# Precision measurement of photon detection efficiency of silicon photomultipliers

**Michal Tesař**, Johannes Sailer, Christian Jendrysik, Frank Simon, Jelena Ninković, Hans-Günther Moser, Rainer Richter

Max Planck Intitute for Physics

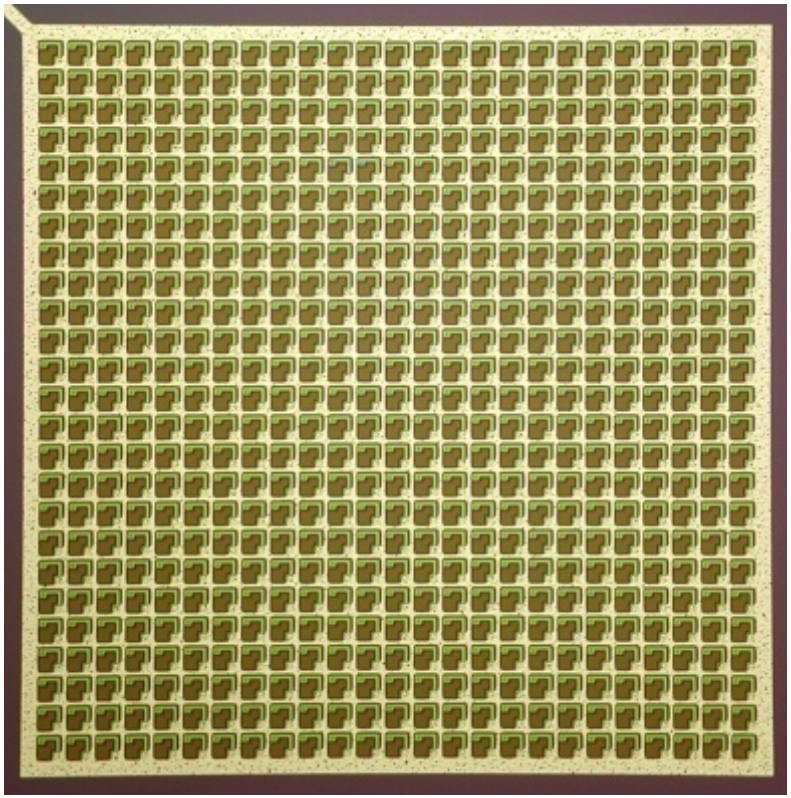
DPG Karlsruhe 29.3.2011



# Outline

# Silicon Photomultipliers (SiPM)

- silicon photon detectors made of an array of avalanche photodiodes (APD)
- APDs are operated in Geiger mode (slightly above breakdown voltage)
- incident photon induces an avalanche
- the avalanche is quenched by a decrease of bias voltage over a quenching resistor

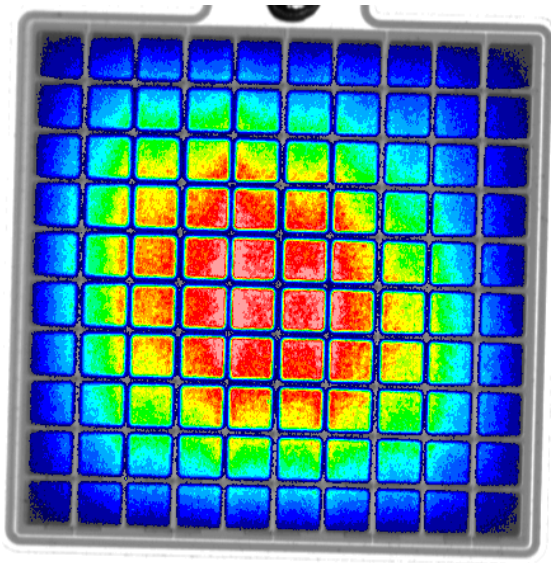


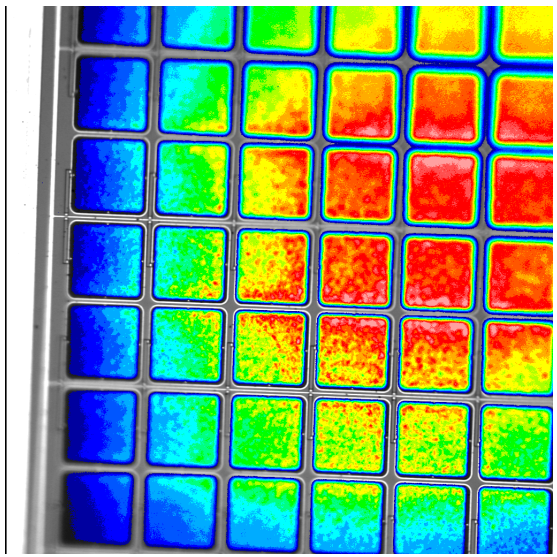
# Goal of the study

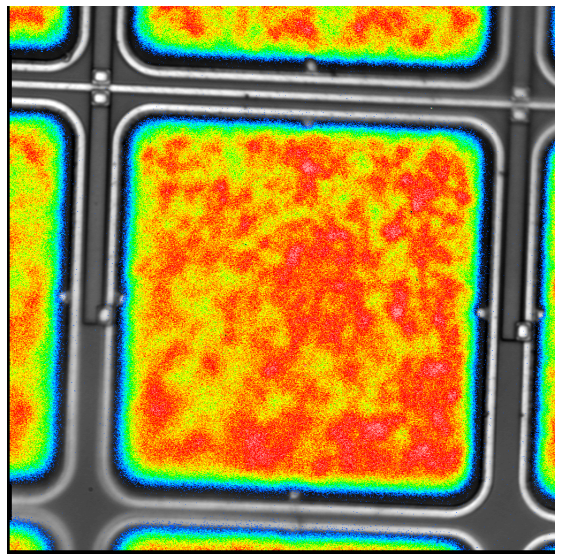
## Ultimate goal

Discovering of sensitivity distribution of a SiPM over its area

- separating signal from dark count and leakage current
- photon emission measurement in not capable of providing that information
- small light spot size allows us to perform such scan even within a single microcell



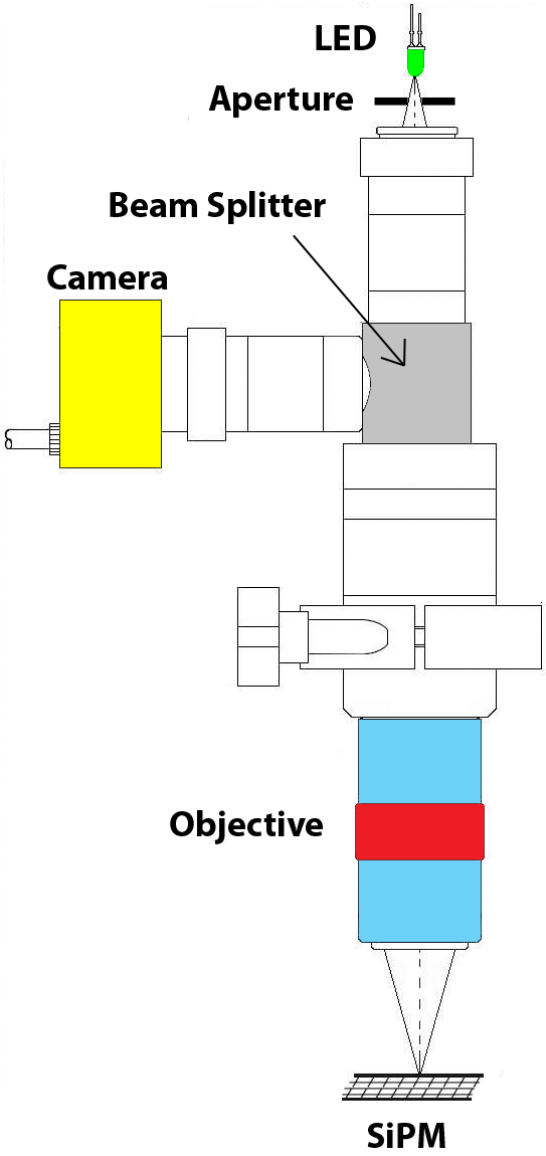




Photoemission images

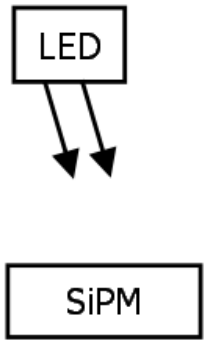
# Basic idea of the setup

- light from an LED is focused to a small point ($\phi \sim 1.5\ \mu$m)
- the LED is pulsed (10 ns long pulses, 10 000 shots per step)
- SiPM response is measured in coincidence with LED pulses
- the light beam is driven through any part a SiPM matrix in discrete steps ($\geq 2\ \mu$m)
- a sensitivity scan of a $1 \times 1$ mm$^2$ device with 2 $\mu$m step size can be completed in $\sim$ 10 hours



