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Around the Laboratories

Cover photograph: The turn on of Europe's 400 GeV proton synchrotron, the SPS, was commemorated in France by the issue of a CERN stamp. The date of issue, 22 October, coincided with the first tests of the beam-line taking particles to experiments in the West Hall. The stamp proved much stickier than the tests which went perfectly.

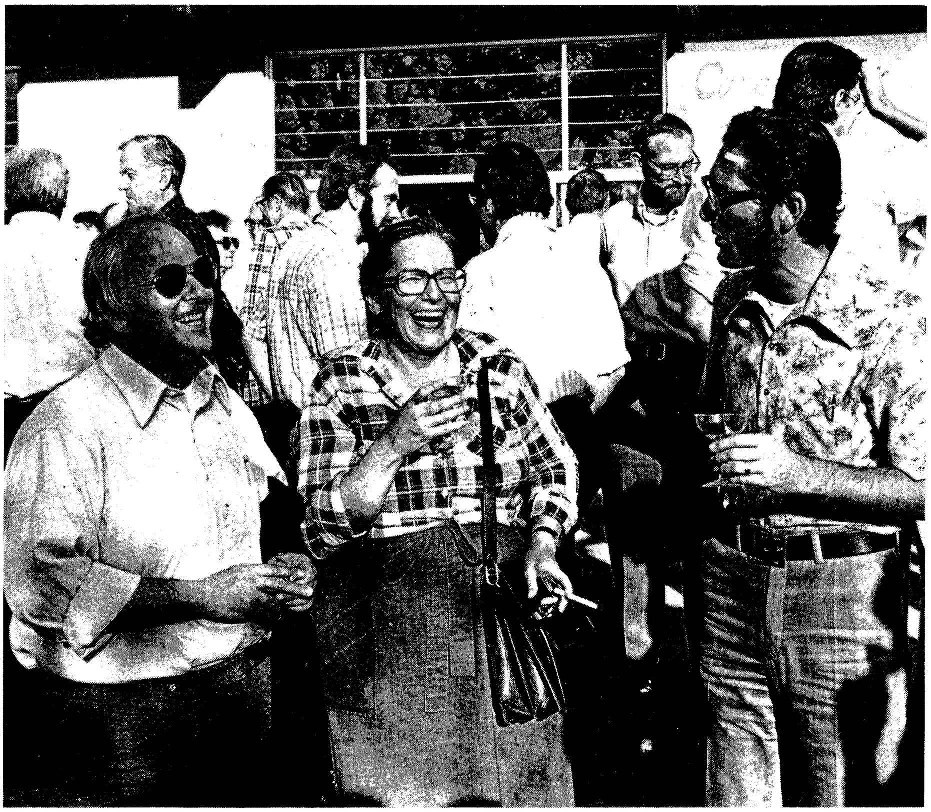
1976 Nobel Prize for Physics

. . . to be shared equally between Professor Burton Richter, Stanford Linear Accelerator Center USA, and Professor Samuel C.C. Ting, Massachusetts Institute of Technology Cambridge USA, for their pioneering work in the discovery of a heavy elementary particle of a new kind.'

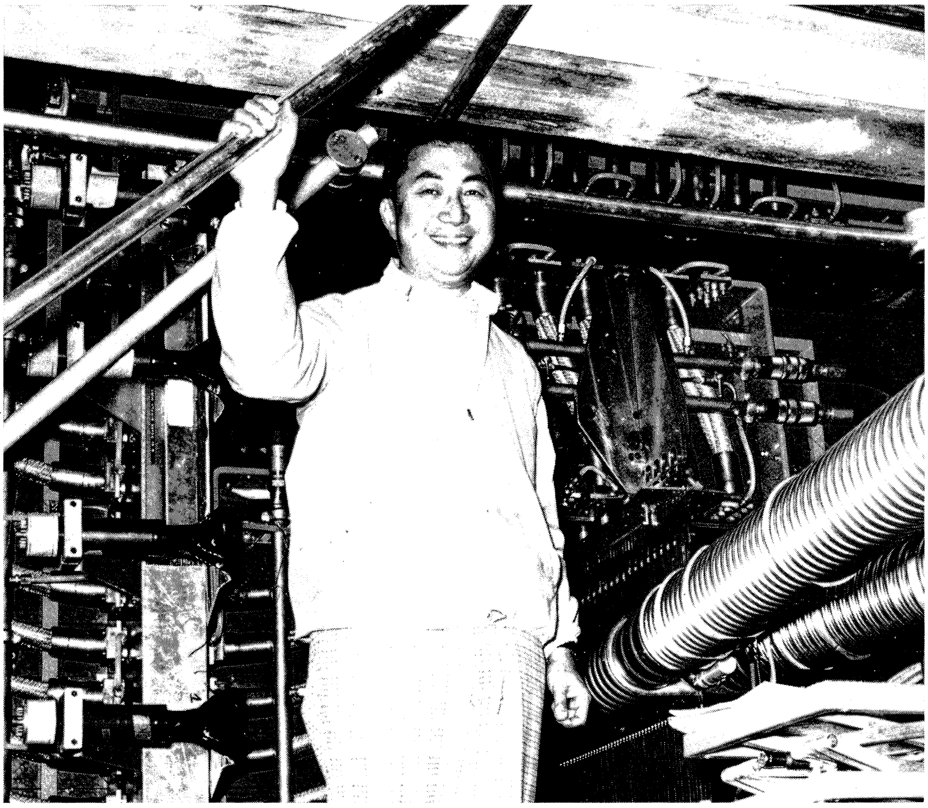
With this citation the physics Nobel Prize went to Burt Richter and Sam Ting who led the teams which found the J/psi particle just two years ago. It is rare that discoveries are so rapidly recognized by the highest award in science. This reflects the dramatic effect of J/psi on the world of high energy physics — so dramatic that since the events of 1974, we talk of 'the new physics'.

Sam Ting was born in the USA in 1936 of Chinese parents. His early years were spent in China in a University environment but without regular schooling until he was 12 years old. At the age of 20 he returned to the USA and took a physics degree at the University of Michigan. His first schooling in experimental techniques was at Berkeley with W. Jones and Martin Perl and then at CERN with Giuseppe Cocconi. He worked at CERN with Marcel Vivargent, Klaus Winter and Gustaf Weber. In 1965 he joined Columbia University, which was then blessed with Leon Lederman, Jack Steinberger, Mel Schwartz, T.D. Lee and I.I. Rabi, and a year later launched on a long, painstaking programme of research looking at lepton pairs emerging from particle interactions.

The programme started at the DESY electron synchrotron at Hamburg, then moved to the Brookhaven proton synchrotron and now continues at the CERN Intersecting Storage Rings. During this time, Sam Ting has refined to a remarkable extent the experimental techniques which are necessary to sift out leptons from whatever other particle debris is flying around. He has



Burt Richter (left) with his wife Laurose enjoy a joke with Stan Flatté during the party at SLAC to celebrate the Nobel prize award. (Photo Stanford News Service)



A smiling Sam Ting at his experiment at the CERN Intersecting Storage Rings where he continues the search for leptons which has dominated his research life.

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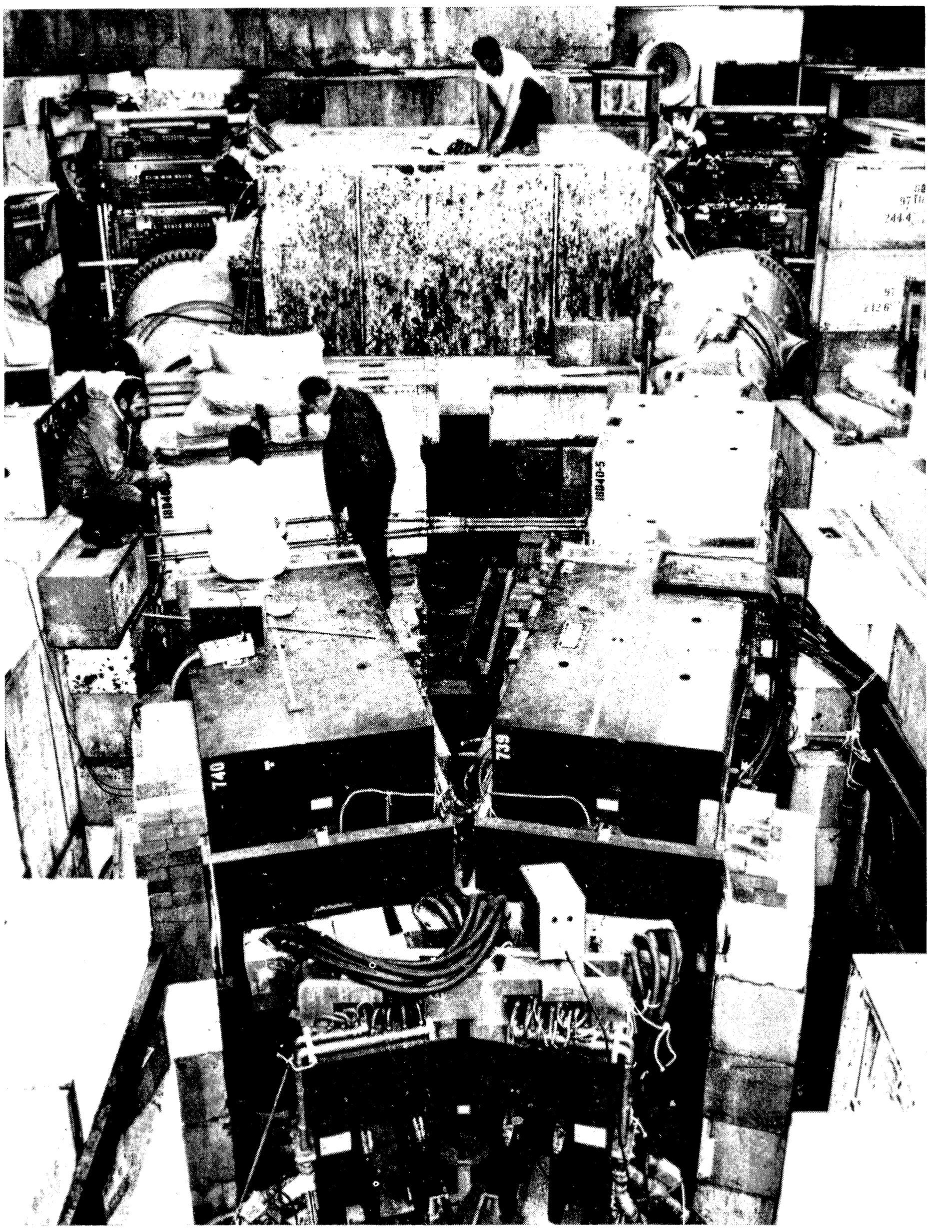


The double arm spectrometer of the MIT/Brookhaven beam which detected electron-positron pairs coming from the decay of the J/psi particle. The measurement of the decay in the midst of a very high background from other interactions was a triumph of experimental technique.

(Photo BNL)

been driven by a strong intuition, now so abundantly confirmed, that good physics is hiding in the study of particles which materialize into lepton pairs.

Burt Richter was born in New York in 1931. In 1956 he took his Ph.D. at Massachusetts Institute of Technology (where he was particularly influenced by Francis Friedman) and moved to Stanford to devote his research life to electrons since the study of quantum electrodynamics at short distances had caught his imagination. A key point in determining his future career was involvement with Gerry O'Neil and others from Stanford and Princeton in the building of the 300 MeV electron storage rings which first collided beams in 1965. During the building of this machine he sketched, together with Dave Ritson, an outline of a 3 GeV electron-positron colliding beam facility which evolved to become the famous SPEAR storage ring at the Stanford Linear Accelerator Center.

The construction of SPEAR, under Burt Richter and John Rees, began in 1970 and was completed, with great rapidity and at modest cost, in 1972. At the same time he led, with Martin Perl, Willy Chinowsky, Gerson Goldhaber and George Trilling, a Berkeley/Stanford team which built a multipurpose detection system surrounding one of the SPEAR interaction regions.

This dual role of storage ring builder and experimenter gives him a rare understanding of the physics possibilities with colliding beams. Like Sam Ting he has been driven by a strong conviction that the electron-positron system, which does not have the complications of colliding hadron systems, is a clean way to extract physics.

Burt Richter continues to pursue the same path. He is prominent in the experimental programme being prepared for the Stanford PEP storage ring. Also, during a sabbatical year at CERN in 1975-76, in addition to participating in an ISR experiment, he outlined the physics interest and the design of an electron-positron storage ring with an energy of about 100 GeV per ring.

The discovery of J/psi

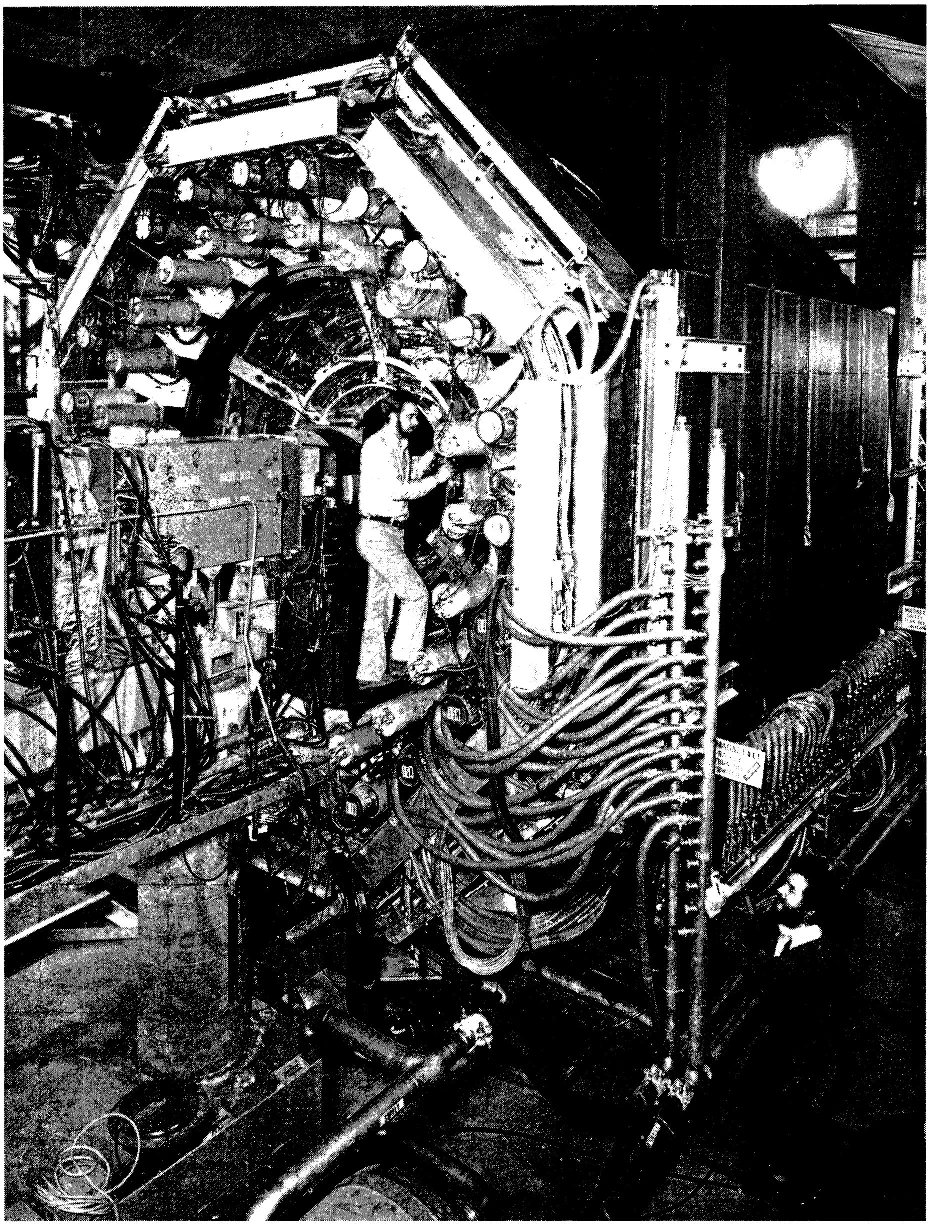
Returning to 1974, the story of the discovery which led to the Nobel Prize awards bears retelling:

Sam Ting led a MIT/Brookhaven team looking at collisions between two protons which yielded (amongst many other things) an electron and a positron. The aim was to study some of the electromagnetic features of particles where energy is manifest in the form of a photon which materialized in an electron-positron pair. The experiments are not easy to do because the probability that the collisions will yield such a pair is very low. The detection system has to be capable of picking out an event from a million or more other types of event.

It was with long experience of such problems behind them that the MIT/Brookhaven team led by Ting, Jean Aubert, Ulrich Becker and Peter Biggs brought into action a detection system with a double arm spectrometer in a slow ejected proton beam at the Brookhaven 33 GeV synchrotron in the Spring of 1974. They used beams of 28.5 GeV bombarding a beryllium target.

From about August, the realization that they were on to something important began to grow. The spectrometer was totting up an unusually large number of events where the combined energies of the electron and positron were equal to 3.1 GeV. This is the classic way of spotting a resonance. An unstable particle, which breaks up too quickly to be seen itself, *The famous magnetic detector of the Berkeley/Stanford team which surrounds one of the intersection regions at the SLAC SPEAR electron-positron storage ring. This detector found the J/psi and several other members of the 'charmonium' family of particles and, this year, has added the discovery of charmed mesons.*

(Photo SLAC)



is identified by adding up the energies of more stable particles which emerge from its decay.

The particle decaying into the electron and positron they were measuring was a difficult one to swallow. The energy region has been scoured before, though not so thoroughly, without anything being seen. Also the resonance was looking 'narrow' — the energy sums were coming out at 3.1 GeV with great precision rather than, for example, spanning from 2.9 to 3.3 GeV. The width is a measure of the stability of the particle and a narrow width means that the particle lives a long time. No other particle of such a heavy mass (over three times the mass of the proton) has anything like that stability.

