Study about behavior of a prototype ASIC for the upgraded ATLAS pixel detectors with low thresholds

Year-End-Meeting

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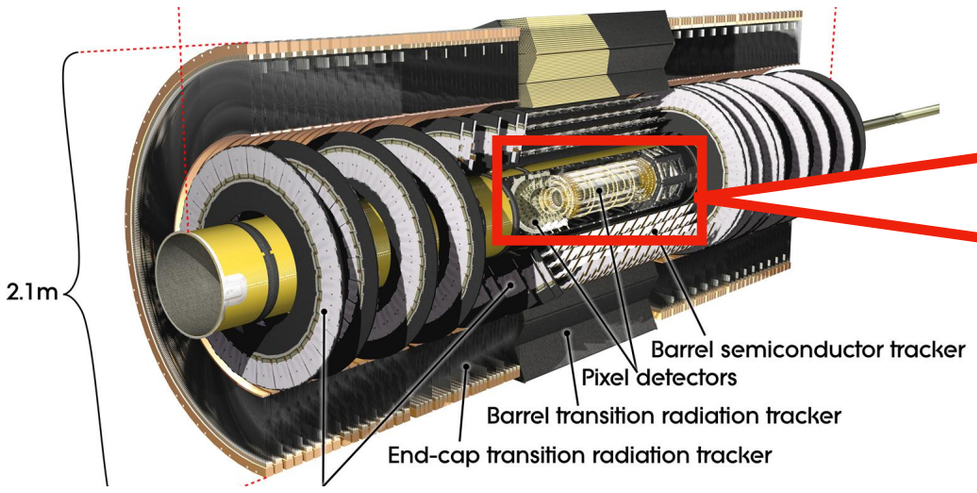
Introduction

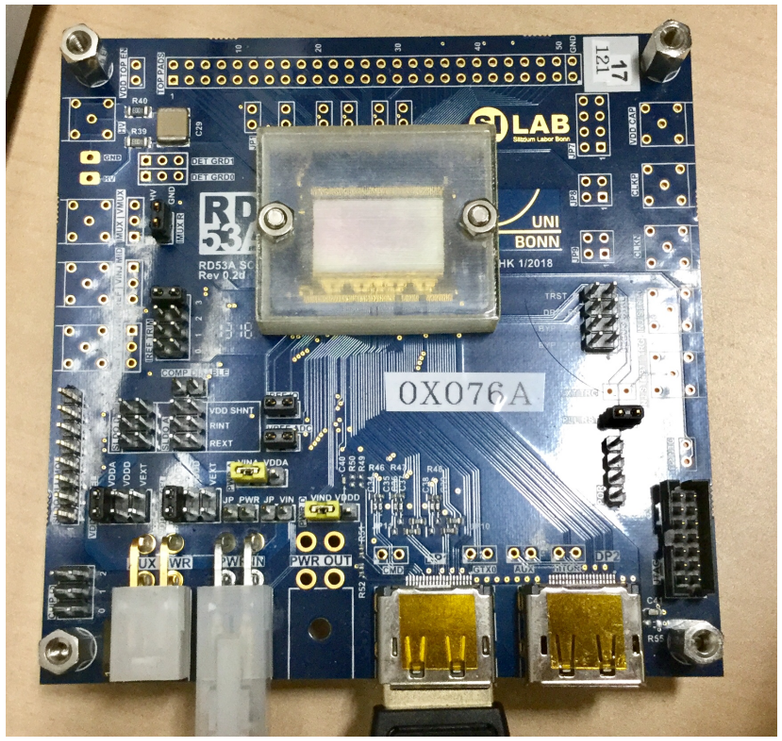
ATLAS pixel detector will be upgraded for HL-LHC.

