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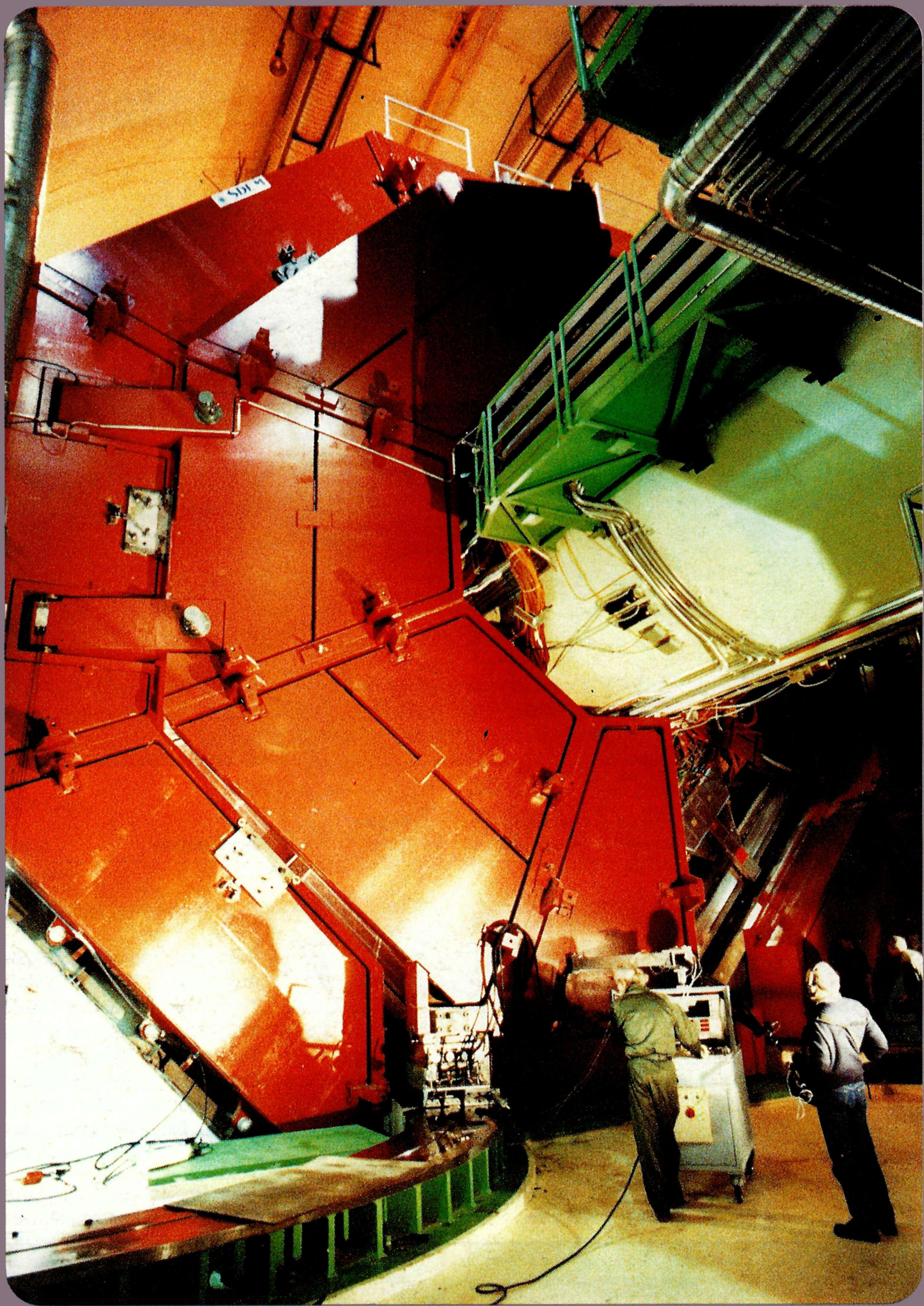
International Journal of High Energy Physics



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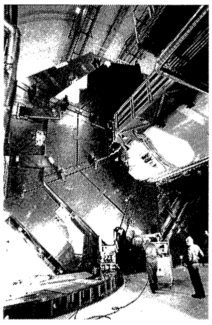

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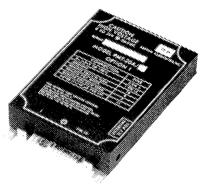

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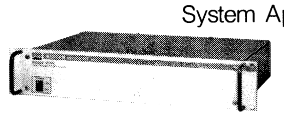

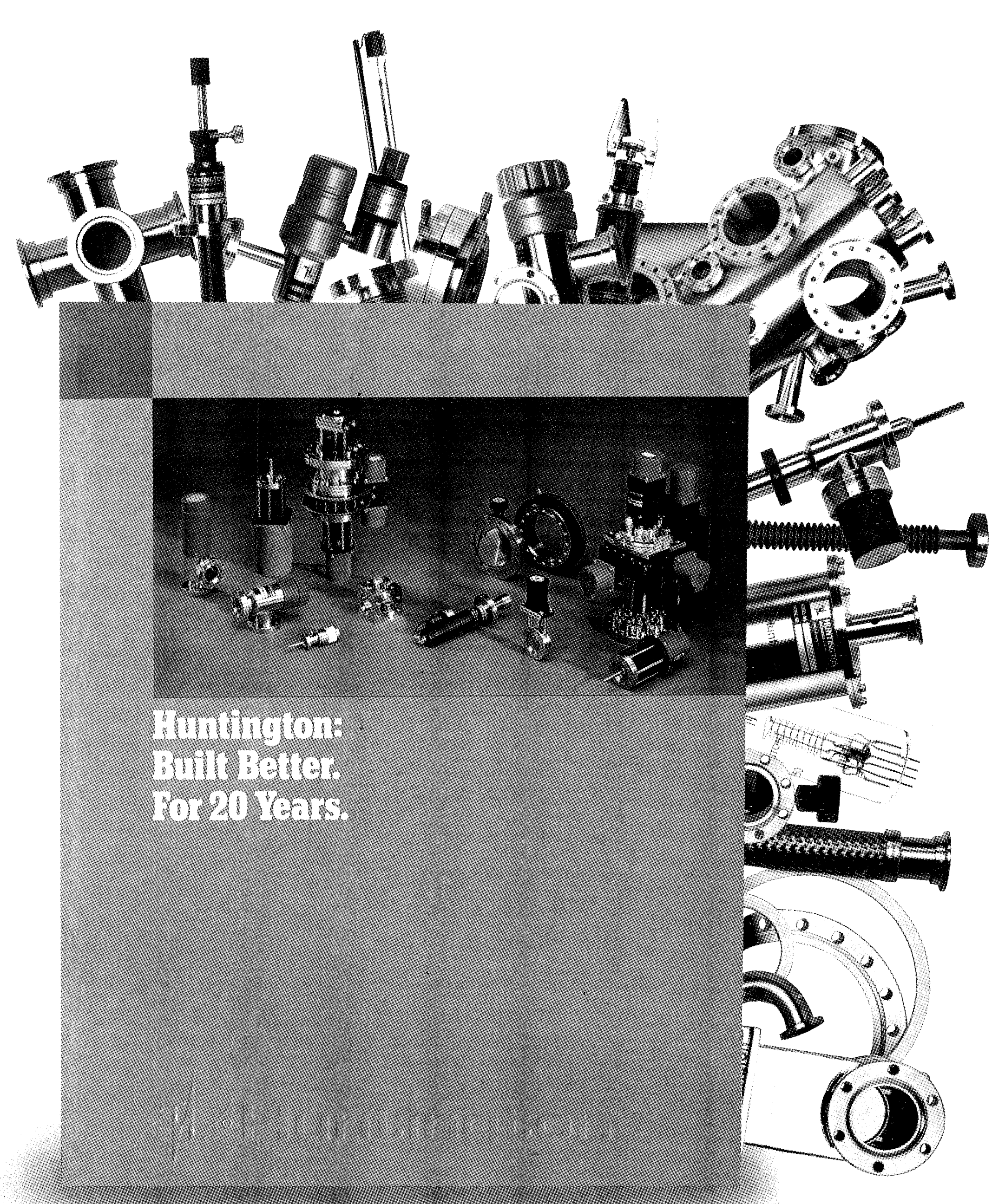
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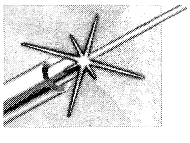
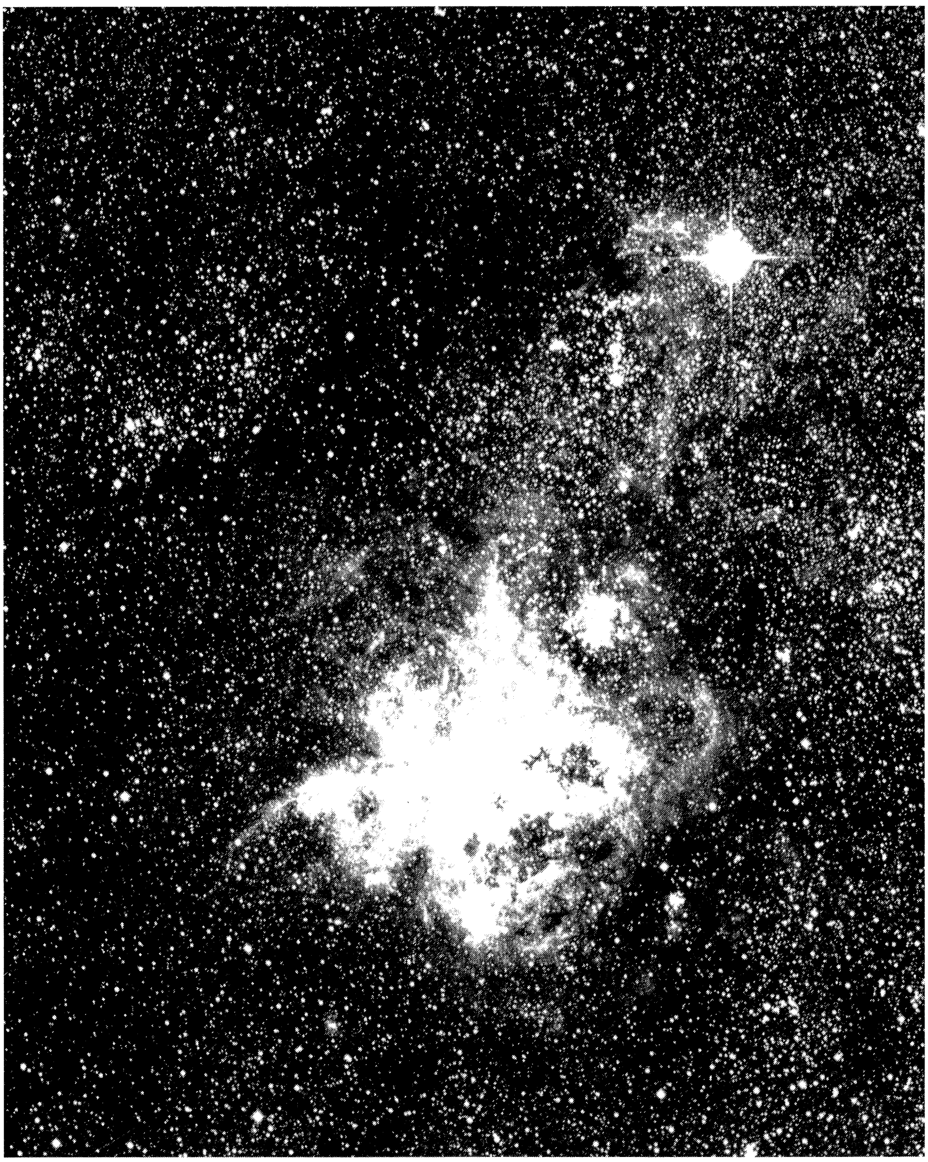


The great supernova of 1987

SN 1987 A.



