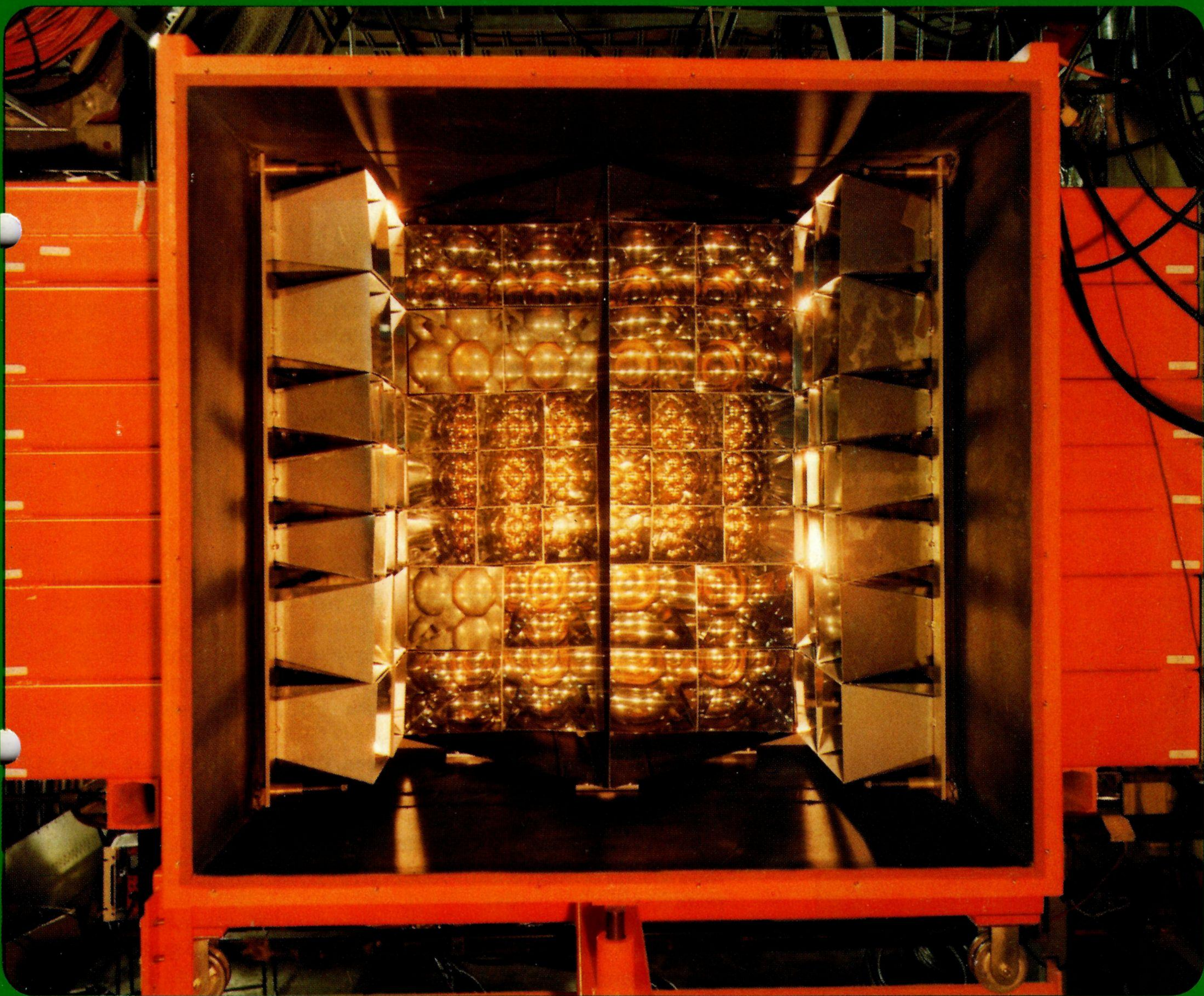
CERN COURIER

International Journal of High Energy Physics



VOLUME 23 5 JUNE 1983

Laboratory correspondents:
Argonne National Laboratory, USA
W. R. Ditzler
Brookhaven National Laboratory, USA
N. V. Baggett
Cornell University, USA
D. G. Cassel
Daresbury Laboratory, UK
V. Suller
DESY Laboratory, Fed. Rep. of Germany
P. Waloschek
Fermi National Accelerator Laboratory, USA
R. A. Carrigan
KfK Karlsruhe, Fed. Rep. of Germany
M. Kuntze
GSI Darmstadt, Fed. Rep. of Germany
H. Prange
INFN, Italy
M. Gigliarelli Fiumi
Institute of High Energy Physics, Peking, China
Tu Tung-sheng
JINR Dubna, USSR
V. Sandukovsky
KEK National Laboratory, Japan
K. Kikuchi
Lawrence Berkeley Laboratory, USA
W. Carithers
Los Alamos National Laboratory, USA
O. B. van Dyck
Novosibirsk Institute, USSR
V. Balakin
Orsay Laboratory, France
Anne-Marie Lutz
Rutherford Appleton Laboratory, UK
D. Cragg
Saclay Laboratory, France
A. Zylberstejn
SIN Villigen, Switzerland
J. F. Crawford
Stanford Linear Accelerator Center, USA
L. Keller
TRIUMF Laboratory, Canada
M. K. Craddock

Copies are available on request from:
Federal Republic of Germany —
Gerda v. Schlenther
DESY, Notkestr. 85, 2000 Hamburg 52
Italy —
INFN, Casella Postale 56
00044 Frascati
Roma
United Kingdom —
Elizabeth Marsh
Rutherford Appleton Laboratory, Chilton, Didcot
Oxfordshire OX11 0QX
USA/Canada —
Margaret Pearson
Fermilab, P. O. Box 500, Batavia
Illinois 60510
General distribution —
Monika Wilson
CERN, 1211 Geneva 23, Switzerland

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

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

Published by:
European Laboratory for Particle Physics
CERN, 1211 Geneva 23, Switzerland
Tel. (022) 83 61 11, Telex 23 698
(CERN COURIER only Tel. (022) 83 41 03)
USA: Controlled Circulation
Postage paid at Batavia, Illinois

CERN COURIER

International Journal of the High Energy Physics Community

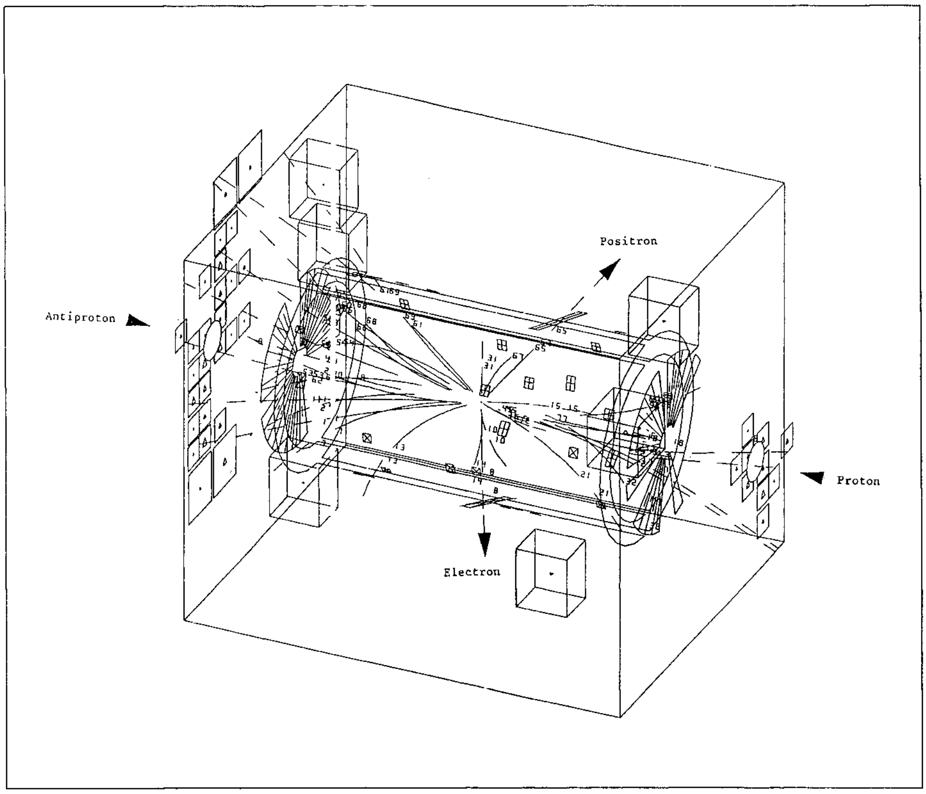
Editors: Brian Southworth, Gordon Fraser, Henri-Luc Felder (French edition) / Advertisements: Micheline Falciola / Advisory Panel: J. Prentki (Chairman), J. Allaby, J. Cronin, K. Hübner, E. Lillestøl

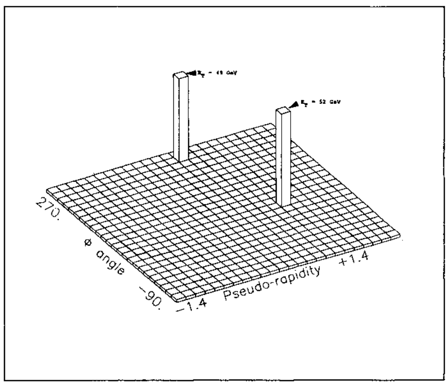
VOLUME 23 N° 5 JUNE 1983

Cover photograph: The smallest of three multicell Cherenkov counters used in Fermilab experiment E400 — a study of charm produced by 300 GeV neutrons. The opaque upstream window of the counter has been removed, giving a beam's eye view of the 34 light collection cones reflected through two thin aluminized windows at 45° to the beam. The counter was designed and built by Carl Lindenmeyer of Fermilab and Jim Wiss and Mike Diesburg of the University of Illinois (Photo Fermilab).

First sign of the Z?

**** A second Z candidate event, this time producing a muon pair, has also been found.***





A remarkable 540 GeV event recorded by the big UA1 detector at the CERN SPS proton-antiproton collider. Top, two very high energy tracks, identified as an electron and a positron from their calorimetry information, flying away from each other at a wide angle. Bottom, the 'lego plot' of the very clean electron-positron pair.

The big UA1 experiment at the CERN SPS collider has seen a 540 GeV proton-antiproton collision which produces a very energetic electron-positron pair, very suggestive of the production and decay of the long-awaited Z^0 particle.*

During the run at the end of 1982, the two collider experiments (UA1 and UA2) amassed nine events producing a lone energetic electron and 'missing energy', indicative of an accompanying neutrino. These looked like decays of W bosons, the carriers of the charged weak current, with a mass some 90 times that of the proton.

At the start of the 1983 collider run in April, hopes were high that the collision rate in the SPS could be coaxed higher so that the experiments would have a good chance of seeing the electrically neutral Z boson, the carrier of the neutral current of the weak interaction. The Z is predicted to be about ten times rarer than its charged W counterparts, and slightly heavier, about 100 times the mass of the proton.

To have a good chance of intercepting a single Z, the experiments needed to amass at least several times the amount of data already recorded. As the 1983 run got under way, it proved difficult at first to boost the collision rate and hopes of a quick Z sighting began to fade. But luck seems to have been with the experimentalists, and the UA1 team triumphantly unearthed a Z candidate event on 4 May (from data recorded a few days earlier) . The Z signal, a clean very high energy electron-positron pair, is less questionable than the W events. A first estimate of its mass from the single event puts it in the range near 100 GeV, as predicted.

If confirmed, this means that the electroweak theory is now fully established. This would be the crowning glory of fifty years of diligent work by several generations of physicists. Pioneer work in the 1930s suggested that the weak force could be carried by a messenger particle, just as electromagnetism is transmitted by the photon. But while the photon is massless, the weak carrier would have to be heavy.

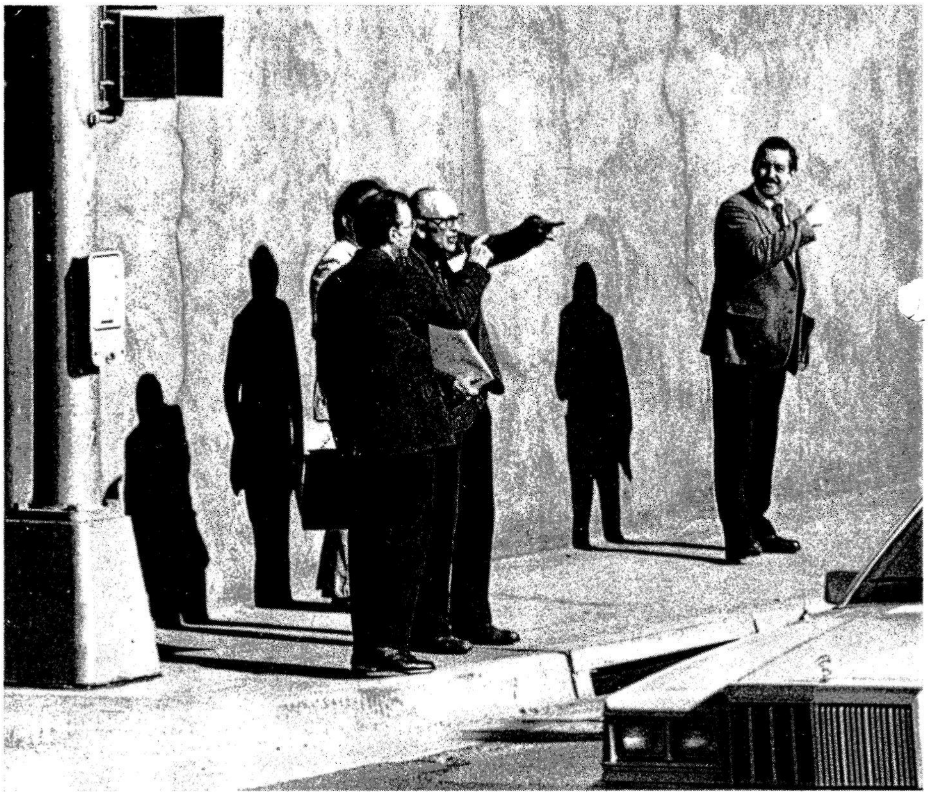
In the 1950s and 60s, theorists slowly pieced together the ideas for a unified electroweak force which brought together electromagnetism and the weak force. One by-product of this work was the seemingly bizarre prediction that the weak interaction should also exist in a form which did not permute electrical charges. This was the neutral current, eventually discovered in the Gargamelle bubble chamber at CERN in 1973.

However the W and Z particles predicted by the electroweak theory were at first out of reach. It needed the inventiveness and superb accelerator physics behind the CERN antiproton project to make the dream of seeing these particles a reality.

Later this year, a special issue of the CERN COURIER will be given over to the electroweak saga and the CERN antiproton project.

Santa Fe Accelerator Conference

A group of participants from the Accelerator Conference, visiting downtown Santa Fe, have different ideas as to the best direction to take for the future.



The 10th USA National Particle Accelerator Conference was hosted this year by the Los Alamos National Laboratory in Santa Fe from 21-23 March. It was a resounding success in emphasizing the ferment of activity in the accelerator field. About 900 people registered and about 500 papers were presented in invited and contributed talks and poster sessions. About a third of the papers and attendees were from outside the USA.

The opening session emphasized some of the newsworthy current events, ranging over Giorgio Brianti's and Rich Orr's coverage of the present status of the CERN proton-antiproton complex and the Fermilab Energy Saver, the applications of accelerators in magnetic fusion by N. Rostoker, and the experience with new heavy ion accelerators now coming on-line at GANIL (see April and May issues) and other institutes as covered by Pierre Lapostolle.

