Fermilab Main Injector Beam Position Monitor Upgrade

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Introduction

A project to upgrade the readout electronics of the Fermilab Main Injector (MI) Beam Position Monitors (BPMs) was begun in 2005. This project, part of improvements to the entire Fermilab accelerator complex meant to provide increased luminosity and reliability for the Run 2 collider physics program, is being performed by a team from the Accelerator and Computing Divisions at Fermilab. The design uses many of the technologies and techniques used to upgrade the BPM electronics in the Fermilab Recycler Ring, the Fermilab Tevatron1, and some of the transfer lines.

Operational Requirements

The Fermilab Main Inject (MI) is designed to accelerate either protons or antiprotons with an injection energy as low as 8.9 GeV and an extraction energy as high as 150 GeV. At any time, however, only one of the two beam species may be present. The time structure of the beam may be one of the following:

- **53 MHz Protons.** From 1 bunch up to a full batch of 84 bunches in successive 53 MHz buckets (19 ns apart). Up to 6 batches, each one of 84 bunches, can be loaded in the MI.
- **53 MHz Anti-protons.** Four consecutive groups of antiprotons, spaced by 396 ns, of typically 5 (up to 9) 53 MHz bunches, are present in MI.
- **2.5 MHz - Protons or anti-protons**. Four 2.5 MHz bunches in successive 2.5 MHz RF buckets (396 ns spacing).

MI BPM Read-Out Electronics Hardware

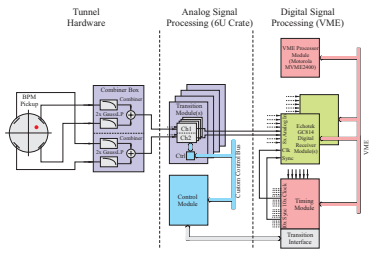
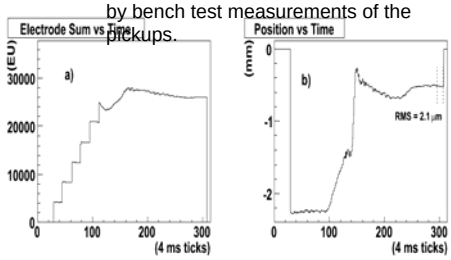


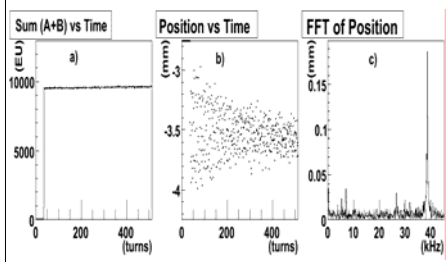
Figure 1

Figure 1 gives an overview of the hardware components of the upgraded Main Injector BPM system. The figure shows 2 signal channels which produce one position channel. With the exception of 7 so-called *Extra Wide Aperture* BPM pickups, all 201 stripline BPM pickups and their tunnel cabling remains unchanged3. Upgraded components are the *Combiner Boxes*, located in the accelerator tunnel and all read-out electronics hardware, concentrated in 7 locations around the ring. The analog electronics – several 8-channel so-called *Transition Modules* and a *Controller Module* - are located in a 6U high crate frame, supplied by an external, linear power supply. A core component of the BPM system is the commercial *Echotek GC814* digital signal receiver (DSR). Several 8-channel DSR modules, together with a processor module (*Motorola MVME5500*) and an in-house developed *Timing & Fan-out Generator (TFG)* are arranged in a VME crate. All the cabling within a rack and between crates is completely renewed.

Performance

Approximately two weeks before the spring 2006 Fermilab accelerator shutdown a pre-production system was installed to read out 11 BPMs. The results presented in this section were obtained using this pre-production system. Fig. 3 illustrates the narrow band capability for an MI cycle in which six batches are injected from the Booster, accelerated to 120 GeV, moved onto the extraction orbit and delivered to the neutrino production target for the NuMI beamline. The six injections occur at intervals of 1/15 second and the beam is extracted in a single turn. In the following the symbols A and B denote the voltages reported by the Echotek for the two BPM channels. Part a) of Fig. 3 shows the electrode sum, A+B, as a function of time. For constant machine energy and bunch structure the electrode sum is proportional to the beam intensity and the six injections can be seen. The modulation in A+B after the sixth injection is due to changes in the bunch length as the beam energy is increased. Part b) of Fig. 3. shows the measured position for this same dataset; the position is given by a polynomial in (A-B)/(A+B), with coefficients determined by bench test measurements of the pickups.





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