By the end of October, the team had about 500 events from the 3.1 GeV particle and were getting ready to publish their result. They baptised it J which is a letter close to the Chinese symbol for 'ting'.

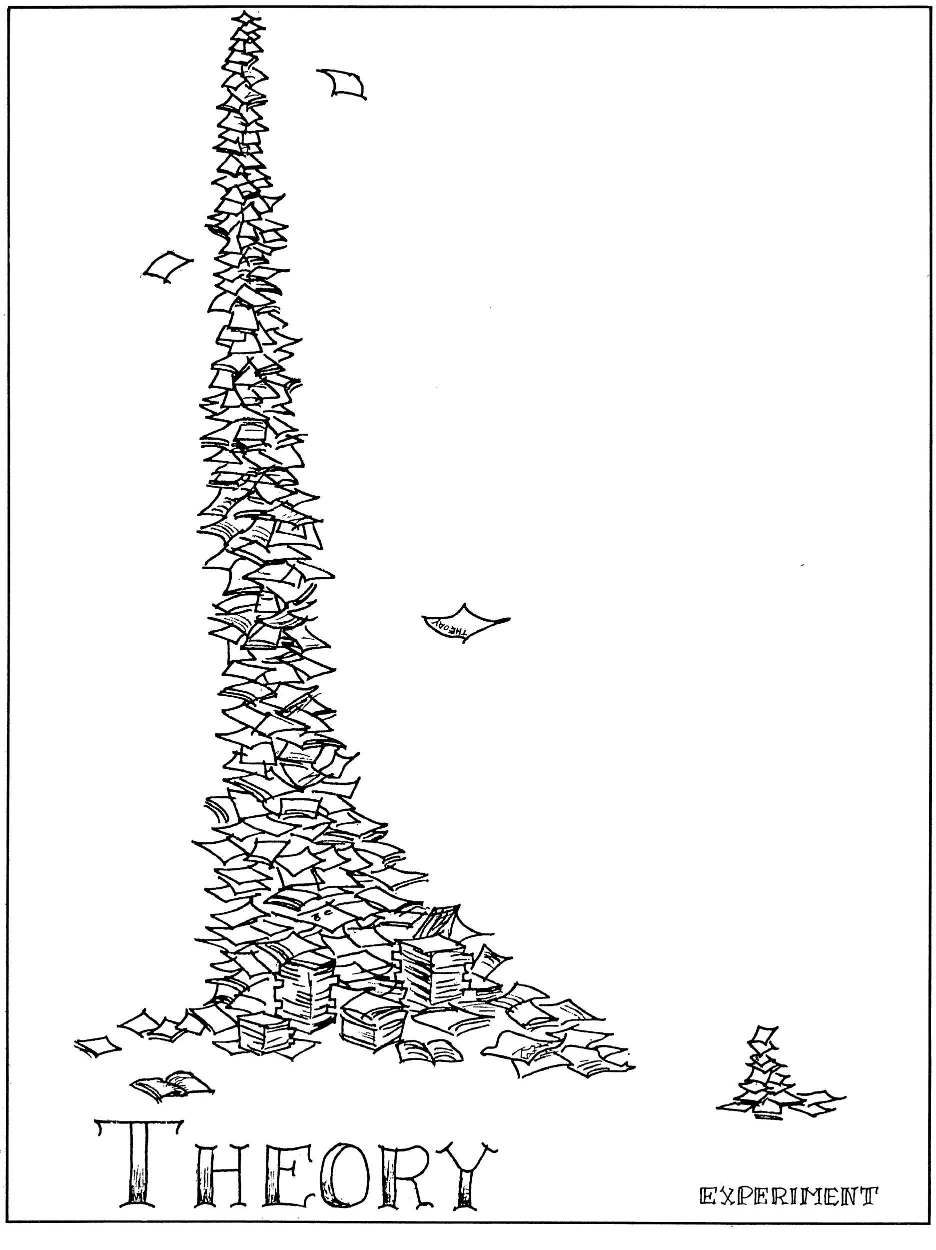
The apparition of the same particle at the Stanford Linear Accelerator Center was nothing short of shattering. Burt Richter described it as 'the most exciting and frantic week-end in particle physics I have ever been through'.

The Berkeley/Stanford team went into action during the week-end 9 - 10 November to check back on some 'funny' readings they had seen in June, when cross sections (the probability of an interaction between an electron and positron occurring) were measured with electrons and positrons at 1.5, 1.55 and 1.6 and 1.65 GeV energy in each beam. The measurement at 1.6 GeV was a little high but 1.55 GeV was even more peculiar. In eight runs, six measurements agreed with the 1.5 GeV data while two were higher (one of them five times higher). It was John Kadyk who first spotted the anomalies. Obviously, a gremlin had crept into the apparatus? While meditating in the following months during the transformation of the storage ring, from SPEAR I to SPEAR II, the gremlin was looked for but not found. It was then that the suspicion grew that between 3.1 and 3.2 GeV collision energies could lie a resonance.

During the night of 9 - 10 November the hunt began, changing the beam energies in 0.5 MeV steps. By 11.00 a.m. Sunday morning the new particle had been unequivocally found. A set of cross section measurements around 3.1 GeV showed that the probability of interaction jumped by a factor of ten from 20 to 200 nanobarns. In a state of euphoria, the champagne was cracked open and the team began celebrating an important discovery.

While Gerson Goldhaber retired to write up the findings 'on-line' for immediate publication, it was decided to polish up the data by going slowly over the resonance again. The beams were nudged from 1.55 to 1.57 and everything went crazy. The interaction probability soared higher; from around 20 nanobarns the cross section jumped to 2000 nanobarns and the detector was flooded with events producing hadrons. Pief Panofsky, the Director of SLAC, paced around the control room invoking the Deity in utter amazement at what was being seen. This heavy particle, displaying such extraordinary stability, they called psi and they announced it in a paper beginning with the words 'We have observed a very sharp peak. . .'.

Within hours of the SPEAR measurements, the telephone wires across the Atlantic were humming as information, enquiries and rumours were exchanged. On the Monday morning following the week-end of the discovery at Stanford, Sam Ting was at SLAC to attend a scheduling committee meeting. He went to Burt



Dave Jackson's 'very sharp peak' in the number of theoretical papers stemming from a small number of experimental results. It illustrates what the discovery of J/psi has meant in attempting to interpret the workings of Nature.

Richter's office and announced 'Burt, I have some interesting physics to tell you about'. To which the reply came 'Sam, I have some interesting physics to tell you about'.

Very quickly afterwards, the electron-positron storage rings of Frascati and DESY were successfully in on the act (DESY adding some teutonic precision and correcting the SLAC mass value slightly by a more accurate calibration) and the theorists were let loose in pastures new where they have gorged themselves ever since (as is amusingly portrayed on Dave Jackson's cartoon).

The new physics

Why all the excitement! After all, we could draw up a list of some 200 particles, before the J/psi discovery. Why should one more provoke invocation of the Deity? The answer lies in its extraordinary stability. Such a heavy particle would normally have dozens of ways of breaking up and, with so many possibilities open to it, would not stay together for longer than about 10^{-23} seconds. In fact the particle is stable for 10^{-20} seconds. If a man lived for 70 000 years, rather than for 70, he also would be likely to provoke invocation of the Deity!

It is obvious that there must be some special characteristic of the J/psi which prevents it from breaking up. One characteristic had already been mooted for other reasons, though no convincing evidence of its existence had been seen; it is called 'charm'. (The use of everyday words to describe particle properties can be confusing but when observing a completely new phenomenon, it can be described by any word whatsoever. The choice of words like 'strangeness' and 'charm' only reveal the little known fact that physicists are human beings capable of indulging their own whimsies. 'Charm' is simply the word used for a particle property that has never been seen before.)

Charm was in the air as a consequence of the discovery of neutral current interactions at CERN in 1973. During neutrino experiments in the heavy liquid bubble chamber, Gargamelle, it was found that the neutrino can collide with a particle and emerge from the interaction as a neutrino. Previously only charged current interactions, where the neutrino converted to a muon, had been seen.

This discovery has broad implications for the interpretation of the weak and electromagnetic forces but, for the present story, the important consequence is that the existence of neutral currents should mean that other interactions (like the decay of a kaon into two muons) should be seen. Since they are not seen, the new property called charm was proposed (particularly by S.L. Glashow, J. Iliopoulos and L. Maiani — leading to the notation 'the GIM theory') as the reason which prevents the interactions taking place.

It is by now well established that the properties of the strongly interacting particles, the hadrons, are carried by the quarks from which they are built. Prior to 1973/74, the evidence pointed to the existence of three quarks, called u (proton-like quark), d (neutron-like quark) and s (strange quark). The GIM theory suggested adding a fourth, c (charmed quark).

The J/psi was interpreted as a two quark combination, a meson, consisting of a charmed quark and a charmed antiquark sometimes known as 'charmonium'. (M.B. Einharn and C. Quigg of Fermilab maintained that the new property should have been called 'panda'. The J/psi would then have been 'pandamonium' which is a fair reflection of the furore its discovery provoked.)

The charmonium interpretation of the J/psi is in direct analogy to the interpretation of another very stable heavy meson, the phi meson. The phi is built up of a strange quark and a strange antiquark. Despite its high mass of about 1 GeV, it has difficulty breaking up because it likes to go to two kaons, which also each contain a strange quark or antiquark, so as not to lose the strangeness property. But the kaons are each of mass about 0.5 GeV and the phi has not enough mass to break up easily into kaons.

The stability of the J/psi is then interpreted as due to its charm quark constitution. It likes to go to two charmed particles which each contain a charmed quark or antiquark, so as not to lose the charm property. But the charmed particles are of too high a mass to allow an easy break up.

The idea explains the J/psi away but says a lot more besides. If we buy the idea of a charmed quark we must be able to build hadrons with it in three quark and two quark combinations just as we can build them with the u, d and s quarks. Thus previously unobserved families of particles must exist — for example, mesons such as D^0 ($u\bar{c}$), D^- ($d\bar{c}$) and baryons such as Λ_c (udc) etc. . . .

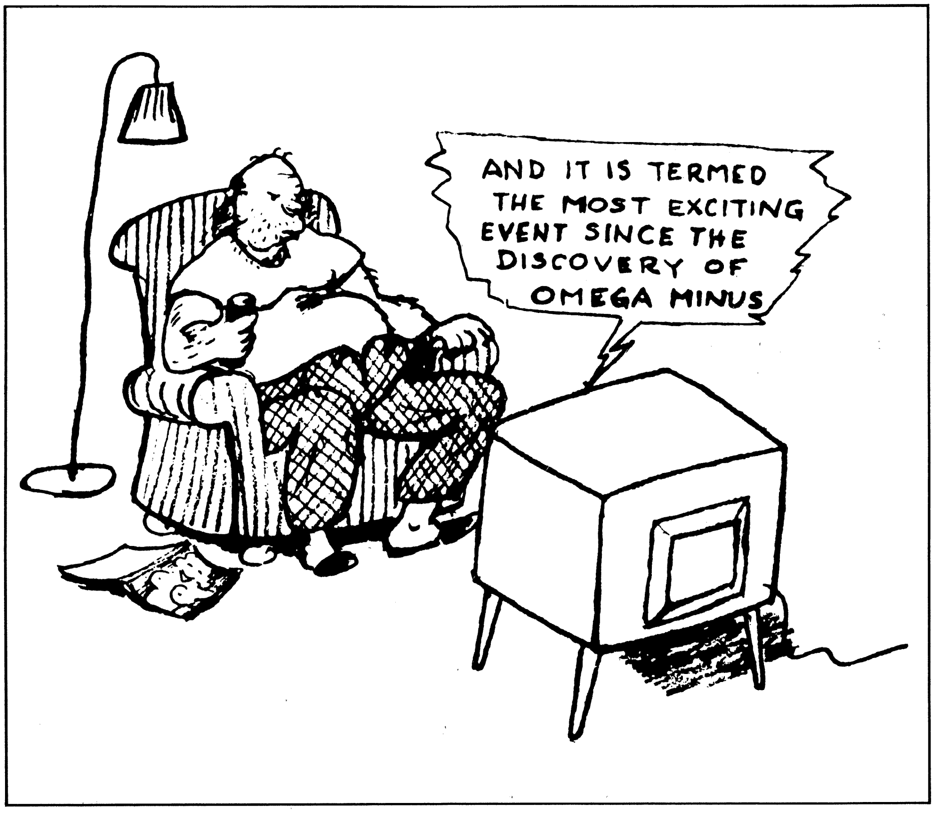
What has been found?

While the theorists have been wearing out pencils at high speed, experimentalists have been searching for signs of the charmed particles.

Ten days after the J/psi discovery, SPEAR struck again with a second psi at a mass of 3.7 GeV. The theorists were then able to predict a series of mass states of charmonium — equivalent to different configurations of the charmed quark and antiquark orbiting one another. (Such configurations have been familiar from back in the days of atomic physics when the positronium system of an electron and positron orbiting one another was studied.) The storage ring DORIS at DESY and SPEAR at Stanford have now clocked up at least seven members of the charmonium family, with masses in excellent agreement with the theoretical predictions. But these particles are not charmed particles, properly so called. The quark-antiquark combination cancels out the charm.

In looking for charmed mesons and baryons, the clue is the conversion of the charmed quark into a strange quark either in semileptonic decay where it would be accompanied by a positron and a neutrino or in hadronic decay where it would be accompanied by mesons.

During 1975 bubble chamber pictures of neutrino interactions in the 7 foot chamber at Brookhaven, in the Gargamelle chamber at CERN and in the 15 foot chamber at Fermilab



One of our favourite cartoons from the era of the discovery of the J/psi is this projection by Bob Gould from SLAC of the reaction of the 'man in the street' at a time when high energy physicists were in a state of euphoria. Salutary reminder to all who attempt to popularize science.

recorded interactions which could not be explained by the old physics but which fitted the new physics predictions of semileptonic decays of charmed particles. In addition there was a lot of evidence, particularly from Fermilab, of the direct production of two leptons in neutrino interactions which again requires new physics for their interpretation.

These observations could not, however, be used to estimate charmed particle masses with accuracy (though the Brookhaven event could have a good shot at it). Specific identification with mass assignments came this year. At SPEAR, the D mesons were seen via their hadronic decays — the neutral D meson with a mass of 1.86 GeV and the charged D mesons with masses of 2.02 GeV and 2.12 GeV. The same mesons have been seen in semileptonic decays on DORIS. At Fermilab the antiΛ_c baryon with a mass of 2.26 GeV has been seen in its hadronic decay.

The pro-charm evidence is now overwhelming.

The discovery of J/psi rejuvenated high energy physics. It has revealed aspects of Nature's behaviour which were totally unexpected and has prompted one of the major advances in understanding matter. The award of the 1976 Nobel Prize for Physics to Burt Richter and Sam Ting recognizes this achievement.

Physics at PETRA

Will the next generation of electron-positron storage rings be as successful as those now in action or even more so? The rush of high energy physicists to the interaction regions of PETRA, the storage ring under construction at DESY, indicates a world-wide belief that very interesting physics is going to be unearthed at centre of mass energies up to 40 GeV.

One obvious reason is that, at PETRA, physicists will be penetrating a new energy region and unexpected phenomena may be seen. They will also be able to ask some vital questions even on the basis of what we know now. For example, is there an interference between weak and electromagnetic interactions at the new high energies (this would be a crucial test of the theories which attempt to unify our interpretation of the two forces). Will R, the ratio of hadron production over muon pair production, become asymptotic at PETRA energies, or will a change indicate new degrees of freedom in hadronic matter and new 'flavours' for the quarks to add to strangeness, charm...? Are there more heavy leptons and, if so, will we begin to see some reason for the lepton spectrum?

On 19 October, the PETRA research committee, PRC, met for its fourth meeting and had to do some crystal ball gazing on all these questions in order to make recommendations on the initial experimental programme to the DESY Directorate.

