Fermilab

Preventing onset of beam instabilities in the e-cooled pbars in the Recycler

C. M. Bhat
Accelerator Division, Fermilab,
P.O. Box 500, Batavia, IL 60510

Version-2 (Sept. 20, 2005)
Version-2a (April. 10,2006)

Abstract:
This note presents a method to prevent onset of beam instabilities in the e-cooled beam in the Recycler via a controlled way of pbar beam smearing.

Issue:
Recently, controlling the pbar instability in the ultra cooled core of the beam in the Recycler has become a serious problem. This has lead to undesirable beam-life time as well as occasional beam losses. It is important to eliminate the instability. In order to control the beam instability set of transverse dampers have been installed in the Recycler. A combination of the technique proposed below and the use of the transverse dampers should mitigate the problem of beam instability in the Recycler.

Present Status:
At the moment, we have stochastic cooling as well as the electron cooling at the Recycler. Stochastic cooling rate is inversely proportional to the number of pbars and becomes slow as the intensity of pbar increases. The current system in the Recycler is found to be more effective if the Schottky rms width (σ) is about 4 MeV. Therefore during cooling we continuously adjust the barrier bucket width to keep the σ close to an optimum value. Well optimized electron cooling, on the other hand, cools the core very rapidly and cools slowly the rest of the distribution. A typical Schottky data for the pbar beam of about 65E10, cooled with stochastic cooling (Fig.1a) and, stochastic + e-cool (Fig.1b) are shown below. The beam distributions are quite different for these two cases. Note that the vertical scale on the longitudinal Schottky data shown on the left side in each of the figures is in dB (log) scale. In the case shown here, the e-cool has increased the “core peak particle density” by about a factor of three as compared with that obtained with stochastic cooling alone. Instability is observed in the cooled beam. The general perception is that the ultra-cooled pbars in the core are susceptible to instability once the 6-dimentional particle density is greater than certain limit.

Proposal:
I propose to smear the particles in the core obtained by e-cool in a controlled way such that the core peak particle density in 6-d phase space will be quite below the instability limit while the overall longitudinal and transverse emittances are still the same as that obtained from the e-cool.

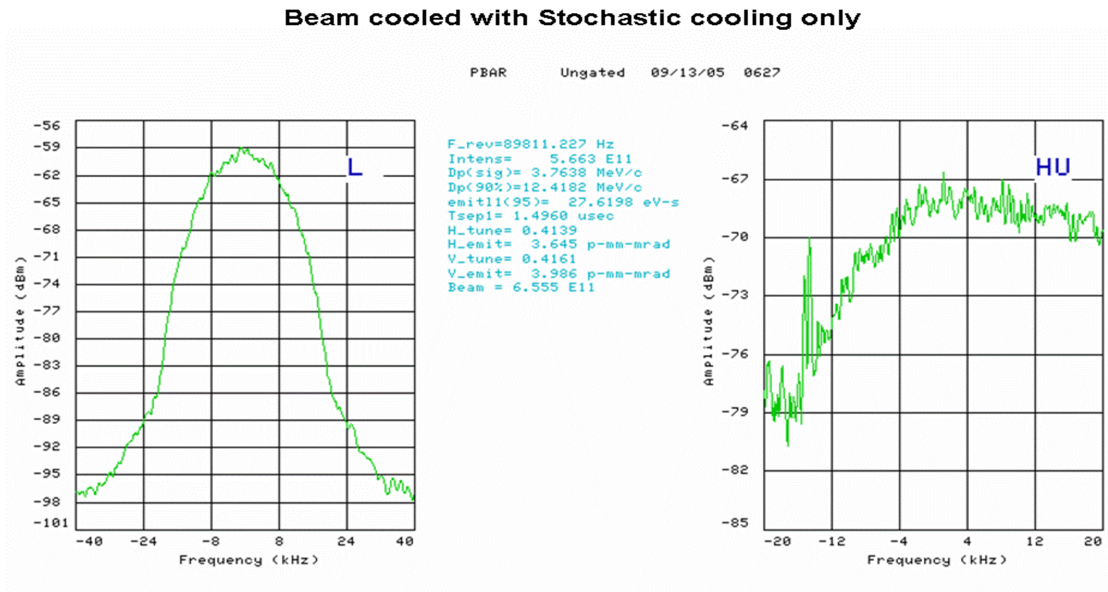

Fig.1a: Schottky data for pbar beam cooled with mainly stochastic cooling technique in the RR. The Schottky spectrum on the right side is the horizontal upper band.

