Neutrino sunshine

At the Neutrino 92 meeting held.in Grenada, Spain, from 7-12 June, Till Kirsten (left) of Heidelberg's Max Planck Institute gave a historic presentation of the first detection by the Gallex experiment of solar neutrinos from proton-proton fusion. Here he is with Angel Morales of Zaragoza, Chairman of the Conference Organizing Committee.

Neutrinos and 1492

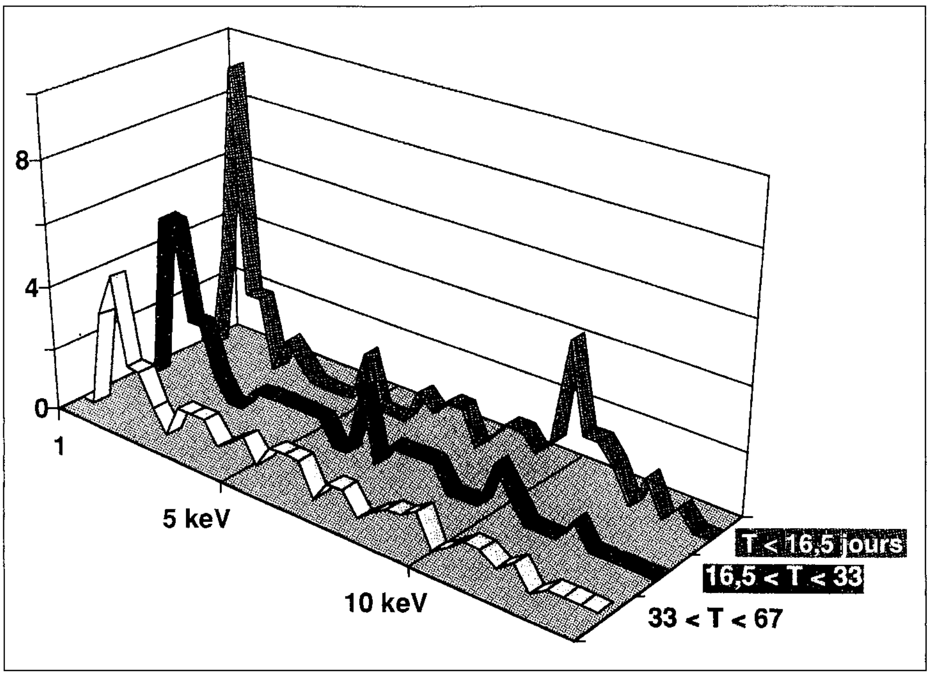
Particle physics seems to operate on a twenty-year cycle, suggested neutrino pioneer Fred Reines, introducing the international Neutrino 92 meeting in Grenada from 7-12 June. Twenty years ago, at the first meeting of this series, which took place at Lake Balaton, Hungary, participants had heard how Ray Davis had detected the first solar neutrinos in his giant tank of perchloroethylene. This year's meeting saw a second major solar neutrino milestone, with the Gallex gallium-based detector in the Italian Gran Sasso underground Laboratory reporting the first direct neutrino signal from the proton fusion chain which provides most of the sun's power.

This year, Spain is the scene of several major international events (Olympic Games, Seville Expo,....). Although Neutrino 92 was well down in this list, the meeting was held in the historic city of Grenada, where exactly 500 years ago the flag of Ferdinand and Isabella finally forced the surrender of the remaining Moorish bastion in Spain, marking the beginning of a new era of national history. One immediate outcome was Columbus' epic voyage westwards.

Most of the Sun's energy comes from the fusion of protons into deuterium. Sunshine is necessary for life, but the first evidence for the neutrinos which accompany and explain this basic process still makes science history. This result naturally dominated the Neutrino 92 meeting, held in Grenada, Spain, from 7-12 June. The talk, by Till Kirsten of Heidelberg's Max Planck Institute, formed part of a special solar neutrino session, with presentations from all experiments presently looking at this physics, and from theorists doing the complicated calculations on solar fusion.

It was in 1970 that Ray Davis and his team began taking data with a tank of 615 tons of perchloroethylene (dry cleaning fluid) deep underground in the Homestake gold mine, South Dakota. Some solar neutrinos convert chlorine nuclei into argon, and the count rate is determined by delicate radiochemical analysis.