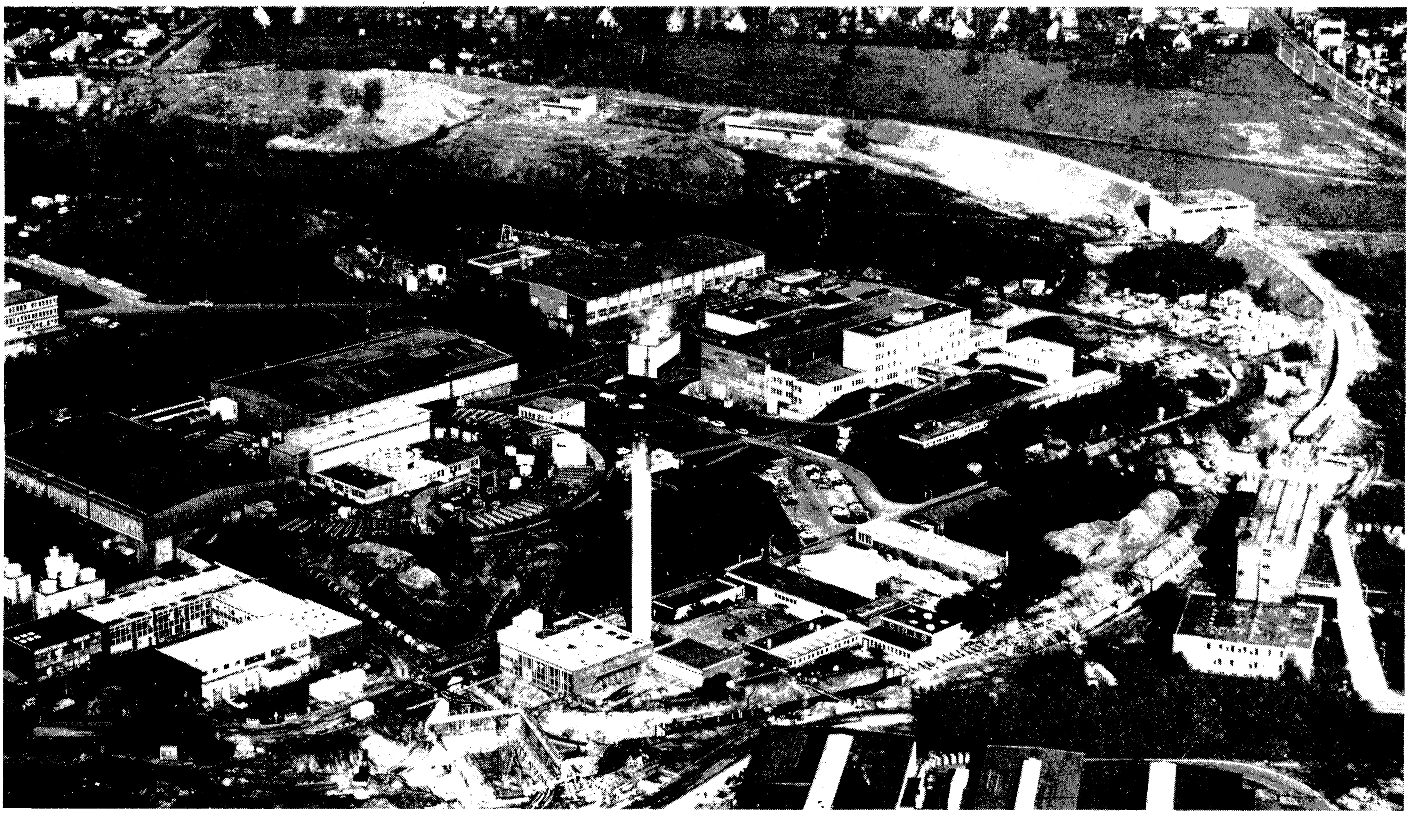
In view of the expected international participation, six experimental halls are under construction among the eight intersection regions of PETRA. One of the difficult decisions was to specify how many of these available halls should already be committed at this time. Since only a little more than two years remain until the start-up of PETRA, some people felt that experiments which were not recommended now would come too late for the first generation. On the other hand, a certain flexibility to leave the door open for new ideas and future proposals has to be preserved. As a result of these deliberations, it was decided that four interaction regions should be committed now, leaving two empty for later decision. Fortunately, it turns out that more than one experiment can be accommodated per hall thus, as far as space is concerned, more than four experiments can be installed.

The proposed experiments fell into two classes — those which are specifically designed for PETRA and those which use existing apparatus. Although the latter may have some shortcomings, they have the advantage of being fully tested and debugged with a complete set of analysis programs.

The PRC recommended five experiments, two others, 'PHOENIX' of an Athens / DESY / Frascati / Pisa / Rome / Stony Brook / Wisconsin collaboration and the 'Iron Ball' of a Pennsylvania / Wisconsin collaboration were not recommended, and two more will be considered at a later time. The experiments were approved under the following conditions:

It should be possible to remove the installation from the intersection region and to reinstall it in working condition within not more than five days for each operation, since long repairs cannot be tolerated at the intersection region. The installation should be such as to permit a second experiment to be installed in the same region. The PRC will review the preparations for experiments at regular intervals, and, if necessary, priorities will be recommended for the installation of various experiments at a later time. The running schedule for all experiments will be considered by the PRC at a later time.

The question whether four or only two interaction regions should get



luminosity at the same time will have to be answered taking into account the request for beam energies (only two regions can get luminosity at the highest energies). It is not excluded that a more effective programme will be achieved by giving luminosity to only two intersections at a time, alternating between intersections at appropriate time intervals.

The priorities for beam energies and luminosities for different interaction regions can be settled when operation begins, taking into account also the state of readiness of the different experiments. Each experimental set-up should be ready for physics at the time PETRA starts operating, even if not all components of the detection systems are completed. Since there is not much time before the machine is operating, 'conventional' detection techniques are generally preferred for the first round of experiments but new developments will be brought in whenever possible. The recommended experiments are as follows:

A DESY / Karlsruhe / München / Orsay / Paris / Saclay collaboration takes as primary goals for their detector, 'CELLO', the identification and measurement of leptons and photons. They will study new leptonic and hadronic states, QED processes and weak current effects, the total cross section and particle production. The main components of CELLO are a superconducting high field magnet with thinner coils than any existing so far, a tracking device consisting of proportional and drift chambers for good track recognition and momentum resolution, electromagnetic shower detectors using the lead-liquid argon technique for good energy and angular resolution and efficient hadron rejection, a hadron filter and muon detectors with low hadron background, and a small angle forward detector to tag electrons.

A collaboration of Aachen / Bonn / DESY / Hamburg / Imperial College London / Oxford / Rutherford / Weizmann Institute is building a detector called 'TASSO' which will be capable of identifying charged hadrons over the total range of momenta even down to 0.6 GeV/c. TASSO will be able to measure charged particles and photons over almost the full 4π solid angle. The main characteristics of the detector are a thin wall solenoid with a radius of 1.35 m and a length of 4.4 m (which provides a field of 5 T parallel to the beam axis), Cherenkov counters on either side of the beam for π, K and p separation, liquid argon shower counters covering about 90 % of the full solid angle to identify and measure photons and electrons, and a system of time-of-flight counters to identify hadrons in the low energy region.

The detector of a DESY/Dutch/MIT collaboration will concentrate on a search for weak and electromagnetic interference effects (showing itself as an asymmetry in inclusive production of muons or in parity violating effects), and will examine structure in R and QED processes. This experiment uses magnetized iron as spectrometer and muon filter with a toroidal field around the electron-positron beams of about 2 T. There will be two layers of hodoscopes which cover the entire 4π solid angle. A unique feature of this detector is that it can be rotated in both the polar and azimuthal directions thus it is hoped that the systematic errors can be kept at a 1 % level.

A Daresbury / DESY / Hamburg / Heidelberg / Lancaster / Manchester / Tokyo collaboration is building a detector called 'JADE' to look for leptons over a large momentum region, starting at about 100 MeV/c. Weak interactions will be studied by making a good separation of muons from electrons and hadrons. Also good electron detection will enable JADE to search for heavy leptons and possible new quantum numbers. The apparatus consists essentially of a system of

The sweep of the PETRA storage ring dominates the aerial view of the DESY site. The electron synchrotron (left-centre) and DORIS storage ring (right-centre) are now encircled by the 2.3 km PETRA ring. The injection link between the synchrotron and PETRA can just about be picked out at the bottom of the picture and in between them is an experimental hall where the rapid ring construction will be celebrated on 2 December.

(Photo DESY)

Around the Laboratories

cylindrical chambers with large drift spaces in a gas of high pressure which yields very good spatial resolution (100 μm) by sampling. In addition, measuring dE/dx may be possible.

Finally, an Aachen / DESY / Hamburg / Frascati / Siegen / Wuppertal collaboration will carry the PLUTO detector now in use on DORIS (see the April issue, page 139) to PETRA. To use PLUTO at PETRA energies, additional components will be necessary, such as a barrel shower counter, end cap shower counters (to close up the solid angle down to 15° for measuring the energy of neutral particles), drift chambers to improve the momentum resolution, and a liquid argon dE/dx counter to identify pions, kaons and protons. All these components will be tested and used at DORIS so as to be confident of having a well-debugged and well-understood detector ready for doing physics at the time when PETRA starts running. The main physics aim of the PLUTO collaboration will be to measure the total cross section for electron-positron annihilation into hadrons and to look for peaks and steps in the cross section variation with energy since these are the signals for resonances or for new degrees of freedom in the world of hadron constituents. Since PLUTO is small in radius, it can also achieve good muon identification as pion decay corrections will be small.

There is some overlap in the physics programmes of the solenoidal magnetic detectors but the technical approaches were considered sufficiently different to justify the approval of all the mentioned experiments. DESY will now contact the groups and their Laboratories to clarify some administrative and financial questions. However, the enthusiasm of the physicists transcends these formal steps and preparations for the experiments have started with great vigour.

FERMILAB
Second generation neutrino experiments

After four years of intense operation, the first round of neutrino experiments at Fermilab is now being succeeded by a second generation. In total, the new experiments have more than a thousand tons of target material and a thousand tons of spectrometer material among them.

The Harvard/Wisconsin/Pennsylvania/Fermilab collaboration has grown to include Rutgers. The building used for their first experiment has been doubled in size and is jam packed with equipment for the coming runs. The new apparatus will be used to investigate the kinematics and target density effects in dimuon production. Another major aim is to clarify the much discussed 'high y anomaly' (the relationship of the muon energy to the incoming neutrino energy seems to be deviating from what is expected). The detection system is constructed so that this kinematic region can be studied in substantially more detail.

Starting upstream, the first element in the array is a 250 ton iron slab target intended principally for dimuon production studies. Following the target are 50 tons of liquid scintillators, followed in turn by an iron and liquid scintillator calorimeter. Beyond that is a 24 foot diameter toroidal iron magnet (whose large diameter will be particularly helpful for analysing high y events) with a folded-in scintillation hodoscope to give a two muon trigger. The previously used 12 foot diameter magnet completes the chain after the 24 foot spectrometer; it will be used for additional momentum measurements on forward muons. The new system can be triggered on multimuons and on energy deposited in the apparatus, taken alone or together. The experimenters hope to collect about a thousand dimuon candidates. Preliminary runs are under way.

The CalTech/Fermilab collaboration, now including Northwestern and Rockefeller, has moved downstream from their old location in the 'wonder building' halfway down the muon berm to a location just in front of the 15 foot bubble chamber. They are pushing to investigate deep inelastic charged and neutral current effects at very high energies. They also plan an early run on dimuons that will simultaneously shed some light on the question of target density using two sets of spark chambers mounted side by side to give two different net target densities. The equipment operated on the same basic concept as the earlier experiment but the target calorimeter has grown a factor of six larger, to 700 tons. The muon analysis magnet toroid has gone from a 5 foot to an 11 foot diameter device with a gross weight of 350 tons. The new toroid has spark chambers and counter planes interspersed throughout.

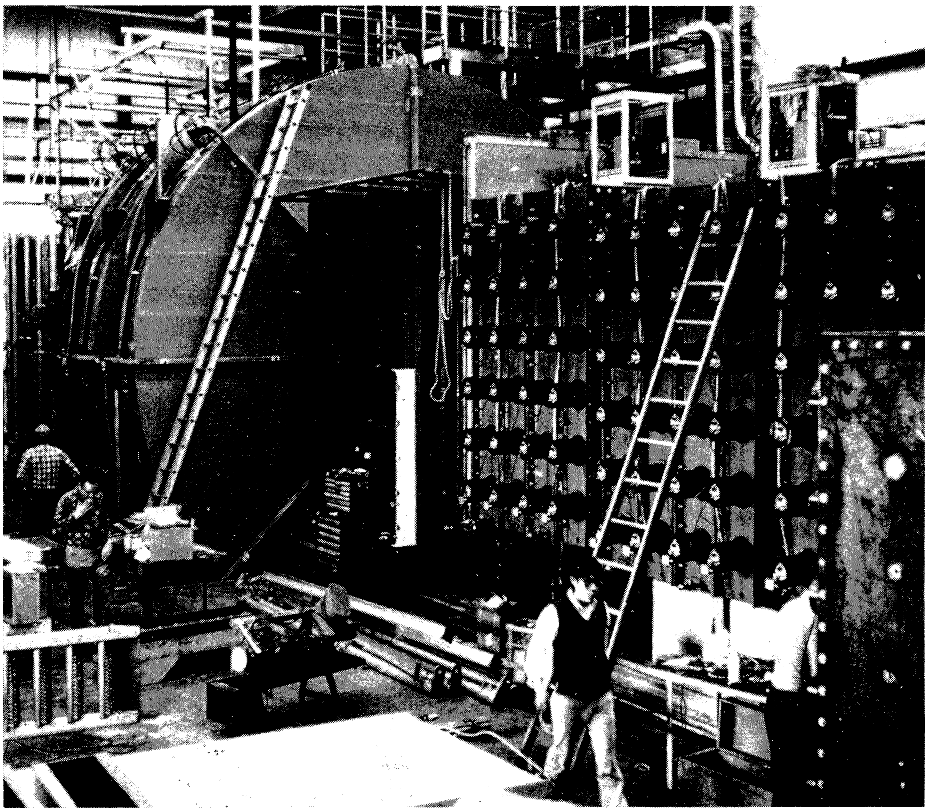
The toroid for this experiment is at present in operation for a Stanford/CalTech search for short-lived states produced by hadrons that decay via leptonic modes (they have run for 200 hours and are studying their data). The experiment sits beside the neutrino experiment in the same building and when it is complete, the toroid will be moved into place for neutrinos.

The vacated space halfway down the muon berm has been taken over by an elegant experiment to look for electrons produced by the muon neutrinos. This experiment is being mounted by a VPI/Oxford/Maryland, collaboration with a detector consisting of a 20 ton system of spark planes interlaced with sheets of aluminium, one radiation length thick, which can measure the energy and direction of electron showers. A module of six of these planes has been tested in an electron beam at Cornell

Second generation counter neutrino experiments taking shape at Fermilab:

1. The detection system of the Harvard/Wisconsin/Pennsylvania/Fermilab/Rutgers experiment has been greatly increased in size. On the left can be seen the iron discs of new toroidal magnets 24 foot in diameter.

2. The CalTech/Fermilab/Northwestern/Rockefeller experiment has also increased the volume of its detection system which is now located close to the 15 foot bubble chamber. In the photograph their toroidal magnets are seen temporarily installed for a Stanford/CalTech search for short-lived particles.



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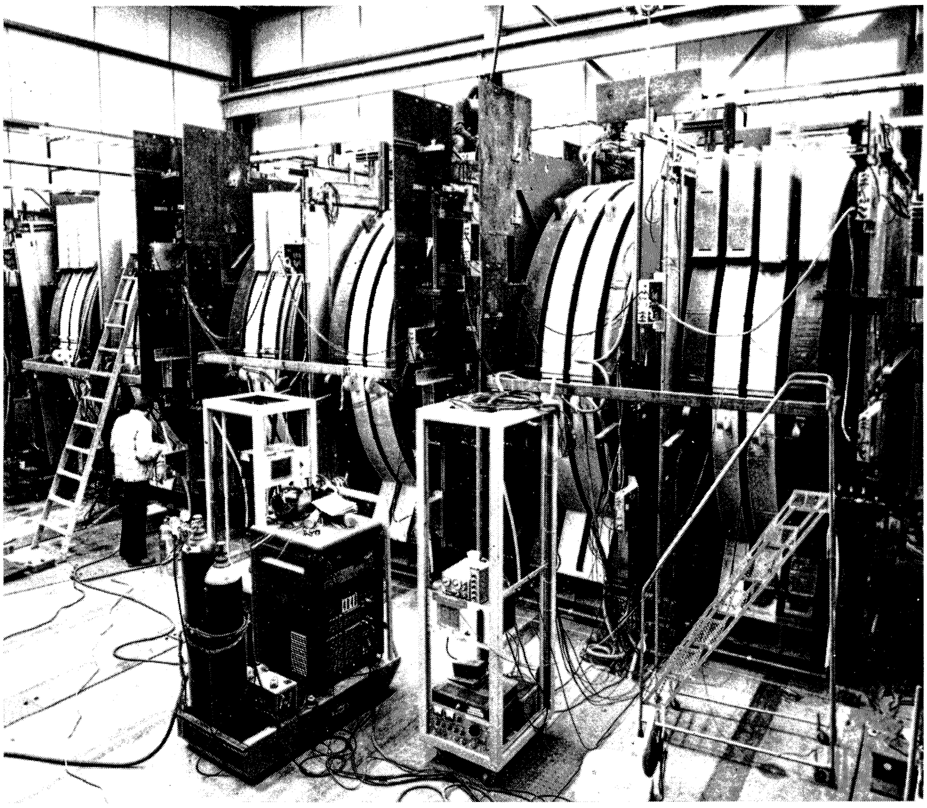

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at energies up to 10 GeV. The experiment will operate parasitically and about a hundred events in a thousand hours of operation are hoped for. This experiment is a significant test of weak interaction theory — classical theory predicts no cross section for the process of a muon neutrino producing an electron, while Weinberg-Salam theory predicts a non-zero cross section.

Further improvements lie ahead in neutrino beam performance. The construction of an improved dichromatic trainload (neutrino parent focusing system) is now under way — magnets have been ordered and completion is expected in about a year and a half. This beam will go to 350 GeV as opposed to the old 250 GeV upper limit and will be a particularly important improvement for the production of antineutrinos. The CalTech/Fermilab/Rockefeller/Northwestern group plans to use this beam when it is available while the Harvard/Wisconsin / Pennsylvania / Fermilab / Rutgers group is presently planning to use a quadrupole triplet.

There is still discussion about the most effective way to proceed for antineutrinos. For the electron search, the experimenters prefer a triplet trainload to provide a slow spill. In part, this is related to their position midway down the berm where the muon background is larger. It is planned to install a toroidal magnet at the end of the decay pipe to help kill the muon flux in the region of the 'wonder building'. This is scheduled for late summer 1977 and, with that in place, it may be possible to do the electron search experiment with a neutrino beam produced using a focusing horn.

Meson Lab. upgraded

During a September shutdown, major modifications were made on the MI beam in the Meson area at Fermilab. The changes permit experiments on the MI line to operate the beam at 350 GeV for the first time (the previous upper limit was 280 GeV). The addition of several power supplies will take this to 400 GeV shortly.

First operation of MI at 350 GeV occurred in mid October, when particles were brought to the Meson Detector Building for a Pennsylvania experiment studying inclusive scattering. The beam performed satisfactorily and paved the way for a second generation total cross section experiment by Fermilab/Rockefeller/Brookhaven. This is the same group that demonstrated in 1974 that the rise in total cross section, seen earlier for protons, also holds for other hadrons. By raising the energy to 400 GeV, it should be possible to track the rise higher.

