Low-Pressure IMS Construction

Clowers Research Group at WSU
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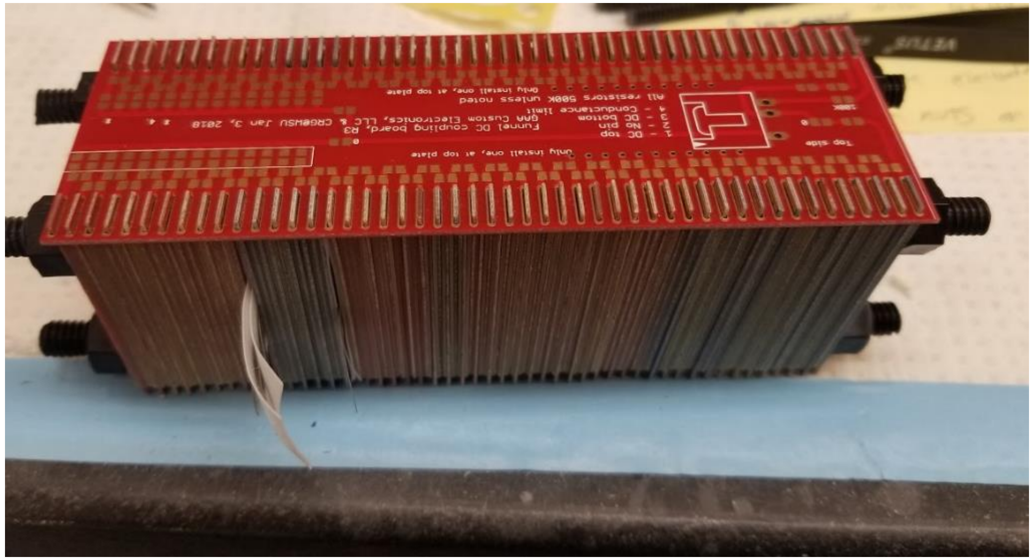
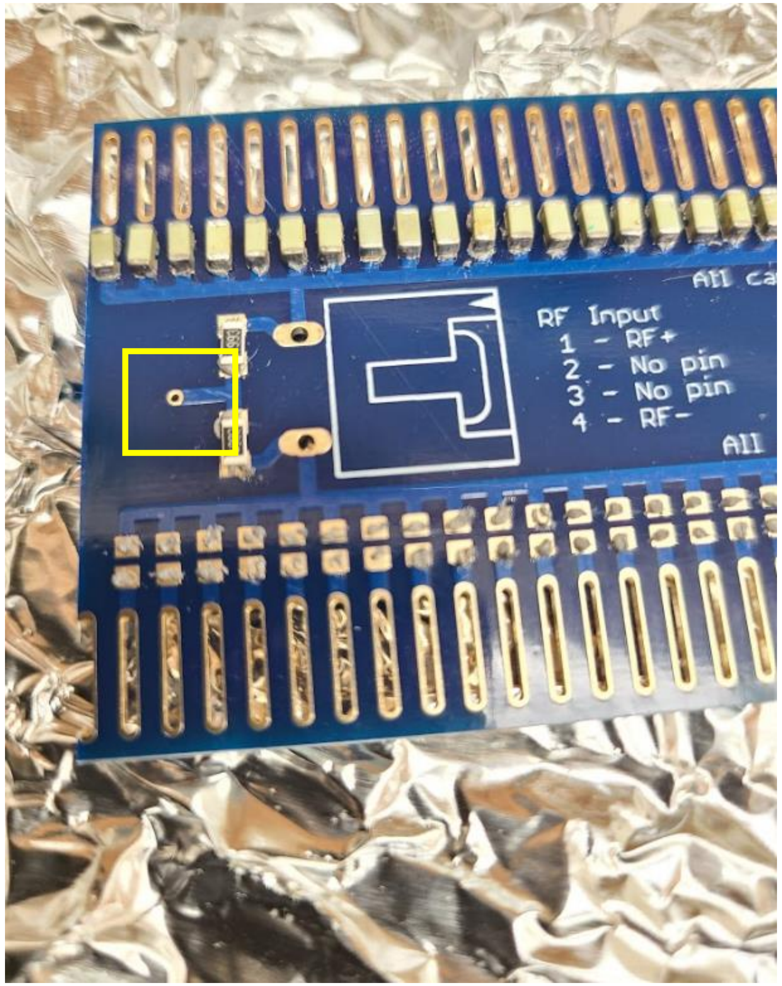
Low-Pressure IMS Construction: Front Ion Funnel

Front Funnel



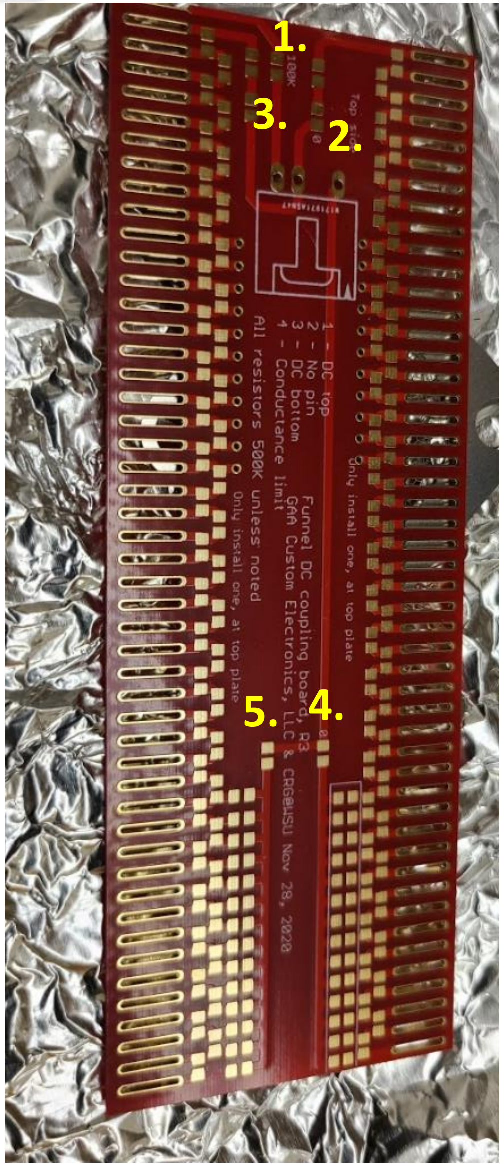
- Resistors are soldered into place, new funnel top board is designed to remove need for special resistors.
- Electrodes are soldered into place after careful alignment.
- Ensure any ion gates are in line (grid pattern overlaps cleanly)
- Adding spacers (~6) on either end of funnel helps to not compress the electrodes during soldering assembly.
- When applying the Molex in for DC in, out, and Conductance limit. Remove any unused pins from the connector.

Front Funnel RF Board



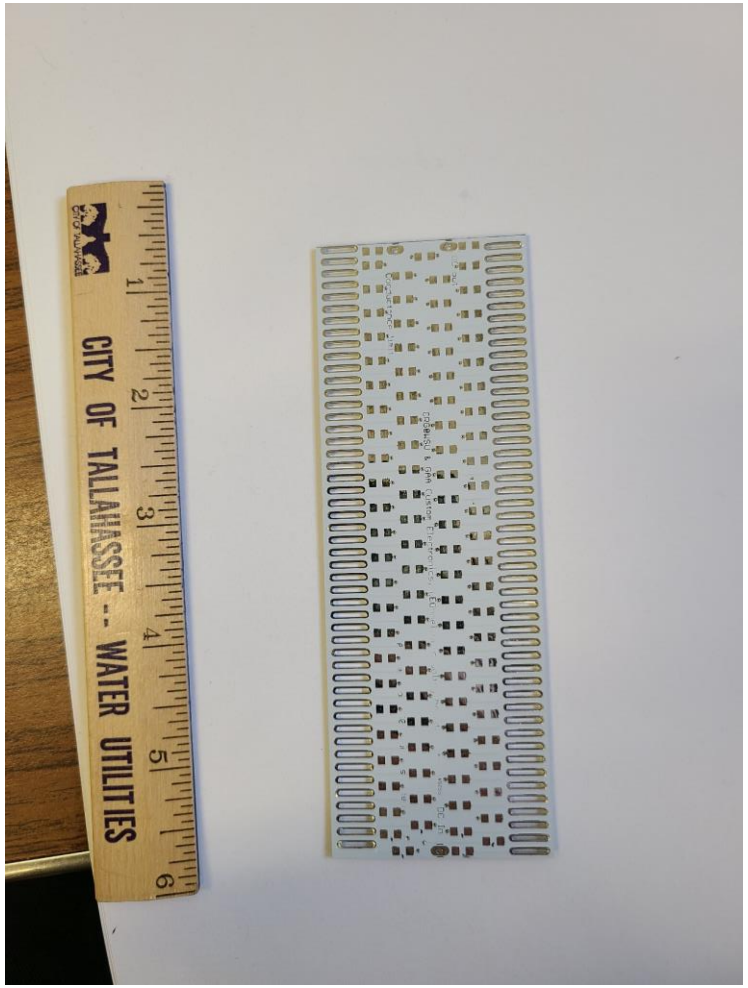
- Place capacitors carefully, solder electrodes at same time as DC board
- Ensure the two resistors are in place (resistors are of same size as DC board)
- If funnel is floated, connect a wire from middle of the DC board to the marked spot on the photo
- When applying the Molex in for RF in and RF out, remove any unused pins from the connector.

Front Funnel DC Board

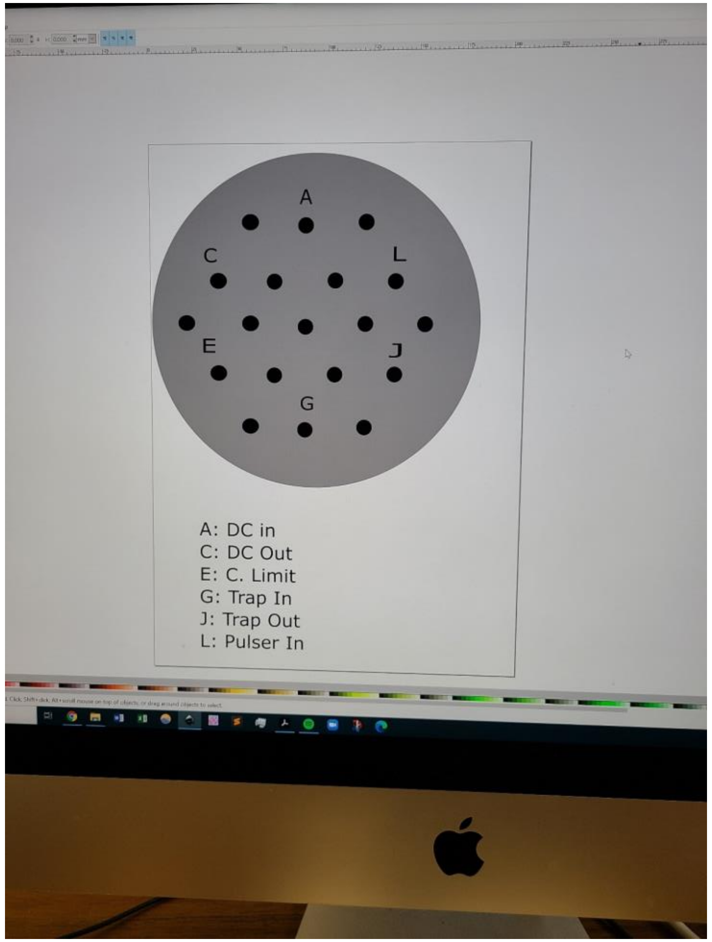


- Old board requires resistors of variable value in order to maintain correct voltages on both sides at marked locations.
- **1**.= 100 kΩ
- **2**.= 0 Ω
- **3**.= 250 kΩ
- **4**.= 0 Ω
- **5**.= 250 kΩ

- New board all resistors are the same.