For 20 years, the signal from this detector has been consistently below the value expected from calculations, hence the famous 'solar neutrino problem'. To explain this dearth of solar particles, new mechanisms have been put forward. Classically, *The footprint of neutrinos from proton-proton fusion deep inside the Sun. The active medium in the Gallex solar neutrino detector is gallium, where neutrino interactions produce germanium-71. This shows the characteristic initial signal of the detected germanium (rear curve) with two peaks and its subsequent radioactive decay with a half-life of about 16 days.*



neutrinos come in three immutable types - electron, muon, and tau - according to their parentage. Those from the Sun should be electron-type. However under certain conditions, such as those deep inside the sun, neutrinos could oscillate between these three states, producing a marked change in solar neutrino composition

At Grenada, Kenneth Lande of Pennsylvania presented the latest results from the chlorine-based detector in the Homestake mine. Their signal is interpreted as coming from two solar process, one involving electron capture in beryllium-7, the other boron-8 decay. The count rate is consistently about one every two days, only about a half of what the calculations predict. New insights could come from a new project by this group, using an iodine-based detector sensitive to other areas of the solar neutrino spectrum.

The second major detector to look at this problem was the Japanese Kamiokande group, picking up Cherenkov light from neutrino interactions in some 700 tons of water. This detector was originally constructed to look for proton decay, and sees directional signals. A larger version ('Superkamiokande') is being prepared (May 1991, page 9). At Grenada, Kenzo Nakamura of Tokyo presented results from an improved Kamiokande set-up. Sensitive to the boron-8 process, this detector sees about 60 per cent of the expected signal. This boron fix is helpful to the Homestake mine team, who see a mixture of two solar processes.

However the majority of solar neutrinos come from the fusion of protons into deuterium. To get at this signal, two big new detectors, using gallium, have been built and commissioned in the last few years These are SAGE ('Soviet'-American Gallium Experiment) in the Baksan Neutrino Observatory, and Gallex, a collaboration from France, Germany, Israel, Italy and the US with a detector in the Italian Gran Sasso underground Laboratory.

The SAGE detector now uses 57 tons of gallium metal, although initial exposures used less, and there have been contamination problems. At Grenada, SAGE progress was covered by Tim Bowles of Los Alamos. With the analysis not yet complete it was too early to present a final number. Initial results already published (March, page 11), did not see a substantial signal, but this data is currently being reexamined.

And so to Kirsten's historic paper. Gallex data-taking, using 30 tons of gallium (as gallium chloride solution) began in May 1991, with 15 distinct exposures ('runs') ending in April. The experiment sees a clear signal for the neutrino conversion of gallium-71 to germanium-71 equivalent to about 83 'Solar Neutrino Units' (SNU).

Following Kirsten at Grenada came John Bahcall of Princeton, who has made a speciality of solar neutrino calculations. The total signal expected is about 132 SNU, of which 71 come from the proton-proton process, the remainder from heavier nuclei. Bahcall called for a laboratory investigation of beryllium-proton reactions to help clear up some of the uncertainties inherent in the calculations.

With the Gallex result still compatible with missing neutrinos, Bahcall said 'if you believed in new physics before Gallex, you should not be disappointed.'

Solar neutrinos are not the easiest things to calculate, and Sylvaine Turk-Chieze of Saclay described some alternative approaches which slightly reduce the expected signal.

In a continuation of the solar neutrino session, Sergei Petcov (who wrote the excellent solar neutrino article we published last year - May 1991, page 16) compared the suppression rates for the different

observed processes, and speculated on a connection between suppression of solar neutrinos and their energy.

Introducing the conference, Sheldon Glashow of Harvard alluded to the new solar neutrino results which everyone was eagerly waiting for. 'Does the Sun sputter?', he asked. 'Are there periodic or even chaotic fluctuations inside the Sun?' This message was relayed by Alvaro de Rujula of CERN in a final ('inconclusive') talk. Despite some solar properties being very well understood, the Sun could be more complicated than we think.

Other Grenada results

After the introductory talks, the Grenada meeting opened with a heavyweight review of neutrino properties by Alexei Smirnov of Moscow (one of the authors of the resonating neutrino oscillation idea). The minimal neutrino scenario is where all three types are massless and they do not mix. Smirnoff pointed to plenty of suggestions that this is not the case, but so far the minimal scenario cannot be excluded.

