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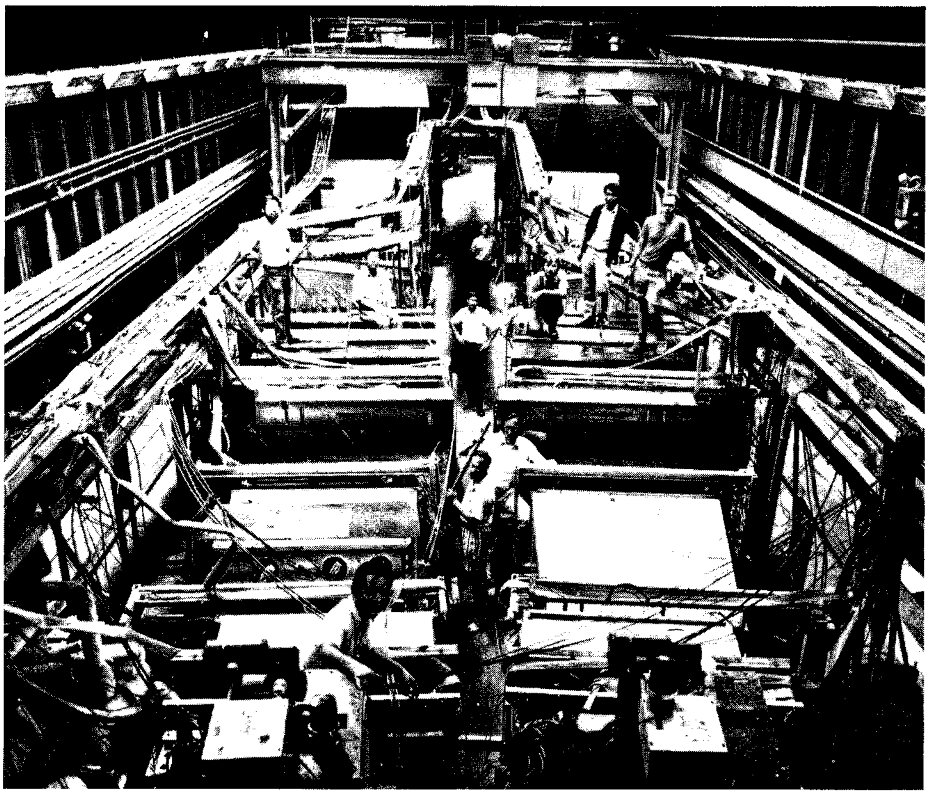
Contents

Cover photograph: Leon Lederman presents the evidence for Upsilon at the Budapest Particle Physics Conference. The Upsilon at a mass of 9.5 GeV was the topic which carried most weight at the Conference. (Photo A. Montvay)

The discovery of Upsilon



The two muon spectrometer arms of the experiment at Fermilab which has evidence for a new particle at 9.5 GeV. The view is looking downstream from above the target box in the Proton-Center Experimental Pit. Two large analyzing magnets are followed by symmetric arrays of trigger counters, multiwire proportional chambers, a Cherenkov counter and muon ranging steel. Experimenters are photogenically distributed throughout the apparatus.

(Photo Fermilab)

The highlight of the Budapest particle physics Conference in July was the announcement from Fermilab that an 'enhancement' has been seen in the high energy two muon spectrum at 9.5 GeV. It strongly suggests that a particle (or particles) decaying into two muons exists at that mass. They would be three times heavier than the famous J/psi fgmily discovered three years go.

The experiment was carried out by the Columbia / Fermilab / Stony Brook collaboration led by Leon Lederman — the pioneer of lepton pair experiments at proton machines some ten years ago. They looked at muon pairs produced when a 400 GeV proton beam of high intensity was fired onto a target. Their detection system was crowded close to the target to catch muons emerging over a wide opening angle and pairs of muons carrying over 10% of the 400 GeV of available momentum were recorded.

At a muon pair mass of 9.5 GeV, a prominent structure about 1 GeV wide is seen. Lederman calls it the Υ (9.5). Upsilon, a hitherto little used reek letter, means 'slender u' referring to the abbreviated pronunciation of the vowel, and the name could have added significance if the structure turns out to be composed of slender peaks corresponding to highly stable particle states like the J/psi.

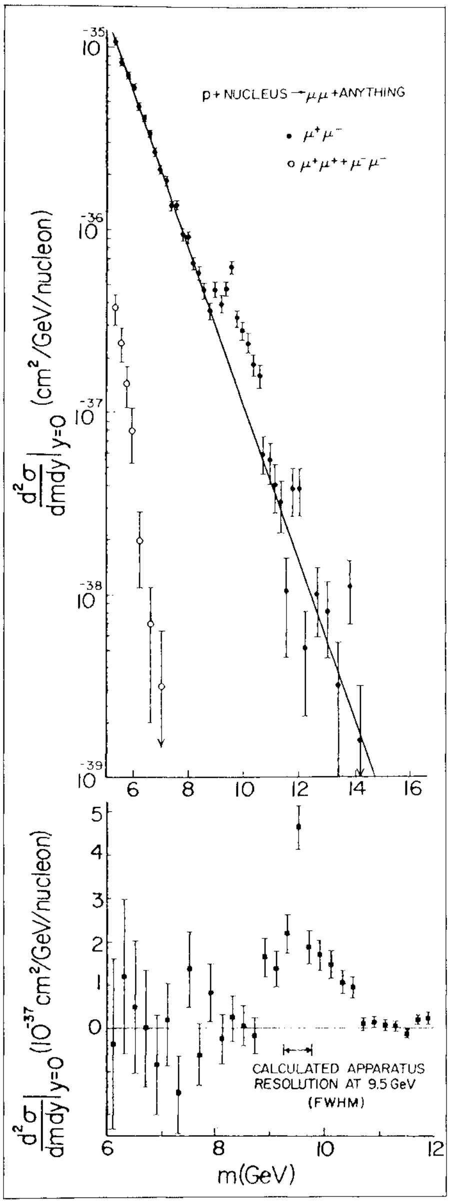
The announcement by Lederman in Budapest came as a great surprise for this is another phenomenon for which no-one has written the recipe. To add further drama, the city's electricity supply failed half-way through his talk. Lights went out everywhere and trams came to a standstill. 'Could be a sign from God that he thinks we're getting too near his secrets', commented Lederman.

The collaboration at Fermilab have been studying lepton pair production in high energy proton-nucleus collisions since September 1975. First runs looked at electron-positron pairs and some forty events were seen where the effective mass of the pair exceeded 5 GeV. Rerunning the experiment looking for muon pairs yielded over two hundred heavy mass events.

In the latest run, which began in May this year, all detectors were moved upstream and the apparatus generally compressed to increase the opening angle which was covered. In addition, the Fermilab Proton Department rebuilt the target box, which now contains beryllium hadron filters about 5 m long in the muon apertures and a massive tungsten beam dump. This permits a combination of high rate and good mass resolution unique to the experiment. A mass resolution of 2% was obtained while recording about twenty muon pairs, of combined mass over 5 GeV, per hour of beam.

By the end of May, structure near 9.5 GeV was becoming evident and a series of checks were carried out to make sure that the enhancement was real. Data was taken using different magnet currents and the effect stayed put. Measurements of J/psi and psi prime production confirmed the mass calibration and resolution of the apparatus and monitored the stability of the equipment. One additional check, which had not been intended, was a trial by fire. There was a fire near the magnet power supplies. To halt the smoke damage to the electronic detectors as quickly as possible, G. Jesse, a fire salvage expert from Europe was brought in. The equipment was quickly scrubbed clean and the enhancement reappeared after the fire at exactly the same mass.

One month later, a total of 9000 high mass muon pairs had been detected. The spectrum, apart from the region of the enhancement, appears to be a smooth continuum which drops off approximately as e^{-M}, where M is the effective muon pair mass in GeV. In the region between 8.8 and 10.6 GeV,



The data on Upsilon collected in the experiment at Fermilab observing pairs of muons of high mass. The combined muon mass is plotted on the x-axis; the upper graph shows the falling spectrum with the enhancement at 9.5 GeV and the lower graph shows more detail in the Upsilon mass region.

350 events are expected from the continuum but the data actually contains 770 events.

The surplus events can fit either a single Gaussian peak centred at 9.5 GeV with a width of 1.2 GeV, or two narrower peaks at 9.44 and 10.17 GeV whose width is dominated by the resolution of the apparatus (about 0.5 GeV). The single resonance fit is less likely, statistically, and is also worrisome on other grounds. A 1 GeV natural width would require that hadronic decays vastly outnumber the muon decays, leading to a production cross-section of the Upsilon comparable to that of the J/psi.

The continuum observed is similar to that predicted by models of muon production through electromagnetic annihilation of the quarks and antiquarks carried by the target and projectile nucleons. Extrapolation to higher energies, using the Drell-Yan scaling prediction for the annihilations, results in cross-sections which would be a factor of ten to thirty higher at the CERN ISR than those at Fermilab. If the Upsilon has a similar energy dependence, it should be visible in the ISR where several experiments, including the CERN / Columbia / Oxford / Rockefeller collaboration, with Lederman himself, are studying high transverse momentum phenomena.

What could the Upsilon be ? The experimenters themselves are being rather reticent in speculating about the significance of the discovery but others are only too happy to do it for them. The finding of a heavy lepton at Stanford and DESY is a strong motivation for having another kind of quark. This would fit conveniently in a unified picture of weak and electromagnetic interactions with five quarks matching the five leptons.

'Truth' or 'Beauty' are names which have been flaunted as possibilities for such a new quark 'flavour' to join up, down, strange and charmed. The Upsilon would then, for example, be beautionium formed from the new quark and its antiquark. The observed structure might well include excited beautionium states. But the Upsilon could well confound all these speculations and be something completely different, as yet 'undreamt of in our present philosophy'.

The collaboration at Fermilab is now taking more data which should resolve the question of one versus two or more peaks and thus initiate the study of the spectroscopy of the Upsilon. A shutdown of the Fermilab accelerator is scheduled in August and by then it is hoped to have three to four times the May-June data under the belt. After the shutdown data will be collected at 200 and 300 GeV before returning to 400 GeV with substantially improved mass resolution. Meanwhile there will be some bright eyes scouring the data from the CERN ISR. After all, we might be at the beginning of the new new physics !

Budapest

The European Physical Society held its 'Particle Physics Conference' in Budapest from 4 to 9 July. It was the ninth of the European series, begun in Aix-en-Provence in 1961, which takes place in alternate years to the international 'Rochester' series.

Excellently organized by the European Physical Society, the Lorand Eötvös Physical Society, the Hungarian Academy of Sciences, the Central Research Institute for Physics, Budapest, and Lorand Eötvös University, the Conference provided a well-rounded view of current activities in particle physics balanced by a nicely-arranged schedule of social events. It coincided with the fiftieth anniversary of the quantization of the radiation field, and who better than Paul Dirac to blow out the (less than 50) candles on the cake at the welcoming party, made additionally memorable by a continual supply of anonymous but highly potent Hungarian drinks.

Dirac's talk on the history of relativistic wave equations was the best-attended event of the Conference, although not part of the physics programme proper. Dirac obviously has great box-office appeal and it was gratifying to see many experienced physicists in the audience, all ears and smiles.

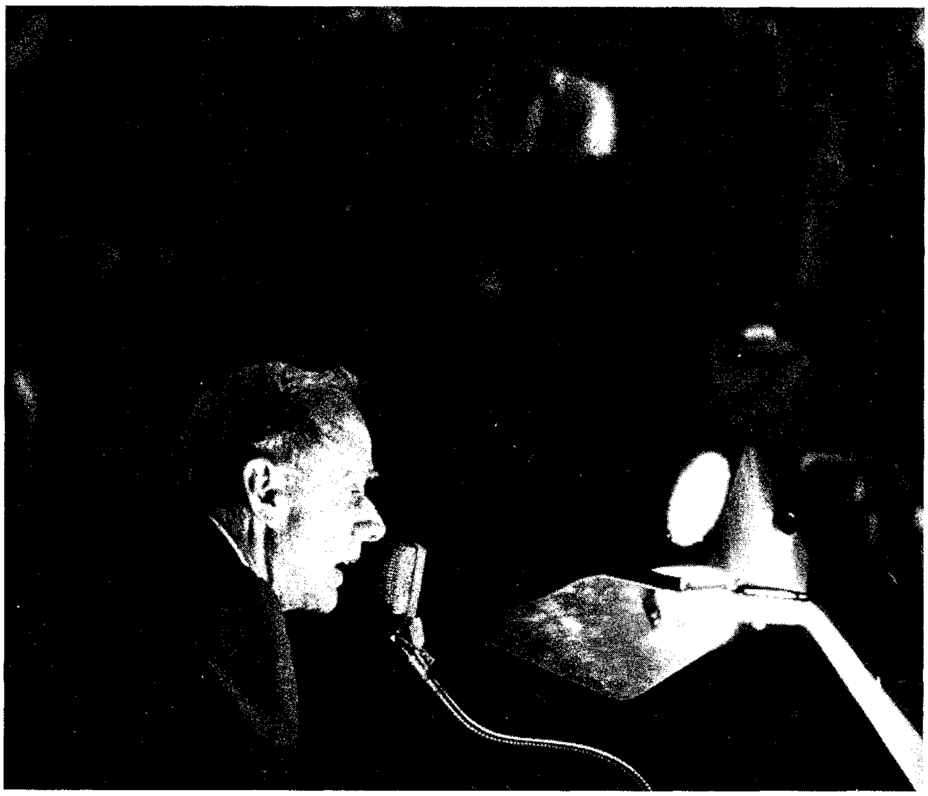
In Paul Dirac and Sam Ting, the Conference was graced by two Nobel prizewinners spanning some 50 years of physics and their presentations underlined the evolution which has taken place in that time. Dirac recalled how he had first tried to accommodate the proton in the additional energy state required by his equation for the electron. Electrons and protons (through quarks) were not to be linked until the Salam-Weinberg model was proposed some forty years later.

Charm was the focus of attention at Tbilisi in 1976 and the most the Budapest Conference could have reasonably hoped for was a substantial, if not spicy, programme with more

Particle Physics Conference

Paul Dirac reminiscing on the fiftieth anniversary of the quantization of the radiation field. His talk drew the biggest audience of the Conference.

(Photo A. Montvay)



news on charm, developments in the heavy lepton area and fresh statistics on neutrino experiments topping the bill.

It was natural that the first results from the CERN SPS provided some of the highlights at this first major Conference to take place since the commencement of physics at the 400 GeV synchrotron. Important results there were from the SPS but, paradoxically, they were sobering results in the sense that they submerged previously-reported abnormalities by a wealth of new statistics, and showed that neutrino physics remains 'well behaved' up to high energies.

Few could have expected the bombshell announcement by Leon Lederman of the new 'Upsilon' effects in high mass muon pairs seen at Fermilab. Although Lederman did not speak until the Conference was almost over, the news was in the wind all the time. As Gerson Goldhaber put it, 'I was supposed to be talking about the spectroscopy of 'new' particles, but that seems to be a bit difficult now.'

None of the speakers on 'new' (i.e. charmed) particles could hope to steal Lederman's still newer thunder but the SPEAR and DORIS electron-positron storage rings at Stanford and DESY still had some fresh results to offer. In other areas the picture which emerged was one of steady progress on a number of fronts, both experimental and theoretical.

SPEAR results

SPEAR had a good batch of new results to report, including a new J/psi-type 'hidden charm' resonance at 3772 MeV just above the threshold for decay into D and $\bar{D}$ charmed mesons. This also enabled new information to be gleaned on the $D\bar{D}$ system.

Experimenters at SPEAR had long been aware of a complicated structure in the analysis of the electron-positron annihilation into hadrons around 4 GeV and decided to explore more fully the area between the J/psi resonances, below the threshold for explicit decay into charm, and the higher charmonium states seen so far.

The result was the observation by the so-called 'lead-glass wall' collaboration of a new particle at 3772 MeV, with a width of about 30 MeV, contrasting with the much narrower widths of the J/psi particles seen below the charm threshold. The new particle is given a spin-parity assignment of 1^-, and as J.D. Jackson pointed out, had been predicted by a host of theoreticians using a variety of methods, all of which had contrived to come out with the correct mass!

The production of $D\bar{D}$ pairs by the new resonance has very clean kinematics and enabled the SPEAR team to fix the D^0 mass as 1863.6 $\pm$ 2 MeV and the D^+ mass as 1868.7 $\pm$ 2 MeV. Goldhaber later gave an independent measurement of this mass difference which agreed. Examination of the neutral kaon-pion mass spectra at SPEAR showed the first clues of the decay $D^+ \rightarrow K^0_S\pi^+$ and its charge conjugate.

Other experiments at SPEAR have looked carefully at 'anomalous' electron production in electron-positron annihilations. Analysis of two-prong final states is compatible with electron-production from the new heavy lepton, τ , previously observed at about 1.9 GeV, while the multiprong final states show a totally different behaviour and point more towards being of charmed origin.

DORIS results

The report from DORIS indicated that experimenters at DESY had been no less active and had exploited to the full the range of detection equipment available. Overwhelming evidence for charm has been accumulated, while there is apparently still some portion of the cross-section for electron-positron annihilation into hadrons to be accounted for.

The sequential heavy lepton reported by Stanford has now been seen in a variety of reactions and the spectroscopy and decay patterns of charmonium have been explored in detail. Interesting preliminary data from the DASP double-arm spectrometer indicates the existence of a new type of charmed meson, the F and F*, from electron-positron annihilations. These results give the F and F* masses as about 2030 and 2140 MeV respectively and they are probably compiled of a charmed quark and a strange antiquark (see page 235).

Goldhaber and Jackson both gave informative talks on the spectroscopy of 'new' (i.e. post-J/psi but pre-Lederman) particles. Jackson showed how many of the features could be reproduced by a readily understandable potential model, surmising that if still heavier quarks exist a rich spectrum of bound states should show up at about 10 GeV. This is just what Lederman's first results seem to show and, according to Jackson, could pave the way for a bonanza of new bound states with atomic physics-like classifications.

Goldhaber got down to the details of the various decay modes of the D mesons, although the observed decays still only apparently make up a small percentage of the observed widths and there should be many more multihadron decay modes still waiting to be discovered.

Neutrino experiments

CERN, with presentations from Don Cundy on the SPS neutrino experiments using BEBC and from Jack Steinberger on the WA1 counter experiment, was eager to spread the word that the 'high-y anomaly' and related abnormalities in high energy antineutrino interactions had been wiped out by new data (see Physics Monitor, page 244).

The timetable allowed Charlie Baltay to get there first and present new results on neutrino interactions using the Fermilab 15 foot bubble chamber. Although Baltay hastened to identify himself with the anti-anomaly camp, some results had big error bars and so teetered mid-way between the old anomalous results and what was to come later from CERN.

