CERN COURIER

International Journal of High Energy Physics

VOLUME 25 7 SEPTEMBER 1985

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

Printed by: Cranford Press
Croydon, England.

Published by:
European Laboratory for Particle Physics
CERN, 1211 Geneva 23, Switzerland
Tel. (022) 83 61 11, Telex 419 000
(CERN COURIER only Tel. (022) 83 41 03)

USA: Controlled Circulation
Postage paid at Batavia, Illinois

CERN COURIER

International Journal of the High Energy Physics Community

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Cover photograph: The first 30 metres of the 6.3 kilometre tunnel for the HERA electron-proton collider now under construction at the German DESY Laboratory in Hamburg. Tunnelling work will take about two years to complete (Photo DESY).

And then there were fourteen

At the CERN Council session in June, delegates voted unanimously in favour of Portugal joining the Organization, just three years after Spain became the thirteenth Member State. (Before officially becoming a Member State, Portugal has to ratify the decision, but this is expected to be accomplished quite quickly.) The financial details of Portugal's accession were also agreed unanimously by CERN Council, and during the next few years particle physics research in Portugal will be strengthened so as to obtain maximum benefit from the work at CERN.

After the vote, Council President Wolfgang Kummer welcomed the Portuguese delegation, and Antonio Costa Lobo, Portugal's Ambassador to the United Nations in Geneva, expressed his country's pride and pleasure in being able to join this prestigious scientific effort.

At the same meeting of CERN Council, it was decided to accord observer status at CERN to the European Communities in order to strengthen the links between CERN and the European Communities in the field of scientific and technical cooperation. In parallel, CERN has also become an observer at the Comité de développement européen de la science et de la technologie (CODEST), which deals with the broad lines of European scientific and technical policy.

The links between CERN and the European Communities have so far covered some involvement of senior personnel and participation in special projects, notably the STELLA experiment for fast data transmission using the OTS-2 communications satellite launched in 1978.

So begins another chapter in the history of CERN and its Member States. Back in 1955, there were twelve founder members – Belgium, Denmark, the Federal Republic of Germany, France, Greece, Italy, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom, and Yugoslavia.

Austria joined in 1959, followed by Spain two years later. For a brief period in 1961, CERN had, like now, fourteen Member States. However Yugoslavia left the Organization in December of that year, retaining the status of observer. Turkey was also granted observer status that year. Poland became an observer in 1963.

Spain withdrew from CERN in December 1968 for financial reasons, leaving twelve Member States, a situation which lasted until 1982, when Spain rejoined.

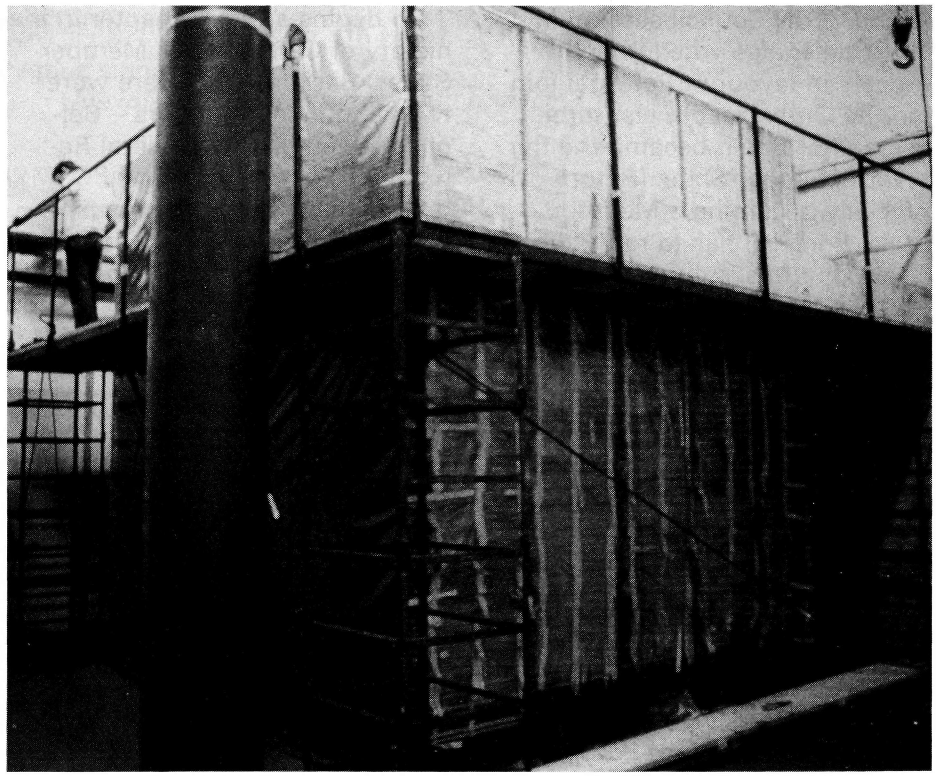
In addition to newly-increased formal membership, CERN's unique facilities continue to attract growing participation from scientists in other European states, the US, the Soviet Union, China, Israel, Japan,.... a shining example of successful and widely admired international collaboration and scientific achievement.

After CERN Council had voted unanimously in favour of Portugal becoming the Organization's fourteenth Member State – Antonio Costa Lobo, Portugal's Ambassador to the United Nations in Geneva, flanked, left, by Council President Wolfgang Kummer, and Director General Herwig Schopper.

(Photo CERN 519.6.85)

Physics monitor

The NUSEX experiment by a CERN/Frascati/Milan/Turin group in a gallery off the Mont-Blanc road tunnel – an unexplained source of particles coming from a binary star.



Cygnus signal

The advent of big underground detectors looks to be bringing in its wake a new branch of physics – elementary particle astronomy. One of its first results is confirmation of an intense source of particles coming from the binary star Cygnus X-3.

Some ten years ago, the first formulations of 'Grand Unified Theories' ambitiously tried to pull together the new electroweak unification with the strong force binding quarks into nucleons (and in turn into nuclei). The big spin-off prediction from these ideas was the instability of the proton, especially in the (in principle) easily observable decay into a positron and a neutral pion.

To check this out, a range of big underground experiments quickly got off the mark, with hundreds of metres of rock screening off cosmic rays. With samples weighing hundreds, even thousands, of tons, these experiments had plenty of protons to watch.

The first big new experiment to become fully operational was by an Irvine/Michigan/Brookhaven group in the Morton Salt Mine, Ohio. Using several thousand tons of water, this experiment should fairly quickly have picked up signs of proton decay if it happened at the predicted rate. It didn't.

The negative result was underlined by other underground experiments (NUSEX by the CERN/Frascati/Milan/Turin group in the Mont-Blanc road tunnel, the Japanese Kamioka study, and other projects – see April 1983 issue, page 79). Protons just don't decay fast enough for the simplest Grand Unified Theory to be right. (With the predicted proton lifetime of 10^{32} years, just one human proton in a medium sized city should decay every hour.)

If protons decay more slowly, then the detectors have to look harder. The main problem now is to disentangle any signal from the background caused by cosmic neutrinos. During this time, the underground detectors might well find other things...

Cygnus X-3 was discovered in 1961. Five times brighter than the sun, it emits radiation with a period of 4.8 hours – too long for a pulsar. It was quickly identified as a binary star, emitting ultra high energy photons as well as X-rays.

After the initial astronomical surveys, cosmic ray experiments on the earth's surface picked up air showers with a relatively high muon content coming from the direction of Cygnus X-3 and which oscillated in time with the X-rays. Such a high muon flux was surprising as even ultra high energy photons crashing into the earth's atmosphere should be a relatively weak source of muons. The observed muon signal was more in line with what would be expected if the binary star also emitted heavier primary particles.

Ultra high energy muons are highly penetrating particles, capable of piercing the earth's surface before being absorbed, and therefore easily seen in the big underground detectors.

Both NUSEX and the smaller Soudan (Argonne/Minnesota/Oxford) experiment in a Minnesota mine have now identified high energy muons reaching their detectors from a narrow cone around the direction of Cygnus X-3, and whose signal comes and goes every 4.8 hrs.

However the origin of these muons is a mystery. As they are electrically charged, they cannot emanate directly from Cygnus X-3 (they would be bent by galactic magnetic fields). Particles arriving from the direction of the star have to come from electrically neutral radiation hitting the earth's atmosphere.

Neutrons are ruled out because they are inherently unstable and would decay long before reaching the earth. Photons of several 10^{14} eV (hundreds of TeV) could produce muons capable of piercing hundreds of metres of rock. However the measured rate of such photons on the earth's surface is much lower than the level required to produce the observed underground muon signal. Another possible explanation is muons produced by neutrinos. This is ruled out by both experiments, who observe that as their detectors move relative to Cygnus X-3, the muon signal is modulated by the changing thickness of rock the particles have to pass through. This would not be the case for cosmic neutrinos.

The observed angular spread of the muons around the star's position is also a puzzle. Although only a few degrees, at these energies this implies transverse momenta of up to 0.5 TeV, many times higher than expected by extrapolating behaviour seen under laboratory conditions.

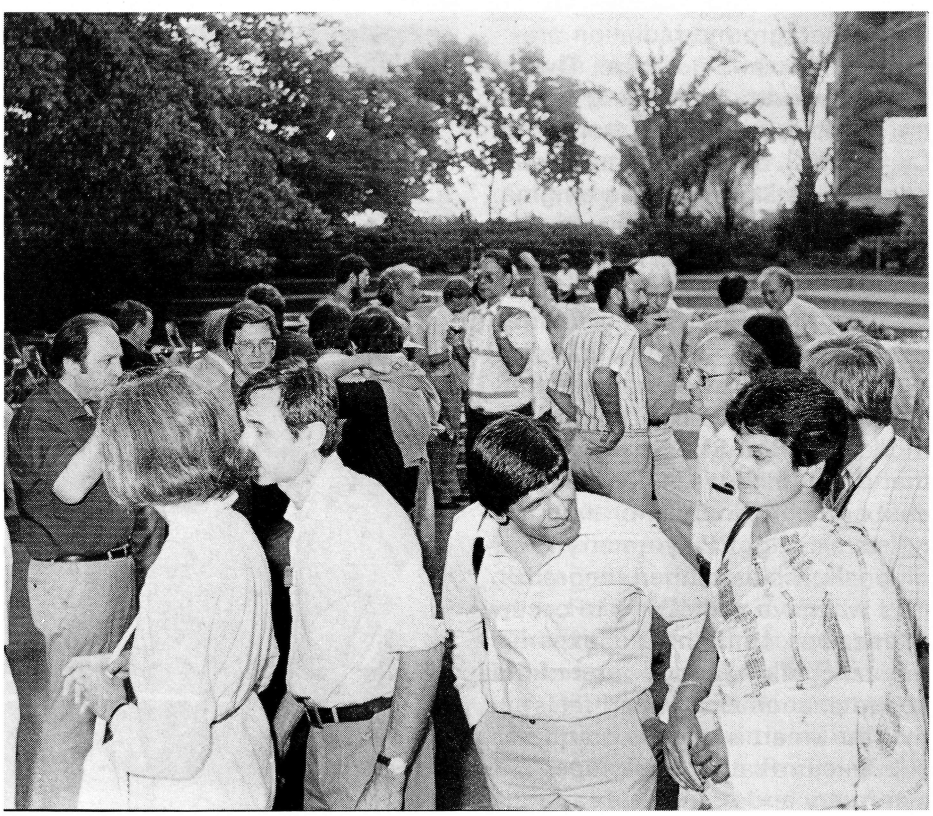
Which leaves a question mark on the origin of the high energy particles coming from the binary star. Results are eagerly awaited from other underground experiments, especially the Japanese Kamioka study and the Orsay/Saclay/Ecole Polytechnique/Wuppertal group in the Frejus tunnel linking France and Italy.

SYMPOSIUM Multiparticle dynamics

The annual International Symposia on Multiparticle Dynamics, a tradition dating back to the 1970 meeting at Paris, continue to provide a valuable focus for current particle physics research. This year's meeting was held in Israel at the guesthouse of kibbutz Kiryat Anavim, from 9-14 June. This choice setting 15 kilometres northwest of Jerusalem enabled the 110 participants from 18 countries to get acquainted with this unique form of communal living and served as a base for a number of exciting tours of historical interest in the area.

For physics, the lasting impression that one took away from the Symposium was how well the Standard Model is standing up to both the experimental and theoretical onslaught. As was so ably put by Haim Harari in his summary talk, 'the silence of UA1 on monojets made the biggest noise at the conference.'

(Last year the big experiments at CERN proton-antiproton Collider reported a number of unusual events, including the so-called 'monojets', – see May 1984 issue, page 139. After the Collider experiments accumulated much more



Participants at the International Symposium on Multiparticle Dynamics, held at Kiryat Anavim in Israel.

(Photo Tel Aviv University)

NEWS from the Summer Conferences will appear in our next issue.

data last year, the noise seems to be abating.)

New preliminary results coming from the UA5 detector at the CERN Collider caused a great stir. The data was taken while operating the Collider in a pulsed mode at a record collision energy of 900 GeV (see May issue, page 131). John Rushbrooke made a beautiful presentation of the data, stressing the new features that are seen. These include the fast increase of the average number of charged particles with energy, and violation of so-called 'KNO' scaling over the collision energy range 200 to 900 GeV. A new form of scaling manifests itself in the central region, and there is approximate scaling in the fragmentation (quark interaction) region. A search for Centauro-like events, seen in cosmic rays and possibly expected at these energies, turned out to be negative. Gösta Ekspong, also of UA5, showed that his experiment's particle multiplicity distributions could be well parametrized by a negative binomial distribution, however the underlying mechanism remains a mystery.

The session on 'fragmentation' models was well attended. The three most popular schemes for describing the release of hadrons by quarks and gluons were each defended by a leading protagonist: the case for the cluster model by Bryan Webber, the Lund model by Gösta Ekspong and the revised Isajet model, including gluon radiation corrections, by Frank Paige. The first two models appear to successfully reproduce the experimental data, while Isajet still has problems with at least electron-positron annihilation producing three jets. Anne Kernan discussed evidence for the existence of the top quark based on UA1 data. The quoted mass limits, between 30 and 50 GeV, were determined from semileptonic decays of W bosons.

John Ellis held the attention of the audience with his talk on 'Supersymmetry and anything beyond the Standard Model in hadron interactions,' however in the light of the new UA1 and UA2 data presented by Peter Watkins and Michele Livan, this lecture took on a speculative tone.

Arnon Dar gave a fascinating survey of Cosmic Accelerators, a topic which seems to have become an integral part of high energy physics, and a novel way of studying reactions at ultra high energies. Recent data measured at the Fly's eye detector in Utah have confirmed that the source of the ultra high energy cosmic rays and the 3K background radiation are extragalactic and not local. The nature of the ultra high energy neutral particles emanating from Cygnus X-3, and other stars (see page 264) still remains an enigma.

Summarizing the 59 papers presented over the week, Harari stressed the paucity of experimental clues that might suggest something beyond the Standard Model (SM) is required. Among the phenomena which cannot be accommodated in the SM, he mentioned that if the universe is not baryon-antibaryon symmetric, or that monojets exist, or CP symmetry is additionally violated, then theoreticians will have something to occupy themselves. Until there is experimental confirmation for any of the above phenomena, Harari feels that the smart money is on quark substructure rather than supersymmetry and grand unification.

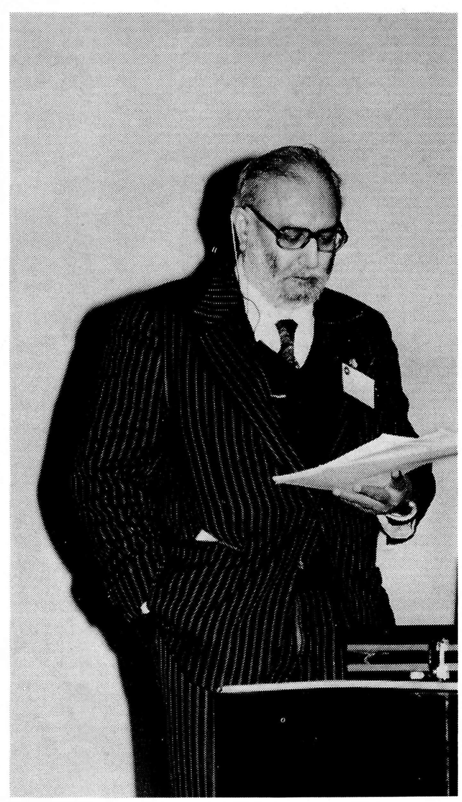
The Symposium, which was under the auspices of Tel Aviv University, was ably organized by Jacob Grunhaus, and all the participants owe him a vote of thanks.

From Errol Gotsman

Pions to quarks

This was the title of an international symposium on particle physics in the 1950s, held at Fermilab from 1-4 May and which attracted 170 participants from ten countries, as well as other visitors from Fermilab and the surrounding area. The main sessions dealt with new particle discoveries in the cosmic rays; with strong, weak, and electromagnetic interactions; with accelerator and detec-

Abdus Salam addresses the International Symposium on Particle Physics in the 1950s, held at Fermilab from 1-4 May.



Arthur Roberts, one of the fathers of the Rochester Conference series, sings his famous ballad 'Take back your billion dollars and let's do physics again'.

(Photos Fermilab)

tor developments; with social, political, and institutional dimensions of particle physics in the 1950s; and with the hopes and expectations of particle physicists during that era.

This symposium continued the historical work begun at an earlier symposium held at Fermilab in May 1980, devoted to the birth of particle physics in the 1930s and 1940s. The proceedings of that meeting – *The Birth of Particle Physics* edited by Laurie Brown and Lillian Hoddeson – was published by Cambridge University Press in 1983.

