The ATLAS New Small Wheel Upgrade
A Status Report

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- With the input and material from many other people -

ATLAS Upgrades

- The ATLAS detector, as the other LHC experiments, was originally designed for a LHC luminosity of $10^{34}\ s^{-1}\ cm^{-2}$,
- and something like 10 years of operations …..

As we all know, time has voided this original plans:

- Luminosities exceeding $2\cdot 10^{34}\ s^{-1}\ cm^{-2}$ have been reached regularly during the last year of run-2 data taking;
- The discovery of the Higgs has pushed the High-Lumi LHC,
- And we now aim at data taking up to around 2035, aiming at a total integrated luminosity of 3000 fb^{-1}

As good as the detectors are, to cope with this conditions, upgrades are needed;

and ATLAS as the other experiments will do them in 2 phases, which link to the LHC long shutdowns:

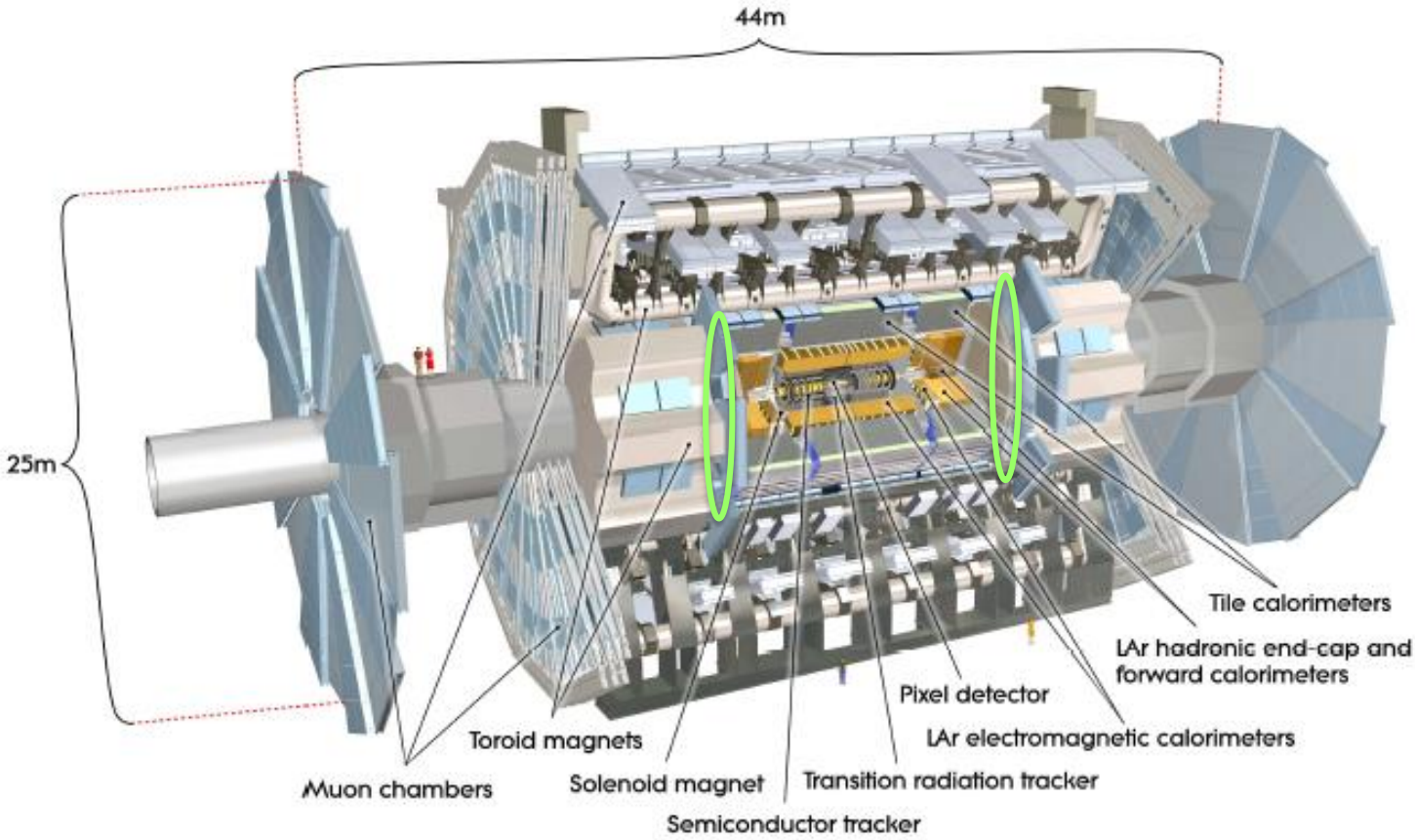
LS2 in 2019/20, and LS3 in 2025-2027 ….

ATLAS Upgrades

- The New Small Wheel is a Phase-1 Upgrade, and both its sides were originally foreseen to be installed this shutdown;

- While delays and time needed to overcome various problems now make the installation of both sides before end of 2020 no longer realistic → ATLAS highest priority remains however to install NSW-A, next year in summer

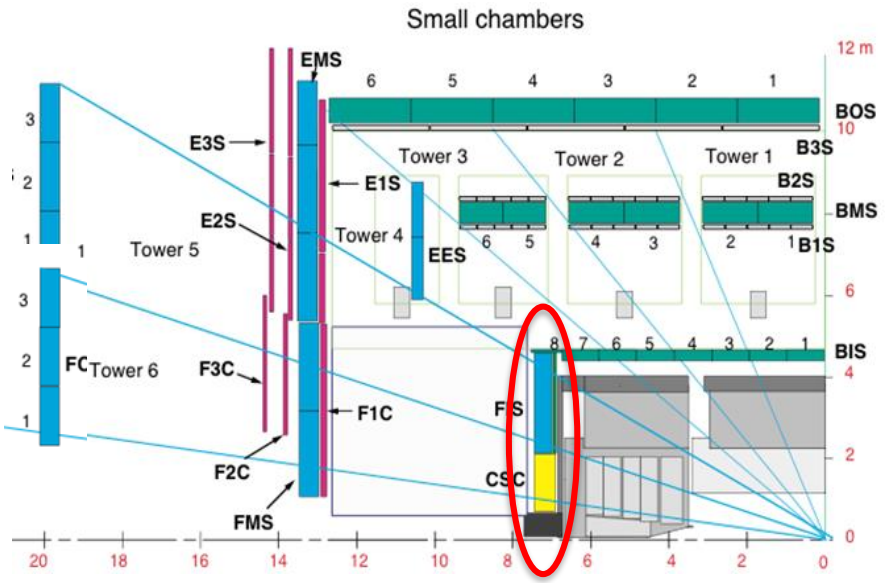
The NSW Upgrade: what it is …



- In the ATLAS Muon Spectrometer, the highest background rates are seen in the innermost stations of the endcaps --- known as the Small Wheels

- The New Small Wheels aim to replace the present Small Wheels, with new detectors and electronics, which can cope with the HL-LHC pile-up and background, and which can provide improved triggering

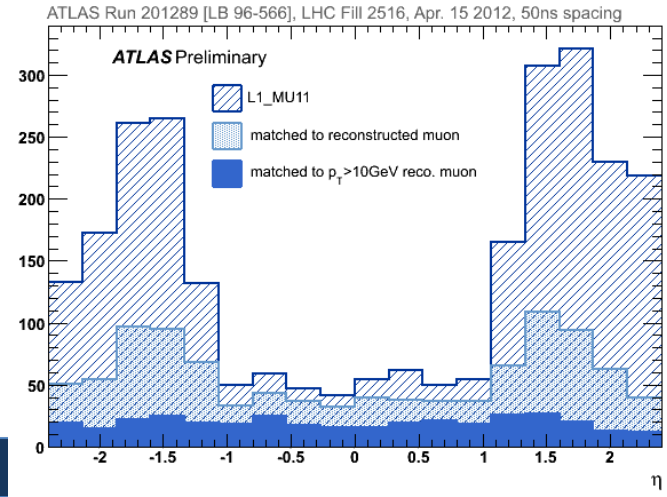
NSW Upgrade– Motivation and Components



Present Muon endcap:

- Trigger is based essentially on the Middle Stations (The Big Wheel), and there on TGC chambers
- Track segments are then matched with being compatible with them being high momentum muons coming from the IP
- Cathode Strip Chambers (CSCs) and Monitored Drift Tubes (MDTs) used for tracking, and offline momentum reconstruction

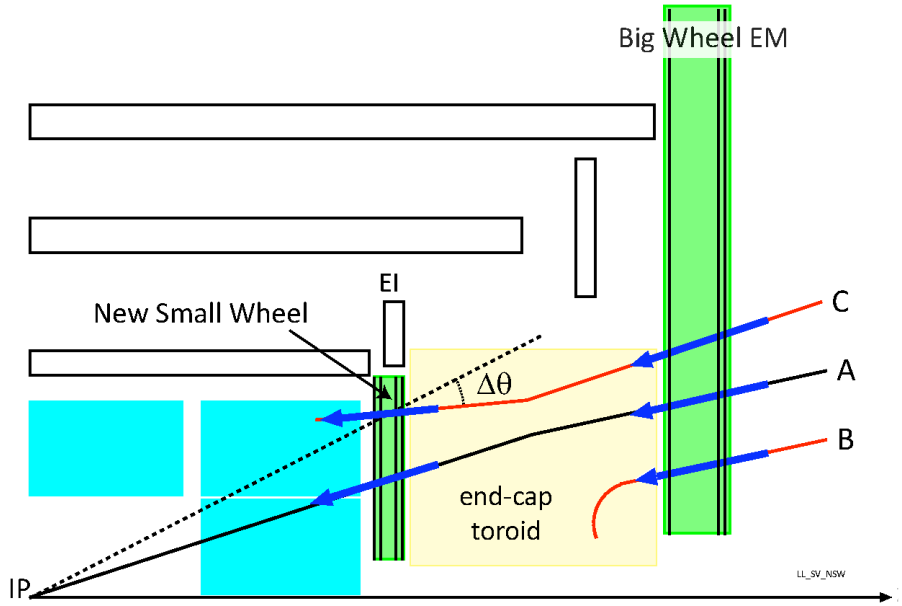
→ Results in a high fraction of fake candidates, from multiple-scattering and delta rays !

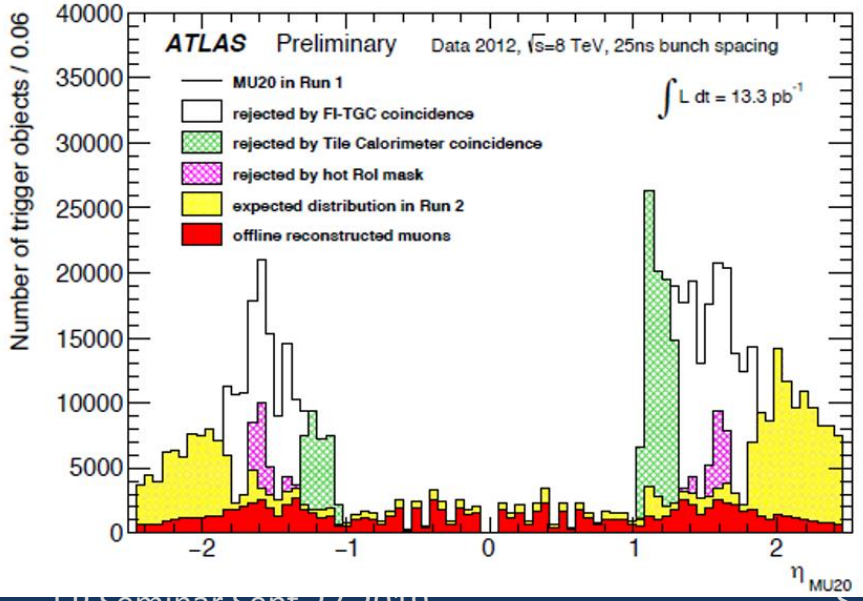


Explosion of the trigger rates → need to increase threshold

Not sustainable for higher luminosity, even with improved processing power …..

NSW Upgrade– Motivation and Components





What can one do ?

- Combine the information of the Big wheel with track information from the innermost station, already at L1
- Robust rejection against multi scattering (“C”) and delta rays (“B”)

→ Need trigger detectors in the full (New) Small Wheel, with fast time resolution

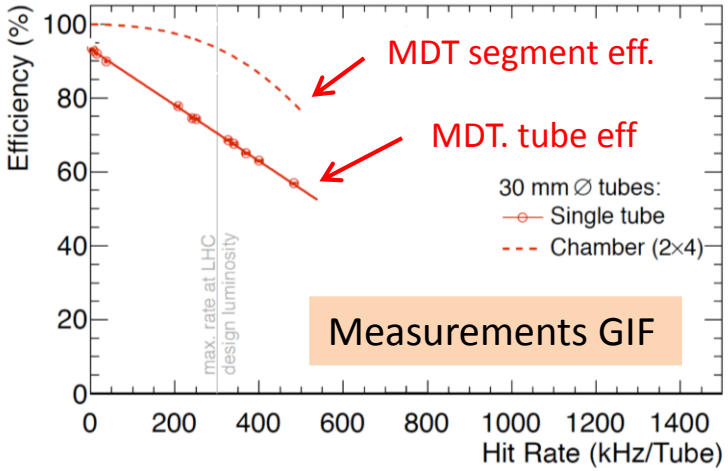
In the NSW, Micromegas (MM, Micro-gaseous structures) and small strip Thin Gap chambers (sTGC) replace the CSC, MDT, and TGC,

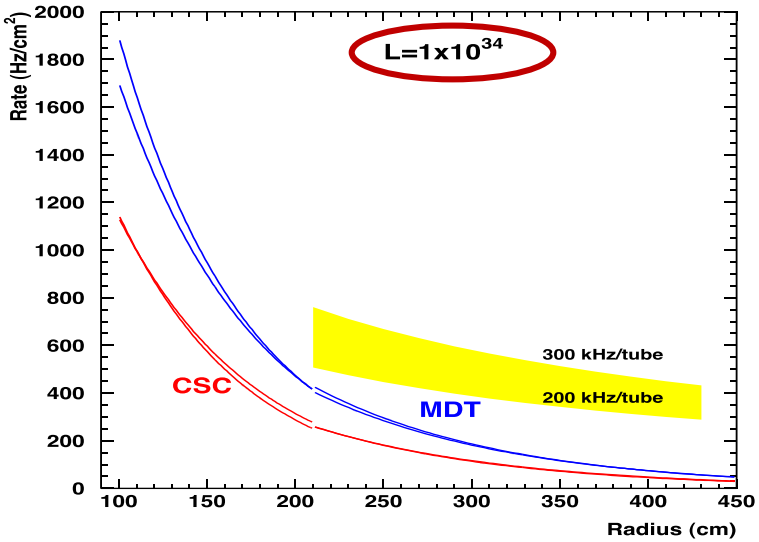
- Covering the reaching up to eta = 2.4 (trigger) and eta = 2.7 Tracking

(Eta range below 1.8 can be covered by other additional combinations (BIS78, TGC FI, TILE))

NSW Upgrade – Motivation and Components

There is a second motivation for the NSW – preserve the excellent position resolution and tracking efficiency which we currently have also in the HL-LHC environment

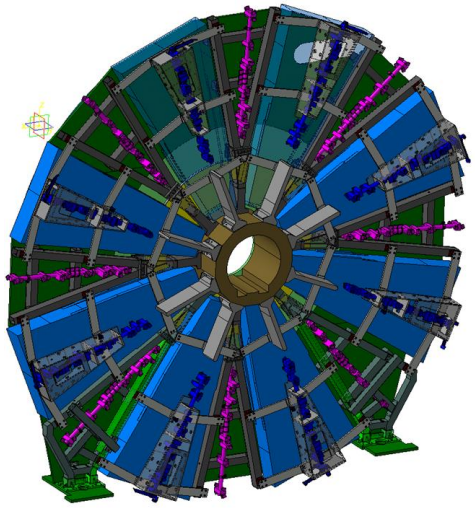




- Standard ATLAS drift tubes with 30mm diameter loose efficiency (and resolution) above L = 2-2.5 $\cdot 10^{34} s^{-1} cm^{-2}$
  → NSW: Replace by Micromegas, and sTGC

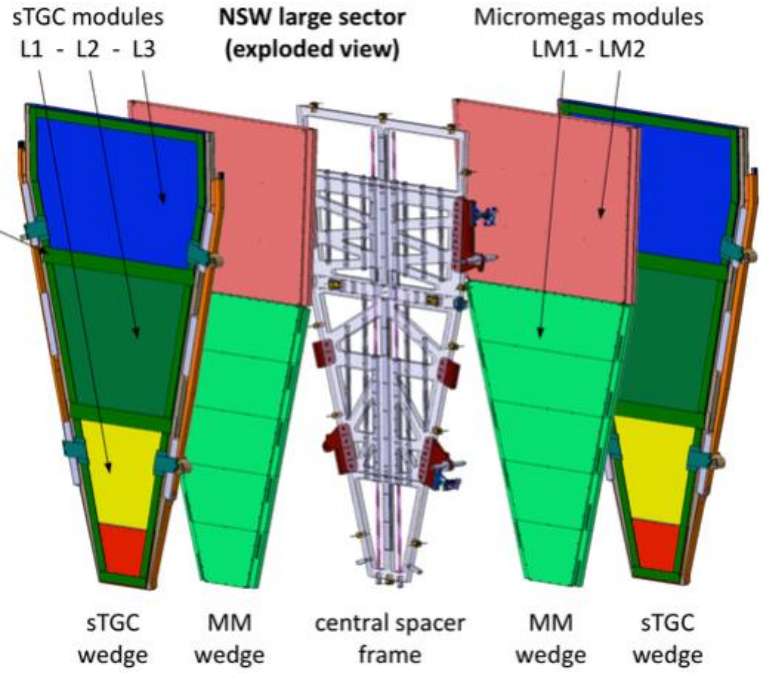
- Pattern recognition becomes more and more challenging the higher the pile up and background rates are
  → NSW: 16 detection layers in total, instead of 4 (CSC) and 8 (MDT) in the present Small Wheels

NSW Upgrade: Layout and Components



Since installed in the existing space of the present Small Wheel,

- NSWs need to preserve the geometry and segmentation
- 8 large + 8 small sectors per side
- Installed on a mechanical support structure which combines the NJD disk (steel, shielding, flux return) and a web like aluminium structure (so called spokes) bolted to it
- Spokes support the detectors, and hold the alignment bars
- Installation: Small sectors → LS support structure → large sectors