Because of the quark/parton interpretation, every talk on neutrino experiments these days has to be prefaced by an introduction to the special nomenclature used. This is unfortunate, but without such preambles many of the results on x-distributions, y-distributions, structure functions and various specially-defined ratios would be comprehensible only to the initiated.

If it were not for the presence of 'sea' quarks — virtual quark-antiquark pairs which accompany the usual hadronic valence quarks — the cross-section for the interaction of neutrinos with nuclei would be three times that of antineutrinos. If no other special production thresholds occur, this value should not vary too much with energy. So the measurement of this cross-section ratio together with careful observation of antineutrino behaviour over a wide energy range gives an insight into the quark constitution of the target nuclei.

Baltay maintained that the Fermilab bubble chamber experiments show a smooth variation with energy, suggesting that most of the neutrino-nucleon interaction goes through real valence quarks except in a few odd kinematical corners. No trilepton events are seen yet in the 15 foot bubble chamber.

Incidentally Baltay introduced the word 'ocean' to describe his quark-antiquark sea, so as not to get his audience confused with 'c' (charmed) quarks, however, the name 'ocean' seems rather generous to describe an effect which amounts to only about a few per cent of the whole.

Good statistics on neutrino interactions were reported by Don Cundy from the BEBC bubble chamber at CERN. They show that while the antineutrino cross-section increases linearly with energy, the neutrino cross-section increases less quickly at higher energies. This means that the ratio of antineutrino to neutrino cross-sections increases steadily with energy from the low-energy value of 0.4 determined with Gargamelle some years ago. This data is in agreement with the latest Caltech / Fermilab figures and implies that sea quarks become more important at higher energy.

The BEBC data on the nucleon structure functions is in good agreement with the earlier Gargamelle data, while the scaling violations detected are similar to those seen in muon and electron scattering experiments. No anomalous antineutrino effects are seen.

Jack Steinberger's results from the WA1 experiment, which carefully probes the kinematical regions where the anomalous antineutrino effects were previously reported, seemed to administer the coup de grâce and bury the idea of odd antineutrino happenings once and for all. However this data seems to point to an energy independent fraction of sea quarks and to a constant ratio between antineutrino and neutrino cross-sections over a wide energy range, while other experiments say this ratio is rising slowly.

Preliminary results on neutral current interactions give a number of independent checks on the Weinberg-Salam model all of which are good and point to the existence of parity violation in neutral current interactions. According to Steinberger, this makes the

Abdus Salam, always an excellent communicator, giving a 'round the world in 60 minutes' talk at Budapest.

(Photo A. Montvay)

continual non-observation of parity violation in atomic physics experiments even more of a puzzle.

The WA1 collaboration at the SPS get a preliminary upper limit of about one per cent for a charm-changing neutral current, in agreement with Goldhaber's indication of charm conserving neutral currents.

Mesons galore

All this work on new particles and neutrino experiments overshadowed developments in more familiar fields but Richard Hemingway from CERN gave a thorough presentation on the expanding spectroscopy of pre-charm mesons. He also reported that a team working at the Omega Spectrometer at CERN has evidence for a high mass nucleon-antinucleon state near 3 GeV, further increasing the number of candidate resonances for baryonium (see page 243).

New vector mesons seem to abound at the electron-positron storage rings Adone at Frascati and DCI at Orsay. Evidence has been amassed for narrow states at 1500, 1780 and 1820 MeV. Signs of a heavier state at 2130 MeV are now appearing. Some people attribute these states to recurrences or excitations of the well-known phi vector meson, while others are less sure.

In theory

While theory can never really rival experiment for spectator appeal at Conferences, there was a whole gamut of papers covering theoretical topics from the outright esoteric to straight phenomenology.

Although billed only as a seminar, and as such not part of the Conference proper, V. Gribov presented some new non-Abelian gauge theory techniques which had previously been overlooked but which excited some of the gauge theorists. The approach ties in with other work on instantons and topological considerations and could offer additional hope for those trying to develop field-theoretic methods which avoid the problems besetting conventional perturbation theory for strong fields.

Abdus Salam did his favourite trick of trying to predict the Universe from scratch in whatever time is allotted to him, without using a computer. His idea is to plug the strong interaction numbers into the equations of gravity to obtain closed 'microuniverses' where strong interactions take the place of gravity. These microuniverses can have event horizons in the same way as black holes and so can produce the temperature radiation predicted by Stephen Hawking.

In Salam's picture, this spin-2 world of microuniverses then has to be combined with the spin-1 world of a combined theory of strong, weak and electromagnetic interactions in some way which is not yet clear. Salam's model is also an illustration of a growing trend in theoretical work to share methods with relativity and cosmology.

Salam too is waiting for some definite answer from the atomic physics parity violation experiment, which seems to be among the biggest impediments to progress in particle physics these days.

Serpukhov Accelerator Conference

The Xth International Conference on High Energy Accelerators attracted specialists from throughout the world to the town of Protvino near Moscow — the site of the Serpukhov Institute for High Energy Physics. The Conference was held from 11-16 July and was excellently organized by the USSR Academy of Sciences and the USSR State Committee for the Utilization of Atomic Energy. The Organizing Committee under the Chairmanship of A.A. Logunov with A.A. Vasiliev, V.A. Yarba and V.I. Kotov had done an excellent job of preparation to ensure a smoothly running Conference.

It was the third in this series of Conferences to be held in the Soviet Union, being preceded by Dubna in 1963 and Yerevan in 1969. In these years the contacts between scientists from all countries working in high energy physics have ripened very successfully. There is free exchange of information about all aspects of our work. The doors of the Laboratories are open to all scientists in the field and individual exchanges of people are commonplace. There are formal large collaborations which have taken Western European teams to the 76 GeV proton synchrotron at Serpukhov and Soviet teams to the 400 GeV proton synchrotron at Fermilab and the 400 GeV SPS at CERN. These collaborations have brought progress in our science and the enrichment of human relationships, which are invaluable.

The Conference was yet another manifestation of the strength of the friendships and of the understanding which have built up. One reflection of this was the warm hospitality of the Russian hosts who provided social highlights in a reception at the Institute and in an evening's entertainment by the Ukranian dance ensemble. Another reflection was the considerable discussion and concern about our colleague Yuri Orlov.

In this report of the Conference we shall concentrate on those topics where new information is available and which have not been covered extensively in recent issues of the COURIER.

The big machines

The CERN SPS, and the KEK proton synchrotron in Japan were spotlighted as high energy accelerators which had come into operation since the 1974 meeting in Stanford. John Adams, Ted Wilson and Michael Crowley-Milling reported different aspects of SPS performance and plans, Crowley-Milling's talk on the philosophy and implementation of the control system being among those which aroused most interest at the Conference.

The present intensity is around 6×10^{12} protons per pulse and the aim is to push to 3×10^{13} ppp by 1980. This will involve more correction magnets in the SPS ring, additional r.f. power and modified injection from the PS. Next year experiments will begin in the North Area where a third hall is to be built to accommodate experiments capable of using the highest intensity and energy available from the machine.

The major proposed extension of the experimental possibilities at the SPS is the addition of antiproton injection to achieve proton-antiproton colliding beams. Using the cooling techniques mentioned below, the present proposed scheme involves ejection of 10^{13} ppp at 26 GeV from the PS to yield 2.5×10^7 antiprotons at 3.5 GeV from a target. The antiprotons would be decelerated in a shuttle ring to 0.45 GeV/c and transferred to a cooling ring where successive pulses would be accumulated at a rate of 5×10^{11} $\bar{p}$ per day. A day's worth of beam could give luminosities of 8×10^{29} per cm^2 per s when colliding at 270 GeV in a low beta insertion in the SPS. Depending to a large extent on the results of ICE (Initial Cooling Experiment), it could be implemented by 1980.

Russ Huson had a similar report on the twin machine at Fermilab. It has already achieved 2.6×10^{13} protons per pulse and improvements towards reaching 5×10^{13} include a negative hydrogen ion injector, a modified Booster (operating at 10 GeV rather than 8 GeV), more powerful r.f. in the main ring, etc. A long list of modest modifications is likely to be needed to squeeze out the last protons rather than the sizable advances in intensity which have been made in the past.

Fermilab also have an antiproton colliding beam scheme under development and, in addition, are installing a ring of superconducting magnets under the existing main ring as an Energy Doubler / Saver (reported by Bill Fowler) aiming for 1000 GeV (1 TeV). It is hoped to bypass beam through a sixth of the Doubler ring next year at 100 GeV d.c. The R and D phase of the Doubler project (achieving circulating beam in the superconducting ring) is scheduled for completion by the end of 1979. Use of the 1 TeV machine, now christened the Tevatron, could start in 1980 and the refurbishing of the experimental areas to take the higher energies (superconducting beam-lines, etc.) is planned to be complete in 1981. Various colliding beam schemes are obviously opened up by having a second ring.

Projects under way and planned

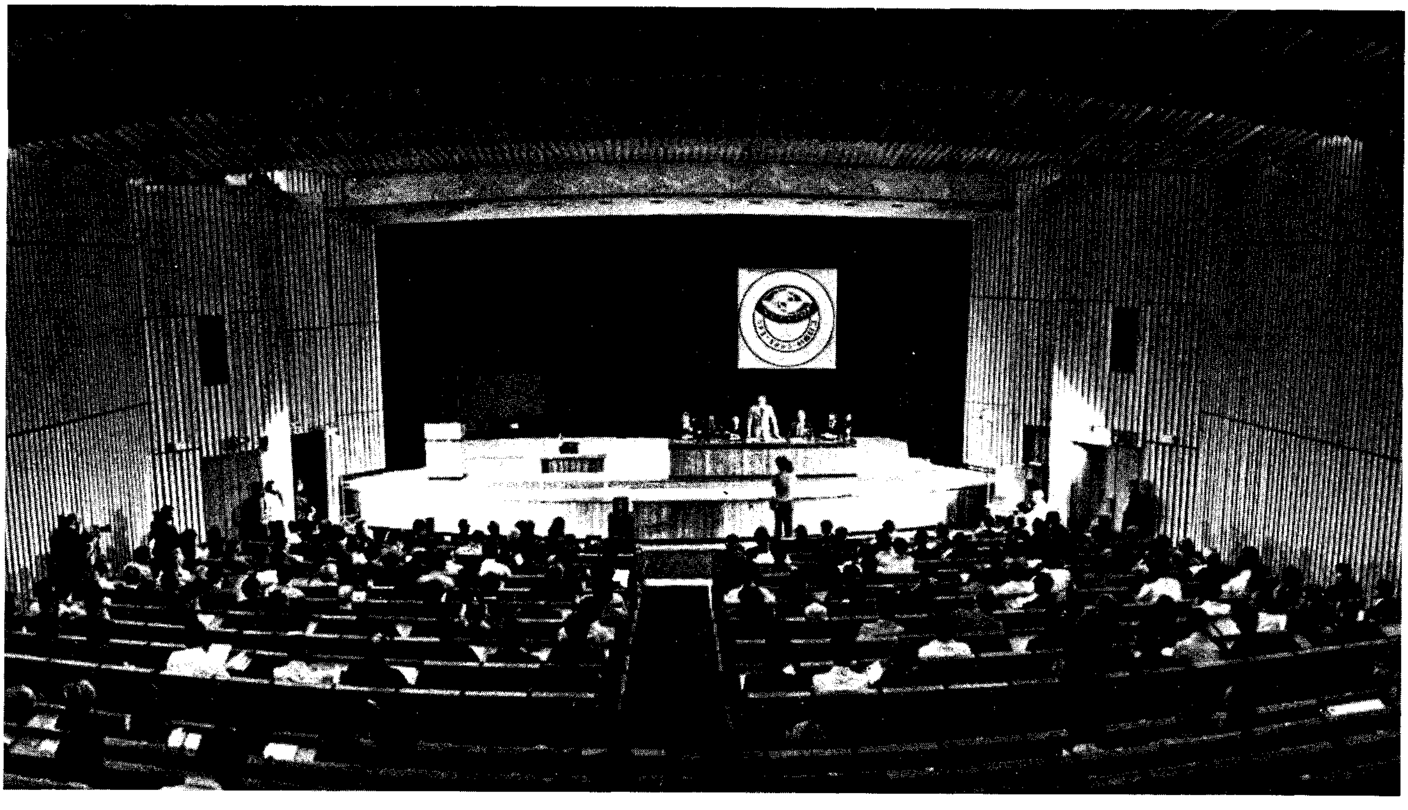
These possibilities at Fermilab were one of the major topics deliberated by the USA 1977 Subpanel on New Facilities which met at Woods Hole in June chaired by Jack Sandweiss. The Subpanel recommendations had as first priority the authorization in Fiscal Year 1979 of construction for the proton-proton storage rings, ISABELLE, at Brookhaven. The second recommendation was for money to the Tevatron for fixed target physics at 1 TeV and for colliding beam physics; the emphasis from the Subpanel was on fixed target physics at high intensities. The third recommendation was for the upgrading of the electron-positron storage ring, PEP, which is now under construction at Stanford, to higher energies (up to 24 GeV).

Work on ISABELLE was reported by Ernie Courant and Arie van Steenbergen. The important change is that the accent is now on a design for 400 eV per beam (rather than 200 GeV) with a peak luminosity aim of 10^{33} per cm^2 per s. Progress on the superconducting magnets reported by P.F. Dahl (see page 236) gives confidence that 5 T field is feasible. The Subpanel has urged that the number of intersection regions be increased from six to eight. Since the ISABELLE parameters are unlikely to be duplicated elsewhere in the world, additional experimental regions could well attract international participation, in line with the thinking of the Serpukhov Study Group on future high energy physics facilities (see June issue 1976).

The start of construction at PEP was covered by H. Wiedeman and the impressive progress on the electron-positron storage ring PETRA at DESY, where particles were taken through the first octant of the machine in July, was reported by Gus Voss. Joe Kirchgessner described the CESR electron-positron scheme at Cornell. E. Sommer covered progress in bringing into operation the two ring DCI electron-positron machine at Orsay. Possible future European projects for electron-proton (CHEEP) and very high energy electron-positron (LEP) systems were described by Eberhard Keil. These topics have been covered in recent issues of the COURIER.

In the Soviet Union, the future research facilities centre on a multi-TeV project, UNK, at Serpukhov described by K.P. Myznikov. It involves IHEP and the Radiotechnical Institute Moscow where the development of the necessary superconducting magnets, reported by E.S. Mironov, is under way. They have built two 4 T dipoles (SPD-3 and SPD-3'). They are warm bore, 5 cm aperture, with eight coil layers using 10 µm niobium-titanium superconductor. Both magnets exhibited similar training characteristics and achieved field uniformities better than 4×10^{-4}.

UNK aims for fixed target physics at energies of several TeV and there would be various options (described in the September issue 1976) for colliding beam physics. The project may start with a conventional ring of several hundred GeV (which could subsequently be incorporated in the colliding beam schemes) before adding the TeV superconducting ring. A location on the Serpukhov site has been selected and civil engineering aspects are now to be examined. Work on models of machine components is scheduled to begin next year.



The opening session at the Xth International Conference on High Energy Accelerators with a speech of welcome from Academician Anatoly Alexeevich Logunov, Chairman of the Organizing Committee and Director of the Serpukhov Institute of High Energy Physics.

(Photo A. Stepanets, IHEP)

Outside the House of Culture where the Conference sessions were held. The pines of the town of Protvino, where the Serpukhov Laboratory is located, can be seen reflected in the windows of the building.

(Photo A. Stepanets, IHEP)

The injection system for UNK will use the existing 76 GeV proton synchrotron whose present performance was covered by Yu.M.Ado. Intensities of 5×10^{12} ppp can be accelerated and a 1.5 GeV fast cycling (20 Hz) booster is scheduled to come into operation in 1979 to increase this to 5×10^{13}.

At Novosibirsk the 7 GeV electron-positron ring VEPP-4, which uses VEPP-3 as injector at 1.8 GeV, is nearing completion. I. Ya. Protopopov reported that electron beams have been circulated and it remains to achieve adequate positron beam intensities for injection. A new linac has been successfully tested and will be moved to VEPP-4 for operation next year to give high positron intensities.

Beam cooling techniques

Novosibirsk was top of the bill in the beam cooling session (which was dedicated to the memory of the late Gersh Budker who promoted electron cooling at the Institute of Nuclear Physics). Three papers, given by V.V. Parhomchuk, N.S. Dikansky and Ya. S. Derbenev, covered their pioneering experimental and theoretical work on this method of reducing the momentum spread in proton beams. (For a description of electron and stochastic cooling and of their importance in accelerator technology, see December issue 1976.)

The theory of electron cooling is fiendishly complicated and has certainly not yet achieved its final form. On the experimental front, the Novosibirsk team have been examining the effect on the proton beam cooling rate of varying the parameters of the electron beam. An important result for the proposed schemes at CERN and Fermilab is that they tried increasing the electron current to 1 A using a 20 mm diameter cathode. Cooling was still observed but not at as fast a rate as theory predicted. There may be space charge problems with intense beams which will make some form of space charge neutralization necessary. Novosibirsk is now collaborating with Serpukhov on an electron cooling scheme to give intense antiproton beams in the IHEP machine.

For stochastic cooling, the theory, initiated by Simon van der Meer and refined by Hugh Hereward, is much better understood. O. Groebner reported recent results from the CERN Intersecting Storage Rings on cooling of vertical betatron oscillations and of momentum spread.

Two improved systems — one high frequency, 1 to 2 GHz, and one low frequency, 80 to 360 MHz — have achieved cooling rates for low intensity beams of 89 % per hour (with a 26 GeV beam) and of 71 % per hour (with a 11 GeV beam) respectively. Stochastic acceleration is also possible with both systems and further improvements in performance can be assured.

The problem of r.f.

Very high energy electron-positron storage rings and accelerators for fusion reactors or fission breeders, will have voracious appetites for r.f. power and the efficient and economic production of r.f. power is one of the major challenges in accelerator technology at the present time.

In some cases, though not all, superconducting r.f. cavities could make considerable impact on the problem and there was an optimistic report from A. Citron on the work at Karlsruhe. They have been developing superconducting cavities in collaborations with CERN and DESY. Two superconducting r.f. separators will be delivered to CERN later this year to be used on an SPS beam to the Omega spectrometer. They are each 3 m long, operate at the frequency of 3865 MHz with a temperature of 1.8 K and provide deflecting fields of 3.3 MV/m. A heavy ion post accelerator, 1 m long, has operated at 100 MHz and 4 K providing 2.3 MV/m. A linear accelerator with helical structure is scheduled for completion before the end of this year.

