ROC4SENS

Flexible and Radiation-Hard Readout Chip for Hybrid Pixel Detectors

Stephan Wiederkehr

PAUL SCHERRER INSTITUT

PSI

30.04.2018

Overview

1. Introduction
2. Design Considerations
3. Geometry
   - Pads
4. Readout Control
5. Analogue Chain
6. Calibration Methods
7. Performance
   - Pulse Height Variation per Pixel
   - Pulse Height
8. Status
   - R4S Development
   - Readout Systems
9. Summary
10. References

Introduction

Flexible and Radiation-Hard Readout Chip for Hybrid Pixel Detectors?

ROC4SENS: Readout Chip for Sensors

Pixel: "Picture Cross Element"
$\rightarrow$ segmented image (high granularity)

Hybrid Pixel Detector:
Separate sensor and readout chip (ROC)

$\rightarrow$ test sensors with *generic* ROC

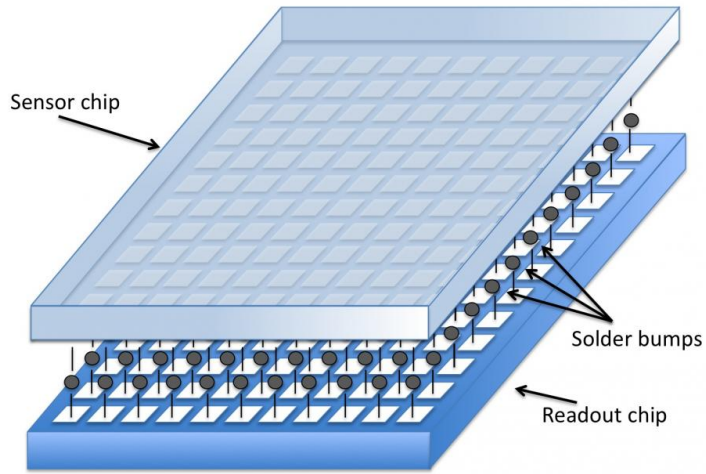


Figure from [1]

Introduction

Flexible (?) and Radiation-Hard Readout Chip for Hybrid Pixel Detectors

generic ROC within context of particle physics at LHC:

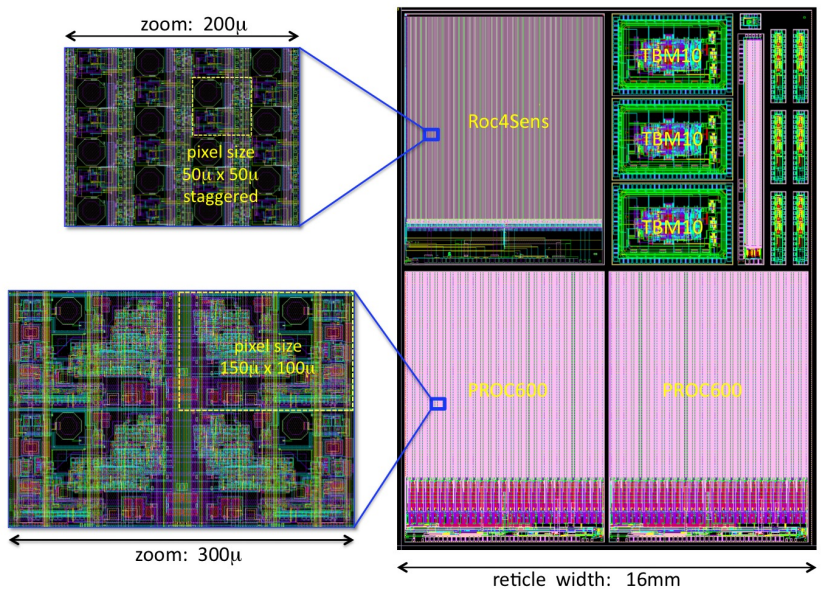
- Not experiment specific ROC
- Wide range of sensor geometries
- Readout externally triggered
- $\approx$ 1k frames/s
- No zero suppression
- Easy to use

Design Considerations

- Fast pulse shaping
- No threshold
- Small pixel size
- Staggered bond pattern
  $\rightarrow$ flexible sensor bonding
- No on-chip programming
- Analogue output
- Radiation hard transistors
- Compatible with PSI test systems
- 0.25 μm technology

