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INDUSTRY/TECHNOLOGY

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Covering current developments in high energy physics and related fields worldwide

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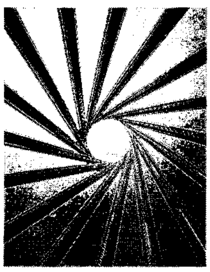


Cover photograph:
A new Fermilab outdoor sculpture viewed from the inside. Designed by former Laboratory Director Robert Wilson, it uses old cryostat tubes from an early design for the superconducting magnets of the Fermilab Tevatron. Superconductivity is a key area for particle physics collaboration with industry. (Photo Reidar Hahn)

***The Dr. B. Struck company**) has extended its range of available VMEbus products by some very interesting modules. These include intelligent FADC readout systems using Digital Signal Processors as well as simple level converters.**

STR730 FDDP Fast Digital Data Processor

The STR730 System (INFN Torino) serves as a fast read-in and processing system for analog data. The VME-module STR730/DSP consists of the VME-interface and two identical logical units with a fast Digital Signal Processor (DSP) TMS32010 and 4 Kbyte program memory in each of these.

The DSP can read and process the data from a piggyback analog input card to perform e.g. programmable trigger decisions or on-line data reduction. The results are stored in a 512-word FIFO memory which n be read either through a front panel nnector or the VMEbus. Additional FIFOs enable the exchange of data between adjacent logical units.

The piggyback input card STR730/AN1 comprises eight FADCs with 8 bit resolution (linear), 50 Ohms input impedance, 10 mV/LSB sensitivity and 200 ns conversion time. 4 channel FADC boards with 256 byte memory per channel and charge integrating ADC boards are under development.

DL400 Modular VME Front-End System

The DL400 system (Univ. of Heidelberg) is suited for applications where FADC sampling rates up to 100 MHz are necessary. The base module DL400 contains the whole VMEbus interface.

The DL401 submodule is a piggyback board which is placed onto the base module. It contains 4 Flash-ADCs with 8 resolution. If a larger dynamic range is quired, it is possible to run the FADCs in a nonlinear mode with an effective dynamic range of 10 bits. The maximum sampling rate is 100 MHz, controlled by the trigger input. For each FADC a fast 1024 byte memory will serve as intermediate storage. The data of the four memories can be read as one 32-bit word via the VMEbus to enable fast read-out of the data.

The DL403 submodule will generate all the necessary timing and control signals for the DL401 modules. The DL403 supports both, the common start mode and the common stop mode.

A Time-to-Digital converter DL404 is now available for the DL400 system. It has 16 analog inputs with programmable discriminator thresholds. The conversion is digital and the resolution is defined by the clock frequency (10 ns minimum). Different operating modes include multi-hit and multi-event capability. Depending on the operating mode the time range is 41µ s to 10.5 ms at maximum clock frequency.

DL410 USBM

The DL410 ultra high speed buffer memory (USBM) submodule can record fast digital data. It has two 10-bit input channels with differential ECL input and a maximum input rate of 100 MHz per channel. Each of the two channels has a memory of 128 Kwords.

Its specific application is to record data from an external transient recorder (TEKTRONIX type RTD710, 10 bit, 200 MHz) and make it available to the VMEbus.

STR721 VSC

The VME module STR721 (UPL) is a scaler/counter with 32 16-bit channels or 16 32-bit channels. It contains 8 of the versatile AM9513A system timing controller chips on a single VME board. Four inputs of each chip are connected to the P2 connector via a signal conditioning circuit. The fifth counter in each chip may use the on-board crystal oscillator to provide gating signals for the other counters.

The main feature of the board is the facility to provide a number of different input conditioning options. This is achieved by the general purpose input configuration area. Two basic options are available: TTL or ECL inputs, either of them can be configured as single-ended or differential inputs. The ECL version can also be modified to give single ended NIM-level inputs. The input impedance and bias voltage can be matched to the requirements. An RC pulse stretching circuit is provided after the input buffers to allow counting of narrow pulses down to 10 ns at rates in excess of 6 MHz.

STR712 VIP Processor board

The STR712 VIP processor module (K. Honscheid) gives excellent performance for a reasonable price. It consists of an MC68010 processor with up to 768 Kbyte of static dual-port RAM, up to 256 Kbyte EPROM, two RS-232C interfaces and an Ethernet or Cheapernet interface. Simple interface boards can be used between the internal bus of the VIP board and the P2 connector to give different functions: A CAMAC branch interface (STR722) to drive up to seven CAMAC crates and an interface to the DL300 FADC system are available.

Another application is an add-on EEPROM card developed at CERN to store system parameters of the OS-9 operating system. A special OS-9 device handler simulates virtual floppy disks on a VAX or PC host, which is connected to the VIP via Cheapernet.

STR711 VME-TAXI Crate Interconnect

The STR711 VME-TAXI (E. Pietarinen) utilizes the TAXIchip (TM) set of AMD for fast data exchange between VME crates. The connection between the crates is done by coaxial cables (few meters), fibre optic links (up to 1 km) or monomode fibres with laser transmitters (up to 10 km). Each module has two input and two output links. A high performance MC68020 processor takes care of the communication protocol and a special hardware allows a continuous transfer rate up to 12.5 Mbyte/s between the fibre optic media and the VMEbus. The module is also useful as a general purpose processor for other data acquisition tasks.

The module contains 128 Kbyte of static dual port RAM (expandable to 1 Mbyte) for use as buffer and program memory and two RS-232C interfaces. It has a full 32-bit VMEbus as well as a VSB connection.

Block transfer between crates is very fast because only local flow control is necessary inside the crate. It is also possible to use the module in transparent mode to address any VME module in a distant crate. But because one cannot profit from pipelining in this mode the resulting speed is not as spectacular as it is for block transfer.

STR723 Differential VSB Extension

This is a small adapter board, which is plugged into the rear of a VSB backplane (GSI Darmstadt). It converts the VSB signals into differential signals to extend the VSB-bus over long distances up to 50 m.

One application at the GSI is to connect the VSB to an Aleph Event Builder. The interface on the FASTBUS side is connected to the Event Builder like an Event Memory. The interface has a maximum of 4 Mbyte static RAM which can be accessed independently from the AEB and the VSB. It contains several registers to enable and set interrupts on both ports and to control the data channels.

STR79x NIM Logic on VME boards

Very often there is the need for some NIM-level "glue logic" to build simple circuits. If one does not need a whole NIM crate and there is some spare room in a VME crate, Dr. B. Struck now offers an interesting alternative: NIM logic on VME boards. No connection to the VMEbus is made except for the power supply lines. The -5V supply is generated internally by a DC-DC converter. Following modules are available soon:

STR791 Fast AND, 8 AND gates with 2 inputs and 2 outputs each;

STR792 Fast OR, 8 OR gates with 2 inputs and 2 outputs each;

STR793 AND/OR-Unit, 4 AND gates and 4 OR gates with 2 inputs and 2 outputs each;

STR794 Fast FAN-OUT, 4 times 4-fold FAN-OUT, input via 1, 2 or 4 inputs;

STR795 Fast FAN-OUT including inverting output, like STR794 but one additional inverting output for each of the 4 groups;

STR796 16 channel TTL/NIM level converter;

STR797 NIM to differential ECL level converter.

*) DR. B. STRUCK, P.O.Box 1147, D-2000 Tangstedt, W. Germany

What particle physics gives to technology

Particle physics and industry

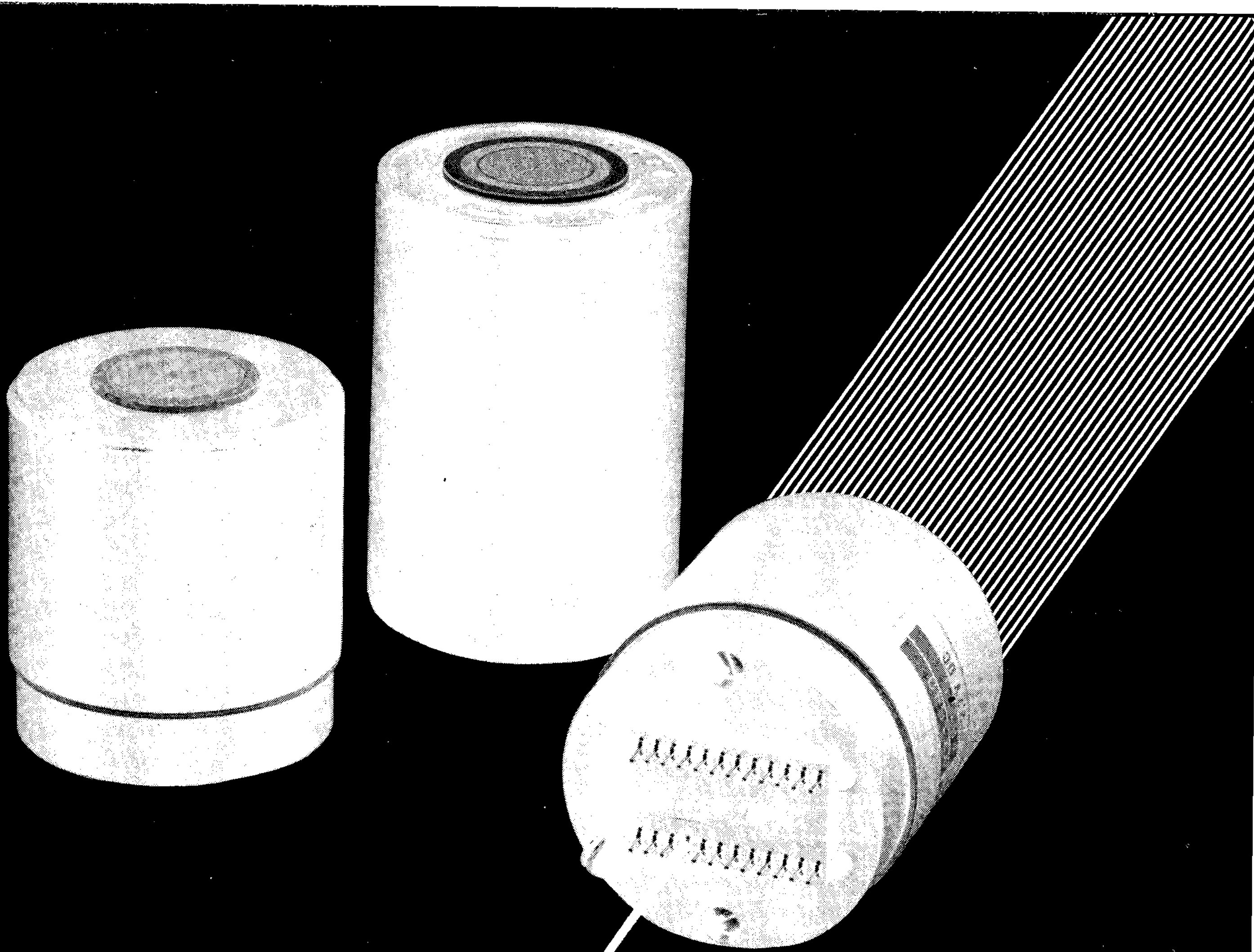
Following a suggestion by CERN Director General Herwig Schopper, this special issue of the CERN Courier covers the growing interplay between high energy physics and industrial high technology. Contributions from major Laboratories indicate the range of development partnerships now underway, but are by no means exhaustive – in particular work on cryogenics and superconductivity, on fast electronics, on photoelectronics, on computers, on ultra high vacuum, on data communications, ... is pushing ahead in parallel at several research centres, particularly at the major Laboratories such as CERN.

Pure research and current technology feed off each other. Technology operates within known limits, while pure research using this technology pushes back those limits, opening up in turn new technological domains to boost ongoing research, and so the cycle continues. How does an apparently arcane research field like particle physics contribute to this symbiosis? Particle physics studies phenomena which existed in the early seconds of the Universe and which survive only in remote stellar conflagrations. It concerns miniscule particles and their fleeting interactions, remote from daily life. How come it has made important contributions to advances in the ways we communicate, feed ourselves, cure our diseases, travel, manufacture goods, and so on?

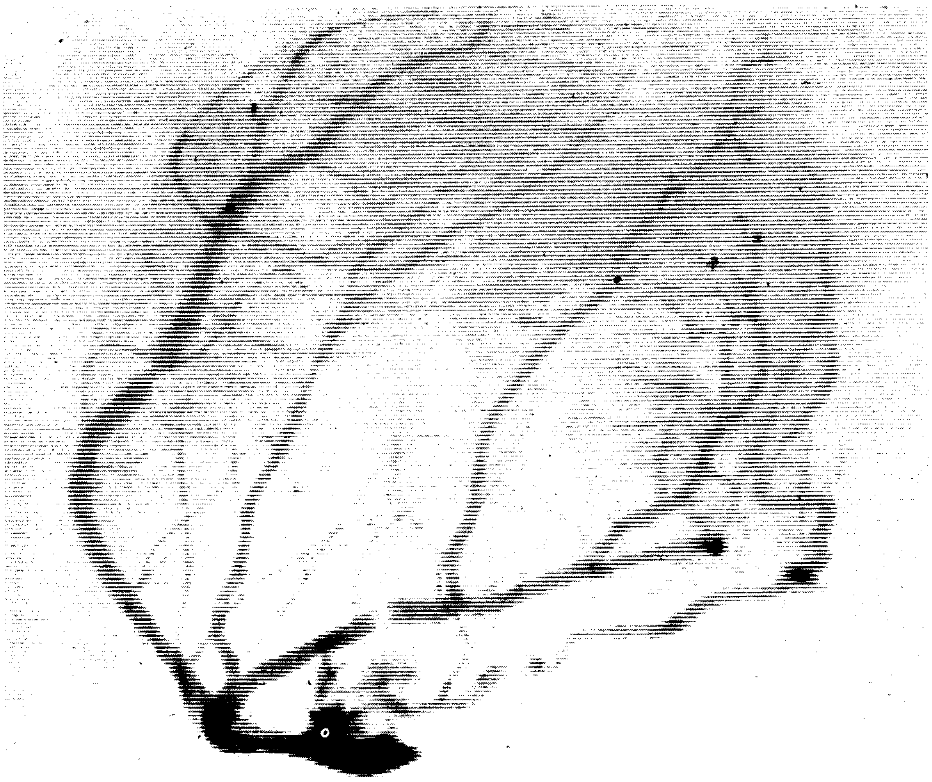
Fundamental impact on technology

Profound influences on technological progress came in the early days of what is now called particle physics. The vital discoveries of the electron and of X-rays, turning points in the history of modern physics, themselves would not have been possible without the vacuum pumps and seals developed and made available as industrial products at the end of the last century. From this work, in combination with quantum theory, came the understanding of the electron cloud around the atom. This explains the whole of chemistry, mechanical properties, the phenomena of light emission and X-radiation, lasers and superconductivity, ... It

Admiring the world's most ubiquitous particle accelerator. The cathode ray tube was invented at the end of the 19th century to measure the charge and mass of the electron.



The angiography technique, using synchrotron radiation X-rays with a suitable contrast medium, provides new scope for medical diagnosis.



opened the door, for example, to the dramatic advances in electronics, computing and communications with the development of semiconductors.

One of the discoverers of the transistor, Walter Brattain, wrote, 'The transistor came about because fundamental knowledge had developed to a stage where human minds could understand phenomena that had been observed for a long time. In the case of a device of such consequence to technology, it is noteworthy that a breakthrough came from work dedicated to the understanding of fundamental physical phenomena, rather than the cut-and-try method of producing a useful device.'

The second wave of fundamental technological impact from particle physics came from the study of the nucleus at the heart of the atom. Exploitation of the transformation of mass into energy via fission and fusion (leading to reactors, nuclear weapons and the attempt to provide an everlasting energy source with thermonuclear fusion) and radioactivity (leading to the use of isotopes in medicine, agriculture and industry), have had profound implications.

It is too early to see the technological impact of studying quarks. In general, man's imagination has proved to be hopelessly inadequate in estimating the practical value of today's discoveries for tomorrow. But increased knowledge about how matter behaves gives increased ability to manipulate that matter. It would be unwise to assume that understanding of the deepest level of the structure of matter will never be usable by mankind. To cite just one speculative technology involving particles – the muon, mysterious heavy replica of the electron, could play a catalytic role in nuclear fusion avoiding many of the complications of plasma or implosion techniques.

These progressively deeper insights into the nature of matter are the most important contributions of particle physics to technology. They have extended man's knowledge of his environment and changed his thinking.

Direct impact on technology

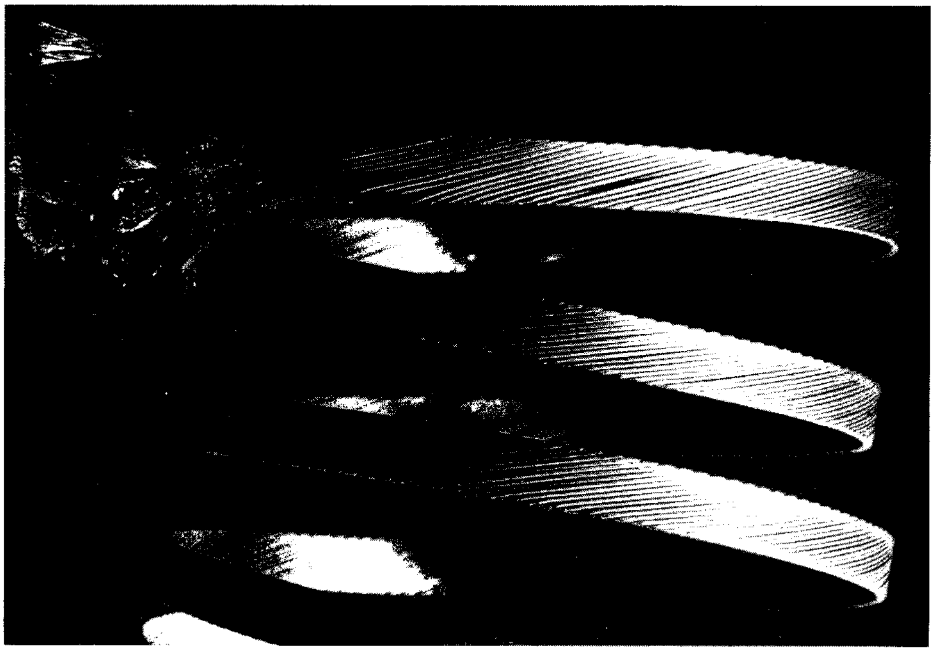
There are also significant short-term spin-offs from particle physics research.

Accelerators and the handling of particle beams

The demands of particle physics have driven the mastery of acceleration and storage of particle beams to extraordinary perfection. In the wake of such mastery, thousands of accelerators are built for routine use by operators who have little, if any, knowledge of particle physics. Although no longer worthy of the label, even a television set is a refined replica of one of the very first particle physics experiments – the measurements on the electron at the turn of the century. Less than 1 % of the world's accelerators are used in the particle physics field where they were created and perfected. The rest are used in medical applications and commercial processes involving markets of tens of billions of dollars.

Over thirty centres throughout the world now operate electron or positron storage rings as sources of synchrotron (electromagnetic) radiation, and more are being built. Providing beams millions of times more intense than were available

Superconducting cable of the type pioneering at the UK Rutherford Laboratory ('Rutherford cable') is now produced by industry.



twenty years ago, they are used in research in solid state physics, chemistry, biology, medicine, ... They have potential in mass scanning for heart disease, and are starting to be used commercially in the production of new semiconductor chips with circuit elements packed 100 to a 1000 times more densely, promising faster, more powerful, and cheaper computers (see page 24).

Free electron lasers use accelerator techniques to produce undreamed of intensities of radiation. They are under development as research instruments for similar purposes as the synchrotron radiation sources, and as heat sources for thermonuclear plasmas.

Accelerators are used to produce radioisotopes for use in medical diagnosis. Several types of accelerated particle beams are also used in diagnosis (X-rays), and treatment (radiotherapy), where electrons and electron-generated gamma rays, neutrons, protons, pions and heavy ions have been exploited for their different biological effects.

The use of accelerators to implant ions in the production of integrated circuit chips is now a big market. The implantation process is also used in the production of alloys involving traces of rare metals.

Accelerated particle beams are used in food processing, killing bacteria to prolong shelf-life. Such radiation is also used to improve the mechanical properties of materials like plastics.

A comparatively new application of accelerator technology is in dating materials by measuring their radioisotope content. This has uses in archaeology (the Turin shroud), energy physics, geology, astrophysics, oceanography and climatology. Mass spectrography of accelerated ions needs only tiny samples (milligrams rather than the grams used in conventional radiocarbon dating).

Superconductivity

Many accelerator technologies rely on superconductivity. The needs of particle physics for high field magnets to guide high energy beams and for large energy-efficient magnets for detectors has been a driving force in the superconductivity industry in recent decades. Among the major technological contributions are the invention of twisted fine-filament superconductor, allowing pulsed operation of superconducting wire, and the mastery of superconducting radiofrequency cavities.

