Tevatron Ionization Profile Monitor

Involved at different levels (and in no particular order)

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Goals:

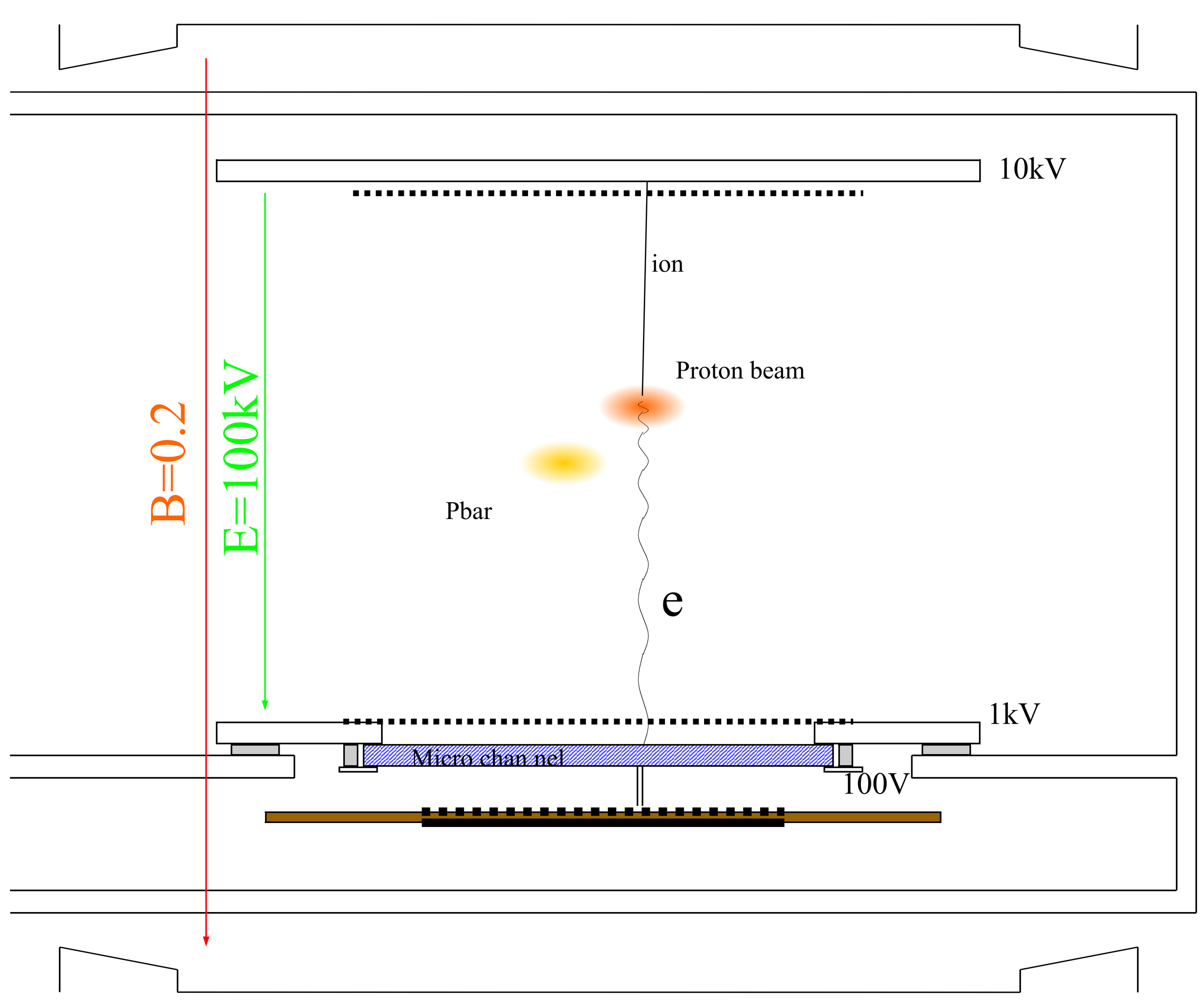
To measure...
...beam size turn by turn at injection to about 10%
...beam size evolution on during the ramp to a few %
...both protons and pbars

Why:

