

GEANT4-based simulation of light production/propagation/detection in bar shaped PSD with SiPM readout @ GSSI

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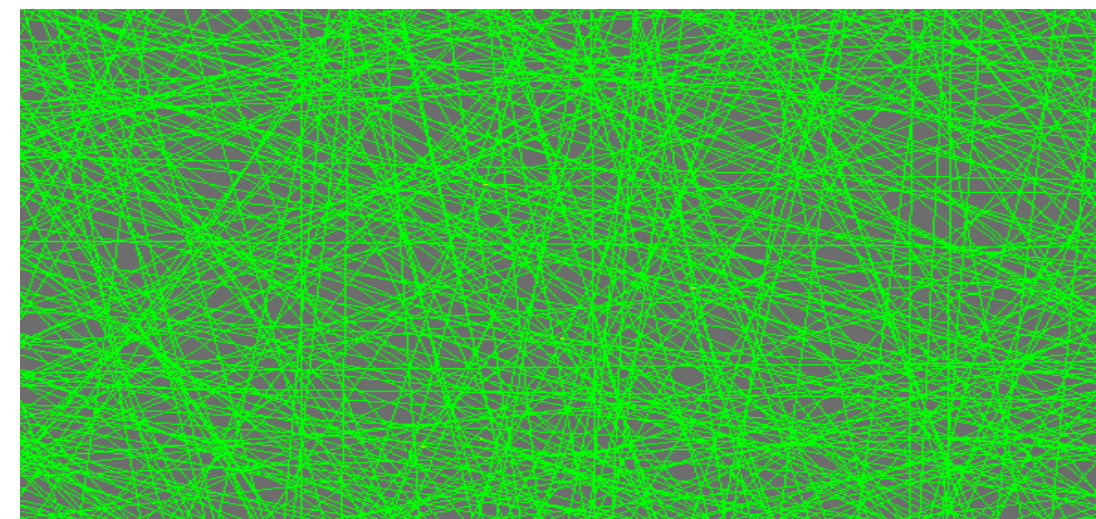
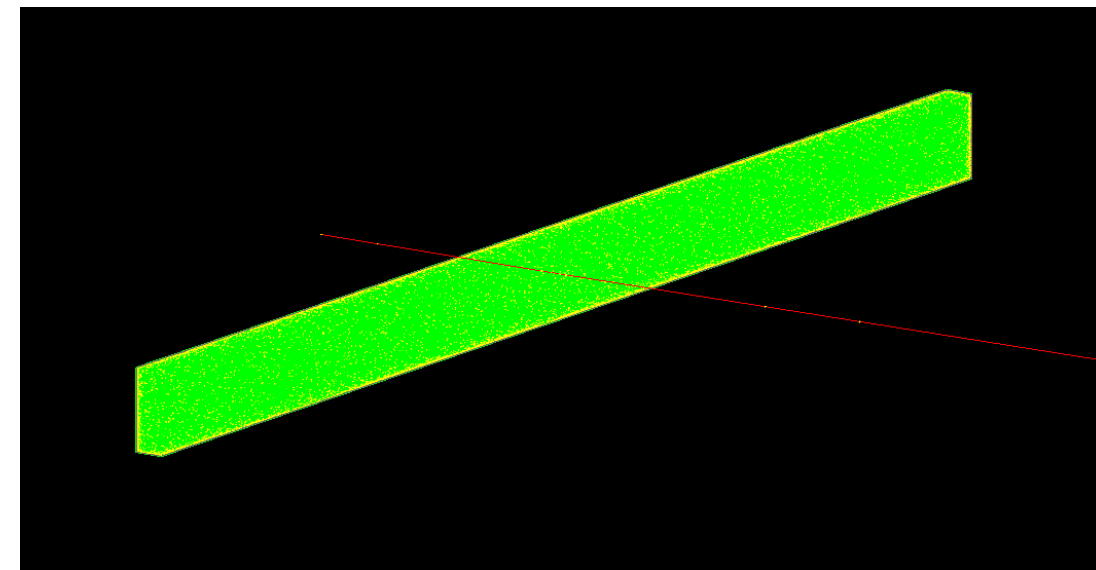
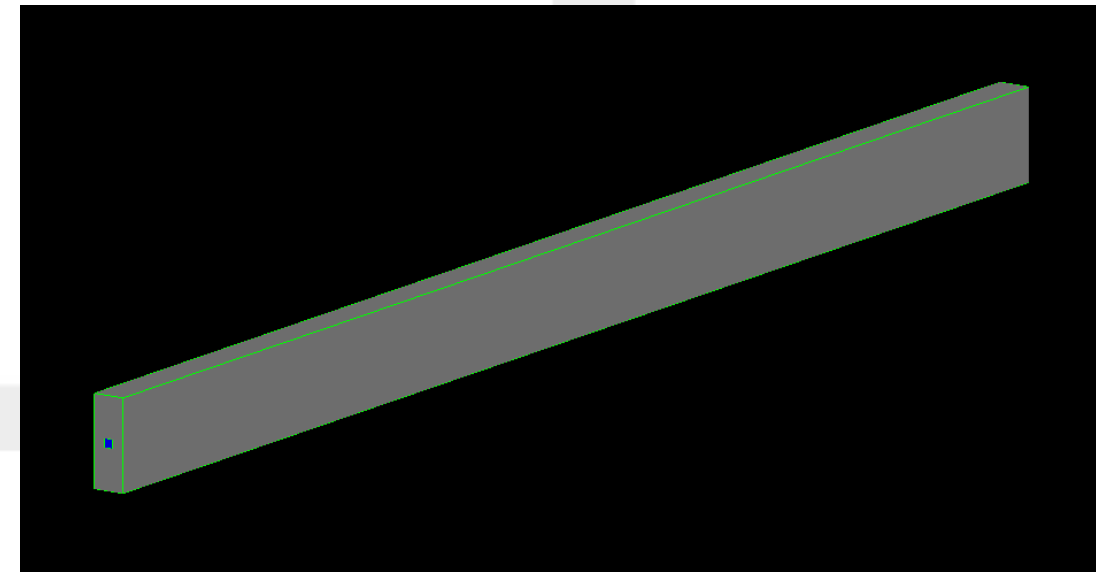


Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Gran Sasso



GEANT4-based simulation of the PSD

- GEANT4-based simulation of production, propagation and detection of photons in the bar
- Tool developed in Bari
- Adjusted in GSSI in order to simulate and optimize the bar shaped PSD geometry with SiPM readout



Outline

- 1 PSD Bar Geometry
- 2 Characteristics of the used particles
- 3 Number of photons reaching each SiPM
- 4 Comparison between different geometries
- 5 Propagation time of photons in the bar
- 6 Conclusions and future prospects

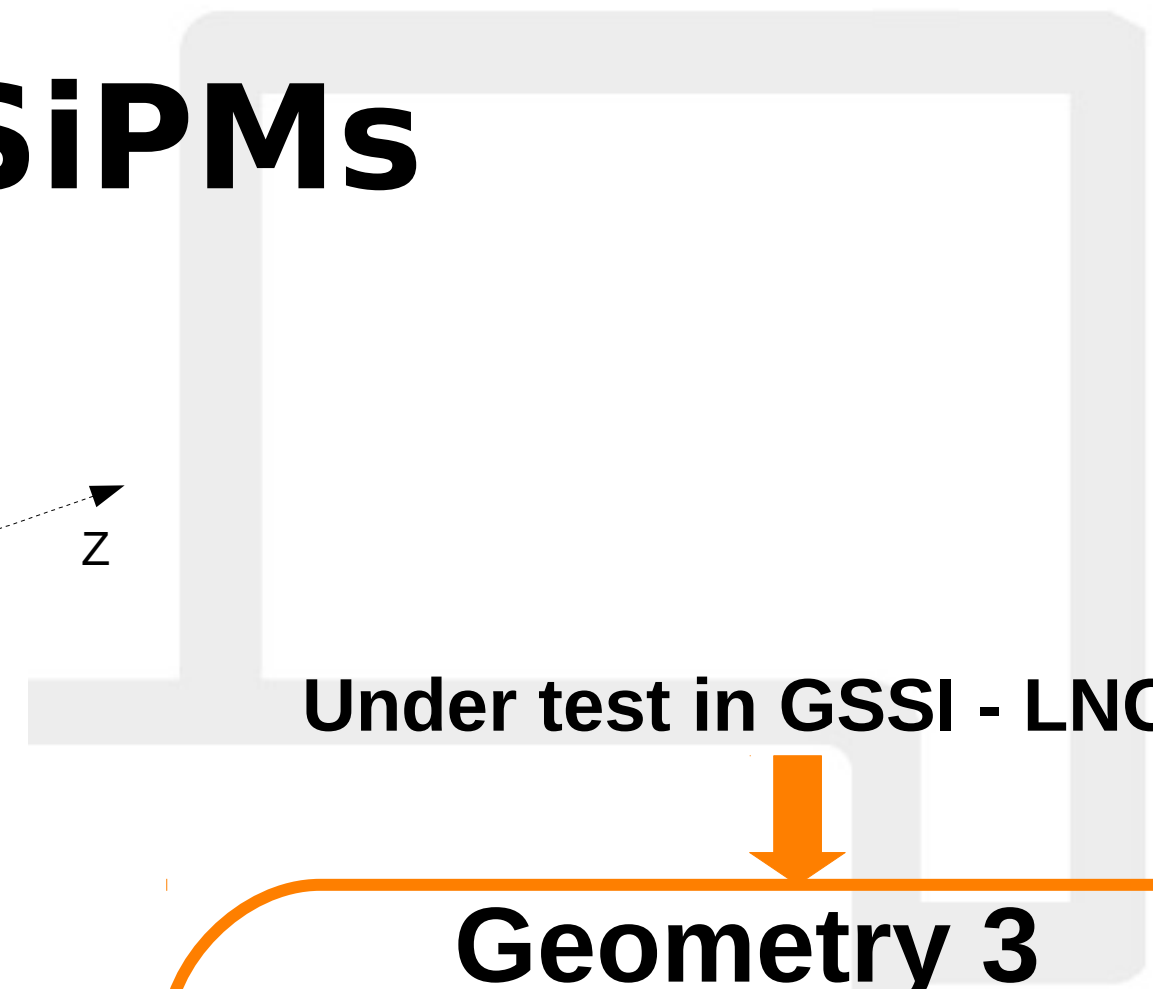
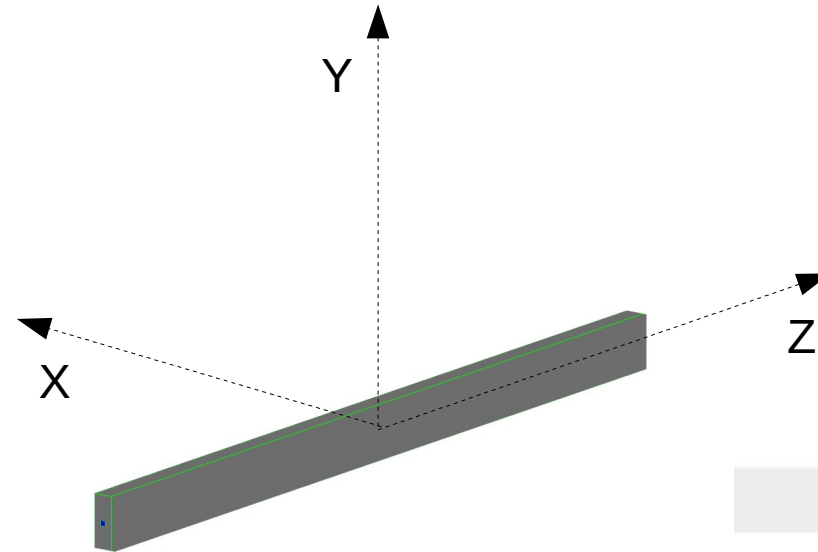
PSD Bar geometry with 2 SiPMs

