S4 Documentation

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1. Assembling the S4

1.1 Introduction

As a quick explanation for anyone who is reading this documentation for the first time I'd like to take a moment to clarify some of the phrases I will use in this paper. During section 1 there will be reference to Araldite and Threebond 134B glues. The former is the epoxy used to seal the outer gas frame of the detector, while the latter is the cyanoacrylate glue used to bond the O-ring to itself. In subsection 1.4 the word "GEM sandwich" will be used occasionally, and this is merely a nickname created for the stack of three GEM foils placed in their frame pieces. Please keep in mind that there will also be references to tools or items used that have no formal name and in this circumstance an accompanying visual will be provided for explanation. REMEMBER, that at ALL stages of construction you are to take pictures and document as much of your construction as is possible.

1.2 The Gas Frame

If you've received your detector without the outer gas frame already constructed and glued than this will most likely be the first step of your construction (if your detector's gas frame has already been assembled than feel free to jump to Part 1.3 of this documentation). The gas frame consists of five separate pieces. The drift frame, O-ring, frame sides, and readout board. There will also be an assortment of screws, pegs, and nuts needed; however, we'll discuss those as they become important.

As you can see in Figure 1, this is what your gas frame will look like when completed. The large gold base is your drift frame and the sides of the square are your four main frame pieces. In this photo, the O-ring is in place, along with side-tightening screws. What may be harder to notice are a small pair of silver dots that flank the side tightening screws (see Figure 2). These are the frame pegs (small metallic cylinders about the diameter of a tooth-pick), and you should have quite a few of them. The first thing you must practice is placing the frame pieces (with their pegs) into the drift. All of the frame pieces are interchangeable, and can form any side you wish; however, you may want to place your frame pieces based on which side of the detector you want your gas connections to be made.

The reason you must practice placing the frame will become clear once you have attempted assembly. As you will quickly learn the pegs do not slide into their respective places (as least not easily). When you place a frame side, there will always be at least peg that either sticks out of the bottom of the drift, or the top of your side piece. There are many different methods you can try to fix this,

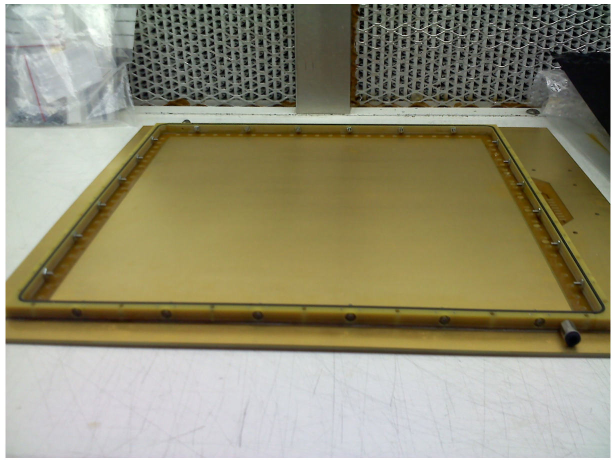

Figure 1: Completed Gas Frame with O-ring in place

but to save time I'm skipping to the method I used.

Take your frame side and place every peg, make sure to press them in until they are flat with the O-ring side. Place the piece into the drift so that every peg is just barely into its corresponding hole (you should be left with a gap similar to, but larger than that in Figure 3). Now when you want to get the frame side completely flat with the drift board you will place a long piece of metal or strong plastic on top of your frame side and hold it in place with four fingers from each hand (the piece of plastic I used is pictured in Figure 4). Wrap your thumbs under the bottom of the drift and start to pull the frame side towards the drift. The idea is that this piece of metal and your fingers will stop the pegs from sliding up and out of the frame side, and thus with nowhere else to go, they will be forced into the drift.

For the purposes of practice I would not suggest fully placing the frame sides until you are ready to glue. They are extremely difficult to remove once you have pressed them flat to the drift board, so for now, I would always suggest leaving a gap. Once you feel comfortable that you can handle the frame pieces you will set everything in place for gluing. This means simply to prepare everything as you see in Figure 3. Remember to leave the small gap shown in Figure 3 as this will allow you to place glue under the frame pieces before pulling them to the drift board.

Now that your gas frame is ready to be glued you will start your Ardalite mixture. The instructions for this process can be found both online or in the guides present in the lab filing cabinet. In practice you will not need much glue; however, I suggest you mix an amount that is 1.5 times what you think you will need. It will not be a fun situation to run out of glue midway through this next

