The New Small Wheel project of ATLAS

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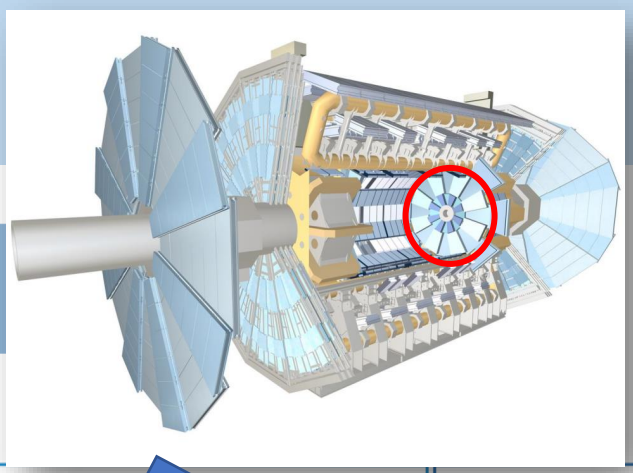
CERN EP Detector Seminar 17/6/2022

Outline

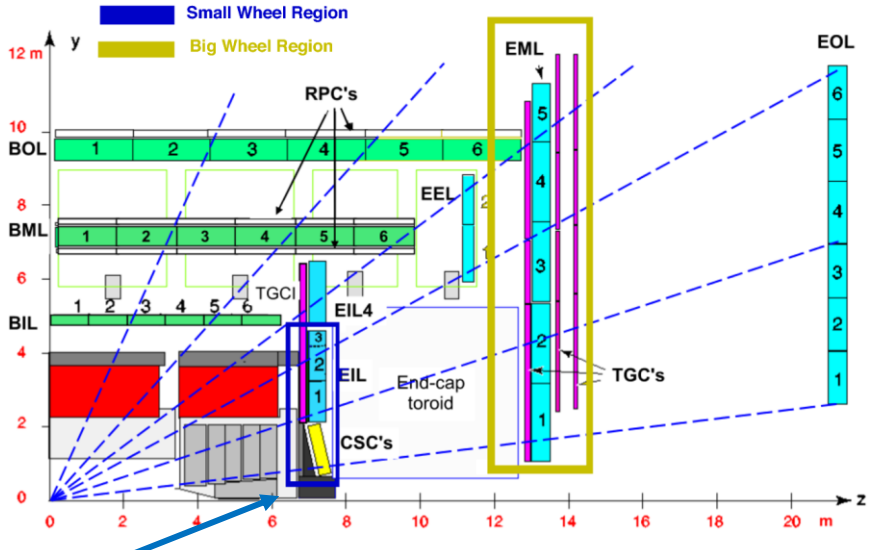
- Motivation
- Introduction
  - The New Small Wheel (NSW) Project
  - Micromegas (MM) for the NSW
  - Small Strip Thin Gas Chambers (sTGC) for the NSW
  - NSW Electronics
- Integration of Sector Components in BB5 and b.180
  - MM Double Wedge (DW) Integration
  - sTGC quadruplet integration
- NSW integration in b.191
  - Integration of a sector
  - Intstallation of a sector on the wheel
  - Commissioning
- P1 activities
  - Integration
  - Status
  - Commissioning Highlights
  - Conclusions and next steps

Motivation



- After LS2 the accelerator luminosity will be increased to 2–3 × 10^{34} $cm^{-2}s^{-1}$
- After LS3 the luminosity will raise to 5-7.5 × 10^{34} $cm^{-2}s^{-1}$

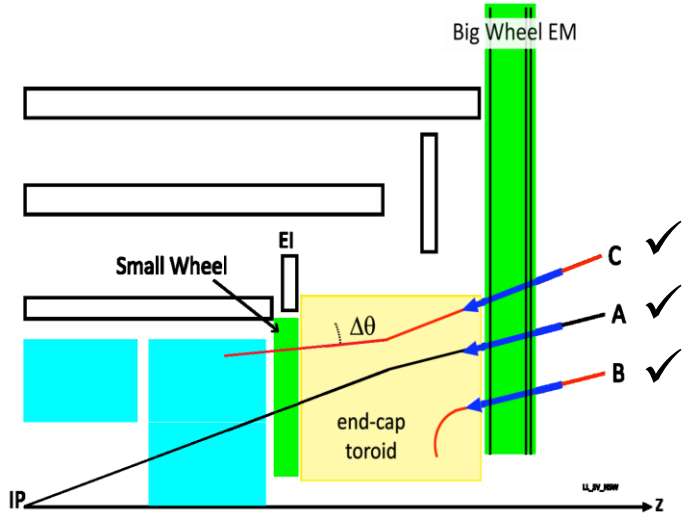
Motivation

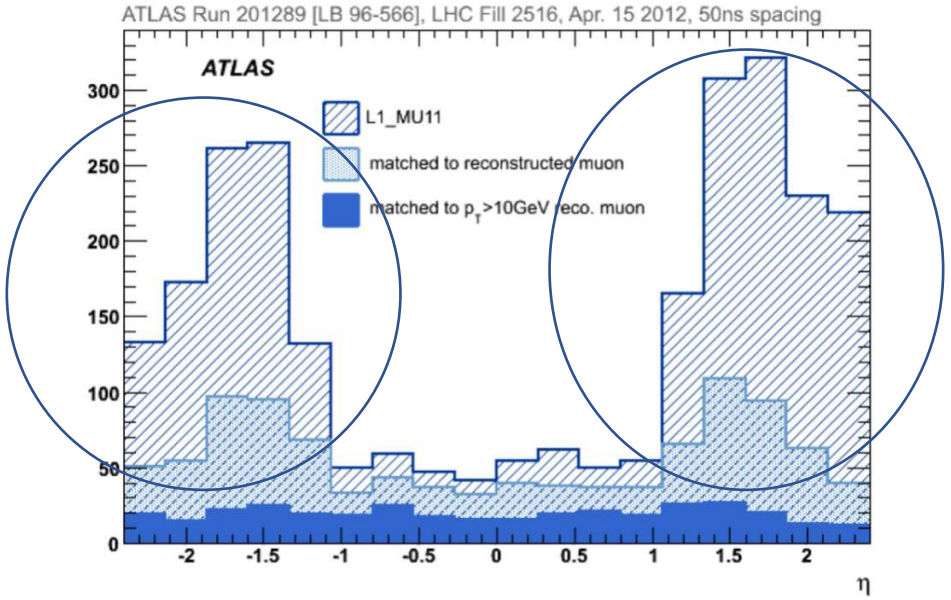


The Small Wheel region

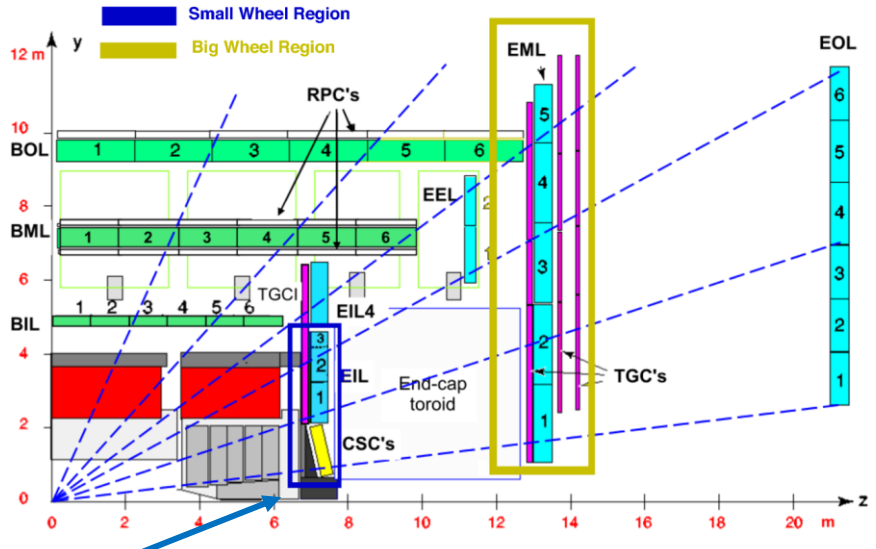
The Big Wheel

- In the ATLAS muon Spectrometer the highest rates are seen in the SW region.
- In the previous setup the trigger in the muon endcaps was coming from the TGC chambers of the Big wheel.
- This resulted in a high number of fake events.



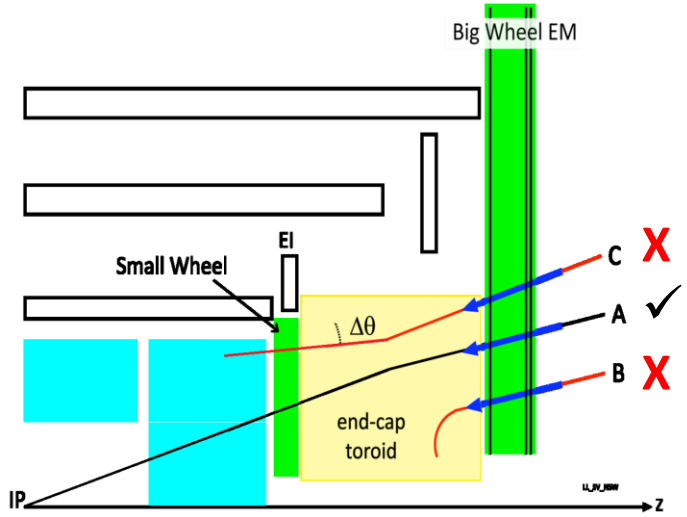


Motivation



The Small Wheel region

The Big Wheel

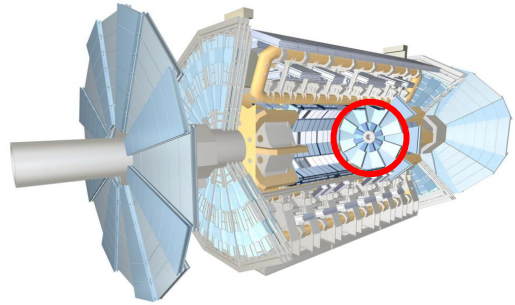


- If we combined the trigger info from the big wheel with information pointing to the IP from the small wheel we can have efficient rejection of background.
- **Need detectors with fast time resolution and good angular resolution.**

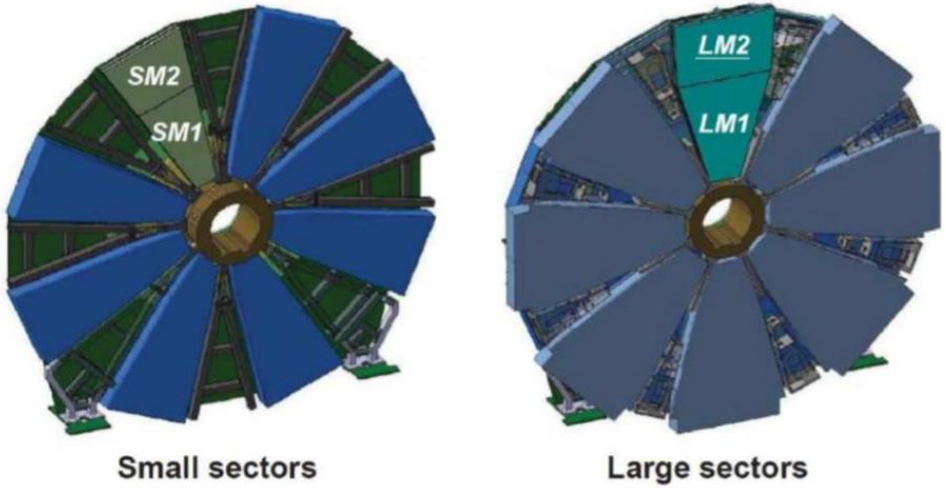
- With the increase of the rate (15kHz/cm^2 for HL-LHC), substantial degradation of tracking performance is expected both in efficiency and resolution in the 'Small Wheels'.

- **Need detectors with good spatial resolution & efficiency in the HL-LHC conditions.**
- **Need to preserve the same basic geometry.**

The New Small Wheel

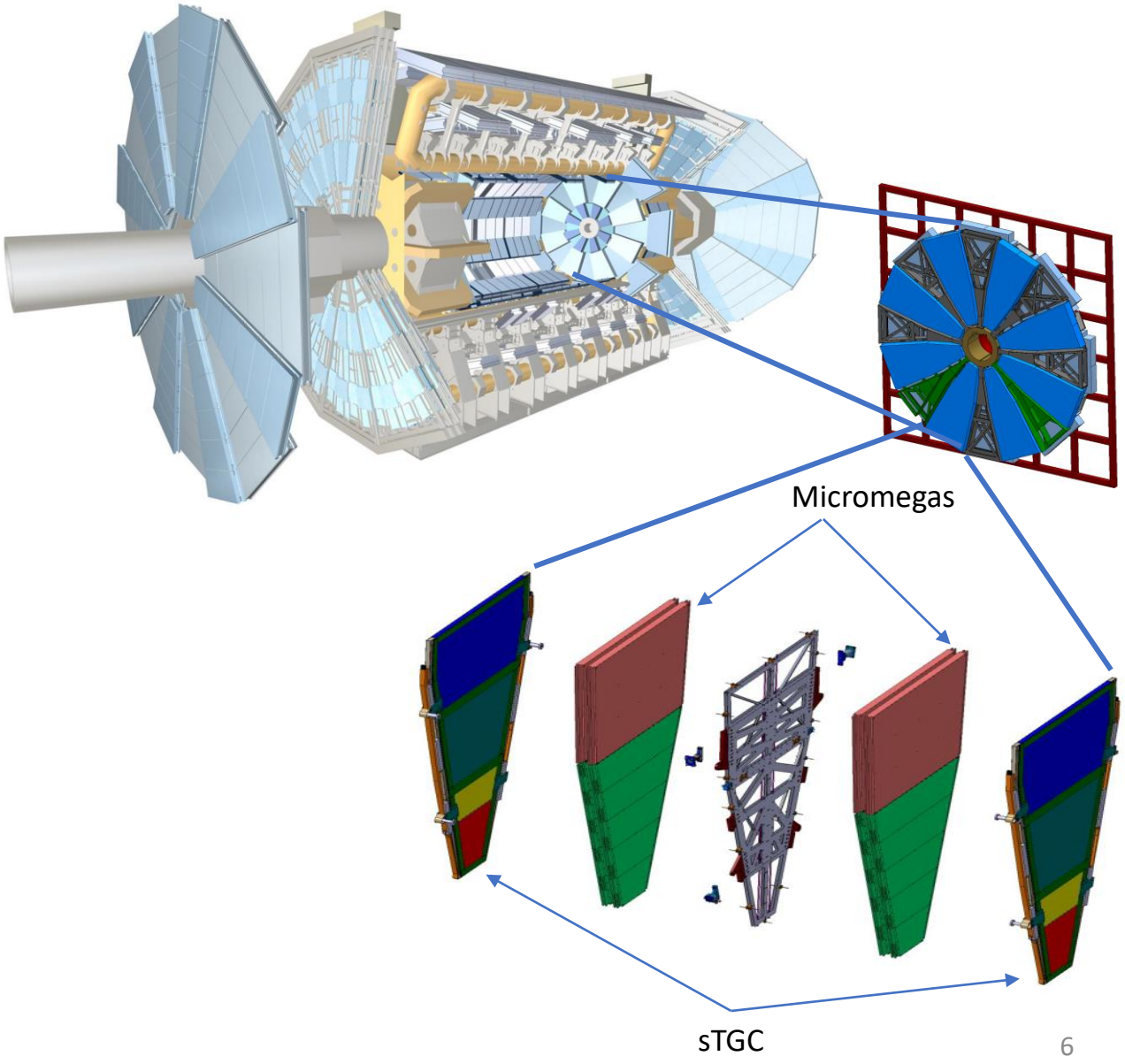


The New Small Wheel (NSW)



Small sectors

Large sectors



- 2 x Wheels ~10 m diameter.

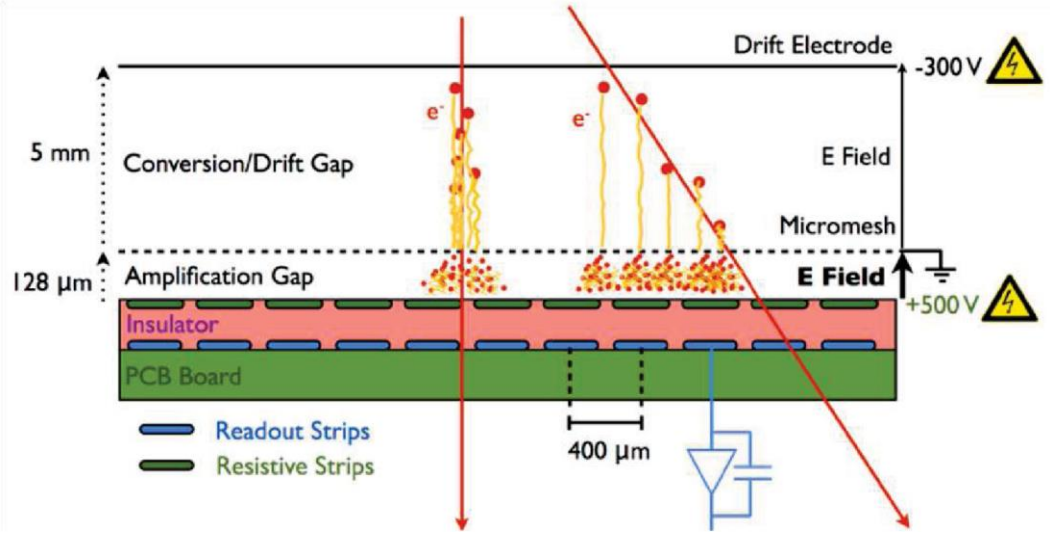
NSW sectors

- 8 Small and 8 Large Sectors, same geometry and segmentation with the SW.

Each Sector consists of:

- 16 detection layers in total.
- 8 layers per detection technology (8 layers of Micromegas, 8 layers of sTGC).

Micromegas for the NSW - Introduction



Micromesh Gaseous Structure (Micromegas)

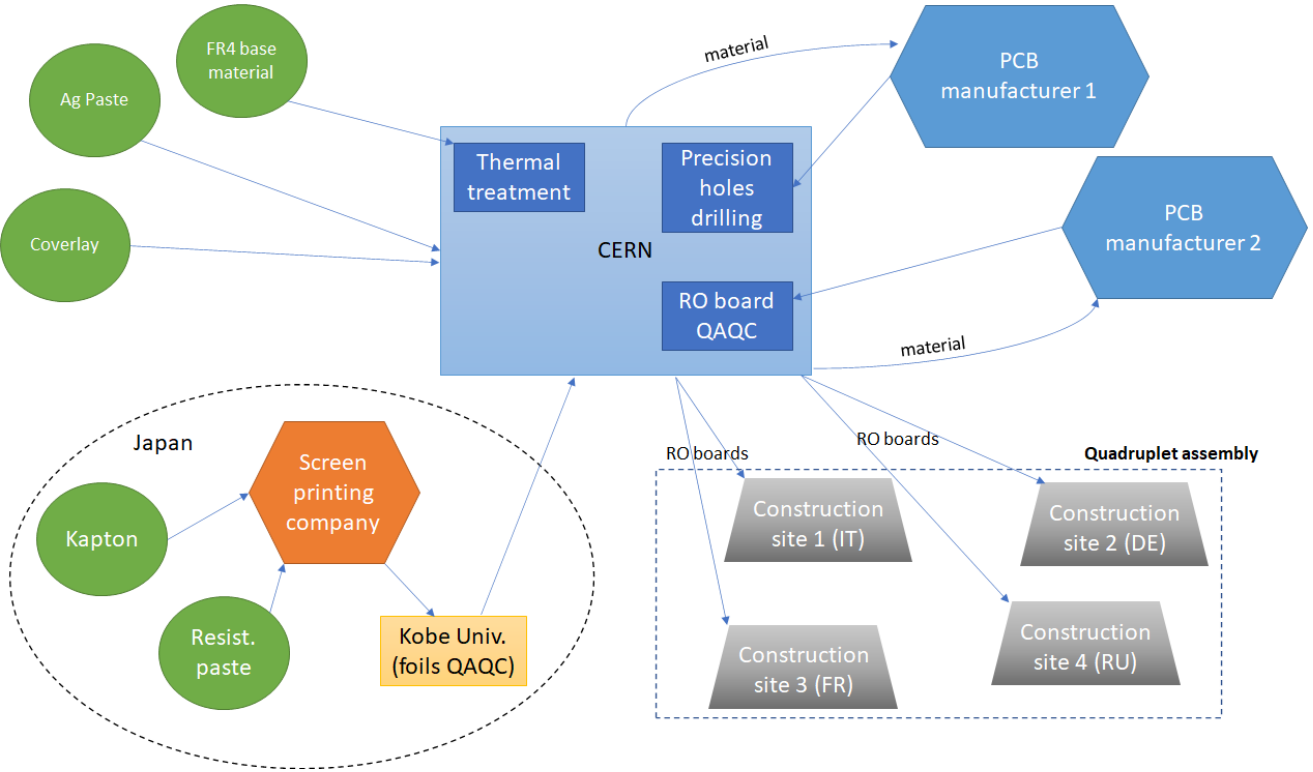
primary tracking detector

- Spatial resolution ~ 100 µm up to 32°.
- High granularity.
- Excellent high-rate capability.

- The readout plane consists of Cu strips on large scale readout PCBs. They are covered by a Kapton layer with resistive screen pattern (graphite) printed on it for spark protection.
- The mesh is integrated in the drift panel structure and not coupled with the pillars (floating).
- Mesh and PCB form the amplification gap.
- While a cathode at 5mm distance closes the gas gap and forms a drift space.

- Strip width 300 µm (pitch 425-450 µm)
- Mesh at ground potential, type 70:30
- Drift gap (5 mm), HVdrift= -300V
- Amplification gap (120 µm), HV_{RO} = 570 V / 520 V
- Baseline gas mixture: 93% Ar - 7% CO_2 / 93% Ar - 5% CO_2 – 2% iC_4H_{10}

Micromegas for the NSW – Board production



Production of readout boards in industry which was an additional challenge

ELVIA (F): (LM1, LM2, SM2 eta)

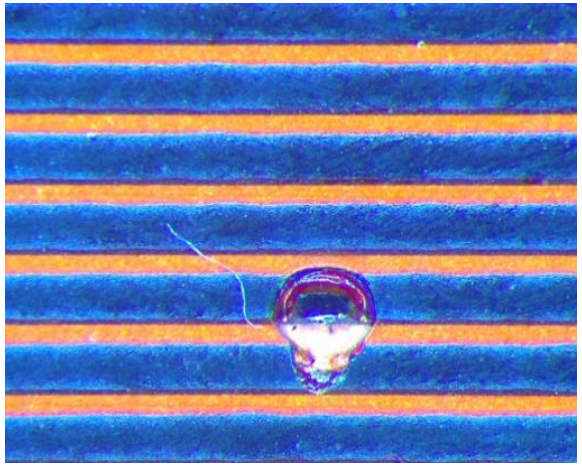
ELTOS (IT): (SM1, SM2 stereo)

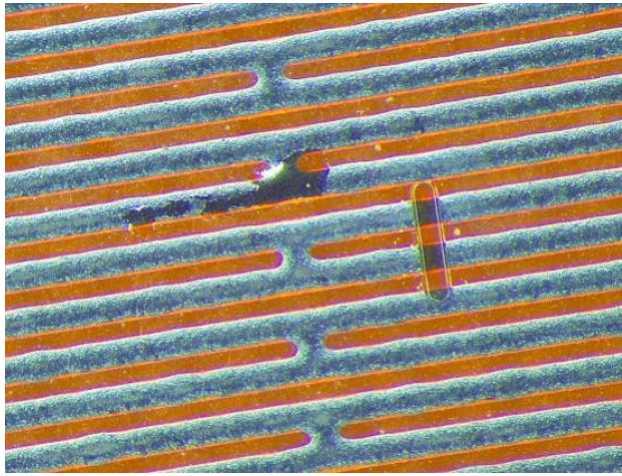
In total ~3000 boards were produced and tested

QAQC Typical visual defects:

- Bubbles/bumps in active area
- Enclosures
- Damage to the Kapton foil
- Rough edges
- Faults in the HV Ag line ..

Dedicated Lab in B188





Micromegas for the NSW – HV stability

End 2017

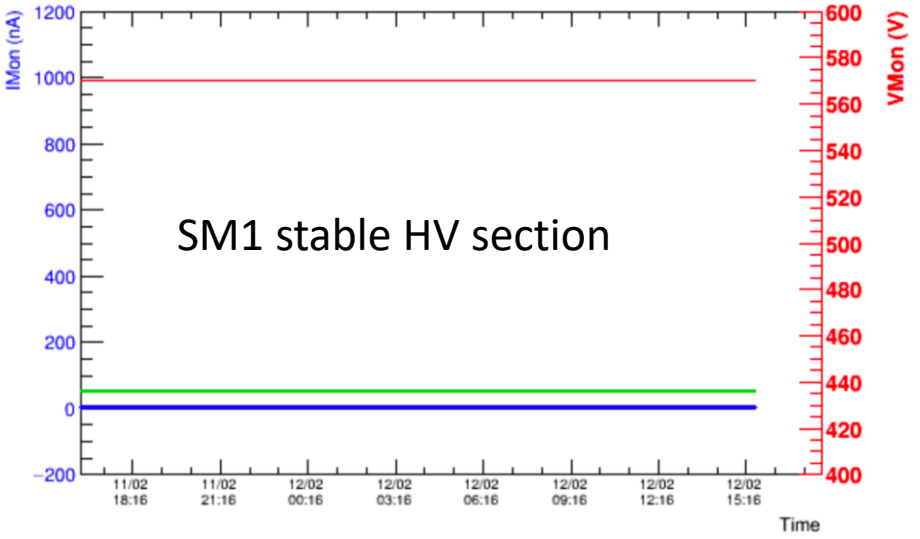
- First production MM NSW quadruplets showed problems of HV instability.

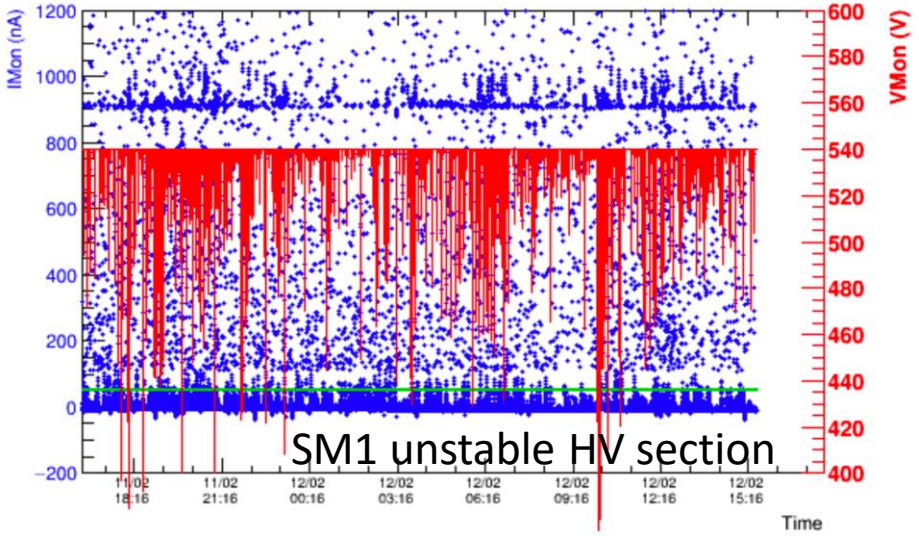
End of 2018

- R&D focused on the causes of the sparks and possible solutions.

Spark causes & solutions

- Impurities / imperfections
  - Thorough QAQC of PCBs, Detailed cleaning protocol during construction
- Humidity
  - Operate HV when RH<15%
- Mesh mechanical imperfections
  - Polishing of the mesh
- Resistivity of the boards …



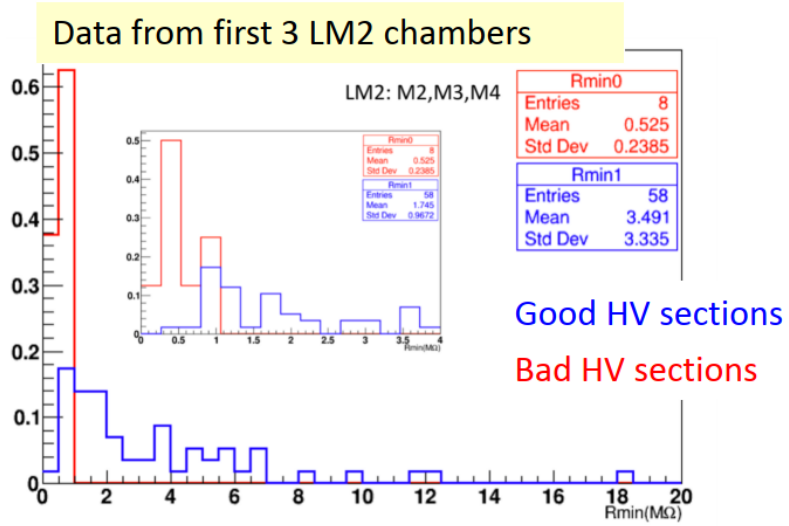


Micromegas for the NSW – HV stability

Jan 2019 Resistivity vs HV

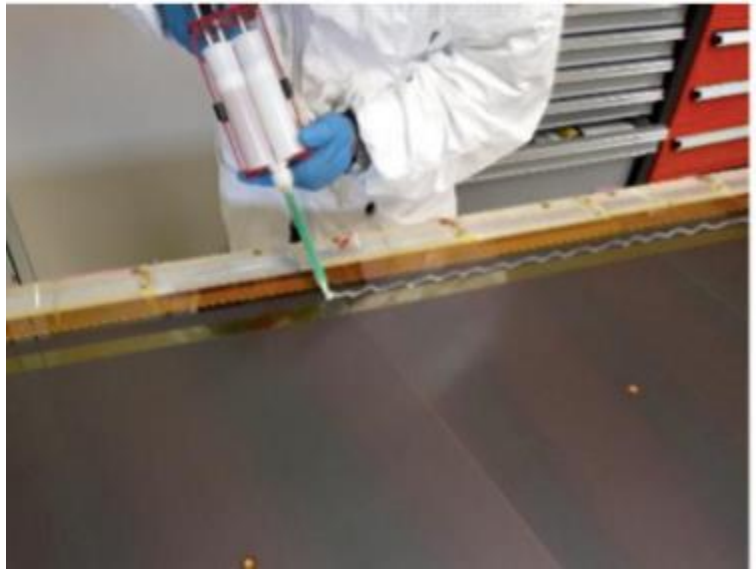
Correlation between low Resistance in the boundary of the active area and the HV behavior of the detector:

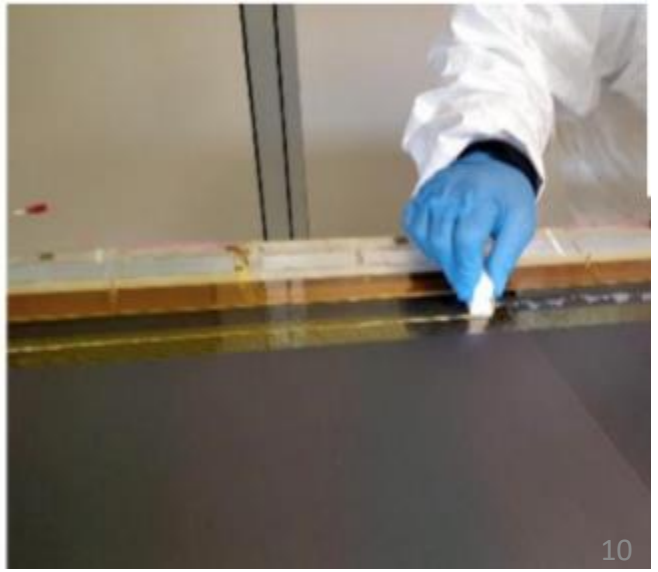
- In presence of a defect (defect of components, impurities, humidity etc) a board with low resistivity will show higher current peaks.



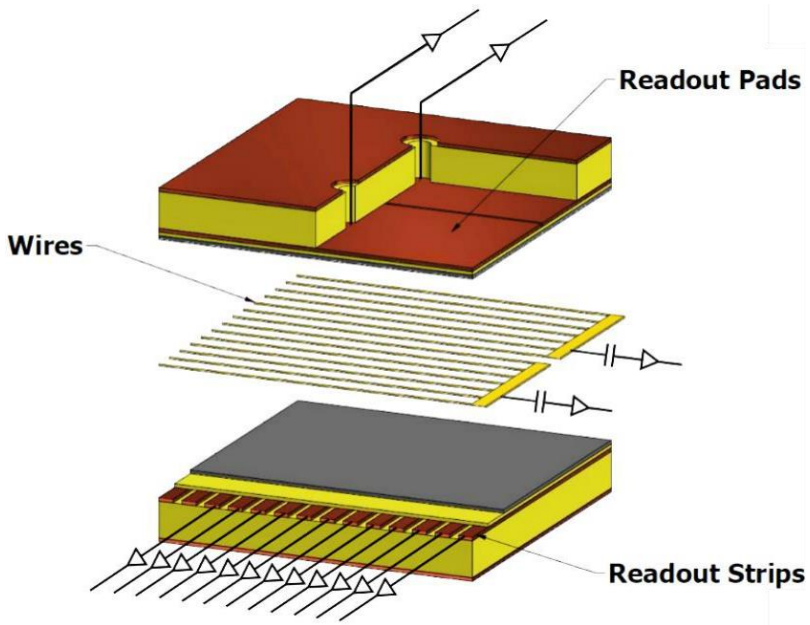
Solution: passivation (araldite or polyurethane)

- Increase min Resistance by extending the inactive region of the detector by few cm.
- Passivation increased the fraction of good HV sections from 82% to 94%.





sTGC for the NSW - Introduction



Small-strip Thin Gap Chambers (sTGC)

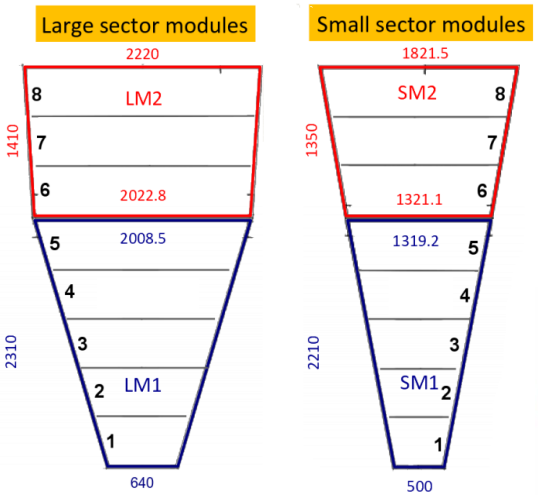
primary trigger detector

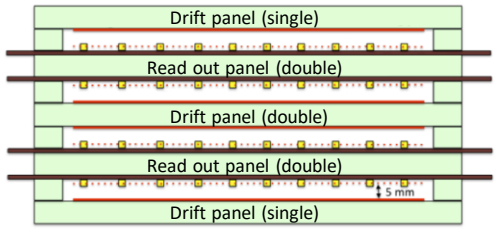
- Very fast response
- 1 mrad angular resolution
  - for online reconstructed segments
- Spatial resolution ~100-120 µm
- The operational gas is a mixture of 55% CO_2 and 45% n-pentane

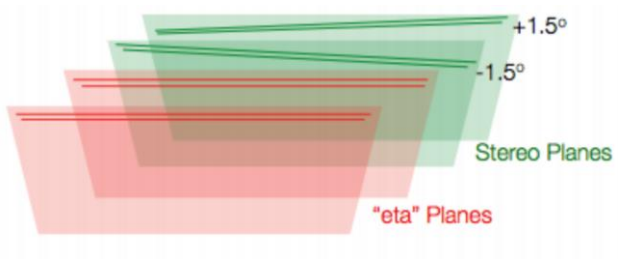
- TGC concept well known, used at OPAL and ATLAS end-cap muon trigger system.
- Grid of 50 µm gold plated tungsten wires at a potential of 2.8 kV and 1.8 mm pitch.
- Two cathode planes, 1.4 mm from the wire plane with resistive layer. At the back:
  1. Strips. Pitch 3mm (much smaller than TGC) -> resolution of 100 –120 µm can be achieved with a charge centroid reconstruction
  2. Pads. Pitch 80 mm.

