More about the beam dump

from David J. Miller

PRELIMINARY results of the CERN neutrino beam dump experiment were discussed in a News and Views report some weeks ago (**272**, 205; 1978). Now that the papers of the three experimental groups are published (*Phys. Lett.* **74B**, 134, 139, 143; 1978) it is possible to examine the agreements and differences between them more closely.

They all agree on one new effect; the rate of production of events with an electron and no muon in the final state, compared with the rate for muon production, is much too high to be accounted for by the 'old fashioned' particles, the pion and the kaon. Such particles prefer to produce muon neutrinos which in turn prefer to give muons in the final state when the neutrinos interact. The beam dump experiment uses a special massive copper target in which the pions and kaons from high energy proton reactions are rapidly absorbed, instead of being allowed to decay and produce neutrinos as they do in normal neutrino experiments. To account for the high rate of electron events a 'prompt' neutrino source has been postulated, some short-lived particle which gives roughly equal numbers of all four kinds of neutrino—muon and electron, particle and antiparticle. The bubble chamber collaborations (the BEBC collaboration of Aachen-Bonn-CERN-London, Imperial College-Oxford-Saclay (Bosetti *et al. Phys. Lett. op. cit.*, 143), and the Gargamelle Milan-Orsay-Strasbourg-London, University College (Alibran *et al. Phys. Lett. op. cit.*, 134) suggest that the production rate for this new prompt source should be around one in 200 proton interactions. The CERN-Dortmund-Heidelberg-Saclay (CDHS) counter collaboration (Hansl *et al. Phys. Lett. op. cit.*, 139) claim that they can explain this observed rate of electron events if prompt neutrinos are produced in around 1 in 1,000 proton interactions. It is not yet clear where the difference comes from. It may be in the beam flux calculations or in the model used to calculate the way in which heavy parent particles would be produced by the proton beam. At the rate seen by CDHS it is just possible that the prompt parents could be the charmed D mesons, although some special arguments are needed to explain why D decays have not been seen in experiments which looked directly for them.

CDHS group also sees an excess of positive muon events over the expected number. This fits in well with the idea of a prompt source giving equal numbers of all four types of neutrinos. Pions and kaons from proton interactions produce many more neutrinos than antineutrinos. This is because both the proton beam and nuclei in the upper target have positive electric charge, so positive pions and kaons are more readily produced and these decay largely to positive muons accompanied by neutrinos. Negative pions and kaons give negative muons with antineutrinos. When neutrinos interact in charged current processes they produce negative muons (particles) and when antineutrinos interact they give positive muons (antiparticles, c.f. the positron, the anti-electron). If D mesons are the prompt source then they are probably produced as particle-antiparticle pairs, conserving the charm quantum number in the strong production process, and giving equal numbers of neutrinos and antineutrinos in their decays. So the CDHS data are again consistent with the D meson.

Trimuon events were the trigger for doing the beam dump experiment. In one of their previous runs with a normal neutrino beam CDHS saw 13 events with three final state muons with a total of 2.3×10^{17} protons on the target at 400 GeV/c. It was suggested that these might be caused by a new type of neutrino which would be produced promptly. In the beam dump experiment, with 4.3×10^{17} protons on target at 400 GeV/c, no trimuons were seen, so it is established that the trimuons come from the interactions of normally produced neutrinos.

All three collaborations have been able to place limits on the production and interaction of axions. These postulated neutral particles, with 'semiweak' interactions and a very low mass were invented in order to solve a problem on the construction of gauge-field theories with parity and time-reversal invariance (Weinberg *Phys. Rev. Lett.* **40**, 223; 1978). The beam dump experiment is a good place to look for them, since they are supposed to be produced directly in proton collisions, not through an intermediate pion or kaon decay, and their semiweak interaction should allow many of them to pass through the thick shield of steel and rock which absorbs charged particles from the neutrino beam. The BEBC beam dump results show that axion production must be less than 1/30 of the predicted rate. This is in agreement both with the Gargamelle result and with a recent paper from an old Gargamelle beam dump experiment, reanalysed for the axion by a group in Milan (Milan University preprint; Bellotti, Fiorini and Zanotti). The CDHS collaboration have larger statistics than these bubble chamber experiments. Their limit on axion production and interaction is a factor of 200 smaller than the predicted rate for one class of axion interaction, and 20,000 times smaller than predicted for another class of interaction. Unless its inventors can adjust their theories, the axion seems to be dead. □

David J. Miller is in the Department of Physics and Astronomy, University College London.

Plasma on the wall at Culham

from M. W. Thompson

THE new mood of optimism in the plasma fusion business and the decision to site JET, the Joint European Torus experiment, at the Culham Laboratory of the UK Atomic Energy Authority, brought a sense of purpose to the Third International Conference on Plasma Surface Interactions held there recently*. If power-producing fusion reactors become a reality next century, solutions will have been found to the problems of radiation damage in the reactor structure.

Outside the fusion reactor vessel there will be neutron and gamma radiation similar to that outside the core of a fast fission reactor, for which the materials problems are already solved, although the upward shift of neutron energy from 2 MeV to 14 MeV, and the different intensities, will move us on to less familiar ground. But the real problems will be inside the reactor vessel. If, as many people expect, fusion reactors confine their plasma within electromagnetic fields, the vessel will be a vacuum chamber and its inner walls will be bombarded by almost every conceivable kind of radiation. Electrons, ions and neutral atoms of hydrogen and helium, a few heavier ions and atoms and electromagnetic radiation from visible light through X rays to gamma rays are expected. These particle energies will spread all the way from a few eV to several MeV. Besides these there will be the 14 MeV neutrons from the fusion reaction. In the current experimental systems only the neutrons and gamma rays are missing. Although the containment fields are intended to confine the ions and

* Held on 3-7 April. The proceedings will be published by North Holland as a special issue of the *Journal of Nuclear Materials*.

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