CLAS 12 Drift Chamber Wire Stringing Manual

George Jacobs - 14 May 2008 GENERAL DRAFT
ODU Group - R2 Rev
ISU Group - R1 Rev
JLAB Group - R3 -Rev

Purpose

This manual is written for the detector wire stringing and instrumentation crews who may not be familiar with the technical aspects of the detectors they will be building. It is intended to provide a basic project orientation for the personnel hired as stringers and fabricators for this part of the project. This is a training manual as well as a practices and procedures manual for detector fabrication, stringing, testing, and instrumentation. Requirements and procedures are listed and explained and safety issues as they pertain to the tasks outlined. This manual should be used as a basis for a more detailed and Region specific manual. This manual should be edited by each group, ODU, ISU, and JLAB as needed to directly apply to their project. The current contents may not all apply to each CLAS 12 project as it is based on the CLAS 6 R2 and R3 manuals written over a decade ago.

Introduction

The CLAS 12 is a multiple component detector system designed to track and identify subatomic particles resulting from an electron beam or photon beam interaction with a target. The drift chambers track the path of these particles as they pass through the detector. The 18 drift chambers will be configured in 3 regions of 6 sectors each to track these particles. Each of the 18 detectors has the same basic geometry. Each of the 6 sectors in each region are identical. Region 3 (R3) is approximately 50% larger than region 2 (R2) and region 2 is approximately 50% larger than region 1 (R1). When complete, they will be arranged into a 360 degree array of approximately 45 degrees acceptance.

Each region of drift chambers will be strung by a different group in a different location. The R1 detectors will be strung at Idaho State University (ISU), the R2 detectors will be strung at Old Dominion University (ODU), and the R3 detectors at JLAB. Each location will have it's own team to string and instrument the detectors they are responsible for. The same basic stringing procedures and requirements will apply to all 3 regions of detectors.

The scientific basis for detector operation is unrelated to the structure or type of mechanical framework used to position and support the wires. A drift chamber (DC) operates because of the gas, wires, high voltage, and electronics. DC detectors have been in use for decades in many sizes and geometries. They are usually designed for use in a particular experiment or experimental station at a particle accelerator or collider. DC design and operational characteristics have been well studied and documented. DC operation can be explained using elementary physics.

As a charged particle or photon passes through a gas-filled chamber containing field and sense wires biased at negative and positive high voltages it ionizes the gas due to the strong electric field. The resulting electrons drift toward the sense wire further ionizing the gas creating more electrons in an avalanche effect until the reach the sense wire where they create a current pulse. This current pulse is amplified by the on board electronics and then to the data acquisition system. The position of the original ionizing track can be determined from the time it takes the ionization electrons to travel to the sense wire as both the electron drift velocity and signal processing times are known. The drift velocity is determined from the voltages, size, and shape of the drift cells. The data acquisition system then processes the data to reconstruct the particle tracks.

CLAS 12 central detector consists of 3 regions of drift chambers and a superconducting toroidal magnet. The particles first pass through the R1 chambers and then enter the magnetic field created by the magnet. The magnetic field causes the particle track to bend according to it's momentum. The particle then leaves the magnetic field and enters the R3 detector to track the resulting path. This information used in conjunction with the data from the other parts of the spectrometer can then be used to identify the particles.

The Detectors

The detector is made up of 2 end plates which position the wires and support the wire tensions. A back plate, nose plate, and frame support and position the end plates relative to one another. The gas volume is contained by aluminized mylar windows, 0.001 in thick in R1 and R2. For R3 the upstream window will also be a 1 mil aluminized mylar window, but the downstream seal will be a composite shell for structural strength. Each of the 18 detectors will have ~1440 sense wires and 3600 field and guard wires. The total force on the end plates due to wire tensions is ~1000 lbs.