All of these achievements have been hard to come by. To obtain the required surface quality is difficult and they must be nursed very carefully — a vacuum accident can require reprocessing. Breakdown can occur at much lower magnetic fields than anticipated, due to trouble with field emission or multipactoring. Avoiding these troubles can dictate the operating frequency range and the cavity structure. Nevertheless, Citron maintained that we should have the courage to get used to a new technology, in order to cut construction and operating costs very considerably.

However, if superconducting r.f. is not completely mastered or is not mastered in time, we have to rely on room temperature systems. Here we can hope to gain over present performance by increasing the efficiency of the microwave amplifier which provides the high frequency r.f. fields needed for accelerating particles. The conventional power amplifier is the klystron and the Stanford Linear Accelerator Center has been at the forefront of their development for use in the electron linac and storage rings.

Gregg Loew reviewed progress and plans at SLAC. They now operate three power types (20, 30 and 38 MW) and are gradually replacing lower power versions by the new 38 MW types. The more powerful klystrons are introduced on failure of the older versions and this is nudging the peak energy upwards.

To reach higher energies, SLAC are in the midst of their Stanford Linac Energy Development programme, SLED, (see July issue 1974) which packs more r.f. power into shorter pulses. A quarter of the SLED cavities are now in place and this will be increased to a half by the end of the Summer. Completion is scheduled for 1980 and will give a peak energy of over 30 GeV. On 27 June, with SLED cavities in action on 61 stations on the linac, a new energy record of 25.52 GeV was achieved.

Klystron efficiencies are currently near 50 % and it is believed that, with further development, this could be pushed as high as 70 %. It is here that news from Novosibirsk caused a stir at the Conference because they are working on a device, reported by I. Ya. Protopopov, which has achieved 80 % and which they expect to reach 90 %.

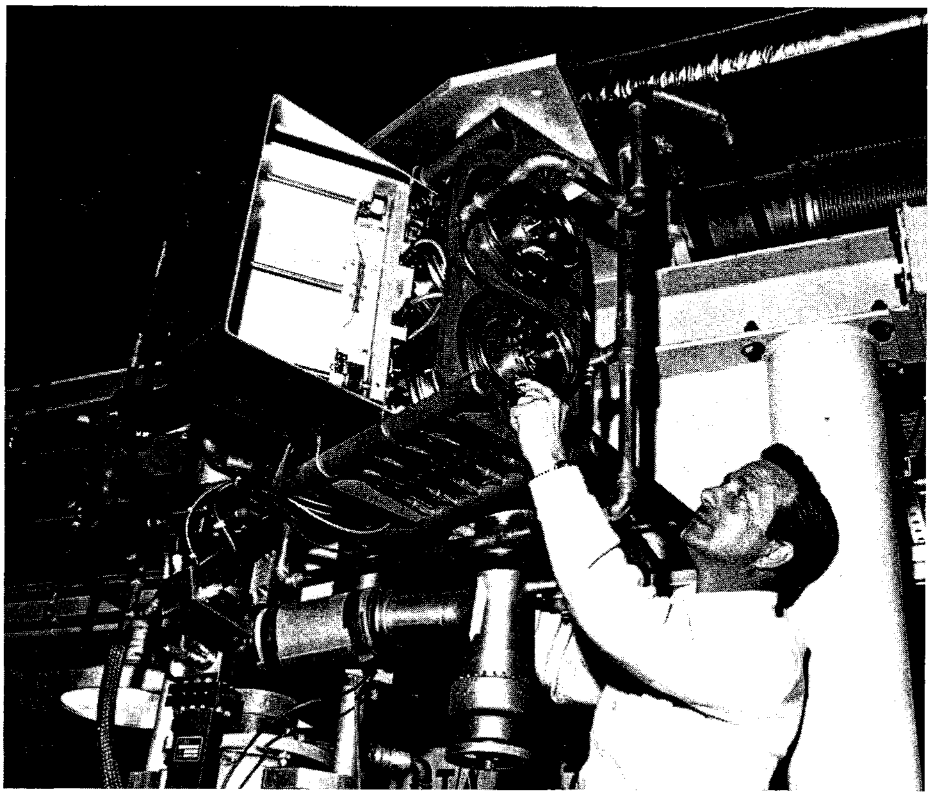
The new type of r.f. power amplifier is called the gyrocon. It involves the injection of an intense electron beam into a structure where alternating fields are applied to result in a spiralling electron beam travelling down a magnetic field with a conical lower pole. The spiral is flattened out at the bottom of the magnet and the beam runs through an unloaded waveguide. It is driven against an electric field so that it gives up almost all its energy before it is deposited on a collector.

Two gyrocons are in action at Novosibirsk. One is scheduled to feed ten cavities of the r.f. system on VEPP-4. It runs c.w. and is theoretically capable of 5 MW at 181 MHz. It has a 10 A electron beam injected at 500 kV and has given 1 MW with an efficiency of 81 %. The second gyrocon is a large device designed for 100 MW pulsed (pulses of 10 μs per s) at 430 MHz using a 70 A electron beam at 15 MeV. It has so far performed with 40 A beams at 1.3 MeV and has given 40 MW pulses.

Permanent quadrupoles

Another interesting technical novelty on a very different scale from the big gyrocons was reported by Don Swenson from Los Alamos. They have produced some tiny permanent magnet quadrupoles while working on the PIGMI (PIon Generator for Medical Irradiations) project — an attempt to determine an optimum accelerator system for medical applications of pions. A proton linac was recognized as potentially the best choice in an investigation chaired by John Blewett at Stanford in the Summer of 1975, though electron linacs were then recommended as being more technically developed. The Los Alamos work, supported by the National Cancer Institute, aims to realize the proton potential.

The present scheme involves a 650 MeV, 100 μA linac operating at 450 and 1350 MHz. Such high frequencies are an innovation which involves higher field gradients. Alternating phase focusing structure is under study for the injection end and would allow injection at the low energy of 250 MeV. For the higher energy end the 'disk and washer' structure, proposed by V.G. Andreev of the



Adjustments to a SLED cavity on the SLAC electron linac. These cavities are one technique for solving the r.f. power problem by increasing the peak energy at the cost of pulse length. On 27 June SLED cavities took the linac energy to 25 GeV.

(Photo Stanford)

The Novosibirsk team waxed lyrical during the reception given at the Conference. A schematic translation is given below. The 40 degrees refers to the reading on a bottle of vodka, which was not without influence in the writing of the poem. The 40 below refers to the temperature.

В СИБИРИ МНОГО МЕСТА

Когда и в мире
    и в науке тесно
Проекты на масштабы
    ориентированы
У нас в Сибири очень
    много места
К тому же охлажденье -
    - гарантировано .

В кругу медведей
    и в тайге без края
Среди снегов
    и голубого льда
И минус 40 иногда
    бывает
И 40 - плюс
    - с гарантией всегда .

Siberia — land of plenty

The population boom,
And the lack of adequate room,
To build big science machines,
Make Siberia's open space,
The ideal place,
To cool one's particle beams.

In the land of the bear,
And the limitless taiga,
Amidst the icy wastes and the snow
Where the physicist sees
His proof at 40 degrees
And sometimes at 40 below.

Radiotechnical Institute, looks promising since it achieves excellent coupling and good beam loading characteristics.

The new quadrupoles have become feasible following the considerable advances in permanent magnet materials (rare earths plus cobalt) in recent years. Using samarium-cobalt, tiny permanent quadrupoles which fit easily into a hand, have been made of four disks of this material magnetised across the diameter and set in a soft iron yoke. They have an aperture of 12 mm diameter, give gradients of 1.1 T/cm, can withstand high radiation and can be directly copper plated to provide drift tubes. Such quadrupoles will be used in a first section of PIGMI to be built at Los Alamos.

Fission and fusion

Practical applications are not so prominent at the international Conferences, which tend to be more 'academic' than their national counterparts. There were nevertheless talks on accelerators in medicine by I.V. Chuvilo and on accelerators in energy generation — both fission and fusion varieties.

S.O. Schriber reported work at Chalk River, Canada, on accelerator based spallation breeding of fuel for fission reactors to ensure the supply of fissile material for centuries to come. They are considering a high current (say 300 mA) linac with energy 1 to 2 GeV, to bombard a target / breeder assembly giving high neutron fluxes for uranium and thorium conversion. The design thinking has a 'son of ING' look about it, coming in the wake of the Chalk River Intense Neutron Generator project. Schriber maintained that such a system could be economically competitive by the end of the century and his talk certainly stimulated a lot of discussion.

Heavy ion accelerators in inertial fusion has become a headline topic in the accelerator world during the past year (see for example the April issue page 97). Two leading USA proponents, Dennis Keefe and Ron Martin, described possible systems at the Conference. The American investment in the necessary studies is beginning to take on significant proportions. At present, for Fiscal Year 1978, ERDA is assigning $3.5 million — 3 million from Laser Fusion resources and 0.5 million from the High Energy and Nuclear Research resources. (The former ERDA Division of Physical Research has recently been split into Basic Energy Science and High Energy and Nuclear Research sections.) About $6 million could be used in FY78 and, for FY79, $10 million is projected.

This money will be spread among the Laboratories active on this topic — Argonne, Berkeley and Brookhaven. The aim is to evolve a proposal for a Heavy Ion Demonstration Experiment (HIDE) by about 1980 so as to establish the feasibility of the technique before 1985. In 1985 it is the tentative intention to take a decision on which technology for inertial fusion to pursue in the USA.

The topic has spilled across the Atlantic and a Euratom Liaison Group is looking at the potential. Kjell Johnsen and Kees Zilverschoon at CERN, Marshall King at Rutherford and Guy von Dardel in Sweden are taking an active interest.

Information from experiments is needed before a selection between the different possible schemes is made and relevant data is beginning to be accumulated. Al Maschke at Brookhaven gathered some encouraging measurements on bunch compression (see April issue page 97), which is important since the deuterium-tritium pellets have to be hit by ion pulses only a few nanoseconds long. Jose Alonso, Bob Force, Marsh Tekawa and Hermann Grunder collected some data on charge exchange cross-sections during the acceleration of partially stripped ions in the Berkeley Bevalac, which is important since ions changing charge during acceleration will be lost to the beam. They tried neon and argon, Ne^9 and Ar^{17}, and observed exponential beam loss at rates in surprisingly good agreement with those calculated (based on theoretical ideas which did not previously command great confidence). Further experiments with other ions are planned.

No-one doubts that there are very severe problems in applying accelerators in such ambitious energy production schemes. But there is also a confidence that accelerator technology is amongst the most thoroughly mastered in the world. The Serpukhov Conference was a demonstration that such confidence is built on many years of experience and achievement.

Around the Laboratories

Components for the Spallation Neutron Source, which was authorized by the UK government only on 20 June, are already arriving at the Rutherford Laboratory site. An energy storage choke, which was previously in operation on the NINA electron synchrotron at Daresbury, rolled through the gates on 21 July.

(Photo Rutherford)

RUTHERFORD
Go ahead for neutron source

On 20 June there was an official inauguration of the new high power laser facility at the Rutherford Laboratory. The day was made doubly joyful by the announcement from the UK Secretary of State for Education and Science, Rt. Hon. Shirley Williams, that the government has approved the construction of a facility to provide intense fluxes of neutrons. Neutron beams will be used for studying solid and liquid states with applications in physics, chemistry, biology and materials science.

This project, known as the Spallation Neutron Source (SNS), was described in the May issue 1976. It involves an 800 MeV proton synchrotron able to provide beams of 2.5×10^{13} per pulse at a repetition rate of 53 Hz. The protons will be directed into a heavy target to produce neutrons by spallation. Moderators and reflectors around the target will slow the neutrons to thermal energies providing fluxes ten to a hundred times higher (over 10^{16} per cm^2 per s) than are available from the present high flux reactors such as that at the Institut Laue-Langevin in Grenoble.

The UK participates with France and Germany in the operation and exploitation of the Grenoble reactor and it is hoped that there will be international participation in the SNS project.

The SNS will succeed the Nimrod proton synchrotron which has been in operation for high energy physics since 1963 and is scheduled to be closed down next year. By using Nimrod components, including the new 70 MeV injector, buildings etc..., the cost of the new project can be held down to £8 million, plus £3 million for the research equipment. It is hoped to begin experiments before the end of 1982.

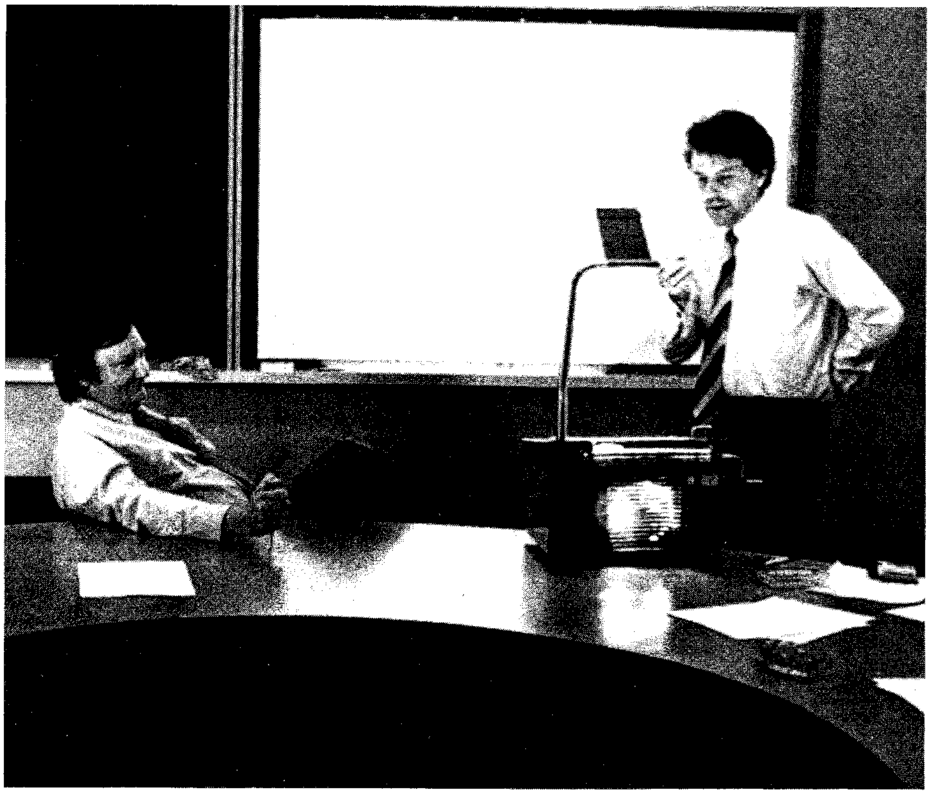
TRIUMF
Topping 100 μA

TRIUMF passed its graduating test as a meson factory with flying colours on 29 July when the design aim of 100 μA at 500 MeV was achieved for the first time. Under the magic fingers of Gerardo Dutto, who has co-ordinated the efforts of the various Groups towards this goal over the past two years, currents over 100 μA were run for forty-five minutes, including a short period at 114 μA.

These runs were made possible the previous week when the cooling capacity of the temporary beamstop was increased to cope with a beam power of 50 kW. (The stop had originally been designed for 10 μA although it had been found possible to run it at 30 μA continuously.)

The only retuning required while raising the current was in the ion source and injection line, due to changes in the source emittance. (The cyclotron is supplied from an external 'Ehlers' d.c. negative hydrogen ion source through a 35 m long electrostatically focused 300 keV injection line.) To study the tuning at high currents while avoiding radiation and heating problems, a variable duty factor pulser was used with great success. It enabled the macrostructure duty factor (otherwise 100 %) to be adjusted anywhere between 99.9 % and 1 %, while reading the beam current in the injection and external lines by non-intercepting monitors.

To achieve 100 μA at 500 MeV the ion source was required to deliver 500 μA d.c., of which 350 μA (bunched) was injected into the cyclotron. More time for tuning should raise the injection line transmission from 70 % to 90 %, (as for currents of up to 10 μA) and reduce the current



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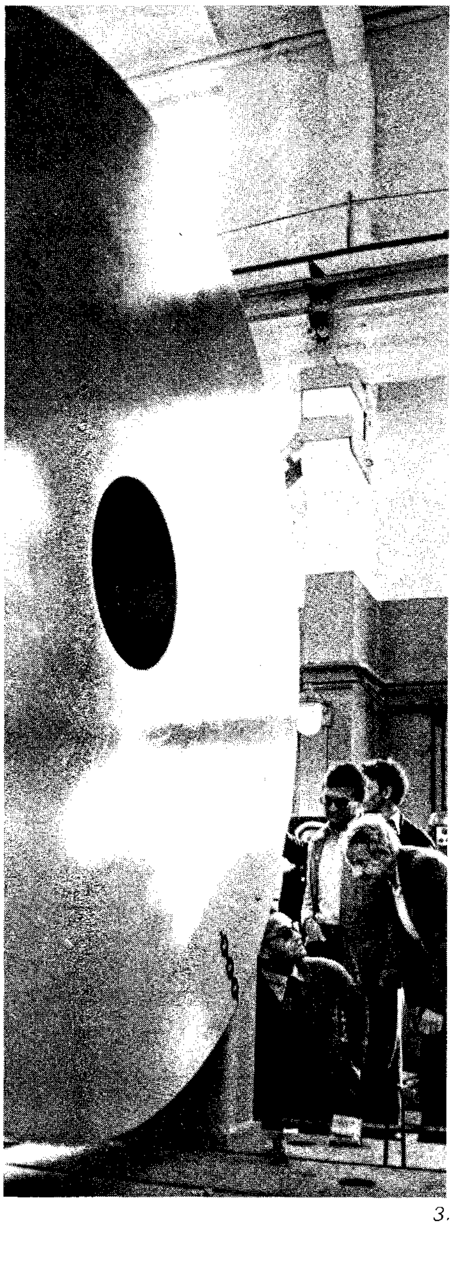


3.

Preparations at the Joint Institute for Nuclear Research, Dubna, for a muon scattering experiment in the CERN SPS North Area:
1. One of the regular meetings at Dubna to review progress — Carlo Rubbia, who leads the collaboration, is on the left and I. Golutvin is giving a progress report.
2. Participants at the meeting watch the start of fabrication of one of the toroidal magnet modules in the Dubna workshop.
3. I. Savin shows a completed module. These modules, with a total weight of 1640 tons, are being supplied by Dubna for the experiment.

(Photos Yu. Tumanov, Dubna)

required from the ion source to 400 μA d.c.

A 500 MeV beam was first extracted from the TRIUMF cyclotron in December 1974 (see January issue 1975). During 1975 the current was kept to 300 nA while the two external proton lines and the secondary pion and muon lines were constructed and surrounded by a limited amount of shielding. During the same year the previously untried concept of simultaneously extracting two proton beams of independently variable energy (180 to 520 MeV) and intensity (split ratio 1/1 to 1/5000) was successfully demonstrated.