Despite their apparently very different objectives, astrophysics – the study of the largest structures in the Universe – and particle physics – the study of the smallest – have always had common ground. On 23 February 1987 a supernova explosion provided additional impetus to reinforce these links. In this article, David Schramm of the University of Chicago and the NASA/Fermilab Astrophysics Center, explains why.

One of the most spectacular events in modern astrophysics occurred on 23 February 1987, when light and neutrinos from a supernova explosion in the Large Magellanic Cloud (LMC) first reached Earth. The LMC (a satellite of our Milky Way Galaxy) is 170,000 light years away, making the event, codenamed SN 1987A, the closest visual supernova since Kepler observed one almost 400 years ago.

Most of our knowledge of supernovae has come either from observations of outbursts in distant galaxies, too far away to obtain neutrinos, or from studies of old remnants in our Galaxy, thus missing the fireworks.

Having a supernova blast off relatively nearby while neutrino and electromagnetic radiation detectors were in action has been fantastic. In addition, the pre-supernova star was identified as a blue giant rather than a red giant supernova stereotype.

The detection of the initial neutrino burst made the supernova a weak interaction laboratory as well as founding extra-solar system neutrino astronomy. The supernova also proved that our ideas about element formation in exploding stars were basically correct. In particular, the gamma rays from radioactive cobalt-56 indicated that heavy elements had been 'cooked' – nucleosynthesis had indeed occurred.

This supernova also might affect estimates of stellar collapse rates in our Galaxy. In particular, if many blue stars collapse, then there could be many dim Type II supernovae that were missed in previous supernova rate estimates. Another exciting ingredient was the recent report of a 0.5 ms pulsar remnant in the supernova. This led to a lot of speculation but has now been withdrawn.

Supernovae – lore and laws

Astronomers classify supernovae by whether or not they have hy-

Supernova encounters of the second type

In a star more than about ten times heavier than the sun, the gravitational pressure can retain a thermonuclear furnace generating successive layers of heavier elements – hydrogen on the outside, then helium, then carbon, neon, oxygen and silicon, accreting a core of nickel, cobalt and iron, the most tightly bound nuclei, where the thermonuclear chain fizzles out.

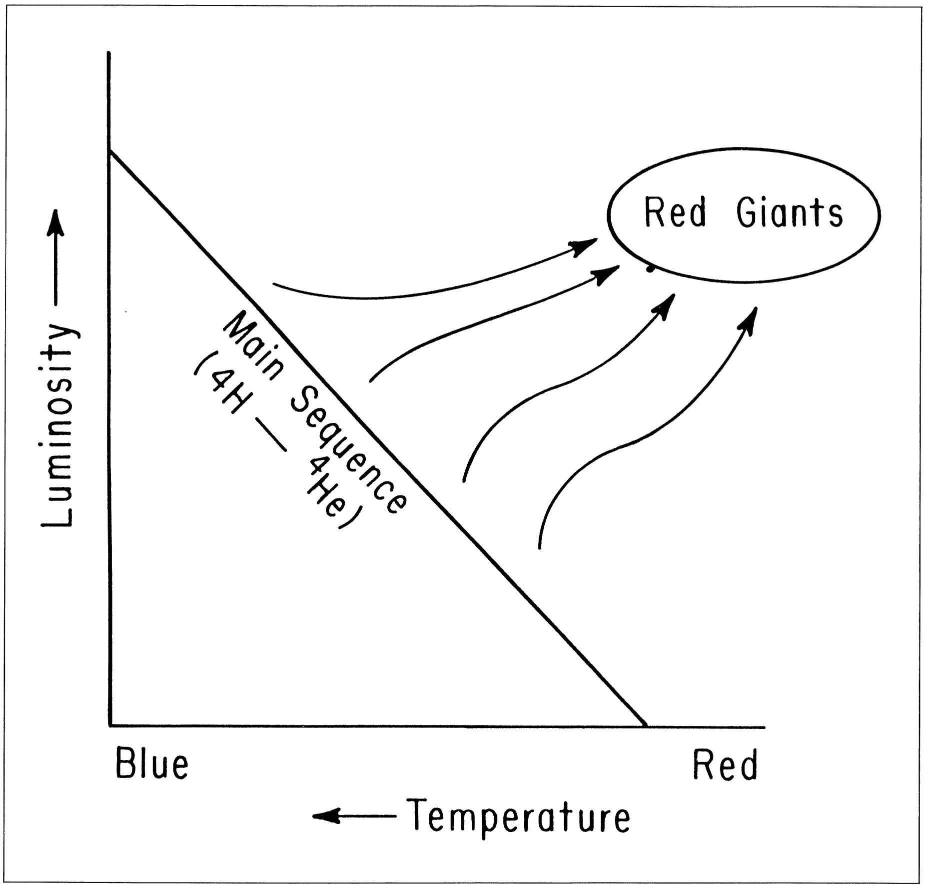
In the 1930s Subramanyan Chandrasekhar pointed to a critical mass, about 1.4 times the mass of the sun, when stellar material succumbs to the compression of gravity.

At about the same time Fritz Zwicky had suggested that under extreme conditions, atoms could be crushed, with orbital electrons being pushed into nuclei, producing neutrons and neutrinos, and forming a neutron star of uniform nuclear density, a few cubic centimetres weighing hundreds of millions of tons!

Such compact nuclear matter is highly incompressible, and the gravitational collapse of the metallic core bounces back as a mighty shock wave, blowing apart the outer layers of the star. The energy released in such a supernova is enormous – as though everyone on Earth were to explode a million million million megaton hydrogen bomb at the same time – outclassed only by the Big Bang itself!

Such a supernova (Type II) produces two signals – an initial burst of neutrinos as its inner core collapses, and a subsequent wave of radiant energy as the shock wave bounces back. The 1987 supernova was the first time that physicists had been equipped to catch these neutrinos. It was also the first time that a supernova had lit up in a well-mapped part of the sky, so that astronomers were soon able to identify the culprit 'progenitor' star.

Figure 1 – Stars are characterized by a luminosity/temperature chart (Hertzsprung-Russell diagram). Heavier stars are found from the upper left of the 'main sequence' (which includes the sun).



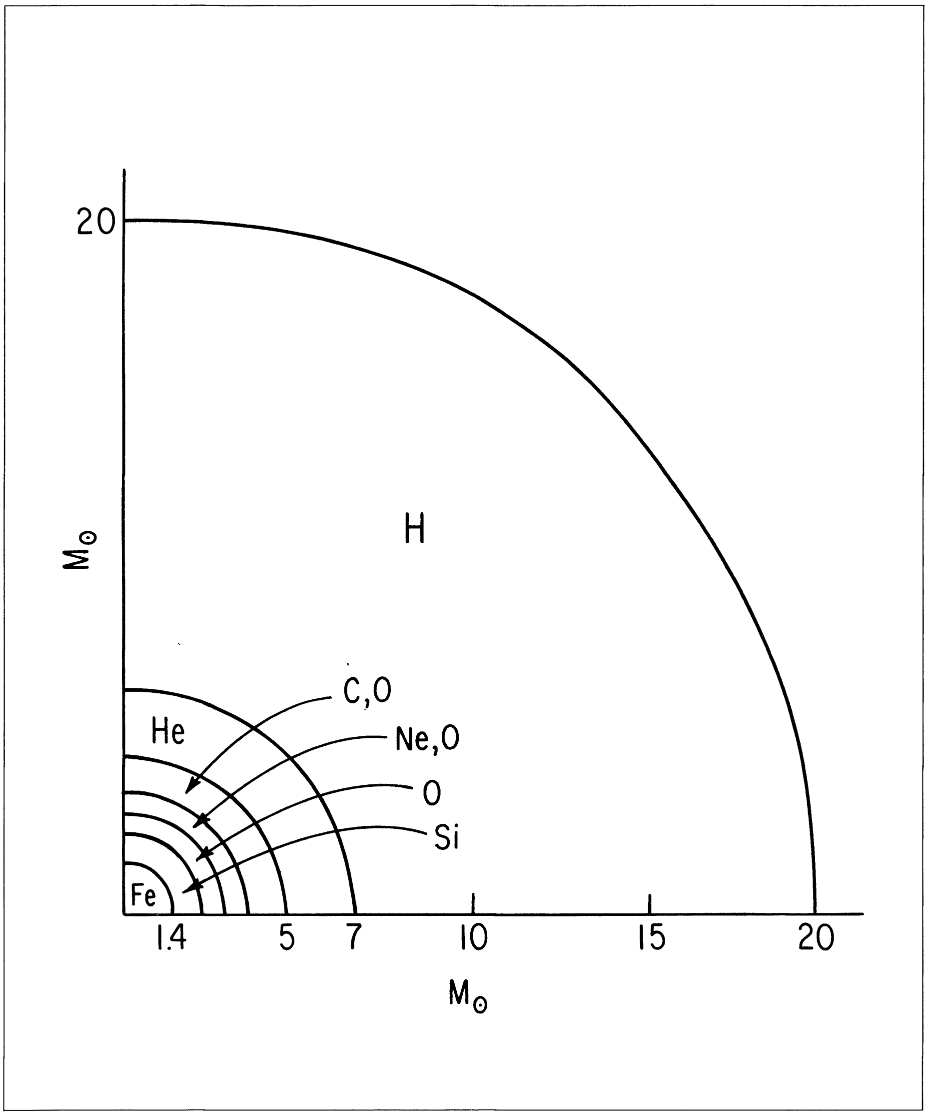
drogen: Type I have no hydrogen, Type II do. Supernova explosions also fall into two categories – nuclear detonation (when the pressure of gravitation pushes the interior temperature of a star to thermonuclear ignition) and gravitational core collapse (when gravitation crushes the atomic nuclei, producing a neutron star – see box). SN 1987A had hydrogen, so it is definitely Type II, and it had the neutrino footprint of core collapse.

The star which exploded was definitely the blue supergiant Sanduleak –69 202, estimated to be about 20 times heavier than the sun. Massive stars (more than about ten solar masses) have been generally assumed to be the progenitors of Type II supernova, and SN 1987A confirms this.

Such stars eventually evolve to an onionskin configuration with an iron core surrounded by successive shells of silicon, oxygen, neon, carbon, helium and an outer envelope of hydrogen. This structure develops through various stages of nuclear burning. The first stage is hydrogen burning to helium, when the outer surface temperature and luminosity are related by the main sequence line on Figure I. Our sun is currently on the main sequence. When the core helium mass reaches a critical level, it starts to collapse under its own gravity until it gets hot and dense enough for the helium to burn to carbon. As this core collapses, the outer envelope expands and the star becomes a 'red giant'.

The next stage occurs when the

Figure 2 – A schematic cross-section of a star of about 20 solar masses, showing successive formation zones of heavier elements. Only the dominant elements are shown, significant amounts of nearby alpha-particle type nuclei also being present. When a supernova explodes and its iron core collapses to form a neutron star, several solar masses of heavy elements will be ejected. As Fred Hoyle first suggested in the 1940s, this could be the origin of the bulk of heavy elements.



carbon ashes of helium burning reach a critical mass and begin to collapse. Carbon cores go critical at the Chandrasekhar mass, about 1.4 solar masses. Because of matter evaporation (like the solar wind) stars lighter than about ten solar masses never get carbon cores this large, and so don't burn carbon, settling down instead to become white dwarves. On the other hand heavier stars do eventually go through carbon burning, followed by several successive stages before reaching iron (Figure 2). Here the burning sequence stops because iron has the maximum nucleon binding energy of any nucleus.