More work has been needed to unravel the history of particle physics and bring it within reach of scholars and the public. The symposia identify the major contributors to the field and help to understand how the physics research fits into the larger context of science and culture. Finally the symposia examine science from a long range perspective, thereby helping to guide future projects. For example, the course of particle physics in the fifties has important bearings on the proposal to construct a superaccelerator in the 1990s.

Such meetings are also cross-cultural gatherings. They bring together humanists and scientists. An important distinguishing feature of this history symposium was that it included one or more historians of science as speakers at nearly every session. For example, the opening session, introduced by Leon Lederman (Fermilab), was shared by C.N. Yang (Stony Brook) and historian John Heilbron (Berkeley).

The meeting covered the entire gamut of developments in the fifties. The important particle discoveries in cosmic rays were reviewed with Don Perkins (Oxford) covering the emulsion work and George Rochester (Durham) reviewing the cloud chamber results.

The rapidly evolving concept of strong interactions was covered with talks by a number of distinguished contributors. Robert Hofstadter (Stanford) discussed nucleon structure as seen with electron scattering. Luis Alvarez and Willy Chinowksy (Berkeley) noted the impact of hydrogen bubble chambers on progress in understanding strange particles, while Robert Walker (Caltech) reviewed the pion resonances seen in photoproduction. Jack Steinberger (CERN) reminisced about particles and their properties circa 1950. Abraham Pais (Rockefeller), an important theoretical contributor to the period, served as resident historian for the topic.

One of the most striking features of the physics of the fifties was the advent of accelerators and the increasing sophistication of the detectors. Peter Galison (Stanford) acted as the history rapporteur for the detectors while Ernest Courant (Brookhaven) and Mathew Sands (Santa Cruz) reviewed the accelerator developments. Owen Chamberlain (Berkeley) knitted the two themes together with the story of the discovery of the antiproton at the Bevatron.

The startling developments in weak interactions were the subject of another session. One question – why parity violation was not discovered earlier – was probed by Allan Franklin (Colorado). Dick Dalitz (Oxford), Val Telegdi (Zurich) and Val Fitch (Princeton) showed how experiments shed light on the possibility of parity violation in weak interactions. Fred Reines (Irvine) reviewed the detection of the neutrino. Sam Treiman (Princeton) discussed connections between strong and weak interactions while French theorist Louis Michel emphasized the increasing significance of symmetries and conservation laws.

The social, political and institutional dimensions of the subject were given a substantial airing with presentations by Helmut Rechenberg (Max Planck Institute), Andrew Pickering (Illinois), Hywel White (Brookhaven) and Robert Seidel (Albany). Particularly interesting were the evolution of CERN, with talks by Edoardo Amaldi (Rome) and Armin Hermann (Stuttgart/CERN), and Japanese particle physics as described by Michiji Konuma (Keio).

The conference closed with an assessment of the hopes and expectations of particle physics as seen in the fifties with Silvan Schweber (Brandeis) handling the historical synthesis. E.C.G. Sudarshan (Texas) covered the implications of parity violation. Gerson Goldhaber (Berkeley) recapitulated the early work at the Bevatron. Geoffrey Chew (Berkeley) reviewed particles as S-matrix poles – the famous nuclear democracy concept, while Yoichiro Nambu (Chicago) discussed spontaneous symmetry breaking, vector meson dominance, and gauge theory. Murray Gell-Mann (Caltech), whose theoretical ideas helped to shape the decade and also led to the important subsequent developments summarized the physics of the fifties and its interaction with later developments.

For achievements made in particle physics during the 1950s, six Nobel Prizes have been awarded to eight physicists. Most of these were numbered among the speakers, and several later Nobelists also participated.

Social events included an evening banquet, followed by speeches from Robert Marshak (Virginia Polytechnic) and Abdus Salam (Trieste). Next evening there was an outdoor buffet and party at the home of J.D. Bjorken. There was an art exhibit, a talk on Darwin by Stephen J. Gould, an exhibit of historical pictures and documents arranged by George Rochester, and a rousing live performance of 1950s particle physics songs (like 'Take Away Your Billion Dollars') by physicist/composer Arthur Roberts.

The proceedings will be published by Cambridge University Press. Sponsors of the Symposium included the Sloan Foundation and the Argonne Universities Association Trust Funds. 'Pions to Quarks' was organized by Laurie Brown (Northwestern), Lillian Hoddeson (Illinois/Fermilab), and Max Dresden of Stony Brook.

Where were you when Kennedy was assassinated?

The inauguration of Burt Richter as Director of the Stanford Linear Accelerator Center last November coincided with the tenth anniversary of the 'November Revolution' – the simultaneous discovery by Sam Ting and his group at Brookhaven and by Richter and the Mark I collaboration working at the SPEAR electron-positron collider at SLAC of a new kind of particle (the J/psi) which did not fit in with the established ideas of the time.

Extracts from Richter's inaugural address were published in our May issue, page 144. At the same meeting, James D. Bjorken described the impact that the J/psi discovery had on him, and on particle theorists in general.

'Most high energy physicists will probably remember where they were when they first heard about the psi. It was like the moon landing, Pearl Harbour or the Kennedy assassination.

I was home and it was dinner hour. Burt Richter called me up and told me the basic parameters over the phone. He said three GeV. I said three GeV per beam, right? He said no, three GeV in the centre of mass. I couldn't believe such a crazy thing was so low in mass, was so narrow, and had such a high peak cross-section. It was sensational!

I went back and sat down to finish dinner. I don't remember what we had. But my family does; it included baked potatoes. I scooped up an enormous spoonful of what I thought was sour cream to put on my baked potato. It happened to be very sharp horseradish sauce. I sat there with a glazed look on my face, not responding to anybody, eating my baked potato while my family looked at me with surprise and puzzlement. When I finished my meal, my wife turned to me and said in an uncharacteristic, rather quiet voice, 'Bj, I think you had better go to the lab now.' So, off I went.

The next memory of those days was the electricity in the *SLAC* auditorium on Monday morning when the results were publicly announced. In the theory group there was a continuous workshop organized. Most of the theorists worked on interpreting the data, classifying the theories and trying to help, in whatever way one could, to expedite the experimental development of the subject.

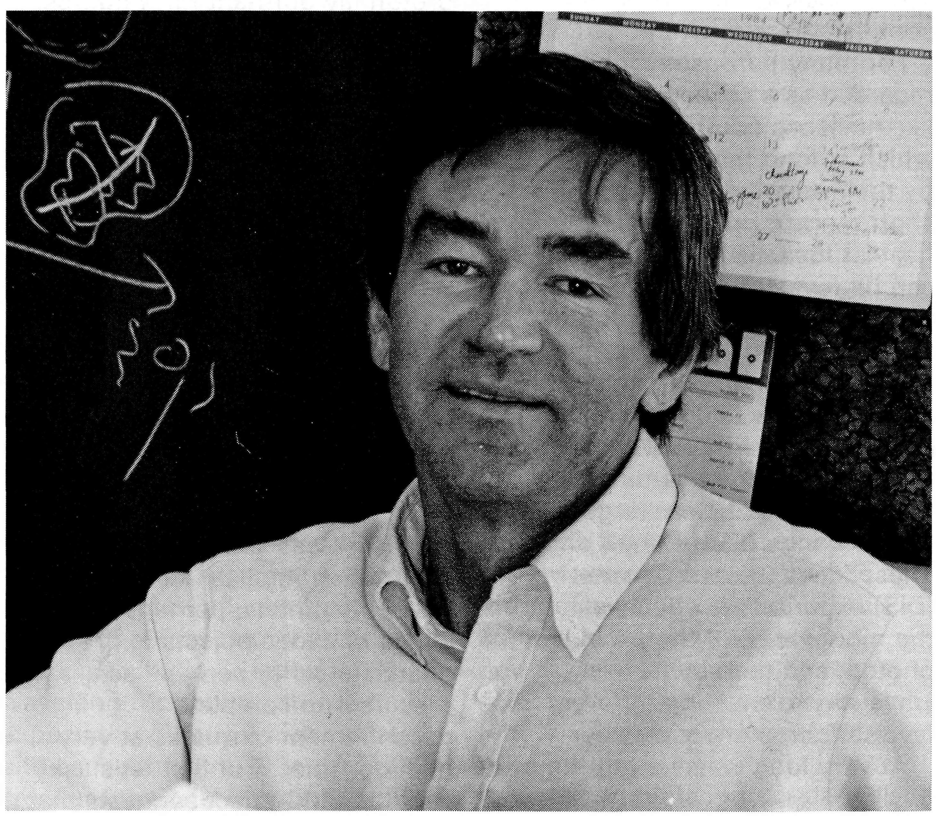
I remember the cathartic nature of the enterprise. The lines of communication were very open. There was little thought about the usual kinds of priority and proprietary attitudes toward 'ownership' of new ideas. The activity was extremely intense and very exciting. It was this way not only at *SLAC*, I am told. At many institutions it was somewhat the same way; the psi just electrified everybody. There was no question that it was important and a great turning point right from the start.

Nevertheless, there was no instant consensus about what it all meant. Certainly, the new quantum number, charm, was the leading candidate from the start. At the time I quoted 50-50 odds that it was charm. But 50-50 is not good enough. One had to hack away at all of the different hypotheses before being sure. The 'hidden colour' hypothesis was maybe 20 per cent probable. Others thought the psi was an electroweak intermediate boson – that was a serious proposition! This idea didn't take long to eliminate, along with more bizarre ones. One of these was that psi was a bound state of the omega baryon with its antiparticle. That interpretation lasted for even less time.

Anyway, there was a long list of theories, and it took a while to sort through all of the new 'background noise' and really confirm charm by finding the *D* meson after two more years of confusion.

I think that our future will be a new adventure in confusion. For a long time the evidence that can be uncovered about nature of the Higgs sector (the source of mass in the electroweak sector – Ed.) is likely to be small compared to the number of hypotheses bandied about upon what it really is – too small for decisive conclusions. We will be forced back into the mode I remember so vividly in the 1960s – one with a great variety of hypotheses, a great variety of approaches, a great uncertainty as to which approach is going to win and which one isn't, and a great uncertainty as to which energy scale is going to provide the key to the solution. It may be as surprising as in 1974, when 3 GeV was sufficient, and when an unfashionable experiment at an old, antique laboratory like Brookhaven was a big key to the future.

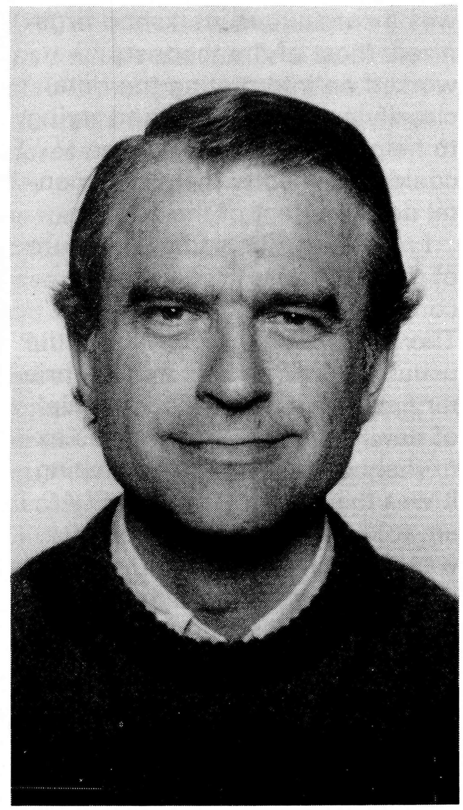
So in closing, I hope that as we look forward to these next ten years preceding the commissioning of a new super-machine, they will be just as rich and fruitful as the last ten years have been. In order to ensure that, I think we have to protect the variety and the richness of techniques, instruments, and experimental approaches in order to maximize our chances for happening upon the key to the next revolution.'



J.D. Bjorken – sharp horseradish sauce

Freedom for quarks in the nucleus?

Particle theorist Richard Roberts of the Rutherford Appleton Laboratory, UK, increasingly talking the same language as nuclear physicists.



by Richard Roberts

A number of recent conferences have highlighted how particle physicists and nuclear physicists are increasingly talking the same language. Indeed a few meetings specifically set out to cover the common interests and aims of the two fields (Steamboat Springs, see September 1984 issue, page 283 and Heidelberg, see December 1984 issue, page 435). This reflects a growing feeling that a nucleus provides a means of testing the way quarks are confined within nucleons (protons and neutrons). Surprisingly, there may be hints that this usual severe restriction on the quarks' movements may be partially lifted in a nucleus – adding weight to current speculations that at high densities the quarks, instead of being locked inside nucleons, could achieve complete freedom.

For many purposes a nucleus is regarded as a collection of point-like nucleons bound by a force which at long range is described by the exchange of pions and at short range by the exchange of heavier mesons. Detailed structure can be revealed by illuminating the nucleus with 'light' (photons) whose resolving power can be varied by changing its wavelength. In practice this is done by experiments using high energy electron or muon beams which scatter off the nuclear target via the exchange of a (virtual) photon. These 'deep inelastic' scattering (DIS) experiments effectively vary the momentum of the probing photon, and thereby its wavelength, enabling different levels of structure to be seen.

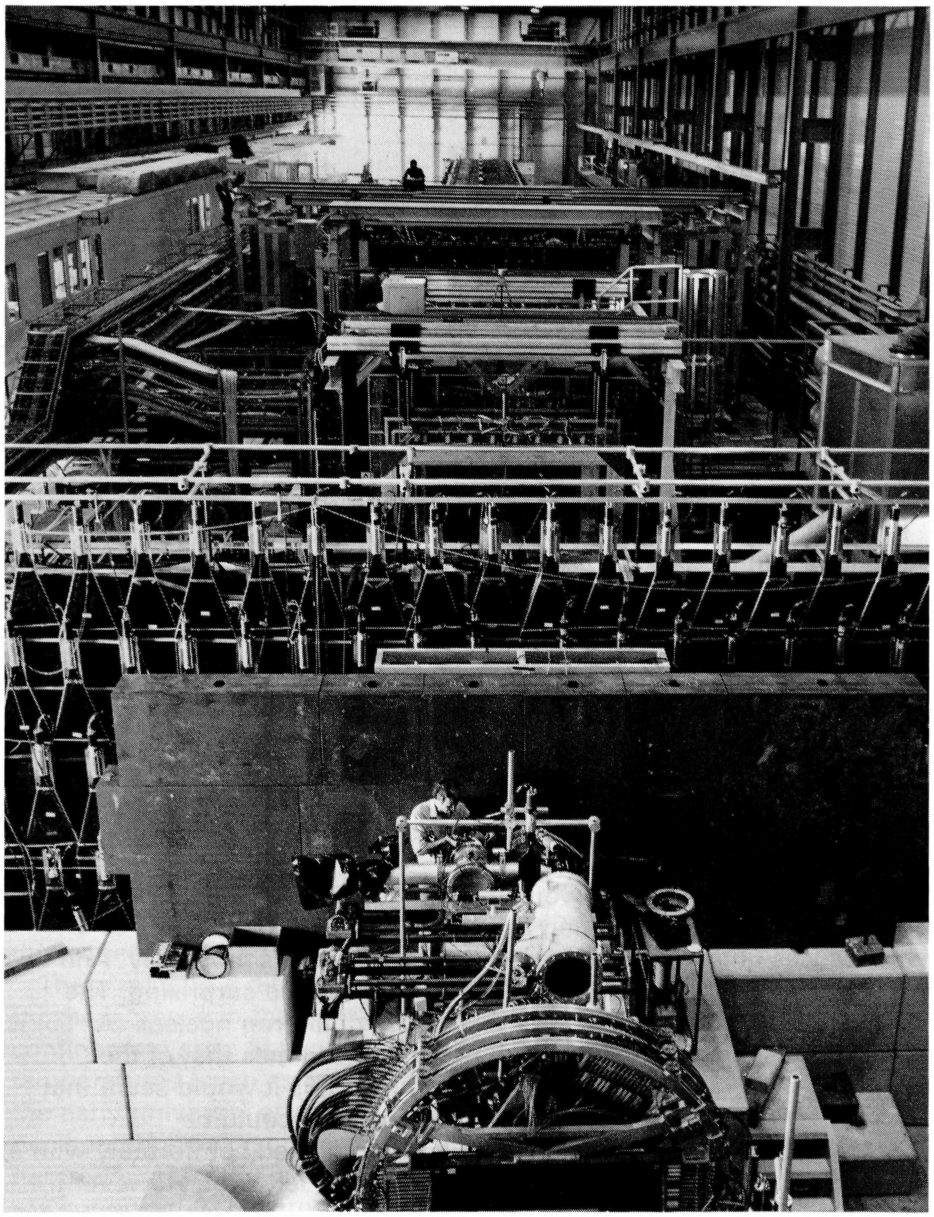
At very long wavelength the nuclear structure is barely resolved but as the wavelength shortens we begin to see individual nucleons, and as the resolution improves still further the constituent quarks are 'exposed'. At first it might seem completely irrelevant that the nucleons were bound together in a nucleus, as our probe of the nucleus is highlighting the quark structure of a proton which could just as well be done with an isolated proton target.

But is there any way that the nuclear environment could affect the apparent structure of the individual nucleon? Well firstly, because the nucleons are jostling one another a small distortion is produced, but this is well understood and easily corrected for. The old question of whether a nucleon bound in a nucleus is really different from an isolated proton lay dormant for a number of years until 1982 at CERN when the European Muon Collaboration (EMC), scattering muons off iron and off deuterium, discovered a significant discrepancy between the results from the two targets. The surprise of the 'EMC effect', as it came to be known, was the clear difference between the structure of bound and free nucleons.