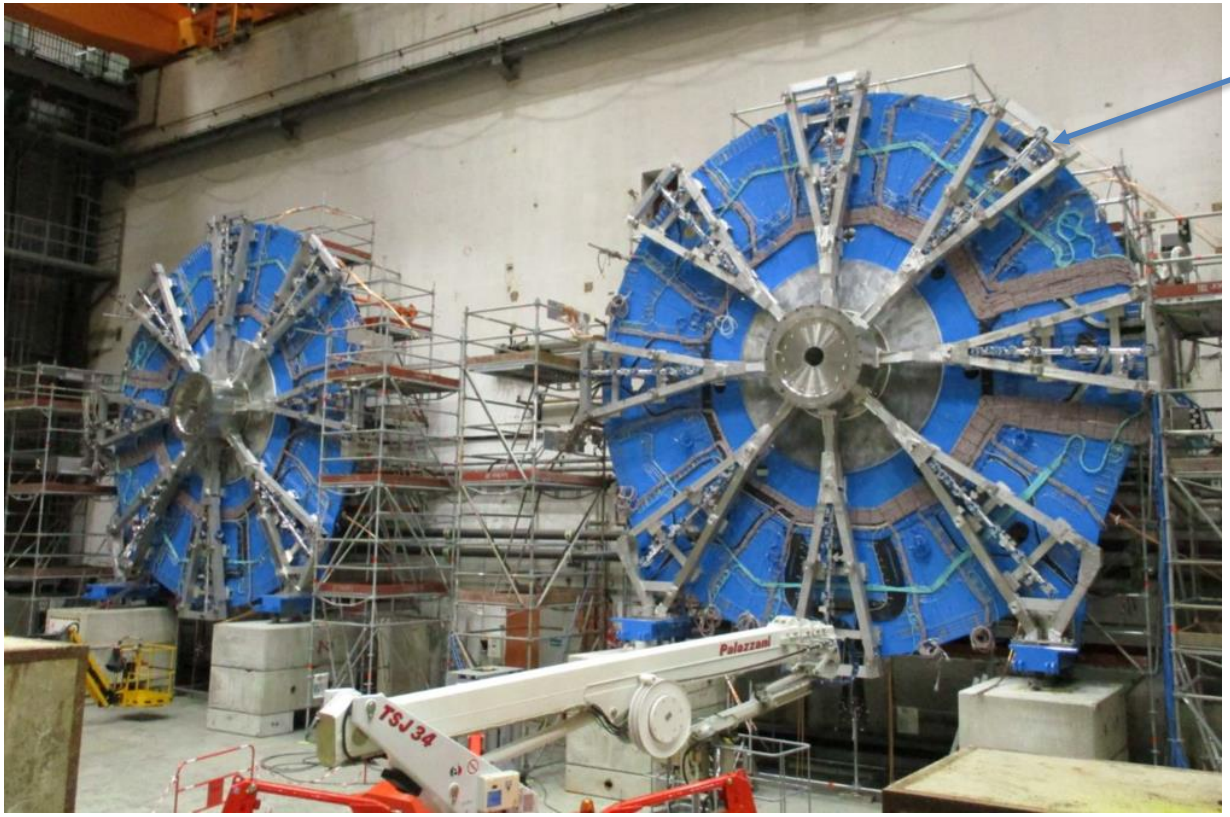
NSW sectors:

- Consist of 2 sTGC wedges and 1 Micromegas (MM) double wedge each
- sTGC wedges contain 3 sTGC chambers, glued to a FR4 support frame
- MM double wedge contains 2x2 MM chambers, screwed to both side of a aluminium support
- The integration of wedges/double wedges happens at CERN, while sTGC chambers are built in CA,CL,CN, IL and PNPI, and MM chambers in Germany, Italy, Saclay and Dubna/Thessaloniki

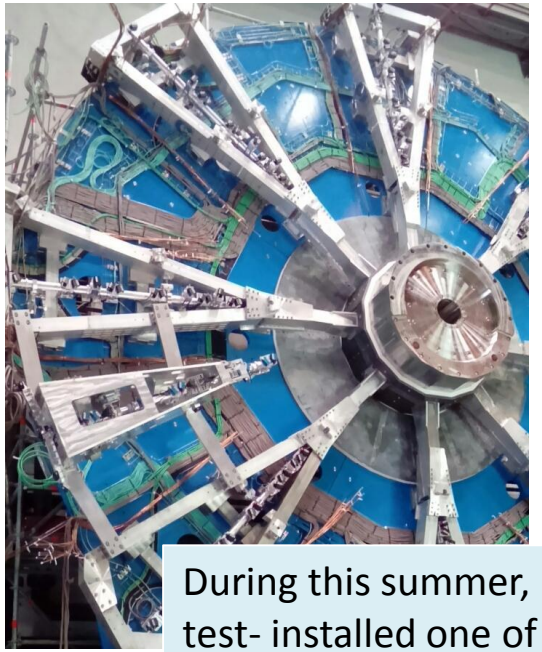
NSW Mechanics/Engineering Status

- Design of the NSW support structure took mostly place during 2015 and 2016;
- Fabrication during 2017 and 2018;
- And assembly in building 191 from autumn 2018 to spring this year

All on track with structures, both for side A and side C, awaiting the detector sectors !



Also, alignment bars are already pre-mounted …



During this summer, test- installed one of the large sector spoke

NSW Mechanics/Engineering Status

- We physicists often only think or see detectors, chambers and electronics ….
- The NSW however also has hundreds of km of cables, pipes and optical fibres, to cool its ~10000 on detector electronics cards, readout its more than 2 million channels and supply detectors with HV and elx with LV …
- 2019 was thus dedicated also to the pre-installation of all Services – this work is now completed for side A, and very well advanced for side C.

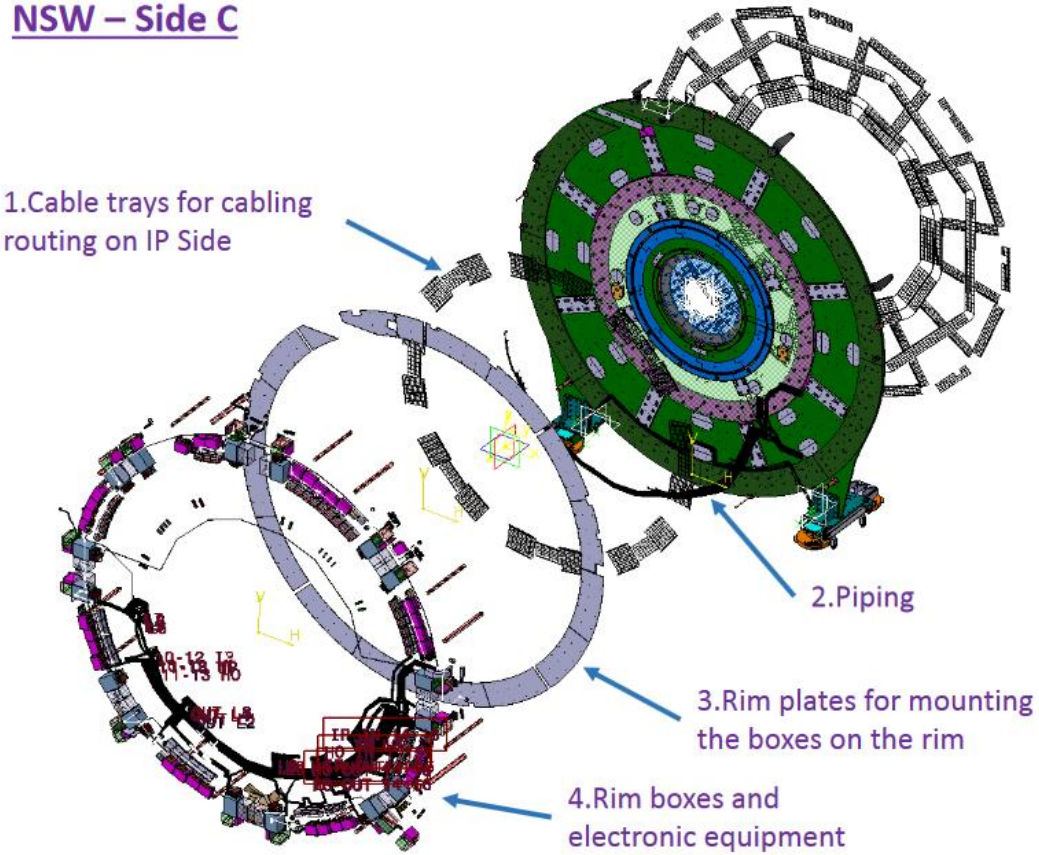
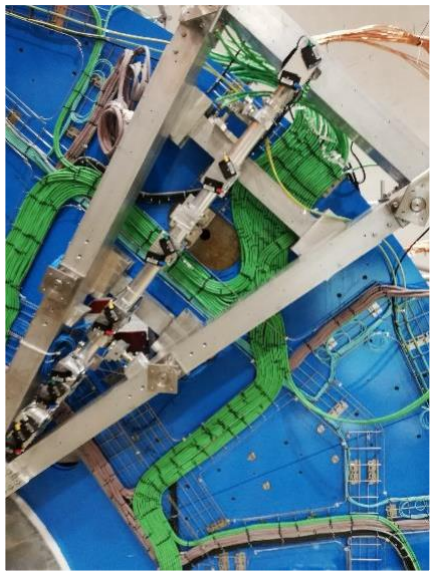
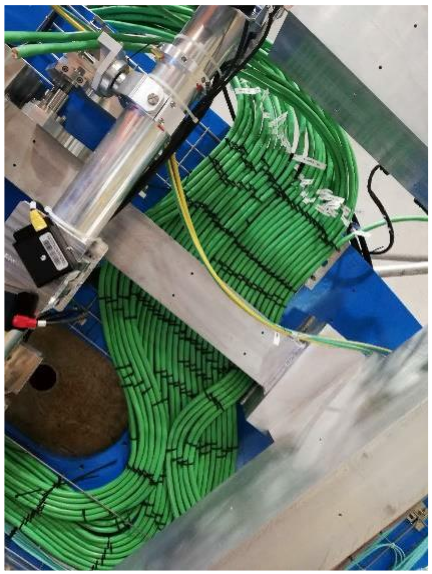
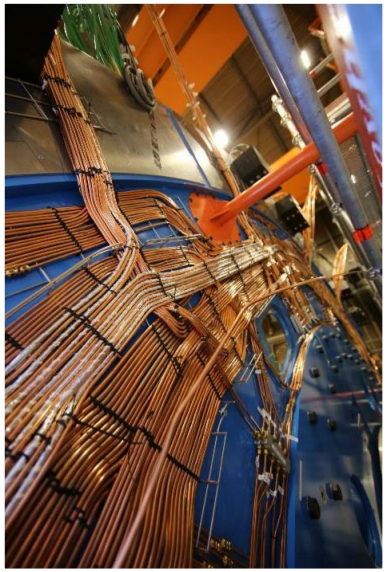
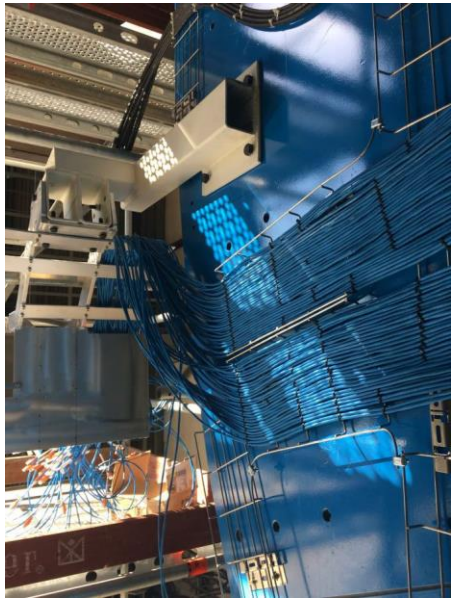


Figure 1 IP Side

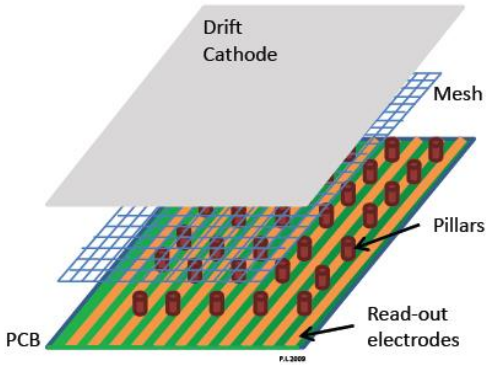
NSW Mechanics/Engineering Status

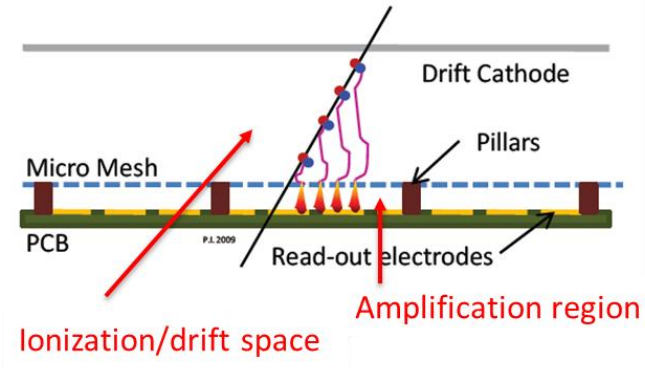






Cables, pipes and fibres everywhere …
And a proud installation team !

NSW Detectors: Micromegas



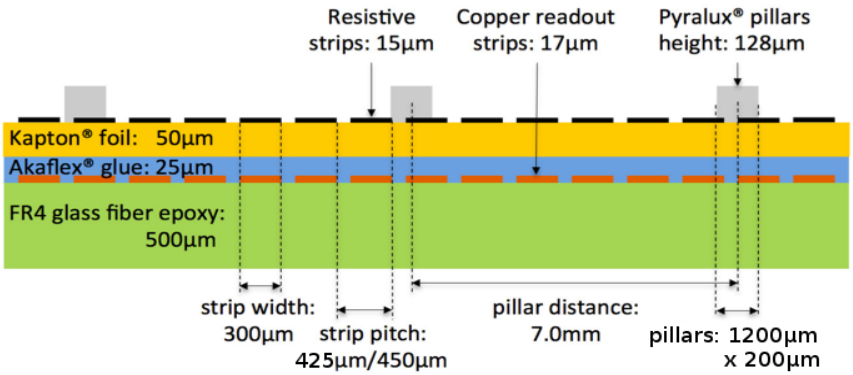


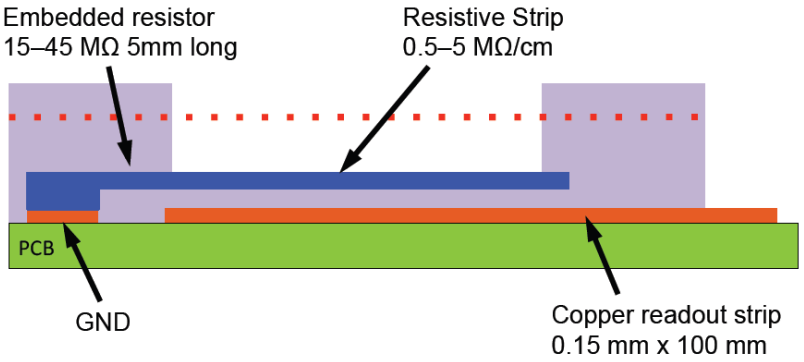
NSW Micromegas:

- Cu strips on large scale readout PCBs
- 128 µm pillars supporting a (floating) mesh
- Mesh and PCB form the amplification gap

- While a additional cathode in 5mm distance closes the gas gap and forms a drift space

NSW Micromegas are resistive MMs for spark protection. Cu strips are covered by a Kapton layer with resistive strip pattern screen printed on it (graphite), HV is applied to the resistive layer

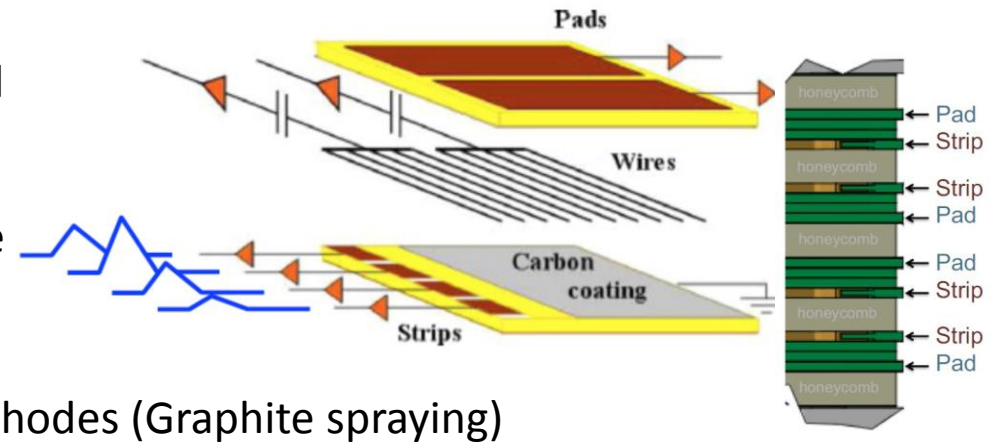




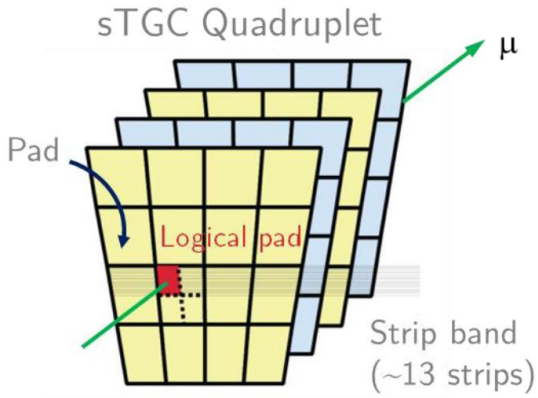
Large area of the NSW chambers, up to ~ 2m x 2m, requires production of readout boards in industry --- an additional challenge !

NSW Detectors: sTGC

- Detector technology is a well established one, same as was used in OPAL @ LEP, and for the ATLAS TGCs
- Wire chambers with a wire – wire distance which is equal to the distance beween cathodes
- and with a resistive layer as part of the cathodes (Graphite spraying)



- sTGC operate in quasi-saturated mode, with a n-pentane : CO2 flammable gas mixture → very fast response, crucial for BCID identification and trigger under high rates

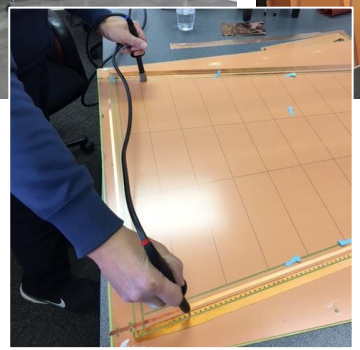


- Strip pitch for NSW sTGC is 3mm → resolution of 100 – 120 μm can be achieved with a charge centroid reconstruction
- Chambers have 4 gas gaps, each with a strip and a pad segmented cathode,
- Pad signals used in the trigger to define a trigger tower and initiate readout of a limited number of strips to the NSW trigger processor ….

NSW Detectors: sTGC

- As for the Micromegas, cathode/readout boards were produced in industry.
- Not at all trivial, since chambers, up to 2.2m x 2m, are made of a single cathode plate !

- Only very few firms which can do such PCBs
  - NSW choice was for Triangle Labs, US (classical PCB techniques: etching, PTH, …)
  - And a consortium of 2 European and 1 Israeli firm (machine the Cu strip/pattern on a CNC machine, create through-hole connections with conductive epoxy, then press pre-preg insulating layers in the same way as @ TriLabs)



Electrical test

MM Readout PCB & sTGC cathode Status

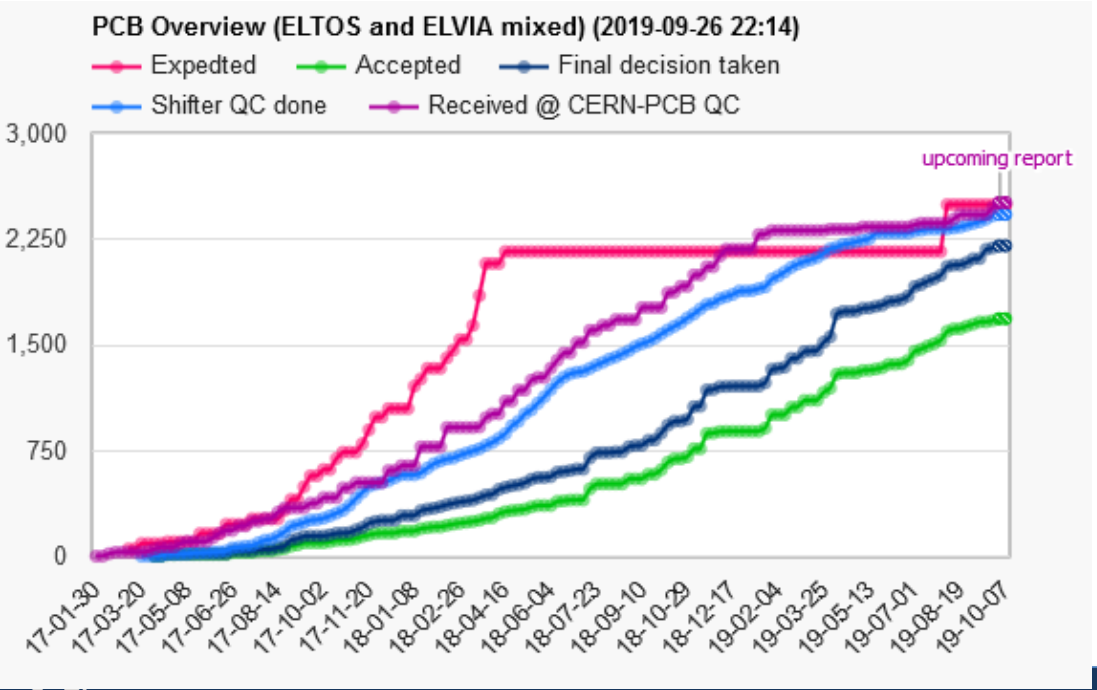
sTGC

- Production of all ~1750 sTGC cathodes is complete.
- Last batch was delivered to CERN in early summer, and last batch left CERN to the construction sites (PNPI) just 2 weeks ago !