After the carbon burning stage, the centre of the star is so dense that energy produced by burning cannot radiate, and escapes mainly as neutrinos. Since these particles flow unscathed through the outer part of the star, these regions have no knowledge of what is happening inside. Thus once a star becomes a red giant, it is difficult to tell whether its core is burning helium or is iron on the verge of collapse. Furthermore the outer envelope may puff up and be blown off, or may contract due to hydrogen-helium mechanisms that have nothing to do with the interior goings-on.

The most discussed although not totally unexpected feature of the progenitor Sanduleak –69 202 is the fact that it was a blue supergiant. Standard descriptions for progenitors of Type II supernovae generally assume red supergiants. Such supernova lore was naturally biased, since standard Type IIs observed in distant galaxies require a large progenitor to achieve their high luminosities, and low luminosity, blue progenitor Type IIs would be easily missed. However even before 1987 it was known that massive blue stars could also undergo final collapse, depending on convection, mass loss, and composition. SN 1987A ultra-violet observations reveal the previously ejected red giant envelope as a circumstellar shell about 0.7 light years around a progenitor which was once red and subsequently eroded to blue.

Detailed nucleosynthesis calculations indicate that oxygen and nuclei from neon to calcium are produced in approximately solar proportions in massive stars and associated Type II supernovae, while carbon is somewhat underproduced. While there is general qualitative agreement on this, numerical results differ considerably. Nevertheless it was expected that the 1987 supernova should show significant levels of nuclei from oxygen to iron.

The amount of ejected iron from a Type II supernova is sensitive to the temperatures and densities near the boundary between the col-

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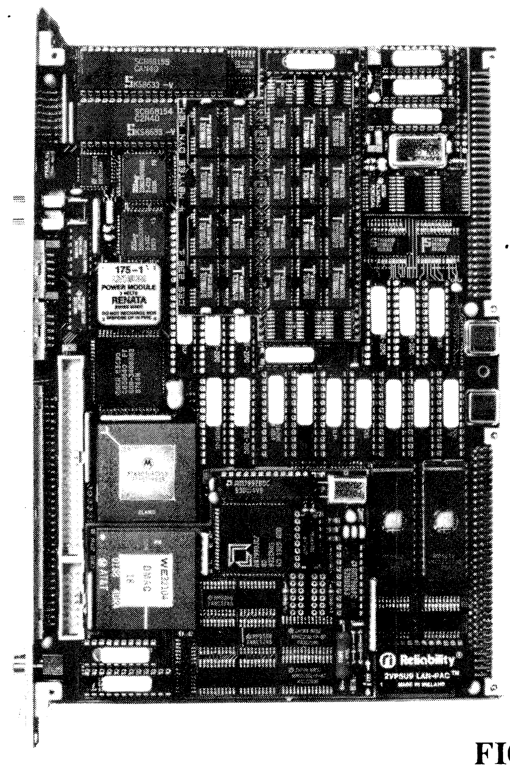

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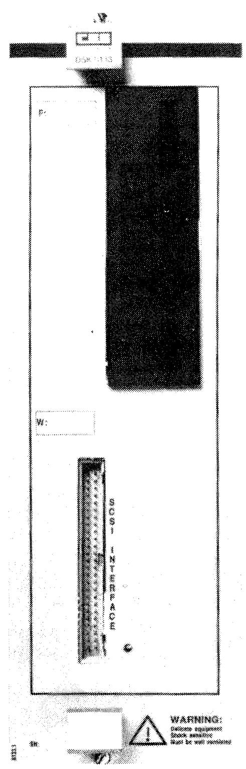

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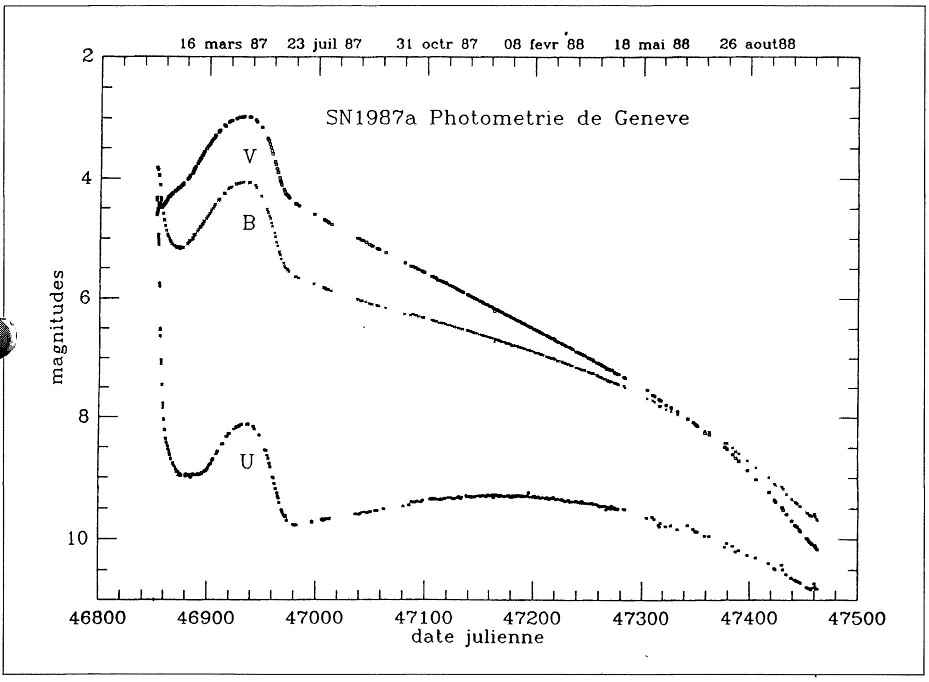
Figure 3 – Visual signal from the 1987 supernova as seen by the Geneva group using the European Southern Observatory.



lapsing core and the ejected material. The strength of the rebound shock shows both the extent to which silicon and intermediate mass nuclei are converted to iron and the rebound velocity due to the incompressibility of the core.

Iron production in SN 1987A determines the detected gamma ray signal and the role of decay heating in later stages. As iron is primarily formed from alpha particle nuclei with equal numbers of neutrons and protons, nuclei of mass 56 are formed as nickel-56, which decays with a 6.1-day half-life to cobalt-56, decaying in turn with a 79-day half-life to iron-56. The longer cobalt lifetime enables gamma-rays to be detected for a year or more after the initial explosion. By following the gradual fading of the supernova (Figure 3), astrophysicists estimated that it ejected 0.075 solar masses of cobalt-56. In addition, NASA's Solar Maximum Mission (SMM) space probe picked up the characteristic gamma rays less than nine months after the explosion, proving that fresh cobalt-56 had been synthesized in SN 1987A and confirming a prediction made twenty years earlier, as well as vindicating the arguments for gamma-ray line astronomy.

Following the light curve

Observations in Chile, Australia, New Zealand and South Africa gave a precise picture of how the light from SN 1987A varied with time (Figure 3). After its initial sighting, when the progenitor star's humble 12th magnitude shot up to about 6th magnitude, the supernova gradually intensified over the next 90 days, eventually reaching 3rd magnitude.

The 1987 Supernova differs from 'typical' supernovae observed in other galaxies, most, if not all, of these differences deriving from its origin as a blue star (radius 3 x 10^{12} m) as opposed to a red giant (radius 10^{13-14} m). Blue supergiant envelopes are smaller, denser and have steeper density gradients, giving higher velocities and converting more supernova energy into released kinetic energy, at the expense of radiative output. In addition, the time between collapse (neutrino emission) and the shock emerging from the surface (first light) would be hours for a blue star rather than days for a red giant. In 1987 this time lag was about three hours.

Hydrodynamic models indicate that the rapid rise in the initial visible light from SN 1987A ties in with a collapse at the same time as the emission of the detected neutrinos. It seems likely that the luminous energy over the first hundred days came from shock deposition and atomic recombination. The subsequent fading, with a half-life of 79 days, suggests that 0.075 solar masses of nickel-56 were ejected.

Remnant expectations – neutron star or black hole?

An important and still outstanding question is the character of the supernova's remnant. As well as giving neutron stars, the massive star progenitors of Type II supernovae can produce black holes. If the remnant core mass exceeds the limit for a stable neutron star (about two solar masses), the gravitation is so strong that a black hole is formed. Standard assumptions for the Sanduleak star favour a 1.4 ± 0.2 solar mass remnant, suggesting a neutron star, unless later accretion occurred.

Neutron star or black hole? The question should soon be answered. The supernova is no longer fading, having recently levelled off at value

consistent with pulsar powering. A report of a 0.5 ms-period pulsar observed for 15 consecutive 30-minute intervals in January 1989 showed no variations in timing down to the 10^{-14} level, however this report has now been withdrawn.

Any pulsar should eventually show up as the debris thins out, and especially when the satellite ROSAT flies later this year and looks for the X-rays from the young neutron star. A fast rotating pulsar (such as that suggested by the initial report) would severely constrain the nature of nuclear and/or quark matter – only very soft matter theories can be consistent with such high rotation. In fact most nuclear matter theories had trouble with the 0.5 ms period pulsar.

Whatever the remnant turns out to be, the 1987 supernova has already taught us a lot. We now know that blue as well as red stars collapse, and that supernovae from the former are less bright. The cobalt-56 gamma rays give dramatic proof of nucleosynthesis. In the next issue, the second part of this article will go on to cover the other major triumph – the detection of supernova neutrinos.

Top twenty of the 1980s

What was the hottest particle physics of the past decade? When CERN information specialist David Dallman looked into the high energy physics database to find the most frequently cited papers of the 1980s he found two dominant themes, one theoretical – string theory, and one experimental – the discovery of the W and Z carriers of the weak nuclear force at CERN in 1983.

(The rankings cover only work originating during the 1980s – obviously frequent references were made during the decade to papers written earlier. The results were compiled using the HEPDATA high energy physics information system managed on the CERNVM computer system by the UK Particle Data Group at Durham, which uses the SLAC preprint database.)

The discovery of the W and Z particles at CERN's proton-antiproton collider in 1983 was a watershed in modern science, providing the final rivets for the already solid structure of the electroweak picture – the synthesis of electromagnetism and the weak nuclear force. (Before becoming CERN library's subject specialist, David Dallman had been part of the Vienna team in the UA1 experiment which discovered the W and Z particles in 1983.)

The finding of the W and Z particles by the UA1 and UA2 experiments at CERN were reported in four 1983 Physics Letters, together providing a formidable block of 2254 citations.

With or without big discoveries, the periodic summaries of current information by the international Particle Data Group are well appreciated, the most frequently cited being those in 1986, 1980 and 1988.

The citation rankings show that strings, supersymmetry and related developments became a major industry among theoretical physicists.

Initial efforts to merge the successful electroweak picture with quark forces and with gravity to form a single 'Grand Unified Theory' (GUT) describing everything had been plagued with several major difficulties, notably the vastly different mass scales of the various forces. While electromagnetism and the weak force merge smoothly together at the W and Z mass scale (about 100 GeV), electroweak and quark effects only become comparable at 10^{15} GeV, and gravity has to wait until 10^{19} GeV before it gets an equal vote.

The new ingredient in supersymmetry is to double the number of basic particles – every fundamental quark or lepton gets a supersymmetric field particle counterpart ('squark' or 'slepton'), while the known field particles (photon, W, Z, gluon, graviton) acquire supersymmetric partners (photino, Wino, Zino, gluino, gravitino). With this extra layer of particles, the theory becomes much neater. While no sign of superparticles has yet been found, the search goes on as new machines open up higher energy ranges. Physics Reports review

papers on supergravity in 1981 by P. van Nieuwenhuizen (404 citations) and on supersymmetry in 1984 by H.P. Nilles (426) were prominent.