  Pads: used at a 3-out-of-4 coincidence to identify muon tracks roughly pointing to the interaction point and define which strips need to be readout to obtain a precise measurement in the bending coordinate (region of interest), for the trigger.
  For offline the azimuthal coordinate is obtained from the wires.

NSW – quadruplet construction





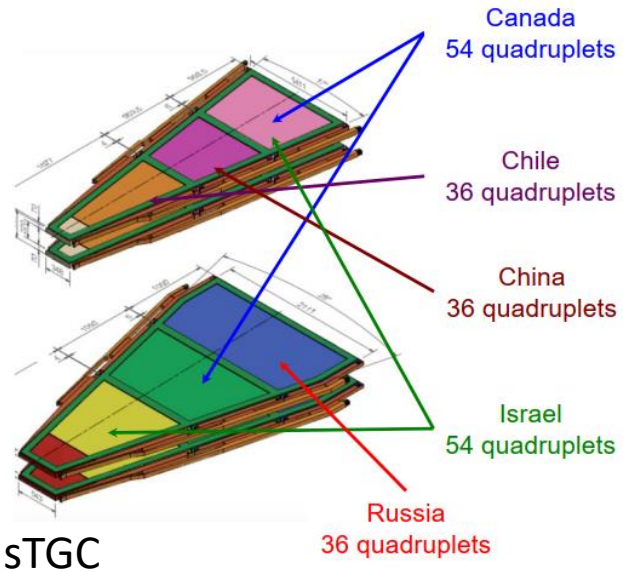


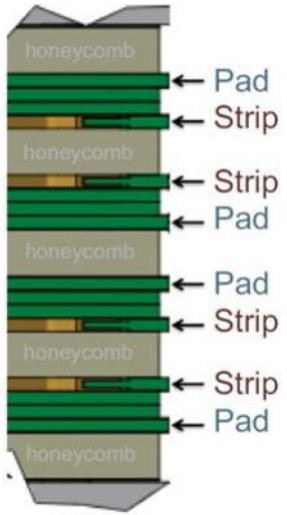
Micromegas

Type
SM1 (Italy INFN)
SM2 (Germany)
LM1 (France)
LM2 (Greece, Russia)

10-12 weeks / quadruplet

- 128 quadruplets of 4 different types.
- Surface 2-3 m^2.
- Total area larger than 1200 m^2 – Largest Micromegas project.
- **Production completed April 2021.**



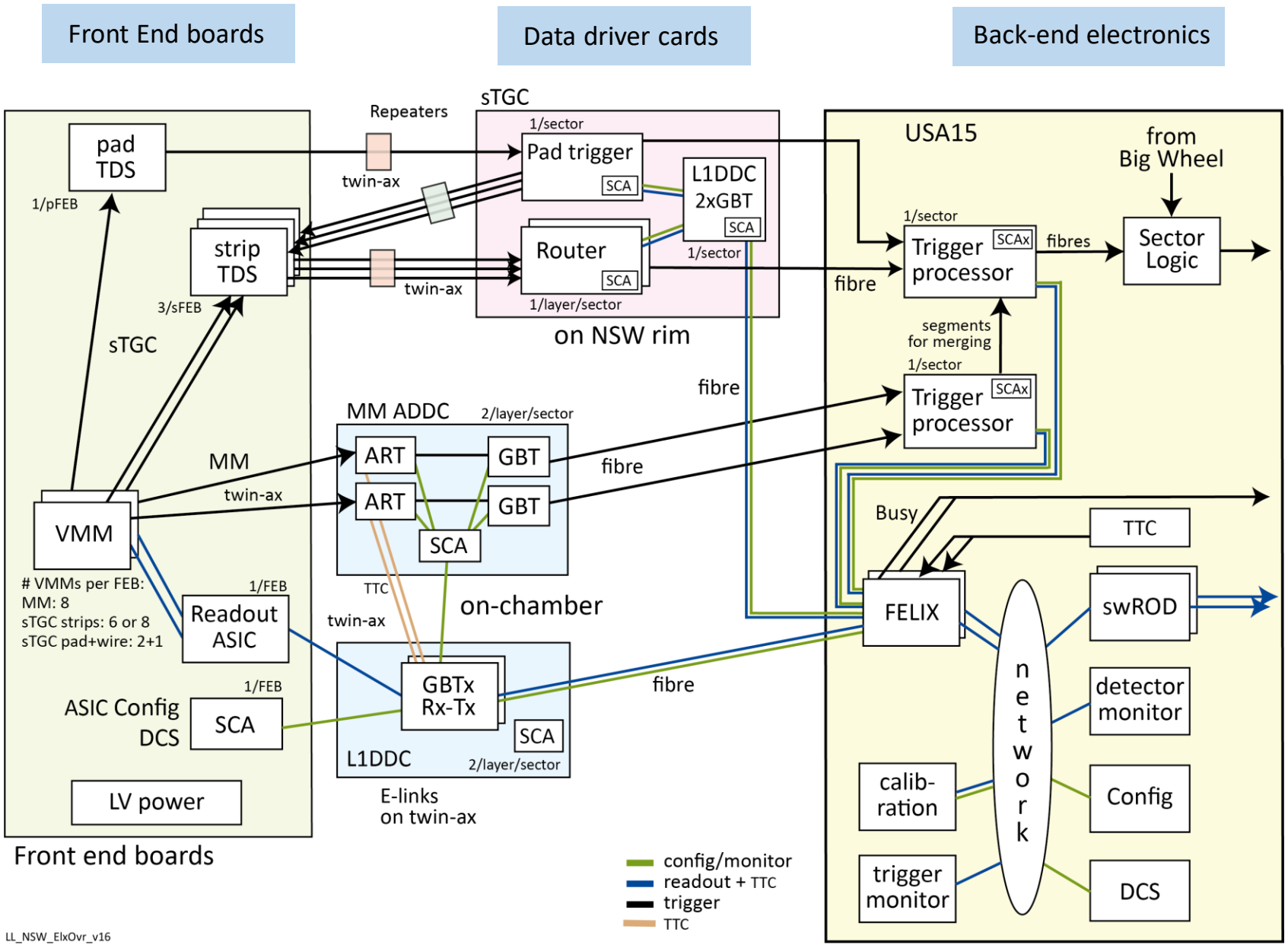


sTGC

Type
QS1 (Chile / Israel)
QS2 (China)
QS3 (Canada / Israel)
QL1 (Israel)
QL2 (Canada)
QL3 (Russia)

- 32 quadruplets + 4 spares of each type required
- **Production completed June 2021.**

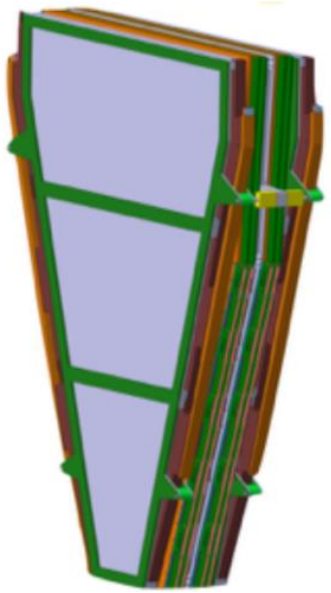
NSW electronics - Overview



NSW electronics - VMM ASIC

Used both on MM and sTGC

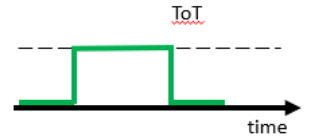
- 64 channels read out signals.
- Encodes pulse timing info in an 8-bit word (TDO) & pulse height in a 10-bit word (PDO).
- Timestamps the event with the BCID.
- Provides trigger primitives.



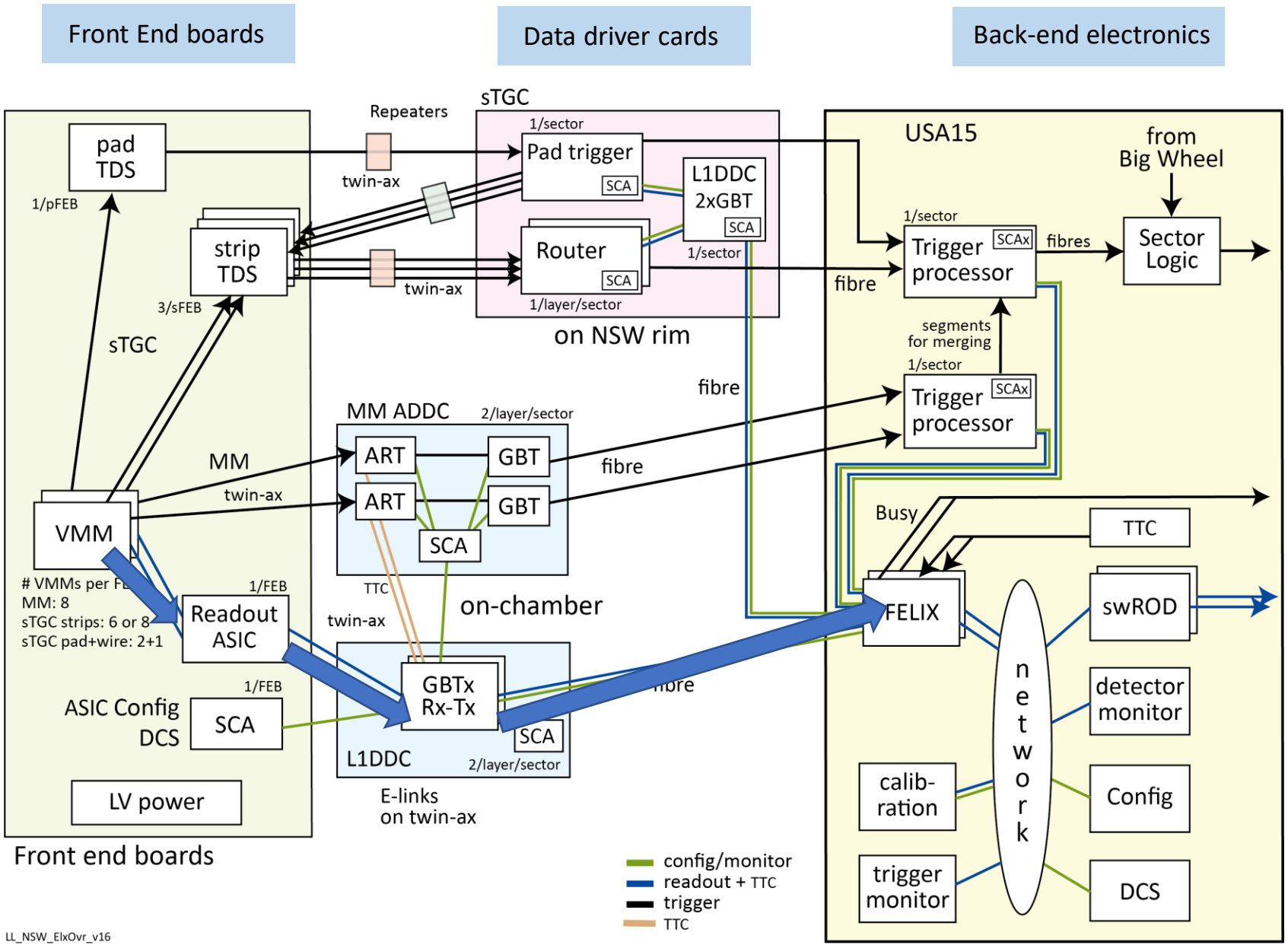
VMM

Four independent data output paths

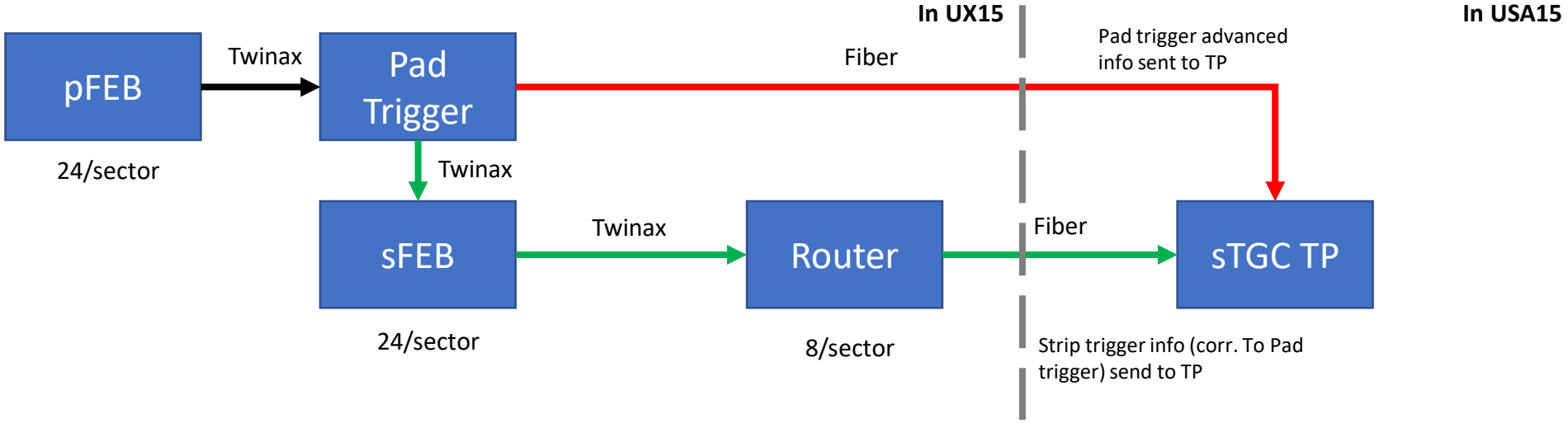
Readout Path	channel ID, TDO, PDO
sTGC Trigger Path-pads	Time-over-Threshold
sTGC Trigger Path-strips	6b pulse amplitude
MM Trigger Path	ID of first channel that fired per BC and Vmm (Address in Real Time-ART)



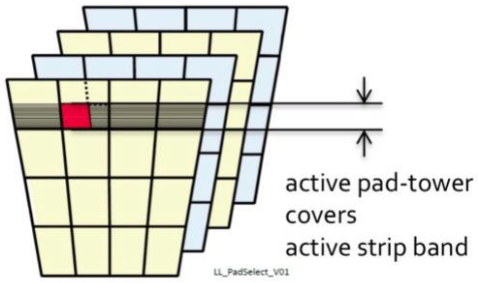
NSW electronics – readout path



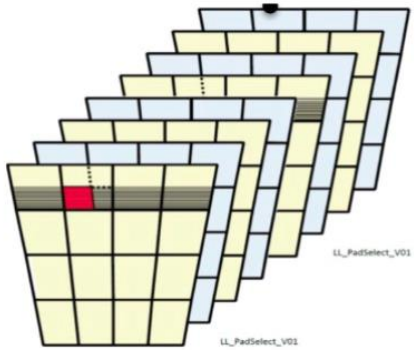
NSW electronics - sTGC Trigger path



Pad Trigger: ¾ & ¾ hit coincidence
Select up to 4 candidates



Pad request: sTDS to Router to Trigger Processor
Send strip charges for selected Bands



- pFEBs -> pads
- sFEBs -> strips
- Trigger Data Serializer (TDS) ASIC: samples/deserializes the VMM's trigger outputs.

When a muon passes the sTGC layers:

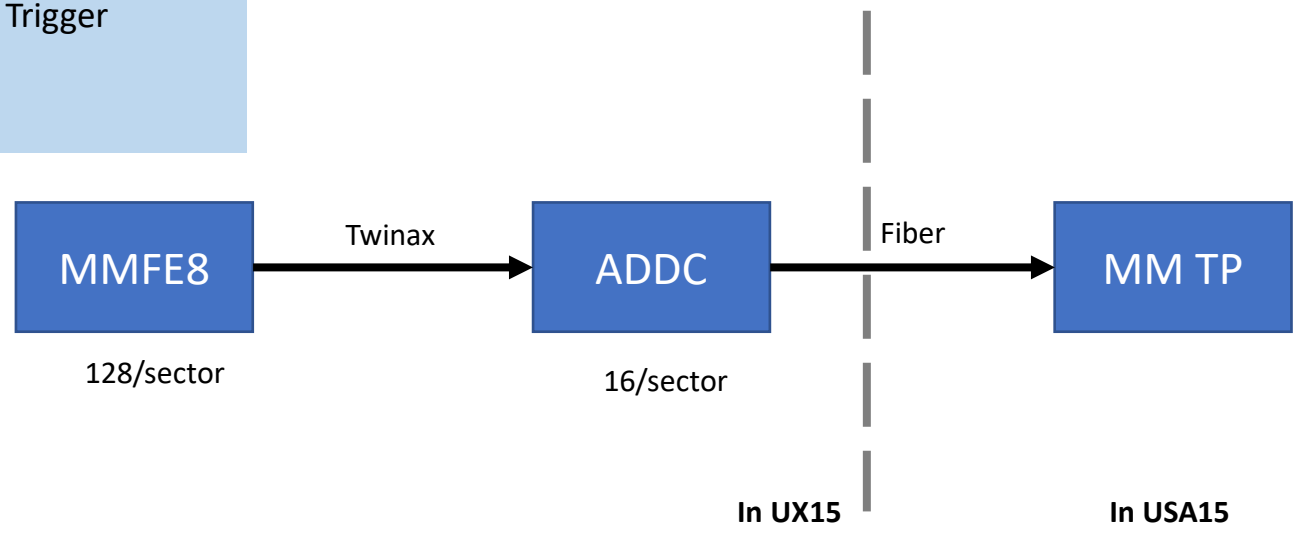
- pFEB -> Pad trigger : ToT signal from the VMM.
- Pad Trigger : implements a 3-out-of-4 coincidence logic to create a RoI.
- sFEB -> sTGC TP : pulse amplitude (6-bit ADC output).

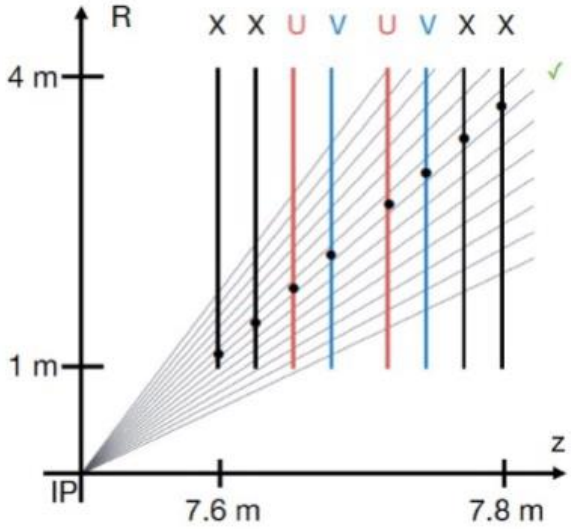
NSW electronics - MM Trigger path

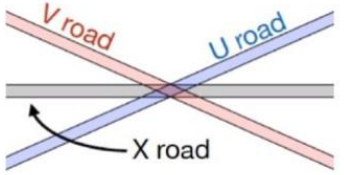
- VMM -> sends location of first hit every 25ns (Address in real time/ART) to ART data driver card (ADDC).
- 2 x ART ASICs align and deserialize 32x input data streams.
- Send a package of hit data (<8) + BCID time stamp to onboard GBTx (Gigabit transceiver) and then to MM Trigger Processor.

MM TP

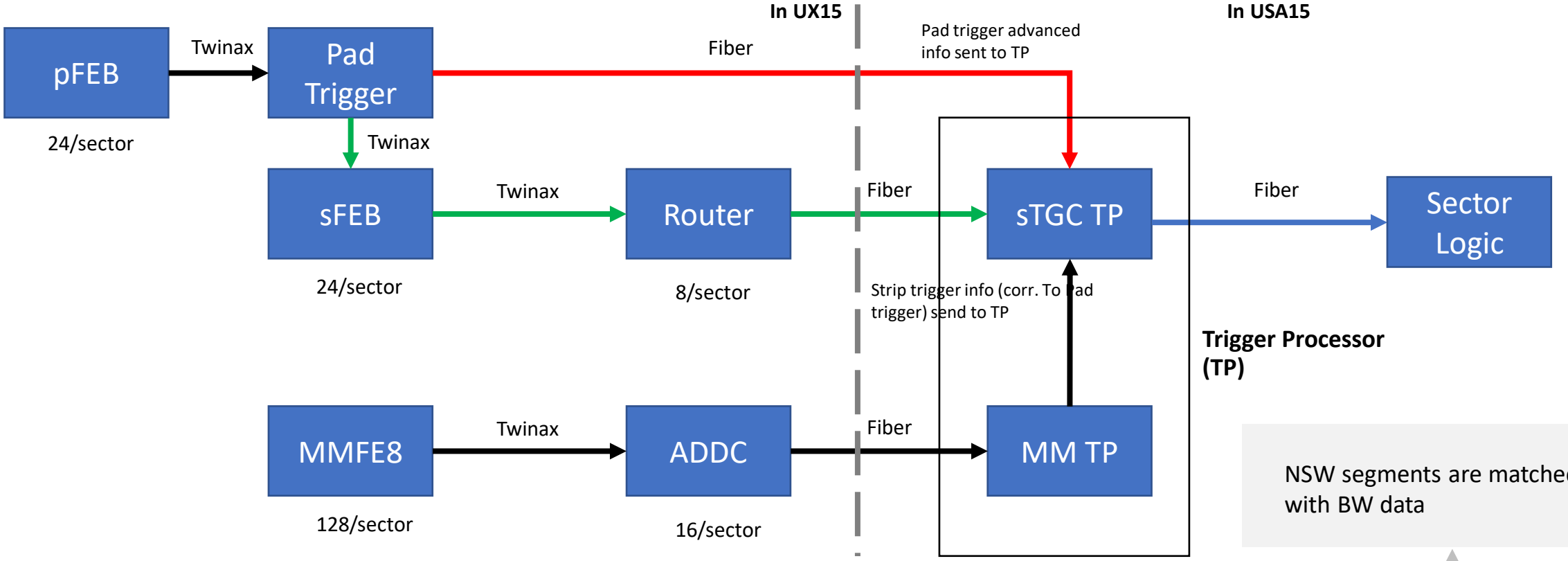
- Looks for hits that line up along road of strips pointing to the interaction point.
- Stereo layers (U, V) tilted by 1.5 degrees (wrt X) narrow down the RoI.







NSW electronics - NSW Trigger path



NSW segments are matched with BW data

MM & sTGC build segments independently

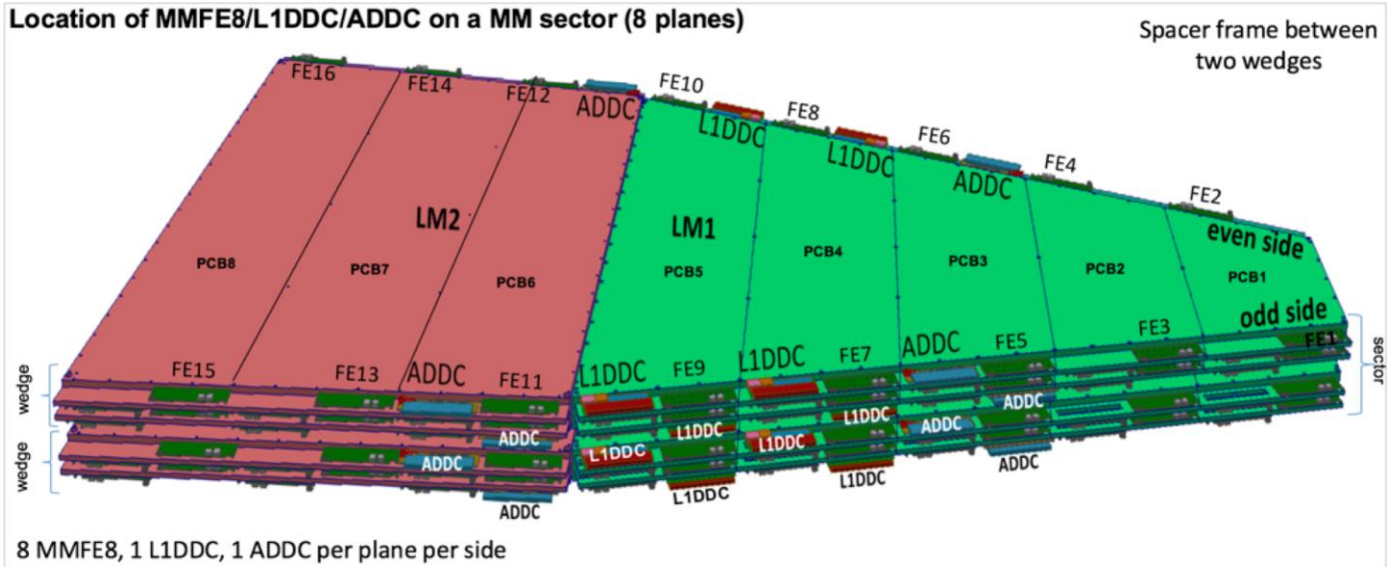
MM & sTGC segments are merged at sTGC TP to send to Sector Logic

Total Latency to SL = 1090 ns ~ 43.6 BC

https://indico.cern.ch/event/1121643/contributions/4778074/attachments/2409827/4123339/NSW%20Trigger%20Latency.pdf

NSW electronics – MM FE

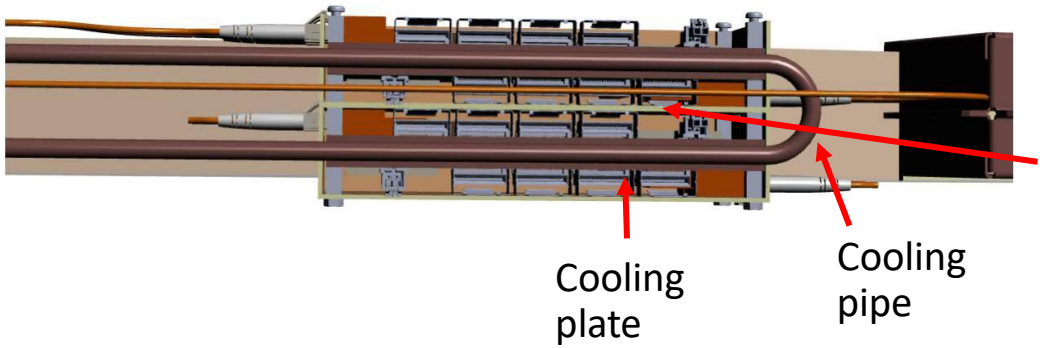
- **The NSW MM has over 2 million channels!**
- 4096 MMFE8,
- 512 L1DDC,
- 512 ADDC,
- 1 L1DDC & 1 ADDC serve the 8 MMFE8 of one layer.

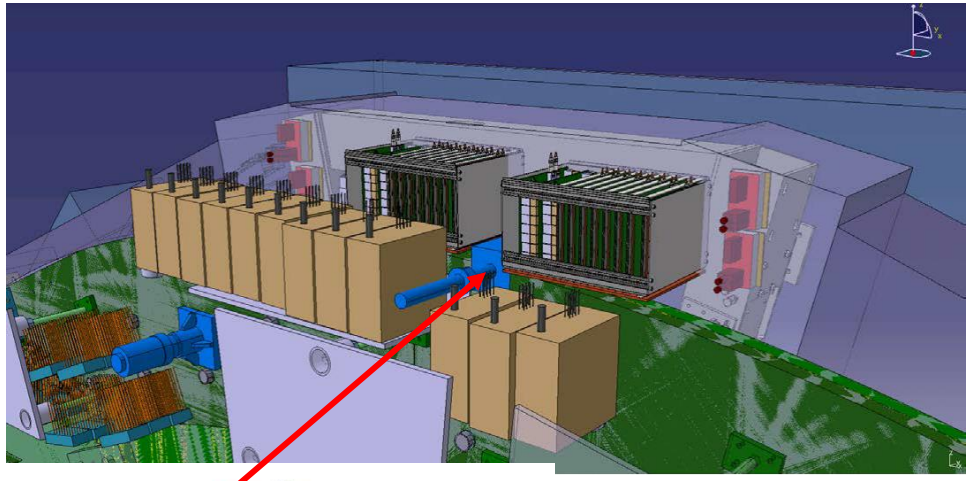


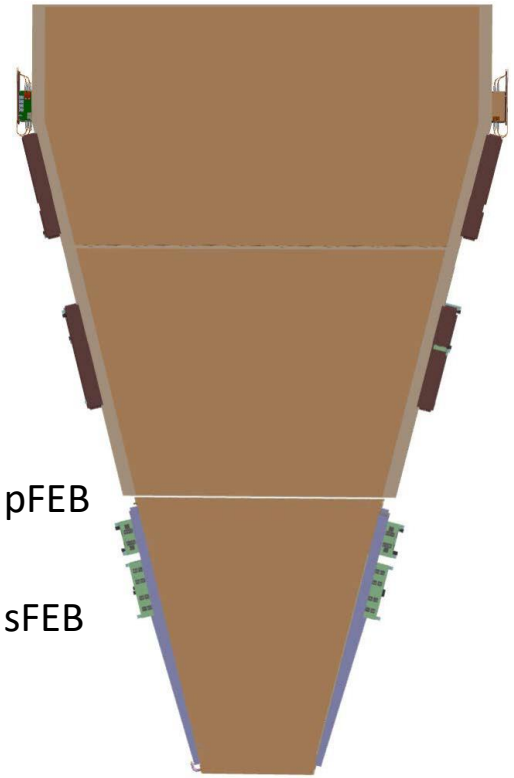
- Each MM sector has:
- 128 x MMFE8,
- 16 x L1DDC,
- 16 x ADDC,
- 16 x LVDB.

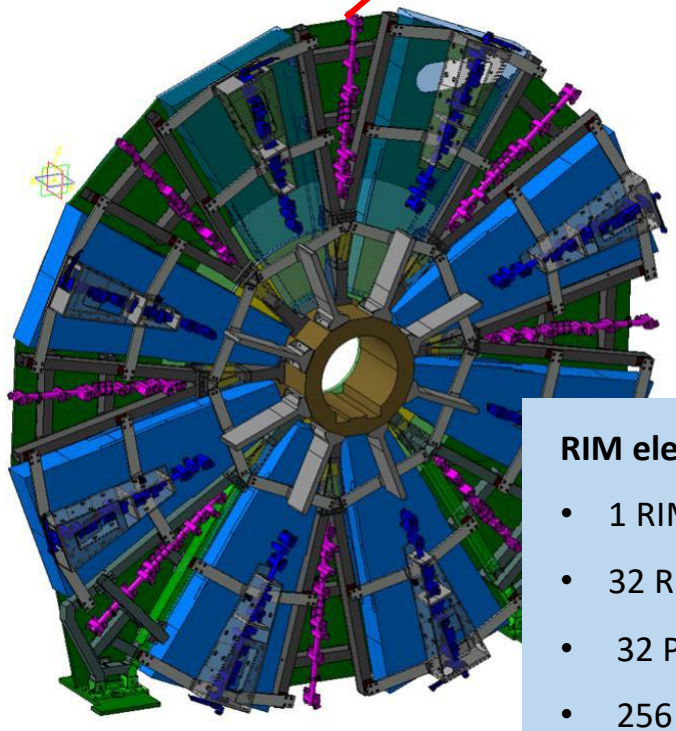
176 cards / MM sector need to be installed & tested

NSW electronics - sTGC FE









The NSW sTGC has ~350k channels

- L1DDC is placed on the upper part close to the rim for accessibility reasons
- 1 L1DDC will serve 3 front ends of each plane
- 768 sFEB
- 768 pFEB
- 512 L1DDC

RIM electronics

- 1 RIM box per sector
- 32 RIM-L1DDC
- 32 PAD trigger boards
- 256 Routers

MM DW Integration

Reception
GIF++

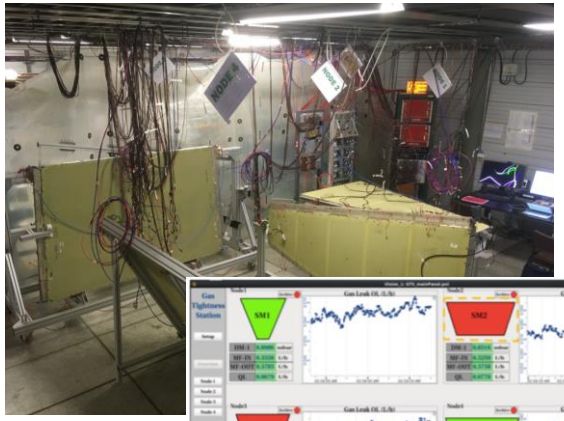
Mechanical assembly & services

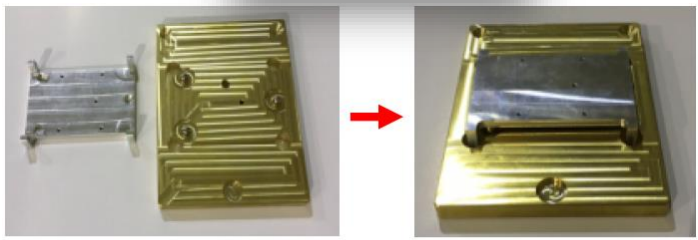
Electronics installation

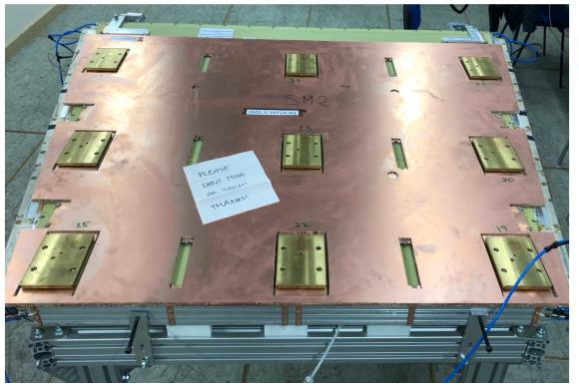
Cosmic tests & Sign off

Work on single detector modules

- Acceptance tests:
  - HV in gas (Ar:CO_2) and gas tightness.
  - HV map of module.
- Alignment platform installation.