All of the beams in the Meson area operate essentially as secondary particle beams. Protons from the accelerator strike a production target located a quarter of a mile upstream from the Meson Detector Building and six beam-lines are clustered at angles of several milliradians from the incident beam direction to catch the forward-going particles from the target. Originally, the area was designed for operation with 200 GeV protons but the energy available from the accelerator soon outstripped these design specifications. Many clever innovations have been used that have permitted the beams to work at higher energies as the accelerator has moved up in energy. These include modifications to the external proton beam-line supplying the Meson Laboratory to go to 400 GeV, and the individual beam-lines have used more tightly packed septum magnets, normal bends, and quadrupoles.

MI is a three-focus, charged particle beam. A split is provided in the last several hundred feet so that particles can be routed to one of two side by side regions permitting alternate experiments to be set up. The beam contains several sets of Cherenkov counters which make good particle tagging possible. Typically, the flux for MI gives 3 × 10^6 negative pions at 175 GeV for 10^{12} protons on target; for positive particles, the fluxes are approximately a factor of five higher. The Meson Laboratory often operates with two to three times 10^{12} protons on target.

Improving the MI beam for 350 GeV has been a difficult achievement but a more ambitious future is planned. Meson Laboratory personnel have reviewed the possibility of upgrading the external beam-line to 1000 GeV when the Energy Doubler/Saver comes on and of upgrading the secondary beams accordingly. Use of the superconducting technology that is developing now around the Laboratory for many purposes, including the Doubler/Saver, should make this possible. 1.

CERN
SPS tops 10^{13}

The 400 GeV proton synchrotron laid on an impressive display of its abilities at the end of October. Protons were sent to the West experimental hall for the first time, intensities of over 10^{13} protons per pulse were accelerated a few days later and, a week after that, experiments received their first particles. In the midst of all this, the machine even showed style in blowing a vacuum leak in a very unexpected way!

On the night of 22/23 October protons were sent for the first time up (literally, since there is a vertical climb from the underground machine to the hall on the surface) the beam-line TT60 to the target zone at the end of the West Hall. Special septum magnets at the zone make two horizontal slices to split the beam in three so that three targets can be irradiated simultaneously. These magnets were powered and the splitting worked perfectly; protons were received at the target positions exactly as required.

The targets themselves were not in place, to avoid unnecessary irradiation, and the protons were deposited in beam dumps. Nevertheless some secondary particles from these dumps entered the Hall and some experimenters had sneaked in to see if they could pick anything up with their detection systems. Most interesting of all was that the neutrino counter experiment was seeing lovely muon tracks. This means that they could even do equipment calibration during the West Hall 200 GeV part of the SPS pulse while waiting for the 400 GeV burst which gives them their neutrinos.

On 25 October a successful attempt was made to increase the peak accelerated beam intensity in the SPS by injecting two 10 GeV pulses from the PS rather than one. This requires holding the magnet fields at the injection values while the PS goes through another 10 GeV acceleration cycle, adding about 1 s to the SPS cycle time.

During the morning the machine settings were improved using comparatively low intensity injected beams and in the afternoon the PS was called on to send high intensities. With two injected pulses of close to 8 × 10^{12} ppp, intensities as high as 1.25 × 10^{13} ppp were accelerated to 200 GeV. To accelerate 10^{13} in the SPS so soon after first operation is a fine achievement and the PS deserves an accolade also — the old war horse continues to do whatever is asked of it.

There is still work to be done on the two pulse injection. A lot of beam is lost when the second pulse is added. Nevertheless, the performance was so good and reliable that it may become the standard operation. This would involve increasing the SPS cycle time from 6 s to 8.4 s. The longer cycle would allow an increase in the 200 GeV flat top, when beams are fed to the counter experiments, from 0.7 s to 1.2 s. The decision depends mainly on whether difficulties can be overcome in accelerating further to 400 GeV after this flat top, when high intensities are present. (On 3 November a 10^{13} beam was accelerated to 400 GeV but without the intermediate flat top.)

To achieve multipulse injection into the SPS, the PS has worked with a 'supercycle' of 8.4 s. The sequence comprised three 10 GeV cycles followed by two 26/24 GeV cycles for the ISR and the PS experimental areas. Even the intensity was changed from pulse to pulse in the Booster and when a user did not need his cycle, an 'on-line' rearrangement of the utilisation of the beam was made immediately. Machine developments were carried out using the 10 GeV cycle not called for by the SPS. With double pulse five turn extraction, 1.7×10^{13} protons were transferred to the SPS within 1.2 s. The ISR first received a few bunches at a time and then the full beam on either one or both of the 26/24 GeV cycles. For the PS experimental areas, the usual pattern of operation was slow extraction to the East Hall sharing with internal target 1, plus fast extraction of a few bunches for the 2 m bubble chamber and the g-2 experiment. The PS needs a computer just to remember all this.

On the morning of 26 October, after the high intensity run, a sizable leak occurred in sector 2 of the SPS. It was on a pick-up unit in a short straight section, probably in a weld. The sector vacuum valves closed so that the rest of the machine was protected.

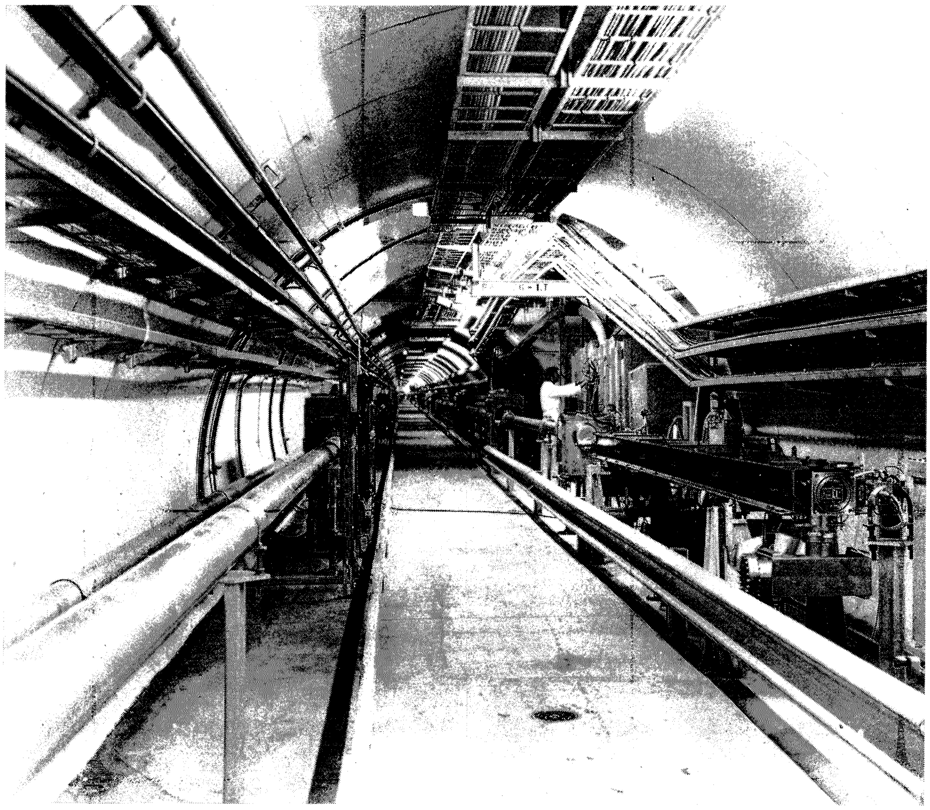
What was surprising, when the vacuum people went to tackle the problem, was that they found the sector to be very radioactive (over 70 rads per hour on contact) and the repair could not be tackled until the night of 27 October. The symmetrically opposite point around the ring, sector 6, was also very hot. It was clear that both regions had been heavily sprayed with protons. Obviously, this should not have happened — the protons are intended to end in the beam dump.

It was found that the beam dump system at the end of the acceleration cycle was coming into operation after the end of the flat top because of an error in the timing circuits. Thus the magnetic fields were falling and the beam was moving towards the outside of the vacuum vessel. The beam characteristics are such that sectors 2 and 6 are the first to be hit. The fault has been corrected.

On 2 November the first attempts to operate the beam-lines in the West Hall itself were made. The machine was having an off-day and the time available for the tests was short. Beam was fired onto two targets, as scheduled, and the corresponding secondary beam-lines received their particles. With the magnets set to nominal values, without any tuning, intensities in the desired 10^6 range were achieved, leaving many happy experimental physicists in their wake.

Now that the West Area is in action, it leaves the North Area as the major item of unfinished business in the SPS project. Civil engineering work is almost complete and everything is on schedule for bringing this Area into operation in about a year's time. The initial experimental programme will be housed in two halls — one with top quality hadron and electron beams, the other with top quality muon beams, all drawn from targets receiving proton beams of the highest energy and intensity that the SPS is able to provide.

One beam-line in the North Area



On the right in this tunnel photograph is the beam-line which brought protons from the underground CERN SPS towards experiments in the West Hall for the first time at the end of October. On the left, is the r.f. separated beam-line which can take particles to the 3.7 m European bubble chamber, BEBC.

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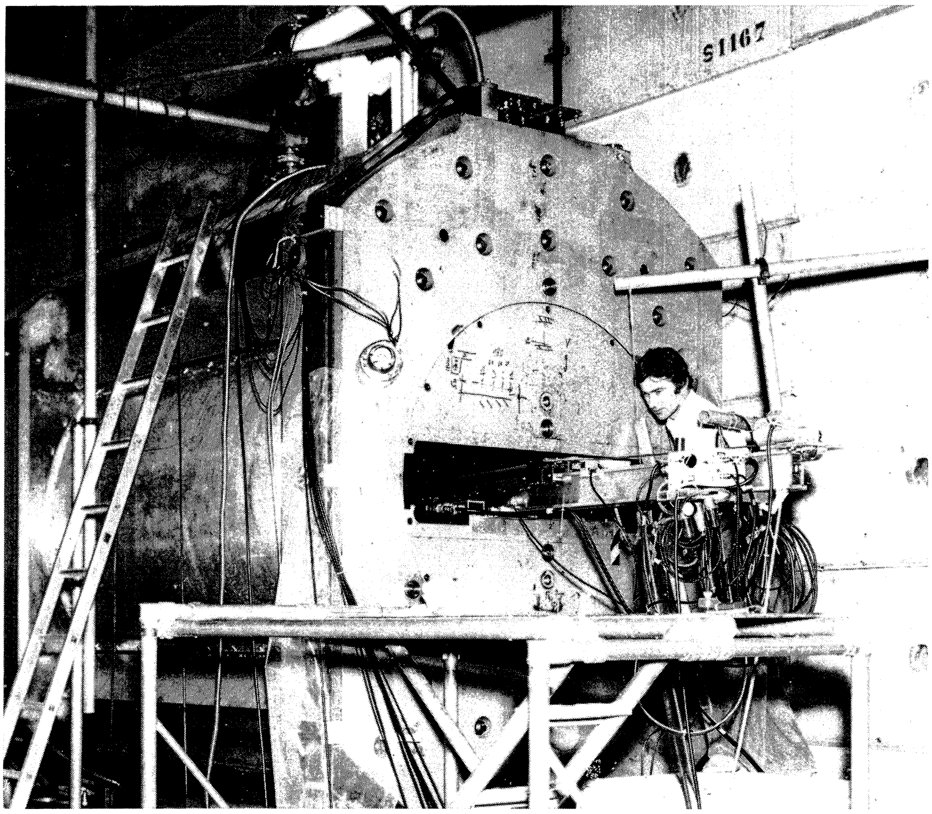

During an October shutdown of the ISR several new detection systems were wheeled into place. They can be considered as a 'second generation' of detectors presenting greater abilities and complexities. The major elements of two of them can be seen in the photographs:

1. Field tests under way on a superconducting solenoid which is now installed at intersection I-1. The magnet has drift chambers incorporated in the field volume and is flanked by two lead glass walls. It is being used by a CERN/Columbia/Oxford/Rockefeller collaboration in a study of high transverse momentum phenomena.

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can take the ejected proton beam beyond the two halls and is allocated for further developments of the Area. A Working Group, under Giorgio Brianti, is now studying what such further developments might be. For example, the full intensity proton beam could be brought to a single target in a new hall. The full intensity could not be used in this way in the existing halls because the background of secondary particles from the target would be too high for the other experiments, with the existing shielding. Alternatively, a very high intensity pion beam (10^{10} negative pions rather than 10^{8}) or a very high intensity wide-band photon beam (similar to that used in the charmed baryon discovery at Fermilab) could be generated. The Working Group needs input from the experimenters to help in deciding which scheme to adopt.

ISR Workshop

During October, a two week 'Workshop' was held at CERN to examine the future of the Intersecting Storage Rings after the present generation of experiments is completed (i.e. from about 1980). The subject was tackled in a series of working groups and the Workshop proved to be much livelier than expected with discussions often veering off in unexpected directions. On the final day, there were a series of summary talks from the working groups from which this brief review is drawn.

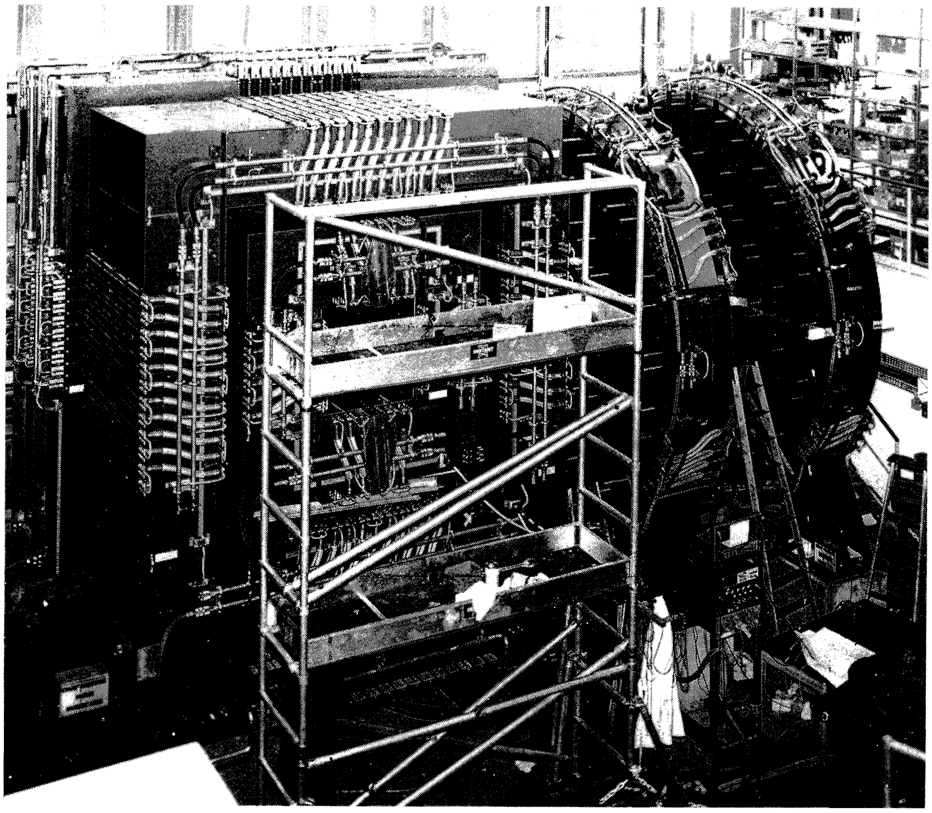
The physics categories were covered under the headings of low transverse momentum phenomena (summarized by J.C. Sens), high transverse momentum phenomena (M. Della Negra) and lepton and photon physics (Carlo Rubbia).

In the low transverse momentum region, one of the first important discoveries at the ISR was the growth of the proton-proton cross section with increasing interaction energy. Then came the information on the diffraction peak lining up with an optical model and indicating that the proton is not completely opaque (protons can pass through one another without interacting). There does not seem to be much more on these topics that can be extracted from the existing machine. To unearth further information requires higher collision energies and from the point of view of these experiments higher energy is the parameter to aim for in the 1980s.

The high transverse momentum region, however, still seems very rich. One of the major discoveries at the ISR was to find that, with much higher probability than expected, protons can bounce off one another giving jets of particles emerging at wide angles to the beam directions. This ties up with data from electron and neutrino experiments indicating point-like constituents within the protons. Although some of the global features of the hadron jets are known, there is much to be learned about the detailed nature of the jets. One intriguing possibility suggested by J.D. Bjorken is that it might even be possible to deduce the type of colliding quark within the proton if all the produce in the two opposing jets could be identified. This could reveal 'missing quarks' or 'quark holes'. A programme extending into the 1980s seems desirable for this work with more sophisticated 4π detection systems. Jet studies seem likely to be the most fruitful field of research at the ISR. The experiments would be complementary to what could be done at the 400 GeV SPS and would obviously go to higher centre of mass energies. They, also, would benefit from still higher collision energies.

The interest in lepton events at the ISR is part of the general wave of lepton searches stimulated by the charmed particle picture (see opening article). This wave has grown to such proportions that Val Telegdi has identified a new type of physicist — the leptomaniac. The direct production of electrons has been seen at the ISR with a ratio of electron to pion production remarkably constant (about 10^{-4}) over a wide range of transverse momentum, and there is new evidence for a surprisingly high rate for direct photons. Dilepton searches are also under way. The special characteristics of the ISR — the high centre of mass energy, the duty cycle and the geometry of the collisions might make these lepton experiments a source of good physics well into the 1980s particularly with the improvement of detection systems.

