Large size multi-gap resistive Micromegas for the ATLAS New Small Wheel at CERN

Dimitris Fassouliotis
on behalf of ATLAS MUON Collaboration

National and Kapodistrian
UNIVERSITY OF ATHENS

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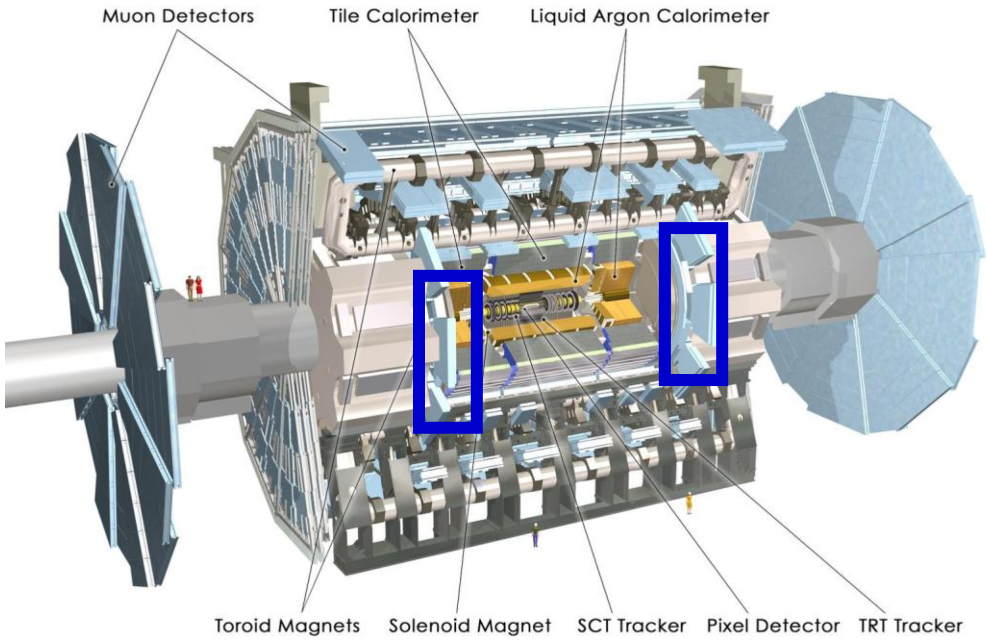
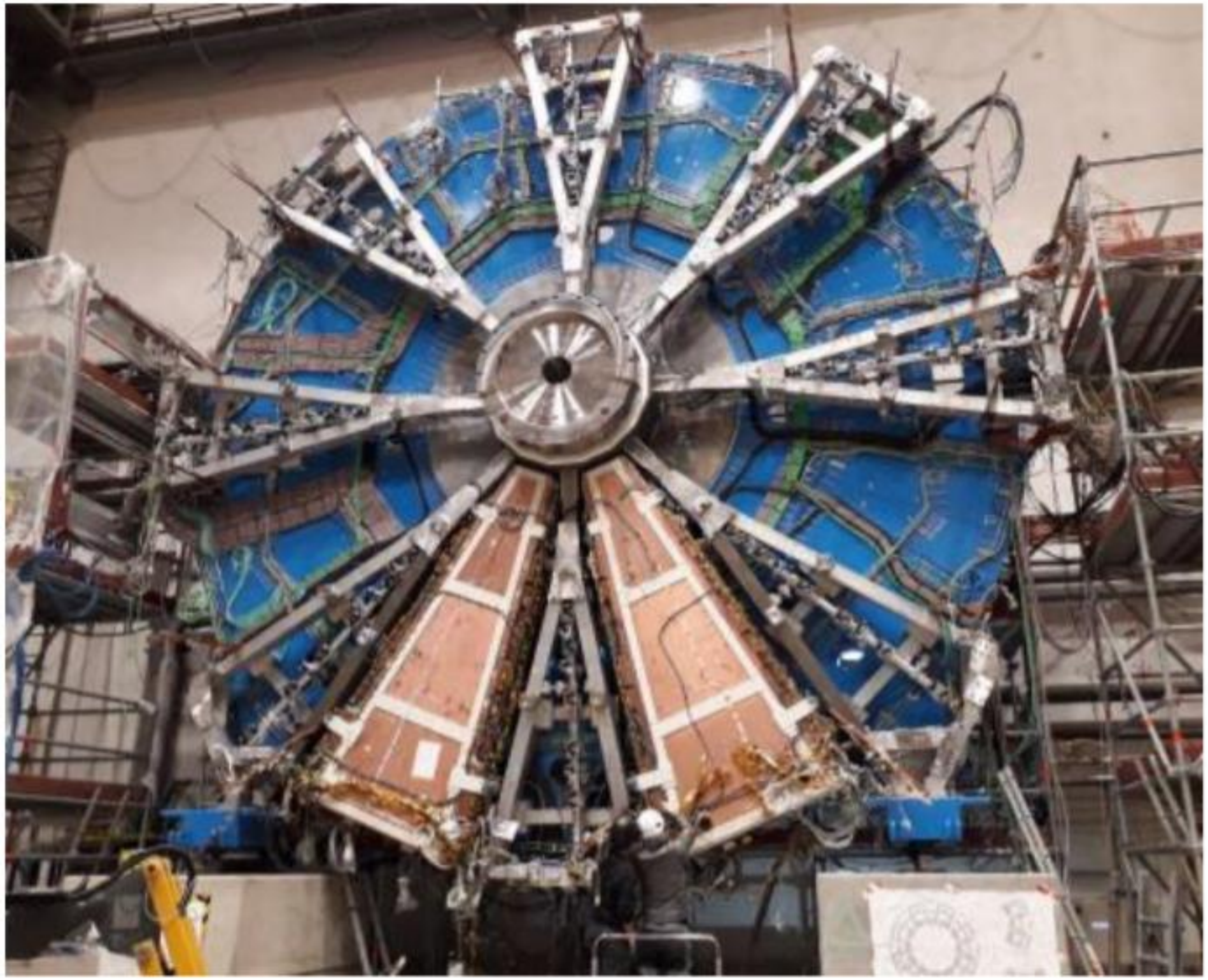
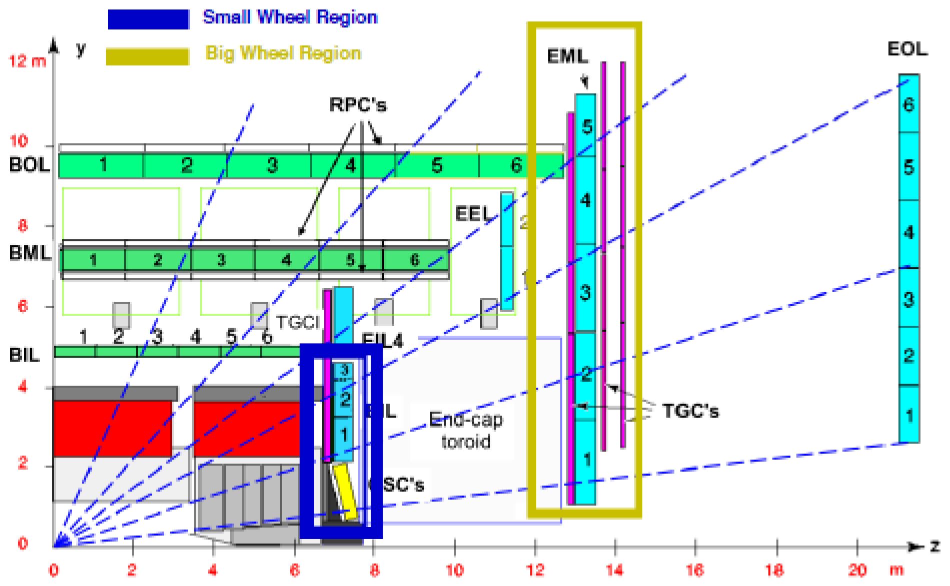
Content

- Introduction
- Chamber construction and quality control on production sites
- Installation
- Quality assurance and commissioning





Introduction: The New Small Wheel



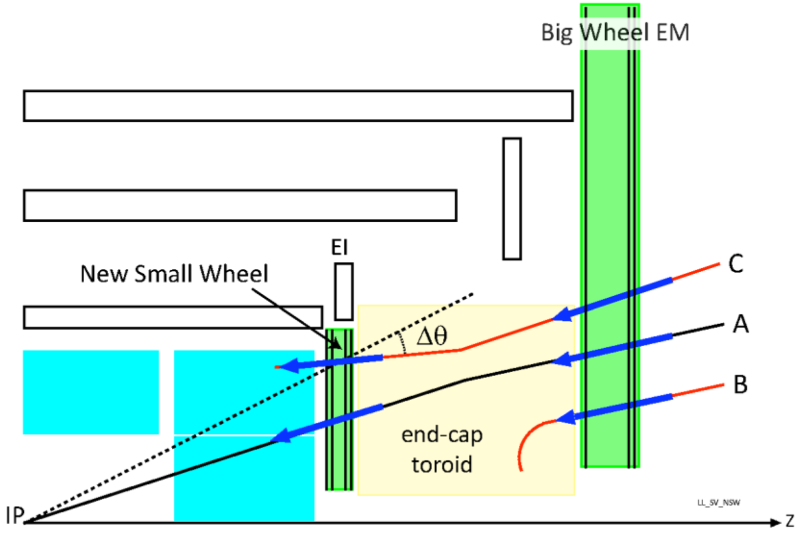
Current Small Wheel → CSC and MDT (tracking), TGC (trigger)

NSW →

Micromesh Gaseous Structure (Micromegas) primarily tracking

Small strip Thin Gap Chambers (sTGC) primarily trigger

- Main ATLAS upgrade during the Long Shutdown 2 (Phase-I)
- Designed to operate also at HL-LHC
- Angular coverage: 1.3<|η|<2.7
- 10 meter diameter - Located at *z* 7m from IP

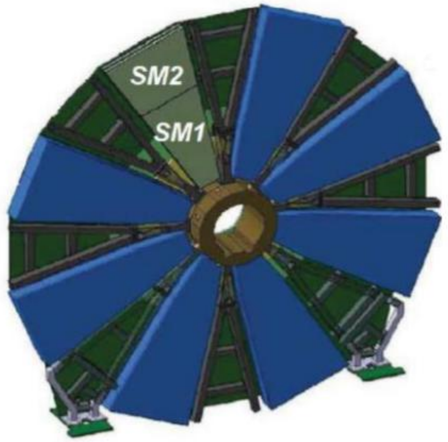


NSW Motivation

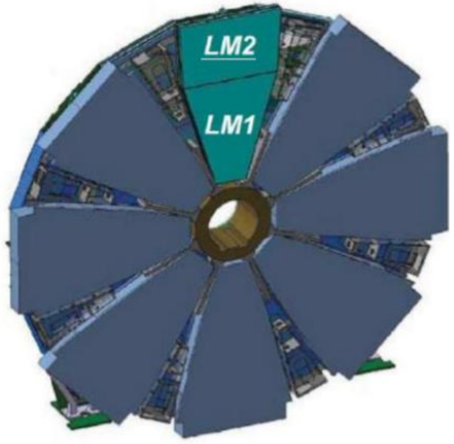
- Reduce substantially single muon trigger fake rate
- Maintain excellent efficiency and resolution of tracking at very high rates
- 16 active layers → redundancy for tracking and pattern recognition