A series of talks underlined the improving limits on neutrino mass, particularly for the lightest, the electron-neutrino. Several experiments in fact come in with a negative result for the square of the mass, with mass limits deduced to be less than about 10 electronvolts. A new result comes from an experiment at Mainz with an electrostatic spectrometer, reported by Jochen Bonn, giving a mass less than 7.2 electronvolts.

The 17 keV neutrino has been a dilemma for several years, with signals coming in from several experiments using semiconductor detectors, but no sign with magnetic spectrometers. (De Rujula describes this neutrino as 'magnetophobic'.) At Grenada, 17 keV neutrino proponent Andrew Hime of Los Alamos presented the latest evidence in favour, but admitted to be 'baffled' by initial negative reports from a new experiment still being analysed at Argonne.

Anti-17keV, Felix Bohm of Caltech had a lot to talk about, and pointed to the best limits coming from the recent experiment at the Japanese KEK Laboratory (April, page 15). The feeling at Grenada was that the credibility of the17 keV neutrino is, at least temporarily, diminished

Following the 1987 supernova, neutrinos now also have astrophysics status, and many new studies are now equipped, or are being equipped to look for neutrinos from outer space. Next time a near supernova goes off, there will be a lot of detectors looking at it.

John Learned of Hawaii sketched the impressive world-wide effort in this field, with neutrino telescopes sited underground, in lakes, in seas and oceans, and in the South Polar ice cap. Barry Barish of Caltech and Piero Galeotti of Turin described initial results respectively from the Macro and LVD underground detectors in the Gran Sasso Laboratory.

As well as solar neutrinos, the Japanese Kamioka detector sees neutrinos from cosmic ray interactions in the atmosphere. Yoji Totsuka of Tokyo described these as 'junk events' in the experiment's original search for proton decay. However atmospheric muon-type neutrinos appear to be reduced by about 40 per cent, suggested by some as evidence for neutrino oscillations. With several detectors now looking at it, this effect persists, concluded Totsuka.

With overwhelming evidence for most of the Universe being made of as-yet invisible 'Dark Matter', neutrino technology and thinking provide useful levers in this continuing search. This work got good coverage at Grenada.

Neutrino beams provide a major part of the diet for experiments at high energy accelerators. Talking point in this sector was a heroic presentation by an injured Sanjib Mishra of Harvard on double interactions seen in neutrino interactions by the CCFR detector at Fermilab's Tevatron.

In a careful analysis of 750,000 events, they see about nine candidates for contained double interactions, which could be interpreted as the primary neutrino interaction producing a second, much heavier, particle. The experiment has had these events for some time, but they have not been talked about before undergoing exhaustive data analysis.

Another new neutrino result came in initial data from the KARMEN experiment at the ISIS machine at the UK Rutherford Appleton Lab, which sees neutral current excitation of nuclei.

For completeness, the Grenada meeting also contained ample coverage of ongoing physics away from the strictly neutrino sector, with latest results from the four experiments at CERN's LEP electron-positron ring, and several other major studies. Here the Standard Model reigns supreme, and the results will come under detailed scrutiny at this summer's major high energy physics meeting in Dallas in August.

Neutrino physics is always interesting, but rarely moves quickly, with new results taking some time to