MM

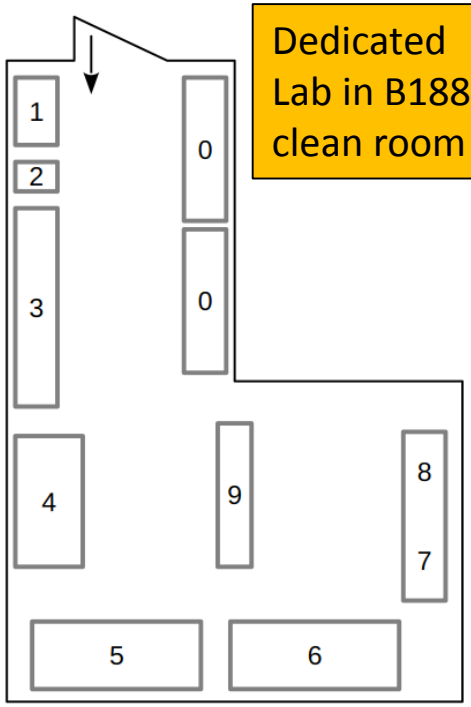
- Slowly nearing the end of the original production, then need to produce some extra spares and replacement boards
- Expect the production, and especially QA/QC for every single of the PCBs here at CERN, to still continue to end of this year ..

- Yield is about 75%
- Continous follow-up and interaction with the manufacturer is crucial --- monthly visits, weekly conf calls, standardized QA/QC forms, ….



MM Readout PCB QA/QC

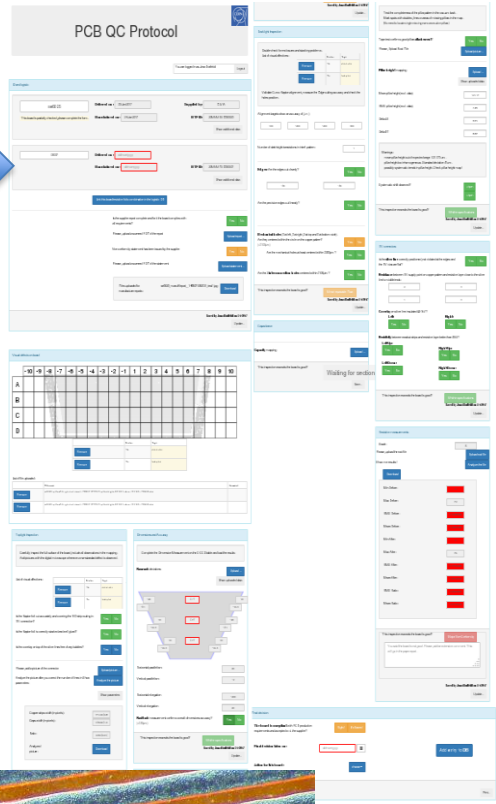
Material courtesy of O. Sidiropoulou



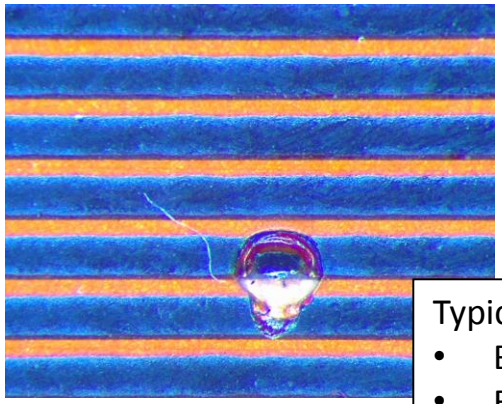
Dedicated Lab in B188 clean room

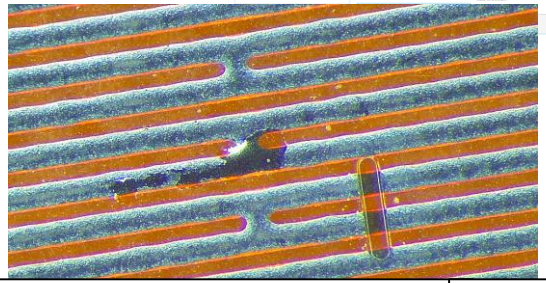
0. shelf & table
   unwrapping
1. computer table
   logistics
2. tool chest
3. top light table
   visual inspection, electrical tests
4. back light table
   agreement btw. holes & Cu pattern,
   edge precision & straightness, pillar pattern
5. rasmask granite table
   absolute dimensions & shape O(30µm)
6. granite table
   pillar height measurement
7. table
   resistivity mapping
8. table
   strip capacitance measurement
9. shelf

Dedicated checklists and automatic guidance to QA/QC ops



More details → Backup slides



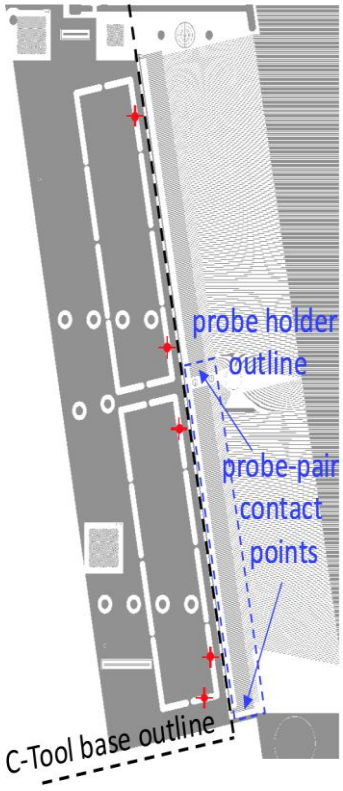


Typical visual defects:
- Bubbles/bumps in active area
- Enclosures
- Damage to the Kapton foil

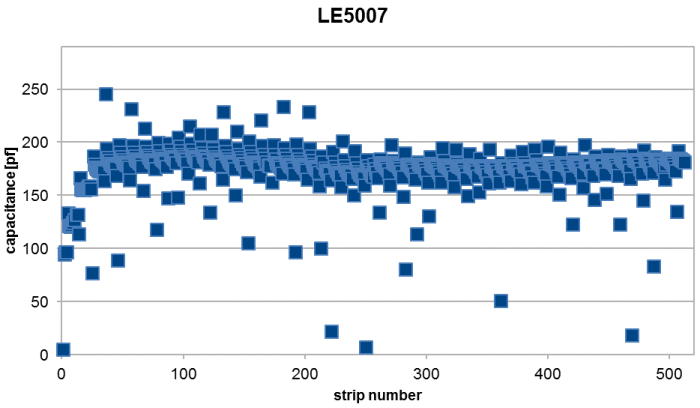
- Rough edges
- Faults in the HV Ag line
- ….

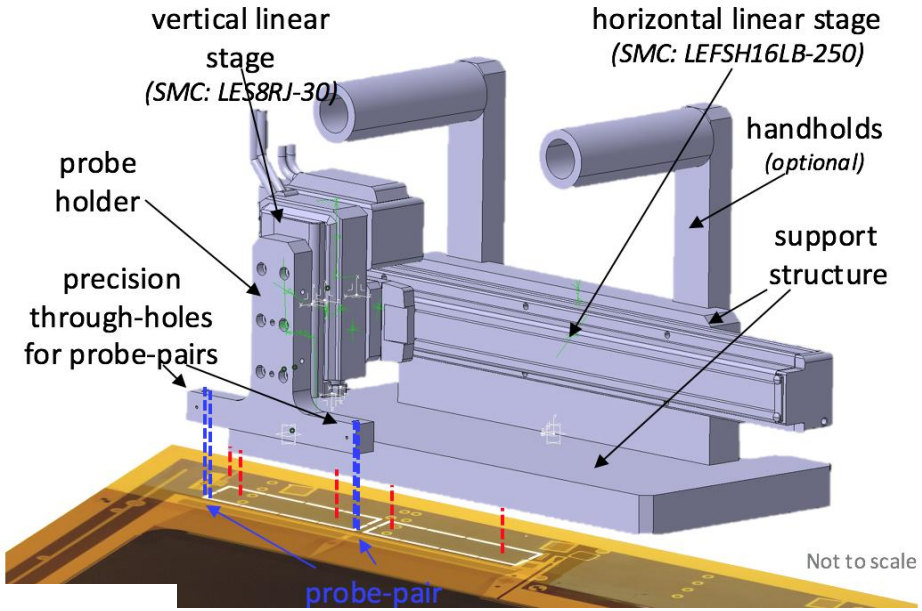
MM Readout PCB QA/QC

- Capacitance measurement for all strips → detection of interrupted strips
  - Automated probe
  - Measure capacitance w.r.t. to HV silver line and resistive pattern



- Reliable detection of interrupted strips as well as shorts, independent form optical methods



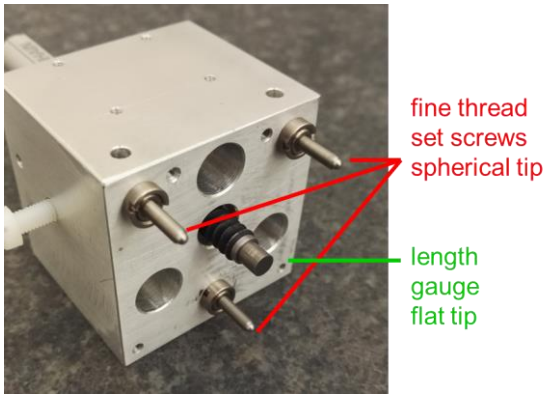


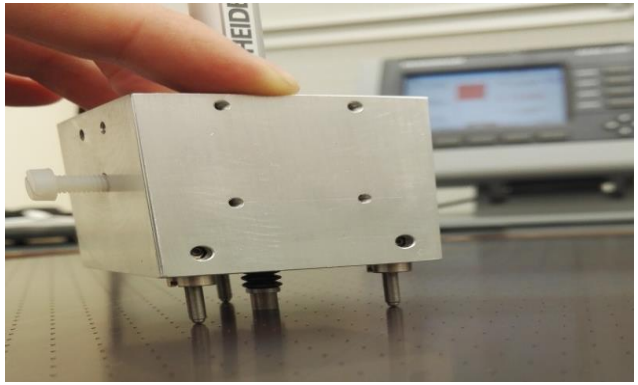
Acceptance criteria: less than 3% disconnected strips

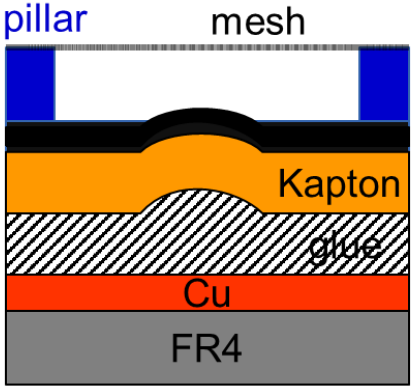
(false positive 1-2%)

MM Readout PCB QA/QC

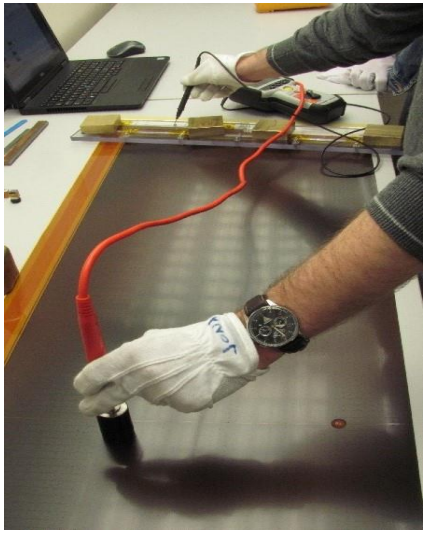
- Dedicated tool was developed to measure height of bumps, acceptance presently < 10µm





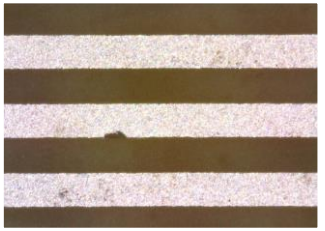


- Electrical tests



- Check connectivity of HV contact to resistive pattern
  @ low voltage accept if 0.3 <= R <= 5 MΩ

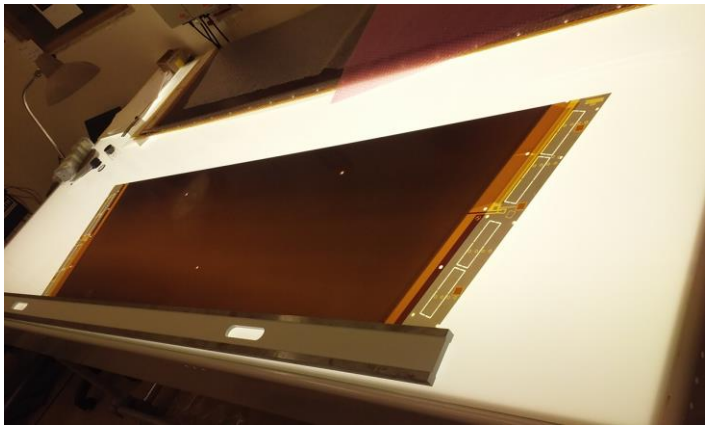
- Verify HV integrity
  - Insulation of readout strips versus resistive pattern
  - Insulation of coverlay on HV silver line verus mesh
  - Automatic inspection of connector pattern for zebra elastomer connector pads

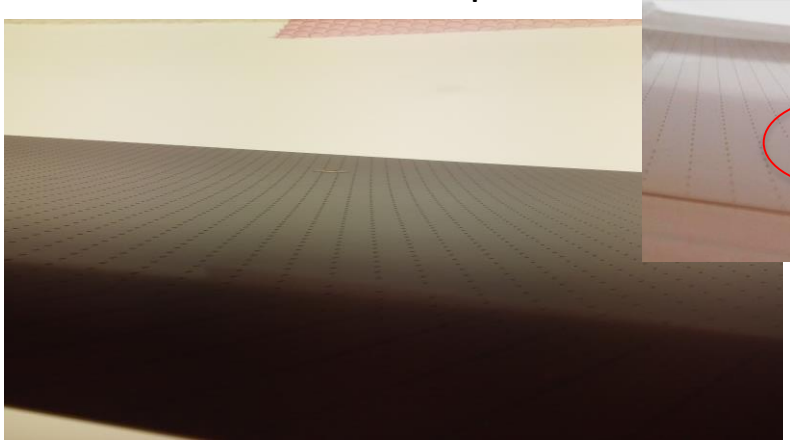


Microscope picture + image analysis

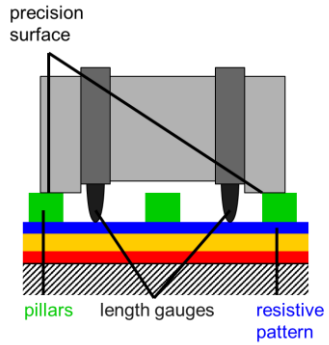
MM Readout PCB QA/QC

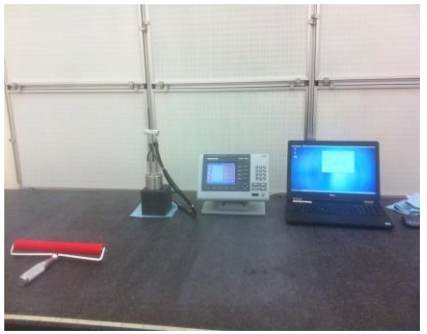
- Backlight table inspection → agreement of holes with Cu pattern, straightness, edges





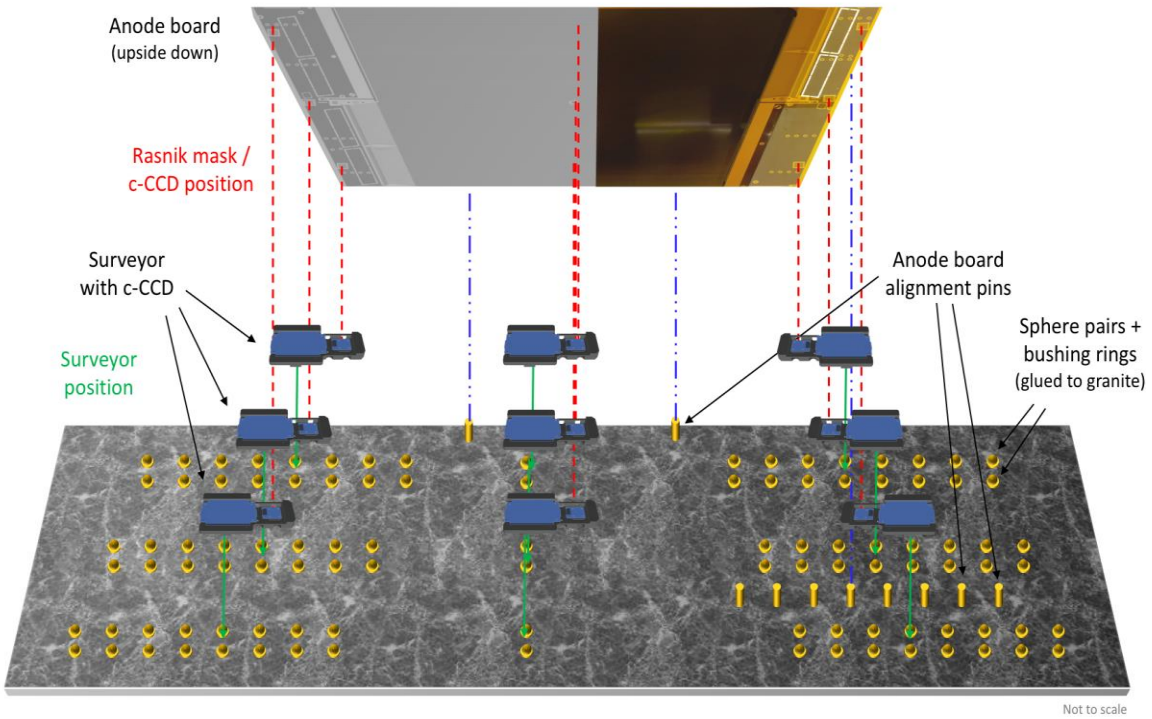
- One of the most important tests: Check for missing pillars and pillar attachment
  - Visual check on the inclined board
  - Attachment tested with Kapton-tape peel-off test (same as at company)
  - Rejection criteria
    - More than 8-10 pillars missing totally/board (boards have 3-20k pillars)
    - Bad pillar attachment
    - 2 or more neighbouring pillars missing