Each of the detectors is assembled in a precise manner and to align the end plates relative to on another. This will position the wires withing the design tolerance. Wire position must be precise in order to track the particles within design resolution. Because of the high voltages required to operate this type of detector, materials and cleanliness standards must be strictly adhered to. High voltage breakdown can be caused by an inviable fingerprint on a surface. High voltage can cause chemical breakdown and chemical reactions in contaminant materials and vapors.

Requirements for an operational detector are a pure and exact gas mixture, perfectly clean and smooth wires, the proper combination of wire diameters, proper voltages, infinite ground planes, and an operational data acquisition system.

The total lifetime of a detector is determined by 4 major factors;
1) TOTAL RADIATION EXPOSURE
2) GAS CHARACTERISTICS
3) DETECTOR DESIGN
4) FABRICATION TECHNIQUES

The total radiation a detector can be exposed to represents the maximum possible life span a detector can have under perfect circumstances. This is the bottom line in detector longevity. This is determined by wire damage due to current. Nothing lasts forever and even gold plated wires wear out.

Perfect circumstances include a perfect gas mixture which has no contaminants. All contaminants cause detector degradation. Some contaminants can rapidly and permanently degrade a detector. The planned gas mixture if Argon and CO2 is a clean mixture of pure gases. Most of the contaminants in these gases are not harmful. So in our case the greatest change for contamination is during the fabrication and stringing process.

Solvents and lubricants used in the manufacturing process of many detector components must be removed and the components cleaned to vacuum standards. This is not a viable option for some components which may require alternative manufacturing and fabrication techniques to produce clean components free from contaminants. The use of solvents, glues, epoxies, tape, lubricants, and improper materials will shorten detector life. Using materials that out gas, using the wrong glues or epoxies, using excessive amounts of glues or epoxies will create an ongoing long term source of contamination.

Detectors are strung in a clean room with all persons wearing appropriate clean room clothing. Gloves are worn and changes frequently to prevent any contamination from human touch. Hair nets are worn with all hair tucked inside to prevent hair contamination. Masks are worn in the case you must work in close proximity to the wires to prevent breathing on the wires or interior surface of the detector. A single human hair can permanently short out the wires it touches and coat the wires around it creating excessive current. A fingerprint may cause a high voltage breakdown with permanent carbon tracks requiring that area of the detector to be turned off. Proper quality control is a critical factor for detector lifetime.

General Principals and Definitions for Stringing the Wires

1) The **operator** is the person at the upper end plate who lowers the wire and makes the top crimp.

2) The **catcher** is the person at the lower end plate who uses the magnetic catcher to pull the wire out of the chamber.

3) The **tensioner** is the person who tensions the wire and crimps the pin.

4) The **assembler** is the person who attaches the pre-tensioners to the pre-tensioning wires.

5) When more than one stringing team are working in close proximity, they shall position themselves in a manner as to minimize interfering with each other.

6) The catcher must work away from the wires which have already been caught.

7) The tensioner must have enough free space to position and tension the wire using the pulley assembly.

8) The catcher must be able to see in the chamber to catch the wire using the magnet.

9) The assembler or tensioner must work toward the wires that are being caught.

10) All persons working in the vicinity of the pretensioners must wear safety glasses.

11) All pre-tensioners shall have a short section of tygon tube installed over the end the adjuster screw for safety.

12) All persons working on or near the chamber must wear clean nitrile gloves.

13) Only properly trained and specifically authorized persons are permitted to operate, move, or adjust any fixture in the clean room. This includes the gantry crane, stringing fixture, stringing platform, material handling equipment, or ladders.

14) Clear mylar approx 0.010 in thick must be used to cover the window opening of the chamber before stringing begins.

15) All wires are cut as close as possible to the pin to prevent stray pieces of wire from entering the chamber.

16) Double sticky tape should be used to hold small scraps of wire such that they do not migrate into the chamber.

17) The wires must be cut cleanly such that it easily threads through the crimp pin.

18) The operator and catcher must pay special attention to the wire as it is lowered in order to prevent twisted or crossed wires.

