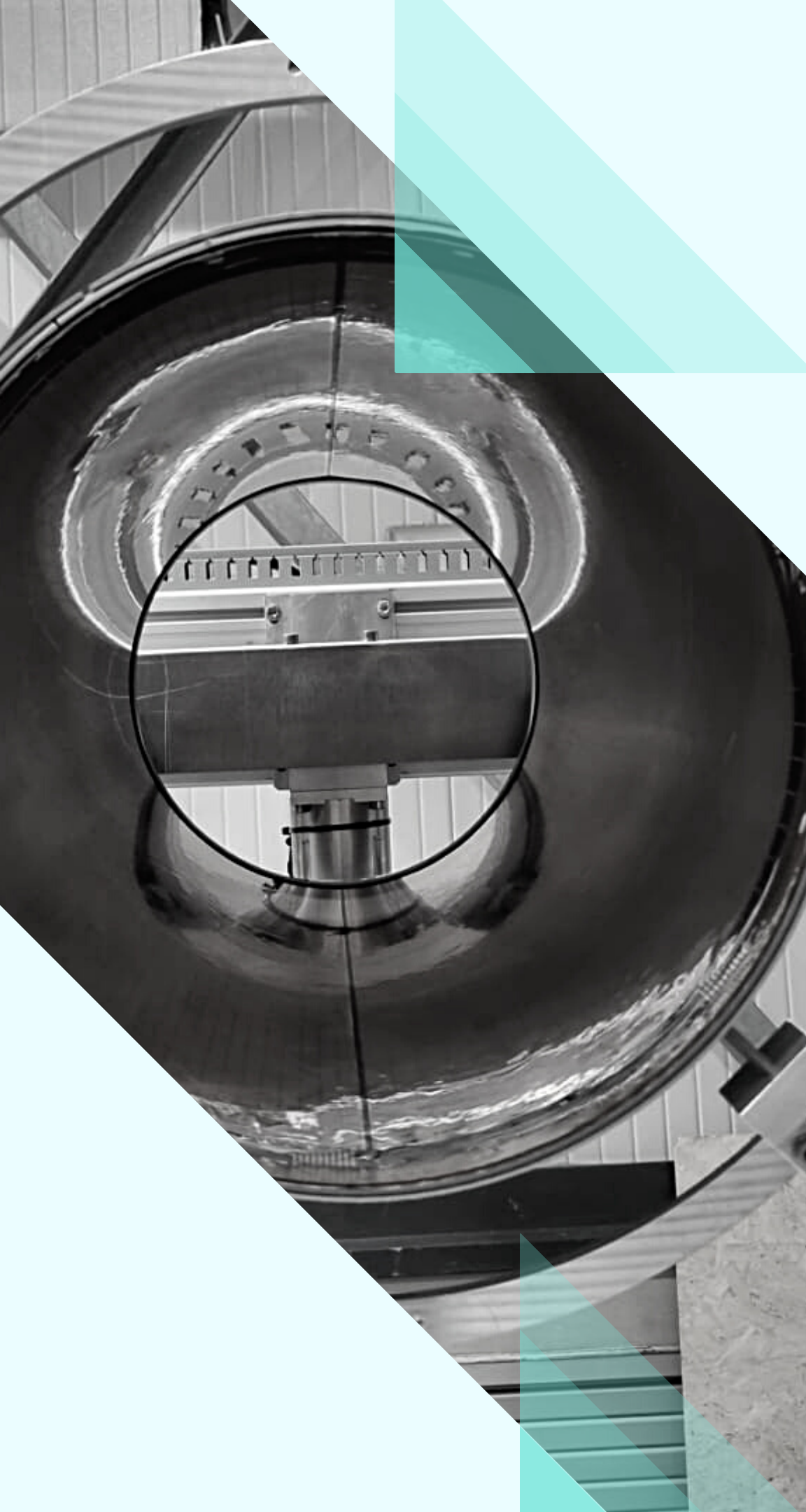


CGEM-IT MECHANICS TEAM

L3 Mockup Construction

Dalla A alla Z



Presentation goals

Retrace the construction steps

Highlight basic steps

Present difficulties encountered

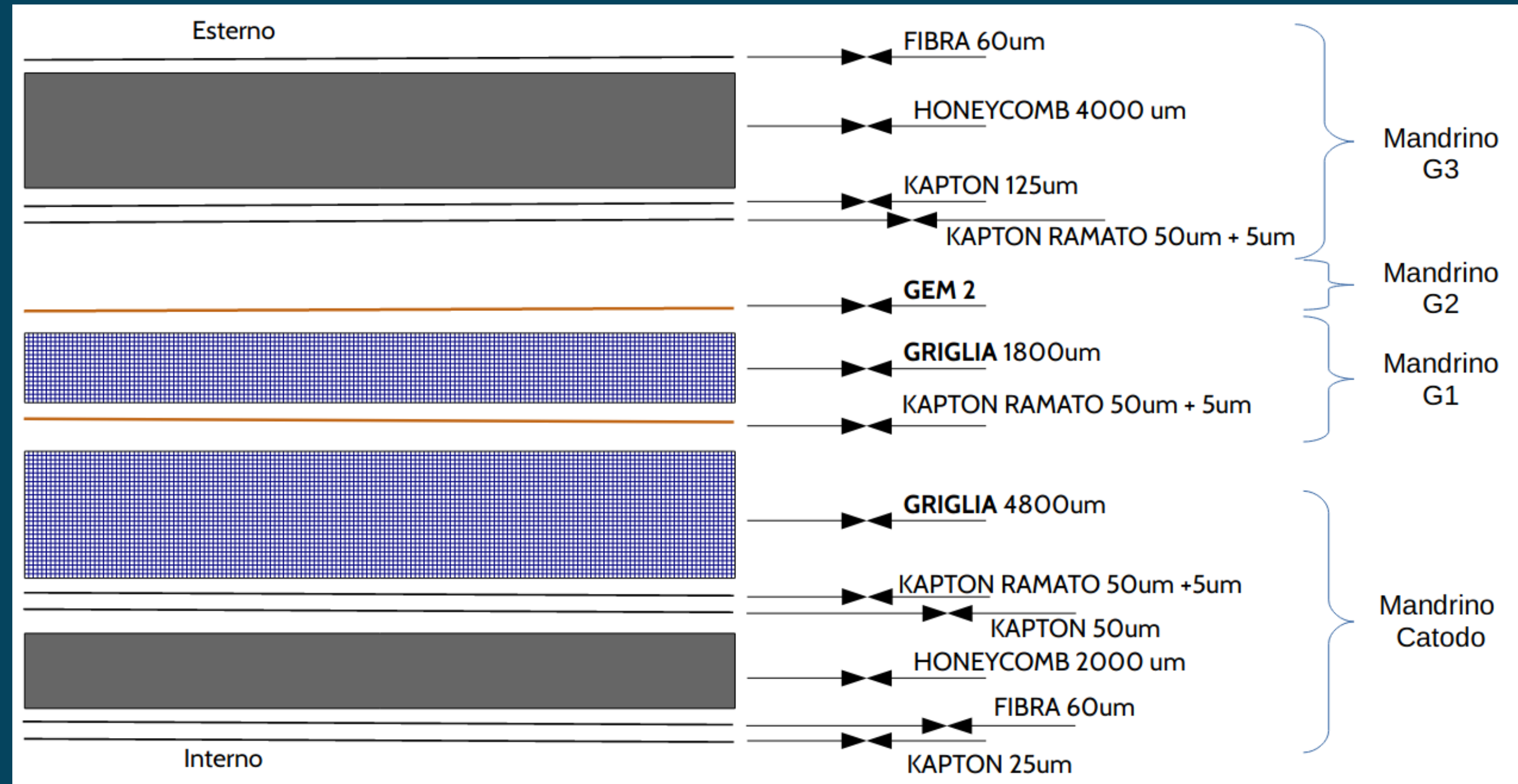
Propose solutions to the difficulties encountered

Create a basis for future work