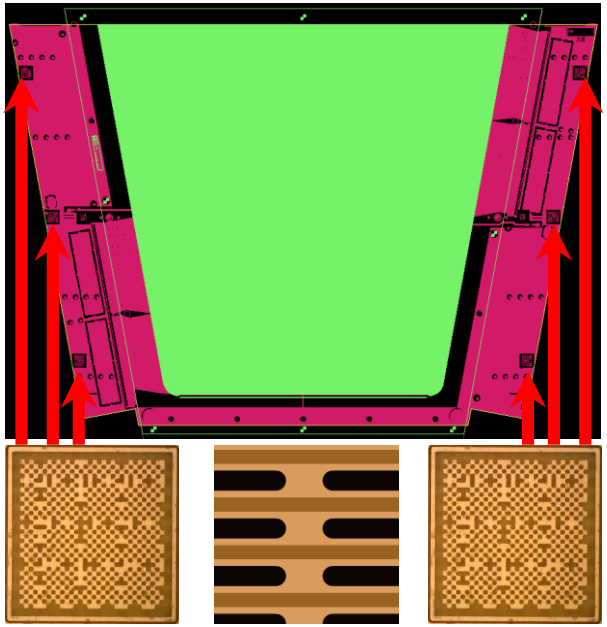




- Pillar height measurement (Map)

MM Readout PCB QA/QC



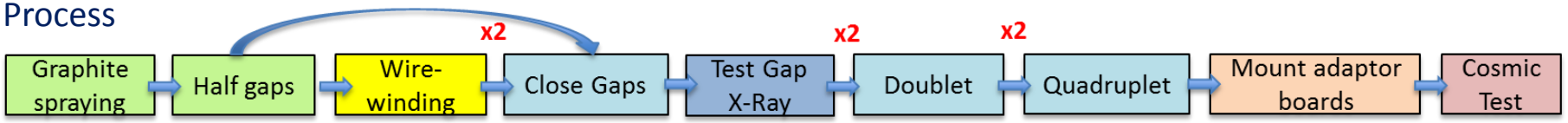


- Board dimensions (accuracy of strip pattern) is verified using a system of contact-CCDs together with Rasmask patterns on the boards
- Boards are placed on a granite table with precision spheres insets which have been surveyed; board aligment thru bushes.
- Surveyors placed on top of spheres, dimension determination through image analysis “a la” LWDAQ (Brandeis)

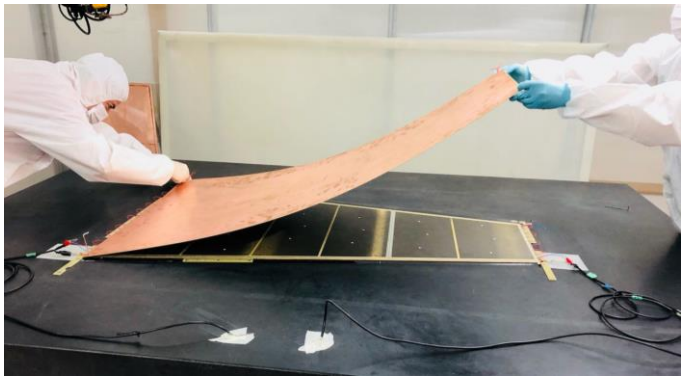
- Good relative measurements, absolute scale is influenced in addition by humidity

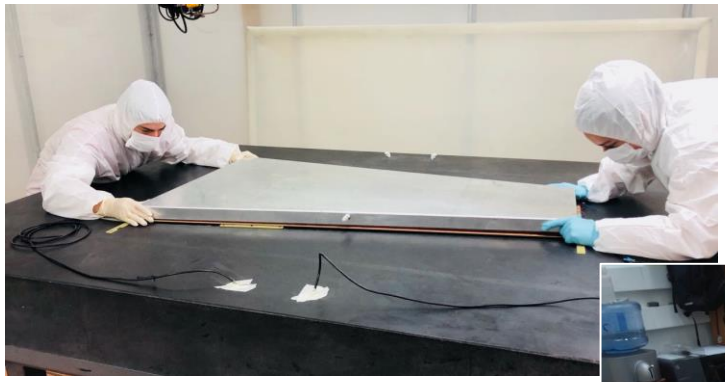
Chamber production Status: sTGC

Process



- About 11 weeks from start to finish for building a sTGC quadruplet
- Gap, doublet and quadruplet construction all take place on dedicated granite tables, under clean room conditions
- Adaptor boards are the interface from the strip/pad boards to the frontend electronics

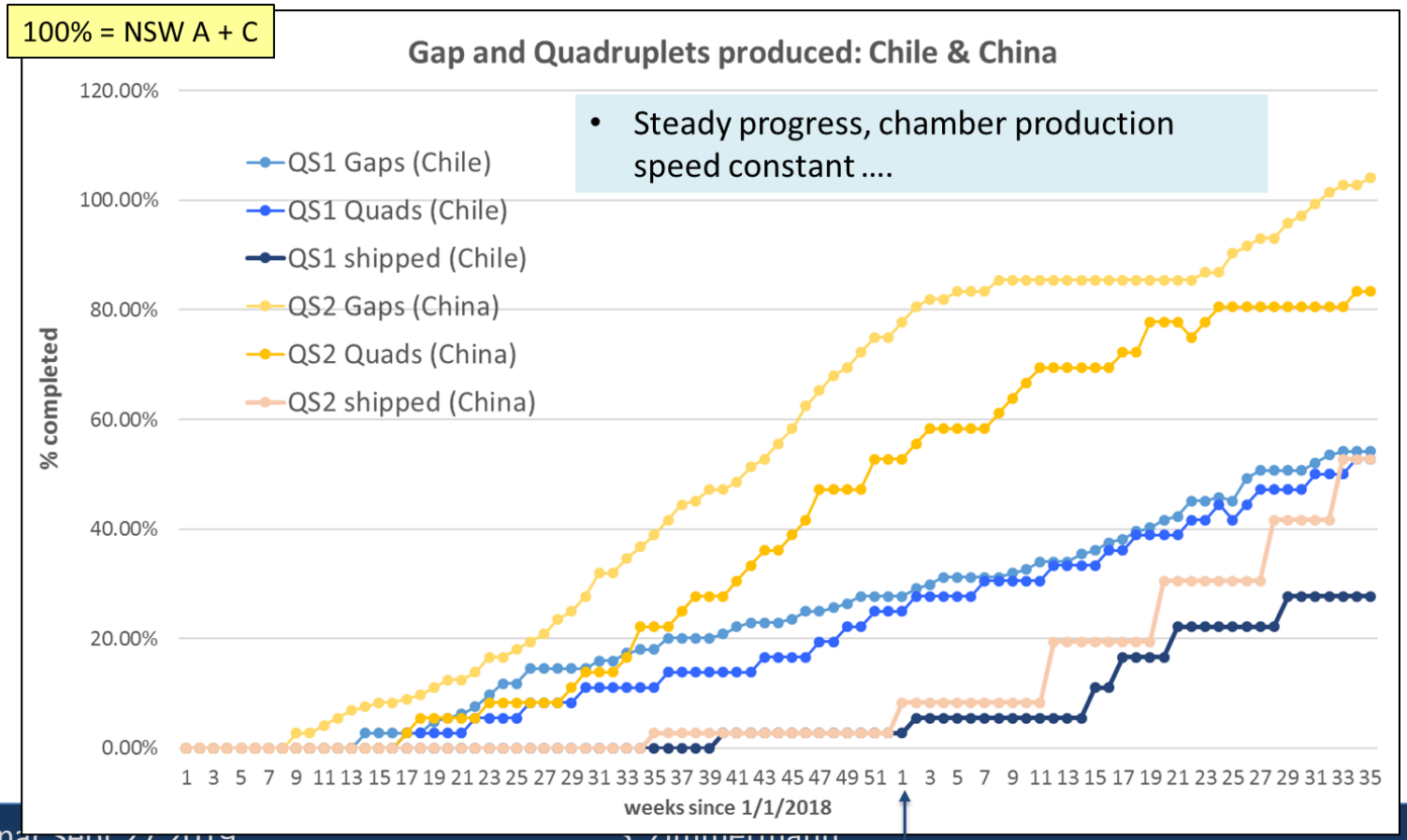




Chamber production Status: sTGC

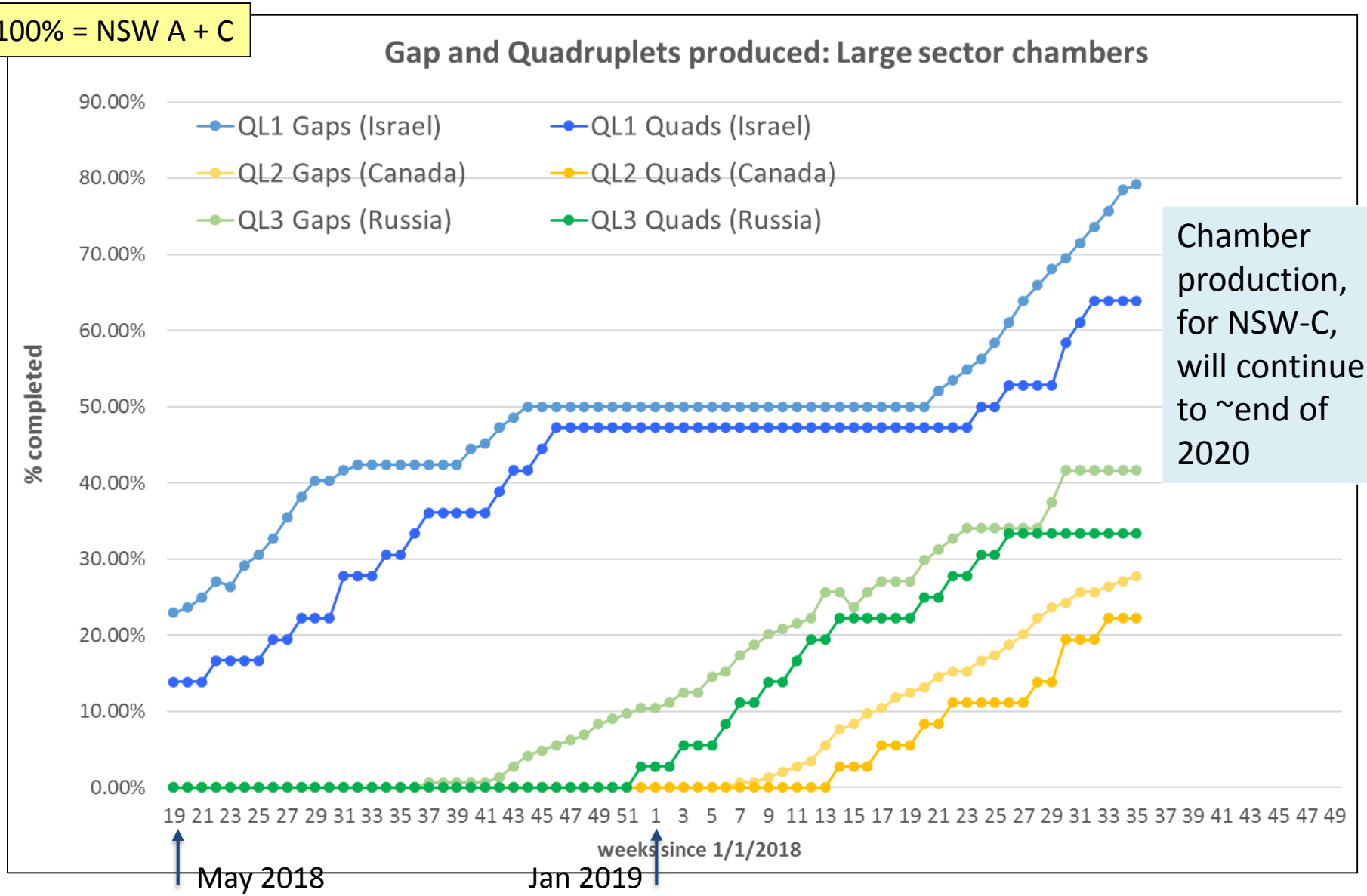
- Production is progressing well in all of the 5 construction sites
- It was a long way; but production progress/rates has become pretty stable !

- >~ 50% of chambers completed (assembled) in all sites → sufficient for the NSW-A
- Nearing already the completion of the production in eg China ☺



Chamber production Status: sTGC

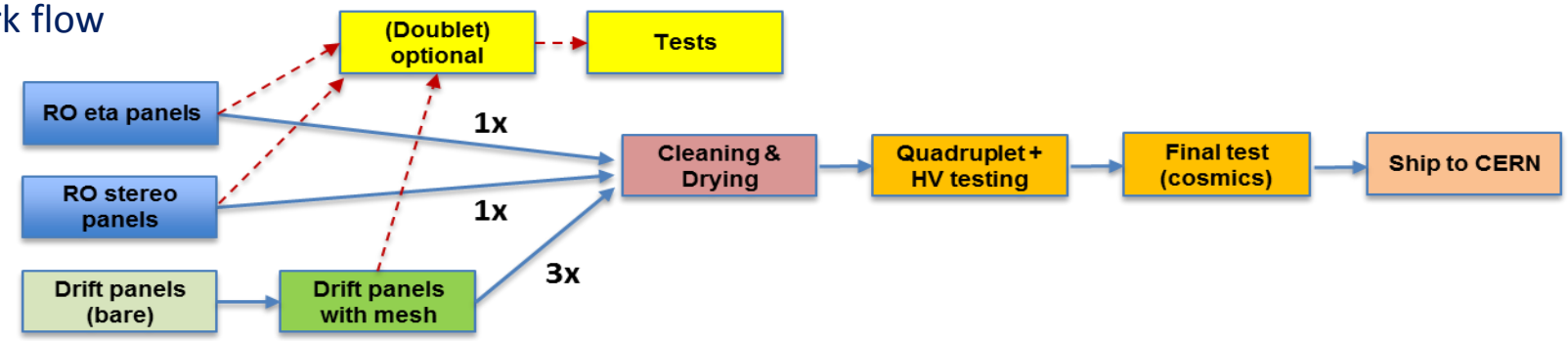
100% = NSW A + C



Chamber production, for NSW-C, will continue to ~end of 2020

Chamber production Status: MM

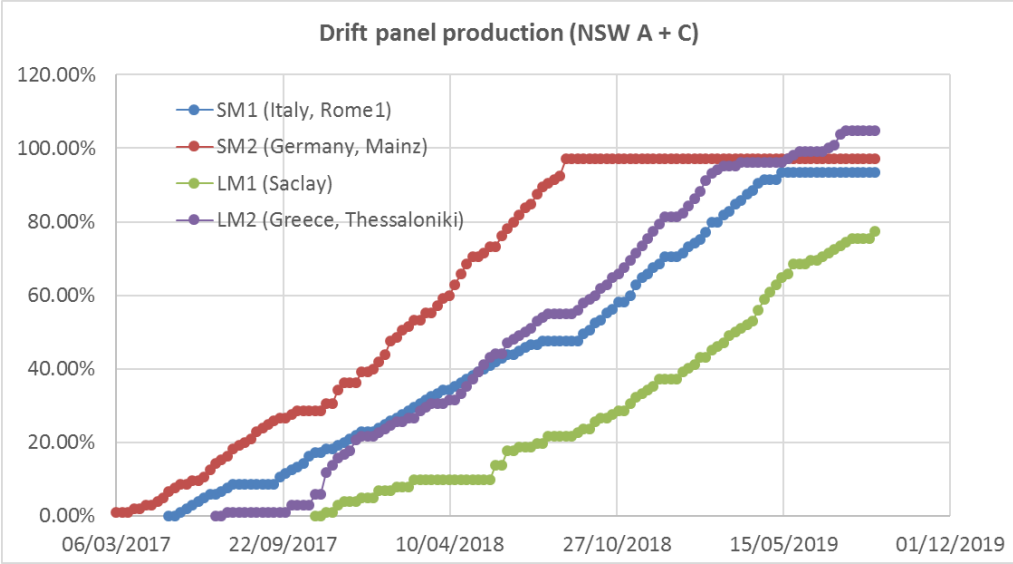
Work flow



- Start to finish for building a quadruplet: 10 – 12 weeks
- Except for Saclay, distributed production --- panels in one place, assembly in another, …

- Panel production is running smoothly since a long time,
- With the drift panel part ~finished in 3 of the 4 sites already

- Quadruplet assembly was however suspended during first 8 months of 2018, due to HV instability problems !

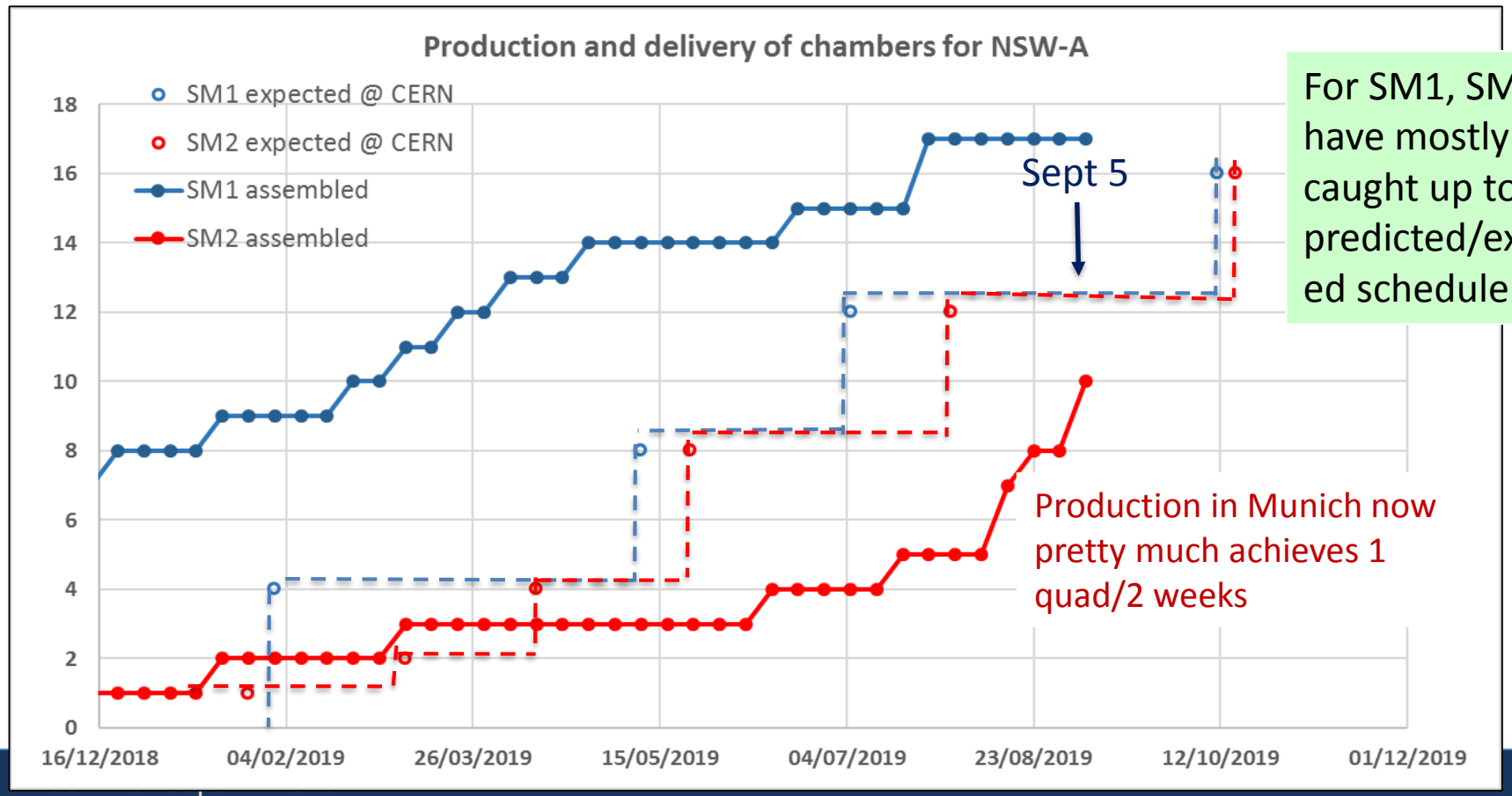


Chamber production Status: MM

Chambers so far delivered to CERN
(out of 128 chambers total)