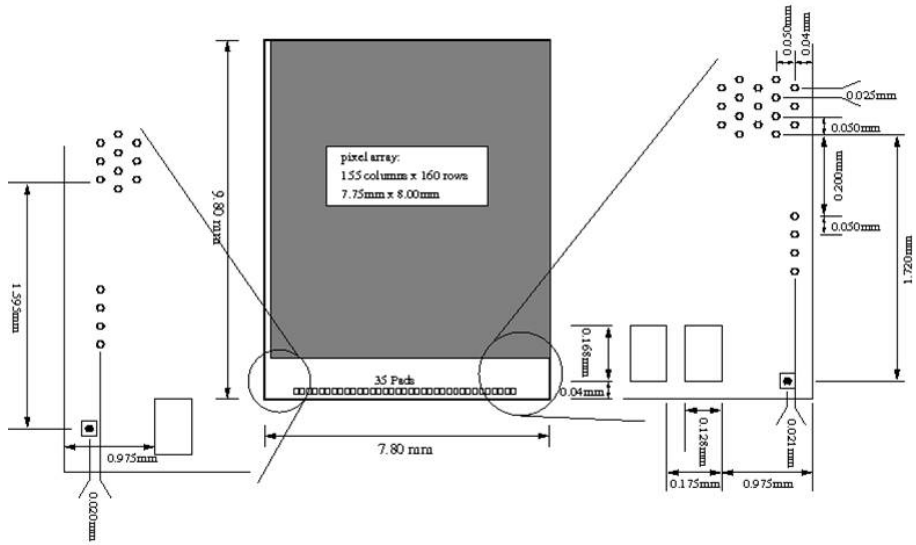
$\rightarrow$ DAQ outside of the chip, require:

- Sequencer
- 6 Reference voltages (e.g. potentiometers)
- 1 ADC



Geometry

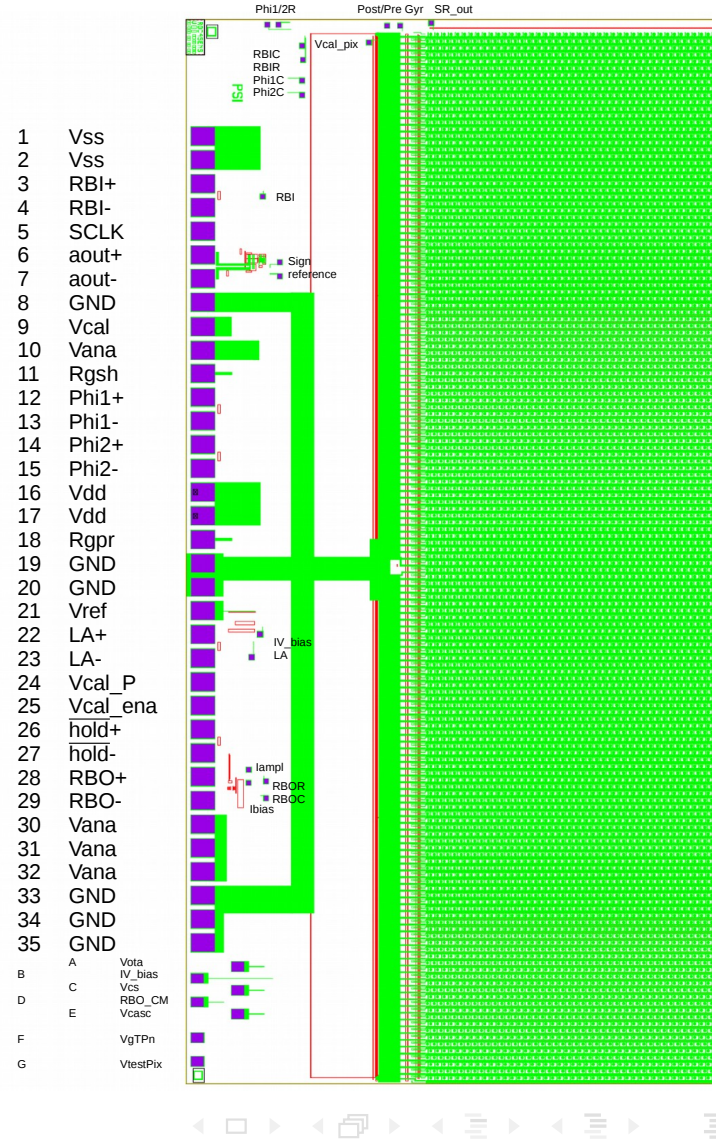
- Total size:
  7.848 mm x 9.778 mm
- Pixel Cell size:
  50 μm x 50 μm
- 155 x 160 pixels
- Alternating bond pad pattern
  $\rightarrow$ facilitate bonding of sensor strips with width $< 50\ \mu m$
- $\approx$ 400k transistors



ROC4SENS Geometry [2]

