Third Generation Residual Gas Ionization Profile Monitor At Fermilab*

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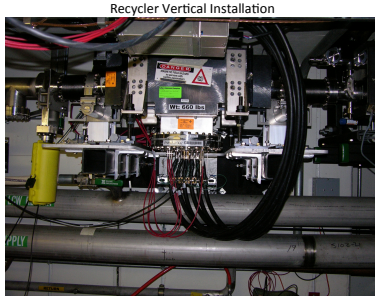
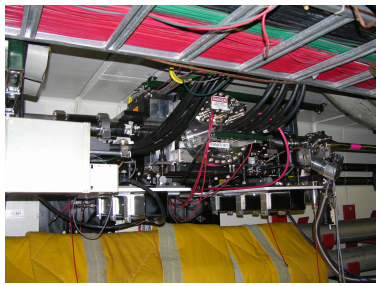
Abstract

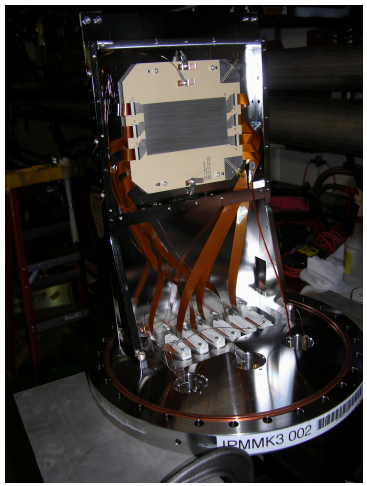
The latest generation of IPM's installed in the Fermilab Main Injector and Recycler incorporate a 1 kG permanent magnet, a newly designed high-gain, rad-tolerant preamp, and a control grid to moderate the charge that is allowed to arrive on the anode pick-up strips. The control grid is intended to select a single Booster batch measurement per turn. Initially it is being used to allow for a faster turn-on of a single, high-intensity cycle in either machine. The expectation is that this will extend the Micro Channel Plate lifetime, which is the high-cost consumable in the measurement system. We discuss the new design and data acquired with this system.

Recycler Vertical Installation



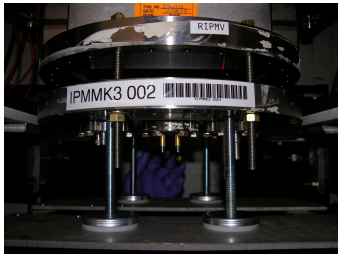
Recycler Horizontal Installation



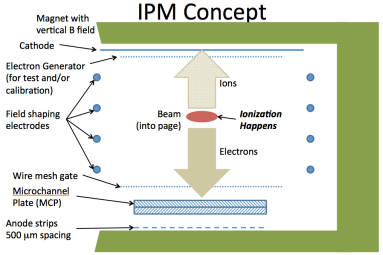


Assembly Removed for Maintenance

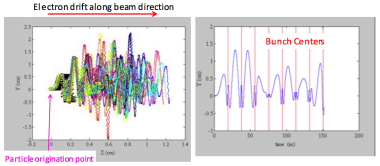
Setup for Removal for Maintenance



IPM Concept



Drift trajectories of electrons with the control grid gated off. The plot on the right shows the trajectory of a single electron where one can see the constraining of the trajectory that occurs when a proton bunch passes by.



* Operated by Fermi Research Alliance, LLC under Contract No. De-AC02-07CH11359 with the United States Department of Energy.

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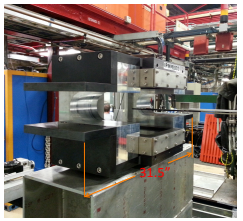
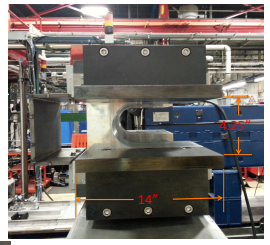
Magnet Design

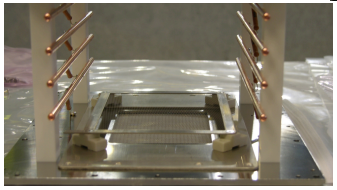
Designed using $SmCo_5$ permanent magnets. A standard brick is 1" by 2" by 1/2".
The magnet is 1 KG in the detector area, with the return flux half upstream and half downstream, The beam sees a total integrated field of zero.
The magnet is 31.5"L x 14"D with a minimum aperture of 4.25" to allow for a 4" diameter beam pipe suitable to both horizontal and vertical planes in the Main Injector and Recycler





Anode Strip Board

The anode strip pick-up board for both Main Injector and Recycler is a ceramic circuit board with 120 copper strips spaced at 0.5mm.
The copper occupies 80% of that pitch with 20% space between strips.
All signals are connected via 20 pin, ceramic mounted, quick release connectors.
A "Flash Test" strip has been added to the bottom of the board to facilitate testing of the full analog signal path integrity.



