RHIC IPM

Electrons from ionization give accurate profiles.

We have demonstrated single-bunch profiles. Turn-turn measurements of a single bunch at injection show dipole and quadrupole oscillation.

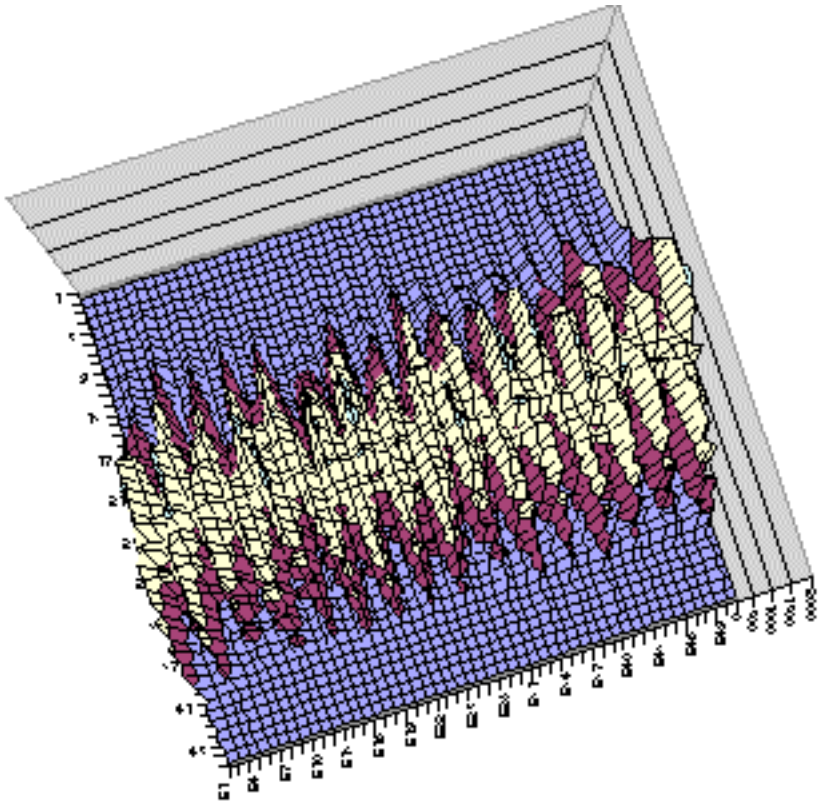
The original detector was sensitive to background and noise from,

1. Rf coupling to beam
2. Radiation spray from beam loss
3. Secondary electrons

Rebuild in 2002 greatly reduced these backgrounds.

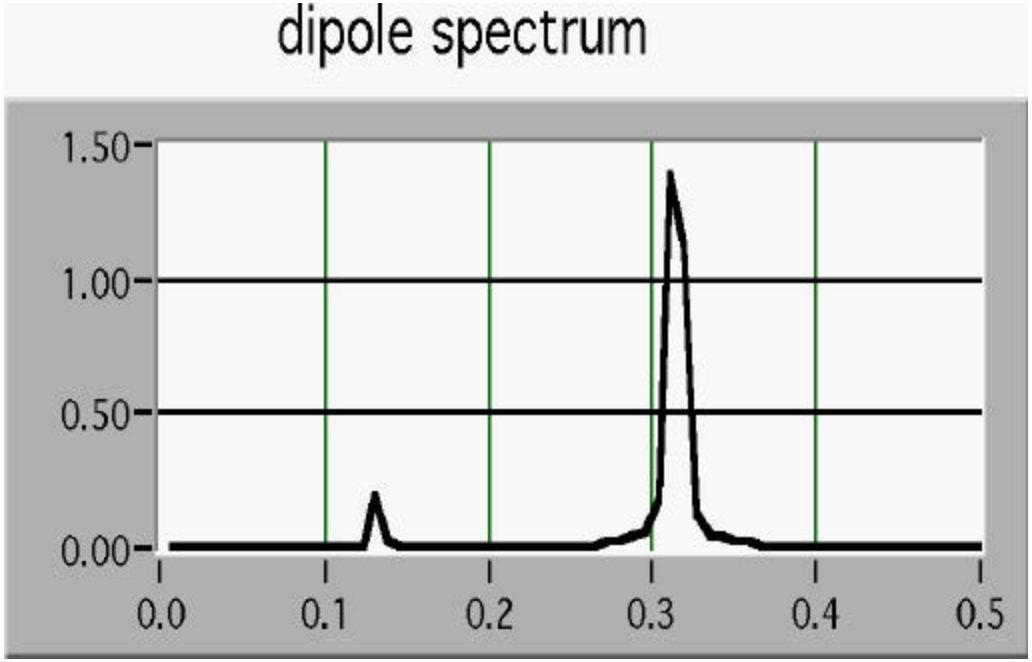
Rebuild in 2003 will have more accurate collection electric field and internal calibration source.