SM1	SM2	LM1	LM2	Total
10*	9* + 2	2	4	25 (+ 2)

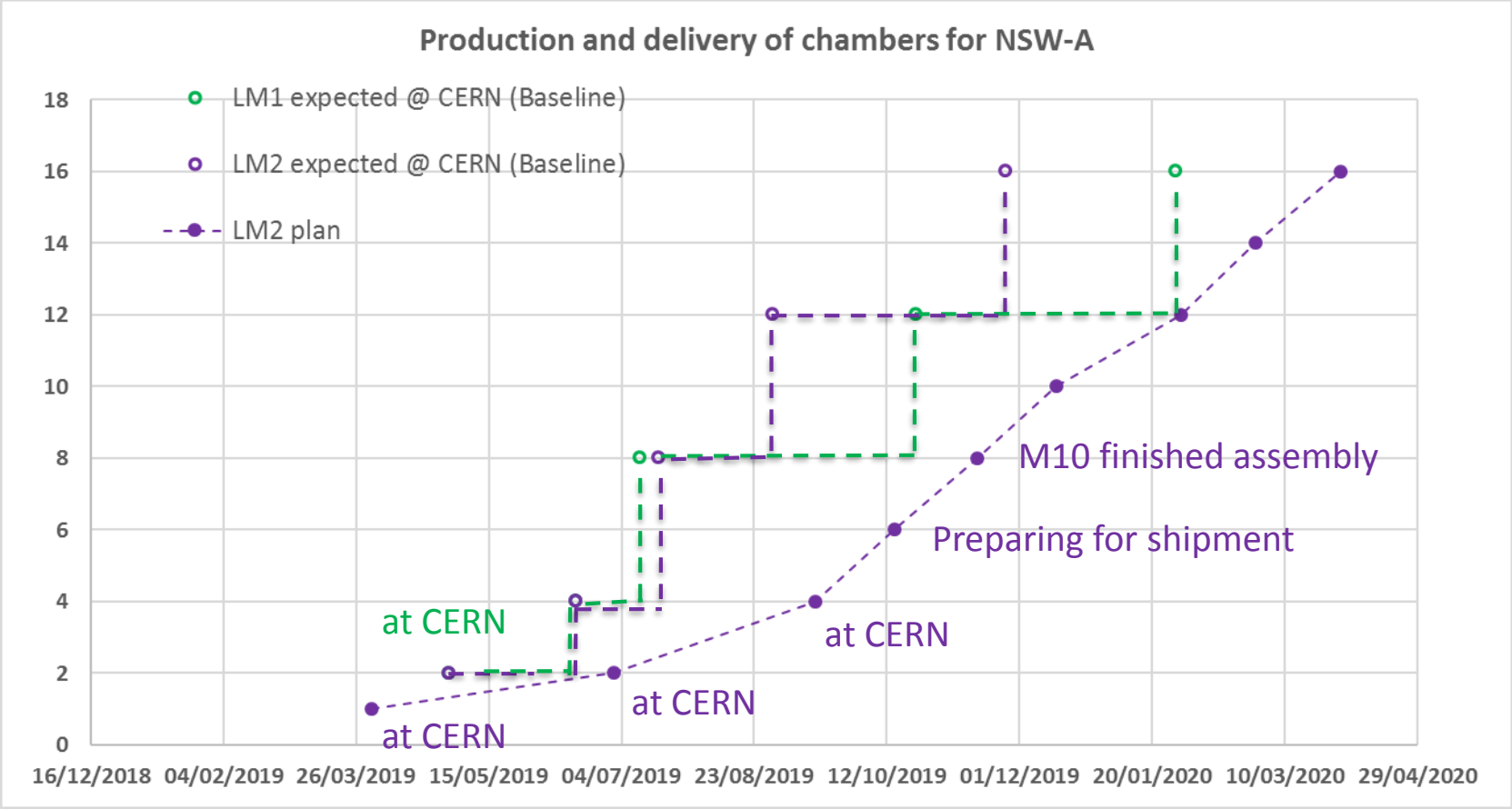
- Significant difference between chambers for small (SM1, SM2) and for large sectors (LM1, LM2)



For SM1, SM2, have mostly caught up to the predicted/expected schedule

Chamber production Status: MM

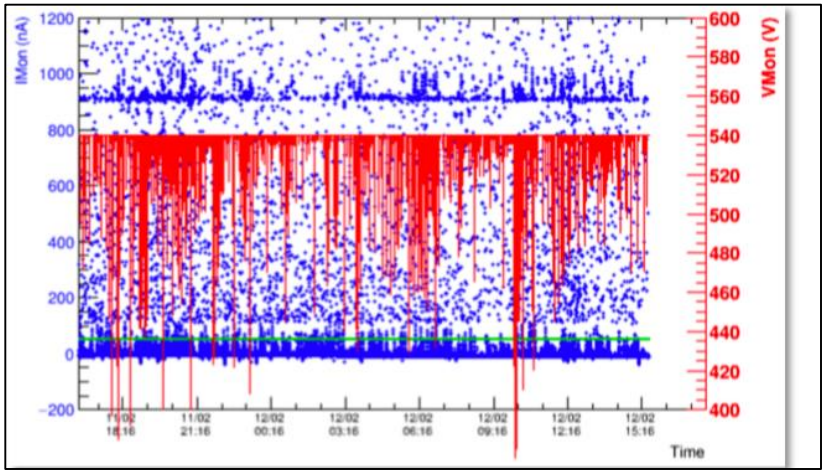
- While for LM1 & LM2 this is not yet the case !



For Dubna, delays were mostly logistics – confident to catch up;
For Saclay (LM1), we still have issues with HV stability – less easy to make a prediction …

Micromegas chambers: HV stability

- HV problems became first evident when we had assembled module 1, and tested it -- end 2017
  - High currents and discharges,
  - with or without HV trips (and concern re permanent damage to the chamber)



During the last year, we understood

- Margin between onset of systematic discharging and original operating point is small → nominal operating voltage lowered to 570V (from 590, 600V assumed before)
- Thorough washing/cleaning/drying of panels prior to assembly is crucial → dedicated multi-step protocol in place in all construction sites
- Relative humidity inside the chamber is crucial, require <~10-20% to have low current

Despite this, chambers other than SM1 did not pass HV acceptance criteria easily;
And, most worrisome, discharges migrated between HV sections !

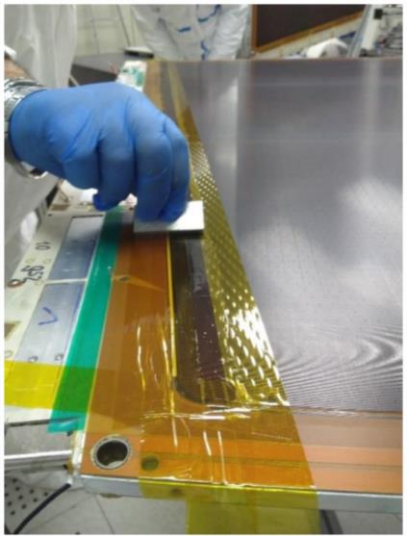
Micromegas chambers: HV stability

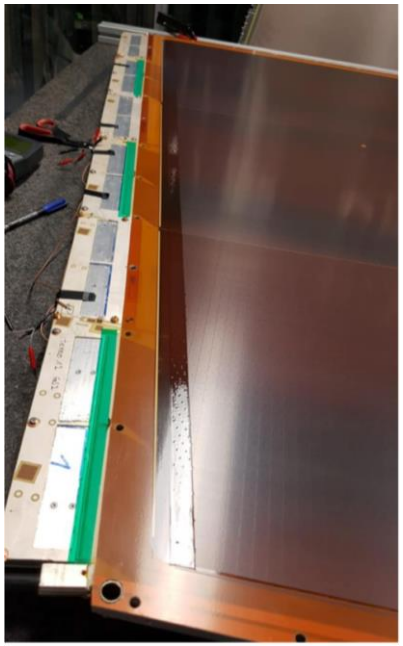
One example -- SM1 M3 discharge rate

BB5/vertical	GIF	GIF	GIF	GIF	BB5/vertical	GIF	GIF no rad
20190325	20190409	20190411	20190418	20190430	20190502	20190509	20190522
Spike (n/min)	Spike (n/min)	Spike (n/min)	Spike (n/min)	Spike (n/min)	Spike (n/min)	Spike (n/min)	
30,96	0,00	0,00	0,19	0,00	0,00	0,00	0,19
4,15	0,00	0,00	0,00	0,00	0,00	0,00	0,19
3,04	0,02	0,03	9,11	0,28	2,54	0,23	3,46
0,03	0,00	0,00	0,08	0,27	0,03	0,00	0,29
0,06	0,00	1,69	0,01	0,00	0,00	0,03	0,32
0,16	0,11	0,02	0,48	1,83	3,30	0,32	0,45
0,65	0,11	0,00	0,96	0,62	1,87	0,66	3,27
0,06	0,00	0,00	0,00	0,29	0,00	0,29	1,46
0,16	0,23	2,94	2,56	0,01	0,00	0,00	0,00
0,09	2,62	8,39	0,01	0,00	0,00	0,00	0,19
0,09	0,02	3,39	1,38	0,00	0,00	0,34	0,19
1,89	0,21	0,31	0,01	0,20	0,00	0,10	0,74
31,89	0,00	0,00	0,00	0,00	0,00	0,00	0,00
0,09	0,30	0,00	4,31	0,18	1,16	0,27	2,56
0,12	0,05	0,00	0,77	0,64	4,63	0,22	0,58
0,56	0,00	0,00	0,13	0,23	0,00	0,01	0,55
0,06	0,30	0,00	0,00	0,15	0,31	0,26	0,97
0,03	0,00	0,00	0,16	0,33	0,03	0,19	1,78
0,03	0,00	0,00	0,07	0,15	0,00	0,00	0,29
0,03	0,00	0,00	0,05	0,03	0,00	0,00	0,00
0,06	0,00	0,00	0,08	0,08	0,00	0,00	0,26
0,31	0,01	0,00	4,43	9,03	3,34	2,48	2,56
0,34	0,01	0,01	0,40	0,46	3,42	0,00	1,07

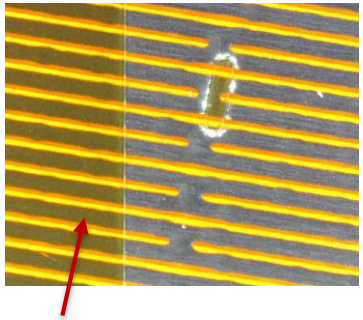
- Statistics from ~10 chambers tested then → no deterioration with irradiation ! Very important hint, and relief

Micromegas chambers: HV stability





- Opening and inspection of discharging chambers often showed evidence of the discharge happening close to the boundary between the Pyralux overlay region and the active area



→ Hypothesis of insufficient resistivity to sufficiently quench discharges ?

Recall, NSW chambers are based on the resistive Micromegas technology which made the MM chamber technology spark resistant to start with, and which was newly developed by the MAMMA collaboration together with RD51 in the years prior to the NSW TDR ….

- Frascati started investigations into “Edge Passivation” --- take out an additional 1.5 cm band from the active area, covering it with glue

→ ensures there is a (larger) minimum resistivity “seen” by any spark, ie we increase the minimum path length to the common HV point

Micromegas chambers: HV stability

Proof that Edge Passivation is working:

- Technique applied to SM1 modules M13, M14, M15

	Sectors @ 570 V	Bad sectors (< 560 V)	Eff from theor. curve
M13	40	0	93%
M14	38	1 540V, 1 560 V	92.45%
M15	40	0	93%

- SM2 module M9 shipped from Munich to Frascati in June, and edge passivation applied to all layers
  - Successful ! more details: next slide

→ Edge passivation systematically applied for all following modules:
  - M16 (outer layers only);
  - M11, M14, M15 all layers;
  - These chambers all are at CERN now, having passed HV qualification at the construction site, and work well

Micromegas chambers: HV stability

- We believe we have finally understood the origin of the HV stability issues, which we have observed despite the lowered working point

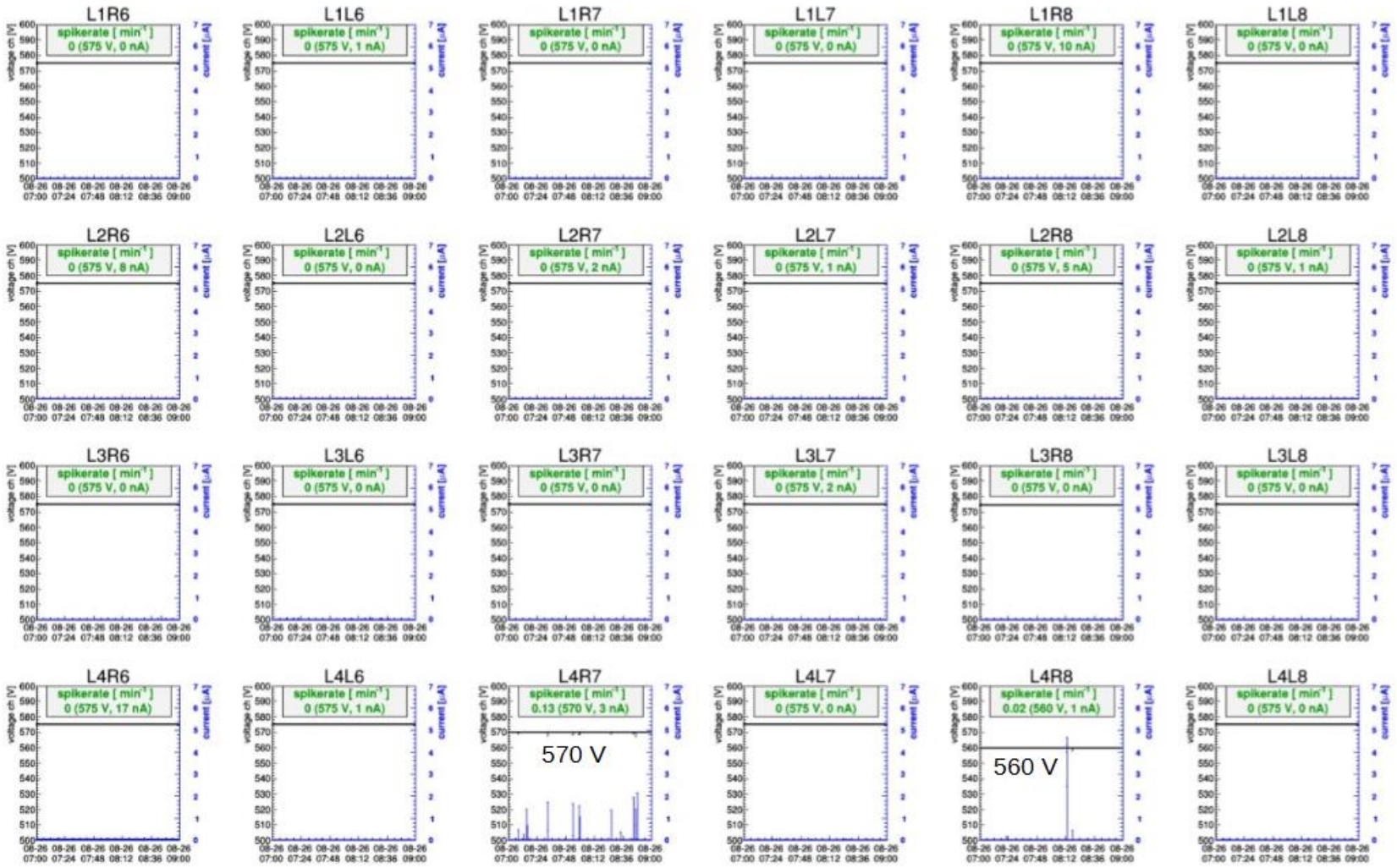
  Insufficient spark suppression by too low resistivity in localized spots

- With the edge passivation, we have a method with which we can mitigate the low local resistivity values
- The method has been used on ~10 chambers now, and results are reliable good

→ For both SM1 and SM2, we are (back) in a stable production ….

Micromegas chambers: HV stability

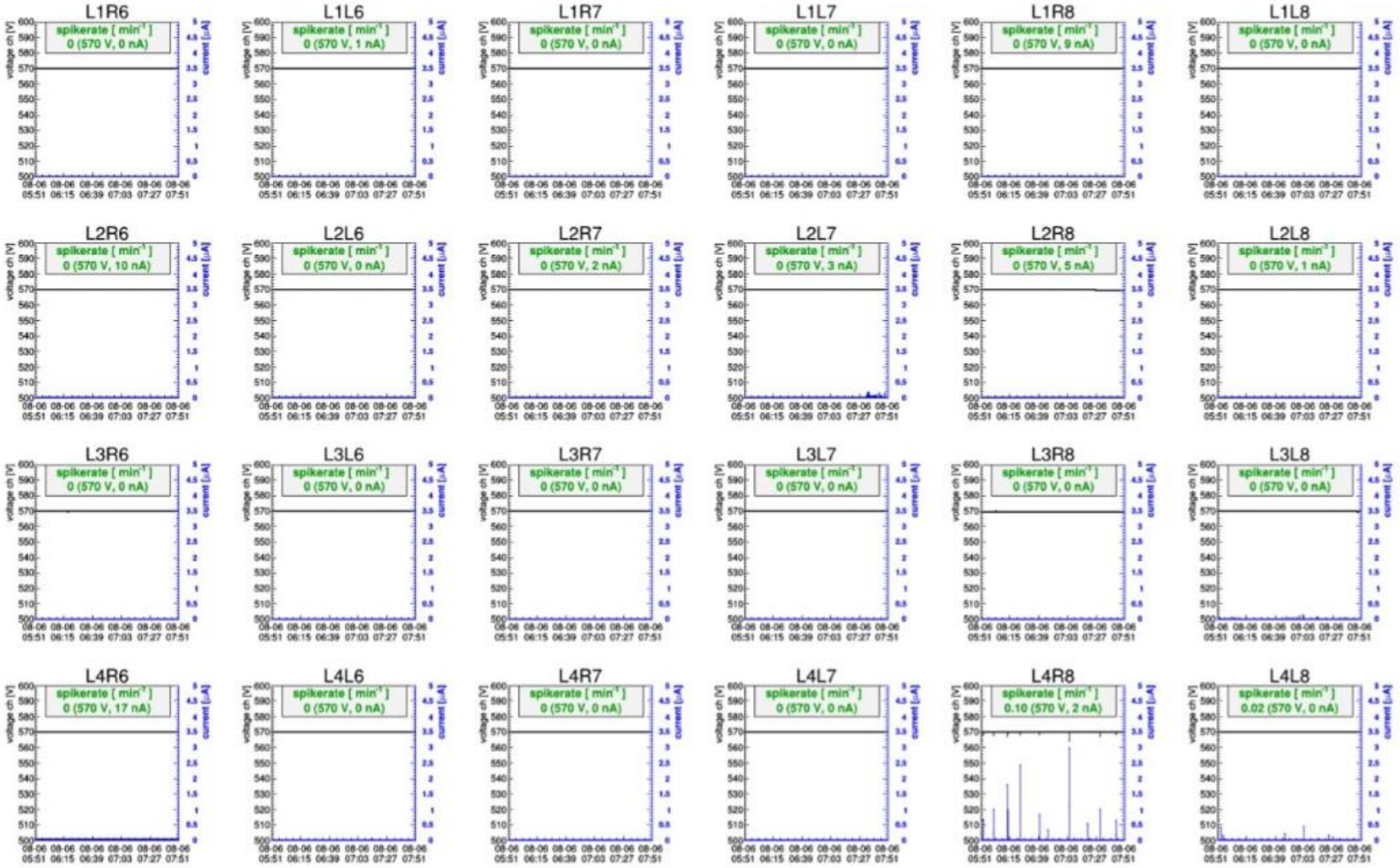
SM2 **M14**, edge passivation on all layers, data from LMU prior to shipment to CERN



