ISTITUTO NAZIONALE DI FISICA NUCLEARE

Laboratori Nazionali di Frascati

INFN-23-15-LNF
26 Aprile 2023

Assembly of the SM1 Micromegas chambers for the muon spectrometer upgrade of the ATLAS experiment at LHC

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Abstract

MicroMegas (MICRO MEsh GAseous Structure) detectors are the new precision tracking detectors installed in the forward muon spectrometer of the ATLAS experiment, composing the New Small Wheel (NSW). The INFN built 32 (+2 spare) MicroMegas chambers for the small sector of the NSW (SM1). The SM1 modules have 2m^2 surface area and they are composed of four gaps, each one made of a catodic plane, a metallic micro–mesh and an anodic plane with the readout strips to reconstruct the precision coordinate and the second coordinate stereo. The assembly procedure of the SM1 modules is presented.

Published by
Laboratori Nazionali di Frascati

1 Introduction

An upgrade programme of the LHC is planned, aimed to reach peak luminosity of 5 - 7 times the initial design values and a final integrated luminosity of about 3000 fb^{-1}. To cope with the increase of the particle rate, the innermost muon station in the end–caps of the ATLAS experiment (called *Small Wheel*) were replaced with the New Small Wheel (NSW)[1], consisting in a completely new detectors technology, the MicroMegas detectors (MM) [2][3], and the small Thin Gas Chamber (sTGC) detectors [4].

MicroMegas chambers is an abbreviation for MICRO MEsh GASeous Structure and it is an innovative design concept for Micro-Pattern Gaseous Detectors first introduced by Charpak and Giomataris during the 1990s [2]. MicroMegas are gas detectors in which a 5 mm gap between two parallel electrodes is filled with a 93 : 7 $Ar : CO_2$ gas mixture and a thin metallic micromesh is placed between the two electrodes, held by pillars with a pitch of few millimetres and a height of about 128 μm (Figure 1). In this way two different region are defined: a *drift region* defined by the drift electrode, with a -300 V voltage applied, and the grounded mesh; and an *amplification region* between the mesh and the anode that is done with resistive strips kept at 570 V. In the drift region the primary ionisation takes place and the low electric field ($\sim$ 600 V/cm) leads the produced electrons towards the mesh. Following the field lines they enter the very thin amplification region, in which the avalanche takes place due to the very high electric field (40 - 50 kV/cm), with a gain of the order of 10^4. Furthermore the thin amplification gap allows a fast ions evacuation, which occurs in about 100 ns, and allows MM to operate in highly irradiated environments. Finally the produced signal is then read by the readout strips capacitively coupled to the resistive ones (pitch of about 400 μm) in order to reduce the performance degradation due to discharges in the detector.

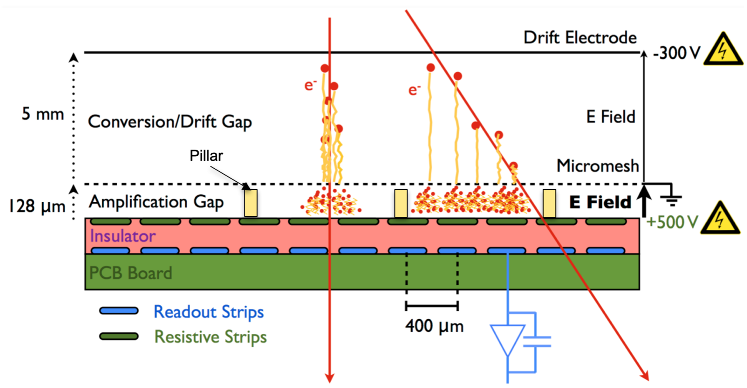


Figure 1: Schematic view of the micromegas detector and the principles of operation.