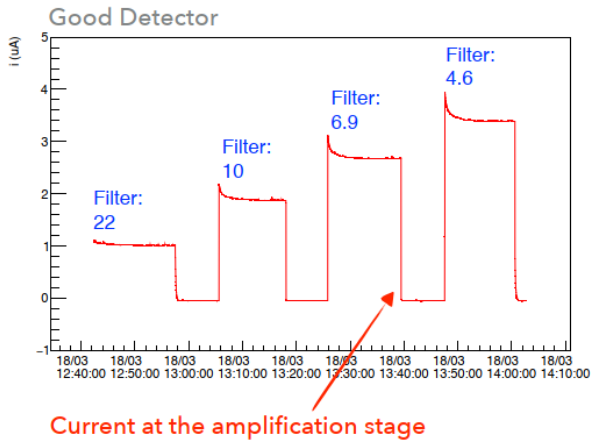


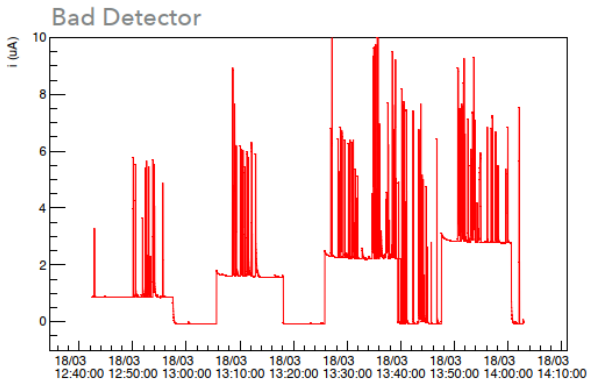


Alignment platform and installation sequence

GIF++ Irradiation testing

- Conditioning: RH < 12%
- ~14 TBq 137Cs -> 662 KeV photons
- Spike rate for each HV channel with / without irradiation -> In case of severe sparking lower the HV





MM DW Integration

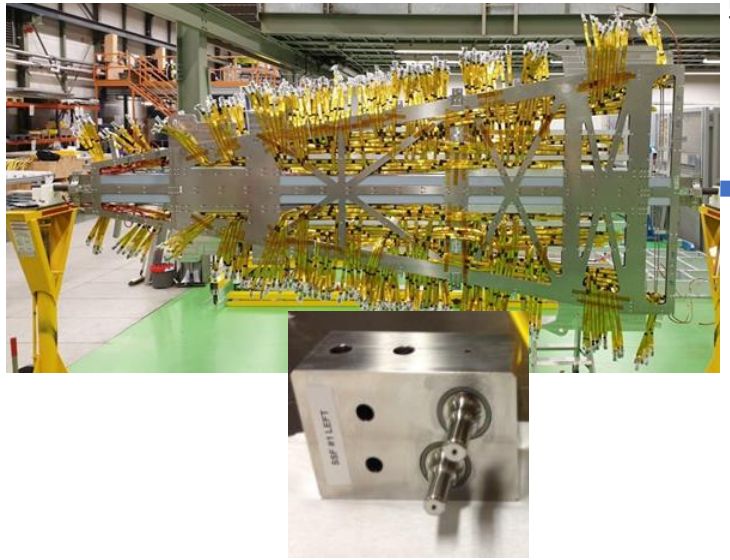
Reception

GIF++

Mechanical assembly & services

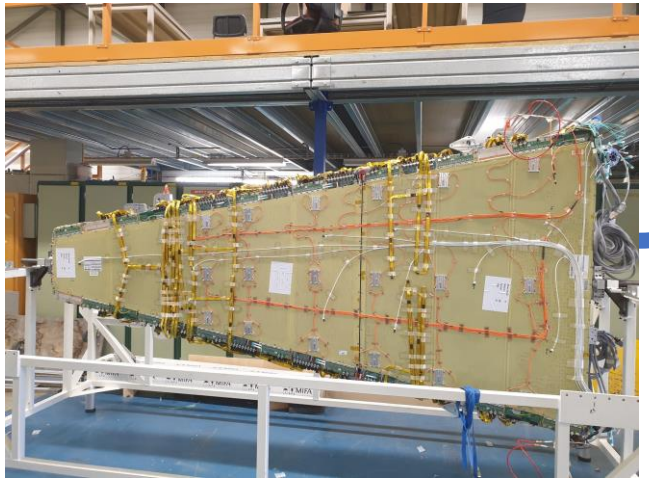
Electronics installation

Cosmic tests & Sign off



54 km of twinax cables kaptonised

- Spacer Frame preparation ->288 twinax & gas system
- Integration with quadruplets
- Finalisation of services & tests



MM DW Integration

Reception

GIF++

Mechanical assembly & services

Electronics installation

Cosmic tests & Sign off

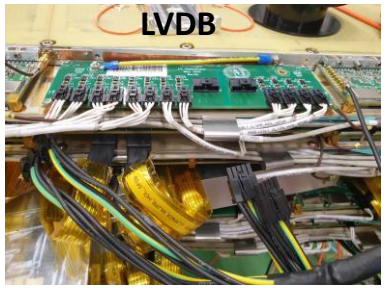
Preparatory work

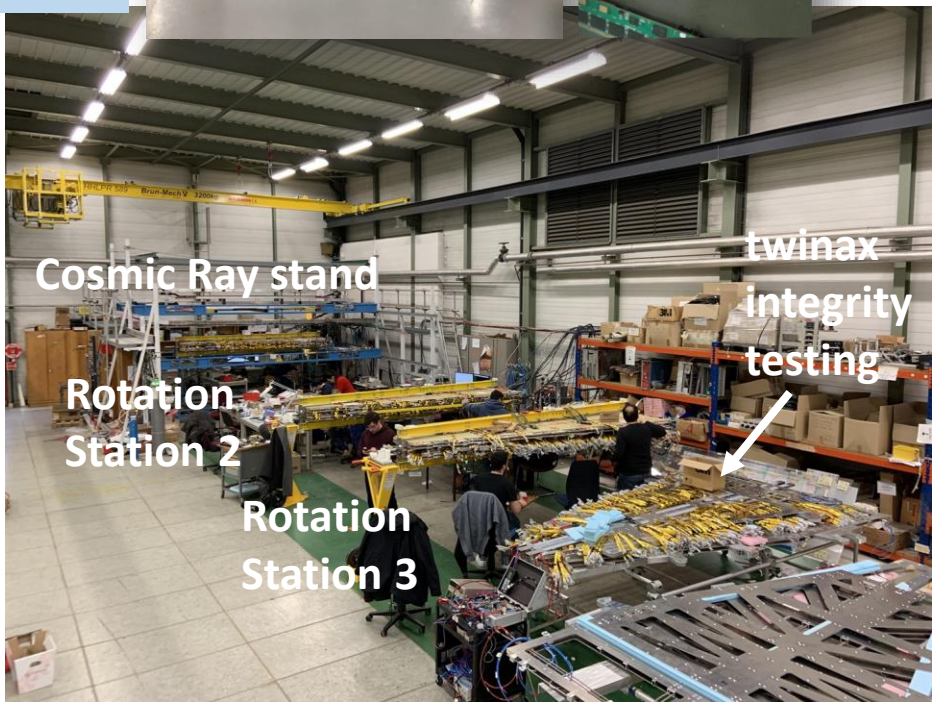
- Cooling pads
- Connectors (MMFE8).
- Cable integrity testing.

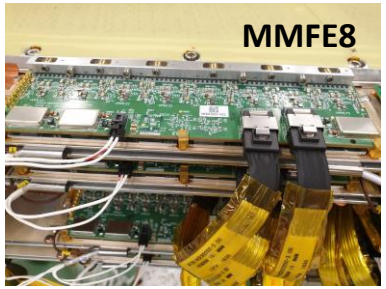
- Three stations to allow for work at 3 MM sectors in a ‘sliding mode’.

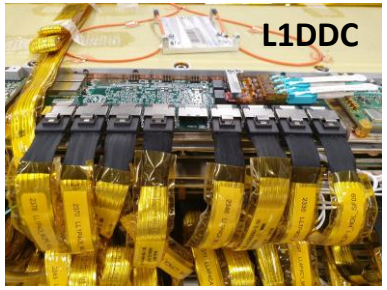
Rotation Station 3:

- Mounting and cabling of FEBs.









Tricky to align!

MM DW Integration

Reception

GIF++

Mechanical assembly & services

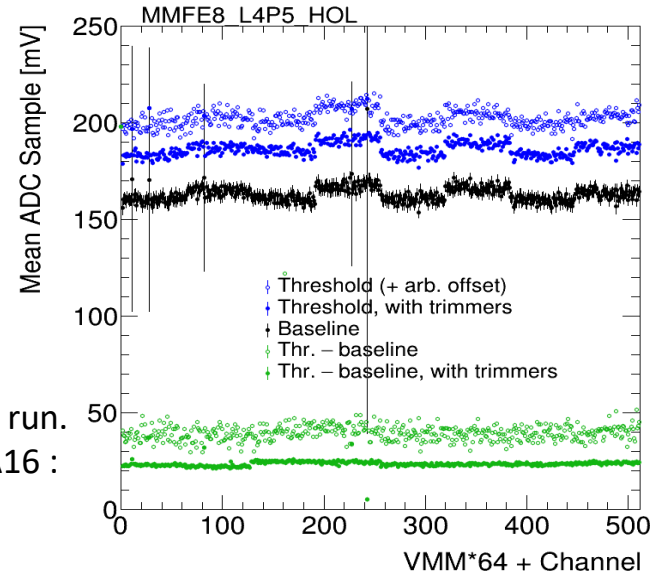
Electronics installation

Cosmic tests & Sign off

Cosmic Ray stand

- Baseline/noise measurements and VMM channels threshold & trimmer calibrations.
- Internal pulser run : Dead channels & validation of readout path.

Baselines and trimmer run.
Example from Sector A16 :
MMFE8_L4P5_HOL



MM DW Integration

Reception

GIF++

Mechanical assembly & services

Electronics installation

Cosmic tests & Sign off

Cosmic Ray stand

- Baseline/noise measurements and VMM channels threshold & trimmer calibrations.
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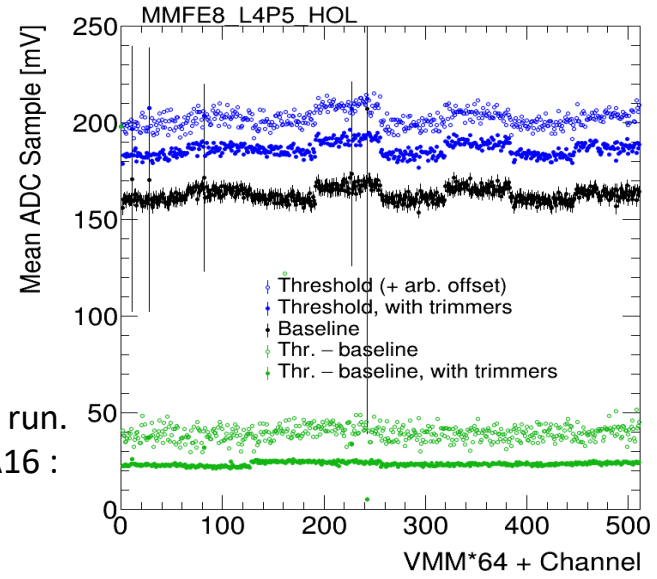
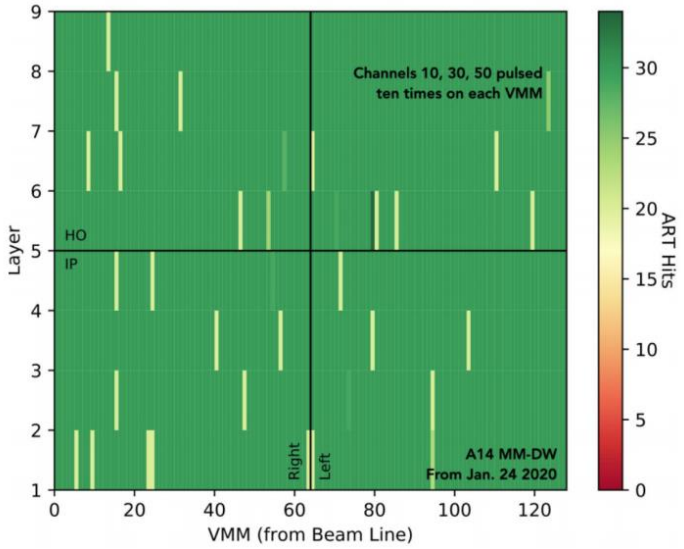


Baselines and trimmer run.
Example from Sector A16 : MMFE8_L4P5_HOL

Trigger path validation
test pulses to all the VMMs of the sector and read out the ART data from the TP

Objective:
- Confirmation of electrical and optical connectivity of each channel.
- All VMM channels are pulsed sequentially.



Map of ART data read out by the TP

MM DW Integration

Reception

GIF++

Mechanical assembly & services

Electronics installation

Cosmic tests & Sign off

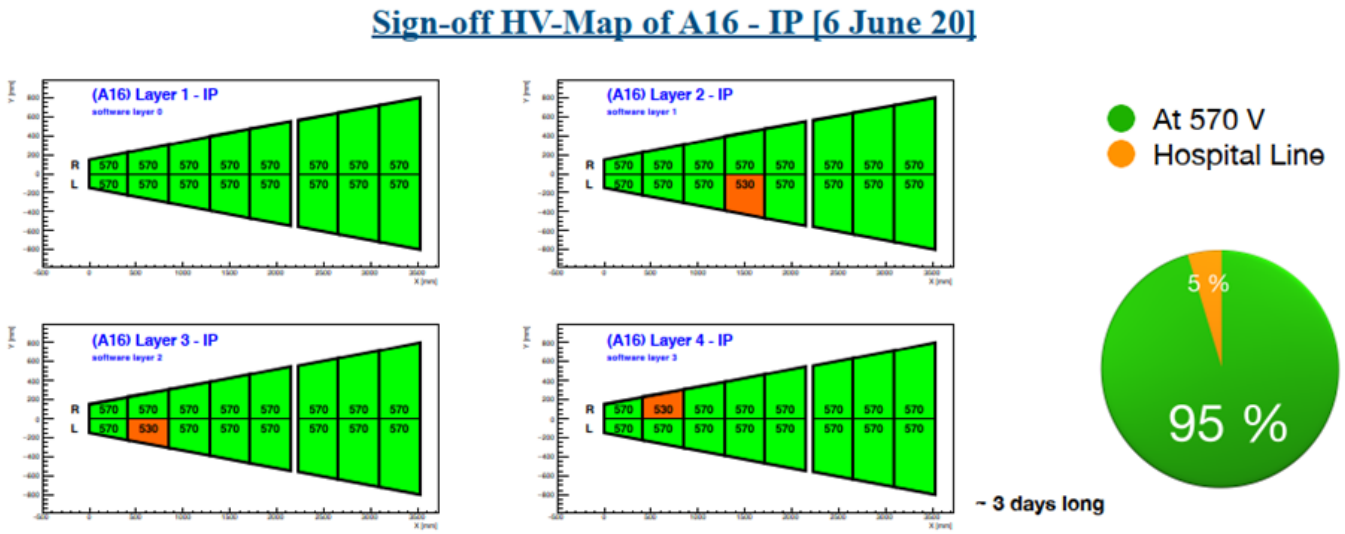
Cosmic test

- The final step of the electronics integration.
- Trigger by scintillators: Full coverage along precision coordinate, partial coverage along φ coordinate.

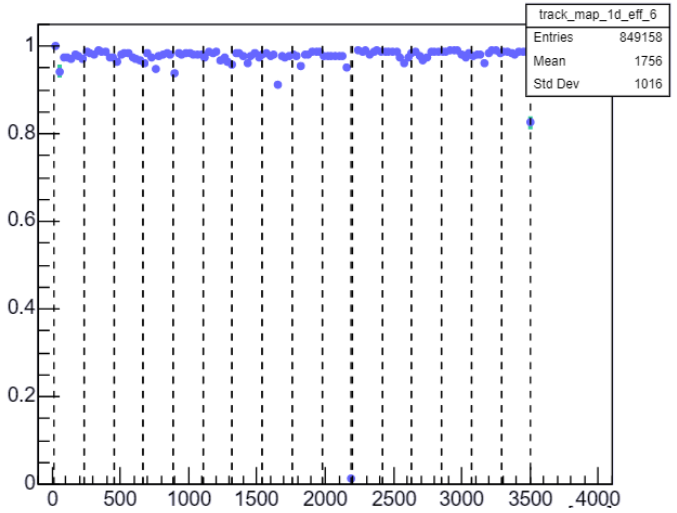
Validation of the MM sector (detector and electronics):

- Finalisation of HV settings.
- Final validation of electronics and trigger output.
- Efficiency map

Acceptance: >85% of sections at 570 V

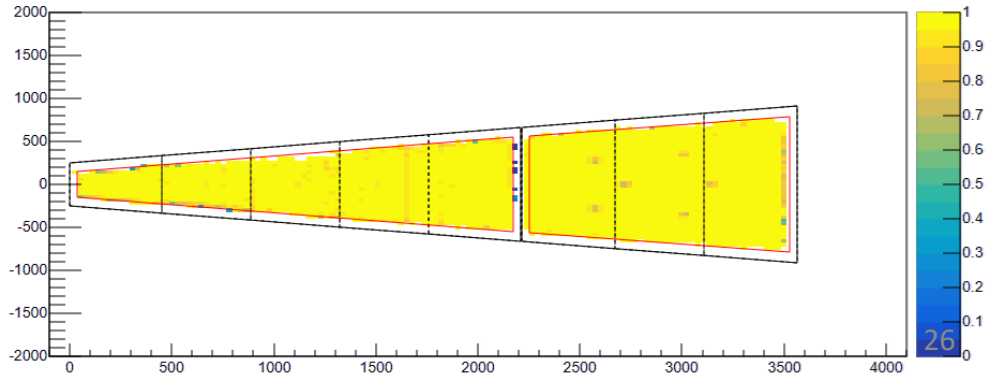


Efficiency of HV sections (A08_HO_L6)



Example: Sector A08, HO side, Layer 6

Efficiency plot (A08_HO_L6)



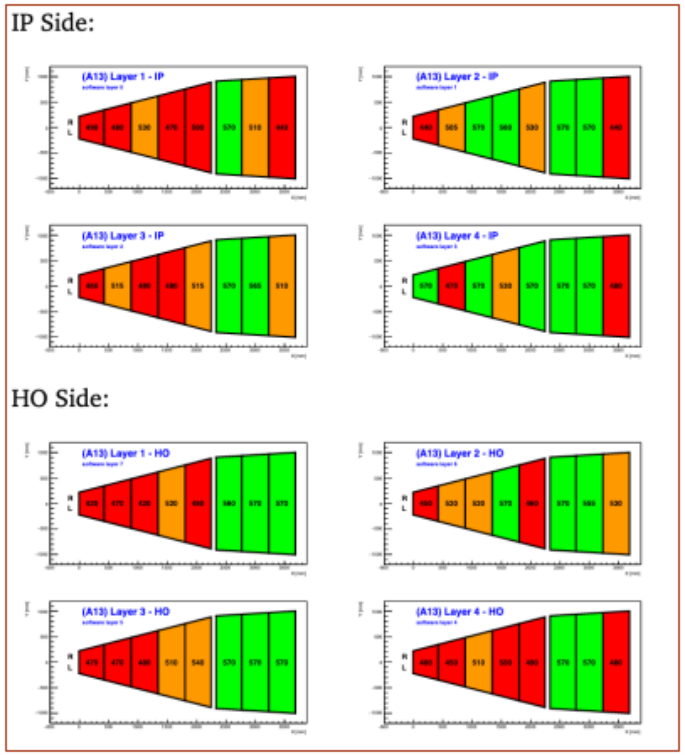
MM DW Integration - Performance of OLD_Double Wedge A13

- The first Large MM DW that was assembled in BB5 showed very bad results in the Cosmic stand.
- Motivated the study of the $Ar:CO_2:iC_4H_{10}$ (93:5:2) as gas mixture of choice.
- WG : study long term behavior & perform ageing studies at GIF++ (gamma) and LMU Munich (neutrons).

- Irradiation studies ongoing.

- Results : Positive – **CERN accepted the change of gas mixture.**

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



insufficient performance

green:
sector is on
nominal HV

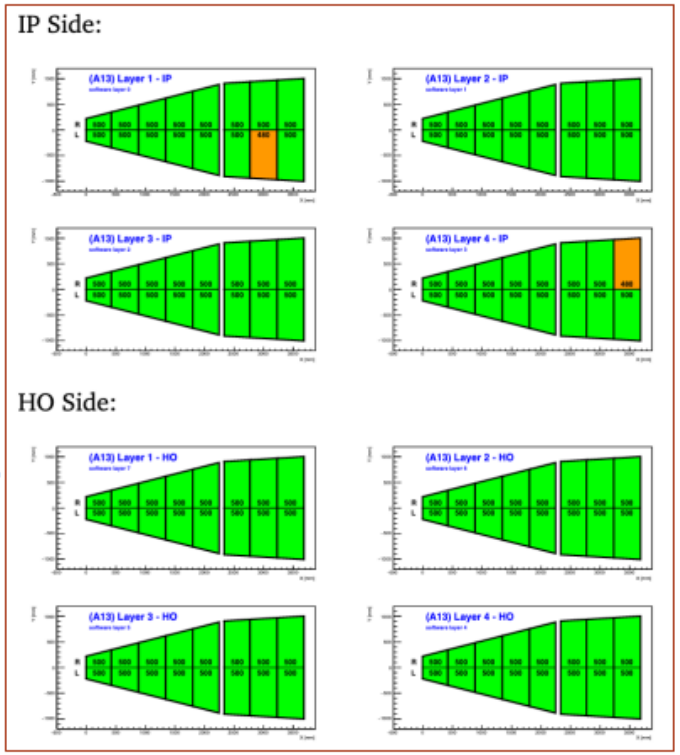
red:
sector is below
nominal HV

-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

OLD A13 (not passivated) -> REJECTED
Demonstration on a DW of the improvement given by $Ar:CO_2:iC_4H_{10}$ (93:5:2)

MM DW Integration - Transport to NSW integration facility

MM Integration facility – BB5 (899)

MM DW#4 Sector A16 EDMS: AT1-MW-NG-0059v1 n. 2384605

Sign-off document of NSW Micromegas
DW#4 for Sector A16

Table of Contents

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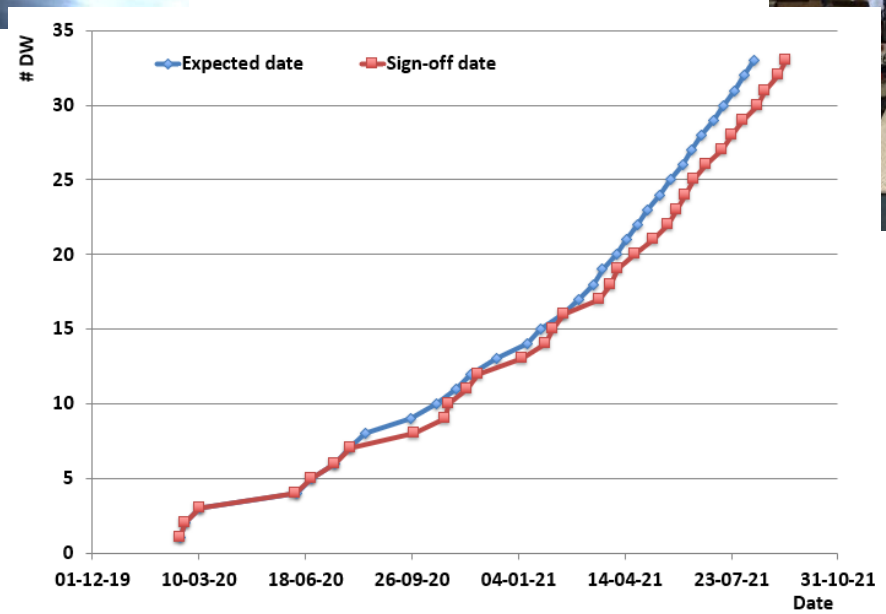
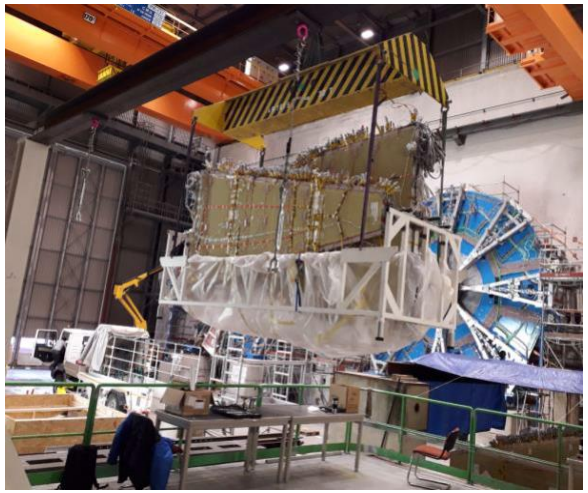
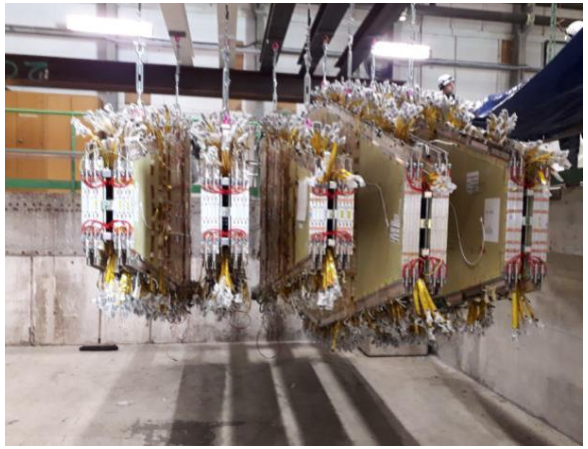
Created by P. Iengo on June 04, 2020 1



NSW integration facility (191)





STGC quadruplet Integration

Reception (887) & GIF++

Assembly

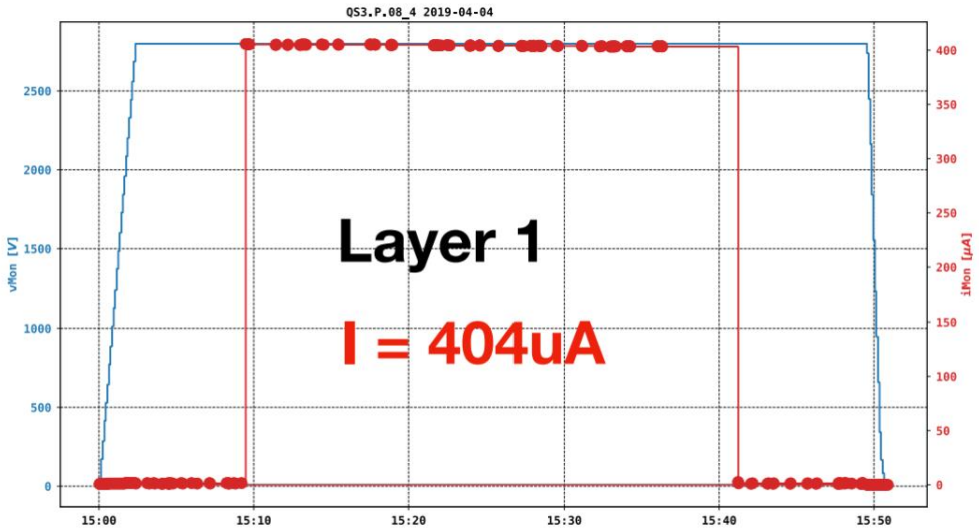
HV testing

X-ray survey

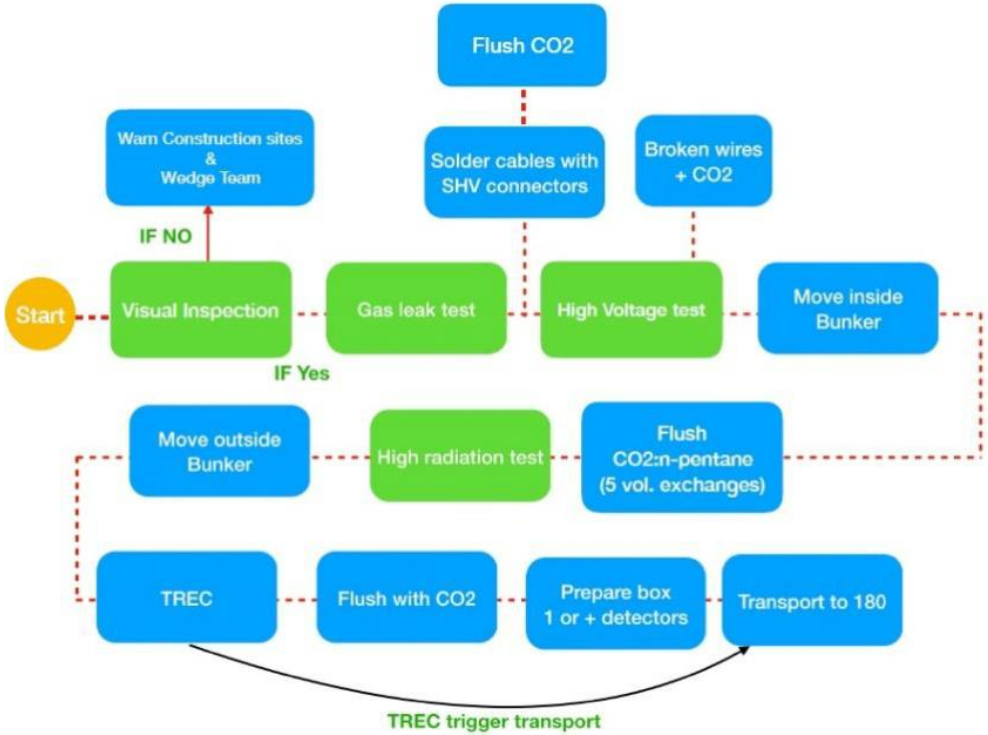
Electronics, services & testing

Survey

- Visual inspection check list
- Short circuits
- Gas tightness
- HV tests
- HV and nominal current under high irradiation in GIF++



Current evolution with source OFF/ON/OFF



- CO_2/nPentane and 2.8 kV
- 10min without source, 30min with source, 10min without source

b. 180

Reception (887) & GIF++

Assembly

HV testing

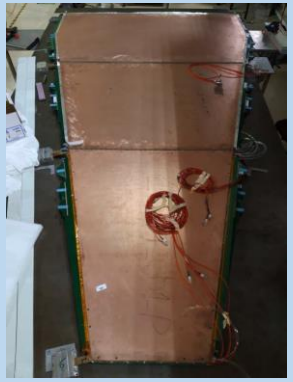
X-ray survey

Electronics, services & testing

Survey

1. Clean Room

- Wedge assembly
  - On a granite table, align quads with jig then glue a fiberglass support
  - Rotate and install support frame.
  - Installation of Faraday cage .
- Installation of alignment & survey targets.
- Noise tests.



b. 180

Reception (887) & GIF++

Assembly

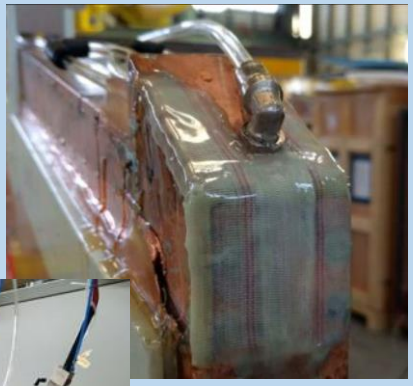
HV testing

X-ray survey

Electronics, services & testing

Survey

2. Long term HV testing & Faraday Cage sealing

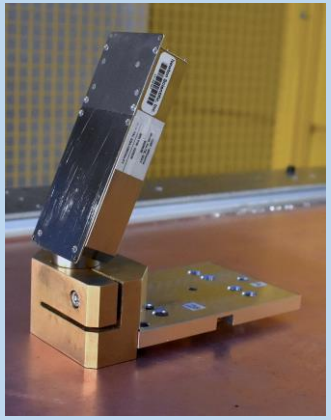


3. X-ray survey

- Extract the location of the sTGC readout strips after detector assembly.

Goal:

- Link the position of the sTGC strips with respect to the alignment platforms and extract the as-built constants.