Mountain-range plot of 50 turns at injection



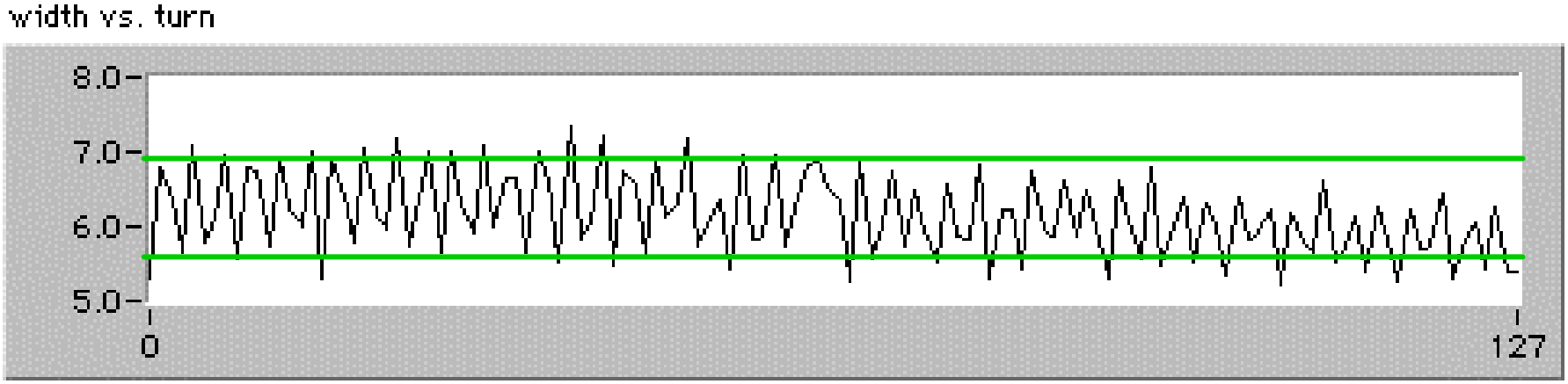
Detector channels are plotted on the vertical axis and turn number is on the horizontal axis. The betatron oscillation is the vertical tune of 0.32

Dipole oscillations at injection



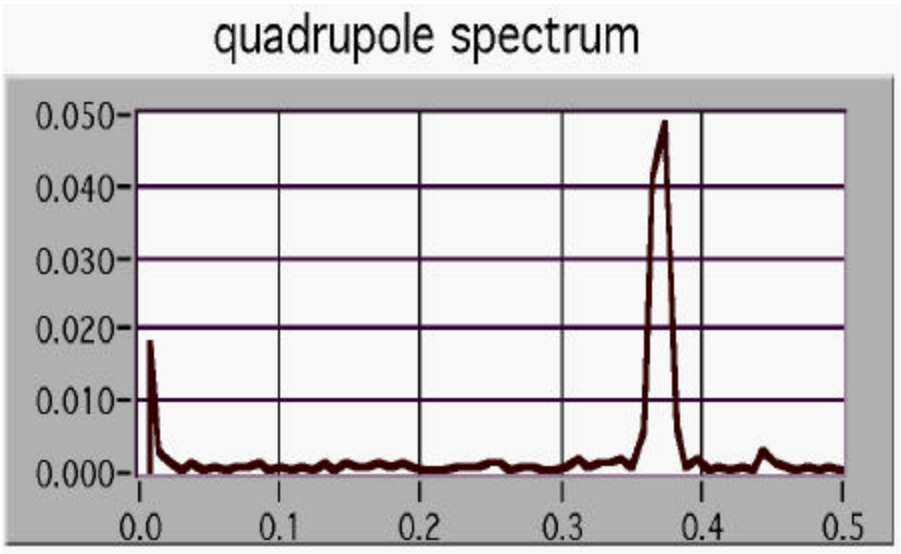
The centers of the bunch for 128 turns after injection were calculated by fitting Gaussian curves to data from each turn. This sequence was Fourier transformed to give a power spectrum. Data are from the vertical IPM and shows the vertical tune of 0.32 and the horizontal tune of 0.13.

Plot of 128 measured rms widths



Plot of measured rms beam widths over 128 consecutive turns. A Fourier transform of this sequence gives the quadrupole power spectrum. Width units are mm. Width is 6.2mm and width oscillation amplitude is 0.6mm, about 10%.

