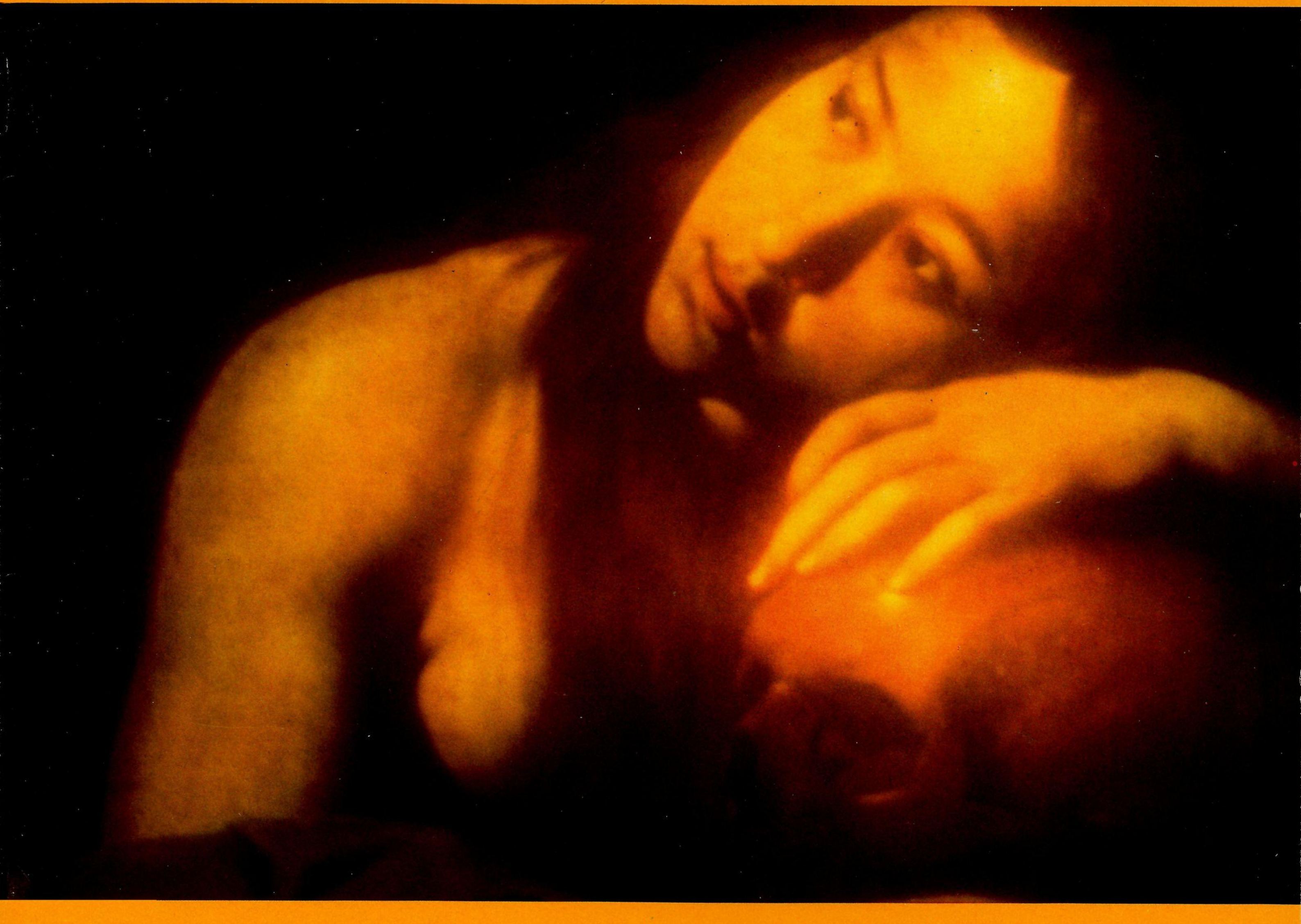
CERN COURIER

International Journal of High Energy Physics



VOLUME 26 9 NOVEMBER 1986

LeCroy on-line

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The ECLine Series of programmable logic and trigger processing units is expanding with the Model 2378 Arithmetic Logic Unit (ALU). The ALU provides for 16-bit Arithmetic or Logical operations, and is fully compatible with other LeCroy ECLine trigger processor and data handler modules.

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LeCroy on-line 2: 1986

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LeCroy

Innovators in Instrumentation

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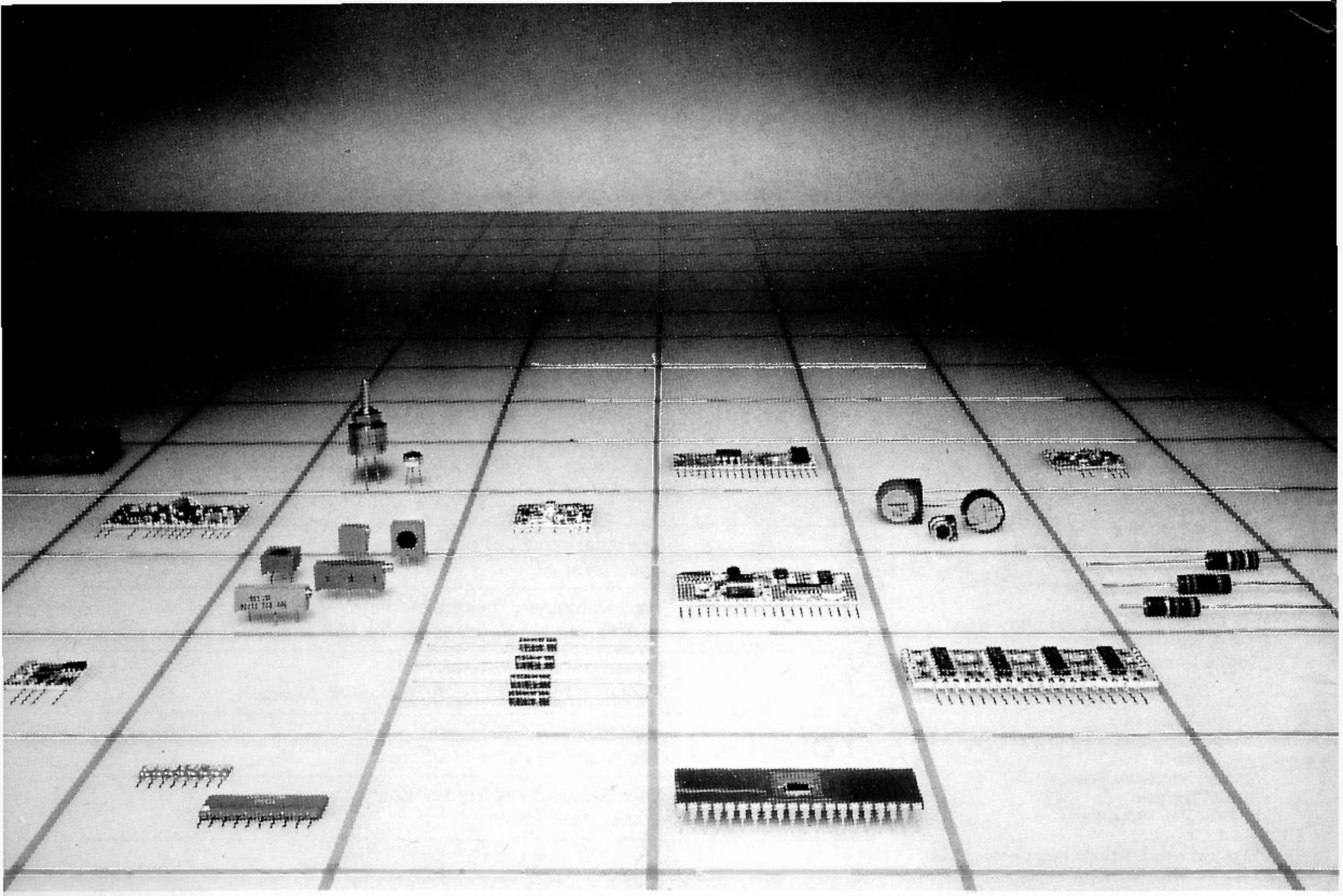
Cover photograph:
Detail from a striking exhibition of photographs of 17th Century Neapolitan paintings presented at CERN earlier this year. The exhibition was one of many activities of the Istituto Italiano per gli Studi Filosofici which cross the cultural boundries between the arts and science — see page 39. (Photo Mimmo lodice)



Industrial impact of particle physics

The aim of particle physics is to advance Man's knowledge of the structure of the Universe around him. However attention is turning increasingly to links between the Laboratory and the growth area of high technology. What is the natural timescale for 'spinoff'? Can it be accelerated?

It was Albert Einstein, perhaps the archetype of the idealistic scientist, who said, 'Concern for man himself and his fate must always form the chief interest of all technical endeavours, concern for the great unsolved problems of the organization of labour and the distribution of goods — in order that the creations of our minds shall be a blessing and not a curse to mankind. Never forget this in the midst of your diagrams and equations.'

Immediately after the Second World War, support for particle physics research was influenced by the involvement of scientists who had helped unlock the power of the nucleus. It was not politically easy to abandon support for those whose daily pursuit was the interrelationship of energy and matter.

This momentum has died away but the particle physicist can point to the tremendous wave of practical applications which has flowed from the increasing knowledge of the structure of matter. Previous generations of this research — atomic and nuclear as well as particle physics — have led to electronics, lasers, X-rays, isotopes, reactors, nuclear armaments,... all having a major influence on our daily lives. The accompanying technologies have led to advances in accelerators, superconductivity, cryogenics, magnets, radiofrequency, vacuum, particle detection... with applications in many other fields of science, in medicine and in industry. To pull out just one figure — two thousand five hundred linear accelerators are in operation in the world today. Less than one per cent of them are involved in particle physics research yet every one of them has emerged from the technology developed for particle physics research.

Case history — the UK

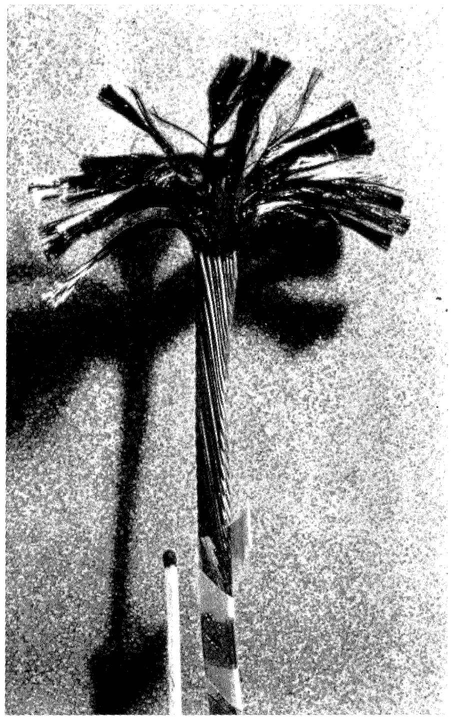
One of the events during this year's meeting of the British Association for the Advancement of Science held at Bristol University was a conference on 'High Energy Physics — Industry Link-up'. It was chaired by former CERN Research Director Ian Butterworth, with Brian Foster of the Wills Physics Laboratory as the main organizer. CERN set up a small exhibition on the theme of the conference in which UK firms also took part.

Martin Wood from Oxford Instruments emphasized the role of particle physics in rescuing superconducting magnet technology from its 'prolonged adolescence'. The potential in medical imaging, in power generation, in storage and transportation, in metal separation, for high speed trains, fusion devices, ultrafast computers... had been obvious for a long time. But it was the development of the superconducting bubble chamber magnet at Argonne and particularly of the 'Rutherford cable' (by the Rutherford Laboratory in collaboration with IMI) followed by the Tevatron work at Fermilab, that mastered the technological problems.

By now several cryogenic power generators in the megawatt range are under construction, a power storage system is funded in the USA, a levitated train is in operation in Japan, oil enrichment developments are underway. Oxford Instruments has been mainly concerned with the construction of superconducting magnets for medical diagnostics in NMR (nuclear magnetic resonance) scanners. This involves several hundred tons of superconducting material compared to the few tons involved up to now in particle research. Over 200 hospitals throughout the world are now equipped with NMR scanners and the potential world market is estimated at some $ 2000 million.

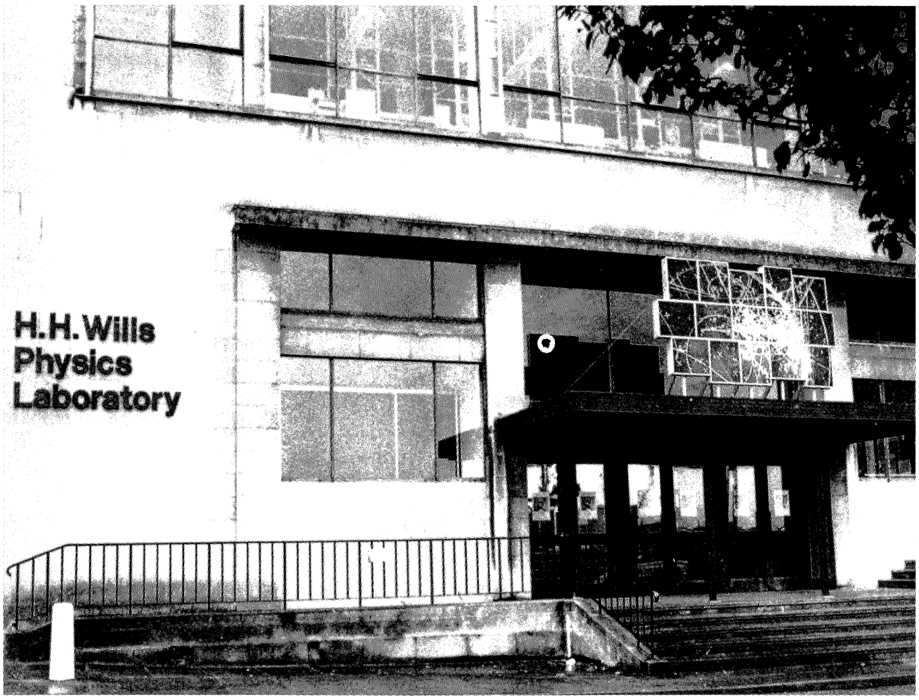
With most products stemming from particle physics Oxford Instruments now employs some 1300 people and had a turnover in 1985 of £ 55 million. One of its most interesting new products now under development is a very small superconducting electron synchrotron to serve as a synchrotron radiation source for semiconductor lithography.

The development of superconducting cable was a landmark spinoff from particle physics.



The Physics Building at Bristol University, UK, was the scene of a recent conference and exhibition on the high energy physics links with industry.

(Photo CERN 7.9.86)



John Wheatley of Tesla Engineering turned to conventional magnets where his company has had many contracts with CERN and other particle physics laboratories. He maintained that to remain competitive for such contracts a company had to sustain high standards and stay at the forefront of magnet technology (to give an example, the mechanical precision of fifty magnets being built for the University of Bonn is required to be within 0.05 mm). These requirements then made the company very competitive in other fields also. Tesla has now expanded into the space, defence, fusion reactor and medical fields. Other products are underwater sonic transducers, coils for NMR scanners, radiation shielded windows, etc.

To give an example of a direct spinoff from work on particle physics magnets — experience with high quality resin encapsulation of coils was applied to underwater instrumentation, with improvements on previously existing techniques.

From the medical imaging field, Alan Jeavons spoke on Oxford Positron Systems, a company set up to develop the HIDAC positron camera. This follows the invention of multiwire proportional chambers and drift chambers by Georges Charpak at CERN which were applied in collaboration with Geneva Hospital to the idea of localizing positron annihilation sites in the body by looking for the two gammas emerging back-to-back from the annihilation.

