Particle physics

After the W boson . . . the Z?

from Frank Close

THIS week physicists at CERN, Geneva hope to begin the second round of experiments that could prove definitive in isolating the W and Z bosons — the carriers of the weak nuclear force. The results of the first experiments were announced in January; the media announced the discovery of the W boson, two independent groups of theorists claimed that the top quark had also been seen, but the experimentalists (who are, of course, closest to the data) have so far only claimed to find "electrons with large transverse energy and missing associated energy . . . which have the signature of a two body decay . . . fitting well the hypothesis that they are produced by a W^+ or W^- boson". The interpretation is that the missing energy is carried by an undetected neutrino, the W having decayed into the electron and the neutrino.

The events are singularly impressive, yet, as Norman Dombey (*New Scientist* 17 February 1983) reminds us, "the experimentalists do not see a W *per se* . . . a single electron cannot identify a W with certainty". This caution, correctly exercised in the two experimental papers (UA1 and UA2 collaborations *Phys. Lett.* **122B**, pages 103 and 476 respectively) has been relaxed during recent weeks as more and more physicists received detailed first-hand seminar reports about the discovery. There is no doubt that the two teams have seen a new phenomenon and no alternative mechanisms can satisfactorily explain them.

The abundance of the events and also their electron energy distribution are as expected if a W boson has been produced and has a mass of 81±5 GeV (UA1 report) or 80^{+10}_{-6} GeV (UA2 report). This is truly exciting, for the unification of weak and electromagnetic forces can be achieved if the W mass is 82±2 GeV.

Nuclear γ decay is an 'electromagnetic' process; β decay, by contrast, is brought about by the weak force. The probability of neutron β decay into a proton, an electron and an antineutrino is controlled by Fermi's weak coupling constant G; electromagnetic effects, by contrast, involve the fine-structure constant α. The weak force, as its name implies, appears to be more feeble than the electromagnetic force and its range is much less. In β- decay and other low-energy phenomena the two forces appear to be unrelated.

A quantitative measure of their relative apparent strengths is given by the ratio of $G/\alpha \simeq 10^{-3}$ at an energy of 1 GeV. This rather opaque caveat 'at 1 GeV' is important: G has dimensions of $(\text{energy})^{-2}$ whereas α is dimensionless $\simeq 1/137$. The dimensionless quantity $G \times (\text{energy})^2$ can be sizeable at high energy and comparable with α in magnitude.

It was realised that if effects due to the absence of mirror symmetry in weak interactions were allowed for, then electromagnetic and weak interactions could have identical intrinsic strength — provided the weak force contains an important 37 GeV energy scale. In low-energy experiments, such as neutron β-decay, this 37 GeV is hidden and the force appears to be weak ($\simeq 10^{-5}$). But at high energies the 37 GeV will be out in the open and the true strength α will be revealed.

The 37 GeV is a measure of the mass of the weak force quantum (the analogue of electromagnetism's massless photon) — the W boson. In β decay, energy-momentum conservation prevents creation of a 37 GeV quantum — the uncertainty principle can, however, allow it to exist fleetingly. Indeed, its existence would be so Pickwickian at low energies that it can transmit the force for only 10^{-15} cm. The feeble strength and limited range of the weak force at low energies can thus both be understood.

The germ of this theory was put forward by Julian Schwinger in 1957 and contained γ and W^+, W^-. Two decades of theoretical work on gauge field theories (of which quantum electrodynamics is the simplest example) and an increased awareness of the role of hidden symmetries (spontaneous symmetry breaking) in renormalizable field theories, culminated in the powerful modern theory due to Sheldon Glashow, Abdus Salam and Steven Weinberg.

The theory requires γ, W^+, W^- and also a Z° boson, the latter being the carrier of a new weak force (discovered in 1973). Clebsch Gordan coefficients and other numerical factors cause the old 37 GeV to be modified as follows. The weak forces have intrinsic electromagnetic strength if

$$W^+ = W^- = 82 \pm 2 \text{ GeV}$$
$$Z = 92 \pm 2 \text{ GeV}$$

Other aspects of the theory relate the W and Z masses, so that if the theory is right, and if the W has indeed been detected at about 80 GeV, then the Z° must exist with the cited 90 GeV mass.

The good news about Z° is that it can decay into e^- and e^+ which, being charged, are easy to detect. Hence a Z° can be cleanly and unambiguously identified if it is produced in the experiment. The bad news is that this type of event is expected to be only one-tenth as likely as the W events — as only nine of the latter have been seen so far, it is no surprise that the Z° is still undetected.

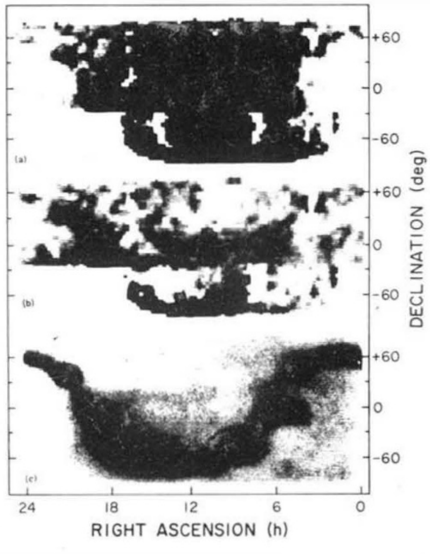
But this should change when the new experiments are started. With improved efficiency of the accelerator the optimists hope that up to 100 W and 10 Z° events will be found in the modes $W^\pm \rightarrow e^\pm +$ neutrino; $Z^\circ \rightarrow e^+ e^-$. The masses, production rate, lifetime of W and Z and the angular distributions of the decay electrons are all predicted. The $Z^\circ \rightarrow e^- e^+$ events provide a potentially clean unambiguous signature. A larger sample of W candidates will also generate more confidence in their interpretation. Not least, the ratio of W and Z masses is a crucial prediction of the model. It may be possible to spot other decay modes of the W.

In addition to the events containing an isolated electron moving transverse to the beams with no visible energy balance (the

Cosmology

Quadrupole fades away

THERE is, after all, no quadrupole component currently detectable in the cosmic microwave background, according to two recent papers[1,2]. The result is significant for cosmologists who, following earlier reports of a possible quadrupole, were relating such inhomogeneities to distributions of matter in the early Universe[3]. Analysis of the data shown here[2] failed to confirm the reported quadrupole, which is now attributed to experimental artefacts. (a) A map of the sky at 24.5 GHz showing the dipole effect caused by the Earth's motion relative to the 2.7K microwave background. The measurements were made during three flights of a balloon-borne radiometer. The gaps in the data result from malfunction and the limited sky coverage available. (b) The same data with a best-fit dipole subtracted, revealing the galactic plane. (c) A map derived from a model for galactic emission at this frequency.



Phillip Campbell, Physical Sciences Editor of Nature.

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2. Fixsen, D.J., Cheng, E.S. & Wilkinson, D.T. *Phys. Rev. Lett.* **50**, 620 (1983).
3. Muller, R.A. *Nature* **291**, 609 (1981).

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