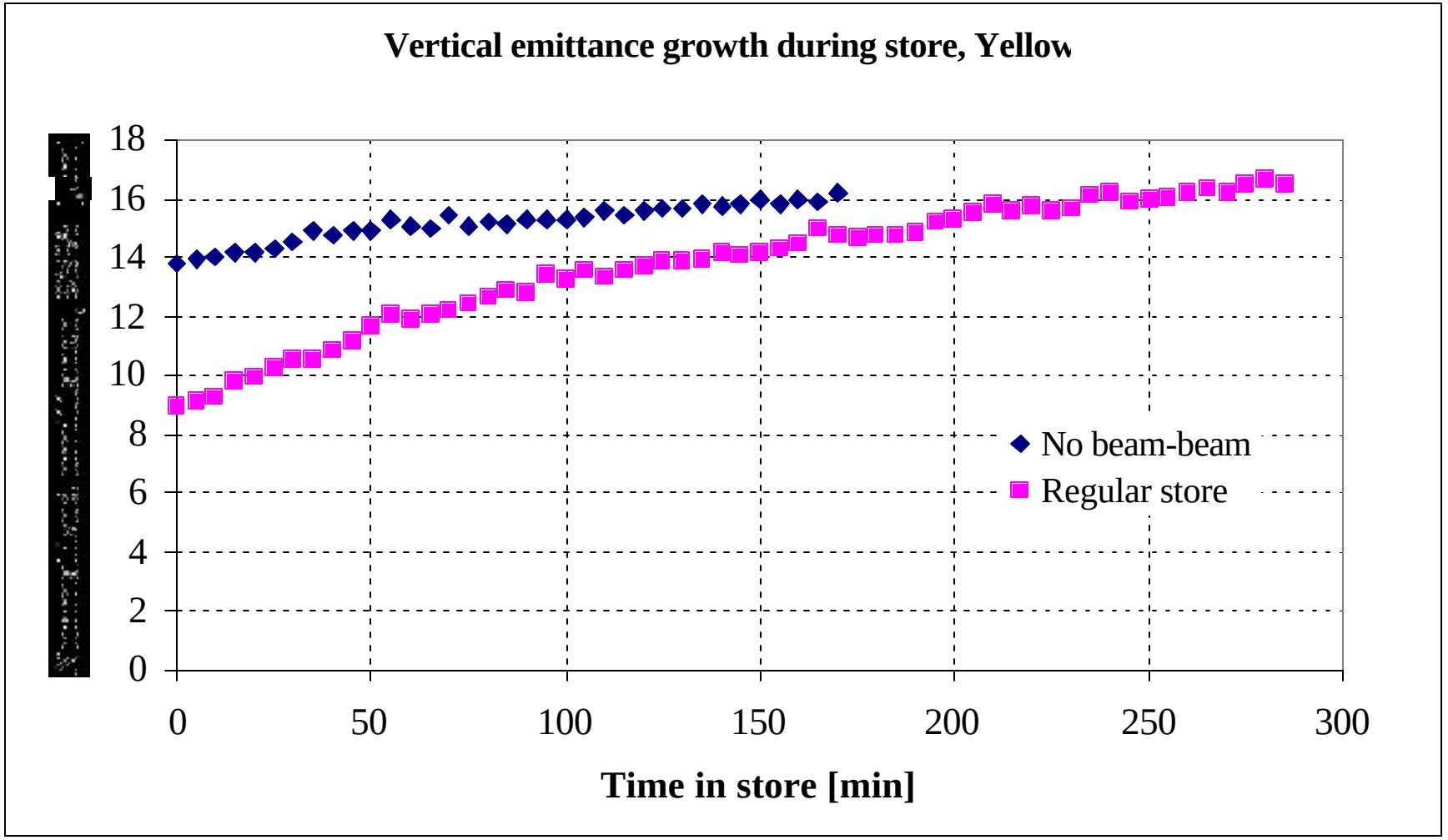
Quadrupole oscillations at injection.