Reception (887) &
GIF++

Assembly

HV testin

X-ray surv

Electroni
& testing

Survey

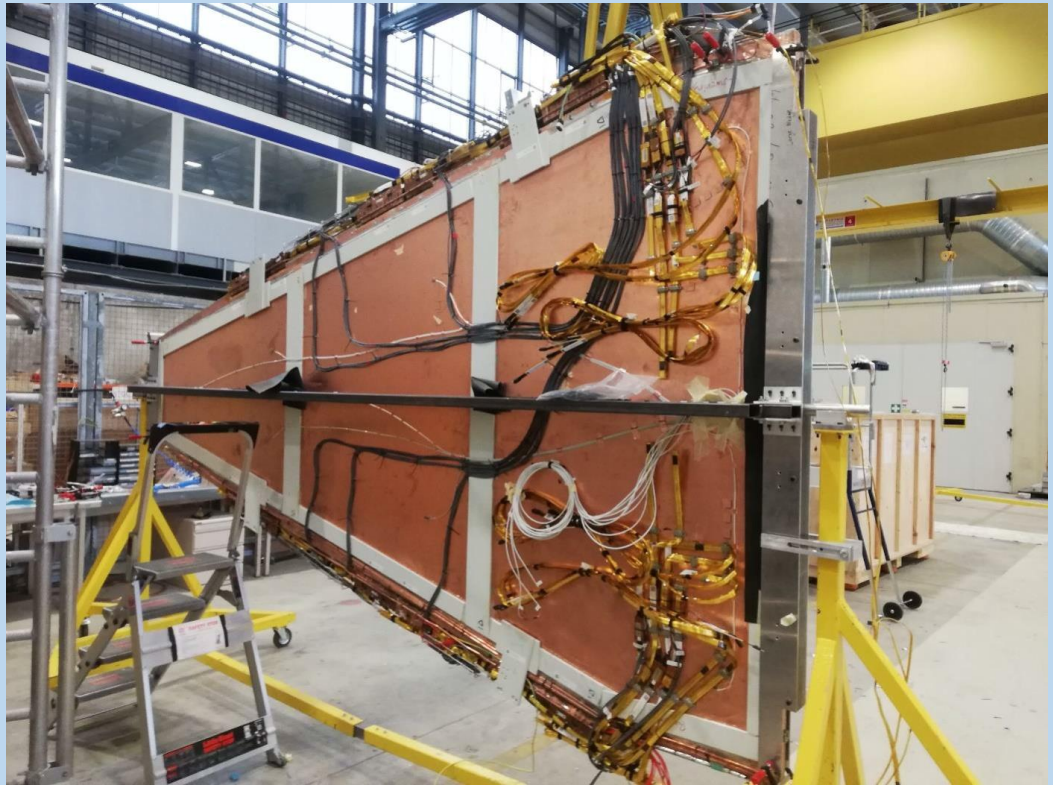
b. 180

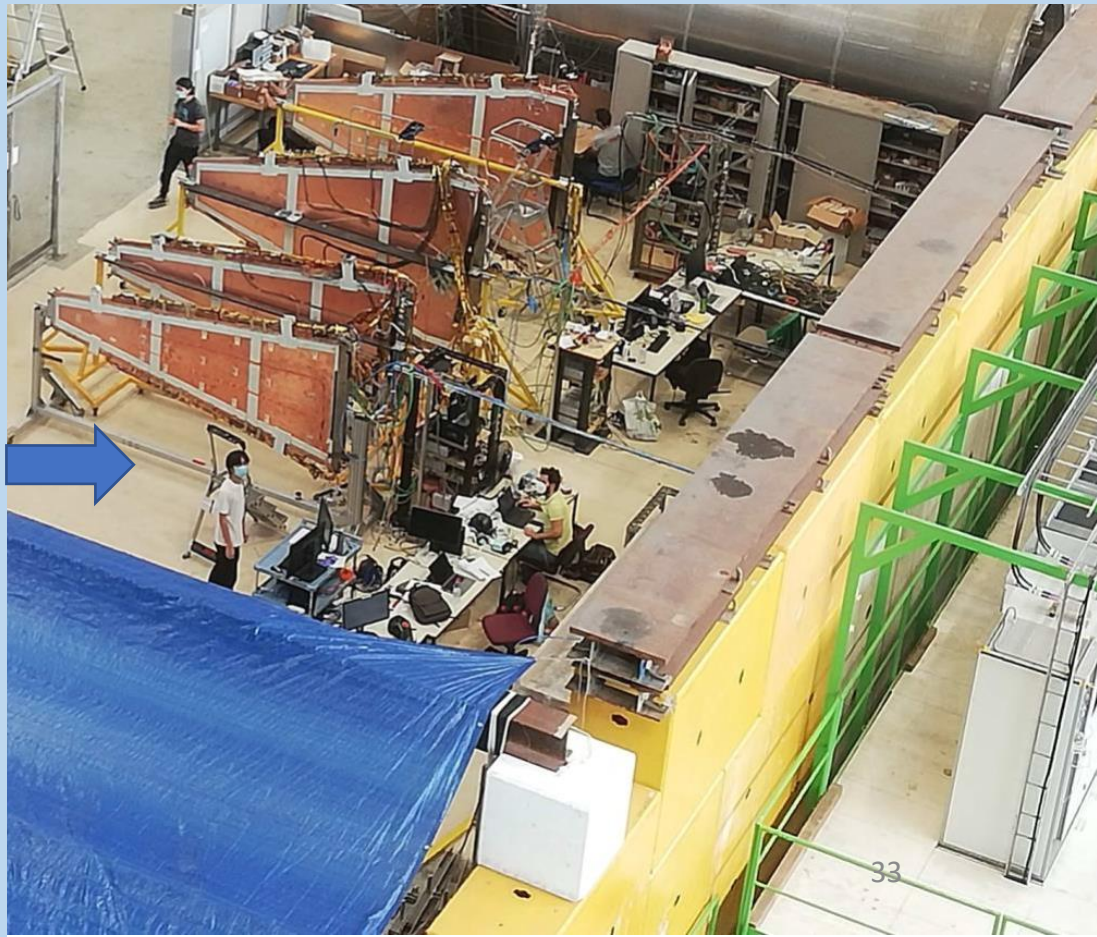
Testing sequence

- ElX temperature and Power consumption Monitoring.
- Noise scan.
- **Readout Path**
  - VMM to ROC to L1DDC : Checked by reading out test pulse data.
- **Trigger Path**
  - VMM to pTDS to Pad-Trigger : Checked by reading out TP ToT data.
  - VMM to sTDS to Router : Checked by reading out TP 6 bit ADC data.

4. FEB & services installation and testing

Installation of cooling & gas pipes





b. 180

6 weeks from reception to NSW sector assembly

Reception (887) & GIF++

Assembly

HV testing

X-ray survey

Electronics, services & testing

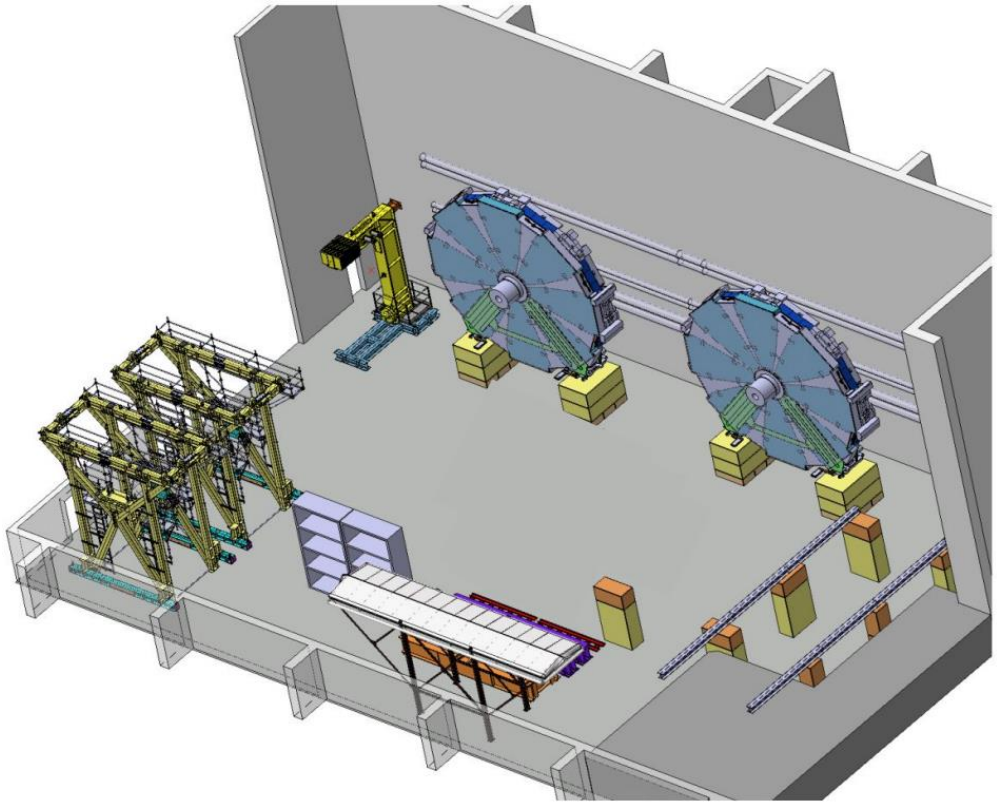
Survey & transport

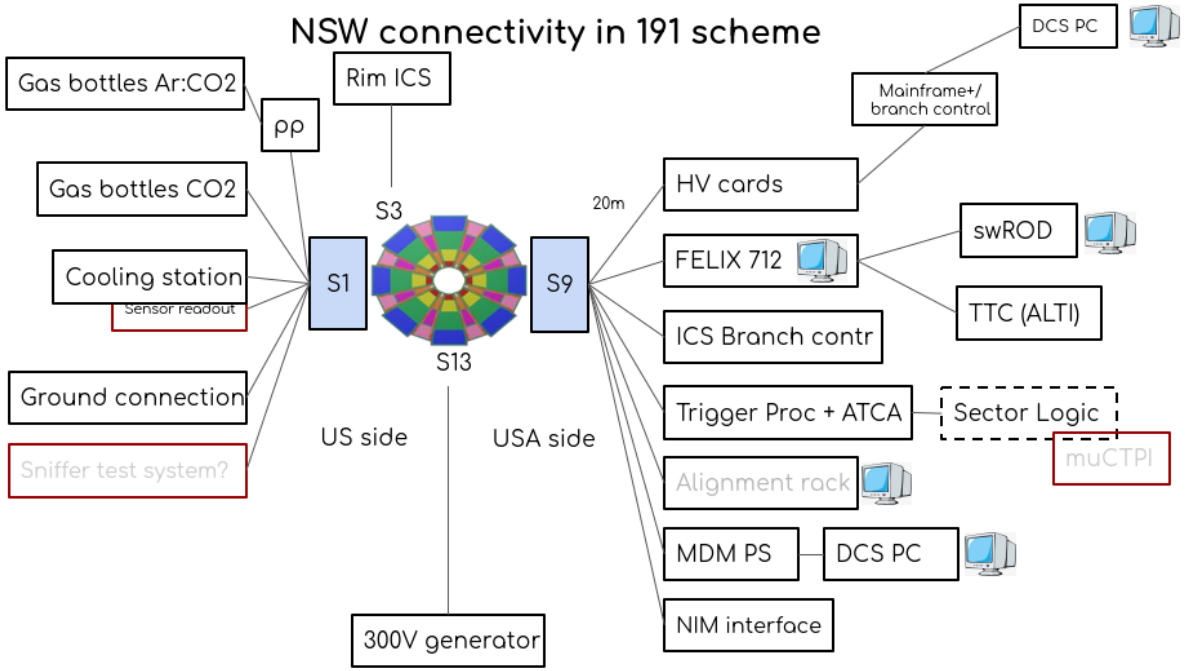
Survey of 2 sTGC wedges for a sector

- Measurement of X-Y position of the reference points C1 & C2 used to align angularly both sTGC wedges during sector assembly.
- Measurement of Z position of the mechanical interfaces (epoxy glass wings) to adjust the length of the sTGC supports.

To b.191

191 infrastructure





B.191 : Integration of the New Small Wheels

- Surface commissioning of all the sectors.
- Temporary operational infrastructure.

Commissioning of up to 2 sectors at a time / wheel

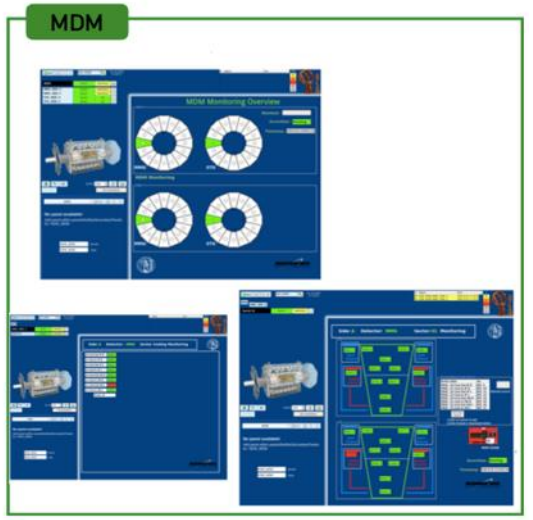
b.191 electronics racks for NSW-A

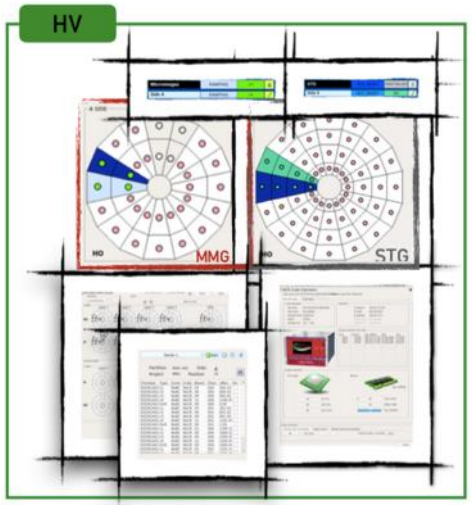
DCS & commissioning in 191

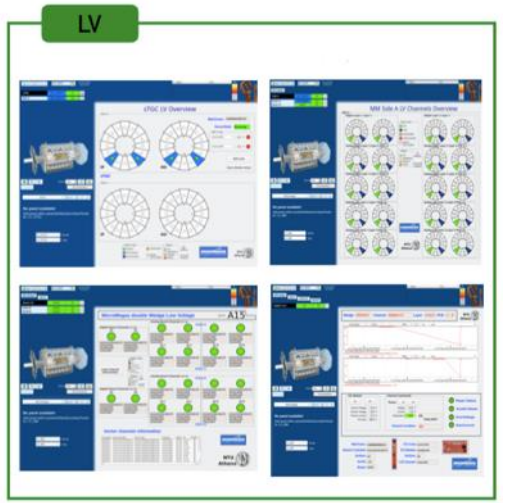
Detector Control System setup in b191 followed the sector by sector installation and commissioning

- Prototype DCS projects have been developed in order to support the integration phase of the project.
- The projects were being refined with time.
- Aim: Monitoring of the whole NSW hardware via the DCS.

The NSW-DCS team support has been critical

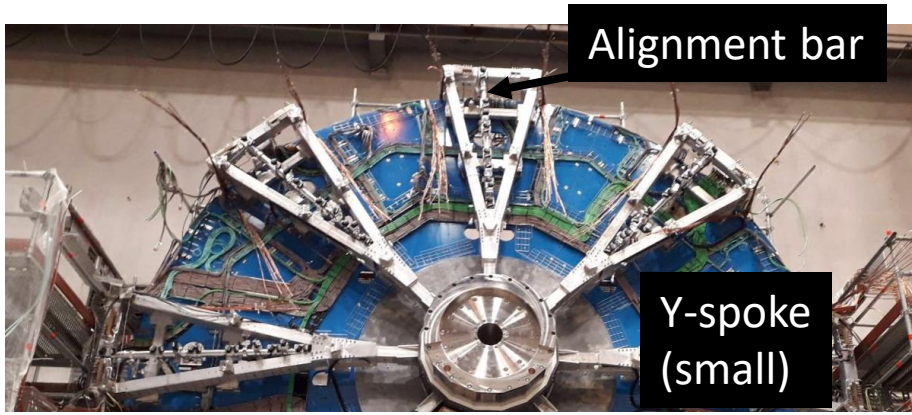






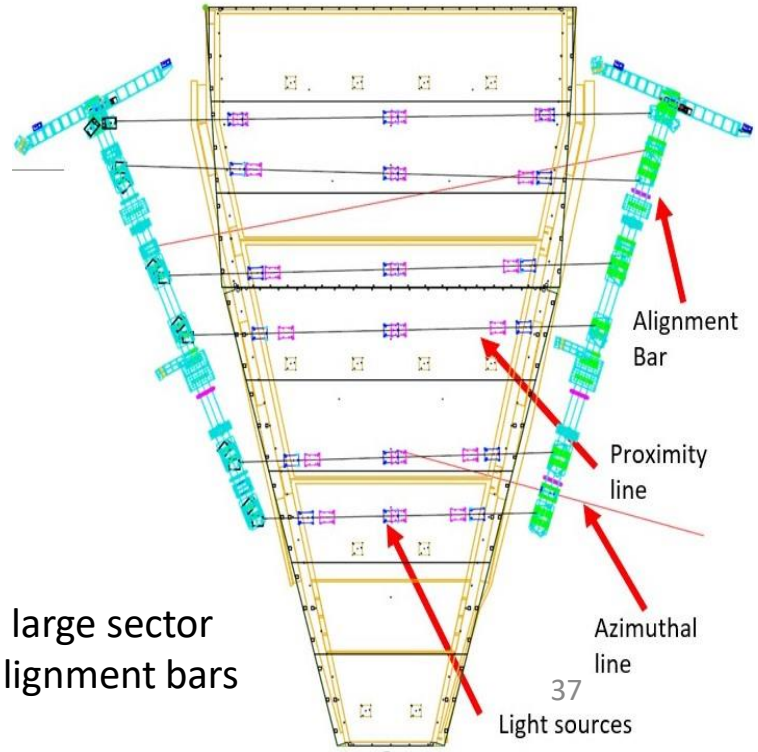
The NSW Alignment System - The concept

Large bar preparation and installation at b.191



- Grid of alignment bars which locate each other by an over-constrained set of CCD-based cameras (BCAMs) looking at each other.
- With the help of the surveys, the bars define the ATLAS coordinate system for all of the muon endcap chambers.
- Goal : locate the active detector elements in the NSW chambers

  Multistep process that starts in the chamber construction:
  - Light sources are placed precisely on the outer surface of the wedges.
  - Relation to the active detector elements of the outer layers defined via several fiducial reference points.
  - BCAMs on the alignment bars, locate the light sources in the grid coordinates.
  - The relation of the inner layers is determined by construction parameters and internal chamber measurements during construction.



Sketch of a large sector within two alignment bars

Sector integration


The MMDW transported from BB5 to b. 191


sTGC quad. transport


Small sector integration

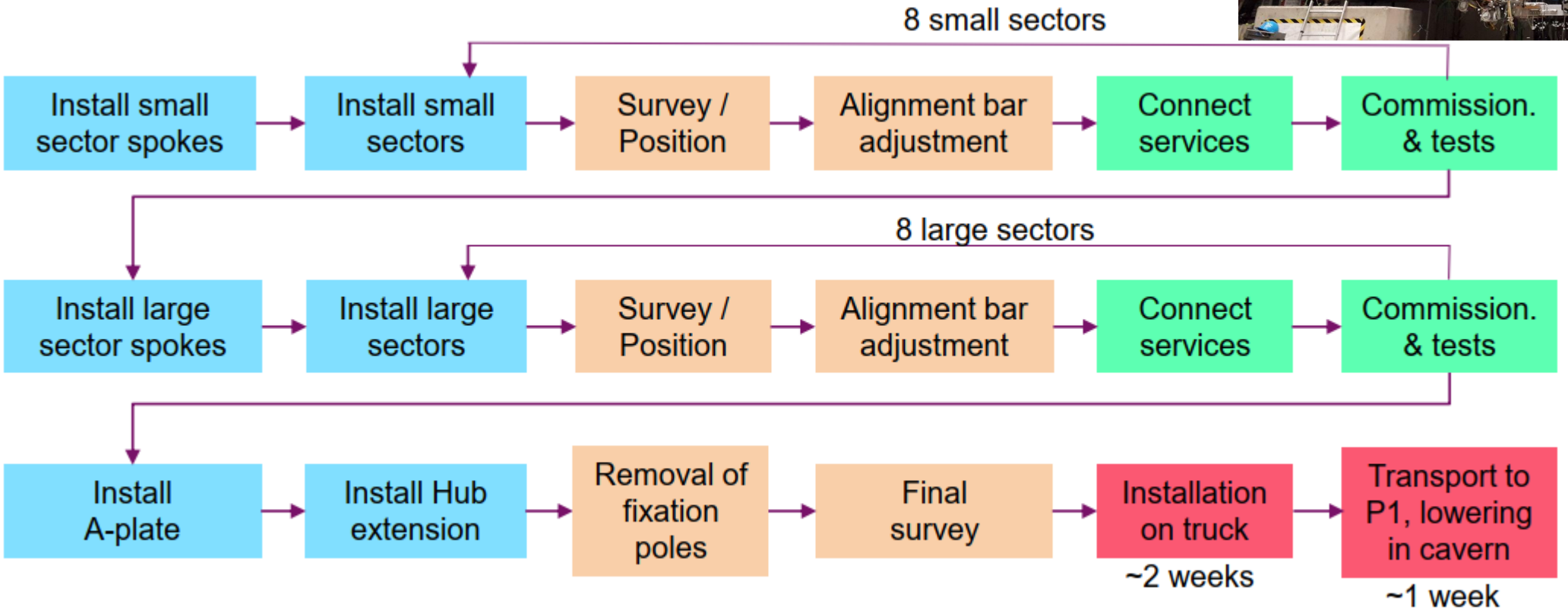

Small sector survey

At the balcony (b.191)

- Finalization of services for both technologies & inspection.
- Integration & angular alignment of both sTGC wedges + Survey after assembly.
- Removal of supports.
- Installation of Kinematic mounts.
- Survey and readjustment of sTGC.

Sector installation on the wheel

Procedure



Sector installation on the wheel

Grabbing of the Sector

Adjustment of center of gravity*

Lifting and moving the sector

*Later done after the final orientation of the sector

Angular orientation of the sector

Sector installation on the wheel

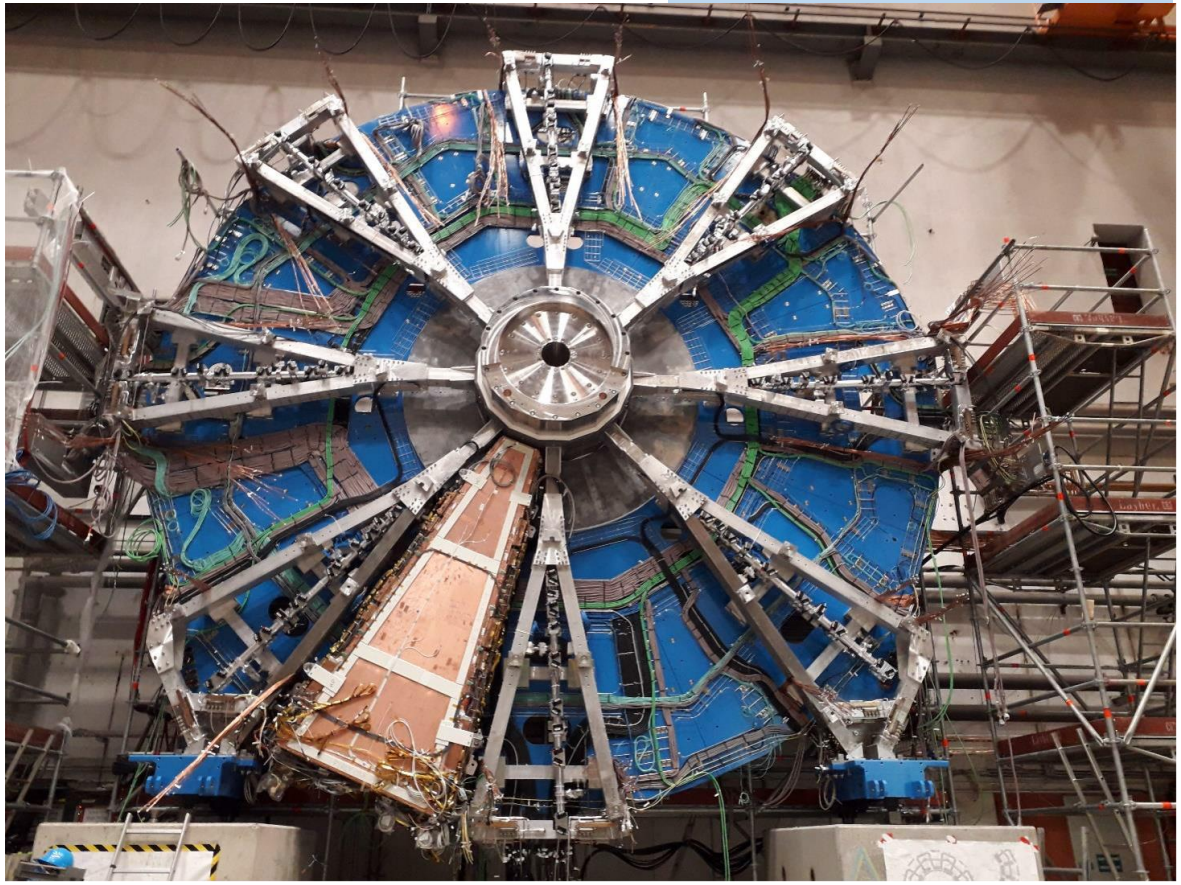
Installing the sector

Sector installation

Alignment of the sector w.r.t. the nominal position (Max ±3mm).

- Survey of sector reference points.
- Survey of both sTGC wedges reference points.

A12 installed (5 Dec 2019)



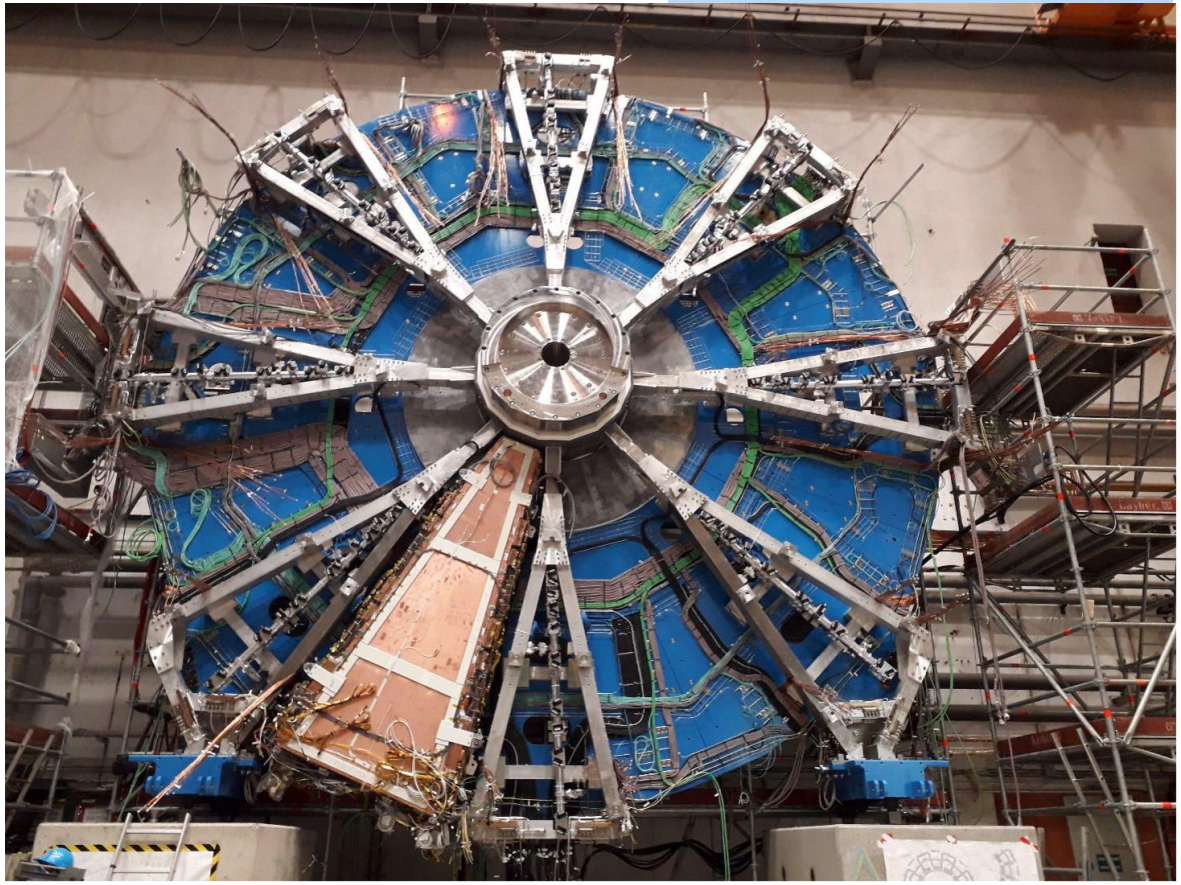
Sector installation on the wheel

Installing the sector

Sector installation times

- Transport and manipulation of the MM-DW -> 0.5 d
- Sector assembly -> 0.5 d
- Sector survey and alignment of both sTGC wedges in assembly station -> 0.5 d
- Installation on NSW -> 0.5 d
- Survey and alignment on NSW -> 0.5d
- Connection of services -> 4-5d

A12 installed (5 Dec 2019)



MM commissioning in 191

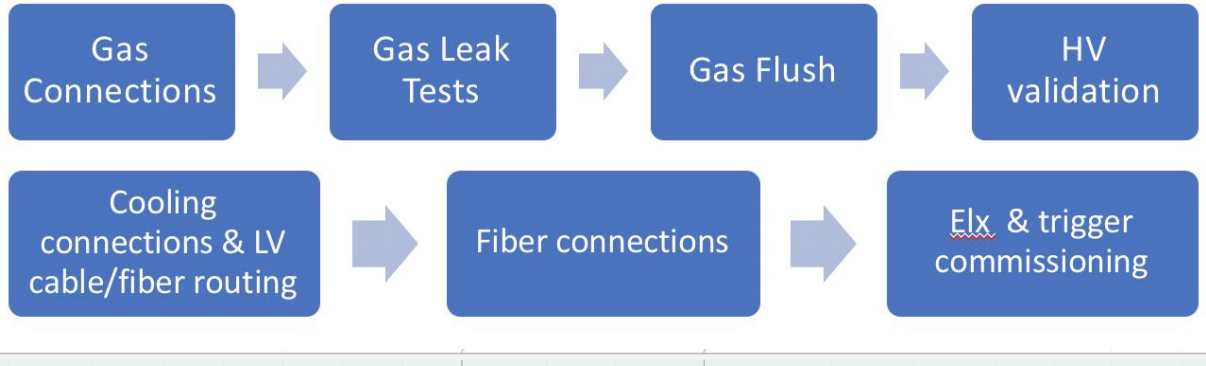
Pre installation validation

(Long check list)

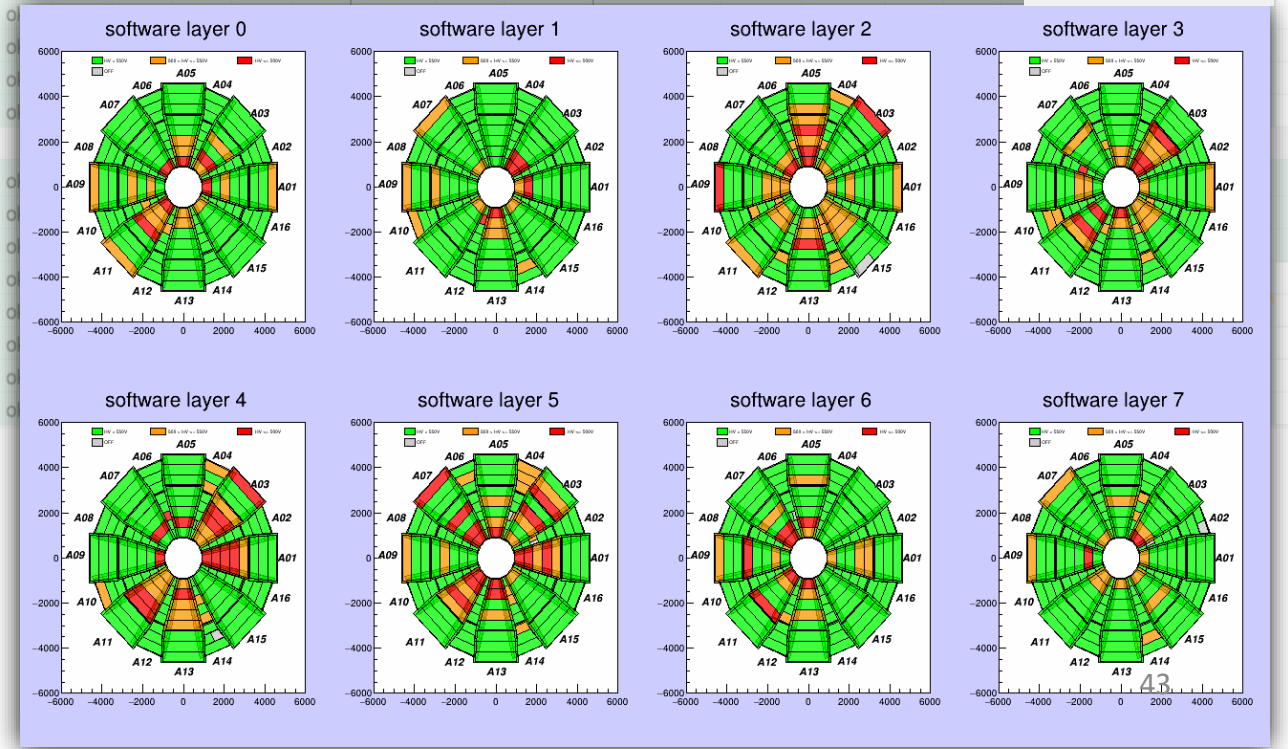
- Integrity of fibers, T-sensors, power cables and gas pipes.
- Polarity of intermediate power cables.
- Grounding connections.
- Envelope checks.

After routing of services & gas/cooling connections

- Regulation of the cooling system.
  - based on the temperature reading at the output of the cooling channels.
- Flushing - Gas Leak tests (Ar:CO_2 93:7).
- Connection & verification of fibers.
- HV validation : Performed at min 24h.