Introduction: NSW layout

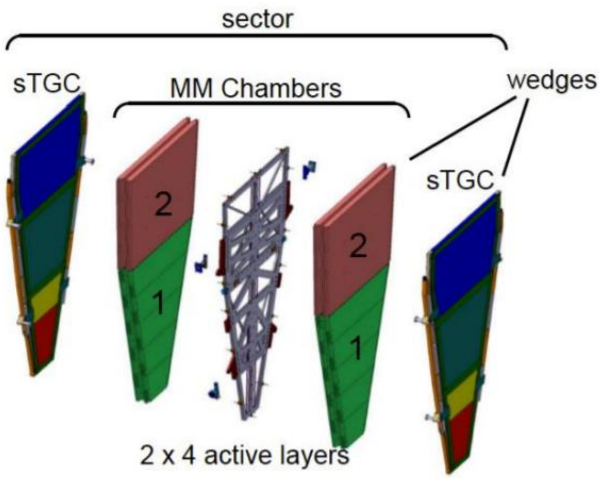
- NSWs preserve the geometry and segmentation of present SWs
- 8 Large and 8 Small sectors with Micromegas and sTGC on each side
- Installed on mechanical support which combines the NJD steel disk (shielding, flux return) and aluminum structure (spokes) bolted on it
- Spokes support the detectors and hold the alignment bars
- Each sector consists of 2 sTGC and 2 Micromegas wedges
- The two Micromegas wedges are placed on an aluminum support (spacer frame) to make a double wedge

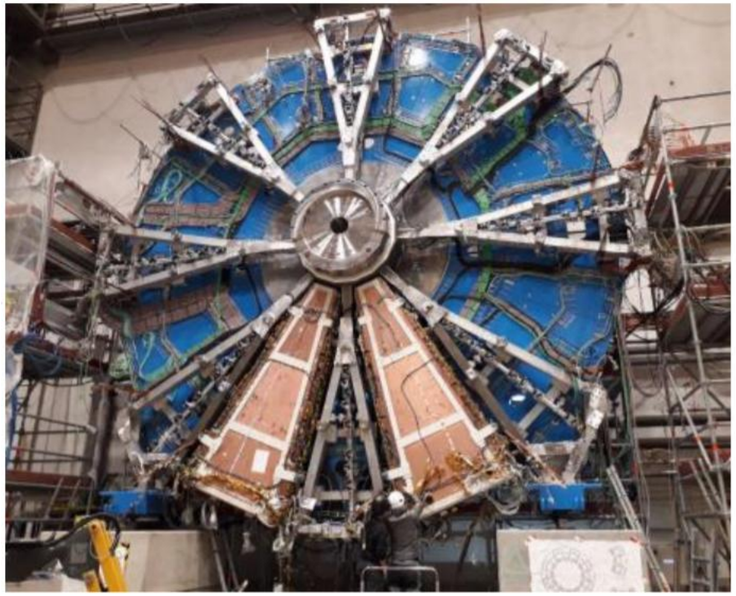


Small sectors

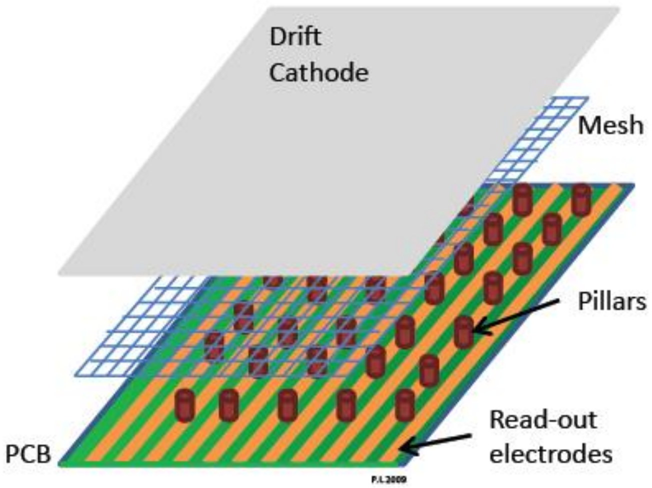


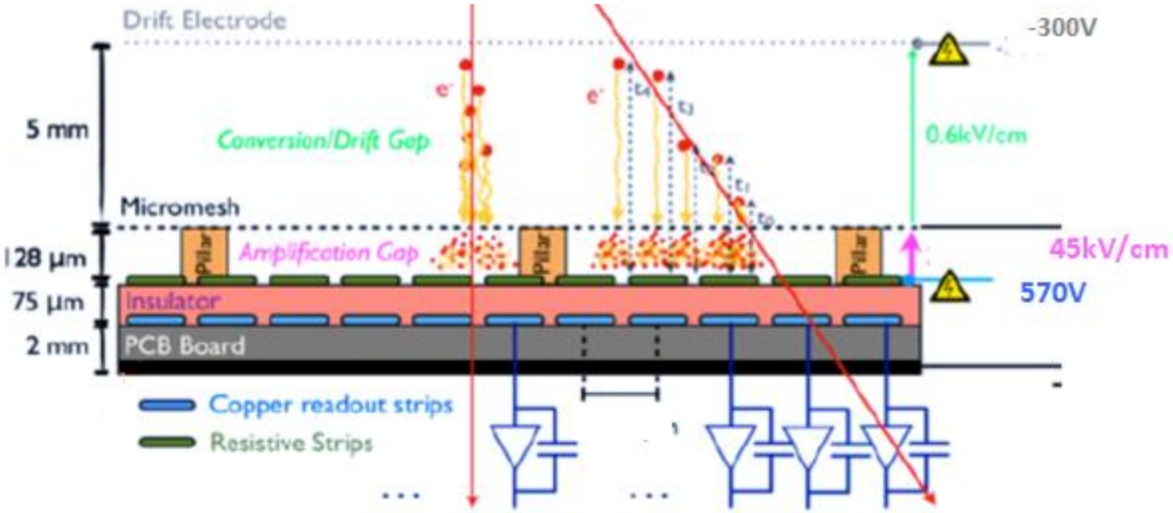
Large sectors

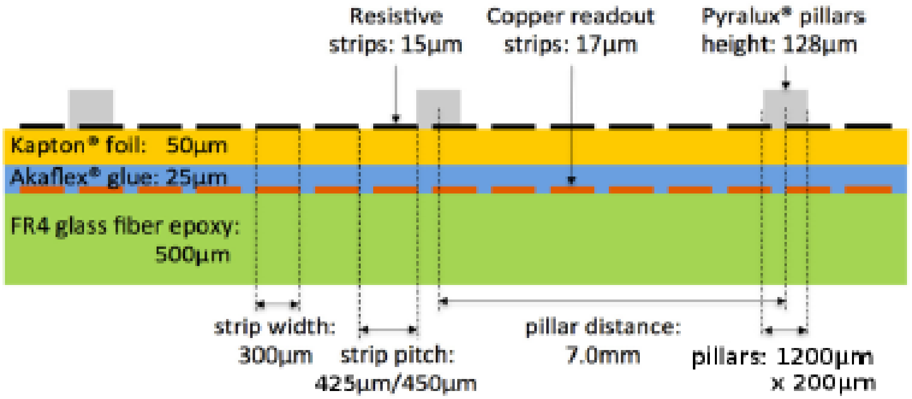




Introduction: Micromegas Operational principle





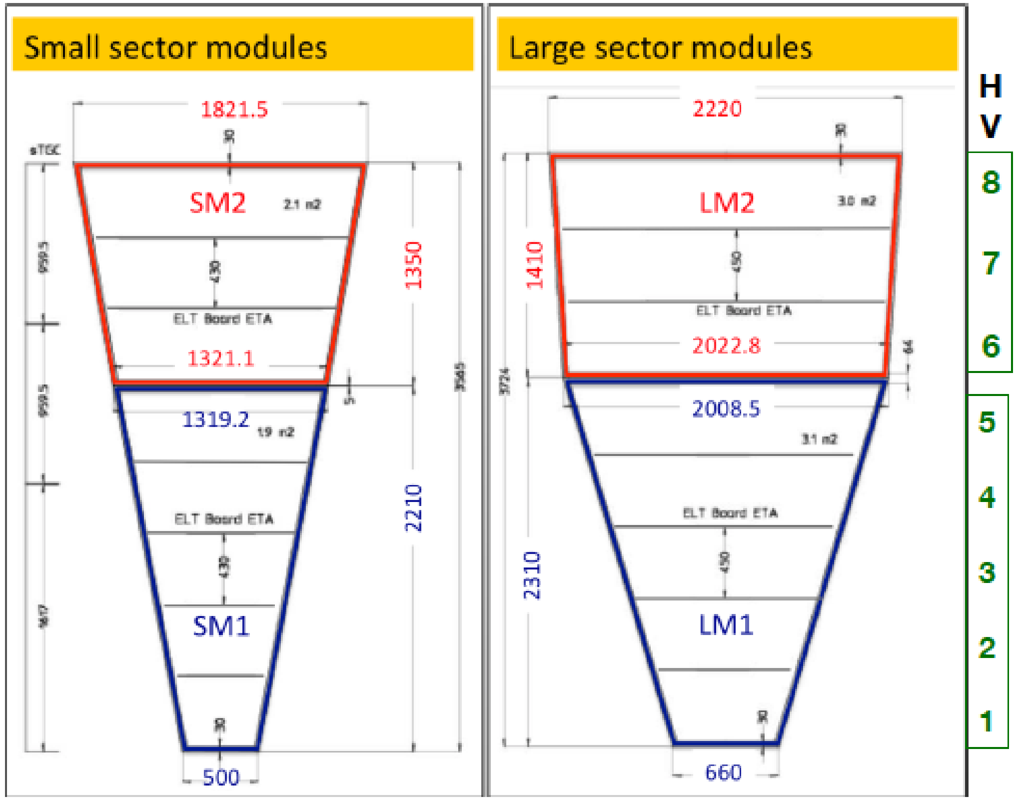


ATLAS Micromegas characteristics

- **NSW Micromegas** are **resistive for spark protection**. Cu strips are covered by a Kapton layer with resistive screen pattern (graphite) printed on it. HV is applied on the resistive layer.
- The mesh is integrated in the drift panel structure and not coupled with the pillars
- Strip width 300 µm (pitch 425-450 µm)
- The mesh is at ground potential
- Drift gap (5 mm), HV_{drift}= -300V , E_C = 600 V/cm
- Amplification gap (128 µm), **HV_{RO} = 570 V**, E_A = 45 kV/cm
- Baseline gas mixture: 93% Ar - 7% CO_2

Chamber production: Layout

- Each Micromegas Double Wedge is composed by 2 wedges with 4 layers each
- 4 η layers for measuring the η coordinate
- 4 stereo layers with inclined strips (+/-1.5°) to provide 2nd coordinate
- Each wedge has 2 modules (quadruplets) 1 & 2



2210 mm + 1350 mm = 3560 mm

2310 mm + 1410 mm = 3720 mm

Construction of the Micromegas modules

Large Module 1 (LM1):
France
CEA, Saclay

Large Module 2 (LM2):
Greece, Russia
Thessaloniki,
Dubna, CERN

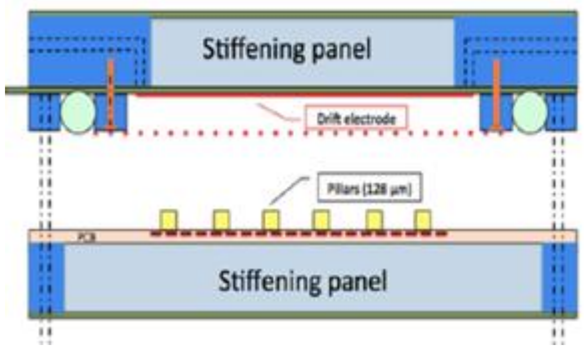
Small Module 1 (SM1):
Italy/INFN
Pavia, Rome1, Rome3,
Frascati, Lecce, Cosenza,
Napoli.

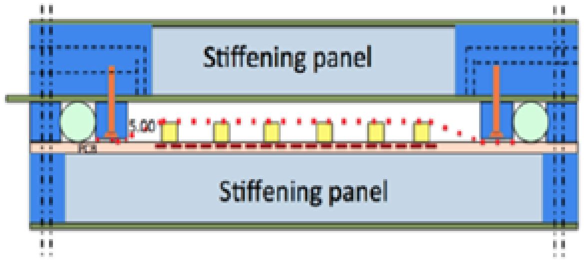
Small Module 2 (SM2):
Germany
Munich, Freiburg, Würzburg,
Mainz.

