Introduction

At Fermilab, beam diagnostics play a crucial role in the operation of the accelerators. These systems allow one to perceive what properties a beam has and how it behaves within the machine. For optimum performance, it is critical to have the most accurate representation of the characteristics and behavior of the parameter under investigation. In practically all cases, errors are inevitable and one must deal with determined tolerances. However, it is important to understand what cases the errors and by what means the instrumentation can be improved to be of practical usage in daily operations. A parameter of interest is Luminosity. The initial goal for Run II at Fermilab is to provide a peak luminosity of 5.1E31 cm^-2 sec^-1 with 36 proton x 36 antiproton bunches at an energy of 2 TeV in a center of mass system. The integrated luminosity goal is 2 fb^-1.

Another important parameter is emittance. Fermilab has several devices which measure this parameter in various locations around the complex, such as the Booster, Recycler, Main Injector, and Tevatron. In the Tevatron, the emittance monitoring devices include Flying Wires and a Sync Light monitor. However there is a discrepancy surrounding the emittance that each device reports. It is desired to obtain more instrumentation to measure this quantity within the Tevatron. Primary candidates include an Ionization Profile Monitor, and a Schottky detector. A IPM is currently being developed and designed for use in the Tevatron. The properties of two devices used in the implementation of this tool need to be understood. The devices in question are the microchannel plate and the QIE ASIC.

Background.

Some quantities that are of interest in the operation of accerators will be discussed. The event rate R of a collider is proportional to the interaction cross section, with the factor of proportionality being luminosity:

Considering two bunches consisting of n1 and n2 particles that collide with a frequency f, then luminosity may be defined as:

where σx and σy characterizing the transverse Gaussion beam profiles in horizontal and vertical directions. Although the initial distribution of particles are not quite Gaussian, by the time the beam has been accelerated to its final energy, the normal form at this high energy is a very good approximation of a Gaussian. This aspect is due to a diminished importance of space charge effects and the central limit theorem of probability. [7] In practically all cases, it will be assumed that the r.m.s. value of the beam density distribution will provide a measure of beam size. Beam size may be expressed in terms of two quantities, the transverse emittance and the amplitude function. Transverse emittance is a quality factor describing bunches, where the amplitude function is a beam optics quantitity determined by an accelerators configuration. Equations of motion in an accelerator are formalized in terms of Hamiltonian mechanics, where the Hamiltonian H(qi,pi,t) is a function of coordinates qi, conjugate momenta pi, and time t. It should be noted that if H is not expliciately dependent on t, then H is the total energy of the system that is invariant. The trajectories of a point M(t), where M(t) is described by coordinates qi(t) and pi(t) in canonical phase space, form a curve called the phase trajectory. Usually the longitudinal motion along the beam axis can be decoupled from the motion in the transverse axis. If the transverse axis can be decomposed into two independent motions along two orthogonal directions, the phase space can also be split into two, 2-dimensional phase spaces. Emittance is typically defined as the area in phase space which contains 95% of all particles in its interior. It may also be defined as the product of the semi-axes, where the two semi-axes are half the beam size Δx and the beam divergence $\Delta x'$. If the particle energy is varied, then the emittance is not invariant. Then one may define the normalized emittance which is conserved during acceleration. A crucial task for the operation of particle accelerators is to preserve beam emittance and even further, to reduce it. This may be challenging as there are many phenomena that tend to affect emittance. The following processes cause non-conservation of transverse beam emittance: coupling between transverse degrees of freedom, chromaticity, intrabeam scattering, space charge effects, wake fields, beam-beam scattering, scattering on residual gas, synchrotron radiation emission, stochastic cooling, and filamentation due to non-linearities. [8] It should be noted that this list does not encompass all processes which are responsible for the degradation of emittance. However, it is reassuring to note that some Hamiltonian process, such as transverse coupling, chromaticity, filamentation, etc., in principle have the capability to be compensated in order to avoid emittance dilution.

