



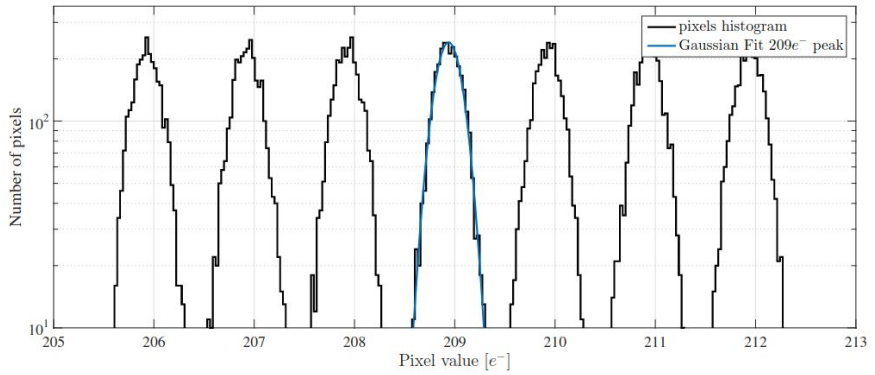
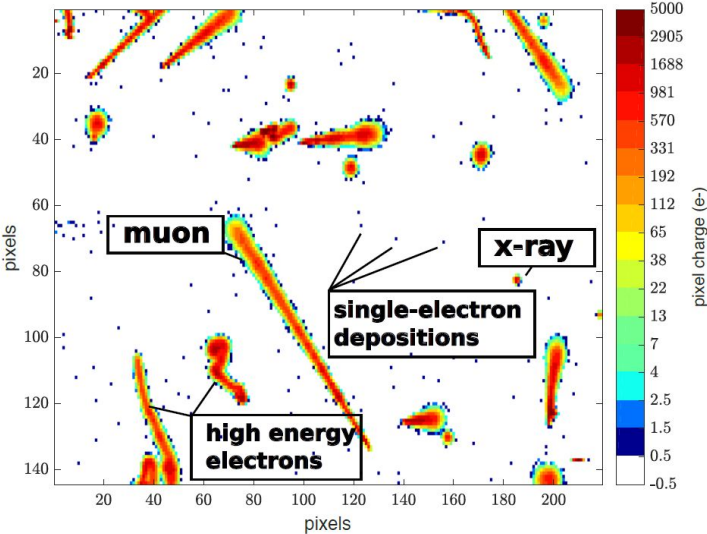
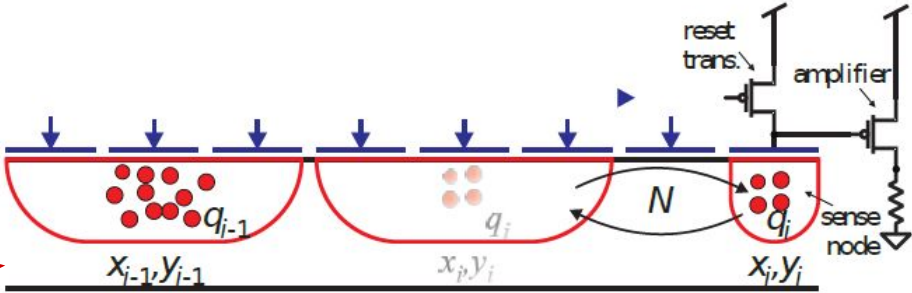
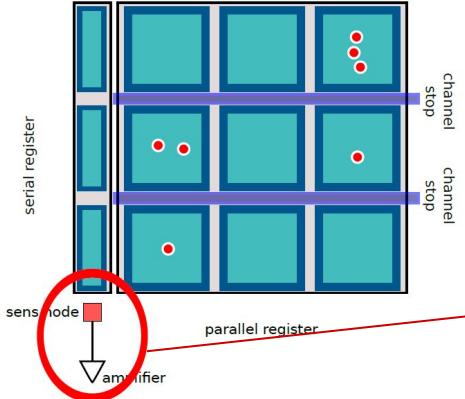
## Recent developments for fast readout of Skipper CCD sensors for particle physics and optical applications

Guillermo Fernandez Moroni

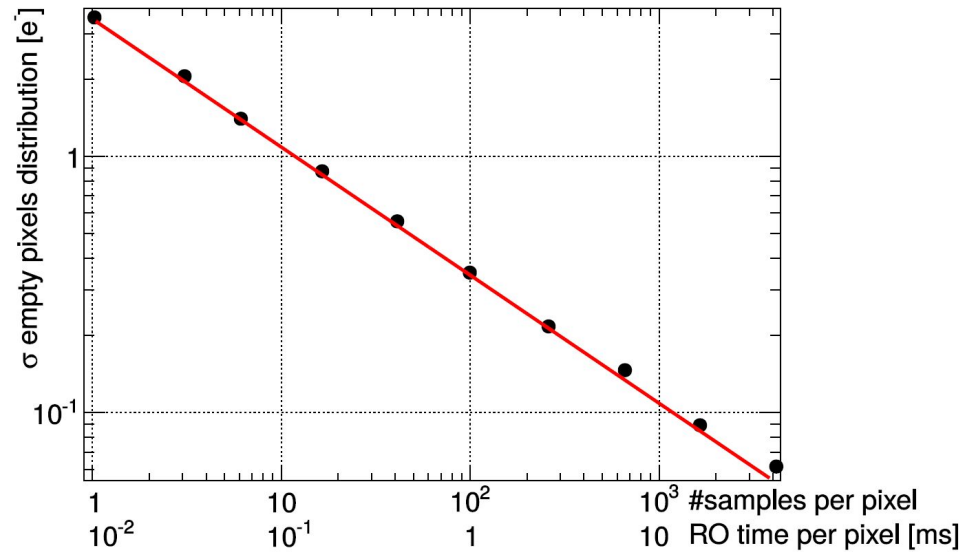
CPAD Workshop 2022, Stony Brook, 2022.