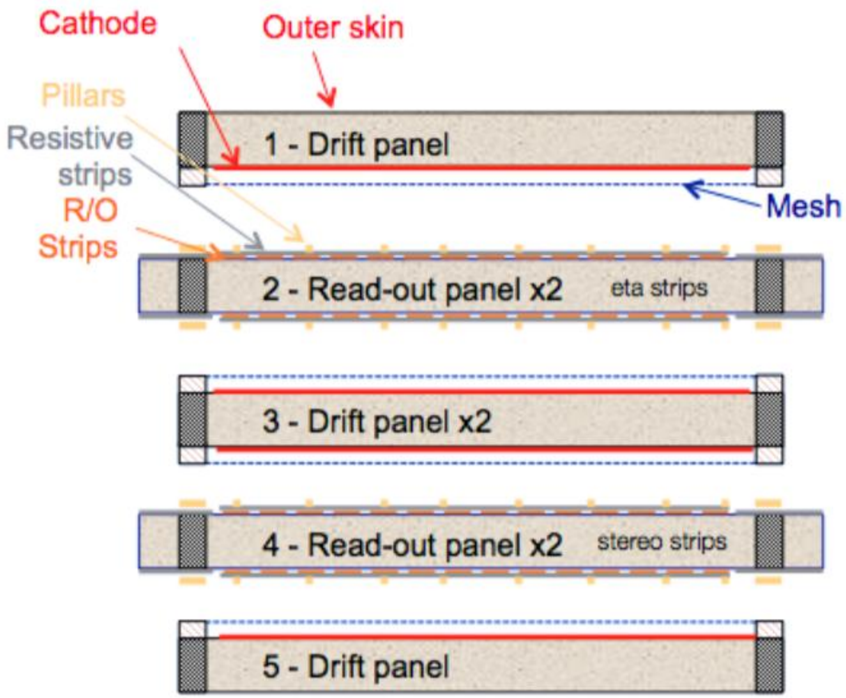
- 128 modules of 4 different types
- Surface /module /layer 2-3 m^2
- Total area larger than 1200 m^2 → **The largest Micromegas project**

Chamber production: Construction

Cathode (*drift*) and anode (*read-out*) planes built on sides of five panels stiffened through the use of honeycomb structures

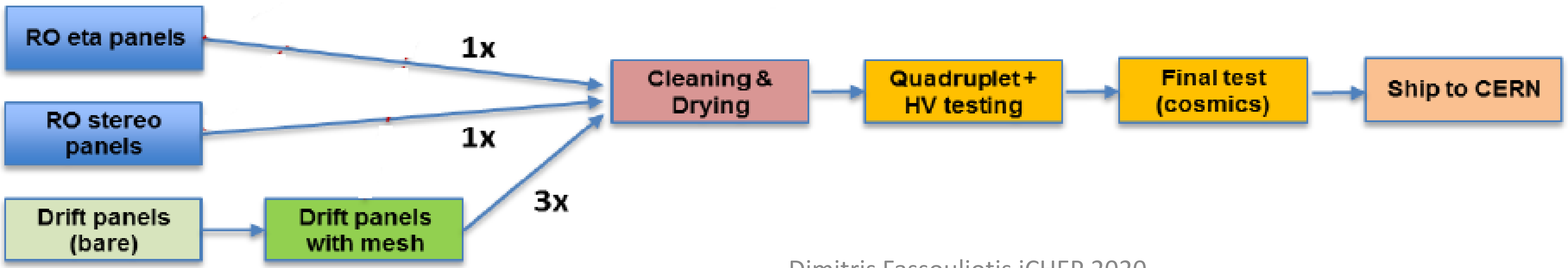






Start to finish for building a module (quadruplet) 10-12 weeks

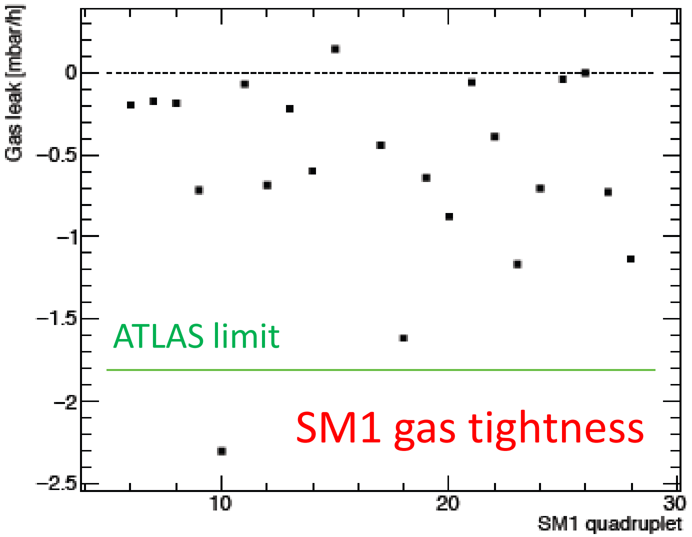
Work flow



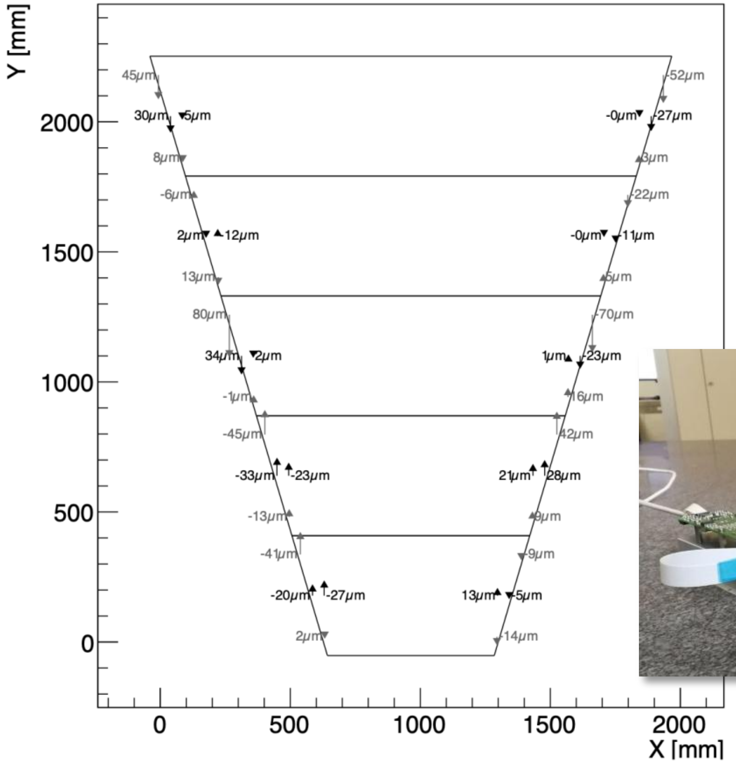
Chamber production: Quality control

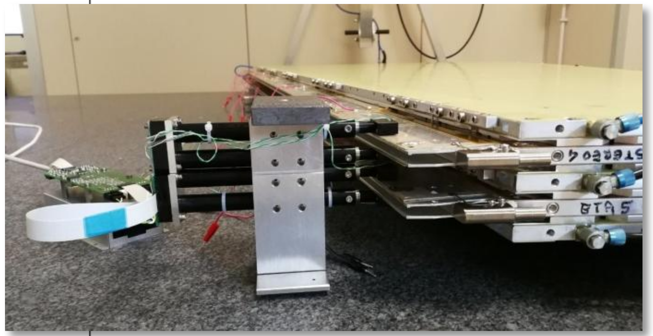
QA/QC per panel and / or quadruplet

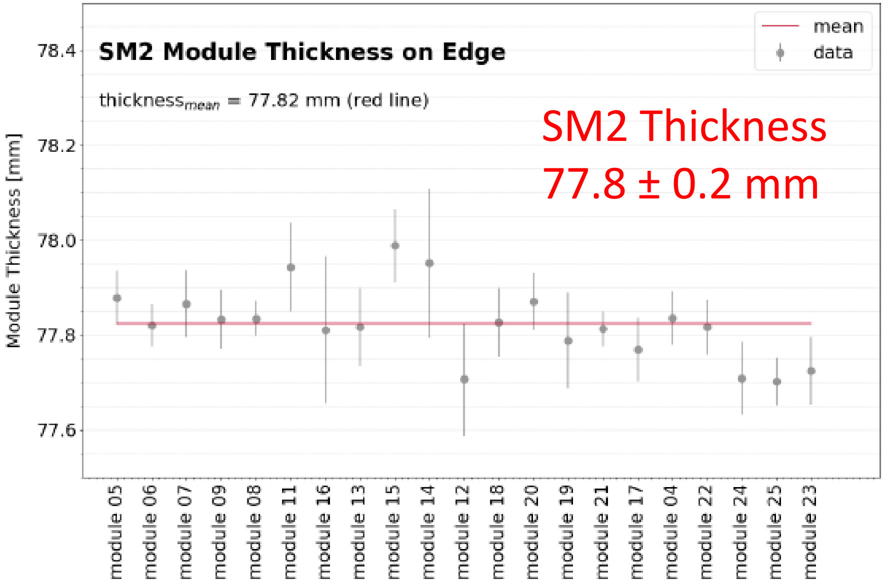
- Thickness
- Planarity
- Gas tightness
- Alignment
- HV stability
- Efficiency
- Gain homogeneity

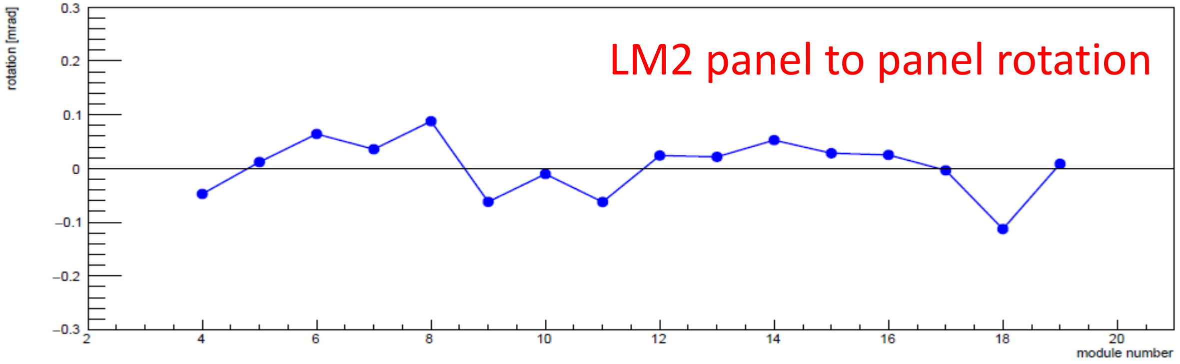


LM1 example of RasFork alignment measurement



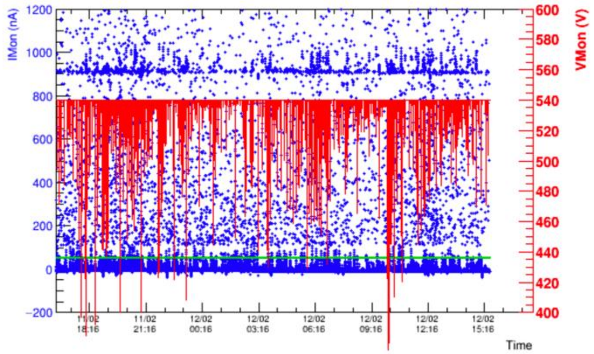






Chamber production: HV stability

End 2017 → Issues of HV Stability with first production MM NSW Quadruplet
High currents and discharges - concern for possible permanent damages
Jan 2018 → R&D focused on the cause of sparks and possible means of protection



Spark causes

- Residual material humidity
- Residual ionic contamination
- Mesh mechanical imperfections
- Other imperfections

- **Detailed quality control of PCBs targeting imperfections**
- **Thorough cleaning/ drying of panels prior to assembly**
- **Polishing of the mesh**
- **Reduce relative humidity inside chamber ≤ ~15%**

- **Jan 2019**: Evidence of discharge happening close to the boundary between Pyralux overlay region and the active area

Insufficient spark suppression **due to low resistivity in localized spots**

Spark protection

- Act on the resistive layer
- Introduce HV filter (under study)
- Modify gas mixture (under study)
- Increase HV granularity (under study)

