteen cavities will be installed this summer to take the TRISTAN energy to 32 GeV per beam.

Ken Shepard pointed out that r.f. superconductivity has been around 25 years since the pioneering work at Stanford's High Energy Physics Laboratory. A wide variety of structures are used in accelerators for low velocity particles. Argonne is prominent among the Laboratories using superconducting elements in the acceleration of ions. Lowell Bollinger reported on the ATLAS (Argonne Tandem Linear Accelerator System) machine, where five low-beta resonators came into action for their injector linac at the end of February.

The Laboratories going for high energies, such as KEK, Cornell, DESY and CERN, have all now settled on iris-loaded waveguide structures. Improvements in the thermal conductivity of the niobium cells and greater care in surface treatment and cleanliness have yielded the results crowned by the recent work at KEK. At CERN, a cavity has had a successful long-term test (8000 hours) operating on the SPS and four cavities are being installed in LEP.

The nuclear physics project which depends crucially on successful production and operation of superconducting cavities, the recirculating linac of CEBAF, was not featured at the conference in a major presentation. The news is that work on their prototype cavities is yielding accelerating field gradients well above the design value of 5 MV per m and the first deliveries of production cavities from industry are scheduled for later this year.

The innovative teams at Wuppertal and Cornell are continuing their investigations. They have encouraging results with niobium-tin structures and have recently experimented with the new high temperature superconductors sputtered onto other surfaces. No intrinsically adverse properties have been found so far.

Other big machines

News from the SLC Stanford Linear Collider has been overtaken by more recent events (see page 1). It had been plagued with component unreliability, particularly in the old linac, and it took a long time to get bunches of a few 10^{10} particles to the final focus consistently.

However this is a vital contribution to the effort to take electron collision energies beyond those of LEP at CERN, showing that it is not that difficult to make beams only a few microns across collide head-on.

A number of contributions from the LEP team at CERN illustrated the intense but careful effort preparing for first collisions this coming summer (May issue, page 5) and development work to get the most from the machine.

There was encouraging news about the proposed 30 GeV kaon factory at TRIUMF, Vancouver, reported by Mike Craddock, a prominent advocate of the project for many years. It has become a top priority federal project in Canada, the Laboratory has been joined by two more Canadian universities and international interest is emerging in several countries (including the USA, Italy and Germany). The $11 million assigned for pre-construction work by the Canadian government and British Columbia province (September 1988, page 1) will finance the 'project definition study', including the building machine component prototypes.

Synchrotron radiation

Herman Winick gave his usual thorough review of the ever-escalating field of the use of synchrotron radiation; some 32 Laboratories in thirteen countries employ (or will employ) 42 rings to produce intense fluxes of radiation, from ultra-violet to hard X-rays, and the user community is in excess of 6000. There are many pleasing features of this escalation – it is a spinoff from the supposedly esoteric world of particle physics, it involves a very large number of research disciplines, fruitful work can be done on comparatively modest machines within the scope of developing countries and modest university departments, and there are immediate commercial applications (in the leading Laboratories about a third of the present research has industrial aims).

The latest generation of machines employ undulators and wigglers to augment flux intensities. Super-ACO at Orsay is the first of these to be in operation with a storage ring energy of 0.8 GeV. The Advanced Light Source, ALS, with a ring energy of 1.5 GeV had its groundbreaking ceremony at Berkeley last July and is scheduled for completion in Spring 1993. The Advanced Photon Source, APS, at Argonne with a ring energy of 7 GeV hopes to have construction authorization next year. Europe (ESRF at Grenoble), Japan and Korea also have projects in this energy range incorporating the latest advances in technology.

The largest of the present particle physics storage rings also have excellent properties as radiation sources. When they are operating somewhat below peak energy, they can cope with intense beams while retaining low emittance resulting in high-brightness X-ray sources. PEP is a prime example where synchrotron radiation research has been most successfully added recently. Winick concluded with the provocative thought that the very low emittance in the SSC could make it 'the world's most powerful lightbulb'.

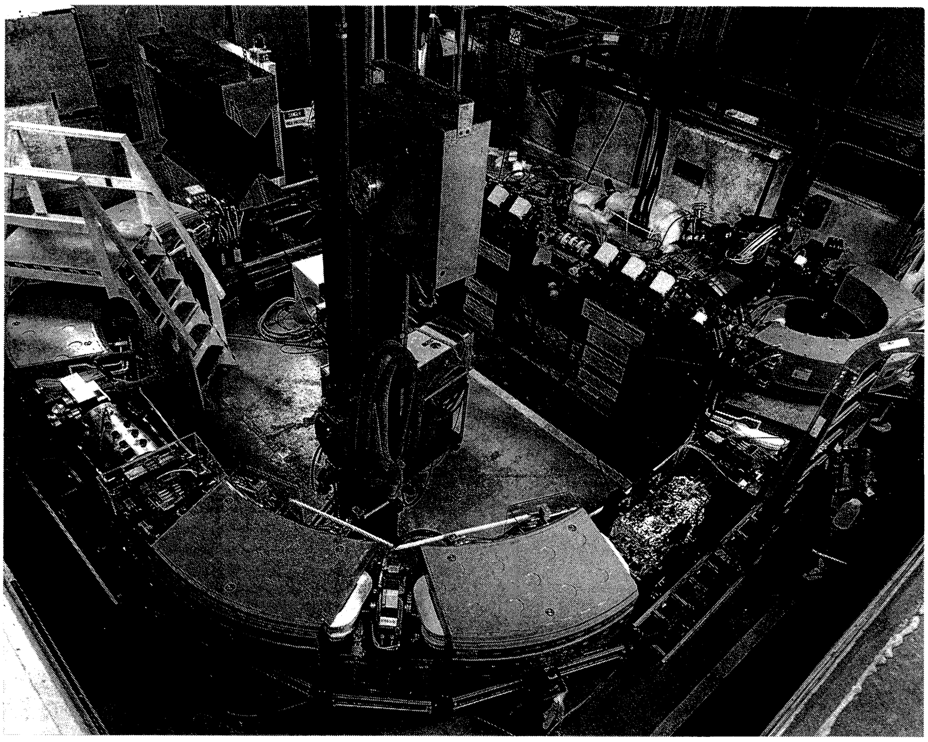
In one of the concluding talks, David Moncton, recently appointed to lead the APS project, summarized scientific results, which he maintained could have great benefits for the nation's economy, health and environment. There is work in the fields of physics, chemistry, biotechnology, nuclear waste treatment, medicine, defence technology, materials science, surface science, industrial processes, and earth sciences.

In some of these fields the properties of synchrotron radiation are particularly appropriate. Moncton pointed out that for most technological problems, the fundamental interactions are understood much better than the complexities which develop in microscopic aggregations in condensed matter, and synchrotron radiation can look at these complexities in both space and time.

In the commercial field, specific topics are microstructures of catalysts (with heavy implications for

Technology Award

At the Chicago conference a new award for 'outstanding contributions to the development of particle accelerator technology' was presented to Jackson Laslett. In making the presentation, Mark Barton, Chairman of a Technical Committee on Particle Accelerator Science and Technology, referred to Laslett's work on beam dynamics, magnet design, space charge forces and collective instabilities, with unique contributions to computational methods on most of these topics.



Protons for cancer therapy. The tiny proton synchrotron, 7m across, built at Fermilab for the Loma Linda University Medical Center. The synchrotron will be shipped from Fermilab to the hospital in July.

possible new progress towards cold nuclear fusion), lubricants, superconductors, ceramics, magnetic recording materials, virus structure, medical imaging and angiography.

Now receiving most attention is the X-ray lithographic production of integrated circuits with line structures a fraction of a micron across. Prototype work at several of the major Laboratories, such as the Brookhaven National Synchrotron Light Source (November 1988, page 24), has been very successful and commercial interest is mushrooming, particularly in Japan, Germany, the UK and the US. Both room temperature and superconducting rings have been designed and the first are being commissioned. It seems likely that this will become the technique of choice for producing sub-micron structures and as many as a hundred machines in the 0.5 to 1 GeV energy range could be needed by the semiconductor industry.

Other applications

In medicine, accelerator technologies are in growing use in radioisotope production and in diagnosis (precise tumour location). However it is in the use of particle beams for tumour therapy that new steps are being taken. In Europe there is the Eulima project for light-ion therapy (January/February issue, page 2). In the USA, a proton therapy machine will soon be moved to Loma Linda University Medical Center after design and construction at Fermilab with Scientific Applications International Corporation as industrial partner (May issue, page 14). Work at Michigan on superconducting cyclotrons to produce neutron beams for cancer therapy was covered by H. Blosser and the Eulima project by P. Mandrillon.

At several Laboratories (Los Alamos, Livermore, Sandia) work continues as part of the USA SDI programme to develop directed-energy weapons systems for use in space. Because of the problems of propagating over a long distance while retaining concentration, the accelerator would have to provide very intense beams of high quality. Research and development at this stage is therefore concentrated on modest acceleration systems aimed at perfecting particle beam production.