With powerful superconducting magnets available, the nuclear magnetic resonance technique, itself a particle physics spinoff, has become a major tool of modern medicine. In addition to improved diagnosis, the pinpointing of tumours by NMR tomography also permits precision treatment by particle beams. NMR is also being used increasingly in biological research for 'non-invasive' studies of metabolisms.

As well as in nuclear magnetic resonance, superconducting magnets have applications, or potential applications, in thermonuclear fusion, mineral separation, coal purification, high speed trains, energy storage, and power generators. Superconducting cable could be used in energy transmission, and superconducting coils for energy storage. Superconducting radiofrequency cavities have applications in free electron lasers, and medical linear accelerators.

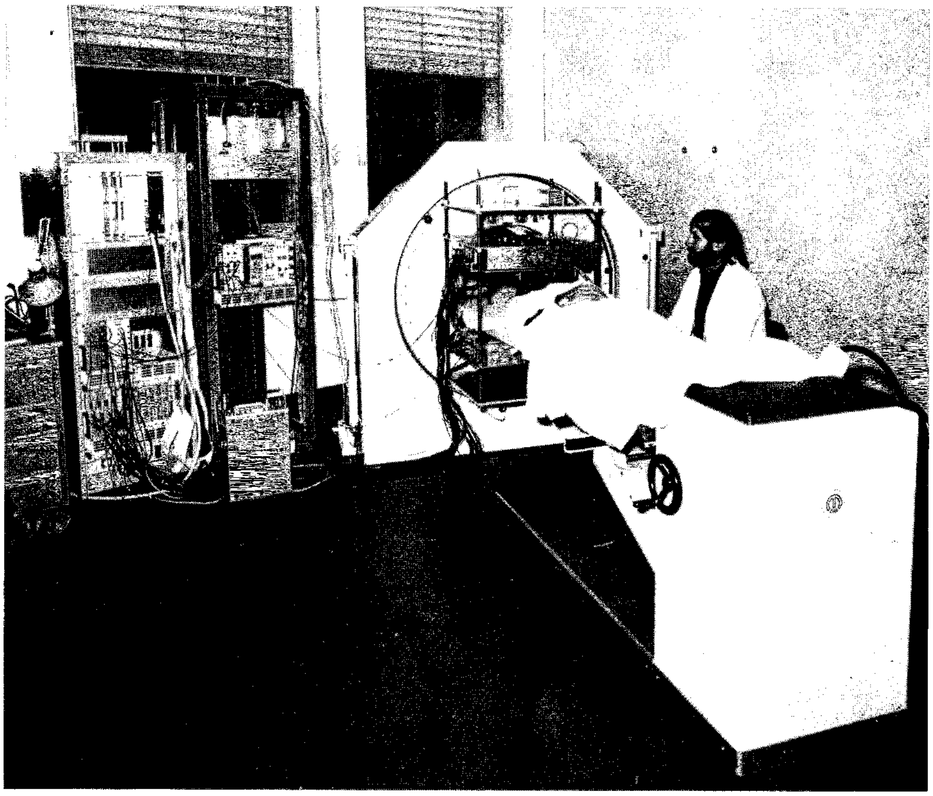
Particle detectors

There are also many applications of the particle detection techniques developed in particle physics. Researchers need to measure particles in time and space, handling large volumes of data at very high speeds.

From early Geiger counters and scintillation counters to their mod-

A positron camera developed at CERN being used for tomographic imaging at a Geneva hospital.

(Photo CERN 419.2.82)



ern equivalents, particle counters have been important in radiation detection and intensity measurement. They told the world about Chernobyl. Scintillators are now manufactured for use in the oil, food, steel, coal, medical and defence industries. A serendipitous result of the development of mirrors to concentrate the weak Cherenkov radiation from particles has been the use of this form of mirror to make inexpensive non-steerable collectors to concentrate sunlight.

The invention of multiwire proportional chambers and drift chambers has led to applications particularly in the medical field. Their higher resolution has made them an important tool for medical diagnostics, usually reducing the required radiation dose by a factor of ten or more. A technique of electron-positron detection for body scans is now being marketed commercially. With accurate location of tumours, particle beams can be precision guided to their target.

From the days of bubble chamber physics came the techniques of computerized scanning and measurement of tracks on film, which has been described as providing the computer with an eye. These techniques are now in commercial use in automated map reading and map production, biological cell recognition in specimen analysis and monitoring of industrial processes (such as detection of defects in welds or production line control).

The need to collect a lot of data fast and the subsequent large volume 'number-crunching' have had a major impact on the electronics and computer industries. Particle physics has always played a leading role in establishing widely accepted standards (such as NIM, CAMAC and FASTBUS) which has helped industry and kept prices down. Data communications, especially using computer networks, is another field where the science has influenced development work.

Some feeling for the scale of the markets for these spinoff technologies come from US 'ball-park' figures pulled together by Leon Lederman and Dick Carrigan for a Fermilab Industrial Affiliates Roundtable on Research Technology for the 21st Century. In dollars, with some inevitable double counting across the selected categories, transistors account for nearly 10 billion in electronic systems sold for 144 billion; laser sales are at half a billion and growing fast; summing the revenues of the largest computer companies gives over 100 billion; television sales and television-station revenues totalled over 50 billion; revenue from nuclear power plants corresponds to 24 billion; biotechnological products are at a fifth of a billion and expected to grow rapidly.

Impact from working with industry

The contracts placed by particle physics in industry frequently have significant results. The construction and operation of complex but necessarily highly reliable accelerators and particle detectors to rigorous specifications very often push back the frontiers of technology.

The most detailed analysis of this impact has been made at CERN, in two detailed surveys of European industry, in 1975 and 1984. In 1975, industry estimated that for every Swiss franc spent by CERN in the initial contract, on average about 3.5 francs of additional business elsewhere followed for the firm.

The second survey, using more data and more sophisticated statistical techniques, essentially confirmed that the high technology 'economic utility' generated by working with CERN is worth three times the initial contract. The areas investigated were electronics and computers, electrical equipment, vacuum and cryogenics, steel and welding, and precision mechanics.

The impact is felt in various ways – quality improvements, increased productivity, generation of new products, 'launching pad' effects assuring sufficient production to merit investment, 'shop window' benefits of a higher reputation, inter-company collaboration with reduced costs, internal reorganization, etc.

Over the years the efforts at CERN to stimulate exchange of technological information with industry have steadily gained momentum. A 'Meeting on technology arising from high energy physics' was held in April 1974. Over 300 participants from industry, other research centres and universities heard three days of review talks on advanced technology and were able to see over 250 exhibits of equipment and the techniques emerging from the European particle physics programme. The talks and technical leaflets on all the exhibits were published.

A Technology Exhibition was also set up for CERN's 25th anniversary celebrations in 1979. 600 square metres of exhibition space were divided into displays of magnet, vacuum, computer and data handling, survey and alignment, radiation protection, beam monitoring, detector, and workshop techniques.

Round-table discussions with national industry are regularly organized in parallel with exhibitions of CERN's work in the Member States.

A 'Committee for Relations with Industry' was set up in 1985. It studied CERN's technical activities, the division of work between CERN and industry, possibilities for increased collaboration with industry,

CERN's 27-kilometre LEP electron-positron collider and its four big experiments now being assembled called for special contributions from industry.

(Photo CERN 128.9.88)

CERN purchasing procedures, technology transfer and the need for more information on technology.

In 1987, six Technical Boards of CERN experts were set up for electrical engineering, mechanical engineering, process controls and electronics for accelerators, electronics for research, communications, and beam instrumentation. The Boards harmonize technical approaches throughout CERN, ensure collaboration in design and development both inside and outside the Laboratory, and stimulate relations with European industry. They help in the exchange of information with firms and ensure a more uniform approach for technical specifications when tenders for contracts are prepared.

Common technological developments are being implemented with industry or other national centres on topics involving superconductivity, cryogenics, fast electronics, special electronic circuits, particle detectors, computer interfaces, and computer networks. An 'Industry and Technical Liaison Office' has been set up to improve the contacts with European industry, promote common development projects, and help in the collection and transfer of technological information.

This work has received additional impetus following last year's recommendations of the CERN Review Committee chaired by Anatole Abragam. There is more concern to improve the flow of information to industry so that CERN's technological work is better known. Guidelines on common development projects are being worked out. A more flexible policy will make it more attractive for industries involved in joint developments, and others, to take out patents evolving from these technologies. Direct contacts are being set up between industries with specific needs and the appropriate experts within CERN. (An example is underwater remote handling, now benefiting from CERN's work on remote manipulation in highly radioactive areas.)

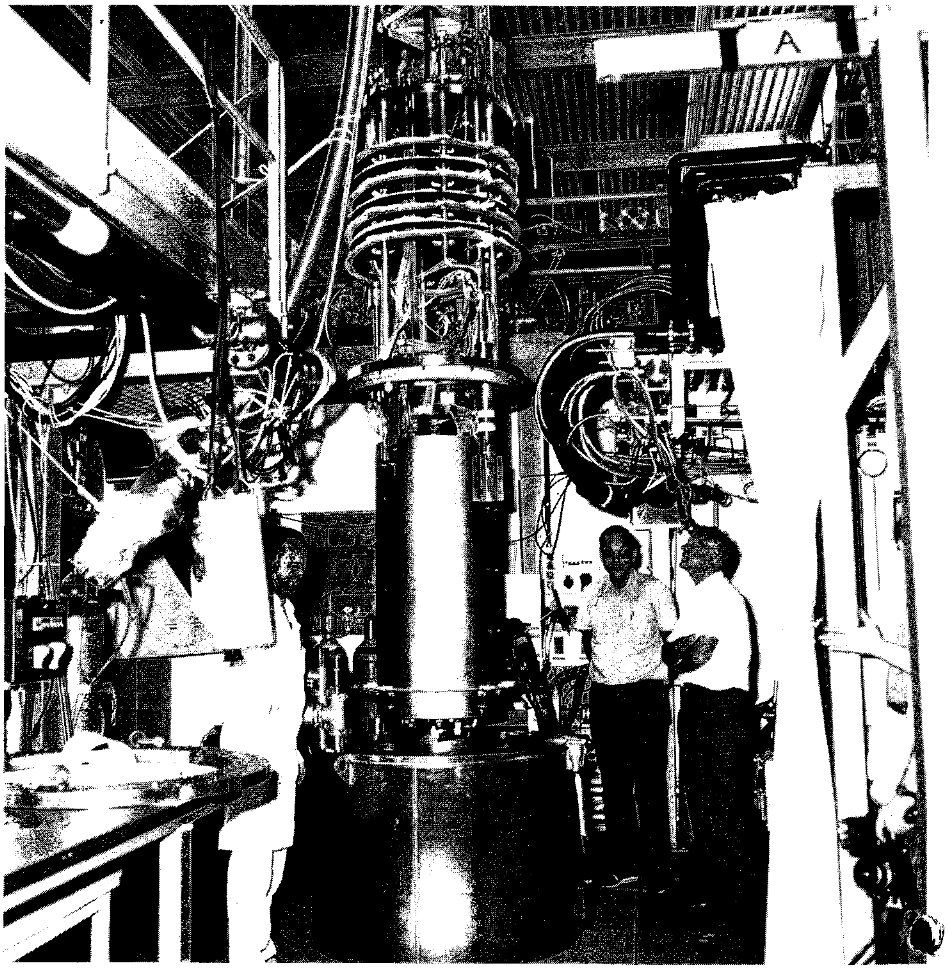
CERN is also becoming involved in the research and development projects of the European Economic Community. The EEC recently took up observer status at CERN Council meetings and collaboration is being prepared on topics of mutual interest like high temperature superconductivity. The EEC has started financing fellowships for work on applied physics projects at CERN.

The world's largest superconducting magnet – 7.4 metres long, 6.2 metres across and weighing 84 tonnes – made at the UK Rutherford Appleton Laboratory emerges from the access shaft of the Delphi experiment, now being assembled in its underground cavern at CERN's new LEP electron-positron collider.

(Photo CERN 365.6.88)

The first model high field superconducting magnet for the proposed LHC proton collider project at CERN is lifted from its cryostat after successful tests, attaining a field of 9.3 teslas.

(Photo CERN 307.7.88)



CERN
High field superconducting magnets

With the 27 kilometre tunnel for the LEP electron-positron collider at CERN now being fitted out in preparation for commissioning of the machine next summer, imaginative minds look further ahead to the next generation of physics experiments.

To get maximum benefit from the huge civil engineering investment in LEP, the machine design left enough space in the tunnel for a second magnet ring, mounted above the LEP ring. To handle protons, this project has been dubbed LHC – Large Hadron Collider.

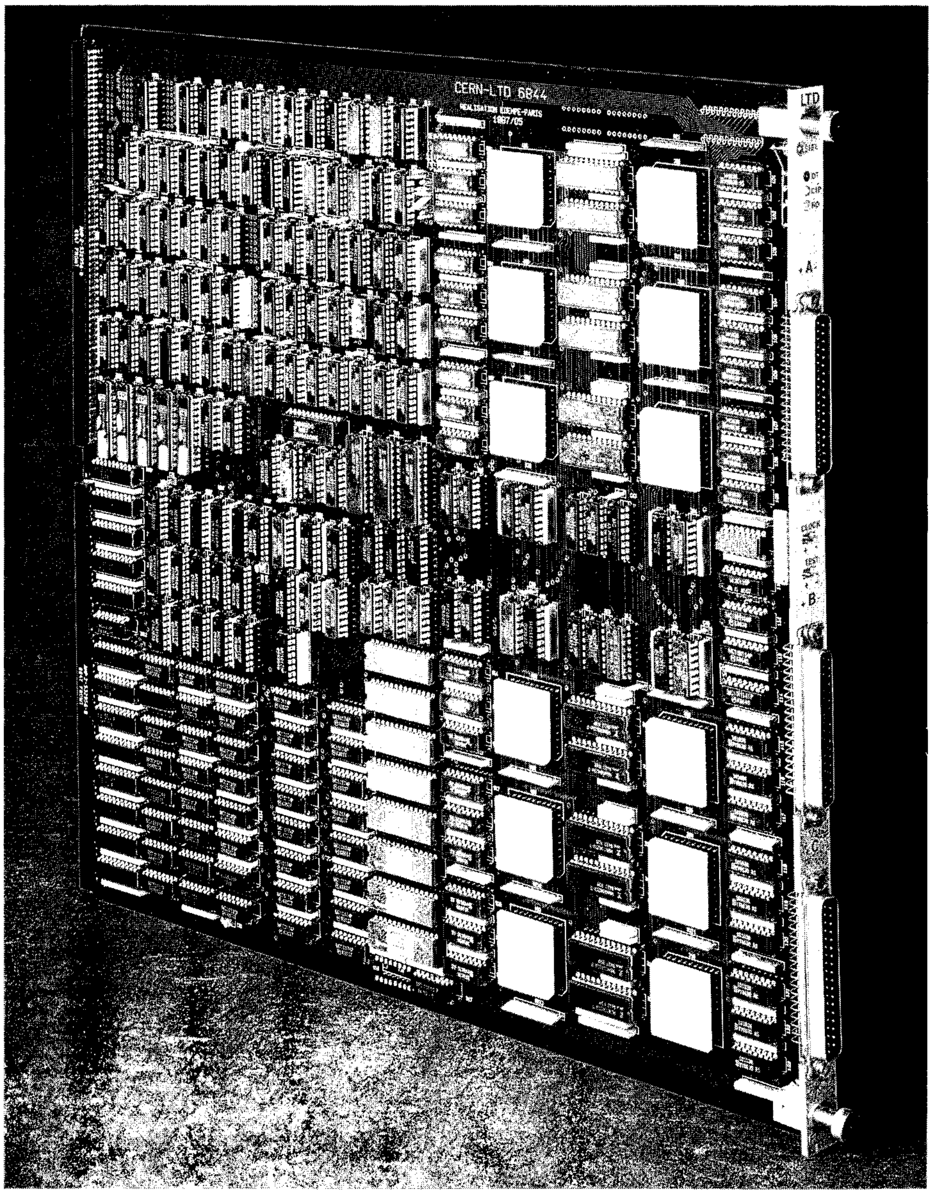
To bend the heavier protons needs much more powerful dipole magnets than are used for the electron-positron ring, with the field also being ramped up to keep pace with proton acceleration. With energy one of the prime goals, the output of LHC would be governed by the maximum magnetic field attainable with the steering magnets. In its recommendations last year, the CERN Long Range Planning Committee, chaired by Carlo Rubbia, underlined the importance of LHC magnet development work.

Only superconducting coils can provide feasible currents to power the electromagnets for a large proton accelerator. Initial work for the ill-fated Isabelle project at Brookhaven blazed a trail. The world's first large superconducting proton accelerator, the four-mile ring at Fermilab in the US, used a different magnet design and attains fields of about 44 kilogauss – 4.4 teslas – to guide its beams.

The next stage came with the decision to build the 6.4 kilometre HERA electron-proton collider at the German DESY Laboratory in Hamburg. Drawing on Isabelle and Fermilab experience, the HERA team developed a hybrid design with Fermilab-type coil configurations and collaring (to counteract the huge electromagnetic forces which would otherwise tear the magnet apart) and with Isabelle-type cold iron inside the cryostat.

In tests, these magnets have produced fields of up to about 6 tesla, well above the level required to handle the HERA proton beam design energy of 820 GeV. Series production of these dipole steering magnets, along with quadrupoles and correction coils, is now underway in European industry (see page 21).

For LHC, the dipole field goal is in the range 8-10 tesla. To steer the contra-rotating proton beams, twin apertures in a common magnetic circuit and cryostat are envisaged – the 'two-in-one' approach. Two superconductor approaches are being worked on – niobium-tin at 4.5K is seen as having greater potential, while niobium-titanium at 2K with its increased cryogenic demands and higher space requirements, but more straightforward magnet fabrication technology, is the subject of a parallel effort, and most of the initial encouraging results come from this sector. The



A Fastbus-based time digitizer module for LEP experiments developed at CERN in collaboration with specialists from European industry and Laboratories – a good example of high technology partnership.

technology is difficult and requires a sustained research and development effort. A European collaboration, open also to other interested parties, has been set up involving Laboratories and research centres in France, Italy, Germany, the Netherlands, the UK, Switzerland, Austria and Belgium.

CERN foresees ordering all LHC magnets and ancillary equipment from industry, and industrial firms are involved from the outset in the development of components such as suitable conductors and insulation systems and the design and construction of model magnets.

Three one-metre single aperture model magnets are under study. For an 8T nominal field single aperture dipole using niobium-titanium at 2K, CERN provided the superconductor and know-how, while the Italian firm Ansaldo took over for manufacture. The first model attained fields above 9 teslas without any problems (June issue, page 13). To explore the niobium-tin approach at the higher 4.5K temperatures, tests are getting underway of a model single aperture one-metre dipole with a nominal field of 10 T, the result of a close collaboration between CERN and Elin-Union of Austria, with aluminium alloy from Austria-Metall.

To test the 'two-in-one' design proposed for LHC, one twin aperture one-metre model using niobium-titanium will be built by each of four firms – Holec (Netherlands), Jeumont-Schneider (France), Ansaldo (Italy) and Elin (Austria). In parallel with the effort on one-metre models, a nine-metre twin aperture prototype using superconducting coils of the same type and geometry as those in HERA, with a nominal field of 7.5 T, is being built by Asea-Brown-Boveri in Germany, with the cryostat being manufactured by FBM in Italy. The unit is scheduled for testing at the French Saclay Laboratory next Spring.

Possibilities are also being explored for the other superconducting magnets needed for LHC, and a full-size prototype sextupole/dipole corrector magnet is being built by Tesla (UK).