One explanation was to attribute this to the existence of 'extra' pions in the nucleus. Another, more startling, suggestion was that quarks in a nucleus actually 'leak' outside the confining region normally associated with a proton. This notion implies interesting new phenomena, perhaps in the shape of exotic objects (e.g. six-quark states) or perhaps as a precursor to complete deconfinment of quarks at very high densities. But first let's ask why the EMC effect suggests that quarks acquire more room to move in the nucleus.

As we said above, DIS experiments shooting electrons, muons (or neutrinos) on a proton can be regarded as probing the quark structure of the proton via a virtual photon (or weak force boson) whose wavelength can be varied to resolve various levels of detail. We learn how the momentum of the proton is shared among its constituent quarks and the results are usually plotted as a distribution of quark fractional momentum, x. If the proton consisted of only three valence quarks, we would expect each quark distribution to be centred around $x = 1/3$.

According to the standard theory of quarks (quantum chromodynamics-QCD), varying the wavelength of the probing



The European Muon Collaboration (EMC) experiment at CERN, which discovered that the quark content of nucleons depends on the surrounding nuclear environment – the 'EMC Effect'.

(Photo CERN 30.7.78)

photon reveals the subtleties of the interactions between quarks and gluons. Increasing the momentum of the photon probes quark dynamics at smaller and smaller distances. In this way, the quark is discovered to have radiated gluons which carried off some momentum. It was reassuring for the theory when DIS experiments clearly showed the mean value of x falling as the probing wavelength was reduced. This 'degrading' of the fractional momentum distribution thus became associated with a change of scale – in this case the wavelength of the resolving photon.

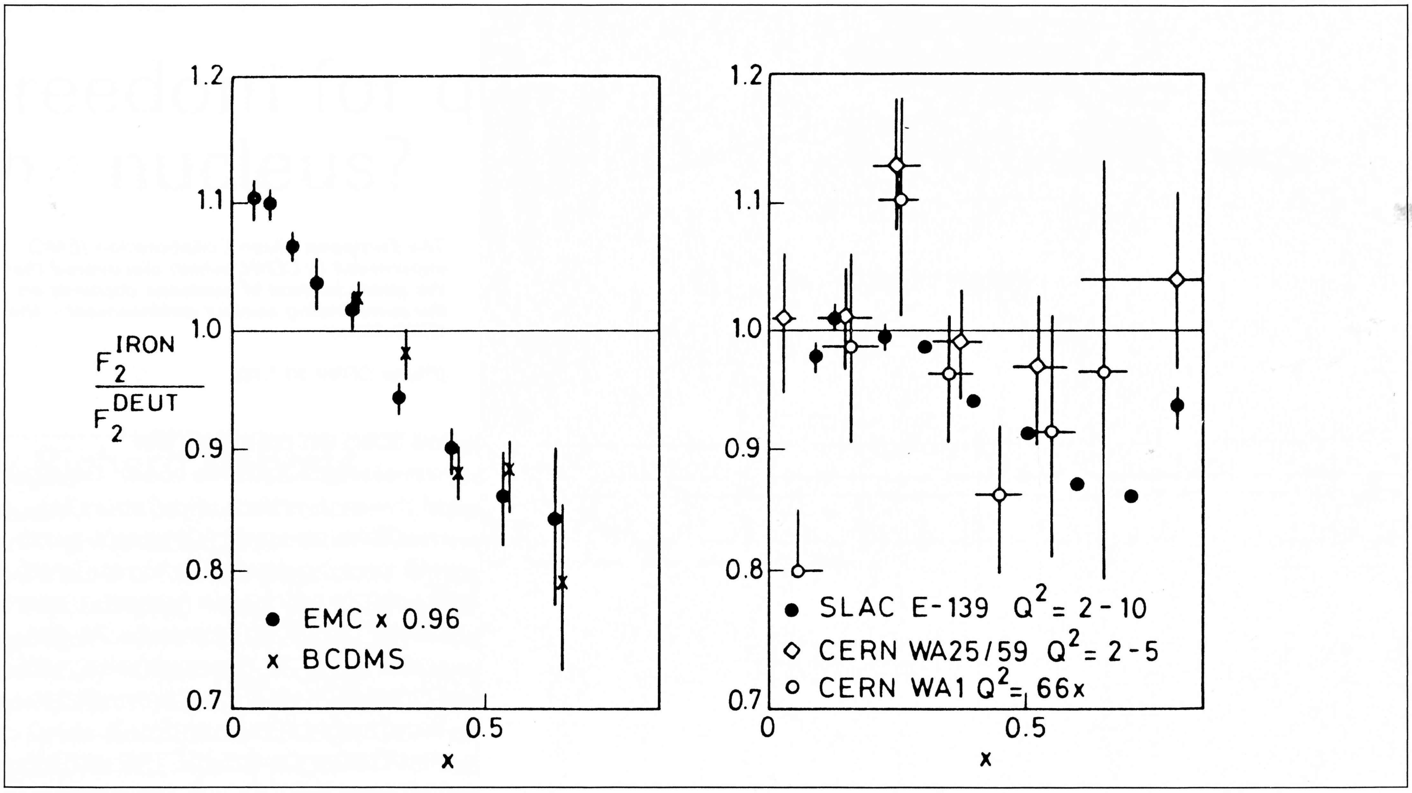
Weakening the resolving power of the photon would naturally show the reverse trend. However this would have to stop at some point. The quarks are confined within the proton which has a definite size (1fm or 10^{-13}cm) and this introduces an obvious cut-off for the wavelength. Shining light with this frequency onto the proton would, in an oversimplified world, reveal just the valence quarks and nothing more. In practice other effects complicate the situation at these relatively long distances but the notion of a natural scale set by the size of the region in which quarks are confined is basic to the theory.

Now let's imagine a world where the 'proton' is much bigger. Probing with wavelengths equal to the size of this inflated proton would, of course, show the initial quark distribution. Reducing the wavelength of our torch will then expose the gluons which radiate and cause the quarks to carry a smaller fractional momentum. If we keep on reducing the wavelength until we reach the size of the real proton, the fractional momentum carried by each quark will now be considerably reduced. So shining light on the real proton and our 'inflated' proton with the *same* wavelength would show them to have different structures. The fractional momentum distribution in the inflated proton is degraded to smaller values, and this remains true as the wavelength continues to decrease.

The fact that the EMC measurements of the quark fractional momentum distributions for nucleons making up a heavy nucleus differed in a very similar way from those of a free nucleon strongly suggested that the confinement size for quarks in a nucleus was indeed 'inflated'. How much 'swelling' of the nucleon is needed to describe the EMC effect? Taking into account that there is another scale buried in QCD, (the scale parameter of the coupling constant) the answer is around 10 per cent.

Our comparison between the 'real' and 'inflated' protons suggested that in this simplified picture the effective resolving power of the photon was not the wavelength itself but rather the wavelength scaled by the confinement size. If this were correct then the mismatch in the confinement size of quarks in the nucleon and in the free proton could be 're-scaled' away by simply tuning the wavelengths of the probing photons exactly to compensate – i.e. the resolving powers are adjusted to be the same again. The experiments go a long way to supporting this idea of re-scaling.

However this appealing



Comparison of the nucleon quark structure in iron and deuterium as measured in experiments at CERN using muon beams (left), and (right) in experiments at SLAC (electron beams) and at CERN (neutrino beams). The x variable is the fraction of the momentum carried by the quark.

explanation of the EMC effect is far from being the only one on the market. Pions surely play an important role in the nucleus and if the nucleus contains extra pions then they would modify the quark structure. Some controversy surrounds the interpretation of experiments which attempt to confirm the presence of extra pions. In fact, the whole experimental situation in nuclear DIS experiments, now that the initial excitement of the discovery of the EMC effect and its qualitative confirmation from other groups has subsided, is rather confusing. This situation will have to be tidied up before detailed testing of different mechanisms can proceed.

Part of the satisfaction in understanding a new phenomenon in quark language is the implication that QCD is relevant to nuclear physics. The aim of recent meetings in examining what common ground exists between particle and nuclear physics reflects the fact that both fields are using the same basic theory to understand the dynamics involved. The really interesting question is what causes quarks and gluons to widen their confines when they find themselves in a nucleus? There is no shortage of suggestions.

One very novel suggestion is that the confinement size itself changes with the wavelength of the resolution. As the resolution becomes finer and finer, the quarks and gluons are conjectured to tunnel further and further into the internucleon space. Finally the resolution would reach a critical value where colour is conducted over the entire nucleus, so that quarks could roam over a region several fermis long.

This idea seems somewhat dramatic, but to understand present data it is not necessary to require more than about a 15 per cent increase in the confinement size in an iron nucleus. What could produce even this modest expansion? One clue could lie in the variation of the confinement size with nuclear density. A DIS experiment at SLAC in 1983 studied the variation of the quark x distribution for eight different nuclei to see how the EMC effect changed from helium to gold. The pattern of behaviour strongly suggested that the EMC effect depended on the density of nucleons in a simple way. And this is really not so surprising. The radius of an iron nucleus (A=56) is about four times that of the proton. Thus it would seem that 56 nucleons could be accommodated comfortably with a little space left over. However if we try to pack hard spheres into a given volume even the most efficient packing leaves 25 per cent of the space unoccupied. Applying this reasoning to nucleons packed into an iron nucleus implies that the nucleons must overlap with each other and be deformed in some way.

Once we accept that two nucleons have a reasonable chance of overlapping in a nucleus, the possibility of quarks occasionally extending their wanderings to cover two nucleon volumes seems plausible. Clearly the more densely packed a given nucleus, the greater the chance for this extra quark freedom. In fact this geometric picture gives an excellent description of the SLAC data on different nuclei. Some nuclei are anomalously dense, so measurements on these could be expected to show extra large EMC effect deviations.

It seems a small step to go from discussing two nucleons overlapping to the dynamical formation of six-quark objects in the nucleus. Indeed such exotic states were the first suggestion for the observed distortion of quark distributions in a heavy nucleus. It is natural to expect each quark in a six-quark 'bag' to carry a smaller fractional momentum than in a nucleon or three-quark bag. QCD (in principle) allows a host of exotic states to exist and a heavy nucleus may turn out to have just the right sort of environment for this variety to breed.

There may be a different reason for the increase in the quark's confinement size. At very high temperatures (such as existed in the early universe) or at very high nucleon densities (such as those in neutron stars), quarks and gluons are supposed to become completely deconfined. These superhigh densities may be 10-20 times that of nuclear matter but it is tempting to speculate that even at the lower densities a degree of partial deconfinement precedes a phase transition to quark-gluon matter. Using a model it is possible to calculate the effective increase in radius of the nucleon as a function of the density of the nucleons and obtain remarkable agreement with the estimates interpreted from the SLAC experimental data. This gives encouragement to the idea that the nucleus – even with the relatively modest densities it implies – may shed light on the dynamics of the deconfining phase transition.

Conventionally the short range description of the nucleon-nucleon interaction is given by heavy meson (rho, omega) exchange, but there are signs that an equivalent description can be given by the exchange of gluons as two nucleon bags overlap.

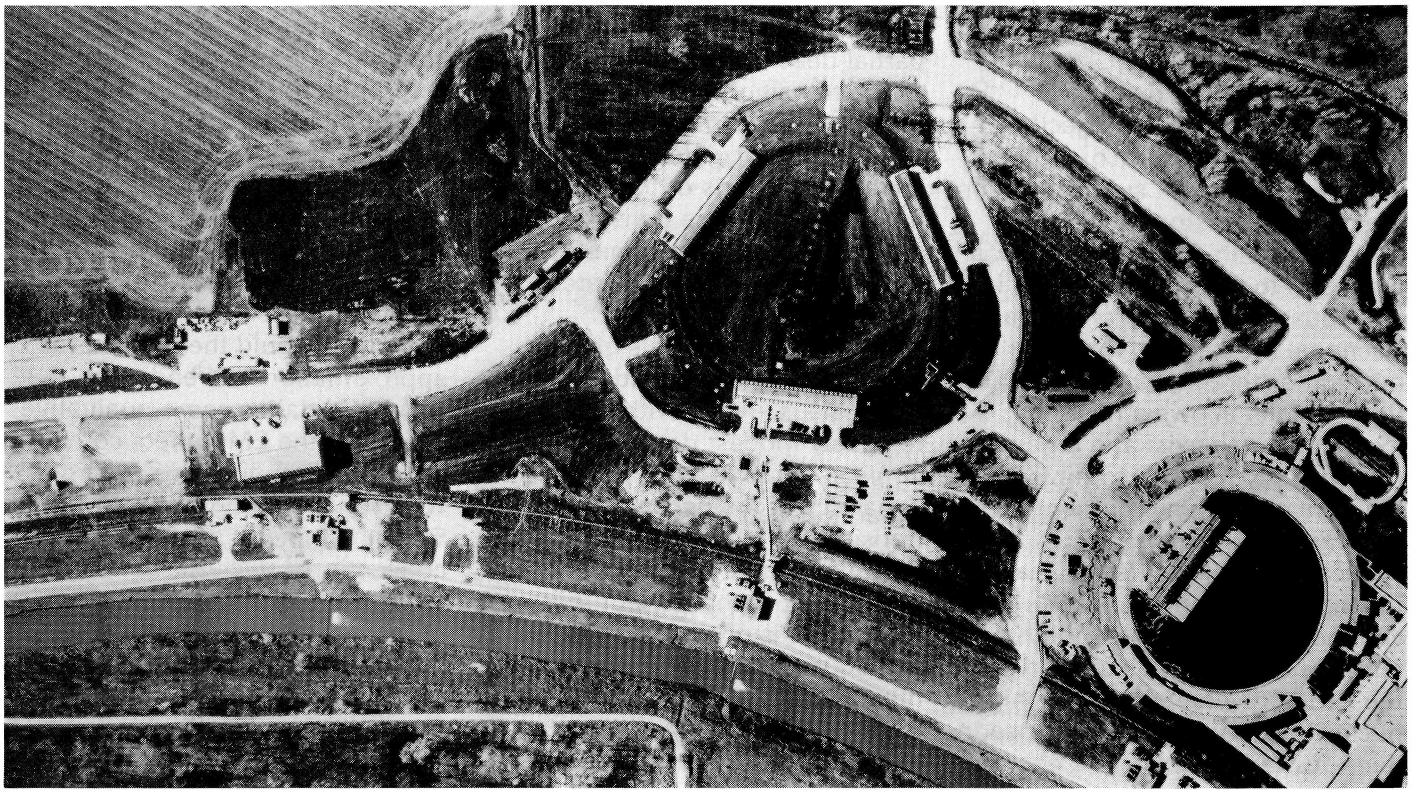
The temptation now is to start from scratch again with a multi-quark configuration whose interactions are described by some QCD mechanism which includes confinement and attempt to confront all the physics of the nucleus with this relatively well specified theory. The aim of this ambitious approach is to calculate nuclear binding energies and excitation spectra directly in terms of quarks and gluons. The traditional 'nucleon-nucleon' potentials would then appear as approximations. Already this approach claims some qualitative success – the EMC effect comes out and quasi-nucleons emerge with some binding between them. Even the general properties of conventional nuclear shell structure look as if they can be obtained from a model in which the nucleus is visualised as a system of quarks only. There is a long way to go, but if this approach eventually succeeds then another big unification of physics will have been achieved – a common theory for the structure of nuclei and nucleons.

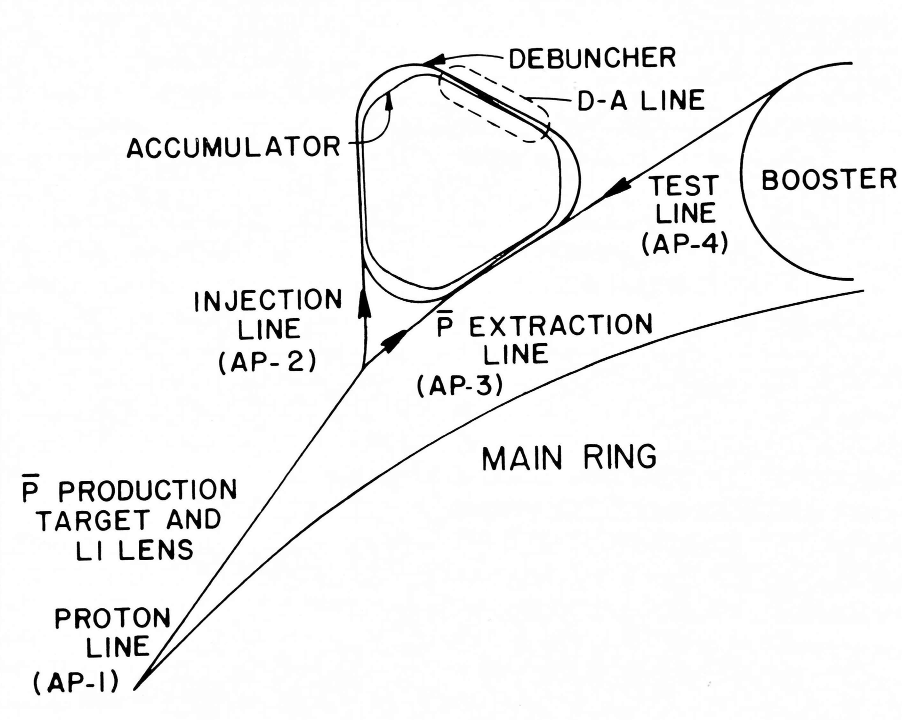
Commissioning Fermilab's antiprotons

Installation is complete for Fermilab's Antiproton Source and rapid commissioning progress is being made. The Fermilab Antiproton Source is the heart of Tevatron I, the project to achieve collisions between protons and antiprotons in the superconducting Energy Doubler ring at a collision energy of 2 TeV and a luminosity of 10^{30} per cm^2 per sec. The system is based on the highly successful stochastic cooling method of Simon van der Meer and his colleagues at CERN, and is designed to accumulate 10^{11} antiprotons per hour. The Antiproton Source is the complex of target station, beamlines, and two rings, the Debuncher and the Accumulator, where the antiprotons are made, 'cooled', and stored.

