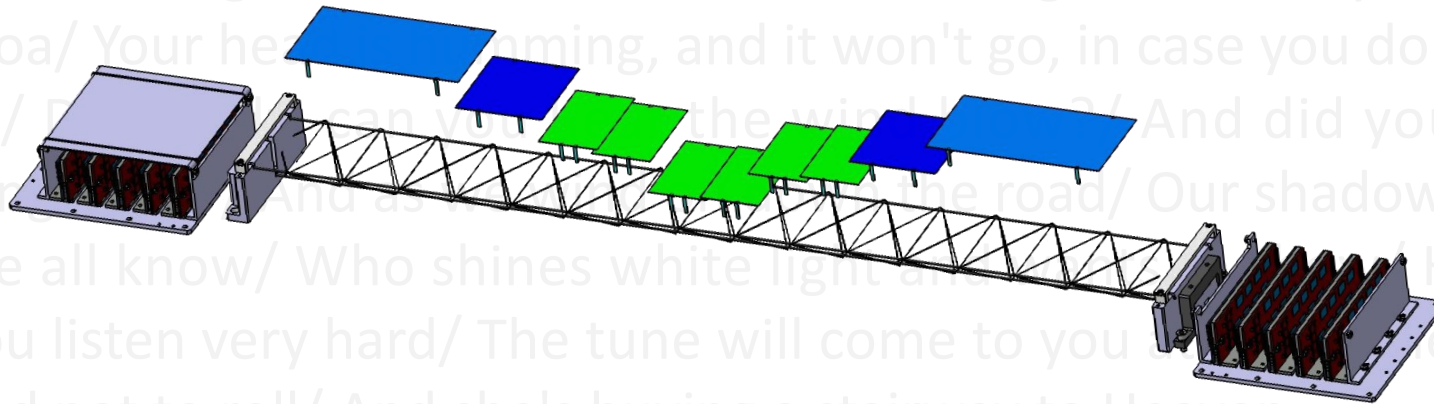


Stairways to heaven: the STS Ladder

46th CBM Collaboration meeting

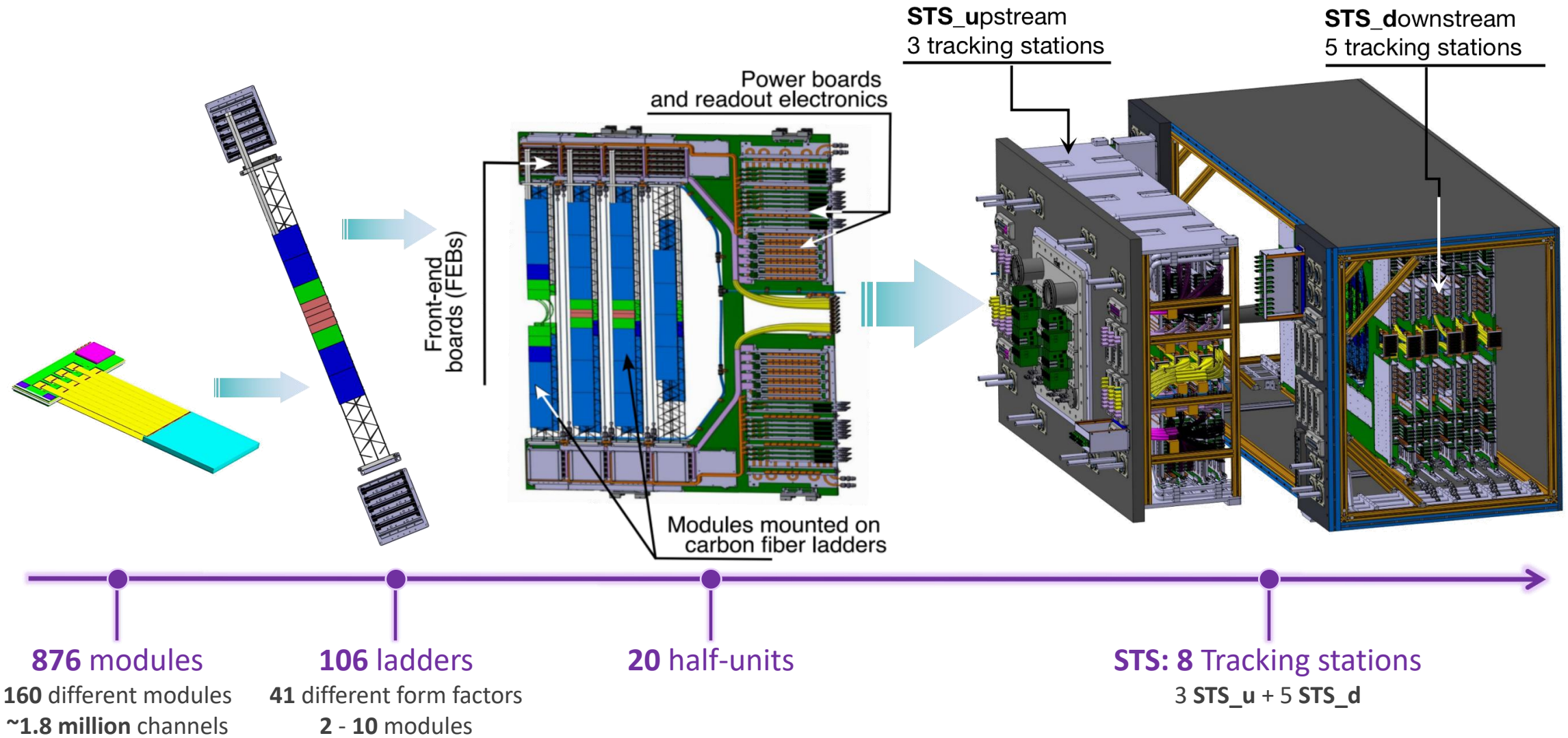
L.M. Collazo Sánchez for the STS team



October 24th , 2025

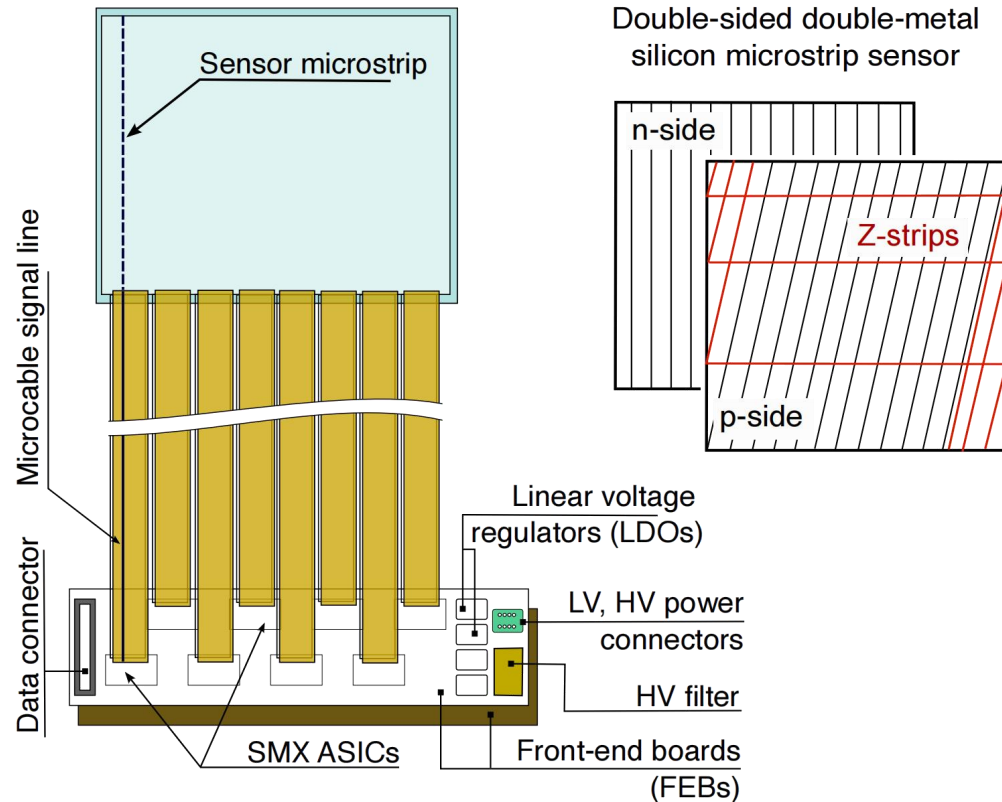
Lanzhou, China

BRIEF INTRODUCTION TO THE SILICON TRACKING SYSTEM OF CBM

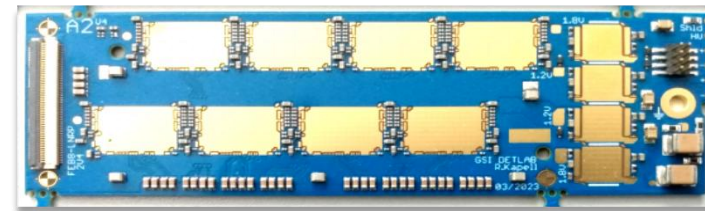
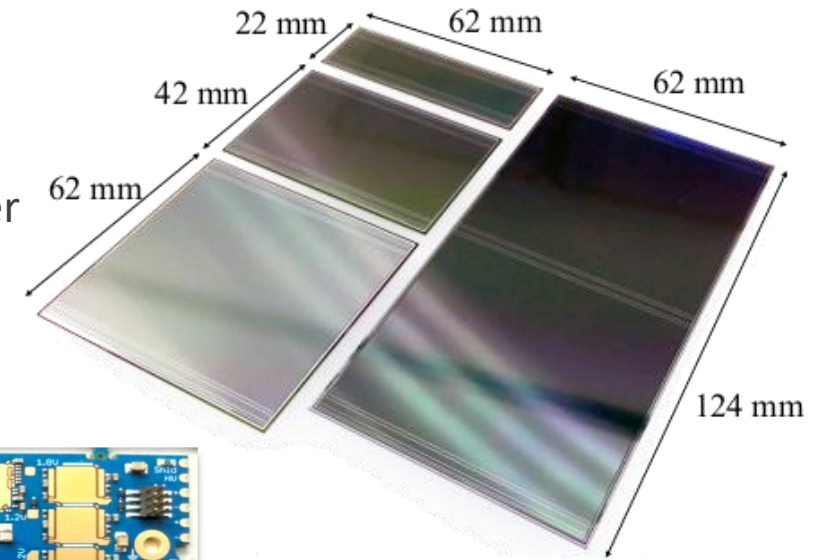


WHAT IS THE STS MODULE?

- 876 modules for STS
- 160 module variants (sensor + microcables)



- Thickness: 320 μm
- 1024 strips per side
- Pitch: 58 μm
- Double metalization layer in p-side
- 32 microcable stacks



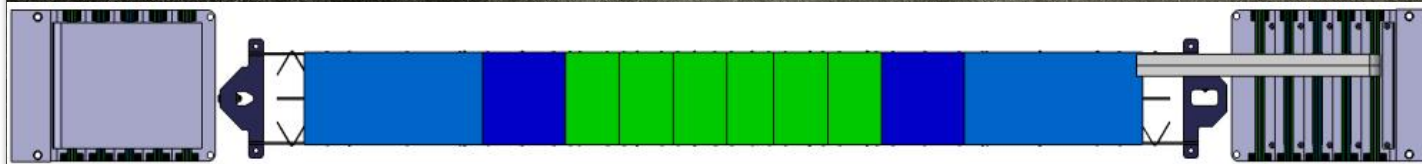
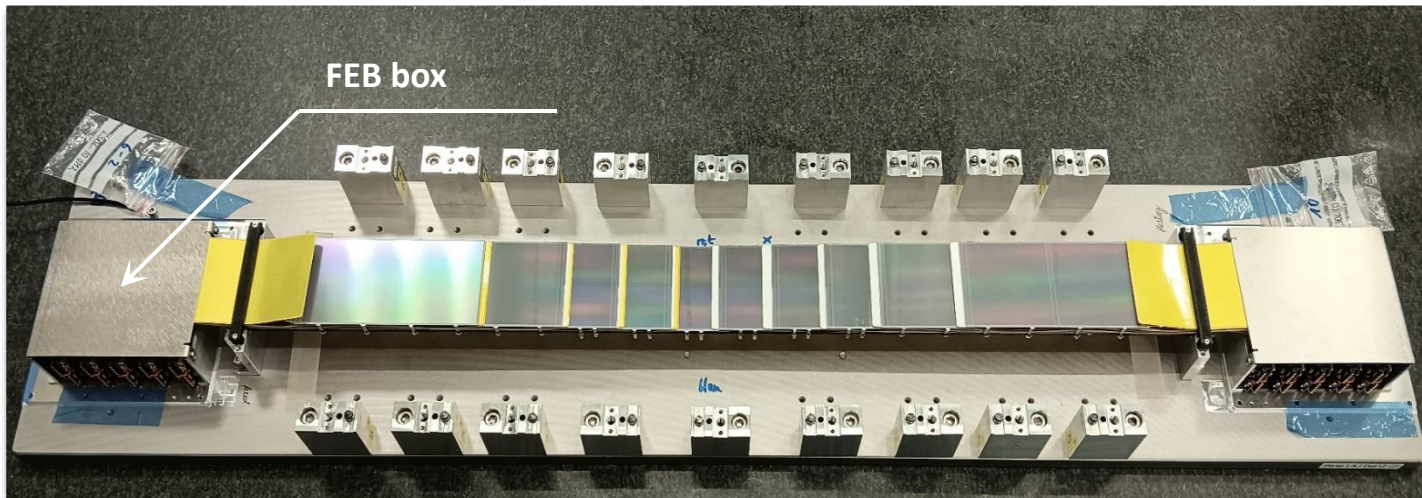
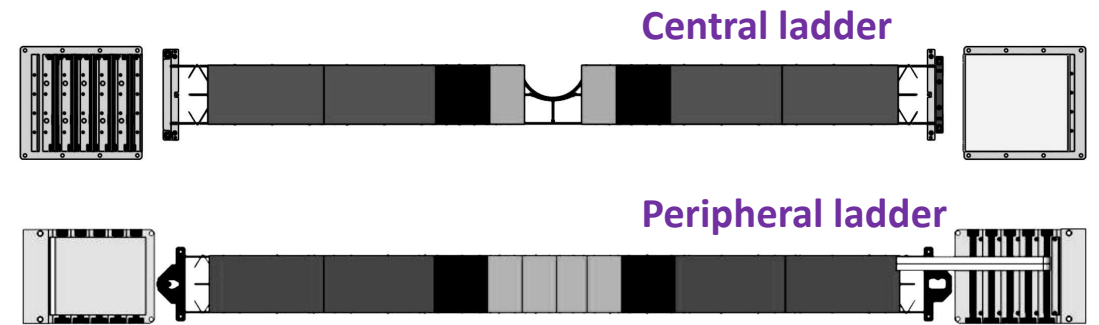
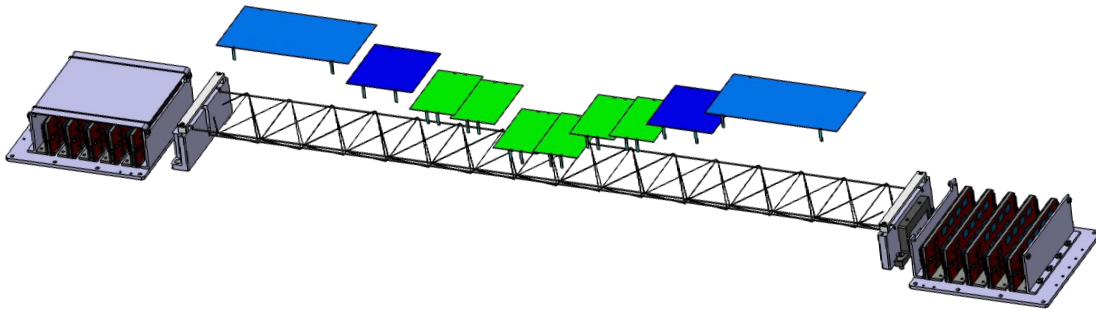
- 8 custom-design ASICs per Front-End Board (FEB)
- 128 channels per ASIC

Schematics of the STS detector module and its main components



STS module before the shielding layers are soldered

WHAT ARE STS LADDERS?