- 22 HV sections @ 575V, 1 @ 570V, 1 @ 560V

Micromegas chambers: HV stability

SM2 **M15**, edge passivation on all layers, data from LMU prior to shipment to CERN



- All HV sections @ 570V

Micromegas chambers: HV stability

- We try and so far managed to send almost all chambers received @ CERN up to now to GIF++
  → Not an ageing test, but a validation of the HV behaviour under high rate

SM2 M9: HV test @ GIF, August 26rd

Sector	HV	spark/min	Efficiency	Flag
L1L6	569	0.72	92.3	V
L1R6	569	0.72	92.3	V
L1L7	569	0.6	92.3	V
L1R7	569	1.22	92.3	V
L1L8	569	0.2	92.3	V
L1R8	569	0.37	92.3	V
L2L6	569	0.35	92.3	V
L2R6	570	0.17	92.4	V
L2L7	565	6.79	91.1	V
L2R7	570	1.82	92.3	V
L2L8	570	0.0	92.3	V
L2R8	570	0.47	92.4	V
L3L6	570	0.85	92.4	V
L3R6	569	0.8	92.3	V
L3L7	569	0.22	92.3	V
L3R7	569	0.65	92.3	V
L3L8	569	1.7	92.3	V
L3R8	569	1.26	92.3	V
L4L6	569	0.75	92.3	V
L4R6	565	2.2	91.1	V
L4L7	565	26.33	91.1	V
L4R7	569	25.32	92.3	V
L4L8	569	6.61	92.3	V
L4R8	569	5.61	92.3	V

Overall efficiency:

92 %

4 out of specs (spikewise, but improving with time)

Early on, still had some HV sections with issues …

Micromegas chambers: HV stability

Slide from sign-off meeting Aug 26

SM2 M16: HV test @ BB5

Sector	HV	spark/min	Efficiency	Flag
L1L6	569	0.0	92.3	V
L1R6	569	0.0	92.3	V
L1L7	569	0.0	92.3	V
L1R7	569	0.0	92.3	V
L1L8	569	0.0	92.3	V
L1R8	569	0.05	92.3	V
L2L6	570	0.0	92.3	V
L2R6	569	0.0	92.3	V
L2L7	569	0.0	92.3	V
L2R7	569	0.0	92.3	V
L2L8	570	0.0	92.3	V
L2R8	569	0.03	92.3	V
L3L6	569	0.03	92.3	V
L3R6	569	0.0	92.3	V
L3L7	570	0.0	92.3	V
L3R7	569	0.0	92.3	V
L3L8	569	0.0	92.3	V
L3R8	569	0.0	92.3	V
L4L6	569	0.0	92.3	V
L4R6	569	0.0	92.3	V
L4L7	569	0.02	92.3	V
L4R7	569	0.0	92.3	V
L4L8	569	0.0	92.3	V
L4R8	570	0.0	92.3	V

out of specs: 0

Overall eff: 92.3%

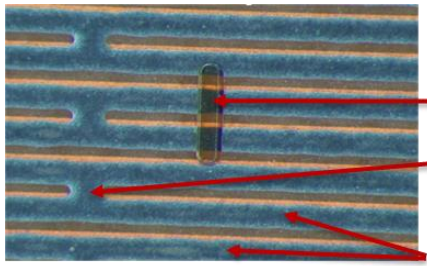
GIF++ test

then

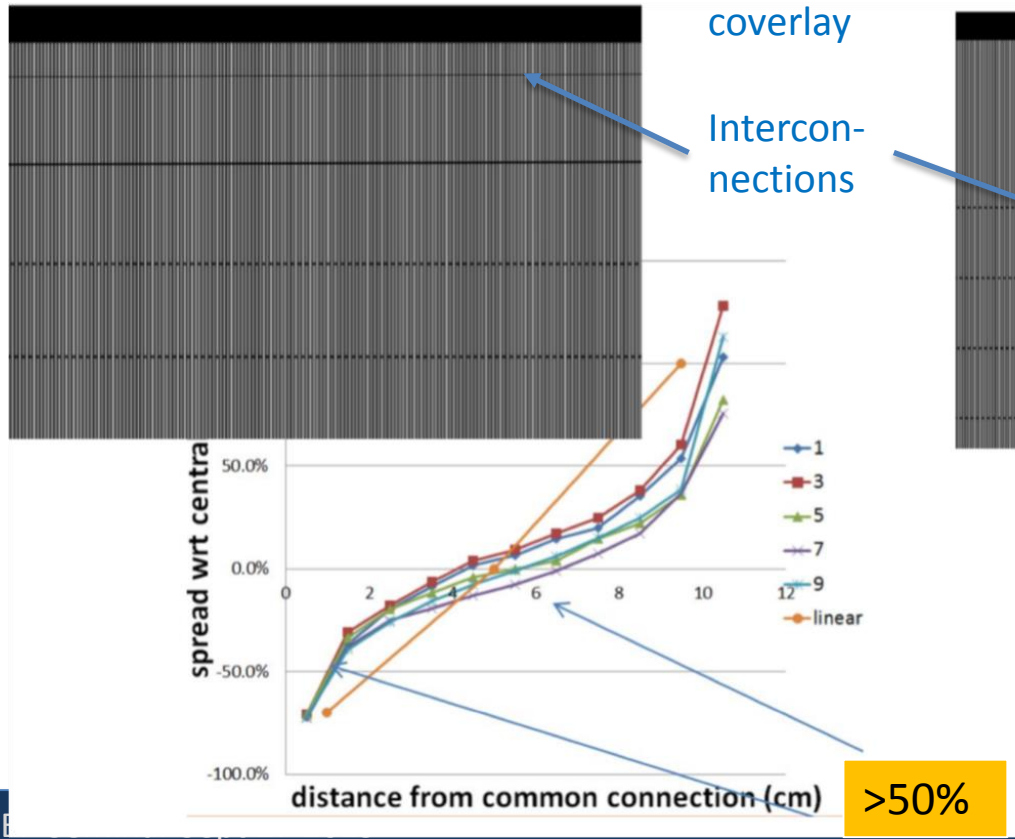
to alignment

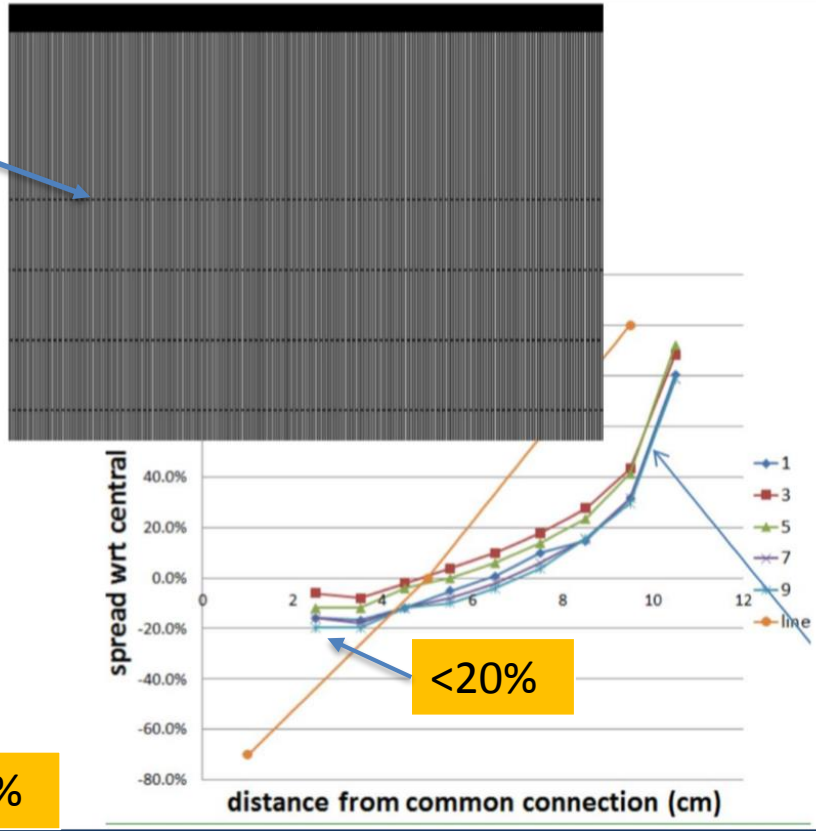
Micromegas chambers: HV stability

With the statistics from ~20 chambers built up to the summer, and evidence of the edge passivation as well as from chambers that failed in GIF++ --- **Resistivity** revisited:



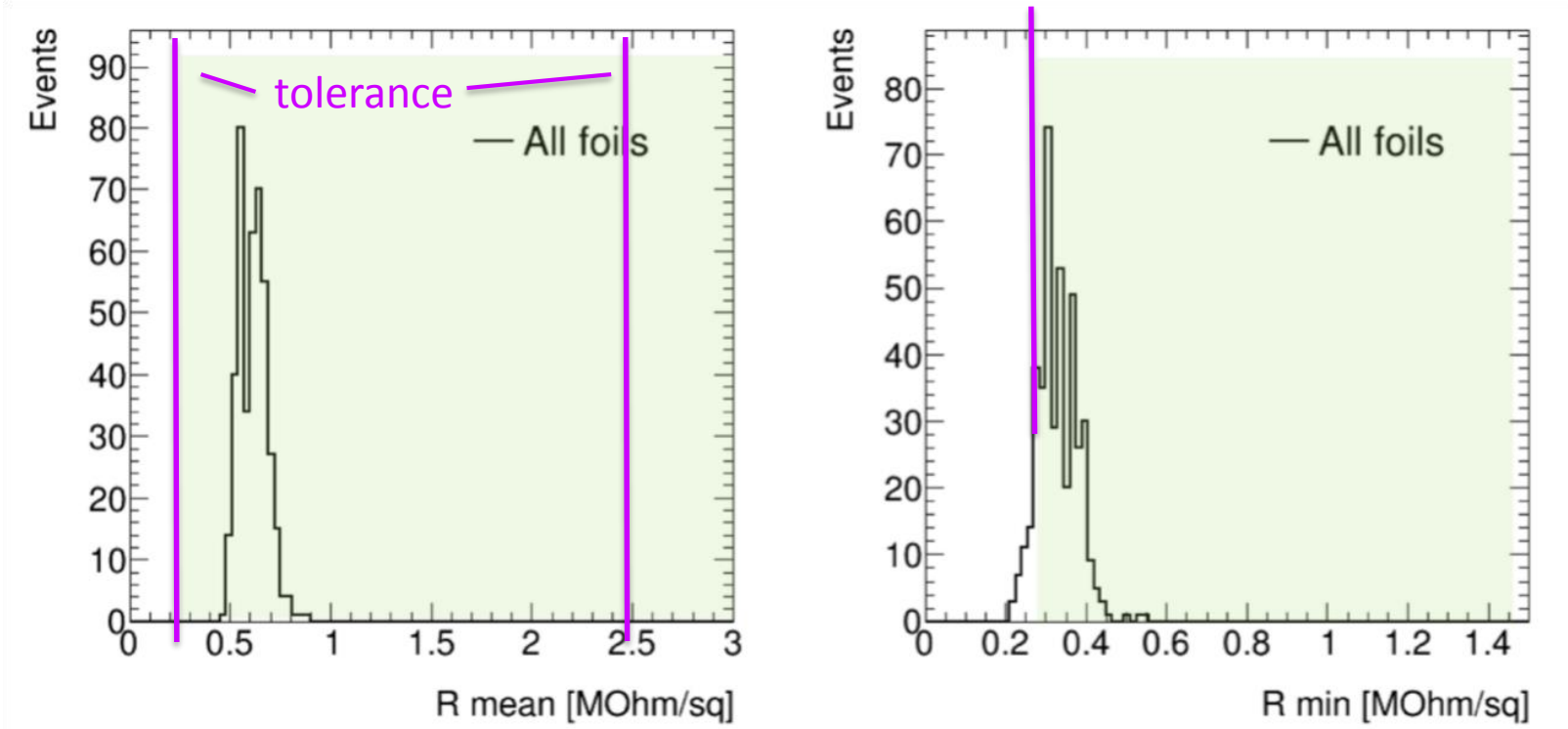
- Effective resistance along the strip varies less if closest interconnection is away from the boundary of the coverlay (right)
- And more if the interconnection is close by (left)





Micromegas chambers: HV stability

Checked the QA/QC data for the MM resistive foils: Resistance per Square

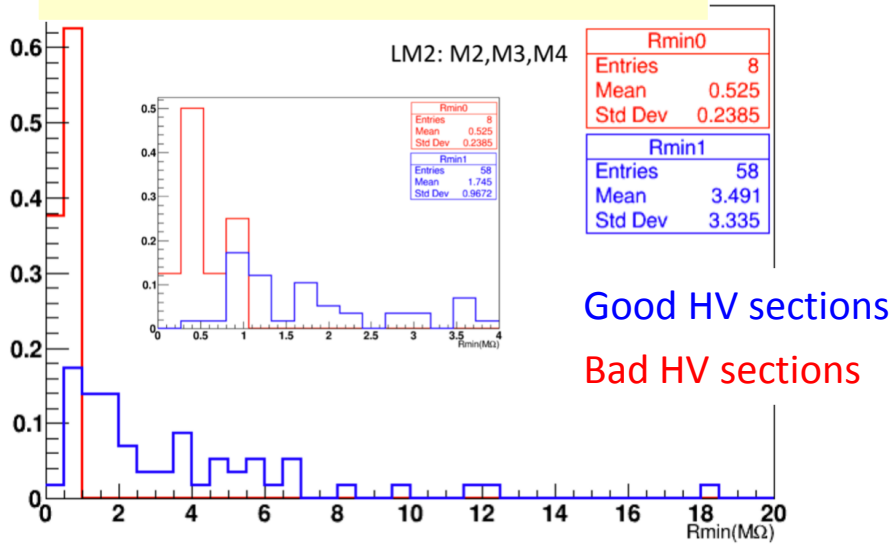


- Unfortunately we are quite close to the lower limit of 0.28 MΩ/□, with local resistance points even below
- Per se, low resistance is not a problem, especially if localised – but, in combination with any other weakness/defect (mesh, impurity, surface roughness, ….) the spark quenching mechanism no longer works efficiently, and this is what we have been seeing !

Micromegas chambers: HV stability

Correlation between minimum resistivity and good/bad HV sections

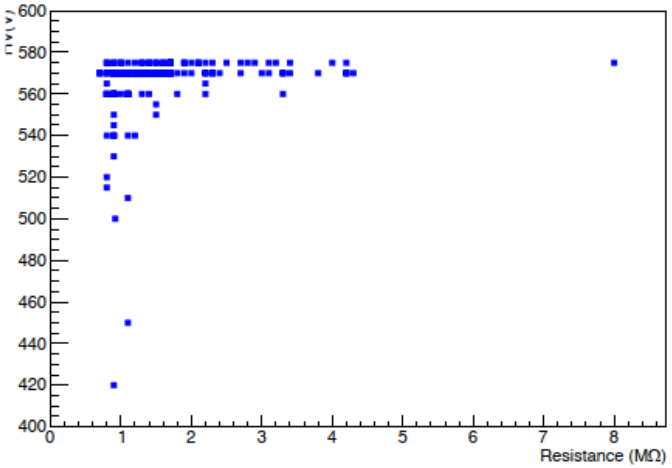
Data from first 3 LM2 chambers



Good HV sections

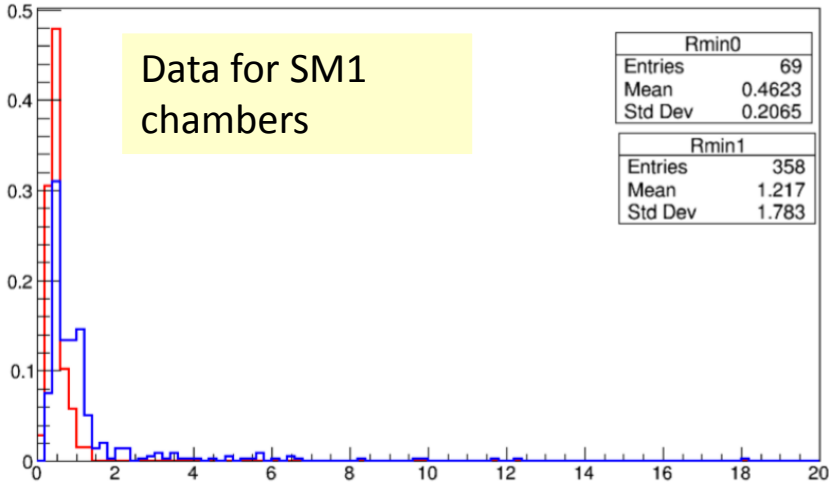
Bad HV sections

Example: HVmax vs. R, data from SM1

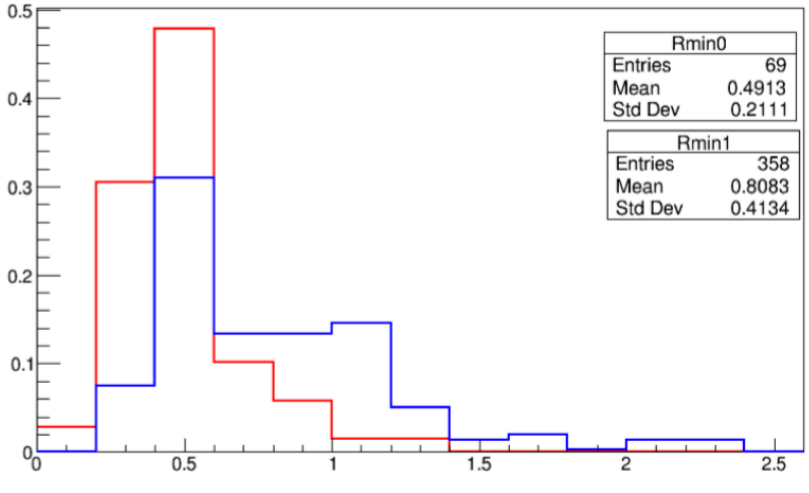


R min for bad sectors

Data for SM1 chambers

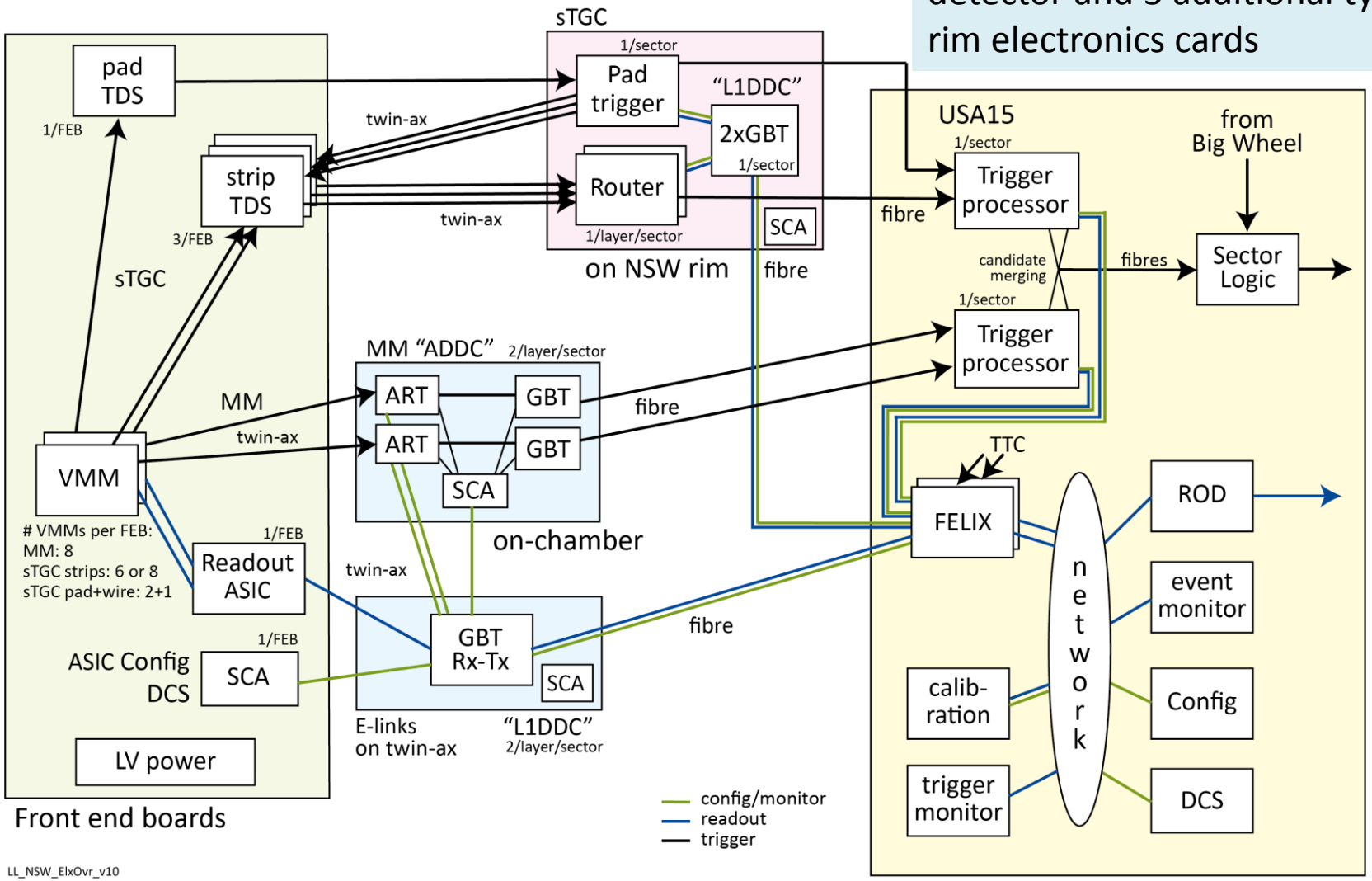


R min for bad sectors



NSW Electronics

4 custom ASICs, 5 different on-detector and 3 additional types of rim electronics cards