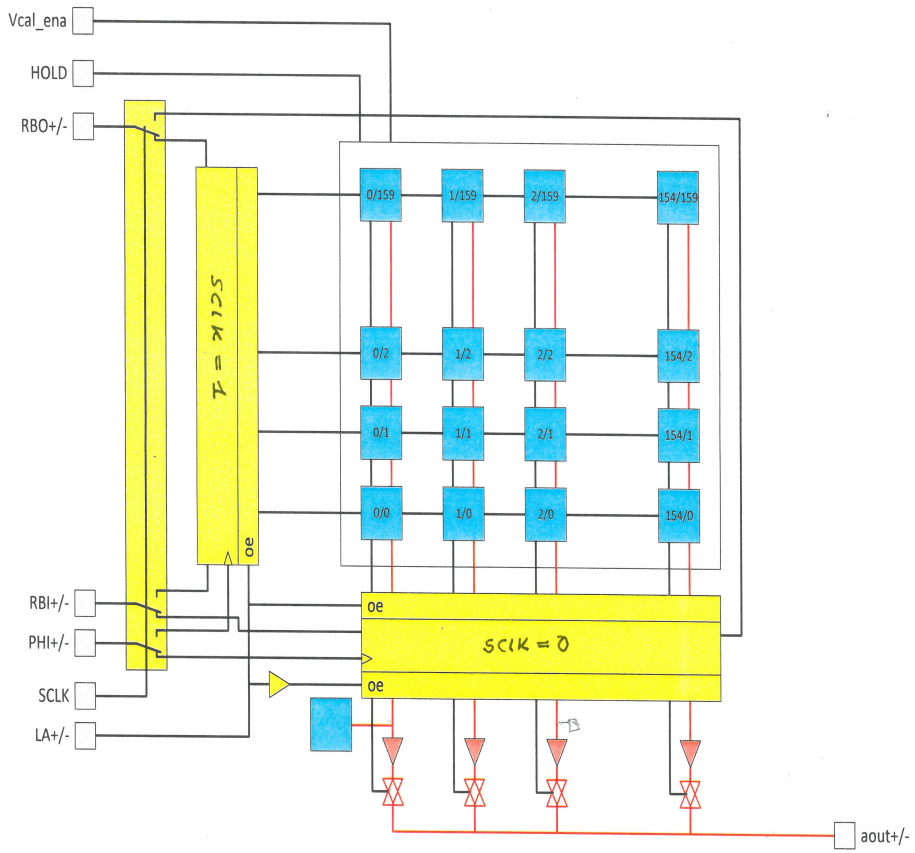
Pads

- 35 pads
- 20 small spypads for debugging
- 4 optional pads for column amplifier control
- 1 optional pad to control SR output bit amplifier
- 2 optional pads to control test pixel (c.f. slide 11)



Readout

- Pixel selected by bits in shift registers (SRs)
- Two clocks $\varphi 1$ & $\varphi 2$ clock the SRs
- SRs accessed separately, controlled by *switch* signal
- Select pixels to
  - send calibration pulse
  - read out
- Pixel selection & readout controlled by software
  $\rightarrow$ arbitrary patterns possible