19) Wires are strung row to row in each superlayer from the upstream side to the downstream to prevent crossing wires. (string in the direction away from the previously strung wire)

20) Wire stringing operations require great team coordination and communication. Member must stay focused and concentrate on stringing at all times.

21) The stringing machine pulley alignment must be checked hourly when stringing sense wires.

22) Crimper jaw gap must be checked each shift prior to use and every hour when in use.

23) Clean room clothing, shoes, etc, shall not be worn outside of the clean room. When transferring equipment into or out of the clean room a second crew will be used on the outside of the clean room.

24) Special care must be taken when crimping the pins as not to bend or misalign them.

25) The catcher and tensioner can be the same person and perform both duties simultaneously.

26) All stringing team members must be familiar with the safe and proper use of ladders, mobile stairs, and mobile work platforms.

27) All stringing team members must be familiar with the general safety precautions related to adjusting the detector on the stringing fixture.

28) All persons must take special care not to bump, touch, or come into contact with the crimped pins of already strung wires on the chamber.

29) Special care must be used such that no action or operations in the clean room could result in damage to the detector.

30) The catcher should frequently visually inspect the already strung wires for any abnormality such as twisted or broken wires.

31) Tension testing should be performed at the beginning of the shift on wires strung during the previous shift or day. It's more efficient to restring the removed wires and continue stringing operations until the end of that shift. Then test the restrung wires along with the newly strung ones beginning of the next shift.

32) Safety comes first for all action or operations. When ever any question arises as to safety, stop all related work and contact your supervisor.

33) Turn off the magnet, o-scope, and tension tester after each use.

34) Always verify the magnet is off before stringing wires or working near it.

Pre-Tensioning

Pre-tensioning is performed prior to stringing the other wires in the chamber. For the CLAS12 R1 we plan on pretensioning using the CLAS 6 R2 devices. This uses a cable which is later removed.

The CLAS12 R1 prototype uses a frame to hold the endplates. The frame is very strong, but still deflects due to wire tensions. In order to minimize wire position error, the frame is pretensioned to simulate the full wire load and the endplate is adjusted via survey or precision fixture to lie flat in the deflected frame.

Removable Cable Method

1) The operator lowers the SS wire rope through the upper hole and into the chamber by hand.

2) The cable is threaded through the corresponding lower hole by the catcher

3) The assembler then threads the load washers and then a crimp sleeve onto the cable and loops the cable around and back through the hole in the crimp while minimizing the size of the loop and then finally crimping it with the special crimp tool.

4) The operator then cuts the cable and threads a crimp.

5) The operator then threads a thimble onto the stud and loops the cable around the thimble and through the hole in the stud.

6) While pulling the wire rope tight, the operator crimps the crimp and cuts the excess cable as close to the crimp as possible.

7) The assembler then assembles the pretensioner and compresses the spring about 1/4 inch such that the assembly is stable. The threaded stud must not be permitted to turn and twist the cable during this process.

8) Once all pretensioner assemblies are in place, they are tensioned from the ends of the chamber to the middle. Springs are compressed to the proper height using the pretension gage. This will take at least 3 separate iterations.

Stringing and Tensioning the Wires

Special Considerations for Tensioning the Wires

1) Due to the angle of the end plate and the required tensioning procedure, the tensioner must always work from the long end, back plate, toward the small end, nose, of the chamber.

2) The tensioning pulley assembly must be used in a manner as to minimize interference with the catcher.

3) The wire must exit the pin perpendicular to the end plate in order to be properly tensioned and crimped. When the wire is perpendicular to the end plate any binding or friction from the wire contacting the pin or feed through will not effect the the wire tension.

4) The pretensioners must not be adjusted or altered in any manner after the tension has been set.

5) Special care must be taken not to perform any actions which could cause any change in wire tensions such as pushing or pressing on the pin, pulling or twisting the pin, or bending the pin.