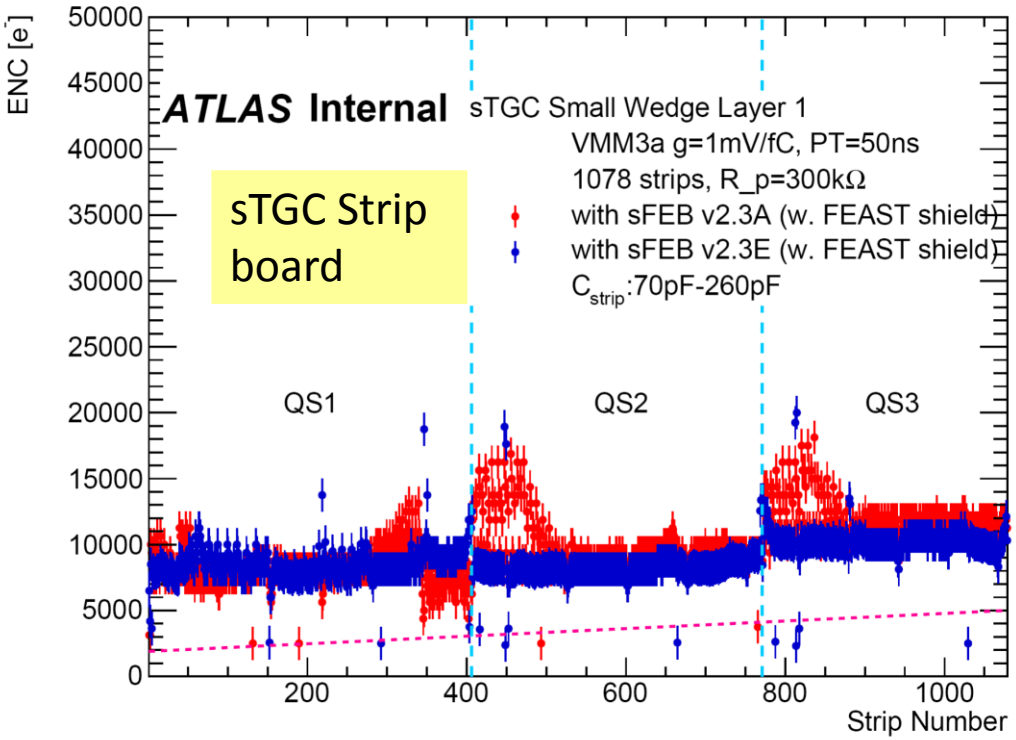


NSW Electronics Status

Generally, electronics status is advanced

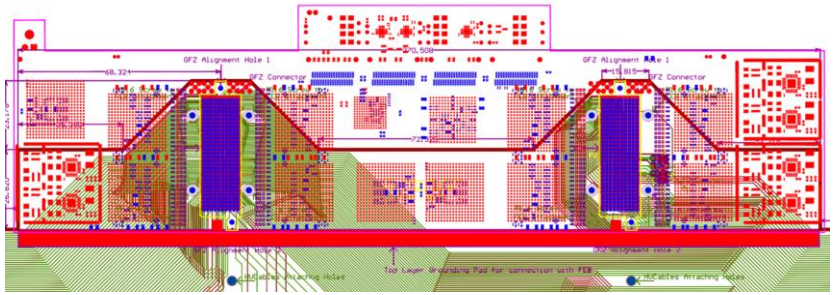
- All on-detector cards are in pre-production or production,
- With all production readiness review passed except for the MM FEB → mid October

Some challenges encountered: Noise !!



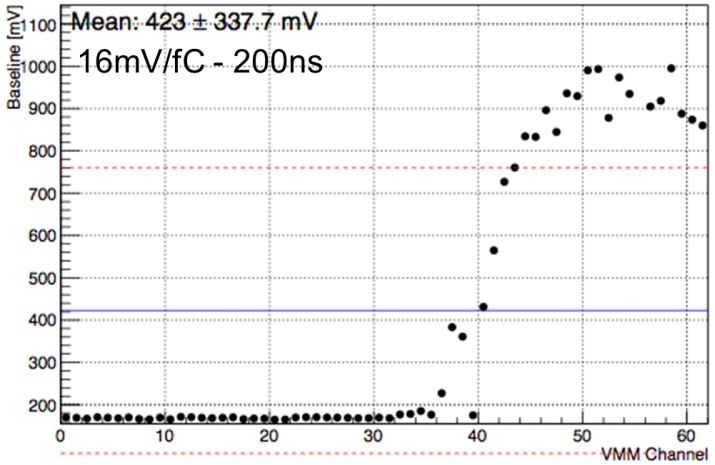
Example:

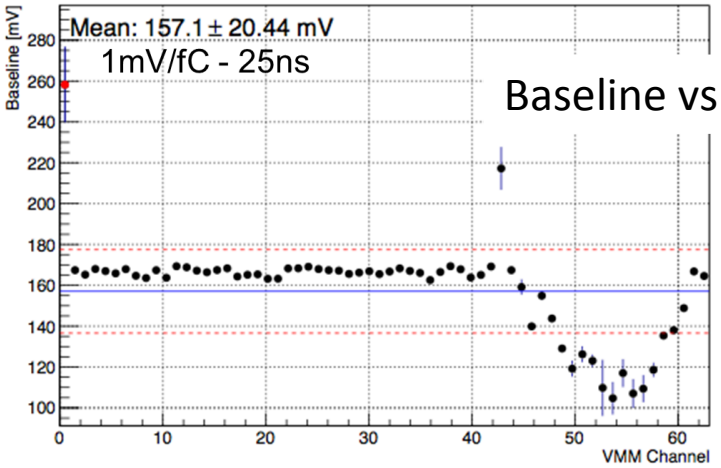
Coupling of FEAST power converter switching into the traces on the detector adaptor boards which go to the VMM input



… resolved by a layout change, new version 2.3E works very well !

NSW Electronics – VMM ASIC



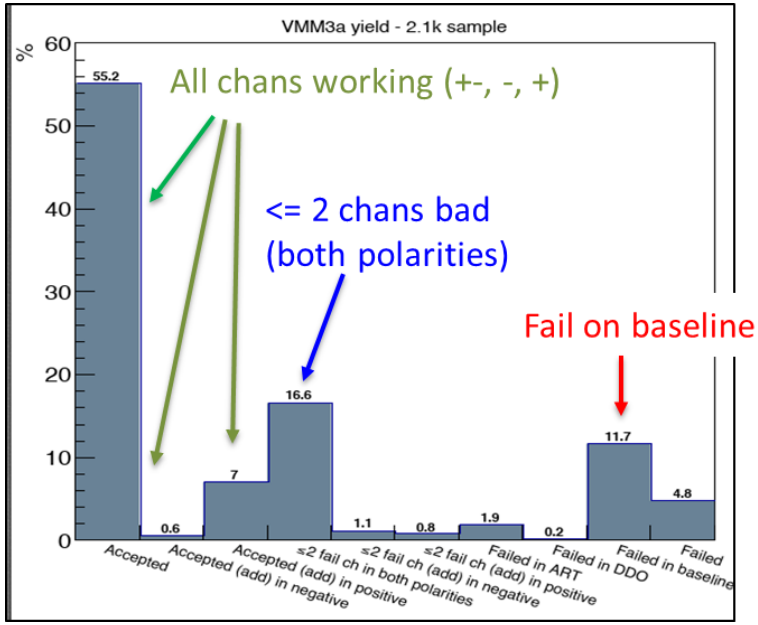


Baseline vs channel

- VMM baseline not ok for ~30% of chips in at least one channel …
- Believed to be a metalization issue on one of the layers, despite passing all DRCs

- Have to and can live with it, doing a careful selection of chips

Have the first half of the series production VMMs back from packaging since August, testing is ongoing ….

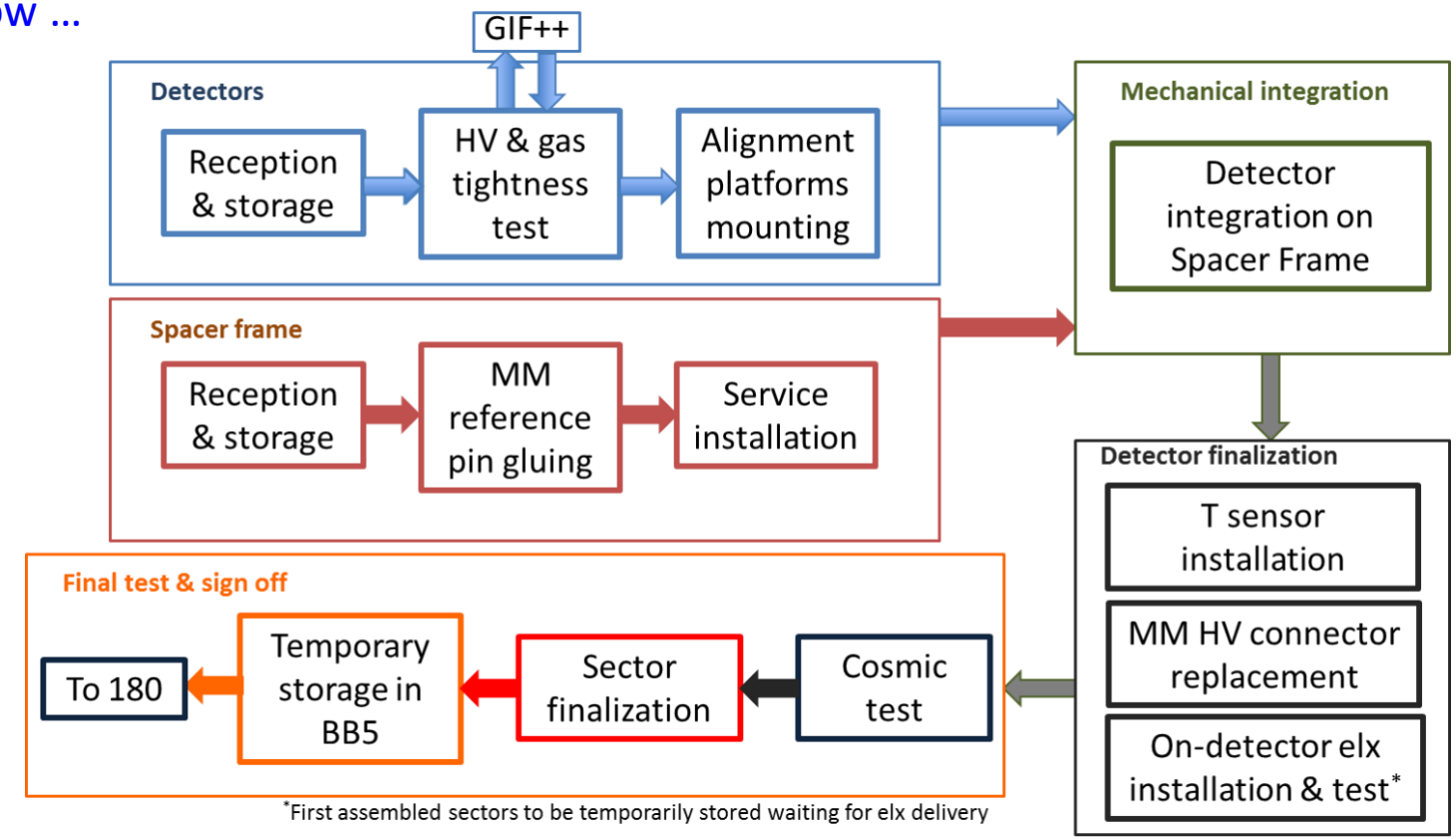


While we consider the VMM yield under control, it's still one of items I feel not completely at ease about … until all chips are indeed tested and classified !!

Integration Activities @ CERN

Micromegas integration

Work flow …



- Work organized in 4 main work packages – Detector reception/preparation; Mechanical integration; Services; Electronics installation and final testing

- Working very well

Micromegas integration

Present status:

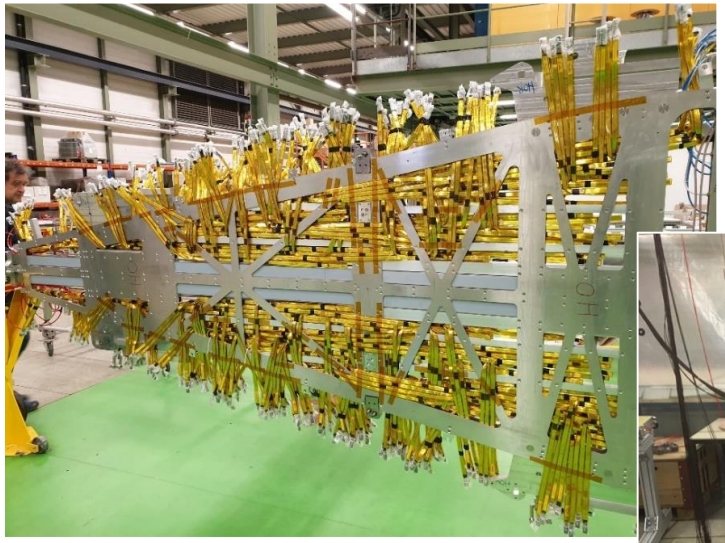
- Double wedge for sector 12 (#1) is completed, including installation of all electronics – 128 MMFE8, 16 L1DDC, 16 ADDC cards
- Currently undergoing readout tests with the full chain up to FELIX and all 128 MMFE8
- Double wedge for sector 14 (#2) is assembled, waiting for electronics
- Double wedge for sector 10 (#3) is assembled then will have to wait for electronics
- Double wedge for sector 16 (#4) ongoing …

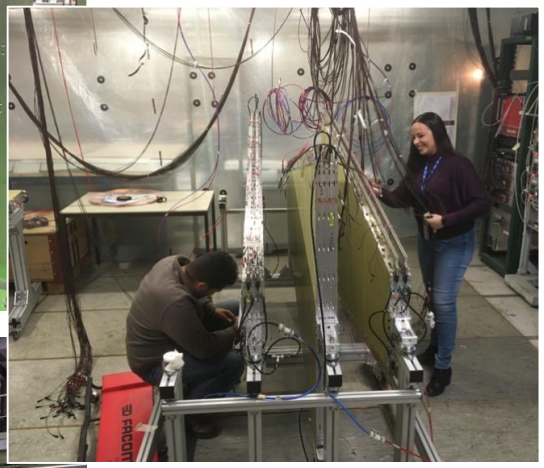
DW Sector 12

DW Sector 14

Micromegas integration

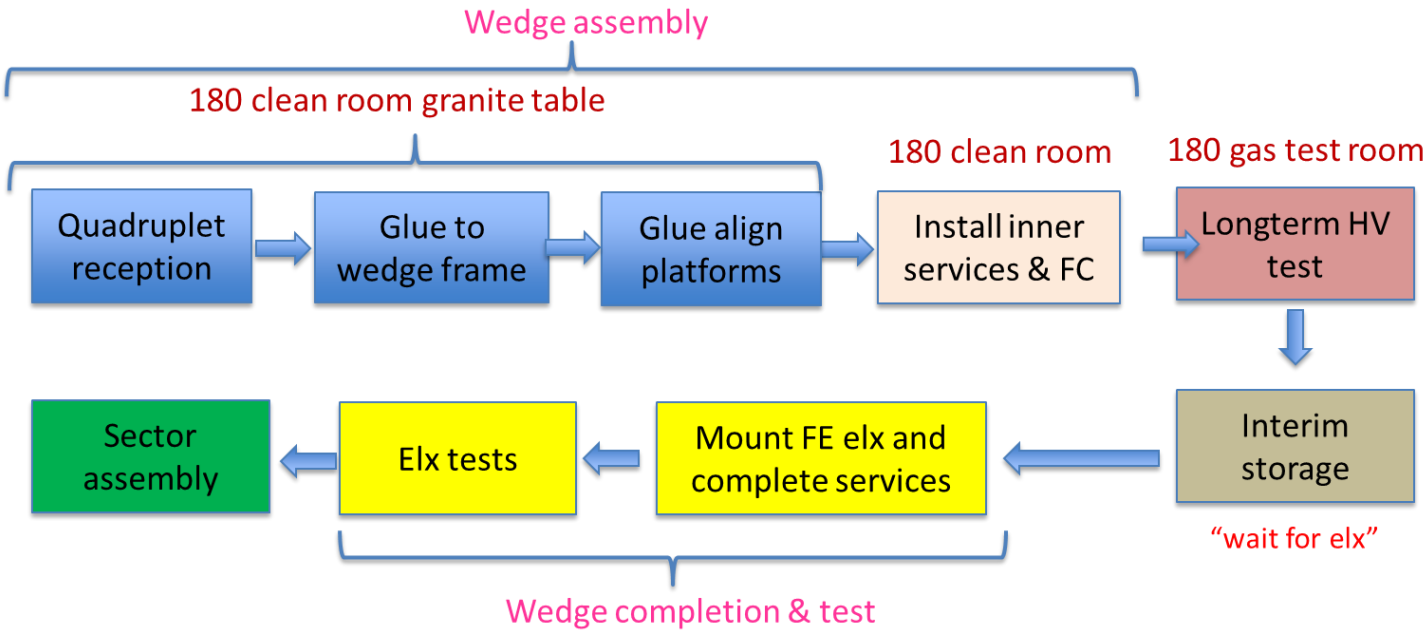
Pictures sometimes telling more than words – complexity …





sTGC Integration

Work flow …



Similar strategy as for the Micromegas, but taking place in building 180 instead of in BB5

