Technical Assembly Manual for GE1/1 Chambers

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October 10, 2017

Abstract

This document describes in details the procedure for the assembly procedure of GE1/1 detectors to be used in the forward region of the CMS Muon spectrometer during the LS2 shutdown. The document serves as a technical manual for GE1/1 production community for the detector construction. Furthermore, a video tutorial which shows in detail the chamber construction is provided with this document to assist the detector production community.

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1 Preparation of the readout board

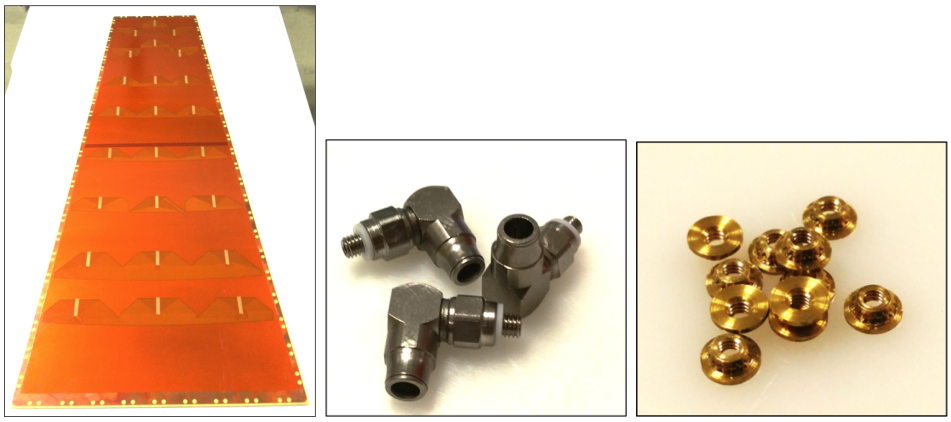
Preliminary Note : In this section some of the assembly steps were performed in a clean room for the purpose of improving the quality of the pictures. It was done in a very conscientious way and the work was immediately followed by a special cleaning. However the forthcoming steps are likely to produce dust and hence must be performed outside the clean room to prevent contamination.

1.1 Materials and tooling

The preparation of the GE1/1-X readout board includes the mounting of the brass inserts in the lateral flanges, the threading of the gas holes and the glueing of the gas connectors. The following list describes all the components that are required for the preparation of the board. All these components are provided with the shipment box:

1. One readout board.
2. Two gas connectors Parker Legris PN:3299 03 09.
3. Eight brass inserts Titanox PN: M0002292.

The components are shown on Fig. 1.

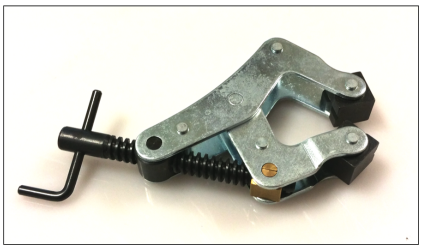


(a) Readout board. **(b)** Gas connectors. **(c)** Brass inserts.

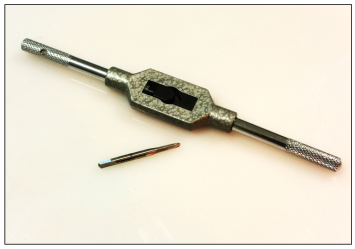
Figure 1: List of components required for the readout board preparation.

The tools required for proper assembly are listed below, and shown on Fig. 2.

1. One clamping hand with flat head.
2. A tap wrench with M3 to 0.5 mm hand tap.
3. Two-part epoxy glue Araldite 20 11 with glue gun.
4. A small metallic support.
5. Pure ethanol and clean pieces of tissue.
6. A vacuum cleaner.

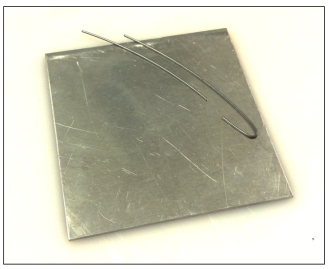


(a) Clamping hand.



(b) Tap wrench.

(c) Araldite 20 11.



(d) Metallic support.

Figure 2: List of components required for the readout board preparation.

1.2 Step-by-step procedure

::Mounting of the brass inserts::

Step 1: Place the readout board on the working table with the strips facing up. It is recommended to use a soft material or a sheet of foam in between to avoid scratching the Panasonic connectors when working on the board (Fig. 3).

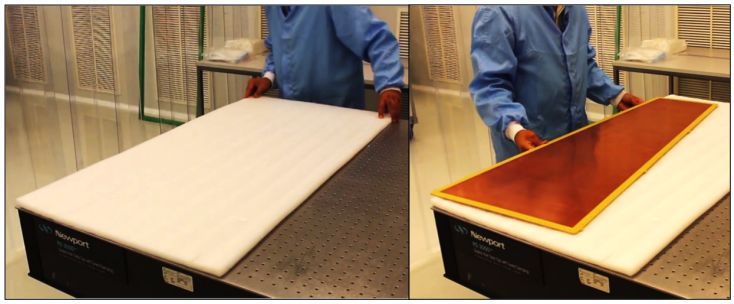


Figure 3: Preparing the working table and the board.

Step 2: Place each brass insert in the dedicated housing in the flanges, with the threaded side sitting inside of the holes (Fig. 4 left).

Step 3: Use the clamping hand to press the insert against of the holes until it gets fixed in it (Fig. 4 right).

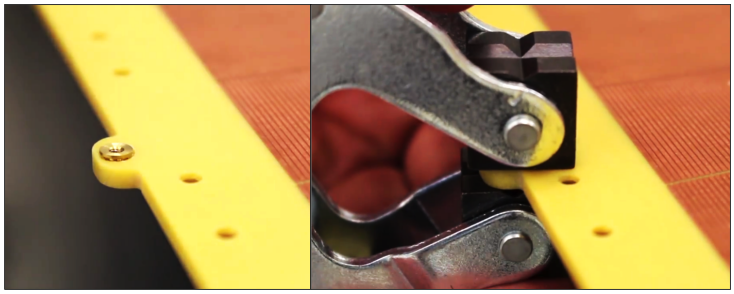


Figure 4: Clamping of the brass inserts.

Step 4: Finally, use your finger to make sure the heads of the inserts fit flush with the surface of the board.

::Glueing of the gas connectors::

Step 1: Flip the readout board upside down so that the Panasonic connectors face up (Fig. 5 left).

Step 2: Insert the 3 mm tap in the hole dedicated to the gas connector. Keep the tool vertical while slowly screwing it by hand to create the thread pattern in the material (Fig. 5 right).

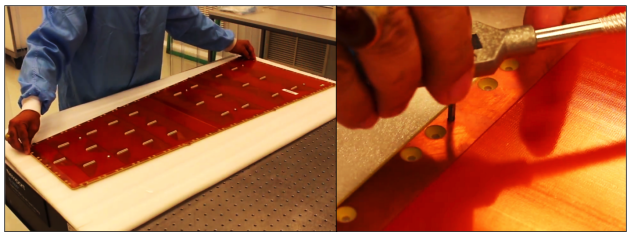


Figure 5: Clamping of the brass inserts.

Step 3: After screwing all the way through the hole, gently unscrew the tap to take it out (Fig. 6).

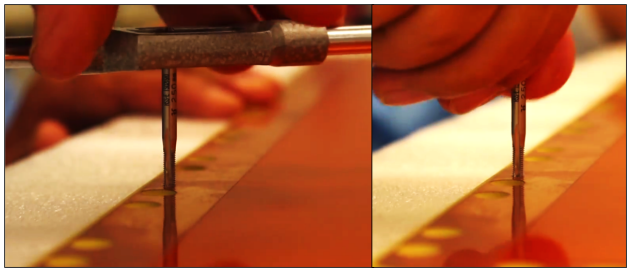


Figure 6: Making the thread in the gas in/outlets (1).

Step 4: Remove the resulting dust with a vacuum cleaner and clean both sides of the board around the hole with a clean tissue paper and ethanol (Fig. 7).

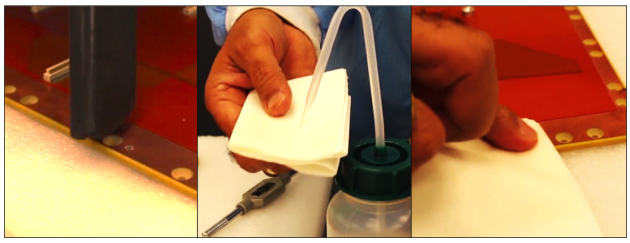


Figure 7: Cleaning of the gas in/outlets.

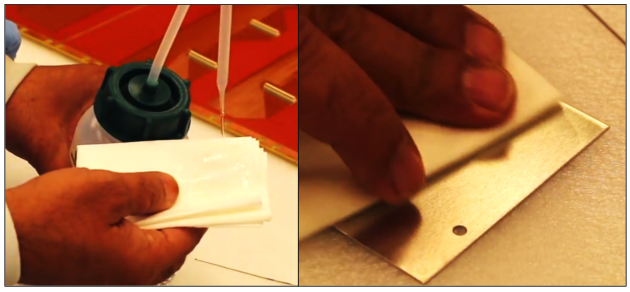


Figure 8: Preparing the metallic support for the glue.

Step 5: Use again the ethanol to clean up the small metallic support where you will mix the glue (Fig. 8).

Step 6: Pour the two-part epoxy glue onto the support and vigorously mix it with a clean metallic stick until you obtain an opaque and uniform paste (Fig. 9).

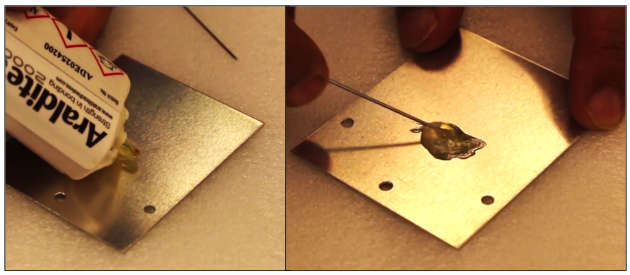


Figure 9: Mixing the epoxy glue.

Step 7: Before applying the glue, remove the teflon washer from the gas plugs. This washer is a white circular piece sitting under the body of the connector (Fig. 10).

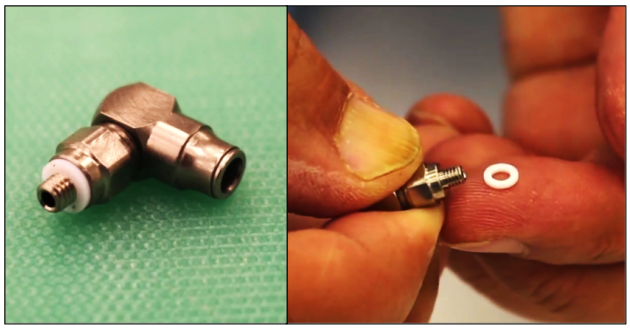


Figure 10: Removing the O-ring front he gas connector.

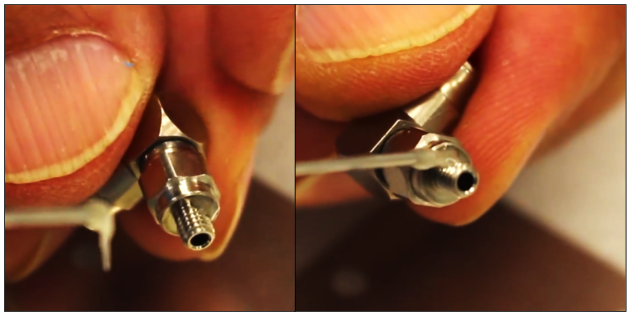


Figure 11: Applying glue to the gas connector.

Step 8: Then use the metallic stick to apply a thin ring of glue between the body and the threaded part of the connector (Fig. 11).

Step 9: Gently screw the connector on the board until the base of the connector's body touches the readout board (Fig. 12 left). Make sure that the glue forms a nice and smooth ring all around the base of the connector (Fig. 12 right).

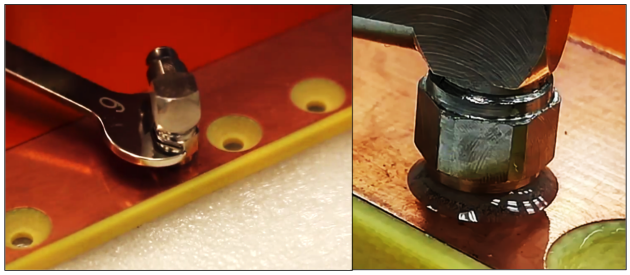


Figure 12: Fixing the gas connector onto the board.

1.3 Comments and recommendations

The use of soft material between the table and the readout board is strongly recommended to prevent the damage of the fragile Panasonic connectors while clamping the brass inserts.

You should never touch the readout strips with bare fingers under the penalty of triggering copper oxidation that may affect later the operation of the detector.

2 Preparation of the drift board

Preliminary Note : In this section some of the assembly steps were performed in a clean room for the purpose of improving the quality of the pictures. It was done in a very conscientious way and the work was immediately followed by a special cleaning. However the forthcoming steps are likely to produce dust and hence must be performed outside the clean room to prevent contamination.

