Detector Construction

CGEM-IT Mechanics team

Goals

This document is intended as a guide for the construction of a cylindrical triple-GEM detector.
In this specific case is build on the necessity of the construciton of the **Layer 3 of the CGEM-IT** for the BESIII experiment.
The document is intended to be read following the left column of the page and follow the comments and support images on the right column.

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1 Equipment

- Table with reference holes and vacuum system (Fig. 30)
- Table with mandrel holding structure
- Mandrels
- Mandrel horizontal holding structure so-called *cart* spessori necessari - foto
- Instrumentation to bring the mandrel in vertical position: cross and base foto
- Mandrel with the element ready so-called *dressed*
- Two foils each planar gluing
- Foil or joint foils for cylindrical gluing
- 2011, 2012, 103 Microsphere diametro, HY991 Glue
- Glue cartridge, gun or syringe 5,10,3 cl with dispenser
- Vacuum foil patches to be used in the transfer and contro-transfer operation
- Mylar 50 μmthick, 5 cm high roll (mask the foil during gluing procedure)
- Vacuum bag of the needed size lista misure?
- Butyl sealant ready for use già in ordine
- Peel-ply sheet: texture green and white for the GEM foils, elastic blue for the mechanical structures (cover the foils during the vacuum. It lets the air pass through and does not stick to the glue)
- Necessary Magic tape rimovibile - DA ORDINARE(to hold the instrumentation still without damages)
- Rings 12 + 2 catodo spare
- Carbon fiber, Honeycom foils, Soft coverage $\rightarrow$ LOSON
- Kapton foils (25 μm, 50 μm, 125 μm and with holes from LOSON for the Anode's structure)
- GEM foils, Cathode foils, Anode Foil
- Semi-permanent detaching agent marca?
- Urethane-isolation (element passivation)
- Demineralized water
- Nitrogen
- VASCA ULTRASUONI x lavaggio fogli?
- Table for HV testing with all its supplies (CAEN HV system, hygrometer, gas system and PC)
- Custom-made cutter
- Vertical Insertion Machine (VIM)
- PC for VIM control
- Lifter (blu $\rightarrow$ commercial; item $\rightarrow$ custom-made; spreader beam)
- Brushes (to clean the rings) da controllare
- Rollers for gluing

2 Preparation

2.1 Precautions and Care

- CLOTHING
  - Outside the clean room, always wear gloves and mask to operate
  - Inside the clean room, always wear the full cover, feet to head
- HANDLING
  - Foils: grab the foils always from the corners, better to be always 4 people, minimum to operate is 2
  - Mandrels: always be careful about them hitting the surrounding or falling
  - Tools: always be careful to operate and store them properly and do not hit anything
- CLEANING
  - Foils: they can be cleaned with Argon gas or ionised gas for the dust
  - Surfaces: they can be cleaned with Alcohol, but always double check and pay attention

2.2 Quality check

- MANDRELS (Example Fig. 3)
  - Check for deformations: no ovalization, bumps or scratches allowed
  - Check the pins: they should enter and exit from the flanges without trouble and the mandrel on its pins must regularly rotates.
  - Check the flanges: they should be perfectly flat, clean and whitout scratches
- FOILS (Example Fig. 1)
  - Visual check the foils in the shipping box
  - Mechanical check: measure cuts and sizes
  - Check for deformations: no creases and bumps allowed
  - (for the anode) Check the strips thoroughly
- RINGS
  - Mechanical check:
    measure holes, thicknesses and diameters precisely
- SPACING GRIDS
  - Mechanical check:
    measure groove, thicknesses and diameters precisely
  - Visual check of single elements for deformations
- VERTICAL INSERTION MACHINE (Example Fig. 2)
  - tensioni, piano d'appoggio, controllo autocentrante

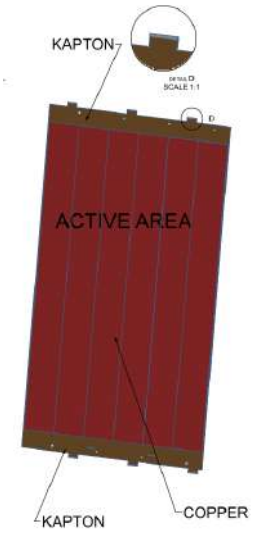

Figure 1: GEM drawing

Figure 2: VIM and custom lifter

2.3 Mandrels

The madrels needs to be prepared for every operation. There are five mandrels for each layer. They should be stored in three separate boxes: one box for Catode and GEM1; one box for GEM2 and GEM3; one box for the Anode. Each one of them is composed as shown in Fig. 3.

- *Teflon coated surface* that will hold the active area
- *Construction pin holes* that will be used to fix foils and rings
- *Anular flanges* at the end of the Teflon surface
- *Ring housing* that will be used for the so-called int-ring
- *GEM HV tail housing* for the mandrels of the three GEMs
- *Flange* on both sides, that will be used for references and movements
- *Pin* on both sides, important for the mandrel placement
- *Eye* on both sides, for mandrel handling before and after construction
- *IN-side (WEST)* the construction pin holes are on the Teflon part
- *OUT-side (EAST)* the construction pin holes are on the anular ring

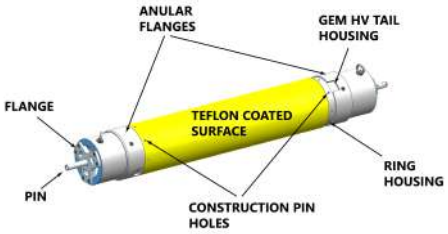

Figure 3: Mandrel Scheme to define its components

Basic Importat Rules

- The mandrel must be handled carefully either if it is dressed (with the element on) or naked
- The Teflon area must be treated carefully
- The dressed mandrel can not be touched in the active area
- The mandrel can be moved by means of a crane (small and portable or fixed ones) with lifting straps
- The mandrel can be hold horizontal by the pins at the extremities
- The mandrel can be hold with strops by the flanges or, if naked and properly protected, from the middle with the spreader beam as shown in Fig. 4
- The mandrel can rest on the V structure supporter by the anodized apart but not on the anular flanges

Horizontal Movements

- The un-used mandrel, dressed or naked, can be holed in its cradle with long pins on both sides fixed with mechanical blocks with a small layer of mylar to preserve it (Fig. 5)
- The mandrel to be used for cylindrical gluing must be placed on its support on the table and fixed as in the cradle (Fig. 6)
- Three persons (two is the minimum) are needed while the mandrel is in movement with one person handling the crane and the other two checking its movement to ensure its safety

