Micromegas sectors for the ATLAS Muon Upgrade, towards the installation of the New Small Wheel in 2021

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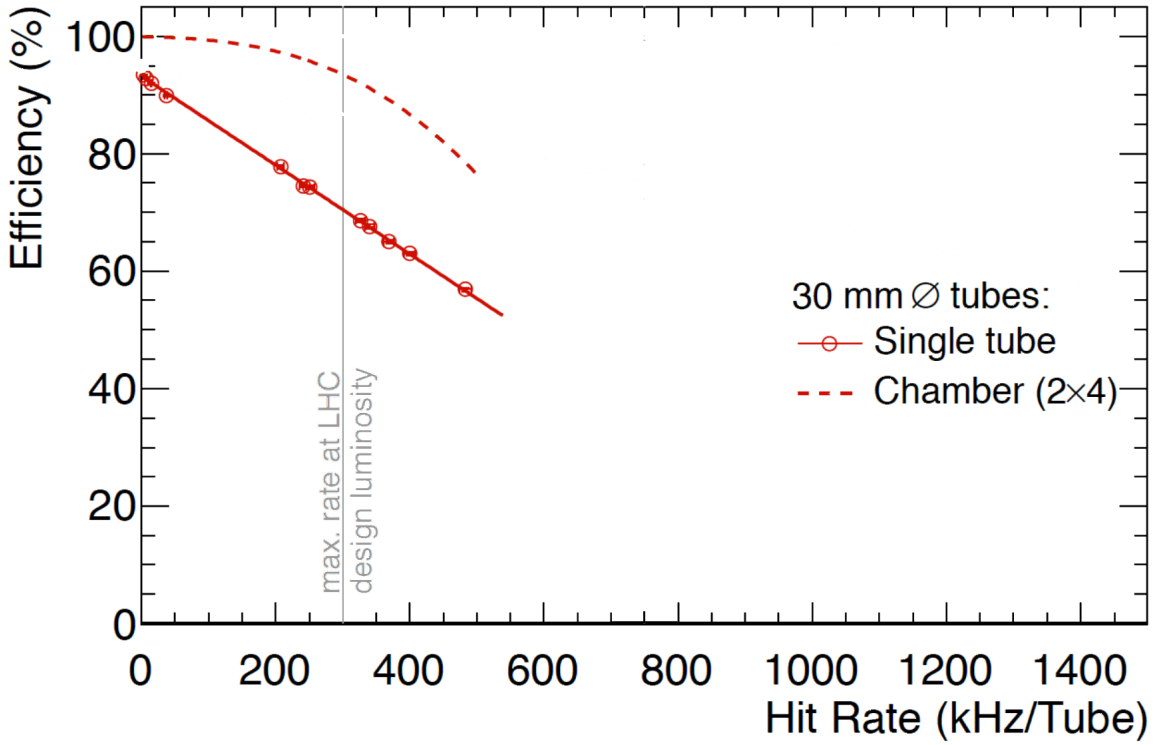
on behalf of the ATLAS Muon Collaboration

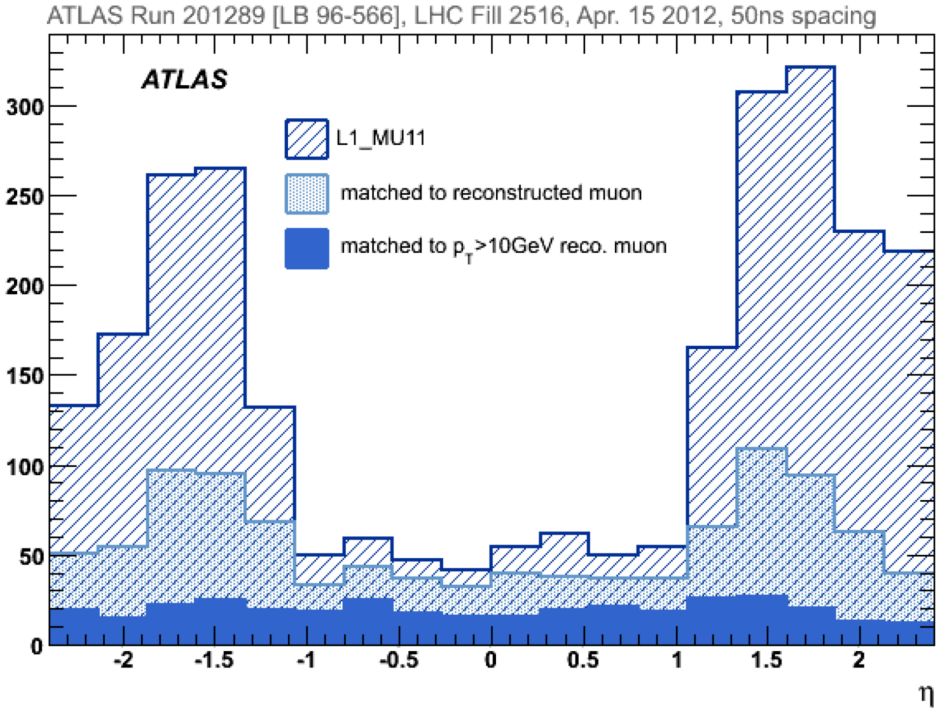
Università "La Sapienza" e INFN Roma1

PDS12 - 2021
13/09/2021

LHC luminosity increase – impact on the Small Wheel



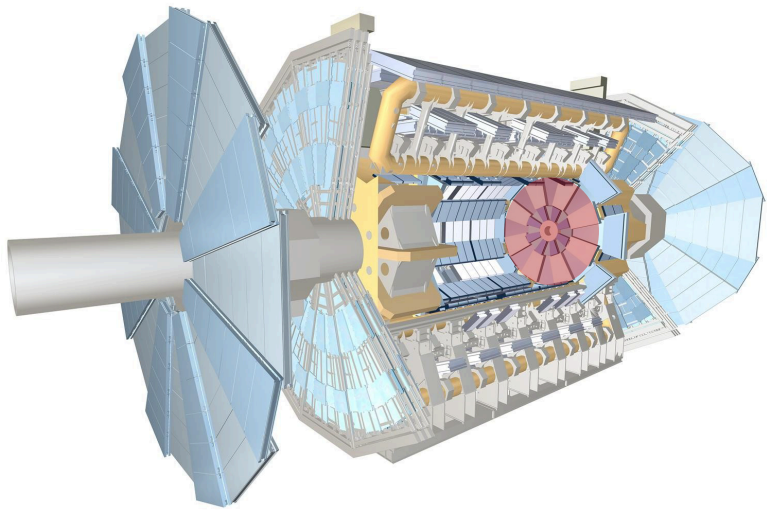
MDT efficiency decreases as a function of the luminosity due to the dead time of the detectors.



The muon trigger rate dominated by “fake” muons on the end-caps. With the luminosity increase, this rate will become prohibitive.

<u>New detectors are needed</u> to substitute the innermost station of the end-cap muon spectrometer to keep the current performance (and to improve them) also with an higher rate

The New Small Wheel project

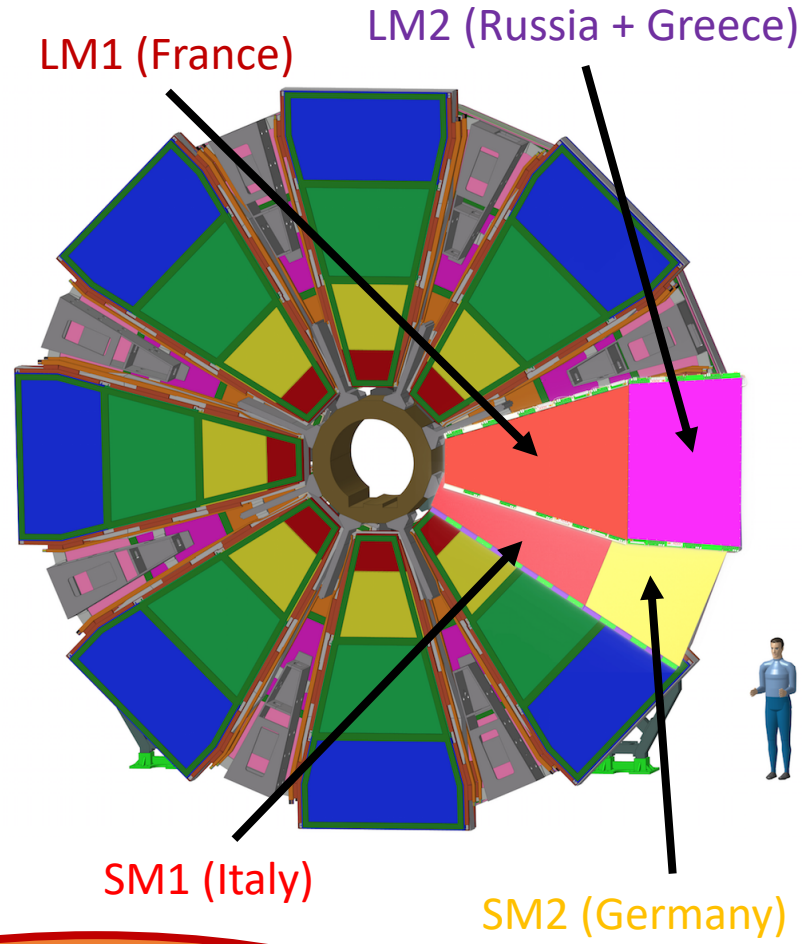


Two detector technologies:

- **MicroMegas** (primarly for tracking)
- **small-strip Thin Gas Chambers** (primarly for trigger)

16 layers to have redundancies and to reconstruct also the second coordinate

16 “petals” [8 small + 8 large]

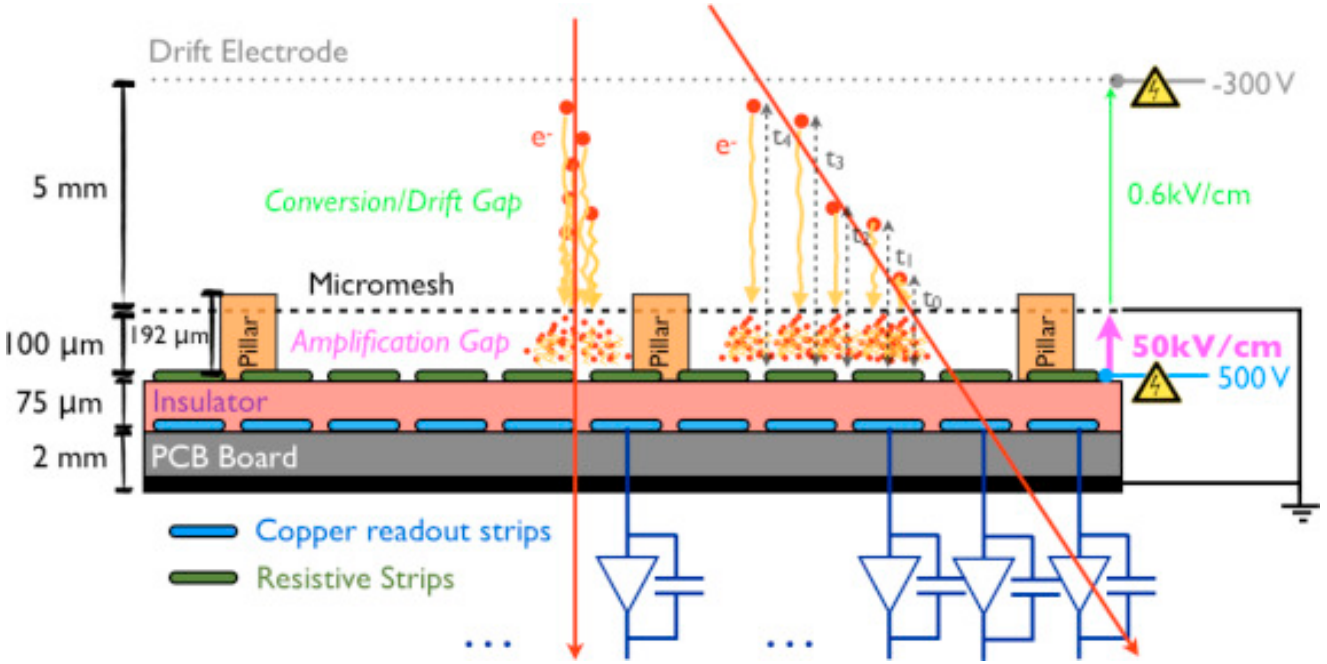


Collaboration	Module Name	MicroMegas Modules
France	LM1	32/32 + 2 spares
Greece/Russia	LM2	32/32 + 1 spares
Italy	SM1	32/32 + 1 spares
Germany	SM2	32/32 + 1 spares

All MM modules assembled for both NSW-A and NSW-C

First time large area Micromegas modules were built!

