New particles from old data

A search for an explanation of positrons in heavy-ion collisions has led to firm evidence of light neutral particles and an explanation of a forgotten anomaly in the lifetime of the π^0 meson.

PALAEONTOLOGISTS are the people able most commonly to boast of having made important discoveries in material already worked over by others, but the identification of the Crab Nebula with a long-since exploded star seen by the Chinese shows that they do not have a monopoly of delayed discovery. But now, surprisingly, almost forgotten data have been turned to good use in particle physics, helping to confirm what appears to be the discovery of a new particle.

It is a curious tale. It is now five years since the first reports from the Heavy-Ion Research Laboratory (GSI) at Darmstadt that collisions between heavy ions were often followed by the emission of positrons with characteristic (but not particularly large) energy. The data have never been sharp enough to persuade everybody that the phenomenon is real, but the theoreticians have from the outset been eager to demonstrate that the positrons are real and interesting. One ingenious attempt to show that the observed positrons are nothing but particles released directly from the universal Dirac sea of electrons with negative energy appears not to hold water, but most excitement has centred on the possibility that the positrons observed are the decay products of light neutral particles, of which that known as the axion would be the most desirable.

While the theoreticians have been saying what the explanation is, some experimenters have been looking for confirmatory data. A Berkeley-Stanford collaboration produced some intriguing data towards the end of last year. But now M. El-Nadi and E. O. Bawady, from the Physics Department at the University of Cairo, have produced what seems to be telling evidence that there is indeed a phenomenon to be explained (*Phys. Rev. Lett.* **61**, 1271; 1988). Their demonstration is all the more appealing because they used techniques that first came into their own four decades ago.

Plainly it is not essential, in the study of the interaction between heavy nuclei, to build a huge detector full of electronics, install it near a heavy-ion accelerator and then patiently collect information about events of predefined character over a period of weeks or months. What El-Nadi and Bawady did was to expose a stack of nuclear emulsions (of the kind used for identifying heavy ions in the cosmic rays reaching the upper levels of the atmosphere) to a beam of ^{12}C or ^{22}Ne ions at the

Institute of Nuclear Research at Dubna, looking for the interaction patterns revealed by the tracks in the exposed emulsion after it has been developed.

What the authors have done is to scan their emulsions for cases of patterns in which a primary nucleus has been broken up into smaller pieces in a collision with unidentified nuclei in the emulsion, and then to look for cases in which at least one of the secondary particles interacts with a further nucleus in the emulsion to yield an electron pair — a positron and an ordinary electron.

The outcome is satisfyingly graphic. El-Nadi and Badawy show a representation of an interaction track in which a ^{12}C nucleus disintegrates into three α particles, one of which, in a further interaction, yields a proton, a pion and a kaon (both mesons, one strange) and, downstream of the second interaction by $46\ \mu\text{m}$, the apex of a narrowly diverging pair of tracks apparently caused by particles with the characteristics of electrons. The inference is that some electrically neutral particle spans the $46\ \mu\text{m}$ gap. Out of 2,600 primary interactions in the emulsion, the authors collected 13 examples of electron-positron pairs produced in this way.

As in all these circumstances, there is an intricate argument about the likelihood that some of the observed electron pairs are produced by other means than by a previously unrecognised particle. El-Nadi and Badawy note that electron pairs can be produced by energetic photons and that energetic photons result from the decay of electrically-neutral π^0 mesons. Luckily, the background expected from this source is less than a third of the events recovered, leaving El-Nadi and Badawy able to estimate that the mass of their neutral particle is within 1.15 electron-masses of 3.13 electron-masses and that its lifetime (at rest) is just over 10^{15} seconds.

Forgotten data enter the argument at two places, but some of wit is the authors' own; they explain that the emulsion track they show (described above) was first presented at a conference at Darmstadt in 1985. But the data presented from Cairo may explain why the first measurements of the lifetime of the π^0 meson were two orders of magnitude greater than the value accepted when accurate measurements became possible. That at least is the assertion of F.W.N. de Boer and R. van Dantzig from the University of Amsterdam, in an accompanying paper which

reads as if it is a referees' report turned into print (*Phys. Rev. Lett.* **61**, 1274; 1988), an inference supported by the submission dates. (The Amsterdam paper was first submitted after a revised version of the Cairo paper had been received.)

de Boer and van Dantzig do not quarrel with the Cairo group about the background to be expected from other processes for forming electron-pairs, but they plot measured lifetimes and masses of the neutral particles inferred for fourteen events, finding that they fall naturally into three clusters more widely separated from each other than their error bars.

This is where the forgotten data count, for the authors also note that the first measurements of the lifetime of the π^0 meson were made in essentially the method followed by El-Nadi and Badawy — C.F. Powell's group at the University of Bristol looked for pairs of electrons in nuclear emulsions exposed to cosmic rays, reckoning that these would all have been the products of photons themselves produced from π^0 mesons. By good luck, there are even detailed analyses of the kinematics of two of the tracks observed at Bristol, which fall ("amusingly", as the authors put it) right at the centres of two of the clusters in their diagram. The inference is that the first lifetime measurements were really measurements of a quite different neutral particle.

It is strange how convincing, no doubt irrationally, is this unexpected coincidence. If El-Nadi and Badawy are right, their neutral particles will account not just for the puzzle they set out to solve, but for another of which they appear to have been unaware. It is enough to drive people into the arms of Bayesian probability.

Indeed, there is more to say. de Boer and van Dantzig note that at least one of the masses corresponds closely with one of those singled out by the Stanford-Berkeley experiment last year. Cautionously, they agree that there is at least one, and possibly three, neutral particles which decay into electron-pairs, with masses of 1.1, 2.1 and 9.2 MeV (the first coincides with the Cairo estimate). But none of them appears to be an axion in the simplest sense. Perhaps pairs of axions with opposite polarity might be involved, but that is for the time being speculation. But nobody will now deny that the phenomenon needs further investigation. There will be a brisk demand for nuclear emulsion.

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