Improving Resolution in Ion Mass Measurements in the Ion Mass Spectrum Analyzer

James Kilpeck[1], Mark Popecki[1], Lynn Kistler[1], Harald Kucharek[1]

University of New Hampshire, Durham

Introduction

The earth's magnetosphere is a region surrounding earth inhabited by many charged particles. These particles can originate either from the earth's own atmosphere or they can become trapped as the solar wind passes earth. These particles can interact with both electromagnetic waves as well as other particles via coulomb interactions. The CODIF instrument on the CLUSTER spacecraft is designed as a ion spectrometer for our magnetosphere. It is able to take energy-per-charge and velocity measurements to get time-of-flight data as well as directional measurements for ions that enter the instrument. From this data we are able to see what species of ions are present and from what direction they are moving within the magnetosphere. From this as well as other measurements made on CLUSTER we can find out exactly where these particles come from and how they interact. Modifications have recently been made to CODIF to improve its performance. One major change is the insertion of a new set of microchannel plates(MCPs). This research is done look at how these changes have improved the instrument, specifically azimuthal crosstalk as a function of the new MCP voltage

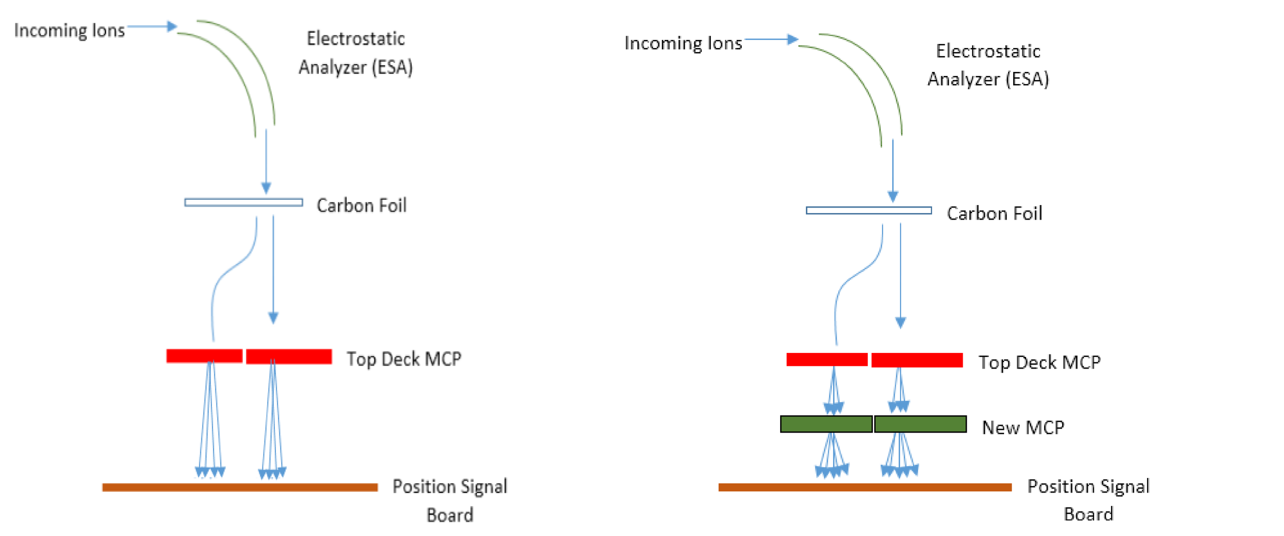
Instrument Operation and Methods

CODIF can differentiate between multiple ion species from their charge-to mass ratio as well as measure the speed of an incoming particle. The ion will hit one of eight pixels that form a circle around the instrument entrance section known as PF1-8. Each covers 22.5 degrees. Ions entering the instrument are sorted by their energy-to- charge ratio and are accelerated through a voltage called the PAC where they can then enter the detector section of the instrument. When particles enter the detector section they are steered to a carbon foil window where they will knock free an electron which will hit an MCP and will trigger a start pulse to begin the timing measurement. The ion will then hit an MCP to trigger a stop pulse. Knowing the energy per charge and the speed of a particle can allow us to determine its mass per charge. The freed electron will hit a the bottom deck MCPs which allow for electron multiplication and will spray electrons onto the signal board.

