

Experience with the New Reverse Injection Scheme in the Tevatron

S.SARITEPE*, G.GODERRE, G.ANNALA, B.HANNA, A.BRAUN

Fermilab†, P.O. Box 500, Batavia, IL 60510

Introduction

In the new injection scenario the antiproton beam is injected onto a helical Tevatron orbit to avoid the detrimental effects of the beam-beam interaction at 150 GeV. The new scenario required changes in the tuning procedures. Antiprotons are too precious to be used for tuning, therefore the antiproton injection line has to be tuned with protons by reverse injecting them from the Tevatron into the Main Ring.

Previously, the reverse injection was performed in one supercycle. One batch of uncoalesced bunches was injected into the Tevatron and ejected after 40 seconds. The orbit closure was performed in the Main Ring. In the new scheme the lambertson magnets have to be moved, separator polarities have to be switched, activities that cannot be completed in one supercycle. Therefore, the reverse injection sequence was changed. This involved the redefinition of TVBS (Tevatron Beam Synchronized Clock) event \$D8 as MRBS (Main Ring Beam Synchronized Clock) \$D8 [1] thus making it possible to inject 6 proton batches (or coalesced bunches) and eject them one at a time on command, performing orbit closure each time in the Main Ring.

Reverse (Antiproton) Injection Line

The details of the reverse injection line can be found in reference [2]. Here we present the injection line sketch and the circuit diagram showing the reverse injection shunt (Fig.(1) and Fig.(2)).

Tuning Procedure

There are basically four modes of tuning for the reverse injection.

* current address: SSCL, MS 1040, 2550 Beckleymeade Ave. Dallas, TX 75237

† Operated by the Universities Research Association, Inc., under contract with the U.S. Department of Energy.

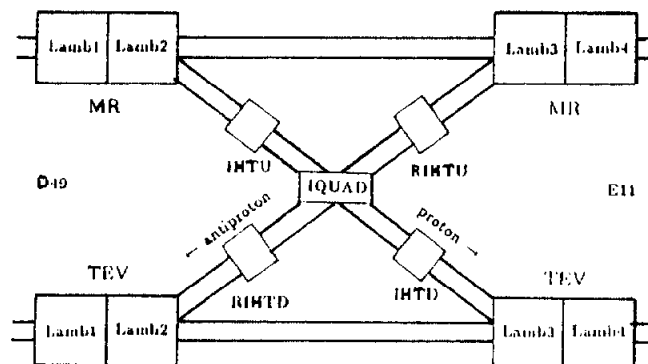


Figure 1: Proton and Antiproton injection lines.

- (1) Routine tuning, i.e. orbit closure before each shot
- (2) Adjustments after orbit smoothing
- (3) Adjustments after helix amplitude changes
- (4) Reverse Injection checkout. This is done during startup after long shutdowns

Routine Tuning:

In the new reverse injection scheme, 6 proton bunches are injected onto the injection orbit. Proton lambertsons are moved out, the injection bump at E0 is removed, the separator polarities are switched, then finally the separators are powered. The resultant orbit is the same one that the antiproton beam would be launched onto. Ejecting proton bunches from this orbit is equivalent to injecting antiprotons onto the same orbit.

Adjustments after orbit smoothing:

If the position and angle differences resulting from orbit smoothing are small, a simple orbit closure would be sufficient. If the orbit differences around E0 (injection location) are substantial then one has to adjust the reverse injection time bump. In principle a reverse injection time bump in the vertical plane is not needed. One may have to create one if it helps the kicker or the shunt. The goal in this tuning is to find the compromise between the kicker strength,

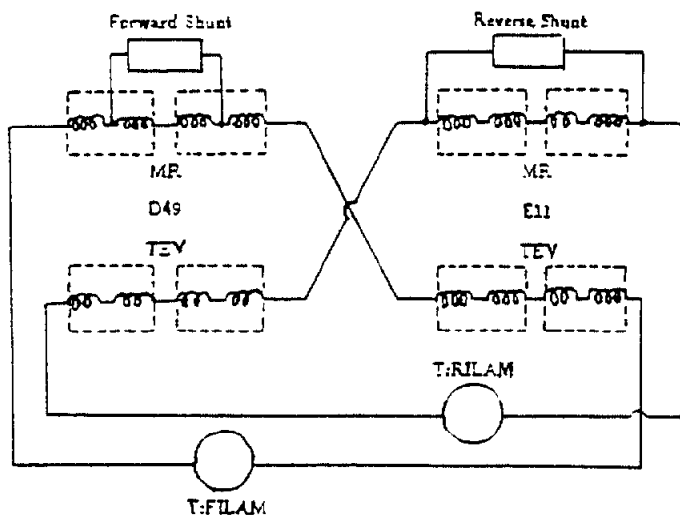


Figure 2: Circuit diagram showing the shunt connections. This diagram was drawn from tunnel observations by J. Annala. If the forward shunt and the reverse shunt both remove, for instance, 5 Amps from the circuit, the angle adjustment provided by the reverse shunt will be twice as big as that provided by the forward shunt.

shunt current and the losses.