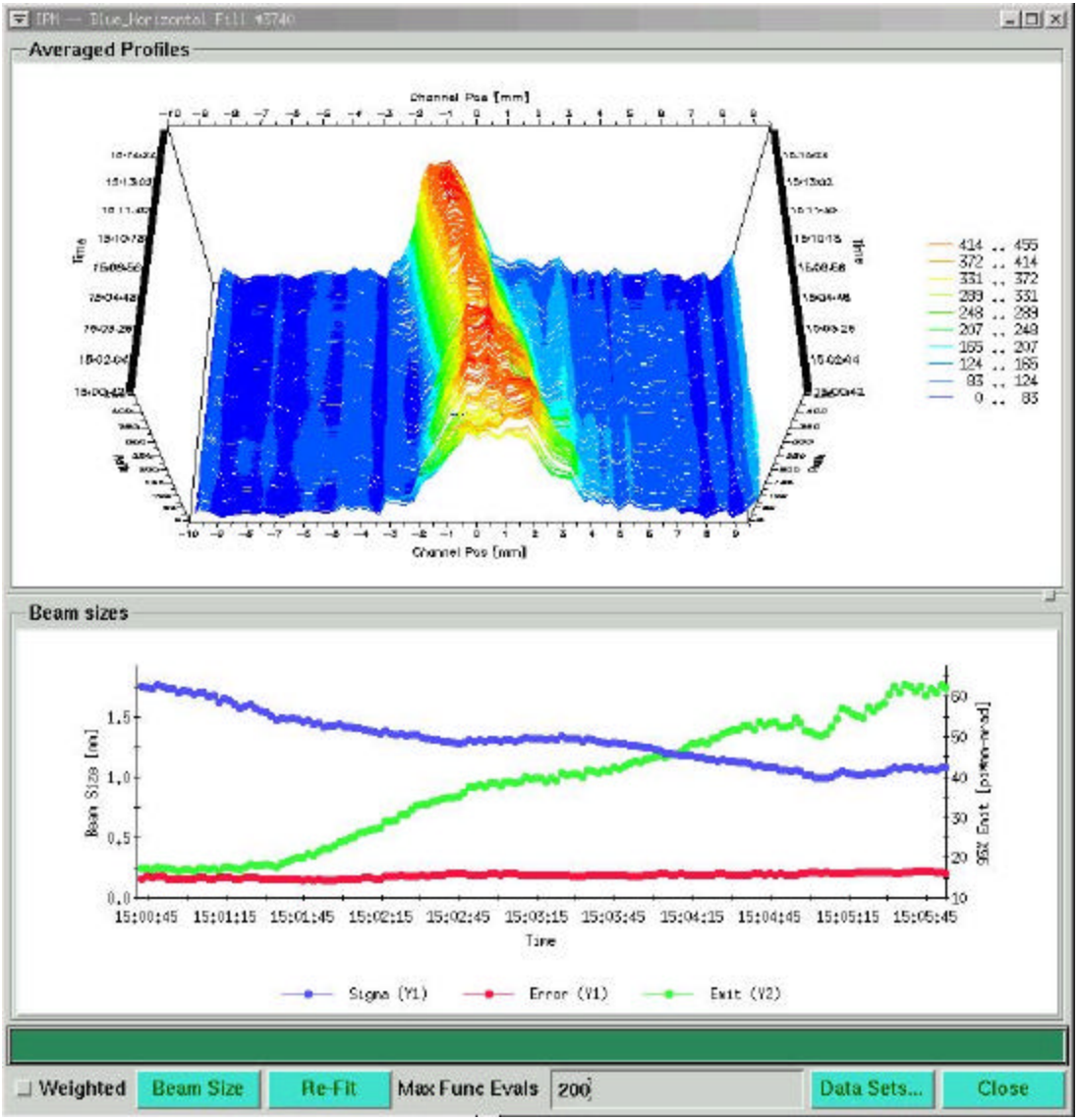
The rms widths of the bunch for 128 turns after injection were measured. This sequence was Fourier transformed to give a power spectrum. The betatron frequency was measured to be 0.32 so the quadrupole frequency is 0.64. Since sampling is done at the rotation frequency the quadrupole frequency appears at the aliased frequency of 0.36.

This is a linear plot with the peak at 0.048 and the noise floor at 0.002, giving a S/N=24. Since the data had a width oscillation amplitude of 10% this measurement was sensitive to a minimum width oscillation of 2%.

