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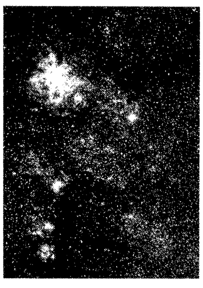
Around the Laboratories

Physics monitor



Cover photograph:
While astronomers continue to admire the celestial fireworks of the 'close' 1987a supernova (160 000 light years away), particle physicists pore over their neutrino data — scanty, but the first particle information from a gravitational collapse. This colour photograph is a composite of three monochrome exposures from the European Southern Observatory's 1 m Schmidt telescope at La Silla, Chile. The bright supernova is to the right of the centre. Most of the fainter stars belong to the Large Magellanic Cloud, a satellite galaxy to our own Milky Way. Blue stars are hot (10 000 degrees or more) while red and yellow are between 2 000 and 3 000 degrees. Astronomical observations of the evolving supernova should provide additional clues as to what happened on 23 February 160 000 years ago (Photo European Southern Observatory).

Around the Laboratories

Karl-Heinz Pape with the rod radiofrequency quadrupole after its successful test for the new Linac III at the DESY Laboratory in Hamburg.

(Photo P. Waloschek)

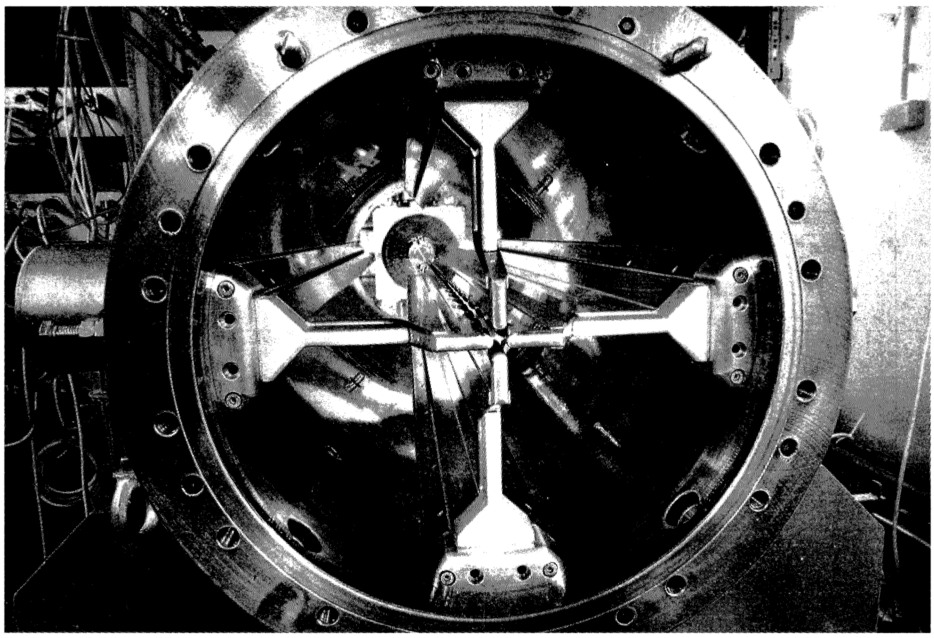
DESY
Preparing for protons

The protons for the new HERA electron-proton collider now being built at the German DESY Laboratory in Hamburg will come from negative hydrogen ions accelerated up to 50 MeV in a new linac, Linac III. After stripping off electrons in a foil, the protons will be injected into the DESY III synchrotron, soon to be built. Protons will reach the PETRA II ring (see May issue, page 17) at about 7 GeV, leaving at 40 GeV ready for injection into the main HERA ring.

Good progress has been made in setting up the first sections of Linac III. The ion source with bending magnet and solenoids for beam matching provides currents much higher than required for HERA. The 18 keV negative hydrogen ion beam is sent into a radiofrequency quadrupole (RFQ) designed at the Institute for Applied Physics of the University of Frankfurt and precision-built by industrial specialists (Balzers/Pfeiffer at Aslar).

The 118 cm RFQ has been successfully tested. It provides a 750 keV beam ready for the linac, 27 mA having been accelerated without measurable loss. At the highest current supplied by the ion source (55 mA), the RFQ still transmitted 42 mA, compared to the 10 mA demanded in the HERA proposal.

Before installing the definitive RFQ, the Frankfurt group tested a much simpler device made of four rods instead of precision machined and adjusted vanes (see page 3). A beam of about 35 mA reached the 750 keV output level.



Conventional precision-built four-vane radiofrequency quadrupole (RFQ).

The RFQ story

In the last few years, the radio-frequency quadrupole (RFQ) has been replacing the traditional Cockcroft-Walton high-voltage generator for the acceleration of charged particles to the 1 MeV energy range. The idea of I. M. Kapchinsky and V. A. Teplyakov from ITEP Moscow in 1970 was subsequently developed at Los Alamos, in particular for proton acceleration.

From 1979, RFQs for heavy ions were also studied at Darmstadt (GSI) and by a Frankfurt group. Many laboratories are now using RFQs in their injection systems, a notable example being the one provided by Berkeley for CERN's nuclear beams. Interesting applications are being found for this simple and compact ion accelerator and progress has been made in further simplifying its construction.

In its present design the RFQ not only accelerates particles but also focuses the beam and separates it into bunches well suited for further acceleration (good emittance). All this is achieved practically without particle losses.

There are many other advantages. The ion source for an RFQ does not have to be placed in a high voltage cage, as was the case with d.c. voltage acceleration, so that sophisticated, very intense and very large ion sources can now be used. No high pressure tank is required for electrostatic insulation. The cost of a working installation has been reduced by more than an order of magnitude, while the RFQs themselves have modest dimensions, about 1 to 1.5 metres for 1 MeV energies. An RFQ designed to accelerate a specific ion type can also be used for lighter particles.

The ability to handle currents of several hundred milliamps opens the door to industrial applications, in particular ion implantation. Surface hardening treatments are of prime interest, as well as semiconductor applications. Implantation of ions like nitrogen, silicon or zinc in a one micron layer provides surface hardening without heating up the rest of the material. Drill bits, stamping tools, ball bearings and pistons are just a few examples of where the technique could be applied.

For particle accelerators, the RFQ still offers additional possibilities. New applications being studied include beam deceleration, accelerating very heavy clusters, and beam 'funnelling'.

The four electrodes of an RFQ are usually made as 'vanes' with accurately machined three-dimensional surfaces. The characteristic dimpled longitudinal profile of the vanes is essential to produce the required accelerating field. Tolerances are at the ten micron level, including the adjustment of the relative positions of the four vanes.

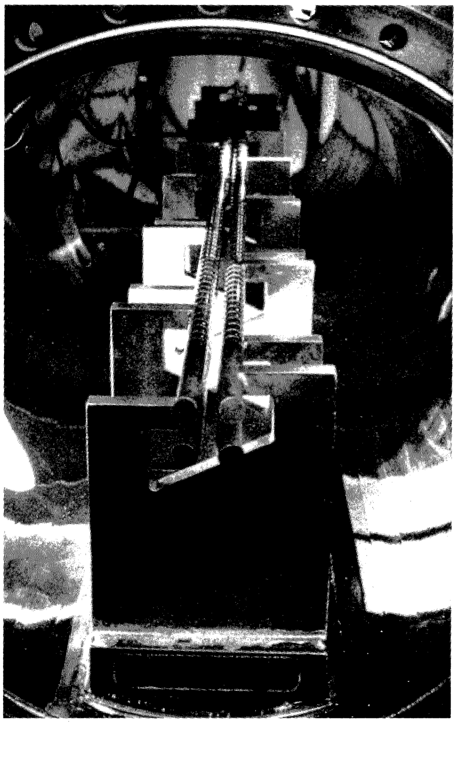
In a new development at Frankfurt a simpler structure has been successfully tested. A new resonating system for the supporting structure allows the electrodes to be simple rods with longitudinal modulations, made and mounted to 100 micron tolerances. No fine adjustment is required and the resonating structure is welded into its final position. This reduces the cost and complexity of the unit by an order of magnitude!

The successful testing of such a rod-RFQ (RRFQ) at the DESY Laboratory in Hamburg for the new proton linac promises well for the future of these devices.

From A. Schempp

The four-rod RFQ developed at Frankfurt is easier to manufacture and still gives good results, providing 750 keV negative hydrogen ions ready for the new Linac III at the DESY Laboratory in Hamburg.

(Photos DESY)



BEIJING
Chinaware

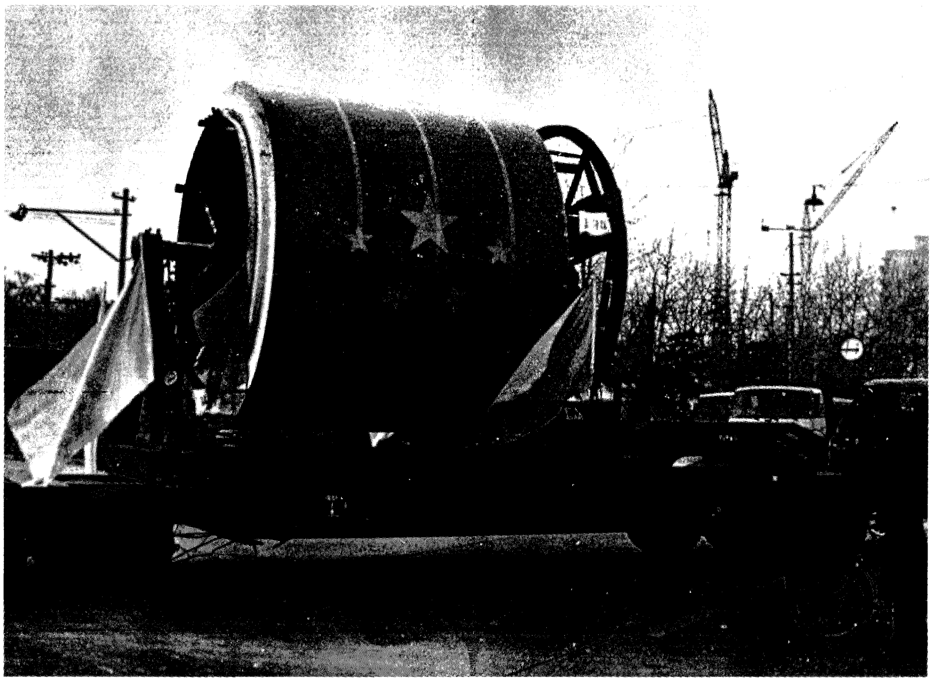
Good progress is being made for the BEPC Beijing Electron Positron Collider, designed to provide beams of between 2.2 and 2.8 GeV in a storage ring supplied by a linac taking the electrons and positrons to 1.4 GeV.

Civil engineering work for the linac was completed in the middle of last year, eighteen months after a memorable ground-breaking ceremony attended by many high-ranking party and government officials. The rapid pace of the construction work demonstrated how much importance the national authorities attach to basic research, with the local government according the project high priority in the face of a heavy demand for dwelling construction.

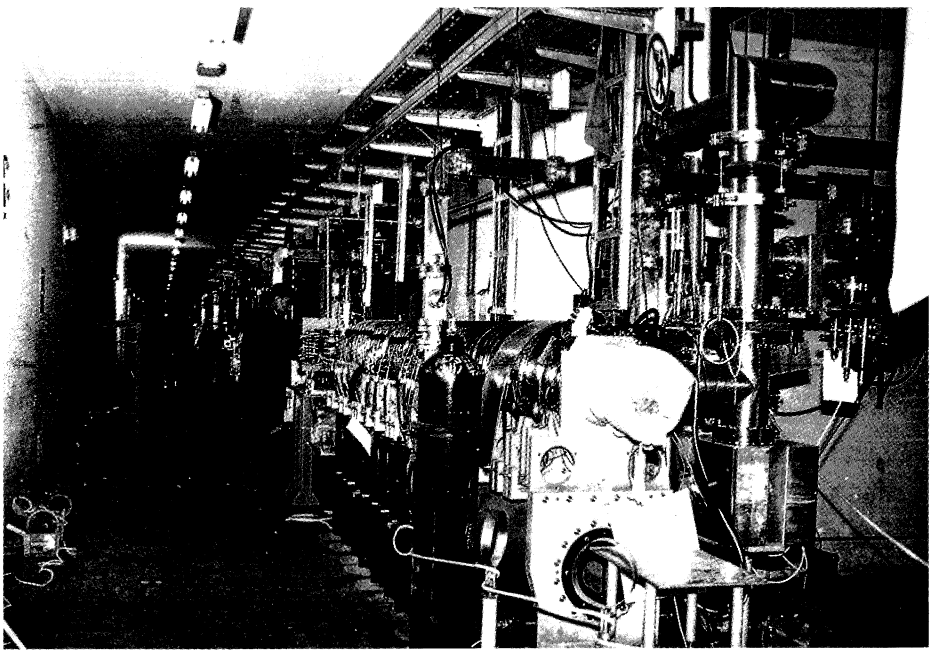
The linac building is 217 metres long and with the accelerator tunnel and klystron gallery occupies 2400 square metres. Installation in the klystron gallery began in January 1986, and in the tunnel the following May while water supply and air conditioning systems were still incomplete. The initial few months were difficult, with an abnormally wet summer, while the high humidity inside the non-air-conditioned tunnel stopped installation work for about 50 days. However subsequent progress has been quite good.

All linac components have been received and transported to the site. Accelerating sections are being installed in parallel at both ends of the linac. Equipment at the north (electron gun) end includes eight accelerating sections powered by four klystrons, and has provided 250 MeV electrons. All subsystems — radiofrequency, vacuum, water cooling, beam control and measurement, local control, etc. — are working well.

The largest coil in China — 32 ton solenoid for the Beijing spectrometer — en route from the winding factory to the Laboratory.

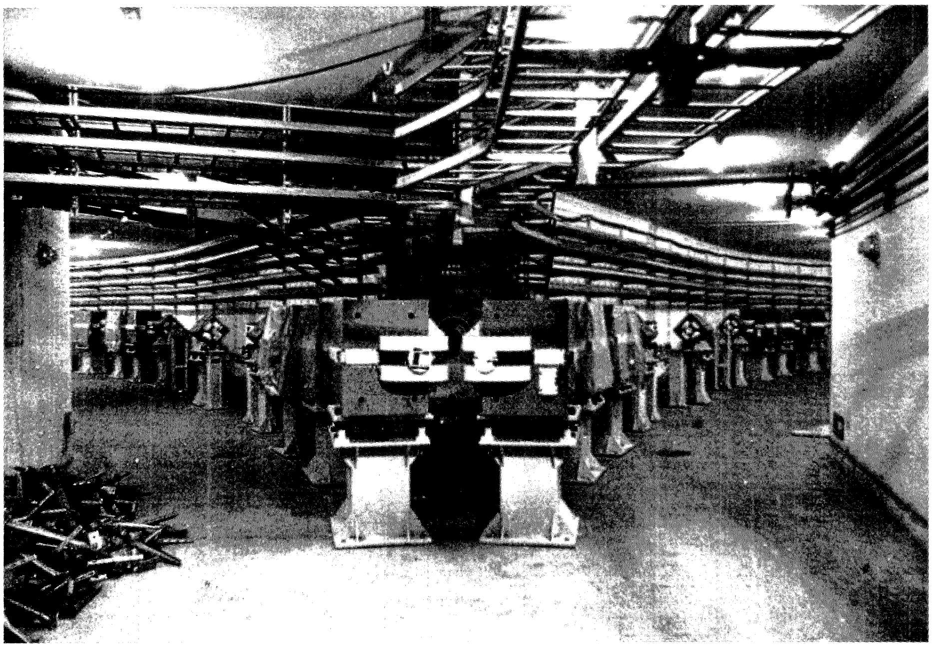


First detector to use the BEPC beams will be the BES BEijing Spectrometer based on a conventional solenoid coil producing a field of 0.4 tesla. The coil — the largest in China — was designed by a group from the first physics division of the Institute of High



Installation for the 1.4 GeV electron/positron linac for the Beijing Collider is progressing well.

