Construction and Commissioning of the ATLAS New Small Wheel

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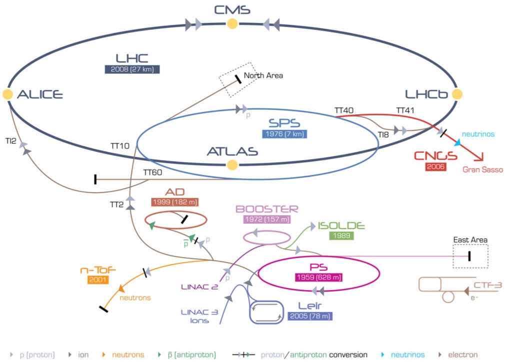
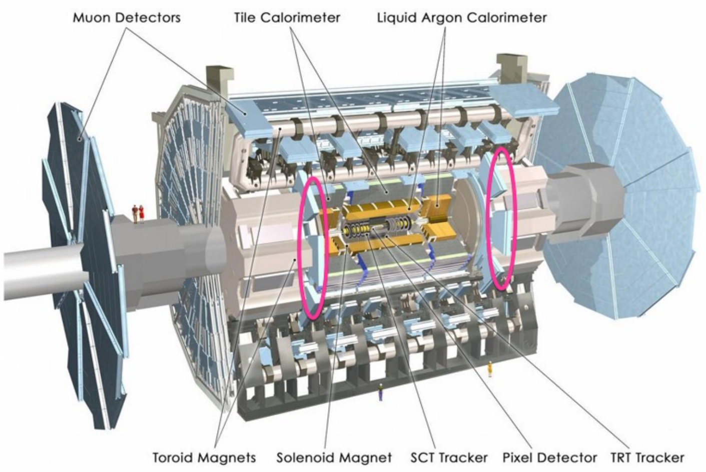
Outline

- NSW in ATLAS and the need for a new detector in view of the future LHC runs
- Brief overview of the working principles and structure of a MicroMegas (MM)
- Production of MicroMegas and challenges
- Integration and commissioning of the MM NSW
- NSW A in the cavern and NSW C commissioning

LHC and ATLAS

- ATLAS is one of the main experiments at the Large Hadron Collider
- LHC: high-luminosity p-p collider at a maximum center-of-mass energy of 14 TeV
  - it can operate also with ion beams
  - it sets the present energy frontier for collider physics

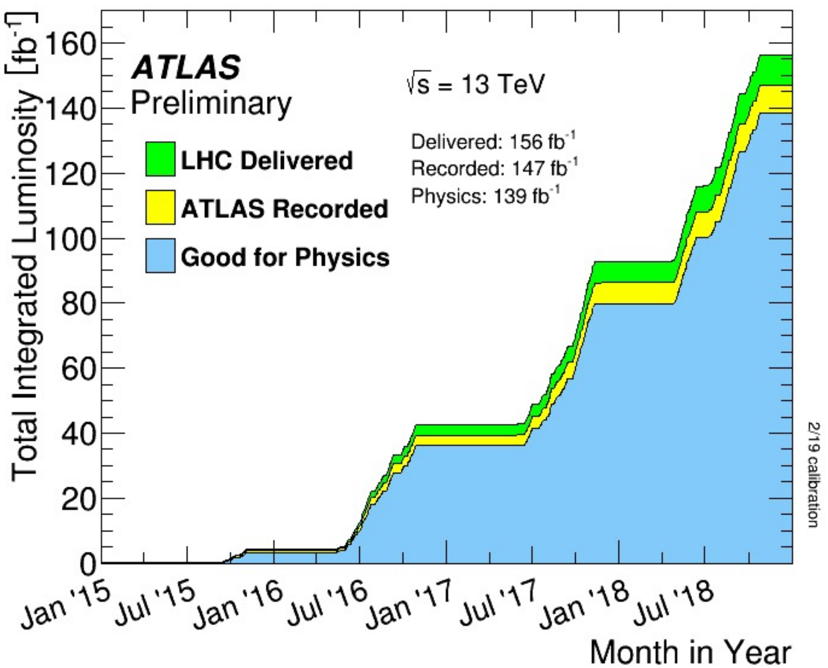




- Main Physics goals of the experiment:
  - Higgs boson discovery
  - Precision study of Higgs properties
  - Direct search for New Physics particles (as well as for inconsistencies in the SM)
- High energy is not enough: it needs also a huge amount of data for discoveries and to study rare phenomena

LHC and ATLAS Upgrades

LHC luminosity recorded by ATLAS in RUN2



- LHC will undergo two major upgrades to increase the luminosity:
  - *LS2*: $L \gtrsim 2\text{x}10^{34}$ cm^{-2}s^{-1}, L_{int} ~350 fb^{-1}
  - *LS3*: L ~ 6-7x10^{34} cm^{-2}s^{-1}
  - *Final integrated luminosity:*
    - L_{int} ~3000 fb^{-1}

All experiments must also be upgraded to cope with the increased rate of events

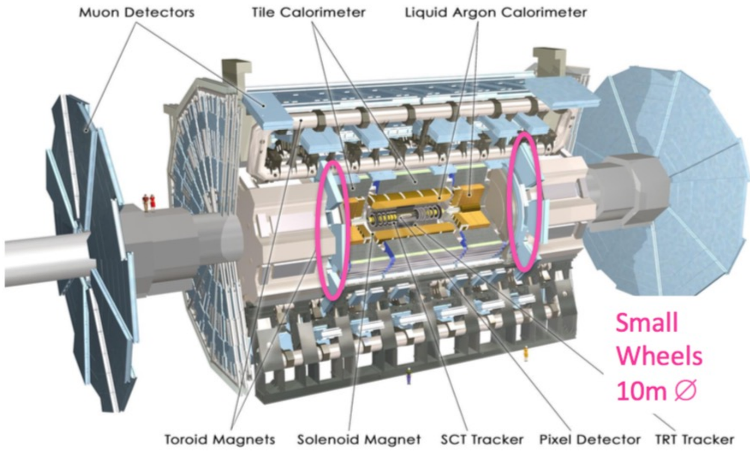
- Long Shutdown 2 => experimental upgrade Phase-I
- Long Shutdown 3 => experimental upgrade Phase-II

This Seminar will focus on the ATLAS upgrade of the muon forward detector during the *LS2*

NSW performances

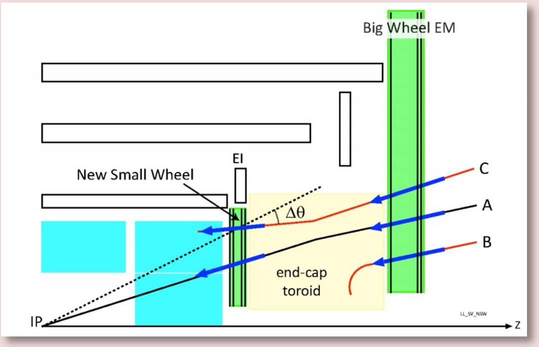
The old SW (Small Wheels):

- the first muon spectrometer station in the forward region (End-Cap)
- angular coverage: 1.3<|η|<2.7
- between the End-Cap calorimeter and the toroid (z = ± 7 m)
- CSC and MDT (TGCs for the 2 coord.)

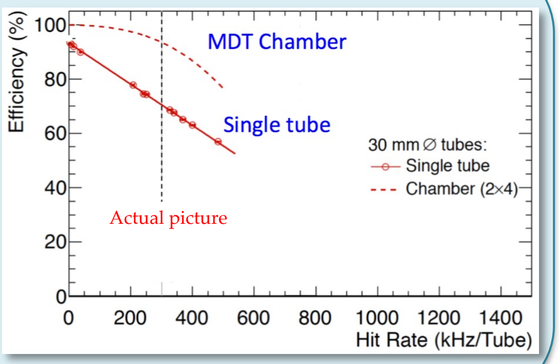


An improvement in the performances is required both for the trigger and tracking in view of the increasing luminosity for the future LHC runs (5-7 10^{34} cm^{-2} s^{-1})

Level 1 End-Cap trigger, dominated by fake trigger events (type B e C)



HL-LHC:
(MDT) expected frequency > 500 kHz / tube -> efficiency decrease significantly



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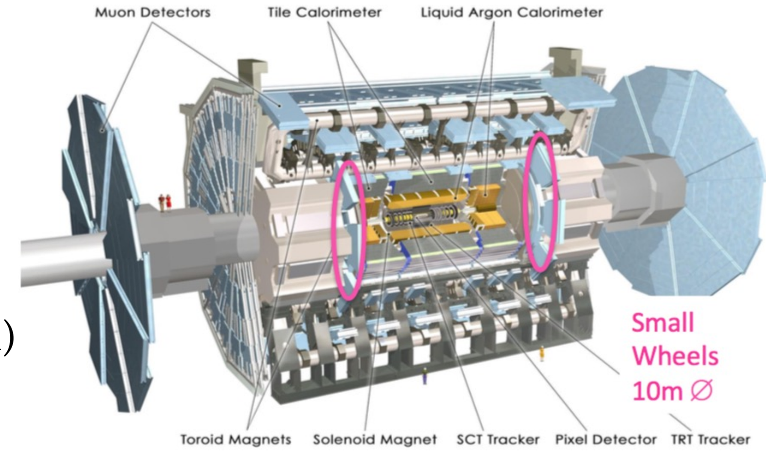

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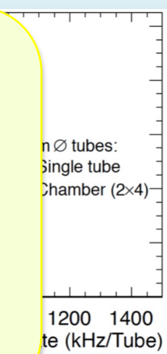
HL-LHC:

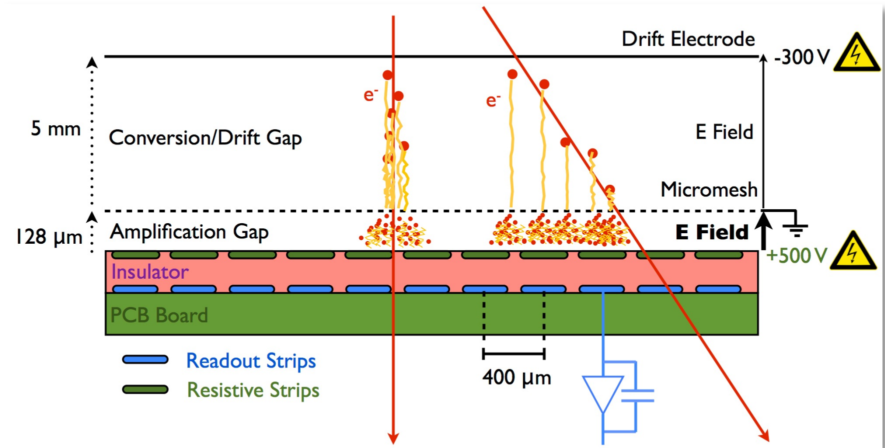


Need detectors:
- fast and able to perform a precision tracking (~100 μm per plane)
- able to cope with the increasing background particle flux (pileup) as the luminosity increases
- reject fake triggers

-> MM + TGCs

MM detectors

- MM detector construction and challenges

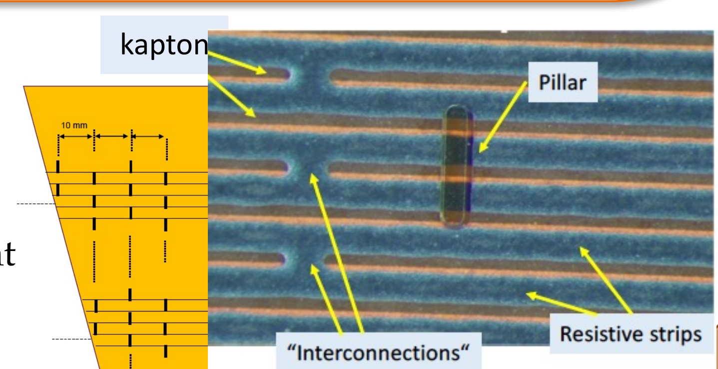


MM Working conditions:

- gas: 93% Ar - 7% CO_2 -> studies on the ternary gas mixture ($Ar:CO_2:Iso$ 93:5:2) ongoing
- conversion gap 5 mm, amplification gap 128 μm
- Stainless-steel mesh grounded: 30 µm thick wires 70 µm openings
- strip width 300 µm, strip pitch 425-450 µm
- HV (mesh to ground):
  - Conversion: HV_{drift}= -300 V, h=5mm, E_C~600 V/cm
  - Amplification: HV_{RO}= 570 V, h=128µm, E_A~50 kV/cm
- resistivity strip ≈ 10 MΩ/cm (introduced to reduce the probability of discharges)
- E_A/E_D ~100 => ~100% mesh transparency
- Gain ~10^4; ions collection time ~100 ns

Features specific to ATLAS MM:

- Floating mesh: the mesh is integrated in the drift panel structure and not embedded in the anodic structure
  - necessary for large area detectors
  - the chamber can be re-opened for intervention
- Mesh at ground potential
  - easier construction procedure
  - allows separation of RO boards in independent HV sectors
- Resistive strips are overlayed to copper signal strips
  - reduction of local current and of risk of discharges
  - resistive layout (screen printing technique) with equidistant interconnections to have uniform resistance across the pcb



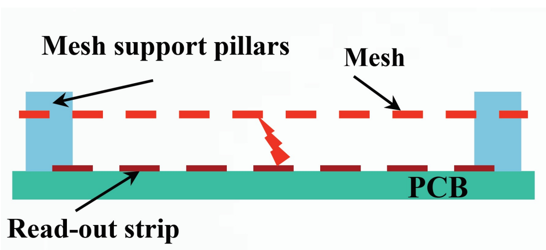
The MM detectors within the ATLAS NSW

Original scheme:

- no resistive strips
- charge directly collected by RO strips

High spark probability for highly ionizing particles in a high rate environment

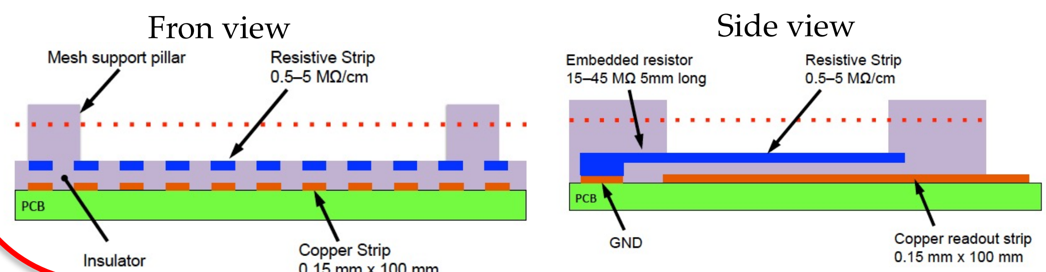
Dead time due to HV breakdown



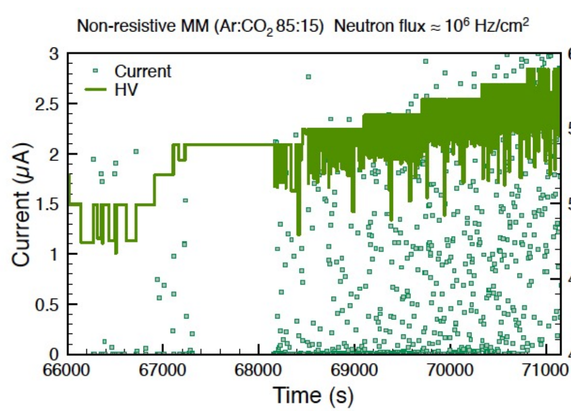
Resistive strips scheme:

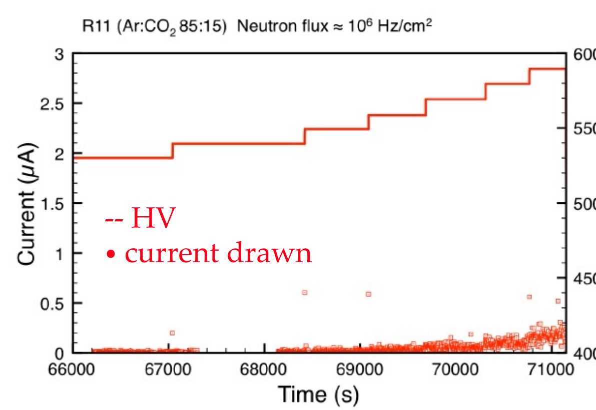
- strips with ϱ ≳ a few MΩ/cm on top of readout strips, with a 50 μm kapton layer in between
- signal induced by capacitive coupling on RO strips
- resistive strips instead of a resistive layer to limit the spread of charge to neighbouring strips

Strong suppression of sparks also in very harsh environment



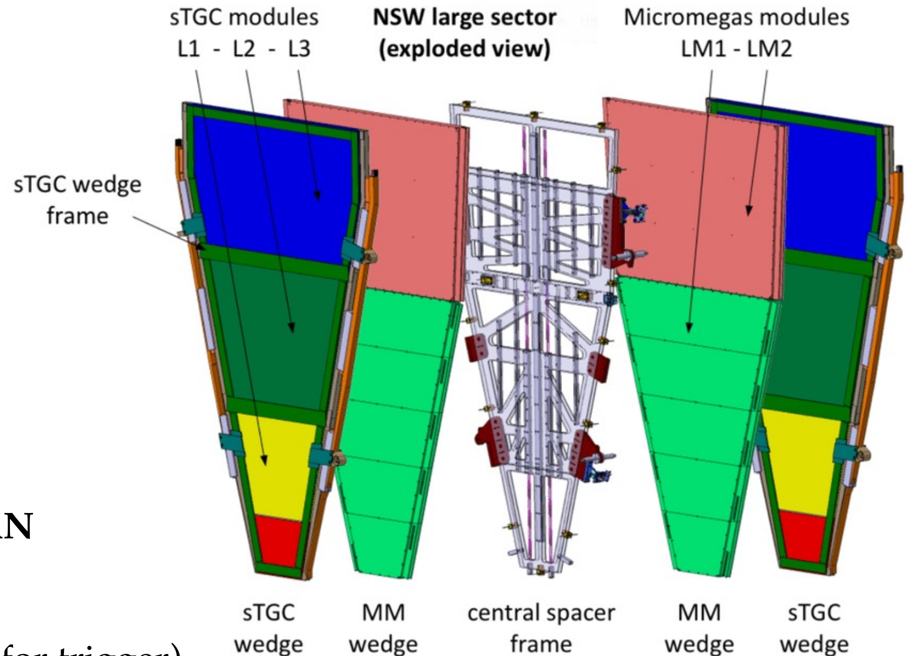
Standard and resistive-strip MM under intense neutron flux





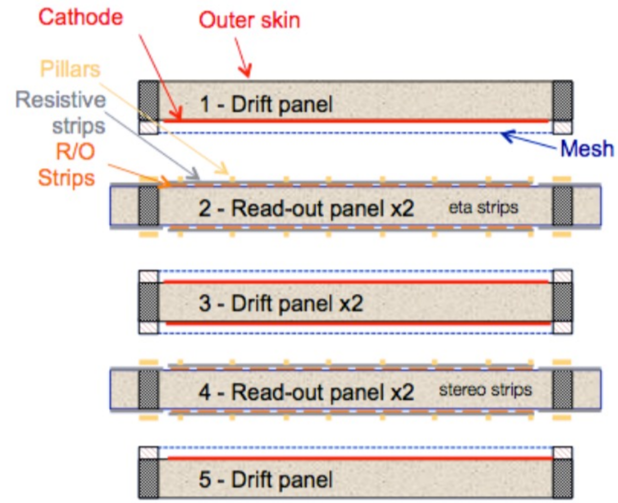
NSW, wheel structure:

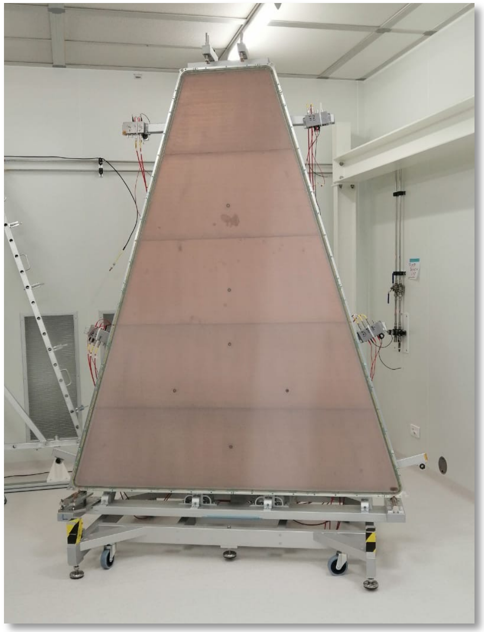
- **16 sectors per side (8 small + 8 large sectors)**
- **Each sector made of 2 sTGC wedges and a Micromegas (MM) double wedge**
- **sTGC wedge:**
  - made of 3 quadruplets; QS1, QS2, QS3 for small sectors and QL1, QL2, QL3 for large sectors
  - production in Canada, Chile, China, Israel and Russia
- **Micromegas double wedge:**
  - made of 2x2 quadruplets and a central support element
  - Separate types for small (SM1, SM2) and large (LM1, LM2) sectors
  - Production in Italy, Germany, CEA Saclay and Thessaloniki+Dubna
- **Wedge integration and NSW assembly done at CERN**
- MM aim:
  - **precision tracking** (between 2 sTGC chambers for trigger)
  - **p_T resolution ~15% at 1TeV**

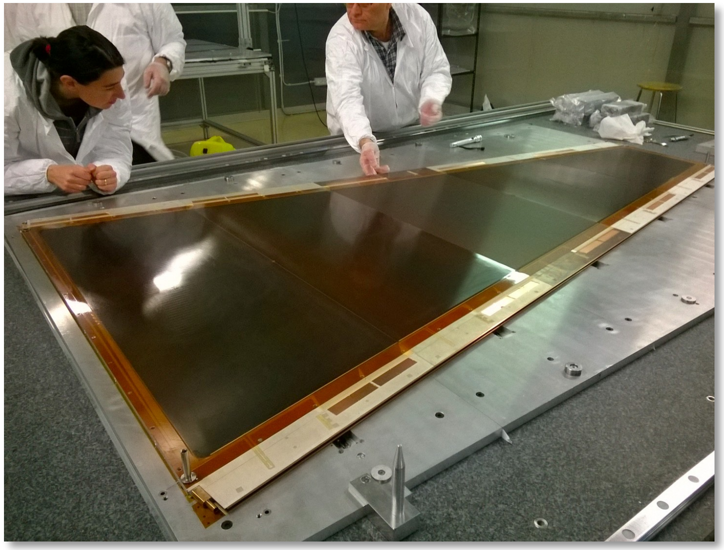


MM quadruplet:

- 5 stiff panels needed to form 4 gaps when coupled
    - stiff panels to guarantee planarity
- 2 read out panels (1 eta and 1 stereo with strips inclined by ±1.5° in order to reconstruct the 2nd coordinate) -> RO pcbs are based on boards done in industries
- 1 central drift panel (cathode pcbs + glued meshes)
- 2 external drift panels







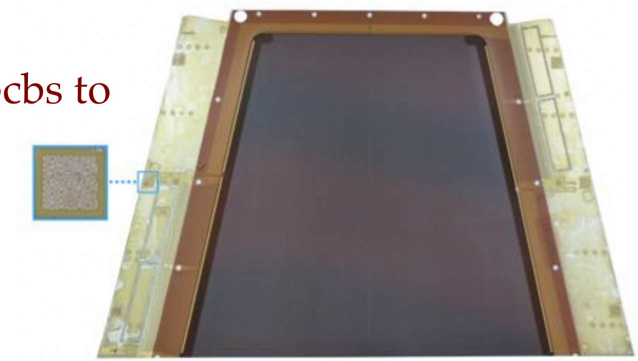
The resistive MicroMegas chambers are frontier Micro-Pattern Gas Detector which are designed and built for the first time on large dimensions O(m^2).