The ATLAS resistive MicroMegas chambers



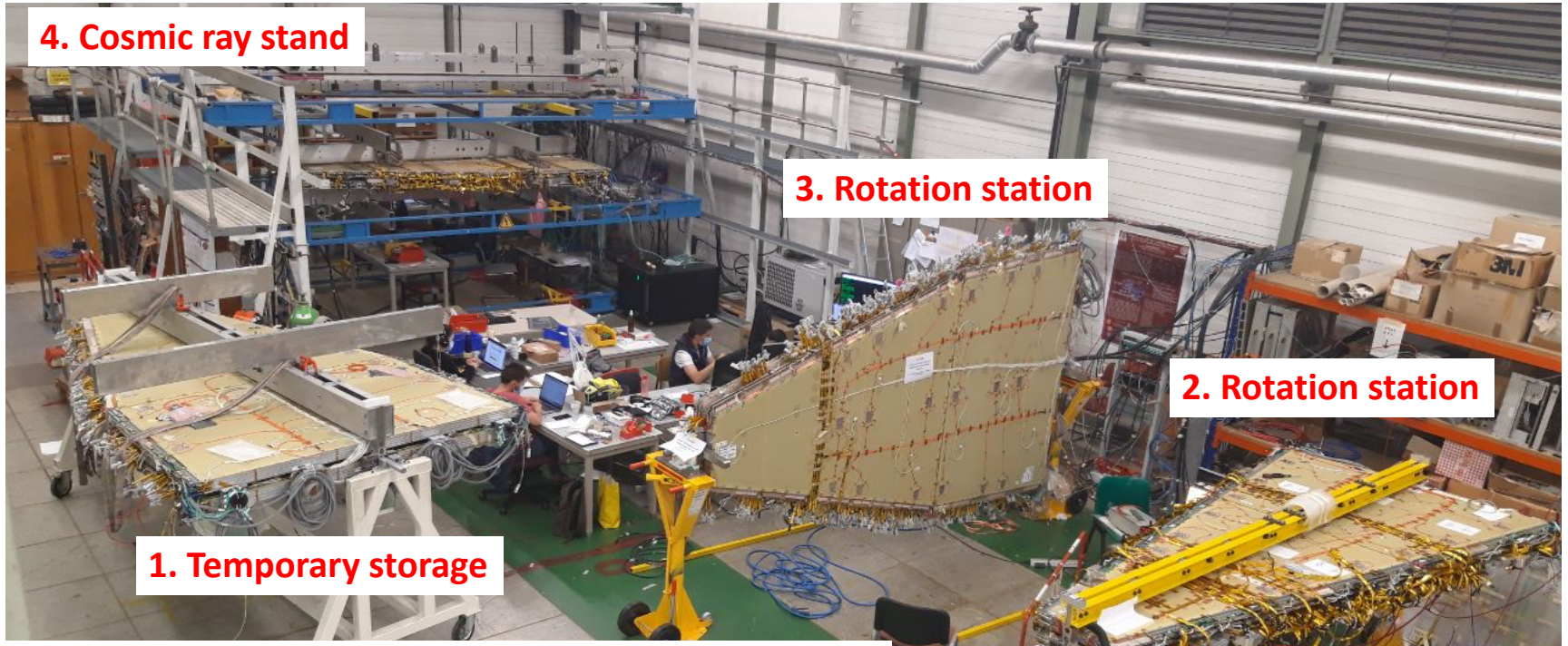
- **Drift cathode plane**
- **Conversion** (and drift) **gap** [5 mm] with low electric field ($E \sim 600\ V/cm$)
- **Metallic mesh** at ground
- **Amplification gap** of 128 µm (hold at same height thanks to the mesh tension and the pillars supporting it). High electric field ($E \sim 50/60\ kV/cm$)
- **Resistive strips** (to have a spark protection)
- **Readout strips** (to read the charge signal) the readout strips are capacitively coupled to the resistive strips

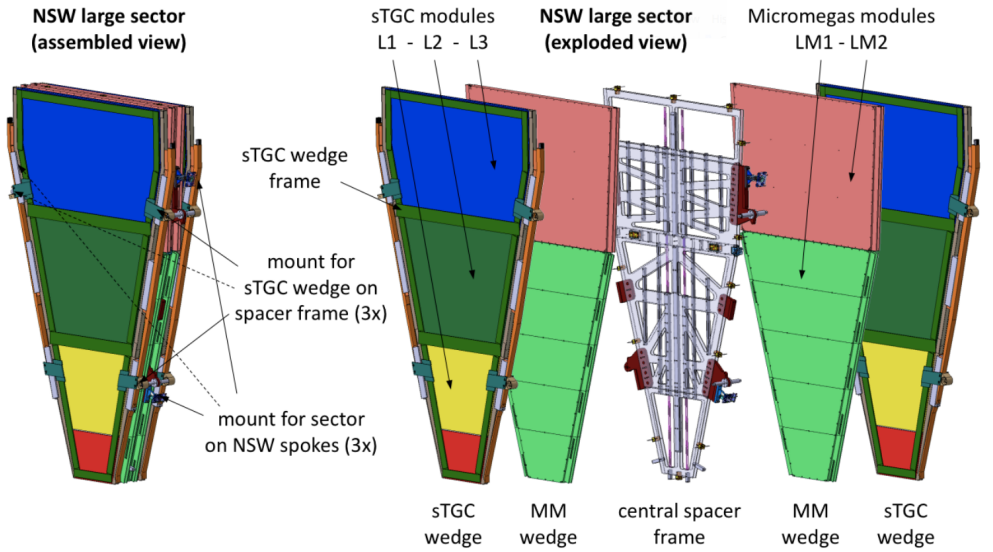
Fast positive ions evacuation $\Longrightarrow$ high rate capability

Resolution flat as a function of the angle ($\sim$150 µm)

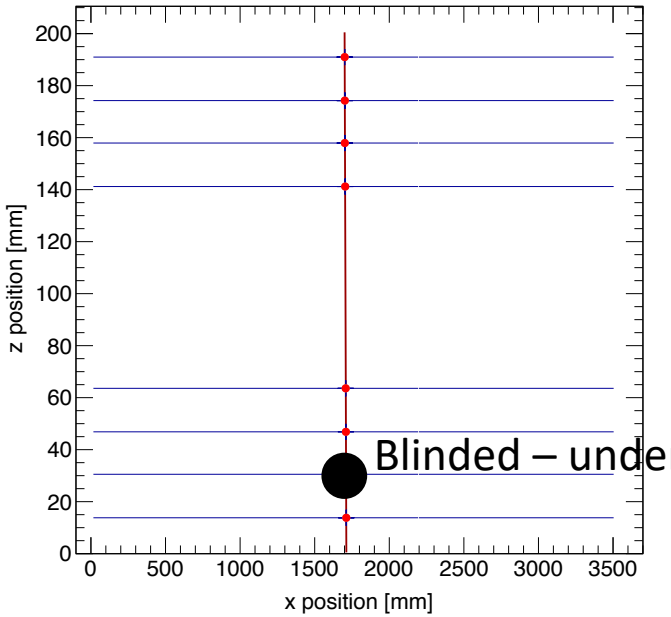
MicroMegas integration: CERN

- Modules from construction sites
- HV and gas leak tests
- Integration into a double-wedge
- Alignment of the wedges
- Installation of the services (LV, HV, cooling, …)
- Electronics installation
- Cosmic stand



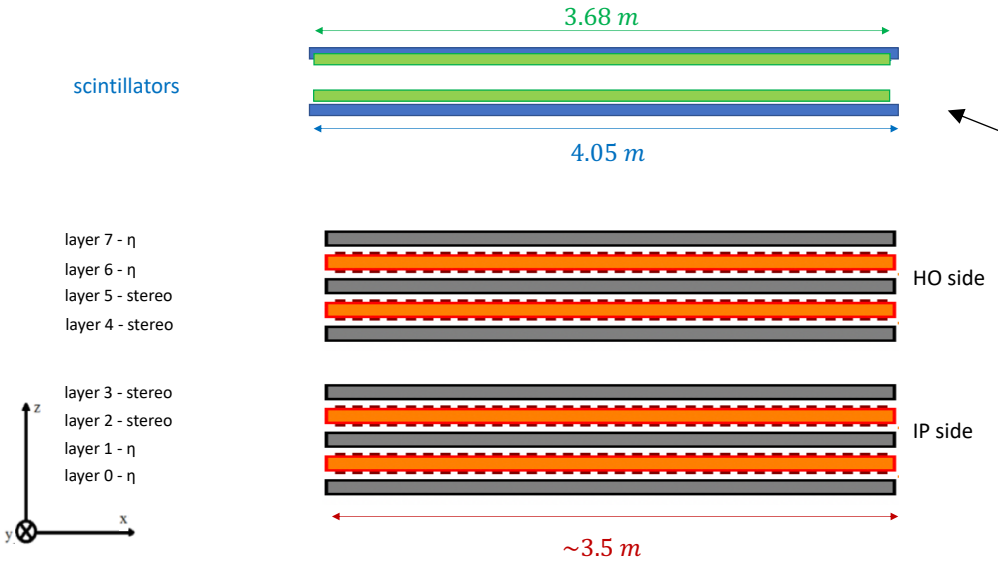


MicroMegas integration: CERN – track reconstruction



Blinded – under analysis

Track reconstructed with a 3D fit
- At least 5 layers
- At least 2 eta + 2 stereo layers
- Cut on the χ^2 probability

