CTA report 152:

Comparison of photon detection performance of photomultiplier tube and silicon photomultiplier for Medium Sized Telescopes

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Outline

Introduction

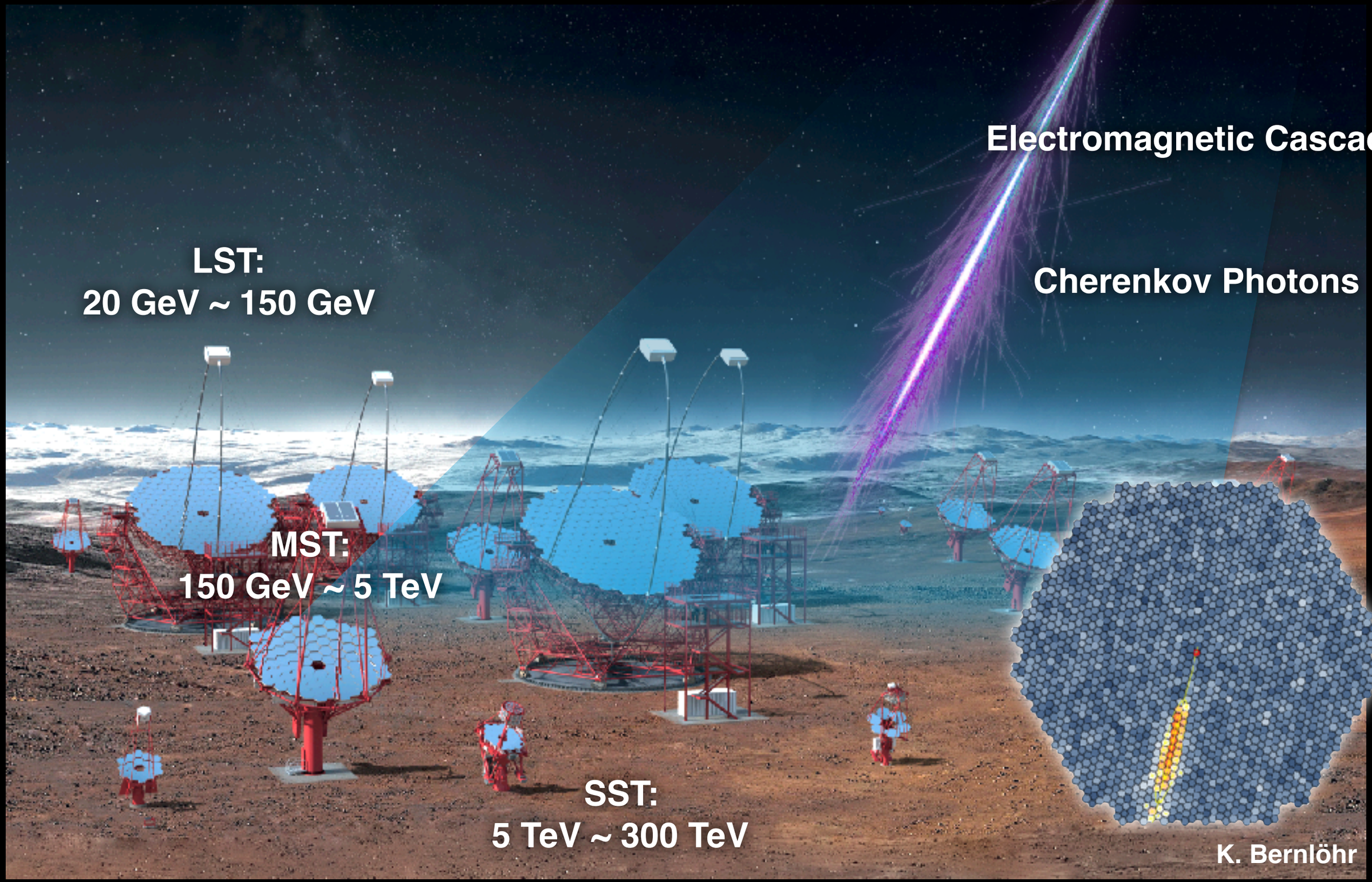
- CTA and Cherenkov imaging
- Motivation
- PMT and SiPM
- Medium-sized telescope

Main Part

- Setup and analysis technique
- Measurement results
- Discussion

CTA and atmospheric Cherenkov imaging

Very-high-energy
Gamma Ray
(20 GeV –300 TeV)



Motivation

Advantages of SiPM:

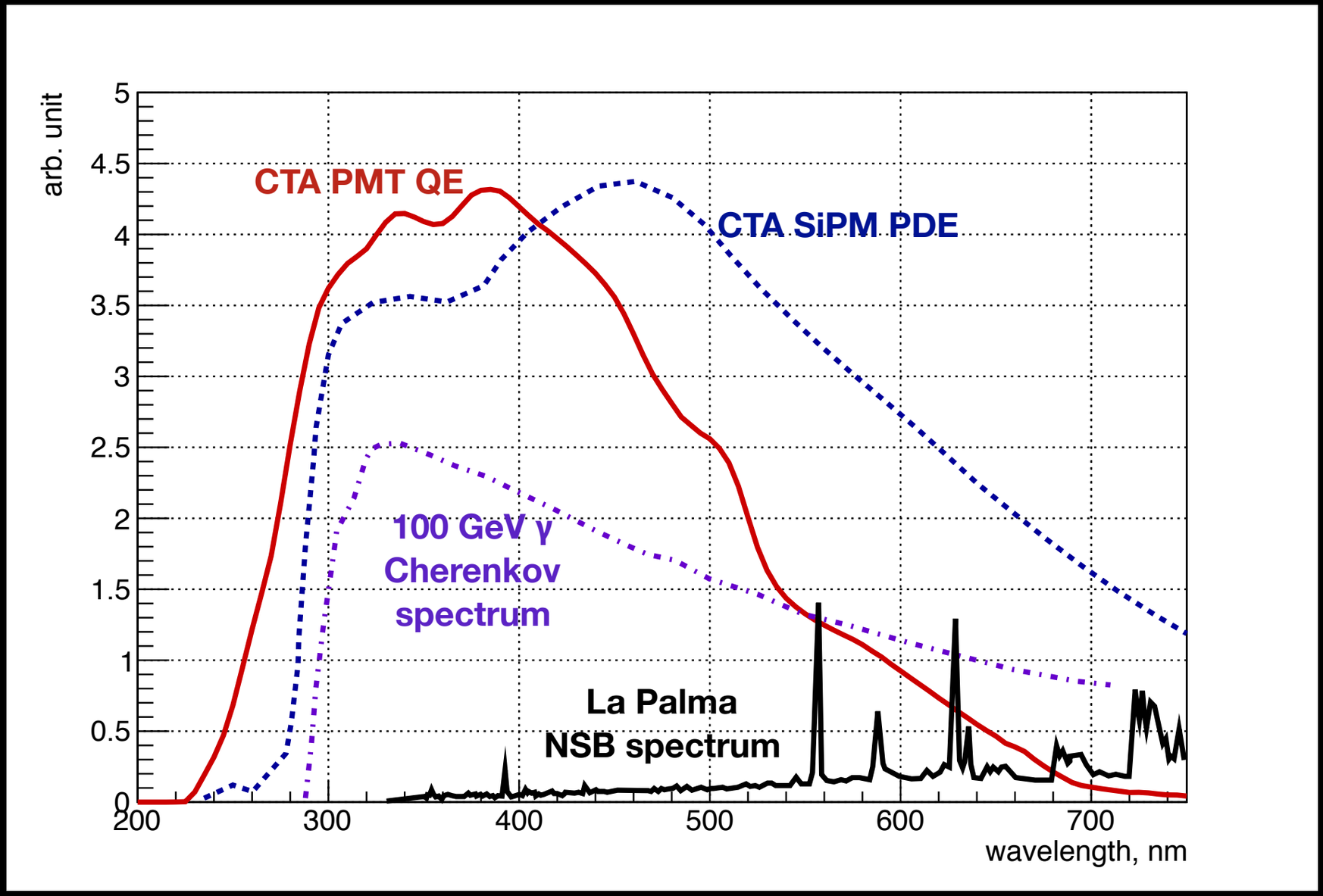
- Background-tolerant, no degradation over time
- Stable quantum efficiency and photon detection efficiency
- Can be operated with 60V
- Lightweight, compact

PMT and SiPM

To ensure that the performance of SiPM cameras will not be inferior to the current PMT cameras, we have to compare:

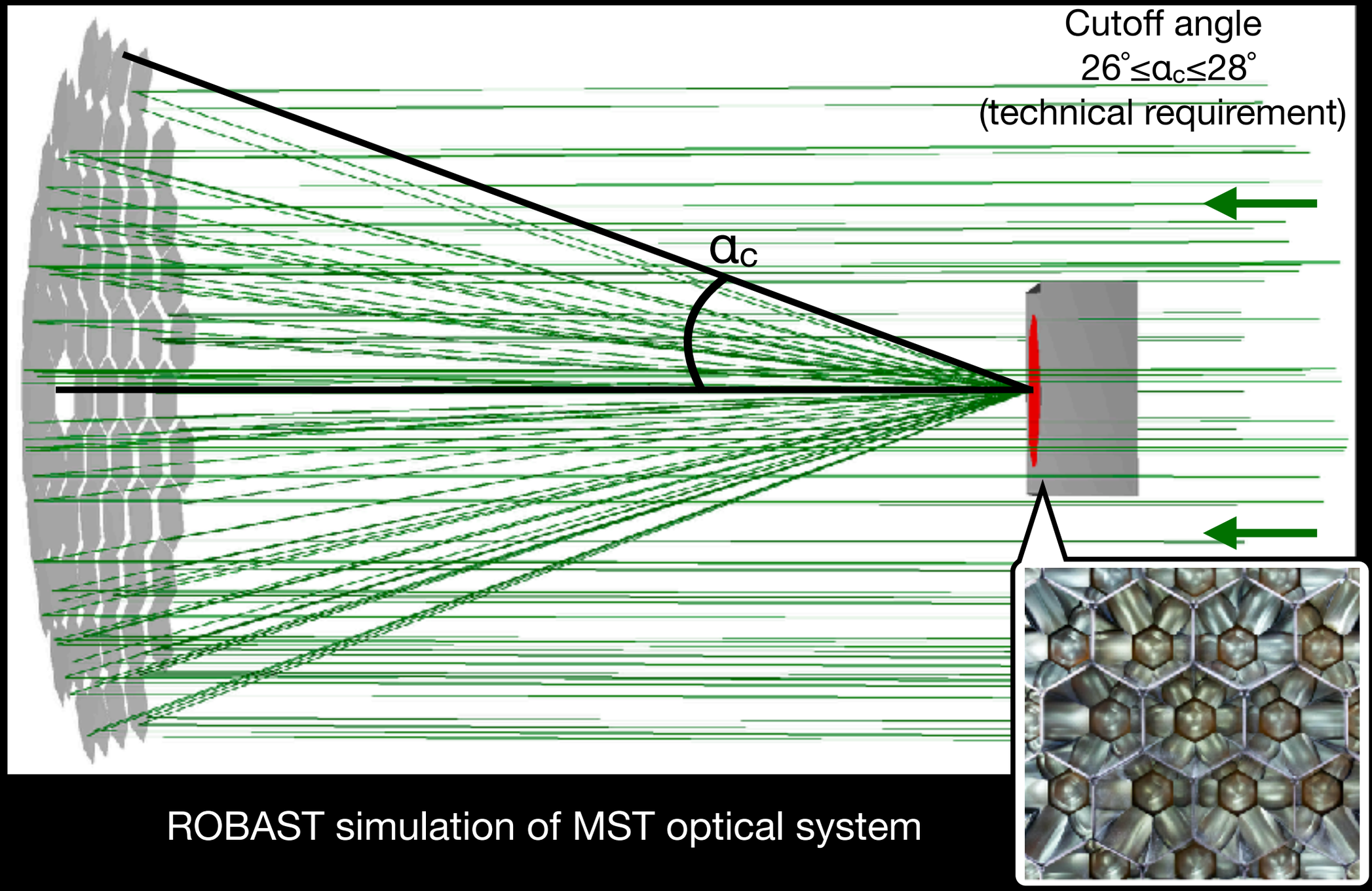
- QE / PDE
- Sensitivity to signal
- Sensitivity to noise

- High NSB (moonlight) tolerance and performance under high NSB conditions
- Overall telescope performance (the end goal of this work)



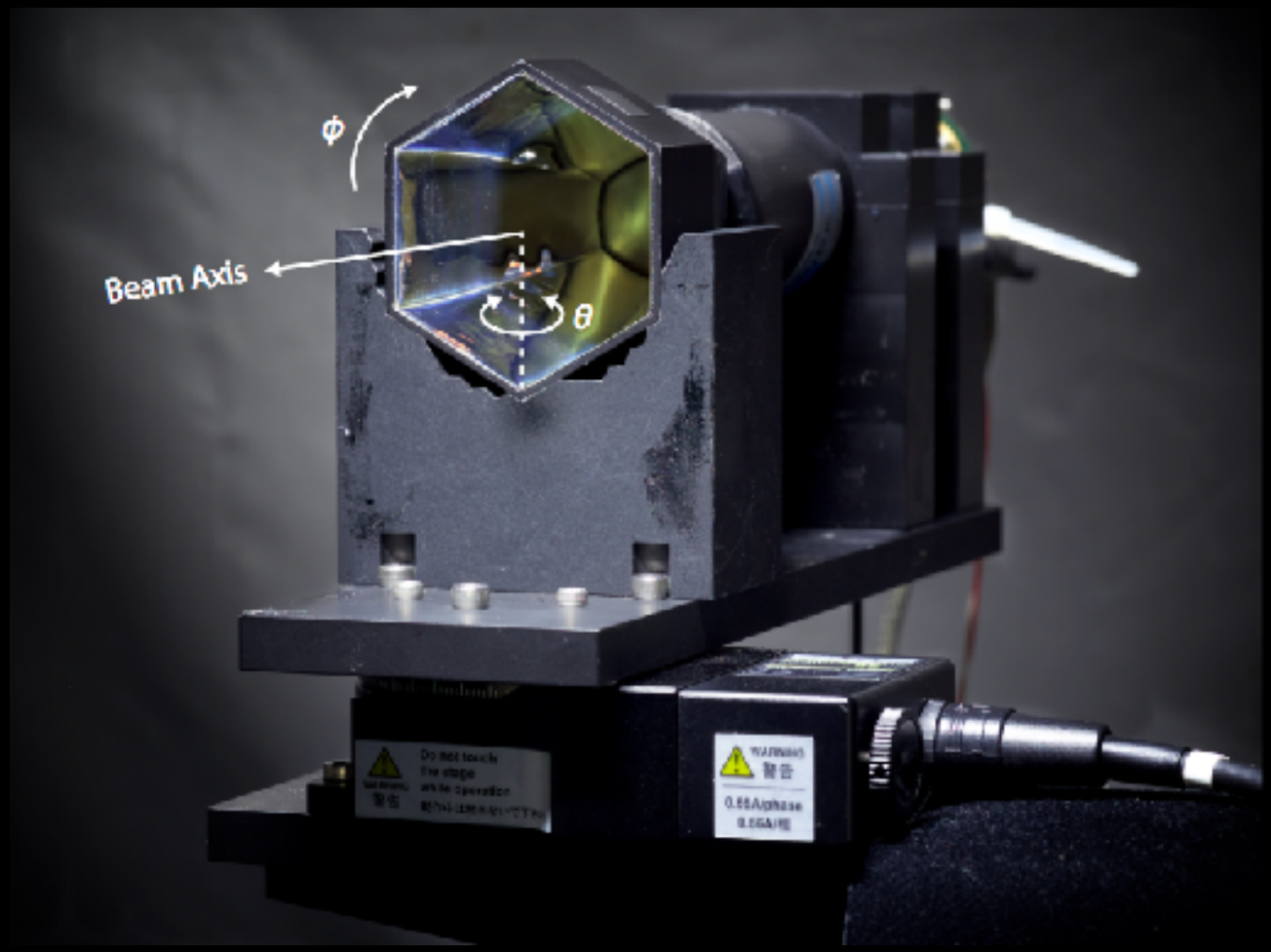
PMT and SiPM sensitivity comparison
(not to scale)