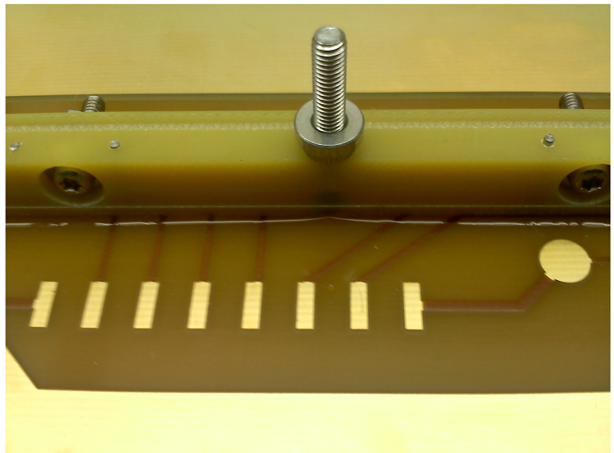

Figure 2: Notice the small silver pegs that sit on either side of the horizontal side tightening screws

process. Once the glue is mixed, quickly pour some into the empty syringe of your pressurized glue applicator. Make sure to leave about 1 inch of free space from the top of the syringe so you can easily connect the applicator to the syringe. Once you've connected your applicator to the nitrogen gas line you can turn the pressure up and practice extruding glue. I highly suggest you practice before actually applying glue to the frame pieces. It is simple enough to just merely make smooth lines or shapes of glue on a scrap piece of paper. Keep in mind that the goal of this practice is to reduce the size of the globs of glue you will make when you start and finish a line.

Now that you can confidently make lines of glue, you can begin the permanent part. Utilizing the small gap you left you'll apply small lines of glue under the frame pieces and between the large vertical screws that you see in Figure 3. Once there is glue along the bottom length of the frame piece you'll use your piece of plastic or metal to bring the piece completely flat with the drift board (exactly like you see in Figure 2). It is not a problem if you apply glue to or around the small pegs in the frame sides; however, you should try if you can to avoid putting excessive amounts of glue on the large vertical screws. Just keep in mind that the reason you have the large vertical screws in place during this process is to make sure that you don't get large globs of glue smeared over the holes for these screws. If that happened you would have to go back through and remove this glue manually so that you could actually use these screw holes.

Now that all of your frame pieces have been pulled to the drift you'll notice that the glue you put under each piece got pushed outwards to both sides of the frame piece (similar to what you see in Figure 2). As a quick check before

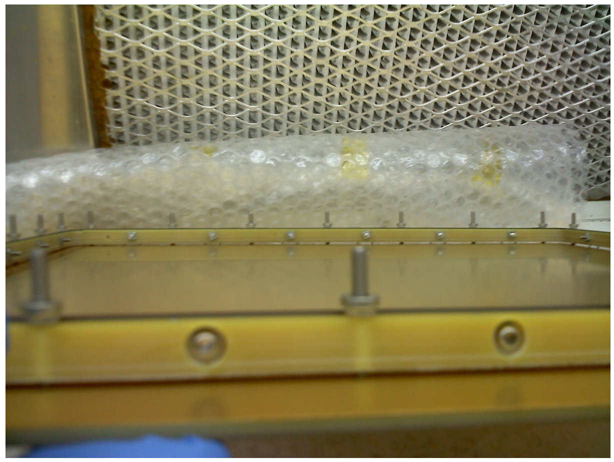

Figure 3: The gap that you should leave between your frame sides and the drift board

Figure 4: Small piece of hard plastic used to place the frame sides

you continue, make sure the O-ring fits properly in the square groove you've just created. If it fits you're perfectly fine to continue finishing the gluing process, if not, you'll have to make small adjustments to each piece until the grooves line up. Now go along both sides (outer and inner) and make a thin line of glue at the point where the drift meets the frame pieces (exactly like you see in Figure 2). Once this is complete the last thing to glue are the points where the frame sides meet. For this part you want to be a tad cautious as applying too much glue to the top of the frame sides will make it difficult to fit the O-ring or readout board. The method I employed was to simply make a line of glue that covers this completely and on all sides (top, outside, inside). After making the line of glue, I would take my finger and smear the bit of glue that runs over the top of the frame into a thin film. Employing this technique should still give you some glue to make a good seal but not enough to actually make it difficult to place the O-ring or readout board. Keep in mind that if glue falls into the seam between two frame pieces it is perfectly fine, just make sure you have enough in place to cover the outside of the seam.

Now that you have the frame pieces in place and glued you must decide whether to leave the vertical tightening screws in place. As was stated previously the only reason those screws are in place is to keep glue out of their holes when pulling the frame pieces to the drift. For the purpose of this document I'm going to suggest you remove the vertical screws after securing the frame sides. For my first build I left the vertical screws in place (with the hope that they would provide strong pressure to the frame sides during the glue setting period); however, this led to the formation of thread-like glue structures on the inside of each hole that were quite annoying to remove. It will most likely be easier for you to just remove the vertical screws, and place something atop the frame pieces to provide a bit of downward pressure while the glue sets.