One of the eagerly attended talks was a report on China's accelerator projects by Xie Jialin. The Beijing electron-positron collider will provide an entry into charmed meson and heavy-lepton physics, a source of synchrotron radiation, and a fixed-target capability for nuclear physics. A cascade cyclotron at Lanzhou will support heavy-ion research and the Hefei Synchrotron Radiation Facility will enable China to begin work in the very wide range of research which synchrotron light makes accessible. These projects are in the planning, engineering, or prototype stage.

High energy machines were covered in talks on the Fermilab antiproton source, the Stanford linear collider, LEP at CERN, Tristan in Japan, the Berkeley Bevalac, a review of kaon factory plans, and the Brookhaven CBA. In low and intermediate energy accelerator centres, the successful initial operation of the first superconducting cyclotron, at Michigan, was reported. Two other superconducting machines — linear accelerators operated as boosters for tandems — were also reported operating, with up to 3 MeV per m accelerating field and 20 MeV output energy. Great interest was generated by the discussion of the first work on the Indiana electron cooling ring.

Technology developments

The development of the advanced technologies for accelerators was detailed in several sessions. Optimism was expressed on the role that superconducting magnets and r.f. cavities could play in the next generation of accelerators since recent experience has been good. The optimism is based, not on the appearance of some fantastic new material, but rather on the excellent prospects for continued development of the materials already at hand. It was stated that we now have the tools and understanding to increase the critic' current density at 10 T by improvements in the purity and microstructure of the materials and developments in manufacturing and fabrication processes. For r.f. cavities, field gradients of 2 to 3 MV per m have been demonstrated, and the prospect for doubling these figures seems good. Superconductivity promises 10 T dipoles and around 5 MV per m accelerating gradients in the near future.

Fourteen years after the invention of the 'spatially uniform strong focusing' principle in the USSR, many Laboratories are developing radio-frequency quadrupole (RFQ) accelerating structures. Horst Klein, from Frankfurt, gave an up-to-date review of activities at some fifteen Laboratories, listing twenty RFQs, eight of which have now accelerated beam, Cocktail time: (left to right) John Lawson, Giorgio Brianti, Phil Morton and Bob Jameson (Conference Chairman).

while the remaining twelve are near completion. These should provide a wealth of information on the practicality of this exciting new accelerating structure. Y. Hirao from Tokyo discussed their 132 cell RFQ Linac 'LITL'. It has successfully accelerated ions from hydrogen to lithium, operating at 100 MHz. A proton current of 70 μA has been measured with a transmission of 95% and the beam parameters agree satisfactorily with the computer simulations.

Beam physics

In beam dynamics, it was clear that computer simulation has reached a new level of sophistication. Elaborate programs, some running for hours on the latest high speed computers, have been written to study the long-standing problem of the stability of high current (amp to mega-amp) beams under the influence of self fields. Results are in reasonable agreement with measurements wherever available.

New levels of maturity were seen in the understanding of stochastic cooling especially of bunched proton and antiproton beams and of depolarization processes in stored polarized electron and positron beams. The former investigation indicates the possibility of cooling bunched beams and prescribes better optimized designs of cooling systems; the latter suggests methods of preserving polarization in high energy colliders such as PEP, PETRA, and LEP.

Topics pertinent to the many modern facilities requiring high currents fell into three main categories: instabilities in multi-kiloampere, high current electron accelerators; emittance growth and current limits of intense heavy ion beams in long transport lines; high order r.f. modes limiting performance of electron storage rings.

Q and transverse impedance measurements of accelerating modules for the multi-kiloampere Advanced Test Accelerator (ATA) were reported, with the implications for beam break-up instability. A companion paper discussed two methods — one measured, one proposed — of reducing beam oscillations by special Landau damping cells. Other methods were proposed to handle intense electron beams, including recirculation through induction cavities or betatrons with or without a toroidal field. Standing wave r.f. linacs with very high gradients may also be useful at very high currents.

The generation of intense, low emittance beams is crucial for driving inertial fusion with heavy ions. Several groups reported early phases of experiments to check emittance behaviour under space-charge conditions in electrostatic quadrupole (Berkeley, Brookhaven), magnetic quadrupole (Darmstadt) and solenoidal (Maryland-Rutherford) transport channels.

High order r.f. modes coupling to transverse beam motion constrain single bunch currents and bunch lengths in electron storage rings; wake field effects also limit ring performance. Three CERN papers discussed the design implications for bunch energy spread and bunch length in LEP. Comparison with PETRA performance provides a benchmark for optimizing the LEP design. An experimental study of single bunch instabilities in PETRA suggested several means of raising threshold currents. New computer codes have been written at DESY to study cylindrically symmetric cavity modes and wake fields including components up to the octupole.

The Chinese outlined a method of using Hertz potentials to solve for azimuthally periodic modes of axisymmetric r.f. cavities. The finite element approach has been extended to three dimensions, but we are still waiting for a versatile 3D code to handle a useful number of modes.

Special topics

All major US proposals for a medium-energy c.w. electron machine were aired in a special session where there was also a progress report, by H. Herminghaus, on the commissioning, in less than two months, of the second stage of the MAMI project at Mainz. In March, this stage delivered 15 μA at 178 MeV. A beam monitoring device, based on observing synchrotron light, gives precision information on the beam during each of the 58 turns. This will provide useful data on the performance of a microtron in the intermediate energy range.

Charlie Baltay giving one of the concluding talks about future particle physics facilities in the USA. His talk was based mainly on the American Physical Society Aspen meeting reported in the October issue last year.

Ion sources, electrostatic accelerators, and polarized beams received their share of attention. C. K. Sinclair of SLAC summarized polarized electron sources. The highest intensity type uses photoemission from GaAs with circularly polarized (up to 50%) photons of more than 1.4 eV. Intensity is up to 100 A peak and 0.1 A average.

Y. Jorgen of Louvain reported the performance of a superconducting ECR (electron cyclotron resonance) high charge state heavy ion source running reliably on the Louvain cyclotron. This is the latest and highest performance version of the ECR source: currents are 10 eμA of the most abundant charge states of oxygen, neon, argon and krypton.

Antiproton production at Fermilab and CERN was described in several talks and posters. Intense-beam targeting, previously the province of the meson factories, must be dealt with. In similar vein was a well illustrated talk by M. Wilson of Los Alamos on state-of-the-art devices and techniques to install and service components in the high radiation environments of today's powerful accelerators.

Control systems

Instrumentation and control reports ranged from the awesome multi-accelerator control system at DESY (a real tour de force) to esoteric descriptions of software modeling and snoop Fastbus diagnostic modules. Surprisingly, most of the papers dealt with non-commercially-available hardware, though the CERN LEP and the Los Alamos PSR control systems were exceptions. Even in the custom hardware, however, heavy emphasis is placed on standard bus structures (Multibus is one of the clear favourites) and distributed intelligence. The latter emphasis results from the growing sophistication of inexpensive microprocessors, and the recognition that control system costs are increasingly dominated by software. Distributed intelligence is being exploited primarily to simplify the software and a prime example of this trend is the control system for the heavy ion medical accelerator at Berkeley.

An overview of the Fastbus system for data acquisition and control was given in a lively talk by Lou Costrell. This development is a major interlaboratory effort to cope with the vast amount of data generated in high energy accelerators and detectors.

Several novel devices to measure beam profiles were presented and attracted a great deal of interest. Devices from Los Alamos include a compact unit which is inserted in low energy beams, to provide rapid measurement of phase space density in one transverse dimension, and an ingenious and versatile system which digitizes multiple images of a beam from beam-emitted light and does phase space reconstruction. A mechanically simple, pneumatically-driven wirescanner developed at the National Bureau of Standards measures two-dimensional beam density profiles at a rate of up to ten per second. These devices all use microprocessors.

Permanent magnets

J. LeDuff and Y. Petroff presented a review of permanent magnet technology which is developing very rapidly. It is already possible to use it for electron storage rings for microlithography and the free electron laser. The machine energies would be in the several hundred MeV range. Klaus Halbach and Bob Gluckstern presented papers on permanent multipole magnets with variable strength. Halbach described an arrangement of both steel and permanent magnet material that results in a variable strength multipole unit. Gluckstern described an arrangement of quadrupoles where the effective strength of the combinations could be varied by rotation of the individual quadrupole units. Both schemes look promising for practical applications.

Applications

It is a particular feature of the USA Accelerator Conference that a lot of attention is given to the practical applications of accelerator technology. J. Duggan spoke on applications of accelerators in greater and greater numbers to the solution of immediate problems, especially in medicine and industry. There are today more than 3000 accelerators in use in the USA for medical purposes

At the Conference banquet: (left to right) Gunther Plass, Bob Jameson and his wife, and foreground, Caltech astronomer Roger Blandford, banquet speaker on the subject of 'Cosmic accelerators'.

alone. They produce isotopes for a wide variety of radiopharmaceuticals and they are used in diagnosis and therapy; they are a dramatic example of the transfer of science and technology to vital human needs.

It is now possible to consider seriously the application of heavy ion accelerators as driver candidates for power generators by inertial confinement fusion. However, many critical and difficult technological questions remain to be answered before economic feasibility can be evaluated. An alternate approach, presented by Al Maschke, would use low energy heavy ions, with velocities of about 75 cm per s to implode a sphere of deuterium-tritium gas. The drive energy required is 2.5 kJ per µg, and the driver mass is then about ten times greater than that of the fuel being imploded.

A new session on Radiation Sources was included for the first time at this Conference, since these applications have recently gone through a major expansion in the area of synchrotron radiation and the development of other novel radiation sources. The major emphasis was on special radiation sources, such as the free electron laser, FEL (driven either in the single pass mode or by an electron storage ring), undulators and wigglers in an electron storage ring and Compton backscattered laser radiation. Impressive laser amplification results for a single pass FEL were presented by C. Brau of Los Alamos, clearly indicating the benefit of using the tapered wiggler approach. Radiation enhancement by as much as 3% was observed, which holds great promise for early results in the oscillator mode; the modifications for this are now being carried out.

A highlight was the presentation by S. Krinsky of the National Synchrotron Light Source, NSLS, at Brookhaven, during which he systematically derived the optimization criteria for undulators and wigglers in an electron ring and enumerated the limiting factors on source brightness due to diffraction limit, non-zero beam emittance magnitude and finite length of the special radiation undulator or wiggler source. These arguments will certainly play a role in the evolution of synchrotron radiation rings such as the Advanced Light Source (ALS) project, a 1.3 GeV, low emittance, synchrotron radiation source, described by R. Shah from Berkeley, and other rings being studied in the USA and Western Europe.

The scope of present electron storage ring synchrotron radiation sources is being broadened by the possibility of gamma radiation generation by Compton backscattering. A. Sandorfi spoke of a very high flux (over 10^7 per s) of polarized gammas up to 300 MeV in energy, which will be produced by colliding 3 eV laser photons with the 2.5 GeV electrons of the NSLS. This approach has been funded for construction and will extend the scientific disciplines at the NSLS to include low energy nuclear physics.

Techniques for the future

There was lively interest in new accelerator techniques, including collective accelerators such as recirculating linacs. Two such accelerators that control the potential well at the front of an intense relativistic electron beam were discussed — the ionization front accelerator (IFA) and the helix controlled accelerator. A second generation IFA was reported nearing completion at Sandia; it is designed to produce controlled accelerating fields of 100 MV per m over 1 m. Experiments at Maryland were reported for a helix structure and for ions collectively accelerated from laser-produced plasmas; ion energies up to several MeV per nucleon are routinely achieved. New collective accelerator ideas include use of a space charge wave instability in a dielectric guide and a travelling magnetic wave on a toroidal electron cloud.

Laser accelerator schemes, and particle simulations of them, attracted discussion. Some of these schemes employ lasers to produce a beatwave in a plasma at the electron plasma frequency. A very large electric field results over a very small region. It is speculated that very high electron energies (about 1 TeV) might be produced, but very high laser intensities are needed and the number of accelerated particles would be small. No experiments were reported for these concepts.

Several novel ideas were presented that deal with more conventional technologies. A racetrack induction accelerator was proposed with stellerator windings on the curved section to provide beam stability. A beam extracted from an induction accelerator was focused with a series of foils. And a transverse focusing field accelerator was proposed that produces a ribbon-shaped beam that is focused and accelerated between pairs of curved plates with alternating curvatures. An interesting design for a high-current induction accelerator with nine parallel beam channels (Hermes III) was presented.

The closing session offered three talks by renowned experts on areas of special interest. Eric Vogt from TRIUMF reviewed electron and heavy-ion machines for nuclear research. He denoted these approaches as conservative and speculative, respectively, and both have strong adherents. Charlie Baltay of Columbia gave a vigorous report on the Aspen reaction on future high energy facilities in the USA — what technology will be sufficiently powerful to go beyond the Tevatron, LEP, etc? What Laboratory will be big enough to hold the Desertron — the accelerator which will step into, or across, the 'desert' just over the present energy horizon? Finally, Pief Panofsky reminded us that it is difficult to see too far ahead. The utility of a new machine can be different from our expectations, and plans may therefore need to change. He encouraged the planners: although the cost scaling rules for increasing energy look ominous, Laboratories have reduced unit cost per MeV to the point where total costs are not dominated by the accelerator alone. With development of the necessary talents for these great facilities, we always seem able to make the next step.

(We are grateful to Bob Jameson and Olin van Dyck for organizing coverage of this Conference and providing the information for this article.)

Theoretical science and the future of large scale computing

Kenneth G. Wilson

There are extraordinary changes taking place in the business community, driven by the twin pressures of Japan and the computer. The change is not always recognized in the academic community or in government, which evolve much more slowly.

The timescale for research and development is shrinking fast. The old picture of research and development can be illustrated by the laser, discovered more than twenty years ago. Now there is going to be a revolution in communications based on lasers and optical fibres. In that twenty-year period, the laser has gone from being a scientific curiosity to the subject of a standard industrial R and D operation. But especially in the computing business, one no longer has twenty years to do R and D. One has maybe three or five years. A product lasts for three to five years, and then it's back to the drawing board. This pressure means that the style of R and D which tinkers with a well-defined object does not work any more. It also requires greater scientific understanding, to enable moving into new areas faster.

In the traditional industrial approach everything inside the industry is secret. Progress is now towards a situation where to gain industrial advantage companies have to learn early on about new developments

The computer message

This article is based on a talk given by Kenneth Wilson at CERN in the CERN Computer Seminar series. Wilson, who was awarded the Nobel Prize for Physics last year (see December 1982 issue, page 403), is a strong advocate of extending and improving the use made of computers in physics.

Over the years, physics and computer science have tended to go their own ways, and although many physicists use computers in their work, their methods are often highly traditional. However, it is becoming clear that a lot of present activity in computer science and software engineering is relevant to high energy physics.

Last year, a workshop on high energy physics software was held at CERN with the subtitle — 'Where do we go from here?' Its aim was to stimulate exchanges of programming experience between computer oriented people in high energy physics and in other professions and fields of research. This meeting provided a glimpse of how physics could benefit from computing developments in other areas. However few lines of direct communication exist, and recommendations were made for ways of improving this awareness. Following what Ken Wilson has to say on the subject is surely one of them.

outside. This will be more important than keeping things secret. Industries have now to reorganize so that outsiders can talk to people in industry and bring ideas in.

This kind of change means that the role of science and scientists in society is going to become quite different from what it has been in the past. Scientific operations should be much more integrated with business operations as business seeks to be informed and to take advantage of basic research. The lead area where this is going to take place is computing because it is here where the R and D times are the shortest.

How will computing developments affect basic research? In elementary particle physics, experimentalists have to analyse events which include hundreds of particles, and a Monte Carlo simulation clearly eats up a major amount of computing power. But the principle of energy conservation helps. Hundreds of particles are involved, rather than millions. But today's theorists face the problem of having to study on a very short timescale the events that the experimentalists measure. Hundreds of particles are not suited to simple analytic theories like the theory of the hydrogen atom or the theory of the earth going around the sun. One has to rely, at least in part, on computer simulation.

