Optical feasibility of an upgrade of the CTA LST Camera to SiPM

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cherenkov telescope array

Introduction

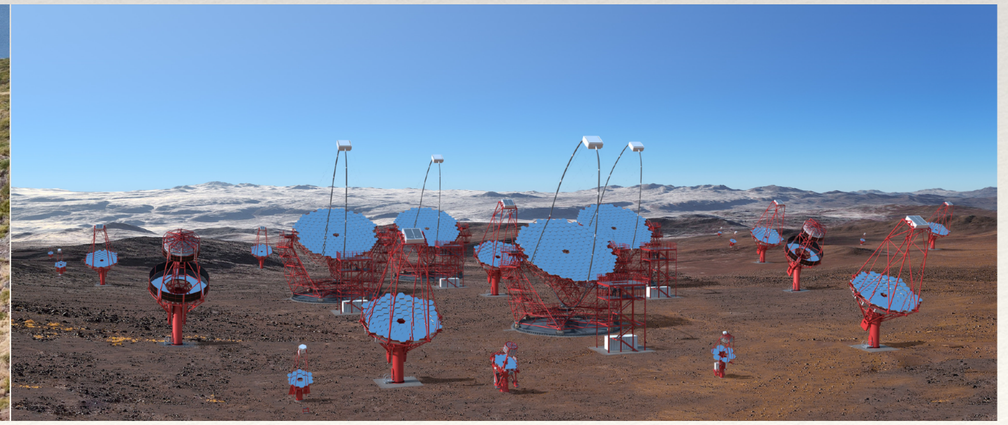
CTA (Cherenkov Telescope Array) is a assembly of | **70 Small** size telescopes
35 Medium
8 Large

Detection of gamma-ray from air showers between **30 GeV up to 300 TeV**

A site in each hemisphere for full sky coverage :

✤ **Canary Island (La Palma)** for the North

✤ **Chile** for the South (ESO)



LST specifications

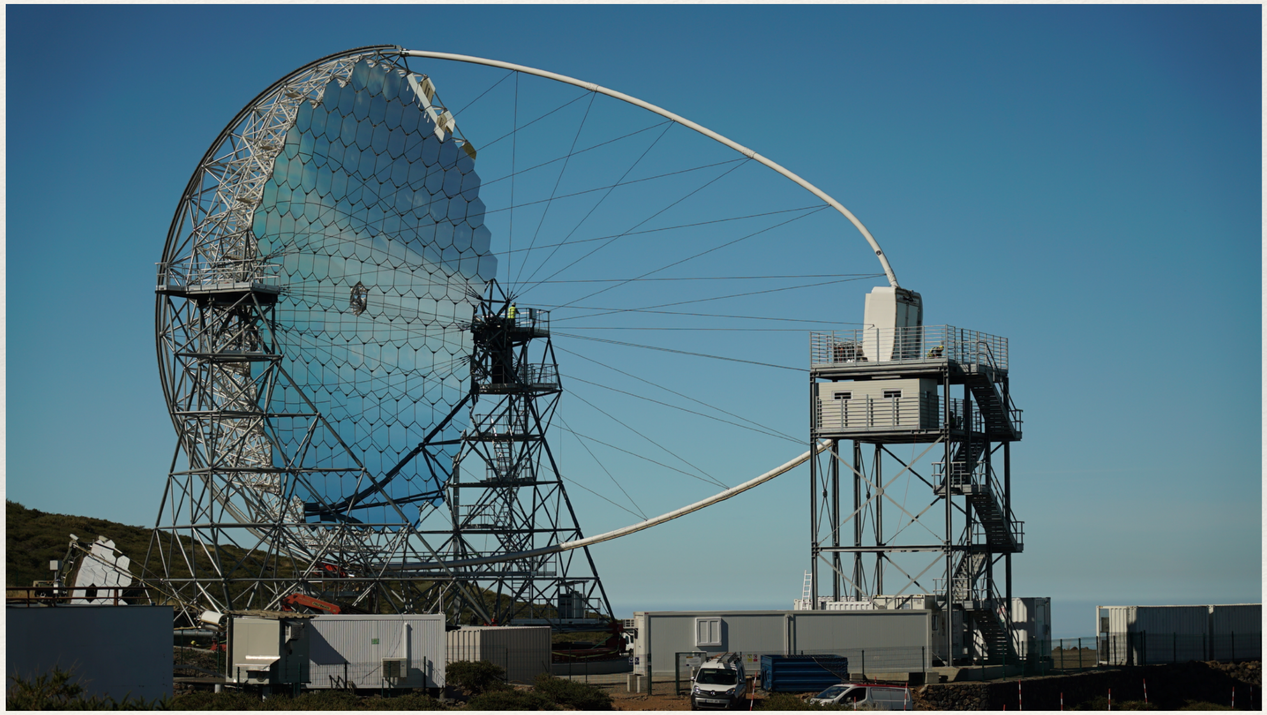
Large Size Telescopes (LST) are the **biggest telescopes** (23m mirror)

They are designed to:

- **Detect low energy gamma-rays using a** large collection surface
- **Catch transient events** (GRB, AGN flare, GW signals…) with ~**30s slew time**

4 LST are planned to be built in each site

About CTA, see also : Loporchio et al. (talk)
Rando et al. (poster)
Zenin et al. (talk)

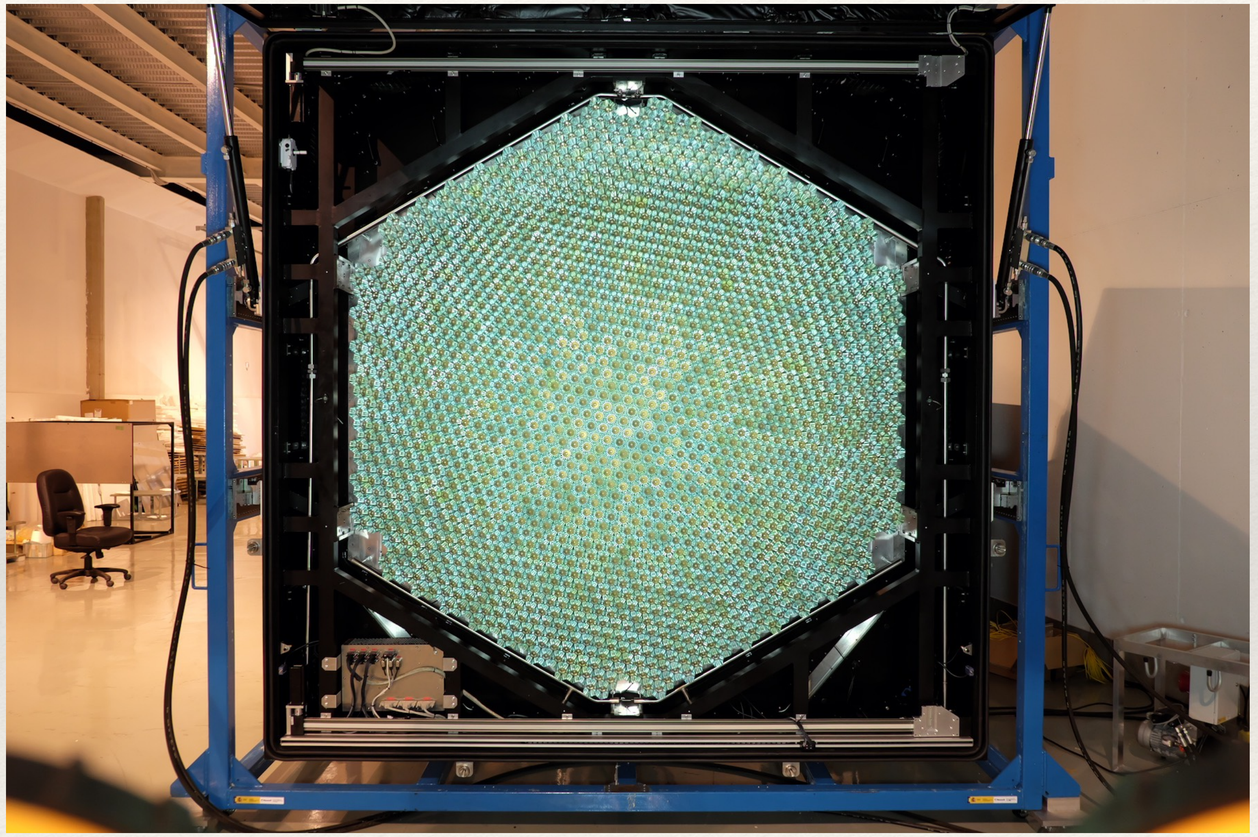


LST1 on the North Site (La Palma, Spain)

