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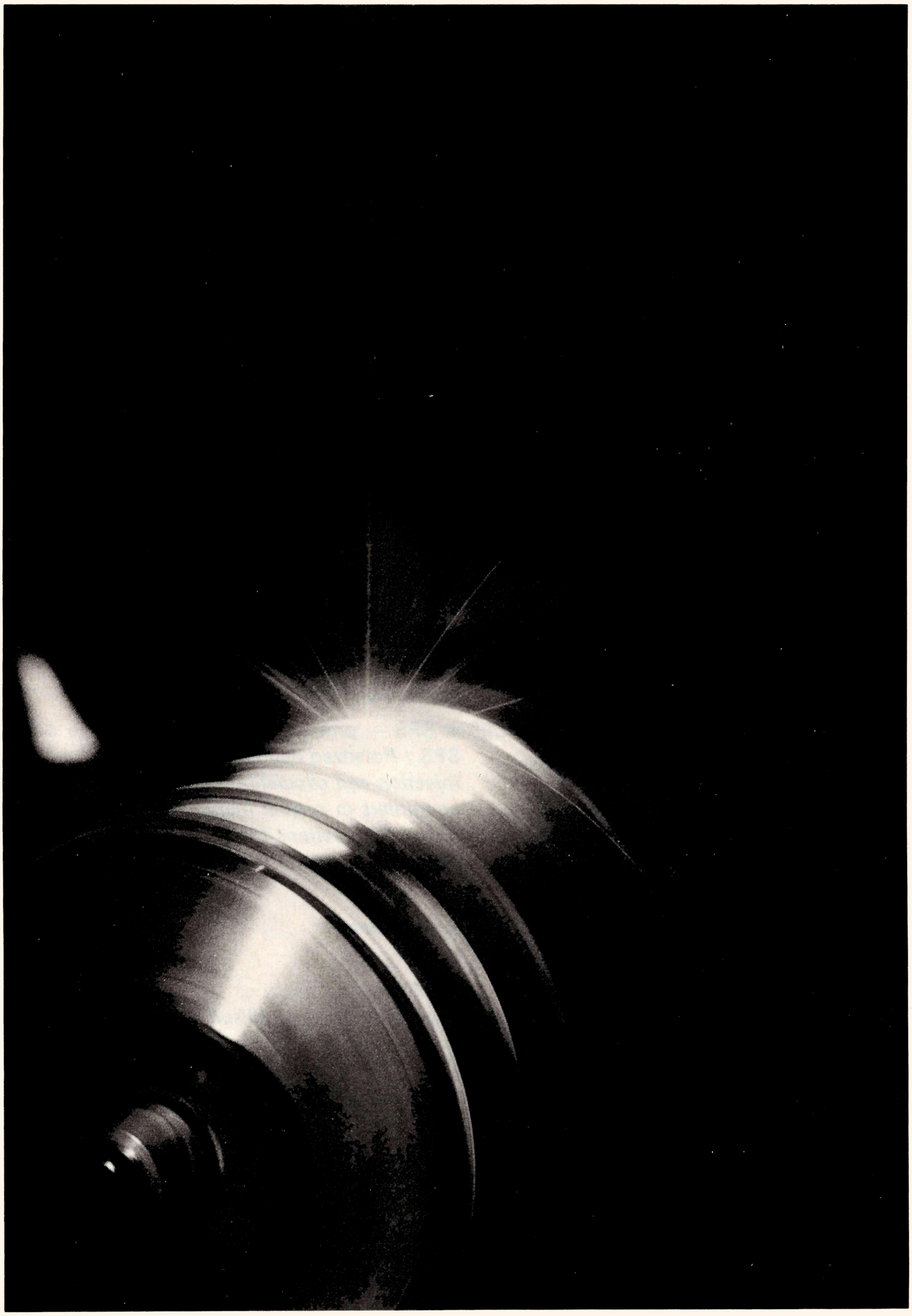

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Cover photograph: Electron beam welding of the prototype aluminium r.f. cavity for the PETRA 19 GeV electron-positron storage ring at DESY. The cylindrical cavity components are mounted in a rotating chuck and they are welded under vacuum by a 120 keV beam of electrons. The beam can be seen coming in from above due to its interaction with the residual gas. (Photo DESY)

VBA — Very Big Accelerator

A meeting is taking place at Serpukhov to consider the possibility of building a very big accelerator as a 'world machine'.

The idea of a machine with world-wide participation in its financing, construction and exploitation has been talked about at intervals for many years. With the present scale of particle physics research facilities, it seems inevitable that wider collaborations between countries will be necessary to finance and use a forthcoming generation of machines.

Whether the idea of a world machine is coloured more by idealism than by realism will always be difficult to judge until it is finally examined in detail. It does, however, reflect the international nature of particle physics research, the close contacts between scientists of many nations and the overall satisfaction with the way international collaborations have succeeded at high energy physics Laboratories.

CERN is regarded as the world's finest example of international collaboration in science, USA-Western Europe relations in high energy physics operate so smoothly that we take them completely for granted. CERN-Dubna, CERN-Serpukhov and the more recent USA-USSR collaborations have all gone well. A new phase of CERN-USSR relations opened last year (see July COURIER 1975). It is doubtful if any other field of activity can claim such a fine track record in international cooperation.

It was at the Topical Seminar on Perspectives in High Energy Physics held in New Orleans in March 1975 (see April issue of last year) that the subject of a very big accelerator and the possibility of its being a world machine was raised again. Major protagonists were Leon Lederman (Columbia University), Victor Weisskopf (MIT) and Bob Wilson (Director of Fermilab). The discussion involved representatives of the high energy physics communities in North America, Western Europe, CERN, Soviet Union, Dubna and Japan.

To carry the discussions further, a Study Meeting, attended by scientists from all the regions mentioned above, is being held at the Institute for High Energy Physics, Serpukhov near Moscow from 17-26 May. The Meeting opens with a survey of the presently operating machines, the machines under construction and the projects for future accelerators or storage rings which are already on the table. It will then turn to a study of the physics case and the technical aspects of the construction and utilisation of a very big accelerator. As usual, accelerator builders are unable to discuss a machine without abbreviating it to some set of initials and the very big accelerator has become 'the VBA'.

What the VBA might be is not defined at this stage, except that the scale is set by giving as examples a 10 000 GeV (10 TeV) proton synchrotron or a 100 GeV electron-positron storage ring. Anything on this scale would absorb a sizable piece of pure science budgets and of accelerator expertise, even thinking of some ten or more years ahead. This lines up naturally with the suggestion that such a machine would be constructed and exploited by broader international collaborations than have been the case so far. Hence the second title of World Machine.

While we are struggling with present economic difficulties, we cannot anticipate such a project going ahead for some years to come. We have to recognize that it is now difficult to sustain existing research programmes let alone launch new ones. Nevertheless, it is always important to lift our eyes, from time to time, from the immediate situation and to look to the future. In any case, it takes many years to develop from the ideas stage to a realistic project and to obtain the necessary financial support.

It is the responsibility of the high energy physics community to attempt to predict the needs of their research for the future and it is the responsibility of the accelerator physics community to investigate how far their techniques can be extended to meet these needs. Also, it is the responsibility of everyone to continue to promote the high energy physics contribution to international cooperation wherever it is reasonable to do so. And what could be more reasonable than a world collaboration on a very large enterprise devoted to the increase of human knowledge.

Future communications

The method of transmitting news of the Athenian victory over the Persians at Marathon instituted one of the most dramatic events in sport. What was right for 490 B.C., however, is not necessarily right for the end of the 20th Century. Developments in the techniques of communication have been one of the key factors in the evolution of mankind, particularly in recent decades, and these developments are certainly not at an end.

The field of particle physics demands very advanced communication techniques and there are features of the present high energy physics scene which make it an ideal testing ground for techniques which will probably later come into general use. This article attempts to indicate some of our needs, how they are being confronted at the moment and how they could be tackled in the future.

One approach to the needs is to consider the present environment of particle physics research. It is becoming more and more concentrated on a few well equipped centres — the Laboratories such as CERN, DESY, Fermilab, Stanford... housing the big accelerators and storage rings. These centres serve many experimental groups predominantly based in Universities. The scale of the experiments is such that groups must collaborate and often half a dozen Universities, widely scattered geographically, are likely to be involved in a particular experiment.

These scattered groups must communicate at all stages of the experiment — its design, construction, operation (data collection), analysis and publication of results. The present techniques of communication span from letters, telephone calls, group meetings, conferences, experimental data carried on tapes, written reports and, in a few cases, links between computers. Most of these techniques involve time delays of days, whereas delays of only minutes would be involved inside one Laboratory.

Communications are ripe for further development and the direction of the development obviously has to take into account the nature of the communications. At the early and closing stages of an experiment, they impose quite modest demands on communication techniques in terms of volume of data whether in the form of letters, drawings, computer programs.... Ideally, however, they should be rapid, interactive and able to link flexibly many centres to many sources (both people and machines). A medium speed data transmission network (operating at up to say 10 kbit/s) with versatile input/output devices would be adequate. At the data taking stage, and perhaps afterwards, there is the added requirement of being able to handle a large quantity of information at higher speeds (Mbit/s) needing communication links with a wide bandwidth.

There have been moves in the direction of providing some of these facilities going on for several years. PTTs are beginning to offer higher speed telex and facsimile services and are studying nationwide electronic mail systems. Several high energy physics Laboratories have 'star networks' — data links to some user stations which can serve for 'remote job entry' to the Laboratory main computers. Probably the most extensive of these star networks is at the Lawrence Berkeley Laboratory and there are several in Europe, for example at Bologna. They use post office telephone lines both leased, so as to be permanently available, or switched (available on dialling). The terminal devices range from teletypes to fairly sophisticated work stations with cards or keyboards. Some of them, such as those linked to Daresbury, allow modest interactive computing, information retrieval and even sample data acquisition.

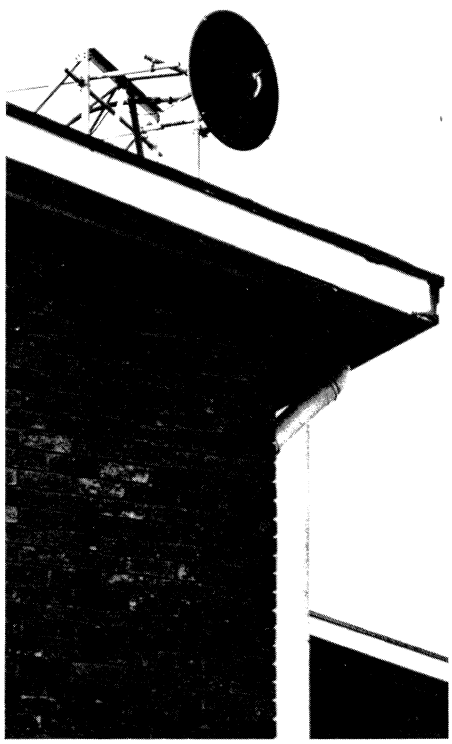
Remote access from work stations is now standard practice. In some networks it is done in a uniform way (for example, work stations into the Rutherford computer are built around a GEC 2050 computer). There is, however, great variety of networks which makes interlinking difficult. A neat way around one of the problems is implemented at CERN where Daresbury and Rutherford have different work stations to feed information to their home computers. They share the same telephone line back to the UK by using multiplexing Modems. This technique allows several sources and receivers of communications without extra line cost but limited by the fixed total capacity of the line.

The problem of a work station being able to have access to more than one host computer without physically changing connections is complicated. This is because of the choice and definition of the communication protocols and the availability and transfer of the relevant data bases. Internationally agreed specifications are only just beginning to emerge. There is a Daresbury-Rutherford system which links the main computers in each centre via nodal switching systems so that work stations can select between two host computers and send communications to either of them.

A few large shared networks are now in operation. The best known is ARPA (Advanced Research Projects Agency) in the USA where a commercial system, Telenet (for 'Teletype networking') has also started recently. They go a long way towards meeting the requirements for a general medium speed network, making many host computers accessible to many users. There is some use of ARPA by the high energy physics community but its full abilities are rarely exploited. It is still used overwhelmingly for communication from a single source to a single host.

The aerial, on top of a building at the Daresbury Laboratory, which has been used in experiments on high speed data communication between Daresbury and Manchester University.

(Photo Daresbury)



In Europe there is an experimental system with similar performance called Cyclades and several PTT systems still under development — for example, EPSS in the UK and Transpac in France — which offer some of the facilities found in ARPA though without high speed. Rutherford and Daresbury are being linked to EPSS.

An experimental network called EIN (European Informatics Network) will come into operation very soon and will link centres in the UK, France, Italy and Switzerland. CERN hopes to hook on to this network and it could be useful as a test facility to the European high energy physics community though it also is limited in speed. Also CEPT, the joint European PTT Organization, is to set up a similar network called Euronet specifically for connecting large data bases. These networks use 'packet switching' which offers a great cost saving for users who would pay only for the packets of information transmitted and not for the continuous rental of lines to all collaborating Laboratories.

Experiments on high speed communications have already started because this is the major bottle neck in exploiting the full potential of links between remote work stations and large central computers. Microwave data links have been successfully tested based on existing telephone trunk systems. For example, the Bell Laboratories in the USA are experts of some years standing, the Royal Radar Establishment at Malvern in the UK has portable microwave links operating at 100 Mbit/s over several kilometers, Daresbury has a microwave link to Manchester University and Fermilab has a microwave link to Argonne. There is extensive use of microwave systems in the military field.

More recently high speed communications via infra-red lasers have been developed for example at Belfast and Cambridge. Portable and inexpensive microwave and optical links are now available and are likely to be used extensively in the future for point to point communication within large sites or over modest distances between centres.

For high speed, long distance communications the use of satellites is by far the most promising technique. It is also a multi-source and multi-host method which is ideal for linking many centres. There is already experience in the USA where a system has been running providing 1.3 Mbit/s between five Government centres via a satellite. More recently Satellite Business Systems (which involves particularly IBM and Comsat) has decided to invest $ 250 million during the next five years in the development of a general purpose network in the USA for mixed voice, data and image communications via satellite with small antennae located on customer's premises to avoid expensive land lines. When business interests of the acumen of IBM propose to sink such a quantity of money into a project, they are likely to have made a very thorough assessment of the future market and the commercial benefit.