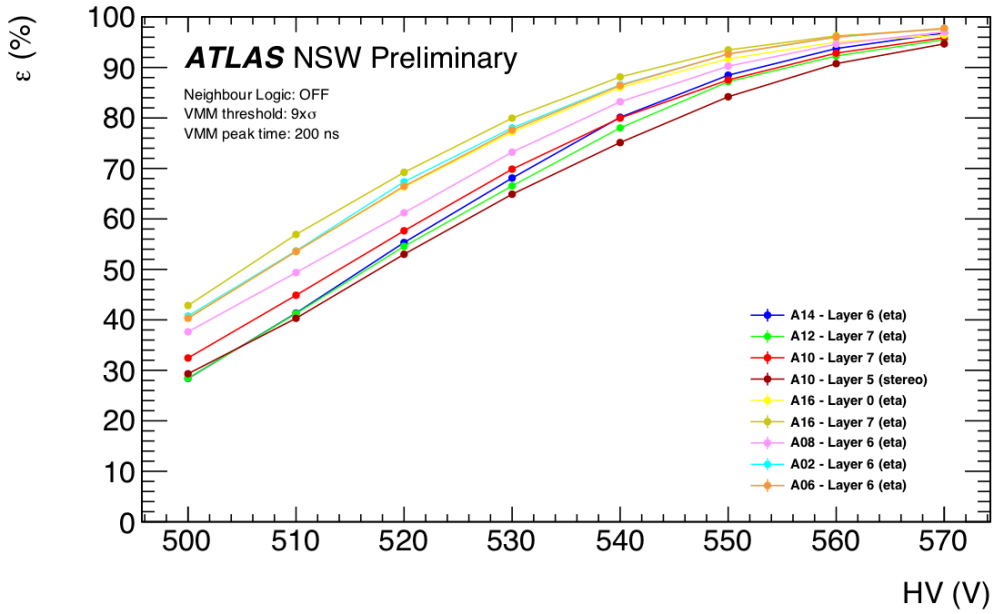


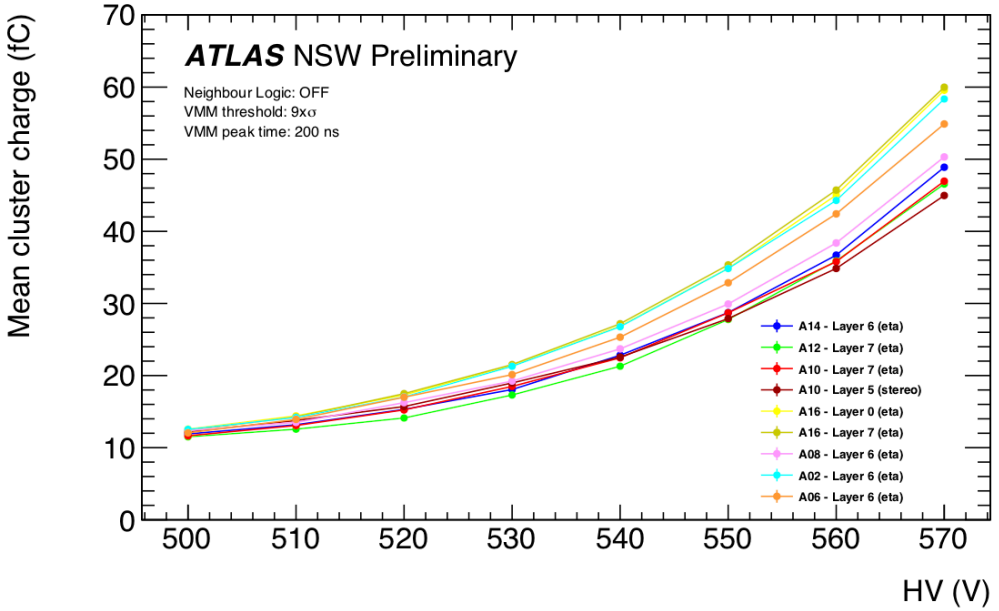
trigger

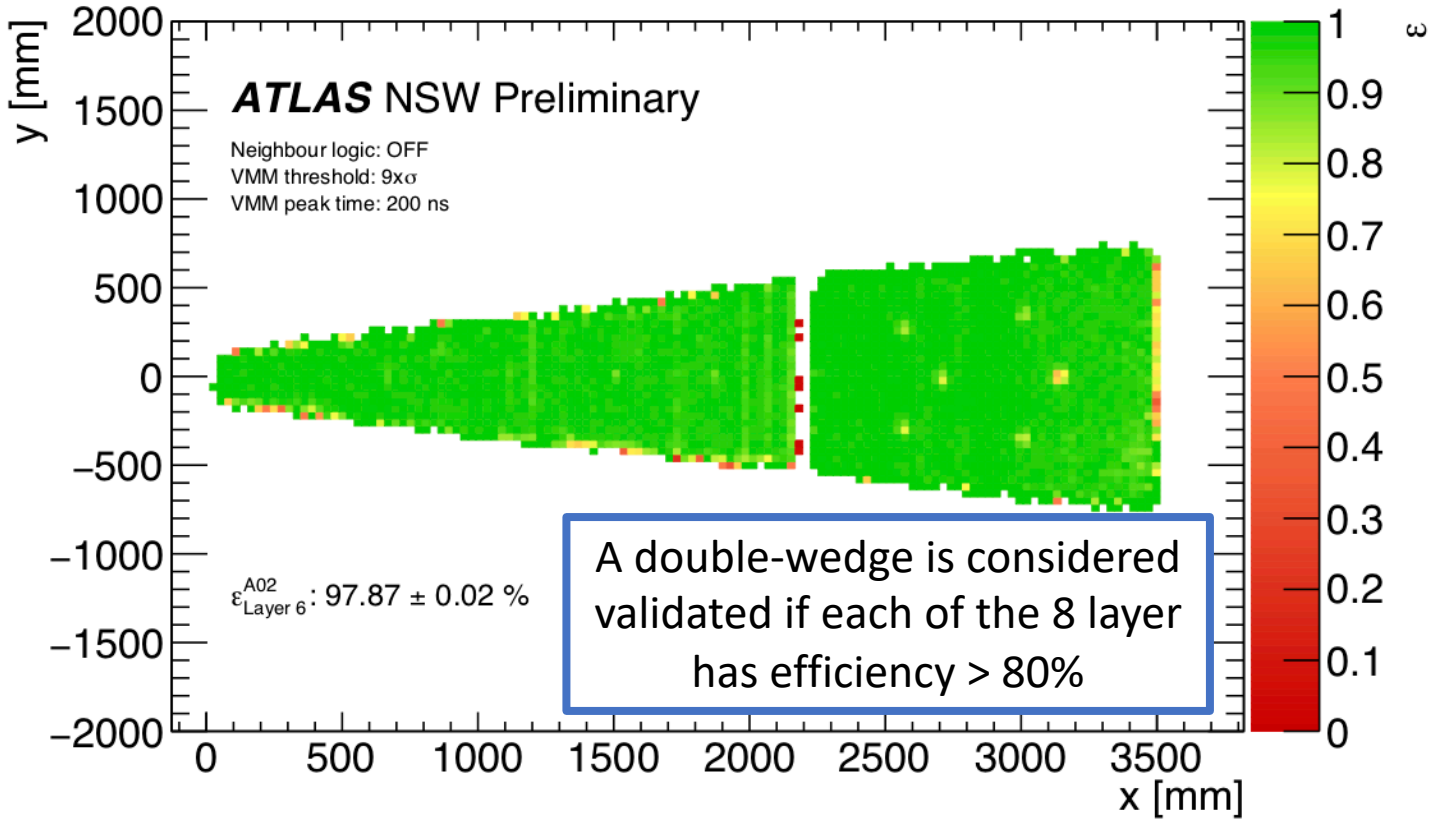
Double-wedge: self-tracking

Good control sample to study the performances of these chambers

MM performance analysis – efficiency and cluster charge





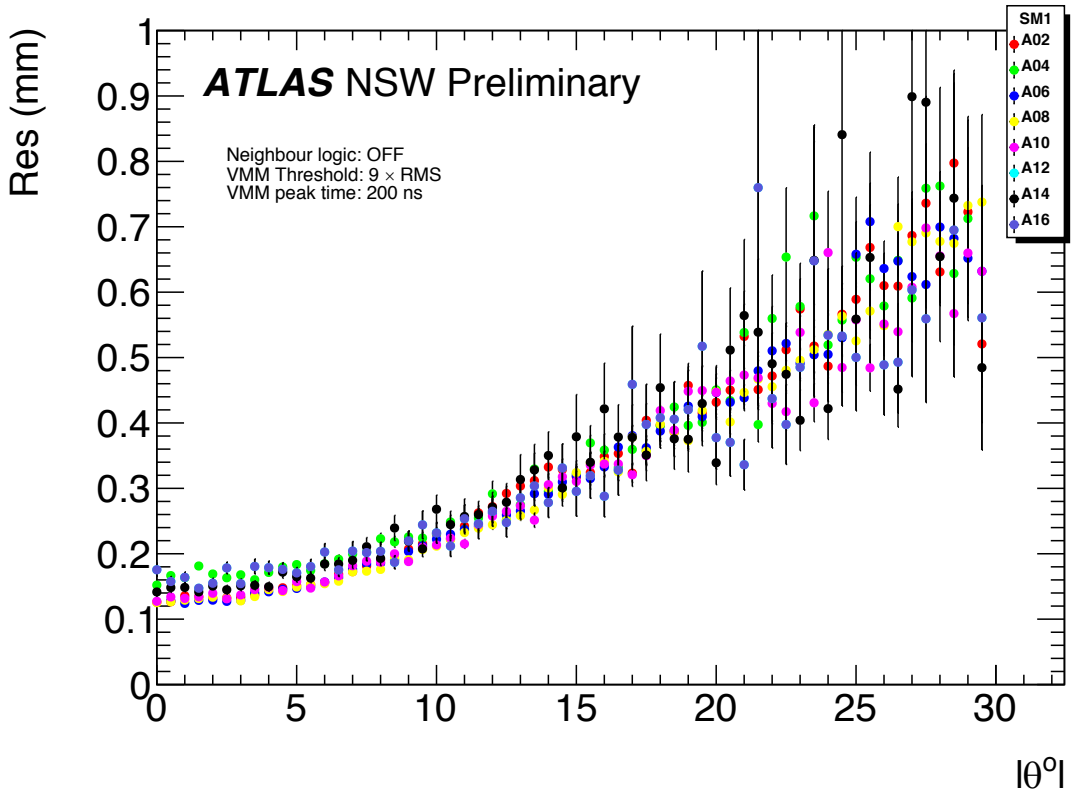


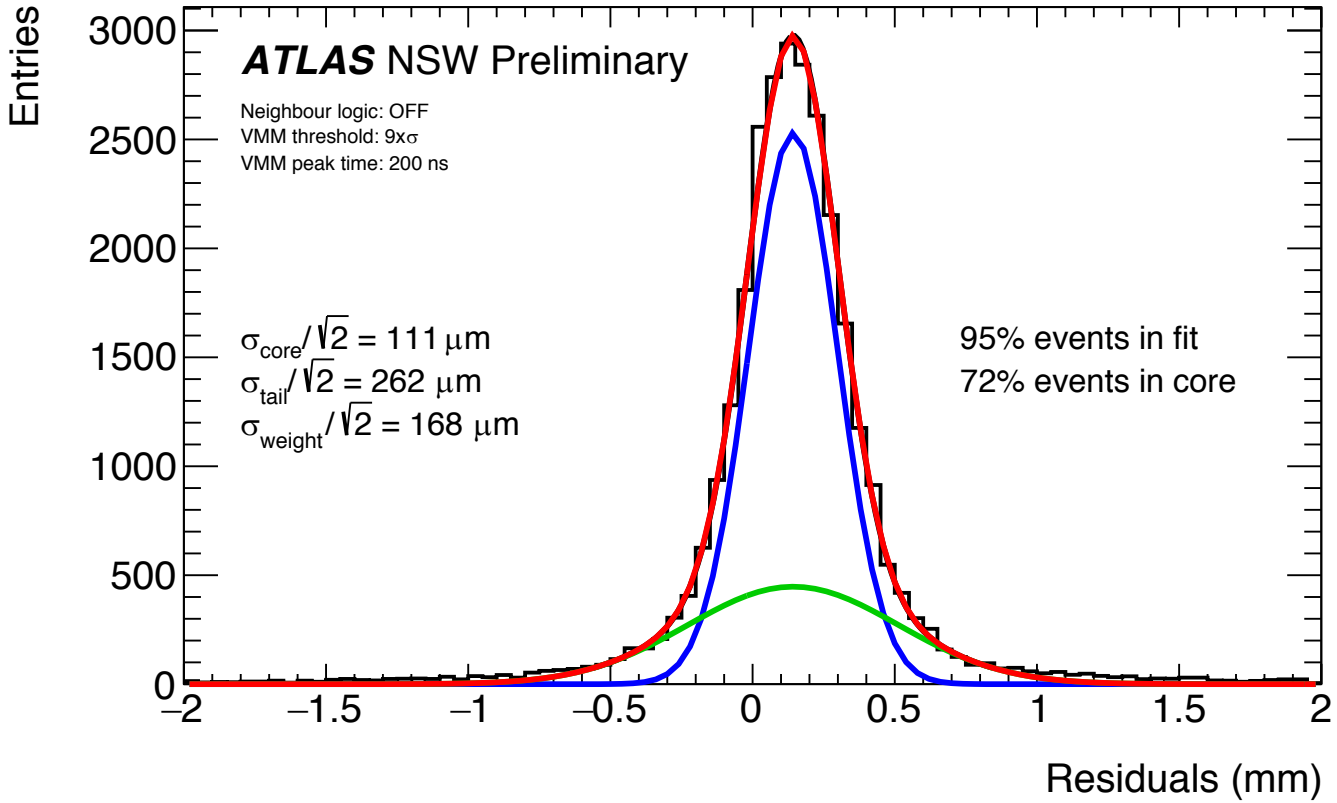
A double-wedge is considered validated if each of the 8 layer has efficiency > 80%