Fully assembled STS ladder carrying 10 modules

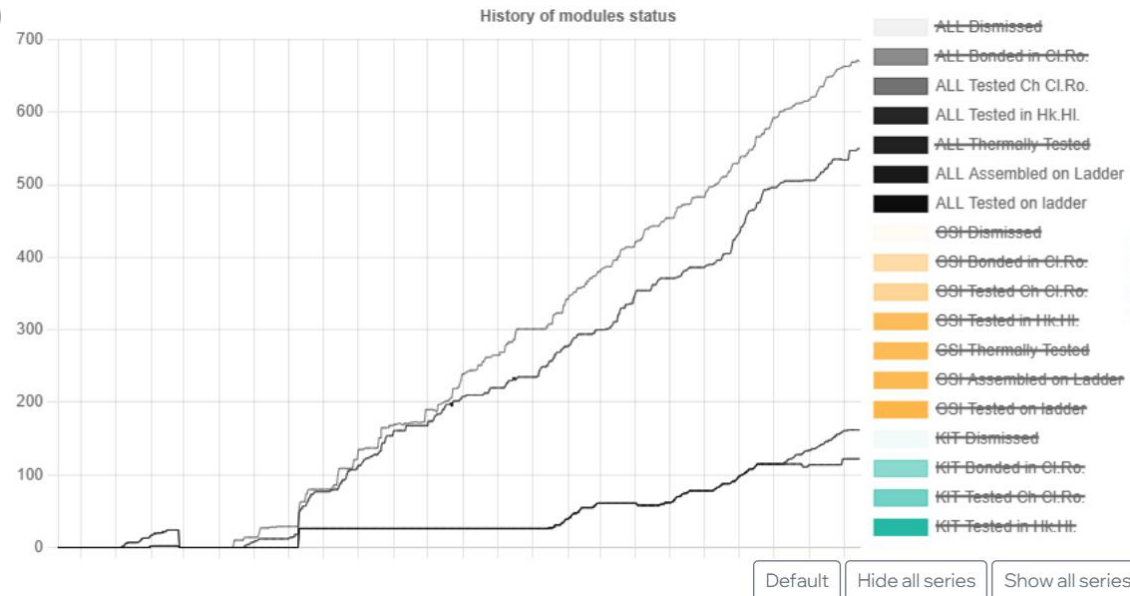
Towards STS full assembly:

- o 106 ladders with different form factors (2-10 modules per ladder)

ASSEMBLY & TESTING STATUS

Where is STS today in terms of Assembly and Testing?

- o Data/Status can be consulted under: [STS database](#)
- o Up to today **672** modules have been [PRODUCED](#) (77%)
- o **550** modules have been [TESTED](#) (63%)
- o Already **21** ladders have been [BUILT](#) with **162** out of the **550** tested modules (18%)
- o From them **15** ladders have been fully [TESTED](#) with **122** out of the **162** modules (14%)



Module statuses - All (GSI, KIT)

	Total		GSI		KIT		
	#	%	#	%	#	%	
122	14	99	80	23	20		Tested on ladder
162	18	125	80	37	20		Assembled on Ladder
550	63	367	70	183	30		Tested in Hk.Hl.
552	63	367	70	185	30		Undef. status at Hk.Hl.
582	66	394	70	188	30		Test started in Hk.Hl.
582	66	394	70	188	30		Tested HV in Cl.Ro.
672	77	448	70	224	30		Tested Ch Cl.Ro.
675	77	448	70	227	30		Bonded in Cl.Ro.
6	1	1	20	5	80		Wrongly built
34	4						Rebuilt modules
197	22	53	30	144	70		Reserved

ASSEMBLY & TESTING STATUS

How do they distribute in STS?



Ladders

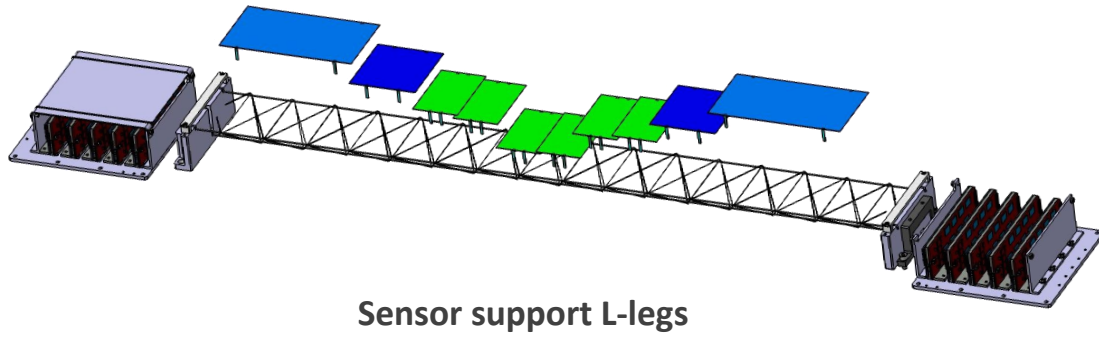
☒ **ASSEMBLED: 21**
☒ **TESTED: 15**
☒ **FAILED: 1**

0D		L0DR300010		L0DR100009		L0DL000150		L0DL200109										
1U			L1UR201109		L1UR001151		L1UL101009		L1UL301010									
1D		L1DR400010		L1DR200009		L1DR000051		L1DL100109		L1DL300110	L1DL500111							
2U		L2UR501130		L2UR301129		L2UR101128		L2UL001052		L2UL201028		L2UL401029						
2D		L2DR500014		L2DR300012		L2DR100012		L2DL000153		L2DL200112		L2DL400113						
3U			L3UR401113		L3UR201112		L3UR001154		L3UL101012		L3UL301012		L3UL501014					
3D		L3DR600015		L3DR400013		L3DR200012		L3DR000054		L3DL100112		L3DL300112		L3DL500114				
4U			L4UR501133		L4UR301131		L4UR101131		L4UL001055		L4UL201031		L4UL401032		L4UL601034			
4D			L4DR500018		L4DR300017		L4DR100016		L4DL000161		L4DL200116		L4DL400117		L4DL600119			
5U			L5UR601119		L5UR401117		L5UR201116		L5UR001156		L5UL101016		L5UL301017		L5UL501018			
5D			L5DR600019		L5DR400017		L5DR200016		L5DR000056		L5DL100116		L5DL300117		L5DL500118			
6U				L6UR501137		L6UR301136		L6UR101135		L6UL001057		L6UL201035		L6UL401036		L6UL601038		
6D		L6DR700021		L6DR500025		L6DR300020		L6DR100020		L6DL000158		L6DL200120		L6DL400120		L6DL600127		
7U			L7UR601126		L7UR401139		L7UR201139		L7UR001159		L7UL101039		L7UL301039		L7UL501040		L7UL701041	
7D			L7DR600024		L7DR400022		L7DR200022		L7DR000060		L7DL100122		L7DL300122		L7DL500123		L7DL700126	
8U			L8UR701126			L8UR501123		L8UR301122		L8UR101122		L8UL001060		L8UL201022		L8UL401022		L8UL601024

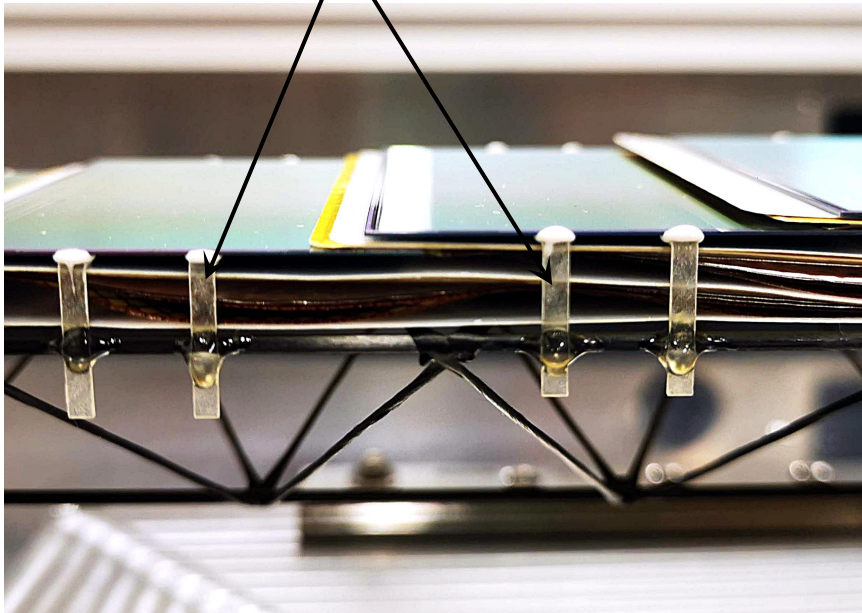
OUTLINE

- **LADDER ASSEMBLY & METROLOGY**
- **LADDER TESTING SETUPS**
- **TESTING PROTOCOL**
- **OVERALL RESULTS**
- **ENCOUNTERED ISSUES & SOLUTIONS**
- **SUMMARY & OUTLOOK**

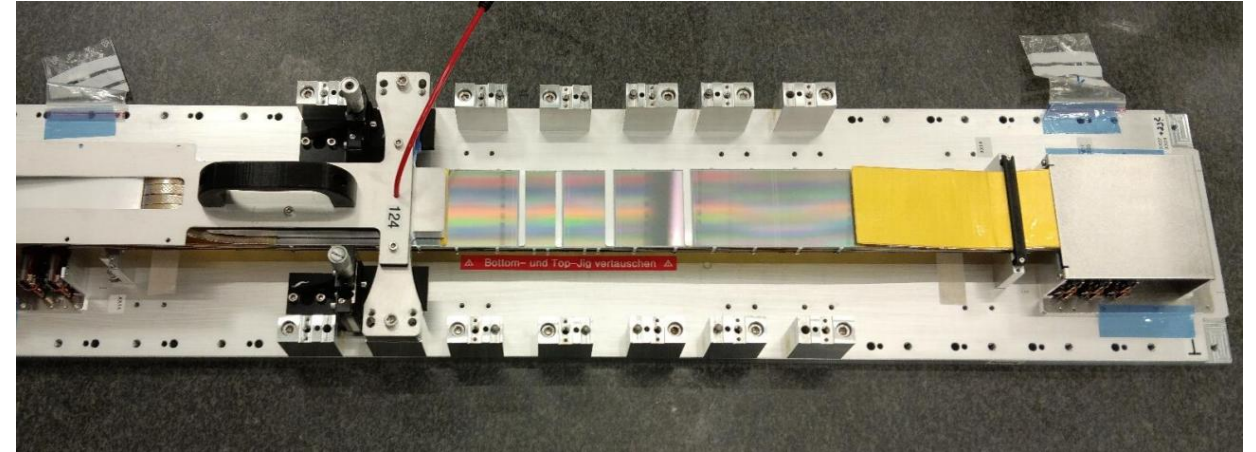
LADDER ASSEMBLY



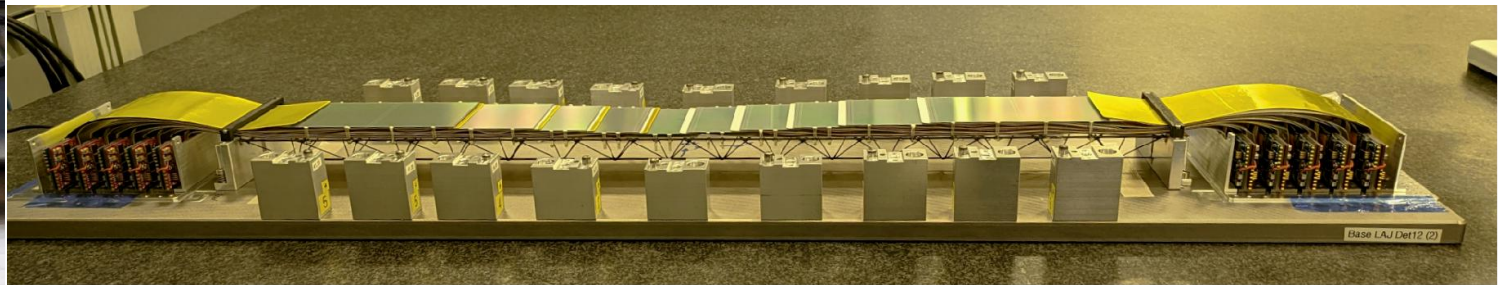
Sensor support L-legs



Detail of an assembled ladder, where sensors can be seen glued to the so-called "L-legs"