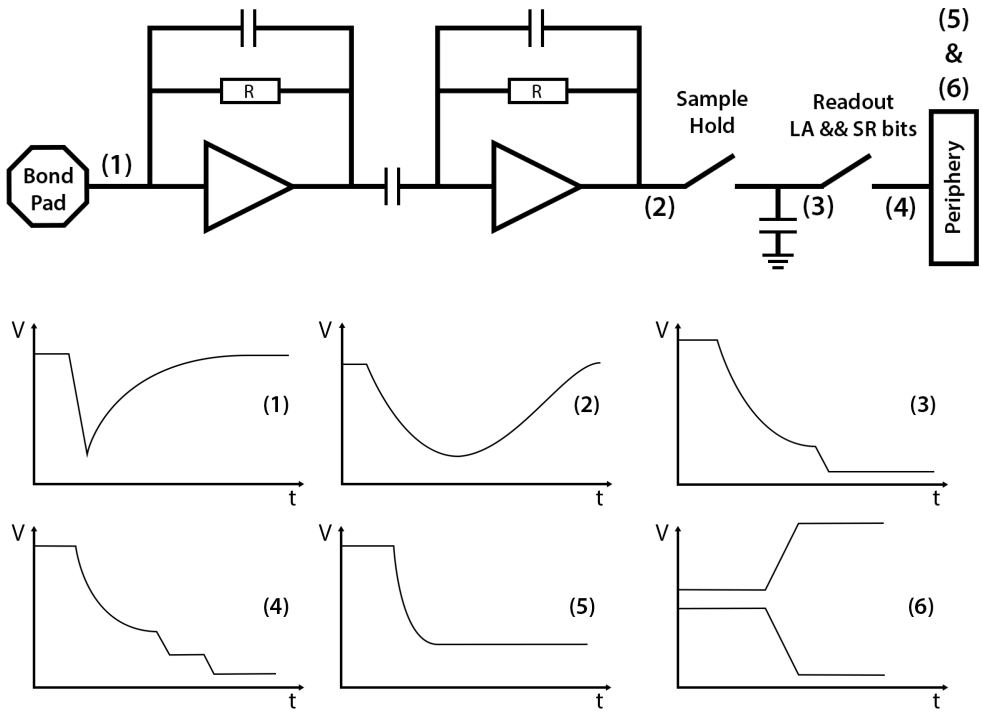


Analogue Chain

One column amplifier per column

All column amplifiers connected to output amplifier.

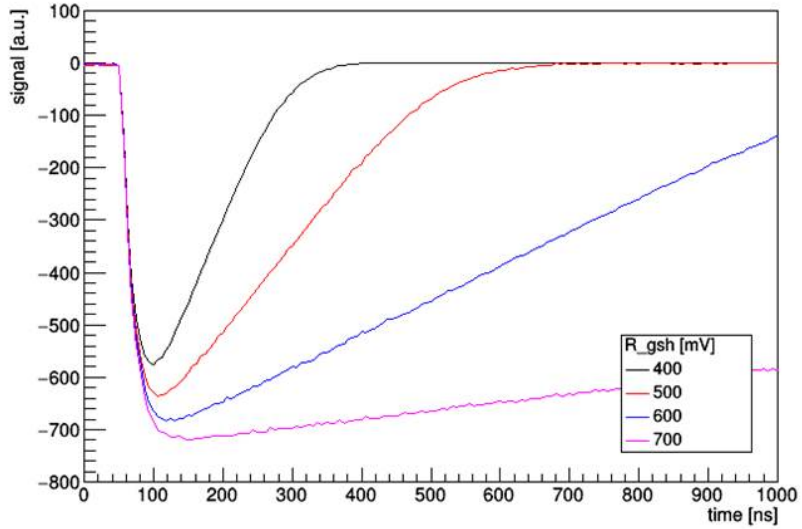
Output amplifier transforms signal into a differential signal.

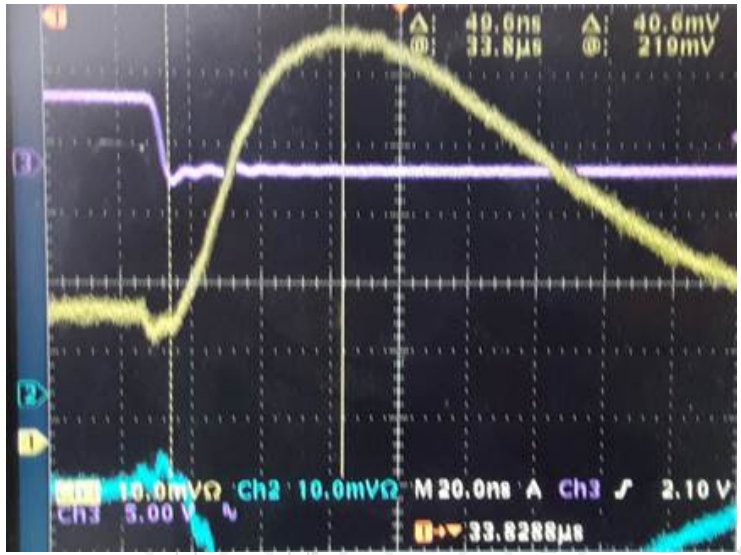


Signal Pulse

Pulse shape modifiable through feedback or analogue power.

Need a fast ($\approx$ 100ns) trigger!





