The setup of the Athens/CERN/Paris/Rome neutrino experiment at the CERN PS proton synchrotron with its helium gasbag which in 1984 saw an unexplained excess of electrons.

One possible explanation is neutrino 'oscillations'. In the conventional neutrino picture, these ethereal particles have no mass and the various types do not mix. But if the rules are slightly modified, the composition of a neutrino beam changes as it travels.

However the flimsy statistics of the experiment carried little weight, and the decision was taken to rerun with improved apparatus in the high intensity beam at Brookhaven's Alternating Gradient Synchrotron. (The collaboration now read Boston/Brookhaven/CERN/Paris.) The main part of the second-generation detector, 175 metres downstream of the neutrino source, was a 30 ton multiple sandwich of 3 mm iron plates and flash tubes of the type used by the Frejus (France) underground experiment looking for proton decay.

Again the electron-type neutrino content of the beam was estimated at less than one per cent. With 325,000 neutrino and 168,000 antineutrino events in the bag, careful analysis got underway, and after painstaking work to eliminate background effects and contamination, a net electron excess still remained, corresponding to about twice the estimated electron-neutrino content of the beam from the accelerator, tying in with the original result.

Despite the vastly increased data sample, the possible sources of error compound to reduce the reliability of the final result. The estimation of the electron-neutrino content of the beam also includes assumptions untested at the energies used by the experiment.

In the meantime many other experiments have looked for oscillations, without success, so the idea is going out of fashion, at least as far as terrestrial neutrinos are concerned. When it comes to neutrinos from outer space, there are still many interesting possibilities to explore.

WORKSHOP Electron-positron mystery

The tightly correlated electron-positron pairs seen in experiments at the GSI Darmstadt heavy ion Laboratory and elsewhere have yet to be explained. New particle or new effect? The question was highlighted at a recent Moriond workshop held at Les Arcs in the French Alps in January.

Fast-moving particles can experience enormous localized electromagnetic fields, and interesting effects can result. For example an electron traveling near the velocity of light can feel a magnetic effect due to its spin alignment that is comparable to its own rest mass. Other effects have been seen using the local fields inside crystals (June 1987, page 17). For two colliding heavy nuclear ions, these effects are large enough to produce electron-positron pairs. Moreover the electrons could be tightly bound, while the positrons are repelled by the positive electric charge of the nuclei and emerge alone.

Several years ago, experiments got underway at GSI to investigate positron production in heavy ion

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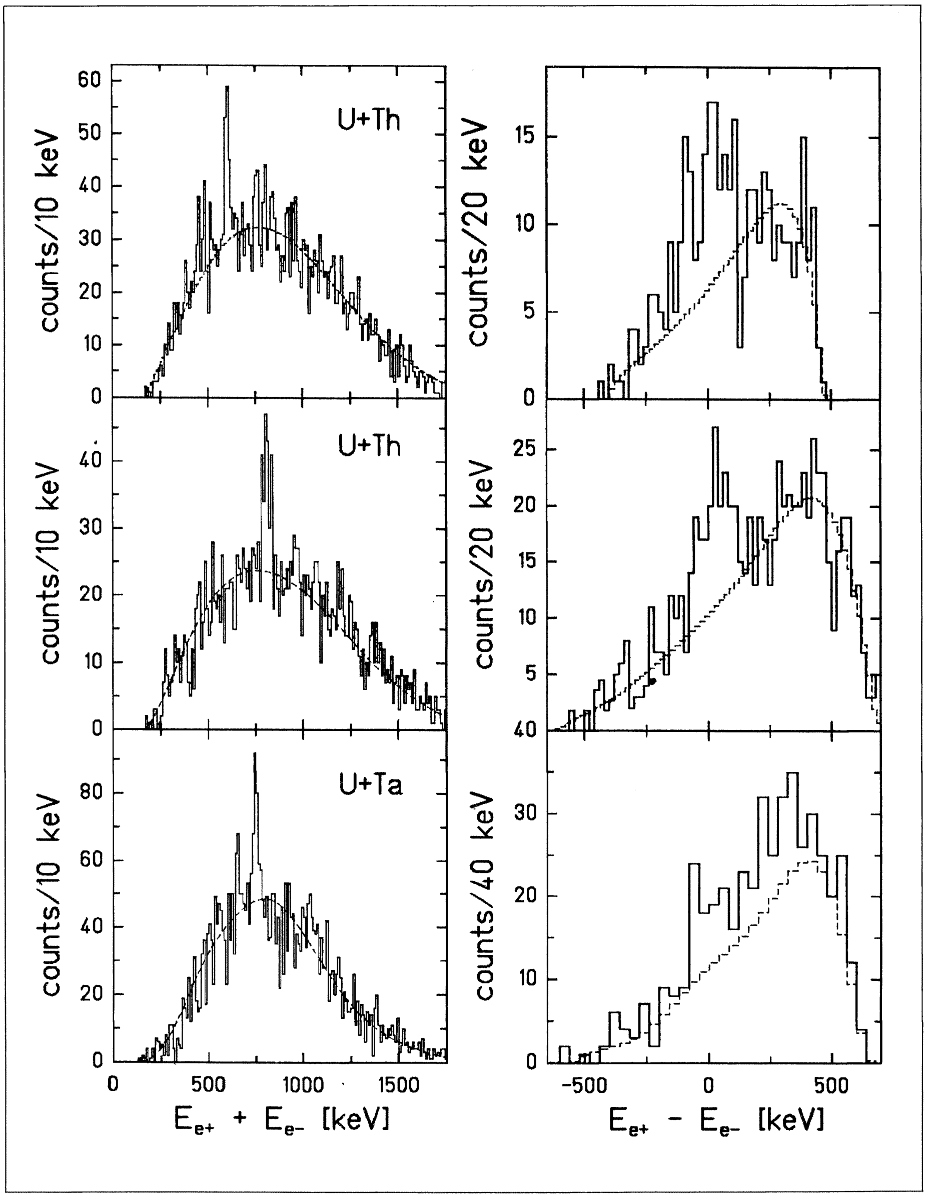

