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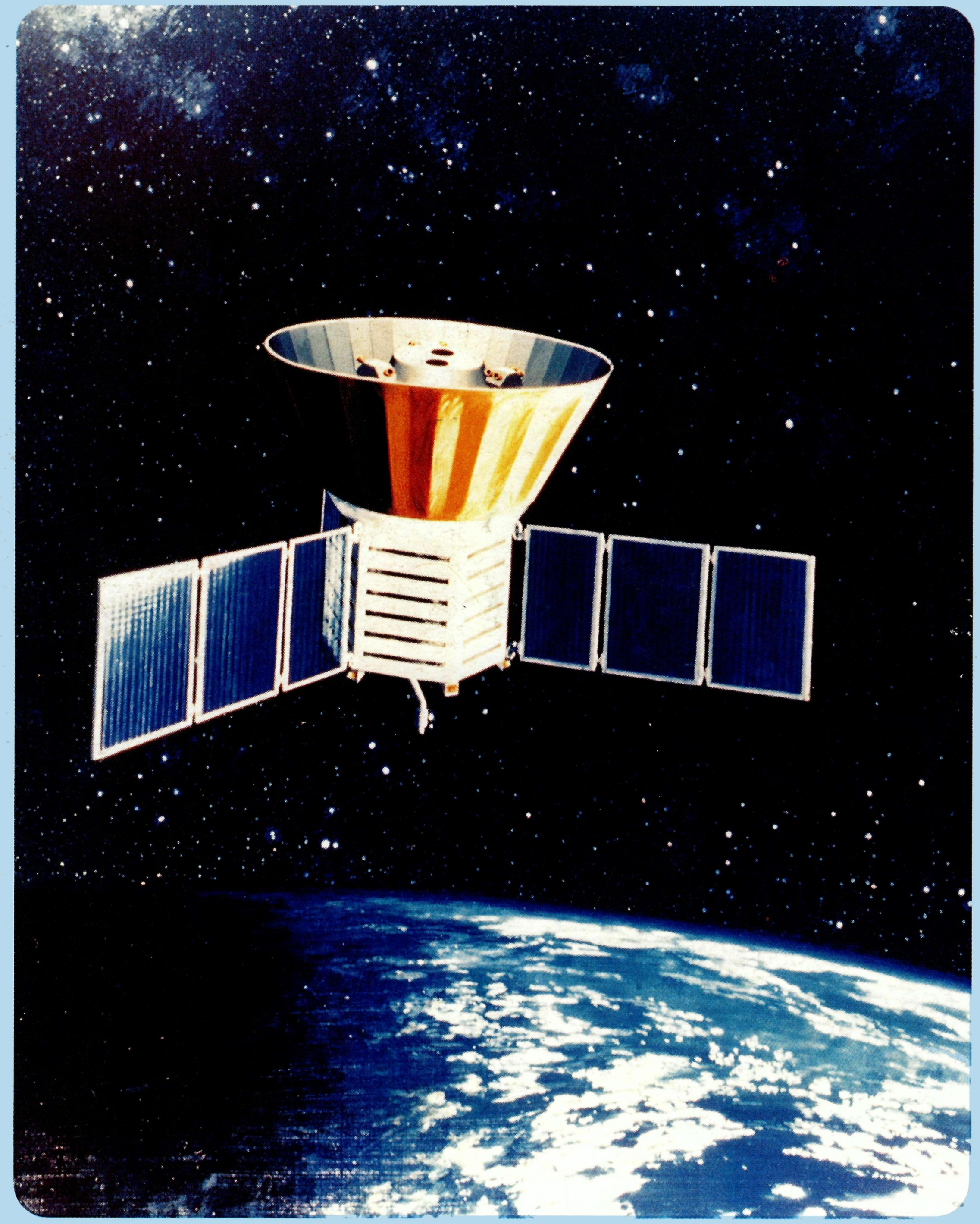

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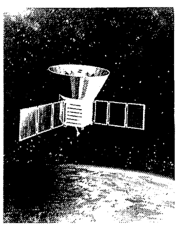

Cover photograph:
NASA's COBE satellite has given a close look at the cosmic background radiation and underlines the 'Big Bang' origin of the Universe (see page 1).

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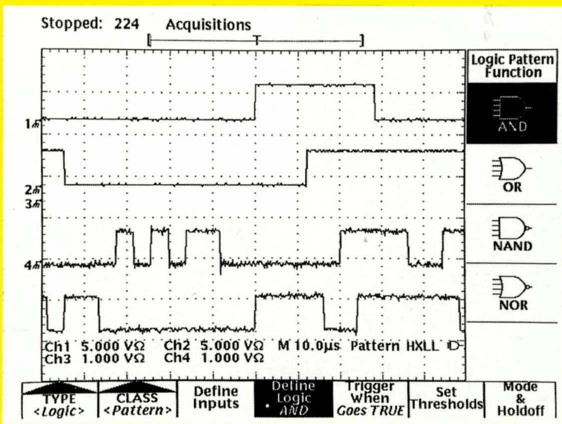

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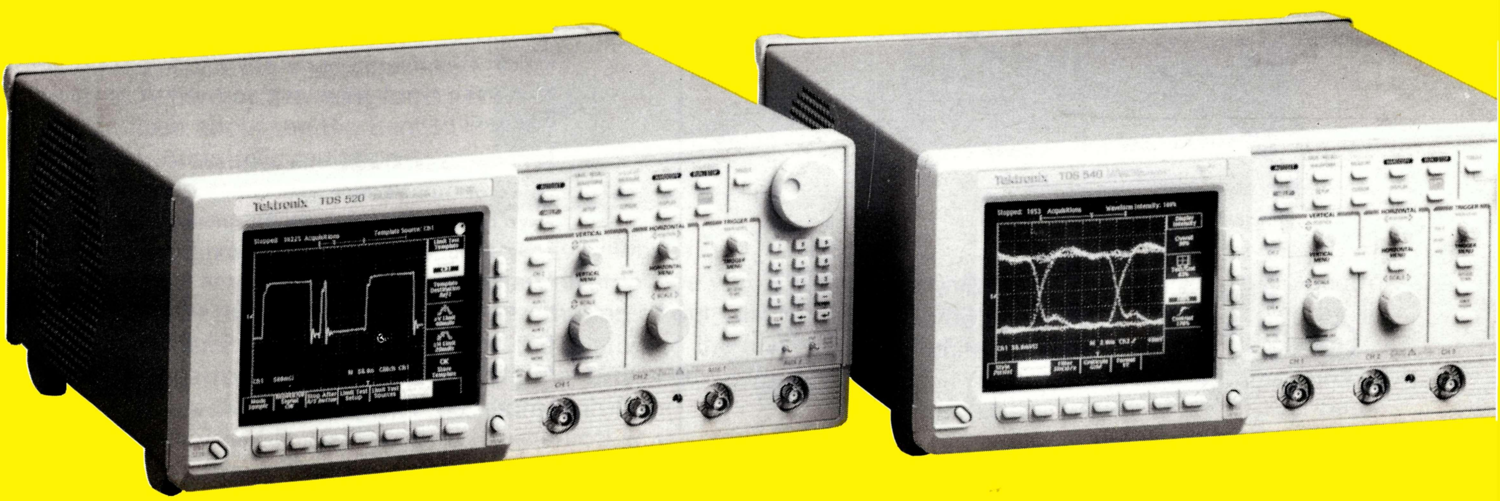

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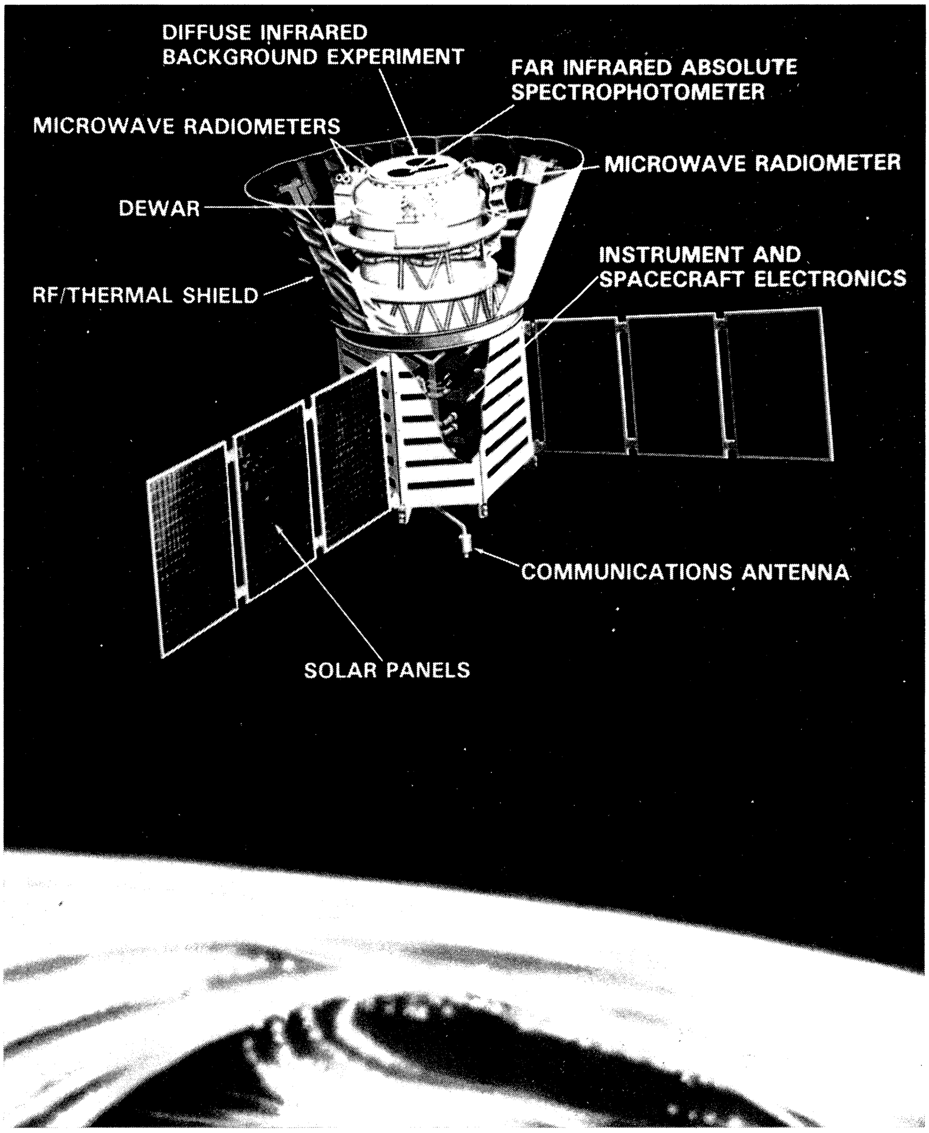
Mapping the early Universe

NASA's Cosmic Ray Background Explorer (COBE) satellite in orbit 900 kilometres above the Earth's surface is providing astonishing new insights into cosmology.



From its unique vantage point 900 kilometres above the earth's surface, NASA's Cosmic Background Explorer (COBE) satellite has a privileged view of cosmic background radiation – the remnants of the early (radiation-dominated) Universe which followed the Big Bang some ten Gigayears ago, and possibly some subsequent history. In this way astroparticle physicists get a first peek at the quantum cosmology which moulded the infant Universe.

The cosmic microwave background radiation (CMB) was discovered in 1964-65 by Arno Penzias and Robert Wilson working at Bell Labs, New Jersey, while investigating noise problems in satellite communications systems. This faint signal, equivalent to the radiation emitted by a black body at about 3 degrees absolute, was interpreted as the distant rumblings of the Big Bang, opening a new chapter in cosmology and earning the Nobel Prize for Penzias and Wilson in 1978.