The camera is now giving remarkably clear images in brain, thyroid, bone and liver scans. Cameras have been ordered in Belgium, Germany, Switzerland and the USA. There is interest in their possible application in monitoring oil flow in engines.

From the golden days of bubble chamber physics, Peter Woodsford of the company Laser Scan described how film analysis techniques (specifically the Sweepnik method promoted by Otto Frisch) are now being used in a developed form as a high precision laser deflection system with large screen projection.

Applications are in security printing and particularly in cartography. Here the system follows lines on a map rather than bubble chamber tracks and a version called Fastrack has been of great help in converting existing archives into a form which can be stored in a computer. Also a version called Lasertrack has been sold to the USA Geographical Survey for computer-aided mapping. Public utilities mapping, terrain mapping, air traffic displays are all feasible. The company now employs 130 people and current developments include a laser-addressed liquid crystal system which would allow selective erasure in images.

Another product emerging from the techniques of bubble chamber film analysis (this time from the PEPR machine developed at Oxford) is a 'Robot Vision System' described by Peter Davey of Meta Machines. Working with Fujitsu they have built a laser-guided arc welding system which can correct the progress of a weld by recognizing the features of the desired structure and any deviations from it. The method of filtering out unwanted information is that used for bubble chamber pictures. The small company set up to develop the instrument achieves a million pound annual turnover after three years.

Colin Wilburn of Micron Semiconductors described progress in producing large area silicon detectors for precise position measurements for charged particles. The technique has proved so successful

for particle physics detectors that people talk of tons of such silicon units in future detectors. Now that the techniques of ion implantation using highest purity silicon have been perfected giving 5 to 500 micron channel separation on wafers 300 micron thick, applications in other fields are opening up. Thus a quarter of the present contracts of Micron Semiconductors are in defence and space applications.

In the accompanying exhibition there were other examples of successful transfer of particle physics technology. Nuclear Enterprises, a company of the Thorn-EMI Group, is a world leader in the supply of plastic scintillators and associated electronics. Products developed for particle physics are now used in the oil, food, steel, and coal industries, in medicine (health physics, environmental monitors, radiological instrumentation) and in power production.

GEC in collaboration with the Rutherford Laboratory has been working on CCDs (charged coupled devices) for particle detectors. This has reached very high precision in the location of charged particles or photons. Mosaics of a few hundred square centimetres have been built and give 5 micron precision. There is interest in their application in X-ray imaging astronomy, and in microfocus X-ray cameras in medicine and biology. They make it possible, for example, to X-ray down to single cell level.

More examples

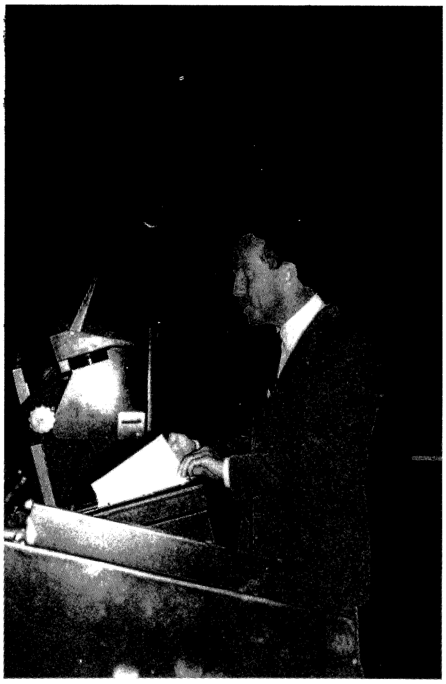
Also on show at Bristol was US instrumentation specialist LeCroy. This company has a tradition of work with particle physics Laboratories and has developed a range of high quality electronics. Its instruments such as waveform digitizers, modular transient recorders and digital storage oscilloscopes now find application in industrial and other scientific fields such as non-destructive testing, plasma research, laser work and medical diagnosis.

Almost concurrent with the Conference in Bristol, a seminar on 'Advanced Technology Arising from General Accelerator Physics' was held at Aarhus in Denmark in the context of the CERN Accelerator School. Here there were some dominant themes such as the exploitation of synchrotron radiation, but, as at Bristol, there was also an effort to focus on examples of companies who have developed from their association with particle physics.

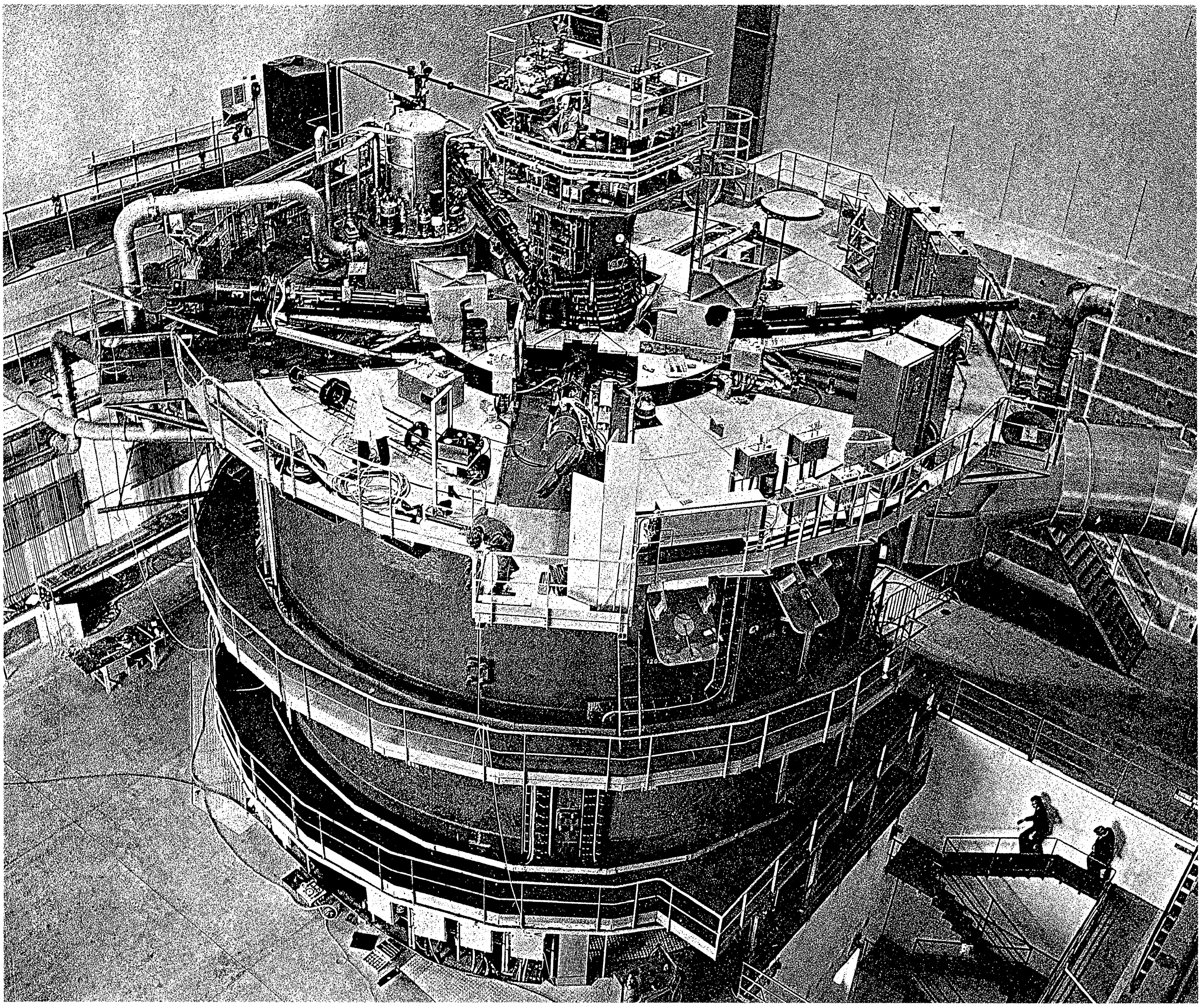
Norsk Data of Norway, one of the most successful European minicomputer manufacturers, acknowledges a great debt to its work with CERN on the SPS control system and beyond, in developing its know-how and establishing its reputation.

Interatom from West Germany built up its abilities and advanced equipment while working on accelerator radiofrequency cavities. Danfysik from Denmark has extended mechanical design work, initiated in work with particle physics laboratories, to applications in medical, fusion and coal, oil and gas industries. Scanditronix of Sweden specializes in accelerator design and production.

These are just a few examples of the strong links between particle physics and high technology. The list is growing fast.



Oscar Barbalat of CERN describes the advanced technology resulting from high energy physics at an Advanced Technology Seminar at Aarhus, Denmark, organized by Aarhus in the context of the CERN Accelerator School.



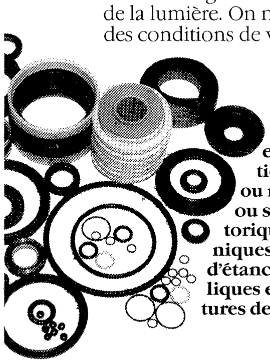
CERN Genève: BEBC. Grande chambre à bulles européenne. Dimensions du corps de la chambre: 3 m de hauteur, 3,7 m de diamètre intérieur, 39 000 litres de capacité.

Le plus petit de nos joints tient au moins 50 ans... et le plus grand résiste à un dosage d'irradiation 166666 fois supérieur à ce qu'un être humain peut supporter.

Au CERN, à Genève, on accélère des particules à charge électrique jusqu'à la vitesse de la lumière. On ne peut le faire que dans des conditions de vide poussé. Les joints d'étanchéité de 7 m de circonférence dont sont dotées les chambres doivent donc présenter une précision et une qualité de surface élevées. Afin qu'ils puissent résister à un dosage d'irradiation à haute charge énergétique représentant 166 666 fois ce qu'un être humain peut supporter, nous avons conçu, chez Maag Technic, un mélange de caoutchouc tout à fait particulier.

Bien sûr, nous n'avons pas à résoudre des problèmes aussi ardus tous les jours. Parfois, il s'agit «simplement» de minuscules joints d'étanchéité destinés à des arroseurs anti-incendie. Quoi qu'il en soit, chaque joint doit répondre à des impératifs plus ou moins grands. Vous en trouverez chez nous un vaste assortiment. En plus, vous pouvez compter, sans aucune contrainte matérielle, sur nos conseils fondés sur des années d'expérience portant sur tout le spectre de la technique.

Maag Technic se fait fort de résoudre vos problèmes de joints d'étanchéité.



Joints d'étanchéité normalisés ou sur mesure, en caoutchouc, en matière plastique, textiles ou métalliques, à l'amiante ou sans amiante, etc. Joints toriques. Garnitures mécaniques FLEXIBOX. Bagues d'étanchéité. Joints hydrauliques et pneumatiques. Garnitures de presse-étoupe.

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Supercomputers make their mark

Just before leaving CERN earlier this year to become Principal of London's Queen Mary College, Research Director Ian Butterworth described how what had once appeared a formidable objective for CERN's central computers now looks attainable, thanks to the power of 'supercomputers'.

Particle physics has always involved computing, largely because the underlying quantum mechanics makes statements about probabilities, implying statistical analysis of large data samples. But the amount of computing has markedly increased for a variety of reasons. Some of these result just from the general spread of computing: to design the complex electronics of modern detectors requires computer-aided design; even the mechanical design and assembly of large systems is best guided by computer; and now personal computers are helping in many aspects of modern life. However modern particle physics has its own special requirements.

First there is the growing complexity of large general-purpose detectors built up from a set of ten or so sub-detectors built and assembled world-wide. These have to be tested and operated autonomously with their own data acquisition systems, yet must work in harmony to form the complete detector. Such a detector can require read-out of 100 000 individual electronic channels.

Moreover the use of drift chambers or time projection chambers, where secondary electrons are drifted over some distance to a detecting element, requires time-slicing of the output signal so that even a single event can yield tens of Megabits of information.

The large and dispersed collaborations required to develop and use the detectors lead naturally to long-distance networking, just as the geographical scale of the accelerator makes advanced site-wide communications essential.

We see, with the four LEP experiments at CERN, the two for HERA at DESY in Hamburg, and the two at the Fermilab Tevatron, the shift to a small number of very large complex facilities involving extended collaborations.

Finally a significant contribution to the remarkable success of the physics programme at CERN's proton-antiproton Collider was the speed with which data could be analysed during initial runs — and that lesson has not been lost on the LEP experiments.

Computing for LEP experiments

At CERN a considerable effort has gone into developing a coherent strategy for computing up to and including exploitation of the new LEP electron-positron Collider, scheduled to become operational in 1988.

Realizing that it was neither possible nor desirable to do everything at CERN, the High Energy Physics Coordinating Committee has been established, consisting of Directors responsible for computing at various national centres, plus CERN and DESY, chaired by Walter Hoogland of NIKHEF (Amsterdam). That committee constantly struggles, as we have to individually, with the constant conflict between standardization of approach, necessary for efficiency

Ian Butterworth — thanks to supercomputers, a formidable objective looks attainable.

in international collaborations, and the use of the latest technology (particle physicists always demand the newest and best which has not had time to be standardized).

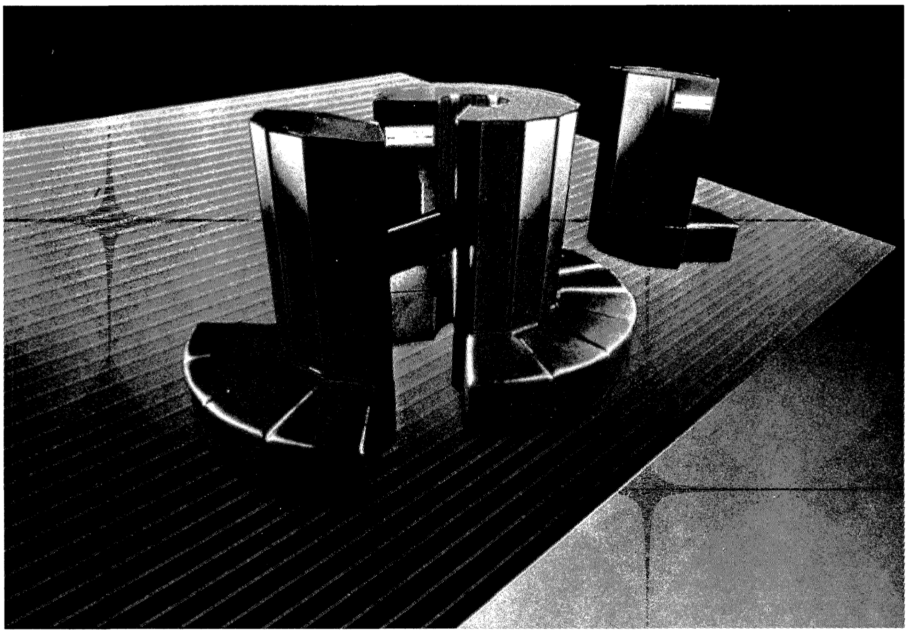
Within CERN we have set up MEDDLE (Meeting between Electronics and Data Division and LEP Experiments), at which representatives of the four experiments meet with those responsible for central services so as to establish norms and priorities. It has proved highly successful because although the four collaborations perhaps feel strong rivalry at the higher levels, when it comes down to data acquisition and analysis there is a great readiness to exchange ideas and share efforts.