In Europe there are three experimental communication satellite projects — Symphonie (France and Germany), Sirio (Italy) and OTS (European Space Agency). OTS is a prototype for a future European Communication Satellite system (ECS) and will be launched mid-1977. CERN, DESY and Rutherford have been collaborating with the European Space Agency and with EIN to sound out the possibility of participating in the first experiments with the OTS satellite and with the EIN network. The high energy physics needs are typical of what could be common practice in many other fields in the future. Experimental use of the project communication systems would provide a thorough testing ground for the purposes of the European Space Agency and EIN and a good insight into the problems and the potential for the high energy physics community. Funding for these experiments in communications are under discussion at Government level.

The ultimate aim would be a communications system which would make life during all stages of an experiment as easy as if all participants and facilities were lodged in the same Laboratory. It looks as if the necessary technology is becoming available but needs testing and optimizing to arrive at the best system at a reasonable cost.

The communications which resulted in this article were transmitted to the Editor by very conventional techniques of modest bandwidth particularly from Basil Zacharov at Daresbury and Mervyn Hine at CERN.

Neutron source at Rutherford

Beams of neutrons are playing an increasingly important role in the investigation of the structure of matter but, in the constant search for new and better experimental facilities, the limitations of fission reactors as neutron sources are becoming more and more evident. Scientists are likely to turn to accelerator based systems for improved neutron sources and proton synchrotrons could soon be in use as the 'next generation' of neutron sources.

Low energy neutron beams are widely used by physicists, chemists, materials scientists, biologists, etc., to investigate the structure and properties of a wide range of materials including alloys, defect solids, liquid crystals, ferroelectrics, amorphous polymers, organic molecules and membranes and macromolecules such as proteins and viruses. As is the case with high energy physics, few Universities have their own experimental facilities for neutron beam research.

In the UK, the Science Research Council (SRC) supports the work of university scientists by providing access to the necessary neutron beams and by supplying instrumentation support for experiments. At present the beams are provided mainly by fission reactors at a number of research centres — notably the UK Atomic Energy Research Establishment (AERE) at Harwell and the Institut Laue-Langevin (ILL) at Grenoble — and there is also modest but significant use of the AERE 30 MeV electron linac as a pulsed neutron source.

The importance of neutron beam experiments lies in matching the beam energies and other parameters to the binding energies and dimensions characteristic of the condensed matter being studied. These binding energies are typically in the thermal (up to say 100 millielectronvolts — meV) or epithermal (hundreds of meV) regions and, as a result, the maximum neutron energy available is of no consequence — a marked contrast to the high energy physicists' obsession with maximum energy.

Of major importance, however, is the intensity of the neutron beam. Neutron scattering is a notoriously low intensity activity and beam currents at the experiment are usually whole orders of magnitude down on the maximum flux close to the beam source. This decrease comes mainly from beam collimation and from the requirement to make the 'white' beam from the source, with its wide spread of neutron wavelengths, into a monochromatic beam. To put this inevitable beam attenuation into perspective, a hypothetical beam in which each neutron carried unit electric charge would, even at the highest flux fission reactors such as that at ILL, achieve a current at the experiment of only about 10^{-4} μA.

Recently the SRC, through its Neutron Beam Research Committee, has been considering new neutron sources to extend the application of neutron scattering beyond what is possible with present facilities. It is already apparent that the further development of reactor systems would be prohibitively expensive while the use of pulsed neutron sources based on particle accelerators looks a more economic alternative.

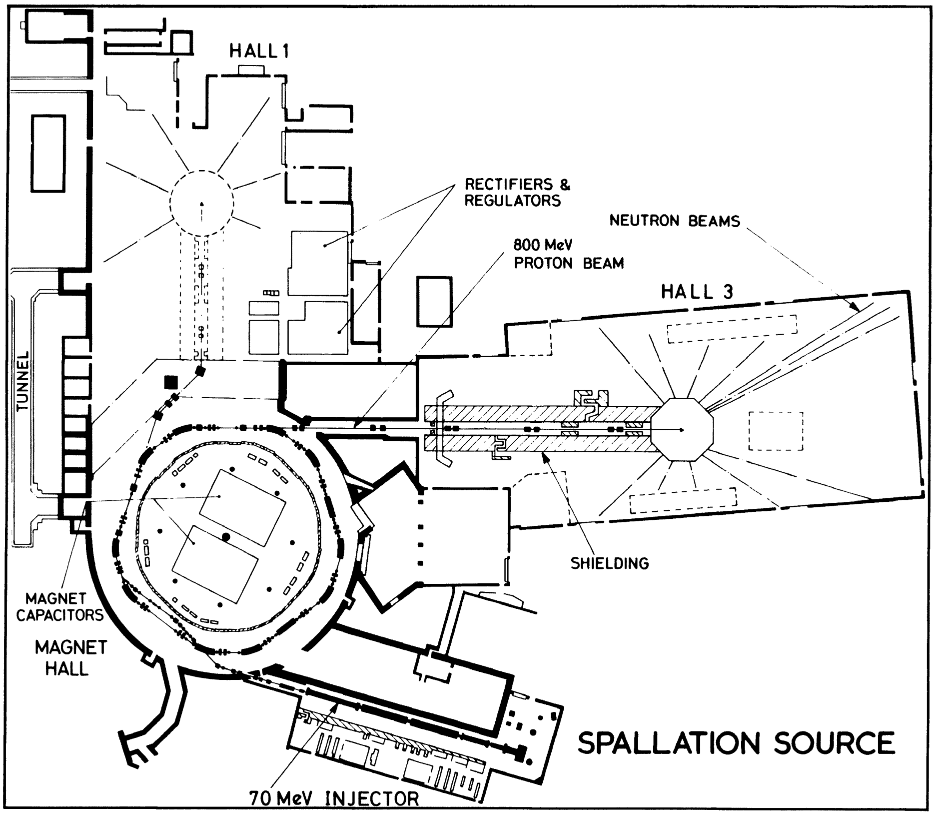
The Committee is now closely examining the scientific potential of a high intensity pulsed source of neutrons obtained by proton spallation of heavy targets. At the same time, the Rutherford Laboratory is studying the possibility of modifying the Nimrod complex into a high repetition rate, high intensity machine suitable for providing intense bursts of neutrons.

In the spallation mechanism, neutrons are produced by bombarding a target of a heavy element such as lead or uranium with protons of about 1 GeV energy. Spallation is a prolific neutron production mechanism and, more important, develops heat at the rate of about 50 MeV per neutron compared with 200 MeV per neutron in fission reactors. (Heat production is a limiting factor in reactor based systems.)

The advantages to be gained from accelerator based neutron sources are becoming widely recognised. In the USA, Argonne has a detailed project, under Jack Carpenter, for an Intense Pulsed Neutron Source (IPNS) ultimately using a dedicated 800 MeV proton machine (see COURIER, June 1975) and there are also moves afoot to install a condensed-matter research facility on the 500 MeV Booster at KEK in Japan (COURIER, October 1975). At the Los Alamos 800 MeV proton linear accelerator, LAMPF, there is a proposal to use the Weapons Neutron Research Facility, which is now nearing completion, also for general neutron research. At Oak Ridge they are thinking of converting their existing electron linear accelerator to produce neutron beams.

The ideas for the Rutherford Laboratory machine indicate that the main accelerator modification could be made in three or four years for less than £7 million. This estimate assumes that the new source will be able to use much of the existing equipment at the 8 GeV Nimrod synchrotron together with the magnet power supply from NINA (the Daresbury Laboratory electron synchrotron which is soon to close down). Without this existing equipment and surrounding resources, the cost of the new source would be about £30 million.

The machine would also use the new 70 MeV Nimrod injector which is being commissioned. All four accelerating tanks for this linac have been installed and protons have been accelerated to 10 MeV through the first tank with currents of 75 mA. The second tank will shortly come into



Possible layout of an 800 MeV proton accelerator and experimental facilities within the Nimrod complex at the Rutherford Laboratory. The machine would be used to produce pulsed high fluxes of neutrons.

Parameters of the machine	
Proton energy	*800 MeV*
Protons/pulse	*2.5×10^{13}*
Protons/s	*1.3×10^{15}*
Injection energy	*70 MeV*
Frequency	*53 Hz*
Peak magnetic field	*0.7 T*
Vertical emittance	*500 mm mrad*
Horizontal emittance	*950 mm mrad*
Bending radius	*7 m*
Mean radius	*26 m*

operation and progress on this injector will be described in a future article.

The main parameters for the new synchrotron are given in the table. The machine requires long straight sections for extraction of the large emittance beam and this leads to a relatively large mean machine radius, although one which fits conveniently into the existing Nimrod magnet hall.

The peak r.f. accelerating voltage is 140 kV and there is a frequency swing from 0.7 MHz to 1.6 MHz requiring cavities tuned by biassed ferrite. A total of 12 m of r.f. cavity would be required, distributed in two of the five straight sections of the machine, while one of the remaining straight sections would contain the necessary equipment to extract the protons and guide them into the experimental area and the heavy metal target.

The existing Nimrod magnet hall also provides sufficient shielding for the new accelerator but care would have to be taken to control beam losses and minimise the level of induced radioactivity. This would be reflected in the design of components for the new system, but existing electrical, cooling and other mechanical services could be easily adapted for the new machine configuration.

In addition to the condensed matter research programme, other uses for the new source are possible. Copious production of 150 MeV/c pions is feasible and, as well as being used in nuclear structure work, such beams would be of assistance in medical studies on the effect of pions on tumours and in general pion therapy. This would extend the radiobiological work currently in progress at Rutherford.

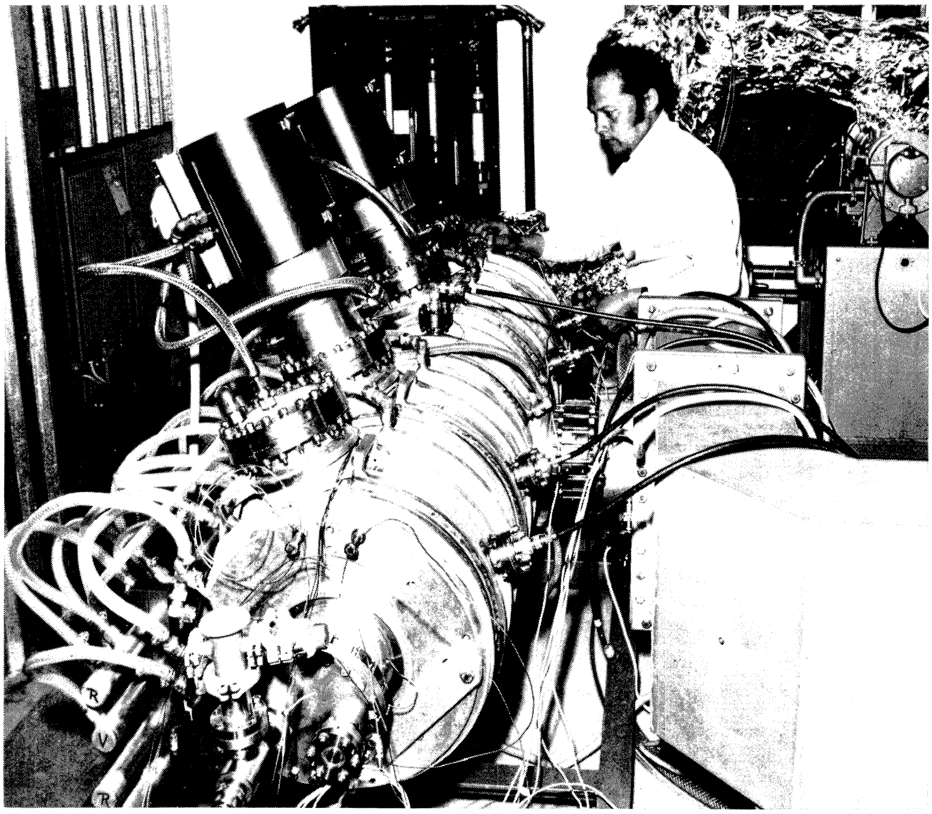
Other possible uses for the new machine, which would give it a multidisciplinary research role, include isotope production (both for commercial purposes and for hot-atom chemistry) and radiation damage studies (for fission and fusion research). Muon precession in solids is increasingly being used in other Laboratories to study the internal fields in ferromagnetics, type II superconductors and spin glasses where dilute random alloys have their spin orientations frozen in the matrix. Other applications for muon precession are the study of defects in solids, biological work and critical fluctuations in antiferromagnetics. The study of X-rays from exotic atoms would also be a significant field.

The Rutherford Laboratory is no newcomer to neutron research. For several years a Neutron Beam Research Unit, under Leo Hobbis, has been supporting the research by University physicists using facilities in the UK and at ILL. The unit is involved with the development of new instruments and techniques, the study of new neutron sources and in neutron experiments. The proposal for a higher flux neutron source would be a major extension of this work and would provide the Rutherford Laboratory, as the national high energy physics programme is curtailed, with a significant central project.

Around the Laboratories

Prototype r.f. cavity for the 19 GeV electron-positron storage ring, PETRA, being built at DESY. The cavity has been successfully tested at full power. It was thermally stable and no multipactoring was observed.

(Photo DESY)



DESY
PETRA cavity prototype tested

On 9 April, the first prototype radio-frequency cavity for the 19 GeV electron-positron storage ring, PETRA, was successfully tested with r.f. power. The results exceeded the design requirements.

About 100 MV is needed from the PETRA r.f. accelerating system when it is operating at full energy to compensate for synchrotron radiation losses and to ensure a useful beam lifetime. The r.f. system will use four 500 MHz transmitters with 8 klystrons having a nominal power output of 600 kW each. The total output power of 4.8 MW is distributed to 64 accelerating structures comprising five slot-coupled π-mode drift tube cavities.

The requirement of c.w. operation at high energy gain, together with the need to minimize the higher order mode losses and the space occupied by the r.f. system, demands a cavity structure with high shunt-impedance per unit length. There are, in addition, design considerations such as the need for rapid cavity fabrication at low cost and for a simple tuning system to compensate for reactive beam loading and thermal detuning effects.

These requirements have led to a drift tube structure with five slot coupled cavities with simple mechanical components. The geometry and dimensions have been determined on aluminium models, where the tuning system was also optimized. The cavity components are carefully designed to achieve the required high cooling rate while avoiding dangerous welds between water channels and vacuum.

An electron beam welding technique was successfully used to join the cavity components. This technique was specially developed in cooperation with the Lufthansa Aircraft Repair Factory in Hamburg. The most obvious advantages are minimal distortion, the elimination of oxidation effects, and the ability fully to penetrate thick plate sections without the use of a filler rod. Disadvantages can include weld defects such as cold shuts, root porosity and spiking. The first two, which lead to leaks or increased gas desorption during cavity operation, have been eliminated by finding the optimal beam welding parameters. Also the typical spikes of electron beam welds, which can be very dangerous because they can initiate multipactoring in the cavities, have been eliminated by careful design of the cavity component joints.