- **MOST IMPORTANT GOAL**: measure the efficiency of each layer of each double-wedge
- Search for a cluster within $\pm 5\ mm$ ($\pm 10\ mm$) the extrapolated position

MM performance analysis – resolutions

- Centroid resolutions measured using the reconstructed track with the other layers



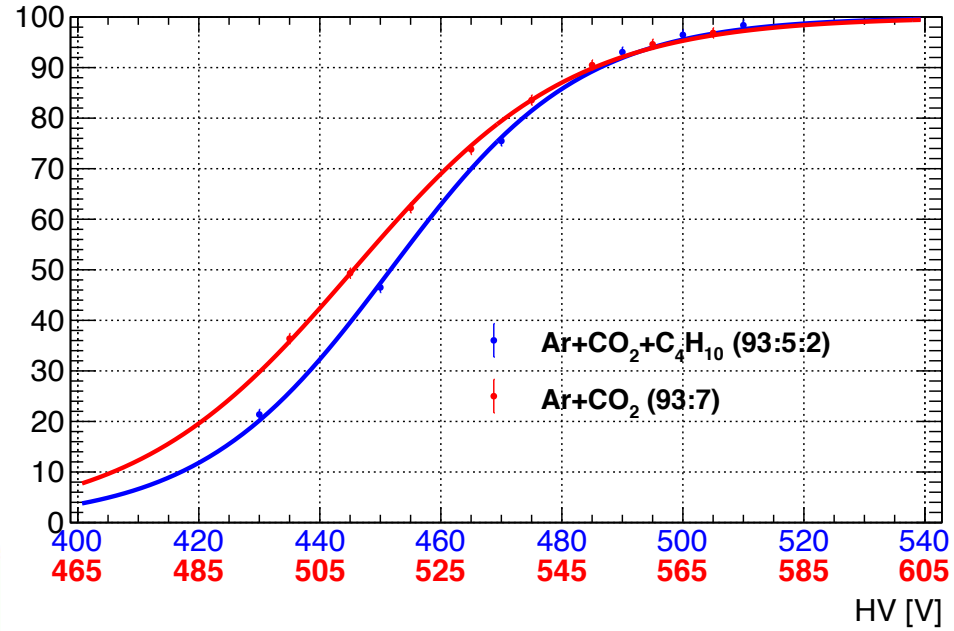


Measurements a bit worst than expected due to multiple scattering + mis-alignment between layers (not considered)

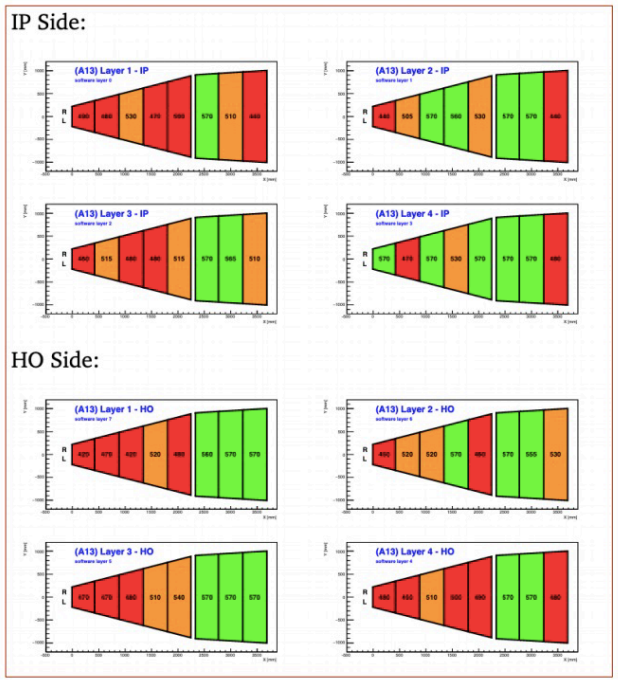
Expected $50\ \mu m$ of track reconstruction resolution in the NSW $\Rightarrow 150\ \mu m$ of resolution per plane

MM performance analysis – isobutane

- New gas mixture under study: $Ar: CO_2: C_4H_{10}$ $(93: 5: 2)$
- Better performances in terms of HV
- Same efficiency with lower gain wrt nominal gas mixture



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



insufficient performance

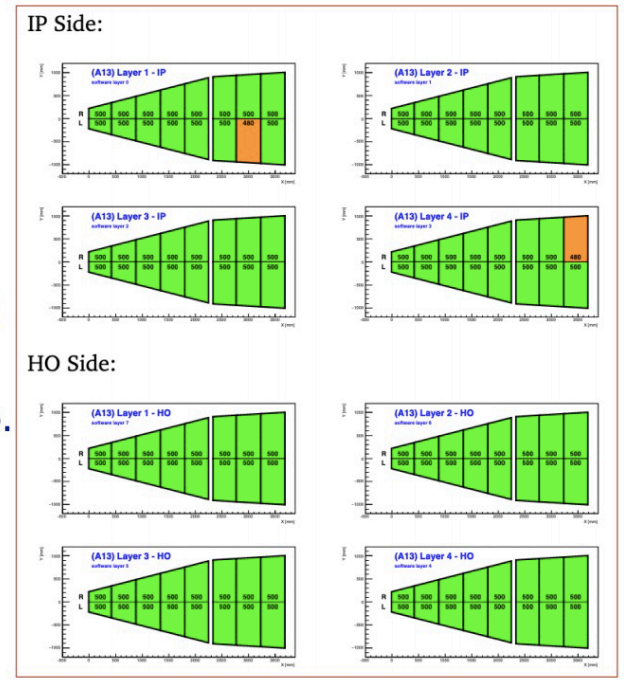
green:
sector is on
nominal HV

-2% of CO2

+2% of Isob.

red:
sector is below
nominal HV

$Ar:CO_2:iC_4H_{10}$ 93:5:2
HV: 500 V nom. similar ε



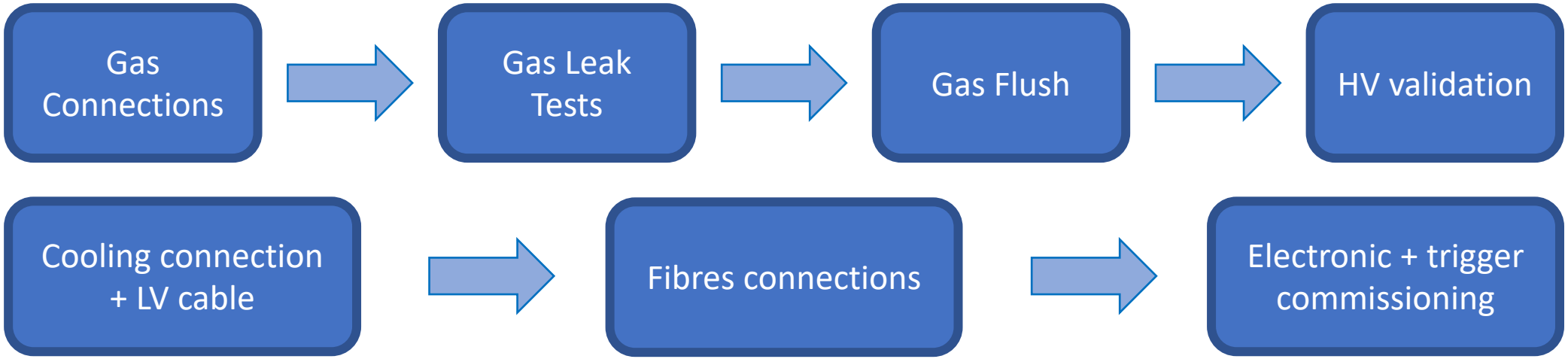
almost perfect performance

- GIF++* long term studies
- Goal: reach accumulated charge to compare with HL LHC
- Aim to reach within 2021 about 3 years of HL-LHC allowing also validation for Run3

* = Gamma Ray Facility

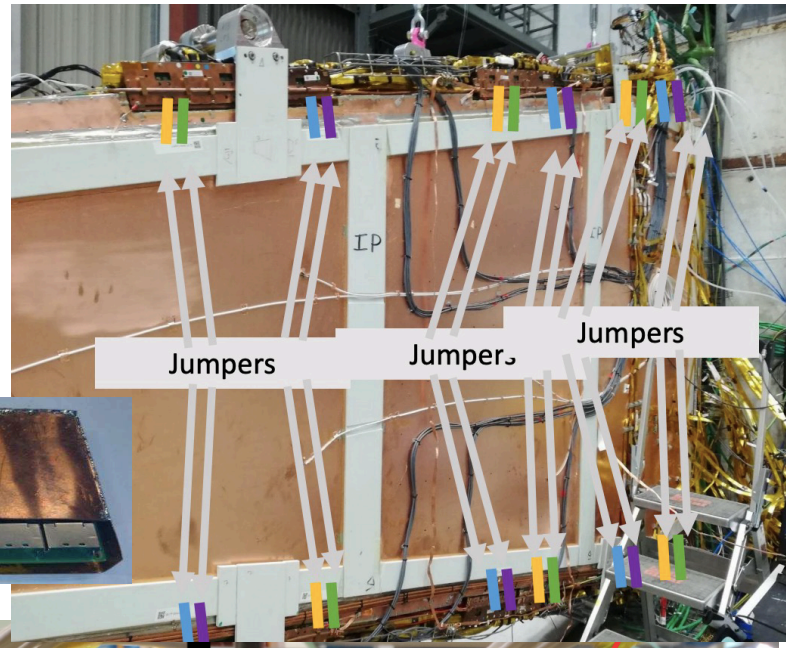
NSW integration

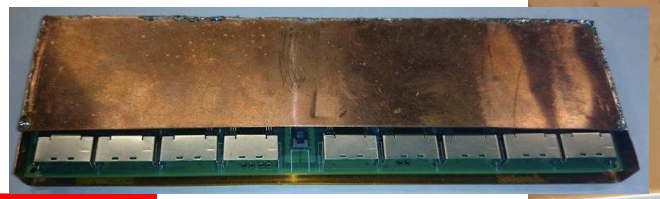
- Standard procedure defined to do the commissioning of the Sectors.
- Commissioning of a Sector takes ~5 days.
- The commissioning of the NSW-A is completed.
- The commissioning of the NSW-C is ongoing.