MicroMegas construction challenges:

- strip alignment on each layer of **30 μm of precision in η** on positions of strips over meters
- **planarity within 100 μm RMS**
- **technological transfer of Read-Out pcbs production** with extremely high quality (pillars shape, resistivity homogeneity, quality of the pcb edges)
- **stability against discharges** with an high electric field (~50 kV/cm) on a surface of O(m^2)

Alignment:

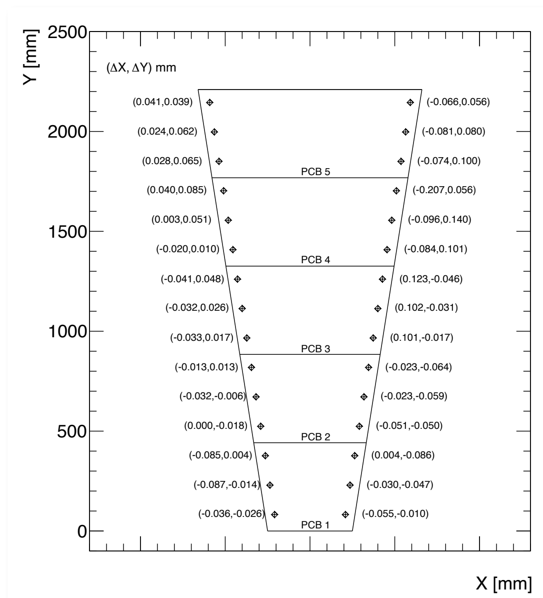
- mechanical supports to the PCB during panel construction
- coded masks read by contact-CCD on the external side of pcbs to ensure for the alignment and rotation of the strip:
  - absolute alignment of the strips $\Delta\eta < 40\ \mu m$
  - relative alignment of the layers $\Delta\eta < 60\ \mu m$

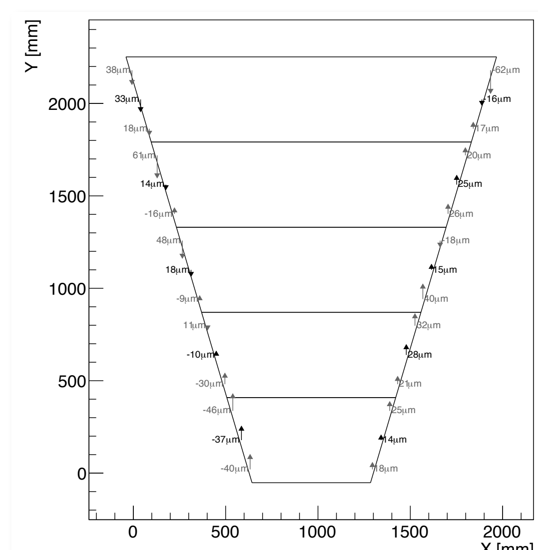


Rasnik technique:

optical measurements of reference masks etched on the boards, aligned with the strips.

Return the relative alignments of boards side-to-side measuring position bias between top and down masks at <10 μm

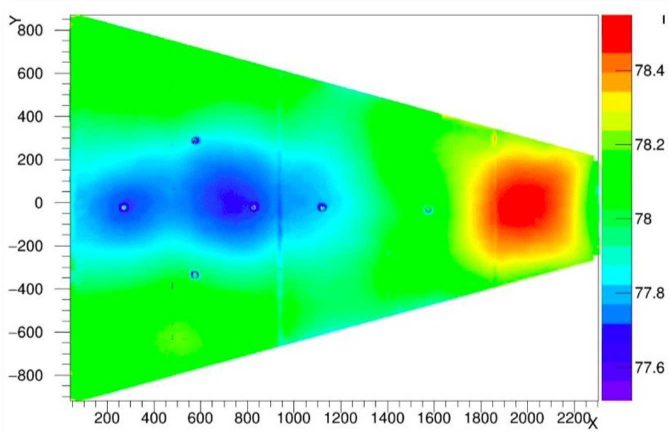




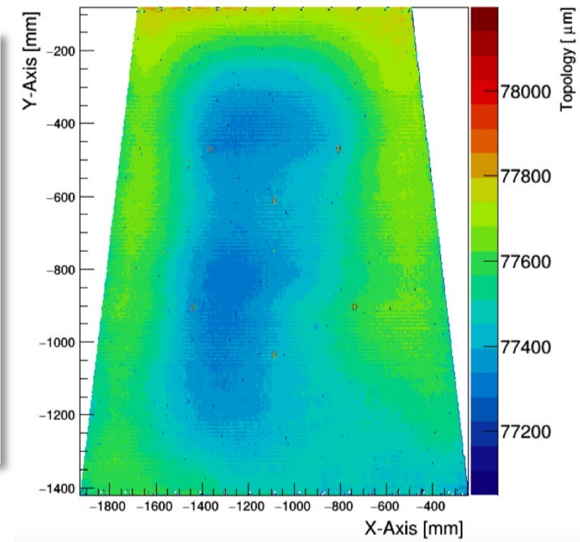
Planarity

- Measurement of the planarity of the chambers surfaces via different methods
- Maps of the 2 surfaces
- Fit of the point-clouds
- Thickness: Δz between sides
- RMS ~100 μm

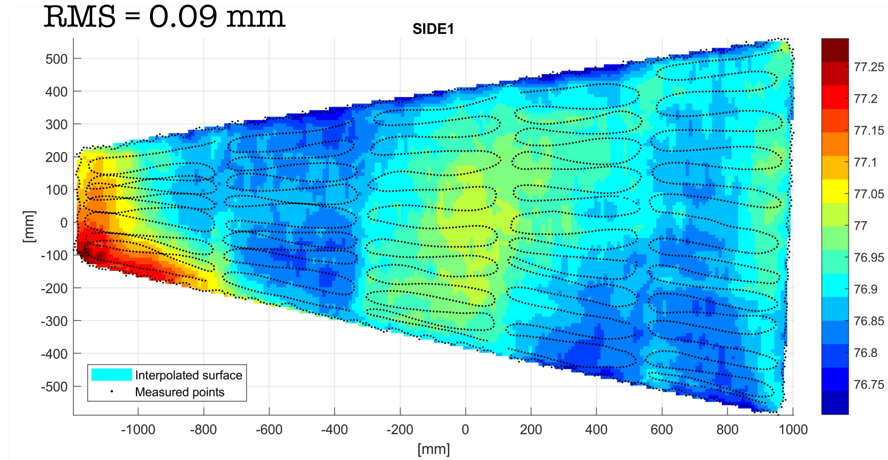
Thickness = 78.06 mm
RMS = 0.18 mm



Thickness = 77.51 mm
RMS = 0.11 mm



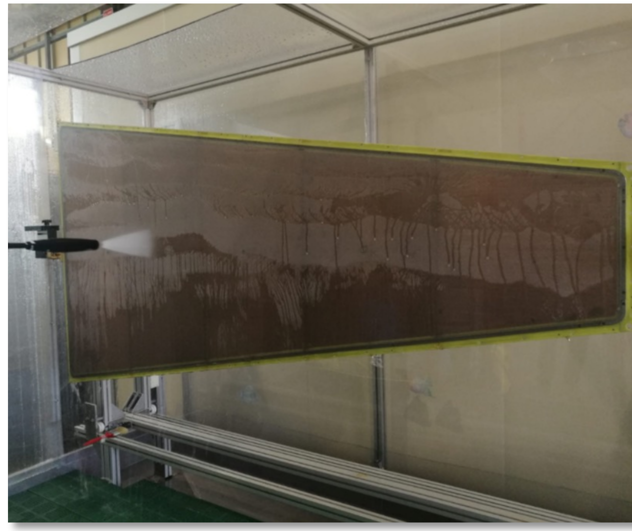
Thickness = 76.91 mm
RMS = 0.09 mm



HV stability issues: updated cleaning procedure

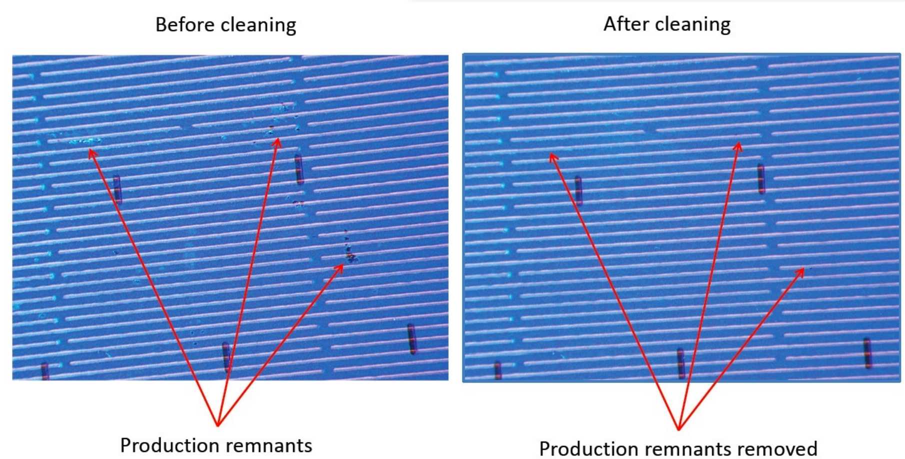
Micropolishing cleaning procedure:

- Hard and soft brushes to distribute detergents
- Accurate washing with hot and demineralized water
- Drying in a box with a ventilation system at ~40°



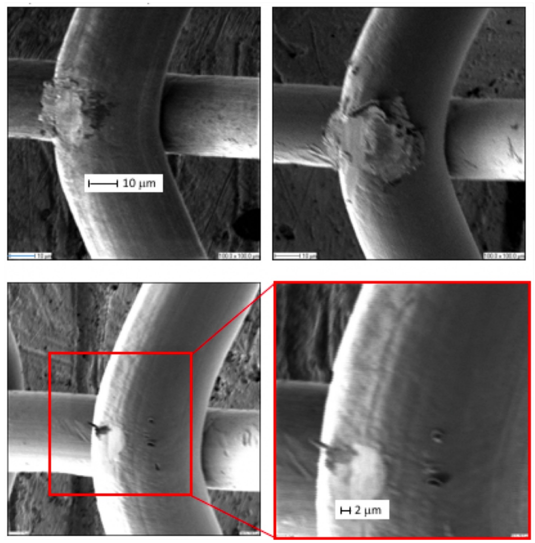
Main purpose of wet cleaning (and scrubbing):

- remove remnants from the pcb production: dirt and solid deposits from the RO boards -> mostly responsible of "ionic component"
- remove dirt from the mesh (and trapped wires/chips)



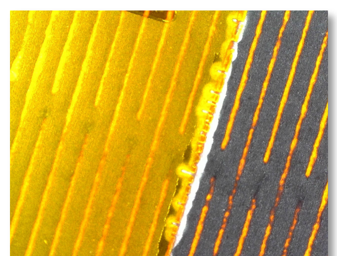
RH impact and mesh imperfections:

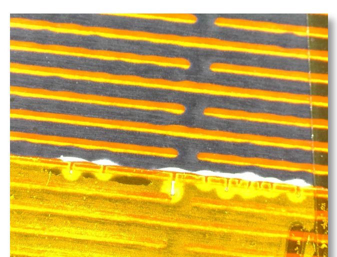
- strongly correlated to the humidity (FR4 hygroscopic)
  - Board dimension affected by humidity: ~400 µm/m from 0 to 50% RH
- Imperfections of the meshes -> Polishing required



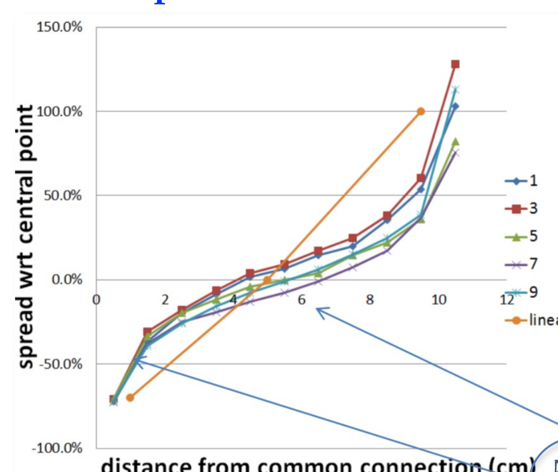
HV discharges:

- Analysis of discharges showed that in many cases they were localized on resistive strips junctions crossing the piralux rim (< 1 cm). Resistivity scheme -> **weak point** due to a low resistivity region that therefore enhances problems





Resistance variation along the strip from model



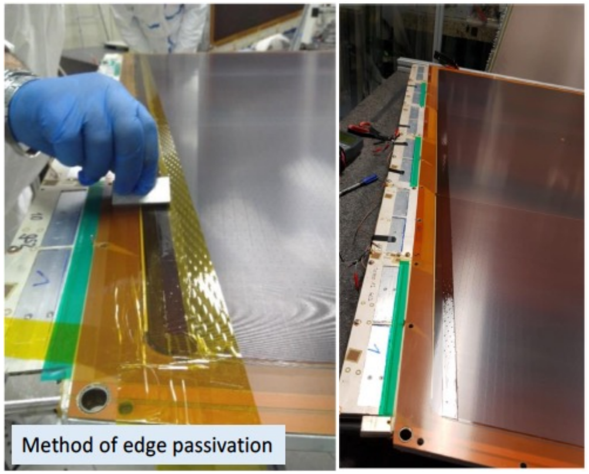
HV stability issues

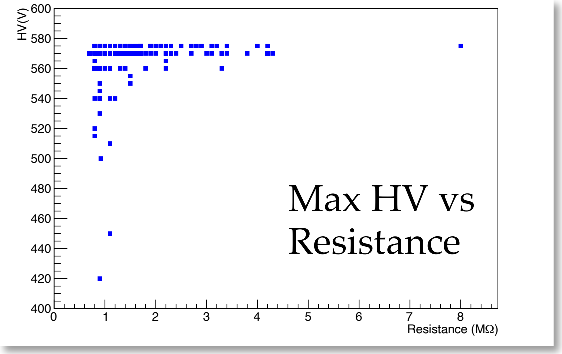
Summarizing the main issues are identified to be:

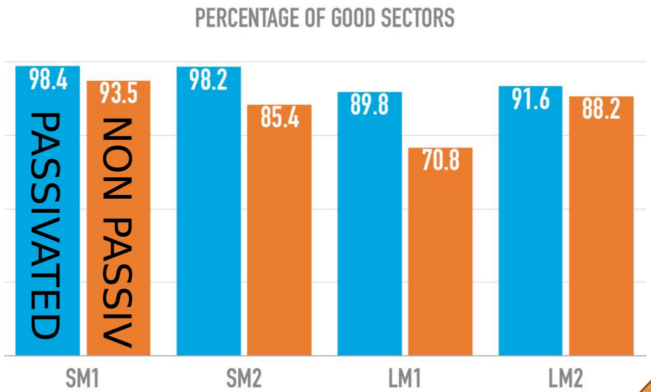
- **Residual ionic contamination** of boards and panels from industrial processing and handling

  => **improve the cleaning procedures**
- Possible effects from **mesh mechanical imperfections** => **implement mesh polishing**
- Clear **correlation of currents with humidity**

  => **monitor humidity and increase flux**
- **Low resistance of resistive layer:**
  - Strong dependence on the layout (design issue)
  - non-uniformity of the restistive paste distribution via the screen printing technique
  - **Clear correlation between HV bad sectors and R_{min}!**
  - **=> edge passivation**



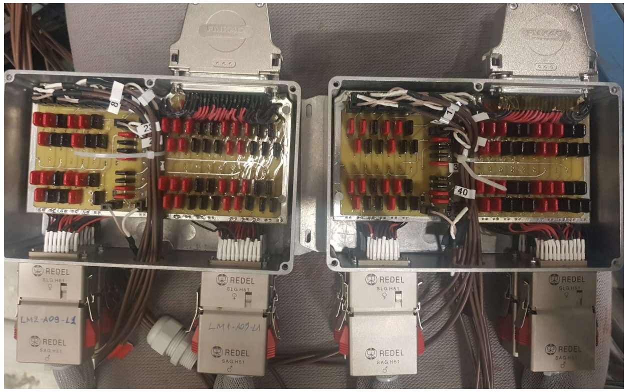




HV new scheme to cope with weak HV sections

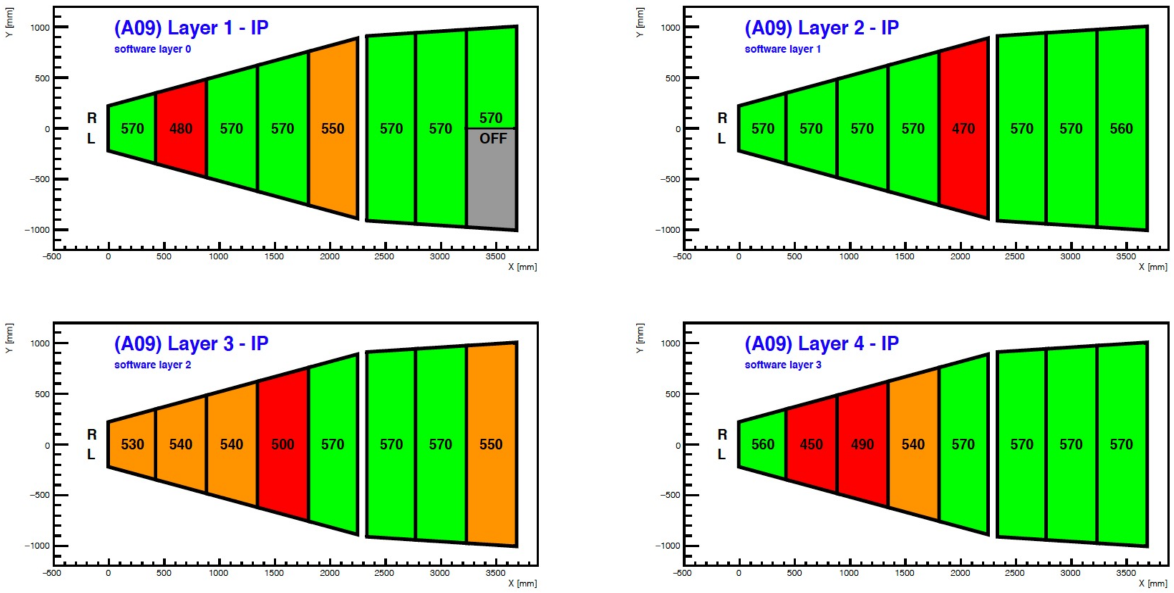
New splitter boxes needed to go from the layer granularity to the so called half granularity scheme:

- OLD: 1 HV channel per chamber layer + only 1 spare channel available per chamber (20 HV ch per DW): weak channels either OFF either at the lower HV value for each chamber
- NEW: 1 pcb per HV ch, 2 adiacent HV sections (64 HV ch per DW)!