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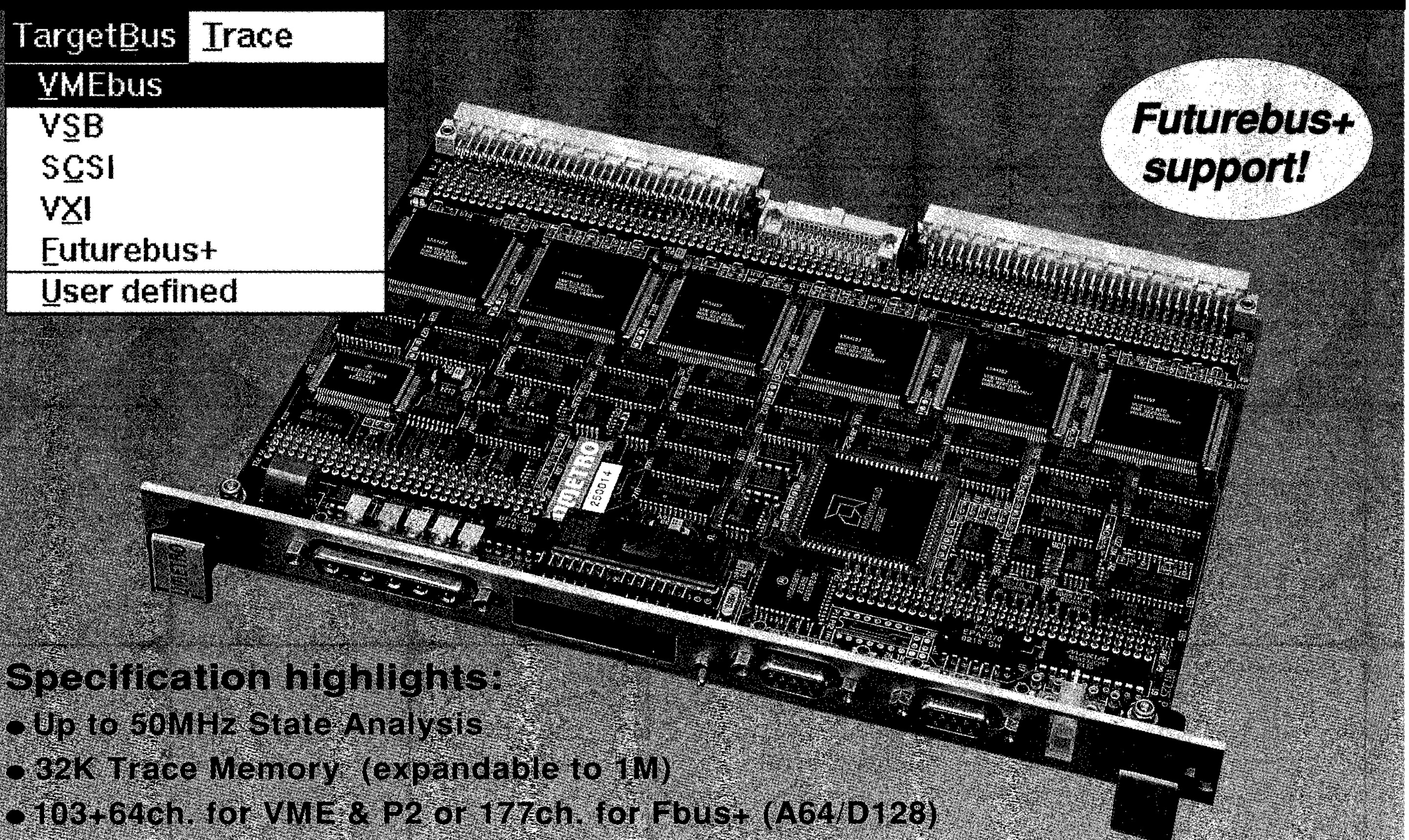

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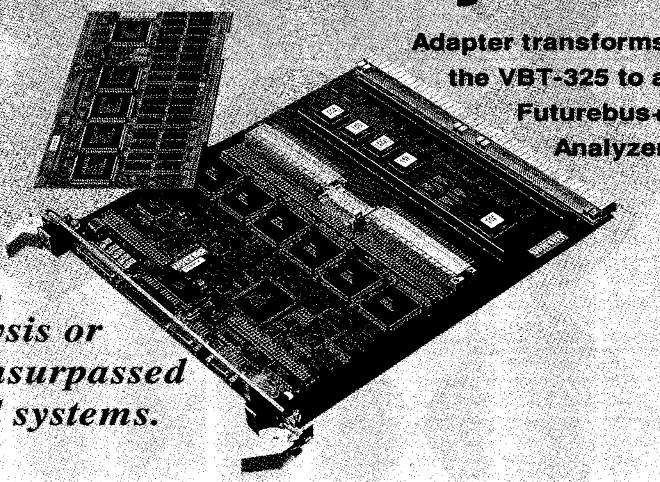

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Towards SSC machine and detectors

consolidate. 'Many of us have been coming to neutrino conferences for years waiting for something to happen,' remarked Sheldon Glashow in his introductory Grenada talk - 'Neutrinos, the endless frontier'. At Grenada, they were not disappointed.

Neutrino 92 was organized by a committee under Angel Morales of Zaragoza.