One LEP event could involve tens of Megabits of information. Moreover the LEP beam bunches will collide in any detector at a rate of 50 kHz, every 20 microseconds. This demands a trigger system rejecting uninteresting events, recognizing interesting ones and doing the maximum of data selection and compacting on line.

Typically this involves a chain of successively more detailed decisions with a sequence of triggering levels. At the first level one must decide before the next beam collision, i.e. within 20 microseconds, if the event is potentially interesting. At the second level a more rigid selection uses the time-sliced readout of the detector elements where electrons drift for say 100 microseconds. Thus the events selected at the first level have to wait that long and so a few percent of beam crossings are wasted. At this stage something like the full data is available and so one can spend hundreds of milliseconds in something approaching the power of a mainframe computer to do a thorough, but not yet final, off-line analysis of the event, putting the data on tape at a rate of 1-2 Hz.

Such on-line data handling is possible thanks to a number of major recent developments:

- The availability of 32-bit microprocessors, permitting detectors to have hundreds of computing units;
- New bus systems to manipulate the data. Two new standards (VMEbus and FASTBUS) are in use for LEP experiments (together with slower bus systems linking less critical elements);
- Detector subsystems using separate superminis;
- Distributed intelligence has led to the use of a Local Area Network linking parts of the system, e.g. Ethernet;
- The use of emulators — purpose-built processors that emulate the instruction set of a mainframe computer (usually without its full complexity) — which can be used in the on-line event filtering at the deeper levels of selectivity. Clusters of commercial processors like micro-VAX may be used in the same way.



A Cray 'supercomputer' (Photo Cray Research)

Communications bring us to standardization. Eventually there should be agreed international protocols at all levels, from the basic physical transmission system to the highest level of message handling. In practice we need to communicate now, across a mass of incompatible networks, so we have to put considerable effort into 'gateways' — computer systems that permit different networks to communicate. The high energy physics community has considerable experience in communicating through heterogeneous systems, and its experts are in great demand in standardization discussions at the RARE organization (Réseaux Associés pour la Recherche Européenne), etc.

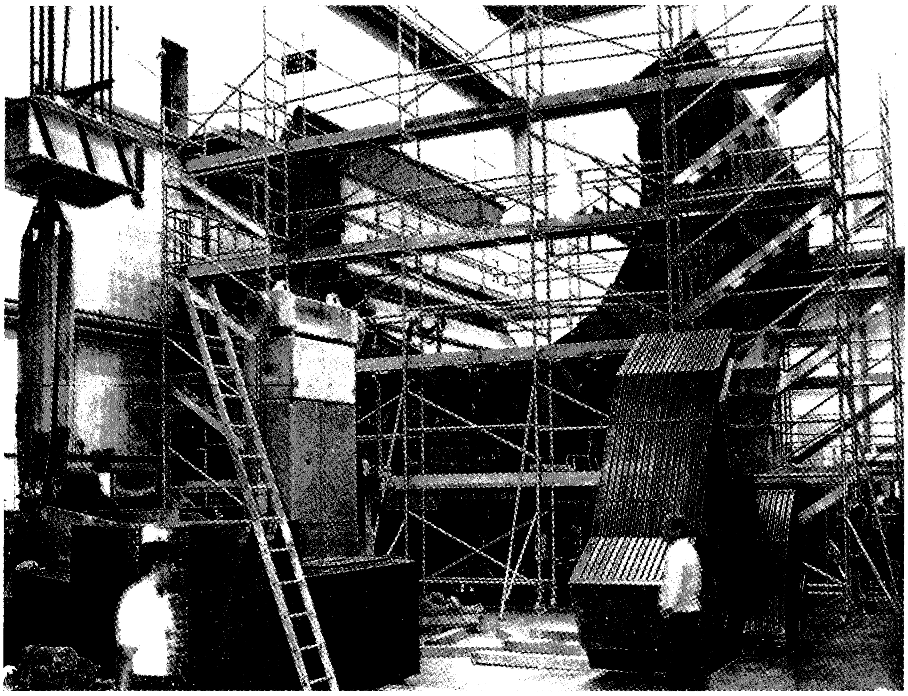
Central computing

We measure computing power, rather archaically, in units of 'IBM 168 equivalent'. Of course different computers do not necessarily have a simple constant relation one to another independent of the type of job, but this unit gives an approximate guide. It roughly corresponds to a Digital Equipment Corp. VAX 8600 or to 3-4 million instructions per second.

At the start of 1984 the LEP experiments decided that for full analyses of their data they needed on average 12 such units each. Moreover they argued that initially, say for two years, just as for the proton-antiproton Collider, virtually all the computing load would fall on the CERN centre. On the other hand LEP's beam intensity would presumably start low and so perhaps six units each would be good enough, with the additional workload from increasing beam intensity being taken up by computers at

Particle physics experiments are betting bigger and require more computing power: assembly of the hadron calorimeter mainframe for the ALEPH experiment at the LEP electron-positron Collider at CERN.

(Photo CERN 45.9.86)



home institutes. That makes 24 units. Including the rest of CERN, a total requirement for 1989 of 50-60 units is not implausible.

Early in1984 CERN's installed capacity amounted to 14.2 units, so an upgrading programme got underway, resulting in today's capacity of about 30 units.

For purely budgetary reasons CERN's rental agreement with Control Data Corp. has been terminated, with no replacement envisaged until the end of next year. Thus during 1987 computing power will be reduced by 25 per cent — regrettable but not too scientifically damaging, since antiproton operations are on 'hold' pending completion of the new ACOL antiproton collector.

The future

During the past decade, development work for extremely powerful and cost-effective computers has concentrated on new architectures. In place of 'scalar' processors, the emphasis has moved towards 'vector' and 'parallel' processors, commonly referred to as 'supercomputers'.

These machines are now in fairly widespread use in many branches of science. About 175 supercomputers have been installed worldwide, and a further 50 are on order; of the former, some 125 were supplied by Cray Research. More than a quarter of all supercomputers have been installed in Europe, and at least ten of these are in principle accessible to particle physicists. For example a Cray X-MP/48 has recently been ordered for installation at the Rutherford Appleton Laboratory in the UK.

In the USA, major programmes to provide access to supercomputers for the academic community are being implemented. The National Science Foundation has agreements with a number of institutes (Resource Centres) to provide supercomputer services to the research community. Some 500 scientists have already been trained in the use and applications of supercomputers at these centres.

In the past, the particle physics community has been relatively slow to show interest in supercomputers, principally because of the need for a high degree of portability of programmes. However this situation has started to change. The Central Design Group for the proposed US Superconducting Supercollider uses supercomputers for much of its design work. Vectorization of quark field calculations on lattices has improved performance by factors of ten or twenty compared with the traditional scalar algorithms. Techniques for vectorizing the simulation of particle interactions work 20 to 85 times faster.

But most significantly groups at Stanford and Florida State have reported very encouraging progress with the use of vector algorithms for pattern recognition in modern tracking chambers. Substantial improvements over the scalar performances have been quoted for some components of the pattern recognition process.

We therefore believe that, given time and a period of development, vector processing could lead to significant increases in computing power for experimental particle physics, and could provide sufficient capacity for the LEP experiments. In order to allow time for the LEP experiments to adapt to the opportunities opened up by vector processing, such a machine would have to be available at CERN no later than the end of 1987.

We set ourselves the initially daunting task of exploring whether, using essentially no more than the

resources released by cancelling the existing rental contract and despite high list prices, we could negotiate a contract for a supercomputer. Despite our trust in vectorization, we adopted a careful approach, demanding a good base of scalar power.

Cray Research has proposed a Cray X-MP/48 computer including 4 processors, 128 Mwords of backing memory, 8 Mwords of main memory, 10 Gbytes of disk storage accessed via 2 controllers and 8 drives, 4 interfaces to permit access from other computers at CERN, and 1 adapter to access on-line magnetic tapes.

Benchmark tests run by CERN have shown that this configuration has a scalar performance of 24 units. Significant extra capacity would be available following successful vectorization of programmes widely used at CERN.

In addition, CERN would have an option to exchange the X-MP/48 for a Cray-2 configuration which has a slightly lower scalar capacity, but a greater potential for gains from vectorization. This proposal was accepted in July, with installation at the end of 1987.

Thus by 1988 the installed capacity will be 48 scalar units, to which must be added whatever is the potential gain from vectorization, which I am convinced will be eventually very great. It would appear that we are able to satisfy the ravenous demands of the experimenters!

Moreover this solution represents excellent value for money — the overall CERN spending on computing, including accelerator controls etc., runs at a very constant 10 per cent of the materials budget. This results from the steady fall in costs of computing power, and the recognition by manufacturers of CERN as a 'shop window'. Within the limits of a tight budget, one can then be reasonably happy about the funding prospects for computing.

However I am left with two connected worries. Firstly the insufficiency of manpower we have in this area, for despite the very real growth in our reliance on computing and related technology there has not been a corresponding growth in the manpower we can allocate. Moreover it is an area where recruitment and staff retention is difficult.

Secondly it appears that while high energy physics once was the leading area in the use of computing, this is no longer true. It is not just that computer scientists look down on us for still using Fortran. For example it seems obvious that expert systems and artificial intelligence have great potential and will come to be regarded as essential for control of complex systems like accelerators and detectors. We have a small group of enthusiasts here, but the resources we can devote to this area and certainly our expertise are very limited. This is one of the reasons why we believe that there would be considerable benefits from increasing collaborative ventures with industry and other areas of science, with CERN playing the role of enlightened and demanding user. We have established a number of such collaborations, and are looking for more.

Stanford's new Collider

As the year draws towards a close, work for the new Stanford Linear Collider (SLC) approaches the culmination of seven years of careful planning, design, construction and testing.

If all goes according to plan, SLC should collide its first electrons and positrons at around 50 GeV per beam (possibly slightly lower) early next year. This means that SLC should steal a march on the new LEP electron-positron Collider being built at CERN, which will cover the same energy region.

However the 27 kilometre LEP ring will be a conventional machine using tried and tested techniques and should attain its designed performance levels relatively soon after turnon, scheduled for late 1988. SLC on the other hand is an experimental machine, probably demanding a lot of development work and fine tuning before design figures can be reached and then routinely maintained.

Stanford's plan is to use the Mark II detector, now rebuilt after service at lower energies, to exploit the initial physics from SLC. Meanwhile work goes on to prepare the new Stanford Large Detector, SLD, scheduled to be ready towards the end of 1988, about the same time as LEP is switched on at CERN.

First of its kind

From the scaling laws governing the construction of conventional circular machines, it is clear that sooner or later they will be priced out of the market. Towards the end of the seventies this motivated machine specialists to look for new alternatives for electron beams, which lose lots of energy when bent, and require much bigger machines than protons.

Thus the linear collider idea was launched — instead of a going round and round a circular racetrack, beams of particles would be accelerated in straight machines and fired at each other.

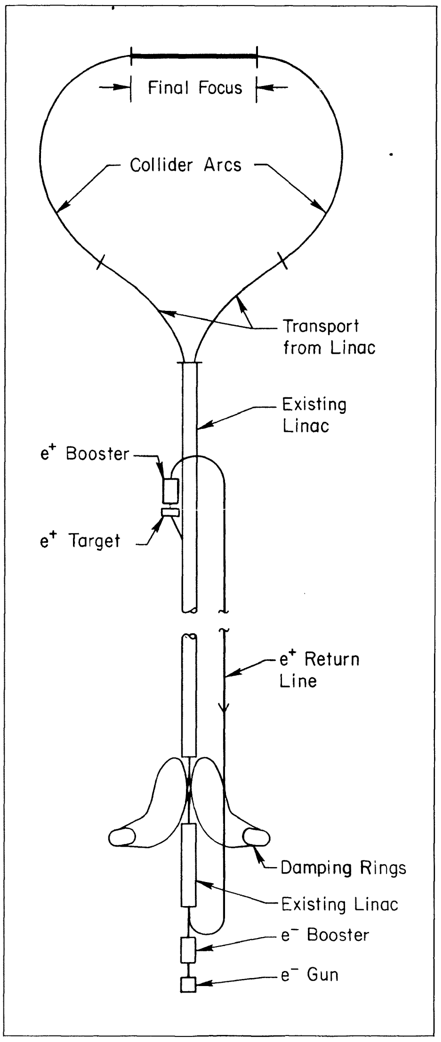
Stanford boasts the world's longest (3 kilometre) linear accelerator, providing beams of electrons. Rather than building a second linac to handle positrons, an ingenious scheme was developed to add a positron source and to accelerate both electrons and positrons down the same machine.

After emerging from the end of the main linac, the beams of electrons and positrons would initially diverge into long arcs, swinging round to collide once and once only at a final focus. This gives the now familiar 'banjo' shape of the SLC.

Although the new machine faced (and still faces) many formidable technical challenges, at least the funding road was less rocky than that of the previous big Stanford project — the PEP electron-positron storage ring.

The front end of the SLC consists of an electron gun and

Schematic layout of Stanford's new Linear Collider (SLC).



booster and the first of the 30 sectors of the main linac. Here a pair of electron bunches at about 200 MeV will be joined by a single bunch of 200 MeV positrons fed back from the positron source further down the linac. SLC positrons made their initial appearance several months ago, but then perversely went into hiding.

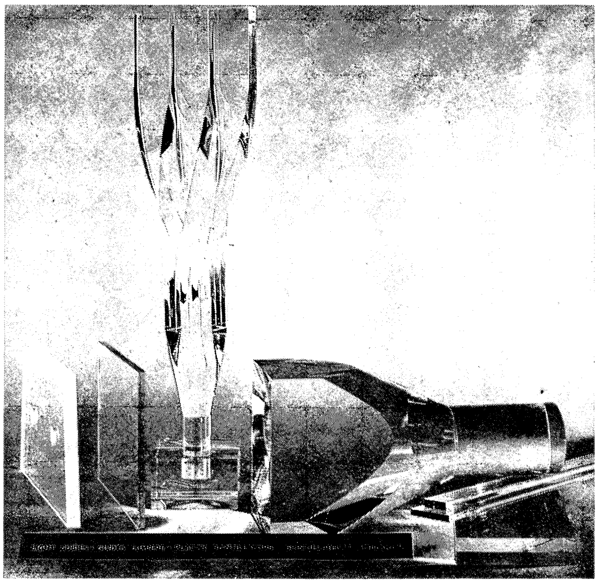
Sector 1 will take the three bunches to 1.21 GeV before passing them into damping rings on either side of the main linac. (The initial plan had been to place the two rings one on top of the other in the same vault, but this was dropped in favour of the two rings in separate vaults, one for electrons and the other for positrons.) The South ring (eventually for positrons) was run reasonably successfully several years ago, but was rebuilt to eliminate troublesome combined function magnets. The rebuilding is now complete, and beam should hopefully be reestablished soon. The North Ring (electrons) is running routinely.

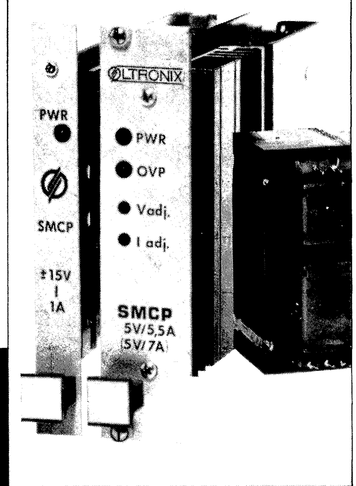
Downstream of the damping rings, the remaining 2900 metres of the linac must be powered by 240 50 MW klystrons to take the beams up to 50 GeV, with a focusing and guidance system using hundreds of quadrupoles and dipoles, now being put through its paces.