Early in 1976 the removal of vacuum windows and improved beamline tunes allowed the current to be raised to 1 μA. At the same time, the Canadian government announced that extra capital funds would be provided to permit further development (see March issue 1976), including 100 μA operation and the provision of additional beam lines, a thermal neutron source and a medium resolution spectrometer for light nuclei.

By Autumn 1976 extra shielding allowed one 10 μA shift to be scheduled each week. In November a high current test achieved 30 μA for several hours, as desired, and reached a maximum of 50 μA (see December issue 1976). During 1977 the machine has been operated regularly at 3 μA and 10 μA, the mixture being about 50 : 50 at present. The caution with which the current is being increased is not just a matter of limitations imposed by hardware but is to avoid any part of the machine becoming too active to work on before its operation is fully understood.

15 to 20 % of the beam is lost in the cyclotron, mostly at high energy, due to electric stripping of the H^- ions with the resultant protons passing out through the vacuum tank walls. Considerable success has been achieved in reducing the radiation field in the tank

DASP, the double arm spectrometer detector at one of the intersection regions on the DORIS electron-positron storage rings at DESY, photographed when the two arms were pulled back. The central section, which is receiving attention, and the counters, which are visible on the right and on the left, are part of the inner detector elements. DASP was the source of the F meson discovery.

(Photo DESY)

due to this loss. Firstly, beam scrapers have been mounted above and below the beam plane so as to direct any beam lost vertically to localized spots on the wall. Secondly, the space between the tank walls and the magnet yoke has been filled with graphite blocks surrounded by boriated gypsum sheets; this has given a factor five improvement in residual adiation at the centre of the tank and ten at the wall. Thirdly, 5 cm thick lead shields are remotely installed inside the tank wall during shutdowns; these give a further factor two in the middle and five at the wall. As a result, after six months' running at 3 and 10 µA, the activity is still only 5 mrem/hr over most of the 17 m diameter tank and 10 mrem/hr at the wall.

The first regular operation at 100 µA, for say one shift / week, is scheduled for the beginning of 1978. To achieve this the permanent beam dump, thermal neutron source, and beam line extension to it must be completed and commissioned. To make this possible the high intensity beam line and the Meson Experimental Hall will be closed in September for three months. In addition, the front ends of two additional lines (one for protons and one for pions) will be installed on the high intensity line.

There are three longer term plans. Next year it is planned to introduce third harmonic r.f. into the cavity resonators to 'flat top' the r.f. wave. This will improve regular operation and make it possible to extract separate turns with an energy spread of 0.1 MeV rather than the present 1.5 MeV. Secondly, the possibility of extracting beams at lower energies (70–180 MeV) is being studied and the feasibility of extracting a 75 MeV beam for isotope production has recently been demonstrated experimentally. Thirdly, it is planned to raise the current to 300 µA, extracting at 450 MeV to avoid electric stripping losses.

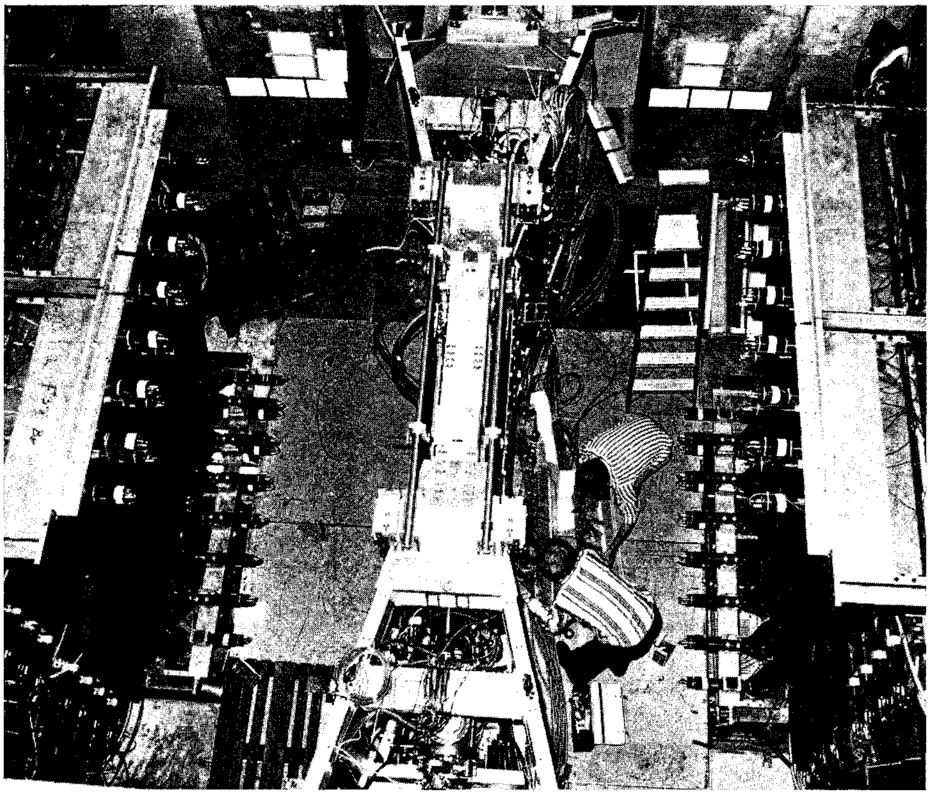
The 114 µA is not the only new record. On 20 June the polarized ion source gave a current of 960 nA; the external beam current at 500 MeV was 120 nA with over 70% polarization. The improvement is attributed to cleaning and adjustment of the matching section between source and acceleration tube. The source is of the Lamb shift type with a Sona zero field-crossing region. The design aim was 60 nA.

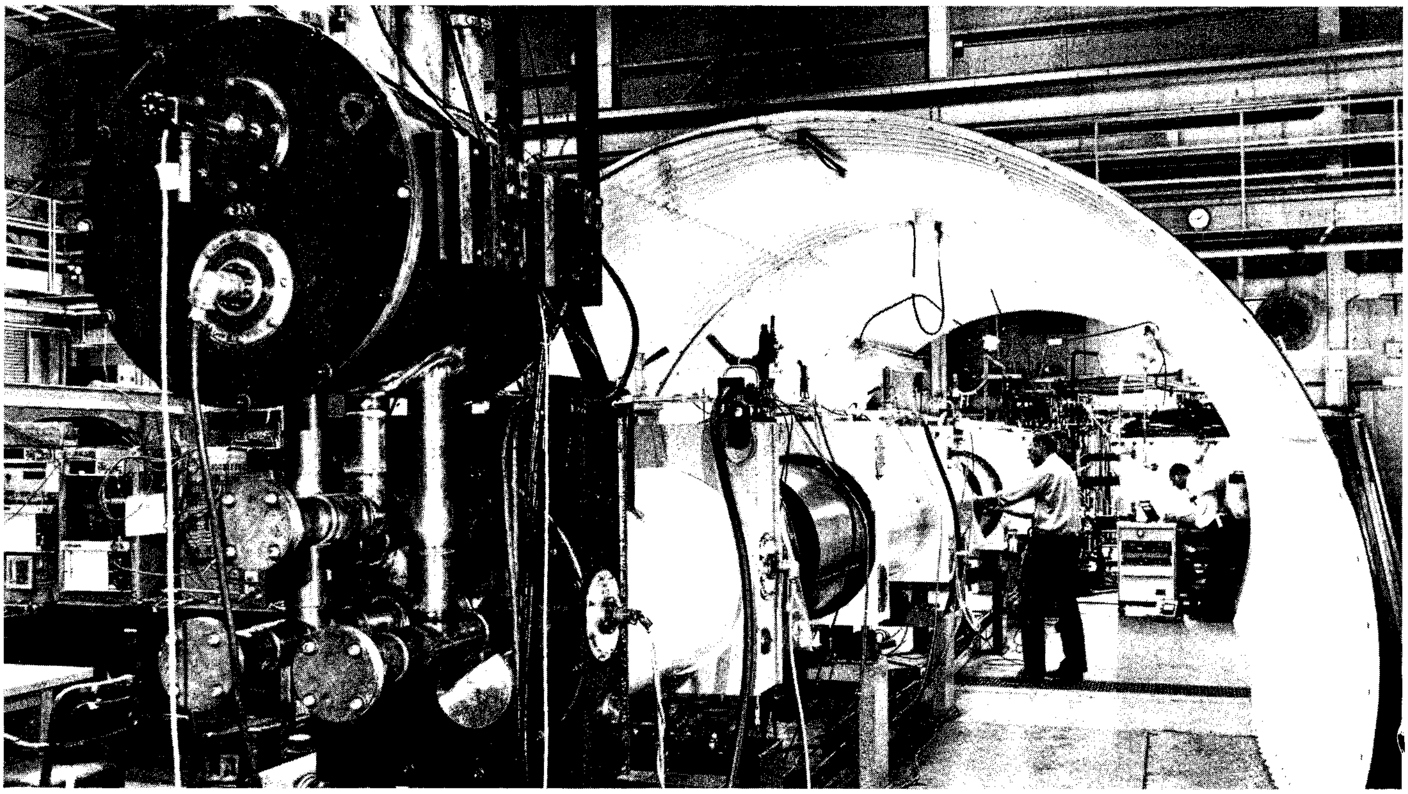
DESY The evidence for the F meson

The discovery of the J/psi family of particles added a fourth type of quark, called the charm quark c, to the familiar three quarks u, d, and s. Since the c quark should be able to combine with any of the three others, an immediate consequence was the existence of particles made of charm and non-charm quarks. Mesons called D made of charm quark and non-strange quarks ($c\bar{u}$ or $c\bar{d}$), as well as baryons carrying charm, have already been found. Mesons consisting of a charm quark and a strange quark ($c\bar{s}$) called F mesons were still at large.

A team from Aachen / DESY / Hamburg / Max-Planck-Institute, Munich / Tokyo reported evidence for the elusive F meson at the Budapest Conference. The discovery was made with data collected over several months in the double arm spectrometer DASP on the electron-positron storage rings DORIS.

The way the F meson was found amongst the massive background of other events from electron-positron annihilation resembles feats of archeology. The strategy was as follows: if the F is not much heavier than the D, it will decay only weakly and will show up mainly in states containing a strange quark and its antiquark ($s\bar{s}$).





Thus, the final states will contain a pair of kaons or, for example, an eta meson which has a sizable $s\bar{s}$ component. A likely F decay mode is therefore $F^+ \rightarrow \pi^+\eta$.

There was a good chance that F mesons have production features like D's, that is that near threshold the F meson appears mainly associated with its first excited state F*. The F* was expected to be only slightly heavier than the F and it therefore would decay into the F by emitting a photon. If the F* is almost at rest the energy of the photon is of the order of the (F* - F) mass difference and therefore small. The recipe to look for F mesons was therefore to search for an eta meson associated with a low energy photon.

Having decided how to look, the next question was where to look. The most promising place appeared to be the region just above the charm threshold at energies 4 to 4.5 GeV where the total cross-section exhibits several spikes, for example at 4.4 GeV.

In scanning the energy region from 4 to 5 GeV, DASP found about sixty events at 4.4 GeV which had an eta together with a low energy photon in a nonmagnetic part of the detector. No such signal was observed at other energies. The eta-photon events had the taste of the F meson and a frantic search was made for other events which, besides eta and a low energetic photon, had a pion detected in the magnetic spectrometer. Nineteen events were found, six of which fitted the FF* and F*F* hypotheses. Four of the events gave F and F* masses which were the same to within 40 MeV with no other events in the vicinity.

The mass values for F and F* are 2.03 $\pm$ 0.06 GeV and 2.14 $\pm$ 0.06 GeV. Hence F and F* are about one pion mass heavier than their charm non-strange counterparts D and D*.

BROOKHAVEN ISABELLE half-cell tests

A superconducting half-cell of the ISABELLE magnet lattice has been powered to full field. The assembly, erected in a mock-up tunnel section, consists of two prototype dipoles plus a quadrupole connected in series, both electrically and cryogenically, in a configuration simulating an element of the proposed proton storage rings.

Refrigeration, vacuum, and controls systems were all in action. The refrigeration is based on forced convection of high pressure (15 atm) supercritical helium gas. Prior to entering the string of magnets, the refrigerant is further cooled when it passes through a subcooler heat exchanger containing a bath of liquid helium at subatmospheric pressure. The bath is achieved by pumping on the helium vapour with an ejector nozzle of novel design. (The nozzle will be replaced by a turbocompressor system in the full-sized ISABELLE system.)

A vacuum of 6 $\times$ 10^{-12} torr was achieved after the initial bake-out using a combination of titanium sublimation pumps and vac-ion pumps and an aluminium vacuum chamber. (The ISABELLE design now calls for a stainless steel vacuum jacket.) The vacuum was much better than the ISABELLE design requirement of 3 $\times$ 10^{-11} torr. The main magnet power supply, as well as the supplies required for the various tuning windings in each of the magnets, were controlled by a PDP 11/10 computer system.

Of primary concern was a test of methods for 'quench' protection. The scheme employed in the half-cell uses the switching capabilities of silicon diodes to protect the other magnets when one of them quenches (fails to remain superconducting). One or more such diodes are connected across each magnet. If a magnet quenches, the induced voltage exceeds the diode forward bias voltage (which normally prevents any leakage current from flowing) and the main magnet series current (3300 A at the full excitation of 4 T) passes through that diode, bypassing the magnet.

The first quench occurred at a dipole bore field of 3.9 T (corresponding to 48 T/m in the quadrupole). With subsequent 'training', the dipole field reached approximately 4.3 T on the sixth and last quench initiated. This is close to the expected limit at the presently attainable temperature

The prototype half cell, two dipoles and a quadrupole, for the ISABELLE proton-proton storage rings at Brookhaven during successful tests.

(Photo Brookhaven)

(about 5.7 K at the magnet furthest downstream from the refrigerator), set by refrigerator capacity and the heat load in the connecting pipes between the magnets, which was larger than expected. During previous tests on the individual magnets both dipoles trained to 4.9 T, and the quadrupole to 71 T/m. After adjustments, the quench protection system performed entirely satisfactorily, confining the quench to the magnet which initiated it.

The next major step is the assembly of a full cell (four dipoles and two quadrupoles) from industrially produced magnets. Contracts for the four dipoles have been let.

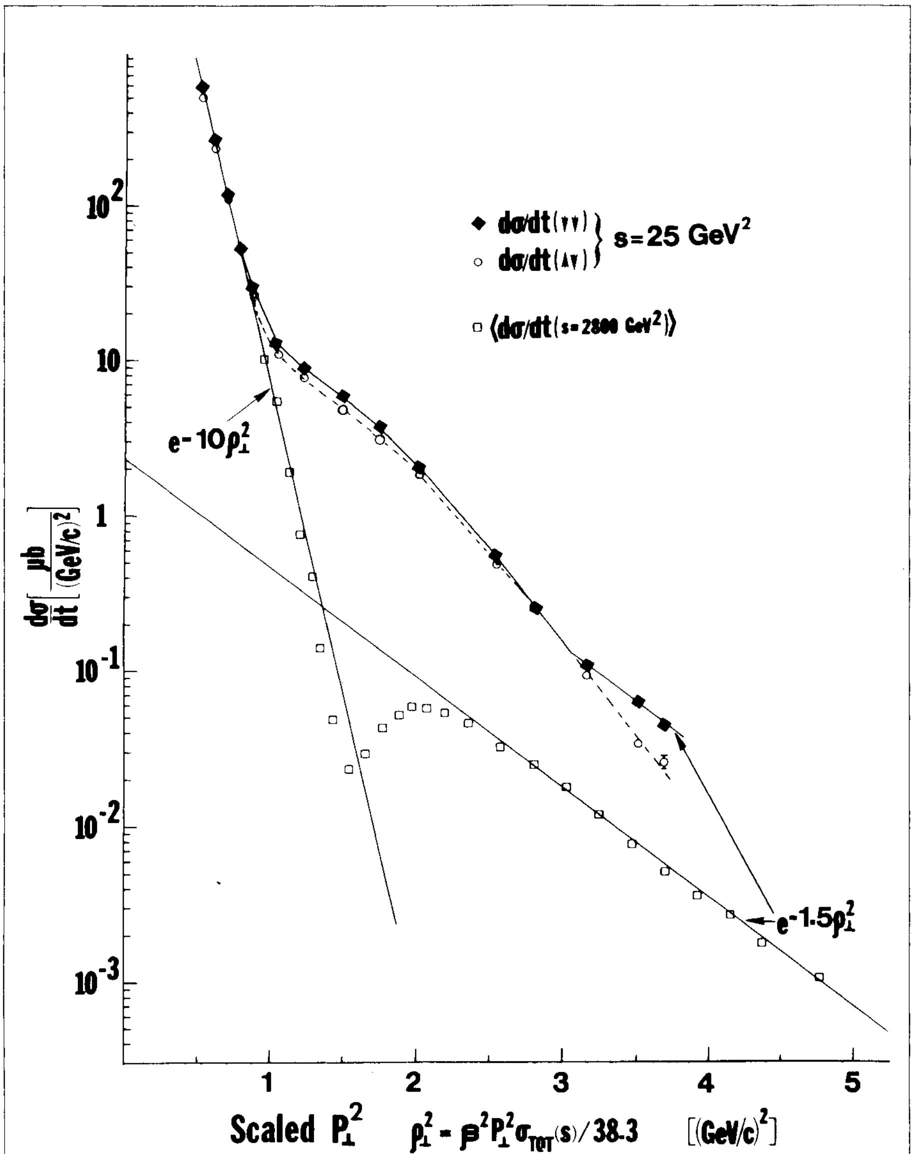
ARGONNE The influence of spin

A recent measurement of proton-proton elastic scattering at large momentum transfer indicates that 'hard' scattering occurs much more readily if the two protons are spinning in the same direction. The increased intensity and polarization of the proton beam from the Argonne ZGS (see June issue, page 193) allowed the first measurements of spin effects out to 4 $(GeV/c)^2$ and the data indicates that this region is strongly dominated by scattering when the beam and target proton spins are parallel.

The experiment was done by an Argonne / AUA / Copenhagen / Michigan / Oxford collaboration led by A.D. Krisch, which measured the cross-section for elastic scattering at large momentum transfer using the polarized proton beam and a polarized proton target. Both polarizations were oriented perpendicular to the horizontal scattering plane. The experimenters compared the scattering probabilities when the beam and target protons were both spinning in the same direction and when they were spinning in opposite directions. They found that the difference suddenly becomes very large near 4 $(GeV/c)^2$.