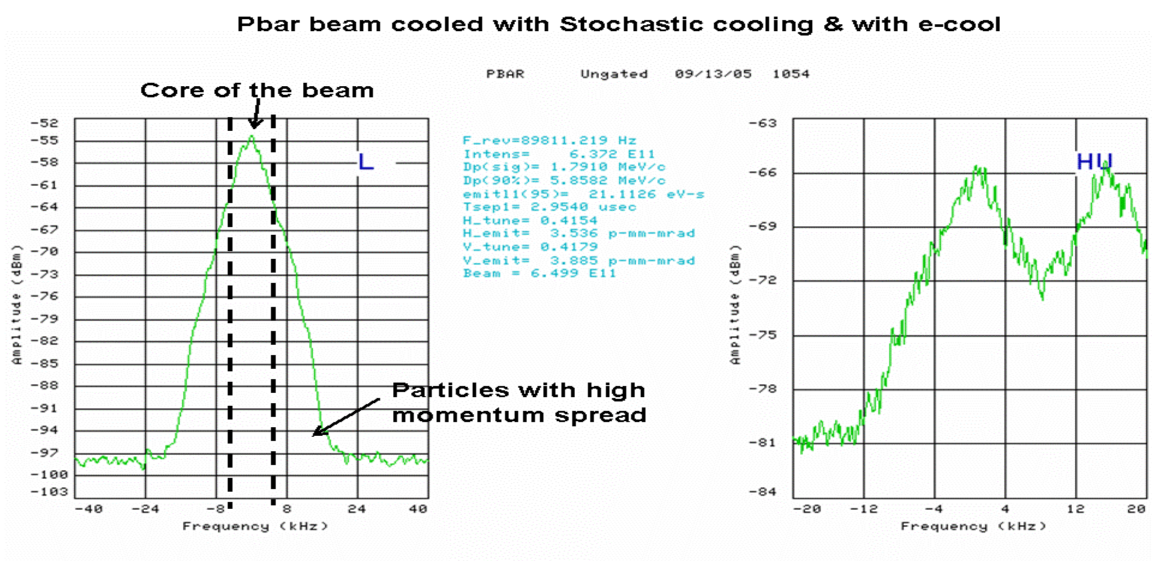

Fig 1b: Schottky data for pbar beam cooled with both stochastic cooling and e-cool techniques in the RR.

Presently, the RR stochastic cooling system used as noise source (D.R. Broemmelsiek private communications) is used for heating the pbar, whenever needed, especially during dedicated beam studies. However, smearing the particles in the core without affecting the rest of the beam distribution is difficult by this technique. We need a method to heat and smear the beam particles in the core and get quite uniform distribution only for the core region in ($\Delta E, \Delta\theta$) phase space. This may be achieved by use of a relatively fast moving anti-barrier bucket as shown schematically in Fig 2b.