Installation of equipment for the source reached a peak level of activity in March. Components arrived daily, were installed, hooked up, and tested in preparation for intense commissioning activities that started in April. The scope of the installation effort can best be measured by the count of 467 large multi-ton objects through which the beam passes: bending magnets and quadrupoles, radiofrequency cavities, stochastic cooling tanks, septa, kickers, and target station modules. In addition thousands of cables were pulled and correction magnets, beam diagnostics, and controls installed.

Aerial view of the antiproton source area at Fermilab just outside a sector of the Main Ring. Below, a schematic of the set-up, with a slightly different orientation.





The Target Station

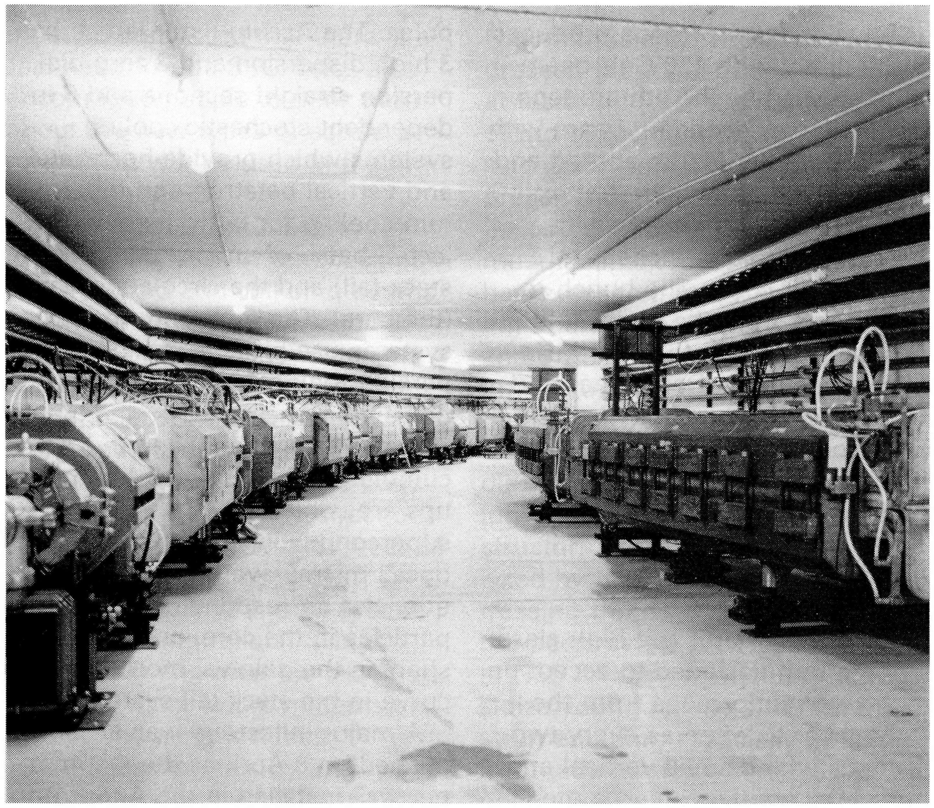
The Target Station consists of 13 removable steel modules each of which serves both as a radiation shield and a stable mounting for target components. Antiprotons are produced by 120 GeV protons extracted from the Main Ring and transported to the target station in the proton (AP1) beamline.

Stochastic cooling is more effective if the initial beam size and time spread are minimized. Beam size is limited by heating in the 6 cm-long tungsten-rhenium target. Beam has been focussed at the target to a spot with a radius of less than 400 microns.

The time spread is reduced to less than one nanosecond by first adiabatically lowering the Main Ring r.f. voltage until the bunch has a momentum spread of 0.03

A view inside the Fermilab Antiproton Source during installation. The Debuncher is on the outside of the tunnel, the Accumulator on the inside.

(Photos Fermilab)



per cent. The r.f. voltage is then suddenly snapped on to 4 megavolts and the entire bunch rotates until the time spread is minimized and the momentum spread is 0.04 per cent. Bunch rotation has been successfully done in the Main Ring.

Antiprotons are collected in a 60 milliradian cone using a pulsed lithium lens similar to the one used at CERN and built at Fermilab to focus the incident proton beam for antiproton accumulation. Over the weekend of 25 April the antiproton target station and lithium lens were turned on for the first antiproton yield measurements. The lithium lens originated from a joint project with Novosibirsk (see July/August 1981 issue, page 249).

The Debuncher

The purpose of the Debuncher is to reduce the large momentum spread of the 8 GeV antiproton beam by r.f. bunch rotation and adiabatic debunching. This is the opposite of the bunch narrowing process which occurs in the Main Ring prior to targetting. Debunching is done by six 53.1 MHz r.f. cavities each developing 750 kilovolts. The Debuncher lies on the outside of the tunnel and is 200 nanoseconds longer than the Accumulator because of the extra space needed for extraction. It contains 66 dipoles and 114 quadrupoles.

Commissioning (running in) of the Debuncher is done with 8 GeV protons delivered from the Main Ring once every five seconds. The commissioning process has no impact on fixed target running: after the Main Ring injects into the Tevatron for fixed target physics it continues to cycle at a five second rate for antiproton source studies. Protons are delivered to the Debuncher via the AP1 and AP2 beamlines in either 10 or 80 bunches with each bunch containing approximately 10^9 protons.

On 21 April, 8 GeV protons were injected into the Debuncher and observed to complete one revolution of the ring for the first time. Shortly thereafter, adjustments to the injection septum produced a circulating beam which persisted for 30 msec (20 000 turns). Studies continued on the evening of 22 April with the first measurement of the tune of the Debuncher and the capturing of the beam with the diagnostic r.f. system. The beam was observed to circulate for several seconds and the closed orbit was measured. The closed orbit distortions were found to be less than a few millimetres.

The Debuncher ran routinely through May. The chromaticity has been measured, the working space precisely mapped out, and the dispersion carefully determined. The beam position monitor system has been the primary diagnostic tool used during commissioning to date. Three Schottky pickups and DC current transformers are also being used. Two remotely controlled scrapers have been used to make emittance measurements.

By 5 May the Debuncher was operating as a storage ring with the injection orbit, closed orbit, tune, aperture and chromaticity understood and within the design tolerances. Protons have been stored in the Debuncher with a measured lifetime of 83 minutes.

The problems of working with antiprotons can be well simulated

Jim Leiss, retiring Associate Director for High Energy and Nuclear Physics at the US Department of Energy, was one of the speakers at the recent Fermilab Users Meeting.

using secondary protons produced in the target with 120 GeV beam and focussed by the lithium lens. On 27 May a secondary beam with emittance, momentum spread and intensity comparable to that expected for antiprotons was injected into the Debuncher and observed to coast. The bunch-rotated beam from the Main Ring was captured with the 53.1 MHz r.f. cavities in the Debuncher and successfully debunched. Protons were cooled with the vertical betatron Debuncher stochastic cooling systems on 15 June.

The Accumulator

The Accumulator is a high class storage ring designed to accept up to 8×10^7 antiprotons from the Debuncher as often as every two seconds with a small vertical and horizontal emittance and a momentum spread of 0.2 per cent. In the Accumulator the antiprotons are stacked in momentum space and compressed into a high density core containing 4×10^{11} antiprotons with a momentum spread of 0.05 per cent. The antiprotons, travelling at 99.5 per cent of the speed of light, are accumulated over a period of several hours. Ultrahigh vacuum is required to minimize interaction of the circulating beam with the outgassed molecules of the chamber wall. A nominal pressure of 3×10^{-10} torr is required in the beam tubes to avoid beam intensity loss from excessive beam-gas collisions. This pressure will be met with a combination of sublimation and sputter ion pumps, and with well conditioned chambers to reduce the rate of gas desorption.

The main magnet system consists of 30 dipoles and 84 quadrupoles. The Accumulator lattice has 3 high dispersion and 3 zero dispersion straight sections and 6 independent stochastic cooling systems which provide horizontal and vertical betatron and momentum cooling for both the newly injected batch of antiprotons (the stack-tail) and the circulating beam (the core). The momentum cooling systems use pickups in high dispersion regions and kickers in zero dispersion ones.

In both the Debuncher and Accumulator stochastic cooling pickups are cooled to 77 K. A superconducting notch filter reduces microwave power at frequencies corresponding to particles in the core, and assists in shaping the gain vs. momentum curve in the stack-tail system.

A major milestone was accomplished on 8 April as the last magnet was installed in the Antiproton Source Accumulator. A vacuum in the entire Accumulator Ring was established on 31 May. Multiple turns were achieved in the Accumulator for the first time on 6 June, and coasting beam on the injection orbit (in the Accumulator) was achieved during the night of 20-21 June. The proton beam was injected into the Accumulator backwards through the extraction (AP-3) line, and captured in buckets phase locked to the Main Ring r.f.

Milestones are now occurring in rapid succession. Many dedicated people from the entire Laboratory are contributing to the success of this project. These next few months promise to be very exciting as efforts are made to bring the Tevatron I systems into operation and start exploring the physics frontier opened by these ultra high energy collisions.

Users Meeting

The Fermilab Users Organization held its annual meeting at Fermilab on 10-11 May. In his state of the Laboratory report, Director Leon Lederman emphasized the tremendous R&D and construction feats that have brought Bob Wilson's vision of a 1 TeV superconducting synchrotron to the successful physics seen at the Laboratory today. The next few years look extremely exciting for both fixed target and collider physics. Lederman listed the Laboratory priorities as finishing construction, reliability, intensity, energy, and R&D for the proposed US Superconducting Super Collider (SSC).

Two distinguished participants in the Washington scene who have been very important to Fermilab announced their retirement at the meeting. Guy Stever, retiring president of the Universities Research Association Inc. governing body, reported on the activities of URA. Much of the recent URA effort has been directed toward progress on the SSC. An important step was in agreeing on a board of overseers within URA to concentrate on SSC decisions and problems. Stever believes that it is important that the project be approved soon and that broad regional support be maintained for the project even after a site has been selected.

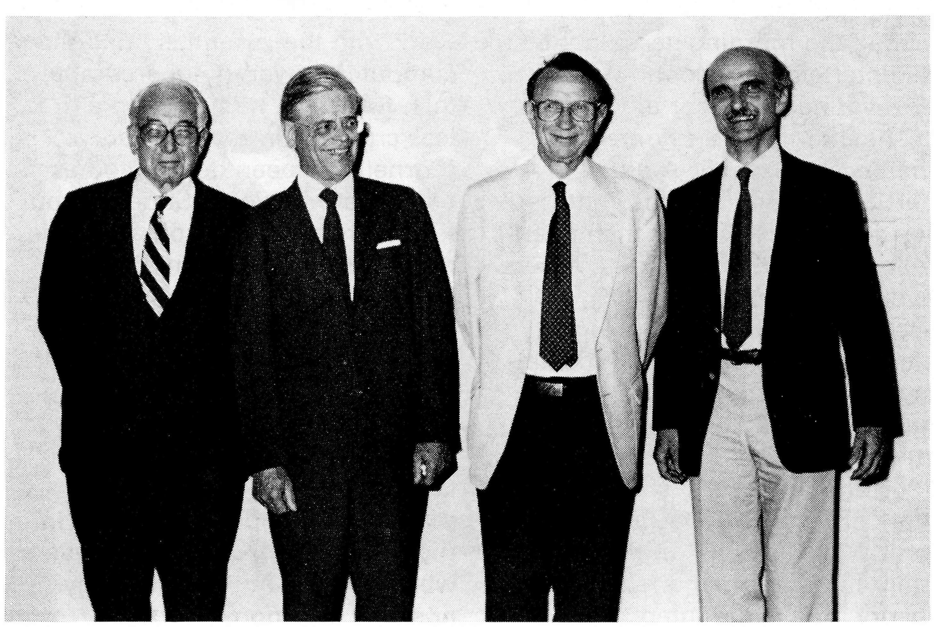
Jim Leiss, retiring Associate Director for High Energy and Nuclear Physics at the US Department of Energy, gave his views on the directions needed in particle physics. The current facilities must be exploited, there must be effective use of foreign facilities, and others must be convinced that there is a real need for the SSC. Leiss also encouraged people to think hard about the new types of accelerators which will be used in the era beyond the SSC.

Other talks at the meeting reviewed the status of the machine and the fixed and colliding beams programme. The rich possibilities with two major collider detectors and an extensive fixed target programme lead to demands for more running time, more protons, more equipment, and more housing. Reports from many directions indicated progress on a number of fronts – 1.37×10^{13} protons per 56-second cycle with a 23-second spill, increasing reliability in the present running after a shaky start, and even more improvements on the user housing facilities.

An interesting talk by Erich Bloch, the new director of the US National Science Foundation, addressed the issue of science policy at the NSF. After the flat funding of the 1970s, funding for the hard sciences has improved under the present administration. He believes the Federal government must face its responsibility for basic research in a world of shifting international trade patterns and a trend toward a service economy in the US Universities are the most important resource but also the hardest to change. Multidisciplinary efforts and modernizing of the university infrastructure can, hopefully, be catalyzed by NSF. He also noted a distressing trend toward bypassing the peer review process. Increases in NSF funding are helping to subsidize young faculty and new instrumentation, especially in fields like mathematics where NSF is the only significant source of funds.

Cornell honours McDaniel

The four Directors of Cornell's Laboratory of Nuclear Studies during its forty year history: left to right and in order of seniority, Robert F. Bacher, Robert R. Wilson, retiring Director Boyce D. McDaniel and new Director Karl Berkelman.



On May 22 and 23, the Laboratory of Nuclear Studies at Cornell held a Symposium to honour Boyce McDaniel, who after being Laboratory Director since 1967, retired from that position on 1 July (see July/August issue, page 241). McDaniel led ten years of productive physics with the 12 GeV electron synchrotron, and the intense effort that culminated in the construction and successful operation of the CESR electron-positron ring in 1979. The Symposium was also the occasion to celebrate the fortieth anniversary of the Laboratory. Albert Silverman was chairman of the organizing committee.

Former Cornell and Fermilab Director Robert R. Wilson (left) and current Fermilab Director Leon Lederman give their rendition of the song 'Old McDaniel had a Lab'.

(Photos Cornell)

The first day was devoted to an overview of 40 years of research at Cornell, including the series of accelerators, ranging from the 1.2 MeV cyclotron built by Stanley Livingston in 1935 to the present CESR complex, built in 'Cornell Style'.

Robert Bacher, Professor Emeritus at Caltech, started off with the events leading up to the formation of the Laboratory in 1945 and his year as its first Director before he left to join the newly formed US Atomic Energy Commission. The First Twenty Years was the subject of talks by Hans Bethe, who described the wide range of theoretical work in quantum field theory and nuclear and elementary particle physics that parallelled and built upon Richard Feynman's epic work on quantum electrodynamics at Cornell, and by Robert R. Wilson, who gave an account of how the 'Cornell Style' developed while he was Laboratory Director and how a 'rebellion' of staff members led to the design of the 12 GeV electron synchrotron. Richard Feynman, now at Caltech, concluded the morning session with an entertaining account of his life as a young professor at Cornell.

The afternoon session covered the Second Twenty Years with Albert Silverman and Kurt Gottfried relating the exploits of the experimenters and the theorists, respectively. Silverman reviewed accomplishments in photo- and electroproduction and in elucidating the properties of b (beauty) quarks. Gottfried compared the status of theoretical physics in 1965 and today, and showed how work at Cornell, especially Kenneth Wilson's work on the renormalization group and lattice gauge theory, had contributed.

The second morning was devoted to future directions in elementary particle physics. Nobel laureate Kenneth Wilson described the prospects for doing theoretical work with the essentially unlimited computer power of supercomputers, for which he has been a tireless crusader in recent years. (Cornell has been designated as one of four National Supercomputer Centres, with Wilson as its Director.) Karl Berkelman, the new Laboratory Director, showed a glimpse of how the future of experimental particle physics might develop, although he insisted he should not be held responsible if events take a different turn! Orlando Alvarez of Berkeley described the outlook for theory. In the final talk, Maury Tigner gave a whirlwind account of the many possible directions for breakthroughs in the world of accelerators. These are the advances that will supply the energy needed to push through to further frontiers.

