Upgrades to the Ionization Profile Monitor Systems at Fermilab

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I. INTRODUCTION

The practice of high energy physics requires the precise alignment of particle beams. Greater precision allows higher luminosities[1] and thus greater chances of seeing rare events or gathering good statistics on well known processes. Here at Fermilab, protons and anti-protons ($\overline{p}$) counter rotate and collide at two interaction regions around the Tevatron. One at the Collider/Detector at Fermilab (CDF) and the other at the DØ experiment. To determine beam position and to assure beam quality, monitors of different functions are employed to determine the beam's position, its emittance and parameters about the individual buckets[2] There are many different types of monitors used on the accelerator complex. The Ionization Profile Monitors (IPMs) are a mostly unperturbative approach to measuring the distribution of particles within the buckets. The goal of the summer project was to upgrade the IPMs to be run in LabVIEW 5.1.1 proper. There are seven IPM systems located throughout the accelerator complex. A horizontal and vertical IPM are implemented on Booster, Main Injector and the Recycler Ring and a Mark II Horizontal IPM[3] is installed on Main Injector. The virtual instruments (VIs) used to run the IPMs were originally written in LabVIEW 4 but were run in 5.1.1. With LabVIEW 5 came an advanced error reporting scheme using error clusters that would report to the user the error status (a boolean), an error code (an integer) and a source string detailing where the problem occurred. Once the new error clusters were incorporated into the VIs running the Mark II Horizontal IPM on Main Injector and standard IPMs on Booster, the VIs running all three Main Injector IPMs and the two on the Recycler Ring were combined into one VI.

II. SYSTEM SPECIFICS

The IPM systems rely on the residual gas that exists in the beam pipe to function. When the beam passes through the residual gas, some of the gas gets ionized. The standard IPMs (which is the type of IPM except the Mark II on

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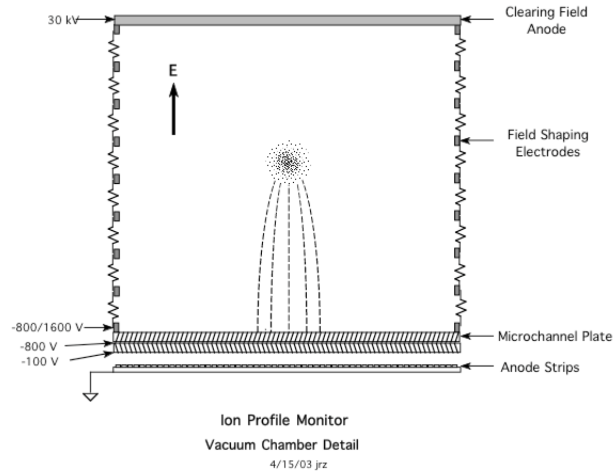

FIG. 1: A diagram of the standard IPMs.

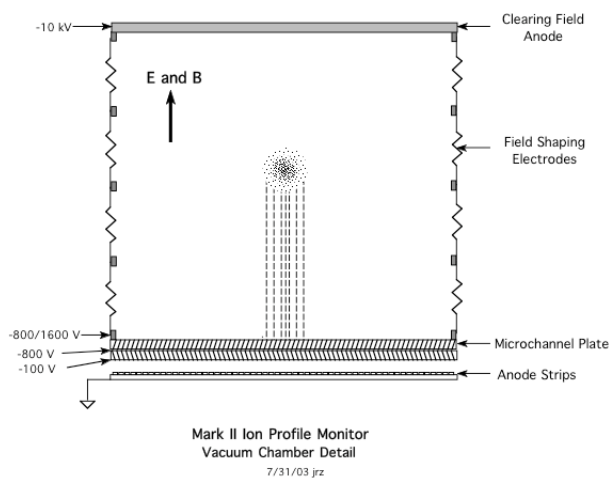

FIG. 2: A diagram of the Mark II Horizontal IPM.