LST camera

The LST camera comprises **1855 PhotoMultiplier Tubes (PMT)** coupled with **light guides** offering:

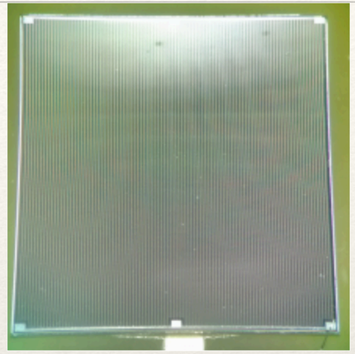
- **An increase of the collection surface** of the pixel
- **A reduction of the dead space** between pixels
- a limitation of the pixel field of view, **reducing stray light** (not reflected by the telescope mirror)



LST1 Camera

Silicon multiplied tube properties

We want to investigate **SiPM for a future update of the CTA Large Size Telescope** (LST)

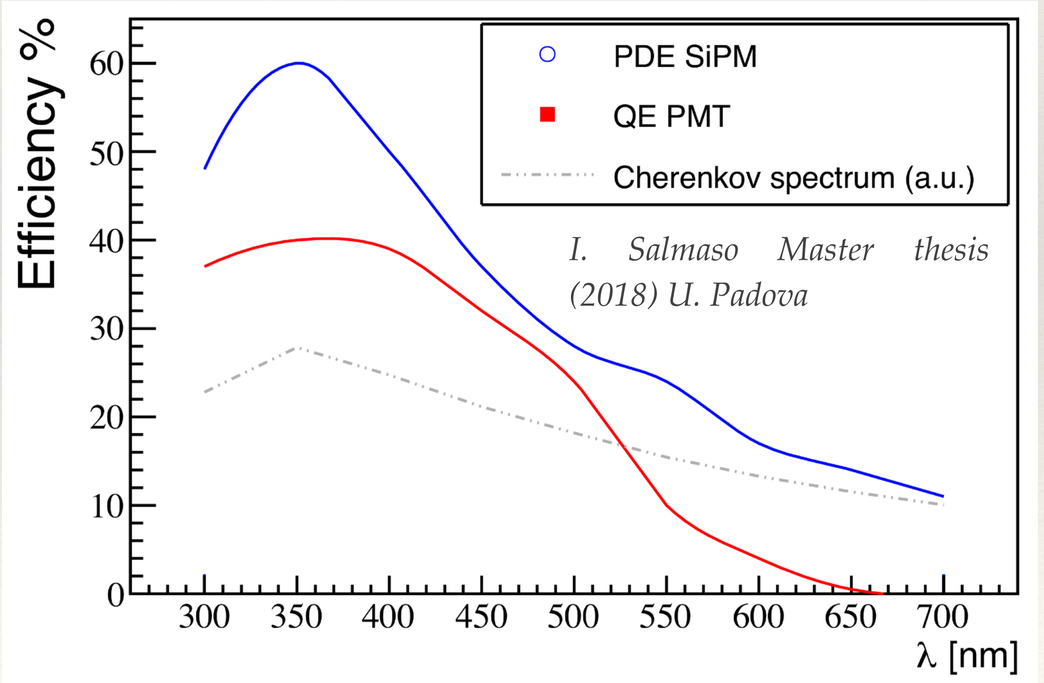


One SiPM unit

SiPMs offer **several pro/cons** compared to conventional PMTs:

+ Better efficiency
+ Lower operating voltage
+ Better geometrical arrangement

- Low sensitive area
- Cost
- Optical cross-talks

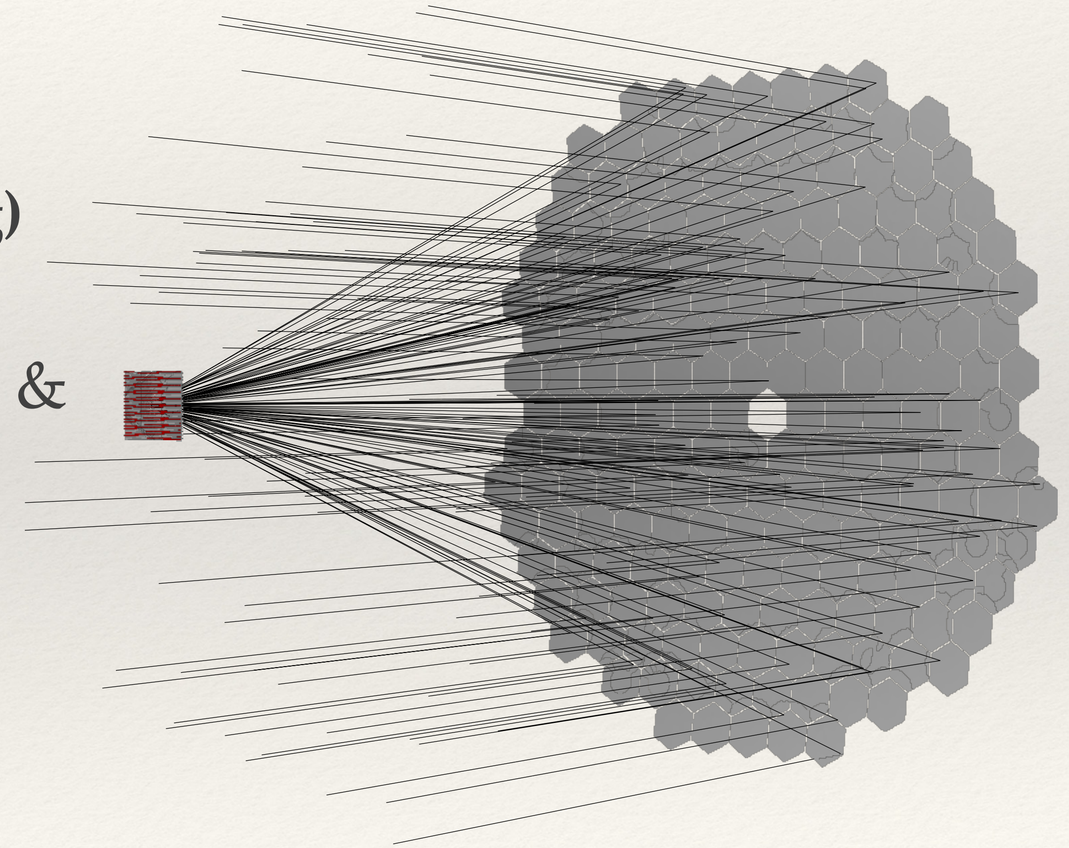


LST Simulations

Evaluation of the response of the SiPM using **ROBAST**
Okumura et al. (2015)

ROBAST (ROOT-based simulator for ray tracing)