Medium-sized telescope

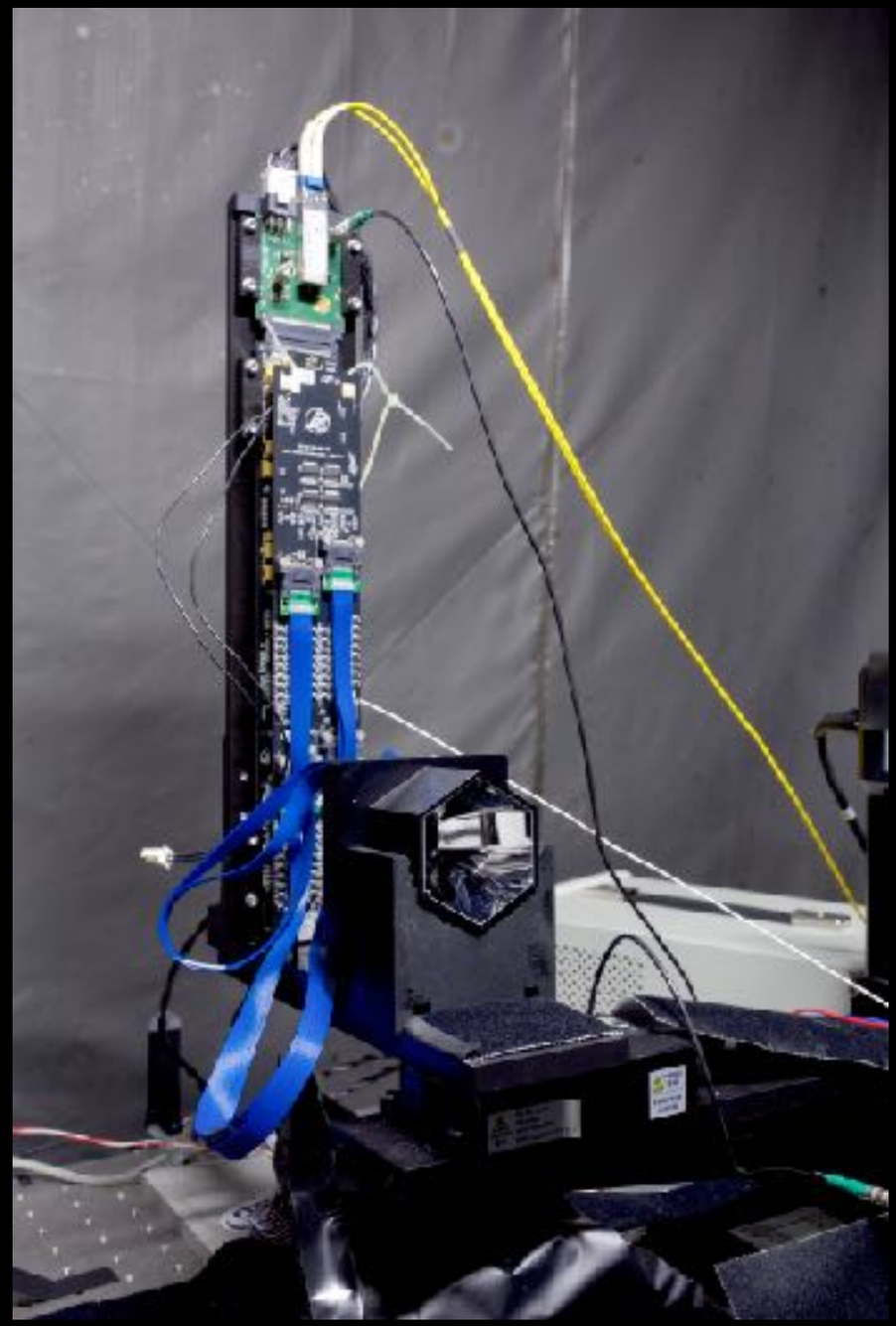


ROBAST simulation of MST optical system

Measurement setup