The first four cavity prototypes have been made out of AlMgSiO,S aluminium alloy, which has good electrical and thermal conductivity as well as high mechanical strength. It has, however, a tendency to crack at the weld and this has been overcome by additional electron beam oscillations during the welding.

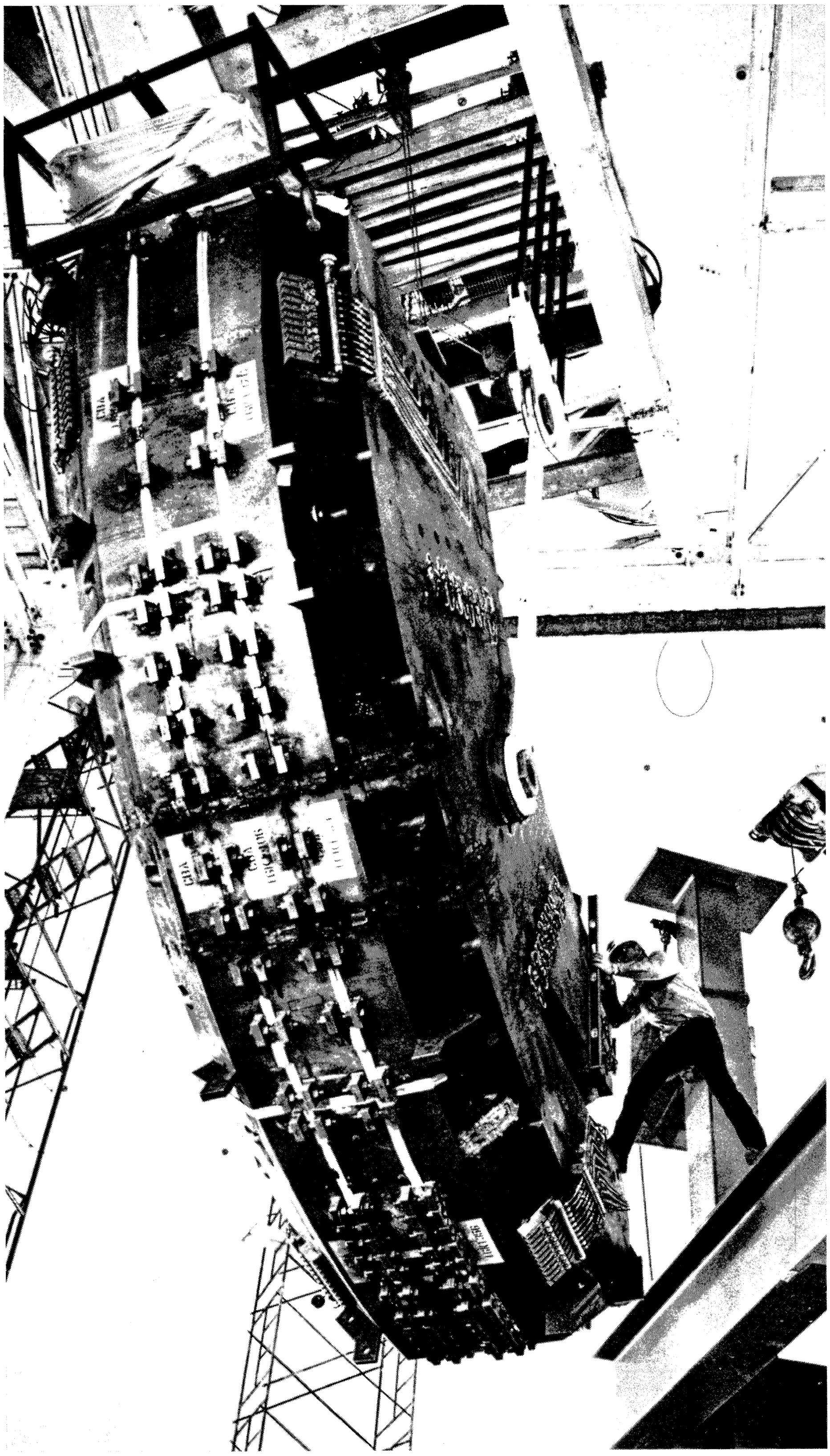
Each cavity has 17 different stainless steel flanges for r.f. feed-throughs, for tuning plungers, for pick-up and absorbing antennaes, and for vacuum components. The transitions between aluminium and stainless steel were made using the DEPI-welding procedure (see April issue). To reduce thermal problems resulting from power losses, all the stainless steel inner surfaces are copper-plated 'in situ' using d.c. sputtering. Due to the optimal design and the application of new fabrication techniques, the cavity costs were drastically reduced.

The first of the four cavities has already been successfully tested at the design power of 125 kW. No measurable changes of the resonance frequency were observed after the electron beam welding of the cavity components. During operation at full power the cavity pressure stayed in

* See page 186.

Huge magnet of the high resolution spectrometer (HRS) is lifted into place in an experimental area at the LAMPF 800 MeV proton linear accelerator. The magnet weighs 135 tons and is designed to allow energy resolution of a few parts in 10^5. It is mounted vertically and can be moved horizontally about the incoming beam direction on an air cushion.

(Photo LASL)



the ultrahigh vacuum range with only one 400 litre/s sputter-ion pump in action. Multipactoring was not observed, probably due to careful design of the coupling slots and to the clean cavity surfaces. The tuning system with only two plungers gave an equal power distribution in all five cells and it was thermally stable over the whole power range.

After the r.f. tests, the inner surface of the aluminium cavities will be copperplated by d.c. sputtering in order to increase the shunt-impedance to 13 MΩ/m. Finally they will be installed in the DORIS storage ring to increase the maximum possible beam energy to about 5 GeV.

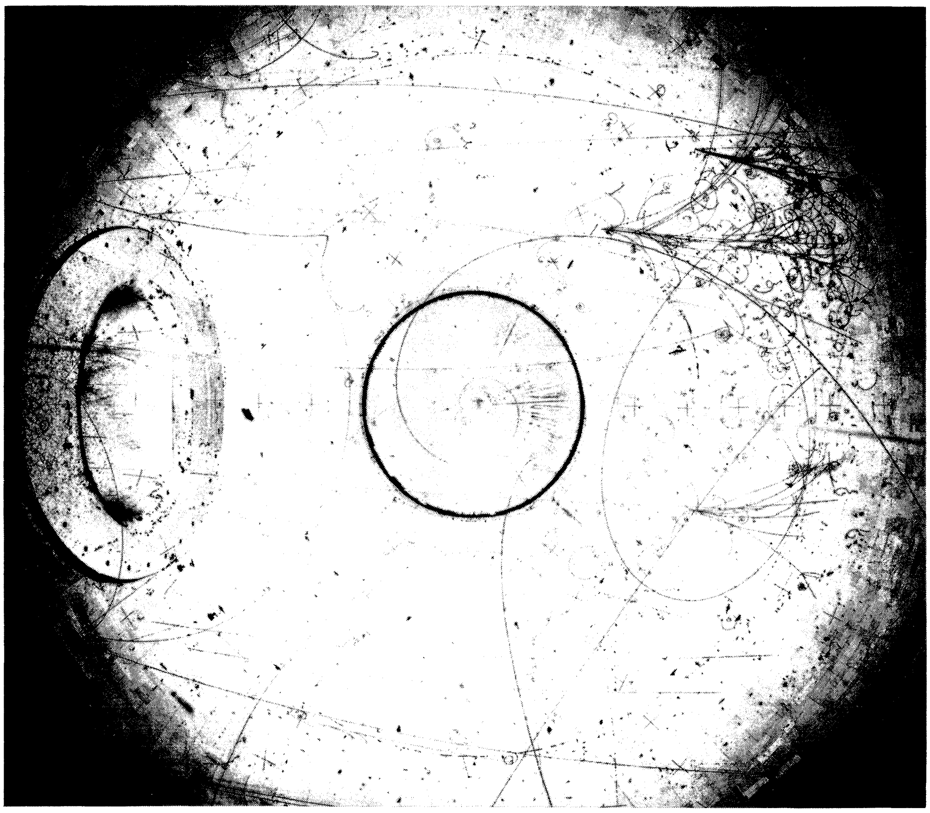
The copperplating of the aluminium cavities is a complicated technique. It has been found that, using the same electron beam welding technique, the cost of a copper structure would be almost the same as the cost of a copperplated aluminium structure. Therefore it has been decided to make the PETRA cavities out of copper. The technological problems for the production of copper cavities have already been solved and the order for series production can be placed.

FERMILAB * Experiments

Some results, some experiments under way and some future experiments planned for the 400 GeV proton synchrotron at the Fermi National Accelerator Laboratory:

First measurement of neutrino velocity

The first direct measurement of neutrino velocity has been made in an experiment by a team from Brookhaven / Cal.Tech / Fermilab / Purdue / Rockefeller. The measurement was



Neutrino interactions in the Fermilab 15 foot bubble chamber with a neon-hydrogen liquid mixture (77 mole percent) photographed in April. An average of almost one neutrino interaction per picture is found with 10^{13} protons at 400 GeV on the target. Frequently, the chamber is flooded with tracks from several neutrino interactions in the same exposure. In addition to increasing the interaction rate, the heavy liquid mixture allows many of the particles from neutrino interactions to be recognized by direct inspection of the track appearance - protons, charged pions and kaons producing secondary interactions, neutral pions giving gamma rays converting to electron pairs, muons sailing through without interacting and direct electrons or positrons with successive kinks and associated gamma ray conversions along their tracks. A major interest in the present experiment by a Columbia/Brookhaven collaboration is the study of di-lepton events in which two muons or a muon and an electron are produced.

made to a precision of about five parts in ten thousand which is possible given the large scale of the Fermilab neutrino area, with a neutrino beam line a kilometre long.

Within the precision of this first measurement, the neutrinos fly through the 1800 feet of earth and steel at the same speed as light in free space. The fact that the neutrinos move with the speed of light is not surprising since it is considered to be a massless particle like the particle of light, the photon. Whenever it is possible, it is wise to check beliefs like this. The neutrino is such a peculiar object that precise measurements may well show that its velocity differs slightly from that of light.

When particles are produced with moderate energy protons on the target, only neutrinos penetrate the 1800 foot shield between the decay pipe and the 150 ton detector (first used for the Cal.Tech/Fermilab neutrino experiment). At the highest available proton energy (400 GeV), muons also reach the detector and the measurement was made by comparing the distribution of arrival times of the neutrinos and the muons at the same counter. This pattern reproduced the short bursts of the protons originally striking the target indicating that all the particles travelled at the velocity of light.

Another clue to something at 6 GeV

We reported in the March issue (page 83) the evidence from an experiment of the Leon Lederman team at Fermilab for a particle of mass close to 6 GeV. It appeared in measurements on electron-positron pairs. Since then there has been a careful search at the SPEAR storage ring at Stanford which found nothing emerging from electron-positron collisions at that energy.

There is another clue from Fermilab in a simple experiment set up by D. Eartly (Fermilab), G. Giacomelli (Bologna) and K. Pretz (Max Planck Institute Munich). They had a couple of range telescopes behind a beam dump and measured muon pairs, produced by proton collisions with nucleons in the dump, whenever they penetrated the two arms of the detector. The muon momentum was measured from its range along an arm consisting of interspersed steel blocks and scintillation counters.

Such a simple system could only hope to find gross structure in the dimuon spectrum. Nevertheless the famous 3.1 GeV particle appeared clearly as a knee in the dimuon mass distribution. There was nothing noticeable at 3.7 or 4.1 GeV but at 6 GeV a similar prominent knee occurred. Their paper to Phys. Rev. Letters (which appeared as a Fermilab report a year ago) mentions that an exotic state of charmed quarks ($c\bar{c}c\bar{c}$, which is a sort of double J/ψ if the charmed quark interpretation of the 3.1 GeV particle is correct) was predicted at 6.2 GeV by Y. Iwasaki.

Hybridized emulsion experiments

The recent interest in the search for short lived particles, including charmed particles and heavy leptons, has stimulated a revival of research with nuclear emulsions at Fermilab and elsewhere. The reason is that nuclear emulsions, although a clumsy detector in other ways, are capable of extraordinarily high spatial resolution (a few microns) and might sort out what happens at the vertex of interactions with such short lived particles better than other detectors. In two experiments which are now under way at Fermilab, emulsion stacks are used in hybrid systems with electronic tagging to overcome the difficulty of searching

Hydrogen jet intersected by the internal beam of about 10^{13} circulating protons or 5×10^{17} protons/s in the Fermilab accelerator. The accelerator beam traverses the jet about 45 mm from the nozzle exit and the whole jet becomes visible giving a good idea of the small jet divergence.

for low cross section processes with emulsions alone.

One experiment, a search for short lived particles produced in deep inelastic muon interactions, has used a hybrid system of nuclear emulsions, drift chambers and muon spectrometer mounted in the muon laboratory by a team from Cornell/Fermilab/Krakow/Michigan State/Washington. Inelastic muon scatters at large Q^2 are tagged by the drift chamber, muon spectrometer system and the location of the muon interaction vertex is pinpointed within a volume of about 1/2 mm × 1/2 mm × 10 mm in the nuclear emulsion. The experiment used the muon spectrometer employed earlier by a Cornell / LBL / Michigan State / UCSD collaboration which observed a small but significant violation of scaling in deep inelastic muon interactions.

The experiment was set up in the summer of 1975 and had a short test run in September followed by a data run in December. A total of 24 emulsion stacks, each of area 40 cm^2 and 5 cm thick, were exposed to a beam of 150 GeV positive muons. Typically, the total beam exposure for an emulsion stack was 5×10^5 muons/cm^2. Several hundred high Q^2 events have been tagged.

Analysis is now in progress. The data from proportional and drift chambers in the incident beam can be used to locate the x and y position of an interaction vertex to within $\pm$ 200 μm. Software to locate the position of an interaction vertex along the beam is being developed.

Using tagging data from the electronics detectors, the emulsion groups at Seattle and Krakow have begun to search for muon scattering events. The first tagged event in the emulsion was identified in February. The space angles of eight downstream charged reaction products from the interaction were measured both in the emulsion and in proportional chambers located about 1 m downstream from the emulsion stack. The agreement between the two sets of measurements was excellent and one of the downstream charged particle tracks was also seen in the muon spectrometer.