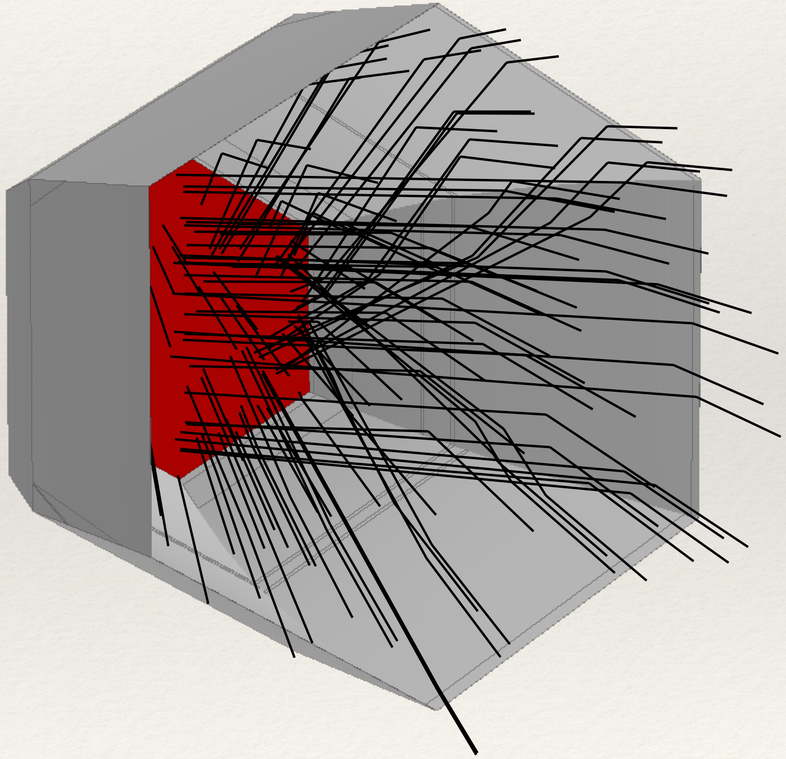
- non-sequential ray-tracing simulation
- **Ideal for optical study** of gamma-ray & cosmic ray telescopes



We can simulate the LST mirror as well as the 1855 pixels of the LST camera

LST Simulations

Each pixel has an associated light guide (LG) in front which is an **improved Winston cone designed for LST**
[Okumura et al. (2017)]



The **performances of SiPMs depends on the photon angular distribution** at the LG exit

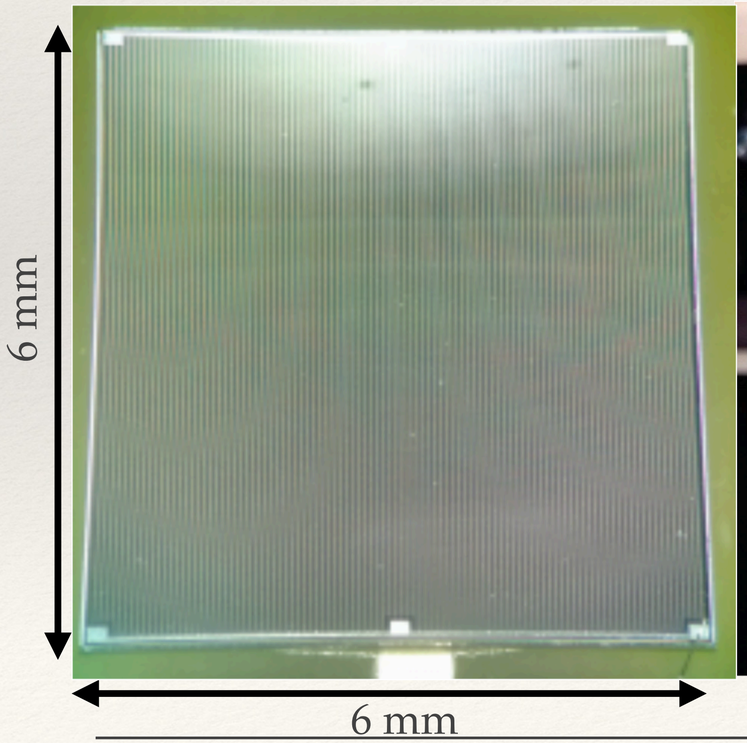
We are going to **evaluate the response of SiPM** as a function of the **photon angle**

Measurement of angular response

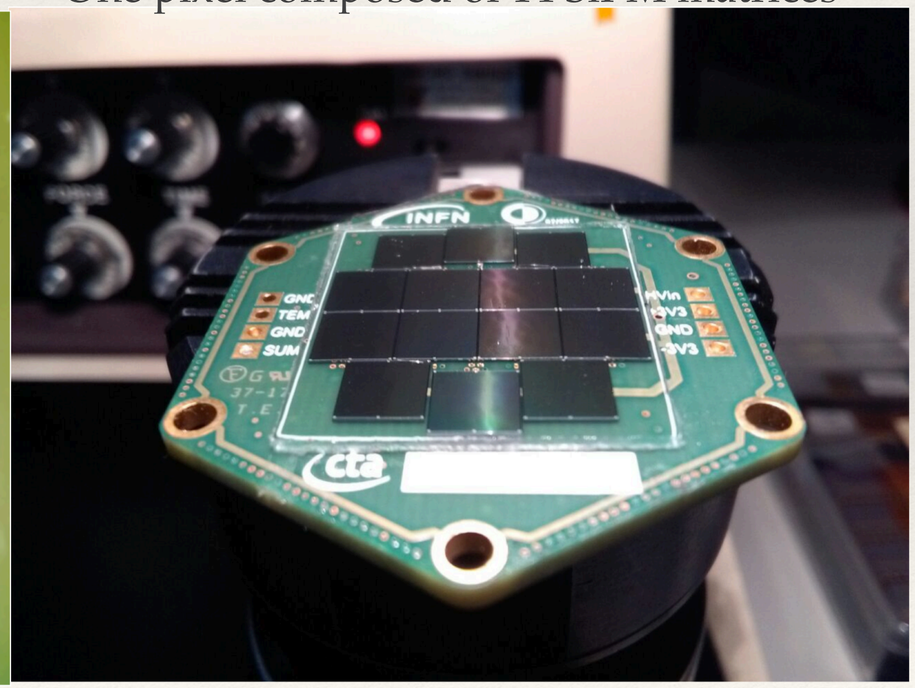
We used one **SiPM matrix** (6x6 mm² FBK[a] NUV HD3_2) and one **pixel of 14 SiPM matrices** to evaluate their angular acceptance