*CERN's ISR machine, turned off in 1984, achieved a maximum proton-proton luminosity of $1.3 \times 10^{32}\ cm^{-2}\ s^{-1}$.



The parting of the ways — the Beijing electron and positron injection tunnels.

Energy Physics (IHEP), responsible for the detector, but manufactured by the Institute of Atomic Energy (IAE).

The solenoid has an outer diameter of 4.2 metres and weighs about 32 tons. About 4000 metres of hollow aluminium conductor of cross-section 20 square centimetres (purchased from the US) were wound at IAE.

Transportation of the finished coil was a major local event. Even though IAE and IHEP are only 50 kilometres apart, the epic journey took two days and 150 stops, and involved several hundred people.

Once safely in the experimental hall, the coil was covered with its iron yoke consisting of 300 tons of Japanese steel processed by Xinhe shipyard in Tianjin, northern China.

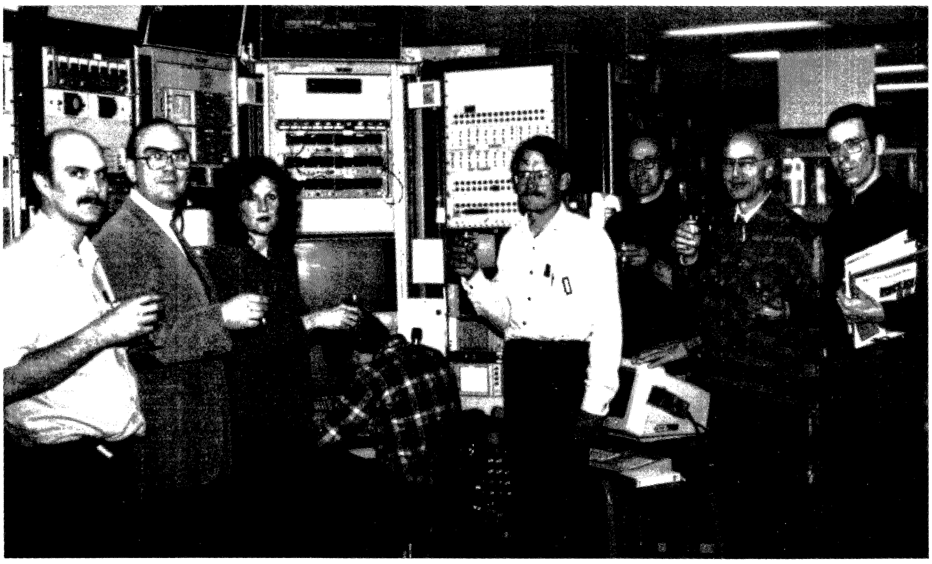
CORNELL Record

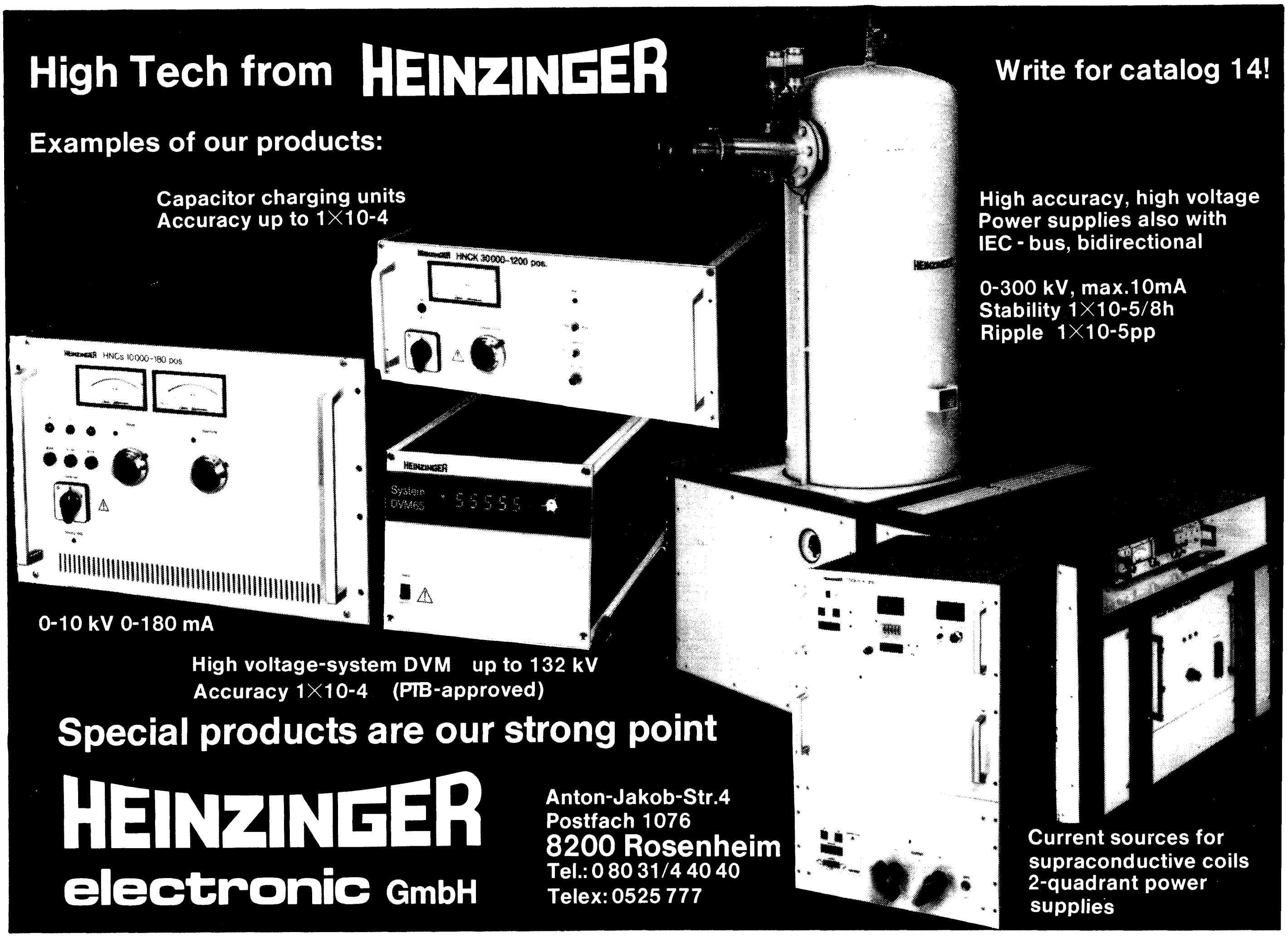
Cornell's CESR electron-positron storage ring reached new heights recently with a peak luminosity of $5 \times 10^{31}\ cm^{-2}\ s^{-1}$ during runs at the fourth (4S) upsilon resonance at 10.58 GeV, a world record for electron-positron collisions*. It was achieved with seven bunches in each beam, and an average of some 50 mA per beam.

Both the CUSB II and CLEO experiments operate in 'micro-beta' mode, squeezing the beams tightly together at the collision points. Both experiments have been taking data at 1.5 pb^{-1} per day. Future efforts to boost the luminosity still higher will concentrate on shortening the bunch length (presently 2.2 cm). The present beam current is limited by problems due to higher-order mode fields induced by the beam bunches in electrostatic separators and radiofrequency cavities.

(The DORIS electron-positron storage ring at the DESY Laboratory in Hamburg achieved 1.563 pb^{-1} over one day in 1984, while the PEP electron-positron ring at Stanford had a 1.6 pb^{-1} day in 1983.)

Operating crew of Cornell's CESR electron-positron ring celebrate a world record (peak luminosity $5 \times 10^{31}\ cm^{-2}\ s^{-1}$): left to right R. Eshelman, M. Billing, Barbara Gardner, D. Kematick (seated at console), D. Rice, D. Morse, R. Littauer and D. Sagan.

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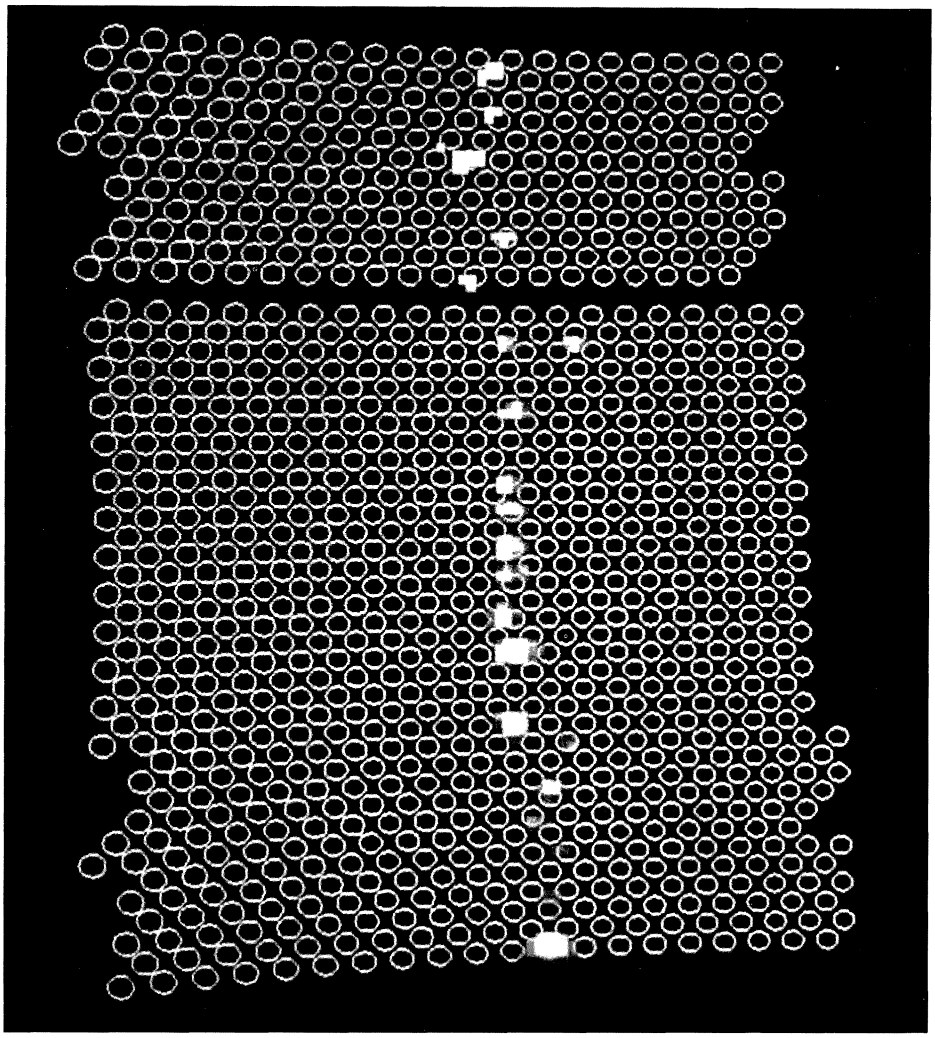
Scintillating results. Results from a test by the UA2 collaboration at CERN show how particle tracks are nicely picked up by an array of 1 mm diameter scintillating fibres. This tracking will form an integral part of the substantially modified UA2 experiment for the CERN proton-antiproton collider.



CERN
Tracking by fibres

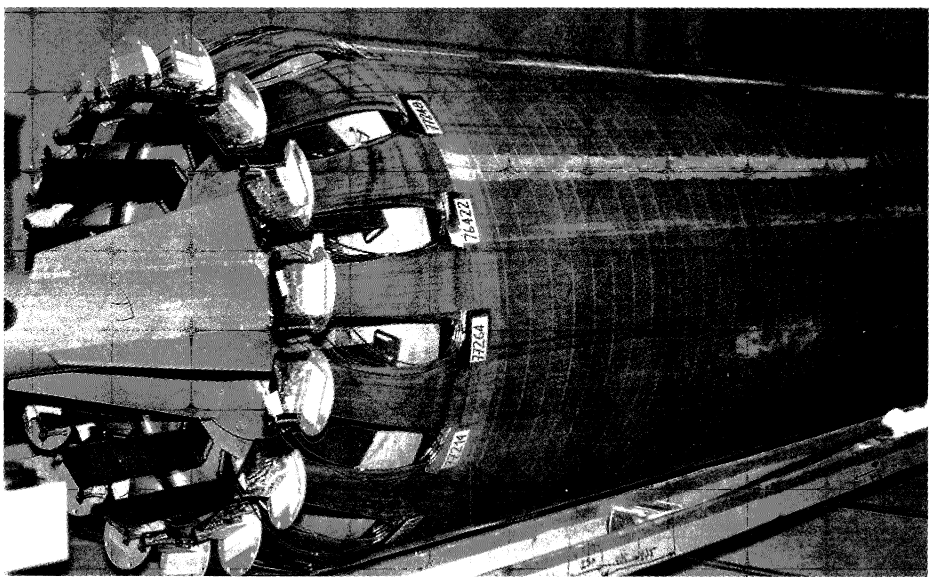
The upgrade of the UA2 experiment at CERN's proton-antiproton collider aims to take advantage of the higher antiproton levels provided by the new ACOL Antiproton Collector. In particular improved electron identification in the new UA2 vertex detector should help in the search for signs of the sixth ('top') quark.

With a vertex/inner tracking detector (jet chamber), a matrix of silicon pads for ionization measurement and assistance in pattern recognition, and a transition radiation detector to help reject fake electrons, the available space in the central detector is limited.

