

Monolithic Active Pixel Sensor with multidimensional measurement for future experiments at HIAF



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Introduction

The High-Intensity Heavy-ion Accelerator Facility (HIAF) is a leading platform for heavy-ion scientific research in China. Currently, several significant physics experiments are being constructed at HIAF, including the Electron-Ion Collider in China (EicC), the All-Silicon High Energy Spectrometer, and the High Energy Fragment Separator (HFRS). The Monolithic Active Pixel Sensors (MAPS) are extensively utilized in these projects, especially for vertex and tracking detectors. Following shows the recent progress in MAPS development for the physics terminals at HIAF.

The Latest Generation of Nupix-H Series

Key Features

- **Multi-dimensional measurements:**
 - Position, time, and energy.
- **High precision:**
 - Spatial resolution: $\leq 10 \mu\text{m}$.
 - Time resolution: $\leq 10 \text{ ns}$.
 - Energy measurement: Up to 15 ke- with ENC of ~ 50 to 100 e-.
- **Continuous readout:**
 - Novel reset scheme for continuous readout.

Chip Specifications

- **Process:** GSMC 130 nm quadra-well process.
- **Chip size:** 2.3 cm \times 1.5 cm.
- **Pixel array:** 256 \times 448 pixels.
- **Pixel size:** 45 μm \times 45 μm .

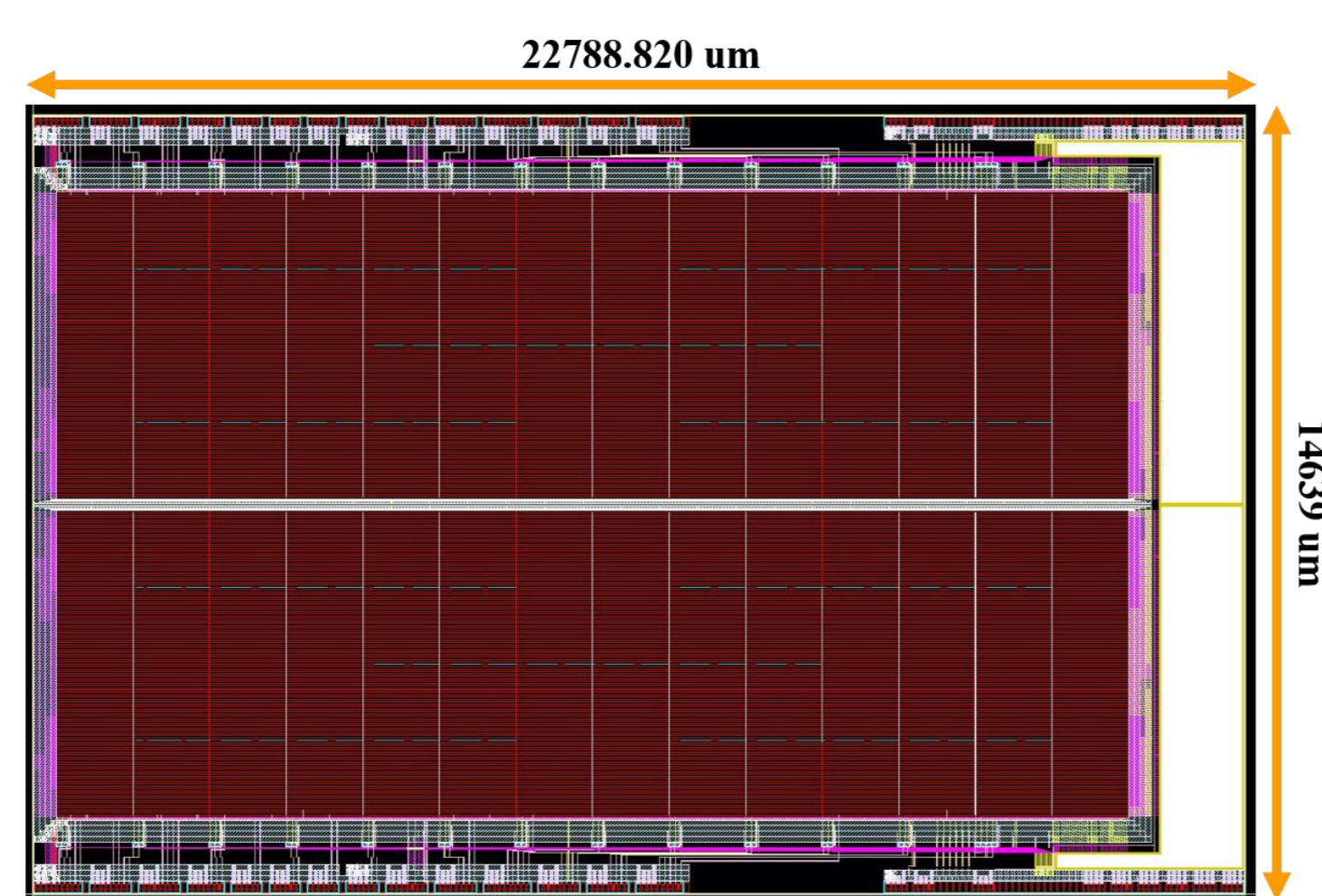


Figure 1. Layout of the Nupix-H3

Super pixels (16 pixels)