A) Stringing the guard wires

(The following steps are repeated for each wire)

1) The wire is lowered through the upper feed through into the chamber by the operator using the stringing machine and gold chain with steel needle assembly. This is performed extremely carefully as not to fall off the wire, twist the wire, wrap around adjacent wires, or damage adjacent wires.

2) The magnetic catcher is inserted through the corresponding lower feed through by the catcher to pull the wire out of the chamber.

3) The wire is lowered by the stringing machine. The stringing machine can be operated by the operator who will then listen to the instructions of the catcher as when to lower and stop the wire. The stringing machine can also be operated by the catcher using the remote. (there are advantages and disadvantages according to the situation)

4) The wire is lowered until approximately 6-10 inches of wire comes out of the bottom of the chamber.

(steps 5-8 are performed simultaneously)

5) The catcher threads the pin over the wire while not pulling the wire out of the operators hands.

6) The operator cuts the wire with the carbide cutting tool while not pulling the wire out of the catchers hands.

7) The operator threads the pin over the wire while not pulling the wire out of the catchers hands.

8) The operator slides the pin down the wire and carefully seats it in the feed through.

9) (NEW STEP) The operator and catcher coordinate lowering the wire until only 1-2 inches remain above the pin, this gives the extra length needed for tensioning and verifies the wire is not pinched between the upper feed through and pin. (NEW STEP)

10) The operator then double crimps the pin and then signals the catcher to attach the temporary weight.

11) The catcher attaches the temporary weight near the bottom of the wire.

12) The operator and catcher repeat steps 1 -12 until all guard wires are strung.

13) The tensioner positions the wire tensioning pulley assembly such that the wire hangs perpendicular to the end plate and concentric to the pin. The wires perpendicular position must be visually verified from 2 directions 90 degrees apart.

14) The tensioner replaces the temporary weight clip with the tensioning weight clip for the guard wires.

15) The tensioner does a final check of the pin seating and wire perpendicularity.

16) The tensioner then slightly reduces the tension of the weight with their hand by partially supporting the tensioning clip with their hand.

17) The tensioner then slowly reapplies the tension by slowly and gently releasing the weight.

18) The tensioner once again slightly reduces the tension of the weight with their hand by partially supporting the tensioning clip with their hand.

19) The tensioner then slowly reapplies the tension by slowly and gently releasing the weight.

20) The tensioner then carefully crimps the pin, taking care not to push the pin further into the feed through or to pull it out.

B) Field Wire Stringing

<u>Verify the magnet is off prior to beginning stringing operations</u>

(The following steps are repeated for each wire)

1) The wire is lowered through the upper feed through into the chamber by the operator using the stringing machine and gold chain with steel needle assembly. This is performed extremely carefully as not to fall off the wire, twist the wire, wrap around adjacent wires, or damage adjacent wires.

2) The magnetic catcher is inserted through the corresponding lower feed through by the catcher to pull the wire out of the chamber.

3) The wire is lowered by the stringing machine. The stringing machine can be operated by the operator who will then listen to the instructions of the catcher as when to lower and stop the

wire. The stringing machine can also be operated by the catcher using the remote. (there are advantages and disadvantages according to the situation)

4) The wire is lowered until approximately 6-10 inches of wire comes out of the bottom of the chamber.

(steps 5-8 are performed simultaneously)

5) The catcher threads the pin over the wire and seats it in the feedthrough while not pulling the wire out of the operators hands.

6) The operator cuts the wire with the carbide cutting tool while not pulling the wire out of the catchers hands.

7) The operator threads the pin over the wire while not pulling the wire out of the catchers hands.

8) The operator slides the pin down the wire and carefully seats it in the feed through.

9) (NEW STEP) The operator and catcher coordinate lowering the wire until only 1-2 inches remain above the pin, this gives the extra length needed for tensioning and verifies the wire is not pinched between the upper feed through and pin. (NEW STEP)

10) The operator then crimps the pin and then signals the catcher to attach the temporary weight.