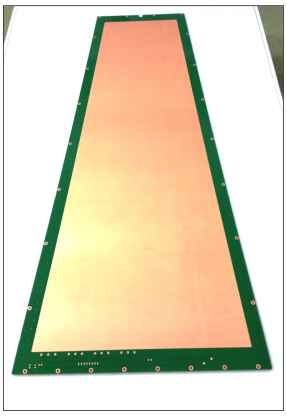
2.1 Materials and tooling

The preparation of the GE1/1-X drift board includes the mounting of the pull-outs, the soldering of the HV pins, the soldering of the SMD components and the cleaning of the board. The following list describes all the components that are required for the preparation of the board (Fig. 13). All these components are provided with the shipment box:

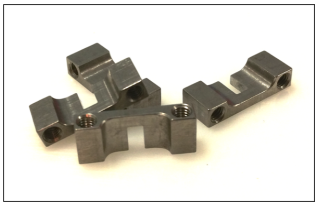
1. One drift board.
2. 58 (short) or 62 (long) stainless steel pull-outs.
3. 116 (short) or 124 (long) screws M3x6 Bossard PN: 3183904.
4. 116 (short) or 124 (long) nylon washers Bossard PN: 3139487.
5. HV contact pins (four FK_480, four FK_381 and four FK_519).
6. SMD components (one 10 MΩ resistor, one 100 kΩ resistor and one 330 pF capacitor).

The tools required for a proper assembly are listed below and are shown on Fig. 14.

1. A manual torque screw driver with a working range up to 1.2 Nm.
2. A pair of fine tweezers.
3. A soldering station with regular soldering tips and SMD tips.
4. Pure ethanol, acetone and clean pieces of tissue.
5. A metallic tub to collect excess ethanol.



(a) Drift board.

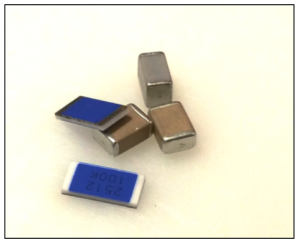


(b) Pull-outs.

(c) Screws M3x6.

(d) Nylon washers.

(e) HV contact pins.

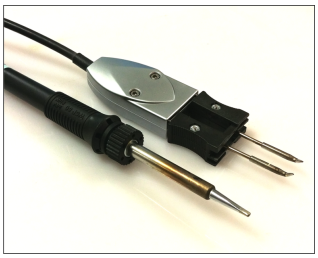


(f) SMD components.

Figure 13: List of components required for the drift board preparation.

(a) Torque screw driver.

(b) Tweezers.



(c) Soldering tips.

Figure 14: List of components required for the drift board preparation.

2.2 Step-by-step procedure

::Mounting of the pull-outs::

Step 1: Place the pull-outs on the dedicated hole of the drift board (Fig. 15 left). The active area of the board should face up.

Step 2: Attach the pull-outs with the screws and the nylon washers. When both screws are in place, tighten it with the torque screw driver at 1.2 Nm (Fig. 15 right).

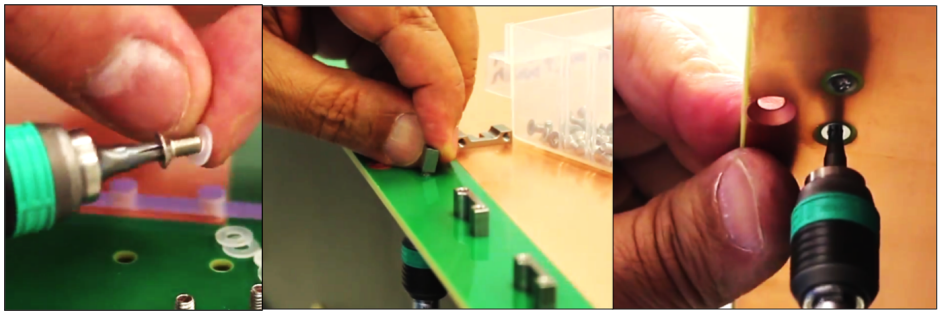


Figure 15: Mounting the pull-outs on the drift board.

Step 3: Proceed like this all around the perimeter of the board, except on the large base of the trapezoid. This area must remain clear before soldering the HV components (Fig. 16).

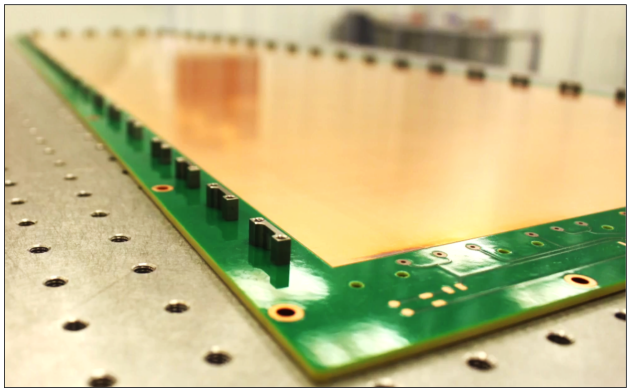


Figure 16: Drift board after mounting the pull-outs.

::Soldering of the HV components::

Step 1: Clean the HV circuit with a clean piece of tissue ethanol (Fig. 17).

Figure 17: Cleaning of the HV circuit.

Step 2: The schematics in Fig. 18 shows the location of the HV pins: the 6.1 mm pins FK-480 should go in the GEM 1 pads, the 8 mm FK-381 should go on the GEM 2 pads and the 9.28 mm FK-519 should go on the GEM 3 pads.

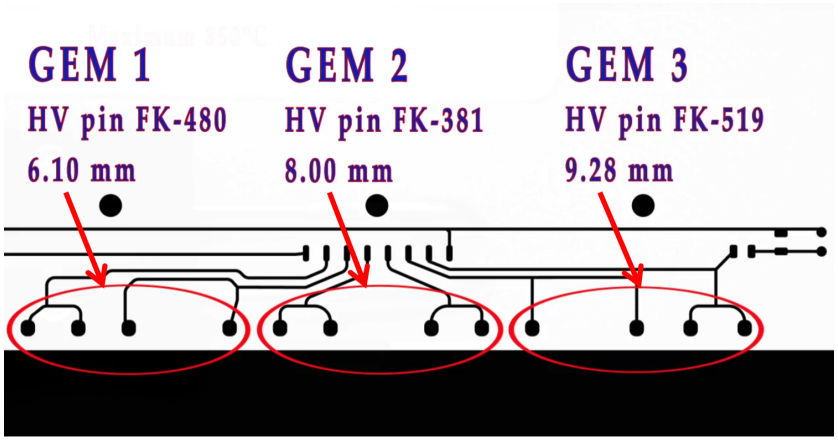


Figure 18: Positioning of the HV pins on the drift board.

Step 3: Gently place the HV pins in the dedicated housing, making sure that the pins are vertically aligned within the holes (Fig. 19 left).

Step 4: Apply the soldering tin all around the base of the pins while heating the pads with the iron (Fig. 19 right). Keep the temperature below 350 °C to avoid melting the glue that keeps the copper pads attached to the PCB.

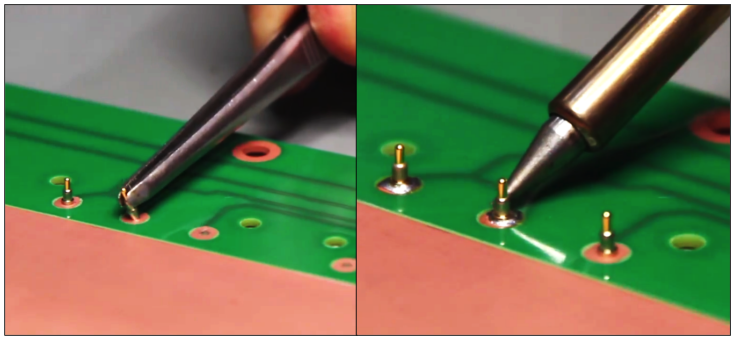


Figure 19: Soldering of the HV pins.

Step 5: Similarly, clean the pads for the SMD components with tissue using ethanol (Fig. 20 left).

Step 6: Apply a small amount of soldering tin to "wet" the pads before mounting the SMD components (Fig. 20 right).

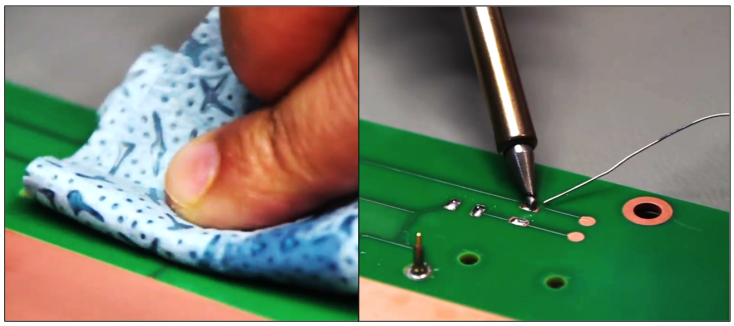


Figure 20: Preparation of the SMD pads.

Step 7: The location of each components is shown on Fig. 21.

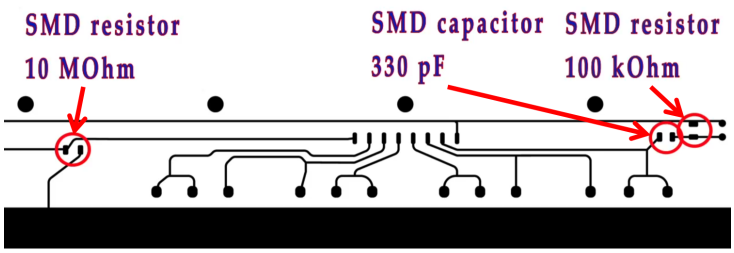


Figure 21: Positioning of the SMD components on the drift board.

Step 8: To mount a given SMD component, hold it with the soldering tweezers and place it on the pad. Then maintain it in position with another

tool while removing carefully the soldering iron. Keep the component in place until the tin is fully solidified (Fig. 22).

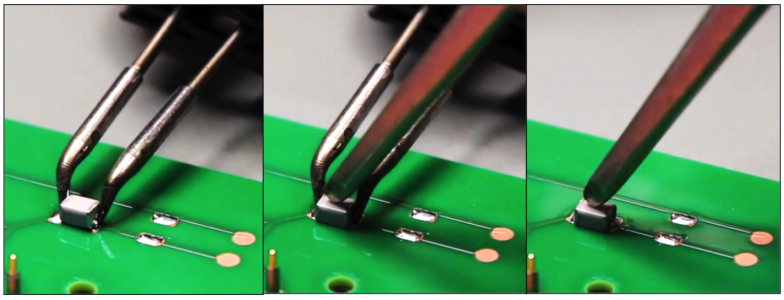


Figure 22: Soldering of the SMD components.

::Cleaning of the drift board::

Step 1: Place the board in vertical position in the tub, the large base facing down. Tilt the tub to ensure that the acetone will flow before drying and leave contaminants on the edge of the PCB. (Fig. 23).

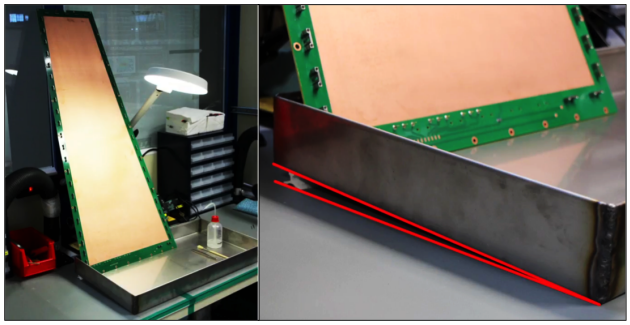


Figure 23: Preparation for cleaning.

Step 2: Generously pour acetone just above the HV circuit while brushing all the soldering points. Repeat this step several times to ensure that all contaminants are removed (Fig. 24).

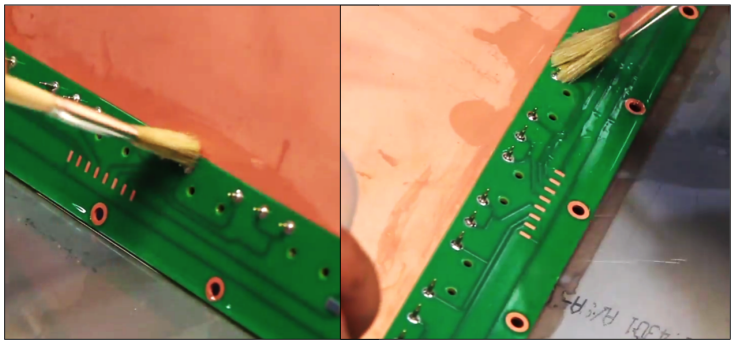


Figure 24: Cleaning of the HV circuit.

Step 3: Clean the rest of the drift board with a clean piece of tissue using ethanol, insisting on the areas surrounding the pull-outs. Repeat this step until all stains and contaminants disappear (Fig. 25).

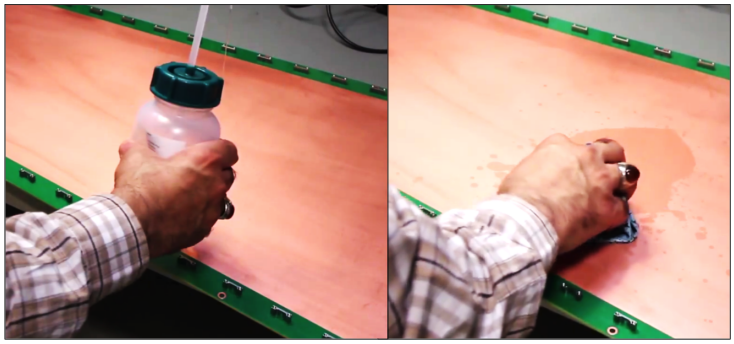


Figure 25: Cleaning of the active area.