Fermilab has various forms of emittance monitoring devices. These include Flying wires, Sync lite monitors, and Ionization Profile Monitors (IPM's). The Flying wires are located in the Tevatron and Main Injector (MI) accelerators, and tend to be evasive diagnostic devices. Sync lite monitors are in the Tevatron, and are non-evasive diagnostic devices. The energy level is much too low in the MI to utilize these instruments in that particular accelerator. The IPM diagnostic tools are also non-evasive and are located in the Booster, Recycler, MI, and are planned for the Tevatron. The Tevatron IPM, or more appropriately ePM, is currently being developed and designed, with a demonstration of proof of principle to follow within the next few months. The current progress of the project is satisfactory, and will soon be commissioned. The primary motivation for implementing an ePM in the Tevatron is to have a diagnostic tool that will accurately report emittance at injection and on the ramp. It will also be used to observe quadropole oscillations during injection and observe any transverse coupling. The distinction between an IPM and ePM, the reasons for this choice, and fundamentals of operation will now be discussed.

Principles of operation

Ionization Profile Monitors (IPM's) are non-destructive diagnostic tools that utilize the residual gas ionization produced by the beam in a synchrotron. These devices typically provide transverse beam profiles, with independent detectors for the horizontal and vertical directions. The IPM's collect the distribution of ions, in the case of IPM's (or electrons in the case of ePM's) in the beamline that result from residual gas ionization with each bunch passage. The electrons are swept away from the beamline by means of an electric clearing field that is perpendicular to the beam. The electrons are incident to a microchannel plate (MCP), which produces an amplified signal of the charge. These signals are collected by an anode strip, or printed circuit array, that is orientated parallel to the MCP. The charge on the strips are then integrated, amplified, digitized, then saved to memory where they will eventually be sent to a processor for data analysis producing single pass histogram profiles. [9]

This technique is successful due to the fact that the transverse density of ionization events in the residual gas can be considered as a mapping of the transverse beam distribution, for the transverse direction being observed. However, there are drawbacks to this method that must be considered. The ionizing events tend to impart momenta to the liberated electrons, due to the impulsive collisions with the beam. In addition, the space charge effects of the electrons have an electric field component in the transverse direction. These effects tends to move the electrons perpendicular to the electric clearing field direction which can provide a dispersive effect that widens the measured beam width. This effect can be countered by providing a magnetic field, which is parallel to the electric clearing field, which provides a focusing effect. The liberated electrons are captured in cycloidal motion with velocity and radius of gyration, Larmor radius:

Therefore the broadening of the profile can be practically eliminated, along with potential profile distortion errors from the sweep field. [10] Electrons are the more favored species because they require lower voltages for the clearing field, although with reversed polarity; are more immune to space charge effects than positive ions, ?and tend to be less energetic? In the case of electron collection, it is favorable to employ a secondary-electron suppression grid over the collection MCP in order to reduce noise. [11]

An important device used to implement the IPM is the MCP and warrants a section describing its functionality, characteristics, and design considerations.

<u>MCP fundamentals</u>

Microchannel plates (MCP's) are essentially an array of electron multipliers(dynodes) orientated parallel to one another. There are typically a large number of these dynodes (~1e4-1E7) on each plate. An important parameter of these devices is the length to diameter ratio, α. The range of this parameter is typically to the order of 40-400, with the diameter of the channel being in the range of 5-25 microns. In order to increase the electron multiplication efficiency, the axes of the channels are biased at a small angle (~8º) with respect to the input surface. The devices are fabricated with a channel matrix consisting of a lead glass, treated in such a way to optimize the secondary electron characteristics of each channel. It is also favorable to render the channel walls semiconducting to allow charge replenishment for an external bias voltage. Parallel electrical connectivity of the front and rear surfaces of the device is accomplished by the deposition of a metallic coating, typically Inconel or Nichrome. This then allows the two surfaces to act as the input and output electrodes respectively. Given that the device has two electrodes, one can then characterize the device with an intrinsic impeadence, usually ~ 1e9 Ω. The devices provide a gain factor of 1e4 – 1e7, which may be used singly or in cascade. It should be noted that MCP's connected in cascade do not exhibit gains that are muplicative, but tend to be characterized as :