Fully assembled STS ladder carrying 10 modules

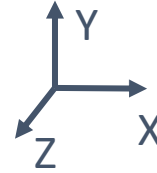


Fully assembled STS ladder carrying 10 modules

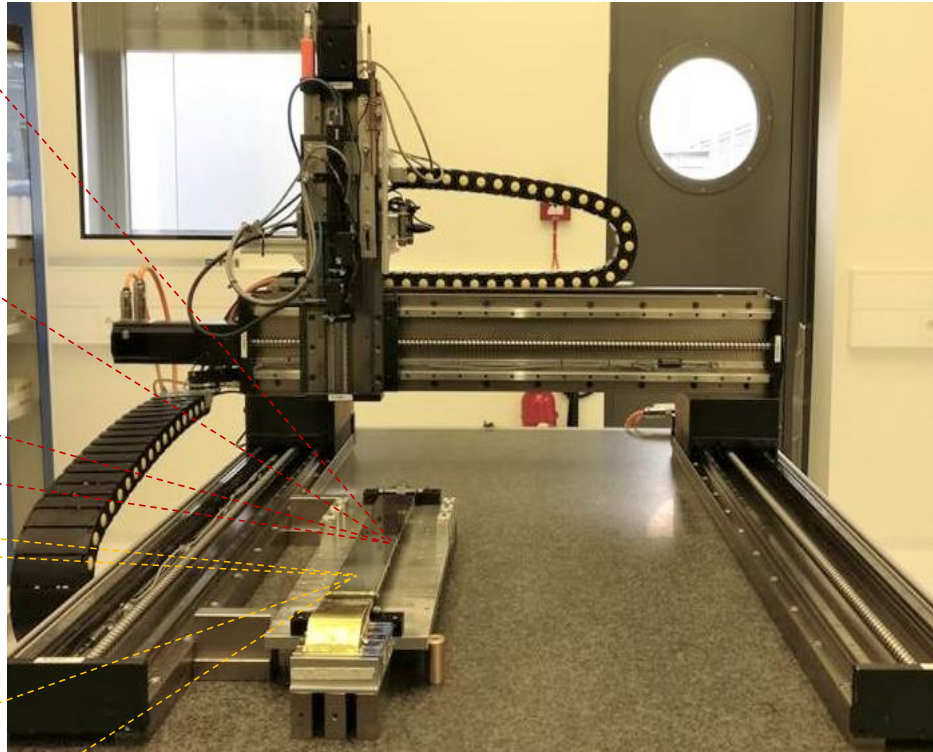
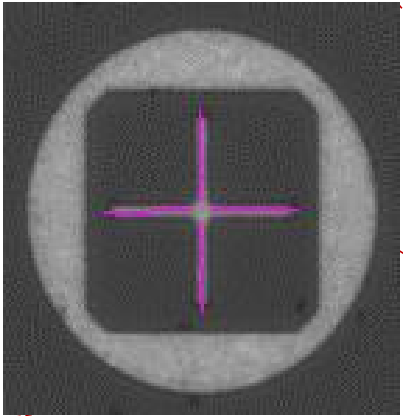
LADDER METROLOGY

Setup to evaluate ladder assembly based on optical inspection of the sensor surface with precision better than $10\text{ }\mu\text{m}$

- XY based on pattern recognition
- Z (high) based on focus variation



marker on the sensor



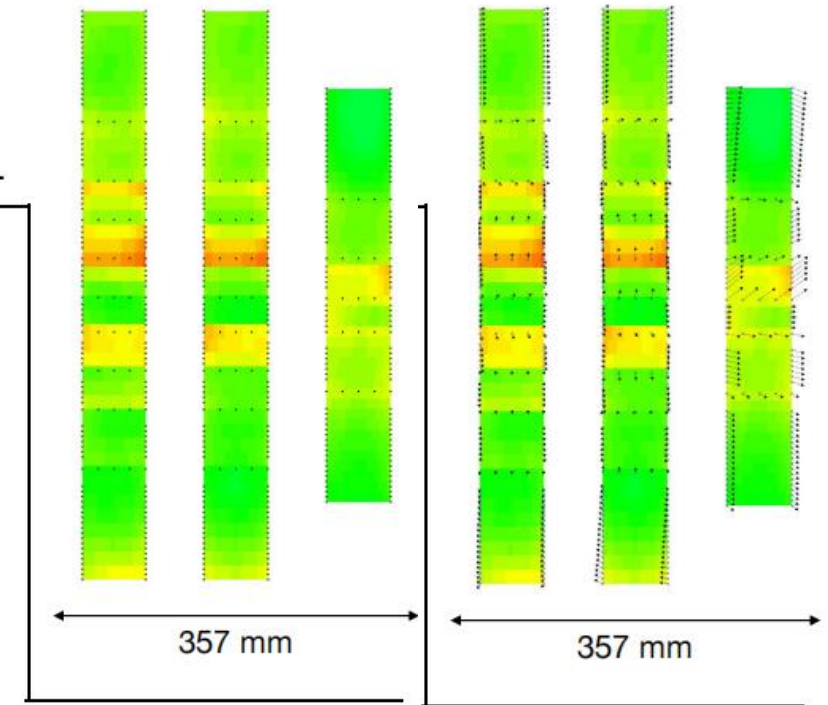
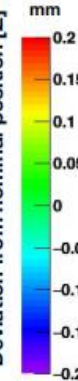
Optical inspection setup



strips on the sensor

Unit3D L

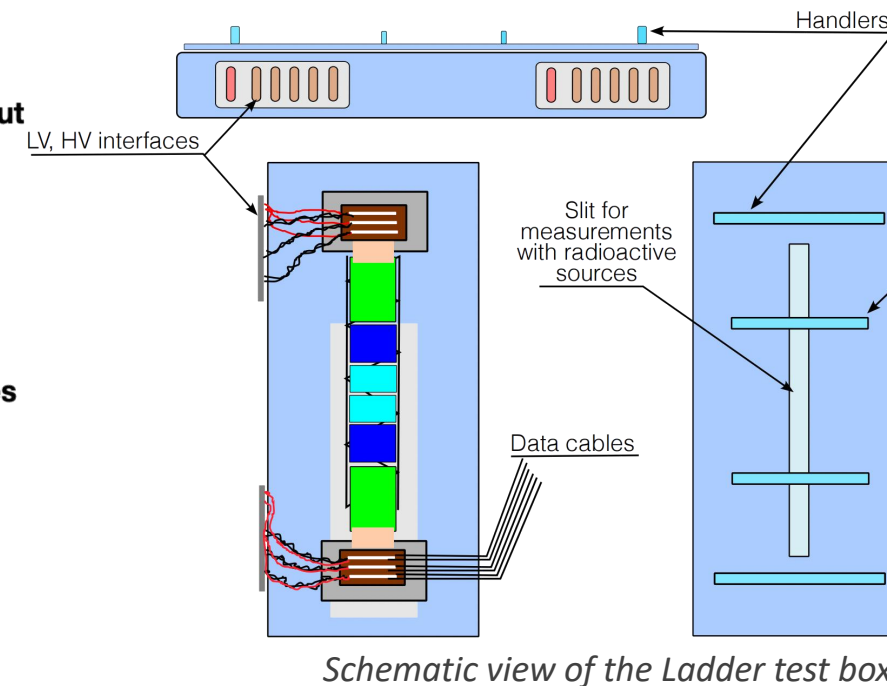
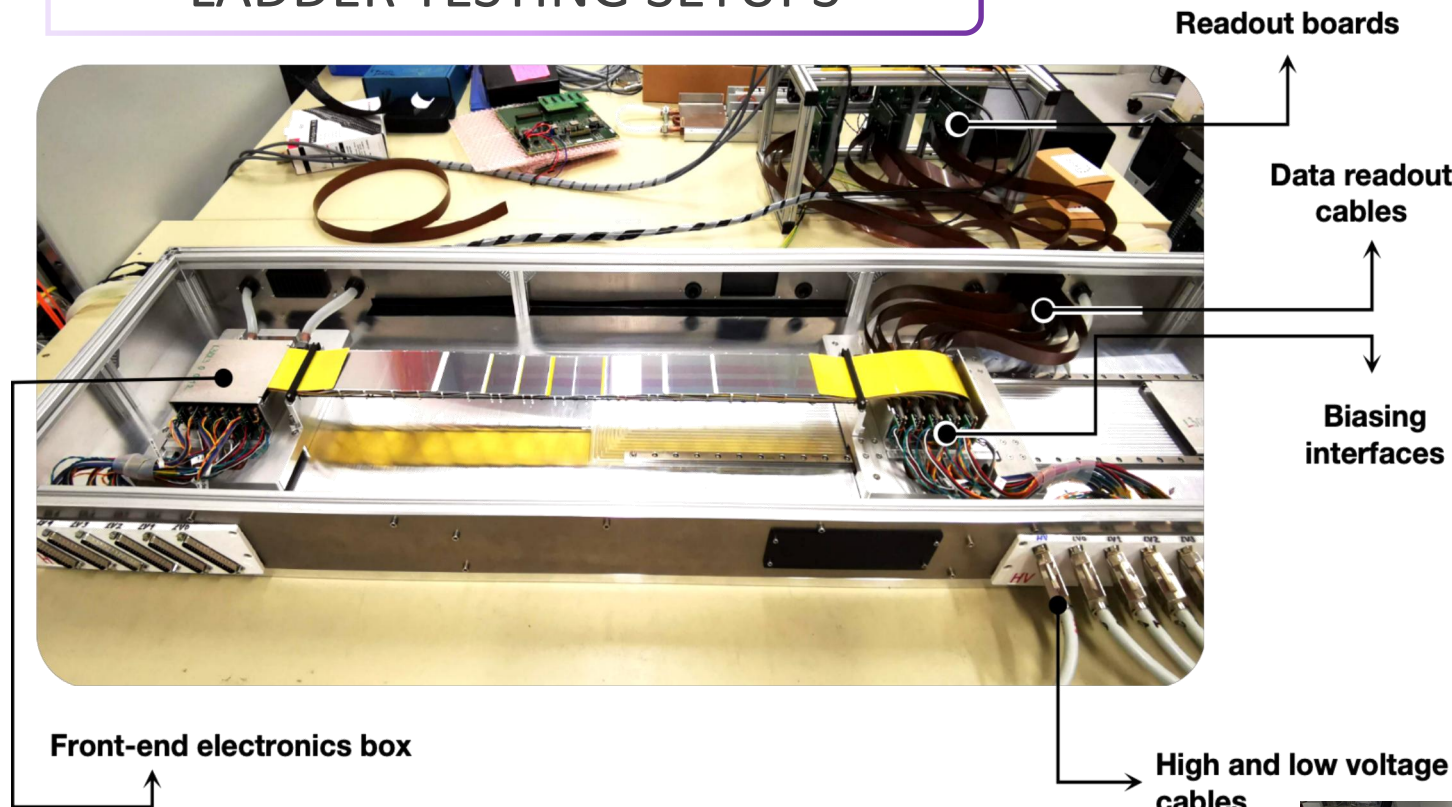
Deviation from nominal position [Z]
mm



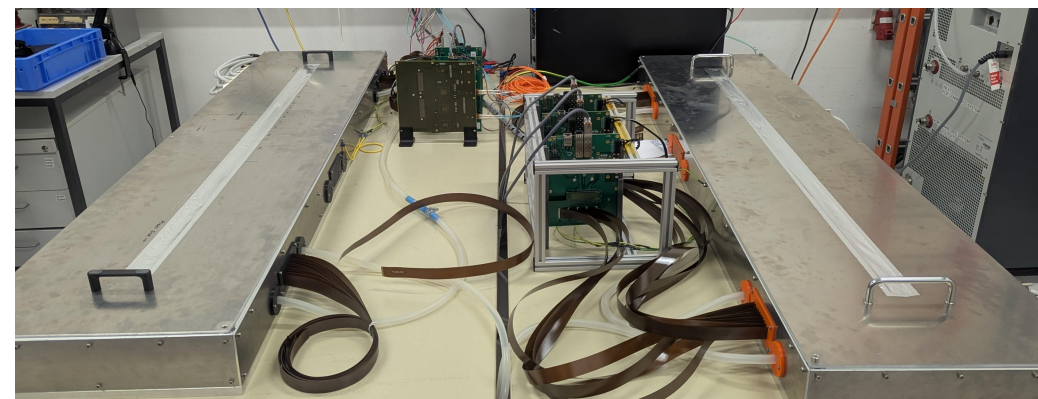
XY deviations enhanced factor 100

Optical inspection confirmed the precise mounting of sensors, meeting the STS requirement of $\sim 100\text{ }\mu\text{m}$ accuracy

LADDER TESTING SETUPS



- Modular design that can accommodate all ladder types
- All interfaces for operation (LV, HV, data readout, cooling)
- Light tight, EMI protection
- Slit for measurements with radioactive sources
- Two testing stations are used to streamline ladder testing

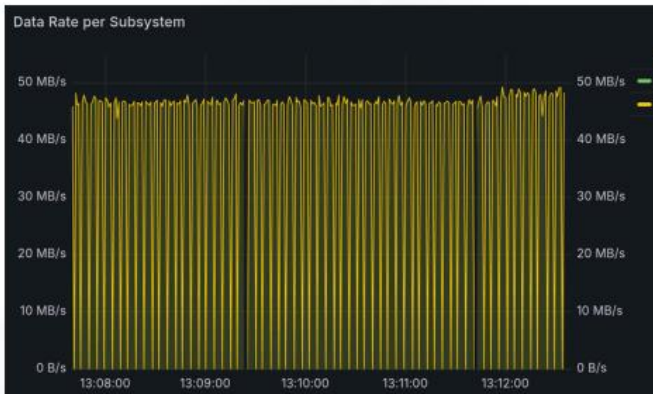
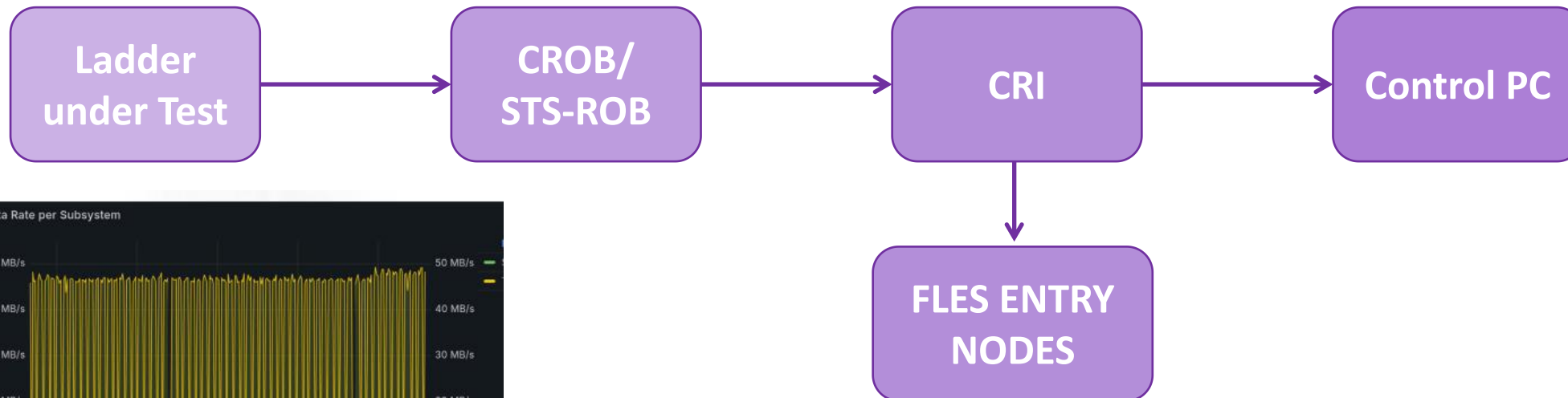