C. Fabjan summarized the thinking on detection systems. They will undoubtedly become bigger, more complex and more expensive. There is, however, confidence that the detection techniques which are now known



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2. Tests on the detection system of the Frascati/Genoa/Harvard/MIT/Naples/Pisa collaboration which is now installed at intersection I-2. It incorporates large magnetised iron toroids, drift chambers and scintillators for a study of muon pairs emerging from the proton collisions. As mentioned in our lead article, this is the experiment in which Sam Ting is involved.

can be developed to meet the requirements of the next generation of ISR experiments even taking into account higher luminosities.

At present the ISR have reached a maximum beam current of 39 A and currents of over 30 A are routinely available for the physics runs. The maximum luminosity at 26 GeV has been 2.9×10^{31} per cm^2 per s in normal intersections and 4.9×10^{31} in the special low beta insertion. L. Dilella described the possibilities for further luminosity improvements. Using superconducting magnets (eight quadrupoles) for the low beta insertion could take the value to over 10^{32} and this modification could be achieved with comparatively little disruption to the machine programme. A scheme developed by Brian Montague and Bruno Zotter could take the value even higher to over 10^{33} by reducing the beam crossing angle. This would, however, require a major rebuild of part of the ISR and involve a 6 month shutdown.

The ISR have already operated with deuteron beams as well as protons (a proton-deuteron luminosity of 6.8×10^{29} with 11 A protons and 4.1 A deuterons and a deuteron-deuteron luminosity of 3.5×10^{29} with 4.3 A and 4.4 A deuterons). Further deuteron runs are planned before the end of this year. P. Strolin summarized the work on the possibilities and desirabilities of colliding other particles. Both deuterons and alpha particles present no difficulties, can give acceptable luminosities and have interesting physics to offer, though probably not through to the 1980s. Other ions, such as nitrogen, would also be of interest but development of appropriate sources would be needed and the ions would probably be most usefully employed at the SPS.

The most intriguing possibility is that of colliding antiprotons with protons. The recent emergence of 'cooling' techniques — electron cooling at Novosibirsk and stochastic cooling at CERN — makes it possible to reach adequate luminosities with antiprotons for the first time. (Since these cooling techniques may prove to be one of the most important advances ever in accelerator physics, we shall return to them in more detail in a forthcoming issue.) Without cooling, proton-antiproton luminosities in the 10^{25} region were anticipated; with electron cooling this could move to 10^{30} and physics becomes possible. It is likely that some work on cooling will be initiated soon at CERN, perhaps using the PS Booster or the muon storage ring of the g-2 experiment. A cooling ring installed so that it could take antiprotons from the PS and inject them into the ISR or the 400 GeV SPS offers an extremely interesting improvement in CERN's research possibilities.

There was a letting down of hair in a working group on unconventional ideas reported by Bernard Pope. The ideas included an ISR bypass so that beams in one ring could be collided with beams in the SPS (involving some remarkable geometry since the SPS is deep underground), an ISR rebuilt underground with magnets from both rings in sequence to collide 60 GeV protons with the SPS beam (limited to 270 GeV corresponding to the peak SPS magnet fields which can be held d.c.), and an ISR rebuilt in its existing tunnel using superconducting magnets (named the SSR).

This last idea attracted most of the attention. It has two variants — a machine geometry close to the existing geometry enabling an energy of 100 GeV per ring to be reached with fields of 5 T in the bending magnets, and a new geometry which just squeezes in the tunnel with four intersection regions and an energy of 120 GeV per ring. Surprisingly the SSR possibility turned out to be a main theme of the whole Workshop.

This first Workshop has spread the thinking about the future of the ISR more widely. There is no need for decisions in the immediate future and the ideas have time to mature before there is a second look at the possibilities in the summer of next year when another Workshop will be held. In the meantime other external factors which influence the decisions (such as the broader discussions on the optimum future at CERN, the possibility of a start of construction of the ISABELLE 200 GeV proton storage rings at Brookhaven, and so on...) may become clearer.

TRIUMF
Muon spin experiments

A programme of muon spin rotation (μSR) studies is now under way at the

TRIUMF cyclotron. A Tokyo/British Columbia collaboration has concentrated on the behaviour of positive muons in ferromagnetic fields and several new features have been brought to light. A UBC/Berkeley collaboration has begun a definitive study of the chemical reactions of muonium atoms in low pressure gases and a UBC group has successfully identified such atoms in vacuum, produced from positive muons stopping in quartz powder.

These experiments use TRIUMF's μSR Facility, which consists of a muon channel (M20), several types of precession magnets, some special purpose counting equipment, and a dedicated computing facility based on a graphics oriented PDP 11/40 contributed by the University of Tokyo. The beam-line was constructed at minimum expense using components loaned by Berkeley and Harvard (eight of the quadrupoles having served before as part of the Chicago muon channel).

When tuned for muons from forward-decaying pions at 170 MeV/c, there are about 10^4 stopped muons per second in a thick (50 cm^2) target for every μA of 400 MeV protons on a 10 cm beryllium target. (The cyclotron delivered a 10 μA beam on target in August.) The polarization is only about 60 %, apparently due to a large contamination of 'cloud' muons from pion decay before the first bend. At higher proton intensity the channel will be tuned for 'backward' muons, whose polarization and beam purity are much improved at the expense of a factor of 10 to 20 in flux.

The channel is also operated in the 'Arizona mode' (named after Ted Bowen's group from the University of Arizona, which pioneered the technique at the Berkeley 184 inch cyclotron), collecting 4.1 MeV positive 'surface' muons from μ^+ decay at rest in the skin of the production target. The flux in this mode is about 5×10^3 per μA on the target. The M9 channel (described in the June issue) is also being used in this mode; it produced a flux of about 2×10^4 surface muons with a polarization close to 100 %. The spot size should be nearly the same as for pions and the momentum spread is very small. This type of beam is being used first for gas phase muonium chemistry experiments and studies of muonium in powdered insulators.

The standard μSR technique consists of measuring the time interval between the stopping of a spin-polarized muon and the detection in a fixed direction of its decay electron. Since the electron tends to come off aligned with the spin of the muon, a time spectrum accumulated from many muon decays will display oscillations with the frequency of the muon precession. Time intervals up to many μs can be measured with an accuracy of less than 1 ns at TRIUMF, yielding spectra with high precision information about precession, relaxation, and lifetime of the muons.

The technique lends itself to studies of μ^+SR, μ^-SR, μ^- lifetimes and radiative capture which are all planned or under way at TRIUMF. The first results were from μ^+SR studies in ferromagnetic metals. Positive muons stopped in metals are thought to come to thermal equilibrium within a few ps, taking up interstitial positions in the lattice and then diffusing from site to site on a timescale which varies dramatically with temperature and may be qualitatively different in different crystals. After stopping, the μ^+ spin is subjected to internal magnetic fields consisting of bulk magnetization, dipolar fields from neighbouring moments and the contact or hyperfine field from polarized conduction electrons.

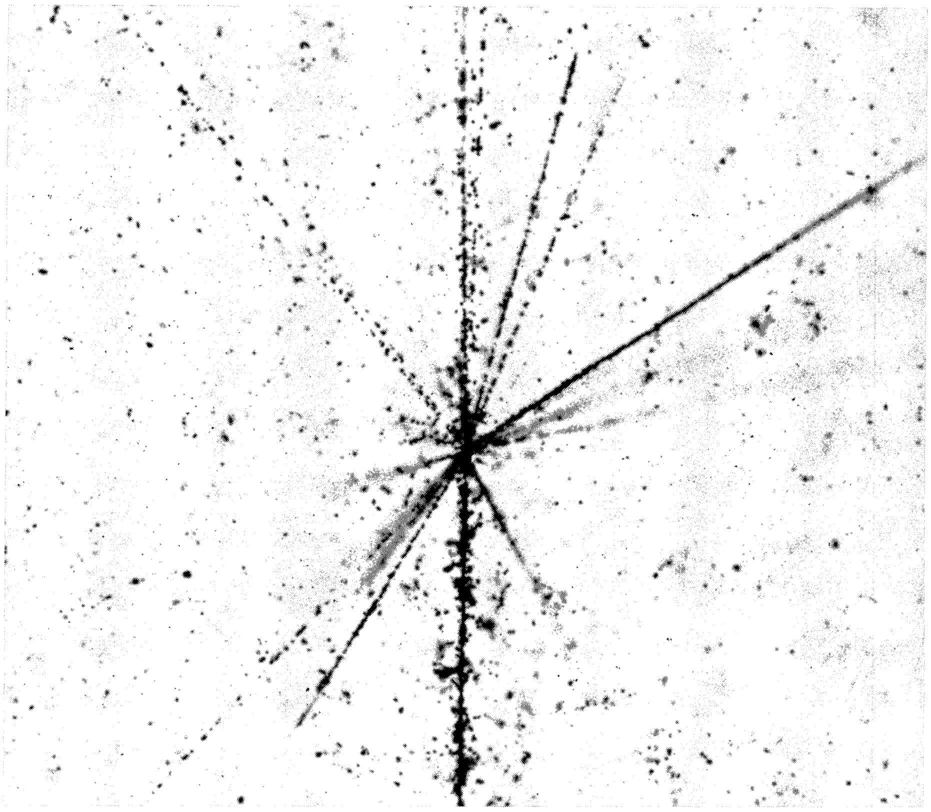
In a large, extremely pure single crystal of iron, muon precession has been observed at temperatures down to 23 K in zero applied field, extending previous observations which went down to 100 K. Both the precession frequency (reflecting the average internal field seen by the muon) and the relaxation rate (probably reflecting diffusion between sites with different dipolar fields) have been found to be smoothly varying functions of temperature.

The results suggest high temperature diffusion of the muon by thermally activated 'hops' with an activation energy of 17 meV, superseded below 44 K by quantum tunnelling between sites. The temperature variation of the hyperfine field seen by the muon deviates from that of the saturation magnetization in a sense opposite to that previously observed in nickel, suggesting that the perturbation of conduction electrons by the muon is qualitatively different in these two important ferromagnets.

In gadolinium and cobalt, temperature variations of the relative directions of internal dipolar and hyperfine fields lead to drastic changes in muon precession and relaxation as functions of temperature. These effects have been studied between 4.2 K and 600 K in zero applied field and further measurements are under way.

Using the 4.1 MeV 'surface' muons, muonium atoms have been found in argon gas targets at 1 atmosphere pressure. When impurities such as chlorine were added, the muonium precession signal showed a concentration-dependent quenching rate from which chemical reaction rate constants have been extracted. This makes it possible to compare the chemistry of Mu, H and D atoms which is an important test of the theory of absolute rates. Experiments to measure activation energies through the temperature dependence of the rate constants are being prepared.

An experiment on fine quartz powders, also using 'surface' muons, showed strong evidence that Mu atoms, formed when the μ^+ stops in a powder grain, diffuse rapidly out of the grain and into vacuum. This discovery paves the way for new studies using quartz powders as a sort of 'moderator gas' for chemistry experiments, as well as for measurements of the diffusion rate of Mu in quartz. Other powders will also be studied, as well as exfoliated graphite, in which it might be possible to perform 'two-dimensional chemistry' experiments in monomolecular layers of absorbed gases. In the particle physics realm, this discovery will be applied to a search for muonium-antimuonium conversion in vacuum.



A 1.9 GeV iron nucleus fragments in a silver bromide emulsion. This event was captured during one of the first experiments using the beam of iron nuclei accelerated in the Berkeley Bevalac at the beginning of October. The study of iron fragmentation has a lot to tell the astrophysicists since iron is abundant in cosmic rays.

BERKELEY Cosmic rays in the Laboratory

The accelerator team at the Lawrence Berkeley Laboratory have brought delight to the hearts of their astrophysical colleagues by accelerating beams in iron nuclei to high energies in the Bevalac complex. Iron is the most abundant heavy element in cosmic rays and the study of its behaviour in high energy conditions could convey a lot of information relating to the composition of matter in interstellar space and the evolution of relative abundances of different elements tracing back to the origin of Universe.

The Bevalac (the combination of the SuperHILAC heavy ion linear accelerator with the Bevatron synchrotron) accelerated a low intensity beam of iron nuclei to an energy of 1.9 GeV per nucleon (corresponding to 106 GeV per nucleus). Iron is thus added to carbon, nitrogen, oxygen, neon and argon in the list of available high energy ions available from the Bevalac.

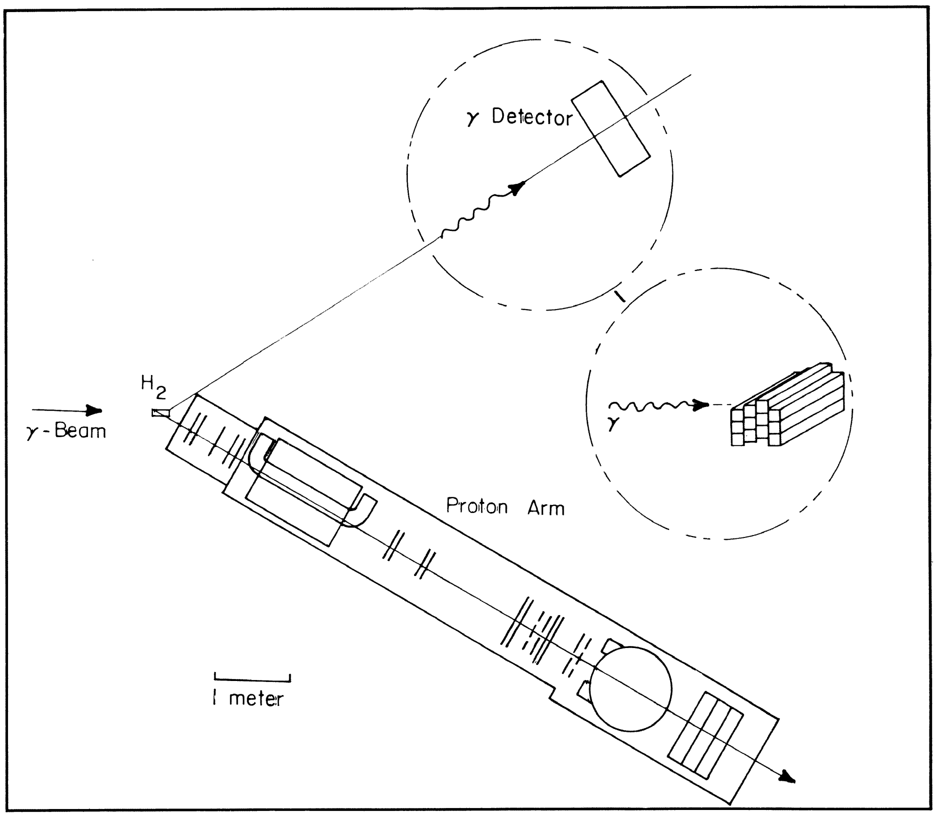
A four day period was set aside for the iron tests at the beginning of October. The first stage was to set up the beam transfer from the linac, the synchrotron and the ejected beam-line using nitrogen 15 ions which have a charge to mass ratio of 0.4666, almost identical to that of iron nuclei which is 0.4655. This procedure went very smoothly but the second stage, the switch to iron, initially brought a lot of frustration.

Four ion sources in succession broke down after only a few hours of operation. They are of the Penning gauge type with a stainless steel sputtering electrode which yields about 70% iron. The reason for the failures is not clear but may be due to the use of titanium as the cathode which is contaminated by iron resulting in the formation of an alloy. The alloy does not adhere to the normal plating surfaces. The use of vanadium rather than titanium is under investigation.

The short source lifetimes made the tuning of the linac a frustrating exercise. However, source number 5 operated for 38 hours without trouble yielding triply ionized iron and the linac was set up to pass +17 iron. The remaining electrons were stripped by a foil at the exit of the linac and +26 iron was fed to the synchrotron. The previous nitrogen settings made it possible to tune on to the necessary iron settings with no difficulty.

The accelerated beam intensity was very low, 3×10^3 nuclei per pulse, though obviously very much better for the astrophysicists than catching cosmic rays. A dozen experimentalists shared thirty hours of iron beam time. There were fragmentation studies on targets ranging from hydrogen to uranium, nuclear emulsion exposures and a calibration of a cosmic ray lexan detector.

Much higher intensities will be available after completion of the Bevalac improvement programme in 1980 (assuming funding in Fiscal Year 1978). The major modifications will be the addition of a higher mass injector to the SuperHILAC, so that all elements through to uranium can be accelerated, and a new vacuum system in the synchrotron to improve the pressure from 10^{-7} Torr to 10^{-9} Torr.



Schematic diagram of the experiment at the Cornell electron synchrotron which has studied large angle Compton scattering. The 'proton arm' consists of the CLASP spectrometer supplemented by multiwire proportional chambers and the scattered photon is detected in a special lead glass block array which is illustrated.

CORNELL Large angle Compton scattering

The present interest in high momentum transfer collisions, which seem such a promising route to understanding the interior composition of the hadrons, has prompted a first look at high energy elastic proton Compton scattering ($\gamma + p \rightarrow \gamma + p$) at centre-of-mass angles around 90°. Some parton models of the hadron predict that, in this kinematic regime, the Compton scattering cross section may be quite similar to that of electron scattering. Dimensional counting arguments predict that the cross section will decrease with energy according to some power law and the decrease will be less steep than for meson photoproduction and for pion elastic scattering. A number of theorists believe that evidence for 'fixed poles' may also show up in the scattering data.

A collaboration of physicists from Cornell/Massachusetts Institute of Technology/University of Massachusetts/Tufts University has taken data between 2 and 6 GeV at the Cornell electron synchrotron out to momentum transfer values as high as 4.3 GeV^2. The experiment detected the recoil proton in the Cornell Large Aperture Spectrometer (CLASP), to which were added five multiwire proportional chambers in front of the bending magnet to measure the angle of the recoil proton with the required precision.