Stan Schriber described the Ground Test Accelerator being built at Los Alamos. It aims to funnel negative hydrogen ions from a surface plasma ion source through a radiofrequency quadrupole (RFQ), drift tube linac and coupled cavity linac to reach an energy of 100 MeV. They have bettered the LAMPF figures on a test stand at 7 MeV accelerating 100 mA at 425 MHz and schedule a demonstration of long distance transmission of a 24 MeV beam in about three years.

Los Alamos has been the scene of preparations for the first man-made accelerator to be used in space, the BEAR (Beam Experiments Aboard Rocket) accelerator, aboard a Minuteman rocket. Operational just for a few minutes, it is designed to measure accelerator effects due to the special conditions in space, particularly gravitation and radiation. Negative hydrogen ions go to 1 MeV in an RFQ and are then neutralized in xenon gas, a 10 mA neutral hydrogen beam being ejected from the spacecraft through diagnostic units. Components successfully endured a flight-simulation test last August.

The meeting was the 13th Particle Accelerator Conference to be organized in the USA. It attracted some 700 papers (about a hundred more than at the previous conference in Washington in 1987), underlining the increasing practical applications of accelerators.

By Brian Southworth

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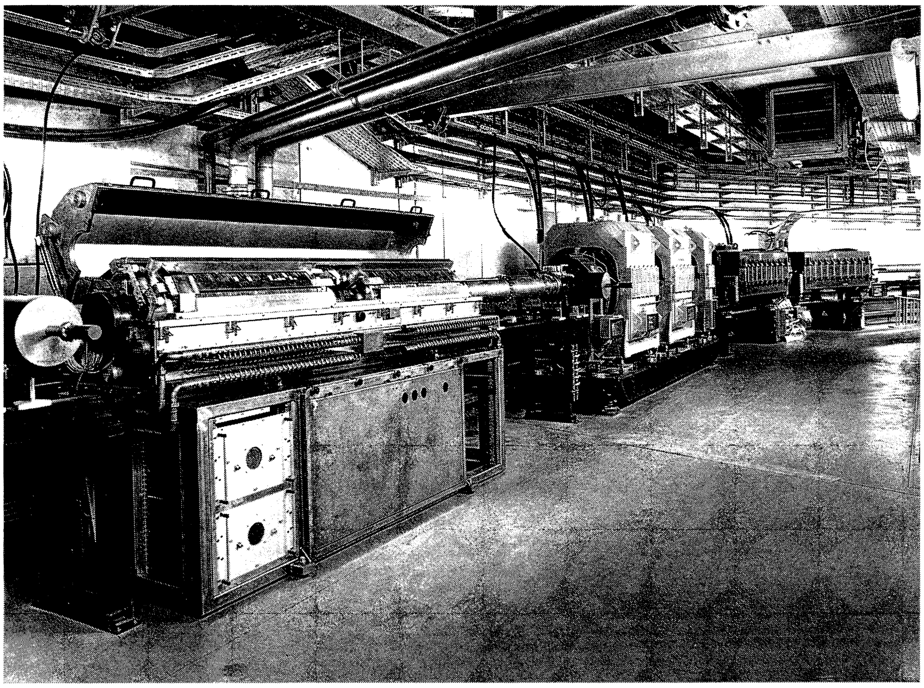
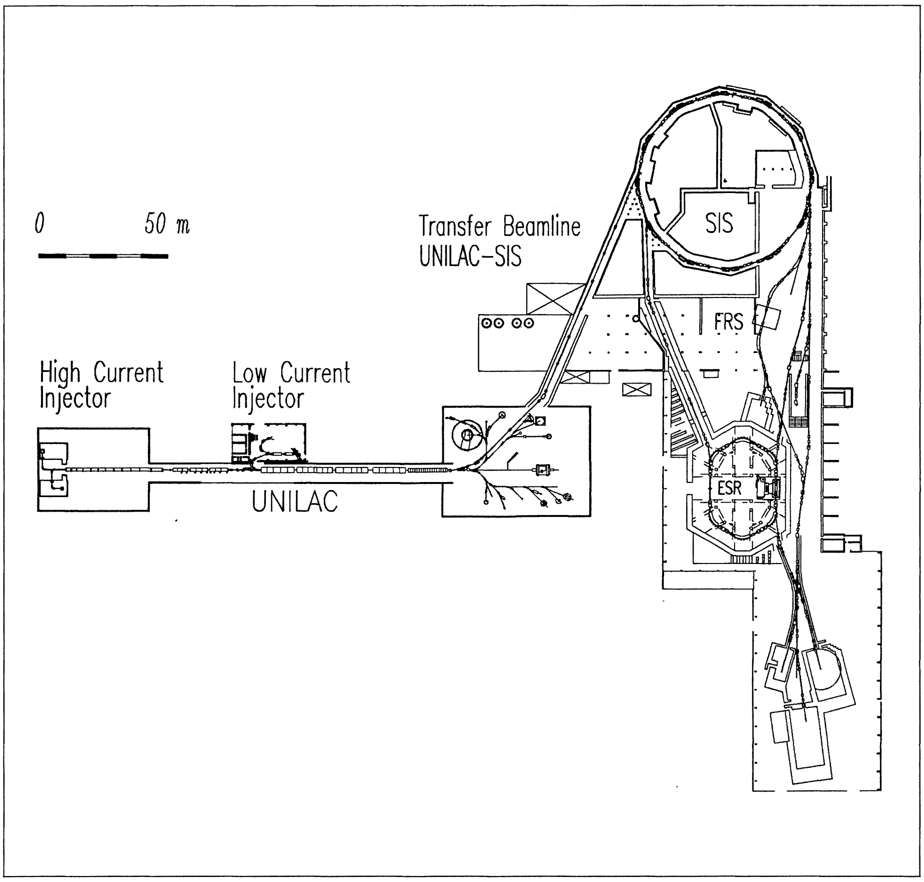
Heavy use of heavy ions

A section of the GSI SIS synchrotron ring, with its radiofrequency accelerating unit opened up. The ring is now being commissioned.





Now being put through its paces at the Gesellschaft für Schwerionenforschung (GSI) Laboratory in Darmstadt, Germany, is the new 216 metre-circumference SIS heavy ion synchrotron, designed to handle beams from several MeV to a few GeV per nucleon, the maximum energy depending on the ion charge (number of stripped electrons).

In the same experimental hall, a second ring, ESR, is being assembled. Half the size of SIS, it has a wide aperture and will be equipped with both stochastic and electron beam cooling to trim the momentum spread of its stored beams.

Together, these two rings will be able to supply well-defined beams both of completely stripped ions, right across the Periodic Table, and of unstable nuclides, separated from secondary particles produced by primary beams. In addition to pure physics, these new heavy ion tools will provide increased scope to investigate routes towards energy production from nuclear fusion, and explore prospects for 'frozen' beams.

Beams for SIS are provided by the UNILAC, operational since 1975 and the scene of much important physics. For the SIS era, a new high intensity ion source and radiofrequency quadrupole injector is being prepared for the UNILAC. Because SIS demands on the UNILAC are not high, an independent

Overview of the beams at the Gesellschaft für Schwerionenforschung (GSI) Laboratory, Darmstadt, Germany. The 15-year-old UNILAC injects beams into the SIS synchrotron, to be linked to the ESR storage ring, still under construction. The FRS separator will select out specific nuclides from the secondary fragments produced by the primary SIS beam. At the UNILAC, the high current injector will provide the particles destined for the SIS, while the second injector will permit parallel UNILAC running for low energy studies.

UNILAC injector will provide a parallel channel with free choice of ions, enabling the linac to continue its traditional role for low energy studies.

For SIS, beam will be accelerated in the UNILAC up to 11.4 MeV/nucleon and enough electrons stripped off to ensure the desired energy and intensity. Circulating SIS beam has been achieved, initial injection into the new ring coinciding with the 80th birthday of GSI pioneer Christoph Schmelzer (January/February, page 24). SIS commissioning will probably last until September.

Ejected beams can be supplied either directly to experiments or to the ESR storage ring now taking shape downstream. Its bending power will handle fully stripped uranium ions at up to 556 MeV/nucleon, or, for example, 834 MeV/nucleon for fully stripped neon. Stochastic pre-cooling will improve the profile of beams with a wide momentum spread, such as secondary particles from the SIS.

An electron cooling unit, installed in one of the two 9.5 m straight sections, will put the finishing touches to the beams. An internal target in the second straight section would provide high luminosity collisions. In addition to external beams supplied to the downstream experimental area, ESR particles could also be fed back to the SIS for further acceleration/deceleration. Clearly with the two rings in operation, GSI will have a lot of beam options to offer and explore.

Much of this variety will be the result of the FRS projectile fragment separator, to be installed between the two rings. Here, secondary beams of unstable nuclides will be produced by fragmentation and dissociation of primary SIS particles, the required nuclides being separated out in flight and injected into ESR or supplied directly to experiments. The physics of the fragmentation process itself will also be an important field of study, while fusion mechanisms could be studied, the heavy nuclei being the projectile.