# Skipper Charge Coupled Device (CCD) technology

example of a 3x3 CCD



# Current speed limitation of non-destructive readout



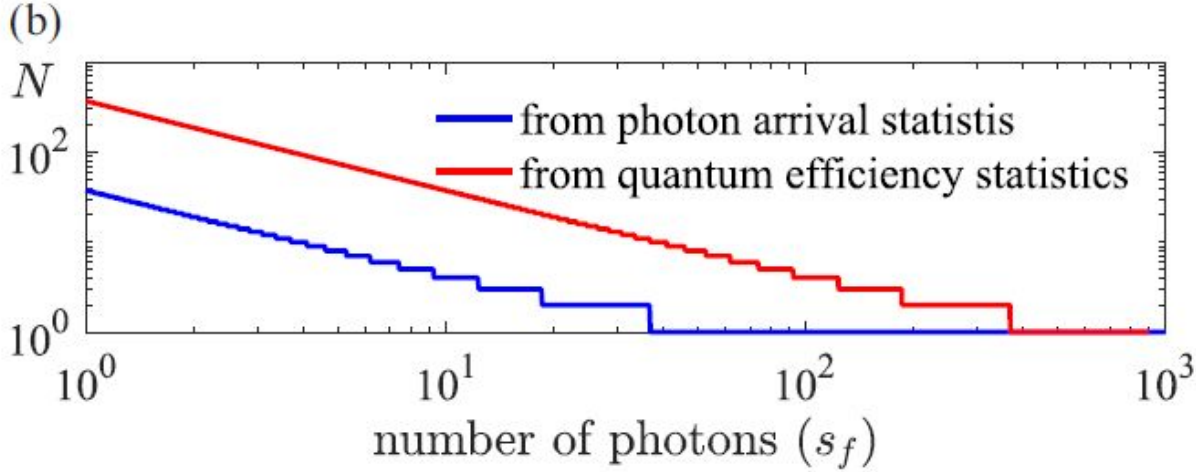
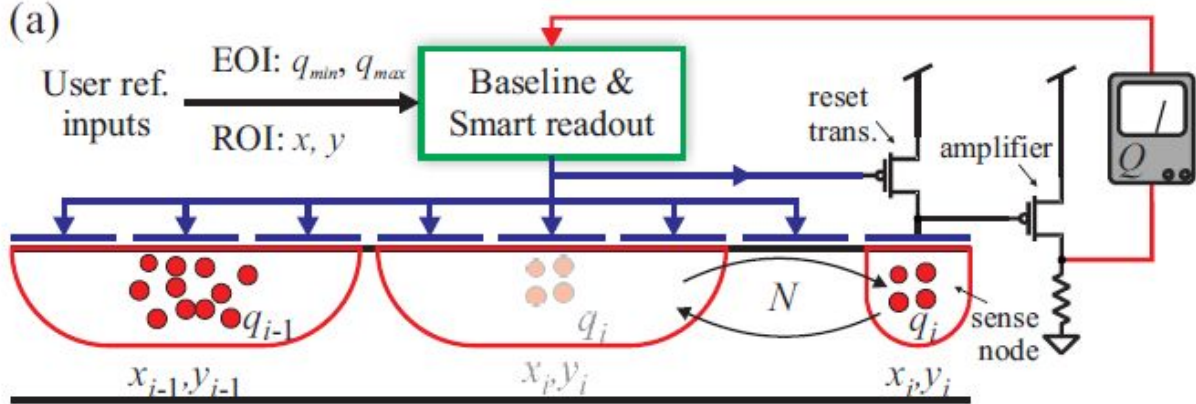
## How we can overcome this limitation

- ❑ Parallel readout through many amplifiers.
- ❑ Improve the sensitivity of output amplifier (or reduce the equivalent noise of each sample)
- ❑ Used the optimum number of samples per pixel

## Why we want to go fast?

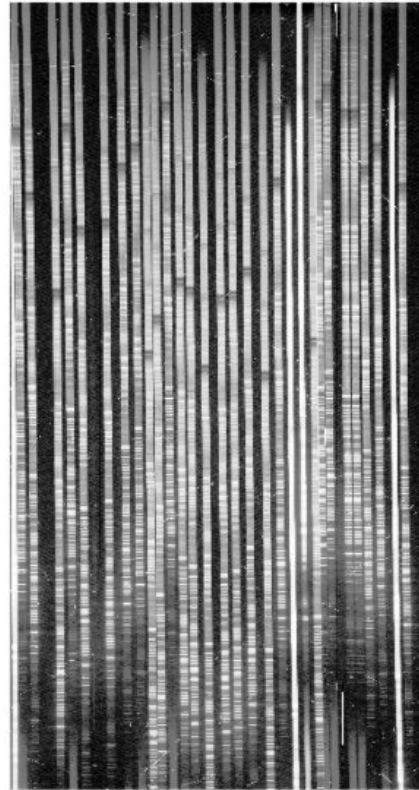
- New ground based and space based astronomical instruments.
- Quantum information science.
- Particle detection: have timing information and reduce backgrounds.

