14. $\bar{p}p$ COLLIDING BEAMS

14.1. Performance

It will be assumed here that the present Main-Ring proton intensity of 2×10^{13} can be debunched at 150 GeV and that about 10% can be recaptured into 21 bunches. The rf details of how this relocation is to be done are discussed in Section 9.6.

In the superconducting ring, a single bunch will cause a $\Delta\nu = 2 \times 10^{-3}$ tune shift per crossing for the antiprotons, within acceptable limits. Collision of a single proton bunch with a single bunch of 6×10^{9} antiprotons will yield a luminosity of 5×10^{28} cm^{-2} s^{-1}.

Development of higher-luminosity schemes will primarily use more antiprotons and more bunches. For modest luminosity schemes in which there is no high-momentum precooler or accumulator ring, it is necessary to accelerate the antiprotons in single bunches from the 200-MeV cooling ring through the Booster and Main Ring. For more than about 10^{10} particles per bunch, serious deterioration of transmission and beam quality occurs in the Booster. The luminosity per bunch is therefore limited to about 10^{29} cm^{-2} s^{-1}. Optimistic estimates of antiproton collection rates would limit the total number to about 3 to 4×10^{10} for a reasonable collection time, so there might be 6 bunches of protons and antiprotons, with a total luminosity of approximately 5×10^{29}, assuming the interaction β could be reduced to about 1.5 m.

Addition of a high-momentum precooling ring or accumulator ring would allow more rapid collection of antiprotons, and also the possibility of rebunching at higher momentum, removing the restriction on single-bunch intensities imposed by the Booster. As an example, if 6×10^{11} antiprotons were collected at 200 MeV in a Booster-length cooling ring, they could be rebunched at 30 MHz, accelerated through the Booster with approximately 10^{10}/bunch, reinjected into the precooler and rebunched with 12 bunches. These bunches would be individually extracted, accelerated to 150 GeV and placed in proper location in the superconducting ring. The luminosity would be in the high 10^{30} range. The bunches in each beam would be separated by about 1 μs, which is adequate for kicker rise and fall times (approx. 0.8 μs) and desirable for experimental instrumentation. About one-fourth of the ring would be left vacant to accommodate the abort system.

At this luminosity, there is on the average almost one interaction per crossing. Higher luminosity schemes must then employ more bunches. This conflicts with single-bunch kicker rise and fall times and it will be necessary to regroup the larger number of bunches into about one-third the circumference of the Main Ring and to transfer all the bunches of protons or antiprotons at a single time. This scheme, although not worked out in detail, is compatible with abort and kicker capabilities.

14.2. Specific needs for Antiproton Collisions

(i) Injection kicker. The schemes described above are within the present abilities of kicker systems. Details are described in Section 10.

(ii) Low-beta section. The correction package for the ring (Section 7) will be influenced by the need to compensate for the low-β section. The tune shift caused by the insertion should be minimal and, as in Case E of Table 2-II, the momentum dispersion should be compensated, so that retuning for low β can be done locally.

(iii) Radio-Frequency systems. These systems are described in Section 9.6. Here we emphasize again that a low-frequency system is needed in the Main Ring. In addition, it may be necessary to employ a high-frequency Landau cavity to maintain the stability of these bunches. In order to reverse-accelerate antiprotons in the Main Ring, the cavities must be rephased at a low power level.

The rf system should be capable of independent acceleration of protons and antiprotons. This can be achieved by proper cavity spacing, as described in Section 9.2. It appears possible to perform the necessary steps with 6 cavities. If high-frequency cavities are necessary for the stability of the proton bunches, then two must be employed in order to cancel out the antiproton acceleration by these cavities.

(iv) Electrostatic Beam Separators. Measurement of collision parameters and luminosity calibration can be achieved by an electrostatic system to separate the beams at the collision point. This is most easily done by placing deflection plates at quadrature points of betatron phase from the intersection point, at, for example, approximately 7 m from the center of adjacent long straight sections. In order to reduce the interaction rate to about 1% of the undeflected rate (for Gaussian profiles), an electric field-length product of approximately 20 MV is required at each quadrature point ($\beta \simeq 68$ m). If a 5-MV/m field can be sustained over the 2-cm aperture, 4 m of electrode is required. In principle systems should exist for separating both the horizontal and vertical directions.

A discussion of antiproton production is given in Reference 1. A discussion of proton-proton collisions is given in Reference 2.

References

[1] F. E. Mills and D. E. Young, A Scenario to Achieve a Luminosity of Approximately 5×10^{29} $cm^{-2}s^{-1}$ for $\bar{p}\,p$ Collisions in the Fermilab Energy Doubler. Fermilab report UPC-73 (unpublished) Nov. 11, 1978.

[2] D. Ayres et al., Kissing Magnet Design for the pp Collider. Fermilab report UPC-76 (unpublished) Nov. 8, 1978, revised Dec. 21, 1978.