Passivation of a region along the sides of the PCB through deposit of a thin layer of araldite, in order to increase the minimum resistivity of the active area

Local grinding seems also promising

See Lorenzo Pezzoti's talk

Assembly, integration and commissioning

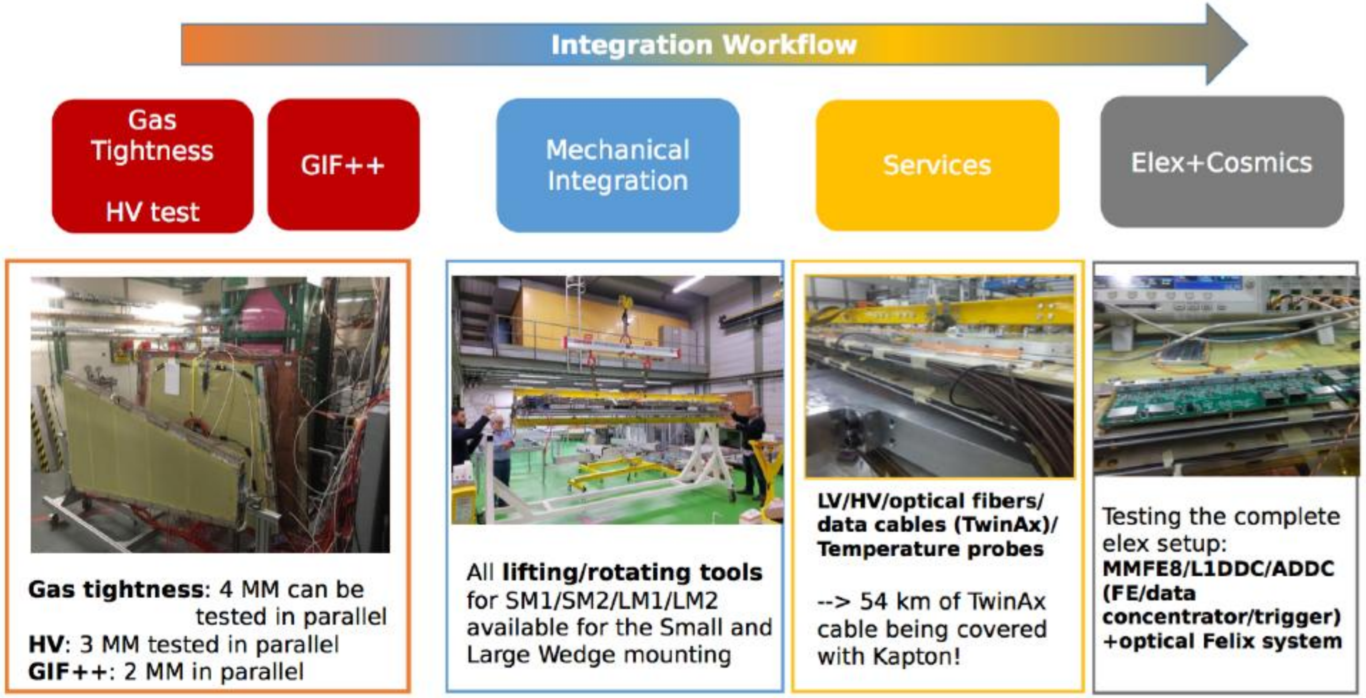
Integration and commissioning activities are performed at CERN in parallel in two buildings

BB5 (integration)

- Components tests
- Mechanical assembly
- Integration
- Elx test and calibration
- Cosmic rays test

191 (installation)

- Installation on NSW
- Services connection
- Surface commissioning



All the information about the integration in **Theo Vafeiadis talk**

All the information about GIF++ activity in **Lorenzo Pezzoti's talk**

Installation

Join with sTGC → **Installation on NSW** → **Alignment** → **LV and HV cables, fibers , T sensors Gas and Cooling pipes**

→

Commissioning

Operation test → **Sign off**

Performance and commissioning of HV

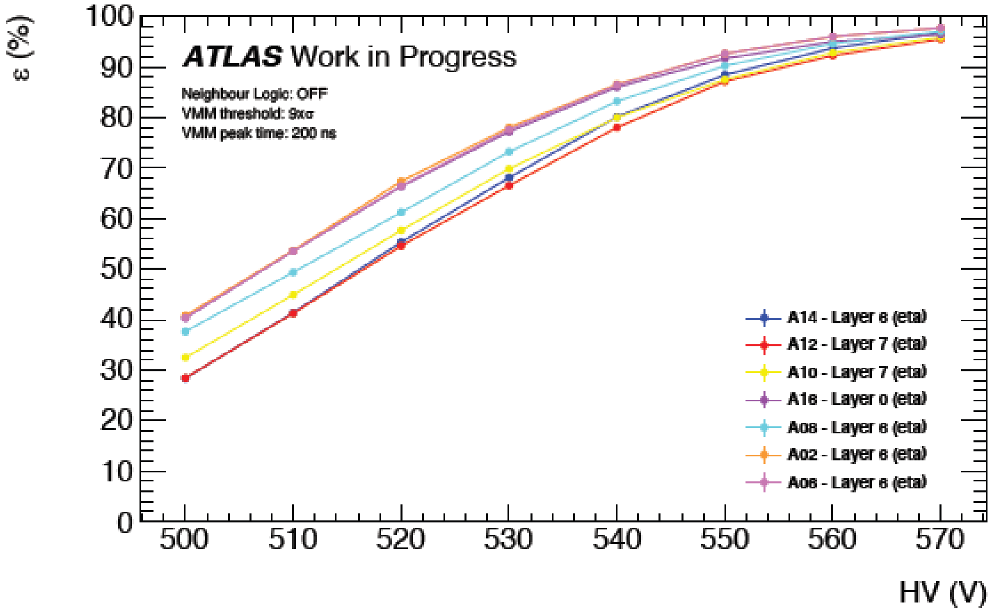
Nominal HV is 570 V --- several tests to ensure stability

- **128 HV sections per sector**
- Test are performed by ramping the HV and recording the current & the spike rate
- Modules which present some issues are send for irradiation scan to GIF++
- If nominal HV is not stable for some section, connect to hospital line (4 additional HV channels per sector with reduced HV values)
- Finalize the HV configuration and confirm efficiency from cosmic data
- **The same HV configuration is validated at 191 after installation**

Fraction of sections set to

Nominal value	**90%**
Reduced value	**9%**
Disconnected	**1%**

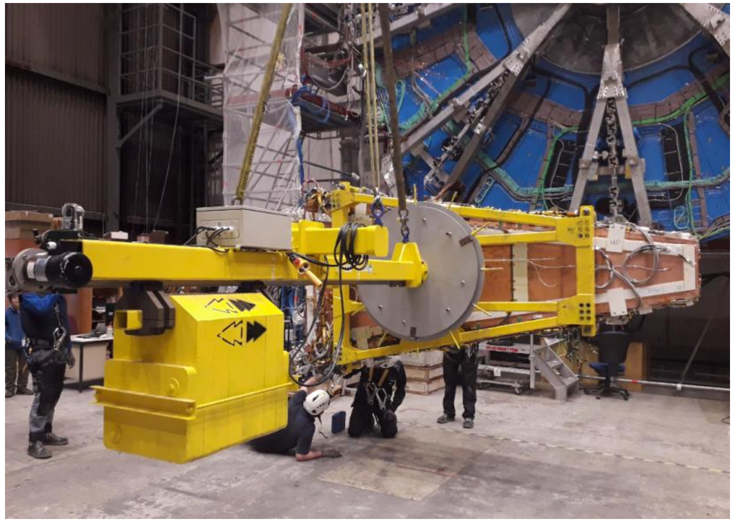
HV Efficiency at BB5 cosmic stand (η-strips)



Sector Installation

Grabbing of the sector

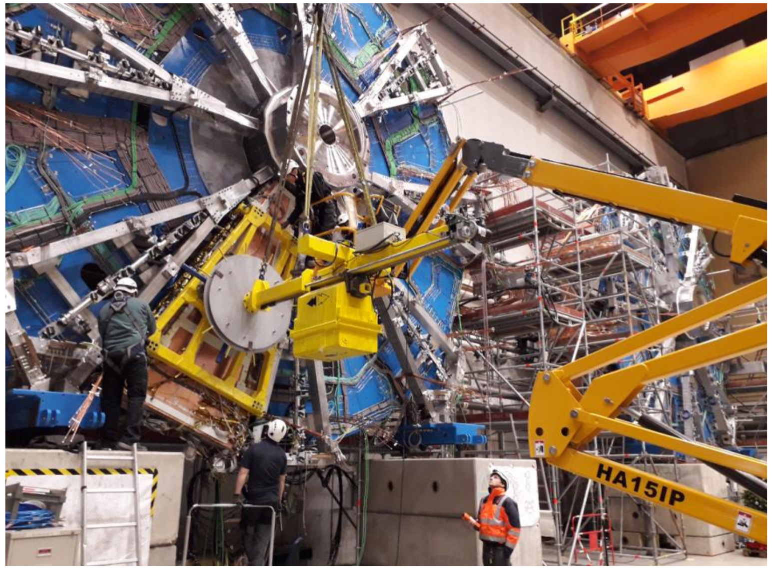
Adjusting center of gravity



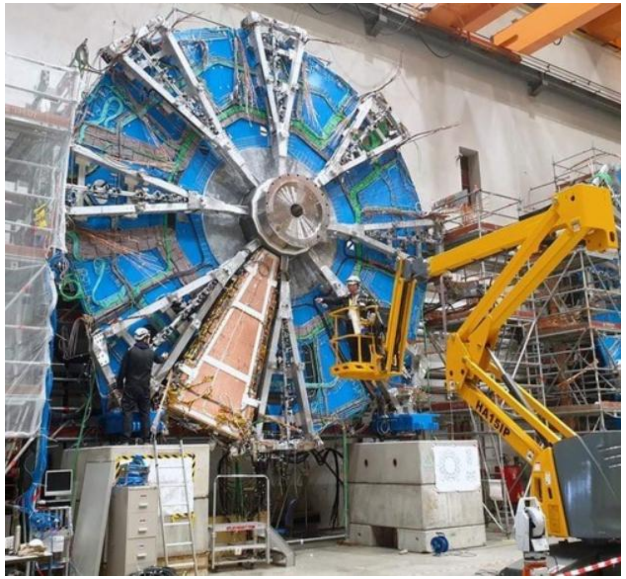
Moving towards the wheel

Set orientation to 22.5 deg

Installation Fixation on NSW A



Ready for survey

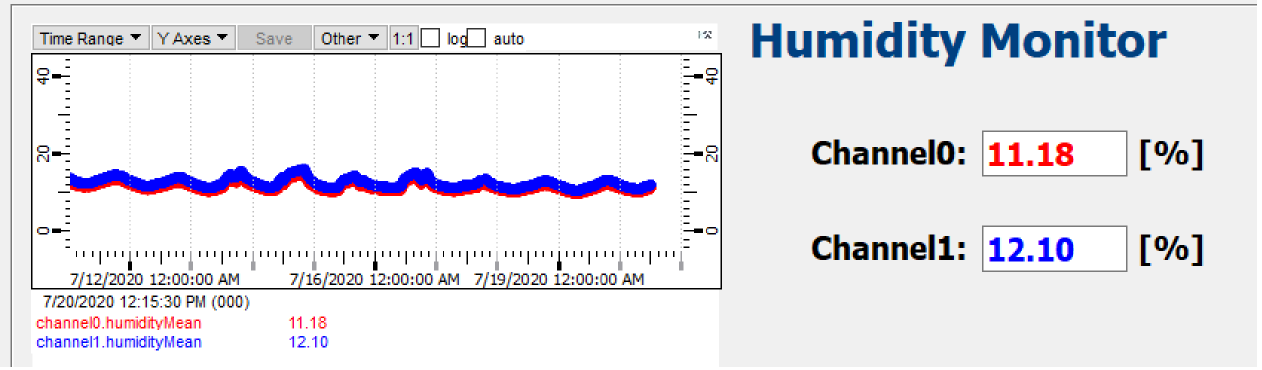


Services connection and validation

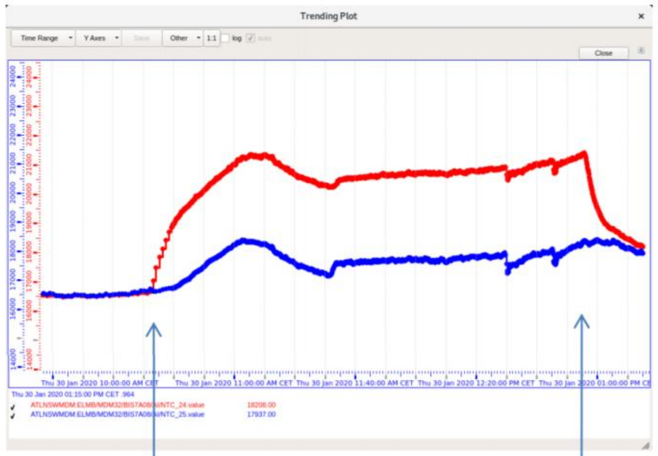
Connections and systems validation

- Survey and alignment
- Cooling
- Gas
- Low voltage
- High voltage
- Read out fibers
- Monitoring of electronics