In the original setup of CODIF, we were seeing that as we increased MCP voltage (which increased the detection efficiency) we were seeing a large percentage of particle detection on adjacent pixels. With a second MCP deck near the bottom we hope to improve this by only having a few particles in the detector section, and then multiply them in the bottom MCP deck near the signal board.

Our goal is to test the new setup with a second deck of MCPs. We can compare mass and time-of-flight resolution between both setups. The second deck allows for:

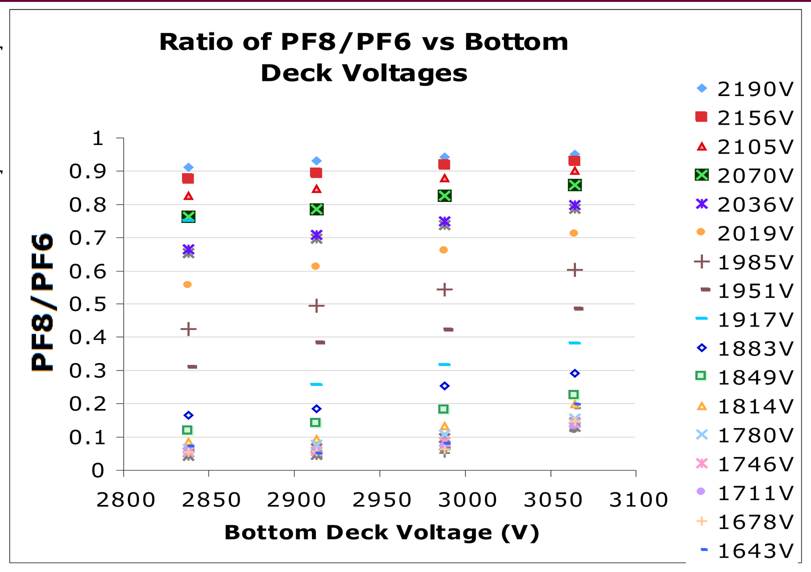
- More gain and hence better probability of detecting particles
- Most of the electron multiplication now occurs near ground
- Crosstalk between azimuthal pixels is minimized