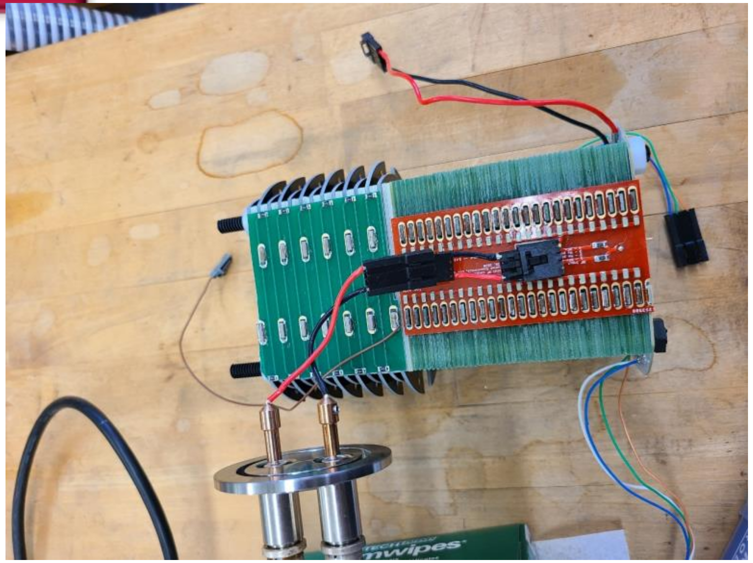
Front Funnel Electrical Connections

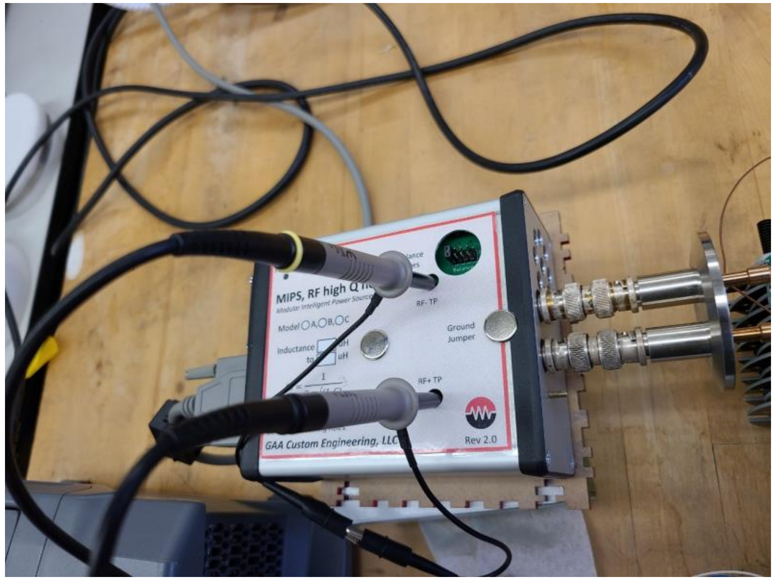


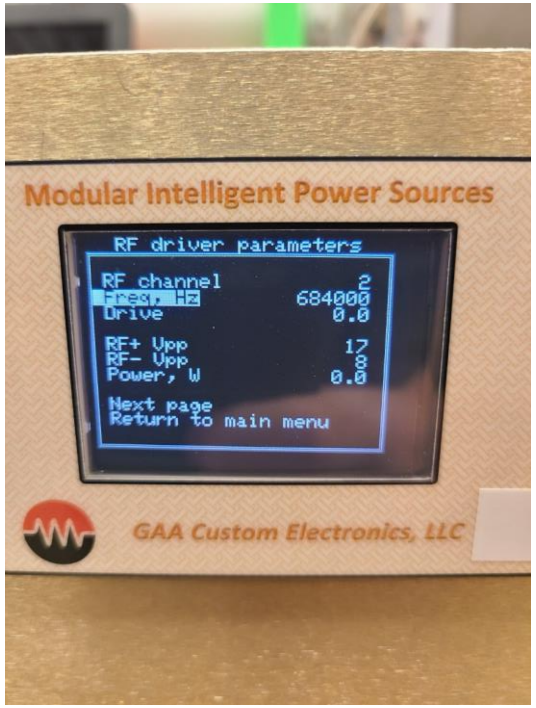
- Representative connections will change depending on electrical connectors used
- This schematic was for the original ion trap funnel that was designed
- Utilization of different configurations will change electrical connections, ensure proper documentation during assemble of electrical components.

Low-Pressure IMS Construction: Ion Funnel Testing

Ion Funnel Testing

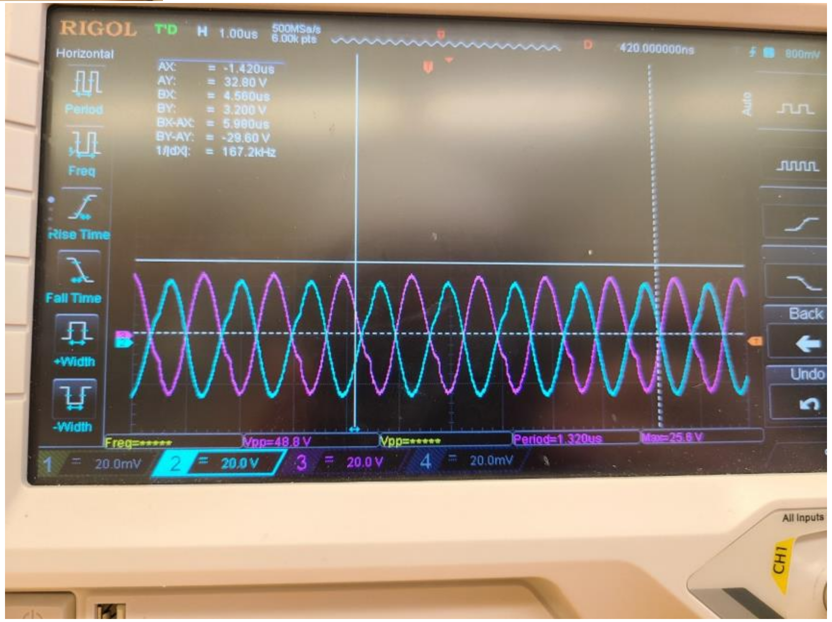






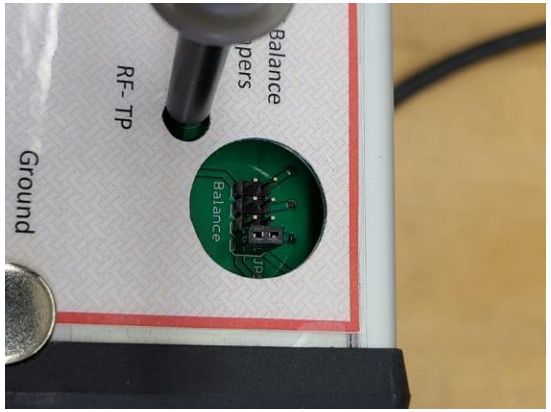
- Rear and Front ion funnel tested the same way
- Using the MIPS RF channel readout, ensure the drive is zero before connecting anything.
- On Benchtop, connect the RF power feeds to the RF quad driver (High Q head)
- Connect oscilloscope probes (10x attenuation ONLY) to testing points. Scale trigger levels and ensure voltage scale for the two channels are identical

Ion Funnel Testing

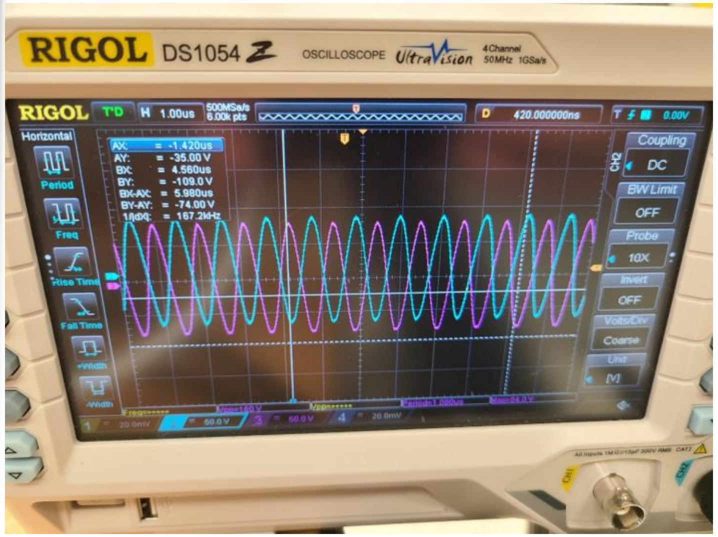


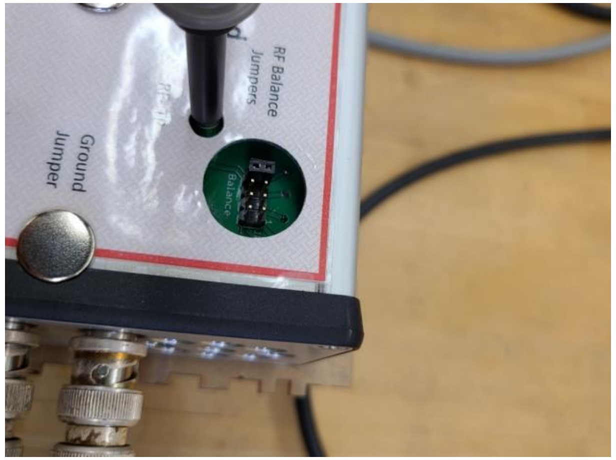
- Rear and Front ion funnel tested the same way
- Using the MIPS RF channel readout, apply a drive of about 20, which should be about 150 volts RF P2P
- Change the frequency of the system until the two traces are in relative alignment. Most likely between 750 kHz to 1 MHz
- Upper trace is at low RF and non resonant frequency.
- Lower trace is at correct frequency and RF voltage

Ion Funnel Testing



- Rear and Front ion funnel tested the same way
- After finding resonant frequency, turn off RF power and adjust the jumper to a different spot if needed
- Location of jumper might change resonant frequency slightly. Adjust frequency until the two traces are near identical

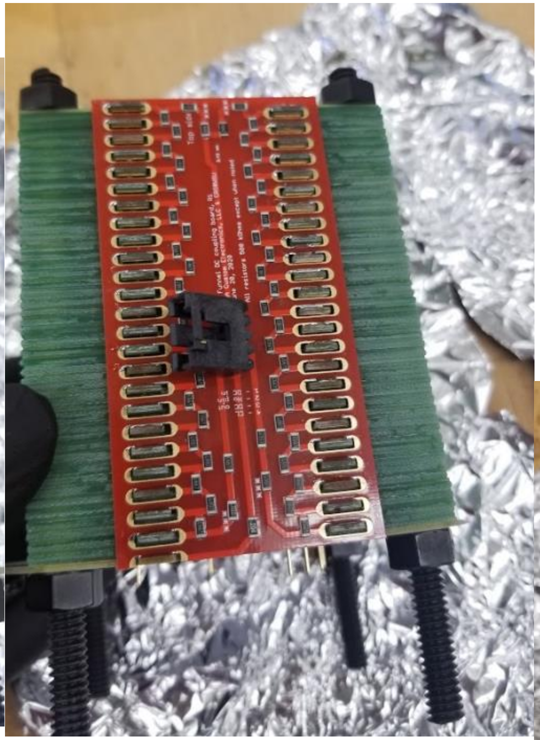


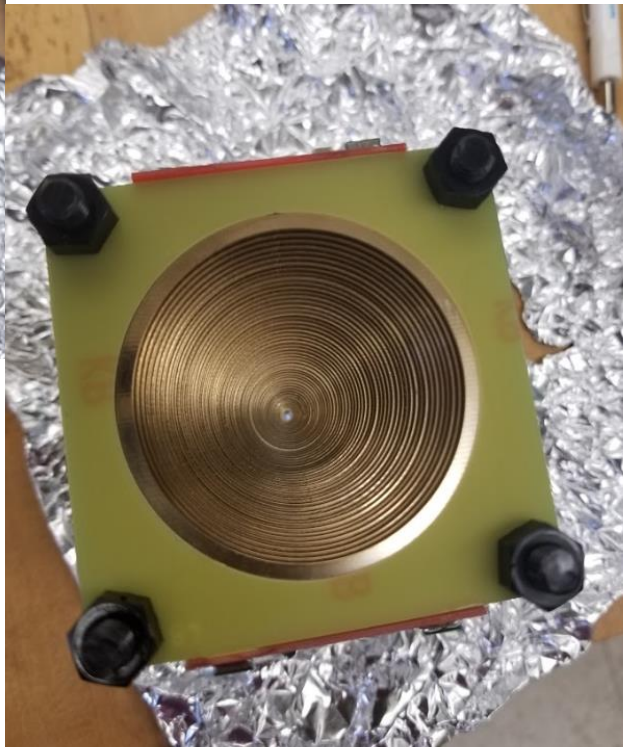


- If traces are unable to be in alignment, check wire connectors, BNC connectors, RF feedthrough ports, and all connections on funnel

Low-Pressure IMS Construction: Rear Ion Funnel

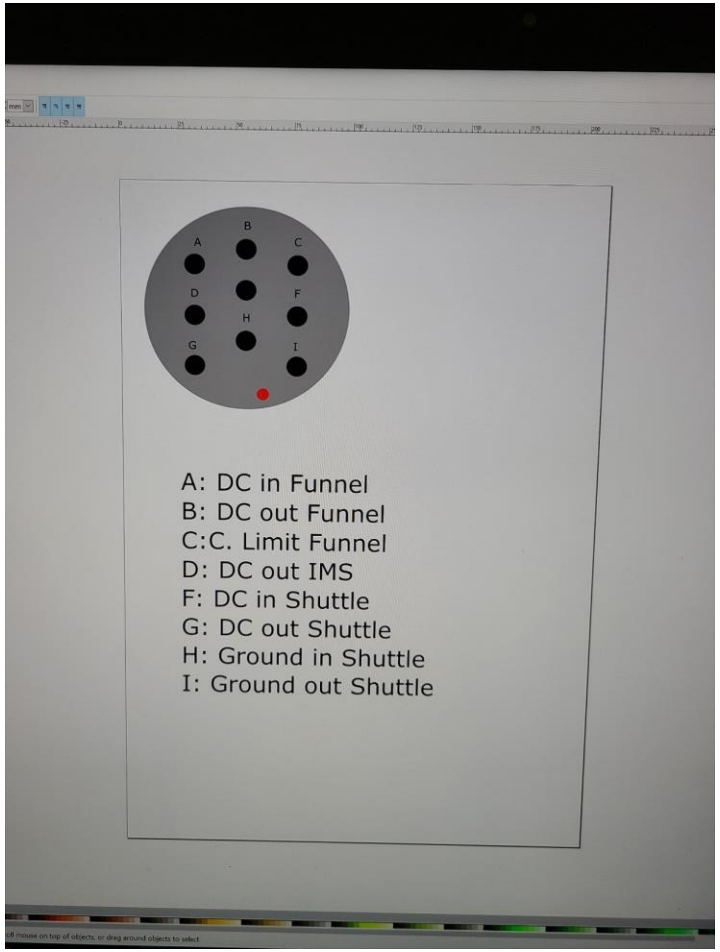
Rear Funnel Construction





- Assemble the rear ion funnel the same way as the front ion funnel
- Note that the DC board has the same resistor deviances as the front funnel
- Test the same as front funnel