See also Rando et al. about the same SiPM cluster

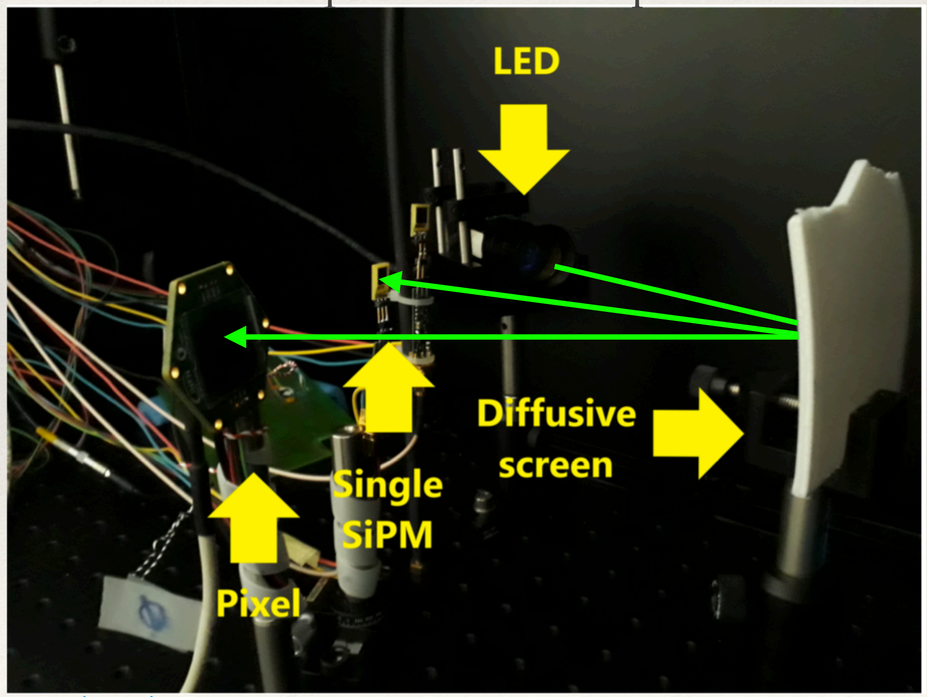
One 6x6 SiPM matrix



One pixel composed of 14 SiPM matrices



Experimental set up



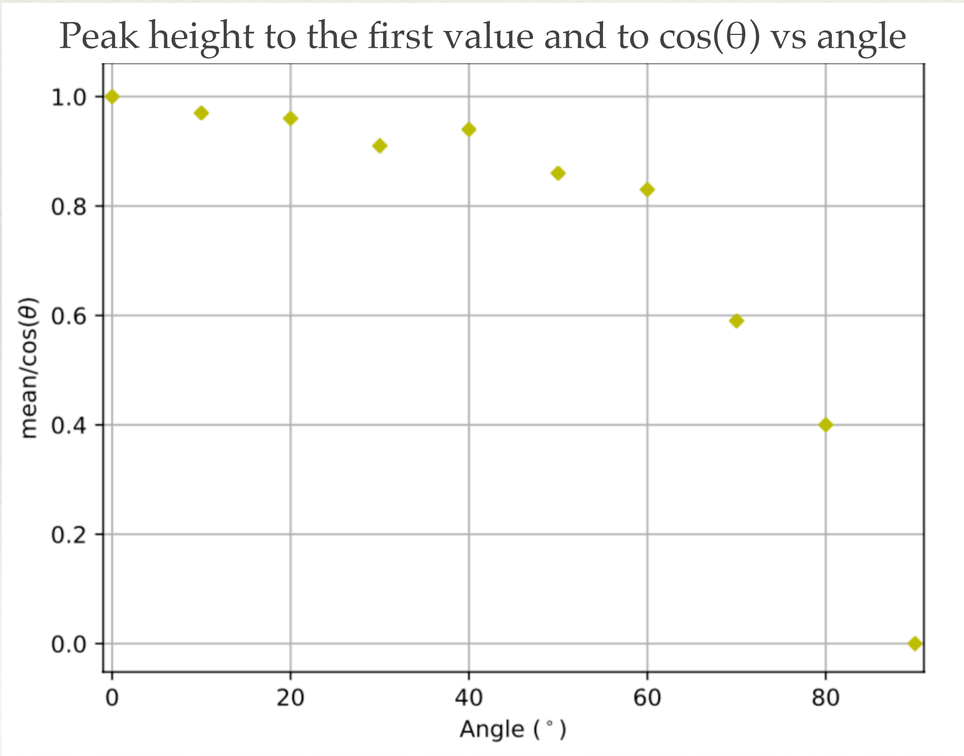
a: Fundazione Bruno Kessler https://www.fbk.eu/en/

SiPM Angular response

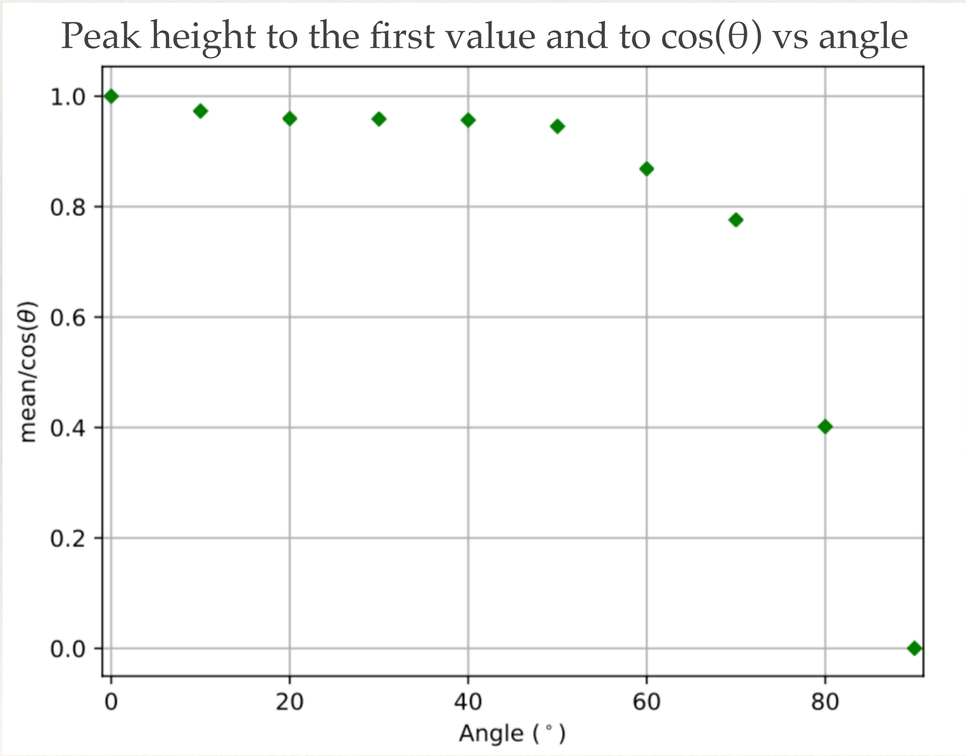
We used 2 different light sources Lasers Picoquant: PLS 8-2-592 ($\lambda = 376$ nm)
PLS 8-2-519 ($\lambda = 499$ nm)

Single SiPM matrix measurement

$\lambda = 376$ nm



$\lambda = 499$ nm



I. Salmaso Master thesis (2018)
U. Padova

SiPM Angular response

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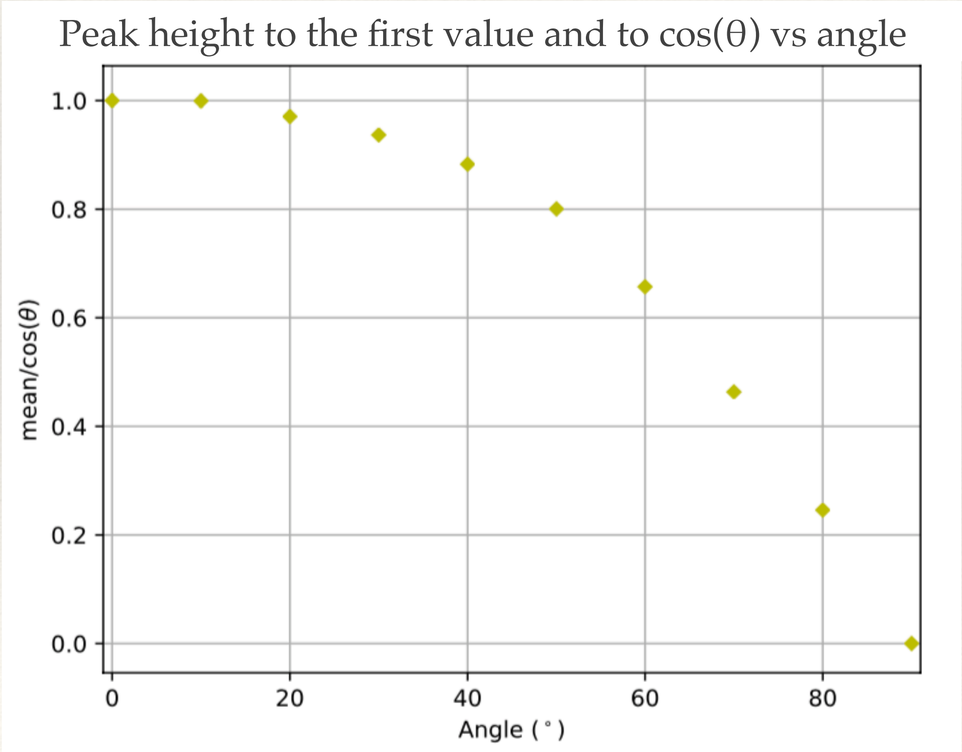
Pixel of 14 SiPMs measurement