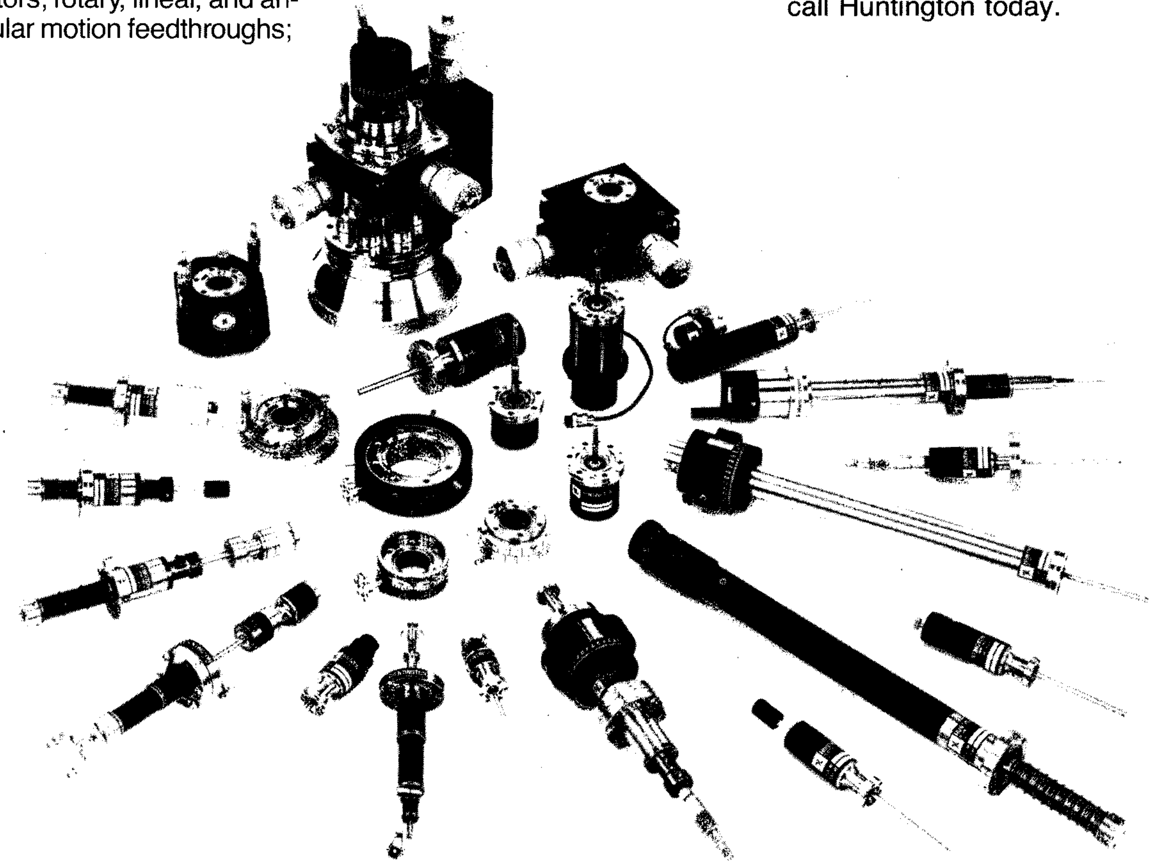
LEP electronics

Because of its sheer size and its implications for physics, the 27 kilometre LEP electron-positron collider and its four experiments now being fitted out at CERN have special requirements in the electronics sector.

The widely dispersed LEP control functions (in surface buildings, pits, alcoves, etc.) are handled by a distributed system, with microprocessor-based units and workstations interconnected by networks. Because of the long distances involved, two main decisions were taken:

- all LEP communications, including exchange of data between computers, are to be handled by industrial standard time division multiplex (TDM) equipment;
- the TDM bandwidth is to be shared by token-ring protocol. IBM has decided to develop this protocol, by now an international standard.

A joint study contract has been signed between CERN and IBM to evaluate the use of the token-ring protocol over a large real time control network. The collaboration, involving the LEP controls group, IBM's Ruschlikon (Switzerland) Research Laboratory, and IBM's Raleigh (US) Communication Products Division, resulted in the develop-



ment of code conversion equipment allowing token-ring protocols to be handled by TDM. Several long token rings are operational both in LEP and the SPS proton synchrotron (which will act as the LEP injector), and were successfully used for the LEP injection test in July (September issue, page 7).

The four big experiments now being constructed for LEP have radically changed the face of electronics development at CERN. Instead of a sizeable turnover of smaller experiments with relatively modest electronics requirements, considerable investment has gone into design, preparation and construction of these major projects, each requiring many tens of thousands of readout channels and considerable electronics 'overhead'. With the big detectors being installed deep underground, ancillary features like cooling also called for special attention.

Typically electronics development work for these big projects is done at the laboratories and research centres participating in the LEP experiments, with subsequent production work passed to industry.

Following earlier work at the UA1 experiment at CERN's proton-antiproton collider, and with an eye to ongoing developments in the TV industry, a major collaboration with industry (Thomson-EFCIS in France, and in Germany Philips, Siemens and Intermetall) resulted in the design of very fast ('flash') analog-digital converters for LEP experiments. The work with Thomson-EFCIS was also supported by French Laboratories. Following this joint effort, components from this firm were finally adopted for three LEP experiments – Aleph, Delphi and Opal, while the products from the other suppliers also benefited from the collaboration.

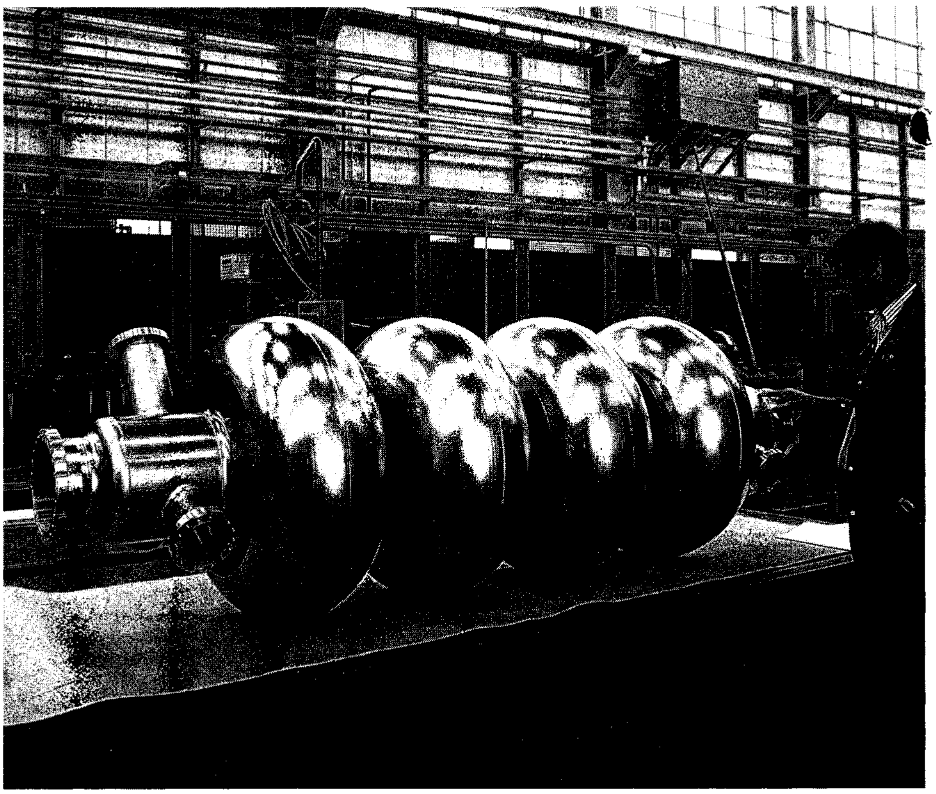
Standard data acquisition systems and modules have always been a strong spinoff from nuclear physics experiments. NIM and Camac are two success stories, and more recently the Fastbus system and developments based on the VME standard have also made their mark. For LEP, a Fastbus amplitude and time digitizer for Aleph and Opal is being produced by Sagem (France) and EED (Italy), while a time digitizer for Delphi is in the hands of Portuguese, Greek and Austrian industry, working in collaboration with local research centres.

Fastbus electronics developed at CERN is especially in demand, and manufacturing licences have been granted to firms in Denmark, France, Holland, Italy, Switzerland, the US and West Germany.

Other CERN electronics work includes Application Specific Integrated Circuits (ASICs, or semi-custom circuits), where there have been fruitful design collaborations with Motorola, Philips and Fujitsu, and thick-film hybrid circuits, mainly for analog applications, where several joint projects with European firms have gone on to be of interest in other fields.

Superconducting accelerating cavities

At an early stage in the design of LEP, it was realized that taking the beam energy beyond about 55 GeV to explore more physics called for the increased efficiencies and



Four-cell superconducting niobium accelerating cavity for LEP at CERN.

(Photo CERN 038.5.88)

high accelerating fields promised by superconducting radiofrequency cavities.

Work got underway in 1979 and eventually centred on two lines of attack at a working frequency of 352 MHz – one using cavities made from niobium sheet, and the other using copper covered with a thin layer of niobium. After much ainstaking work to develop and refine techniques for construction and for performance monitoring, four-cell niobium cavities have reached accelerating fields of up to 7.5 MV/m, however electron loading due to localized field emitters means that long helium processing is needed to nurse the fields above 5 MV/m. Quality (Q) factors at 5 MV/m are well above the design level of 3 x 10^9.

With prototype cavities now undergoing thorough tests (January/February issue, page 7), further prototypes are being made at CERN and by Interatom in Germany

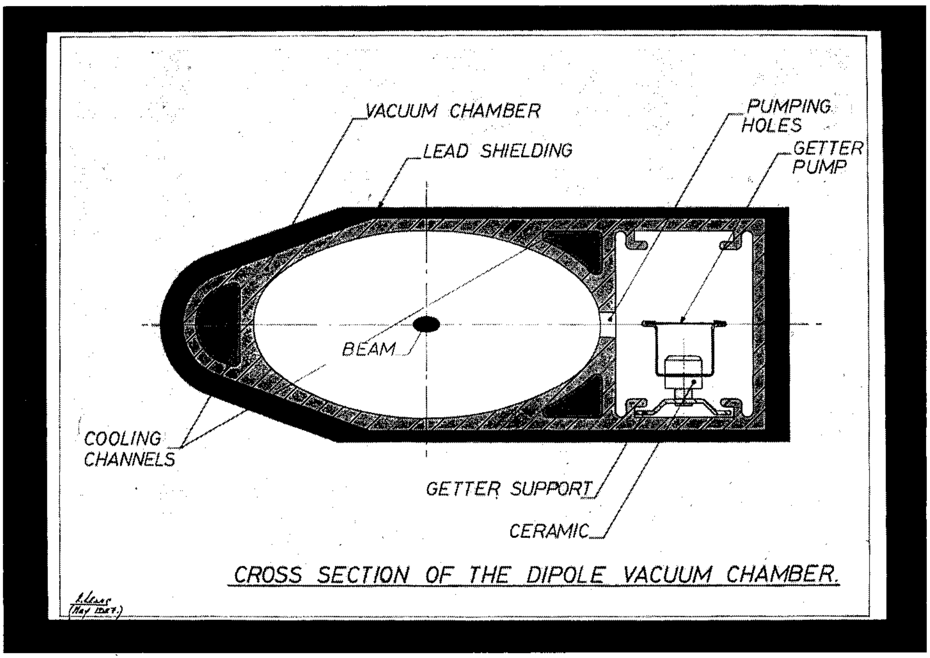
The need for very pure niobium n this work led industry to develop techniques for producing the sheet metal with much improved thermal conductivity.

Breakdowns can also be avoided by making cavities of copper sputter-coated with a few microns of niobium. The resulting cavities are also less sensitive to stray magnetic fields, and give good results, however the long-term reliability of the coating approach still needs to be studied.

In parallel with the development of the cavities themselves, effort has also gone into the design, construction and testing of the myriad of ancillary equipment – cryostats, couplers, tuners,....

Equipping LEP with superconducting cavities to boost its energy towards 100 GeV per beam will require considerable involvement with industry, and specifications have been drawn up for an initial series of 32 cavities to be installed in the ring as soon as possible, and coming into operation a few years after LEP is switched on next year, with more cavities to follow.

Following pioneer work some years ago at Stanford's High Energy Physics Laboratory, the need for higher beam energies has also driven development work for superconducting accelerating cavities at Cornell (see page 39), at DESY in Hamburg (see page 21), at Wuppertal, and at the Japanese KEK Laboratory.



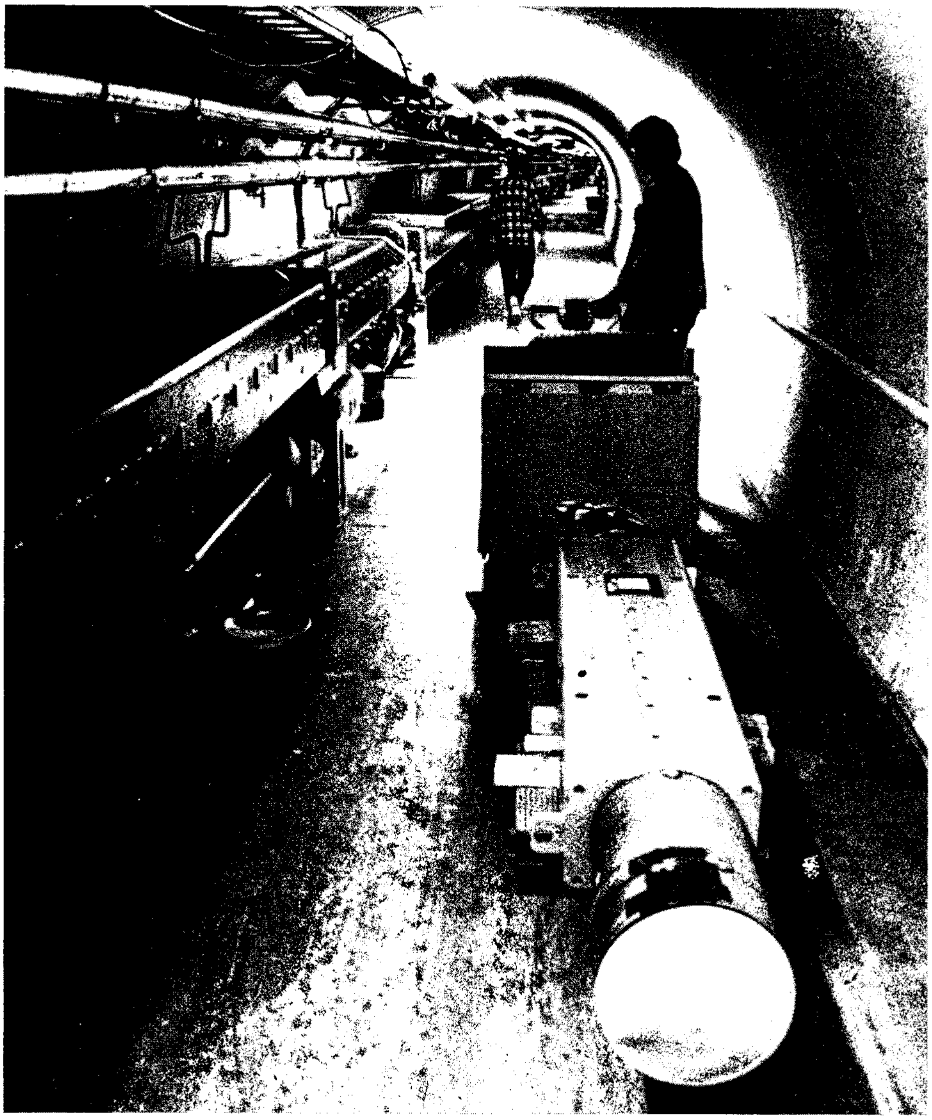
Cross-section of the vacuum chamber for the 27 kilometre LEP electron-positron ring being constructed at CERN. Such big high vacuum systems provide a challenge for industry.

High vacuum – much ado about nothing

Particles circulating in a particle accelerator near the speed of light cover enormous distances. In synchrotrons, where beams are only held for a few seconds at the most, the tube containing the particles has to be evacuated down to at least 10^{-6} mbar. In storage rings, where the particles have to circulate for hours and sometimes days, pressures need to be taken down still further, to about 10^{-12} mbar, to minimize beam-gas collisions and maximize machine output.

The development of light bulbs and electronic tubes earlier this century provided the first big boost to vacuum technology, and further impetus came in the 1950s where the development of the first big particle accelerators and of space simulation chambers called for industrial participation in both prototype development and actual construction.

In this work, the need for 'clean' vacuum free of hydrocarbons pushed the performance of oil and mercury diffusion pumps. Later, the more exacting demands of storage rings led to a swing to turbomolecular and sputter ion pumps. The first major series of turbopumps from Pfeiffer (Germany) was in-



The installation of the superconducting magnets for Fermilab's four-mile Tevatron ring helped transform superconductivity from a laboratory curiosity to a commercially and industrially viable activity.

stalled in CERN's PS proton synchrotron and ISR Intersecting Storage Rings, while sputter ion pumps, requiring little maintenance, with no moving parts and with almost infinite lifetime, have become the preferred pump for the high reliability large systems needed for particle physics.

Ion pumps initially had difficulties both at high pressures and in handling chemically inert gases (helium, argon, etc.) but continuous 'pressure' from the accelerator sector led to improved performance, such as in the Leybold (Germany) differential diode developed for the CERN's SPS Super Proton Synchrotron and the Varian (Italy) Starcell triode ion pump, developed from the stringent rare gas pumping specifications for the 27 kilometre LEP storage ring at CERN.

Particle accelerators underlined the importance of surface cleanliness in reducing desorption. Pioneering work at the ISR on the famous 'pressure bump instability' led to increased understanding of particle-surface interactions, and the curing techniques have benefited other vacuum applications (plasma fusion devices, thin film technology, microelectronics,....).

Experience from particle physics has also stressed the importance of 'outgassing' from the myriad of materials in contact with the vacuum system. Now a wide range of materials (stainless steel, ceramics, ferrites, aluminium, alloys, plastics,...) has been specially studied for high vacuum applications, while in situ bakeout at high temperatures is standard practice.

A special problem in accelerators, typically using a narrow but very long vacuum pipe, is that of conductance – ensuring a uniform vacuum with grouped pumping systems. One approach is to reduce the space between pumps, or even have one long continuous pump.

For LEP, a non-evaporable getter (NEG) pump was designed in close collaboration with industry (SAES Getters, Italy) Although getters had been used for 30 years to evacuate lamps and electronic tubes, the 27 kilometre LEP tube provided a new challenge.

Built to handle protons, CERN's seven kilometre SPS proton synchrotron faced new problems when called on to store antiprotons in CERN's antiproton project, launched ten years ago. Flashed titanium sublimation getter pumps for the SPS and for the AC and LEAR antiproton rings were designed to meet CERN specifications (Vacuum Generators, UK, and Balzers, Switzerland), and improvements to such sublimators have gone on to be available commercially from industry.

Physics demands for high reliability and efficiency have also brought in their wake much new vacuum hardware (seals, flanges, joints, all-metal valves, etc.).

FERMILAB
Technology transfer

A large range of technological developments have come from Fermilab science – major innovations in superconductivity, cryogenics, fast electronics, computers, and medical accelerators have had their genesis at the Laboratory. In May Phil Livdahl, formerly of the Fermilab Directorate, who has spearheaded the Fermilab-Loma Linda proton accelerator for medicine project, received a 1988 Special Award for Excellence in Technology Transfer from the US Federal Laboratory Consortium. Since 1980 Fermilab has received 11 of the IR-100 awards given by Research and Development magazine.

Much Fermilab technology has been put to general use by close interaction with industrial suppliers who go on to exploit the technology in other ways. A second important technology transfer system is through Fermilab Industrial Affiliates, a group of about forty companies ranging from industrial giants to small start-up electronics firms.

Proton accelerator for medicine

Construction is nearly complete at Fermilab of a proton accelerator for Loma Linda University Medical Center in California. As well as being a natural target for enquiries about accelerators, Fermilab is well known to the medical radiation community through the decade-long neutron therapy scheme using the injection linac.

Loma Linda's involvement with Fermilab grew from a Proton Therapy Co-Operative Group (PTCOG) – a consortium of hospitals, universities, companies, and laboratories which has explored the use of modern accelerator construction techniques for proton therapy at hospitals.

An important part of the Loma Linda technology transfer plan is the participation of an industrial partner to handle subsequent commercialization and service. The partner is SAIC, Science Applications International Corporation, a Fermilab Industrial Affiliate.

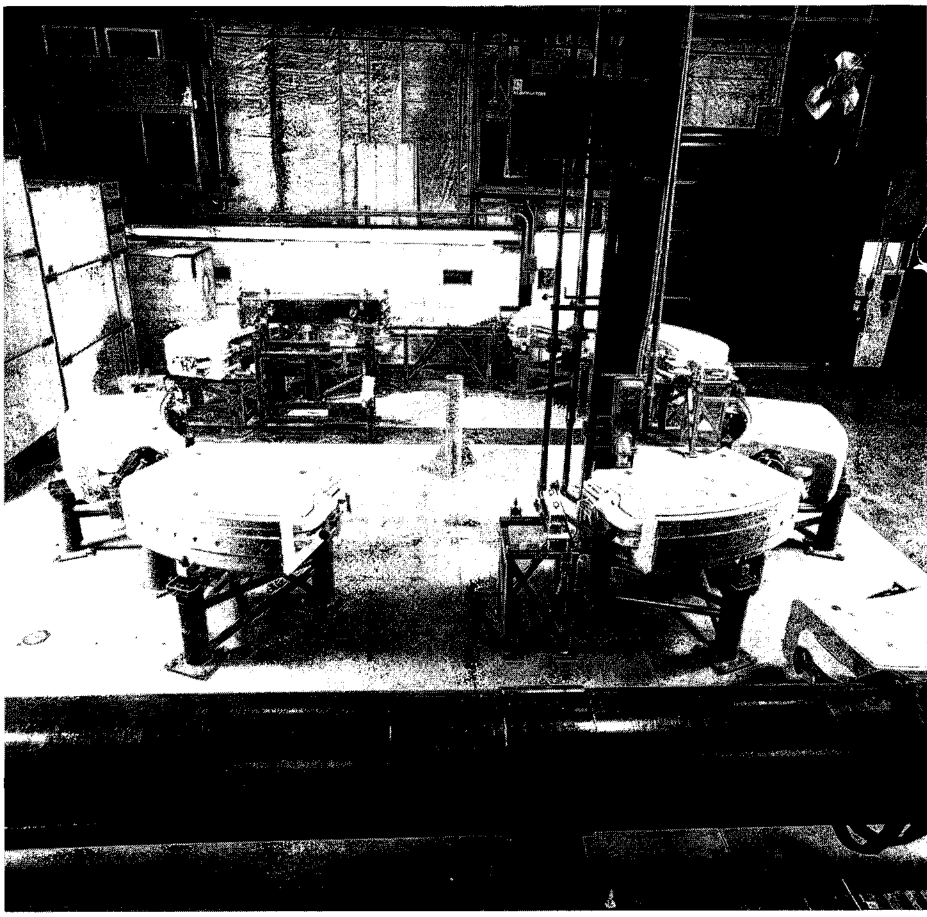
After completion of the Loma Linda design last year, construction of the accelerator has bounded ahead, and by early summer the modules of the accelerator were coming together. After testing, the machine will be taken apart for shipment to Loma Linda.