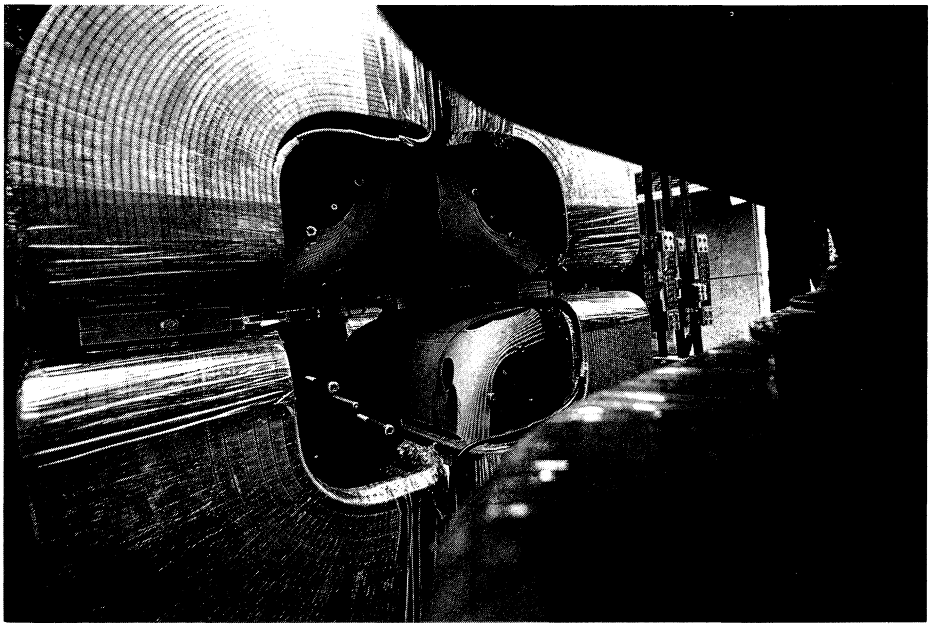
Several large facilities will be set up in the experimental area downstream of the two rings. A full solid-angle charged particle detector, including a forward spectrometer, will concentrate on central (almost head-on) collisions. The detector arsenal will also include a two-arm barium fluoride photon detector and a large-area neutron detector. A magnetic spectrometer in a separate cave will be well tuned for picking up kaons.

Despite its new role as an injector, the faithful UNILAC will still continue to supply beams directly to experiments. Highlights of the 15-year research programme so far have included the synthesis of new superheavy nuclei, and the joint discovery by the ORANGE and EPOS groups of sharp positron lines in 1981, and the subsequent finding of correlated electron-positron signals by EPOS in 1985. (See April issue, page 13. This report should have referred to the earlier positron sightings as well as the EPOS 1985 result.)

Additional research goals include investigating the possibilities of 'crystalline beams' in ESR (March issue, page 8), and of using heavy ion beams to drive nuclear fusion (September 1988, page 29). With the first steps in heavy ion plasma physics having been made, the dense plasmas available with the ESR ring would significantly extend this research.

The wide aperture ESR storage ring at GSI, seen here before installation of its beam pipe, will use stochastic cooling for an initial taming of unruly beams before applying the finishing touches via electron cooling.

(Photos GSI)



Around the Laboratories

FERMILAB
Looking to upgrade

Now taking shape is an imaginative upgrade plan to ensure Fermilab's unique accelerators retain their physics attraction for the future decade and beyond.

Initial results from the Tevatron collider suggest that new physics will probably require lots of data. Furthermore, if the proposed US Superconducting Supercollider (SSC) goes ahead and begins to give physics results sometime after 1998, the upgrade would fill the intervening gap and provide useful physics opportunities such as intense energetic kaons and neutrino beams well into the SSC era.

Earlier upgrade ideas included options such as the addition of two 20 GeV synchrotrons, one as a booster into the existing Main Ring and a second as an antiproton storage depository, but this turned out to be unnecessarily complicated.

The upgrade is now seen as unfolding in three phases, the overall goal being a hundredfold increase in luminosity (a measure of collision rate) in the antiproton-proton collider, and tripling beam intensities for fixed target experiments.

The first phase (already underway – September 1988, page 16) involves upgrading the existing linac to 400 MeV. This will increase the luminosity of the superconducting Tevatron to about $10^{31}cm^{-2}s^{-1}$ with 1 TeV colliding beams. It will also double fixed target intensity to about 3 x 10^{13} protons per pulse. In addition, refrigeration improvements will provide a modest increase in incident beam energy to 900 GeV for fixed target operation.

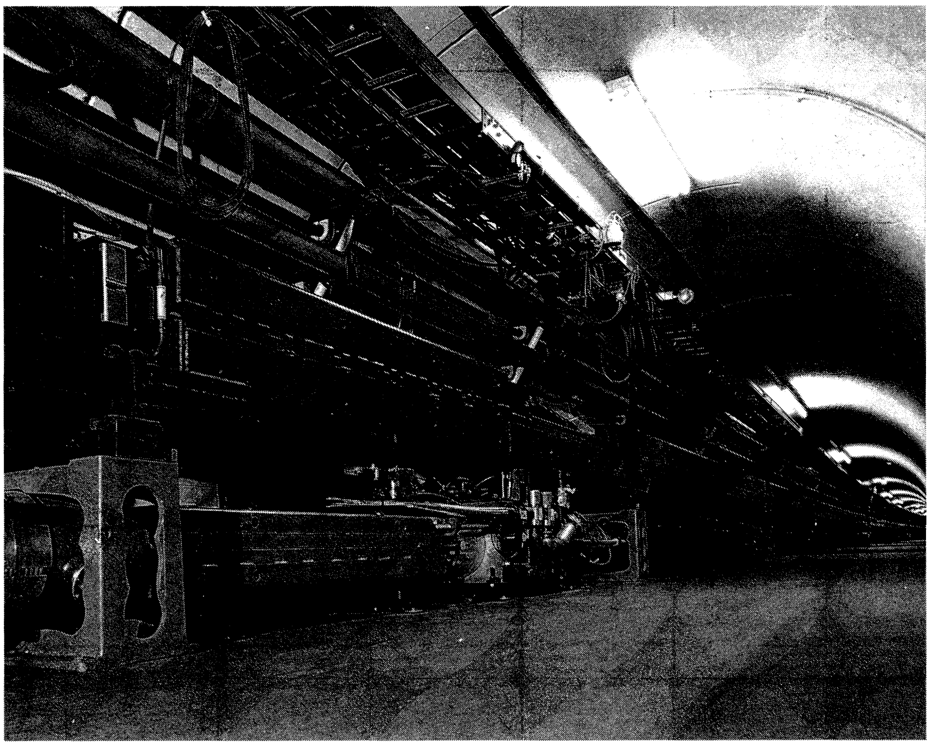
In a second phase, the present four-mile Main Ring would be decommissioned and replaced with a new 120 GeV Main Injector in a separate underground enclosure. This large aperture, rapid cycling proton synchrotron is designed with an eye to the limitations inherent in the present Main Ring when used as a collider. (Collision physics was not even on the horizon when the Main Ring was designed.)

With the new Main Injector, the initial (peak) collider luminosity is expected to increase to about $2.5x10^{31}$. The new machine would also be capable of delivering about $6x10^{13}$ protons per pulse to the Tevatron and because of its high repetition rate would also be a source of 120 GeV fixed target test and calibration beams in parallel with collider operation. The plan foresees development for the Main Injector getting underway in 1990 with construction beginning in 1991 for completion 1994.

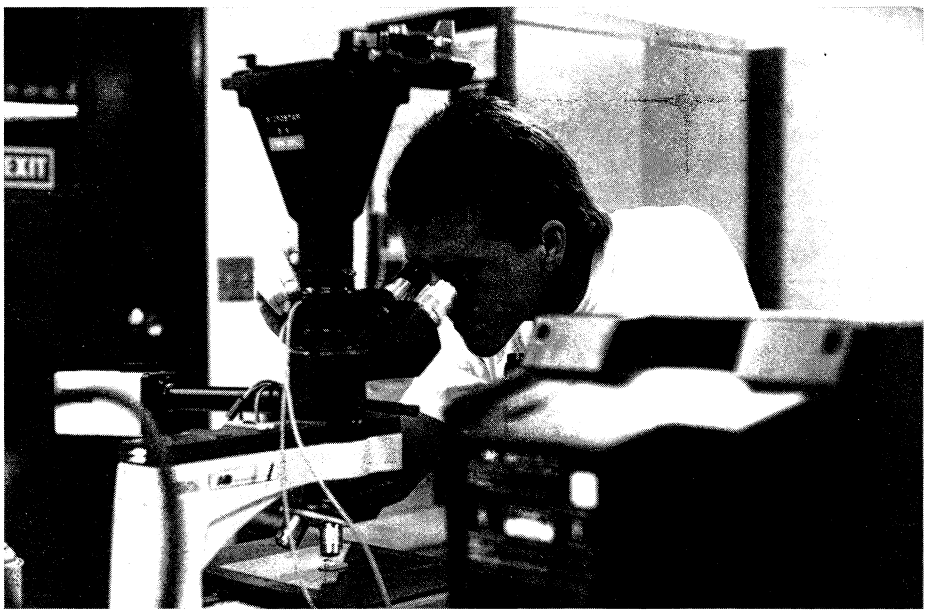
The third phase would be the replacement of the present Tevatron magnets with new, more powerful superconducting magnets, boosting energy to 1.8 TeV per beam and luminosity to $4x10^{31}$.