Figure 4: An example on how to hold the naked mandrel

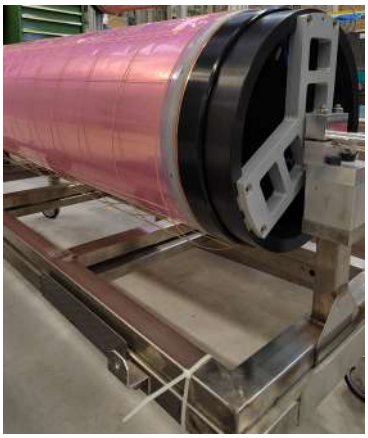

Figure 5: Dressed mandrel secured on the cradle

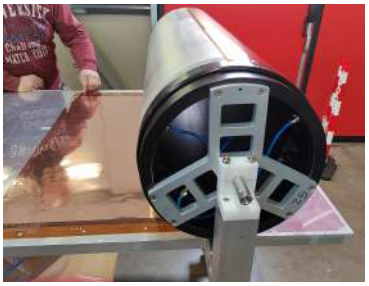

Figure 6: Mandrel secured on the table for cylindrical gluing

Horizontal to Vertical Movements

1. The mandrel lies on the cart, secured at both sides
2. Secure the mandrel with 2 strops at the extremities from the flanges
3. Free the two blocks at the extremities
4. Lift the mandrel slowly with 2 people checking that it does not hit the cart and remove the cart from below
5. Connect on the IN-end the cross and prepare on the other side the V support (Fig. 9)
6. Lower the mandrel on the V support checking that it does not hit the anular flange
7. Place an eyebolt at the center of the flange on the out side
8. Change the strop position: place one strop in the eyebolt for one-side lifting
9. Raise the mandrel in the vertical position
10. Remove the cross below
11. Place the mandrel on its base to stay vertical (Fig. 10)

Vertical Movements

1. The mandrel is in vertical position on its base
2. Remove the eye from the top flanges and, if there, also the pin. The flange should be as shown in Fig. 7 with the brass head threaded installed
3. Approach the VIM lifter (Fig. 11) and connect it to the mandrel
4. Lift the mandrel
5. Change the bottom pin from the long one to the short one
6. Place the reference pin in the bottom flange of the mandrel
7. Raise at maximum the detector support in the VIM
8. Move carefully the mandrel inside the VIM until it is center at best
9. Lower slowly the mandrel and center it with the jaw at the base of the VIM (Fig. 12)
10. Carefully center the mandrel over the pin sites precisely (Fig. 8)
11. Disconnect the VIM lifter from the mandrel and carefully take it out of the way
12. Remove the top anular flange from the mandrel
13. Lower the bottom anular flange

Figure 7: Flange ready for the VIM filter

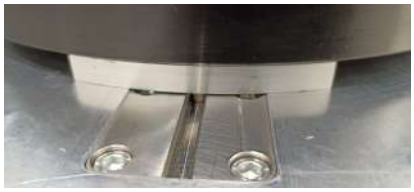

Figure 8: Mandrel centered with the reference pin

Figure 9: An example of the procedure to raise the mandrel in vertical position

Figure 10: Dressed mandrel on the vertical base

Figure 11: VIM lifter

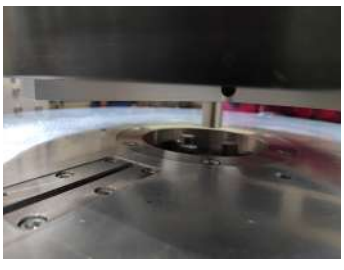

Figure 12: Jaws at the base of the VIM

2.4 Vacuum System

The vacuum systems are important in the gluing phases both for the planar and cylindrical operations.

Planar system The planar system is composed by the planar table, tubes and vacuum pump.
The planar table is characterized by having 4 through holes to extract air and other holes (not through) to hold the foils in the right position.
To prepare this system it is necessary to cover the full table (except the air holes) with mylar 50 μm to protect foils and tables. Then is it necessary to check that the tubes are properly connected at the bottom of the table and at the vacuum pump. Install on the table the vacuum bag sealed with mastic sealant (on all the table or only on the holes) and check from the monitor that the vacuum level reaches acceptable values (around 10^0 mbar).
In Fig. 13 is shown the table during the gluing pose with the two foils in position, covered with peel-ply sheet and contained below the vacuum bag sealed with mastic sealant.

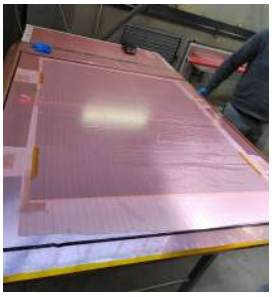

Figure 13: Planar table with gluin pose on-going

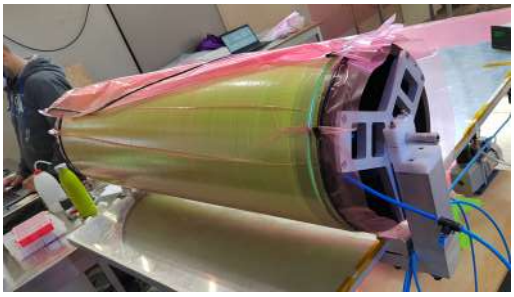

Figure 14: Planar table with gluin pose on-going

Cylindrical system The cylindrical system is composed by each mandrel independently, tubes and vacuum pump. The mandrel has a tube system on the inner part that needs to be connected to the external vacuum pump. Additionally, for construction requirements, the mandrel has some passing-through holes that need to be closed to assure the vacuum. To do so a vacuum bag patch with mastic sealant could be placed as it is possible to see in the Fig. 7 looking inside the mandrel on the right of the picture: the pink patch is the vacuum bag, the black triangle is the mastic sealand around the visible hole. This has to be performed from the inside for each hole that doesn't have a tube connected.
Fig. 14 shows the mandrel during the cylindrical gluing pose of a GEM foil. The foils are layed on the Teflon part of the mandrel, on top of which has been positioned the peel ply and all around them the vacuum bag closed with some pences to minimize the creases.

2.5 Rings

The Permaglass rings (Fig. 15) are part of the mechanical structure and they need to be cleaned, washed, and passivated before starting each operation. Always wear protective gloves and mask.

Figure 15: Examples of Permaglass rings

Figure 16: Examples of Permaglass rings cleaning instrumentation

Cleaning The cleaning is performed *oustide the clean room* with the instrumentation presented in Fig. 16. The brushes should have hairs 2 cm long and flat. The brush will degrade, therefore for the 12 rings probably at least 4 brushes are needed. The process will require more than one cycle of the following operation.

1. Wear protective dress all the time
2. Position yourself with lenses and in a good light to be able to see small fibers on the ring (Fig. 17)
3. Brush the surface until no fibers are visible
4. Wash the object with alcohol
5. Dry with compressed air
6. Check the status and eventually repeat

Figure 17: Examples of Permaglass rings defects

Washing The washing is performed *inside the clean room* with an ultra sound bath (US-bath) following these instructions. The number of rings to clean per cycles depends on the rings diameter and their position in the bath.

- Temperature 40°C
- Time for washing 30 min
- Two cycles each set of rings changing clean water
- The water of the second cycles may be reused for the follow first cycle
- The drying can be performed by leaving the rings inside the clean room for more than one day

Passivation The passivation must be performed separately for the inner part (facing the inner part of the chamber) and the outer part. For this operation is suggested to wear a mask with active filters. The glue layer should be thinner than 10 μm.