# Smart Skipper idea

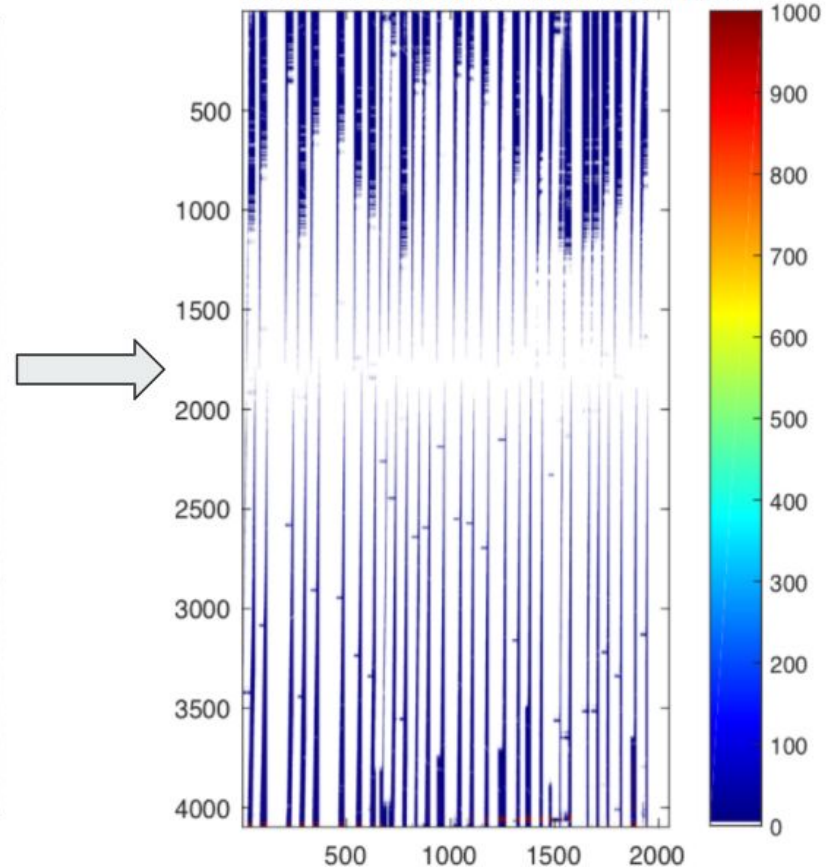


# One of our goals is to use Skipper CCD for new astronomical instruments

Image from spectrograph

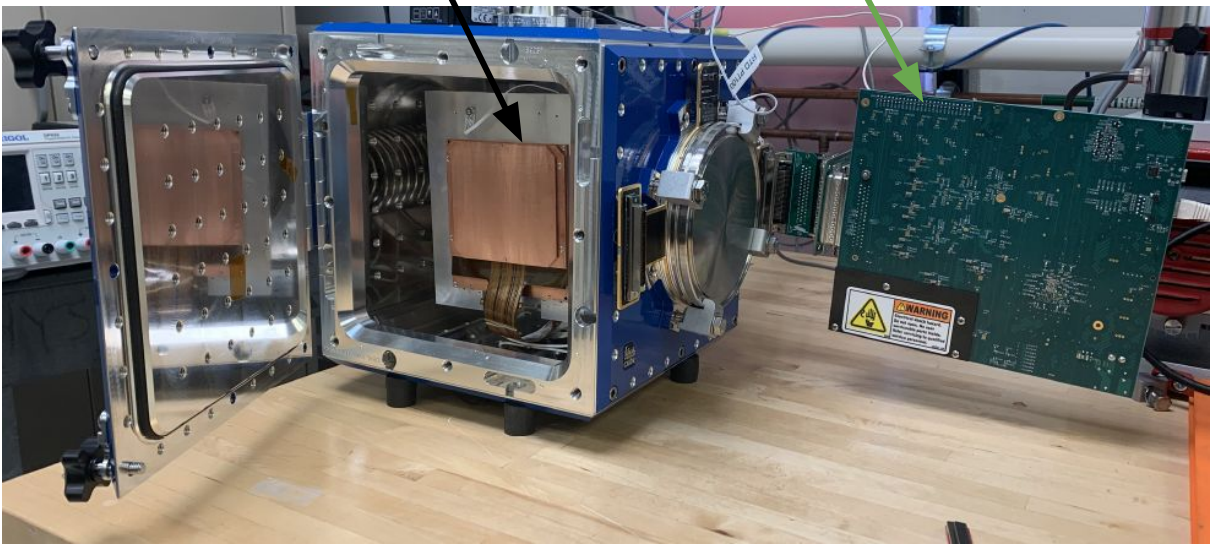
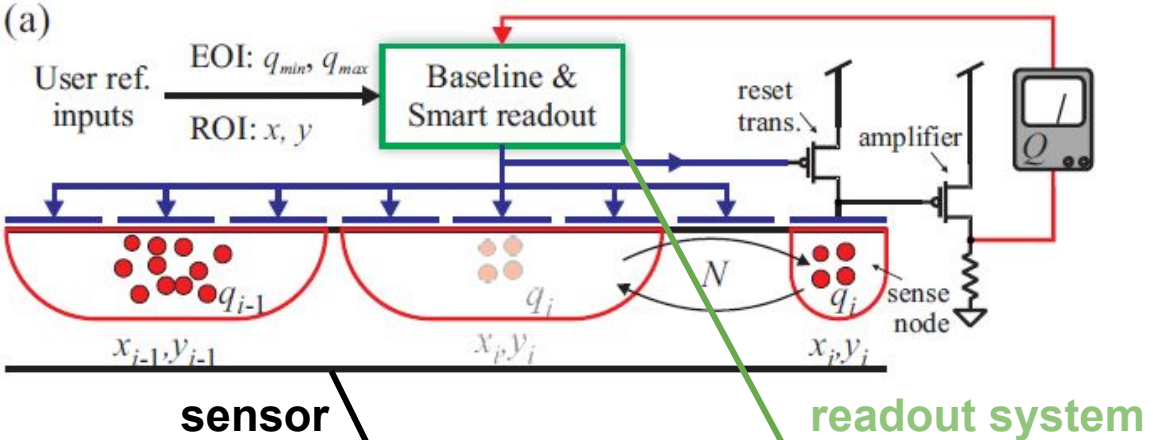