The experimenters interpret their data in terms of the several different transfer momentum components in proton-proton elastic scattering. In the forward direction, there is the diffraction peak which can be interpreted as the shadow scattering caused by inelastic processes. Its slope of 10 $(GeV/c)^2$ corresponds to the normal proton size of 1 fermi.

There is also a 'hard' component, which is presumably masked at small momentum transfer by the diffraction peak. At the energies investigated at the CERN ISR this hard component is very clearly seen beyond about 2.5 $(GeV/c)^2$. Just before this is the dramatic dip which looks much like a destructive interference between the two components. At ZGS energies the 'hard' component does not show itself



The probability for proton-proton elastic scattering plotted against a scaled momentum transfer at ZGS and ISR energies. The values with both protons spinning in the same direction (solid diamonds) and with the protons spinning in opposite directions (open circles) are shown. Note how parallel spins dominate at high momentum transfers. The ISR data (open squares) averages over the two cases.

until almost 4 $(GeV/c)^2$, since it is masked by the shoulder at medium momentum transfers. This medium component disappears with increasing energy and at Fermilab and SPS energies sinks below the dip. The hard component seen at the ISR has approximately the same scaled slope as the large momentum transfer parallel spin cross-section, seen at the ZGS.

This hard component was first seen in experiments at the ZGS and PS more than 10 years ago. It corresponds to scattering from a region or constituents about 1/3 of a fermi in radius, or 1/3 the size of the proton. Different evidence for constituents in the proton was later discovered in deep-inelastic electron-proton scattering experiments at SLAC and then in other lepton scattering experiments accumulating strong experimental evidence that the proton has some sort of substructure. There is a widespread belief in the quark-parton model for this substructure but there is a need for more direct experimental evidence on the exact nature of the constituents.

The new experiment seems to indicate that the hard scattering of the constituents rarely occurs unless the two protons are spinning in the same direction, and this simple and unexpected result might shed light on the nature of the constituents.

The experimenters plan to extend these measurements to larger momentum transfers to see if the antiparallel spin cross-section continues its trend of dropping rapidly below the parallel spin cross-section. This will require an even higher polarized beam intensity (as well as a long run) and the ZGS accelerator staff is trying to rise to the challenge.

FERMILAB
Polarized lambdas

Almost two years ago, the neutral hyperon group at Fermilab observed that lambda hyperons are produced polarized by 300 GeV protons interacting in nuclear targets. The polarization is 30% at a transverse momentum of 1.5 GeV/c. This was a major surprise — it had been thought that there should be many ways to make a lambda in a high energy interaction and that polarization effects, sometimes quite pronounced at much lower energy, would disappear. The large polarization indicates that the production of a lambda at high energy must be a fairly simple process.

The neutral hyperon collaboration (Wisconsin / Michigan / Rutgers) has proceeded along two paths with this result. One was to try to learn as much as possible about the polarization mechanism. So far, investigations of the polarization reveal remarkably little dependence on the incident energy, and the phenomenon appears to be quite widespread. Essentially the same lambda polarization was found at 24 GeV in data from the 1974 sigma zero lifetime experiment at the CERN PS. Furthermore, a recent result from the CERN 2 m bubble chamber shows that a 4 GeV negative kaon beam produces polarized lambdas in the target fragmentation region, with a transverse momentum dependence strikingly similar to the Fermilab result. A search is being made for the polarization of slow protons produced in an internal target at Fermilab by Indiana University and the protons do indeed appear to be polarized. In a run completed this July, the neutral hyperon group observed polarized lambdas produced in a hydrogen target, which excludes the possibility that the polarization is somehow related to the nuclear target.

The second path opened by the discovery is that polarized lambda beams can be used as a tool to study spin-dependent phenomena. In February the neutral hyperon group used the world's first polarized lambda beam to make a precise measurement of the lambda magnetic moment. The magnetic moment of a particle is a static property (much like charge, spin or mass) and a theory such as the quark model must ultimately predict the moment in terms of masses and spins. For example, confidence in the theory of quantum electrodynamics is so strong partly because it can predict the value of the electron or muon magnetic moment to many decimal places.

At present, the moments of the baryon family of particles are known to precisions varying from 10^{-6} (proton) to not at all (ksi zero). Although no strong interaction theory is sufficiently developed to predict the lambda moment much more precisely than 10%, the high energy polarized lambda beam allowed the moment to be measured to a 1% accuracy.

A 400 GeV proton beam interacted in a beryllium target to produce the polarized lambdas. The neutral beam was defined by a collimator with a 4 mm diameter hole embedded in a magnet. The magnetic moment was measured by observing the direction of polarization of the lambdas after traversal of the field in the magnet. The moment is calculated from the amount of spin rotation divided by the field strength, and precision is obtained by rotating the spins through as large an angle as possible (150° with the magnet at full field). A downstream spectrometer observed the decay into a proton and negative pion and reconstruction of the charged tracks gave the direction that the proton was emitted, which tagged the direction of the lambda spin. With two million observed lambdas, the polarization direction was obtained with an error of about 1.5°.

The scale of this experiment should be compared with the very difficult previous measurement when polarized lambdas were drawn from the reaction $\pi^- p \rightarrow \Delta K^\circ$ at 1 GeV. A CERN / Ankara / Lausanne / Munich / Rome group

Two historic events in the life of CERN during this Summer —
1. The 600 MeV synchro-cyclotron celebrated the 20th anniversary of first beam which was achieved on 1 August 1957. The first of CERN's accelerators, it has had a major face-lift in recent years (including the installation of the rotary condenser seen in the left foreground of the picture). The SC celebrated its anniversary in fine style by sustaining a steady beam of 4 μA for the first time.

(Photo CERN 15.6.75)

2. The CERN 2 m bubble chamber has been closed down at the end of June for reasons of economy. The chamber, shown here with its two magnet yoke halves rolled back during maintenance, had taken 40 million pictures since it first came into operation in December 1964. It has been a source of data for some fifty research centres who drew from it some 600 publications.

(Photo CERN 76.3.70)

placed a target and detector in a magnet that was energized during the beam spill to give a field of up to 20 T. The lambda was required to travel 11 cm to reach the detector and the average precession angle was 20°. At Fermilab energies, it was possible to use a large magnet to rotate the spins because of the long lifetime of the high energy lambdas (typically 10 m).

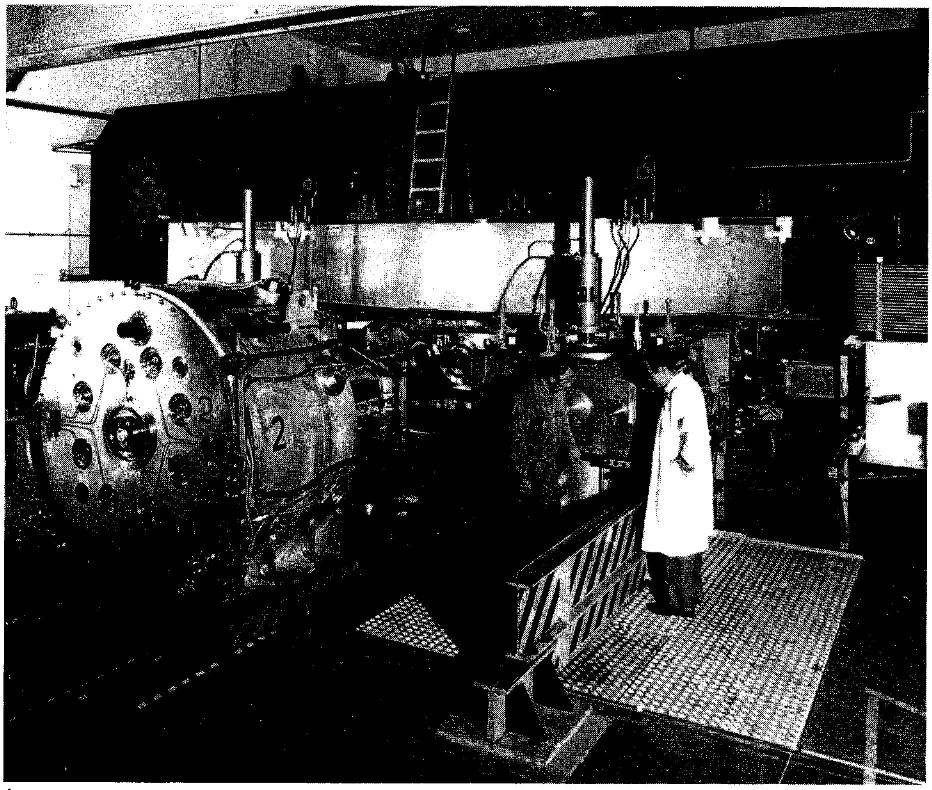
Other experiments planned for the beam include a search for polarization of two other neutral particles which are produced a hundred times less frequently than the lambda — the antilambda and the ksi zero. If the ksi zero is polarized, the group will make the first measurement of its magnetic moment.

First Doubler quadrupole

Progress on the Fermilab Energy Doubler / Saver recently led to the test of one of the most powerful superconducting quadrupoles ever developed. The quadrupole team, led by George Kalbfleisch and John O'Meara, has recently tested the quadrupole to gradients of nearly 100 T/m.

Using the same lattice as for the Main Ring, the Doubler requires 216 quads (180 of a normal length and 36 special ones). The prototype design consists of a three shell coil structure with an inner bore of 8.3 cm, a length of 1.4 m and a field gradient of about 100 T/m. The cryostat design closely follows that for the Doubler dipoles, except that a number of specialized functions will be provided (for correction coils, power leads, safety leads, warm-cold junctions, vacuum pumps, instrumentation leads, clearing electrodes and beam position monitors).

A programme for producing eight quadrupoles is under way, and vertical dewar testing of the first of these, QA-1, was done on 1 June. It was trained to 98 % of the current carrying



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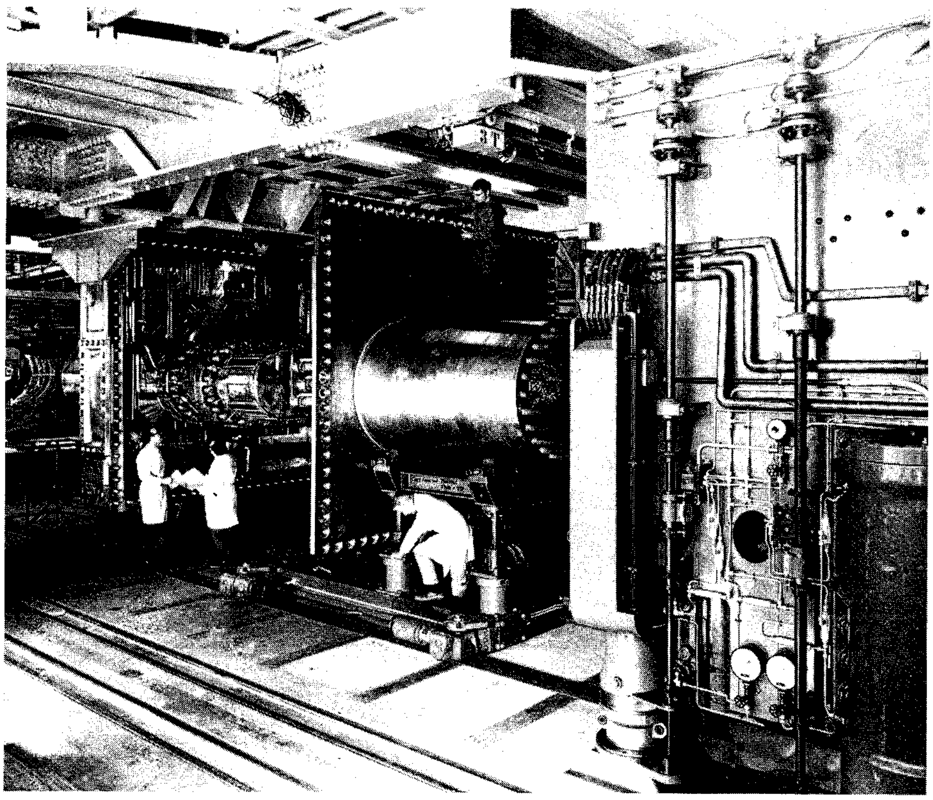
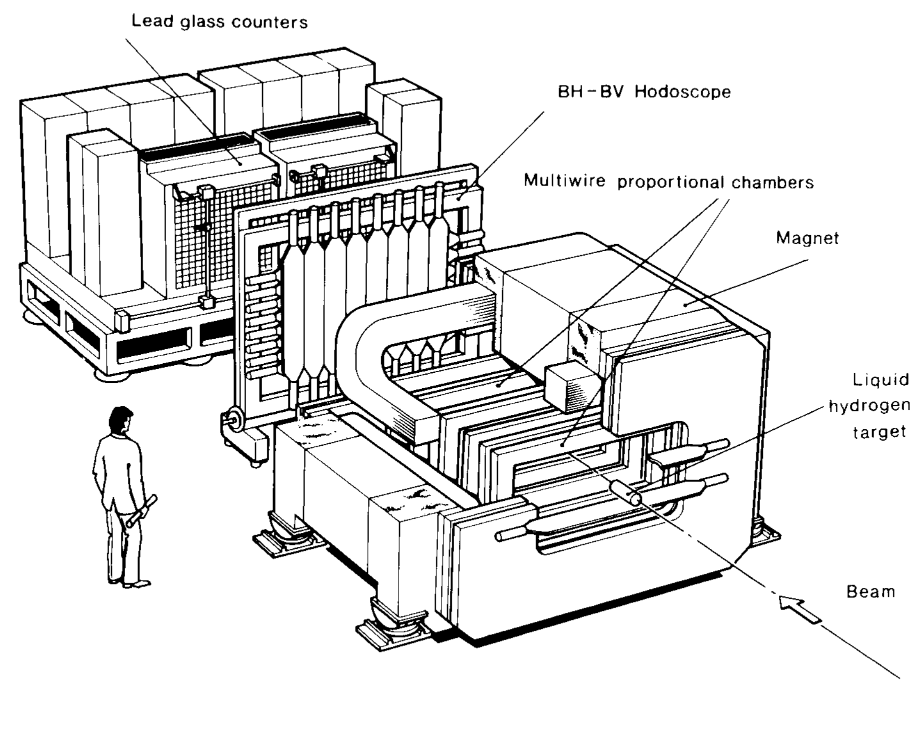


2.

Schematic view of the LAMP apparatus at Daresbury. The aim was to study the photoproduction of multi-pion states in the photon energy range from 1 to 5 GeV. 15 million events were collected over 15 months of running time.



limit of the cable in four quenches and a current of 4.93 kA was achieved. The design gradient is 20 T/m/kA corresponding to a gradient of 98 T/m for the 4.93 kA current. This meets the requirement to focus 1000 GeV protons and the gradient measured in the test corresponds almost exactly to the design value.

Vertical dewar testing of QA-2 and QA-3 is now in progress together with preparations for precision field measurements, using a harmonic coil. These multipole measurements for the first three quadrupoles are scheduled for completion in August. After this the quadrupoles will begin to be 'canned' into their cryostats and the first of them should be finished in September. All eight prototypes should be ready by the end of the year and four of them will be tested, along with a string of sixteen Energy Doubler dipoles, later this year.

DARESBURY 15 million events from LAMP 2

The 5 GeV electron synchrotron, NINA, at Daresbury was shut down on 1 April but the data obtained during its last year of running should continue to provide physics information for the next few years. The emphasis towards the end was to provide long periods of running for three remaining high energy physics facilities, thus allowing high statistics experiments to be carried out.

One of these three, the LAMP 2 experiment, collected a total of 15 million events in a period of running spread over 15 months. Its aim was to study the photoproduction of multi-pion final states in the photon energy range 1 to 5 GeV. A high resolution (about 7 MeV) tagged photon beam was used in conjunction with a large aperture spectrometer consisting of an array of proportional chambers in a wide gap magnet. A wall of lead glass counters, with 480 channels, detected photons and electrons thus enabling a complete reconstruction of final states consisting of both charged and neutral pions.

The vector momentum of charged particles detected by the proportional chambers was obtained using the techniques of quintic spline and significant variables, which were developed at CERN and subsequently at Daresbury to meet the needs of this experiment.

The total data will allow the observation and measurement of many photoproduction final states which have hitherto been undetected.

CERN News from experiments

Some results from experiments in different fields using different CERN machines — SC, PS, ISR, SPS.

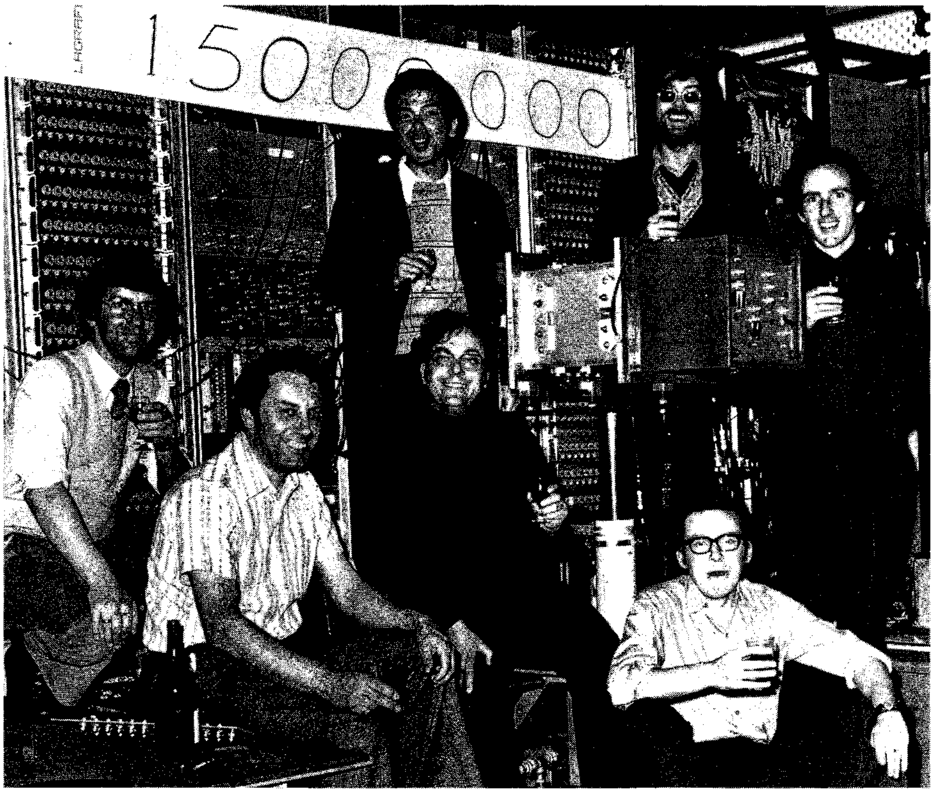
Direct evidence of nuclear pions

A team from the University of Louvain has successfully completed a novel nuclear physics experiment, looking for the pions which we believe are exchanged among the protons and neutrons in the atomic nucleus and are instrumental in holding the nucleus together. The presence of these virtual pions can be seen indirectly by their effect on nuclear properties such as the magnetic moment. The idea of the Louvain experiment was to spot nuclear positive pions directly via their annihilation with negative pions giving two photons.

