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Reader service form, page 38.

Cover photograph: In 100-degree temperatures, the water garden at Fort Worth, Texas, was one of the welcome day-off attractions for participations at this year's international physics conference at nearby Dallas. The conference report features on page 1. (Photo John Bird, SSCL)

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CES PRESENTS:

a Twin 68040 OS-9 Data Acquisition System

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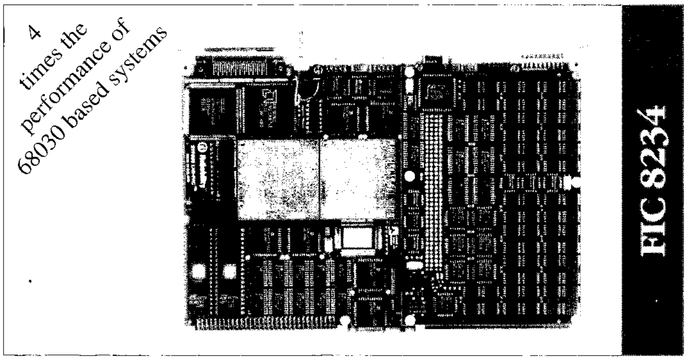
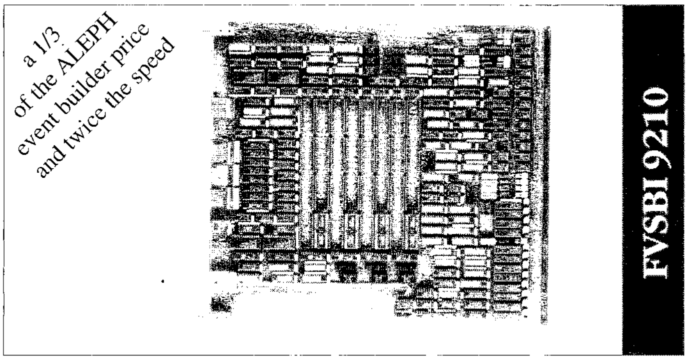


The FVSBI 9210 / FADAP 9211: FASTBUS master / slave interface, offering more than 6 Mbytes/s when coupled with the FIC 8234 on a long distance VSB cable.



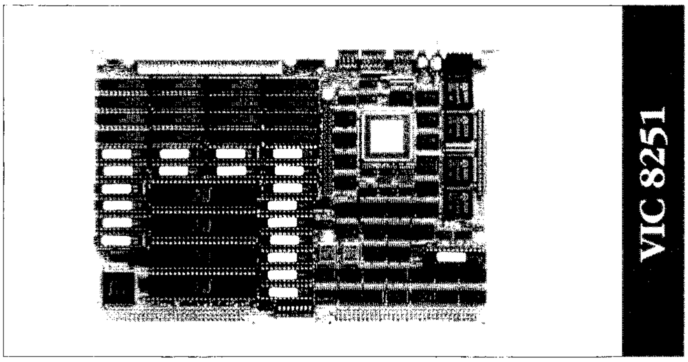
A unique complete OS-9 system package has been designed by CES to make the user unaware of the twin engine architecture as one processor runs OS-9 in the same environment as in the FIC 8232 based workstations.

In case of the FIC 8234B/25/1, the two processors are running in parallel, one performing the front-end task, typically handling the block mover operations, while the other one distributes the reduced data to other elements through the VIC bus, Ethernet or SCSI.

Application software

A complete set of libraries supporting the different elements of the system is already available.

Contact Person: Dr. A. LOUNIS lounis@lancy.ces.ch



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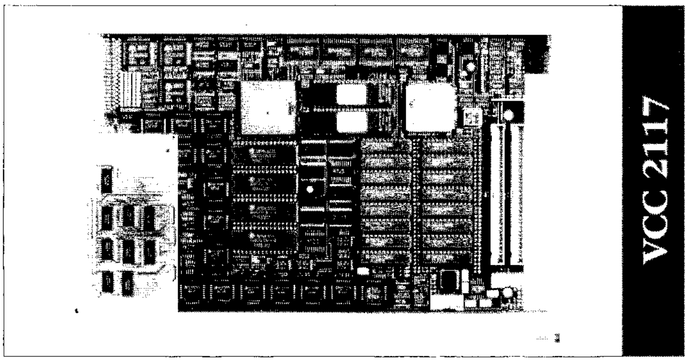

The transparent VME to CAMAC interface: the VCC 2117. It features an embedded CAMAC list processor with simple memory mapped VIC addressing. It includes a combination of 3 units into 1 (CCA2 back-end, FIC 8232 on-board processor (optional), VIC 8250 front-end).

CES Latest News:

- After more than 10 years of activity as a hardware design company, CES is evolving to a system company with a full blown software design team whose products will be incorporated in our complete solutions.
- A Turbo-Channel to VIC bus interface will be added to the VIC family. This is a joint development with KFA Julich.
- A special firmware enables the VCC 2117 to be driven directly under TPC-IP for long distance connections between CAMAC and workstations.
- An electronic bulletin will be made available from September 92. Requests for consultation have to be sent to: news@lancy.ces.ch

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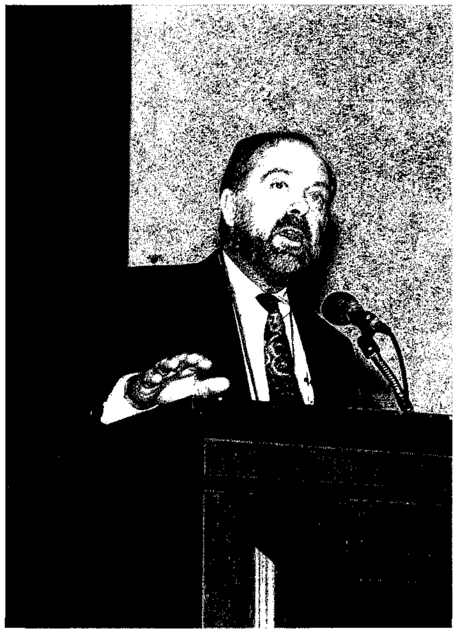
Rochester comes to Dallas

Opening the International Conference on High Energy Physics in Dallas on 6 August, Conference Chairman and Superconducting Supercollider (SSC) Laboratory Director Roy Schwitters read an encouraging message from US President George Bush.
(Photos John Bird, SSC Lab)



Every two years, the traditional International Conference on High Energy Physics, organized for the International Union of Pure and Applied Physics (IUPAP), provides a major world stage. There are intervening meetings, but the two-year 'Rochester' cycle (named after the first Conference in the series, held in Rochester in 1950) is well matched to the natural growth and development of the subject.

This year's meeting, held in Dallas, Texas, from 6-12 August reflected how verifying the Standard Model and producing precision electroweak physics results, particularly at CERN's LEP electron-positron collider, has now become a major research industry. It also marked the physics debut of the new HERA electron-proton collider at the DESY Hamburg Laboratory. By the time of the next Rochester meeting, in Glasgow, Scotland, in July 1994, HERA's new physics frontiers will be major physics.

At any Rochester meeting, the forthcoming venue is traditionally confirmed, and at the 1990 Rochester meeting in Singapore, the decision had been to stage the 1992 event in Moscow. Subsequent events made this impossible, and the meeting was rapidly rescheduled for Dallas, Texas, hosted by the Superconducting Supercollider (SSC) Laboratory.

In his keynote address at the opening session of the Dallas meeting, William Happer, Director of the Office of Energy Research at the US Department of Energy said 'efforts to internationalize scientific projects will increase as time goes by'.

The decision could not have turned out to be more timely. On 17 June, an unexpected vote in the US House of Representatives had threatened the future of the SSC. If that decision had been upheld by the Senate, the project for an 87-kilometre machine to collide 20 TeV proton beams would have been in real trouble. However on 3 August the Senate wisely decided to back the SSC, so the Dallas physics conference opened on 6 August in a party-like atmosphere.

Conference Chairman and SSC Laboratory Director Roy Schwitters began the meeting, held in the Southern Methodist University campus in Dallas, by reading a letter from US President George Bush which assured the audience that his Administration is committed to ensuring funding for the SSC and maintaining its high priority. Only a few days earlier, and before the Senate vote, President Bush had visited the SSC Laboratory to underline his support for the project.

In his opening speech, Schwitters went on to pay tribute to the international support and cohesiveness which had challenged the initial unfavourable vote from the House of Representatives. This support, with CERN prominent, had been helpful in restoring the SSC project to its rightful place.

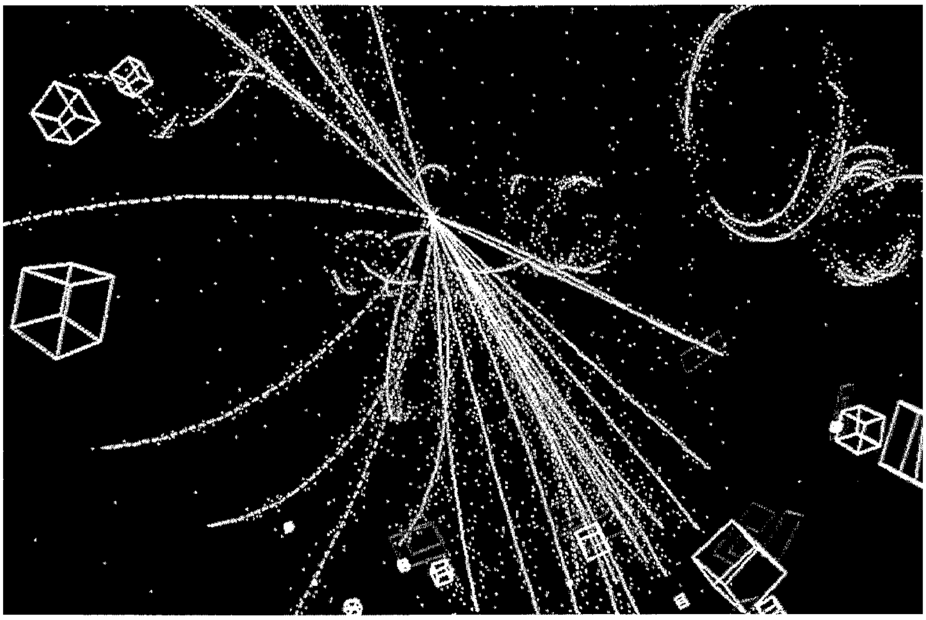
Keynote speaker at the opening ceremony was William Happer, Director of the Office of Energy Research of the US Department of Energy, the major paymasters (or 'cheerleaders' as Happer preferred to call them) of US high energy physics.

Looking forward to SSC news featuring at future Rochester meetings, Happer saw the SSC being transformed into a truly international project, much more so than had originally been conceived. He illustrated the increasing international collaboration in major scientific projects by the proposed ITER scheme for a next generation Tokamak for thermonuclear fusion, supported by Japan, Europe, Russia and the US. 'Such efforts to internationalize scientific projects will increase as times goes by,' he said.

Standard Model

For more than a decade, major physics meetings have been

Precision electroweak physics, dominated by the contributions from the four experiments at CERN's LEP electron-positron collider, was the bread and butter of the Dallas meeting. This shows a Z decay recorded by the Opal detector.



In his summary talk, Steven Weinberg underlined how electroweak physics has reached a new level of precision before he went on to look hard at theoretical trends.

Standard Model festivals. With this twin picture of the electroweak unification of electromagnetism and the weak force coupled with the quantum chromodynamics theory of inter-quark forces looking impregnable, Dallas summary speaker Steven Weinberg could show a 'Standard Conference Summary' transparency.

The standard status of the Standard Model is that it is in good shape experimentally, but the sixth ('top') quark still needs to be found, the mechanism of CP violation has to be explained, quantum chromodynamics has yet to be made completely solvable, and the symmetry-breaking ('Higgs') mechanism which provides particles with mass must be uncovered.

Electroweak physics now attains an impressive level of precision, largely due to the great success of the experiments at LEP, said Weinberg. Electroweak physics precision is now rivalling what once used to characterize quantum electrodynamics.

While the long-expected sixth ('top') quark is constrained by Standard Model consistency to lie somewhere between 130 and 170 GeV, the mass of the Higgs particles, responsible for the symmetry breaking at the heart of the electroweak theory, still roams relatively freely. However Weinberg looked forward to dramatic improvements in the near future, finding the top at the Fermilab Tevatron, and then measuring the mass of the W boson to high precision once LEP is upgraded to attain its full collision energy around 200 GeV.

Then, the emerging precision picture could make a very close check on the Standard Model, said Weinberg, following the current approach of 'oblique' radiative correction analyses (October 1991, page 2).

Earlier, Luigi Rolandi of CERN (who is also the current coordinator for the LEP experiments) had summarized the status of electroweak physics, where a major fraction of the world high energy physics effort provides a wealth of data. Here the tau lepton sector has emerged as a major physics arena in its own right, providing Standard Model parameters to complement those coming from other lepton sectors. Valuable input here comes from the new measurements of the tau mass at Beijing (BES), Cornell (CLEO) and DESY (Argus).