$\lambda = 376$ nm



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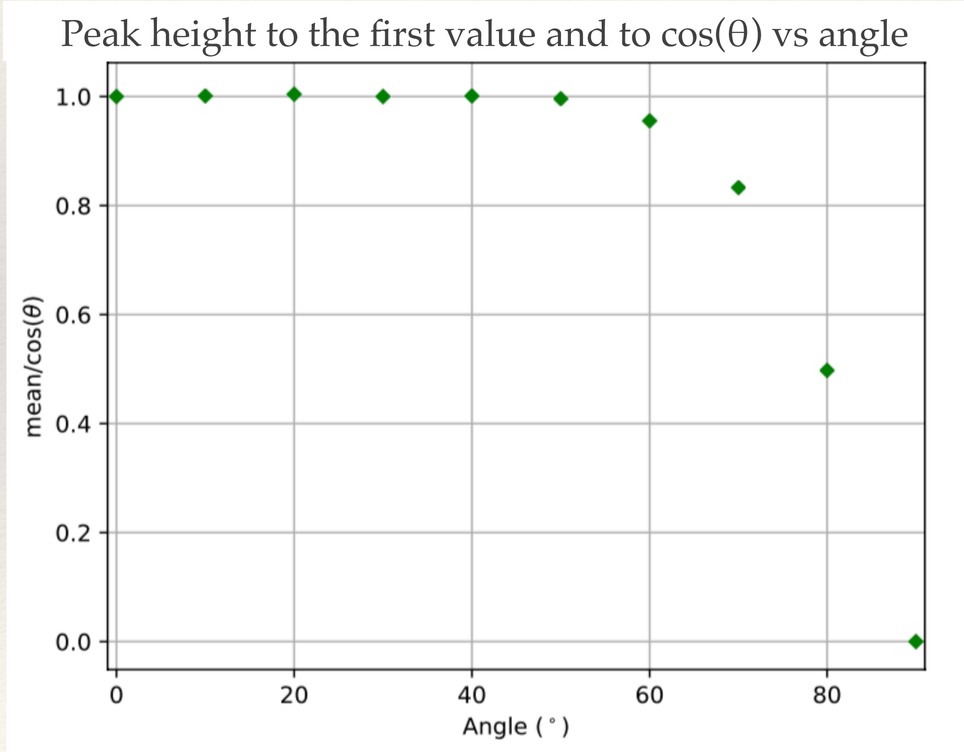

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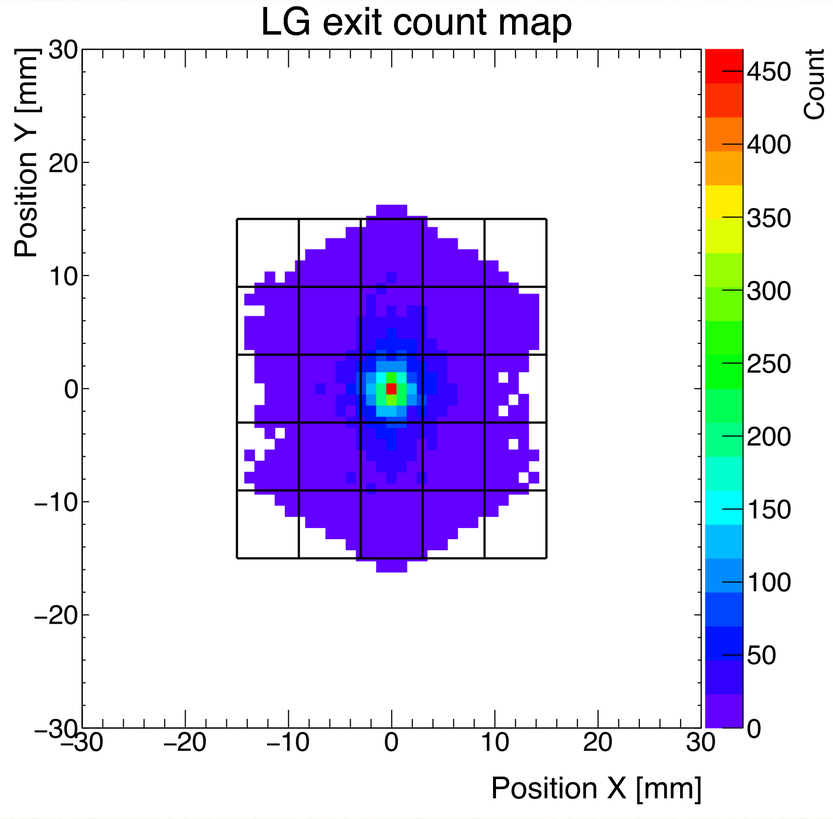
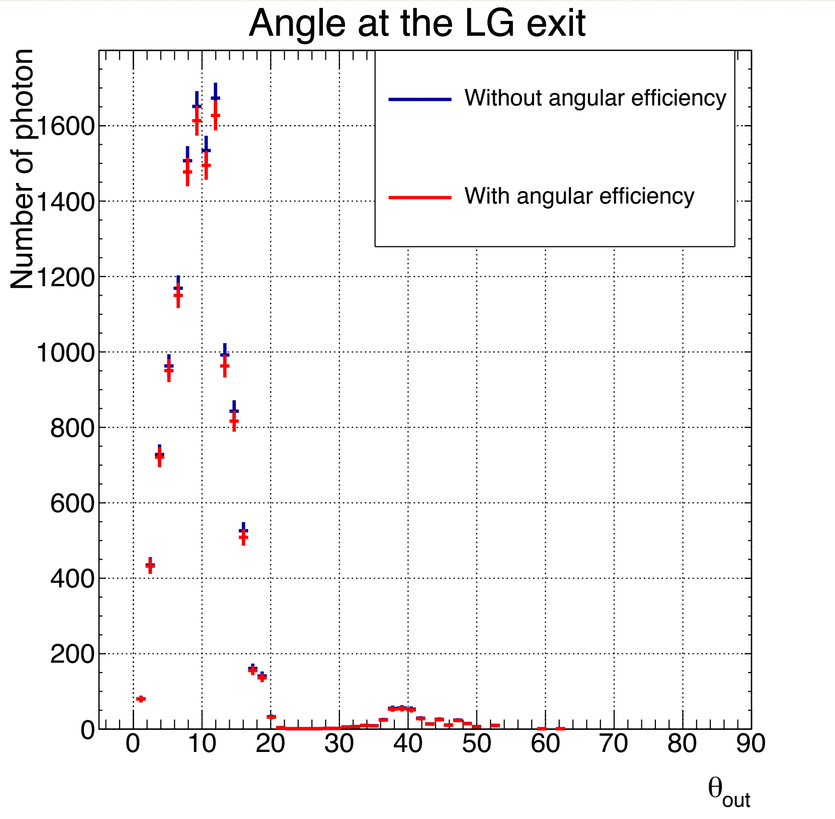
LST ray-tracing simulations

Using ROBAST we test one SiPM **equipped with an LST light guide** under light reflected by LST mirror





Incidence angle θ = 0°

The angular response of SiPM does not affect significantly the number of photons detected