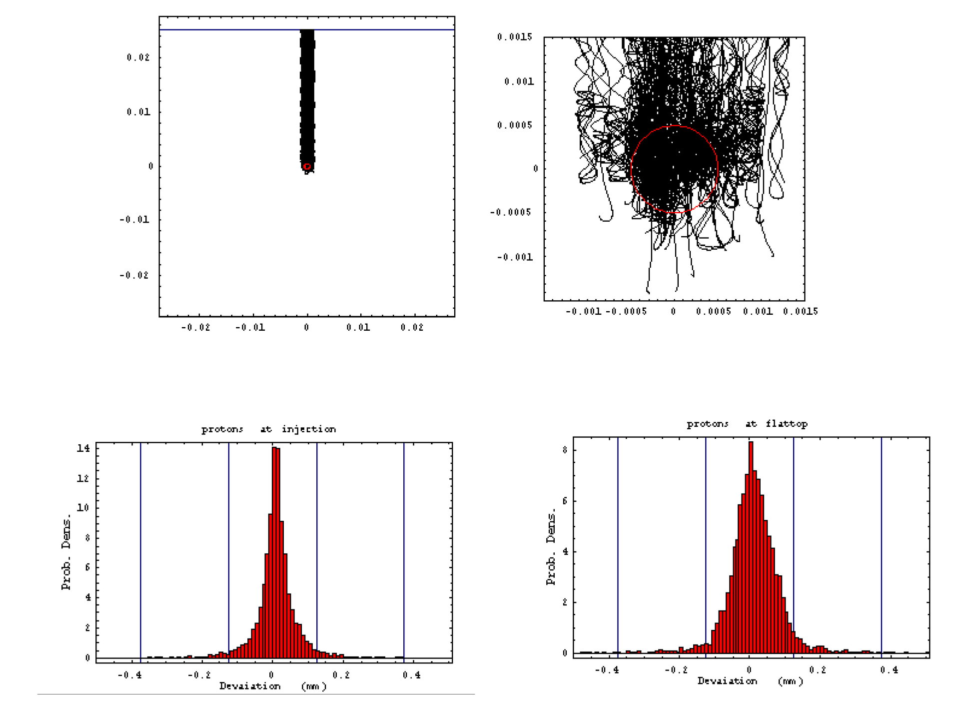
To...
...directly detect emittance blow-up at injection
...diagnose emittance blow-up during the ramp
…increase luminosity

Detector

The detector is based on experience from a prototype installed in the Main Injector. Ionization electrons are drifted onto a detector using an E || B field. The magnetic field is necessary to overcome space charge defocusing. A micro-channel plate amplifies the signal before it is detected on 1/4 wide millimeter anode strips.
To distinguish protons from pbars, both time and space separation will be used.

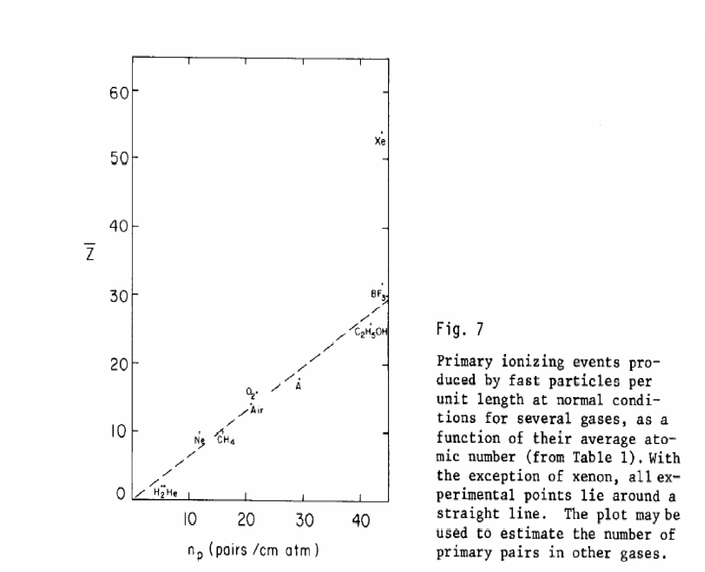


Electron Tracking

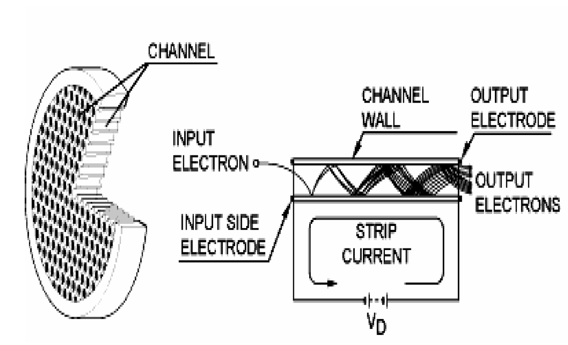


Tracking of electrons in the E||B field (top) show only a negligible spreading in the transverse coordinate. Bottom plots are histograms of displacement with respect to initial transverse position.

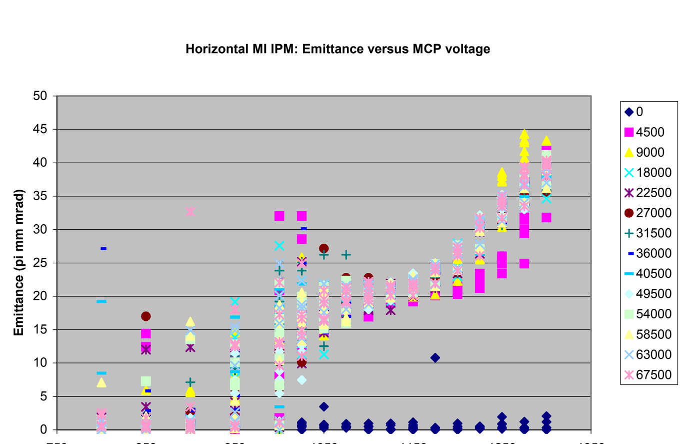
Signal and gain limitations



Expected ionization for Tevatron rest gas mixture is 1.3×10^{-2} cm^{-1} $Torr^{-1}$, or about 1000e for a 10 cm detector at 3×10^{8} torr and 2.7×10^{11} protons.