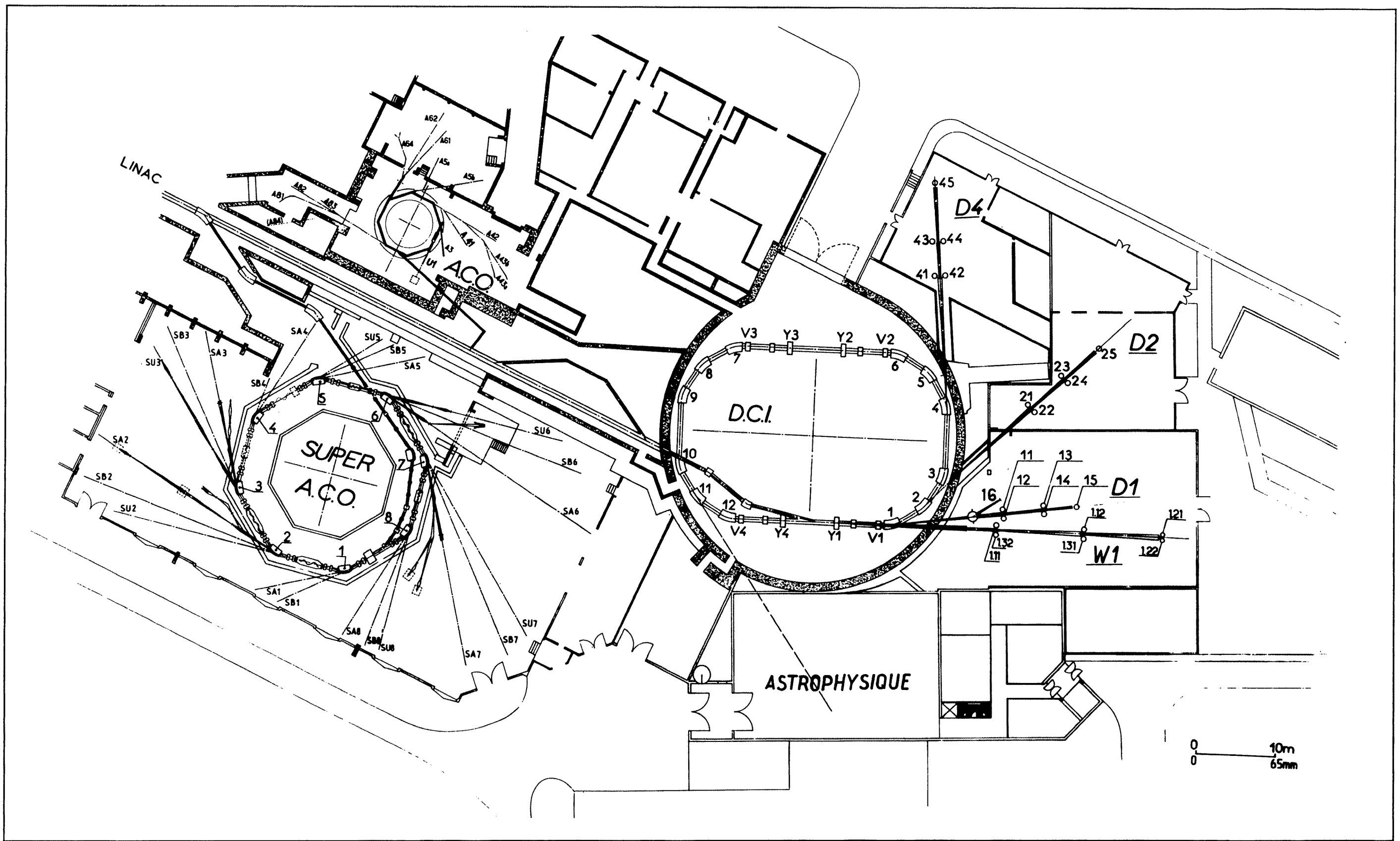
Thus the solution adopted for additional tracking and for measuring the formation of electromagnetic showers is a novel multilayer arrangement of 60 000 1 mm diameter scintillating plastic fibres. The 2.1 metre-long detector's inner radius is 39 cm, extending out to 44 cm, almost to the central calorimeter.

The 24 layers are arranged in 8 stereo triplets, with the inner 6 triplets used for tracking. These are followed by a lead converter, the outer pair of triplets being used as a preshower detector.

The doped polystyrene fibre cores are optically cladded so that some of the scintillation light is channelled along the fibres by total internal reflection. An outer covering of sputtered aluminium effec-



The scintillating fibre tracking and preshower detector being built at Saclay for the improved UA2 detector to exploit the higher proton-antiproton collision rates expected when CERN's new ACOL antiproton collector comes into operation later this year.



Plan of the storage rings at the French LURE synchrotron radiation Laboratory at Orsay.

tively removes cross-talk between fibres.

The fibre ends are optically coupled to a specially developed system of three image intensifiers, reducing the image and boosting the light output by a factor of 40 000. This output is measured in a charge-coupled device (CCD) containing an array of 32 000 photosensitive detectors on a single silicon chip. This video signal is digitized by a Fastbus module custom-built by Cambridge. There are 32 such readout chains for the complete detector.

A full-scale test setup of 960 fibres with a complete readout chain has been tried out in a variety of beams.

Tracking resolution was better than 0.2 mm with an angular resolution of 13 mrad. The preshower component's electron signals were 20 times higher than those for pions, promising good hadron rejection. The match between the electron preshower and the tracker information is good to within 0.76 mm and will be used to distinguish between an electron and a charged hadron accompanied by a photon.

ORSAY
The LURE of synchrotron radiation

When electron-positron experiments at the Orsay (France) Linear Accelerator Laboratory's DCI collider ended in 1984, all its accelerators were transferred to the LURE synchrotron radiation Laboratory which had already long been using them anyway. The accelerators involved were the Linac (total energy 2.3 GeV, positron energy 1.1 GeV) and DCI ring (1.85 GeV). This step completed a transfer which had been scheduled for some time.

In anticipation of this event, LURE has greatly extended its beam facilities over the past four or five years. A third output beam has been fitted to DCI following completion of a suitable building wing. At the same time the CEA (French Atomic Energy Commission) has built a five-pole wiggler magnet with a maximum field of 4.8 T to LURE's specifications, now installed in the machine's injection straight section. Installation work on a special vacuum chamber followed by three X-ray beam exploitation lines is almost complete. Within just three days at the end of March the machine was restarted and the vacuum chamber run in with the beam. The wiggler magnet field was then taken to its maximum without any perceptible effect on the life (27 hours) of a 1.72 GeV positron beam.

The next few months will see the construction of an astrophysics detector test station on the southern side of the Igloo building housing DCI. This station, covering an area of 1600 m^2 and with clean rooms, is sited so as to receive X-rays from DCI and photons in the far ultraviolet range from LURE's new Super-ACO ring.

Super-ACO is a low-emittance 800 MeV positron machine optimized for synchrotron radiation. With its eight 45° dipole magnets and four families of eight quadrupoles, it will be able to supply beams to 21 different lines. Six of them will originate from undulators in the machine's straight sections. It is intended to run the machine in the multibunch mode or with a single bunch, providing fundamental time information in certain experiments. Of the two radiofrequency accelerating systems, of 500 and 100 MHz, included in the project, only the latter is currently operational. As a special optical feature, Super-ACO, like DCI, has no individual sextupoles but rather sextupole windings fitted in the quadrupoles. Four different families make it possible to correct the machine's horizontal and vertical chromaticities and to optimize the dynamic aperture needed for beam injection.

After the 100 MHz system had become operational, the ring was tested on 16 March in the low-emittance mode with sextupole corrections. A positron beam with an intensity of about 30 mA was stored in the multibunch mode (24) with a lifetime of 20 minutes. No guiding corrector was used.

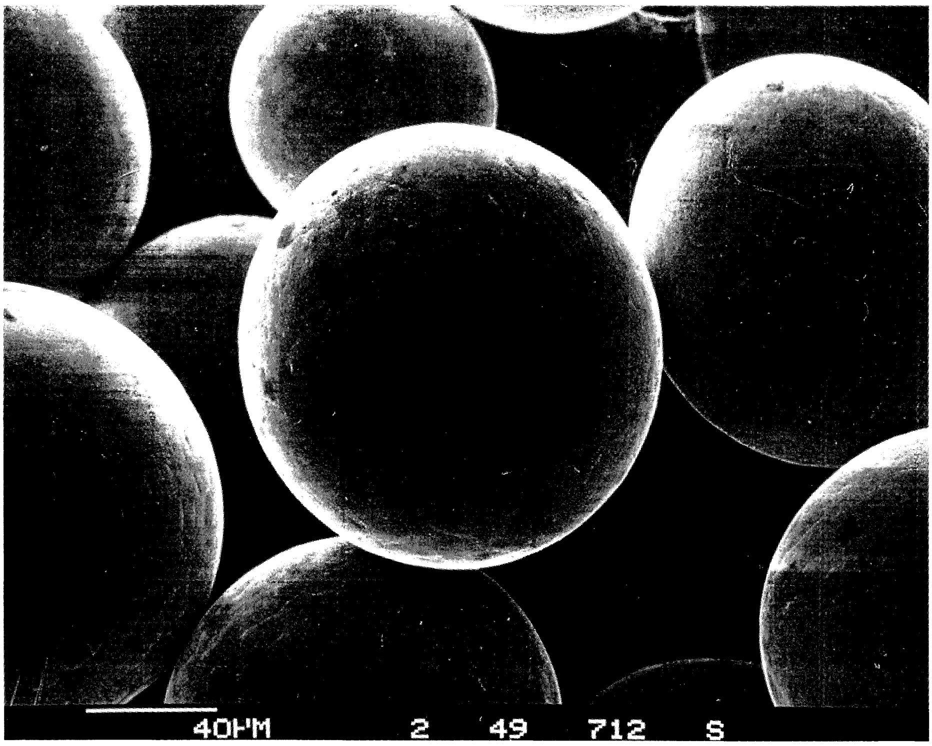
The LURE staff is very proud of this rapid start-up. It is hoped that performance will soon be good enough to complete this first testing phase so that the first four light lines, two undulators and more sophisticated measuring systems can be installed. The machine should start to provide its first users with beams by the end of the year.

The ACO ring, providing sterling service since 1965, is then once again scheduled for retirement from its duties at LURE – unless some ingenious researchers find a further unexpected use for it, as has already happened several times.

Physics monitor

WORKSHOP Low temperature devices

With extraterrestrial neutrinos (whether from the sun or further afield) continuing to make science news, and with the search for the so far invisible 'dark matter' of the universe a continual preoccupation, physicists from different walks of life (solid state, low temperature, particles, astrophysics) gathered at a workshop on low temperature devices for the detection of neutrinos and dark matter, held from 12-13 March at Ringberg Castle on Lake Tegernsee in the Bavarian Alps, and organized by the Max Planck Institute for Physics and Astrophysics in Munich (K. Pretzl, L. Stodolsky, N. Schmitz). Ringberg Castle was given by the late Herzog Luitpold of Bavaria to the Max



Tin granules. Neutrino recoil energy could heat low temperature granules and 'quench' their superconductivity, providing a detectable signal.

Participants at the recent workshop on low temperature devices for the detection of low energy neutrinos and dark matter at Ringberg Castle in the Bavarian Alps, organized by the Max Planck Institute for Physics and Astrophysics, Munich.

Planck Society as a gift with the wish that the Castle serve as a meeting place for scientists.

The first day was mainly devoted to techniques using superheated superconducting granules (SSG). For solar neutrino detection two main ideas were discussed. The first, developed by L. Stodolsky and A. Drukier, is using coherent neutrino-nucleus scattering. This method has the advantage that the reaction rates are a thousand times larger than those of other processes like inverse beta decay. Thus an SSG detector of a few kilograms would measure the same event rate as a multiton detector based on other processes. The second advantage is that the SSG detector responds to all kinds of neutrinos equally. The principal difficulty with this method is, of course, the detection of the very low nuclear recoil energy about 1 eV for tin grains and solar neutrinos of 0.4 MeV. In a uniform heating model most of this recoil energy will be transferred into heat, leading to a temperature change of the grain. This temperature jump can flip a grain from superconducting to the normal state, detected with a pickup measuring the flux change due to the disappearance of the Meissner effect. Tiny tin grains two microns in diameter have to be cooled down to 50 mK to be sensitive to 400 keV solar neutrinos.

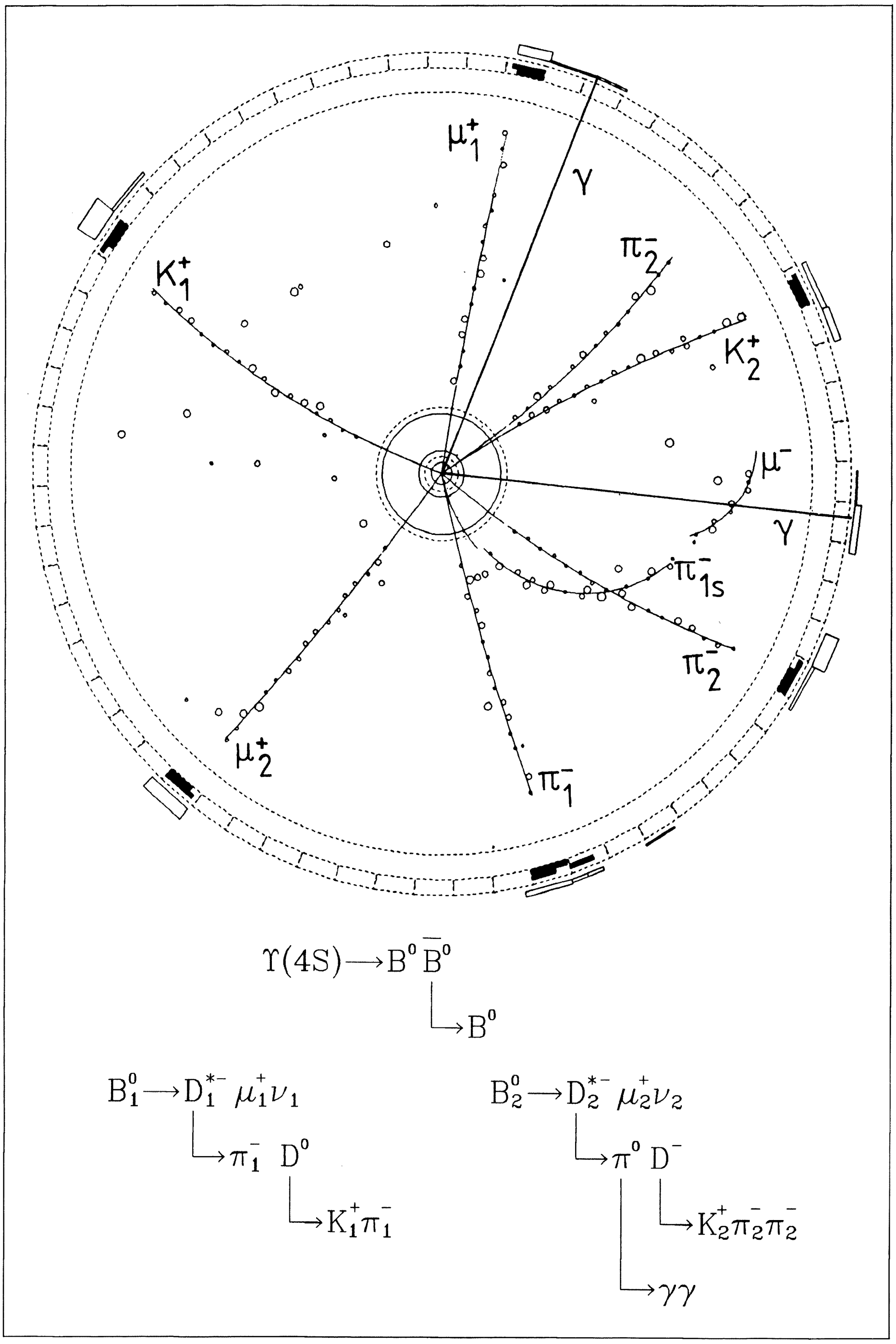
The other solar neutrino detection method using indium granules and inverse beta decay reactions was discussed by G. Waysand (Paris VII). This method has the advantage that the sensitivity of the granules can be relaxed by several orders of magnitude, but a lot of indium granules (4 tons) have to be cooled down to 1 K. For solar neutrinos the two approaches are complementary, since the first method is independent of neutrino type (insensitive to neutrino oscillations) while the second is dependent (sensitive to neutrino oscillations). SSG could also look for dark matter and magnetic monopoles and be used for double beta decay experiments.