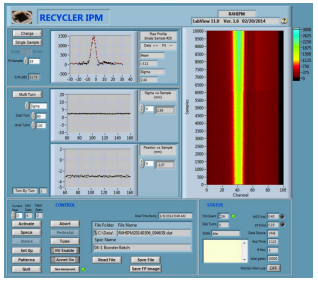
Control Grid

Control Grid is placed on the beam side of the MCP's. The function of this control grid is to trap electrons and force them either upstream or downstream, outside of the detector area.
The grid material is electroformed nickel, 20 lines per inch with 0.00363" diameter wire, and open area of 86% .
The control grid is kept at the full clearing field voltage until the batch of interest is passing through the detector. It is then pulsed to ground to allow the electrons to pass, un-deflected, on to the MCP.
The capacitance of this grid is such that it can be pulsed with a rise time of 100nsec. The external cable adds approximately 190nsec per meter.

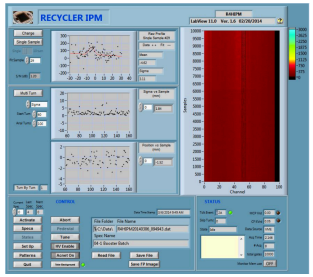
Control Grid Test

The electron drift velocity along the proton beam line in the simulation is ~8 cm/ms compared to ~10 cm/ms estimated analytically assuming a uniform electric and magnetic field and no protons. This velocity implies that the ionized electrons will drift out of the region of the MCP in ~1 ms.

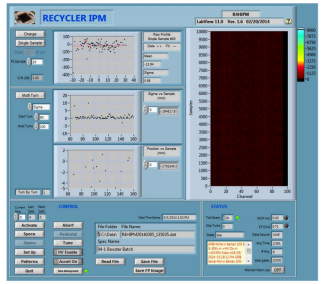
Grid Grounded for Normal Acquisition.



Grid Held at 10 KV.

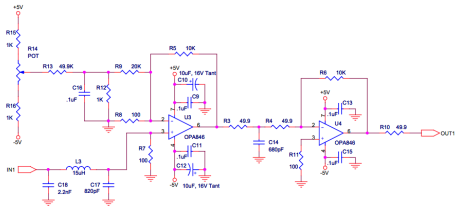


No Beam



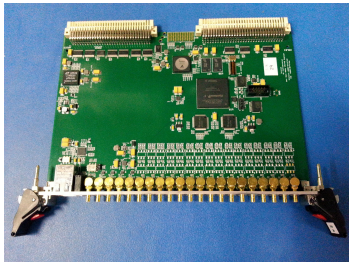
Pre-Amplifier

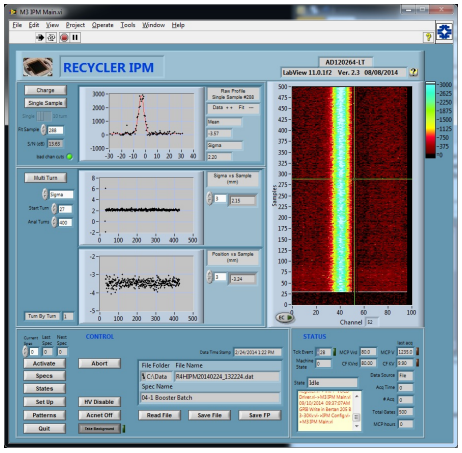
Redesigned preamplifier that lives within 2 meters of the detector.
The amplifier was designed with a 100 ohm input impedance, a bandwidth of 1.2MHz providing sufficient rise time for the 1.6 µsec batch length and high frequency signal rejection (53 MHz).
An OPA846, was chosen for the two stages for its low input voltage noise, high bandwidth, dc accuracy and output drive.
The amplifiers have an overall voltage gain of 5K into 50 ohms and an input impedance of 100 ohms that together form a trans-impedance of 500 kOhm.
The analog front end is +/- 1.5 Volts full scale.
Input of the amplifier is a 1.2 MHz low pass filter to reduce the beams 53 MHz signal that couples onto the strips, this was measured to be less than -80dB.



Analog to Digital Converter

VME Analog to Digital Converter's (ADC) have 16 channels of 14 bit 80MHz parts.
Field Programmable Gate Array (FPGA) that allows us great flexibility to sample multiple times during a gate that is centered on the batch of interest.
The sample depth is limited only by the amount of memory installed on the board, and the processing time desired for a result.
The FPGA has a Magnet Data (MDAT) Reference Frame Decoder that supplies our system with the intensity and energy of the beam in the machine at the time that the analog data is sampled.
A total of 96 Channels are digitized to create the beam profiles.





LabVIEW™ User Interface

2D display now has XY cursors enabled. When the Y cursor is moved, the new sample number is captured and used to initiate a single turn analysis. The X cursor destination (channnel) is displayed below the X axis scale as an aid for identifying individual channels of interest .
There is now a running total stored and displayed that represents the amount of time high voltage has been applied to the micro channel plate. The S/N (db) is provided to help analyze micro channel plate lifetime.
A MCP accumulated plate charge correction button is available for the 2D display. This correction assumes there is no significant change in amplitude, sigma, or position from the reference sample (default sample 500).
Channel data values above or below predetermined limits are now automatically eliminated from display in the Single Turn analysis plot. Limits are established using the specifications of the ADC and the expected normal data range.
Channels outside this range are still represented in the 2D raw data display.
Position and sigma FFT data is now reported to ACNET devices in addition to the front panel display.