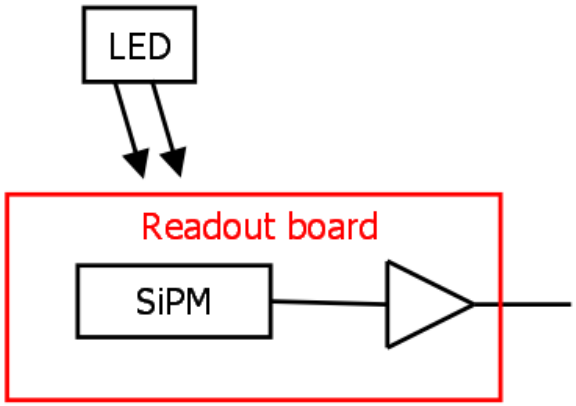
# Block scheme

## Measurement process



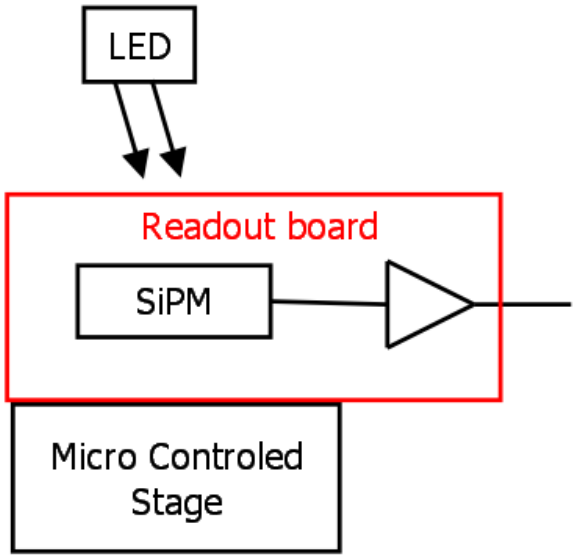
# Block scheme

## Measurement process



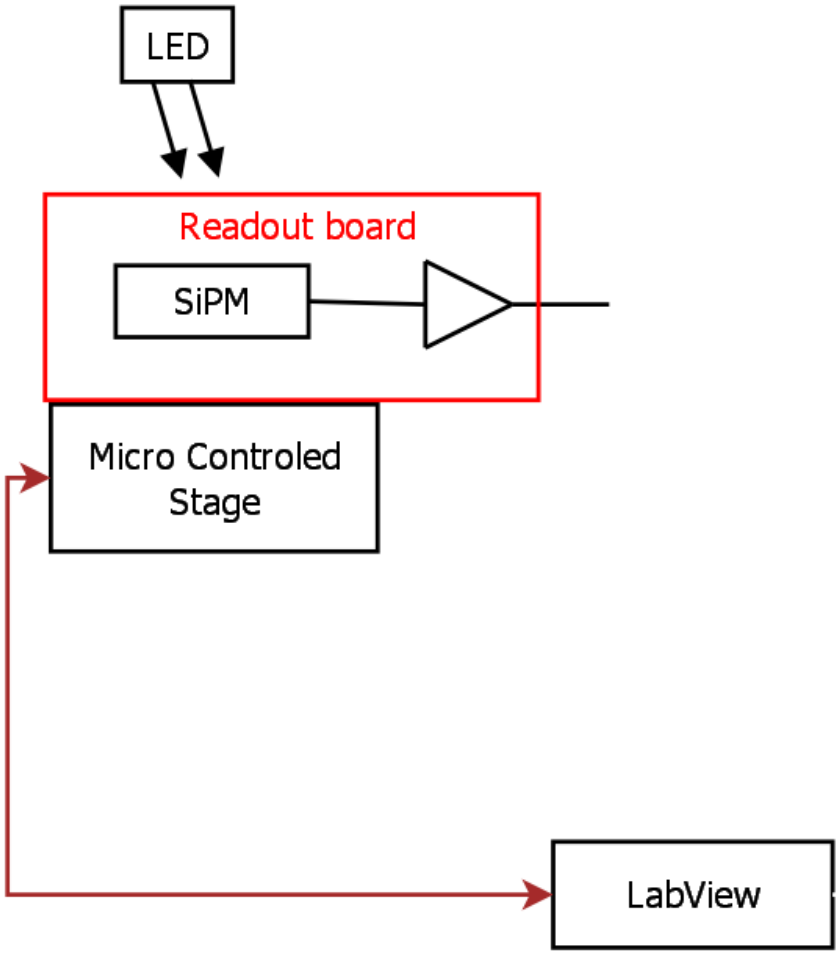
# Block scheme

## Measurement process



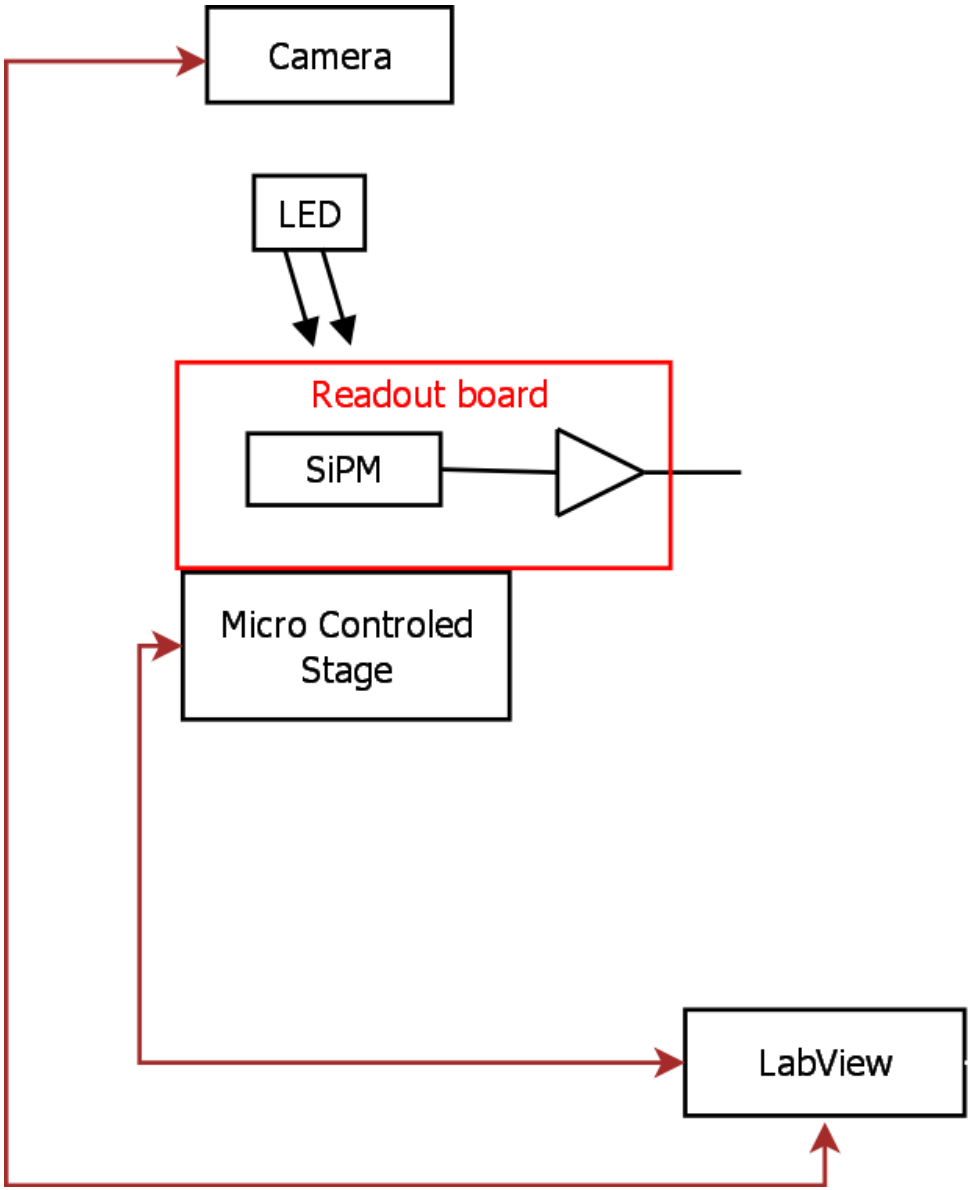
# Block scheme

## Measurement process



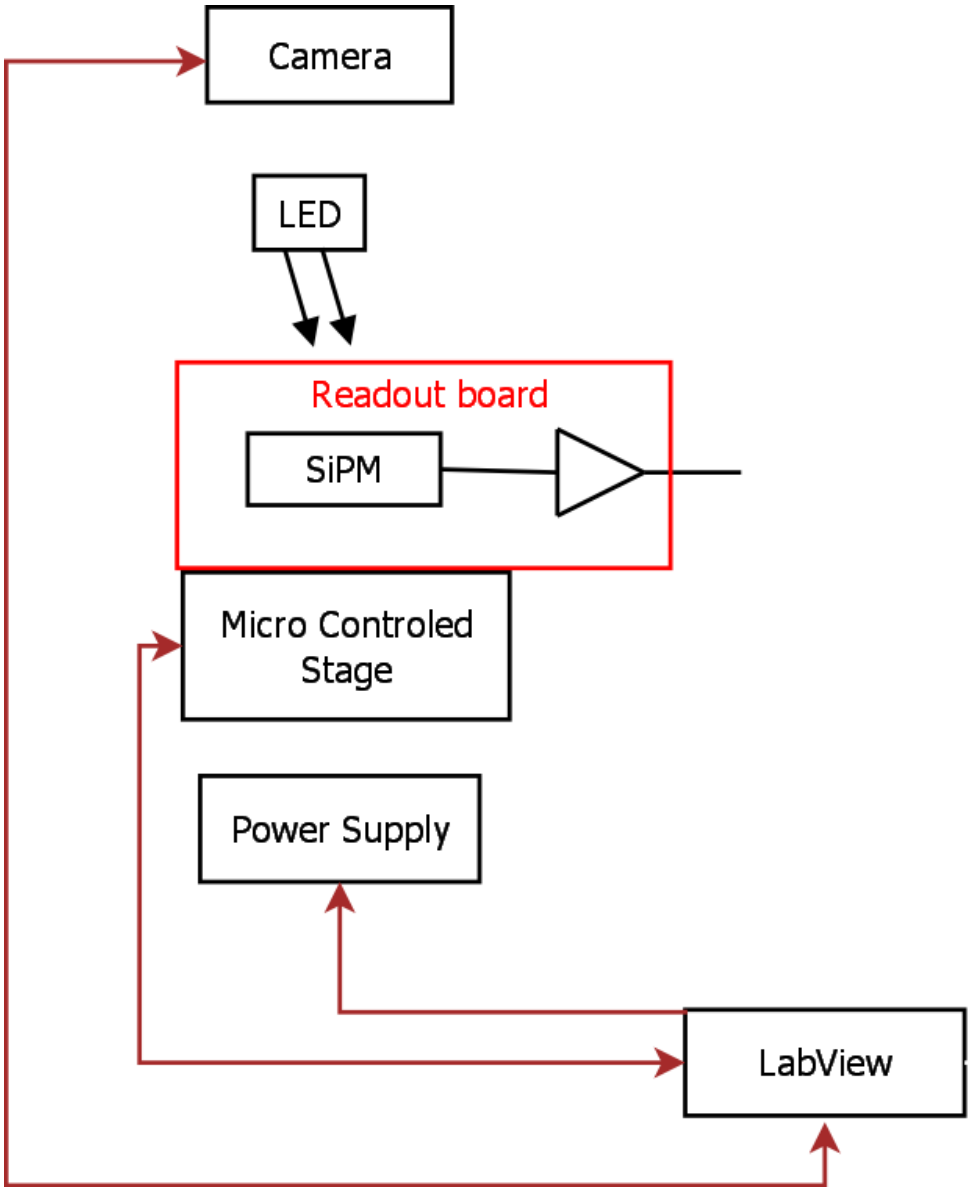
