Another red herring leads nowhere

Why, these days, are so many brave new ideas destined to bite the dust? And why are so many of them in the physical sciences, supposedly the more exact, rather than in biology?

THE fate of cold fusion remains in doubt, but does not look bright. The fifth force, the notion that newtonian gravitational attraction is modified by a short-range force dependent on the composition of materials and which might be mediated by one of the missing particles of high-energy physics, has ceased to attract excitement. Now the latest casualty may be the idea that the observation of positrons with well-defined energy in the collision of heavy ions might similarly be the signature of one of the missing particles.

The first observations were made six years ago at the West German heavy-ion accelerator laboratory at Darmstadt, during measurements by a US–German collaboration of the products of the collision of uranium and curium ions (J. Schweppe *et al. Phys. Rev. Lett.* **51**, 2261; 1983). One of the objectives of the experiments was to search for "islands of stability" in the periodic table at atomic numbers much greater than those of even the artificial transuranium elements.

The surprise, instead, was a clutch of positrons with an energy of 320 keV crammed into a narrow range of energy spread over 75 keV. The mystery was sharpened (T. Cowan *et al. Phys. Rev. Lett.* **54**, 1761; 1985) when an apparently identical positron line appeared among the collision products of uranium and thorium ions with each other, with themselves and with curium ions.

Speculation was constrained, as it has been almost ever since. Daring possibilities were raised only to be dismissed. That the positrons might come from the radioactive decay of some excited state of one or other of the colliding nucleons or from the nucleus which, briefly, would be their conjunction was ruled out once there were several nuclei in the field. The lifetime of the supposed compound nucleus (estimated at 10^{-20} seconds) was in any case too short to allow the narrowness of the peak observed. So might the positrons come from the disturbance of the electromagnetic vacuum by close nuclear collisions or even from "the two-body decay of a previously undetected particle"? The collaboration promised new experiments collecting evidence of the presumed accompanying electron would be sought.

A year later, the group at Darmstadt had reported both the discovery of the partner electrons and an estimate of the mass of the supposed neutral particle — something like 1.78 MeV (T. Cowan *et al. Phys. Rev. Lett.* **56**, 44; 1986). But the measurements then available provoked an awkward question — the presumed mass could be anything between 1.5 MeV and 1.8 MeV, a large spread for such narrow electron and positron lines. Later that year, a Stanford–Berkeley collaboration reported its failure, at a parallel installation at Berkeley, to find the pairs of energetic photons into which a neutral particle with mass should also, less often, decay (W. E. Meyerhof *et al. Phys. Rev. Lett.* **57**, 2,139; 1986).

Soon afterwards, at Darmstadt and Berkeley, there were more surprises — in particular, the appearance of positron–electron pairs with energy different from that first observed. There seemed to be at least three distinct electron–positron lines, corresponding either to neutral particles with energies of 1.64 MeV, 1.77 MeV and 1.83 MeV or, alternatively, to a single neutral particle with a complicated way of shedding energy. The striking technical achievement of that period was a switch from positron to photon counting, which made it possible to pin down the presumed mass more accurately, to within a few keV either way — making the mystery more puzzling.

For the Stanford and Berkeley collaboration (now joined by people from Rochester and the Lawrence Livermore National Laboratory), growing complexity has evidently been frustrating. Somehow, the group persuaded the Lawrence Berkeley Laboratory to allow it seven weeks of run-time on Super-HILAC, the linear accelerator for heavy ions. For practical purposes, they have run through the experiments first reported in 1985, keeping to roughly the same energy of just about 6 MeV for each nucleon in the projectile nucleus. The statistics are inevitably much better than in any previous measurements.

And the result? The objective was to record the coincident emission of pairs of photons (γ-rays at this energy), to measure the energy of each of them and to equate the sum with the energy of the presumed neutral particle. For the collision of uranium projectiles with a thorium target, there are no fewer than five peaks between 900 keV and 1,000 keV, with others at greater energy.

But why so many peaks? Three peaks were bad enough, but, as Groucho Marx would have said, "five is ridiculous!" But the Stanford–Berkeley collaboration has the neatest answer: the peaks in the energy of the photon-pairs have nothing at all to do with an unknown neutral particle, but arise simply because some heavy ions in collision are excited into high rotational states, perhaps with 30 quanta of rotational energy, from which they decay with the emission of photons (K. Danzmann *et al. Phys. Rev. Lett.* **62**, 2353; 1989).

This simple interpretation is convincing for reasons other than its simplicity. For heavy nuclei, the difference between successive rotational states is not constant (as it is for some molecules) because rotation flattens a nucleus, so that the single measurements of the slightly different energy of photons in an apparently coincident pair can be used to show that the measured peaks are consistent with being successive rotational de-excitations of a uranium nucleus. The equipment, luckily, also records the energy of many photons which are not apparently one of a pair; some of the peaks in that record correspond to the loss of a single rotational quantum from a highly excited state.

This interpretation does not prove that the positrons observed cannot arise from the decay of an unknown neutral particle, although the Stanford–Berkeley group say flatly that at least one of their peaks cannot be a two-body decay. More formally, they argue that if their photon-coincidences come from the decay of a neutral particle, the electron–positron peaks reported both from Darmstadt and (previously) Berkeley are almost certainly too small.

The positrons previously observed are, in all likelihood, secondary products of single γ-rays released from nuclei put into high rotational states by collision (which, counter-intuitively, requires that the collisions should be nearly head-on, which explains why they are rare).

There are no morals to be drawn from this tale. If neutral bosons were created in heavy-ion collisions, that would have been important, but it is also good to know the truth. That the search may have occupied a few hundred man-years of researchers' time, not to mention two of the world's most sophisticated accelerators off and on, is in the long run neither here nor there; those concerned have learned a lot of physics and have improved the state of the art. They also have the comfort of knowing that their working hypothesis began life as a well-founded puzzle. Who can ask for more? **John Maddox**