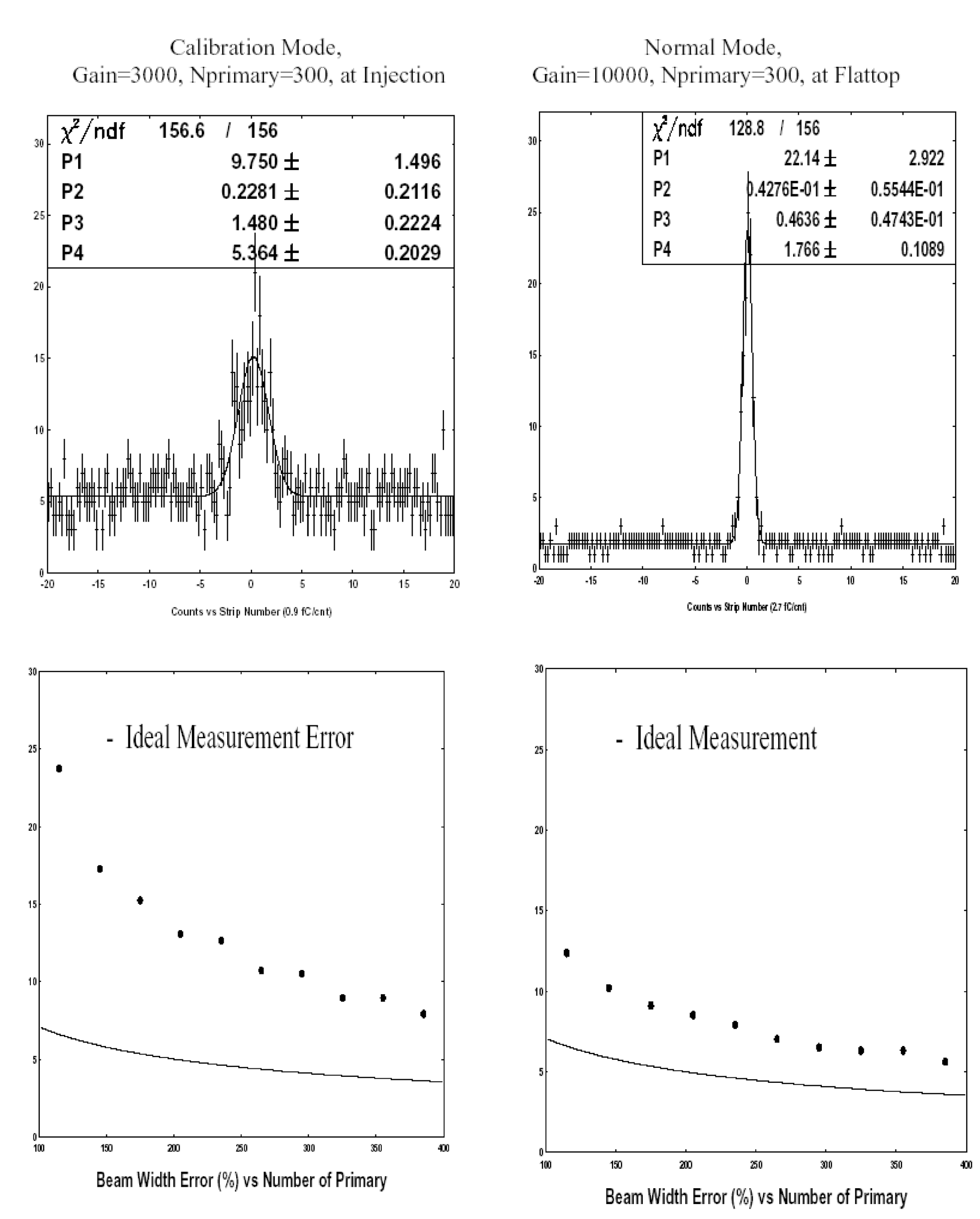


"Extended dynamic range" MCPs allow a current draw of up to ~1.4 uA/cm^2 (at maximum gain) without saturation. This gives a max signal per bunch and anode strip of 1.3×10^{6} electrons (200fC)., and effectively limits gain to ~10000 or less for the expected signal levels. This can be provided by a single plate.



Signs of saturation have been seen in the Main Injector IPMs. Above plot shows beam emittance versus MCP voltage at different points in the cycle. The suppression of the peak leads to a wider distribution for high voltages.

Beam width reconstruction



Simulations by H. Nguyen.

Monte Carlo calculations, taking into account the gain dispersion of the MCP, show that about 300 primaries are needed to reconstruct the beam width to 10% accuracy. This is a factor 2-3 higher than expected from pure counting statistics and will, at least for pbars, require gas injection to increase signal.

Since pbars are injected into the Tevatron in batches of four, one can also average over those four bunches.