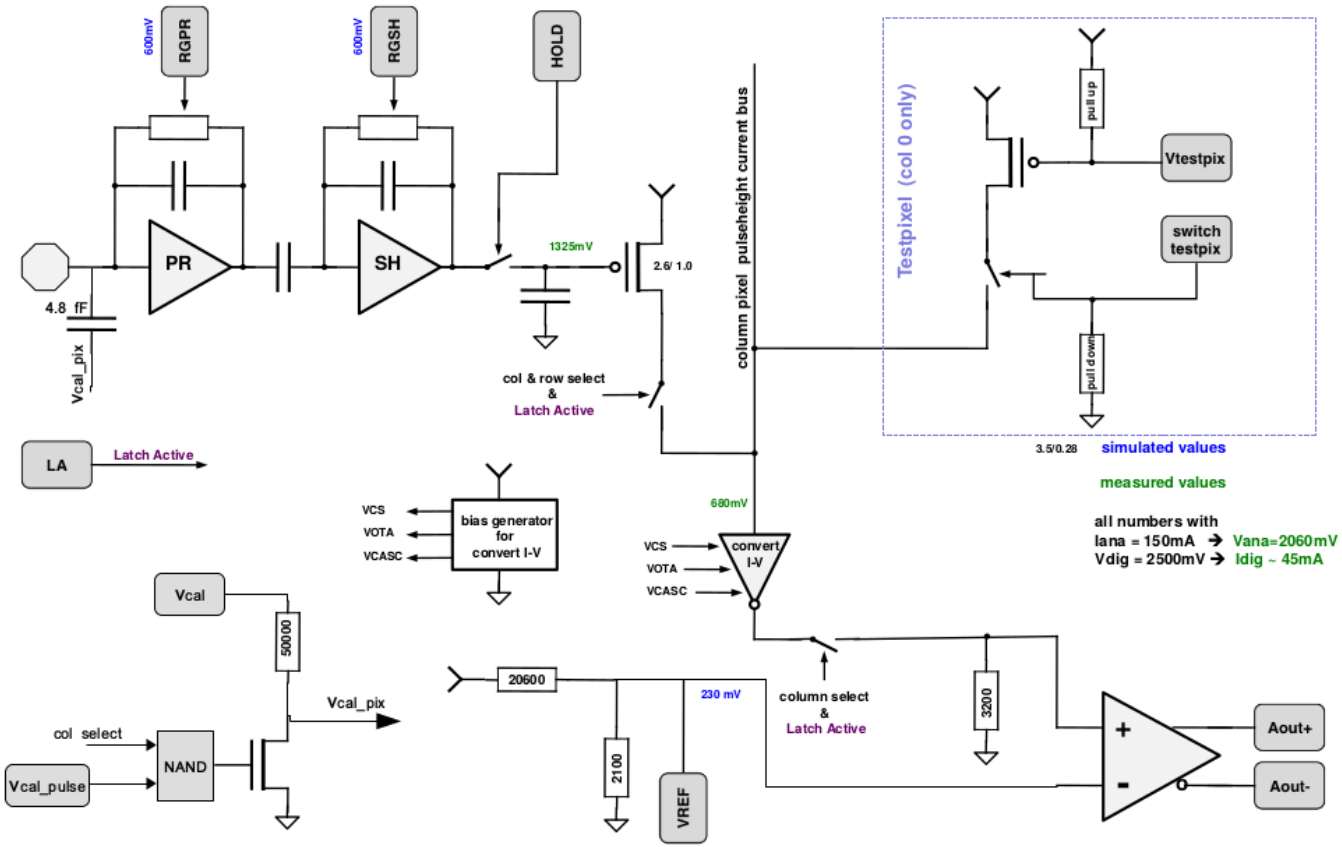
Calibration Methods

Calibration pulse injection

Inject adjustable pulse mimicking real signal

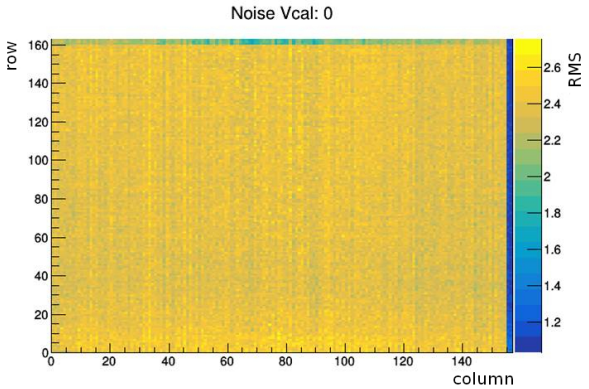
Test pixel

Replica of readout stage of pixels

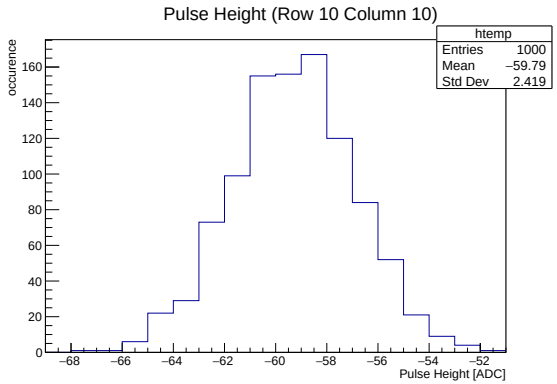


Pulse Height Variation per Pixel

- Read out same pixel 1000 times
- Variation (RMS) in pulse height
- Noise is homogeneous
- *noise* < 3 *ADC counts* $\approx 200\ e^-$
- With a signal of 400 ADC counts
  $\rightarrow$ Signal/Noise ≈ 150
- Outside of chip columns
  $\rightarrow$ column amplifiers effects
- Outside of chip rows
  $\rightarrow$ output amplifier effects