# Block scheme

## Measurement process



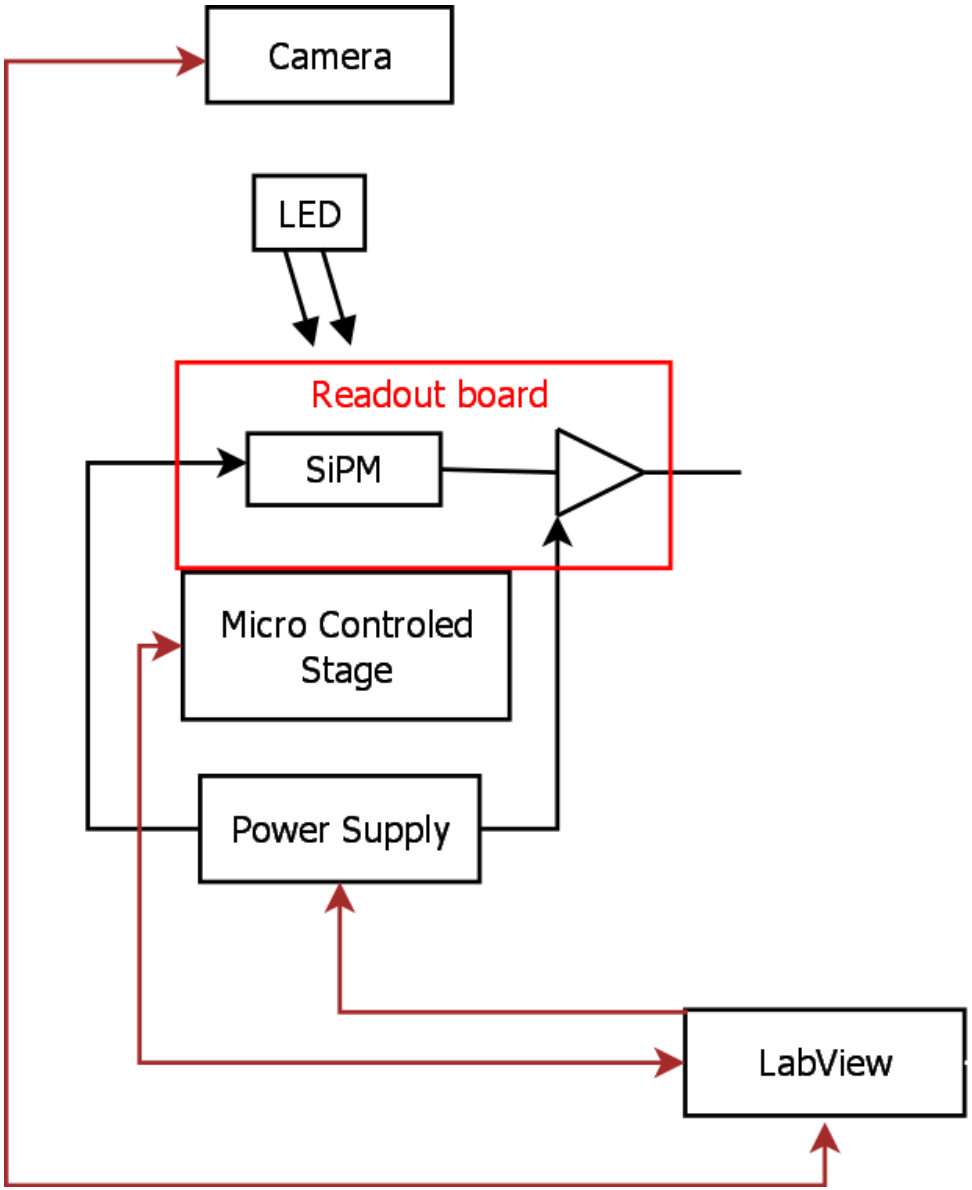
# Block scheme

## Measurement process



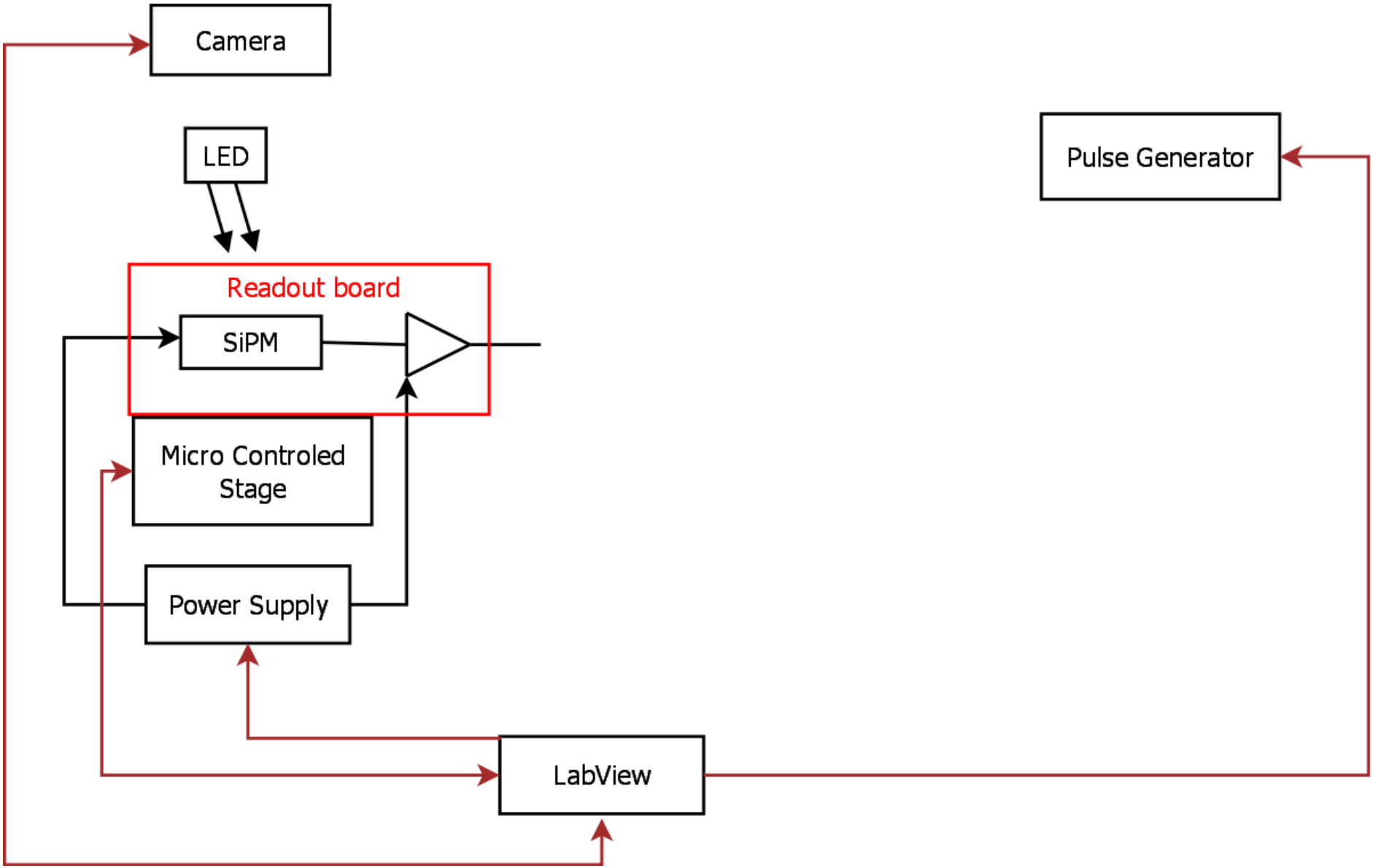
# Block scheme

## Measurement process



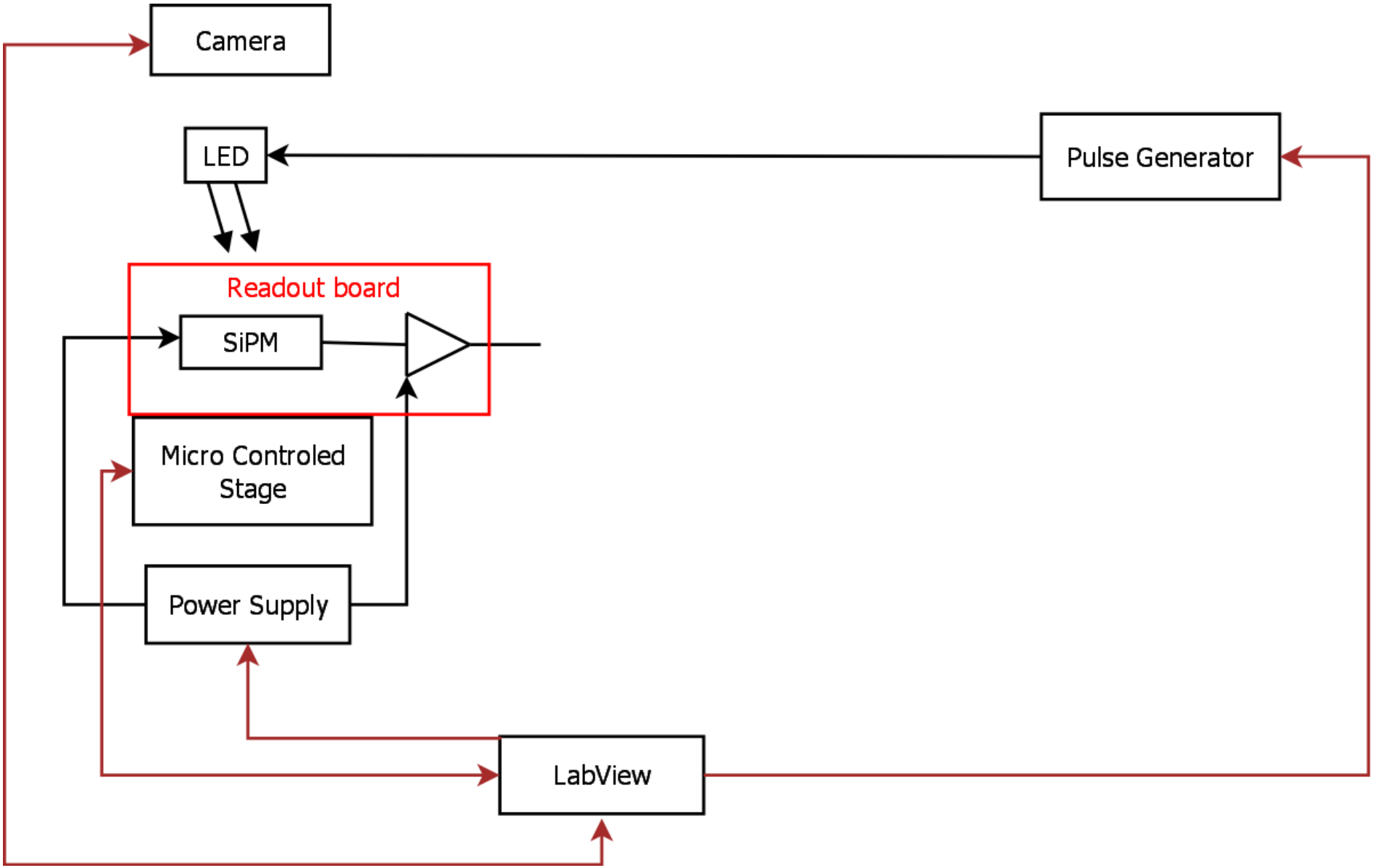
# Block scheme

## Measurement process



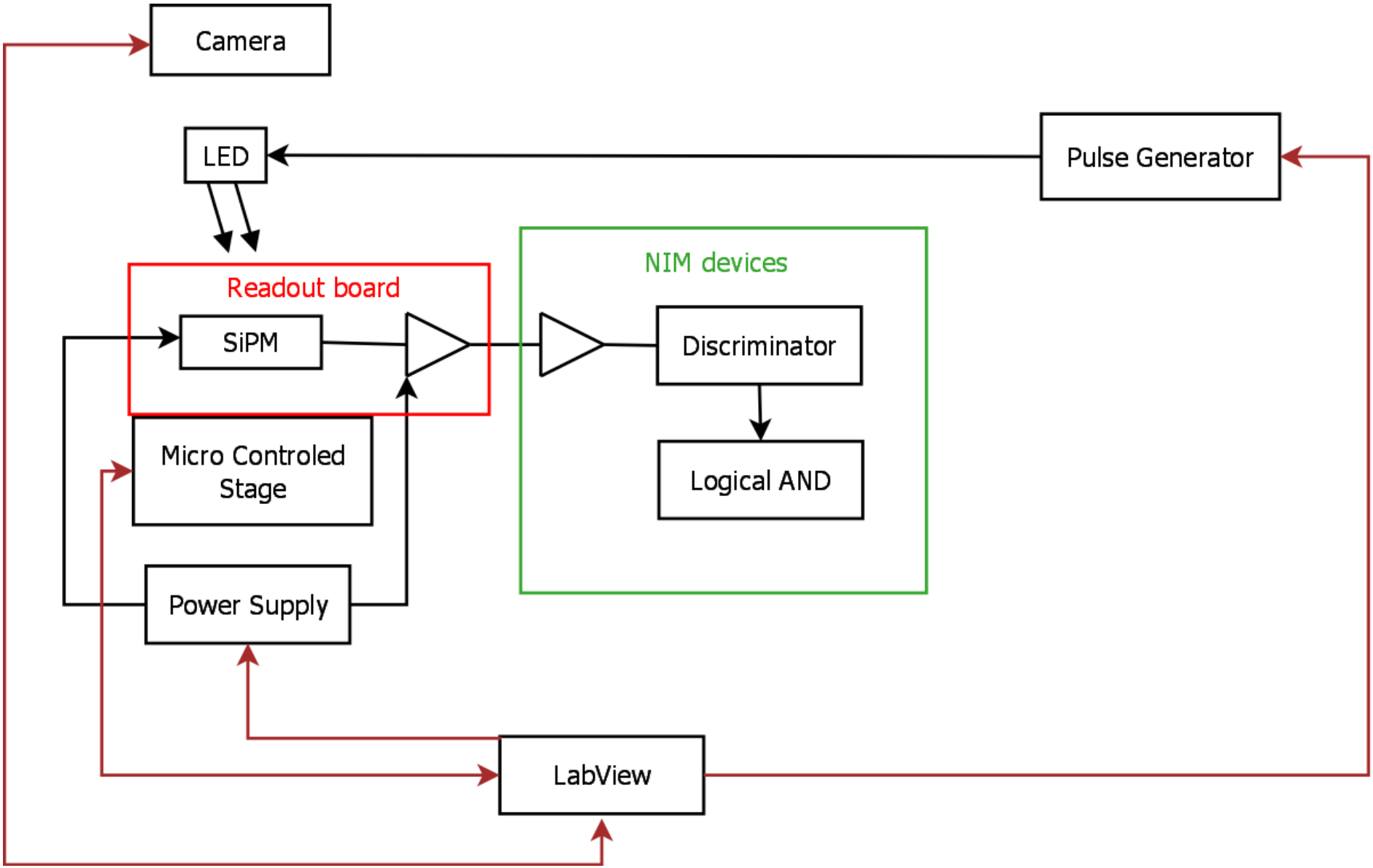