Rear Funnel Electrical Connections



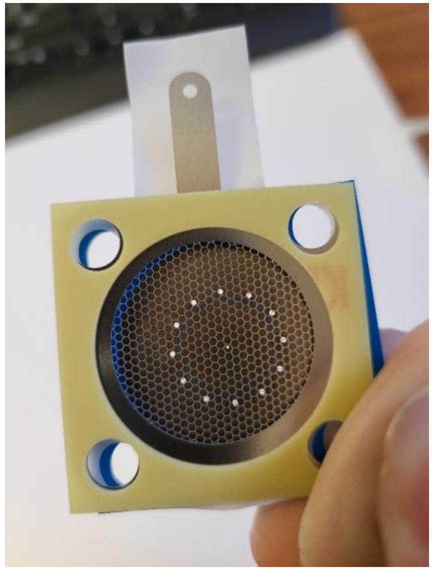
- Representative connections will change depending on electrical connectors used
- This schematic was for the original rear ion funnel and Ion Shuttle configuration

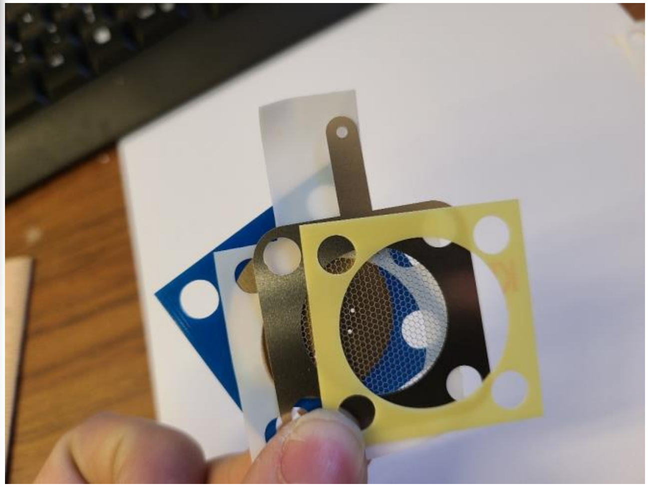
Rear Funnel

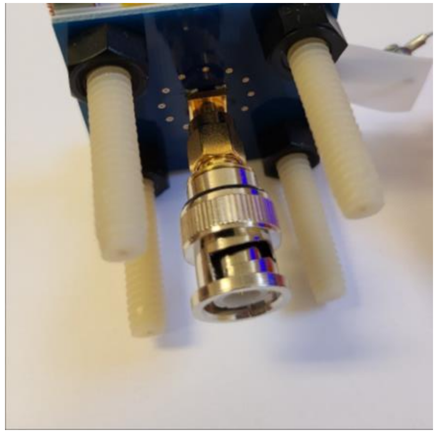
- The Rear ion funnel used with a Faraday plate is **NOT** compatible with the ion shuttle.
- The ion shuttle ion funnel has these connectors in place (shown on image)
- We built a second ion funnel which does not have these pins to use with a Faraday Plate. When we utilize the ion shuttle we will switch funnels for the ones with these connectors.

Low-Pressure IMS Construction: Faraday Plate

Faraday Plate Construction

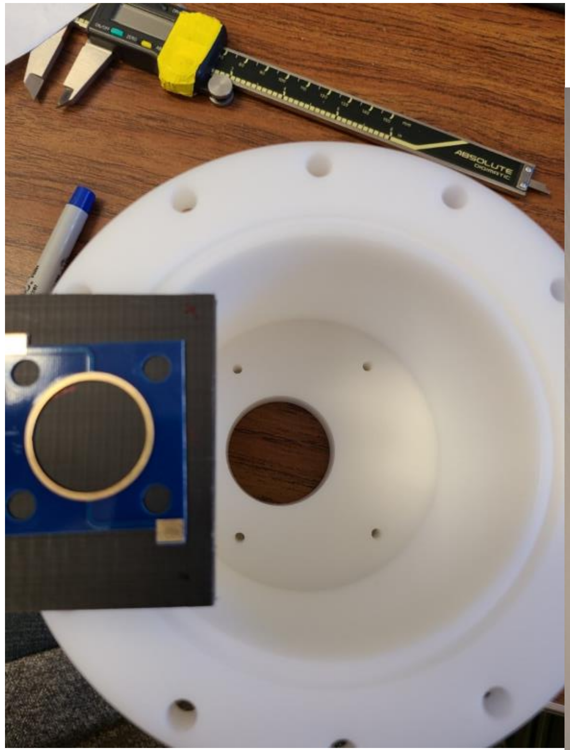


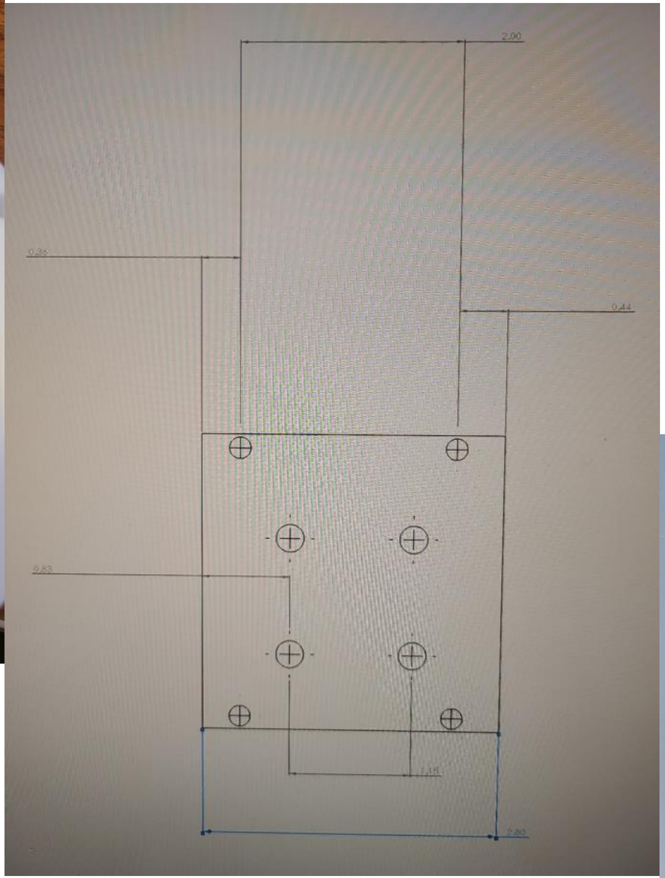


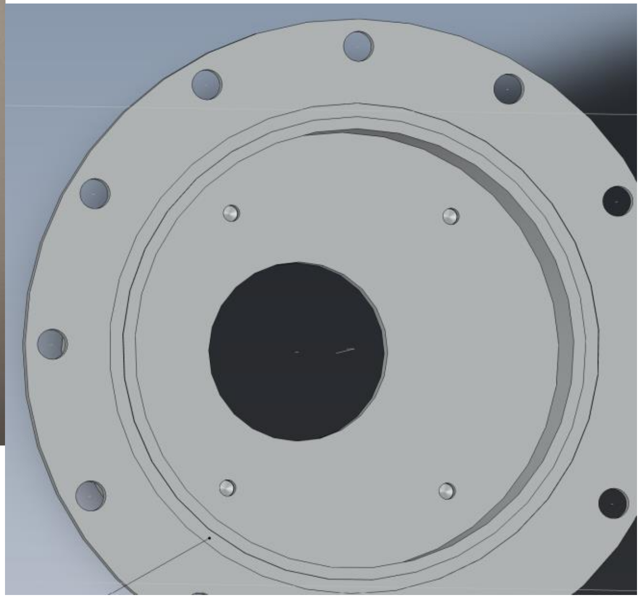


- A SMA connector to BNC needs to be connected to the rear of the Faraday detector (Alternatively a SMA to other connector can be used depending on the output of the MIPS)
- A wire will be needed to connect the Aperture Grid to the MIPS readout. A No. 2 screw and nut can be used to securely attach a wire connector
- A Teflon spacer is placed between the Faraday detector and the aperture grid.
- ¼” x 20 nylon rods and nuts can be used to secure the Faraday Plate assembly in conjunction with the custom mount on following slide
- Ensure Faraday plate does not make contact with aperture grid

Faraday Plate Construction

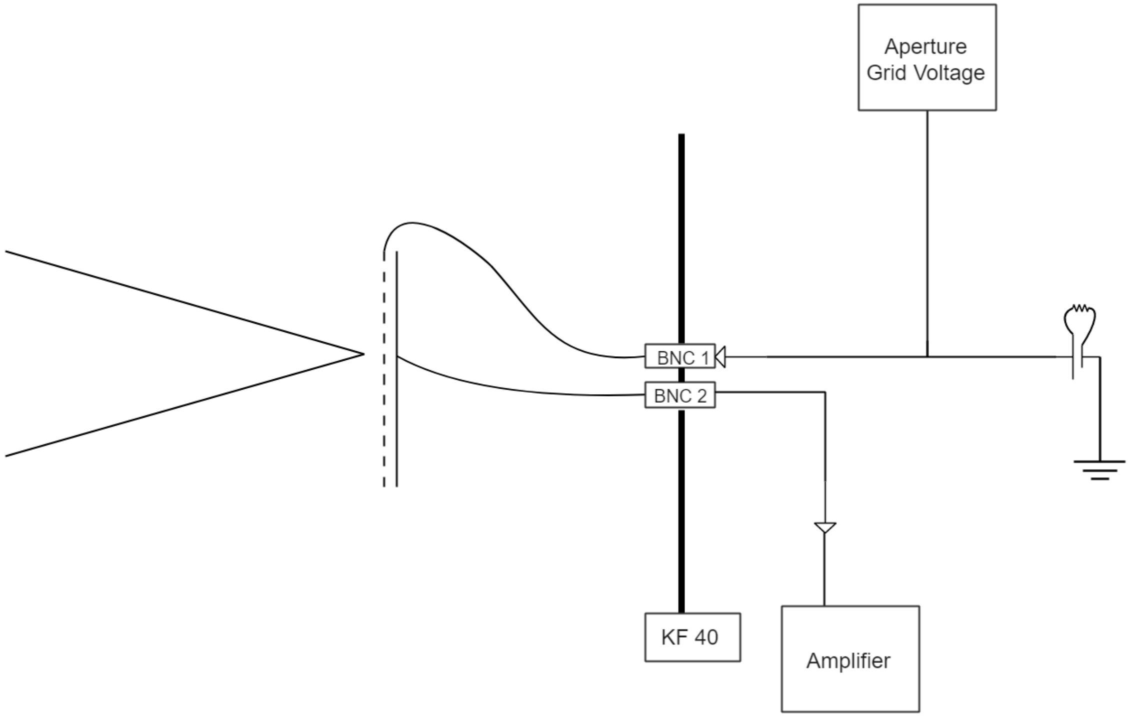






- The solution we used for mounting the Faraday plate as close to the edge was utilizing a square of Delrin and machining it to have clearance holes for No. 4 screws and clearance holes for ¼ x 20 nylon rods. Appropriate sized nuts were used to secure everything in place at the desired height.
- Note that the Teflon chamber we used had asymmetrically placed threaded holes.