Computer simulation for the theorist has to deal not with the final outcome of an experiment, so much as with the factors that govern its final outcome. In a very short time interval energy conservation no longer restricts the number of particles. To be precise, when dealing with short-lived gluons inside a proton or neutron, ten or fifty are not enough. In fact a lattice is needed in order to have a finite number of gluons. But even a finite lattice inside the proton is going to involve thousands, if not millions of points, and gluons should be present at every point of that mesh. The computing power needed for these theoretical simulations, which are still Monte Carlo simulations, are enormously larger than experimental requirements, simply because the number of objects involved is so much larger. And that is why I started thinking about how one would justify getting enormous amounts of computing power into theoretical science.

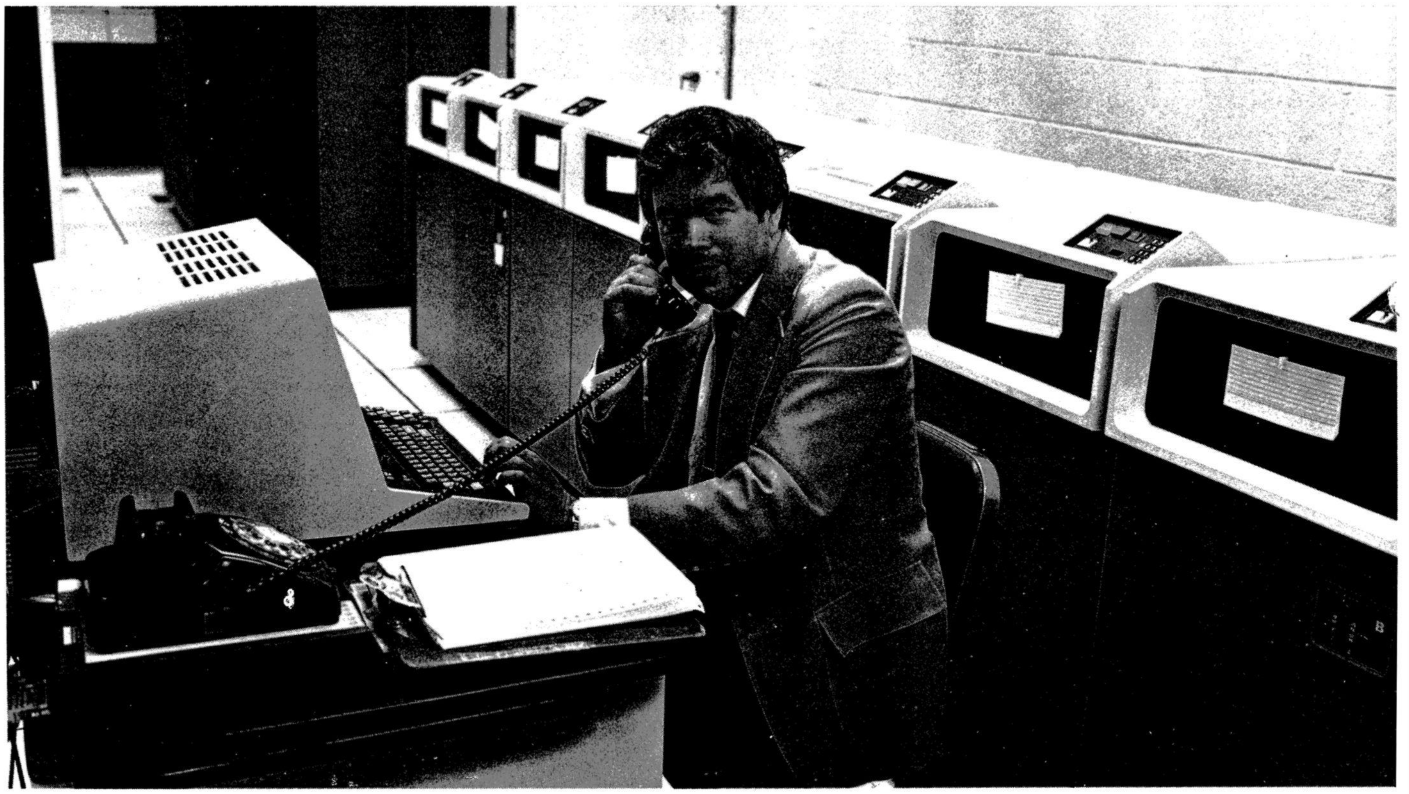
When I added up the total computing requirements that I needed, I discovered nobody was making that kind of computer. So the first problem was not that I did not have any money, but that even if I did, there would be nothing to spend it on. And pursuing that same line of reasoning, I have gradually come to get an overview of the computing situation, not only in universities but in industry as well, where the big need lies.

One problem is the question of training. The standard attitude of physicists towards computing is that to be ready to do serious computing, whether it be computer simulation for theory or data analysis for experiment, they need only a two-week course in FORTRAN.

> 'Nobody would suggest that someone is ready to do serious experimental work in physics if they have just had a two-week course in soldering. And yet the attitude is that a two-week course in FORTRAN gets people ready to do computing!'

Spreading the computer message — Kenneth Wilson.

(Photo Cornell University)



Now computer simulation for a theorist is extremely close to the idea of an experiment. A computer simulation has to come up with a number as an answer, it does not come up with functions or ideas. So first one has to know how to design a computer simulation whose number is worth getting, which is analogous to setting up an experiment and determining all its parameters. One has to analyse the numbers that come out, and face all the same problems as an analysis of experimental data.

Nobody would suggest that someone is ready to do serious experimental work in physics if they have had just a two-week course in soldering. And yet the attitude is that a two-week course in FORTRAN gets people ready to do computing!

What kind of training is required? Training has two parts. One part is like experimental training — an apprenticeship of several years writing a PhD, working with an experienced person who knows how to formulate an experiment, how to do data analysis, how to make sure that the systematic errors do not wipe out the result, etc. The same set of problems applies to computer simulation. So it is clear that people who want to do that should go through the same kind of apprenticeship.

The other requirement is training in computer science, in the management of large scale software. This has been pooh-poohed by the scientific community. Meanwhile, the scientific community, along with the business community and the national Laboratory community, is building up a backlog of huge piles of FORTRAN which cannot be read or modified and is just an incredible drag on the whole scientific operation. It eats up infinite amounts of people's time which could be better spent elsewhere and directs projects along rigid directions when one really wants to be doing something else!

Throughout the 1960s, industry and US national Laboratories were busily building these huge programs, not worrying much about what was happening. About 1971 they reached a limit. In US national Laboratories today there are few programs that were written less than ten years ago.

The main thrust in computer science is how to deal with this problem. How do you write large pieces of software so that you know what you have got when you have finished and you can work with it afterwards? Rather than exhortations to write in specific programming languages, computer scientists discuss techniques for software management which apply in any language. Then there is algorithm design and a whole list of topics which have been developed over 20 years.

Any graduate student who is to use a computer as part of his PhD should have about a three-month training course in relevant aspects of computer science. Computer training should also be more integrated with college level courses at both the undergraduate and graduate stage. But this means changing the language or the framework of computing because a student cannot prepare a FORTRAN program in the time that it takes to do a normal course assignment.

Then there is networking. Many physicists face the issue of wanting to work from a home institution on an experiment elsewhere, wanting to talk to colleagues at other institutions, and to exchange data and programs, etc.

There is one additional aspect of networking which I find many scientists are unaware of. This is interdisciplinary communication. For example, an electrical engineer at Cornell was preparing a computer architecture course. He had to cover about eight different computers, about half of which he knew, but he needed information on the other half. So he put a request on the ARPANET bulletin board for information about the unfamiliar computers. Experts on those four computers sent him replies over ARPANET.

As more theorists move towards computers, they are moving towards solving problems from first principles. Not just in elementary particle physics where one expects to work from first principles anyway, but in solid state physics, applied physics, chemistry, geology, and many areas of engineering. These people need to communicate with each other so they do not keep reinventing the same thing. The computer network is needed to enable this communication to take place.

This is especially important to bring the academic community in contact with industry as industrial R and D moves from a closed operation which would not accept information, even if it were supplied, to an open operation seeking information. Industrial research people can use the network to ask for help from outside. I am pressing very hard in Washington for a computer network serving all scientists.

Next there is software. The software problem led in the end to the stop in development both at big Laboratories and in business. I think this was a primary reason the demand did not appear immediately for a supercomputer like the Cray. If the demand had developed in the normal way from progress in the 60s, supercomputers would be commonplace now.

The software problem is one word — FORTRAN. FORTRAN is restrictive because there is a limit to the complexity of the programs that one can write using it. FORTRAN has two problems. One is that you cannot read it and the other is that you cannot modify it. Computer scientists have been complaining about this for years, but they have not been very helpful. First they touted ALGOL. Then PL/1. Then PASCAL. But as far as I can see none of these languages really solve the problems of FORTRAN.

An analogy shows the heart of the problem. A 60-page FORTRAN program has roughly as much information as an advanced textbook. To take that textbook and give it the quality of FORTRAN program, scramble all the words. For example, trying to figure out a big FORTRAN program requires continually leaping back and forth through the entire listing. Can something be done about this? I have been trying to understand what computer science ideas might be truly helpful and I am convinced that there are ideas, which if properly packaged, would easily supersede FORTRAN. But the ideas have not been packaged for scientific processing. They are being used in other areas like database management or operating systems because the scientific programmers have said that they do not want anything other than FORTRAN, and the computer scientists have taken them at their word. Furthermore the packaging requires somebody who really understands what a scientific programmer wants. This the computer scientists do not understand.

But I would like to give an idea of what programming might be like using some of these computer science ideas in a scientific programming system. The problem is not to eliminate FORTRAN but to demote it to the level of assembly language, a language produced by machines and not by people. It doesn't matter if assembly language is unreadable because you never read it anyway. Or you shouldn't!

Computer scientists are thinking about how to take models which humans have developed over thousands of years to handle complex organizational problems and use the computer in the framework of these models. As an example, take a textbook, a framework of information organized so that it can be read. Sup-

> 'The scientific community... is building up a backlog of huge piles of FORTRAN which cannot be read or modified and is just an incredible drag on the whole scientific operation.'

pose we want a program to look like a textbook. Chapter 1 will list the equations to be solved. (I am talking as a theorist so I am interested in equations!) Chapter 2 introduces the numerical methods to solve these equations. Chapter 3 lists the boundary conditions. Chapter 4 describes the data structures. Later the book deals with the optimization methods to make the program superfast on one's favourite computer. In a normal FORTRAN program part of each of these different chapters is present in every loop.

How could this sytem of separate chapters actually work? One way is at the end of Chapter 2, after introducing specific codes for numerical methods, a transformation is defined which inserts that code into the equations in Chapter 1. Such a transformation would say, for example, that an integral sign is to be replaced by a certain piece of code. Transformational systems already exist which come quite close to being able to do that. The advantage of transformations is that the equations in Chapter 1 are part of the final program and therefore if the program is changed, but not the equations, the program does not run. The equations have to conform with the program. If the equations were written in a nice orderly fashion but are not part of the program, then they are the equations for what the program did before, not what it does now.

Scientific input is required for a system which serves scientists, so I have set up the GIBBS project at Cornell of which I am the director but all the workers will be computer scientists. I hope there will be other such projects because it is clear that any single project has a very high probability of failure, as in the case of operating systems.

Finally, there is the hardware question. How are we going to get sufficient computing power to tackle basic theoretical questions, and no doubt experimental questions as well? The main trend in computer components is not that they get faster but that they get cheaper. To get maximum computing power the question is not one of having a single computer which gets faster and faster, but having lots and lots of computers running in parallel.

The industry is becoming increasingly aware that it has to think about parallel processing at all levels. But there is also an incredible opportunity for scientists to get into the development of parallel processing by being guinea-pigs for systems very early in their development, where it takes a PhD physicist to make it work. If industry sees all the things that we have trouble with, then they can go back and fix them. What industry wants is to produce something which a PhD physicist can use in his sleep. Maybe then the man in the street can start to use it.

To illustrate various kinds of parallel processing I shall use a human analogy again, namely an airline counter. The first possibility, of not much interest, is to have one clerk behind the counter. If that clerk cannot keep up with the work, then a development project is launched for a single clerk with four arms!

The next approach to parallel processing is the so-called vector supercomputer architecture. Here there are a number of clerks behind the counter and a queue of customers. The first customer advances to the first clerk, the first clerk pulls out a ticket and the customer with his ticket goes to the second clerk. The second clerk writes the customer's name on the ticket. The customer then goes to the third clerk who puts the destination on the ticket. It is an assembly line.

This form of organization works fine as long as all the customers want tickets, but what if a customer wants his lost baggage traced? When that happens, the entire assembly line grinds to a halt while one clerk sits there processing lost baggage and only when he is finished does the assembly line start processing tickets again.

Some supercomputers have th same problem. They are incredibly fast in doing multiplies and adds but a complicated address calculation has to be done elsewhere, using a single much slower system.

The next form of organization was illustrated originally by the Illiac 4 and now has been reincarnated in several commercial machines. In this organization the customers line up in front of all the clerks and there is another clerk with a megaphone. He barks out 'Customers advance to counter', and they all come up. The clerk with the megaphone says 'Pull out a ticket' and then proceeds to shout out al the instructions for filling out tickets. Again it is very good for producing tickets, just as effective as the assembly line approach. But it has exactly the same problem. When a single customer wants lost baggage traced, one clerk traces baggage in response to the instructions from the clerk with the megaphone.

In the actual computers, the processors are connected in a square array and one processor can only pass information to its nearest neighbour. That is the most common and

> 'What industry wants is something which a PhD physicist can use in his sleep. Maybe then the man in the street can start to use it.'

fastest form of communication. For problems which are very regular in structure, like Monte Carlo calculations, in lattice gauge theory, this organization is extremely effective. But for things like tracking surfaces of singularities in a fluid dynamics flow, then the computing requirements at one point are very different from the computing requirements elsewhere.

None of these organizations seem to be very useful for detailed experimental data analysis. Another and more promising form of parallel processing has now been developed, but its only commercial realization to date is expensive and not very cost effective. It uses the same organization used in the most effective airline counters. There is a queue of customers and the customers go to the first available clerk. Each clerk can process any request independently of what any other clerk does. One of the big differences with this approach is that whole subroutines or loops can be handled at a time, so each processor can process on its own for a long time before it has to communicate with the rest of the system. This is extremely important because while computer scientists have been studying operating systems for parallel processing for some time, invariably they wind up with an operating system which can handle parallel processing except that every time a message has to go from one process to another it takes about a hundred times longer than they originally desired.

What is needed in parallel processing is a way of cutting down the number of times that any processor has to communicate with another, so huge jobs can run before they have to talk to each other.

Now I would like to finish with a variant on this design which was developed at New York University. It does not yet exist as a piece of hardware. Only the basic concept has been simulated. It deals with the situation where there are 4000 clerks behind the counter. Then the single queue of customers can be a bottleneck. People cannot get to the clerks fast enough. The new approach is that when one of these clerks finishes with a customer, the clerk heads for the queue. If two clerks collide on the way to the queue, one clerk stands aside and the other goes to the queue and fetches two customers, gives one to his friend and takes the other one back.

With 4000 clerks, each clerk that actually makes it to the customer queue is typically taking 32 or 64 customers and distributing them to the colleagues he bumped into.

The 'ultracomputer' design has 4000 processors and 4000 memory modules and a network of criss-crossing wires and network nodes that enables every processor to access any memory module. But when two processors make a request for the same data location, those requests will collide at a network node and get coalesced into a single request. There are no delays even if all 4000 processors want access to the same memory location, for example when all the processors are trying to work on the same loop. Rather than merely accessing the loop index, they want to increase it by one as they process the loop body. For this purpose the ultracomputer people invented an operation called Fetch and Add. When a request to fetch the value of the index and increase it by one is coalesced, it becomes a request to fetch the index and update it by two. When the result comes back, the value of the index goes back to one processor and the value of the index increased by one goes to the other side, so that each processor gets a different value of the index.