2 Assembly of SM1 Micromegas Modules

A Micromegas module for the NSW (Figure 2) is made of four gas gap (*Quadruplet*) and it consists of 5 panels: two external Drift panels, one central Drift Panel and two Readout panels, the *Eta* (with vertical strip to measure the η coordinate) and the *Stereo* (with strip tilted at $\pm 1.5°$ to allow also the measurement of the second ϕ coordinate).

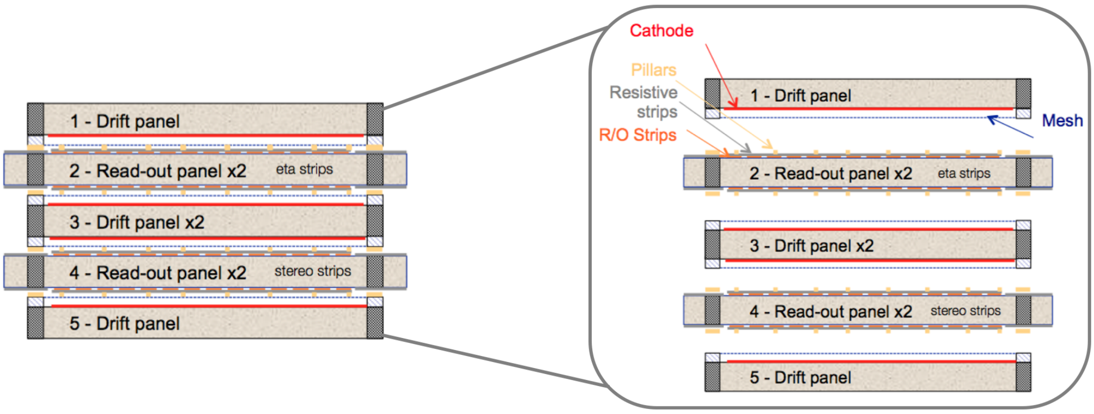


Figure 2: A schematic view of the five panels of a MM quadruplet.

The INFN Italian production for the SM1 chambers is summarised as shown in Figure 3.

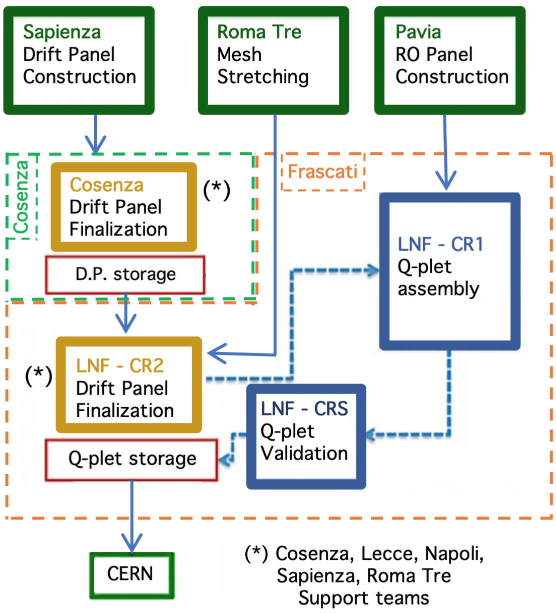


Figure 3: INFN production scheme of SM1.

In this note, an overview of the assembly of a full SM1 quadruplet performed at LNF is presented.

2.1 Assembly procedure

The assembly and the validation of a full MM quadruplet was estimated to take about one week; with experience, it has been reduced to 5 working days. It includes the assembly steps itself, but also the intermediate HV tests performed at each gap closure. A gap is built when the active areas of a Drift panel and of a Readout one are placed face-to-face to each other.