Throwing all electroweak information into the melting pot, consistency arguments point to a top mass in the range 118-170 GeV. The mass of the Higgs particle looks at first glance like being around 300 GeV, but really could be anywhere in the range 50-1000 GeV, lower masses now having definitely been excluded by LEP data. Finding where the top quark sits, either from experiments at Fermilab's Tevatron or further down the line, will provide a surer indication of where the Higgs should be found.

LEP dominates the electroweak sector. Most results so far come from the two million Zs seen by the four experiments - Aleph, Delphi, L3 and Opal - from 1989 to 1991. Rolandi hinted that this year's run was going well, promising a bumper harvest of

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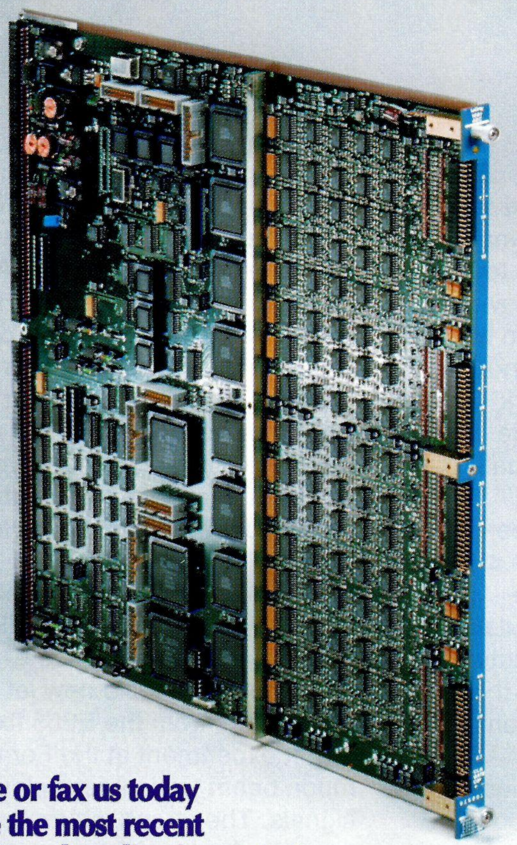

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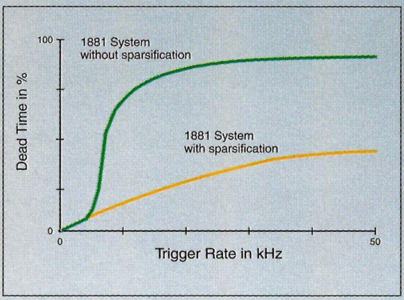

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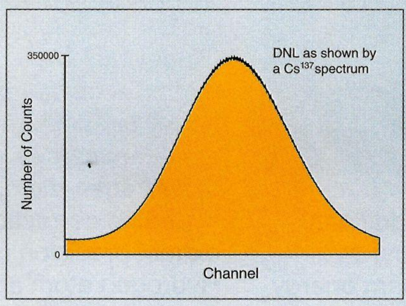

. . . of *less than ±0.1 LSB DNL* (typically ±0.05 LSB) with high channel density of 64 channels, in a single FASTBUS width, is achieved with 64 800 MHz Wilkinson converters operating simultaneously.

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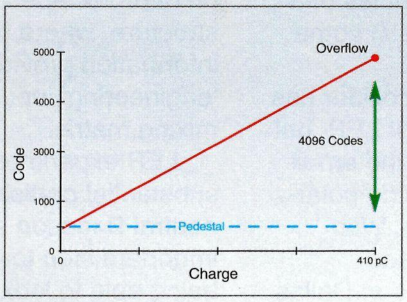

. . . of a true 12-bit resolution with a *full 12 bits of range above pedestal,* for wide dynamic range detector requirements.

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Innovators in Instrumentation

Persis Drell of Cornell - defining and testing the Standard Model

Siegfried Bethke of Heidelberg - tests of quantum chromodynamics

Zs. In addition, valuable additional precision has come this year by better fixes on the LEP beam energy using the resonance depolarization method (November 1991, page 12), where remaining uncertaincies of a few MeV (in about 100 GeV) come from tidal effects!

Stanford's SLC linear collider has long been in the shadow of LEP, but a new feature this year is the emergence of valuable data using polarized beams (July, page 1). With some 5,000 events analysed, asymmetry data presented at Dallas could not yet rival LEP precision in this particular sector, but this should soon be rectified, with a similar number still in the SLC data analysis pipeline.

Earlier, Persis Drell of Cornell had summarized the situation in weak decays, another physics area now benefiting from a lot of precision data. Much effort has gone into measuring the various B mesons (containing the fifth 'beauty' quark), with experiments at LEP, CLEO at Cornell's CESR ring, and Argus at DESY, as well as the E653 fixed target study at Fermilab all contributing. Unlike the comparable situation in the charm sector, where different mesons have different lifetimes, the B mesons (neutral, charged and containing a strange quark) appear to have fairly similar lifetimes. The recent appearance on the scene of B_s mesons, containing a strange quark, adds a new richness to this physics.

Another precision business is fixing quantitatively how the various quarks are related in weak decays, measuring the elements of the (Kobayashi-Maskawa) quark mixing matrix. A meson consisting of a heavy quark bound to a light antiquark can be looked on as a sort of hydrogen atom, and all sorts of hyperfine corrections applied to extract precision quark information. Hydrogen atom approaches to heavy quarks systems were also covered by Nathan Isgur of CEBAF in his talk on hadronic spectroscopy and structure, where heavy quark information provides valuable 'engineering' input for the quark mixing matrix.

LEP experiments now see substantial particle mixing in the neutral B meson system, an important step towards one day being able to look at CP violation in this sector and complement the information learned so far from neutral kaons.

In tau physics, concern has persisted for seven years about an apparent deficit of certain decays, where the sum of all the possibilities did not add up to 100%. Taking a hard look at the latest data, Drell did not advocate taking this deficit too seriously.

Another presentation reflecting the new wave precision physics came from Siegfried Bethke of Heidelberg, speaking on tests of quantum chromodynamics. A welcome arrival in this sector is fresh data on the quark structure of nucleons (structure functions) coming from the New Muon Collaboration (NMC) experiment at CERN. This helps to reconcile differences between previous measurements, although it comes too late for inclusion in some cases.

The analysis of hadron jet data from LEP has become a skilled trade, with the introduction of new algorithms. Valuable new jet data also comes from the E665 fixed target experiment at the Fermilab muon beam, which sees clear signals. The strong interaction coupling (alpha-s) has now been measured in a wide range of experiments, together covering a wide kinematic range and showing how it varies with energy, becoming very small as quarks effectively get closer together, a condition known in the trade as asymptotic freedom.

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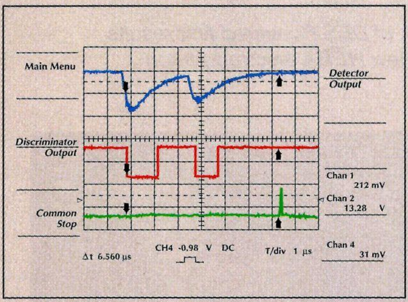

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4E060489	2	3	1161	-
4A07055F	2	3	1375	+
4E120369	2	9	873	-
4A130381	2	9	897	+

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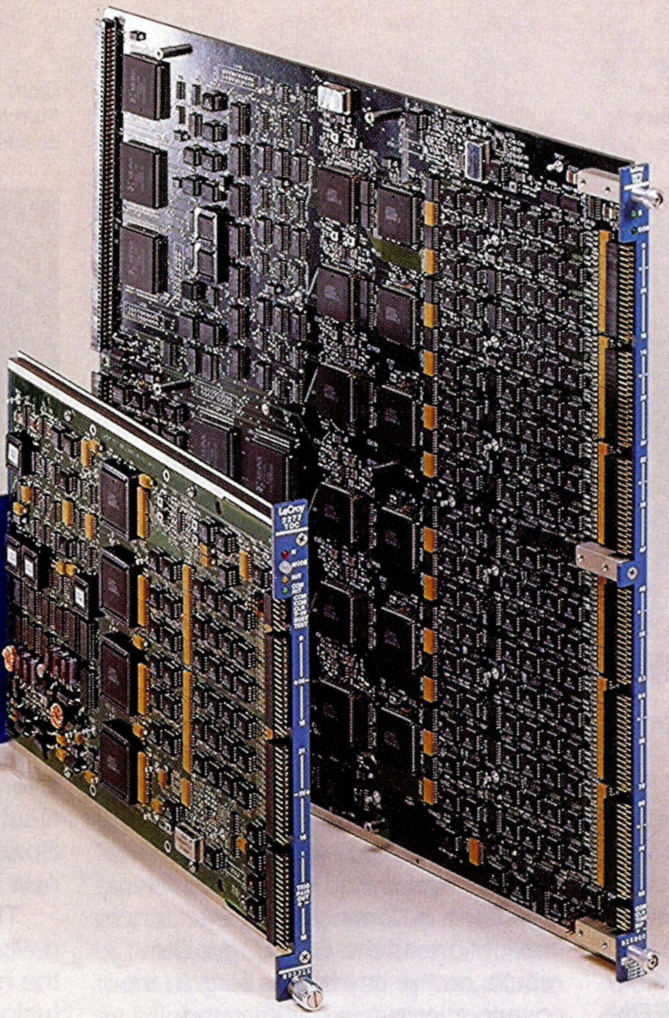

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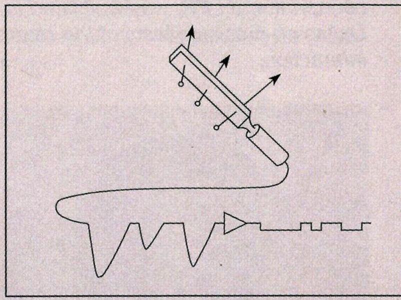

. . . of up to 16 leading and/or trailin edges can be digitized. Signals may b produced by one detector or detector multiplexed together. Pulse width capa bility allows pile-up affects to be see and measures time intervals which ca contain information such as pulse area.

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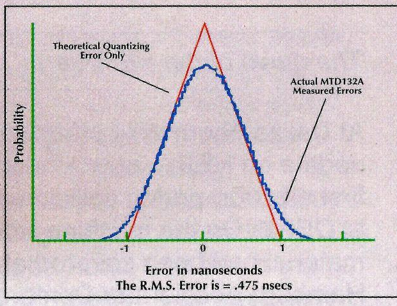

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Innovators in Instrumentation

Luigi Rolandi, as the current experimental coordinator at LEP, was well fitted to talk at Dallas on precision tests of the electroweak interaction.

Bjorn Wiik of DESY covered first results from the new HERA electron-proton collider.

The dawn of the HERA era

At Dallas, Bjorn Wiik proudly gave an update on HERA, now producing its first electron-proton collision physics at DESY. On the machine side, this material had been covered at the Hamburg Accelerator Conference (see page 9). After Wiik's talk, CERN Director General Carlo Rubbia initiated applause for DESY's 'nice achievement'.

Earlier, a historic parallel session included the first physics talks from the two HERA experiments (B. Lohr for Zeus and F. Eisele for H1). Both speakers showed how their detectors were producing very clean electron-proton collision data and probing some kinematic regions far removed from anything seen previously. In particular, they can already track how photoproduction rates behave in a new energy range, so that some bold theories can be scrapped.

With such clean physics information so soon, and with HERA still having a lot more luminosity up its sleeve, the future looks bright. This data will be invaluable for future SSC/LHC studies in the same way that structure functions from fixed target studies found ready application in the analysis of high energy proton-antiproton collisions.

Astrophysics and cosmology

There are two Standard Models in modern physics - the combined electroweak and QCD picture used by the particle physicists, and Big Bang cosmology. Astrophysics and cosmology sessions were once curiosities on the periphery of the programme at high energy physics conferences, but with these two Standard Models reaching out for each other, there is increasing contact between scientists studying the micro- and macrocosmos.

At Dallas, Lawrence Krauss of Yale summarized new developments in astrophysics and cosmology. Here, the scene is dominated by the implications of the COBE satellite results on the tiny fluctuations in the cosmic microwave background radiation announced earlier this year (June, page 1), and described in a Dallas parallel session by COBE senior investigator George Smoot of Berkeley.

Krauss explained how the COBE fluctuations, of the order of one part in a hundred thousand, give new insights into quantum gravity, into the inflation mechanism which is thought to have dominated the early Universe, and 'dark matter' - invisible material which has to be there to account for the observed motion of galaxies.

While the COBE fluctuations have been greeted as indicators of the initial quantum 'seeding' which gave birth to the Universe as we now know it, gravitational waves could also be playing a role. Smoot and his team are now processing the second year of COBE data, and the updated results are eagerly awaited.

Neutrinos

Neutrinos are always controversial. Even in the short time since the Neutrino 92 meeting in Grenada, Spain, in June (September, page 1) new results had emerged.