1. Start from the inner part
2. Protect the inner part of the pin holes with Kapton tape
3. Spray the insulation for 1 s directly on the inner part of the ring
4. Spread the insulation with a roller evenly
5. Remove the excess with a vacuum foil patch with a transfer operation
6. Remove the Kapton tape from the pin holes
7. Let rest for one day to dry
8. Protect the outer part of the pin holes with Kapton tape
9. Spray the insulation on a mylar patch
10. Transfer the insulation by applying it from the mylar patch
11. Remove the Kapton tape from the pin holes
12. Transfer carefully the insulation on the sides of the pin holes
13. Let rest for one day to dry

2.6 Anode and GEM foils

Each foil that is intended to be used in our detector must be checked, eventually resized and tested for HV.

Precision Cutting This is performed to be sure that the foils fits the mechanical drawing requirements and they are performed with the specific cutting tool shown in Fig. 18.

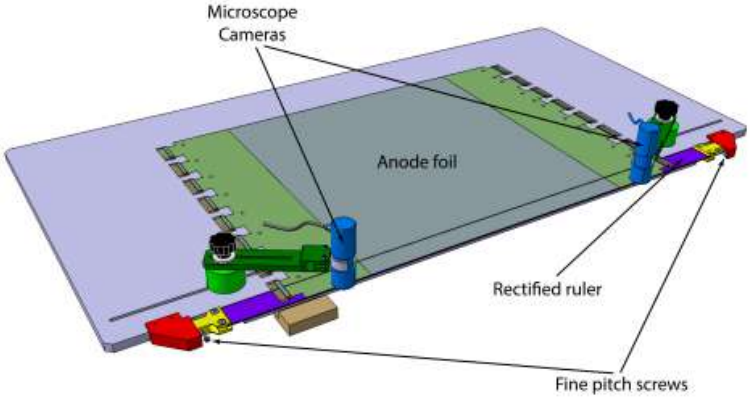

Figure 18: Drawing of the tool for resizing the foil.

The foil of interest has to be placed on the base plate with kapton tape. Adjust the alignment of the foil with respect to the blade using adjustable ruler (purple), the micrometric screws and the microscope cameras (blue). Once the foil is in position, slide the blade with its support (brown block). Probably the operation is needed on both sides of the foil.

Cathode HV test To check the status of the cathode after the visual check and validate the HV status. Inside the clean room, place the cathode foil on the HV table (Fig. 19) whitout closing it with the copper part facing the bottom part.

1. Connect the copper tail to the ground
2. Connect the HV probe to HV at 2-3 kV
3. While keeping a 3 mm from the kapton side of the foil, move the probe all around the area
4. If there is a hole in the foil, a spark should occur and be visible

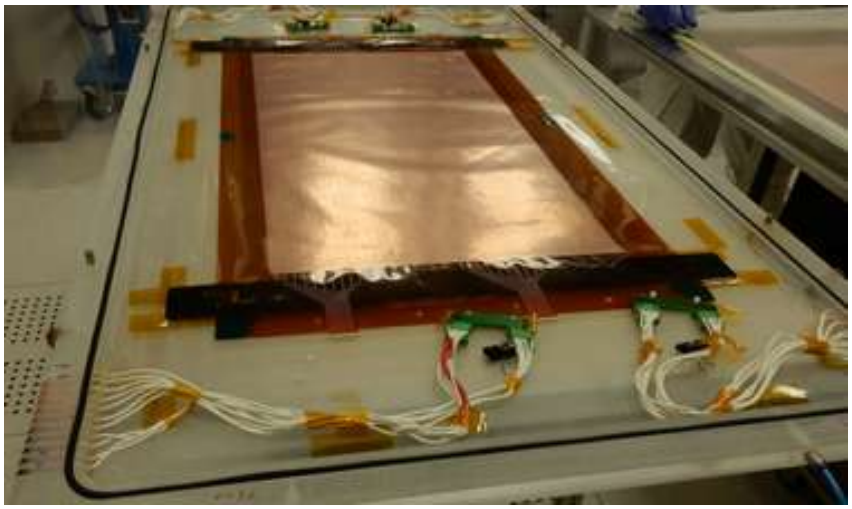

Figure 19: Picture of the HV test table with a GEM foil in position.

GEM HV test To check the status of the GEM foils after the visual check and validate the HV status. This operation requires several steps described in the following points. Be careful to prevent metal dust from getting into the plastic box - avoid screws or connectors that could scratch the plastic.

- HV TABLE INSTRUMENTATION
  - Gas system
  - PC
  - Hygrometer (Fig. 20):

    a low humidity level ($< 5\%$) is needed for the HV test; a probe is prepared to be installed inside the table and to be connected with the PC to monitor it.
  - Plastic box
  - CAEN HV and Nano-Ampere Meter system
  - HV box (Fig. 21):

    it acts as a patch panel to connect 10 SHV cables connected to the CAEN/Nano-Ampere Meter system to 10 male HV cables that will be connected to the table through $500\,\mathrm{M}\Omega$ resistors. On the side of the box, two ground connection are placed.
- GEM FOIL CONNECTION

  Clean the table with alcohol and flush it with Nitrogen.

  The foil must be positioned on the table with the macro-sectors on the bottom side and the micro-sectors on the top side and with side with the gas holes facing the gas-out side. To organize the test by numbering the micro-sectors it can be used the side of the foil with gas holes. By looking at this side, the N1 micro-sector can be identified as the one of the left.

  Perfom an additional visual check on the active area. If everything is ok, fix the foil on the table with Kapton.

  The table is designed to have, for each GEM tail, a pad with 11 cables connected (10 micro- and 1 macro-sector). The electrical contact between tails and pads is made by pressing the two components together with the help of a clamp. Secure the position of the connectors with tape. During the test all the tails must be connected to the cables. Follow Fig. 22 for reference.

  To check the connection of the micro-sectors use a multimeter with one pointer inside the female connector of the HV cable on the side of the table and the other carefully pointed on the open line on the GEM trail.

  To check the connection of the macro-sectors the system follows almost the micro-sector's one. Since the macro-sector open line is on the bottom part of the foil a copper foil square must be positioned below the foil. A person can carefully press the tail on the cupper foil to guarantee the electric contact while a second persone start the electric check. One pointer should be inserted in the female connector of the HV cable while the second can be place to touch the cupper foil.

  Perform a capacity test between ground and each micro-sector (nominal value $3.5\,\mathrm{nF}$).

Figure 20: Picture of the HV test table hygrometer system.

Figure 21: Picture of the HV box for the HV test.

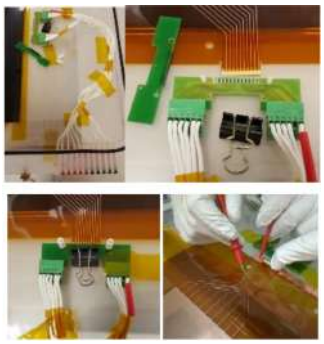

Figure 22: Picture of the HV test table cable system.

