Test beam and clean room studies of ATLAS PPS modules with alternative bias rail geometries

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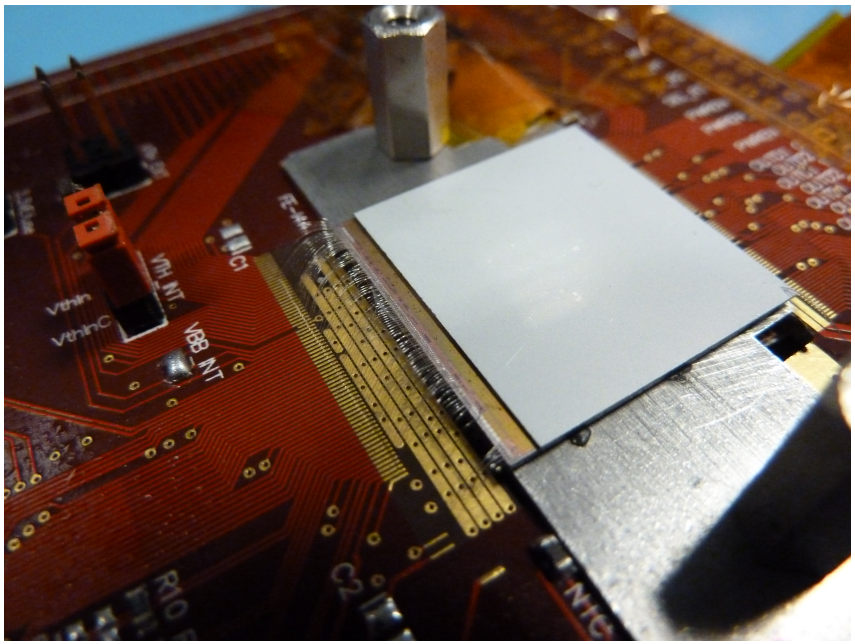
Contents

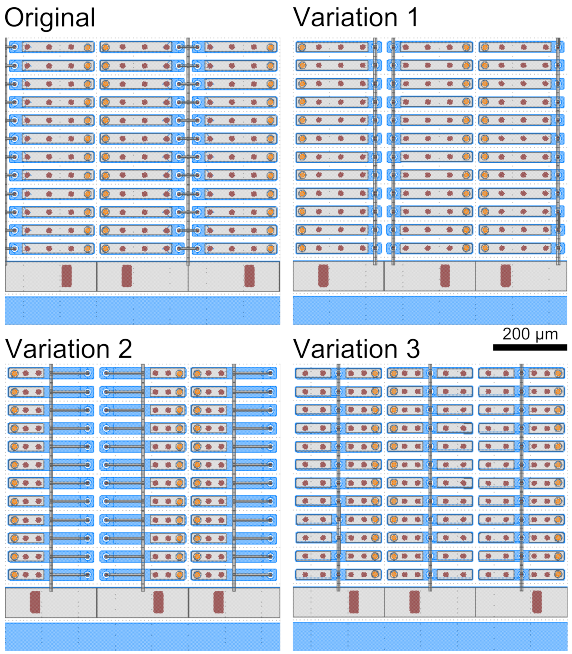


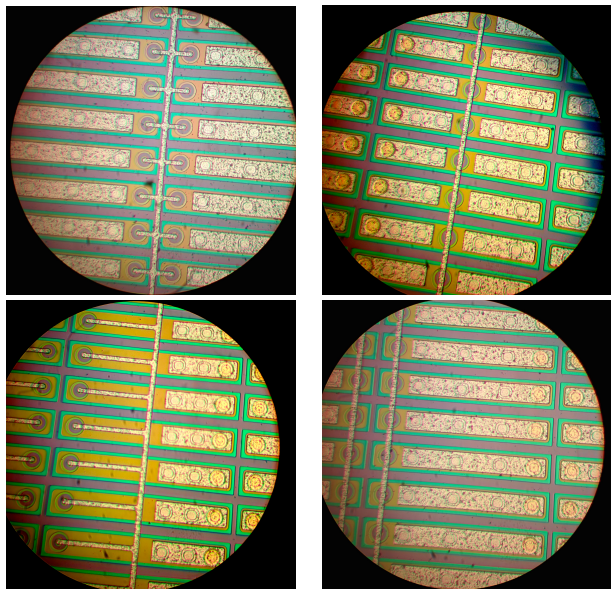
Introduction

- It is a known issue with planar pixel sensors that there is an efficiency loss under the bias rail after irradiation.
- This could be solved by removing the bias rail entirely.
  - The sensor could not then be tested before bonding to a readout card.
  - Possibly leading to a lower yield.
- Instead investigate alternative routing of the bias rail to see if a different design could improve the efficiency.
- Studies are done through tuning in the clean room and test beams.

Bias rail - collaboration with CiS

- FE-I4 compatible pixel sensors with alternative bias rail geometries to the current PPS layout.
- Aim is to find a solution that reduces the inefficiencies seen for this region within the pixel cell.
- Matrix contains several versions of bias rail geometry.

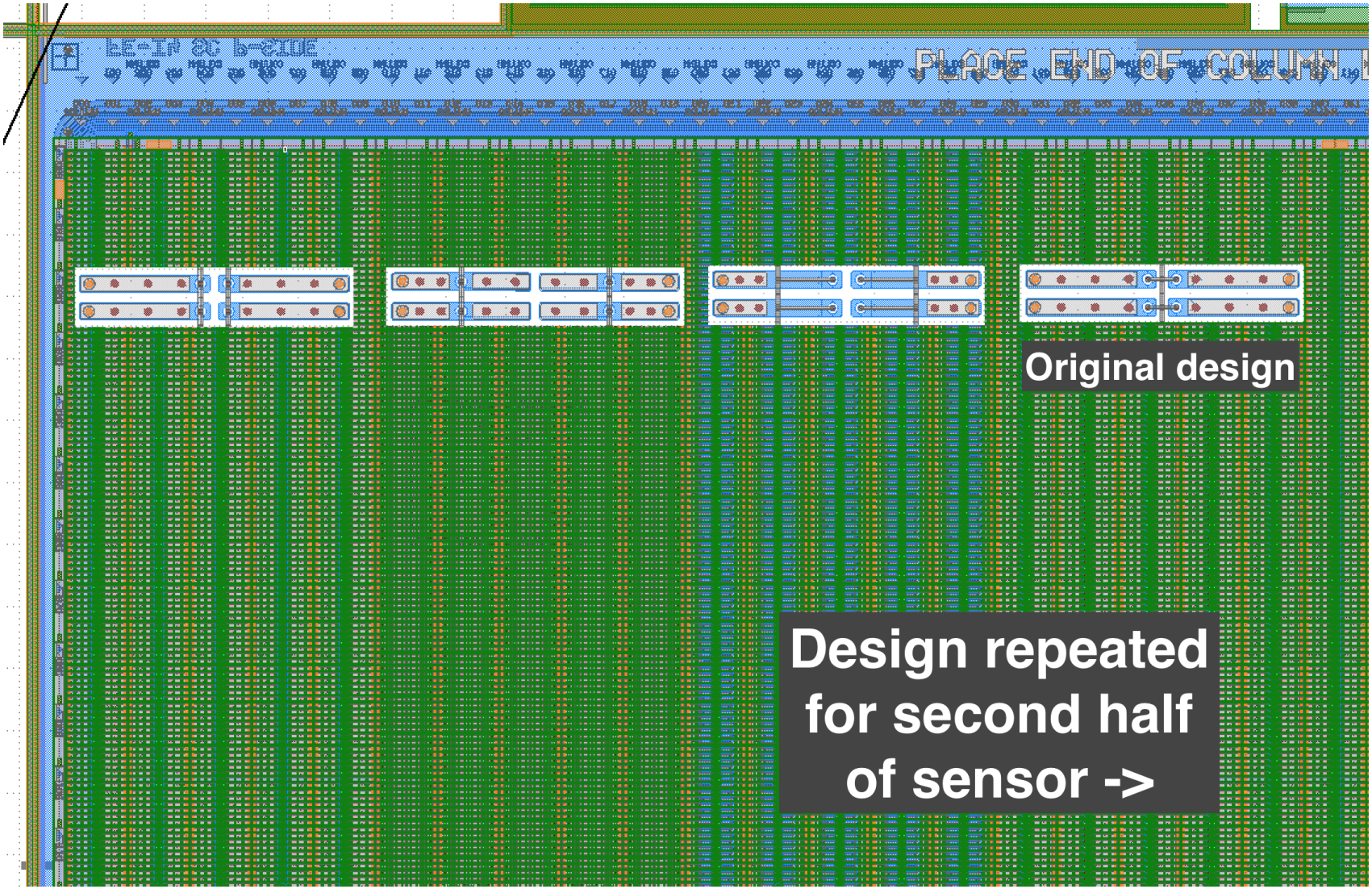




- All bias rail geometries photographed are on the same sensor, which was subsequently flip-chipped, and then wire-bonded to an FE-I4b readout card at CERN.
- Design by CiS.