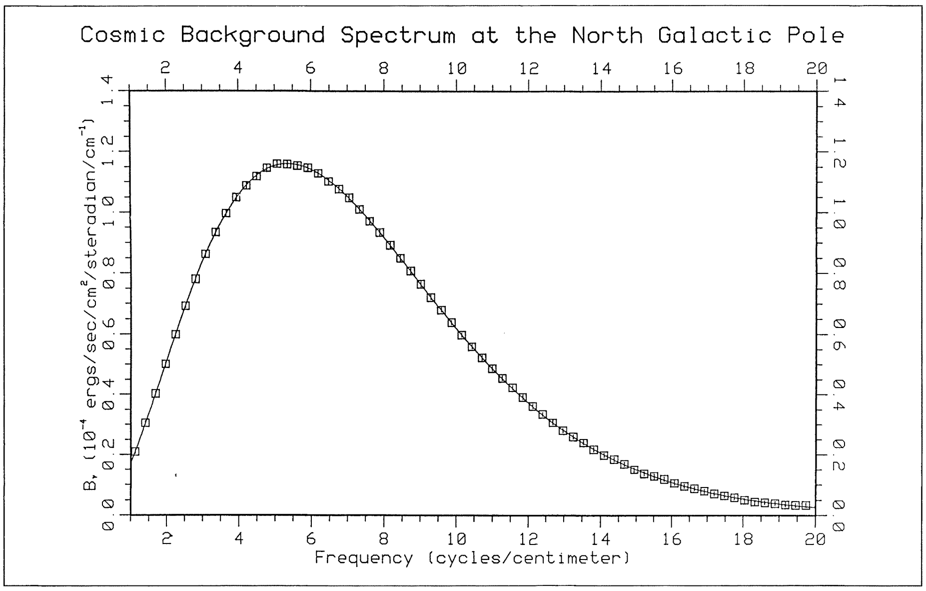
With the CMB signal confirmed, and, to a first approximation, appearing isotropic, the challenge was to look hard at this faint footprint for clues about the Big Bang. In addition, other relic radiation could show up at shorter wavelengths, providing information on galaxy formation in the young Universe.

Blanketed by the atmosphere, earthbound measurements are restricted to a narrow wavelength window. A directional (dipole) effect was discovered in 1977 in a detector carried by a high-flying aircraft and subsequently confirmed by balloon and satellite measurements. This could be due to the Big Bang having pointed somewhere (a directional Hubble 'constant'), to matter inhomogeneities, to gravity waves, to a rotation of the Universe as a whole, or simply to a motion of our part of the Universe relative to the rest of it. During the 1980s new information from high-flying detectors suggested other spectral distortions.

Launched by a Delta rocket in November 1989 into a near-polar orbit, the COBE satellite's detectors are designed to make a precision CMB frequency analysis and to map the radiation over the entire sky to look for directional effects.

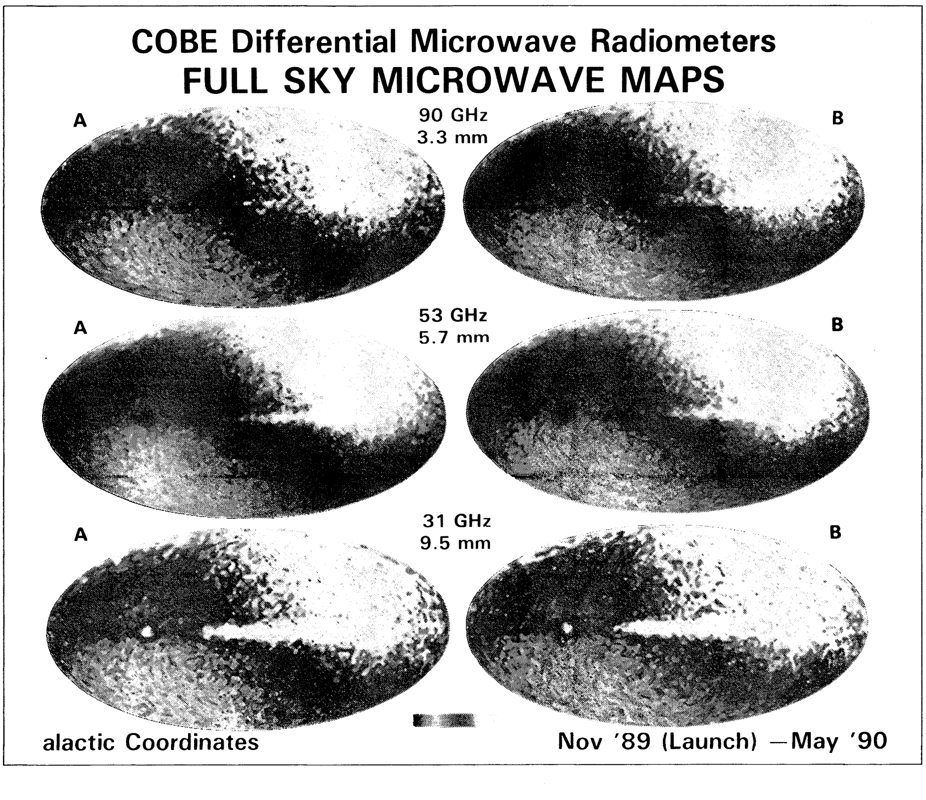
Frequency analysis is the job of the Far InfraRed Absolute Spectrophotometer (FIRAS), cooled by liquid helium to 1.5K in the same way as the US/UK/Netherlands IRAS InfraRed Astronomical Satellite. Covering a wide frequency range (in fact two ranges), FIRAS carries its own temperature-controlled black-body calibration source, the first time this has been done in flight.

The CMB signal is consistent with a black body at 2.735 ±



▲ *The spectrum of cosmic background radiation measured by COBE. The boxes are the data points and the curve is a black body at 2.735K.*

▼ *Six all-sky maps from preliminary COBE data (two at each of three wavelengths), with the plane of the Milky Way horizontal across the centre, showing the smooth variation of background radiation temperature on opposite sides of the sky. This asymmetry, only one thousandth of brightness of the sky, is due to the Solar System's local movement. Radiation from the Milky Way is also visible across the central band, especially at the lowest detector frequency.*



0.06K, with deviations of less than a per cent. These errors, due to uncertainties in the thermometer calibration, are being worked on.

FIRAS actually counts the majority of CMB photons, providing a fix on the photon content of the Universe to within 5 per cent, a useful new reference for cosmologists. With little room left for deviations from a black-body spectrum, the door practically closes on other primordial cosmology. For example a 17 keV neutrino, a particle much in the news recently (April, page 9), should decay either inside a few days or last longer than 10^{12} years.

COBE's radiation mapping is carried out by six Differential Microwave Radiometers (DMR), two operating at each of three frequencies where the CMB is at least a thousand times bigger than foreground galactic radiation. Monitoring at a number of frequencies moreover enables the galactic signals to be subtracted, and with the spacecraft's motion giving good coverage of the sky, results in a unique precision CMB picture.

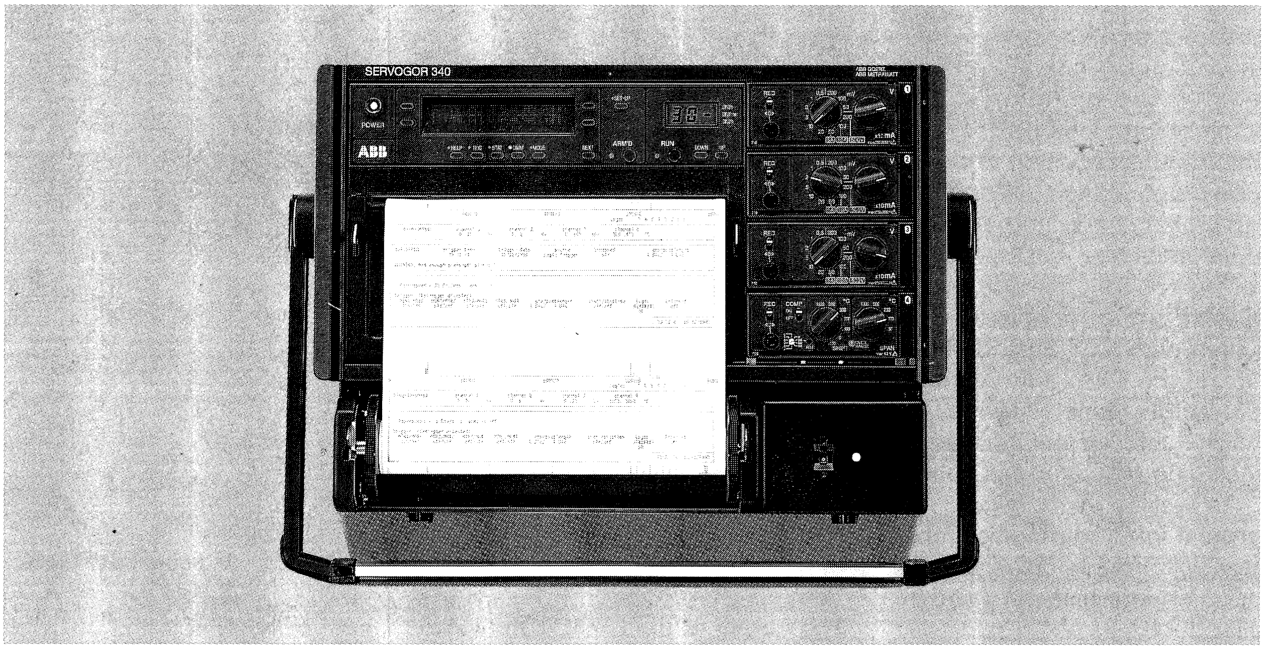
The initial most striking effect in the data collected over six months is the extreme uniformity of the signal. However close analysis reveals a slight (a thousandth of the total brightness) but nevertheless smooth variation from one side of the sky to the other. Radiation from the Milky Way is also clearly visible.

The anisotropy can be totally accounted for by the Solar System moving towards Virgo at about 370 kilometres per second, and subtracting the dipole effect due to such motion shows that the Big Bang was smooth to at least one part in 25,000. No other directional effect is called for.

As well as underlining the validi-

Avec lui, ça déclenche!

Le Servogor 340 est plus qu'un enregistreur normal



Enregistrer, beaucoup d'appareils le peuvent, mais le nouveau Servogor 340 peut plus. Le travail de base d'un enregistreur, il le résout mieux que tous les autres. Il est portatif, robuste et très flexible de par sa construction modulaire – exactement l'appareil qu'il faut dans l'industrie. Le nouveau Servogor est configuré par des boîtiers de mesure embrochables. Il en existe pour des tensions (jusqu'à 750 V), des courants, courant fort inclus, et des températures. Quatre signaux analogiques et huit signaux digitaux peuvent être enregistrés par le 340 avec une grande résolution. Pour cela, il n'a besoin ni de plumes, ni de pointes. Une imprimante thermique ne nécessitant pas d'entretien écrit en plus des signaux de mesure, des textes et des cadrages. Tout cela est bien, mais il y a encore mieux. Le Servogor 340 a une mémoire incorporée et des possibilités de déclenchement. Quand apparaît un déclenchement, le contenu de la mémoire est sorti avec une deuxième vitesse. Ainsi la résolution du domaine qui intéresse est nettement augmentée et vous voyez exactement ce qui se passe. Malgré cette fonction supplémentaire très agréable, la manipulation reste très simple. Les conditions de déclenchement sont réglées par des touches programmables. Et si, une fois, vous ne saviez vraiment pas que faire, il vous suffit d'appuyer sur la touche «Help». Vous devriez absolument regarder le Servogor 340 de plus près, car c'est ainsi que se présentent des enregistreurs modernes.

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ty of the Big Bang picture, this Great Uniformity is in itself a major cosmological result, providing significant new limits on the dynamics and physical processes in the infant Universe.

The third major COBE detector is looking for signs of another kind of cosmic background radiation. The Diffuse Infrared Background Experiment (DIRBE) looks in the 1-300 micron band for radiation from galactic evolution – signals not as old as the CMB, coming from the first formation of luminous objects.