Considerable progress has been made in understanding the basic properties of superheated granule detectors. Results of irradiation experiments (L. Gonzales-Mestres, D. Perret-Gallix, K. Pretzl, and A. de Bellefon) have shown that the superconductivity of the grain starts to be broken locally around a region where the incoming particles release most of their energy. This leads to a fast local break-up of Cooper pairs, which apparently occurs before the grain is globally heated by phonons. Experimental results on granule readout systems were presented by A. Kotlicki and G. Waysand.

The second day was mainly devoted to other techniques like bolometry, superconducting tunnel junctions, ballistic phonons, and the detection of solar neutrinos in superfluid helium (G. Seidel, Brown).

B. Sadoulet (Berkeley) covered US cryogenic detector efforts. The physics motivations are detection of astrophysical X-rays with 1 eV resolution, dark matter searches, solar neutrinos, and double beta decay. The techniques under study are SSG, ballistic phonons in connection with tunnel junctions and trapping, semiconducting thermistors and rotons in the superfluid helium. Good results were obtained by the Wisconsin-Goddard Space Center collaboration (D. McCammon, S. H. Moseley, and J. C. Mather) with thermistors reaching an energy resolution of 35 eV.

An interesting possibility for a solar neutrino detector was presented by G. Seidel. The principle is based on the calorimetric detection of electrons recoiling from neutrinos. One event per day needs a ton of target. As ideal detection material, liquid helium 4 at low temperatures is proposed. It is self-cleaning and has no nuclear reactions. An important feature is that a substantial portion of the recoil energy appears as rotons-long lived excitations which propagate ballistically at low tempera-



The decay products of a pair of neutral B mesons formed in the disintegration of an upsilon (4S) resonance as observed by the ARGUS experiment at the DORIS electron-positron storage ring at the DESY Laboratory in Hamburg. This shows that the neutral B mesons and their antiparticles appear to mix.

tures with a velocity of 10^4 cm/s. At the liquid helium surface, rotons have a 30% probability of evaporating a helium atom, so the problem of detecting one neutrino is transformed into the problem of detecting 10^7 to 10^8 evaporated helium atoms with bolometers mounted above the liquid surface. The physics of the electron energy loss in liquid helium as well as the reflectivity of rotons from the liquid surface have to be further investigated.

Norman Booth and his collaborators from Cambridge and Queen Mary College have developed a novel indium detector for a solar neutrino experiment, having successfully worked out a method to grow indium crystals over superconducting tunnel junctions. The energy released when a solar neutrino is captured in indium is mostly transformed into phonons. These can break up Cooper pairs in the junction, leading to quasiparticles. The tunnel junction acts as a semipermeable membrane letting the quasiparticles pass, thus giving rise to a signal current, albeit very small. However the sensitivity of the junction could be enhanced considerably by trapping the quasiparticles in another superconductor of lower gap in the region of the tunnel junction. If the relative gap energies are right, a multiplication process can occur, leading to a'quasiparticle multiplier'.

The workshop showed that while these innovations still require a lot of work, enthusiasm is high and the potential physics rewards are large. Next year's workshop at LAPP (Annecy) will show how much progress has been made.

From Klaus Pretzl

Mixing particles

The ARGUS experiment (a DESY / Dortmund / Heidelberg / IPP Canada / Kansas / Ljubljana / Lund / Moscow / South Carolina /Stockholm collaboration) at the DORIS II electron-positron collider at the German DESY Laboratory in Hamburg has provided valuable new evidence for particle 'mixing'.

Every particle of matter has an antimatter counterpart, or antiparticle, carrying equal but opposite quantum numbers. For mesons, composed of quark-antiquark pairs, the antiparticles have the corresponding antiquark-quark configuration. Thus mesons (like neutral pions) with symmetric quark-antiquark compositions are their own antiparticles.

Other electrically neutral mesons are distinguished from their antiparticles by a quark label (quantum number) which is only conserved in strong nuclear interactions. When the weak nuclear force is in action, these quantum numbers are no longer conserved and interesting things can happen.

For example the neutral kaon and its antiparticle are distinguished by the strong interaction label of strangeness. This is not conserved in weak interactions, so that the neutral kaon and its antiparticle get mixed up.

Additional symmetries, such as combined particle-antiparticle switching and space reflection (CP) become useful, and the neutral kaons provide a rich scenario for the subtleties of the weak force.

Last year the UA1 experiment at CERN's proton-antiproton collider provided evidence for an analogous mixing of the neutral B mesons (see October 1986 issue, page 17).

Neutral B mesons exist in two varieties, with and without strange quarks. The lighter non-strange particles can be isolated by looking below the threshold for production of the strange quark variety.

The ARGUS experiment studied the formation of neutral non-strange B meson pairs coming from the decay of upsilon resonances (the 4S state at 10.6 GeV). Great importance was attached to particle identification, and from data collected over five years of running evidence for mixing is found in three different ways.

Firstly, from 88 000 upsilon (4S) events analysed, one example is found of an explicitly mixed decay into two neutral B mesons (rather than a neutral B and its antiparticle). All the B decay products (other than neutrinos) are fully identified and the event is very clean.

The neutral B mesons subsequently decay in a variety of ways, emitting leptons (electrons or muons). The ratio of positively charged to negatively charged leptons is an indicator of mixing, and the ARGUS group went about a careful analysis of their electron and/or muon pairs.

After painstaking elimination of backgrounds, they found some 25 lepton pairs carrying two equal electric charges, compared with 270 carrying opposite charges. This gives a B meson mixing parameter in the region of 20 per cent.

Another method used, less sensitive to background, consisted of reconstructing one neutral B meson and tagging the second by the charge of an accompanying energetic lepton. Five mixing candidates were found, where only about one was expected due to background, again a suggestive signal.

In today's 'Standard Model', six varieties of quark are grouped into three doublets (up and down, strange and charm, beauty and top), and all the corresponding quantum number changes produced by the weak force are described by the 'Kobayashi-Maskawa' (KM) matrix. As yet no theory gives all the parameters of this matrix, but predictions can be made using input from experiments.

The relatively large rate of mixing seen by ARGUS provides more input to this matrix, and indicates that the as yet unseen top quark is heavier than about 50 GeV. If this is correct, mesons consisting of top quark-antiquark pairs would occur near 100 GeV, out of reach of the new TRISTAN electron-positron collider at the Japanese KEK Laboratory.

B mixing limits also come from other experiments at electron-positron colliders at Stanford, Cornell and DESY.

Encounters with strong fields

A series of experiments at CERN using high energy beams and crystal targets show some interesting quantum effects.

The energy of an electron in an external field depends on whether it lines up spinning parallel or antiparallel to the field direction. Normally this (spin-orbit) coupling is very small, about a thousandth of an electronvolt at 10 tesla (100 kgauss).

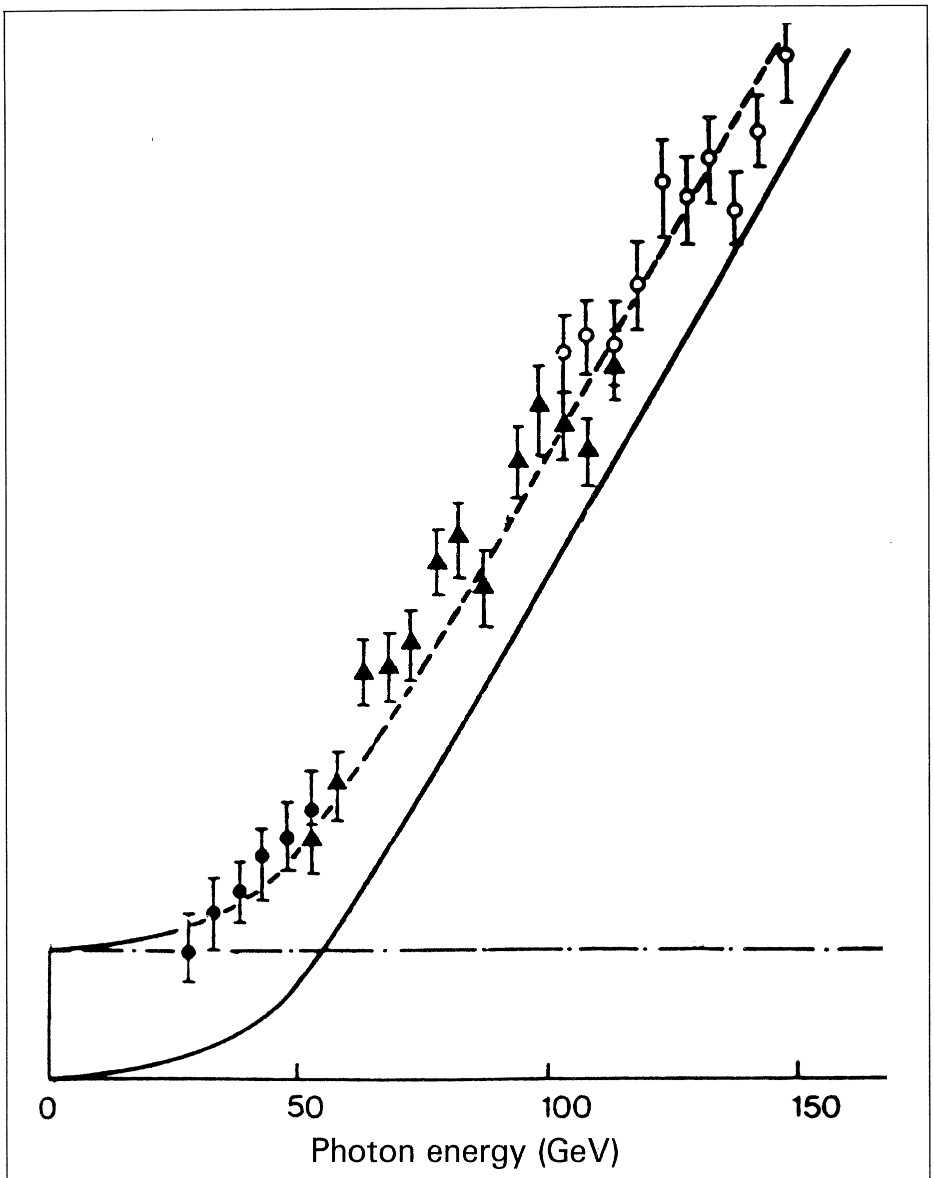
If a particle is relativistic (travelling with a velocity comparable to that of light), it experiences a highly velocity-dependent field. Thus if an electron moves so fast that the magnetic field it 'sees' reaches about 4×10^9 tesla, the energy due to spin alignment becomes comparable to the electron's mass, and interesting effects become possible.

Using external fields, even high energy beams from a particle accelerator do not reach these thresholds (a 10 T field would need an electron beam of 250 000 GeV!). However higher macroscopic fields are supplied along axial directions inside crystals. With these very strong fields interesting quantum phenomena should become possible.

These effects have been studied in a series of experiments at CERN by researchers from Albany (New York), Annecy and Lyon. 150 GeV electron and photon beams were injected along an axis of an 0.2 mm-thick germanium crystal cooled to 100 K with an angular spread of about 25 microradians.

Physicists saw a spectacular increase in the photoproduction of electron-positron pairs at perfect alignment, not due to the reinforcement (coherence) of the interactions at different sites in the crystal, but to an interaction of photons with the very strong field. Starting at a photon threshold energy of 30 GeV, the effect eventually attained ten times the level resulting from (incoherent) background effects using an unaligned crystal.

Further studies of the effect of the strong crystal field on the electron beam showed an intense nar-



Dramatic increase in photoproduction of electron-positron pairs by a high energy photon beam in perfect alignment with an axis of a cooled crystal of germanium, as observed at CERN by an Albany / Annecy / Lyon experiment. The flat dotted line shows the photoproduction from an unaligned crystal. The steeply rising line under the data points shows the field in the crystal 'felt' by the particles.

row release of radiation along the crystal axis, with about 80 per cent of the electron beam energy converted into photons when angular conditions are right for electron channeling.

Although the total radiated energy agrees with (quantum electrodynamics) theory, it is not clear why such hard photons come out forwards. A new series of experiments using thinner crystals will try to understand why.

These phenomena have also been investigated by the Aarhus / CERN / Strasbourg channeling collaboration.

Same sign muon pairs OK?

Prime 'charm' physics from the high energy neutrino beams at Fermilab and CERN which became available in the 1970s emerged from the study of the produced pairs of muons.

A charmed quark can be produced when an incident neutrino burrows deep inside a target nucleon and hits one of its three 'valence' quarks, the weak interaction characteristically switching the 'flavour' of the struck quark. A charmed quark can also be produced through a neutrino interaction with the gluons (carriers of the inter-quark force) and transient quark-antiquark pairs binding the valence quarks together.

In these reactions, one electrically charged lepton (muon or electron) is produced when the incoming neutrino hits a target quark. In addition, the subsequent decay of the particle carrying the charmed quark can produce a second lepton.

Thus the study of charged lepton (particularly muon, because the incoming neutrinos are mostly of the muon type) pairs provides a window on charm production.

However the majority of these muon pairs should contain particles of opposite electric charge. Pairs of muons each carrying the same electric charge can also occur, but are expected to be much rarer.

However more same sign muon pairs were seen than expected. This was worrying in a corner of the subject where other loose ends had quickly been tidied up.