- HV TABLE SEALING

  Before close the table all the micro- and macro-sector must be verified with a multimeter.

  Once the connections are validated, it is necessary to clean the system by carefully blowing Nitrogen on the full surface.

  Place the butyl sealant close to the border of the plastic table to assure an effective sealing bewteen the top and bottom part of the table (Fig. 23).

Place the top part of the table and press it with 8 clamps placed around the table (Fig. 24).

Start the Nitrogen flow using the 4 gas connectors placed on the side of the table.

Figure 23: Picture of the HV test table with the sealand in position.

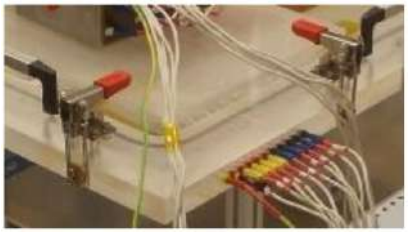

Figure 24: Picture of the HV test table secured with clamps.

- MEASUREMENT OF THE CURRENT ABSORPTION

  CAEN Mainframe, Nano-Ampere Meter and the Hygrometer must be connected to the PC. The programs to be used are 'currentHVtest2.vi' and 'HygroclipText.vi'. At the beginning check that all the CAEN's channels are OFF.

  Connect the macro-sectors to the ground and the micro-sectors to the HV channels. The 10 micro-sectors are tested together. Check the background current.

  Operational Parameters:

  - Humidity must be lower than 5%
  - Max Current $2 - 5\,\mathrm{mA}$
  - Ramp up and ramp down $5\,\mathrm{V}$
  - Max HV for test $600\,\mathrm{V}$
  - From 0 to $400\,\mathrm{V}$ proceed with $50\,\mathrm{V}$ steps
  - From 400 to $540\,\mathrm{V}$ proceed with $20\,\mathrm{V}$ steps
  - From 540 to $600\,\mathrm{V}$ proceed with $10\,\mathrm{V}$ steps

  Procedure:

  - Start the test while checking the humidity
  - Log every operation
  - After each step, wait 5 minutes for the current to be stable
  - If a discharge happens, not which is the microsector. If the dischage continues, open the box and try to clean the area with a Nitrogen flow
  - Once the maximum value of $600\,\mathrm{V}$ is reached, wait 30 minutes
  - If a discharge happens only once in 30 minutes probably it is not to be considered a problema; if it occures more than twice in 30 minutes try to clean the identified problematic area
  -
  - If after cleaning the problem is still there, even in one sector, the foil must be rejeted.
  - If a foil has an high current absorption it can be considered to ship it back to CERN for recovery.
  - The test is not complete until all the macro-sectors are tested. If necessary, change cables connection and restart.

2.7 VIM alignment

3 Construction

3.1 Planar Gluing

Instrumentation

- Table with reference holes and vacuum system (Fig. 30)
- Two foils each planar gluing
- 2011 Glue (cartridge and gun)
- Vacuum foil patches to be use in the transfer and contro-transfer operation
- Mylar to mask the foil during gluing procedure
- Vacuum bag of the needed size
- Mastic sealant ready for use
- Peel-ply sheet to cover the foils during the vacuum
- Necessary tape to hold the instrumentation still

Procedure

1. Prepare the ancillary supplies in number and size as needed
2. Dry test of the foils on the table with 4 pins (2 each foil) to check carefully the dimensions with a lens and to learn operation movements (Fig. 25, Fig 31)
3. Fix the foil that will close the overlap in the final position with 4 pins (2 on each side)
4. Place a vacuum foil patch in the position designed for the overlap below the foils
5. Move and the fix the foil that will be glued in the designated area of the table with tape, paying attention to the active area
6. Measure the overlap sizes to define the glue area and check them with a lens
7. Apply all the necessary masks on the foils to contain the glue area (Fig. 26; Fig. 32, Fig. 33)
8. Prepare the transfer patch with the glue and the roller (half-length each time) (Fig. 27)
9. Apply the glue on the foil with one transfer (Fig. 28)
10. With a clean patch remove the glue excess in the full length
11. Remove all the masks and tape (Fig. 29)
12. Move the glued foil in the final position while the other flap of the overlap is kept high
13. Let the second flap fall in position
14. Remove the starting pins and place them one on each side of the same foil that is below in the overlap (Fig. 34)
15. Place a vacuum foil patch in the position designed for the overlap above the foils
16. Place the peel ply sheet well flat
17. Place the vacuum bag well flat
18. Turn on the vacuum pump while checking the flatness of the different foils (Fig. 28)
19. Measure with the graduated lens the overlap size and log it

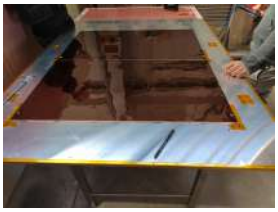

Figure 25: Dry Test with two foils and pins

Figure 26: Gluing mask detail

Figure 27: Glue rolling on the vacuum foil patch for transfer

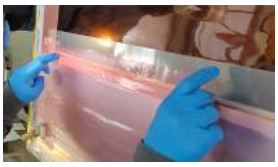

Figure 28: Glue transfer on the GEM foil with a vacuum foil patch

Figure 29: Detail on the glue on the overlap

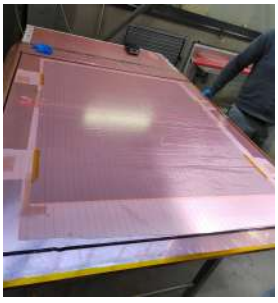

Figure 30: Planar Table with GEM foil in pose

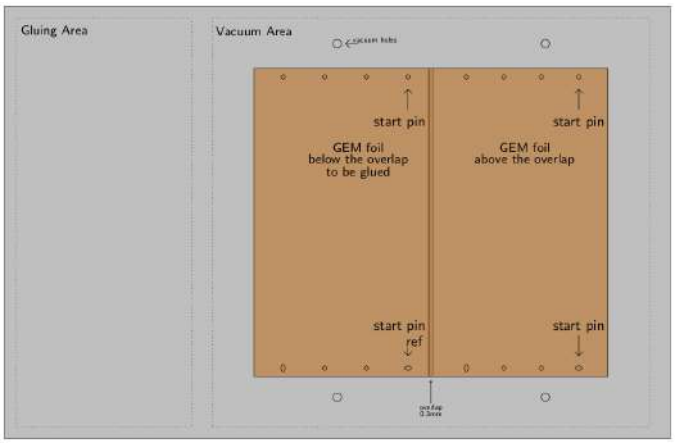

Figure 31: Dry test on the planar table. The planar table is already ready and divided in a *Gluing area* and a *Vacuum Area*. In the vacuum area the two foils must be placed and fixed with the necessary *start pins* and the overlap must be measured with a lens