::Mounting of the last pull-outs::

Step 1: Mount the remaining pull-outs in front of the HV circuit as indicated previously (Fig. 26).

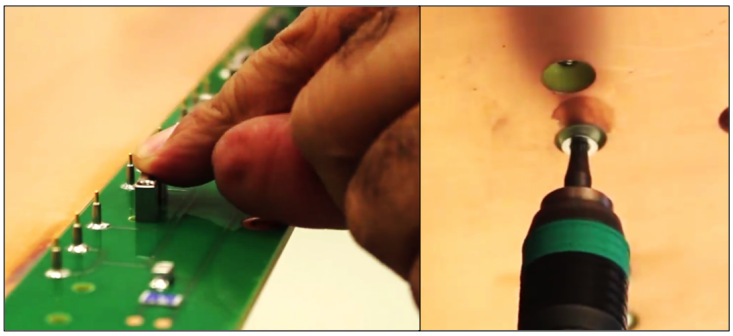


Figure 26: Mounting of the remaining pull-outs.

Step 2: Proceed like this all along the large base of the board (Fig. 27). The drift board is now ready for the assembly.

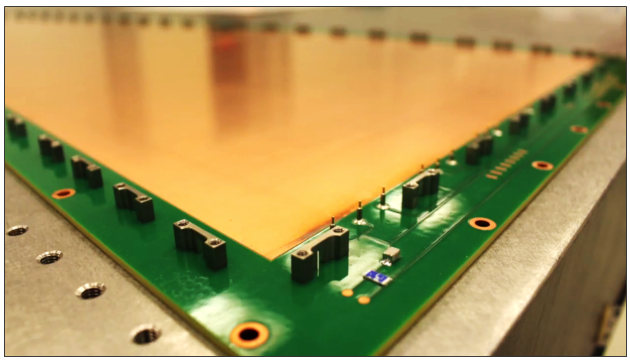


Figure 27: Final state of the drift board.

2.3 Comments and recommendations

We recommended to first pair the M3 screws and the nylon washers before starting mounting the pull-outs. This will facilitate the work and limit the risk of damaging the PCB when pushing the screw inside the holes. One way to do so is shown on Fig. 28.

When mounting the pull-outs, it is strongly suggested to use a guiding rail (Fig. 29) to help in aligning the pull-outs with the perimeter of the trapezoid. With misaligned pull-outs, it will be impossible to close the chamber with the readout board.

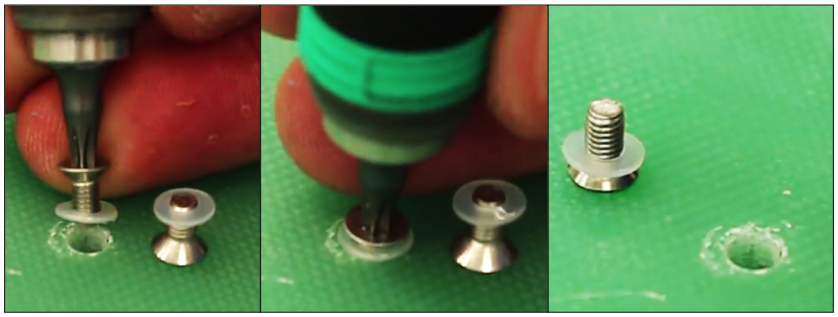


Figure 28: Example of guiding rail to mount the pull-outs.

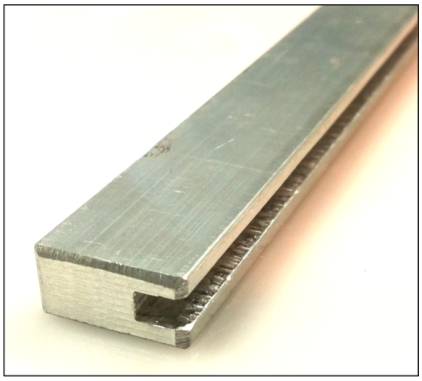


Figure 29: Example of guiding rail to mount the pull-outs.

One should make sure the screws are perfectly concentric with the screw holes of the pull-outs. If not, it will create leak points that might be difficult to identify before closing the chamber. More critical, the friction between the screw and the pull-out may create metallic dust that can seriously harm the detector.

When soldering the SMD components, the temperature of the soldering iron should stay below 350 °C. Above this temperature, the component that maintains the copper trace and the epoxy plate together may melt, leaving the copper detached from the board.

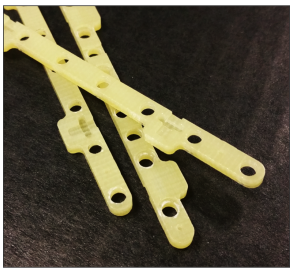
One should never touch the active area of the drift with bare fingers under the penalty of triggering copper oxidation that may later affect the operation of the detector.

3 Preparation of the internal and external frames

3.1 Materials and tooling

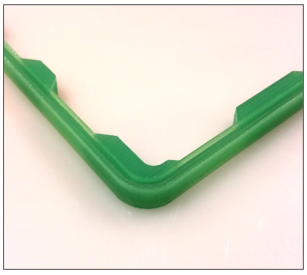
The preparation of the GE1/1-X frames includes the insertion of the brass inserts in the internal frames and the mounting of the VITON O-ring on the external frame. The following list describes all the components that are required for the preparation of the frames (Fig. 30). All these components are provided with the shipment box:

1. All (10 pieces) 3 mm thick internal frames (drift gap).
2. 222 brass inserts Kerb Konus PN : 852 000 020800.
3. One external frame.
4. Two Viton O-rings.



(a) Internal frames.

(b) Brass inserts.



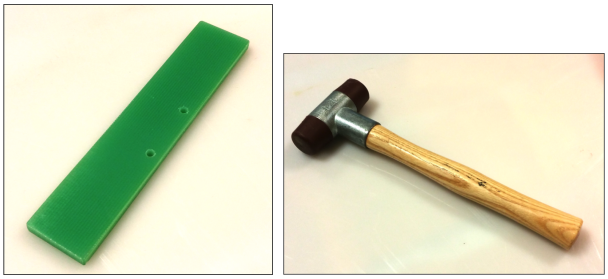
(c) External frame.

(d) O-ring.

Figure 30: List of components required for the frames preparation.

The tools required for a proper assembly are listed below and are shown on Fig. 31.

1. FR4 baseplate with a M4 hole (provided with the GE1/1 kit).
2. A mallet or a hammer with soft head.



(a) Frame baseplate. **(b)** Mallet.

Figure 31: List of components required for the frame prepartion.

3.2 Step-by-step procedure

::Preparation of the internal frames::

Step 1: To remove the frames from their support, hold them in place with one hand while gently removing the tape (Fig. 32). Proceed with great care, the frames are very thin and can be easily damaged when pulling the tape off.

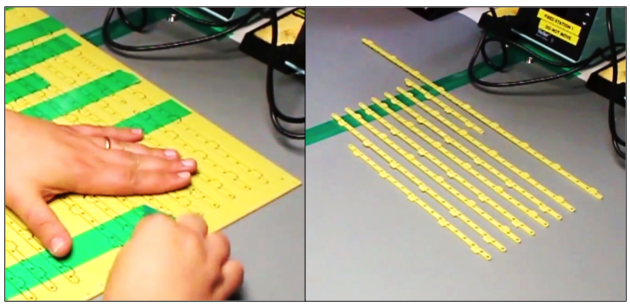


Figure 32: Removing the internal frames.

Step 2: Attach the FR4 baseplate onto the table. Then place the piece of internal frame on top, the chamfer side facing up. Align the hole of the frame with the hole of the baseplate (Fig. 33).

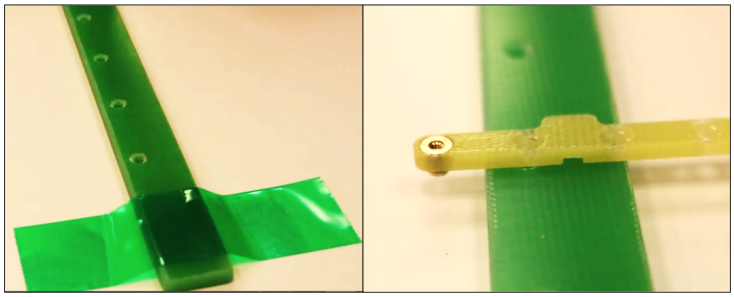


Figure 33: Preparation of the baseplate.

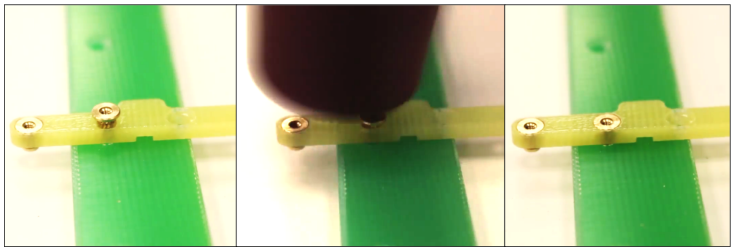


Figure 34: Insertion of the brass inserts.

Step 3: Insert the brass piece into the hole and gently hammer it with the mallet until it is fully inserted (Fig. 34).

Step 4: Follow the same procedure for the entire frame, and for all the other pieces of 3 mm frames. Check with the finger that the heads of the inserts fit flush with the surface of the frame (Fig. 35).

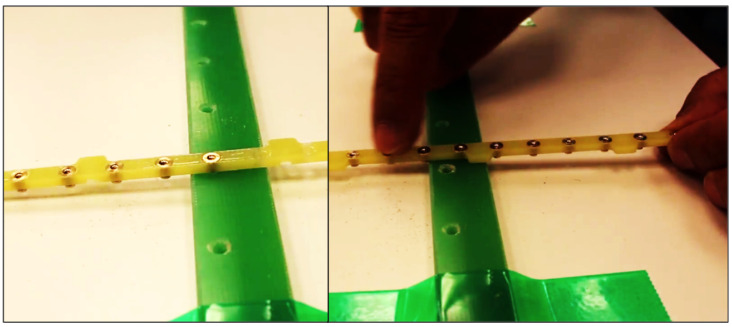


Figure 35: Checking the flatness of the frame.

::Preparation of the external frames::

Step 1: Place the VITON O-ring in the dedicated groove of the external frame. Gently pull the O-ring at the four corners at the same time so that it fits the trapezoidal shape of the groove (Fig. 36).

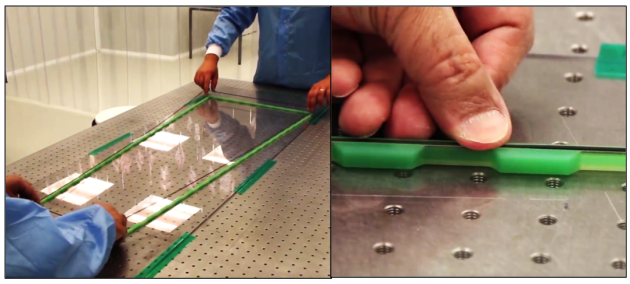


Figure 36: Placing the VITON O-ring (1).

Step 2: Then gently press the O-ring with your finger to insert it in the trench. Check by eye and with your finger that the O-ring is placed properly and slightly exceeding the frame's housing (Fig. 37).

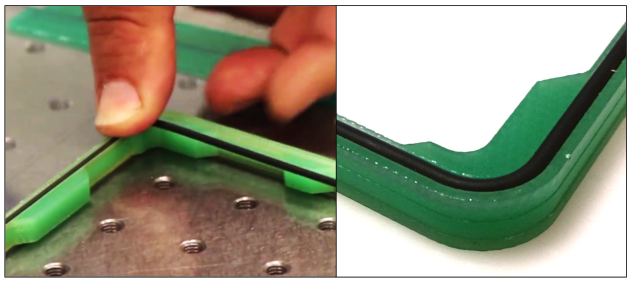


Figure 37: Placing the VITON O-ring (2).

3.3 Comments and recommendations

When placing the VITON O-ring in the external frame, make sure you share the stress uniformly all around the trapezoid. If not, some parts of the O-ring may be too compact, which can later deform the PCB when closing the chamber, or create leak points.

4 Assembly of the GEM stack

4.1 Materials and tooling

The assembly of the GE1/1-X stack includes the preparation of the components, the cleaning and test of the GEM foils and the mounting of the stack. The following list describes all the components that are required for the assembly of the GEM stack (Fig. 38). All these components are provided with the shipment box:

1. Three GEM foils.
2. All (40) internal frames, including the 3mm ones equipped with brass inserts.
3. 222 screws M2 x 6/X6 Bossard PN: 3183884
4. 58 (short) or 62 (long) metallic nuts M2.5 Bossard PN : 3146251
5. 20 guiding pins Bossard PN : 1255568
6. 20 screws M2 x 12 Bossard PN : 1420607 with metallic nuts and washers.

The tools required for a proper assembly are listed below and are shown on Fig. 39.

1. One GE1/1 assembly baseplate.
2. One GE1/1 Plexiglas cover.
3. A Giga-ohm insulation meter (a.k.a. Megger).
4. One silicon static roller and its sticky mat.
5. A pair of HV clips.
6. Polyamide green tape.
7. One or more sharp blades
8. One or more screw drivers X6.
9. Pure ethanol and clean pieces of tissue.