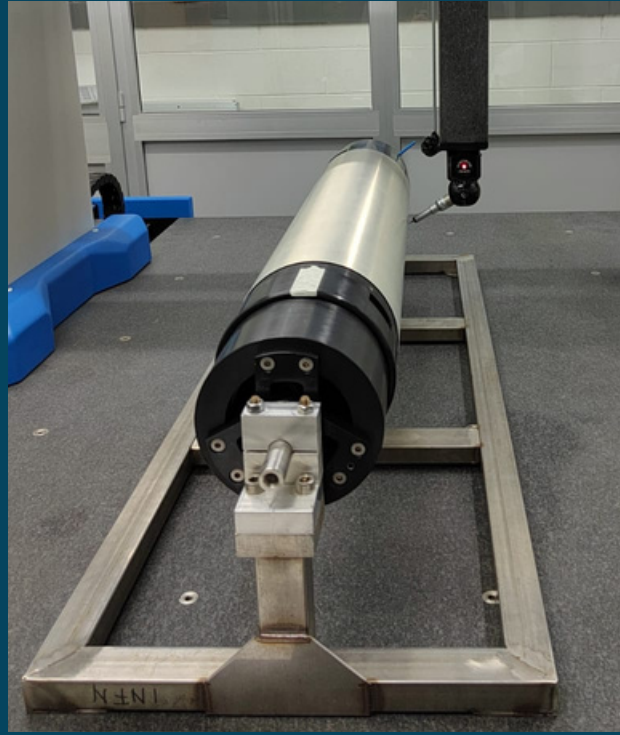
DESIGN

Similar to the final detector to smoothly relate the test results with the final situation
Simpler than the final detector to reduce time and material costs

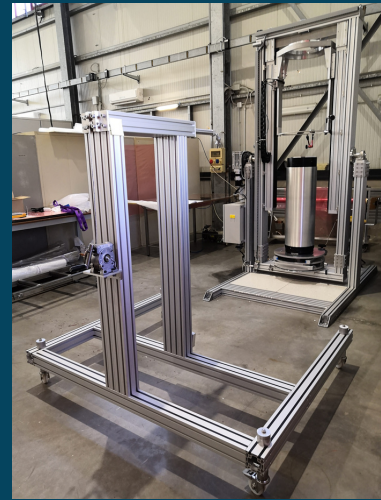
- SAME MECHANICAL SUPPORT
- REAL GEM₂
- REAL SPACING GRIDS
- REAL CATHODE, GEM₁, AND GEM₂ SIZES
- ANODE WITH GEM₃ DIMENSIONS