Last rows and columns are outside of real chip

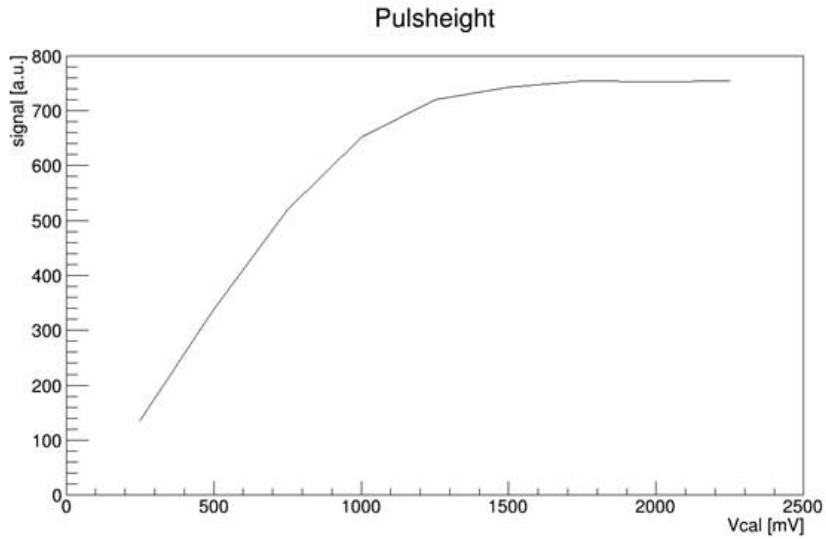


Pixel: 10/10 Vcal = 500 mV

Pulse Height

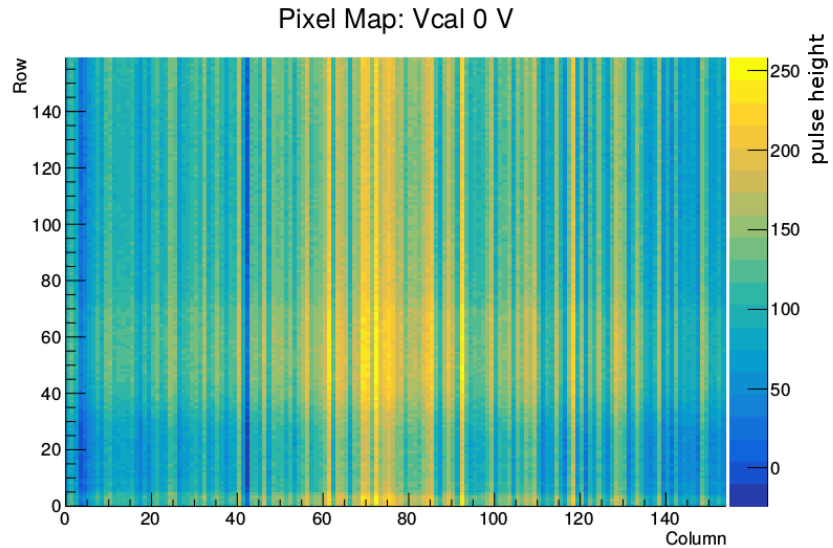
Signal range:

- 1 V calibration pulse $\approx$ 30k e^-
  4.8 fF Capacitor (nominal value)
- Saturation can be slightly
  modified by changing feedback



Column variation due to:

- End of column amplifier
- T shaped bias distributions



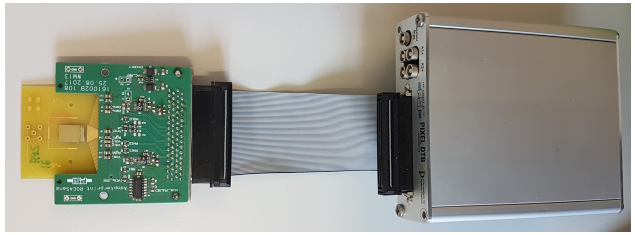
Oscillation along columns
due to ADC?