Figure 32: Scheme of the overlap setup for gluing. The overlap area is identified by a $0.3\,\mathrm{mm}$ boarder at the edge of the GEM foil. Within this area, masks such as the vacuum bag patch and the magic tape are placed to save $0.1\,\mathrm{mm}$ on each side to avoid any glue spread. It can be helpful to place a weight on the vaccum bag patch to ensure its stability during operations

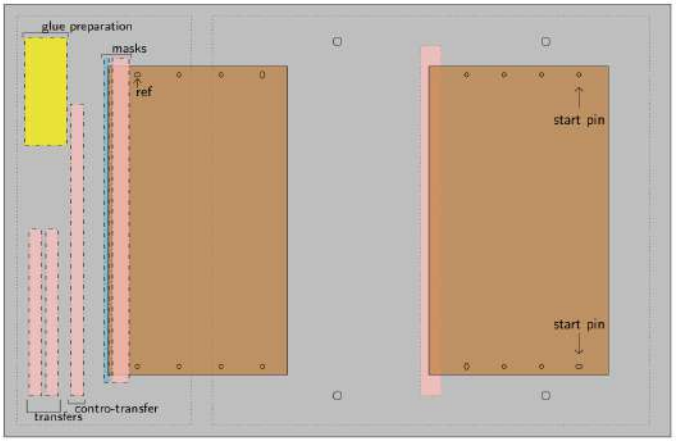

Figure 33: Gluing setup on the planar table. Here the foils masks are represented again. The *glue preparation* is the area where the glue is rolled; the transfer and the contro-transfer are the vaccum bag patch used for gluing and for remoing the excess respectively

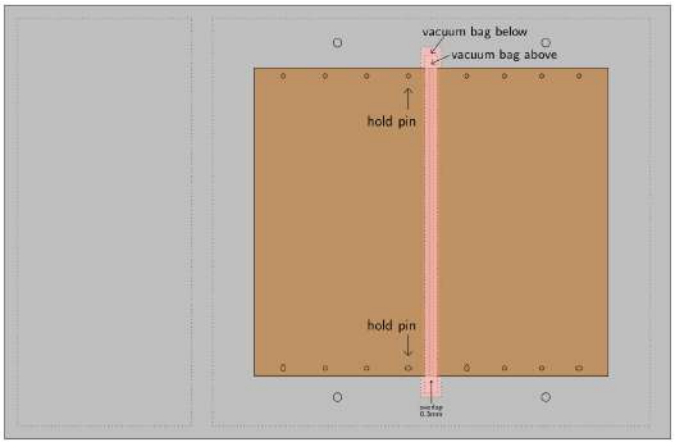

Figure 34: Planar Table with GEM foil in pose. Above and below the overlap a vacuum bag patch is positioned to prevent any glue spread to glue the foils to either the table or the peel ply

3.2 Cylindrical Gluing

Instrumentation

- Table with mandrel holding structure
- 2011 Glue (cartridge and gun)
- Vacuum foil patches to be use in the transfer and contro-transfer operation
- Mastic sealant ready for use
- Peel-ply sheet to cover the foils during the vacuum
- Foil/Joint foils
- Inner ring
- Vacuum foil patches to be use in the transfer and contro-transfer operation
- Vacuum bag of the needed size
- Necessary tape to hold the instrumentation still

Procedure

1. Prepare the ancillary supplies in number and size as needed
2. Prepare the mandrel with the release agent (three application, separate 15min apart update con nuovo prodotto)
3. Dry test of the foils on the table to check the position wrt the pins and learn operation movements (Fig. 35). Note: if the pins create tensions on the foil, it can be considered to substitute a pin with tape only on one side
4. Position the foil horizontal on the table to be glued and placed on the mandrel (Fig. 36, Fig. 38)
5. Measure the overlap sizes to define the glue area and check them with a lens
6. Apply all the necessary masks on the foils to contain the glue area
7. Place the protective (2 vaccum foils) under the int-ring place on the mandel and tape the holes (Fig. 37)
8. Apply the glue with a transfer with 3 patches (one third of the lenght) with vacuum bag
9. With clean patches (10cm long) remove the glue excess in the full ring
10. Remove the tape on the holes and with the finger move a bit of the glue towards the hole
11. Prepare the transfer patch with the glue and the roller (half-length each time)
12. Apply the glue on the foil with one transfer
13. With a clean patch remove the glue excess in the full length
14. Remove all the masks and tape
15. Move the glued foil under the mandrel well aligned (Fig. 39)
16. Raise the foil from the not-glued side(end of the table) up until the reference pin that are located in the lower part of the mandrel and place the pins (Fig. 40)
17. Continue to rotate the mandrel, while two persons hold the foil on the other side stretched and away from the mandrel, and align the foil at the ring until it is glued for half its length
18. Raise the other part of the foils paying attention to the alignement with the help of the two pins close to the end of the foils (Fig. 41)
19. Check that the foil would fall in place before glueing the overlap
20. With the vacuum foil (pin to pin wide and longer than the circumference), help the placing of the foil in position, by stretching it around the GEM and fix it with a tape
21. Wrap everything (one way and back) with the green peel-ply foil without forming air bubbles or creases in the movements
22. Place the vacuum bag with at least three fold not to create too many creases on the surface
23. Turn on the vacuum pump while checking the surface
24. Measure with the graduated lens the overlap size and log it

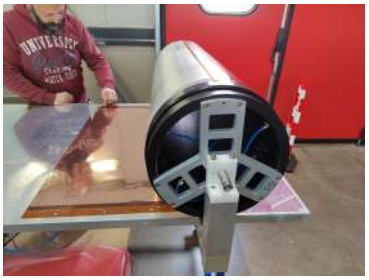

Figure 35: Dry test to check foil sizes and holes' alignment

Figure 36: Cilindrical table ready for cylindrical gluing

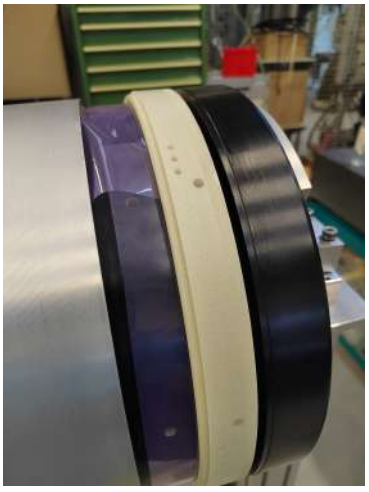

Figure 37: Preparation for the int-ring gluing

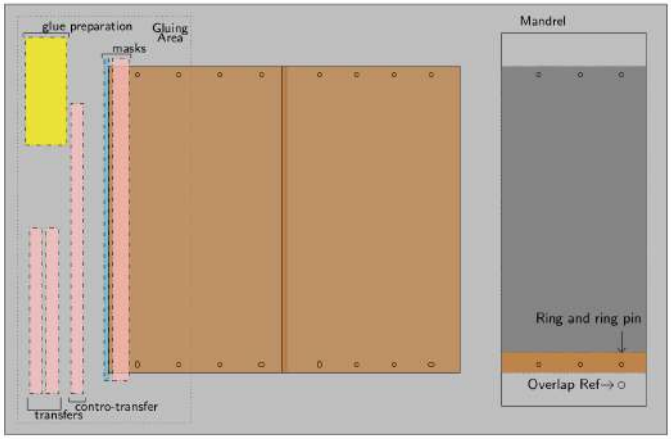

Figure 38: Scheme of the overlap setup for gluing following the instruction as in the planar gluing