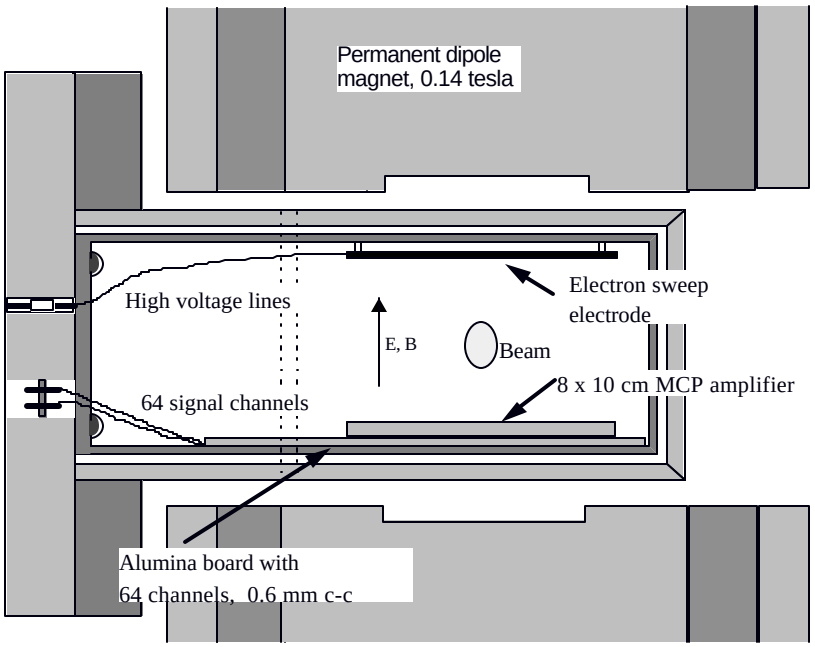
Emittance growth from beam-beam

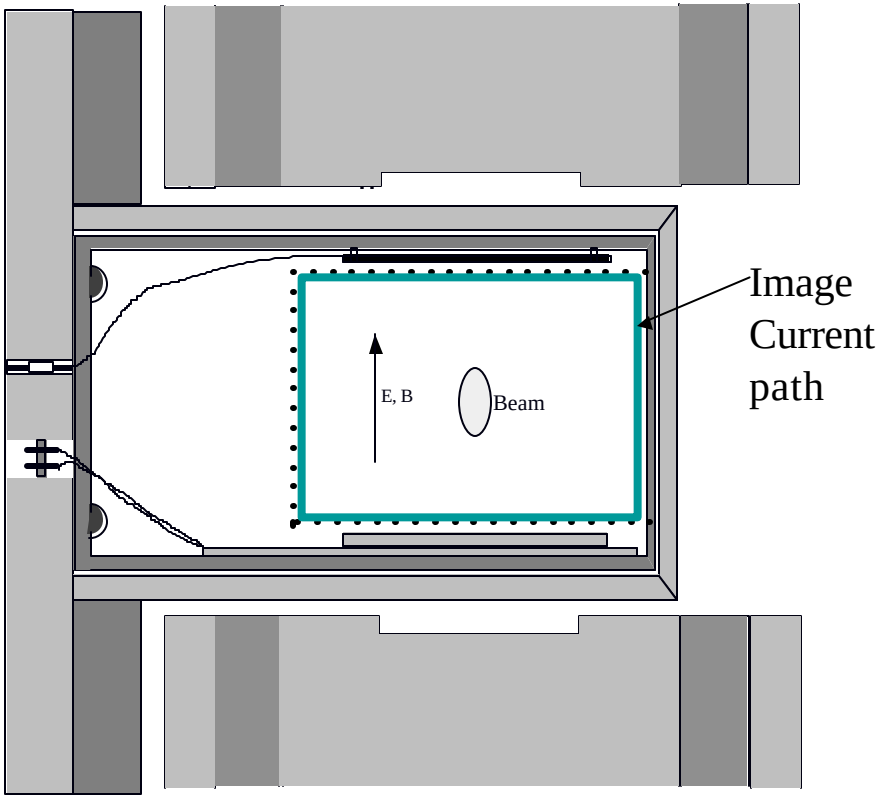


Profile of polarized proton beam up acceleration ramp



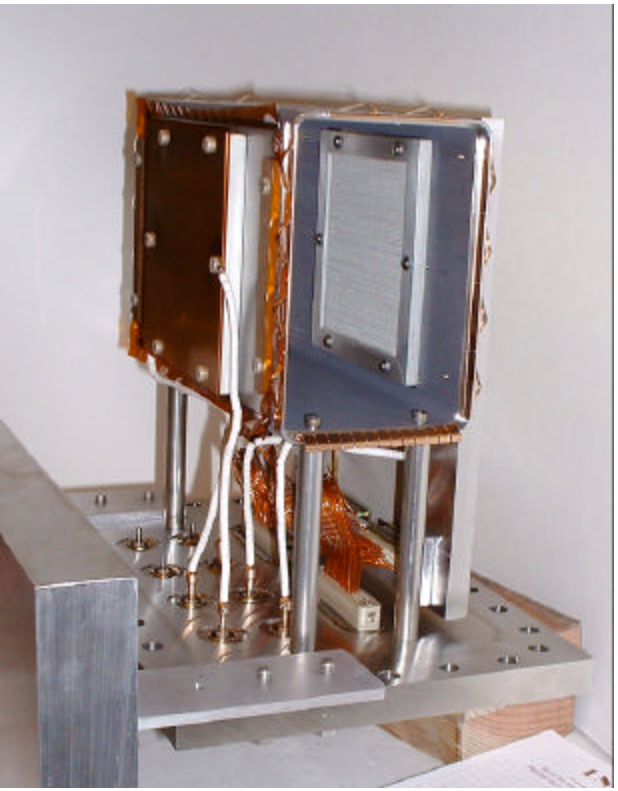
Modification of transducer





The detector components were inserted inside the beamline. This restricted the aperture and made detector components vulnerable to stray beam. The new detector chamber will allow the detector components to be outside of the image current path.