Number of skipper samples per pixel

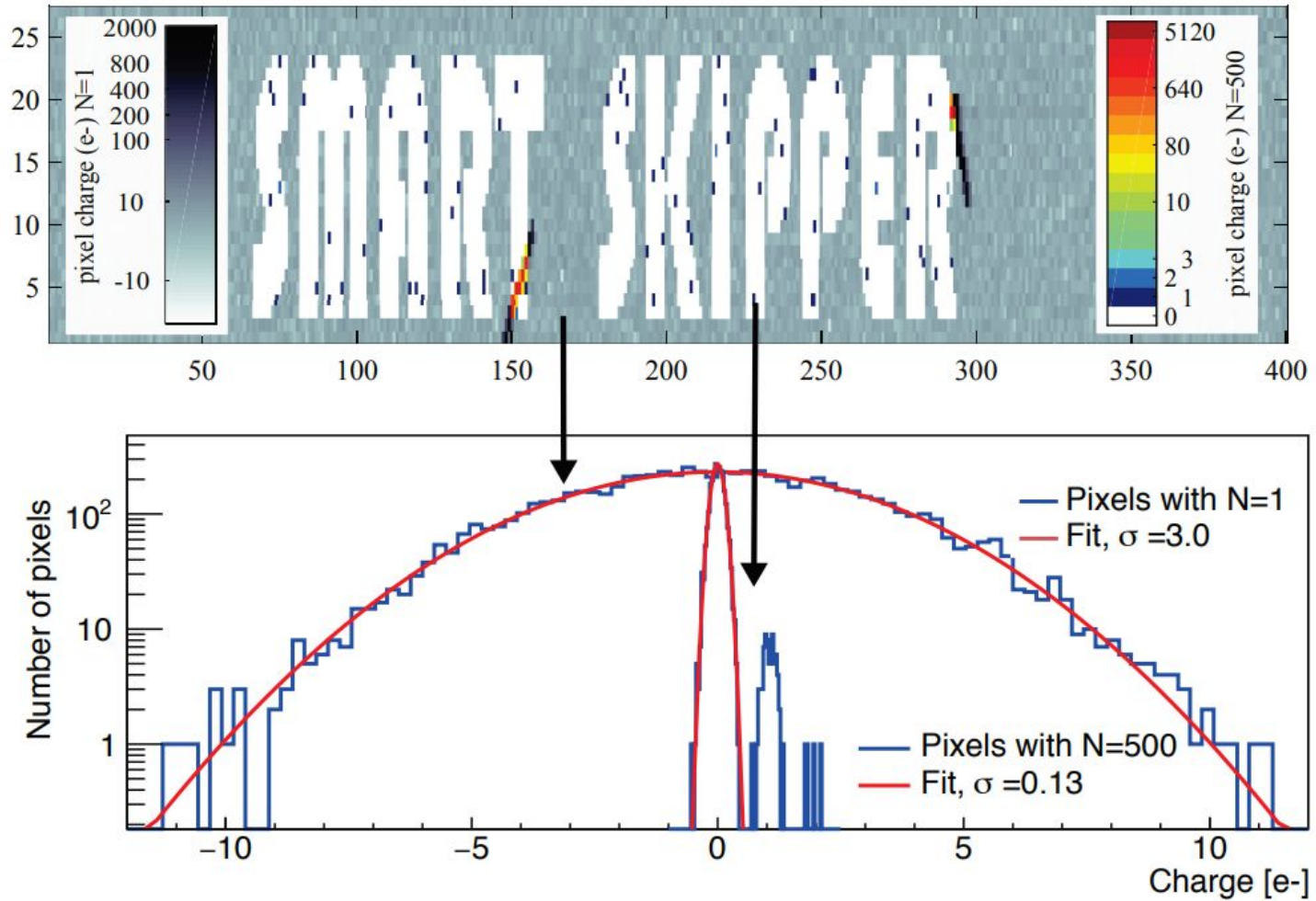


- Real image from an spectrograph.
- 100 times faster readout
- Rule: making noise much smaller than the poisson statistics