(a) GEM foil.

(b) Prepared internal frame.

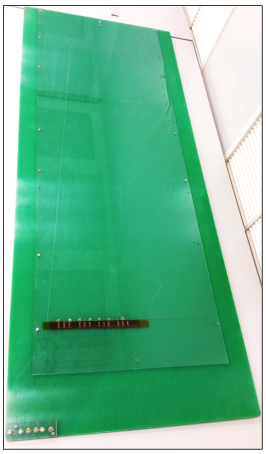
(c) Screws M2x6.

(d) Nuts M2,5.

(e) Guiding pins.

(f) Screws M2x6 long.

Figure 38: List of components required for the assembly of the GEM stack.

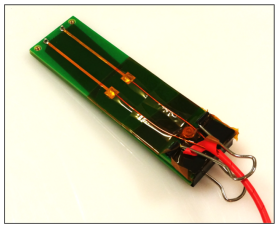


(a) Assembly base-plate.

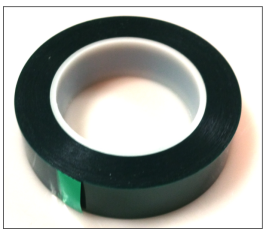
(b) Plexiglas cover.

(c) HV insulation meter.

(d) Dust roller.



(e) High voltage clip.



(f) Polyamide tape.

(g) Sharp blade.

(h) Screw driver X6.

Figure 39: List of components required for the assembly of the GEM stack.

4.2 Step-by-step procedure

::Preparation of the GEM foils::

Step 1: Place all the GEM foils (together with their frames) in vertical position against the wall (Fig. 40).

Figure 40: Setting up the GEM foils in vertical position.

Step 2: Use the static roller to remove the possible dust from the foils. Gently press the roller onto the foil, including the active area and the excess Kapton areas on the sides (Fig. 41).

Figure 41: Cleaning of the first side with the static roller.

Step 3: Flip the frame and continue the cleaning on the other side of the GEM foil (Fig. 42). Regularly clean the roller with the sticky mat and proceed the same way for all the foils.

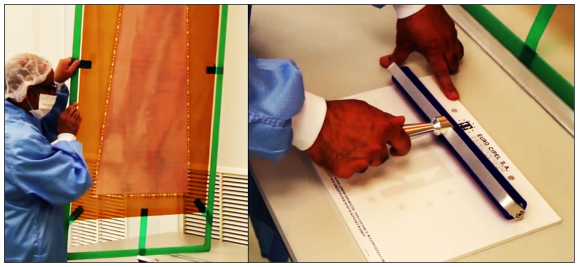


Figure 42: Cleaning of the second side with the static roller.

Step 4: In order to test the GEM foils, place the HV clip so that the HV pins are in contact with of the top and bottom part of the foil (Fig. 43). At this point, all of the HV pads are still connected to the active area of the foil. The location of these pads is shown on Fig. 44.

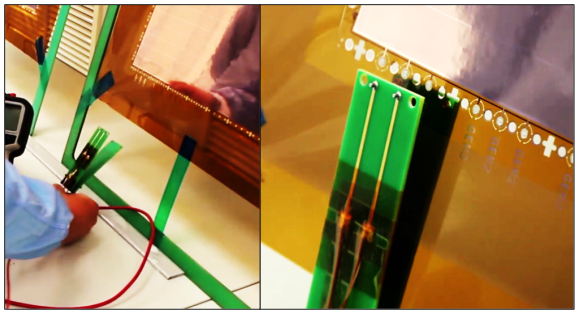


Figure 43: Mounting of the HV clip on the foil.

Figure 44: Location of the HV pads.

Step 5: Set the insulation meter to 550 V and apply the voltage for several minutes, the resistance of the foils should reach 20 GΩ after few seconds with relative humidity lower than 40 % . (Fig. 45). After the test is done, discharge the GEM foil.

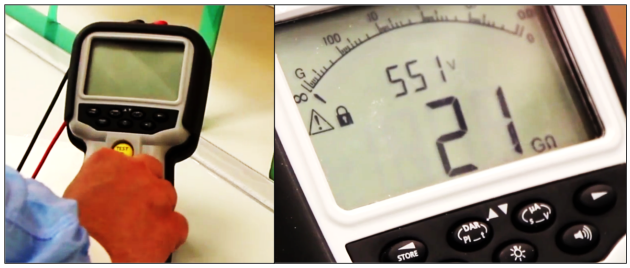


Figure 45: Testing the GEM foil.

Step 6: The next step consists of cutting the spare HV pads to define the position of the foil in the detector. Fig. 47, Fig. 48 and Fig. 49 indicate which pads should be removed in GEM1, GEM2 and GEM3 respectively.

Step 7: To remove the pads, use a very sharp blade and chop the uncut portions along the pre-cut circle (Fig. 46). Carefully work in a comfortable position to avoid scratching the active area of the foils, which is only few millimeters away from the pads. Make sure the chopped-off pads do not remain attached to the foil due to electro-static forces.

Figure 46: Cutting off the spare HV pads.

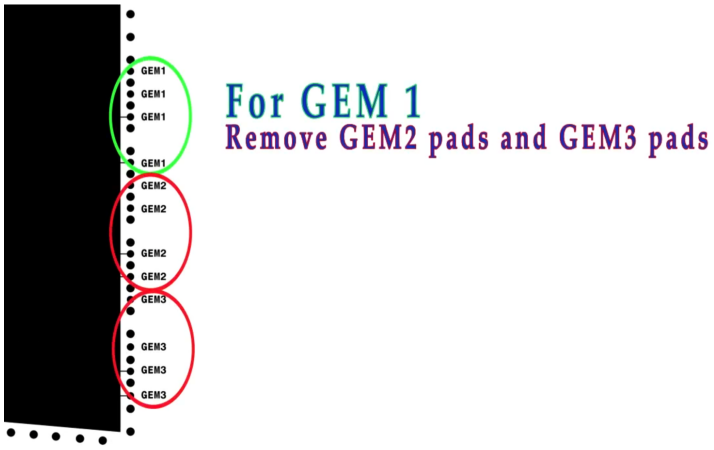


Figure 47: Removing HV pads for GEM1.

Figure 48: Removing HV pads for GEM2.

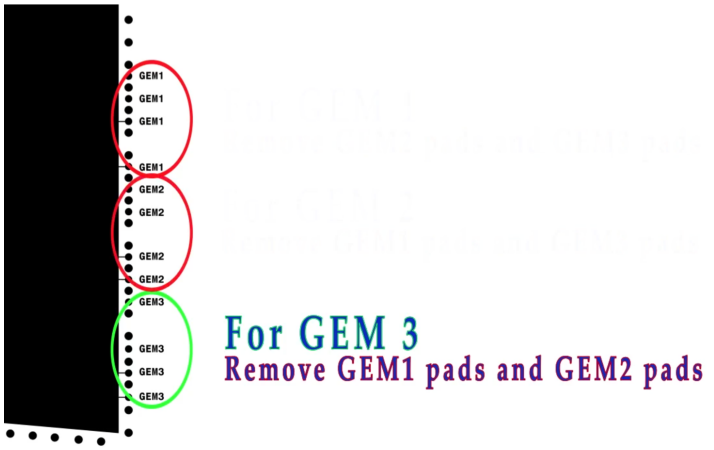


Figure 49: Removing HV pads for GEM3.

::Mounting of the GEM stack::

Step 1: Place the Plexiglas baseplate on the assembly table and fix it with tape (Fig. 50).

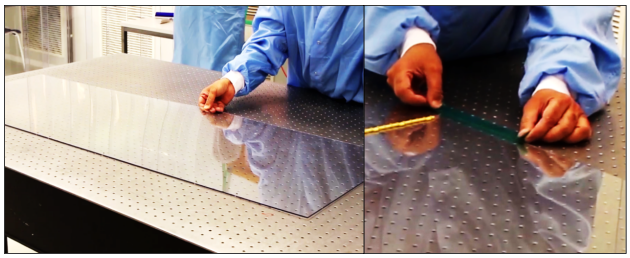


Figure 50: Preparing the assembly baseplte.

Step 2: Clean the entire surface of the baseplate with a clean piece of tissue using ethanol (Fig. 51).

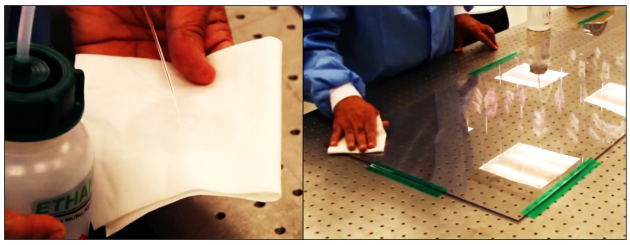


Figure 51: Cleaning of the assembly baseplate.

Step 3: Put the guiding pins in place all around the trapezoid. Place pins in all the single holes, and in one of the grouped holes (Fig. 52).

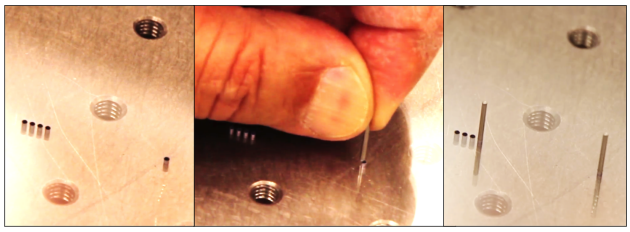


Figure 52: Insertion of the guiding pins.

Step 4: Use the static roller to clean the 3 mm internal frames. Flip the frames upside down and repeat the process (Fig. 53). This set of frames, equipped with the brass inserts, will form the drift gap.

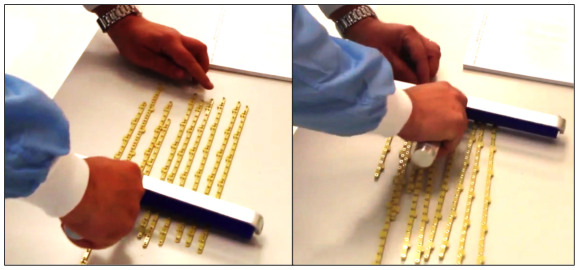


Figure 53: Cleaning of the 3mm internal frames.

Step 5: Place the internal frame on the baseplate. The orientation and the location of each piece of frame is defined by matching the shape of the grouped holes present on the frame and on the baseplate.(Fig. 54). The flanges should always face the inside of the trapezoid.

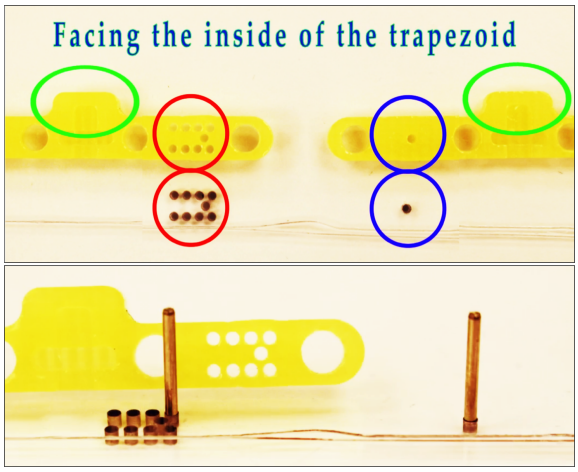


Figure 54: Positioning of the internal frames.

Step 6: Put the frames in position all around the trapezoid using the guiding pins (Fig. 55).

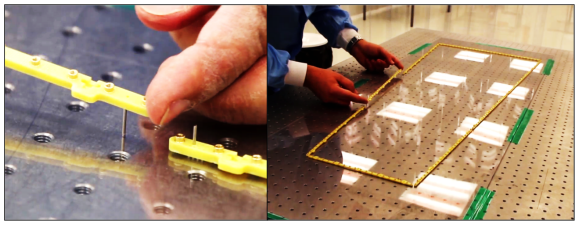


Figure 55: Mounting of the 3 mm internal frames.

Step 7: Place the GEM1 on top of the 3 mm frames using the guiding pins for a proper positioning (Fig. 56). Make sure the foil is well aligned to

prevent scratching of the active area with the guiding pins.

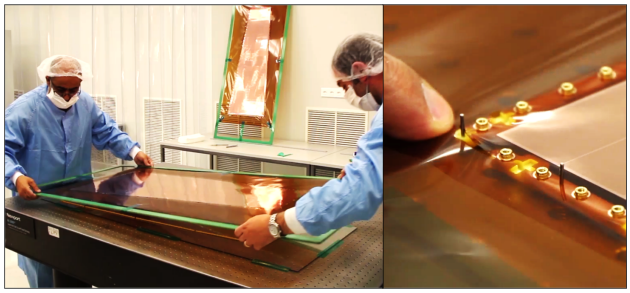


Figure 56: Placing GEM1.

Step 8: When the foil is in place, detach the frame from it by cutting the tape with a sharp blade and remove the frame (Fig. 57).

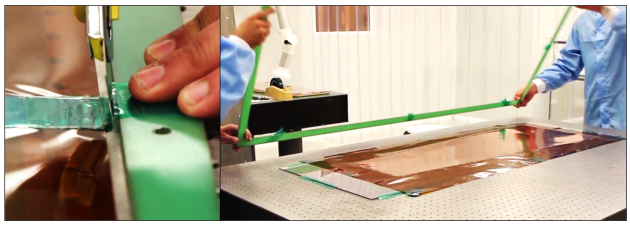


Figure 57: Detaching the foil from its frame.