LADDER TESTING SETUPS: READOUT CHAIN

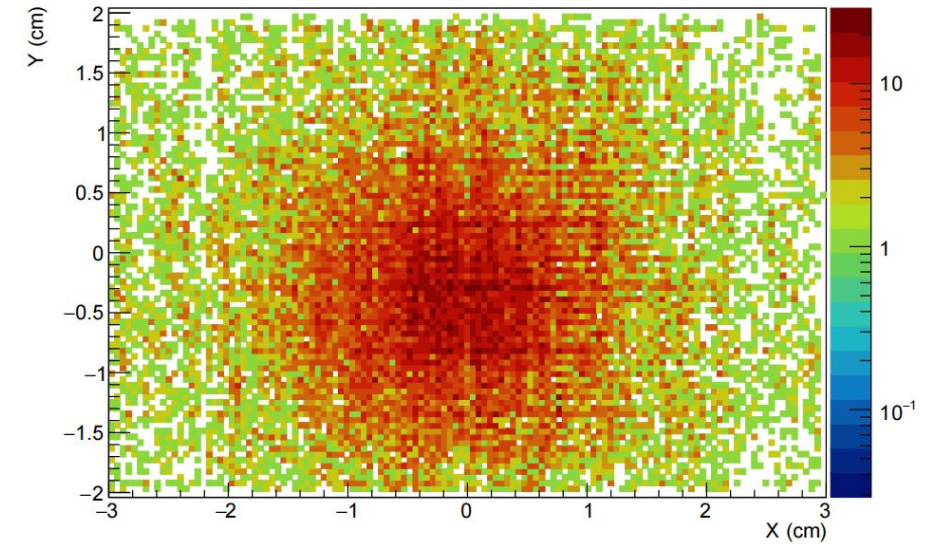
Existing readout chain



New & Final Test readout chain



- Multi-Source real-time monitoring
- Same monitoring functionalities as in mCBM



$^{90}\text{Sr}/\text{Y}$ source spot measured with a module of ladder L3DL100112. Channel artefacts linked to the limited readout bandwidth.

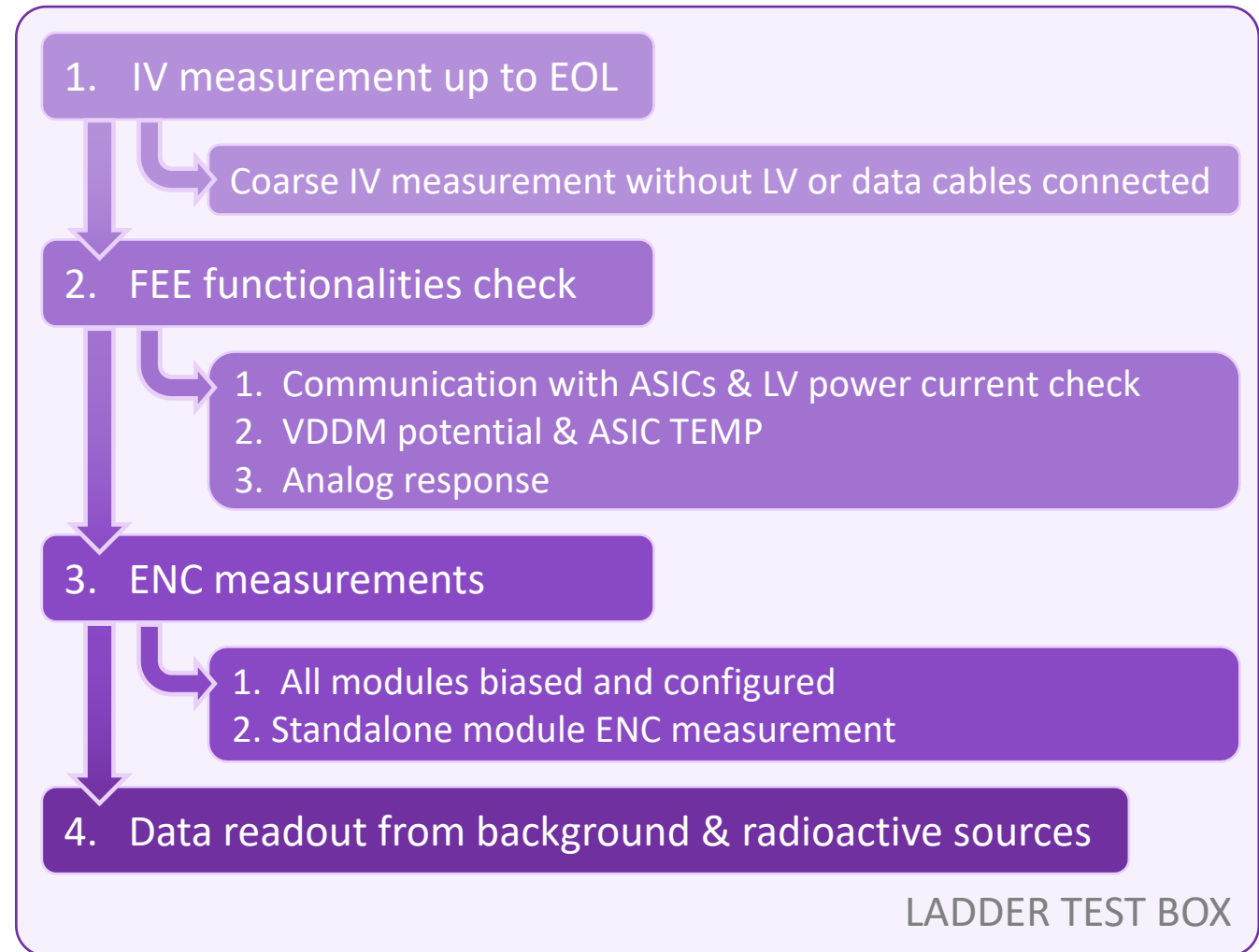
TESTING PROTOCOL

Two main points to address with the assembly and testing of ladders:

- Quality of the assembled ladders
- Functional performance of the modules on the ladders

Simplified protocol for ladder testing:

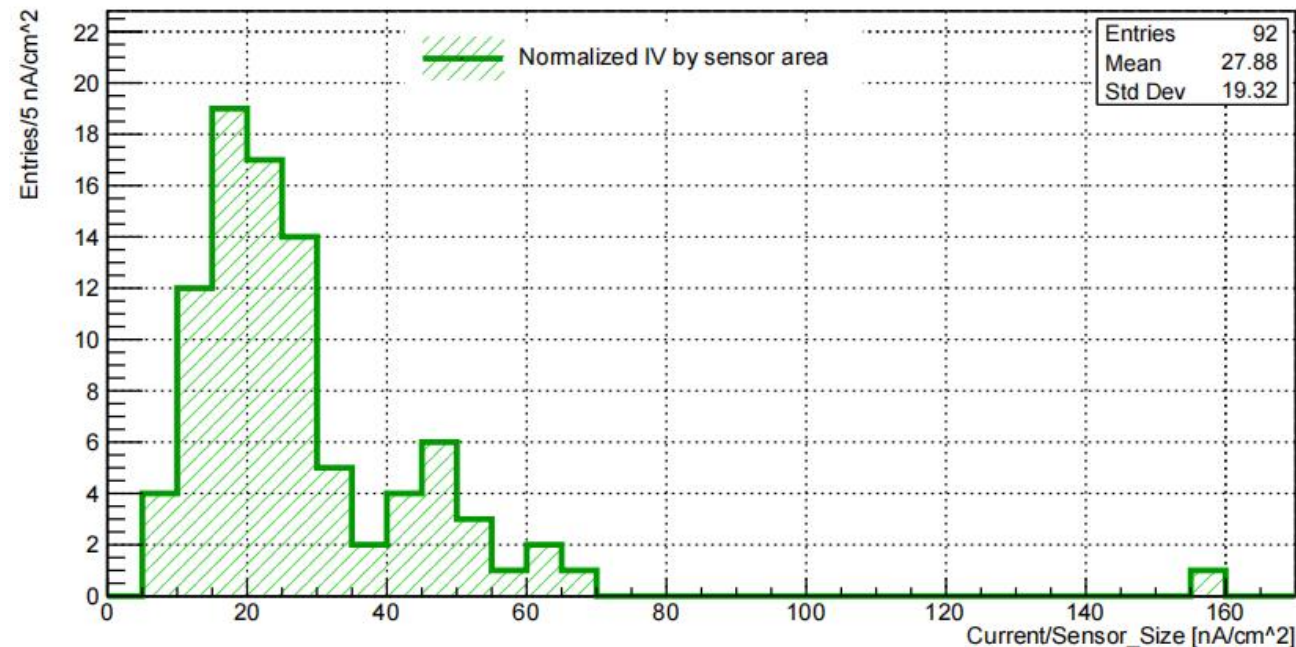
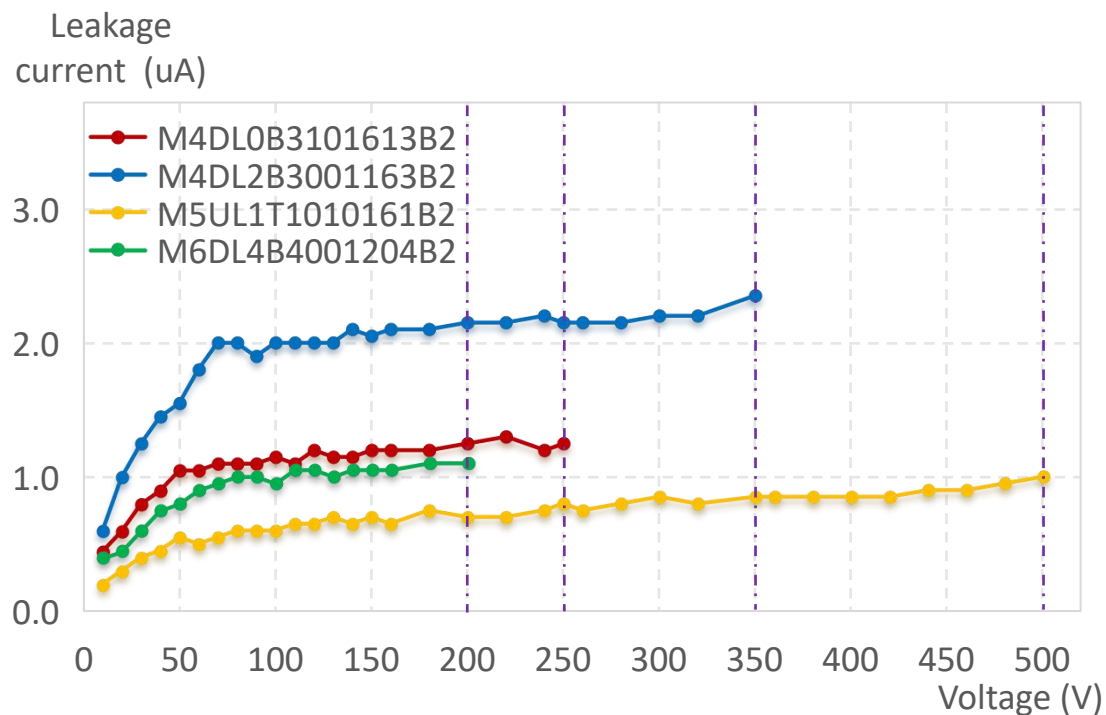
- Derived mostly from the gained experience with module testing.
- For the first-of-series ladders, other tests were also included to study in more detail noise levels and signal response



OVERALL RESULTS: IV

IV measurement with low resolution ($0.1\mu\text{A}$) HV power supply and LV cables unconnected:

- Up to projected End-of-Life (EOL) based on sensor grade [A (500 V), B (350 V), C (250 V), D (200 V)]



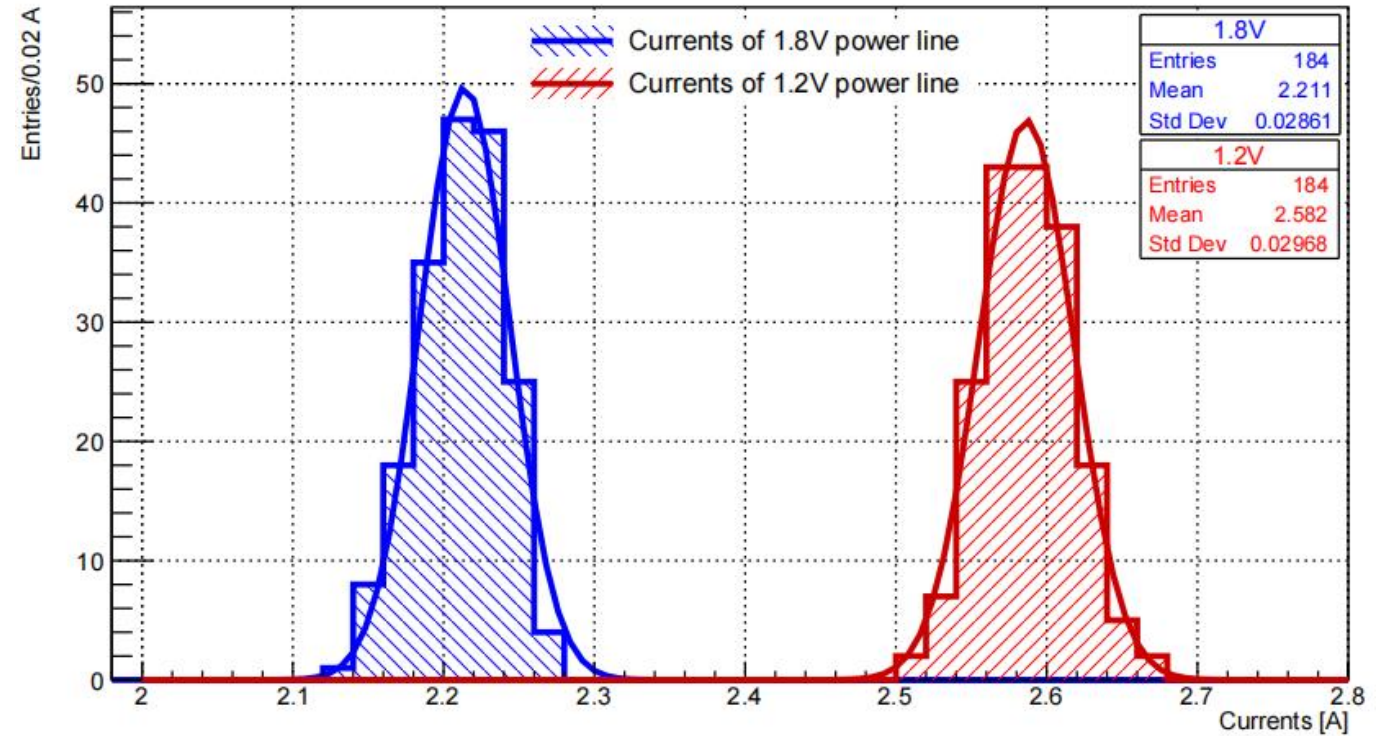
Sensor current measured at 150 V during IV measurements. The values are normalized by sensor area.