- **Energy measurement:**
 - Charge collection diode collects deposited charges.
 - Charge Sensitive Amplifier (CSA) amplifies signals.
 - Peak Holding Unit maintains energy information.
 - Energy Output Unit reads out energy data.
- **Time measurement:**
 - Comparator discriminates signals, triggering time measurement.
 - Time Measurement Unit:
 - 15-bit counter for coarse time measurement.
 - TAC for precise time measurement.

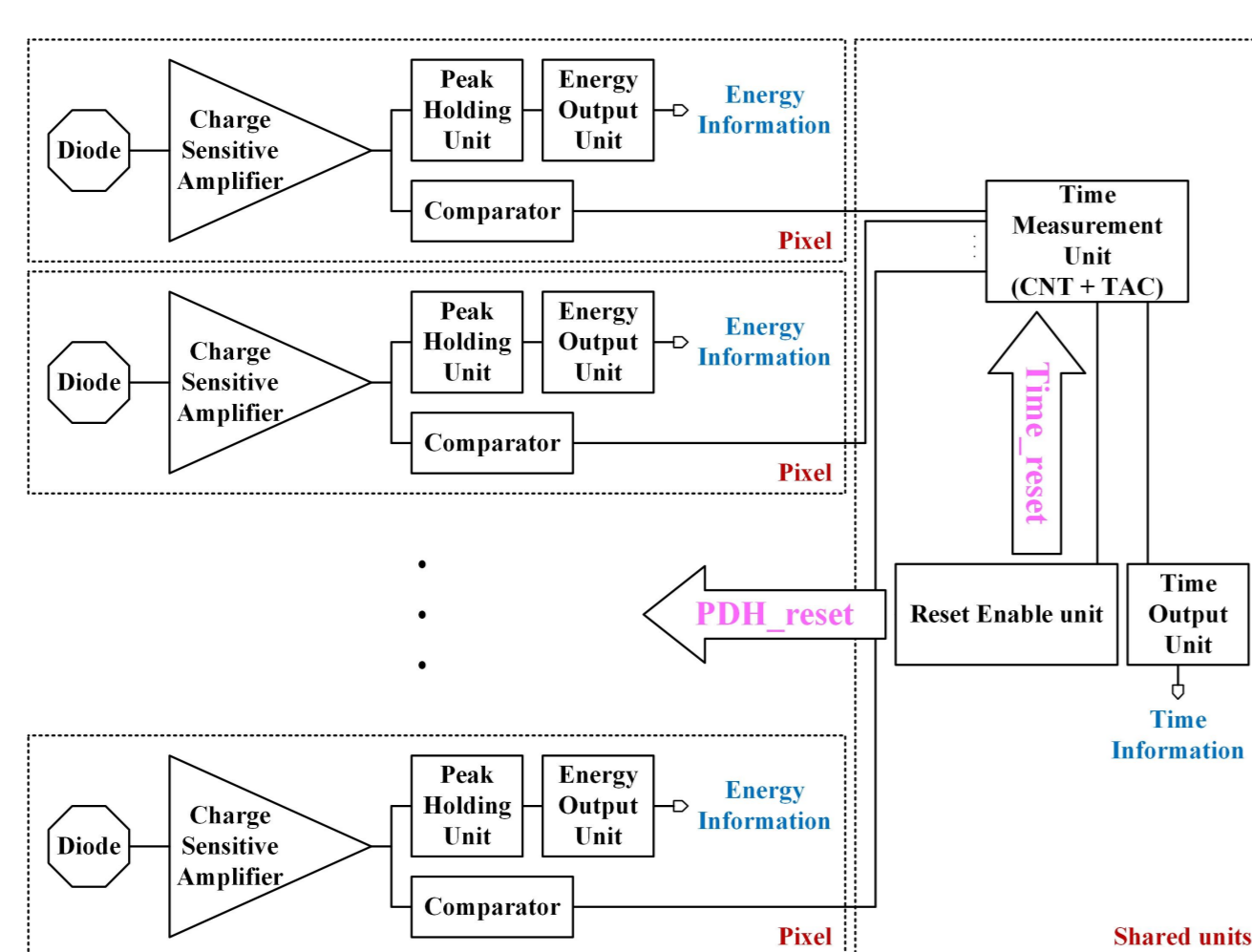


Figure 2. Structure of super-pixel

The Latest Generation of Nupix-A Series

Key Features

- **Application:** Designed for vertex detectors.
- **Accurate position measurements:**
