BEAM PROFILE DETECTORS AT THE NEW FERMILAB INJECTOR AND ASSOCIATED BEAMLINES

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Abstract

During the commissioning of the Main Injector some of the detectors used to optimize the tune of the proton beam were: Flying Wires, Ionization Profile Monitors, and Multiwires.

1 INTRODUCTION

An 8 GeV proton beam is extracted from the Booster and channeled toward the Main Injector (MI) via the MI-8 beamline. From the MI the proton beam can be injected into the Tevatron (TeV) ring for collider and/or fixed target operation via P1 beamline or, to the Antiproton Source, via P1 and P2 beamlines.

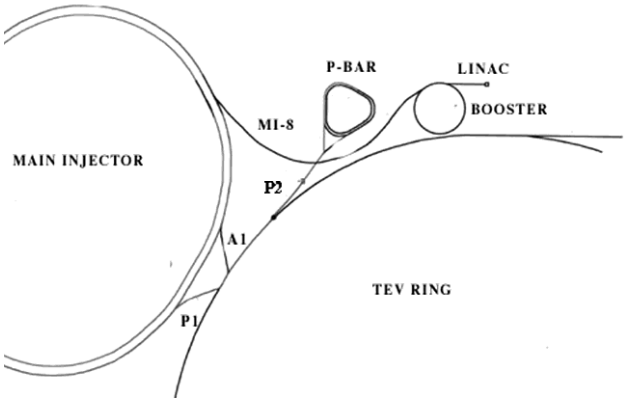

Figure 1: MI and Associated Beamlines Layout

A total of 27 Multiwires are distributed between MI-8, MI, P1, and P2 in order to optimize the beam tune. Just downstream of MI-8 injection is a horizontal (at Quad 102), and vertical (at quad 103), instrumentation section each comprising a multiwire (left) a flying wire (center) and an IPM (right).

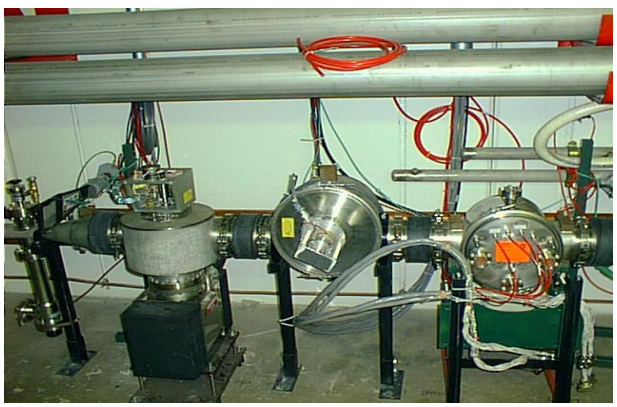

Fig. 2: MI Beam Instrumentation Station

2 MULTIWIRES

These particle detectors are typically used to tune the proton beam and are then removed since they are intercepting devices and degrade the beam. They operate in beamline vacuum, which is of the order of 10^{-8} Torr.

2.1 Types of assemblies

In the 8 GeV transfer line the grids are assembled to display a single profile at the time. In the MI ring, P1, and P2 beamlines the grids are made by first winding a 0.003 inch diameter wire at 80 g of tension on a transfer frame, then, transferring the wind over the wire planes and then soldering the wires on the pads. Each paddle contains both a horizontal and a vertical set of wires. No clearing field plane has been included in the design of this detector. The charge on the wires is measured with a scanner designed by the Controls Group [1].