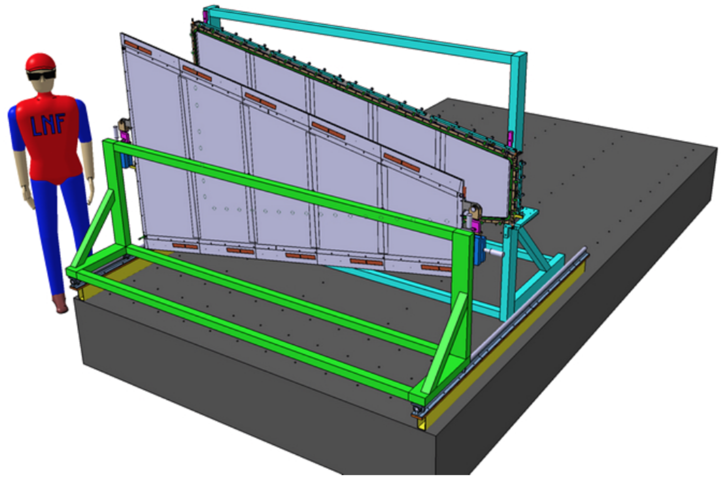


Figure 4: Picture of the assembly tool installed in the Clean Room at LNF.

2.1.1 Layer 4 - External Drift Panel

The assembly starts from the gap which represents the *Layer 4* in the SM1 nomenclature, i.e. the last gap of the detector. The External Drift panel is positioned on the *stiff-frame*, placed on the granite table. The stiff-frame is a mechanical structure used to guarantee the panel planarity during the assembly procedure and was needed to compensate the deformations due to the mesh tension. It is made with selected Al profile glued with Al brackets; its assembly has been performed on a marble table with mechanical tolerances of $\sim 30\ \mu$m. The panel is aligned to the stiff-frame border within 3 mm using adjustment screws. The stiff-frame with the panel is then moved on the assembly tool, mounted on the granite table. It is fixed on that tool using two clamps on the top and with two support brackets with slot on the bottom. The External Drift mounted on the assembly structure is shown in Figure 5. Other two support brackets with inserted screws are mounted on both panel sides, and the screws are tuned in such a way that the weight of the panel and the stiff frame is loaded on a common brass platform on the tool side, where all the other panels will be supported. The o-ring is inserted in the frame slot along the perimeter of the Drift panel, to guarantee the gas tightness of the gap; this action can take place only after a careful cleaning with the vacuum cleaner.

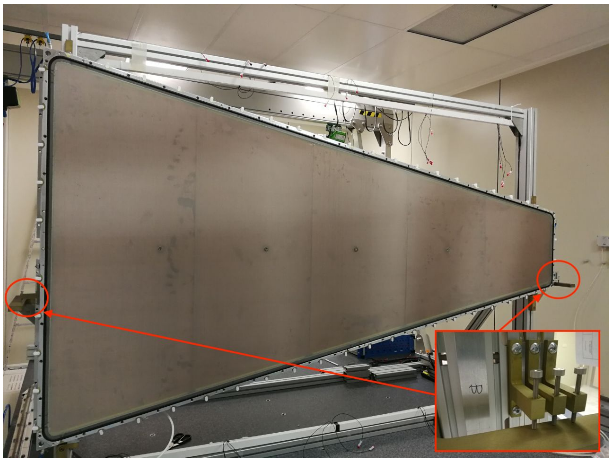
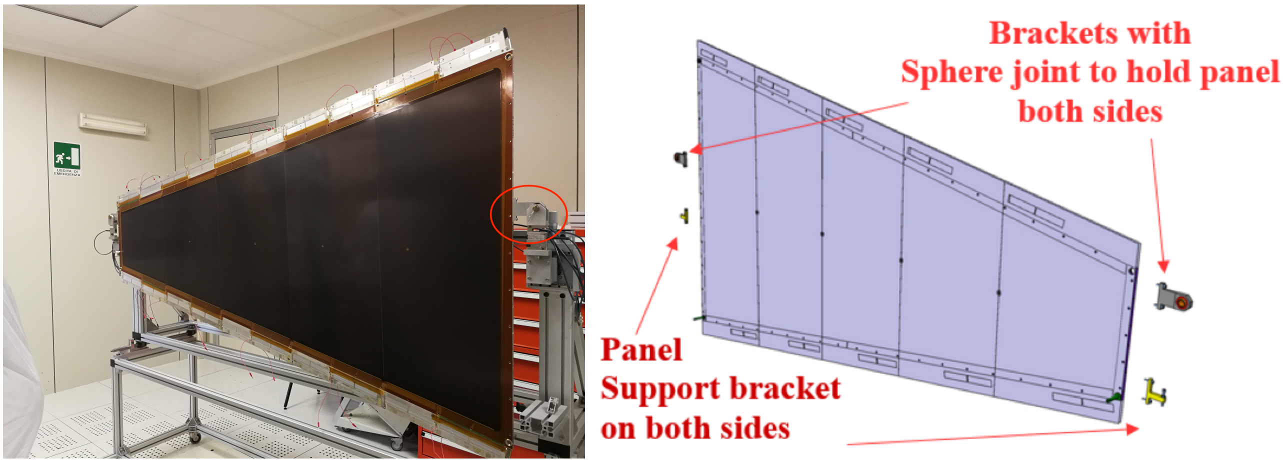