Step 9: In order to pre-stretch the foil, attach the tape on the Kapton area, on both large and small bases of the trapezoid, and then gently pull it towards you before fixing the tape on the table (Fig. 58). Do not exaggerate the stretching strength under the penalty of deforming the GEM foil.

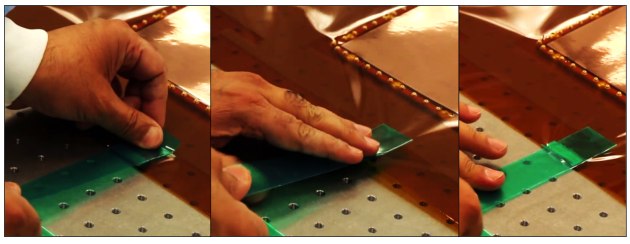


Figure 58: Pre-stretching the foil (1).

Step 10: Always proceed with two persons working in the opposite directions (Fig. 59).

Step 11: The location of the stretching points and the order is shown on Fig. 60.

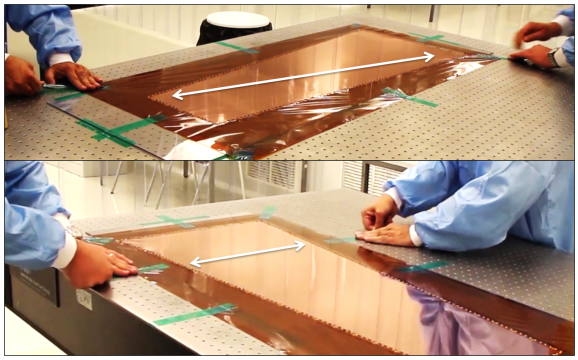


Figure 59: Pre-stretching the foil (2).

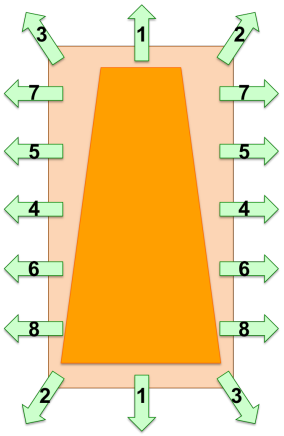


Figure 60: Overview of the stretching points.

Step 12: Use the insulation meter to measure the impedance of the GEM foil. Connect the pins of the Megger to the pads corresponding to GEM1 top and GEM1 bottom, as indicated in Fig. 61.

Figure 61: Connecting the insulation meter to the GEM1 pads.

Step 13: Apply 550 V between the two electrodes during few minutes and check that the resistance reaches at least 20 GΩ after few seconds (Fig. 62). After the test is done, discharge the GEM foil.

Step 14: Clean the set of 1 mm thick internal frames which will form the first

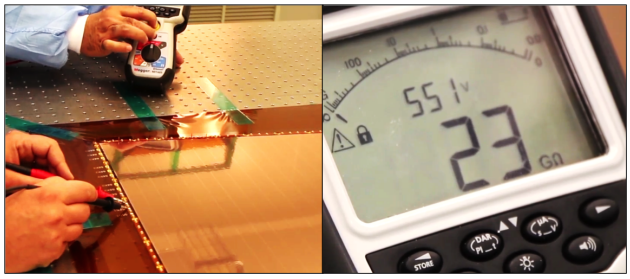


Figure 62: Electrical test of GEM1.

transfer gap (Fig. 63). These frames have the cross-shape holes to accommodate the metallic nuts for the final stretching.

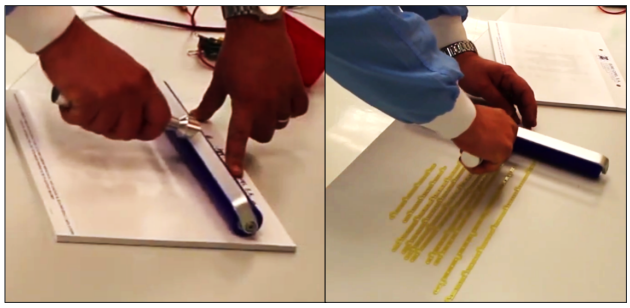


Figure 63: Cleaning of the 1 mm internal frames.

Step 15: Place the frames on the stack using the guiding pins. Match the shape of the grouped holes to proper position and orientate the frames (Fig. 64).

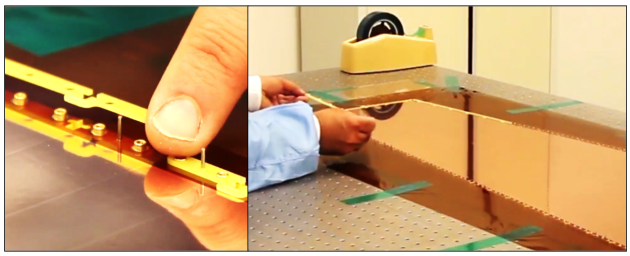


Figure 64: Mounting the 1 mm internal frames.

Step 16: Before mounting the frame on the large base of the trapezoid, test again the GEM foil at 550V with the insulation meter. After the test is passed, discharge the foil and put the last piece of frame in place (Fig. 65).

Step 17: Take the second GEM foil and place it onto the stack using the guiding pins for the alignment (Fig. 66).

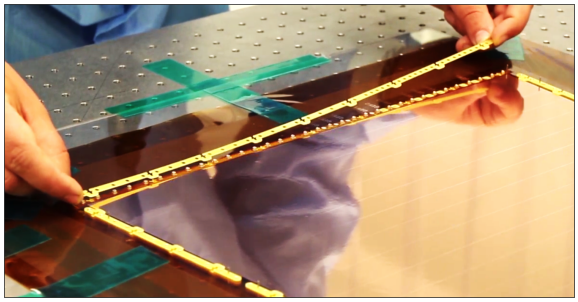


Figure 65: Placing the last internal frame after testing.

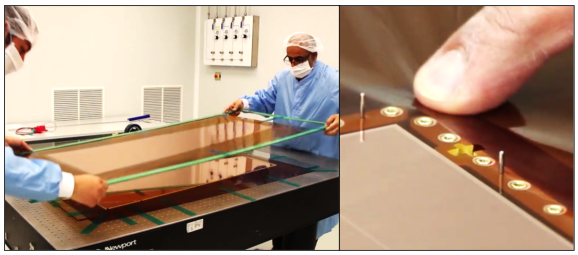


Figure 66: Placing GEM2.

Step 18: Detach the foil from its frame by cutting the piece of tape (Fig. 67).

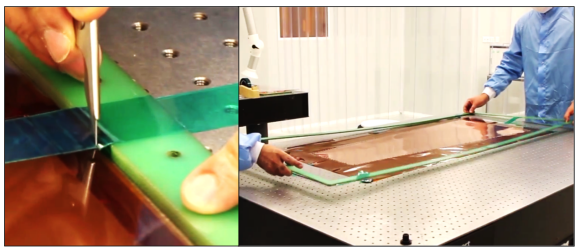


Figure 67: Detaching the GEM frame.

Step 19: Use the green tape to pre-stretch the foil in opposite directions, starting from the large and the small bases of the trapezoid. (Fig. 68). Continue stretching all around the stack until the foil becomes mirror flat.

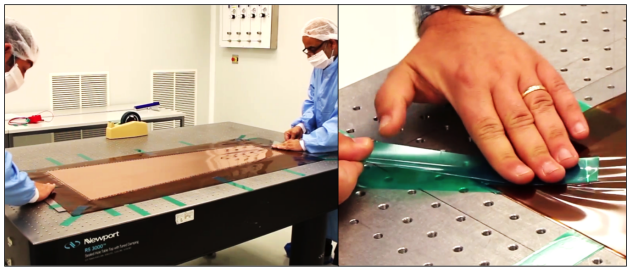


Figure 68: Pre-stretching GEM2.

Step 20: Clean the set of 2 mm thick frames and place it on the stack to make the second transfer gap (Fig. 69).

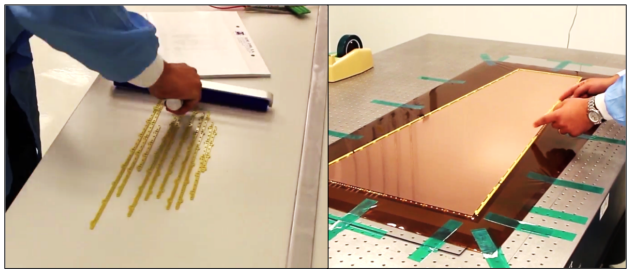


Figure 69: Cleaning and positioning of the 2 mm internal frames.

Step 21: At this point you can insert the M2.5 metallic nuts in the dedicated housing of the internal frames. Take the time to double check that all frames are equipped with the nuts and that the nuts are fully inserted in the stack (Fig. 70).

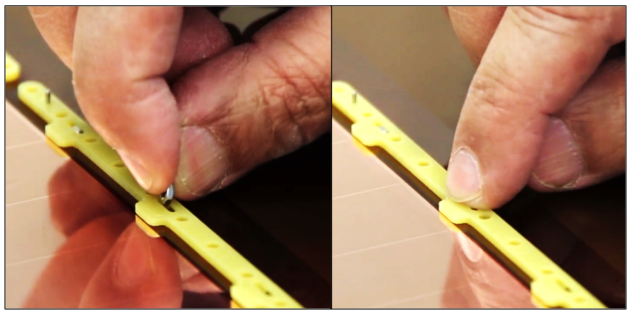


Figure 70: Placing the metallic nuts in the internal frame.

Step 22: Before mounting the last piece on the large base of the trapezoid, check the impedance of the second foil by applying 550V (Fig. 71). After the test is performed, discharge the foil, place the last piece of internal frame and insert the remaining nuts.

Figure 71: Testing GEM2.

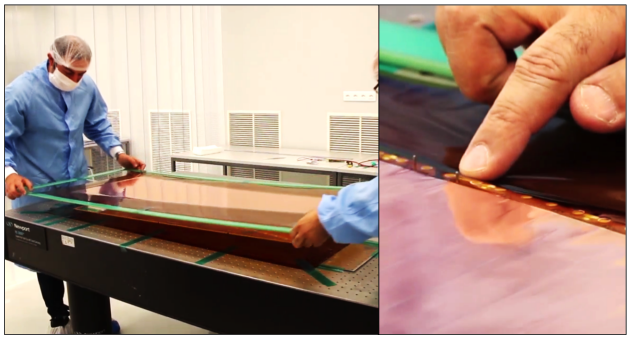


Figure 72: Placing GEM3.

Step 23: Take the third GEM foil and place it on top of the stack (Fig. 72).

Step 24: After careful alignment, remove the tape that holds the foil and its frame together (Fig. 73).

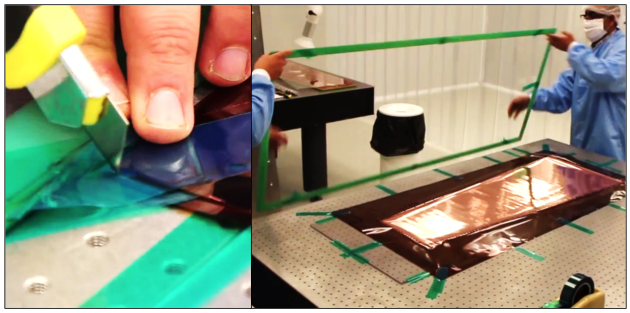


Figure 73: Detaching GEM3.

Step 25: Perform the manual stretching of the last foil following the previous instructions (Fig. 74).

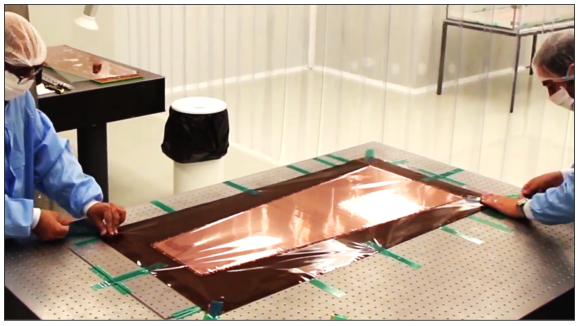


Figure 74: Pre-stretching GEM3.

Step 26: Clean the last set of 1 mm internal frames and place them on the stack so as to form the induction gap (Fig. 75).

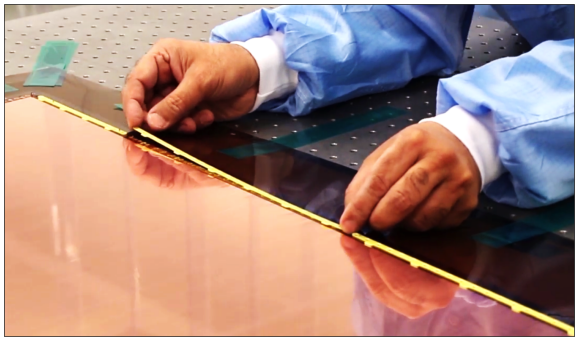


Figure 75: Placing the 1mm internal frames.

Step 27: Before covering the large base, test the last foil by applying 550 V on the pads shown on Fig. 76.