String theory, where pointlike particles are replaced by one-dimensional strings, first emerged in the 1970s as an elegant formulation of the dual resonance structure of strong interactions. At first these ideas languished in a wilderness, but gradually string descriptions were seen to reproduce recognizable physics, especially when combined with supersymmetry. With such 'superstrings', many theorists feel that a framework for a Grand Unified Theory is within their grasp.

Most frequently cited (1091 times) was the 1985 Nuclear Physics B paper by P. Candelas, G.T. Horowitz, A. Strominger and E. Witten which proposed the first quasi-realistic solutions to the 'heterotic string'. More developments in this direction came in E. Witten's 1985 Nuclear Physics B paper (505 citations) on symmetry breaking patterns.

The now famous heterotic string had been introduced by D.J. Gross, J.A. Harvey, E. Martinec and R. Rohm (the so-called 'Princeton String Quartet') in a series of frequently cited papers, two in Nuclear Physics B (969 citations to the 1985 paper and 507 to one in the following year) and one in Physical Review Letters (1985), with 897 citations. In biology, heterosis refers to the vigour and growth potential often seen as a result of cross-breeding. In string theory, the name was adopted when bosonic and fermionic strings were combined, producing new properties not belonging to either.

E. Witten's 1986 Nuclear Physics B paper (470 citations) made a brave attempt at formulating a complete string theory language.

The quantum geometry of bosonic and fermionic strings had been pioneered in successive 1981 Physics Letters by A.M. Polyakov (925 and 446 citations respectively).

Referred to 828 times was the 1984 Physics Letter by M.B. Green and J.H. Schwarz which was a precursor of the heterotic string and pointed out how anomaly cancellations force consistency conditions. Schwarz was also the author of a classic pre-heterotic string 1982 Physics Reports review article (764 citations).

The Green and Schwarz proposal was in turn foreshadowed in a 1984 Nuclear Physics B paper (413 citations) by L. Alvarez-Gaumé and E. Witten which explored the consistency conditions for gravitational and gauge interactions of chiral (left/right asymmetric) matter.

Not superstrings as such, but plenty of citations (811) for the seminal 1984 paper on conformal symmetry by A.A. Belavin, A.M. Polyakov and A.B. Zamolodchikov in Nuclear Physics B, with applications in critical phenomena studies and string theory.

A 1986 Nuclear Physics B paper by D. Friedan, E. Martinec and S. Shenker (598 citations) reformulated superstrings in the conformal language proposed by Belavin et al and now widely used. Also building on the ideas of Belavin et al was the 1984 Physical Review Letter by D. Friedan, Zongan Qiu and S. Shenker (423 citations), with important applications in statistical mechanics.

Outside the superstring area, two successive 1983 Nuclear Physics B papers by E. Witten (652 and 408 citations) looked at the low energy behaviour of strong interactions, with baryons behaving as solitary waves (solitons).

E. Witten's 1984 Communications in Mathematical Physics paper exploring fermion-boson correspondence in two dimensions drew 478 citations.

Another goal of 1980s theory was to explain how our Universe with all its idiosyncrasies emerged from the initial Big Bang. Various scenarios were put forward based on 'inflation' – abrupt phase transitions – early in the Universe's history. Frequently cited ideas were those of A.H. Guth in 1981 (842 citations), A. Albrecht and P.J. Steinhart in 1982 (542) and A.D. Linde, also in 1982 (537).

The 1980s also saw the emergence of 'lattice gauge theory', where the introduction of an artificial lattice facilitates calculations otherwise difficult or impossible. The first published numerical simulations using lattice ideas, by M. Creutz in 1980, were well cited (523 times).

The listings

The initial figure is the citation score:

1091 P. Candelas et al: *Nuclear Physics B258* (1985) 46
969 D.J. Gross et al: *Nuclear Physics B256* (1985) 253
925 A.M. Polyakov: *Physics Letters 103B* (1981) 207
897 D.J. Gross et al: *Phys. Rev. Letters 54* (1985) 502
893 Particle Data Group: *Physics Letters B170* (1986) 1
842 A.H. Guth: *Phys. Rev. D23* (1981) 347
828 M.B. Green, J.H. Schwarz: *Physics Letters 149B* (1984) 117
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Around the Laboratories

CERN
Fixing mixing

While the underlying electroweak model provides a very satisfactory synthesis of electromagnetism and the weak nuclear force, its predictive power is limited, with many basic parameters having to be measured in experiments.

One of these, the mass of the Z particle – the electrically neutral carrier of the weak nuclear force – is now amply covered by the experiments at CERN's LEP high energy electron-positron collider*.

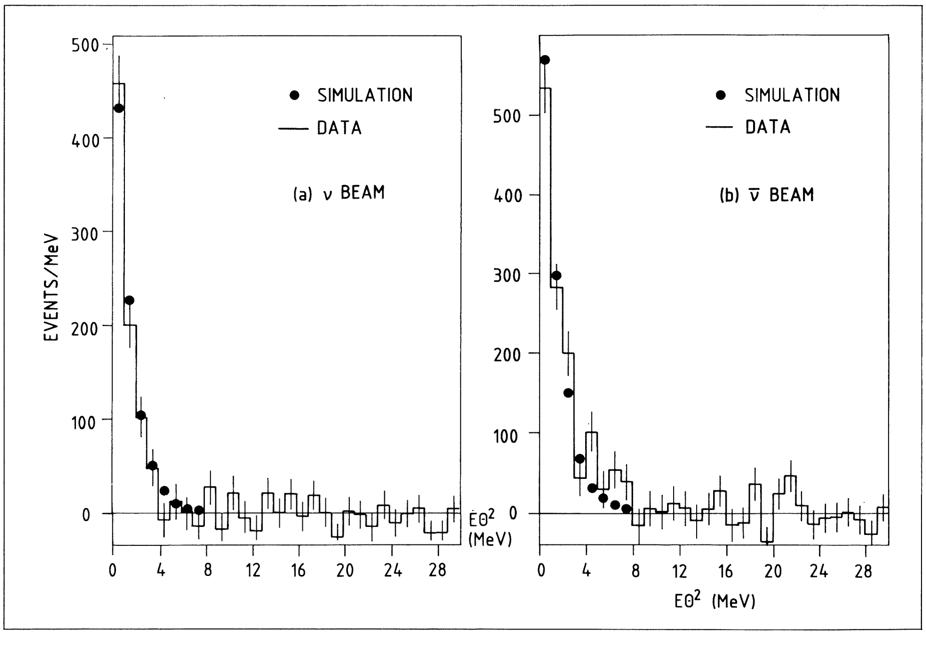
Another vital electroweak quantity is the mixing parameter ('Weinberg angle') relating the electrically neutral fields in the theory to the actual field particles, the Z and the photon. The CHARM-II collaboration at CERN's SPS proton synchrotron makes a speciality of measuring this mixing angle in the cleanest possible process – neutrino scattering off electrons, free of all the complications of quark interactions, where interpretation is clouded by the uncertainties in the quark content of nuclear particles.

The CHARM-II (Brussels/CERN/Hamburg/Louvain/Moscow/Munich/Naples/Rome) collaboration catches its neutrinos in 700 tons of 3.7 m-square glass plates interspersed with scintillator and streamer tubes, with a downstream muon spectrometer. (The acronym comes from the original CERN/Hamburg/Amsterdam/Rome/Moscow collaboration which investigated neutral current neutrino interactions at the SPS from 1976 to 1985.)

With almost all the target mass being carried by nuclear material, the electron events are very rare. From some nine hundred million neutrino interactions, CHARM-II carefully isolates some two thousand cases of a neutrino hitting an electron, basically about one for every two hours of running in the SPS neutrino beam.

The mixing parameter comes from comparing the reaction rates for neutrinos and antineutrinos on

**The UA2 experiment at CERN's proton-antiproton collider has made a precision measurement of the mass of the companion W particle – story next month.*



Forward scattering of neutrinos and antineutrinos off electrons as seen by the CHARM-II neutrino experiment at CERN after subtraction of background.

electrons, the result (expressed as the square of the sine of an angle) being 0.232, compounded with small errors. With the precision Z mass value, this provides interesting consistency constraints on today's six-quark picture, where the sixth ('top') quark still awaits discovery. Now the pundits say that it is likely to remain that way for a while (see page 19).

Meanwhile CHARM-II continues to accumulate data to complement the high energy electroweak results coming from the new generation of electron-positron physics experiments.

SUPERCOLLIDER
Design changes

A major task faced by the new US Superconducting Supercollider (SSC) Laboratory as it began life early last year was to prepare a baseline design, cost and schedule for the site in Ellis County, Texas.

The conceptual design developed by the SSC Central Design Group at Berkeley in 1986 was for a generic site, and served as the basis of the cost estimate submitted to Congress for fiscal year 1990. Under the terms of the contract between Universities Research Association (URA – the SSC parent organization) and the US Department of Energy to establish the SSC Laboratory, signed in January 1989, a report on the Site-Specific Conceptual Design Report was complete by December.

One major change foresees bypasses in the 87-kilometre collider ring at the east and west intersection regions so that detector construction and modification would not hinder machine operation, and obviating the need for special assembly halls.

A second class of design changes arises from the need to control beam loss during the 40-minute injection period when beam pulses from the injector complex are loaded into the twin collider rings.

These losses are due to small but inevitable deviations of the bending and focusing magnetic fields in the collider from their ideal values. To compensate for these deviations modern synchrotrons use correction magnets, but the requirements for these magnets will be more demanding for the SSC than for any previous machine. For example the on-axis bending field must keep the circulating protons within one millimetre of the axis over the entire 87 kilometre orbit. Small non-uniformities in the bending field (one part in 10,000 one centimetre from the axis) could cause some off-axis protons to be lost. During injection when the beam is largest, off-axis protons would pass through the slightly non-uniform bending fields several million times.

The SSC design therefore involves tradeoffs between the cost and/or difficulty of constructing magnets with very uniform field distributions (high field quality) and of building and operating elaborate correction and compensation magnet systems coupled with high accuracy beam diagnostics.

The choices will have substantial impact on the time required for commissioning the machine. A machine with higher quality magnetic fields might cost more to build but, with fewer demands on the correction systems, would be easier to commission. On the other hand a machine with a more finely tuned compensation system, with 'learning curves' being encountered simultaneously on many complex components and systems, would probably take longer to commission, involving higher initial operating costs and delaying the research programme. A valid cost comparison has to take all these factors into account.

Operational experience with the superconducting Tevatron at Fermilab has revealed time-dependent multipole error fields due to so-called 'persistent currents' in the superconducting wire filaments. Since these effects become less important at higher fields, a higher energy SSC injector would help.

Simulation of proton behaviour in the full SSC injection period has become possible with modern supercomputers. These studies predict a progressive loss of particles with time, suggesting more conservative criteria for the allowed field errors and a larger dipole magnet aperture.

After consultation with the SSC Machine Advisory Committee, an Ad Hoc Committee on SSC Physics, the Scientific Policy Committee, the Executive Committee of the Users Organization for the SSC and the URA Board Of Overseers, the SSC Laboratory has recommended to the Department of Energy that the maximum collider energy be maintained at 20 TeV, the injector energy be increased from 1 to 2 TeV, the inner diameter of the collider dipole magnet coil be increased from 4 to 5 cm, and the collider focusing strength be increased by decreasing the half-cell length from 114 to 90 metres.