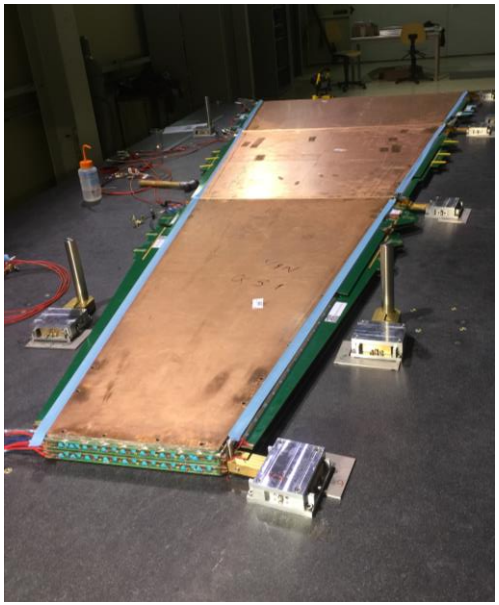
Wedge assembly is ongoing since end of last year, 9 wedges so far built (all for small sectors),

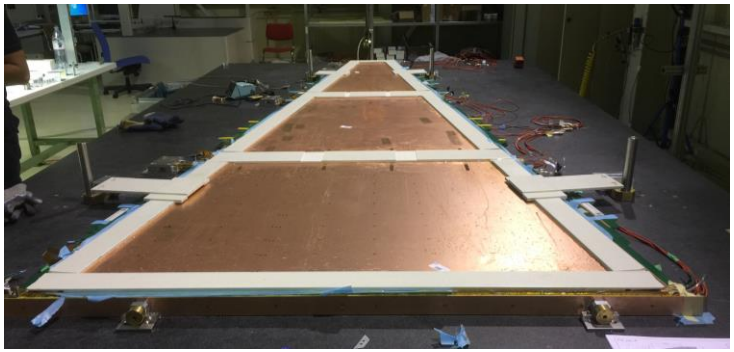
- Generally, proceeds well,
- But behind the Micromegas in so far as no large sector wedge has been built yet

- Electronics installation just started ….

sTGC Integration

Pictures sometimes telling more than words





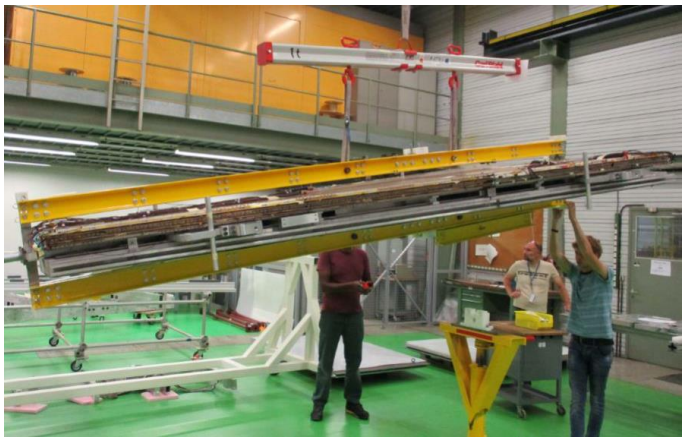
Still a bit in the future: Sector assembly

- Once Micromegas double wedges and sTGC wedges are ready, the both are transported to B191 where they are combined into the sector;
- the sector is then installed on the NJD disk/NSW structure ….

Procedure was excercised twice, last autumn and again few weeks ago → Ready to go !

MM double wedge…

- Manipulation of double wedge, installation into its transport basket and transport to 191



Still a bit in the future: Sector assembly

sTGC:

- Start from wedges in storage, after receiving their electronics…

1. Wedges in their storage area

2. Putting on the kinematic supports

3. Installing into the transport and assembly trolley

Still a bit in the future: Sector assembly

Having fun moving from 180 thru 190 to 191, using “human power”

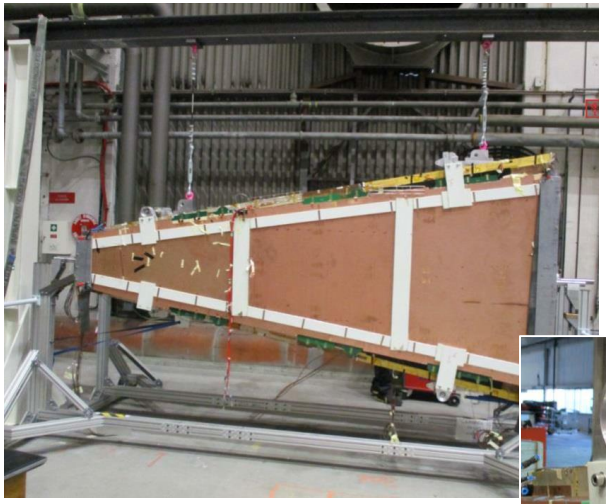
After arrival in 191, next to the sector assembly station (with the MM double wedge already mounted)

Still a bit in the future: Sector assembly

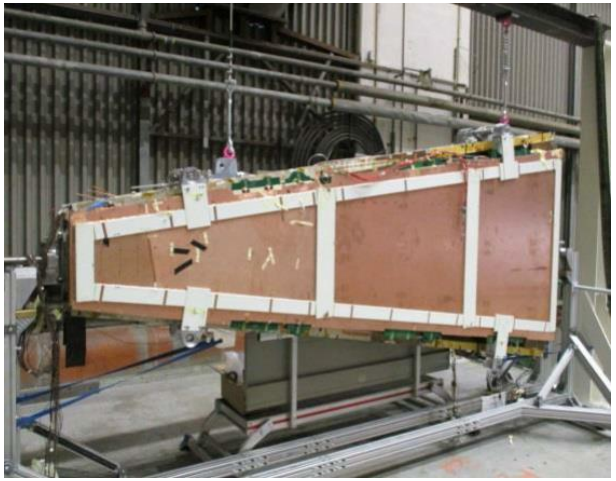
1. Hanging MM from assembly station

2. Installing kinematic mounts

3. Moving sTGC wedges in place



4. Connecting …



5. Remove sTGC end support. Adjust. Survey. Done !

Still a bit in the future: Sector assembly

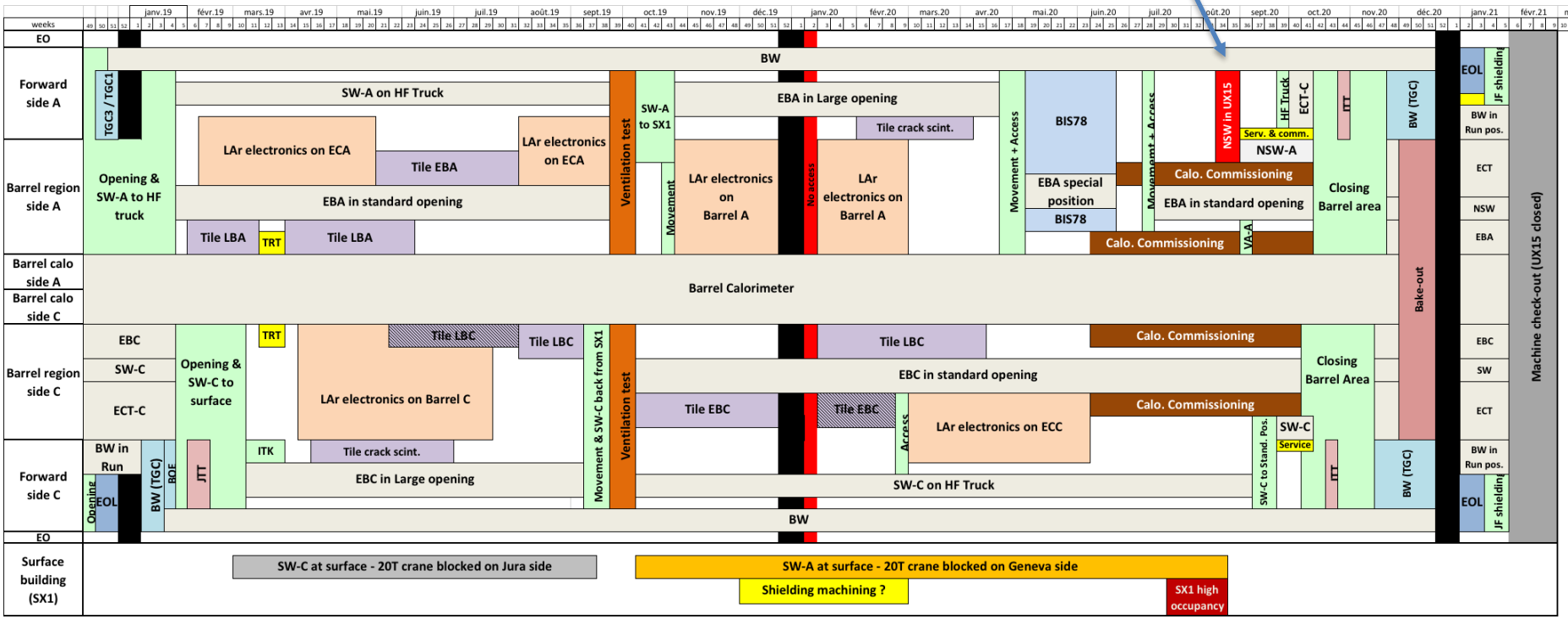
1. Preparing the grabbers

2. Attaching the South Africa lifter/rotator tool

3. Lift and rotate for placement on the NSW and connection ….

Detector commissioning plans

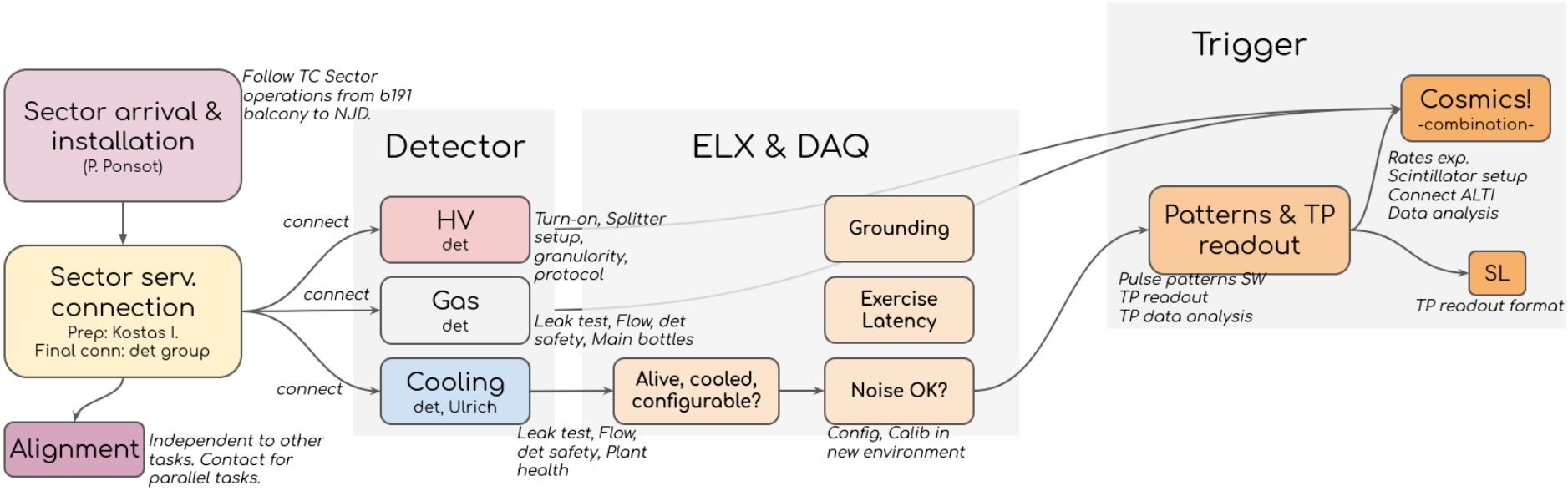
- The NSWs will be fully surface commissioned, in B191, before being transported to P1 for installation into the ATLAS
- This is essential since time, especially with access still possible, is very limited once the wheels are in the cavern



Detector commissioning plans

Commissioning work flow

191 workflow - operation for 1 sector



Currently are preparing infrastructure, gas system, readout system …

NSW Commissioning #1: Positioning

- One beauty of the NSW design is that the alignment system can be used already during sector installation to measure relative position, and guide adjustment
- This step will be done following after sectors are mechanically mounted on the NJD disk
- The procedure is well known and established from the construction of the present Small Wheels
- Results will be validated and confirmed by optical survey (with the help of the CERN geometers)

NSW Commissioning #2: Gas & Cooling

- Once sectors are installed on the NJD, they are connected to the pre-routed cooling and gas pipes
  - Rim electronics crates and LV ICS are installed before and connected to their respective cooling lines

- Sector valves are opened, and impedances adjusted/controlled for each circuit, to ensure equal flushing

- B191 has been equipped with a cooling plant/cooling station that mirrors the one at P1, but for 2 sectors only

- The NSW flexible chain path panel will be connected to gas – flush CO2 for the sTGC, and the operating gas from Micromegas
  - Gas connection left in place throughout the full commissioning, but costs may force us to run sectors under test only at a given time ….

- Redo a leak measurement for the full system (pressure drop), and leak hunt if needed

NSW Commissioning #3: LV + HV

- Connect sectors to pre-installed HV and LV distribution on the NJD

- LV: ICS intermediate converters installed before (rim)
- HV: Will use the NSW-C HV modules in 191 during 2019, or at least half of them. This allows to power the NSW sectors in a final way, and possibly also to do again some longer-term studies (HV operation does not require cooling)

- Power on HV, check for shorts or abnormal currents
  - Final DCS implementation will be used
- Power on LV
  - Read out temperatures of all on-detector cards – validate cooling connections
  - Check voltage values on all on-detector cards (via SCA)

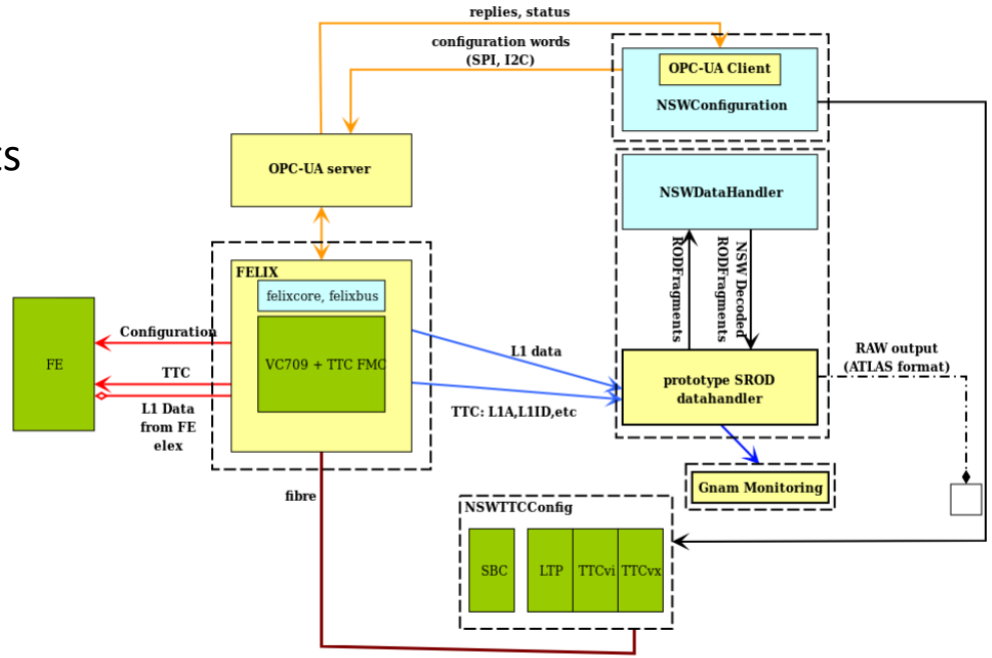
- Once done, configure the sector electronics

NSW Commissioning #4: Readout

After all electronics can be configured,

- Repeat part of the measurements done in BB5 and 180:
  - Determine VMM baseline → store in DB for starting config when the NSW is @ P1
  - Measure noise, ie acquire data with a random trigger
  - Adjust delays and timing (compensate for different fiber lengths) to ensure all hits arrive within the readout wind

Active NSW DAQ working group, but lots of work remains ….



NSW Commissioning #5: Trigger

Final step in NSW commissioning is the trigger

- Will heavily rely on VMM pulsing, using pre-defined patterns of hits which mirror tracks from the IP or other in the cavern

- Full chain including the Trigger processor !

- In B191, test the path up to and including the Sector Logic
- Common effort, with involvement from ATLAS TDAQ L1 community

- Once the NSW is installed in the cavern:
  - Need to time-align it with the Big Wheel and other endcap trigger inputs to the SL
  - Need to establish the relative position alignment --- refine LUTs for ROI definitions

  - Data taking will start in pass-thru mode, and with wide trigger roads

Summary & Conclusions

- The NSW does remain ATLAS' most challenging Phase-1 Upgrade project, and it remains on critical path

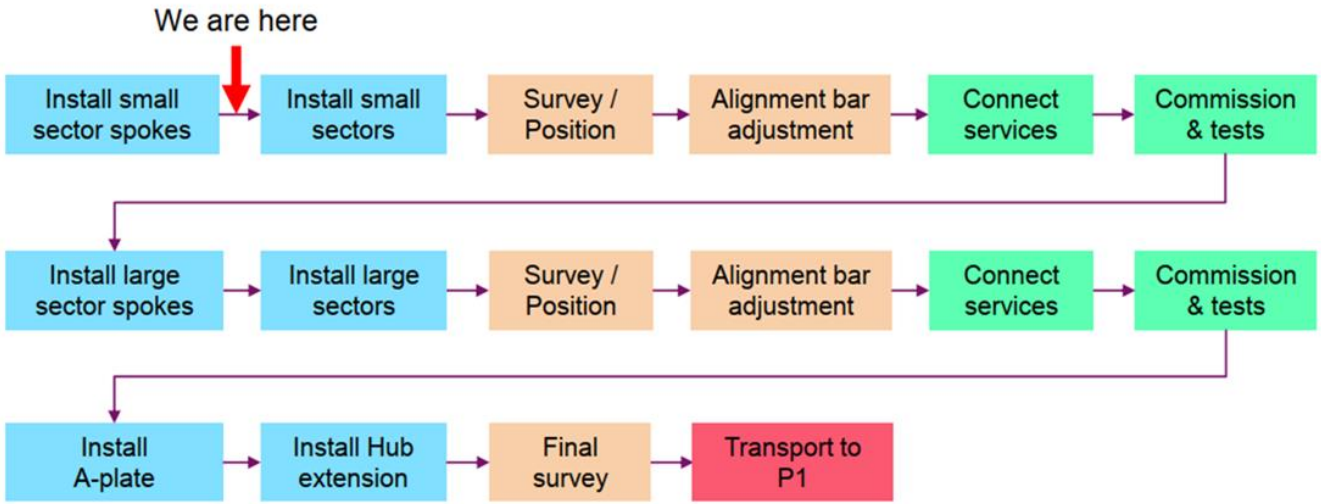
- Many technical difficulties which we faced in the last 2 years have been overcome
- Most notably,
  - Did complete the sTGC cathode board production, and are close to completing the MM readout PCB production together with industry;
  - Believe we understood and "solved" (mitigated) the Micromegas HV problems, and can say we are finally confident that the NSW Micromegas chambers work
  - Understood the VMM baseline issues, and have (so far) a yield which allows to discard chips where more than 2 channels are affected → acceptable
  - Arrived at the final frontend board versions which do show a very good noise behaviour, when mounted on the detectors

Summary & Conclusions

- Chamber and electronics production is in full swing, and will continue throughout most of 2020 for the detectors;
- Electronics should mostly be produced by spring next year, and by end of this year for the NSW-A

- We have equipped the first Micromegas double wedge with its electronics, and are doing the same for the first 2 sTGC wedges

- Once ready, will commence sector installation, and the surface commissioning as the last step in “Making the NSW” !!



Completing the first wheel in time for installation next August remains however a challenge, and is not secured yet !!

Thanks for your attention