Bar: $(x, y, z) = (1, *, 50)$ cm

Wrapping thickness = 500 μm

SiPMs: $(x, y, z) = (3, 3, 0.5)$ mm

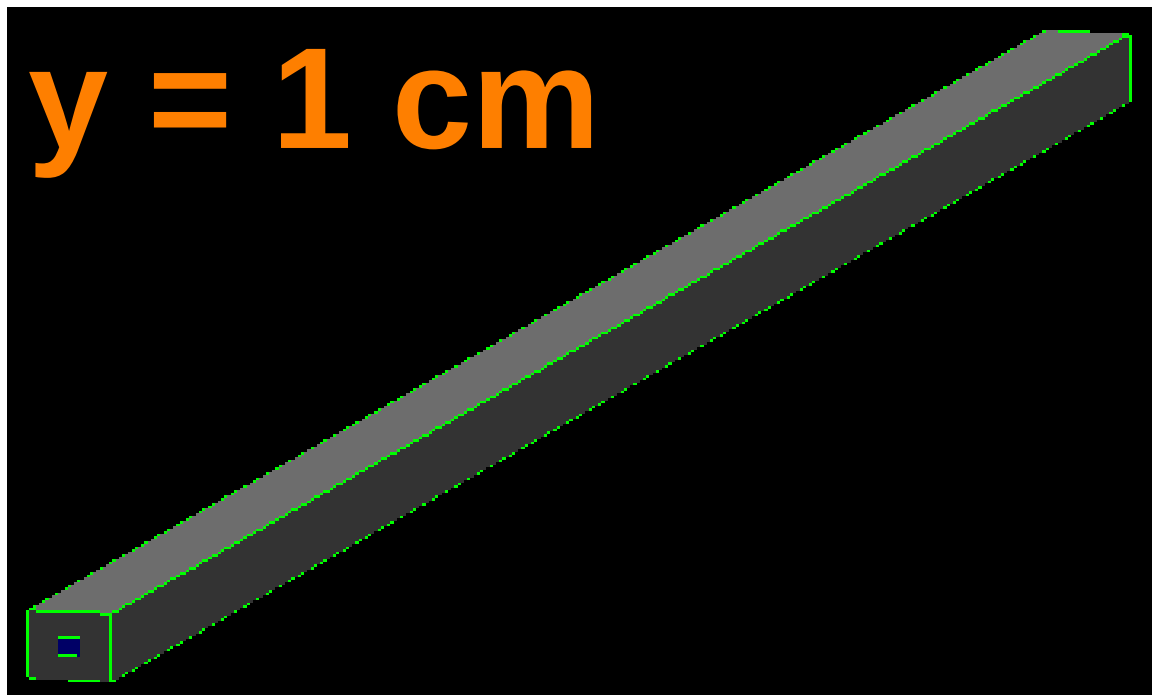