E-I-E-I-O

Fermilab Director Leon Lederman was suspected of being the author of a song specially performed at a banquet during the two-day symposium in honour of retiring Cornell Director Boyce McDaniel:

Old McDaniel had a Lab
E-I-E-I-O
And in the Lab he was the boss
E-I-E-I-O
With a Yes-Yes here and a No-No there
Here a Yes, There a No, Yes you stay, No you go
Old McDaniel had a Lab
E-I-E-I-O

And in the Lab he had some rings
E-I-E-I-O
With an electron here and a photon there
With a Quark-Quark here and a Quark-Quark there
Here a Quark, There a Quark, Everywhere a Quark-Quark
Old McDaniel had a Lab
E-I-E-I-O

And in the Lab he had some Dough (a leetle)
E-I-E-I-O
With a promise here and a promise there
And every year is a menace if
He can't convince the NSF
With a Yes-Yes here and a No-No there
With a Quark-Quark here and a Quark-Quark there
Here a Quark, there a Quark, Everywhere a Quark-Quark
Old McDaniel had a Lab
E-I-E-I-O

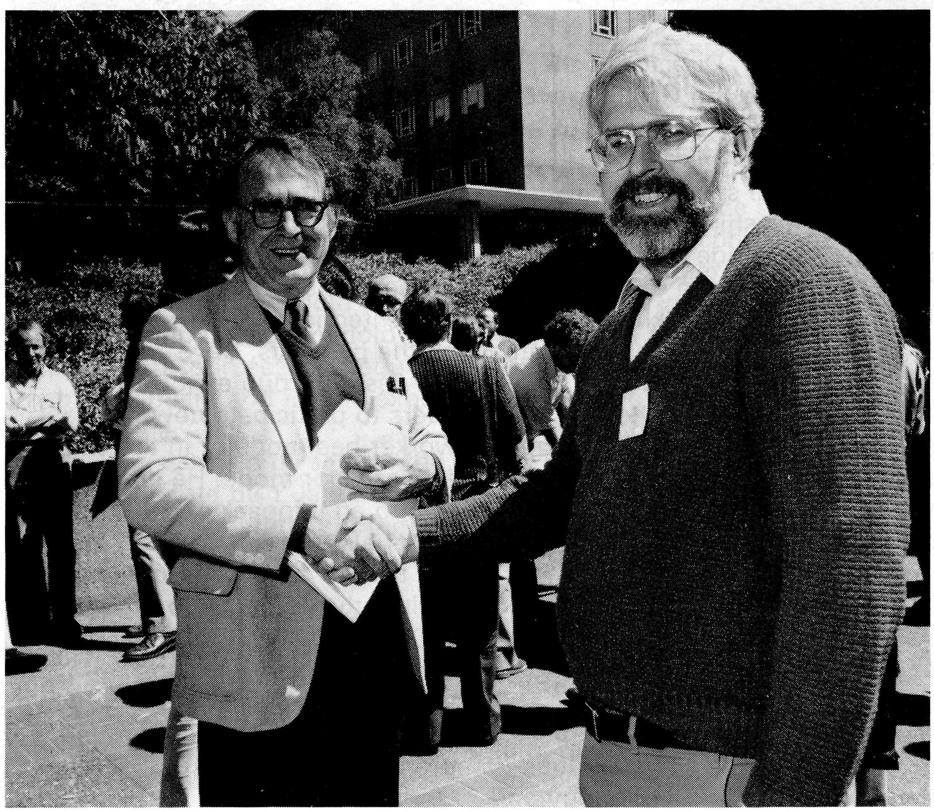
Old McDaniel had a Lab
E-I-E-I-O
He also had a problem too
E-I-E-I-O
Didn't know zactly what to do
E-I-E-I-O
SSC was in a terrible state
So he took time out to ameliorate
Here some scotch, there some beers
He ruled the Board of Overseers
With an SS No and an SS Si!
He even calmed the DOE
Here a Quark, There a Quark, Everywhere a Quark-Quark
Old McDaniel had a Lab
E-I-E-I-O

Old McDaniel had some LABS
E-I-E-I-O
And Newman-Wilson were their names
E-I-E-I-O
With a Tigner here and a Silverman there
Here a Bethe, there a Bacher
Here a Wilson, the Computer Hacker
All to teach, all to inspire
Karl and Kurt and John DeWire
With a Gluon here and a Gluon there
Here some glue, there some boo
E-I-E-I-O

Around the Laboratories

SUPERCOLLIDER
Users meeting

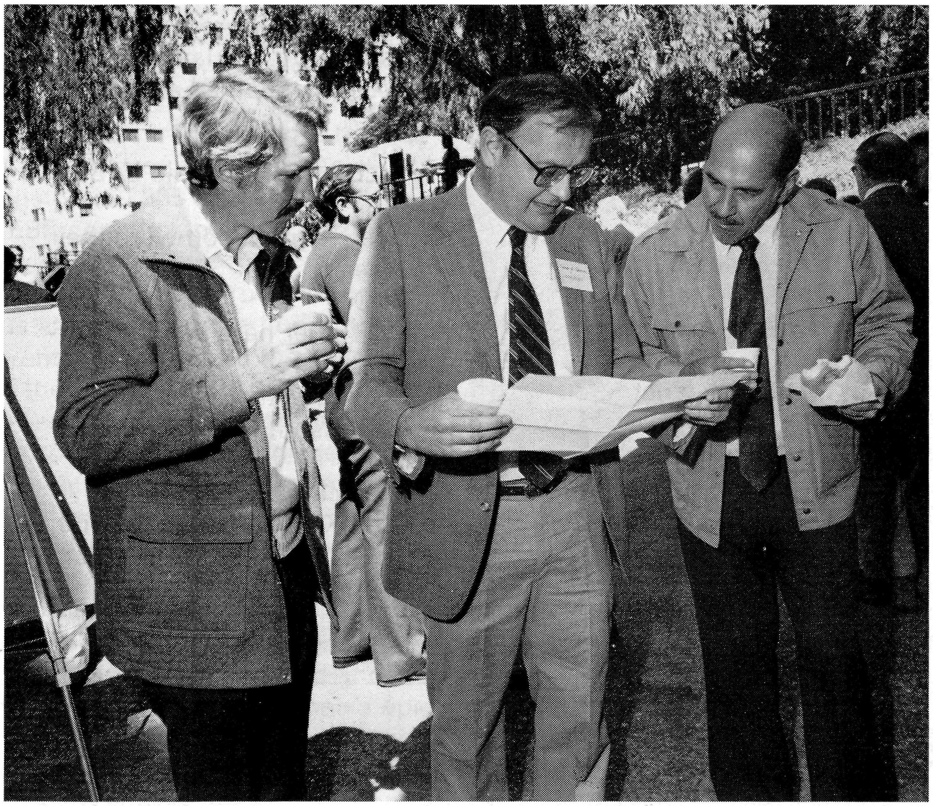
The first US Superconducting Super Collider (SSC) 'Users' Meeting was held on 20-21 May on Berkeley campus. There were 135 attendees from 57 different institutions. Guyford Stever of Universities Research Association and Boyce McDaniel from Cornell University and Chairman of the SSC Board of Overseers welcomed the participants. 'Users' is perhaps an optimistic word as the SSC is not yet authorized, but the meeting reflected the enthusiasm driving the project for the world's largest machine.



At the recent Superconducting Super Collider (SSC) Users Meeting at Berkeley Dave Cline of Wisconsin (left) greets Gil Gilchriese of Cornell. Although it is still only a proposal, the SSC's 'users' had plenty to discuss.

SSC Central Design Group members (left to right) Ron Yourd, James Sanford and Tom Elioff take a break.

(Photos LBL)



Maury Tigner, Director of the SSC Central Design Group, gave the opening talk, 'Overview of the SSC'. Following this presentation, John McTague spoke on 'The View from Washington'. Anne Kernan from Riverside reported on 'Recent Results from CERN', and Paul Reardon of Brookhaven briefed the audience on the 'Status of the Magnet Program'.

Other speakers and their topics included Peter Limon, SSC design group (Accelerator Systems), Ian Hinchliffe, Berkeley (Physics at the SSC), James Sanford, SSC design group (Site and Conventional Facilities), Martha Krebs, Berkeley's Associate Director for Planning and Development (The SSC and the Long Range Energy R&D Study), Alex Chao, SSC design group (Accelerator Physics Questions), Rocky Kolb (Cosmology and the SSC), and Gil Gilchriese (Detector R&D Plans).

The Meeting ended with a Round Table Discussion with audience participation. At the start, various aspects of community involvement in the present and future aspects of the SSC were presented in very brief statements by the panelists. Dave Jackson of the design group exhorted the users to participate now, in the worker bee mode or in the citizen-ambassador mode. He drew attention to an Infopack of SSC-related materials that can assist in preparing talks or answering queries and invited the audience to request it.

Charles Baltay, Columbia, briefly described the origins and purposes of the Summer Study, while James Cronin, Chicago, argued for prompt formation of a SSC Users Organization.

Gilchriese spoke on detector R&D needs in advance of the Round Table. The Texas Accelerator Center's activities were described by Peter McIntyre who plumped for a three-ringed SSC, capable of simultaneous fixed-target, as well as collider, operation. Paul Slattery, Rochester, addressed the sociology and rejuvenation of the field, arguing that a place for 'small' experiments was needed for graduate students to obtain a degree in a reasonable time. The issues of proposal approval and formation of collaborations were covered by Dick Taylor, SLAC, who drew on his experience as a member of the LEP Committee at CERN.

The desirability of fixed-target capability agitated a minority of the audience present. Other issues of concern were the possible centralization of detector R&D efforts, the need for more discussion and presentation of information to the lay public, and the big question of site selection.

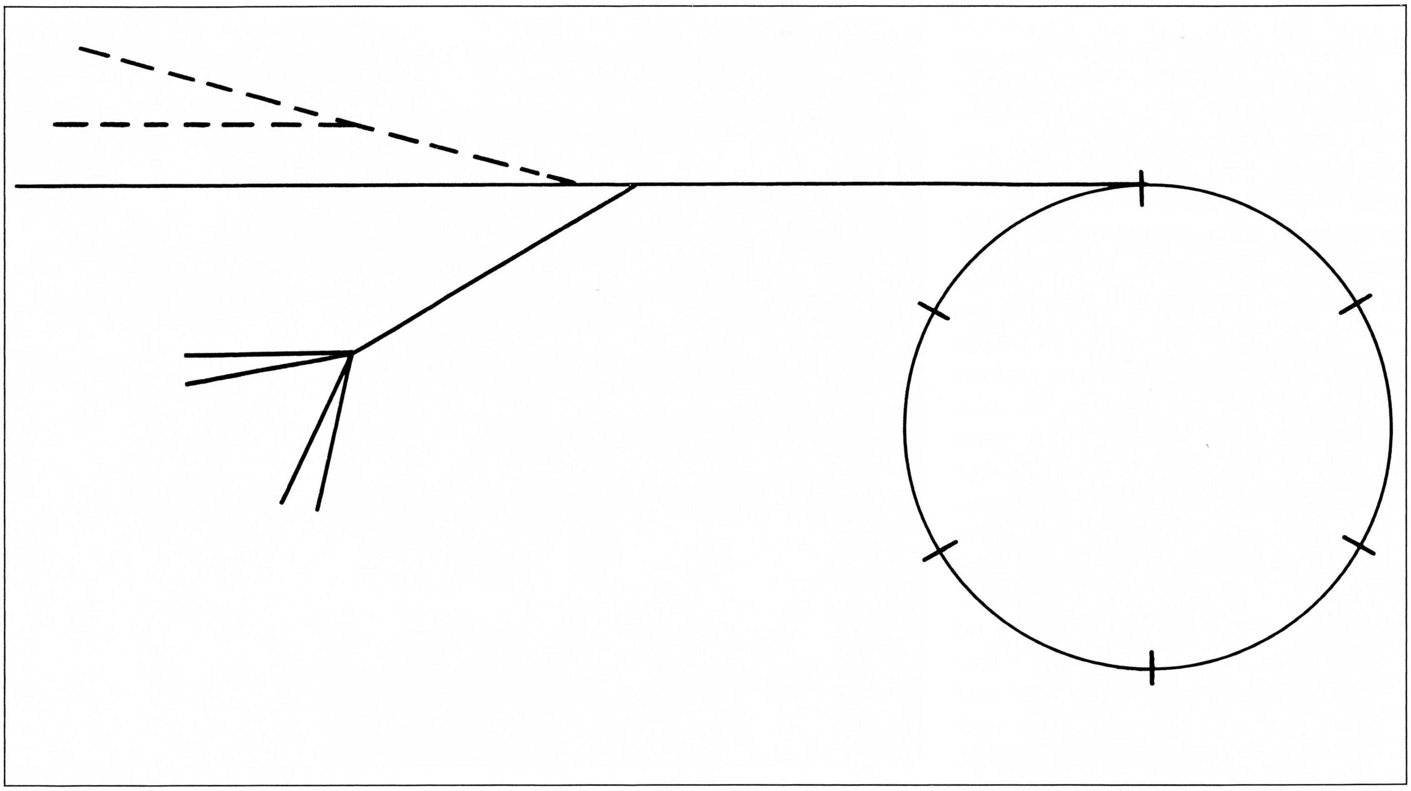
Meanwhile the SSC Central Design Group has published its Site Parameters Document to assist the US Department of Energy in defining technical site requirements for the mighty accelerating ring, which could extend to 100 miles in circumference.

The site criteria presented are derived largely from the Reference Designs Study (see January/February issue, page 3).

SERPUKHOV
Call for experiments

The new UNK accelerating/storage complex, to supply 3 TeV maximum proton energy, is being constructed at the Soviet Institute for High Energy Physics (IHEP), Serpu-

Proposed layout of the UNK accelerator/collider now being constructed at the Soviet Institute for High Energy Physics, Serpukhov. Protons from the existing 76 GeV proton synchrotron will be fed into the 7 km-diameter UNK rings. Conventional magnets will accelerate the protons to 600 GeV and a superconducting ring beneath will take them on to 3000 TeV. Fixed target experiments will use extracted hadron beams (bottom left) and neutrinos, and the use of muons (dotted lines) is also being considered.



khov. It will allow physicists to carry out both fixed target and colliding beam experiments.

Fixed target experiments will be carried out with hadron and neutrino beams, as well as the accelerator's internal beam.

The hadron area will use four secondary beams produced by slowly extracted protons from the main ring. The magnetic structure of the beam channels will cater for a variety of secondary beams – electrons, photons, polarized protons, hyperons, neutrons, etc. Halls will be big enough to house two experiments on each beam channel. The neutrino area will have wide and narrow band beams, tagged neutrino beams and beam dump experiments. The UNK project also foresees colliding beam experiments (see below).

Physics will begin in 1993, and IHEP invites all interested groups to formulate their proposals for UNK experiments. The following items should be considered: the scientific aspect of the experiment; its apparatus and components, and the required manufacturing schedule (attention should be paid to new methods and technology); necessary resources; and requirements for beam and for the experimental zone.

Proposals should be sent to the IHEP directorate by 1 January 1986 for further consideration at the IHEP Scientific Coordinating Board.

UNK will use a tunnel 20 km long and 5 m in diameter. Depending on the relief of the terrain, the tunnel runs from 20 to 60 m below ground. The IHEP 76 GeV proton accelerator will serve as an injector for the first stage of UNK, an accelerator with conventional magnets and maximum energy 600 GeV. After acceleration in the first stage, the beam will then be transported into the second stage beneath. The second stage magnets will be superconducting, providing 3 TeV protons. Three operational modes are foreseen: fixed target operation at 3 TeV; 400 GeV on 3 TeV colliding beams; and 3 TeV on 3 TeV colliding beams. An additional superconducting storage ring will be constructed.

The design intensity of the accelerated proton beam is 6×10^{14} protons per pulse with 120 s cycle time and 40 s extraction period.

The 3 TeV accelerator will comprise a proton beam transport system, hadron area, neutrino area and an underground hall for ex-

Together at Bodega Bay (California) to discuss polarized antiprotons – Simon van der Meer of CERN (left) and Dave Jackson of Berkeley. At another meeting at Berkeley earlier in the year, tributes flowed on on the occasion of Jackson's 60th birthday (see page 287).

periments on internal targets.

A slowly extracted proton beam will be split into two, one feeding the neutrino area and the other the hadron area. It is planned to split the neutrino area beam to provide another experimental area (probably for muons). The beam for the hadron area will also be split into two before being guided upward to the target hall.

Four beam channels will be used to transport secondary beams formed from each of the two targets, two channels handling positively charged particles, and two handling negative particles. A proton beam could be extracted into any beam channel. Maximum intensity on the target will be 1.5×10^{13} protons per pulse, giving 10^9-10^{11} positive pions per s in the momentum range from 500-2000 GeV and $5 \times 10^8 - 5 \times 10^9$ negative pions. Each tunnel will lead into an experimental hall of approximately 30×300 m 1200 m downstream of the target.

In the neutrino area there should be wide and narrow band beams and prompt neutrinos (beam dump experiments). Tagging has been foreseen for kaon-derived neutrinos in the narrow band beam. The pions and kaons will decay in a vacuum pipe some 3.7 km long and maximum diameter 4 m. After the decay path there will come a neutrino tagging station, 500 m of steel muon shielding and a detector for prompt and tagged neutrinos. At 3 TeV and 3×10^{14} protons per pulse, one neutrino interaction per ton is expected for a dichromatic beam.

The accuracy of reconstructing neutrino energy may be almost 3 per cent if a tagging system detects simultaneously the muons and photons deriving from kaon decays. The contribution from background neutrinos should be reduced by an order of magnitude. With 10^{14} protons per pulse, the number of tagged neutrino interactions in 100 t of detector should reach 10^4 particles per day for muon neutrinos and 200 particles per day for electron neutrinos.

A straight section 60 m below the surface will house experiments using internal targets. This main hall will be 60 m long with 9 m diameter, with an adjacent hall 30 m long.

For colliding beams, four matched sections are to be used for experiments. Two halls at a comparatively small depth will be excavated. The halls will be approximately 24×24 m, with preassembling halls of approximately the same size. Maximum luminosity in these intersection points should achieve $10^{32}cm^{-2}s^{-1}$.

WORKSHOP
Polarized antiprotons?

In April, 22 physicists gathered for a long weekend of 'brainstorming' in the isolated village of Bodega Bay overlooking the rugged coastline of north California. They were trying to find some way to polarize (align the spins of) antiprotons. To attack this very difficult problem the physicists were drawn about equally from the fields of high energy physics, atomic physics, nuclear physics and accelerator physics.