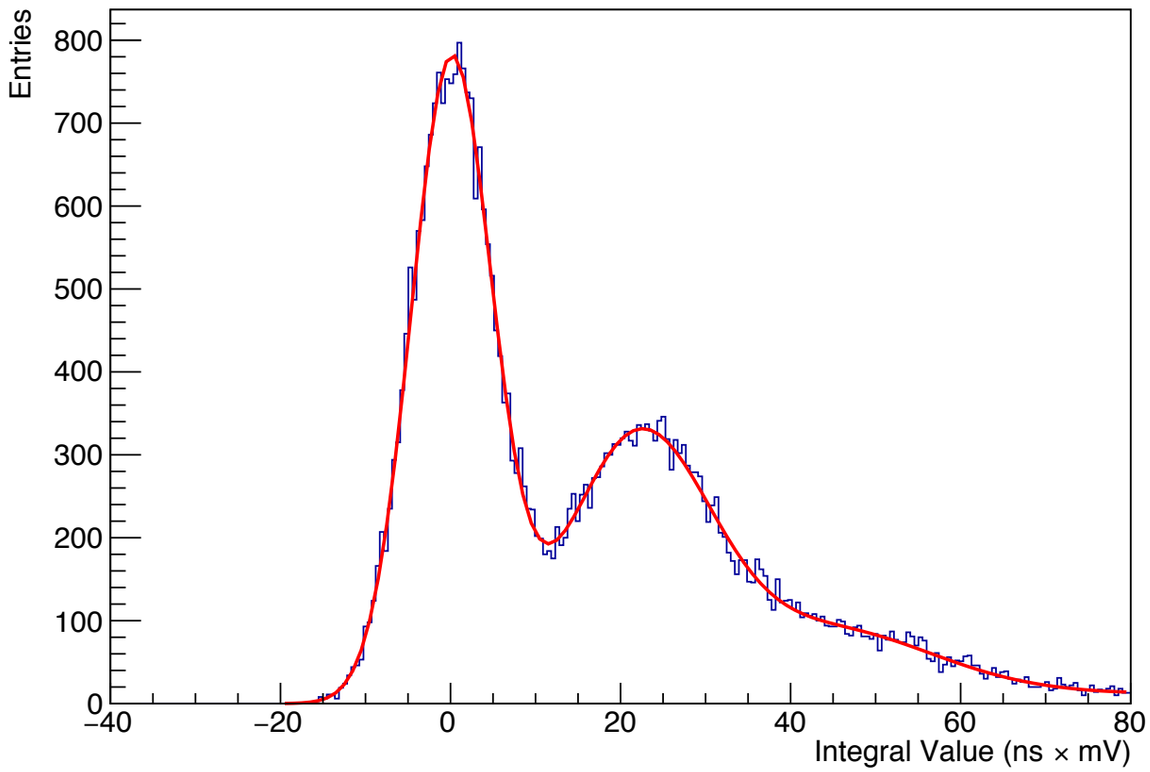
PMT on a rotation stage



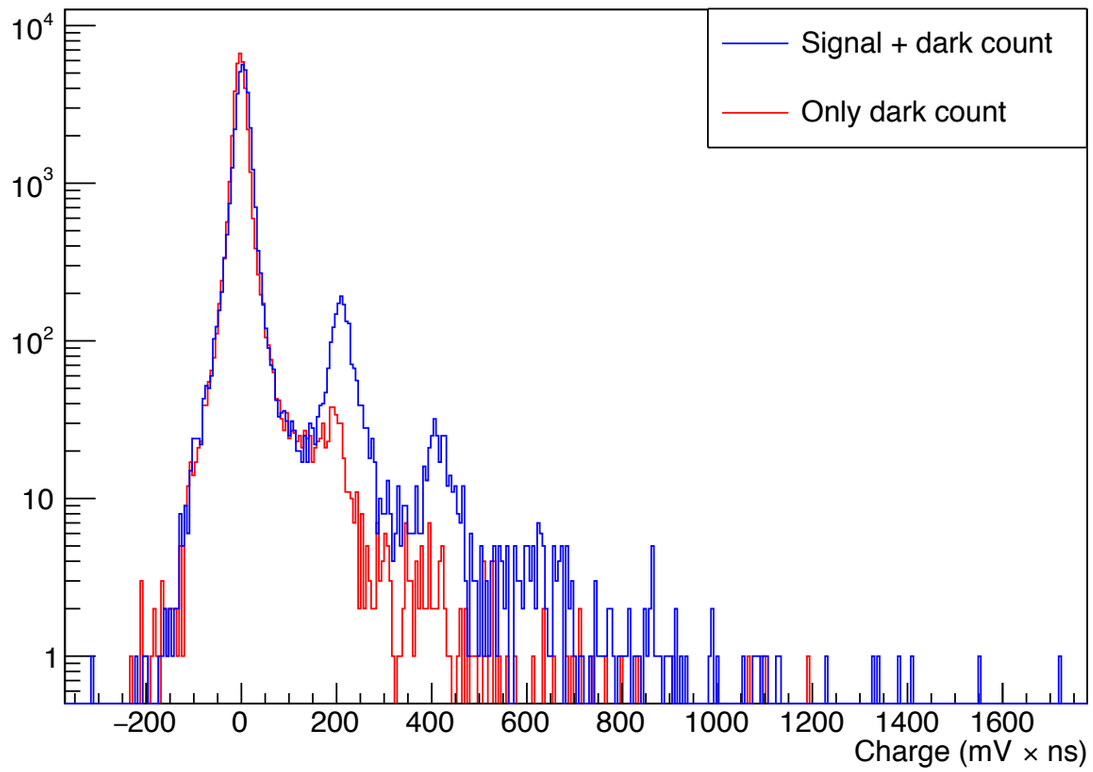
Readout module (TARGET)
on a rotation stage