Main Injector) use a clearing field voltage to force the positive ions onto a dual chevron micro-channel plate. The dual chevron nature as seen in Figure 1 is used to enhance the ion showering that occurs when the first ion hits the inside of the plate. The micro-channel plates are designed like an array of little photomultiplier tubes. The plate has little glass tubes that have a bias offset of vertical in that the tubes are about 8° from being vertical. When an ion hits the inside of the tube, it causes more ions to be released which are pulled further into the tube by an electric potential. When these ions strike the surface of the tube, more ions are ejected and this cascade effect continues until the ions strike the anode strips and are read off as a current.

However, the design in Figure 1 suffers from space charge effects. When a positive ion is created by passing protons (or negative ions for passing $\overline{p}$'s) they are repelled by the electrostatic charge of the passing particles. Thus spreading is induced as seen in Figure 1. A newer design of IPM that has been instituted on Main Injector is the Mark II Horizontal IPM. This IPM has a permanent magnet that has a magnetic field (B-field) parallel to the electric field as seen in Figure 2. The static B-field acts as an ion stabilizer, much like earth's magnetic field for incoming solar particles. When the ions are created they rotate around the magnetic field lines helically since they are being driven by an electric potential onto the micro-channel plate.

The current from the anode strips is then read off and digitized by Comet Quick Digitizers. The signals are then passed through a VME controller to the computer controlling the system via LabVIEW. LabVIEW processes the raw

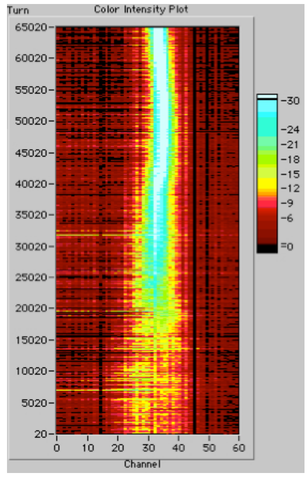

FIG. 3: A sample data spectrum from the Mark II Horizontal IPM showing the beam profile.

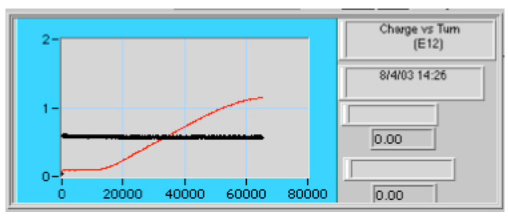

FIG. 4: A sample of the charge vs. turn plot generated by the VI running the Mark II IPM.

data into a profile of the beam, which is then displayed in a 2-D color coded plot as in Figure 3. The bottom axis is the channel number (1-64) which corresponds to a specific anode strip and the vertical axis is the turn number which is usually set for the maximum number of turns that the beam is in Main Injector which is 65000. The color of the plot corresponds to the intensity of the beam on that channel according to the scale on the right side of the plot. The program also produces three other plots useful in determining beam specifics.

The first plot is the charge vs. turn a sample of which appears in Figure 4. The second plot that is generated is one of the standard deviation of the Gaussian nature of the beam (sigma) vs. turn. A sample of this plot is seen in Figure 5. As the beam passes through main injector it undergoes synchrotron damping that damps the emittance[4] of the beam and this is reflected in the exponentially decreasing form of the plot. The position of the beam is an important parameter and is the third plot generated. From this plot, drifts in the beam position can be discovered and corrected.

Buttons on the front panel of the VI allow the user to save the data file, or to save just the sigma array. These files can then be read back into the VI allowing the user to view previously collected data.

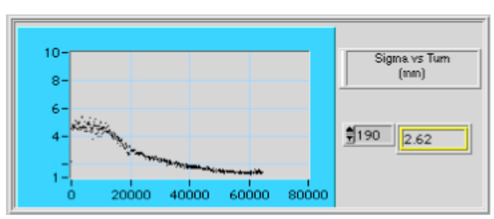

FIG. 5: A sample of the sigma vs. turn plot generated by the VI running the Mark II IPM.