# Block scheme

## Measurement process



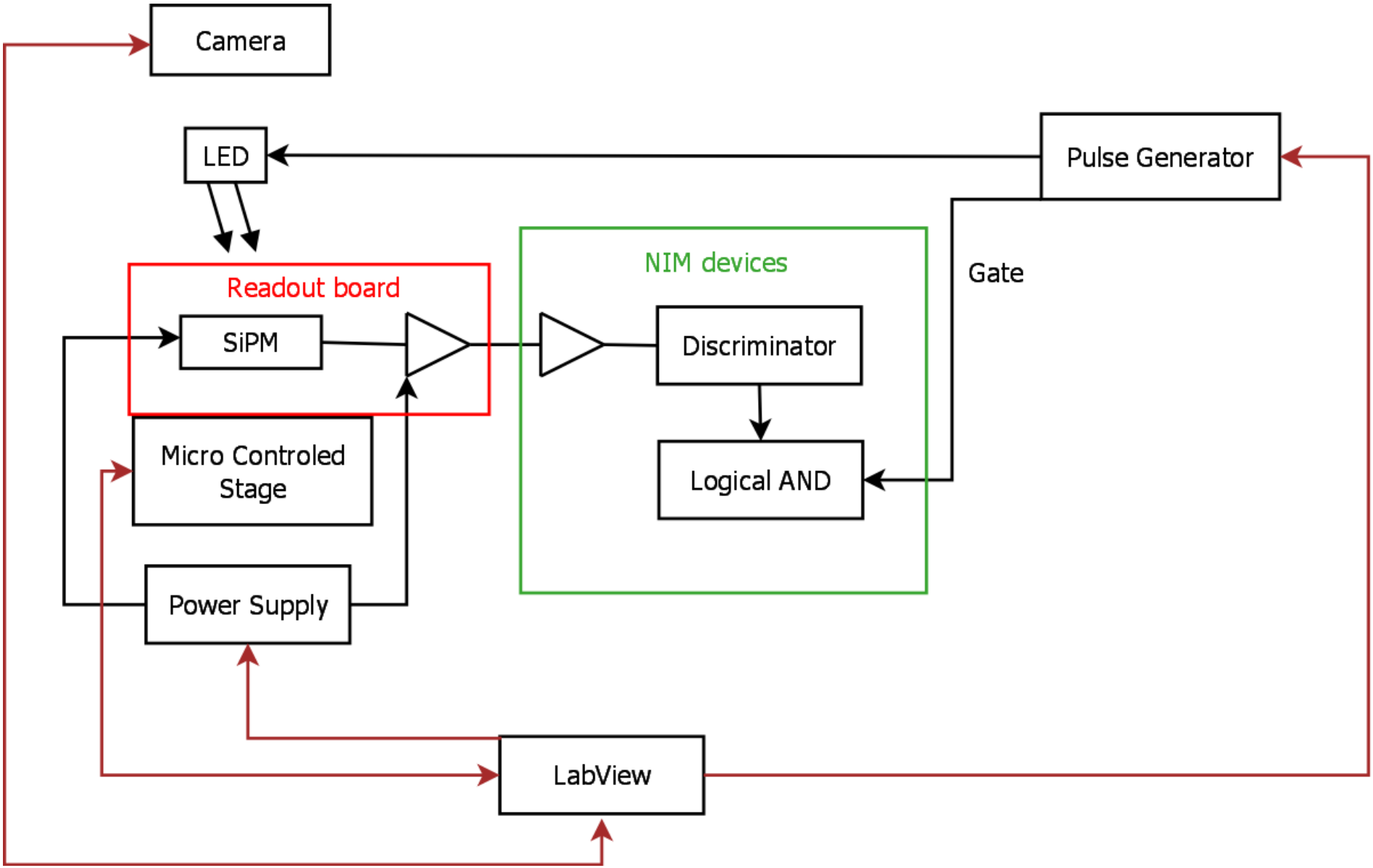
# Block scheme

## Measurement process



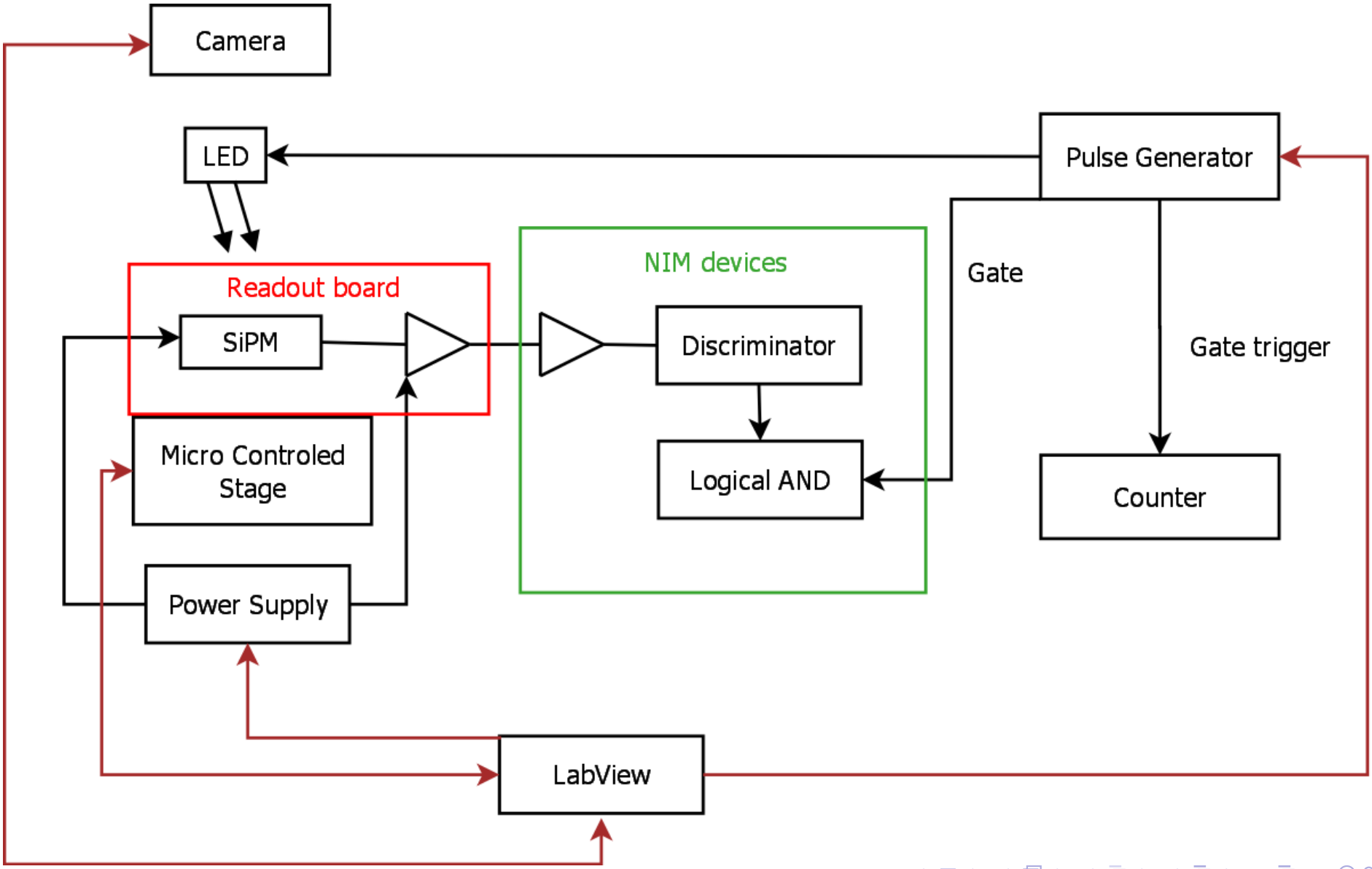
# Block scheme

## Measurement process



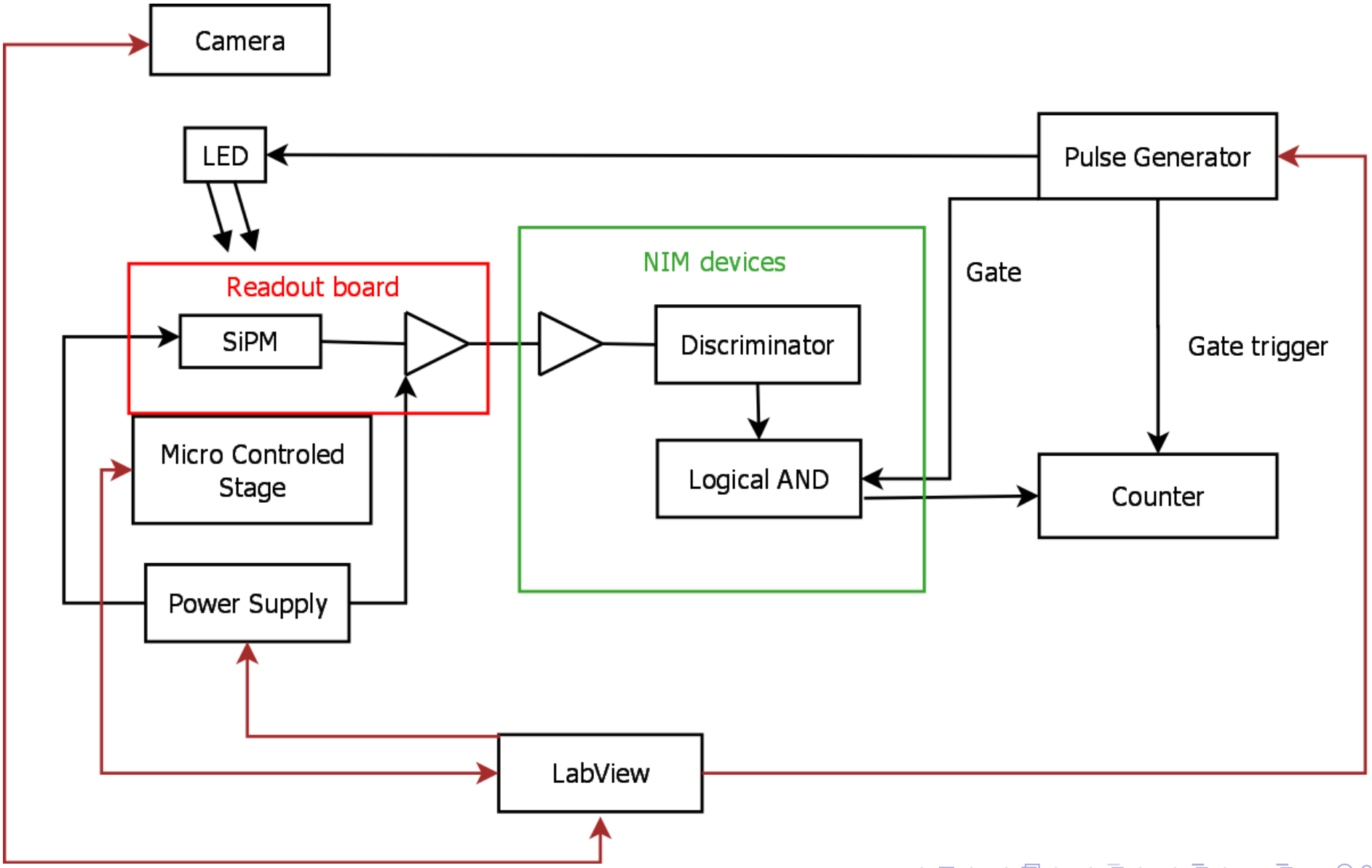
# Block scheme

## Measurement process



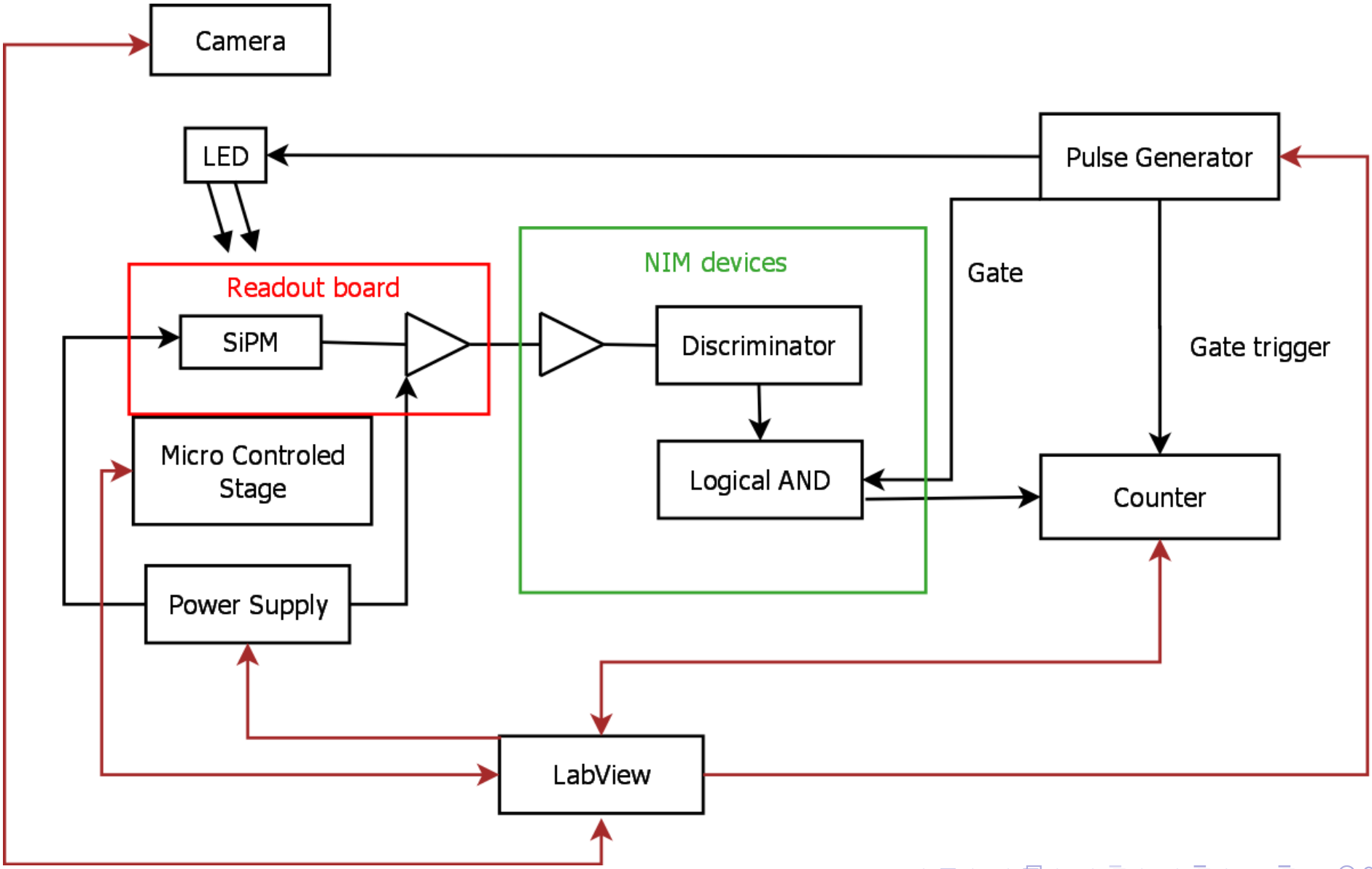