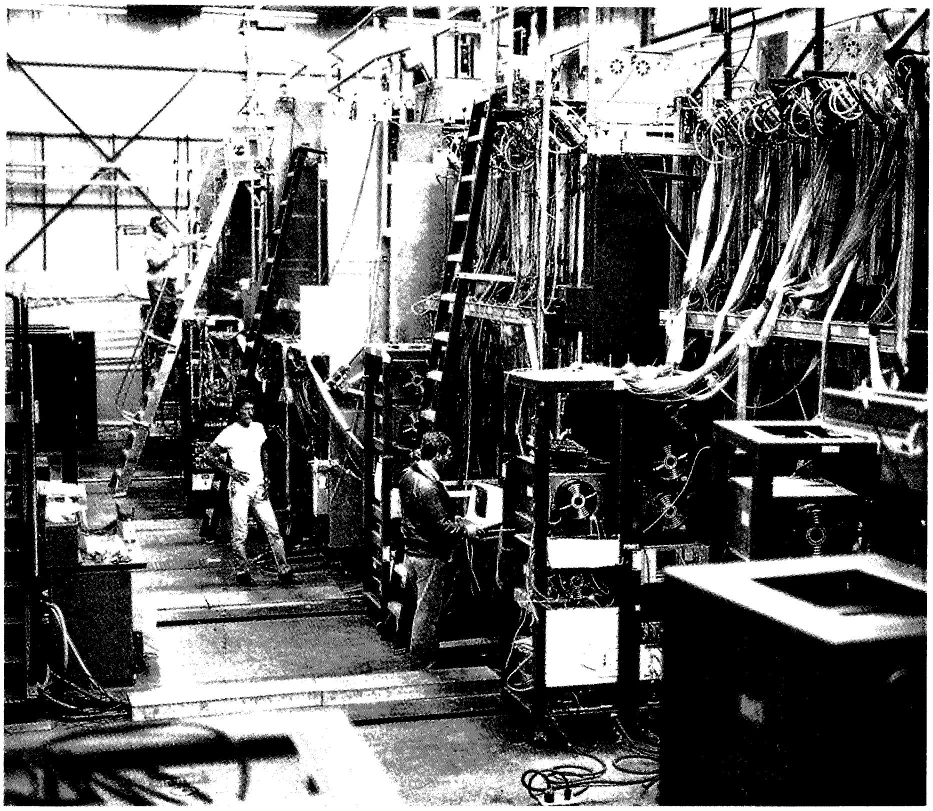
These same sign muon measurements were always tricky because of the possibility of muon contamination from other sources, but experience suggested that the signal becomes clearer with higher neutrino energy and muon momentum.

The baton thus passed to the Chicago / Columbia /Fermilab / Rochester collaboration at Fermilab, using the new 800 GeV Tevatron proton beam to provide the highest energy neutrinos ever used in a laboratory experiment. These were caught in a 690 ton iron-liquid scintillator calorimeter, and the reaction products studied in a ten metre-long toroidal magnetic spectrometer, with magnet sections interspersed with drift chambers.

From a total of three million triggers, the experimenters carefully selected their sample of 117 examples of same sign muon pairs after elimination of background effects providing spurious signals.

The observed level of same sign muon pairs edges lower than before, although they still overlap with measurements at CERN by the CERN / Dortmund / Heidelberg / Saclay / Warsaw /Beijing experiment.

With some daylight still visible between the bottom of the experimental error bars and the theoretical expectation, which moreover depends on the parameters used in the calculation, there is still room to manoeuvre, but the effect is no longer embarrassing for conventional physics.



Apparatus of the Chicago/Columbia/ Fermilab/Rochester collaboration at the Fermilab Tevatron — catching the highest energy neutrinos ever used for a laboratory experiment.

(Photo Fermilab)

Other people's accelerators

The first report from the Washington Accelerator Conference (see May issue, page 7) concentrated on news from the particle physics centres. But the bulk of the Conference covered the use of accelerators in other fields, underlining this valuable spinoff from particle physics.

Let there be light

Herman Winick opened the session on synchrotron radiation facilities with a reminder of the tremendous growth in the use of these intense sources of electromagnetic radiation. There are now 34 storage rings in action in 27 Laboratories in 11 countries... and more are on the way.

The pioneer of this burgeoning field, the Synchrotron Radiation Centre at Wisconsin/Madison has been in pain in recent years trying to bring on the 800 MeV Aladdin ring to replace the famous 240 MeV Tantalus ring. Ed Rowe was able to report that the battle is now won. Average currents of some 100 mA are being held and

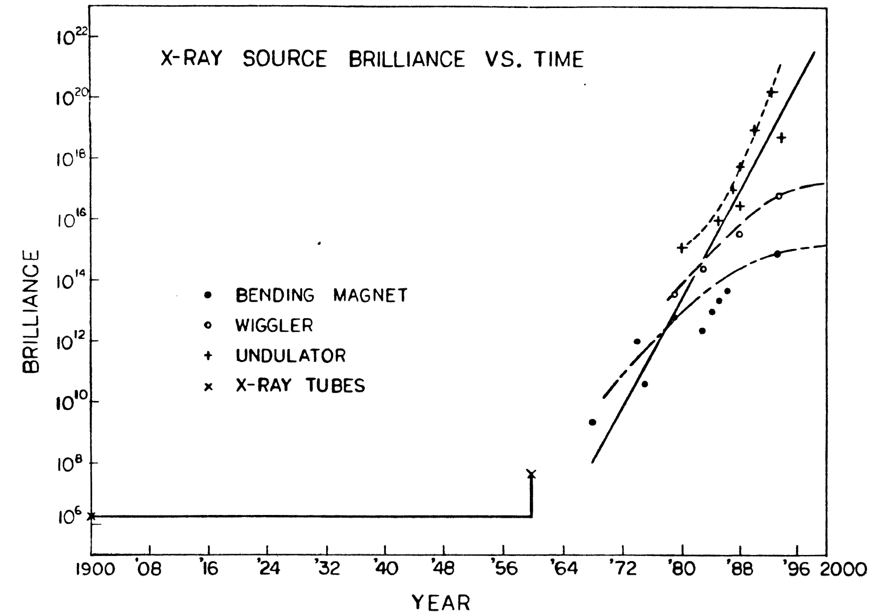
operating efficiency is 93 per cent. An undulator, from Stanford, has been installed and gives two orders of magnitude more flux than the bending magnets. Aladdin had been executed by its funding agency, the National Science Foundation, but can now be regarded as one of the few examples of resurrection from the dead.

Emphasis was obviously on US machines and there were reports of excellent performance from the National Synchrotron Light Source at Brookhaven and from the synchrotron sources at Stanford. The NSLS can now reach 1 A in the 750 MeV UV ring and 250 mA (half design current) in the 2.5 GeV X-ray ring. They are dealing with some fifty end-stations and the experimental floors look very crowded. Seven undulators and wigglers are being installed as part of the Phase II upgrade.

The Stanford Synchrotron Radiation Laboratory continues its crowded programme on the SPEAR storage ring (oversubscribed by a factor of two). Operation is limited by the availability of the injector, the two-mile linac, which has been much involved with the Stanford Linear Collider project over the past year, and there is a proposal to build an independent injector. They have done pioneering work on wigglers and undulators and seven of them are now installed. An extremely interesting start has been made on the use of the PEP ring at energies up to 15 GeV. It has very long straights for insertion devices, very high brightness (which would be even better at lower energies, such as 8 GeV). PEP would also be an ideal place to try the new idea of a bypass as a source of extremely high fluxes.

The two major proposals for multi-GeV machines are the European Synchrotron Radiation Facility, a 6 GeV machine to be built at Grenoble (the site is now being cleared), and the Synchrotron X-ray Source, a 7 GeV machine for which the design report will emerge soon from Argonne (see March issue, page 24). There is a tendency to push both these peak energies (and thus, inevitably, the machine sizes and costs) higher under pressure from the user communities.

In the lower energy range, a 2 GeV machine is going ahead in Trieste, a 1.2 GeV source is under construction on the Stanford campus (the Stanford Photon Research Laboratory) and plans are well advanced for a 1 to 2 GeV machine at Berkeley. It is entertaining to hear the discussions about the ideal machine lattice configuration to give high brightness, low emittance beams suitable for undulators and wigglers. The respective merits of the FODO structure versus the triple-bend-achromatic versus the Chasman-Green are presented with all the ferocity of medieval statements concerning angelic standing room on the head of a pin.



Shining more light — the actual and projected growth of X-ray source brilliance. For the stationary anode X-ray tube there was no variation from the turn of the century until 1960. Then brilliance increased tenfold with the introduction of the rotating anode. The units of brilliance are photons per second per square milliradian per square millimetre.

An important development is the advent of 'table-top' synchrotron light sources for X-ray lithography to allow high speed production of computer chips. Such compact synchrotrons are being worked on in the Soviet Union, Germany, UK, Japan and USA (and probably elsewhere that we did not hear about). They should be available off-the-shelf soon.

Progress in the Soviet Union was reviewed by Peter Kapitza. Novosibirsk remains the front runner since four storage rings had become predominantly used for synchrotron radiation research. They have, however, had a serious

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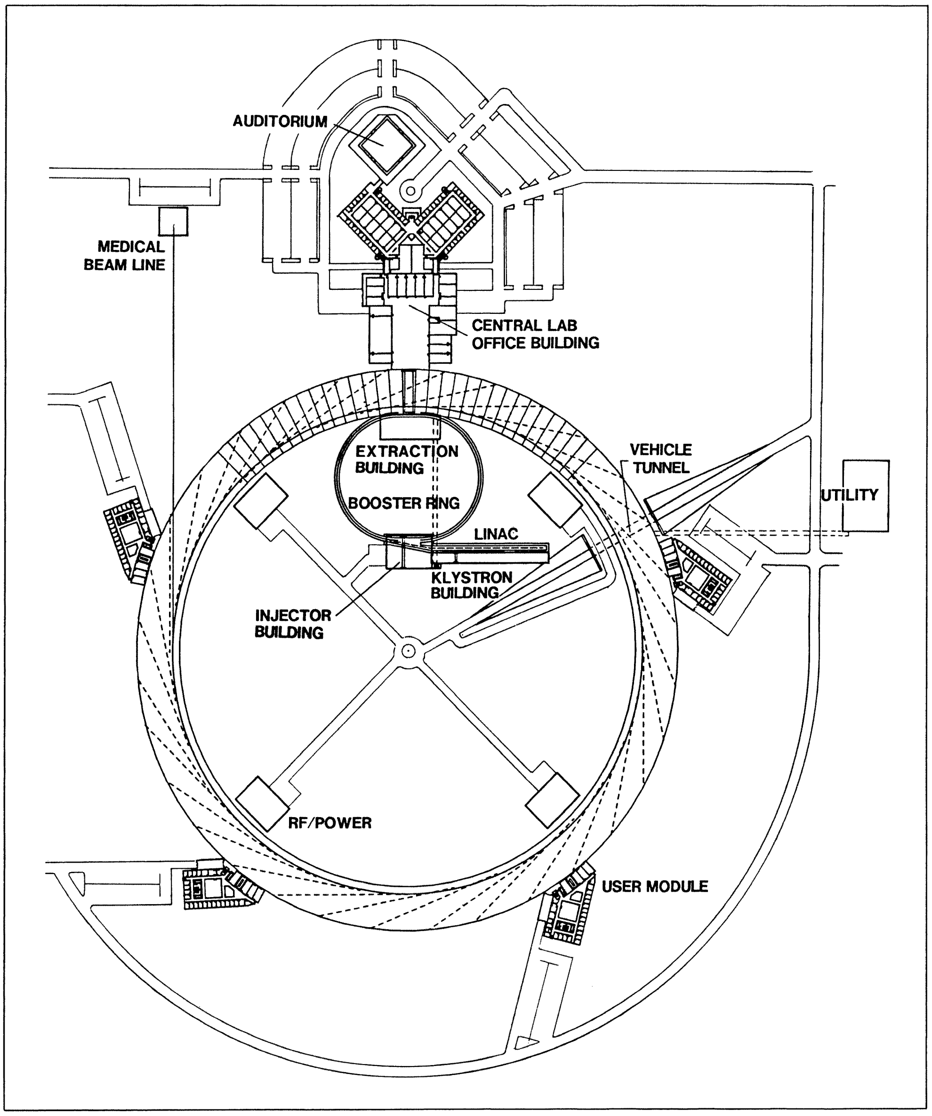
The 7 GeV storage ring project at Argonne for a synchrotron X-ray source.



coherent generation of synchrotron radiation in resonators of special geometry.

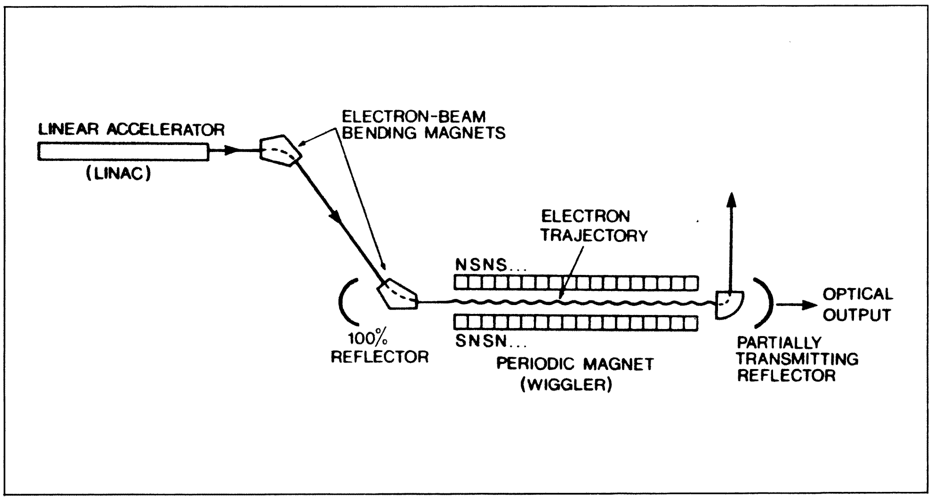
Free Electron Lasers

The free electron laser was invented by John Madey at Stanford in 1971 and the concept was demonstrated in practice by his group ten years ago. Even now, much basic physics and technology concerning free electron lasers remains to be done but the vast potential of these devices as sources of electromagnetic radiation has attracted such wide attention that for the first time a whole session was devoted to the topic at the Conference.

Electrons passing through a wiggler structure together with light of the correct phase can transfer energy to the light wave, increasing its intensity. The light beam, propagating parallel to the electrons, decelerates the electrons slightly and energy is transferred. Mirrors are used to form optical resonant cavities, so that the light can be bounced through the structure many times, the mirror dis-

set-back due to fire. The VEPP-4 machine is being rebuilt as a 6 GeV ring with straights for undulators and wigglers. They have superconducting wiggler magnets with fields as high as 8 T and are considering the use of intense X-radiation in a fast neutron source. They have built a small 450 MeV ring, Siberia I, for use in the Institute of Atomic Energy in Moscow and a 2.5 GeV ring, Siberia II, is under construction. Work is underway on microtrons as appropriate sources for free electron lasers and there are some ideas on the

Schematic of a free electron laser.