Where μ is the total gain, δ is defined as the ratio of the number of secondary electrons emitted to the number of primary electrons incident, and n is the total number of stages. MCP's have ultra-high time resolutions ~ <100ps and a special resolution limited only by physical dimensions of channels themselves, and the spacing between successive channels. [11]

An important property that is of interest, is the saturation of this device. In field distortion saturation, the electric field varies along the channel due to the electron emission. At the far end, the electron depletion becomes significant; in practice the electrons cannot be replenished on the time scale of the pulse transit, imposing an ultimate limit on the output count rate. This is the type of scenerio anticipated in the nominal operation of the Tevatron IPM.

It is of interest to consider the effect that the internal electric field has on the MCP. Under steady state conditions the electric field in the MCP is parallel to the channel axis. However under pertubutions, the electric field in the channel tends deviate away from the azimuth and rotates with a time constant that is equal to the distributed RC equivelent line between the electrodes. This time constant given as:

The product of Rmcp and Cmcp is the natural time constant of the MCP, where Rmcp and Cmcp is the measured resistance and capcitance between the input and output electrodes. Thus the electric field rotates at a much slower rate (~10 times) than the natural time constant. The consequence is that the direction of the electric field inside the MCP has an influence on the electron acceleration along the channel and thus the cascade process. The problem tends to have most significance in the positive ion feedback mechanism, and therefore limits the attainable gain of MCP's without a bias angle. [12] This effect tends to reduce the amount of charge extracted from the wall by the previous part of a pulse, since the charge is not completely replenished for any successive pulse. The recharging current provided by the bias voltage has no time to restore the dynode charge during the pulse if the input current pulse is much longer that of the time constant RC. In this timeframe, the dynode voltage will only be determined by the amount of extracted charge. Thus, this effect will be most notable when considering the response of a MCP to a current pulse much shorter than the recharging time; only the very early leading edge will experience the full linear gain. The rest of the pulse will suffer from gain saturation due to the fact that the charge extracted by the previous portion of the pulse has not been replenished. [13]

A test stand is being developed in order to test the properties of MCP's under the operating conditions they will be imposed within the Tevatron. This includes a vacuum ~ 1e-6 torr, at a temp ~ 4 K. Because the test stand was not operational, a study was conducted to see the effect that the bias voltage of a MCP had on the operation of an existing IPM in the MI.

QIE fundamentals

A large dynamic range is possible by the ASIC (Application Specific Integrated Circuit) QIE (charge, integation, encode), and is accomplished through a multirange technique. An input current is simultaneously integrated on all ranges, where comparators are used to select the lowest range which is not at full scale. A voltage represents the integrated charge and is then fed through an on-chip Flash Analog to Digital Converter (FADC). Output is a five bit mantissa representing the voltage, with a two bit code representing the range, and a two bit code identify the capacitor that integreated the charge; the Cap_Id. The integration interval is the same as the reset interval by time multiplexed operations which are pipelined to allow signals to settle. This is a four stage pipelined device, at 25ns per stage. Clocking occurs at 40Mhz,. The QIE is designed such that there are four sets of integrating capacitors or phase blocks, where at any moment during nominal operation one set is collecting charge, one settling, one being read, and the other being reset. Range weighting processes occur within the range blocks with ranges of 1,5,25,and 125. For a given charge depositation over one clock interval, no more than one capacitor in the set will have its voltage within the specified limits. The voltage of this capacitor is digitized by the piecewise linear FADC. This unit has

This device has three modes of operation, inverting mode, non-inverting mode, and calibration mode. For the TeV IPM the QIE will be used in non-inverting calibration mode, accepting negative current. In this mode the FADC will be strictly linear with 32 linear counts output weighted at 0.87 fC/count. The exponent is forced to be 0, with a range for input charge being -6.1 fC – 26 fC. [6]