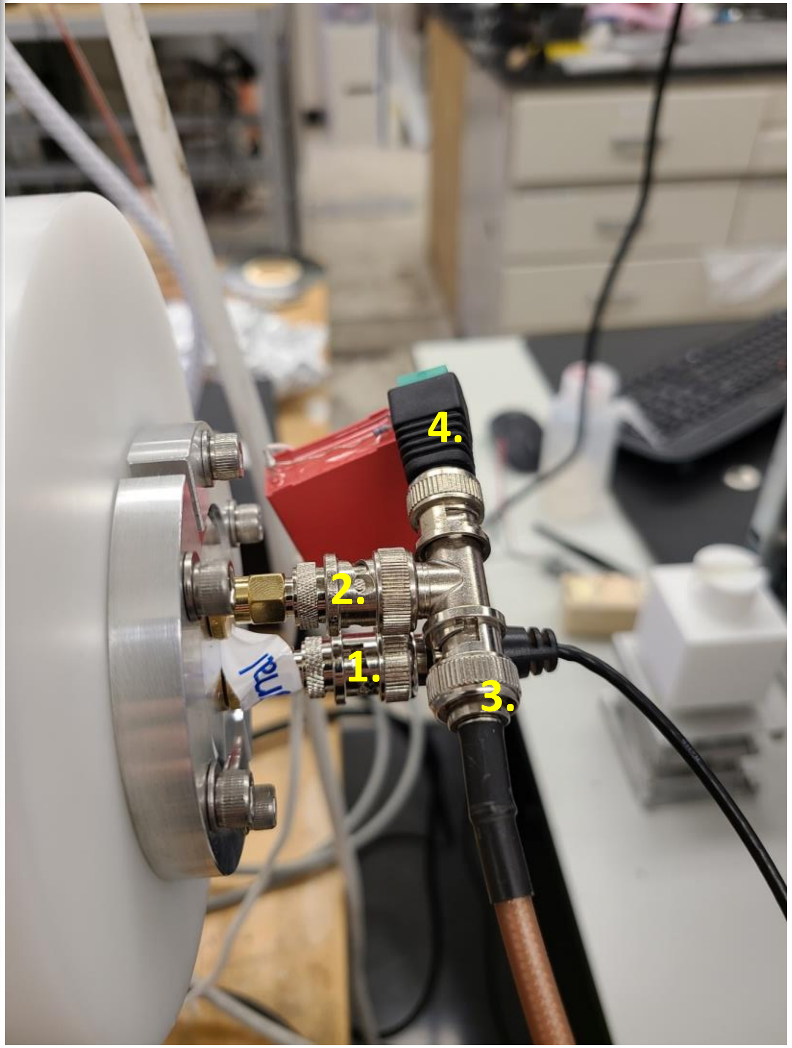
Faraday Plate Schematic

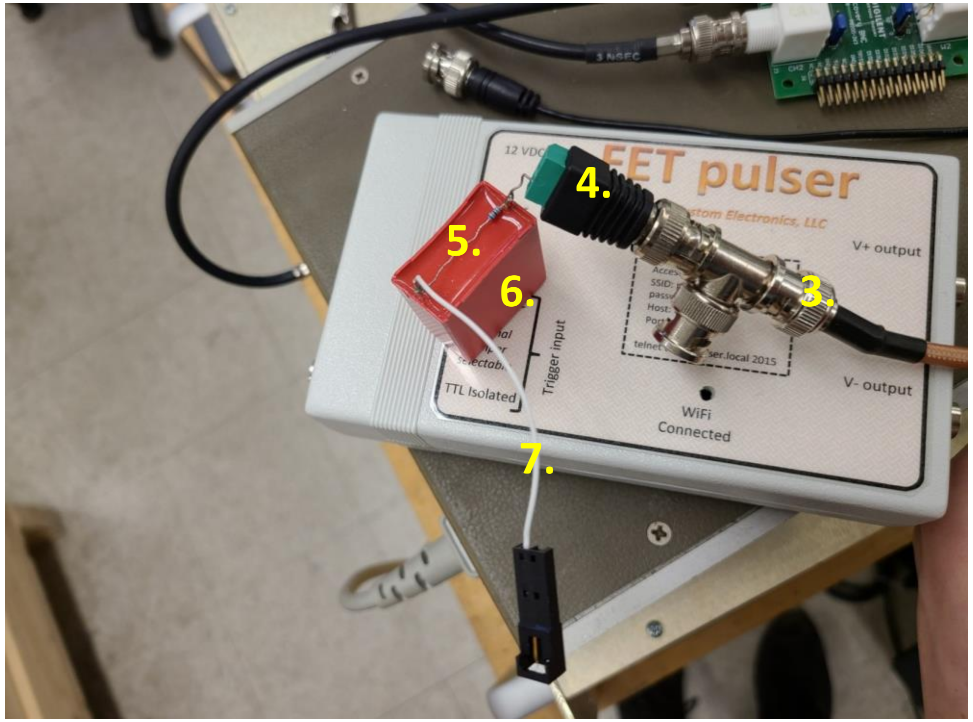


- Ensure that a Teflon spacer is placed between Aperture grid and Faraday plate

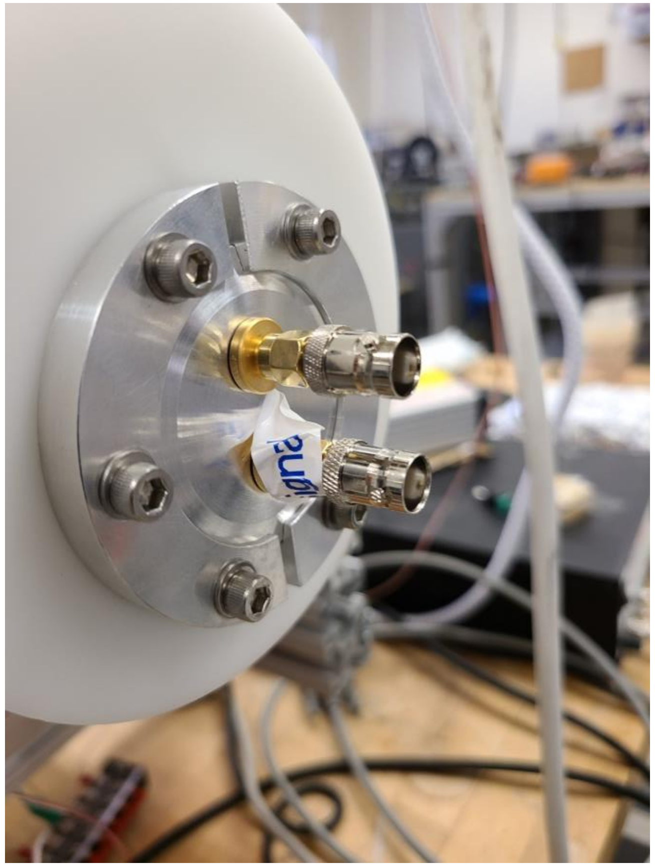
Faraday Plate Connections

- **1**.= Signal out to Amplifier. From SMA connector on Faraday Plate
- **2**.= To Aperture Grid
- **3**.= Aperture Grid voltage from MIPS
- **4**.= Capacitor to ground path
- **5**.= 330 kΩ resistor
- **6**.= 250 nF capacitor
- **7**.= Molex path to ground





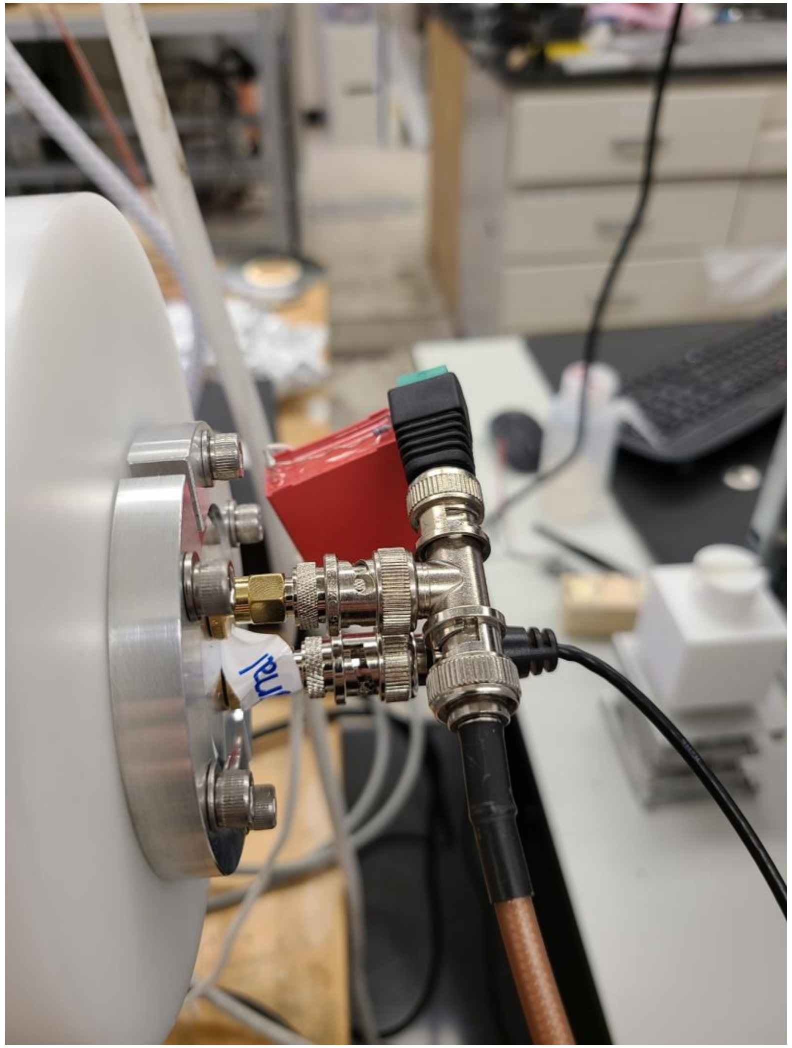
Faraday Plate Construction



- Connect the Faraday plate output to an adaptor from low pressure to atmospheric. We used SMA to SMA cable on the vacuum side, and then had an SMA to BNC vacuum adaptor for making connection to the MIPS.

- Ensure connections are made before placing system under vacuum.
- Label the signal out vs the Aperture Grid in to avoid future headaches.

Faraday Plate Operation

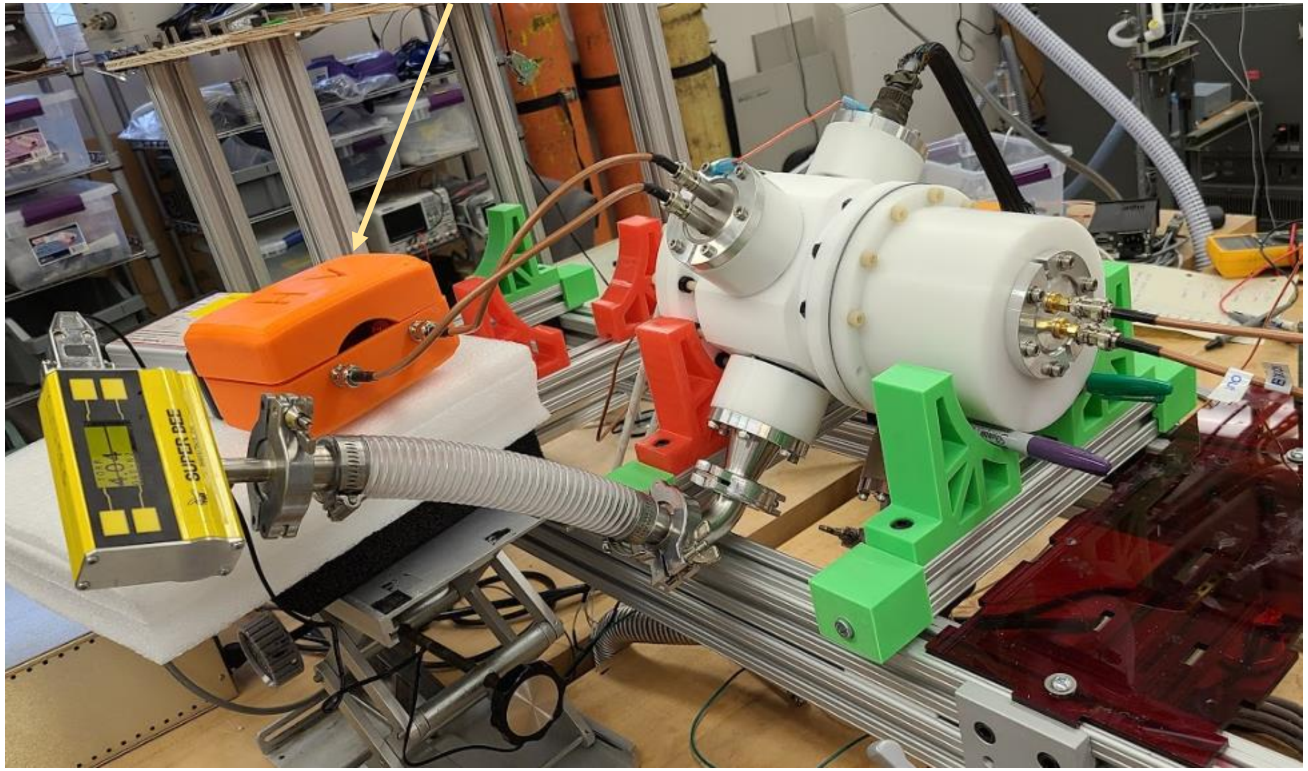


- Applying a positive voltage to the aperture grid will induce a negative current on the signal output which can be observed on an Oscilloscope
- If not observed, recheck connections and that the Faraday plate is not touching the Aperture Grid