Extensive shielding was necessary to reduce the background rates in the chambers to a tolerable level. A novel array of lead-glass Cherenkov counters was employed to catch the scattered photon. Rather than stacking the lead-glass in a 'fly's eye' array, the 72 blocks were stacked transversely, as in a scintillator hodoscope. This gave excellent measurements of the vertical angle of the photon (test beam measurements gave a position resolution of 0.53 cm for 3 GeV positrons) while the horizontal angle was measured with a scintillation counter hodoscope behind the second layer of the blocks.

Good angular resolution for both the photon and the proton helps in separating Compton scattering events from the copious background due to single pion photoproduction. Rates as low as four Compton scattering events per day were recorded and the data are in the final stages of analysis.

ARGONNE Record intensities with H^- injection

The Argonne Zero Gradient Synchrotron, ZGS, was operated throughout the month of October injecting negative hydrogen ions at 50 MeV rather than protons. This resulted in record intensities both for the circulating beam and for the beams delivered to physics experiments. This is the first time that a large proton synchrotron has used negative ion injection for routine operation.

A peak circulating intensity of

6.3×10^{12} protons per pulse at 12 GeV and a monthly average of slightly over 5×10^{12} were achieved, compared to the previous records of 5.4 and 4.2×10^{12} respectively, established in March (see May issue, page 176). The fast extracted proton beam delivered to the production target for the neutrino beam to the 12 foot bubble chamber averaged 3×10^{12} protons per pulse, which is roughly double the best previous monthly average for the neutrino experiment. These intensities resulted from a current of only 7 mA of 50 MeV H^- ions delivered by the ZGS injector, compared to the 35 mA of protons required to establish the previous records. As a result of this run, H^- injection will become the standard mode of future ZGS operation with unpolarized beams.

The H^- ions are injected into the ZGS at 50 MeV and are stripped of their electrons by a fixed foil of Poly(P) Xylylene 3200 angströms thick. The position of the stripping foil is selected so that the ions, injected at an angle of 3° to the central orbit and deflected outward by the magnetic field in the ZGS, are stripped and converted into protons at a point where they travel along an equilibrium orbit in the ZGS. Experience during October has shown that a single stripping foil has a lifetime of around five hours. A mechanism located inside the vacuum of the ZGS, loaded with up to 44 foils, is used to replace burned out foils, a process taking about five minutes. A weekly shutdown of about six hours duration is needed to restock the mechanism. Future improvements involving a vacuum lock could considerably reduce this amount of down time.

At injection, the ZGS magnetic field is increased at the relatively slow rate of 0.8 T/s and the circulating protons move gradually inward. (The energy of the injected H^- beam is ramped at the same time, so that the equilibrium orbit for a newly-stripped proton remains fixed.) Injection continues for more than three hundred turns, resulting in the filling of most of the ZGS aperture. In contrast, injection of protons requires an inflector magnet and the field rise must be considerably greater to keep the orbiting protons from colliding with the inflector septum. Furthermore, the absence of the inflector makes the tune up of the machine with H^- considerably easier and faster.

There are some indications that the ZGS, with the new 50 MeV H^- injection, has reached the space charge limit at capture, where intensities of 1.1×10^{13} protons per pulse have been achieved. Methods to reduce the space charge, and thus further to increase the accelerated beam intensity, will be tested in the next scheduled ZGS operation with unpolarized beams in January 1977.

The technique of charge exchange injection, promoted by Gersh Budker at Novosibirsk in 1959 (it had also been discussed by Milt White and others, for example, at the CERN Symposium in 1956), was clearly verified in early ZGS tests in 1969 (see August 1969 issue, page 239) and has now been demonstrated to be both practical and advantageous. It is an irreversible process, not subject to the restrictions of Liouville's theorem, so that the phase space density of the proton beam can be much higher than that of the original H^- beam, a situation which permits very efficient use of the lower H^- beam currents.

The advantages of H^- injection will be used to even better advantage in the operation of the 500 MeV rapid cycling Booster II accelerator scheduled for operation early in 1977 (see May issue). H^- ions will be delivered to Booster II, rather than directly to the ZGS, where they will be stripped, accelerated to 500 MeV and transported to the ZGS for injection. The ZGS intensity, with 500 MeV injection, is expected to climb to a level of several times 10^{13} protons per pulse. The present H^- source will be used for early tune up and studies of Booster II operation, but for production running it will be replaced by a source capable of 30 Hz operation to match the Booster pulse rate. Further increases in H^- source current are anticipated from a sodium charge exchange cell which is under development.

DESY Synchrotron radiation meeting

On 21 October, about a hundred physicists gathered at DESY to discuss recent results and new projects making use of synchrotron light. The meeting, which was organized by E.E. Koch and C. Kunz (who provided the information for this article), used the new presentation technique of poster sessions to spread information on the more than twenty experimental programmes under way at the DESY electron machines and on the research at the Bonn synchrotron. There were representatives of the synchrotron radiation laboratories at Orsay, Daresbury and Stanford and of the groups working at DESY which come from universities and scientific institutions all over the

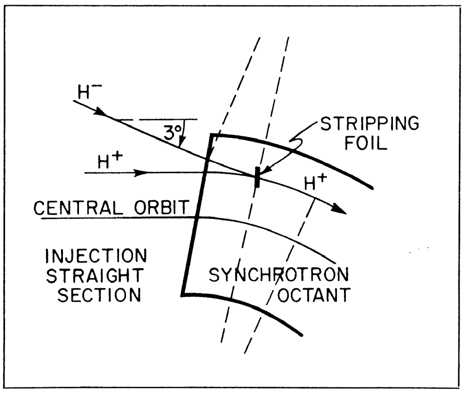


Diagram of the negative hydrogen ion injection routine which has worked so successfully at Argonne. The foil strips the ions to protons and the technique enables higher intensity proton beams to be built up.

Federal Republic of Germany plus several from abroad.

Exchange of information was very intense. After a minute or so of peering at the posted graphs, an expert would recognize what was new and exciting; no long introductions were needed and discussions would start immediately at the heart of a problem, such as the understanding of surface excitations on solid argon. Others would ask for a five minute briefing on a subject not familiar to them such as energy dispersive diffraction under high pressure. One group even built a model from wooden rods and rope to explain how they hope to filter out the extremely narrow (10^{-9} eV) interval useful for Mössbauer spectroscopy from the continuum of X-rays — the proverbial needle in the haystack.

Plenty of molecular physics and photo-electron spectroscopy of solids was presented and three studies on soft X-ray microscopy at different stages of development were displayed. Real images of living cells have already been obtained with a microscope using holographically produced zone plate lenses. Lithography, another simple but efficient technique, bears great promise for biological research as well as for the duplication of super miniaturized computer memories.

Last but not least, those methodical experts who calibrate secondary standard lamps for astrophysical and plasmaphysical applications were around. They fight to push the error bars down below 1 %, but this has not yet been reached. In the afternoon discussion session devoted to the future of synchrotron radiation work, one of them even proposed a storage ring to serve as the standard of radiation from the visible to the soft X-ray region, which is not a bad idea in principle, since the synchrotron spectrum is accurately calculable unlike that of any other source.

This discussion conveyed some of the excitement which inspires those who have come to appreciate synchrotron radiation as a marvellous tool for research. It makes it possible to learn things which were not accessible before and storage rings designed and built for the purpose will make the research even better. This idea has found world-wide resonance. In Daresbury and in Moscow the building of a dedicated synchrotron radiation source is already decided and one is in operation in Wisconsin. We shall be returning to the projects in the USA, probably in the next issue.

One of the attractive features of such a light source is that it is not linked specifically to a single field which could be called synchrotron radiation research. The radiation is a tool which finds use in many fields. Physicists, chemists, biologists, physicians, mineralogists, material scientists and even the computer industries use it, or will use it, to learn information which was never accessible before.

SERPUKHOV
Collaboration emphasis swings to SPS

On 14, 15 October the 13th Session of the Joint Scientific Committee which has supervised the collaboration between CERN and the Institute for High Energy Physics, Serpukhov, was held at Serpukhov. It reviewed the current collaborative experiments at the IHEP 76 GeV proton synchrotron and also the coming collaborative experiments at the CERN 400 GeV SPS. It is obvious that the emphasis in the collaboration is moving towards the use of the higher energies available at the SPS.

Since the Serpukhov machine started physics in the late 1960's, Western European groups, via CERN, have benefited from the extension of the energy range at a fixed target proton machine beyond what was available at CERN. There have been five collaborative counter experiments with Soviet and Western European groups and they have given some fine results including the first observation of the 'flattening' of total cross sections with increasing energy (prior to the rise now seen at still higher energies), extension of heavy meson data in a missing mass experiment and higher energy data on neutron-proton scattering.

The latest results from the 4th and 5th experiments were reported at the Serpukhov Session. A Karlsruhe / Pisa / Serpukhov / Vienna collaboration has amassed high statistics on neutral mesons including for example 100 000 events of eta production and decay into two gammas (compared to a few thousand from previous experiments). They also spotted a candidate for neutral charmed meson production (D° and $\overline{D^\circ}$) with a mass of 1.88 GeV.

The Pisa and IHEP component of this collaboration has continued detector development at Serpukhov with a view to future SPS experiments. They have studied lead scintillator sandwiches with different granularity and Cherenkov hodoscopes with various types of lead glass and photomultiplier. The purpose is to develop a shower detector system, with 4000 lead glass counters capable of a spatial accuracy of 1 mm, for use at the SPS. A fine sampling liquid argon-iron calorimeter has also been tested and has achieved an energy resolution of 2.5 % with 25 GeV electrons.

The 5th collaborative experiment is a particle/nuclear physics experiment involving Dubna and Milan which is following up the remarkable observation that multipion systems can pass through matter more easily than single pions. About 30 000 pictures using a silicon detector target have been measured at the two Laboratories and data taking will continue until mid-77.

Bubble chamber experiments, using the Saclay-built Mirabelle hydrogen bubble chamber have involved many groups. During 1976 there were two 400 000 picture exposures with positive and with negative kaons. Some of these pictures have been measured on the ERASME automatic measurement system at CERN. The chamber is presently dismounted for maintenance and will be back in action towards the end of next year.

Many experiments for the SPS involving groups from Dubna, ITEP, Leningrad, Kurchatov Institute, Novosibirsk and Serpukhov have been proposed and several of them are in the initial programme which has already been approved. In the same way as the Western European groups have participated at the Serpukhov machine, the Soviet groups will be bringing detection systems etc... to join those of the other collaboration groups at the SPS.

People and things

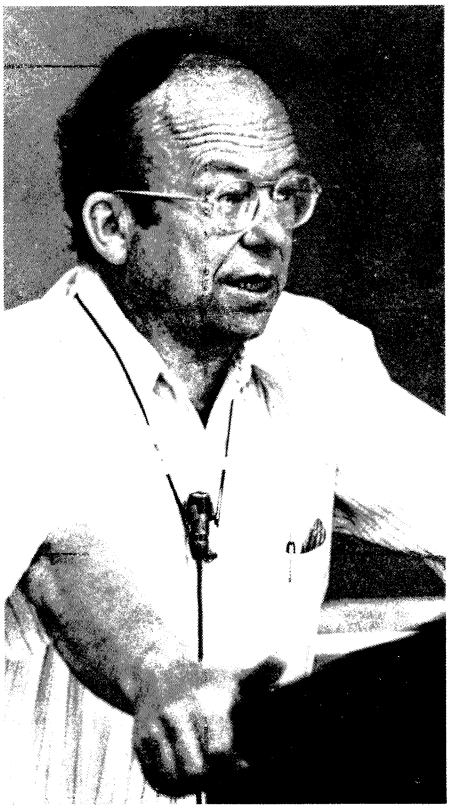
On people

Pief Panofsky, Director of SLAC, and his wife, Adele, visited the People's Republic of China from 5–22 October at the invitation of Chang Wen-yu, Chairman of the Revolutionary Committee of the High Energy Physics Institute of the Academia Sinica. During the visit there were long discussions on the role that China might play in HEP research including the possibility of constructing a large accelerator and storage ring. On 11 October, the visitors were feted at a dinner by Chou Pei-yuan, Vice-Chairman of the Chinese Association of Science and Technology.

K.P. Myznikov has been appointed to lead the Study Group on the 2-5 TeV proton synchrotron proposed in the Soviet Union. The project, known as UNK, was described in the September issue, page 293. The Soviet government is reported to have pledged 200 million roubles for its construction.

Bernard Gregory, former Director General of CERN, now leads the Délégation Générale de la Recherche scientifique et technique (DGRST) which coordinates the research and development programmes in science and technology in France. Since 1973 Bernard Gregory has headed the Centre National de la Recherche Scientifique (CNRS) which organizes fundamental research in France. He is also Chairman of the Particle and Fields Division of the International Union of Pure and Applied Physics (IUPAP).

Tribute was paid by the CERN Finance Committee to M. Alline who has left the Committee to take up other important duties after eleven



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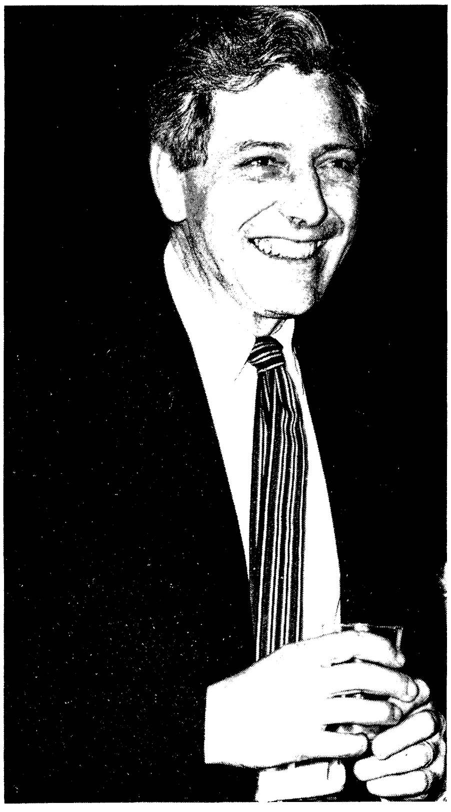


2.

1. Pief Panofsky

2. Bernard Gregory

years as delegate of France. M. Alline did much to smooth the negotiations between CERN and France during the extensions of the Laboratory site for the construction of the ISR and the SPS and has been a strong advocate of CERN in his country.

Dick Carrigan has joined the Fermilab Directorate with a six month appointment as Acting Assistant Director. Some of his responsibilities in the Administrative Division have been taken over by Chuck Marofske who has been appointed Acting Director of Personnel Services.

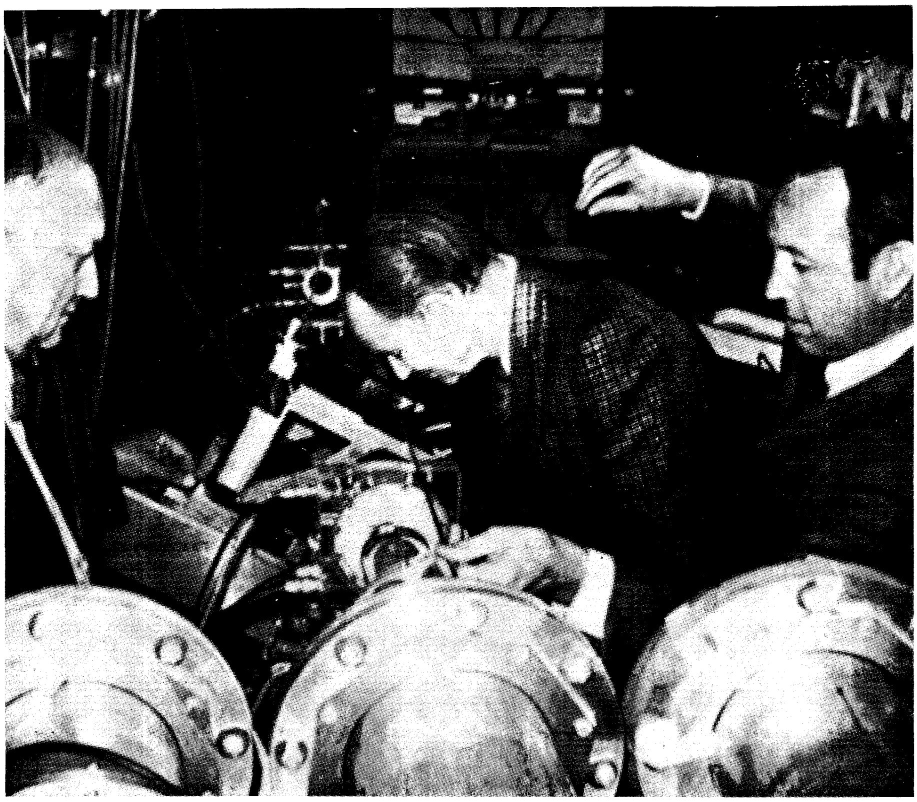
Brian Davies has succeeded Basil Zacharov as Head of the Computing Systems and Electronics Division at the Daresbury Laboratory. Basil Zacharov will continue his scientific work on computer systems and instrumentation.

William Steward and Andreas Koehler have moved their proton radiography research, previously done at the Harvard cyclotron and at Argonne, to Fermilab where they will use spare protons from the linac. They will be joined in their work by Joseph Curry.

Alan Gibson from the University of Essex will join the Rutherford Laboratory on 1 January as Head of the Laser Division. He will manage the Science Research Council's Laser Centre at the Laboratory which is being equipped with a 800 GW neodymium glass laser for the use of University scientists.

Ed McMillan, then Director of the Lawrence Berkeley Laboratory, submitting his eyes to heavy ions from the Bevatron during investigations of the source of the light flashes seen by astronauts on space flights.

