The Higgs Factor

A Europhysics News section devoted to the undiscovered Higgs boson, the search for which costs Europe billions of Ecus a year, but the discovery of which should finally settle where particles get their mass

In Pursuit of Supersymmetry: Results from Lep 2 by Marc Besançon *page 180*

Of particles, pencils and unification

Theoretical physicists always aim for unification. Newton recognised the fall of an apple, the tides and the orbits of the planets as aspects of a single phenomenon, gravity. Maxwell unified electricity, magnetism and light. Each synthesis extends our understanding and leads eventually to new applications.

In the 1960's the time was ripe for a further step. We had a marvellously accurate theory of electromagnetic forces, quantum electrodynamics, or QED, a quantum version of Maxwell's theory. In it, electromagnetic forces are seen as due to the exchange between electrically charged particles of photons, packets (or quanta) of electromagnetic waves. (The distinction between particle and wave has disappeared in quantum theory.) The 'weak' forces, involved in radioactivity and in the Sun's power generation, are in many ways very similar, save for being much weaker and restricted in range. A beautiful unified theory of weak and electromagnetic forces was proposed in 1967 by Steven Weinberg and Abdus Salam (independently). The weak forces are due to the exchange of W and Z particles. Their short range, and their apparent weakness at ordinary ranges, is because, unlike the photon, the w and Z are, by our standards, very massive particles, 100 times heavier than a hydrogen atom.

The 'electro-weak' theory has been convincingly verified, in particular by the discovery of the W and Z at CERN in 1983, and by many tests of their properties. However, the origin of their masses remains mysterious. Our best guess is the 'Higgs mechanism' - but that aspect of the theory remains untested.

The fundamental theory exhibits a beautiful symmetry between W, Z, and photon. But this is a spontaneously broken symmetry. Spontaneous symmetry breaking is a ubiquitous phenomenon. For example, a pencil balanced on its tip shows complete rotational symmetry – it looks the same from every side – but when it falls it must do so in some particular direction, breaking the symmetry. We think the masses of the W and Z (and of the electron) arise through a similar mechanism. It is as though there are 'pencils' throughout space, even in vacuum. (Of course, these are not real physical pencils – they represent the 'Higgs field' – nor is their direction a direction in real physical space, but the analogy is fairly close.) The pencils are all coupled together, so they all tend to fall in the same direction. Their presence in the vacuum influences waves travelling through it. The waves have of course a direction in space, but they also have a 'direction' in this conceptual space. In some 'directions', waves have to move the pencils too, so they are more sluggish; those waves are the W and Z quanta.

The theory can be tested, because it suggests that there should be another kind of wave, a wave in the pencils alone, where they are bouncing up and down. That wave is the Higgs particle. Finding it would confirm that we really do understand the origin of mass, and allow us to put the capstone on the electro-weak theory, filling in the few remaining gaps.

Once the theory is complete, we can hope to build further on it: a longer-term goal is a unified theory involving also the 'strong' interactions that bind protons and neutrons together in atomic nuclei – and if we are really optimistic, even gravity, seemingly the hardest force to bring into a unified scheme.

There are strong hints that a 'grand unified' synthesis is possible, but the details are still very vague. Finding the Higgs would give us very significant clues the the nature of that greater synthesis.

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PRIZE WINNERS

The Europhysics High-Energy Prize was awarded this year to Robert Brout and François Englert of the Université Libre of Brussels, Belgium, and Peter Higgs, of the University of Edinburgh, Scotland. The ceremony took place at the High-Energy Conference in Jerusalem in August

The Particle Drought

For the participants at the EPS High Energy Physics Conference in Jerusalem in August, the contemplation of the Jerusalem desert must have been reminiscent of some bleak predictions, *writes Denis Weaire*. A desert is the current metaphor for a possible impasse in which no new particles are to be found in the energy range of conceivable experimental facilities. Does it really lie ahead?

In the past such pessimism has generally been proved wrong. When Comte pronounced the impossibility of any knowledge of the composition of the stars,he was only just in time to be made to look foolish by the invention of spectroscopy. But, given the sums involved, who can deny the need to worry about what remains to be discovered after the Higgs boson party is over?

At the Jerusalem conference, yet more evidence was adduced which, give or take a few discrepancies, vindicates the Standard Model. Is it only in physics that triumph engenders crisis in this way? (On *page 180* Marc Besançon reviews the 1996 data for the search for supersymmetric particles).

Despite the feeling of impending drought, high energy physics has not lost its high excitement. For one thing, the quest goes on for the identification of dark matter. It may yet turn out to consist of invisible stars, a mere litter of dead leaves in the universe.But probably won't, and if not, it is up to the particle physicists to tell us what is out there.They can still end a glorious century, or start the new one, with a flourish. The desert may yet flower.