Once your glue sets (and you have fitted and joined your O-ring using the Threebond glues in Figure 5) the final step will be gas tightness testing. By this I mean you will place the O-ring, side-tightening screws, vertical screws, and readout board in place to form the complete gas frame (see Figure 6). Insert the gas inlet/outlet connections into the holes (they screw into place and shouldn't require glue, although you can glue them if you want) in the frame sides and connect the detector to your gas system. You will want to place one flow-meter at your gas input (before entering the detector) and one at the gas output (right after leaving the detector). The idea being, that if the flow-meters do not closely match each other than your detector must be leaking. The one common problem that you want to watch out for during this step are the pegs (that's right, as if they weren't already annoying enough). As you may notice in Figure 2, the one peg visible near the right edge of the picture is slightly elevated. If you have pegs

Figure 5: Threebond cyanoacrylate glues. The white container is the glue, while the brown container is an accelerator.

sitting like this after the glue has set it's survivable, all you have to do is file them flat. Those elevated pegs can cause deformations in the readout board which cause you to lose gas tightness so they must be made as flat as possible with the top of the frame side.

If your detector passes gas tightness testing, you are perfectly set to move onto section 1.3 of construction. You're going to want to remove the readout board, side-tightening screws, O-ring, and vertical screws for these next parts as they will only get in the way when not needed. Make sure though before continuing that you have taken plenty of pictures, and have made notes concerning any problems or difficulties you encountered during construction.

1.3 The GEM Foils

The first step to working with the GEM foils is quality control. You should visually inspect each of your GEM foils for tears and irregular markings (black spots or indentations for instance). This is also a good oppurtunity for you to familarize yourself with the construction of the foils. Pay close attention to the HV connections. How are they routed? Which HV connector is routed to the "top" and "bottom" of the foil? Do the surface mounts making connection to the sectors look appropriately sautered?

The most important thing you need to understand about the GEM foils are the sectoring and the HV routing. If you look closely at the foil you will notice that it is broken into a series of rectangles (in the case of the S4 10 rectangles) stacked side by side. There should also be a small line that runs along the side of your foil making individual connection with each of these rectangles through small

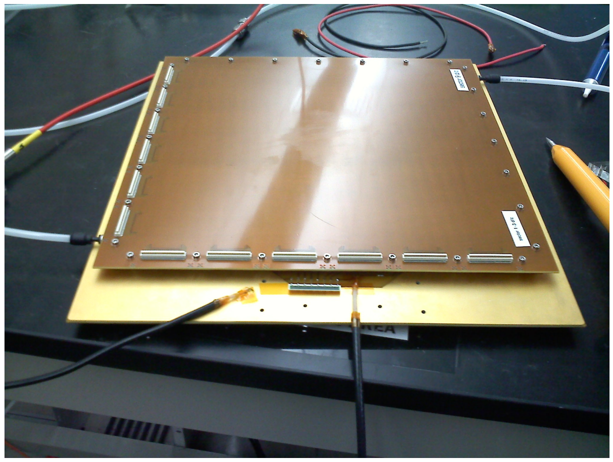

Figure 6: Sealed detector awaiting gas tightness testing

black resistors called surface mounts. If one of the sectors of your foil becomes damaged you will need to disconnect these surface mounts in order to still allow your foil to operate. Unfortunately though all the specifics of HV routing is a bit more important and complicated.

For now let us call the side of your foil with the small black surface mounts "facing up" while the opposite side will logically be "facing down". There should be at minimum two small silver circles I'm calling the High-Voltage (HV) connectors on one of the four sides of your foil. Move this side so that it is closest to you. Now when you look at the foil there should be a small line that runs either to the left or right of your foil from one (or multiple) of those HV connectors. We will call the HV connectors attached to this line, "In", while all others are "Out". For the foil to operate there must be at least one pair of In and Out connectors. It may seem like I'm going into an inordinate amount of detail here, but you need to understand that these connectors govern how you build the GEM sandwich. Let's say your unlucky and your foils only have one pair of In and Out connectors. What you will notice is that they are not in the same location for each foil. They will be staggered, and it is this staggering which will govern their location in the GEM sandwich. The foil will the connectors furtherest to the left while facing up will be the lowest foil in the stack, while furthest to right while facing up is the highest foil in the stack. If this doesn't make sense to you look at Figure 2 again and then read the next paragraph until things become more clear.

If you've looked at Figure 2 you'll notice a bunch of small rectangular connectors and one circle. You can imagine this all as one really simplified circuit. The current of your circuit should start at the circle (this is the drift), it should then flow from right to left through these small rectangles. The rectangle on the right of each pair should be connected to your foil's In and the left rectangle connected to the Out. If it is the case that your foils only have one pair of HV connectors then that pair will coorespond to one of the pairs of rectangles. You just have to really think this through though, because you flip the foils upside down when assmebling the sandwich. If you're lucky your foils come with three pairs of HV connectors. Three In and three Out connectors. If this is the case, then you do not have to worry about where you place each foil in the sandwich. Each foil would be able to make connection with any pair of the rectangles. Unfortunately though, there is one last detail to worry about.

Hopefully I haven't lost you up to this point (big hopefully there). What you now need to worry about is how the In connectors of your foils route. If you have the foil facing up and you now look at one of the HV connector pairs, which connector is on the left? If it is the In connector your set. This means that when you flip the foil upside down in the sandwich its In connector will make contact with the right rectangle of each pair we see in Figure 2. That's exactly as it should be. If your In connector is on the right then make a note, it will not effect your construction of the GEM sandwich at all; however, it will effect some of the last stages of construction we will discuss later in this document.