Meanwhile the PTCOG group has helped to develop innovative devices such as a patient treatment gantry, and has stimulated interest at other medical centres.

Advanced Computer Project

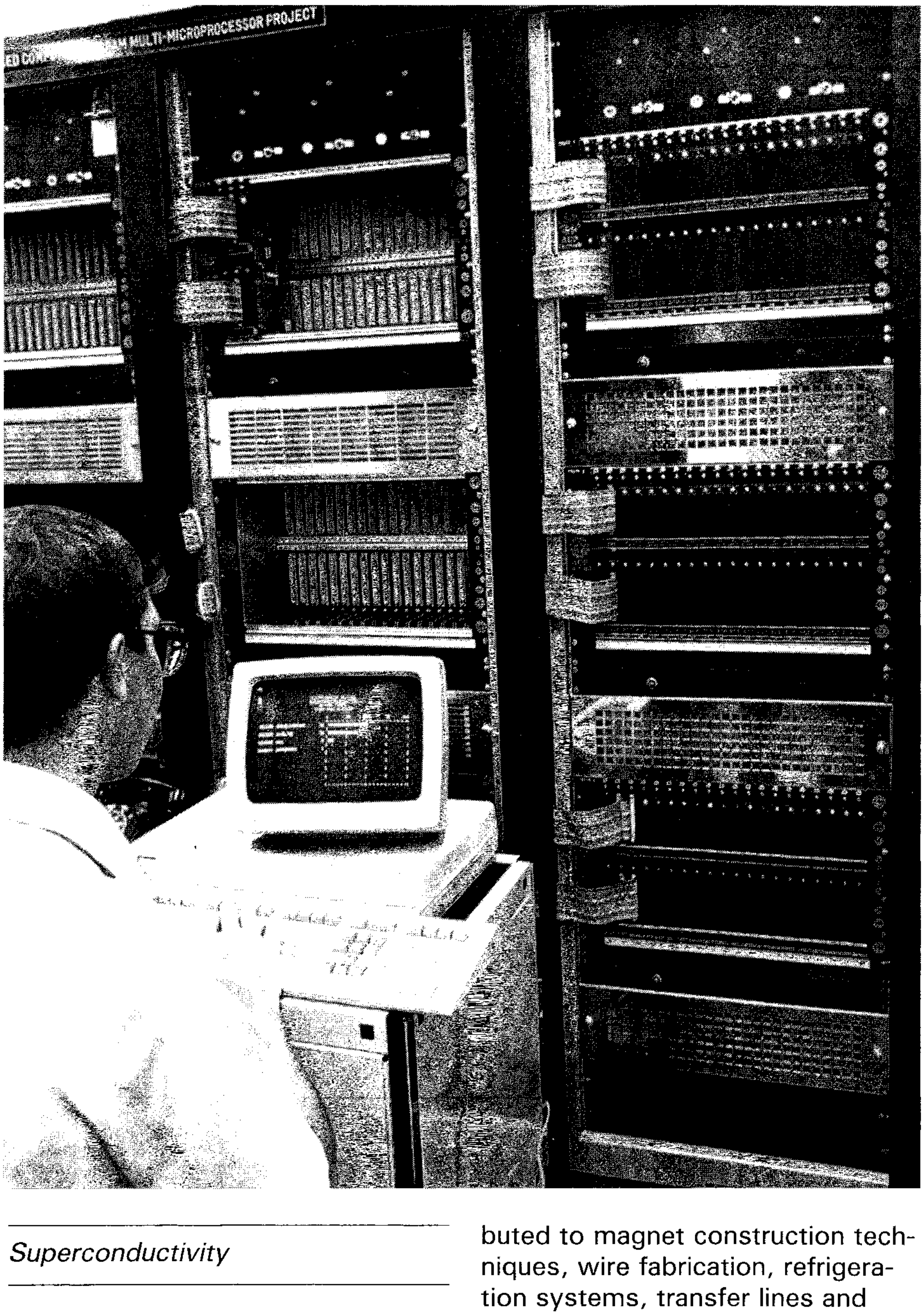
Fermilab's Advanced Computer Project (ACP) involved the construction of a loosely parallel supercomputer using commercially available 32-bit microprocessor chips. A system now running with 100 microprocessors analyses the output from high energy particle collisions at about the same speed as the Fermilab Central Computer Facility. With huge amounts of data coming from a full programme of fixed-target and colliding beam experiments, this has been a welcome addition to Fermilab's number crunching power. Currently local electronics firm Omnibyte (also an Industrial Affiliate) is supplying the ACP circuit boards.

In addition to its inexpensive hardware, the ACP also has very flexible software, which has led to applications outside particle physics. Meanwhile the ACP group is now working on an even more sophisticated version to handle more general problems such as those in quark field theory.



Elements coming together at Fermilab for the proton therapy machine for the Loma Linda University Medical Centre, California. In the foreground is part of one of the 17-metre prototype superconducting magnets being tested at Fermilab for the proposed US Superconducting Supercollider, SSC.

High energy physics has a voracious appetite for computing. Fermilab's Advanced Computer Program produced its own multi-microprocessor solutions.



Superconductivity

The construction of Fermilab's Tevatron accelerator, by far the largest single working application of superconductivity in the world, helped to transform superconductivity from a laboratory curiosity to a commercially and industrially viable activity.

The work at Fermilab contributed to magnet construction techniques, wire fabrication, refrigeration systems, transfer lines and storage systems, and cryogenic controls. A partial list of some of the companies that have used this cryogenic technology includes Airco, Brown- Boveri, CTI/Helix/Koch, Convair-General Dynamics, General Electric, Insulator Seal Company, Intermagnetics General, Johnson and Johnson, Meyer Tool, Mycom, New England Electric Teledyne-Wah Chang, and Western Pneumatic.

The history of Medical Resonance Imaging (MRI) is an interesting case study. Before the technology for the Tevatron developed in the 1970s there was limited superconducting wire available on an industrial scale, and construction of the new accelerator played a key role in boosting industrial production, paving the way for the recent demand for wire from medical imaging applications. There are now about 1000 MRI devices in operation with a US market in the billion dollar range.

The push from the high energy physics probably meant that these devices came onto the market two years earlier than they would have otherwise. If each device examines 1000 patients per year, this means that an additional two million people have benefited from MRI.

Technology transfer mechanisms

The Fermilab Industrial Affiliates programme continues to be one of Fermilab's most effective tools in this field. Over the years the roster of members has become better suited to Laboratory technology, leading to better contacts.

The past year has also seen important developments in the marketing of Fermilab technology. Recent US legislation aims to stimulate technology transfer by vesting patent ownership in the national Laboratories. To exploit this increased marketing capability called for the appointment of a licensing officer, and the introduction of a system of royalty sharing.

The first licence has been granted to Vern Kiebler and Associates, a nearby electronics firm, for a computer-controlled high voltage system.

A new programme of industrial exchanges sponsored by the US Department of Energy encourages extended industrial visits. Last year several companies sent their engineers to Fermilab for stays of many months.

Fermilab also operates a Technology Information Transfer Center with the State of Illinois, providing a good opportunity to forge new links with industries in the important Chicago area.

As well as these formal mechanisms, technology transfer comes about through the natural ebb and flow of scientific talks and publication, people from high energy physics migrating to other fields, and the challenge to industrial suppliers of meeting technological problems on the cutting edge. This is stimulated by Fermilab's open atmosphere, by the competitive character of high energy physics, and last but by no means least, by personal excellence.

DESY
Major projects

Excellent examples of the deep relation between science and industrial technology can be found at the German research centre DESY in Hamburg, where several big projects have been carried out in close contact or collaboration with industry.

High power klystrons...

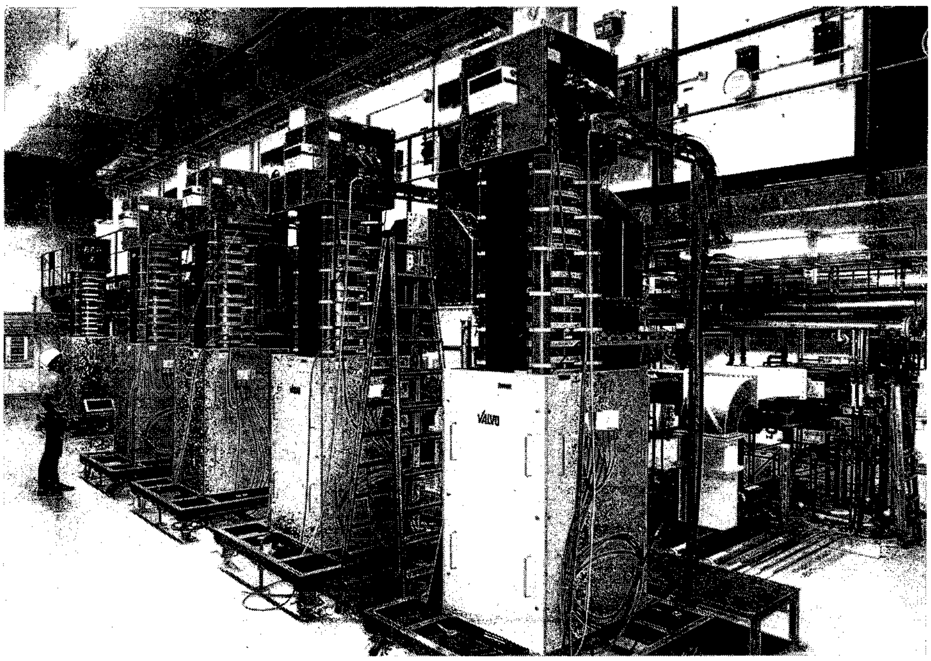
High power klystron valves were developed as transmitters for the resonating cavities needed to accelerate electrons and to keep them for many hours in storage rings.

The history of klystron fabrication in Hamburg started very early. Bruno Touschek, the talented physicist who first proposed the construction of electron-positron storage rings in 1960, had worked in Hamburg during the War for the 'Studiengesellschaft für Elektronengeräte', a company affiliated to the Dutch Philips firm, developing 'drift tubes', ancestors of today's klystron tubes. Many years later, the same Hamburg company, now Philips-Valvo, is still very active in the field, making klystrons for many applications, including pulsed units for linear accelerators and those for continuous operation at electron-positron storage rings.

In 1977 Valvo started to develop the YK 1300 klystron, the first of a very successful series of high power devices. A close and long lasting collaboration with SLAC, the Stanford Linear Accelerator Center in the US, provided the necessary theoretical background. The first tube had an output power of 600 kW and a frequency of 500 MHz. The improved YK 1301 had better efficiency (65%) and gave 800 kW. More than 40 klystrons were supplied for the PETRA storage ring at DESY.

For the TRISTAN storage ring at the Japanese KEK Laboratory, 18 specially made units (YK 1302 and 1303) had increased power output (1000/1100 kW). Big klystrons were also provided to other electron Laboratories.

A second type of continuous wave klystron was designed for bunch length adjustments in storage rings according to specifications prepared by DESY. This was the YK 1250, working at 1000 MHz and with 350 kW output. Following the YK 1300-line developed for PETRA, the YK 1350 horizontal klystrons with 1.1 MW output power were developed for the LEP electron-positron ring at CERN. A



The 800 kW Valvo YK 1301 klystrons used for HERA were developed from Valvo's first big klystrons used in the PETRA ring at DESY.

total of nine have been delivered to CERN, a similar number coming from Thomson.

The pulsed klystrons used in linear accelerators and for radar equipment have quite different specifications and their fabrication in Hamburg started even earlier. The latest and most sophisticated type was supplied to CERN for the LEP injection system of LEP, providing 100 pulses of 4.5 microseconds per second at 35 MW and 3 GHz. These units were also supplied by Thomson.

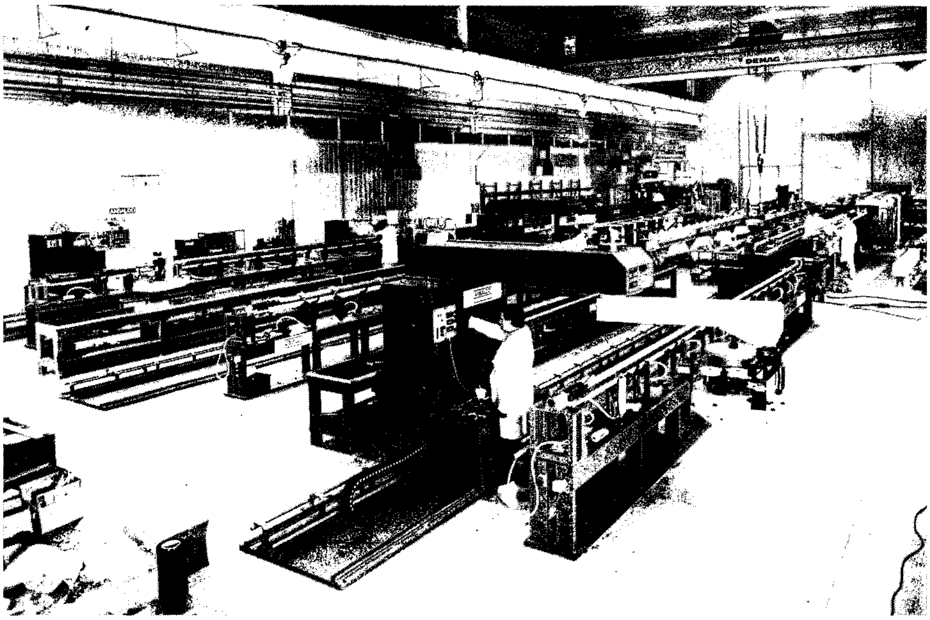
This work has had considerable impact on the development of klystrons for other applications.

... Superconductivity...

Superconductivity has been for many years an important part of the DESY research and development programme. In preparation for the HERA electron-proton collider, many superconducting dipole magnets were made at DESY. The result, the HERA-type hybrid magnet, with the coil held in position by metal clamps and the iron yoke inside the cryostat, offers considerable advantages over older designs and has been adopted for most ongoing superconducting accelerator projects.

The superconducting quadrupoles for the HERA proton ring were developed at Saclay using the HERA hybrid principle.

Half of the 420 nine-metre superconducting HERA dipoles are being manufactured by an Italian consortium (Ansaldo, LMI and Zanon) as an Italian contribution to HERA, and the other half at Brown Boveri Co. (BBC) Mannheim. The quadrupoles are being made by Alsthom of Belfort as a French contribution to HERA, and by Noell of Wurzburg in Germany.



Assembly unit for HERA superconducting dipoles at Ansaldo's Genoa factory.

The superconducting cable used for these magnets is an excellent example of research-industry partnership. Using the technique pioneered at the UK Rutherford Laboratory, HERA cable is being produced by BBC (Switzerland), LMI (Italy) and Vacuumschmelze (Germany). Cable for test coils with similar properties was previously provided by Airco and IGC in the US and by Furukawa (Japan). The cable (2mm x 10mm) supplied for the first prototype magnets a few years ago allowed for currents of about 6000 amps at a temperature of 4.6 K and with 5 teslas fields. Under the same conditions, cable with similar dimensions now reaches over 9000 amps.

Special superconducting correction coils are being wound directly on the vacuum pipe of the HERA proton ring. This pipe is cooled with liquid helium and also acts as a cryopump for the beam region. The correction coils have been developed in collaboration with the Dutch NIKHEF Laboratories and are being made by Holec in the Netherlands (see page 42).

A very active group at DESY is working on the development of superconducting cavities for particle acceleration. In close collaboration with Dornier, Interatom and NTG, the cavities are being made according to DESY specifications and then tested in a special rig at the PETRA storage ring. 1987 tests were so successful that eight cavities (of eight cells each) were ordered to boost the energy of HERA's electron ring above 30 GeV.

DESY's contributions have helped industry to be able to produce superconducting devices to the high standards required by research projects.

Large superconducting cryogenics require lots of liquid helium. In collaboration with several companies under the leadership of Sulzer, DESY built the biggest refrigeration plant in Europe. Sulzer has also taken over responsibility for running this plant during its initial years. To provide cold helium for the HERA proton ring magnets, for the electron ring cavities, for the two HERA experiments and for a big magnet testing facility, switching between the different users and between the three refrigeration units (only two of them are required to run HERA) a valve box built by the Linde Company is used.

...Synchrotron radiation...

Electron accelerators for high energy physics can still provide very useful beams of synchrotron radiation – even compared to the dedicated machines. At DESY the DORIS storage ring provides synchrotron radiation to more than 30 well-equipped measurement stations, and for 1991 seven more beams are being prepared.

New ideas to use the larger PETRA ring as an X-ray source – using long undulator magnets in the straight sections – are emerging. Hundreds of applications – many of direct practical and industrial interest – are foreseen, examples being accurate investigation of catalytic processes, chemical analysis with X-ray-induced fluorescence, medical diagnosis with angiography, surface and semiconductor physics, structure of crystals and polymers.

...Superlative mirrors for X-rays...

Focusing synchrotron radiation X-rays demands large totally reflecting mirrors with extremely accurate surfaces. At the HASYLAB synchrotron radiation facility at the DORIS storage ring, four such mirrors with typical dimensions 100 cm x 13 cm, are from a new set made by the Zeiss Company of Oberkochen to extremely demanding specifications.

With the heat load requiring the use of metals, these mirrors are made of aluminium-magnesium coated with 50 microns of electronless nickel ('Kanigen') and 300 angstroms of gold. This surface has to be smooth to within 10 angstroms. X-rays are totally reflected at less than 0.4 degrees to the surface and a toroidal shape is essential for accurate focusing, the two radii of this surface being 158.5 mm and 3.12 km!

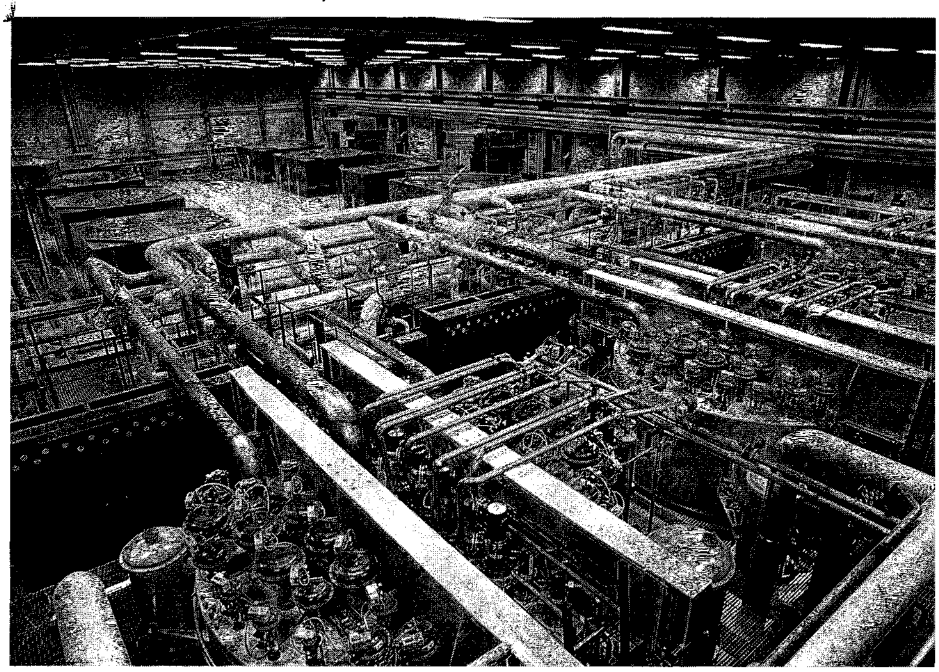
Though such mirrors are not themselves useful in other applications, the completely new set of measurement tools for their fabrication can be applied in many other fields.

...X-ray lithography...

The 7.4 GeV DESY electron synchrotron was the scene of the first IBM (Yorktown Heights, USA) tests of X-ray lithography in 1976. This work was later continued by the Fraunhofer Gesellschaft at DORIS and was one of the reasons which led to the construction of the dedicated storage ring BESSY in Berlin, where this work continues in collaboration with industry. In the near future this technique should lead to unprecedentedly compact integrated circuits (see page 24).