To date, some 30 tagged events have been found. The experimenters are trying to speed the rate of emulsion scanning and to sort out the procedures to be used in searching downstream of the interaction for kinks and vees — that is, to search for evidence of decays of short lived particles.

A second hybrid emulsion experiment is searching for short lived particles produced in the interactions of high energy neutrinos. A team from Brussels / Dublin / Fermilab / London / Mulhouse/Rome/Strasbourg has assembled a detection system which includes nuclear emulsions, wide gap spark chambers, a shower detector and a scintillation counter hodoscope muon identifier. The experiment is housed about 30 m downstream of the 15 foot bubble chamber.

During the fall of 1975, the experiment was installed in the neutrino beam and three test runs were carried out in December with an emulsion stack in place. An exposure of six large emulsion stacks with a total mass of about one-tenth of a ton started in March. The experimenters anticipate a total exposure of 2×10^{18} protons on the neutrino target, with the horn system usually tuned for neutrinos, sometimes for antineutrinos. By late April, 25% of the exposure was complete. This should give rise to 100 high energy neutrino interactions and scanning and measuring of the spark chamber film is under way.

Developments at the Internal Target Area

The Internal Target Area has been in operation at Fermilab for four years and a series of experiments, including proton-nucleon elastic and inelastic scattering, searches for new particles and studies of lepton production by protons, has been completed. These experiments are characterized by variable incident energies from 8 GeV to 400 GeV or more, the use of very thin targets so that very low energy recoils can be studied, and a point geometry.

In the past year, a substantial addition has been made with the construction of an underground hall next to the main ring. The hall, completed in July 1975, is approximately 50 foot by 50 foot with two penetrations into the main ring tunnel. A superconducting spectrometer was installed during the Fall of 1975 and apparatus for the continuing US/USSR collaboration is being installed now.

Several new gas jets have been developed and put into operation. The original experiments alternated between operation with rotating solid targets and a cold hydrogen jet, built by a Dubna group, which operated very successfully. Increasing demand for internal target experiments of greater sophistication has led to the need for new targets. In a significant development, warm jets have been built by Paul Mantsch and Frank Turkot of Fermilab, Paolo Franzini and Juliette Lee Franzini from Columbia and Stony Brook and by Dan Gross at Rochester. Ernie Malamud reports that the Dubna Cryogenics Group led by Yuri Pilipenko has also constructed a warm jet.

The use of true de Laval nozzles can produce very high density (10^{-7} grams/cm^3) hydrogen jets with opening angles of only a few degrees. They typically have a diameter of 1 to 2 mm, giving a well defined interaction point which is important for recoil experiments. Another advantage of a small divergence supersonic jet is that it can be captured in a small hole and pumped away with small mechanical pumps.

Present operation employs an upstream warm jet for the Columbia/Stony Brook collaboration, a Dubna cold jet (shortly to be installed) along with a rotating target, followed downstream by another warm jet and rotating target for the superconducting spectrometer.

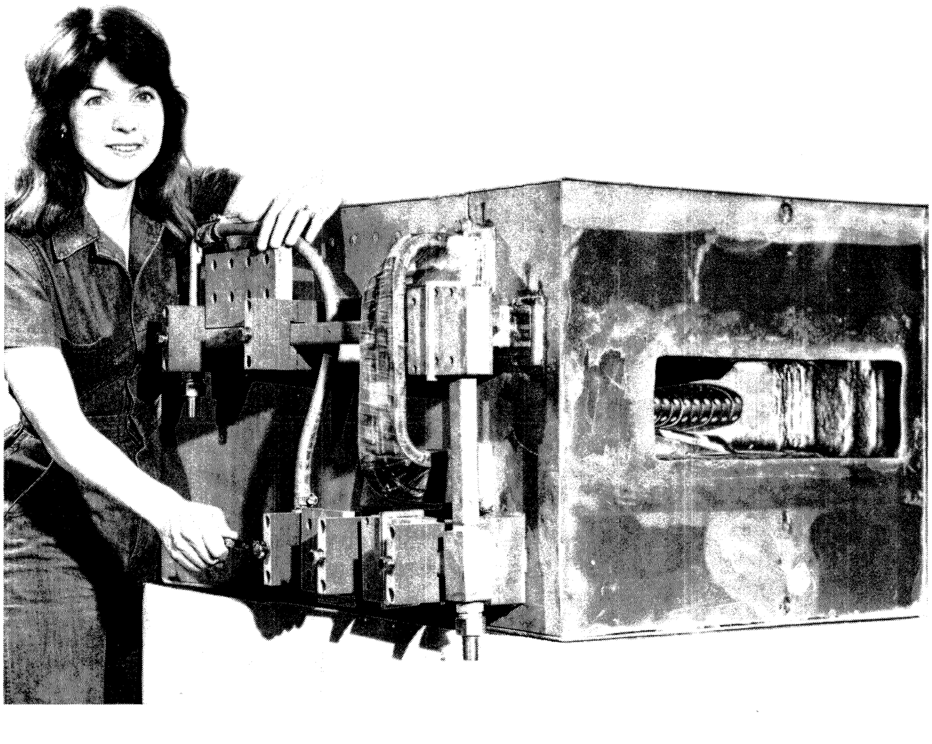
Tom Nash, new head of the Internal Target Area, relates that five different experiments are now using, or preparing to use, the area. The Columbia/Stony Brook experiment is extending to elastic and diffractive scattering on hydrogen and deuterium. The US/USSR experiment is continuing work on proton scattering off various targets. For the future, they are aiming for operation of a helium jet to measure the energy dependence of interference between single and double scattering in the helium nucleus. The new superconducting spectrometer will be used by a Rochester/Rutgers/Imperial College group to study proton elastic scattering, particularly in the region of the dip observed at the CERN ISR and at Fermilab. The superconducting spectrometer consists of an upstream quadrupole pair coupled to a 4 T bending magnet borrowed from a beam line at the Bevatron.

A group from Indiana has a proton polarimeter behind the spectrometer; a similar polarimeter was calibrated and used in an experiment at Argonne. This group will check polarization predictions of various models of proton-proton scattering. Measurements near the dip in the elastic differential cross section will provide a new tool for unraveling what is happening in that region. A Fermilab/Purdue team will use the same jet to do proton scattering on different gases.

For the future, all of the experiments presently operating can be converted in a straightforward way to the higher energies that will be available with the Doubler/Saver and the new location proposed for the Doubler (below the Main Ring) will make it convenient to operate experiments in the new target hall. Also some preliminary work has recently been done on the possibility of producing polarized jets suggesting that jets may be feasible with polarizations in the neighbourhood of 70 to 95 %. If these indications are correct other polarization experiments could be done at the Internal Target Area provided the jet densities can be made high enough.

ARGONNE
First magnet for Booster

In early April, the first magnet for Booster II arrived at Argonne and assembly of the ring started. The machine is a small, rapid cycling



First magnet for the 500 MeV Booster II to be used to increase the injection energy into the Argonne Zero Gradient Synchrotron so as to achieve higher proton beam intensities. Just visible in the magnet gap is the 'electromagnetic shield liner' which surrounds the beam region to limit beam energy loss.

The completed enclosure for Booster II at the position where it is opened for installation of the magnets. Construction of the magnet ring has started and it is hoped to have circulating beam in September of this year.

(Photos Argonne)

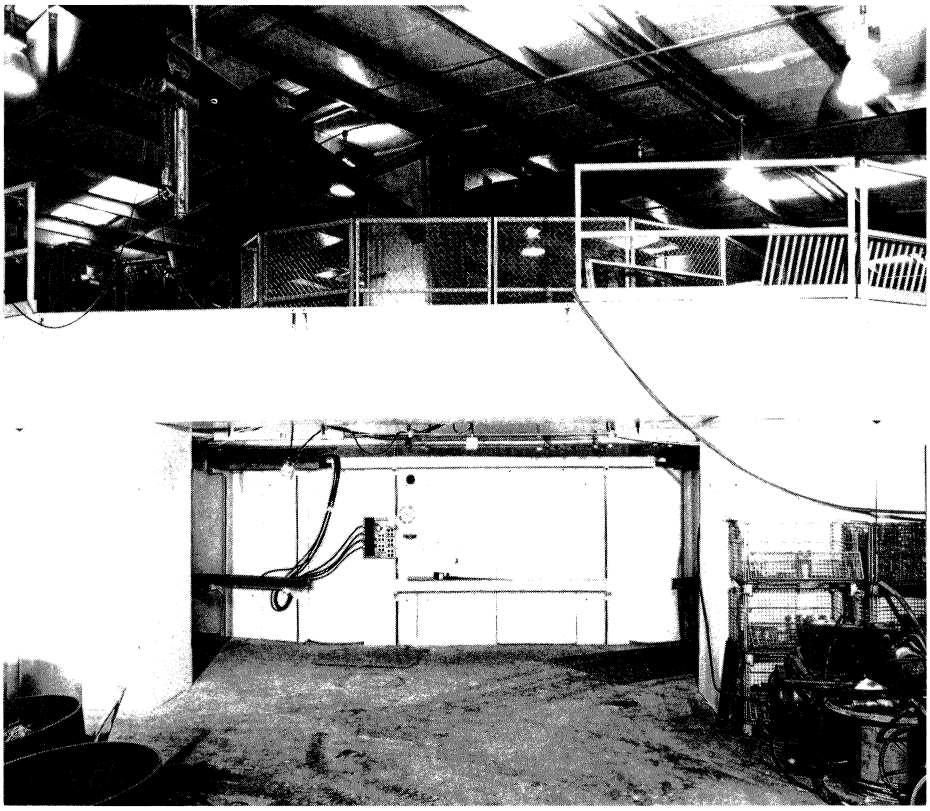
(30 pulses per second), combined-function, alternating gradient synchrotron, designed to accept 50 MeV negatively charged hydrogen ions from the present ZGS linac, strip them at injection to positively charged protons and accelerate them to 500 MeV for injection into the ZGS.

The use of H^- injection, a unique feature of Booster II that allows much more intense circulating beams than conventional proton injection, has been successfully tested with the experimental Booster I as well as by direct H^- injection into the ZGS. The increased injection energy into the ZGS using Booster II instead of the 50 MeV linac will avoid low energy losses and should enable the ZGS to attain circulating beam intensities well over 10^{13} protons per pulse.

In addition to feeding the ZGS, the 500 MeV protons may be used directly for research. The use of Booster II as a prototype for an intense pulsed neutron source for condensed matter studies is under serious consideration. Another possible application is the production of intense low energy muon beams. Such uses of Booster II could be simultaneous with its use as the ZGS injector, which requires relatively little of the Booster II duty cycle.

The newly delivered magnet is constructed of 0.35 mm thick iron laminations, each singlet magnet having 1700 of these laminations and each triplet magnet 8000. Electromagnetic shield liners are mounted within the magnets to prevent image currents developing within the resistive walls of the laminations. The liners will reduce the beam energy loss to less than 1 keV/turn. The remaining losses will be removed later by utilizing betatron induction magnets that apply an induction field for the last millisecond or so prior to extraction.

Booster II will have six singlet and six triplet magnets, arranged on a 66.7 m circumference. The magnets will be mounted on support columns mechanically decoupled from the building floor which should greatly reduce the alignment problems encountered with Booster I caused by movements of the concrete slab floor. The straight section boxes to be placed between the singlet and triplet magnets, containing the extraction septum, injection bumpers, the H^- stripper mechanism and beam diagnostic equipment, have been fabricated. Components of the 50 MeV line supplying the negative ions are almost all in position.



The booster tunnel has recently been completed and services installed. The centre core of the tunnel contains large capacitor banks to resonate the ring magnets at their 30 Hz operating frequency. Two r.f. stations operating in the 2 to 5 MHz band will provide 22 kV of accelerating voltage to single gap resonant cavities placed 180° apart. R.f. energy of 50 kW (25 kW per station) is required to produce the accelerating voltage, with another 25 kW supplied to the proton beam. To accomplish this and to provide some reserve power, two power amplifiers, capable of 100 kW each are mounted below the 1.32 m long accelerating cavities.

Delivery of all Booster II components is on schedule for producing the first circulating beam in September of this year.

Spin-spin forces increasing with energy

An experiment using the polarized proton beam from the ZGS to probe the inner structure of the proton has demonstrated that the spin-spin force in high energy large angle proton-proton elastic scattering becomes larger with increasing energy. This effect was observed during the February 1976 run of the polarized proton beam. The run was at 11.75 GeV/c and provided the first opportunity to study spin-spin interactions above 6 GeV/c. A.D. Krisch (Michigan/Niels Bohr Institute) qualifies this growth with energy as 'a very surprising result'. It was generally assumed that all strong interaction spin effects would become less important at higher energy or at best be independent of energy.

In atomic physics, where the typical energy is a few eV, the effects due to the proton spin are very important. For example, the Pauli exclusion principle makes it impossible for two electrons with the same spin to occupy the same position in an atom and thus the spin forces in atoms determine many of the chemical properties of the elements. In high energy physics, where the typical energy is a few GeV, many scientists believed that spin could not have a very important effect on proton-proton scattering cross sections. However, the proton can easily have a rotational energy of 100 MeV caused by its spin.

The experiment was done by a group of physicists from Michigan/Argonne/Niels Bohr Institute/CERN/Max Planck Institute/St. Louis. They measured the differential cross section for proton-proton elastic scattering when both the beam proton and the target proton are in pure spin states. The beam protons came from the ZGS polarized beam which had an intensity of almost 10^{10} protons per pulse, and a polarization of just above 50 %. The target protons were in the Michigan/Argonne polarized proton target where the polarization averaged about 65 %. The elastic cross section in each spin state was measured using a simple double arm spectrometer containing three magnets and six scintillation counters.

The spin of both the target proton and the beam proton were oriented vertically and thus perpendicular to the horizontal scattering plane. The four measured cross sections correspond to the four possible spin combination states from which the spin-spin part of the interaction can be calculated. This was never studied before above 6 GeV/c because it requires both a polarized beam and a polarized target.

The group also measured the left-right scattering asymmetry parameter, which had previously been measured at CERN and Argonne using a polarized target and an unpolarized beam. This measures the spin-orbit forces in proton-proton elastic scattering. The new measurements confirm these earlier results with high precision. This makes two effects very clear — the asymmetry parameter clearly decreases with energy at small transverse momentum and is approximately independent of energy at large transverse momentum.