EQUIPMENT



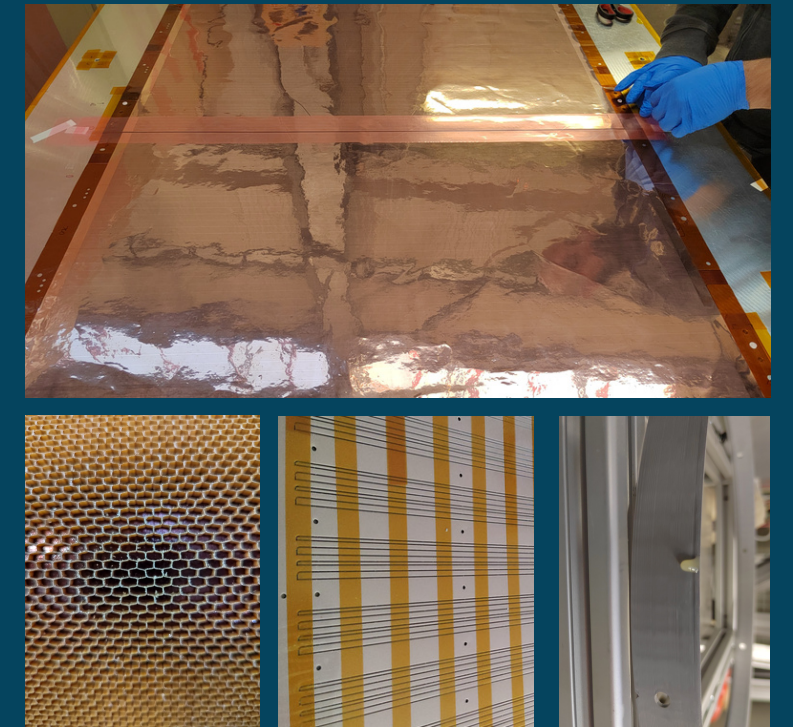
MANDRELS



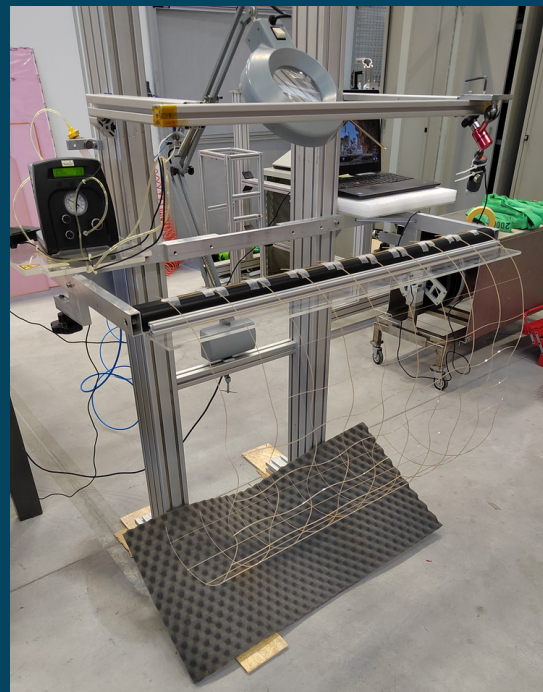
Mandrel's lifting Support



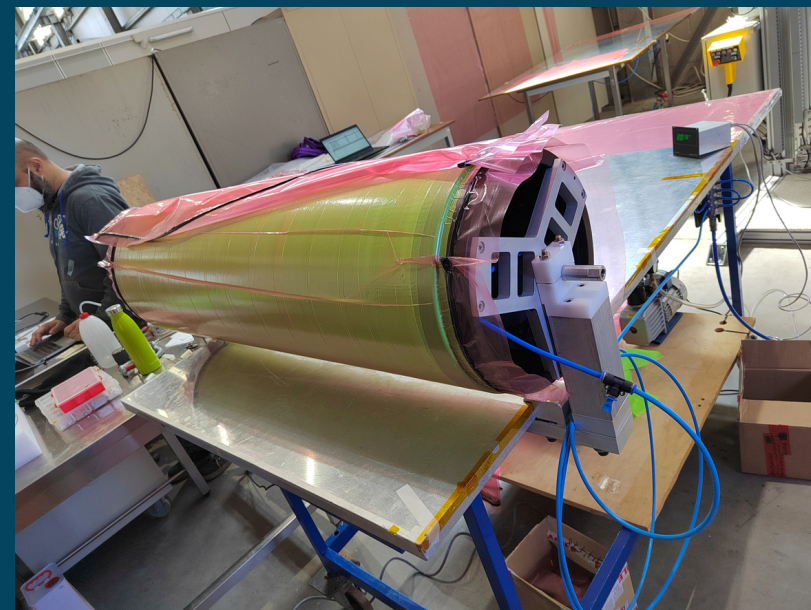
Vertical Insertion Machine



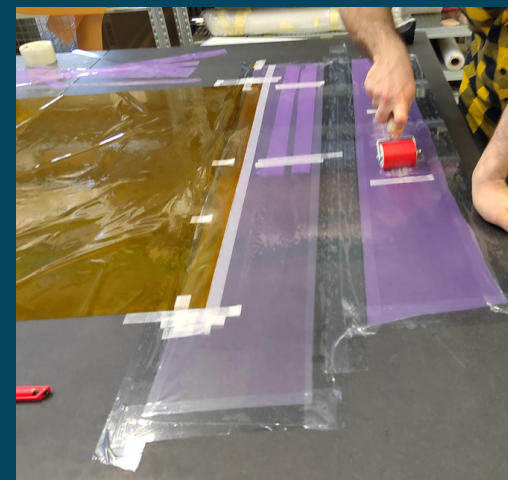
MATERIALS



GRID GLUING MACHINE



Vacuum System



Ancillary setup



TABLES

STEP 1

PREPARATION

MANDRELS

1M

1. Removed from the boxes
2. Visually checked
3. Prepared on their cradle

VACUUM SYSTEM

1V

On each mandrel, the vacuum system has been restored and tested.

RINGS

1R

3D printed @LNF, each ring has been measured on the mandrels and re-printed or modified (mostly polished) as needed

VIM ALIGNMENT

1C



STEP 1C

VIM ALIGNMENT

INSTRUMENTATION

- 2 COMPARATORS ON THE ASSEMBLY FLANGE @120°
- ALL MANDRELS
- 3 POINTS AT THE BASE FOR INCLINATION (1,2,3)
- THICKNESSES
- MOVEMENTS ON THE X-Y OF THE BASE (X,Y)

PROCEDURE USED

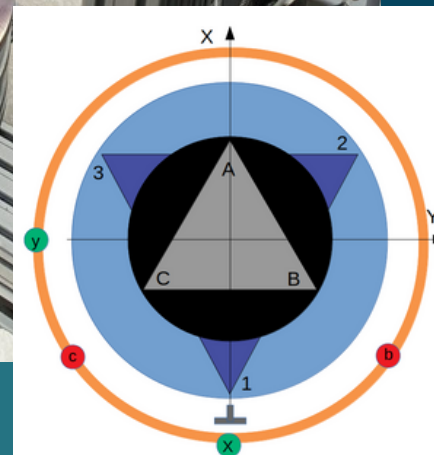
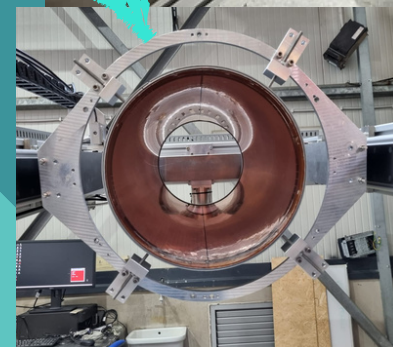
1. Placed the cathode on the VIM
2. Run the comparators up and down along the mandrel
3. Regulate the inclination with 1,2, and 3 until the comparators are stable within 0,1 mm
4. Regulate the x-y movement to center the mandrel wrt the flange
5. Substitute the cathode with each other mandrel and regulate the inclination with thicknesses on the mandrel support