R4S Development

- Version V1.0
  - Submitted in October 2015
  - Limited readout range
  - Faulty calibration injection system
- V1.1
  - Submitted in May 2016
  - Extended readout range
  - Fixed calibration pulse injection
- V1.2
  - Submitted in February 2018
  - Reduced cross talk of clock*
  - Improved cross talk of calibration pulse injection*
  - Reduced column distribution*
  - *To be tested: Expected in May 2018

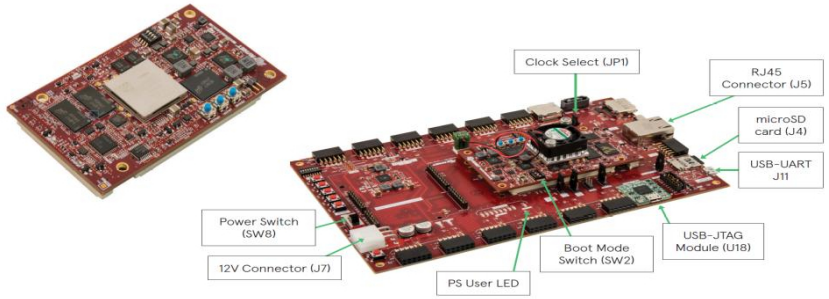
Readout Systems

- First readout system developed at PSI (single chip only)



DTB (PSI/ETH)

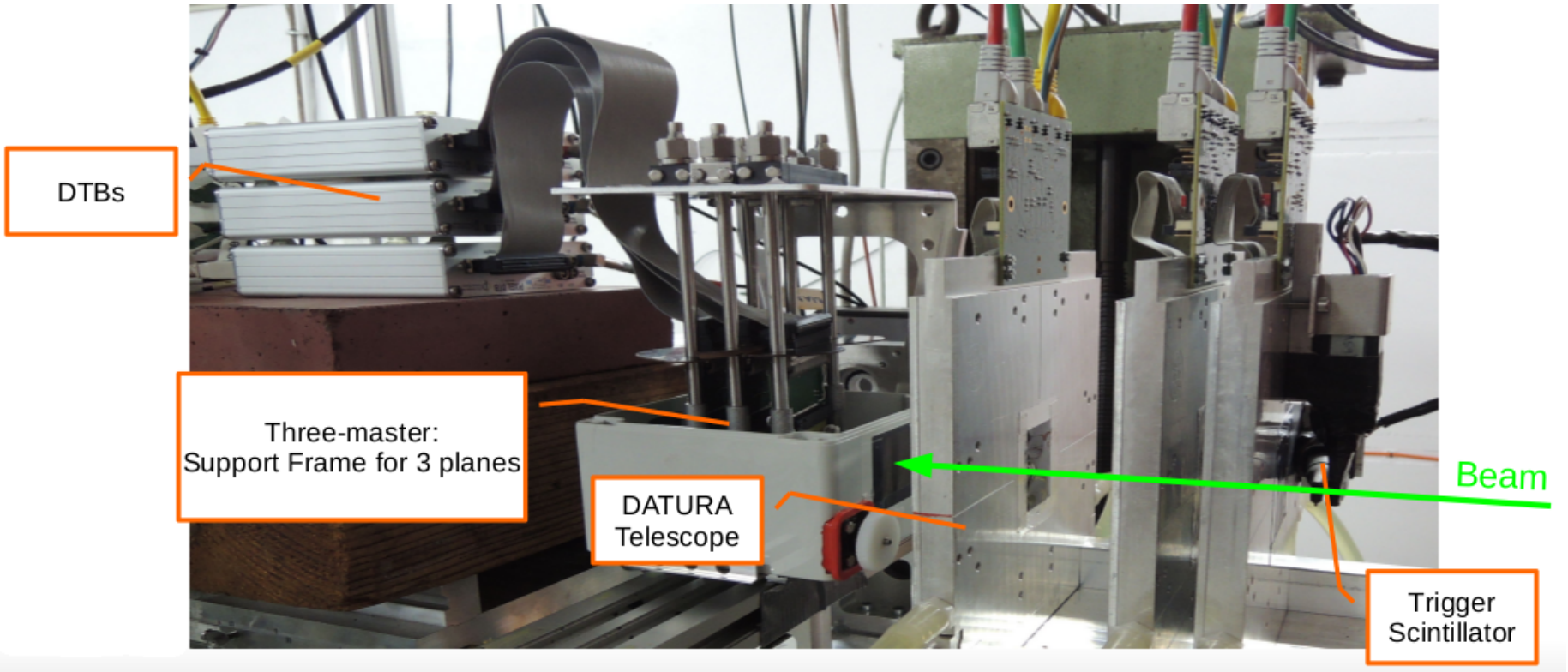
- Multi-chip readout system: Sevilla / Santander [3]
  development ongoing



Multi-chip readout system
Sevilla / Santander [3]