The most surprising result is that at large transverse momentum the spin-spin part of the interaction increases strongly with energy. It is about three times larger at 11.75 GeV/c than at 6 GeV/c. The results mean that the forces causing proton-proton scattering are stronger when the two spinning protons rotate in the same direction than when they rotate in opposite directions and that this difference is increasing with energy.

Thus the spin dependence of strong interactions appears to be rather different than was expected. In large transverse momentum elastic scattering, which probes the core of the proton, the spin forces seem to remain important. The spin-orbit force seems independent of energy, while the spin-spin force grows with energy.

One simple picture of what is happening uses the old 'onion model' of the proton, which sees the proton as having several layers like an onion. The outer layers are involved in the low transverse momentum interactions while the inner core is involved in the high transverse momentum interactions. The new results indicate that the proton may be a spinning onion with the outer cloud spinning slowly and the inner core spinning very rapidly.

TRIUMF Pions stopped in hydrogen and deuterium

Three secondary beams of pions and muons are currently in use at TRIUMF. All are produced from target T2 which intercepts the more intense of the two primary proton beams extracted simultaneously from the 500 MeV negative hydrogen ion cyclotron. The target ladder actually offers a choice of six targets of beryllium, water or copper of various lengths. The target, which was designed and built at the University of Victoria by T.A. Hodges, was moved into position in its 30 ton lead shielded vacuum vessel early in 1975 and produced its first mesons in June. This year it has run steadily with the 1 μA proton beams to which TRIUMF is temporarily limited by the amount of shielding available.

Two of the three secondary beams are taken off in the forward direction — the biomedical channel (M8) at 30° upwards then bending to the right, and the stopped muon channel (M20), which is dedicated to muon spin precession studies, at 55° to the left. The third channel (M9), with which the remainder of this article is concerned, accepts pions and muons emitted at 135° to the left. It was originally designed as a stopped pion/muon channel, but in view of the postponement

Bird's eye view of TRIUMF's three pion and muon beam lines emanating from the pion production target T2 — before being immured in concrete. Working counter-clockwise from the right are (i) the negative pion biomedical channel M8, (ii) the stopped muon channel M20, (iii) the stopped pion/muon channel M9, (iv) the incoming proton beam line which is due to be extended beyond T2 to a 180 kW beam dump and thermal neutron source during the coming year.

(Photo TRIUMF)

of the high resolution pion channel (M11) for lack of funds, it will also be used temporarily as a source of low energy pions. (The extra capital funds for TRIUMF, announced by the Canadian government in February, will enable a start to be made on M11 in addition to allowing the primary beam intensity to be increased to 10 μA this year.)

The analyzing section of M9 begins with a radiation-hard 20 cm quadrupole, followed by four 30 cm quadrupoles and two 45° bending magnets, giving a dispersed focus for momentum selection near the midpoint and an achromatic focus at the end. This is followed by a quadrupole triplet which can be used either to collect decay muons or to form a third pion focus 4 m downstream. Alternatively the triplet can be removed on air pads to allow stopped pion experiments at the second focus. The final element in the channel is a rehabilitated cyclotron magnet (courtesy of Oregon State University) for muon momentum analysis.

In practice, the most promising feature of the channel appears to be its ability to provide very low energy pion beams with low background and small spot size (3 cm diameter). Even 15 MeV negative pions can be clearly separated from electrons and muons by time-of-flight analysis, utilizing the r.f. microstructure of the primary beam. The channel will accept up to 65 MeV pions but is normally tuned at 30 MeV. For a 10 cm beryllium target the positive pion flux is then $1.5 \times 10^6/\mu$A s with 13 % each positron and muon contamination; the negative pion flux is $0.3 \times 10^6/\mu$A s with 50 % electron and 13 % muon. The design, construction and commissioning of M9 are the responsibility of N. Al-Qazzaz, D. Bryman, R.M. Pearce and P.A. Reeve of Victoria.

Experiments have so far used stopped beams of μ^-, π^- and π^+. They include a search for enhanced polarization of μ^- captured in rare earth elements at low temperature (Tokyo, British Columbia and Queens), π^- X-rays from ^{3}He and other light nuclei (Victoria), measurement of the $\pi^+ \rightarrow e^+\nu$ branching ratio (Victoria) and emission of heavy fragments in pion absorption (Alberta/British Columbia/Saskatchewan/Oregon State).

A major item of equipment also being tested on M9 is a neutral pion spectrometer, developed by a group led by P. Depommier and J.-M. Poutissou (Montreal) and M.D. Hasinoff, D.F. Measday and M. Salomon (British Columbia). It consists of two very large sodium iodide crystals — MINA (for Montreal INa) measures 36 cm diameter by 36 cm and TINA (for TRIUMF INa) measures 46 cm diameter by 51 cm. The use of large NaI crystals in an accelerator environment is quite rare because they have a fairly slow time response (about 250 ns) and so cannot tolerate a high count-rate. Because of their large active volume (and mass), they are very sensitive to high energy neutrons, but with a combination of good shielding and the 100 % duty-cycle of the TRIUMF cyclotron, it has proved relatively straightforward to use these excellent gamma ray spectrometers at a meson factory. The initial tests were performed by stopping a 50 MeV negative pion beam in a 1 litre flask of liquid hydrogen and observing the following reactions:

$$\pi^- + p \rightarrow \gamma + n$$

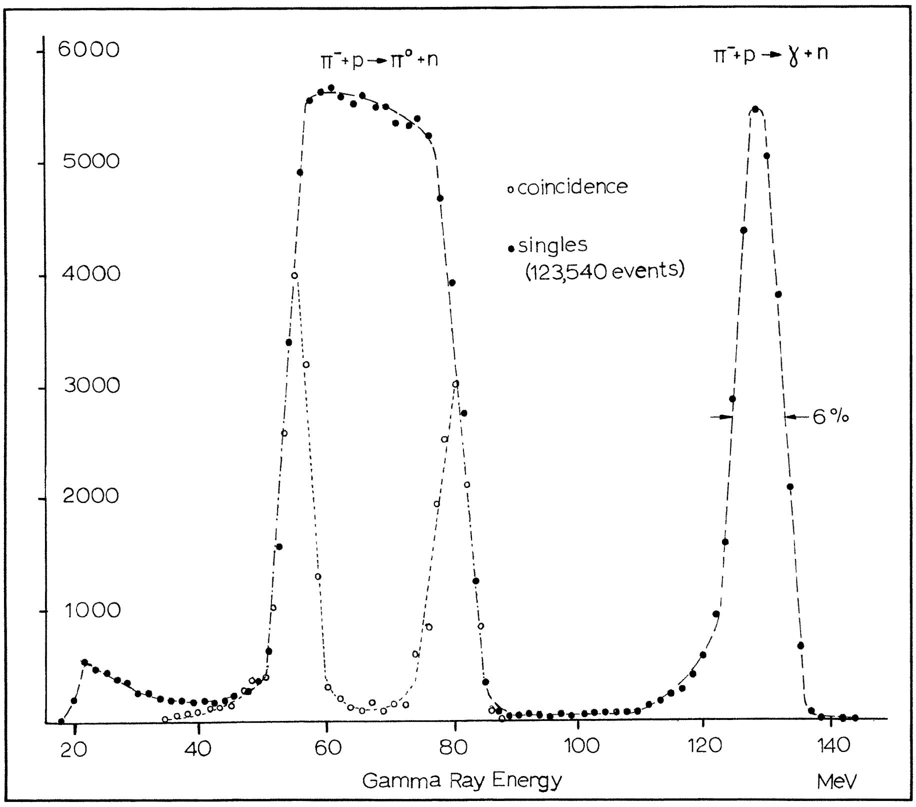
(where $E\gamma$ is 129 MeV)

$$\pi^- + p \rightarrow \pi^0 + n \rightarrow \gamma + \gamma + n$$

(where $E\gamma$ is between 55 and 83 MeV)

The ratio of the rate of neutral pion production to that for the direct production of gamma rays is the famous Panofsky ratio (P) and prior to these TRIUMF measurements, the best data were obtained on the CERN SC over 15 years ago by a group which in-

Spectrum of gamma counts which measures the Panofsky ratio (the ratio of neutral pion production to direct gamma production in negative pion-proton interactions) from an experiment at the TRIUMF cyclotron. The geometry of the gamma detectors, sodium iodide crystals either side of the hydrogen target, restricts coincidence measurements to the highest and lowest energy gammas — hence the two peak structure of open circles on the left. The coincidence spectrum is arbitrarily normalized to the data on single gamma detection; the efficiency for detecting two gammas in coincidence is about 3 % of that for single gammas.



cluded V.T. Cocconi, G. Fidecaro, N.H. Lipman and A.W. Merrison.

A spectrum of the observed gammas is illustrated with the single gamma events on TINA plotted as full circles and the coincidence events as open circles. The ratio of the pulse heights of the two peaks is a sensitive measure of the velocity of the neutral pion. The preliminary value for the Panofsky ratio is P = 1.542 ± 0.008 in agreement with the previous value 1.533 ± 0.021.

When a deuterium target is used to stop the negative pion beam the following reactions are possible:

$$\pi^- + d \rightarrow n + n$$
$$\pi^- + d \rightarrow n + n + \gamma$$
$$\pi^- + d \rightarrow n + n + \pi^0$$

The π^0 production has never been observed (branching ratio less than 10^{-3}) and twenty years ago this very low branching ratio proved that the negative and neutral pions were different charge states of the same particle. The TRIUMF spectrometer is searching for this reaction and there are indications that it has been seen at the level of 10^{-4} or so, somewhat lower than was expected.

CERN SPS — protons in and around

On 3 May the second big stage in commissioning of the CERN 400 GeV proton synchrotron (the SPS) was confronted. Last month we reported the successful transfer of the 10 GeV beam from the PS to the SPS ring. At the beginning of May it was time for the first attempt at injection and circulation of the protons.

A few days earlier, on 29 April, the PS had prepared in style with further tests on the continuous transfer system which peals the PS beam off during ten turns to give the long ribbon of protons to almost fill the circumference of the SPS ring. With a stable beam from the 50 MeV Linac, 1.25 × 10^{13} protons per pulse were accelerated in the 800 MeV Booster and the PS took 1.1 × 10^{13} to the SPS injection energy of 10 GeV. The continuous transfer ejection operated with an efficiency of 93 % so that 1.025 × 10^{13} protons were out of the PS and en route for the big machine. The design intensity of the SPS is 10^{13} protons per pulse.

On 3 May, there were two fine achievements in quick succession. First of all, about mid-day, the bending and focusing magnet fields were set up to take the 10 GeV beam and the injection system was powered. The beam went in and around the full turn at the very first attempt. Even without the orbit correction dipoles in circuit, the machine settings were so perfect that protons toured the 7 km circumference to arrive at a beam stop, near where they were injected, only millimetres away from their scheduled position.

This tells us that the injection system is working well, that the machine alignment has been impeccably done, that the magnet system (with some 744 bending magnets and 216 quadrupoles) is near perfect, that the power supplies are ticking over exactly as required and that the vacuum system is providing the necessary hole all the way around the ring.

In the course of the afternoon refined measurements and corrections were carried out and the excellent beam monitoring and control system came into its own. The beam intensities were kept to around 2 × 10^{12} protons per pulse (in case high losses occurred and resulted in unnecessary irradiation of the accelerator) and there was hardly any noticeable loss around the single turn.

The intense throng in the SPS control room on 3 May when injection and circulation of the 10 GeV protons coming from the PS was achieved without difficulty.

Oscilloscope trace from a pick up in the SPS ring indicates protons circulating almost without loss for some 300 ms, corresponding to about 12 000 turns.

In the evening the beam dump was brought into action so that the beam stop could be lifted out and the protons allowed to circulate for several turns. This brought the second success. The protons orbited for many turns immediately. Before the machine was switched off at the end of the run the injected beam was circulating during about 300 ms for some 12 000 turns. This tells us that we have a stable beam which we can hold in the ring.

At the time of writing the third stage is being confronted. This involves bringing on the radiofrequency system to capture the circulating beam into bunches which can then be accelerated. This is one of the trickiest operations requiring extremely precise timing. It is necessary to tune the time taken for the beam orbit and the r.f. travelling wave, which has a frequency of 200 MHz, so that the protons pass through the two r.f. cavities during the right part of the r.f. cycle.

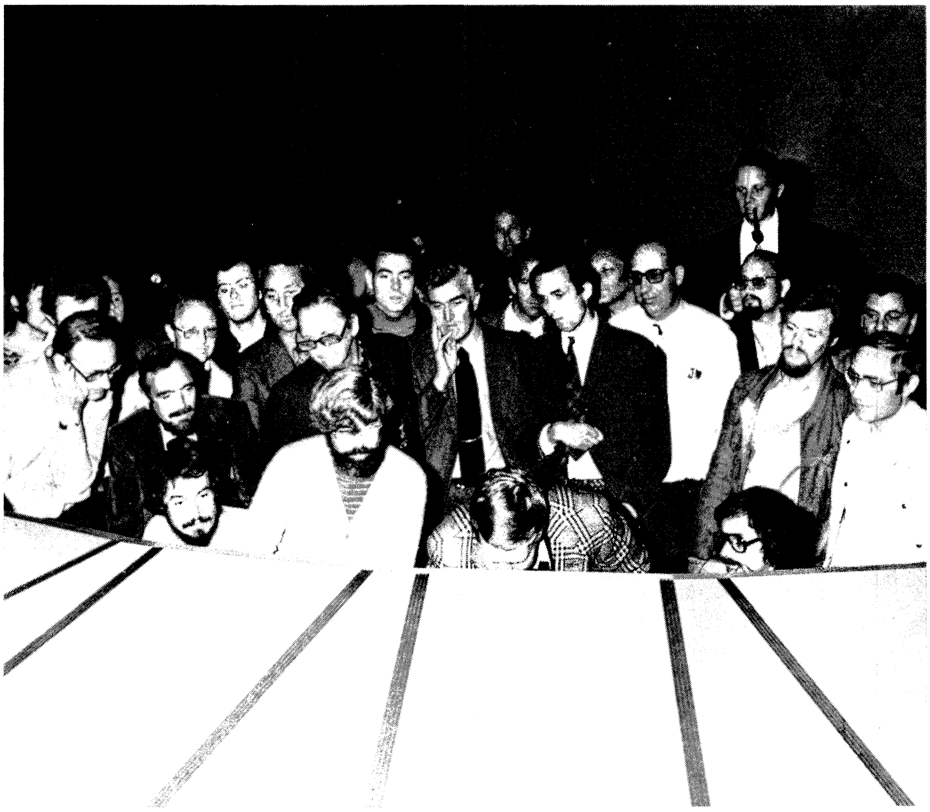
There are several more runs planned before the end of May and with luck we could carry the story of the SPS start up in our next issue.