1.4 Testing the GEM Foils

The final step before you can begin assembling the sandwich is High-Voltage (or Leakage Current) testing. This is a relatively simple test we can employ to make sure our foils are functioning properly. As I stated above, the foils can be imagined as massive resistors. If this was a perfect world they would exhibit infinite resistance and allow no current to flow from the up side to the down side. In reality there is an extremely small amount of current that "leaks" from the up side to the down side whenever a voltage is applied to a GEM foil. Remember, the two sides of the GEM foil when placed in the detector are kept at two different voltages. When you have a voltage difference across a resistor you get a current. What you are going to do is measure this small current across your foil by applying a static voltage difference. If the current we measure is small enough, we know our foil is functioning properly as a massive resistor, if the current is large there may be some puncture or damage that is easily allowing current to pass from one side to the other.

To conduct these tests you're going to need an acrylic box, nitrogen source, GEM foil, picoammeter, voltage source, and some cables to do the routing. Here's the general idea, we put the GEM foil in a sealed acrylic box and flush it with nitrogen so that our foil is operating in a "pure" nitrogen enviornment. We choose nitrogen because it is "dry" or lacking in water vapor that would alter the amount of leakage current our detector shows. Once the foil is in place we apply a static voltage (say 300 volts) to the In connector while keeping the Out at ground (or zero). If the picoammeter is properly in series (for instance after the Out of the foil but before the ground connection) then it will give us some small current reading, hopefully a current that can be measured in nanoamps.

What you see in Figures 7 and 8 is the cable routing for leakage current testing. The idea here is that we are taking input from our high voltage source and splitting it. The left connection in these pictures carries voltage, while the right connection is making your ground (what you cant tell in this picture is how the ground connection is made). The interior of the cable you run from your voltage source is what delivers the voltage to your foil, the exterior (which is a thin metal shielding wrapped around the cable, which you can't see) of that same cable is what connects you to ground. What you are doing is breaking this up so you can connect to each part individually. It is also good practice to try and get in the habit of using red cables when carrying voltage, and black cables when connecting to ground.

So if we follow the red cable after the split in Figure 7 we see that it makes connection to our acrylic box (which has a little connector inside of it that you attached to the In of your foil). Current will flow through the foil to the Out and from the Out it will connect to the black cable with the wierd splice in Figure 8. That black cable in Figure 8 is both connected to our picoammeter (left side of the picture) and our ground. What's happening is that current flows out the foil and into the interior of that black cable. From there is flows into the picoammeter through the inside of the BNC connection. After current has flown through the picoammter it flows out through the exterior of that BNC connection and into the exterior of the black cable. That wierd splice you see is connected to only the exterior of our black cable and from there it can safely deliver the current to ground. If this does not make sense to you I suggest you follow the conventional current of this circuit with your finger. Everything should be placed in series so your finger should be able to follow one smooth path with no splits or junctions. Keep in mind there should also be a small silver box in lab that you can use to make the connection seen in Figure 7 safely.

Just a few side notes. Be careful with the picoammeter it can be easily damaged. Before using it I highly suggest you read through its manual (you can find it online by simply googling the name on the front of the picoammeter). You have to keep in mind though, that when you ramp up or change the voltage your source is delievering it causes a spike in current which can damage your picoammeter. Whenever you are changing the voltage source, whether that be ramping up or down, make sure that you engage the picoammeters ZEROCHECK option (which you'll understand if you read the manual). Once the voltage is stable you can