Scintillator: EJ200



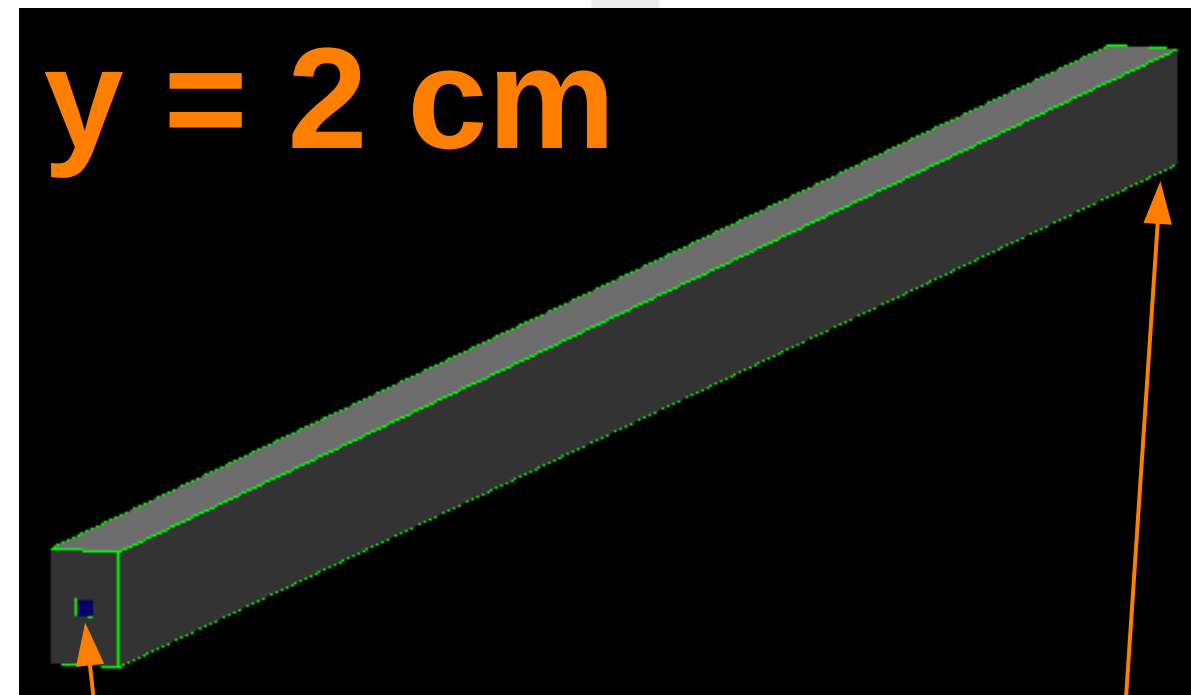
Under test in GSSI - LNGS



Geometry 1

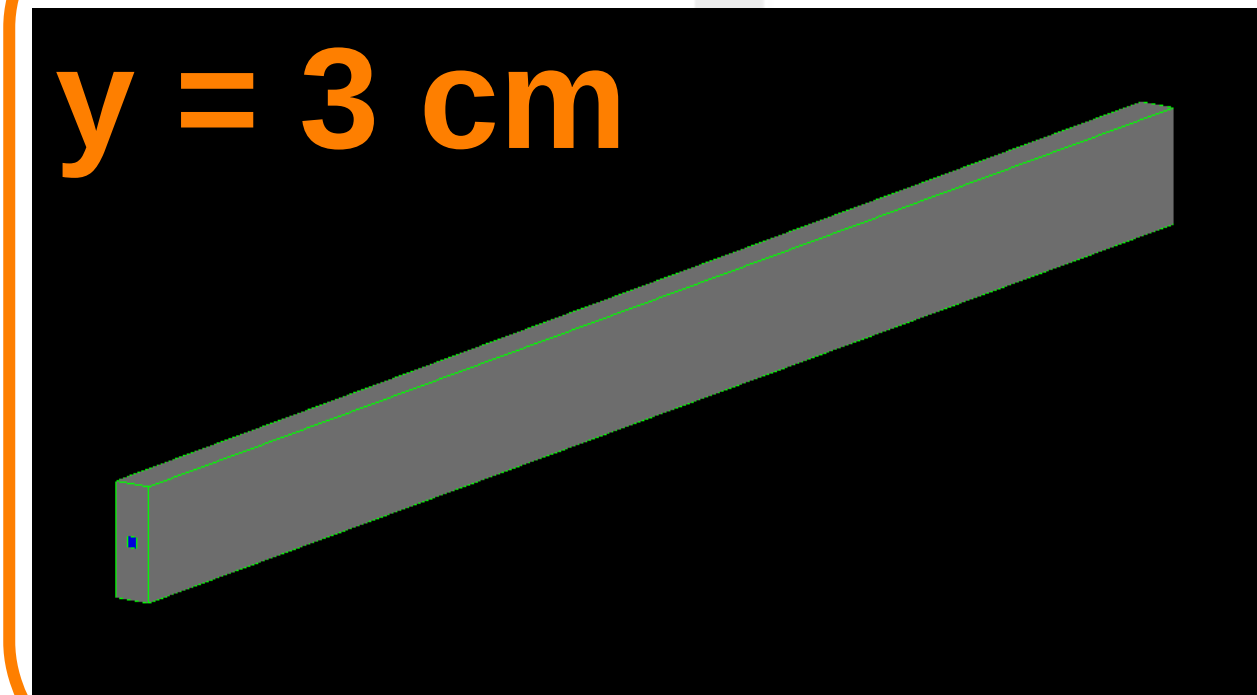


Geometry 2