Figure 5: First External Drift in vertical position on the assembly tool.

2.1.2 Layer 4 and 3 - Readout Stereo Panel

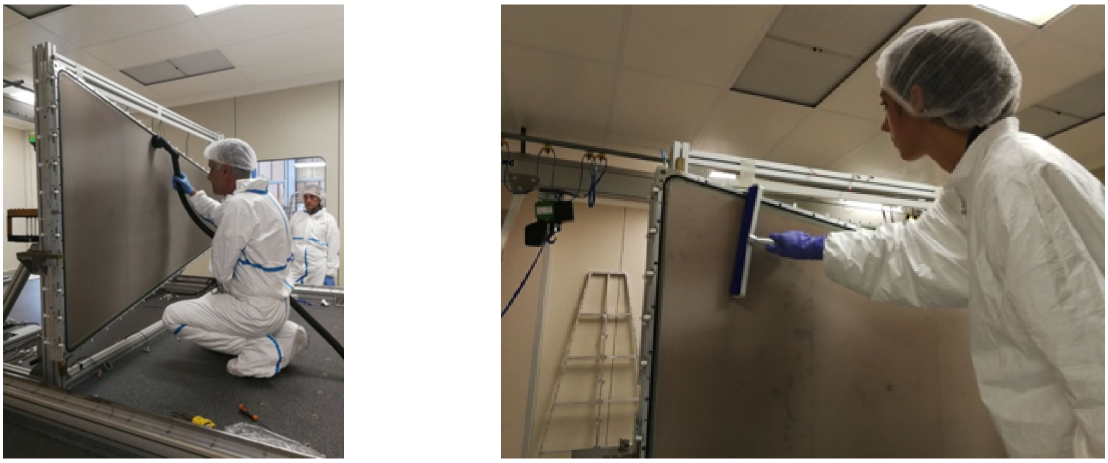
The Layer 4 is a Stereo layer (as also the Layer 3). To close the first gap, the Stereo Readout panel is put in vertical position on the *assembly cart*. This is a movable assembly tool mounted on a trolley. The panel is held on that cart by two brackets equipped with spherical joints on both sides, as shown in Figure 6. The *assembly cart* is made of a trolley equipped with 4 wheels, with two linear guides allowing the upper structure hosting the panel to be assembled to slide towards the chamber in assembly phase on the assembly structure fixed on the marble table. The relative panel position is adjusted via a plate micrometer; this is particularly important to align the 2 Readout panels, but also used to align the holes for the assembly screws on all panels.



(a) (b)

Figure 6: (a) Stereo Readout panel on the movable assembly tool. (b) Support bracket to hold the panel on the tool.

When both the panels are in vertical position, a *dry cleaning* procedure is performed on the panel surfaces, removing the dust with a vacuum cleaner and then with an electrostatic roller, as shown in Figure 7.