 - Spatial resolution: $\sim 5 \mu\text{m}$.
 - Equivalent Noise Charge (ENC): $\sim 30 \text{ e-}$.
- **Hit-only readout mode:**
 - Zero compression and readout.

Chip Specifications

- **Process:** GSMC 130 nm quadra-well process.
- **Chip size:** 5 mm \times 6 mm.
- **Pixel array:** 128 \times 128 pixels.
- **Pixel size:** 30 μm \times 30 μm .

Test results

- **Laboratory test**
 - Bias setting by adjustable DAC.
 - S-Curve fitting.
 - Evaluate the fake hit ratio and noisy pixels.

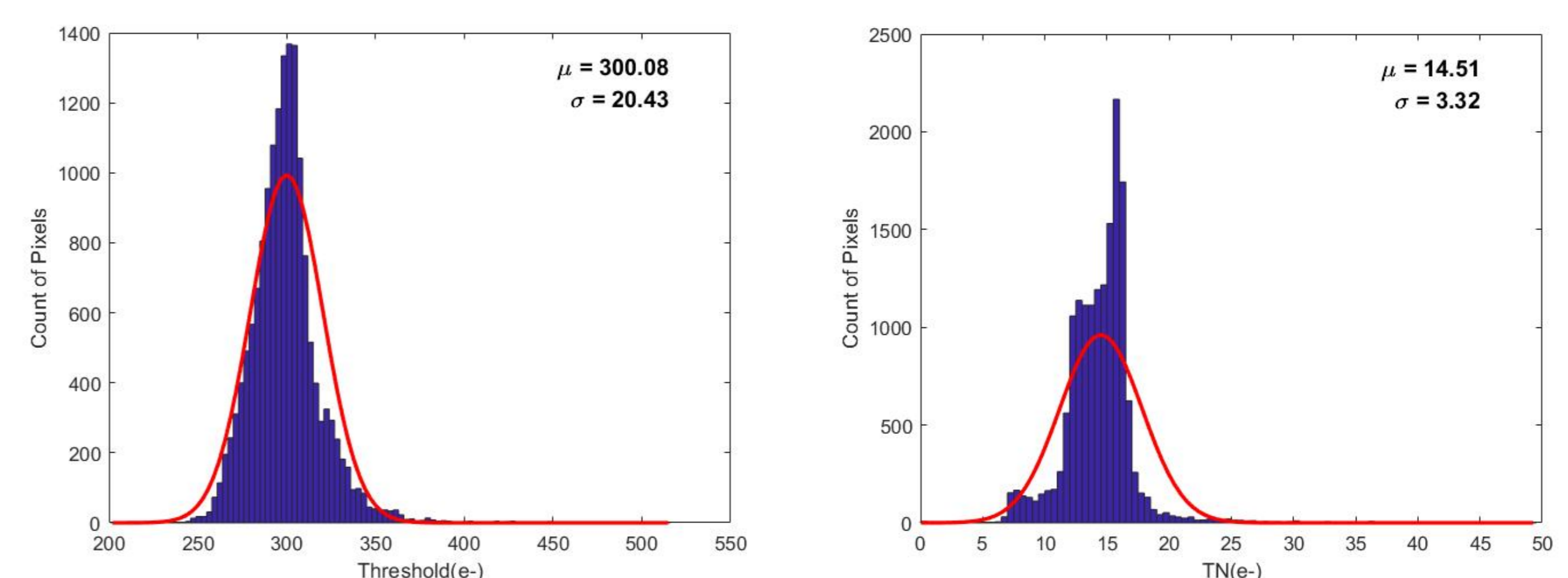


Figure 4. Distribution of pixels' threshold (left) and noise (right)

- **Sr⁹⁰ test:** Response to MIPs.