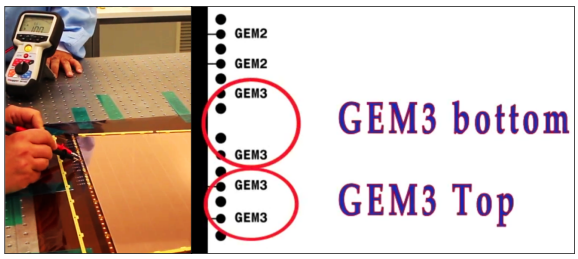


Figure 76: Testing GEM3.

::Protecting the GEM stack::

Step 1: First use the static roller to clean the table and the entire surface of the Plexiglas cover (Fig. 77).

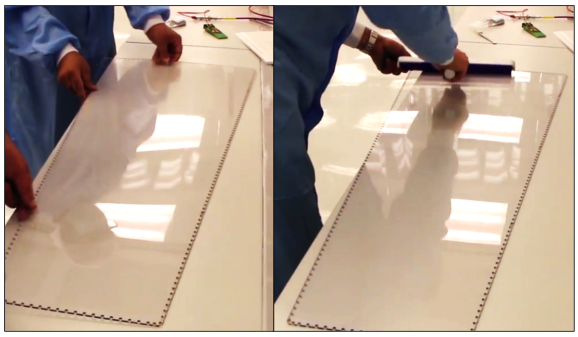


Figure 77: Cleaning the Plexiglas cover (1).

Step 2: Clean the cover with a clean piece of tissue using ethanol (Fig. 78).

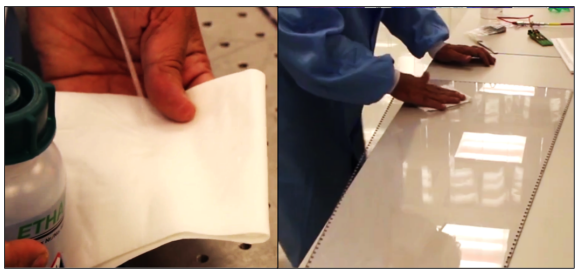


Figure 78: Cleaning the Plexiglas cover (2).

Step 3: Flip the cover upside down and repeat step 2 (Fig. 79).

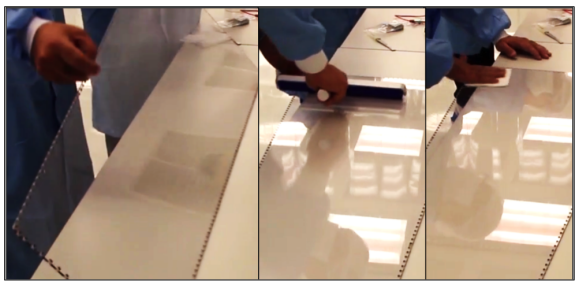


Figure 79: Cleaning the Plexiglas cover (3).

Step 4: When the Plexiglas cover is perfectly clean, carefully place it on top of the GEM stack, using the guiding pins for proper positioning. (Fig. 80).

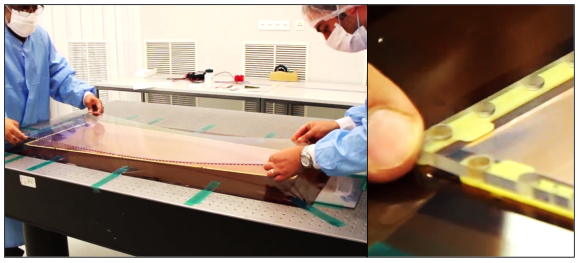


Figure 80: Placing the Plexiglas cover.

Step 5: Use the long M2 screws and washers in order to attach the Plexiglas cover to the stack. Insert the screws into the holes to catch the brass insert fixed in the 3 mm internal frames (Fig. 81). Put these screws on the edges of each piece of internal frame and in the corners of the trapezoid.

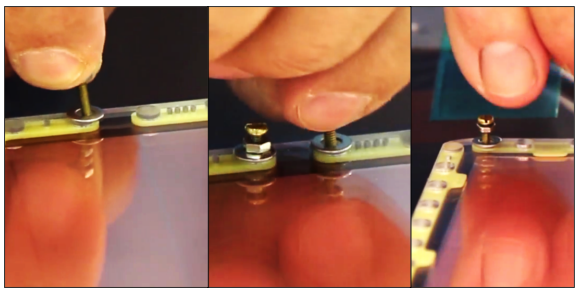


Figure 81: Attaching the cover to the GEM stack.

Step 6: In order to hold the layers of internal frames together, place the M2x6mm screws provided with the GE1/1 kit in the dedicated holes of the Plexiglas cover (Fig. 82). Tighten these screws with a manual X6 screwdriver without stressing too much against the thin pieces of frame.

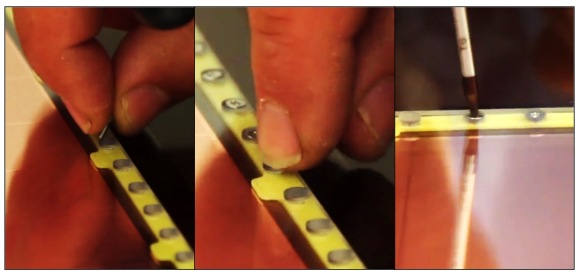


Figure 82: Closing the internal frame (1).

Step 7: Follow the same procedure all around the GEM stack. All the holes should be equipped with M2x6 screws except on the edges of the frames where the longer screws are already fixed (Fig. 83).

Figure 83: Closing the internal frame (2).

4.3 Comments and recommendations

For this step it is strongly suggested have a fourth (spare) GEM foil available, dry and tested. In case a problem which may happen during the assembly, this additional foil can be used as an immediate replacement without leaving the stack opened in air for a longer period.

We recommend to reinforce the Plexiglas cover with a cross-shape stiffener, as shown on Fig. 39 (b). In this way it will be easier to manipulate it and appose it on the GEM stack. Similarity, we recommend to modify the assembly baseplate and to equip it with HV pins to allow the electrical test of all the GEM foils during the assembly. Without these modifications it won't be possible to test the GEMs lying below the topmost foil.

5 Closing of the chamber

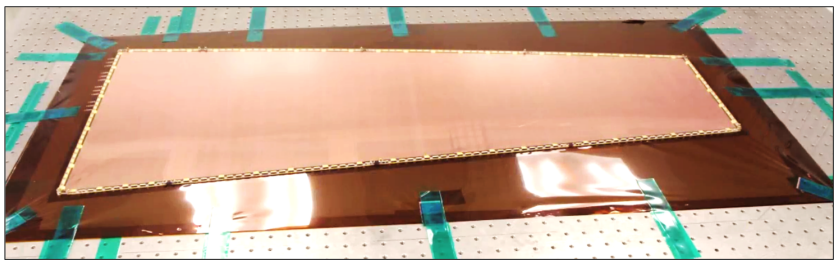
5.1 Materials and tooling

The closing of the GE1/1-X chamber includes the final preparation of the GEM stack, the stretching of the foils and the final electrical test after closure. The following list describes all the components that are required (Fig. 84). All these components are provided with the shipment box:

1. The GEM stack already assembled.
2. One drift board equipped with pull-outs and SMD components.
3. One readout board equipped with brass inserts.
4. 58 (short) or 62 (long) screws M2,5x8 Bossard PN: 3136081
5. 116 (short) or 124 (long) screws M3x6 Bossard PN: 3183904.
6. 116 (short) or 124 (long) nylon washers Bossard PN: 3139487.

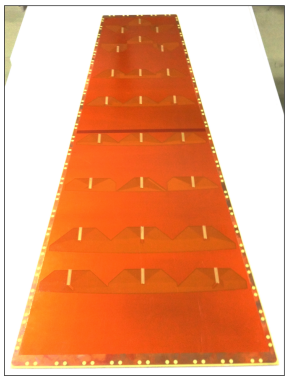
The tools required for a proper assembly are listed below and are shown on Fig. 85.

1. One GE1/1 assembly jig (baseplate and aluminum bars).
2. A Giga-ohm insulation meter (a.k.a. Megger).
3. One silicon static roller and its sticky mat.
4. A Panasonic-to-Lemo adapter board.
5. One or more sharp blades.
6. One electronic torque screw driver with a working range between 5 and 20 cNm.
7. One or more manual torque screw driver with a working range up to 1.2 Nm.
8. A pair of tweezers.
9. Pure ethanol and clean pieces of tissue.
10. A vacuum cleaner with HEPA filter.



(a) Assembled GEM stack.

(b) Prepared drift board.



(c) Prepared readout board.

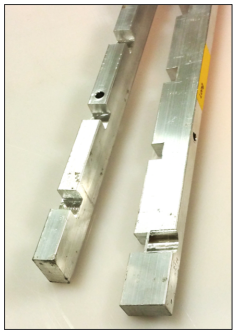
(d) Stretching screws M2,5.

(e) Screws M3x6.

(f) Nylon washers.

Figure 84: List of components required for the closing of the chamber.

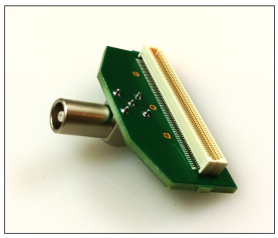
(a) Assembly jig baseplate.



(b) Assembly jig bars.

(c) HV insulation meter.

(d) Dust roller.



(e) Panasonic-to-Lemo adapter.

(f) Sharp blade.

(g) Torque screw driver.

(h) Electronic torque screw driver.

(i) Tweezers.

(j) HEPA vacuum cleaner.

Figure 85: List of components required for the closing of the chamber.

5.2 Step-by-step procedure

::Finalizing the GEM stack::

Step 1: Clean the GEM stack with the vacuum cleaner, focusing on the edges of the internal frame and in the holes of the Plexiglas cover (Fig. 86).

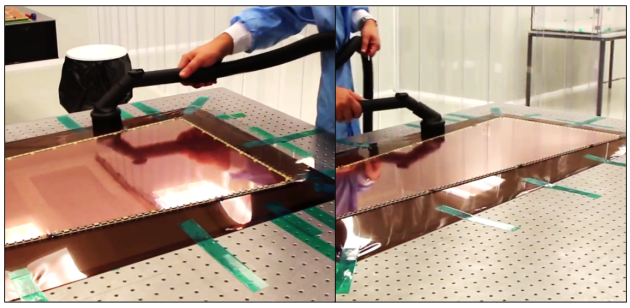


Figure 86: Cleaning the GEM stack with the vacuum cleaner.

Step 2: Use a sharp blade to remove the excess Kapton foil. Start in the corners where the foil is partially pre-cut, and continue carefully all around the trapezoid (Fig. 87). Use the Plexiglas cover as a stencil when cutting along the frames.

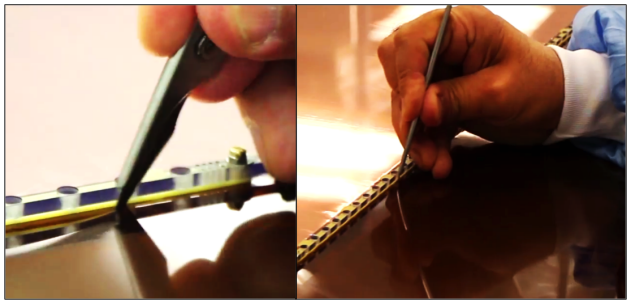


Figure 87: Cutting the excess Kapton foil.

Step 3: Gently remove the excess Kapton making sure not to detach the baseplate from the assembly table (Fig. 88).

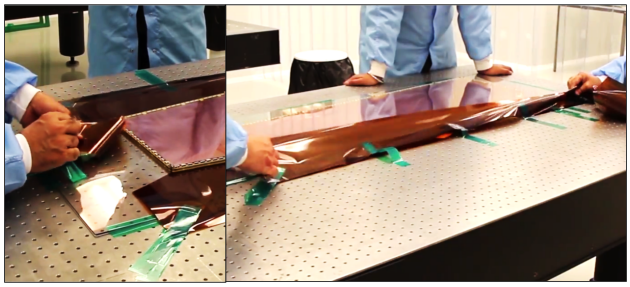


Figure 88: Removing the excess Kapton foil

Step 4: Finally, check the quality of the cut around the stack and adjust if necessary (Fig. 89 left). The remaining piece of Kapton that exceeds the frame stack should not be longer than a fraction of millimeter. Use the vacuum cleaner to remove the possible shavings left after cutting (Fig. 89 right).

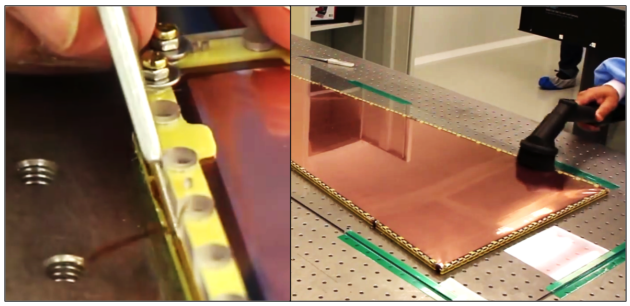


Figure 89: Adjusting the cut and cleaning the stack.

Step 5: Clean the board with the vacuum cleaner, focusing on the pull-out and the electrical circuit and then use the static roller to clean the active area (Fig. 90).