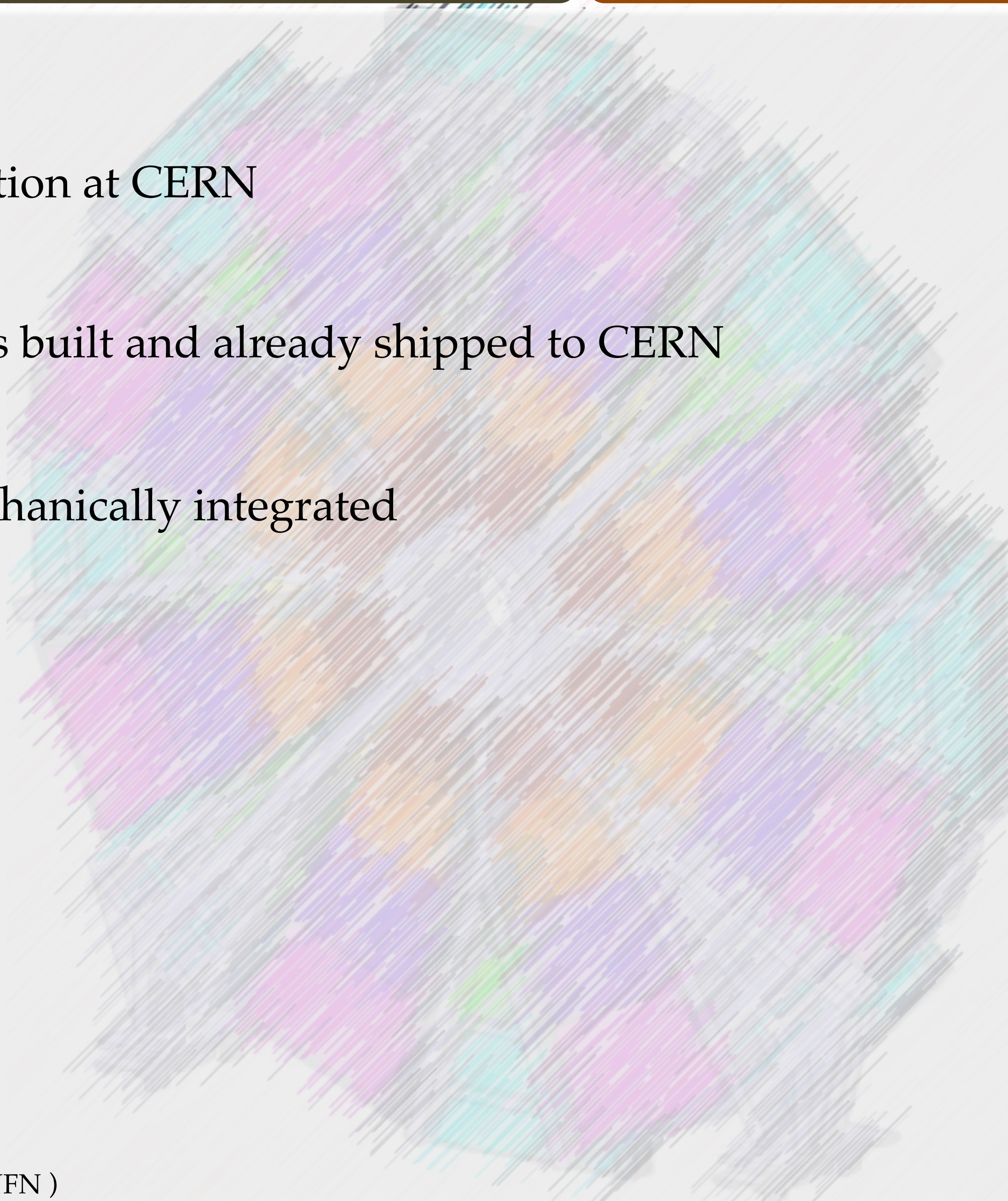
New scheme succesfully tested!

Possibility to remove jumpers to unplug bad HV sections.

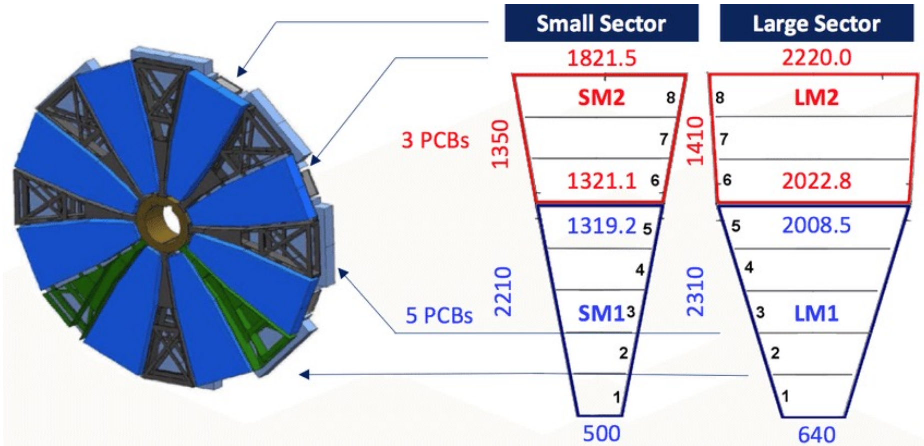


NSW at CERN

- MM integration at CERN
- All detectors built and already shipped to CERN
- All DW mechanically integrated

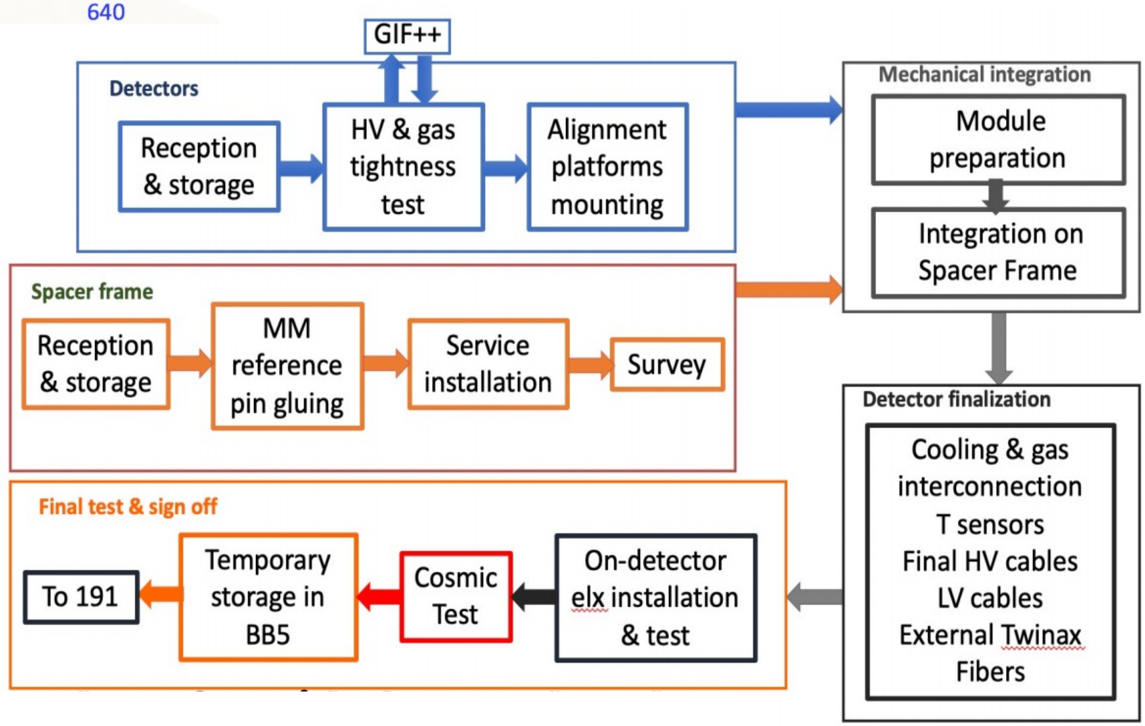


MM integration procedure



- Few chambers have been sent to GIF++ to test them under irradiation
- If chambers does not fulfill the specs: re-opening, repairing and testing again needed -> done at CERN to save time: Hospital facility + CRS2

- As we speak only 3 Large DW are missing to complete the MM integration
- **Elex availability is currently the most critical point**
  - 40-50% of the produced boards need to be fixed by replacing VMMs, or other components
  - done at CERN to save time



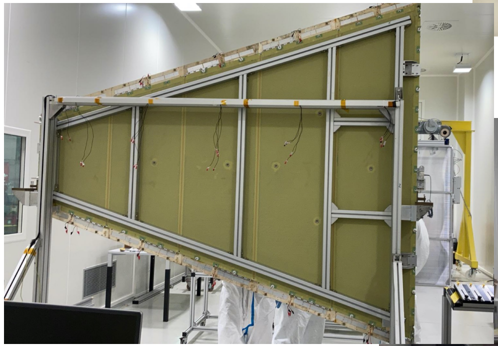
Completion expected by 6th September!

Reparation of modules in situ:

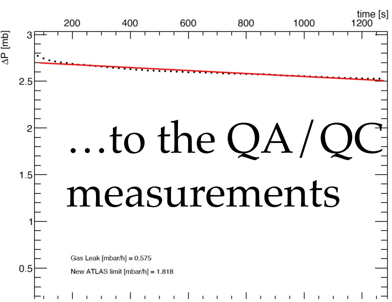
- Washing/ drying machine from LNF
- LM2 assembly table
- SM1 Assembly tool (adapted to work also on LM1 modules)
- Table to perform planarity and rasfork measurements
- **3 SM1s, 3 LM1s and 1 LM2 reassembled!**

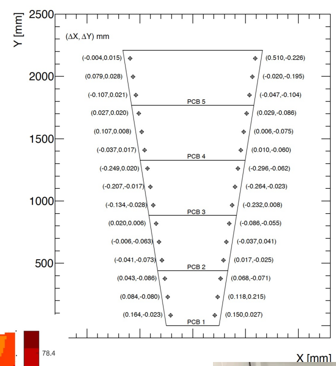
Hospital facility at CERN (LNF effort)

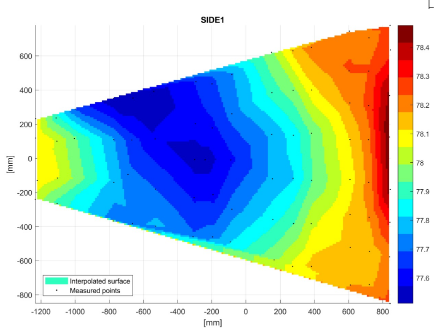
From the cleaning…



…to the QA/QC measurements



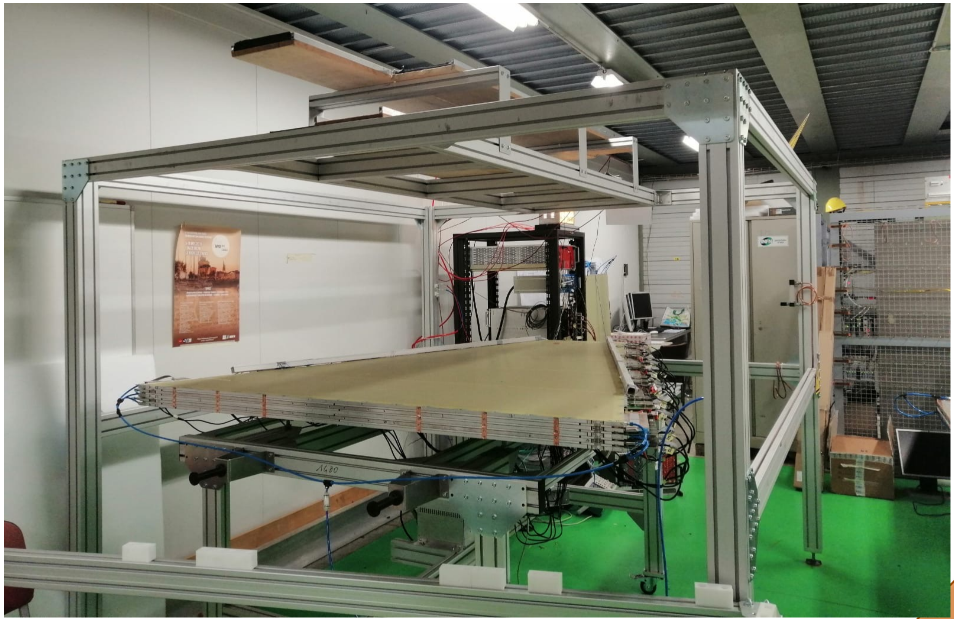




CRS2 at CERN

INFN + CERN for material and running (INFN effort)

- Scintillators for trigger and self tracking method for track reconstruction
- 1 chamber under cosmic-test and 1 vertically on the trolley for HV validation
- 21 chamber-tests (LM1, LM2 and SM1) since October 2020!
- Validation of chambers refurbiushed
- Studies of chamber behaviour under different conditions



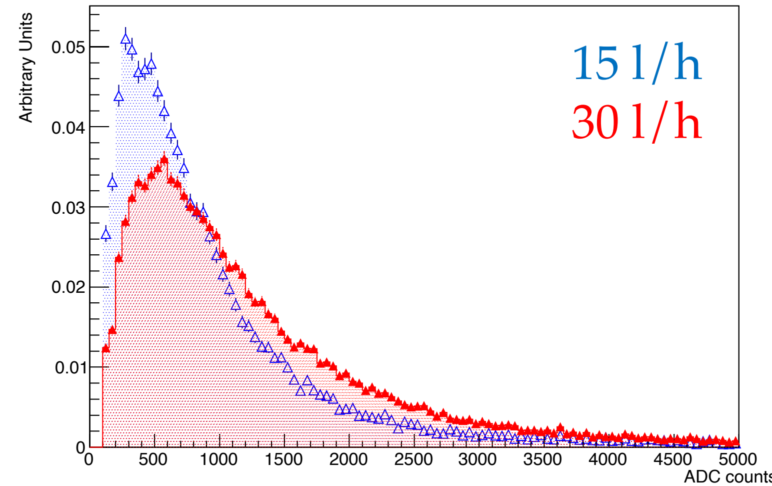
Cluster charge dependence on gas flux:

Test on the impact of the **gas leak on the performances of the LM1 Modules** in order to give green light to the module acceptance

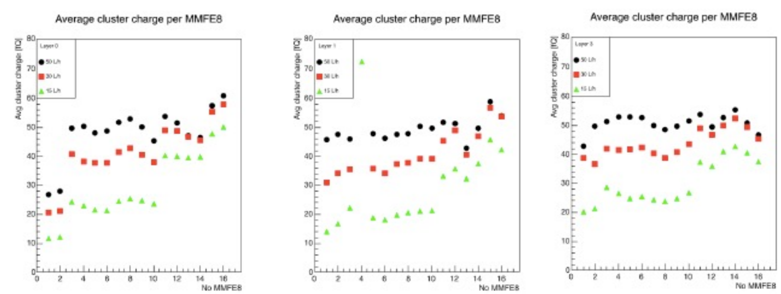
Cluster charge comparison of pcbs at 570V with high stat shows an overall increase on the cluster charge (of the order of 10-30%) as a function of the gas flux (good cluster taken into account) for the LM1 leaking chambers.

Results confirmed also by checks on non leaking chambers!

Cluster charge comparison:



A05 DW tests



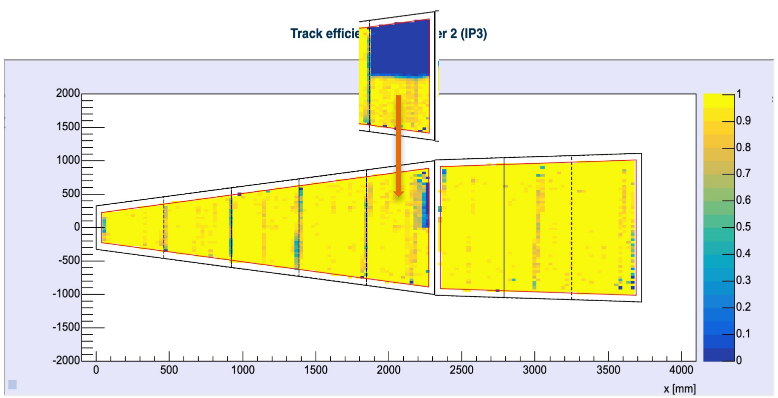
Gasflow [L/h per wedge]	Tracking efficiency [%]	<Cluster charge> [fC] per layer (software layer-0 to layer-7)
50	87.9	49.1; 50.6; 35.2; 51.2; 49.1; 45.0; 44.8; 49.0
30	86.4	43.8; 43.0; 33.0; 45.0; 43.0; 43; 0 41.0; 44.4
15	83.6	35.3; 31.7; 27.8; 34.2; 33.4; 37.9; 33.1; 37.6
Cluster charge reduction from 50 to 15 L/h		28%; 37%; 21%; 33%; 32%; 18%; 26%; 23%

Data taking having sections drawing uA of current

Tested both in Ar-CO_2-Iso and Ar-CO_2:

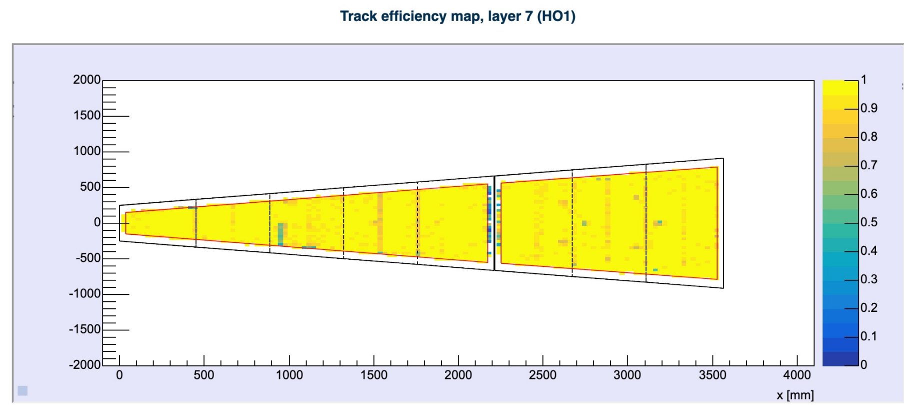
- Instead of having OFF sections we only loose few cm, ~20 strips of the whole layer
- Typical resistance of O(5-10 MOhm) -> weak known points
- Resistive layout allows for Voltage drop only on small region

A07 Ar-CO_2-Iso @ 520V

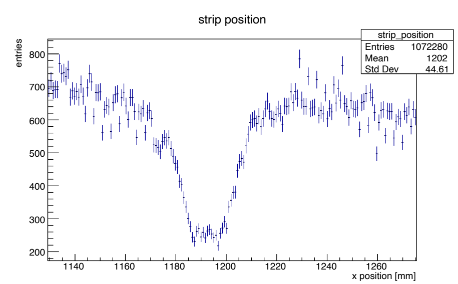


IP L3R5: 5 MOhm

C16 Ar-CO_2 @ 570V

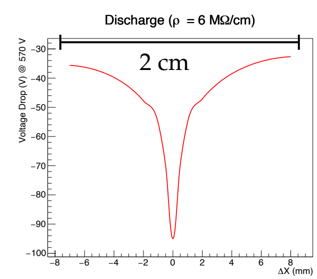


HO L1R3: 6 MOhm



'hole' reveals resistor's place (20 strips wide)