Analysis technique

PMT charge spectrum sample



SiPM charge spectrum sample



Poisson distribution:

$$P(k) = \frac{\lambda^k}{k!} e^{-\lambda}$$

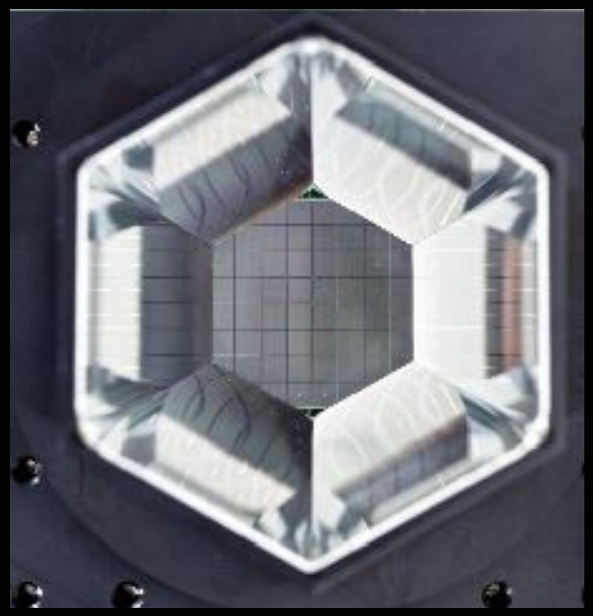
Can extract mean value from pedestal:

$$\lambda = -\ln P(0)$$

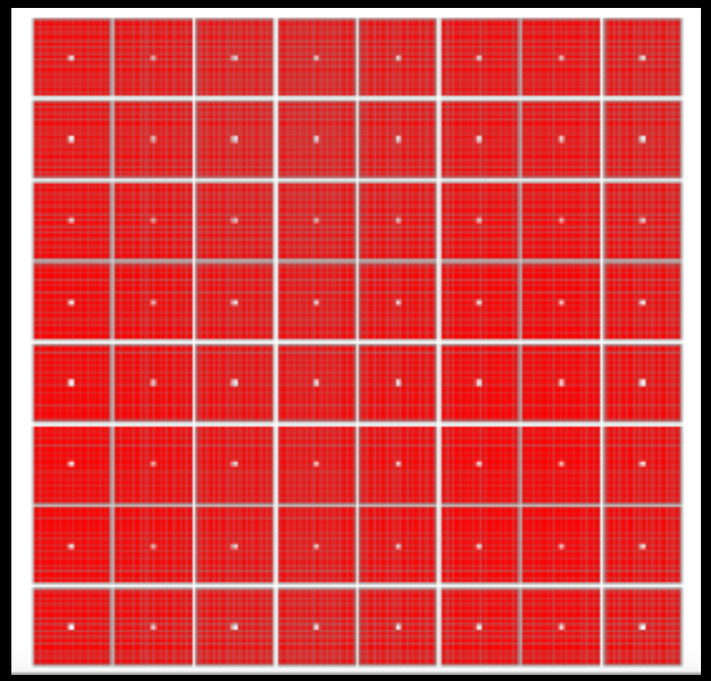
Crosstalk does not affect
0pe peaks in SiPM