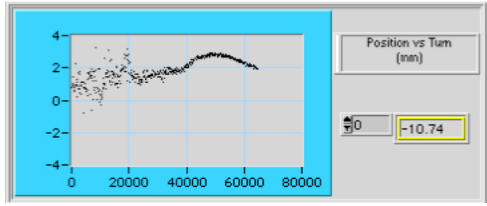

FIG. 6: A sample of the position vs. turn plot generated by the VI running the Mark II IPM.

III. UPGRADE DETAILS

New to LabVIEW 5 were error clusters that allowed error reporting that was more advanced than previous versions. The new clusters would report the status, the error code (bundled with LabVIEW is a VI to decode the code for more specifics on the error that occurred.) and a string detailing where the error occurred. Since the original VI was written in LabVIEW 4, these new error features were not included in the VI. The first upgrade to be done was to add the error clusters into the MIPM Operator FP VI that runs the system. Upgrading involved moving sequentially and hierarchically through the diagram of the VI and replacing old instrument I/O functions with the new ones that had error reporting. The instrument I/O consisted of VXImove, VXIout, VXIin and VXIoutreg in the VXI high level commands. The GPIB commands used to communicate with the Bertan power supplies were also replaced. These were found mainly in the section of code dedicated to taking and transmitting data but were found in other sections of the code as well. Once an old function was found, it was replaced with a new one and the error was wired through the rest of the VI or sub-VI and the connections to the VI were altered to allow the calling VI to feed and retrieve error.

Once the error blocks were correctly added to the Mark II IPM the same process was repeated on the Booster IPM systems. Upon completion of the Booster upgrades the three systems on the Main Injector were combined into one VI. There were several steps to this integration. The first was to manually compare the Mark II VI with the standard horizontal and vertical IPM VIs. A large majority of the differences were found in the IPM setup sub-VI. The original sub-VI in the Mark II IPM was altered into a generic IPM set-up VI. The input parameters that differ among the systems were placed within case structures. The value sent to the case structure was determined by a global variable (IPM system.vi) that was set when the Acnet top level VI was run. The Acnet top level searches the ”Data” hard drive that is present on all five systems for a file called ”system.txt” and then reads the characters found in the file. It sends those characters to a case structure that sets the global variable to the appropriate setting for the system it is on. The user will be able to detect if the correct system has been selected by the system string that is displayed in the top right of the front panel. It will display the name of the system that it is on. This VI integration scheme was adopted so that when the Acnet top level VI is launched, the system on which the VI is run is automatically selected thus reducing the need for the user to select the system and streamlining remote startups.

In the near future, the goal is to upgrade the Macs that these systems run on to PCs running either LabVIEW 6.1 or 7. The PC that runs the synchrotron light monitors at CØ was used to update the combined Main Injector VI into LabVIEW 6.1. This upgrade allowed the Code Interface Node “Alan's Magic CIN” to be replaced by a LabVIEW function that was new to 6.1. With the VI in 6.1, the IPMs on the Recycler Ring were combined into the Main Injector VI. Once all the computers have been upgraded to PCs running LabVIEW 6.1, an executable of the VI can be compiled and then five LabVIEW licenses can be freed for other tasks.

IV. FUTURE WORK

With the Main Injector and Recycler Ring IPMs combined into one VI and recompiled in LabVIEW 6.1, the next step would be to move the VIs onto rack mounted PCs. Two PCs have already been ordered and three more will be needed. Once the PCs have been installed the VI can be upgraded to LabVIEW 7 so that any future developments to it can take advantage of new features. Once in LabVIEW 7, executables of the VI can be compiled and LabVIEW removed from the computers to free up licenses. When future developments need to be made, they can be done a computer with LabVIEW and then the executable redistributed onto other computers.