- Beam test: DESY / UniHH [4]
  use PSI readout system with modified firmware

Beam Test at DESY II: Setup



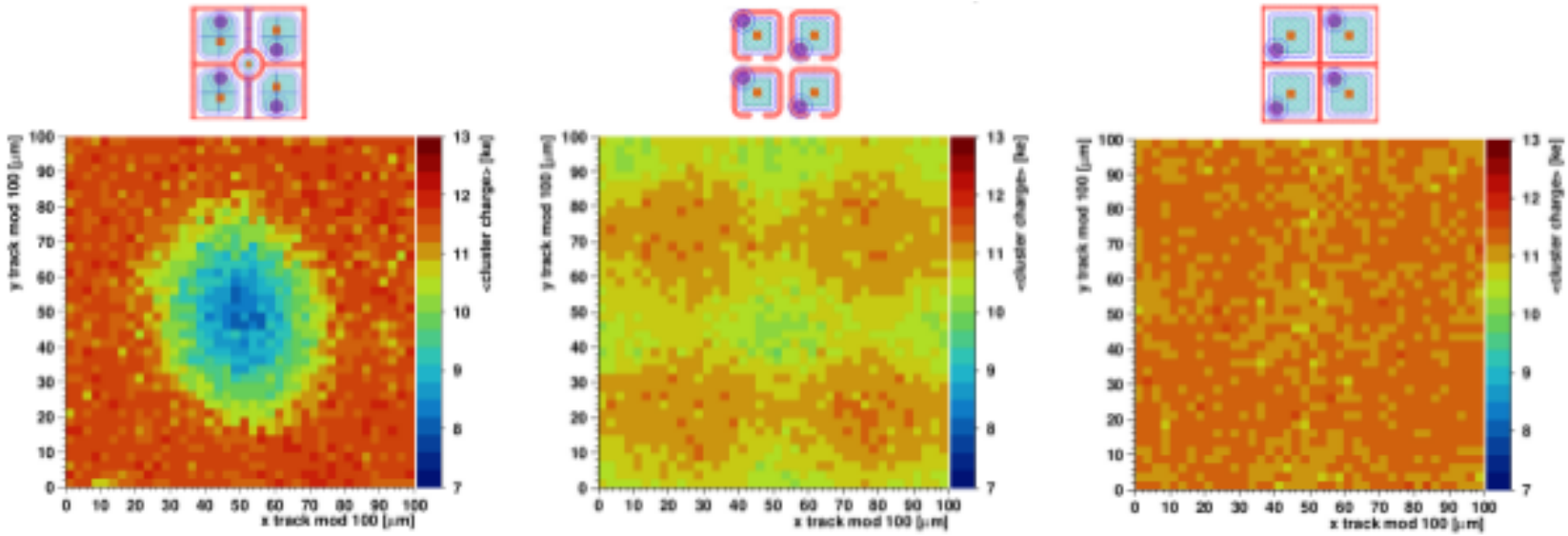
DESY / UniHH [4]

DATURA Telescope: high-precision beam tracking ($\approx 2\ \mu$m)

$\rightarrow$ setup allows to scan the DUT(s)

Beam Test at DESY II: Results

Measurement of charge collection efficiency scanning the R4S with DATURA Telescope



Common punch trough | Open p-stop | Common p-stop

Charge collection efficiency measured at DESY II.
Tested several 50 x 50 μm sensor designs [5].

Absence of threshold in R4S can be fully exploited when extending measurements to irradiated samples.

Summary

- Designed generic readout chip for sensor tests
- No signal threshold
- No on-chip programming
- Successfully tested, e.g. at PSI and DESY/UniHH
- Multi-chip data acquisition systems currently being developed

References

[1] In: (). URL: https://ep-news.web.cern.ch/content/designing-pixel-readout-chips-cern-dream-reality.

[2] Tilman Rohe. "ROC4SENS – a generic readout chip for sensor studies". In: (2017). URL: https://indico.cern.ch/event/663851/contributions/2788211/attachments/1562585/2460787/R4S_RD50-22-11-2017.pdf.

[3] Rafael Luis Millan Vazquez De La Torre. "Update on R4S readout: Spain". In: (2017). URL: https://indico.cern.ch/event/671617/contributions/2767798/attachments/1547005/2430892/r4sdaq.pdf.

[4] Aliakbar Ebrahimi. "ROC4SENS: First Impressions at Beam Tests". In: (2017). URL: https://indico.cern.ch/event/647001/contributions/2722044/attachments/1535606/2405441/2017-10-05_FSP.pdf#search=roc4sens.

[5] Finn Feindt. "HPK Sensors – First Beam Test Results". In: (2017). URL: https://indico.cern.ch/event/671617/contributions/2754124/attachments/1546997/2428441/finnFeindtTB06_03.pdf.