Left, sharp lines in the electron-positron spectra seen by the EPOS experiment at the GSI Darmstadt heavy ion Laboratory in collisions of uranium ions with thorium and with tantalum. Right, the energy difference of the electrons and positrons shows a much broader structure, suggesting that the particle pairs result from the decay of something at rest in the centre-of-mass of the colliding ions. (The energies are kinetic, and do not include rest masses.)

collisions. One unexpected result was the discovery by the EPOS experiment in 1985 of sharp positron peaks, and further investigation showed the positrons coming off back-to-back with electrons.

The Moriond meeting included detailed presentations of the ongoing heavy ion studies at GSI. P. Kienle reported on the ORANGE experiment with its additional spectrometer enabling electrons and positrons to be measured in coincidence. Recent data for uranium-uranium and uranium-lead collisions at energies around 5.9 MeV per nucleon show an 809 keV electron-positron line together with indications of additional lines. The electrons and positrons emerge back-to-back and the energies preclude conventional mechanisms (nuclear internal pair conversion).

The current status of the pioneer EPOS experiment was reviewed by D. Schwalm (Heidelberg) and P. Salabura (Frankfurt, Cracow). EPOS has now looked closely at collisions of uranium ions with thorium and with tantalum, and has consistently found a group of three sharp lines in the electron-positron energy spectrum, with broad distributions in the spectrum of the corresponding energy difference. The lines are at 608 ± 8, 760 ± 20 and 809 ± 8 keV with thorium and 620 ± 8, 748 ± 8 and 805 ± 8 with tantalum.

The narrowness of the lines together with the broad structure in the electron-positron energy difference suggests a cancellation of kinematical effects such as would occur if the two particles resulted from the decay of an object at rest in the centre-of-mass of the colliding ions. On the other hand, first direct measurements by EPOS of the correlation of the electron-positron pairs for uranium/tantalum show only the 620 and 805 keV lines being back-to-back decays, the 748 line being less easy to accommodate.

EPOS also sees how the line intensities depend on beam energy. The two GSI experiments do not see the same dependence of the production rate on total atomic mass.

Possible explanations concentrated on three themes. Strong field electrodynamics was the original motivation for the experiments and reproduces satisfactorily the smooth electron-positron background, but it is difficult to concoct a mechanism producing such sharp lines. Exotic new electrodynamics is another possibility, but no other such effects have ever been found. The third option is the decay of new extremely light particles, only a few times the mass of the electron. However such entities have not been seen in other searches, despite considerable effort. The results so far imply that the light particles would have to be more than about a hundred times the size of a nucleon, with the number of observed lines suggesting a complex behaviour. A. Schäfer reviewed the situation.

There was general agreement that more data is needed so that the unexplained lines can be better analysed. New projects were described by K. Stiebing (Frankfurt) for EPOS and F. Calaprice (Princeton) for the new APEX study to be installed at the ATLAS tandem linear accelerator at the US Argonne Laboratory (March 1987, page 22).

From H. Bokemeyer (GSI Darmstadt) and B. Müller (Frankfurt)