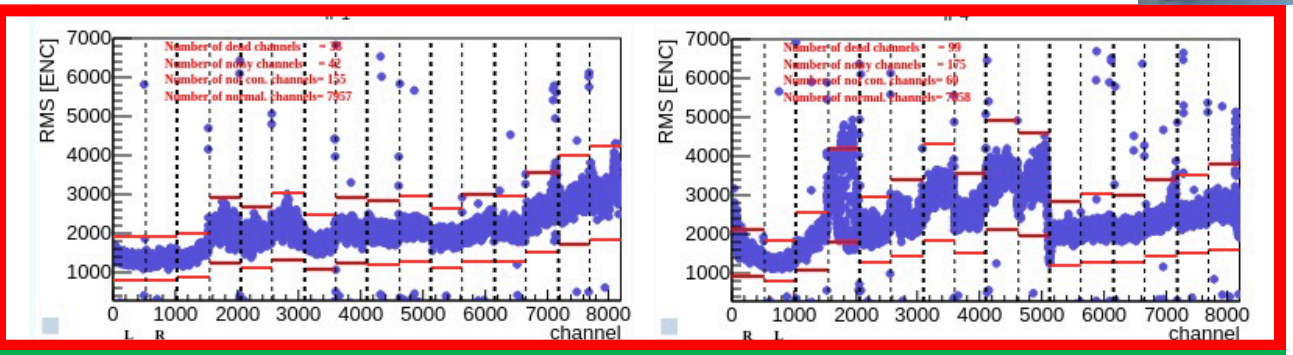


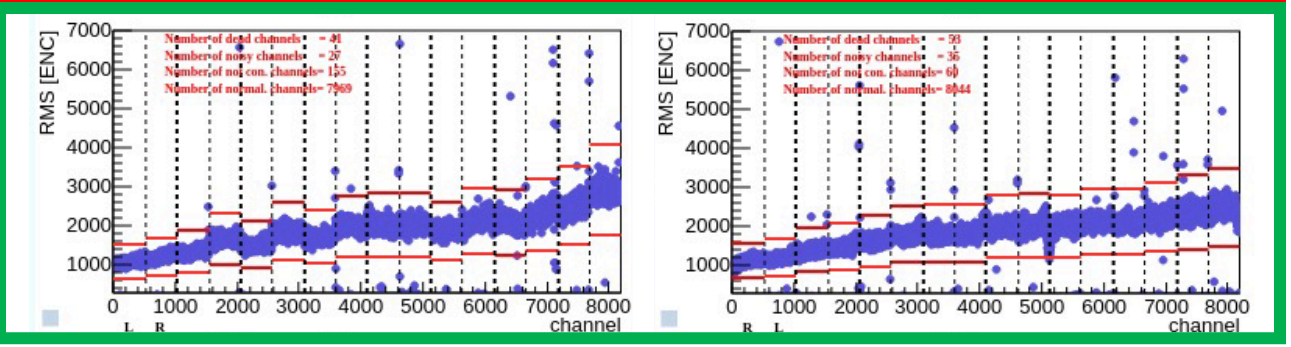
Reducing Sectors noise

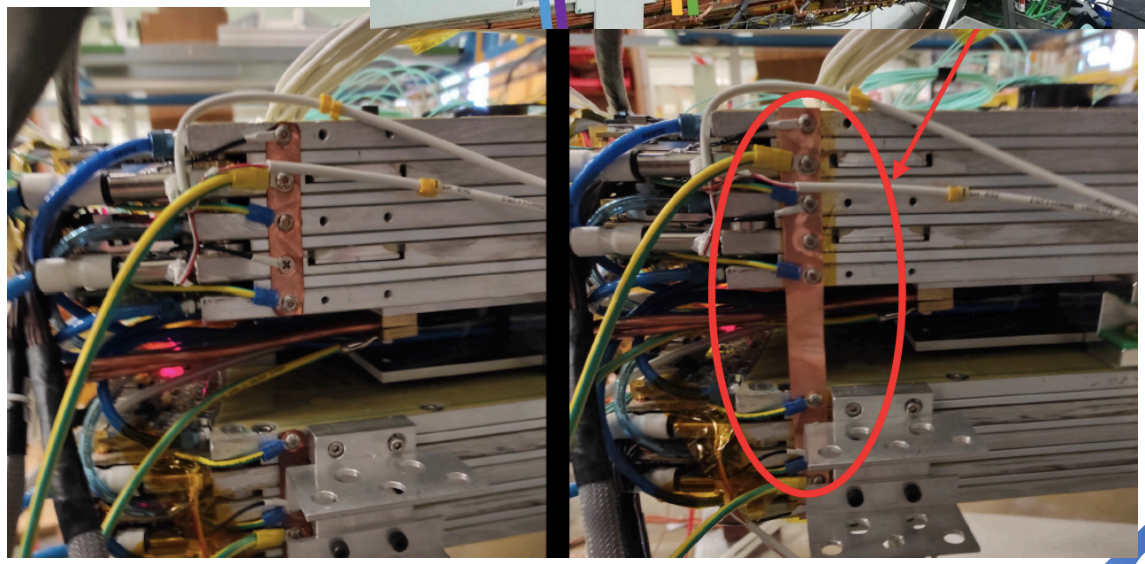
- Recent commissioning activities have lead to the discovery of increased noise in the sectors on wheel (both sTGC and Micromegas)
- Task force formed to investigate and potentially mitigate the problem.
- Modification of grounding scheme and the addition of grounds on detector have further improved noise levels.
- Addition of Faraday cages on some specific electronics boards.
- **Before** and **After** the modifications on the MM layers





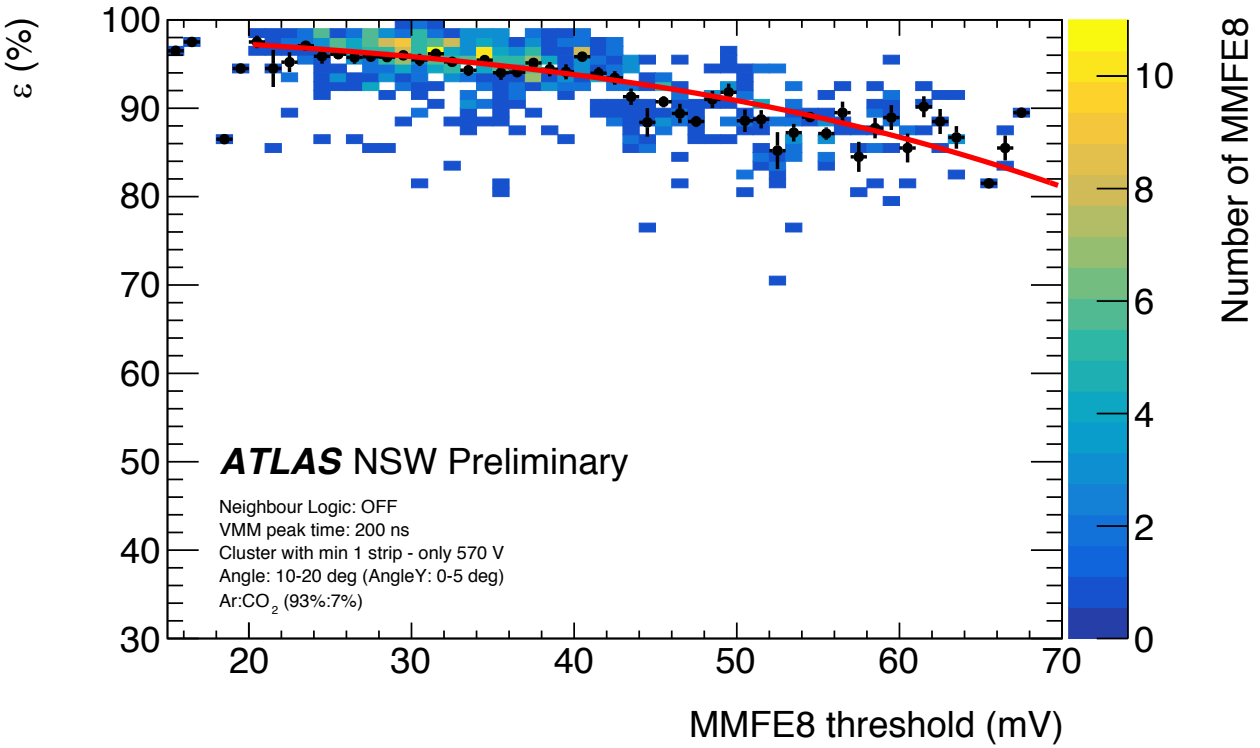


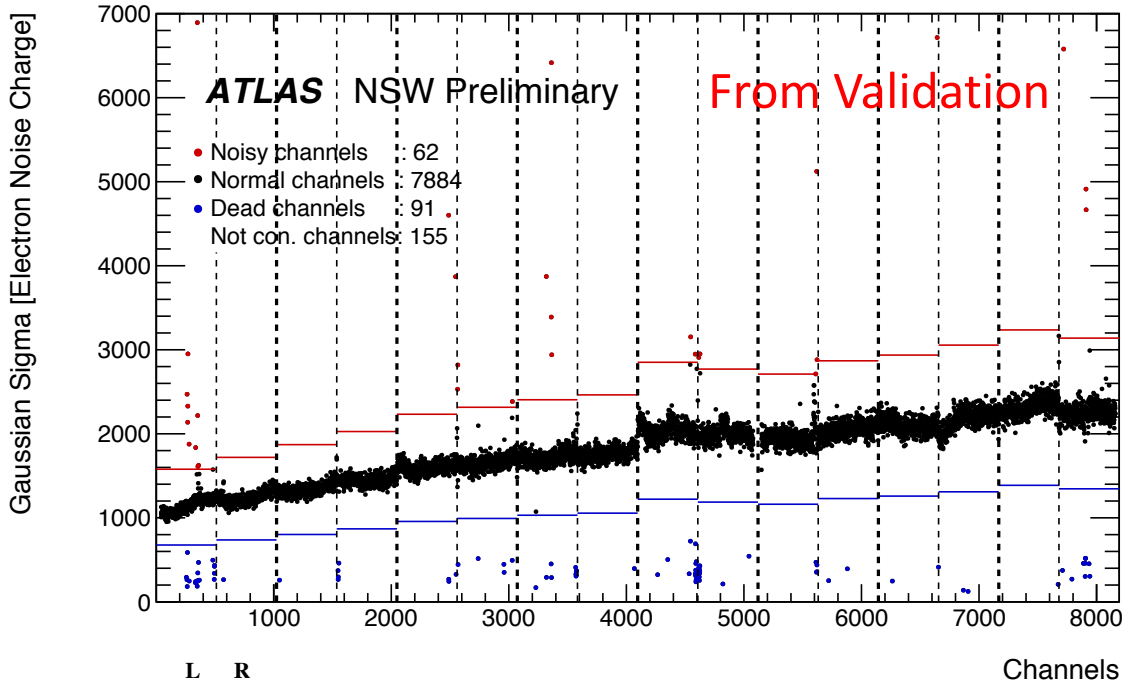




MM performance analysis – noise

- Noise increase with the strip number due to capacitive effects between the strips (expected)
- Studies made at the cosmic stand (controlled situation) show that increasing the strip charge thresholds, the effect on the single plane efficiency is negligible

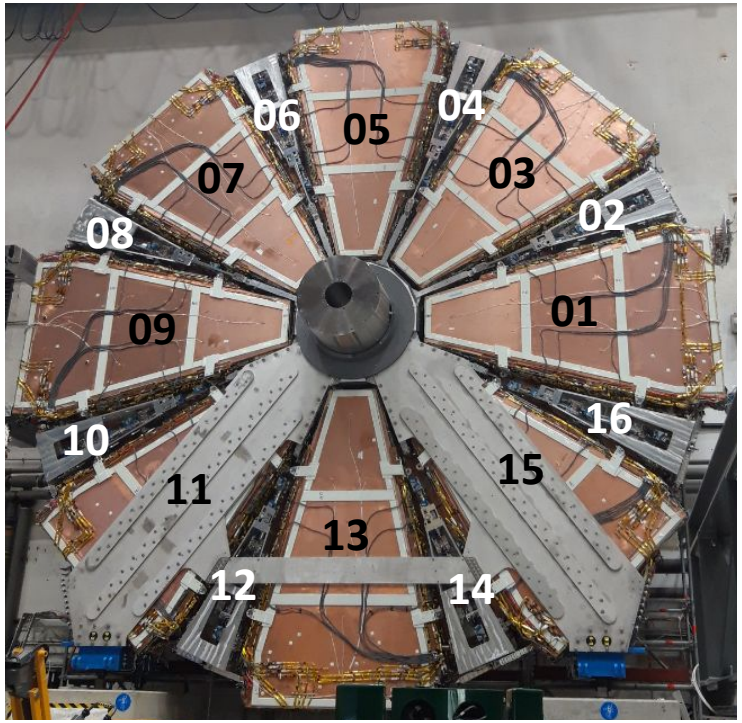




The noise problem on the Wheel now is solved!

Sector Installation and Commissioning

Name	Type	Status
A12	Small	done
A14	Small	done
A16	Small	done
A10	Small	done
A08	Small	done
A02	Small	done
A06	Small	done
A04	Small	done
A13	Large	done
A11	Large	done
A15	Large	done
A09	Large	done
A01	Large	done
A07	Large	done
A03	Large	done
A05	Large	done



Name	Type	Status
C14	Small	done
C12	Small	done
C16	Small	done
C10	Small	done
C08	Small	done
C13	Large	done
C11	Large	done
C09	Large	done
C02	Small	done
C06	Small	done
C04	Small	done
C15	Large	done
C01	Large	ongoing
C07	Large	ongoing
C03	Large	ongoing
C05	Large	today

NSW–A steps


Sept 2019 – during CERN open days
(before COVID!)