Experience has shown that the klystrons operate better at higher levels (60-70 MW) with a shorter pulse, however production proved to be a bottleneck. According to project director John Rees, one-off klystron production was no problem with Stanford's 'loving care', however mass production with all the problems of quality control was another matter. Not all the klystron sockets have to be filled to attain the goal of the Z particle (93 GeV collision energy). However there look to be enough klystrons available to approach design energy.

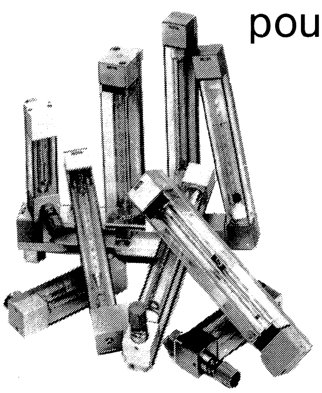
The ambitious project has also revealed unsuspected weaknesses in the main linac, constructed with different criteria over twenty years ago, however beam positioning work is making steady progress.

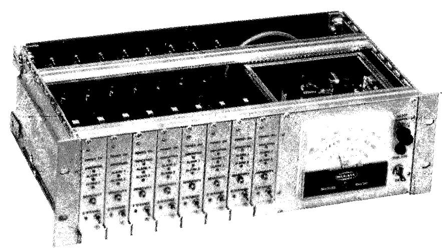
Totally new are the two arcs, requiring some 900 strong focusing, small aperture magnets to contain the tiny beams. The final touches to the colliding beams will be provided by a focusing system extending for 500 feet on either



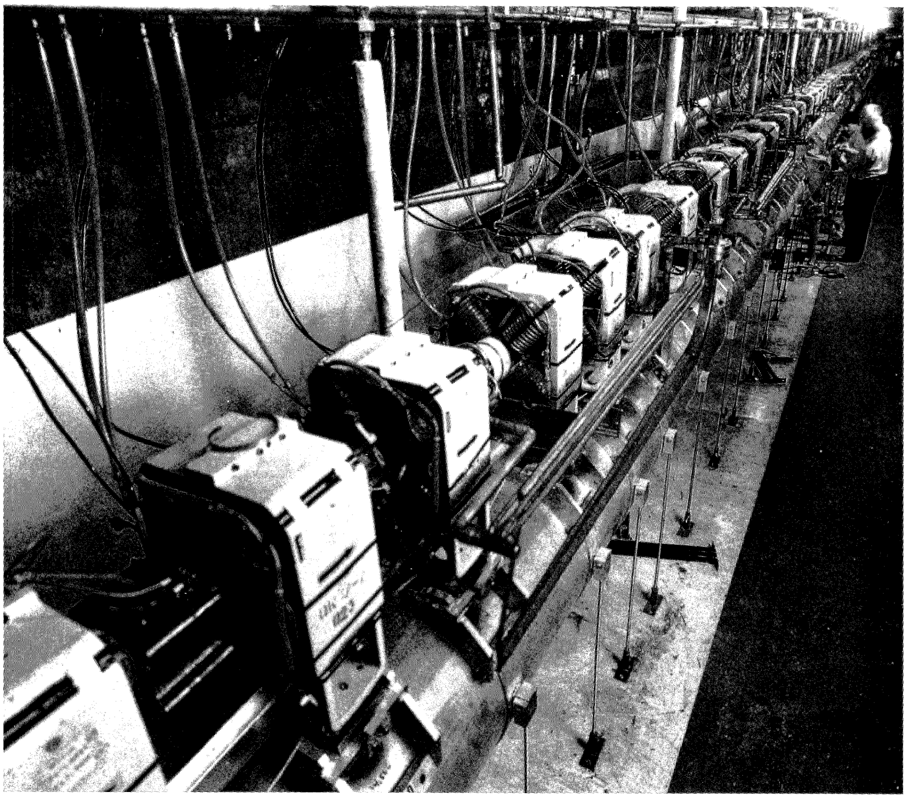


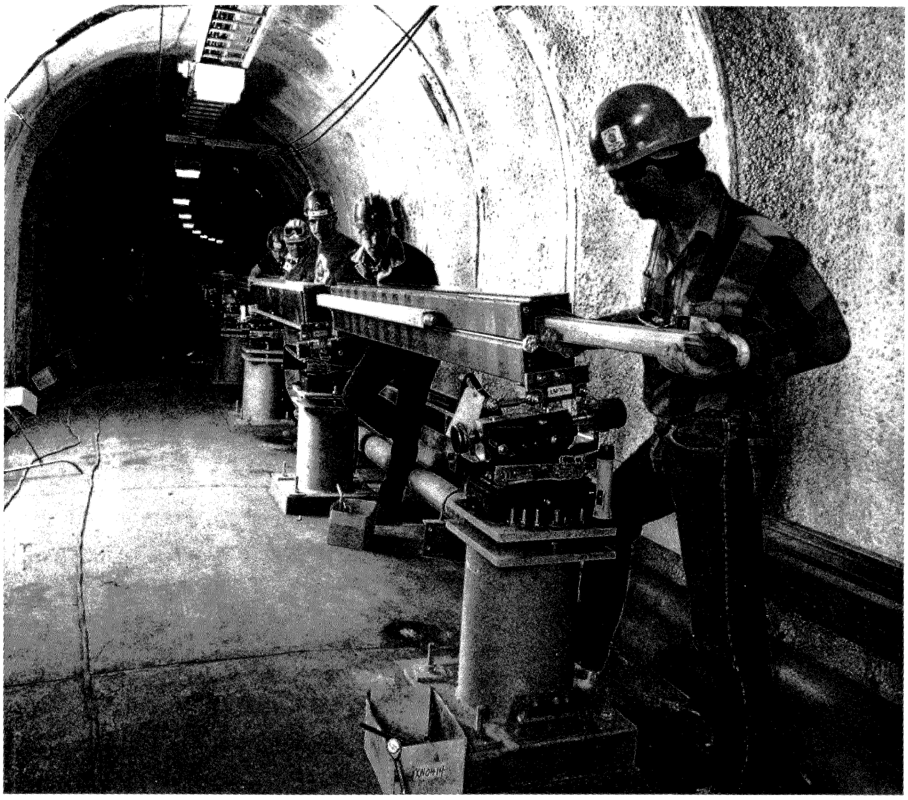
PWR
SMCP
±15V
1A
OLTRONIX
PWR
OVP
Vadj.
I adj.
SMCP
5V/5,5A
5V/7A





A view along the main Stanford linac, showing the new external focusing system.





side of the collision point. Here the beams will be compressed into a pencil several microns across, steered into collision with each other, and the distorted emerging beams led off into dumps on either side.

To house experiments, an experimental hall 56 feet deep, 65 feet across and 233 feet long has been built straddling the point where the electron and positron beams will collide 38 feet below ground.

Detective work

First SLC physics will come from the Mark II detector, substantially rebuilt after a long career first at the SPEAR electron-positron ring, then at the higher energies of the larger PEP ring.

Previously a 50-strong SLAC/ Berkeley collaboration, the Mark II project has grown to involve 120 physicists also from Hawaii, Santa Cruz, Caltech, Michigan, Indiana, Johns Hopkins and Colorado.

All that remains of the original Mark II is the iron, the liquid argon electromagnetic shower counter and the muon proportional tubes.

The main change is the new 72 layer drift chamber, replacing the old 16 layer chamber which was beginning to show its age. In addition, the new-look Mark II hopes pick up 30 micron detail with a precision drift chamber around the collision point. A simpler version used for PEP running got down to 100 microns. The electromagnetic energy coverage has also been improved.

Installation work underway for the arcs which will take the particles towards the collision point.

(Photos Joe Faust)

Important initial Mark II physics objectives are to pin down the exact parameters of the Z particle (the carrier of the electrically neutral part of the weak nuclear force). Precision measurements around the Z will help improve limits on the possible number of neutrino types. A search for the sixth ('top') quark is also high on the agenda.

The plans for the bigger SLD detector only began to take shape a few years ago. This comprehensive instrument (see October 1984 issue, page 325) includes hadronic energy measurement (calorimetry).

Preassembly and magnet measurements are scheduled for next year. Interesting features of the new detector include the use of charge-coupled devices (CCDs) around the beam pipe for picking up short tracks and the CRID/RICH ring imaging Cherenkov. A lead/liquid argon composition has been adopted for calorimetry (energy deposition measurement — see June issue, page 21).

With five or more milliseconds between SLC pulses, experiments should have plenty of time for sophisticated triggers and on-line data handling to sort out interesting data before new information arrives, however CCD readout might require more time.

By packing in more klystrons, SLC's energy could be pushed as high as 140 GeV or so, but some eyes at Stanford are already scanning more distant horizons.

By Gordon Fraser

Supercollider at Snowmass

While the proposed US Superconducting Supercollider — SSC, an 85 kilometre ring to provide 20 000 GeV (20 TeV) proton beams — waits hopefully for the go-ahead, the US physics community is preparing for life at the supercollider.

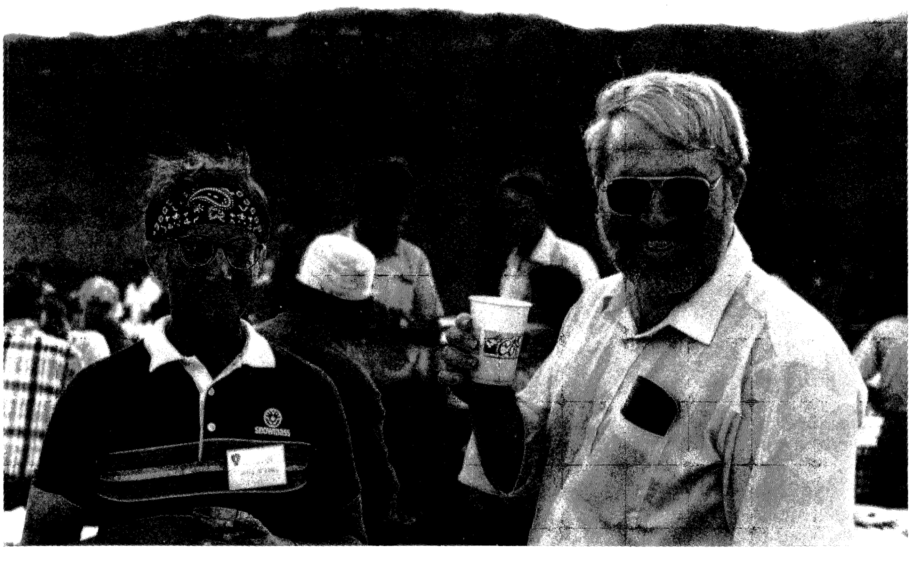
A Summer Study on SSC physics was held at Snowmass Village, Colorado, this summer. Successor to similar workshops held in 1982 and 1984, this year's study was organized by Lee Pondrom of Wisconsin under the sponsorship of the Division of Particles and Fields (DPF) of the American Physical Society, and was attended by over 250 physicists from 61 US organizations and 25 overseas institutions.

The principal goal was the critical evaluation of all aspects of the SSC, in the light of the recently submitted Conceptual Design Report (CDR — see July/August issue, page 12), and of progress in accelerator technology, collider physics, and instrumentation.

Working Groups

To achieve this goal, the Summer Study was organized into four principal working groups: Accelerator Physics, concerned with the storage ring complex itself, organized by Alex Dragt of Maryland; Physics and Monte Carlo Studies, looking at processes of likely interest at 40 TeV, organized by Gordon Kane of Michigan and Thomas Gottschalk, California Institute of Technology; Instrumentation and Detectors, organized by H. H. Williams of Pennsylvania, and Nonaccelerator Physics, such as proton decay searches, cosmic ray phenomena, or detection of solar neutrinos, organized by David Ayres of Argonne.

The Accelerator Physics working group concluded that overall, the SSC conceptual design withstood scrutiny and rated high marks. The primary design goal is to achieve 20 TeV proton on proton collisions (40 TeV total energy) at a high rate



Relaxing at the recent Summer Study on the proposed US Superconducting Supercollider (SSC) held at Snowmass, Colorado — Study Organizer Lee Pondrom of Wisconsin (left) and Murdock Gilchriese of Cornell and the SSC Central Design Group.

(Photos Esther Wojcicki)

(luminosity $10^{33}/cm^2$). Considerable attention has been given to the aperture used in the conceptual design. A detailed examination of linear and dynamic apertures concluded that conditions needed for a luminosity of 10^{33} are achievable. Considerable effort was also devoted to the analysis of methods for compensation of magnet errors, with the aim of most cheaply increasing the dynamic aperture; in particular, changes in the design to permit the incorporation of local corrections were suggested. Continued analysis should give more detailed answers on the aperture and long-term stability issues than are contained in the CDR; however no drastic changes from the CDR are anticipated.

The Accelerator Physics group also studied the layout of test beams, and particularly the key issue of the design of the proton beam interaction regions. The major proposal to emerge from Snowmass was a relatively small bypass to accommodate the interaction regions. This would require a small enlargement of the main ring, and the addition of the bypass tunnel and its components, but it would greatly add to the accelerator's flexibility. By permitting the assembly of ciritical components of large detectors on the spot, it would make possible future development without long interruptions in the physics programme. A bypass could also provide a long straight section for detectors to study the physics of softer collision processes.

The Physics and Monte Carlo, Instrumentation and Detectors, and Nonaccelerator Physics working groups looked at a range of related questions. What are the best signatures, and the relevant backgrounds, for SSC experiments? What requirements do the physics and the high design luminosity impose on detector design? How can non-accelerator physics experiments complement the SSC programme?