- The bias rail is metallisation on top of an insulator without an implant below. It provides a reference potential to each pixel and connects to virtual ground.

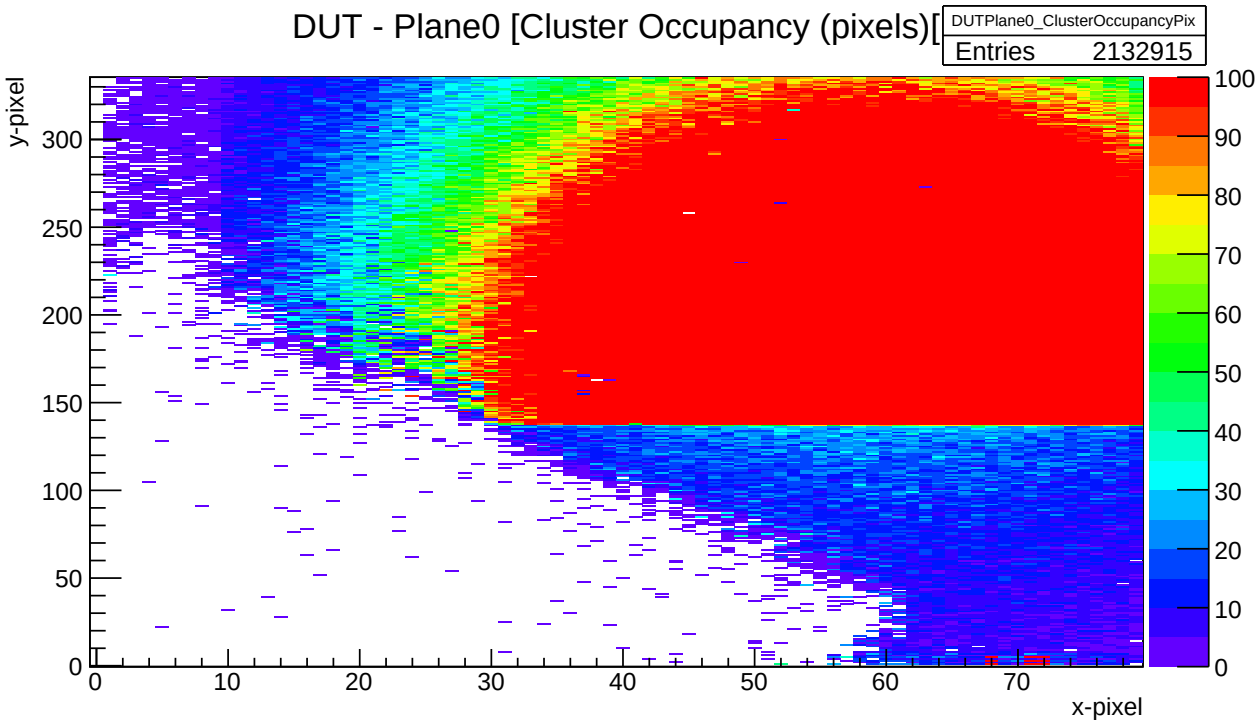
Bias rail layout



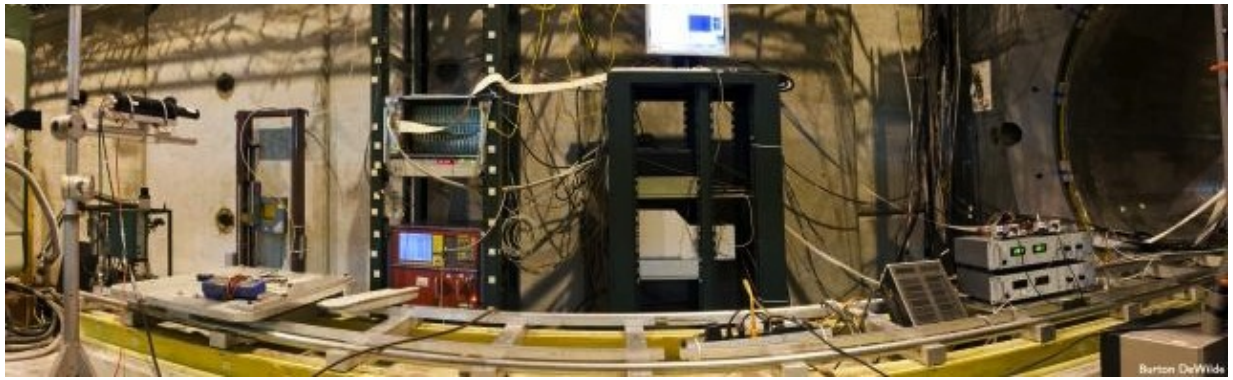
CERN 2014 Test Beam(s).
With sample No. 1.

The sensor

- Sample tuned to 3200e threshold, 7 TOT at 24k with RCE.
- It was already known that the sensor has a section of disconnected pixels due to uneven applied pressure during bonding to the FEI4 read-out chip.
  - Should not effect comparison of different bias rail regions as the geometry is repeated, as shown in the previous slide.