June 2021 – first NSW completed


July 2021 –
NSW-A ready to go in the cavern


July 2021 – lowering of the NSW-A


July 2021 – Finally in ATLAS

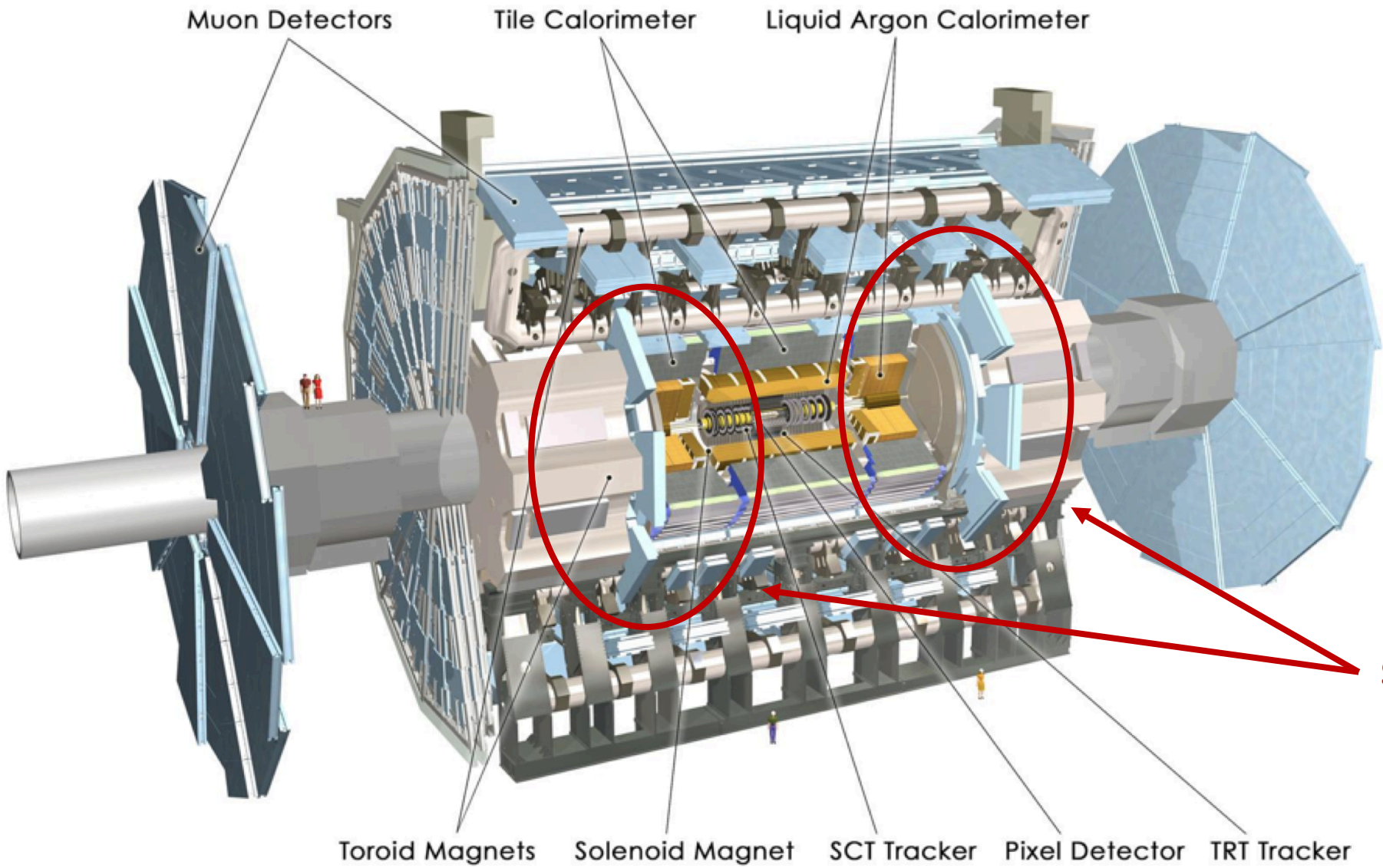
Conclusions

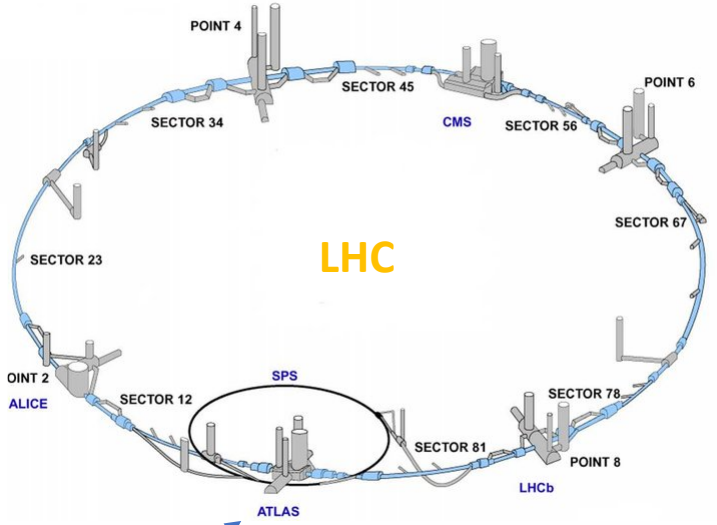
- Inclusion of the NSW into the ATLAS detector is imperative in order to maintain high trigger efficiency and momentum resolution in the high-luminosity environment of the LHC and HL-LHC for years to come.
- Production of both sTGC and Micromegas modules is completed while wedge assembly at CERN has kept pace.
- Performance studies shows that the MicroMegas are performing well as expected.
- Results with the Ar:CO_2:C_4H_{10} show a more stable HV behaviour for MM; ongoing long term ageing study.
- Noise investigation: major effort to fix unexpected high levels; remaining effects have negligible impact on the performance.

- NSW-A is ready to take data.
- NSW-C is going to be ready in the beginning of October.