The increased physics potential from this third phase comes mainly from the increase in beam energy for fixed target physics rather than the modest increase in collision luminosity. R&D for the high field superconducting magnets is already underway at a modest level, and would accelerate next year. Construction could start as early as 1992, with project completion scheduled for 1995, with installation of both the Main Injector and the New Tevatron during a single shutdown of 9-11 months.

The Fermilab superconducting Tevatron ring (below) with the Main Ring of conventional magnets above. Collision physics was an afterthought for the Main Ring.



Students getting hands-on experience at Fermilab.



Physicists of the future

The students that will carry out key experiments at Fermilab or the proposed US Superconducting Supercollider (SSC) in the late 1990s are today in high school, many of them still wondering about a career.

Attracting new talent to particle physics has to overcome many difficulties. Other fields have stolen some of the glamour that once belonged to the quest to understand the ultimate composition of matter. Potential students can be deterred by first having first to master difficult concepts and grapple with recondite mathematics.

With physicists traditionally communicating in a hermetically sealed language, how does one reach and motivate these young people?

First, scientists can try to communicate to a general audience in as simple a way as possible (this not-so-simple exercise can benefit the scientists as well as the audience). Second, modern particle physics must be incorporated into the textbooks and teaching curricula of secondary students.

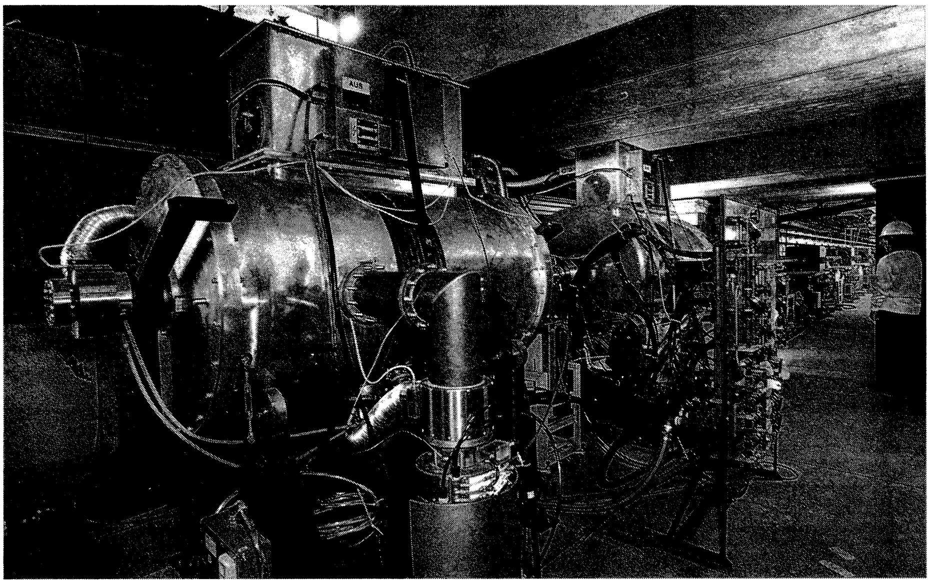
For the last nine years Fermilab has been involved in projects to introduce modern particle physics to students and their teachers in secondary schools. A not-for-profit corporation called Friends of Fermilab Inc. aims to communicate Fermilab's research mission to young people.

The approach begins with a Needs Assessment Workshop to determine how the curriculum should be developed and implemented. This is done at Fermilab under a project director with teachers and administrators from local schools, while Fermilab scientists monitor course content. An important result is documentation ('how-to' manuals) to introduce similar teaching projects elsewhere.

For teachers, a four-week Summer Institute for Science and Mathematics includes lively teaching techniques for existing textbooks, supplemented by Friends of Fermilab material. A two-week Topics in Modern Physics programme provides advanced instruction for teachers, while in 'Beauty and Charm at Fermilab' junior high teachers come to Fermilab for a one-week course on communicating the basic principles of modern particle physics.

Another effort focuses on young students, bringing them to Fermilab for first-hand experience of a basic research environment. Thus after a

Built at the Canadian Chalk River Laboratories, the two 52 MHz radiofrequency cavities installed in the PETRA ring at DESY take protons from 7.5 to the 40 GeV injection energy for the HERA electron-proton collider now being installed.



classroom introduction, students may return to Fermilab for a visit and a discussion session. In a special two-week US Department of Energy-sponsored programme about 50 gifted high school students from the United States and other economic 'summit' countries spend two weeks working and studying at Fermilab.

A third project caters for Latin American science teachers. In 1986 Latin American delegates attended a Conference on the Teaching of Modern Physics at Fermilab. This was followed up by a series of mini-courses in particle physics, general relativity, and cosmology in Mexico City, attracting hundreds of teachers. Another course planned for this summer is expected to attract 300 Mexican teachers.

A future goal is to extend the efforts towards elementary school. In addition to elementary curriculum development, a 'FermiCenter' is under design where students of all ages will be able to carry out experiments introducing physics principles through hands-on experience. FermiCenter will also provide a base for Friends of Fermilab activities.

By introducing the modern concepts of physics at an early age and providing a stimulating atmosphere, high energy physicists assure a harvest of students to carry on the traditions of particle physics research well into the next millennium.

DESY Radiofrequency systems for HERA protons

The German DESY Laboratory in Hamburg is having its first successes in accelerating protons destined eventually for the HERA electron-proton collider.

Protons (or rather negative hydrogen ions) are injected from Linac III into the DESY III synchrotron at 50 MeV. After stripping off the electrons, the protons are taken to 7.5 GeV for injection into the specially modified PETRA ring. Here they will be taken to 40 GeV ready for injection into HERA. First tests are scheduled for the summer, and the proton ring should be complete next year.

HERA's protons will be accelerated to 820 GeV and stored for about ten hours for collision with electrons (or positrons). The HERA electron ring stored its first electrons last year, and the beam should reach 26 GeV in the next series of tests. Superconducting radiofrequency cavities should subsequently boost this energy to 30 GeV.

The DESY III radiofrequency (r.f.) system operates between 3.27 and 10.33 MHz during the 1.8 s acceleration time, using a single cavity with two quarter-wavelength ferrite-loaded resonators, formerly a spare for the CERN PS proton synchrotron. Up to 50 kW of power can be delivered by a Siemens tetrode.

The DESY III r.f. voltage is raised from 500 V at injection to 18 kV at 7.5 GeV. The final frequency and voltage determine both the bunch length (2.8 m) and the bunch spacing (96 ns).

In PETRA's two identical proton cavities, built at the Canadian Chalk River Laboratories and commissioned last year, the frequency changes from 51.64 to 52.03 MHz as the protons are taken from 7.5 to 40 GeV.

The maximum number of bunches in DESY III is 11 and in PETRA 80, so that with a DESY III cycle time of 3.6 s, PETRA filling takes 30 s. Subsequent acceleration takes 2 min and is limited by eddy currents in the aluminium vacuum chambers. Deviations of r.f. voltage and phase are most severe during injection and can be reduced by a feedback loop. Cavity voltages are raised to 93 kV after

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acceleration for adiabatic compression of the bunches to 2.16 m.

The HERA proton ring has two r.f. systems, one operating at the PETRA frequency of 52.03 MHz to handle the 2.16 metre injected bunches, the second operating at 208.13 MHz at 40 GeV, and 208.19 MHz at 820 GeV, giving a final bunch length of 27 cm.

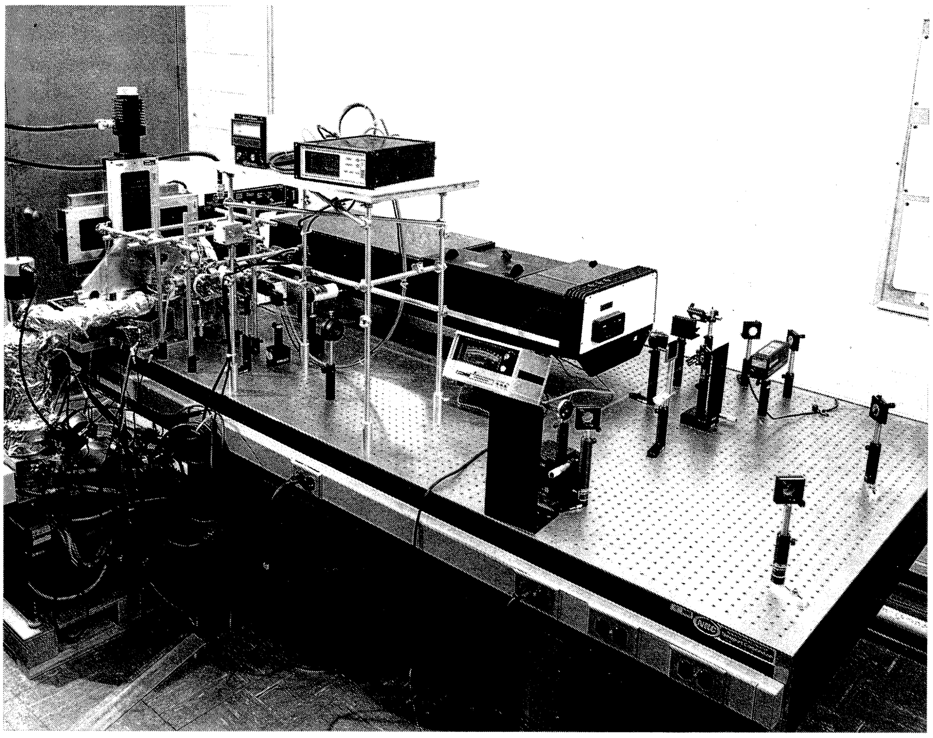
At least three PETRA shots would be needed to fill HERA. During this time, about 20 min, only the lower frequency system would be active. Now being built at Chalk River, it will include two cavities similar to those in PETRA and will be commissioned later this year. A feedback loop (gain 50) should handle beam-induced fields.