Humidity measurement at the exit of the detector gas lines



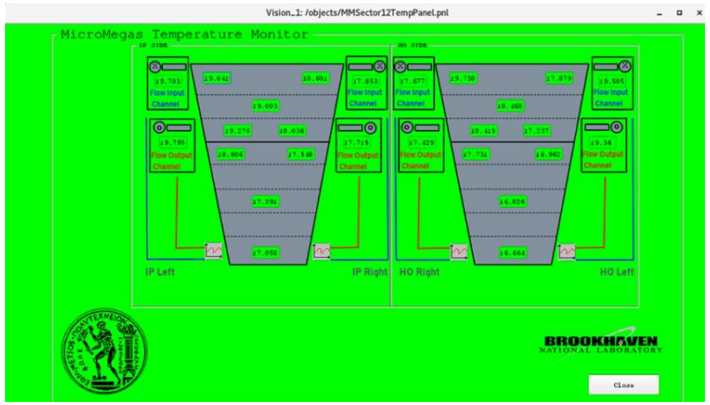
Water input and output temperatures



Turn ON elx

Turn OFF elx

Temperatures on detector



Electronic components monitoring

Commissioning: Data Acquisition

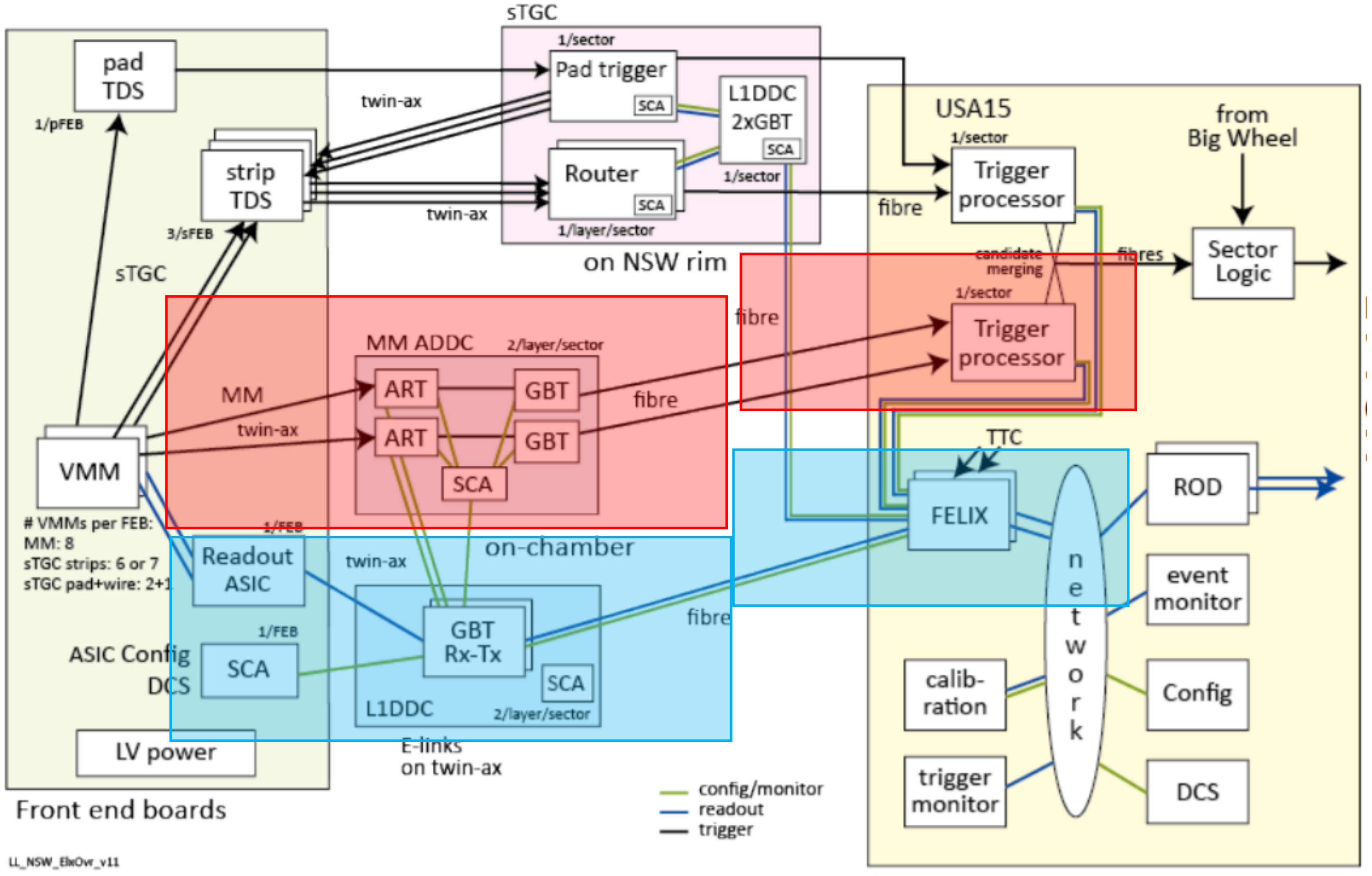
The NSW DAQ architecture lies on the newly introduced readout scheme of ATLAS
It uses the final FELIX based readout system for all the data taking

Read-out Validation
65536 read out channels / sector

Read out for LHC Run III, detector quality control

Read out for HL-LHC

Trigger path

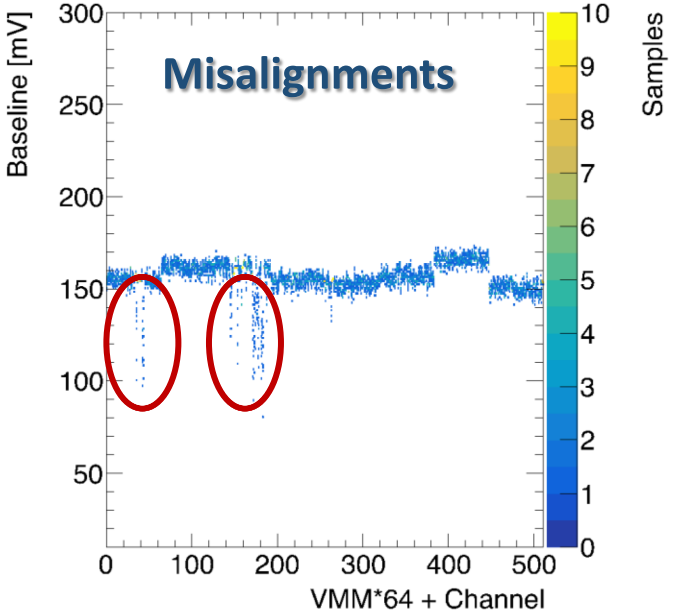


The data acquisition system is fully functional for the needs of the commissioning

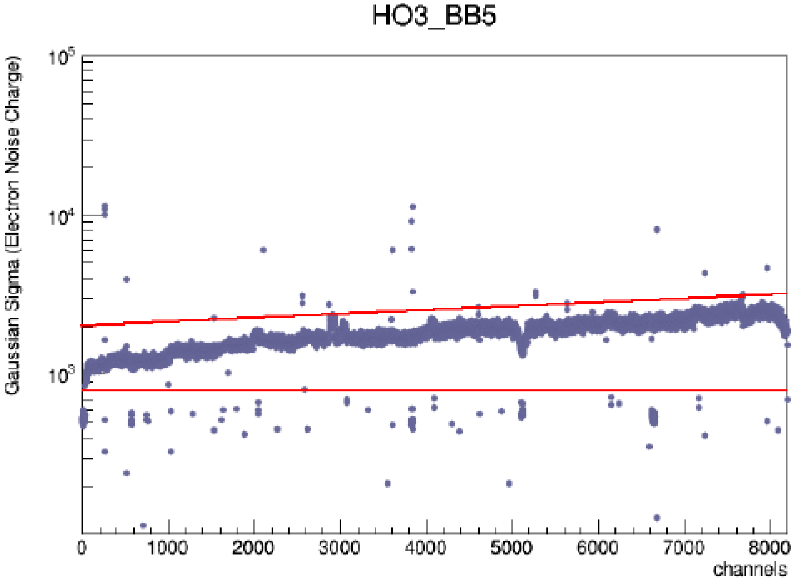
Commissioning: Baselines

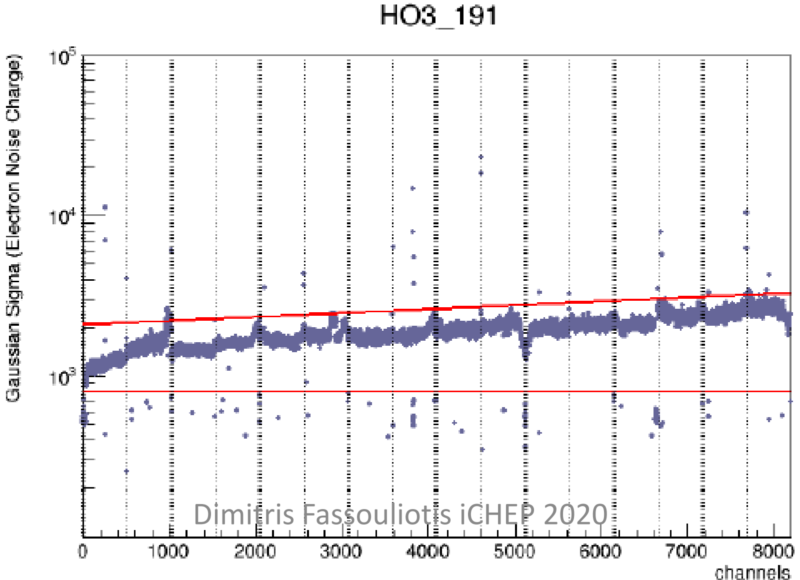
Baselines are studied in order to

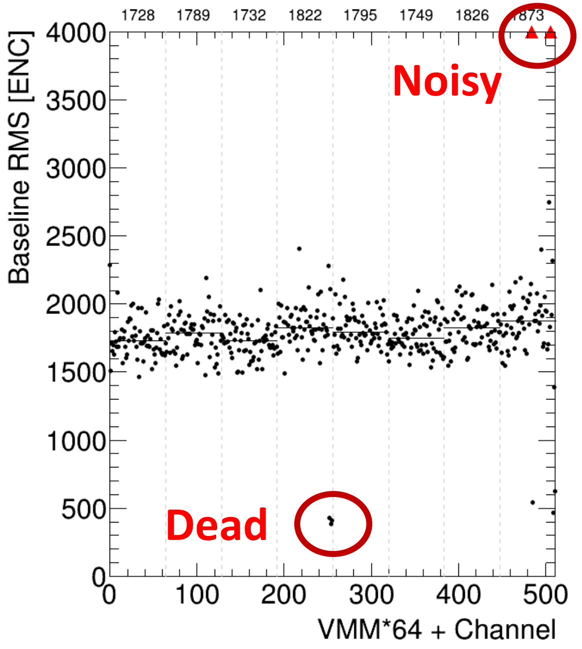
- Identify and correct misalignment between chamber and board strips causing sorts between neighboring channels (making them unusable)
- Check for noisy or dead channels
- Baselines are measured again at 191 after installation to ensure that no board or connector was moved and evaluate the noise conditions on NSW
- Estimate the dead and noisy channels