NSW-A HV map with Ar:CO_2 (93:7)

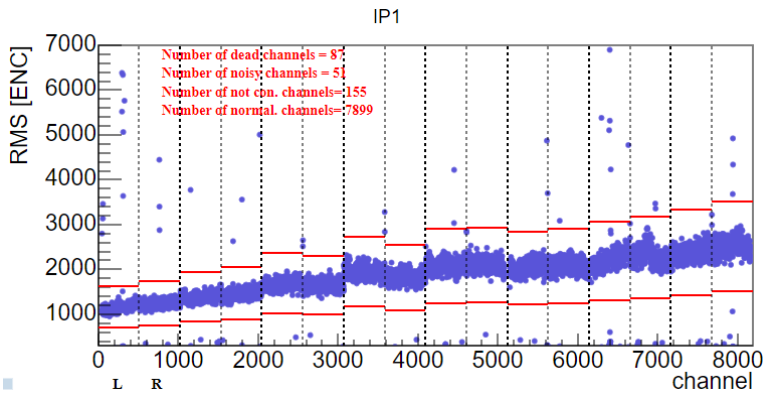


MM commissioning in 191

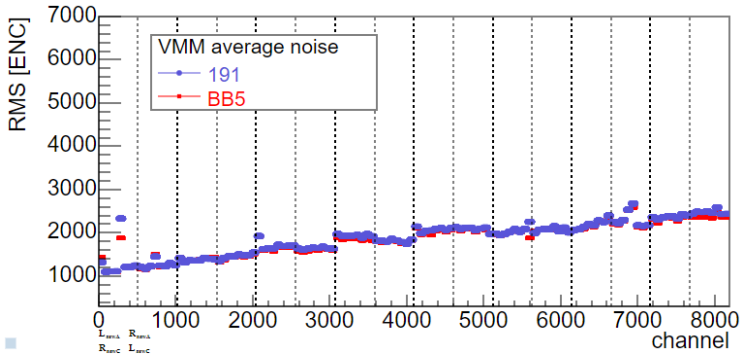
Readout path

- Baselines, trimmers & threshold setting
- Noise measurements & comparison with BB5
- Pulser runs
- Check of fiber optics power, e-link alignment
- Phase-2 tests

Examples from C06 L1, IP



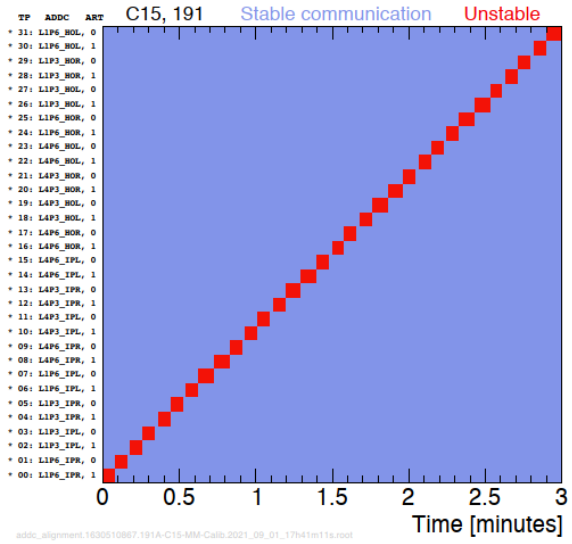
Baselines – Noise measurement



VMM average noise

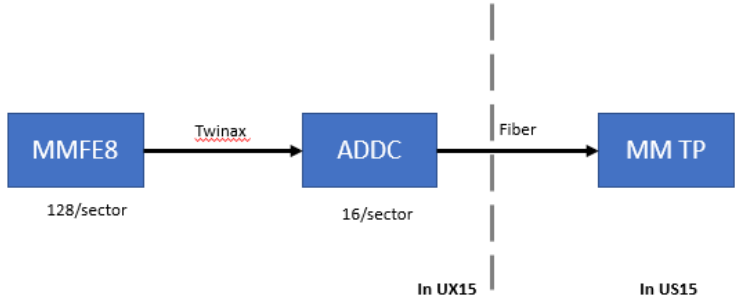
Trigger path

- Connectivity tests: aim to see if all the cables/fibers are connected correctly:
  - MMFE8 to ADDC to Micromegas Trigger Processor.
- Timing calibration that aligns the clock phase between ART-VMM and TP-ADDC.



MMStaircase (identify if there are swapped or broken fibers)

Plots from b.191 commissioning (2020)



sTGC commissioning in 191

- No operating gas mixture available in b191, sTGC was operated with CO_2 only.
- CO_2 safety envelope.

Pre-installation validation

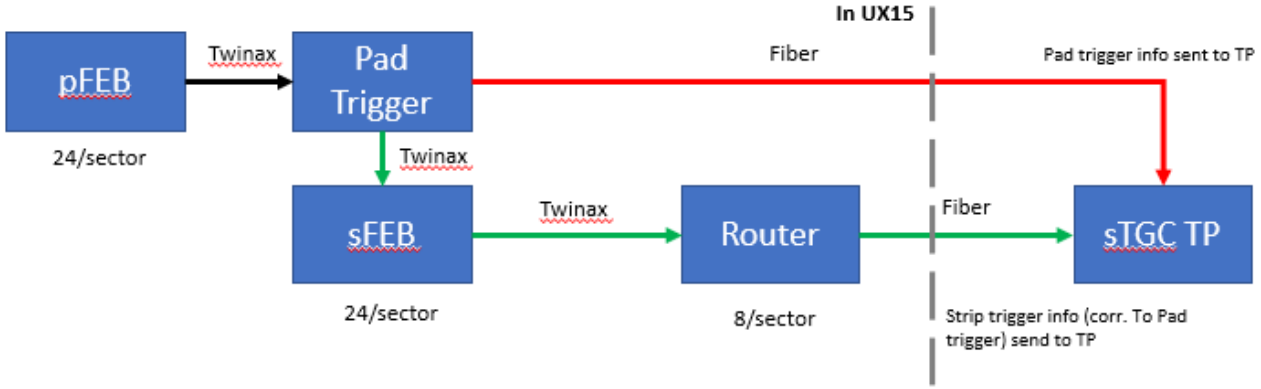
Connections & checks of services

Post-installation checks

- …..Detector Ground, Chamber leak test, CO_2 envelope Leak test, B-Field Sensors (LS only), HV 2800V test, HV Long term Validation test…..

Readout path

- Baselines
- Trimmers
- Pulser runs
- Noise runs
- Phase-2 Tests



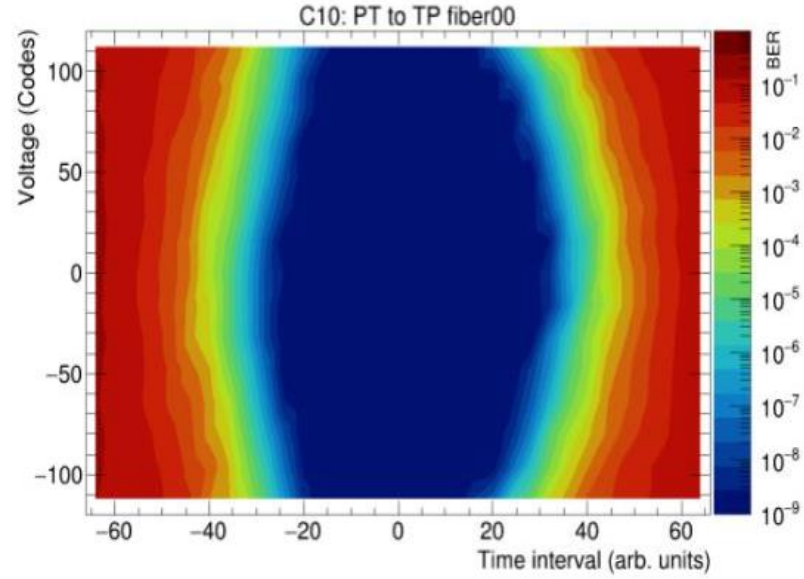
Trigger path

Connectivity checks

- pFEB →Pad Trigger
- Pad Trigger →sFEB
- sFEB →Router
- Router →Trigger Processor

Data quality checks

- sFEB (TDS) →Router
- Pad Trigger →Trigger Processor
- Router →Trigger Processor



Pad-Trigger →Trigger-Processor eye diagram for C10
Bit Error Rate given by color map
From b.191 commissioning (2020)

Cosmics in 191

Some cosmics runs were taken in b.191

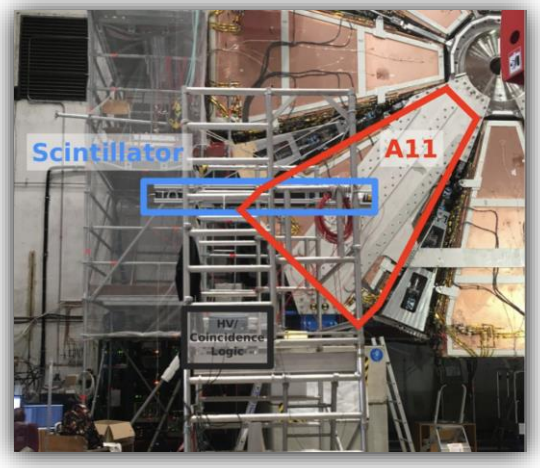
- Sectors A11, A13, A15, C13.
- Small rate due to angle (long runs needed).

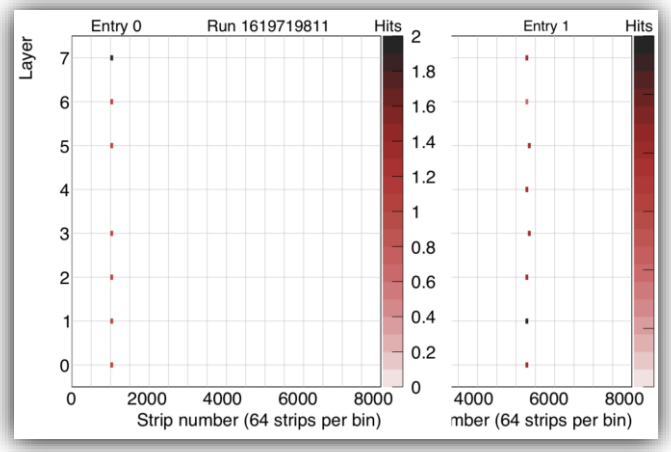
MM

- Cosmics run with scintillator coincidences to produce L1A for readout path.
- Self triggering : MM TP pushes data to readout after finding coincidence.

sTGC

- Setting Pad Trigger in self-readout mode.
- Test the trigger path : pFEb->Pad Trigger->Trigger Processor->L1A.





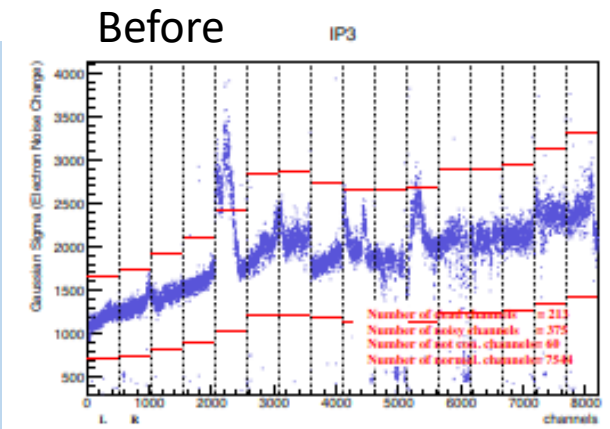
MM cosmics tracks on A11 (2021)

Issues during commissioning in 191 – MM Noise & Refurbishment of sectors

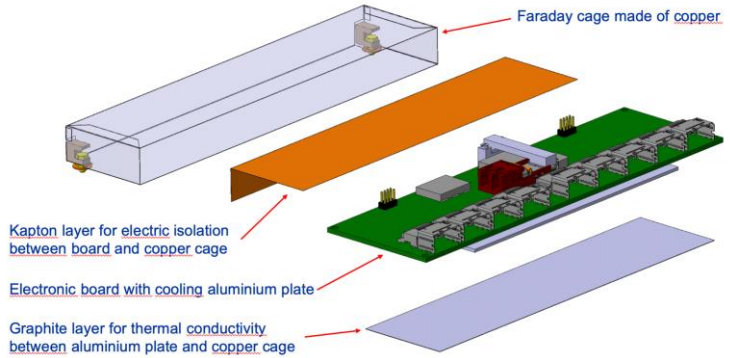
Very high noise observed on the first small sectors in NSW-A (installed during summer 2020)

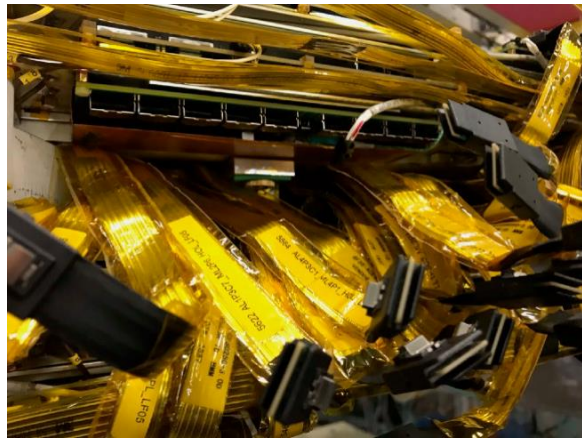
Noise investigations at BB5 identified that the main source was the improper design of the shielding of the FEAST of the ADDC boards.

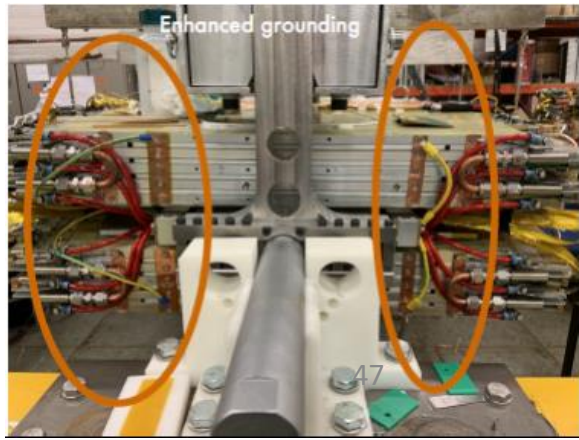
- Solution -> Enclose the ADDCs in 200 µm thick Cu faraday cage.
- Weaknesses in the overall grounding have been identified and addressed as well.



Baselines – Noise measurement







Issues during commissioning in 191 – MM Noise & Refurbishment of sectors

Sector A14 and A12 (already removed)

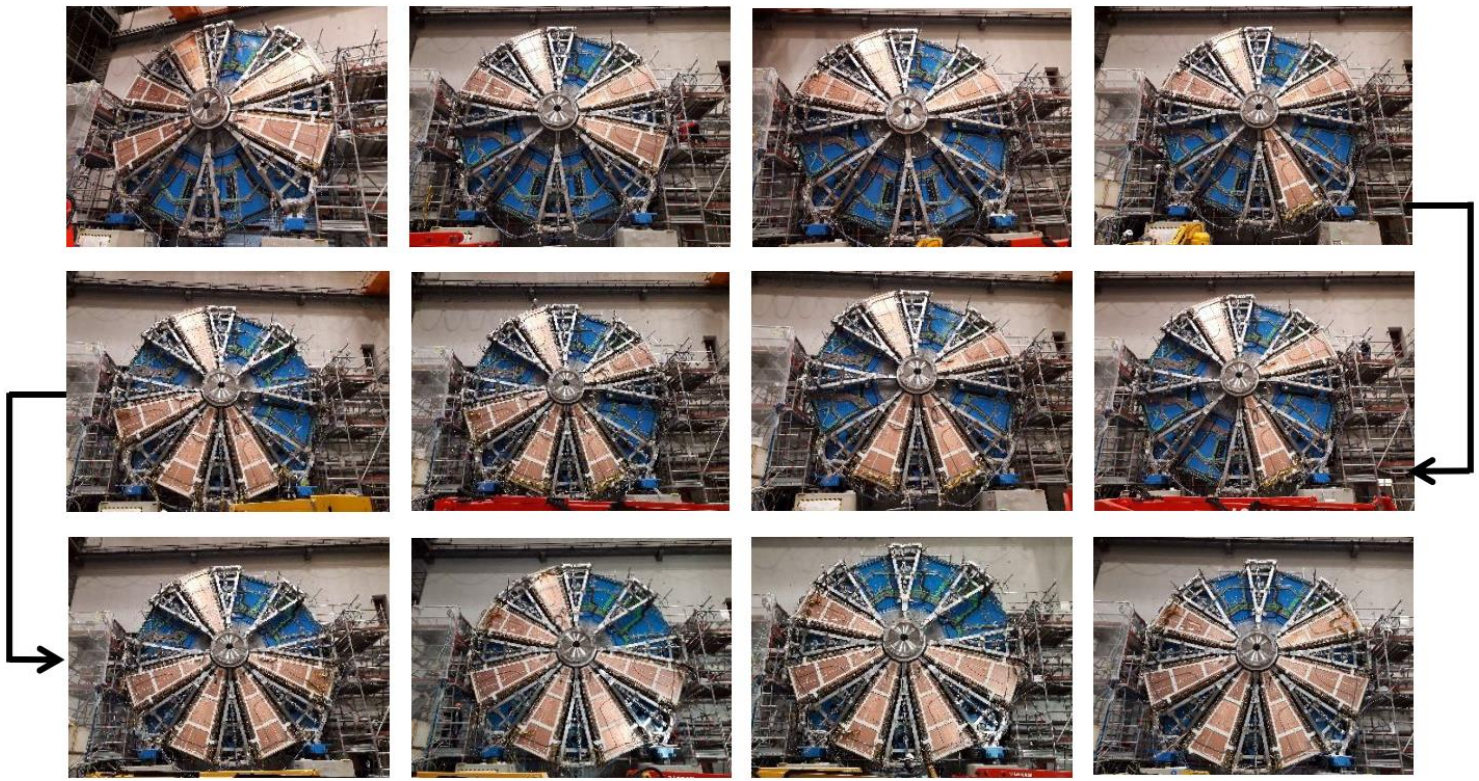
- Faraday cages on MM ADDC boards, and with modification of the grounding scheme.
- **Solutions validated on concrete blocks**

Decided to dismount and refurbish all small sectors already installed!

- The sectors needed to be disassembled so that the BB5 EIX team can work.
- Work in parallel with integration workflow.

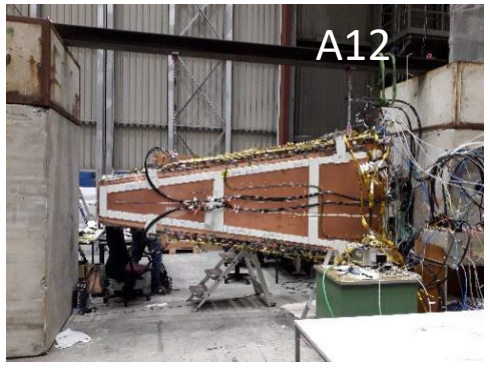
Huge effort by all teams!

19/11/2020



01/02/2021

Concrete blocks validation



New storage area @ BB5 (reduce logistics)

Two new rotation stations @BB5

Issues during commissioning in 191 – Noise part 2

Both technologies see higher noise in 191 compared to BB5 or 180.

March 2021 : Dedicated ‘Noise task Force’ to try to understand the NSW noise issue and try to identify possible mitigations.

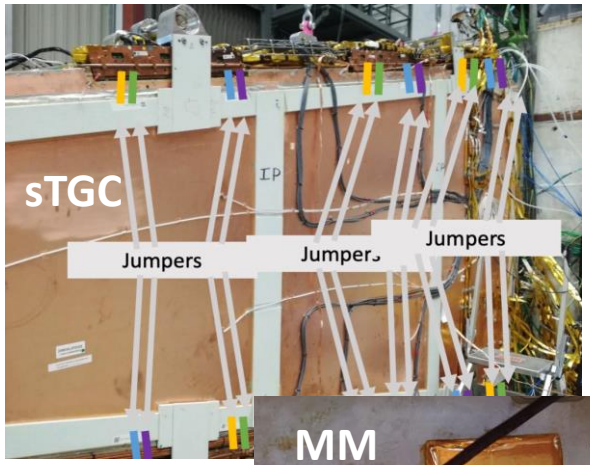
sTGC:

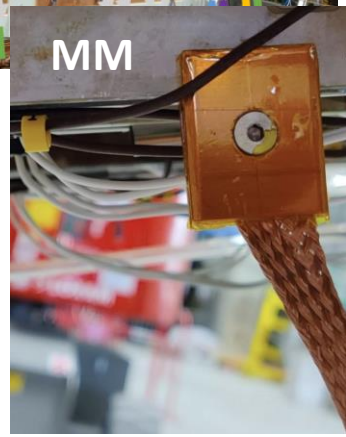
- Jumpers from adapter board to faraday cage for all the layers (tested on A11 and partially on A13).
- Grounding RIM crate to detector.

MM:

- Clamp braids connecting PCBs 2/5/6/8 to the Spacer Frame.

Both : Add common mode filter to the output of the LV power supply (ICS).





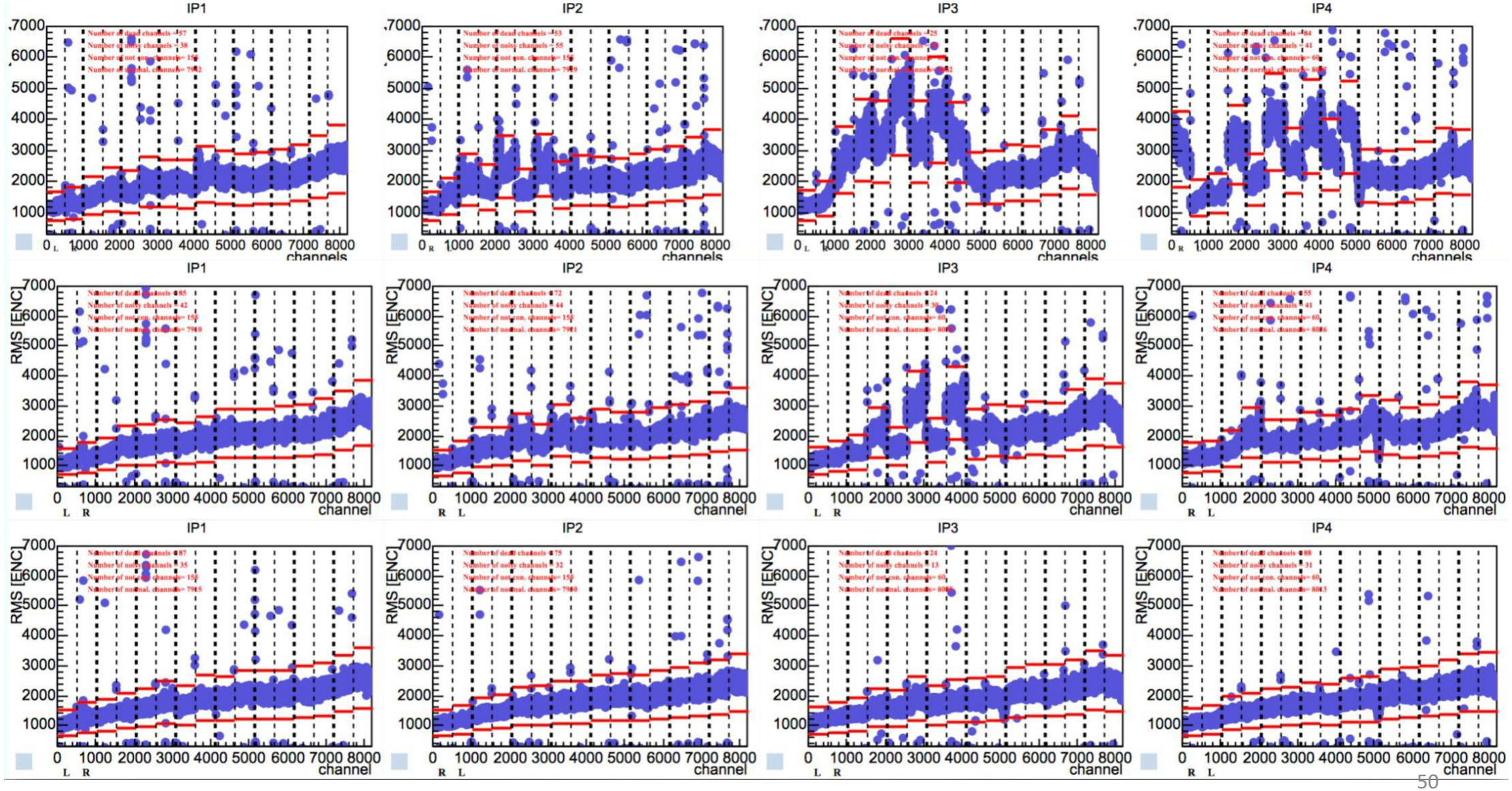
ICS crate

Issues during commissioning in 191 – Noise part 2

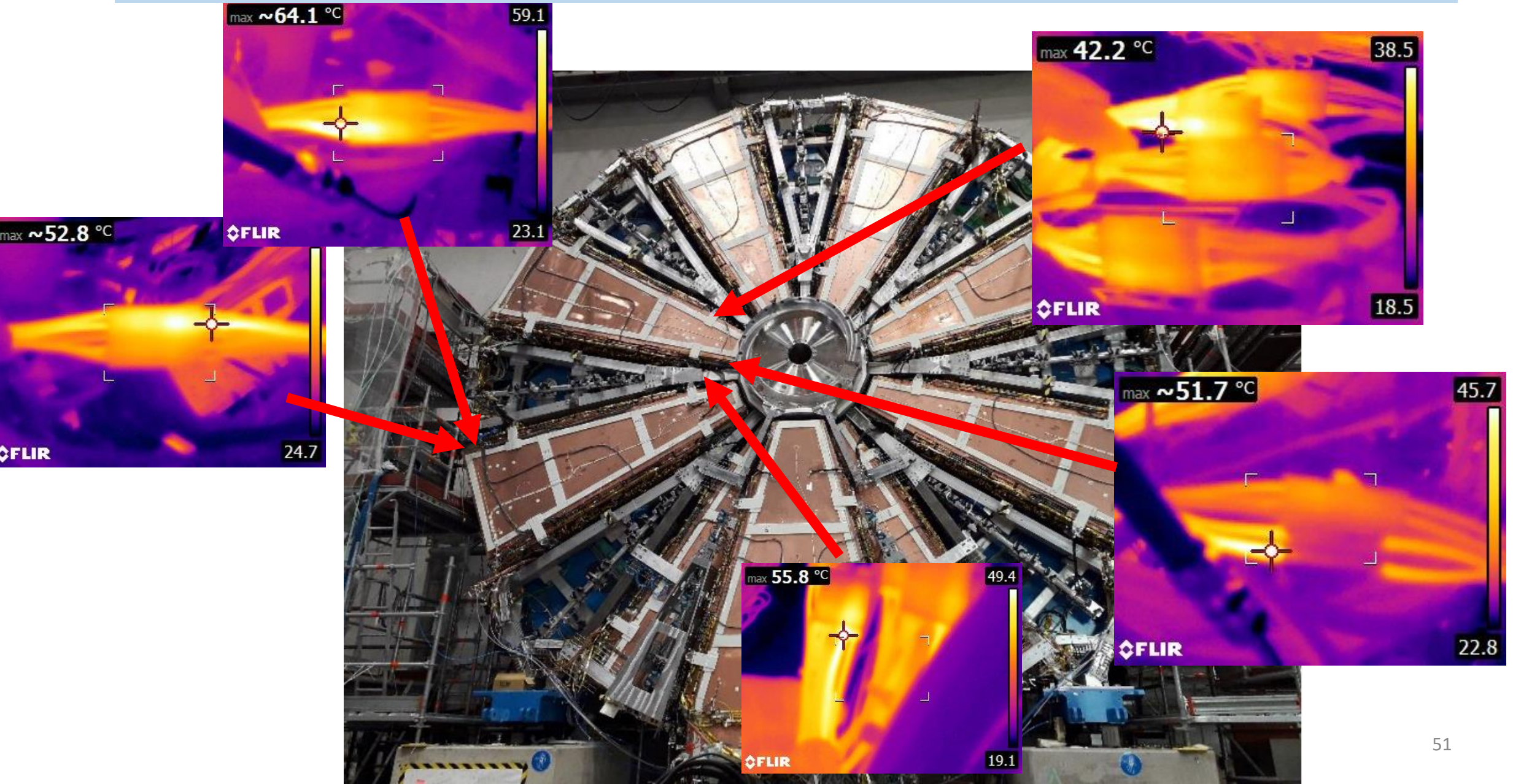
Original

Improvements on ground

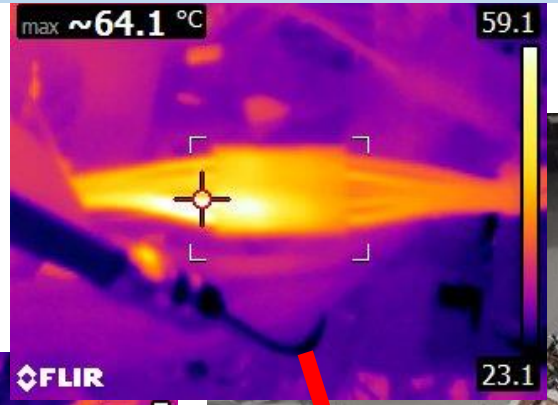
Improvements on ground & PS filter

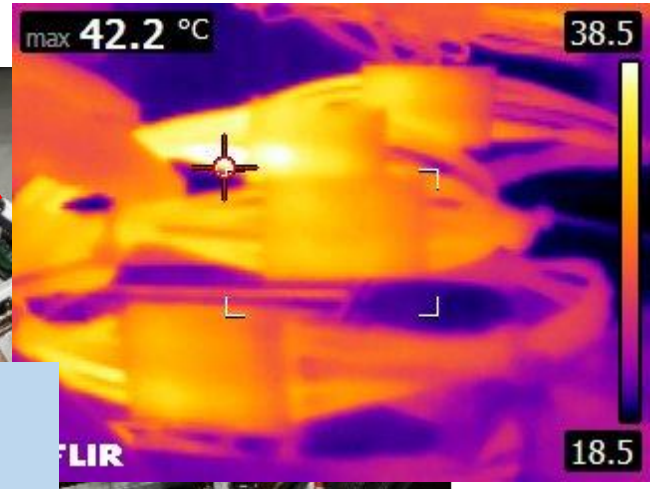


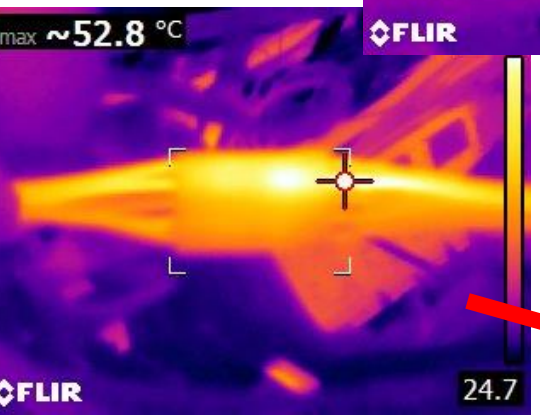
Issues during commissioning in 191 – overheating intermediate LV connectors



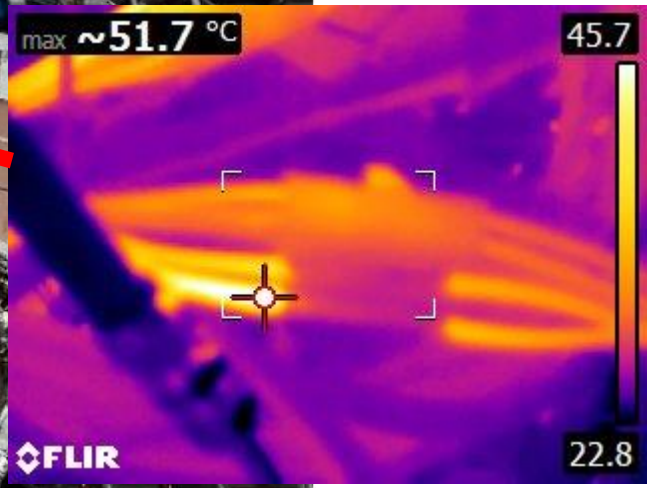
Issues during commissioning in 191 – overheating intermediate LV connectors

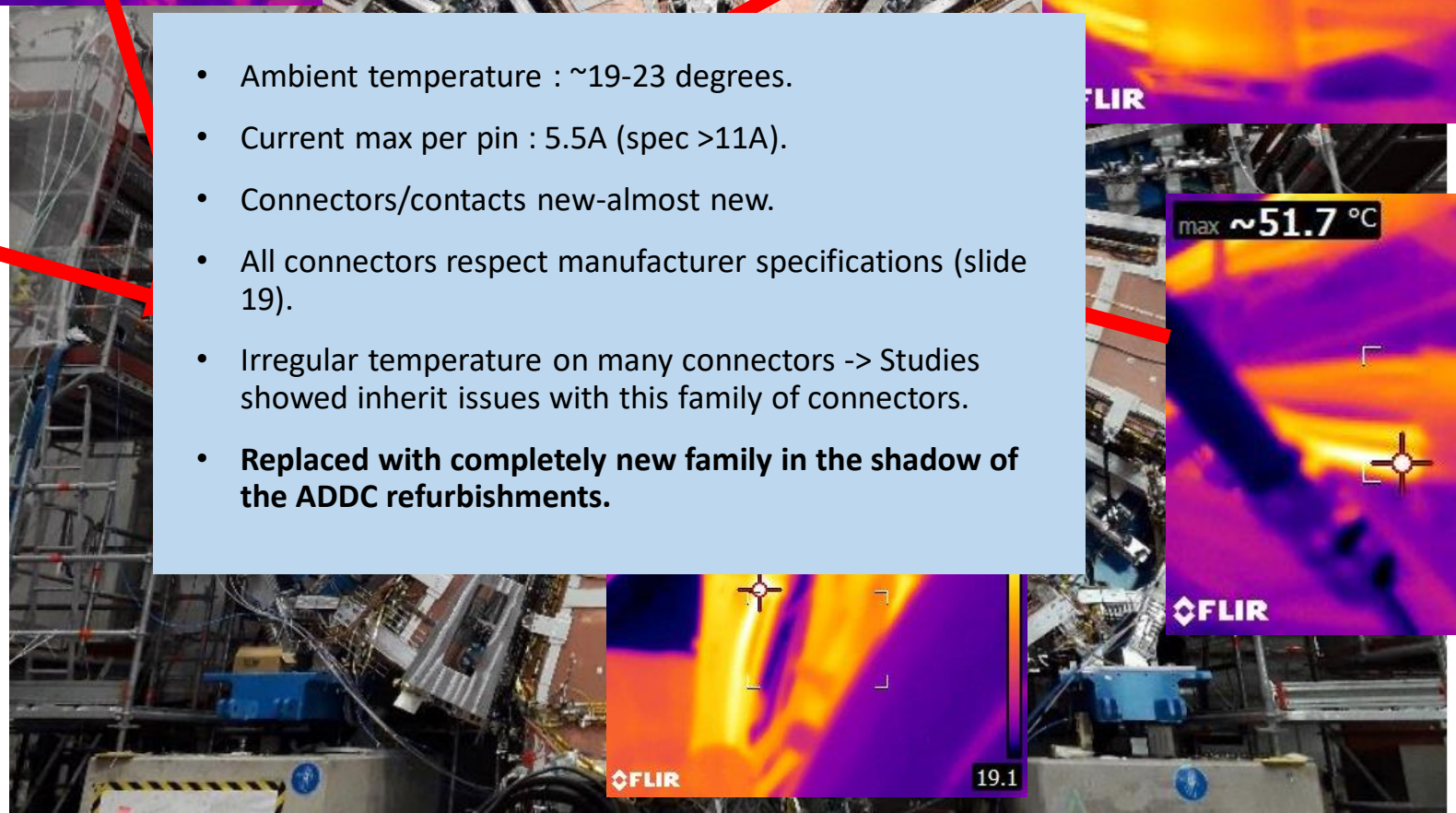




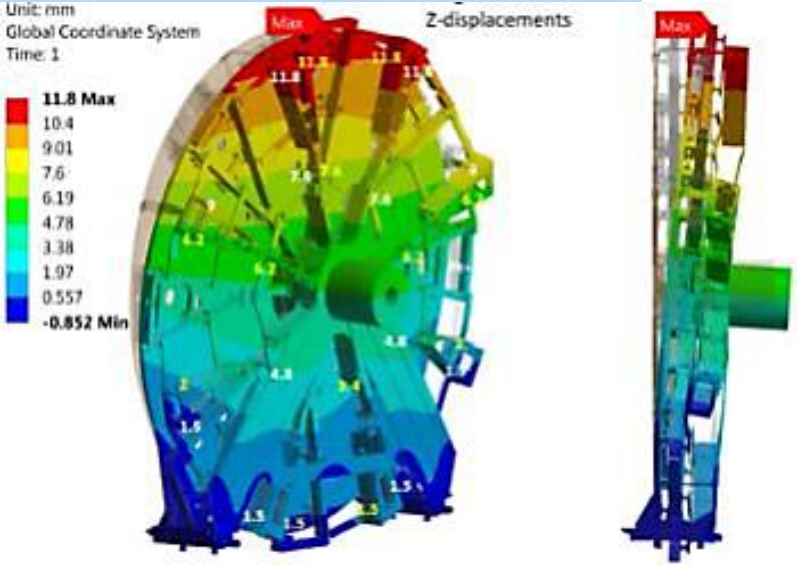


- Ambient temperature : ~19-23 degrees.
- Current max per pin : 5.5A (spec >11A).
- Connectors/contacts new-almost new.
- All connectors respect manufacturer specifications (slide 19).
- Irregular temperature on many connectors -> Studies showed inherit issues with this family of connectors.
- **Replaced with completely new family in the shadow of the ADDC refurbishments.**





