ANTIPROTON MOMENTUM COMPACTOR-DEBUNCHER LINAC

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The momentum acceptance of the Fermilab booster for 5.18 GeV$\bar{p}$'s limits the accepted $\bar{p}$ momentum spread to $\delta P/P = 3 \times 10^{-3}$. It is noted here that a larger momentum spread from a $\bar{p}$ production target may be accepted if a short linac section is used to give the $\bar{p}$'s an energy kick following a drift space from their production target, so that their time of arrival at the linac is related to their momentum error.

The scenario would be as follows: first the 80 GeV protons in the MR would be debunched (not necessarily completely) and then rebunched tightly at a high frequency f by a linac section. Then the extracted protons would strike the $\bar{p}$ production target in tight bunches, e.g., spread in time by $\lesssim 0.1\ f^{-1}$. Then a drift space Z would follow (occupied by the $\bar{p}$ beam transfer optics). Finally, a linac section, also at f and phased with the section in the main ring, would transmit the central particles of each spread bunch at 0^o phase angle but would accelerate the late particles and decelerate the early particles in order to leave an ongoing beam debunched in time (over $\lesssim \pi$ radians) but homogenized in momentum. This beam is then inflected into the booster for deceleration and cooling.

The time dispersion of particles starting simultaneously after drifting a distance z meters in terms of their energy difference is given by

$$\delta t = \frac{\beta z}{c} = \frac{\delta\gamma}{\gamma^3}\frac{z}{c}, \qquad (\gamma >> 1),$$

so that

$$\frac{dE}{dt} = \frac{E_o\gamma^2 c}{z}, \quad \left(\frac{\delta\gamma}{\gamma} \cong \frac{dE}{E_o}\right) .$$

This energy spread can be compensated by an energy kick from the linac section where, from the linac rf,

$$\frac{dE}{dt} = 2\pi f E_L,$$

and E_L is the peak energy of the linac.

The momentum spread which can be compressed is just $2E_L$ for a maximum, although the linear portion of dE/dt is ~ 2/3 of that. Combining the two above expressions,

$$2\pi f E_L = \frac{E_o\gamma^2 c}{z},$$

or

$$z = \frac{E_o\gamma^2 c}{2\pi f E_L} .$$

As a numerical example, consider 5.18 GeV $\bar{p}$ ($\gamma = 6.51$) with a 3% momentum spread compressed by a linac section of 1.0 GHz. The linac energy E_L would have to be at least 0.015 x 6 GeV = 90 MeV.

To preserve a greater region of linear dE/dt, E_L = 130 MeV. These values give

$$z = 121 \text{ meters.}$$

The 3% momentum spread will be compressed to a fraction of 3% corresponding to the tightness of the 1 GHz bunching of the protons; if they are bunched to $1/20 \times 10^{-9}$ sec (1.5 cm), the 3% should compress to about 0.2% $\Delta p/p$.

There are some questions. The rf on-time required for the high frequency bunching hardware in the main ring is long, corresponding to a phase oscillation period at that frequency. Of course only one booster batch need be bunched each booster extraction cycle (60 millisec, the rf could be on for 1.5 μsec and off for 19 μsec each revolution). The second, debunching rf, would only need to be on for 2 μsec.

The path length dispersion from the betatron phase space in the $\bar{p}$ beam transport must be small compared to the energy-related dispersion. Hence if the beam crosses the axis at 10 mr, the path length spread of extreme rays is ~ $\frac{2}{3}\frac{\theta^2}{2} \cong 3 \times 10^{-5}$. This corresponds to $\delta E/E_o = 1.26 \times 10^{-3}$.

If the rf systems are reasonable, technically and economically, it seems that a scheme such as this could gain a factor of 10 in $\bar{p}$ flux and require minimal new construction or engineering. In particular, this could obviate the need for a stochastic cooling ring.