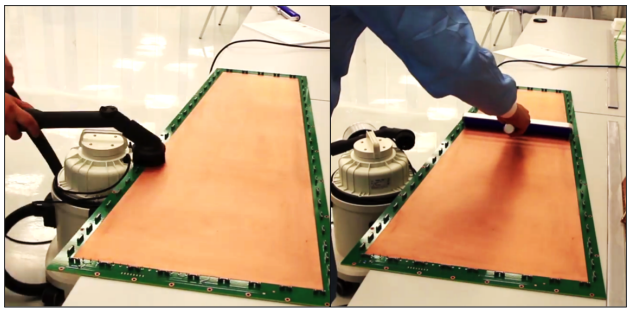


Figure 90: Cleaning of the drift board.

Step 6: Without touching the active area, place the drift board just next to the GEM stack (Fig. 91).

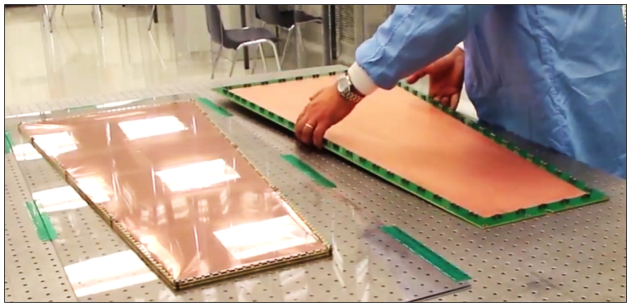


Figure 91: Preparing the transfer of the GEM stack.

Step 7: Dissociate the stack from the Plexiglas base plate by gently pulling it upward (Fig. 92 left). Make sure not to touch the bottom of GEM3 with your fingers or with the guiding pins that may remain attached to the baseplate. Then place the stack on the drift board in the area delimited by the pull-outs (Fig. 92 right).

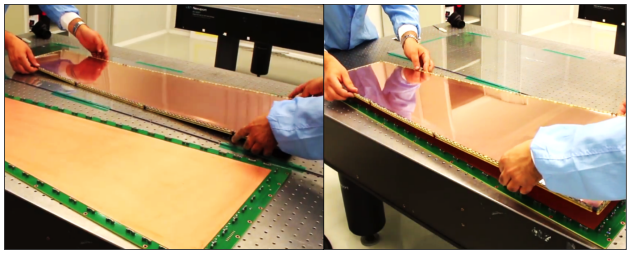


Figure 92: Transferring the GEM stack to the drift board.

Step 8: Use tweezers to remove the guiding pins left in the frame stack (Fig. 93).

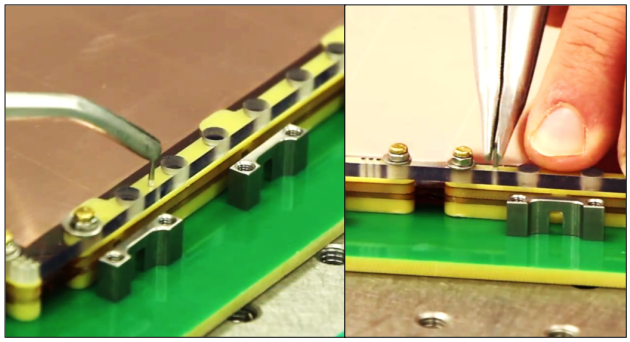


Figure 93: Removing the guiding pins (1).

Step 9: Rub your finger along the frame to make sure all the pins were removed before moving to the next step (Fig. 94).

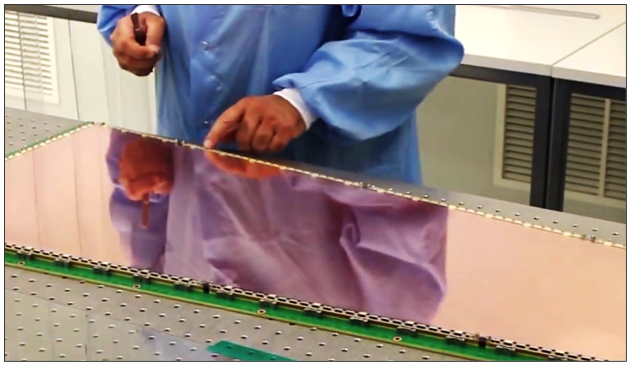


Figure 94: Removing the guiding pins (2).

Step 10: Move the chamber to the assembly jig, where the stretching will be performed (Fig. 95).

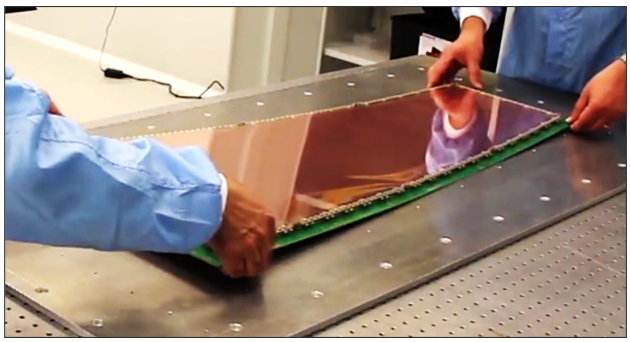


Figure 95: Moving to the stretching table.

Step 11: Clamp the drift board to the assembly table with the aluminum bars, the chamfers should be oriented towards the inner side of the trapezoid (Fig. 96).

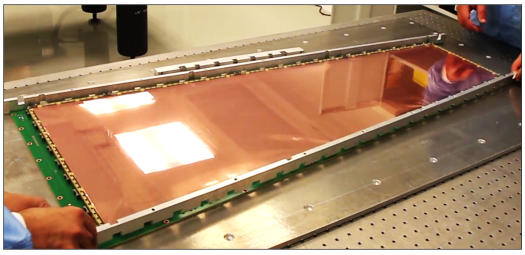


Figure 96: Fixing the assembly jig (1).

Step 12: Screw the aluminum bars to the assembly jig (Fig. 97). Apply sufficient strength to ensure the system will maintain the flatness of the board while performing the stretching of the foils.

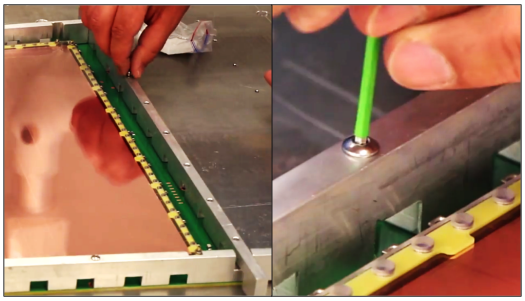


Figure 97: Fixing the assembly jig (2).

Step 13: Remove the long M2 screws that hold the Plexiglas cover and the GEM stack together (Fig. 98 left). Replace it with the final M2x6 mm screws as it was done for the other holes in the frame stack (Fig. 98 right). You will need to keep the Plexiglas cover without screws in place to protect the foil. The internal frames will be free to move while stretching the foils.

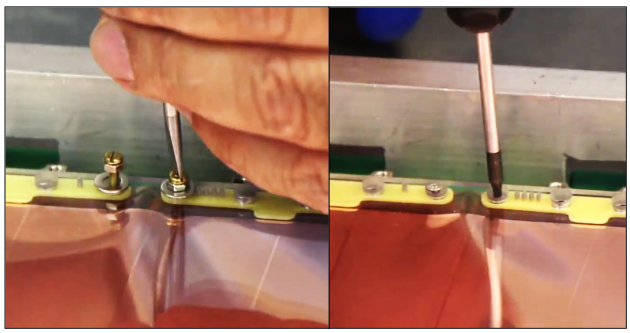


Figure 98: Detaching the Plexiglas cover from the GEM stack.

::Stretching the GEM foils::

Step 1: The stretching of the GEM foil is described in Fig. 99. It should be performed exactly in the same order to avoid creation of waves on the foils, especially between the different pieces of internal frames. Firstly, align the large and small bases of the GEM stack with their corresponding pull-outs on the drift board. Then stretch the opposite corners at the same time in order to remove the waves and to align all the lateral nuts with the lateral pull-outs, then continue with the lateral sides until all the screws are in place. Do not tighten the screws to the nominal value yet.

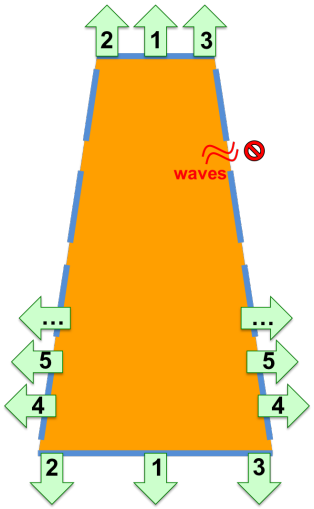


Figure 99: description of the stretching procedure.

Step 2: Insert the M2.5x8 mm screws in the lateral holes of the aluminum bars, starting with the large and the small base of the trapezoid (Fig. 100).

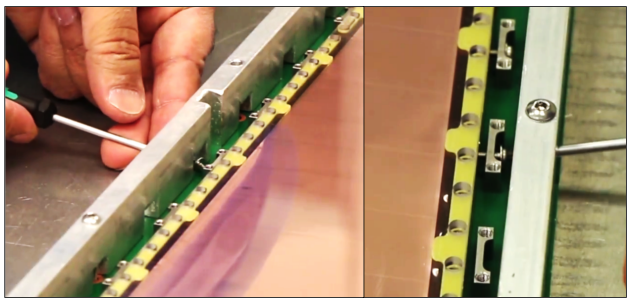


Figure 100: Stretching of the foils (1).

Step 3: Continue with the lateral sides. Always proceed with two persons stretching in the opposite directions. (Fig. 101).

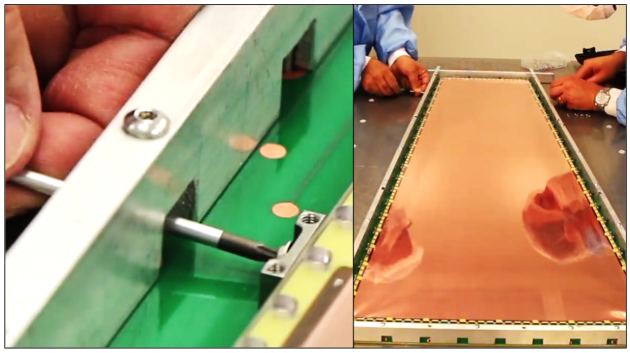


Figure 101: Stretching of the foils (2).

Step 4: When all the screws are in place, remove the Plexiglas cover (Fig. 102).

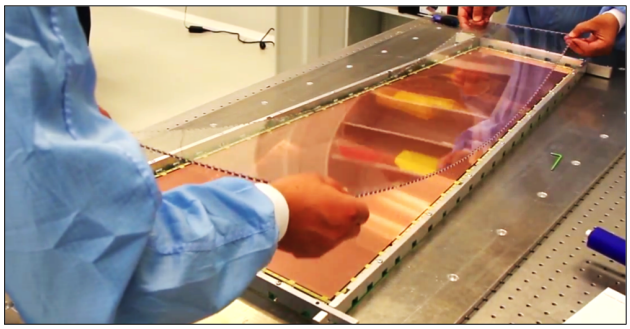


Figure 102: Removing the plexiglass cover.

Step 5: Clean the top surface of the GEM stack with the static roller without applying too much force on the foils (Fig. 103).

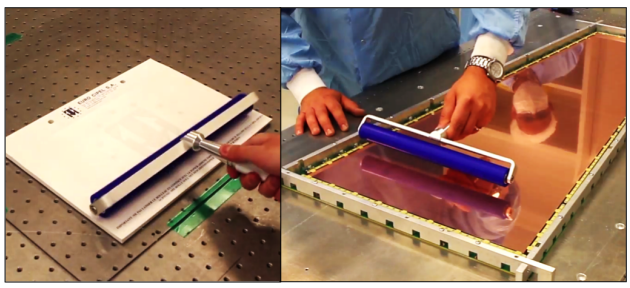


Figure 103: Cleaning the top GEM foil.

Step 6: Test the three GEM foils one after the other at 550 V using the dedicated pads on the drift board (Fig. 104). Discharge the foil after each test.

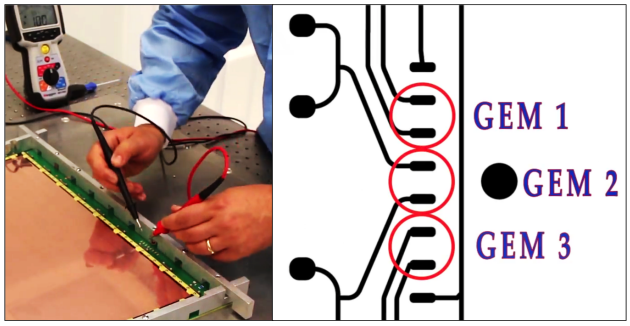


Figure 104: Testing the GEM foils

Step 7: Similarly, Test the three first gaps one after the other at 550 V, using the dedicated pads on the drift board (Fig. 105). Note that at this point the induction gap is not yet defined.

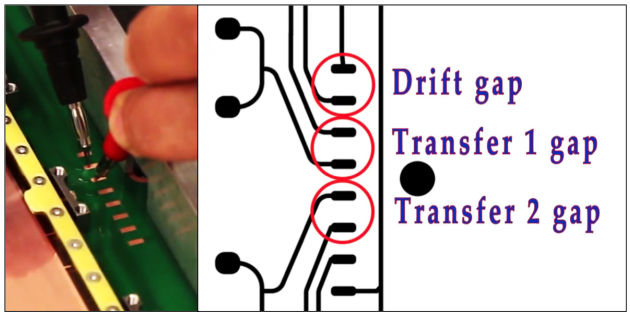


Figure 105: Testing the gaps.