After injection comes a first compression phase where the 52 MHz r.f. voltage is raised to 280 kV, reducing the bunch length to 1.15 m. The 208 MHz system is then switched on, the voltage attaining 2.4 MV and the bunches shrinking to 27 cm. Final acceleration will take about 10 minutes, the speed being limited by the voltage from the power supply.

There will be four 208 MHz cavities in HERA, each with its power amplifier using a Siemens tetrode. Apart from a few modifications, this system, being built at DESY, copies from the 200 MHz system at CERN's SPS ring to handle the electrons and positrons destined for the new LEP collider (April 1987, page 14).

Recently the first of these 208 MHz cavities was installed in the HERA tunnel with its tuner and power amplifier, as shown in the photograph on page 20 of the April issue. (Unfortunately the caption wrongly attributed the work – the Canadian TRIUMF Laboratory has provided the beam transport linking Linac III and DESY III.)

Apparatus used for photoemission studies at Brookhaven. The optical beam path shows up as a line (produced by a helium-neon laser). The photocathode is inside the six-way cross on the left.



BROOKHAVEN
Fast photoemission for novel accelerators

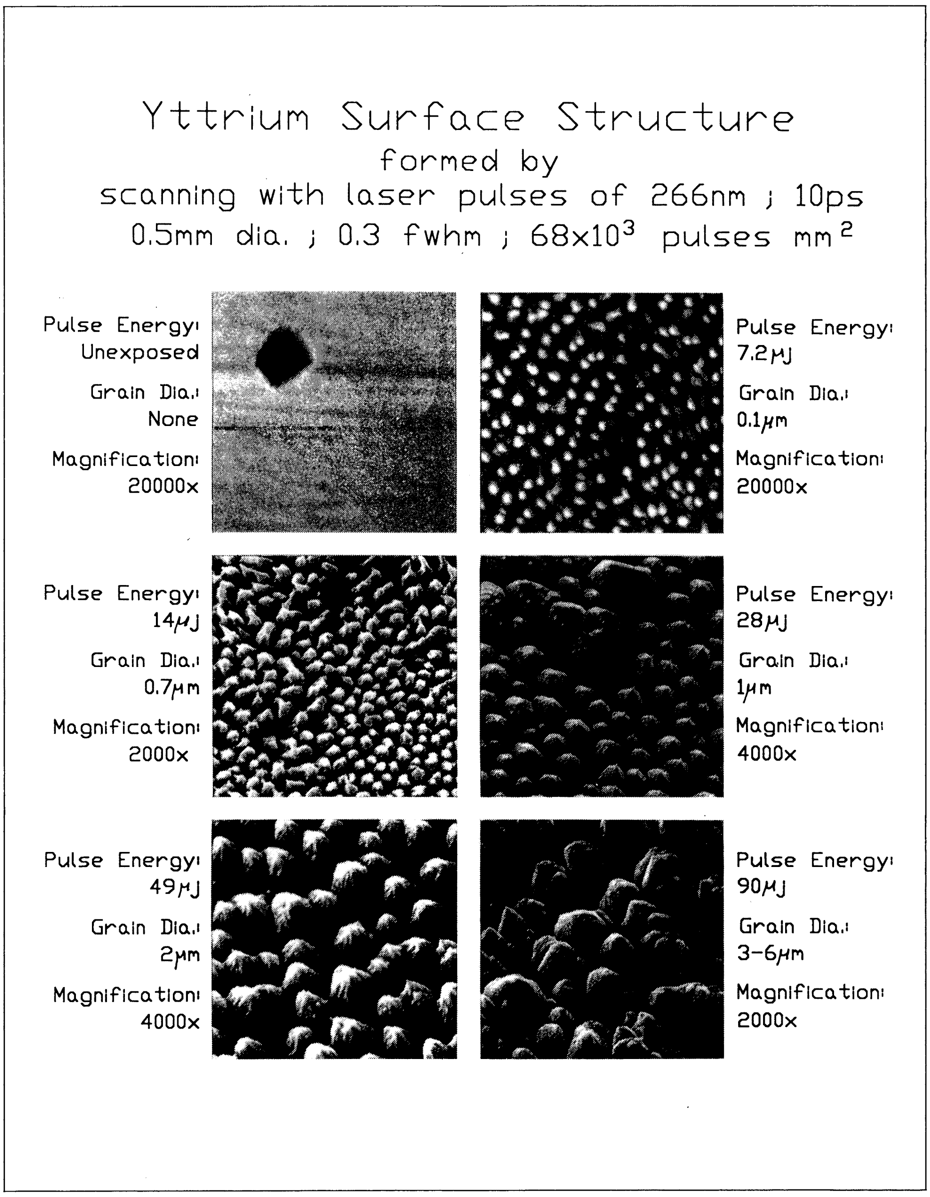
In the past, photoemission has been used for a variety of applications, such as measurement of light fluxes and the study of atomic and molecular structures. The exploration of laser-illuminated photocathodes at Los Alamos showed how to produce high intensity electron beams.

Recent work on photoemission at Brookhaven may lead to novel applications: a new family of intense pulsed electron sources (radiofrequency guns) and fast high-power switches that could greatly reduce the size and at the same time increase the energy of a new breed of particle accelerators (switched power linacs – see May issue, page 21). Other applications include development of X-ray lasers and of lasertrons as sources of microwaves at millimetre and sub-millimetre wavelengths. Such sources could be used to drive conventional linacs.

In all these potential applications, the task is to produce a large number of electrons per unit area in a very short time (about 100 kA per sq cm in a few picoseconds). This is achieved by shining a short, intense laser pulse on a photocathode that responds instantly to light. Photocathodes with a high yield of electrons per photon and tolerance to brief exposure to air are also desirable.

At present, photoemission studies at Brookhaven are directed towards characterizing photocathodes to determine their quantum efficiencies, increasing the quantum efficiency by operating the cathode under high surface fields, and obtaining large currents and current densities.

Structures formed on yttrium surfaces irradiated with UV laser pulses of various energies. The 1 micron diameter grains seen at center right proved most effective at enhancing the quantum efficiency.



The laser chosen for these experiments is a frequency quadrupled Nd:YAG delivering 10^{15} 4.6 eV photons in 10 picoseconds. Metallic photocathodes, with a high density of electrons in the conduction band, give an effectively instantaneous response to the light pulse.

Of the several metals investigated, quantum efficiencies exceeding 0.05% have been obtained from activated samarium, yttrium, and magnesium at low applied fields. Studies of photoemission from yttrium surfaces with microstructures indicate that surface structures improve the low field quantum efficiency by approximately a factor of 5-20 over the applied field, thereby facilitating emission and further increasing the quantum efficiency. The low field efficiency and the surface field enhancement appear to reach a maximum value (quantum efficiency 0.13%) when the surface is closely packed with 1 micron diameter structures.

Current density measurements have yielded 60 kA per sq cm from a 0.05 mm sq magnesium photocathode irradiated by 3 microjoules of UV laser light, very high for such relatively large cathodes. However, this current density was limited by space charge effects. With higher applied fields, these effects could be overcome, and the current density under these conditions would be boosted to 84 kA per sq cm.