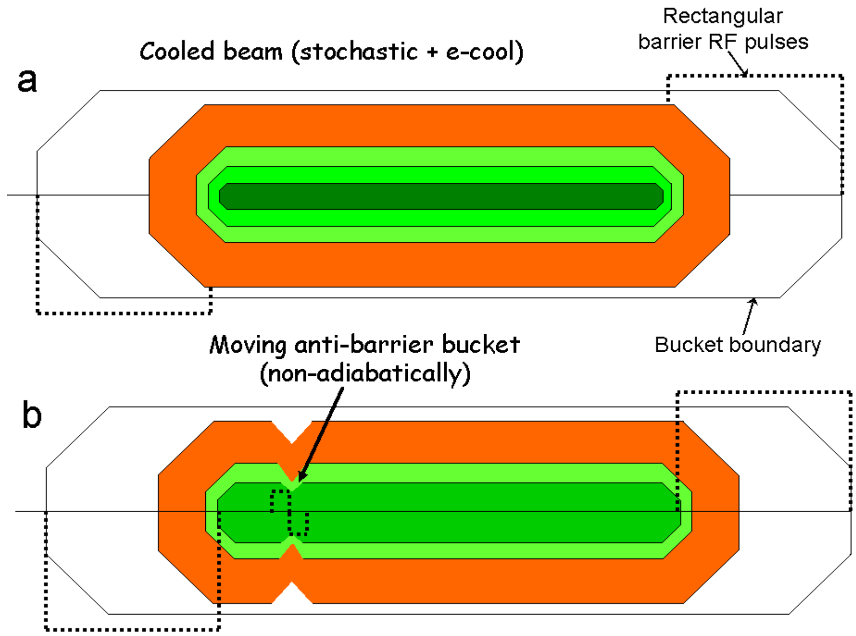

Fig. 2a: Schematic of phase space distribution of beam particles a) after stochastic and e-cool b) after introducing an anti-bucket to heat the core. The core heating is accomplished by moving non-adiabatically between the two big barriers.

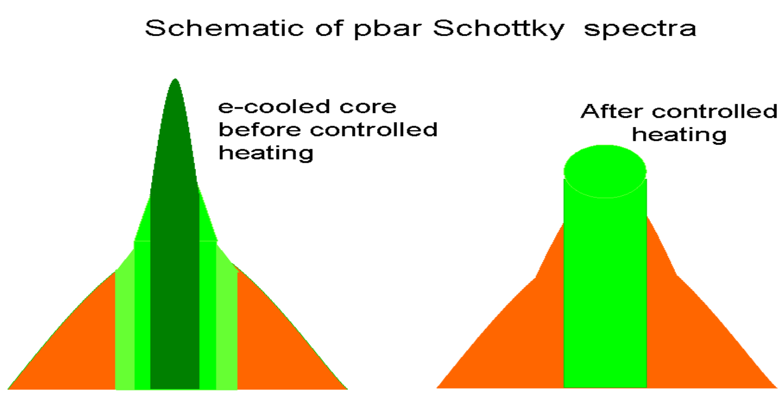

Fig. 2b: Schematic of the Schottky spectrum for e-cooled beam and after controlled heating with an anti-bucket.

It is interesting to note that for the beam distribution in a barrier bucket shown above there will be a range of synchrotron oscillation frequency. The frequency will be zero for synchronous particles and maximum for the particles in the boundary. As a result of this phenomenon, the rate of displacement of the core smearing bucket can be chosen so that for the particles in the boundary the process of smearing is adiabatic while for core particles the process is non-adiabatic. As a result of this one can keep the over all emittance the same.

For the data shown in Fig. 1b, the high density pbar beam resulted from the e-cool has a width of about ±2.4 MeV. To smear the core beam particle distribution to somewhat rectangular distribution one might use a heating barrier of about ±1 MeV (which can be generated by barrier pulses of width = 340 nsec and pulse height = 20 V). Move the anti-bucket at a “medium speed (~200 nsec/sec). These have to be optimized by beam measurements.