Data Base Management at the SPS

The introduction of the CDC 7600 computer at CERN in 1972 pretty well coincided with the start of construction of the SPS and its 'front-end' 6000 computers have been used extensively in managing the assembly and installation of nearly all components of the machine. Data Base Management is a rapidly evolving branch of Computer Science but in 1972 there was no commercially available complete system which could do the job on the CDC computers and one called TABLOID (because it was based on Tables) was developed at CERN on a front-end computer while the 7600 was being tamed for the analysis of experiments.

Today, there are about 40 million characters of information concerning the SPS in about ten Data Bases (a character is a 6-bit code representing a digit or letter or other standard symbol and all this data is contained in part of a disk pack). These Data Bases have been built up and modified continuously to reflect the status of various types of equipment in the SPS tunnels and buildings.

There are two very similar Data Bases containing detailed information about some 25 000 cables in the control system and power supply system. The engineer can request up to fifty standard reports already programmed in the TABLOID language, based on these two Data Bases, or on other closely associated Data Bases concerned with drawings, stocks, ac-



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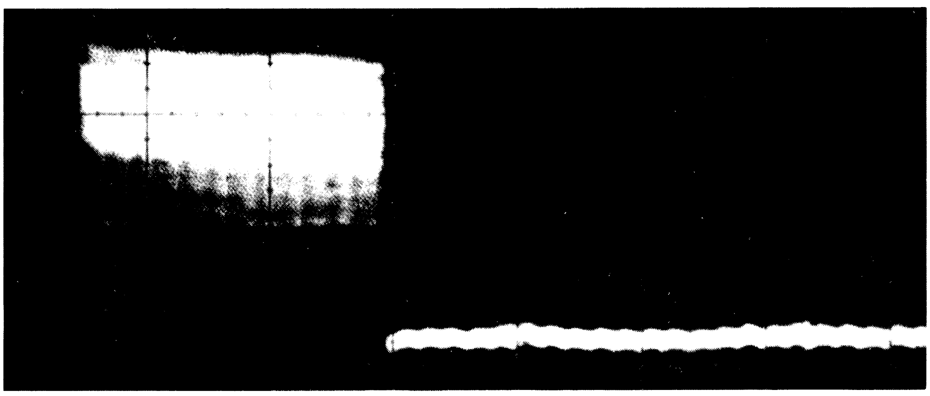


counting, etc., for the cables. A report may, for example, list full details about all cables belonging to a particular system or connected to a particular piece of apparatus. A recent refinement is that, when a new batch of cables is input to the Data Base, the computer can decide from which drums to cut them in order to minimize waste.

The largest TABLOID Data Base is the one built up by the Installation Section, which contains descriptions of approximately 100 000 accelerator elements and subassemblies together with all their connections to the various service utilities — hydraulic, electric, etc. For systems ranging from distribution boxes to mechanical supports, TABLOID has been furnishing detailed reports showing what material is to be prepared from the stores, how it is to be transported, and how the installation is proceeding. For other systems, such as magnet and vacuum, reports give just the status of the installation and lists of the material involved.

For the whole SPS, various reports are produced about every three months giving an inventory of all the material in the tunnel, and showing the structure of the machine. This Installation Data Base is supplemented by three others describing materials as they are received and stored. In addition, TABLOID is used to maintain an inventory of all movable items such as oscilloscopes or the Director's desk.

TABLOID is a batch system, and jobs are normally submitted at a Remote Input/Output Station (RIOS), the data being punched on cards and the reports received at the RIOS printer. A stack of between one and two metres of paper was being produced each week in this way for the SPS at the peak of the installation. To alleviate this paper consumption and to provide more immediate information, a separate program for interactive inspection of data in a TABLOID Data Base has been provided for some applications and microfiche is being used for the complete inventory of the SPS tunnel.

TABLOID, although designed for the SPS applications, is now being used for the production of the High Energy Reaction Analysis (HERA) reports, and several Divisions have adopted it for keeping their inventories of equipment.

Polarized deuterons

A deuteron target with a polarization of 41 to 43 % (a new high for this type of target) has recently been developed by the CERN Polarized Target Group. Work has also started on an experiment to study polarized neutrons in the $K^+n \rightarrow K^\circ p$ reaction at 6 GeV/c. The experiment will supplement the information obtained in 1971 from studies of the $K^-p \rightarrow \bar{K}^\circ n$ reaction at 6 GeV/c, using polarized protons.

The new deuteron target is much larger than the previous one. It is 12 cm long with a diameter of 16 mm. For chemical reasons, the substance used is a mixture of two propanediols, one partly containing deuterons and the other with a total deuteron content.

The high polarization rate is due to the use of a He^3/He^4 dilution cryostat, which is an improved version of that used for the frozen spin target, built by the same group (see September issue 1974). The temperature of the He^3/He^4 liquid is 0.2 K, and that of the specimen is 0.35 to 0.4 K.

The interest in experiments with polarized deuteron targets goes back a number of years. In 1970 (see July issue 1970) an experiment was carried out at CERN with a butanol target containing deuterium in which a polarization of 20 % was achieved. Some time later, a group from Bonn made tests with a propanediol containing deuterium advancing the polarization to 25 to 30 %. At present, the Rutherford Laboratory is building a target which will be used for the same experiment as at CERN but at a lower energy.

Polarized deuteron targets will be increasingly used in years to come. For example, a CERN/Annecy/Oxford group is proposing a measurement of the reactions $pn \rightarrow pn$ (elastic) and $pn \rightarrow np$ (charge exchange) at 24 GeV/c.

New look for Omega

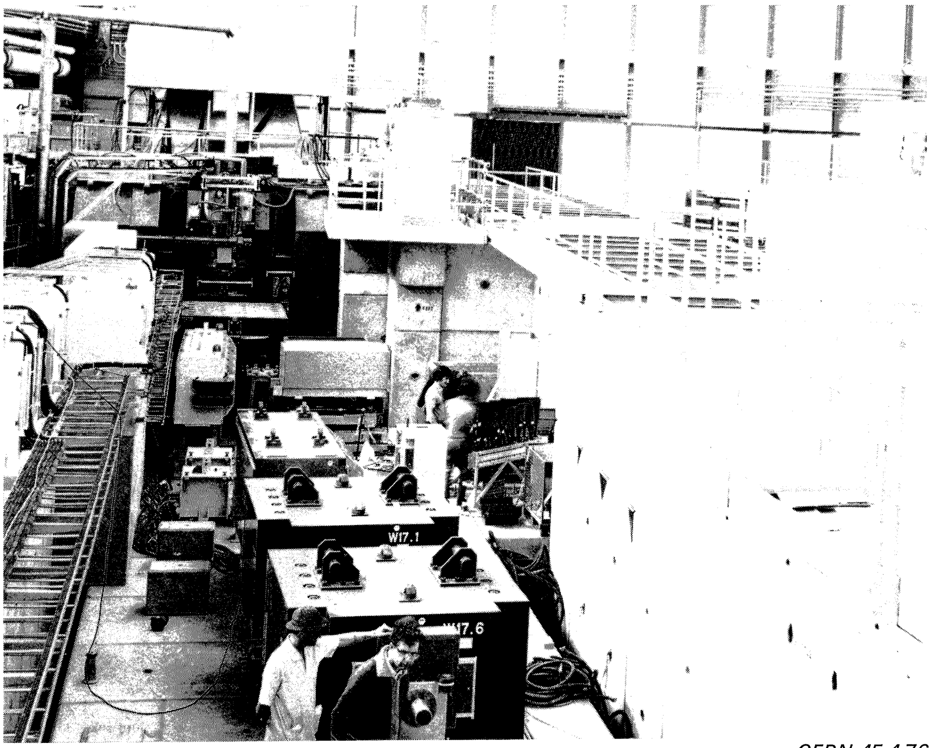
In the West Hall, the Omega spectrometer is being made ready to receive the higher energy beams from the SPS.

Two drift chambers of very large area (3.2 m × 1.7 m) will be positioned behind the Omega magnet to improve the accuracy when measuring the momenta of forward-going particles. A large gamma detector, 3 m in diameter, will also be installed. It is composed of a leadglass mosaic plane preceded by a position detector consisting of leadglass converter and a scintillation hodoscope with 800 elements. This complex represents the contribution of a large European collaboration for photon physics.

To identify the high energy particles emerging from the spectrometer, an 8 m long atmospheric pressure Cherenkov counter will be added and, to improve the resolution of multitrack events, three multiwire proportional chambers with a wire spacing of 0.5 mm will be installed downstream of the target.

All of this equipment is either under construction or testing and will be ready to be used in experiments by October. Omega will then be fed by two beam lines. The first is an 80 GeV electron beam line where the electrons will be converted into tagged photons (the tagging being done by measuring the energy of the electrons which have produced a photon in the converter).

The Omega spectrometer, sitting under its 'igloo' top left of the picture, will be fed by two beam lines when the SPS is in action. One of these beam lines is seen being installed. It incorporates a photon tagging system which is to be used in a search for charmed particles with an incoming photon beam.



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It will also be possible to use this same beam line to convey non-separated hadrons into the spectrometer.

The second beam line will convey separated hadrons which have an energy up to 40 GeV. Separation will be done by two superconducting r.f. cavities which are being built at Karlsruhe — the first of their kind to be brought into operation. They are due to be delivered at CERN towards the end of the year and it is expected that the beam line will be in action in mid-1977. Most of the installation is complete and the first tests on the cooling plant, which will keep the separators at a temperature of 1.8 K, have started.

Omega offers the possibility of a wide range of experiments which can be carried out in succession with only very slight modifications. Because of the new particle discoveries, the experimental programme has been revised. With Omega's versatility, there is no urgency to fix the programme and it can be rapidly adjusted to developments in the physics. If present ideas on charm are still valid when the SPS provides particles, experimentalists will look for charmed particles produced in pairs using a triggering system which will give a very substantial increase in the 'luminosity' for this type of event. 7-pronged events are of particular interest.

Pion beams will be used to find events producing muon pairs by installing a copper absorber through which only muons can pass. Studies will be made of J/ψ production and it should be possible to record several thousand a day. Special attention will be paid to finding events in which three muons are produced (two from the J/ψ decay and one from a charmed particle).

For the r.f. beam, several experiments have been proposed, particularly in connection with the study of strange particles and the study of $\bar{p}p \rightarrow \bar{p}p$ in the range 5 to 10 GeV (where the SPS will provide a very intense beam of antiprotons).

The experiments will be carried out by large collaborations in which many European laboratories are participating. Experiments with tagged photons and those with hadrons can follow one another in quick succession (each lasting about three weeks). Data from one can be analysed whilst the other is collecting more.

There is a general hubbub elsewhere in the West Area as excitement mounts with the commissioning of the 400 GeV proton synchrotron which is scheduled to give beams into the Area by February of next year. Experiments are, in fact, likely to start before the end of this year.

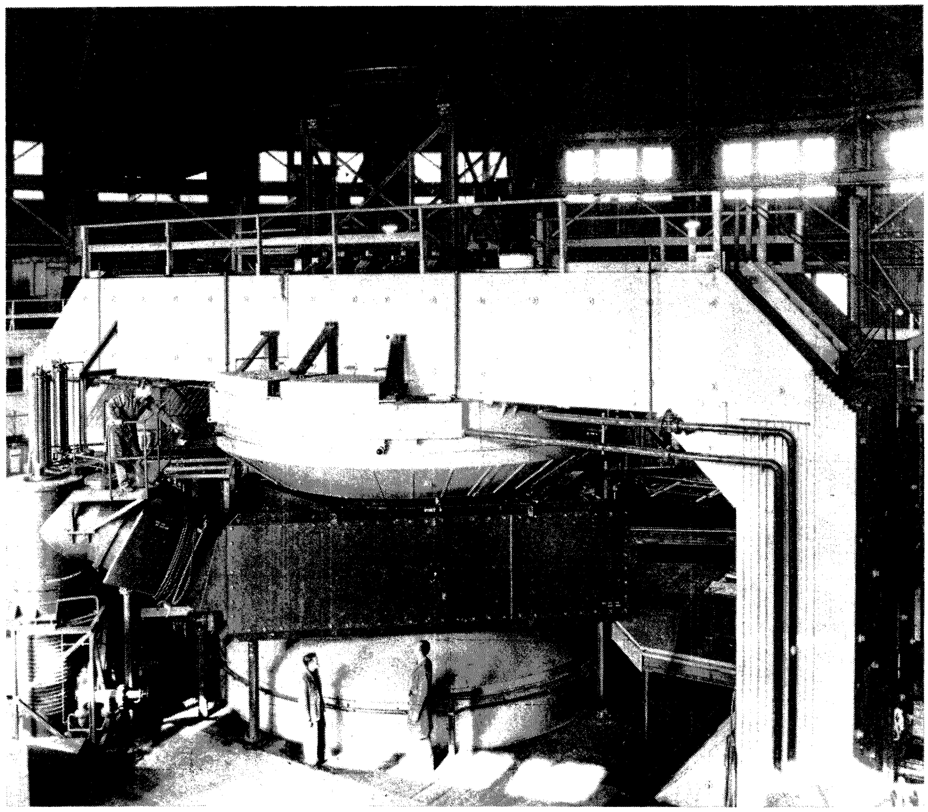
The West Hall will receive beams generated by protons of energy up to 200 GeV (the area of the Hall limits the peak energy which can usefully be used). Nine experiments are in preparation and, regardless of the detection systems themselves, some idea of the scale of the preparations can be obtained from the fact that these experiments need to be embedded in some 40 000 tons of concrete and up to 6000 tons of iron shielding. In addition to Omega, there will be other large spectrometer magnets (Orsay spectrometer magnet, AEG magnet and the imposingly named Goliath spectrometer magnet).

At the end of the Hall, the 3.7 m European bubble chamber BEBC, a counter experiment and the heavy liquid bubble chamber Gargamelle are being made ready to receive neutrino beams generated by 400 GeV protons. A track sensitive target is installed in BEBC ready for testing towards the end of May. The iron cored magnet units, scintillators, drift chambers and electronics of the counter experiment are coming together. The move of Gargamelle from the PS is well under way.

People and things

The 184 inch synchro-cyclotron built by E.O. Lawrence at Berkeley, photographed shortly after completion in 1946. Originally designed for 100 MeV protons, it accelerated deuterons to 200 MeV and was able to produce the newly discovered mesons in the late 40's. It was a prolific source of particle and nuclear physics results but has now dropped its physics role to become a medical facility for therapy and biological studies.