Other future developments would be to replace the color intensity plot with a 3-D plot of the data, where the height of the array of data would correspond to the intensity of the beam. A request from a user of the Booster IPM would be to add the ability to take data over multiple triggers. Thus a set of data for multiple injections could be recorded. Also, to save life on the micro-channel plates (MCP), it would be useful to see if there was a way to ramp the MCP

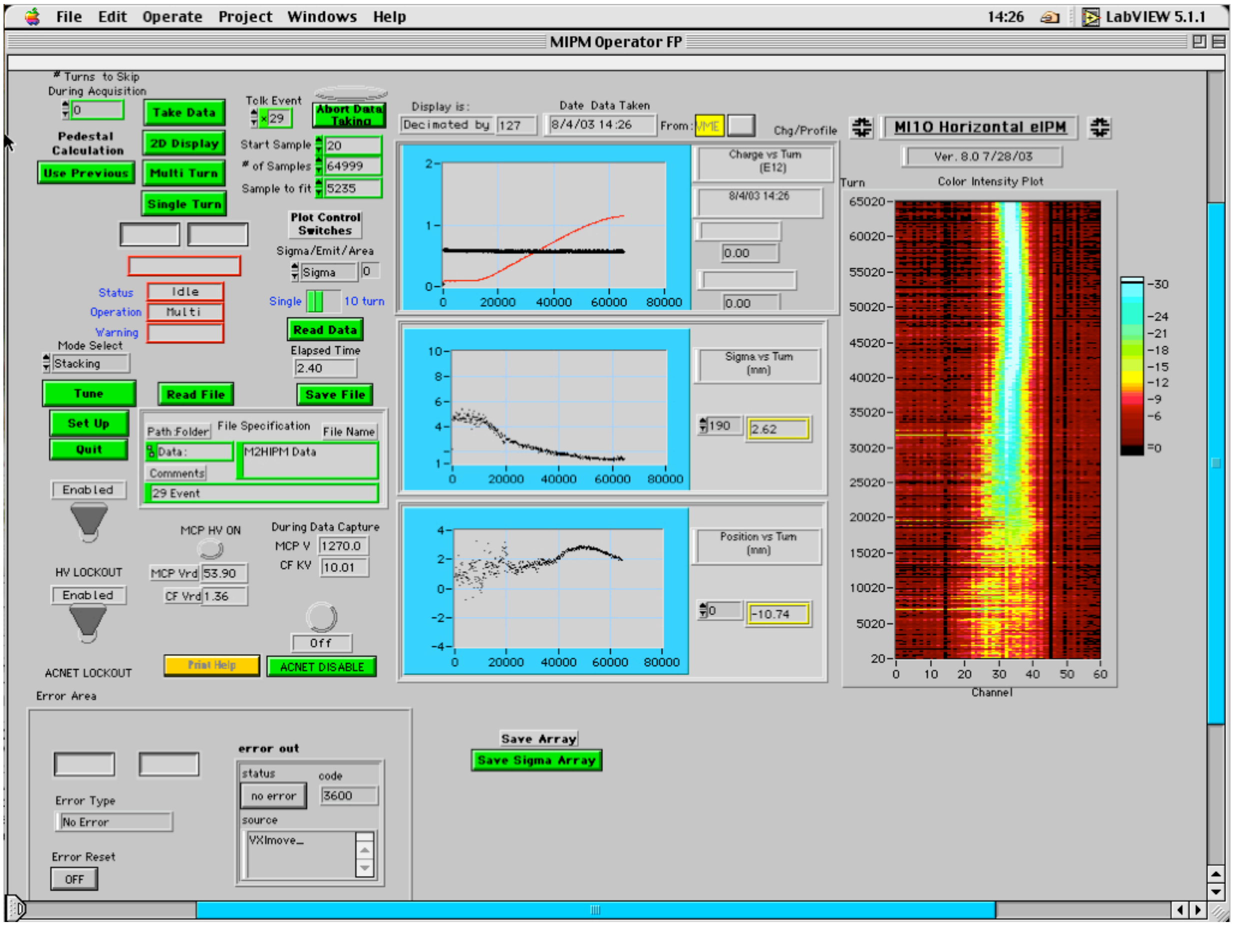

FIG. 7: The front panel of the IPM controller.

voltage when it detects the clock event. This may not be possible because there may not be enough time between the detection of the signal and the arrival of beam to ramp up the voltage.