# Block scheme

## Measurement process



# Block scheme

## Measurement process



# Quantities of interest

$\Rightarrow$ first of all, noise is determined and subtracted

## Quantities of interest

- noise
- fill factor (can be obtained separately for a single microcell)
- uniformity of efficiency over the device
- photon detection efficiency ★

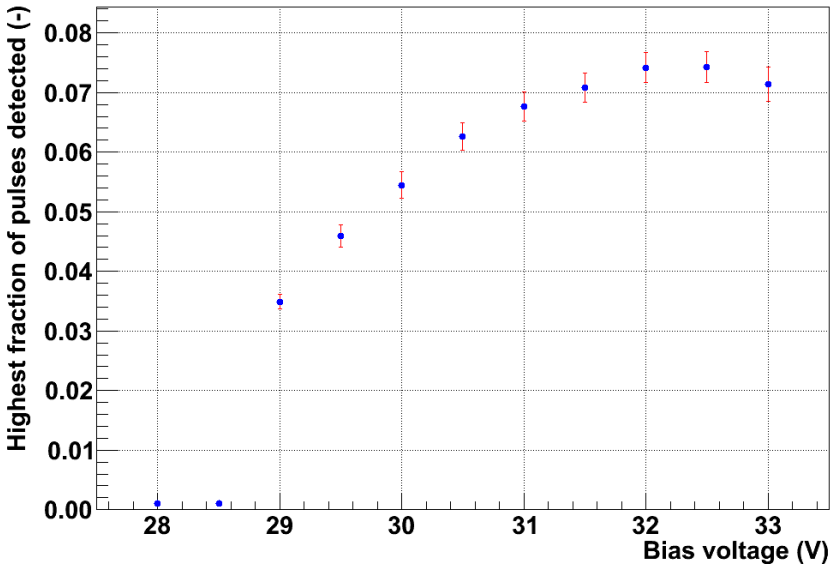