Simulation of short in 1 strip

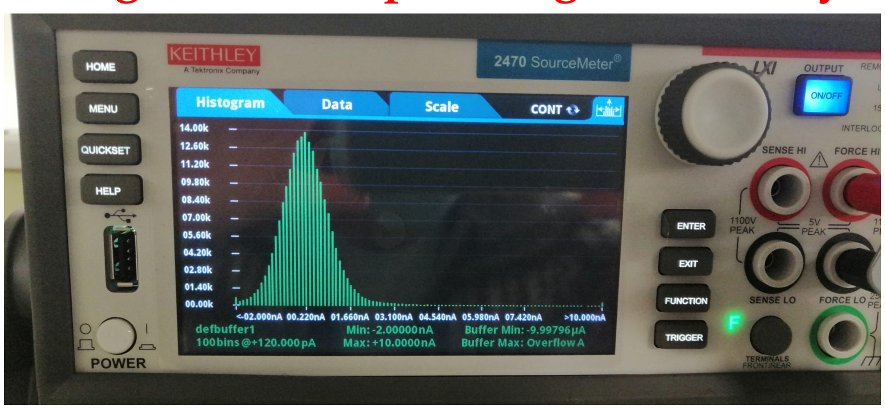


The idea: try to use pure Argon to clean the region by means of sparks -> need to stay in the working region

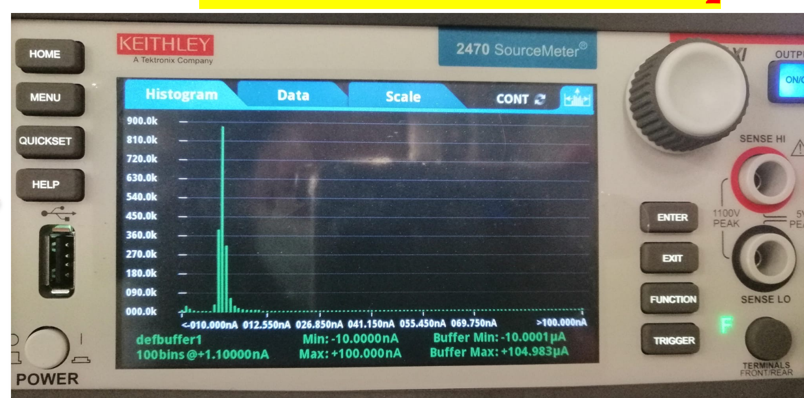
Recovery procedure tried in pure Argon for SM1 M31 at CRS2 (with RD51 team)

- One highly problematic channel (L4L3: high current and spikes above 350 V) powered with the Keithley power supply up to 460 V in pure Argon
- We used a very good sector to define the break down HV in pure Argon: 480 V
- Then tried to go slowly up to that value using Keithley

Overnight at 430 V pure Argon, next day up to 460 V

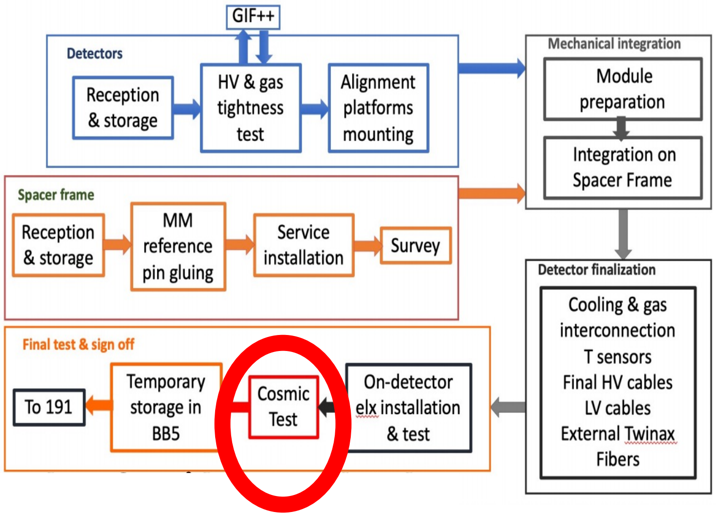


L4L3 At 530 V in $ArCO_2$



Succesfull also on other few attempts! Promising!

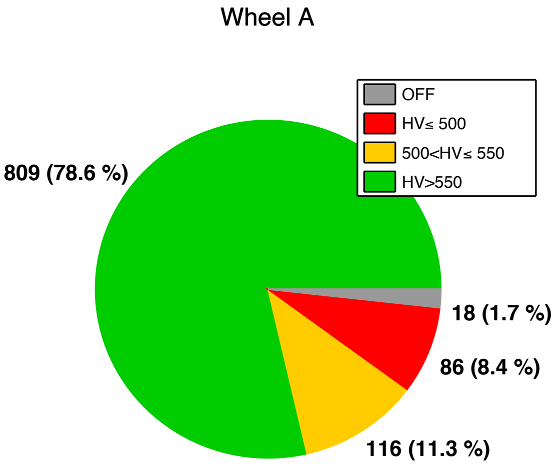
Last step in BB5: DW test at the CRS

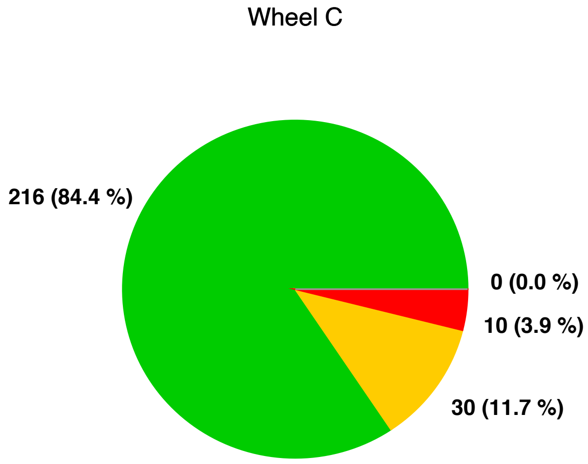


- We are able to test 2 sectors in parallel -> gave a consistent speed up
- Allows to validate 1 MM DW per week!
- Many tests carried out

Fraction of good sections in terms of HV

BB5

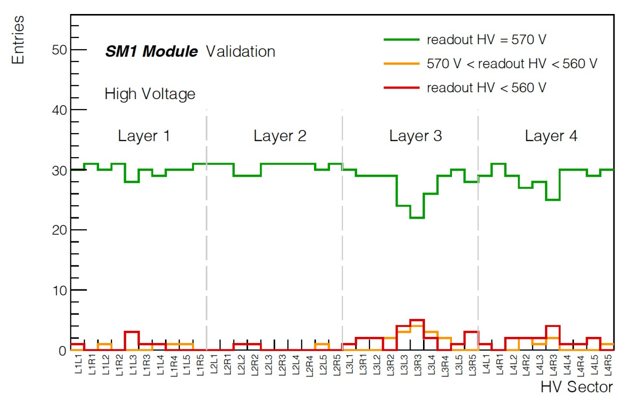




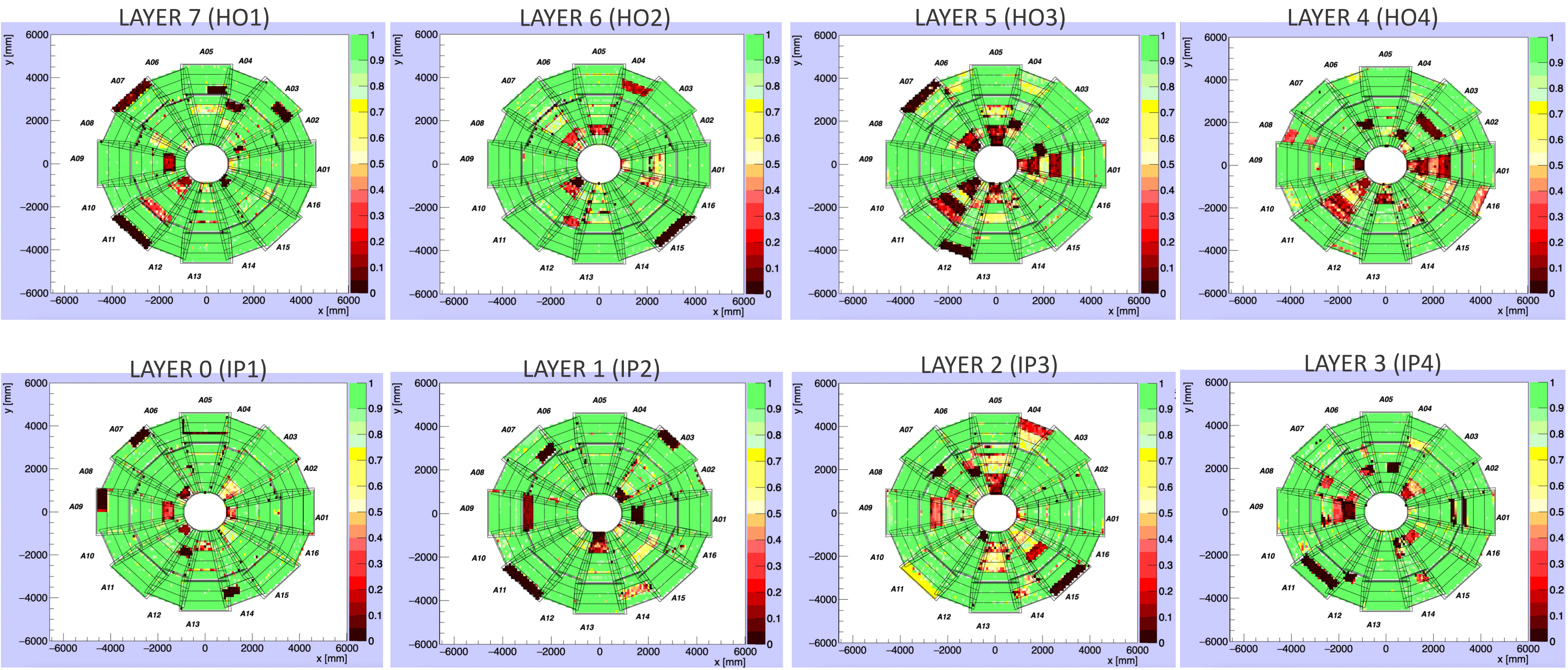
- Improved percentage of good sectors
- No OFF sections ;)

The status presented so far is very conservative:

- Most of the small sectors tested with the layer granularity scheme in bb5
- Still not taken into account the possibility of adding Isobutane to the gas mixture
- High current sections were OFF
- Weak points identified:
  - pcb3 of SM1 weak resistance
  - pcb8 of LM2 and pcb5 of LM1 on the corner not good isolation

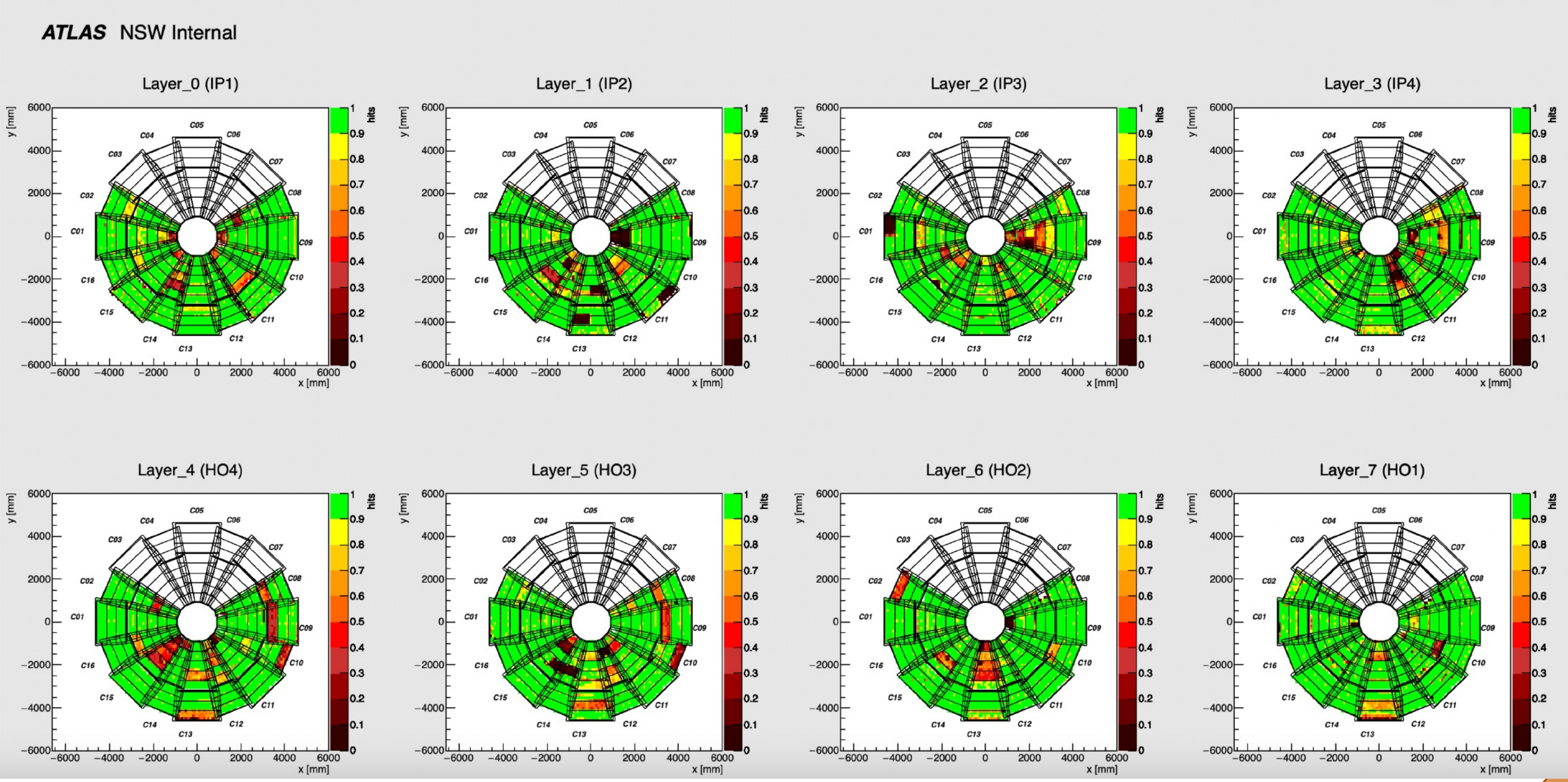


Display *on the wheel* of the measured efficiency for each layer of the **NSW A** and early NSW C measured with cosmics at the DW CRS in bb5



Remember that most of the NSW A has been tested with the old-HV scheme, not optimal

Display *on the wheel* of the measured efficiency for each layer of the NSW A and early **NSW C** measured with cosmics at the DW CRS in bb5

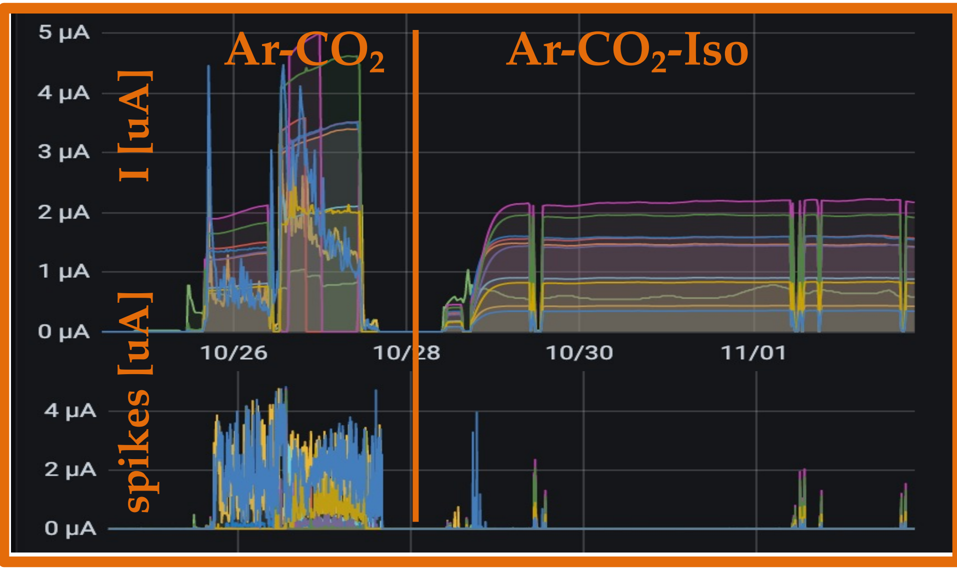


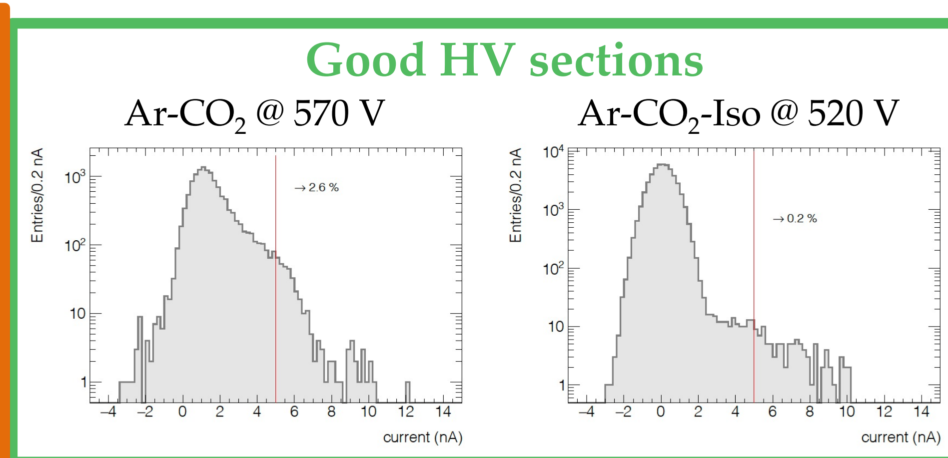
Isobutane addition to the gas mixture

Testing Iso enriched gas mixture at GIF++

Ternary gas mixture (Ar-CO_2-Iso 93-5-2):

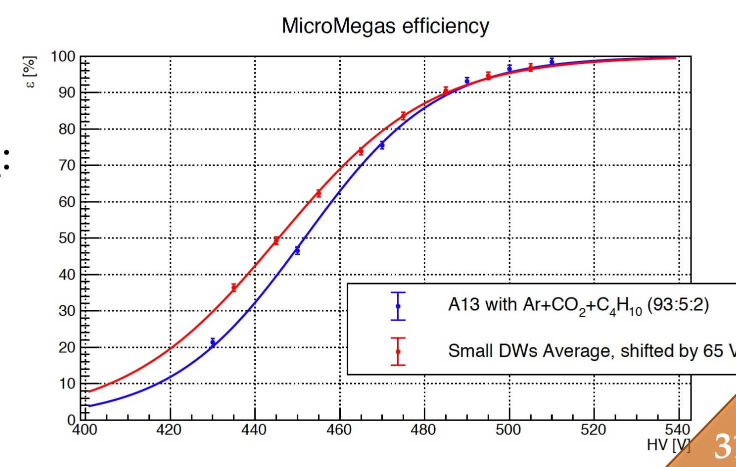
- **Iso allows to run at significantly lower amplification voltages**
- **Bad** HV-sectors behave better with the Isobutane enriched mixture
- Iso improves the sparking picture for NSW MMs





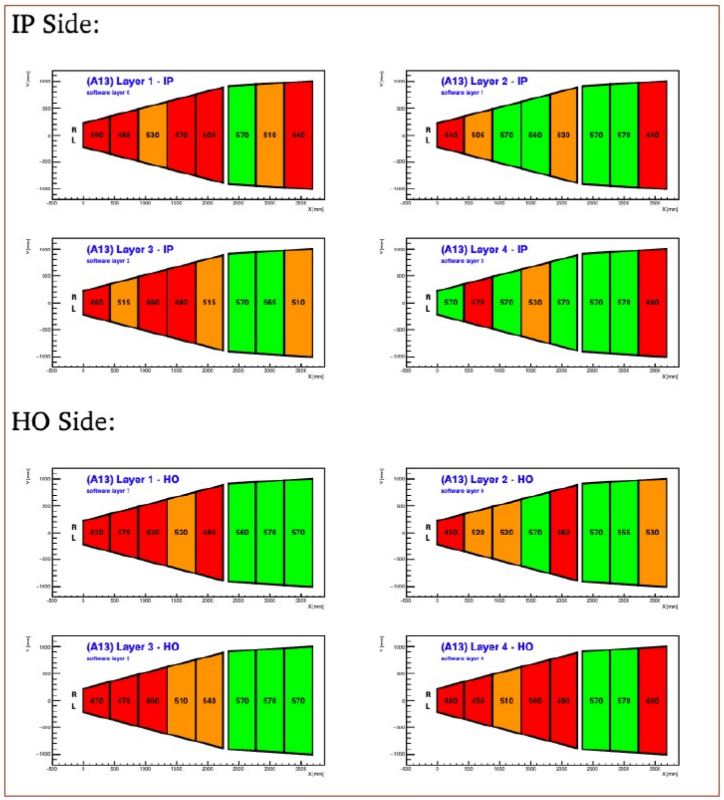
iC$_4$H$_{10}$ allows to lower the working HV, wrt 570 V in Ar-CO_2:

- Same efficiency @ 495 V
- Same cluster charge @ 507 V
- Higher gain (+30%) for uTPC @ 520V



HV picture of oldA13 under binary and ternary gas mixture:

$Ar:CO_2$ 93:7 vol%
nom. HV: 570 V



insufficient performance

green:
sector is on
nominal HV

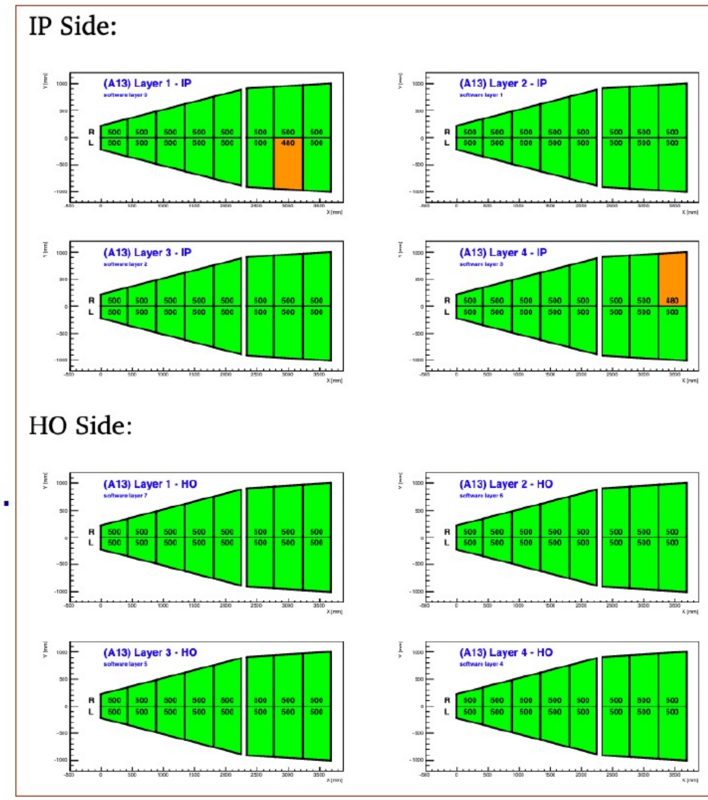
red:
sector is below
nominal HV

-2% of CO2

+2% of Isob.

non-burning
non-explosive
gas-mixture

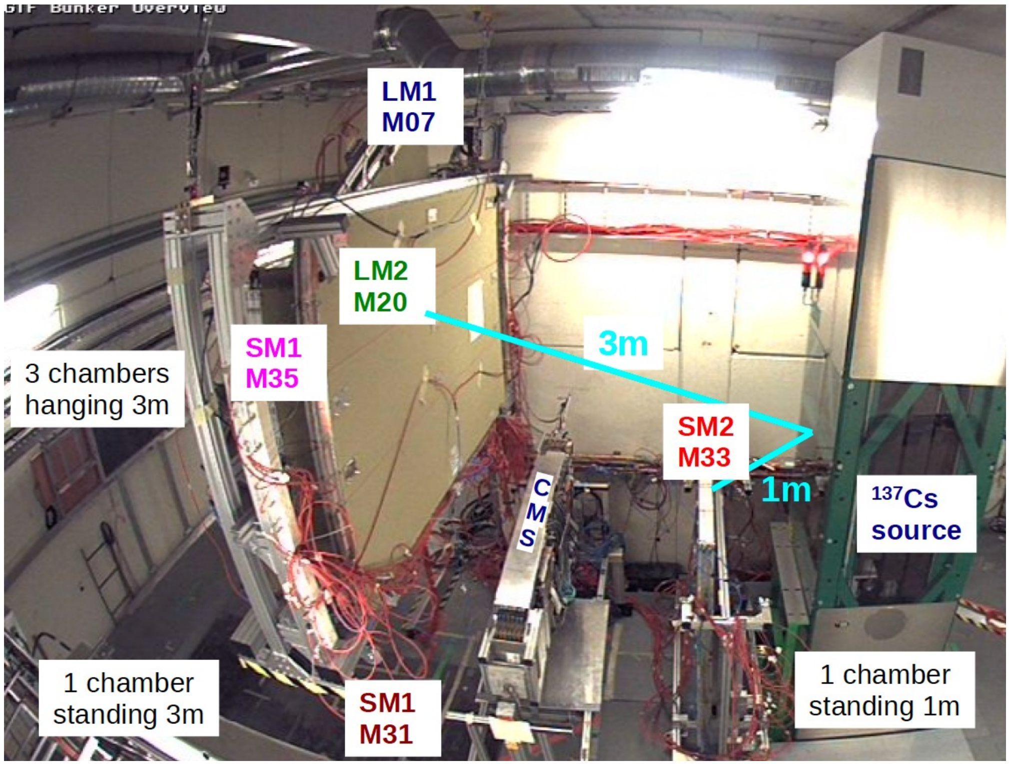
$Ar:CO_2:iC_4H_{10}$ 93:5:2 vol%
HV: 500 V

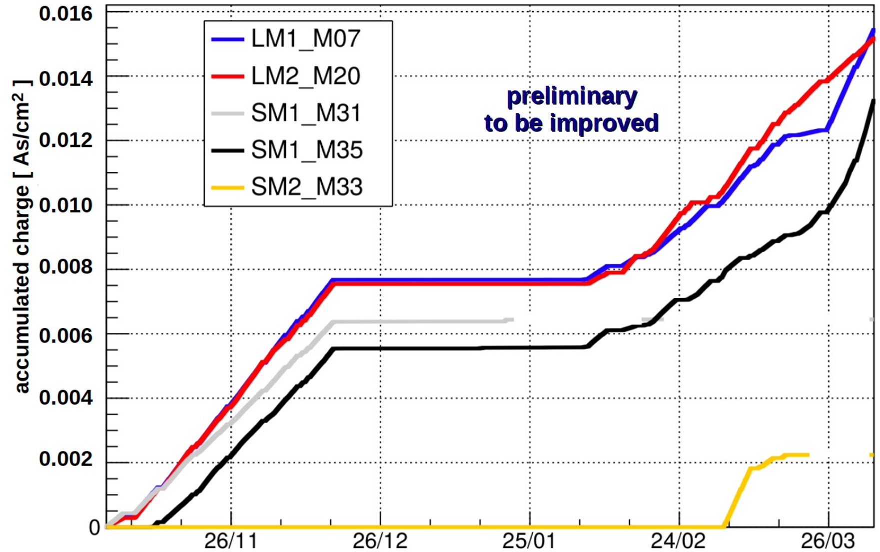


almost perfect performance
similar efficiency @ cosmics

substantial improvement of the performance of DW A13 using Ar:CO2:iso 93:5:2 vol%

^{137}CS 662 keV Gammas 14 TBq 15 kHz/cm^2 at 3m distance





- irradiation of 5 chambers at the same time
- all four chamber types were irradiated
- ≈ factor 10 variation in kHz/cm^2 at 1-3m distance

Goal: reach O(As/cm^2) of accumulated charge to compare with HL LHC! -> 0.015 As/cm^2 accumulated at April 2021

1m Distance: 3 months, 1Cb/cm^2 = 1year of HL-LHC)

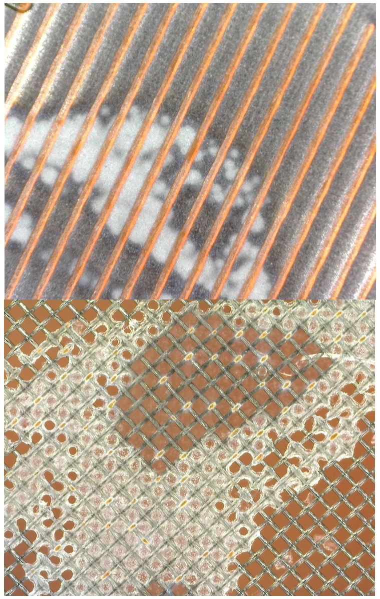
Aim to reach within 2021 about 3 years of HL-LHC allowing Iso validation for Run3!

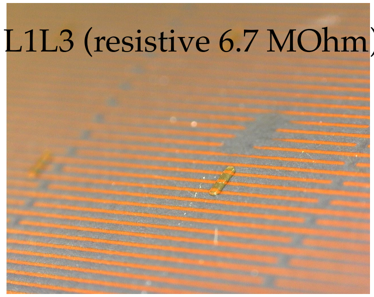
Isobutane long term studies at GIF++

SM1 M31 (1 month at GIF, 6 mAs/cm^2):

- This chamber experienced 2 sectors going bad under Iso-run
- Has been reopened and inspected for hydro-carbon remnants or carbon deposit due to isobutane -> the issues as been identified as weak points (glue on the mesh, resistive blob)
- No issues to be related to isobutane found
    - both spots were removed to be investigated further by cutting off the resistive layer and Araldite protection applied -> nothing found
- After reassembly the chamber was perfectly working and tested with cosmics
- **Defects lead to bad behaviour independently to the gas mixture!**

L3L2 (glue on the mesh)

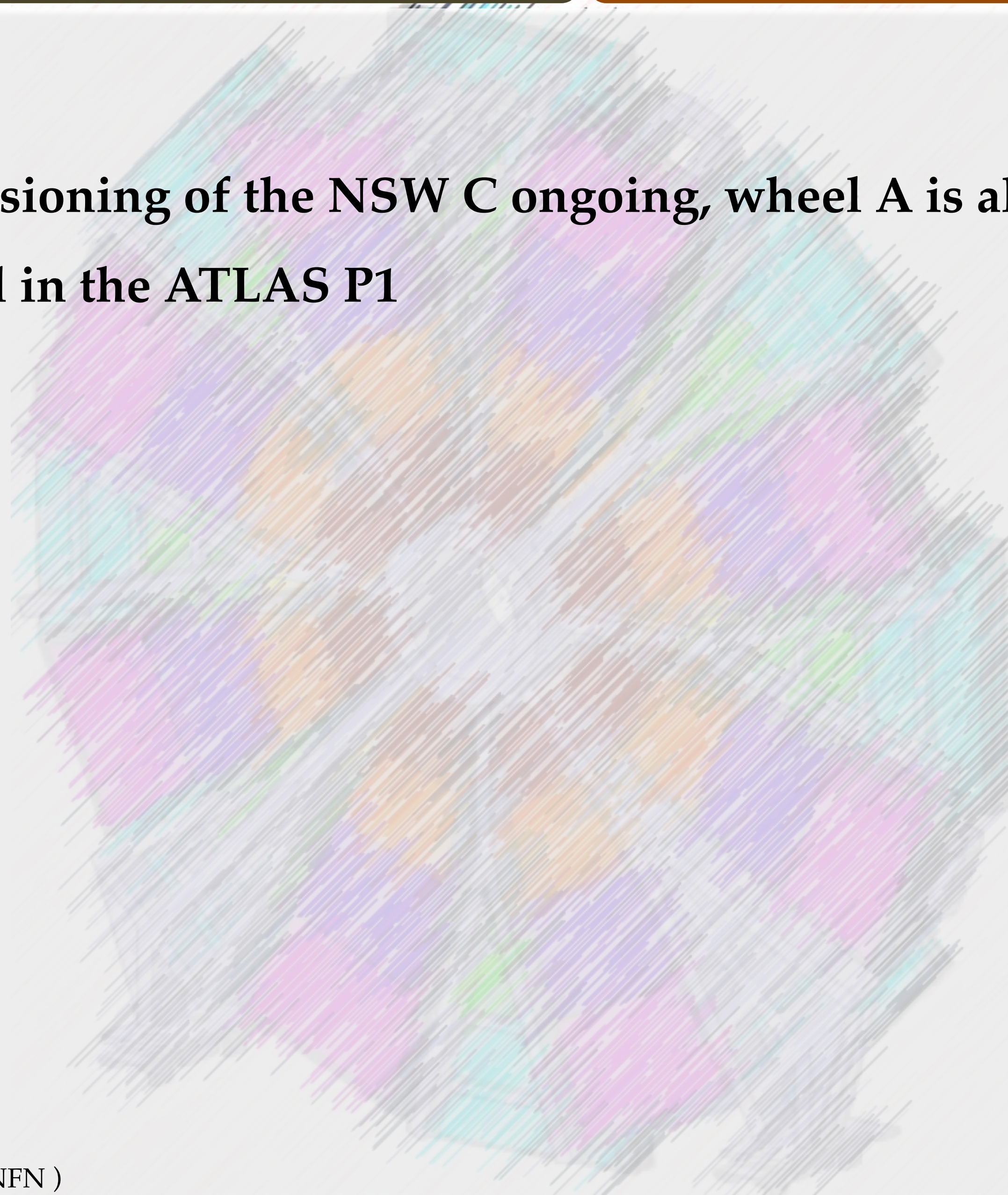




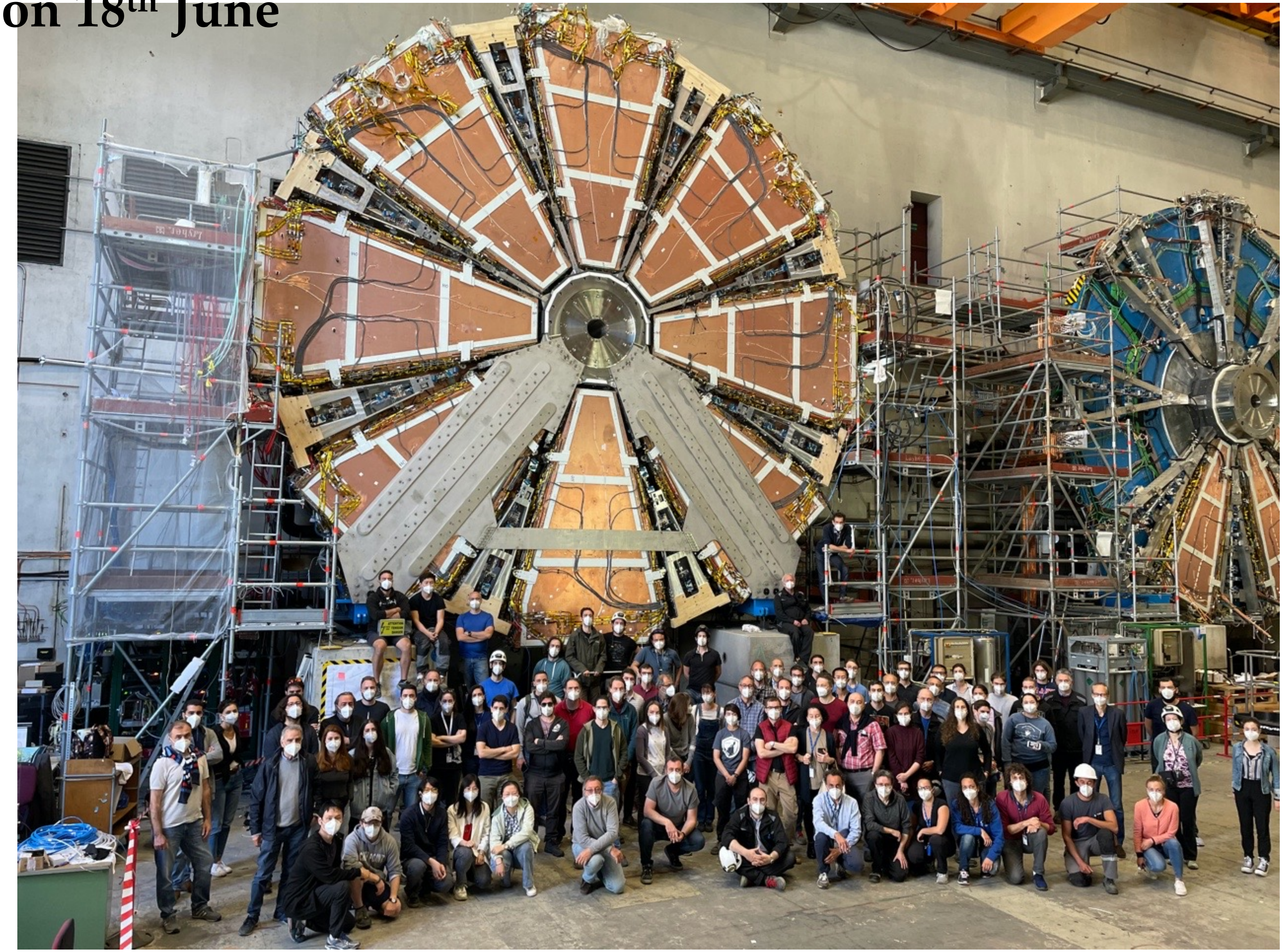
Sector (Layer PCB side)	HV [V]	Efficiency [%]	Sector (Layer PCB side)	HV [V]	Efficiency [%]
L1 1 pin (L)	570	98.6	L2 1 pin (L)	570	98.6
L1 1 no-pin (R)	570		L2 1 no-pin (R)	570	
L1 2 pin (L)	570	98.2	L2 2 pin (L)	570	98.8
L1 2 no-pin (R)	570		L2 2 no-pin (R)	570	
L1 3 pin (L)	570	98.4	L2 3 pin (L)	570	98.8
L1 3 no-pin (R)	570		L2 3 no-pin (R)	570	
L1 4 pin (L)	570	98.5	L2 4 pin (L)	570	98.0
L1 4 no-pin (R)	570		L2 4 no-pin (R)	570	
L1 5 pin (L)	570	95.0	L2 5 pin (L)	570	96.4
L1 5 no-pin (R)	570		L2 5 no-pin (R)	570	
L3 1 pin (L)	570	98.0	L4 1 pin (L)	570	91.4
L3 1 no-pin (R)	570		L4 1 no-pin (R)	570	
L3 2 pin (L)	530	88.8	L4 2 pin (L)	560	95.4
L3 2 no-pin (R)	570		L4 2 no-pin (R)	570	
L3 3 pin (L)	570	97.4	L4 3 pin (L)	570	95.9
L3 3 no-pin (R)	570		L4 3 no-pin (R)	570	
L3 4 pin (L)	570	94.2	L4 4 pin (L)	570	97.2
L3 4 no-pin (R)	570		L4 4 no-pin (R)	570	
L3 5 pin (L)	570	97.5	L4 5 pin (L)	570	95.5
L3 5 no-pin (R)	570		L4 5 no-pin (R)	570	
Module area at 570 V: 96.1 %			Mean efficiency = 96.5 %		
Total module bad sectors (HV < 550 V): 1 (2.5 %)			Mean efficiency without bad PCBs (1) = 96.9 %		

NSW A and C

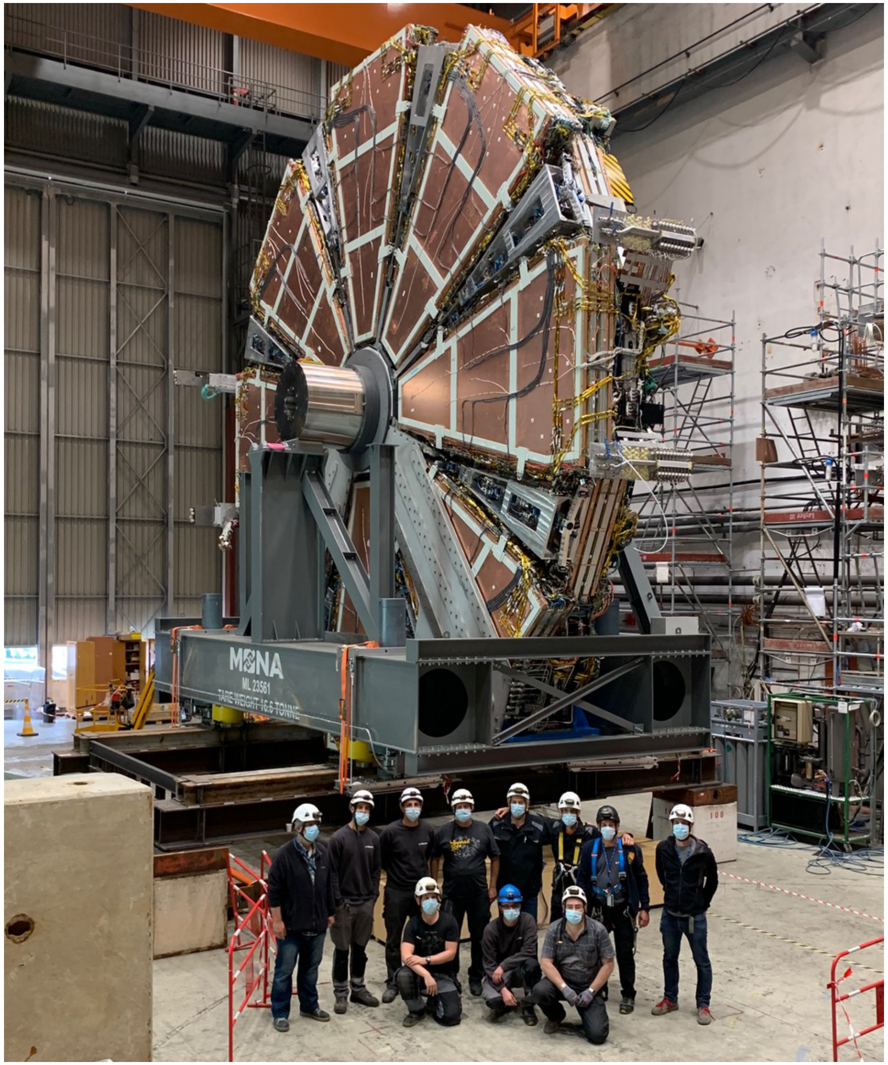
Commissioning of the NSW C ongoing, wheel A is already being installed in the ATLAS P1



