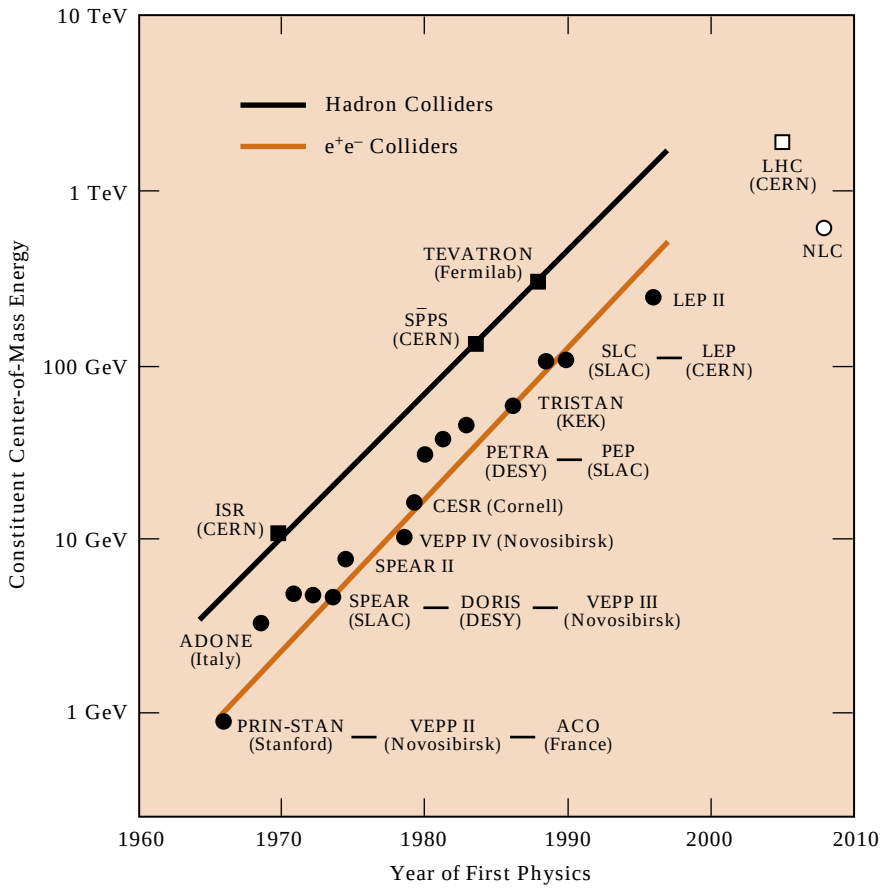
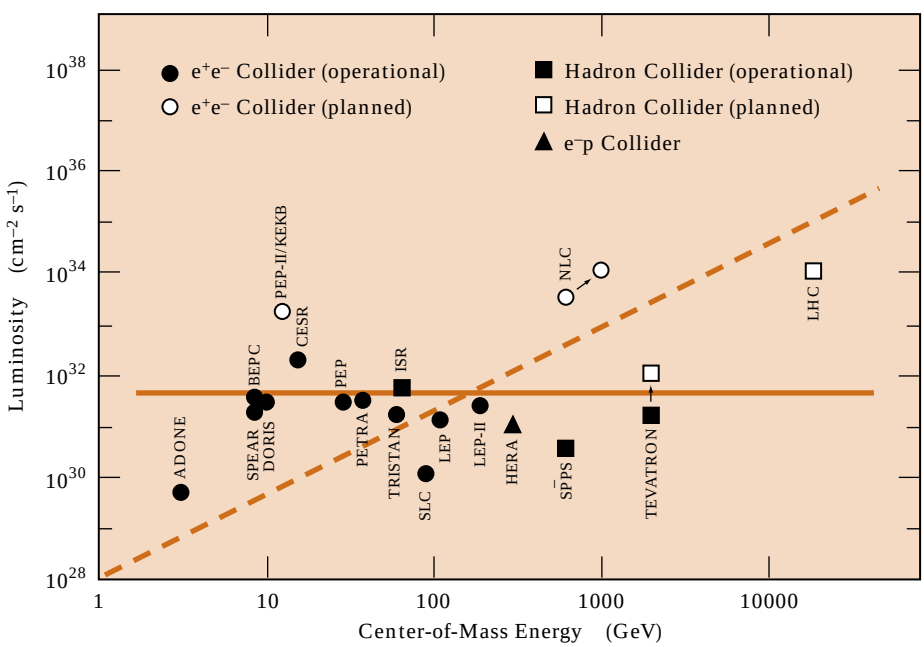
Right: The energy in the constituent frame of electron-positron and hadron colliders constructed (filled circles and squares) or planned. The energy of hadron colliders has here been derated by factors of 6–10 in accordance with the fact that the incident proton energy is shared among its quark and gluon constituents.



is worthless unless (as discussed above) higher interaction rates can be generated, too. To succeed, the density of the two beams must be high enough—approaching that of atoms in ordinary matter—and their interaction cross sections must be sufficient to generate an adequate data rate. In colliding-beam machines the critical figure is the luminosity L, which is the interaction rate per second per unit cross section. The bottom graph on this page illustrates the luminosity of some of these machines. In contrast to the constituent collision energy, which has continued the tradition of exponential growth begun in the Livingston plot, the luminosity has grown much more slowly. There are good reasons for this trend that I will discuss shortly.

Naturally there are differences that must be evaluated when choosing which particles to use in accelerators and colliders. In addition to the energy advantage mentioned for electrons, there are other factors. As protons experience the strong interaction, their use is desirable, at least in respect to hadron-hadron interactions. Moreover, the cross sections involved in hadron interactions are generally much larger than those encountered in electron machines, which therefore require higher luminosity to be equally productive.

Proton accelerators are generally much more efficient than electron machines when used to produce secondary beams of neutrons, pions, kaons, muons, and neutrinos. But electrons produce secondary beams that are sharply concentrated in the forward direction, and these beams are less contaminated by neutrons.



Peak luminosities achieved at existing colliders and values projected for planned or upgraded machines. The dashed line indicates luminosity increasing as the square of the center-of-mass energy Note that the rated machine energy has been used in calculating the abscissa. (Data updated courtesy Greg Loew, SLAC)