(a) (b)

Figure 7: Dry cleaning procedure performed on the panel surfaces (a) with vacuum cleaner and (b) with electrostatic roller.

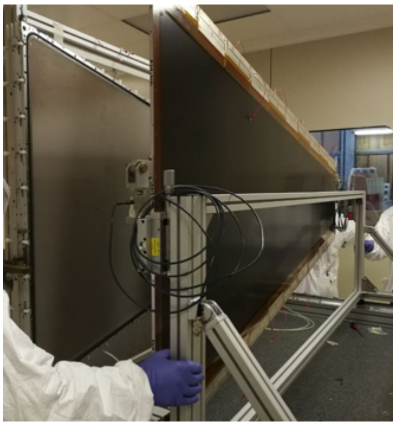
The assembly trolley is brought closer to the granite table and fixed to the linear guides. In this way, the cart with the Readout panel can slide along the linear guides to approach the Drift panel (Figure 8a). To align the Readout and the Drift panels, four *Delrin* pins of 5.5-6.0 mm diameter are inserted in the holes for the gap closure. As for the Drift panel, and for both sides of the Readout panel, two support brackets with inserted screws are installed for not-loading the panel weight on the assembly structure. In this case, the screw is a micrometrical screw, which allows for a finer alignment of the panel.

The capacitors of the HV filters installed on the Readout panel are tested by connecting the HV of each section of the layer (10 sections for the SM1 modules). The two panels are then connected using *expansion rods*, as shown in Figure 8b, on half of the screw holes. The expansion rods are designed to be fixed by turning the screw on one side and locking them with a wheel on the other side. In this way the panels are fixed and the o-ring compression is ensured without leaving metallic dust inside the gap.

When the first gap is closed, the HV test in air is performed by applying 750 V and requiring current values smaller than $\sim$ 10-20 nA. If some sections show instabilities, or do not work properly, the gap is re-opened, checked for defects on the panels and cleaned again. Time by time, depending on the needs, the test has also been performed with $Ar : CO_2$ gas mixture, ensuring the tighness with dedicated caps on the interconnection holes.

2.1.3 Layer 3 and 2 - Central Drift Panel

To close the second gap (*Layer 3*), the Central Drift panel is added at this stage. It is a double-faced panel, then it builds the Layer 3 gap as well as the Layer 2 gap. As for the Stereo Readout, the Drift panel is put on the assembly trolley facing the Layer 3 - side of the Stereo panel. The dry cleaning is performed, the panel is aligned with respect to the Readout panel screw holes using *Delrin* pins and the capacitors are tested. Then the gap



(a) Closure of the first gap.

(b) Expansion Rods

Figure 8: (a) Closure of the first gap approaching the Stereo readout to the drift panel installed on the assembly tool.(b) The Expansion rods used to fix the two panels during the assembly procedure, compressing the o-ring.

is closed, assembling the new Drift panel and the Stereo one using the expansion rods on the second half screw holes. The support brackets are mounted on the sides of the panel. Finally the HV test in air is performed as for the previous gap.