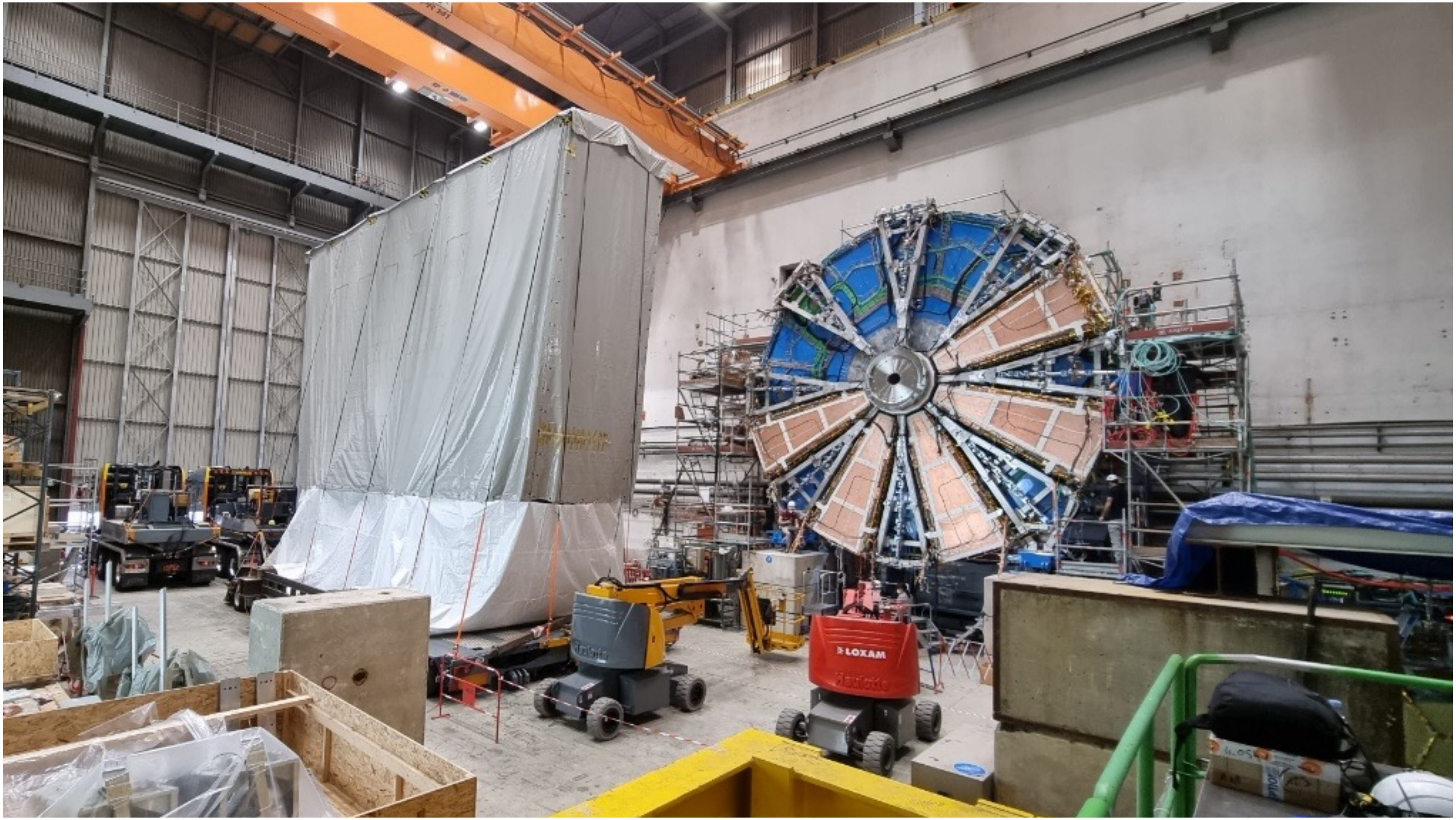
Ready on 18^{th} June



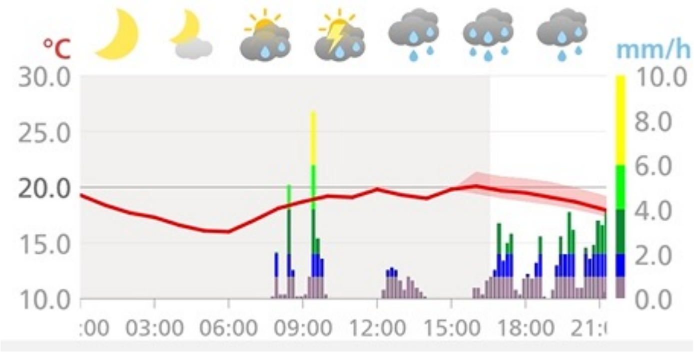
The following weeks…



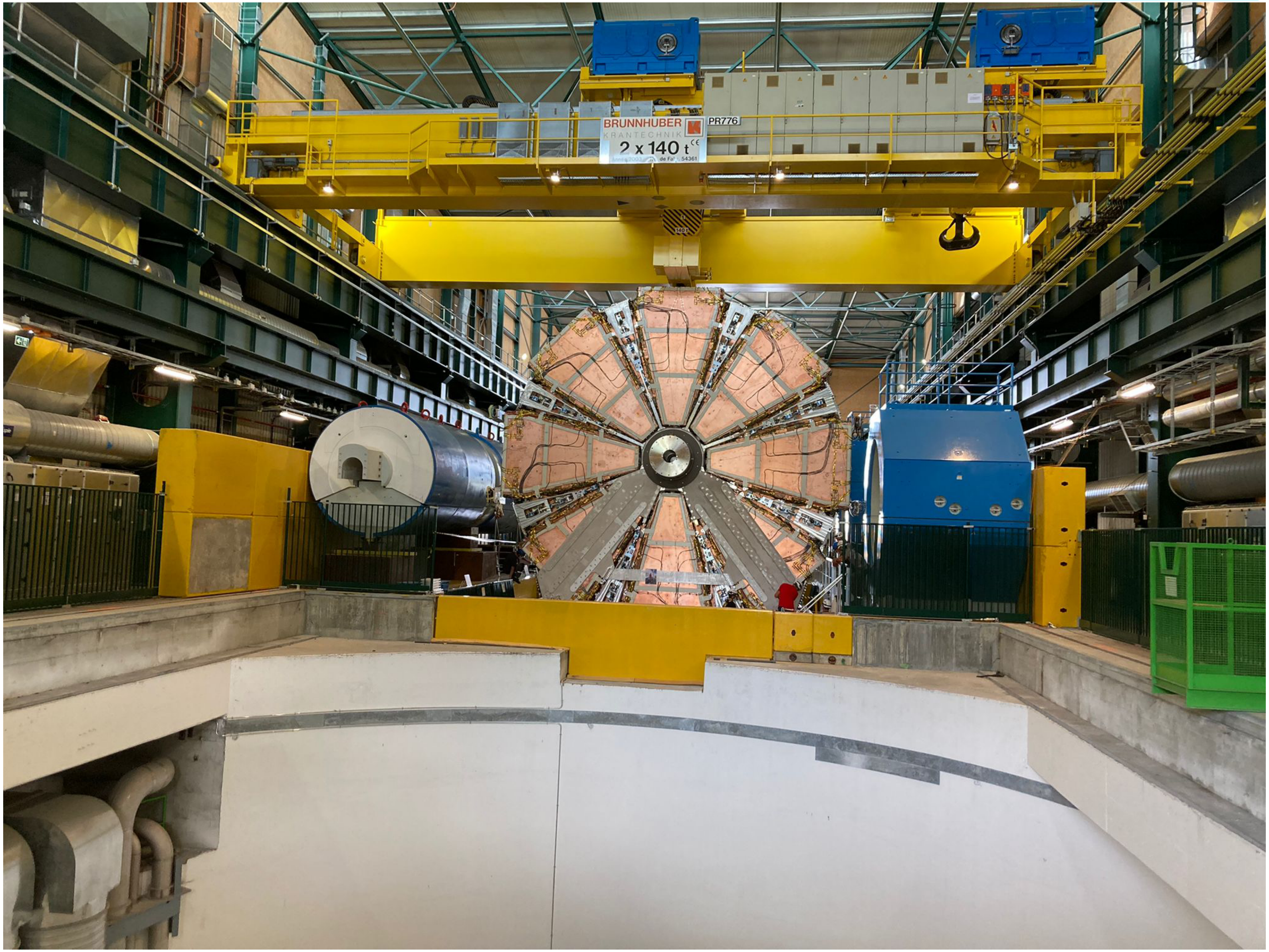
Transport on 6th July



Transport on 6th July

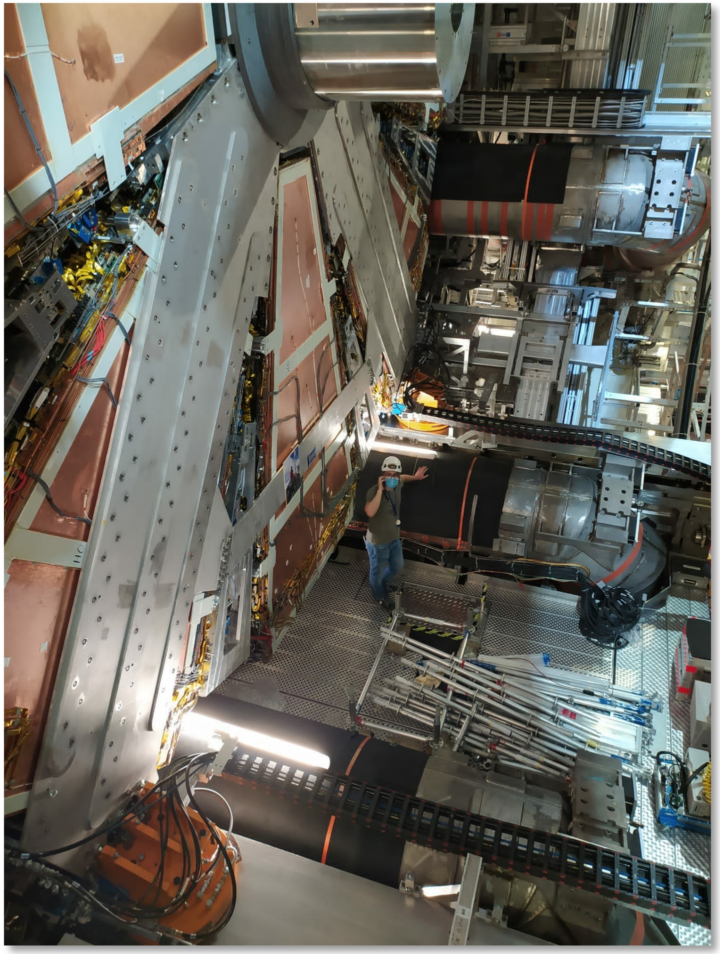


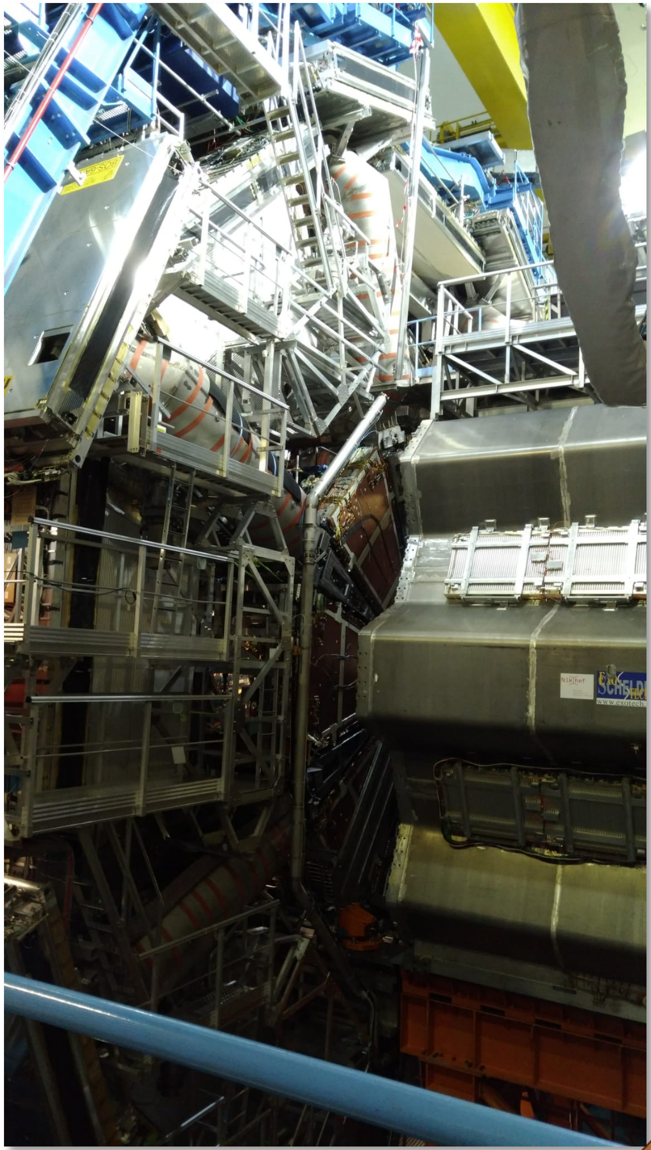
Down in the cavern on 12^{th} July

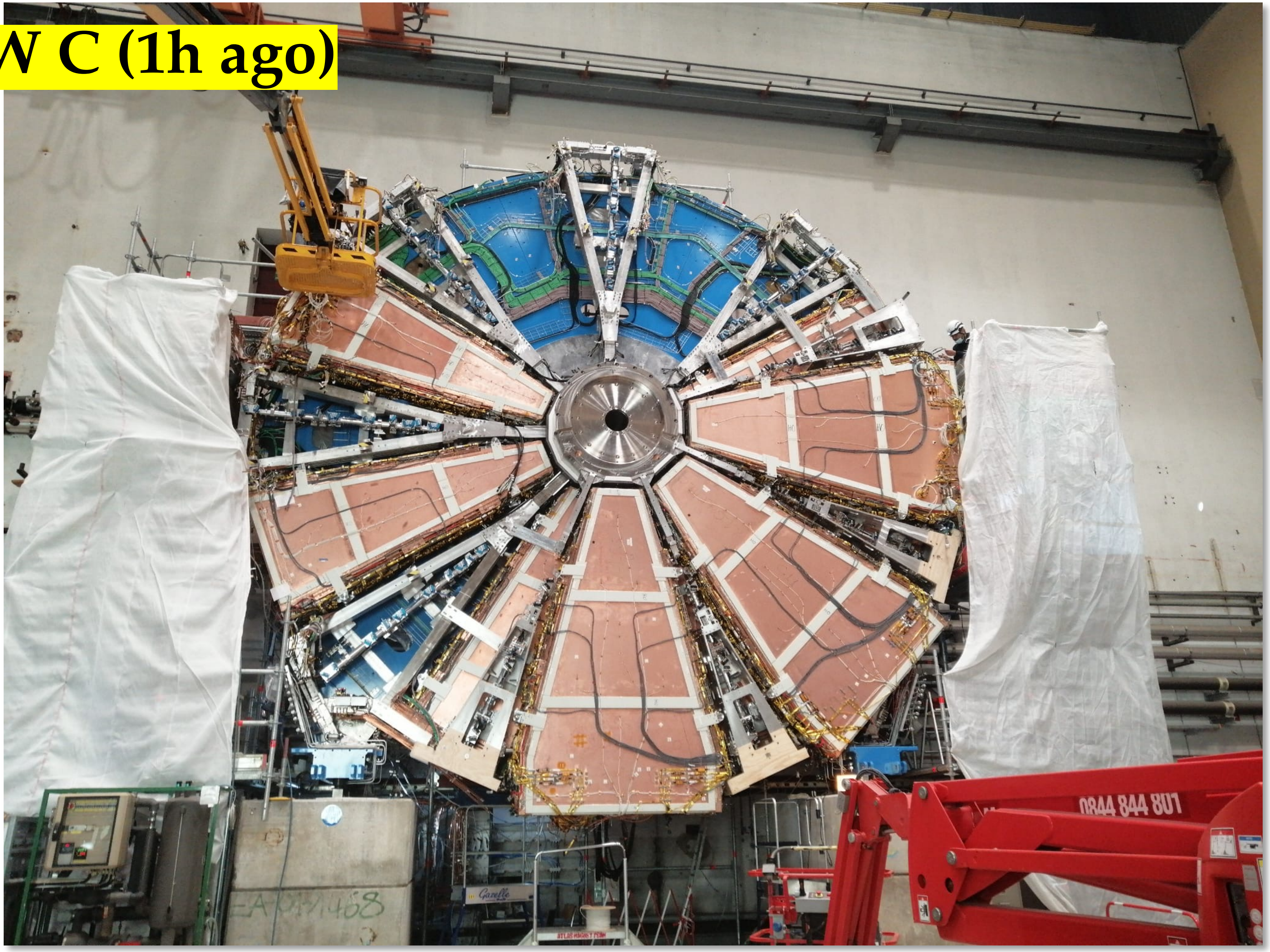


Currently in the cavern:

- Connecting the wheel A services
- Testing HV connections
- To be ready be the end of this week






NSW C (1h ago)
0844 844 801

Installation of sectors

- MM DW to the balcony
- sTGC integration
- Installation on the wheel

Commissioning 191

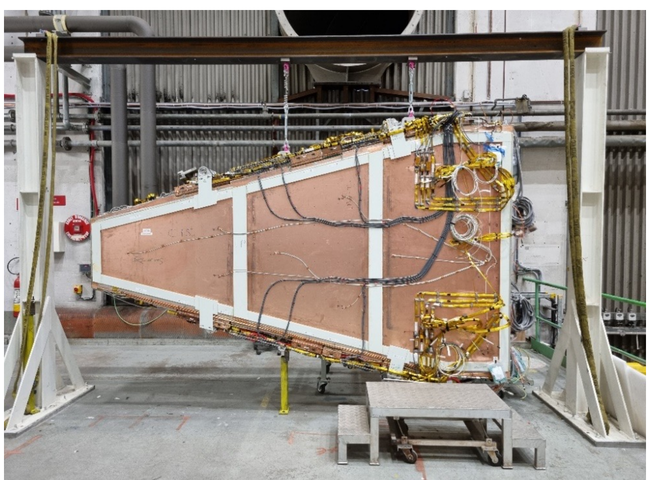
With the latest setup we have managed to fully commission sectors in 2 days (after service installation)!