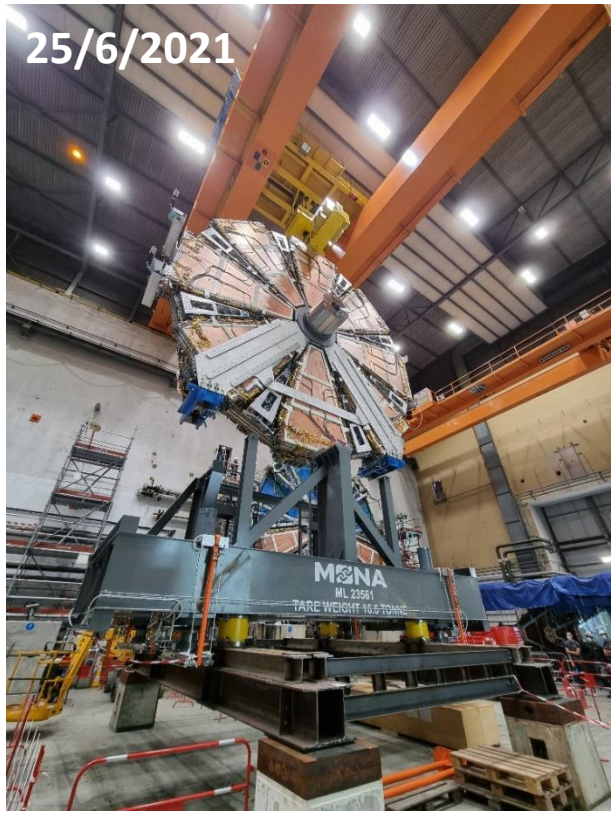
NSW-A completed

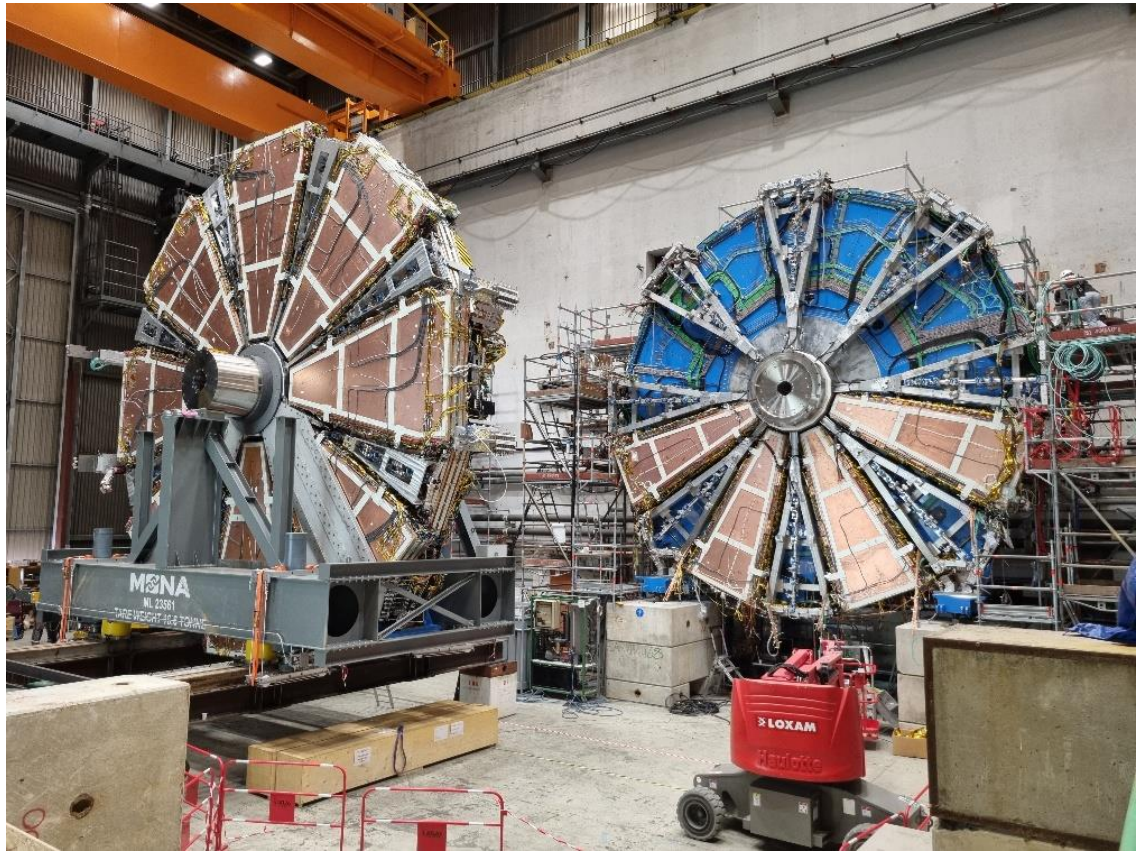


Milestone (1) 15/6/2021

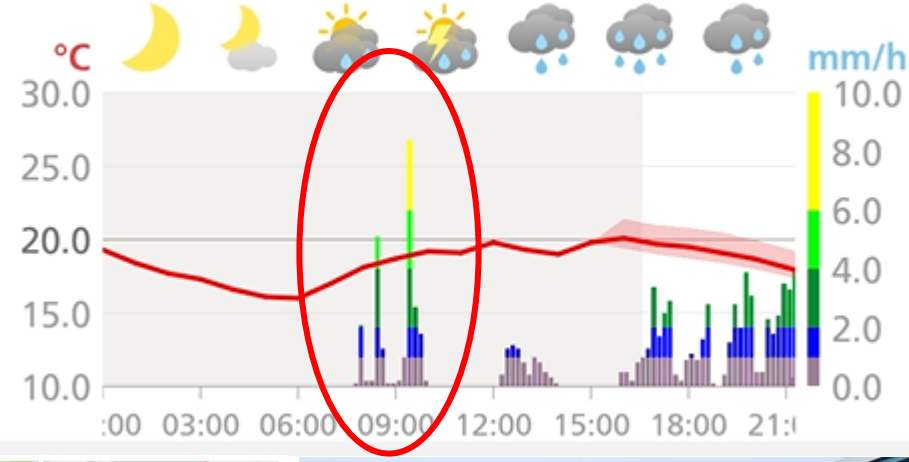
- Disconnection of NSW-A from the wall with an online survey.
- Maximum Z deviation ~12.5mm with ~11.5mm predicted using simulations -> A very good result!

Milestone (2) 18/6/2021 : Completion of the commissioning!

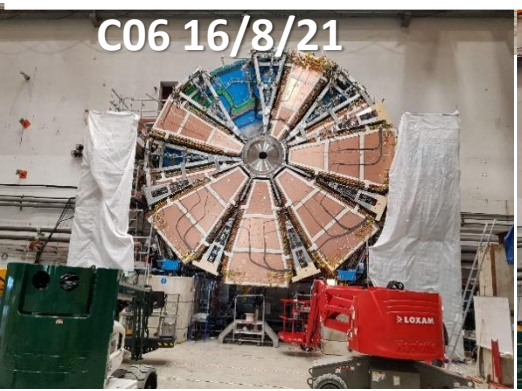




NSW-A transport to SX1



NSW-C integration



22/9/21

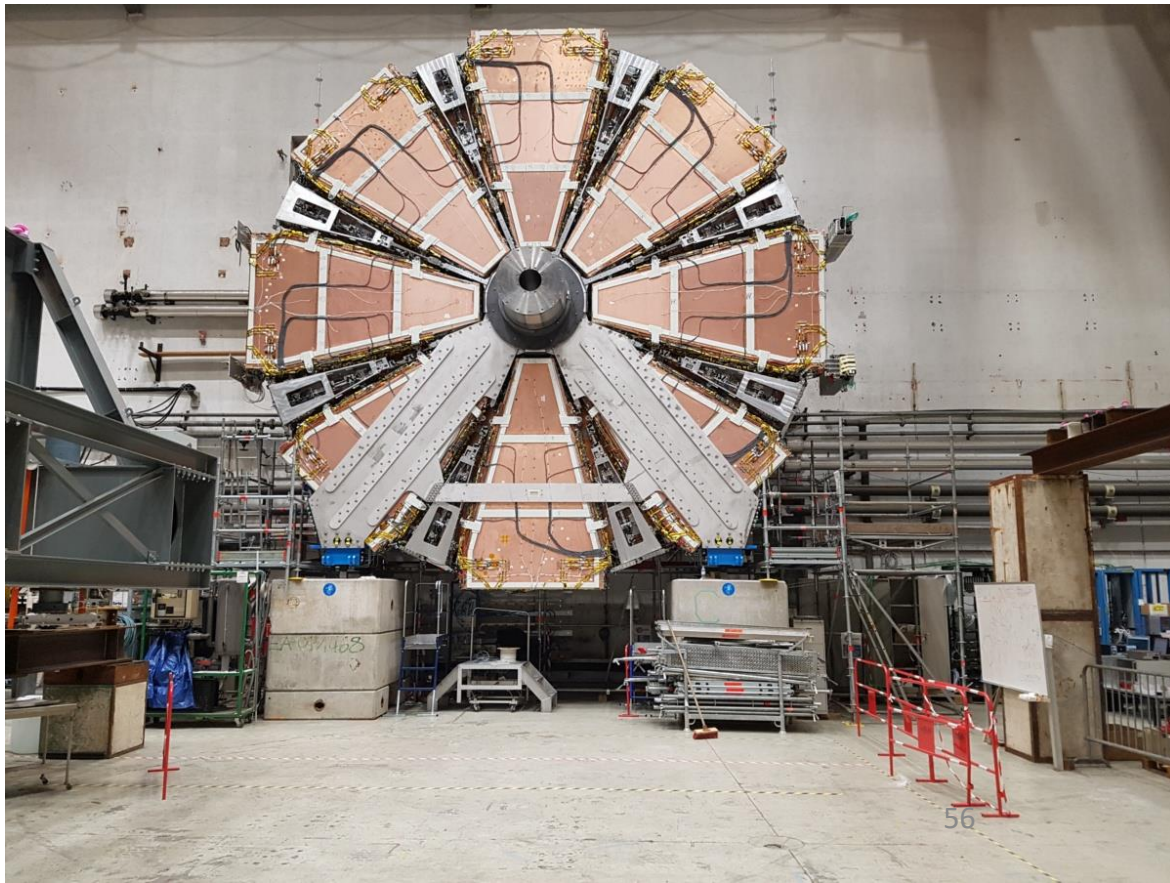
- HUB extension installation
- Disconnection from the wall

27/9/21

All Detector Commissioning finished

30/9/21

Alignment system commissioning finished



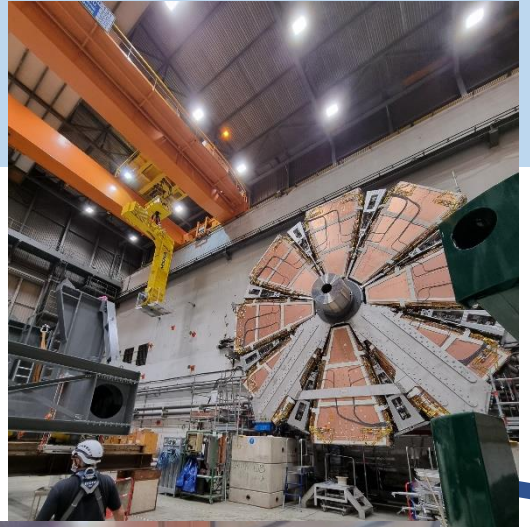
NSW-C integration

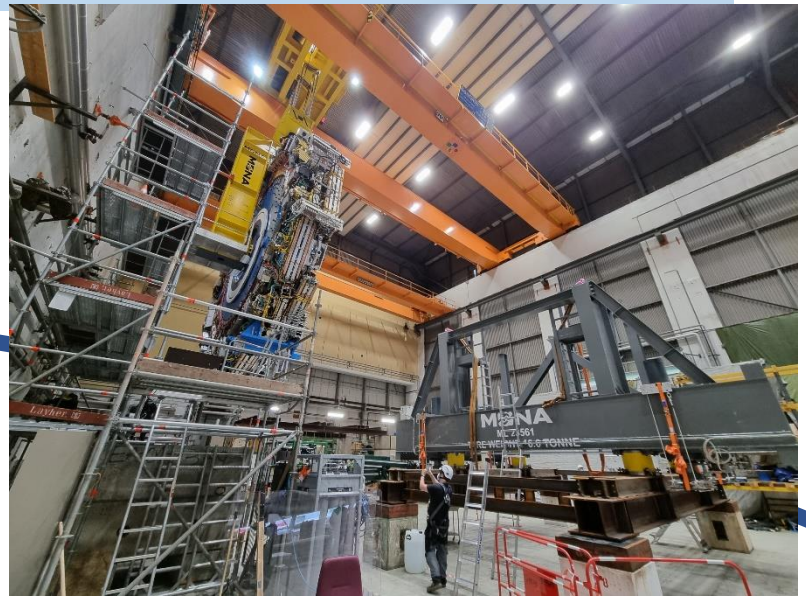
Tuesday 5/10/2021

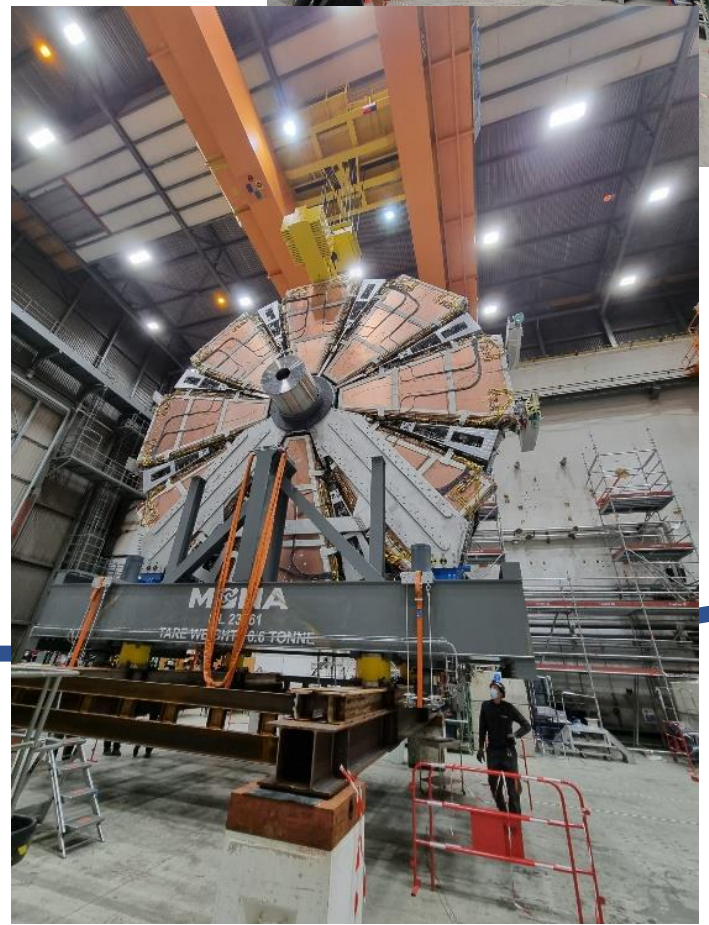
- Transport of NSW-C to the resting frame.

Wednesday 6/10/2021

PARTY





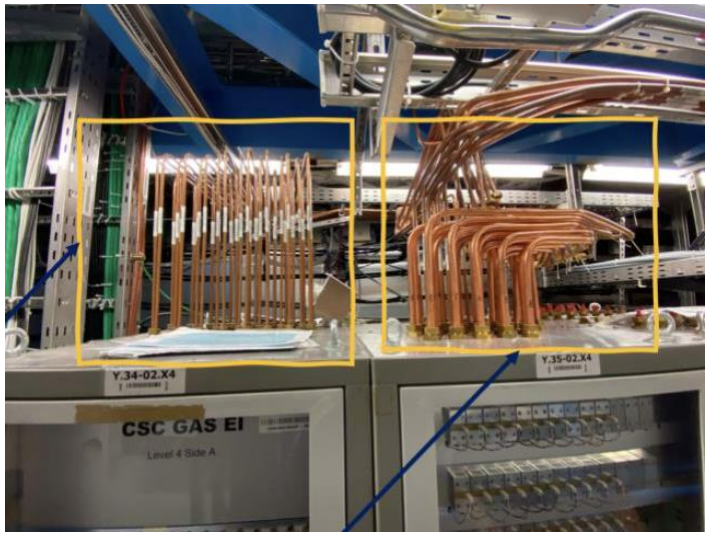


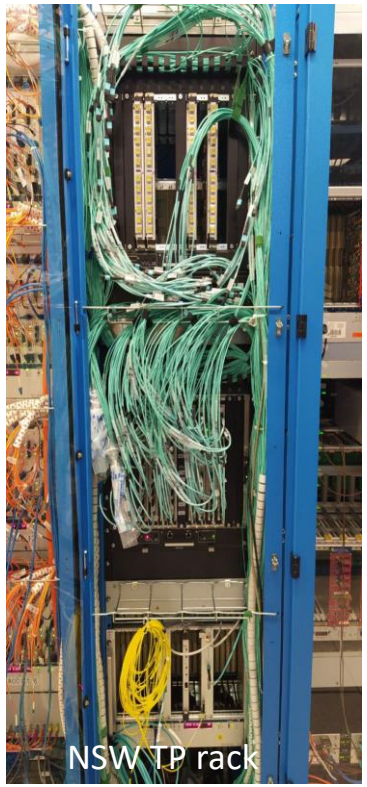
Meanwhile @ P1

Intensive preparatory work has been going on to route the services and prepare the racks:

- HV, LV, DCS, DAQ, Trigger racks have been installed.
- Services (cables, pipes, fibers) for power, DAQ, alignment, gas and cooling were routed and tested.
- Lengthy and intense work.

NSW-A gas racks in UX15




NSW TP rack


NSW-A MMG HV sytem


NSW racks in US15

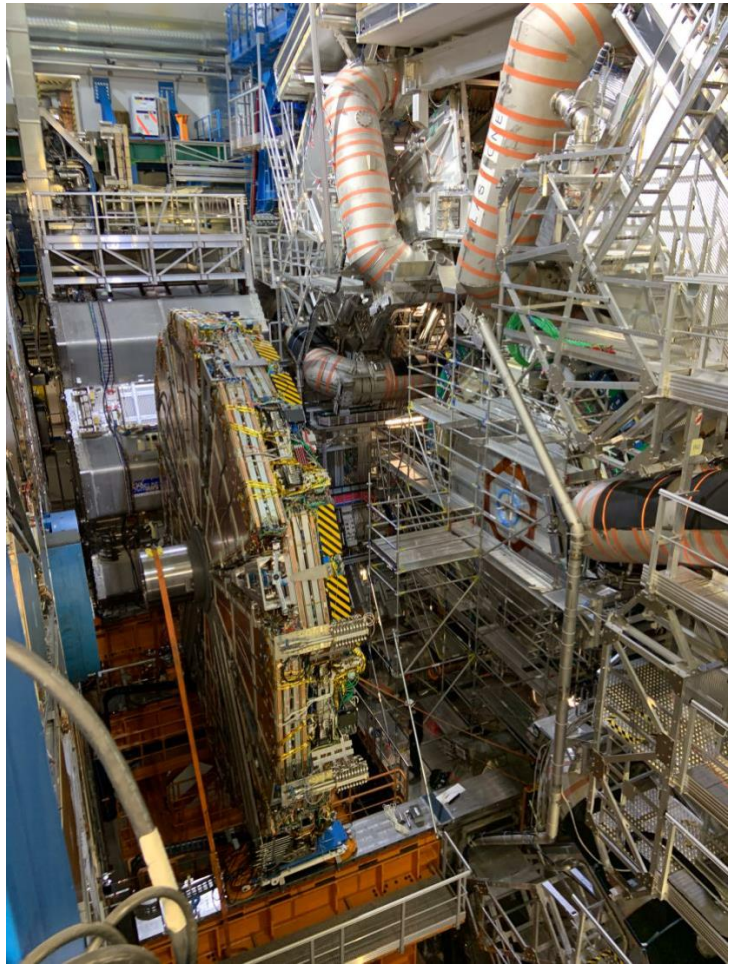
NSW-A S09, services bracket

NSW-A @ P1

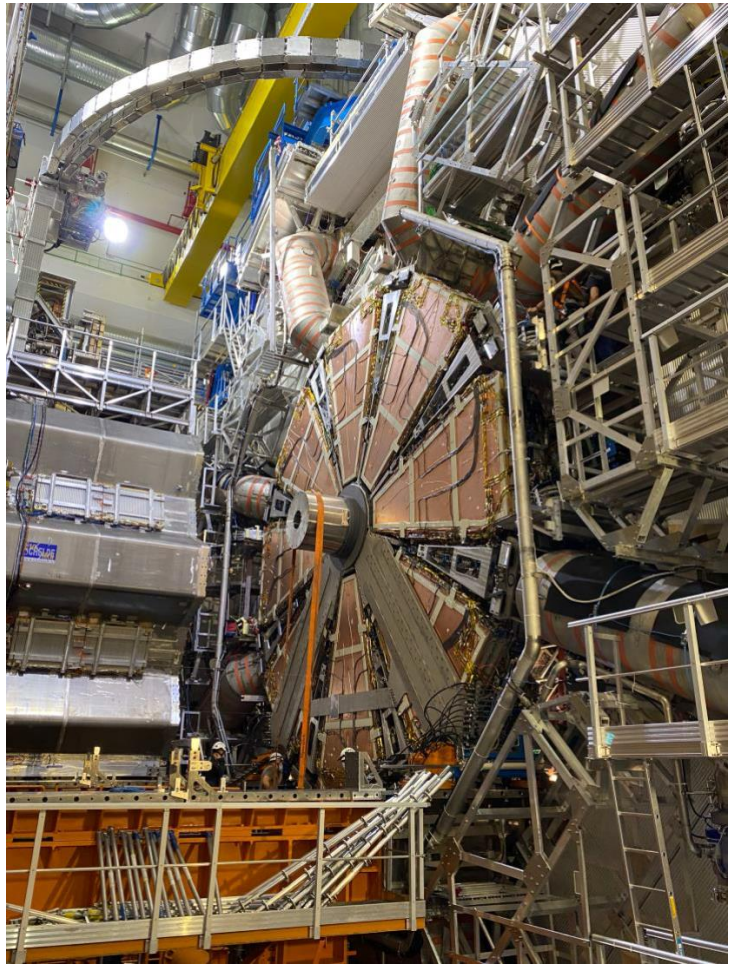
12/7/2021
Lowered to the cavern.
16/7/2021
Move to Standard Opening position.
30/7/2021
Move to intermediate position.
5/8/2021
Connected all the services.
7/8/2021
Move to the Run position for Pilot Beam.

Connectivity tests & commissioning started

- Tune cooling system & gas system.
- Understand noise environment of P1.
- Repeat the sequence of tests done in the surface.
- In parallel : development of DAQ, DSS, DCS + preparations for the services for NSW-C.



NSW-A in Parking position



NSW-A in Standard opening

18-31/10/2021
Pilot beam

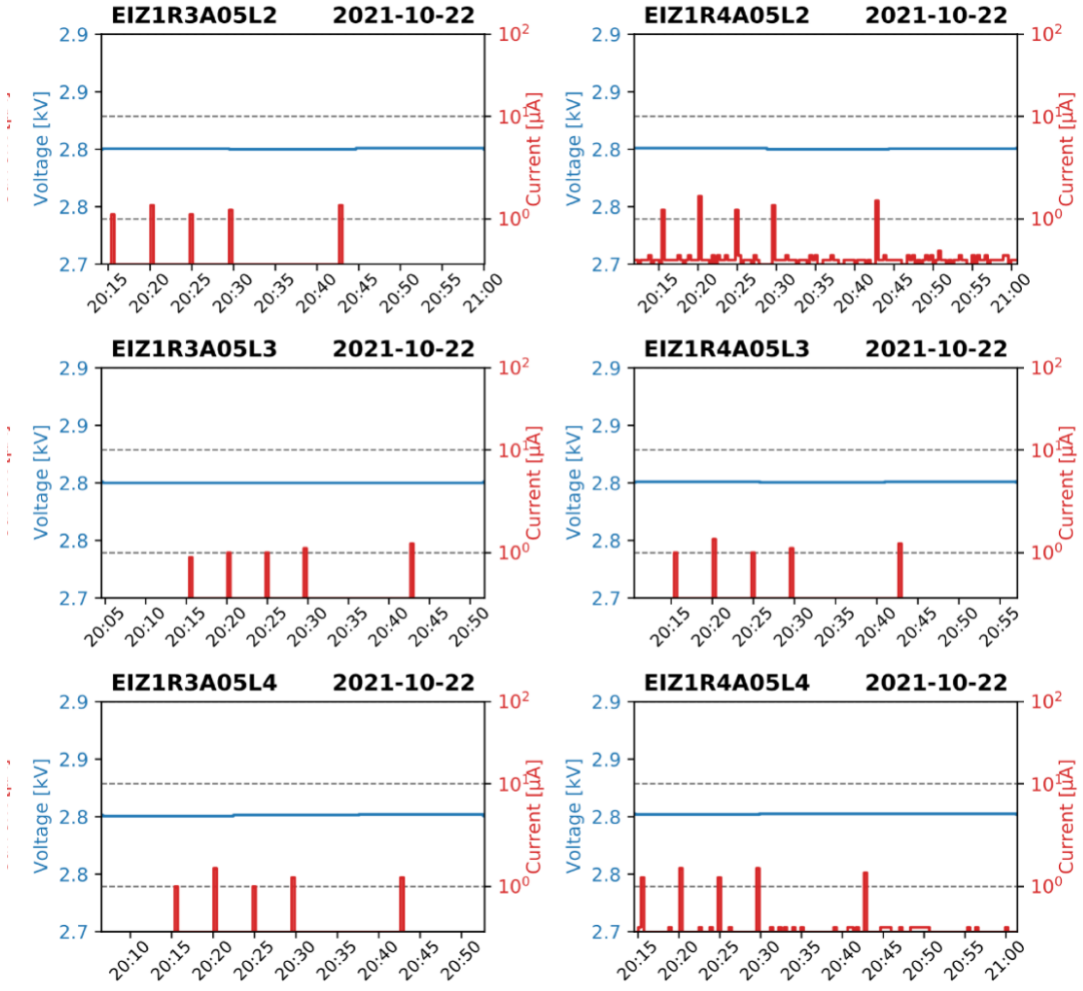
22/10/2021

First splashes on MM at ~20:12 seen as current peaks in the HV of the order of ~20nA.

First splashes on sTGC at ~20:15 on 22nd Oct @2.8kV.
Peaks of current of a few µA registered on current plots.

MM

sTGC



NSW-A @ P1

During NSW-A Commissioning..

Issues

- Several hardware connection issues:
  Disconnected T-sensors, damaged optical fibers, Failed LV channels…
- Envelope improvements.

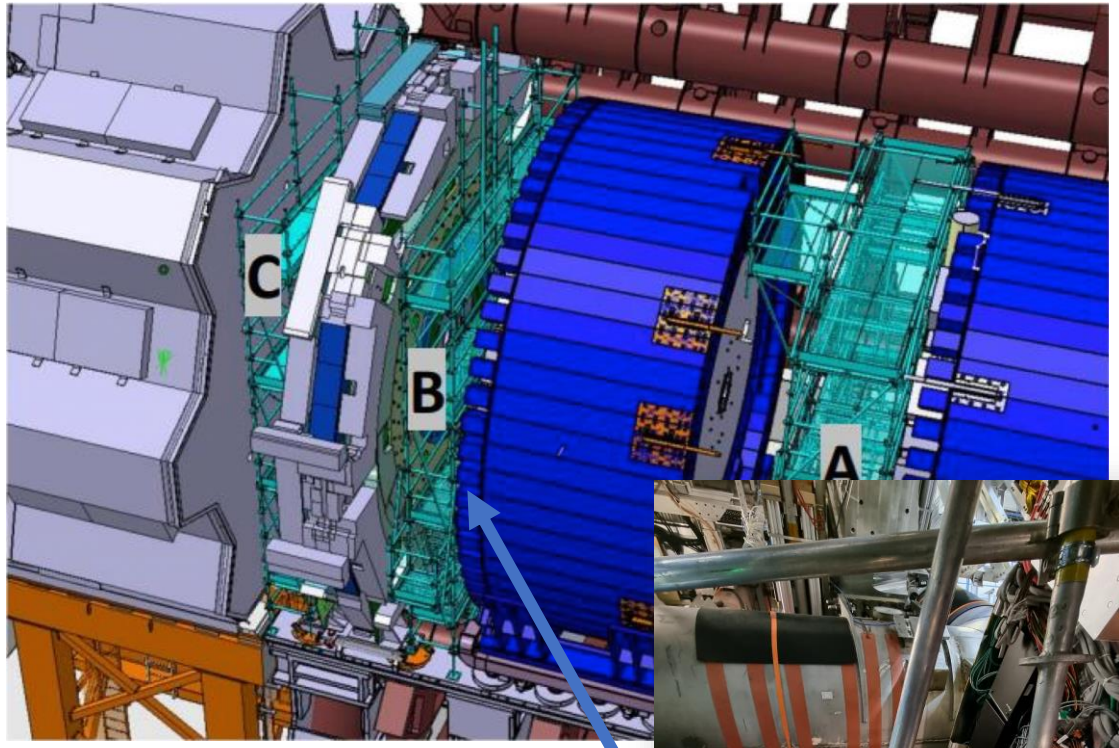
-> Need to be investigated and repaired after the Pilot beam : Intensive activity in parallel with the NSW-C arrival & connections @ P1.

+Survey measurements for both wheels to define the reference system to be used by the alignment & check for deformations on the structure.

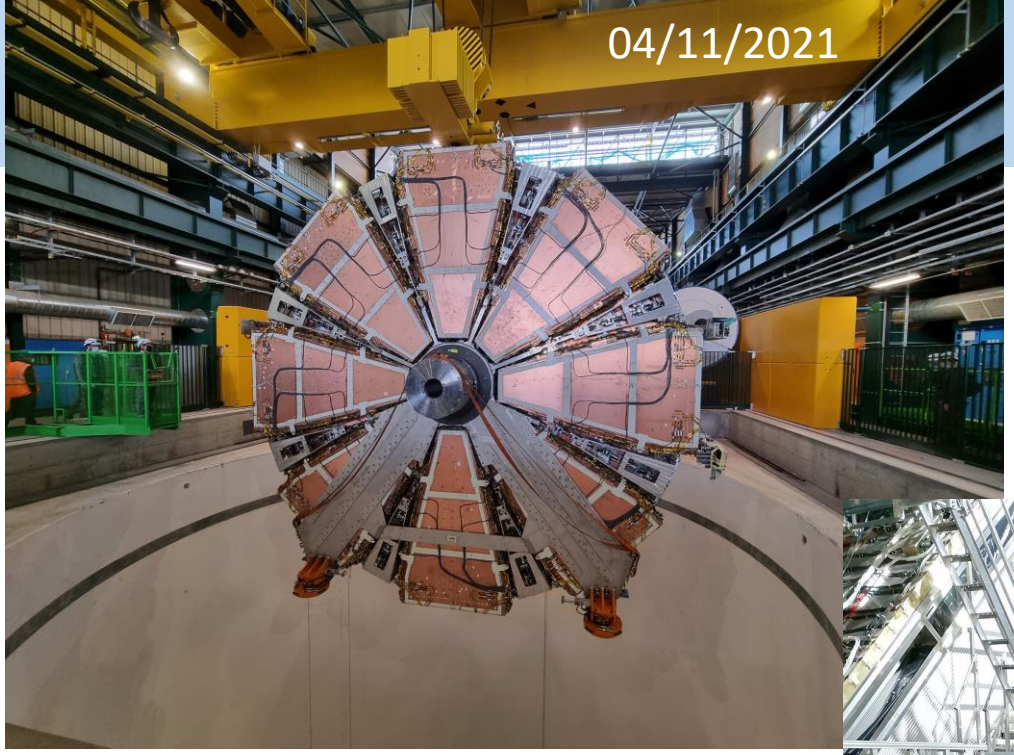
9/11-2/12/2022 reparations period (last days limited power/cooling)

- NSW-A in standard opening with scaffolding on both faces of the wheel.
- Very careful planning (co-activities, difficult accesses, limited time).

13/01/2022
NSW-A in run position



NSW-C @ P1



9/11/2021

- Access to NSW-C in temporary position (experience from NSW-A).
- Some connections can only be done here.
- Services connections in 6 days.

16/11/2021

- Move to Standard Opening position & built scaffoldings asap:
- Finalization of connections.
- Cooling regulations.
- Commissioning (find and fix issues) until 3/12/2021.