(Photo LBL)



Records at the ZGS

On 23 March the ZGS established a new record circulating intensity of 5.4 × 10^{12} protons per pulse passing the 4.1 × 10^{12} achieved in January 1975. The dramatic improvement was the result of using lower rate of field rise at injection, with the debuncher used to control the injected beam energy spread. Corresponding to the new peak intensity record was a new record 24-hour average circulating intensity of 4.6 × 10^{12}, compared to the previous 3.5 × 10^{12}. This increase in circulating intensity, combined with high extraction efficiencies using slow resonant extraction (see January 1976 COURIER) means that many more protons are now available to experimenters.

Another record performer in March was the 12 foot bubble chamber, where 708 000 pictures of 6.5 GeV/c negative kaons in hydrogen were taken. The chamber was double pulsed with the two pulses separated by 300 ms. Combined with 200 000 pictures of 12 GeV/c polarized protons in hydrogen taken at the end of February and 200 000 pictures of low energy antiprotons in deuterium being taken during April, the chamber will have logged 1.1 million pictures in a little over two months.

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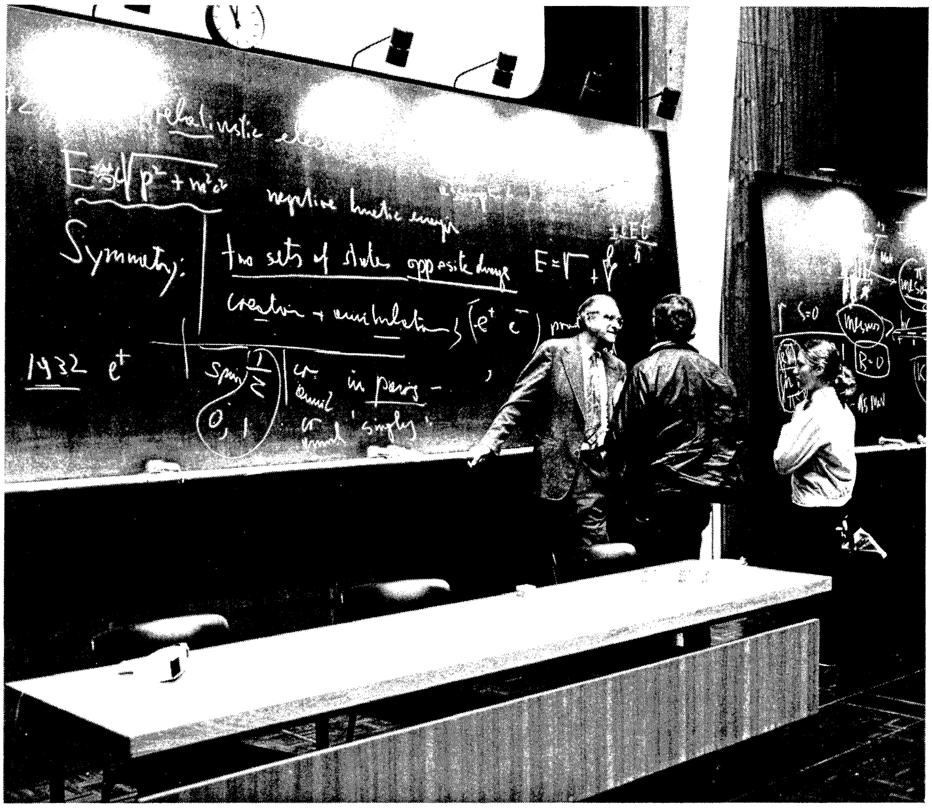
Some like it cold

The world's largest helium liquefier is to be built by CTi-Cryogenics in collaboration with Sulzer and to be installed at Fermilab before the end of 1977. CTi have also recently delivered a new refrigeration system to Brookhaven to be used in their development programme on superconducting power transmission lines.

Appointments at DESY Scientific Council

At its April session, the Scientific Council of DESY elected Prof. V. Soergel (Heidelberg) as Chairman in succession to Prof. W. Paul (Bonn). The Council also decided to extend its representation by electing foreign members. A PETRA Machine Committee is being nominated in addition to the PETRA Research Committee. Secretary of the Research Committee is Dr. W. Bartel of DESY who may be contacted on all questions in connection with letters of intent or proposals for PETRA experiments. The first meeting of the PETRA Research Committee is planned for 1 June.

Professor Weisskopf, who has received the Oersted Medal from the American Association of Physics Teachers, lectures to the vacation students at CERN during his regular summer visits. He is seen here in discussion after one of these lectures.



CERN 146.7.73

Conferences

28 June–9 July: A study on the uses of the Energy Doubler/Saver will be held at Fermilab. The study will concentrate on the new physics that will be opened up by the Doubler, on the modifications needed in the present experimental areas and what a new area, whimsically christened the 'Quark Area', might look like. Further information from Joe Lach at Fermilab, P.O. Box 500, Batavia, Illinois 60510.
12–16 July: The Third Study Group on High Energy Heavy Ion Physics will be held at Berkeley. There will be talks and discussion on the experimental and theoretical accomplishments of the past year and on the perspectives for the future in heavy ion physics covering the range 20 MeV/nucleon to 2 GeV/nucleon. Further information from N.K. Glendenning or L. Schroeder, Summer Study Group, Lawrence Berkeley Laboratory, Berkeley, California 94720.

New accelerator column at Fermilab

During the March shutdown, a new accelerator column was installed in the Cockcroft-Walton pre-injector at the Fermilab. The new column has a larger aperture in the accelerating electrodes permitting more protons to be accelerated. First operation has boosted the current out of the linac from a previous high of 160 mA for normal operation to 215 mA. Aging of the ion source and column is expected to increase the current further with the goal of 240 mA for single turn (2.8 μs) injection into the booster. This will enable over 5 × 10^{13} protons to be injected into the main ring with the 13 booster pulses needed to fill the main ring. The 8 GeV beam extracted from the booster so far has been increased to 2.54 × 10^{13} protons.

Physics awards

Victor F. Weisskopf has been awarded the Oersted Medal — the highest award of the American Association of Physics Teachers. The medal is given for outstanding contributions in the teaching of physics and can rarely have had a more deserving recipient than Vikki Weisskopf who continues to give a great deal of his time and energy to the communication of science. His general lectures on physics draw large audiences wherever he goes. For example, for his recent talks on 'Modern Physics without Mathematics' at MIT, no lecture room large enough to hold all who wished to attend could be found. His written work on science is no less popular.

Professor E.C.G. Stueckelberg has been awarded the Max Planck Medal for 1976 for his basic work on field theory. Ernest Stueckelberg is presently Honorary Professor at the University of Geneva and also works in the Theory Division at CERN. He was born at Bale in Switzerland and this year has also been elected Honorary Member of the Swiss Physical Society.

Superconducting quad for ISR

A prototype superconducting quadrupole for a possible high luminosity insertion in the CERN Intersecting Storage Rings was successfully tested in a vertical cryostat in the first week of May. Already at its second quench the magnet produced a field gradient in excess of the design value (40 T/m in a 173 mm warm bore) and after a few further quenches reached the wire limit conditions. The maximum gradient was 47 T/m with a maximum induction of 6 T in the windings and a stored energy of 700 kJ. The magnet has to be fitted with 6-pole and 12-pole windings, presently under fabrication, and will then be inserted into a horizontal cryostat for final testing and magnetic measurements.

Soviet neutrino telescope

A vast detector is being installed under a mountain in the Caucasians to detect solar neutrinos. The hunt for solar neutrinos has been led by R. Davis of Brookhaven and the low rate that has been observed, compared to that calculated from the assumed burning cycle of the sun, has been one of the physics mysteries of recent years. The Soviet neutrino telescope has a first module covering 2000 m² composed of cubic tanks each holding 150 litres of liquid scintillator (white spirit). Eight modules are planned (four vertical and four horizontal) for the complete detector. A huge cave has been cut out to hold the tanks and it has been lined with special rock, which has low radioactivity, and steel. The neutrino telescope is part of an astrophysics research station of the Soviet Academy of Sciences. The world's largest optical telescope with a 6 m mirror and a radio-telescope are in the same region.

500 GeV at Fermilab

On 14 May protons were accelerated to 500 GeV in the Fermilab synchrotron for the first time. Beam was ejected to the neutrino area and bubble chamber pictures were taken at the new high energy. More next month.

A point of view

From time to time we hope to carry individual comment on aspects of the high energy physics scene under the title of 'A Point of view'. This month we reprint (with kind permission) an editorial which appeared in the November 1975 issue of the fine American science journal 'Physics Today'. It is written by R.R. Wilson, Director of the Fermi National Accelerator Laboratory and relates to our opening article in this issue concerning a 'very big accelerator'. We could hardly choose anyone more appropriate to begin a series of 'individual comment' since we could hardly choose anyone more 'individual'. Bob Wilson has repeatedly distinguished himself by feats of imagination which take his thoughts beyond what is preoccupying most of his colleagues. The Fermilab itself is a monument to this vision. It is a pleasure to open our pages to his comment.

It has been a long-time ambition of scientists to build an international laboratory, one with participation from every nation in the world. In CERN, Centre Européen pour la Recherche Nucléaire (how it rolls off the tongue), we already have the prototype, the paradigm, the Platonian ideal for such a laboratory. When suggested some twenty-five years ago, CERN was regarded as the impossible dream of visionaries. How could those divisive nations ever come together and agree upon anything? But now it is taken for granted as the successful vehicle of European collaboration. France may pull out of NATO, but is it thinkable that she pull out of CERN? Nor can there be any question of the scientific value of CERN. Had Western Europe proceeded on narrow nationalistic lines, then each of the nations would have been swamped by the order-of-magnitude larger effort of the USSR

or the US. Instead, through CERN they have managed to achieve a degree of scientific excellence that must be reflected by their political leaders in a pride of culture, a sense of self that may be an important background for playing a significant role in world affairs.

CERN grew out of a long tradition of the universality of scientific knowledge. Every country takes pride in its own contributions, but, as every scientist knows, a separate and distinct German electricity did not develop in isolation nor did a Russian chemistry. This tradition of internationalism has infused and informed science, has contributed importantly to its growth. In the very communality of this development a direct communication has developed between scientists of different countries, and this has led to personal friendships which in turn provide a mutual basis for understanding important problems that transcend those of science.

During the 'cold war' the cultural interchange between the USSR and US almost came to a halt. Immediately following the 'thaw', among the first to establish exchanges were physicists. Resumption of physics talk — ah, that was easy. But very soon the conversations were cautiously extended to social and political questions much more difficult to discuss with any understanding. However, here scientists have an advantage over statesmen, because they can start from the friendly, neutral and well calibrated statements of science and then go on to the charged and tenuous terms of politics.

Those tentative discussions led to the Pugwash Conferences, designed largely to discuss disarmament. The success of the Pugwash conversations led directly to the official discussions about the Nuclear Weapons Test Ban Agreement and, less directly, to the SALT talks. This is not to say that scientists can bring about disarmament or peace between nations — political leaders do that.

However, scientists can be among the first to sense areas of possible agreement — they may even be among the first to recognize the urgency for it, they may be useful in giving technical advice — none of this having much to do with science itself — except that for science to survive, we must all survive.

Perhaps the international experience of scientists in living in accord and cooperation is relevant in this present crisis of survival and can be of some help. Maybe CERN will stand as a hopeful beacon, the impossible become real. And perhaps a world laboratory, aside from the obvious scientific benefits, could carry this experience an important step further. Just as CERN had to solve problems of currencies, of languages, of national prerogatives, of industrial cooperation between the European nations, the solution to all of which may have contributed seminally to the establishment of the Common Market, so might a world laboratory break similar ground on a truly global scale.

Space physics, astronomy and high energy physics as well as other disciplines, can offer projects appropriate to this scale. In particular, high energy physicists have met together, perhaps for about 15 years each year in a different country, to discuss collaboration in general, the world laboratory in particular. Although a healthy collaboration now takes place between many of the countries, attempts to form a world laboratory have been confounded by national plans for immediate projects. An 80 GeV synchrotron at Serpukhov, intersecting storage rings at CERN, a 400 GeV synchrotron at Batavia, an even larger machine at CERN, all stand in mute testimony of what might have been done more economically, perhaps more intensely, at one world laboratory. However, it can be said of all those facilities that their exploitation has indeed been on a truly international basis — and to everyone's benefit.

But a new opportunity for a world laboratory is in the air. We can now see that the multi-hundred GeV level will not be enough, that an accelerator ten miles in diameter rather than one mile will be required to give a more complete picture of elementary particles. Particle physicists need ten-thousand-billion electronvolts — ten TeV — one billion dollars. If they and the statesmen of *all* the nations of the world can get together to build and operate such a laboratory — on a really world scale — then the individual nations will get more knowledge, more technology and more opportunities in science for their money and effort. Even more important to the nations, such an undertaking might well provide some of the experience in international living so necessary for human survival — a candle in the darkness.