By Gordon Fraser

Massive neutrinos

A book which is certainly of interest to neutrino specialists is 'The Physics of Massive Neutrinos' by Felix Boehm and Petr Vogel of Caltech, published by Cambridge University Press (ISBN 0 521 41824 0 hardback, and 0 21 42849 1, paperback), now available in its second edition. Both authors gave presentations at the Grenada 92 meeting, Boehm on 'Not finding the 17 keV neutrino', and Vogel on 'Nuclear physics and the detection of solar neutrinos and dark matter'.

A stab in the back...

On June 17, just after the July/August issue of the CERN Courier went to press, the physics world was shocked and stunned by an unexpected vote by the US House of Representatives to kill the Superconducting Supercollider project, now under construction in Ellis County, Texas.

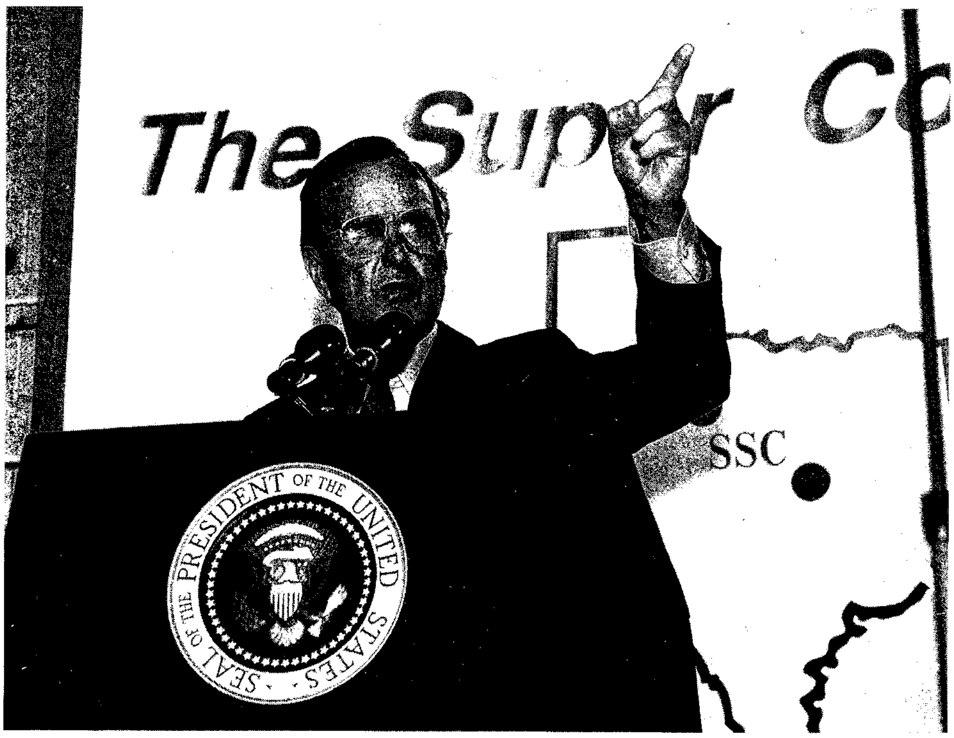
By a 232-181 majority, a House preoccupied with balancing the US budget excluded any significant ongoing SSC funding in a big package of energy-related items.

CERN management immediately issued a statement saying that it was 'shocked by the vote, and hopes that it will be reversed lest it creates an alarming vacuum in an important field of scientific research'.

'European high energy physicists have maintained excellent relations in scientific cooperation with their American colleagues and have shared freely the use of larger facilities,' the statement continued. 'In that spirit, CERN's project for a Large Hadron Collider and the US SSC were from the start intended as complementary machines. Both Europeans and Americans have been engaged for years in friendly competition on the fascinating road towards the discovery of the most basic constituents of matter. There is no doubt that cancellation of the SSC would adversely affect the progress of knowledge in the field of elementary particle physics.'

The fate of the SSC was in the hands of the US Senate, and on 3 August the pro-SSC motion was voted in, 62-32..

...and a pat on the back



On 30 July, shortly before the pro-SSC Senate vote, US President George Bush visited the Superconducting Supercollider (SSC) Laboratory in Ellis County, Texas, saying 'I will fight hard and continue to fight hard for the Supercollider'. After alluding to Columbus' voyage five hundred years ago, the President continued 'Our adventure is not to sail the open ocean, but rather to go to the edge of the Universe and see birth of space and of time. Our vessel is not called Santa Maria. It is the Supercollider.'
(Photo John Bird)