Comparison at integration and after installation







Commissioning: Different sets of data taking

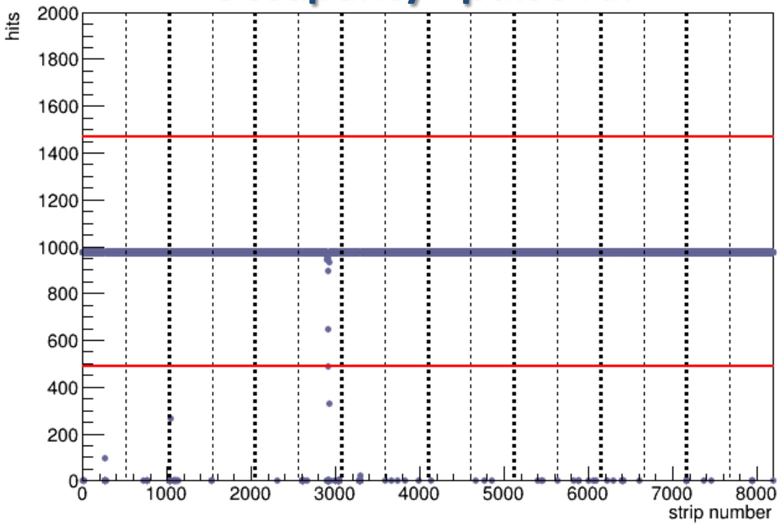
In order to

- ➢ **Check electronics response**
- ➢ **Identify dead or noisy channels**
- ➢ **Check detector performance**

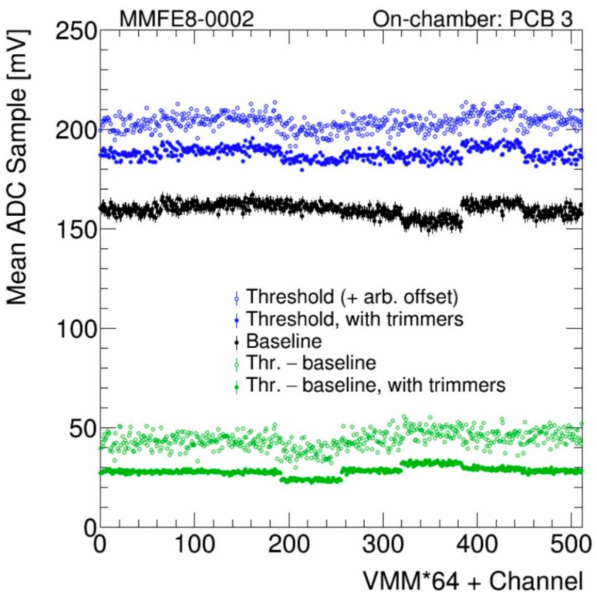
Different kind of data taking runs are performed

- Noise runs - varying thresholds, trigger frequency
- Pulse runs - varying pulse height, frequency , channels
- Cosmic runs - varying thresholds

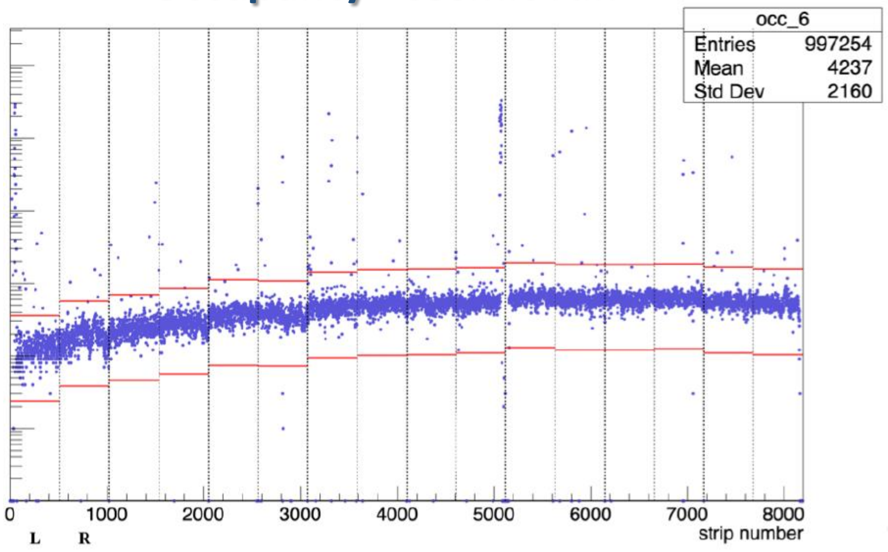
Occupancy - pulse run



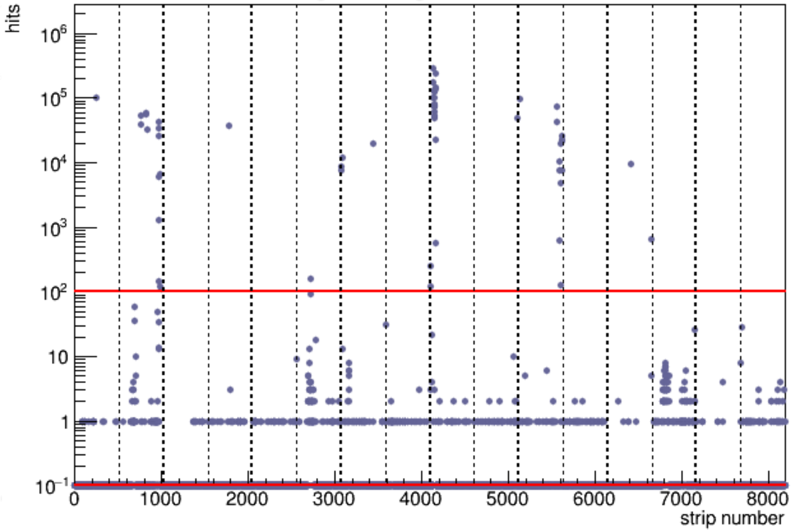
Threshold setting per channel



Occupancy - cosmic run

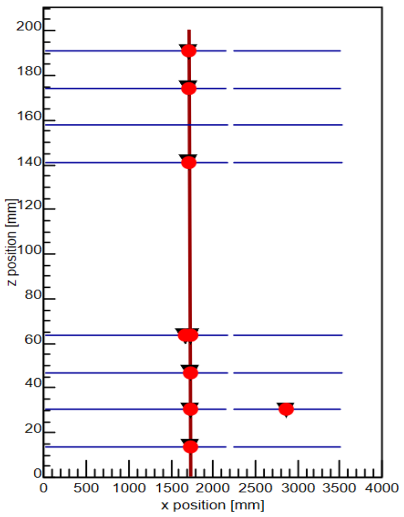


Occupancy - noise run

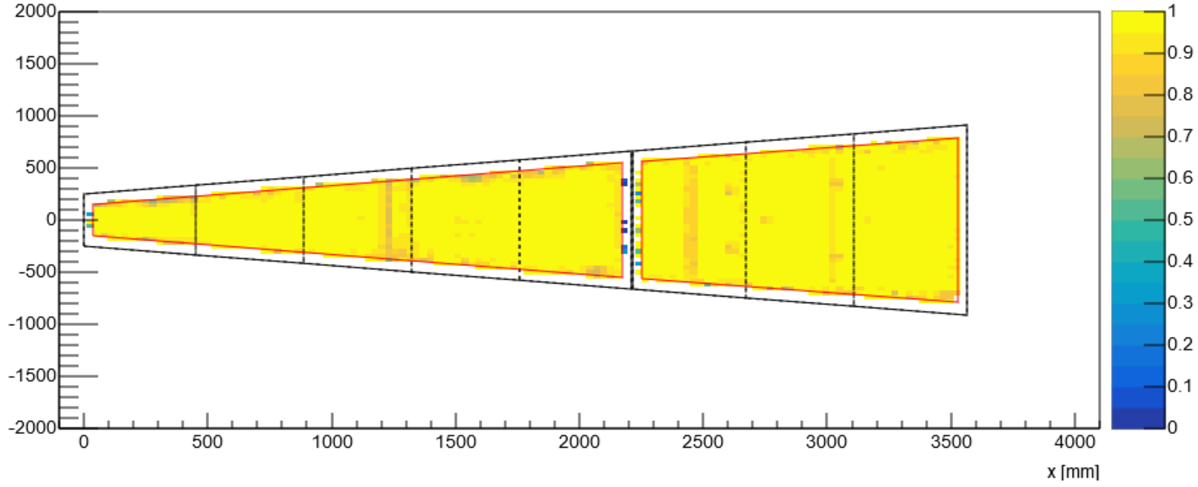


Commissioning: Cosmic data

Track projection

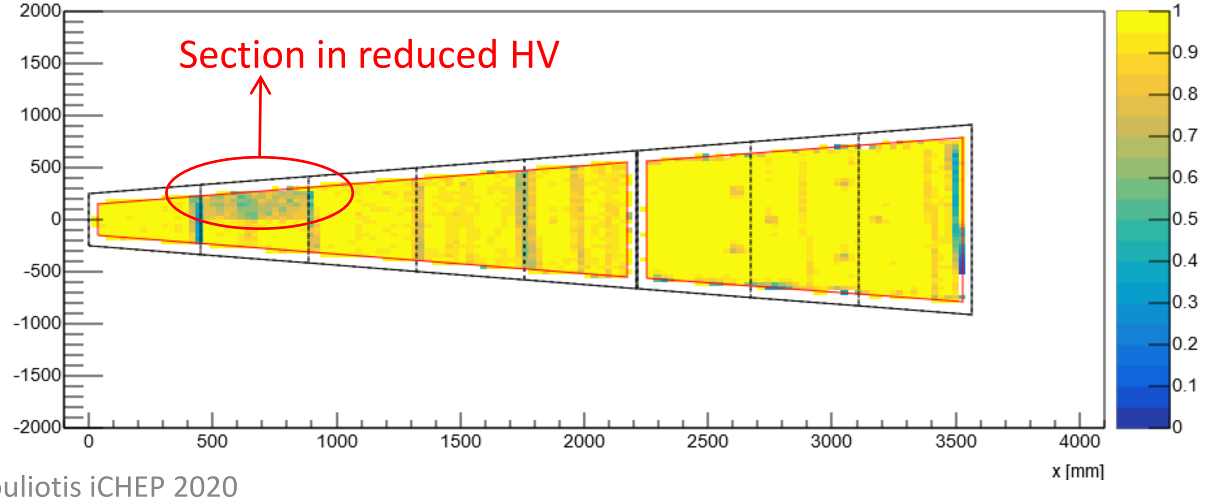


Example of Efficiency map



[All the information on cosmic results in **Gabriel Rabanal Bolanos's talk**]

Example of Efficiency map



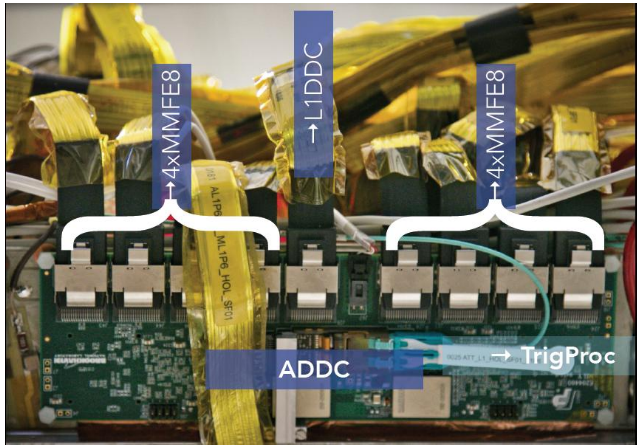
Out of 48 layers from 6 micromegas sectors integrated so far