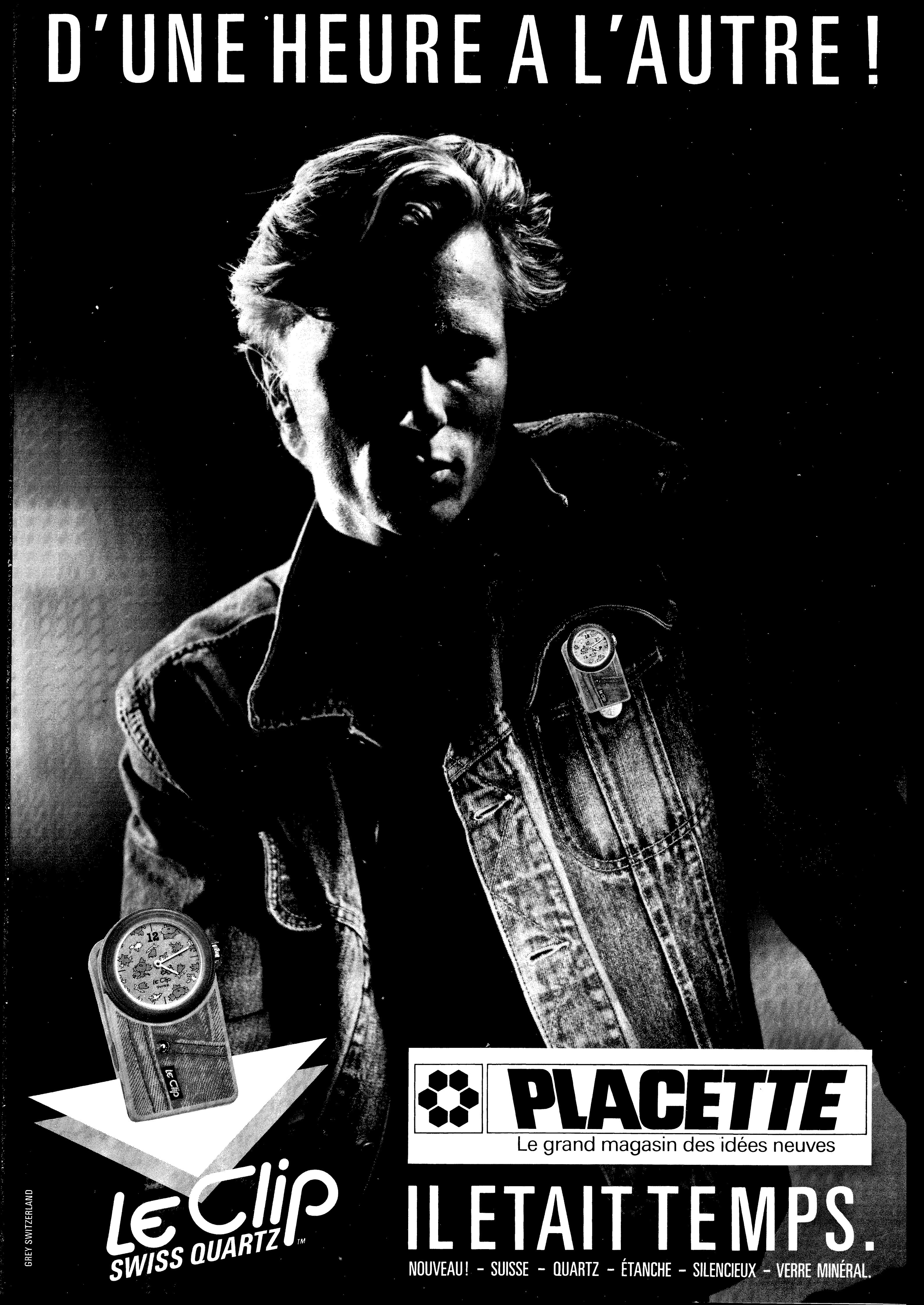
The Physics and Monte Carlo discussions took place in a context set by two previous workshops, one at UCLA in January, dealing with standard model physics, and one at Wisconsin, Madison, in April dealing with new physics. As compared with two years ago, Snowmass 86 found improved simulation techniques, improved knowledge of the quark structure of nuclei, etc.

The Instrumentation and Detectors working group reported encouraging progress towards the design of detectors covering the full solid angle and capable of working at the SSC design luminosity. The prospects for muon detection look very good, and the problems associated with silicon chip microvertex detectors, and with the needed electronics and triggering, appear solvable. Electron identification is likely to achieve good pion rejection, and high quality calorimetry should be feasible using a uranium/lead and liquid argon combination (see June issue, page 21).

In addition to considering detector components, layout studies were done for two overall detector designs. These studies indicate that the muon system should be built in place and that strong consideration should also be given to building the central detector in the interaction hall, thus eliminating the need for an extensive underground assembly area.

The Nonaccelerator Physics working group reported a number of interesting new developments in cosmic ray and neutrino physics, and in proton decay and monopole search experiments. Also discussed were solid state detectors for neutrinos and other candidates

At Snowmass, an enthralled audience watches Jon Rosner of Chicago use a plastic bag to demonstrate the implications of superstrings.


D'UNE HEURE A L'AUTRE !
PLACETTE
Le grand magasin des idées neuves
IL ETAIT TEMPS.
NOUVEAU! - SUISSE - QUARTZ - ÉTANCHE - SILENCIEUX - VERRE MINÉRAL.
Le Clip
SWISS QUARTZ ™
GREY SWITZERLAND

for the invisible 'dark matter' of the Universe.

Town Meetings

Ancillary activities at Snowmass included two 'Town Meetings' to discuss matters of general high energy physics interest. One was devoted to SSC detector issues and the other concentrated on the establishment of an SSC Users Organization.

Three related topics were discussed at the Town Meeting on detectors: i) the continuation of the work begun at Snowmass to prepare an SSC detector reference design study; ii) the R & D work to prepare for SSC detectors; and iii) the organization of the large collaborations required to construct and operate the SSC detectors.

There was a general consensus to continue the Snowmass work on a detector reference design study, and a task force of Snowmass participants plus other interested parties should be formed with the goal of preparing a Detector Reference Design Study.

It was also clear that much SSC detector R & D needs to be done, that this should be international in scope, and that a central coordinating office should be established to ensure that critical questions are answered in time. Normal channels for funding detector R & D would continue, and university groups would play a crucial role in SSC detector R & D projects.

An ad hoc committee was set up to prepare a specific proposal for an administrative structure to accomplish the necessary SSC detector R & D. Members were Y. Nagashima, Osaka; L. Pondrom, Wisconsin; R. Schwitters, Harvard; G. Trilling, Berkeley; and H. H. Williams, Pennsylvania; M. Gilchriese, M. Tigner, and S. Wojcicki from the SSC Central Design Group (CDG) were members ex officio. In the suggested proposal a coordinator for detector R & D would be appointed within the CDG. An international advisory committee would be appointed to assist the coordinator and to keep the R & D programme abreast of world-wide activities. This proposal is now being refined for presentation to the CDG Board of Overseers at their November meeting.

The discussion regarding the formation of experimental groups and the handling of proposals was more diffuse, partly because of the longer timescale involved. However it was recognized that experiments at the SSC will be much larger than those at fixed-target machines. In addition, since the SSC will be the biggest high energy research facility in the world, it will necessarily have considerable impact on the sociology, funding and training of graduate students, and many other aspects of life in the physics community. The creation of SSC detector groups will no doubt be the subject of future meetings.

The second Town Meeting looked at the establishment of an SSC Users Organization. In 1985 an ad hoc committee was appointed to consider the formation of such a Users Organization and to draft a constitution. The community at Snowmass underlined the need for such an organization with a broadly based international membership. An American Physical Society committee will draw up necessary plans and will appoint a nominating committee to propose candidate officers in the user organization. It is anticipated that the first elections will be held in the spring of 1987.

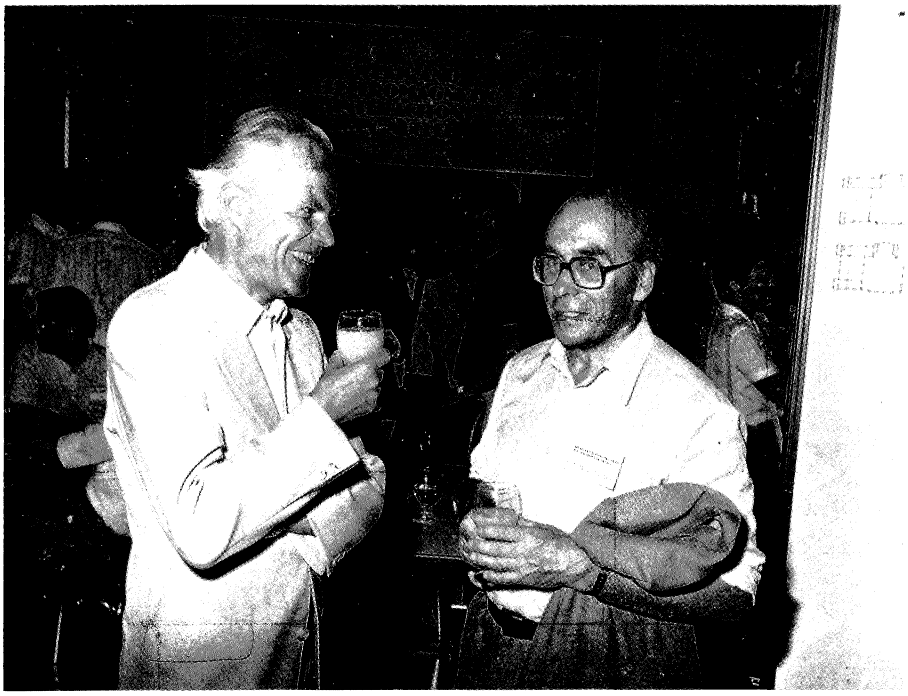
Altogether, the Snowmass meetings did much to pave the way for the SSC.

New perspectives from nuclear physics

Connections between nuclear physics and neighbouring disciplines of elementary particle physics, astrophysics and cosmology were emphasized at the International Symposium on Weak and Electromagnetic Interactions in Nuclei held in Heidelberg this summer in conjunction with the 600th anniversary of the University of Heidelberg.

The meeting reflected the new trend in nuclear physics towards fundamental physics questions. Important subjects included the roles of the neutrino and of proton decay and their deep implications. Low energy experiments become very important for testing beyond today's standard model: the search for neutrino masses by endpoint spectroscopy, neutrinoless double beta decay, neutrino oscillations, neutrino decays, and rare and forbidden muon decays.

Rudolf Mössbauer (left) from Munich and Vladimir Lobashev from Moscow at the recent International Symposium on Weak and Electromagnetic Interactions in Nuclei, held in Heidelberg.



These experiments are complementary to direct searches for new particles and symmetries in high energy experiments.

About 300 participants from all over the world attended the meeting, sponsored by the International Union of Pure and Applied Physics, and the European Physical Society. Chairman of the meeting, held under the patronage of the Rector of the University, Gisbert zu Putlitz, was Hans Volker Klapdor from the Max-Planck-Institut für Kernphysik in Heidelberg.

Neutrinos

Major contributions in the neutrino sector included new limits on the neutrino mass from the beta decay of tritium (see October issue, page 4) and from double beta decay, where measurement of the half-life allows extraction of the neutrino mass by comparison with a calculation of the lifetime. The most active groups in this field reported their results, among them Hiroyasu Ejiri from Osaka, Frank T. Avignone from Columbia, Enrico Bellotti from Milano, A. Morales from Zaragoza and the Santa Barbara group.

H. V. Klapdor from Heidelberg reported that a collaboration of Heidelberg, Leningrad, Moscow and Bordeaux groups plans to improve the limit on the half-life for neutrinoless double beta decay of germanium 76 by about an order of magnitude. They will use detectors made of enriched germanium 76 (provided by Soviet scientists) inside a well-shielded cavity. Germanium 76 provides a limit of 1 electronvolt for the electron neutrino's mass.

Of particular interest are also the investigations of transitions to excited states in germanium 76 by the Osaka group, which provide interesting contrasts to the ground state transitions.

Important constraints for the neutrino mass are provided by nuclear reactions. Measurements of charge exchange reactions help infer the efficiency of solar neutrino detectors such as those using gallium. Important data is being provided by Richard Madey's group from Kent State University working at the Indiana University Cyclotron.

Muon physics

The question of muon-to-electron conversion is as old as the muon itself. When it was realized that the muon does not decay into electron and photon, the concept of separately conserved muonic and electronic lepton numbers was introduced as an ad hoc hypothesis. Recently this question has assumed additional importance because of its implications for extensions of the standard model.

Pierre Depommier from Montreal reported from the TRIUMF Canadian meson facility a preliminary upper limit for the branching ratio of muon-to-electron conversion to total muon capture of less than 4×10^{-12}. Roland Engfer and Richard Mischke reported the status of the SIN (Switzerland) and Los Alamos experiments. Theoretical aspects of muon-electron conversion in the presence of nuclei and complementary aspects of neutrinoless double beta decay were discussed by John Vergados from Ioannina.

Grand unification and superstrings

Ling-Lie Chau from Davis/California and Klaus Schubert from Heidelberg reported the status of electroweak gauge theories and in particular quark mixing in weak interactions. Today's results sug-

Left to right: Peter Brix, Senior Director of Heidelberg's Max-Planck-Institut für Kernphysik, Gisbert zu Putlitz, Rector of Heidelberg University, and Symposium Chairman Hans Volker Klapdor toast a successful conference.

(Photos Schloss-Photo Heidelberg)

gest that either there is no fourth family of quarks or its mixing with the known three families is very weak. Since subtle radiative electroweak corrections are important for the interpretation of experimental results, there is no indication for neutral gauge bosons other than the photon and Z^o.

Paul Langacker from Philadelphia and Norbert Dragon from Hanover discussed Grand Unification Theories (GUTs) and supersymmetry models which would accommodate today's limits on the proton lifetime. Extensions of the standard model were discussed by Roberto Peccei from DESY. It is possible to envisage models in which apparently disconnected phenomena, like small neutrino masses, invisible axions and the universe's baryon asymmetry, have a common origin. This suggests again that besides exploring the high energy frontier it is worthwhile to look for subtle effects in low energy experiments.

Jean-Pierre Derendinger from Paris stated that there are no simple GUTs below the Planck mass of 10^{19} GeV (when gravitation and electromagnetic interactions become comparable). At energies beyond this level superstring theories could lead to GUTs. Quantum number violation in superstring models was discussed by Quaisar Shafi from Delaware.

Dark matter and the early Universe

In the most current models of the Universe only 10 per cent of its mass consists of nucleons. According to David Schramm (Chicago), neutrinos are the best candidates for the mysterious dark matter interacting only feebly with the rest of the Universe.

Although there is not yet a fully consistent picture of 'inflationary' expansion in the early cosmos, conference speaker Robert Brandenberger from Cambridge suggested that the mechanism provides the most natural explanations for the observed isotropy of the 3K microwave background radiation, the flatness of space and for the elimination of 'unwanted' particles.

There seems to be increasing evidence that the universe is older than 15 billion years. Gustav Tammann from Basel reported 18 ± 3 billion years from globular clusters,consistent with the recent Heidelberg figure of about 20 billion years from cosmochronometers. As pointed out by Wolfgang Priester's group from Bonn and by Klapdor's group, this would indicate a nonvanishing cosmological constant (source of vacuum energy density) for values of the Hubble constant (which gives the observed rate of expansion of the universe) greater than 45 km Megaparsec^{-1} sec^{-1}. The energy density of the vacuum corresponding to a positive value of the cosmological constant could lead to a quite different solution of the dark matter problem.

Input from nuclear physics experiments is providing new limits on the existence (or non-existence) of possible new particles, such as the short-lived 'axion'.

Results for the electric dipole moment of the neutron were reported by Norman Ramsey from Harvard and Vladimir Lobashev from Moscow. The latest value is measuring down to $(-1.8 \pm 2.9) \times 10^{-25}$ cm, equivalent to enlarging the neutron to the size of the earth and observing that the radius of the charge distribution at the pole would differ from that at the equator by only 0.01 mm!

Initial results were reported from Ernst Otten's group in Mainz on the measurement of quasi-elastic electron scattering in beryllium 9. Together with other results this experiment yields new sharper limits for the coupling of weak neutral hadronic currents.

John Sharpey-Schafer and his group from Liverpool working at Daresbury reported a measurement of the highest spin seen in an atomic nucleus. A spin of 60, about 20 units higher than previous observations, was discovered in a superdeformed rotational band of dysprosium 152.

Exotic nuclei and astrophysics

Considerable progress is being made in investigations of nuclei far from stability. This is the conclusion from reports by Alex Mueller and Jean-Pierre Dufour from GANIL (Caen), Alexander Bykov from Gatchina (Leningrad), Richard W. Hoff from Livermore, Otto Klepper from GSI (Darmstadt) and others. The new information is of great importance for theories of inaccessible nuclei, required for understanding element synthesis in the Universe and for deducing the age of our galaxy from cosmochronometers.

The decisive role of nuclear electron capture at several stages of the evolution of massive stars was reported by Jochen Wambach from Urbana. Electron capture on the iron group nuclei in the core partly triggers the gravitational collapse of (Type II) supernova progenitors once the conditions are right. Also hydrodynamical shock propagation in the post-bound phase and 'delayed' explosions depend on the neutrino luminosity behind the shock, which is governed by capture in the core. How the weak interaction controls the early life of a neutron star was discussed also by Adam Burrows from Stony Brook.