Low-Pressure IMS Construction: Ion Funnel Current Testing

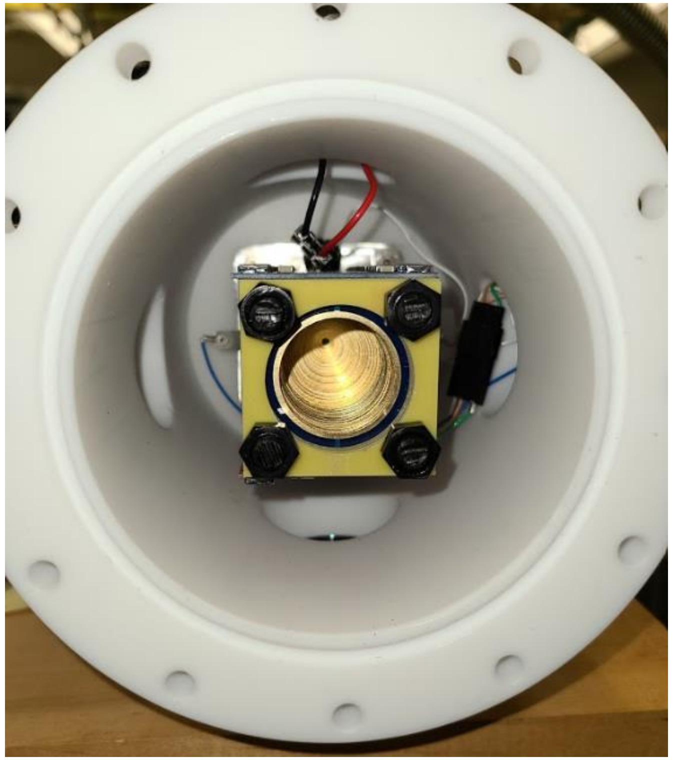
Front Funnel

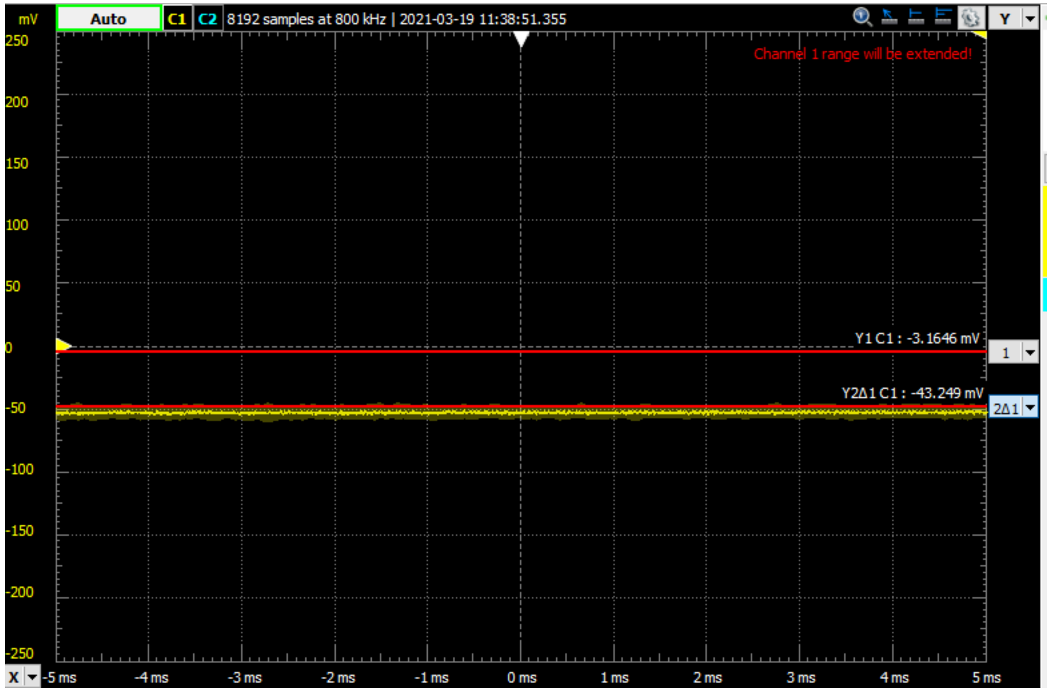
HV Isolation
Door Knobs



- Testing the ion current with just the front ion funnel, and the faraday plate. (Structural support sharpies are recommended, but not required)
- An ESI needle was placed at the inlet capillary and total ion current was measured.

Front Funnel ION CURRENT

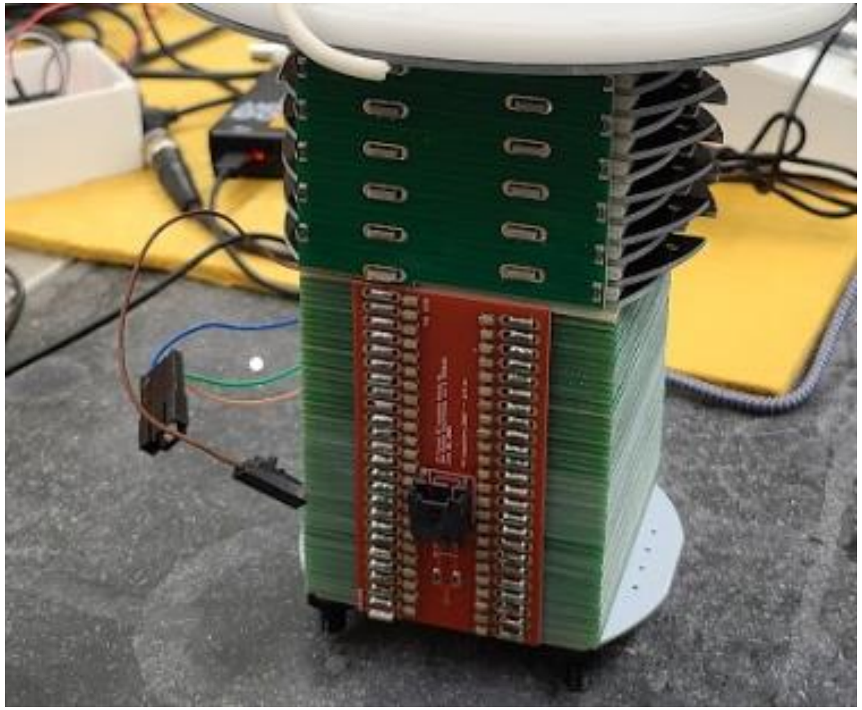


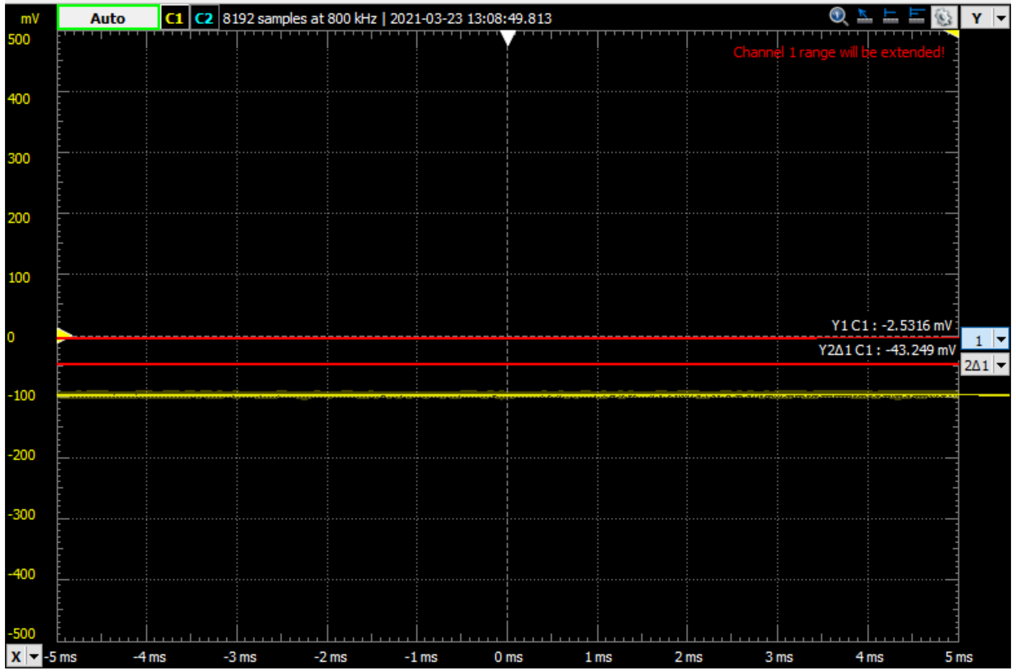


- Red line at zero is baseline current, ESI solvent (80:20:0.1% MeOH, Water, Formic Acid) was electrosprayed
- Faraday plate was placed at the end of ion funnel
- Positive ions induce a negative recorded current.

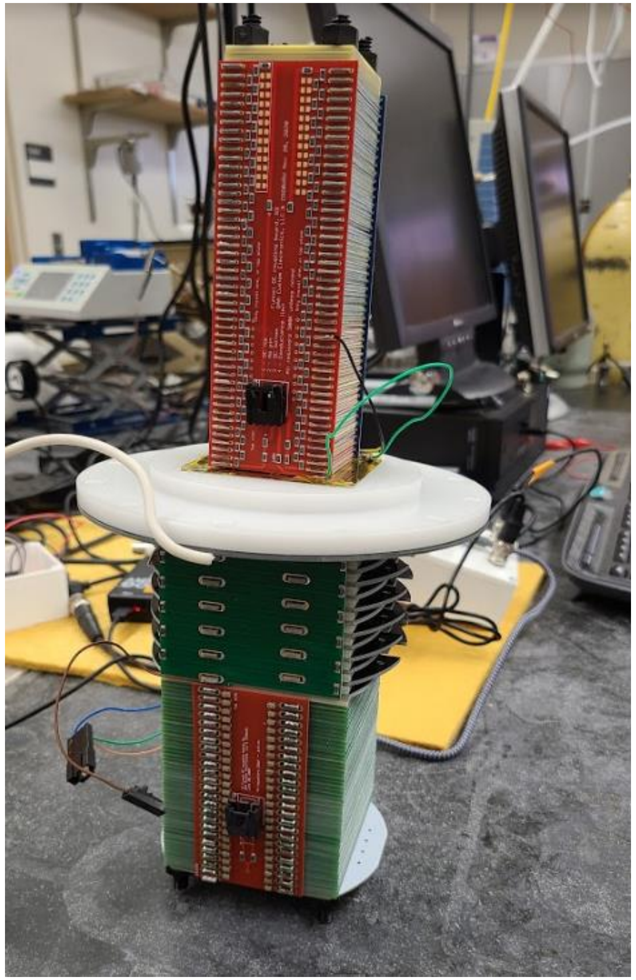
Rear Funnel

- Add ~20 V cm^{-1} DC field to IMS portion by applying DC in and DC out to IMS
- Test the Rear Ion Funnel the same as the Front ion Funnel. Set DC in Funnel to be about 15 volts lower than IMS DC out

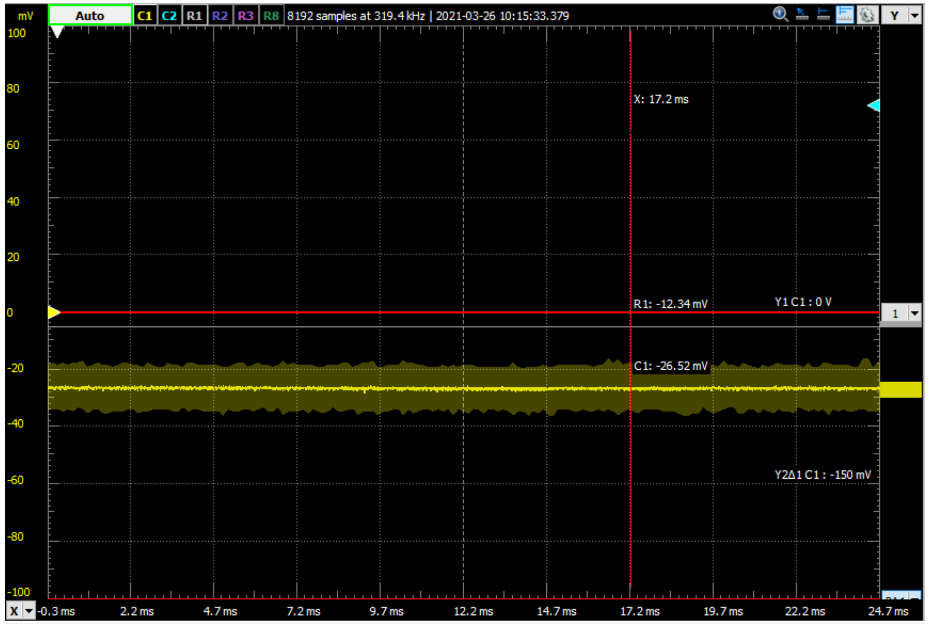




Testing Funnel Ion Current

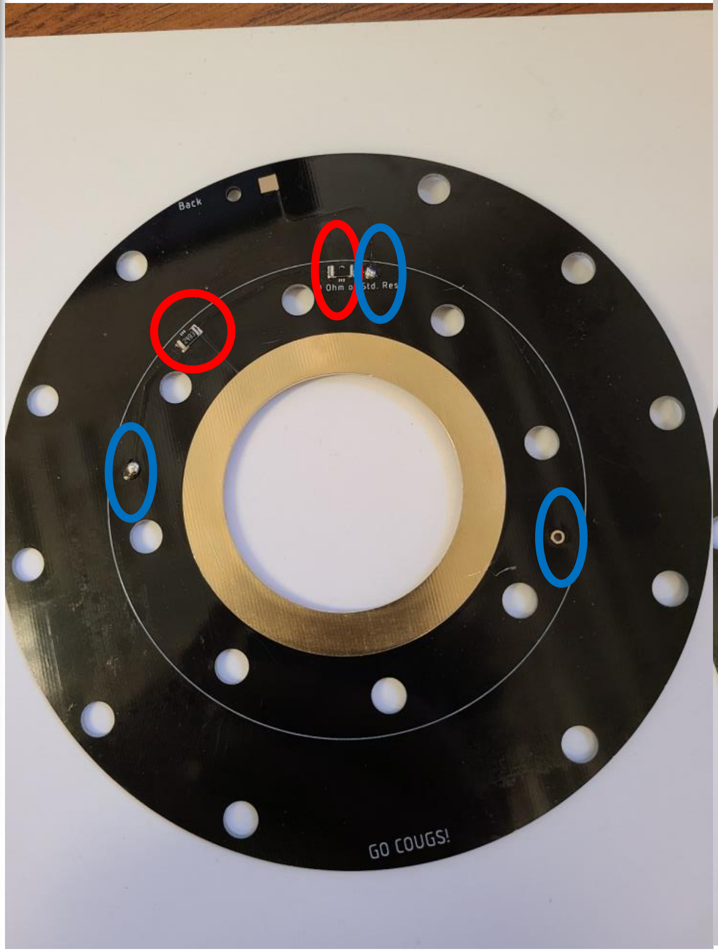


- Both ion funnels were used in tandem to ensure ion current.
- Creative modifications to vacuum lines, pressure gauges, and electrical connections are required to ensure connections and successful operation
- Ensure that the front chamber has a slightly higher (~0.1 Torr) than the rear chamber or ion current will not be observed.
- Same testing parameters as for individual funnel