80% have efficiency above 90%
and 20% have efficiency above 80%

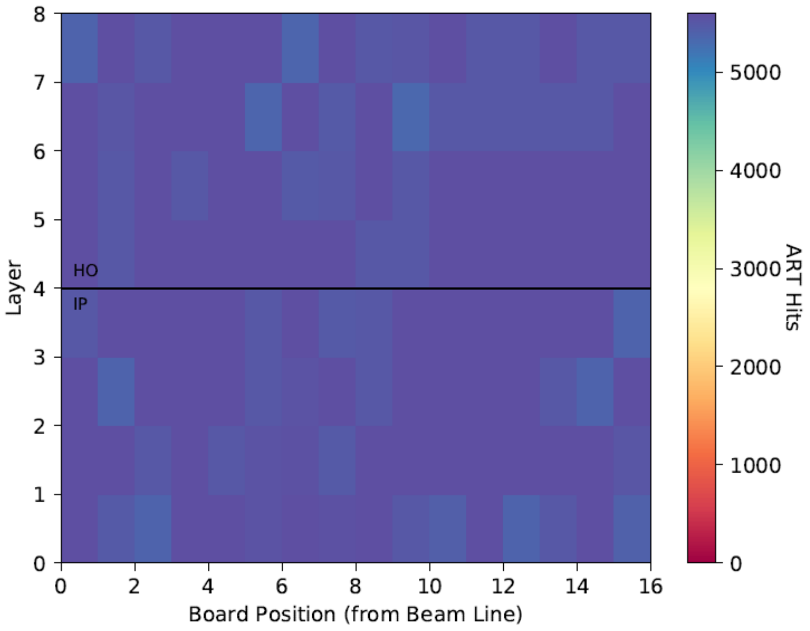
Commissioning: Trigger path

Trigger path test for micromegas

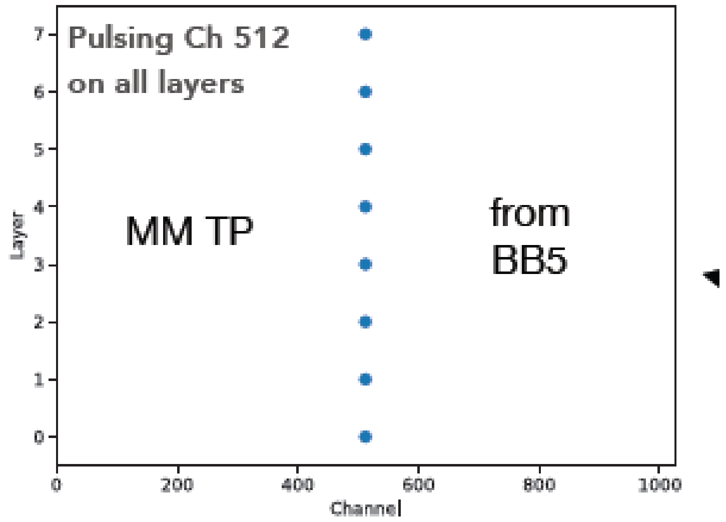
- Configuration of ADDCs
- Connectivity tests
- Coincidence logic validation with test pulses
- Trigger processor validation with test pulses (both Micromegas and sTGC)



Example of connectivity test



Test pulse example



Summary

- ATLAS NSW is (a) the largest ATLAS phase I upgrade and (b) the largest Micromegas project curried out so far.
- Considerable effort has been invested to understand and overcome the issue of HV instability, leading to significant improvement of the behavior of large area resistive Micromegas.
- Construction and integration of Micromegas detectors continue at full speed after the restrictions due to Covid-19 were relaxed.
- **The average layer efficiency of all sectors built so far exceeds 90%.**
- Most of the commissioning procedures are finalized and are performed successfully in routine mode.
- **The level of dead (or noisy) electronic channels is well below 1% (2%).**
- Most of the modules and all the electronic components for the 16 sectors of side A are available. Two sectors have been already installed and are currently commissioned. Therefore, **the goal of having side A ready in Spring 2021 is achievable.**
- The successful accomplishment of NSW side C in time depends also on international restrictions due to Covid-19.

Thank you

Back up slides

Similar topics at iCHEP 2020

Presentations

- Integration and commissioning of ATLAS New Small Wheel Micromegas detectors with electronics at CERN, **Theodoros Vafeiadis**
- Irradiation and Gas studies of production chambers for the ATLAS-NSW MM, **Lorenzo Pezzotti**
- Cosmic results with the final Micromegas sectors for the ATLAS Muon upgrade, **Gabriel Rabanal Bolanos**

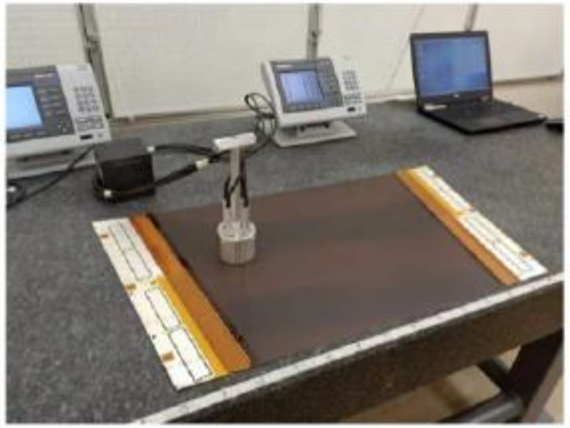
Posters

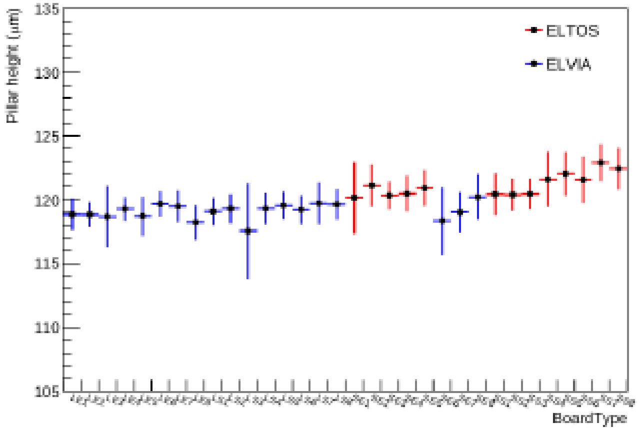
- Production and Test of Micromegas boards for the ATLAS New Small Wheel project, **Luigi Longo**
- Geometrical precision alignment of the Micromegas detectors for the ATLAS New Small Wheel upgrade, **Manisha Lohan**

Chamber production: PCB quality control

Dedicated lab at CERN for PCB QA/QC

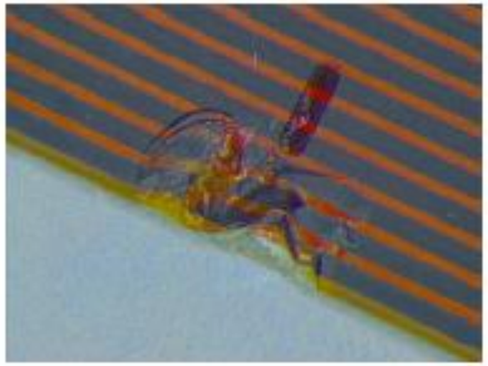
- Visual inspection
- Electric tests
- **Cu strips and pillar pattern**
- Edge precision and straightness
- Absolute dimensions and shape
- **Pillar height**
- **Strip capacitance**
- **Resistivity mapping**

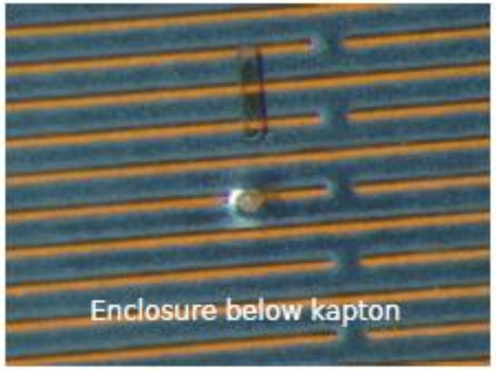




Pillar height mapping as a function of the board type

Edge damage



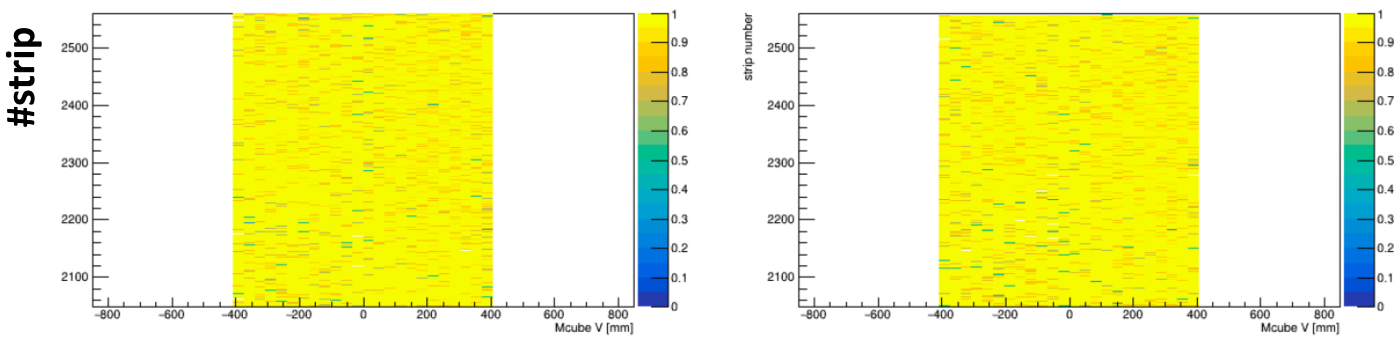


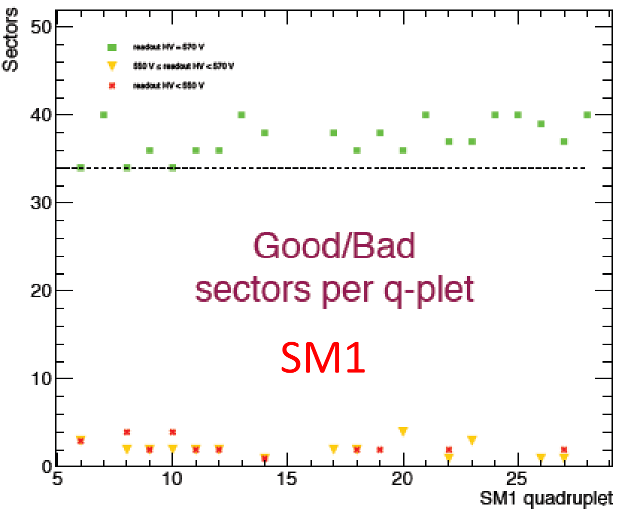
All information can be found at:
Production and Test of Micromegas boards for the ATLAS New Small Wheel project, **Poster by Luigi Longo**