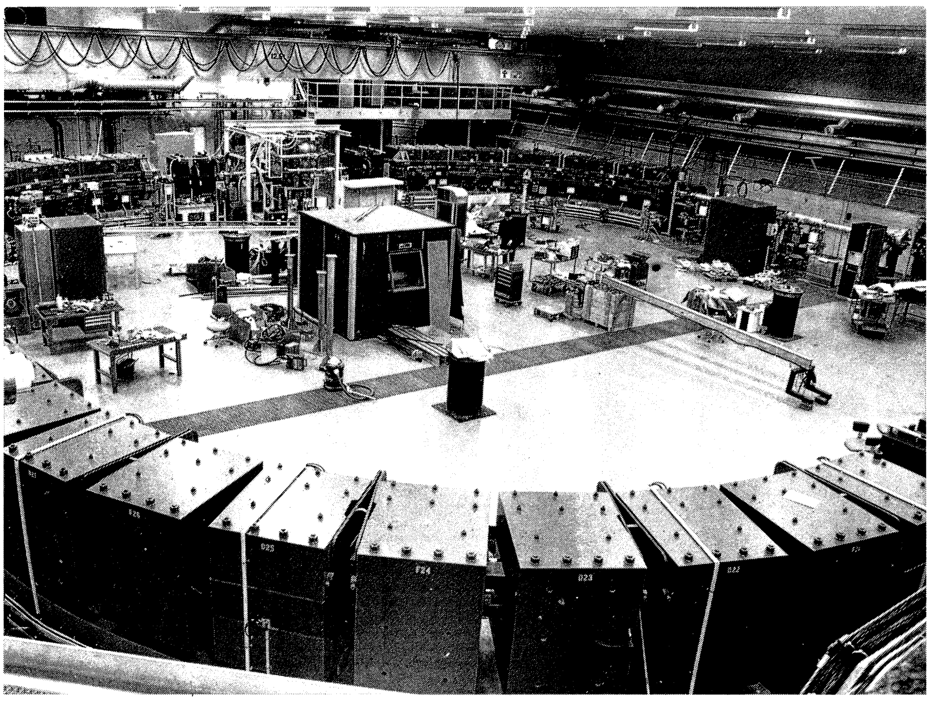
Future plans include applying a pulsed high voltage to establish high fields comparable to those needed in radiofrequency guns and switched power linacs, measuring quantum efficiency at these high fields, determining the pulse duration of the electron bunch and studying photoemission induced by subpicosecond optical pulses.

At CERN, electron emission from ferroelectric crystals is being explored as a possible route to new beam sources (January/February issue, page 21).

INDIANA
Siberian snakes on the move

After fifteen years of reptile-like inactivity, 'Siberian Snakes' are beginning to move – in Indiana. The Siberian Snake concept was proposed by Yaroslav Derbenev and Anatoly Kondratenko of the Soviet Novosibirsk Laboratory in the mid-70s. To overcome the depolarizing resonances acting on a stored polarized (spin oriented) beam, the idea is to rotate the spin through

The magnets of the Celsius cooler/storage beam at Uppsala, now handling its first beams, were previously used in the ICE (Initial Cooling Experiment) at CERN, and before that in the CERN g-2 ring built to measure the anomalous magnetic moment of the muon.



180° on each turn in the ring. With this spin flip, the depolarizing magnetic fields on one turn could be cancelled by an exactly opposite effect on the next turn.

Siberian Snakes would be very useful for high energy polarized beams, obviating the painful tradition of eliminating one depolarizing resonance at a time, each one requiring a few hours' work. The proposed US Superconducting Supercollider (SSC) would have 36,000 depolarizing resonances!

Thus in 1985 an SSC polarized beam workshop (organized in Ann Arbor, Michigan, by Owen Chamberlain, Ernest Courant, Alan Krisch and the late Kent Terwilliger) concluded that SSC polarized protons were feasible provided the Siberian Snake idea really worked, with the recommendation that this should be established as soon as possible.

A candidate testbed was the new electron Cooler Ring at Indiana University's Cyclotron Facility (July/August 1988, page 13), where accelerating polarized protons from the cyclotron injector would have to negotiate two depolarizing resonances.

Built by a Michigan/Brookhaven/Indiana team led by Krisch, the Siberian Snake installed in March contains a superconducting solenoid, four quadrupoles and four skew quadrupoles to correct orbit distortions caused by the solenoid.

Beforehand the team had used a symmetric polarimeter capable of measuring the vertical and radial polarization of the 120 MeV beam near a depolarizing resonance at 108 MeV.

Using three small solenoids to vary the net field in the Cooler Ring, it was found that with perfect correction (zero net field) the vertical polarization peaked near 77 per cent while the radial polarization was zero. With poor correction, the vertical polarization decreased to about 30 per cent while the radial value increased to about 35 per cent (positive or negative according to the direction of the mismatch). Thus the 'stable polarization direction' appeared to rotate as the solenoids were adjusted. Without the solenoids, this direction was vertical – the beam was vertically polarized.

These tests showed that non-vertical stable polarizations are possible in a stored beam, a hint that the Siberian Snake idea might be on the right track – the three solenoids acting as a 'partial Siberian Snake'. Studies with the full Snake will begin later this year.

UPPSALA First beams in Celsius

The Celsius cooler/storage ring at Uppsala, Sweden, equipped with magnets previously used in two rings at CERN, has stored and accelerated its first beams. Celsius is aimed at intermediate energy physics research using thin internal targets and stored, cooled beams of both light and heavy (up to atomic mass 100) ions with momenta of up to 2.1 GeV per nucleon. Experiments will begin this year.

The injected ions come from the recently reconstructed Gustaf Werner cyclotron, able to handle protons up to 200 MeV and once (1951) Western Europe's biggest accelerator. It combines sector focusing with frequency modulation and can accelerate a range of ions across a range of energies. It will be equipped with two external ion sources in addition to the present internal (PIG) source – an ECR source for heavy ions being built at the University of Jyväskylä in Finland, and a polarized proton/deuteron source ordered from Balzers.

The Celsius progamme was born in the summer of 1982, when the

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ICE (Initial Cooling Experiment) ring at CERN completed its investigations of beam cooling techniques. 40 ICE magnets, containing 440 tons of steel and 20 tons of copper, were shipped to Uppsala in the summer of 1983. ICE had inherited its magnets from the famous g-2 experiments at CERN to measure the anomalous magnetic moment of the muon, so they are now enjoying a third lease of life!

Celsius has four arcs and four intervening straight sections for injection, beam diagnostics, cooling and acceleration, and targets. In initial tests, 70 MeV protons were stored last November. Current machine development is aimed at beam acceleration, 600 MeV having been achieved without major problems.

A particular concern with acceleration is that the solid-core (unlaminated) magnets' eddy currents require compensation with appropriate programming of the main and some auxiliary power supplies. Pickup coils to monitor the magnetic field and fix the correct power supply pattern are built into all magnets in one quadrant. Acceleration time is usually 10-20 seconds.

A multi-turn injection scheme with two ferrite magnets creates a closed orbit bump, gradually decreasing during injection. CERN's PS Division helped with all the injection elements, especially the septum magnet, a CERN-built copy of a unit of the LEAR low energy antiproton ring at the Geneva Laboratory.

A stripper foil is envisaged for the first bending magnet for charge-exchange injection. An electron cooling device, being built at Stockholm's Royal Institute of Technology, will be installed this summer for improving beam resolution and lifetime. In the same straight section as the cooler is a radiofrequency cavity (range 0.4 – 5 MHz) for beam acceleration or deceleration. This unit and its beam control system was also built at the CERN PS.

An experimental station, with cluster-jet target, fibre target and common scattering chamber, has been installed in one straight section. The cluster-jet consists of a differentially pumped beam source where gas is pushed through a cooled nozzle. After passing a skimmer and a set of collimators, the beam enters the scattering chamber, and is finally collected in a cryogenic beam dump. The oval target beam at the intersection with the Celsius beam, 250 mm from the nozzle, is 8 mm along the stored beam and 5 mm across. Target thicknesses of 3×10^{14}, 5×10^{13} and 2.4×10^{13} atoms per sq cm have been obtained for hydrogen, nitrogen and argon respectively. Gas pressure in the scattering chamber with the target beam is 10^{-7} mbar.

Fibre targets may be used in the scattering chamber, and fibres of carbon, molybdenum and tungsten and of carbide compounds show promise. First nuclear reactions have been seen using a 7-micron carbon fibre, and luminosities are estimated to be in the range 10^{30}-10^{32} cm^{-2} s^{-1}.

The Celsius particle physics programme requires a hydrogen target, high luminosity, and free access for detectors. A 'pellet' target, with the stored beam exposed to a spray of 10-50 micron frozen hydrogen or deuterium droplets, is being developed by the international WASA (Wide Angle Shower Apparatus) collaboration (Osaka/Stockholm/Studsvik/Swierk/Uppsala/Warsaw). The goal is to study rare meson decays.

Ultra-thin targets are also essential for the CHIC (Celsius Heavy Ion) collaboration (Bergen/Catania/Copenhagen/Gothenburg/Grenoble/Lund/Saclay/ Uppsala/Warsaw) looking at intermediate energy reactions. Very slow recoils (30-200 keV/A) can be studied, and the possibility of measuring all secondary fragments in a full solid-angle detector opens up the possibility of studying nuclear phase transitions.

CHALK RIVER
More superconducting beams

At the Tandem Accelerator Superconducting Cyclotron (TASCC) at the Canadian Chalk River Laboratory, two-thirds of the operating time has been given to a full range of experiments, the remaining time since completion of four major experimental beamlines (December 1988, page 18) having been reserved for cyclotron development.

The four-sector spiral-ridge cyclotron was designed for radiofrequency operation in both 0- and pi-mode. In the former all four 'dees' are in phase, while in the latter, pairs of dees are driven (pi radians) out of phase.

Initial operation in this mode gave troublesome currents, but after improving the internal cooling a 5.12 MeV per nucleon beam of iodine-127 was produced.

Recent additions to 0-mode beams have included silver-107 at 5.6, 6.5 and 10 MeV per nucleon, and bromine-79 at 6.5 MeV per nucleon.