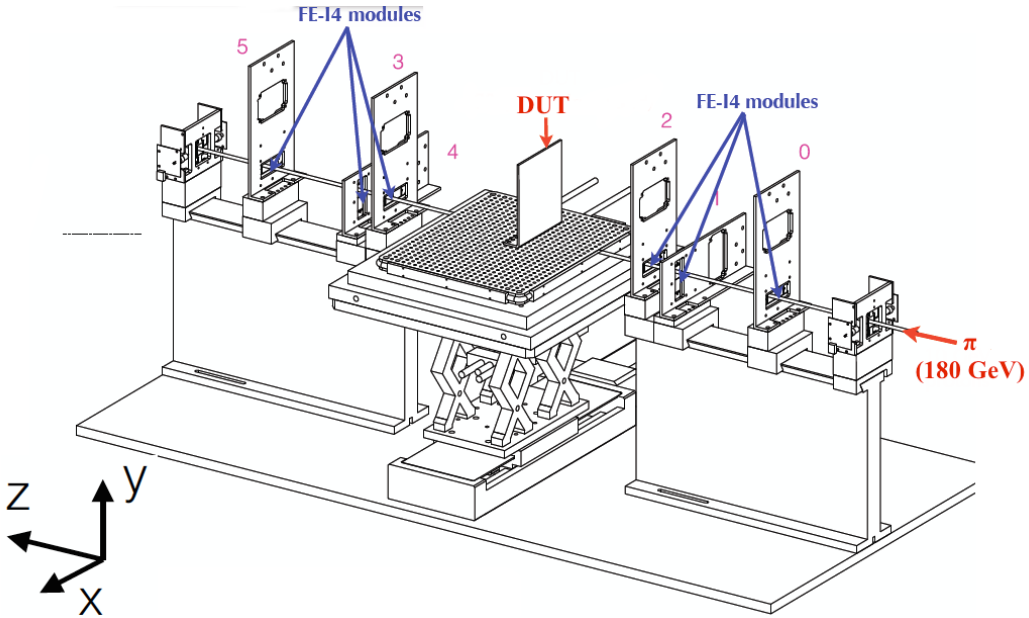


Test Beam Setup

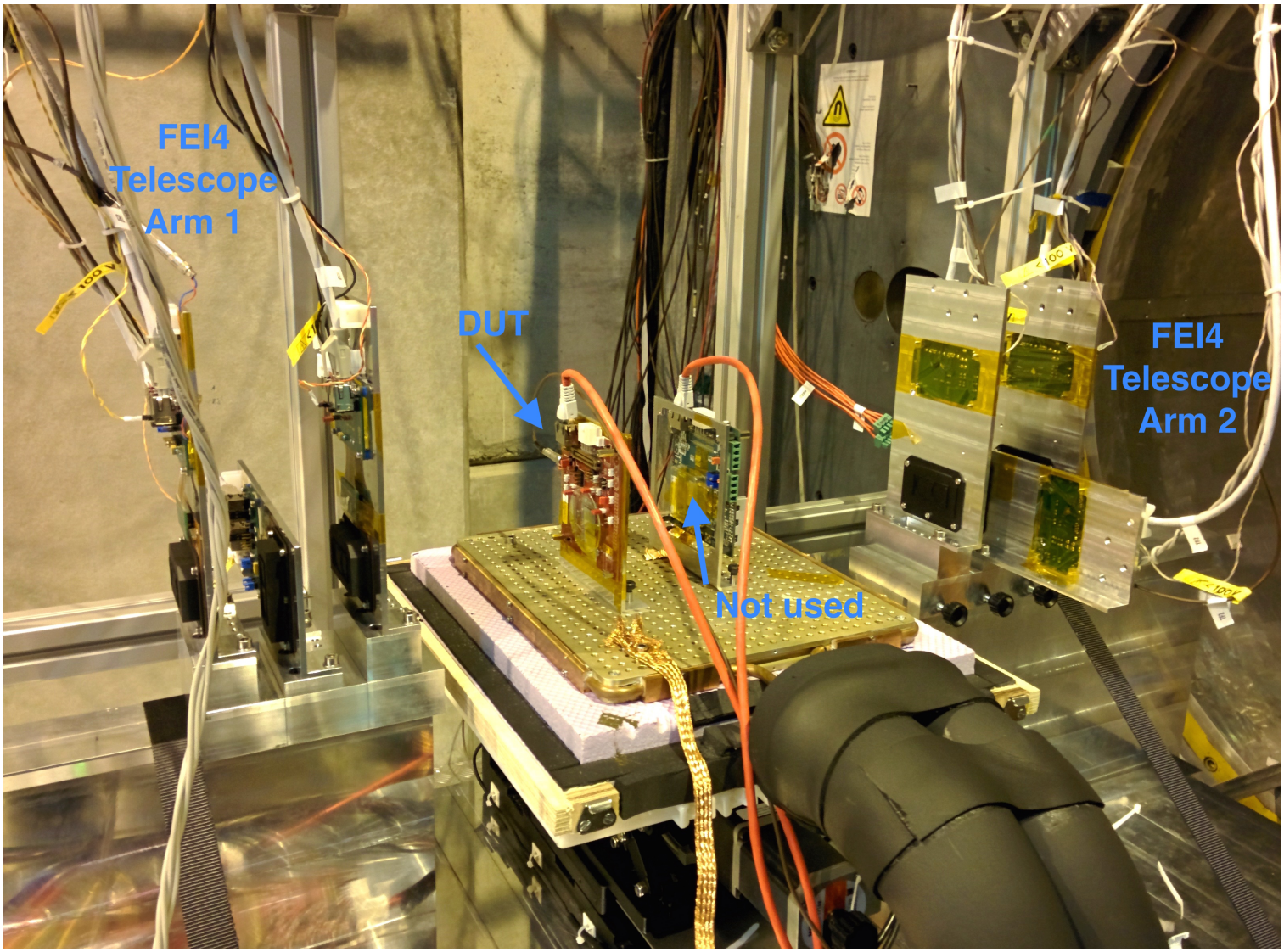


- Data taken at the CERN SPS beam line in November 2014.
- Used the Geneva University FE-I4 telescope.

- Made of six FE-I4 modules (250 μm x 50 μm), with the DUT in the centre.
- Readout with the RCE.
- Triggered with telescope planes 0 and 5.
- Many thanks to Bane and Mathieu for their support in taking the data.