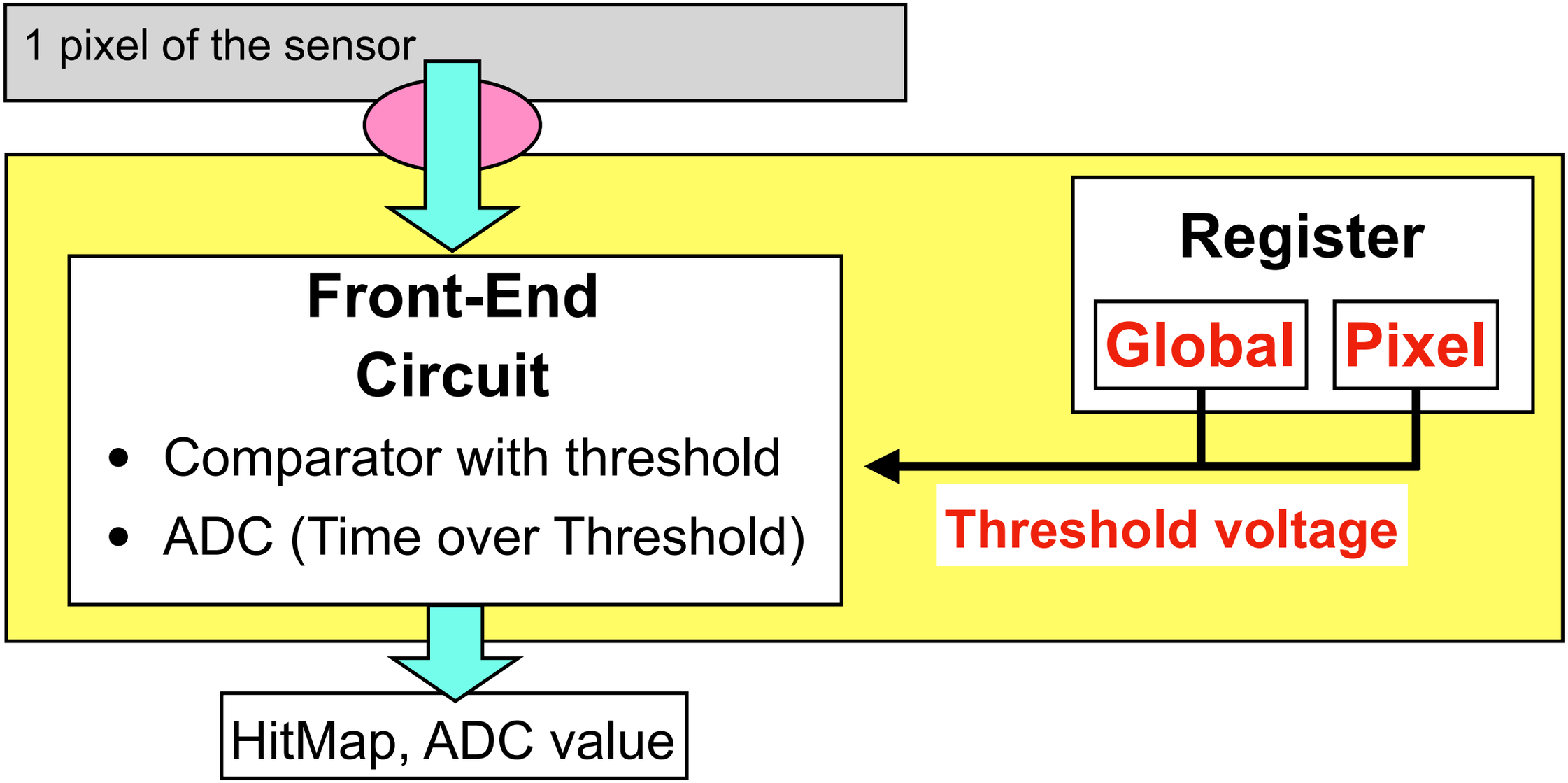


New Pixel Detector

- Total Size : 4cm × 4cm
- Pixel Size : 50um × 50um
- 4 ASICs with 1.28 Gbps readout

- **Prototype ASIC for the new pixel detector**
  - **Name : RD53A**
  - Can judge if there is a hit or not
  - Can estimate amount of input charge
  - It has registers to configure its circuits.



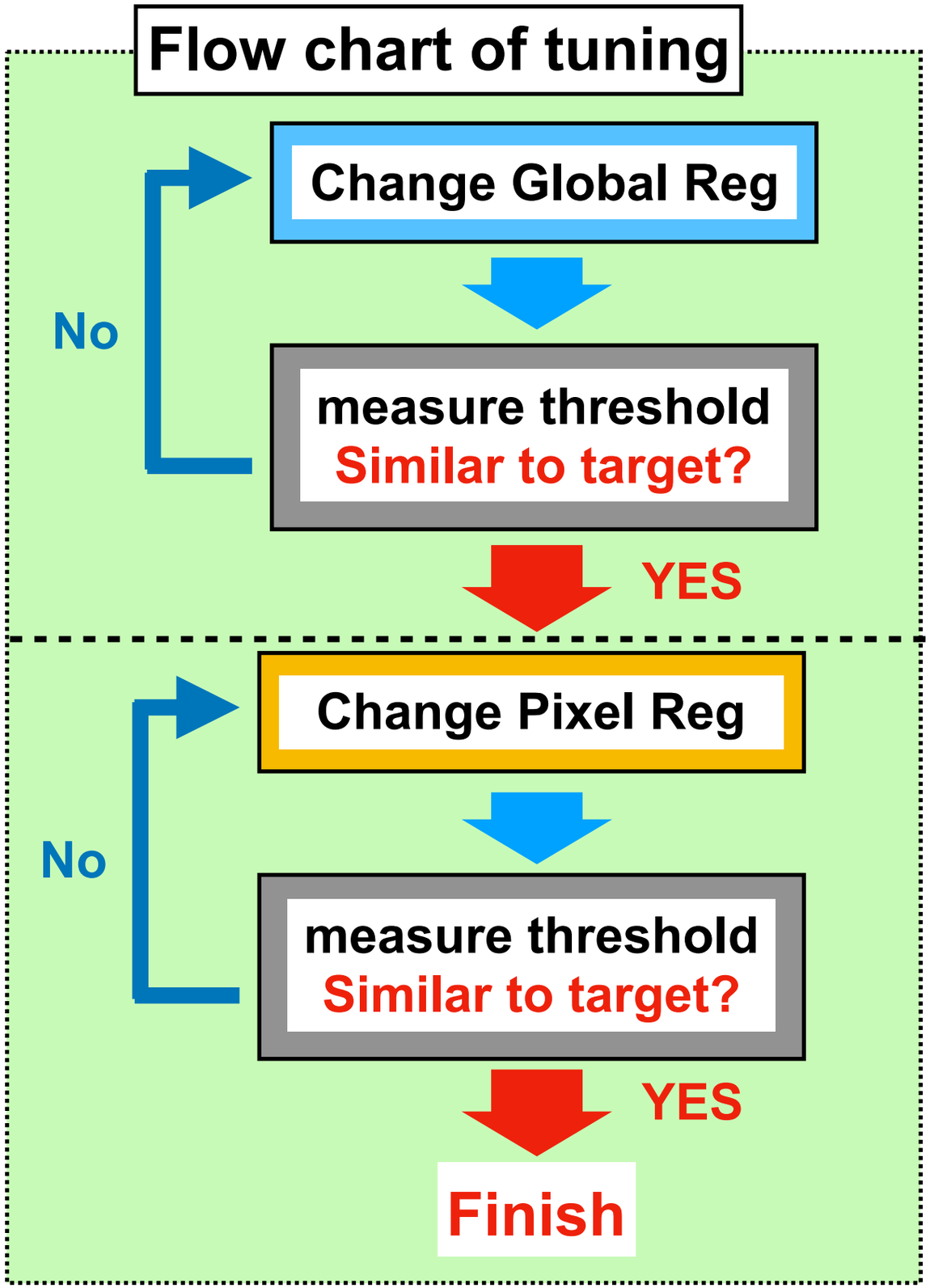


A threshold voltage is set by ASIC's register values.