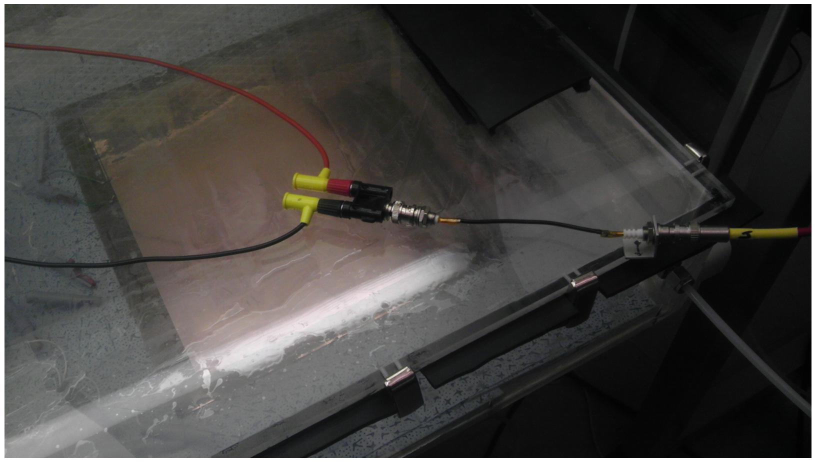

Figure 7: Leakage Current Testing - Part 2

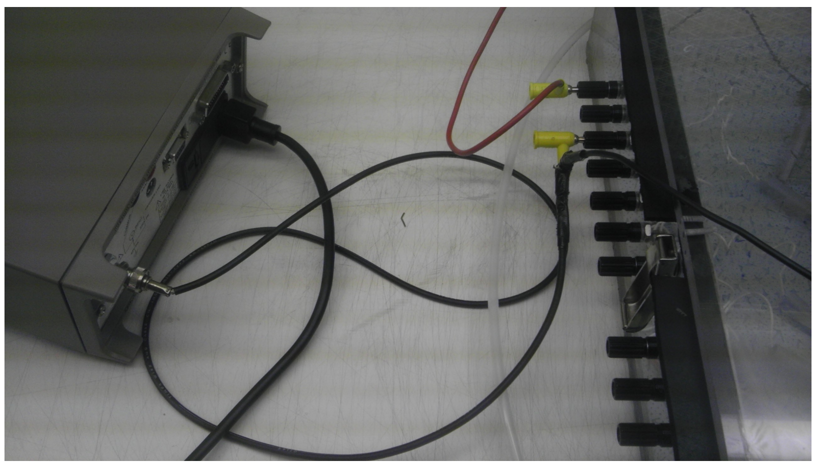

Figure 8: Leakage Current Testing - Part 3

disable this option to continue taking measurements.

1.5 The GEM Sandwich

Now for the really difficult part (sorry to say). The point to emphasize right from the start is that you will be working (sometimes roughly) with GEM foils (see Figure 9). They should be treated with the extreme care and caution. Do your best never to forget that they are easily ripped, torn, and ruined. One gloriously simple trick that saved me from puncturing the GEM foils on multiple occasions is to put whatever tool I was working with flat on a table when not using it (as in immediately). If you are not literally in the process of turning a screw then the screwdriver should be on the table. It is intuitive to want to keep these tools in

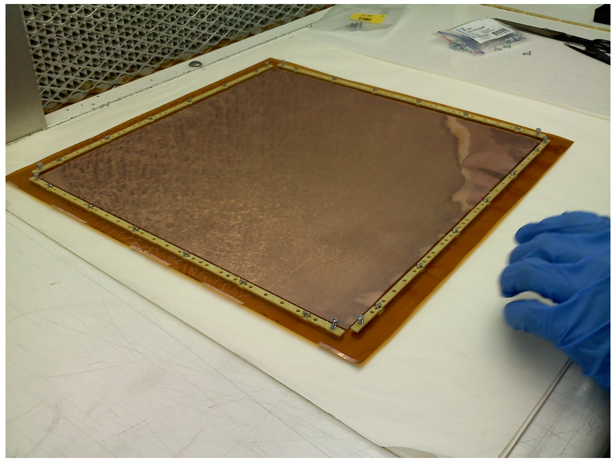

Figure 9: Raw S4 Foil Stack

your hand while you take just a few seconds to turn the foils or adjust some small element of your construction. I implore you to fight this urge. I assure you there will be some moment while constructing the GEM sandwich were your hand will slip or the sandwich will move and if you had been unlucky enough to have a pointed object in hand you would have easily destroyed a foil.

With the words of caution behind us let's move on to the work. Assuming you've high-voltage tested your foils with no problems then let's move on to assembly of the GEM sandwich. The sandwich is held together by four frame sides, just like the gas frame. These sides will consist of four parts, the base, two spacers, and a top. You'll notice that when you look at all the parts you've received there is one piece that is three millimeters tall, and has brown Kapton along one side, this is the base. The two spacers will be pieces with multiple holes and grooves cut into them, that look nearly identical. The top with be a thin flat piece with grooved holes to catch the heads of screws. Together and stacked appropriately these pieces will collectively form one side of your GEM sandwich. I highly suggest analyzing and playing with the frame pieces until you understand exactly how they stack.

Once you understand which pieces are which you can quickly and easily arrange them to form three of the sides, the one difficulty will be the side that must allow high-voltage connections. Remember for this detector you will be using springs to make the HV connections to the foils. This means that the springs have to pass through the holes in the frame pieces to reach the connections for the foils. If the frame pieces aren't arranged properly the foils don't get high-voltage. This next part is going to seem complicated and confusing so I suggest you re-read until you are quite comfortable with the situation.

Remember that with this detector when you are looking at the HV connections on the drift board you work your way from right to left. Meaning that the two HV connections on the farthest right make connection to the lowest GEM foil in your sandwich, the next two to the left make connection to the next GEM up in your sandwich, and so on. What this means is that the springs that are attached to the right most HV connections are the shortest, the next two to the left will be slightly taller and so on. A good rule of thumb is to cut the springs one millimeter taller than they are going to have to reach. This means the right two springs should be 4 millimeters tall, the middle two should be 6 millimeters, and the far left two should be 8 millimeters (since we are working with a GEM that maintains a 3/2/2 spacing scheme).