I feel this ultracomputer design is the best for the long range future of parallel processing for scientific work. Artificial intelligence, speech processing and areas like that are moving in a different direction. They are thinking of parallel processing in the sense of tree structures. And they like this organization because it is two dimensional and fits very nicely on a chip. There is a kind of organization which is nice for a number of artificial intelligence problems but is not very useful for physics because there would be a bottleneck with the communications between all the processors.

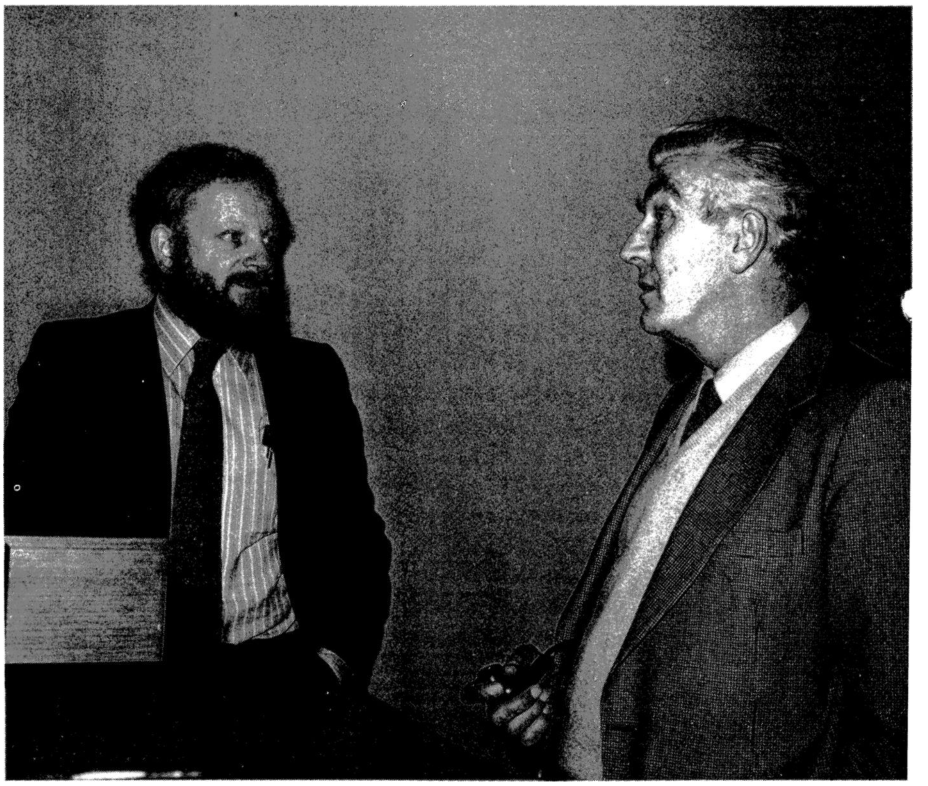
I have no doubt that in the years ahead we are going to see more of this kind of hardware and probably all the processing frameworks I have described.

European Committee for Future Accelerators

A view by ECFA Chairman John Mulvey

ECFA chairman John Mulvey, seen here (left) in conversation with former CERN Director General Sir John Adams.

(Photo CERN 424.12.80)



Nearly 21 years ago, in December 1962, Viktor Weisskopf and Cecil Powell, then respectively CERN's Director General and Chairman of the Scientific Policy Committee, called together a group of European high energy physicists to advise on steps to reach higher energy. The CERN PS had been in operation since 1959, its experimental programme was well established and the time had come to think of the future.

The Chairman of the group, which later took the title 'European Committee for Future Accelerators', was Edoardo Amaldi and his influential report, presented to the CERN Council in June 1963, reviewed the whole structure and possible development of the field in the CERN Member States. Its proposals included the construction of the Intersecting Storage Rings (ISR), and of a 300 GeV proton accelerator which was then envisaged as being the major facility of a second CERN Laboratory elsewhere in Europe.

The ISR project was then far in advance of its time and widely predicted to be 'impossible'. The project was nevertheless approved and this still unique machine came into operation in 1971. It eventually exceeded its design specifications by a wide margin and remained top of the energy league until displaced by the SPS proton-antiproton collider in 1981. Approval of the 300 GeV project, later called the SPS, was however delayed and the European Committee was re-convened early in 1966, again under Amaldi, to review its recommendations. After this it met regularly and took the form it has today.

A few months ago I asked Amaldi about the years when ECFA was formed, and how he viewed its role today. The first point he stressed was that although created on an initiative from CERN, ECFA has from its beginnings been an independent body. Amaldi's letter of invitation to the 1966 meeting explains that the Committee '...should represent the opinions... of the physicists of the Member States working in the field of high energy physics. Thus the collaboration with CERN is supposed to offer, besides technical and scientific suggestions, also constructive criticism.'

ECFA is not part of the CERN organization and this independence is essential to its role in presenting the views of the community on all matters relating to high energy physics in Europe. For example, an important item on ECFA's current agenda is the future programme of research at DESY and the HERA project.

Another aspect of ECFA's work, emphasized by Amaldi and very well illustrated by the reports of the Committee under his chairmanship, is the task of reviewing European high energy physics activities as a whole — not just the plans for future accelerators but also their utilization, the resources necessary in the universities to support experiments, and the character of the community itself. His reports covered the full spectrum of activities and set a pattern for those to follow. The most recent report in 1978 was prepared in the context of the proposal to build LEP and it will be updated in 1984.

ECFA has no formal links with Governments in the Member States and no budget; its only resources are the efforts and the enthusiasm of the members. Its main work is done by the members of the community in the Workshops and Meetings it organizes and sponsors. These studies are useful in themselves and may also lead to recommendations agreed by Plenary ECFA which carry the authority of the community, influencing the Laboratories and the

Scientific Councils of Governments.

The major activity of recent years has been the thorough assessment of the physics potential and the feasibility of the LEP project. In close collaboration with the CERN team, these studies led to the main specifications of the design, including the optimization for beam energies of about 90 GeV (or approaching 120 GeV with superconducting r.f. cavities). ECFA brought many European physicists into these considerations, thus paving the way for a remarkably wide consensus within the community, which resulted in rapid approval — only one year after LEP's first formal presentation to the CERN Council.

As part of the LEP studies, ECFA considered the development of high energy physics in Europe over the last decades of this century. It concluded that although the physics potential of LEP gave it priority as the next step, the range of fundamental questions to be tackled called for another new front-line machine in Europe. The next most attractive idea was the electron-proton collider proposed by DESY, and ECFA collaborated with DESY in a number of studies, culminating in the HERA proposal for a 30 GeV electron ring plus an 820 GeV superconducting proton ring, with four experimental areas. A Workshop on electron-proton physics was held at Wuppertal in October 1981, and in June last year Plenary ECFA again considered the proposal, in the context of a review of world-wide plans for accelerators, and confirmed its strong support for HERA.

Recently, the Minister of Science and Technology of the Federal Republic of Germany has taken a decision in principle that HERA should go ahead provided certain conditions are met, including a requirement that a share of the construction is borne by other countries. This is very welcome news and we must encourage our countries to join this first-rate enterprise while maintaining their commitment to CERN

In today's economic climate, less clement than in ECFA's early years, the support for fundamental research like high energy physics is under great pressure in many countries and has declined in proportion to national wealth, rather than moving in parallel. But the high cost of high energy physics experiments makes long periods of 'marking time' difficult to justify. Progress, as recent events at CERN clearly demonstrate, demands better experimental equipment to use with existing machines, and new accelerators to bring new phenomena within range. Balance between investment and exploitation, construction and research becomes precarious and one of ECFA's main tasks is to stand watch over this balance in Europe.

LEP was approved as part of the CERN programme under a constant annual budget. Part of this 'package' foresaw closure of the ISR which although overshadowed by the dramatic discoveries at the SPS proton-antiproton collider still has a unique programme. Its scientifically premature closure will be a sad consequence of today's economic constraints. The CERN materials budget (which has not been held constant in real terms) is now under great strain. Manpower is also a serious limitation, and the recent decision of CERN Council to allow some recruitment to replace departing staff is very welcome. The squeeze which LEP construction is putting on the continuing research programme at CERN is sev-

ECFA father-figure Edoardo Amaldi whose influential report in 1963 paved the way for the future development of the European accelerator scene.

ere. Its effects are being amplified by the very health and vigour of the research, with several excellent proposals for SPS fixed target experiments and improvements to the proton-antiproton collider operation vying for support. LEAR is another novel application of CERN's accelerator ingenuity bringing a lively new community of users to CERN. To match available resources, more very difficult decisions will have to be made.

Also, since more of CERN's resources are needed for the accelerators, the CERN contribution to the LEP experiments will be less than a third of that typical for the ISR and SPS experiments. A greater share of the support for experiments will fall on the home institutions. In some ways this should be welcomed, since there has been a tendency to overcentralize detector development and construction at CERN. It does however put greater emphasis on the need for adequate technical and financial support in the universities and research institutes of the Member States. ECFA will review this as part of the 1984 survey.

Other current activities of ECFA range from the use of computers and networks to the accelerators of the far future. A series of Working Groups have been defining standards for a wide range of software and hardware used in data analysis and data acquisition. Copies of reports can be obtained from the leader of the Working Groups, Egil Lillestol at Bergen, or from Peggy Rimmer at CERN. Another aspect of this activity is a study aimed at linking the European high energy physics groups in a communications network, HEP-NET. This Group has a participant from each Member State; agreement has been reached on a number of tasks and work has started on a file-transfer protocol conversion which would allow file-transfers between CERNET and the Italian, Scandinavian and UK systems. (Information can be obtained from Mike Sendall at CERN.)

For the future, an energy range thought not long ago to be a featureless desert is blooming with all manner of exotic species and the theoreticians bemuse us with tales of great discoveries to be made beyond the TeV horizon, where clues to a super unification of the basic forces of Nature might be found. Even without these temptations, experimenters have to go and see. With 10 T magnets, a 10 TeV per beam proton-antiproton collider is an attractive long-term possibility for the LEP tunnel after the electron-positron programme. A 'Desertron', a larger ring in the American desert, might go somewhat higher but it is hard to contemplate the size and cost of a proton machine of significantly greater energy, and equally difficult to believe that more than 1 TeV could be reached in an electron-positron collider... unless a new way is found which increases the accelerat

Constitution of ECFA

The members of Plenary ECFA, which normally meets twice a year, are chosen by the thirteen Member States of CERN and include a delegation from CERN itself. The meetings of Plenary ECFA are open and are also attended by observers from the European Science Foundation, the European Physical Society and two non-Member States: Israel and Finland.

On a smaller body, 'Restricted ECFA', one physicist represents each of the Member States and one represents the CERN physicists. It meets more frequently to discuss the affairs of high energy physics, to advise the Chairman on the work of ECFA and to prepare for the Plenary meetings. The Director General of CERN and the Director of DESY are ex-officio members of Restricted ECFA. Recently, Restricted ECFA has held more of its meetings in the Member States and has preceded them with a discussion meeting with members of the local high energy physics community.

The Chairman is elected by Plenary ECFA for a three year term, not normally renewable. Through the Chairman, ECFA has a voice on the CERN Council; he is an ex-officio member of the CERN Scientific Policy Committee (SPC) and Committee of Council, attends meetings of the Finance Committee, and advises the Director General. The Chairman has also been invited to attend meetings of the DESY Extended Scientific Council.

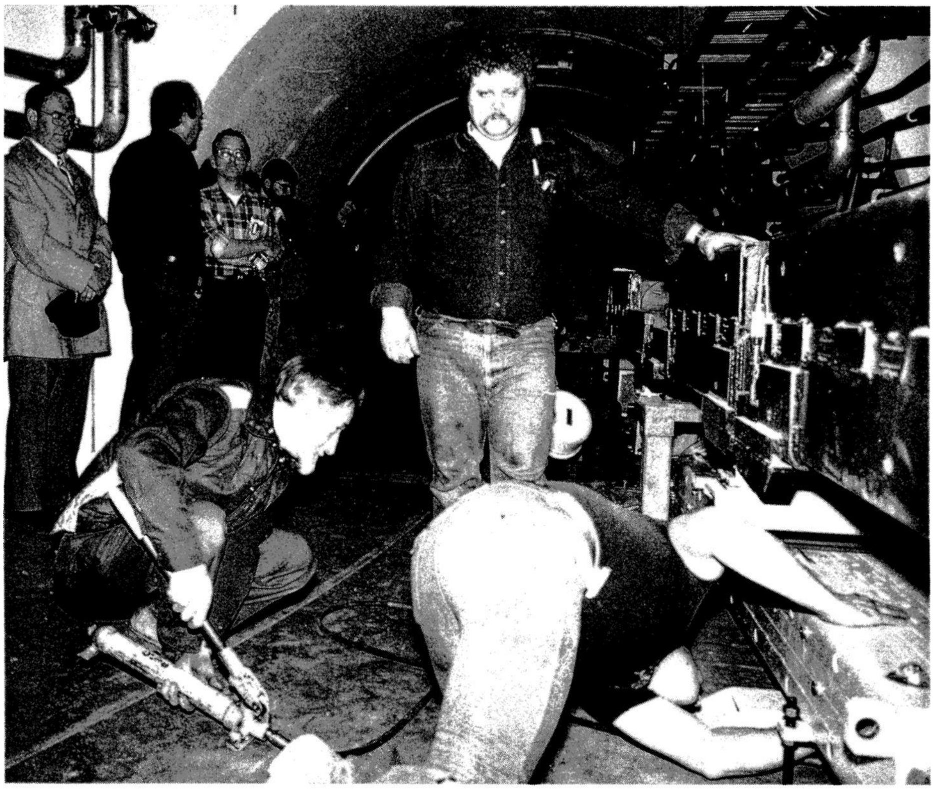
Since its formation by the IUPAP Commission for Particles and Fields in 1976, the International Committee for Future Accelerators (ICFA) has had three West European members: the CERN Director General, the Chairman of the CERN SPC and the Chairman of ECFA.

ing gradients from the present 10 MV/m or so (100 MV/m has been demonstrated) up to 1 to 10 GeV/m. This was the main topic of the ECFA-Rutherford meeting held last September in Oxford (see December 1982 issue, page 405). Ingenious ideas were described, but few were really new, and practical demonstrations of feasibility are far away. And if the challenge of reaching such energies is formidable, that of delivering the power to attain desirable luminosities seems greater.

The proceedings of the meeting are now available from Rutherford Appleton Laboratory or CERN, and ECFA invited European scientists who are working in the field, or who are interested in starting, to a short meeting at Trieste on 1 June following the 'Workshop on Laser and Collective Accelerators', which the International Centre for Theoretical Physics organized on 31 May and 1 June. If we, or, rather, our children, are to look beyond the several TeV horizon some effort must be put into this research; we must encourage more scientists to become involved in this very challenging physics and build collaborations with other areas of research such as plasma and high power laser physics. We must also attract and train young physicists who will take over from the present ageing population of experts. A new initiative, which ECFA is strongly supporting, is the proposal by CERN to establish a School in accelerator physics. The idea is to give this a European-wide framework, with courses at CERN and other Laboratories, and to provide lecturers for universities. A small group, led by Kjell Johnsen, is now drawing up plans for this new venture, which should help to produce the physicists to devise and build the really high energy accelerators of the future.

The final superconducting quadrupole is eased into position for the new Fermilab Saver/Doubler ring, which threads its way through the supports of the Main Ring's conventional magnets.