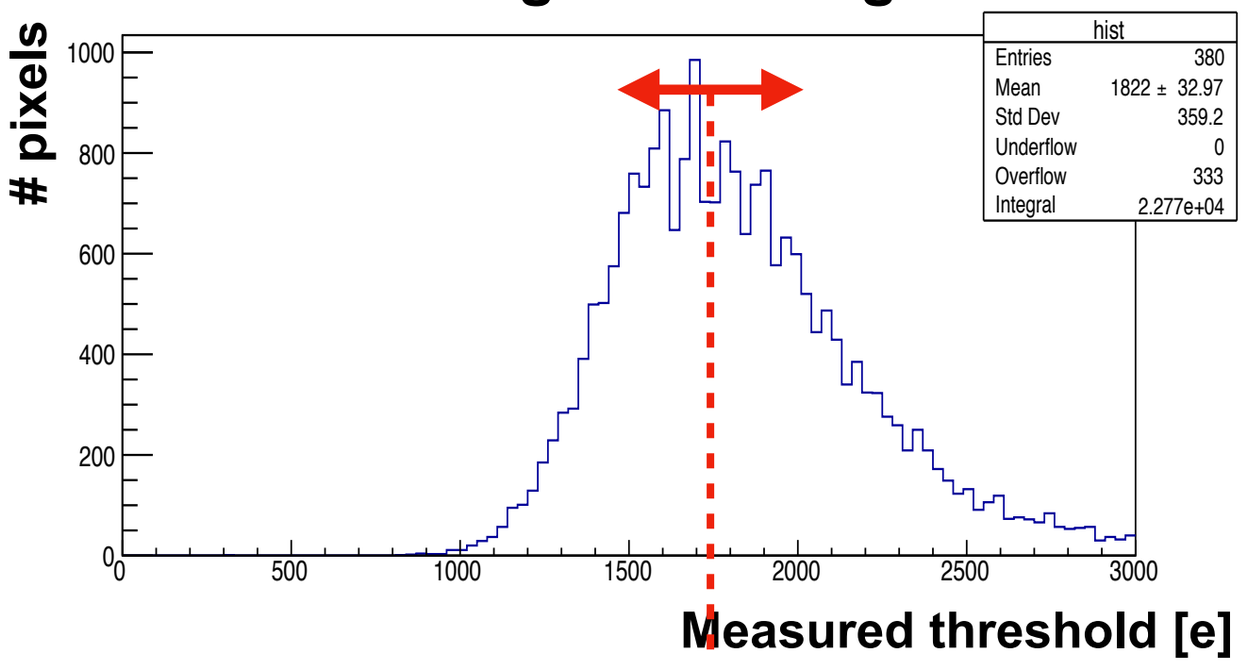
- **We have to tune them to set the threshold as we aim for.**
- **All pixels should have similar thresholds after tuning.**