The cost implications for the SSC have been carefully assessed. In addition to preparing a 'bottoms-up' cost estimate of the recommended design, the Laboratory developed several other options, including one in which the cost was pinned to the $5.9 billion previously submitted to Congress. To build an SSC at that budget, the ring would have to be made smaller, with the maximum proton energy educed to about 15 TeV.

Following a preliminary discussion of the options with SSC Laboratory Director Roy Schwitters, Energy Secretary Watkins requested a peer review of the science issues that might be involved in changing the performance goals of the SSC, and a formal DoE review of the SSC cost estimates.

A High Energy Physics Advisory Panel (HEPAP) SSC physics group chaired by Sidney Drell met at the Laboratory in January to consider the physics impact of possible changes in machine parameters, especially the maximum energy. The conclusion was that 'the SSC Laboratory, in its current proposal, has chosen wisely among the alternatives and that the project should move forward expeditiously.... Lowering the beam energy to below 15 TeV would unacceptably increase the risk of missing important new physics. We feel strongly about the need for a flexible and reliable facility at 20 TeV for decades to come, and therefore, we believe it would be very unwise to redesign the machine with a reduced circumference'. This recommendation was unanimously endorsed by HEPAP on January 12 and transmitted to the DoE.

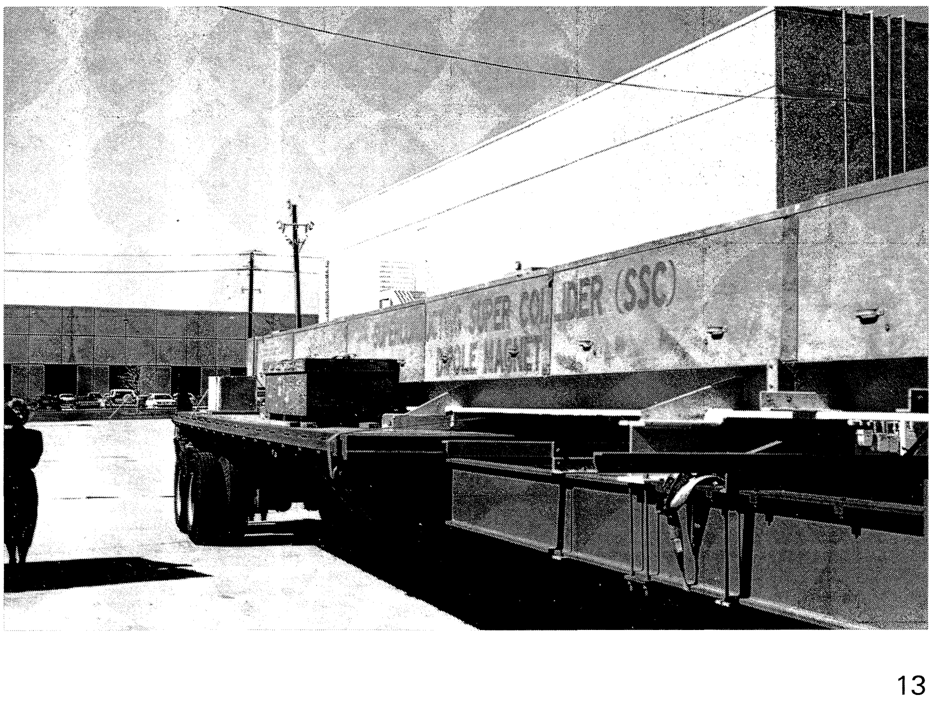
The DoE cost review concluded that the estimates provided were 'reasonable'. The DoE is currently considering the Laboratory's recommended design, cost and schedule and is expected to announce its position shortly. In the meantime, the Secretary of Energy has indicated the Department's and the Administration's continued strong support of the project.

Meanwhile the team of Parsons, Brinckerhoff, Quade and Douglas Inc. of New York, NY, and Morrison Knudsen Corp. of Boise, Idaho, in association with CRSS Inc. of Houston, Texas, has been selected for negotiation to become the architect, engineer and construction

Magnet work begins at SSC Lab

The first superconducting dipole for the US Superconducting Supercollider (SSC) arrived at the Texas Laboratory from Brookhaven on 16 February. Tests found turn-to-turn shorts and the magnet will be completely disassembled and 'autopsied' in a workshop area now being prepared in the nearby Stoneridge Business Park. This marks the start of hands-on SSC magnet work on-site.

A complete magnet arrived from Fermilab in March and will be used in vibration tests. Another magnet from Brookhaven will be used in vibration analysis and then disassembled. The new workshop will be used for preliminary engineering studies such as electrical interconnections. Extensive magnet work will begin on site next year when the Magnet Test Facility is complete.



A 17-metre dipole for the US Superconducting Supercollider (SSC) arrives at the Texas site from Brookhaven (New York), marking the start of on-site magnet work. Because of design changes, production magnets will be 16 metres. About 8,000 will be needed for the 87-kilometre SSC ring.

manager for the SSC. This task covers responsibility for the design and construction of the tunnels, underground halls and the campus for the Laboratory, but not for the accelerator's technical components. The total cost of the conventional facilities is estimated at about $1 billion.

The next step is submission of a cost proposal and negotiation of a formal contract with URA. The negotiations are expected to be completed this spring and a contract awarded in early summer. Parsons Brinckerhoff et al were one of fourteen competing teams in the selection process that began in October 1988.

DESY
Handling persistent eddy currents

The vanishing electrical resistance of superconducting coils as well as their ability to provide magnetic fields far beyond those of saturated iron is the main motivation behind the push to use superconducting technology in big new proton accelerators.

But this advantage can turn into a drawback at low excitations when the eddy currents – induced in any electromagnet when the field is changed – do not decay, but continue to flow. Preparations for the proton ring of the HERA electron-proton collider nearing completion at the German DESY Laboratory in Hamburg have borne this in mind.

Bipolar eddy currents generate higher-order multipole fields which may become intolerable. A well-known example is the sextupole component measured in all superconducting dipoles, but in the HERA proton ring whose injection energy is only five per cent of the 820 GeV design energy even higher order multipoles come in – a 10-pole in the dipole magnets and a 12-pole in the quadrupoles. Sextupole, 10-pole and 12-pole correction coils are used in HERA to compensate the resulting field distortions.

Compensation requires a precise knowledge of the persistent current effects. Thus all dipoles and quadrupoles are subjected to extensive magnetic measurements, especially near the injection field, and multipole components are determined to a precision of 2 x 10^{-5} relative to the main field.

Figure 1 shows the average sextupole coefficient from measurements of 200 dipoles. A pronounced offset (hysteresis) is seen between increasing and decreasing currents, as the persistent currents rotate differently in the two cases. The curves are the predictions of a computer model, showing excellent agreement, with no adjustable parameter, the only input being the way the critical current density of the superconductor changes with magnetic field and with temperature.

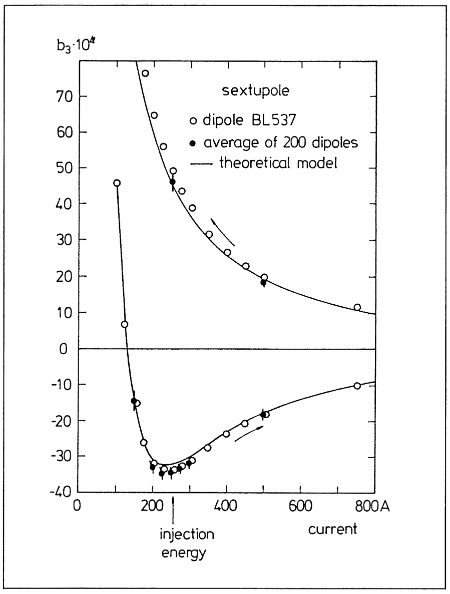


Figure 1 – The superconducting magnets in the HERA electron-proton collider at DESY will have to contend with eddy currents. The resulting sextupole coefficient at 25 mm radius in the dipoles (compared with the dipole field itself) is shown for increasing and decreasing magnet current. The black points are the average values from 200 dipoles, compared with theoretical predictions. The effects are well understood.

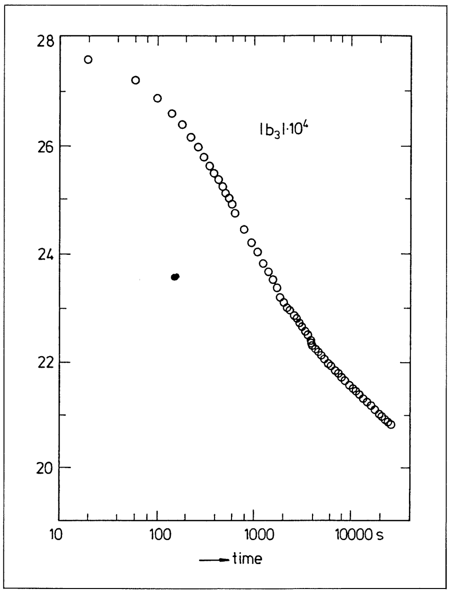


Figure 2 – Time dependence of the sextupole field in a HERA dipole, taken on the lower branch of the hysteresis cycle (see Figure 1) at 250A, corresponding to proton injection at 40 GeV.

The persistent currents also have a significant effect on the magnets' main field. Their contribution to the dipole field shows similar hysteresis and is again well described by the model. At the injection energy the dipole field is reduced by 0.5 %, corrected by dipoles to ensure a proper injection match.

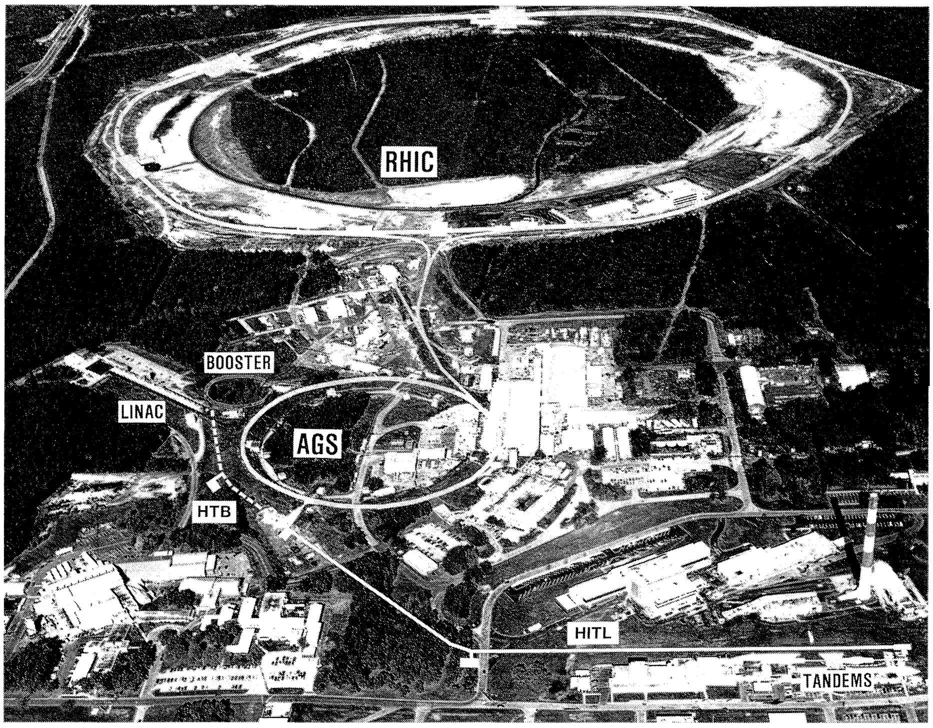
The first indication that persistent current fields change with time came during careful observations of beam behaviour during the hour-long injection of antiprotons into Fermilab's superconducting Tevatron. The HERA magnets' field distortions vary logarithmically with time – during the 30-minute proton injection process the sextupole component changes by about 2 x 10^{-4} compared to the dipole field, and the current in the sextupole correction coils has to be adjusted to compensate this drift.