Although this radiation density could be comparable to that of its older microwave counterpart, it would inevitably be masked by bright foreground signals from our own Galaxy and from solar system dust, even with a cryogenic detector outside the Earth's atmosphere.

Initial DIRBE scans show the expected character of the infrared sky, including patchy cirrus seen by IRAS. As well as searching for background infrared radiation, this detector will provide invaluable information on interplanetary and interstellar dust.

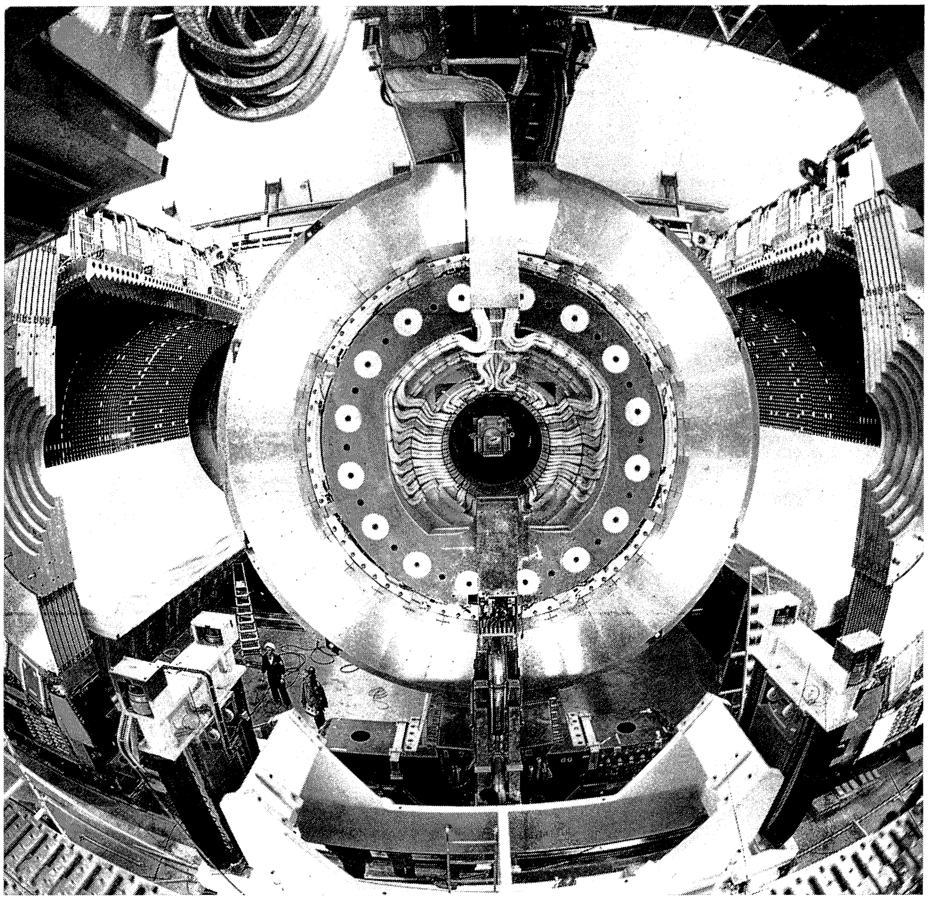
With its detectors improving their coverage of the sky, COBE's new insights will continue to shed new light on the innermost secrets of the Universe. Meanwhile with the Hubble Space Telescope not as badly handicapped as originally feared for its surveys in the visible, ultraviolet and near-infrared regions, and with the new Gamma Ray Observatory now deployed, satellite astronomy promises a new wide-angle view of the Universe.

From information supplied by George Smoot, Lawrence Berkeley Laboratory.

OPAL

A fish-eye view of the OPAL detector along the beamline direction of CERN's LEP electron-positron collider. Centre is the rear side of the pole-tip hadron calorimeter with the cables of the end-cap lead-glass detector passing through the hole where the mini-beta quadrupole is normally situated. The photograph, taken during a shutdown when the detector was open, shows, left and right, the two arrays of the barrel lead-glass counters.

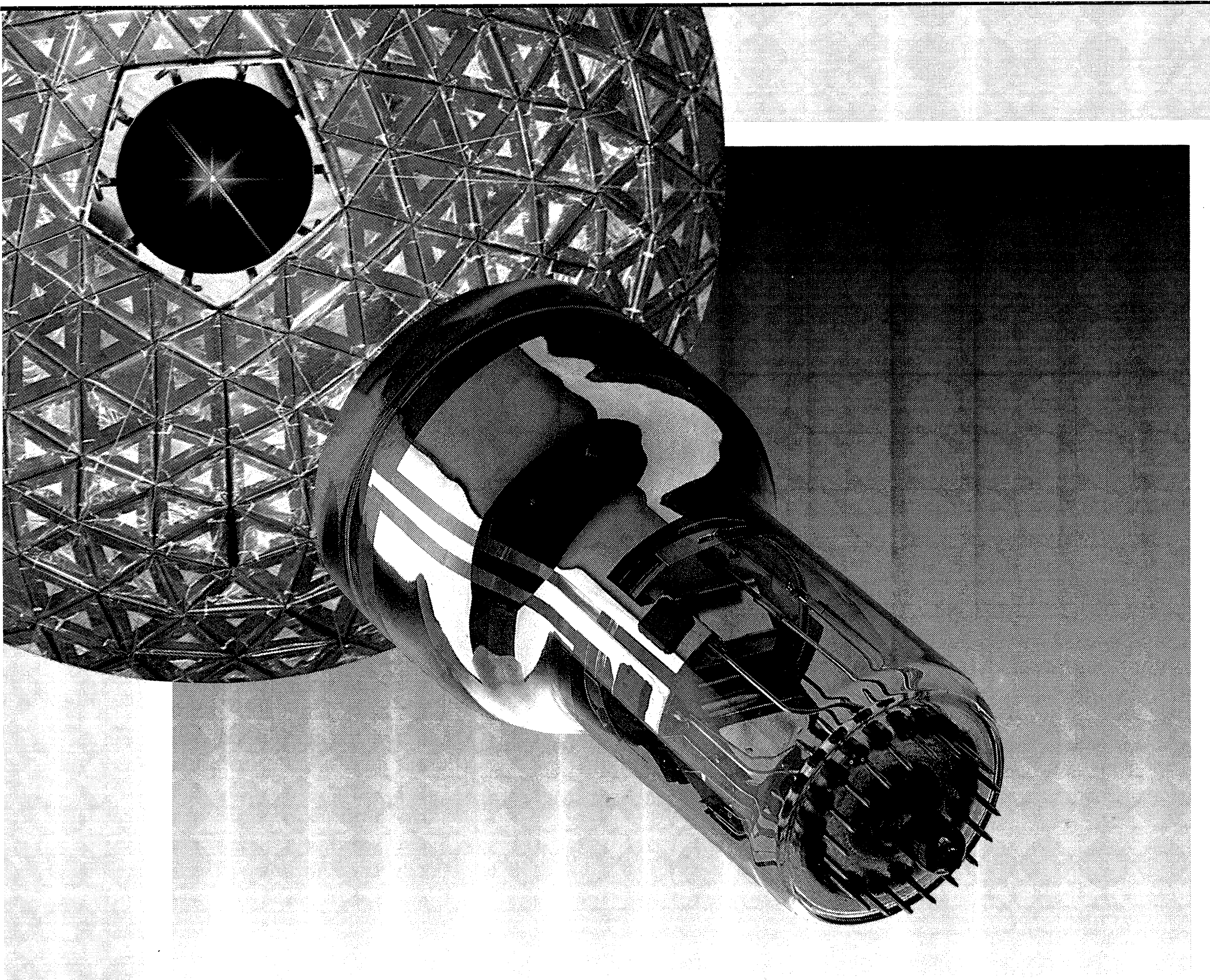
(Photo CERN 343.4.89)



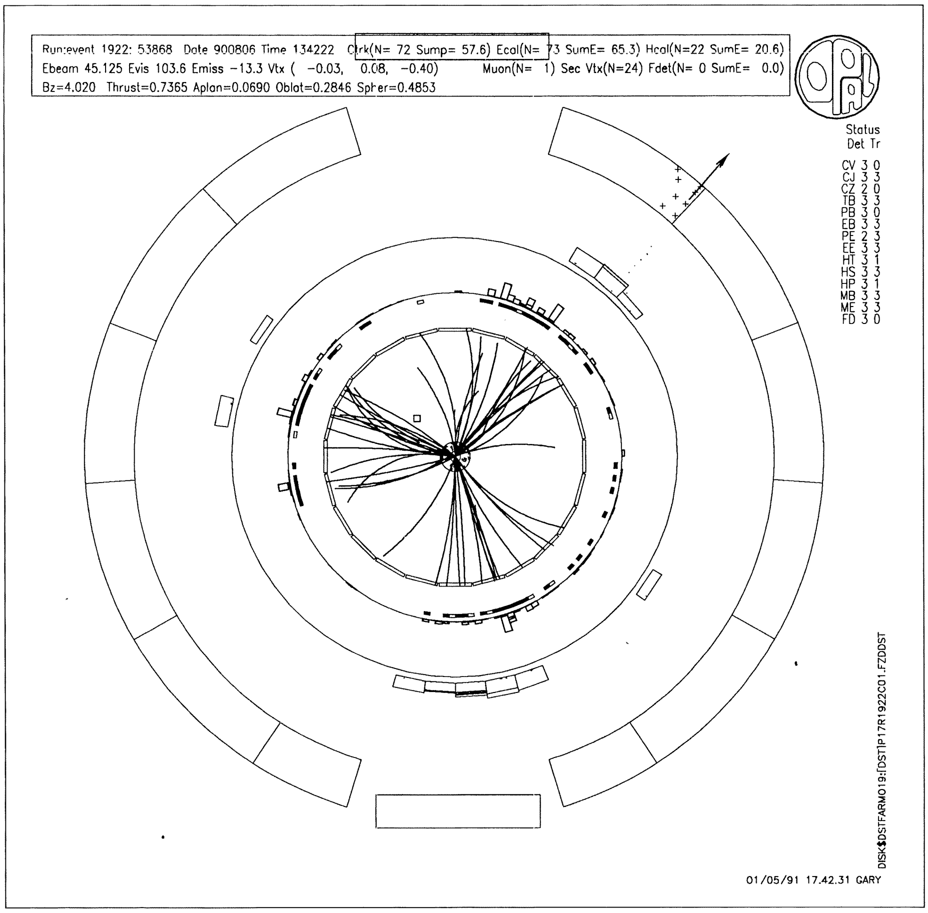
The kernel of the OPAL (Omni Purpose Apparatus for LEP) collaboration at CERN's LEP electron-positron collider came from the JADE (JApan, Deutschland, England) experiment at the lower energy PETRA electron positron collider at DESY, Hamburg. The name of a semi-precious stone is a reminder of the JADE tradition, while the spelled-out version conveys versatility.

Three successful JADE elements, the Jet Chamber, the lead-glass calorimeter and the muon drift chambers, were used as models for OPAL. The Jet Chamber is a pictorial drift chamber, 4 metres in diameter and 4 metres long. In event display pictures the Jet Chamber tracks give a very vivid impression of what is going on, while many other pieces have been added to make a detector much more flexible and comprehensive than JADE ever was.

By the time the OPAL technical proposal was accepted in 1982 the original JADE collaborators had been outnumbered by the rest, including survivors from unsuccessful bids for LEP experiments. OPAL had also developed its characteristic way of taking decisions – very democratically, after long and exhaustive debate. A CERN collaboration is not an industrial consortium – there is no binding contract compelling any of the more than twenty groups to obey spokesman Aldo Michelini. We cooperate because that is the only way to get results.



A three-jet event as seen in OPAL. The emerging muon (top right) strongly suggests a quark jet, its companion being the bottom jet, tagged by its high energy (wide opening angle). The top left cluster is thus probably due to gluon radiation. Such events enabled the OPAL collaboration to make an early accurate determination of the quark-gluon interaction strength (alpha-s).