Now these springs have to pass through the holes in sandwich walls. Obviously make sure that when you are stacking the foils all of their HV connections point towards the same wall of the sandwich, that way you only have to worry about the order of the pieces for one side. Now when you're arranging the pieces for this one side you want to make sure that as you stack the pieces you see fewer and fewer springs. For instance, take the base piece, place all six of your cut springs into this base. Place the first of the two spacers onto the base. If this piece is arranged properly there should only be four springs visible, the middle two and left two. Now place the second frame piece, the only springs that should be showing are the left two. If you place the top on now, all the springs should be covered. Once you have figured out this configuration, set the pieces aside in the exact order you are going to assemble them, so as not to lose this critical detail.

Now the scary part (do not attempt this part unless you have at least two pairs of hands, preferably three). You need to build your foil stack one layer at a time. First, lay all the base pieces in a square, and place your bottom-most GEM foil upon them. Now you are going to want to put the first set of spacer pieces upon the first GEM foil. Directly upon the first set of spacers you should now place the second GEM foil (REMEMBER the foils face down when placed in the sandwich). At this point, it will be difficult to keep this all steady, so I suggest you put the small square bolts into their grooves. This will provide a small amount of stability. Now you are going to place the second spacer upon the second GEM foil. The final GEM foil will then be placed upon the second spacers, and to finish everything off you'll place the top as quickly as you safely can. Once the top is on, you're mostly home-free as now the screws your going to place through the sides will hold everything together (see Figure 10 for a completed foil stack).

The assembly will not be as easy as the previous paragraph makes it seem, the foils and all of the parts are quite movement prone until they are screwed in place. If you are having serious problems getting everything to hold together you can use pegs. If you look closely at either end of a frame piece you'll notice one small

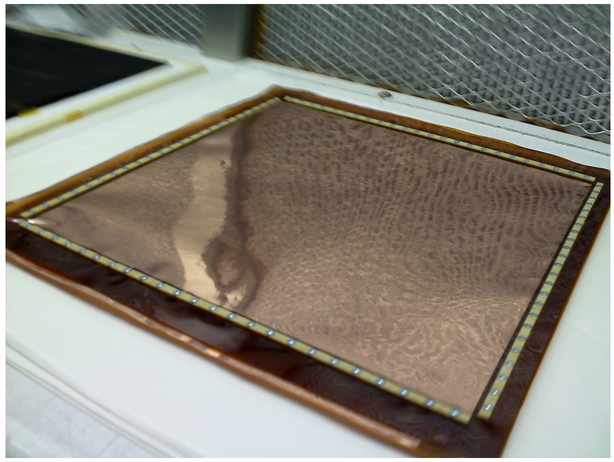

Figure 10: Almost Complete S4 Foil Stack

hole. These allow you to use pegs as a stabilizing mechanism while building the foil stack. I personally did not use these while building the stack as they must be removed at the end, and they did not considerably reduce the amount of work required to build the stack. By far the easiest strategy is to have enough hands to hold the frame steady while one person continues to build the stack upward.

The most frightening part by far of assembling the sandwich will be tightening the screws that hold it all together. There are a large number of screws and they are all midly difficult to actual put in place. What you will notice as you try to put the screws in place is that tightening them, causes the sandwich to want to rotate. What this means is that whenever you are tightening screws you must have other people applying gentle pressure to the walls of the sandwich to keep them from moving. As if this process was terrifying enough the screws require excessive (you will notice) force to actually be placed properly. If you look at Figure 10 you'll notice that all of the silver screws look almost flat with the frame pieces. This is not an accident, for the stack to be placed properly you must be able to run your finger over each sandwich wall without feeling any screws sticking up. As the screws getting lower and lower they become harder and harder to turn. The final few turns will require you to seriously put some effort into the process.

At this point the most immediate danger is your screwdriver slipping out of the screw head and puncturing a GEM foil. To stop this from happening I highly suggest that you place two fingers on the side of the head of the screwdriver that is nearest to the foil center. If your screwdriver slips out from the screw the gentle pressure you're applying with your two fingers should push the head of the screwdriver out and away from the foil center. It is anything from a fool-proof method, but it is surprisingly effective.

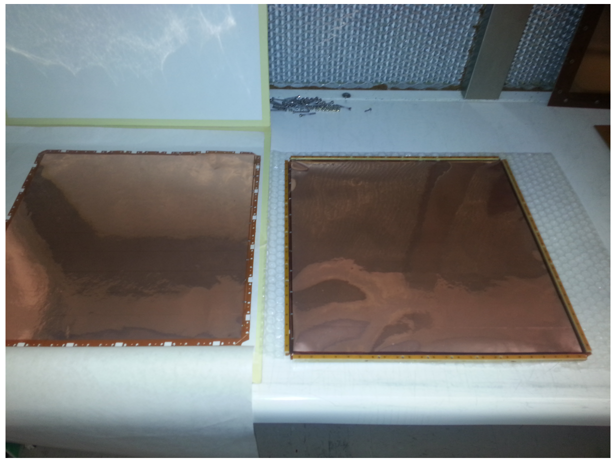

Figure 11: Fully Complete S4 Foil Stack

Once you have assmebled your sandwich and have double-checked that the screws are properly placed you can use a scalpel to cut away the excess Kapton that sticks out from the sandwich. I suggest you go one foil at a time. It is possible to complete each side in one pass; however, the gain in time is not worth the increase in risk of damage. What you should be left with is a sandwich that look almost identical to the right hand side of Figure 11.