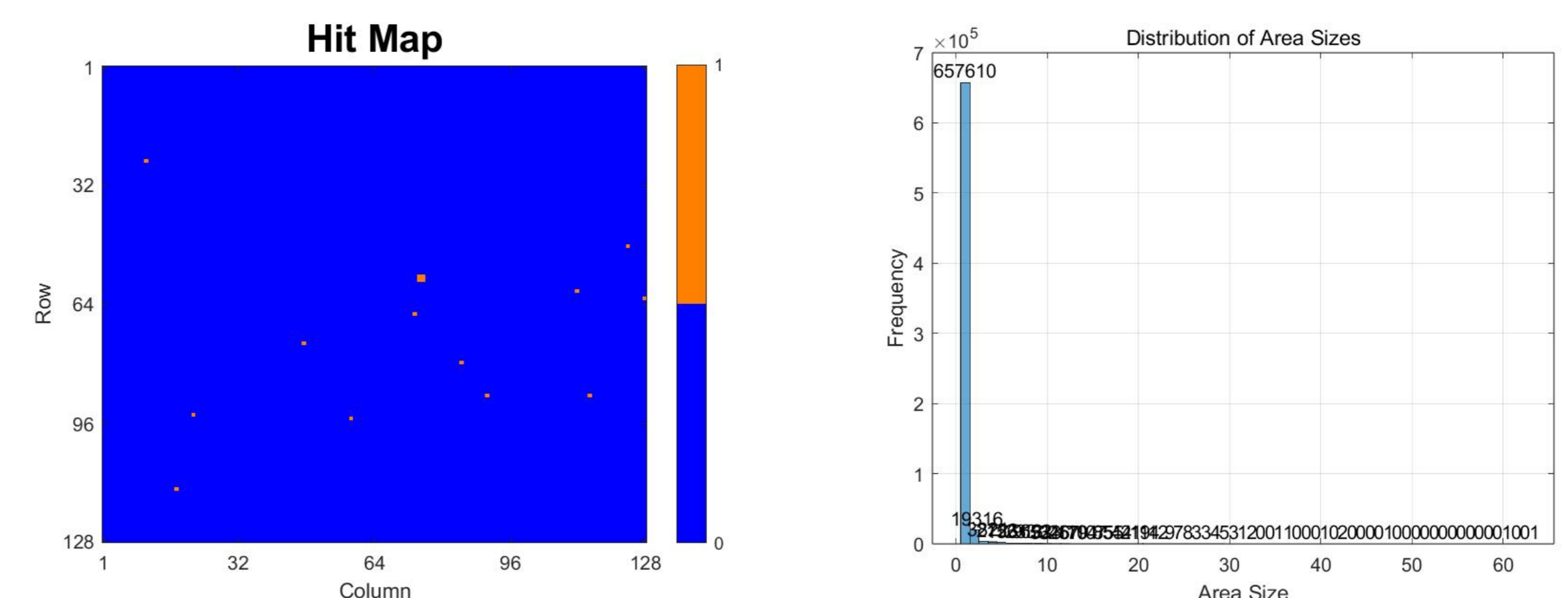


Figure 5. Response to Sr⁹⁰ (left) and statistical distribution (right)

- **Beam test:** Response to protons.