SiPM0 - Left

Geometry 3



SiPM3 - Right

Particles

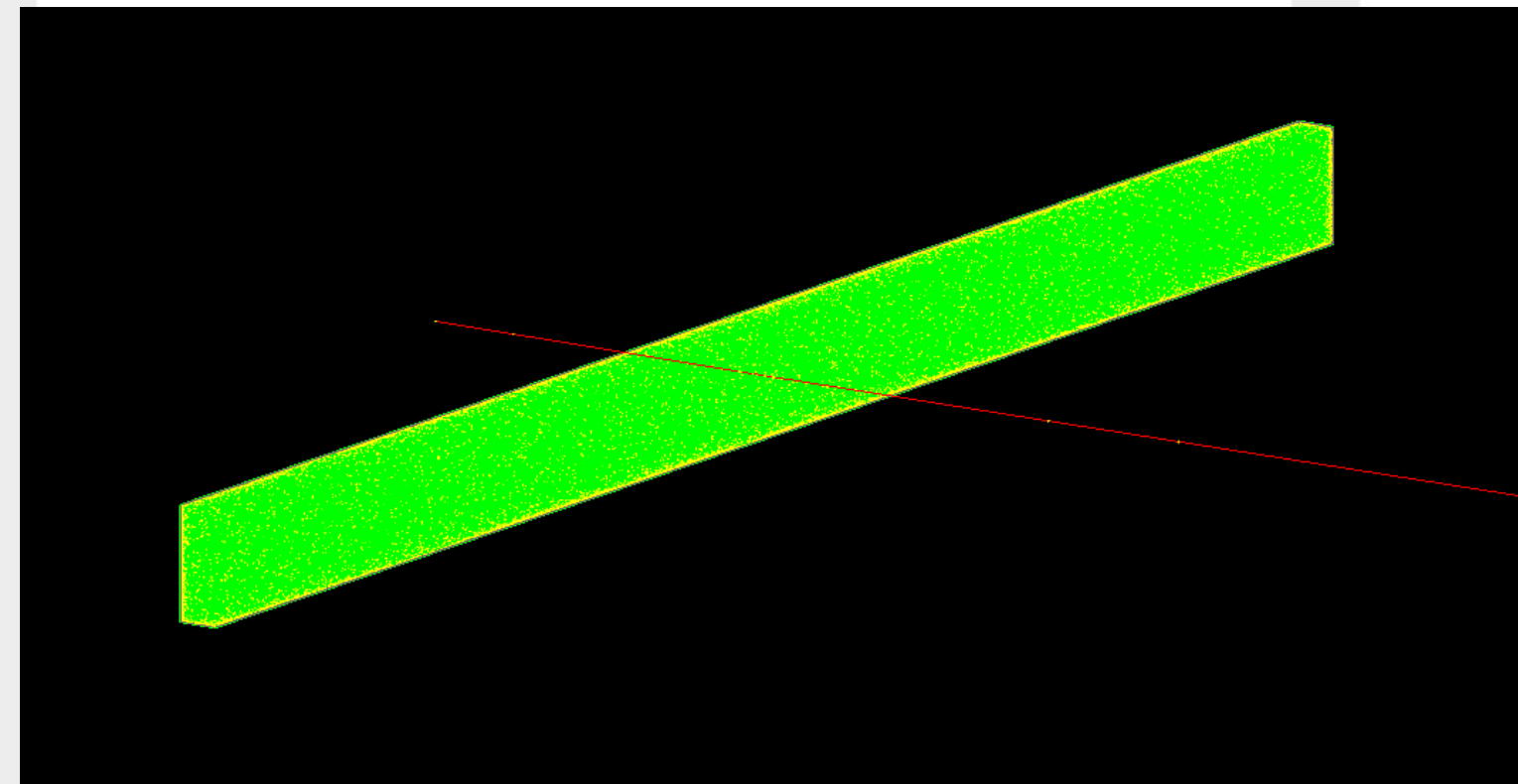
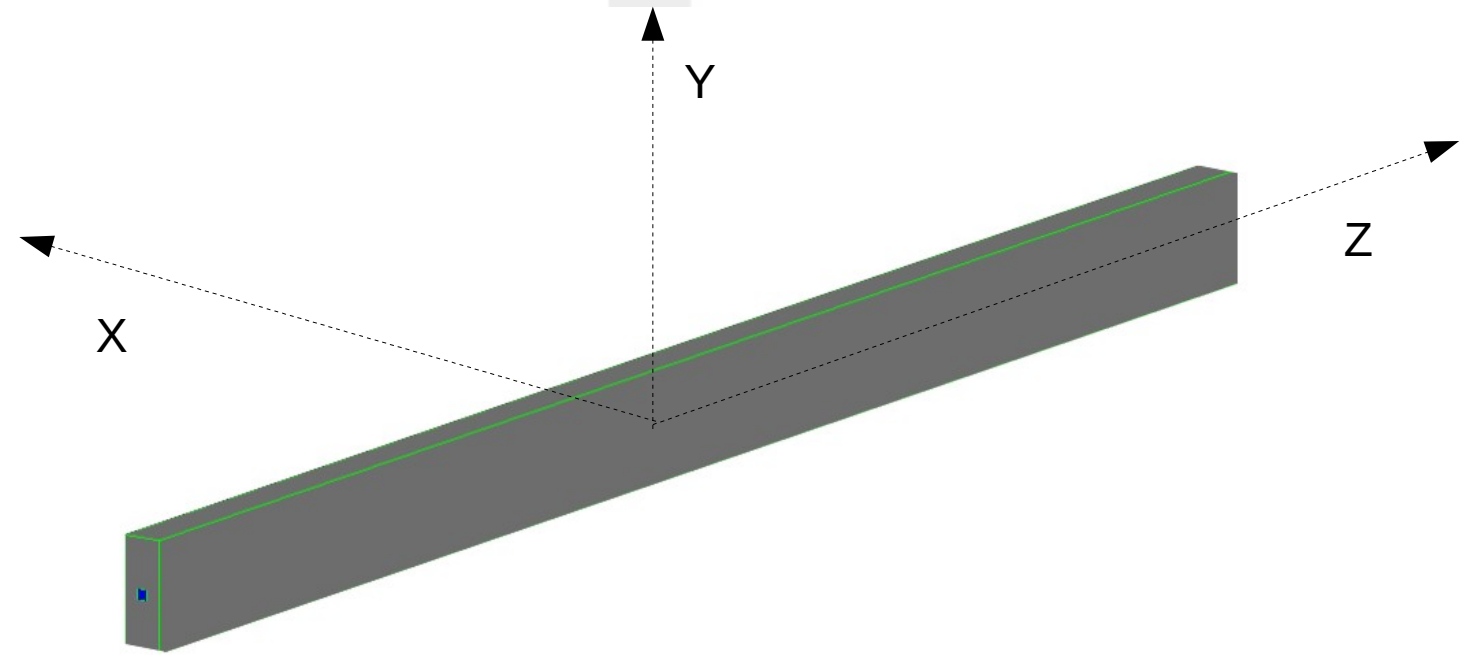
Particle: μ^-