★ normalisation with other absolute measurement needed

\+ bias voltage dependencies

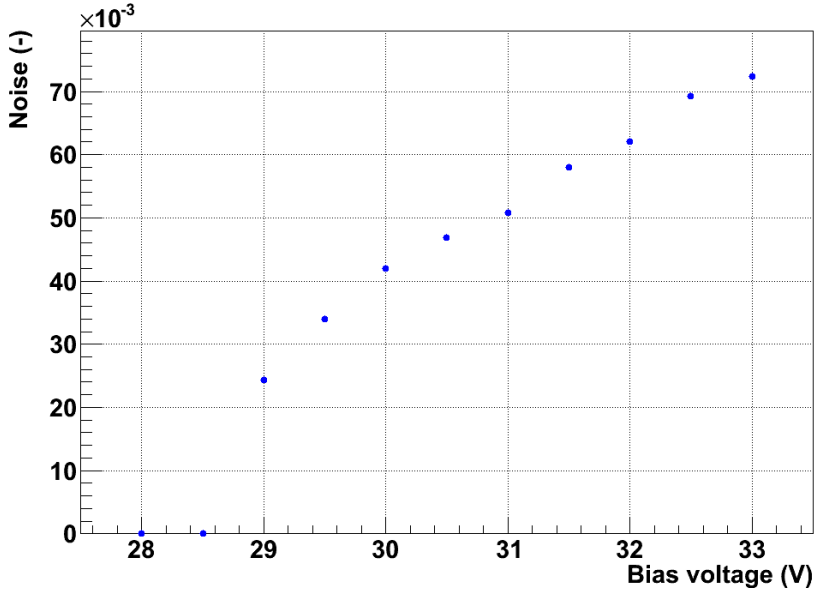
# Bias voltage dependencies

- can be used as a cross check of stage calibration (LED focus), correct settings of thresholds etc.
- shows when quenching ceases
- possible later comparison of different wavelengths (further improvements needed)