Gas Connections → Gas Leak Tests → Gas Flush → HV validation

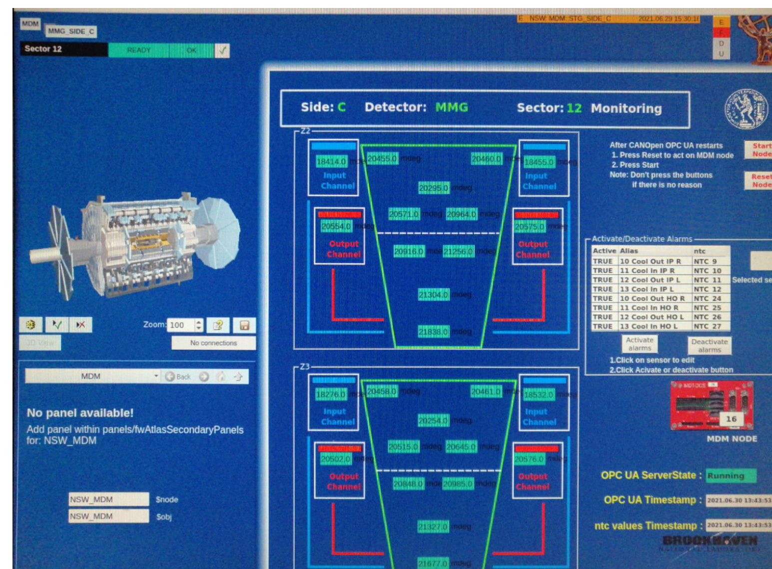
Cooling connections & LV cable/fiber routing → Fiber connections → Elx & trigger commissioning

Commissioning can be done with 3 sectors in parallel

Sectors are fully checked on the balcony (when MM Double Wedges are integrated with sTGC Wedges) before the on-wheel installation

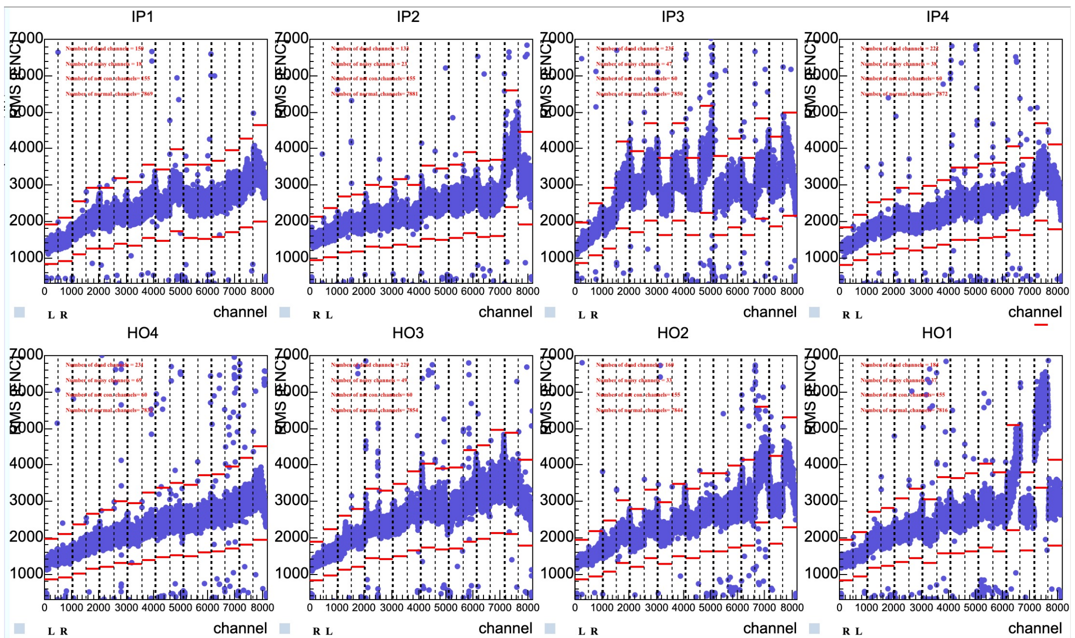


Cooling temperature is checked constantly



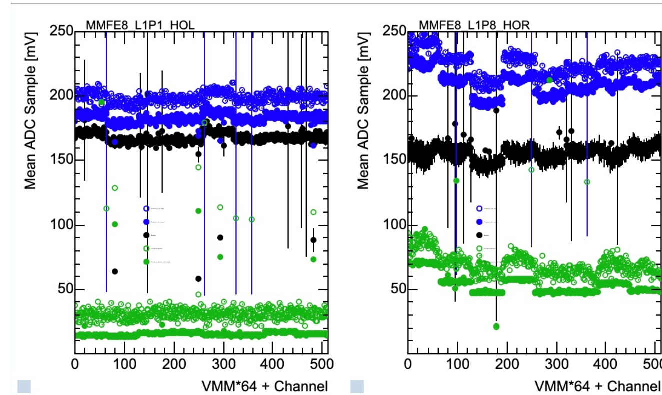
LV, DAQ and Elx:

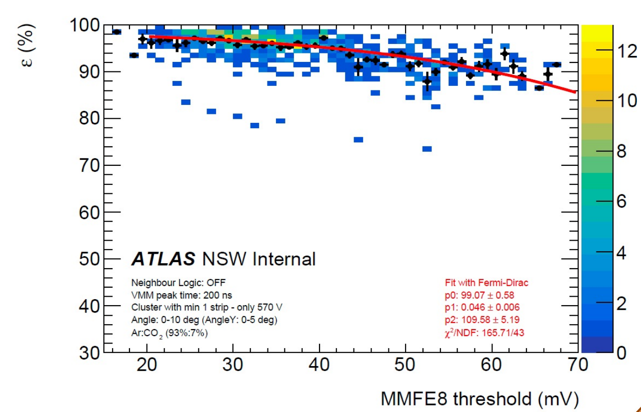
- Elx noise issue has been faced during wheel A commissioning -> **not affordable!**



- Baseline RMS has a dependence on the strip length
- For the shortest strips, it deviates from the linear trend, expected in the approximation of microstrip as ideal parallel capacitor

The **effective threshold** is the difference between the **absolute threshold** and the **baseline**) and is equalized using the peculiarity of VMMs to decrease the single channel threshold in a [0,30]mV range reducing the threshold spread





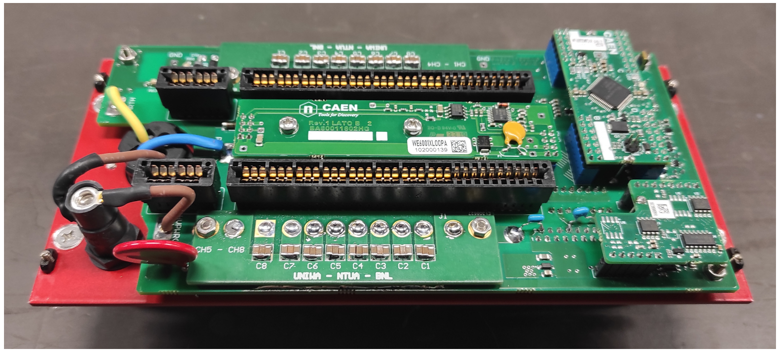
Noise issue addressed!

Several studies performed by the MM community with the help of external experts

Main issues identified in the grounding quality and in the power distribution!

Solutions:

- Adding clamp-braids on PCB 2/5/6/8 to spacer frame
- Grounding reinforced on large base
- Implementations of faraday cages on trigger elex boards on the chamber
- **Power Distribution**
    - ICS refurbishment (Low Voltage power supply)
        - Adding output common mode filter capacitive filter to cut the common mode noise (2-10 MHz)
        - Grounding the floating handle
        - Minimizing the loop of input cable
    - Improved grounding of the power modules of the T-sensors (B-sensors for sTGC)

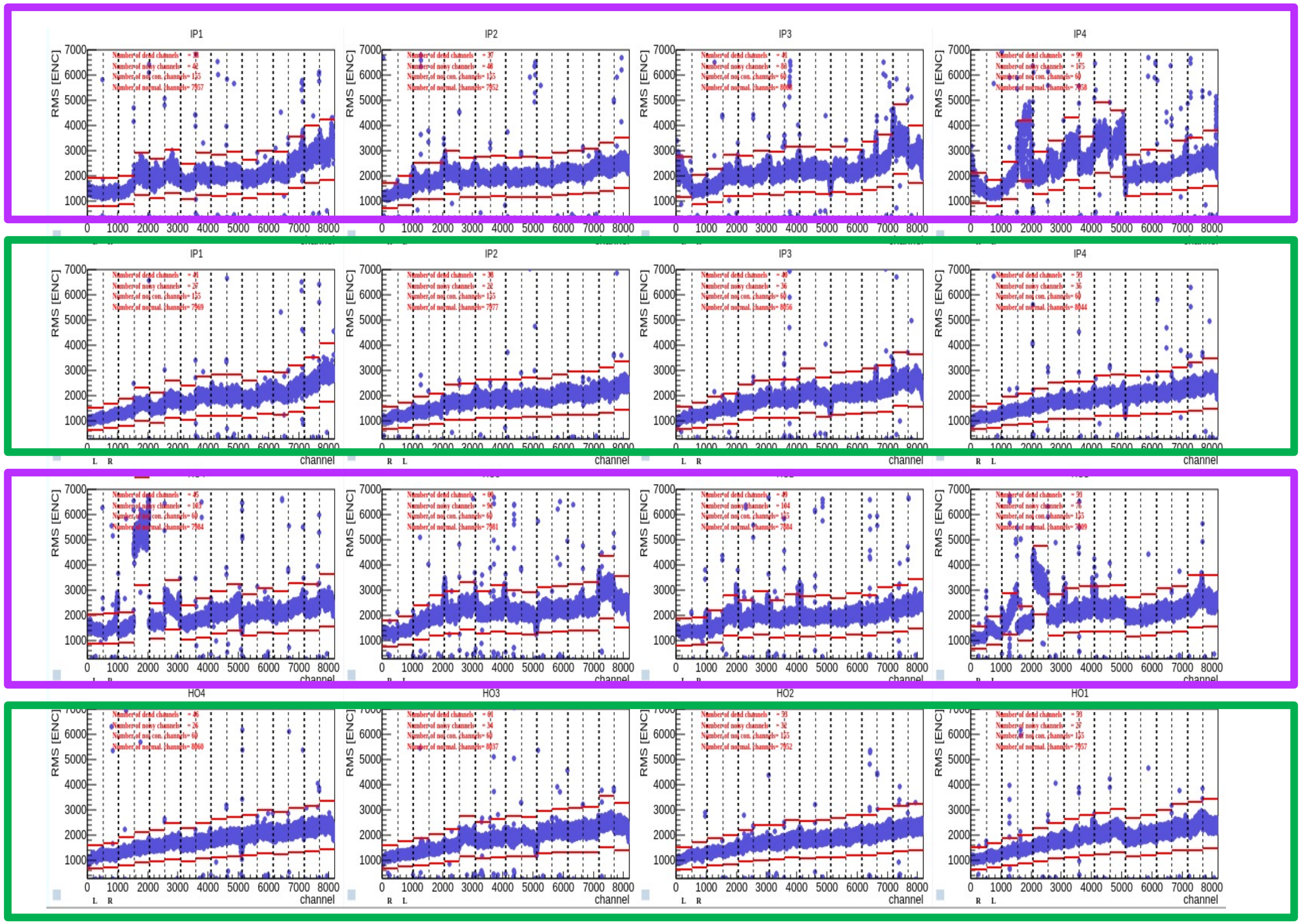


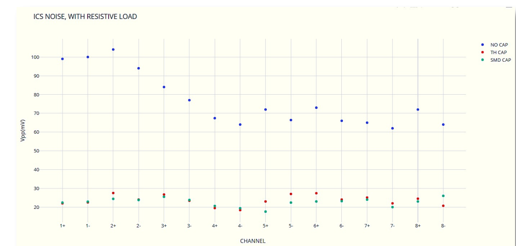
Similar issue observed by sTGC with similar solutions

Noise issue addressed!

Noise issue addressed!

Before and after (braids +ICS modifications)



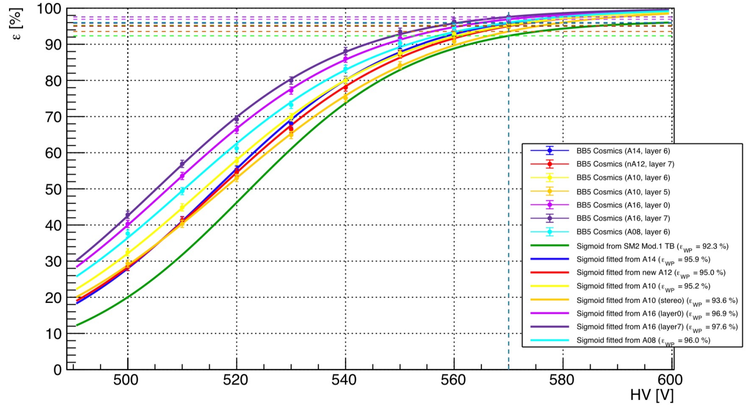


Simulations were performed to choose the optimal capacitor values in order to minimize the impedance in the frequency range of 2 to 10 MHz -> to ground the noise

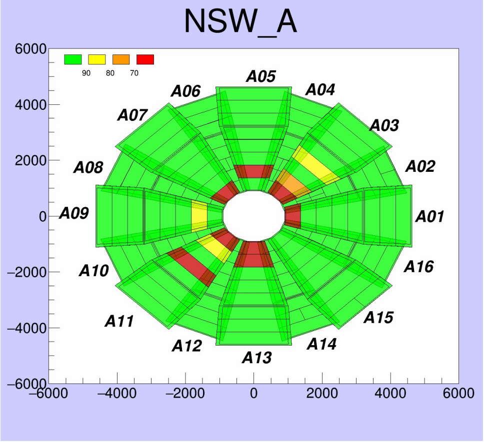
Commissioning 191: HV

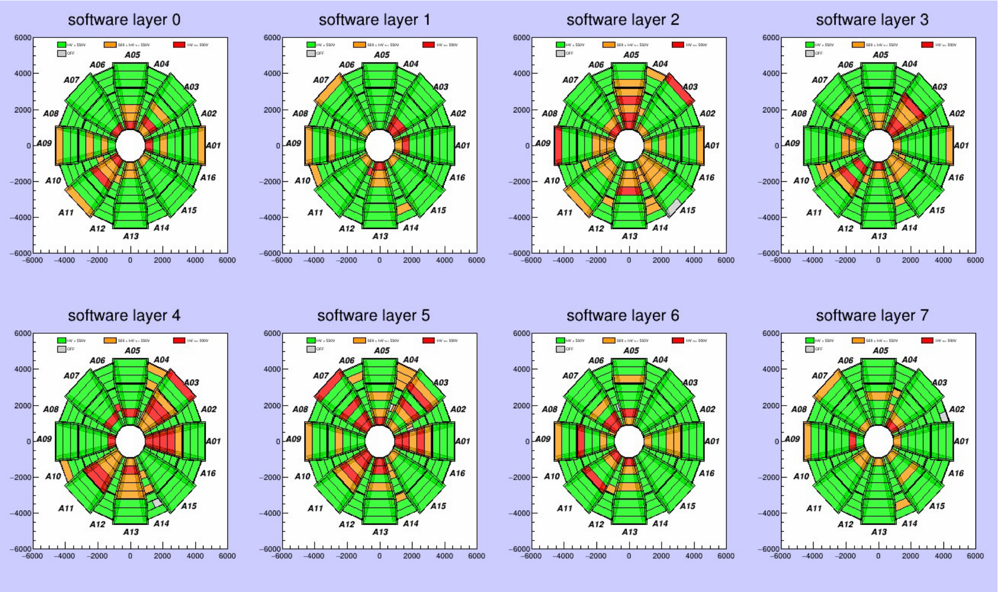
Results in terms of efficiency (nominal as from HV)

- Nominal Efficiency in Ar-CO_2 used to validate the chambers (from NSWA Small DW statistics)
- Good agreement with measured efficiencies with cosmics at bb5



Expected efficiency based on the HV map 4/8 majority (at least 1 stereo hit)





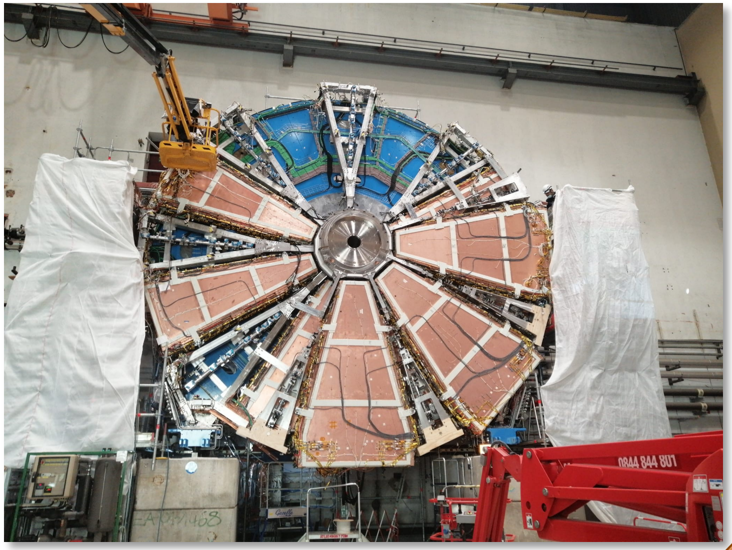
Commissioning 191: Wheel C Status

Wheel C Sector Situation

		PRE-INSTALLATION VALIDATION									CONNECTION ACTIVITIES & VALIDATION								HV COMMISSIONING			DAQ and ELX							TRIGGER		
Update: 05/08/2021	Installed	Extension Cables	GND tests	Clamps with braids	Impedances ok & not naked fibers	Cu plates on large & small base	Splitter box mounting	Cable connection and polarity on ICS	T-sensors checked	Redels + drifts checked	Water regulation and Cooling	Gas Leak+ Impedance tests	LV cables (**polarity** & GND tests)	HV Cable connection	Fibers	GND checks before & after services	T-sensor cable connection	T-sensor monitor	Gas flush	HV raise	24h HV validation	Config/Monitor	LVDB connector temperature check	Baselines	Trimmers	Pulser	Noise	Phase II	Connectivity	Phases	Cosmics
C12	12/apr	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ongoing,
C14	26/apr	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	
C10	17/mag	ok	ok	bb5	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	
C16	14/giu	ok	ok	bb5	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	
C08	29/giu	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	
C02	05/aug	ok	ok	ok	ok	ok			ok	ok			ok																		
C06													ok																		
C04													ok																		
C13	9/lug	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok		ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	
C11	20/lug	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok		ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	
C15	-	ok	ok	ok	ok	ok		ok	ok	ok			ok																		
C09	30/lug	ok	ok	ok	ok	ok		ok	ok	ok			ok																		
C01				ok	ok	ok		ok	ok	ok			ok																		
C07													ok																		
C03													ok																		
C05													ok																		

- All the Sectors on the wheel ready from the service have been fully validated!
- 7 fully commissioned + 2 with the service team
- 4 to be installed in August
- 3 left in September
- **Aiming for completion by the end of September, ready for the installation in ATLAS!**

1 hour ago



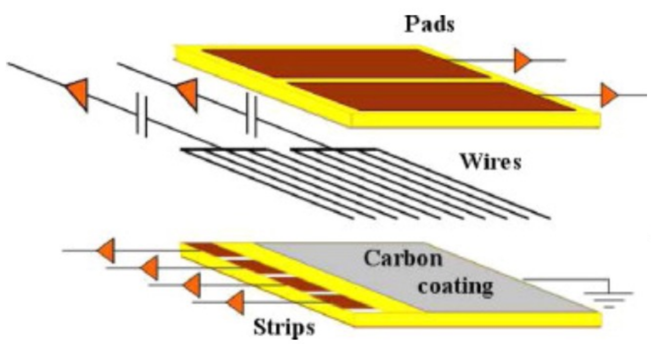
Conclusions

- With all the knowledge acquired in the past years we managed to address the main issues affecting the MM detectors
- Studies with Isobutane enriched gas mixture show promising results in terms of improving the performances of the chambers

  -> aim to use it from start
- NSW A already in the cavern being installed in ATLAS
- NSW C ready ~end of September
- **This huge achievement has been possible thanks to the commitment and dedicated effort of hundreds of people!**

Thanks for your attention

Sketch of a sTGC layer



A fully equipped sTGC chamber

- Strips pitch: 3.2 mm
- Signal readout from strips, wires and pads
  - pads used in a 3-out-4 coincidence to find tracks roughly pointing the IP
  - the pads also define the strips to be readout for measuring the bending coordinate
  - σ_η ~60-150 μm depending on track incident angle
  - wires are grouped to measure the azimuthal coordinate (10 mm resolution)