11) The operator and catcher repeat steps 1 -12 until all field wires are strung.

13) The tensioner positions the wire tensioning pulley assembly such that the wire hangs perpendicularly to the end plate and concentric to the pin. The wires perpendicular position must be visually verified from 2 directions 90 degrees apart.

14) The tensioner replaces the temporary weight clip with the tensioning weight clip for the field wires.

15) The tensioner does a final check of the pin seating and wire perpendicularity.

16) The tensioner then slightly reduces the tension of the weight with their hand by partially supporting the tensioning clip with their hand.

17) The tensioner then slowly reapplies the tension by slowly and gently releasing the weight.

18) The tensioner once again slightly reduces the tension of the weight with their hand by partially supporting the tensioning clip with their hand.

19) The tensioner then slowly reapplies the tension by slowly and gently releasing the weight.

20) The tensioner then carefully crimps the pin, taking care not to push the pin further into the

feed through or to pull it out.

C) Sense Wire Stringing

Verify the magnet is off prior to beginning stringing operations

(The following steps are repeated for each wire)

1) The wire is lowered through the upper feed through into the chamber by the operator using the stringing machine and gold chain with steel needle assembly. This is performed extremely carefully as not to break or fall off the wire, twist the wire, wrap around adjacent wires, or damage adjacent wires.

2) The magnetic catcher is inserted through the corresponding lower feed through by the catcher to pull the wire out of the chamber.

3) The wire is lowered by the stringing machine. The stringing machine can be operated by the operator who will then listen to the instructions of the catcher as when to lower and stop the wire. The stringing machine can be operated by the catcher using the remote. (there are advantages and disadvantages according to the situation)

4) The wire is lowered until approximately 6-10 inches of wire comes out of the bottom of the chamber.

(steps 5-8 are performed simultaneously)

5) The catcher threads the pin over the wire and seats it in the feedthrough while not pulling the wire out of the operators hands.

6) The operator cuts the wire with the carbide cutting tool while not pulling the wire out of the catchers hands.

7) The operator threads the pin over the wire while not pulling the wire out of the catchers hands.

8) The operator slides the pin down the wire and carefully seats it in the feed through.

9) (NEW STEP) The operator and catcher coordinate lowering the wire until only 1-2 inches remain above the pin, this gives the extra length needed for tensioning and verifies the wire is not pinched between the upper feed through and pin. (NEW STEP)

10) The operator then crimps the pin and then signals the catcher to attach the temporary weight.

11) The operator and catcher repeat steps 1 -12 until all field wires are strung.

13) The tensioner positions the wire tensioning pulley assembly such that the wire hangs perpendicularly to the end plate and concentric to the pin. The wires perpendicular position

must be visually verified from 2 directions 90 degrees apart.

14) The tensioner replaces the temporary weight clip with the tensioning weight clip for the field wires.

15) The tensioner does a final check of the pin seating and wire perpendicularity.

16) The tensioner then slightly reduces the tension of the weight with their hand by partially supporting the tensioning clip with their hand.

17) The tensioner then slowly reapplies the tension by slowly and gently releasing the weight.

18) The tensioner once again slightly reduces the tension of the weight with their hand by partially supporting the tensioning clip with their hand.

19) The tensioner then slowly reapplies the tension by slowly and gently releasing the weight.

20) The tensioner then carefully crimps the pin, taking care not to push the pin further into the feed through or to pull it out.

Testing Procedures

Wire Tension Measurement Method

Wire tensions are measured by varying the frequency of a current source with the wire in a magnetic field. The results are observed on an oscilloscope. The period is found by observing the resonance frequency on the oscilloscope using the X-Y scale. The observed period is then compared to the known period for that wire at that length at proper tension. The allowable range of tensions is determined by difference between the calibration period and the observed period at resonance for that particular wire. If the observed period is more than 10% higher or lower than the calibration period, the wire is replaced.