LESSONS LEARNED

- It is a very long and slow process
- The use of comparators installed on the assembly flange introduces a big error in the measurements due to possible not controlled movements of the flange itself
- Any possible deformation on the mandrel could result in a wrong alignment: they must be checked thoroughly
- We decided to use the thicknesses on the others mandrels not to change the inclination of the base every time. Such an operation would have required checking multiple times each mandrel

FUTURE

- New laser alignment is under investigation to overcome the comparators and the use of naked mandrels



STEP 2

CONSTRUCTION

PLANAR GLUING

2P

To assemble 2 foils:

- GEM1
- GEM2
- Anode
- Cathode

CYLINDRICAL GLUING

2C

To prepare the single
element:

- Cathode
- GEM1
- GEM2
- Anode
- Kapton foils with
overlap

MECHANICAL STRUCTURE

2M

To complete the
structure:

- Cathode
- Anode

EXTERNAL RINGS

2R

To finish the elements:

- Cathode
- Anode
- GEM1
- GEM2

SPACING GRIDS

2G

To be assembled on

- Cathode
- GEM1

INSTRUMENTATION

- BIG TABLE WITH REFERENCE HOLES AND VACUUM SYSTEM READY
- 2 FOIL EACH PLANAR GLUING
- 2011 GLUE
- MYLAR, VACUUM BAGS, MASTIC SEALANT, TAPE

PROCEDURE USED

1. Prepare the ancillary supplies in number and measurements as needed
2. Dry test of the foils on the table to check the dimensions and operation movements
3. Fix the foil that will close the overlap in the final position with pins
4. Fix the foil that will be glued in the designated area of the table with tape
5. Measure the overlap sizes to define the glue area
6. Apply all the necessary masks on the foils to contain the glue area
7. Prepare the transfer patch with the glue and the roller (half-length each time)
8. Apply once the glue on the foil with one transfer
9. With a clean patch remove the glue excess in the full length
10. Remove all the masks and tape
11. Move the glued foil in the final position while the other flap of the overlap is kept high
12. Let the second flap fall in position
13. Remove the starting pins and place them one on each side of the same foils that is below in the overlap
14. Place the peel ply sheet well flat
15. Place the vacuum bag well flat
16. Turn on the vacuum pump while checking the flatness of the different foils

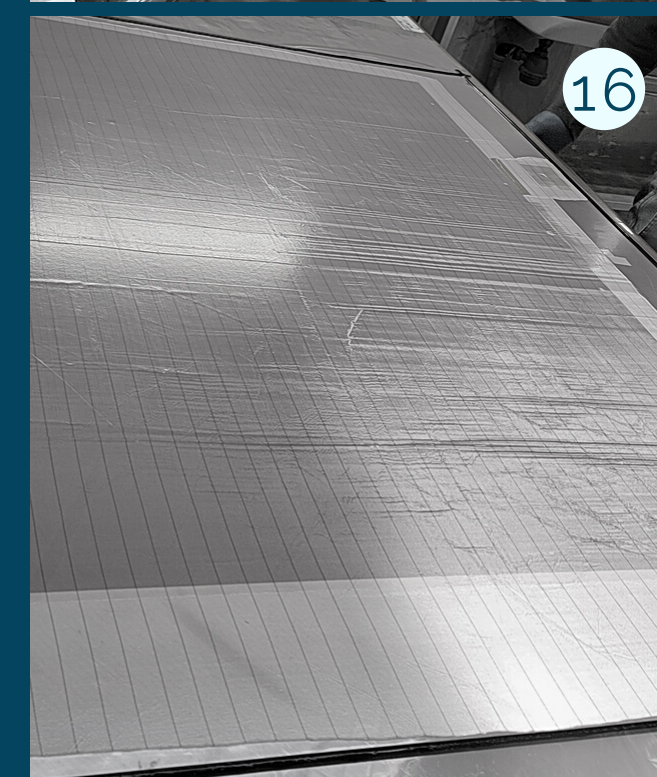
LESSONS LEARNED

- All the ancillary supplies must be prepared in advance
- 4 people are better than 3 to follow the whole operation
- To have a good and strong overlap it is not necessary a big amount of glue
- It could be considered a weight to keep the foil well fixed while transferring the glue
- New and softer roller can help the operations