A low energy beam of negative pions was produced at the CERN 600 MeV synchro-cyclotron. Intensities of over a million pions per second were achieved and it was the fine performance of the SC in July (a stable proton beam of 4 μA with a 60% duty cycle) which made it possible to detect the rare annihilation events (five to ten events per hour). The pions were stopped in carbon or beryllium targets and the stopped negative pions could go into orbit around the positive nuclei. The orbits of the heavier pions are much closer to the nucleus than those of electrons and occasionally a negative pion could encounter a positive pion within the nucleus and annihilate to give two photons.

The target was surrounded by lead glass detectors to measure the photons and the main experimental problem was to distinguish the good events from the copious background due to neutral pion decay into two photons. This was done by selecting very low energy incoming pions and by measuring the photon directions.

Calculations on the rate at which these pion annihilations can be expected have been done in the CERN



The combination of the end of an accelerator's working life and of a long and complicated experiment arouses mixed feelings. A few of the Daresbury physicists involved in the LAMP experiment found a way to simultaneously celebrate and drown their sorrows. Left to right: D.T. Williams, R. Marshall, L.C.Y. Lee (standing), D.P. Barber, J.B. Dainton (seated), P.N. Johnson and J.C. Thompson.

Theory Division. A first look at the experimental results indicates that the rate is somewhat higher than a rough estimate on the basis of a simple model of pion exchange in the nucleus. This first direct information on the pion content in the nucleus hints, therefore, at a larger number than expected from a simple exchange mechanism. One possibility for such an increase is sometimes referred to as pion condensation.

New information on old mesons

Although often overshadowed these days by developments in the 'new physics' of charm, there is still a lot of work to be done before the spectroscopy of the 'old' mesons is completely unravelled. CERN experiments have recently made significant contributions to the picture of pre-charm mesons.

Some of the particle families corresponding to the SU3/quark ideas are well studied but others are poorly known. Among the latter are the nonets of mesons which have unit spin and positive parity — including the A_1 and the Q mesons. Experimental evidence for these mesons has fluctuated in conviction over the years. The first signs of the A_1 date from 1963 but the observations are complicated by diffractive excitation effects, sometimes known as the 'Deck Effect'. This occurs when an exchanged particle is scattered quasi-elastically and emerges from the reaction as a real particle. Because of kinematics, this produces a fairly sharp enhancement in a small region of effective mass and can mask any real resonance which might be present.

Recent CERN experiments have avoided this experimental complication by looking for mesons produced 'backwards'. The disadvantage is that the production rate is greatly reduced and high statistics experiments were necessary. Also the underlying theoretical interpretation of the interaction was not as well developed.

An Amsterdam / CERN / Nijmegen / Oxford collaboration used the 2 m bubble chamber to take over three million pictures to study medium-energy resonance production. In an investigation of the three pion mass spectrum for the reaction $K^-p \longrightarrow \Sigma^-\pi^+\pi^+\pi^-$ at 4 GeV/c under such 'backward production' conditions, they have clear evidence for an A_1 type resonance since they were able to establish the spin and parity (1^+). They set the mass at about 1050 MeV with a width of about 200 MeV. The collaboration also looked for the counterpart Q meson, carrying strangeness, and come up with an enhancement at a mass of 1280 MeV which decays preferentially into a kaon and a rho.

A CERN / Collège de France / Ecole Polytechnique / Orsay collaboration using the Omega spectrometer confirmed the A_1 result looking at the reaction $\pi^-p \rightarrow p\,\pi^-\pi^+\pi^-$ at 9 and 12 GeV. They selected fast protons coming out forwards from the reaction again to remove the background effects and saw the bump at 1050 MeV.

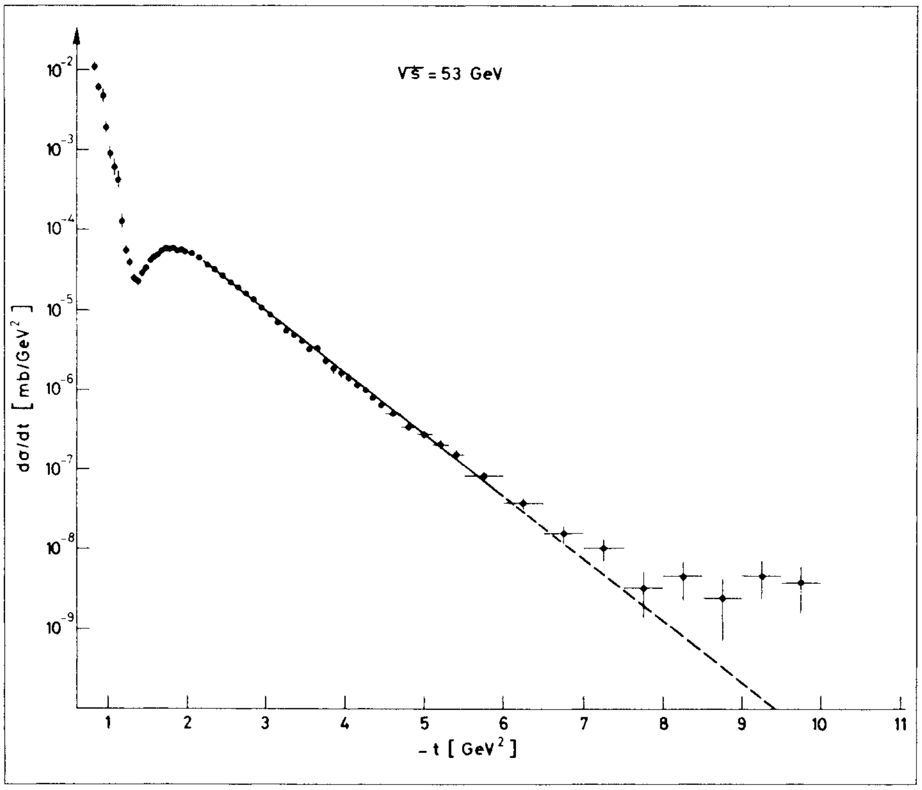
To definitely establish that an enhancement is indeed a resonance, it must be shown that the wave function undergoes a 90° phase change at the 'resonant' energy. A CERN/ETH Zurich/ London / Milan group looked at the reaction $\pi^-A \rightarrow \pi^-\pi^-\pi^+A$, where A is a nucleus and the three final pions are coherent, at a number of energies. In the analysis of the three final pions they saw clear evidence for the necessary phase variation in the A_1 mass region. Taken together, these three experiments show that the A_1 is very much alive and well.

Beyond the dip

One of the major discoveries at the CERN Intersecting Storage Rings was the 'diffraction-like' dip in the differential cross-section for elastic proton-proton scattering. This is a consequence of the apparent size the protons present, one to the other, and of their relative opacity. Since these first results, experiments have strived to look at elastic scatterings involving larger and larger momentum transfers to see if there are any additional dips in the cross-section.

A CERN / Hamburg / Heidelberg / LAPP / Vienna collaboration has measured proton-proton elastic cross-sections at the ISR out to very large momentum transfers (t, the momentum transfer squared, going up now to -10 GeV^2) at a centre-of-mass energy of 53 GeV. They find no further dips in the cross-section but a new type of behaviour has been seen.

At these high momentum transfers, the number of events goes down about 10^{10} times compared with the levels seen in the forward direction and careful work is required to separate the



Differential cross-section for proton-proton scattering as measured by the CERN/Hamburg/ Heidelberg / LAPP / Vienna collaboration with the Split Field Magnet detection system on the CERN ISR at a centre-of-mass energy of 53 GeV. After the first diffraction-like dip at a squared momentum transfer, t, of 1.34 GeV², the cross-section rises again for a short time, but then decreases much more slowly than expected. At a t of 6.5 GeV², the cross-section suddenly flattens out.

good events from background. Using the Split Field Magnet detection system, the collaboration finds that after the first diffraction-type minimum (at $t = -1.34\,GeV^2$) and subsequent maximum (at $t = -1.8\,GeV^2$) the differential cross-section drops off again, but much more slowly than expected, going as $e^{1.8t}$. This behaviour continues out to $t = -6.5\ GeV^2$, where the cross-section suddenly flattens and goes like $e^{0.9t}$ out to $t = -10\,GeV^2$.

This change is not expected from a geometrical picture of elastic scattering governed by a proton 'shape'. What is being seen may instead reflect the internal structure of the proton with its valence quarks and gluons.

Progress, real and imaginary

Although data on total cross-sections at very high energy seems to be the thing which grips physicists most tightly to their seats, this is not the whole picture of what is happening in scattering experiments. Measurement of other parameters, notably the ratio of the real to the imaginary part of the scattering amplitude, gives further insight into the mechanisms which are contributing to the scattering behaviour.

Using special calculational techniques (dispersion relations), the behaviour of the total cross-section can be extrapolated over a much wider energy range if this ratio is known than is possible from the total cross-section data alone. However, the ratio is not easy to measure and usually has to be determined through the delicate interference effects between strong interactions and Coulomb forces.

While the ratio for proton-proton interactions has been measured up to very high energies at the ISR, comparable data did not exist for pion-proton scattering beyond 60 GeV. Only some preliminary data existed up to 150 GeV, while total cross-section measurements extended to 280 GeV. Now a Clermont-Ferrand / Leningrad / Lyon / Uppsala collaboration at the SPS has obtained its first results in forward pion-proton scattering at 100 and 140 GeV. The group finds that the ratio changes sign, going from negative to positive values at about 100 GeV.

Similar behaviour has been seen in proton-proton scattering at the ISR and at Fermilab but the ratio for proton-proton scattering does not change sign until 270 GeV. These results together could show that the much-sought 'asymptotic region', where the total cross-section increases slowly but smoothly with energy, sets in much earlier for pion-proton than for proton-proton interactions.

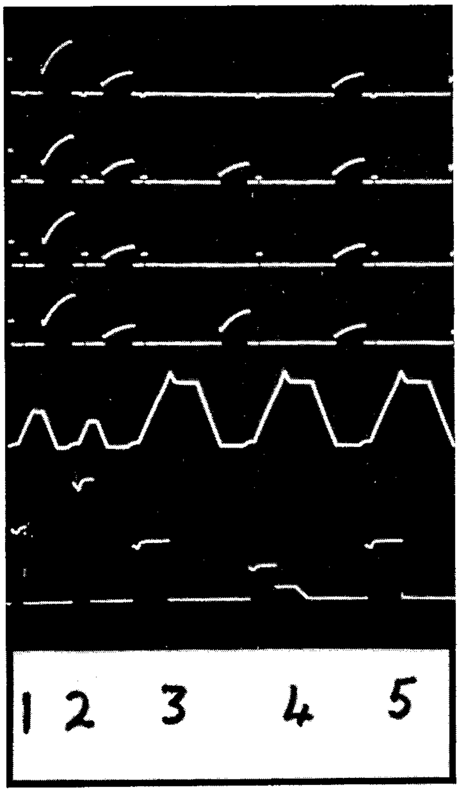
After a detailed determination of the behaviour of the real part of the pion-proton forward scattering amplitude over a wide energy range, the group at the SPS hopes to be able to predict the behaviour of the pion-proton total cross-section at energies well above the range of conventional accelerators.

LOS ALAMOS Summer Schools

Summertime traditionally brings Summer Schools and, in June, Los Alamos hosted two such schools pertinent to the experimental programme on the 800 MeV proton linear accelerator, LAMPF. A meeting on Nuclear Structure with Pions and Protons featured lectures by G.E. Brown (Stony Brook), J.P. Egger (SIN), R.J. Peterson (Colorado), G.A. Miller (Carnegie Mellon), M. Leon (LASL), C.A. Whitten (UCLA), S. Frankel (Pennsylvania) and G.E. Walker (Indiana). The lectures covered theory, particularly of the pion-nucleus interaction, and status reports on experimental programmes.

A 'Polarized Beam Summer Study Program' covered status reports on polarization experiments by the TRIUMF BASQUE group, given by G. Ludgate (Victoria), and the SIN group, given by D.W. Werren (Geneva). Theory was covered by D.C. Dodder, S. Young and G. Stephenson, all of LASL. Since operation of the LAMPF polarized negative hydrogen ion beam has just begun (see June issue, page 202), several sessions focused on practical matters such as facility status and requirements for spin precision hardware to provide independent control of beam polarization direction with beam delivered simultaneously to more than one experimental area. Another interesting topic for all the H^- beam-line users was the possibility, discussed by D.C. Hagerman, of running the LAMPF H^- beam at a lower energy than the proton beam. Exploration of this difficult manoeuvre is very preliminary.

At LAMPF, all eyes are on the search



Back in action after the May-June shutdown the CERN 28 GeV proton synchrotron has further extended its abilities to please a wide variety of users. The traces in the photograph are from a 'supercycle' of 9.6 s where pulse 1 was of medium intensity at 14 GeV for machine physics, pulse 2 was of high intensity at 10 GeV for injection into the SPS, pulses 3 and 5 were of low intensity at 26 GeV for the ISR and pulse 4 of high intensity at 26 GeV was for the PS physics programme. Note a small flat-top at 1 GeV during which longitudinal characteristics of the beam can be improved. From 3 August the PS has regularly been injecting 10^{13} protons in a single pulse into the SPS.

being mounted this Summer for muon decay into electron and gamma. The experiment, by a Chicago / LASL / Stanford collaboration, is designed to measure a branching ratio of 10^{-10}, which is below present experimental limits and below some estimates from gauge theory as to the level at which such decays could exist (see March issue, page 51). The electrons will be detected in a magnetic spectrometer and the photons in a sodium-iodide crystal array.

The surface muon beam development at LAMPF is expected to be a great help to this experiment (and many other positive muon experiments). In conventional muon channel operation, the first leg of the channel is tuned for pion acceptance and the second leg to contain the energetic muons from pion decay in flight. Both TRIUMF and LAMPF have found that a channel tuned to accept 28 MeV/c positive muons from essentially stationary positive pions near the production target surface gives a beam with good focal properties and extremely short stopping range. At LAMPF, the unseparated beam has an electron contamination of about 100/1 which is reduced to 1/1 by a differential degrader and collimator. The 10 cm diameter separated beam has a rate of 3×10^6 positive muons per second with a 200 µA beam on target.

MICHIGAN
Cyclotron operation

Champagne celebrations marked successful completion of first full current tests of a prototype 500 MeV superconducting cyclotron magnet at Michigan State University. Full design current was achieved on 26 May. The prototype is part of a project for research with heavy ions described in the December issue 1976 (page 431).

Sensing devices gave no indication of either wire movement or flux jumps in the coil during turn-on, indicating that the design objective of a tight stable winding had been satisfactorily achieved. Initial field measurements at selected key points also yielded results in excellent agreement with design calculations. One point was measured at a range of excitations from 200 to 700 A and the data indicate that the saturated iron approximation used in the pole tip calculation is working significantly better than expected. Any need to make modifications to the pole tips seems eliminated since the observed field errors are small in comparison with the correction capability of pole face windings.

Thermally the magnet was in marginal shape because the nitrogen shield could not be used owing to an internal leak in the nitrogen plumbing. Helium boil-off rates were in the vicinity of 20 litres per hour, which is uncomfortably close to the maximum capacity of the refrigerator. When the baffle is repaired, the consumption should be in reasonable accord with the predicted 7 litres per hour.

At present the magnet has been warmed up for repairs on the baffle and for installation of an automated field mapping system which will give detailed 10 000 point maps at a series of excitations. Orbit calculations will be repeated in the measured fields as a final check to ascertain if there are any significant deviations between actual orbit properties and design expectations.

Physics monitor

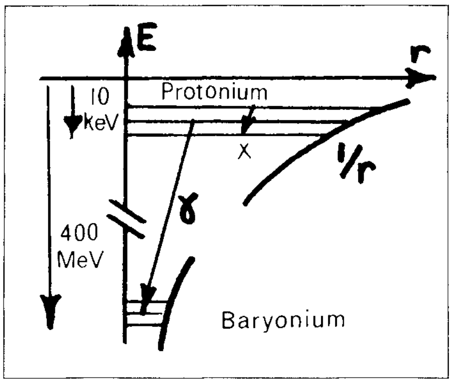
From protonium to baryonium

More evidence has been accumulated at CERN for the existence of quasinuclear or baryonium states (see June issue, page 197) in which baryons and antibaryons form tightly bound resonances.

Indications of such states near 1940 MeV with narrow widths have been reported by a CERN/Heidelberg collaboration (see CERN COURIER March 1977, page 71) and by a CERN / Liverpool / Mons / Padua / Rome / Trieste group. States at 2020 and 2204 MeV have been seen in scattering experiments by the CERN/Collège de France/ Ecole Polytechnique / Orsay collaboration, and there is now news of a narrow enhancement at 2950 MeV from another team working at the Omega spectrometer. In addition, the Brussels / CERN / London / Mons / Orsay group looking at proton-antiproton annihilations at 12 GeV has seen a narrow peak in the neutral kaon — three pion mass spectrum at 2600 MeV. Called the I resonance, this could be the first example of a baryonium state carrying strangeness.

The latest baryonium evidence comes from a different type of experiment. The study of 'exotic' atoms, where heavier negatively charged particles are substituted for atomic electrons, has long been a speciality at CERN and one of the more recent exotic states to be discovered was 'protonium' — a bound state of a proton and a stopped antiproton orbiting round each other under the influence of the electromagnetic force.

When one of these orbiting particles moves down from a higher energy level, characteristic X-rays are seen and these in themselves are interesting. However, a proton and an antiproton apparently can live together in more ways than one, as shown by the observation at CERN of a discrete



Schematic representation of protonium and baryonium bound states, showing the origin of the observed X-ray and gamma-ray spectra.

system of gamma rays coming from stopped antiprotons in hydrogen. These gamma rays, with energies of 100 to 400 MeV, are emitted when protonium, an atomic system with a first Bohr orbit radius of about 60 fermis, collapses into baryonium, a tightly bound quasinuclear strong interaction state of radius about 1 fermi.

Previous experiments by T. Kalogeropoulos from Syracuse claimed to see discrete gamma-ray spectra in antiproton-deuteron annihilations, but statistics were poor. Now, at CERN, the Basel / Karlsruhe / Stockholm collaboration has carried out a thorough search for gamma transitions in antiproton annihilations in hydrogen. The result is at least four discrete gamma-ray lines in the energy range 100 to 400 MeV.