The explanation is superconducting 'flux creep' – some of the magnetic flux bundles trapped at pinning centres in the superconductor may be released by thermal activation. Surprisingly, the creep rates in the HERA magnets depend on who made them – the Italian dipoles show about twice the effect of the German ones.

To improve knowledge of the persistent current effects during machine operation, two reference dipoles (one Italian, one German) will be connected in series with the ring magnets. NMR and Hall probes and pickup coils will accurately determine dipole and sextupole components, and this information will be used to adjust the current in the ring's correction coils.

A superconducting accelerator is obviously more complicated to control than a normal machine, however the wealth of knowledge on persistent current effects and the provisions for accurate measurements make the HERA specialists confident that their machine will perform as planned.

From Peter Schmueser



Aerial view of the accelerators at Brookhaven, showing the existing tunnel in which the RHIC collider will be built, with the Tandem-Booster-AGS complex as injector.

BROOKHAVEN Ready for RHIC

With its RHIC – Relativistic Heavy Ion Collider – project now part of the budget proposed by US President Bush for fiscal year 1991 (March issue, page 28), Brookhaven is about to start construction of a unique kind of high energy collider. At a time when accelerators handling particles – electrons, protons and their antimatter counterparts – are boosting beam energies for microscopes to probe ever-shorter distances, RHIC is envisioned as a great pressure-cooker for strongly interacting matter.

A relativistic (ultra high energy) heavy ion collider has been a key element of the long range planning for US nuclear physics for many years. In its most recent plan, developed last summer, the Department of Energy/National Science Foundation's Nuclear Science Advisory Committee (NSAC) said 'RHIC has the highest priority for new construction in the nuclear physics program. We urge a swift beginning for this important project'.

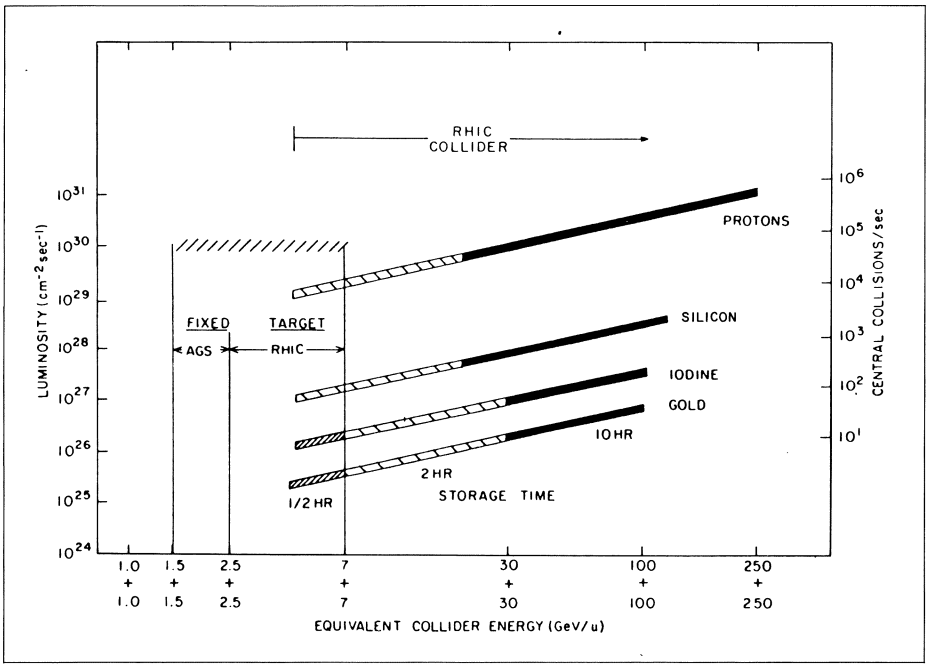
President George Bush and the DoE responded with a call to authorize 397 million dollars of construction funds for RHIC, about one-quarter being earmarked for detectors. If Congress approves, construction will start early in 1991 and RHIC will be ready for experiments in 1997.

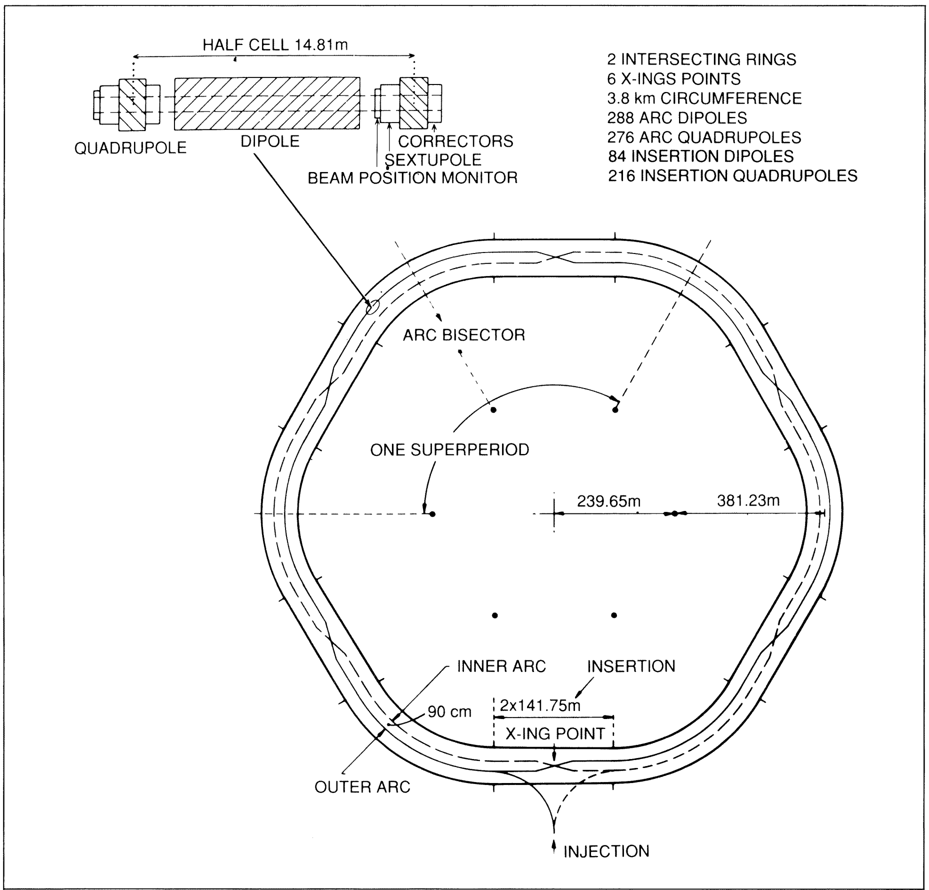
RHIC is designed to explore the extremely high temperatures and densities when ordinary nuclear matter is transformed to a plasma of quarks and gluons. For this, RHIC's heavy ion beams will collide at energies orders of magnitude beyond those used in ion experiments at Brookhaven and at CERN.

With its two rings of superconducting magnets, the RHIC collider will be the final link in Brookhaven's chain of heavy ion accelerators. Ion beams from the Tandem van de Graaff are transported through a 550-metre transfer line and injected into the AGS Alternating Gradient Synchrotron. Currently silicon ions (mass 28) are accelerated to 14.6 GeV per nucleon in the AGS and extracted for fixed-target experiments. The AGS Booster Synchrotron is currently under construction, and when this is complete in 1992, ions from the Tandem van de Graaff will be pre-accelerated prior to injection into the AGS – allowing much heavier ions to be handled.

The AGS will inject into RHIC, which will be able to handle the full

Performance specifications for RHIC, showing the design luminosity against collision energy for various ion masses. On the right-hand scale, central collisions mean that ions pass within 1 fermi (10^{-13}) of each other.





range of ion species, from protons up to the heaviest available. Parameters are optimized for experiments with gold beams at a maximum energy of 100 GeV per nucleon per beam, but heavier beams such as uranium will be on tap if required. In addition, RHIC will be able to operate over a wide range of collision energies, from those provided by the AGS upwards. The luminosity for maximum energy gold beams will be 2 x 10^{26} per sq cm per s, while proton beams of up to 250 GeV will give luminosities of about 10^{31}. Mixed collisions (eg protons on gold) will also be possible.

The two interlaced rings of the collider will cross six times. Four experimental areas will be used initially, with the remaining two free for future expansion.

As preparations are made to begin construction of RHIC and its detectors, R&D for the project has been in high gear for the past several years. The earliest R&D work for the machine focussed on accelerator physics and the problems of accelerating, storing, and colliding intense beams of heavy ions. In many respects standard high energy particle accelerator know-how had to be re-evaluated for RHIC, the first facility of its kind in the world.

A major development effort has centred on the collider's superconducting magnets. The 9.7-metre dipoles are the largest of these, and with 288 required are by far the largest cost item. The dipole design follows the basic 'cosine theta' coil geometry originally developed at Brookhaven ten years ago for the Isabelle project, and which

The layout of the two superconducting rings in the RHIC tunnel. One-half of one magnet lattice cell is shown.

went on to be adopted into design for subsequent projects elsewhere.

RHIC's dipole design incorporates several special features – a relatively large bore (80mm) accommodates the beam growth inherent in tightly-bunched beams of highly charged ions; the magnets have a relatively modest field of 3.45 tesla, achieved with a single layer of superconducting cable; and the iron yoke assembly is used to constrain the coil. A primary goal has been to fine-tune these features to produce a reliable magnet which is as simple and inexpensive as possible to manufacture.

So far eight full-size prototype RHIC dipoles have been produced, and all have been successfully tested, even at fields well above the nominal 3.45 tesla.

The DoE has held two major reviews of RHIC technical readiness over the past year, the most recent focussing specifically on the magnet system. Both concluded that RHIC is ready for construction.

An Information Meeting at Brookhaven on May 4 will discuss the Laboratory's plans for RHIC's research programme, and a workshop on experiments and detectors for RHIC will be held at Brookhaven from 2-7 July.

From Tom Ludlam

DETECTORS
Scintillating fibre readout

Scintillating fibres are being used increasingly as a detector medium for calorimetry, tracking and preshower counters (May 1988, page 27), where their excellent granularity gives better resolution than conventional scintillator sheets, etc.

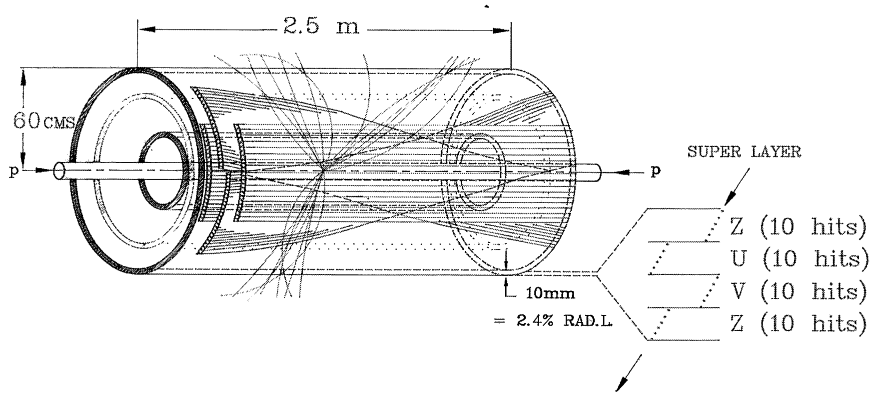
In particular, these fibres are a natural candidate for the detectors needed to exploit planned very high energy proton colliders, such as the SSC Superconducting Supercollider in the US and LHC at CERN, where the intense beams (luminosities of 10^{33} or more) would produce at least one event per ballpark spacing of ten nanoseconds between the proton bunches in the beams.