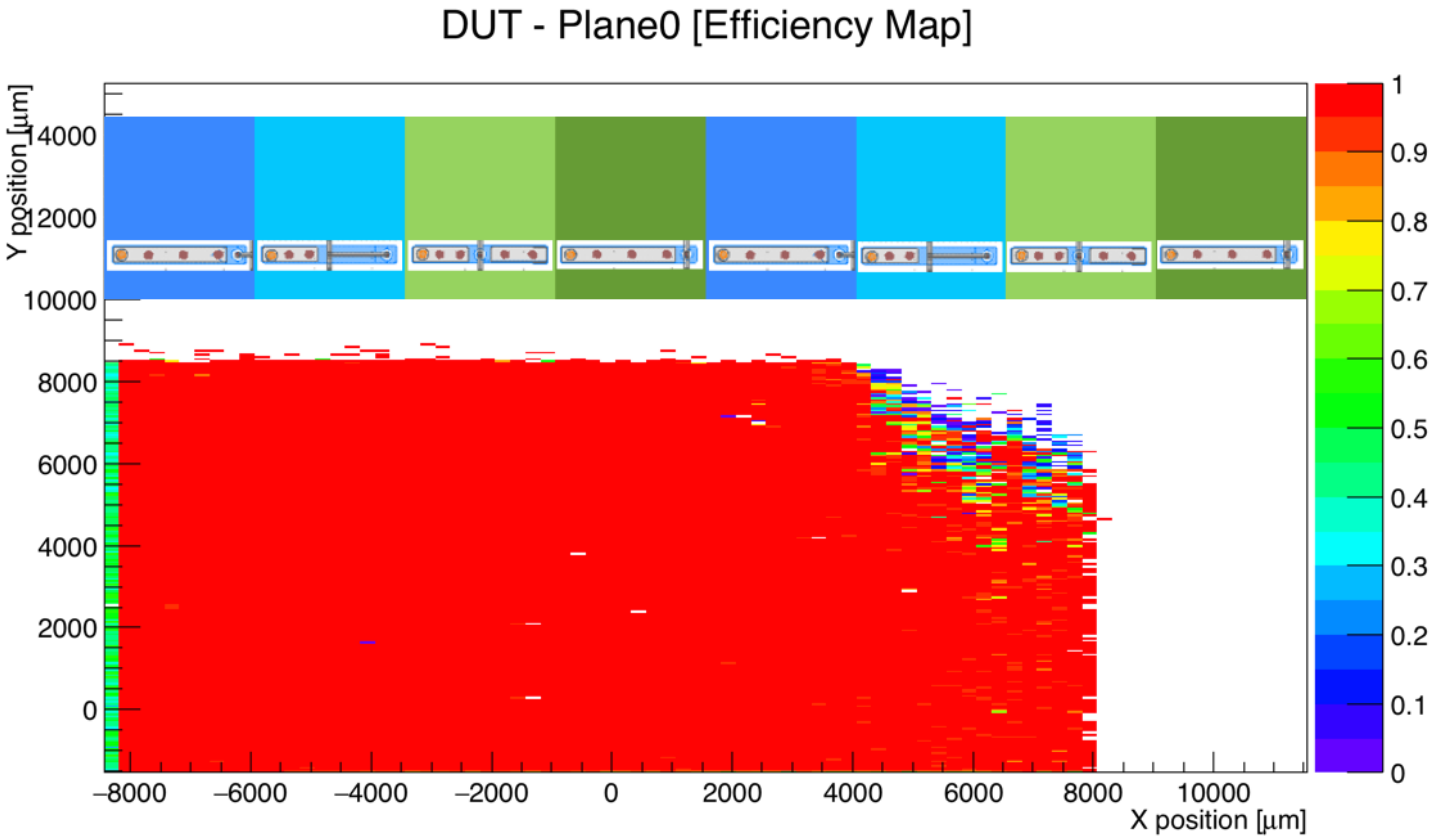


Test Beam Setup



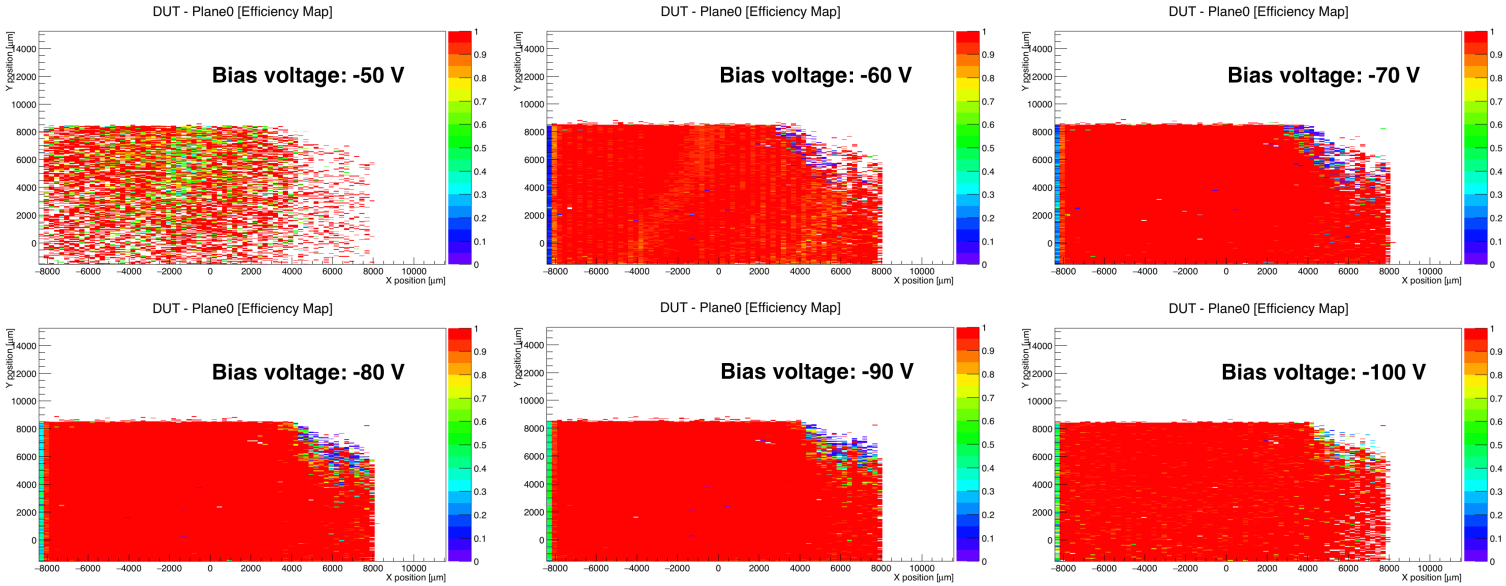
Efficiency

Note: the plot is rotated compared to the occupancy plot and so the pixel geometry is reversed (colours show repetition).

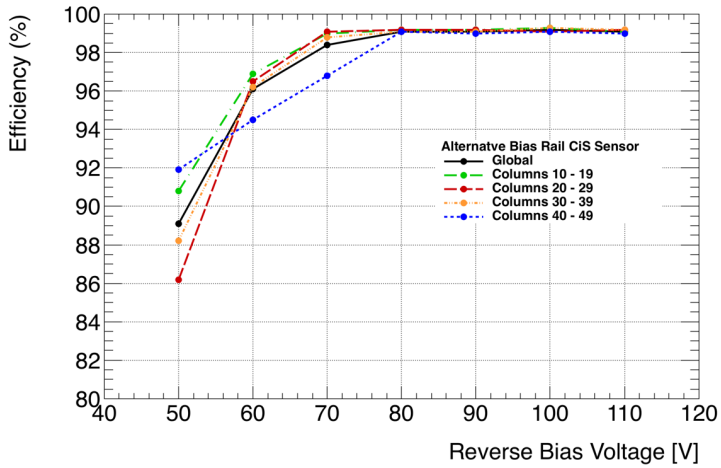


- Majority of pixels show an efficiency of $\sim$1.
- No sign of lower efficiency for a specific layout.

Efficiency

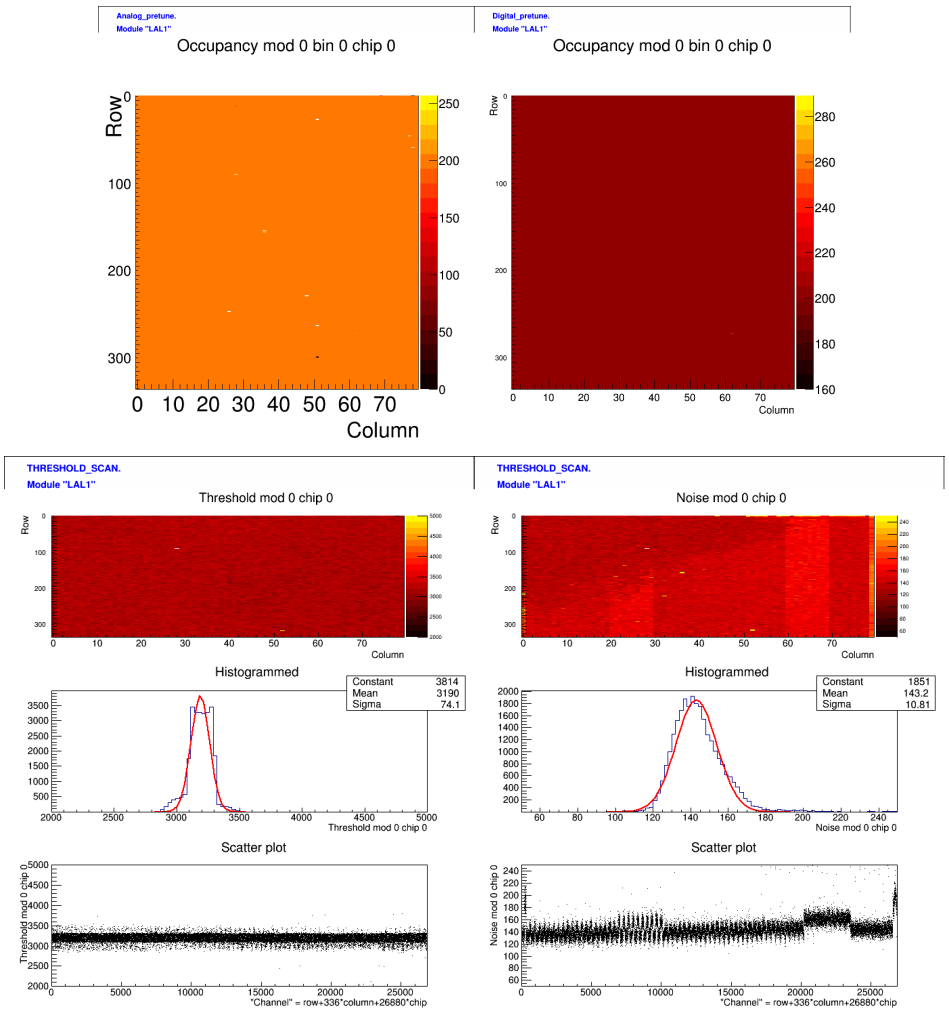


- Lower efficiency when sensor is not fully depleted (as expected).



Clean Room Testing
With samples No. 1 and No. 2.

