New physics from new accelerators

Even before the foundations of the Superconducting Super Collider (SSC) have been laid in Texas, people are brooding about the next generation of particle accelerators.

IN the demonology of the particles of matter that should exist but which, as yet, do not, the Higgs boson (called H_0) is among the most conspicuous. Its predicated existence is a cornerstone of the grand unified theories of matter — a consequence of the asymmetries that mark the low-energy world we live in. Naturally, every new accelerator coming into operation raises people's hopes that, this time, that elusive particle will be found. And each new accelerator disappoints.

But is it possible that the accelerator people have been looking in the wrong places? Or in the right places in the wrong ways? That may be the implication of an argument now put forward by Richard Blankenbecler and Sidney D. Drell of the Stanford Linear Accelerator Center (*Phys. Rev. Lett.* **61**, 2324; 1988). To be fair, Blankenbecler and Drell are not so much concerned to cheer on the hunt for the Higgs boson as to guide the design of the generation of particle accelerators next after those now being built (LEP at Geneva and its equivalent at Serpukhov) or about to be (SSC in Texas).

Beyond those machines, all circular accelerators, there are likely to follow machines consisting of a pair of linear electron accelerators firing beams of electrons and positrons (or just electrons) at each other. To be worthwhile, the particles in each beam will have to be given energy greater than 500 GeV, ideally 1 TeV or more, which would not be possible in a circular machine because most of the energy put into acceleration would be promptly radiated away again as synchrotron radiation. Soviet physicists at Novosibirsk have already designed a linear collider of this kind — and have been frustrated by the decision that, when the time comes, it will be built at Serpukhov. In the United States and Europe, there are also people working away.

Blankenbecler and Drell are first concerned with a mechanism by which colliding beams of electrons and positrons are robbed of energy in more familiar accelerators, and which rejoices in the name (deliberately a near-pun) of beamstrahlung. In circular accelerators in which pulses of positrons and electrons are circulating in opposite directions, for example, pairs of particles will produce photons when they come close to each other even if their interaction is not so intimate as to produce other kinds of particles. As a consequence, it is customary to reduce the

loss of energy in those parts of a trajectory in which interactions are supposed not to occur by shaping the counter-circulating beams appropriately — giving each of them a ribbon-like cross-section, for example, so that their interpenetration is a minimum.

But what happens when the oppositely travelling beams are shaped not so as to minimize the loss of energy by this mechanism, but to maximize it? Then, the argument goes, there will be copious production of single photons, but the chance of producing pairs of photons simultaneously will be disproportionately enhanced. Is it possible that the process will even lead to the production of pairs of photons sufficiently energetic for their interaction to exhibit physical phenomena not otherwise easily observable?

The answer, it will have been guessed, is yes. The first step, the calculation of the chance that a single electron in a travelling pulse of, say, electrons will interact with a positron held, for the sake of the argument, fixed in space is a calculation for the text-books of quantum electrodynamics. What emerges from it is a function — essentially a probability distribution — specifying the chance that the moving electron will surrender a certain fraction of its momentum to radiation in the form of single photons. Strangely, calculating the chance that pairs of photons will be produced is then a classical probability calculation, partly because the repulsive Coulomb forces within a travelling pulse of charged particles repeatedly destroy the coherence of the motion. In the end, the calculation has to be numerical, but the results are clear-cut.

Briefly, the interaction of ribbon-shaped pulses will yield few cases in which pairs of energetic photons may interact with each other, but pulses with squat elliptical cross-sections will be relatively prolific sources of them. The essence of the argument is the conclusion that there should be circumstances in which careful shaping of the cross-section of the separate pulses of particles travelling in an accelerator will maximize the chance of photon-photon interactions by several orders of magnitude, four or five perhaps.

It is worth reflecting on the magnitude of what is proposed, which can be told from the numerical examples with which Blankenbecler and Drell illustrate their argument. As if in passing, they refer to electron pulses (travelling with a velocity

indistinguishable from that of light) such that, seen end-on, there are 10^{30} electrons or positrons per square centimetre of cross-section. They do not mention that, for practical purposes, the lateral dimension of the pulses will be measured in μm , not centimetres, but that is standard practice in electron accelerator laboratories. And the length (at rest in the laboratory frame) of each pulse will be rather less than a millimetre.

What, in these circumstances, will the copious production of energetic photon pairs produce? This is where the Higgs boson comes in. For, as a particle whose existence stems from the asymmetry in the real world between strong, weak and electromagnetic forces, H_0 must interact with almost everything in sight. In particular, even though it may lack electric charge, it should be produced as a single and recognizable entity in the interaction of two sufficiently energetic photons.

Part of the trouble with H_0 is that nobody knows how massive it may be relative to other particles, but there is at least a chance that, if the mass is less than those of the intermediate vector bosons mediating the weak nuclear interaction, the $W^\pm$ and Z^0 so far recognized only at CERN, examples may already have been produced, but have not been recognized in the welter of particles generated by other means.

But if the mass of the Higgs boson is greater than the equivalent of 100 GeV, there will be a greater chance of finding Higgs bosons in an electron collider whose beams have been appropriately shaped to enhance double-photon interaction than in the direct collision of oppositely charged electrons. Blankenbecler and Drell say that the obvious experiment, based on direct electron interaction, would be expected to yield 10 events a day, but that optimizing the beam shape to enhance photon collision should yield ten times as many.

The interest of this argument is not, of course, that it shows in what range of energy people should be looking for H_0 , or even that double-photon interactions are the mechanism by which it should be sought, but that the conventional wisdom of machine designers that beamstrahlung are an unmitigated nuisance may be mistaken. It will be interesting to see how quickly the designers respond by arranging to tune the shapes of the cross-sections of their pulses of particles.

John Maddox