While this group continues to investigate this gamma-ray spectrum, another group at CERN, a Daresbury / Mainz / TRIUMF collaboration, is looking at the X-ray spectrum seen coming from energy level transitions in atomic protonium.

The idea that the $N\bar{N}$ system can form tightly bound states which would show up as gamma transitions from protonium was suggested by I. Shapiro from ITEP (Moscow). He said that resonant $N\bar{N}$ states should exist as a result of the same meson exchanges which occur in the NN channel. A complementary point of view comes from the quark model, where the discovery of baryonium solves the 'duality' puzzle of baryon-antibaryon reactions which had long been worrying theorists.

In this channel, the deuteron is the only well-known bound state, although evidence now exists for another (see May issue, page 152). However the contributions of mesons with odd G-parity (like the omega), have opposite signs in the NN and $N\bar{N}$ channels. If the relative absence of bound states in the NN channel is interpreted as the result of a repulsion, then there should be a strong attractive force for $N\bar{N}$.

In other words the dearth of bound states in the NN channel could be indicative of a relative abundance of resonances in the crossed channel, and more baryonium states could yet be discovered.

Another heavy lepton sighting ?

At Stanford, a Santa Cruz / SLAC collaboration has long been puzzled by a narrow enhancement at 1840 MeV in the muon-rho mass distribution coming from the reaction $\mu N \rightarrow \mu\rho N$. This signal is defying all attempts to make it go away and could perhaps be related to the heavy lepton seen in electron-positron annihilation experiments at the SPEAR and DORIS storage rings.

Using streamer chamber techniques to pick up the small signals involved, the Santa Cruz / SLAC experiment looks at the interactions of a high quality 14 GeV muon beam producing fast forward muons. For $\pi^+\pi^-$ production reactions, the $\mu\pi\pi$ mass spectrum is unremarkable, but when the $\pi\pi$ events corresponding to rho production are selected out, things begin to happen. Some 30 events are seen at 1840 MeV with a width of 25 MeV.

Far from heralding this discovery as more evidence for a heavy lepton, the collaboration has spent a long time trying to find some alternative explanation for it. Other muon experiments at SLAC do not see it, and the signal is not reproduced in neutrino experiments.

One of the first things the collaboration tried was to repeat the experiment with hadron beams in place of the muons to see if the signal was being faked by contamination of the muon beam. Nothing was seen.

Could the signal be the same heavy lepton seen in the annihilation experiments at SLAC and DESY ? One big problem for this viewpoint is the requirement to keep in line with the accurate muon data from the g-2 experiment at CERN. To do this, special couplings between the muon, the rho and any new heavy lepton would have to be introduced.

High-y OK

Fermilab bubble chamber experiments and the Caltech/Fermilab counter group, together with two major collaborations at the CERN SPS — the CERN / Dortmund / Heidelberg / Saclay counter experiment and the Aachen / Bonn / CERN / London / Oxford / Saclay group using the BEBC bubble chamber — have obtained comprehensive statistics for neutrino interactions. Taken together, they are free of the anomalies suggested by earlier results which would have called for major upheavals in the underlying theory.

Neutrino-nucleon interactions at high energy are usually interpreted in terms of the parton model which treats the target nucleon like a box of small, hard scattering centres. Evidence for such small scattering centres deep inside the nucleon was first seen in electron-proton experiments at Stanford. The quark model postulates constituents inside the proton and results from neutrino experiments led to an amalgamation of the two ideas, showing that quark-like objects were indeed responsible for the effects seen in high energy lepton-nucleon scattering experiments.

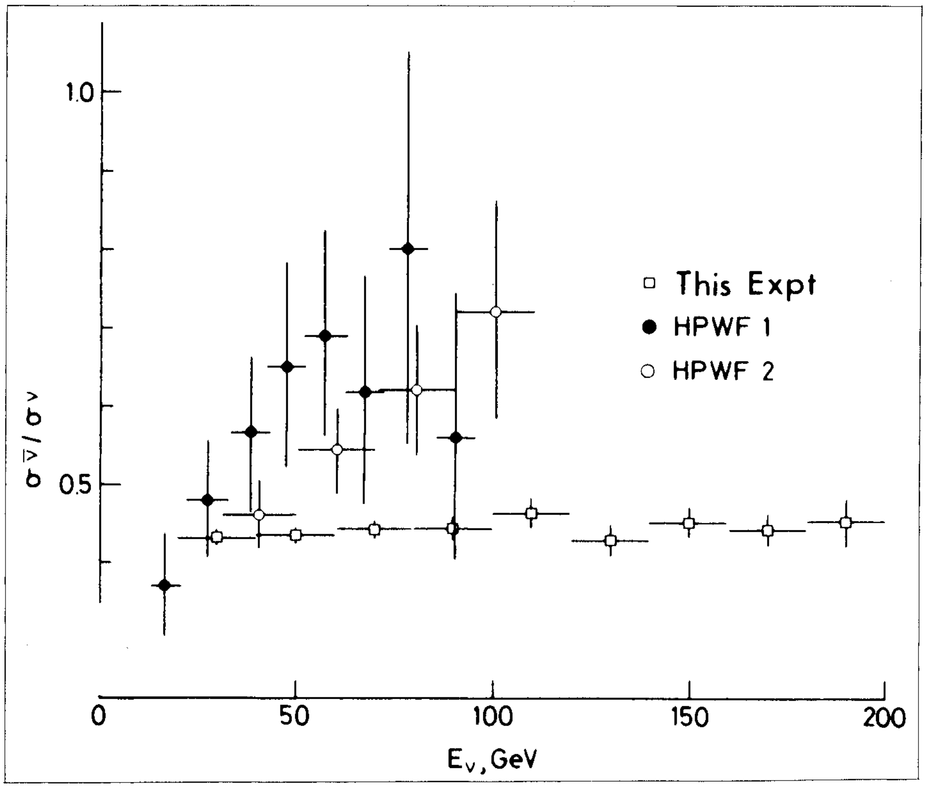
The quark / parton model makes definite predictions about the way the leptons should transfer their energy to the proton constituents, and these spectra, known in the trade as 'y-distributions', should have one form for neutrinos and another for anti-neutrinos.

If the target proton appeared simply as a box containing three quarks, as might be naively assumed from the quark model, then total cross-sections for antineutrinos should be one-third of those for neutrinos. The data gathered at low energies in the Gargamelle bubble chamber at CERN gives a ratio of nearly one-third, but there is a small but systematic deviation from this value. This is attributed to the virtual quark-antiquark pairs which are constantly emitted and absorbed by the proton state. These virtual quark pairs are often termed 'sea' quarks to differentiate them from the permanent or 'valence' quarks.

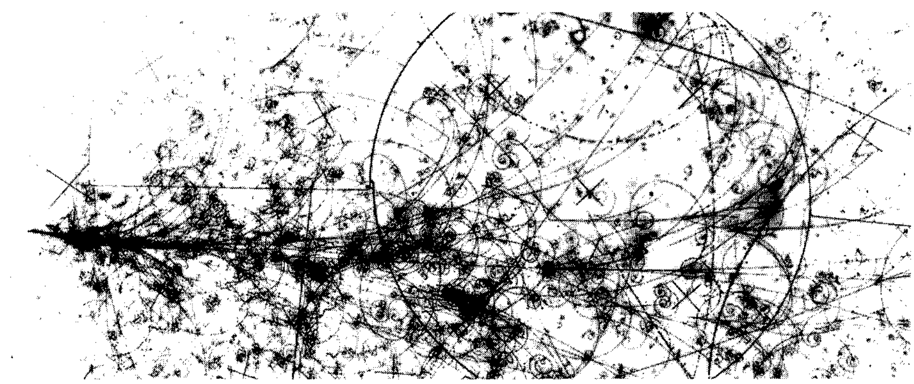
Investigations at higher energies produced a steady trickle of results from the Fermilab / Harvard / Pennsylvania / Wisconsin group which suggested that the ratio of neutrino and antineutrino cross-sections behaved erratically at high energies, while the antineutrinos did not transfer their energy to the quarks in the predicted way.

Because of the deviation of these spectra from the predicted form, the effects came to be collectively known as the 'high-y anomaly'. To explain the observations, additional particle production mechanisms for antineutrinos were needed, and the so-called 'bottom' quark with right-handed coupling was brought in to augment the up-down-strange-charm quark family.

The latest experimental results do not show this erratic behaviour. Instead, they all have the antineutrino to neutrino cross-section ratio varying smoothly with energy and obtain statistics compatible with the standard quark / parton predictions. They also have the same fairly gentle deviations from scaling already seen in electron and muon scattering experiments at Stanford and Fermilab. The quark / parton model fits the observed behaviour remarkably well.



The variation of the ratio of antineutrino to neutrino cross-sections with energy as measured by the CERN/Dortmund/Heidelberg/Saclay counter experiment at the SPS ('This Expt'), showing that the anomalous behaviour (the high-y anomaly) previously reported is not confirmed.



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Contributing to the latest results on high energy neutrino interactions are experiments in the 3.7 m European bubble chamber, BEBC. They gathered 280 000 pictures with neutrinos generated by a 200 GeV SPS beam and have 520 neutrino and 250 antineutrino photographs. The chamber is performing efficiently (over 95 % during the first operating period) and giving pictures of good quality.

1. The typical complexity of the interactions seen in BEBC by the Aachen / Bonn / CERN / London / Oxford / Saclay collaboration when a high energy neutrino interacts in the chamber liquid.

2. An enlargement of the primary interaction area of the above photograph which shows just how well the bubble chamber records this maze of particle tracks.

People and things

1. Gersh Budker photographed while giving a seminar on the work of his Institute of Nuclear Physics during a visit to CERN in 1967.

(CERN 356.4.67)

2. Ben Lee at a press conference during the Chicago meeting of the American Physical Society in February.

(Photo American Institute of Physics)

Gersh Budker and Ben Lee

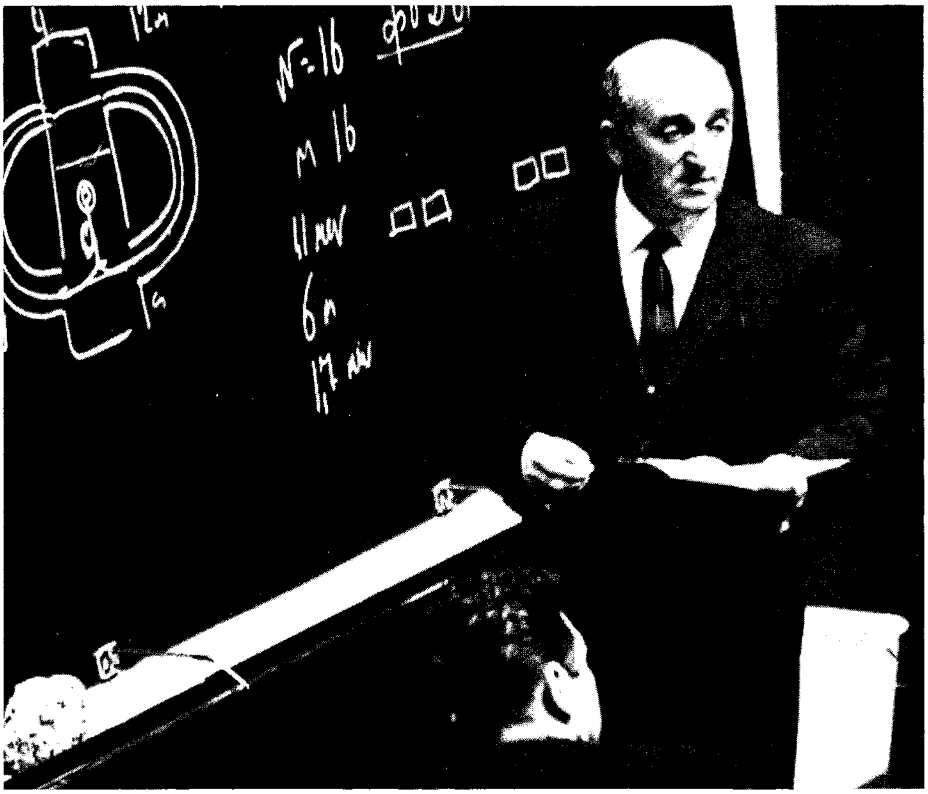
High energy physics has lost two of its prominent personalities — Gersh Budker, one of the greatest accelerator physicists, and Ben Lee, an outstanding particle physics theorist.

Gersh Itskovich Budker, Director of the Institute of Nuclear Physics of the Siberian Branch of the Soviet Academy of Sciences, died on 5 July at the age of 59. Budker moved from Dubna to take over the Institute of the newly founded science city of Akademgorodok just outside Novosibirsk in 1957 and established there a very individual and independent style of designing and building accelerators and, particularly, electron positron storage rings.

His powerful personality and ability drew many talented young physicists to the Institute, which now has one of the most able accelerator teams in the world. In 1967, Budker and several of his colleagues received the high honour of the Lenin prize for their contributions to 'the study of the colliding beams method of high energy physics research'. They have been a prolific source of new ideas in accelerator technology, many of them stemming from Budker himself. One of the latest to come to fruition is the idea of electron cooling of antiproton beams which is being taken up by CERN and Fermilab.

Not all of Budker's ideas will have lasting impact in machine technology but it has been a stimulus over the past two decades to have a character of his individual genius around and the accelerator world will be less rich without him.

Benjamin W. Lee, Head of the Theoretical Physics Department at Fermilab, was killed in a traffic accident on 16 June at the age of 42. Ben Lee moved to the USA from Korea in 1956, taking American citizenship in 1968, and earned a high reputation as author of over 100 papers in the field



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1. Chris Quigg, new Head of the Theoretical Physics Department of Fermilab.
2. Percy Bowles who retires as Chief Engineer at Rutherford.
3. Hildred Blewett on the night of first operation of the CERN PS.

of particle physics. He was particularly prominent in the development of gauge theory and the linking of weak and electromagnetic phenomena which has been one of the highlights of recent years.

Ben Lee held appointments in many Institutes prior to settling at Fermilab in 1971 where he also held a joint appointment as Professor at Chicago University. He took full part in the life of the Laboratory, helped to create and stimulate a Theory Department of high quality, and communicated with great enthusiasm his love of physics.

The Fermilab and particle physics in general have lost an outstanding colleague who still, potentially, had a great deal to contribute.

Reorganization at Karlsruhe

Some administrative changes have been made at the Gesellschaft für Kernforschung (GfK), Karlsruhe, in the high energy physics and accelerator sections. The Institut für Experimentelle Kernphysik (IEKP) in which these activities became concentrated had become the largest unit within GfK. To streamline management, it has been split into two smaller Institutes — the Institut für Kernphysik (IK) and the Institut für Technische Physik (ITP). IK is under the joint Directorship of A. Citron and a new Director to be nominated from the experimental nuclear physics field. Prof. Citron will supervise the continuing development of superconducting r.f. techniques, in close collaboration with CERN and DESY, while the second Director will be concerned with high energy physics experiments, particularly the participation in the CERN and DESY programmes. ITP is under the Directorship of W. Heinz. It specialises in the study and applications of type-II superconductors. Basic research will continue while technical applications are investigated in close cooperation with industry. Special emphasis is being put on the possibility of plasma confinement in fusion devices by means of superconducting magnets. ITP will continue to participate in the activities of the Group on European Superconducting Systems Studies (GESSS).

On People

The Max Planck Medal of the German Physical Society has been awarded this year to Walter Thirring of the University of Vienna. Professor Thirring, who was for two years Head of the Theoretical Physics Department at CERN, received this honour for his extensive contributions to theory in particle physics and in gravitation. He will receive the award at a Society meeting in Karlsruhe on 21 September.

Chris Quigg has been appointed head of the Theoretical Physics Department at Fermilab in succession to Ben Lee. Chris joined Fermilab from Stony Brook in 1974 and is also visiting scholar at Chicago University. He is the author of more than 70 scientific papers. It is intended to seek out senior theorists, with a competence and eminence similar to Ben Lee, to work in the Fermilab Theory Department during the next years.

At the end of July, P.J. Bowles retired from the post of Chief Engineer at Rutherford Laboratory, a position he had held throughout the Laboratory's life. He moved to Rutherford from the UK Atomic Energy Authority to oversee the engineering side of the construction of the Nimrod proton synchrotron. Percy Bowles will be remembered for his high professional ability and for the gentlemanliness of his relations with all who came into contact with him.

Hildred Blewett retired from the CERN ISR Division in July. Hildred is well known throughout the accelerator world and was involved in the bringing into operation of a large number of machines — the Brookhaven Cosmotron and AGS, the CERN PS and ISR, the Argonne ZGS. She will be remembered for her devotion to our field of research (and perhaps particularly to the ideals of CERN) and for the thoroughness and competence of her work.

At its meeting on 23-24 June the CERN Council took leave of M. Pihl from Copenhagen University who has for many years been Danish delegate

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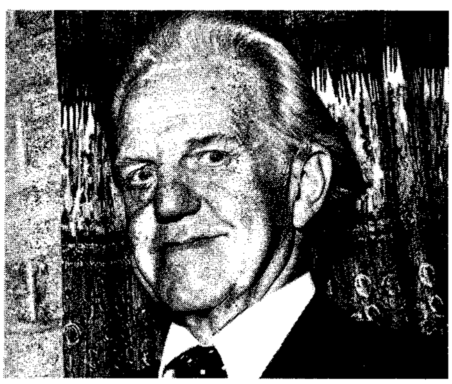

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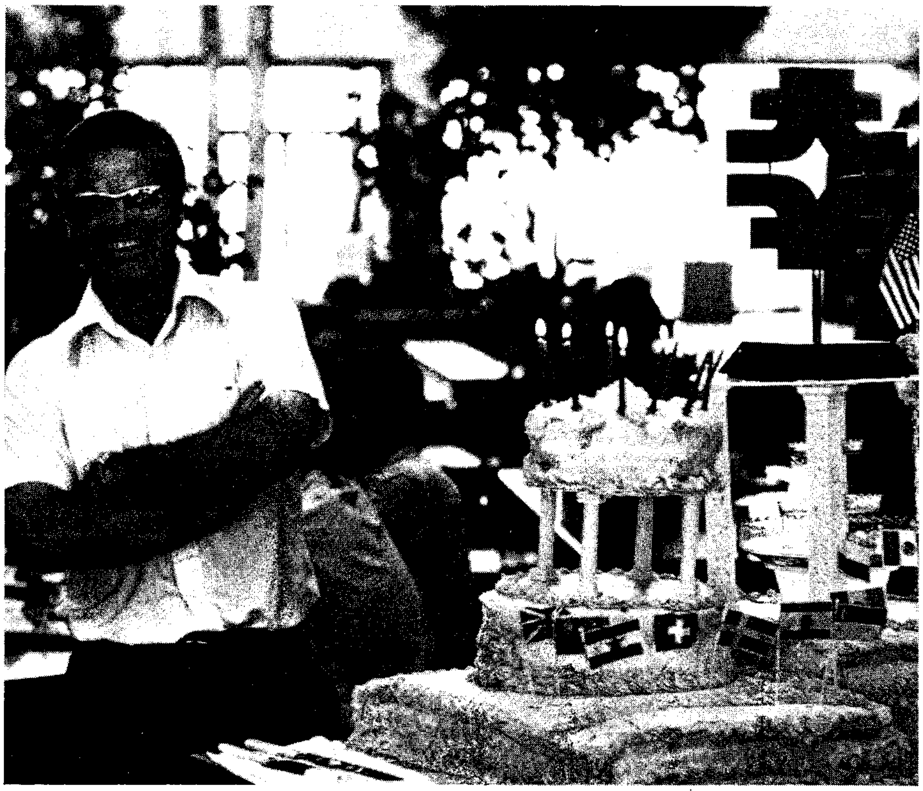


On 15 June, Fermilab celebrated the 10th anniversary of the date when the first Laboratory staff met to begin the design of the accelerator. The photograph shows Director, Bob Wilson, alongside the anniversary cake.