* See also page 33 for the findings of a report 'The Science and Technology of Directed Energy Weapons' commissioned by the American Physical Society.

tances being chosen to keep the light pulses in coincidence with the electron bunches.With the right conditions exponential gains are possible. The electrons can also be used again (a number of important FEL experiments have used storage ring beams).

The wavelength of the FEL light is given by the energy of the electrons and the period and strength of the magnet field. Thus an FEL is tunable over a range of frequencies, from far infrared to short wavelength (though the full range is not accessible from the same device) as opposed to the fixed-frequency conventional lasers. The range however can be very large; an FEL is being built at the National Bureau of Standards in Maryland which will cover from 10 micron wavelength in the infrared to 0.2 microns in the ultraviolet.

They are also capable of converting electrical to optical power with very high efficiency. To give an example of what has been achieved, the Electron Laser Facility, ELF, at Livermore has produced more than 1 GW of microwave power with over 40 per cent extraction efficiency. It has been used, in part, to study the two-beam approach to very high energy particle accelerators promoted by Andy Sessler (whose ideas are now moving more to the idea of a relativistic klystron rather than an FEL as the drive mechanism). A new facility, called PALADIN, has been constructed at Livermore to carry the studies beyond what can be achieved in ELF.

The list of Laboratories pursuing the potential of FELs is long — Stanford, Brookhaven, Santa Barbara, Glasgow, Seattle, Bell Labs, Orsay, Los Alamos, Frascati, etc. Many applications can be foreseen. Defence ministries are interested in their use for laser weapons; in the US a huge ground-based laser facility is proposed for the White Sands Missile Range in New Mexico. For controlled thermonuclear fusion, FELs could serve as the heat source for the plasma. The high fluxes and tunability have great potential in all the many manifestations of spectroscopy — chemistry, biology, solid-state physics, etc.

Star Wars

Another first at the Washington Conference was the completely open acknowledgement of the role of accelerator technology in several aspects of the Strategic Defense Initiative, SDI, more commonly known as 'Star Wars'.* In a plenary session Colonel Gullickson from the Office of the Secretary of Defense spoke about 'Accelerator requirements for SDI'.

The requirements are for high brightness, high intensity beams produced in compact accelerator systems, together with some method of efficient propagation over very long distances. Much work has therefore been done to improve ion sources and initial beam quality. For example, the development of laser-illuminated photocathodes at Los Alamos, described by John Fraser, is producing very low emittance electron beams of high intensity (which could also be relevant to the very high energy electron linacs projected for the future in particle physics). On the Accelerator Test Stand at Los Alamos, using a radiofrequency quadrupole, it has been shown that good emittance can be preserved in low energy beams.

The ground-based laser beam proposal has been mentioned above and experiments with PALADIN are just beginning. Livermore has also successfully tested the concept of transmitting high current electron beams through a channel in a gas which has been pre-ionized by a laser beam. The laser beam causes partial ionization. An electron beam from the Advanced Test Accelerator, ATA, is then fired through the same channel and ejects the ionization electrons. The remaining positive ions serve to keep the electron beam focused in the channel and 10 kA beams have travelled over 80 m reaching 50 MeV in the ATA. Other experiments at Sandia have used the pre-ionization technique for bending beams as well.

A further SDI series of experiments is scheduled to start next year under the title of BEAR, for Beams Aboard Rockets. An obvious interest here is to reduce the weight of the radiofrequency powering systems and effort is going into the development of solid state devices.

Fowl play

Turning to more savoury topics, M. E. Wilmer spoke about work in the US and Europe on processing food with beams from linear accelerators. Experiments have shown that some foods can withstand irradiation with no noticeable deterioration in taste or appearance, the object being to improve hygiene and extend shelf life.

Irradiation produces free radicals and breaks the DNA chains. It can also obviously adversely affect the molecular chains in the food itself so experimentation on dose rates and surrounding conditions such as temperature and atmosphere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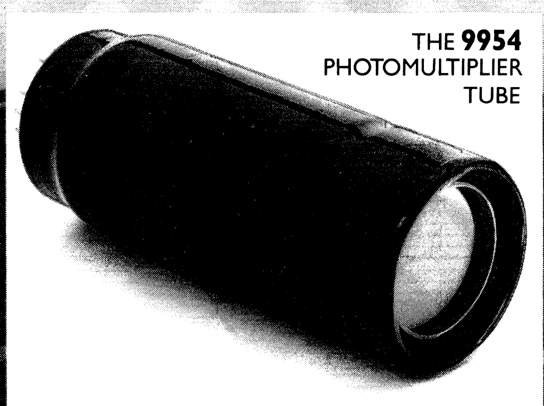

A 10 MeV electron linac could be used to irradiate chickens and eliminate potentially dangerous bacteria.

are needed. Generally the faster the irradiation, the less damage to the food.

Many examples of useful applications were given, particularly in support of the food and agricultural industries of developing countries, concluding with the important case of the irradiation of chickens which are a potential source of salmonella. To take this as a practical example, a 10 MeV electron linac could successfully irradiate chickens in two passes to a depth of 8 cm. (It was pointed out that this would be simplified if the chickens were squashed into a rectangular block but they would then not look so attractive at the dinner party.) Such an accelerator could probably cope with some 10 000 pounds of chicken per hour.

To put such prospects into perspective, in the US alone 12 billion pounds of chicken are consumed every year. To process this quantity would need about 300 accelerators. Counting one's chickens takes on a new meaning for accelerators.

By Brian Southworth

The interplay of theory and experiment

by Maurice Jacob

This is an extract from an article by the Head of CERN's Theory Division which appeared in a special issue of the French monthly magazine 'Sciences et Avenir'.

Physics is an experimental science. Considered as a scientific discipline, it is a set of results whose value lies in the fact that the experiment can be reproduced. Or better still, it is a set of concepts from which our knowledge of the material world takes organized shape, has light shed on it and is given precise definition, to the point where prediction is possible. Such concepts must be freely discovered, even if experience can sometimes point the way to them. The urge for simplicity and symmetry is also of major importance

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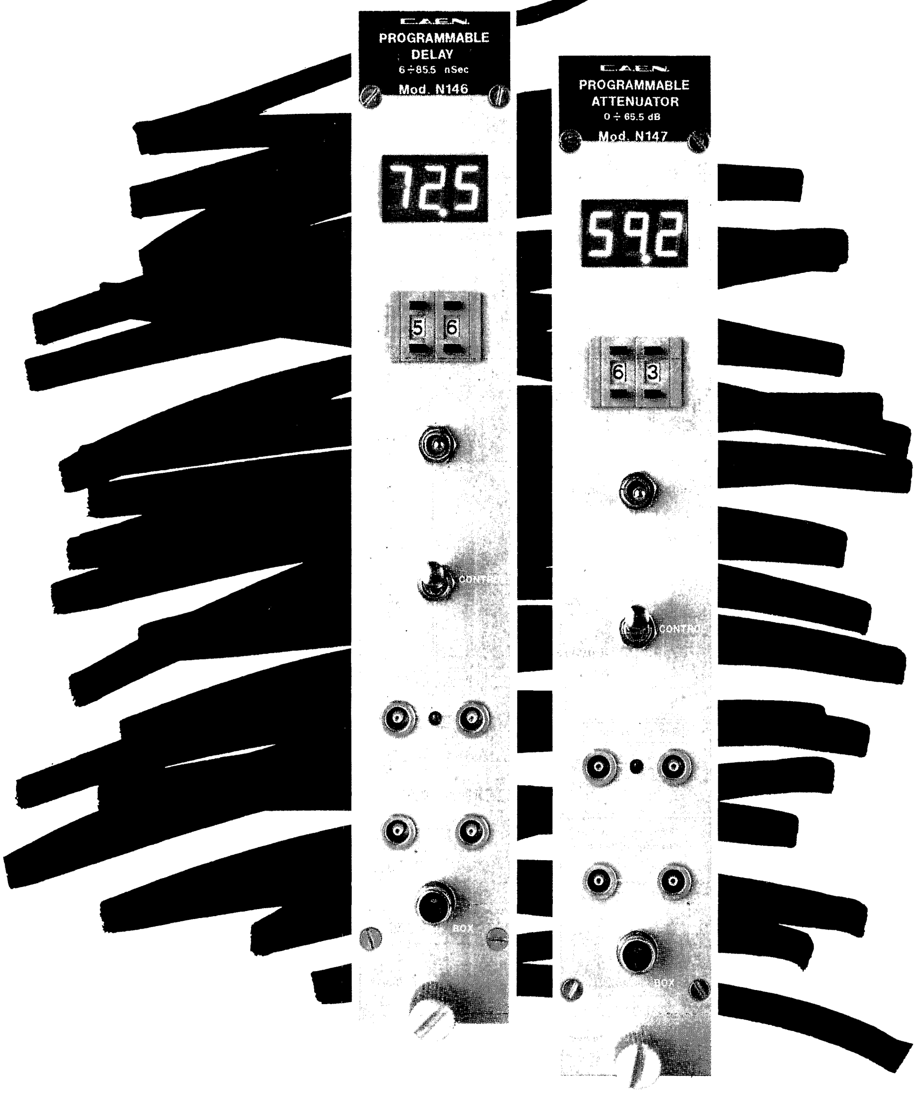

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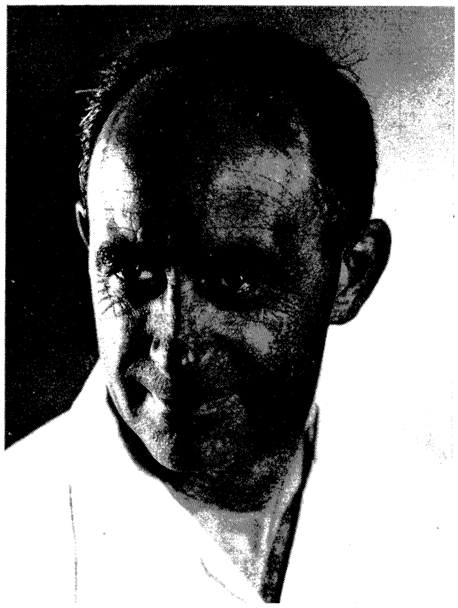
in formulating them. It is often essential to stand back from experiment in order to gain a clear and overall view.

Wolfgang Pauli wrote: ' The link between random presentation of experimental data and a theory (which organizes and explains them) arises from primordial images present at the root of being. These primordial images cannot be formulated in conscious fashion, nor associated with ideas presenting a rational order. Rather, they represent forms that are specific to the human subconscious. They are images with a deep emotional content. They are not thoughts but visions'. He added, and it is here that the scientific method becomes clear: 'The pleasure felt in realizing that one has reached a new level of knowledge stems from the fact that these pre-existing images are in perfect harmony with the behaviour of material objects.' How much effort, however, for a reliable result! As Henri Poincaré stated: 'Thought is merely a lightning flash in the middle of a long night, but it is the flash that is all-important.'

The two quotations are a perfect illustration of the theoretical approach accompanying the accumulation of data. Physics is a mental construction nurtured and strictly controlled by experiment. The physicist describes, interprets and predicts phenomena, i.e. the way phenomena interlink. He reflects, experiments, reflects again and dreams, and goes back to his experiments. This constant to-and-fro between facts and the way they are organized lies at the heart of all research, in the mind and hands of every physicist.

The complexity of research and the sophistication of experimental apparatus and of theoretical ideas involve, however, some degree of specialization. Enrico Fermi was surely one of the last great physicists to be both a master theoretician for the theoreticians and a master experimentalist for the experimenters. In the past few decades the great names in particle physics have been clearly associated either with theoretical physics or with experimental work. Particle physics, which requires large experimental facilities and which its very nature places at the frontier of the unknown, where suitable concepts are still missing, was bound to be the sphere where specialization of this sort would first make itself felt most clearly. But other areas have not lagged behind. Although a physicist can acquire a good degree of expertise both as a theoretician and as an experimentalist and have an appreciation of new results, whether theoretical or experimental, it has become practically impossible for him to contribute at one and the same time to both types of research. On the world scale, physics moves ahead by means of fruitful, stimulating yet stiff competition, and it is very difficult to be the leader in different fields each of which calls for an equally high degree of specialization. A choice has to be made. The good experimentalist asks the proper questions with powerful and effective methods and apparatus that he often has to design from scratch. He is also awake to the possibility of picking up a signal from background noise others might consider impenetrable, particularly when it relates to an unexpected phenomenon. The good theoretician will go more deeply into things by showing how phenomena that are *a priori* different from one another are simply separate aspects of a more general process; but sometimes in order to do so he must develop his own strict system of theory. Genius is when in a flash a new concept sheds light on an entire field of knowledge or when a phenomenon may appear for the first time, suddenly and indisputably.

Enrico Fermi – master theoretician and master experimenter.

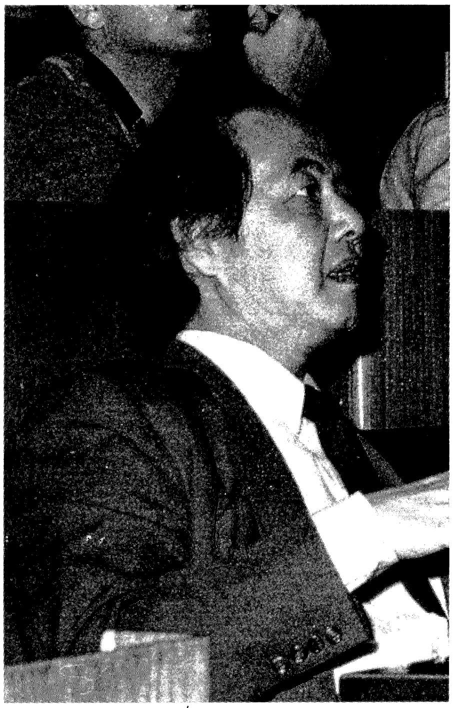


The competitive element should not be underestimated. The theoretician can seem to outpace the experimenter in his approach, and penetrate more thoroughly the underlying reality of the physical world. But the experimentalist whose great desire it is to reveal to the world something completely unexpected can also spring surprises on the theoretician, by showing that nature sometimes negates the seemingly satisfactory predictions of theory. Our imagination is no match for nature!

This interplay between theory and experimental science greatly stimulates both, but the key point is their beneficial complementarity. In a recent review of the history of weak interactions (see January-February issue, page 7), T.D. Lee

People and things

T.D. Lee – two laws of physicists.



put forward two laws that he deduced from studying the enthralling history of this area of physics over the past forty years, and which he calls the 'laws of physicists'.

The first of these is: 'Without experimentalists, theorists tend to drift'; and the second: 'Without theorists, experimentalists tend to falter'.

There are no rules. Behind the great discoveries of particle physics there can just as easily lie an experimental origin as a theoretical one.

The history of particle physics during the half-century between the first steps towards the modern electroweak theory, taken by Fermi, and its confirmation at CERN in 1983 provides a good illustration of this complementarity.

