A giant leap for physics — where to?

Physicists in Geneva have discovered the intermediate vector boson; and in an experiment under Lake Eyrie the proton has failed to decay.

ONE of the gods of high-energy physics has revealed himself: the intermediate vector boson, the massive counterpart (for the weak force) of the photon (for the electromagnetic force), a particle predicted by the Salam–Weinberg unified theory of the two forces. But despite the Nobel Prize that will no doubt follow for at least one of the 180 experimenters involved, the two groups that discovered the particle at the European Centre for Nuclear Research (CERN) in Geneva were still arguing last week about whether to admit they had found it. The official phrase is that the data "begins to reveal the expected signature" of the particle.

The problem is a very commendable degree of scientific professionalism, which may yet prove wise: according to Alan Astbury, the cautious British spokesman for one of the groups, the intermediate vector boson is the most desired and well predicted object in the history of particle physics. It certainly falls in the class of the pion, predicted by Yukawa, and the Ω^- predicted by Gell-Mann. And its discovery would be a crucial sign of the virility of contemporary theoretical physics. It is thus all too easy to jump to conclusions. Wary physicists remember the muon — a particle loudly hailed as the pion until it turned out to be the new and totally unpredicted heavy electron.

But once that is put neatly on the record like an insurance premium against disaster, the result is almost certainly a triumph. It is a triumph in particular for Carlo Rubbia, the Italian-American whose irascible dynamism and self-confidence drove CERN into building the facility that eventually created the particle, the proton–antiproton collider. It's a triumph for CERN management, it's a triumph for the physicists and engineers who designed and built the collider (in particular one extraordinary and crucial part of it, which grasps a hot 'gas' of antiprotons and cools it before acceleration). It's a triumph for Europe, too, for this discovery comes well ahead of any American, Soviet or Japanese competition.

So what has been discovered? Experimentally, nine events among thousands of millions of others have shown the collision at 540 GeV (in the centre of mass) of a proton and antiproton. As usual, these 1-GeV-mass particles 'fragment', each creating a shower of particles. One shower follows the line of the antiproton, the other the proton. But in the nine events there is something else: the track, in some cases of an electron and in others of a positron — the antiparticle of the electron — shoots off nearly at right angles to the other tracks and at high energy (20–40 GeV). Nothing balances it on the other side.

This is a textbook example of what Rubbia wanted to see. Even Astbury admits "you could teach a schoolchild with these". The interpretation: one of the three quarks in the proton has collided 'head-on' with one of the three antiquarks in the antiproton. Interacting by the weak force, the particles have created an 80-GeV-mass charged W, one of the intermediate vector bosons. Because the quarks have only a fraction of the total proton kinetic energy, just enough to create a W, it is almost at rest in the laboratory. The W has then decayed into an electron (or positron) and a neutrino, which have shared the mass-energy of the W and gone in opposite directions. The neutrino went undetected, as neutrinos interact very rarely with matter. The electron (or positron) was detected whenever it was out of line with the fragmentation showers of the rest of the proton and antiproton.

The mass of the W from these few events is calculated to be 81 ± 5 GeV, bang on target for the 82 ± 2 GeV prediction of the Salam–Weinberg model. The production rate of the particle is also just as predicted. The neutral partner of the W, the Z, which should weigh 92 ± 2 GeV according to Salam–Weinberg, is produced at a ten times lower rate, and should be seen in the next collider run at CERN, which will take place about Easter and should bring in ten times more events. Easter is also the time when the more precise theoretical predictions for the intermediate vector bosons will be tested, and when we shall see whether caution was justified: for example, it will be determined whether the particle decays violate left–right symmetry (that is, break 'parity') as expected from the weak interaction.

Meanwhile, another important result for particle physics was announced last week: a lower limit on the proton lifetime determined by the Irvine–Michigan–Brookhaven collaboration down a salt mine 2,000 ft beneath Lake Eyrie. This places the lifetime of proton against positron–π^0 decay at more than 6.5×10^{31} years. This is nearly an order of magnitude longer than the longest prediction of minimal SU(5), one of the simplest of the 'grand unified theories', or GUTs, which links all the non-gravitational forces in a unified scheme, and so throws that model into doubt. "Supersymmetric" theories, which are more favoured among theorists these days, and also bear on gravity, are as yet untouched by the result.

The result is significant in being the first to begin to sort out the wheat from the chaff among the many different GUTs — and the experiment promises more, stretching the detection limit to a lifetime of 10^{33} years, and seeking other decay modes (including the kaonic modes predicted by supersymmetry) in the next three years of running. 'Detections' of proton decay in other competing experiments (under Mont Blanc and in an Indian gold mine) may be neutrino events from cosmic rays, the group believes.

So a marvellous week for particle physics — but what does it all mean? Clearly the subject — which underlies all physics — is at one of the most creative phases in its history. On the whole, at accelerator energies, theory is leading the subject, while experiment appears merely to confirm. But way up ahead, at the 10^{15} GeV energy regions probed by the GUTs, where only proton and neutron decay experiments can shed observational light, there are worms in the golden apple. There is not one GUT to test, like a theory of general relativity, but several. The principal reason is that an essential sector of the theories is being neglected: the Higgs fields, which fill space-time and gnaw away at an underlying symmetry of forces to break it into the very different forces we observe. The symmetry may be beautiful; and the Higgs fields may exist (they are needed in the Salam–Weinberg model, which now appears to be confirmed). But what are the Higgs fields? All the untidy problems — such as the matter of why the intermediate vector bosons are heavy — are essentially disposed of as properties of the Higgs fields.

Physics now appears like a tapestry: beautiful on the surface, but full of knots and crossed threads behind. It will remain so until the problem of the Higgs fields is solved.

Robert Walgate

On page 287, Frank Close describes the historical background to the concept of the intermediate vector boson. Dr Close wrote just before last week's news broke.