The calibration period was found by actual measurement of the resonant period of different lengths of the actual wire. A straight line was fitted to the observed data. A comma delineated table of individual wires and their lengths was inserted into a spreadsheet and the calibration periods for each were generated. The observed periods were entered into the spreadsheet and compared to the calibration values. The results were listed a percentage in the next column to the right and either a green OK or a red BAD in the one next to that. The spread sheet was setup that six columns were visible, wire, min period, observed period, max period, percentage difference, and OK/BAD. The only editable column was for entering the observed period. This was designed to be fast, problem free, and simple to use in order to maximize efficiency.

Wire Tension Measurement Procedure

Preliminary Discussion:

This process works most efficiently with 3 people, an upper pin connector, a lower pin connector, and a computer-tension tester operator. The connections are made at each end of the wire at the pins by the upper and lower connector persons while the operator adjusts the frequency driver and enter the results into the spreadsheet. The spreadsheet should be setup such that the order of testing is the order of the rows listed so time is not wasted searching for the correct line in the file. Tension testing requires skill and experience. This can be a very time consuming process and errors can occur. Experience using the o-scope and driver box is critical in order to find crossed wires. Not all stringers will have the same level of observational and analytical skills. Supervisors should identify and assign jobs according to the skill of the stringers.

This test, by it's nature verifies continuity in each wire tested. This test will also identify crossed or twisted wires because of the drastic decrease in signal amplitude seen on the o-scope. Whenever a wire is removed or restrung all adjacent wires must be retested for proper tensioning. This is the only opportunity there is to restring and retest wires. Once the detector is removed from the stringing fixture your options are very limited.

Tension Testing Procedure

1) Position and turn on the magnet.

2) Position the testing station o-scope far enough from the magnet so it works correctly.

3) Open the spreadsheet file for the wires being tested.

4) The upper and lower connections are made on the wire to be tested.

5) The tension tester driver is set to a period slightly below the minimum value in the spreadsheet row for that wire.
(This speeds up the process significantly by eliminating hunting, there is no need for a more time consuming search for the period if the wire requires pulling and restringing)

6) The period is increased until a resonance is seen on the o-scope or until slightly above the maximum value. Tensions which are only slightly too high can be reduced very slightly by pushing the pin in a tiny bit into the feed through. Wires with tensions that are too low are not salvageable.

7) The resonance value is recorded in the appropriate column if found or if the value is not found, either too high or too low outside the range, the box is left blank. Blank boxes represent wires which need to be pulled and restrung.

8) Return to step 4 to test the next wire.

9) Turn off the magnet and test equipment. **If you do not turn off the magnet, all the wires you string will be tangled and crossed as the chain and needle are deflected in the magnetic field.**

10) Remove failed wires if required. It's most efficient to restring the removed wires and then test them.

Final Pre-Instrumentation Testing and Wire Wrapping the Buses

The next tests are as a second or last chance check for broken, shorted, or twisted wires that were somehow missed during the continuous visual inspection performed during the stringing process and then missed again during tension testing. These are the final tests prior to running cosmics . Wire wrapping the Field and Guard wire layers is a critical part of the testing process. The order and type of wire wrap performed is integrated into the testing process. Testing at each step verifies your ok at that point. This verification make troubleshooting simpler and less time consuming. It's much less time consuming to identify these problems as they occur preventing unneeded labor and time unistalling and then re-installing boards, cables, etc.

Sense Wire to Field Wire Shorts

The most common problem found has been and will be sense wires wrapper around or crossed with field wires. This is because the sense wires are strung after the field wires are already in place. Prior to signal and high voltage board installation the Field and Guard wire layers are wire wrapped on the high voltage side only. Wire wrapping is done such that the buses face each other as in the below photo.

Each layer is wrapped in a single continuous bus with the buses facing each other as shown in the above photo or CLAS6 R2. The maximizes the distance between the negative HV bus and the positive HV sense wire connection boots. When the end of the one Field wire layer is reached wrapping continues to the next without a break in the wrap. This permits faster and better quality wire wrapping as well as a simpler testing procedure.