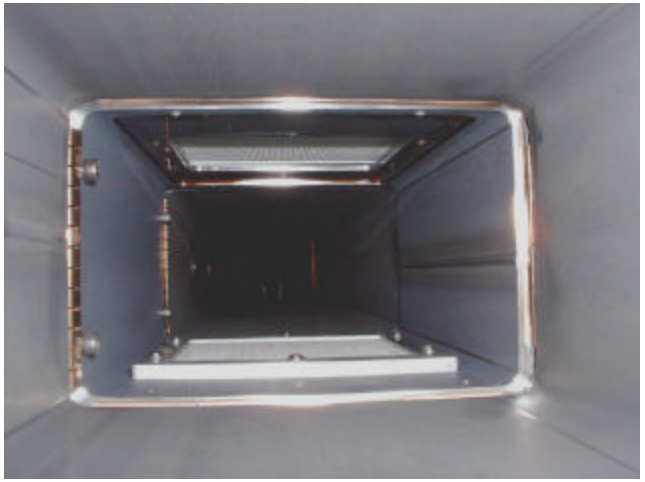
New IPM



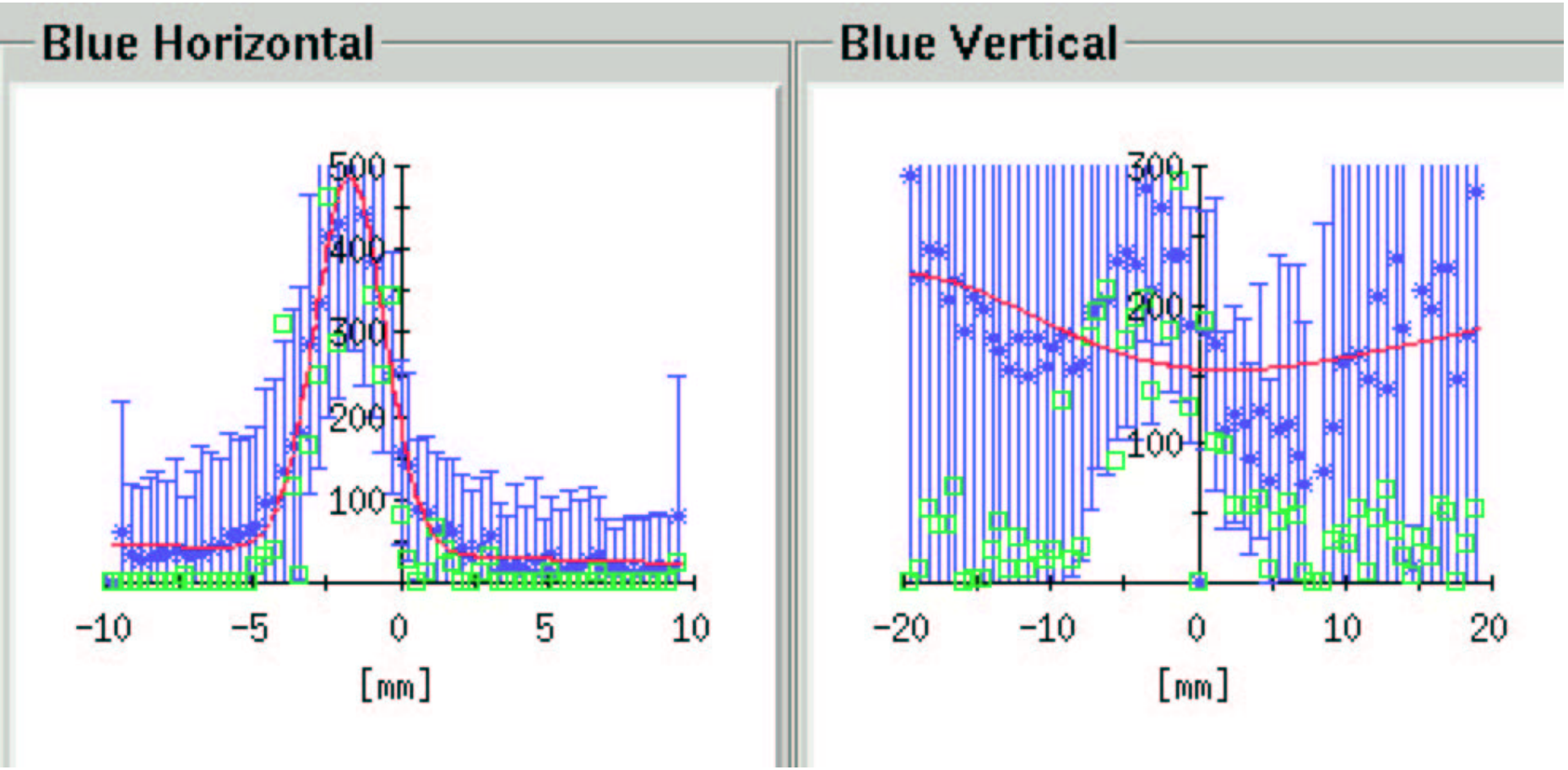
Completed transducer head. The electron sweep electrode and secondary electron suppressor grid are on the left. The microchannel plate and collector board are on the right.

Partially assembled head being inserted into vacuum chamber.

View down beampipe.