GEM1
GEM2
CATODIC CIRCUIT
ANODIC CIRCUIT

STEP 2P

PLANAR GLUING



INSTRUMENTATION

- FOIL / JOINT FOILS
- INTERNAL RING

- TABLE WITH MANDREL HOLDING STRUCTURE
- MYLAR, VACUUM BAGS, MASTIC SEALANT, TAPE
- 2011 GLUE

GEM1
GEM2
CATODIC CIRCUIT
ANODIC CIRCUIT

STEP 2C

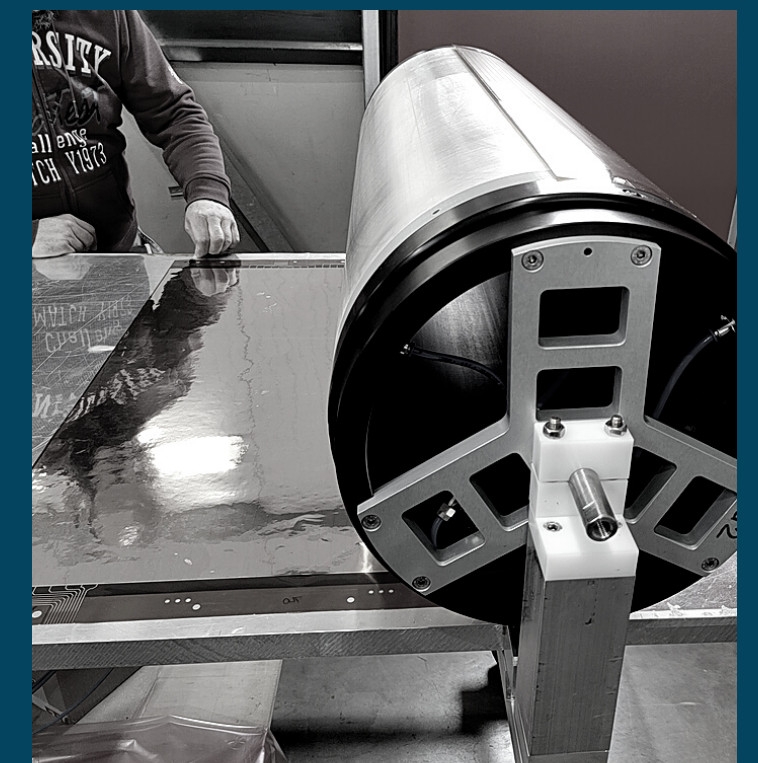
CYLINDRICAL GLUING

PROCEDURE USED FOR THE FOIL AND THE RING

1. Prepare the ancillary supplies in number and measurements as needed
2. Prepare the mandrel with the release agent
3. Dry test of the foils on the table to check the position wrt the pins and operation movements
4. Position the foil on the table to be glued and placed on the mandrel
5. Measure the overlap sizes to define the glue area
6. Apply all the necessary masks on the foils to contain the glue area
7. Place the protective (vacuum foils) under the int-ring place on the mandrel and tape the holes
8. Apply the glue with the roller on the ring
9. With clean patches 10cm long remove the glue excess in the full ring
10. Prepare the transfer patch with the glue and the roller (half-length each time)
11. Apply the glue on the foil with one precise transfer
12. With a clean patch remove the glue excess in the full length
13. Remove all the masks and tape
14. Move the glued foil under the mandrel well aligned
15. Raise the foil from the not-glued side(end of the table) up until the reference pin
16. Continue to glue and align the foil until it is glued for half its length using pins on both sides of the ring
17. Raise the other part of the foils paying attention to the alignment with the help of the pins
18. Check that the foil would fall in place before glue ing the overlap
19. Remove all the pins except the reference ones
20. With a vacuum foil help the placing of the foil in position, stretch it in position and fix it with a tape
21. Wrap everything with the 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

LESSONS LEARNED

- Test the technique to stretch the foils in position is necessary
- The movement must be precise, especially the gluing on the ring



INSTRUMENTATION

- 1 FOIL KAPTON 25UM
- INTERNAL RING
- 2011 GLUE

- 1 FOIL CARBON FIBER
- HONEYCOMB 2MM
- 1 FOIL KAPTON 50UM
- 1 FOIL CU KAPTON 50+5UM

- MYLAR TRANSFER FOILS
- PEEL PLY (ELASTIC AND FABRIC)
- SOFT COVERAGE
- VACUUM FOILS

CATHODE STEP 2M

MECHANICAL STRUCTURE

PROCEDURE

1. Prepare the ancillary supplies in number and measurements as needed
2. Prepare the mandrel with the release agent
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

LESSONS LEARNED

- The dry test for the size check is very important

INSTRUMENTATION

- 1 FOIL KAPTON 25UM
- INTERNAL RING
- 2011 GLUE
- 1 FOIL CARBON FIBER
- HONEYCOMB 2MM
- 1 FOIL KAPTON 50UM
- 1 FOIL CU KAPTON 50+5UM

- MYLAR TRANSFER FOILS
- PEEL PLY (ELASTIC AND FABRIC)
- SOFT COVERAGE
- VACUUM FOILS

ANODE STEP 2M

MECHANICAL STRUCTURE

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

LESSONS LEARNED

- The use of the peel ply is very important must be tested and a choice on which one to use must be made

STEP 2M

EXTERNAL RINGS

INSTRUMENTATION

- EXTERNAL RING
- 2011 / 2012 GLUE

PROCEDURE

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): sands wherever it is necessary
2. Tape the internal surface to cover the pins' holes
3. Apply the glue to the inner surface of the ring with a soft roller
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. Stretch as much as possible the ring around the surface and fix it with Kapton tape on the split
6. Fix the ring in position for the rest with Kapton tape all along the circumference

1. Prepare the external ring split to close it with glue with Kapton tape
2. Use the syringe of glue directly on the wanted part until the ring split is filled; let rest for the necessary time

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. Use the syringe of glue directly on top of the ring between the foil and the Kapton tape along all the circumference; let rest for the necessary time
4. Measure the external circumference and compare it with the designed one

LESSONS LEARNED

- The amount of glue necessary must be tested before starting
- It is an easier operation but still requires time and concentration