This year sees the first data from gallium-based detectors sensitive to the neutrinos from proton-proton fusion reaction which supplies the vast majority of the Sun's energy. At Grenada, the Gallex international team using a gallium detector in the Italian underground Gran Sasso Laboratory had announced the first signals of proton-proton fusion neutrinos. However the SAGE detector, operated by a US/Russian team in Russia, had declined to announce any results in June. At Dallas, SAGE reported a figure around 58 solar neutrino units (SNU), less than the result around 83 SNU reported by Gallex earlier.

With conventional solar neutrino calculations by John Bahcall predicting a total signal of 132 SNU, neutrino summarizer Hamish Robertson of Los Alamos preferred to take the average of the SAGE and Gallex results to get an observed signal which is 56% of the predicted figure. This discrepancy - the famous 'solar neutrino problem' - invites explanation in terms of Micheyev/ Smirnov/Wolfenstein (MSW) resonant mixing, an effect which has been described as 'so beautiful that Nature would be crazy not to use it'.

However the gallium results, based on small event samples, are still potentially unstable and the reported signals could yet change. Results reported by SAGE have been mobile.

A traditional feature in the neutrino sector is usually improved mass limits. This year the electron neutrino has been confined below about 10 electronvolts, and the tau neutrino below 31, rather than 35 MeV, with an improved result from the Argus experiment at DESY. However the muon neutrino has taken a step back from a previous limit of 270 keV out to 500 keV. Although still on the agenda, a possible17 keV neutrino continued to be shaky.

The Dallas meeting began, following the Rochester tradition, with a packed programme of parallel sessions, sometimes with up to six streams. With precision data and fine details now becoming the physics norm, it is in these sessions where much of the work is done. In these parallel streams, the mass of data from the four big LEP experiments was very evident in sessions on weak decays, B particle mixing, heavy quark production, searches for new particles, and electroweak parameters.

A detail emerging in the parallel sessions was news that the double vertex events previously reported from neutrino interactions by the CCFR collaboration at Fermilab (September, page 4) have not survived ongoing analysis.

For theorists, there was ample material to digest, and current theoretical developments were usefully summarized for everyone's benefit by H. Leutwyler of Bern (Nonperturbative approaches), L. Alvarez-Gaume of CERN (Field Theory and String Theory) and R. Petronzio of Rome (Lattice calculations).

Ongoing experimental work in heavy quark production was covered by Joel Butler of Fermilab, while Jürgen Schukraft of CERN dealt with heavy ion interactions, a field where useful progress is being made en route to higher energies and heavier ions.

The future

As the end of the Dallas meeting neared, the emphasis turned to future projects. Takahiko Kondo from the Japanese KEK Laboratory looked at detector development on a variety of timescales, from completed technologies now entering use, such as silicon microvertex detectors and ring-imaging Cherenkovs, to the intense development work now underway for experiments at the next generation of hadron colliders, where detector dimensions are set to enter a new ballpark and new technologies will play an important role. On the machine side, Robert Siemann of SLAC summarized future accelerator technologies.

CERN Director General Carlo Rubbia looked to the future of Europe in general and CERN in particular. Europe, with LEP at CERN pumping out prime data, with HERA at DESY now coming on, and with major experiments at the unique Italian Gran Sasso underground Laboratory beginning to be productive, is in a strong position.

'LEP is our crystal ball', declared Rubbia. With preparations at LEP now pushing ahead for its full collision energy of nearly 200 GeV, the

Michael Peskin of SLAC - looking beyond the Standard Model

crystal ball will become even clearer, and the upgraded machine could intercept some prime physics goals.

To maintain CERN's position requires a machine initially complementary to LEP and HERA before finally taking over as the physics spearhead, and this is the role of LHC - the 7.7 TeV per beam proton collider to be built in the LEP tunnel. A string of full scale superconducting magnets will be tested next year, while other preparations for LHC give promising results. Its injection system - CERN's existing chain of proton accelerators - has been tested in LHC-like conditions. Cryogenic plant is appearing as part of the LEP 200 programme. Rubbia also pointed out the attraction that LHC experiments have for physicists outside CERN Member States.

For the SSC, being built just a few miles away from Dallas, Roy Schwitters emphasized the international aspect of the project. For example Beijing is helping with the final stages of the injection linac and Novosibirsk is assisting with the challenging task of the Low Energy Booster.

The link between the linac and this booster was a critical SSC

bottleneck, said Schwitters. Increasing the transfer energy could pay handsome dividends in the brightness of the final beams. Meanwhile the first batch of 50mm diameter dipole magnets was delivering promising results (see page 21).

Trying to peer over the impenetrable Standard Model wall and look beyond, Michael Peskin of SLAC saw the Higgs mechanism as a parametrization, not an explanation. Despite the impenetrability of the wall, there could still be a map on the far side, with possibilities for strong and weak interaction routes. Comparing today's Standard Model with Columbus' picture of the world in 1492, Peskin looked forward to a voyage of discovery encountering an unexpected New World of physics.

With Texas-style organization, the 1400 participants at the Dallas meeting sometimes looked like a dot on the vast landscape. As well as having a chance to see SSC preparations at first hand, participants also profited from a specially arranged musical evening at Dallas' superb Myerson Auditorium, featuring Pinchas Zuckerman. Here was an object lesson how, after almost two hundred years, a Standard Model (of Mozart chamber music) is no obstacle to genius and technical mastery.

By Gordon Fraser

Hamburg Accelerator Conference

From 20-24 July, Hamburg welcomed the Fifteenth International Conference on High Energy Accelerators (HEACC). Although close on the heels of the European Particle Accelerator Conference, held in Berlin at the end of March (June, page 5), the Hamburg meeting emphasised the world rather than European view, avoiding the danger of repetition. A natural highlight was the recent commissioning success of the HERA electron-proton collider at Hamburg's DESY Laboratory and its first high energy electron-proton collision data. This gave the meeting the feel of a family event celebrating a newborn.

In his opening remarks, Conference Chairman Gus Voss of DESY related that six years ago, when DESY had offered to host the Conference, they had taken the risk that HERA might not be ready in time. He had been reminded of the risk many times during HERA construction but was happy to be able to report that the first collisions had already been observed and at full energy (July, page 2).

Tadao Fujii, representing the International Union of Pure and Applied Physics, was quick to congratulate the HERA team on its achievement - sentiments shared by all present, for HERA, the most recent and original addition to the world of large colliders was clearly star of the Hamburg show.

Since the previous HEACC, held three years ago in Japan, it appears that everyone, given the money, knows how to build a synchrotron. Now specialists either flock around the ultimate challenge of luminosity in the electron-ring factories or join the mushrooming R&D in the even more intriguing prospect of colliding two linac beams head-on. Another HEACC innovation noted by Gus Voss in his opening address was the large participation from the Commonwealth of Independent States - over 60 participants in all.

CERN Theory Division Leader John Ellis led 'morning prayer', as he put it, with a review of today's Standard Model physics and a look beyond. An outstanding physics objective is to find the sixth ('top')

The HERA electron-proton collider, now operating at DESY, Hamburg, was naturally the star of the International Conference on High Energy Accelerators, held in Hamburg from 20-24 July. Here conference participants get a close look at the new machine.

In his opening remarks, Hamburg Conference Chairman Gus Voss of DESY related that six years ago, when DESY had offered to host the Conference, there was a risk that HERA might not be ready. He had been reminded of that many times during HERA construction but was happy to report the first collisions at full energy.

quark at the upgraded Fermilab Tevatron. Once found, the next question is how precisely subsequent accelerators can measure its mass.

The LHC and SSC big proton colliders should produce millions of tops. Nevertheless to refine the precision of measurements of the top mass to 400 MeV might need a linear collider like TESLA (TeV Superconducting Linear Accelerator).

A major LHC and SSC objective is to search for the Higgs, although it might be found on the way with LEP upgraded to its full 200 GeV collision energy. HERA has outstanding potential for making discoveries in electron-proton physics probing unexplored kinematics to look for structure in quarks and/or electrons. Ellis wished HERA "Gute Reise - viel Vergnügung".

HERA

Following Ellis, session Chairman Gunther Plass moved the discussion to machines in general and HERA in particular. Bemused by the nomenclature of Ellis' SUSY particles, he was tempted to ask for a report on HERINO or SHERA. Unfazed, Ferdinand Willeke described the status of HERA, stressing international contributions from at least ten countries from North America through Europe to China.

The project to collide 820 GeV protons on 30 GeV electrons was approved in 1984 - three years after the proposal had been published as a design report. The electron ring was complete and had received its first beam at the time of the previous HEACC in Japan in 1989. The subsequent three years have seen completion of the superconducting proton ring, first cooldown at the end of 1990 and first stored beam in April 1991.

Effort had then alternated between installing the superconducting cavities to bring the electron ring up to full 30 GeV energy, and bringing the proton ring and its injector train towards full energy and intensity. There had been collisions at about half the design energy in October 1991 and this April, following tests of the superconducting proton ring at full energy, the detectors were made ready.

Prior to the Conference there were 40 runs with the luminosity monitors running. It normally takes five to ten shots to adjust the injector and fill the proton ring, each shot taking about five minutes. The injection field of the proton ring during the fill is only one twentieth of the full field and the HERA team has always been very wary of the effect of persistent currents. These eddy currents within the superconducting strands produce a hysteresis field which, through its non-linear perturbation of the guide field, can severely restrict the usable beam size or 'dynamic aperture'. To combat this, all magnets have been very carefully measured and reference magnets placed in the main magnet circuit so that the error fields can be measured on-line and corrections applied to multipole windings in the main dipoles. Fortunately the persistent current effects are very reproducible.

HERA's dynamic aperture is just a little smaller than simulation might suggest but nevertheless leaves enough room for the beam. The proton beam lifetime at full energy is 11 hours and the protons are often left circulating all day while the electrons are refreshed every four or five hours. This is heartening news for the designers of the next generation of hadron colliders. They may also draw comfort from the fact that the quench protection of HERA seems to operate with commendable reliability and magnets are recooled to 4.5 K within an hour.

At this early stage, the number of bunches in each of the colliding beams is only 10 out of the 200 eventually foreseen. There will be a concerted effort to add the feedback loops and injection controls needed to reach the full number of bunches in the next few months.

The other deliberate restriction is to keep the proton bunches from the DESY III synchrotron injector down to 10% of the full design intensity. Although DESY III has recently reached 70% of the design value, caution prevails until beam stability can be guaranteed. The highest luminosity per crossing recorded in recent runs is 6×10^{28} and is, as one would expect, about 10% of the design value. Averaged over the 40 runs so far the luminosity per crossing is 10^{28} and the specific luminosity (luminosity per milliamp squared) is as theory predicts.


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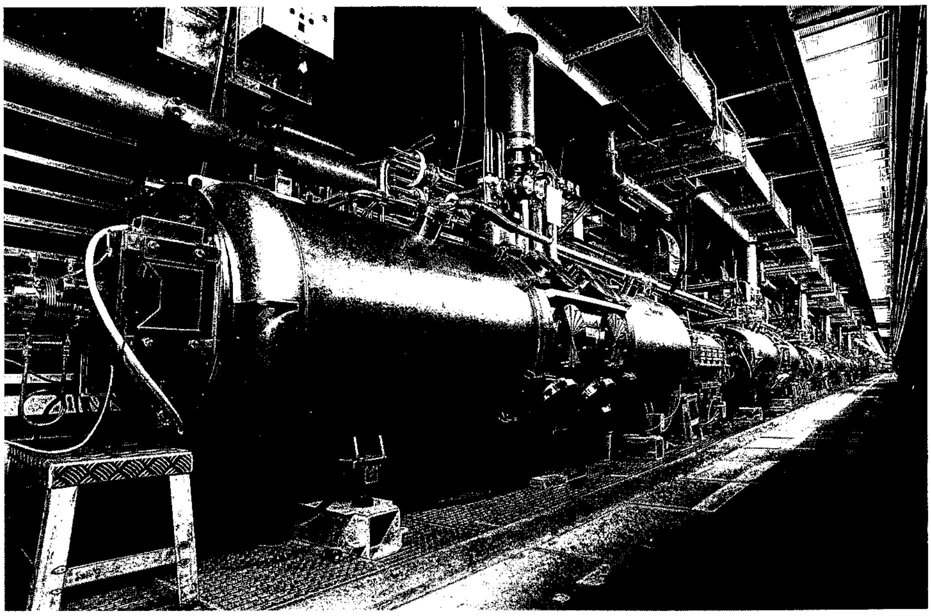
Since February, all 8 groups of superconducting radiofrequency cavities at the HERA electron ring have been in routine operation to enable the beam to attain 30 GeV. They have been extremely reliable.



Big proton machines with superconducting magnets

At HEACC, nobody was allowed to forget that magnets are still the most expensive and difficult single system in large accelerators. Apart from Fermilab's Tevatron and now HERA, where superconducting rings are in daily operation, four big accelerator projects depend on a mastery of this technology. The two mega-colliders - CERN's LHC and the US Superconducting Supercollider (SSC) - bring the superconducting magnet game into a new league. The RHIC heavy ion collider being built at Brookhaven too will be entirely equipped with superconducting magnets, while UNK in Russia also plans a cryogenic ring.