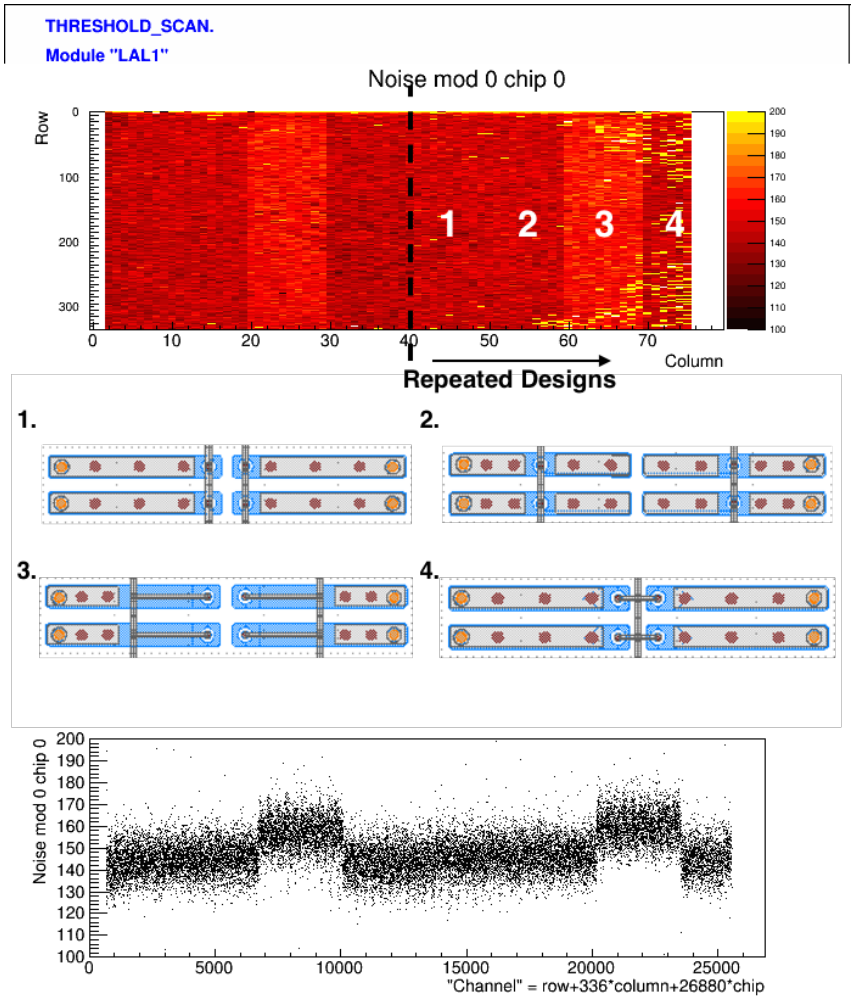
Sample 1 (LAL1)



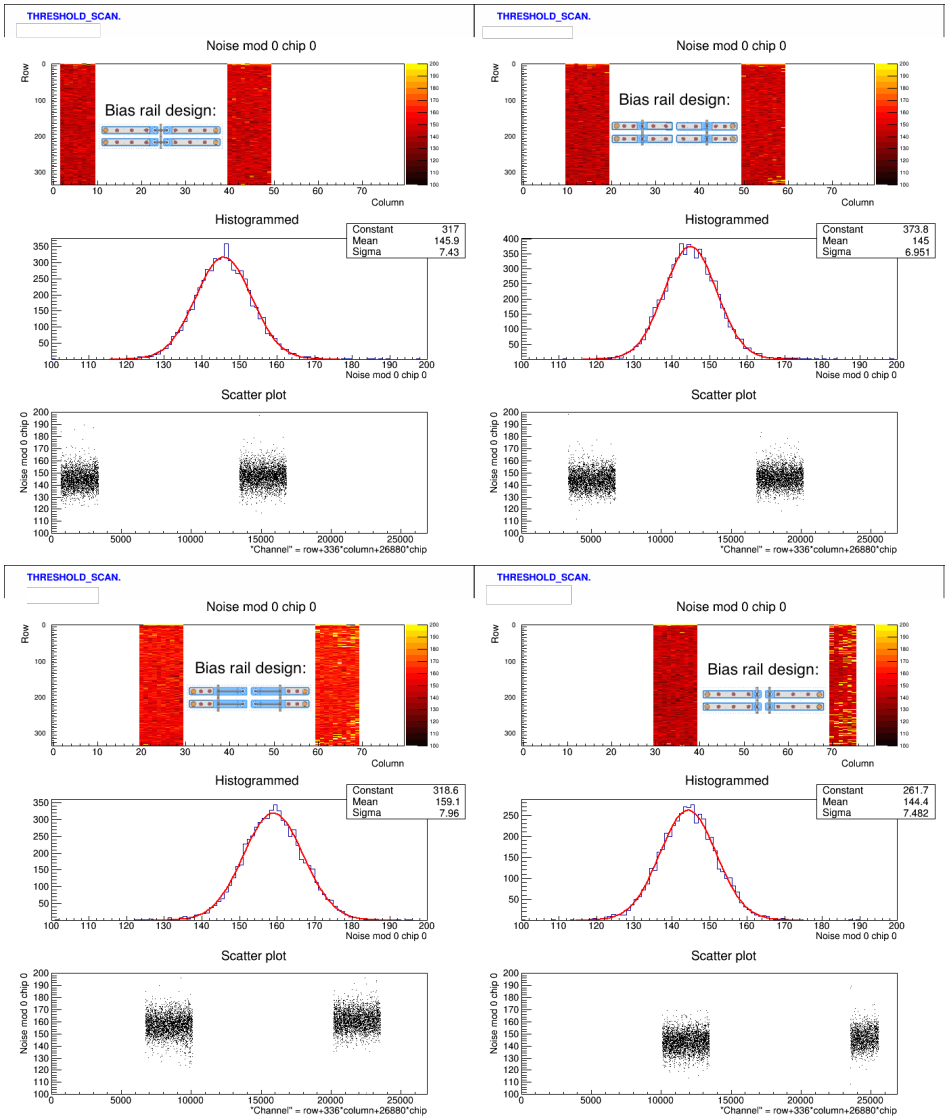
- Device tuned in the clean room with USBPix to 3200e, 7 TOT at 24k.
- A clear increase of noise for one design was observed.
- Some alterations were required to the USBPix board to allow the device to be powered directly (instead of through the flat cable)
  - Thanks to Joern Grosse-Knetter for valuable advice!

Sample 2 (LAL2)

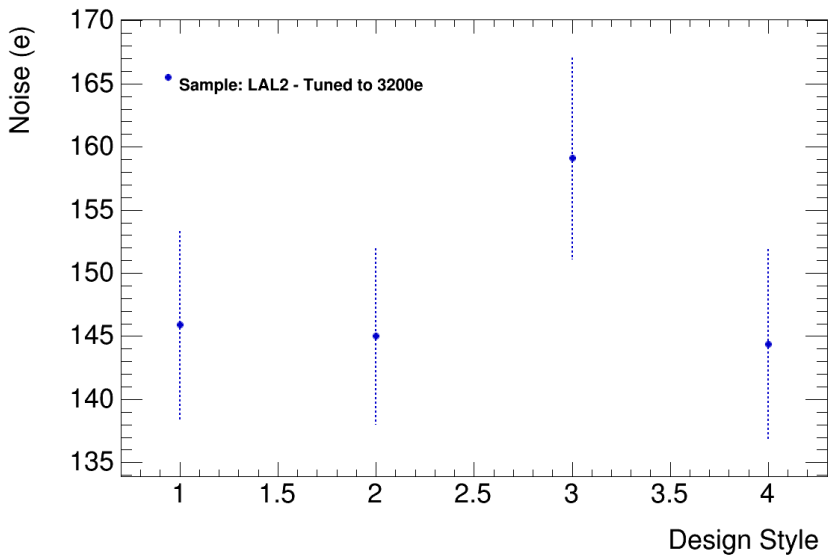
- Second batch of sensors successfully flip-chipped at LETI.
- This sample has the same layout as the previous sensor, but without the large area 'dead' area.
- See the same feature as the previous sensor with increased noise for one design.