Tev IPM design details

The data acquisition modes are: proton injection, measuring one proton bunch over N turns; Pbar injection, measuring four pbar bunches over N turns; and circulating beam, continuously measuring all 36 bunches, averaging over N turns. At the moment, it has been decided that N = 2000 but will have to capability to be changed in the future. The choice for this value was arbitrary. It is desired to have a single turn resolution and should be able to differentiate proton and pbar signals. The design will be a modified version of the MI IPM, using a magnetic field to focus the ionization electrons, eliminating any space charge effects. It will differ from the Mark II in the MI in that the Tev IPM will use an electromagnet, opposed to a permanent magnet. The motivations for this choice are that the magnetic field can be turned off, the intensity of the magnetic field can be varied, and there will be a reduction in costs. Primary design considerations are that there shall be few (~1000) electrons per bunch during normal operating conditions, the time between bunches is ~ 396nsec, the electronics will need to be low-noise, and the electronics that will digitize in the tunnel need to be rad-hard. A MCP will be used as an electron multiplier, and will need a wide dynamic range. The MCP will be used in analog mode, which is sometimes called "unsaturated mode". Therefore a primary concern will be the saturation of the MCP. The MCP gain must be kept relatively low in order to counter any saturation effects.

It is assumed that the distribution of particles is Gaussian, and the raw data will be fit with a Gaussian distribution. The electrons striking the MCP should be roughly the size of the beam. The device can only capture horizontal or vertical profiles. The output of the MCP will strike an anode circuit board with 128 anode strips. The anodes will run parallel to the direction of the beam. There will be 371 samples per turn. The sampling clock will be generated by dividing the proton RF by three. The proton RF is 53 MHz, giving a sampling clock of 17.6 MHz. Each bunch signal should be contained within one sample which is the integration interval. Signals should be synchronized to the proton revolution marker to avoid three-way phase ambiguity. It is also favorable to have a variable delay for fine tuning. This is necessary in order to center samples on bunches. In considering bunch arrival times, it is important to consider that the Pbar arrival times vary during injection and cogging. The minimum spacing for protons and pbars is

~ 100 ns. Trigger signals to be used will be proton and pbar RF, which is 53 MHz. It should be noted that these frequencys are not constant and differ at injection and cogging. Proton and Pbar revolution markers will be used to tag the first bunch. Once the first bunch is known, it will be possible to determine the temporal distribution of the remaining 35. A synchronous trigger used for timing event broadcast will be the Tclock. Synchronous triggering will use the MI beam sync, with a precision of 1 "tick" = 7 RF periods. Data words will be ~8 bytes, giving a total memory requirement of ~ 100Mbyte. The data rate will be relatively high at ~ 18Gbits/sec.

The raw data signals from the anode strips will be feed through the vacuum flange by a high impedance flex circuit. Only signal wires will be pulled through the flange with the reference signals terminated on the outside. A high impedance flex circuit will be required in order to minimize noise. It has been decided that the flex circuit will be fabricated using teflon in order to meet the requirement of being rad-hard. The electronics in the tunnel will need shielding from the beam's image current. This shielding will be done with a Faraday cage. The field cage will need to be optimized to stop the 53 MHz image current signal. A mock-up of the shielding apparatus to be used will be tested to see how much of the image signal makes it through the shielding cage. The raw data signal from the flex circuit will be input into QIE8 ASIC device. The device will be used in calibration mode as a linear amplifier with wide dynamic range. The QIE device will integrate and encode the analog signals. The Tev IPM will use a modified version of the CMS QIE QTBB (QIE Test Beam Board). Each board will house 8 QIE devices, which will be serialized into an optical driver. There will be a total of 16 boards in order to capture all 128 signals from the anode board. The serialized optical signals will be feed via optical fibers to a combiner card. The combiner card will de-serialize the signals and store the data in a fast, wide memory FIFO buffer. A FPGA on the combiner card will perform the logic necessary for this operation. The data will then be feed to a PCI bus, which will send the data to a PC for data analysis. The combiner card is similar to a proposed prototype for the BTev experiment. It was not scheduled to go into production for another 4 years, but the CMS department is collaborating with the Beams Division in order to get a working prototype for the Tev IPM in about 6 months. This card is necessary, as the PCI bus posed a data bottleneck in the DAQ process. An additional header card will be located in the electronics rack in the tunnel. This device will receive timing signals from an off-the-shelf timing card which is located in the upstairs PC. The timing card will provide trigger signals to the header card. The trigger signals provided are the proton and Pbar revolution markers, and the 53 Mhz RF. The header card will use these signals in order to produce signals and triggers to the 16 8-channel QIE boards downstairs. The signals provided by the header card include: the 17.6 MHz sample clock, QIE_reset, QIE_mode, and a header byte. The header byte will be appended to the word output of the individual QIE's in order to identify what bunch was observed, and whether or not it was a proton or Pbar bunch. The format of the data words are <header byte><CAP_ID: 1 bit><exponent: 2 bits><mantissa: 5 bits>. Data sparsification will be performed on the XXXXX card for data reduction purposes.