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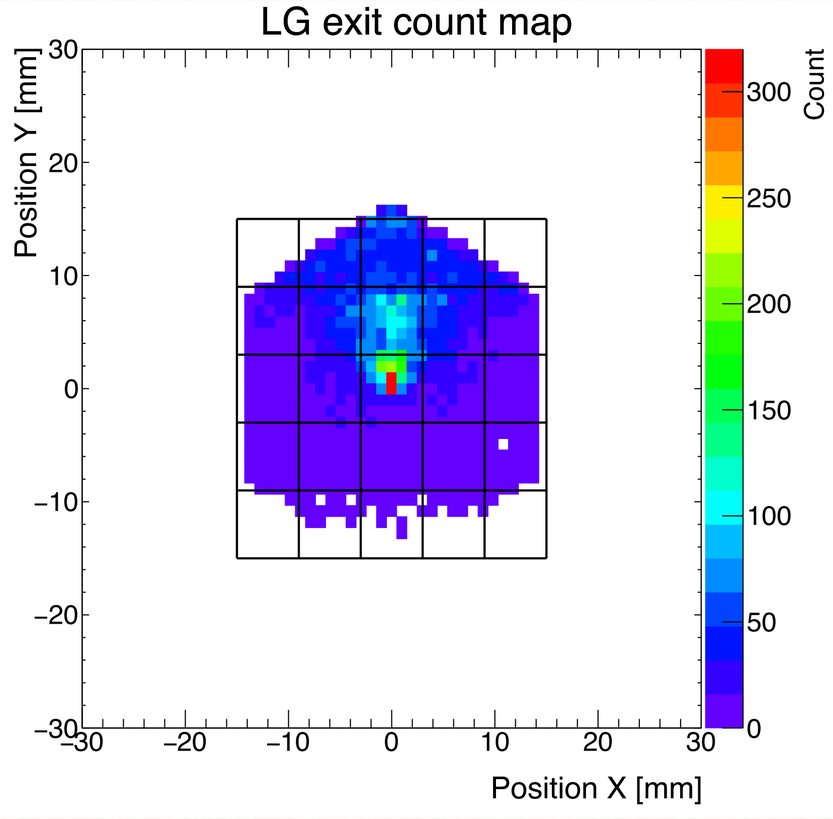

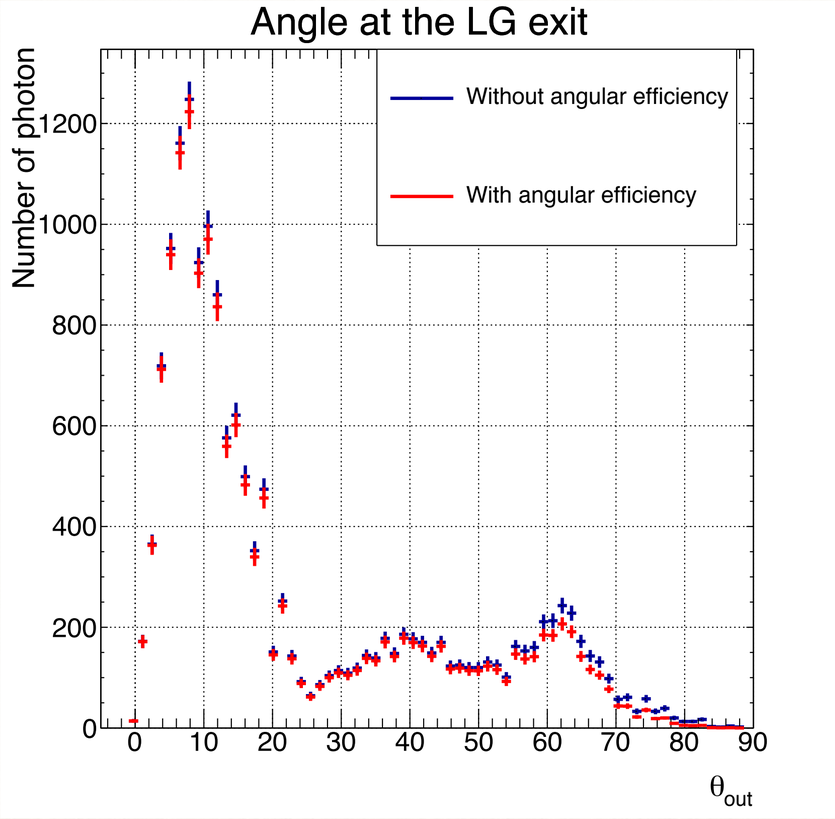

Incidence angle θ = 1.5°

LST ray-tracing simulations

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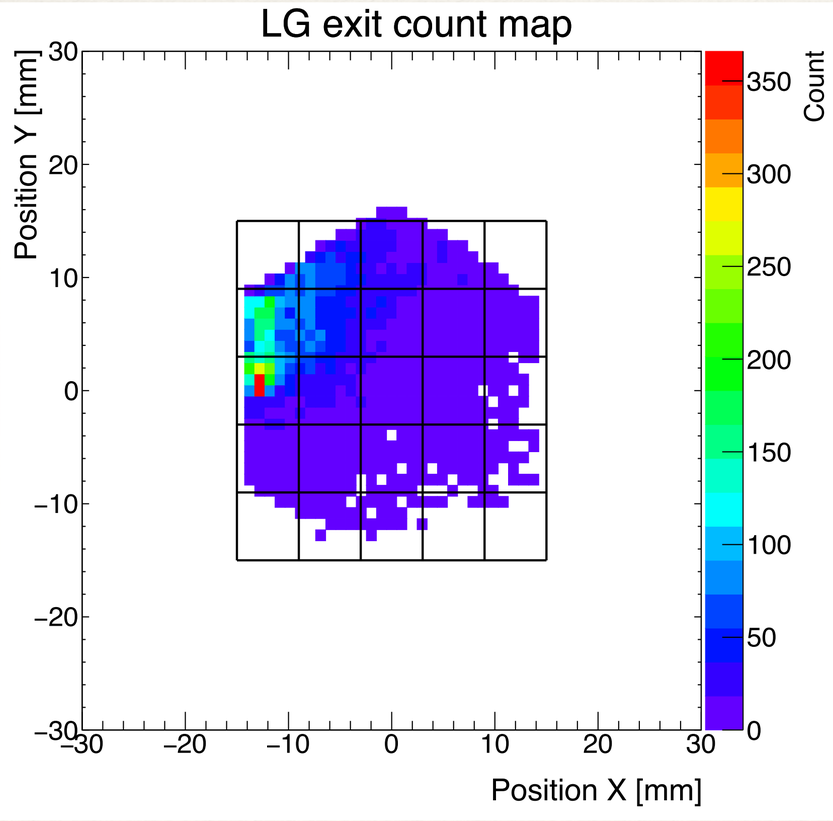
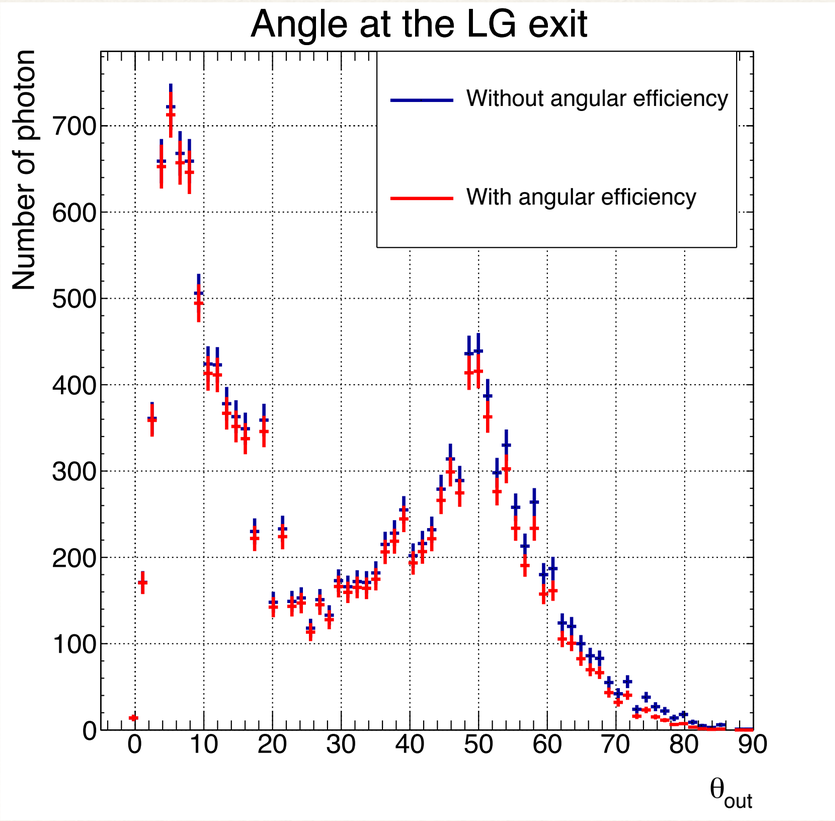