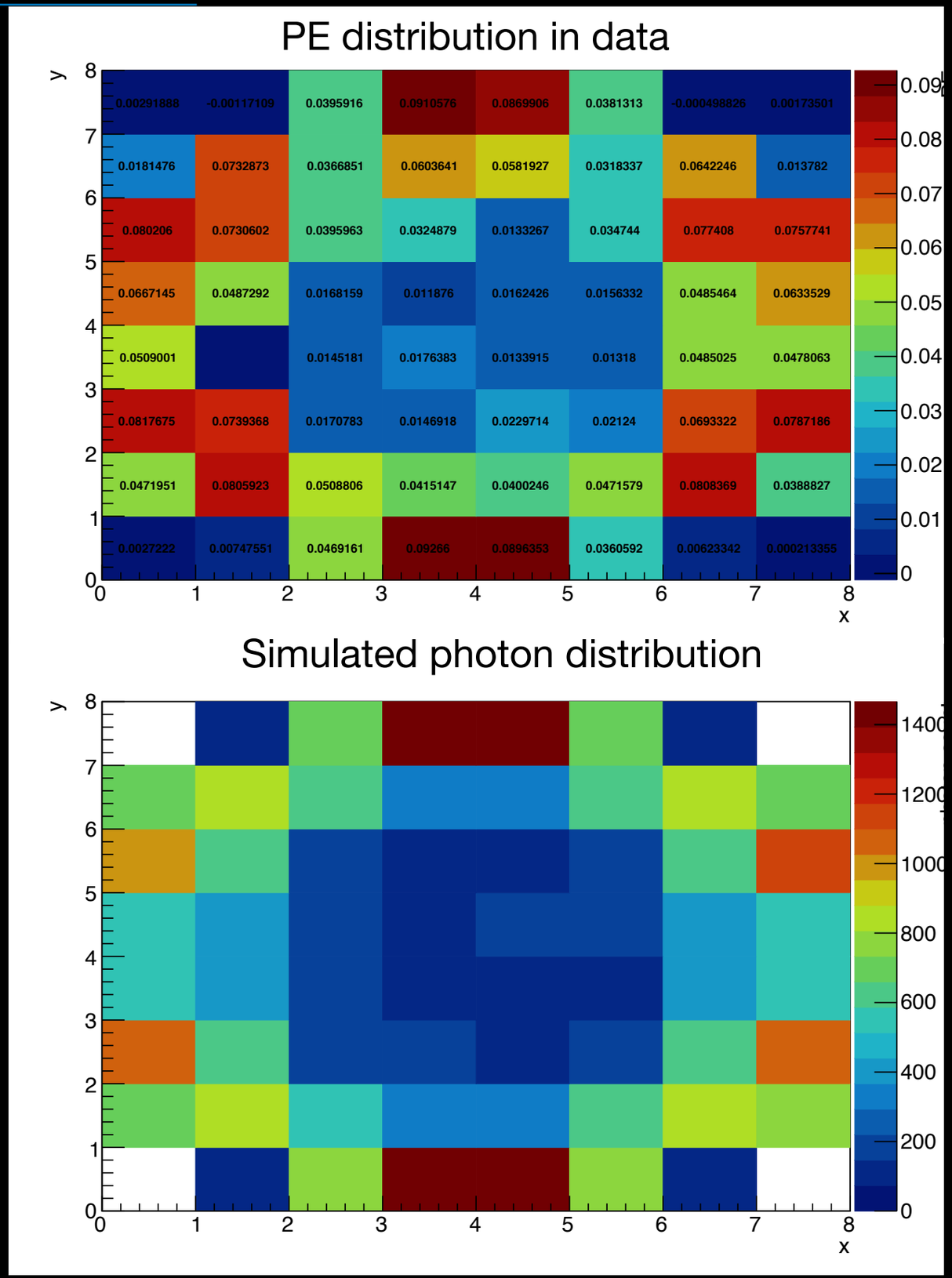
Photoelectron distribution in SiPM

SiPM photo



SiPM geometry



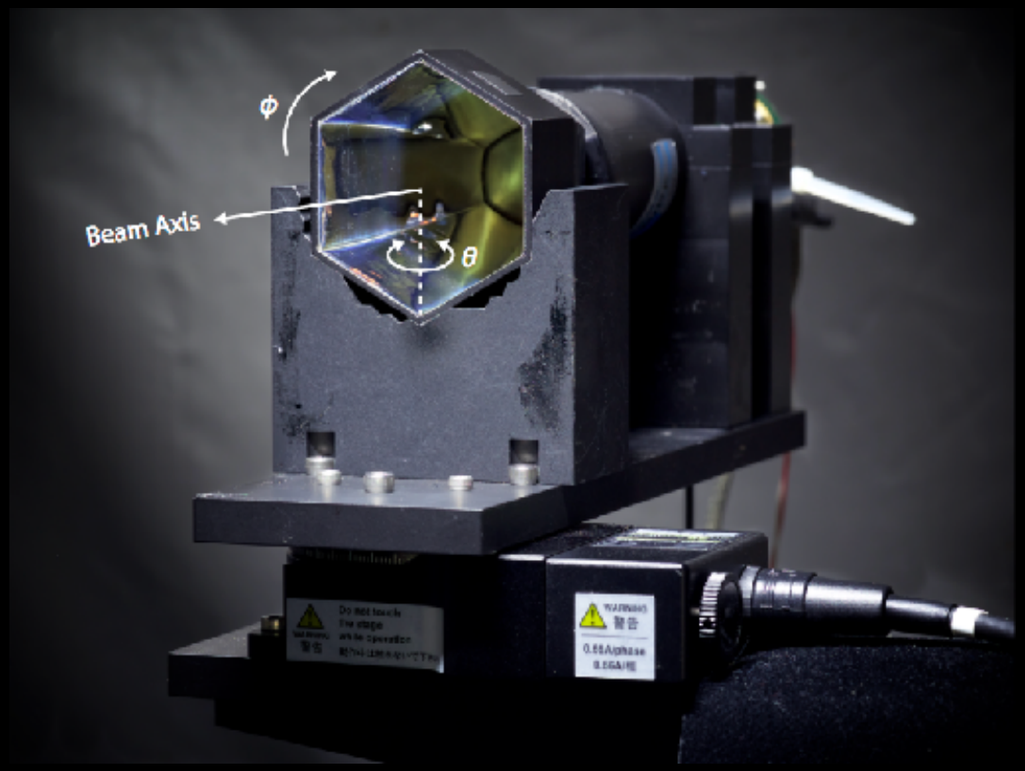


Measurement results

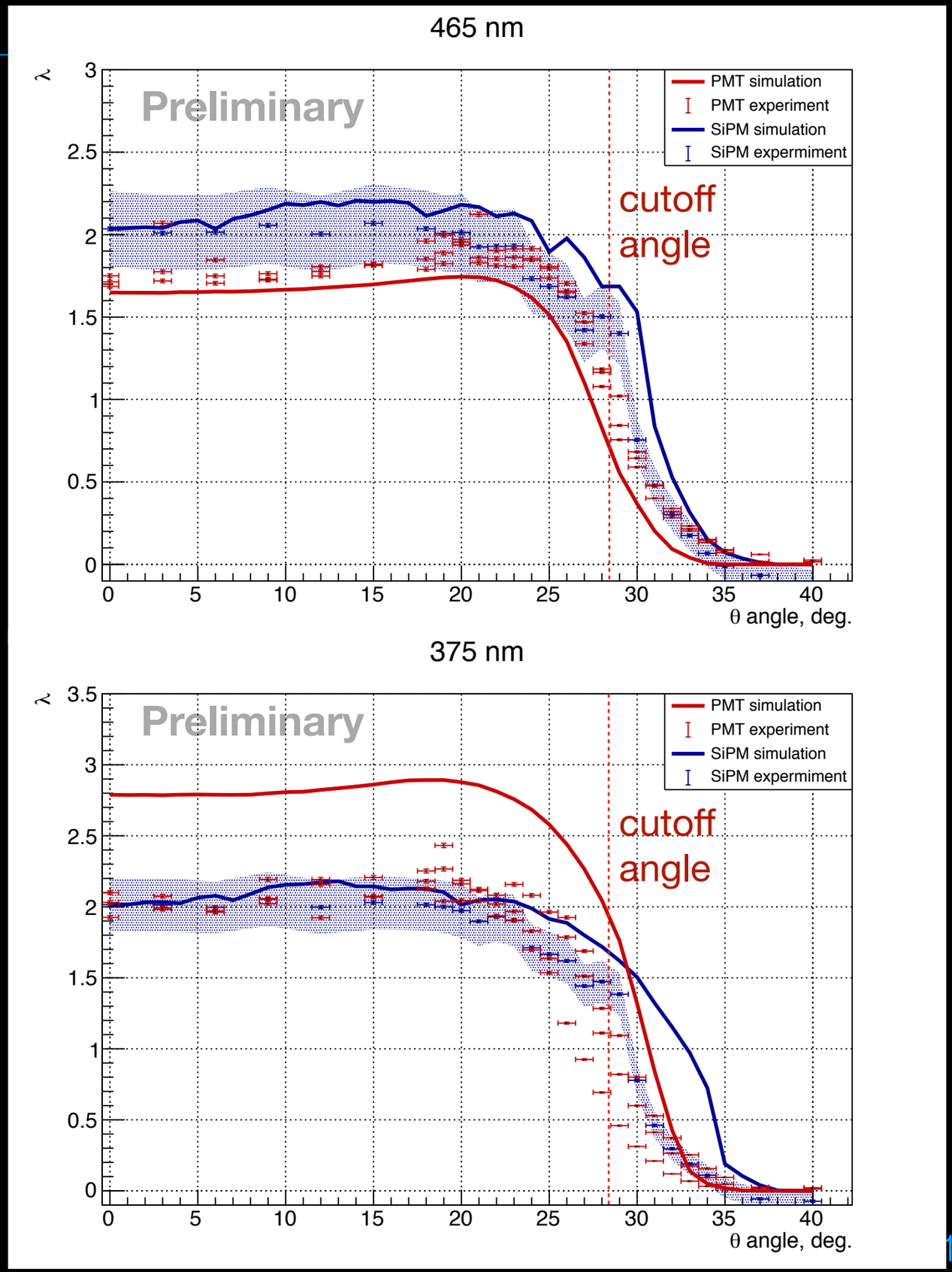
Our simulation can not reproduce absolute values, so it is normalized to fit on-axis SiPM data

There are still some issues with the measurement setup and analysis

It is likely that consideration in terms of only geometrical optics is not good enough to simulate SiPM behavior properly



Results for azimuthal angle ϕ = 0
(see the figure on the left)



Discussion

- Although the results are not final, our measurement technique is usable and only needs a little polishing

- There are still some difficulties with the setup, but that will be solved in a short time

- Relative performance is not consistent with the simulation, likely due to interference effects in Si_3N_4 and SiO_2 layers and on silicon surface

- Cutoff angle for SiPM configuration has to be checked

To do

Several things have to be done before making any solid conclusions:

- Design a new light concentrator to remove the gaps and optimize the cutoff angle
  (in progress)

- Compare the performance of PMT and SiPM by a simple ray-tracing simulation
  (after designing a new light concentrator)

- Perform a full telescope simulation with CORSIKA and sim_telarray and study how NSB affects new cameras
  (the final step)