(Photo Fermilab)



FERMILAB
Last Saver/Doubler magnet installed and first tests

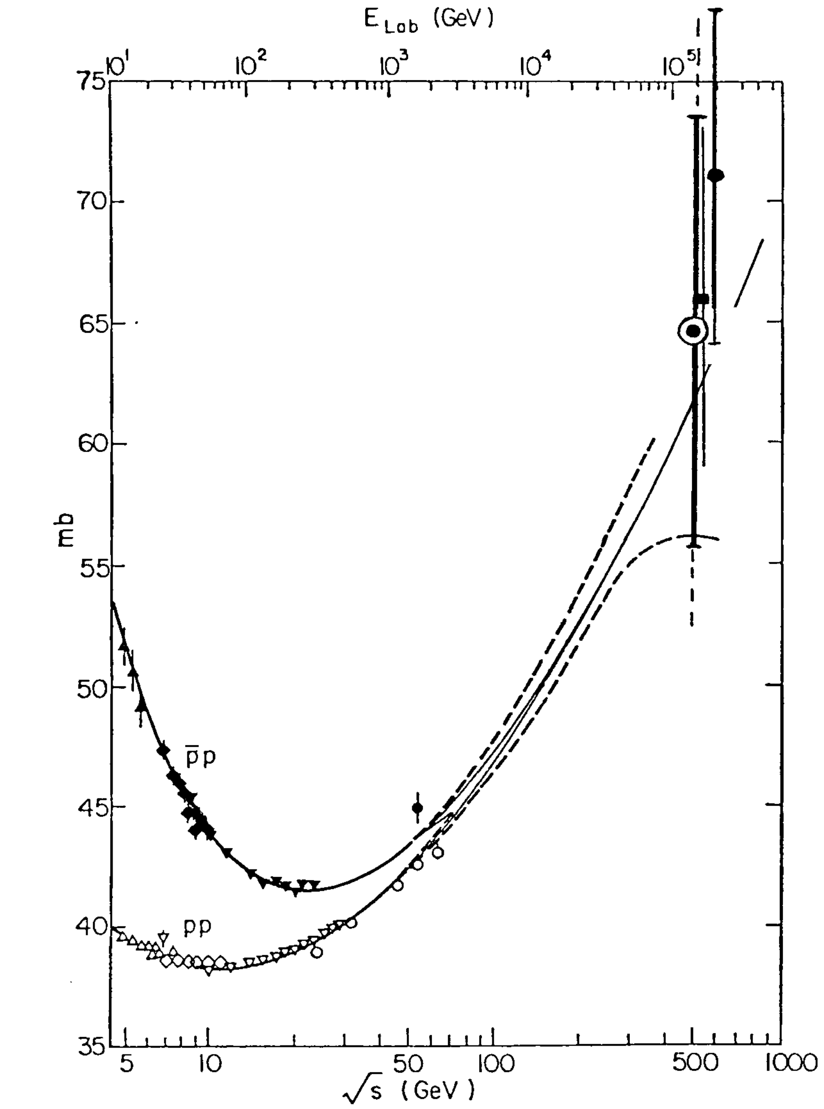
On 18 March, a superconducting quadrupole was installed at position A-49 in the Fermilab Main Ring tunnel to complete the magnet installation for the new Energy Saver/Doubler ring which threads through the supports of the conventional magnets of the existing Main Ring. The Saver/Doubler ring now has 774 dipoles and 216 quadrupoles and will eventually have 204 control spool pieces.

Subsequent recommissioning of the Main Ring and Saver/Doubler tests went well. On 16 April, Sectors E and F of the Saver (one-third of the ring) were powered to 2200 A, equivalent to 500 GeV. The next day, the Main Ring was in action for the first time in nearly a year. Beam was taken to 150 GeV, the injection energy for the Saver.

On 22 April, beam was injected from the Main Ring into the Saver at the E0 straight section. By the following day, a low intensity beam had been transported one-third of the way round the ring to a temporary beam dump. Fine tuning in both rings will continue, but the next major milestone will be completion of Saver installation so that full turns can be attempted.

In this one-third ring exercise, no quench problems were encountered. The fields and alignments of the superconducting magnets required little correction. The new beam position and loss monitoring systems were tested for the first time and worked beautifully.

Comparison of proton-antiproton (top) and proton-proton (bottom) total cross-sections at different collision energies (lower horizontal axis). The points on the right with large errors are the new results from the SPS proton-antiproton collider, showing that the total cross-section countinues to rise, and extrapolates well with what is seen at lower energies. The round data points, centre, come from the Intersecting Storage Rings.



CERN
Hadron horizons

An article in the May issue (page 136) described some of the new hadron scattering results which indicate that at high energies there might be an universal underlying behaviour, independent of the quark composition of the colliding particles.

Just over ten years ago, controversy raged about the general trend of hadron behaviour at higher energies. The dust only settled when the first results appeared from the CERN Intersecting Storage Rings.

Today there is less controversy, but the topic has been given a new lease of life by the ability to compare proton-proton and proton-antiproton behaviour under similar conditions at the ISR, and by the new energy range opened up at the SPS proton-antiproton collider.

Total and elastic cross-sections are important measurements of inter-hadron affinity. The total cross-section indicates how reactive the particular particles are, while the elastic cross-section describes how the scattered particles simply 'bounce' off each other, without changing their relative composition. A systematic comparison of these two important parameters of hadron behaviour provides significant clues about the underlying interaction mechanisms. Comparison of particle-particle (proton-proton) and particle-antiparticle (proton-antiproton) results is also revealing.

Over the years, the behaviour of the proton-proton elastic and total cross-sections has been measured with precision at the ISR. New studies were mounted to profit from the availability from 1981 of proton-antiproton collisions (see June 1981 issue, page 196).

For elastic scattering and total cross-section measurements, these included a CERN / Naples / Pisa / Stony Brook group measuring total cross-sections by the observed reaction rate, a Louvain / Northwestern team using the time-honoured 'Roman Pot' technique of movable detectors to probe the extreme forward scattering cones, and an Ames / Bologna / CERN / Dortmund / Heidelberg / Warsaw team working at the Split Field Magnet.

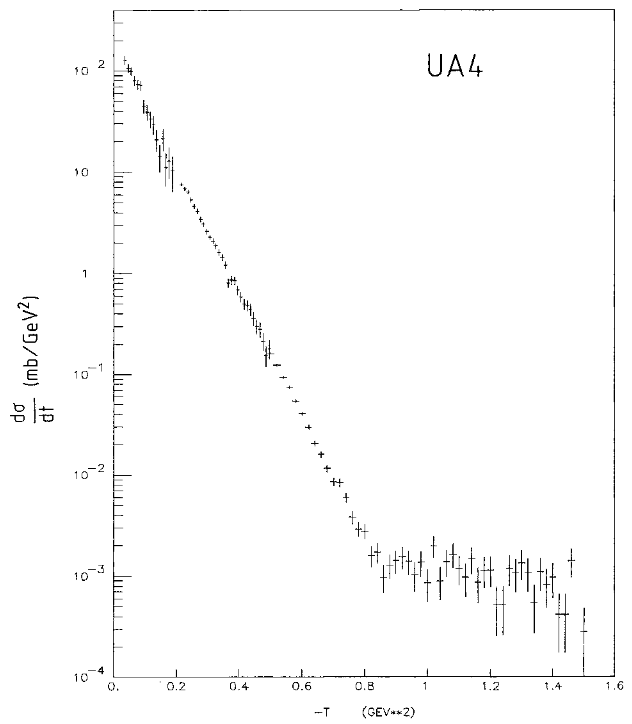
These results, when taken together, now give a good comparison of proton-proton and proton-antiproton scattering over the available kinematic range.

Broadly speaking, the elastic and total cross-sections in the two cases appear to converge as the collision energy is increased. The shape of the elastic scattering spectrum is conventionally described by a decreasing exponential, the exponent being related to the effective 'size' of th colliding particles.

For both proton-proton and prc ton-antiproton scattering, there ap pears to be a slight increase in th exponential falloff at smaller momen tum transfer. At lower energies, th falloff is also sharper in the proto antiproton case, however the diffe ence disappears as the collision e ergy is increased.

Overall, the observed behavio seems to be well described by t conventional model of 'Regge' e changes, without recourse to ne ideas, such as 'odderons'.

When the ISR came into operati just over ten years ago, the observ rise of the proton-proton total cros section was something of a surpris Until then, it had been widely b lieved that particle interaction rat were levelling off at previously av able energies in preparation for asymptotic limit. But the ISR show



Preliminary proton-antiproton elastic scattering spectrum as measured by the UA4 experiment at the CERN SPS proton-antiproton collider. The observed exponential decrease is sharper for small momentum transfers (between 0 and 0.2 GeV²), and then becomes less steep. At about 0.8 GeV², there appears to be a 'shoulder', reminiscent of what is seen at lower energies in the Intersecting Storage Rings.

that asymptopia was still a long way off.

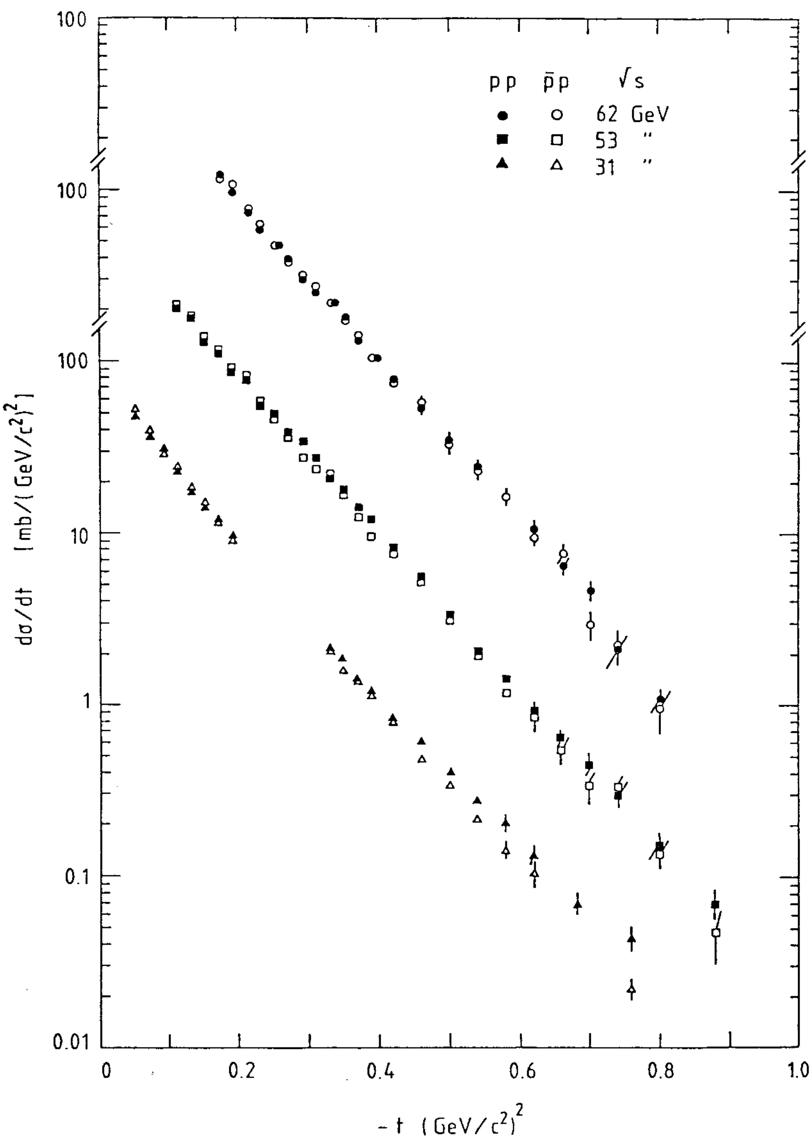
With the advent of the SPS proton-antiproton collider, another new energy range opened up. Proton-antiproton cross-section information comes from the mighty UA1 experiment (which measures as many things as it can) and from the special UA4 study (Amsterdam / CERN / Genoa / Naples / Pisa, see September 1982 issue, page 271).

Results show that the proton-antiproton total cross-section continues to rise, reaching about 65-70 millibarns, broadly in line with extrapolations from lower (ISR) energies. This seems to indicate that the cross-section grows as fast as allowed by the general principles of the theory.

Both experiments now report a relatively sharp exponential decrease (exponent about 17) for small momentum transfers (between 0 and 0.2 GeV²). At larger momentum transfers the exponent falls to about 13.5. It is not yet evident whether there is an abrupt change between these two regions of behaviour, or whether there is an identifiable transition region.

At larger momentum transfers (about 0.8 GeV²) there is a definite 'shoulder' in the elastic scattering spectrum. This looks like the vestige of one of the early discoveries at the ISR — a dip in the proton-proton scattering spectra, strongly reminiscent of optical diffraction.

However, even under ISR conditions its position moves with energy and the dip itself becomes less pronounced. This is underlined by the SPS proton-antiproton results, which show that the shoulder has



Comparison of proton-proton and proton-antiproton elastic scattering at the Intersecting Storage Rings by an Ames / Bologna / CERN / Dortmund / Heidelberg / Warsaw collaboration.

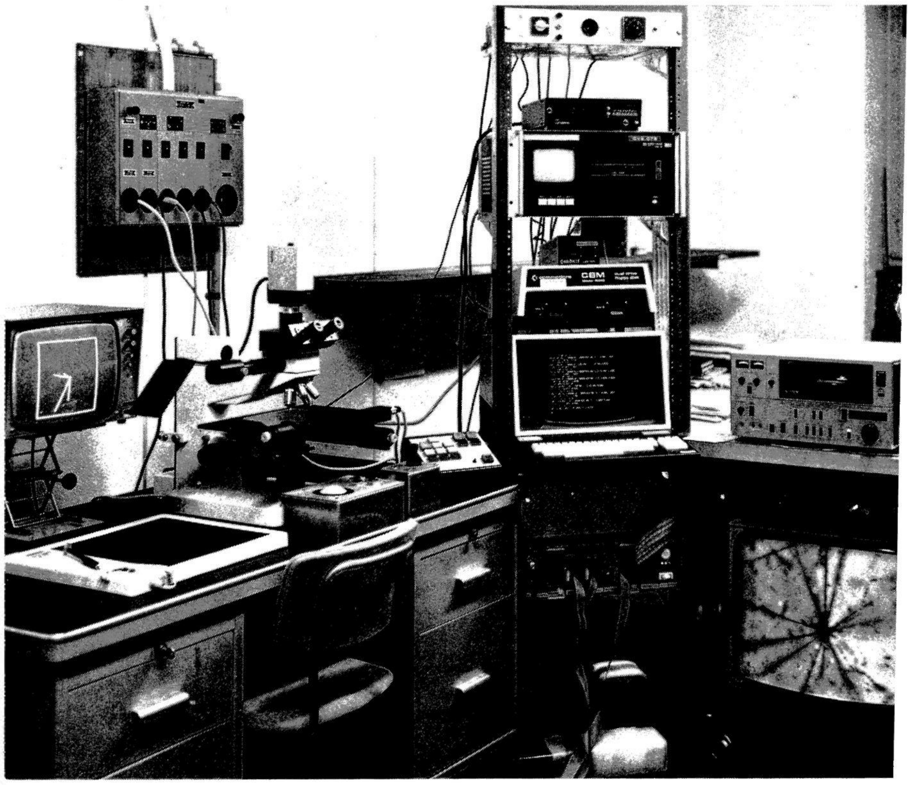
shifted considerably from its ISR position.

Several theoretical models attempt to describe these results. As well as an effective size, the proton (and antiproton) has an 'opacity'. Under laboratory conditions, the proton is not completely opaque ('black') to an incoming beam, but is 'grey' and penetrable. One outstanding question is whether at infinite energy the proton would become opaque, whether it would remain grey, or whether it would become transparent. Further studies at the collider will help provide us with the answer.