The workshop opened with lectures by two experts who defined our present knowledge of the two fields which the workshop hoped to unite: Willy Haeberli (Wisconsin) reviewed polarized proton ion sources and Simon van der Meer (CERN) reviewed storage of antiprotons. The workshop was not publicized in advance partly because the organizers, Owen Chamberlain (Berkeley) and Alan Krisch (Michigan), were concerned that it might be totally impractical to obtain enough polarized antiprotons to do useful high energy physics experiments. They were also eager to maintain a very informal atmosphere where people were willing to propose 'crazy' ideas.

Indeed, most of the twelve ideas which emerged were not very practical. For example the idea of using 'stochastic techniques' to enhance the polarization of a stored antiproton beam was dispatched in a short talk by Simon van der Meer. He pointed out, perhaps with a small smile, that it was a fine idea except that the signal to background ratio was 10^{-42}. However there were two ideas which emerged from the workshop which did seem quite promising and a third idea which might result in some interesting atomic physics.

The atomic physics idea started as a plan to pass beams of positrons and antiprotons together with the same velocity into a drift region, where they could form atoms of antihydrogen. One could then polarize the antihydrogen atoms using the same atomic beam techniques used in polarized proton ion sources. The formation rates were estimated by distinguished atomic physicists Carson Jeffries (Berkeley) and Daniel Kleppner (MIT) to be about 10^3 per second. This is clearly too low to be useful for high energy accelerator experiments. However no one has ever produced one single atom of antihydrogen, polarized or unpolarized. With even a very weak single beam of antihydrogen it would be possible to do some very interesting experiments such as comparing the Lamb shift for antihydrogen with that for hydrogen. A number of the participants, especially K. Imai (Kyoto) and Arthur Rich (Michigan) left the workshop with plans to begin antihydrogen experiments. Antihydrogen has also been discussed by the LEAR Low Energy Antiproton Ring community at CERN (see June issue, page 188).

One promising idea for producing high energy antiproton beams was presented by A. Yokosawa (Argonne). Fermilab is now constructing a polarized proton beam which will use protons captured from hyperon decay. These protons are known to have a polarization of about 50 per cent. The antiprotons from antihyperon decay should have exactly the same polarization. The intensity and kinematics may make it difficult to store and accelerate these polarized antiprotons but it should certainly be possible to scatter them from a polarized (or unpolarized) proton target.

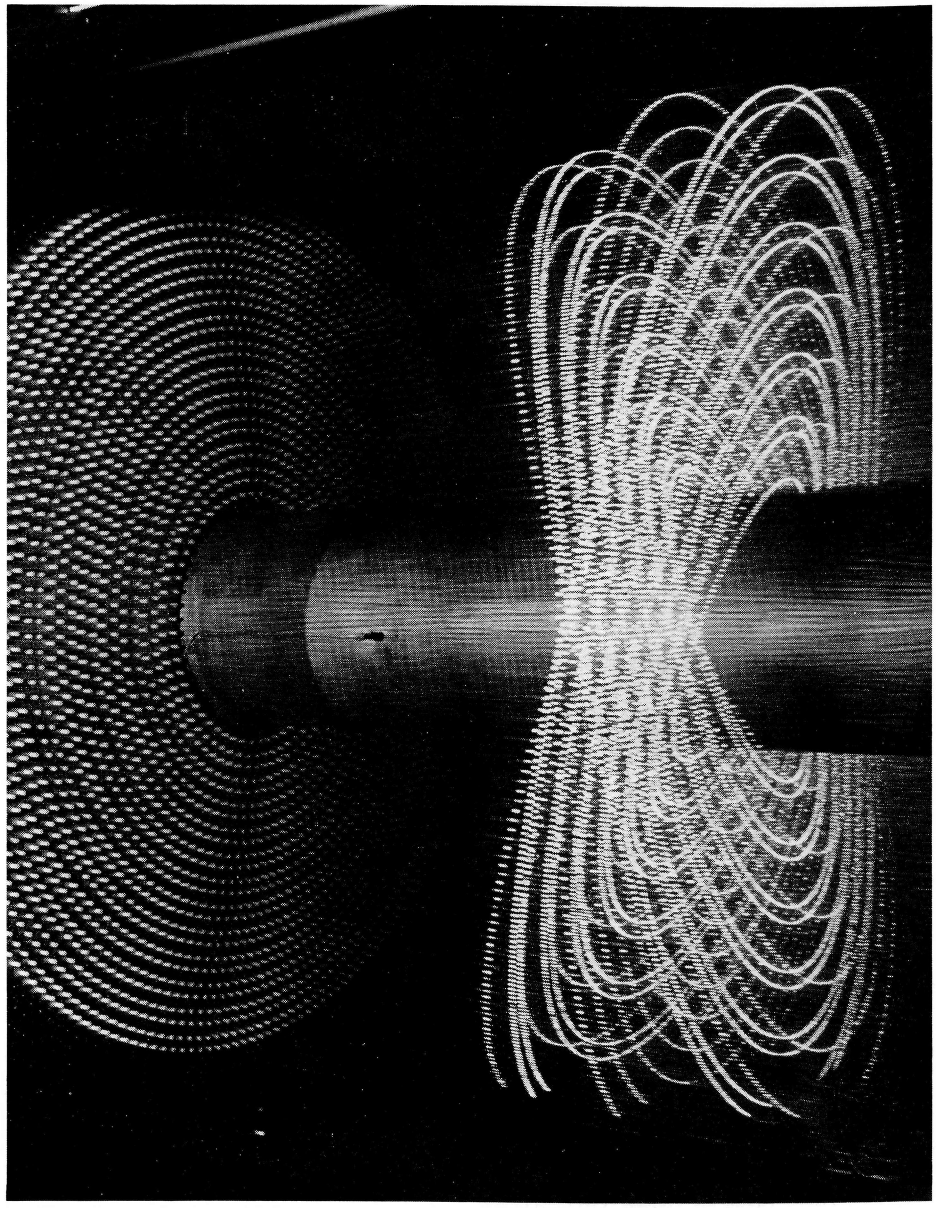
The most promising idea for accelerating polarized antiprotons was named the 'Spin Filter' technique. This uses a polarized proton gas jet which is placed inside an antiproton ring. One then accelerates or decelerates the antiprotons to some energy where the proton-antiproton reaction rate is different when the spins are parallel and antiparallel. The antiprotons in one spin state are then scattered more often and disappear more quickly from the storage ring. After perhaps 10 or 20 hours the remaining antiprotons should have a significant spin polarization. Fortunately several groups are already developing polarized atomic hydrogen jets for various reasons. Tapio Niinikoski (CERN) described some of these efforts including his own at CERN and the Michigan-MIT effort at Brookhaven (see April 1984 issue, page 100).

This Spin Filter technique appeared practical and quite promising provided some energy is found at which the antiproton-proton scattering depends markedly on whether the colliding particles have parallel or antiparallel spins. There are no data on total reaction rates (cross-sections) for polarized antiprotons colliding with polarized protons. Hopefully a significant spin-dependence will be found in the energy region below 1 GeV, where the proton-proton spin dependence is so large that some physicists feel that it indicates the existence of dibaryon resonances or bound states. A low energy beam of antiprotons can be polarized by elastically scattering them at certain angles. By scattering these upon a polarized proton target one can measure the spin dependence of the antiproton-proton total cross-section. This measurement should be made both with the spins parallel to the beam direction and then transverse to the beam direction. A number of participants, especially Willy Haeberli, Erhard Steffens (Heidelberg) and Dave Cline (Wisconsin), began planning such measurements probably at LEAR (CERN) or at Fermilab. The larger the spin effect the easier it will be to polarize a coasting beam of antiprotons.

From Owen Chamberlain and Alan Krisch

A view of the 172 cm diameter inner portion of the ARGUS detector around the beam pipe of the DORIS II electron-positron ring at the DESY Laboratory, strung with 30 000 76-micron wires.

(Photo DESY)



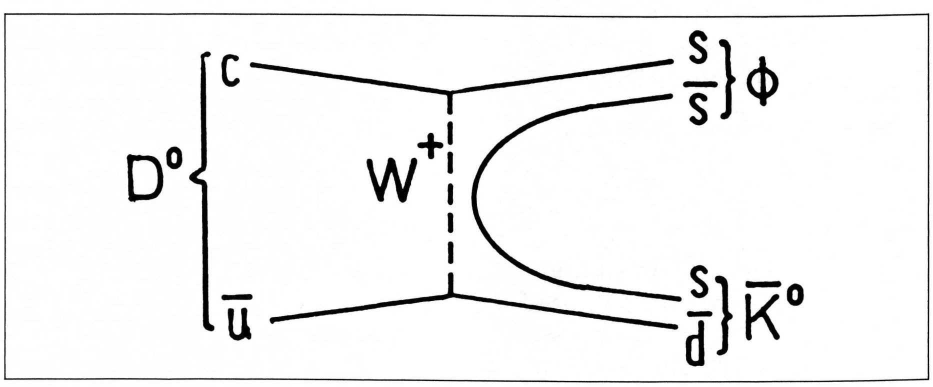
DESY
Physics from ARGUS

While the first few hundred metres of underground tunnel for the new HERA electron-proton collider are being drilled near the site of the German DESY Laboratory in Hamburg, the two big electron-positron storage rings DORIS II and PETRA provide plenty of data for further physics results.

The performance of both machines is very stable. DORIS II is currently producing a mean luminosity of one event per picobarn per day with a re-injection scheme which only requires a few minutes during each hour of operation. The circulating particle bunches (corresponding to a mean current of 32 mA) do not need to be dumped before refilling the ring. The beam energy this year is being kept around 5.3 GeV to obtain data at the third excitation (4S state) of the upsilon resonance.

Under these favorable conditions the ARGUS group, a collaboration now including 64 physicists from six nations, recently produced a series of interesting results. The institutions participating in the ARGUS collaboration at DORIS II are (besides DESY) Dortmund and Heidelberg from Germany, Kansas and South Carolina (USA), Ljubljana (Yugoslavia), Lund (Sweden), the Canadian Institute of Particle Physics, and the Institute of Theoretical and Experimental Physics of Moscow (USSR).

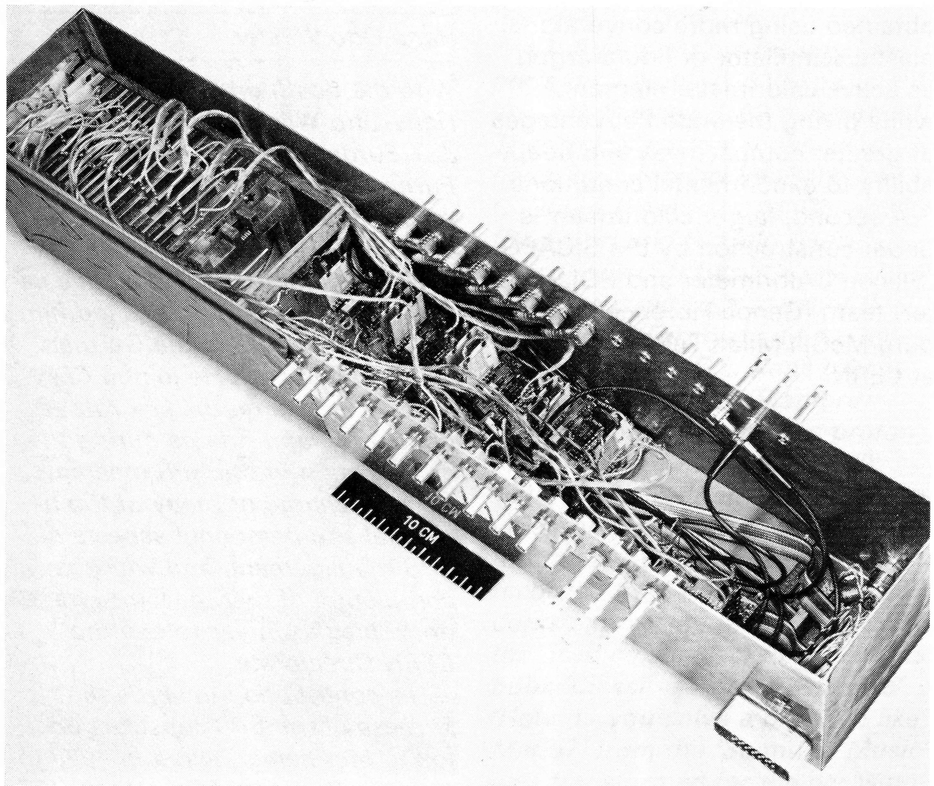
One of these results involves the decay of the neutral D meson. The



Decay of a neutral D (charmed) meson into a phi and a neutral kaon, mediated by exchange of a charged electroweak boson.

Prototype silicon electromagnetic calorimeter built by a CERN/INFN Frascati/Milan/McGill/Tel Aviv team. On the left are the sandwiches of silicon and tungsten absorber. On the right are the readout electronics.

(Photo CERN 1.5.84)



Colour mixing?

The decay of B (beauty) mesons into J/psis should be suppressed by the 'colour' mechanisms of quark dynamics (quantum chromodynamics). However the observation of such a decay could mean that new 'colour mixing' effects come into play. As well as being seen by the ARGUS collaboration at DESY, the decay has also been identified by the CLEO group at Cornell's CESR electron-positron collider. Like DESY's DORIS II ring, CESR was also tuned in to the fourth (4S) upsilon.

decay channel into a (short-lived) neutral kaon and a phi (1020) meson has been clearly established. The branching ratio is found to be about one per cent and gives direct evidence for a contribution from W (weak boson) exchange.

A particularly interesting decay mode of the B (beauty) meson was seen. The colour-suppressed decay of the B into a J/psi plus an arbitrary number of hadrons was clearly established with a branching ratio of about 1.4 per cent. This decay gives information of the subtle interplay of weak and strong interactions in heavy meson decay.

Many tau leptons were recorded in the ARGUS detector. From the study of 1500 tau decays into three charged pions and a tau-type neutrino, it was possible to fix a new upper limit for the mass of the tau neutrino at 70 MeV.

High energy physics research will continue at the DORIS II storage ring and the two groups currently working there, ARGUS and Crystal Ball, hope to carry on their investigations for at least another four years.

DETECTORS
Silicon calorimeters

In the last few years, silicon detectors have become an important high energy physics tool (see March 1982 issue, page 47), exploiting their high spatial resolution, short transit time and ability to be used in magnetic fields and in vacuum.

After these initial successes, attention turned to their potential for electromagnetic calorimetry (energy measurement), thanks to the development of large active areas with low resistivity. The characteristics of these semiconductors (depletion layer) depends on the voltage bias supplied.

A prototype electromagnetic calorimeter has been built at CERN by a CERN/INFN Frascati/Milan/McGill/Tel Aviv team using 12 5×5 cm^2 silicon detectors interspersed every 2 radiation lengths (fraction of a centimetre) with uranium or tungsten absorber. This shows good localization of the showers produced by test electron beams. The energy response of the calorimeter is linear using tungsten and using uranium and using two widely different depletion layers (70 and 200 microns), and giving good energy resolution.

Thus the prototype unit gives comparable performance to that

People and things

obtained using more conventional plastic scintillator or liquid argon as active calorimeter element, while giving the added advantages of greater compactness and adaptability to experimental conditions.

A second, larger calorimeter is under construction by the SICAPO (SIlicon CAlorimeter and POlarimeter) team (Genoa/Florence/Hamburg/McGill/Milan/Tel Aviv/Trieste) at CERN.

Hans-Otto Wüster

With the death on 30 June of Hans-Otto Wüster, Director of the JET European fusion experiment, European science lost one of its most influential and colourful figures.

Wüster's long and productive career in accelerator physics led him to the Directorate of the German DESY Laboratory. He joined CERN in 1971 to take on the key role of deputy to John Adams during the construction of the SPS machine. He took charge of many of the financial and personnel aspects of SPS management, and with the completion of that machine, went on to play a similar role in the CERN Directorate.

His contribution towards the success of the SPS construction led to him being invited in 1978 to become Director of Euratom's JET (Joint European Torus) project, housed at Culham, the UK fusion research centre. Under Wüster's leadership, JET construction was completed and the project is poised to make significant advances towards the goal of mastering thermonuclear fusion by plasma confinement.

He was keenly aware of the human problems of laboratory management. At one of his last visits to CERN, for a memorial meeting to the late Sir John Adams last year, he said, 'I believe the most important and difficult task in creating a laboratory is to maintain the spirit of collaboration and lively discussion, and not to allow it to separate into little compartments with unassailable walls between them.' His managerial; technical and human contributions to Europe's science will be sadly missed.

Hans-Otto Wüster (right) at CERN with the late Sir John Adams in 1977.

(Photo CERN 282.6.77)

Addressing staff on a visit to CERN on 18 June is (centre) Italian Foreign Minister Giulio Andreotti, flanked by CERN Director General Herwig Schopper (right) and Antonino Zichichi.

(Photo CERN 271.6.85)

Appointments at CERN

In its June session (see also page 263), CERN Council renewed the appointments of three members of the Scientific Policy Committee for three years from 1 July – J.D. Dowell of Birmingham, C. Jarlskog of Stockholm and G. Morpurgo of Genoa. The Council also reappointed M. Jacob as Leader of Theoretical Physics Division for three years from 1 July, and P. Zanella as Leader of the Data Handling Division for three years from 1 January 1986, and extended the appointment of J. Andersson of Sweden as Chairman of the Finance Committee to 31 December. M. Gigliarelli Fiumi (Italy) was appointed Chairman of the Consultative Committee on CERN Employment Conditions (CCEC) until 31 December, replacing J. Walsh (UK).

Awards

Fermilab theoretician William A. Bardeen has been awarded a Guggenheim Memorial Foundation Fellowship for 1985.

Associate Head of Fermilab Accelerator Division Lee Teng has been named a Fellow of Argonne National Laboratory.