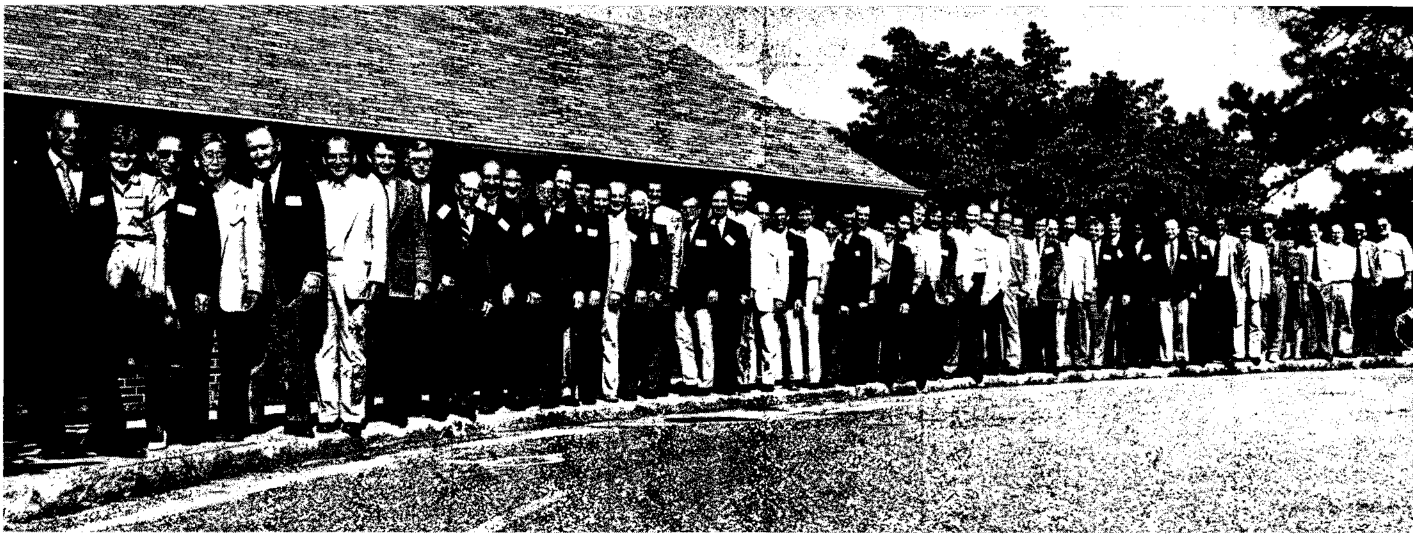
...and elsewhere

A new type of collaboration involving the Italian groups working on HERA gives Italian firm Laben full responsibility for developing and building complete electronic systems (like read-out of drift chambers). Electronics is certainly one of the major interaction points between industry and research, and has led to the emergence of enterprises producing specialized circuit modules. An example at Hamburg is Struck, which after initial contracts with DESY in 1974 now supplies Laboratories all around the world.



Special industrial expertise was needed for the largest refrigeration plant in Europe to handle cryogenics for the HERA electron-proton collider at the DESY Laboratory in Hamburg.

Industry and laboratory participants at a Brookhaven workshop to explore industry's interest in acquiring the technology to produce commercial synchrotrons for X-ray lithography.



BROOKHAVEN Superconducting X-ray lithography source

The computer industry's push for increased capacity and speed for the next generation of machines demands smaller features on the computer chips themselves. With today's feature sizes (1 micron) approaching the wavelength of visible light, the transfer of features to chips by conventional lithography becomes very difficult. Sub-micron features therefore require new techniques employing X-rays, electrons or ions.

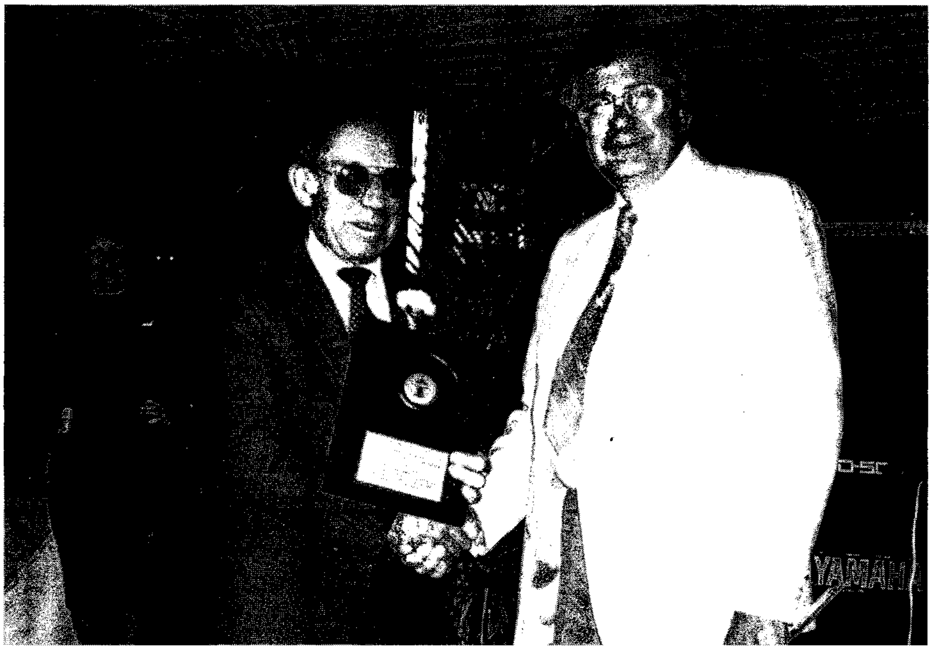
X-rays have many advantages for volume production, and synchrotron radiation sources have the necessary throughput for a volume market. US Department of Energy (DOE) Laboratories know how to build electron storage rings to produce synchrotron radiation.

Brookhaven's National Synchrotron Light Source (NSLS), stimulated by recent successes in developing chips with sub-micron features using the IBM U6 beamline at the NSLS (October issue, page 28) has embarked upon an extensive programme to design and build a compact synchrotron storage ring dedicated to X-ray lithography. Relatively advanced West German and Japanese industry/government collaborations in this area provide an additional incentive for a US programme.

This project had its roots in a series of five workshops held at Brookhaven during 1986-1987. Organized by Brookhaven, (Mark Barton, Ben Craft, Jules Godel, Michael Knotek and Gwyn Williams), the University of Wisconsin and industry, the workshops attracted participants from the semiconductor industry, national laboratories, government agencies and universities. The result was the establishment of a $207 million programme supported by the US Department of Defense. Over seven years, it will combine the skills of national laboratories, universities and industry to develop the full X-ray lithography technology including compact synchrotron sources and techniques for large-scale manufacture of chips with sub-micron features.

The project at the NSLS ($21 million over a planned five year period) covers a prototype superconducting X-ray lithography source (SXLS) and technology transfer. Headed by Richard Heese and Gaetano Vignola, the first phase will be to build within the next 18 months an X-ray lithography source (XLS) prototype using warm magnets, existing hardware and the injection system currently used for the NSLS X-ray and VUV storage rings. Located within the X-ray ring, this prototype will study injection of low energy electrons and electron beam dynamics in a small machine. The second phase (1989-1992) will cover development and construction of a superconducting magnet X-ray source (SXLS) compatible with commercial-scale X-ray lithography. After commissioning at Brookhaven, the SXLS will be sited in an X-ray lithography pilot plant.

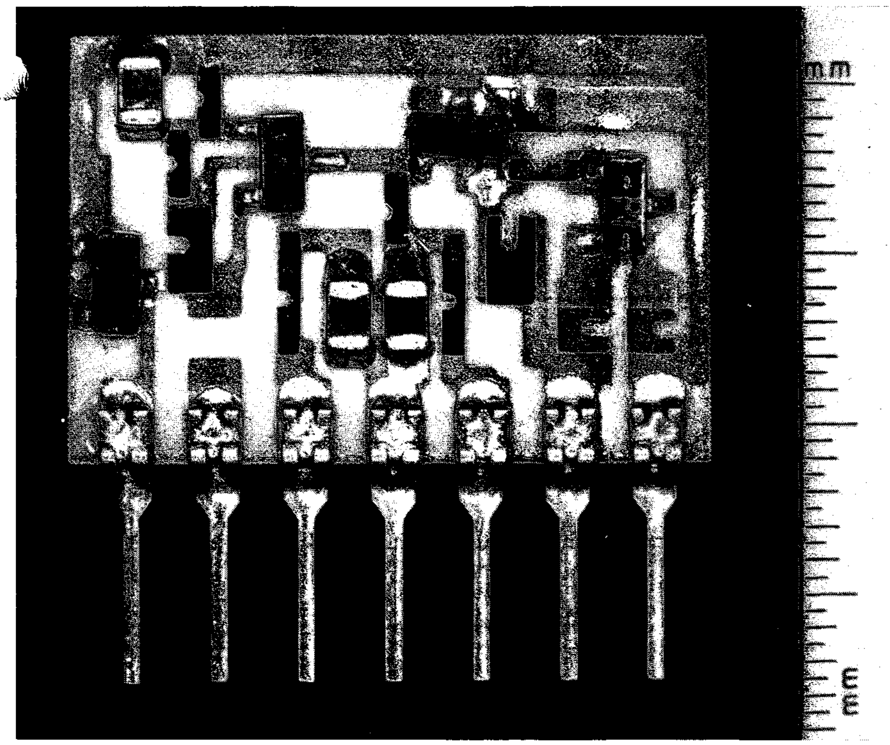
An additional challenge in both phases will be the smooth transfer of state-of-the-art technology to industry. Throughout the design, building and commissioning of the two prototype XLS units, equipment manufacturers will participate through contract work as well as having their own people at NSLS.



Technology transfer award

Brookhaven's William Marcuse (left) has been named 1988 'Technology Transfer Representative of the Year' by the US Federal Laboratory Consortium, a network of several hundred technology transfer representatives established in 1974 to promote the transfer of federally-owned technology to state and local governments and to industry. Brookhaven people have won five FLC Special Awards for Excellence in Technology Transfer since the awards were established in 1985.

Marcuse, cited for his role in Brookhaven's initiative to transfer X-ray lithography and synchrotron radiation technology for the manufacture of high-speed computer chips, was singled out as contributing most this year to technology transfer. As head of Brookhaven's Office of Research and Technology Applications, he helped the NSLS organize the workshops which led to the SXLS project.



Postage-stamp size grounded base preamplifier designed at Brookhaven for detectors with less than 10 pF capacitance, requiring fast response and short pulse shaping.

Hybrid preamplifiers

The growing complexity of multi-element position sensitive detectors such as silicon microstrips encouraged Brookhaven's Instrumentation Division to examine new geometrical concepts for small charge sensitive preamplifiers.

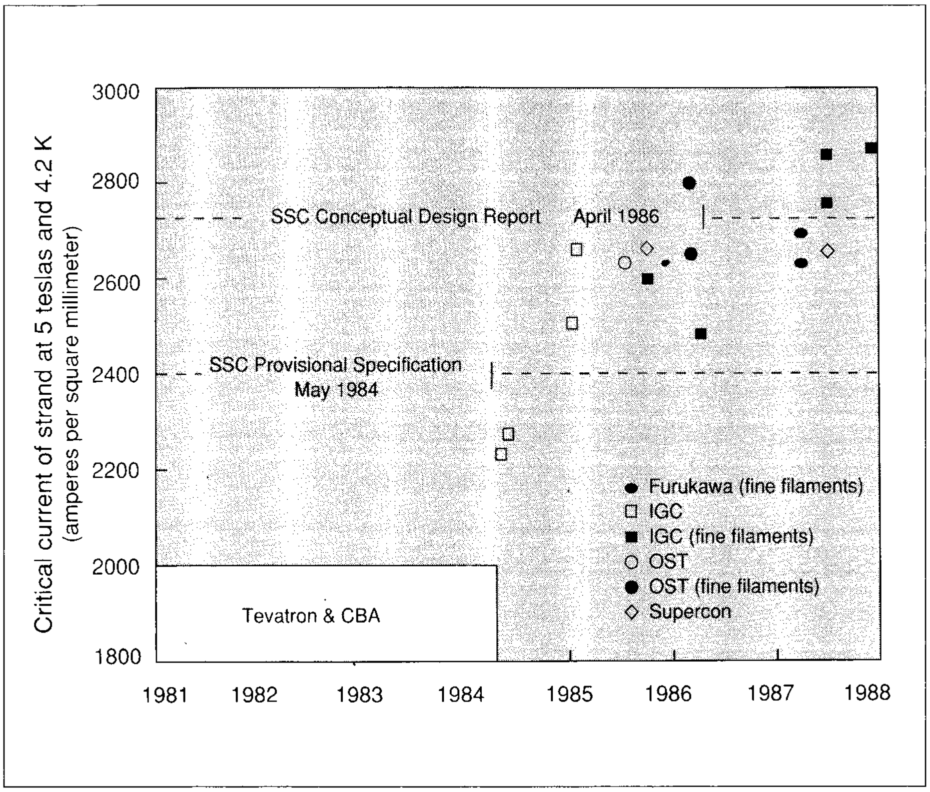
In the initial design, a grounded base preamplifier, chosen for design simplicity and constructed using surface mount technology, was a complete success. This pre-amp, the IO-354, is approximately 1 cm square and only 0.175 cm thick, with a rise time of 2 nanoseconds and a power dissipation of only 18 milliwatts. These devices were readily accepted by the high energy physics community and over 1000 were constructed. Later designs used alumina substrates and thick film technology.

Additional design studies led to field effect transistor input charge sensitive preamps with several different charge capacities and dynamic ranges. Other improvements included a triple hybrid preamp on a single substrate and preamps capable of operation in liquid argon. The NA34 experiment at CERN used 500 of the liquid argon compatible units, and over 1000 of some of the other varieties.

Thousands of these devices now have been manufactured by Rel-Labs and Philips CKT Assembly. Dimitri Stephani, an engineer in Brookhaven's Instrumentation Division, has received three national awards for this work.

Improvement in current-carrying capacity of commercially produced superconducting wire as a result of research and development for the proposed US Superconducting Supercollider, SSC. Wire for magnets of the Fermilab Tevatron and the ill-fated Brookhaven Colliding Beam Accelerator (CBA) project carried 1800 to 2000 A per square millimetre under test conditions. Industrial suppliers are now producing wire approaching 3000 A/mm2.

(Photo Berkeley)



SUPERCOLLIDER Technological partnership

1988 is the fifth year of detailed research and development for the proposed US Superconducting Super Collider (SSC). Mass-production of the 10,000 superconducting magnets and many other components for the 84 kilometre ring to handle 20 TeV (20,000 GeV) colliding proton beams would call for industrial manufacturing and quality control. Design of conventional facilities and all preparatory work for construction involves a collaborative technological venture with architectural and engineering firms.

Superconducting magnets are the technological mainstay of the SSC. Industrial collaboration in this area is a two-pronged effort, involving the development of particular magnet design concepts and components as well as the implementation of a comprehensive Magnet Industrialization Programme.

First priority has been to maximize the performance of industrially produced niobium-titanium composite superconducting wires. Organized with the help of experts at the University of Wisconsin and other Laboratories, superconductor development has involved Intermagnetics General Corporation, Oxford Superconducting Technology, Supercon, and Teledyne Wah-Chang. The development programme has resulted in a more homogeneous basic alloy and more effective mechanical working and heat treatment cycles in the wire preparation, the payoff being nearly 50% improvement in the current-carrying capacity of the superconductor over the last four years. Improvements in the tools and methods used to form the wires into cables have been equally important, an example being a state-of-the-art cabling machine developed to SSC specifications by Belgian firm Dour Metal.

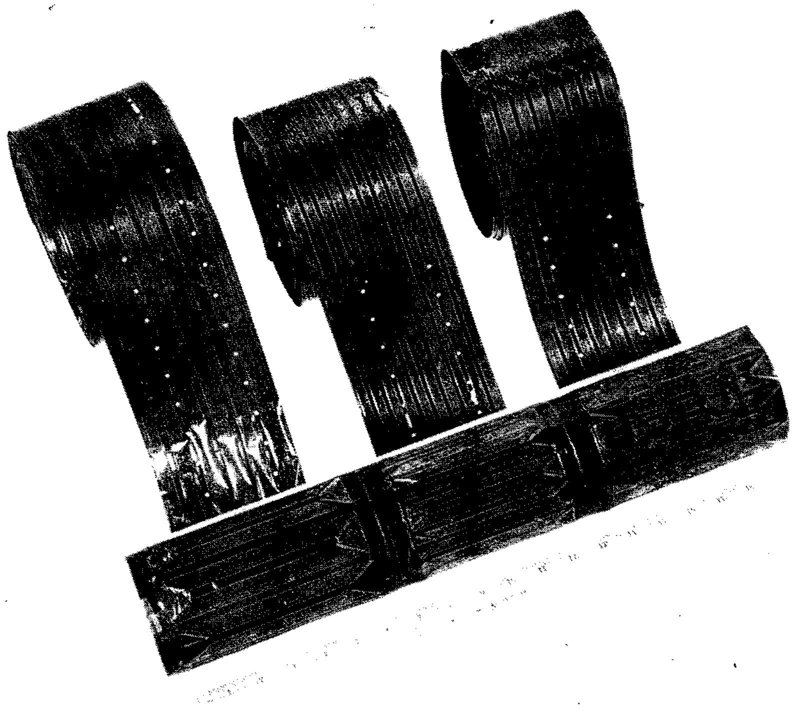
Superconducting magnets for accelerators normally require field correction coils mounted on the beam tube, and this has stimulated a highly productive collaboration. Key player here is the Multiwire Division of Kolmorgan Corporation. Chiefly under the guidance of Brookhaven, Multiwire has adopted a method akin to printed circuit fabrication to 'write' a pattern of superconducting wire on a flexible substrate which can be attached to the beam tube. Several other industrial subcontractors are involved in this development.

Another fruitful area is the SSC magnet cryostat and its complex support system. Components being developed under Fermilab's guidance include a novel precision stainless steel 'skin' hugging the magnet cold mass (in collaboration with Tartan Industries), a cold mass suspension system incorporating reinforced composites meeting demanding structural and thermal specifications (Structural Composites Industries), new forms of multilayer thermal insulation materials (Ishikawajima-Harima Heavy Industries of Japan), and vacuum vessel and cryostat development generally (including Babcock & Wilcox Corporation and Space Systems Division of General Dynamics). Several of these companies have had technicians at Fermilab for one or two years.

Some of this work is carried out under the aegis of the Small Business Innovation Research (SBIR) programme sponsored by the US

Laboratories involved in SSC development are working closely with an industrial firm to develop field correction coils mounted on the beam tube of the SSC dipoles. From left to right, the trim coil sheaths produce sextupole, decapole, and octupole magnetic fields.

(Photo Brookhaven)



Department of Energy (DOE) to stimulate technological innovation in the private sector and strengthen the role of small firms in areas of federally-funded R&D.

Setting the stage for full-scale collider ring magnet production is the recently launched three-phase Magnet Industrialization Programme, designed to make available to industry the knowledge and technology acquired during the past four years in the national Laboratories. Industry will then adapt this for SSC magnet manufacturing. Phase I provides potential contractors with the material and information to bid for magnet construction work. This phase was formally inaugurated late this summer with a public announcement in the US Government publication *Commerce Business Daily* , followed by an introductory Technology Orientation meeting with interested vendors held at Brookhaven. Phase II will involve tooling design and magnet pre-production, and Phase III actual magnet production.

The SSC will require the world's largest helium refrigeration system, and this cryogenics will present a significant challenge in the area of process control. It must not only provide cooling for normal operation of the collider and its experimental programme, but accommodate a variety of transient conditions. The SSC Central Design Group (CDG) has undertaken two computer simulations of the system under contract with the Air Products and Chemicals Company. In the first, refrigeration plant concepts are investigated by static process simulation while the second uses dynamic modeling to study the behaviour of the cryogenic system under time-varying conditions.

Particle detectors for the SSC are beginning to spawn another area of productive collaboration between universities, Laboratories, and industry. At present, detector R&D is concentrating on development of silicon 'pixel' devices with the associated fast readout electronics, new scintillator materials, and radiation-hardened electronics. Prototype pixel detectors are being developed by a collaborative effort involving Hughes Aircraft Company, the Space Sciences Laboratory of the University of California, and the Stanford Linear Accelerator Center. New scintillating materials are being developed by Bicron Corporation. Seven small businesses are being supported this year for detector development under the SBIR programme.