1.6 Combining Pieces

We're almost done, just two hurrdles before the finish line. We must combine the completed GEM sanwich with the glued gas frame. The only part that adds significant complication to this otherwise straightforward process are the springs. When you actually lay the sandwich within the gas frame you can't see your springs. If they did not make it properly into the holes then your foils will not get HV, if they do not rest properly on the HV connectors they will not provide HV. There are two methods I can suggest to overcome these problems (neither are easy). You can insert your springs into the GEM sandwich and hold them in place with a long strip of Kapton (like the bits you just cut from your foils). Lower the sandwich into the gas frame while using the Kapton to keep the springs from falling out. Once the sandwich is in place, press it down with a finger and then slide the Kapton out. If you're lucky the pressure alone will be enough to hold the springs in place and keep them in good electrical contact. I'm going to recommend for the purposes of this paper that you instead use the following technique as it is slightly more effective.

Before placing the sandwich sauter the springs to their corresponding electrical connections inside the gas frame. The difficulty here is actually sautering the

Figure 12: Small probe to test for electrical connection between foils and springs

springs so they stand upright (much more difficult than it seems). If you can successfully do this then carefully lower the sandwich onto the springs and use a small tool to get the springs to enter the holes in the sandwich frame.

Regardless of which method you use, you should try and test the foils to see if they are making electrical contact. Grab a multimeter and set it to beep whenever you make electrical connection. Attach a small piece of sauter (see Figure 12) to one of your multimeter probes so you can reach the HV routing line on the foils that leads to the surface mounts (it should run along the corners of the foil so you should be able to reach it even when the sandwich is in the frame). Place one probe on the corresponding rectangle of the foil's In connector and then try to carefully touch the HV routing line of the foil with your sauter probe. If you hear a beep the connection is perfectly fine, and you can continue with the final steps.

1.7 Foil Stretching

Once your foil sandwich is properly in place within your gas frame you can connect the two pieces using the side tightening screws. You want to be careful as attaching all the screws to one side and then moving to the next will cause your sandwich to be off-centered. What I suggest is that you attach the center screw for each side first. Once this is in place and the sanwich looks ceneterd start attaching screws from the outside and working towards the center. You must be careful to only turn the screws enough to just barely catch the nuts in the GEM sandwich. If you turn too much at this stage you will again off-center the sandwich and create more work for yourself.

Assuming you've been able to place all the side tightening screws you'll be left with something that looks awfully similar to Figure 13. Now the real test becomes

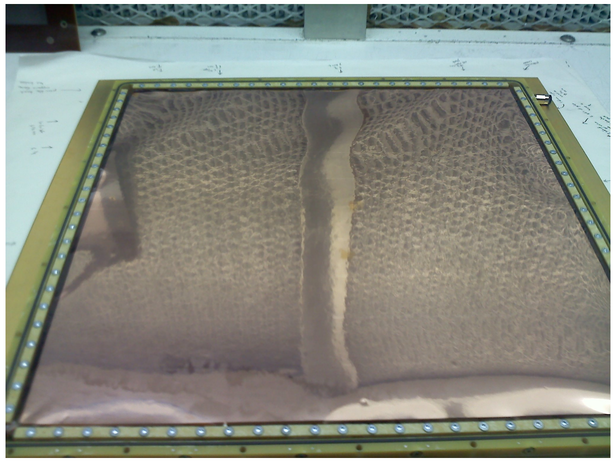

Figure 13: GEM Foils before tightening

tightening the foils as uniformly as possible. What I suggest you do is mark each side screw before tightening with a small green permanent marker. This way you can actually count and track how much you have tightened each particular screw (sounds tedious I know, but it is worth it). Now that you have this mark in place you can go along and tighten each side. I would suggest you adopt a methodical approach, for instance tighten each screw along one side three turns and move onto the next side. The aim is be as symmetric as possible.

Eventually you will reach the point were it becomes difficult to tighten any of the screws. For my build it occured at 7 turns. At this point you shouuld see visible changes in the smoothness of your foils; however, you will likely still encounter wrinkles near the four corners of your sandwich (see Figure 14). From here continue to tighten the screws near the corners until you have eliminated these remaining wrinkles (you want something close to Figure 15). Make sure to keep note of these extra turns. If it ever becomes the case that you must reassemble your detector the information will become invaluable. With your foils stretched you are free to seal the detector with the readout panel.

The last step before you can begin testing is attachment of the HV divider. If you were lucky enough to have foils with the In connection routed to the left you are fine to simply attach the divider with the white side facing down. If your connectors were routed to the right you will need to flip the connectors for that particular foil on the divider (see Figure 16 as compared to Figure 17).