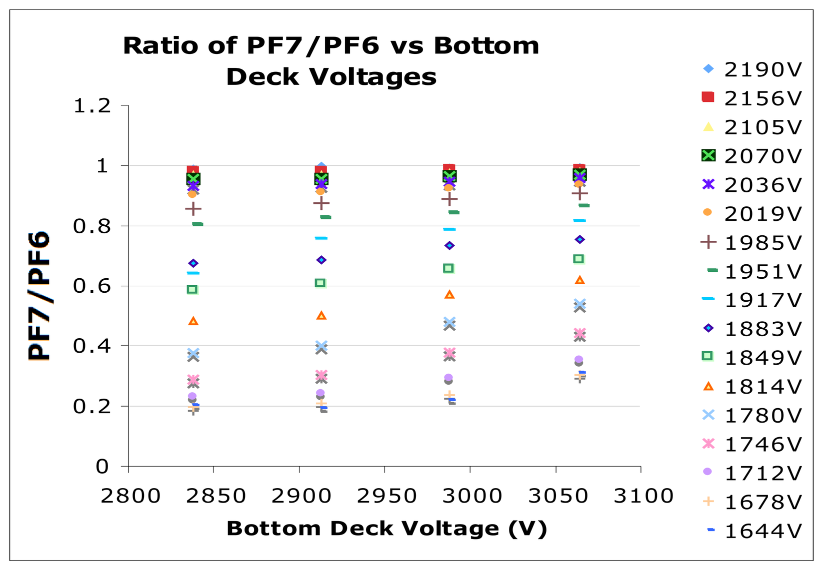


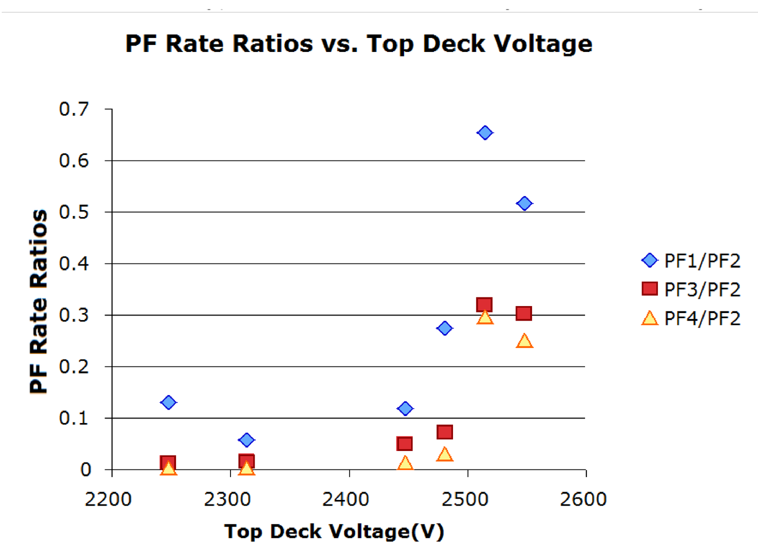
Above: The original setup of CODIF(left) has a larger charge pulse from the top deck MCP. Since the distance to the position signal board is far away, adjacent pixels see a lot of the same charge that the center pixel sees. Larger voltages on the top deck gives us better detection efficiency at the cost of a wider spread of pixel counts. The new setup (right) allows us to put very little gain on the top deck while having a large gain on the bottom deck, which is much closer to the grounded signal board.

Results

Right: These plots show the ratio of count rates for the pixel we expect to see counts on (PF6) over adjacent pixels over a range of different voltages on the bottom deck MCPs while the top deck MCPs remain at a constant voltage. These data are from the new setup of CODIF and ideally we want to see a smaller ratio compared to the old setup. Each color represents a different voltage on the top deck. One of the goals of the new setup is to be able to run the top deck MCP at low gain while getting better position resolution. We can see here that there is better resolution with lower voltages at the top while there is little correlation between the bottom deck voltage and adjacent count rates.