Properties of nuclear matter influence stellar evolution. A new equation of state for nuclear matter at high density was used by Sid Kahana and collaborators from Brookhaven in hydrodynamical simulations of stellar collapse. These calculations are the first to produce a prompt shock-explosive mechanism for type II supernovae using realistic evolutionary supernova models — those of Weaver and Woosley from Livermore with 12 and 15 solar masses.

The new breakthrough is achieved by theoretically altering the experimentally rather uncertain equation of state for nuclear matter at high density, in the direction of softening of high density matter, and by the introduction of relativistic gravitation into the collapse phase. Both lead to an increase of the energy initially pumped into the shock. This result is important also for the understanding of the synthesis of heavy elements in the Universe by the rapid neutron capture process in explosive helium-burning.

The participants were stimulated by the fruitful interactions at this interdisciplinary conference and several countries expressed their interest in hosting a similar conference in 1989. This year's proceedings will be published by Springer-Verlag.

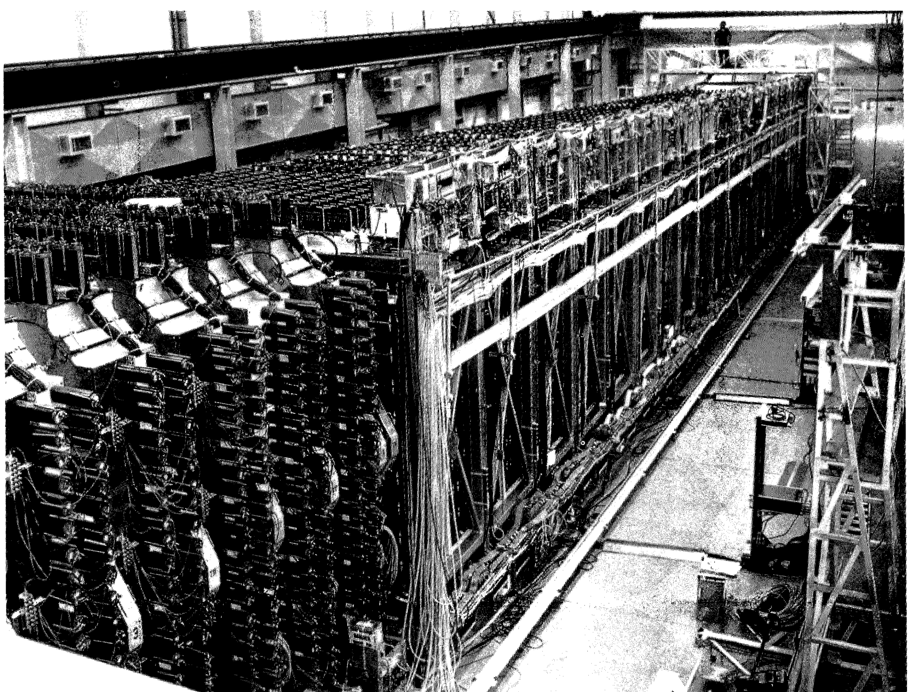
From Hans Volker Klapdor.

Around the Laboratories

CERN
Neutrinos back in town

In September the high energy neutrino beam from the SPS Super Proton Synchrotron was back in business for the first time in two years.

In 1984, there were two big electronic counter experiments catching the neutrinos in the West Area — the WA1 CERN / Dortmund / Heidelberg / Saclay collaboration, followed by the CHARM (CERN / Hamburg / Amsterdam / Rome / Moscow) detector — with the big BEBC bubble chamber downstream. Their work done, the big detectors are no more, but the strong CERN tradition of preci-



Looking upstream at the CHARM II detector now studying the rare but informative interactions of neutrinos with electrons at CERN. The high energy neutrinos first encounter the 36 metre modular target calorimeter equipped with scintillators and drift tubes. Downstream (left) is the muon spectrometer inherited from a previous neutrino experiment (WA 1 — CERN / Dortmund / Heidelberg / Saclay).
(Photo CERN 7.7.86)

Stopping antiprotons

On 23 August, the healthy stack of antimatter in CERN's Antiproton Accumulator AA was ceremonially destroyed, marking the end of an era for the AA, which for six years has provided the CERN machines with antiprotons and has helped propel this research into the forefront of world science. Now begins a one-year antiproton pause to construct the new ACOL Antiproton Collector. From next year, ACOL and AA will work in tandem to provide the CERN machines with more antiprotons than ever.

Earlier, a Washington/Mainz/Fermilab team working at CERN's LEAR Low Energy Antiproton Ring tried to bring antiprotons to a complete stop in their own way. Particles slowed down in LEAR to 21 MeV were further decelerated to 1 keV. These unhurried particles were snared for up to several minutes in the electric and magnetic fields of a Penning trap. When antiproton activities resume at CERN next year, the team hopes to capture the particles for even longer and to make a precision comparison of the masses of the proton and its antiparticle.

sion neutrino studies continues with the CHARM II study, now taking its first data. (Although the Amsterdam contingent from the original CHARM team has been replaced by Naples, Brussels, Louvain and Munich, the handy acronym sticks!)

Drawing on CHARM experience, the new detector uses a total of 155 232 plastic streamer tubes, grouped into 420 modules consisting of a glass target 3.7 m square and 48 mm thick, followed by a plane of 352 streamer tubes. Equipped with digital readout, the streamer tubes measure the position of the neutrino interactions and their subsequent development.

The 36 metres of detector instrumented with streamer tubes is followed by a 9 metre-long spectrometer to track muons emerging from (charged current) neutrino interactions.

Occasionally the incoming neutrinos hit atomic electrons rather than the relatively huge nuclei. These electron interactions are very 'clean' and provided enough can be found, make excellent precision measurements of the parameters of the underlying electroweak theory. CHARM I provided most of the world's stock of electron-neutrino scattering data (200 events), but its successor hopes to boost these relatively meagre statistics tenfold.

Precision measurements of the electroweak parameters provide insights into theories encompassing the electroweak picture. For example results from CHARM I on neutrinos scattering on nucleons give a value for the electroweak mixing parameter (the 'Weinberg angle') which favours supersymmetry as the larger theory, rather than the combined (SU5) symmetry of the electroweak picture with quark/gluon field theory. However these measurements use neutrino interactions with quarks in nuclei, difficult to interpret because of the many unknown quark quantities entering the calculations. On the other hand all the quantities in electron-neutrino scattering are known.

To feed CHARM II, CERN's neutrino beam has been rebuilt to provide more particles.

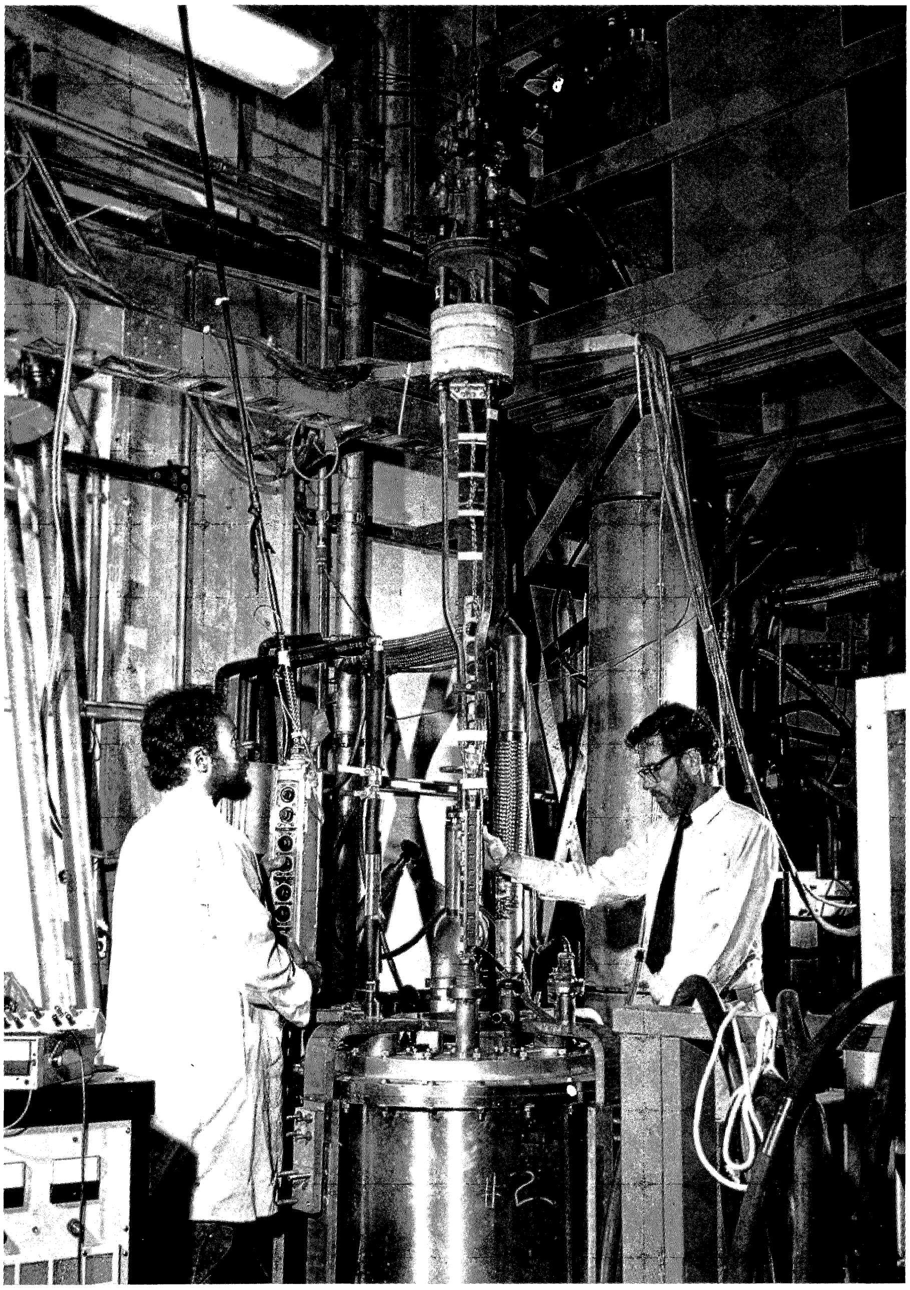
DESY HERA progress

On 10 September, drilling of the second quadrant of the 6.3 km tunnel for the HERA electron-proton collider at the DESY Laboratory in Hamburg was completed. Work is now nearing the deepest part of the ring, 23 metres below the surface and 12 metres below groundwater level. The watertight connection to the North Hall has been successfully completed.

Meanwhile installation of the first quadrant of the ring between the South and West Halls is progressing well. The first of four 'HERA trams' for transporting equipment and components in the tunnel — including the 12-metre electron ring modules — has been delivered.

The tunnels connecting the PETRA storage ring (which will be used as injector for both protons and electrons) with HERA are being constructed. All civil engineering work is scheduled to be finished this year. The main components of the HERA cryogenic plant are also being tested.

Series production of the modular magnet system for the electron ring has started and the 12-metre



Superconducting cable for the magnets of the HERA electron-proton Collider at DESY in Hamburg being tested at Brookhaven in the US. This work is something of a Brookhaven speciality. Meyer Garber (right) who supervises HERA wire and cable measurements at Brookhaven is seen here with Joe d'Ambra lowering a cable test probe into a dewar containing a 1 metre dipole magnet.

(Photo Brookhaven)

modules should continue to arrive at DESY at the rate of several per week. Each module includes a 9-metre conventional dipole magnet providing a field of 1850 Gauss and will also support the required quadrupoles, sextupoles and correction coils.

The fourth 9-metre superconducting dipole magnet has been delivered for the HERA proton ring. It was wound and collared at DESY and mounted in an iron yoke and cryostat at Brown Boveri, Mannheim, using the 'hybrid' technique (collars plus cold iron) developed at DESY in 1984 (see September issue, page 4). The cryogenic properties of this magnet have now been measured at DESY. It reached the short sample current of 6700 A at 4.6 K (5027 A are required for 820 GeV protons at HERA) without training and with a dipole field purity well within the specification. The redesigned support structure resulted in a much reduced heat leak at the 4.6 K level. The observed heat leak of 4.6 watt is within the specifications. The production of 242 dipole magnets by an Italian consortium composed of LMI (cable), Ansaldo (collared coil with yoke) and Zanon (cryostat and assembly) has started, and tendering for an equal number of dipole magnets has begun.

Saclay has designed and constructed two prototype quadrupoles, also of the HERA type, with collar-supported coils and cold iron. These have been tested at DESY with excellent results. The order for the arc quadrupoles will

Aerial dipole — a 9 metre superconducting magnet for the HERA electron-proton Collider at the DESY Laboratory in Hamburg swings aloft at the Brown Boveri plant in Mannheim after final assembly.

(Photo Brown Boveri)

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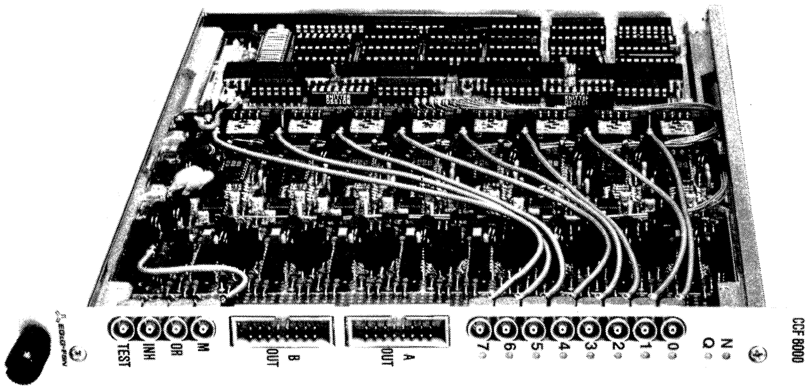

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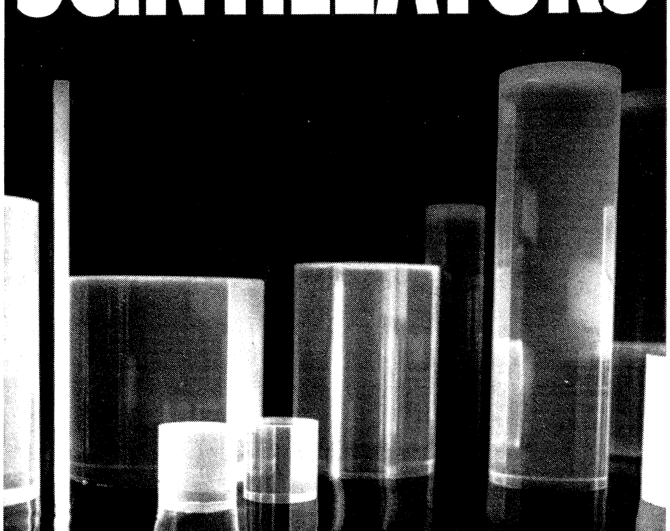

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be placed by the end of the year.

Series production of the 930 km of superconducting cable needed for the dipoles is well underway at Brown Boveri (Switzerland and West Germany) and LMI (Italy). Its critical current is being checked during production with short sample measurements. It is well above 8000 A at 4.6 K and a magnetic field of 6.6 Tesla. A sample from LMI even reached 9010 A. This has to be compared with 6000 A carried by cable of the same type a few years ago. Vakuumschmelze (West Germany) has supplied the 115 km of cable for the quadrupoles. Again the critical current is well above specifications.

