ELECTRON-PROTON COLLIDING BEAMS

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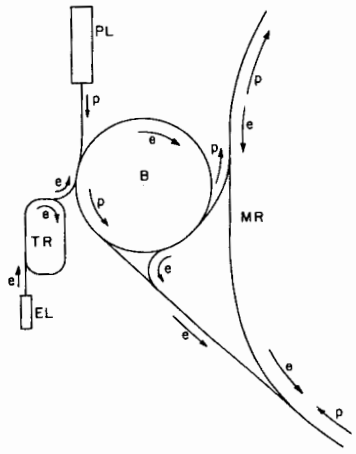
In the past, attention in the colliding-beams field has been focused primarily on proton-proton and proton-antiproton scattering experiments. There are major projects for pp and $\bar{p}p$ with the Energy Doubler. A third kind of colliding-beams experiment is also being considered, with less publicity but with no less attention, by a smaller number of physicists. In this scheme, a 12-GeV electron beam circulating in the Main Ring collides with 1000-GeV protons in the Energy Doubler.

A group of a dozen people have been investigating the feasibility of a scheme that was proposed at the 1977 Aspen Summer Study.[1] The scheme is outlined in the accompanying drawing where the 200-MeV proton Linac, the Booster, the test ring for electron cooling and an arc of the Main Ring are shown. An electron linac of output energy 75 MeV and current 400 mA is also shown attached to the electron-cooling ring. The patterns followed by the two beams are shown by arrows.



Layout of electron injection, acceleration, and stacking.

The protons are injected as usual in the Main Ring, accelerated to 100 GeV, extracted and stacked in the Energy Doubler/Saver in ten pulses for a total current of 1.5 A. These pulses are then accelerated to 1000 GeV, where they coast (bunched) for several hours.

In the meantime, the Main Ring becomes available for the electron beam. Electrons are first injected and accelerated to 750 MeV/c in the Electron Ring, then transferred to the Booster, where they are accelerated to 4 GeV. Finally, they are extracted and injected into the Main Ring. Several pulses are required to fill the Main Ring in boxcar fashion. At the completion of this filling, which takes a time depending on the repetition rate of the Cooling Ring, the electrons are accelerated to 12 GeV and made to collide with the proton beam in one of the six long straight-sections.

When the study group was formed, it was decided to work out the scheme minimizing the hardware modifications or additions needed and to use whatever was available from the development of the other two colliding-beams projects. Thus, for instance, the Cooling Ring is a more than adequate choice for an electron injector to the Booster; its final momentum of 750 MeV/c is a little greater than the Booster injection momentum. In addition, the electrons can be transported to the Main Ring via the channel presently being designed and constructed for reverse injection into the Main Ring. No polarity reversal of the Booster of Main Ring is required. The energy of 12 GeV is determined by the power output of the existing Main Ring rf system. The intensity of 400 mA, equivalent to 5×10^{13} electrons, is the maximum that the present vacuum, magnet, and rf systems can tolerate. All the modifications required are software, except for acquiring a 75-MeV linac, radiation shielding and power supply for the electron cooling ring and a low-beta insertion for the Main Ring. These modifications would probably cost less than the experimental setup itself.

The e-p colliding beams project does not require a major capital investment. Indeed, it can be carried out in the wake of the other two (more expensive) colliding-beams projects. It would require primarily the acquisition of a 75-MeV electron linac.

With these constraints, it is still possible to achieve a luminosity over $10^{31}cm^{-2}s^{-1}$, possibly $10^{32}cm^{-2}s^{-1}$. The main limitation encountered so far is the pressure rise induced by synchrotron radiation. One expects a final pressure of 10^{-7} torr. This sets the beam lifetime of about one hour, not because of the gas scattering or quantum fluctuations, but because of bremsstrahlung.

The present phase of studies will end in March with a summary report. Two more phases are then expected to follow, one to investigate experimentally the combined performances of the Booster and Main Ring at 4 GeV and the other to accelerate electrons and investigate the effects of the synchrotron radiation.

Reference

[1] Colliding Beam Physics at Fermilab, 1977 Summer Study, Vol. II, p. 337.