

Controlled Emittance Blow Up in the Tevatron *

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Abstract

We have designed and commissioned a system which blows up the transverse emittance of the anti-proton beam without affecting the proton beam. It consists of a bandwidth limited noise source centered around the betatron tune, a power amplifier and a directional stripline kicker. The amount of blow up is controlled by the amount of energy delivered to the anti-protons betatron bands.

INTRODUCTION

At around October 2007, the transverse emittance of the anti-protons injected into the Tevatron was reduced horizontally by $\sim 30\%$ and vertically by $\sim 50\%$ due to improved electron cooling of the anti-protons in the Recycler. See Figure 1. As was expected, the initial luminosity of the Tevatron was proportionately increased. However, the performance of the Tevatron should not be measured by the initial luminosity alone because there are other important measures which gauge performance. For example, beam loss and luminosity lifetime became worse because of the smaller emittance of the anti-protons. These problems arise from the beam-beam effect of asymmetrically sized beams when brought into collision [1]. At present, the protons have a transverse emittance which is a factor of 2 larger than the anti-protons. And when the proton and anti-proton beams go into collision, the beam-beam tune shift causes large proton losses. There are two places during this process where the two beams go into collision:

- When the lattice transitions from injection to collision. The protons and anti-protons collide head on momentarily during this transition which causes proton losses.
- When the protons and the anti-protons are brought into collision for HEP (high energy physics). For the same reason discussed above, this also results in high losses at the experiments as well as poor luminosity lifetime.

It has been observed empirically that if the anti-proton emittance is increased by $\sim 1\pi$ mm-mrad from 7.5π mm-mrad, the beam-beam tune shift is sufficiently reduced that losses during the lattice transition and at HEP

is no longer a problem. This effect is dramatically illustrated by just 0.5π difference in emittance between two stores 6834 and 6825 shown in Figure 2. Despite the larger proton intensity (and near equal anti-proton intensity), the proton loss through this transition is smaller by 0.25%.

One possible solution is to increase the anti-proton emittance before the lattice transition. One way to do this is with a kicker which has the following characteristics:

- The kicker must only kick the anti-protons and not the protons.
- The emittance of the anti-protons must grow by π mm-mrad in 1 to 2 minutes because the lifetime of the protons is not optimal at flattop before the injection to collision transition.

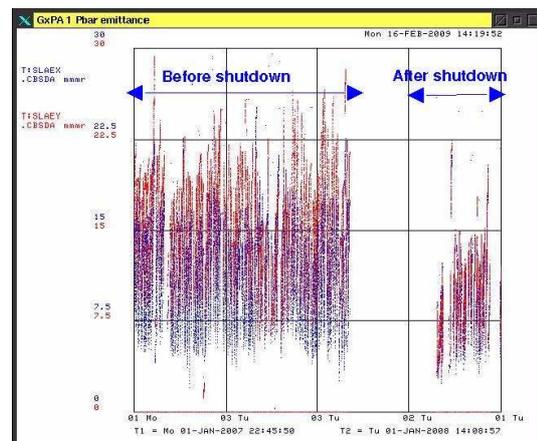


Figure 1: The average anti-proton emittance measured by the sync light monitor at collisions are shown here (T:SLAEX and T:SLAEY are the horizontal and vertical anti-proton emittances respectively). It is apparent that the anti-proton emittances are reduced after the 2007 fall shutdown. Note: the x -axis spans 1 year.

SETUP

The block diagram of the system (known affectionately as the PBJ) which is used to blow up the anti-proton emittance is shown in Figure 3. White noise is bandpass filtered so that it is limited to 0.55 to 0.6 in tune units. The Tevatron betatron tune excursion from ramp to collision lies between these two values. The noise is upconverted to the Tevatron RF frequency of 53 MHz and amplified by 50 to 67 dB before it is sent to 1 m long stripline kickers. The power in

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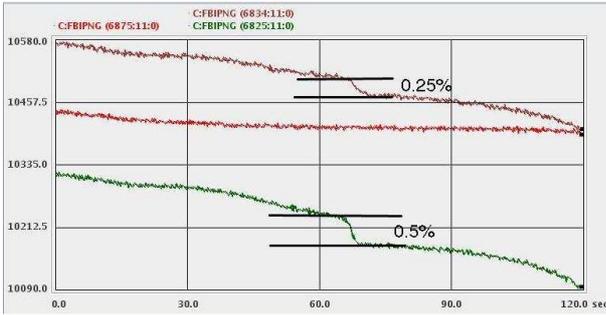


Figure 2: Store 6834 has a smaller loss during the transition from injection to collision helix compared to store 6825. The difference comes chiefly from the anti-protons which are larger by 0.5π mm-mrad. For store 6875, the number of anti-protons at collisions is $2\times$ smaller than stores 6825 and 6834, there is no loss through this transition. This clearly demonstrates that the source of the loss is from the beam-beam effect.

this band that is sent to the beam has been measured to be about 100 W. The advantage of stripline kickers is that the kicks are directional and will only affect the anti-protons and not the protons. At present, the PBJ is run open loop and the active time of the PBJ has been set to 75 s. In the future, when the IPM (ion profile monitor) system is fully commissioned, the PBJ will be run closed-loop with the IPM giving real-time emittance values to the PBJ system.