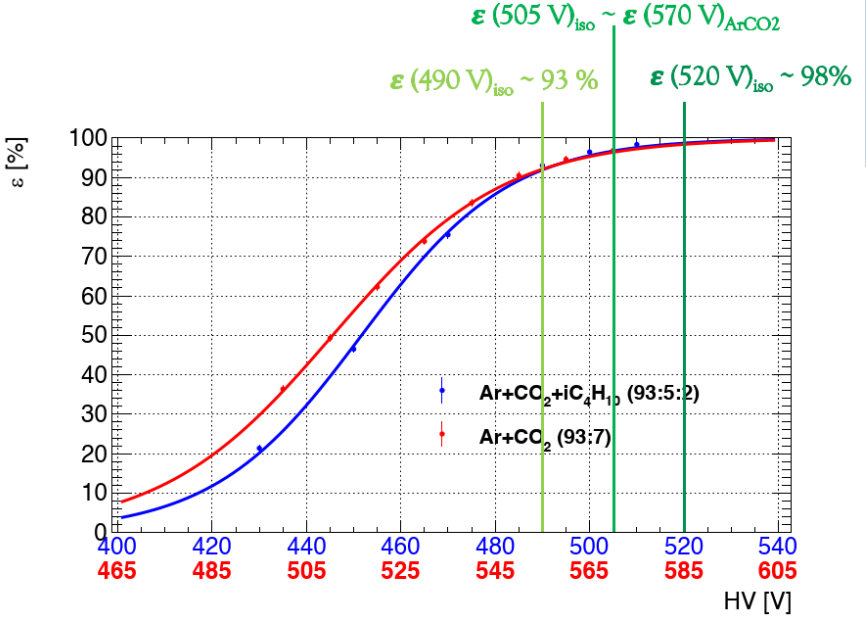
25/01/2022
NSW-C in run position

NSW Commissioning – MM Status

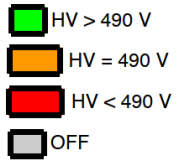
Micromegas : HV tests with Ar:CO_2:iC_4H_{10} (93:5:2)

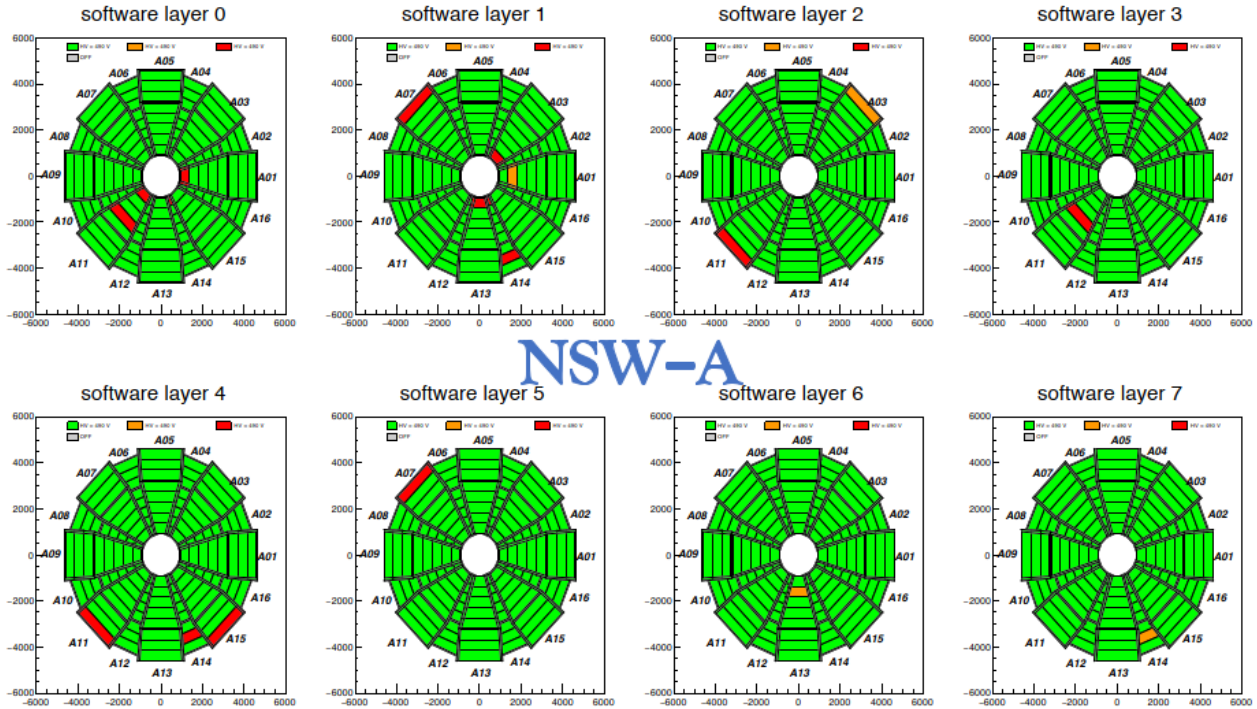
- First ramp up with Iso gas mixture : 17-23/12/2021
  HV at 490V for 5 days
- Beginning of 2022
  XM1 sectors at 505V
  XM2 sectors at 520V

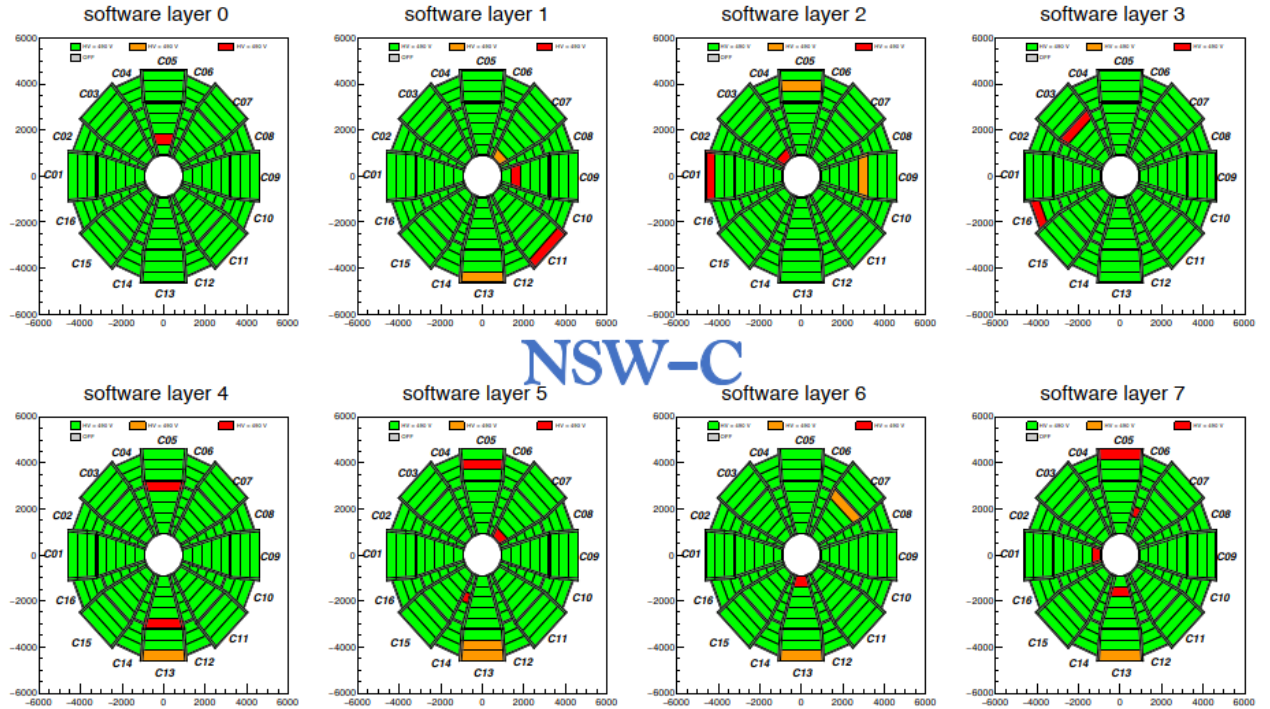
Less than 2% of the sectors <490V!



HV map at P1 with Ar:CO_2:iC_4H_{10} (93:5:2)



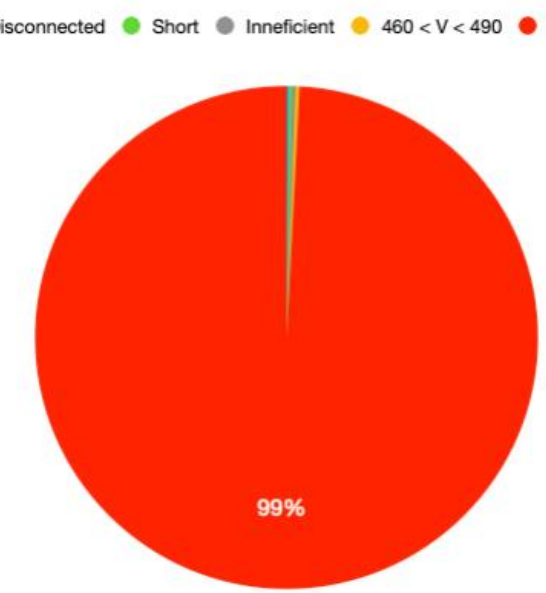


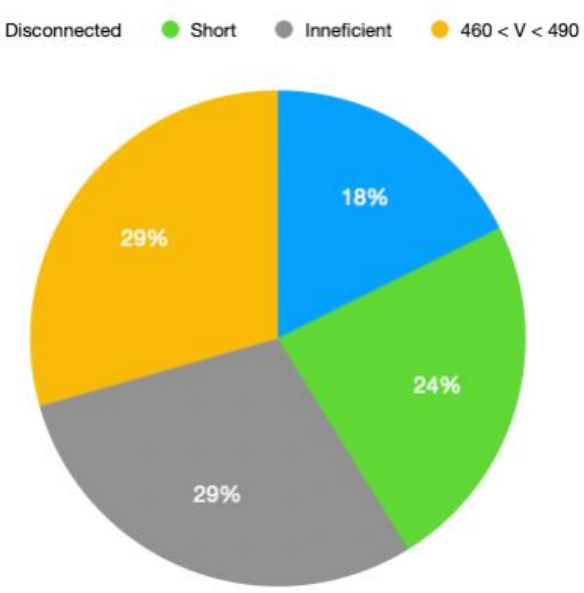


NSW Commissioning – MM Status

HV

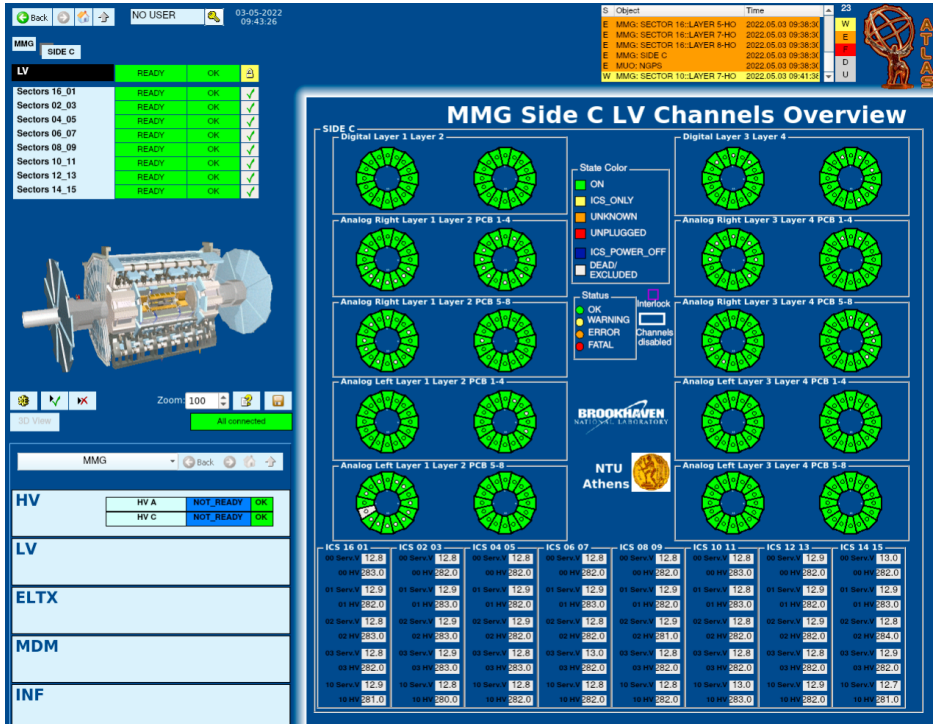
- 0.15% channels disconnected (1/3 of which since the commissioning in 191)
- 1 channel in short (0.05%)
- 1 drift in short (0.2% of drift or 0.15% of RO channels)
- 0.49% channels at low voltage (1/2 of which ~inefficient)
- 1.7% channel resistive (efficient with high current).
- STANDBY and READY (V0=470V, V1=490V) settings in place





Low Voltage supply of FEBs

- 3 LVDB not working. 2 already from 191.
- 5 ICS channels (LV supply of FE) failures observed after the installation at P1.
  - Infant mortality -> A workaround has been put in place to power the corresponding boards and a dedicated test stand has been set up. Investigations will start next week.
- The affected modules are replaceable next time there is access to the IP phase of the wheel.



Noise

- Levels similar to 191.

NSW Commissioning – sTGC Status

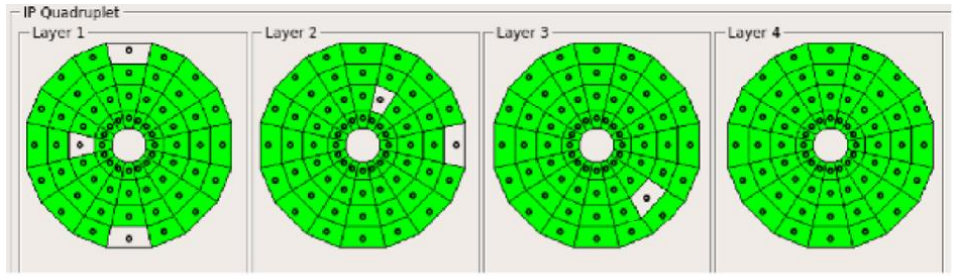
Cooling
- All sectors ON all the time; ELX temperatures are all below 45°C
- Still adjusting flow and purging few cooling circuits.

Gas
- Flushing nominal mixture (CO2:n-pentane) since March.

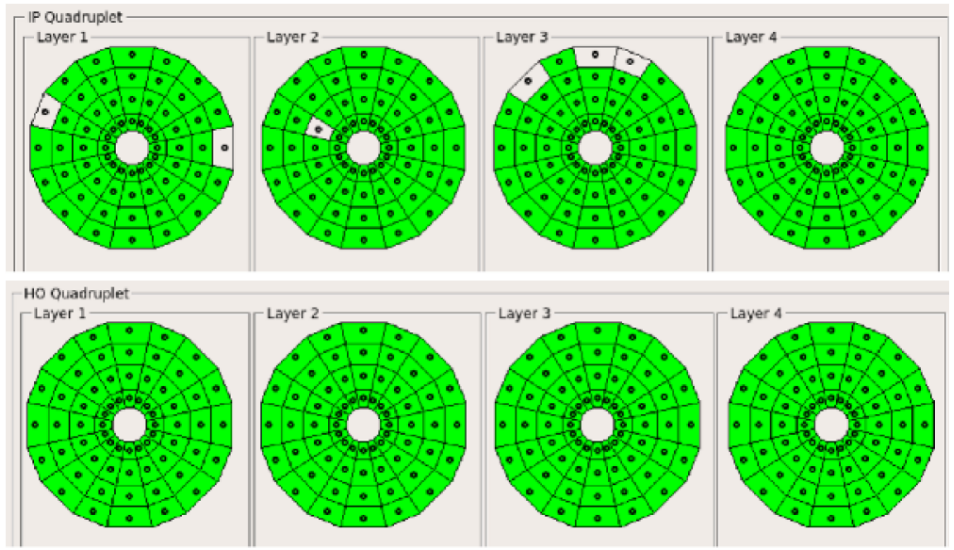
HV
- Less than 2% (22/1024) of the chambers under nominal voltage. (Most already problematic in B191).
- No new problems since flushing of the gas mixture.
- 3 chambers have a resistive behavior (~20 MOhm) and can run in high current mode.
- STANDBY and READY (V0=2.2kV, V1=2.8kV) settings in place.

Other HV issues:
- The service generator of side C has one of the channels not working -> workaround to use only one channel in both sides
- The power generator of side C spontaneously going to “unconnected”-> pinned down to a connection issue in an interlock cable.
- Refresh rate in DCS was too slow for the HV commissioning -> additional branch controllers were added to speed up communication.

HV map at P1

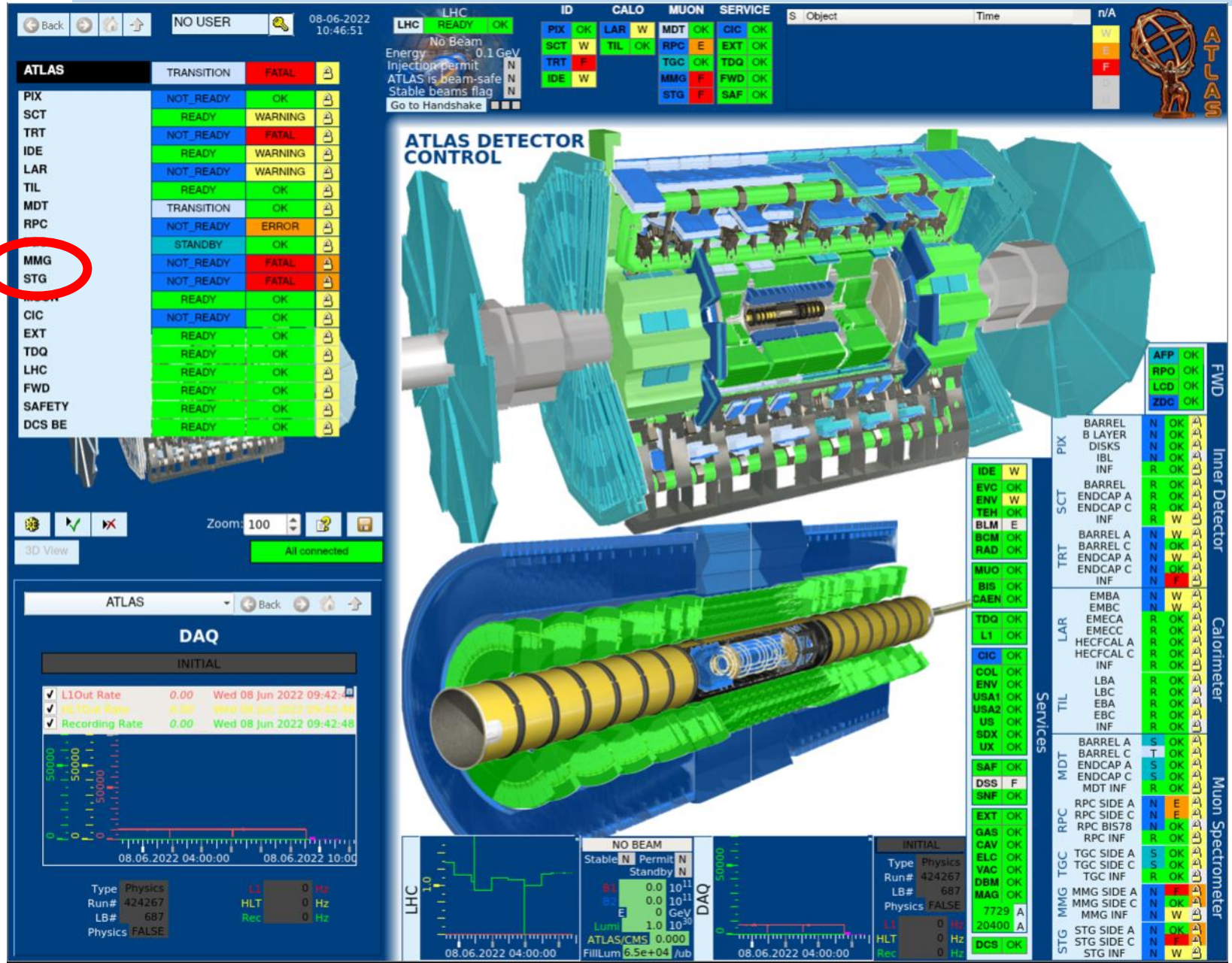


Side A



Side C

NSW Commissioning – DCS Status



Main projects

- High Voltage
- Low Voltage
- ELTX-SCA
- MDM-ELMB
- VME-ATCA
- Cooling
- Gas
- Infrastructure

- 07/06/2022 MMG & STG DCS have been integrated into the ATLAS DCS.

Important milestone towards full integration!

NSW Commissioning – Alignment Status

Connections

Connected the 96 cables at the service brackets (S09).

- Cabling, making new connectors, routing and relabeling CAT-5 cables in the cavern

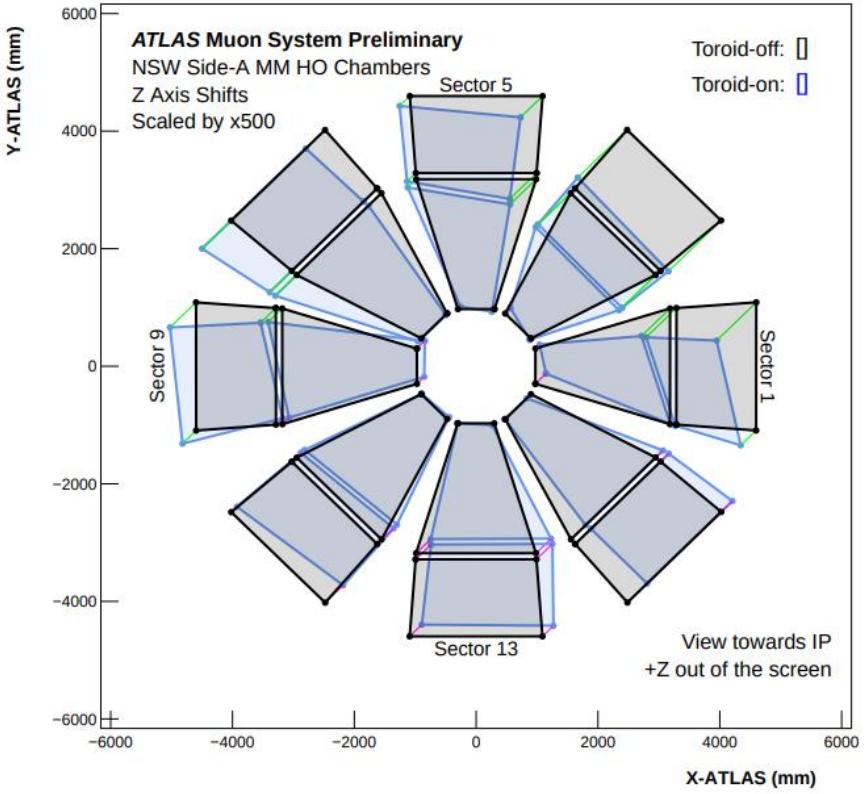
The alignment system is the only NSW component which re-used the readout cables of the Old SW system -> No optimization of lengths.

Commissioning

- New readout software to validate the hardware
- Checking that all the alignment corridors were clear and all devices working -> time consuming
- Few BCAMs have been exchanged; some cables were re-routed; dust and trash removed from the alignment corridors.

Wheels in run-position

- Checked the alignment lines linking to the rest of the endcap systems;
- **Established the position of the NSW**
- With magnet ON : Both wheels tilt away from IP / towards HO.
- On average 1mm shift, but up to 2mm
  - NSW-A tilts towards +Z
  - NSW-C tilts towards –Z



Change in large sector Z positions between toroid-off and toroid-on.

NSW Commissioning – Trigger Status

NSW Trigger HW

- All hardware is available for NSW-A and NSW-C.
- NSW-A: All HW sets installed.
- NSW-C: All 6/8 HW sets installed.

- Fibers to the Sector Logic outputs routed and connected.
- Connectivity of the trigger paths proven to be good. To be completed with the installation of the last TPs.

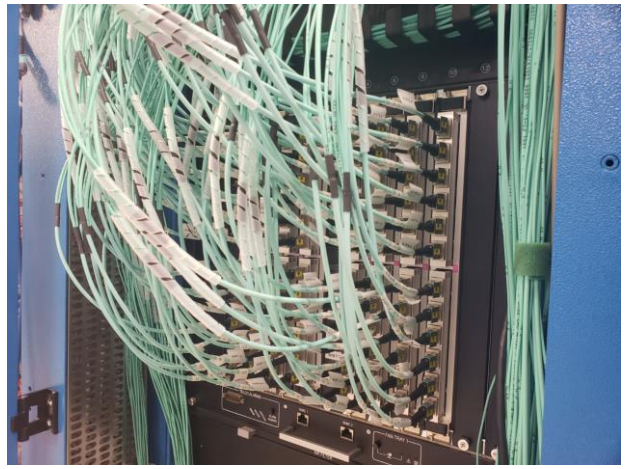
- Tests with the NSW trigger processor & the Sector Logic advancing, focusing on NSW-C.

- (Last week) MM track patterns from FE to ADDC to MM-TP to sTGC-TP, sent and received by Sector Logic. **Major milestone: NSW Trigger chain works!**

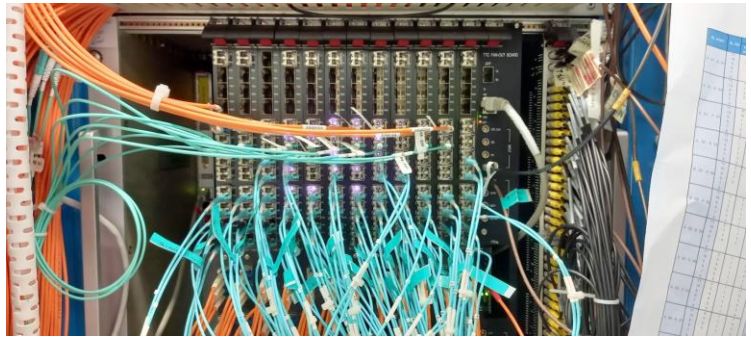
Next steps:

- Validate full trigger chain and progress in integration with ATLAS trigger incrementally.
- Until sTGC strip trigger path is calibrated, run with pad tower ids used to fake sTGC strip-based segments -> **Expect strip-based segments to be ready by Sept**.
- Commission the trigger with beam by running parasitically with the BW to understand the performance.

Trigger Processor (A side)



Fibers from detectors & to Sector Logic



NSW Commissioning – DAQ Status

TTC data path complete
- Both TTC crates are complete and working.

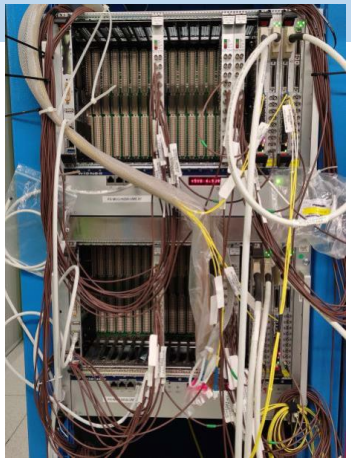
FELIX PCs installed
- Connected to the detector.
- 12 for micromegas.
- 16 for sTGC.
- 2 for trigger processor.
- Will also run OpcUaServer for SCA.

04/05/2022

Prepared a segment just containing A10 (MMG + STG) & **Integrated into ATLAS partition in preparation of splashes.**
- Tested stability over the rest of the week to prove that including NSW in splash run poses no risk for ATLAS.
- **Successfully took splashes** on Saturday morning in ATLAS partition.

07/05/2022
- Saw only empty packets for STG (but also only very short preparation time for splashes).
- Most MMG packets are corrupted (lost synchronization).
- FELIX buffer fills up at higher rates (around 1kHZ).

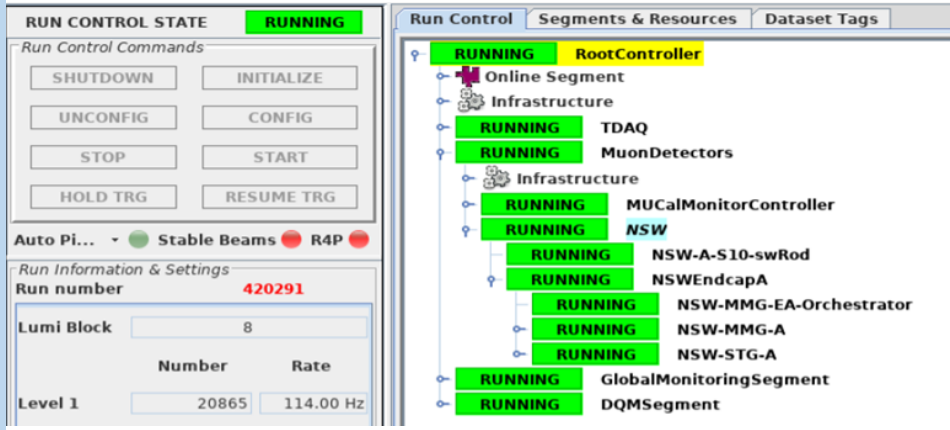
Temp solutions:
- Dumped all data leaving FELIX to text file due to corrupted data in swROD.
- Killed OPC server after going to running to prevent FELIX buffer from filling up and stopped config RC apps.



TTC crates

FELIX pcs

TDAQ – NSW A10 joined the ATLAS partition



NSW Commissioning – DAQ Status

27/5/2022 - Collisions @ 900 GeV: (MM & sTGC A10, MM A09)

- Some data taken with the MM detectors and **some muon tracks reconstructed**.
- High noise level with A09 (lower thresholds than A10).
- No track reconstructed using STG.

02/06/2022 - Horizontal muon runs: (MM & sTGC A10, MMG A09, MMG, C10, sTGC C14)

- MMG A09 and C10 lost before the arrivals of the muons.
- STGC C14 and A10 (both STGC and MMG) **were seeing muons** (there are event displays).

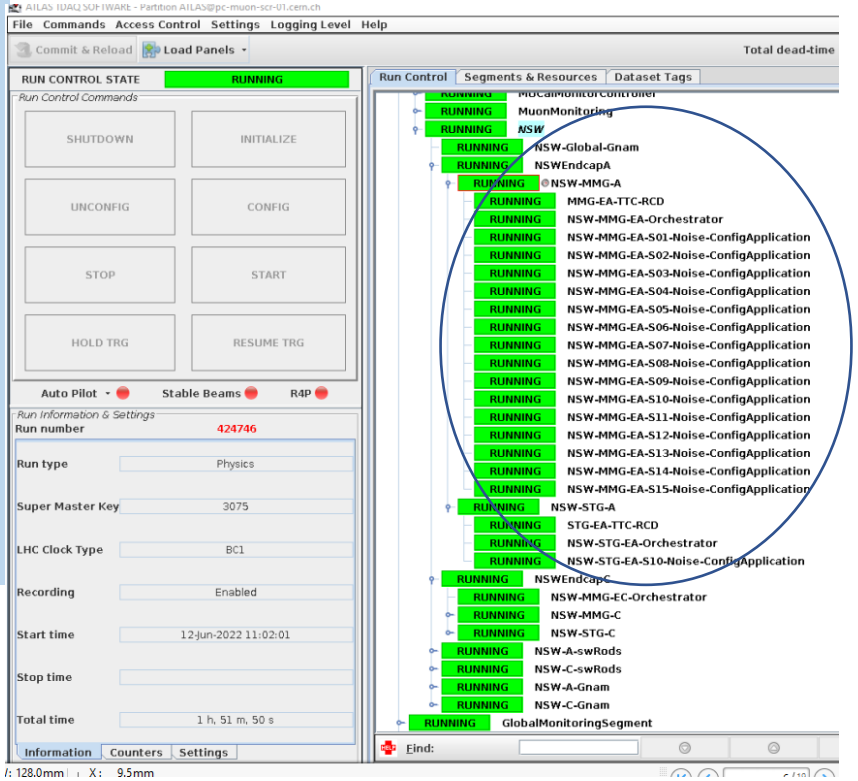
TO SOLVE

- issues that cause filling of buffers (in contact with FELIX group).
- Some FE stop taking data and continue later.
- Implement automated recoveries (required for high-rate running).
- Tune thresholds.

(…)

NSW in ATLAS partition <u>today</u>

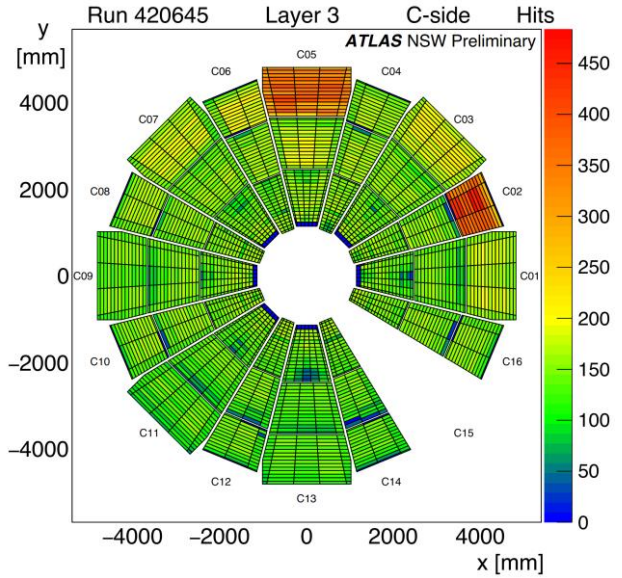
- **Integrated all MMG sectors (except A16) + STG sectors: A10 and C01 C02 C03 C04 C06 C07 C14 C15 C16.**



NSW Commissioning – highlights

sTGC Pad occupancy during ATLAS splashes
(standalone mode with pad trigger in self trigger mode)

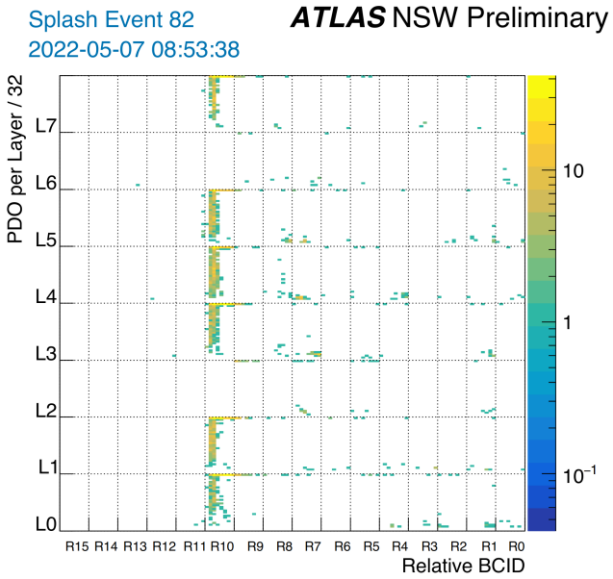
- Pad Trigger in self-trigger mode : Produce L1A when both IP and HO sTGC quadruplets have hits in 3 out of 4 layers.
- Sector C15 had cooling issues and was not switched on.
- Sector C02 and C05 are taken with preliminary threshold therefore the noise level is higher.