Fig. 3: New MI Multiwire paddle

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2.2 Signal strength

The charge collected on a wire due to the secondary emission phenomenon depends on the beam intensity, the beam spot size and the surface area of the wire, and it can be written as:

Q=εNeQe Where: ε=Secondary emission efficiency ≅ 3%
Ne = No of protons on a wire
$Q_e = 1.6 \times 10^{-19}$ Coulomb

Assuming a gaussian distribution: $\frac{1}{\sigma\sqrt{2\pi}} e^{-(x-\mu)^2/2\sigma^2}$

Fig 4 shows profiles in the transfer lines P1 and P2. During MI tune-up a 100 micro Farad capacitor and the gain was set to 10. The beam spot size was about 0.5 cm. With these parameters the profile was 90% of full scale. The estimated charge on the center wire was 24 pCoulomb.

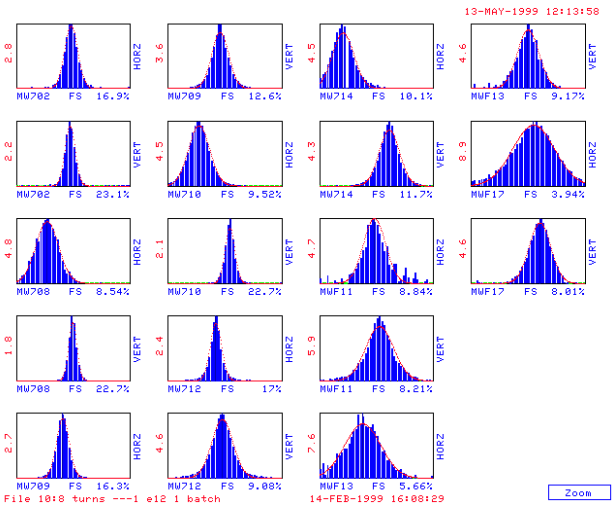

Fig. 4: Multiwire Beam profiles

2.3 Electronics

Charge is accumulated from the multiwire detectors by the individual integrators for a selectable time period.

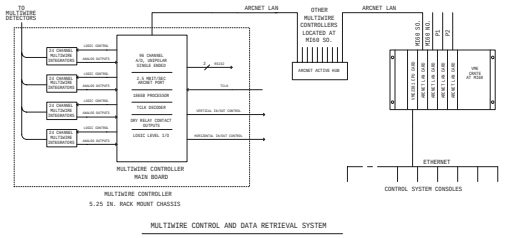

Fig. 5: Multiwire Controls

Both the time aperture and the integrator capacitance are chosen for the charge level anticipated. For the low-level signals, the A/D converters have preamplifier selectable gains of 1, 10, and 100. Simple conversions are held in the controller's memory buffer for retrieval by the VME front end.

5 FLYING WIRES

This system is used to measure the transverse size of the proton beam and also to calculate emittance.

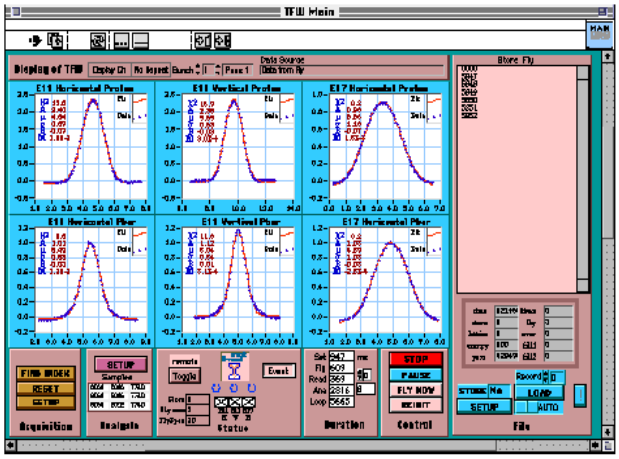

Fig. 6: Flying Wire Beam Profiles

While many old Main Ring systems were transferred to MI [2] this system was cloned from the Tevatron flying wire which had been previously upgraded. The Tevatron systems were discussed in detail in reference [3]. This upgrade included a LabView based system and the use of a resolver instead of an optical encoder for motion control. It also allowed changes to the motion profile that allow a 540 degree fly which results in accelerating to constant speed prior to making two passes through the beam and then decelerating to a final parking position.