The conventional aspects of the SSC – tunnel, experimental halls, campus, site and infrastructure – are strongly geared to industrial involvement. The preliminary facility and site utility design work was carried out in 1984, under the direction of the SSC Reference Designs Study team, by the architect-engineering firm of Parsons, Brinckerhoff, Quade and Douglas. In 1985, the DOE selected RTK, a joint venture of Raymond Kaiser Engineers, Tudor Engineering Company, and Keller and Gannon-Knight, for the detailed engineering studies needed to prepare, under the guidance of the then newly established Central Design Group, a conceptual design for the conventional facilities. Phase I of this effort resulted in the (non-site-specific) conventional facilities section of the Conceptual Design Report issued in 1986 with its accompanying cost estimate. The RTK joint venture is also aiding the DOE in the evaluation of site-specific geotechnical aspects, tunneling and stabilization methods under conditions ranging from open cut to deep excavation, environmental considerations and other factors of

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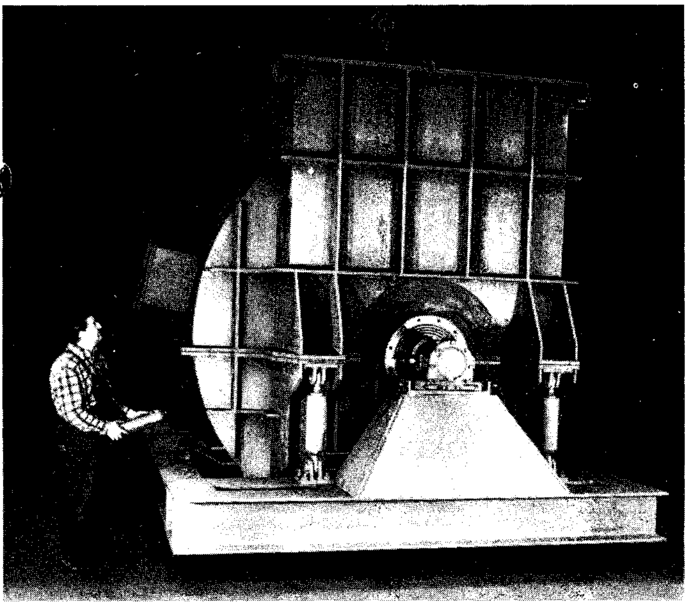

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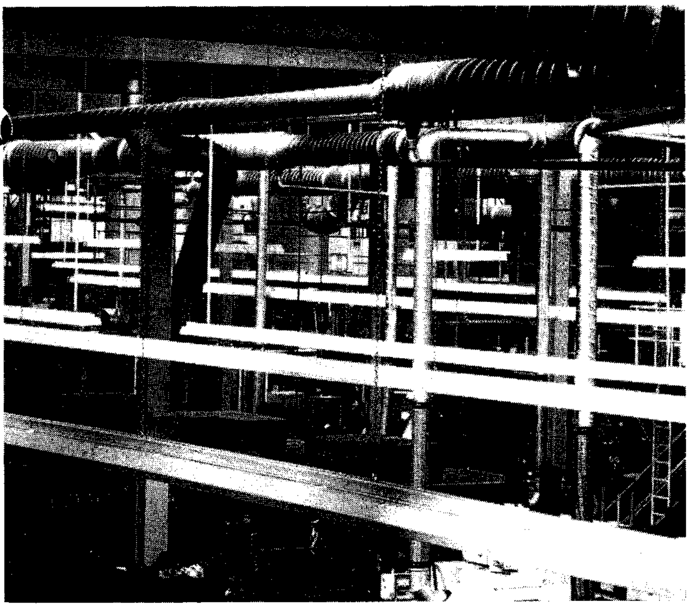

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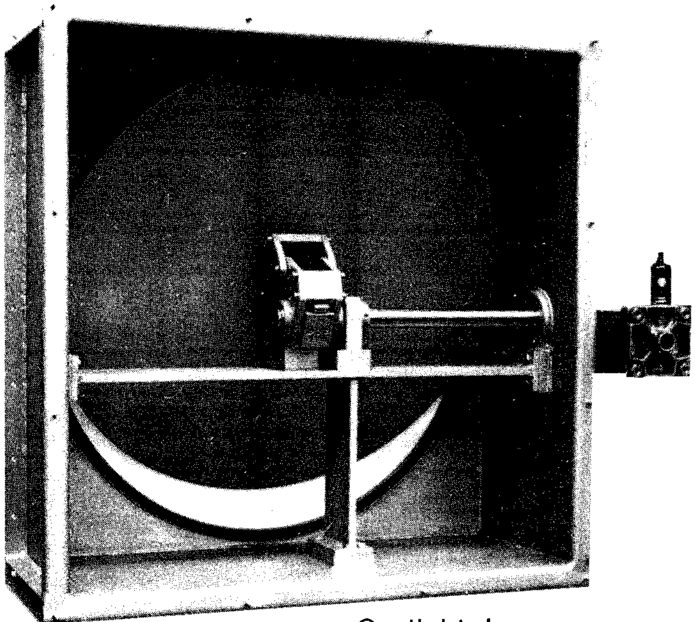

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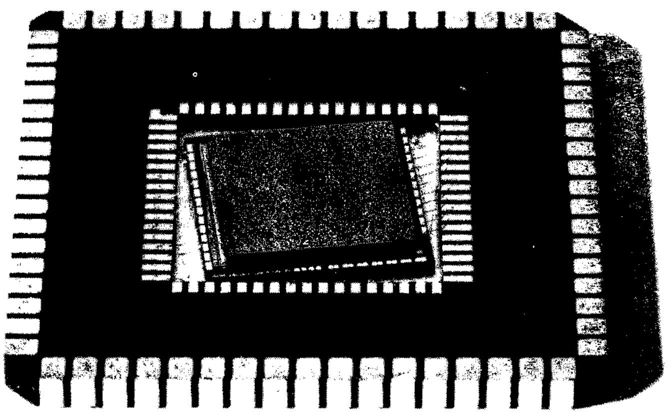
Prototype pixel device for SSC particle detection consisting of an array of 256 x 256 individual sensitive pixel elements bonded to an electronics read-out chip.

(Courtesy of Hughes Aircraft Company; Space Sciences Laboratory, University of California; and the Stanford Linear Accelerator Center.)



the final SSC site contenders. Principal sub-contractor is the Earth Technology Corporation. Selection of the final SSC architect-engineering contractor is expected after selection of a Management and Operating Contractor.

Industrial symposium

An International Industrial Symposium on the proposed US Superconducting Supercollider (SSC), to be held in New Orleans in February, will provide insights into the technologies involved in the design, construction and operation of the SSC and into potential technological spinoffs.

LOS ALAMOS High temperature superconductors – rapid measurements without contacts

The job of the Industrial Applications Office (IAO) at Los Alamos is to ensure that the Laboratory's science and technology base is used to produce significant industrial applications and to boost national security and economic competitiveness in the US private sector.

A good illustration of this IAO work is its current negotiation for the industrial licensing of a device invented by James D. Doss, a Laboratory electrical engineer. C. Wayne Cooke and Marshall Maez, also from the Los Alamos Meson Physics Facility (LAMPF) participated in the research.

The recent development of materials that superconduct at relatively high temperatures has led to considerable interest in applications in areas ranging from particle accelerators to improved infra-red sensors to extremely fast computers. Research directed at refining the characteristics of these materials as well as the development of entirely new classes of superconductors is underway in both government and private-sector research centres.

This effort produces many samples that must be measured to determine the effects of processing techniques, overwhelming the conventional instrumentation used for measurement and characterization of superconductors. Most characterization techniques require lengthy preparation procedures, such as the attachment of leads to the sample, and require several hours for a single measurement because of the time needed to vary the temperature over the appropriate range. Another difficulty arises in the testing of thin films, where the attachment of leads to measure resistivity tends to alter the film's characteristics.

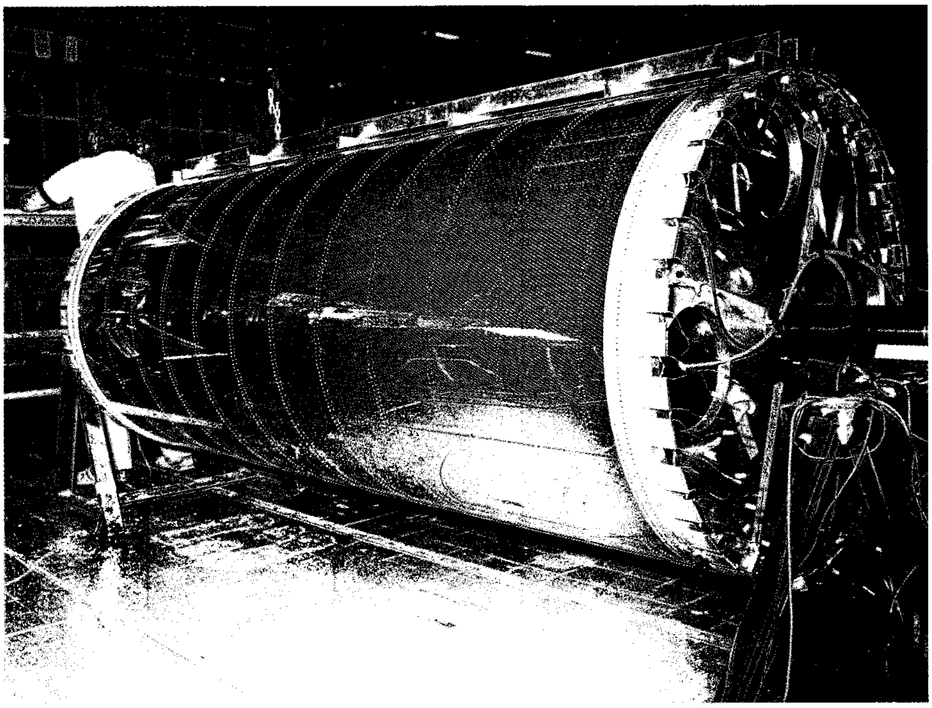
A rapid screening technique is needed to select samples meriting more time-consuming and expensive measurement. Because thin films are so important in potential electronic applications of the new high temperature superconductors, there is also a need for measurement methods that do not require the attachment of electrical contacts.

To meet both of these needs, Los Alamos National Laboratory has developed a rapid non-contact 'eddy-current' technique that relies on the induction of a radiofrequency electric current. This depends on the electrical resistance of the

specimen, which changes dramatically at the critical temperature marking the onset of superconductivity.

A pair of induction coils is able to sense the relative level of current induced and thus the relative change in sample resistance. In one configuration the change in effective inductance of the coils is used to modify the frequency of an oscillator; this shift in frequency can be measured quite accurately. At Los Alamos, this is used to screen samples prior to other more detailed measurements. Because there are no electrical contacts, the technique has proven to be ideal for the characterization of thin superconducting films.

In industrial collaboration at the French Saclay Laboratory, the firm Bollore has developed flexible printed circuitry destined for an experiment at CERN's LEAR low energy antiproton ring.



SACLAY Working together

Saclay's Department of Elementary Particle Physics is busy contributing to experiments and accelerator projects at major world Laboratories – CERN, DESY (Hamburg), Serpukhov (USSR) and Fermilab (US). This work calls for close support from Saclay's own Technical Services, which in turn look to industry, and three types of collaboration have emerged.

Firstly, joint projects allow companies to follow technology further, exploiting skills and know-how for a specific problem related to a particular element of a detector after the Laboratory has outlined the requirement and the tooling needed to adapt or upgrade existing industrial plant.

Some examples – the Bollore company has developed flexible printed circuits for proportional chambers destined for work at CERN's LEAR low energy antiproton ring. This called for gold circuitry on a flexible base with fraction of a millimetre spacing. Gantois developed a technique to warp together optical scintillating fibres for the UA2 experiment at CERN's proton-antiproton collider (June 1987 issue, page 9), while other companies have constructed composite materials destined for the transition radiator detector for the D0 experiment at the Fermilab collider (September issue, page 19), and for the Time Projection Chamber for the Delphi study at CERN's LEP electron-positron collider.

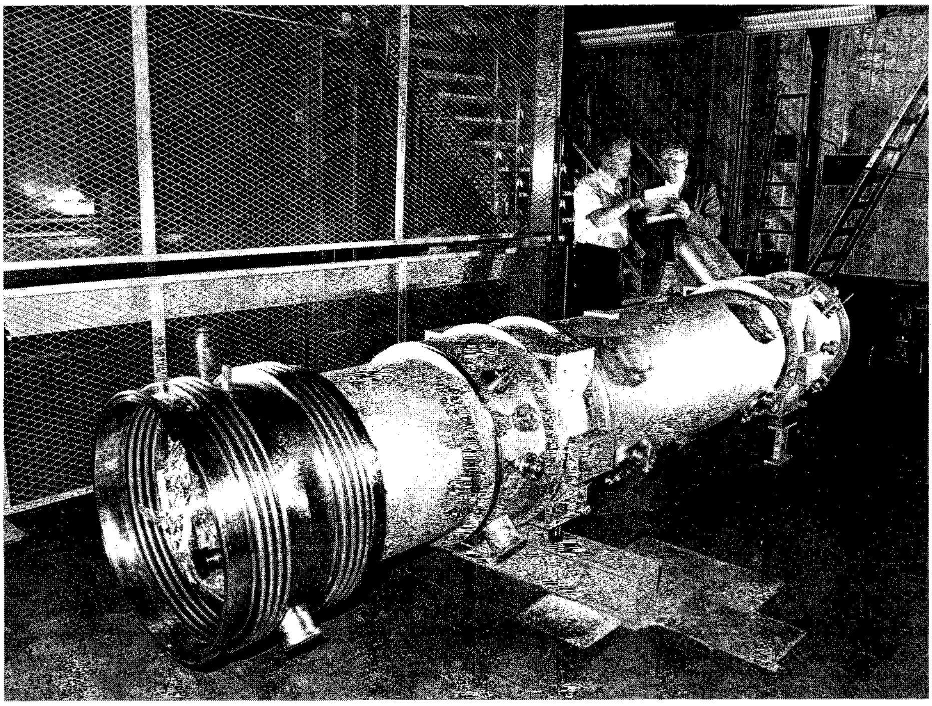
In the second type of approach, a transfer of new technology leads to industrialization. The Laboratory first designs and develops one or more prototypes, and looks into the tooling required for subsequent production. This technology and tooling is then passed on to the contractor, with subsequent acceptance tests at the Laboratory. Examples are superconductors for the Tore Supra Laboratory (Alsthom), patented optical fibres for UA2 (Optectron), and superconducting quadrupoles for the new HERA proton ring at DESY (Alsthom, and West German suppliers).

A third type of collaboration is the 'industrial research contract', under which a young researcher works closely with an industrial firm, while paid partly by the firm and partly by the Laboratory. In this way the firm benefits from the Laboratory's expertise while evaluating a potential future employee. In some cases, the Laboratory entirely funds the research while keeping strong links with industry, pushing studies further before technology transfer takes place.

Niobium cavities

With the technology of the niobium superconducting cavities required for reliable, inexpensive accelerators now well developed, Saclay's Department of Nuclear Physics

Superconducting quadrupoles for the HERA proton ring at the German DESY Laboratory in Hamburg were developed at Saclay for series production in France (Alsthom) and Germany (KWU, Noell).



took the decision to optimize production in partnership with industrial firm Lemer of Nantes, with its tradition of work in the nuclear industry and considerable experience in working with exotic metals.

Schooled by CERN's specialists, the Saclay team adapted cavity design to the 1500MHz level and developed the couplers needed for the linear accelerators foreseen for high intensity electron-positron linear colliders. The contract signed with Lemer extends from initial familiarization with the new technology through to preseries production, with Saclay responsible for the definition of technical procedures where purity and reproducibility are of prime concern.

The company is also developing a forming technique to ensure rapid and effective production, and will undertake the necessary chemical preparation and electron welding, while Saclay will look after less commercially attractive and/or tricky aspects such as final preparation of the radiofrequency surface and cryogenic testing.

Hopefully this innovative collaboration between a research laboratory and industry will go on to achieve both the quality and return on investment needed to make it a mutual success.

RUTHERFORD APPLETON
Close-up tracking

Technological advances applicable in other areas of science will result from the collaboration between Rutherford Appleton Laboratory and Brunel University, working very closely with industry, to develop a novel type of vertex detector to pick up the particles emerging from high energy electron-positron collisions.

The big SLD detector being prepared for the new SLC Stanford Linear Collider will have an innermost layer of close-in tracking detectors of about 5 micron precision to unravel the complex parentage of particles emerging from the decays of Z bosons produced in the SLC electron-positron annihilations.

Many of the decay products of the Z bosons contain heavy quarks, and these decay in turn (with lifetimes around 10^{-13} seconds) to lighter states. Quark decay sequences such as bottom to charm to strange can result in complex tree-like topologies of parent particles, daughters, grand-daughters, etc.

The basic elements of the SLD vertex detector will be two-dimensional CCDs (charge-coupled devices) each about 1cm square and containing 250,000 pixels. Work in a CERN test beam from 1980 first showed that such detectors can track with 5 micron precision, and was followed up in 1985 with an SPS experiment in which CCDs provided very clean reconstruction of even the shortest-lived charm particles.

Compared with other colliding beam machines, SLC has a very narrow beam-pipe, allowing the first layer of detectors to get very close to the interaction point. However the scope of the SLD detector brings many complications.

To surround the interaction point requires many detectors. The SLD vertex detector will use 250 CCDs arranged in 4 barrels, each made up of about 10 'ladders' – 2-sided multilayer ceramic boards with 4 CCDs mounted each side, and overlaps to give continuous coverage lengthwise.

With access limited to annual shutdowns, extremely high reliability is essential.

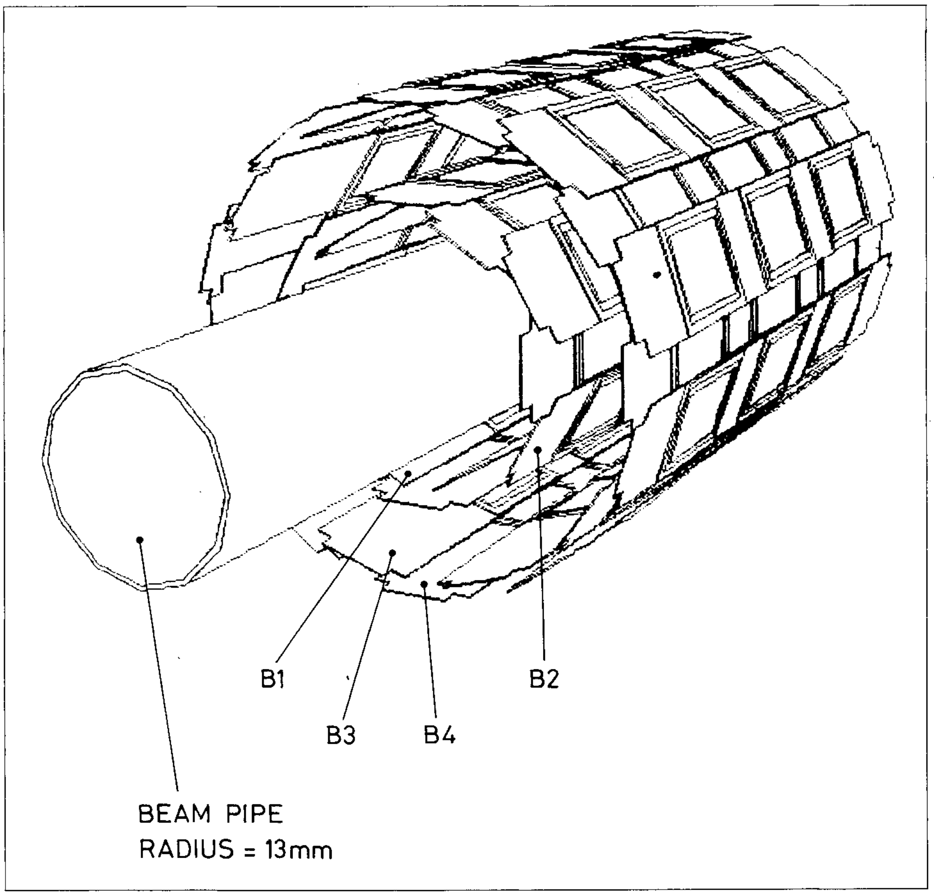
To reduce multiple scattering requires a minimum of material in the detector, while the structure must still be highly rigid.

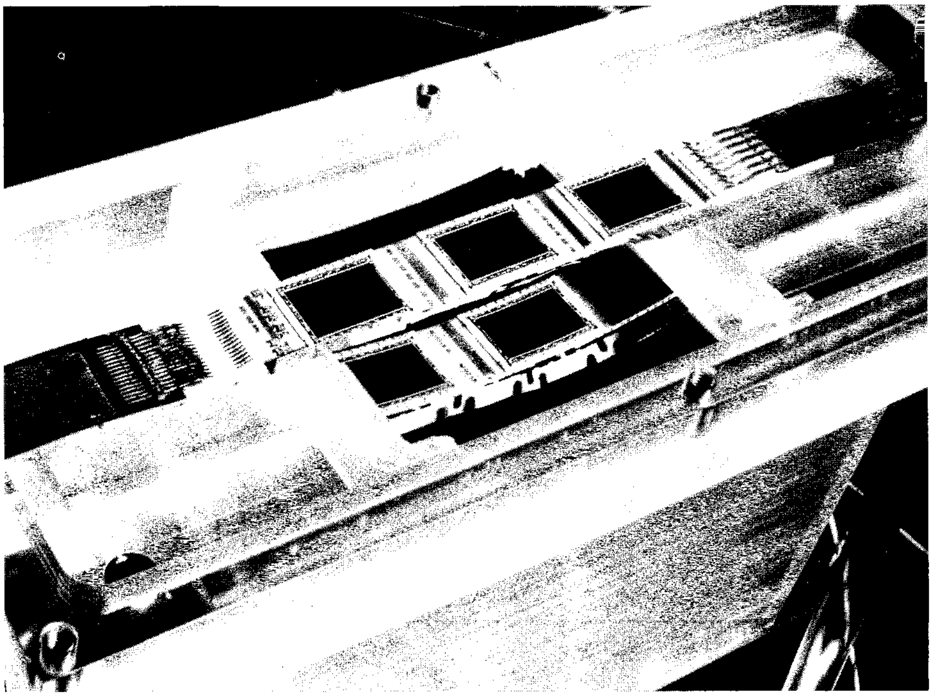
Since the SLD (including the vertex detector) was approved in 1984, the RAL/Brunel collaboration has been working closely with industry to find solutions to all these problems. There are now several companies (including English Electric Valves – EEV – and Thomson) producing CCD devices suitable for specialized scientific applications. Industrial and Laboratory experience suggests that after a suitable burn-in procedure, CCD failure rates of 0.1% or less per year can be achieved, entirely adequate for SLD.