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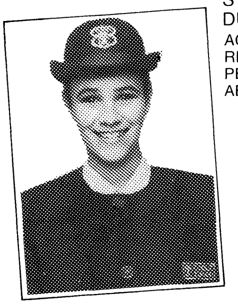

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Experimental Physicist

A position is available for an experimental physicist at the Paul Scherrer Institute (formerly SIN, Swiss Institute for Nuclear Research).

PSI operates a 600 MeV isochronous cyclotron which is used to produce a number of meson beams. The position is initially available for three years.

The successful candidate will be expected initially to participate in experiments using a new large solid angle detector (LADS) for the study of pion-nucleus interactions.

Additional information can be obtained from:
Dr. Q. Ingram (Tel. 056/99 32 58).

Applications, containing curriculum vitae, list of publications and references should be sent as soon as possible, but not later than July 10, 1989 to:

PSI
PAUL SCHERRER INSTITUTE
Personnel Division
CH-5232 Villigen
PSI/Switzerland
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Competition # 588-049

Physicist in Experimental Particle Physics

TRIUMF has an opening for a Physicist in Experimental Particle Physics. The position implies a component of support service, but the candidate is also expected to carry out independent research.

Duties will include the development and operation of facilities for particle physics experiments at TRIUMF – initially, the large acceptance pair spectrometer for the Radiative Muon Capture Experiment. The selected candidate will also act as a support person for outside users wanting to use this facility, and will be expected to participate in experiments, and contribute to the formulation of new proposals.

The successful candidate will have a recent Ph.D. in Nuclear or Particle Physics, and a broad experience in experimental techniques with emphasis on detectors, data acquisition, and associated electronic equipment, as well as data analysis and simulation. Salary will be commensurate with experience.

Initially, the appointment will be for two years, but the successful applicant will be subject to consideration for a continuing appointment.

Curriculum vitae, including an outline of recent experience and research interests, a list of publications and three letters of reference should be sent **before JULY 15, 1989** to: **TRIUMF Personnel (Competition #588), 4004 Wesbrook Mall, Vancouver, B.C., CANADA V6T 2A3.**

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POSTDOCTORAL FELLOW

The Lawrence Berkeley Laboratory's (LBL) Physics Division invites applications for a postdoctoral position from individuals interested in devoting the major part of their research time in the next few years to the design and development of SSC detectors. There would also be an opportunity to participate in one of the hadron collider experiments (CDF or DO) in which LBL is a collaborating institution.

Interested candidates should send a letter of application, a curriculum vitae and the names and addresses of three potential references (Specify Job B/5264) to:

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Physics Division
C/O Gloria Bayne
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People and things

At the recent school and workshop on superstrings at Trieste's International Centre for Theoretical Physics, David Gross of Princeton (left) was presented with the Dirac medal awarded to him last year. The presentation was made by Antonino Zichichi (right). Centre is ICTP Director Abdus Salam.

UK Institute of Physics Awards

Among the UK Institute of Physics Awards for this year are the Guthrie Medal and Prize to Cambridge astrophysicist Martin Rees for his many outstanding contributions to cosmology, and the Paul Dirac Medal and Prize to Oxford theoretician Roger Penrose for his work on 'black holes' and his pioneering efforts to reconcile relativity and quantum field theory.

High Energy Physics Group

The UK Institute of Physics High Energy Physics group was formed in autumn 1985 through the initiative of Brian Foster (Bristol) and Robin Devenish (Oxford) who felt that high energy physicists should play a more prominent role in the national physics community, particularly in the wake of the Kendrew report. The group now has 358 IoP members and runs regular half-day meetings around the country (many in collaboration with other special interest groups of the IoP) in addition to the two-day annual review meeting. Another very important activity is its newsletter – currently edited by David Binnie at Imperial College. At its latest meeting Peter Kalmus (Queen Mary College, London) was elected to replace Robin as group chairman and Norman McCubbin (Rutherford Appleton) to replace Brian as secretary. Other members of the committee for the coming year are John Allison (Manchester), David Binnie, Ken Bowler (Edinburgh), Peter Clarke (Brunel), Mike Green (Royal Holloway, London), Chris Sachrajda (Southampton), Terry Sloan (Lancaster) and Peter Watkins (Birmingham).

Emilio Segré 1905-1989

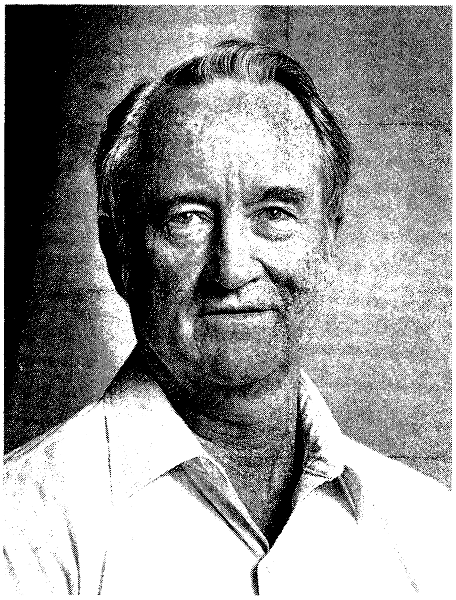
Emilio Segré died on 22 April. As one of Enrico Fermi's earliest collaborators in the 1930s, he looked at the effects of neutron bombardment. In 1937, he discovered the missing element 43, subsequently named technetium, in a sample of irradiated molybdenum brought back from Berkeley. Evicted from his Palermo position, he took up residence in the US, going on collaborate in the epic Berkeley work on the synthesis of transuranic elements before moving to the Manhattan Project.

In peacetime, new particle accelerators wrested the experimental initiative from cosmic ray studies. In 1954, the new Berkeley Bevatron became the world's highest energy machine. The early 1930s had seen the discovery of the positron, antimatter counterpart of the electron. Dirac had also hinted that the proton too should have its antiparticle, and the Bevatron's energy of 6.2 GeV promised that if the antiproton existed, then the machine could make them. Segré, with Owen Chamberlain, found the first examples the following year, their discovery meriting them the 1959 Nobel Physics Prize. After several years in Rome in the mid-70s, Segré returned to Berkeley.

Massive neutrinos

More than fifty years after its prediction and thirty years after its discovery, still nobody knows for sure whether neutrinos have mass – only limits exist. Thus a useful addition to the literature is 'The Physics of Massive Neutrinos', by Boris Kayser, with Françoise Gibrat-Debu and Frederic Perrier, published by World Scientific. Massive particles can be just as fascinating as massless ones.

Kent Terwilliger



Kent Terwilliger

Kent Terwilliger from the University of Michigan died in February. He was a pioneer in experimental particle physics and one of the group at MURA that developed in the mid-1950s the first ideas on colliding beams. He is well known for his work at CERN's Intersecting Storage Rings to increase luminosity by superposing particle equilibrium orbits using special 'Terwilliger quadrupoles'. In recent years he has been one of the world's experts on polarized proton beams (see page 23). He helped on many committees formulating US particle physics policy, was an esteemed teacher and warmly regarded friend.

▲ Participants at the recent symposium 'The Fourth Family of Quarks and Leptons', organized by UCLA and held in Santa Monica, California. The summary talk was given by Lev Okun of Moscow (kneeling, third from right, with meeting organizer David Cline of UCLA on his right).

(Photo Kimberley J. Willis, UCLA)

Soviet physicist Andrei Sakharov (left) recently received an honorary doctorate from Bologna University. With him on the podium are (left to right) University Rector Fabio Roversi-Monaco, Faculty of Science Chairman Sergio Focardi, Astrophysics Department Director Alessandro Braccesi, and Antonino Zichichi, chairman of the university's honorary degree nomination committee.

Colliding towards world collàboration

Particle physics has blazed the trial for international scientific collaboration, and regional centres, such as CERN, cater for a well-defined need. With an eye to the future, ambitious schemes are continually being developed for so-called 'World Machines' – supported and used by scientists from the entire planet.

Speaking at the recent European Physical Society Seminar on International Research Facilities, held in Zagreb, Yugoslavia, Maurice Jacob of CERN pointed out how the new emphasis on colliding beam machines is bringing about world collaboration of its own accord.

'It is clear that when a unique machine is built in a particular region, it attracts users from all over the world. This was the case for CERN's Intersecting Storage Rings and proton-antiproton collider, and is even more so for the LEP electron-positron collider now nearing completion. (At the seminar, CERN Research Director John Thresher described LEP progress.)

World agreement for construction of these machines would have been difficult, if not impossible, but nevertheless the scientific merit of an experiment outweighs national, or even regional, interests.

Now a new factor is becoming clear. While in fixed target work experiments and detectors can come and go as new requirements emerge, the successful exploitation of an expensive collider needs complete detectors ready to intercept the first colliding beams. The ratio of the cost of these sophisticated detectors and the cost of the machine itself is increasing with energy – about 40 per cent for LEP.

Future colliders may still be built and operated by a particular region, but the construction of its detectors will be spread across the worldwide research community. In this sense, a 'world machine' is coming about in an 'adiabatic' way, shortcutting many traditional political and administrative obstacles. The approach taken for the HERA electron-proton collider being built at the German DESY Laboratory in Hamburg, with specific parts of the projects being underwritten by foreign participation, and sharing many points in common with the financing of the LEP detectors, is another pointer.'