**Highest fraction of pulses detected: SENSl, blue LED**




**Noise: SENSl, blue LED**

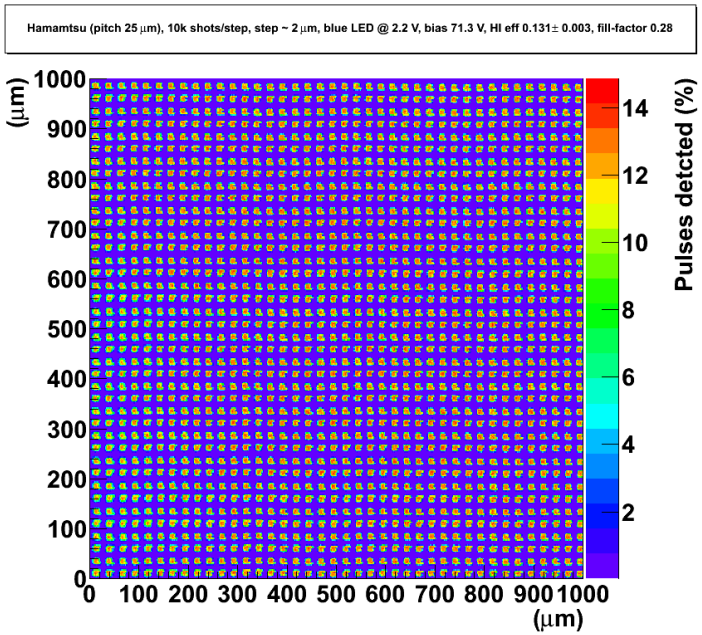


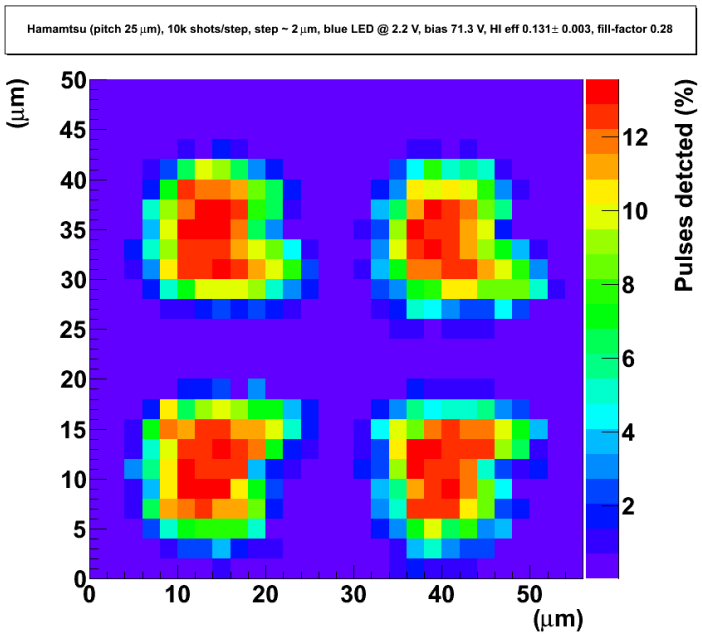
# Device list

| manufacturer | type | pixel pitch ($\mu$m) |
|---|---|---|
| Hamamatsu | S10362-11-025U, C | 25 |
| Hamamatsu | S10362-11-050U, C | 50 |
| Hamamatsu | S10362-11-100U, C | 100 |
| SENSl | SPMMicro1035X13 | 35 |
| SENSl | SPMMicro1100X13 | 100 |
| MEPhI/Pulsar | SiPM576#1 | 32 |
| MEPhI/Pulsar | N/A | 42 |

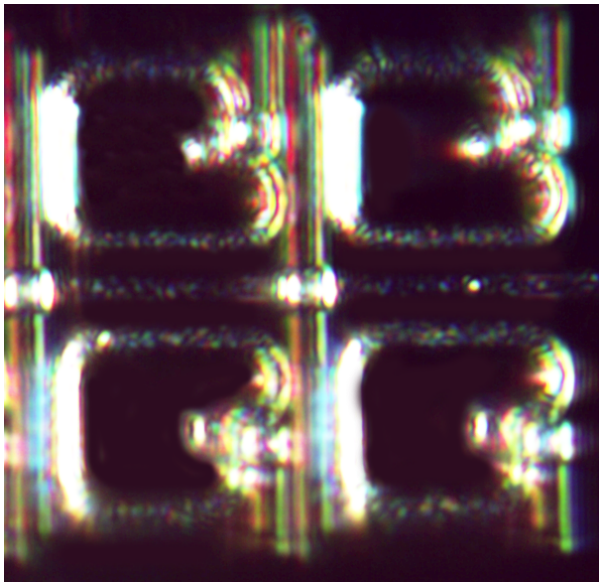
Table: Devices available for tests in MPI HLL

# **Results:** Hamamatsu (MPPC) (25 μm pitch)

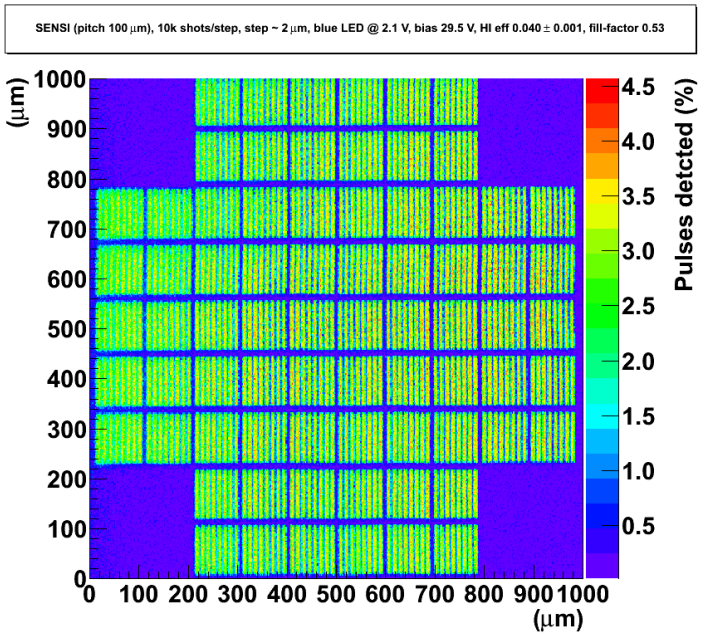


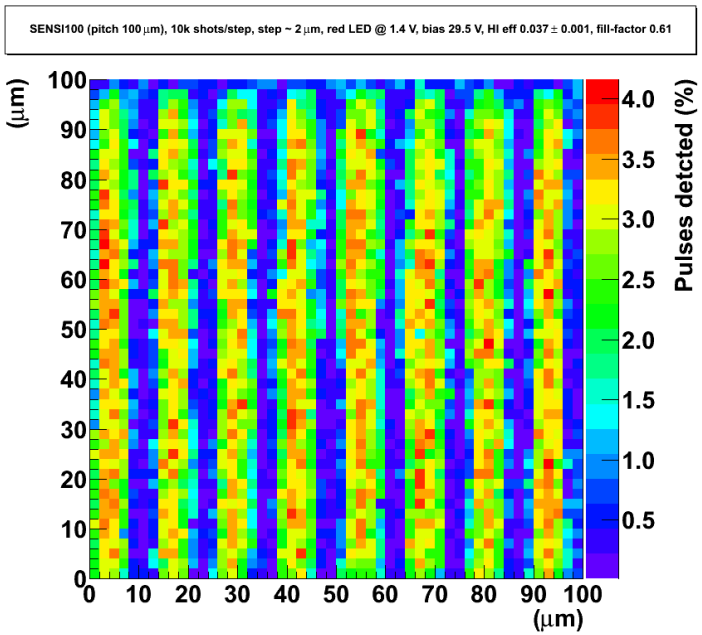




sensitive area is obviously significantly reduced by the quenching resistor placed on surface of the device



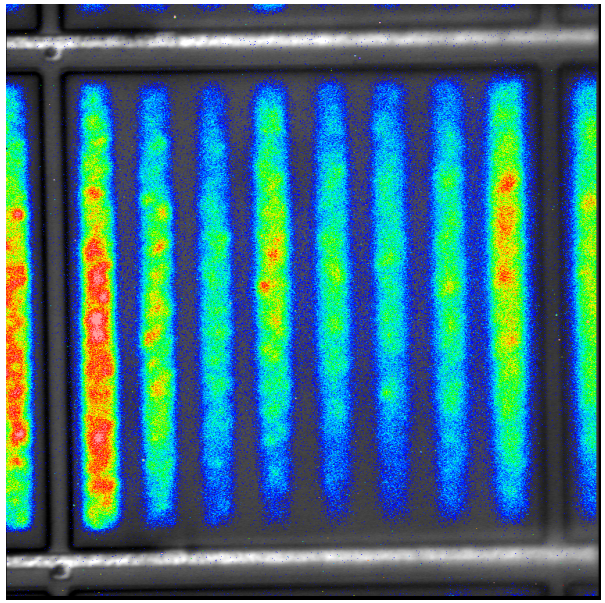
# **Results:** SENSI (100 μm pitch)