V. USER'S GUIDE TO THE NEW IPM VI

A. Launching the VI

To start the program, locate the "Acnet IPM Top Level" VI on the computer and double click. The top level VI will load all of the appropriate sub-VIs, initialize the Acnet interface, and run the IPM operator.

B. Basic Data Taking

To time all of the events in the accelerator complex, a clock is used to transmit information as to the clock cycles that are being executed. These are hexadecimal numbers that correspond to specific events. For example, a 29 event is an injection event into Main Injector. If the IPM is set to take data on a 29 event it will wait for that signal to be sent and then it will activate and collect data from the anode strips which is sent to the quick digitizers and from there, through a VME controller board to the computer. From there it is analyzed to yield the plots mentioned earlier.

To take data locally (the VI is controlled through the front panel and not Acnet), Acnet must be disabled by pressing the "Acnet Disable" button. This will prevent an Acnet user from overriding local commands. To take data, a clock event must be typed into the clock event control box which is situated next to the "Take Data" button. The gain on the MCP usually needs to be increased from 1200 V to 1270 V. This is done by clicking on the setup button, and in the control box labeled "CirPkV" enter the new value, click the button marked "Set New Values" and then the "Return to Main Menu" button. When the front panel appears, click on the "Take Data" button. This will check the power supplies, wait for the clock event, take data and then display it. If at any point a cancellation of data taking is desired, the "Abort Data Taking" button can be pressed to terminate that process.

C. Saving and Reading Data

There are two functions to save the data. The "Save File" button will save the complete set of data to a file with a filename that indicates which system on which the data was taken along with the date and time. The button to the right of the Error Panel labeled "Save Sigma Array" will save an array of the sigma data that appears in Figure 5. The filename for that data has a time and date stamp as well as the data that was taken. To read this data, a binary string translator is needed. One was written by Eugene Lorman and may be requested from him.

To read a full data file, press the "Read File" button, select the data file to be read in, and press "OK." The data file will then be loaded and all the appropriate plots will be generated.

D. Data Manipulation

Once Data has been collected, or read in from a file it can be manipulated. The default setting is to display all plots on a multi turn basis. However, to inspect the quality of data turn by turn. To activate this feature, press the "Multi Turn" button located below the "Take Data" button. This will allow scrolling through the data in the plots turn by turn. The number of turns that are displayed on the color intensity plot can also be changed. This is done by changing the numbers that appear in the "Start Sample" and "# of Samples" control windows. The "Start Sample" is the lower bound on the plot and the "# of Samples" is the upper bound. Pressing the "2D Display" button will cause those changes to take effect.

The default of the bottom plot on the front panel is a sigma vs. turn plot but this can be changed by switching to a new plot by changing the preference under the "Plot Control Switches" sign. Once a new preference is set, the changes can be enacted by pressing the "Read Data" button.

VI. ACKNOWLEDGMENTS

My work this summer has not been done solo and so there are a number of people that I would like to thank. First I would like to thank Eugene Lorman for being my direct advisor, teaching me about LabVIEW, and assisting me when I would get stuck. I would also like to thank Jim Zagel for helping me with the upgrades and being the IPM guru; Stephen Pordes for requesting me to come work for the Instrumentation department and Erik Ramberg and Roger Dixon for organizing the Internship for Physics Majors program.

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[1] Luminosity is an interaction rate per cross sectional area. The higher the luminosity is, the more interactions will be recorded.
[2] Such parameters include the buckets' intensities and distribution of particles.
[3] The Mark II used a permanent magnet to generate a B-field to capture freed electrons, other IPMs do not use this technique
[4] The area of the beam in phase space.