Low-Pressure IMS Construction: Drift Region Construction

PCB Flange Construction

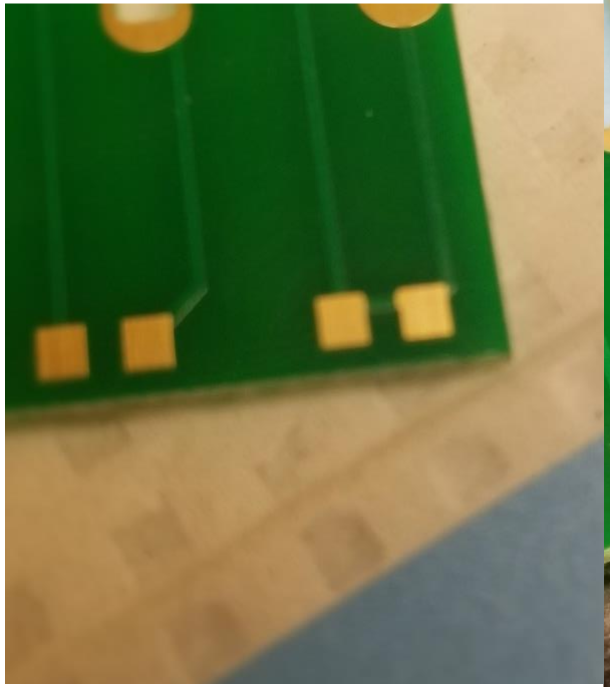


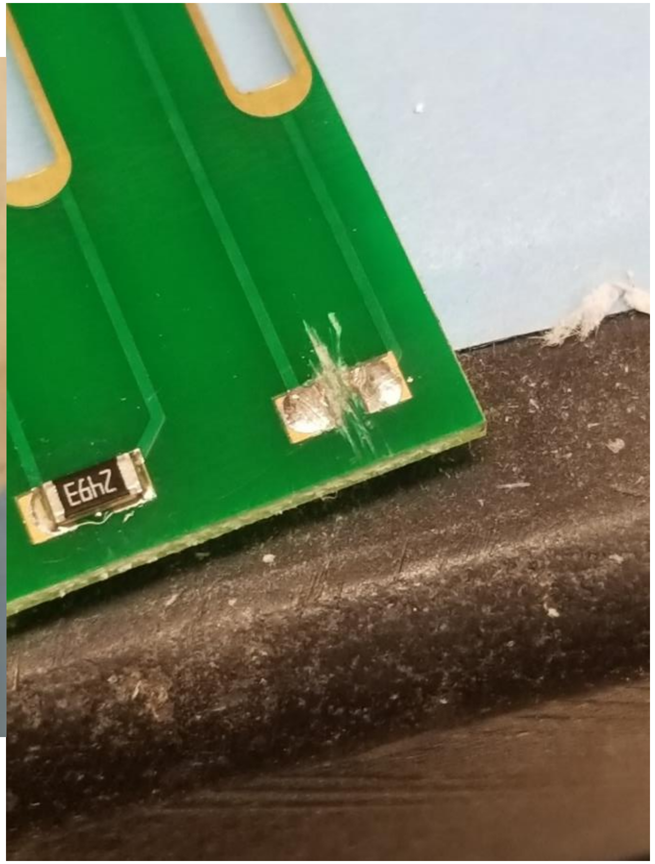
- Both resistors are 250 kΩ except the labeled spot which is for a 0 Ω resistor (Red Circle)
- POGO pins are used to make contact with the drift regions. Ensure proper electrical connection. (Blue Circle)
- POGO pin needs to be placed on the first drift ring for the first drift region (in order to properly seal).
- PCB flange may need to be reversed depending on orientations of drift regions. Ensure that 500 kΩ is measured from POGO pin in to POGO pin out if changing orientations

Drift Tube Region 1

- The first drift region is distinct because of the mounting plate for utilization with front ion funnel.
- A Delrin insert was machined in order to lay flush with the metal ring to keep it in place.
- The PCB ion flange has a pogo pin which is not long enough to make contact with the metal ring. A threaded hole (No. 2) must be bored through this metal ring tab, and after threading a grinder was used to make the screw flush with the back of metal ring

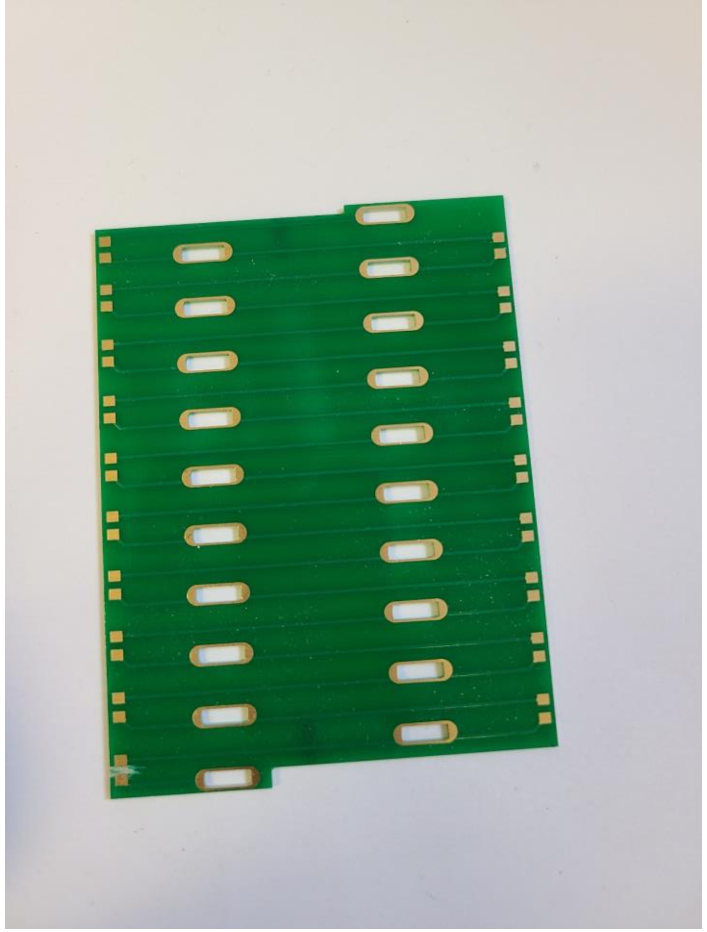
Drift Tube Construction





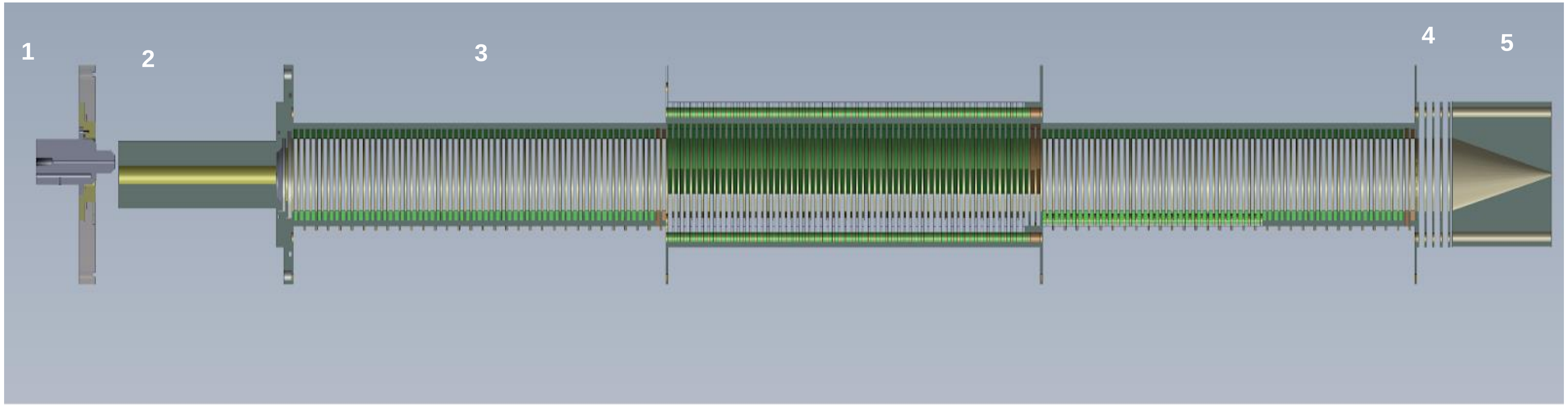
- **WARNING:** Depending on which DC top boards used, there was a flaw where an extra electrical connection was made. Use a razor blade and file to remove the connection or order new boards without the flaw
- Ensure all exposed metal is removed after breaking connection

Drift Tube PCB Construction



- Resistors are all 250 kΩ
- Solder in place and ensure connectivity
- PCB boards are bridged with 250 kΩ resistors
- Ensure that electrodes are soldered into place cleanly, and that the solder is free of any unwanted solder spikes or burrs.
- Each drift region is composed of three top boards and then **ONE** extra electrode to make connection with the PCB flange via POGO pin

Low-Pressure IMS System

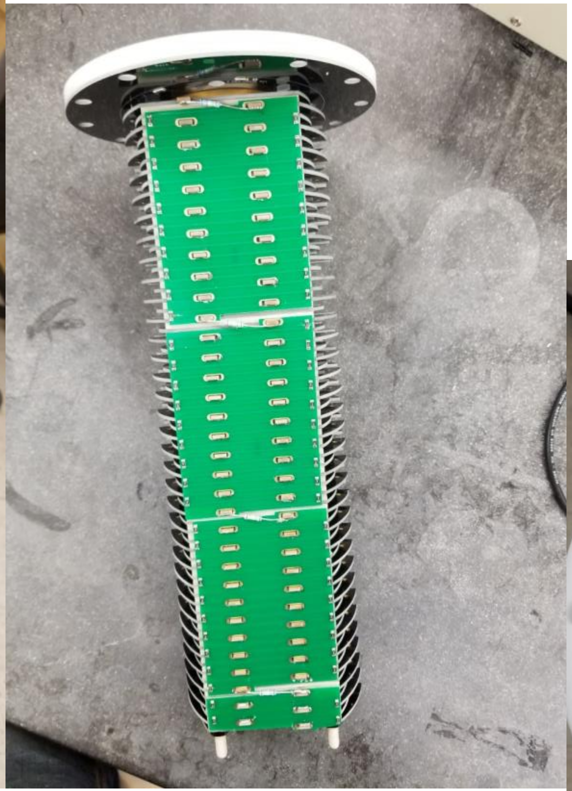


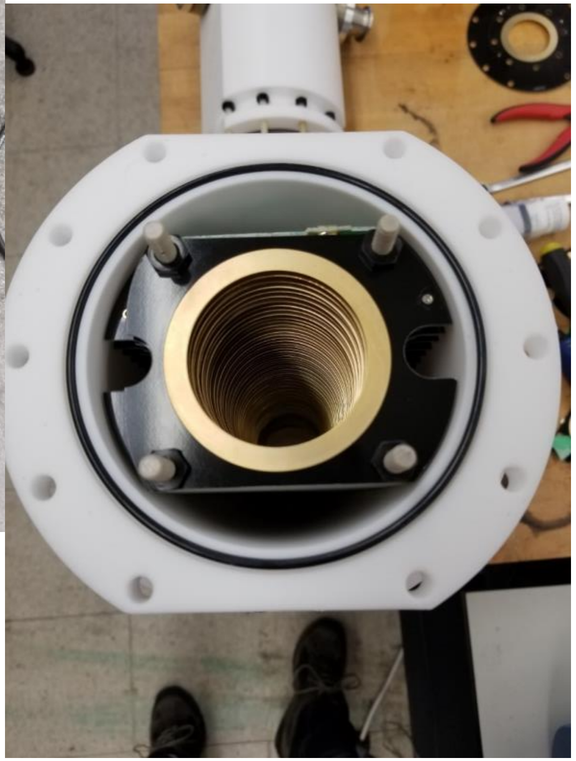
1. Heated capillary inlet
2. Front ion funnel
3. First drift region
4. End of drift region 4
5. Rear Ion funnel