A thing of beauty

After many fundamental contributions in the early days of particle physics, the nuclear emulsion technique had some ten years of almost total neglect in physics at accelerators. The reason was not so much its basic abilities as the fact that searching for events in the emulsion and their subsequent measurement was a process of mind-bending tedium. A revival came with the need to study charm and beauty particles whose lifetimes, though short, are still observable by detectors able to distinguish events at the micron level. This is exactly the special feature of nuclear emulsions — they can resolve events in space to distances of a few microns or less.

Happily this ability can now be exploited without the pain of bygone years. Other detectors in association with the emulsion can select and reconstruct the event and indicate where to look in the emulsion. More modern mechanisms in association with microelectronics can also allow rapid scanning and precise measurement of a whole event recorded in the emulsion.



Units of the system developed at CERN which greatly increases the efficiency and speed of scanning and measuring nuclear emulsions for particle interactions. The introduction of a computer-aided digitized microscope (CADIM) has helped relaunch the emulsion technique, particularly in the study of very short lived particles.

(Photo CERN 233.4.83)

All these developments are brought together in so-called 'hybrid' experiments (such as the WA71 and WA75 studies at CERN) to study the production and the lifetimes of particles containing the beauty quark. WA71 uses the revamped Omega spectrometer, and is a CERN / Genova / Milan / Moscow / Paris / Rome / Santander / Valencia collaboration with G. Diambrini-Palazzi as spokesman. A 350 GeV negative pion beam generated by protons from the SPS hits nuclear emulsion (two pellicles each 0.5 mm thick stacked perpendicular to the beam). Silicon detectors, a time projection chamber and multiwire proportional chambers follow downstream of the emulsion in the magnetic field of the Omega magnet. A beam hodoscope, a ring imaging Cherenkov counter and a gamma detector complete the apparatus.

The beauty search will concentrate on events where the number o tracks seen a few millimetres down stream exceeds the number of track emerging from the vertex in th emulsion, indicating the possible de cay of a charmed particle, which i self may result from the prompt de cay of a beauty particle.

The emulsions are scanned unde a computer-aided digitized micrc scope (CADIM) and can be moved b intervals of less than 1 µm in thre dimensions via refined stepping mc tors. Coordinate digitizers linked t the microscope can record the pos tion of any point in the field of vie when accurate measurements a required. A much magnified image the slice of emulsion in focus can t visualized on a large TV screen.

Analysis proceeds by the compu er reconstruction of the event fro the downstream information indica ing where to look in the emulsion ar also giving a visual display of the pa tern of emerging tracks, for example, at the exit plane of the emulsion. It is thus possible to scan rapidly to a vertex in the emulsion and to follow the produced particles out to the exit plane where the superimposed predicted pattern confirms that the right event is under investigation. This rapid scan is quite fascinating because, as the paths of particles are traced from their production to where they leave the emulsion, there is a real impression of following the event in time as it actually happened.

A disparity between the multiplicity recorded in the downstream detectors and the multiplicity seen near the vertex is the trigger for careful observation and measurement of the tracks in the emulsion. Within five minutes an experienced operator can identify whether an event is to be retained. Because of this, it is feasible to think of looking at over 50 000 events in a year with some ten measuring systems distributed amongst the teams in the collaboration. These improvements in analysis techniques have probably gained a time factor of several tens compared to nuclear emulsion physics of twenty years ago.

F. Bal, S. Tentindo and G. Vanderhaege in particular were involved in the development of the CADIM at CERN. There was some pioneering work several years ago, but the recent developments were triggered by the spectacular advances by K. Nin and his colleagues at Nagoya University in Japan. Similar devices are now being built in many European Universities.

DESY
Upsilons at DORIS II

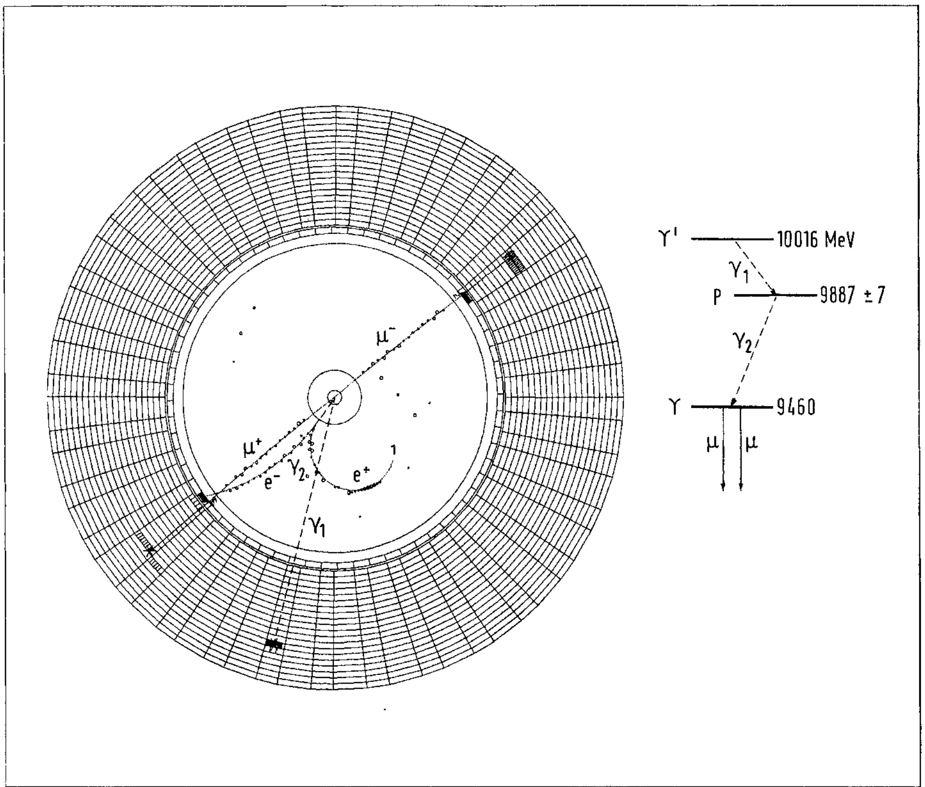
The high luminosity at the DORIS II electron-positron ring is being used at present to improve statistics on decays of the upsilon prime meson. This is a beauty quark-antiquark bound state with no orbital angular momentum (S-wave) at 10.016 GeV. Its decays are well suited for study by the Crystal Ball sodium iodide detector moved in from Stanford.

One important search is for two consecutive gamma rays leading to the ground state upsilon at 9.460 GeV, when the intermediate state is a P-wave upsilon (carrying one unit of orbital angular momentum). These states cannot be formed directly in electron-positron collisions. In fact the P-wave state should consist of three neighbouring levels, separated by only about 10 MeV.

To study these states, the energy of the photons must be measured with high accuracy. This helps to understand the forces at work between quarks, in much the same way that earlier this century optical spectra provided valuable clues to atomic structure.

Intercepting these S-P-S upsilon cascades is difficult and only relatively few have been reported so far. First sightings were at the CUSB detector using the CESR electron-positron ring at Cornell (see September 1982 issue, page 274). However it is hoped that statistics will soon permit measurements sufficiently accurate to satisfy at least some theoreticians.

In the other interaction region at DORIS II is the Argus detector, equipped with lead-scintillator sand-



Decay of an upsilon prime by successive photon emissions, as seen in the Argus detector at the DESY DORIS II ring. The higher energy photon converted into an electron-positron pair, giving a good fix on the mass of the intermediate P-state upsilon.

People and things

wich counters whose accuracy for determining photon energies is not as good as sodium iodide. However Argus incorporates a magnetic spectrometer covering large solid angle. The energy of photons converting to eletron-positron pairs in the beam pipe or the inner walls of the detector can therefore be measured very accurately. For Argus, a single event with such a converted photon is worth several dozen shower counter events.

To avoid inaccuracies due to energy loss of the electrons or positrons in the solid material after the conversion process, it is made as thin as possible. However this also cuts down the number of events — only about three per cent of the photons convert into clearly measurable electron-positron pairs.

The Argus team was lucky and found such an S-P-S cascade event. It gives the energy of the intermediate P-state upsilon as 9.887 GeV with an error of only 7 MeV. In this event it was the higher energy photon (427 MeV) which converted. Now the hunt is on for an event with conversion of one of the lower energy photons (230 MeV). This could improve the accuracy to within 3 MeV.

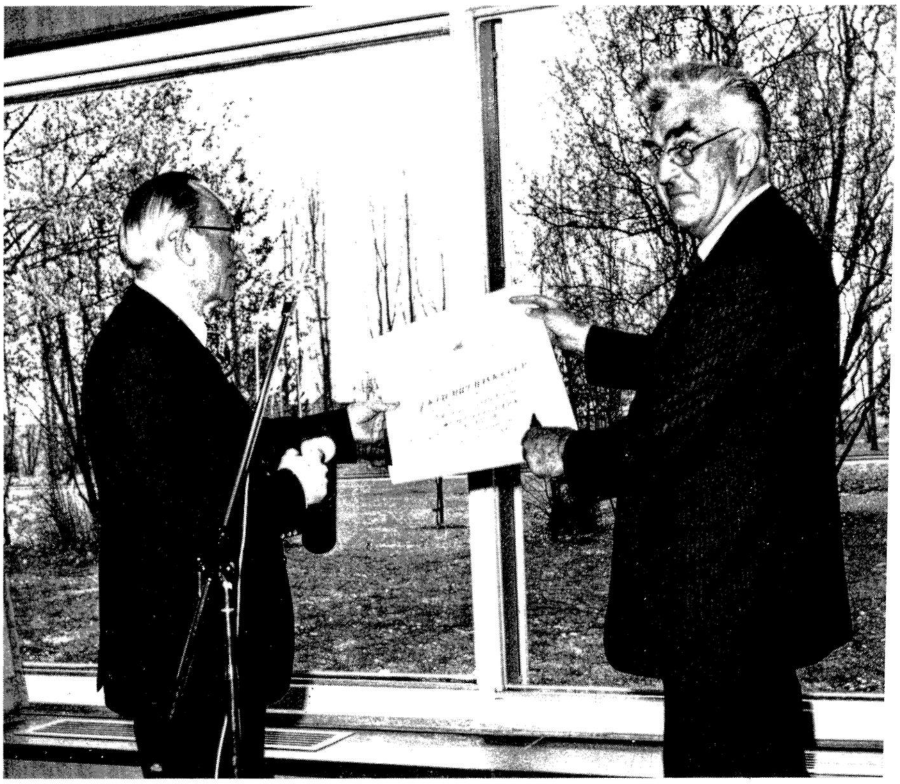
On people

At a ceremony held on 18 April at CERN, Vladimir Lavrov, Soviet Ambassador to Switzerland, presented a diploma of Foreign Member of the USSR Academy of Sciences to Sir John Adams. His election to the Academy was for 'outstanding achievements and contributions to science and technology'. In his reply, Sir John said that it was an honour to himself, the profession of accelerator scientist, and to CERN.

A special colloquium on 30 April at the Swiss Institute of Nuclear Research (SIN) marked the 80th birthday of Rolf Wideröe, accelerator pioneer who has continued to be prominent since the very early days. He invented one of the first linac acceleration techniques, which bears his name.

Following the 25th anniversary of the 'Particle Data Group' (see July/August 1982 issue, page 237), Arthur H. Rosenfeld is to receive the Honorary Degree of Doctor of Science from Durham University, UK. Rosenfeld's work as leader of the Particle Data Group from 1964-74 resulted in an international collaboration which is valued throughout the particle and nuclear physics communities. A whole generation of physicists came to know the famous listings as 'The Rosenfeld Tables'. Since 1975, compilation of particle physics scattering data has been coordinated by a group at Durham in collaboration with the Particle Data Group.

Recently Professor Rosenfeld has concentrated on energy matters and was responsible for the founding of the American Council for an Energy Efficient Economy.



...iet Ambassador to Switzerland Vladimir Lavrov (left) presents Sir John Adams with his diploma as Foreign Member of the USSR Academy of Sciences.

(Photo 145.4.83)

LEP construction work under way at CERN. The housing for the injector linacs takes shape near the 28 GeV proton synchrotron.

(Photo CERN 185.4.83)

Louis Rosen Prize

The Board of Directors of the LAMPF Users Group is establishing and supporting a new award, the Louis Rosen Prize. This prize, consisting of $1000 and a certificate, is to be awarded annually for the outstanding PhD thesis based on LAMPF research. The judging will be done by the Board of Directors. Theses should be submitted to the Users Group Office at LAMPF by 31 August for consideration. To be eligible, a thesis must have been completed since the previous August. Announcement of the winner of the prize will be made at the annual Users Meeting in November.

Dick Lundy (left) explains to US Energy Secretary Donald Hodel the construction of a Fermilab Energy Saver/Doubler magnet.

(Photo Fermilab)

Accelerator Summer School

This year sees the third US National Summer School on High Energy Particle Accelerators. It will be held at Brookhaven National Laboratory and the State University of New York at Stony Brook from 6-16 July. The school aims to provide current knowledge and build up expertise in the area, to stimulate accelerator education in university physics, and to foster interaction between particle and accelerator physicists. Even at this late stage, interested persons are invited to contact the School Administrator, Paula Hughes, Accelerator Department, Brookhaven National Laboratory, Upton, New York 11973, USA.

Five Year Fellowship in High-Energy and Nuclear Physics

LAWRENCE BERKELEY LABORATORY'S Nuclear Science Division has a position open as Divisional Fellow for a person with outstanding promise and creative ability, and with an interest in experimental physics pertinent to high energy, nucleus-nucleus collisions. Experimental programs in this area are presently being carried out at LBL's Bevalac, CERN's ISR and SPS; in addition, LBL is currently developing plans for a new heavy ion facility. Candidates with a background in either nuclear or high-energy physics are welcome. The appointment will be for a term of five years with the intention of promotion to a senior staff position.

Applicants are requested to submit a curriculum vitae , list of publications, statement of research interest, and the names of three referees to:

Howel G. Pugh
Nuclear Science Division
Mail Stop 70A/3317
Lawrence Berkeley Laboratory
Berkeley, CA. 94720

as early as possible, and before the closing date of September 30, 1983. LAWRENCE BERKELEY LABORATORY is an equal opportunity/affirmative action employer.

LAWRENCE
BERKELEY
LABORATORY

RUTHERFORD APPLETON LABORATORY

HIGH ENERGY PHYSICS RESEARCH ASSOCIATES

There are vacancies for Research Associates to work with experimental groups in high energy physics. Groups from the Rutherford Appleton Laboratory are working on experiments at CERN, DESY and SLAC.

Candidates should normally be less than 28 years old. Appointments are made for 3 years, with possible extensions of up to 2 years. RAs are based either at the accelerator laboratory where their experiment is conducted, or at RAL depending on the requirements of the experiment. We have in addition home-based programmes on development of detectors, microprocessor systems, etc. Most experiments include UK university personnel with whom particularly close collaborations are maintained.

Please write for an application form quoting VN 045 to

Recruitment Office, R20,
Rutherford Appleton Laboratory,
Chilton, Didcot, Oxfordshire OX11 0QX,
ENGLAND.

POSTDOCTORAL OPPORTUNITIES IN

EXPERIMENTAL NUCLEAR PHYSICS

The experimental nuclear physics group of the Los Alamos National Laboratory has postdoctoral opportunities available in programs of current interest to the Laboratory's Physics Division. Basic research programs include heavy-ion collisions at low, medium and very high incident energies, low energy antiproton-nucleus collisions, neutrino mass and oscillation measurements, medium energy proton and pion scattering, neutron physics, very low energy reactions of astro physical and fusion reactor interest, kaon-nucleus physics, and high pressure equation-of-state experiments. These positions offer an excellent opportunity for communication with our large theoretical physics divisions and our unsurpassed computer facilities offer superb research opportunities.