Noise comparison, 3200e

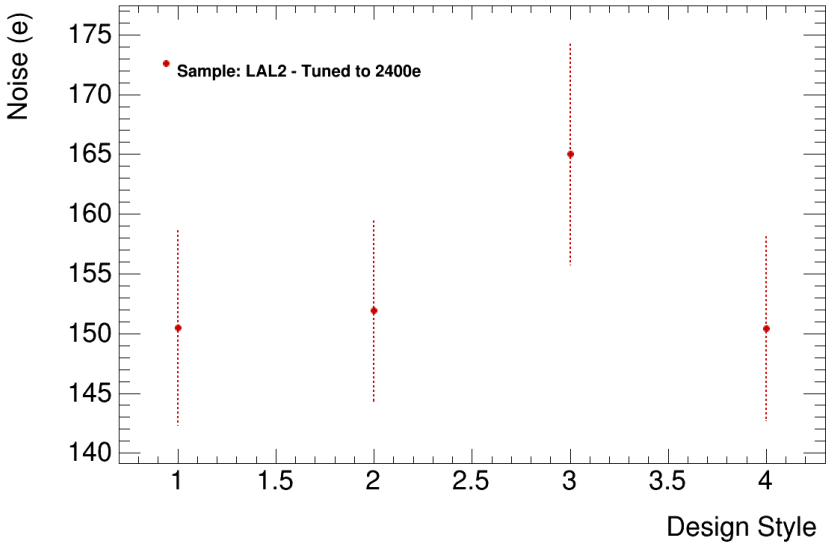


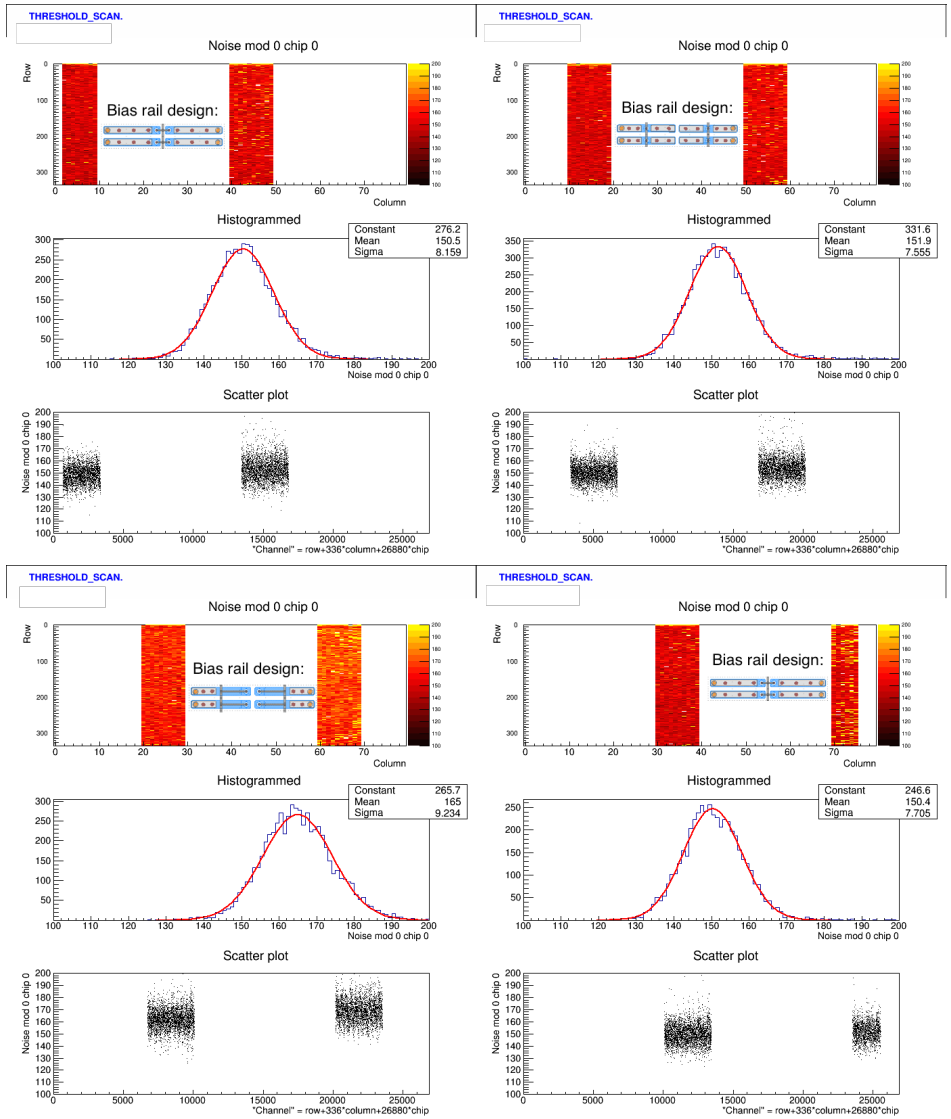
- Masks applied for threshold scans to isolate the noise measurement for each design.
- Clear increase from one design.



Noise comparison, 2400e

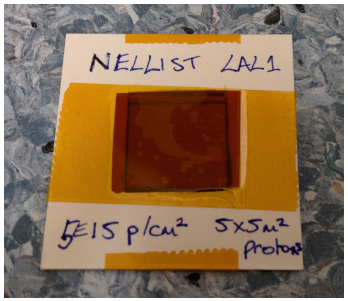
- Same measurements performed for 2400e with Masks applied.
- Again, clear increase from one design (as expected).





Irradiation and wire-bonding

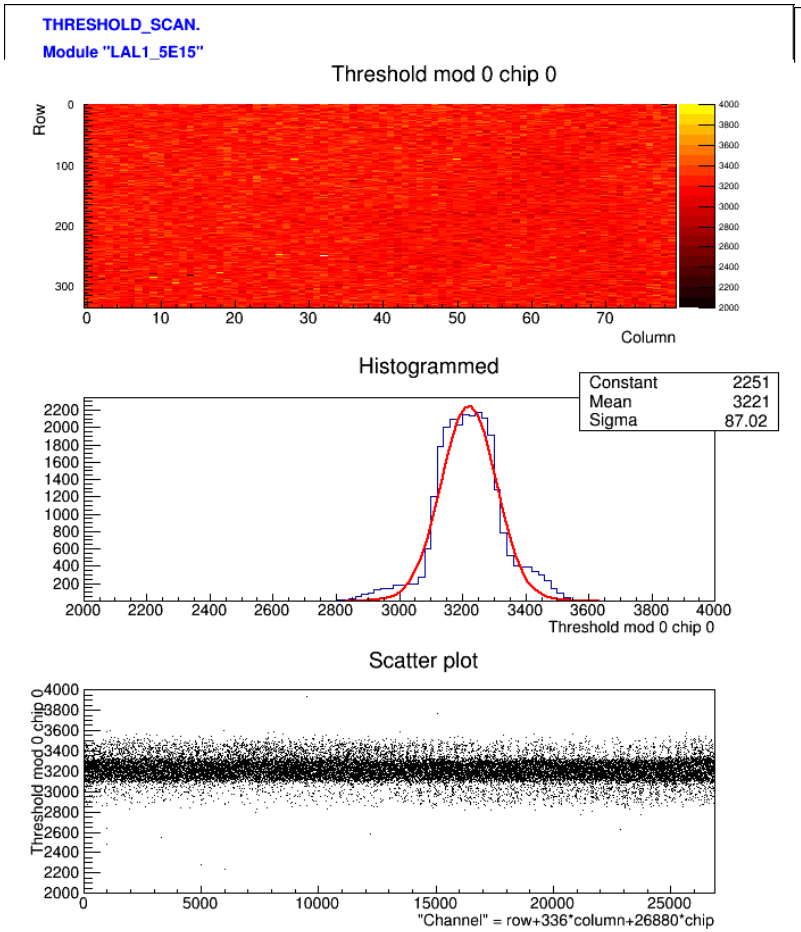
- The first sample, LAL1 has been irradiated at CERN PS to $\sim$ 5 x 10^{15} n_{eq} cm-2 and was wire-bonded at the CERN wire-bonding lab.
- It was then tested in the clean room to see how the noise varies for the different designs after irradiation.

