beams into collision by swinging them through two arcs of magnets and then using other magnets to focus the beams just before collision. In the SLC (and any future linear collider), there is a continuing struggle to attain sufficient luminosity. This problem is more severe for a linear collider than a circular storage ring, in which a single bunch of particles is reused over and over again thousands of times per second. In a linear collider the particles are thrown away in a suitable beam dump after each encounter. Thus it is necessary to generate and focus bunches of exceedingly high density.

An extremely tight focus of the beam is required at the point of collision. There are two fundamental limits to the feasible tightness. The first has to do with the brightness of the sources that generate electrons and positrons, and the second is related to the disruption caused by one bunch on the other as they pass through each other. According to a fundamental physics principle that is of great importance for the design of optical systems, the brightness (by which I mean the intensity that illuminates a given area and is propagated into a given angular aperture) cannot be increased whatever you do with a light beam—or, for that matter, a particle beam. Thus even the fanciest optical or magnetic system cannot concentrate the final beam spot beyond certain fundamental limits set by the brightness of the original source and the ability of the accelerating system to maintain it.

The second limit is more complex. The interaction between one beam and another produces several effects. If beams of opposite charge collide, one pinches the other, usually increasing its density; but if that pinching action becomes too severe, the beam blows up! In addition, the extremely high electric and magnetic fields that arise in the process cause the particles to radiate; the energy thereby lost diversifies the energy of the different particles in the bunch, which makes it less suitable for experiments.

And there is an additional feature that aggravates the problem. As the energy of colliders increases, the cross sections of the interesting reactions decrease as the square of the energy. Therefore the luminosity—and therefore the density of the interacting bunches—must increase sharply with energy. Thus all the problems cited above will become even more severe.

As a result of all these factors, a linear collider is not really linear in all respects; in particular, the brightness of the beam must increase as a high power of its energy. This fact is difficult to express as a simple cost-scaling law. It suffices to say that all these effects eventually lead to a very serious limit on electron-positron linear colliders. Where this limit actually lies remains in dispute. At this time an upper bound of several TeV per beam is a reasonable estimate. We can hope that human ingenuity will come to the rescue again—as it has many times before when older technologies appeared to approach their limits.

THIS DISCUSSION of linear electron-positron colliders is a part of a larger question: "How big can accelerators and colliders, be they for electrons and positrons or for protons, become?" As indicated, the costs of electron-positron linear colliders may be linear for awhile, but then costs increase more sharply because of new physical phenomena. The situation is similar for proton colliders. The cost estimates for the largest proton collider now under construction—CERN's Large Hadron Collider—and for the late lamented SSC are roughly proportional to energy. But this will not remain so if one tries to build machines much larger than the SSC, such as the speculative Eloisatron, which has been discussed by certain European visionaries. At the energy under consideration there, 100 TeV per beam, synchrotron radiation becomes important even for protons and looms as an important cost component. Indeed, physical limits will cause the costs eventually to rise more steeply with energy than linearly for all kinds of machines now under study.

But before that happens the question arises: "To what extent is society willing to support tools for particle physics even if the growth of costs with energy is 'only' linear?" The demise of the SSC has not been a good omen in this regard. Hopefully we can do better in the future.