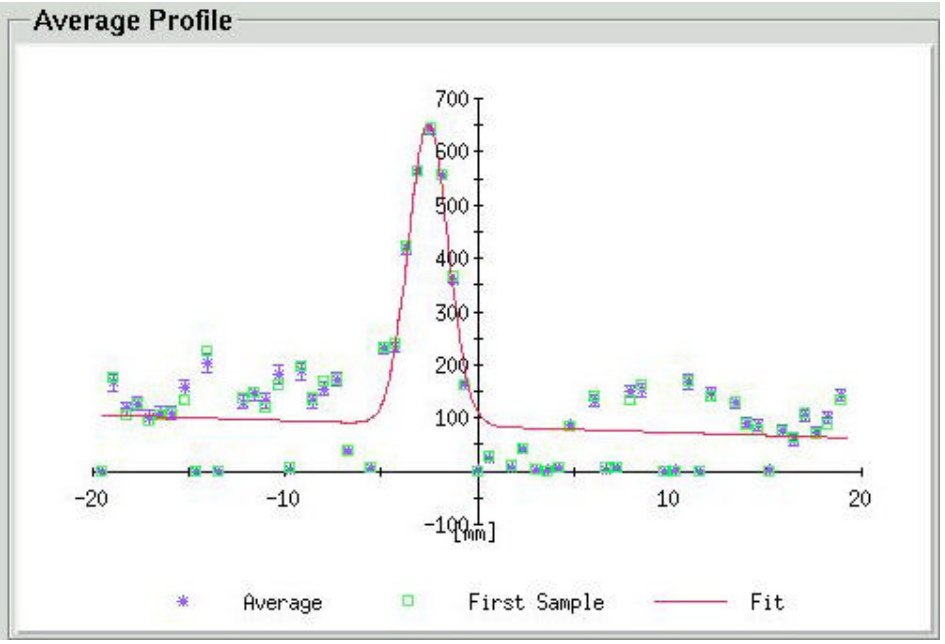
IPM Beam Loss Study - 4 Mar 03

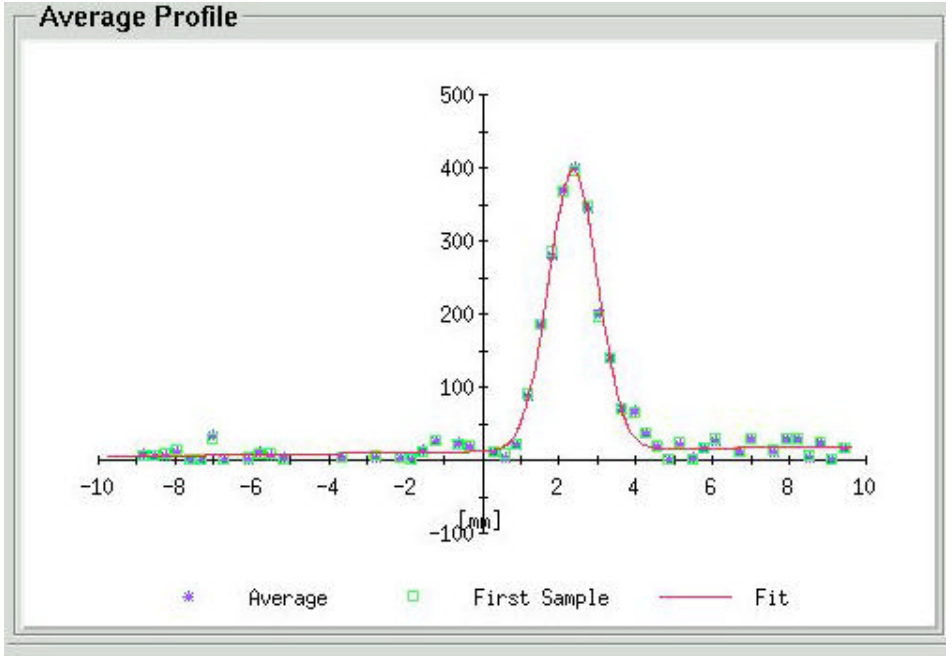


New Detector Design

Old Detector Design

Electron background suppression





Profiles from the horizontal detectors in the yellow ring with gold beam.
The left profile is from the old design IPM (Oct. 2001) and shows a large background.
The right profile is from March 2003. The new design eliminates most of the background.
With gold beam the background is about 2-3% of peak.

LHC considerations

Beam size, Max. sigma in arcs	1.2mm at injection
	0.3mm at store
Collector	64 channels, 0.1mm c-c
Microchannel plate amplification	Collection length = 15cm
MCP resolution	c-c pitch to 3 μm
Amplification	Charge sensitive amps, 25 ns pulse shaping
Digitizers	40MSPS digitizers allow any data collection pattern.
Single bunch acquisition	With pressure bump can get < 5% accuracy

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Technical Brief #3- Spatial Resolution

An important performance parameter of the Microchannel Plate (MCP) is spatial resolution. The ability of a microchannel plate to spatially resolve two adjacent events is called the limiting resolution.

The limiting resolution of a microchannel plate is ultimately dictated by the channel pitch, sometimes referred to as the center-to-center spacing. MCPs are typically fabricated with channel pitches ranging from 6 to 32 microns.

Limiting resolution is characterized in terms of line pairs per millimeter. Figure 1 indicates the relationship between channel pitch and limiting resolution.

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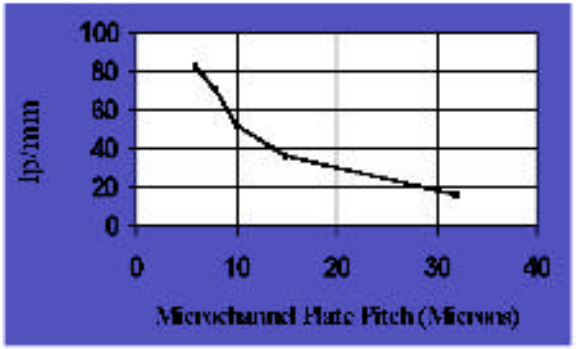

Figure 1

The limiting resolution of a detector system can be affected by parameters other than those dictated by the microchannel plate. The spacing and field strength between the output side of the microchannel plate and the readout device must be optimized in order to preserve the maximum resolution of the detector. In addition, the input events to be imaged must be properly focused on the detector input side.