STEP 2G

SPACING GRIDS

INSTRUMENTATION

- ARCH AND BATTEN
- 2012 GLUE

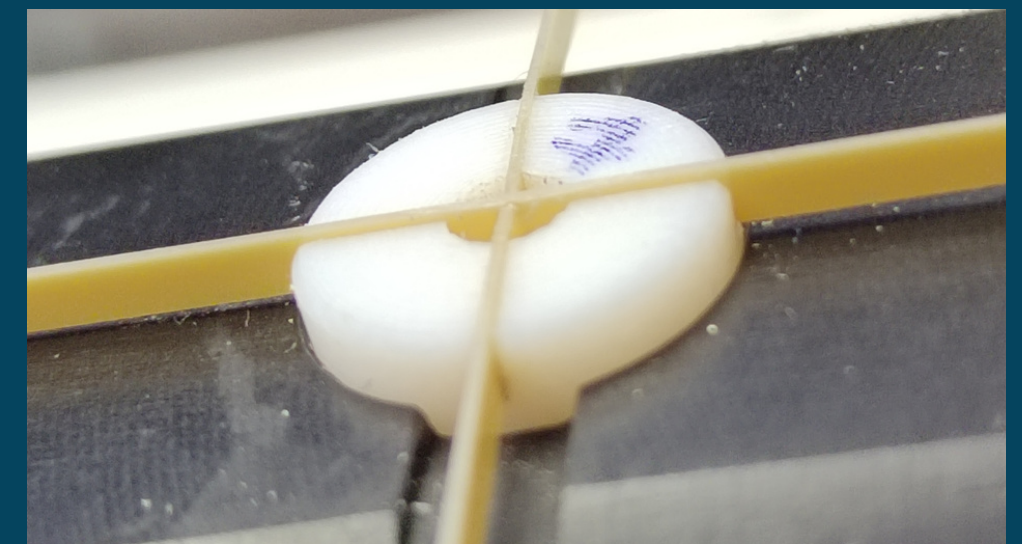
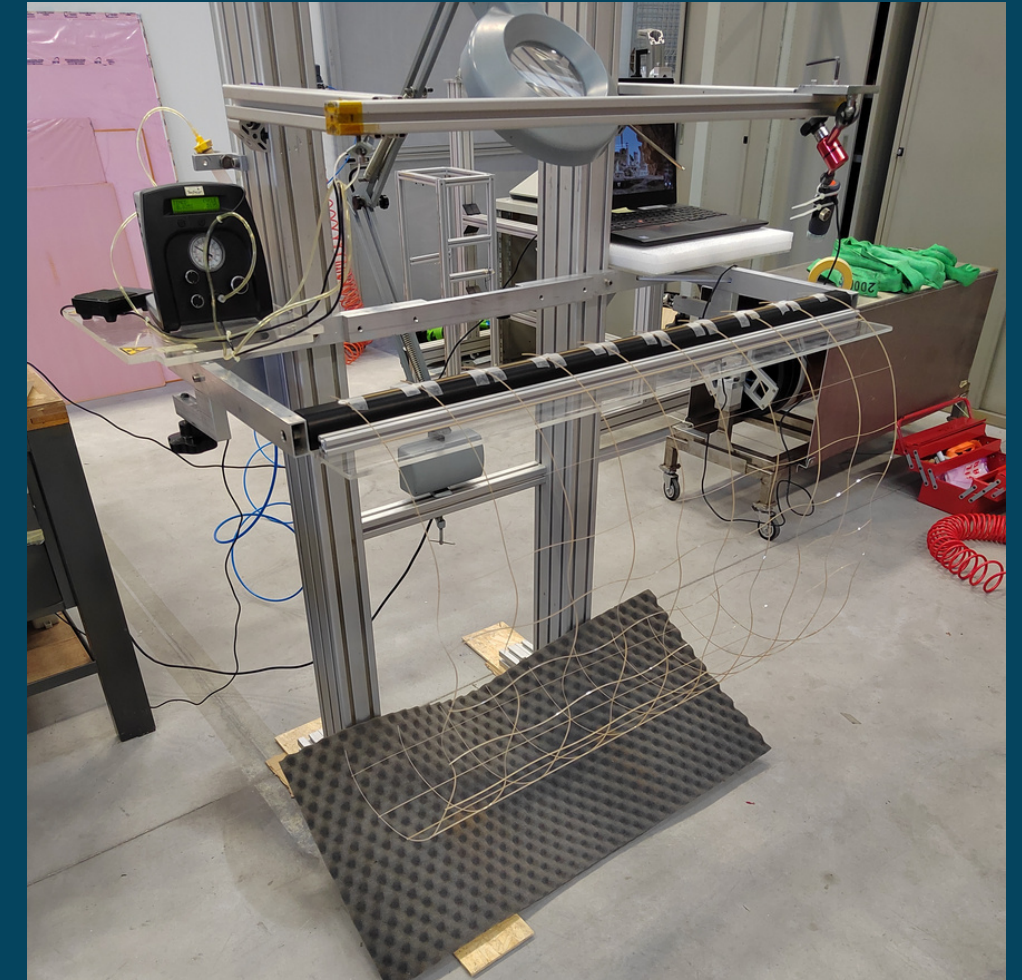
PROCEDURE

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

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

LESSONS LEARNED

- A bit more glue can be used with respect to what we expected
- It must be careful on the crosses not to have spikes that can touch the layer above
- It must be careful while gluing the grid on the foil not to lift it with the glue
- If the glue seems at its end, change the syringe



STEP 3

ASSEMBLY

MANDREL HANDLING

3H

How to:

- place it vertical
- insert it in the VIM

ELEMENT EXTRACTION

3E

How to:

- separate element and mandrel

ELEMENTS INSERTION

3I

How to:

- assembly two elements

ELEMENTS GLUING

3G

How to:

- glue the rings

INTERNAL RING

3R

How to:

- glue the ring

STEP 3M

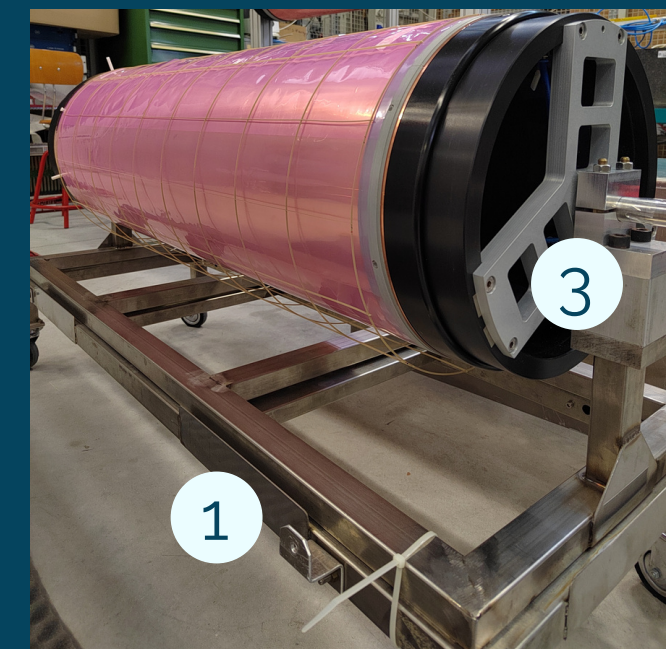
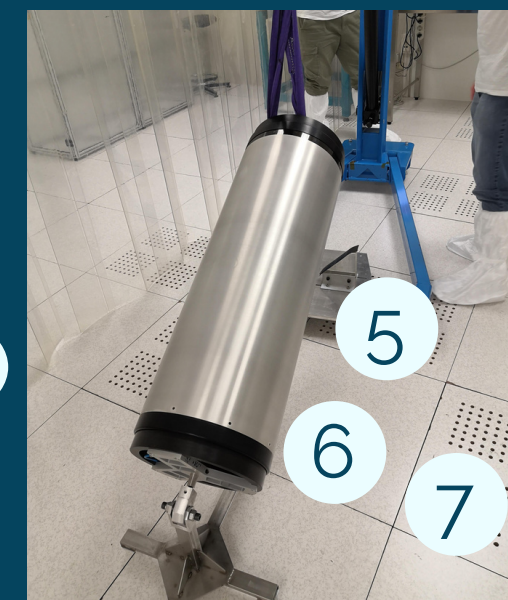
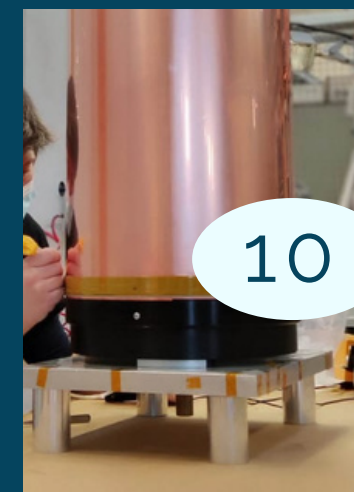
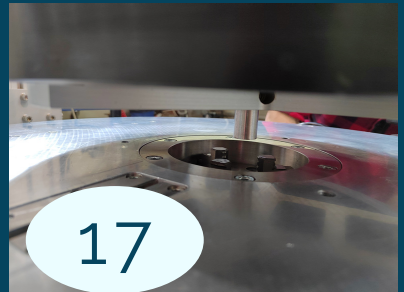
MANDREL HANDLING

BASIC IMPORTANT RULES

- The mandrel must be handled carefully either if it is dressed or naked
- The Teflon area must be treated carefully
- The dressed mandrel can not be touched in the active area
- The mandrel can be hold by the pins at the extremities, by the flanges
- The mandrel can rest on the V structure supporter by the anodized apart but not on the ring-flanges

PROCEDURE - HORIZONTAL TO VERTICAL POSITION AND THEN IN THE VIM

1. The mandrel lies on the cart, secured at both sides
2. Secure the mandrel with 2 strops at the extremities from the flanges if it is dressed, from the middle if it is protected
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
6. Lower the mandrel on the V support checking that it does not hit the ring-flange
7. Place an eye at the center of the flange
8. Change the strop position: place one strop in the eye for one-side lifting
9. Raise carefully the mandrel in the vertical position
10. Remove the cross below
11. Place the mandrel on its base to stay vertical
12. Remove the eye
13. Change the lifter: now it is needed the VIM lifter
14. Lift the mandrel
15. Change the bottom pin from the long one to the short one
16. Place the reference pin in the bottom flange of the mandrel
17. Raise at maximum the detector support in the VIM
18. Move carefully the mandrel inside the VIM until it is center at best
19. Lower slowly the mandrel and center it with the jaw at the base of the VIM
20. Carefully center the mandrel over the pin sites
21. Remove the VIM lifter and carefully take it out of the way
22. Remove the top ring-flange from the mandrel



STEP 3E

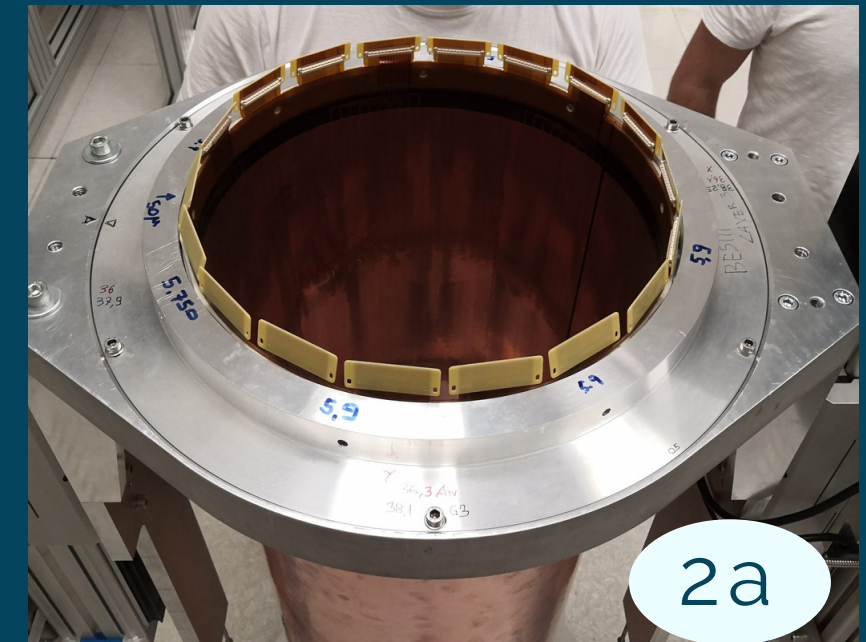
ELEMENT EXTRACTION

BASIC IMPORTANT RULES

- Check the procedure multiple times
- Perform the operation carefully
- If in doubt, stop
- At weird noise, stop

PROCEDURE - HORIZONTAL TO VERTICAL POSITION AND THEN IN THE VIM

1. The dressed mandrel is in the VIM and the VIM flange that holds the detector is lowered with it
2. Secure the mandrel:
 - a. 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
 - b. At the bottom ring with 4 pushers
3. Remove all the pins that are not the ones that hold 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