This is the third in the CERN Courier's series of articles on the four big experiments – Aleph, Delphi, L3 and Opal – at CERN's LEP electron-positron collider. Data-taking started soon after LEP became operational in July 1989, and after a five-month run last year, the experiments are aiming in this year's run, which lasts until November, to substantially increase their data samples. Because of the long lead times involved in today's major physics undertakings, these four experiments already have a decade of history behind them. For Aleph, see January/February, page 1; Delphi, November 1990, page 1. L3's decade will be covered in a forthcoming issue.

Everyone, from youngest student to oldest professor, can speak up. Since young students and post-docs do a lot of the work it does no harm for them to be in on the debate. Some individuals learn how to get their own way whatever the decision-making process – one key figure made sure that the physics programme in the Technical Proposal was to his liking by keeping the discussion going until 11.30 at night, when all the younger members of the editorial committee were worn out!

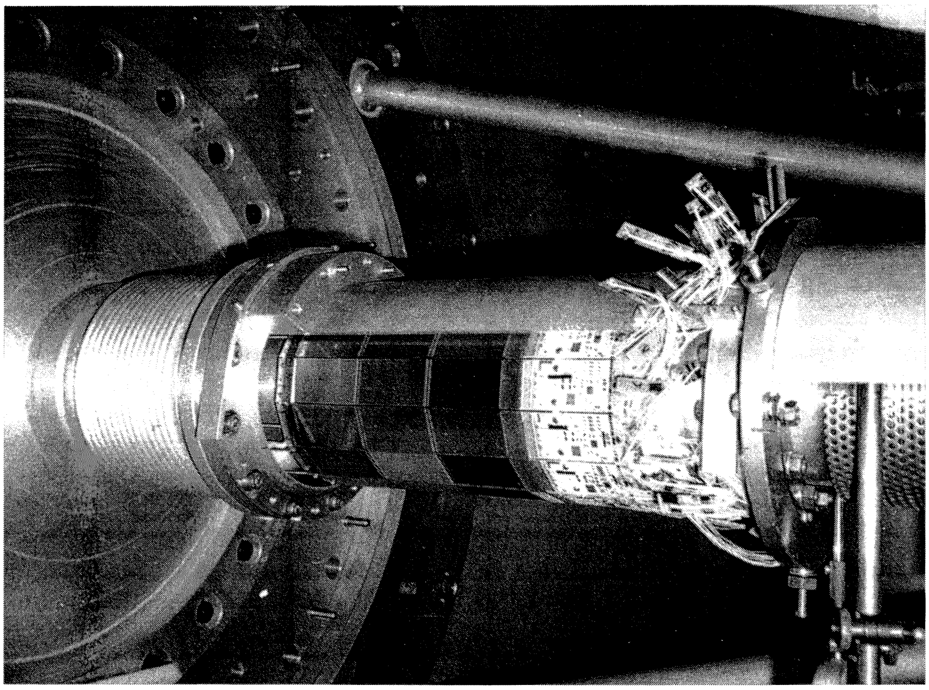
Sub-group culture in OPAL varies widely. Some groups are highly disciplined, rarely represented at any meeting by more than one member. At the other extreme is the independence of the young CERN fellows, who may all decide to turn up at the same meeting to represent themselves.

We had two magnet coil designs, both from the late Mario Morpurgo of CERN. The collaboration wanted a superconducting coil but was overruled by CERN management after the technical proposal had been accepted, the idea being that one of the three experiments with solenoid magnets should start with a normally conducting coil, in case the cryogenics in Aleph and Delphi should prove troublesome. We have now run for two years with the normal coil with great success, but the superconducting design is still available if needed (and if someone will pay for it!).

Aleph and Delphi both use Time Projection Chambers (TPCs) for central tracking. The biggest advantage of Opal's Jet Chamber is that it collects all the drifting charge from its tracks within 10 microseconds, fast enough to use the information in a track-trigger to select interesting events before the next LEP electron-positron beam crossing (within 22.5 microseconds).

Another curious difference between OPAL and the other LEP experiments is its main control room, 100 metres down, in the experimental cavern. We had planned to have a control room on the sur-

A view of the 2-layer silicon microvertex detector recently installed in OPAL.



face, like everyone else, but the rush startup in August 1989 meant that we had to do everything downstairs, even writing output tapes direct from the data-analysis crates. With time, the computer room on the surface took over that task, as well as doing immediate offline reconstructions. But the downstairs control room is a much better place for monitoring equipment and we kept delaying the transfer of main shift personnel to the surface. Now that most safety checks can be done by computer the number of people needed for a shift has been reduced, so we find it more efficient to keep them all downstairs – where the safety shift can see what the physics shift is doing, and the physics shift can back up the safety people in any emergency.

From the outset, we were designated as the 'safe experiment', the one sure to work from the start, and this judgement has motivated the collaboration ever since to avoid being seen as 'safe but dull'.

We were meant to and duly were the first experiment to see Zs at LEP, and performance on central physics topics such as the line-shape of the Z and pushing up the mass limit on the Higgs boson has been sharply competitive. Quick-off-the-mark young OPAL physicists have also contributed pioneering analyses – the first LEP measurement of the quark coupling constant (alpha-s), deduced from the fraction of three-jet events signalling radiation of hard gluons from final state quarks (using the tried and tested 'JADE jet analysis method'); and early results on hard photon bremsstrahlung from quarks.

For 1991 OPAL's competitivity has been extended with the first stage of a silicon microvertex detector to reconstruct events containing short-lived particles such as beauty mesons.

An effective democracy must have an executive arm as well as a parliament. OPAL's coordinators are the people who get things done. After lengthy policy debates on the microvertex detector, one small group was left to get on with it – working intensely throughout the winter to meet the installation coordinator's deadline.

Run coordinators define the short-term programme, organize underground shifts and 'choose volunteers' to get the best data from every run. The online coordinator has to be sure that every subdetector will read out into the common event builder. The offline coordinators organize parallel shifts to put data through the latest versions of the reconstruction programmes and release events for physics analysis.

OPAL coordinators are rarely group leaders – some are CERN staff, some are from outside groups. Most are based in CERN, for obvious reasons – although the coordinator of the simulation program for the detector manages to handle his code by remote control.

Groups have great freedom to choose their physics analysis topics. Inevitably those who built the muon detectors tend to specialize in physics involving muons, electromagnetic calorimeter experts spend some of their time on electron and gamma-ray channels, etc. But no topic is the property of any one group, and a number of parallel analyses of the same data will often be going on, some at CERN, some in the home laboratories. A single analysis team is unlikely to be bigger than six people, often just one PhD student with his supervisor, but all teams report regularly to a 'working group' which reviews progress and coordinates presentation of results.

Just as decisions on installing and running the detectors are ar-

Around the Laboratories

rived at by consensus rather than by executive order, so decisions on publications are debated very openly. An analysis, before approval for publication, must first be presented at an OPAL weekly meeting at CERN. Then a draft will be circulated to every institute in the collaboration, although it can be hard to get all the illustrations for a meaty piece of work to all the outside laboratories in time for everyone to comment. Nobody's text is 'right' until an 'editorial board', with at least two people with no direct hand in that particular piece of work, has gone over the draft. In a final 'public reading' objectors must 'speak now or forever hold their peace'. Nevertheless there have been 34 OPAL papers and letters submitted to journals (as of 8 April 1991), with two or three new ones coming out each month.

The collaboration is still growing. Two major new groups have joined in the past year, bringing expertise and hardware to assist in the online and offline data-analysis. And the physics programme continues to advance. OPAL looks forward to lots more Zs as the luminosity of the machine is increased and to the greater sensitivity to subtleties of the theory with polarized beams. Most of all we look forward to the next great energy threshold and studying the production of W pairs. Whatever the challenge, the Omni Purpose Apparatus for LEP will be ready.

By David Miller

BERKELEY/ STANFORD B factory plans*

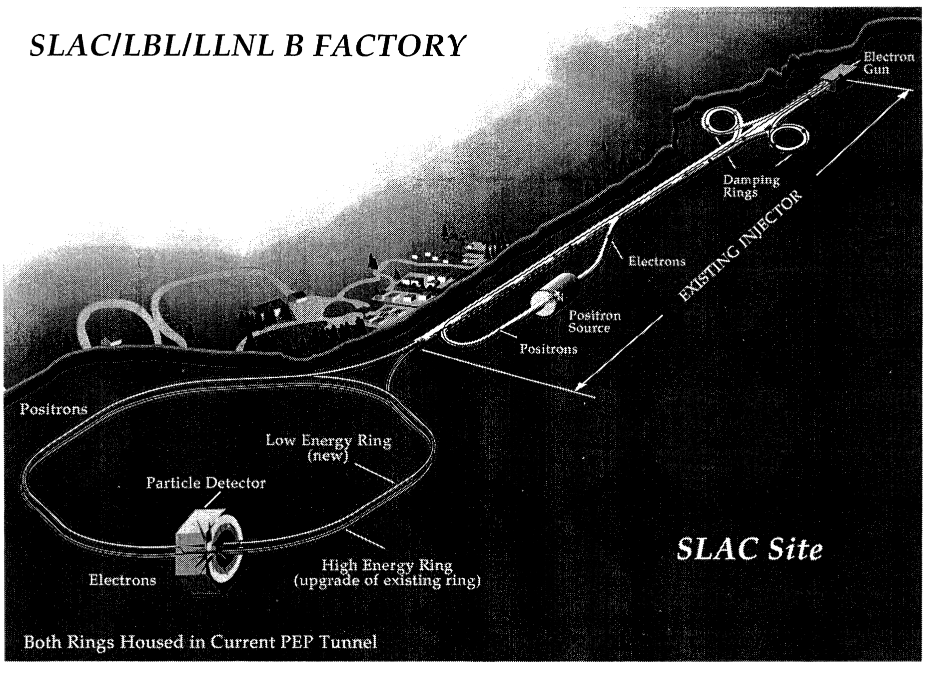
For the past several years, accelerator physicists at Lawrence Berkeley Laboratory (LBL) and the Stanford Linear Accelerator Center (SLAC) have been involved in the design of an Asymmetric B Factory to be sited in the tunnel of the PEP electron-positron collider at SLAC.

This effort comes from a suggestion by LBL's Deputy Director Pier Oddone that a high-luminosity electron-positron collider with unequal beam energies would open up exploration of CP violation with B particles (containing the heavy 'beauty' or 'b' quark – so far CP violating studies have been limited to the neutral kaon system.)

The combined violation of particle-antiparticle (C) and mirror reflection (parity – P) symmetries was discovered by V. Fitch and J. Cronin at Brookhaven in 1964. Although it is intimately related to a six-quark picture, the phenomenon has never been explained, and new information could lead to important advances in understanding.

Capitalizing on recent advances in detector technology and new information on the properties of the b quark, it is now widely accepted that such an asymmetric collider offers a good platform for an in-depth study of CP violation. This was endorsed last year by the US High Energy Physics Advisory Panel (HEPAP) through the deliberations and recommendations of its 1990 subpanel, headed by Frank Sciulli, on the US high energy physics research programme for the 1990s (July/August 1990, page 4).

The design effort was initiated in early 1989, when a group of accelerator and particle physicists from Caltech, LBL, SLAC, and the University of California began looking at the idea of an asymmetric electron-positron collider based on an upgrade of the PEP ring at SLAC.



Schematic of the proposed B Factory at Stanford, fed by the two-mile linac and using the existing PEP electron-positron ring.

**A description of Cornell's B factory plans will appear in the next issue.*

A parallel study looked at the physics capabilities and the luminosity (collision rate) required for a broad-based programme aimed at understanding the origins of CP violation.

This work indicated that, with appropriate care, PEP could be upgraded to achieve the required luminosity of 3 x 10^{33} per sq cm per s. In November 1989 the SLAC Experimental Program Advisory Committee agreed that the B Factory program was indeed very compelling and encouraged the Directors of SLAC and LBL to move from a feasibility study to a conceptual design phase.