Threshold tuning

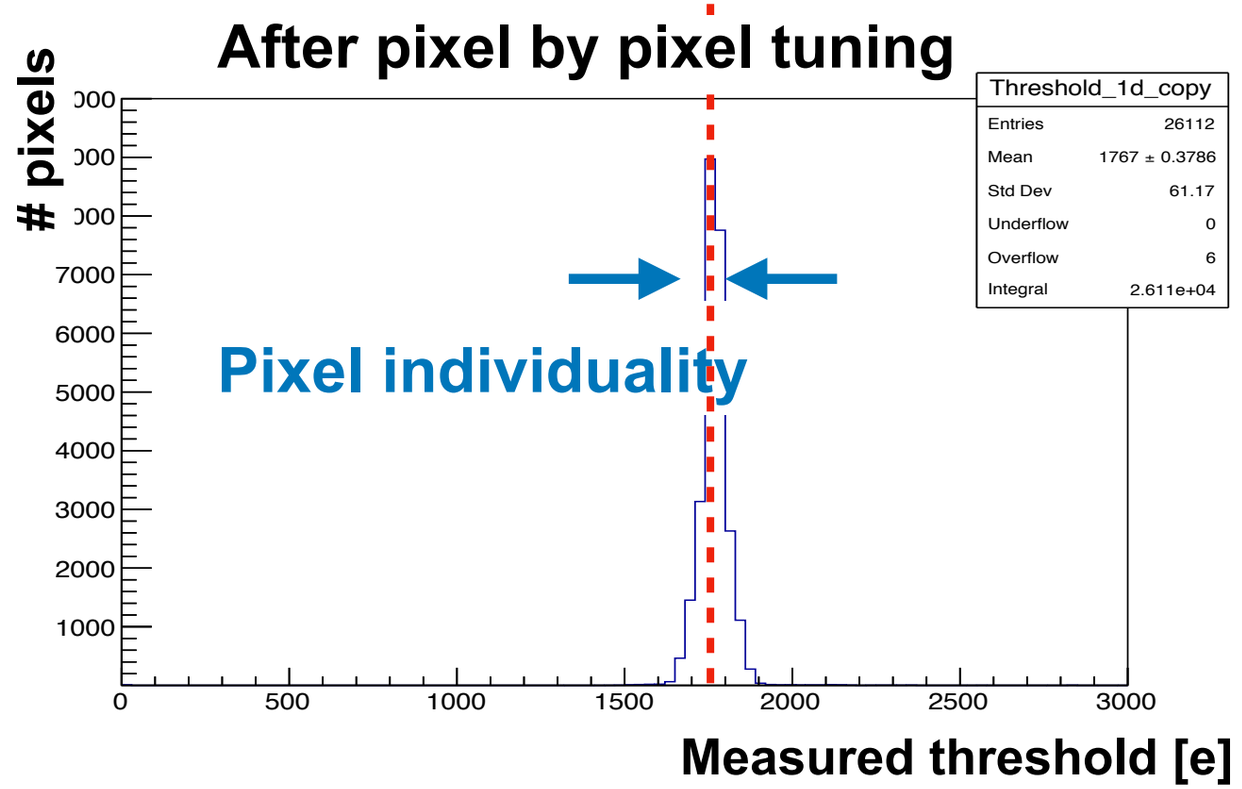
Flow chart of tuning



After global tuning

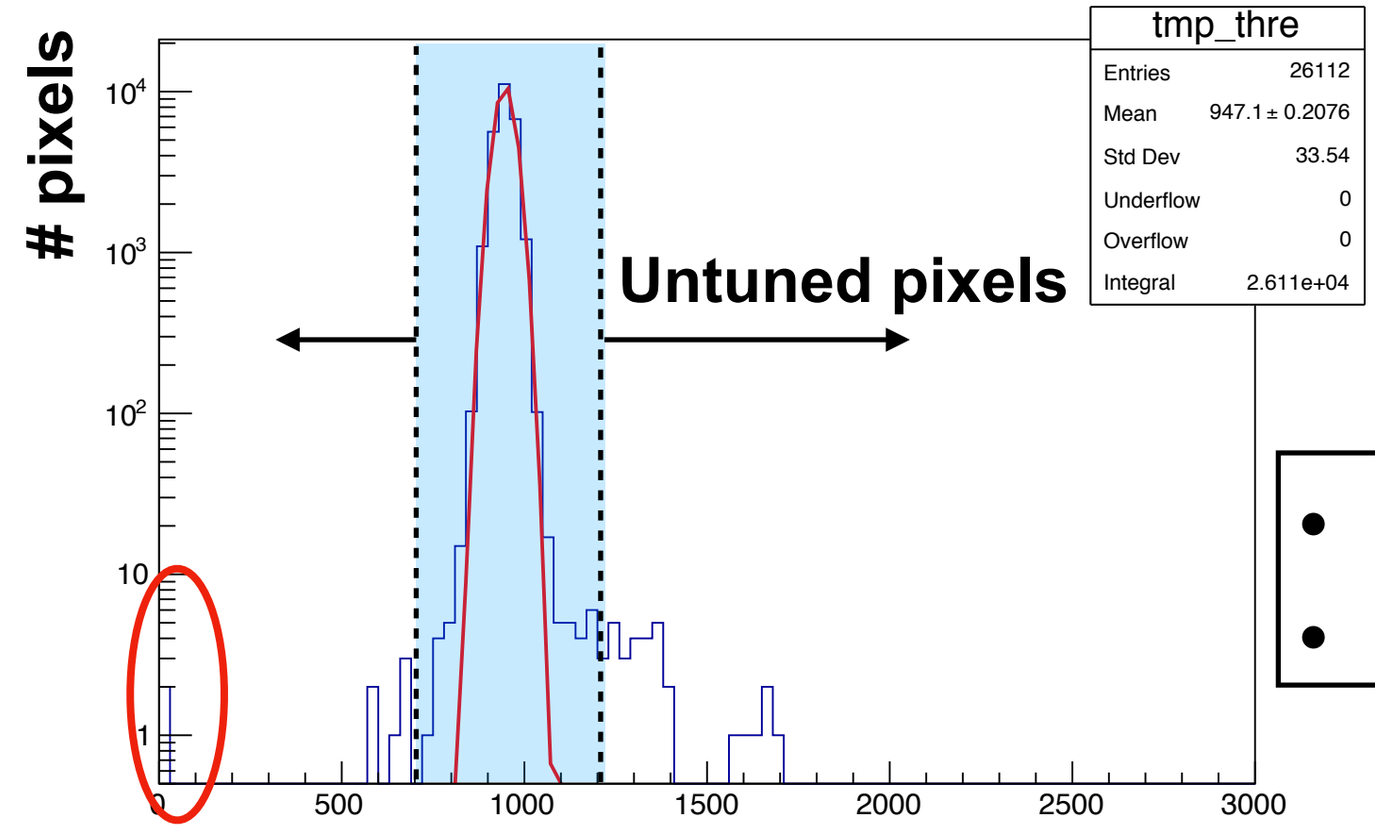


After pixel by pixel tuning



Requirement for ASIC

- One of the requirements for the new ATLAS detector
  - **Untuned pixels < 0.3% of all && threshold dispersion < 40[e]**



Definition of untuned pixels

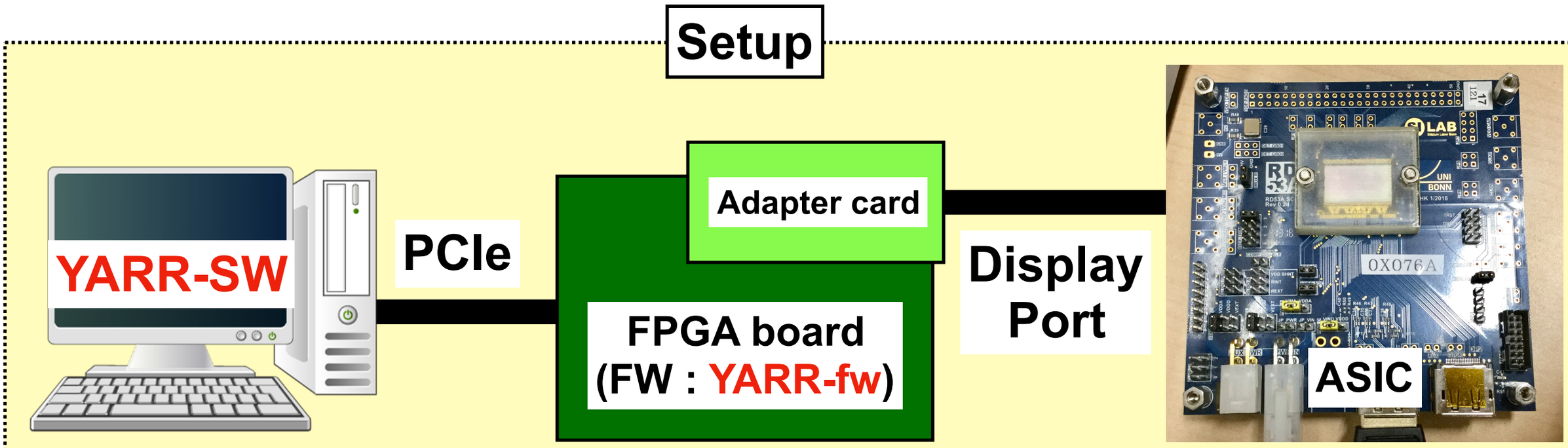
- Measured threshold =0
- |Measured threshold - target one| > 3σ