Adjustments after helix amplitude changes:

Helix amplitude is subject to change during the collider run. Again a simple orbit closure will be sufficient in most cases. If the change in the helix amplitude is big then one must perform orbit closure in small steps. As the helix amplitude is changed in steps orbit closure is performed each time. Once the final closure values are obtained they must be entered in the Sequencer file #13.

Reverse Injection checkout:

A complete checkout of the reverse injection may be necessary after long shutdowns. The details are explained in ref [3]

Orbits

It is paramount to have hardcopies of the Tevatron and Main Ring orbits for the reverse injection. One needs the closed orbit and the last turn orbit in the Tevatron and the closed orbit and the first turn orbit in the Main Ring. Some of the orbits are shown in ref [3].

January 1992 studies

During the January 1992 studies, the reverse injection time bump had to be recreated since we did not know the best last turn Tevatron orbit that would allow a loss-free ejection. The closed orbit positions and angles had to changed also.

After the January studies, during the shutdown the D49 Tevatron lambertsons were raised by 8 mm. The closed orbit and the time bump changed during collider commissioning. Since the closed orbits and the time bump may change again in the future, the orbits shown in ref [3] should be taken as hints for future adjustments.

Problems during January 1992 studies

In the beginning there were hardware problems. One should be vigilant about the T:QUAD reversing switch since it may get stuck in the reverse polarity and do not switch back to the forward polarity. Another problem area was the D48 kicker. We discovered that the D48 kicker was shorted. Diagnosis and replacement of this magnet cost us 5 shifts.

We learned to be careful about the "prepare for beam" and other timers in the Main Ring BPM system. For instance, the Main Ring BPM readings for the S20 cycles were being overwritten by the S29 cycles in the absence of proper precautions. In the current setup "prepare for beam" in the Main Ring is taken care of by the Sequencer.

The new closed orbit positions at D49 and E11 made it necessary to change the horizontal time bump angle between D49 and E11. The initial solution was to have 21 mm at D49 and 6 mm at E11 when the time bump was playing. This worked fine, however, when the proton helix was opened, beam was scraping on something that looked like the backend of the field-free region of the D49 lambertsons. It may have been the flange instead of the backend. Nevertheless, the time-bump at D49 was reduced to 11 mm, the "stored beam" position for the lambertsons was changed from -930 mils to -600 mils. This solved the horizontal aperture problem.

There was a vertical aperture problem at D49 as well. We could not open the proton helix to 100%. We lowered the closed orbit position by 3 mm, we wanted to lower it

further by 8 mm. but the shunt was running at 0 Amps so we could not do it. This limited the helix amplitude at 150 GeV to 60% of the design value. At 900 GeV the helix could be opened to 100% percent since the helix amplitude shrinks with energy.

Conclusion

A record of the previous injection (ejection) orbits is the most important information during commissioning. The next piece of important information is the kicker traces. The correct waveforms must be archived and compared to the observed waveforms. Here we show the correct kicker waveforms for the kickers involved in the reverse injection (Fig.(3) and Fig.(4)). Any deviation from the waveforms shown in these figures indicate kicker hardware problems.

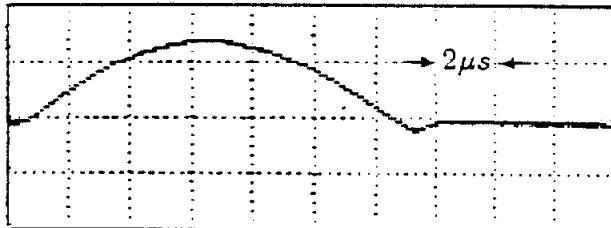


Figure 3: Waveform for the Main Ring E17 Kicker. This kicker places the reverse injected (ejected) Tevatron beam onto the Main Ring orbit.

The kicker timing issues are also crucial during commissioning. The reverse injection timing for the Tevatron are discussed in detail in reference [4].

Acknowledgements

Authors thank the Fermilab Accelerator Division, Operations Group for their invaluable help during the studies.

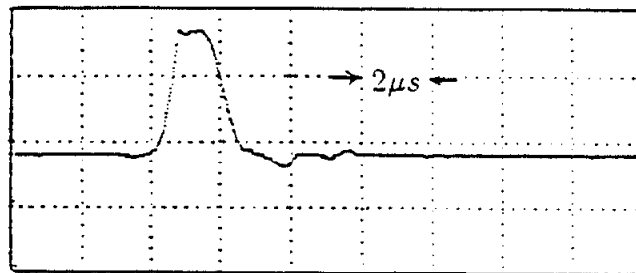


Figure 4: Waveform for the Tevatron D48 Kicker. This kicker ejects the proton beam from Tevatron during reverse injection.

References

- [1] R.J.Ducar, "Why TVBS SD8 Became MRBS SD8", Unpublished Note (July 1991).
- [2] S.Saritepe and G.Annala; "Beam Transfer at E0: An Overview", FERMILAB-TM-1790 (1992).
- [3] S.Saritepe and G.Annala; "Tevatron Reverse Injection", FERMILAB-TM-1791 (1992).
- [4] S.Saritepe and G.Annala; "Tevatron Injection Timing", FERMILAB-TM-1792 (1992).