This culminated in February with the publication of a Conceptual Design Report. The effort has been headed by Jonathan Dorfan at SLAC, with the collider design activity coordinated by Andrew Hutton from SLAC and Michael Zisman from LBL. SLAC and LBL have a long and successful history of design, construction, and operation of electron-positron storage rings – the original PEP project was a joint endeavour of the two Laboratories. Recently Lawrence Livermore Laboratory has joined the collaboration, and is now a full partner in the proposal.

The Asymmetric B Factory collider described in the Conceptual Design Report is a machine that is both responsive to the physics needs and conservative in its approach to high luminosity. It consists of two independent storage rings, one atop the other in the 2.2 kilometre circumference PEP tunnel. The high energy ring, which would store a 9 GeV electron beam, is an upgrade of the existing PEP collider, reutilizing all the PEP magnets and incorporating a copper vacuum chamber (patterned after that used in the HERA electron ring at DESY) and a new room-temperature radiofrequency system capable of supporting a stored beam of very high current.

The low-energy ring, to store 3.1 GeV positrons, would be new, taking advantage of many of the machine component designs that have already proved successful at PEP.

The collider is designed initially for head-on collisions, the configuration successfully employed on existing machines. Although the initial plan has a single interaction region, it would be possible to upgrade the design to include a second interaction region – and therefore a second detector – if required.

The technique to attain the required luminosity is to use, in each ring, high circulating currents (approximately 2 A) separated into more than 1600 bunches. In this way the parameters of individual bunches (current, length, emittance, etc.) are quite conventional. Thus the challenges in the design are restricted to the high-current and multibunch goals. These are mainly engineering challenges and – although by no means easy – are amenable to standard techniques.

SLAC has the world's most powerful positron injector, and the availability of the large PEP tunnel greatly eases the problems of handling the intense synchrotron radiation emitted by the high-current beams. Moreover the parameters of the B Factory high energy ring match almost perfectly those of PEP, so that the project would benefit from the existing infrastructure with no major civil engineering required on the SLAC site.

The programme of CP violation studies envisioned for the Asymmetric B Factory has great discovery potential; should the measurements disagree with today's Standard Model, the observed effects will provide substantial and specific clues as to how the model should be extended.

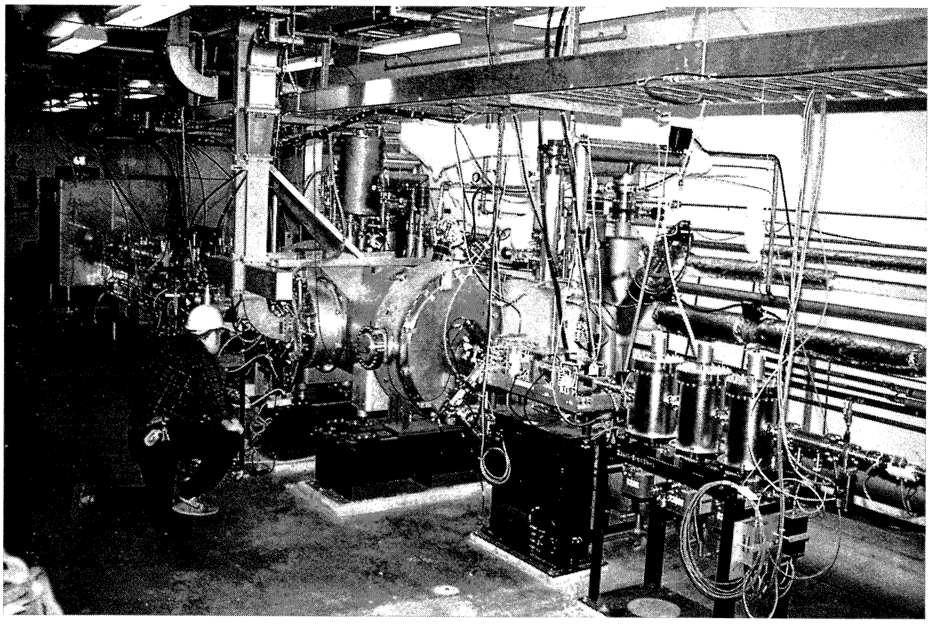
In addition, the collider would host a very exciting and broad-based programme of heavy quark, tau lepton and two-photon physics. As a result, the Asymmetric B Factory would be ideal for training young physicists, and it is anticipated that more than 200 PhD theses would be completed during the programme's estimated 15 year lifetime.

At present, more than 150 PhD physicists are involved in developing the physics arguments and in designing an appropriate detector. This group includes investigators from more than 20 US institutions, as well as from Canada, Europe, Japan, and Israel. It is anticipated that a US B-physics community reaching 250 PhD physicists would ultimately be accommodated at such a national facility.

The US Department of Energy has just completed a full review of the technical feasibility, cost, schedule, and management for the project and has confirmed its readiness for a fiscal year 1993 (October 1992) starting date.

CEBAF
Injector test reaches 25 MeV

On 25 April electrons were accelerated through a superconducting eight-cavity cryomodule in the tunnel of the Continuous Electron Beam Accelerator Facility (CEBAF) at Newport News, Virginia. The beam was taken from 5 to 25 MeV, the design energy for this



Initial superconducting equipment is now operational for the Continuous Electron Beam Accelerator Facility (CEBAF), Newport News, Virginia. This 5-MeV injector section – electron gun cage (rear), room-temperature section, 5-MeV quarter-cryomodule – with its two superconducting cavities, operated in the tunnel on 30 March. Not shown is the 20-MeV cryomodule downstream which reached 25 MeV in April.

portion of the CEBAF injector.

First superconducting acceleration in the tunnel had been achieved on 30 March, when successful operation of the injector's initial 5 MeV quarter-cryomodule, equipped with a twin superconducting cavity, began CEBAF's injector systems test of permanently installed components.

Detailed measurements are being made of electron beam properties as the test's 25 MeV phase continues. With the addition later of a second cryomodule, the test will proceed to 45 MeV, the full CEBAF injection energy.

Injector systems are nearly identical to those being prepared for the full 4 GeV recirculating accelerator.

DESY HERA pause

After an initial taste of protons (May, page 27), commissioning of the 6.3-kilometre HERA electron-proton collider ring at the DESY Laboratory, Hamburg, switches to electrons. In parallel, the quench protection system for the superconducting proton ring will undergo high current testing.

During the initial proton run, single 40 GeV bunches regularly coasted round the superconducting ring for some 30 minutes.

These protons originate from the 50 MeV linac, supplying 6 mA of negatively-charged hydrogen ions which are stripped of their electrons before injection and accumulation in the DESY III proton machine, where about half of them survive being ramped to 7.5 GeV.

The next link in the injector chain is the PETRA ring, where 70 bunches at 10% of design intensity have been stored and taken to 40 GeV, ready for HERA injection. But these are still early days.

The electron ring was ramped to 27.5 GeV in November 1989. For its next run, it will have a damping system, similar to that used in PETRA, and 16 four-cell 500 MHz superconducting cavities to boost the electrons to 30 GeV.

After initial tests with protons in the superconducting ring (above), commissioning of the 6.3-kilometre HERA electron-proton collider ring at the DESY Laboratory in Hamburg switches to electron beams.

FERMILAB
Main injector update

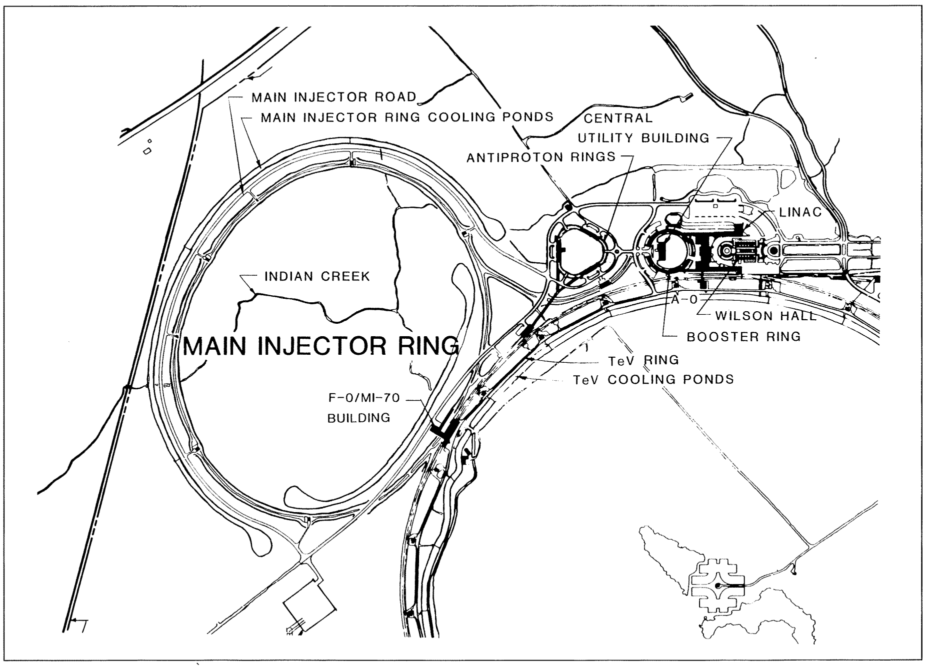
The Fermilab Main Injector (FMI) is the centrepiece of Fermilab's initiative for the 1990s, known as Fermilab III. The goal of Fermilab III is to ensure discovery of the sixth 'top' quark in the present decade assuming our understanding of nature as described by the Standard Model is correct, to provide a factor of two increase in the mass scales characterizing possible extensions to the Standard Model, and to support new initiatives in neutral kaon and neutrino physics.

In order to reach these goals Fermilab is planning to attain by mid-decade a luminosity in excess of 5 x 10^{31} per sq cm per s in the Tevatron proton-antiproton collider, supported by a new 150 GeV accelerator, the Fermilab Main Injector.

The concept of the FMI has been developed over the last several years. A Conceptual Design Report was prepared and submitted to the US Department of Energy (DoE) in January 1990, accompanied by a request for a Fiscal Year 1992 construction start.

In response to identification of the FMI as the highest priority construction project in the 1990s' 'base programme' by the DoE's High Energy Physics Advisory Panel (HEPAP – July/August 1990, page 4) initial funding for the project at the level of $44 million is included in the Fiscal Year 1991 DoE Congressional Budget Request. An initial attempt by the Office of Management and Budget to strike out the item was overruled after skillful maneuvering.

Total project cost is estimated at $197 million with construction extending over 51 months. Construction will require a seven-month hiatus in accelerator operations starting in the Spring of 1995.



Layout of the proposed 3.3-kilometre Main Injector Ring at Fermilab, to feed the superconducting Tevatron.

The Main Injector is specifically designed to carry out much more efficiently the support functions currently being provided by the Main Ring – the original 400 GeV Fermilab accelerator. Through the 1970s the Main Ring was Fermilab's primary high energy physics machine, however with the construction of the superconducting Tevatron in the early 1980s, the Main Ring was reconfigured to support the Tevatron proton-antiproton collider and fixed-target programmes.

This reconfiguration included the addition of (vertical) overpasses around the two interaction regions, and the addition of several new extraction areas required for operations with antiprotons. This reduced the available aperture in the Main Ring to the extent that today the Main Ring represents the primary bottleneck in the delivery of high intensity proton and antiproton beams to the Tevatron, and in the delivery of protons onto the antiproton production target. Construction of the Main Injector will remove this bottleneck once and for all.

The Main Injector will be constructed tangentially to the Tevatron in a separate tunnel on the southwest corner of the Fermilab site. It will be roughly half the size of the existing Main Ring yet will boast greatly improved performance, producing about seven times as many antiprotons per hour as are currently possible using the Main Ring and delivering five times as many protons to the Tevatron (at least 3 x 10^{11} protons/bunch for collider operations).