STEP 31

ELEMENT INSERTION

BASIC IMPORTANT RULES

- Check the procedure multiple times
- Perform the operation carefully
- If in doubt, stop
- At weird noise, stop
- Small movements of the bottom mandrel are admitted to keeping the gap between elements

PROCEDURE - HORIZONTAL TO VERTICAL POSITION AND THEN IN THE VIM

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
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
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



STEP 3G

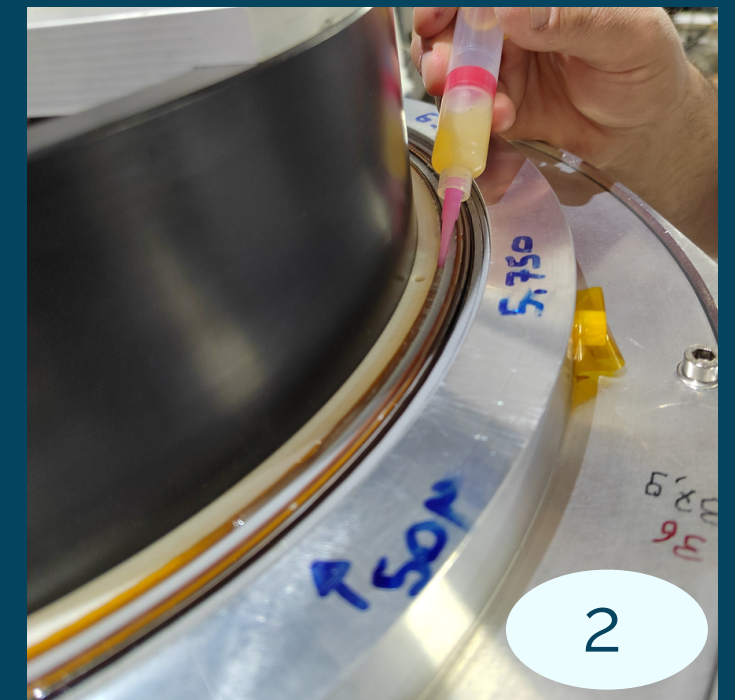
ELEMENT GLUING

BASIC IMPORTANT RULES

- Check the procedure multiple times
- Perform the operation carefully
- If in doubt, stop
- At weird noise, stop
- Small movements of the bottom mandrel are admitted to keeping the gap between elements

PROCEDURE - HORIZONTAL TO VERTICAL POSITION AND THEN IN THE VIM

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
3. Wait a few moments for the glue to drop into the gap
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°, carefully looking and listening for unexpected events



STEP 3R

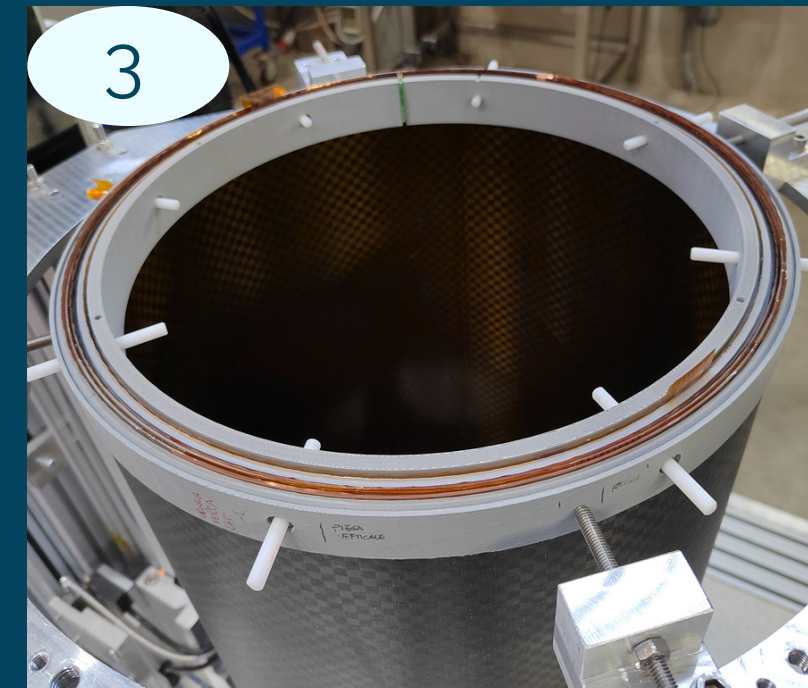
RING GLUING

BASIC IMPORTANT RULES

- Check the procedure multiple times
- Perform the operation carefully
- If in doubt, stop
- At weird noise, stop
- Small movements of the bottom mandrel are admitted to keeping the gap between elements

PROCEDURE - HORIZONTAL TO VERTICAL POSITION AND THEN IN THE VIM

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



STEP 4

FINALIZATION

HANDLING

4H

How to dismount the detector from the VIM

PIN HOLES GLUING

4P

Close the pin holes to complete the structure

CONNECTORS

4C

How to install:

- gas connectors
- anode connectors



ADDITIONAL LAYERS

4L

How to handle and install:

- ground plane
- Faraday cage



Not performed for the mockup

STEP 1

- 1M - Mandrels check
- 1V - Vacuum system preparation
- 1R - Rings preparation and check
- 1C - VIM alignment

STEP 2

- 2P - Planar Gluing
- 2C - Cylindrical Gluing
- 2M - Mechanical Structure
- 2R - External Rings
- 2G - Spacing Grids

STEP 3

- 3H - Mandrel Handling
- 3E - Element Extraction
- 3I - Element Insertion
- 3G - Element Gluing
- 3R - Internal Rings

STEP 4

- 4H - Handling
- 4P - Pin holes gluing
- 4C - Connectors
- 4L - Additional layers



Additional things

A **common logbook** is needed to keep track of the operations or changes in the operations

A **camera** on the laboratory activities helps to trace what has been done in case of a need review