(Photo LBL)



Tandem upgraded

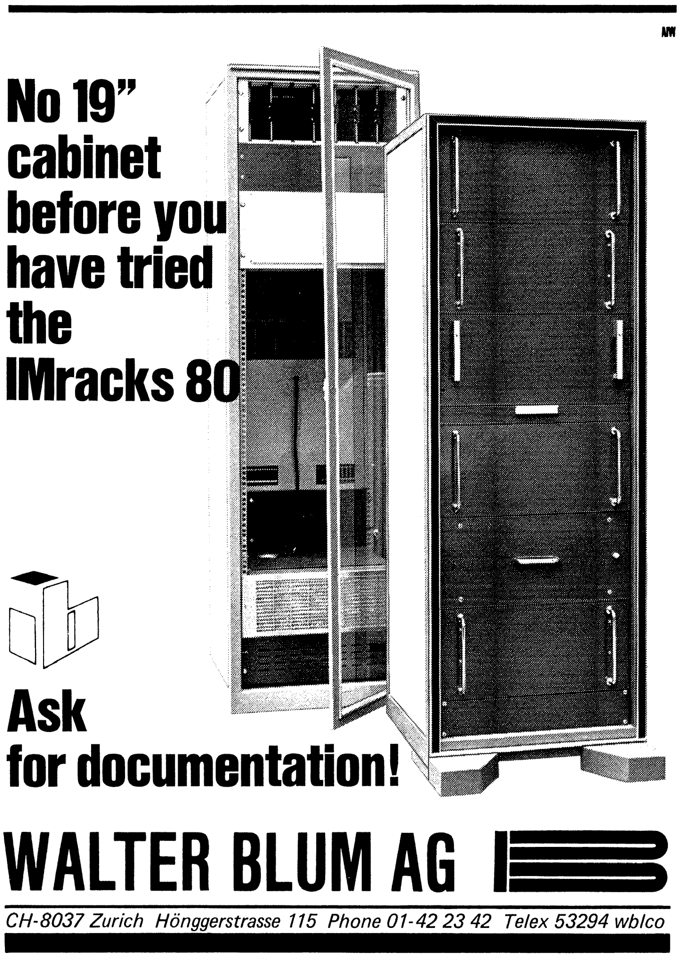
A major programme of improvements at the Brookhaven Tandem Van de Graaff came to fruition in September with the acceleration of several ion species to energies never achieved at electrostatic machines before. The improvements had included a new ion source system (which tripled the number of types of ion available), new accelerator tubes, new belt drive, conversion to sulphur hexafluoride insulating gas, etc. The highest output energies in the first runs were 225 MeV for copper ions and 200 MeV for nickel ions. Carbon and sulphur were also run and with energies (95 MeV and 200 MeV respectively) high enough to penetrate the Coulomb barrier of the uranium nucleus.

Negative ions at Fermilab

Construction of a new pre-accelerator is under way at Fermilab. A building addition at the end of the linac will house a second Cockcroft-Walton set and an ion source to produce a beam of negative hydrogen ions for acceleration in the 200 MeV linac and injection into the 8 GeV booster. As described in the Argonne article on page 398 in this issue, negative ion injection could make it possible to increase the beam intensities available from the accelerator complex and to advance the intensity still further towards the ambitious design goal of 5×10^{13} protons per pulse. Tests with the negative ion pre-accelerator are scheduled for the summer of next year.

Seeing the light

One of the mysteries of the first space flights was that astronauts were seeing flashes of light even in dark conditions in the spacecraft. Phosphenes



(from the Greek, phos — light and phainen — to show) had been known for a long time caused by small electric currents but the astronaut experience led to the study of other causes. In 1971, work at the Seattle cyclotron and at the Berkeley cyclotron and Bevatron showed that particles such as are present in cosmic rays could produce the effects that were being seen. Recent work at Brookhaven lays the effects at the door of Cherenkov radiation. P.J. McNalty and his colleagues submitted 'dark adapted' subjects to high energy pions and they saw light flashes. Varying the pion entry direction they convinced themselves that the source was Cherenkov light rather than nuclear interactions. Finally, work with muons entering the eye from behind resulted in extensive flashes with dark centres. The Apollo 17 astronauts saw such phenomena due to cosmic rays penetrating the eye from behind.

Meetings

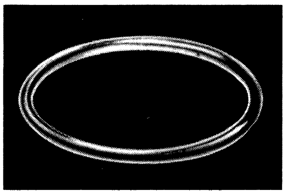
An ECFA Winter Study Week will be held at DESY from 22-26 February 1977. It will review physics with colliding electron-positron beams at energies of 2 × 40 GeV and above. Further information may be obtained from Pierre Darriulat, CERN, 1211 Geneva 23, Switzerland.

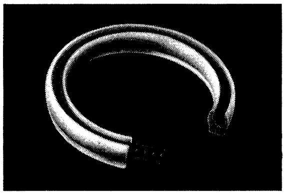
The 1977 CERN-JINR School of Physics will be held at Nafplion, Peloponnese, Greece from 22 May to 4 June 1977. It is the fifth in the series of Schools organized jointly by CERN and Dubna with the basic aim of communicating various aspects of high energy physics, particularly theoretical physics, to young experimentalists from the Member States of both Organizations. Further information may be obtained from Ann Caton, CERN, 1211 Geneva 23, Switzerland.

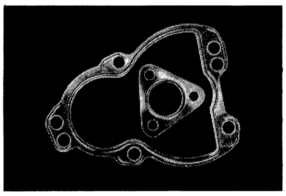
LAMPF operating at 100 μA

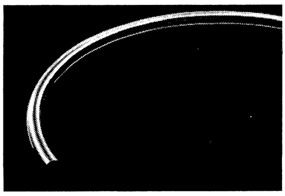
Since August, the 800 MeV proton linear accelerator, LAMPF, at the Los Alamos Scientific Laboratory has run at an output beam intensity of 100 μA and machine reliability both for proton and negative hydrogen ion beams has been over 80 %.

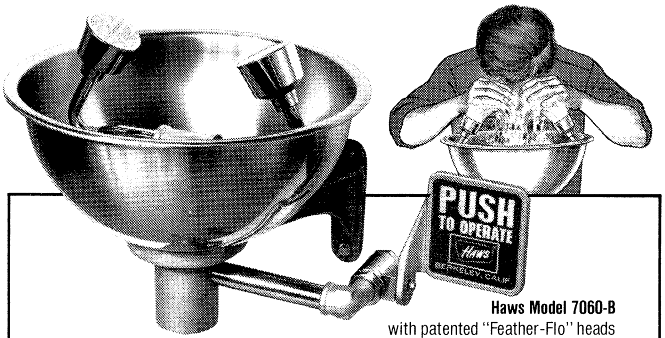
During a five month period, sixty experiments had some beam time with, typically, about ten of them running simultaneously. The two big spectrometer systems are in action — EPICS has reached its design parameters and is being used for experiments, HRS is also beginning its first experiments. Recent results include no sign of parity violation in low energy proton-nucleus scattering on hydrogen and deuterium, no sign of direct electron production at LAMPF energies, and a new magnesium isotope identification in fragments from uranium bombarded by protons. Medically oriented work continues with patient irradiations with negative pion beams, isotope production and proton radiography, which has now advanced to the stage of a LAMPF experiment proposal.







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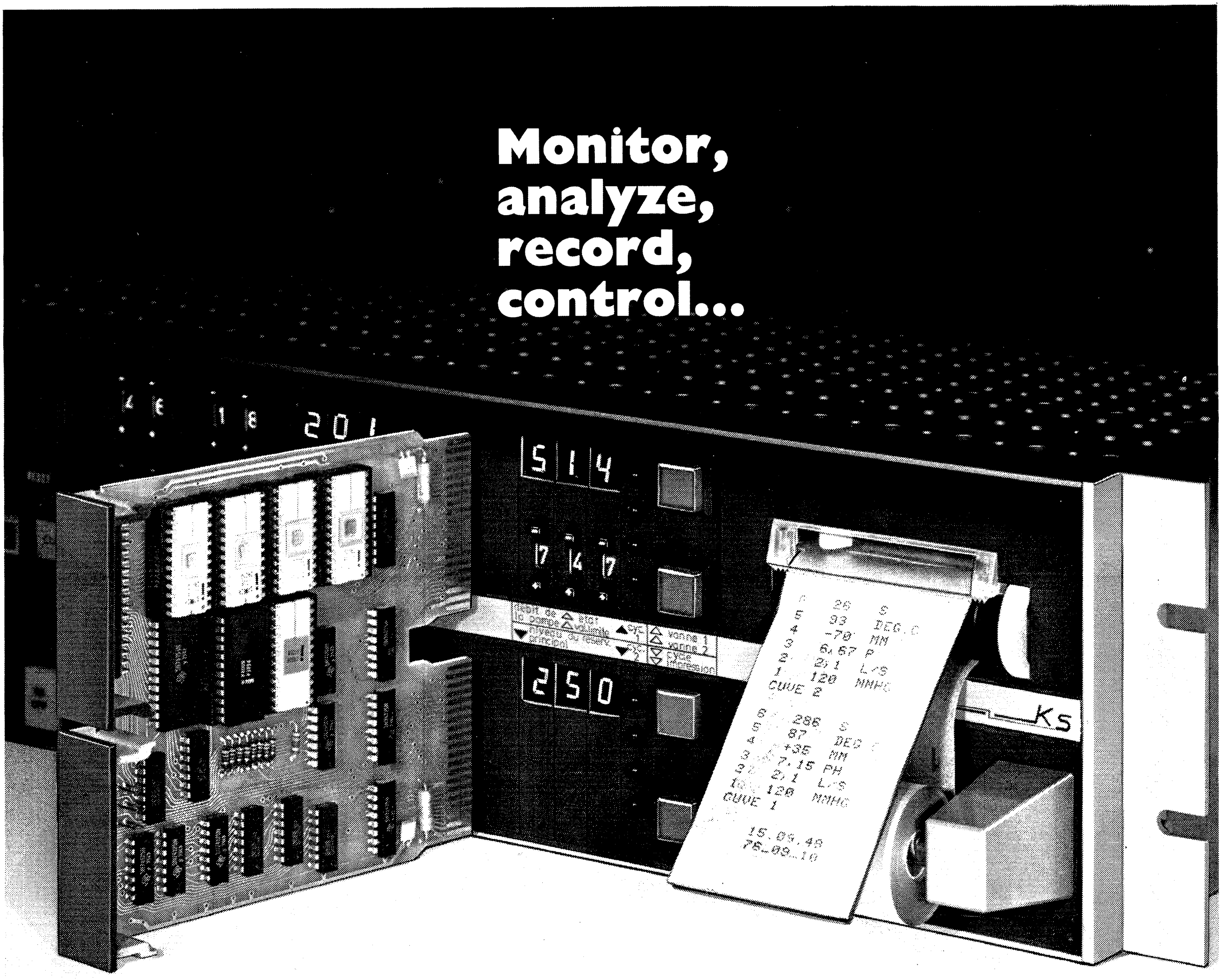
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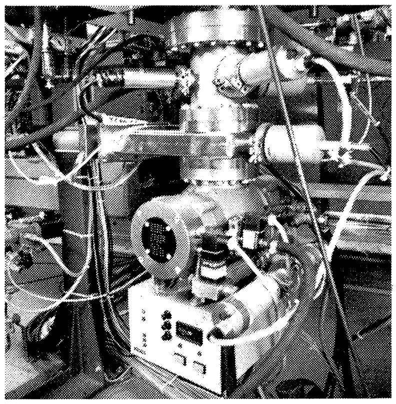

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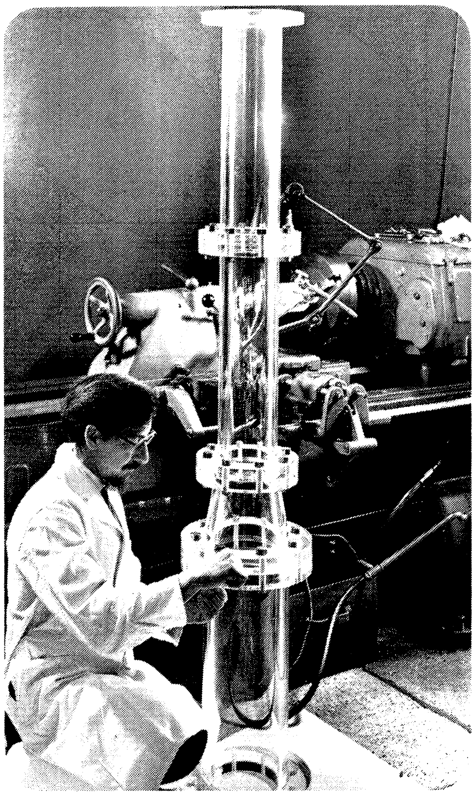

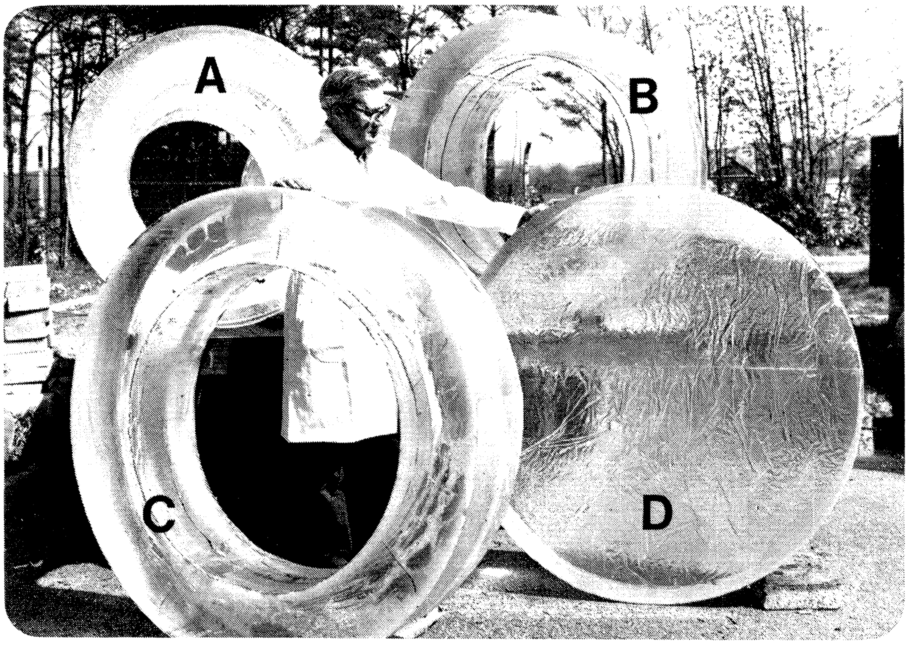
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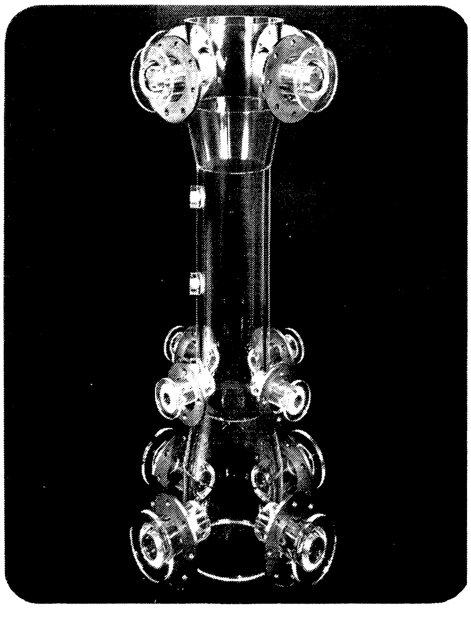