Although today the electroweak theory enjoys so much success, the way it breaks certain symmetries necessary for obtaining the different masses observed, subtle as it may be, seems no more than a way of accounting for facts we do not fully understand. The theoreticians would love to know that new phenomena exist which could shed the necessary light. This is what is expected in the TeV region from collisions between quarks. It is what lies behind the current enthusiasm for the big proton colliders, the SSC in the United States and the LHC in Europe. We have the Standard Model. It is a great success, but... how can it be made to take its place in a larger symmetry? Why does it use these different families of quarks and leptons? How is initial symmetry broken with different masses emerging? And still more importantly, another key question: how is all this bound up with gravity? Do the superstrings provide the answers to these questions? The theorists and experimentalists still have a long way to go. The frequency of major discoveries, observed over thirty years at a rate of one every two years, gives us grounds for hope, and the new machines now being perfected must make for beneficial contact between theoreticians and experimentalists.

On people

Field theorist Bernard Julia of the Ecole Normale Supérieure, Paris, receives this year's Langevin Theoretical Physics Prize of the French Physical Society.

After a brief period as acting Director, Paul Williams becomes Director of the UK Rutherford Appleton Laboratory, succeeding Geoff Manning.

Retiring correspondent

One of CERN COURIER's longest serving correspondents, Dick Carrigan from Fermilab, has laid down his pen to give himself more time for other Laboratory responsibilities. He is succeeded as our Fermilab contact by Mark Bodnarczuk.

Dick has helped us keep abreast of developments at Fermilab ever since the COURIER went international in 1976 following the meeting of Laboratory Directors in New Orleans. Reflecting its position as a major world Laboratory, news from Fermilab has rarely been absent from a COURIER issue in all the subsequent months. We greatly appreciate the work that he has done to ensure this coverage and the COURIER editors remember with pleasure the warm welcome that has always been extended to them on their visits to Fermilab.

Meetings

An International Conference on the Physics and Astrophysics of Quark-Gluon Plasma will be held from 8-12 February 1988 at the

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The College of William and Mary, Williamsburg, Virginia, is seeking candidates for the position of Postdoctoral Research Physicist. Research in progress or planned includes rare kaon decay studies at Brookhaven, muon interactions studies at SIN and LAMPF, and antiproton experiments at CERN-LEAR.

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Tata Institute for Fundamental Research, Bombay, India. Participation is by invitation only. Further information from Organizational Secretary, ICPA-QGP '88, VECC, Bhabha Atomic Research Centre, Sector 1, Block AF, Bidhan Nagar, Calcutta 700 064, India.

This year the Joliot-Curie School of Nuclear Physics, arranged jointly by the French National Institute of Nuclear and Particle Physics (IN2P3) and the Institute for Fundamental Research of the French Atomic Energy Commission, will be held at Maubuisson, Gironde (France) from 14-18 September. This school is intended for all experimental and theoretical nuclear physicists, young or old, and to interested physicists in general. A major effort is made to use language that non-specialists can understand. The 1987 school will look at different types of correlation in energy ranges such as first excited state spectroscopy, heavy ion reactions and intermediate energy nuclear physics. Further information from Mrs. E. Perret, Ecole Joliot-Curie, IN2P3, 20, rue Berbier du Mets, F-75013 Paris.

The Europhysics Conference on Control Systems for Experimental Physics, sponsored by the European Physics Society (EPS) and CERN, and organized by the EPS Interdivisional Group on Experimental Physics Control Systems, will be held in Villars-sur-Ollon, Switzerland, from 28 September to 2 October.

The conference is somewhat of a sequel to the 2nd International Workshop on Accelerator Control Systems, held at Los Alamos from 7-10 October 1985. Although the forthcoming conference will also have a strong particle accelerator bias, the organizers have decided to include control systems of other large experimental physics installations, such as telescopes, fusion reactors, etc. Contributions must have a substantial controls component and pure data taking will be excluded. The conference will consist of invited papers, contributed papers, workshops, tutorials and an excursion to a major existing control system. Following the style of the Los Alamos Workshop, the conference will be open, rather than 'by invitation'.

Further information from 'Controls Conference' c/o B. Kuiper, CERN PS division, 1211 Geneva 23, Switzerland, telephone: international 41/22/83 25 23, EAN Mail <COCONF@CERNVM>, telex: 419 000 CER CH, telegram: CERNLAB GENEVE, telefax: international 41/22/83 65 55.

Report looks at feasibility of Directed Energy Weapons for SDI

The development of an effective ballistic missile defence utilizing directed energy weapons would require performance levels that vastly exceed current capabilities, according to a panel of experts on directed energy technology convened by The American Physical Society. In a report entitled 'The Science and Technology of Directed Energy Weapons,' the study group concludes that insufficient information exists to decide whether the required performance levels can ever be achieved.

The study was headed by C. K. Patel of AT&T Bell Laboratories and Nicolaas Bloembergen of Harvard. President of the American Physical Society Val Fitch of Princeton announced the release of the report.

Directed energy weapons, which include high intensity lasers and energetic particle beams, have been expected to play a crucial role in the Strategic Defense Initiative (SDI). The study group estimates that, 'even in the best of circumstances, a decade or more of intensive research would be required just to provide the technical knowledge needed for an informed decision about the potential effectiveness and survivability of directed energy weapon systems.'

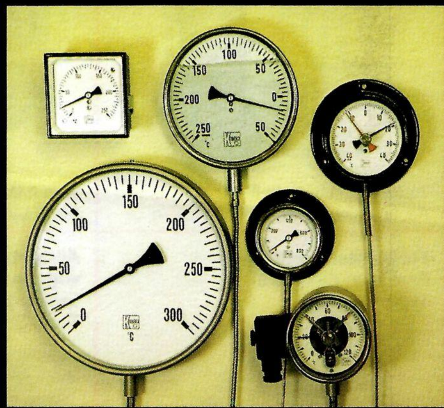
One of the conclusions of the study was that 'all existing candidates for directed energy weapons require improvement by a factor of at least 100 in power output and beam quality before they can be seriously considered for application in ballistic missile defence systems'.


Use VPTs
PHILIPS

CATALOG

KOBOLD MESSRING GMBH

Instrumentati
and control f
FLOW RATE
PRESSURE
FLUID LEVE
TEMPERATU

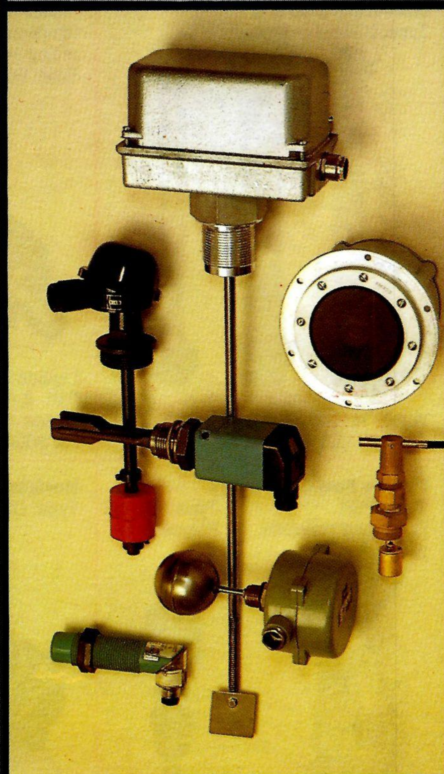


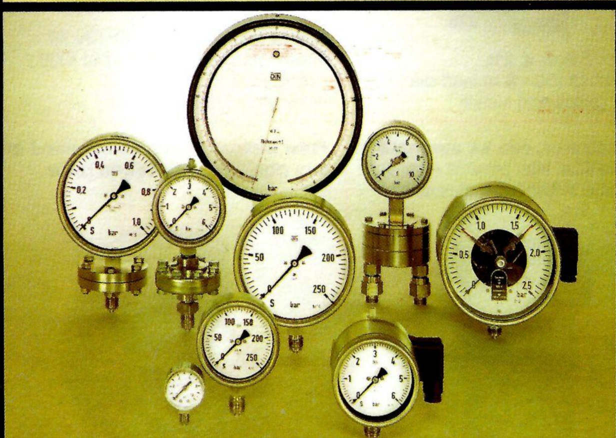
Flow measurement
Indicating instruments, controllers and recorders

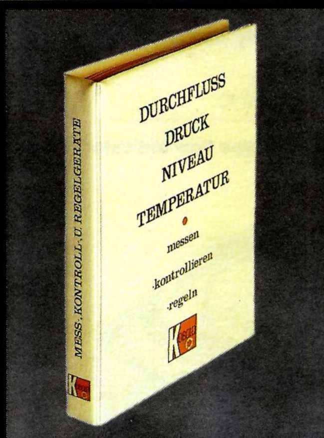
Pressure measurement
Liquid column devices and switches

Level measurement
Indicating instruments, controllers and recorders

Temperature measurement
Thermometers, controllers and monitors





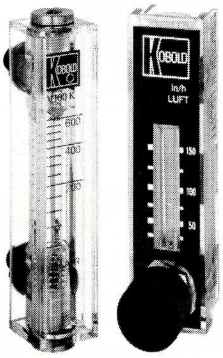


The Kobold Handbook will be sent to you, free of charge, on request.

Sodener Straße 120
D-6233 Kelkheim
Postfach 2052
(0 61 95) 69 11/69 72
Tx 4 072 326 komr d
Telefax (0 61 95) 6 50 00

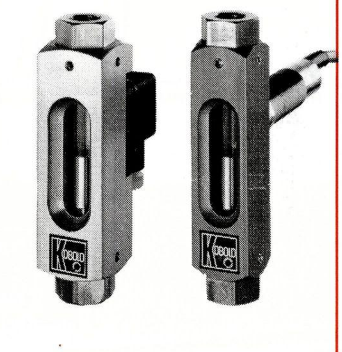
Flow measurement

Microvolume flowmeters
with or without needle valve in **polycarbonate, polysulfone and acrylic glass**



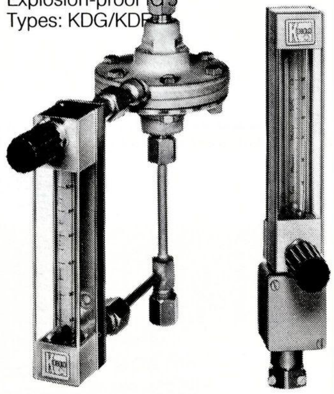
Water: 0.1-1.5 l/h to 5-80 l/h
Air: 0.5-5 L_n/h to 0.2-2.6 Nm^3/h

Microvolume flow controllers
Explosion-proof iG 5
Types: KSR and SVN



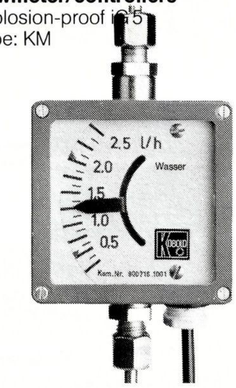
Water: 0.1-120 l/h
Air: 2 l_n/h - 2 Nm^3/h

Microvolume flowmeter/ controllers
Explosion-proof iG 5
Types: KDG/KDF



Water: 0.002-0.02 to 16-160 l/h
Air: 0.03-0.3 l_n/h to 430-4300 l_n/h

All-metal microvolume flowmeter/controllers
Explosion-proof iG 5
Type: KM

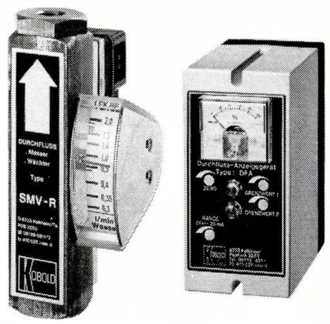


PN 40-PN 100/–20…+150 °C
Water: 0.1-1 l/h to 25-250 l/h
Air: 4.5-45 l_n/h to 0.8-8 Nm^3/h

Flowmeter/controllers
Explosion-proof iG 5
Type: SV-R/S-R

Water: 6-60 l/h to 0.5-9 m^3/h
Air: 0.2-2 Nm^3/h to 20-250 Nm^3/h

All-metal flowmeter/controllers with analog output
Explosion-proof iG 5
Type: SMV-R/VKM-G

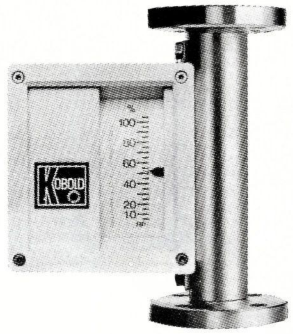


PN 350/–50 °C…+160 °C
Water: 3-60 l/h to 0.5-15 m^3/h
Air: 3-35 l/h to 20-400 Nm^3/h

Flowmeters and controllers with analog output independent of viscosity and location
Types: VKG and VKM

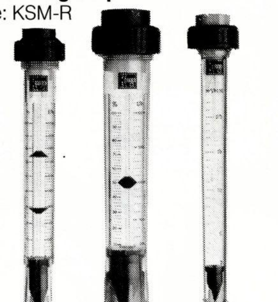
Viscosity range: 1-5000 mm^2/s
e. g.: 0.01-0.07 to 8-80 l/min of oil

All-metal flowmeters and controllers with analog output
Type: MC



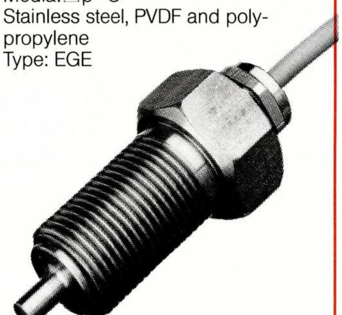
PN 40-PN 600/–50…+300 °C
Water: 2.5-25 l/h to 10-100 m^3/h
Air: 75-750 l_n/h to 180-1800 Nm^3/h

Trogamid and polysulfone flowmeter/controllers with analog output
Type: KSM-R



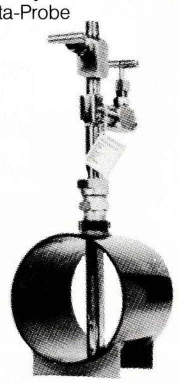
Water: 16-160 l/h to 2-20 m^3/h
Air: 0.25-2.5 Nm^3/h to 58-580 Nm^3/h

Electronic flow controllers
for gases, liquids and powders
Media: $\triangle p = O$
Stainless steel, PVDF and polypropylene
Type: EGE



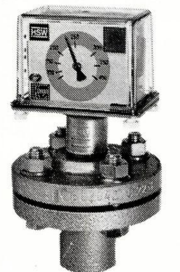
Liquids (incl. **highly viscous):**
0.01-4 m/s.
Gases: 0.1-15 m/s
PN 300/–40…+90 °C

Flow sensors proportional to differential pressure
Type: Beta-Probe



Error: ± 0.5% or ± 2%
R½"-R 2"/DN 50 - 9 m lead dia
Liquids, gases and steam

Paddle-bellows flowmeters and controllers
for heavily contaminated media
Types: HSW-DWU/-DWP/-DWS