Figure 14: Wrinkled corners on a stretched GEM foil

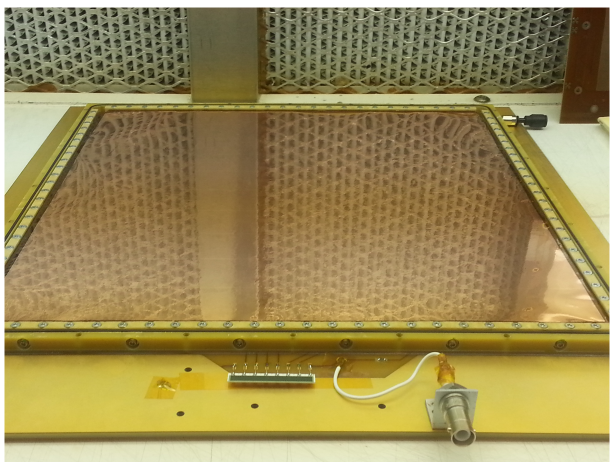

Figure 15: Stretched GEM foil

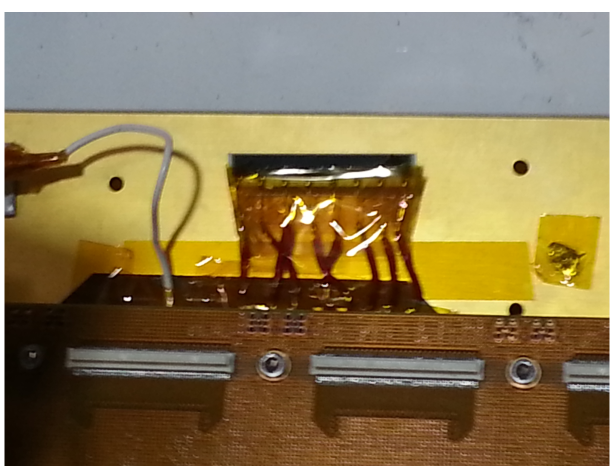

Figure 16: Swapped connections for the HV divider

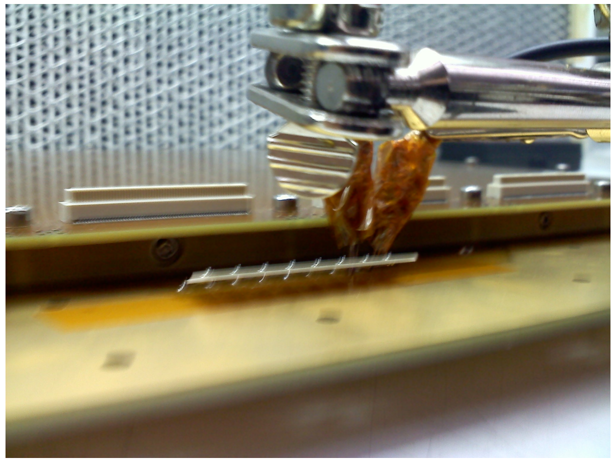

Figure 17: Unswapped HV divider being used for parallel testing of GEM foils

2. Commisioning the S4

2.1 Foil Spacing Test

The first test you must conduct on your detector after assuring a proper gas seal is proper foil alignment. If you stretched your foil sandwich correctly you should be left with almost perfectly parallel foils. In order to test this, you will use the same method of applying static voltages. The important difference in this circumstance is that your applying voltage between different foils.

If you remember from section 1.4, we tested our GEM foils by applying a voltage difference created by our source and ground. We're going to employ this same method without the picoammeter and between different foils. For instance if you wanted to check whether the gap between foil 1 (the closest to the drift) and foil 2 (the middle foil) was parallel you would apply voltage to the down side of foil 1 and have the up side of foil 2 at ground (REMEMBER the foils are now upside down in the sandwich). The easiest method for applying this voltage is to use a small set of clips to make contact through the HV divider (see Figure 17).

Remember this process is almost exactly the same as leakage current testing, just lacking in measurement. What you are concerned with is sparking. If your foils are stretched properly you should be able to apply a voltage difference of 991 volts (in air) without hearing sparks between foils. It may sound a bit frightening but you should use this noise as cue to turn your voltage source off and continue stretching. My strategy was to increase voltage between the gap by 100 volts per step. I would then continue stepping up the voltage until I heard inter-foil sparking (the sounds is unmistakable and quite loud). I would mark the voltage this occured at, stretch the foils by a few screw turns, and then start the test over again.

If you are able to ramp your foils up to 991 volts (or 1.3 times the normal operating voltage difference between foils) without any sparking, great, your stretching was conducted well. If not, simply continue stretching until the sparking does not occur. You'll see that as you stretch the voltage at which sparking occurs goes higher and higher. Before you can be sure your detector works you must conduct this test between all the foil gaps (1 to 2, and 2 to 3). Once these tests are complete you've completed assembly (congratulations). Now on to the real tests (to be discussed further in this document).