Incidence angle θ = 1.5°

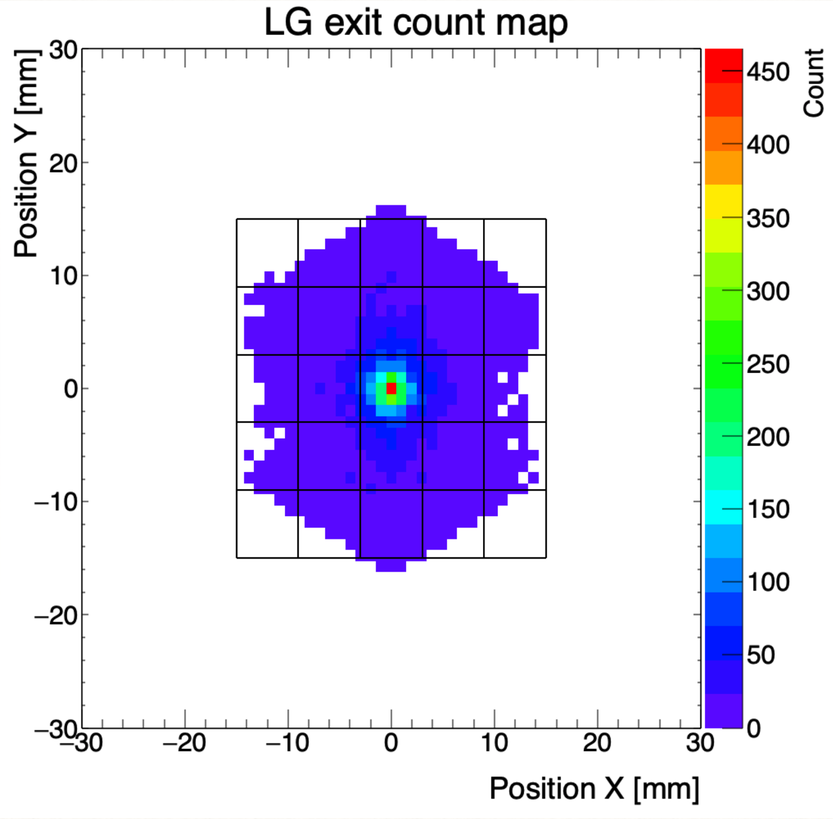
Rotation along the z axis

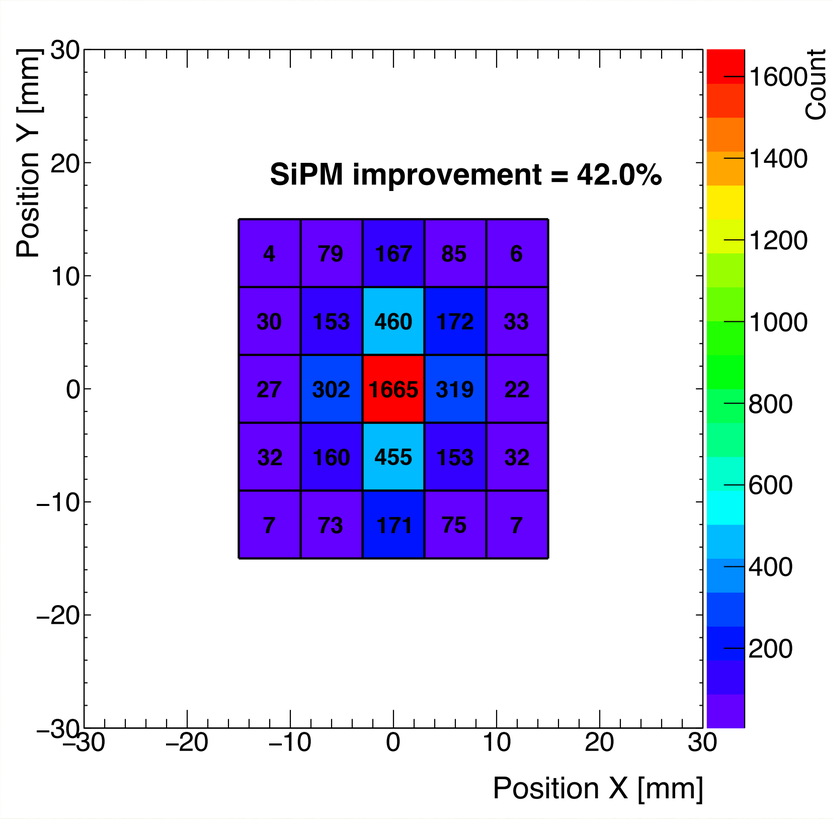
Φ = 1°

SiPM vs PMT ray-tracing simulations

Including **efficiency of SiPM and PMT** for detecting Cherenkov light

$\varepsilon_{SiPM} \sim 0.38 \times \varepsilon(\theta)$ $\varepsilon_{PMT} \sim 0.26$