BACKUP

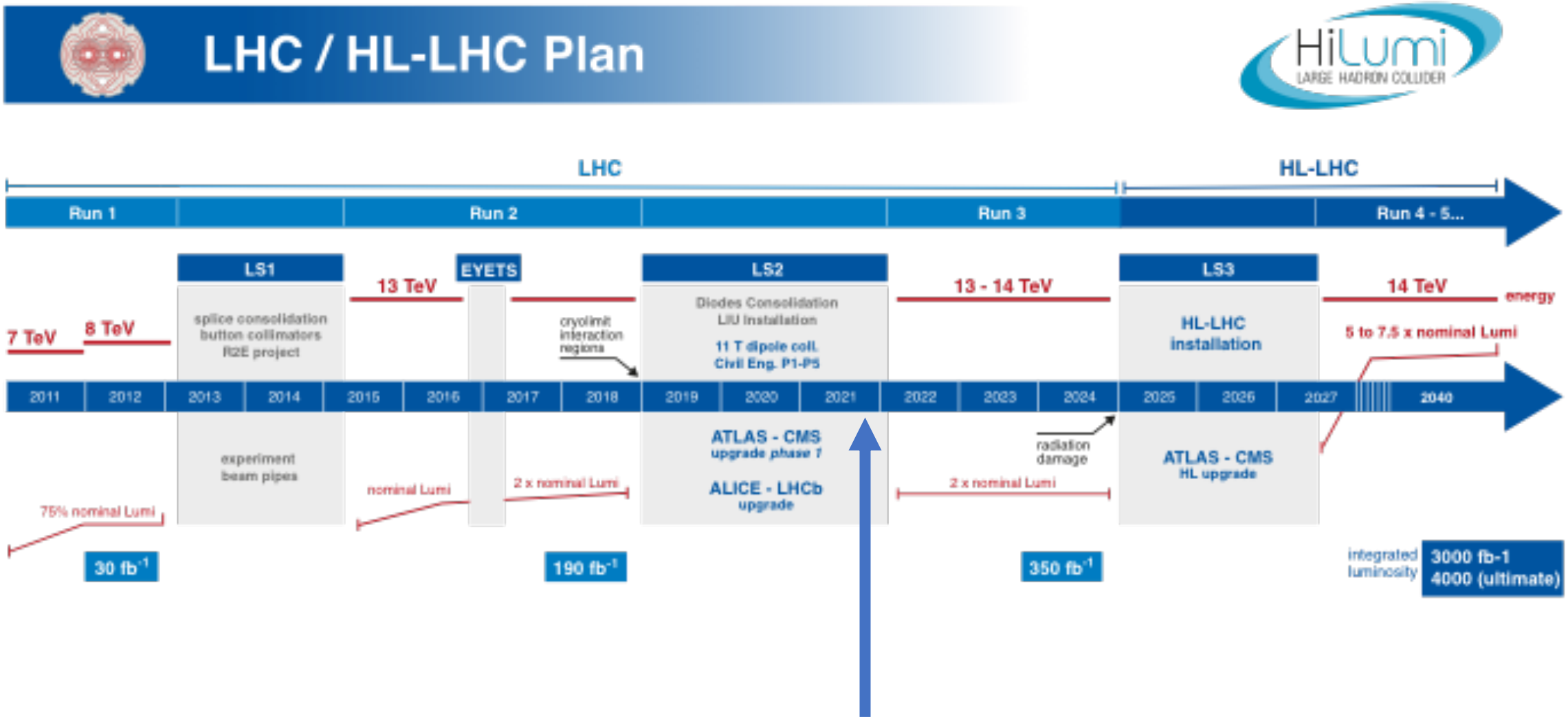
The ATLAS detector



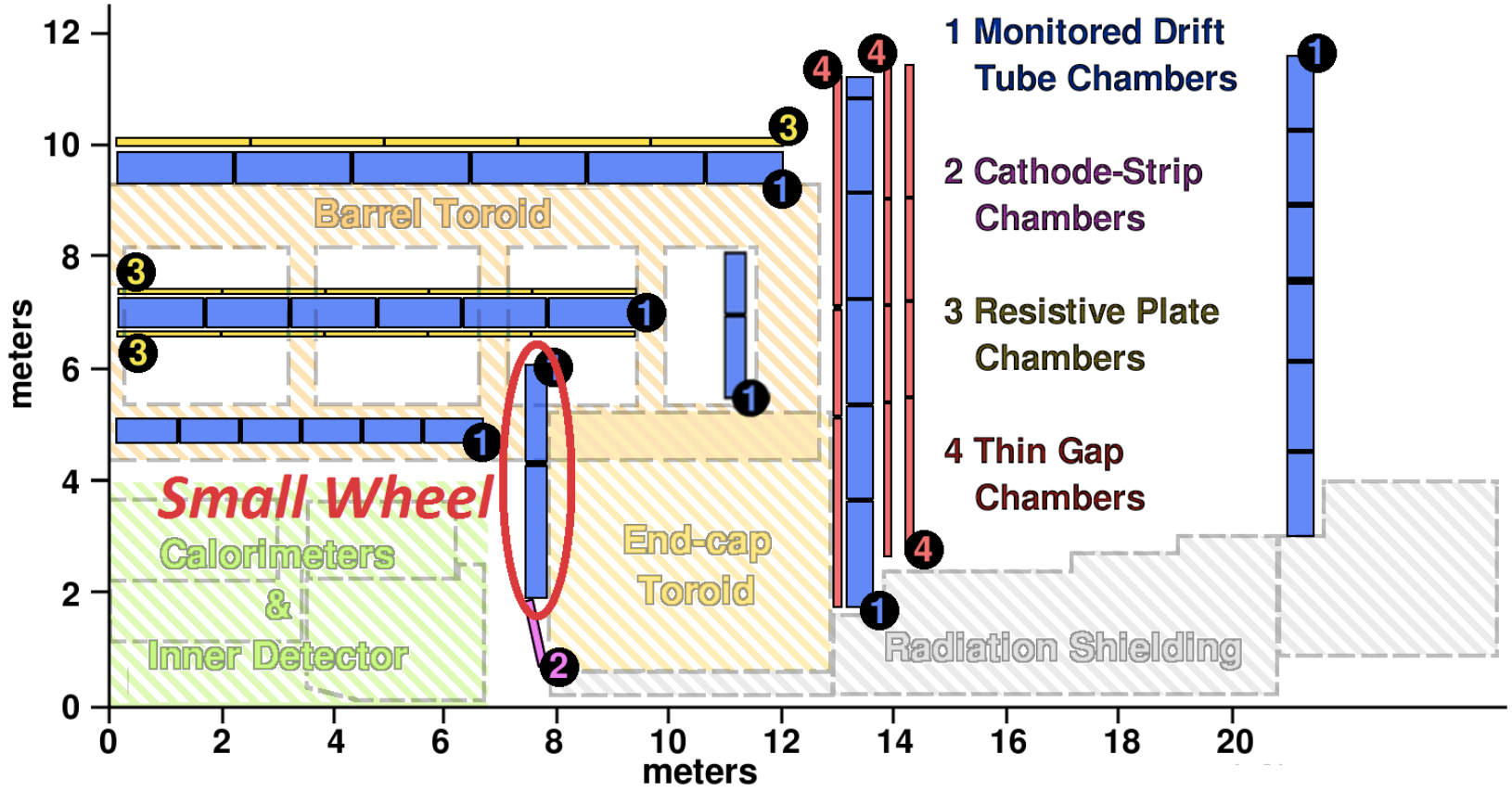


Small Wheel

LHC / HL-LHC plan

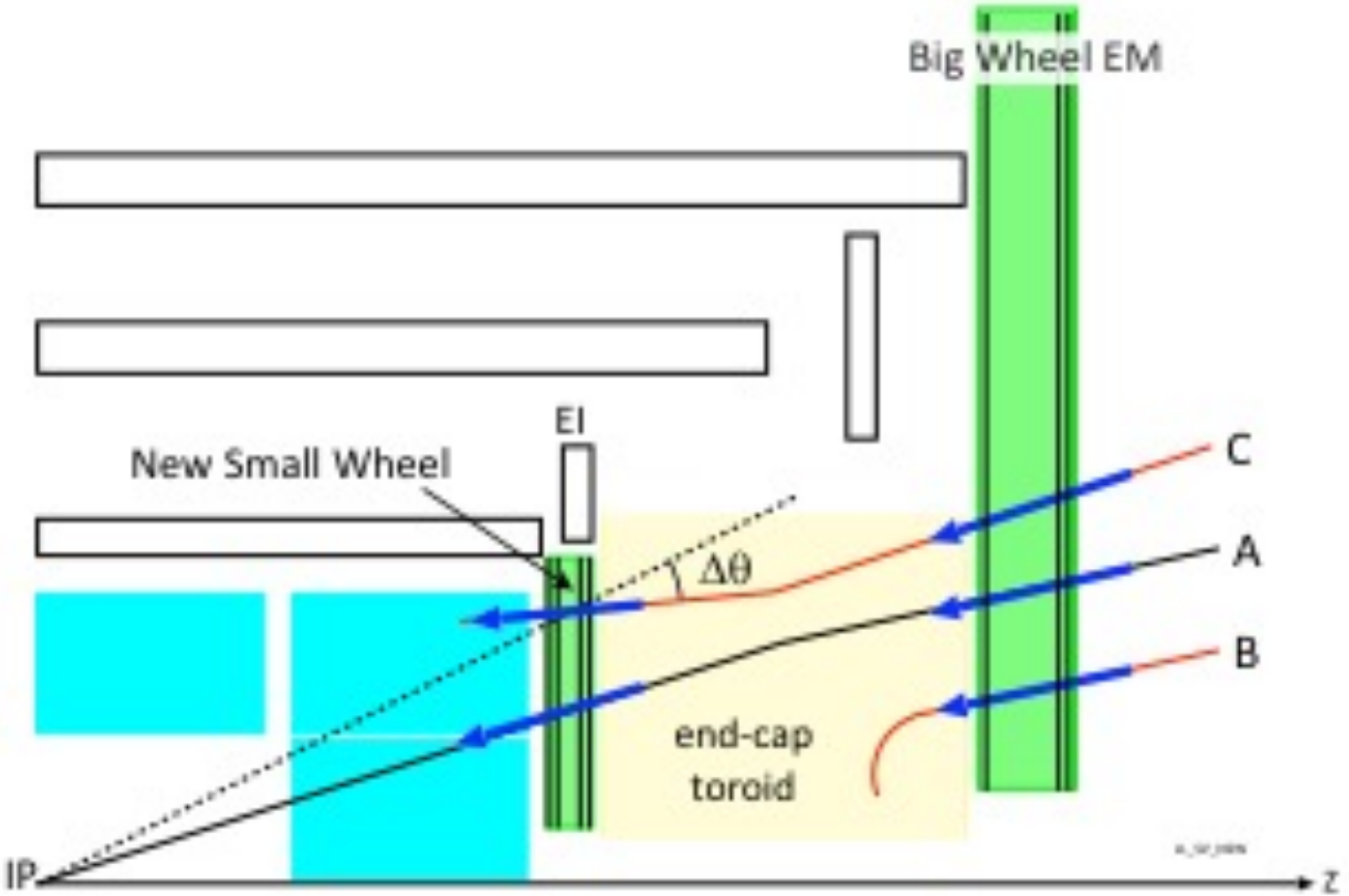


ATLAS Muon Spectrometer



1. Monitored Drift Tubes (End-cap + Barrel) - tracking
2. Catode Strip Chambers (End-cap) - tracking
3. Resistive Plate Chambers (Barrel) - trigger
4. Thin Gap Chambers (End-cap) - trigger

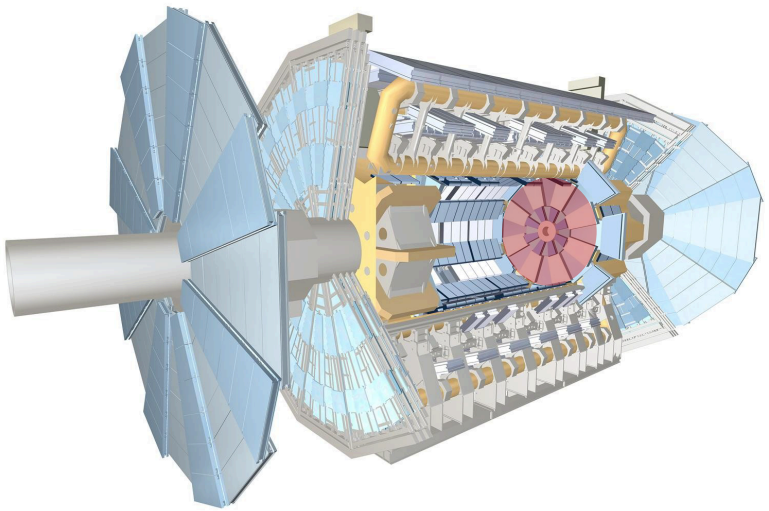
ATLAS trigger logic – end-cap



With NSW:

- Only track A will be accepted
- Track B is discarded since it is not pointing to the IP (created in the passive materials)
- Track B is discarded since it is not pointing to the IP (multiple scattering)

The New Small Wheel project



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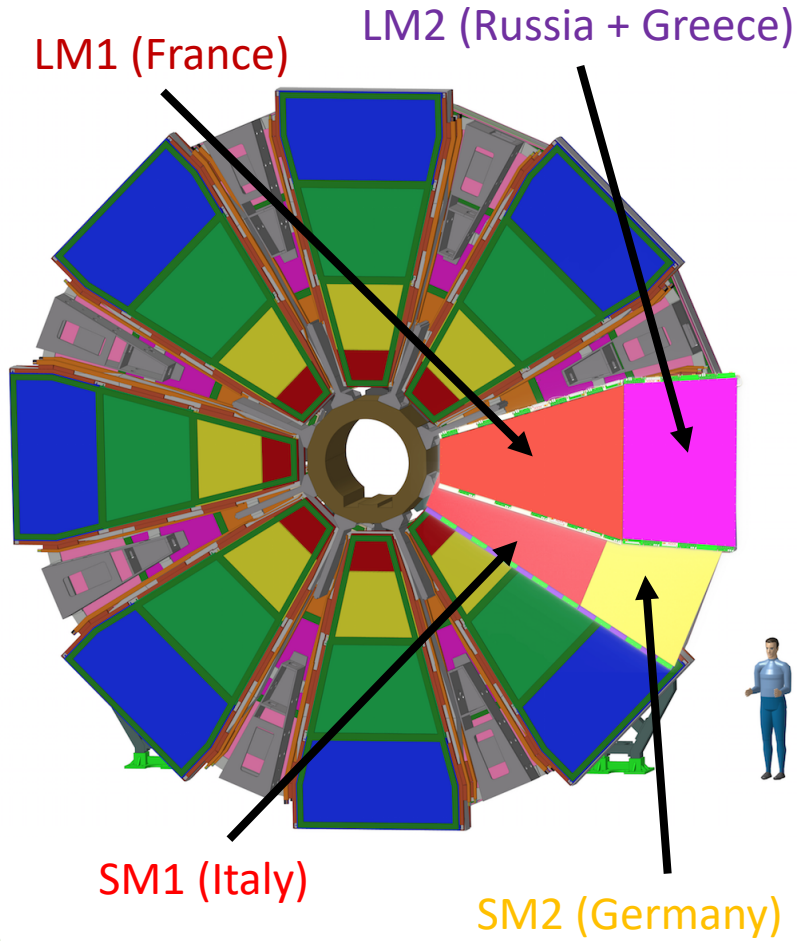
16 “petals” [8 small + 8 large]

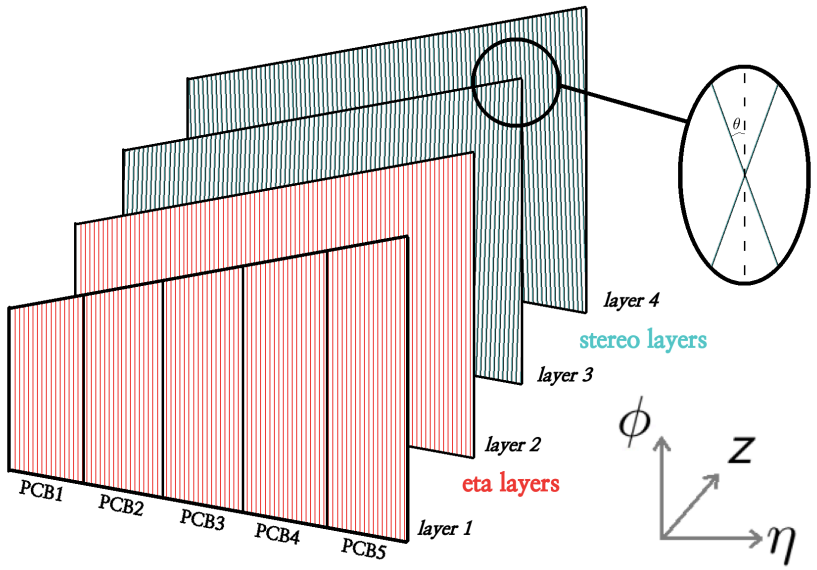


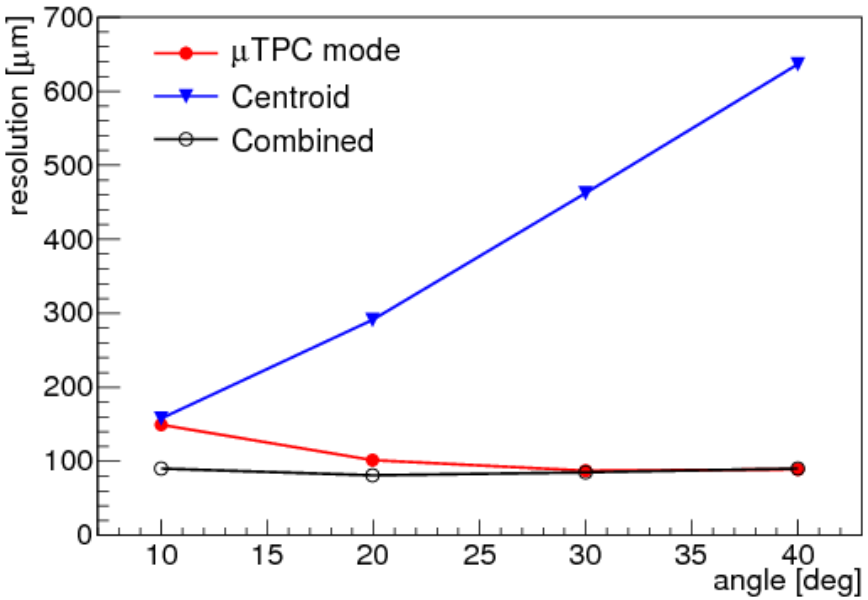
$\frac{\sigma(p_T)}{p_T}$ < 15% (@ 1 TeV)

⟹ single layer position resolution of ∼100 µm

⟹ alignment readout elements ∼100 µm

The ATLAS resistive MicroMegas chambers – working principle





NSW Design/Requirements:

- Reduce fakes trigger rate at L1;
- Reconstruct online muon tracks with 95% efficiency;
- Excellent spatial and angular resolutions: < 50 μm and < 1 mrad;
  for offline momentum reconstruction;
  for online matching with Big Wheel;
- Good spatial resolution on the second coordinate: < 2/3 mm
  for a better pointing of the primary vertex;
- Operate for the entirely of Run-3 and HL-LHC programme.