Additionally, the Main Injector will allow very intense proton beams (3 x 10^{13} protons every 2.9 seconds with a 33% duty factor) for use in state-of-the-art studies of CP violation and rare kaon decays, and for experiments designed to search for transmutation between different neutrino generations. Low

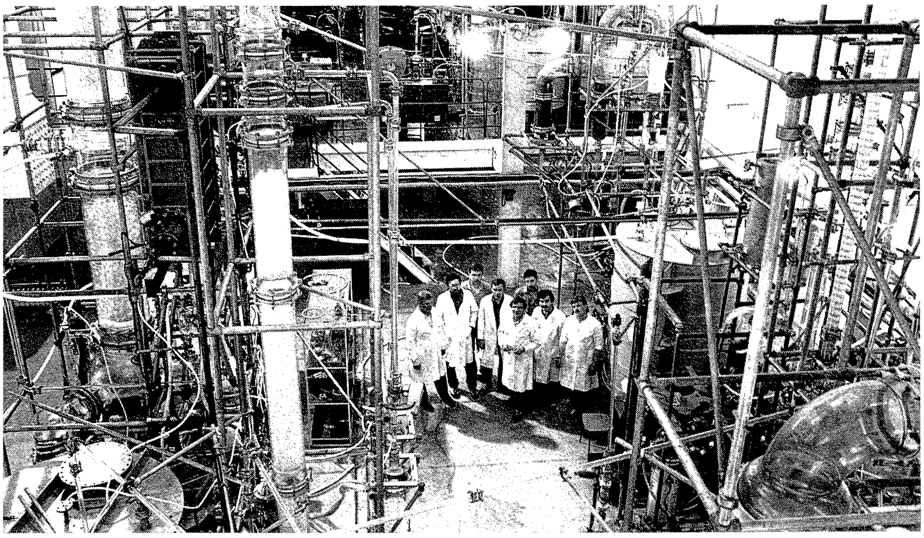
Radiochemical separation apparatus for the SAGE solar neutrino experiment in the Soviet Baksan Laboratory in the Caucasus Mountains. Construction is now underway for another detector using 3000 tons of perchloroethylene.

intensity proton beams emanating from the Main Injector will support test and calibration work for the development of new detectors devices both at Fermilab and at the SSC Superconducting Supercollider to be built in Ellis County, Texas.

In contrast to the present situation at Fermilab, simultaneous antiproton production and Main Injector slow spill operation will be possible under normal circumstances, as will simultaneous Main Injector and Tevatron fixed target operations.

Development work on the new dipole magnet required for the Main Injector was initiated in October 1989. The first full-scale prototype was built at the Fermilab Technical Support Section's Conventional Magnet Facility and delivered to the Magnet Test Facility last September. Measurements indicate that this magnet gives the required field quality. A second generation prototype will soon be ready for testing.

Fermilab has, since its inception under founding Director Robert Wilson, attempted to blend in with the existing environment. Every effort is being expended to continue this tradition in the planning for the Main Injector. A major activity over the past year has been, and will continue to be, the study of design enhancements which minimize any negative environmental impacts, and the preparation, with state and federal agencies, of the required environmental documentation and permit applications. This effort has been largely funded through the State of Illinois Technology Challenge Grant Program. An Environmental Assessment has been prepared and forwarded to the DoE for approval, and the required permit application for construction has been filed.



BAKSAN Solar neutrino telescope

Until all its surrounding mysteries have been solved, neutrinos will remain a major particle physics research preoccupation, with new projects forging ahead all over the world.

In February, a major milestone was passed for a major new project in the Soviet Union when two horizontal tunnels under Mt. Andyrchi in the valley of the North Caucasus met at the point where a new underground Laboratory is to be constructed. It will house a neutrino telescope using 3000 tons of perchloroethylene, with neutrino interactions picked up by looking for transformations of chlorine atoms into argon.

The original such experiment, led by Ray Davis, uses 615 tons of this substance and has been in operation for more than 20 years in a South Dakota mine.

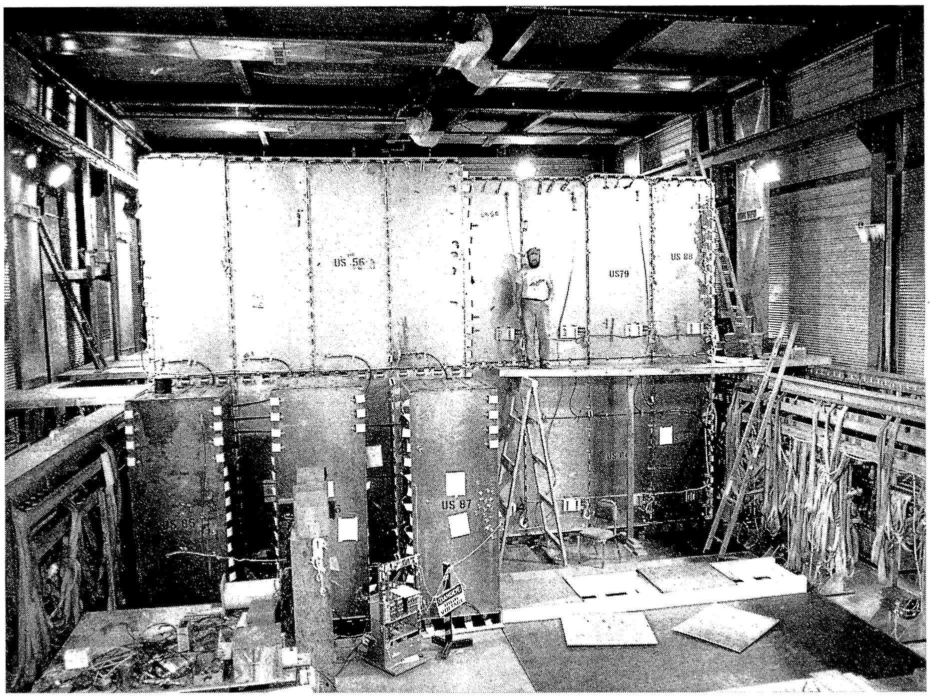
The new Baksan chamber will be 18 m high, 18 m wide and 54 m long. It is a further step in the neutrino physics and astrophysics programme of the USSR Academy of Sciences' Institute for Nuclear Research, supported by the state high energy physics programme.

Baksan is already the scene of a 300-ton Large Scintillator Telescope, operational since 1978, and the SAGE gallium-germanium telescope which began operations last year (June 1990, page 16) with 30 tons of gallium, now uprated to 60 tons. Several double-beta decay detectors are also busy.

The large Baksan chlorine detector, scheduled to begin operations in 1995, will provide a useful complement to the classic Davis study, which discovered that the solar neutrino activity on the Earth's surface is only a fraction of that expected by standard solar calculations (May, page 17).

This 'solar neutrino puzzle' will come under renewed scrutiny with new data from the new generation of solar neutrino studies, including Super-Kamiokande in Japan (May, page 9), SNO in Canada (January/February 1990, page 23), SAGE, and Gallex in the Italian Gran Sasso Laboratory January/February, page 10).

A view of the Soudan 2 detector in its underground Laboratory in Minnesota. The detector modules, stacked 2 high and 8 across, will fill the end of the specially built cave 700 metres below the surface. In the foreground are some modules under test. Some 144 modules are now operational, and the number will grow to 240 over the next two years.



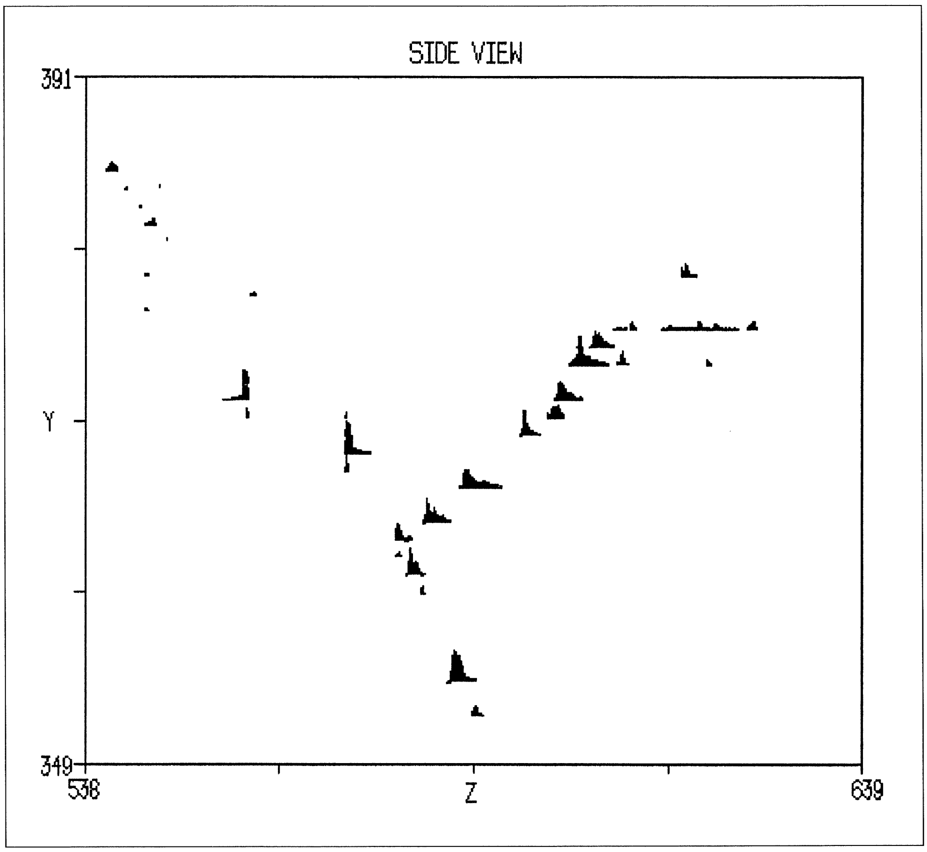
SOUDAN UK contribution complete

Construction of the UK contribution to the Soudan 2 underground proton decay detector was recently completed at Oxford and the Rutherford Appleton Laboratory (RAL). 73 4.3-ton drift calorimeter modules have been built over the past four years, most being now operational at the Soudan Laboratory in Minnesota.

Construction will continue in the US for the next two years to bring the detector to its design size of 240 modules and 1030 tons. An Argonne/Minnesota/Tufts/Oxford/RAL collaboration, the new detector aims to provide a new precision search for proton decay which would hint at an underlying Grand Unified Theory linking the electroweak picture with the quark interactions of strong nuclear interactions.

The 30-ton Soudan 1 detector began operations in 1981 and has only recently been switched off. It soon became too small to be competitive for proton decay, but has continued to take data on cosmic ray muons. For Soudan 2, Argonne and RAL are providing the 240 4.3-ton modules for the full detector. Minnesota and Oxford provide module components while Tufts is building an outer shield to tag cosmic ray muons.

Operation began in autumn 1988 when the first 250 tons was in-



A low energy neutrino interaction producing three tracks in the Soudan 2 Detector. The upper pair are electron showers from gamma-rays coming in turn from the decay of a neutral pion (effective mass 187 ± 77 MeV). The lower track is a muon or pion of momentum about 150 MeV. The recoil nucleus is not visible.

stalled and has continued while new modules are added at the rate of about 50 tons every two months. Currently 650 tons are taking data. As well as proton decay, physics objectives include searches for neutrino oscillations, magnetic monopoles, and astronomical sources of muons, as well as studying multiple muon signatures to probe cosmic ray composition.

Soudan is an old iron mine owned by the Minnesota Department of Natural Resources and is open to tourists during the summer. Conditions are good for underground physics, with the rock dry, solid and free of noxious gases. A new cavern 80x15x12 metres was excavated 700 metres below the surface specifically for the new experiment, which will take up about a third of the space, the rest being available for more proton decay modules or additional experiments. A small double-beta-decay search is also running.