# Implementation



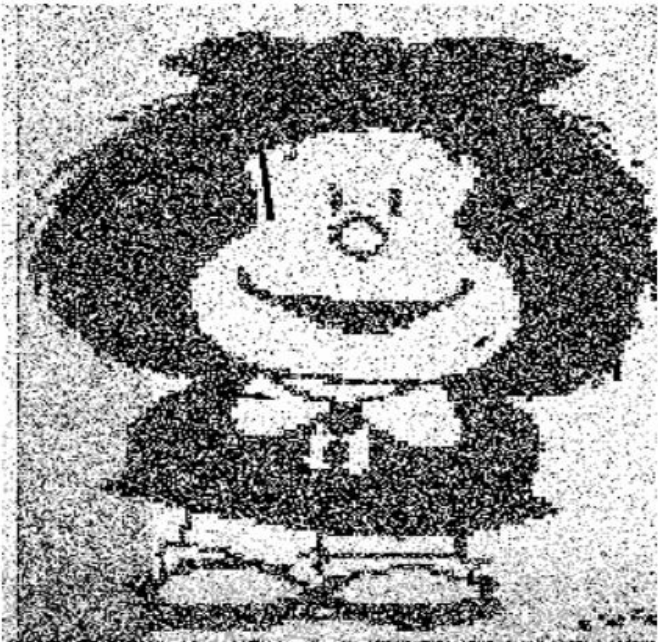
# Region of interest



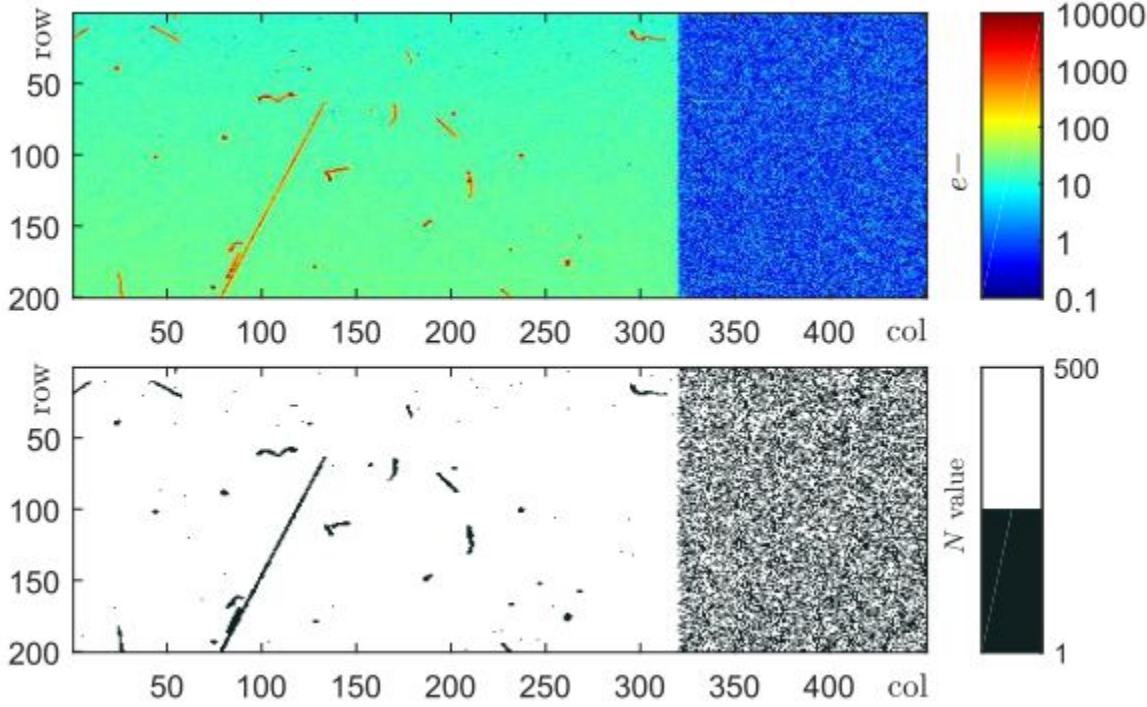
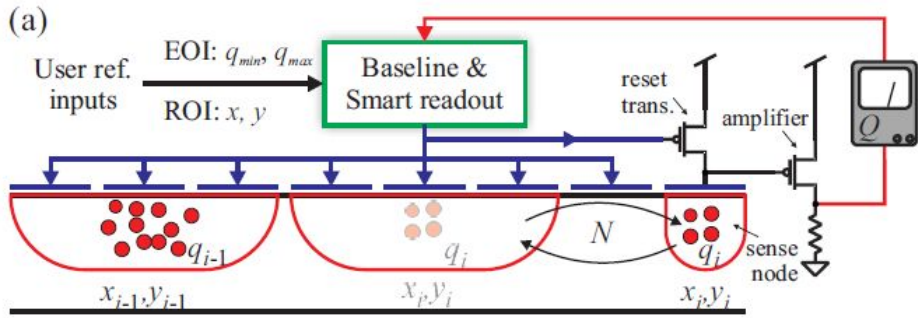