MI IPM studies

The purpose of the study was to determine the effect that the Microchannel plate bias voltage had on the data aquistion. The bias voltage was varied in a linear fashion over the entire operating range of the Main Injector Ionization Profile Monitors. Both IPM's were used in the study, H1 and H2. The primary difference is that H2 has a magnetic field of 0.38T in parallel with the electric clearing field. In addition, H2 is designed to collect electrons rather than ions, resulting in a clearing field that is lower in potential, and has a reversed polarity. The main effects that were anticipated were any saturation effects due to the MCP's. Measurements were taken in two intervals; interval A was before the ramp, in which the beam size is postulated to be constant. The second interval, interval B, was taken through out the ramp, in which the beam size should reduce going up the ramp. During interval A, the MCP should have a constant area of bombardment of incident electrons via the clearing field. Any effects of saturation should manifest in the form of the MCP not having sufficient time to recover and replenish charge to the MCP walls. Saturation for interval B should be present because the beam width decreases, increasing the flux on electrons on an arbitrary unit area, with an increase in relative intensity.

The measurements were taken for a particular mode of operation, which is Pbar production. This mode of operation is initiated by a unique clock event, event $29. This is a clock event that triggers the Main Injector cycle required for Pbar production and originates from the Time Line Generator(TLG). In this mode of operation, a single Booster batch is transferred the Main injector via the MI-8 line located at MI-10. This single batch of protons (84 bunches) is at ~8.9 GeV which is then accelerated to 120 GeV. There are 18 accelerating radio frequency (RF) cavities capable of accelerating the 8 GeV proton bunch to either 120 GeV, or 150 GeV, depending on the final destination. The acceleration process in the Main Injector can occur as fast as every 2.2 seconds. It requires a couple of microseconds for the transfer of beam from the Booster through the 8GeV line, onto the MI orbit. Once the circulating beam becomes stable, the acceleration process may begin. The RF adds the energy to beam, where electromagnets provide the constraining force necessary to keep the proton bunch in the correct orbit. Thus, the current in the magnets are ramped accordingly such as to match the magnetic field to the proton energy. The beginning of the acceleration is not necessarily linear; to avoid an abrupt change in the magnetic field, a parabolic signal to the electromagnets tends to soften the transition. After the parabola, the rate of change does become linear for a short duration. As the final energy is approached an inverted parabola eases the beam into "flattop", which is a short period at the final energy during which the beam continues to circulate. In the case of the $29 clock event the flattop lasts for approximately 40 msec. The entire batch is then deflected out of the ring by means of extraction devices at MI-52 and sent down the P1 line towards the anti-proton source, taking A1 at F17 where A1 leads to the Pbar production target. The magnets are then de-ramped in order to prepare for the next Booster batch. During de-ramping there is no beam in the MI. The entire 120 GeV antiproton production cycle takes approximately 2 seconds to complete.

The ACNET variable name for the horizontal H1:MI_IPM is IPMM1H, IP name mi10hipm.fnal.gov. The horizontal IPM is located immeadiately downstream of Q 102 with cabling to electronics located in the M-10 service building, specifically MI-10105 and MI-10106.