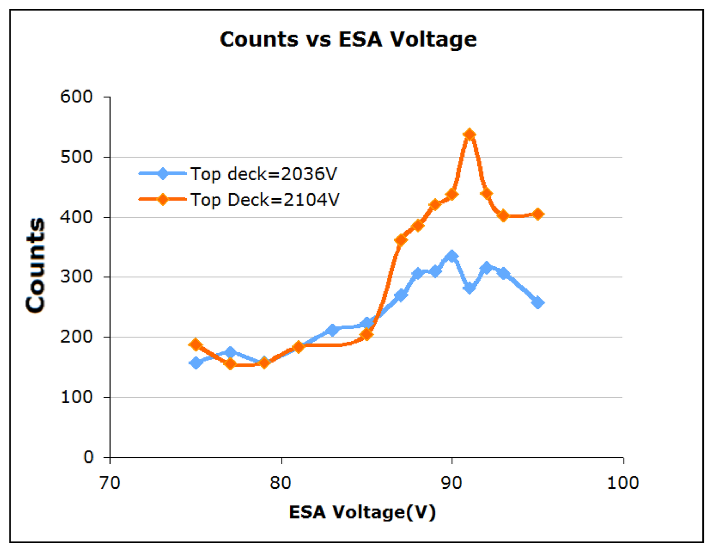


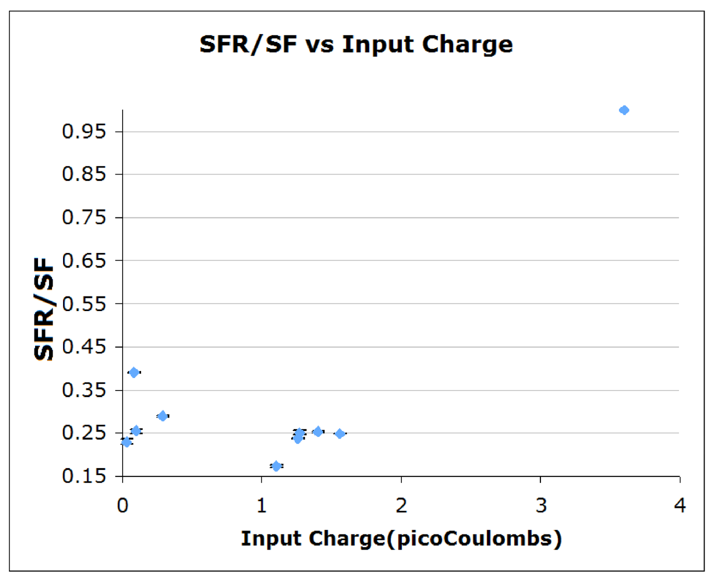




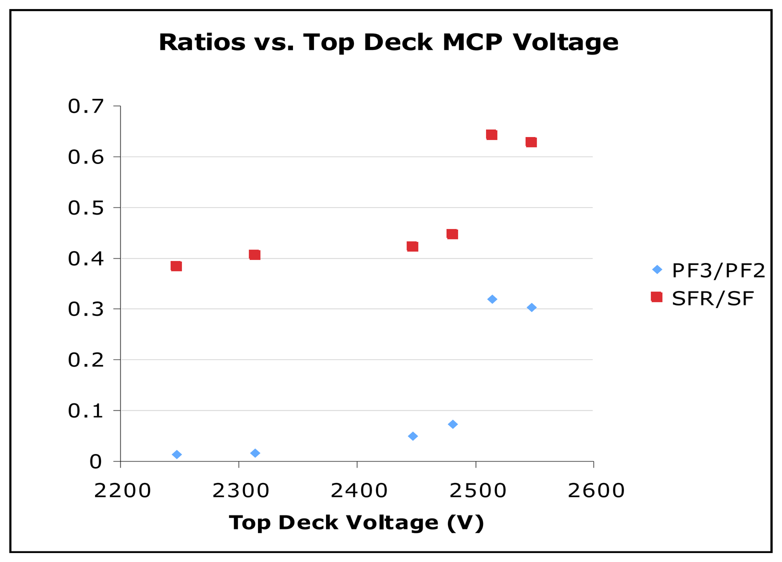
Left: Data taken from the original setup in CODIF. This shows adjacent pixel ratios over a range of MCP voltages. Ideally we should see all counts on PF2, but at larger voltages, the particles are triggering significantly more on nearby pixels. This disallows us from operating at high efficiency for this setup.

Right: Count rates were measured as a function of ESA voltages applied. We can see that setting the ESA voltage to about 91V allows for maximum count rates to be measured. Larger count rates allow us more accurately calculate ratios of incoming particles such as the pixels shown above or SFR/SF rates shown below.