Ion Shuttle or Faraday plate placed at exit of rear ion funnel

Drift Tube Region 1

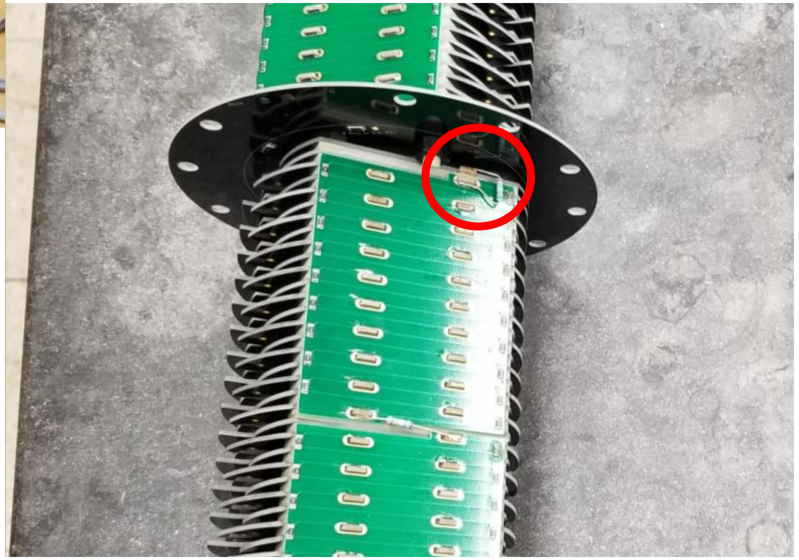
- The first drift region is distinct because of the mounting plate for utilization with front ion funnel.
- Ensure connection with metal ring via POGO pin
- Loosen or tighten thin nylon nuts (3mm) after placing electrodes to ensure drift region fits within Teflon chamber



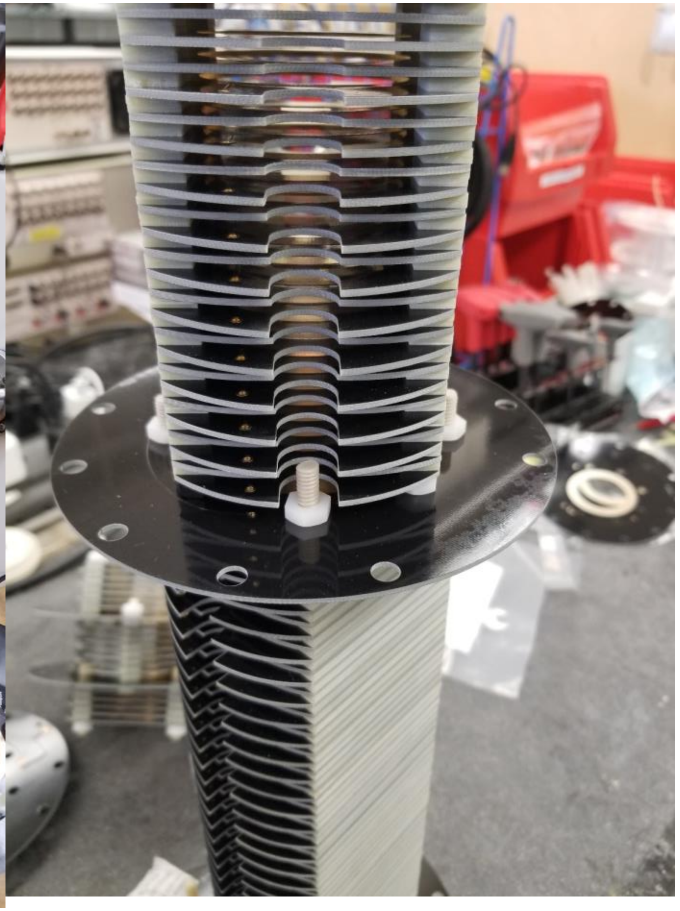


Drift Tube Region 1 to 2

- The connection between drift region 1 and drift region 2 is rotated 45 degrees in order to ensure electrical connection
- Ensure connection via POGO pins from region 1 to region 2 (Each flange contributes 500 kΩ)
- Loosen or tighten thin nylon nuts (3mm) after placing electrodes to ensure drift region fits within Teflon chamber as before
- **NOTE** that there is a deliberate reversal of the **LAST electrode of region 2** which is connected via wire resistor. This is to allow for connection via PPOGO pin to the PCB flange

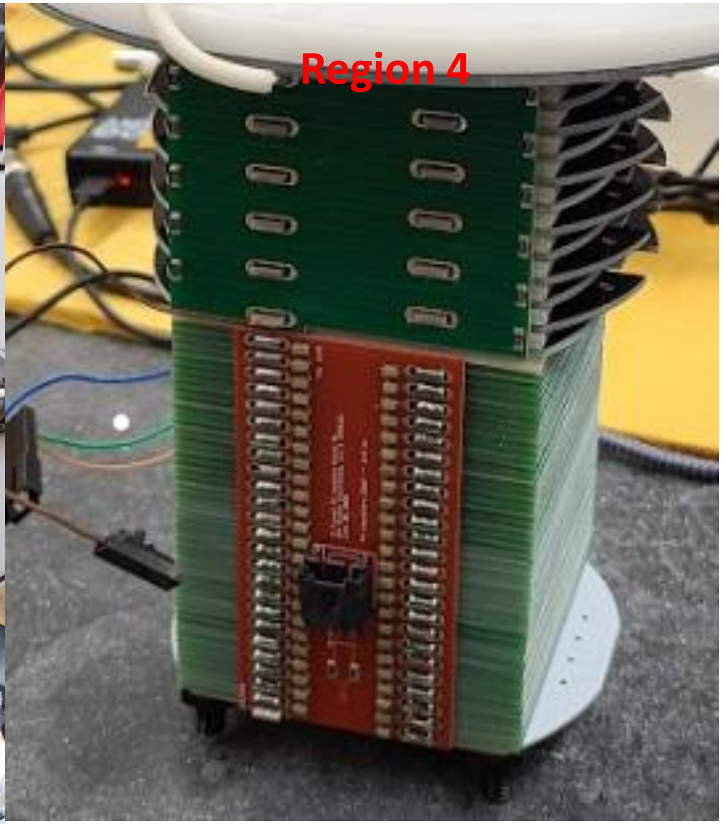


Drift Tube Region 2 to 3

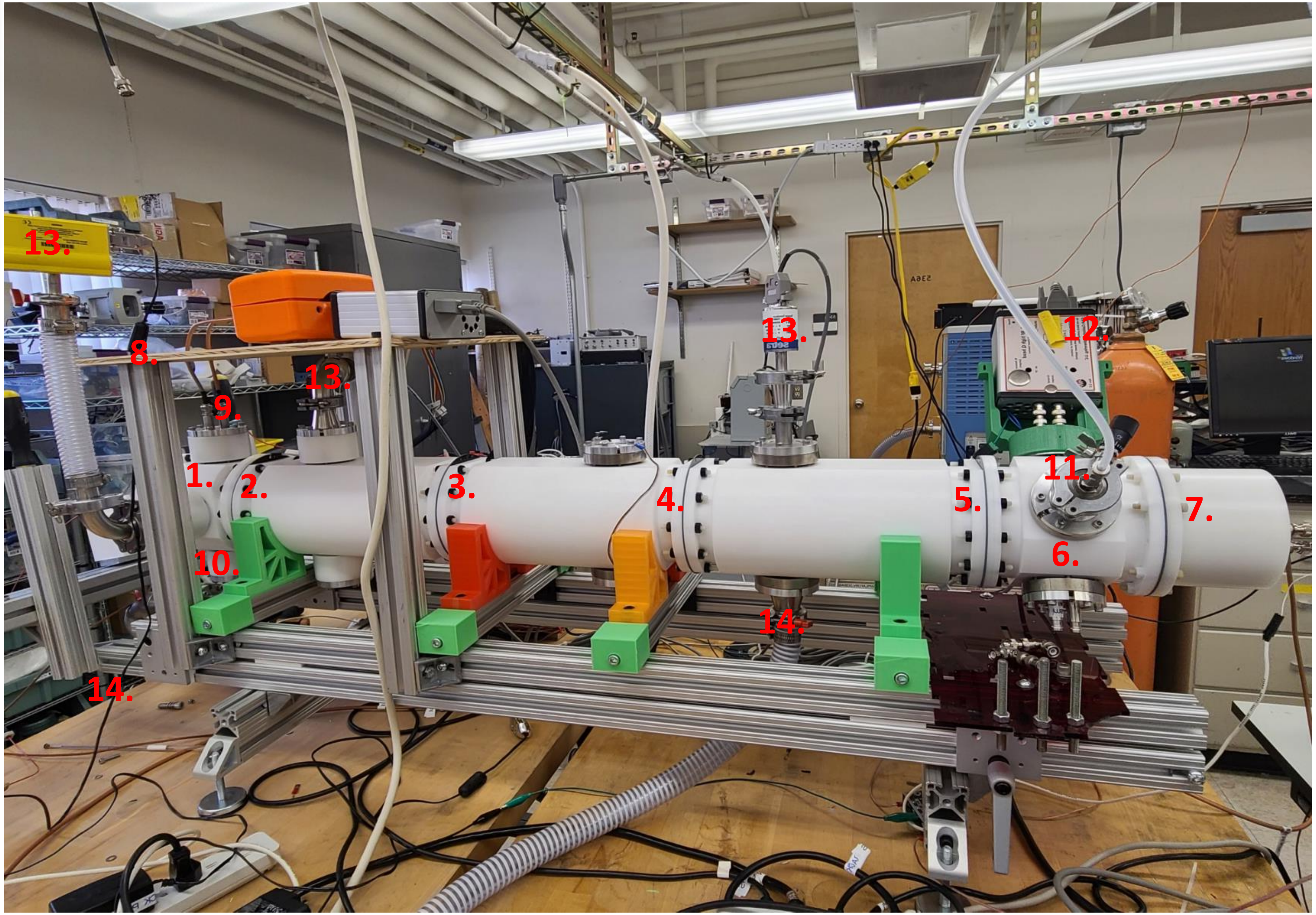
- The connection between drift region 2 and drift region 3 is rotated 45 degrees in order to ensure electrical connection (Region 1 and 3 are in same orientation)
- Ensure connection via POGO pins from region 2 to region 3 (Each flange contributes 500 kΩ)
- Loosen or tighten thin nylon nuts (3mm) after placing electrodes to ensure drift region fits within Teflon chamber as before
- **NOTE** that there is a deliberate reversal of the **FIRST electrode of region 3** which is connected via wire resistor to the next electrode. This is to allow for connection via PPOGO pin to the PCB flange

Drift Tube Region 3 to 4



- The connection between drift region 3 and drift region 4 is distinct as drift region 4 is directly preceding the rear ion funnel
- Ensure connection via POGO pins from region 3 to region 4 (Each flange contributes 500 kΩ)
- DC IMS out is connected to last electrode of IMS
- The length of drift region 4 is however many electrodes it takes to have the rear ion funnel be flush with the exit of the Teflon chamber
- A PCB top board was cut to the correct length using a gravity shear (careful application of wire cutters also works, do not break electrical connection or leave any floating voltages).
- Loosen or tighten thin nylon nuts (3mm) after placing electrodes to ensure drift region fits within Teflon chamber as before

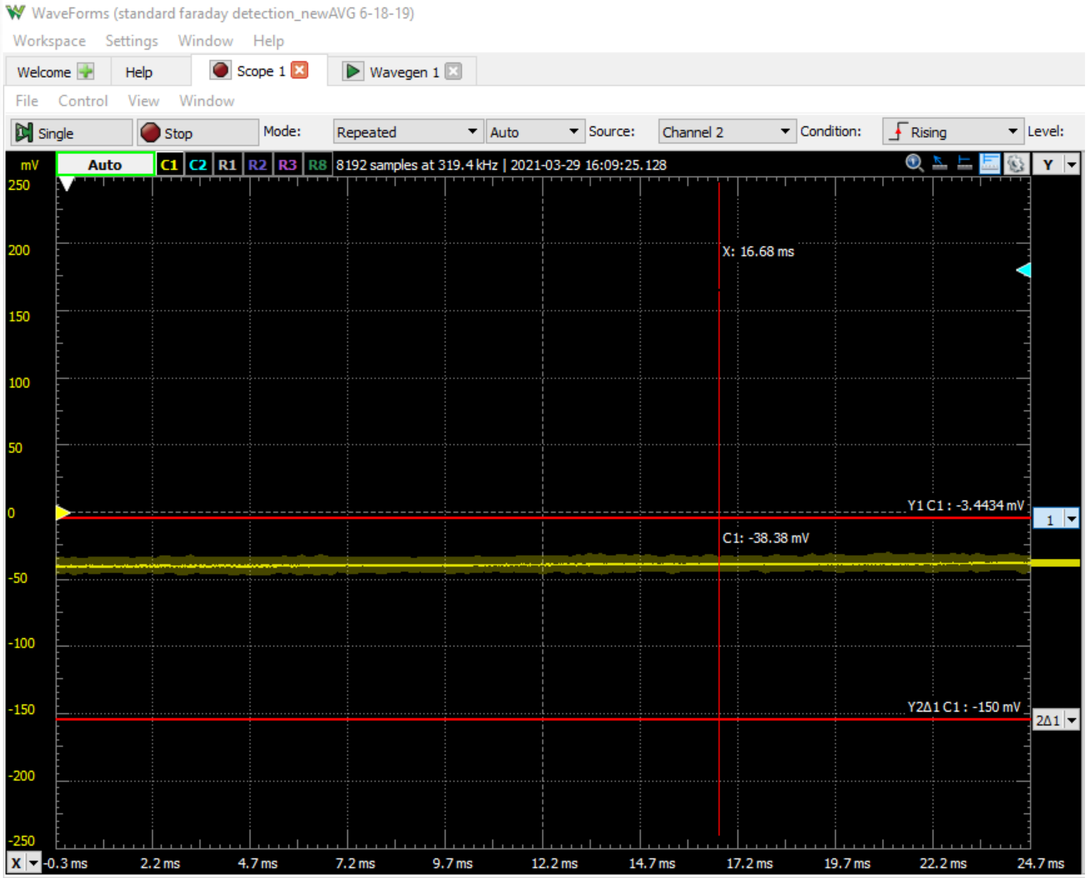
Low-Pressure IMS System



1. Front Ion Funnel
2. Start of Drift Region 1
3. Start of Drift Region 2
4. Start of Drift Region 3
5. Start of Drift Region 4
6. Start of Rear Ion Funnel
7. Faraday Plate Chamber
8. Custom support shelf
9. RF in Front Ion Funnel
10. DC In Front Funnel
11. Drift Gas in
12. RF in Rear Funnel
13. Pressure Gauges
14. Vacuum Lines (behind IMS)