MM Charge vs hit timing

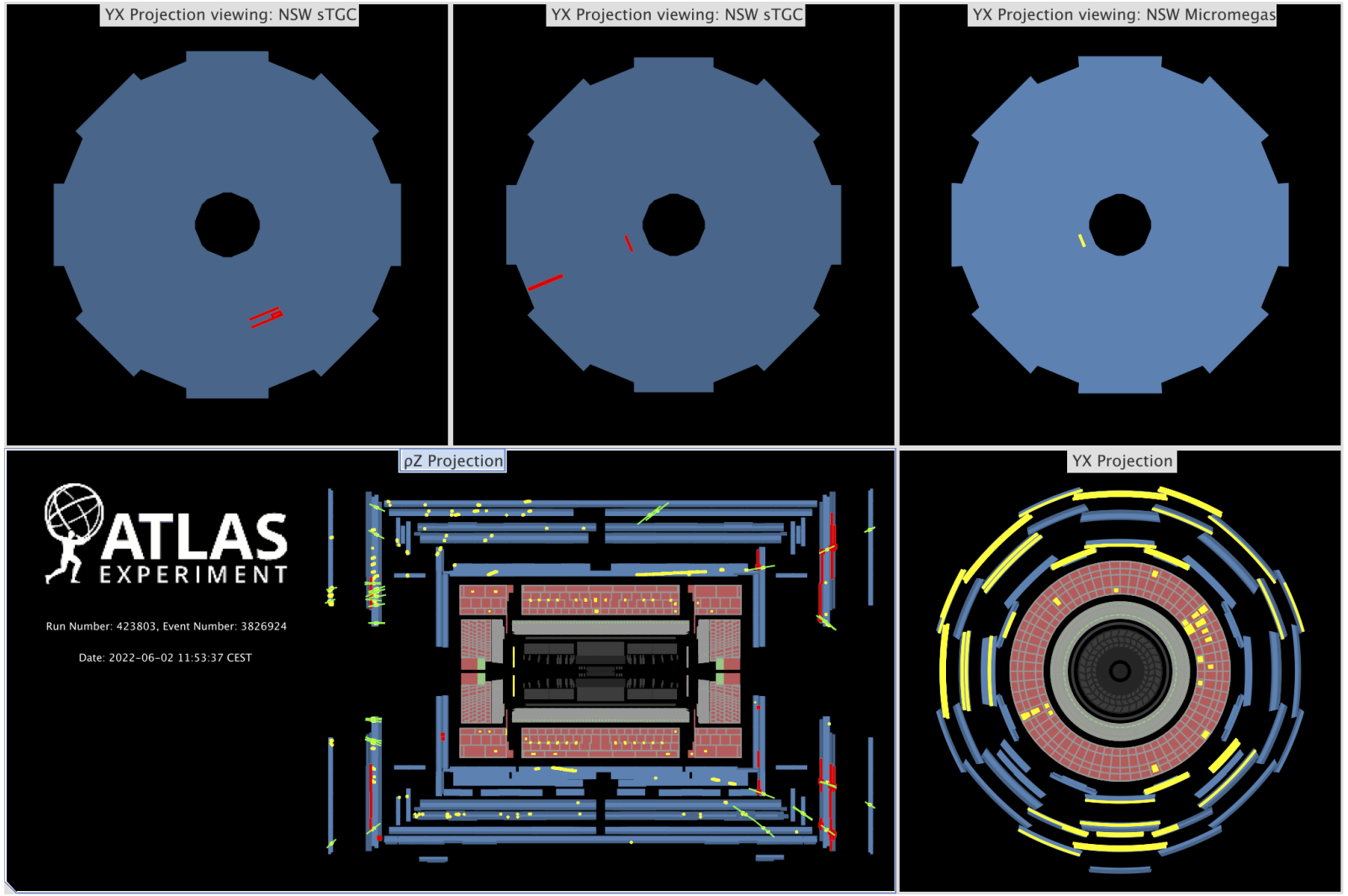
- The MicroMegas A10 charge vs time for each layer and radius.
- Each radius is configured with a different BC offset between L1A and signal.
- Y-axis are hit charges in ADC count plotted for all layers.

- A large number of hits is observed in radius 10, indicating that it has the correct timing configuration.



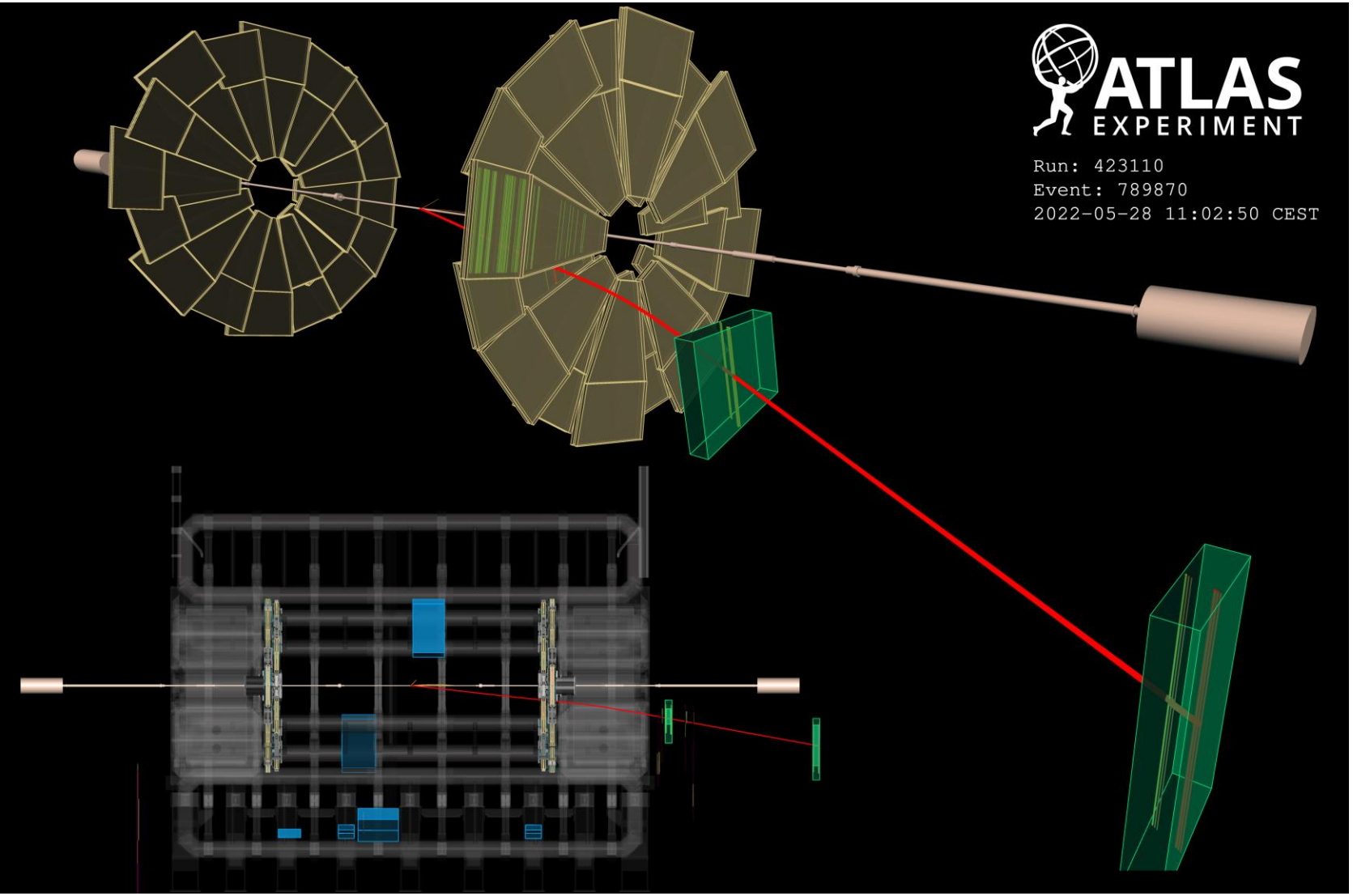
NSW Commissioning – highlights

Hits in the NSW in horizontal muon run (02/06/2022, MM: A09, A10, C10 and sTGC: A10, C14)



Top left: sTGC C-side
Top middle: sTGC A-side
Top right: MM A-side

900 GeV Collisions at ALTAS (28/5/2022)



- The red line shows a muon candidate reconstructed using information from the inner tracking detectors and three stations of the ATLAS Muon Spectrometer end-cap.
- **The muon candidate was reconstructed using hits in the Micromegas chambers of the New Small Wheel on side A**.
- A side view of the event is shown in the lower part of the image. The New Small Wheels are shown together with the MDT chambers (green) used to reconstruct the muon trajectory.

Conclusions & Plans

- NSW was the most ambitious upgrade project of ALTAS for LS2
- It passed through COVID (as many other projects).
- 10/11/2020 Tragic loss of colleague and PL, Stephanie Zimmermann.
- Faced and addressed a plethora of major (and even more minor) issues in NSW-A mostly.
- The NSW-A was completed in b.191 on the 15/6/2021 and quickly after (in record time) NSW-C was completed (30/9/2021).
- **At the end both wheels were installed in P1 before the end of LS2 -> Huge accomplishment of the NSW team.**
- Since then, intense commissioning efforts are ongoing and there is major progress week per week.
- NSW shifts started in February 2022, with one dedicated & trained shifter / technology. Since 9th of May, one NSW shifter for both technologies in the ACR with plans to merge with the Muon shifter as soon as the NSW shifter interfaces (DCS, DAQ, DQ etc.) and operations will be stable.

Current status

- GNAM / Online reconstruction / Online event display : all working well, DQ: in place need to be validated with real data.
- MMG & STG DCS have been integrated into the ATLAS DCS.
- Major milestone! Verification that the trigger chain works (MM-TP-SL).
- DAQ : Integrated all MMG sectors (except A16) + 10 STG sectors & counting.

Plans

- Continue debugging, sector integration in ATLAS partition & complete merge with ATLAS trigger.
- Need to have as many horizontal muon runs as possible before the start of the HE run (05/07/2022) -> **requested for next week**
- End of the year is the projected completion of the commissioning (and the start of the reparations….)

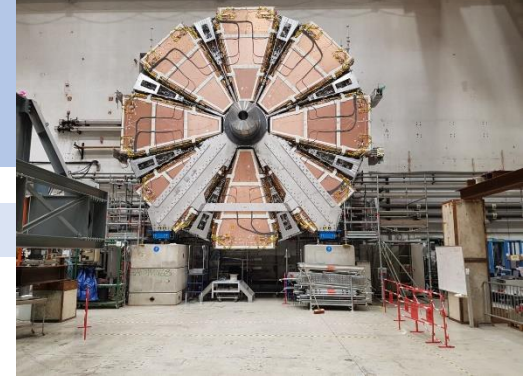
THANK YOU

With material & contributions from : (and possibly many more)

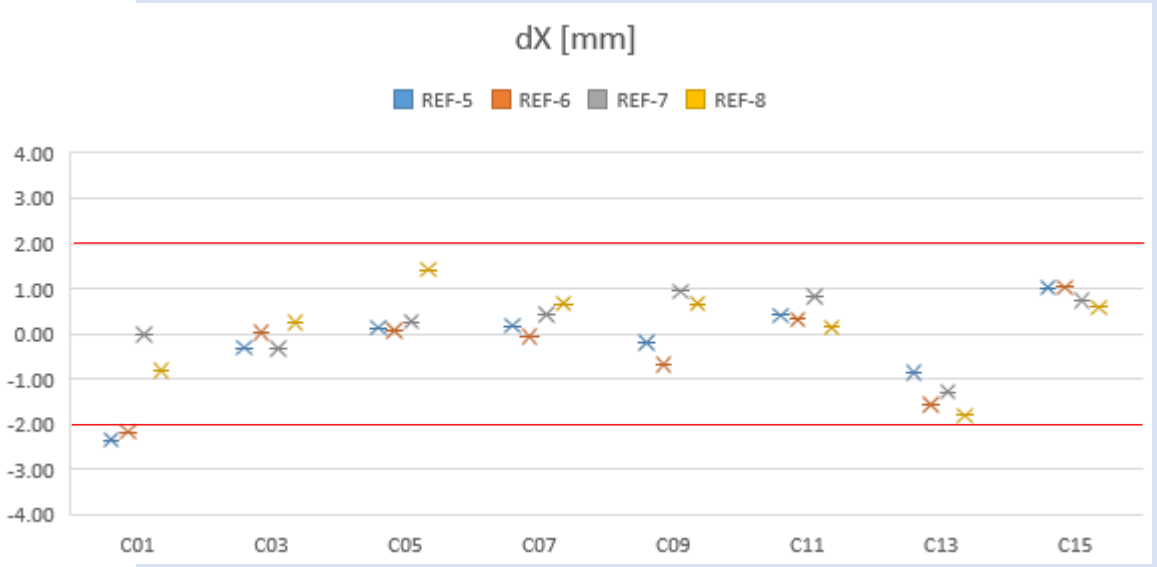
Alexopoulos T., Antonelli M., Arcangeletti C., Coimbra A., D'Amicco V., Fassouliotis, Fleischmann P., D., Geralis T., Gkountoumis P., Graves Kyriacou N., Hertenberger R., Hucheng C., Iakovidis G., Iengo P., Iodice M., Kongsore M., Koulouris A., Kourkoumeli A., Levinson L., Longo L., Kompogiannis S., Mancini G., Martinelli L., Miñano Moya M., Ntekas K., Paraskevopoulos C., Pasqualucci E., Perez E., Pezzotti L., Ponsot P., Roemer J., Romano E., Siyuan S., Tzanis P., Vachon B., Vasquez G., Viaux N., Wang R., Zoch K.

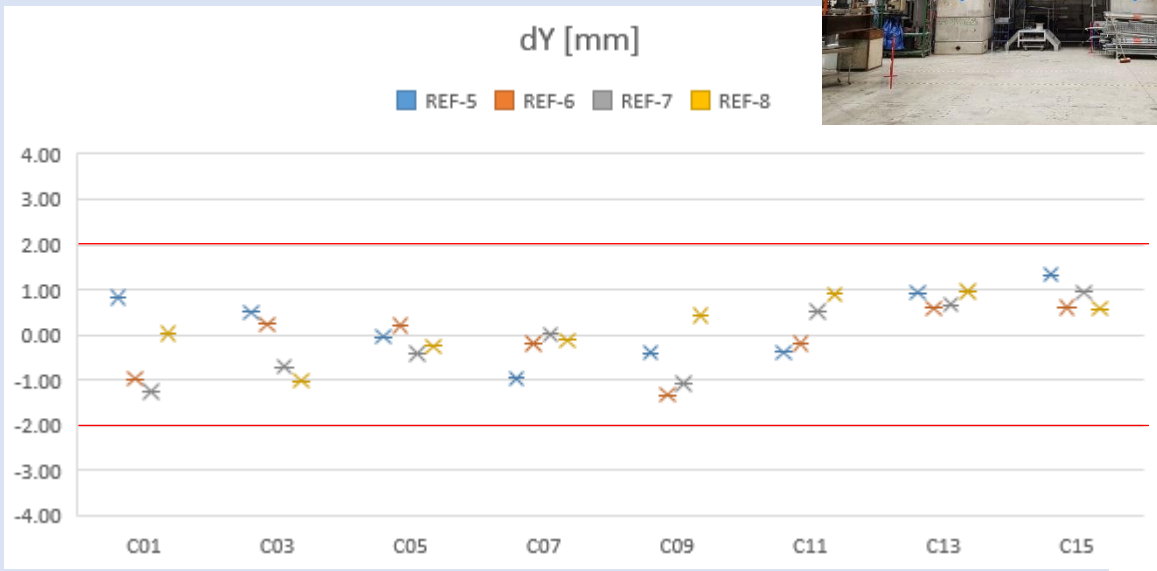
Back up

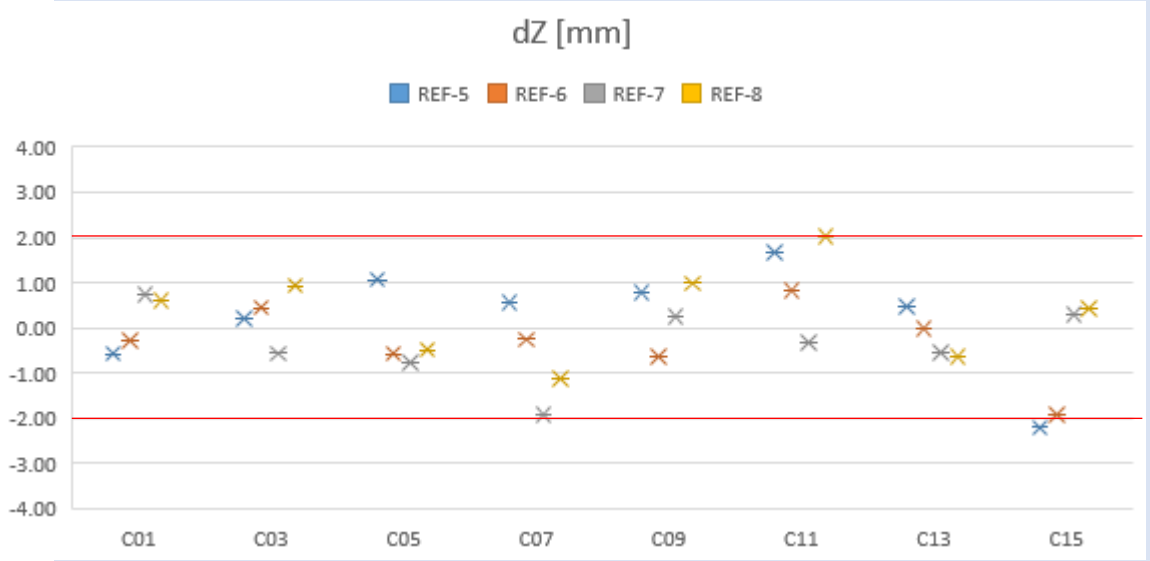
Week #38 & #39 – Final (full) survey of NSW-C after disconnection

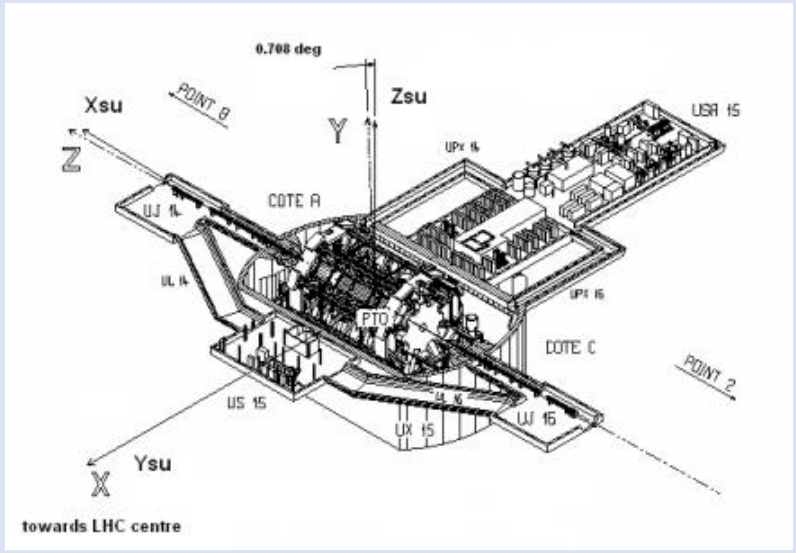


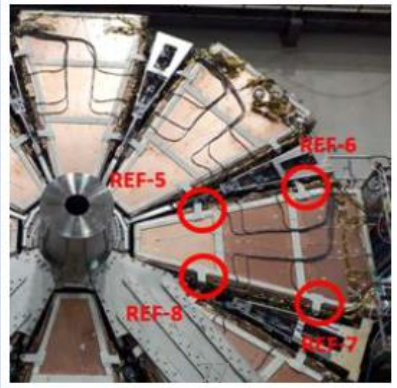
Large sector reference points



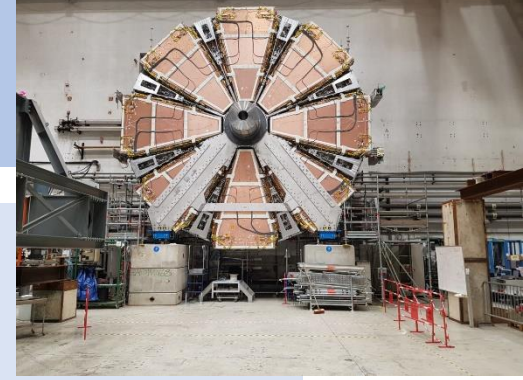




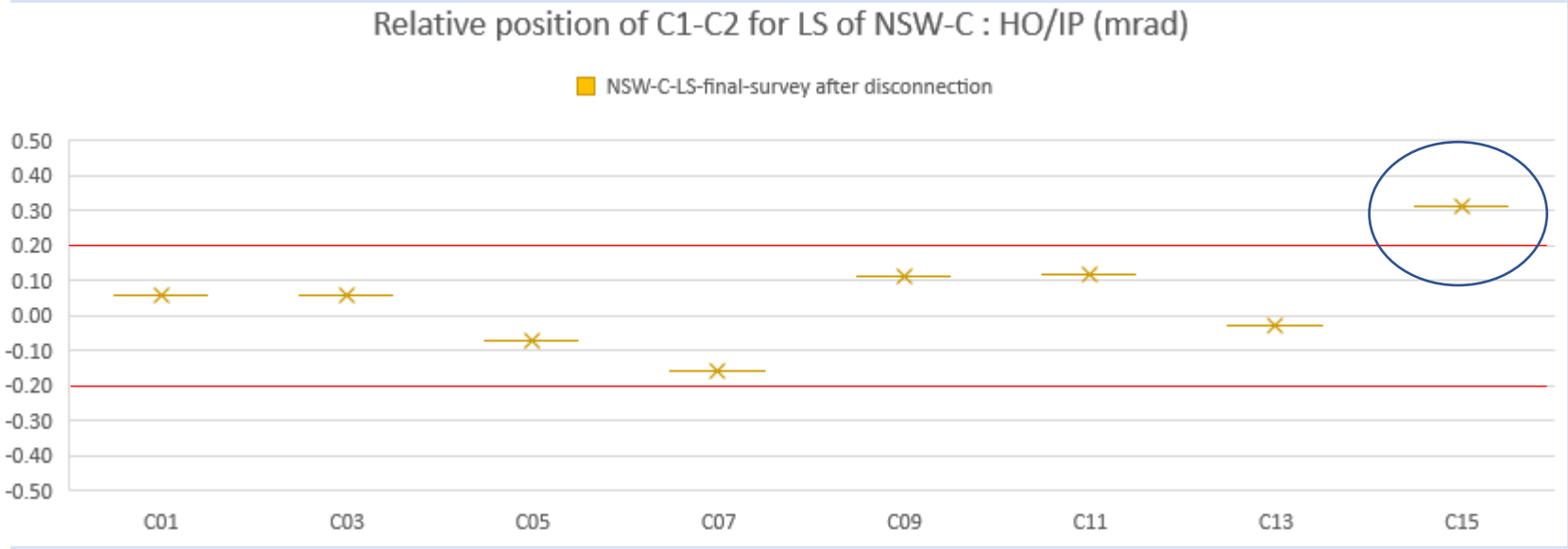




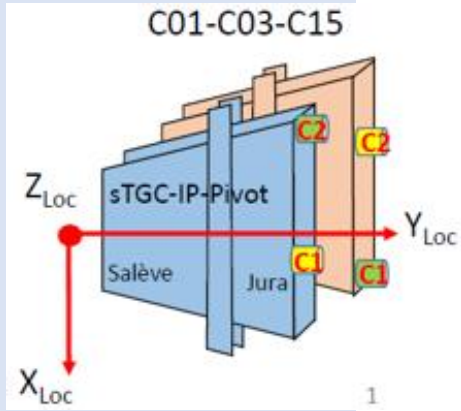
Week #38 & #39 – Final (full) survey of NSW-C after disconnection



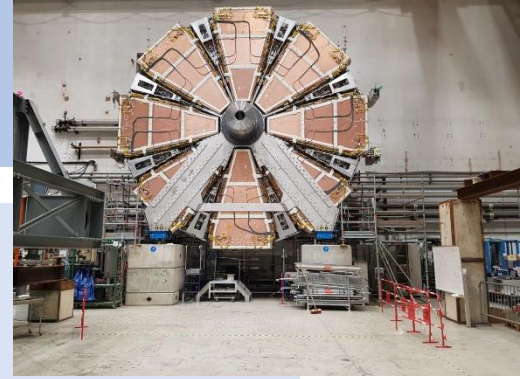
NSW-C angular alignment of sTGC wedges



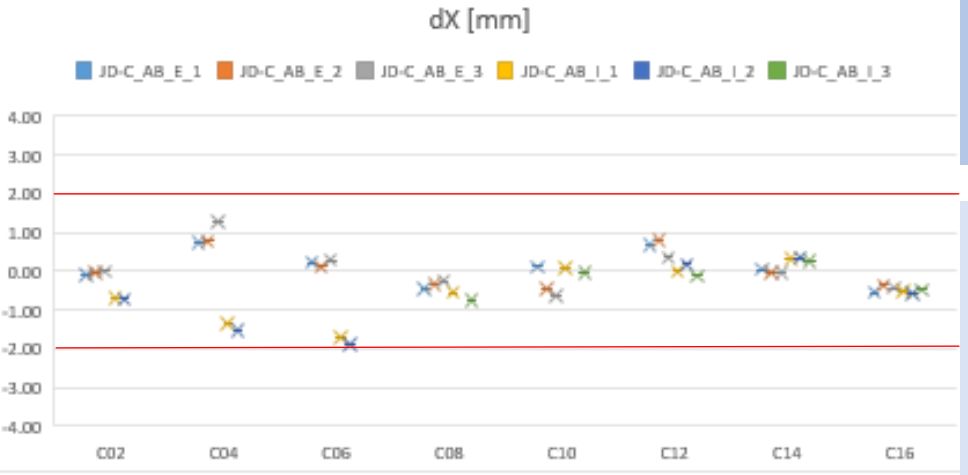
Measurement not possible due to conflict with hydraulic pipes

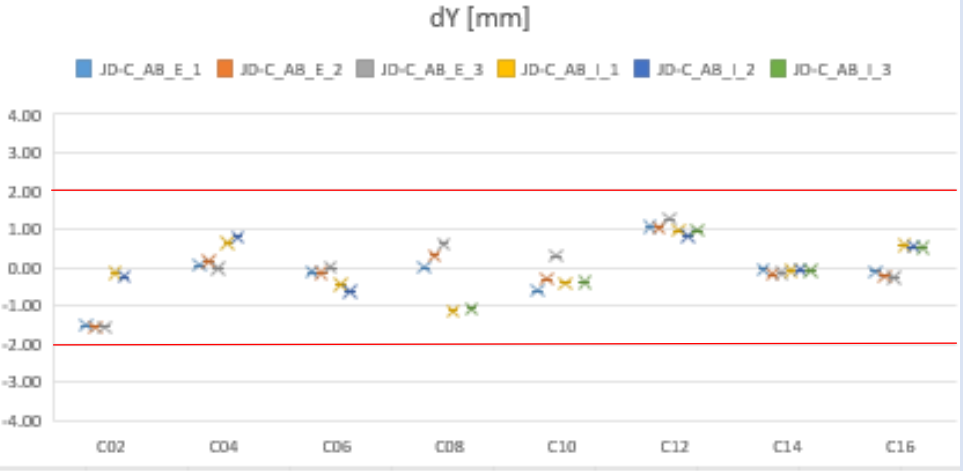


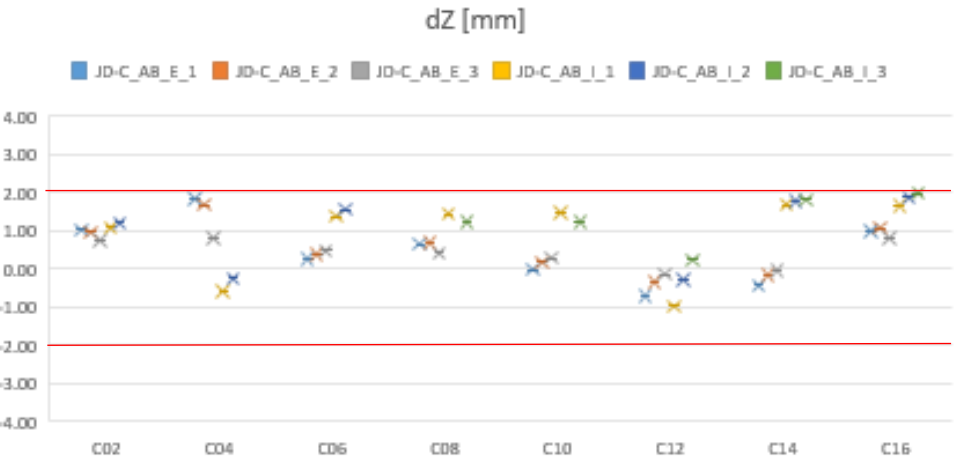
Week #38 & #39
Final (full) survey of NSW-C after disconnection

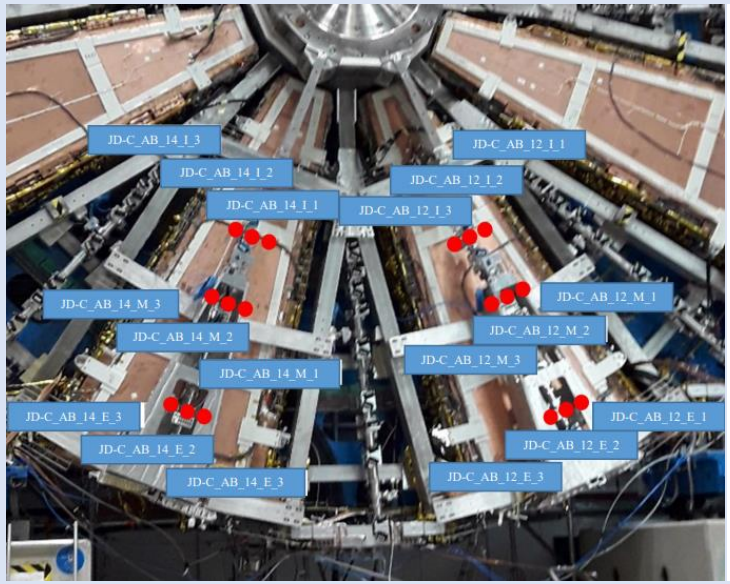


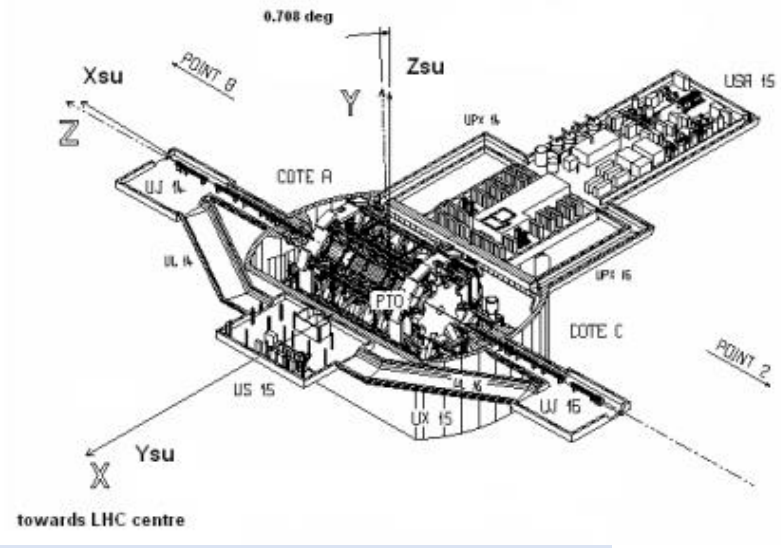
Large alignment bars points











NSW Commissioning – Trigger Status

sTGC Trigger path status

- Several key parts of the sTGC trigger path commissioned in the Vertical Slice.

Ongoing

- Update of Configuration and readout firmware
- Preparing track patterns from Athena simulation for track pulse testing
- Confirm strip pattern data arrives properly to the Trigger Processor
- Next -> Global synchronization test

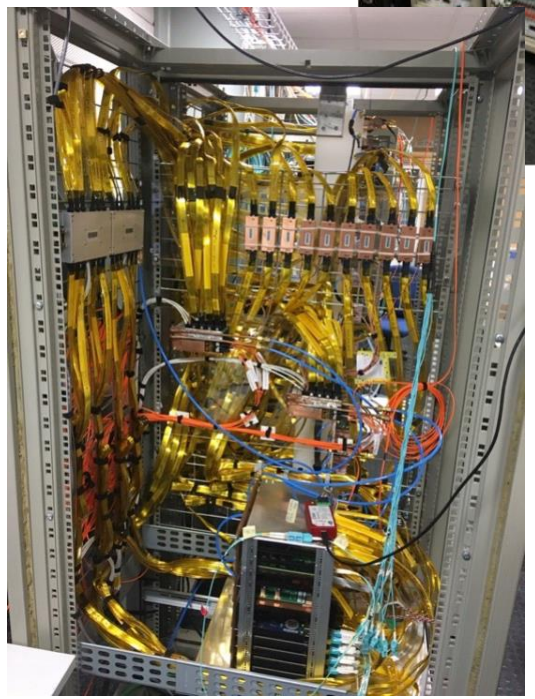
MM Trigger path status

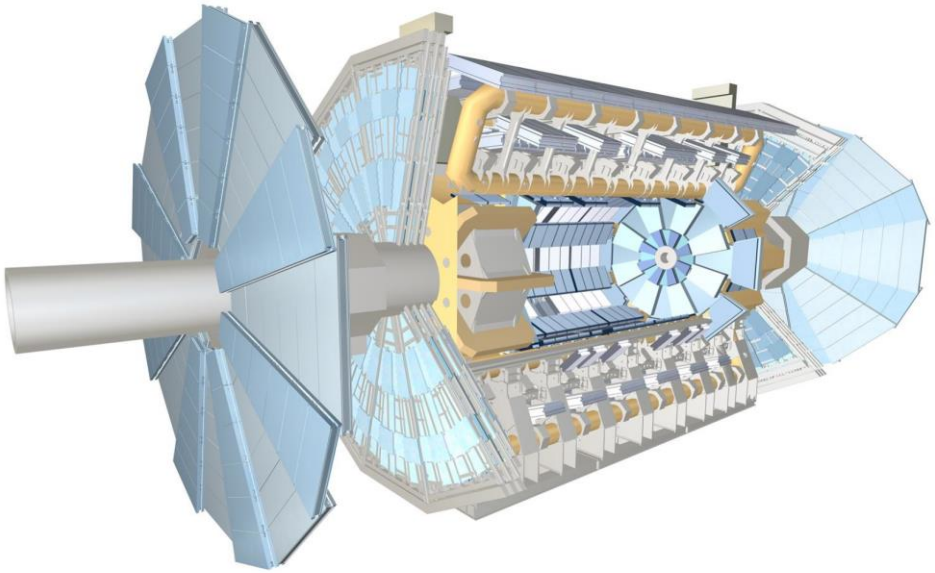
- Connectivity tests are done

Ongoing

- Track pulsing exercise in P1 to validate trigger chain and algorithm.

Vertical Slice
Complete autonomous sTGC Trigger Slice
1 Wedge (1/2 Sector)





Requirements

- Preserve the same basic geometry.
- Spatial resolution ~100 µm per layer in precision coordinate, 1-2 mm in azimuth coordinate.
- Efficiency better than 97% for P_T>10 GeV .