CCDs are conventionally fabricated on silicon wafers about half a millimetre thick, and are mounted in standard dual-in-line chip carriers. This is too much material for a particle detector, and a completely new form of chip carrier (a ceramic window frame 1 mm wide and 0.25 mm thick) has been developed in conjunction with GEC's Hirst Research Centre in the UK. The CCDs are thinned to 0.2 mm and mounted in the chip carriers by tape-automated bonding (TAB). The packaged devices can be tested prior to mounting on the ceramic mother cards to build up the ladders. The development of these mother cards has also been carried out at Hirst Research Centre.

At the Rutherford Appleton Laboratory, the first ladder has recently been assembled and tested.

The 4-barrel arrangement of CCDs to be assembled around the beam pipe of the SLC Stanford Linear Collider for the SLD detector. This provides at least 2 hits per outgoing track over a wide angular range.

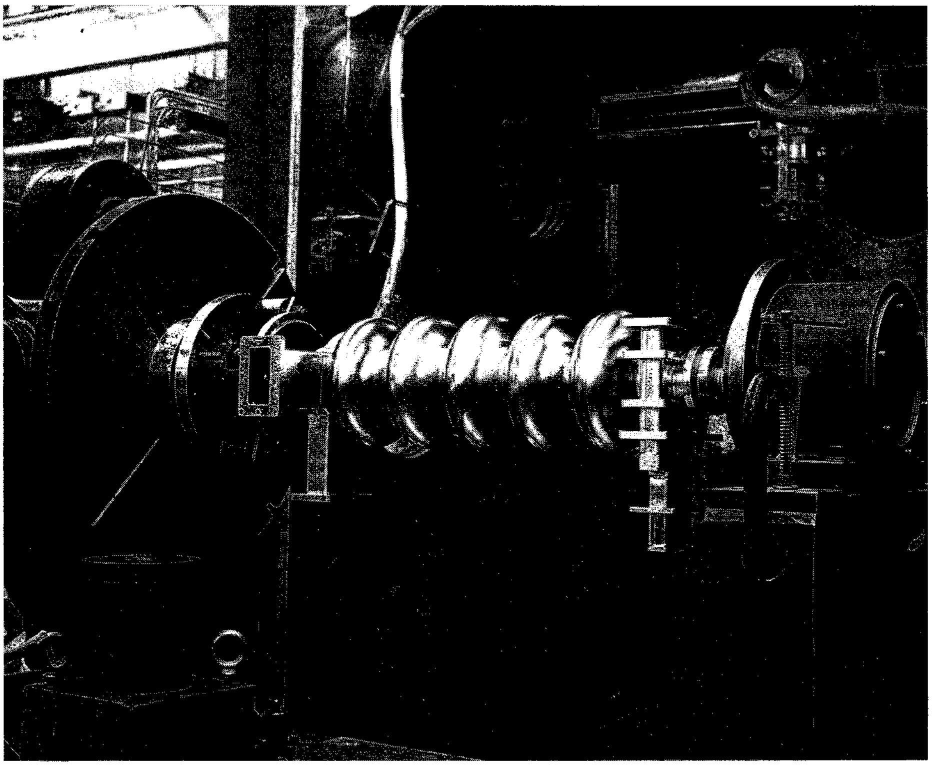




The first 2-sided lightweight 'ladder' of CCDs under test at the Rutherford Appleton Laboratory. It consists of 3 CCDs above and 2 below (seen reflected in a curved sheet of aluminized mylar). Note the micro-connectors at each end which bring in the drive signals from the right, and the analog biases (and CCD output signals) at the left. Using these new techniques, close-packed CCD mosaics could be produced for imaging large areas.

Mounted for electron beam welding is a niobium superconducting radiofrequency accelerating cavity built in the US by Babcock and Wilcox from a Cornell design for the CEBAF electron accelerator being built at Newport News, Virginia.

(Photo Babcock and Wilcox)



With intensive R&D for the ladder support system, an overall stability of 5 microns looks feasible. The most delicate area is the centre of the ladders, susceptible to significant bowing if there are any compressive loads on the ladders (e.g. due to thermal variations). For example, a length compression of 4 microns would induce a 70 micron deformation. Using fixed and sliding ends, such effects can be avoided while still achieving a precise and stable geometry.

The detector contains 70 million pixels. Using a simple pixel threshold for selecting the data would lead to 1 Mbyte of information per collision, swamping the detector's data acquisition system. A special integrated circuit, again developed in close liaison with industry, has been designed for real-time cluster selection and should reduce the data to a more modest 20 kbytes per collision event.

Close-packed arrays of CCDs in these newly developed miniature chip carriers will allow mosaics to be assembled for large area imaging This has stimulated great interest in fields, such as electrophoresis, astronomy and X-ray diffraction, where the 1cm area of typical CCDs is much too small.

The success of pixel-based detectors for such vertex microscopes has triggered a major R&D activity internationally for the development of yet more sophisticated pixel devices for particle tracking in the extreme conditions expected in proposed new big proton colliders. Such detectors will also be useful in areas, such as X-ray imaging, where demands are growing for high rate capability. Increasing circuit miniaturization will allow small pixels each incorporating a considerable amount of parallel processing capability. Instead of serial readout of all pixels as in current CCDs, hit pixels will inform the off-chip electronics of their addresses and contents. Applicable in a wide variety of disciplines including robotics and other industrially important areas, such 'smart pixel' devices point the way to the future.

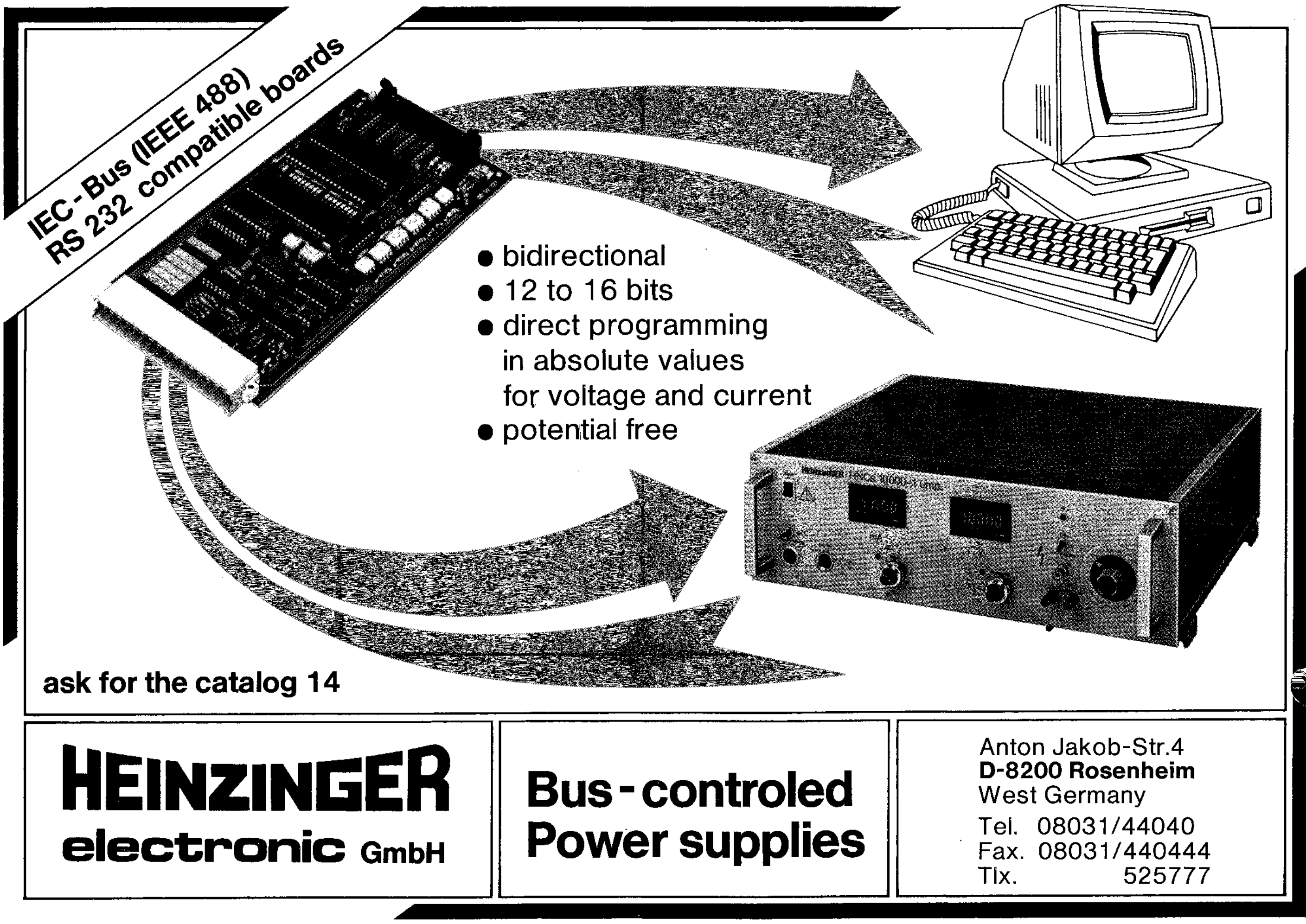
From Chris Damerell

CORNELL Radiofrequency superconductivity

Large scale use of radiofrequency superconducting cavities to accelerate particles to high energies will need to rely heavily on industrial participation for production of high quality raw material and finished accelerator structures.

The Laboratory of Nuclear Studies at Cornell has worked closely with one of the leading US suppliers of niobium, Teledyne Wah Chang Albany (TWCA) in Albany, Oregon, to improve the purity of niobium, and with the US supplier of superconducting niobium cavities, Babcock & Wilcox (B&W) in Lynchburg, Virginia.

With encouragement and guidance from physicists in the superconducting r.f. group at Cornell, TWCA improved the purity of electron beam melted niobium ingots by a factor of ten, and successfully maintained the improved quality in the final sheet product. With advice from Cornell, TWCA developed the capability for measuring niobium RRR (residual resistivity ratio), a purity specification crucial to the thermal stability of superconducting cavities at high accelerating fields.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Cornell has successfully transferred to B&W the technology of superconducting cavities: the development of sound fabrication practices and the control of parameters critical to cavity performance. B&W sent key team members representing project management as well as sheet metal forming, machining, and welding operations to Cornell learn procedures. Cornell made available design drawings, a fabrication procedures document, and assembly fixtures. Final tuning, chemical treatment, and superconducting r.f. tests were carried out at Cornell.

The first tests of the two initial industrial prototype cavities reached accelerating fields of 6.5 MeV/m at quality factor (Q) values of 3×10^9, both in excess of design parameters for the intended application in the Continuous Electron Beam Accelerator Facility (CEBAF) now under construction in Newport News, Virginia.

White the workhorse material niobium will continue to serve the generation of accelerators now under construction, the r.f. superconductivity community is keeping a watchful eye on the new high temperature superconductors. Radiofrequency properties of high quality crystals prepared by AT&T Bell Labs are being measured by the Cornell group. Results provide the first encouraging signs for possible microwave applications of the compound YBaCuO in future accelerators.

CHINA Key project *

The BEPC Beijing electron-positron collider, defined as a key national project by the government with a budget of 240 million yuan (about $80 million), required special equipment, most of which called for advanced technologies.

**** On 16 October, first electron-positron beams in the new BEPC machine at Beijing collided at a total energy of 1.6 GeV.***

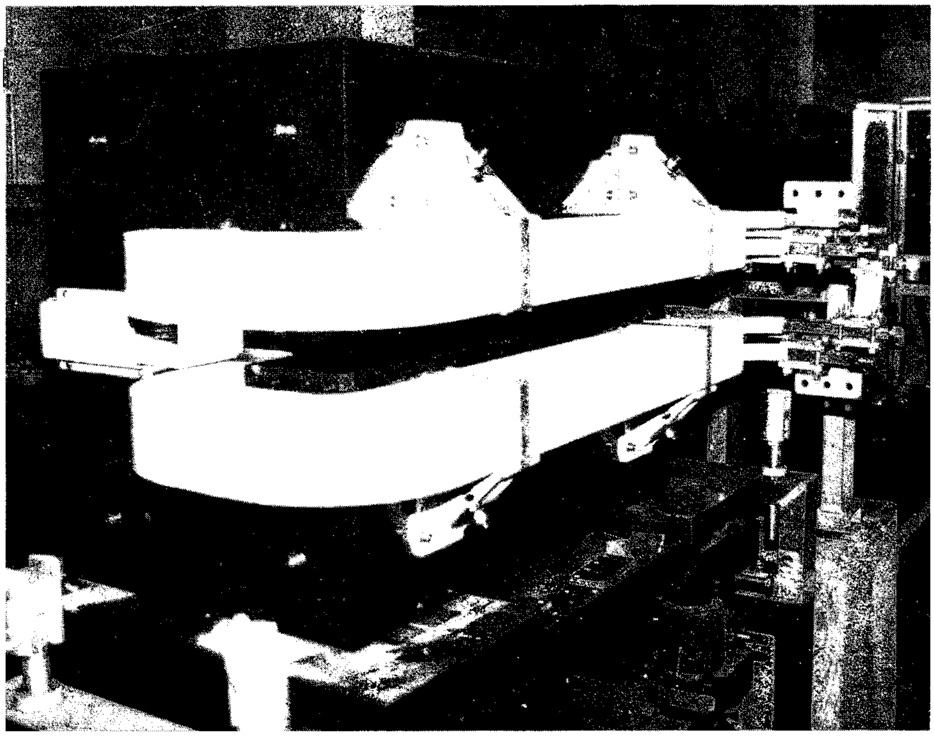
Cooperation between the Beijing Institute of High Energy Physics (IHEP) and industry was organized by a committee under the State Council, and went on to involve more than 200 enterprises all over China, covering machinery, electronics, precision instruments, radiofrequency, ultra-high vacuum, control systems, etc.

In recent years, under China's reformation and 'open door' policies, profits became a major goal of Chinese firms. Although the profits from BEPC might be less than in other areas, nevertheless firms were attracted to such a prestige project, hoping also that the technology would go on to be useful in other areas.

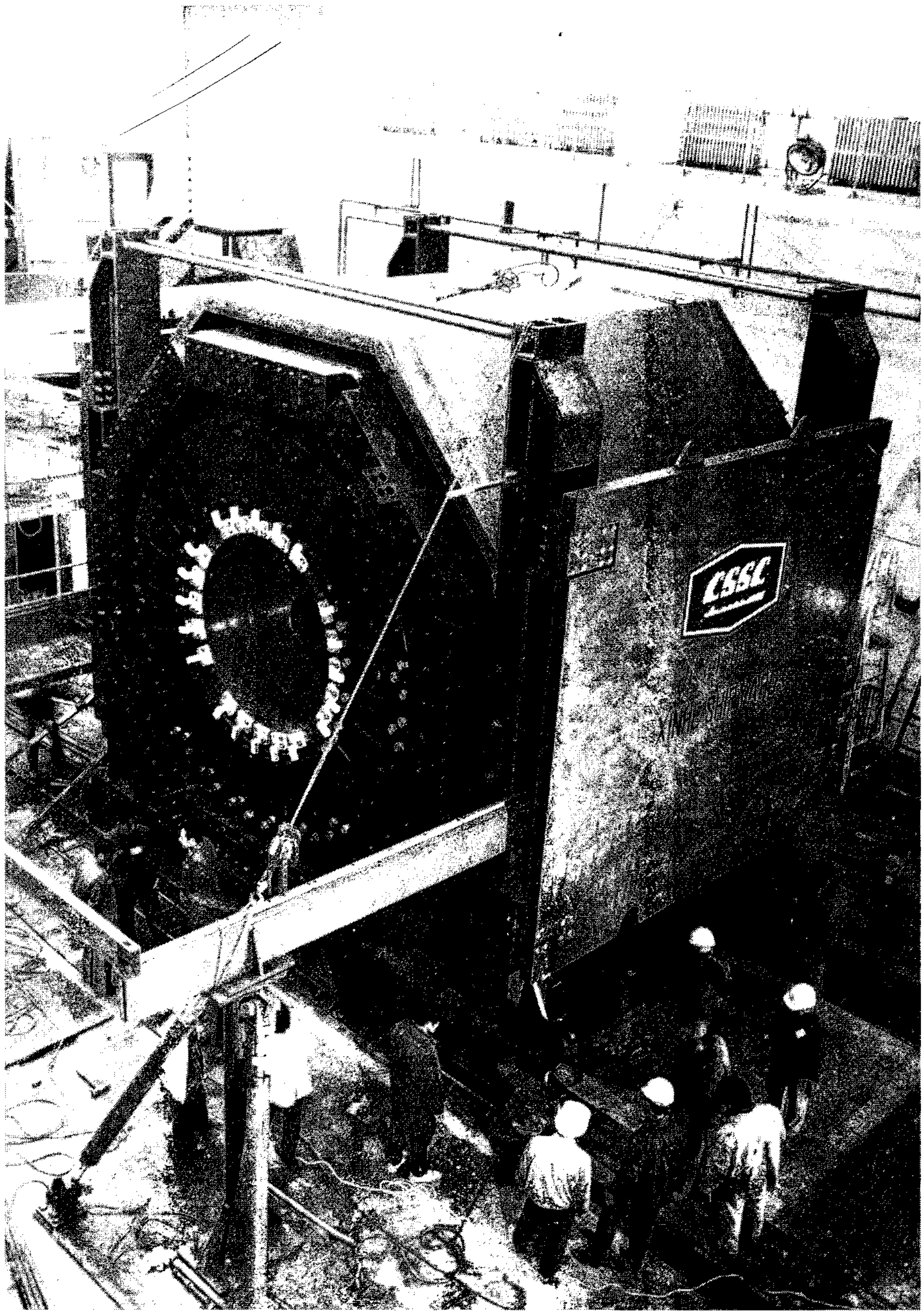
Sixteen S-band klystrons for the BEPC injector linac were manufactured in a factory in Hubei province in middle south China, far from the industrial centre. The upper limit of Chinese klystrons had been 16 MW, far below the 30 MW needed for BEPC. Thanks to cooperation with IHEP, the design power was reached with lifetimes estimated at 6000 hours.

Most of the BEPC dipole magnets were made in the Shanghai Pioneer electrical machinery plant, with its tradition of supplying accelerator laboratories. Plant managers were confident from the outset that the stringent specifications could be met, and skilled workers produced the precision die vital for magnet production.

The frame of the drift chamber for the BES Beijing Spectrometer (the detector being built to study the BEPC collisions) was manufactured in an aerospace factory in Guizhou province in south-west



This BEPC dipole magnet was made in the Shanghai Pioneer electrical machinery plant.



China, taking care of the precision machining of 40,000 4-mm holes with 0.05 mm accuracy.

The Shanghai aircraft factory looked after the frame of the BES shower counter, rolling a 40-mm thick aluminium plate into the 2.4 metre diameter inner barrel. A machinery factory owned by the Shanghai petrochemical company welded the gap, and Jiannan shipyard, over a century old and one of the oldest manufacturing plants in China, lathed the outer circle.

The priority of the BES shower counter at the Shanghai aircraft factory was second only to assembly of MD-82 McDonnell-Douglas aircraft.

During all this work many experienced IHEP engineers, technicians and scientists went to the factories to give assistance and to supervise quality tests.

In parallel, IHEP's own workshop was upgraded. To provide the accelerating sections for the BEPC linac to the required specifications and within the allotted schedule called for a special production line. As well as meeting the deadlines, the workshop went on to supply equipment for the 50 MeV Accelerator Test Facility electron linac at Brookhaven in the US, and to construct the quadrupole magnets for the BEPC ring.

The iron yoke of the spectrometer to study the collisions at the BEPC Beijing electron-positron collider (now being commissioned) was made by Xinhe shipyard in Tianjin, north China.

NIKHEF
Magnets for HERA

In 1981 what turned out to be a highly successful collaboration between the Dutch NIKHEF-H Laboratory and Dutch industry was set up to produce two types of superconducting correction elements – sextupole/quadrupole (S/Q) and dipole correction magnets – for the proton ring of the HERA electron-proton collider, now nearing completion at the German DESY Laboratory in Hamburg.