No one studied tuning and threshold behavior

even though it has the requirement to fulfill

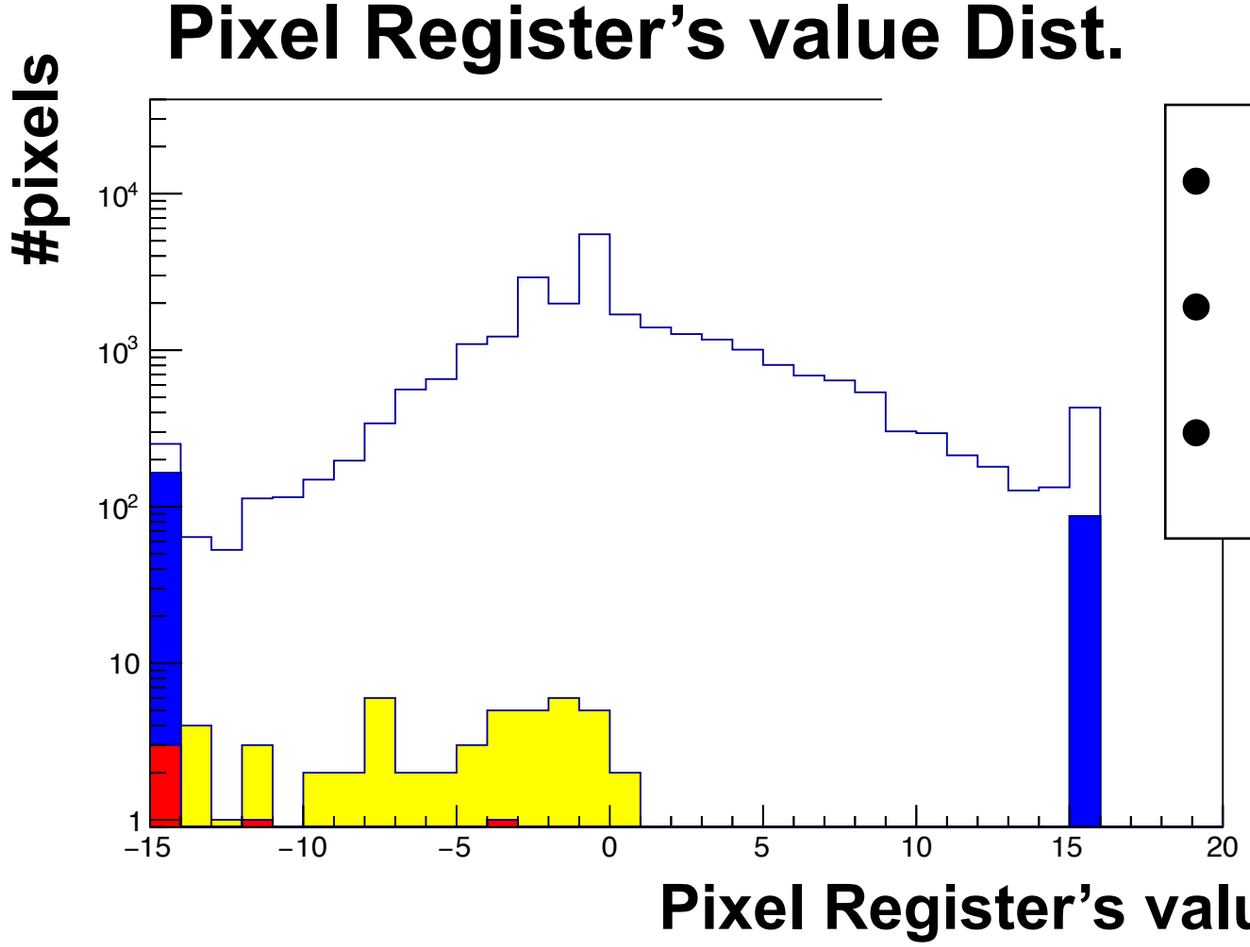
Setup

- YARR : a project for rapid readout from ASIC (developed by LBNL)
  - It has an algorithms to tune each pixel's threshold.
  - **It will be also used for QA/QC test in mass-production.**
- Untuned pixels were counted for each target threshold.
  - Target threshold's range : 0 ~ 2000 [e]
    because pixel detector's threshold will be 600 ~ 800[e].



Untuned pixels

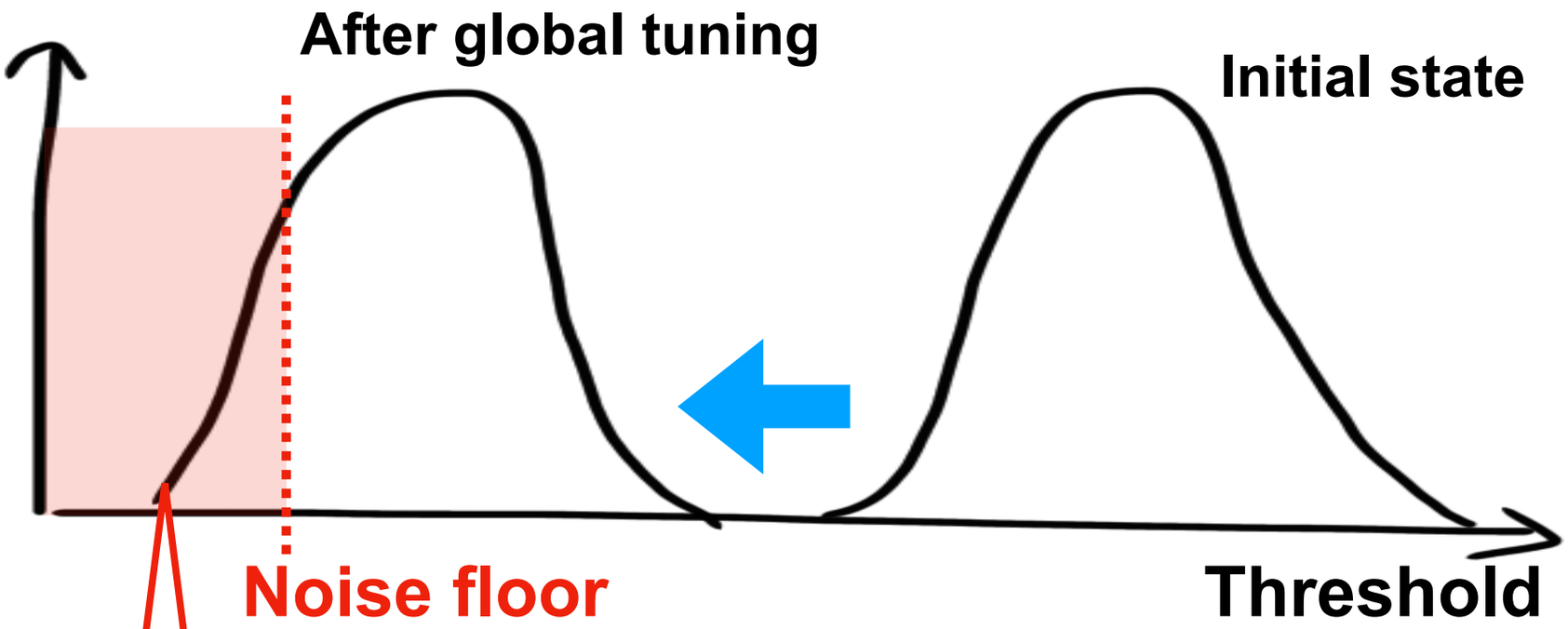
- Case : a threshold is different from target
  - That pixel's individuality is too large for pixel register to tune it.
    - Too low -> pixel register (5bit) = maximum(15)
    - Too high -> pixel register = minimum(-15)
    - other