Energy: 1 GeV

Position of the beam: (-10, 0, 0) cm

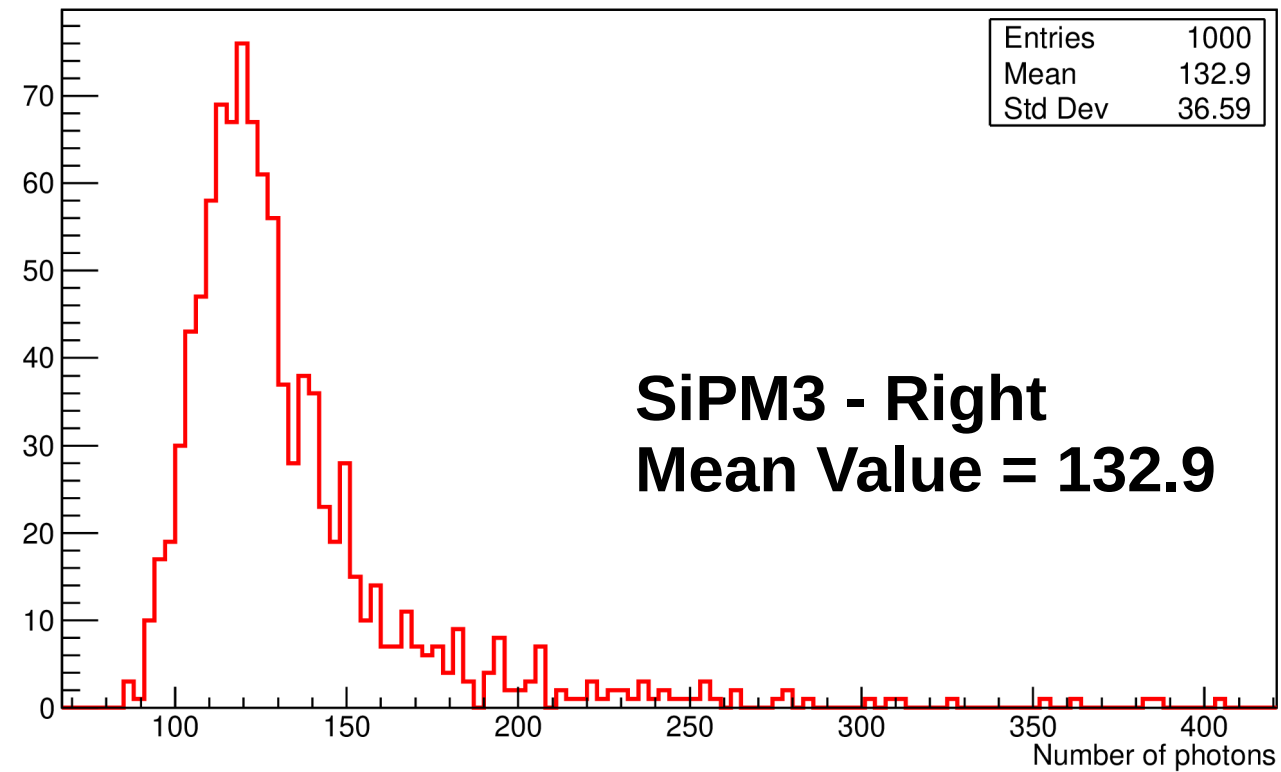
Number of particles: 1000

Scintillation + Cherenkov