# More creative regions of interest

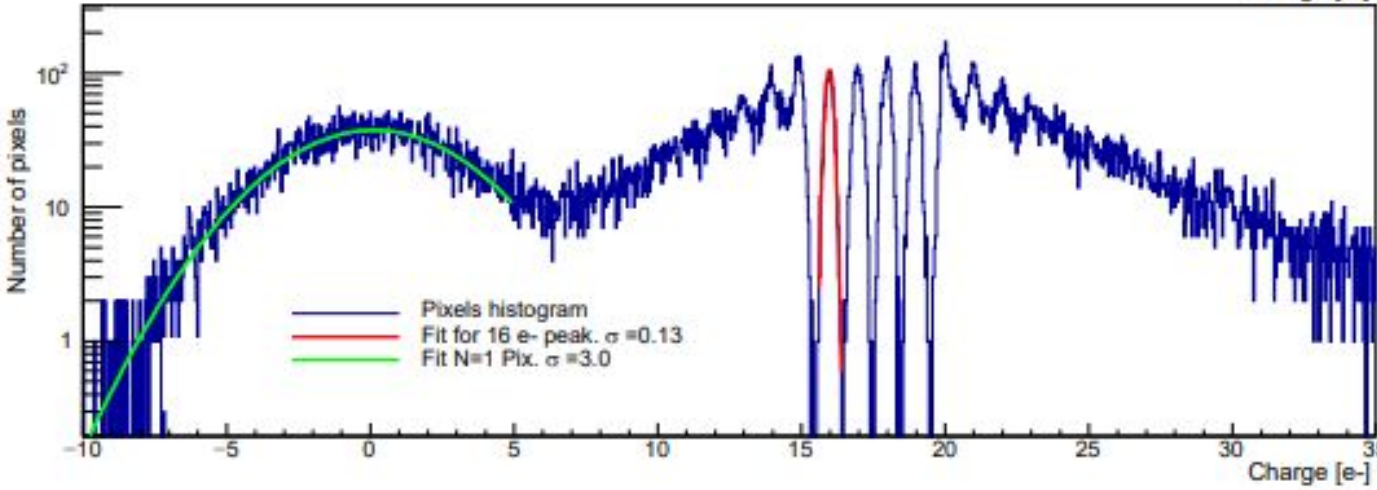
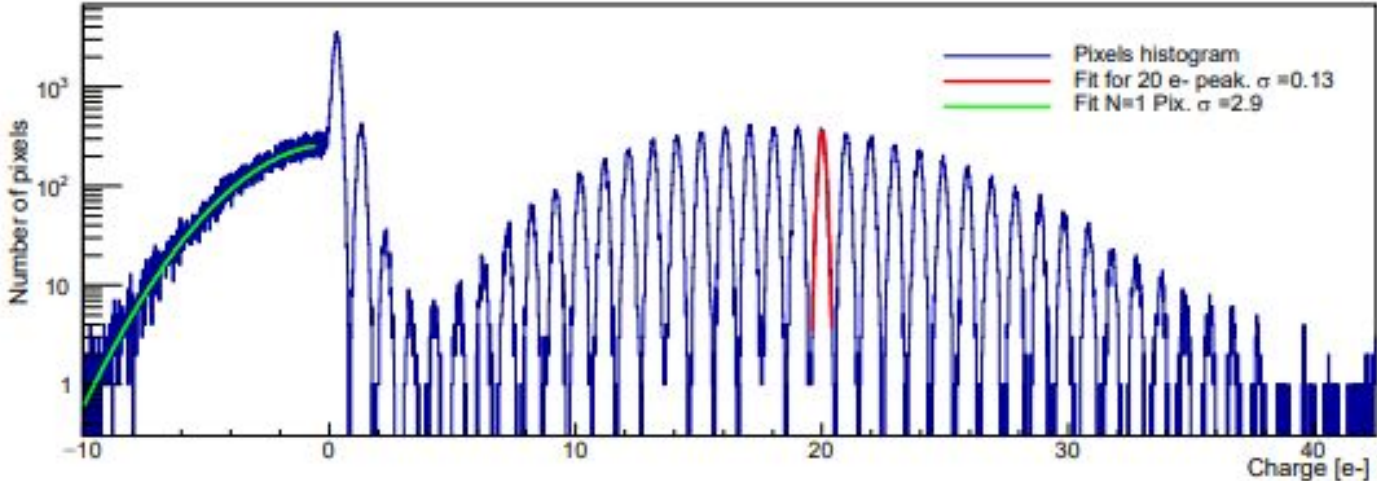
- ❑ Regions of interest with many different samples per pixel
- ❑ Giff figures translated to number of samples to take the image with the detector.
- ❑ Different noise levels in the image produce the different textures in the image