Pipe connection 3/8"-2"
Flange connection DN 10-DN 50
Slip-on flange for DN 40-DN 1000
1-4 l/min to 10 000 m^3/h
PN 6-PN 10/100 °C

Paddle flow controllers
Type: PSR — Brass and stainless steel
Type: PPS-3S — Polysulfone

PSR: 3-5 l/min to 20-28 m^3/h, PN 16-PN 25/100 °C
PPS-3S: 10-110 l/min, PN 10/110 °C

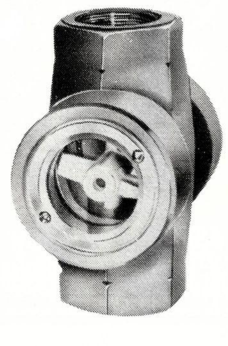
Horizontal ball-type flow indicator
Type: DA-KU

Range
Water: 0.3 l/min-90 l/min
Air: 0.015 Nm^3/min-200 Nm^3/h

Flow indicator, can be mounted in any position,
with plastics rotor and **automatic sight-tube cleaner**
Type: DA-RA

R¼"-R 1½"
PN 16/100 °C

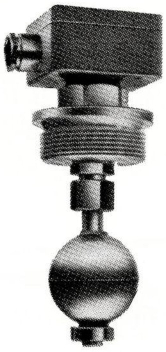
Flow indicator, can be mounted in any position, with Teflon rotor
Type: DA-R



R¼"-R 1½"/ flange DN 25/40/50
suitable for both dark opaque liquids and for gases

Measurement of level

Magnetic float switches
Type: N
180 different types in high-grade steel, titanium, brass, PPH, PVC, PVDF and PTFE

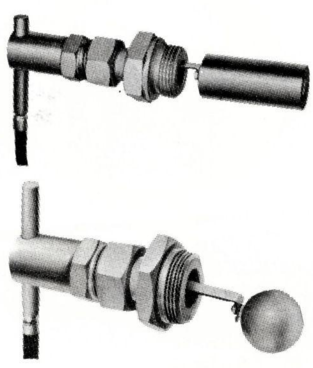


PN 100/180 °C
$\text{Den.}_{liq.}$ min ≥ 0.25 kp/dm^3

Magnetic float switches
Type: NS
for side-fitting

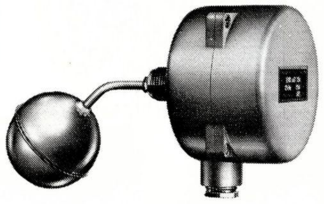
PN 100/180 °C
$\text{Den.}_{liq.}$ min ≥ 0.25 kp/dm^3

Magnetic float switches
Type: NV 1/2" und NV 3/4"
for side-fitting



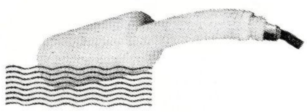
PN 18/110 °C
$\text{Den.}_{liq.}$ min ≥ 0.8 kp/dm^3

Float switches with spring contact
Type: FNS
for side-fitting



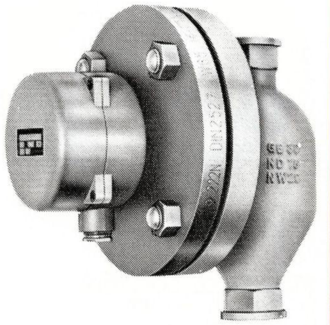
PN 16/350 °C
$\text{Den.}_{liq.}$ min ≥ 0.8 kp/dm^3
I_{max} = **10 A** bei 220 V ~

PTFE float switches
Type: NST
for side-fitting with **mercury contact**



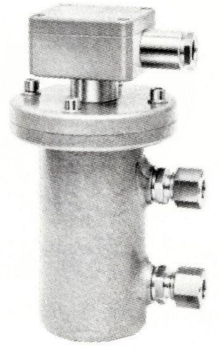
1 bar/160 °C
$\text{Den.}_{liq.}$ min ≥ 0.7 kp/dm^3
I_{max} = **4 A** bei 220 V ~

Bypass float switches
with spring contact
Type: FNS



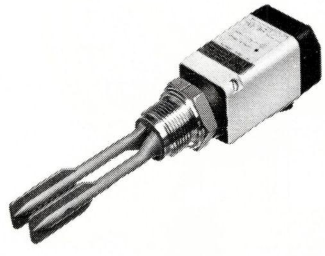
PN 16/350 °C
$\text{Den.}_{liq.}$ min ≥ 0.7 kp/dm^3
I_{max} = **10 A** bei 220 V ~

Bypass magnetic float switches
Type: NB-10



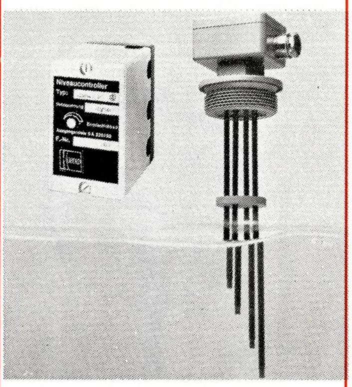
PN 10/150 °C
$\text{Den.}_{liq.}$ min ≥ 0.7 kp/dm^3

All-purpose limit switches
for liquids
Type: FTL 160



$\text{Den.}_{liq.}$ min: independent
max. viscosity: 2000 mm^2/s
PN 16/−40…+150° C
G x 5 Cr Ni Mo Nb 1810 austenitic steel

Limit switches for conductive fluids



PN 100/150 °C
single to quintuple electrodes

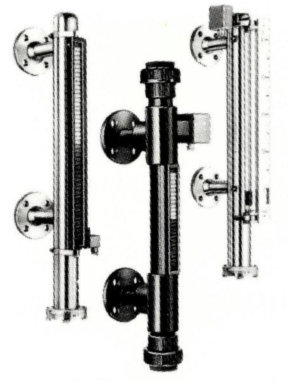
Thermal resistor switches for **nonconductive** liquids

t_{max} = −25 °C… +55 °C
max. viscosity 10 °E

Level indicators
Level pick-ups
Type: NM

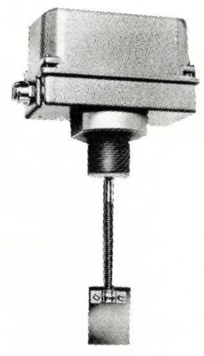
PN 25/−50 °C…+130 °C

Bypass level indicators
with magnetic transmitters
Type: BMG



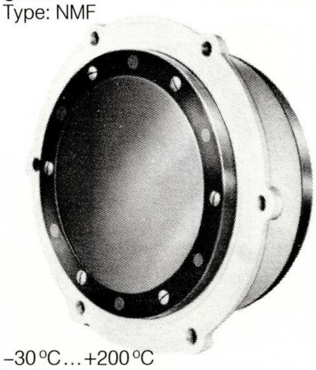
PN 350/300 °C

Vibratory level signalling devices for heavy and viscous media with **flexible** vibratory sensor
Type: NBV



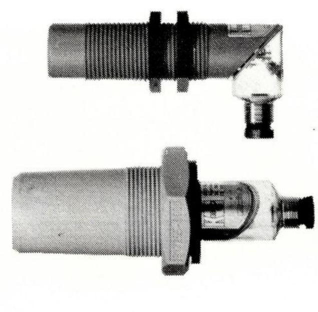
PN 6/80 °C/IP 55
R1 1/2" or flange DN 50 - DN 150

Diaphragm-type level signalling devices for installation in silos, bunkers, etc. for coarse and fine **bulk goods**
Type: NMF



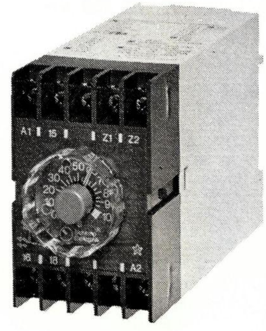
−30 °C…+200 °C
for Zone 11 explosion-proof rooms without ancillary equipment

Capacitive level switch
for fine and powder bulk goods
Type FTC 960



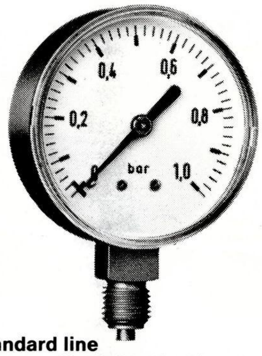
PN 6/−20…+80 °C
R1"/adapter R 1 1/2"

Time-delay starting relays
Contact protector relays

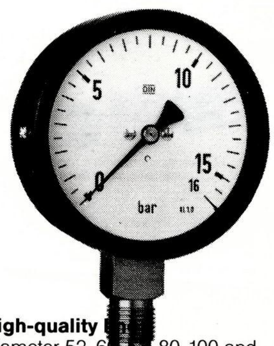


Explosion-proof relays - Zone O
Control systems

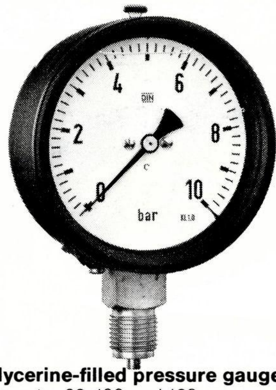
Pressure



Standard line
Diameter 40, 50, 63, 80, 100 and 160 mm,
Quality Class 2.5
Measuring range 0 - 1 bar to 0 - 400 bar

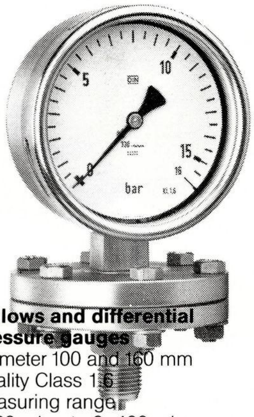


High-quality line
Diameter 52, 60, 63, 80, 100 and 160 mm,
Quality Class 1.0
Measuring range
0 - 60 mbar to 0 - 400 mbar
0 - 0.6 bar to 0 - 1600 bar

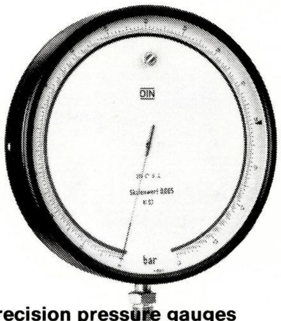


Glycerine-filled pressure gauges
Diameter 63, 100 and 160 mm
Quality Class 1.0 to 2.5
Measuring range
0 - 0.6 bar to 0 - 1000 bar

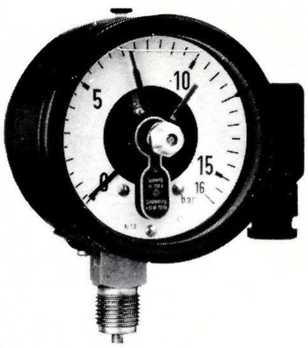
Chemical line
Diameter 40, 50, 63, 100 and 160 mm,
Quality Class 1.0
Measuring range
0 - 0.6 bar to 0 - 1000 bar



Bellows and differential pressure gauges
Diameter 100 and 160 mm
Quality Class 1.6
Measuring range
0 - 60 mbar to 0 - 400 mbar
0 - 0.6 to 0 - 25 bar

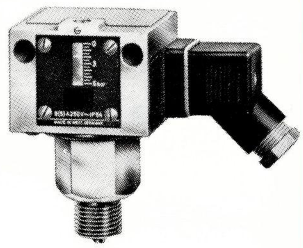


Precision pressure gauges
Diameter 160 mm, Quality Class 0.6 and 0.3
Diameter 250 mm, Quality Class 0.3, 0.2, 0.1
Measuring range
0 - 0.6 bar to 0 - 1600 bar



Contact pressure gauges
- Magnetic snap-action contacts
- Crawl contacts
- Inductive contacts
- Pneumatic contacts

Pressure and differential pressure switches
Adjustable differential setting
Liquids, steam and gases
Type: KD / KV



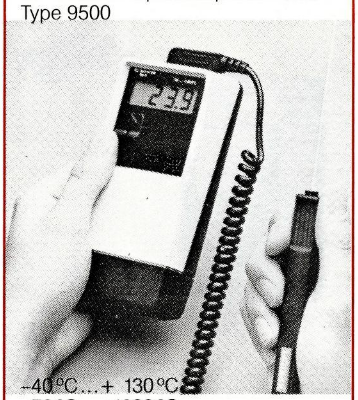
–250 mbar to 100 mbar
15 bar to 63 bar
250 V AC, 10 A

Temperature

Digital hand thermometers
Type: 7300 / 9300

–200 °C … + 600 °C
– 40 °C … +1200 °C

Digital hand thermometers
For **Zone 0** explosion-proof rooms
Type 9500

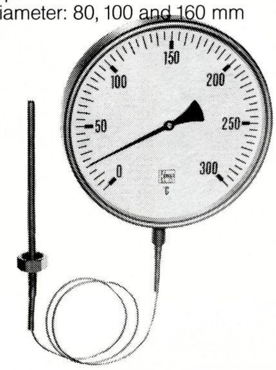


–40 °C … + 130 °C
–70 °C … +1200 °C
–50 °C … +1750 °C

Precision dial thermometers
Nitrogen-filled
For food industry, etc.
Error: ±0.6 and ±1.0% of full-scale reading
Diameter: 80, 100, 160 and 250 mm

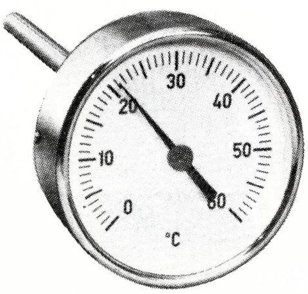
–250 °C … +650 °C

Precision dial thermometers
Mercury-filled,
error ±1.0% of full-scale reading
Type: 610
Diameter: 80, 100 and 160 mm



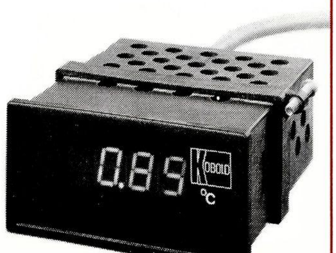
–30 °C … +500 °C

Machine thermometers
Bimetal
50, 63, 80, 100, 160, 250 mm



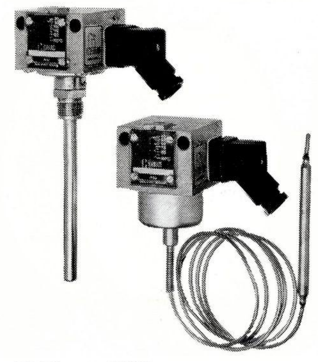
–35 °C … + 50 °C
0 °C … +300 °C

Digital 48x24 thermometers for panel mounting
Type: TT 4600



0 °C … + 99.9 °C
–20 °C … +600 °C

Temperature controllers
with adjustable set point
Type: KTAM/KTXM



–30 °C … + 10 °C
+80 °C … +130 °C

Temperature controllers and monitors with fixed set point
Type: TWR

+30 °C … +120 °C
PN 16 / IP 65