FINDINGS: All sensors from the tested ladders can be biased up to the voltage required at EOL

OVERALL RESULTS: FEE FUNCTIONAL TEST

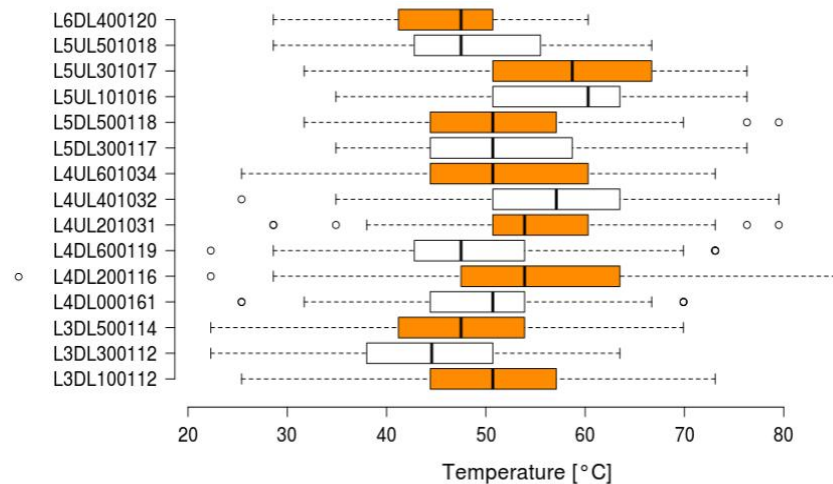
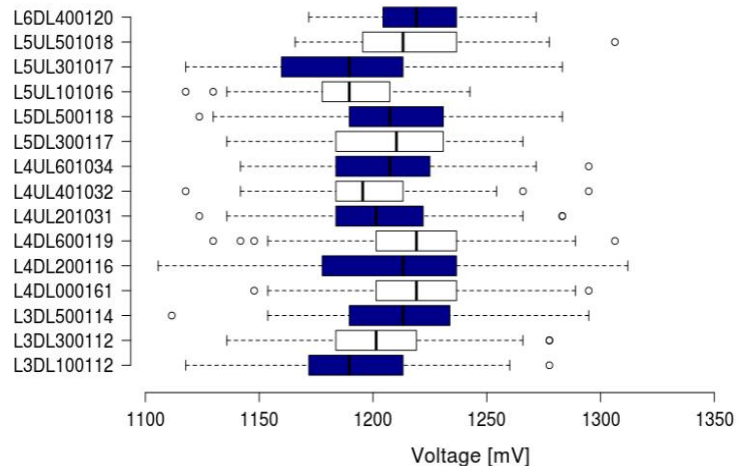
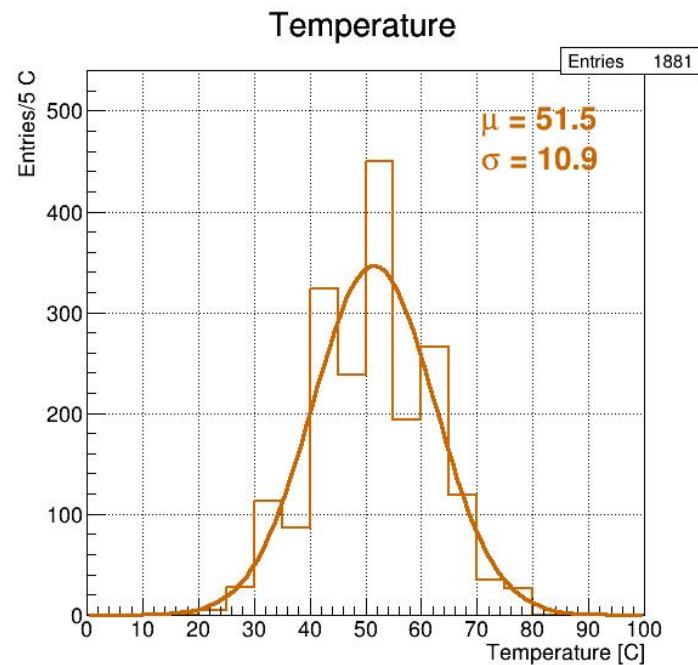
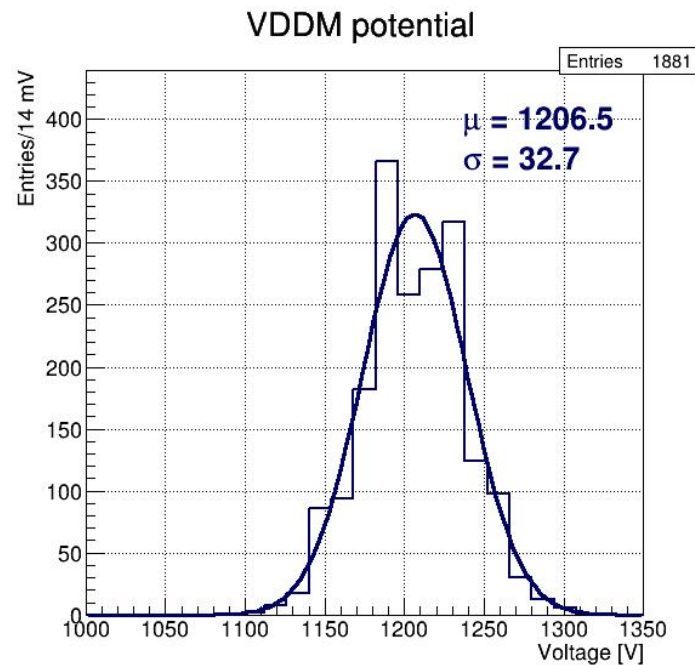
Functional test for all modules on ladders:

Communication w/ ASICs	1888/1888
Register W/R	✓
LV power current check	2.58 A (1.2 V)/ 2.21 A (1.8 V)
Analog front-end issues	4/1888



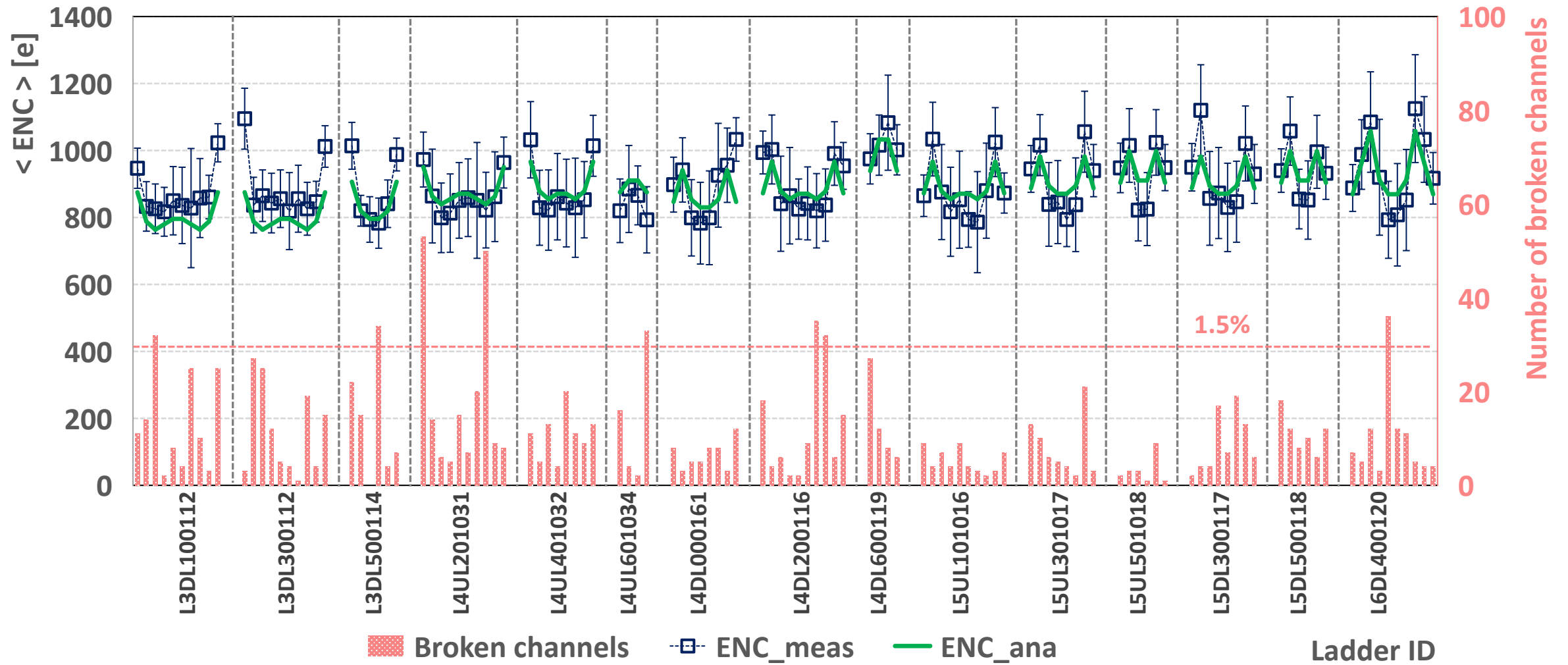
Current consumption measured for the two main power domains of the Front-End Electronics during testing. The red histogram represents the current distribution of the 1.2 V analog power domain, while the blue histogram shows the currents of the 1.8V power line, which combines the analog and digital domains.

OVERALL RESULTS: FEE FUNCTIONAL TEST



Distributions of ASIC operating potential (VDDM) and ASIC temperatures (TEMP) measured for all modules in ladders.

OVERALL RESULTS: ENC CHARACTERIZATION



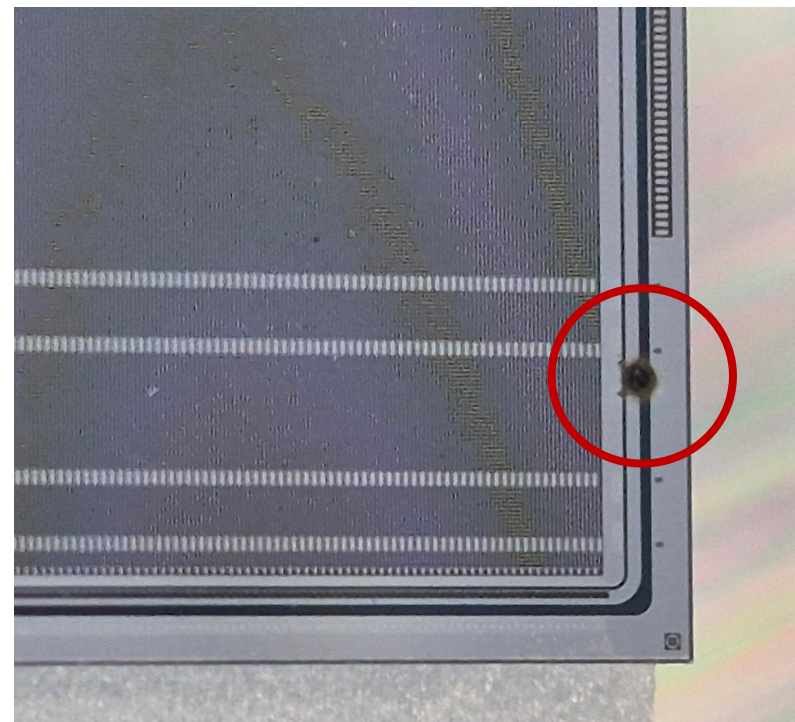
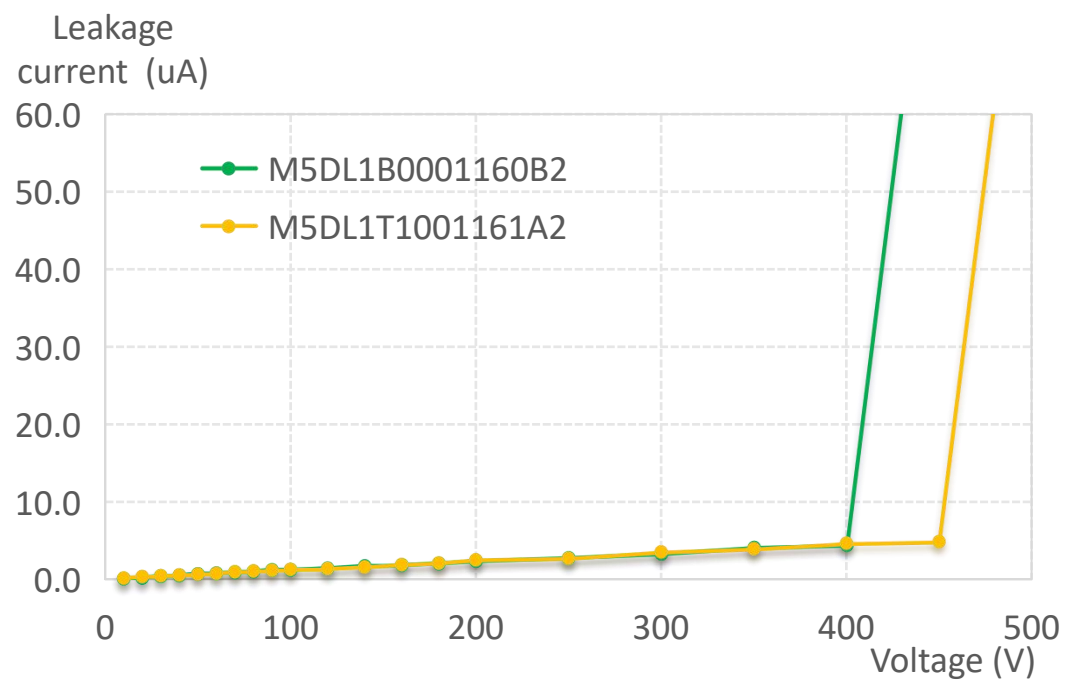
Noise values measured for each N-side module mounted on a ladder. All modules were biased at 150 V and fully configured. The average noise behavior is consistent with the ENC parametrisation based on the overall capacitance. Number of broken channels within the guiding lines of STS.