Low-Pressure IMS Construction: Drift Region Ion Current Testing

Drift Region ION CURRENT



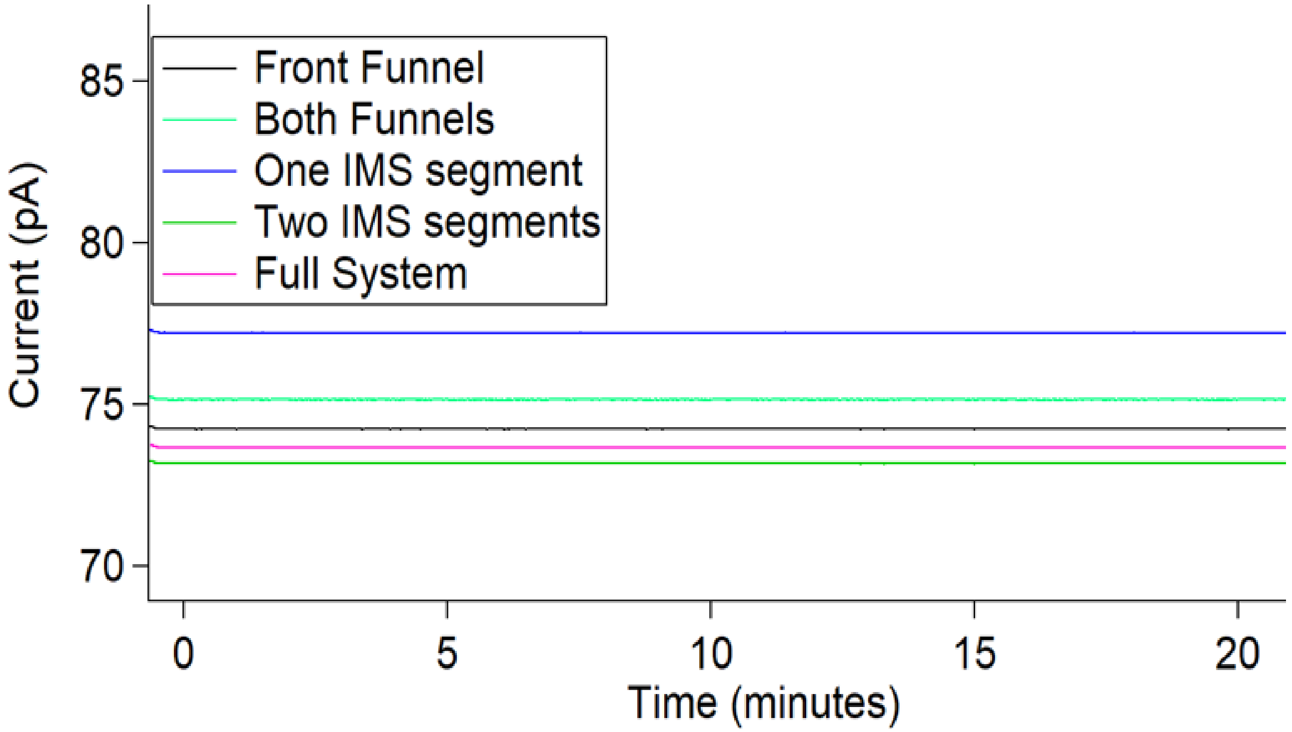
- Before running full system, iteratively test drift region
- With both ion funnels in place, add drift region 1 and test for successful ion current.
    - Front Funnel is capacitivly coupled to drift region 1 voltage
- Creative modifications to vacuum lines, pressure gauges, and electrical connections are required to ensure connections and successful operation
- Ensure that the front chamber has a slightly higher (~0.1 Torr) than the first drift region chamber or ion current will not be observed.
- Same testing parameters as for individual funnel

Drift Region ION CURRENT

- Continue to add additional Drift regions until full length system is operational
- Creative modifications to vacuum lines, pressure gauges, and electrical connections are required to ensure connections and successful operation
- Ensure that the front chamber has a slightly higher (~0.1 Torr) than the first drift region chamber or ion current will not be observed.
- Same testing parameters as for individual funnel

Total Ion Current from Different Configurations

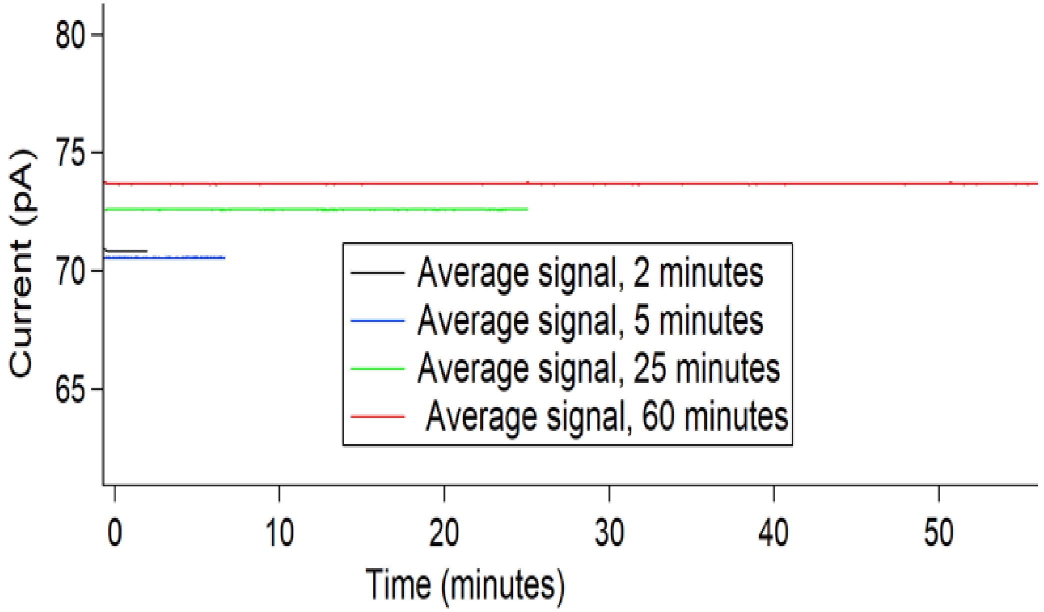
- Drift length = Variable
- Field strength = 20 V cm^{-1}
- Pressure = ~4 ± 10% Torr
- Temperature = 300.5 K



- If the same solution is used for all ion current measurements, observed values should be in close agreement

Stability of Total Ion Current

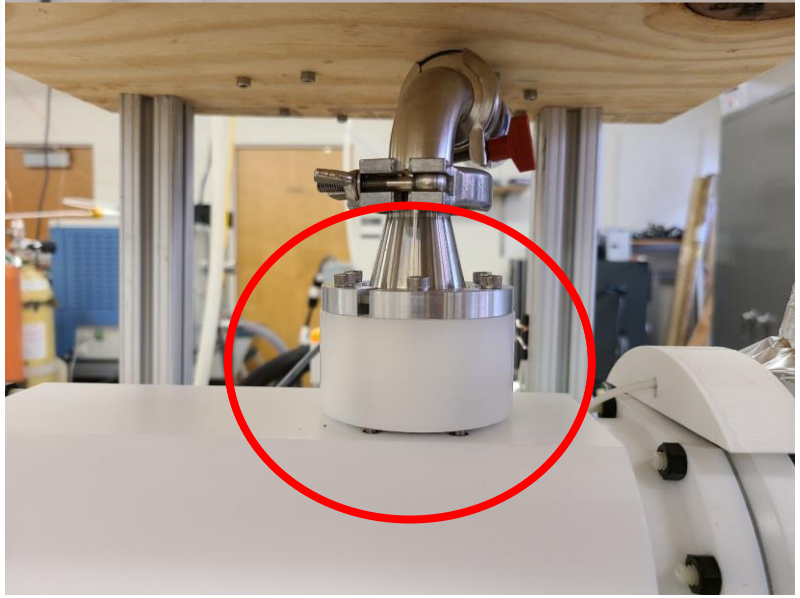
- Drift length = ~104 cm
- Field strength = 20 V cm^{-1}
- Pressure = ~4 ± 10% Torr
- Temperature = 297 K



- To ensure that the system is not charging, measure total ion current at different time increments (signal averaged)
- The longest time increment should have approximately same signal as the shortest. If it is significantly higher, system is building charge

Low-Pressure IMS Construction: Charging Concerns

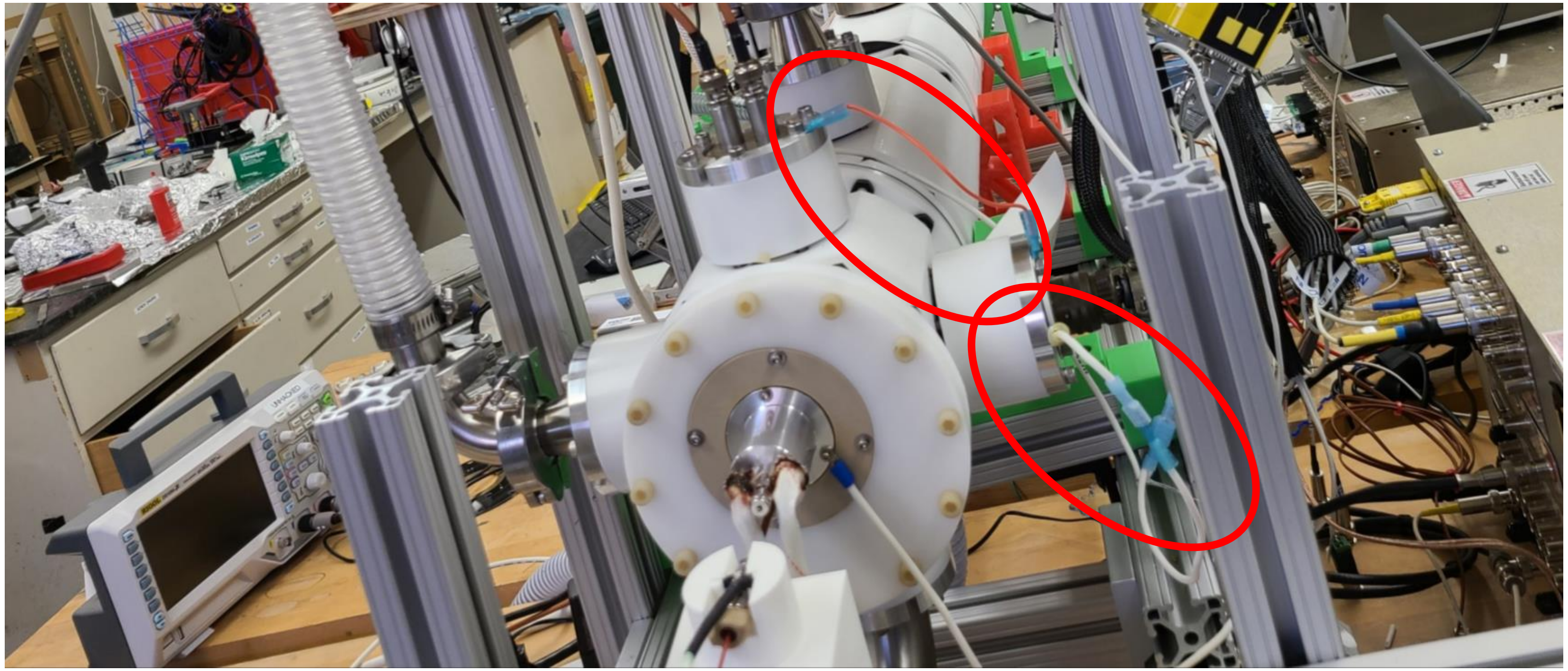
Electrical Discharge Management



- Before addition of these custom Delrin spacers, arcing would occur when trying to bring system up to operational voltage
- Delrin spacers were added on all 6 locations for the front funnel chamber (4 locations) and the first drift region (2 locations) to prevent electrical discharge

Electrical Discharge Management

- The KF 40 plates for the RF in and DC in of the front ion funnel both need to be electrically connected in order to prevent arcing
- The voltage applied to the drift region also needs to be connected to the KF 40 inlet for DC in of the front funnel to prevent arcing



Low-Pressure IMS Construction: Ion Shuttle

Ion Shuttle