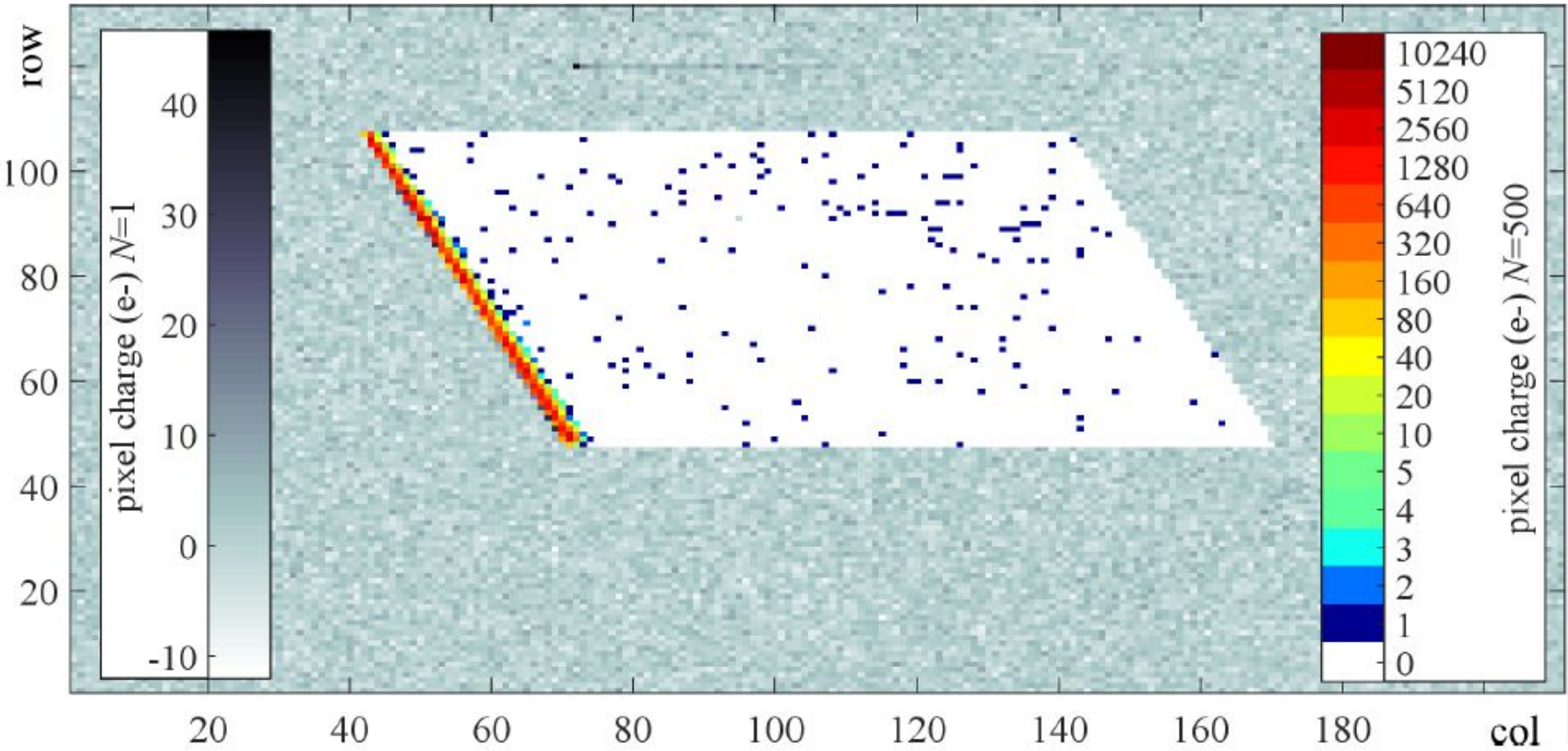
# Online decision based on the pixel value



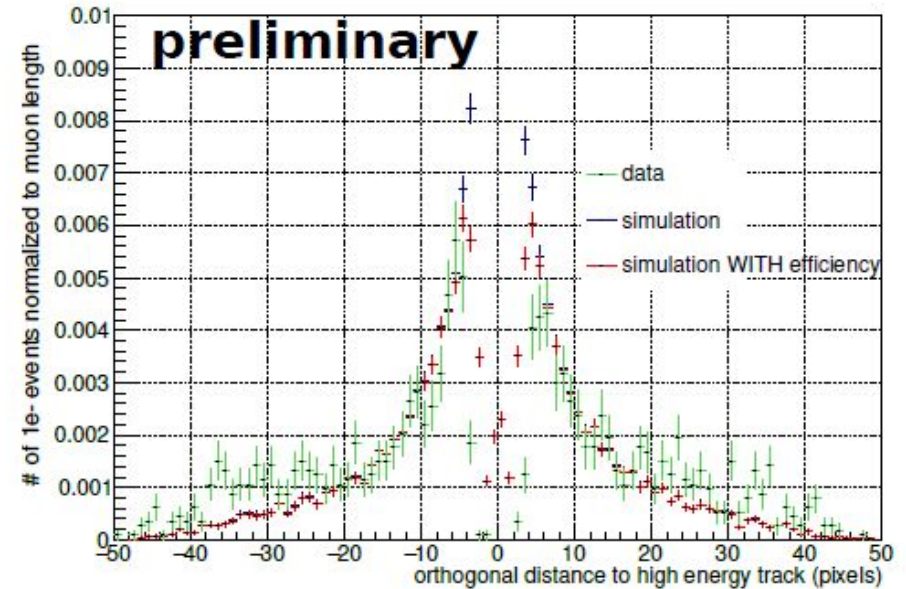
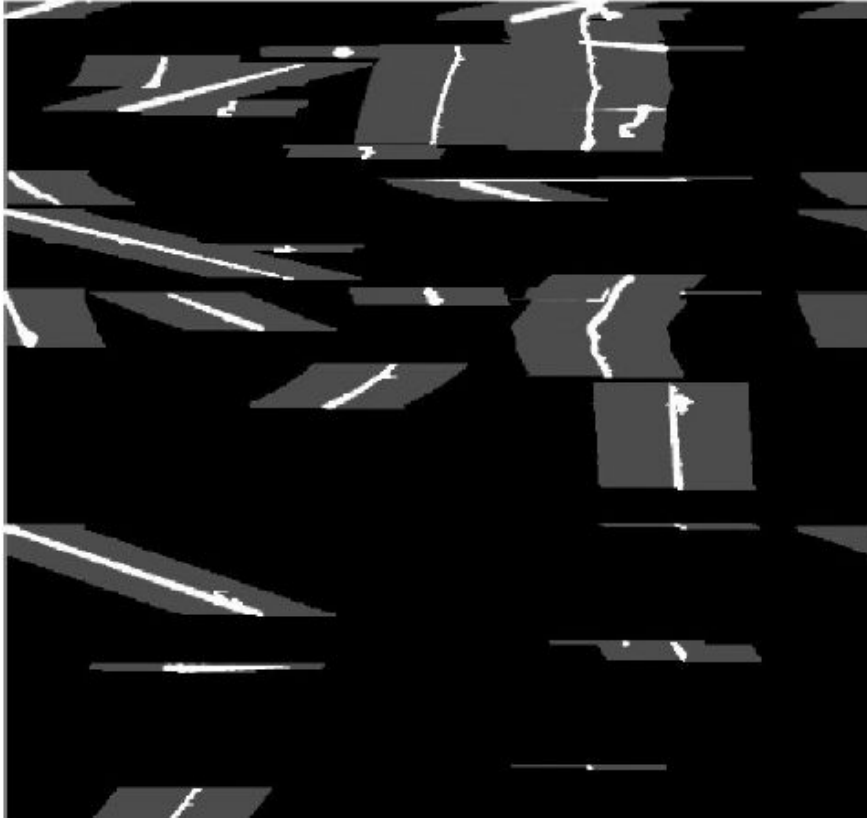
# Online decision based on the pixel value