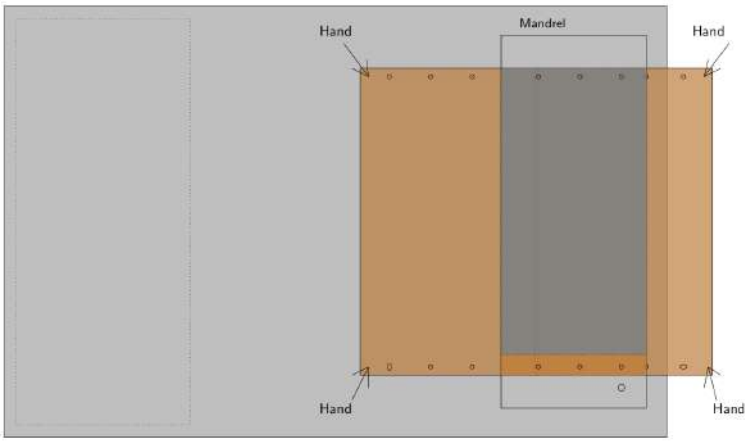

Figure 39: Scheme of the operation to move the glued foil bwloe the mandrel to start the cylindrical gluing. The 4 *hands* indicate the position to hold the foil carefully

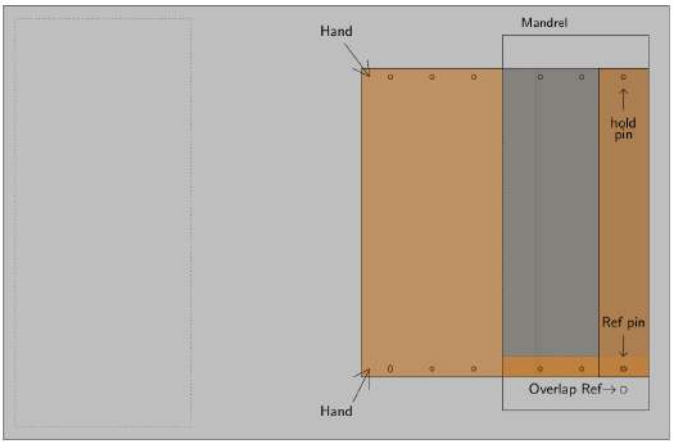

Figure 40: Scheme of the operation to place the foil on the mandrel. The *Overlap Ref* helps to identify the position of the edge of the foil and fix the *ref and hold pins*. If the pins stretch too much the foil, remove one pin and replace it with tape

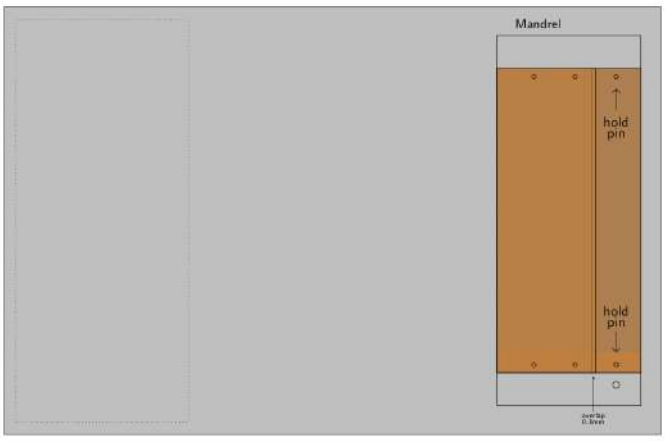

Figure 41: Scheme to conclude the cylindrical gluing. After the first half is ready and fixed on the mandrel raise the second half in position until the glued edge fall on the other one and check the size of the overlap

3.3 Mechanical structure - LOSON - to be checked

Instrumentation

- Mandrel holding structure
- 2011 Glue (cartridge and gun)
- Carbon fiber and honeycomb foils
- Vacuum foil patches to be use in the transfer and contro-transfer operation
- Mastic sealant ready for use
- Peel-ply sheet to cover the foils during the vacuum
- Kapton foils (25 μm, 50 μm, 125 μm);
- Inner ring
- Vacuum foil patches to be use in the transfer and contro-transfer operation
- Vacuum bag of the needed size
- Necessary tape to hold the instrumentation still
- Soft coverage

3.3.1 Cathode

Procedure

1. Prepare the ancillary supplies in number and measurements as needed
2. Prepare the mandrel with the release agent (three application, separate 15min apart)
3. With the 25um Kapton foil follow the cylindrical gluing of the foils (preparation of the int ring and an overlap)
4. Prepare the carbon fiber of the proper size (cut with a scalpel) checking it with dry tests on the mandrel
5. Prepare for the complete glue transfer. Foil width: half the length of the mandrel; foil length: more extended than the circumference; filled with glue. Before and after the application on the surface it must be weighted
6. Apply the complete transfer foil with 2 people holding the transfer foil and a third helping with the precision of the pose and with the spreading of the glue without air bubbles by massaging the transfer foil with a clean patch
7. Repeat the operation for the two half and check if a third application in the middle could be needed
8. Place the fiber foil with 2 people holding it and a third helping with the precision of the pose and checking for air bubbles or creases
9. Close the fiber overlap: with a rigid small brush apply the glue on the lower part of the overlap; lower the top part; apply more glue with the same brush on the edge of the upper foil; use a stiff spatula to remove glue residues
10. Place the elastic peel-ply (blue) on the surface starting from one edge and spiraling it to the other edge without creases. Fix it at the edges with tape outside the area of interest of the gluing
11. Cover the peel ply layer with a new layer of soft material
12. Place the vacuum bag doing at least three-fold to avoid the creation of too many creases on the surface; while powering it on, check the surface and the vacuum
13. Wait the expected time (at least 7h) and remove carefully each layer down to the carbon fiber foil
14. Prepare the honeycomb foil of the proper size (cut with a scalpel) checking it with dry tests on the mandrel to avoid material excess either in length and in circumference
15. Repeat the action at points 5.6.7. for the complete glue transfer
16. Place the honeycomb foil with 2 people holding it and a third helping with the precision of the pose and fixing the honeycomb in position with all the necessary tape
17. Place the fabric peel-ply (green) on the surface starting from one edge and spiraling it to the other edge without creases. Fix it at the edges with tape outside the area of interest of the gluing
18. Cover the peel ply layer with a new layer of soft material
19. Place the vacuum bag doing at least three-fold to avoid the creation of too many creases on the surface; while powering it on, check the surface and the vacuum
20. Wait the expected time (at least 7h) and remove carefully each layer down to the honeycomb
21. Prepare the 50um Kapton foil and dry test it on the mandrel