The host computer is an Apple Macintosh PowerMac 9500, powered by a PowerPC G3 CPU with operating system OS 8.6. The interface software is LabView version 5.1.1, and Timbuktu version 4.8. The ACNET variable name for the horizontal H2:MI_IPM is IPMM2H, IP name ipmm2h.fnal.gov located at MI-10. The host computer is an Apple Macintosh PowerMac 9500, powered by a PowerPC G3 CPU with operating system OS 8.6. The interface software is LabView version 5.1.1, and Timbuktu version 4.8. The MCP bias scheme can be seen in **Figure X.**, and consists of the gated MCP1 triggered by a fast high voltage pulse generator. There is an additional power supply that can be remotely controlled in order to vary the MCP bias voltage. The voltage between MCP2 and the anode strip is held at 100V by means of Zener diodes. The MCP voltage as defined as MCP_V in the measurements, is across the entire bias scheme. The raw data for each turn generates a histogram reflecting the charge collected on the anode strip. A non-linear Gaussion fit is performed, where sigma is the rms of the fit. The emittance is calculated as:

$$\varepsilon = (6*\sigma^2)/\beta$$

where σ is from the gaussian fit, and β is the beta function of the machine. For the analysis, ACNET variables I:H2MCPV, I:H2MCPV, I:H1PMEM[], I:H2PMEM[], I:H1PMSG[], and I:H2PMSG[] were data-logged at node TeVJa on a circular buffer. The circular buffer began recycling its period and overwrote stored data ~ 3 days. ACNET variables that are followed by brackets are array variables. The indices for the arrays correspond to specific turns in the MI, based on the data acquisition settings specified on the LabView interface. The corresponding turn number for the two different settings are summarized in table X. The range of setting A is the section prior to the ramp, where the beam stabilizes and circulates in the MI. The range of setting B is throughout the entire acceleration process in the MI, just after injection and just prior to extraction to the Pbar target. After the measurements were taken, the raw data was extracted from the data-logger and conditioned for data analysis purposes. It should be noted that many factors determine the depth of quality a particular profile will have. Such factors are the quality of the vacuum during the acquisition, beam intensity in the ring, voltage of the clearing field, and MCP gain Microchannel plates will suffer in a decrease in gain, based on the extracted charge. The MCP's suffer permanent gain loss, which is proportional to the integrated output charge density. Therefore in order to maximize the efficiency of the device, and to ensure it performs optimially in the instrumentation, the bias voltage is only applied when an aquistion is to occur.

Electronics Test Bench

There are several properties of the CKM QTBB board that need to be understood. Such as the noise floor of the device in calibration mode, noise characteristics under specific cable configuration conditions, linearity of QIE in calibration mode, phase sensitivity, and electronics cross talk. The specific cable configurations of interest are that of 50Ω cables of several hundred feet connected to signal and reference, cable connected to signal and no reference, and cables attached to shielding mockup.

In order to determine the noise floor of the board studied, the gain factor for each integrating capacitor had to be determined. The circuit used for the test is shown in **Fig. X**. Two 50Ω resistors were used to prevent resonances with a standard RG-58 co-axial cable. The capacitor was used to filter out any introduced noise, while the 3.2MΩ resistor provide the injected current. A voltage of 0.787 V was measured across the input to the QIE ASIC, while a variable DC voltage was used to inject current into the system. It should be noted that for these measurements the QIE pedestal voltage is programmed at its highest setting. Reduction of this parameter is possible by re-programming the chip, by changing an on-board DAC. A change in the LSB of the DAC correspond to a 0.4 bin in the pedestal, where an increase in the LSB corresponds to an increase in the pedestal and vice versa. The voltage was increased in a linear fashion, where the response was noted for each cap_id. The injected charge was calculated and plotted against the QIE output along with the short circuit value of the circuit (no current flow). The gain for each cap_id as given from the experiment is shown in **Figure X**.