- Blue : Too high or Too low
- Other
- Measured threshold = 0

Untuned pixels

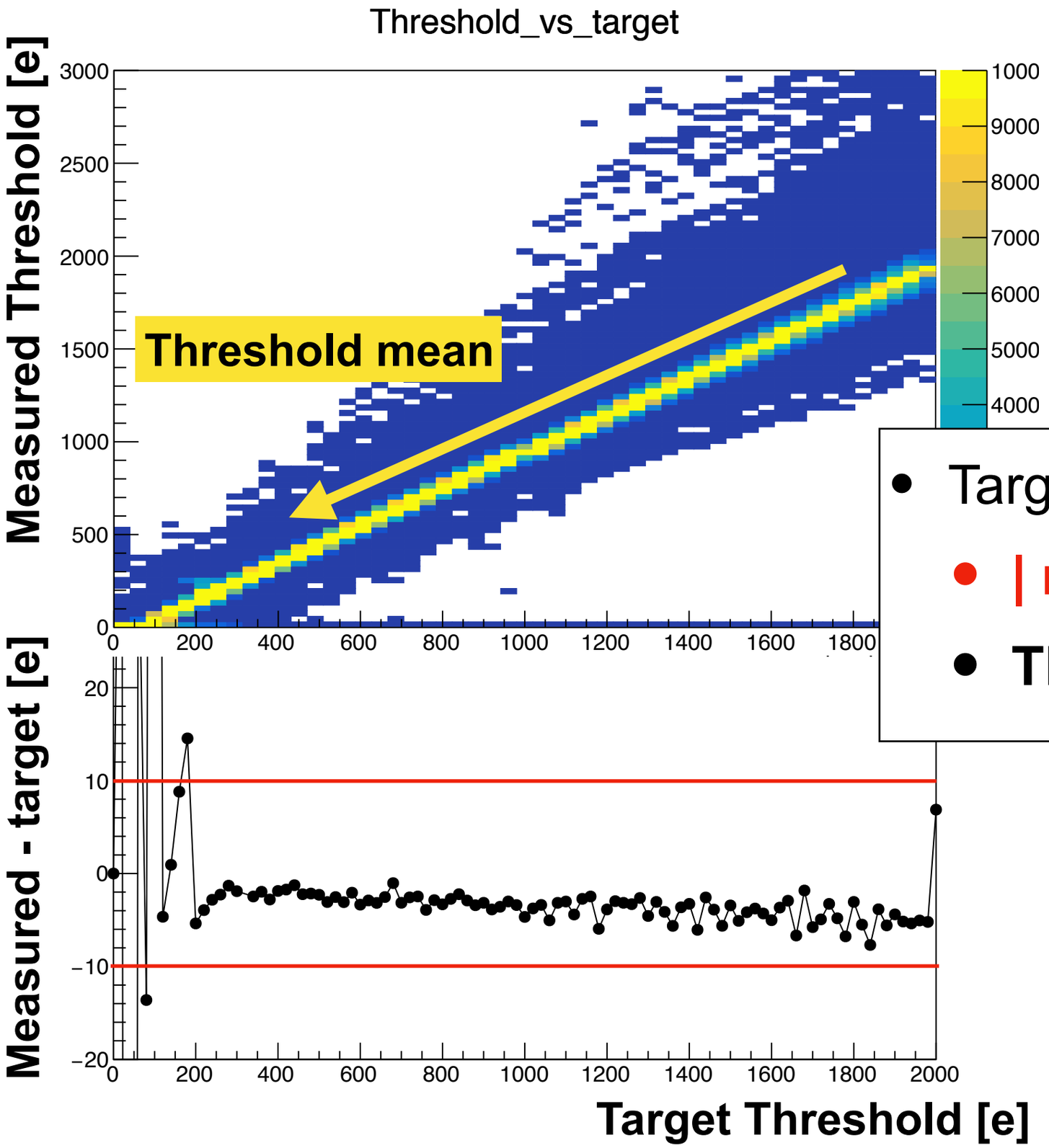
- Measured Threshold = 0 ：divided into 2 types
  - The threshold measurement was failed.
  - Non responsive pixels



Pixels below noise floor output nothing.
Algorithm can’t tune such pixels to target threshold

Non responsive pixels are predicted to increase with low target threshold.