(Photo Fermilab)

to the Council and is also Chairman of the Council for Research and Planning in Denmark. Council appointed A. Rousset and reappointed A. Dalitz as members of the Scientific Policy Committee for the next three years. Erwin Gabathuler was appointed to succeed Emilio Picasso as Leader of the CERN Experimental Physics Division as from 1 January next year.

Meetings

The second session of the ISR Workshop (see November 1976 issue page 394 for an account of the first session) will be held at CERN from 14 to 21 September. It will concentrate on options for the research programme at the storage rings for the next five years. Secretary for the Workshop is Maurice Jacob of the CERN Theory Division.
Synchrotron radiation experts will be attracted to the Physical Sciences Laboratory of the University of Wisconsin on 24-25 October for the 10th Annual Synchrotron Radiation Users Group Meeting and to Stanford University on 27-28 October for the Stanford Synchrotron Radiation Project Users Group Meeting. Contacts are Ed Rowe at Wisconsin and Herman Winick at Stanford.

Bits and Pieces

The refrigeration system for the superconducting power transmission project, led by Eric Forsyth, has operated successfully at Brookhaven. The 500 watt helium refrigerator has achieved a temperature of 7 K. It is now to be connected to 100 m of cryogenic envelope which will surround superconducting cable.
On 16 June the proton synchrotron at the KEK Laboratory in Japan topped 10^{12} protons per pulse for the first time, accelerating a beam of 1.2×10^{12} to 8 GeV.

On 19 June a 40 ton superconducting magnet was airlifted from Chicago to Moscow for use in joint USA-USSR experiments on a magneto-hydrodynamic project. It was built at Argonne where considerable experience in large-scale superconducting magnets has been accumulated with the magnets for the Argonne 12 foot and Fermilab 15 foot bubble chambers. The MHD magnet is 4.4 m long and 2 m in diameter, generating a field of 5 T.

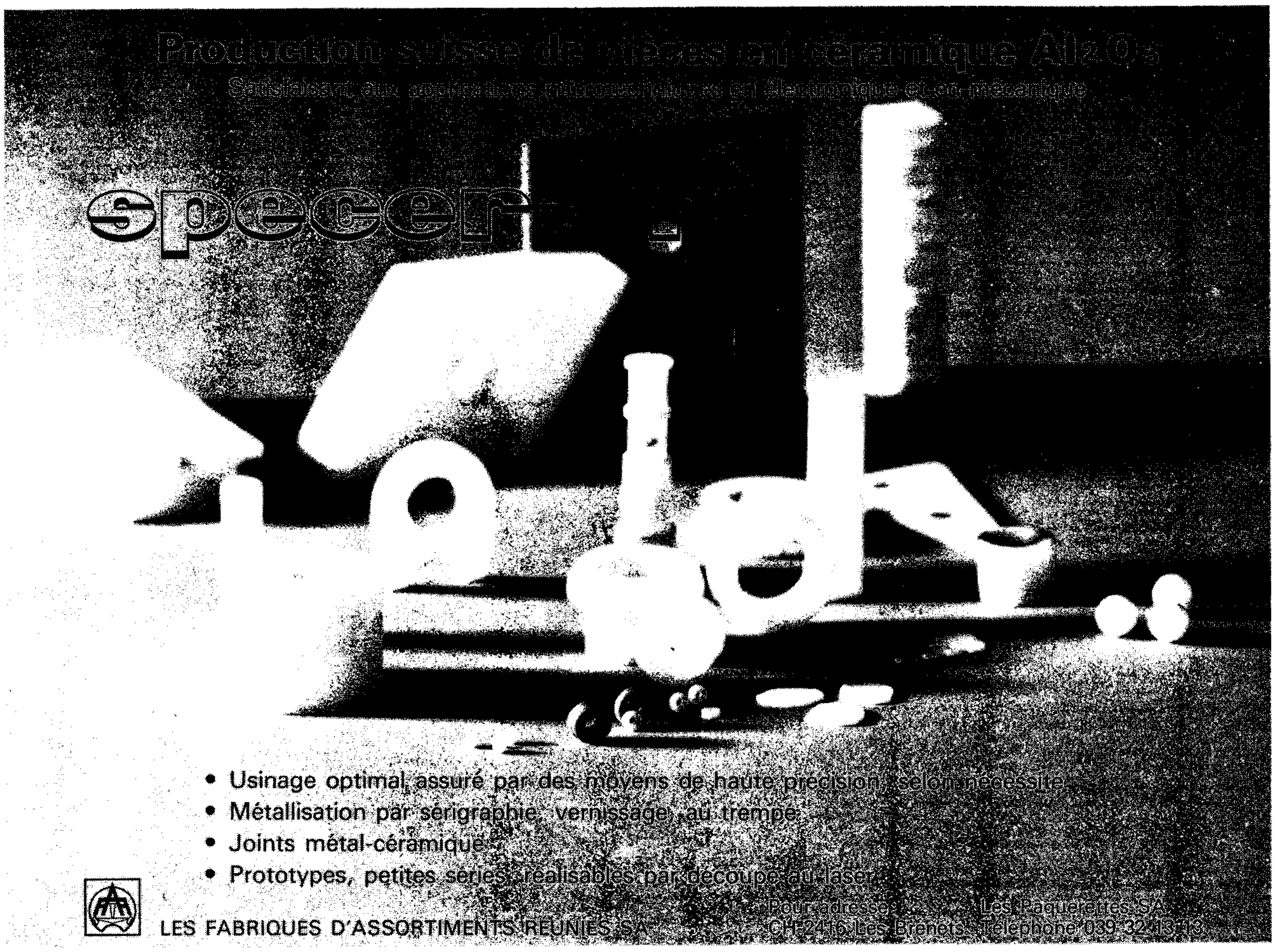
Over 2000 panels of double-sided copper clad epoxy laminate of very large dimensions (12 foot by 8 foot) have been furnished by Norplex UK Division to the group of Paul Murphy at Manchester University for the drift chambers to be used in the JADE experiment (see November issue 1976) of a Daresbury / DESY / Hamburg / Heidelberg / Lancaster / Manchester / Tokyo collaboration at the DESY electron-positron storage ring PETRA.

Mining for superheavies

Several meteorites have been carried down a salt mine by the group of G.N. Flerov from Dubna to study spontaneous fission in this shielded environment. They have evidence for the fission of nuclei yielding many more neutrons (between four and ten) than emerge from known heavy nuclei. In general the number of neutrons per fission increases with the mass of the nucleus and this is another tantalising hint that the long searched-for superheavy nuclei may be present.

God versus Pauli

Vicky Weisskopf in one of his lectures on 'Particles and Symmetries' to summer students at CERN, recounted the following apocryphal tale about the late Wolfgang Pauli who was noted for his intolerant attitude to new ideas which did not have a solid foundation. On arriving in heaven, Pauli was greeted by the Deity who congratulated him on his life's work and asked if there was anything he would like to know, now that he was freed from the need to strive for further understanding of the Universe. 'I would like to comprehend why the fine structure constant has the value that it has', replied Pauli. (The fine structure constant relates the magnitude of the charge on the electron to other natural constants and so governs the scale of the electromagnetic phenomena which make up much of our immediate experience of the world.) The Deity summoned a celestial theoretician who, on paper of finest gold and with a pencil of pure platinum exposed the argument. 'Wrong', bellowed Pauli storming off in disgust.



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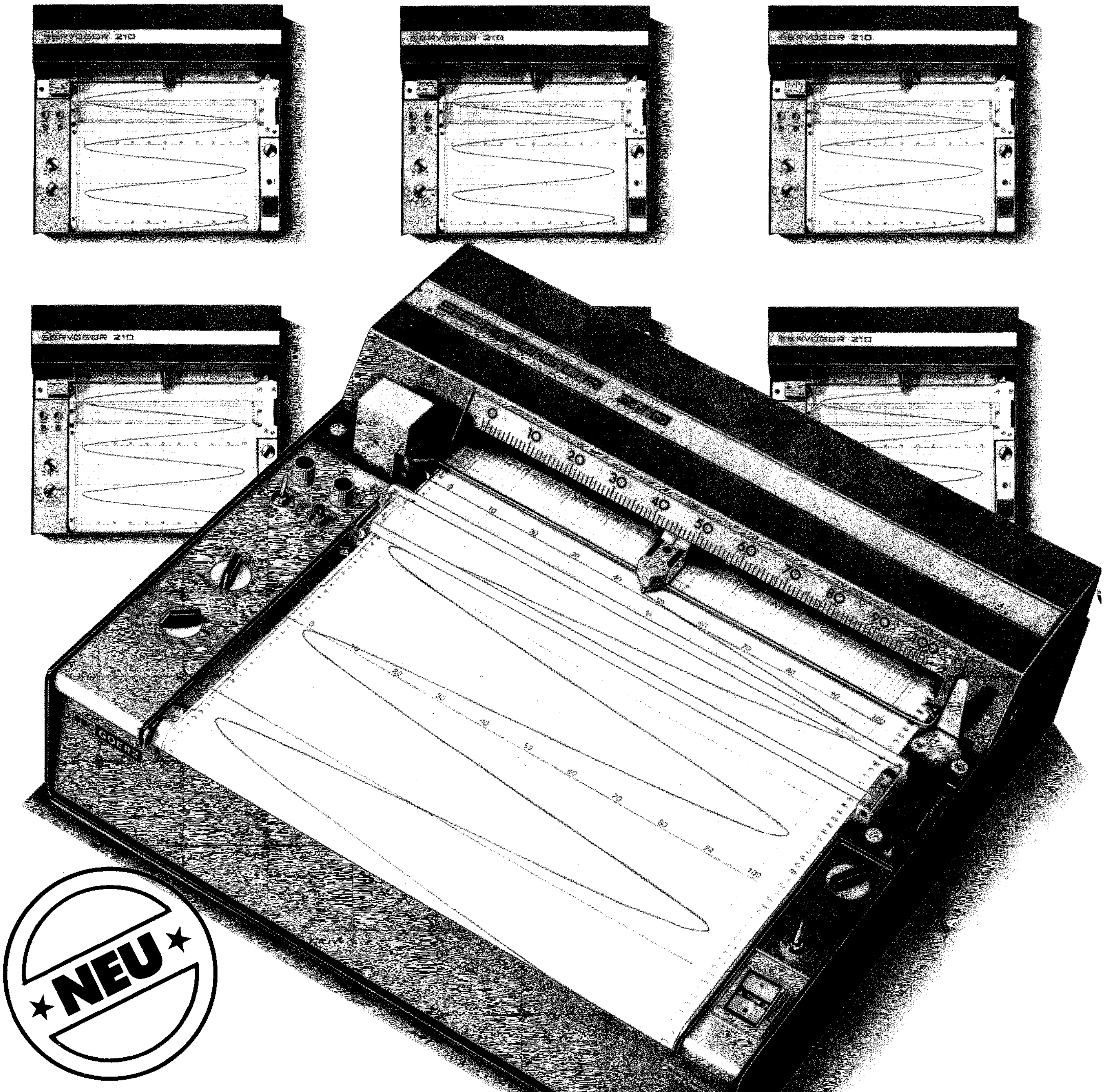

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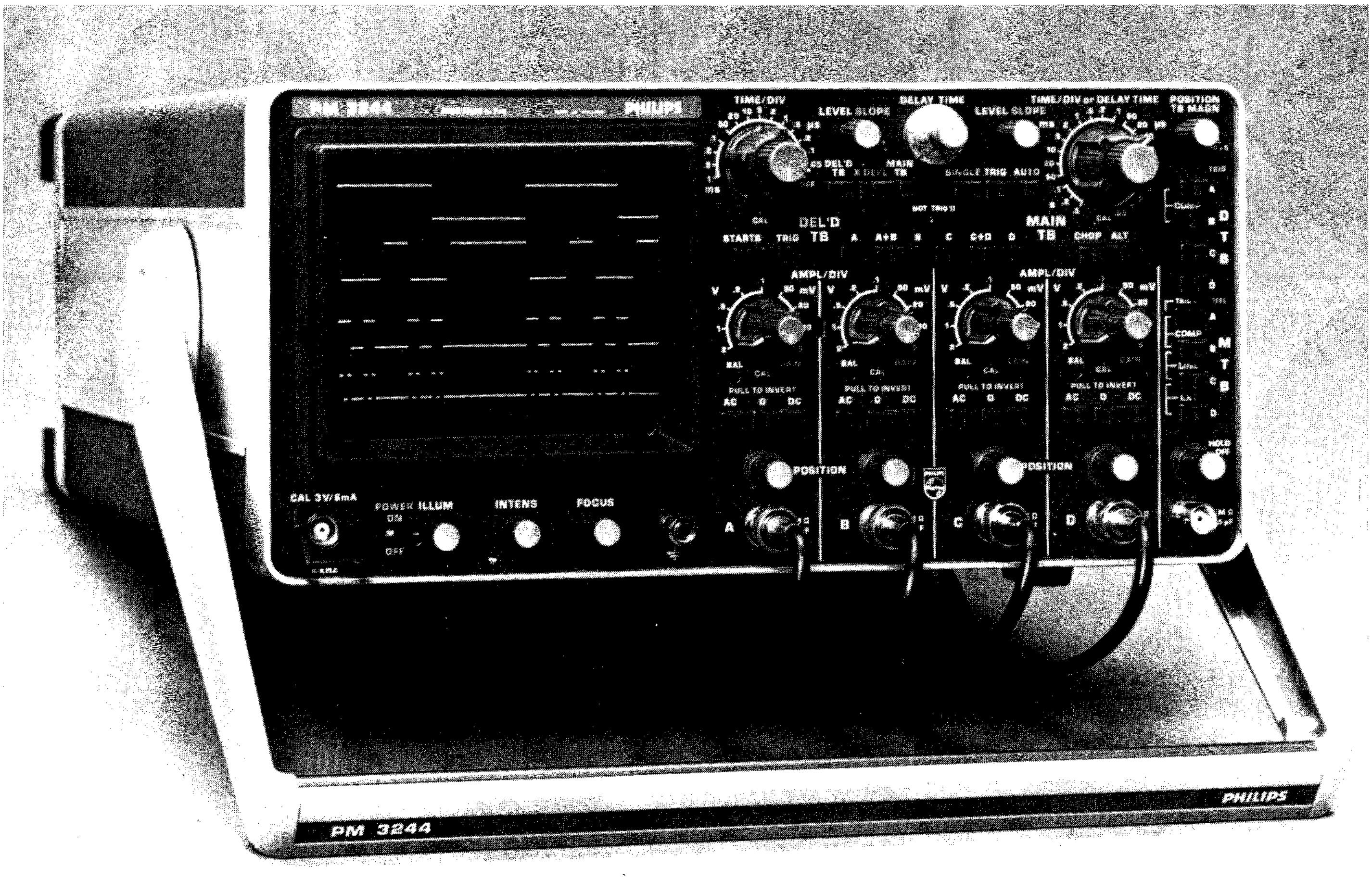

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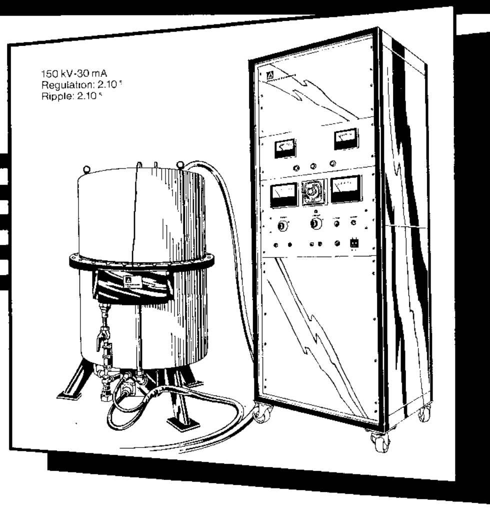

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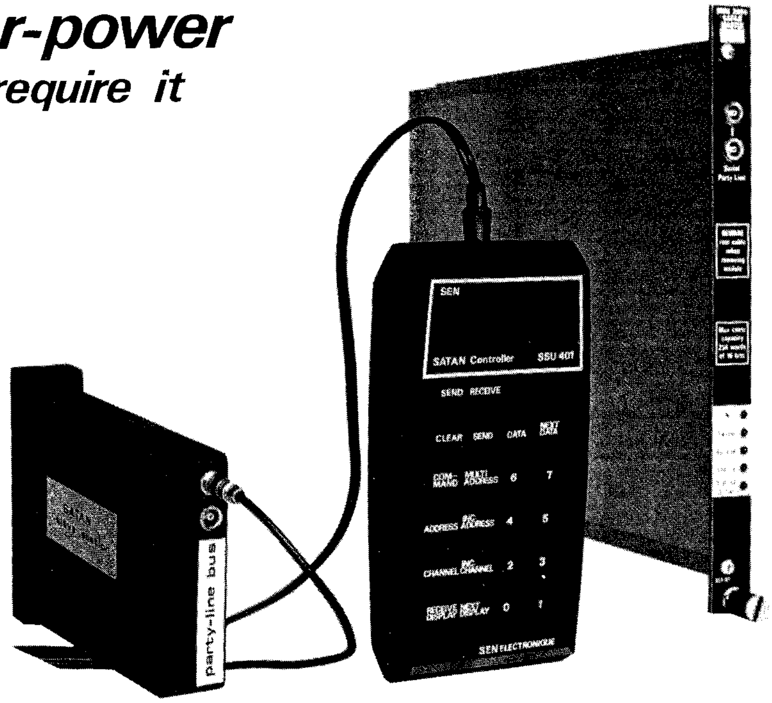

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