Step 8: In the case of GEM foils, the impedance should reach 20 GΩ after few seconds. The impedance of the gaps however should reach more than 100 GΩ immediately after applying the voltage (Fig. 106).

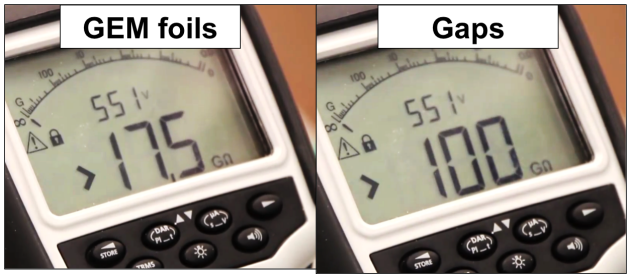


Figure 106: Expected impedance of GEMs and gaps.

Step 9: After the test is complete, use the electronic screw driver to finalize the stretching of the foils (Fig. 107). The nominal strength value on the side of the trapezoid is 9 cNm, while it can be slightly higher in the corners, up to 15 cNm.

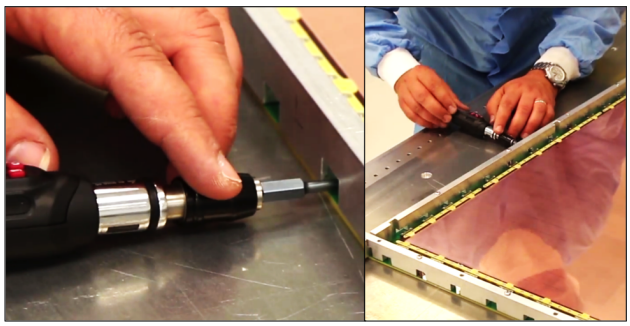


Figure 107: Finalizing the stretching of the stack.

::Closing and electrical test::

Step 1: Place the external frame between the GEM stack and the aluminum bars (Fig. 108). If the frame does not fit, simply unscrew the aluminum bars and adjust their position to accommodate the frame without stress. Then mount back the bars on the jig baseplate.

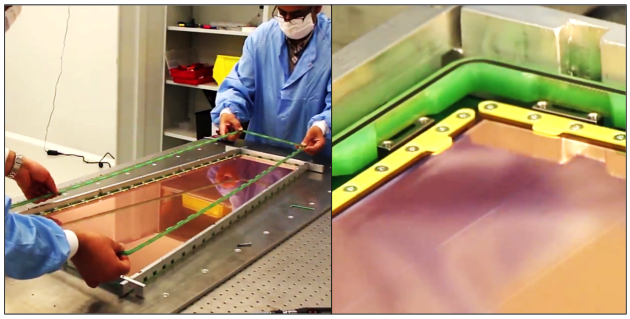


Figure 108: Inserting the external frame.

Step 2: Use the vacuum cleaner on the side of the bars to suck up possible dust produced during the stretching and carefully vacuum the gap between the stack and the bars. Use the static roll to gently clean the top surface of the foil one more time (Fig. 109).

Step 3: Clean the active area of the readout board with the vacuum cleaner and with proper care so as not to scratch the copper traces. As for the drift, use the static roller to catch the possible dust left on the board (Fig. 110).

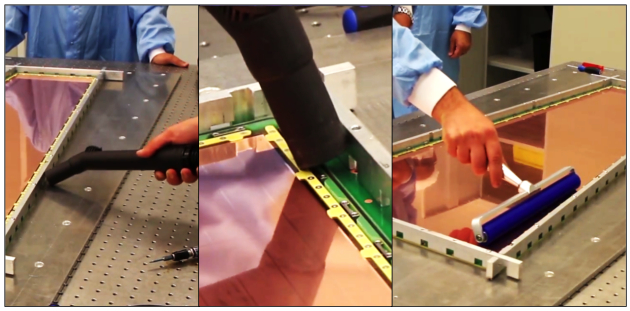


Figure 109: Cleaninig the setup after stretching.

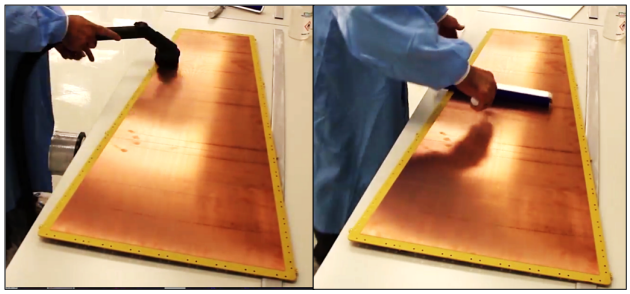


Figure 110: Cleaning the readout board.

Step 4: Without touching the strips with fingers, place the readout board on top of the GEM stack (Fig. 111).

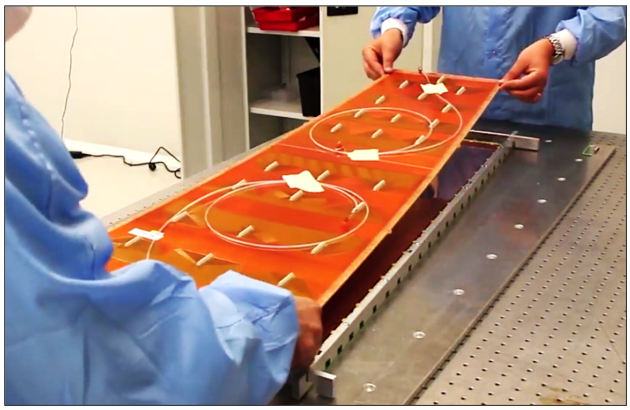


Figure 111: Mouting the readout board on the stack.

Step 5: Place the polyamide washers in the conical holes and insert the M3 screws. As mentioned in the section "Preparation of the drift board", tighten the screws at 1.2 Nm using the manual torque screw driver (Fig. 112).

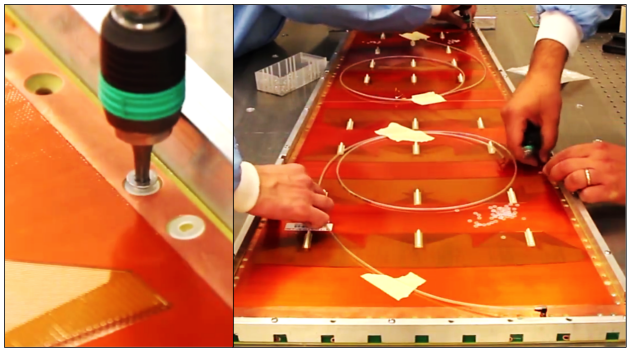


Figure 112: Sealing the detector.

Step 6: When all the screws are in place, remove the aluminum bars to release the chamber.(Fig. 113).

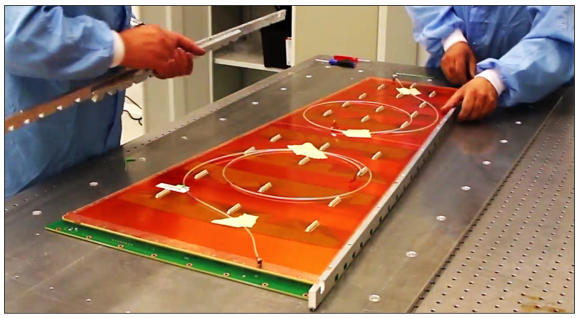


Figure 113: Removing the assembly jig.

Step 7: Test again the GEM foils and the gaps at 550 V (Fig. 114). Discharge the foils after each test.

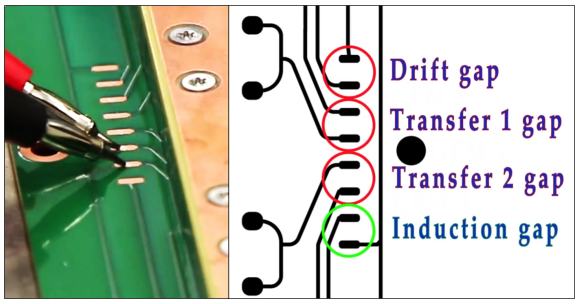


Figure 114: Testing the GEM foils and the gaps.

Step 8: In this configuration, the induction gap can be tested as well. To do so, connect the Panasonic-to-Lemo adapter on one of the readout sectors (Fig. 115 left).

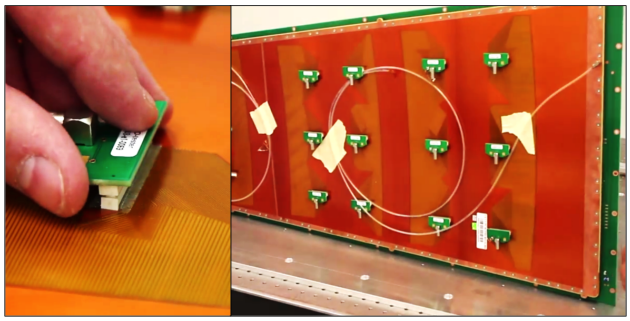


Figure 115: Testing the induction gap (1).

Step 9: Holding the chamber in a vertical position, apply 550 V between the GEM3 bottom and the signal pad of the Panasonic-to-Lemo adapter. The location of the GEM3 bottom pad is shown on Fig. 116 right. The impedance should immediately reach 100 GΩ.

Step 10: Follow the same procedure for all the readout sectors of the detectors (Fig. 117).

Step 11: The GE1/1 chamber is now ready for the next quality controls (Fig. 118).

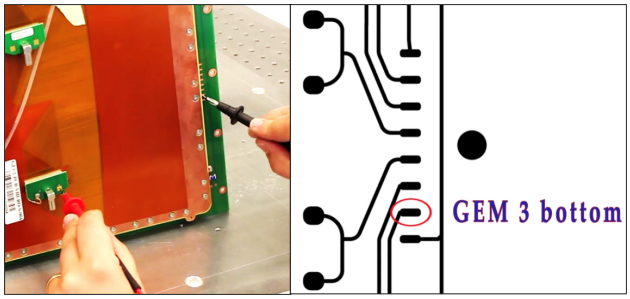


Figure 116: Testing the induction gap (2).

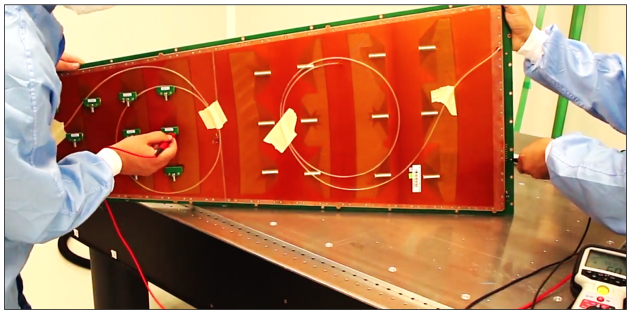


Figure 117: Testing the induction gap (3).

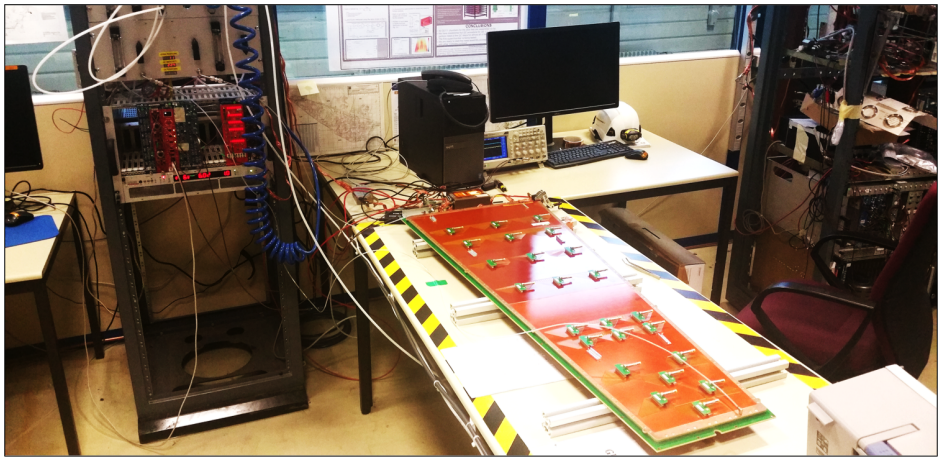


Figure 118: Chamber ready for QCs.

5.3 Comments and recommendations

When closing the readout board, one should make sure that the screws are perfectly concentric with the screw holes of the pull-outs. If not, it may create leak points that won't be identifiable before closing the chamber. More critical, the friction between the screw and the pull-out may create metallic dust that can seriously harm the detector.

As mentioned in the section "Preparation of the drift board", we recommended to first pair the M3 screws and the nylon washers before starting mounting the pull-outs. This will facilitate the work and limit the risk of damaging the PCB when pushing the screw inside the drift holes. One way to do so is shown on Fig. 28.

All the steps following the removal of the Plexiglas cover should be performed with a great care since the GEM foils are directly exposed. In this case it is particularly important not to pass any object on top of the stack that can fall down and damage the GEMs (tools, screws etc ...). It is obviously mandatory to wear a mask and to limit the number of persons working around the setup.

One should never touch the active area of the drift or the readout boards with bare fingers under the penalty of triggering copper oxidation that may affect later the operation of the detector.