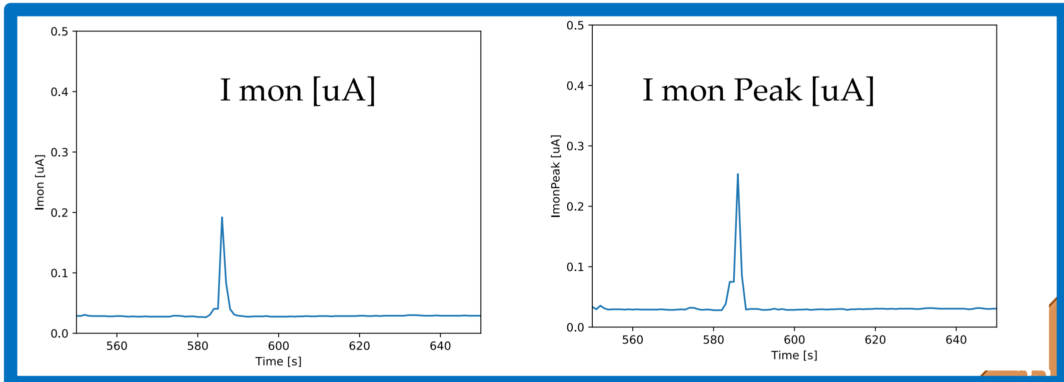
4 sTGC layers for each chamber

New Firmware

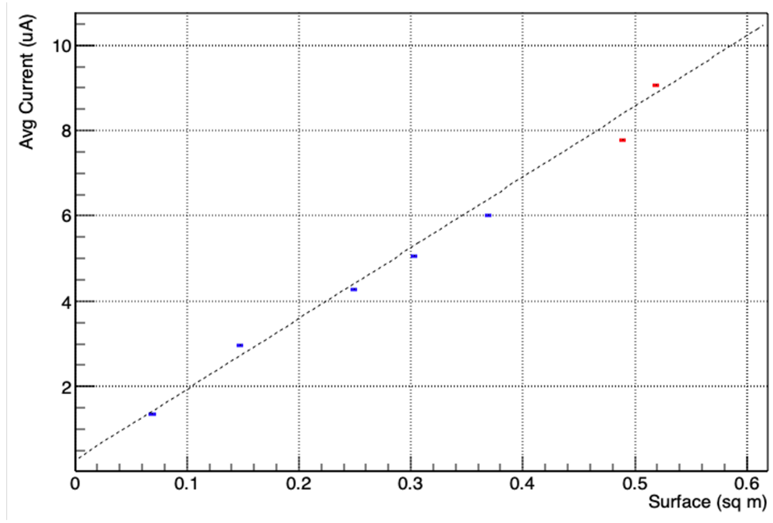
Old firmware: there was an heavy digital filter on the A7038 power supplies between the I mon (mean of 50 ms sampling in 1s) and the I mon peak (peak current within the sampling)

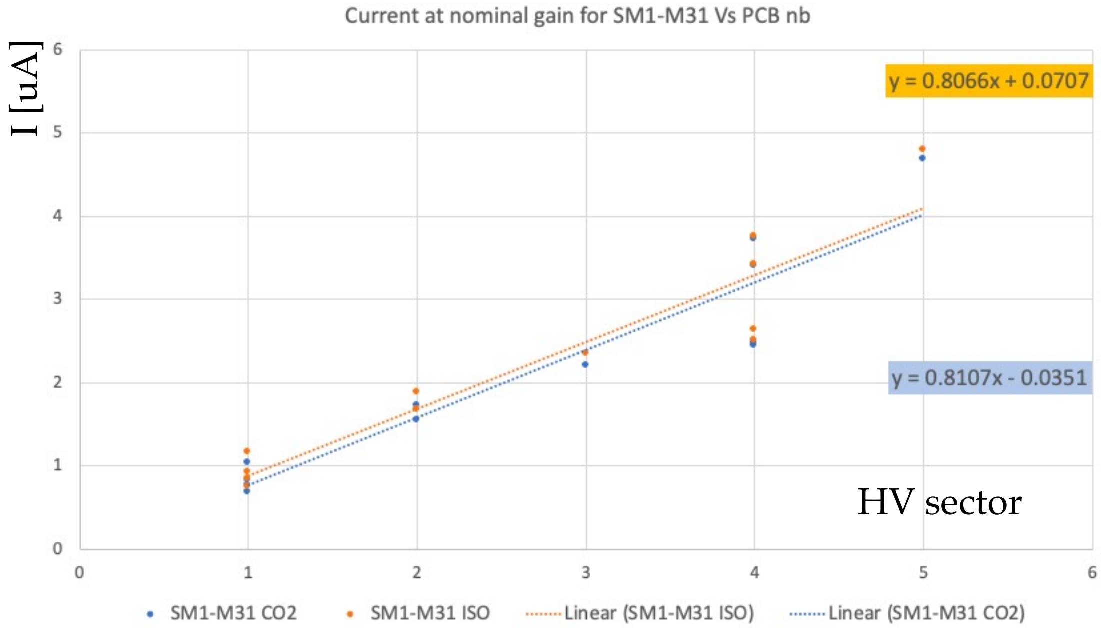
Firmware improved adding the ImonPeak and reducing the digital filter on Imon:

- Comparison by Imon and Imonpeak every sample is really stable, differences in stable conditions of 0.5-1.0 nA
- Improved version of the firmware reflects the fact that sparks are 100ms width -> tail was an effect of the digital filter



Currents scales by area of irradiated sectors: currents from LM1 M20 and LM2 M07 scale linearly with size (different pillar heights not taken into account)





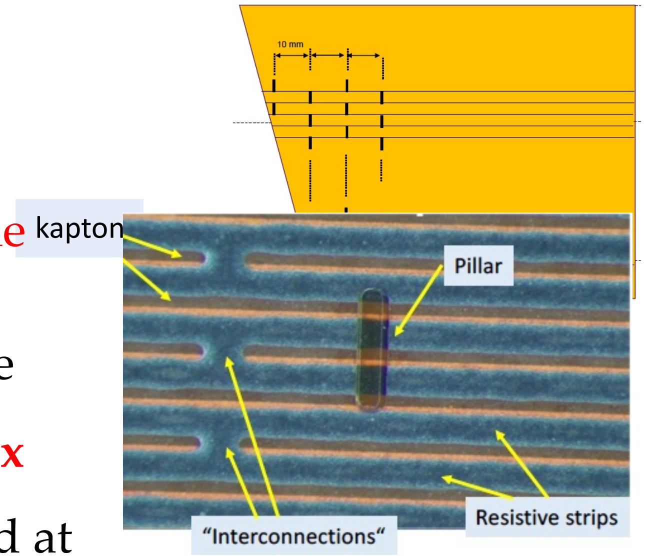
SM1 M31 equivalence of currents (Ar-CO_2, Ar-CO_2-Iso):

- current intensity 0 - 4 μA:
- currents @ 507 V under Ar:CO_2:Iso = currents @ 570 V under Ar:CO_2
- identical gain

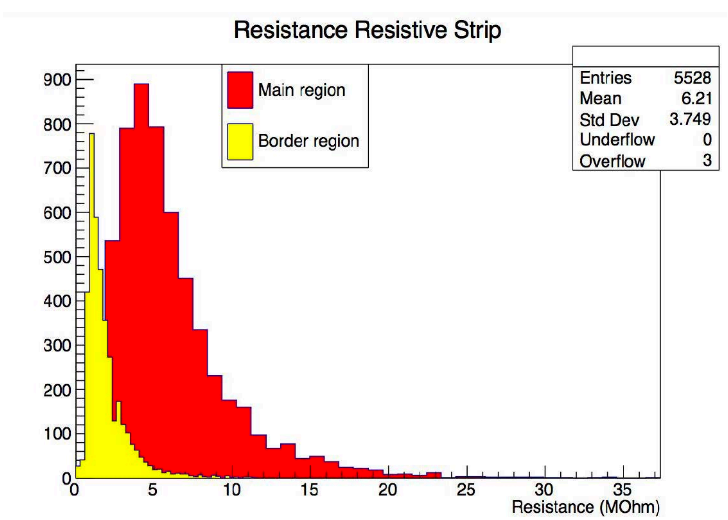
HV stability and board resistivity

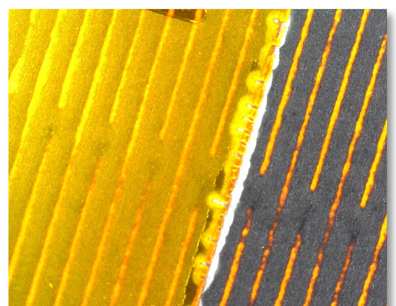
The resistive strips of the ATLAS MM are ink-printed on a kapton support

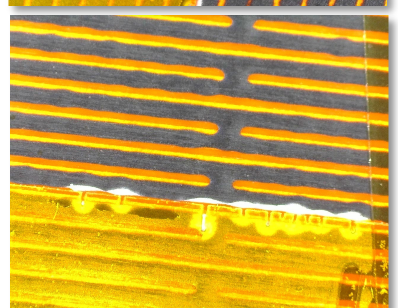
The resistive strip layout presents interconnections with a defined pattern -> to have more uniform resistivity in the board

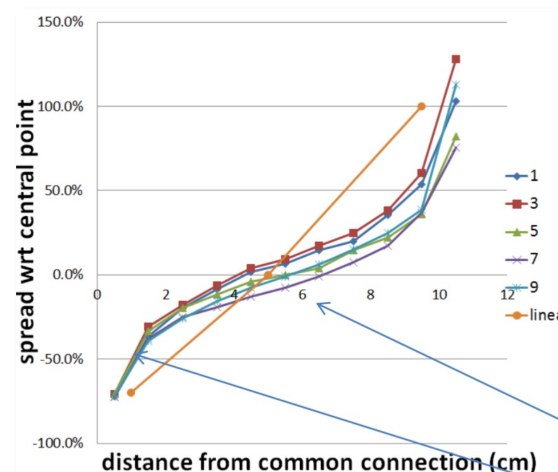


Analysis of **discharges** showed that in many cases they are **localized on resistive strips junctions crossing the piralux rim, the edge of the active area** (1cm wide zone passivated at the factory)



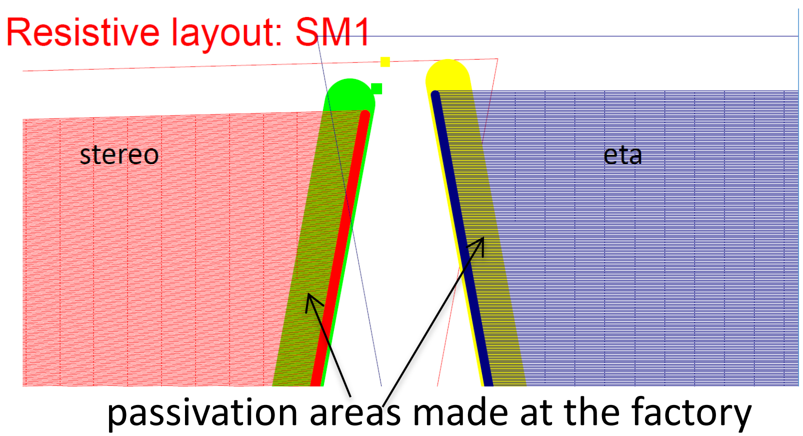


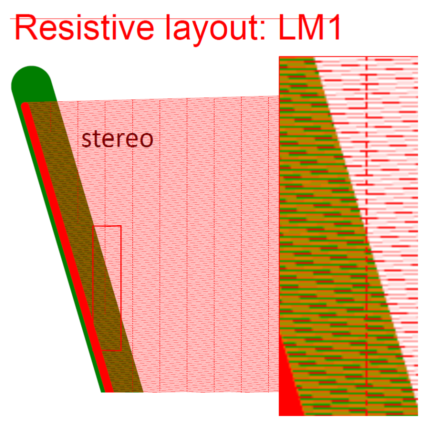




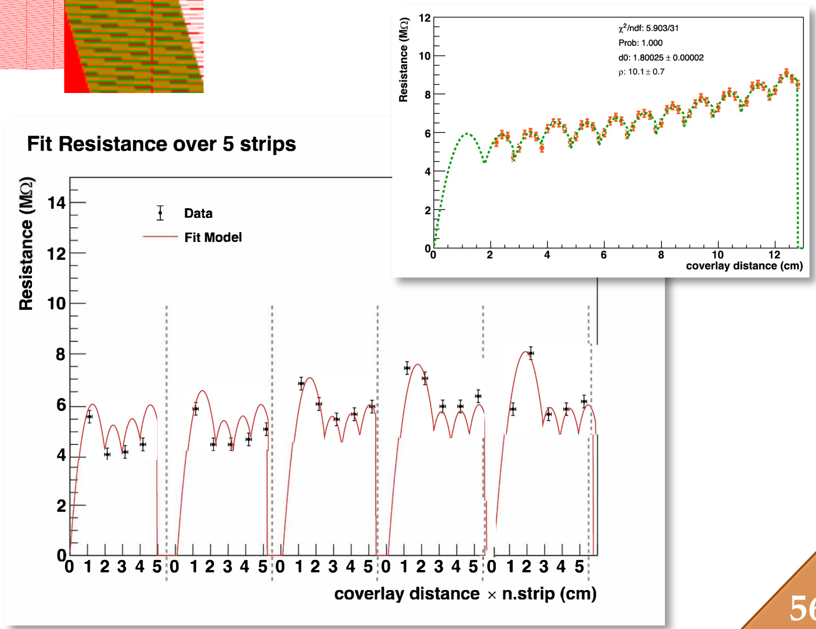
50%

- **The resistive strips layout is not the same for all PCB types (**some PCB types were more affected than others by discharges)
  - For example LM1 both stereo and eta, SM1 stereo but not eta panels





- Resistance locally can be significantly lower than what obtained with 1cm^2 probe
- Strong dependence on the layout
- Local defects can be undetected
- Local resistance behavior can be predicted via simulation

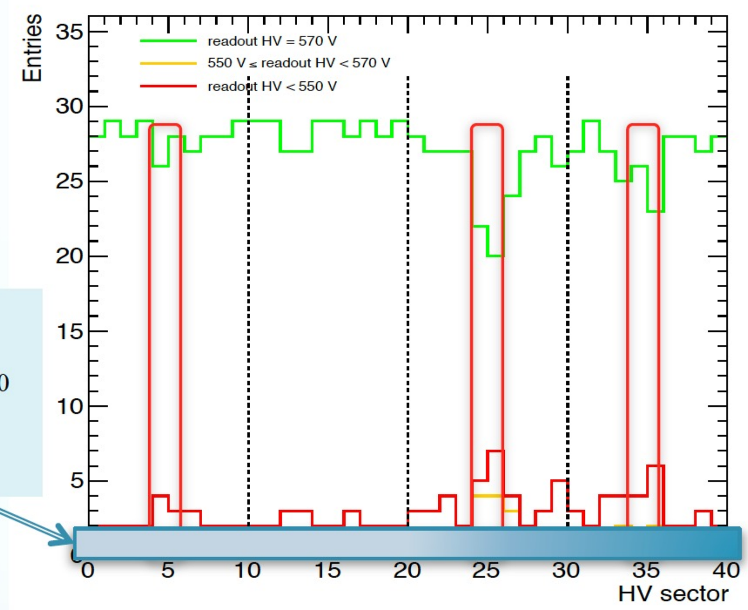


Passivation

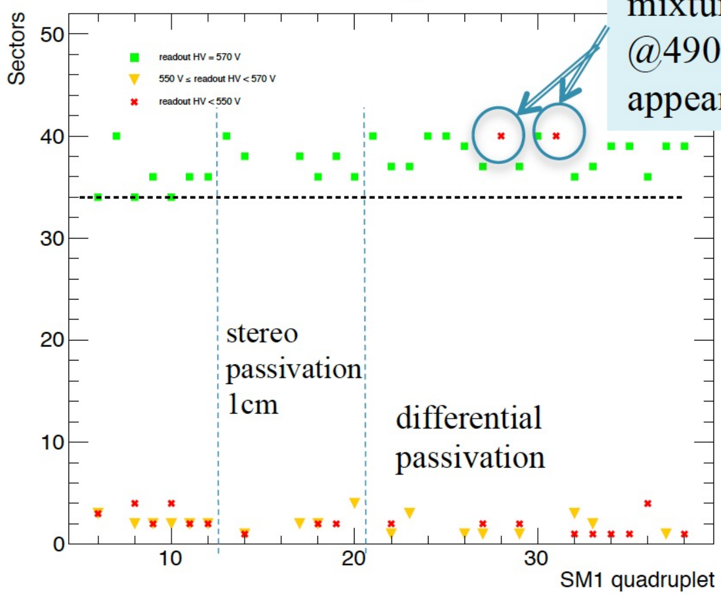
Summary of the HV behavior of SM1 at LNF validation step

- HV sectors categorized according to the maximum voltage reached in stable conditions
- 1 module: 4 layers with 10 HV sector each

HV behavior by HV sectors (all modules)



HV sectors behavior by module



Two modules tested with a mixture containing a 2% iC_4H_{10} @490 V. They work fine but appear red in these plots

- Clear evidence of worst behavior of PCB#3 which had generally lower resistivity w.r.t. the others
- Significant improvement after the passivation procedure was introduced

Results @ CRS2 based on a self tracking method

For all layers (to remove noise):

- Q_{strip} > 60 ADC Count && $Q_{strip} > 3\sigma_{ped}$
- $Q_{cluster}$ > 100 ADC Count
- Q_{strip}^{max} > 90 ADC Count
- $Length_{cluster}$ < 16 ADC Count
- $Holes^{max}_{cluster} = 2$ but not consecutive

For the cluster control sample (to select good event):

- $Q_{cluster}$ > 400 ADC Count
- $Length_{cluster}$ > 1 channel

For the extrapolated track (to avoid to reconstruct a bad track):

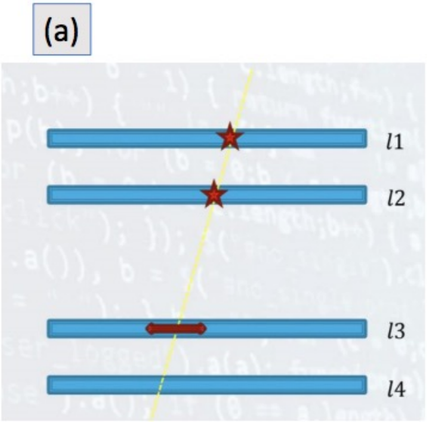
- $\Theta_{track} < \pm 0.5$ rad ~ ± 28 deg.

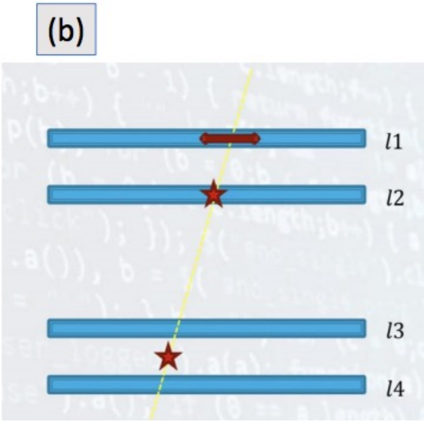
Track extrapolation using 3 layers with 1 cluster:

(a) 2 layer eta + 1 stereo -> track from 2 eta + second coordinate from eta+stereo

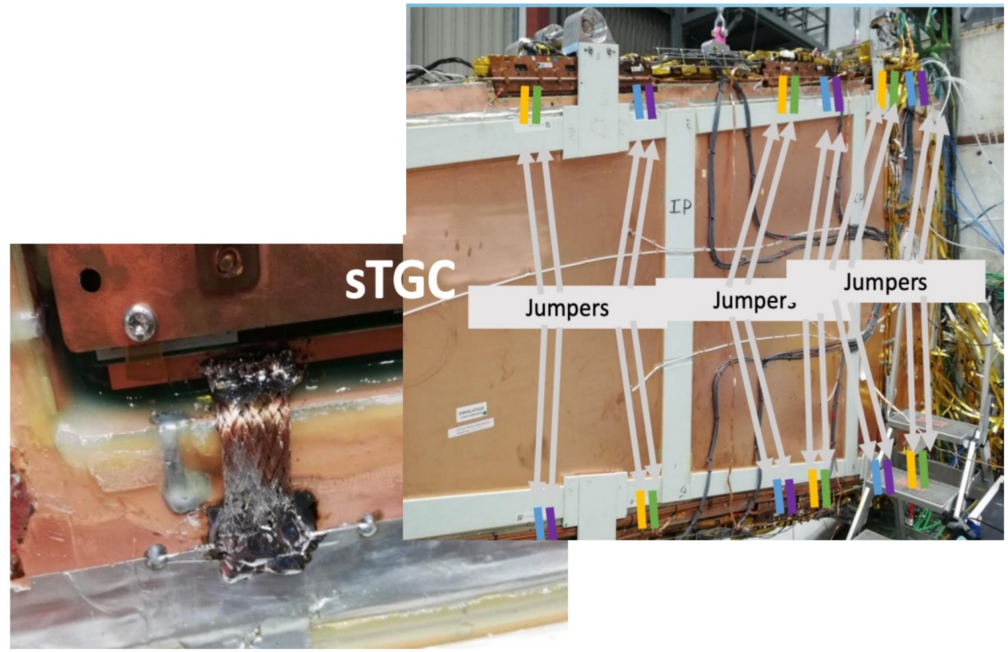
(b) 1 layer eta + 2 stereo -> track from eta and super-point from stereo + second coordinate from stereo

- Good track (angular cut at ±0.5 rad) -> extrapolation of the expected position on the 4th layer looking for a cluster within ±10 mm from the expected position for eta layers and ±25 mm for the stereo ones





To improve the noise level:
jumpers have been added on QL1/2/3
from adapter board to faraday cage



sTGC

- Grounding RIM crate to detector
- Adding jumpers on QL1/2/3 from adapter board to faraday cage