# ACCOMMODATING STOCHASTIC COOLING AT FERMILAB

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Considerable interest has been focused on the possibility of using stochastic cooling to augment or replace electron cooling in an ultimate $\bar{p}$ source at Fermilab. Unfortunately, there is a mismatch between the "natural" $\bar{p}$ production cycle time and the cooling (or precooling) time using stochastic cooling. We calculate here the extent of the mismatch and suggest a possible way of resolving it.

The $\bar{p}$ production cycle using electron cooling proceeds as follows:

1. Fill the Main Ring with $N_p \geq 2 \times 10^{13}$ protons, and accelerate to 80 GeV ($t_p \sim 1.6$ sec);

2. Extract a Booster-length bunch of protons and target to make $\bar{p}$'s;

3. Decelerate $\bar{p}$'s in the Booster and transfer to the cooling ring;

4. Cool $\bar{p}$'s and accumulate ($t_c$).

Steps 2, 3, and 4 are repeated 13 times until all protons have been targeted. The average $\bar{p}$ accumulation rate is $R_{\bar{p}} = N_p\, \eta/T$, where $\eta = N_{\bar{p}}/N_p$ is the $\bar{p}$ yield and $T \simeq 13\, t_c + t_p$ is the production cycle time. For electron cooling, we expect to achieve $t_c \sim 50$ msec, $T \sim 3$ sec, and $\eta \sim 2 \times 10^{-7}$. This corresponds to a $\bar{p}$ collection rate $R_{\bar{p}} = 1.3 \times 10^6$/sec.

Stochastic cooling is characterized by larger phase space acceptance but longer cooling time than electron cooling. CERN expects to achieve $t_c \sim 2$ sec (stochastic momentum cooling), $T \sim 2.5$ sec, $N_p \sim 10^{13}$, $\eta \sim 2.5 \times 10^{-6}$, corresponding to a collection rate $R_{\bar{p}} = 1.0 \times 10^7$/sec.

To realize stochastic $\bar{p}$ cooling and accumulation at Fermilab, one could use a production cycle similar to the one for electron cooling:

1. Fill the Main Ring with $N_p \geq 2 \times 10^{13}$ protons, and accelerate to 80 GeV ($t_p \sim 1.6$ sec);

2. Extract a Booster-length bunch of protons and target to make $\bar{p}$'s;

3. Stochastically cool the $\bar{p}$'s and accumulate successive production cycles until all $N_p$ protons have been targeted.

Long-term accumulation could be accomplished in the stochastic cooling ring itself (the CERN scheme) or by decelerating the stochastically cooled $\bar{p}$'s from each production cycle to 200 MeV and accumulating them in a separate electron cooling ring.

We can now compare the $\bar{p}$ yield using stochastic cooling to that using electron cooling. The cycle time is much longer with stochastic cooling:

$$T = 13\, t_c + t_p \sim 28 \text{ sec!}$$

The $\bar{p}$ yield for the same phase-space acceptance at Fermilab would be greater by a factor of 4 than that of the CERN design due to the higher energy of the targeted protons: $\eta \sim 10^{-5}$. This yield is 50 times greater than that using electron cooling. The collection rate would be $R_{\bar{p}} = 7.0 \times 10^6$/sec. Most of the increased $\bar{p}$ yield is used simply to compensate for the ($\times 10$) longer production cycle time, yielding only modest ($\times 5$) improvement in $\bar{p}$ collection rate.

This mismatch could be largely overcome by using the Energy Doubler/Saver ring to momentum-stack protons at 80 GeV prior to extraction and targetry. Assuming a 10-turn stack, we obtain $N_p \simeq 2 \times 10^{14}$;

$$T = 13\, t_c + 10\, t_p \sim 46; \quad R_{\bar{p}} = 4.3 \times 10^7/\text{sec}.$$

In effect the use of momentum stacking makes the $\bar{p}$ production time (~2 sec/stack for 10 stacks) match the cooling time (2 sec per bunch for 13 bunches), as was the case for electron cooling. This in turn allows efficient use of the increased phase space acceptance.

A crucial requirement for this scheme is clearly a 10-turn stacking capability in the Energy Doubler. Also, the $\bar{p}$ production target must survive the impact of $\sim 10^{13}$ 80-GeV protons.