Giorgio Brianti's LHC report included the good news that the four short models of the twin aperture LHC dipole had reached 9 T in a few quenches. Two; which were fully tested, had even reached 10 T but after many quenches. A full-length (10-metre) twin aperture prototype powered with HERA-type coils had been tested at Saclay and reached the field of 8.3 T expected from these coils - the so-called short sample performance - at 1.9 K in a few quenches. There were no nasty surprises therefore from this crucial initial trial of a two-in-one configuration using a full length prototype.

The quenches in the models seemed to be at the ends and new support structures were being studied with a view to improving coil-end support under the huge forces in this challenging magnet. Computer studies of direct machining of these supports and ways of lowering the field in the ends were also underway.

Other changes to the design - always preserving the aim of 7.7 TeV proton beams - include making the half-period of only three, longer, dipoles rather than four, and replacing the space-consuming central correction assembly with integral correction in all magnet ends. This results in a better ratio of TeV per Tesla which allowed a slight increase in inner bore to 56 mm and a reduction in the field necessary to reach the design energy from 10 to 9.5 T.

January 1993 should see the first long prototypes delivered and others would follow in the course of the year for assembly into a 100 m half-cell for a string test.

The SSC team described the production of full scale industrial 50mm-aperture prototype dipoles. Ten of these had been made by General Dynamics following the design and tooling developed at Fermilab and seven others by Westinghouse following the development at Brookhaven. All were impressive in reaching their design field with little need for training. Some of the design variants tried out in the Fermilab-GD Design would probably be dropped in favour of those in the Brookhaven-Westinghouse configuration in which the two halves of the lamination meet in a horizontal plane. However, judging by the good-natured rivalry between protagonists of the two camps, the decision was still sub-judice.

In a comprehensive review, S. Wolff first gave details of the successful production of the dipoles for HERA. Over 400 dipoles had been delivered by two manufacturers within twelve months and only 26 had been returned for repair to the manufacturers - the majority for vacuum problems. All but a small percentage reached peak current after the second quench and, protected by cold diodes, quenches did not propagate, the persistent currents were reproducible and schemes to correct them worked well. These schemes had to take into account coupling between the main dipole field and that applied by the correction windings in the same assembly

For UNK, G.G.Gurov said the 21-

kilometre tunnel was now essentially complete and more than half the room-temperature magnets for stage 1 were manufactured. All the superconducting magnets for the next stage were being made in-house and already 25 had been tested. There was a certain amount of training in the first 10 quenches but these were all close to 6 T compared with the design value just above 5 T. The droop of the quench current as a function of ramp-rate was 10% at 300 A/sec. A string test was to be mounted in 1995 and the 3 TeV superconducting ring scheduled for completion in 1998.

A prophetic remark came at the end of Wolff's review when he showed recent performance of high temperature superconductors in the form of silver-sheathed wire for winding coils. Wires had as yet been produced only in 100m lengths; but measurements at 4.2 K showed that the critical current was comparable with the value expected in conventional superconductors but with no sign of falling off - so far - up to 30 Tesla. "Start thinking of 20 T magnets!" Wolff challenged.

Linear colliders

Perhaps the biggest innovation on the technical front since the previous HEACC is the growth of worldwide interest in linear colliders. A number of practical tests are underway or planned at CERN, DESY, KEK, and SLAC, as well as in Russia, and not forgetting the TESLA collaboration. Clearly accelerator physicists are taking the challenge of seeing beyond this century's circular colliders very seriously indeed.

There seems to be a general consensus to aim for 500 GeV collision energy and many research

At the Hamburg Accelerator Conference, CERN Theory Division Leader John Ellis led 'morning prayer', with a review of Standard Model physics.

centres feel they should stick to a frequency at which power sources, if not already available, seem to be a reasonable extrapolation of today's technology. Three proposals; In Russia, at KEK for the Japanese JLC, and at SLAC for a proposed NLC are designed for X-band frequencies or thereabouts. Two others are at the more 'conservative' end of the parameter scale. One of these - a collaboration between DESY and Darmstadt's Technische Hochschule (DTH) - is designed for S-band. The other, TESLA, involves an impressive collaboration in which DESY and DTH are joined by CERN, Cornell, Fermilab, Karlsruhe, KEK, Frascati, INFN Milan, Saclay and Wuppertal. This scheme takes the L band approach and proposes superconducting cavities for its main linac.

CERN, with an eye on the far future beyond its LHC proton collider for the LEP tunnel, is on the adventurous flank of the distribution in still proposing its own drive linac as a 30 GHz power source. However it has now lowered the collision energy in its CLIC (CERN Linear Collider) scheme from 2 to 0.5 TeV, in line with other proposals.

The advanced hardware design of some of new collider schemes was evident in the talk of D. Trines of DESY who described the design of the cryogenics for a superconducting linear collider with full engineering detail of the 9-cell cavity and its 1.8 K cryostat.

Reviewing the accelerator issues of these machines, N. Holtkamp of DESY distinguished between those of X-band and above, that economise beam power but reach their design luminosity by virtue of a small spot, and the newer lower frequency designs - DESY and TESLA - where the spot size, tolerances and instability thresholds are less stringent and in which many more bunches of more particles may be accelerated to ensure a high luminosity.

The important issues for linear collider experts remain the design of damping rings and bunch compressors, alignment, the effect of both short- and long-range wakefields which can cause longitudinal and transverse instabilities and problems of final focus design where beams must be collimated against background without the image fields in collimator jaws causing beam deflection. Holtkamp drew attention to recent work on focussing structures by R. Ruth at SLAC, which concluded that the main cause of emittance growth was the chromatic behaviour of the betatron function, and by G. Guignard at CERN who showed how to use beam position monitors and correctors in an algorithm to obtain an orbit independent of chromaticity.

Greg Loew of SLAC made his own review of the S and X- band studies of conventional linear colliders, likening the final focus of the higher aspect ratio machines to unrolling 500 sheets of toilet paper and then trying to collide them head-on. In his tour of klystron development he noted that for the

The Hamburg Accelerator Conference coincided with the 90th birthday of linear accelerator pioneer Rolf Wideroë, who chaired a morning session. Tributes came from far and wide. The role of Wideroë in accelerator history is often overlooked because of the subsequent focus of effort on circular machines.

proposed Japan Linear Collider (JLC), working at 11.4 GHz, Toshiba were developing a klystron which had reached 24 MW for 100 ns and eventually would need eight times this power and four times the pulse length. He singled out the VLEPP klystron, later described in more detail by V. Balakin, which had no modulator but was controlled with a grid and where a compression scheme gave a factor 6 with 66% efficiency. Binary pulse compression was a topic for a later paper by P. Wilson where a series of four directional couplers and four delay lines gave a theoretical pulse compression gain of 2^3 from one klystron.

Looking to the next four years, Loew listed the crucial tests already planned in parallel at many Laboratories. At SLAC there would be an attempt to produce a 60 nanometre flat beam at the Final Focus Test Beam due to be checked out in the spring of 1993. This would be followed by the 600 MeV NLC test accelerator to be developed at SLAC in the next three years. More details were given by J. Paterson of SLAC. Meanwhile in Japan the 1.54 GeV ATF (Advanced test Facility) linac, already in an advanced stage of design and installation, would be used for research and development with the later addition of a damping ring (described by S. Takeda of KEK). Clearly this facility was advancing rapidly and would soon be giving important results of worldwide interest.

Still on Japan Loew remarked how High Power Processing - gradually training cavities to support more and more MV/m - had been shown to increase the peak field by almost a factor 2.

In Europe the S-band test facility planned for 450 MeV at DESY would start in 1993 while in Russia a multi-GeV 14 GHz linac prototype starts an ongoing programme of studies this year.

Maury Tigner expected major economies in the cost per linear metre for these assemblies before the next HEACC as the TESLA linear collider team strives to reduce the cost by a factor four from the present $200,000/m.

Loew concluded his entertaining talk with his suggestion for a site - pointing out that, at least on a Mercator projection of the planet, Antarctica was clearly the most linear of continents and therefore the obvious choice!

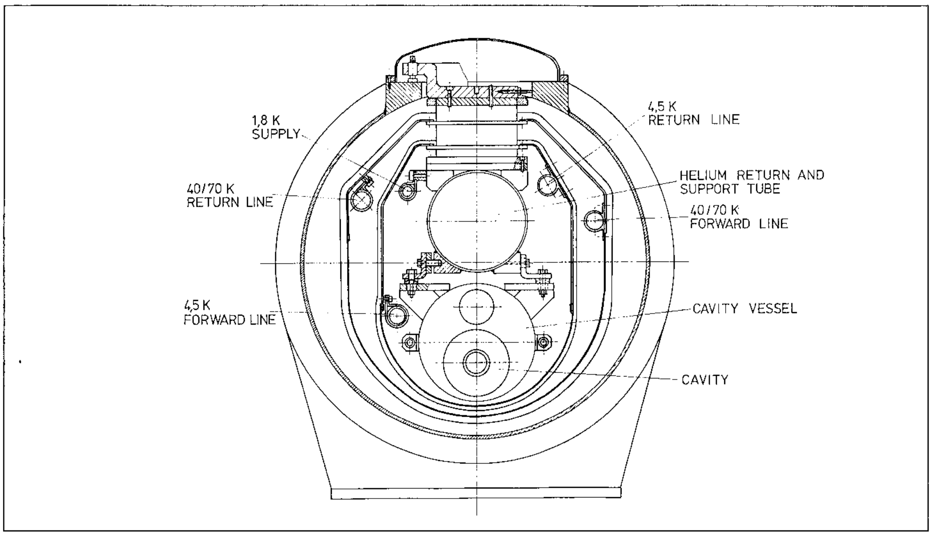
Superconducting cavities

A technology that has boomed since the previous HEACC is the development of superconducting cavities. In Japan in 1989, KEK had reported that the superconducting cavities in TRISTAN had already been operating for many months; S. Noguchi was now able to update this information. After a total of four years there had been no important degradation in performance without beam although for high luminosity runs they had recently had to reduce the field to 75%.

In the interim, HERA's electron ring at DESY has become another machine operating with superconducting cavities - Diether Proch was able to report that HERA has 16 superconducting 500 MHz cavities in 8 cryostats all of which exceed a Q of 10^9 at 5 MV/m. They are limited by power through the input coupler and when the current rises above 20 mA the gradient is reduced as a precaution. However the 16 cavities are most reliable and had been supervised by the normal operations crew without the need to call in experts.

Superconducting cavities have found a place in projects as diverse

TESLA - TeV Superconducting Linear Acceleration - is being hailed as a good route to future high energy linear electron-positron colliders, and many research centres are collaborating in TESLA R&D work. This shows a cross-section for a possible TESLA design.



as particle factories, both linear and circular colliders, recirculating linacs and in heavy ion storage rings. Their low R/Q is an advantage in controlling beam loading in proton and electron rings. Wolfgang Weingarten of CERN, in a review of the superconducting cavity scene, mentioned that production lines at CEBAF, CERN, Darmstadt, DESY and KEK had between them made 200 units with fields averaging 9 to 10 MV/m and at best, in the lab, as high as 16.5 MV/m. The Q values were typically 3.5 to 5.4 x10^9 and at best 7 x10^9. Both at CEBAF and CERN, all but one or two cavities met the specification. This was in spite of the fact that CERN had raised specifications in response to good results from niobium-coated copper cavities

Performance in operation was generally not as good, but every research centre had its own quite different practical reason for this, ranging from insufficient cooling to synchrotron radiation background.

(The second part of this Hamburg report, covering the status of the major current accelerator projects, will feature in our November issue.)

By Edmund J.N. Wilson, Leader, CERN Accelerator School

Around the Laboratories

CERN
The best of the bunch

As other factors governing the electron-positron collision rate in CERN's LEP 27-kilometre storage ring reach their limit, one way of coaxing the collision rate higher is to increase the number of bunches stored in the ring.

Normally LEP operates with four bunches in each of the counter-rotating beams. This gives collisions at eight evenly-spaced points, the four sites occupied by the big LEP experiments - Aleph, Delphi, L3 and Opal - and the intervening points, as yet unoccupied. To avoid the latter unwanted collisions, the beam orbits are locally 'bumped' by electrostatic separators.

Increasing the number of LEP beam bunches beyond four in an effort to increase the luminosity (collision rate) would also result in additional unwanted collisions in the arcs of the machine. These cause deleterious beam-beam effects and reduce the beam lifetime dramatically, but can be avoided by installing additional electrostatic separators to pull the beam orbits apart at many places in the arc.

This technique, known as the 'pretzel' scheme, has resulted in significant performance improvements at Cornell's CESR electron-positron ring. Proton-antiproton colliders have also benefited from pretzels - the performance of CERN's collider improved following a transition from 3- to 6-bunch operation, and electrostatic separators have also been fitted to Fermilab's Tevatron.