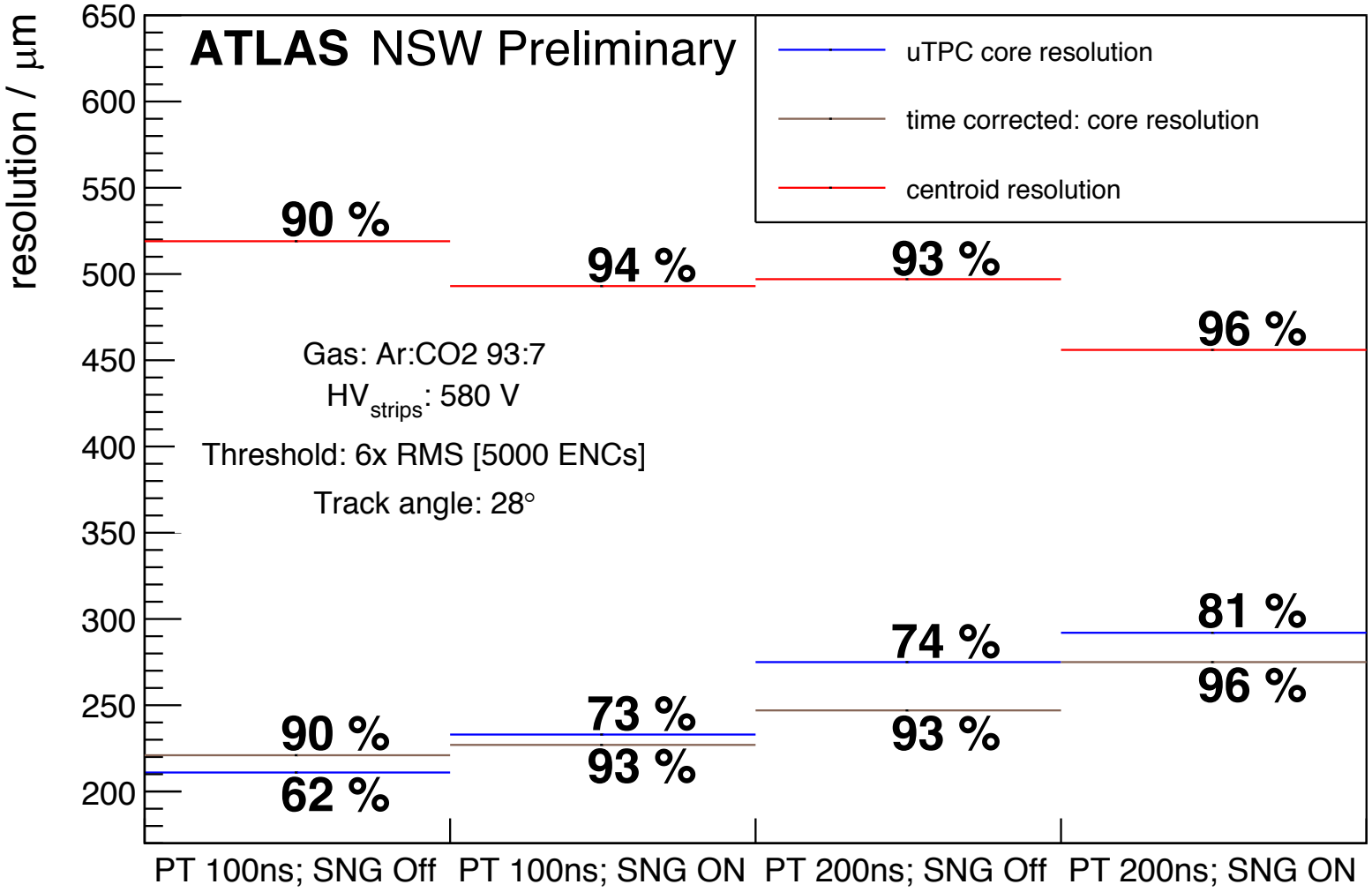
$$\frac{\sigma(p_T)}{p_T} < 15\% \text{ (@ 1 TeV)}$$

⟹ single layer position resolution of ∼150 μm

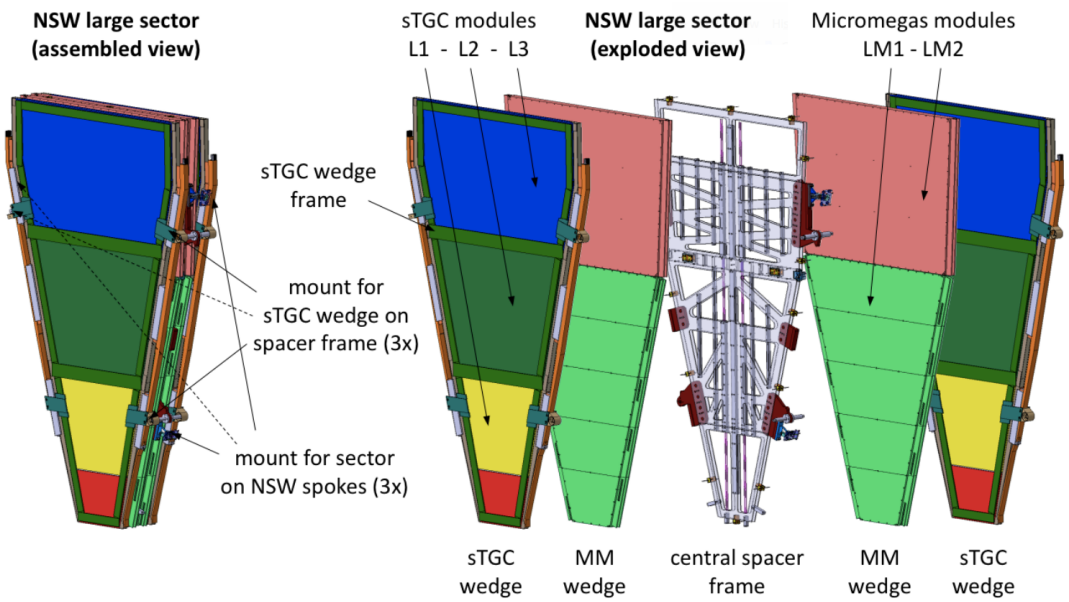
⟹ alignment readout elements ∼100 μm

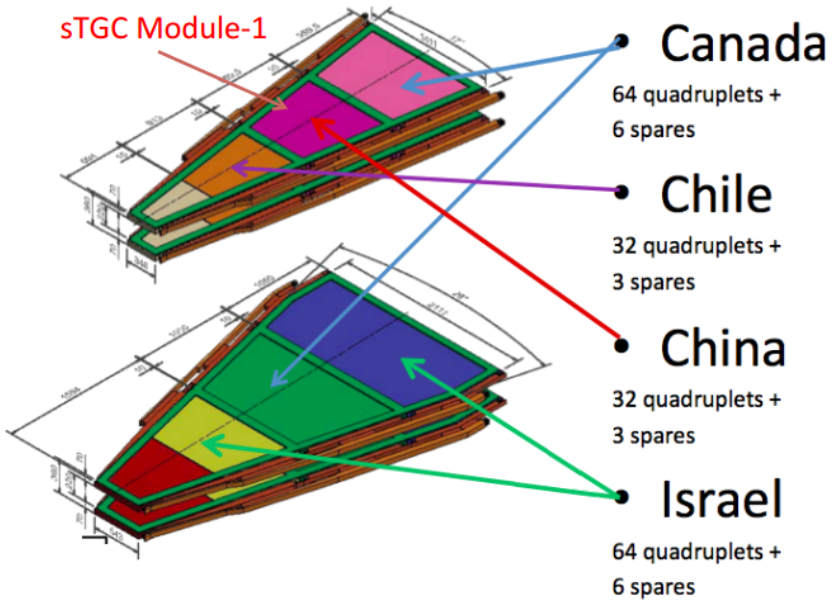
µTPC test beam results

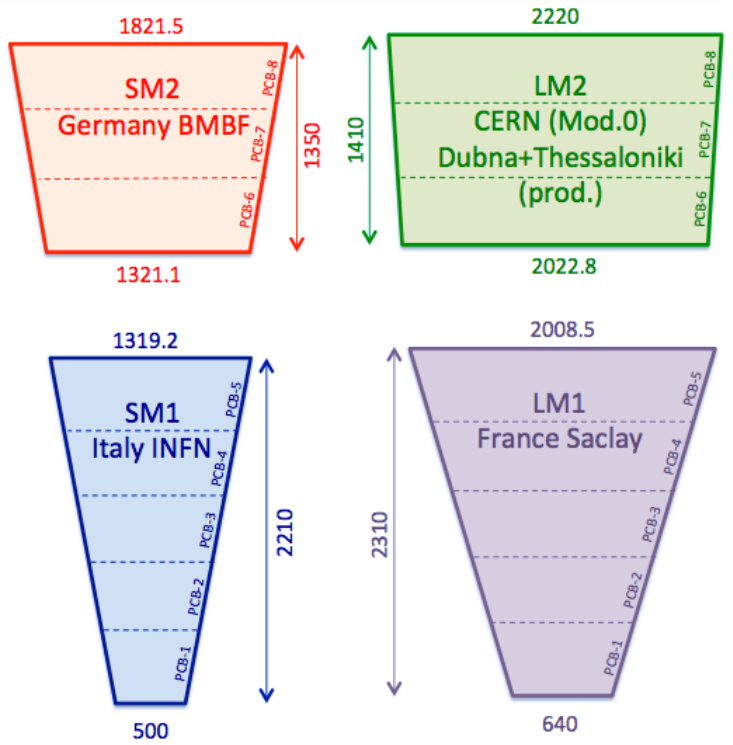
Single layer resolution of SM2 from test beam for different clusterization methods and different setting of the VMM readout chip. The numbers are indicating the single layer efficiencies.



NSW sectors


NSW large sector
(assembled view)
sTGC modules
L1 - L2 - L3
NSW large sector
(exploded view)
Micromegas modules
LM1 - LM2
sTGC wedge
frame
mount for
sTGC wedge on
spacer frame (3x)
mount for sector
on NSW spokes (3x)
sTGC
wedge
MM
wedge
central spacer
frame
MM
wedge
sTGC
wedge


sTGC Module-1
Canada
64 quadruplets +
6 spares
Chile
32 quadruplets +
3 spares
China
32 quadruplets +
3 spares
Israel
64 quadruplets +
6 spares


1821.5
SM2
Germany BMBF
PCB-8
PCB-7
PCB-6
1350
1321.1
2220
LM2
CERN (Mod.0)
Dubna+Thessaloniki
(prod.)
1410
2022.8
1319.2
SM1
Italy INFN
2210
500
2008.5
LM1
France Saclay
2310
640

sTGC

- Primarily used for triggering;
- CO_2-n-pentane gas (55%:45%);
- Wire, pad, and strip readouts;
- Strip pitch: 3.2 mm - much smaller than TGC, hence “small”;
- Pads for local triggering;
- Good timing resolution with short drift time for electrons;
- Construction sites: Canada, Chile, China, Israel, Russia.