Participants at the recent meeting on 'Critical Phenomena in the Early Universe' at the S.N. Bose National Centre for Basic Sciences, Calcutta, India, organized in collaboration with Calcutta's Variable Energy Cyclotron Centre.

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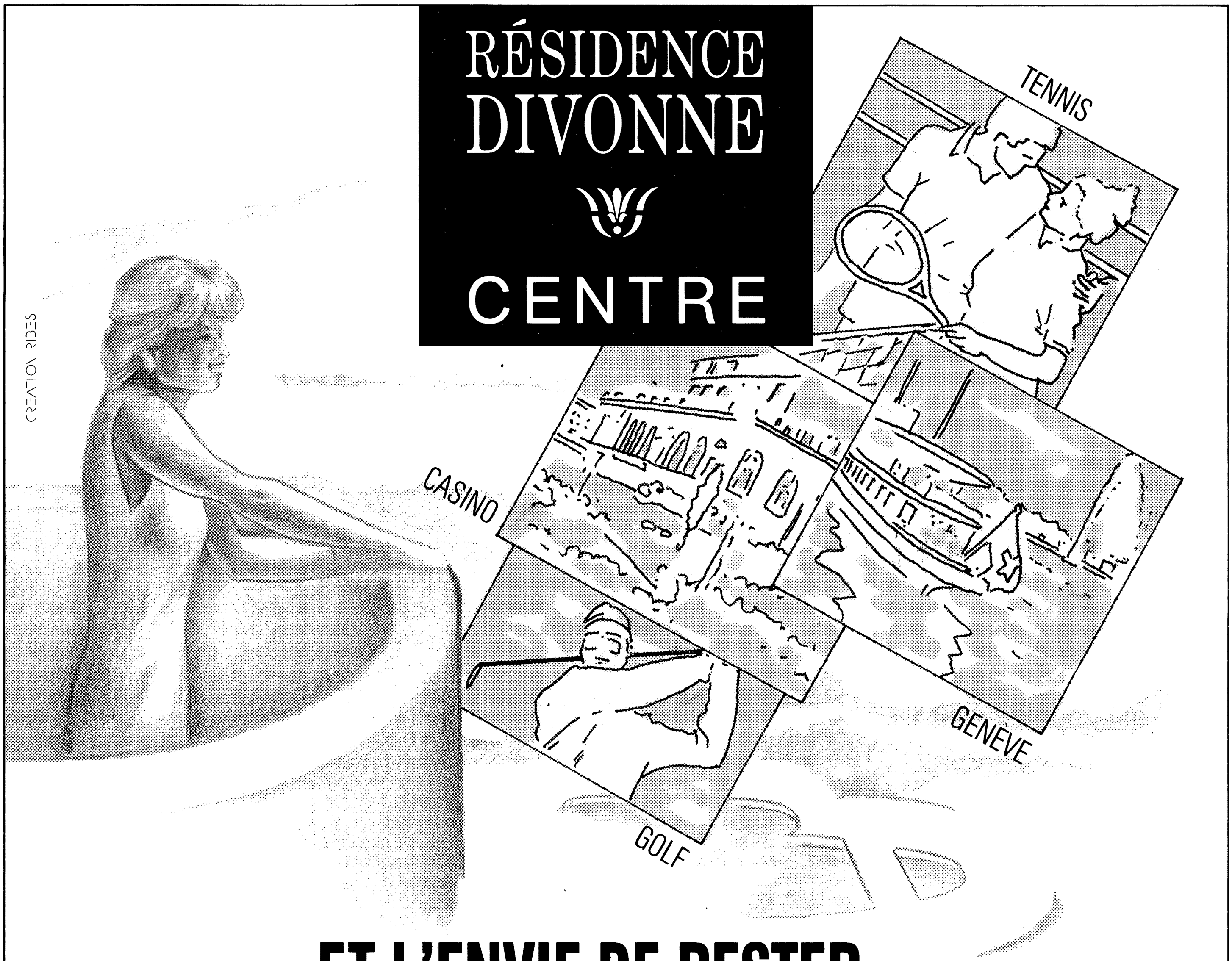

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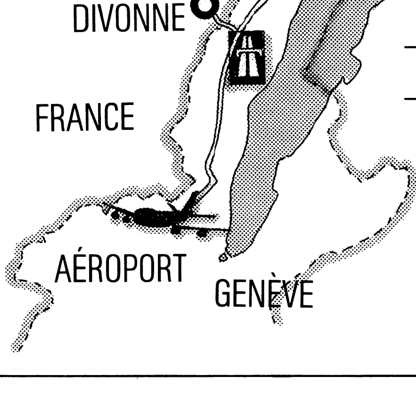

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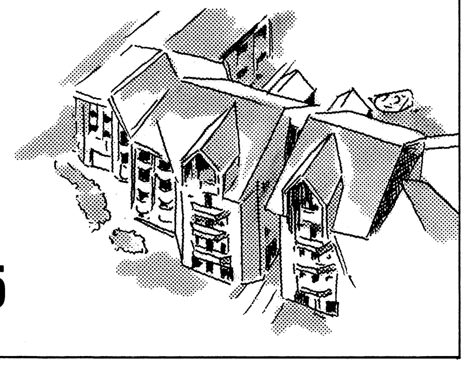

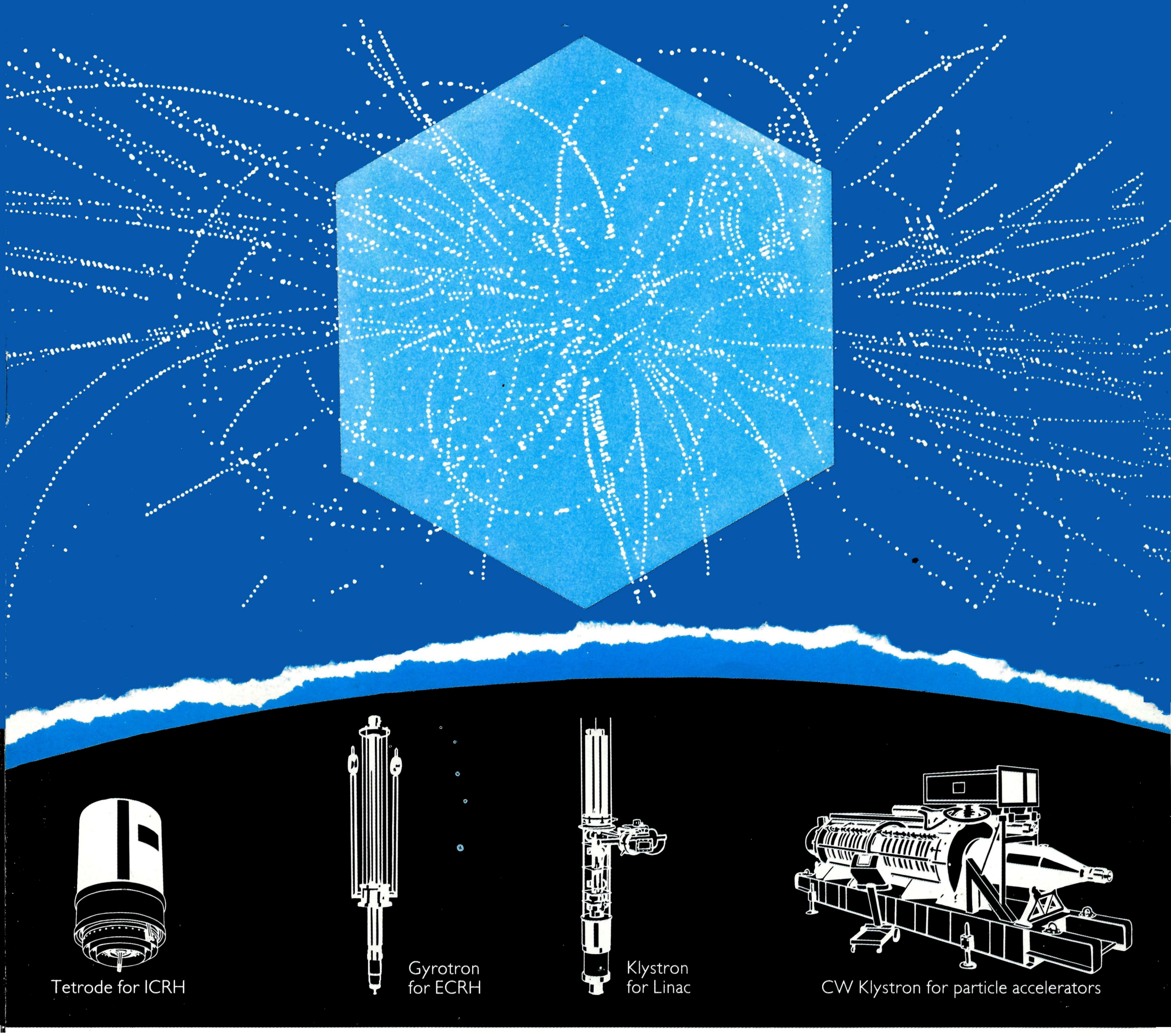

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