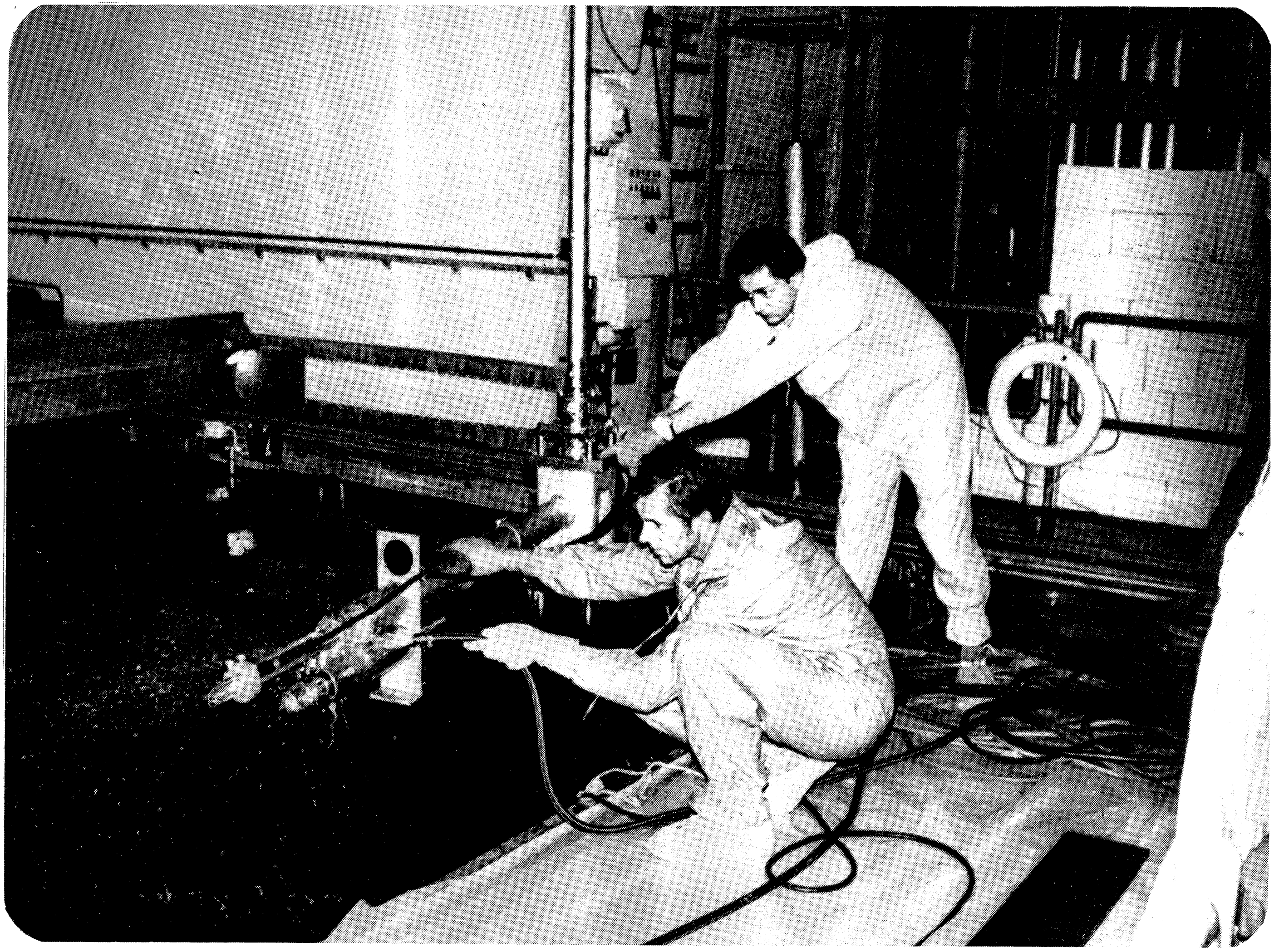

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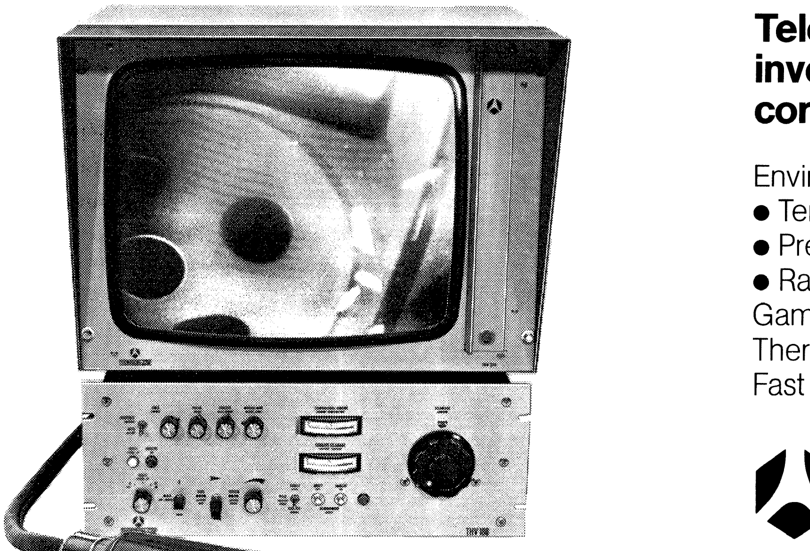

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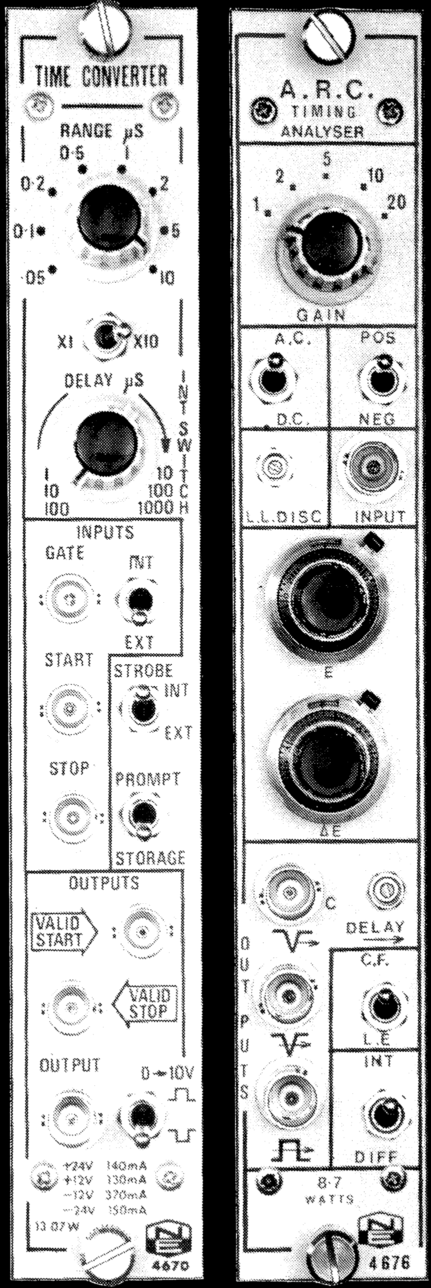

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VALID STOP
OUTPUT 0→10V
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A.C. D.C.
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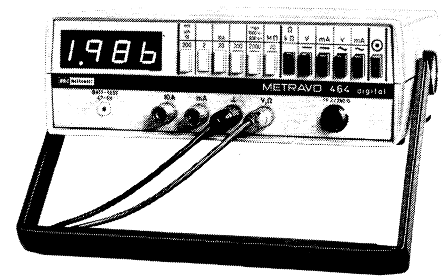


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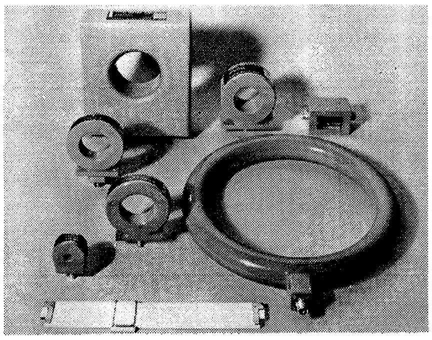

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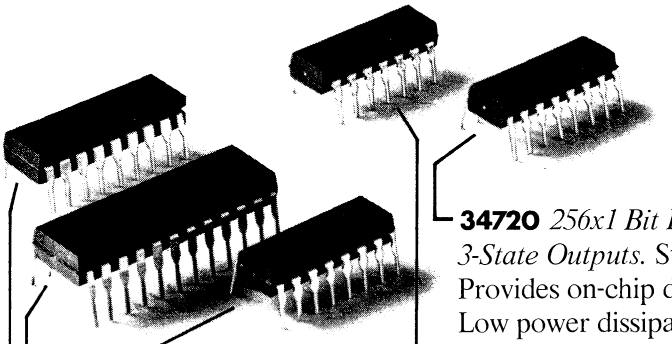

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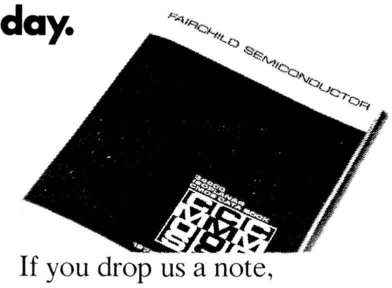

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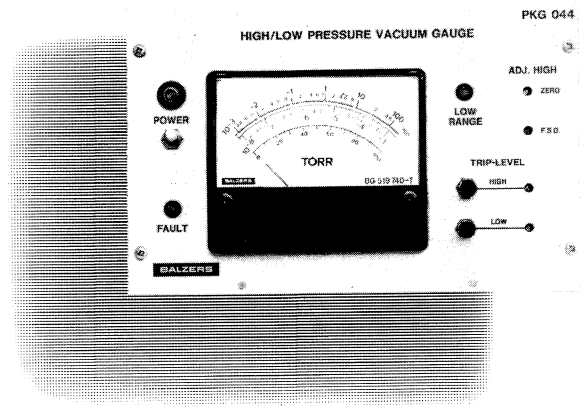

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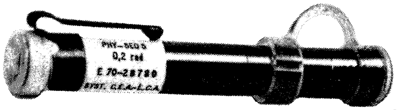
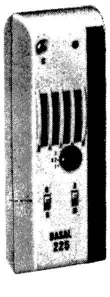


SEQ 5

Measures the absorbed dose in soft tissues at a depth of 300 mg/cm², due to photons of 50 keV or above and electrons of any enegy.

SEQ 6 Measures the absorbed dose in soft tissues at a depth of 300 mg/cm², due to photons of 10 keV or above and electrons of any energy.

SEQ 7 7 mg/cm² (skin dose).



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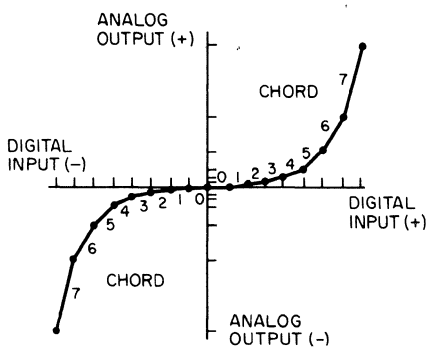
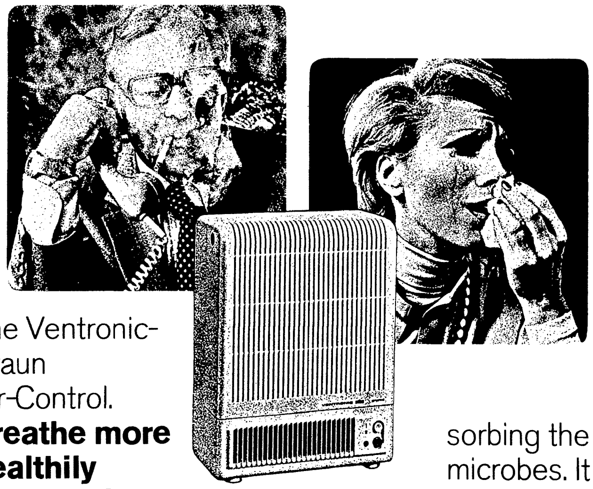

ANALOG OUTPUT (+)
CHORD
7
6
5
4
3
2
1
0
DIGITAL INPUT (−)
DIGITAL INPUT (+)
CHORD
ANALOG OUTPUT (−)



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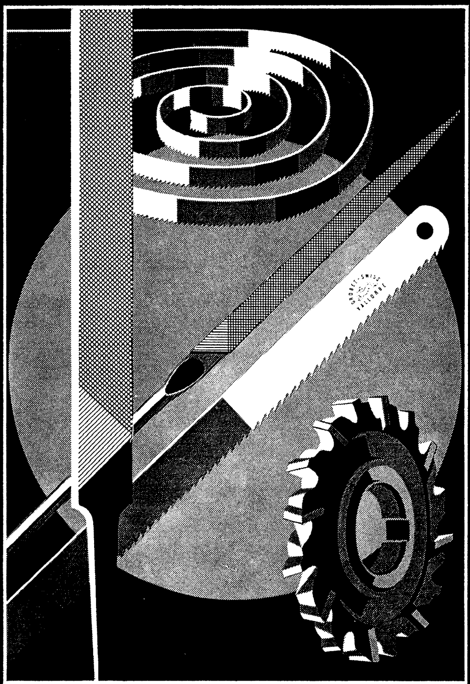

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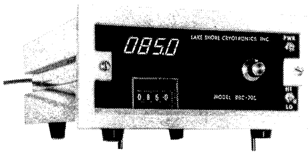

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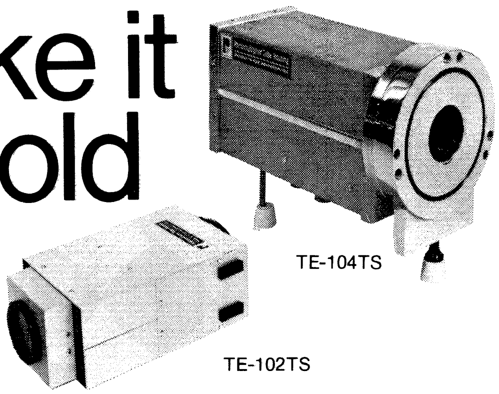

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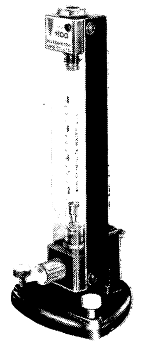
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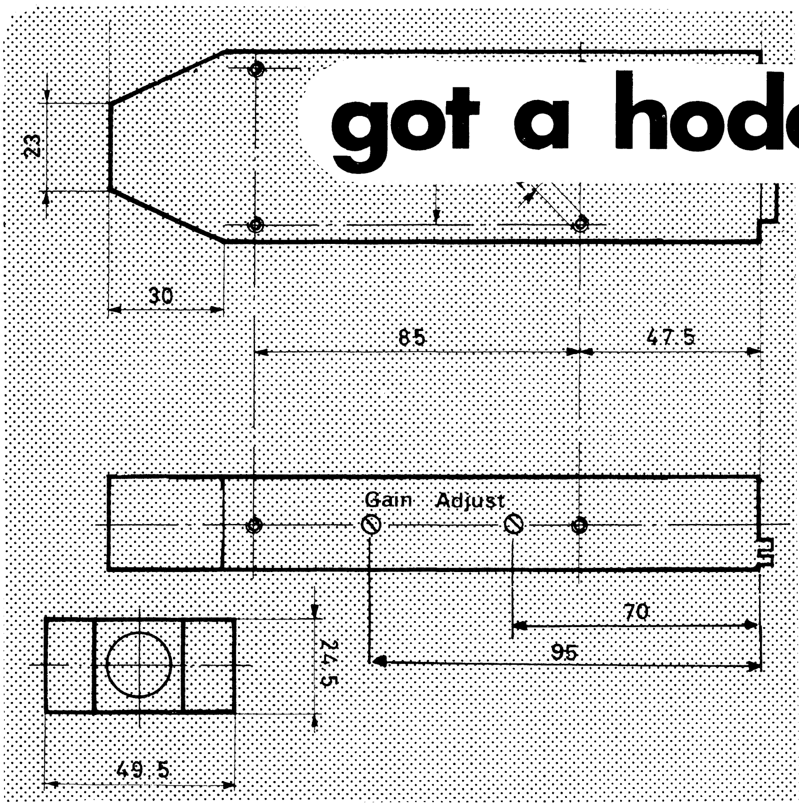
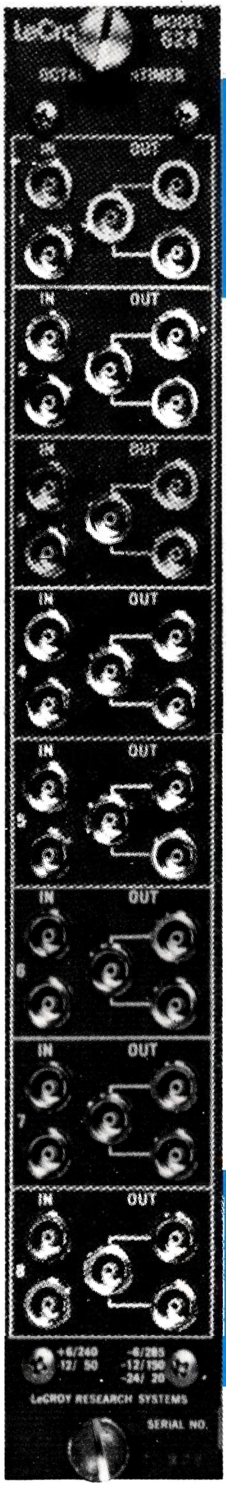
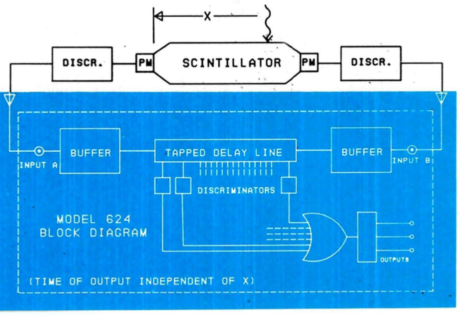


23
30
85
47.5
Gain Adjust
70
95
24.5
49.5

ELIMINATE TIMING UNCERTAINTIES caused by photon transit time through long scintillators





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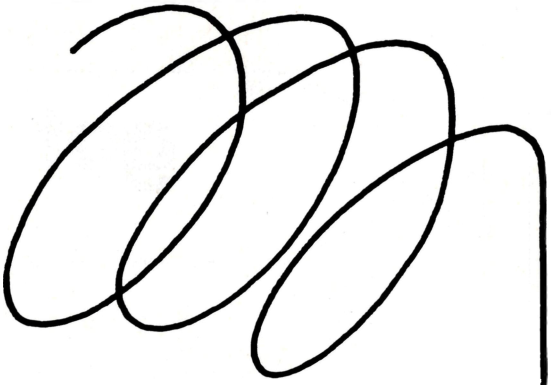

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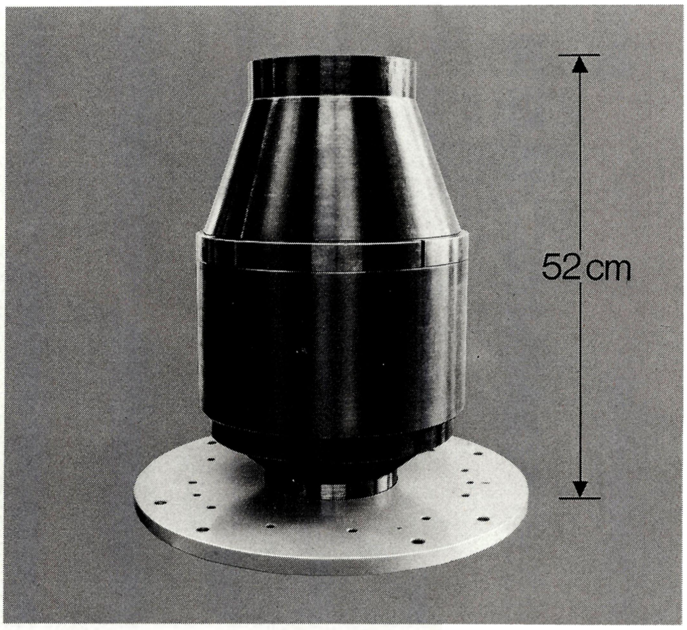

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