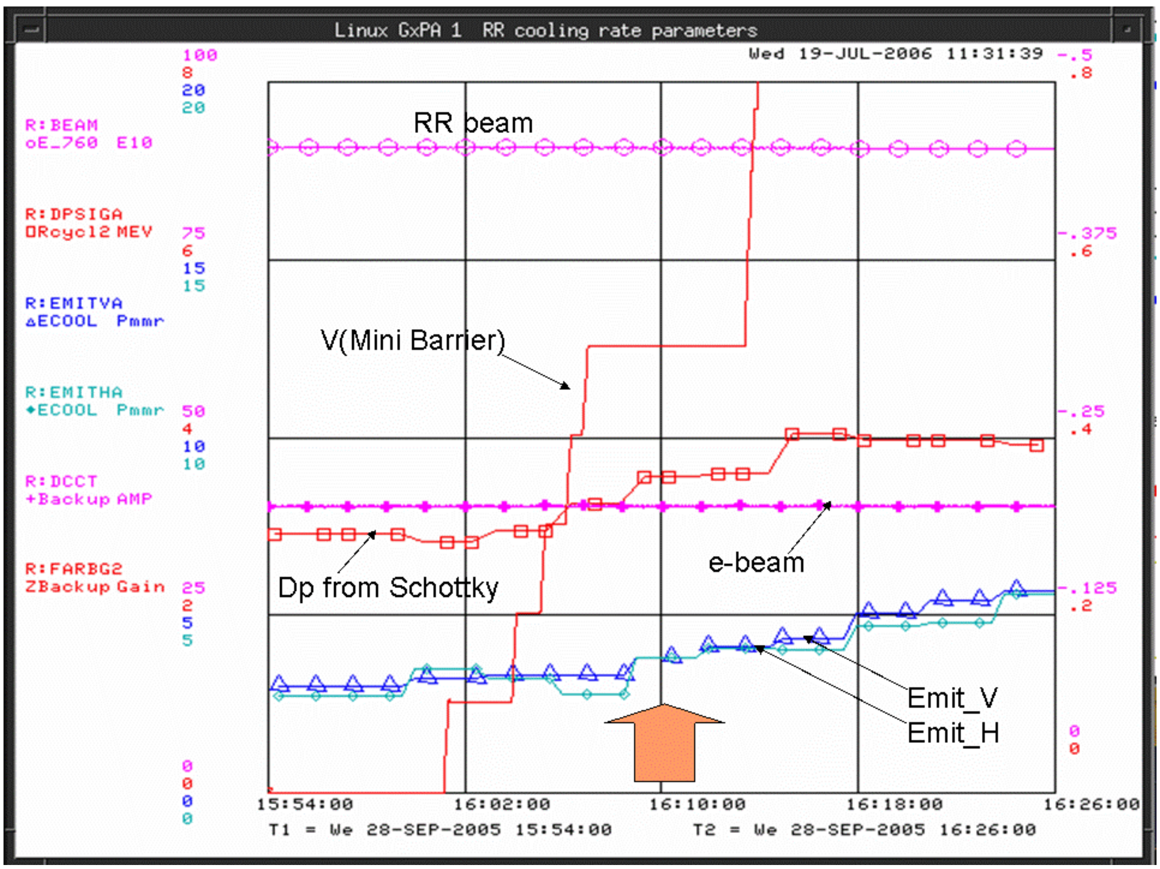

Fig. 3: Beam intensity (R:BEAM xE10pbar), measured one sigma from the longitudinal Schottky spectrum (R:DPSIGA in MeV/c, normalized horizontal emittance (R:EMITHA in π-mm-mr), normalized vertical emittance (R:EMITVA π-mm-mr), e-beam intensity (R:DCCT xE10 electrons) and pulse height of the mini-barrier bucket (R:FARBG2 in units of 2000V). The emittance growth started showing up at about the time indicated by a thick arrow.

The technique proposed for smearing the distribution using the barrier bucket is new; where as, the principle of controlling the beam instability growth by smearing in the phase space is quite well known (J. Marriner private communications, October 2005). This method of beam smearing in 6D space needs further investigation from the point of view of Landau damping in both longitudinal as well as transverse phase space..

Experimental Evidence:

During longitudinal momentum mining the beam distribution in 6-dimensions is disturbed though all the rf manipulation are carried out in longitudinal phase space. Recently, additional attention is given to understand the nature of this emittance growth and cure it which is important for Tevatron shots. One of the solutions to this problem was changing the operating tunes from 0.414/0.418 (H/V) to 0.451/0.468 (H/V).

In view of these observations a dedicated study is conducted in the Recycler to understand the above phenomenon of emittance growth with about 90E10 pbar cooled using stochastic cooling and e-cool with transverse tunes of 0.414/0.418 (H/V). The beam was captured in 2.8μs wide barrier bucket. The initial emittances after cooling were about 34 eVs, $e\_H \approx 4$ pi-mm-mr, $e\_V \approx 4$ pi-mm-mr and measured rms energy spread from the Schottky data was about 2.9 MeV/c. Subsequently, a set of four mini-barrier buckets of 700 ns each were developed and the gain is increased in steps slowly as shown in by R:FARBG2 in Fig. 3. An emittance growth in transverse plane started showing up at about 600V as shown in figure 3. The longitudinal Schottky data showed slow increase in R:DPSIGA representing likely core smearing. We need further data with a special emphasis given on the change in energy spread for the high momentum particles.

The above experiment essentially illustrates the feasibility of the technique proposed. An experiment need to be conducted in future to demonstrate its merit.

I would like to thank John Marriner for some useful discussions