With the decommissioning of CERN's proton-antiproton collider, electrostatic separators became

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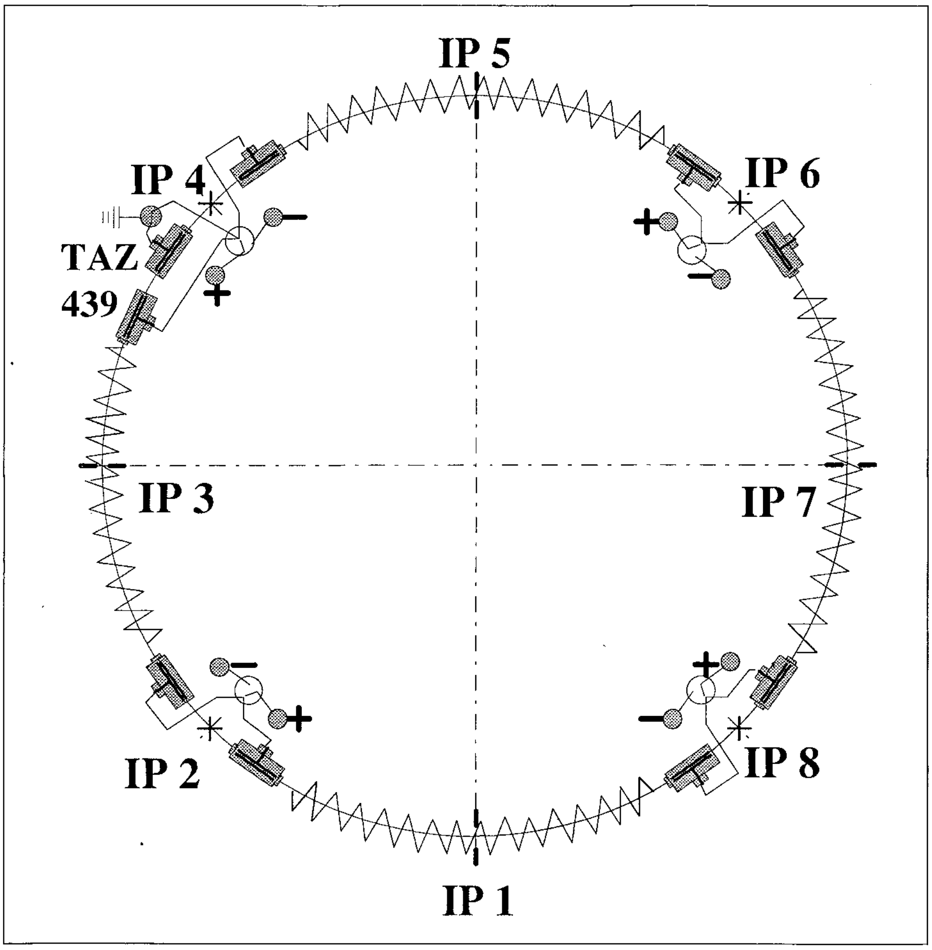
The full 'pretzel' scheme in CERN's LEP electron-positron collider enables the number of colliding bunches to be increased beyond the four initially foreseen. To suppress the additional (unwanted) collisions, extra electrostatic separators have been installed around the (even-numbered) interaction points (IP) to 'bump' the beams. The TAZ is an additional test area.



available for installation in LEP last year. Firsts tests in 1991, with four separators, were hampered by sparking, but this was soon overcome with suitable polarity settings and initial investigations of beam dynamics in the 'half-pretzel' scheme were encouraging.

Most LEP operation this year has used a new 'low emittance' optics (with 90 rather than 60 degrees of betatron phase advance in each arc cell) which provides the smaller beam sizes needed now for the pretzel scheme and later for collision energies near 200 GeV. Although luminosities were initially lower, the use of the 'emittance wiggler' magnets gave more stable beams in collision and boosted the accumulated luminosity, despite slightly lower peak figures.

The powerful new 'polarization wigglers' to lengthen the bunches at the injection energy of 20 GeV, together with additional correction and feedback systems, has provided beam currents to match those achieved with 60 degree operation.

Unlike the pioneer CESR pretzel scheme at Cornell, in which the particles are injected into the storage ring at their nominal energy, LEP operation is complicated by having to accelerate the beams prior to bringing them into collision. Thanks to the new optics, these problems were completely overcome in the first 1992 LEP pretzel trials. With the full complement of eight separators in place, first full pretzel LEP running in 1992 used eight electron bunches with four of positrons, and modest luminosities were recorded.

An unforeseen setback delayed further pretzel studies, and two further machine development runs for pretzel tests were specially scheduled. For the first time, eight bunches were injected in both beams. An interleaved injection scheme to fill the two groups of four bunches per beam on alternate cycles of the SPS (as LEP injector) was tried and worked well. With all the polarization wigglers at maximum field at injection, a 16 mm separation between the bunch encounters in mid-arc gave currents above 300 microamps per bunch with good injection rates.

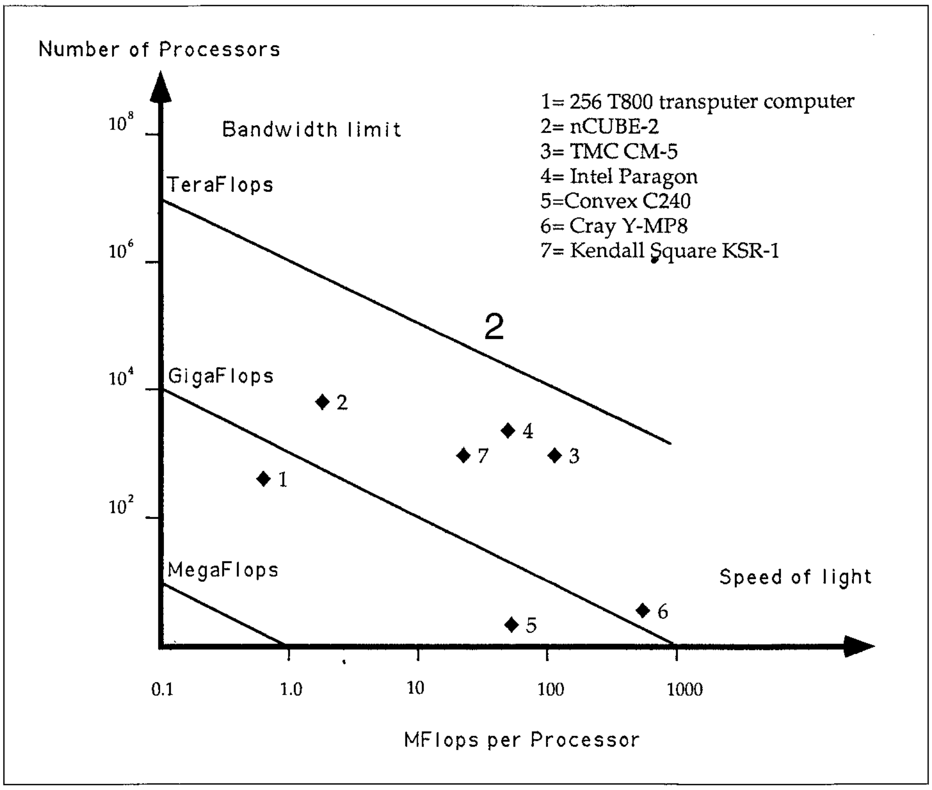
Total beam currents of over 4 mA (in both beams) were successfully ramped to 45.6 GeV with negligible losses. The electrostatic separators were ramped to keep the pretzel separation constant and the beams were squeezed as usual with no losses. Healthy luminosities resulted, comparable to those achieved in four-bunch running.In an attempt to improve the luminosity, some progress was made in improving the beam crossings. The LEP experiments took advantage of this run to test out their triggers and timing systems with eight bunches per beam. Under the optimum polarity scheme, the electrostatic separators behaved themselves. In the second run, on 19 August, physics conditions were officially 'declared' for some 10 hours.

Before the pretzel scheme can be brought into regular operation, the tricky business of eliminating miscrossings has to be mastered. This should result in increased luminosity and reduce background at the experiments.

Meanwhile LEP is now performing well after some initial problems with 90-degree operation earlier this year. The introduction of polarization wigglers to increase the bunch length has improved beam currents, and initial luminosities are now comparable to those seen previously with 60-degree operation (some 7 x 10^{30} per sq cm per s). New software facilitates ramping and squeezing the beams, with shorter turnround times between physics coasts.

With better understanding of the complicated LEP procedures and improved skill in carrying out tricky manipulations, the luminosity can be maintained for longer in the coasts. This gives higher integrated luminosities, so that with the four experiments having already passed last year's score, they should substantially add to their score of accumulated Zs.

Is Massively Parallel Processing the future of supercomputing? Computer performance (measured in Mega-, Giga-, or Teraflops) can be improved by playing on the number of processors used (vertical axis) and the power of each processor (horizontal axis). In the former case, the limiting factor is the ability of all the processors to talk to each other, while in the latter it is simply the speed of light. Some solutions (5, 6) go for a few high performance processors, while others (1, 2) use assemblies of more modest units to achieve their goals.



Massive parallel processing

On 19 June at CERN, an important meeting organized by CERN's recently established Massively Parallel Processing (MPP) steering group highlighted some special future needs of high energy physics computing. It was attended by more than 110 scientists, including physicists from external institutes and representatives from computer industries.

The major aim of the event was to present physicists with preliminary results from investigating this technology at CERN and assessing the commercial market. Another objective was to initiate discussion and establish plans for further action in this field, where Massively Parallel Computing technology could dramatically increase the computing power available for high energy physics.

P. G. Innocenti, leader of CERN's Electronics and Computing for Physics (ECP) Division opened the meeting by reviewing the current understanding of computing for experiments at the LHC proton-proton collider to be built in CERN's LEP tunnel. He presented in general terms the foreseen trigger and data acquisition architecture and explained some basic parameters that make LHC computing a challenge if there is no accompanying breakthrough in computer technology.

L. Robertson, responsible for RISC farming services in the computer centre and co-ordinator of MPP activities in CERN's Computing and Networks (CN) Division, reviewed what has been learnt in developing and exploiting computing farms for several different applications at CERN, explained some limitations of this approach and presented the plans of the MPP steering group.

B. Dobinson, ECP co-ordinator of MPP activities, presented the CERN experience in MPP projects developed in the framework of the European ESPRIT programme. F. Gagliardi from the MPP steering group reviewed existing technology and compared the major MPP products available on the commercial market, and I. Willers, also from the MPP steering group, presented the most relevant programming techniques and software paradigms for MPP. Turning to applications, U. Wolff from the CERN Theory Division surveyed for lattice field theory simulations and concluded with a call for investment in this kind of computing.

F. Carminati of the MPP steering group discussed the potential for data analysis and event simulation. S. Cittolin, leader of the ECP Read-out Architecture group, explained his view of the LHC data acquisition architecture. He expressed some doubts about the cost effectiveness of MPP versus computing farming in this particular field and concluded that interactive data analysis was the most likely application for MPP technology at CERN.

G. Shering reviewed problems in the accelerator and engineering design and on-line control areas. Several programs developed by physicists and by industry require large amounts of computing power and have been traditionally run on powerful supercomputers. Amongst other examples, he mentioned the LHC magnet simulation and particle tracking programs, which can easily take 10 hours of CPU time on a Cray.

However other applications, notably magnets and radiofrequency cavities, will need a major increase in computing power to move from two to three-dimensional design, while the complexity and the prototyping cost of future accelerator design should naturally call for more accurate and powerful simulation.

In a panel discussion, R. Brun set the ball rolling by presenting some benchmarks produced by the College de France, running Geant on a parallel machine (Telmat T800) with different parameters to simulate event, primary track and secondary track level parallelism.

Some physicists shared his scepticism on sub-event parallelism, while others expressed concern on the I/O capability of existing MPP products. However people felt more comfortable with data visualization applications because of the analogy with database applications already successfully demonstrated on MPP commercial platforms.

R. Bock presented some benchmark trigger architectures in RD-11. After explaining the shortcomings and advantages of SIMD, MIMD and other parallel systems in this domain, he concluded that general-purpose MIMD systems could may be of interest if the network latency problem could be minimized.

Physicists from large LEP collaborations underlined the importance of writing code for MPP in portable and hardware independent fashion. The price-performance ratio of MPP versus workstation-based computer farms was deemed to be critical. Everybody concurred that an organized approach is called for to better understand MPP and try out some real applications on a modest, but reasonable, hardware platform. This could be done in collaboration with external institutes and firms.

Summarizing, CN Division Leader D. O. Williams pointed to the need to plan further technical investigations, set up a forum to discuss benchmark results, and explore collaboration with manufacturers and other centres already active in the field. It will be vital to try out typical applications on a real machine as soon as possible. This new technology will be successful only when all involved have easy access to MPP.

(A mailing list has been set up to keep people informed of the MPP steering group's activities. Contact F. Gagliardi, CERN CN Division, e-mail FAB@vxcern.cern.ch.)

From F. Gagliardi

SUPERCOLLIDER
String test success

On 14 August at the Superconducting Supercollider (SSC) Laboratory in Ellis County, Texas, the Accelerator Systems String Test (ASST)successfully met its objective by operating a half-cell of five collider dipole magnets, one quadrupole magnet, and two spool pieces at the design current of 6500 amperes.