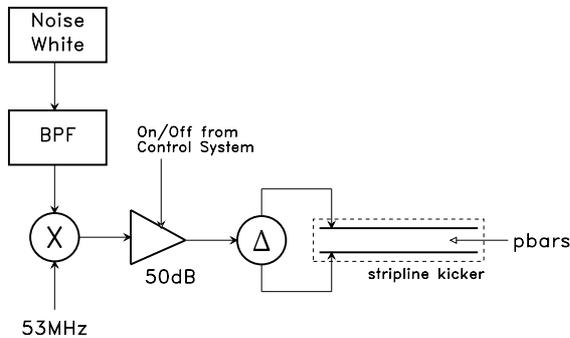


Figure 3: The PBJ kicks the anti-protons vertically. Both horizontal and vertical anti-proton emittances increase because of coupling although the beam is kicked vertically only.

RESULTS

It is expected that the emittance growth from the PBJ is linear and proportional to the spectral power density of the noise [2]. From Figure 4, it can be seen that the anti-proton emittance increases linearly when the PBJ is turned on. In fact, the growth rate has been found to be 2.6 mm-mrad/min.

As a check, Figure 5 shows that only the anti-proton emittances are affected by the PBJ.

Therefore, the PBJ as constructed satisfies the requirements that

- it only affects the anti-protons and not the protons.
- the growth rate is greater than $\sim 1\pi$ mm-mrad/min.

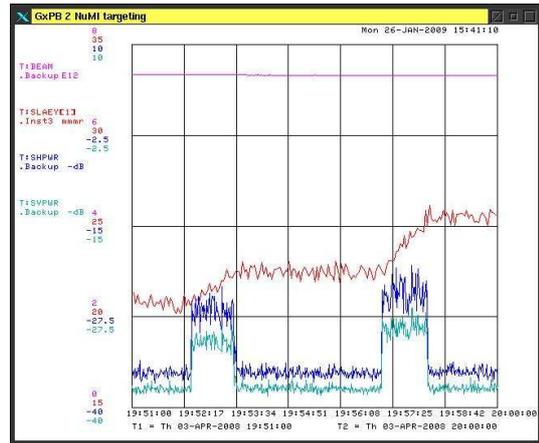


Figure 4: The transverse emittance of the anti-protons are blown up. T:SLAEY is the anti-proton vertical emittance. When the PBJ is turned on, the Schottky power (T:SHPWR and T:SVPWR) increases and the emittance increases. And when the PBJ is turned off the emittance remains constant.

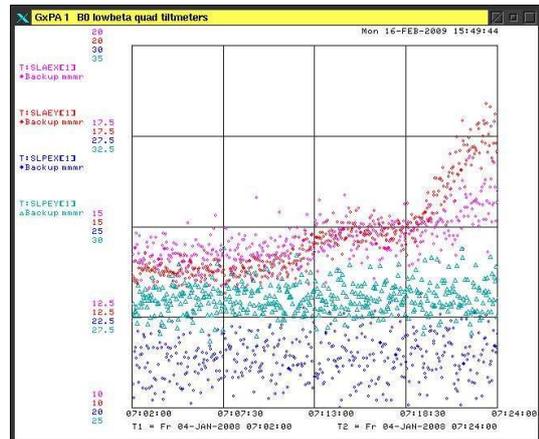


Figure 5: The horizontal and vertical transverse emittances of the protons (T:SLPEX and T:SLPEY respectively) are unaffected by the PBJ while the anti-proton emittances (T:SLAEX and T:SLAEY) are increased. Although the PBJ kicks the anti-protons vertically, there is horizontal emittance growth because of coupling.

CONCLUSION

The PBJ has been operational since the beginning of 2008 and it has become an important part of HEP opera-

tions. However there are at least two improvements that can be made. The first, is that the PBJ is run open loop and so, if for some reason the anti-proton emittance is larger than usual, the PBJ is still employed. This shortcoming can be fixed when the IPM becomes operational because it is able to measure the anti-proton emittance in real time and so allow the PBJ to stop when the desired emittance is achieved. The second is that the PBJ blows up all the anti-protons equally. This is not desirable because the anti-proton injection process causes certain bunches to have a larger emittance than others. The improvement is to have a gating system so that only the small emittance bunches are selectively blown up. Again, this improvement hinges on the success of the IPM being able to measure individual anti-proton emittances in real time.

REFERENCES

- [1] A. Valishev, "Recent Tevatron Operational Experience", this conference.
- [2] J. Steimel & C.Y. Tan, "The Effect of Noise on Transverse Emittance Growth in the Tevatron", Particle Accelerator Conference 2001, p. 1874-1876.