To cope with these rapid rates, detectors need fast response, fine granularity, sophisticated 'triggering' and high tolerance to radiation.

The signals collected by the fibres can be read out by a number of methods depending on the required granularity, ranging from several centimetres using conventional phototubes, through several millimetres using multianode phototubes, to 20 microns or so using image intensifiers with CCD systems (the latter being employed by the UA2 collaboration at CERN's proton-antiproton collider – June 1987, page 9).

With the ceiling of CCD operation typically 10^5 Hz (10 microseconds between events) and an overall collider event rate of 10^8 Hz, the information collected by such a collider detector would have to be temporarily stored in some kind of pipeline. A solution under development at CERN in the context of the Italian-funded LAA project uses an optoelectronic 'delay tube' where a photocathode converts the fibre flashes into electrons, the microsecond delay being introduced by drifting the electrons in a vacuum tube under very weak electric fields (a few volts per metre).

For fibre applications aiming for coarser granularity, one possibility being explored by a LAPP (Annecy)/CERN/Trieste/Fermilab team, working with specialists from Japanese industry, uses position-sensitive photomultiplier tubes with pipelined electronic readout.



Conceptual design for a scintillating fibre tracking chamber. With multiple (30/40) hits with 15 micron accuracy in a 10mm fibre depth, the tracker consists of thin concentric 'superlayer' shells surrounding the beam pipe where the collisions take place.

QUARKS
Two's company, three a crowd?

Last year, careful measurements by the experiments studying electron-positron annihilation in CERN's new LEP ring and at Stanford's SLC li- ear collider showed that the conventional list of the basic constituents of matter is complete. Three types of particles (electron, muon and tau) interacting under the weak nuclear force are linked to six quarks – the constituents of nuclear matter – grouped pairwise into three distinct families ('up' and 'down', 'strange' and 'charm', 'beauty' and 'top'). The question now is to understand why this six-quark model works.

Under the weak force, heavy quarks decay into lighter ones, changing the composition of the particles in which they are embedded, as in the familiar beta-decay transformation of neutrons into protons. In 1963 Nicola Cabibbo showed how weak decays of particles containing strange quarks could be related to beta decays by a mixing parameter, providing a natural framework for the subtle relation between quarks and the weak force.

Looking at the selection rules of weak decays in 1970, Sheldon Glashow, John Iliopoulos and Luciano Maiani realized that an extended picture containing four types of quark gave exactly what was required. This GIM model showed how to extend the electroweak synthesis of weak interactions and electromagnetism to cover also the strongly interacting particles, and the ideas were dramatically confirmed in 1974 with the discovery of charmed particles.

A few years later, Kobayashi and Maskawa introduced a picture covering six types of quark, the minimum number needed to accommodate the delicate violation of combined charge/parity (CP) symmetry.

The subsequent discovery of the tau lepton and of particles containing a fifth ('beauty') quark showed that a six-quark, three-family picture was on the right track. However while natural consistency conditions give this picture a certain amount of predictive power, no new understanding results, and most of its input parameters (quark mixings and quark masses) have to come from experiment (March, page 17).

Looking deep inside this six-quark description, Harald Fritzsch and Johann Plankl of Munich have found several interesting clues. While the mathematics of the two-family (four-quark) subset looks very tidy, with quark masses contributing in a regular 'democratic' way, a third family brings complications.

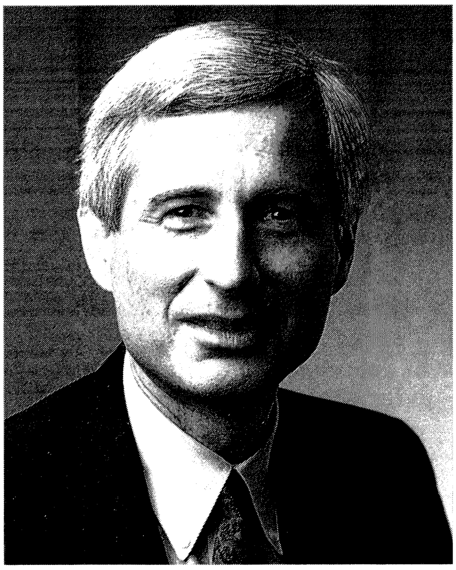
Allowing initially a coupling only between the second and third families, the picture suggests a preferred direction in the three-dimensional family space (if the coupling between the second and third families is switched off, this direction is in fact that of the third family itself). Also the mathematics, in particular for the quark masses, becomes murky and unsatisfactory. Switching on a coupling between the first and third families reinforces these impressions.

The analysis does not depend on parameters having particular 'fine-tuned' values, only that the quark mixing is small, and hints that the reasons for grouping the four lightest quarks into two families are not the same as those for grouping the full set of six into three families. The third family is not just a heavier carbon copy of the first two, suggesting that new ideas are needed to understand why Nature needs its six quarks, and how CP violation appears on the scene.

With the lower limit for the mass of the sixth (top) quark steadily being pushed up, theorists are asking why this quark has to be so heavy.

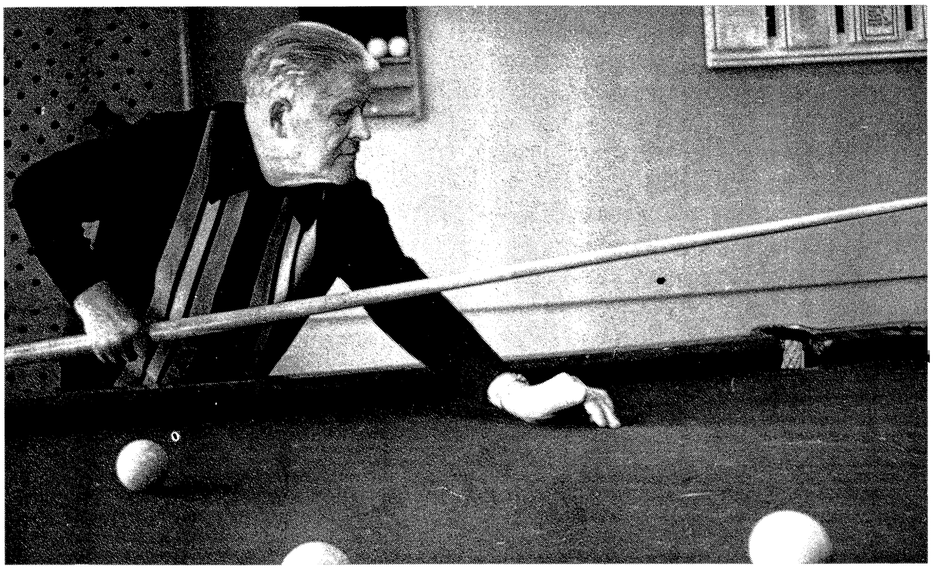
People and things

New SSC Research Division Head Fred Gilman.



Pavel A. Cherenkov.

(Photo Yu. Tumanov)



New head of SSC Research Division

Stanford theorist Fred Gilman has been appointed Associate Director and Head of Research Division for the Superconducting Supercollider (SSC) Laboratory, Texas, succeeding M.G.D. Gilchriese, who is returning to Berkeley after his stint as acting head of SSC research. Gilman has contributed significantly to the work of the American Physical Society, where he was recently Chairman of the Division of Particles and Fields.

On people

Siegmund Brandt (Aleph collaboration) and Hans Dieter Dahmen, both of the University of Siegen, received the German University Software Prize for this year from The Federal Minister for Education and Science for their book and program 'Quantum Mechanics on the Personal Computer' published by Springer last year.

New Frascati Director

Enzo Iarocci has been appointed as new Director of the Italian National Laboratory of Frascati by the Board of Directors of the Istituto Nazionale di Fisica Nucleare. He succeeds Sergio Tazzari, who has completed his second three-year term.

Enzo Iarocci is well known for his contribution to the development of streamer tube detectors. He started his scientific activity at Adone; more recently he took part in Nusex, the Mont Blanc underground experiment, and is at present spokesman of Macro, the large-surface experiment at the Gran Sasso National Laboratory.

The new director has appointed Rinaldo Baldini as new Research Director, succeeding Mario Greco.

P.A. Cherenkov – 1903-1990

Academician Pavel A. Cherenkov died on 6 January at the age of 86. His 1934 discovery that charged particles passing through a material faster than the velocity of light in that medium emit radiation – Cherenkov light – went on to open up a new era in particle detection. For this work, he shared the 1958 Nobel award with Ilya Frank and Igor Tamm. His ideas in other fields were a frequent source of inspiration, and his concern for world peace generated valuable contacts.

Margaret Pearson

We were saddened to learn of the death of Margaret Pearson of Fermilab after a long illness. Margaret was with the Public Information Office at the Laboratory from its early days and worked constantly to promote Fermilab in every way she could. For the CERN Courier, I was in regular contact with her for almost twenty years and have special reason to express appreciation and admiration of her achievements. Margaret was also the key organizer in the late 1970s when we implemented the US distribution of the journal. She was a

Los Alamos National Laboratory is one of the world's largest multidisciplinary scientific labs, where work on fundamental research continues on new energy sources, superconductors, national defense...and literally, hundreds of other projects. Utilizing modeling tools and computer resources so advanced, we're helping to map the human genome.

Minds over Matter

Staff Member

Several leading scientists, specializing in high energy physics are needed in order to help exploit the many capabilities of the Superconducting Super-Collider (SSC) accelerator operations.

Successful applicants will be working in collaboration with the Laboratory's Physics Division and the University of New Mexico in an initiative to address the scientific and technical frontiers which will be created by the existence of the SSC. Responsibilities include identifying the most promising areas of physics and technology appropriate to a national laboratory/university collaboration while building a team that will ultimately make key contributions to a successful SSC detector. Working with Laboratory and University management, you will build a funding and personnel base for this research program.

For consideration in any of these areas, you must have a PhD in Physics or an equivalent combination of relevant education and experience. A distinguished record of accomplishments in experimental high energy physics and notable scientific achievements are essential.

To formally apply for this position, you must reference Job Number **90896** on your resume. Please send resume to Ray Archuleta (MS P280), Personnel Services Division **90896-D**, Los Alamos National Laboratory, Los Alamos, NM 87545.

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NATIONAL LABORATORY

The University of Iowa
Department of Physics & Astronomy

Postdoctoral Associate

The University of Iowa Department of Physics and Astronomy has recently established a group in High Energy Physics. Qualified applicants are invited to apply for a postdoctoral position in Experimental High Energy Particle Physics. The appointment is for an initial two years with possible extensions. Presently, members of the faculty are participating in three fixed target experiments at Fermilab radiative hyperon decay (E761), photoproduction of high p_t jets (E683), and experiments with polarized protons and antiprotons (E704). The group will also participate in testing key elements of an experiment to study production and decay mechanisms of charmed baryons (E781). Research and development opportunities for SSC experiments are also being explored. Applicants should have a recent PhD in experimental particle physics. Interested persons should apply to :

1847

Professor Y. Onel
Chair, Search Committee
Department of Physics & Astronomy
The University of Iowa
Iowa City, Iowa 52242
USA

The University of Iowa is an equal opportunity/affirmative action employer. Women and minorities are encouraged to apply.