The HERA proton ring is equipped with superconducting dipole and quadrupole magnets (see page 21). Adjustment of the working point and chromatic corrections are provided by quadrupole and sextupole correction coils mounted on the cold beam pipe inside the 9 metre main dipoles. Orbit corrections are made by superferric correction dipoles mounted in common cryostats with the main quadrupoles and the beam position monitors.

The (S/Q) correction coils of single strand multifilamentary niobium-titanium superconductor consist of a 5.9 m long layer of sextupole winding surrounded by a 5.83 m long quadrupole winding on a 60 mm beam pipe. They provide a nominal 0.030 Tesla sextupole field at a 25 mm radius with a current of 65 A, and a 0.045 Tesla quadrupole field at this radius with 85 A.

Based on a Brookhaven design, the first prototype S/Q coil was fabricated at NIKHEF-H and successfully tested at DESY. In collaboration with Holec, Ridderkerk, further prototypes led to a satisfactory final design. Field quality was measured at room temperature by Holec using DESY equipment with an online connection to DESY. The data showed that the strengths of the forbidden multipoles were several times less than the maximum allowed values. The final acceptance test was at DESY.

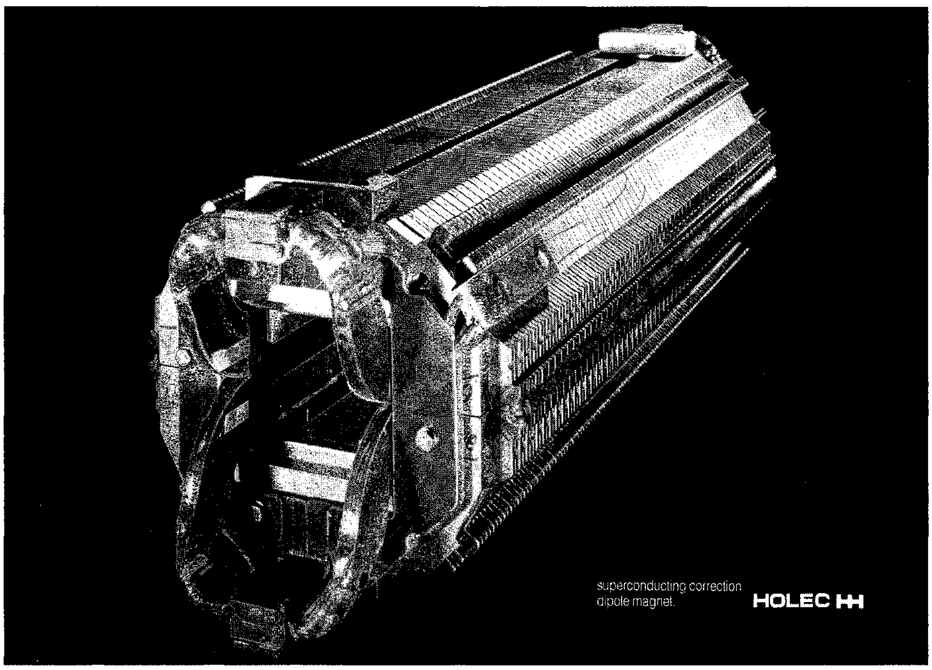
The superferric dipole correction magnets have two saddle-shaped coils of 0.56 mm diameter multifilament niobium-titanium wire in a soft iron yoke 0.61 m long and with 75 mm diameter opening. A technique developed by NIKHEF-H for producing saddle-type coils was transferred to Holec. After initial problems with loose wires and shorts were solved, a nominal field of 1.4 Tesla was reached at 45 A. In general the magnets quench above 100 A, compared to a specification value of 75 A.

Under a 1986 Dutch Ministry of Economic Affairs agreement with DESY, the construction of the correction elements was a Dutch contribution to the HERA project, with NIKHEF-H ensuring that DESY specifications for quality control and time schedule were met. Funding was shared between the Ministry of Economic Affairs and the Ministry of Education and Science. A Technical Coordination Committee included representatives from DESY, NIKHEF-H, the national government, and the Industrial Council for Energy and Environment which promotes new technologies.

The collaboration included two other Dutch firms: SLE (Superconductors LIPS ECN), Drunen, for production of the dipole wire and Smit Draad, Nijmegen, for the wire insulation. Series production at Holec started in 1986, and by the end of that year about 20 dipole magnets and 30 sextupole/quadrupole coils had been produced, tested cryogenically and accepted by DESY. The production of all 462 S/Q coils and 250 superferric dipole magnets was completed this summer.

DARMSTADT
Muth's progress

Up to a few years ago, the usual way to get magnets for beamlines at Darmstadt's GSI Heavy Ion Research Laboratory (Gesellschaft für Schwerionenforschung) was by ordering complete units from industry – yokes and coils together with all auxiliary equipment ready for operation. Only magnets with solid yokes were needed.



Superconducting correction dipole magnet made by the Holec company as part of the Dutch contribution to the HERA electron-proton collider being built at the German DESY Laboratory in Hamburg.

When the SIS/ESR synchrotron/storage ring project was launched in 1984 (for progress, see October issue, page 27), this situation changed. Fruitful discussions with suppliers needed a prior familiarity with the techniques for making laminated yokes for pulsed magnets. In addition, experience at CERN and DESY had shown the economies resulting from splitting the job into subtasks like coil fabrication, sheet orders, profile stamping, yoke shuffling and magnet assembly.

To gain experience, a first step was in-house production of four laminated dipoles and 26 laminated quadrupoles for the beam transfer from the UNILAC linear accelerator to the synchrotron. In October 1984, with the tools for SIS magnet fabrication arriving, a local locksmith, Mr. Muth, together with his (at that time) sole coworker, was engaged to supervise welding work.

In at the beginning, Mr. Muth learned a lot about how to produce the SIS magnets and when tender specifications for the production of series magnets were being prepared, he asked to be included in the list of bidders. An attractive tender resulted, and in autumn 1985, after founding his firm 'Magnetbau Muth', he got the contract for shuffling the yokes of 26 dipoles, 43 quadrupoles, 12 sextupoles and for mounting coils supplied by German and French firms into the magnets. The punched profiles were contributed by a different contractor.

Since then Magnetbau Muth has continued to prosper, with extended premises, new plant and more staff. A recent GSI order covered 73 quadrupoles for the beam guidance system between SIS, ESR and the Target Hall, including punching of the profiles and fabrication of glueing and stacking fixtures.

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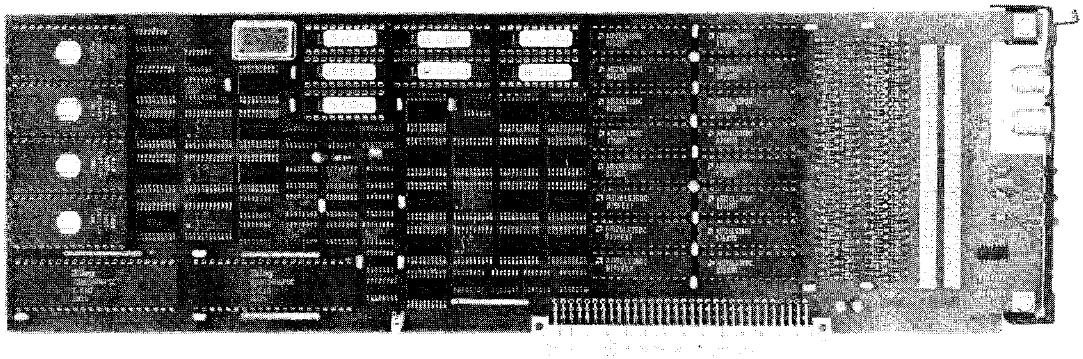

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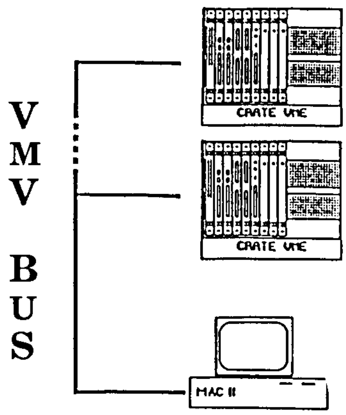

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CEBAF DETECTOR GROUP LEADER

The 4 GeV Electron Beam Accelerator Facility, now under construction in Newport News, VA, is searching for a senior physicist to lead the in-house detector group. This group will have primary responsibility for the development and construction of the large proportional and drift chamber systems needed in the various experimental spectrometer systems. In addition, they should assist in the development and construction of other types of detectors such as Cherenkov and shower counters. The group will also be expected to engage in research and development on new types of detectors appropriate to the research program. The group is expected to consist of four physicists and approximately the same number of technicians. The group leader will have primary responsibility for recruiting this staff.

The candidate is expected to have a minimum of 5 years experience in development and construction of large chamber systems and preferably some experience with other detector types. Management experience is desirable but not absolutely necessary.

For prompt consideration, please send resume with salary history to: **Personnel Director, CEBAF, 12000 Jefferson Avenue, Newport News, VA 23606.**

CEBAF

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SENIOR PROFESSOR POSITION

The Department of Physics at the University of Virginia is seeking qualified applicants for a tenured position at the associate or full professor level for an experimental high energy physics group now in the process of formation.
The selected individual would act as deputy head of the group.
This group has a major involvement at Fermilab in heavy flavor physics in experiment E705 and in beauty physics in experiment E771.
They also have a strong interest in future beauty physics options at both Fermilab and/or the SSC.
Candidates should have compatible research interests.
Interested parties should submit a resume and the names of at least three references to:

Professor Michael Fowler, Chairman
Department of Physics
J.W. Beams Laboratory of Physics
University of Virginia
McCormick Road
Charlottesville, Virginia 22901

Phone: 804/924-3781

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EXPERIMENTAL HIGH ENERGY PHYSICS

ASSISTANT PROFESSORSHIPS

The Department of Physics at the University of Virginia is seeking qualified applicants for tenure track assistant professor positions for an experimental high energy physics group now in the process of formation.

This group has a major involvement at Fermilab in heavy flavor physics in experiment E705 and in beauty physics in experiment E771.

They also have a strong interest in future beauty physics options at both Fermilab and/or the SSC.
Candidates should have compatible research interests.

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UNIVERSITY OF CALIFORNIA, RIVERSIDE

FACULTY POSITION IN EXPERIMENTAL ASTROPHYSICS

As part of a planned expansion in the area of astrophysics, the Physics Deparment at the University of California, Riverside is seeking outstanding candidates for a faculty position in experimental astrophysics beginning July 1, 1989. The appointment will be at an open level. Qualified candidates with established records in research and teaching are invited to apply.

Existing programs at UCR in this area are gamma ray astrophysics from MeV to TeV, solar and atmospheric neutron observations, and neutrino astrophysics. The successful candidate will be expected to teach at the undergraduate and graduate levels and to lead a vigorous and significant research program. Candidates should submit a curriculum vitae, statement of research interests, and arrange to have three letters of recommendation sent to:

Chair, Search Committee
Experimental Astrophysics
Physics Department
University of California, Riverside
Riverside, CA 92521

Completed applications received through December 31, 1988 will be screened.

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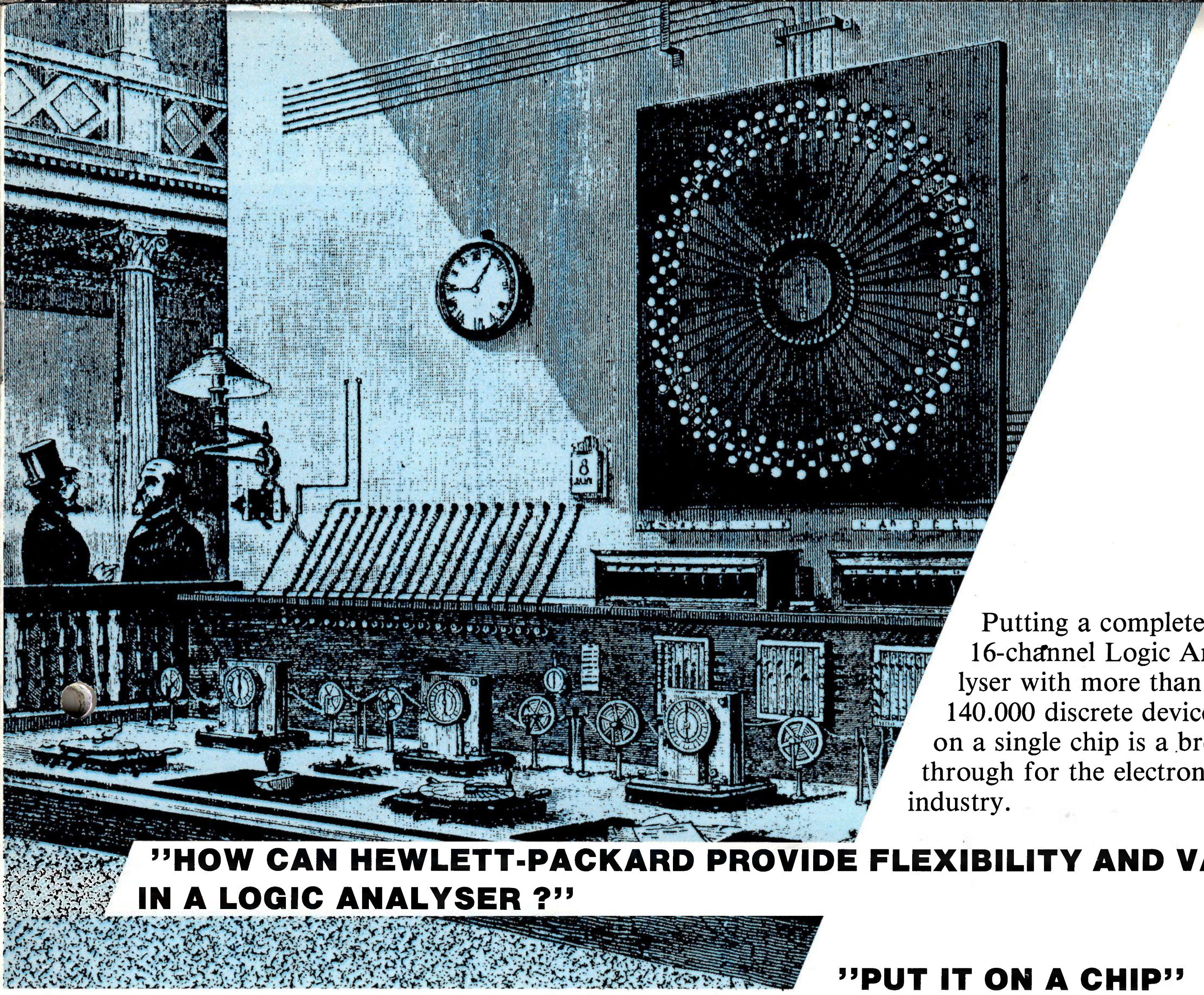

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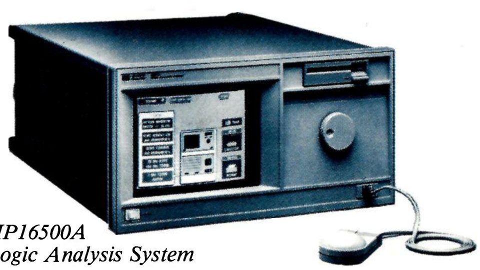

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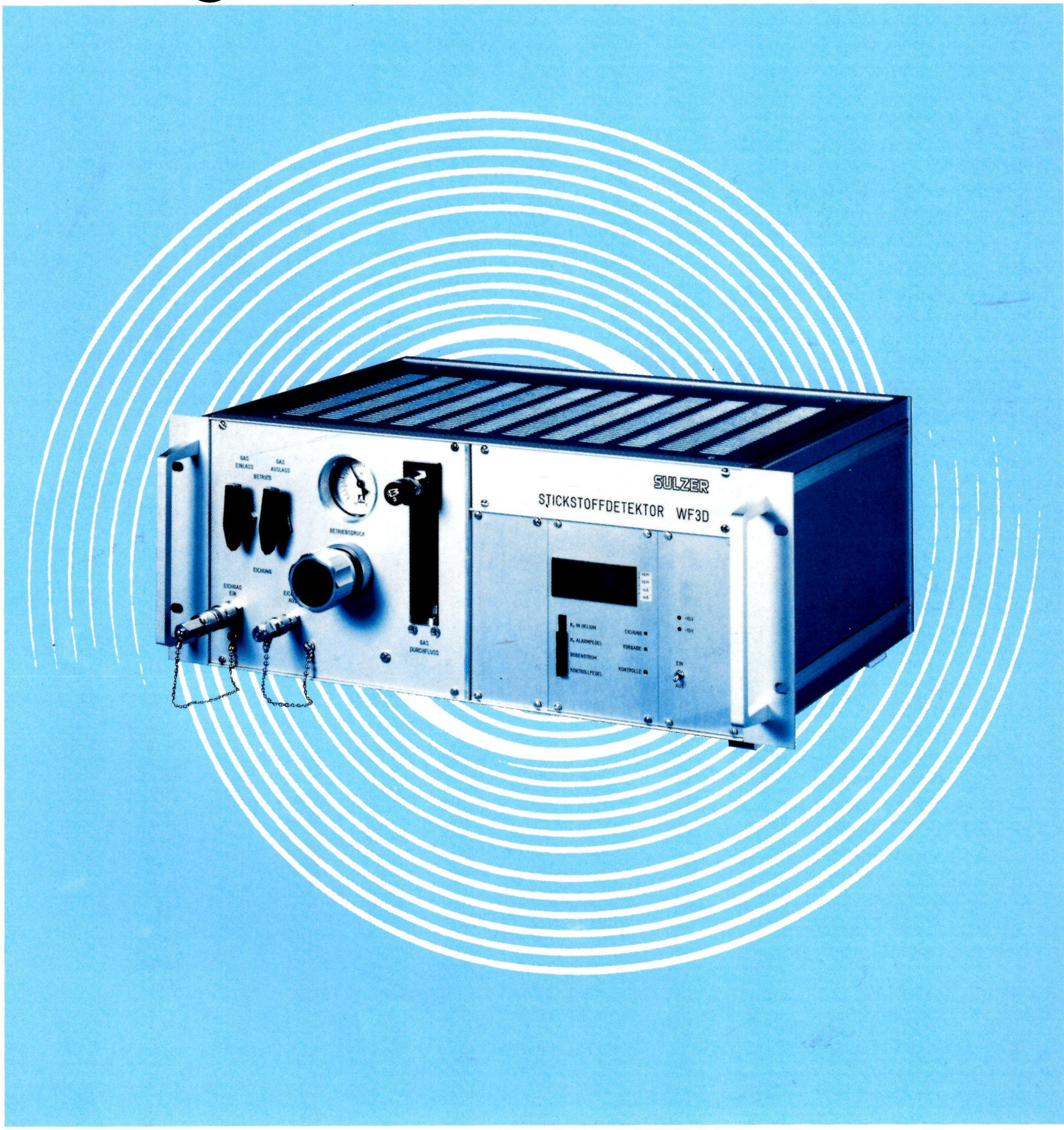
SULZER

Cryogenics

Nitrogen in Helium Detector



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Sulzer Nitrogen in Helium Detector Type WF 3D

- Measures the concentration of nitrogen in helium (ppm range)
- Measurement and indication both continuous
- No dead time
- Remote indication, relais output
- Easy to operate – connect and measure
- No carrier gas required
- High degree of stability
- Inlet pressure 1–20 bar gauge

1. Application

Measurement of nitrogen (N_2) in helium (He).

2. Measurement principle

Optical emission spectroscopy. Excitation of the gas is obtained by use of an electrical discharge between two metal electrodes. Analytical line emission is selected by an interference filter. Measurement of radiation is by means of an Si photo-diode.

3. Data of gas to be measured

- Inlet pressure 1–20 bar gauge
- Outlet pressure 0.05–0.3 bar gauge
- Rate of gas flow 0.03 Nm^3/h

4. Range and accuracy of measurement

- Standard range of measurement 2–50 vpm N_2
- Indicated range 0–199.9 vpm N_2
- Resolving power 0.1 vpm
- Reproducibility $\pm$0.1 vpm, typical value for range 2–30 vpm
- Accuracy without re-calibration $\pm$2 vpm

5. Indication, outputs

- 3½ position liquid crystal indication (LCD)
- Analogue signal 4 to 20 mA, corresponding to a measurement of 0 to 50 vpm N_2. Resistance load min. 250 Ω, max. 500 Ω
- Relais output adjustable over the whole measurement range. Maximum loading:
  DC 30 W, 50 V, 1 A
  AC 250 VA, 250 V, 1 A

6. Dimensions, weight

Equipment size suitable for fitting into 19″ rack to IEC 297/DIN 41494.
- Height 177.8 mm (4 units ≙ 7″)
- Casing depth 305 mm
- Weight ca. 13 kg

7. Power supply, ambient temperature

- Supply voltage 220 V, 50/60 Hz
- Permissible variation in supply voltage $\pm$10%
- Power input max. 150 W
- Permissible ambient temperature range 0 to 40 °C

Cryogenics

SULZER

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