The calorimeter, a tracking device recording trajectories as well as measuring deposited energy, is primarily composed of corrugated steel sheets stacked vertically, the intervening drift channels thus formed being filled with conducting plastic drift tubes. Each module uses 240 steel sheets stacked to a height of 2.5 metres. Large proportional wire chambers mounted on opposite sides of the stack pick up the ionization electrons from the drift tubes.

The design, with good coverage and clean signals, gives improved particle identification, and complements the information from other proton decay searches, probing possible decay channels currently masked by background in other experiments.

The calorimeter is surrounded by the Tufts 1800 sq m shield of proportional tubes, warning of contamination from muon interactions in the surrounding rock and providing increased cosmic ray muon detection power.

By the end of last year, the data showed 23 'contained' neutrino interactions, none of which were a proton decay candidate. Over 2 million cosmic ray muons have been analysed, and are being scanned for signs of astronomical sources. In 1985, several experiments reported muons apparently coming from the binary star Cygnus X-3.

Steering committee for a possible European electron machine for nuclear physics at a recent meeting in Saclay – from the front, left to right; H. Lengeler (CERN), J. Thompson (Daresbury), M. Prome (Saclay), H. Graef (Darmstadt), H. Herminghaus (Mainz), G. Rees (Rutherford), D. Husmann (Bonn), P. Bruinsma (NIKHEF), J.-M. Loiseaux (Grenoble), A. Tkatchenko (Saclay), L. Rivkin (PSI), P. Marin (Orsay), O. Napoly (Saclay), B. Aune (Saclay). P. Grosse Weismann (CERN), J. Spelt (NIKHEF), J. Le Duff (Orsay).

(Photo Saclay)

EUROPEAN NUCLEAR PHYSICS
Electron machine quest

In 1989, initial thinking on the construction of an electron accelerator for nuclear physics in France resulted in an initial plan for a 4 GeV machine with continuous output at 100 microamps. Subsequently a further study recommended a more ambitious European scheme going beyond 10 GeV (May 1990, page 17).

To follow this up, physicists organized a series of workshops, including a meeting at Dourdan (January/February, page 22). The outcome is being considered by NuPECC (Nuclear Physics European Collaboration Committee).

Awaiting a definitive solution, European specialists have been looking in the meantime at ideas on

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Inquiries for Europe **please see page III.**

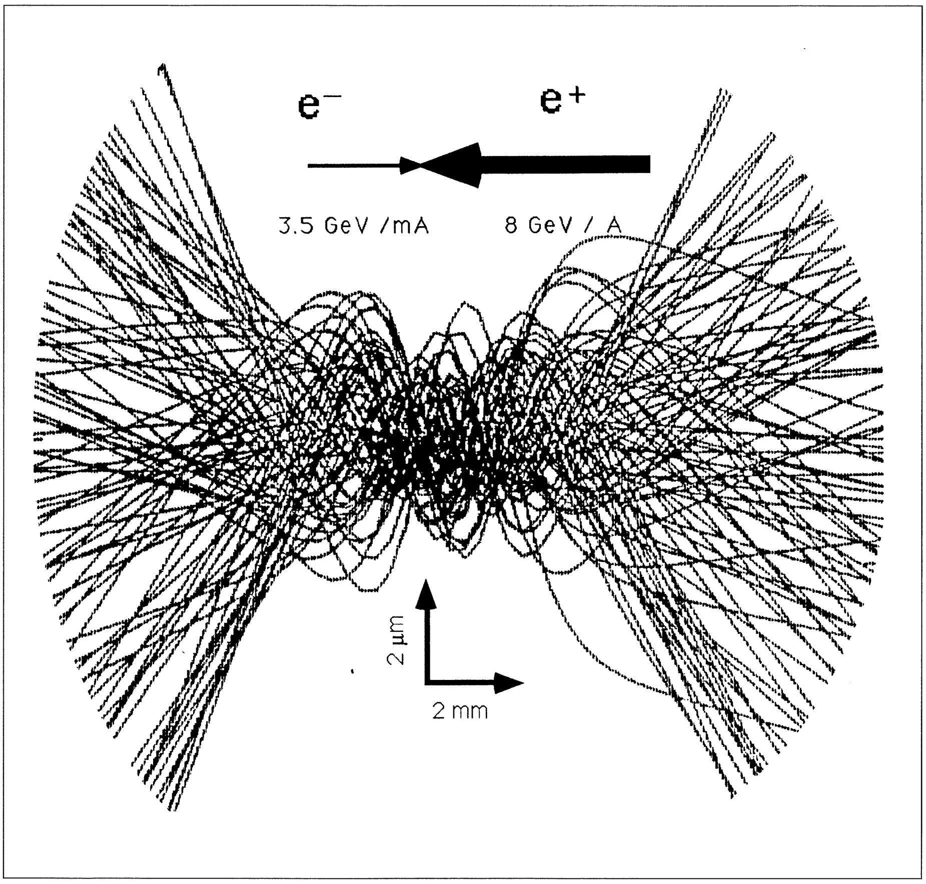
the market, with a study group drawn mainly from Grenoble and Saclay, and a European-wide steering committee.

Ideas examined include isochronous recirculating machines (like the CEBAF accelerator being built at Newport News, Virginia), microtron solutions (similar to the MAMI machine at Mainz – April, page 12 – where higher energy variants have earned the name polytron), and storage rings using gas jet targets.

With this latter solution not promising the required beam luminosity, studies are focusing on recirculating machines, consisting of one or more superconducting linacs with beam transport systems allowing multiple passes in the linacs. The optimal number of passes, in one or two directions, with the machine isochronous or otherwise, needs to be determined. Even a non-recirculating standalone linac cannot be excluded.

Another possibility would be to use the beam not only for nuclear physics but also for B particle physics, colliding the electrons with positrons held in a storage ring (see following story).

A beam-beam simulation program developed at CEBAF (Newport News, Virginia) tracks electrons through a thousand times denser positron bunch in a 3.5 on 8 GeV linac-ring collision.



COLLIDERS
Running rings round linacs

Colliding a linear particle beam with a beam stored in a ring was looked at more than twenty years ago, when CERN's ISR proton storage ring and Stanford's two-mile electron linac were front-runner projects.

Three years ago these linac-on-ring ideas were revived in the continuing attempt to push the energy and luminosity limits of electron colliders, and applications for high energy electron-positron and electron-proton colliders as well as high luminosity particle 'factories' have been considered in several Laboratories.

To get a high luminosity for an affordable beam power, a low current electron bunch has to be brought into collision with a dense storage ring bunch. The forces of the storage ring beam on the electrons would be of unprecedented strength (equivalent to up to several hundred Tesla), and the incident electron beam would be highly disrupted.

Another major concern in such a scenario is the stability of the ring beam. Ideas have been put forward to choose the initial conditions of the electron beam to favorably shape the beam forces. Several simulations are underway to study this unusual beam-beam interaction. Initial conditions and stability requirements for the linac beam are being studied.

Possibilities for a test of this high disruption scenario were among the issues discussed during an informal workshop at CERN at the end of January. Possibilities include moving a low energy linac to an existing storage ring or building a small test storage ring along one leg of an existing continuous electron machine.

In the meantime simulation studies continue and a workshop on linac-ring colliders is planned for early next year.

CERN SC-33

On 22 April a forward-looking CERN also looked back for a day, when the 'SC-33' event reviewed the achievements of CERN's first machine, the 600 MeV Synchro-Cyclotron (SC), which closed down on 17 December after 33 years of valiant service (December 1990, page 7).

Many of those who had built and operated the SC or had used the machine during their research careers, including several pioneers from the early days, participated in an all-day seminar recalling the machine's career and sketching its varied physics contributions. The proceedings will be published in a special issue of 'Physics Reports'.

Introducing the seminar, CERN Director General Carlo Rubbia attributed to Enrico Fermi the choice of 600 MeV for the SC energy, and went on to describe how the SC's illustrious scientific traditions will live on. The ISOLDE on-line isotope separator, catering for several hundred scientists, will find a new home at CERN's 1 GeV Booster machine, which has capacity to handle extra particles. The ISOLDE studies will benefit from the higher energy and pulsed operation of the Booster.

With the achievements firmly set in perspective, the evening ceremony underlined the sagacity of the early decision to provide CERN with multiple machines.

'Our founding fathers had great wisdom when they decided in June 1952 to build two accelerators rather than one,' affirmed CERN's Director General. 'The SC was primarily intended to bridge the gap until the more ambitious 28 GeV Proton Synchrotron would be ready in the 1960s. It was thought of as a tool for training European physicists who were largely unaccustomed to working with particle accelerators,' he continued. 'Originally it was believed that the SC would play – scientifically speaking – only a subordinate role to the PS. However the results exceeded all expectations.'

Although the SC always operated as a stand-alone machine and never formed part of CERN's increasingly complex interconnecting particle beam systems, the ISOLDE on-line isotope separator, one of the SC's most scientifically prolific ventures, will soon reappear in a different setting in a new experimental area being constructed at the 1 GeV Booster.

'This is a good illustration of the advantages brought about at CERN by a synergy of accelerator resources on the same site,' pointed out Rubbia.

CERN Council Chairman Sir William Mitchell emphasized the long career of a successful accelerator. 'If there are those who think that once the first experiment on a new machine is done, that's it, they should be here today.'

As son of Albert Picot, who provided much of the political driving force behind the movement to establish the future CERN in Geneva, François Picot was well qualified to describe the ambivalent mood of the early 1950s and retrace the sometimes rocky path which finally led to the Organization's establishment in Geneva.

Finally Bernard Ziegler, President of Geneva's Conseil d'Etat, recalled the strange quasi-coincidence of the SC's commissioning and the launch of the Soviet Sputnik satellite, a foretaste of the interplay between the physics of the macro- and micro-cosmos which is the hallmark of the physics of today. He also underlined Geneva's pride in providing the home for what has become such a famous venture.

A special symposium at CERN in April surveyed the accomplishments of the 600 MeV Synchro-Cyclotron, CERN's first particle accelerator, which provided its first beams in 1957 and was finally closed last December. At the symposium Franco Bonaudi described the machine itself.

(Photo CERN HI 43.4.91/4)

People and things

Laboratory correspondents

Argonne National Laboratory, USA
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Brookhaven National Laboratory, USA
A. Stevens

CEBAF Laboratory, USA
S. Corneliussen

CERN, Geneva
G. Fraser

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D. G. Cassel

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Fermi National Accelerator Laboratory, USA
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G. Siegert

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Yu. Ryabov

Stanford Linear Accelerator Center, USA
W. Kirk

Superconducting Super Collider, USA
N. V. Baggett

TRIUMF Laboratory, Canada
M. K. Craddock

▲ At CERN in April, CERN Director General Carlo Rubbia (left) and Roy Schwitters, Director of the Superconducting Supercollider (SSC) Laboratory in Ellis County, Texas, signed a Memorandum of Understanding which provides a framework for future collaboration between the two Laboratories.

(Photo CERN 11.4.91)

Maurice Jacob becomes President of European Physical Society

Distinguished CERN theorist Maurice Jacob becomes President of the European Physical Society (EPS) for an initial one-year term, succeeding nuclear physicist R.A. Ricci of INFN Legnaro. Jacob, who was President of the French Physical Society in 1985, has just served for two years as EPS Secretary. EPS President-Elect is Norbert Kroo of Budapest's Solid-State Physics Institute.

On people

Freeman J. Dyson of Princeton's Institute for Advanced Study receives the 1991 Oersted Medal from the American Association of Physics Teachers.

Klaus Winter of CERN has been appointed Guest Professor at Berlin's Humboldt University, where his task will be to help build up the Physics Department.

Australian news

At a recent meeting of the Australian Academy of Sciences, Bruce McKellar of Melbourne was awarded the Lyle Medal for 1991 for his work in High Energy Theory. and A.W. Thomas of Adelaide was one of 9 new fellows admitted to the Academy.