The correction magnets are being produced by a Dutch consortium composed of SLE (conductor), Smith Draad (insulation) and Holec (fabrication). A preseries of ten superferric dipole magnets (to be mounted in the quadrupole cryostats) and 20 superconducting sextupole/quadrupole magnets (wound directly on the vacuum pipe in the dipole cryostats) has been produced and tested at DESY with very satisfying results. The series production of the 250 superferric dipole magnets and the 450 sextupole/quadrupole magnets has started.

FERMILAB
Lots of charm

The world stock of charm has been boosted by Fermilab photoproduction experiment E691, a collaboration consisting of Fermilab, California-Santa Barbara, Carleton, Colorado, NRC-Canada, Rio de Janeiro, Sao Pãolo, and Toronto groups. The experiment took data for a five month run last year, and one hundred million events were written onto tape and an analysis of 15 per cent of this data sample has already produced influential measurements of the lifetimes of charmed particles. This data was singled out for special mention by rapporteur Murdock Gilchriese at the Berkeley conference in July.

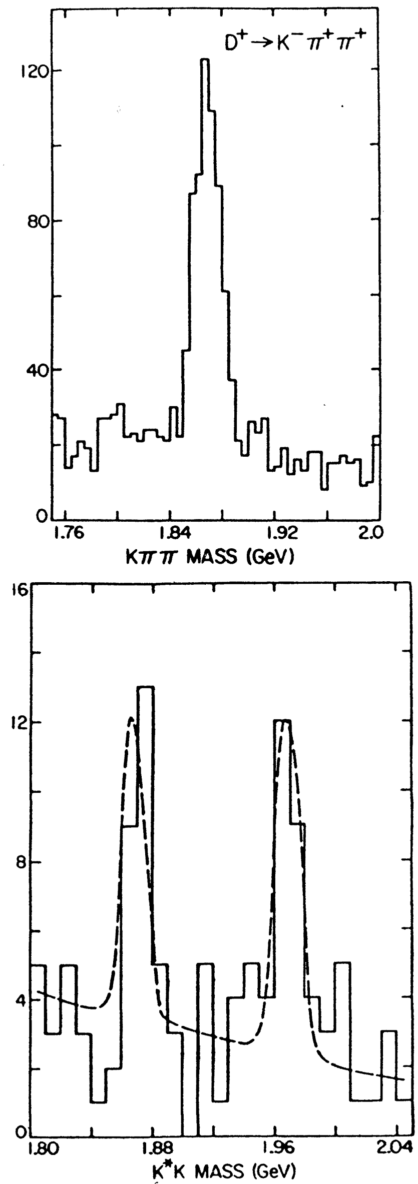
The beam is the Proton-East line, with cryogenic magnets added to accommodate the higher energy of the Tevatron, with the photon beam produced as radiation from a 250 GeV secondary electron beam. The experiment was able to observe such a large number of photon interactions due to the higher energy and improved performance of the accelerator and an increased acceptance of the electron beam.

E691 uses the Tagged Photon Spectrometer which had been used in a previous experiment studying charm photoproduction, but upgraded with improved tracking and particle identification and a vertex detector using the new technology of silicon microstrip detectors. Nine planes of these detectors, placed immediately downstream of the beryllium target, allow the reconstruction of the charm decays. The high resolution of the vertex detector makes clean separation of production and decay, resulting in a several hundred-fold reduction of background.

Over 15 000 charmed particle decays will be reconstructed from the full data sample. Because of the high statistics and low background, E691 will make very precise measurements of the charmed particle lifetimes, and will search for rare decay modes and new charmed particles.

This reconstruction of the entire date sample will require an enormous computing effort. E691 is the first experiment to use the multiprocessor 'farm' developed by the Advanced Computer Program at Fermilab. This system reconstructs many events simultaneously, greatly reducing the analysis time. Complete analysis of the full data sample is eagerly awaited.

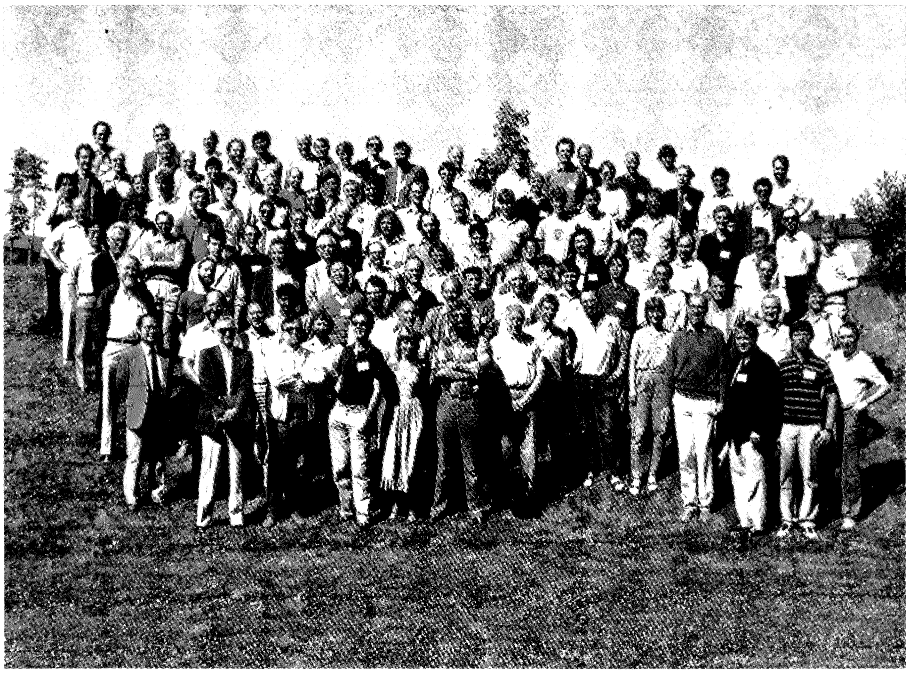
Mass plots from the Fermilab experiment studying photoproduction of charm, showing (top) the D meson peak in a three particle final state and (below) the D and D_s (formerly called F) peaks in a two particle final state.



Physics monitor

CONFERENCE
Muon spin rotation

Participants at the recent conference on muon spin rotation, held at Uppsala, Sweden.



An international physics conference centred on muons without a word about leptons, weak interactions, EMC effects, exotic decay modes or any other standard high energy physics jargon. Could such a thing even have been imagined ten years ago? Yet about 120 physicists and chemists from 16 nations gathered at the end of June in Uppsala (Sweden) for their fourth meeting on Muon Spin Rotation, Relaxation and Resonance, without worrying about the muon as an elementary particle.

This reflects how the experimental techniques based on the muon spin interactions have reached maturity and are widely recognized by condensed matter physicists and specialized chemists as useful tools.

In these applications the positive muon is nothing but a unit charge carrying spin and a useful magnetic moment. These researchers simply follow the advice given in elementary textbooks on electricity and magnetism: to investigate the electric response of a system, introduce a unit charge and study the reaction; for a magnetic system introduce a compass needle (the magnetic moment)! The positive muon is such a probe at an atomic level, with its spin interactions (measured through its decay asymmetry) providing vital information about its environment.

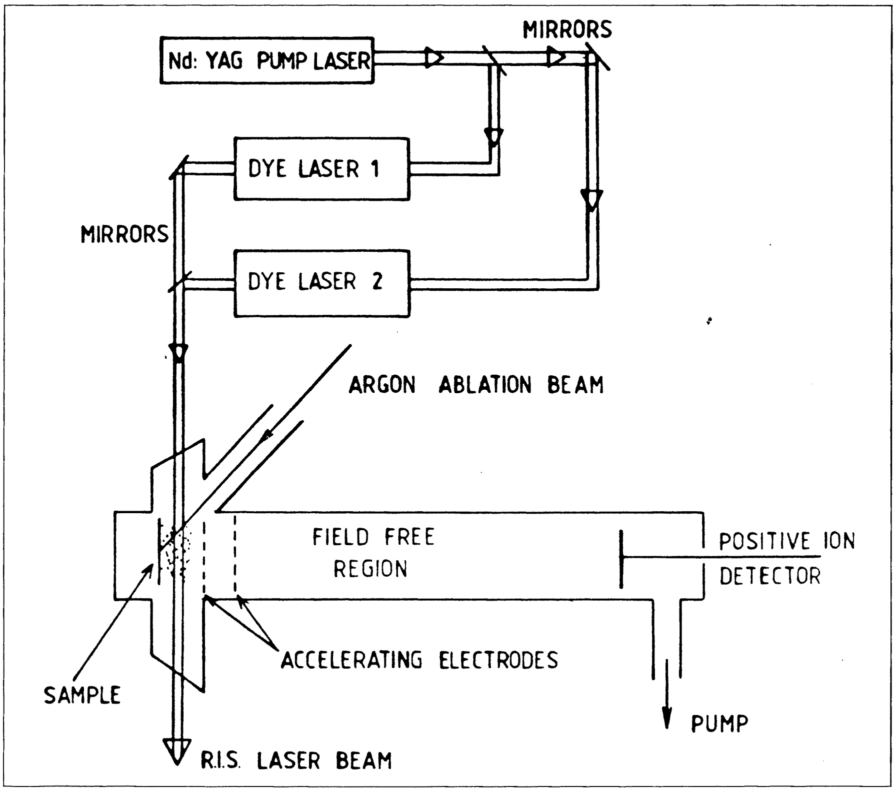
The crystallographic sites of positive muons, in thermal equilibrium within metallic or semiconducting materials, was one of the topics of the Uppsala conference. Another was the motion of muons between such sites. In certain pure crystals muons are mobile even at temperatures below 1 K. The muons with their mass of about 1/9 that of the proton are theoretically very interesting test particles for site occupation and transfer mechanisms, and the results can be compared to those of hydrogen isotopes in similar situations. Positive pions, as shown by experiments from SIN (Switzerland) and Los Alamos, can also be used for the same purpose, using channelling techniques.

Among the fundamental phenomena discussed was the influence of the screening electrons in the transport of muons in metals (a new low temperature quantum effect discussed by J. Kondo) and its experimental evidence supplied by experiments first carried out at CERN and later at KEK (Japan) and TRIUMF (Canada).

The study of magnetic materials was one of the first applications of muon spin rotation. Among more recent applications are the much-debated spin-freezing processes in spin glasses, with phase transitions of unusual character. Newcomers among the magnetic systems are so-called heavy fermion materials, where local magnetic fields at muon sites provide a new aspect on the puzzling properties of these materials (heavy fermions refer to electrons with giant effective masses and not to tau particles!).

For the semiconductor experts, the muon is a defect centre, like that of other atomic impurities (in particular hydrogen). It is paramagnetic since muonium is formed and it can be studied in detail with respect to site, electronic environment, etc. Here, a new technique developed at TRIUMF, based on observation of hyperfine levels, was presented for the first time. In semiconductors like gallium arsenide (shown at the meeting) as well as in metals and in mu-radical chemistry it will have a great impact by its accuracy and flexibility. Important advances in the theoretical description of such centres

Schematic diagram of a Resonant Ionization Mass Spectrometer (RIMS) such as is being built for commercial purposes at Glasgow University following work on the monitoring system for the ALEPH detector. The RIMS can be used to measure minute concentrations of elements and applications in the semiconductor industry, in environmental protection and in medicine have already been identified.



by molecular cluster calculations and other techniques were also presented.

Radical chemistry has long been a pet subject in the field, as has also the study of isotope dependences of reaction rates in simple molecules, a problem of basic interest for the chemists. Lately muon-surface interactions have been opened up, a field promising much new physics. The development of ultra-low momentum beams will help in this respect.

In his introductory talk, Anatole Abragam spoke about 'His Majesty the Spin, and Muon Spin Rotation the youngest Princess' while in the summary talk, A. Schenck showed that while the young princess may be capricious at times, she is showing great potential. As a post-conference trip, about 35 participants boarded the ferry for Helsinki and Leningrad for sightseeing and contact with Soviet specialists at the Gatchina cyclotron (the closest source of muons to Uppsala).

The meeting was organized by Uppsala physicists Erik B. Karlsson, Ola Hartmann, Bergt Lindgren and Roger Wäppling.

By Erik Karlsson

Casting light on individual atoms

In preparing the ALEPH detector for LEP, one of the needs is to check out the large Time Projection Chamber (TPC). One proposed technique was to use laser induced ionization of the TPC gas since tracks left by laser beams could well simulate particles and thus check the configuration of electric and magnetic fields inside the TPC drift volume.

However the mechnisms of laser-induced ionization were not well understood. One of the groups to which this problem was passed was the Glasgow University component of the ALEPH collaboration and a Laser Ionization Group at the University, led by Ken Ledingham, carried out a systematic investigation of the phenomenon using conventional TPC gas.

From this work has come a Resonant Ionization Mass Spectrometer (RIMS) which can be used for commercial purposes. It has proved possible to identify the presence of atoms or molecules with a sensitivity a thousand or more times greater than previous techniques such as mass spectroscopy, neutron activation analysis, etc. The method can be applied to solids, liquids or gases and can pick out every element in the periodic table (including isotopes) with the exception of helium and neon.

The possibility of using laser methods to detect down to single atom level was pioneered in the 1970s particularly by V. S. Letokhov of the Soviet Academy of Sciences in Moscow and G. S. Hurst of Oak Ridge National Laboratory in the USA. In the simplest process a laser is tuned precisely to the wavelength required to raise the atom or molecule from its ground state to an excited state. A second photon from the laser, encountering this atom, can give the electron in the excited state sufficient energy to cause ionization. The liberated positive ion can then be identified in a mass spectrometer.

As an example of the sensitivity of a RIMS, the work on the TPC gas for ALEPH revealed that the molecules at the source of the observed ionization were toluene and phenol which were present as impurities at the level of a few parts per billion.

With sensitivities at the 1 in 10^{-9} level, several applications of the technique immediately suggest themselves. One is in the semiconductor industry where further improvement of the silicon chip manufacturing process requires better detection of impurities in the silicon. Another is the detection of very low activity beta emitters in the environment (presently inaccessible to conventional nuclear counter techniques). Also the medical profession is interested in a way of measuring minute concentrations of trace metals in the human body which are suspected sources of problems in seemingly healthy subjects. Many other applications are likely to emerge.