There's a lady who's sure all that glitters is gold 🎵 / And she's buying a stairway to Heaven/ When she gets there she knows, if the stores are all closed/ With a word she can get what she came for/ Ooh, ooh, and she's buying a stairway to Heaven/ There's a sign on the wall, but she wants to be sure/ 'Cause you know sometimes words have two meanings/ In a tree by the brook, there's a songbird who sings/ Sometimes all of our thoughts are misgiven/ Ooh, it makes me wonder/ Ooh, makes me wonder/ There's a feeling I get when I look to the West/ And my spirit is crying for leaving/ In my thoughts I have seen rings of smoke through the trees/ And the voices of those who stand looking/ Ooh, it makes me wonder/ Ooh, really makes me wonder/ And it's whispered that soon if we all call the tune/ Then the piper will lead us to reason/ And a new day will dawn for those who stand long/ And the forests will echo with laughter/ If these words could burst from your mouth and bustle in your hedgerow, don't be alarmed now/ It's just a spring clean for the May queen/ Yes, there are two paths you can go by, but in the long run/ There's still time to change the road you're on/ And it makes me wonder/ Ohh, whoa/ Your head is humming, and it won't go, in case you don't know/ The piper's calling you to join him/ Dear lady, can you hear the wind blow?/ And did you know/Your stairway lies on the whispering wind?/ And as we wind on down the road/ Our shadows taller than our soul/ There walks a lady we all know/ Who shines white light and wants to show/ How everything still turns to gold/ And if you listen very hard/ The tune will come to you at last/ When all are one, and one is all/ To be a rock and not to roll/ And she's buying a stairway to Heaven.

ENCOUNTERED ISSUES & SOLUTIONS

L5DL100116:

- All modules were biased at the same time to measure the IV
- LV and data cables were connected



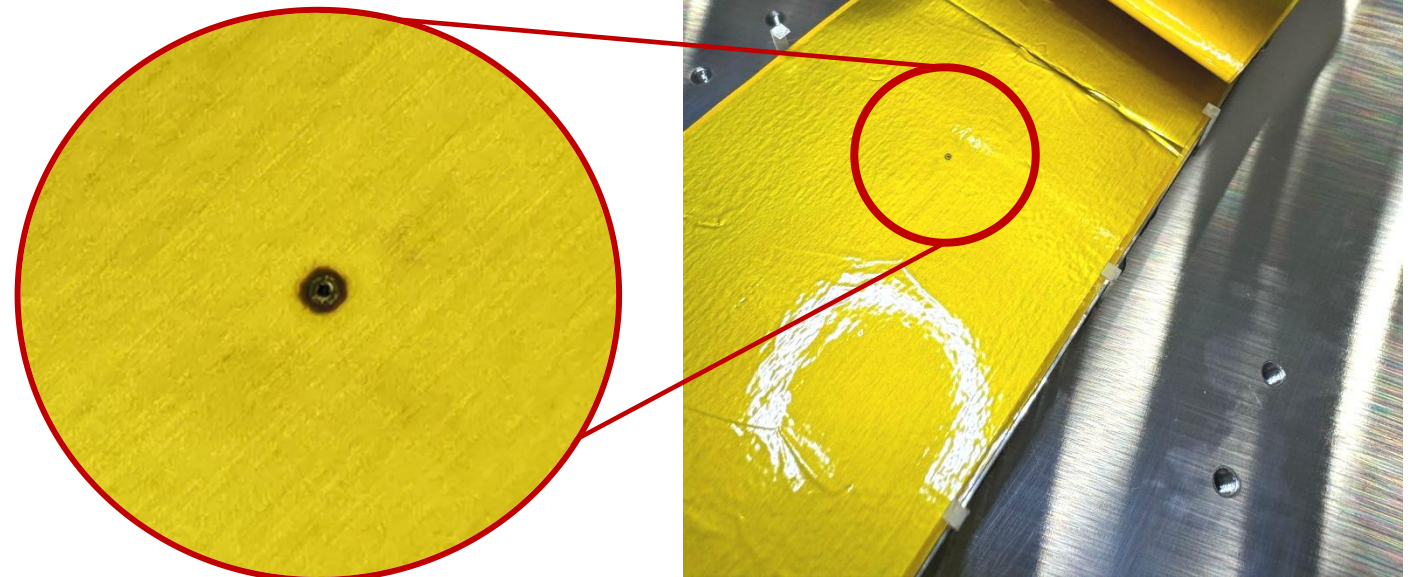
Discharge onto HV-ring of B0 sensor

ENCOUNTERED ISSUES & SOLUTIONS

L5DL100116:

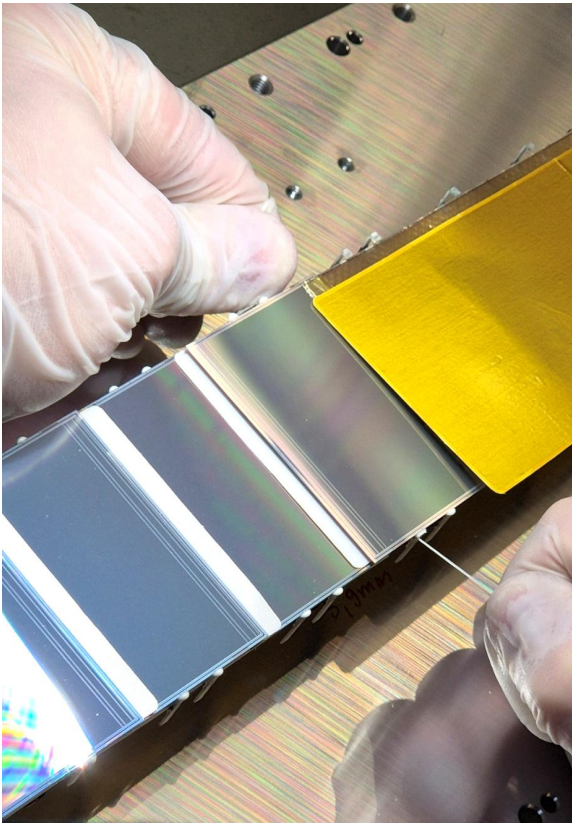
The T1 breakdown triggered multiple malfunctions in the setup:

- The LV PS lost communication with the software
- The EMU board, where T0 and T1 were connected, failed along with the uplink_1 driver on the n-side for T0 and the p-side for T1



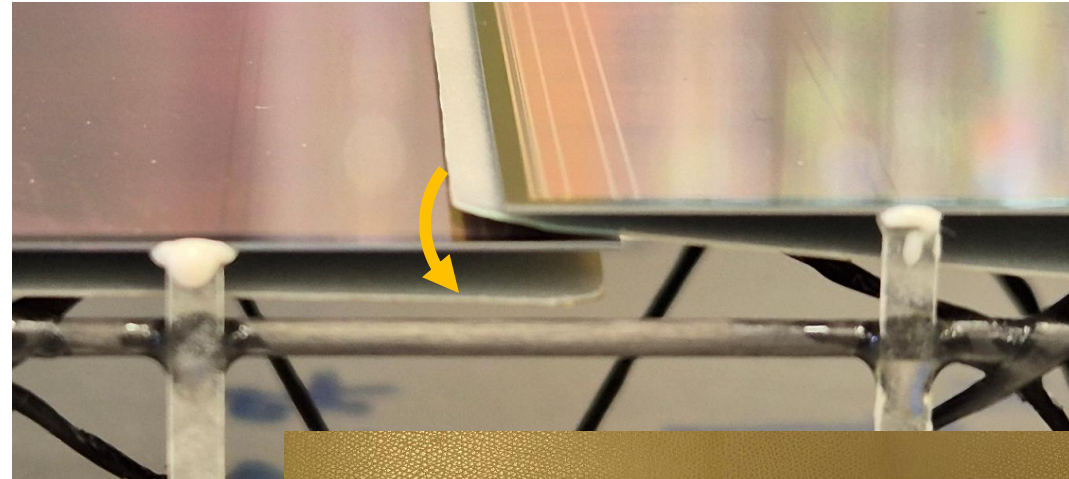
RESULT: Three non-functional modules

ENCOUNTERED ISSUES & SOLUTIONS



L5DL100116: Solutions

- An extra isolation layer of 7.5 um Polyimide (Kapton) was added to each shieling of modules with grade A (500 V)
- Modifications in the IV measurement procedure: LV and data cables are not connected when measuring IV



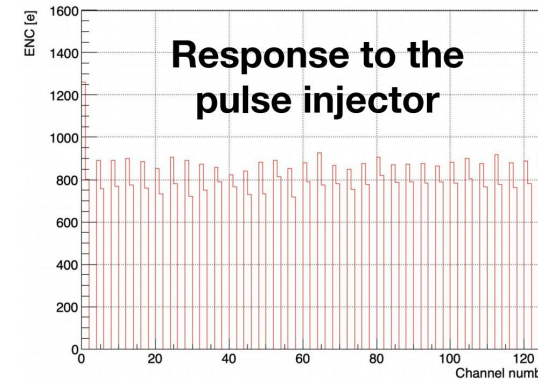
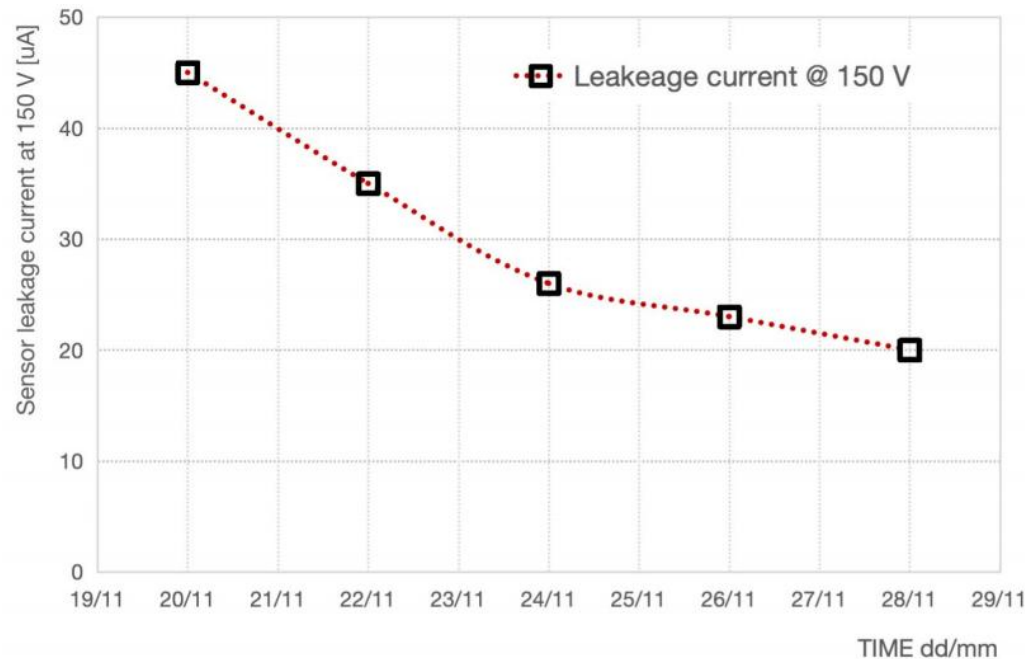
The three non-functional modules:

A procedure was elaborated to dismount modules from an assembled ladder without compromising function → **This makes everything less monolithic**

ENCOUNTERED ISSUES & SOLUTIONS

A module with a high sensor leakage current may indicate humidity or some form of charge-up.

Solution: Biasing the sensor for several hours, which will allow the leakage current to relax over time.

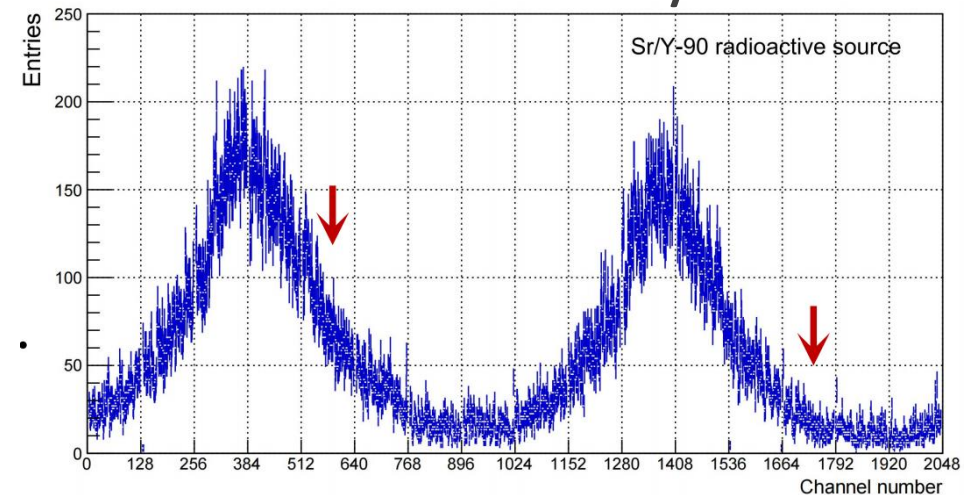


ASIC with problematic analog responses to injected pulses

How to know is not a problematic ASIC?

- Monitoring the noise events in the counter indicates that the AFE of all channels was functioning properly.
- The analog functionalities on the ASICs were verified using $^{90}\text{Sr}/\text{Y}$ measurements.