22. Repeat the action at points 5.6.7. for the complete glue transfer
23. Follow the instruction of the cylindrical gluing to prepare the overlap of the foil
24. Place the Kapton foil with 2 people holding it and a third helping with the precision of the pose and checking for air bubbles or creases; carefully close the overlap in position
25. Place the elastic peel-ply (blue) on the surface starting from one edge and spiraling it to the other edge without creases. Fix it at the edges with tape outside the area of interest of the gluing
26. Place the vacuum bag doing at least three-fold to avoid the creation of too many creases on the surface; while powering it on, check the surface and the vacuum
27. Wait the expected time (at least 7h) and remove carefully each layer down to the Kapton foil
28. For the cathodic circuit, follow the instruction of the cylindrical gluing from the preparation of the overlap until its gluing in position
29. Place the elastic peel-ply (blue) on the surface starting from one edge and spiraling it to the other edge without creases. Fix it at the edges with tape outside the area of interest of the gluing
30. Place the vacuum bag doing at least three-fold to avoid the creation of too many creases on the surface; while powering it on, check the surface and the vacuum
31. Wait the expected time (at least 7h) and remove carefully each layer down to the cathodic circuit

3.3.2 Anode

Procedure

1. Prepare the ancillary supplies in number and measurements as needed
2. Prepare the mandrel with the release agent
3. For the anodic circuit, follow the instruction of the cylindrical gluing from the preparation of the internal ring and of the overlap until its gluing in position
4. Prepare the 125um Kapton foil and dry test it on the mandrel
5. Prepare for the complete glue transfer. Foil width: half the length of the mandrel; foil length: more extended than the circumference; filled with glue. Before and after the application on the surface it must be weighted
6. Follow the instruction of the cylindrical gluing to prepare the overlap of the 125um Kapton foil
7. Apply the complete transfer foil with 2 people holding the transfer foil and a third helping with the precision of the pose and with the spreading of the glue without air bubbles by massaging the transfer foil with a clean patch
8. Repeat the operation for the two half and check if a third application in the middle could be needed
9. Place the 125um Kapton foil with 2 people holding it and a third helping with the precision of the pose and checking for air bubbles or creases; carefully close the overlap in position
10. Place the elastic peel-ply (blue) on the surface starting from one edge and spiraling it to the other edge without creases. Fix it at the edges with tape outside the area of interest of the gluing
11. Place the vacuum bag doing at least three-fold to avoid the creation of too many creases on the surface; while powering it on, check the surface and the vacuum; wait the expected time (7h)
12. Prepare the external rings of the anode: tape the internal surface to cover the pins' holes; apply the glue on the inner surface of the ring with a soft roller; check the sizes of the needed pins
13. Place the ring in position on the mandrel starting from the reference pin and continuing in one direction until all the pins are in the right position
14. Stretch as much as possible the ring around the surface and fix it with Kapton tape on the split; fix the ring in position for the rest with Kapton tape all along the circumference
15. Repeat 12.13.14 for both extremities
16. Prepare the honeycomb foil of the proper size (cut with a scalpel) checking it with dry tests on the mandrel to avoid material excess either in length and in circumference
17. Repeat the action at points 5.7.8. for the complete glue transfer

18. Place the honeycomb foil with 2 people holding it and a third helping with the precision of the pose and fixing the honeycomb in position with all the necessary tape
19. Place the fabric peel-ply (green) on the surface starting from one edge and spiraling it to the other edge without creases. Fix it at the edges with tape outside the area of interest of the gluing
20. Cover the peel ply layer with a new layer of soft material
21. Place the vacuum bag doing at least three-fold to avoid the creation of too many creases on the surface; while powering it on, check the surface and the vacuum; wait the expected time (7h)
22. Prepare the carbon fiber of the proper size (cut with a scalpel) checking it with dry tests on the mandrel
23. Repeat the action at points 5.7.8. for the complete glue transfer
24. Place the fiber foil with 2 people holding it and a third helping with the precision of the pose and checking for air bubbles or creases
25. Close the fiber overlap: with a rigid small brush apply the glue on the lower part of the overlap; lower the top part; apply more glue with the same brush on the edge of the upper foil; use a stiff spatula to remove glue residues
26. Place the elastic peel-ply (blue) on the surface starting from one edge and spiraling it to the other edge without creases. Fix it at the edges with tape outside the area of interest of the gluing
27. Cover the peel ply layer with a new layer of soft material
28. Place the vacuum bag doing at least three-fold to avoid the creation of too many creases on the surface; while powering it on, check the surface and the vacuum
29. Wait the expected time (at least 7h) and remove carefully each layer down to the carbon fiber foil

3.4 External rings

Instrumentation

- Mandrel with the element ready
- 103 Microsphere Glue - syringes and dispenser
- Necessary tape and syringe to operate

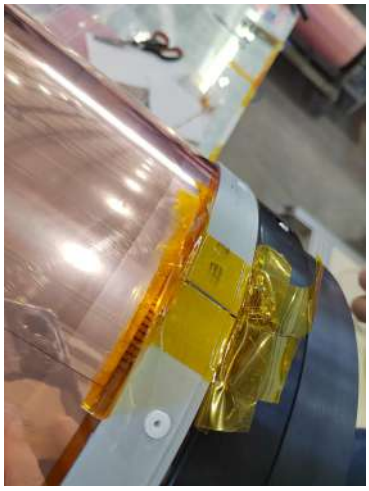

Figure 42: External ring ready to be closed with the glue

Figure 43: Testing the syringe head to seal the ring

Procedure

Gluing the external ring

1. Dry test of the ring on the mandrel to check its size and alignment with pins (to be the same to use in the procedures)
2. Tape the internal surface to cover the pins' holes
3. Apply the glue with transfer. Note: the surface has to be carefully wet, but not lucid. It this occure, remove the excess with a transfer with a vacuum bag patch
4. Place the ring in position on the mandrel starting from the reference pin and continuing in one direction until all the pins are in the right position
5. Protect the foils as performed in the cylindrical gluing with the vacuum foil
6. Place the green peel-ply on the ring (it can be reused)
7. Place the vacuum bag with at least three fold not to create too many creases on the surface
8. Turn on the vacuum pump while checking the surface

Close the external ring's split

1. Prepare the external ring split to close it with glue with Kapton tape and on the GEM leave the vacuum foil used for the external ring
2. Use the syringe of glue directly on the wanted part until the ring split is filled; let rest for the necessary time
3. Check the result and if needed repeat the operation

Seal the external ring

1. Prepare the mandrel in the vertical position with the external ring in the bottom part
2. With Kapton tape protect the external part of the ring all around the circumference
3. With vacuum bag protect the full bottom (tails, mandrel,..)
4. Use the syringe of glue (with the 103 glue it needs to be quick operation) directly on top of the ring in the dedicated space between the foil and the Kapton tape along all the circumference (Fig. 44); let rest for the necessary time
5. Measure the external circumference and compare it with the designed one