# Using Smart Skipper to measure light of high produced by high energy tracks



# Using Smart Skipper to measure light of high produced by high energy tracks

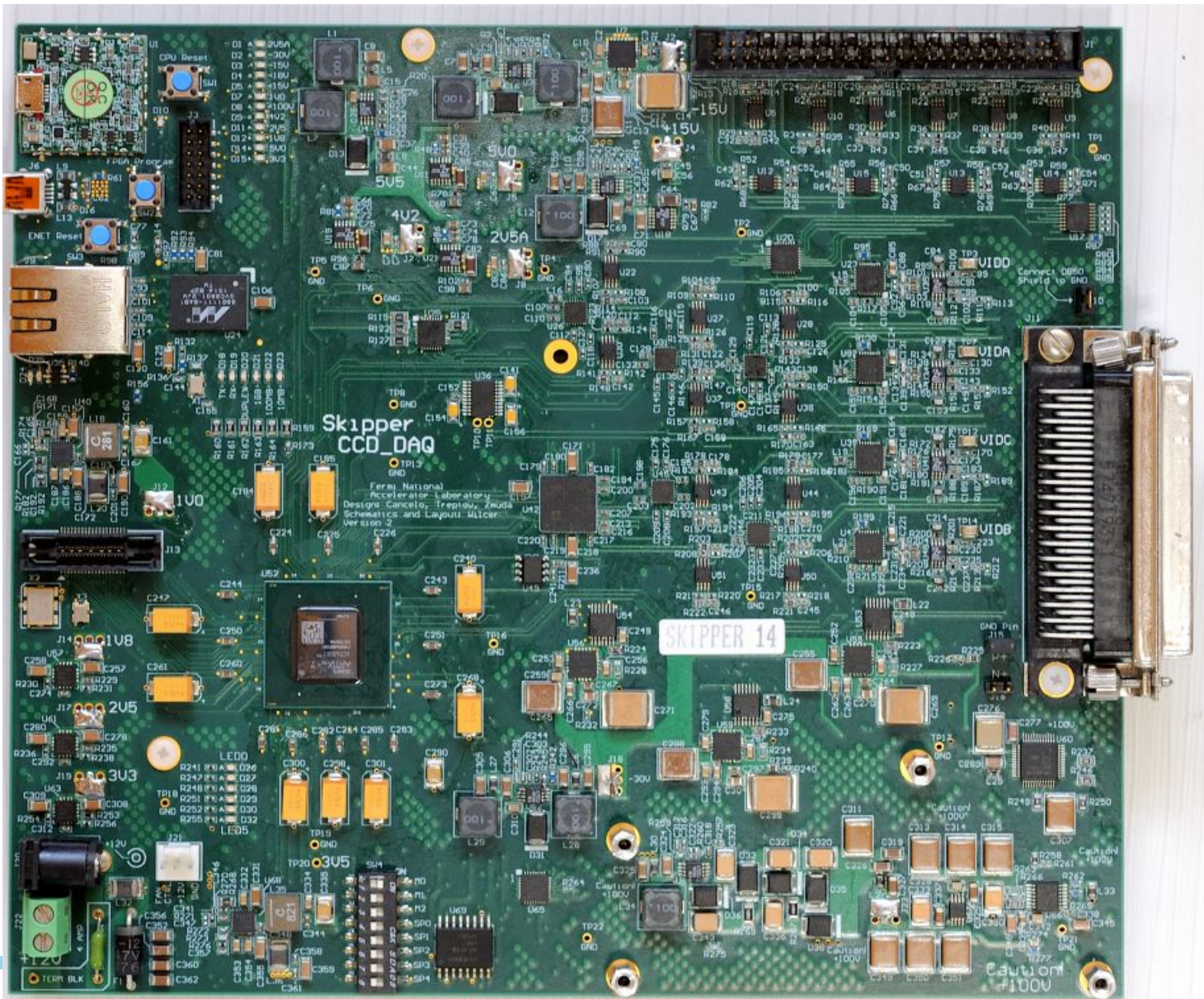


- ❑ White: high energy tracks
- ❑ Gray regions: very low noise regions around high energy tracks
- ❑ Black regions: pixels higher noise (measured faster)

# Conclusions

- ❑ Non-destructive readout provides a way to reduce the readout noise in Charge Coupled Devices.
- ❑ The long readout time of the first devices imposes a limitation on the applications where the technology can be used.
- ❑ We are putting efforts to reduce the readout time while keeping the noise reduction capability.
- ❑ The Smart Skipper idea is one of them, but we are also pushing for new sensor topologies.

# Back up Slides





# Noise (adu) vs number of skipper samples per pixel