Measurements with $^{90}\text{Sr}/\text{Y}$ source

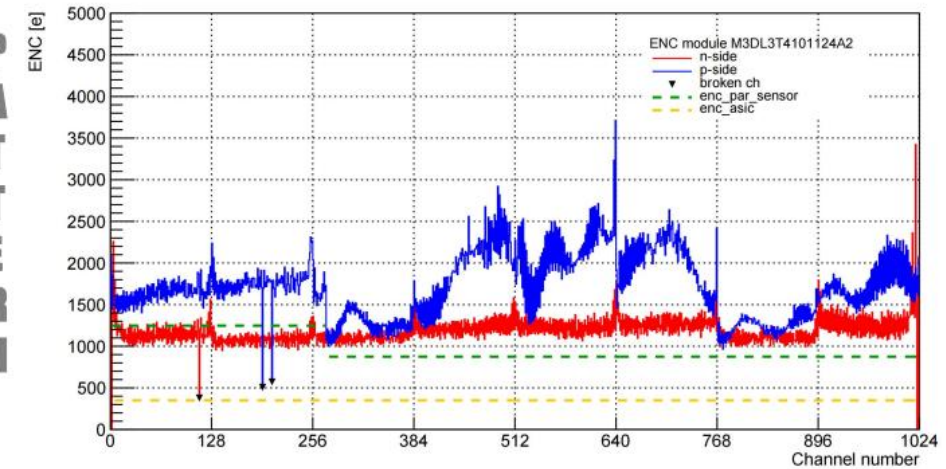


ENCOUNTERED ISSUES & SOLUTIONS

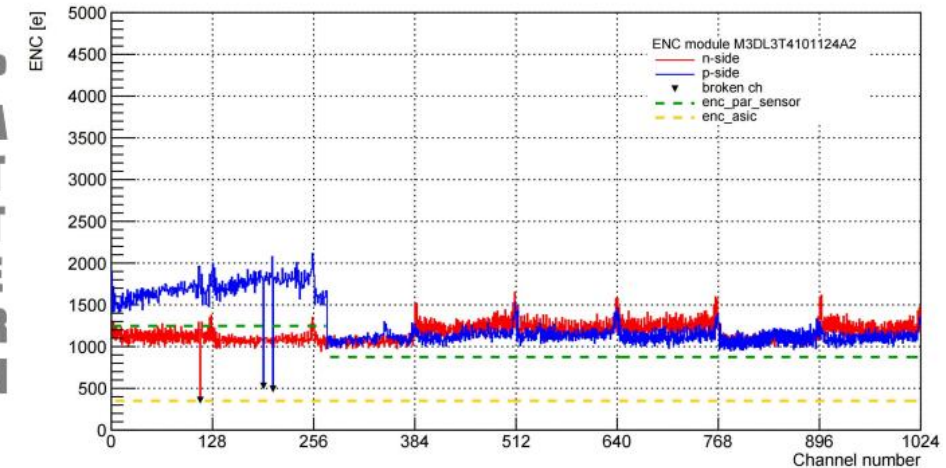
Noise Pattern Characteristics:

- Identified during Ladder Testing
- Also observed in standalone modules
- Up-to-date it has been observed ONLY in p-side.
- Mostly visible in 12 cm sensor modules
- Pattern changes after re-arrangement of the shielding -> (change in C).
- The pattern can be present in all ASICs of p-side.
- Within one ASIC, the pattern has a smooth behaviour (no jumps)
- It is reversible

P
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Summary of the measurements and knowledge regarding this issue can be found:

- [ENC pattern studies summary on Miro](#)
- [STS retreat: The ENC pattern question](#)

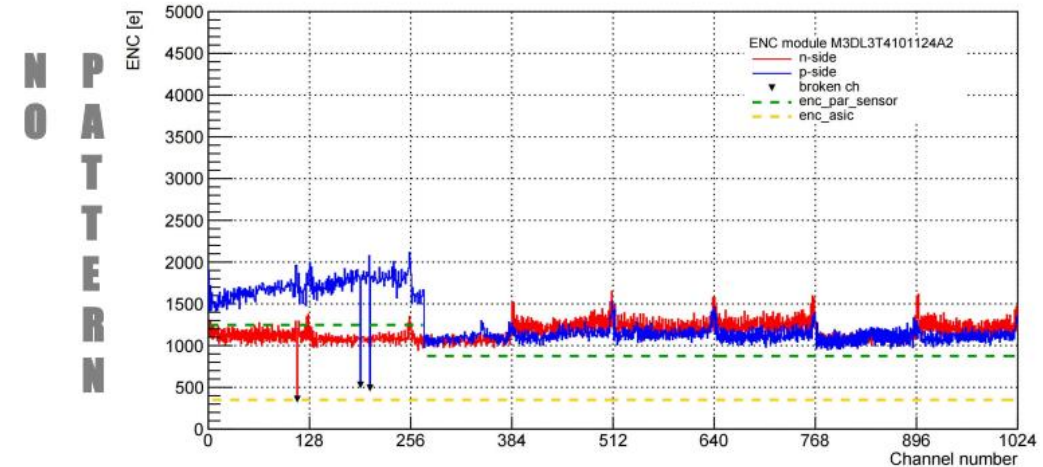
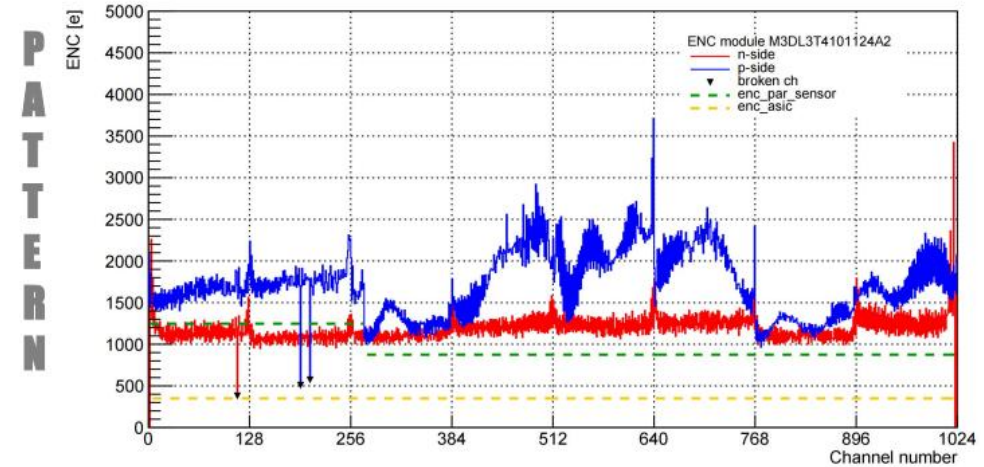
ENCOUNTERED ISSUES & SOLUTIONS

Noise Pattern Characteristics:

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Parameter scan of multiple registers to understand the causes and possible to reduce excess noise:

- Shaping time
- CSA and shaper's current
- Feedback capacitance and resistance
- Power in the 1.8 V LV line
- Different geometrical arrangement or configurations of microcables, shieldings, clamp and lids....



Summary of the measurements and knowledge regarding this issue can be found:

- [ENC pattern studies summary on Miro](#)
- [STS retreat: The ENC pattern question](#)

ENCOUNTERED ISSUES & SOLUTIONS

What did we overlooked?

- o CSA Buffer and Cascode current **Register: [130,14]**

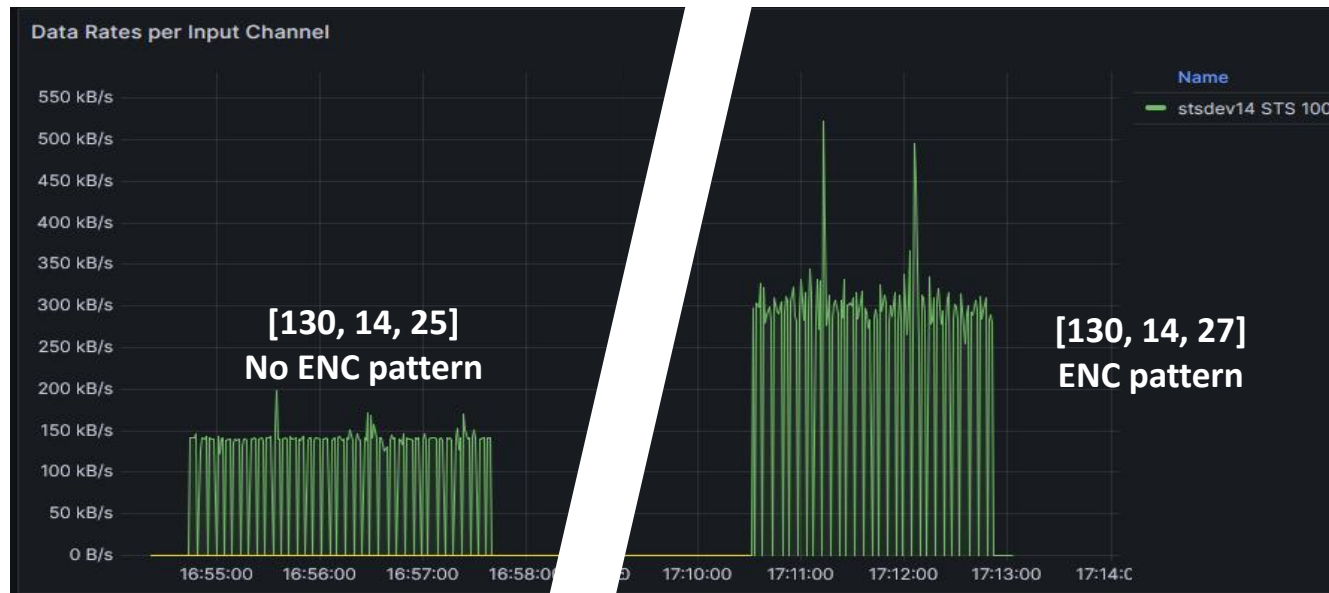
SCAN of the CSA Buffer and Cascode values **Global Register: [130,14] of the SMX_ASIC**

Findings: The **cascode current** plays a fundamental role in suppressing or worsening the ENC pattern.

Large **cascode current** values worsen the ENC levels.

They also induce the first signs of ENC pattern on n-side.

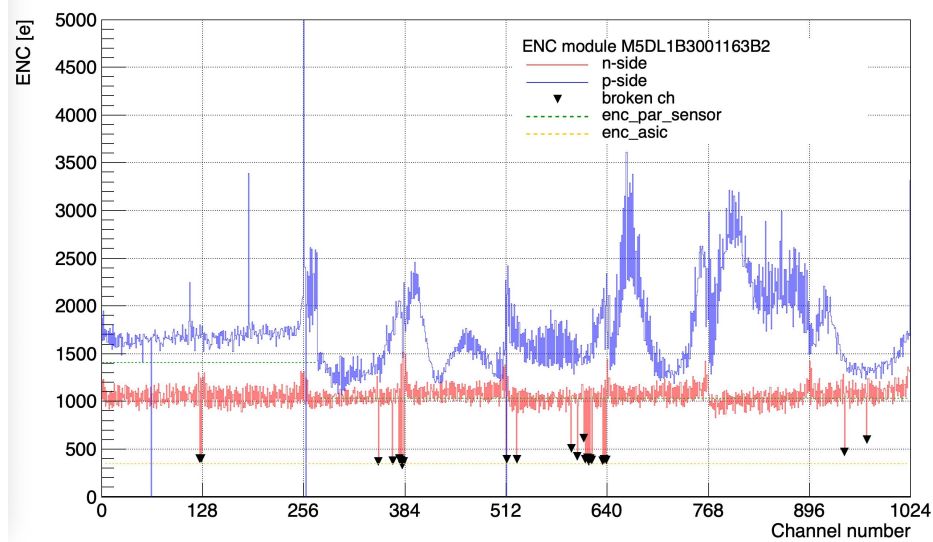
The Buffer cascode contributes very little to the improvement



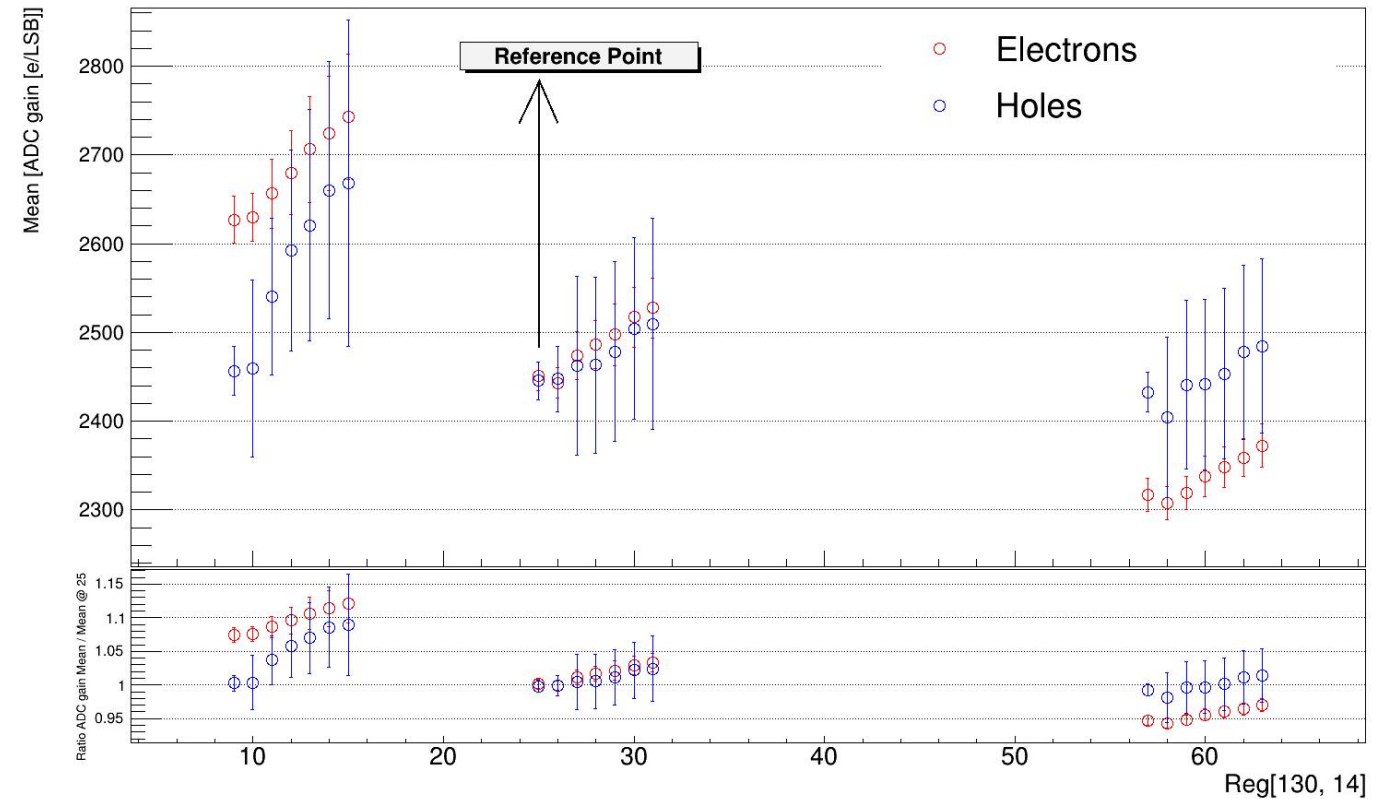
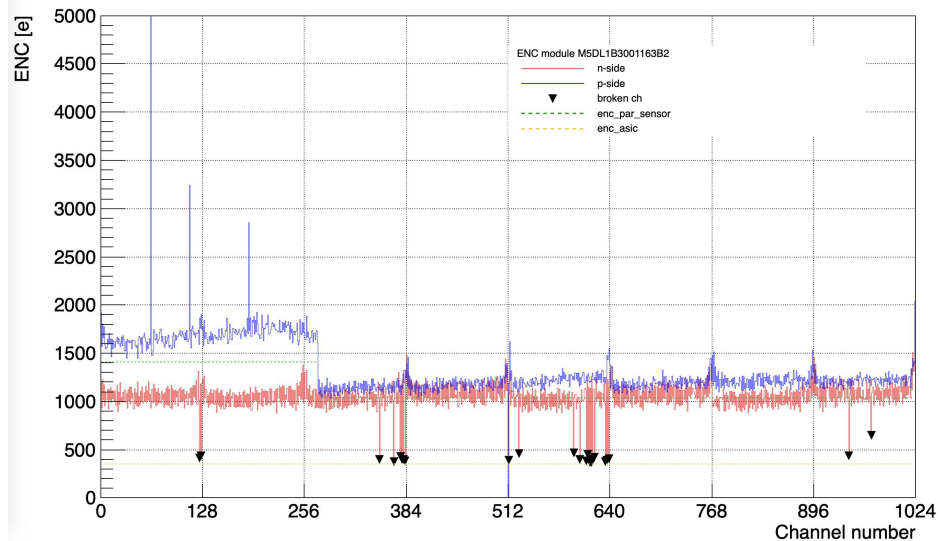
Example of data rates of background measurements at different settings in Grafana. Data rate at high threshold (~10500 e) different settings comparison.