This major milestone for the SSC was met six weeks ahead of the schedule established two years ago. Cooldown began in June and current was slowly raised, testing the quench protection system along the way. The test demonstrated the quality of the industrially assembled magnets and the associated power, cooling, and control equipment to operate together successfully as a system.

The magnets were assembled this spring by General Dynamics personnel working at Fermilab, and were cooled by a specially built helium refrigerator. General Dynamics is now preparing a plant in Hammond, Louisiana for eventual high rate production of collider dipoles, and Westinghouse is preparing a similar facility in Round Rock, Texas. Magnets assembled by Westinghouse workers at Brookhaven will also be tested at the ASST.

The ASST will continue to be a valuable test bed for magnets, spool pieces, control software, refrigerator operating software (optimizing for efficiency), and magnet installation procedures. Magnet tests will be include longevity, thermal cycling effects, ramp rate effects, and other operating conditions. Future ASST activities will involve one and

On 14 August at the Superconducting Supercollider (SSC) Laboratory in Ellis County, Texas, SSC preparations passed a major milestone when a half-cell of five collider dipole magnets, one quadrupole magnet, and two spool pieces operated at the design current of 6500 amperes.
(Photo SSCL)

perhaps two full cells of magnets, mounted one above the other as they will be in the collider. Early next year the first of twelve large helium refrigeration plants, designed to cool a sector of the collider in operation, will be ready and can be tested using the magnet string as a heat load.

AARHUS
ASTRID goes exotic

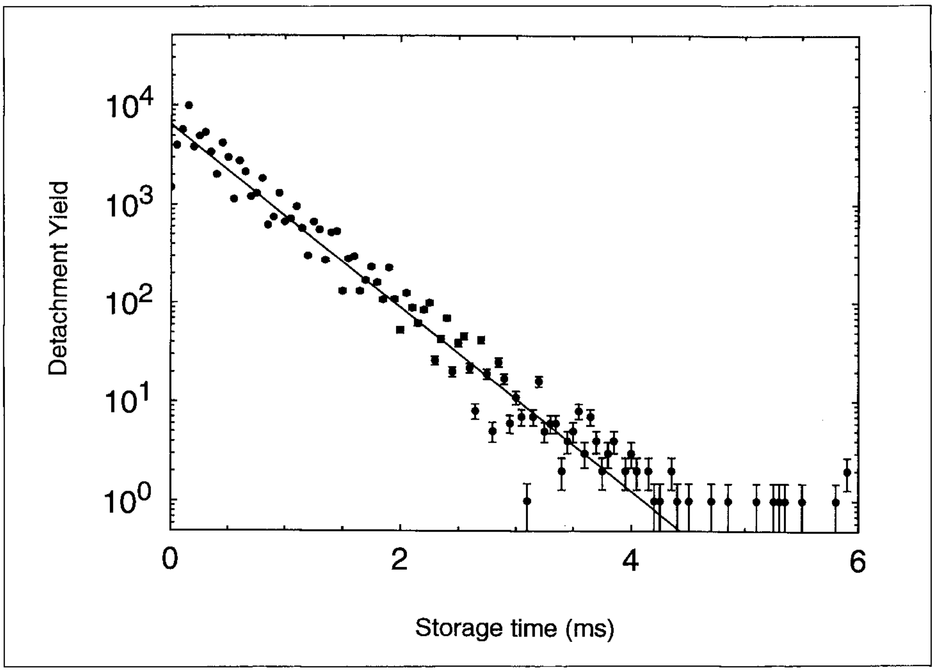
The ASTRID a multi-purpose storage ring at Aarhus, Denmark, built to function as a 560 MeV synchrotron-radiation source and as a heavy-ion storage ring (July/August 1990, page 16), is now the scene of interesting beam cooling experiments.

Laser-cooling experiments using a positive lithium beam have been in progress for two years, giving momentum spreads down to about 10^{-6}. Also electron recombination experiments using an electron cooler are underway. The ring is now also operational for electrons, with circulating currents in excess of 100 mA.

Recently ion species which were not even thought of in the design phase of the project have been stored. Negative ions, with their characteristically low electron affinities and high collision probabilities, are a challenge. Previously negative hydrogen ions had been stored only at CERN's LEAR low energy antiproton ring. With ASTRID, many different ions and molecules of negative charge have been stored to investigate the effects responsible for the finite lifetime of the beam: vacuum pressure, intrabeam stripping and field stripping.

A new stripping mechanism was identified for loosely bound electrons, namely ionization by the black-body radiation emitted from the surrounding vacuum chamber. By heating the vacuum system, usually done for vacuum bakeout, this stripping mechanism could be increased.

Lifetime of a beam of 100 keV negatively-charged calcium ions as measured in the ASTRID storage ring at Aarhus, Denmark, showing the residual submillisecond lifetime due to ionization by black body radiation.



The actual experiment with negative ions was to measure the lifetime of metastable (autoionizing) beams of negative helium, beryllium and calcium ions, with lifetimes of a fraction of a millisecond. The storage ring replaces the multi-kilometre beamline which would otherwise be necessary for the lifetime measurement.

Also positive beams of the recently discovered giant 'buckyball' C-60 molecule have been stored in ASTRID to investigate the lifetime of excited C-60 ions. This is by far the heaviest ion ever held in a storage ring.

DARMSTADT Beta decay into bound states

In nuclear beta decay, a neutron decays, emitting an electron and an antineutrino. Nuclear beta decay should also be possible where the resultant electron, instead of being given off, remains bound in the daughter atom. This is the 'time-mirror' process of electron capture by the nucleus.

In the past, analyses of tritium lifetimes have hinted that such atoms can be formed, and now direct evidence comes from using fully stripped dysprosium-163 ions in the ESR storage ring at Darmstadt's GSI heavy ion Laboratory.

Neutral atoms of dysprosium-163 are stable, but fully stripped (66+) ions can beta decay into hydrogen-like atomic levels of holmium-163 66+ (there are only a few cases where this happens). To detect this, up to 10^8 Dy 66+ ions at 294 MeV per nucleon were stored and electron cooled in ESR.

During the storage, the daughter holmium ions, having very similar charge-to-mass ratio as their parents, were stored and cooled on the same orbit. The holmium daughter atoms were monitored using a gas jet to strip their electrons and produce detectable holmium 67+. Independent confirmation came from analysing the Schottky noise of the stored ions before and after their interaction with the gas jet, which showed a significant signal due to holmium 67+.

Although such decays are only of minor importance for neutral atoms, they might play a major role in the astrophysics of highly ionized atoms of stellar plasmas during nucleosynthesis. In some cases, the lifetimes change drastically, from say a few years to 10^{10} years.

WORKSHOP QCD at 20

The modern theory of strong interactions - Quantum Chromodynamics (QCD), where quarks and gluons carrying the 'colour' quantum number play the essential role, is twenty years old. This birthday was duly celebrated at RWTH Aachen from 9-13 June, where recurring themes were - what has been achieved in the past twenty years?, where do we stand?, and what are the perspectives for the future?

The opening talk by Richard Taylor from Stanford (SLAC) described the high energy physics scene into which QCD was born. He showed how the violent (deep inelastic) lepton-nucleon scattering experiments at SLAC, and subsequently at other Laboratories, revolutionized ideas of hadrons, and he went on to explain how these experiments were inseparably linked to the birth and subsequent development of QCD.

However in the following talk F. Wilczek reminded the audience that many questions which QCD was supposed to answer 20 years ago remain unanswered. As he put it - 'QCD is only half solved'. While we think we understand the short distance regime (asymptotic freedom) where the quark forces are weak, we still lack a good understanding of longer distance effects, in particular when quarks and gluons are 'confined' inside hadrons.

The impressive story of QCD in the short distance regime was unfolded at the workshop by theorists and experimentalists. The structure functions (quark and gluon content) of the nucleon, as measured in various deep inelastic electron, muon and neutrino scattering experiments, are now in very good shape. Previous discrepancies between different measurements seem to be resolved and the kinematic behaviour (violations of Bjorken scaling) are in excellent agreement with QCD (M. Virchaux).

The wide spectrum of hadronic decays of the Z particle obtained at CERN's LEP electron-positron collider are a real bonanza for QCD studies (S. Bethke, J. Drees, B. Webber). In particular, Z decays into four jets open up the gluon self-coupling and its colour structure. Very satisfyingly, the self-coupling of the gluon and its eight colours are now explicitly verified by experiments.

Another important milestone is the experimental demonstration that the strong coupling 'constant' decreases with increasing momentum ('runs') precisely as predicted in 1973 with the discovery of asymptotic freedom, one of the pillars of QCD. Hadron-hadron collisions at high energies provide another QCD testing ground and there too theory generally compares well with experiment (S. Kuhlmann).

The theoretical tool to investigate QCD short distance phenomena is perturbation theory. A. Mueller reviewed its status where various Borel plane singularities like ultraviolet and infrared renormalons lurk to trap the unwary theorist.

Progress was reviewed by G. Altarelli and J. Stirling. For almost all reactions of interest, the next-to-leading-order corrections are known, thanks to heroic efforts by theorists. This allows meaningful extractions of the coupling constant from many hard scattering processes, as summarized by Altarelli. If the various values are scaled to the Z mass for comparison, they are consistent with a mean value at the Z mass of 0.117± 0.007, where the latter figure is a mixture of the experimental error and an educated guess at theoretical uncertainties.

Guido Altarelli - meaningful extractions of the QCD coupling constant from many hard scattering processes.

The transition to the long distance QCD regime, where theoretical understanding is less solid, was taken by E. Reya and E. Levin, who examined the spin structure of the nucleon and quark/gluon densities where a constituent quark carries only a small fraction of the total proton momentum (small Bjorken x). Why does the traditional constituent quark picture of the nucleon come unstuck when trying to explain the spin-dependent quark structure of the nucleon at high energies? Will small x multi-quark/gluon effects be seen in electron-nucleon scattering? Answers will come from the experiments just beginning at DESY's HERA electron-proton collider.

P. Landshoff moved further out in long distance physics, looking at the soft reactions which have only recently started to come under close QCD scrutiny. Here the challenge is to understand simple phenomenological rules, known since the 1960s, in QCD terms.

Deriving the spectrum of hadrons from QCD principles is another perennial theoretical goal. Results from calculations using hypothetical lattices (E. Laermann, R. Kenway, C. Michael) improve slowly but steadily. An example of progress in this sector are the nice results on quark-antiquark binding, which now check with phenomenology. However a milestone still to be reached in these calculations is to have a rho meson heavier than two pions.

QCD also needs glueballs (particles composed of gluons rather than quarks). The experimental search continues and appears to have some new candidates in hadronic reactions (E. Klempt), while the classic iota and theta glueball candidates have a hard time under detailed scrutiny (C. Heusch).

The foundations, successes and limitations of the QCD sum rule approach were reviewed by M. Shifman. Not far from first principle calculations, they have nevertheless become an indispensible tool for correlating various hadronic phenomena in terms of a few 'vacuum condensates'. Indeed the naive picture of the vacuum as being empty was definitely ruled out, at least theoretically, by K. Johnson. In contrast to familiar constituent quarks, he could see no meaning for a 'constituent' gluon.

For massless quarks, the natural chiral (left-right) symmetry of QCD is spontaneously broken by massless pions (as the corresponding Goldstone bosons). At higher temperatures, the chiral symmetry should be restored and the quarks deconfined. The blossoming of chiral perturbation theory, which dates back

36 *Circle advertisement number on reader service form*

25 *Circle advertisement number on reader service form* to the 60s, was described by H. Leutwyler. Among many solid results in this sector, the combination of chiral perturbation and lattice techniques looks a promising way to get low energy hadron physics parameters.

The transition from QCD confinement to deconfinement is still more accessible on the lattice than in laboratory heavy ions collisions. F. Karsch showed exciting hints from lattice simulations for a complicated non-perturbative structure of the quark-gluon plasma near the critical temperature.

Progress in heavy ion collisions was reviewed by H. Satz. Good probes for monitoring the QCD phase transition have now been devised by theorists, and the 'smoking gun' may be provided by the production of the J/psi and related particles.

The future will bring new challenges for QCD. G. Wolf summarized the status of HERA, where a new chapter in deep inelastic scattering is about to begin, with the nucleon structure being explored down to $2x10^{-16}$ cm.

The long awaited sixth (top) quark, where indirect evidence points to a mass around 130 GeV, should soon show up at the Fermilab Tevatron. Startling new QCD effects are predicted for top physics (J. Kühn) due to the interplay between electromagnetic and strong interactions at these energies. Weak decays of hadrons containing heavy quarks (C. Sachrajda and A. Buras) is another frontier.

John Ellis looked at how QCD could fit eventually into a larger Theory of Everything, and Harald Fritzsch summarized. While QCD has some remarkable achievements to its credit after 20 years, there are still challenging problems to be solved in the next 20 years.

By O. Nachtmann

Looking at the antiworld

A popular pastime among amateur scientific historians is tracing key concepts in twentieth century physics back to their origins. Participants at the Antihydrogen Workshop in Munich on July 30-31 were astonished to hear 1989 Nobel prizewinner Wolfgang Paul mention in his introductory remarks that W. Nernst referred to antimatter as far back as 1897.