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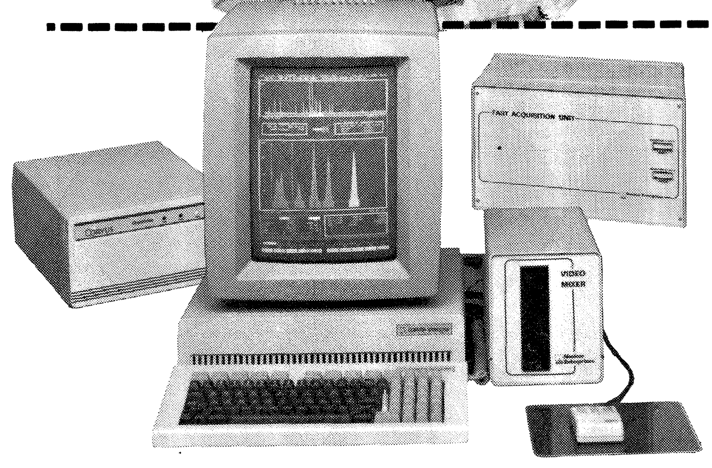

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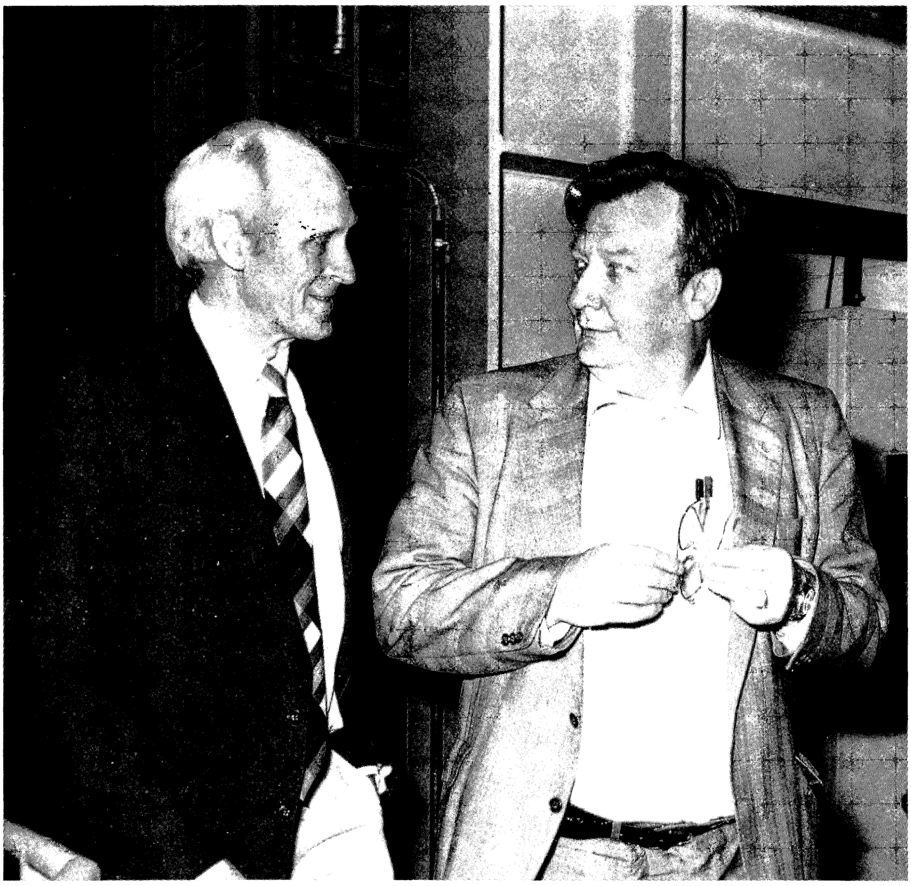
People and things

New CERN Research Director John Thresher (left) seen here with Carlo Rubbia.



On people

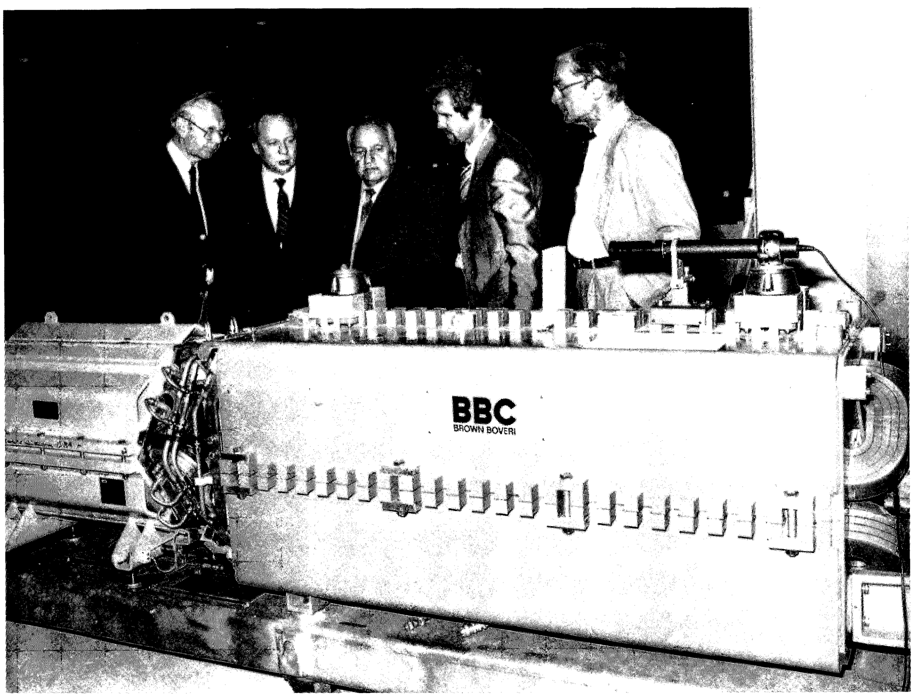
Pierre Darriulat of CERN has been elected corresponding member of the French Academy of Science.

George Kalmus becomes head of High Energy Physics Division at the UK Rutherford Appleton Laboratory. This follows the move to CERN of previous Division Head John Thresher to take up the post of Research Director after Ian Butterworth's departure from CERN to become Principal of London's Queen Mary College.

Norwegian theoretician Jan Wroldsen, now in Oslo after a spell at CERN, has been awarded the King Olaf Gold Medal for his work on quark contributions to nucleon-nucleon interactions, carried out with compatriot Fred Myhrer visiting CERN from South Carolina.

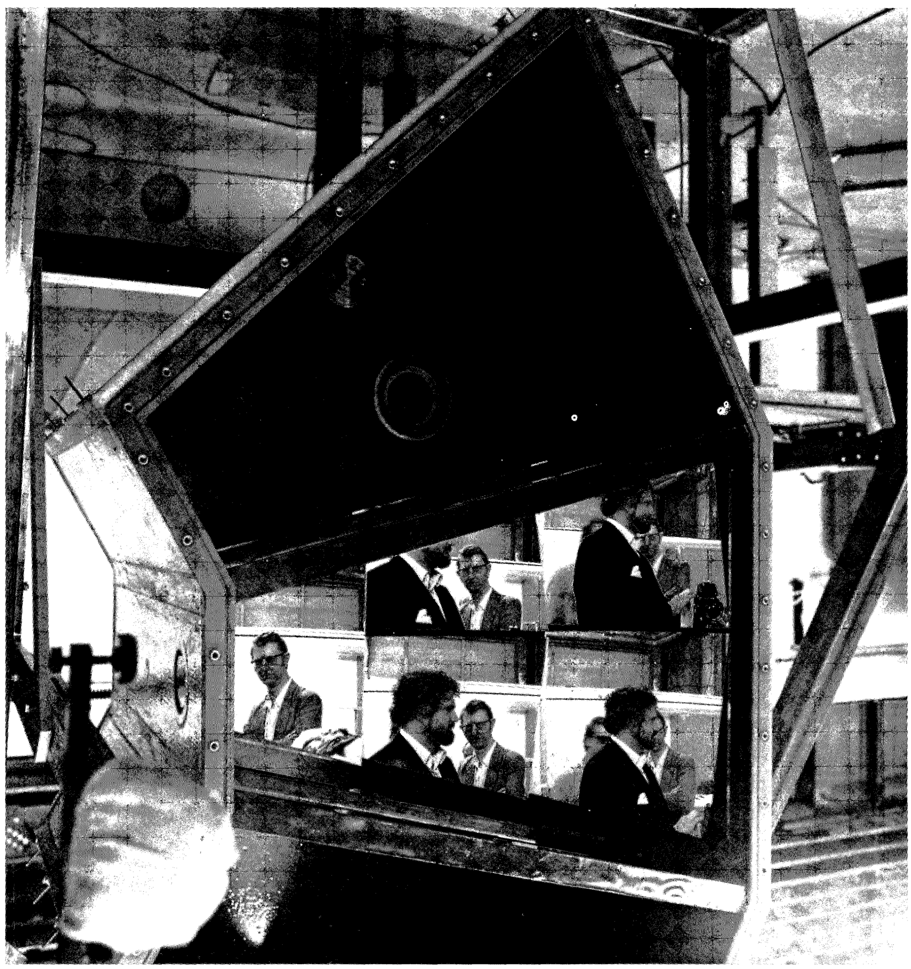
More light at Brookhaven

The design current of 1 ampere was achieved this summer at the 750 MeV vacuum ultra-violet storage ring of the US National Synchrotron Light Source at Brookhav-



Chairman of the USSR State Committee for the Utilization of Atomic Energy Andronik Petrossyants (centre) inspects multipole magnets for CERN's new LEP electron-positron Collider with (left to right) CERN Director General Herwig Schopper, Yuri Galaktionov of ITEP Moscow and the L3 experiment for LEP, CERN-USSR collaboration link-man Yuri Petrovykh and Lucien Montanet of CERN and the L3 experiment. Montanet is now Co-Chairman of the Scientific Committee under the CERN-USSR collaboration agreement, succeeding Giuseppe Fidecaro.

(Photo CERN 275.9.86)



Multiple reflections from the mirror system for the Ring Imaging Cherenkov to be used in the DELPHI detector for experiments at CERN'S LEP electron-positron Collider. The fabrication techniques, entirely developed at CERN by Gilbert Gendre and colleagues, have been taken over by the Swedish firm Bofors. In particular, the method of hot forming of the mirrors has been so well perfected that no subsequent mirror polishing is necessary.

(Photo CERN 757.5.85)

en. The ring is now routinely filled with 800 milliamp currents, almost three times up on the average filling current in 1985. Beam lifetime with 1 amp current is limited to an hour, but efforts are continuing to improve this performance.

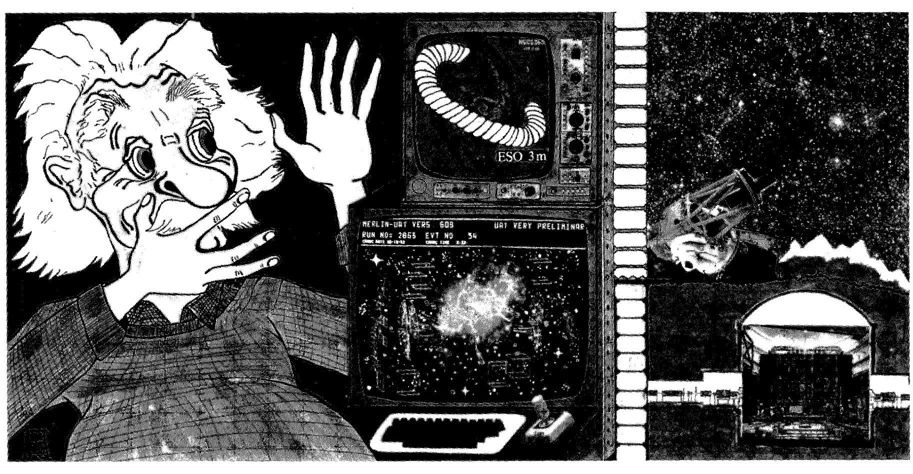
Meetings

The next International Symposium on Lepton and Photon Interactions at High Energies will be held in Hamburg, West Germany, from 27-31 July 1987. The meeting is sponsored by the International Union of Pure and Applied Physics (IUPAP) and attendance will be organized through IUPAP representatives in different countries, however those interested may also write directly to the Conference Chairman, P. Söding, DESY, Notkestrasse 85, 2000 Hamburg 52, West Germany. Between 1000 and 1200 invited participants are expected at the meeting, which will include only plenary sessions with rapporteur and review talks.

The second Lake Louise Winter Institute will be held from 16-22 February at Chateau Lake Louise, Canada. This year the topic for the first three days of pedagogical lectures is 'Selected Topics in Electroweak Interactions'. This will be followed by a short topical conference with contributed presentations by participants. For further information contact: The Secretary, LLWI, Department of Physics, University of Alberta, Edmonton, Canada T6G 2J1.

The proceedings of the Indian National Workshop on Fixed Target Physics, held at Jadavpur University from 10-14 February this year, should shortly be available. Copies from D.K. Bhattacharjee, Dept. of Physics, Post Box No. 17009, Jadavpur University, Calcutta 700 032, India.

The 32nd Scottish Universities' Summer School in Physics will be held from 9-29 August 1987 at the University of St. Andrews. This NATO Advanced Study Institute will review the techniques of computational physics and study recent applications, with special emphasis on lattice gauge theories and condensed matter physics. It is aimed at penultimate/final year PhD students and research fellows, and will be restricted to about 80 participants. Further information from A. Walker, Department of Physics, Room 4409, James Clerk Maxwell Building, University of Edinburgh, Edinburgh EH9 3JZ, UK.



Alvaro de Rújula's illustration for the forthcoming International School on Astro-Particle Physics, organized jointly by CERN and the European Southern Observatory (ESO), see page 39.

Physicists admire a 650-pound leatherback turtle during time off at the recent NATO Advanced Study Institute on Techniques and Concepts of High Energy Physics, held in St. Croix, Virgin Islands. The institute, a regular feature of the US particle physics calendar, coincided with the turtle egg-laying season, when amateur and professional environmentalists keep a watchful eye on this endangered species.

(Photo Richard Breedon)

Sussex University, UK, is organizing a Conference to celebrate Sir Denys Wilkinson's sixty-fifth birthday and to mark his retirement as Vice-Chancellor of the University. The Conference, sponsored by the European Physical Society and the UK Institute of Physics, is entitled Interactions and Structures in Nuclei and will be held from 7-9 September 1987. Further information from W.D. Hamilton, Physics Division, University of Sussex, Brighton BN1 9QH, England.

Promoting art and science

High energy physics Laboratories are often the scene of cultural events where science is not necessarily the dominant theme. CERN and Fermilab, for example, have excellent reputations for nourishing the cultural life of their surrounding communities.

Earlier this year an exhibition of photographs of great beauty was presented at CERN on the invitation of the Staff Association. The photographs, by Mimmo Iodice, were of Neapolitan paintings from the 17th Century. The exhibition was inaugurated by Professor Starobinski, in the presence of the Italian Ambassador and the President of the Italian Physical Society, Nicola Cabibbo.

The exhibition was under the auspices of the Istituto Italiano per gli Studi Filosofici which was founded by G. Marotta to promote the study of philosophy incorporating both humanistic and scientific thought. The Institute has been involved in a wide range of activities including the sponsoring of many seminars on scientific topics. These have not been limited to Italy but have also taken place in other European countries and in the USA. The Institute has also financed young Italian scientists on Fellowships to allow them to work for extended times in the States.

There is close collaboration with the physicists of the University of Naples who help in the preparation of seminars and generally nurture the scientific part of the Institute's work. It is another example of the remarkable concern for scientific culture which is so manifest in Italy.

Aspen organizer Sally Mencimer at the 25th anniversary in August of the Aspen (Colorado) Center for Physics where physicists from all over the world meet informally every summer to discuss specialized physics areas including particle physics, astrophysics, etc.

(Photo Schu Martin)

Astro-Particle physics

Following the success of the Symposium on Cosmology, Astronomy and Particle Physics organized jointly by CERN and the European Southern Observatory (ESO), now a regular feature of the physics international physics calendar, ESO and CERN are organizing an International School on Astro-Particle Physics at the Ettore Majorana Centre for Scientific Culture, Erice, Sicily, from 5-25 January. Further information: Astro-Particle School, TH Secretariat, CERN, 1211 Geneva 23, Switzerland. Potential applicants are advised to make contact as soon as possible.

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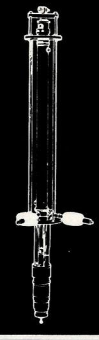

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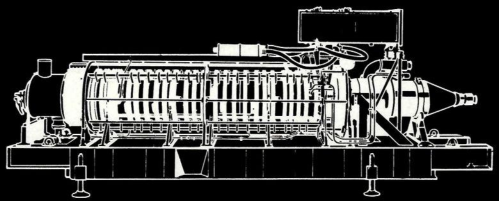

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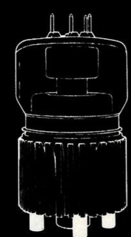

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