ENCOUNTERED ISSUES & SOLUTIONS

CSA buffer and cascode current = 27 (Default)



CSA buffer and cascode current = 25



Average ADC gain shown for different values of the CSA buffer and cascode current. The former value used was 27 while the new value is 25. The variation of the ADC gain for these two values is minimum.

SUMMARY & OUTLOOK

Ladder assembly and testing are well-established and running procedures from the STS series production:

- All modules have been successfully biased to the projected end-of-life (EOL) specifications.
- Communication has been established with all FEBs, and all ASICs were configured and operated.
- ENC noise levels for all modules, when simultaneously powered and configured, align closely with expectations (~ 1000 e ENC).
- The number of broken channels complies with the STS guideline, maintaining approximately 1.5% per module.
- Several issues were identified and thoroughly investigated.

Where do we go?

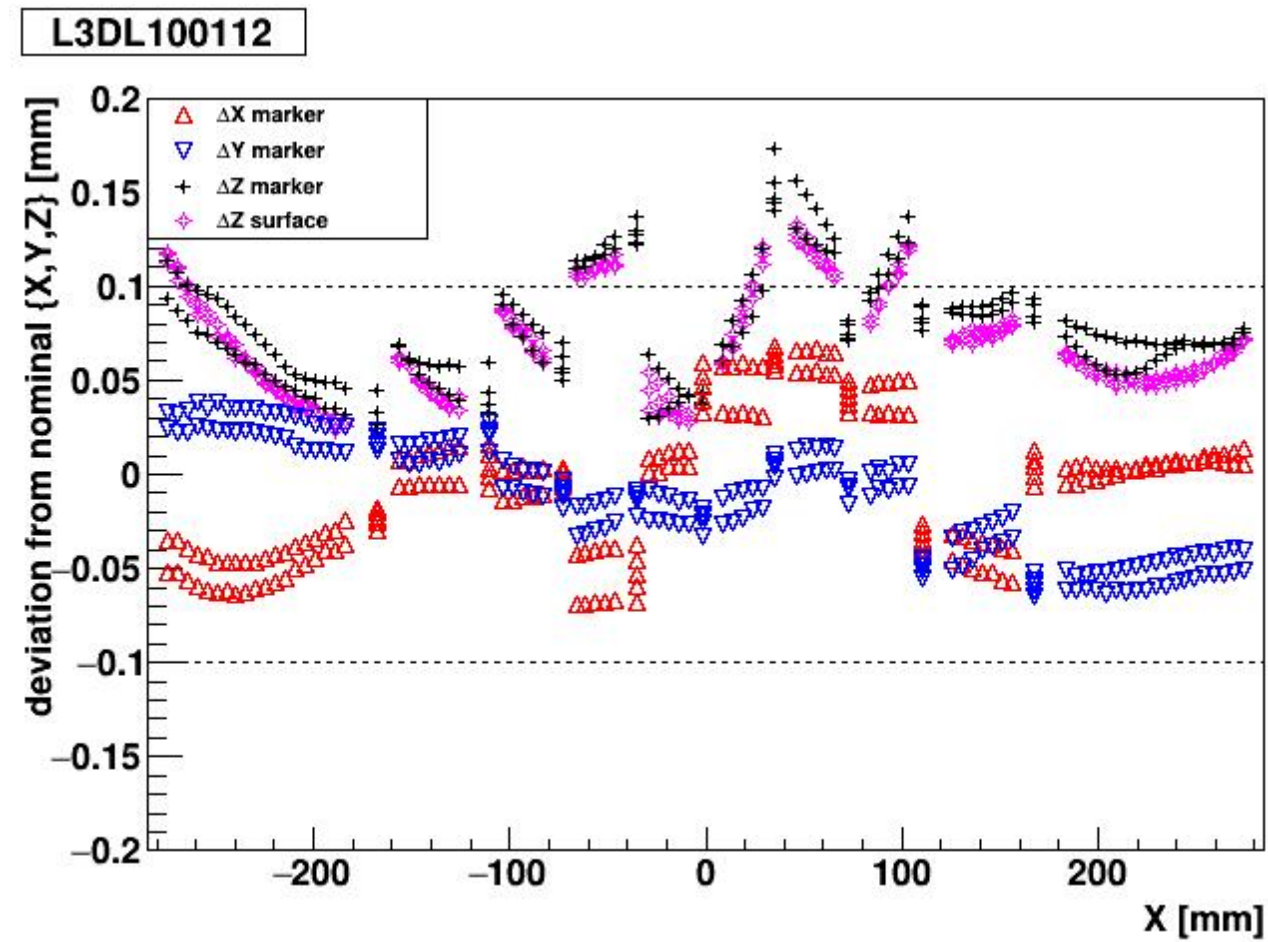
- CRI Based readout with all the functionalities
- Signal readout to check quantitatively the effect of the cascode current
- Testing the ladders as part of the next integration step "Half-unit". It can be considered as a final test, as the ladders will be mounted in its final position and all final services, LV and HV interfaces, will be in use.

THANK YOU

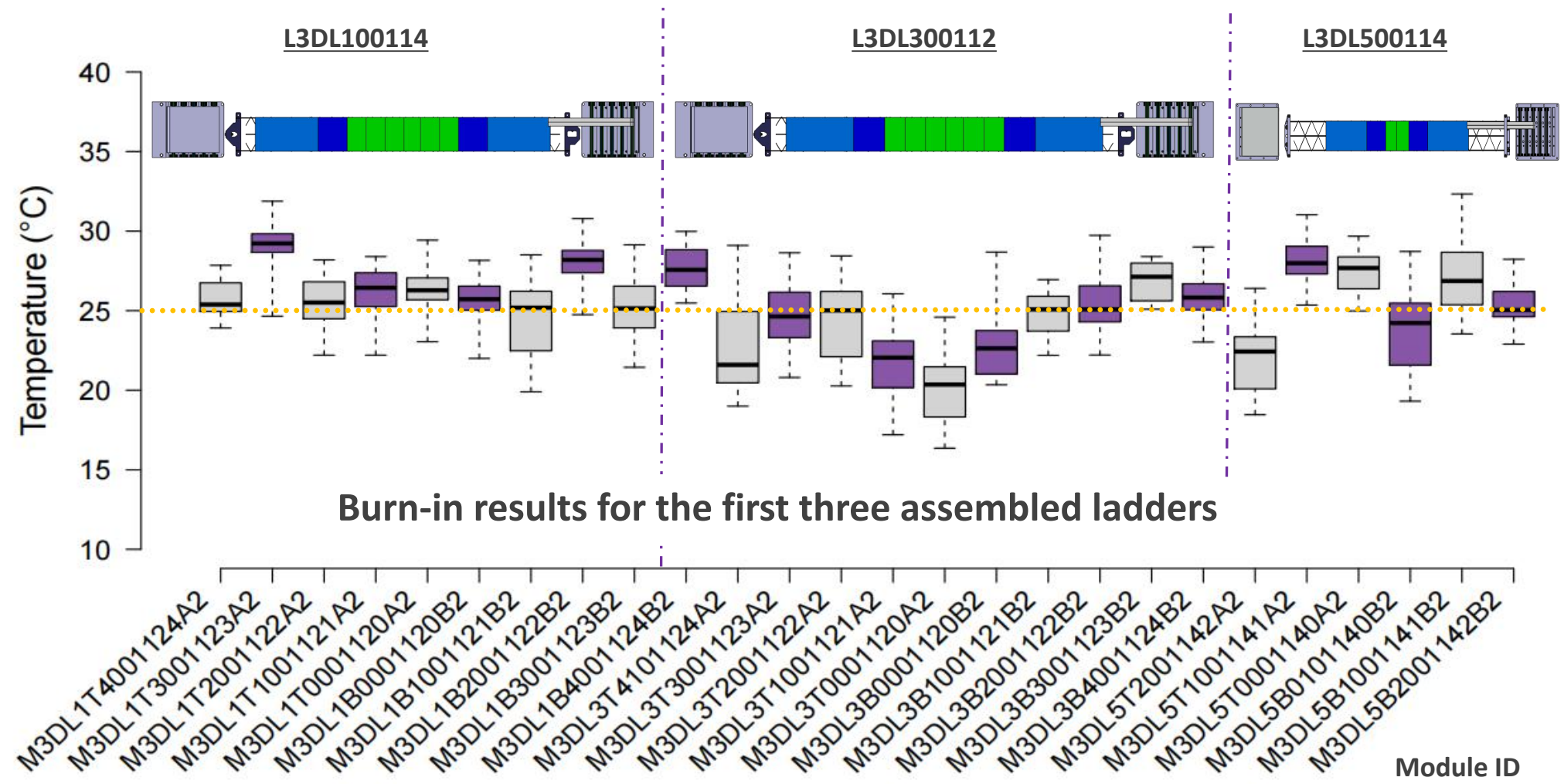
We're not buying a **Stairway to Heaven**;
STS is building one, module by module, ladder by ladder.



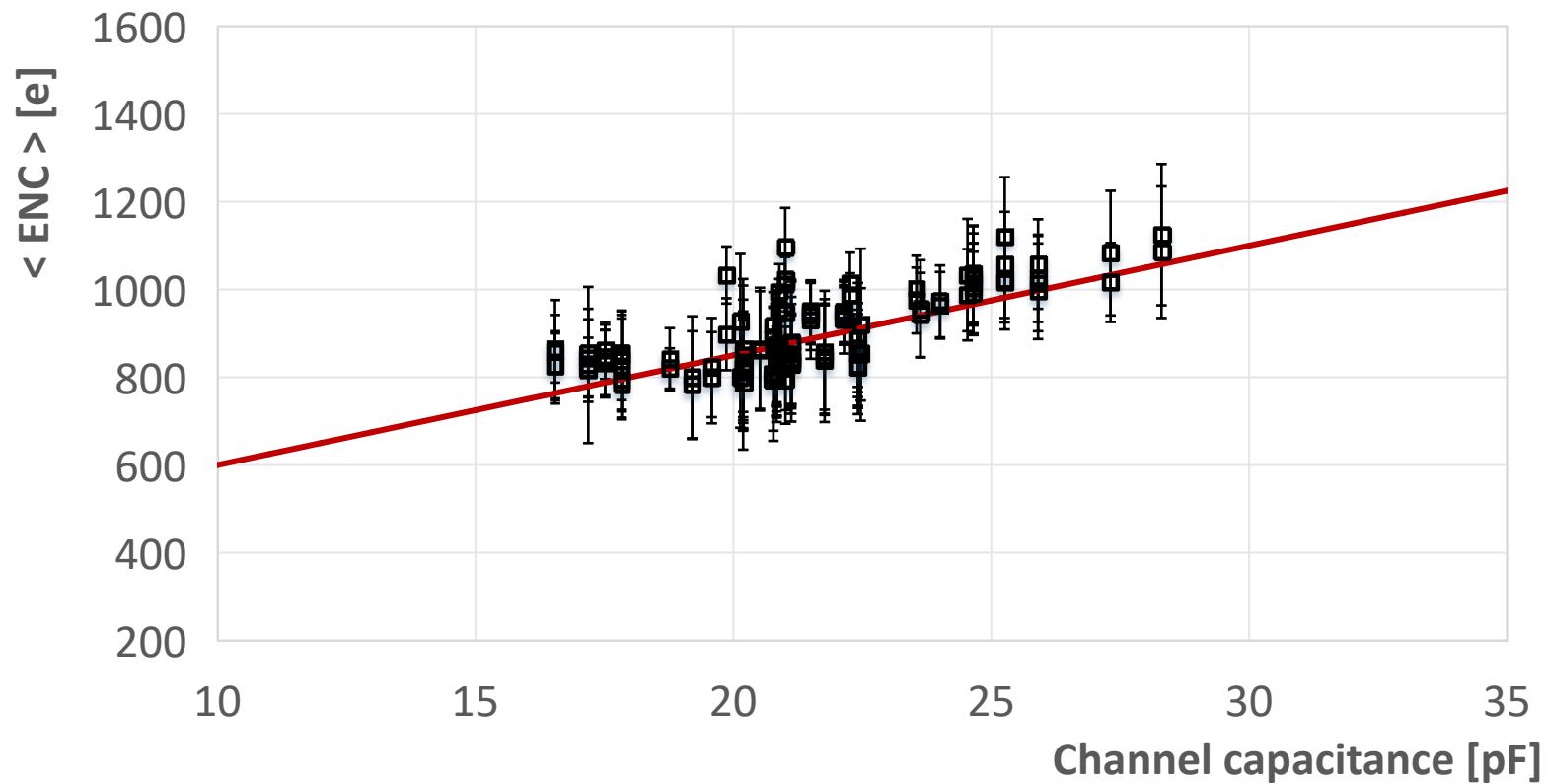
BACK UP SLIDE



BACK UP SLIDE



BACK UP SLIDE



$$ENC = \left[\underbrace{L_{\text{sensor}} \cdot 1.02 \frac{\text{pF}}{\text{cm}}}_{\text{sensor}} + \underbrace{L_{\text{cable}} \cdot 0.38 \frac{\text{pF}}{\text{cm}}}_{\text{microcable}} \right] \cdot 25 \frac{e}{\text{pF}} + \underbrace{350 e}_{\text{ASIC}}$$

Rodríguez, A., Nucl. Instrum. Meth. A 1058 (2024)