Nernst thus 'beat' Dirac by some 30 years, (breaking by a matter of months the previous record, held by A. Schuster's 1898 letter to *Nature*). These historical footnotes enhance Dirac's achievement in demonstrating the existence of antimatter as the price paid for combining quantum mechanics and special relativity.

As every physicist knows, Dirac turned the embarrassing 'redundant' solutions of his relativistic wave equation for electrons to good effect, hypothesising that they corresponded to '...a new kind of particle, unknown to experimental physics, having the same mass and opposite charge to the electron...'. The positron obligingly appeared in 1932, but the discovery of the antiproton had to wait a further quarter of a century, and it was only at that time that the relationship of matter and antimatter was finally seen in terms of the CPT (charge conjugation/parity/time reversal) theorem.

In 1981, CERN began to mass-produce antiprotons, stacking millions of millions of them at a time for physics experiments. A few years later Fermilab too built an antiproton factory.

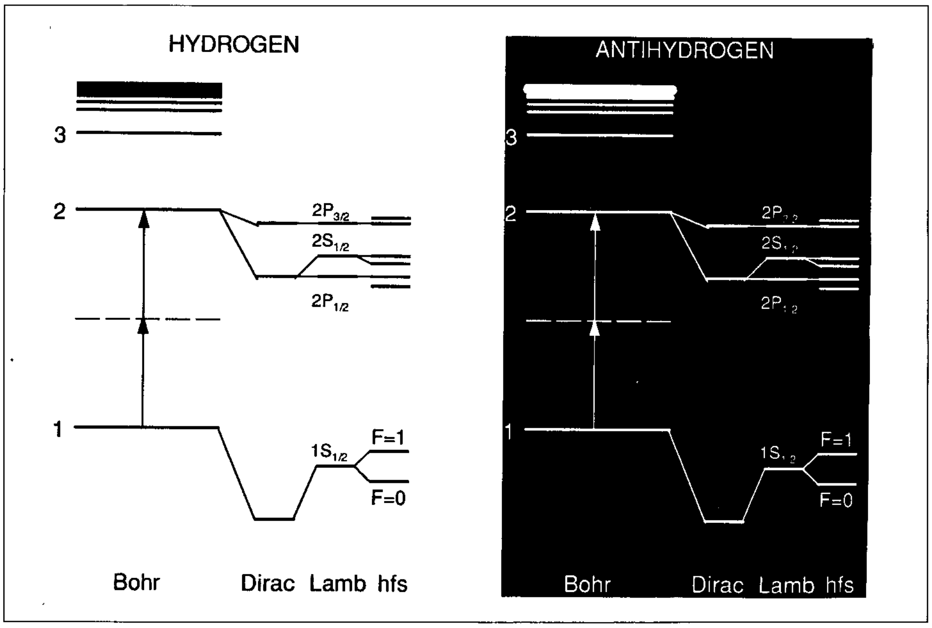
In spite of all this work with antiparticles, not one atom of antihydrogen has yet been synthesized for study in the laboratory. The enormous strides now being made in cooling, trapping, storing and manipulating charged and neutral particles, as well as in ultra high precision laser spectroscopy should soon change this.

The aims of the workshop were to review progress in these areas, assess the potential of antihydrogen as a test bench for answering fundamental questions of physics, and guide current deliberations on the future of the antiproton programme at CERN.

The workshop attracted some 100 participants from all over the world. The unifying nature of anihydrogen studies was evident in the diversity of their research backgrounds, which ranged from atomic to nuclear and particle physics, from laser spectroscopy to permanent magnet design, and from accelerator physics to cosmology. There were some eleven hours of oral presentations and discussions, as well as 23 posters.

Wolfgang Paul's introduction was followed by R.J. Hughes (Los Alamos) who reviewed the physics potential of high precision atomic spectroscopy of antihydrogen. Seen simply as a probe of CPT, such measurements are capable of reaching with atomic matter the four parts in10^{18} precision given by the neutral kaon system.

If sacred physics laws hold good, the atomic spectra of hydrogen and antihydrogen should be identical. Any difference matter and antimatter spectroscopy would signal would signal some profound physics. (Diagram by R.J. Hughes, Los Alamos.)



At this level of precision, the gravitational properties of antimatter play a role. Any anomalous gravitation of antimatter would reveal itself as an annual or daily variation of any difference observed in the behaviour of hydrogen and antihydrogen. The gravitational weak equivalence principle could then be tested on antimatter to about one part in 10^8, a precision approaching that of Eotvos-type measurements on bulk matter. Paradoxically, direct empirical tests at the cosmic scale 'Planck energy' (10^{19} GeV) seem to be achievable by experiments done at the ultra low antiproton and positron energies conducive to antihydrogen formation.

Continuing in cosmic vein, A.D. Dolgov (Moscow) reviewed cosmologies which permit or require overall matter-antimatter symmetry in a Universe which, CPT notwithstanding, appears to contain only one kind of matter, at least up to the galactic cluster scale. In a talk on the astonishingly high precisions now achieved in atomic spectroscopy, workshop chairman T.W. Haensch (Munich), described techniques which push spectroscopy measurements of (ordinary) hydrogen to one part in 10^{12} - like comparing a human hair to the size of the earth. Even this impressive limit could be pushed further with laser techniques rapidly advancing towards an ultimate precision of one part in 10^{18}!

Production of antihydrogen from its antiproton and positron constituents was the topic of a session entitled 'Routes to Antihydrogen'. A third body is required to conserve energy-momentum in such syntheses. For high precision work the most fruitful route seems to be via chemical recombination reactions at meV (milli-eV) energies, in which the third body is either an electron (initially bound with the positron in a positronium atom), or a second positron.

In the first case, being investigated in Aarhus, the positronium atoms would be produced by positrons in the wall of a trap containing cold antiprotons, while the second possibility, under study at Harvard, would use a 'nested trap' to hold particles of different charge at the same time.

The recombination reaction was the most thorny of all the problems addressed in the workshop, and further studies will be needed before either of the two techniques can be favoured. A third 'chemical' possibility was presented by E. Widmann (Tokyo) exploiting the recently discovered metastable antiprotonic helium states (June, page 14), and a 'high energy' method was discussed by C. Munger (SLAC), involving electron-positron pair production by a GeV antiproton beam in the E760 gas jet target at Fermilab. Finally, laser-induced recombination was discussed by A. Wolf (Heidelberg). Although any one of these three possibilities might conceivably produce antihydrogen first, none of them seems to offer the physics potential of the two main experimental approaches.

A further paradox now becomes clear: since antiprotons and positrons are not produced at meV, but at MeV (or GeV) energies, accelerator physicists have to aim for deceleration instead. The CERN team (represented by P. Lefèvre) summarized the progress and perspectives for low energy beams from the LEAR low energy antiproton ring, in which 10^9 antiprotons can now be stored down to 2 MeV.

H. Kalinowsky (Mainz) then reported on the next stage of deceleration, from MeV to keV energies. Degrading by foils is easiest, the foil serving as a window into the high vacuum region needed for long term survival of antimatter. While the overall efficiency is small compared with that of more elaborate post-decelerators such as radiofrequency quadrupoles or

inverse cyclotrons, the simplicity of the method makes it the clear favourite.

G. Gabrielse discussed recent progress in trapping keV antiprotons emerging from deceleration foils and their 'cooling' to meV energies. Electron cooling in such traps works extremely well, and has permitted his PS 196 experiment at CERN to accumulate more than 10^5 antiprotons at 4.2 K (0.3 meV) in their attempt to reach a one part in 10^9 comparison of the charge/mass ratios of protons and antiprotons.

The same group recently demonstrated the feasibility of transporting trapped particles by moving a trap filled with electrons across the United States. 'You can regard this as serious work or as a cheap stunt!', said Gabrielse. If a stunt, it is still necessary since ultra high precision measurements must be done far from the electromagnetically noisy environments near particle accelerators.

Several routes to the production of cold low energy positrons were discussed by M. Charlton (London), including the use of beta emitters produced at CERN's ISOLDE on-line isotope separator and positrons from electromagnetic showers produced either in a special purpose electron accelerator or in the LIL LEP injector linac.

After production, antihydrogen must itself be confined or trapped to prevent it from annihilating on the walls of its container. This can be done using the 'restoring' force produced by a magnetic quadrupole field on the positron's magnetic moment. J.T.M. Walraven described how this technique has been perfected with atomic hydrogen at MIT and Amsterdam and reviewed the prospects for further cooling within such traps from K to mK temperatures using Lyman alpha lasers which are now close to reality.

Summarizing, D. Kleppner of MIT, himself a pioneer in the trapping of spin polarized atomic hydrogen, said that comparison of normal and antihydrogen will be of tremendous interest. The probability of violating sacred physics laws like CPT and the equivalence principle may be low, but these laws have to be tested to the limit.

Comparing the present situation with that of the 1987 Karlsruhe symposium on atomic antimatter, Kleppner added that progress in hydrogen spectroscopy 'exceeds our wildest dreams of five years ago', while trapping and cooling of charged particles to temperatures of a few K and of neutral atoms to millikelvin levels (both of which looked 'wild' in 1987), are now demonstrated facts.

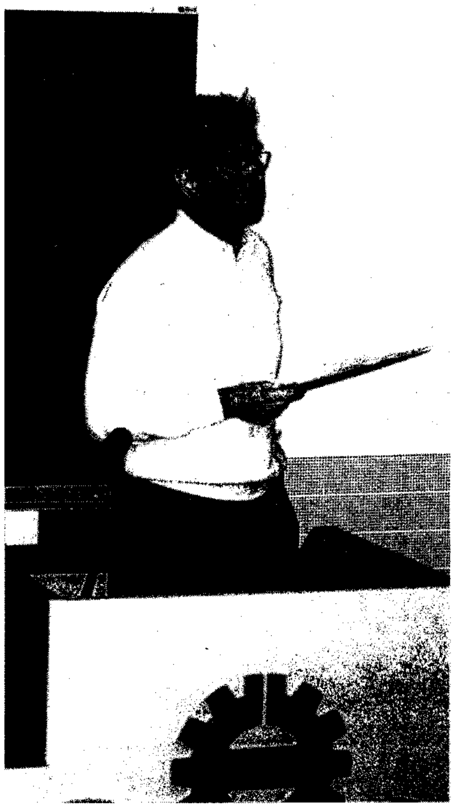
In hydrogen spectroscopy, the attainable resolution is now kHz instead of MHz in 1987 and will soon be reduced to Hz. The challenge in antihydrogen formation is to combine these techniques. Even if deep underlying symmetries withstand the attack, we will learn a lot about both fundamental symmetries and new technology.

From John Eades

Signal Processing

Signal processing techniques, extensively used nowadays to maximize the performance of audio and video equipment, have been a key part in the design of hardware and software for high energy physics detectors since pioneering applications in the UA1 experiment at CERN in 1979.

New technology for physics. Y. Neuvo reviewing median based filters during the recent Signal Processing for LHC workshop in Tampere (Finland).



In addition to the problem of disentangling the signal produced by the particles in the detectors from noise, advanced image processing algorithms will be needed in future experiments to pattern recognize events of interest. Thus a topical Signal Processing Workshop was jointly organized by CERN, the Finnish Research Institute of High Energy Physics (SEFT) and the Tampere University of Technology (TUT), from 2 to 4 July in Finland.

Specifically in the context of applications for the LHC proton-proton collider to be built in CERN's LEP tunnel, the workshop aimed at triggering cross-fertilization between the HEP community and experts eager to contribute. It gathered more than 50 participants and was hosted by TUT's Signal Processing Laboratory.

(This Laboratory, inaugurated in 1988, concentrates on the areas of digital video, digital audio, biomedical signal processing and VLSI system design. Applications of non-linear filters (median based algorithms) are a speciality. It also collaborates extensively with TUT's Electronics laboratory, founded in 1967.)

During the first part of the workshop, engineers and physicists gave an overview of detectors, front-end electronics, trigger and data acquisition systems for LHC and a number of other areas. This was followed by surveys of more than ten ongoing TUT activities, such as Linear Median Hybrid filtering and multi dimensional median signal processing (together with their implementation in VLSI), module generators, floating point formats, neural net hardware (analogue and digital), image processing algorithms, etc.

Three working groups (short floating point format, median and neural net applications, Application Specific Integrated Circuits and processors) were formed to identify areas of common interest to prepare for future collaboration.

People and things

On 4 August, CERN hosted a symposium to celebrate the 80th birthday of Chien Shiung Wu, famous for her 1956 discovery of parity violation in beta decay. The event also underlined Professor Wu's important role model for women physicists. Speakers included (left to right) Marie-Anne Bouchiat, Cecilia Jarlskog, Chien-Shiung Wu herself, Felicitas Pauss and Luisa Cifarelli.