Tributes to J.D. Jackson

'New Phenomena at the SPS Collider – Implications for the Superconducting Super Collider and Beyond' was the title of a day and a half meeting held at Berkeley earlier this year which coincided nicely with the sixtieth birthday of J.D. Jackson, a frequent visitor to the CERN Theory Division and at present Deputy Director for Operations of the Central Design Group of the US Superconducting Super Collider (SSC) project.

A full programme included reports by J. Rohlf (UA1 experiment) and J.R. Hansen (UA2 experiment). Theoretical presentations were given by I. Hinchcliffe (Berkeley), C. Quigg (Fermilab), M. Chanowitz (Berkeley) and R. Field (Florida). The question 'After SSC what?' was discussed by a panel of R. Schwitters (Fermilab), M.K. Gaillard (Berkeley), G.L. Kane (Michigan) and B. Richter (Stanford).

In a talk entitled 'proton-proton interactions from 4 MeV to 40 TeV', Kurt Gottfried of Cornell provided birthday reflections. He also brought a special musical tribute recorded by Cornell graduate students expressing their views on the problems in Jackson's famous book 'Classical Electrodynamics'. 'How do you solve a problem like Maria?' from the 'Sound of Music' was transformed for the occasion, including lines like 'How do you solve a problem out of Jackson in anything less than geological time?'.

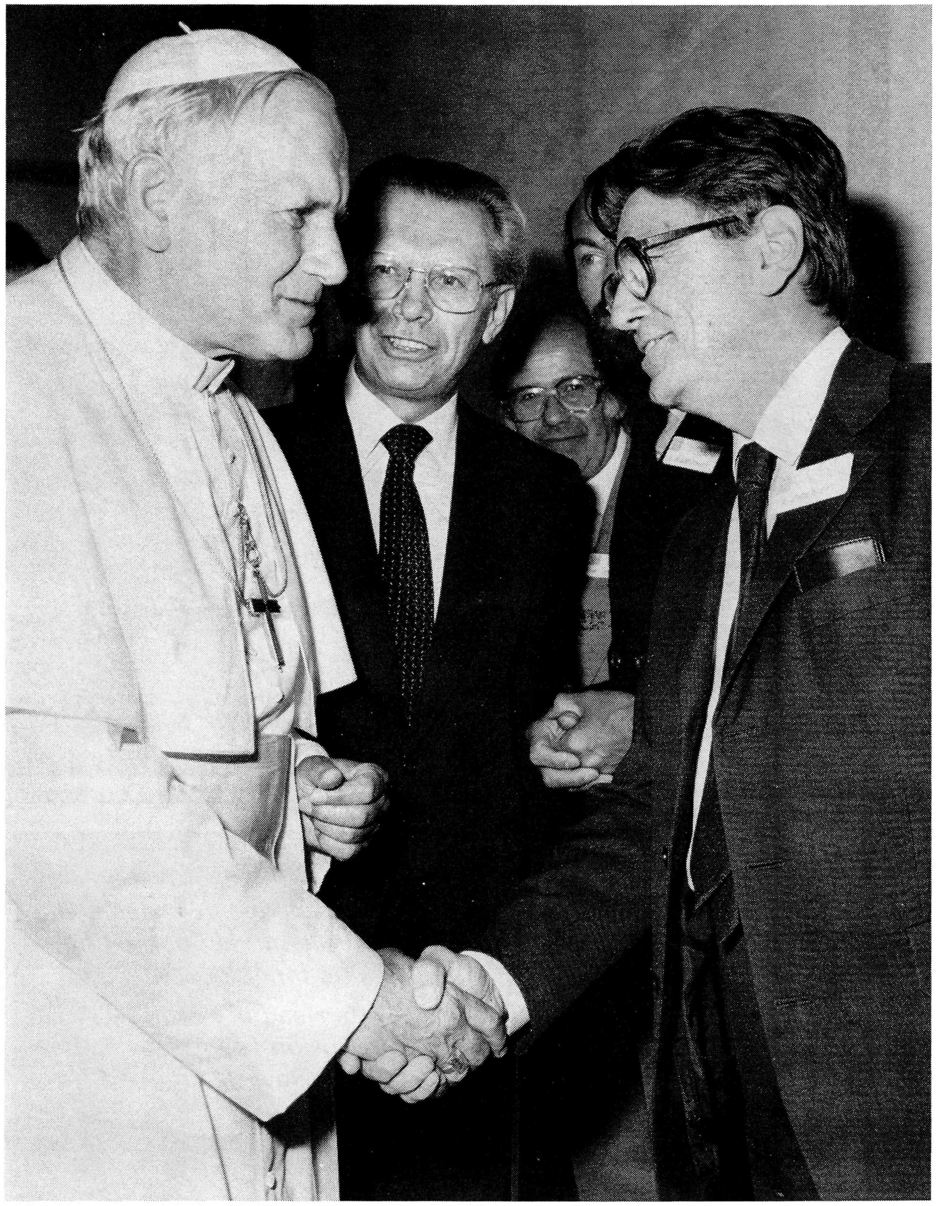
The meeting banquet provided many more tributes to Jackson including one from Bob Cahn of Berkeley – 'His leadership of the Berkeley physics community has kept it at the centre of exciting research. His dedication to human rights has made us proud to be his colleagues. His example has called from the best of all of us'.

Jacques Prentki retires

Earlier this year, theorist Jacques Prentki retired from CERN after a distinguished career which spanned the whole 30-year history of the Organization. He was one of the founder members of the Theory Group, as it was then known, and became well known for his

A proud moment for Jacques Prentki (right) when CERN Director General Herwig Schopper introduces him to Pope John Paul II during the Pope's visit to CERN in 1982.

(Photo CERN 175.6.82)



important contributions to field theory. His scientific work earned him a Chair at the prestigious Collège de France. In addition he has played a vital role in CERN's Theory Division, serving twice as its Division Leader, the second time from 1975-82. Over the years, he has been the genial host to hundreds of visitors to the corridors of Theory Division, from aspiring youngsters to distinguished Nobel prizewinners. He was always sympathetic to their requirements, acting as a catalyst for the close collaboration which is the hallmark of the Theory Division. During the past two years he has been of great assistance to us in his role as Chairman of the CERN Courier Advisory Panel.

Intermediate Bosons in Paris

The French Physical Society held a formal meeting in Paris to honour the two 1984 Nobel laureates for physics, Carlo Rubbia and Simon van der Meer. Held at the Ministry for Research and Technology on 15 April, it was organized under the joint sponsorship of the Minister for Research and Technology, Hubert Curien, the Haut Commissaire à l'Energie Atomique, Jean Teillac (former president of the CERN Council), the Director of the Centre National de la Recherche Scientifique, Maurice Papon, and of the President of the French Physical Society, Maurice Jacob of CERN.

The Minister gave the closing address after the laureates had given their talks. The Italian Ambassador, Mr. Chiuderi, and the Dutch Ambassador, Mr. Vegelin van Claerbergen, were also present.

In his introduction, M. Jacob stressed that this brilliant discovery resulted from the work of large collaborations and that this meeting was also the occasion to honour more specifically the fifty French physicists from the UA1 and UA2 collaborations coming respectively from Annecy (LAPP), CERN, Collège de France, and Saclay, and from CERN, LAL Orsay and Saclay. He also stressed that it was a great success for the European collaboration in particle physics research, an endeavour to which the names of French physicists Gregory and Lagarrigue are closely attached.

Louis Leprince-Ringuet, speaking a few hundred metres away from his former laboratory at Ecole Polytechnique, said some very warm

The seventh meeting of the Japan/US Committee on High Energy Physics was held in May at Stanford. Seated at the centre of the table are delegation leaders J. Leiss of the US Department of Energy and T. Nishikawa, Director General of the Japanese KEK Laboratory, surrounded by other members of the two delegations.

(Photo Stanford)

words at the opening of the meeting, chaired by R. Klapisch, Chairman of the Organizing Committee.

David Tak Leuk Kwok

On 16 June, David Tak Leuk Kwok of Harvard was among the 200 runners who lined up at the start of a 16 km cross-country race at Giron (France), near CERN. He was not among the finishers. A few days before, he had arrived at CERN to begin work on the UA1 experiment. A star physics pupil, he had won the American Physical Society's 1984 Apker Award for an undergraduate student showing great potential, the only US national prize recognizing undergraduate achievement in physics. Kwok collapsed shortly before the finish line and died on the way to hospital.

Brookhaven women's scholarship

To encourage women to continue their studies, Brookhaven Women in Science (WIS) has established the Renate W. Chasman Scholarship. WIS will make one-time awards of $1 000 to Long Island women undergraduates in their last two years, or women graduate students who have returned to college full-time to resume their studies in the sciences or technical fields.

The awards are named in memory of Renate W. Chasman (1932–77), who became the only female physicist in Brookhaven's Accelerator Department. She was chief theorist of the group that designed and built the 200 MeV linac injector for the AGS ring.

Contributions to the Scholarship Fund are extremely welcome. Please contact Brookhaven Women in Science, PO Box 183, Upton, New York 11973, USA.

Meetings

The second in a new series of Accelerator Controls Workshops will be held October 7-10, 1985, at Los Alamos National Laboratory. It will include reports from various control systems and workshop sessions on particular topics. Further information from Stan Brown, MP-1, MS H810, Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA.

A new series of Winter Institutes on Subatomic Physics is being initiated at the Chateau Lake Louise in the Canadian Rockies. The topic of the first meeting to be held from 16 – 22 February 1986 is New Frontiers in Particle Physics, while in 1987 it will be Selected Topics in Electroweak Interactions.

The purpose of the Lake Louise Winter Institute is to explore recent trends in particle physics in an informal setting. There will first be a three day school of pedagogical and review lectures by invited experts. Speakers and topics are to be detailed in a second announcement. Subsequently there will be a three-day topical workshop with contributed presentations by participants. Application forms and additional material from: The Secretary, Lake Louise Winter Institute, University of Alberta, Edmonton, Alberta T6G 2J1, Canada.

DIRECTOR OF THE INDIANA UNIVERSITY CYCLOTRON FACILITY

Applications are invited for the directorship of the Indiana University Cyclotron Facility (IUCF). IUCF is a major and growing national users' facility for intermediate-energy nuclear science with light ion beams. We seek a distinguished nuclear scientist to provide scientific leadership for the laboratory and its program. The director will serve a five-year term starting in the summer of 1986 and will receive a tenured full professorship in the Department of Physics. The five-year term of the directorship will see the start of experimental work with a new electron-cooling storage ring and the development of plans for the future growth of the facility. Salary will be commensurate with experience and qualifications. Applications with a complete resume, including the names of four references, and nominations should be sent as soon as possible, but not later than Nov. 1, 1985, to

Professor S. E. Vigdor,
Chairman, Search and Screen Committee,
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Bryan Hall 104, Indiana University,
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SIN is a Swiss national facility supporting fundamental research into nuclear and particle physics and their applications, and is located in a very pleasant, semi-rural area approximately 40 km north-west of Zurich.

Further information can be obtained from
Mr. K. Emery or Mr. R. Kessi (Telephone 056/99 36 19).

Applications including a CV should be sent to **Swiss Institute for Nuclear Research, Personnel Department, CH-5234 Villigen/Switzerland, Code 522.**

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Please contact Professor P.I.P. Kalmus, Queen Mary College, Mile End Road, London E1 4NS, England.
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The Department of Physics at Carleton University invites applications for a tenure track appointment (subject to budgetary approval) at the assistant professor rank, or in exceptional cases at the associate professor rank, starting July 1, 1986.

The department's instructional program requires additional expertise in digital electronics and the use of microprocessors in the control and analysis of experiments. Preference will be shown to candidates having research experience and interests in experimental high energy physics and, more especially, in the development and operation of instrumentation for high energy physics.

Applications, with curriculum vitae and the names and addresses of three referees, should be sent by November 15, 1985 to:

Dr. L.A. Copley
Chairman
Department of Physics
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Applications consisting of a CV, list of publications, summary of research interests, a detailed research proposal, and the names of three (3) referees should be sent before **October 1, 1985** to Professor R.E. Azuma, Chairman, Department of Physics, University of Toronto, Toronto, Ontario, CANADA M5S 1A7.

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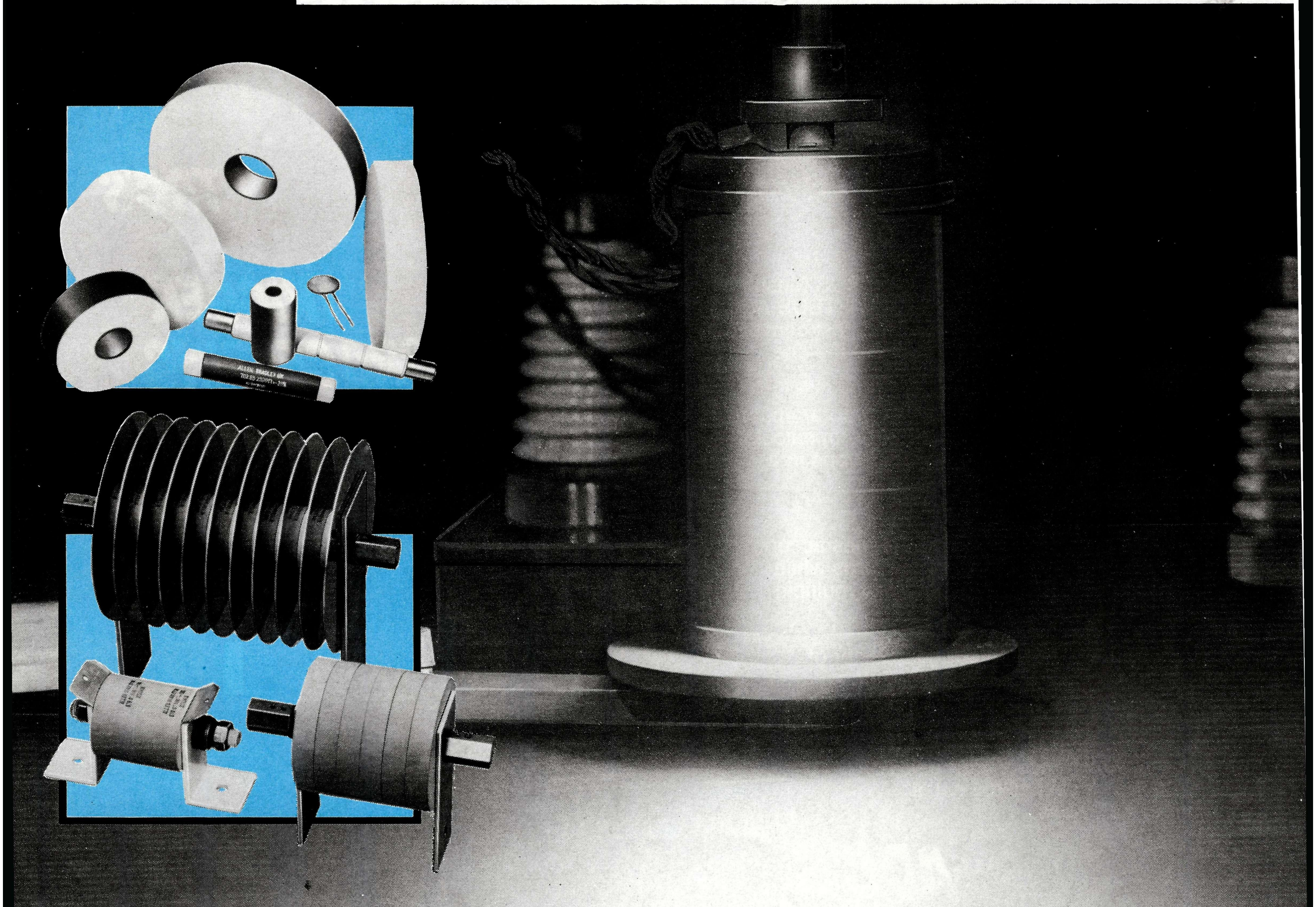