R.R. Wilson

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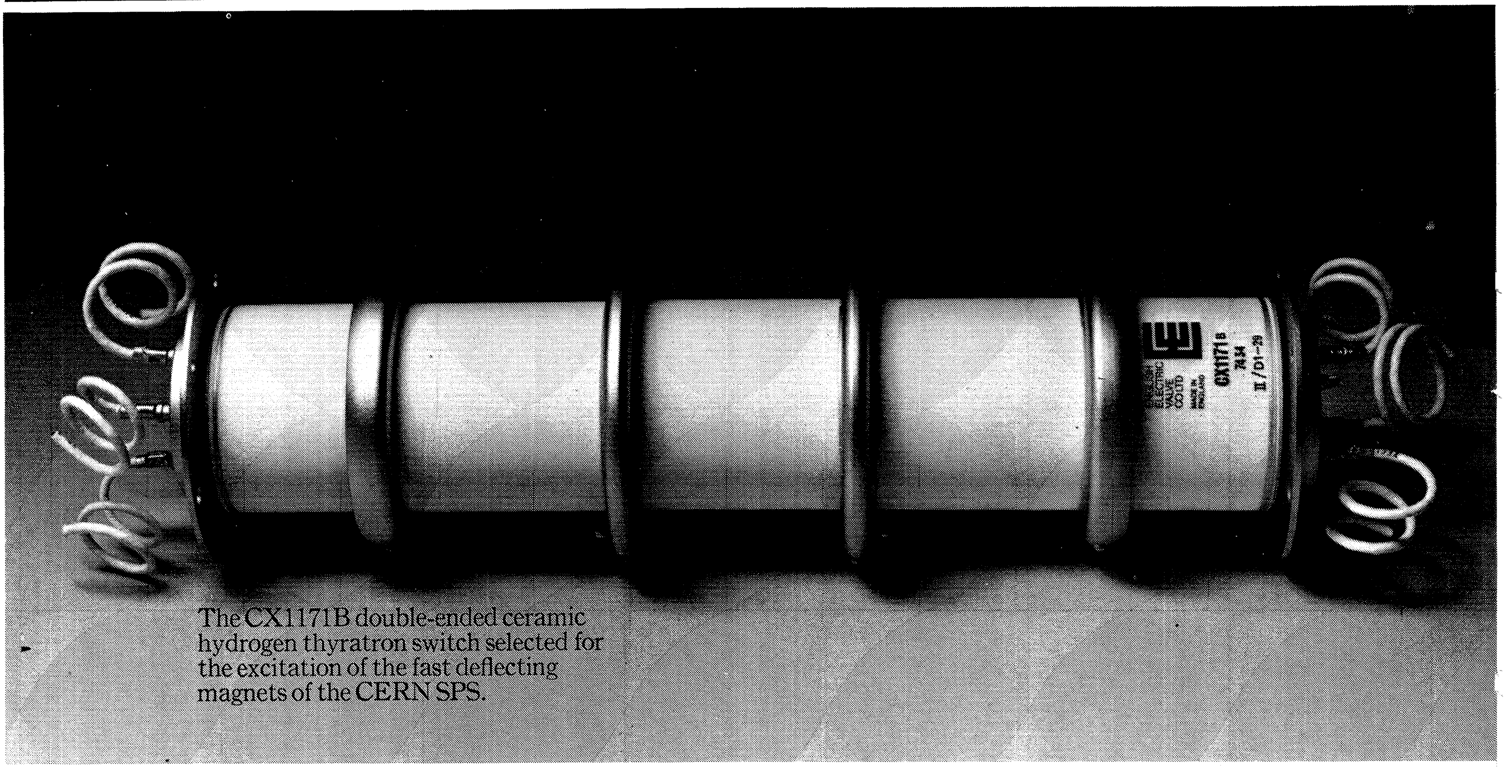

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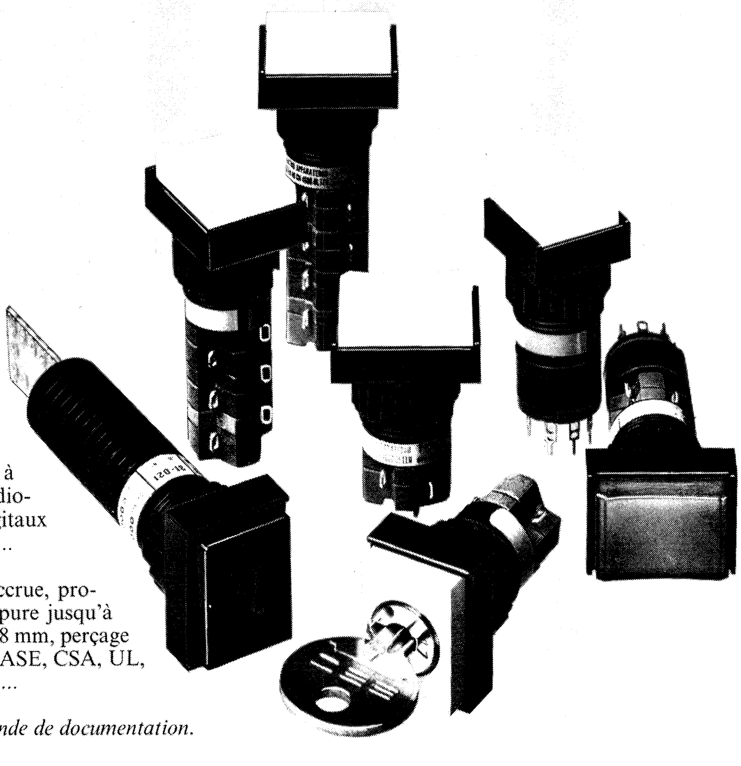

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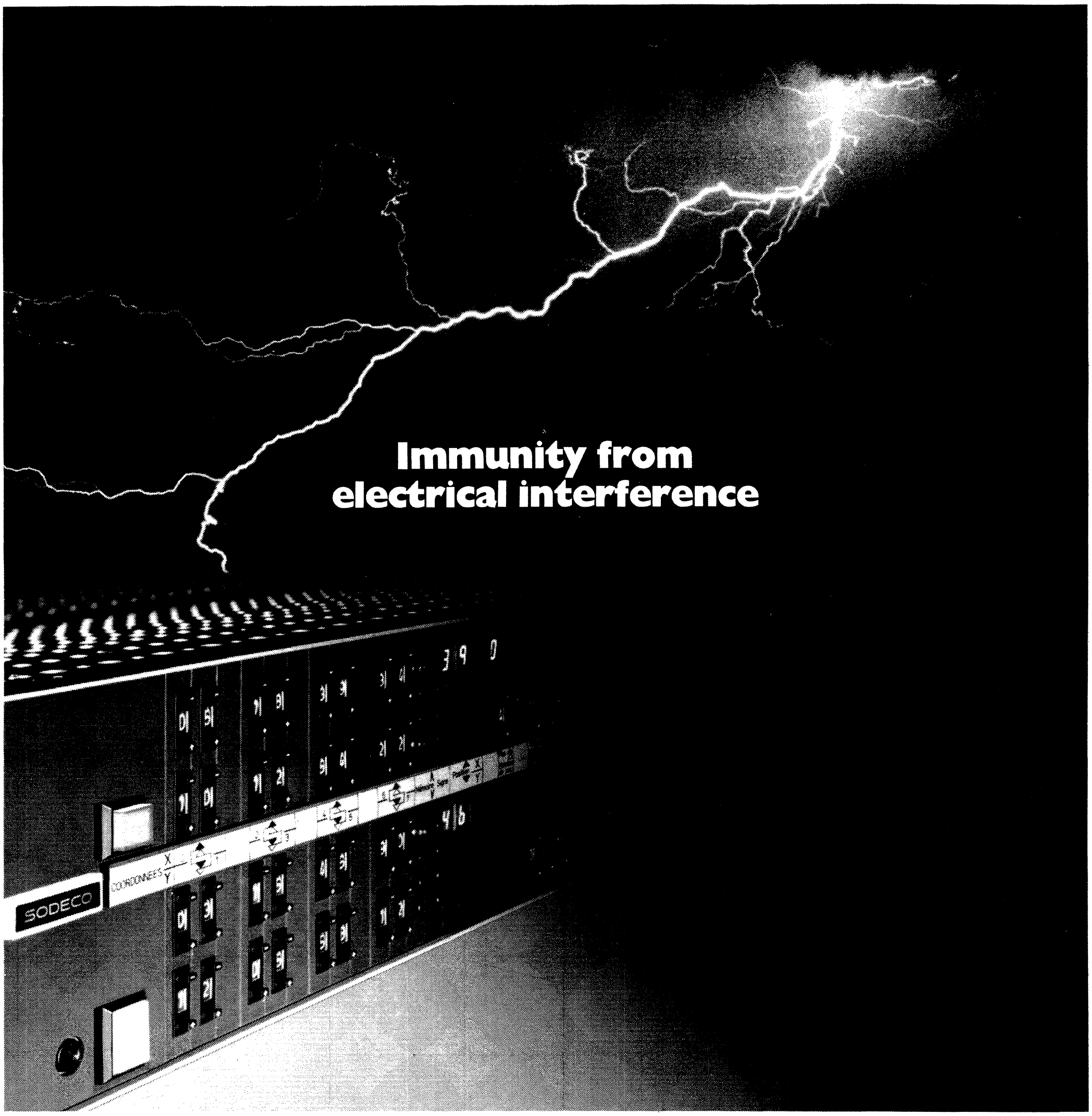

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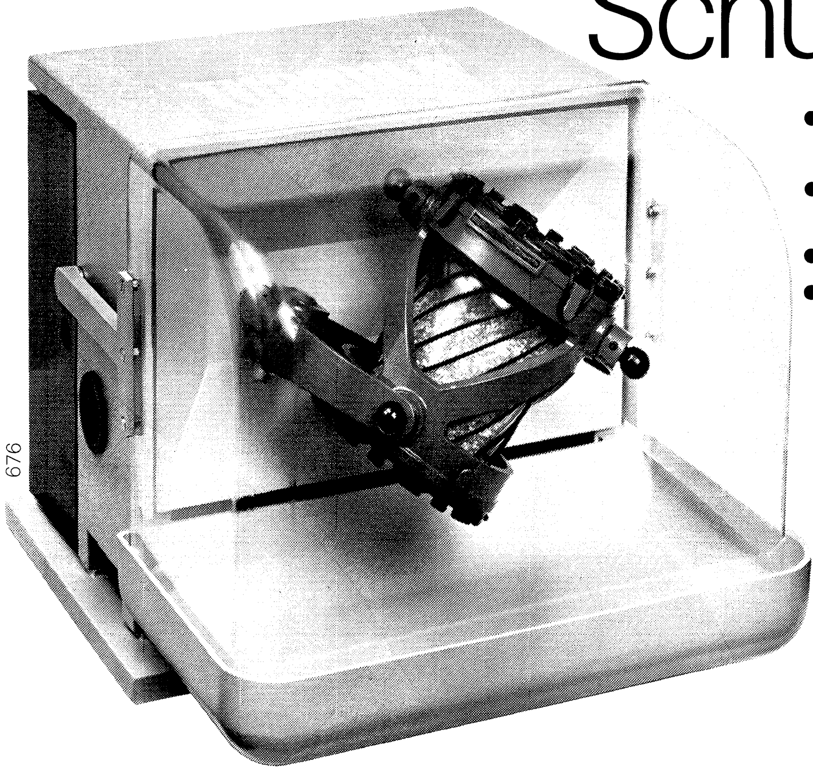

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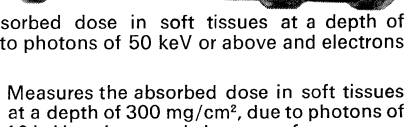

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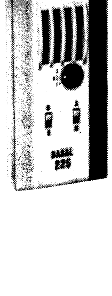

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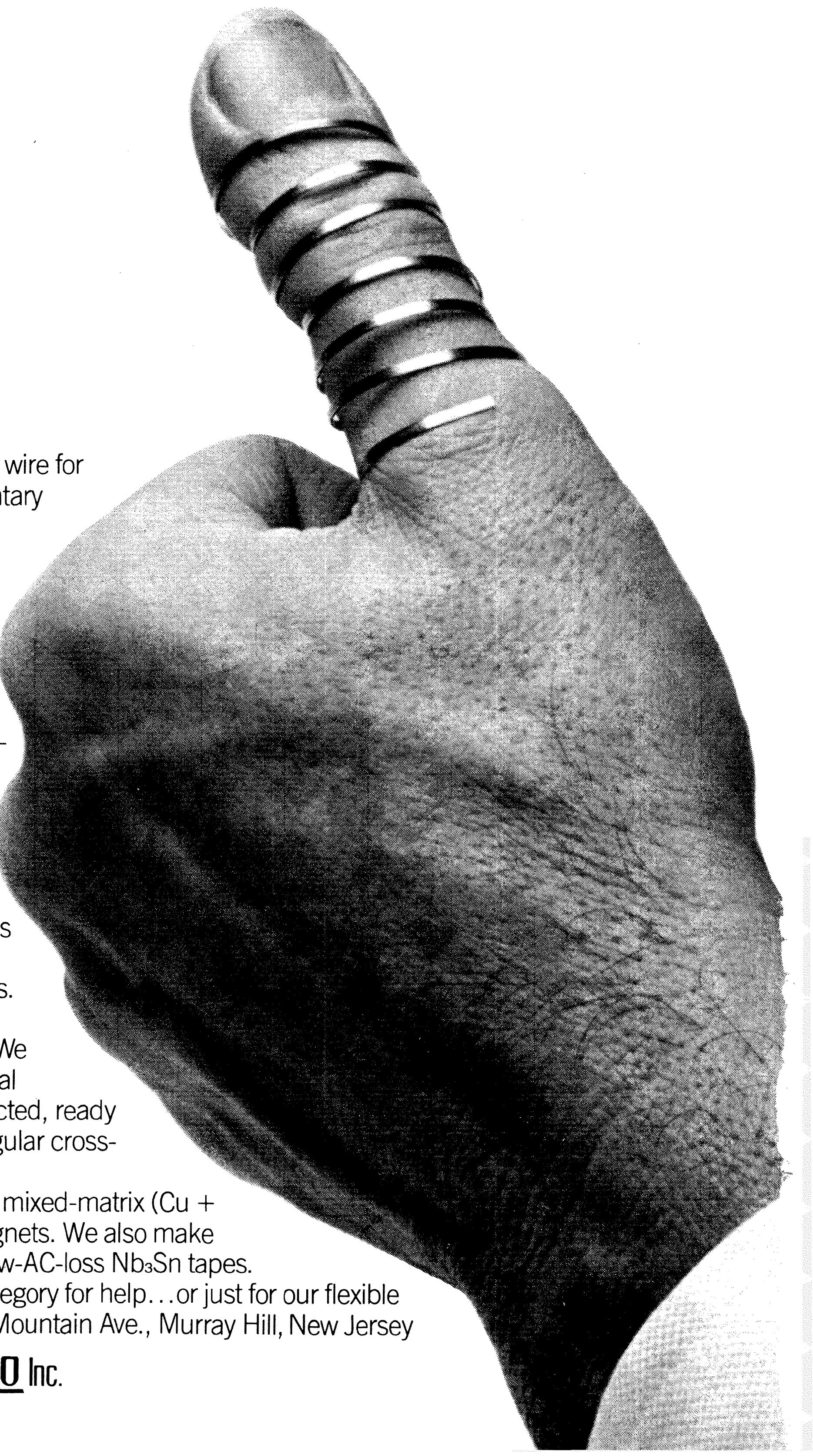

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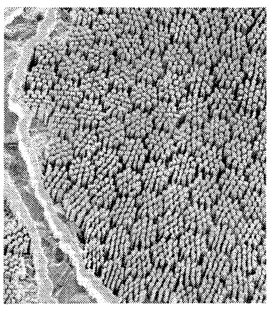

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