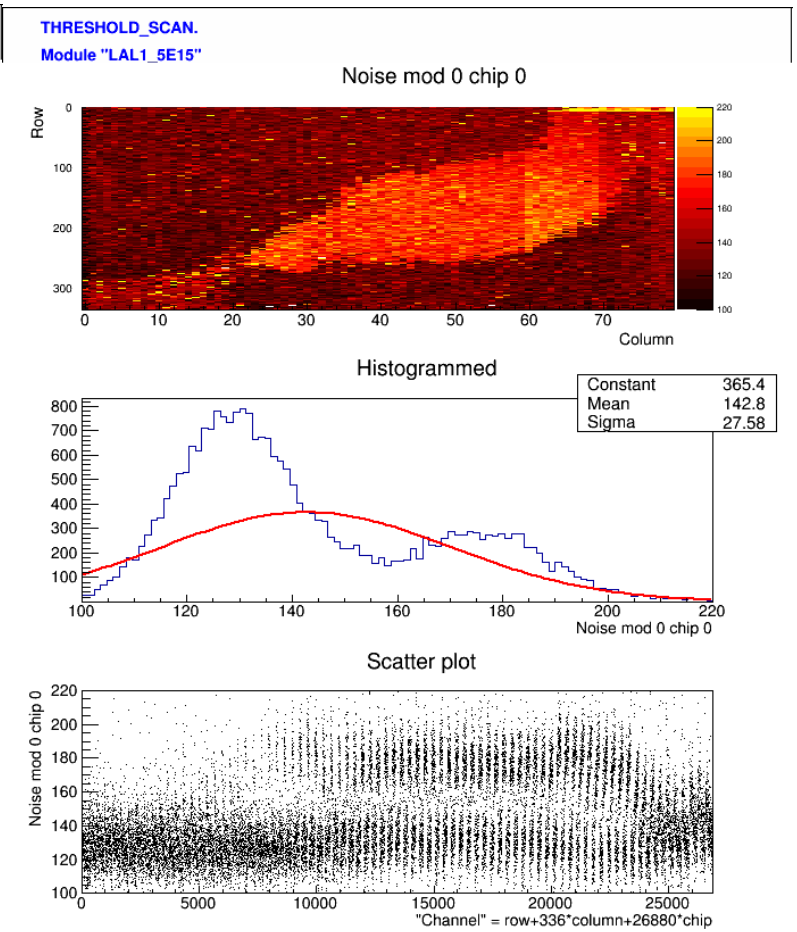


- Many thanks
  - Federico and Maurice for all of their advice and support with the irradiation!
  - Also to the CERN wire-bonding lab for fitting this sample in last week to allow results to be shown today!
  - And to Bane and Karola for the use of the the CERN clean room and especially for troubleshooting the setup over the weekend!

Noise comparison - LAL1 5E15

After irradiation of 5 x 10^{15}, tuned to 3200e at -15 deg, -500V.

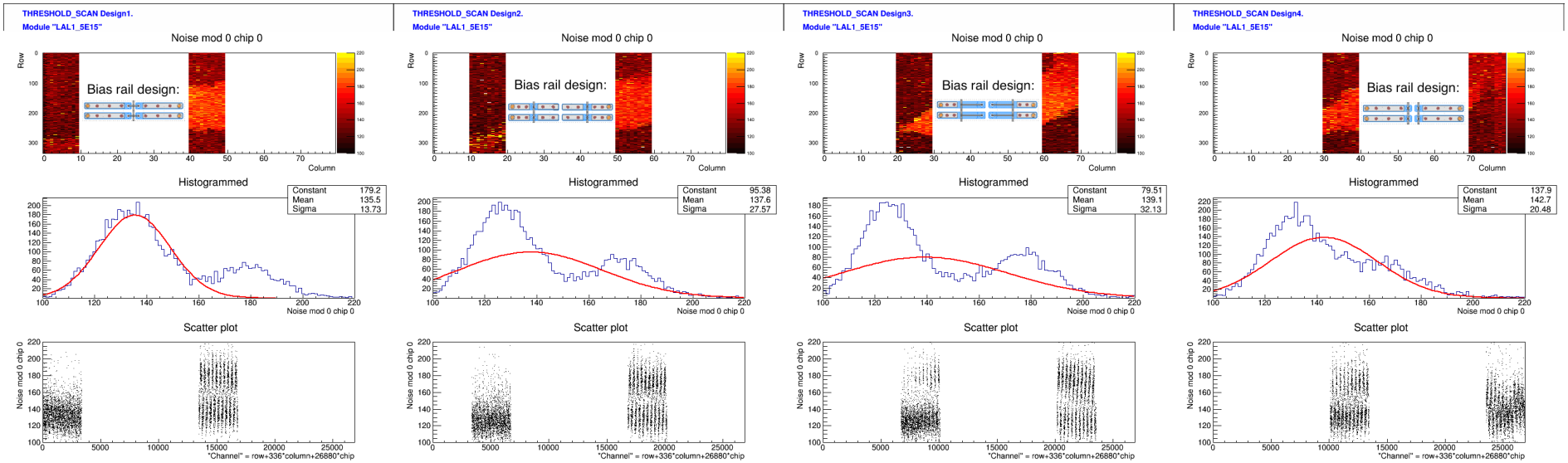




- Damage to the left was there before, but damage to the right occurred due to irradiation.

Noise comparison - LAL1 5E15

- Masks applied for scans to isolate the noise measurement for each design.
- Difficult to separate the low noise of the disconnected pixels to the noise measurement we want.
- Applied a cut of 150e to try to remove this.



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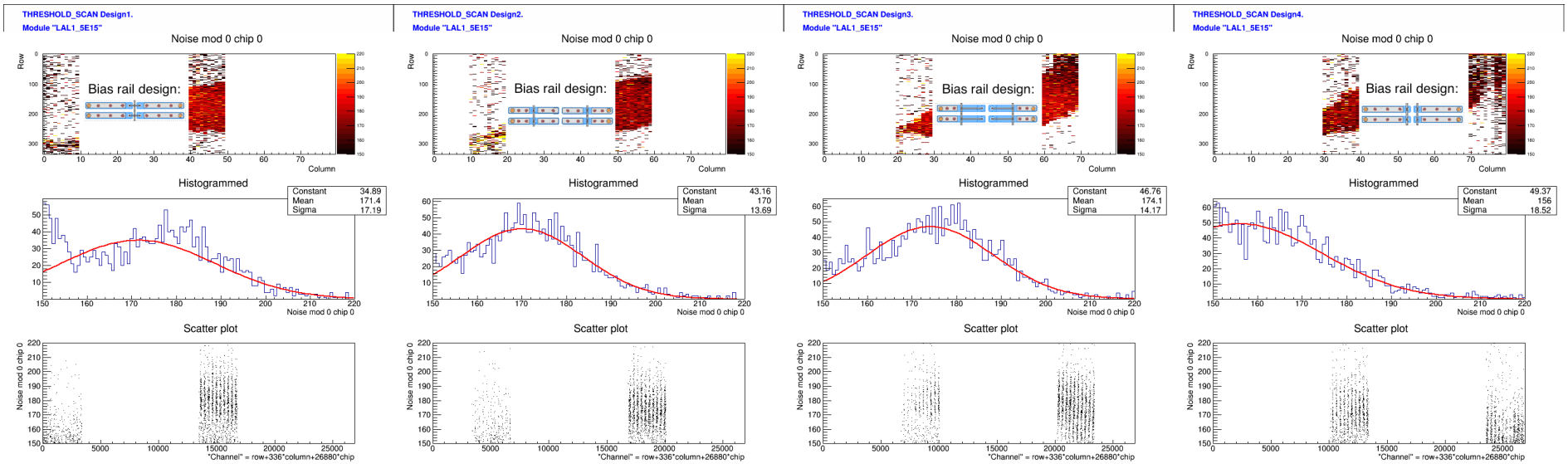