The spatial resolution of an MCP detector may be optimized through the use of small pore microchannel plates and deep output electrode endspoiling.

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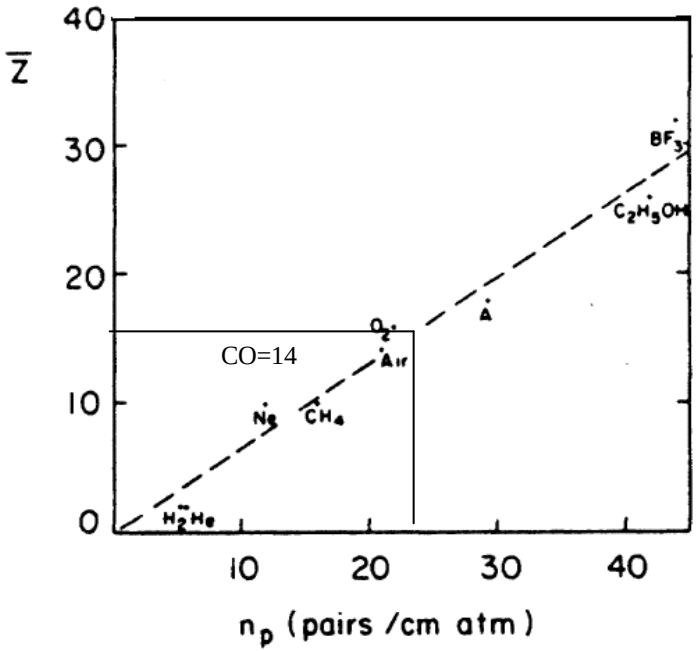
Signal size estimate

Assume the background gas is 2/3 H_2 and 1/3 CO. At STP a 1 GeV proton produces 5.2 ionization events/cm in H2 (measured) and 22/cm in CO (estimated from graph). This mixture will give 10.7 electrons/cm/proton. At 10^{-9} torr a bunch with 10^{11} protons will give 14 electrons.

(10.7 x 10^{11} electrons/cm) x (10^{-9}/760) x (10 cm) = 14 electrons

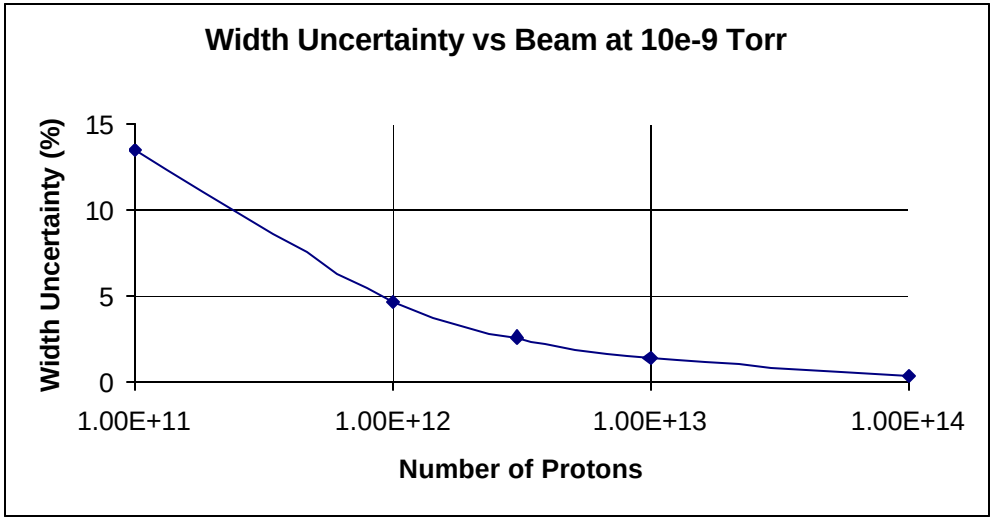


Graph from:
F. Sauli, Principles of Operation of Multiwire Proportional and Drift Chambers, CERN 77-09, Geneva, May 1977

A pressure bump is needed for single-bunch measurement.

From measurement statistics need about 500 electrons for 3% measurement.
At 10^{-9} torr need about 50 bunches to get good measurement (see graph).

To measure single-bunch profiles it is necessary to introduce a pressure bump.



IPM Gas System Installed in RHIC

Conclusions

1. Transverse beam profiles can be measured by collecting electrons from residual gas ionization.

2. With pressure bump a single bunch can be observed turn-turn.

3. On RHIC, at injection, we have measured dipole and quadrupole oscillations.

4. The beam in the RHIC horizontal IPM is nominally σ=0.5mm wide. This is similar to the size of the LHC beam.

5. Improvements in the last rebuild greatly reduced beam coupling and radiation and electron backgrounds.

6. New IPM has stronger and more uniform sweep field, and internal calibration source.