Once the HV side of the detector is wrapped, all Guard wires will be bused together and all field wires will be bussed together. A multimeter will be used to determine if there are any shorts between any Field layers and any sense wires. A single connection from the multimeter to the Field wrap on the high voltage side connects all field wires to the meter. The other lead is used to test every sense wire for a short to any field wire in the detector. This permits an entire chamber to be tested very rapidly. When a shorted sense wire is found, this sense wire should be removed. The pins need to be replaced to seal the resulting hole and it needs to be labeled and yellow mylar tape placed over the pins. The HVTB and STB should also be marked and the holes taped over. A list should be kept of these removed wires.

Field Wire to Field Wire Shorts

The second most common problem found will be the case of 2 field wires twisted together. A multimeter will also be used to determine shorts, twisted wires, by measuring the resistance between each field wire on the signal board side and the Field wire wrap bus on the HV side. Twisted wires will have much lower resistance than the non twisted wires nearby. In this case, you do not get a high voltage short because both wires are at the same negative potential. This problem may cause a hot sense wire or wires due to the localized increased electric field that results. It is not recommended practice to remove field wires due to the high potential of damaging to nearby wires. It is also not recommended to remove the sense wires in this situation. The recommended and least invasive action is to simply disconnect the effected sense wires by labeling and placing yellow mylar tape over the pin. The effected sense wires will the the ones on either side of the cross only. The diagonal cells will lose some efficiency only and do not require any corrective action. The HVTB should also be marked and the hole taped over. A list should be kept of these disconnected wires. The STB side of these wires should be connected so they are not floating.

Sense Wire to Sense Wire Shorts

The least likely problem to find is the sense to sense twisted wire. It is very unlikely that 2 sense wires can be twisted together without touching a field wire, but it is possible. This problem is less likely the smaller the cell size. We did not find any in CLAS 6 R2. But for CLAS 12 R3 this test may be useful. I am including it here for completeness sake. This test will determine if any signal wires are crossed.

This is a HV test and the high voltage side wire wrap buses are now segmented by cutting the long continuous wrap into the prescribed 16 wire lengths. The high voltage boards are then installed and conductive rubber connections are made.

If twisted sense wires are present and the HV is ramped up, these wires will be very "HOT" and draw high current due to their very close proximity to the field wires. These wires will cause the effected positive and negative HV channels to trip as they ramp up in voltage. This is not a hard short between positive and negative The wires are too close at some point and the electric field will be too high and current will flow.

Once the high voltage trips due to high current and the HV boards are identified. Typically this means there is either a sense wire twisted with another in the same layer or that of an adjacent layer. A multimeter can then used to measure the resistance between sense layers on those boards. There should be infinite resistance between layers, any other result indicates a short or twisted pair of sense wires between those layers. The multimeter is also used to measure the resistance from the signal side of the wire to the high voltage bus. This should read ~ 1 megohm, which is the value of the current limiting resistor in the circuit, where as a reading of 0.5 megohm indicates a shorted or twisted pair within the same layer.

These wires must be disconnected from the HV. The holes in the HVTB should be marked and taped over. A list should be kept of these disconnected wires. The STB side of these wires should be connected so they are not floating.

Final HV Testing and Instrumentation

The STB side of the chamber can now be wire wrapped. As was done on the HV side, each layer is wrapped in a single continuous bus. When the end of the one Field wire layer is reached wrapping continues to the next without a break in the wrap. This permits faster and better quality wire wrapping. Once complete, the wire wrap buses are then segmented by cutting the long continuous wrap into the prescribed 16 wire lengths. Once complete, the HV should be turned on to test for problems before installing the signal boards..

The next step is to install the signal boards and conductive boots to the signal pins. Once complete, the HV should be turned on once more to test for problems before installing the mylar or lexan covers to seal the HV areas of the electronics.