Once the weighting factors have been determined, it was desired to see the noise characteristic of the board for varying input capacitiances. The following configurations were of primary interest: input capacitance to the signal input only, the reference input only, and capacitance input to both signal and reference. The results for signal and reference input capacitance only yielded similar results are shown in **Figure X.** These results were not expected, and are subject to further investigation. However, the configuration that is of primary interest is that of both signal and reference having an input capcitance. This is the type of configuration which is to be used in the TeV IPM. The result of this measurement is shown in **Figure X**. Common mode noise appears to have been eliminated due the differential characteristics of the QIE. The noise as calculated with the weighting factor for each cap_id is given in **Figure X**.

The next study conducted was to see the noise characteristics of adding cable to the board. To simulate the conditions of the TeV IPM, 100Ω twisted pair cable was used. The length of the cable was 3.75m with a capacitance of 265pF. A reoccurring issue that arises is that of how to handle the ground and the signal return. Several different schemes were explored to investigate the effect they had on the noise. The first configuration was connecting two cables to the signal and reference, with the end floating. The next configuration was to have the outer shield of the cables connected. Next the shield and signal return path for each cable was connected together. Finally, two 50pF capacitor were connected to the end of the cables, with a common node being the shields for both cables, with one end of each cap connected to this node. The other end of the cap was connected to the signal path. It should be noted that for all measurements the second signal path of the twisted pair was connected to the shield; only one of the signal wires in the twisted pair was utilized. The histograms of the output are given in **Figure X**. The pedestal value, along with RMS and error are provided in **table x**.

The pedestal value was then decreased from a mean of 19.5 to 12.7 counts. The input impedance was increased from 50Ω to 93Ω. The gain factor for the capacitors was found using a circuit identical to that used in **Figure X**. A variable DC voltage was used to inject current into the system, where the measure voltage across the QIE was given at 0.786 V. The injected charge as calculated, is plotted against in output in **Figure X**. The gain factor for each capacitor, in addition to the channel gain factor is given in **Table X**. The calculated noise floor of the QIE in this configuration is 3123e. The histogram is shown in **Figure X**. The noise for each cap_id is given in **Table X.** For comparison, the noise floor of the QIE with a pedestal of 19.5 counts, input impedance 50Ω has been provided with the summary. The next configuration of the cable investigated was to have the signal return and cable shield common for both cables, connected to the signal and reference inputs, where the noise is given in **Table X**. The last configuration examined was to have one twisted pair cable connected to the signal and reference inputs, where the shield is common to both inputs. The measure noise is also given in **Table X**. Diagrams for each cable are provided in **Appendix X**.

For IPM H1, the circuit board consists of 120 signal anode strips situated on 0.5 mm centers, directly below the MCP. The amplified electron charge is detected on the anode strip, where the signal is then amplified, digitized, and saved into memory in order to produce single pass profiles and histograms. The raw data signals are sent from the enclosure to the MI10 service station by several hundred feet of 50Ω cable. The signals are then fed into an amplifier assembly, then to a 12 bit, 4 channel Omnibyte Comet 2 MS/s VME digitizer. In the end, 64 channels are digitized at a turn by turn sample rate to provide 64K profiles. The data is read from the digitizers and data analysis is performed by a MacIntosh 9500/150 using National Instruments PCI-MXI interface and LabView software. The instrument in the service building is remotely accessed and controlled by means of an Ethernet connection to the Fermilab ACNET control system. In addition, access is possible by means of commercial proprietary packages such as Farallon Timbuktu. [2] The Main Injector IPM utilizes Extended Dynamic Range glass MCP's originating from Galileo corporation. The specifications provided are for a bias voltage of 1000V, with a bias current of 420μA, with a gain of 2.6E4. The clearing field operates at 28kV and collects positive ions. [1] The system is timed to observe approximately 1μs of beam, based on a set time delay from each revolution marker.

results
. It should also be noted that the noise pick-up in the relatively long cables considerably degrades the signal to noise ratio.

The front end electronics for H1 and H2 are similar

Because the design of the existing IPM's are significantly different than the design for the Tev IPM, the details surrounding the apparatus, operating conditions, and specifications will be discussed for differentiation.

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