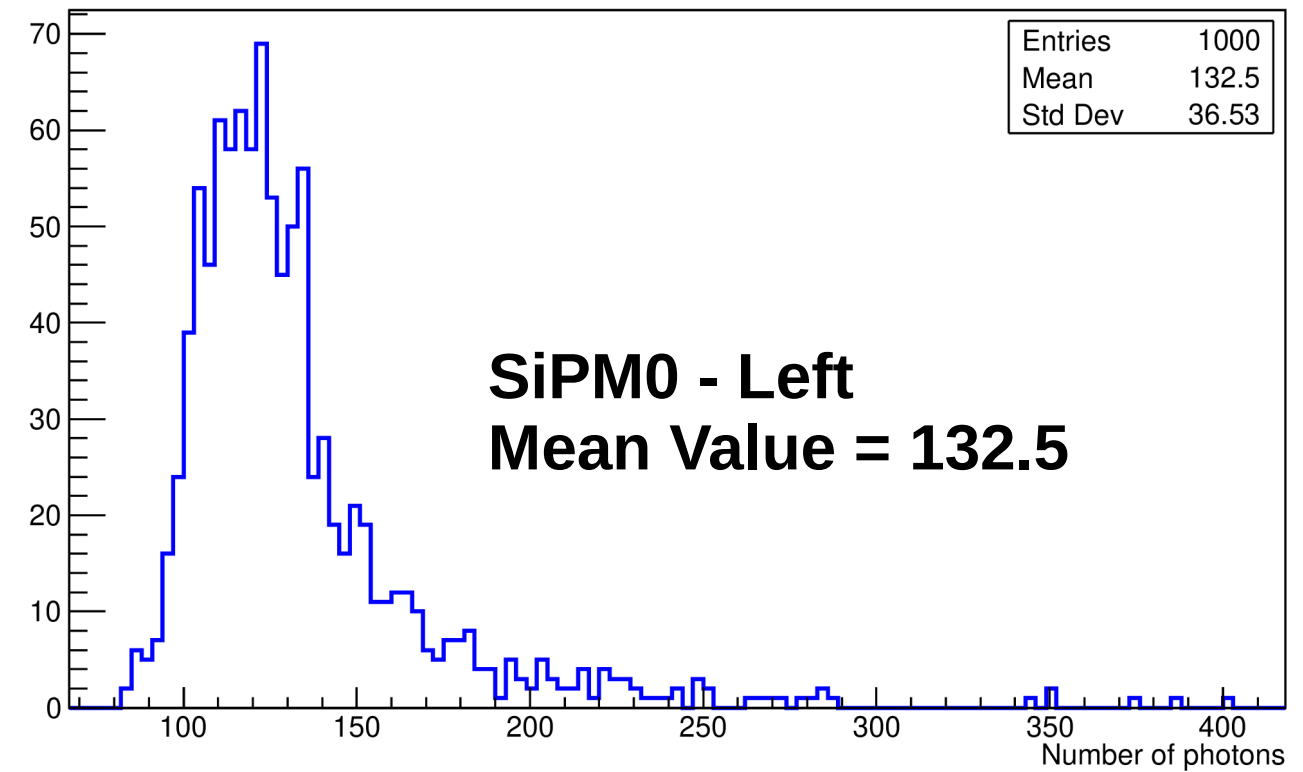


NUMBER OF PHOTONS - Geometry 1

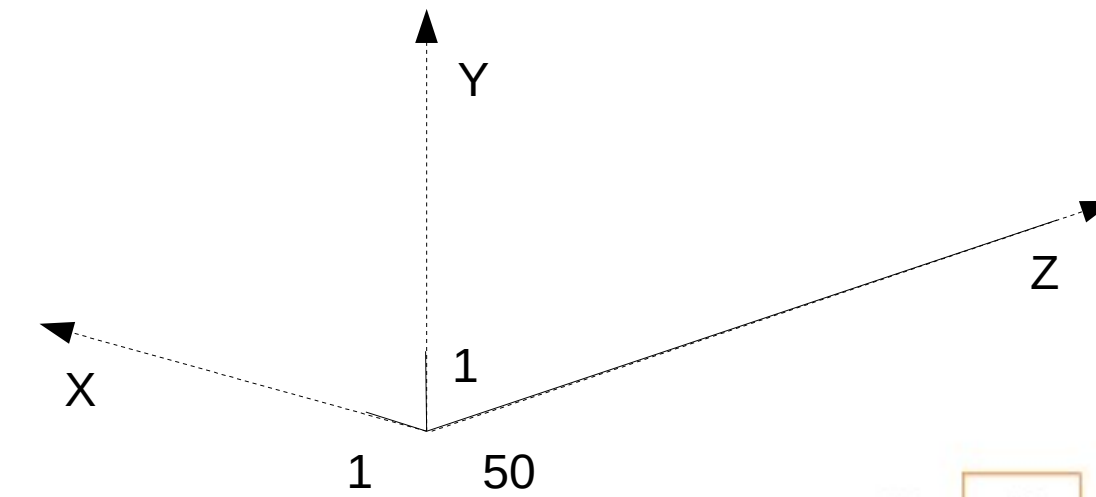
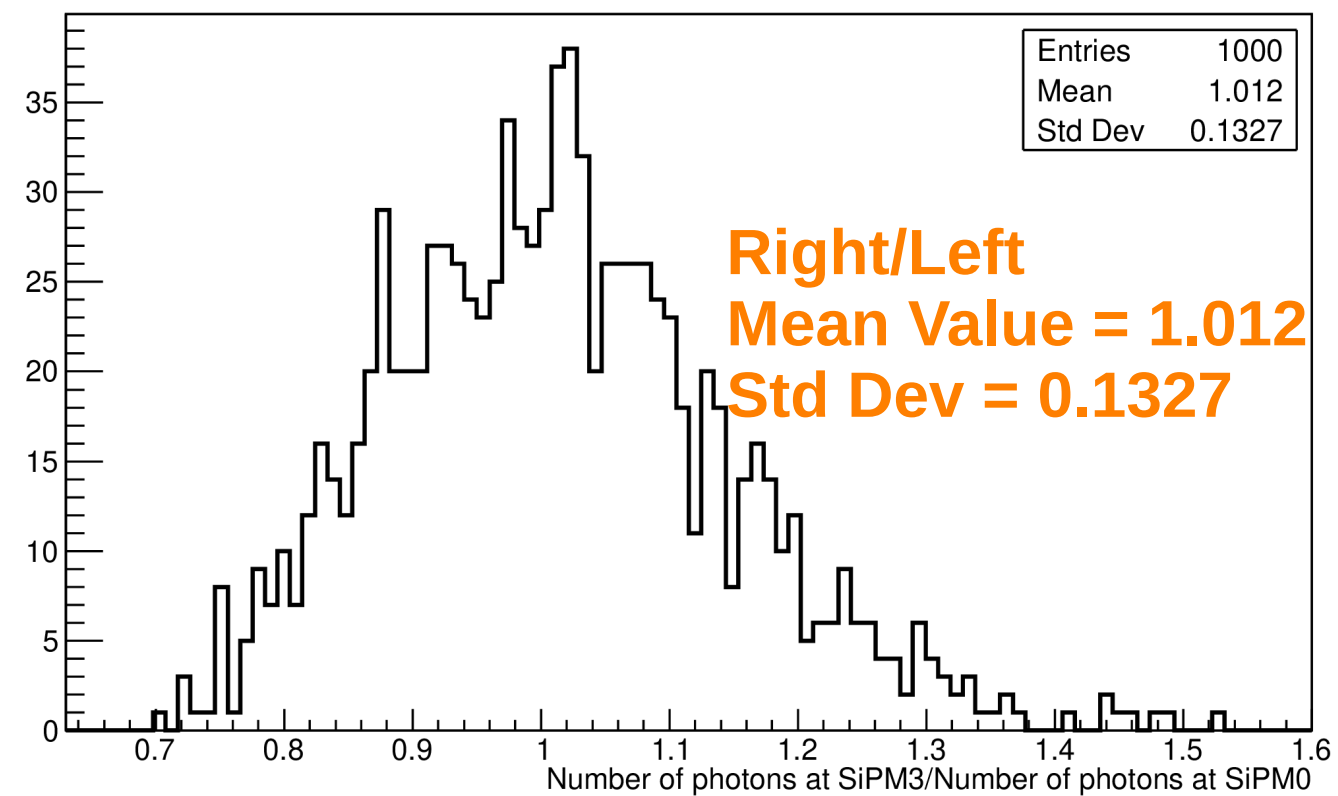
Photons at SiPM3 - Right