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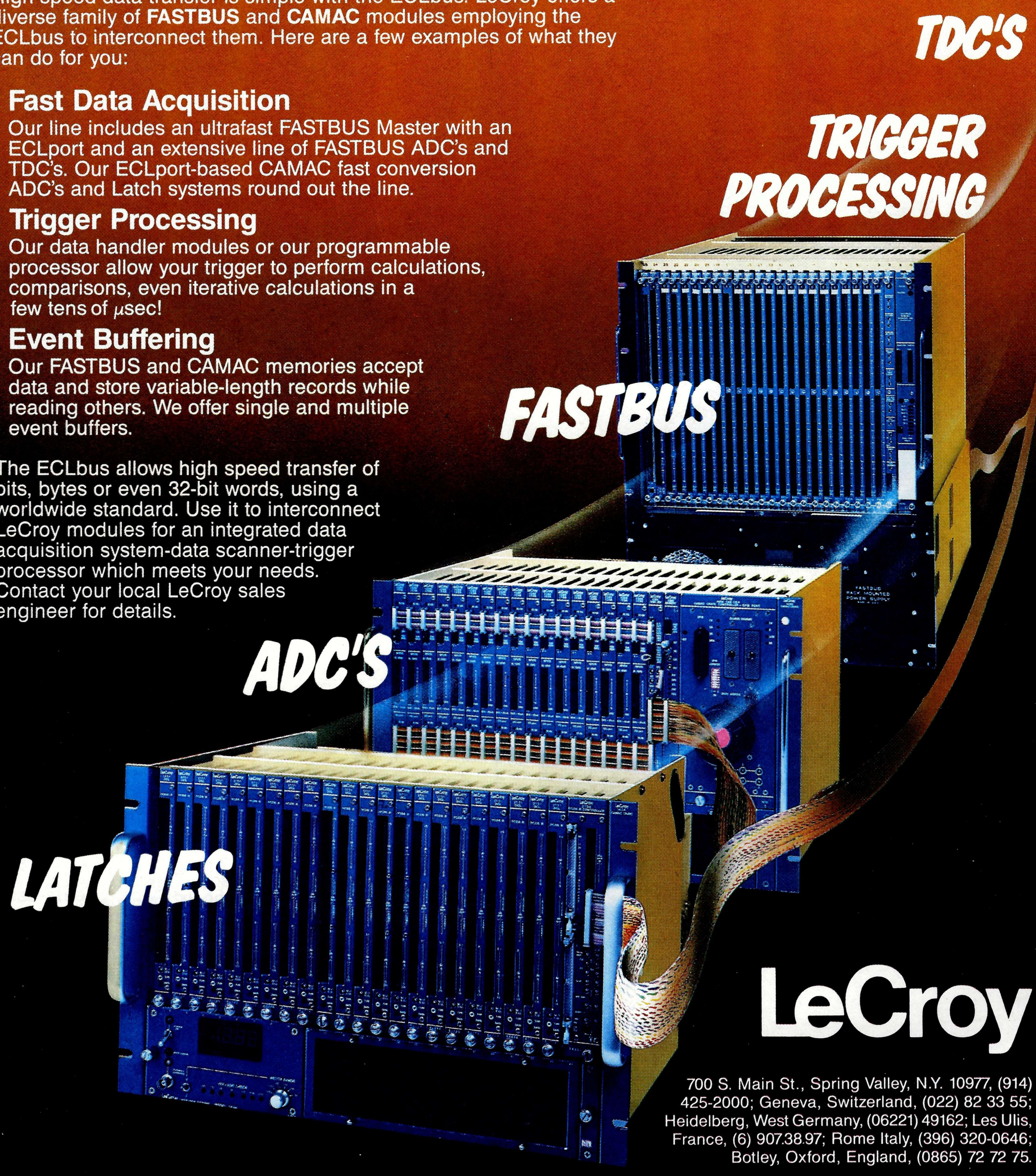

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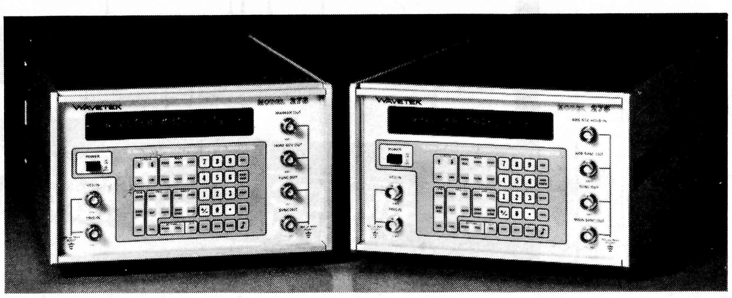

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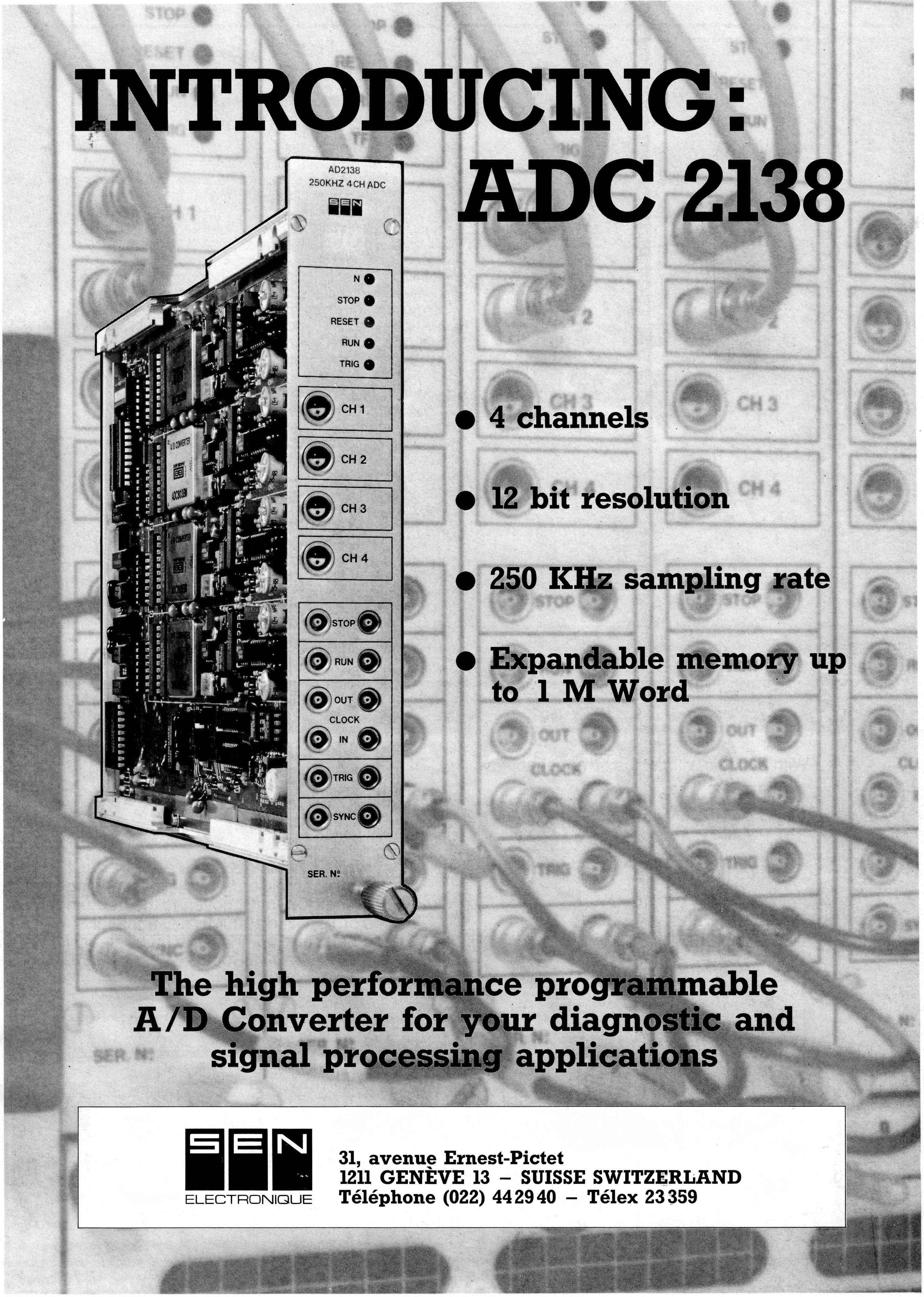
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PMT	number of stages	t_r (ns)	t_w (ns)	σ_t (ns)	Δt_{ce} (ns)	pulse linearity (mA)
XP2262	12	2,0	3,0	0,50	0,70	250
XP2242B	6	1,6	2,4	–	0,70	350
XP2020	12	1,5	2,4	0,25	0,25	280
XP2230	12	1,6	2,7	0,35	0,60	280

High sensitivity bialkali 44 mm diameter cathode

t_r = anode pulse rise time for a delta light pulse

t_w = anode pulse duration FWHM for a delta light pulse

σ_t = transit time spread for single electron mode

Δt_{ce} = transit time difference centre-edge

XP2262 replaces XP2232.

*SER = Single Electron Resolution

Other fast tubes:
3/4″ PM1911 3″ PM2312
1″ PM2982 5″ XP2041

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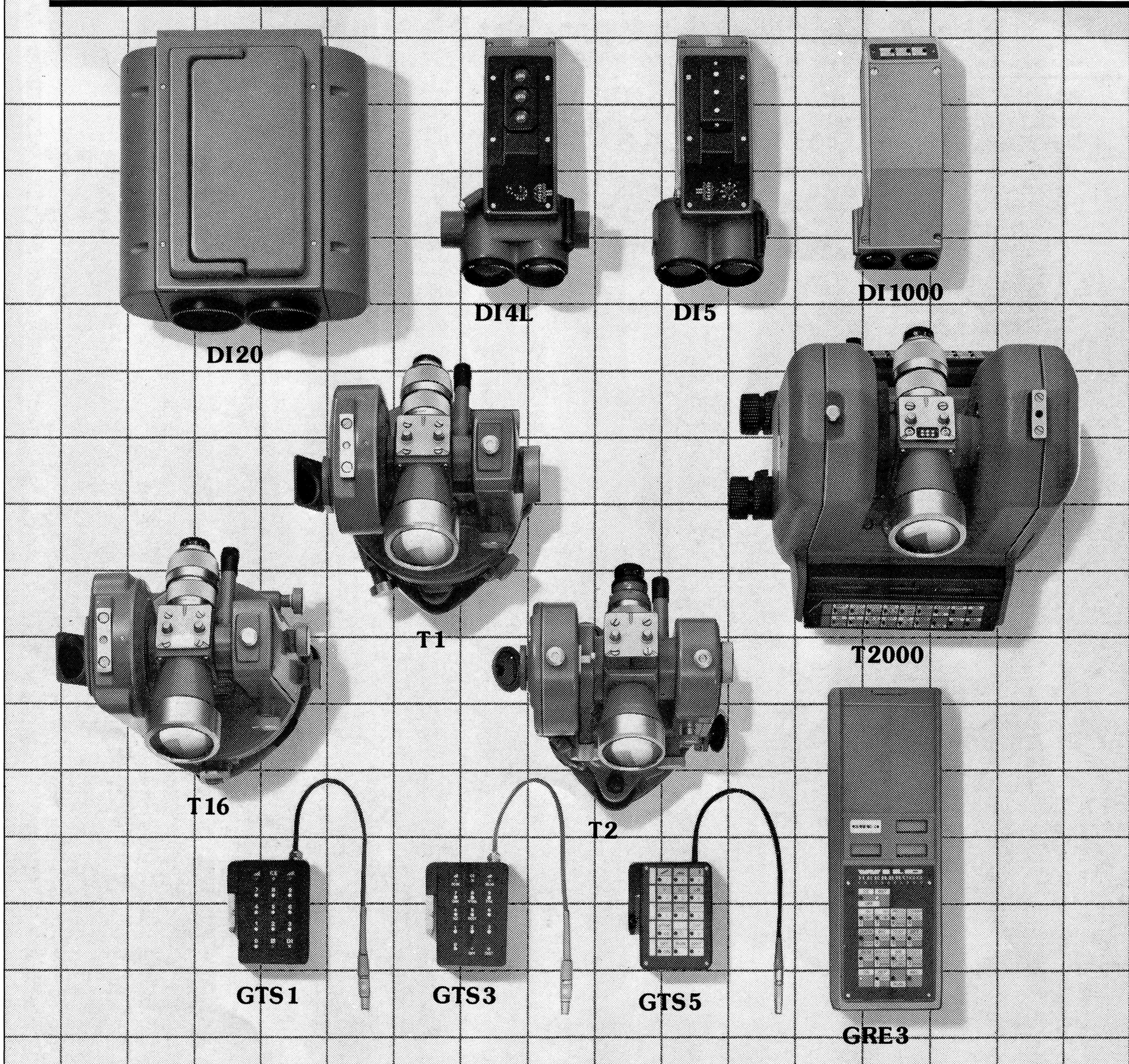

Do you own a Wild T1, T16 or T2 optical theodolite or the new Wild T2000 informatics theodolite? If you do, you can use any one of them as your foundation for the Wild survey system!

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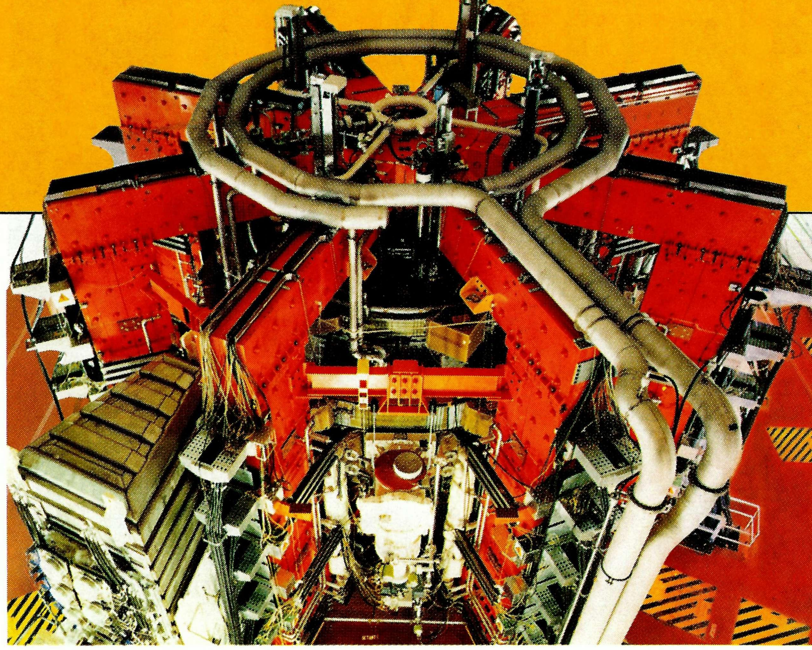
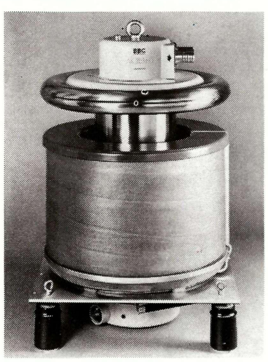


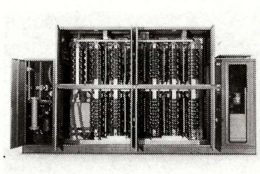
General view of JET, Joint European Torus at Culham, Oxfordshire, GB. For this test tokamak for plasma research BBC has delivered all toroidal field coils, the inner poloidal field coils, the four larger outer poloidal field coils as well as the magnet core. (Photo JET).

Examples of BBC solutions for High Energy Physics and Fusion Research:

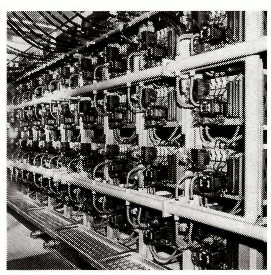
CERN, European Organization for Nuclear Research, Geneva: dipole and quadrupole magnets, spectrometer magnet 3 MW, superconductor and coils for Omega spark chamber magnet. DESY, Deutsches Elektronen-Synchrotron, Hamburg: bending and quadrupole magnets, exciting coils for PETRA bending magnets, super-conductor for HERA dipole magnets. Istituto Nazionale di Fisica Nucleare, Milano: 3 RF generators, 15 to 50 MHz, 90 kW. IREQ Varennes, Canada: 4 power suplies for Tokamak, 1 static bi-directional plasma start-up switch (20 kA/15 kW). Jet Joint Undertaking, Culham GB: poloidal and toroidal field coils, magnet core for Joint European Torus, switching and regulating tetrodes CQK 200-4. KFA Kernforschungsanlage Jülich, FRG: 2 neutral beam injection power supplies 55 kV, 100 A, switching and regulating tetrode CQK 400-1. Lawrence Livermore National Laboratory, Livermore USA: 2 RF generators, 6 to 20 MHz, 1 MW, switching and regulating tetrodes CQK 200-4. Max-Planck-Institut für Plasmapyhsik, Garching/Munich: 2 RF generators, 30 to 115 MHz, 1,5 MW (tests up to 2 MW), poloidal and toroidal field coils for ASDEX and W VII, switching and regulating tetrodes, RF study for ASDEX upgrade. Oak Ridge National Laboratory, Oak Ridge, Tenn., USA: Superconducting toroidal field coil for Large Coil Task. Princeton Plasma Physics Laboratory, Princeton, NJ, USA: Poloidal field coils for TFTR Tokamak. SIN, Schweiz. Institut für Nuklearforschung, Villigen: 4 generator power supplies 16,5 kV, 80 A. Main magnets of isochron cyclotron (2000 tons), bending, quadrupole and experimental magnets. Superconducting coils for muon channel and bio-medical applicator PIOTRON. Switching and regulating tetrodes for Euratom-ENEA Rome, Euratom-CEA Fontenay-aux-Roses F, Fusion Research Center of Japan Atomic Energy Research Institute. High power RF triodes and tetrodes for CRPP, Association Euratom Suisse, Ecole Polytechnique Fédérale, Lausanne CH.



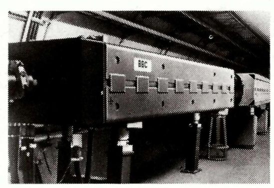
Special high-vacuum tetrodes for fast DC switching and control up to 170 kV, 120 A. Switching times in the order of μs. Integrated x-ray shield, SF_6 insulation and antiparasitic damping.



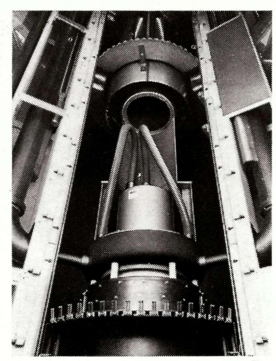
Toroidal field power supply for a Tokamak. Output current rating for quasi-continuous operation 100 kA (max. 120 kA/370 V DC), for 10 sec/900 sec pause.



Fast high-voltage power supply in pulse-step modulator technique.



B 340 type dipole magnets for beam transport of the Super Proton Synchrotron at CERN Geneva (Photo CERN).



ICRH-generator for plasma heating, 30 to 115 MHz, 1,5 MW, for pulses up to 10 s, equipped with BBC tetrode CQK 650-2.

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Power tubes developed and manufactured by Varian EIMAC used in the facilities mentioned include the 8973, 8974, X-2062K/9009 and Y676A/9013. These tube types will be joined by others in development to meet new program requirements.

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