The Los Alamos National Laboratory is operated by the University of California for the Department of Energy. Our location in the mountains of northern New Mexico offers a pleasant life-style, a pollution free environment and ample recreational activities. Postdoctoral appointments are for one year and may be renewable for a second year. We provide competitive salaries and fringe benefits, which includes 24 days annual vacation. Candidates no more than three years past their Ph.D are invited to apply.

To apply, please send resume in confidence, by Sept. 1, 1983 to:

Jane Roberson, Associate Group Leader
Personnel Administration Division, DIV 83-L
Los Alamos National Laboratory
Los Alamos, NM 87545

University of California
Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

An Affirmative Action/Equal Opportunity Employer: Women, Minorities, Handicapped and Veterans are Urged to Apply.

Advertisements in CERN COURIER

Format A4 **Monthly publication**

All advertisements are published in both English and French editions. Second language versions accepted without extra charge.

Space (page)	Actual size (mm) width by height	Cost per insertion (Swiss Francs)			
		1 insertion	3 insertions	5 insertions	10 insertions
1/1	185 x 265	1550	1500	1450	1350
1/2	185 x 130 90 x 265	850	820	800	750
1/4	90 x 130	480	450	430	410

Supplement for:	
— each additional colour	1500 SwF
— Covers:	
Cover 3 (one colour)	1850 SwF
Cover 4 (one colour)	2450 SwF
Publication date	1st of month of cover date:
Closing date for positive films and copy	1st of month preceding cover date The cost of making films and of translation for advertisements are charged in addition.
Screen (offset)	60 or 54 Swiss (150 English) Advertisements cancelled after 1st of month preceding cover date will be invoiced.

Advertising space is limited to 50% of contents and insertions are selected on a strict first-come first-served basis.
These rates are effective for the year 1982.

All enquiries to:
Micheline FALCIOLA / CERN COURIER – CERN
CH-1211 Geneva 23 Switzerland
Tel. (022) 83 41 03 Telex 2 36 98

TRANSIAC

A leading manufacturer of advanced data acquisition systems

TRANSIAC, a major supplier of high-energy and fusion physics research equipment is now represented in Switzerland by SEN Electronique, which is proud to present these latest state-of-the-art products:

TR1024

Budget Priced High Resolution Multilayer Graphics Terminal

* Extra sharp 1024 x 780 pixel CRT display
* Faster graphics drawing at 1 microse per pixel
* Overlaying of multiple image or buf fer menus and graphics with multipl memory planes
* Terminal instruction set conformin entirely to that of Tektronix® 401 Series at a fraction of the cost
* Utilization of Plot-10®, ISSCO® DI-3000® programs, exactly as yo use them now
* Take advantage of TRANSIAC's proprie tary hardware enhancements to use th NEC 7220 Graphics Controller Chip providing horizontal scrolling, ver tical scrolling, zoom, etc.
* ANSI Standard X3.64 VT100® compati bility soon available
* Optional CAMAC packaging

These are several other of TRANSIAC's fine products:

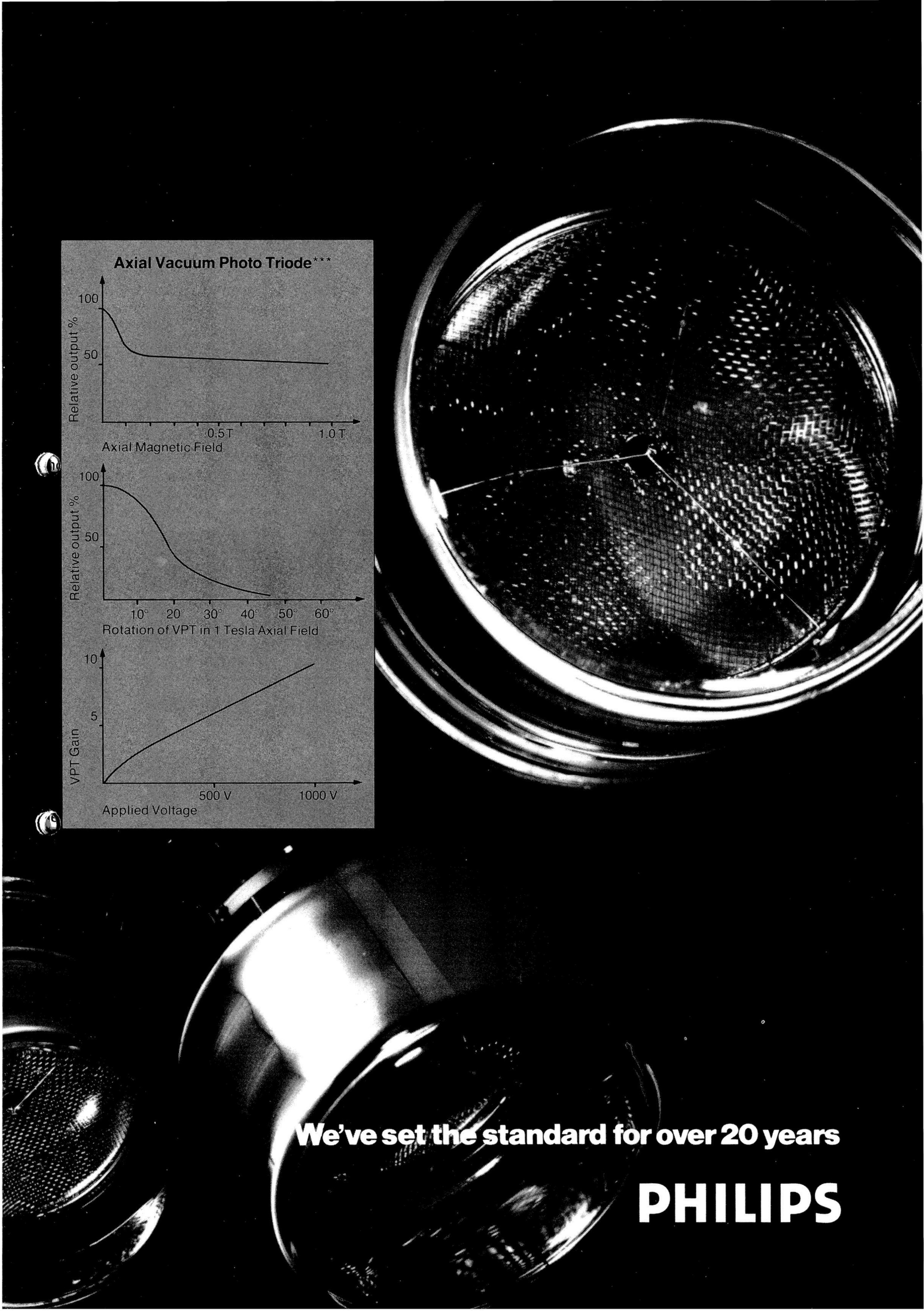
2001 - 100MHz 8-bit Transient Recorder
2008 - 25MHz 8-bit Single Board Transient Recorder
2010 - 20MHz 10-bit Transient Recorder
2012 - 5MHz 12-bit Transient Recorder
2108 - 20MHz Signal Averager
3016 - 16-channel 16-bit DAC
6001 - Microprocessor Crate Controller
7001 - Semi-autonomous Data Acquisition Controller and Digitizer
7004 - 32-channel Fast Gated Integrator
TRAQ I Data Acquisition System

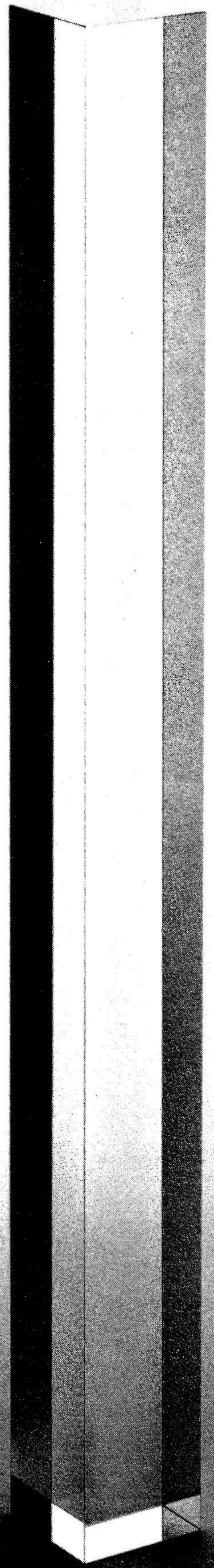
SEN ELECTRONICS S.A.

Avenue Ernest-Pictet 31; Tel. (022) 44 29 40 – Tlx 23 359ch – CH-1211 GENÈVE 13

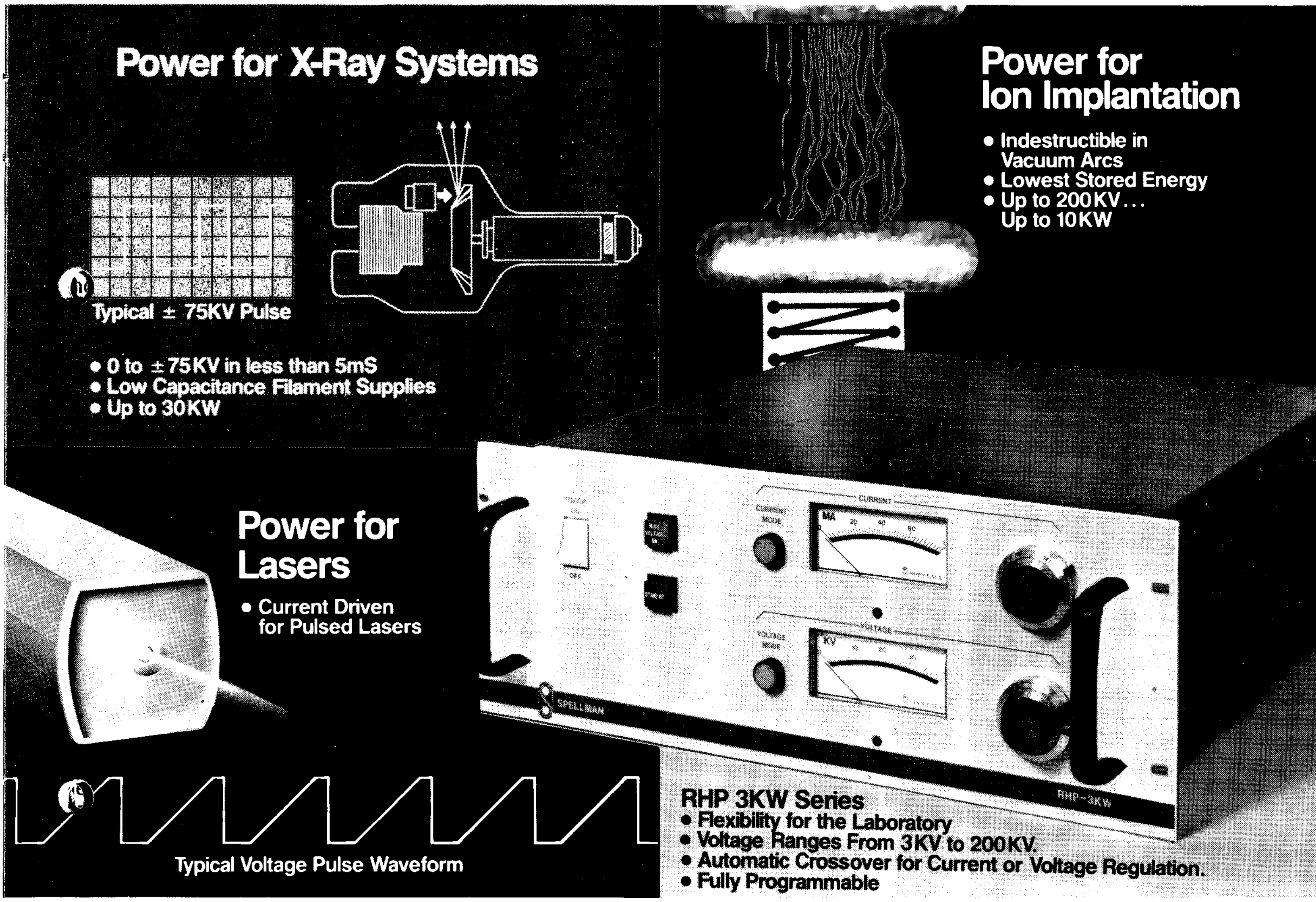
OFFICES THROUGHOUT THE WORLD

SEN ELECTRONIQUE


Axial Vacuum Photo Triode***
100
50
Relative output %
0.5 T
1.0 T
Axial Magnetic Field
100
50
Relative output %
10°
20°
30°
40°
50°
60°
Rotation of VPT in 1 Tesla Axial Field
10
5
VPT Gain
500 V
1000 V
Applied Voltage
We've set the standard for over 20 years
PHILIPS



Spellman's High Power resonant inverter outperforms units 9 times its size



The most important breakthrough in High Voltage Power Supply technology in more than 20 years

Spellman's new series resonant inverter produces pure sinusoidal current to generate high voltage power without the disadvantages inherent in conventional technologies... eliminating line frequency magnetic components... eliminating vacuum tubes... eliminating oil. This high frequency approach reduces size and weight while the sinusoidal shape of the current waveform eliminates electromagnetic interference and provides failsafe current limiting and short circuit protection. Low stored energy and 50KHz ripple frequency contribute to the unit's indestructibility under vacuum arcing.

Other Applications

• Klystron and TWT Supplies • E-Beam Systems
• Capacitor Chargers

Features

• Extremely Compact Design • 0.01% Voltage Regulation
• 0.02% RMS Ripple • High Frequency Operation

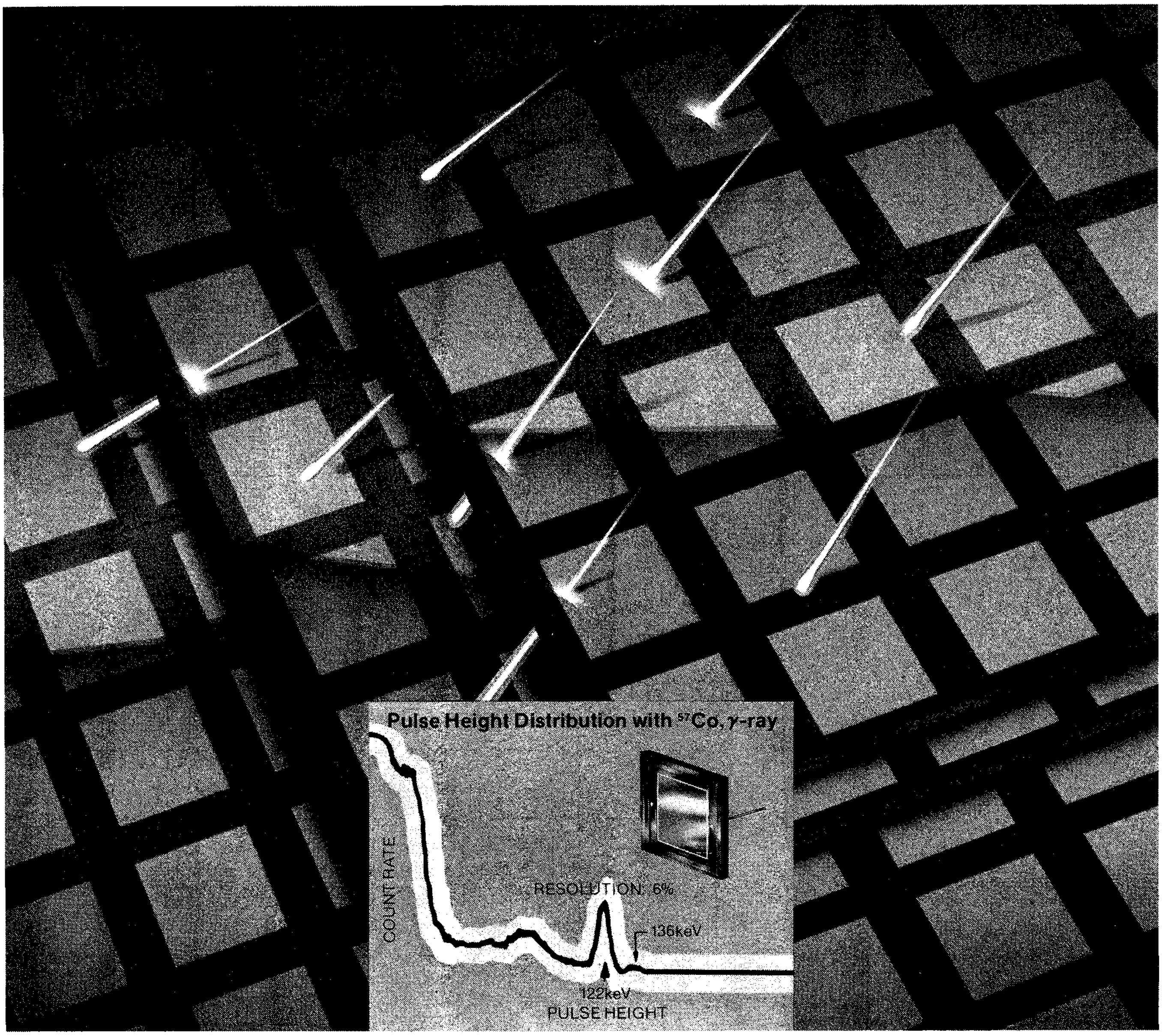
Options

• Remote Voltage Programming • Wide Range of Additional Options • IEEE Bus Interface • Voltage and Current Test Points

Spellman

High Voltage Electronics Corp

7 Fairchild Avenue, Plainview, New York 11803 (516) 349-8686 TWX: 510-221-2155
Engineering opportunities available. Write to personnel department.