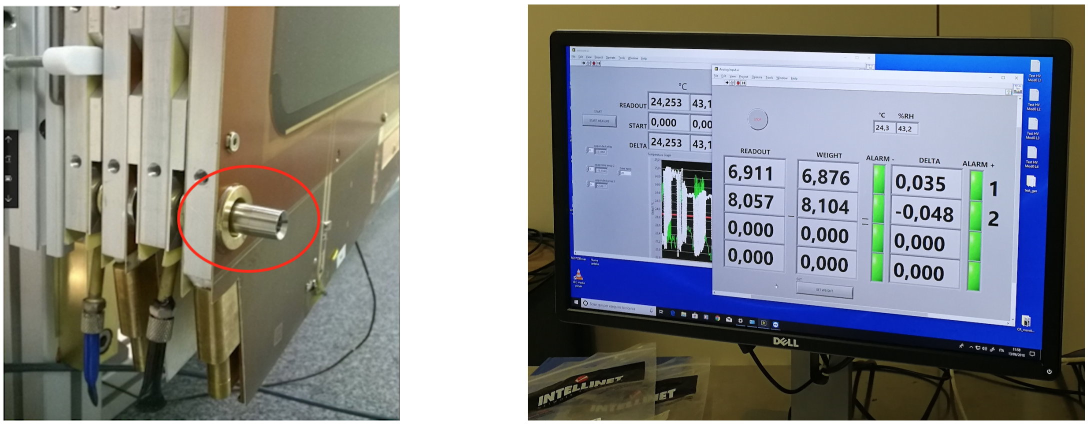
2.1.4 Layer 2 and 1 - Readout Eta Panel

The assembly of the Eta panel closes the third gap (*Layer 2*). As before, the panel is put on the assembly cart and subject to the described cleaning procedure and capacitor test.

In this case the alignment procedure is finer, as at this stage the alignment of the readout strips between the Stereo panel and the Eta one is performed. The Eta panel needs to be aligned with respect to the two *Alignment Pins* (Figure 9) installed at two angles of the Stereo panel, which are put on the bottom side during the assembly of the Stereo panel.

The alignment is performed using two precision pins mounted with dedicated gauge on Readout Stereo Panel and a corresponding hole and a slot mounted with the same accuracy on the Readout Eta Panel. The clearance between the pins and hole/slot is about 20 μm and the insertion of the pin inside the hole/slot is performed with minimal interference through load cells installed on the assembly cart. The fractional change of the load cell measurement during this procedure should not exceed 1% (panel total weight is about 15 kg). The micrometrical screws on the cart, which tune the vertical position of the panel, are turned slowly to minimize the weight loaded on the pins as much as possible, with a tolerance of 100 gr.

Once an acceptable value is achieved on both sides of the panel, the Eta Readout is closed to the Central Drift panel by applying clamps on both linear guides to fix the position of the sliding tool. Then the capacitors are tested and the gap is closed with the expansion rods used to fix the Stereo Readout panel. During this step, it is important that the values of the weight loaded on the pins do not change.



(a) Alignment Pin (installed on the Stereo panel) inserted in the pin slot (installed on the Eta panel).

(b) Monitoring of the weight loaded on the two pins using load cells.

Figure 9: The Eta panel need to be aligned to the Stereo one during the assembly. Load cells are used to measured the weight loaded on the alignment pins, with a tolerance of 100 gr.

2.1.5 Layer 1 - External Drift Panel

Finally, the last External Drift panel is assembled to close the fourth gap (*Layer 1*). Following the same procedure explained before for the assembly of the Central Drift panel, the panel is put on the cart, cleaned, and closed to the Eta Readout panel, performing the alignment with the *Delrin* pin.

Before the module completion and the closure with the final screws, the gap is again closed with the expansion rods used to close the Central Drift panel. Interconnection plugs with o-rings on both side of the module are inserted to minimise the gas leakage. Then a preliminary HV test in Ar:CO_2 is performed, ramping up the HV value up to 550 V. The test is not performed up to the operational HV value of 570 V given that the Relative Humidity (RH) value in the Clean Room is usually quite high ($\sim 40\%$) and the gas tightness of the module is not the optimal one.

If the module passes this preliminary HV test, the expansion rods are substituted with the final screws, closing the gaps with a dynamometric key with a torque of $2.5\ Nm$. The module is then taken out from the assembly tool and put in horizontal position on the granite table to start the QA/QC tests (Figure 10).