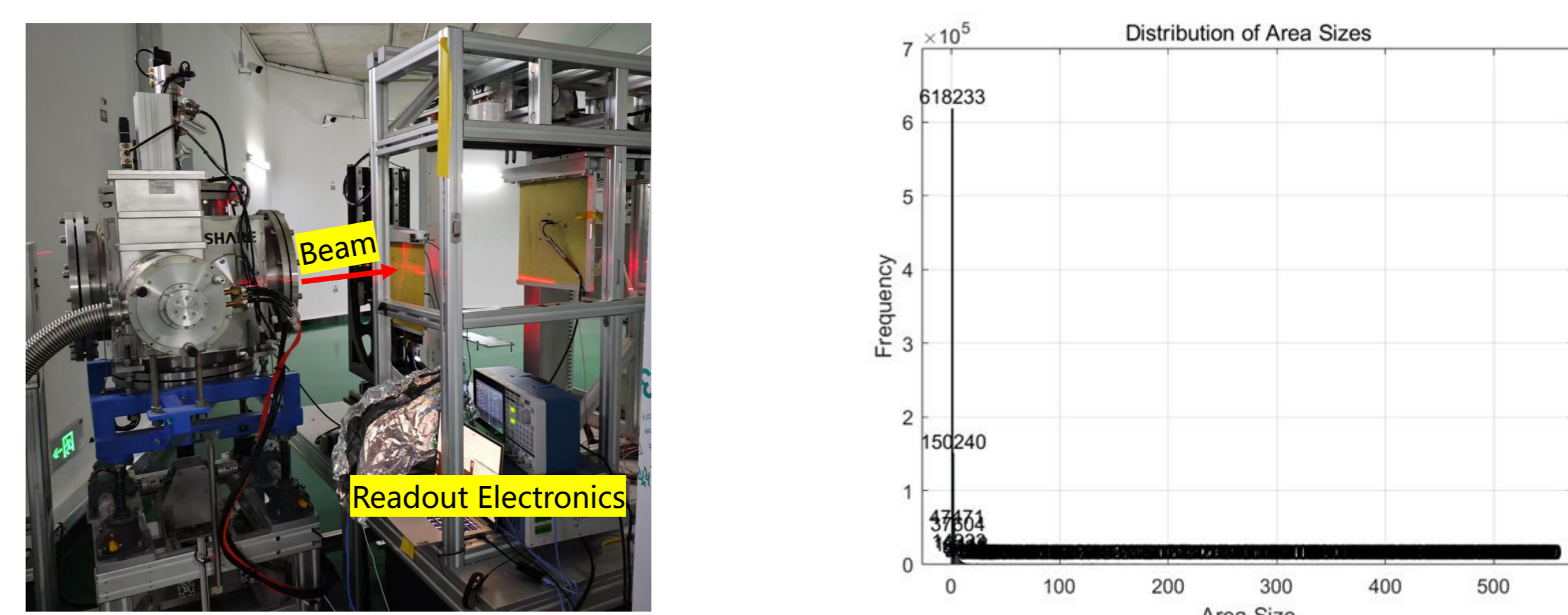


Figure 5. Test setting (left) and statistical distribution of cluster sizes (right)

- **Laser test:** Evaluate the spatial resolution.

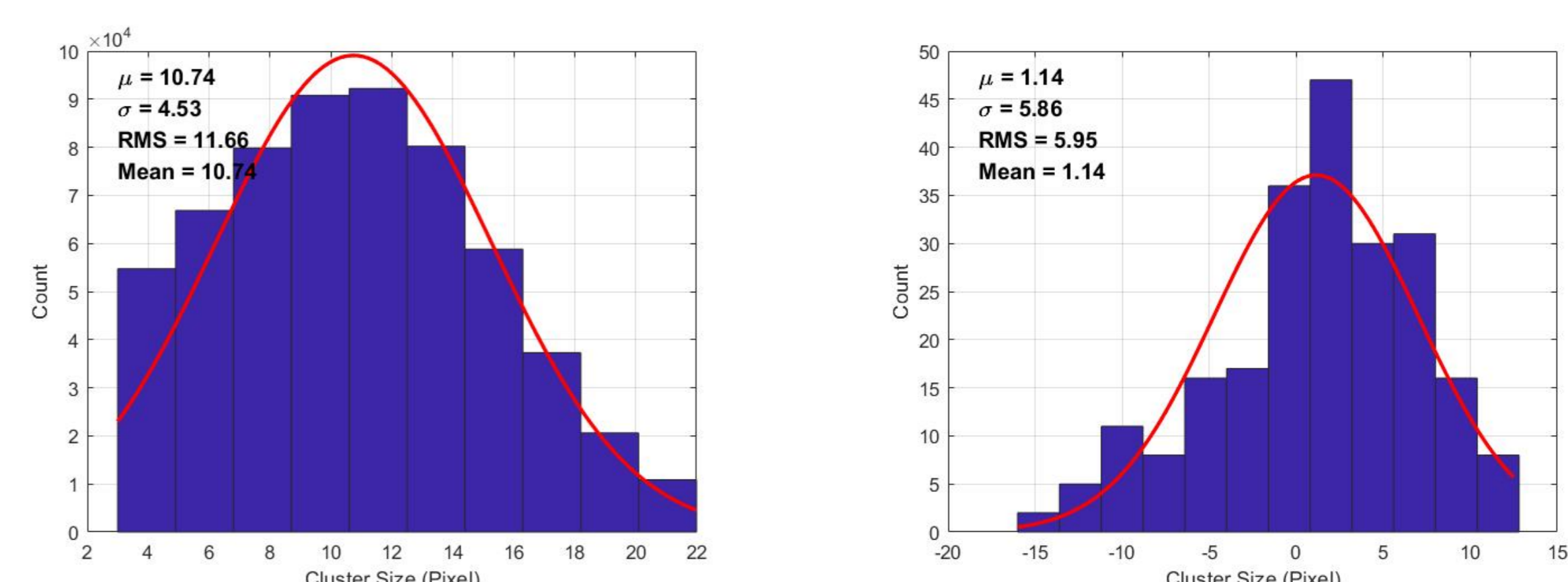


Figure 8. Distribution of area (left) and residual (right) in laser test