Threshold behavior

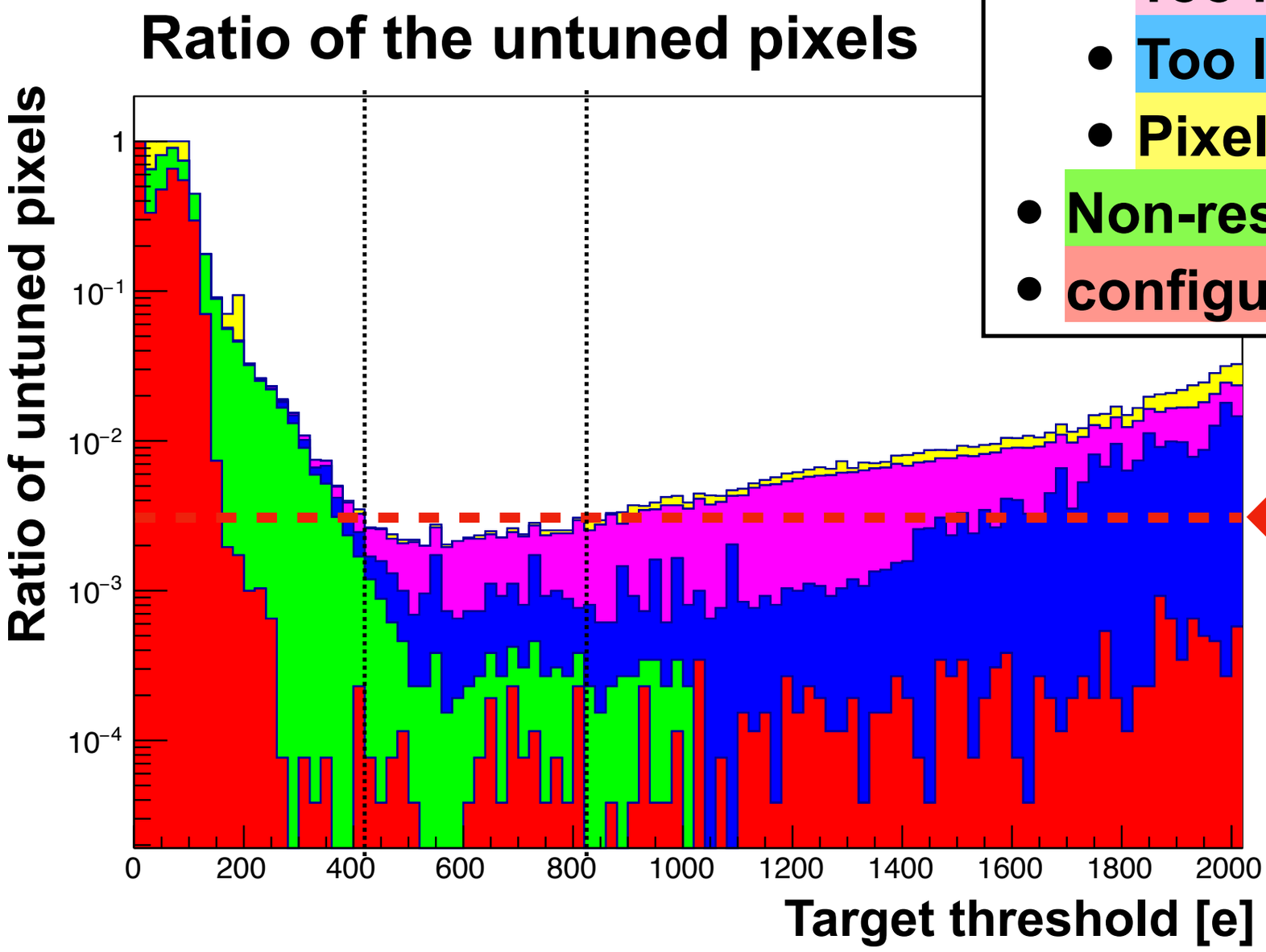


- Target threshold > 200 [e]
- **| measured - target | < 10[e]**
- **Threshold tuning is succeed**

Ratio of untuned

Color rule ▶

- Threshold 3σ away from mean
  - Too high
  - Too low
  - Pixel Reg is not saturated
- Non-responsive pixels
- configuration's problem



Requirement for pixel detector

untuned pixels < 0.3%

The requirement is satisfied! (400 < target threshold < 800[e]).

Conclusion

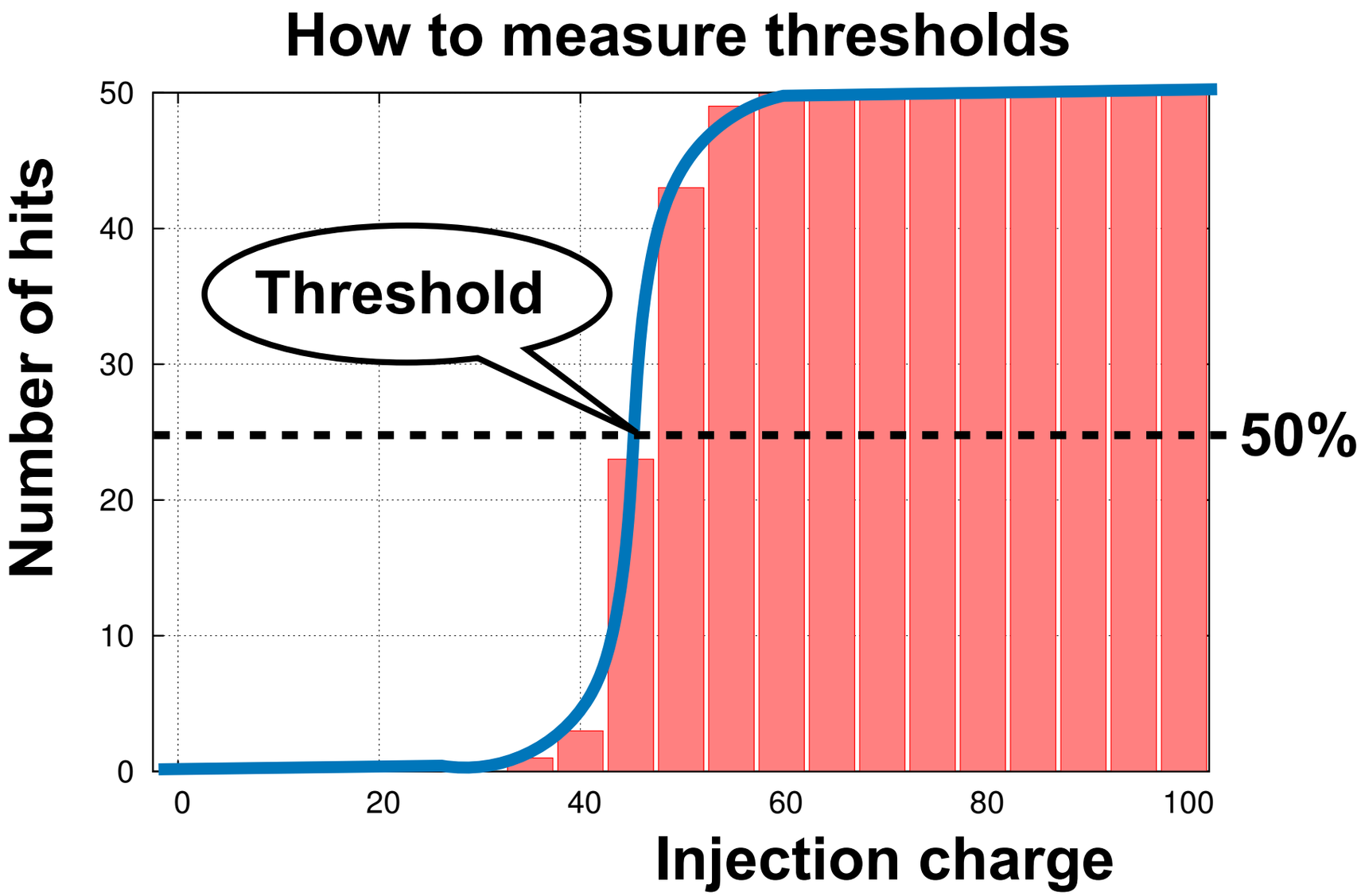
- The ASIC for the new ATLAS pixel detector was tested about a threshold tuning of each pixel.
  - **We found the ASIC satisfy the requirement for it.**
  - **The increase of non responsive pixels with low threshold was revealed for the first time.**