Now, for the first time, high energy resolution from PIN silicon photocells.

The new S1723 PIN silicon photocell provides the low junction capacitance and high shunt resistance needed for high speed response and low noise. Its large, sensitive surface area ($100mm^2$) is ideal for use with BGO and other scintillation crystals. This detector is less than 3mm thick compared with 60mm or more for PMT's, yet has a $100mm^2$ sensitive area. Thus, the S1723 occupies a small fraction of the space, and costs about half as much when used with today's solid state amplifiers.

Applications include scintillation detection in the fields of High Energy Physics, Medical Diagnostics and industrial instrumentation. Hamamatsu engineers will modify the S1723 or other detectors to meet your needs.

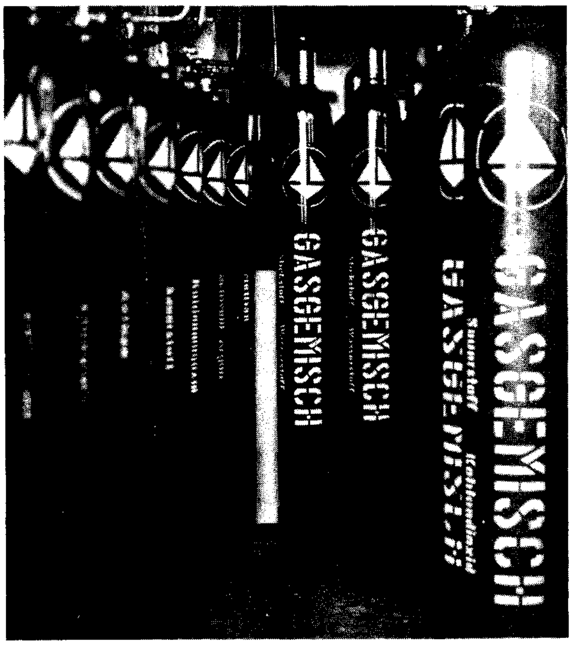
Call or write for product bulletin and prices.

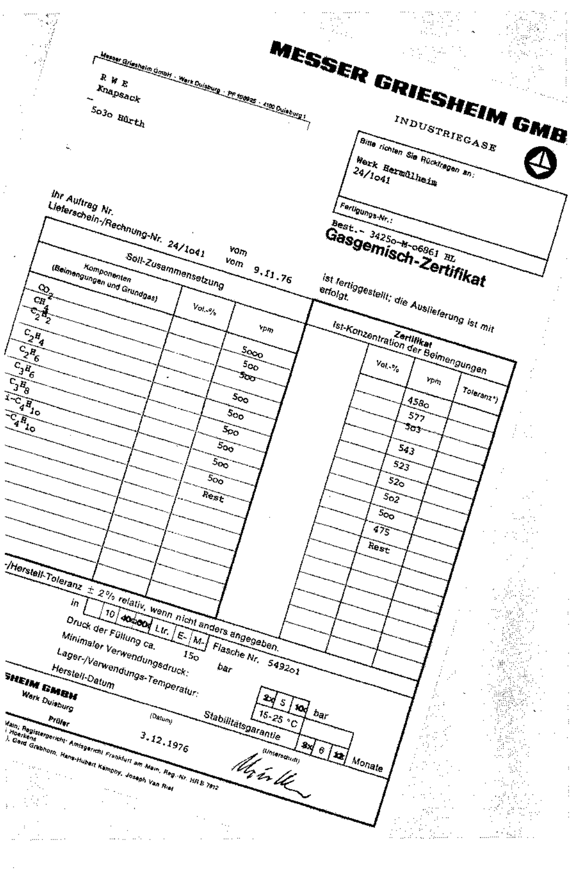
HAMAMATSU

HAMAMATSU CORPORATION • 420 SOUTH AVENUE • MIDDLESEX, NEW JERSEY 08846 • PHONE:(201) 469-6640

International Offices in Major Countries of Europe and Asia.

Gas Mixtures Unlimited





In theory, it is possible to combine 150 individual gases to produce 11,175 two-component mixtures and over half a million three-component mixtures. What's more, there is virtually no limit to the possible number of variations in the concentration of each component.

In practice, this means you can ask Messer Griesheim for any gas mixture you want, in precisely the quality you need. And get it fast.

However specialised and demanding your application – in science, education, industry or research – you can depend on the guaranteed composition of the gas mixture you have ordered.

Messer Griesheim* high purity gases and gas mixtures are supplied in handy pressure cans and in steel cylinders with specially treated linings to preserve the stability of their valuable contents.

If you need a delivery, try us. If you need advice, ask us. Whatever the case, we'll step on the gas.

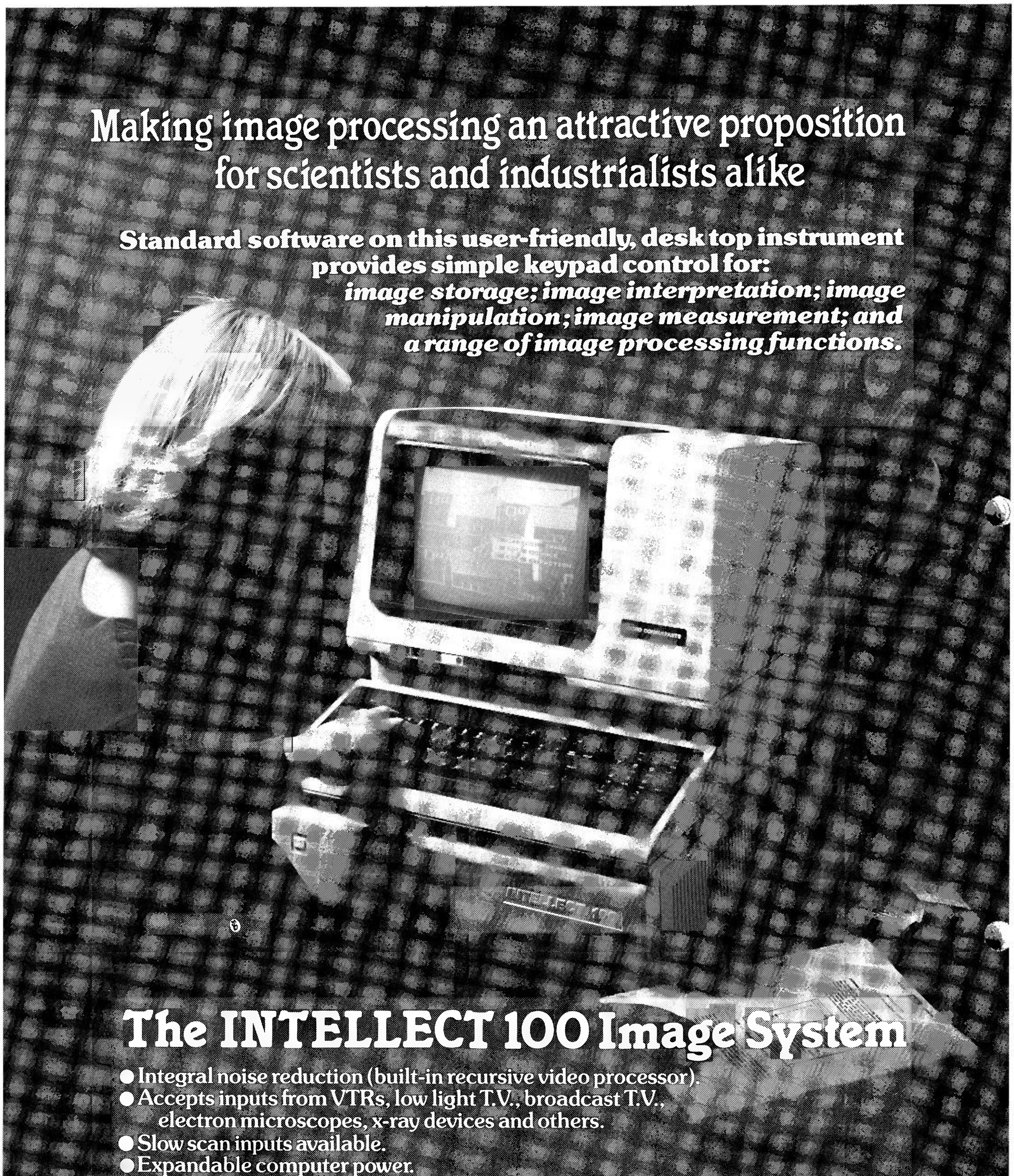
* Represented in Switzerland by
Schweisstechnik AG
Langwiesenstrasse 12,
8108 Dällikon/Zürich
Telephone 01/8 44 27 11

Gases + Cryogenics Messer Griesheim

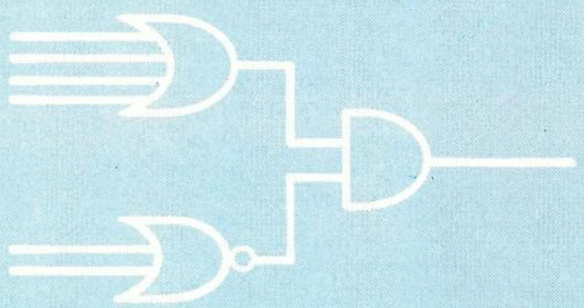
2.8009 e

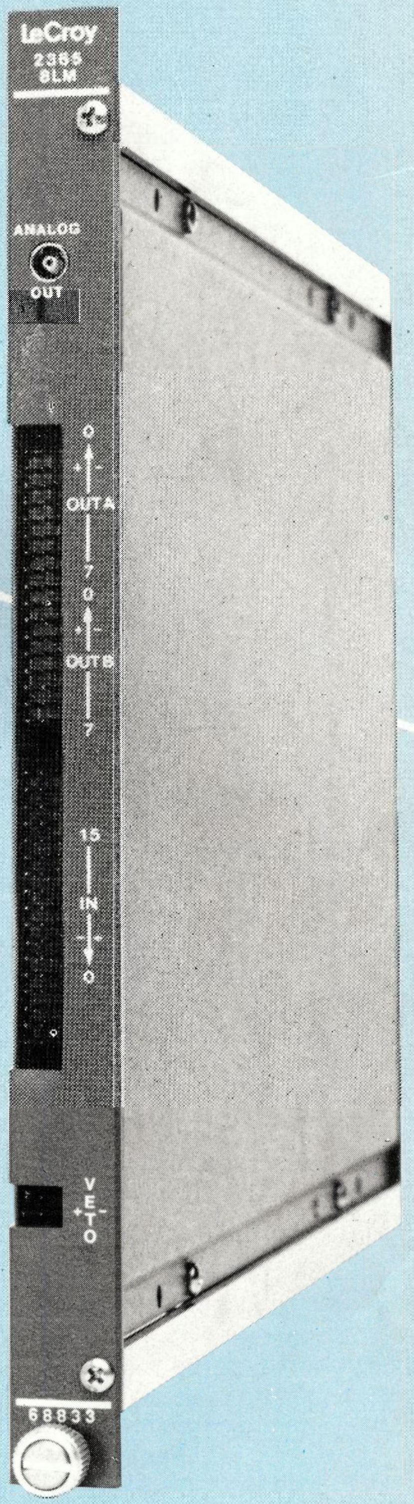
MESSER GRIESHEIM
Industriegase
Homberger Strasse 12 · D-4000 Düsseldorf 1
Telephone 02 11/4 30 31 · Telex 85 84 979 mgd d

– a member of the Hoechst group



Making image processing an attractive proposition for scientists and industrialists alike
Standard software on this user-friendly, desk top instrument provides simple keypad control for: image storage; image interpretation; image manipulation; image measurement; and a range of image processing functions.
The INTELLECT 100 Image System
● Integral noise reduction (built-in recursive video processor).
● Accepts inputs from VTRs, low light T.V., broadcast T.V., electron microscopes, x-ray devices and others.
● Slow scan inputs available.
● Expandable computer power.
● FORTRAN programmable version available.
● Optional bulk electronic picture storage.
For more details of our range of image systems write for our short form brochure today.
MICRO CONSULTANTS LTD., Kenley House, Kenley Lane, Kenley, Surrey CR2 5YR, England Tel: 01-668 4151 Telex: 946643 MICRO G
A member of the Micro Consultants Group
MICRO CONSULTANTS





LeCroy
2365
8LM
ANALOG
OUT
OUT A
OUT B
IN
VETO
68833

EIMAC's 4CW300,000G Power Tetrode. A new generation of high-performance power tubes.

EIMAC's 4CW300,000G combines all the desired features transmitter designers look for: high peak plate current, low grid emission, low internal capacitances and low internal inductance. This is the first of a new generation of high performance power tubes for LF, HF, VHF and pulse service.

Laserfab pyrolytic graphite grids

The control grid and screen structures of the 4CW300,000G are precision-cut by a laser beam. Each element is monolithic and combines extremely low coefficient of expansion with low structural inductance. These features permit the 4CW300,000G to have a very high transconductance—10^6 micromhos—and allow efficient, high-frequency operation.

Rugged mesh filament

The EIMAC mesh filament provides exceptionally high peak plate current and permits low plate voltage operation. This leads to power supply economy, making the 4CW300,000G the economic choice for 300 KW AM broadcast service or long-pulse switch service, each of which demands a reserve of peak emission.

Improved anode structure

EIMAC's multi-phase cooling technique provides high plate dissipation to extract heat evenly and quickly from the anode, contributing to long tube life and operating economy.

EIMAC expertise

EIMAC's expertise in electron ballistics pyrolytic grid production, thermodynamics and circuit techniques combine to bring tomorrow's tubes for today's transmitter designs. More information is available from Varian EIMAC. Or the nearest Varian Electron Device Group sales office.

Electron Device Group
Varian EIMAC
Application Engineering
Department
301 Industrial Way
San Carlos, CA 94070
Telephone: 415•592-1221, ext. 218

Varian AG
Steinhauserstrasse
CH-6300 Zug, Switzerland
Telephone: (042) 23 25 75
Telex: 78 841

varian