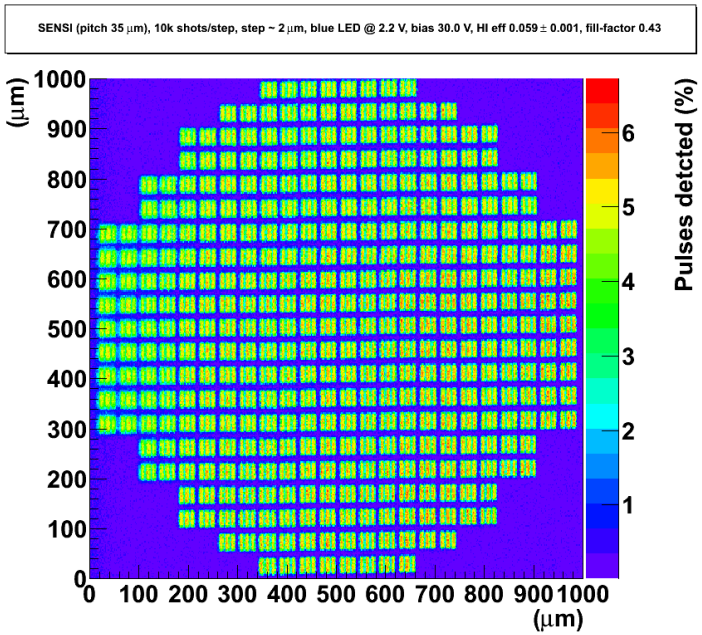



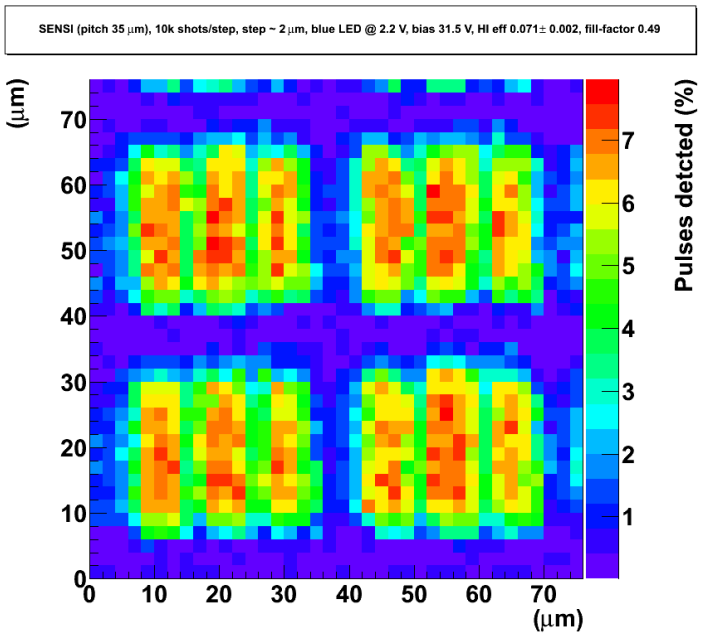

different quenching resistor shape can be observed on the sensitivity map

Photo + photoemission image



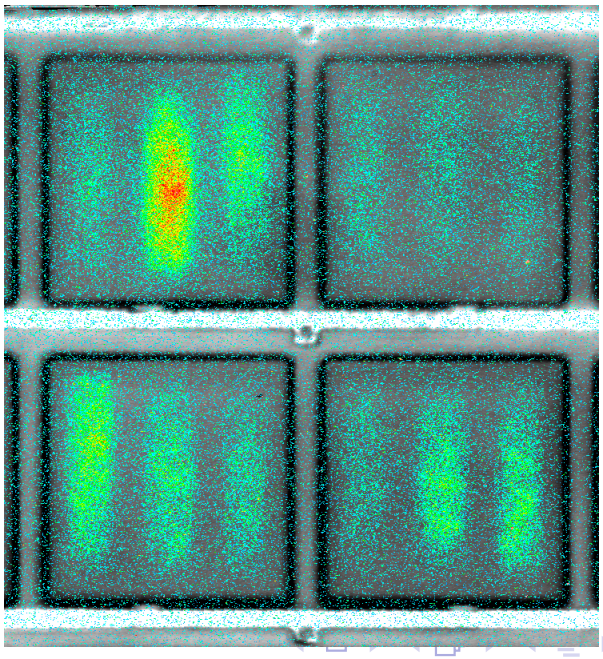
# **Results:** SENSI (35 μm pitch)



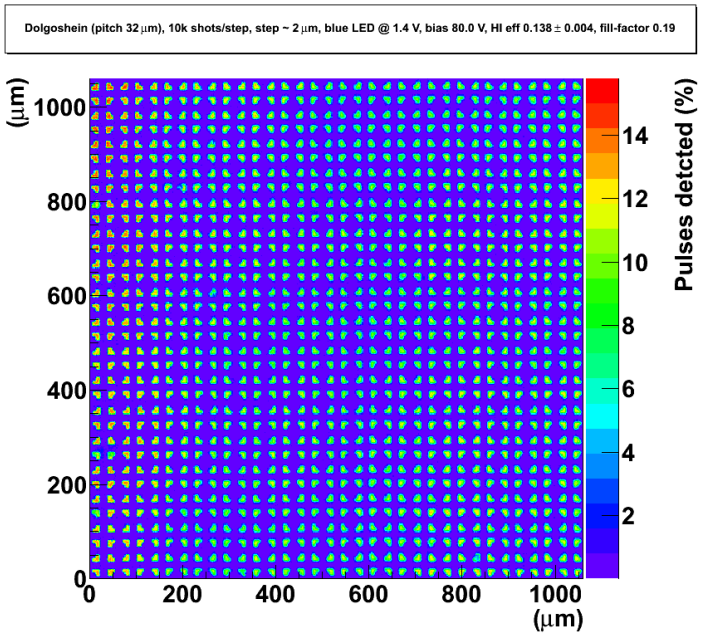



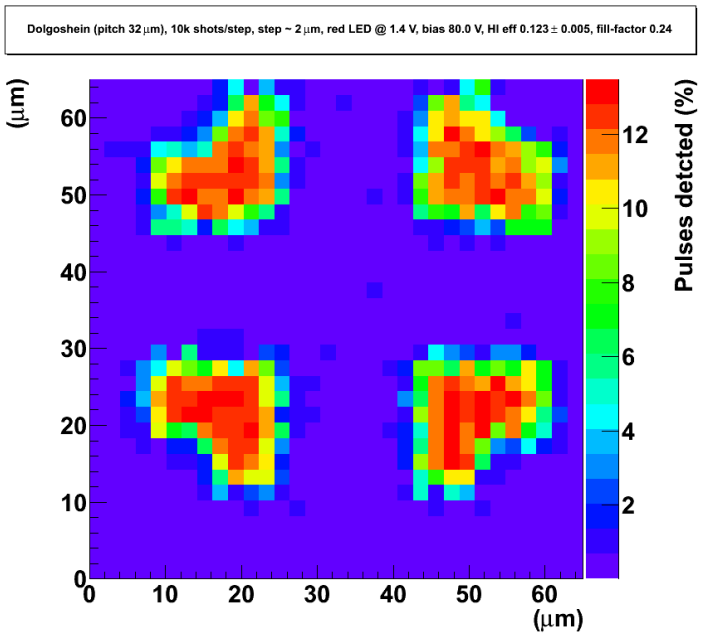

different quenching resistor shape can be observed on the sensitivity map

Photo + photoemission image

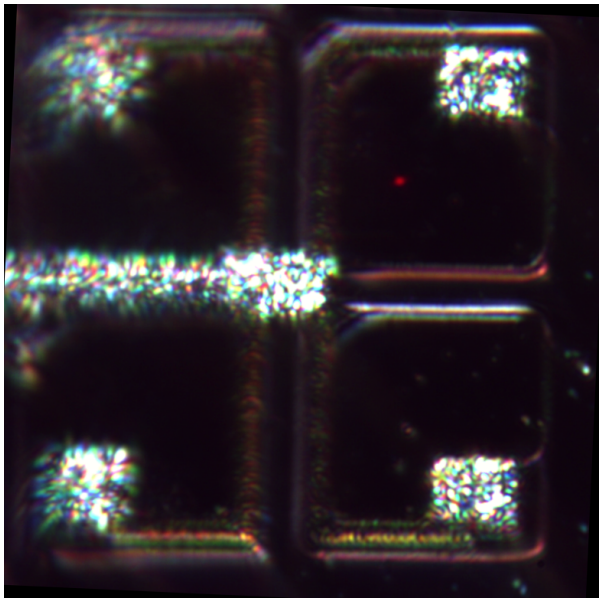


# **Results:** MEPhi (Dolgoshein) (32 μm pitch)




different quenching resistor shape can be observed on the sensitivity map



# Conclusions

## Accomplished

- new stage calibration developed
- new scanning procedure applied
- higher level of automation reached

$\Rightarrow$ scanning time reduced by three orders of magnitude

$\Rightarrow$ capability of scanning arbitrarily aligned SiPM surfaces

## Future plans

- optimisation of data analysis
- scans of further devices
- normalisation with an absolute measurement
- light output estimation of used LEDs