(Photo CERN HI 5.8.92)

On people

1988 Nobellist and former Fermilab Director Leon Lederman joins the Illinois Institute of Technology. As well as continuing physics research, he will also teach introductory physics to freshmen. 'Increased math and science literacy is important to our society,' stresses Lederman.

Robert Kiefl, Assistant Professor at the University of British Columbia, has been awarded the 1992 Herzberg Medal (for outstanding achievement in any field by a physicist under 40) by the Canadian Association of Physicists for his muon spin resonance studies at the Vancouver TRIUMF Laboratory.

ICTP Dirac medals

The Dirac Medals of the International Centre for Theoretical Physics, Trieste, are awarded this year to Yakov Sinai of Moscow's Landau Institute for his work in theoretical physics and mathematics, and (posthumously) to N. N. Bogolubov, formerly of the Joint Institute of Nuclear Research (JINR), Dubna, near Moscow, who made many contributions to theoretical physics (April, page 28) and who directed JINR for more than 25 years. He died in February.

Research Director Pierre Darriulat represented CERN at the opening of the 'Inside the Atom' exhibition which opened at Warsaw's Technical Museum on 17 August and ran until 13 September. The exhibition concentrated on CERN and national particle physics activities. Poland became a CERN Member State in 1991.

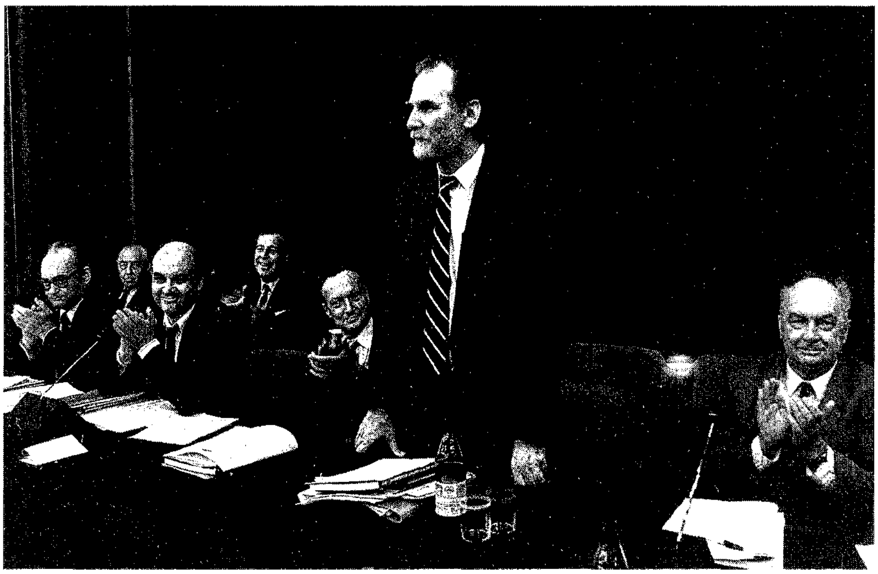
Meetings

The 1993 ICFA School on Instrumentation in Elementary Particle Physics will be held at the Tata Institute for Fundamental Research, Bombay, from 15-27 February 1993. This is the fifth in the series of such schools, which so far have been held at the International Centre for Theoretical Physics (ICTP) Trieste, except for the third School, in 1990, organized by CBPF in Rio de Janeiro. Further information from Suresh Tonwar, Tata Institute for Fundamental Research, Homi Bhabha Marg, Navy Nagar, Colaba, Bombay 400 005 India, fax +91 22 215 2110, e-mail tonwar@tifrvax as soon as possible.

The 42nd in the series of Scottish Universities' Summer Schools in Physics will take place in St. Andrew's, from 1-21 August 1993. With the title 'High Energy Phenomenology', it will be aimed at senior postgrads, at research fellows and at senior staff looking to change fields. School Director is David Saxon at Glasgow. Further information from School Secretary A. Walker, Room 4409, Department of Physics, University of Edinburgh, James Clerk Maxwell Building, Edinburgh EH9 3JZ, Scotland, e-mail A.Walker@uk.ac.ed

In June, Vladimir G. Kadyshevsky was elected Director of the Joint Institute for Nuclear Research (JINR), Dubna, near Moscow, for five years, succeeding D. Kiss. Here Kadyshevsky (standing) is applauded by (left to right) I. Savin, V. Dzhelepov, Ts. Vylov, A. Rumyantsev, R. Pose, and A. Baldin.

(JINR Photo, Yu. Tumanov)



Dubna council meeting

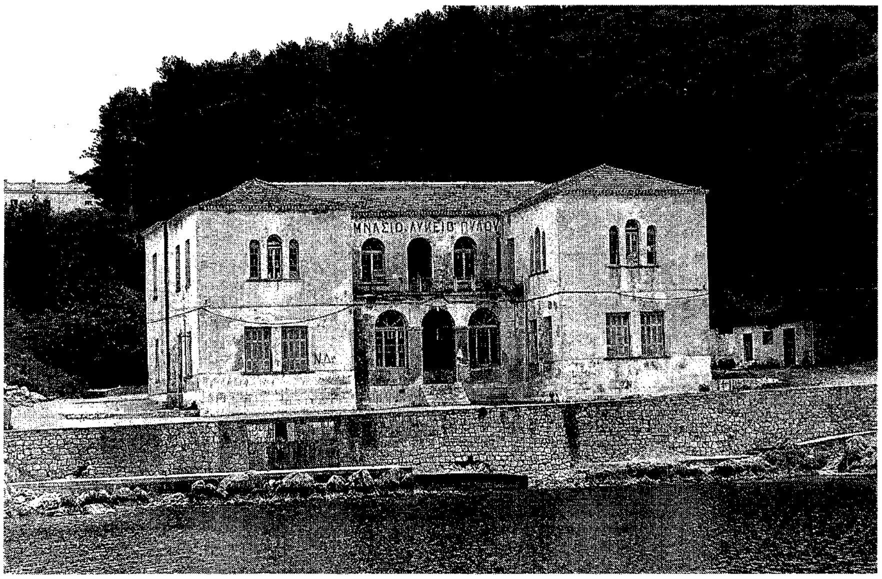
A special session in June of the governing body ('Committee of Plenipoteniaries') of the Joint Institute for Nuclear Research (JINR), Dubna, near Moscow was attended by delegates from the 17 Member States under the chairmanship of Russian vice-premier Boris Saltykov, and with representatives of the governments of Germany, Italy, Latvia and Lithuania attending as observers.

The Committee elected Vladimir G. Kadyshevsky as the Institute's Director for the next 5 years (from 23 June) and expressed their thanks to former Director Deszoe Kiss of Hungary. The Institute's new charter was also approved.

This charter had been drawn up at a previous meeting of the Committee in March, when the Republics of Armenia, Azerbaijan, Georgia, Kazakhstan and Moldova became JINR Member States. Reports on future JINR projects covered a high resolution neutron source based on a 100-150 MeV electron accelerator and uranium breeder, a tau-charm factory, two heavy ion storage rings (K4 and K10, with energies up to 1 GeV per nucleon) and the NK-10 synchrotron radiation source.

It was recommended that work for the high resolution 8-10 GeV neutron source (IREN) should begin this year. Current plans also include completion of construction of the Nuclotron (a superconducting ring for taking nuclei across the whole Periodic Table up to 6-7 GeV per nucleon), and the improvement of heavy ion accelerators and the IBR-2 pulsed neutron reactor, as well as continuation of existing experiments using accelerators at CERN and nearby Serpukhov (IHEP) as well as in the US. The JINR Laboratory of Theoretical Physics was named in honour of former JINR Director and distinguished scientist N.N. Bogolubov who died earlier this year.

The 1992 JINR budget remains at the previous year's level, clearly insufficient in view of economic difficulties in Russia and other JINR Member States.



Now being renovated is this building in Pylos, Greece, made available to the NESTOR collaboration mounting a large-scale underwater neutrino experiment in the sea nearby. The collaboration, which currently has European and national funding for initial construction, is hosting an informal workshop on Pylos from 19-21 October. For further information e-mail 14220::nestor or vxcern::resvanis. An article on this imaginative new project will feature in next month's edition.

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DESY - More electron polarization and more protons

At the end of August at the DESY Laboratory in Hamburg, the HERA electron ring, working at 26.7 GeV, achieved polarization levels of some 50 per cent, a major improvement on initial polarization trials late last year (March, page 18). At the same time, machine specialists also saw the expected rate of increase of polarization.

A few days before, the DESY III synchrotron, which supplies the HERA proton ring, achieved its design level of 1.1 x 10^{12} particles at 7.5 GeV, a current of 165 milliamps.

New Physics

'The New Physics' is the title of a new book from Cambridge University Press (ISBN 0 521 30420 2 hardback, 0 521 43831 4 paperback) edited by Paul Davies. While the first 30 years of this century are traditionally viewed as a 'Golden Age' of physics, the subject is still in rapid evolution, contends Davies, and the book is intended as a 'snapshot' of these new frontiers.

It includes 18 chapters, each written by a specialist. Topics of direct interest to particle physicists include 'The inflationary universe' by Alan Guth and Paul Steinhardt, 'The edge of spacetime' by Stephen Hawking, 'Quantum gravity' by Chris Isham, 'The quark structure of matter' by Frank Close, 'Grand unified theories' and 'Effective quantum field theories' by Howard Georgi, 'Gauge theories in particle physics' by John Taylor, and an overview of particle physics by Abdus Salam.

Benefiting from oscilloscopes

Instrumentation specialists LeCroy Corp of Chestnut Ridge, New York, has just published a new Application Note (Ref ITI 013B) entitled 'Benefits of Digital Oscilloscopes in Communications', describing ten useful oscilloscope applications, including bus testing, phase shift keying, waveshape testing, triggering,....

Copies are available from LeCroy in the US, call 1 800 5 LeCroy, or fax +1 914 425 8967; or in Europe from Marc Schumacher at LeCroy's Geneva office, 2 rue du Pré-de-la-Fontaine, 1217 Meyrin 1, Switzerland, fax +41 22 783 0227.

Fermilab best luminosity

The proton-antiproton collider at Fermilab's Tevatron is performing well in this year's run. On 14 September it broke its previous best luminosity, attaining 3.19 x 10^{30} per sq cm per s, beating its previous best of 2.07 x 10^{30} set on 9 December 1988. At CERN's proton-antiproton collider, which operated at a collision energy of 630 GeV compared with Fermilab's 1800 GeV, a record luminosity of 6.05 x 10^{30} was attained on 25 November 1990.

Hosting the Sunday afternoon 'Cowboys and Culture' entertainment for the attendees at the International High Energy Physics Conference in August was Kay Granger, Mayor of Forth Worth.

How to visit CERN

Comment visiter le CERN

Organized visits take place only on Saturdays, at 9.30 a.m., and/or 2.30 p.m. The visits last about three hours and are free. The minimum age limit is 16 years.

Les visites commentées ont lieu seulement le samedi, à 9 h. 30 et/ou à 14 h. 30. Elles durent environ trois heures et sont gratuites. La limite d'âge minimum imposée est de seize ans.

Please write or call:
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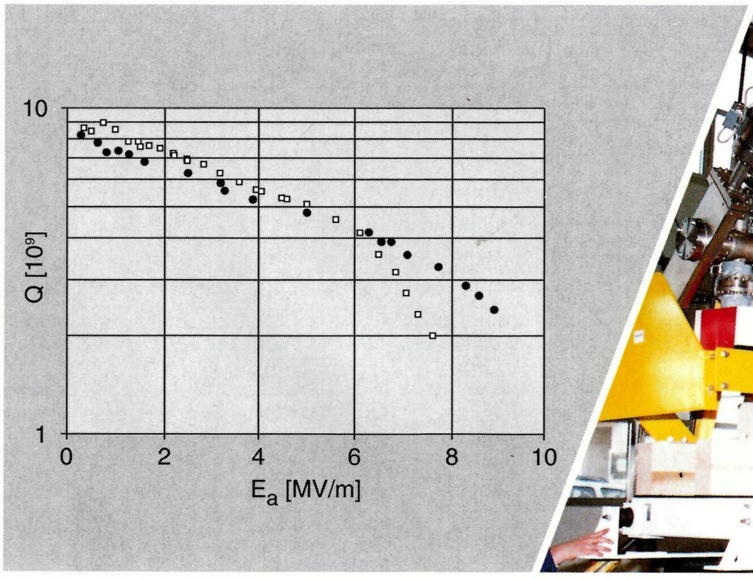

A96001-U02-Z239

Typical curves for cavity Q vs accelerating field E_a

A completely assembled cavity with cryostat before transport to CERN

Up to now, pure niobium has been used to produce superconducting accelerator cavities. Taking into consideration that the rf current only penetrates a few hundred nm into the superconducting surface, CERN followed the idea of sputtering a thin layer of niobium onto a copper cavity and developed the procedure for coating 350 MHz multicell cavities.

This idea was challenge enough for our engineering and fabrication departments: after only one year of intensive technological cooperation with CERN the first niobium sputtered superconducting accelerator cavity surpassed the design values (Cavity $Q = 4 \cdot 10^9$ at $E_a = 6$ MV/m).

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