    And, they are dominant with a target threshold below 400 [e].
- **This result will be a good benchmark** for QA/QC tests in mass-production of the prototype ASIC and revised one.

Back Up

Threshold scan

- YARR's scan consists of the 4 functions.

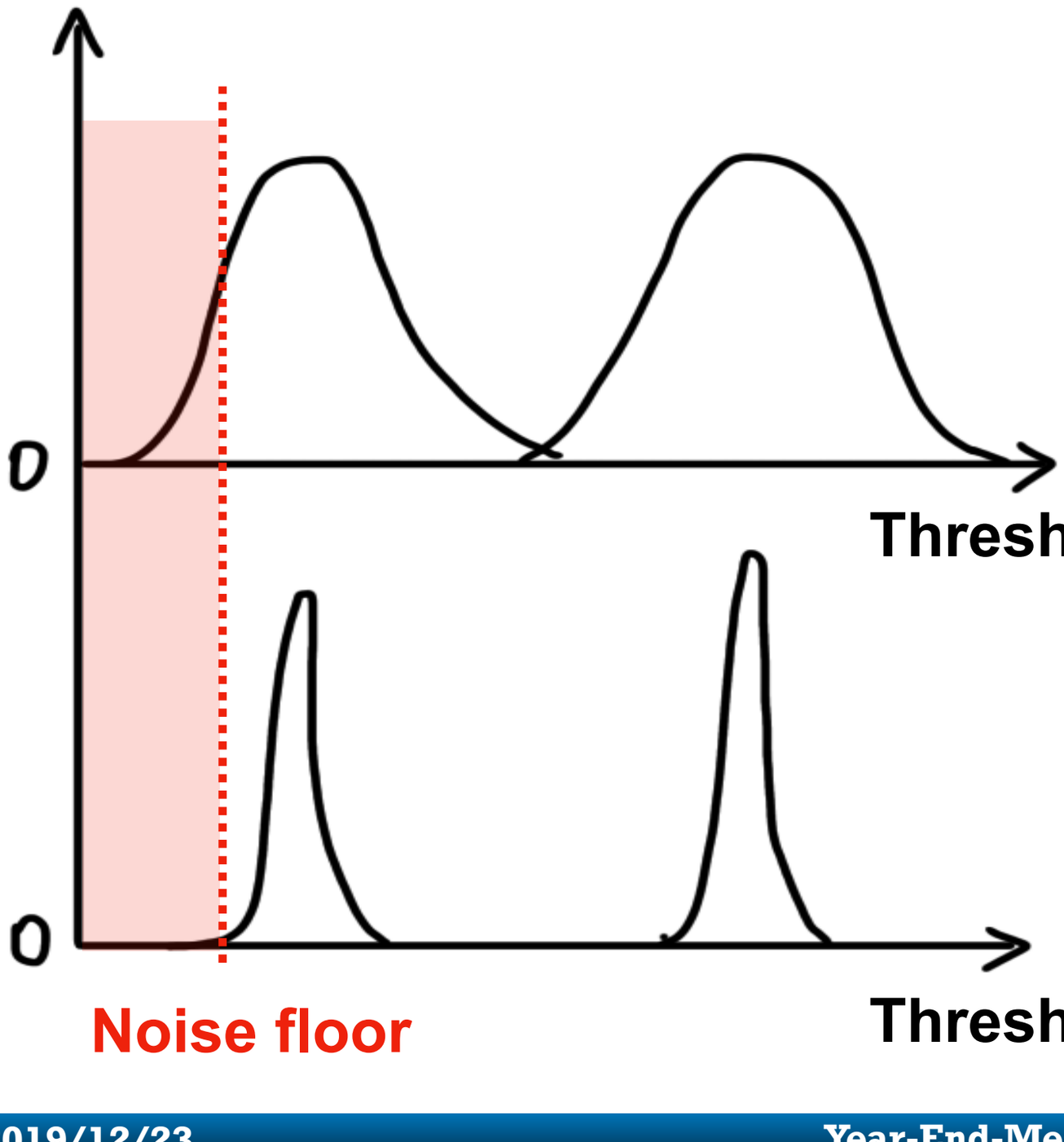


- **Tuning : a scan + change global/pixel register's value**

Avoid “non responsive”

- Before the tuning to target, the one to 800[e] was done.

  -> This process can reduce non-responsive pixels



Pixels with a threshold below noise floor are decreased!

Avoid “non responsive”