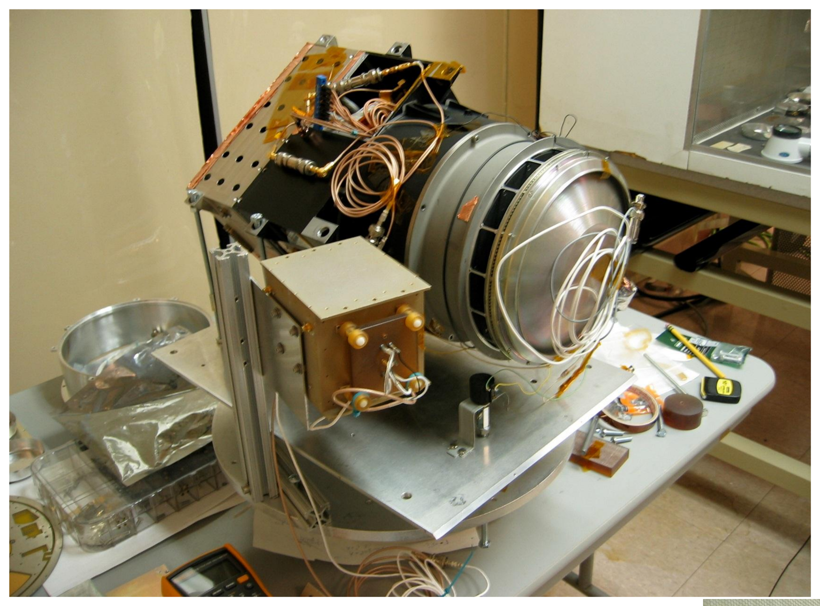


Left: Using a programmable BASIC Stamp board, we were able to apply a small pulse into the start and stop counters in the instrument. We get a count on SF whenever the instrument sees a start pulse and SFR triggers when both a start and stop pulse are seen. Here we have programmed the board to output 4 start pulse for every 1 stop pulse, we should ideally see SFR/SF=0.25 with this setup. With small amounts of charge the count rates are too small to get an accurate measurement, but around 1.25 picoCoulomb input pulses we are seeing data reflecting what we should see. For reasons still unknown, pulses above about 3pC we are seeing SFR counts that are equal to or larger than SF counts. Here, I have only shown one data point above 3pC to make the other points easier to see.



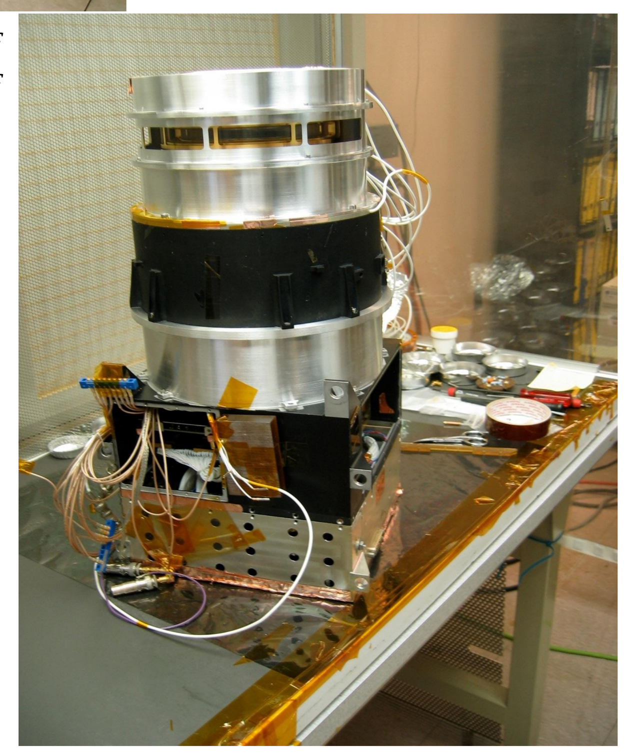
In the original setup for CODIF, the efficiency (SFR/SF) follows almost the exact same pattern as adjacent pixel counts. For this reason it is necessary to choose between position resolution and high efficiency. The addition of a new MCP deck will attempt to rid of this problem.

Instrumentation



Left: The original setup of CODIF. An ion gun is shown in the foreground which enables us to input particles into the entrance system at the front of the table. This allows us to reenact what the instrument will see while in space flight. All of the testing is done within a vacuum chamber

Right: Shown here is a picture of CODIF after the implementation of the new MCP deck. There are other changes that have been made such as a flux reducer which can be seen at the top of the instrument. The new MCP deck is located just above the square section seen in the picture surrounded by a metal ring.



Conclusion and Future work

Azimuthal Resolution

•Resolution was bad at top deck voltages above 2450V in original setup

•In the new setup, having lower voltages on both MCPs allows for low adjacent pixel counts. There is little correlation between bottom deck MCP voltage and adjacent count rates.

Probability of Particle Detection

•In the original setup of CODIF we get better efficiency at the cost of larger adjacent pixel count rates

•ESA Voltages around 91V will give us the most amount of counts

•Pulses above 3pC are triggering SFR more than SF. This has something to do with the internal electronics

FUTURE WORK

-Look at how much charge is being provided at different voltage configurations

-Figure out why SFR rates are falsely triggering above 3pC

-Find best combination of MCP voltages that allows for minimal adjacent pixel counts while still having good detection efficiency

Mass Resolution

•Replace the carbon foil with an MCP

•Compare efficiency tests for having one and two MCPs on the top deck