3 Impact of the LNF Assembly System

The assembly procedure developed at LNF turned out to be the optimal technique to build these large size chambers among all the other construction sites. The vertical assembly reduce the chance to have dust residuals on the active surfaces, as the use of the expansion rods, and the use of the load cells and the micrometric screws to align the panel provide very good alignment between the readout strips. Up to 38 SM1 modules (32 installed, 2 spares, 2 Full Scale Prototypes, 1 Module for Mechanical Testing, 1 Module for Elec-

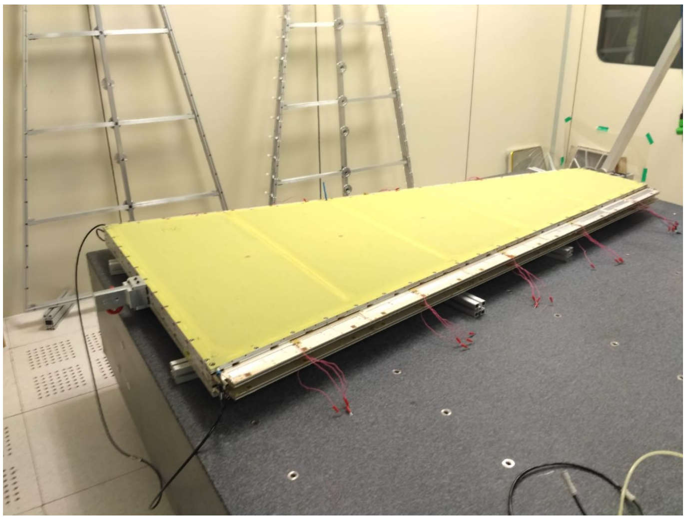


Figure 10: Assembled module on the granite table, ready to start the QA/QC tests.

tronic testing) have been assembled with this technique that has been exported also in the other construction sites and at CERN. Two additional chambers of type LM1 and SM2 have been assembled at Frascati site too.

During the production phase of the modules for the NSW, the Saclay site, responsible for the production of the LM1 type chambers, had serious delay with the schedule. For this reason, a copy of the LNF assembly system has been realised in one month by our team to speed up the LM1 production rate: 4 additional LM1 chambers have been built with this system at Saclay. The replicated setup is showed in Figure 11.

Figure 11: Copy of the LNF assembly system at Saclay production site.

Further use of the assembly system was at CERN where an *Hospital Facility* was set up to repair and re-assemble the modules that arrived at CERN for the integration and did not pass the requirements as well as to inspect modules undergoing irradiation tests. The system installed in the Clean Room located in Building 185 at CERN was able to deal with all type of chambers: SM1, SM2, LM1 and LM2 (Figure 13). Also the cleaning and drying system of the single panels were installed in the same place, as well as the system to perform the metrology measurements. A total of 8 chambers have been re-assembled, out of which two from the irradiation tests. Figure 12 shows the re-assembly schedule. The setup is still in place to further analyse chambers currently undergoing the irradiation tests.

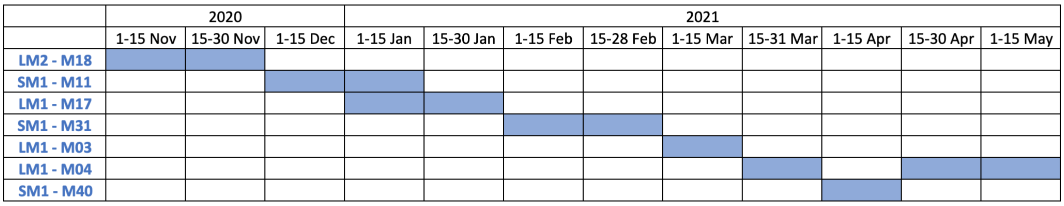


Figure 12: Schedule for the re-assembly at CERN Hospital Facility.

Figure 13: Assembly system at CERN Hospital Facility.

4 Conclusions

The MicroMegas chambers are the new precision tracking detectors, installed in the New Small Wheel of ATLAS. These detectors show very good performance in highly irradiated environment. Up to 50 modules have been assembled with this system, of all the four NSW Micromegas types: SM1, SM2, LM1 and LM2. The system is still in place at CERN to complete the irradiation test studies.

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