Incidence angle $\theta = 0°$

SiPM vs PMT ray-tracing simulations

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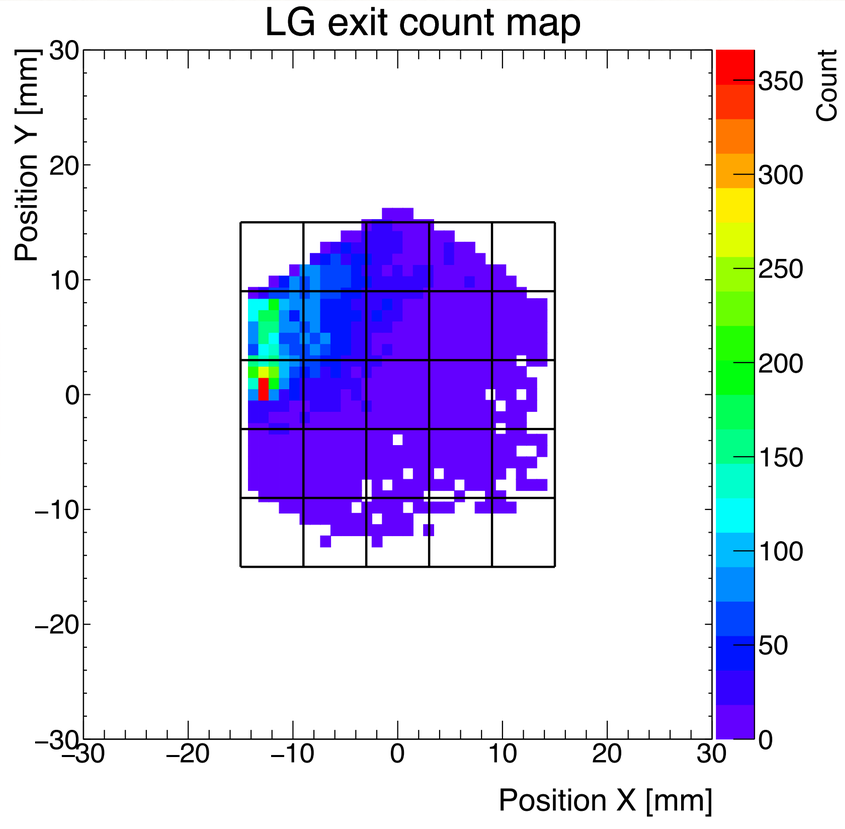
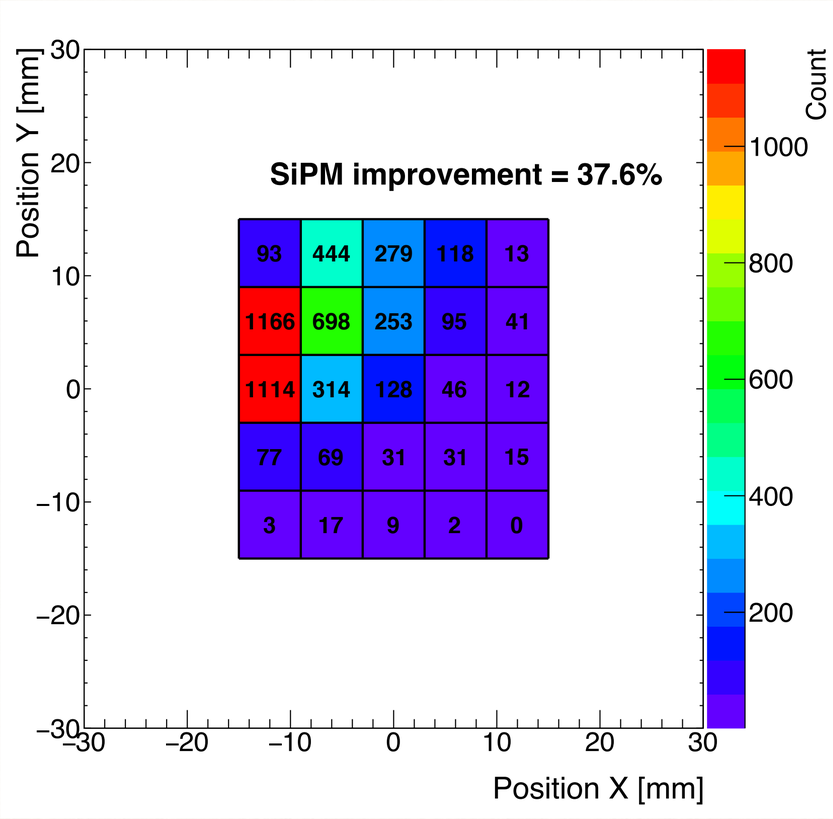




Incidence angle $\theta = 1.5°$

Rotation along the z axis

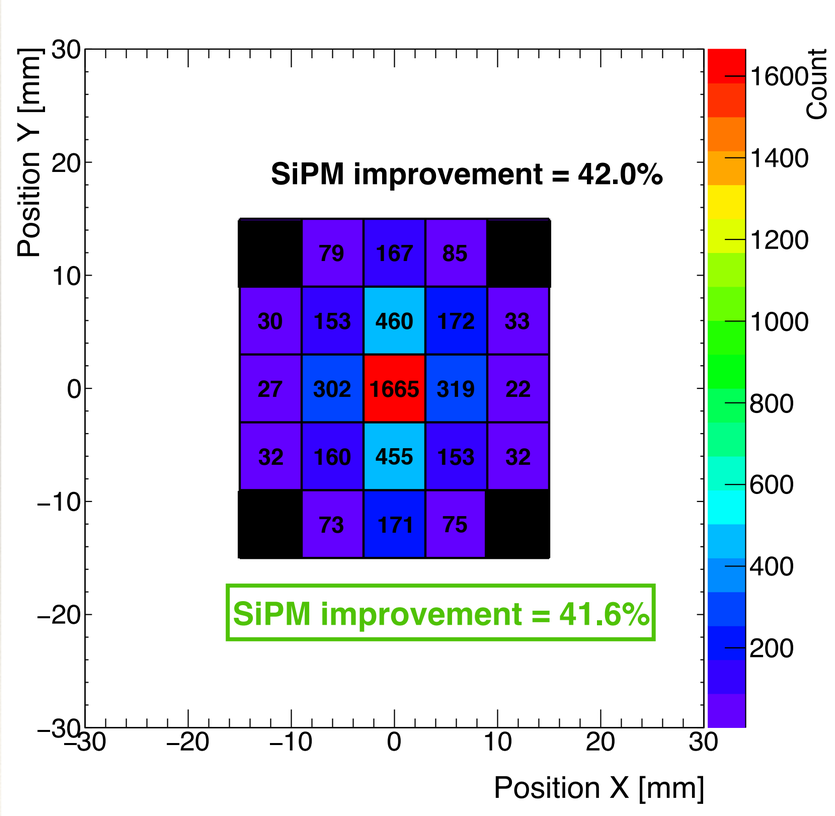
$\Phi = 1°$

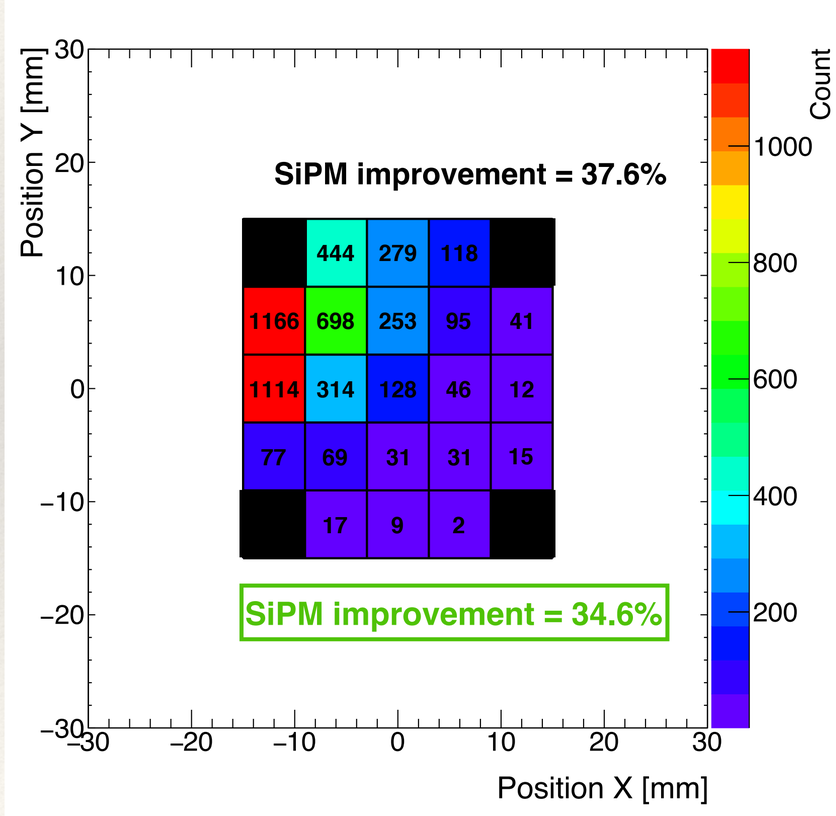
SiPM vs PMT ray-tracing simulations

The number of SiPM can also be adjusted according to the efficiency or cost desired

Incidence

θ = 0°





Incidence

θ = 1.5°

Φ = 1°

Conclusion

SiPM offers **better efficiency** and **easier operation** than PMT

We have shown that given the angular response of SiPM, they can **directly replace PMTs** in the LST camera **without changing the light guide**

The performance of high level analysis is ***to be evaluated***

We demonstrate the feasibility of **a minimal upgrade for LST camera**, replacing PMT **by SiPM detectors**