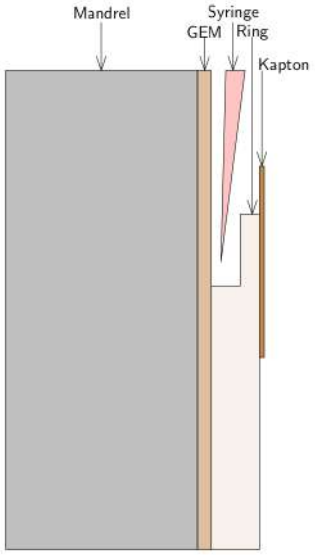

Figure 44: Scheme for the external ring gluing position

3.5 Spacing Grids

Instrumentation

- Setup instrumented
- Arches and battens
- 2011 / 2012 Glue (cartridge and gun)
- Necessary tape and syringe to operate

Figure 45: Eternal ring ready to be closed with the glue

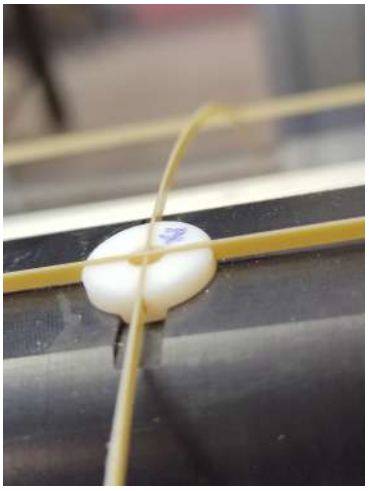

Figure 46: Testing the syringe head to seal the ring

Procedure

Composing the grid

1. Separate the spacing grid from their support carefully not to bend it
2. Measure them and look for major defects
3. Place the arches in position in the each Teflon cylinder
4. Place a batten in the support structure in each Teflon cylinder
5. Check that each cross that there are no spikes
6. Prepare the syringe and place two drops of glue at each cross
7. Wait 20min and check that there are no spikes of glue
8. Move to another line and repeat then 3.4.5.6.7

Place the grid

1. Move the completed grid on top of the detector with 2 people
2. Place it in position with some tape or a patch of vacuum foil
3. Place a drop of glue to fix each batten to the foil carefully not to let the glue fall under the batten

4 Assembly

4.1 Element Extraction

1. The dressed mandrel is in the VIM and the VIM flange that holds the detector is lowered with it (Fig. 47)
2. Secure the mandrel:
   - At the top ring with pins long enough but not to reach through the mandrel (the pins must enter easily). Remove the already present pins by making holes in the vacuum patches and letting them fall inside the mandrel (Fig. 47)
   - At the bottom ring with 4 pushers (Fig. 48)
3. Remove all the pins that are not the ones that olds the element with the VIM's flange
4. Check multiple times
5. Lower the bottom counter-ring of the mandrel with respect to the element
6. Place a camera on one of the pin holes at the bottom to check that the element is moving with respect to the mandrel when requested by the VIM
7. Move the VIM through the interface a few cents of mm each time
8. Continue lifting slowly with one person close to the detector visually checking and listening until the two rings are free
9. Speed a bit the raise of the element, always checking, until the bottom ring reaches the top of the mandrel
10. Lift slowly to check the behavior of the ring while it exits the mandrel
11. Raise it up until the end and check it from the inside
12. Fix the bottom counter-ring on the mandrel and remove it

Figure 47: Elements' holding flange fotodacambiare

Figure 48: Element extraction with a good point of view on the pushers needed to hold the bottom ring

4.2 Element insertion

1. The dressed mandrel is in the VIM and the VIM flange is holding an element on top
2. Remove the upper counter-ring, all the upper pins, and pierce the vacuum patches on the dressed mandrel
3. Remove all the bottom pins on the dressed mandrel
4. Check multiple times
5. Lower the bottom counter-ring of the mandrel with respect to the element
6. Lower the element until its bottom ring is on top of the anodic part of the mandrel in the bottom
7. Measure, through the holes, if the mandrel is centered with respect to the element on top
8. If the bottom element has spacing grids prepare and install mylar patches to help the insertion (Fig. 49)
9. Lower the element through its computer interface very slowly to check that the two rings do not touch along the way
10. At each step, use a Kapton thickness in the gap between the two elements in the full circumference to assure that the gap is respected
11. If the bottom element has spacing grids proceed slowly to lower down the top element and continuously check with a Kapton thickness that the gap is still respected and nothing is stuck
12. When the two bottom rings are entering one into each other, check more frequently the gap with a Kapton thickness (Fig. 50)
13. Eventually, release the 4 pusher from the bottom flanges not to apply unexpected forces on the ring
14. Place a camera on one of the pin holes at the bottom to check that the element is moving with respect to the one on the mandrel when requested by the VIM
15. Continue lowering until the holes of the two elements are aligned
16. The insertion is completed

Figure 49: Mylar patches to help the insertion with the grid

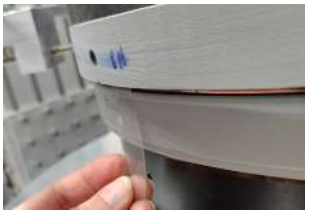

Figure 50: Check during insertion with a thickness the space between the rings

4.3 Elements Gluing

1. The dressed mandrel is in the VIM and the VIM flange holding an element is lowered on it and aligned
2. Apply glue on and between the upper rings with the syringe (Fig. 51)
3. Wait a few moments for the glue to drop into the gap (Fig. 52)
4. Apply once more the glue between the upper rings
5. Wait for the glue rest time
6. Check pins and pushers of the holding flange
7. Extract the elements from the mandrel (see before)
8. Rotate the VIM 180°, carefully looking and listening for unexpected events
9. Place a protective mylar disk on top of the GEM
10. Apply glue on and between the bottom rings (now on top) with the syringe
11. Wait a few moments for the glue to drop into the gap
12. Apply once more the glue between the upper rings
13. Wait for the glue rest time
14. Check pins and pushers of the holding flange
15. Rotate the VIM 180 degrees, carefully looking and listening for unexpected events

Figure 51: Gluing procedure with syringe

Figure 52: Glue between the elements. Wait until it is completely dropped in the gap

4.4 Internal rings

1. The complete detector is in the VIM upside-down and the elements are all glued together
2. Rotate the VIM 180°, carefully looking and listening for unexpected events
3. Choose the thickness to assure a good adherence of the inner ring to the internal surface of the detector, together with the dedicated pins
4. Once everything is in place, apply the glue between the rings
5. Let the glue rest for the necessary time
6. Raise the detector
7. Place a protective Kapton tape layer in the inner circumference
8. Apply the glue to the inner part of the inner ring
9. Let the glue rest for the necessary time
10. Rotate the detector
11. Place a protective Kapton tape layer in the inner circumference
12. Apply the glue to the inner part of the inner ring
13. Let the glue rest for the necessary time

5 Finalization

5.1 Handling

5.2 Pin Holes Gluing

5.3 Connectors

5.4 Additional Layers