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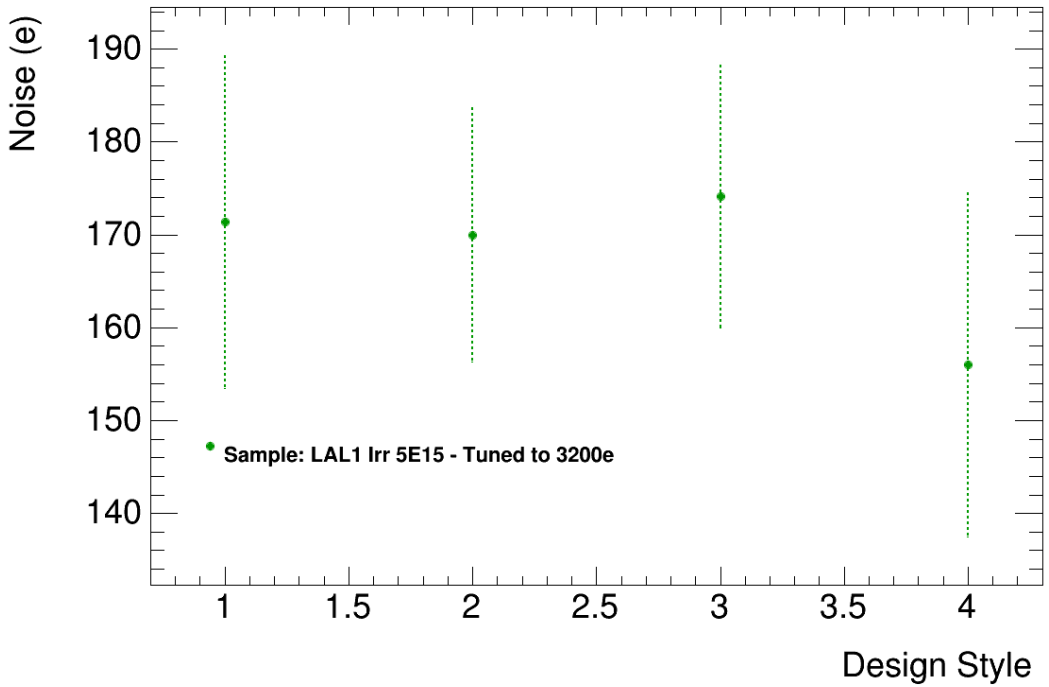
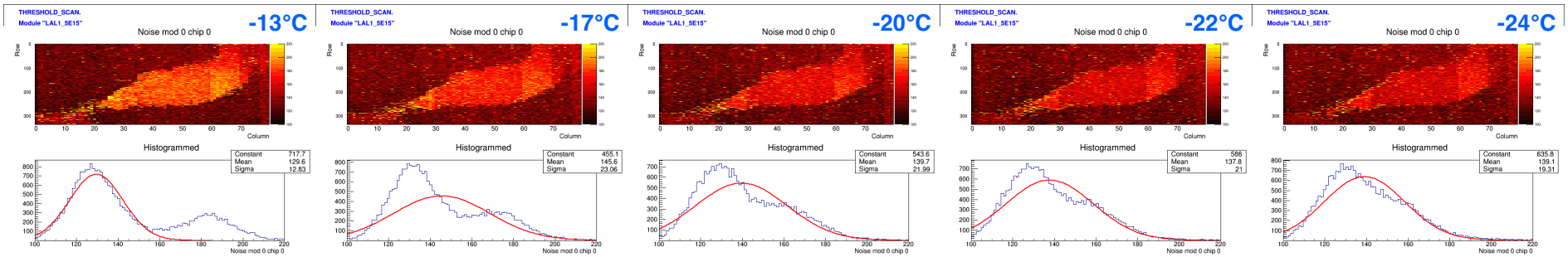
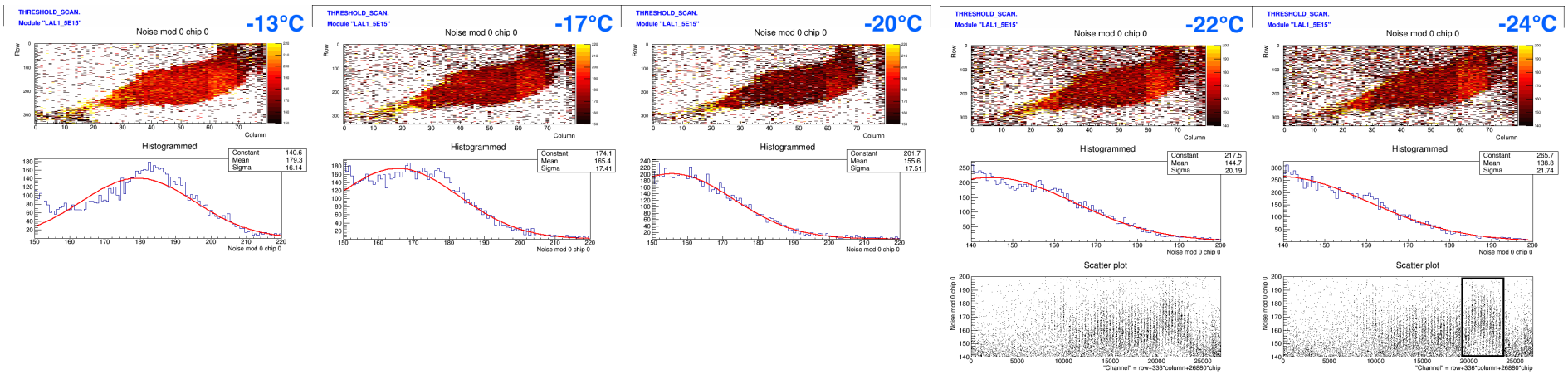


Temperature Scans

- Measurements of the noise as a function of the temperature were performed. From -13°C to -24°C.

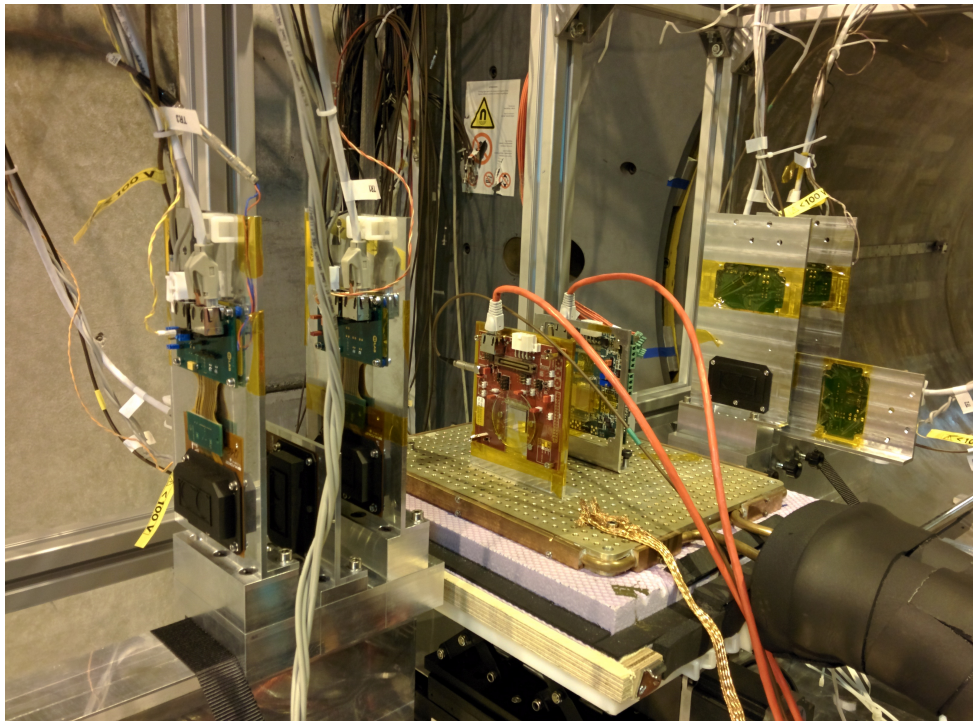


- Cuts applied at 150e, except for 22°C and -24°C, where cuts of 140e-200e were applied.



Test Beam Plans

- Both LAL 1 and LAL 2 will be tested in the CERN test beam in July, along with a control device.
  - Want to focus on studying the efficiency of the various designs within the pixel cell.



Summary and Outlook

- Studies of the alternative bias-rail designs have been performed through test beams at CERN with the FE-I4 telescope and with USBPix in the clean room.
- Before- and after-irradiation, increased noise for one design was observed.
  - Simulations are required to study this effect further.
- Outlook:
  - The first sample has been irradiated at CERN and tested in the cleanroom. The aim is to study the efficiency after irradiation at the July test beam at CERN.

Thank you for your attention

Any questions?

Backup