Meanwhile an official CERN Coordination Committee has been formed to coordinate Australian activity at CERN. The members are: L.Peak (Sydney), S.Tovey (Melbourne), R.Crewther (Adelaide), B.H.J.McKellar (Melbourne), A.W.Thomas (Adelaide) and J. Boldeman (ANSTO). Signing of a cooperation agreement between CERN and Australia is imminent.

Bjorn Wiik, project leader of the superconducting proton ring for the HERA electron-proton collider now being commissioned at the DESY Laboratory, Hamburg, and seen here during one of his regular shifts in the HERA control room, has been elected a Foreign Member of the Norwegian Academy of Science and Letters.

Shadows of Creation

Published by W.H. Freeman is 'Shadows of Creation' (ISBN 0-71767-2157-0) by Michael Riordan and David N. Schramm, subtitled 'Dark Matter and the Structure of the Universe' (see also April, page 18). The book also benefits by a foreword by Stephen Hawking.

The cosmological dark mass problem – that what we see in the Universe is perhaps only about one per cent of it – depends on theoretical prejudice. The astrophysical dark mass problem – that the observed motion of galaxies needs more mass than can be seen – does not. How these arguments are served is a matter of taste.

Dark matter apart, this book is an excellent introduction to the important new links being forged between particle physics, astrophysics and cosmology. Riordan (particles) and Schramm (astrophysics and cosmology) are a good team. They know their subjects well and are used to presenting them persuasively.

Theories of Everything

'Theories of Everything' by John D. Barrow of Sussex (Oxford, ISBN 0-19-853928-2) is a new addition to the growing list of vogue astrophysics and cosmology titles aimed at the general intellectual market. Barrow is no stranger to literary success, with 'The World within the World' (Oxford), 'The Left Hand of Creation' (with J. Silk, Basic Books), and 'The Anthropic Principle' (with Frank Tipler, Oxford), commendably to his credit.

'Theories of Everything' is not 'The Theory of Everything', as the subtitle 'The Quest for Ultimate Explanation' hints. However the title alone will sell, with many eager readers ploughing valiantly through to the end, hoping to discover The Solution. They may be disappointed to find no 'Cosmic Rosetta Stone', but will not go unrewarded.

The origin of everything may turn out to be an insurmountable problem to solve, but the sheer inaccessibility of the problem has long hindered scientific attack. Barrow explains how modern physics and cosmology is at last providing a framework for the problem, and possibly for the solution too.

Return of Uncle Albert

UK physicist Russell Stannard's book 'The Time and Space of Uncle Albert', published by Faber and Faber in 1989 (September 1989, page 33), commendably set out to demystify relativity, which unfortunately remains for most people an impenetrable corner of contemporary culture.

Uncle Albert and his niece Gedanken are back in a new Stannard book 'Black Holes and Uncle Albert' (Faber and Faber, ISBN 0571 16199 5) which continues to explore the heady implications of modern cosmology.

The first book, shortlisted for several literary awards, drew much favourable comment and elicited praise for attacking such a tough subject and trying to present it in an easily assimilable form.

First time round, the CERN Courier admired Stannard for taking on such a tough challenge, but had a suspicion that the resultant packaging was overdone. This was confirmed when Lev Okun of Moscow subsequently questioned one viewpoint, and in a memorable seminar at CERN displayed that relativity is not to be taken lightly.

After reading the sequel, Nathalie Fraser (13) writes: 'Young readers will find it difficult to identify with Gedanken. A talking spaceship called Dick is not my idea of a fun way to explain things. Stannard seems to drown in his own pond trying to explain so many things and so does the reader. After a while you get confused between reality and the strange antics of beetles on a rubber sheet(!), that don't clarify anything.'

Despite this panning, the CERN Courier awards the book a bonus mark for flair and imagination. The forefront of modern physics is difficult to get at, and Dr. Stannard's contrived scenario only reflects this. We eagerly await Lev Okun's opinion.

Meetings

An International Workshop on Electroweak Physics Beyond the Standard Model will be held in Valencia, Spain, from 2-5 October. It will discuss the theoretical implications of the latest results from high energy experiments as well as some non-accelerator experiments. Emphasis will be given to neutrino physics, experimental tests of the standard model and its possible extensions.

Participation is by invitation. The number of participants is limited to about 80. Outstanding graduate

A private visit to CERN on 2 May by Hungarian President Arpad Göncz (left, with CERN Director General Carlo Rubbia) came at a time when discussions are starting on Hungary becoming a CERN Member State.

students and recent PhDs with experience in the field are encouraged to apply.

Further information from Jose W.F. Valle, Dpto. de Fisica Teorica, Universitat de Valencia, Dr. Moliner 50, 46100 Burjassot, Valencia, Spain; tel. (346) 386 4555; fax. (346) 364 2345; e-mail (internet) valle at vm.ci.uv.es (bitnet) valle at EVALUN11 (hepnet) EVALUN::valle

A Workshop will be held at Aussois in the French Alps from 30 September to 4 October on 'X-Ray Detectors for Synchrotron Radiation Sources', including solid-state, gas, image plate and scintillator detector technologies as well as electronics, data acquisition, etc. Science topics will include: protein crystallography, powder, small crystal, time resolved, diffraction, scattering, spectroscopy and imaging. Information from the Secretariat: W. Schenk, Dept. of Physics, Adolf-Reichweinstrasse 2, 5900 Siegen, Germany. Tel: 49 271 740 2342/4344/4140. Fax: 49 271 74515. Places are limited. An ideal opportunity for young high energy physicists to discover another world!

The Balkan Physical Union is organizing the First Balkan School of Physics in Istanbul, Turkey, from 2-13 September. Entitled 'Accelerator Physics Research and Applications', the lecture courses will cover experimental and theoretical particle physics, nuclear physics, and medical and other applications. The School is open to students from the Balkan countries. Further information from Professor Engin Arik, Istanbul University Physics Department, 34459 Vezneciler Istanbul, Turkey, e-mail: FEN10 at TRIUMVM11 Telefax: 0090 1 522 6123 Telex: 22062 sur tr Telephone: 0090 1 511 8480.

As part of the regular review of its journals, the American Institute of Physics has set up a committee to look at 'Journal of Mathematical Physics', chaired by Cecile De Witt of Texas (Austin), seen here with two other members of the committee, Ted Jacobson (left) of Maryland, and Ted Newman of Pittsburgh. The two other members are L. Guttman of Argonne and Maurice Jacob of CERN. Cecile De Witt is well known as founder of the Les Houches Summer School, which contributed so much to the revival of physics in Continental Europe in the 1950s.

(Photo Maurice Jacob)

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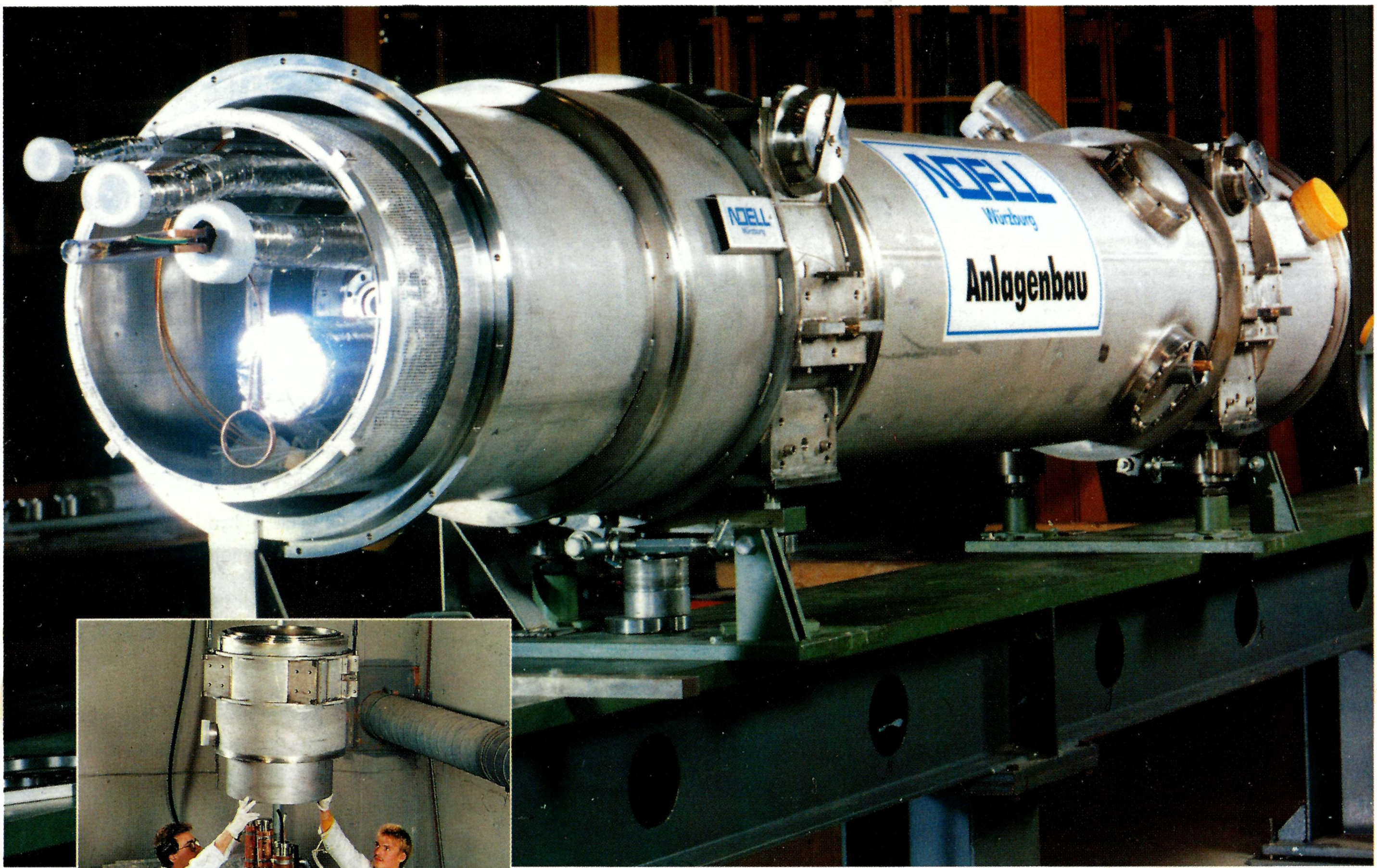
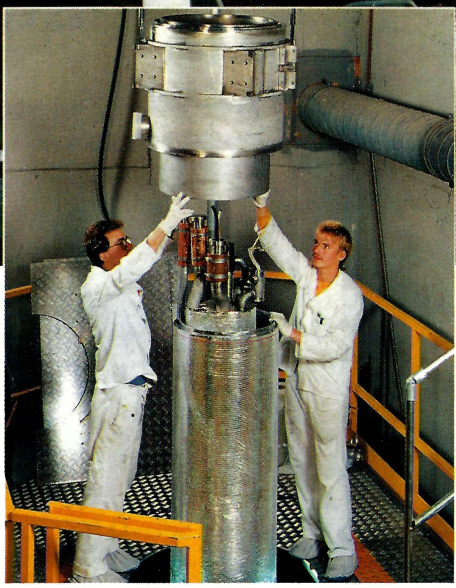
120 quadrupole cryostats

for the HERA storage ring



Cryostat on the measuring platform



Cryostat being manufactured

K 91 GB 3202

The industrial production of storage ring components presents a major challenge. NOELL GmbH, Würzburg, Germany took on this challenge by supplying 120 quadrupole cryostats for the HERA storage ring on schedule and to the full satisfaction of the client. NOELL is currently manufacturing 4 superconducting dipole prototypes.

The take over of the magnet engineering sector of the ABB company has helped NOELL to extend its activities in this field.

NOELL also supplies components for servicing and maintenance of storage rings and for fusion reactors; these include manipulators Tokomak in Princeton, USA and for JET in Culham, UK as well as positioning manipulators for the LEP magnets in Geneva, Switzerland. Contact us if you require any components for particle research and for fusion engineering.

NOELL

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