High Energy Physics *made painless*

Fixed-Target Physics

“Fixed” means stationary, as in “fixed in place,” rather than “repaired.”

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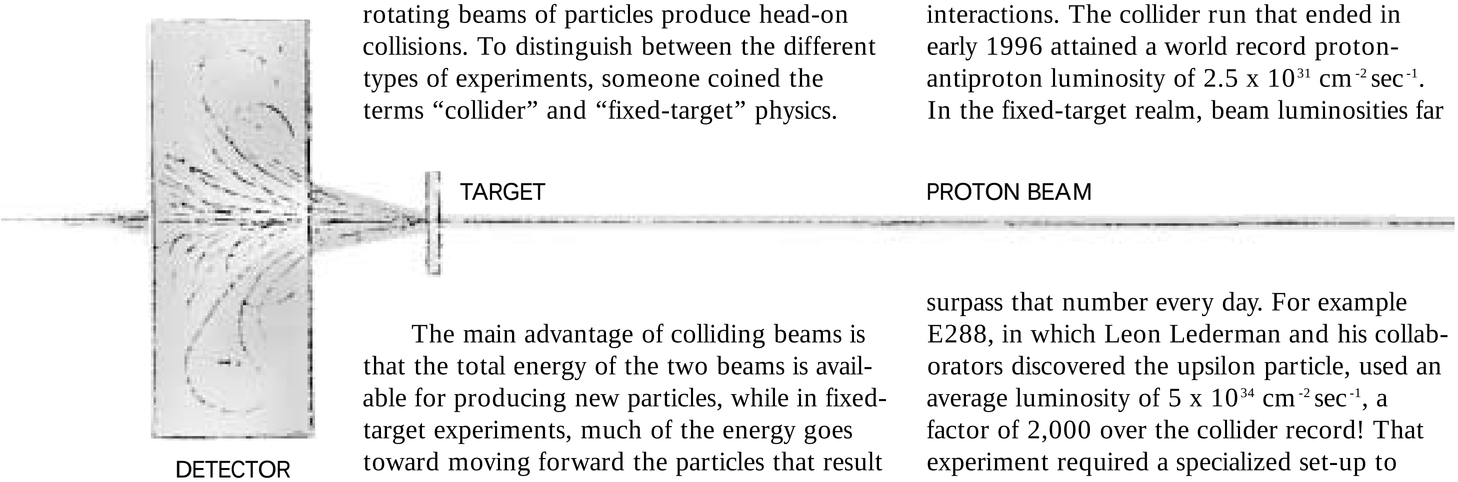
In 1911, New Zealand-born physicist Ernest Rutherford announced that he had used beams of alpha particles (ionized helium atoms) from the decay of radium to discover the atom’s extremely dense core that is its nucleus. Rutherford’s study of particles scattering off a foil target is a prototype of many of today’s “fixed-target” experiments. At Fermilab, fixed-target experiments use high-energy protons from the Tevatron to hit metal targets and create secondary particles or beams at ten experimental halls.

From the late 1930s through the early 1970s, the particle accelerator governed both nuclear and particle physics experiments. Today we would call them fixed-target experiments, in which accelerated particles hit internal or external targets; at the time the experiments were just called “physics.” In the early 1970s a new method of studying fundamental phenomena came into wide use, in which counter-rotating beams of particles produce head-on collisions. To distinguish between the different types of experiments, someone coined the terms “collider” and “fixed-target” physics.



The main advantage of colliding beams is that the total energy of the two beams is available for producing new particles, while in fixed-target experiments, much of the energy goes toward moving forward the particles that result from the impact with the target. Thus, colliding beams represent the high energy frontier—up to 1800 GeV in the last Fermilab collider run. In the current fixed-target run, the energy available for production of particles is considerably less than in the collider, up to a maximum of 39 GeV. Therefore the production of massive particles like the *W* and *Z* bosons and the top quark is possible only with colliders, and even the somewhat lighter bottom quarks are more copious in the colliding beam mode.

Colliding beams are impressive, but we shouldn’t sell fixed-target physics short. In the fixed-target mode, we can use the protons from the accelerator directly, or we can form secondary beams consisting of a combination of other quarks, or leptons, or photons. Like a chemist concentrating and purifying his sample before he begins his measurement, fixed-target experimenters can prepare beams enriched in the specific particles of interest. This allows them to study their interactions or decays relatively cleanly, free from backgrounds of less interesting particles.

Former Director Leon Lederman often spoke proudly of Fermilab’s beams of hot and cold running protons, neutrons, photons, electrons, muons, neutrinos, pions, kaons, and all the stable hyperons, up through the Omega–minus, and, of course, their associated antiparticles. With these beams of quark composites, we can study a number of different quark interactions and decays. Variety is the spice of experimental physics!

Furthermore, fixed-target experiments make use of a higher luminosity, or rate of interactions. The collider run that ended in early 1996 attained a world record proton-antiproton luminosity of 2.5 x 10^{31} cm^{-2} sec^{-1}. In the fixed-target realm, beam luminosities far surpass that number every day. For example E288, in which Leon Lederman and his collaborators discovered the upsilon particle, used an average luminosity of 5 x 10^{34} cm^{-2} sec^{-1}, a factor of 2,000 over the collider record! That experiment required a specialized set-up to make use of such high luminosity, but it yielded a special discovery—the bottom quark.

The point I would like to leave you with is that collider and fixed-target physics approaches are complementary and allow one to study the universe from different viewpoints with different tools. When we require the maximum energy, colliding beams are the only choice. However, in those cases where sheer energy is not the highest consideration, for more controlled environments, for precision experiments, and for searches for and studies of rare phenomena, the fixed-target approach is often better. ■