By making two passes through the beam, offsets can be normalized and a comparison of sigma's calculated. There is a noticeable difference in the profiles generated by the two passes that are thought to arise from the proximity of the loss monitor detector to the near and far pass. Work is being accomplished to help characterize this phenomenon.

The Flying Wires require multiple turns to complete a profile and are also intercepting detectors that will degrade beam over time.

5 IONIZATION PROFILE MONITORS

These systems have been installed in Booster, MI and Recycler ring. Both the horizontal and vertical Main Injector IPM's [4] have been operational since the first

circulating beam. The system captures a complete profile on each turn, takes up to 65K profiles, and causes no beam degradation. The nonlinear gaussian fit routine can easily handle sloping baselines that result from losses at injection any very wide beams that survive the first few revolutions.

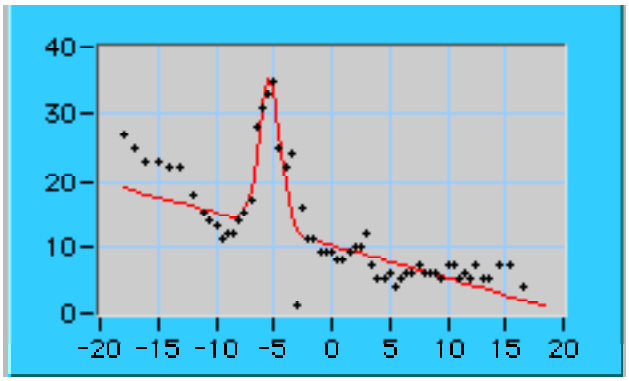

Figure 7: First circulating MI Beam Profile

The system functionality has been continuously upgraded including the latest addition of a tune calculation from the turn by turn samples captured. This feature was used during pinger studies to aid in commissioning the machine.

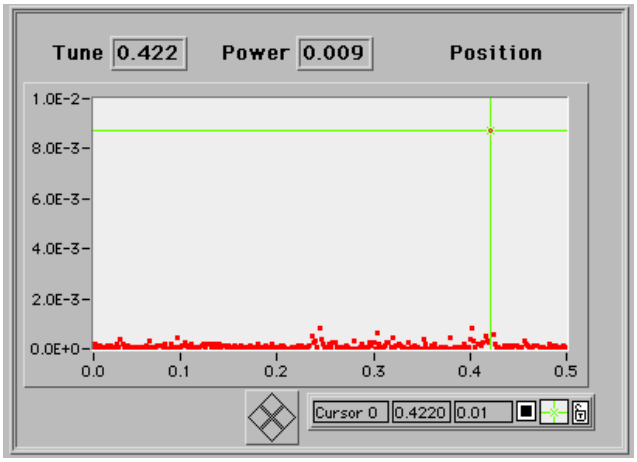

Figure 8: Horizontal Tune Measurement from IPM

The tune calculation is accomplished using the LabView power spectrum function applied to the mean of each sampled profile calculated from turn by turn data. Through the use of various clock delays this measurement can be made any time during the cycle and on any injected bunch.

6 CONCLUSION

The commissioning of the MI has been successfully completed. The Lab is now in the process of accelerating beam in the TeV ring for fixed target operation. During the MI start up phase it was found that some improvements could be made to the Multiwires: The rotary feed thoughs that enable the paddles to be moved in/out of the beam had much more than the manufacturer's specified 0.5 degrees of backlash. Also, to minimize outgassing the plan is to redesign the FR-4 boards that hold the x, y wire planes with ceramic substrates. Finally, to minimize the potential for wiring errors the individual wires that are soldered at one end to the inside of the vacuum feedthrough and at the other to the individual board pads will be replaced with Kapton ribbon cable.

One advantage to collocating the three different profile-monitoring systems is to be able to correlate the data from three different measurements. This work will begin once all of the accelerators are in stable mode of operation.

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