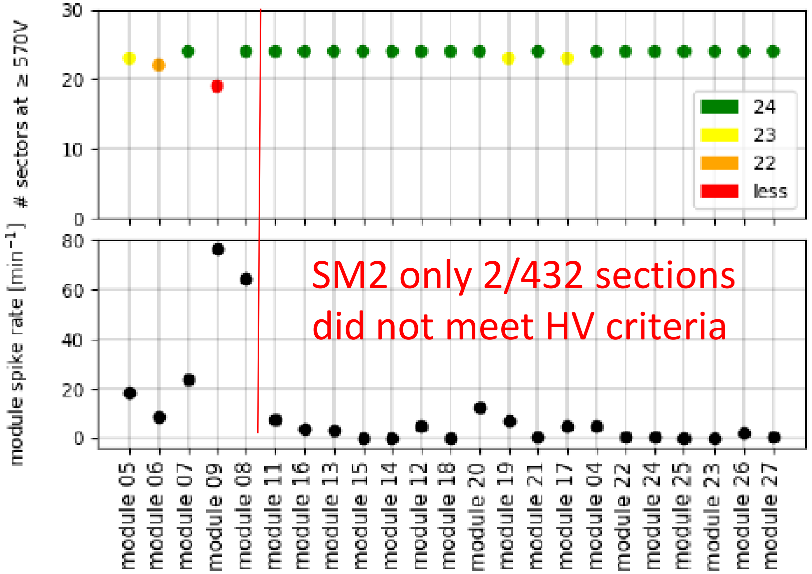
Chamber production: HV stability

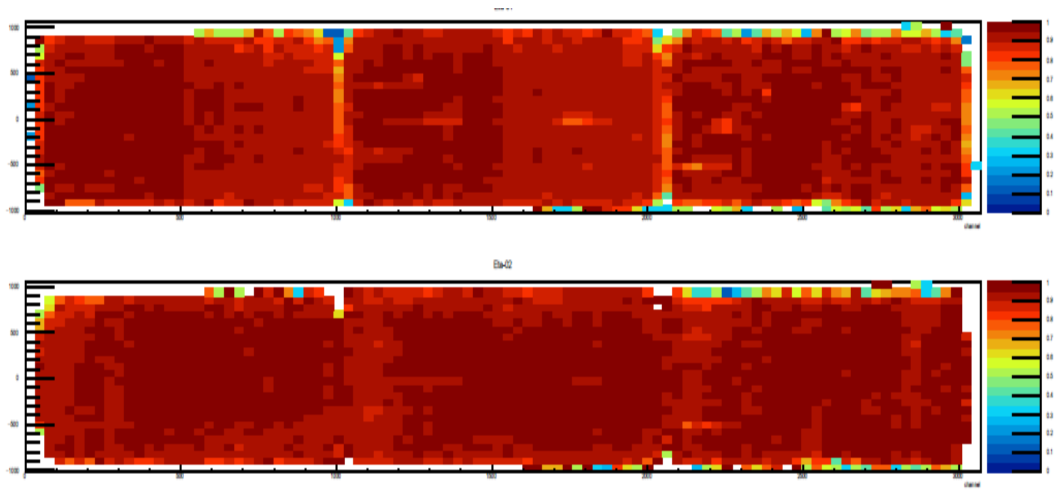
- ➢ The method of passivation was applied to all modules starting from one point, to mitigate the HV stability issues
- ➢ As a result there is a small decrease of the active area in the overlapping small – large sector regions, but a better overall efficiency.

LM1: Example of efficiency in cosmic stand - eff>95%









LM2: Example of efficiency in cosmic stand

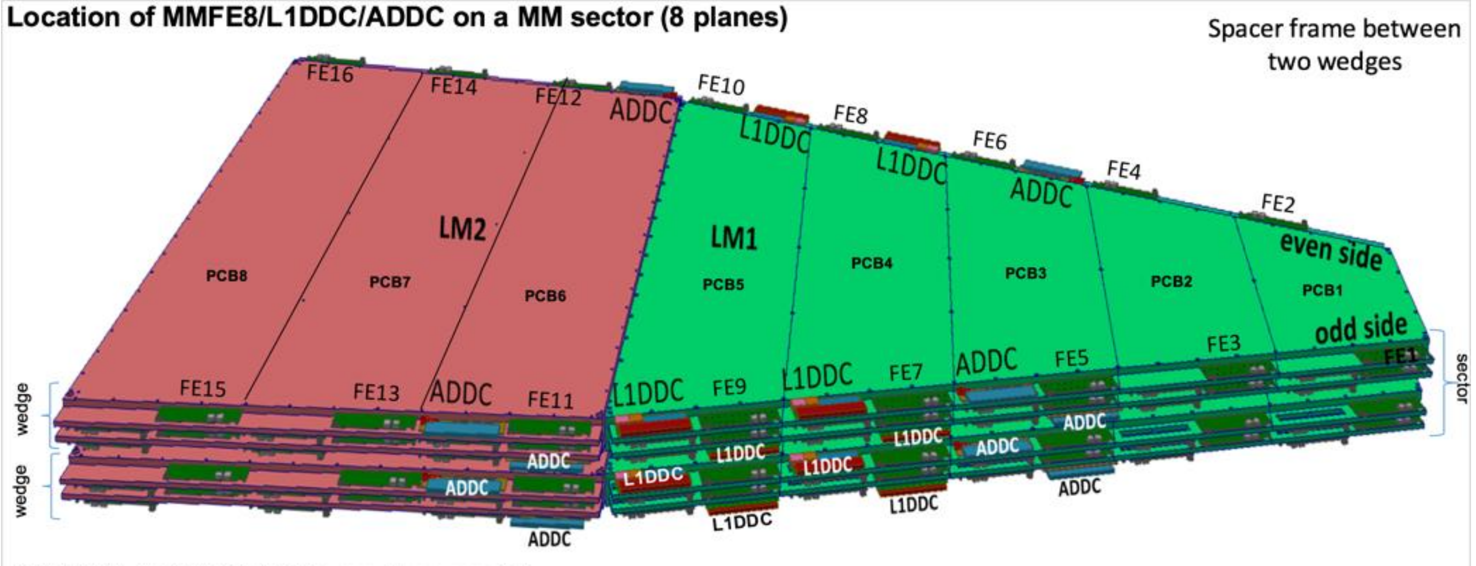
Integration: Electronic boards

Each Micromegas double-wedge

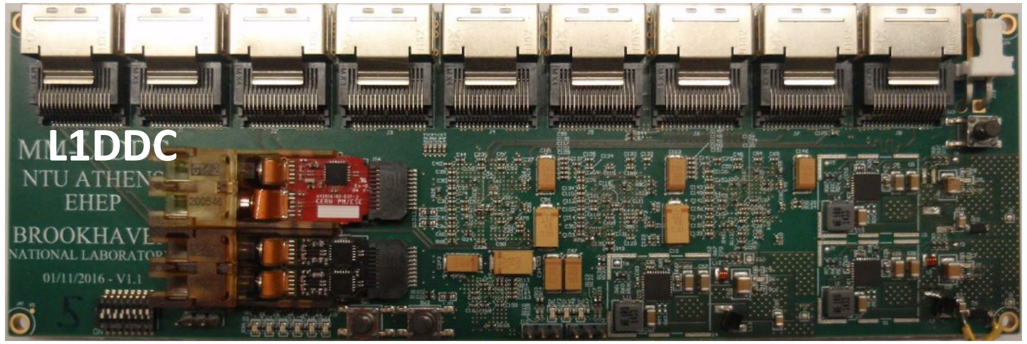
- **Has 65536 read out channels**
- **Combines 4 different types of elx boards**

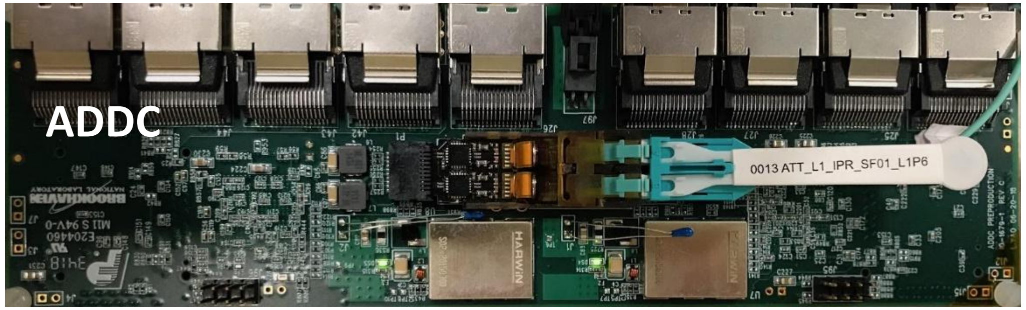
- 128 MMFE8 -- MicroMegas Front-End
- 16 L1DDC -- Level-1 Data Driver Card
- 16 ADDC -- Address in Real Time Data Driver Card
- 16 LVDB -- Low Voltage Distribution Board

All the cards are fully tested on the bench before installation on the detector, at integration site and on NSW



8 MMFE8, 1 L1DDC, 1 ADDC per plane per side

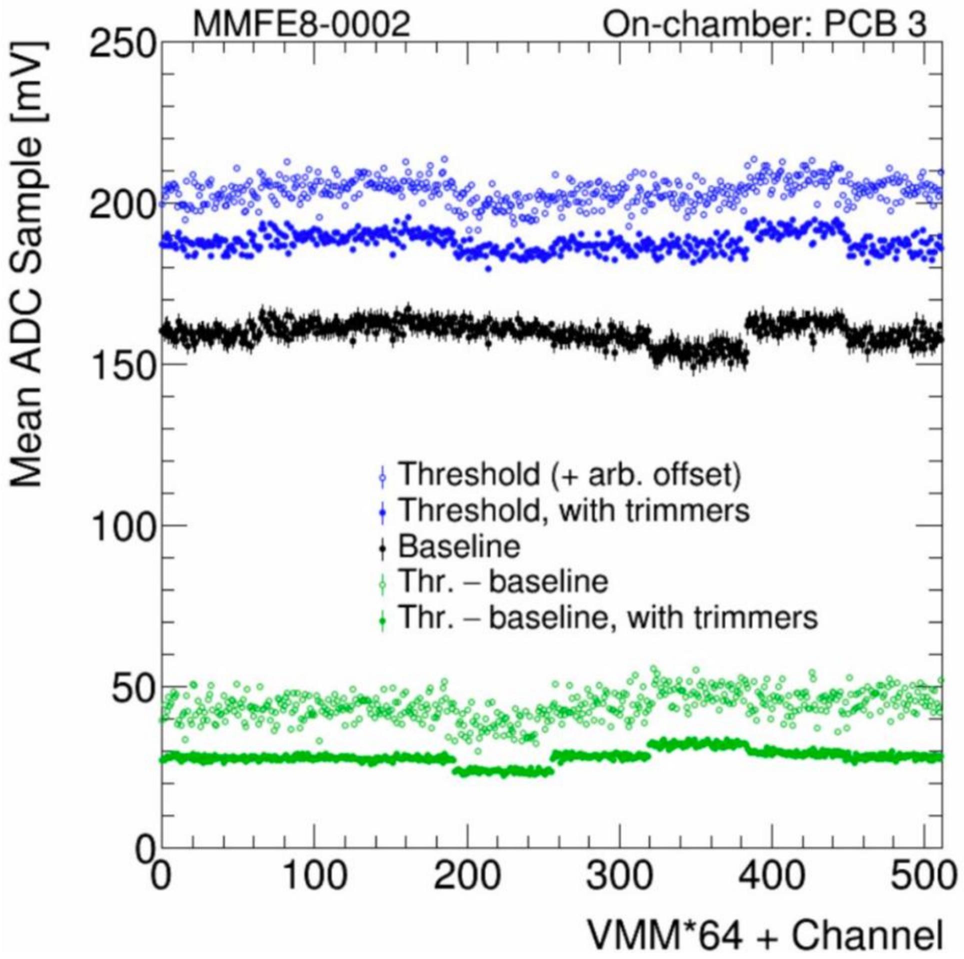




Commissioning: Threshold setting

For every channel a different threshold is set

- VMM is the first level readout having 64 channels
- Each VMM has a slightly different response
- For each VMM a global threshold is set
- Then for each channel the threshold can be further calibrated up to 30 ADC counts (trimming)



Status of side A

Detector Components	Status
Small sector modules	32/32
Large sector modules	28/32
MMFE8	2048/2048
L1DDC	256/256
ADDC	256/256
LVDB	256/256

Detector installation	Status
DWs assembled	13/16
DWs integrated with elx	8/16
DWs validated	7/16
Sectors installed on NSW	2/16

- Most of the hardware is already available
- Integration and tests can be performed in 2 weeks
- Goal for installation and commissioning is also 2 weeks
- Given that works can be done in parallel the estimated time for each sector is 2 weeks

- **One test sector has already gone through the installation and surface commissioning o validate the procedures**
- **Two installed sectors are being surface commissioned at the moment**