High Energy Physics Research Associates

There are vacancies for Research Associates to work with groups in the Particle Physics Department. Groups from the Rutherford Appleton Laboratory are working on experiments at CERN, DESY, ILL and SLAC. There is in addition a vacancy in the HEP Theory Group.

Candidates should normally be not more than 28 years old. Appointments are made for 3 years, with possible extensions of up to 2 years. RAs are based at the accelerator laboratory where their experiment is conducted, and at RAL, depending on the requirements of the work. Most experiments include UK university personnel with whom particularly close collaborations are maintained.

For an application form please contact Recruitment Office, Personnel and Training Division, Rutherford Appleton Laboratory, Science and Engineering Research Council, Chilton, Didcot, Oxon OX11 0QX, England. Tel: (0235) 445435, quoting reference VN 758.

serc Rutherford Appleton Laboratory

A meeting on 19 January at the Ministère de la Recherche, Paris, organized by friends and former students, marked the retirement of Maurice Lévy (left), seen here with French Research Minister Hubert Curien. Among many activities and interests, including, for example, the Science Museum at La Villette, speakers emphasized Lévy's major role in the renaissance of French theoretical physics in the 50s and 60s.

(Photo Khosrow Chadan)

friendly and reliable source of help and ensured a warm welcome on many a visit to the Laboratory. I remember her with respect and affection.

Brian Southworth

First superconducting acceleration at CEBAF

In a January 31 test at the Continuous Electron Beam Accelerator Facility (CEBAF) under construction at Newport News, Virginia, a beam from the injector's 500 keV room temperature section was accelerated to 2.5 MeV in one cavity of the quarter-cryomodule containing the injector's initial superconducting accelerating cavity pair (March, page 21). The encouraging development was a step toward first operation of this 5 MeV quarter-cryomodule, expected soon, when both cavities can be powered with radiofrequency energy.

Both the 45 MeV injector and the 4 GeV recirculating accelerator are based on hermetically joined cavity pairs, each pair providing 5 MeV nominal acceleration. Four pairs are linked within each 20 MeV cryomodule, immersed in 2K liquid helium. Plans call for installing a total of 338 cavities.

Physics and detectors for LHC

To explore in detail and update the physics possibilities for the Large Hadron Collider (LHC) project at CERN (December 1989, page 1), the European Committee for Future Accelerators (ECFA) is now preparing for an LHC Workshop to be held in Aachen from 5-10 October. All the options for physics studies are covered, together with ideas for the detectors, and the requirements for experimental areas and data handling techniques.

Two kinds of working groups have been set up. Scientific evaluation working groups will consider the physics potential of proton-proton, electron-proton and nucleus-nucleus collisions in the light of recent experimental and theoretical developments. The conveners (theorists and experimenters) for these three working groups are respectively: G. Altarelli, D. Denegri and F. Pauss; R. Ruckl, W.Bartel and J. Feltesse; H. Satz and H. Specht.

On the detector side, the following topics and conveners have been selected: event generators, detector simulation and software engineering – R. Brun, D. Denegri and F. Pauss; signal processing, triggering and data acquisition –S. Cittolin, G. Manfredi and A. Walenta; vertex detection - H. Heijne, B. Hyams and M. Tyndel; tracking – M. Giorgi, H. Leutz and D. Saxon; calorimetry – M. Albrow, J. Colas and R. Klanner; electron identification – T. Akesson and E. Fernandez; muon identification – P. Duinker and K. Eggert; consultants on radiation hardness – H. Schonbacher and F. Wulf; consultants on experimental areas – L. Leistam and K. Potter. Machine experts for the three collision options will be W. Scandale (proton-proton), G. Guignard and A. Verdier (electron-proton), D. Brandt (nucleus-nucleus).

The ECFA-LHC Working Groups and Workshop Organization is chaired by J.E.Augustin, G.Jarlskog coordinates detector R&D and G. Flugge is the local organizer for the Aachen workshop. There will be a two-day intermediate meeting of the working groups at CERN on 18-19 June.

1990 CERN School of Computing

The 1990 CERN School of Computing, organized in collaboration with the Inter-University Institute for High Energies, VUB-ULB, Brussels, will take place from 2-15 September at Nieuwpoort, Belgium.

Designed to cater for about 60 postgraduate students and young research workers, the School will cover a wide range of topics in networking, graphics, optical computing, signal processing, etc., and will include both tutorials and practical sessions on transputers. Further information from Mrs. Ingrid Barnett, CERN School of Computing, CERN, 1211 Geneva 23, Switzerland, fax Geneva 767 7155, email barnett at cernvm.cern.ch

Physics at UNK

A workshop will be held at the Institute for High Energy Physics, Protvino, USSR from 25-28 September to focus on the requirements for detectors at the UNK machine. Detectors for both fixed target and collider experiments will be covered. Further information from S.I. Bityukov, IHEP, 142284 Protvino, Moscow region, USSR.

TRIUMF Summer Nuclear Institute

TRIUMF's Summer Nuclear Institute provides short courses for first- or second-year graduate level nuclear physics experimenters and theoreticians. For the second course, to be held from 30 July to 10 August, lecturers include N. Auerbach, F. Close, J. Eisenberg and G. Karl. Participation will be limited to 40. Further information from B.K. Jennings, TRIUMF, 4004 Wesbrook Mall, Vancouver, BC, Canada V6T 2A3, fax (604) 222-1074, email jennings at triumfcl.bitnet

US Accelerator School

This year's US Particle Accelerator School graduate-level credit courses will be held from 11-22 June at Harvard University, Cambridge, Mass. Information from the Accelerator School Office, Fermilab, MS 125, PO Box 500, Batavia, Ill 60510, tel (708) 840-3896 or bitnet USPAS at FNAL.

This year's Joint US-CERN School on Particle Accelerators Topical Course covers Frontiers of Particle Beams Intensity Limitations, and will be held from 7-14 November at Hilton Head Island, South Carolina. Information from the address above.

Meetings

XX Symposium on Multiparticle Dynamics – 10-14 September, near Dortmund. Further information from D. Wegener, Institute of Physics, Universität Dortmund, D46 Dortmund 50, e-mail UPH019 at DDOHRZ11.

DESY is organizing a topical meeting on the small-x behaviour of deep inelastic structure functions in QCD, to be held from May 14-16 at DESY, Hamburg. The aim is a thorough discussion of theoretical issues connected with the behaviour of QCD structure functions at very small x. HERA will be the first machine to reach x-values as small as 10^{-4}. Further information from the the organizers, A.Ali (DESY) and J.Bartels (Univ.Hamburg), bitnet I02BAR at DHHDESY3

The third workshop on common frontiers in particle, astro- and cosmic ray physics organized jointly by the Istituto Nazionale di Fisica Nucleare (INFN), the Istituto di Astrofisica Spaziale and the Istituto di Cosmogeofisica will be held from 21-23 May on the small island of Vulcano, near Sicily. With the title 'Frontier Objects in Astrophysics and Particle Physics', the meeting will concentrate on the physics of accreting matter onto collapsed objects, the sources of cosmic rays and a review of detector techniques. Further information from Istituto di Astrofisica Spaziale, CNR, CP 67, 00044 Frascati, Italy, email vulcano at irmias, fax 39-6-9423847.

Agreeing with CERN

To reinforce the increased spirit of cooperation resulting from CERN's growing attraction for scientists from all over Europe and from further afield, the Laboratory embarked last year on a programme of drawing up bilateral agreements to put ongoing collaboration on a firmer footing (September 1989, page 24).

With Finland already set to become CERN's fifteenth Member State (October 1989, page 26) and with agreements having been drawn up with Yugoslavian research centres (January/February, page 30), further accords were signed with Poland in Warsaw on 13 February, with Brazil in Campinas on 19 February, and with the German Democratic Republic at CERN on 6 March. Other Eastern European countries will soon follow suit.

Top – signing the CERN-Poland agreement in Warsaw on 13 February. Front row, right to left, Polish National Atomic Agency President R. Zelanzy, CERN Director General Carlo Rubbia, and CERN Regional Coordinator for Eastern Europe W.O. Lock; back row, Council of Ministers Vice-Chairman J. Janowski, Deputy Minister of Foreign Affairs H. Jaroszek, Cracow Institute of Nuclear Physics Director Z. Bochnacki, and R. Sosnowski of Warsaw's Institute of Nuclear Science and Observer at CERN Council.

Centre – signing the CERN-Brazil agreement in Campinas on 19 February: right to left, Brazil's National Research Council President C. Pavan, Carlo Rubbia, and CERN's Regional Coordinator for the Americas C. Roche.

Below – signing the CERN-German Democratic Republic agreement at CERN on 6 March: Secretary General of the GDR Academy of Sciences C. Grote, left, and Carlo Rubbia.

Fibre optic networking

Using prototype equipment based on a 100 Mbit/sec Fiber Distributed Data Interface (FDDI) high performance local area communications network, and to extend FDDI's applicability, CERN's Computing and Networks Division, in collaboration with IBM and Hewlett Packard's Apollo Division, has transferred data files between an Apollo DN10000 workstation and an IBM 3090-600E mainframe with encouraging results. To cater for its site-wide Ethernet network linking over 2000 intelligent devices, CERN will shortly begin testing other manufacturer's equipment on an FDDI 'backbone'. This increased communications power will particularly benefit the four big LEP experiments, which together are each expected to record some 10 Terabytes (10^{13} bytes) of data during the next few years.

Eifionydd Jones (1934-1990)

Eifion Jones of CERN's Proton Synchrotron Division died on 2 March of a tragic affliction, bravely borne. He had been at CERN since 1959, with an interlude at Stanford HEPL where he worked on superconducting radiofrequency, and was prominent among CERN's gifted accelerator physicists. His major contributions included work on the ISR vacuum system (particularly in the design of thin-walled chambers for the collision regions), an important role in the design and commissioning of the Antiproton Accumulator, and leadership of the subsequent Antiproton Collector project. With a fine sense of homour, Eifion was very popular and had an excellent rapport with all his colleagues. Characteristically, in spite of his ever increasing physical handicap, he continued to produce new ideas and to help others right to the end. His contribution to accelerator physics and his enthusiasm and joy in life will be sadly missed.

Commissioning CERN's Antiproton Accumulator in July 1980, left to right, Roy Billinge, the late Eifion Jones, and Simon van der Meer.

(Photo CERN 89.7.80)

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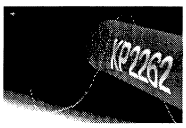

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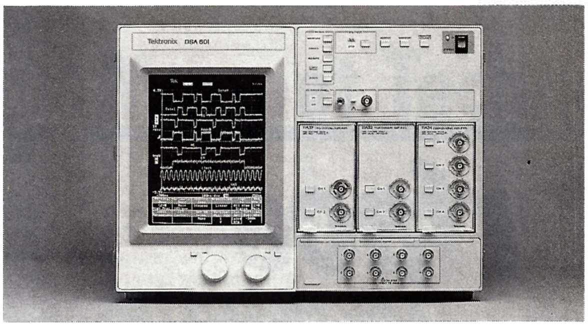

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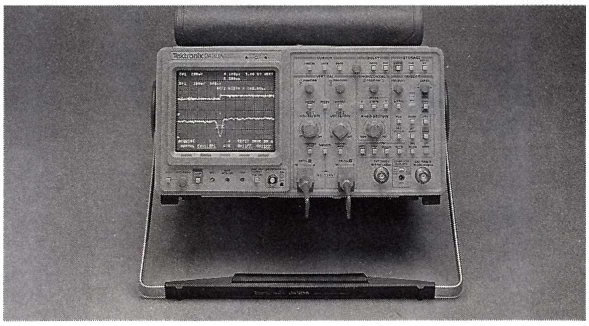

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