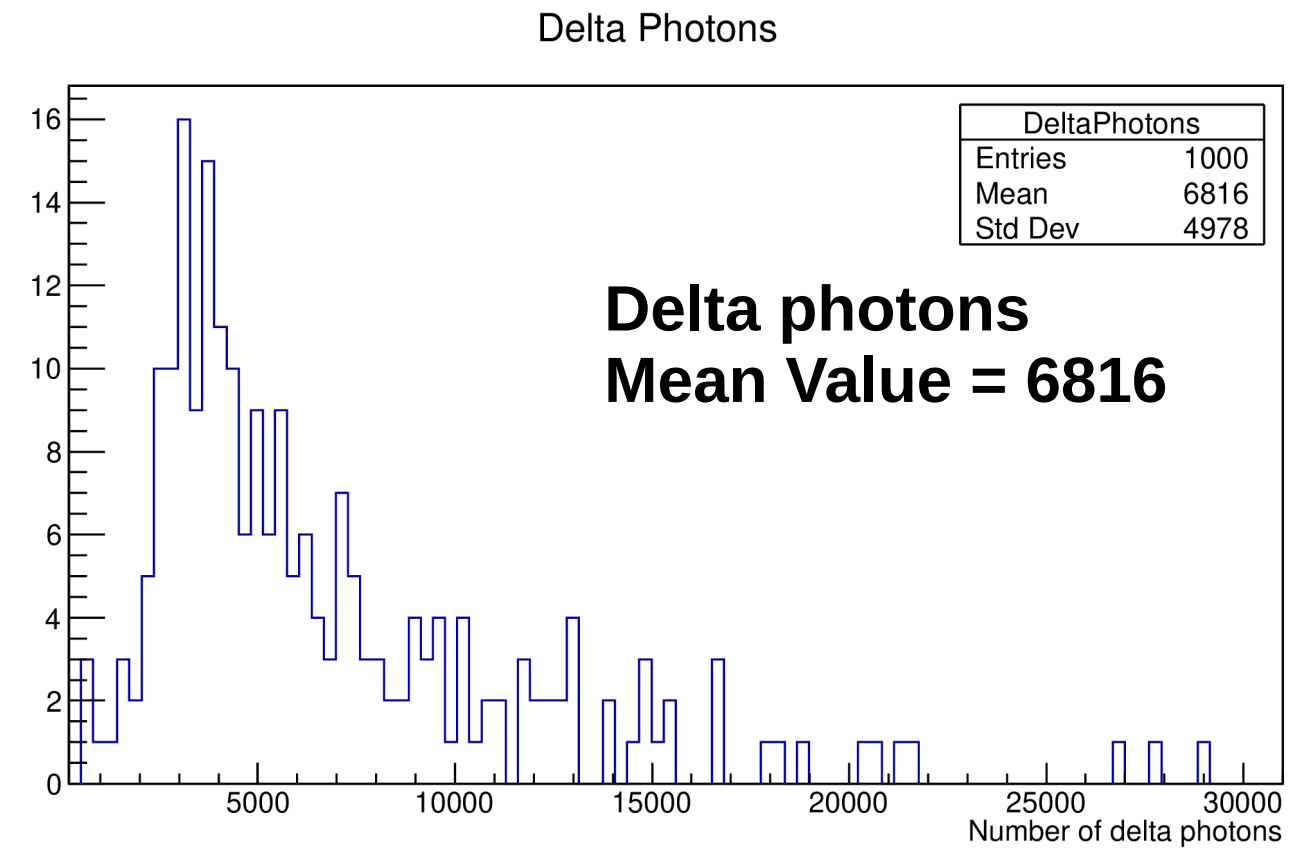
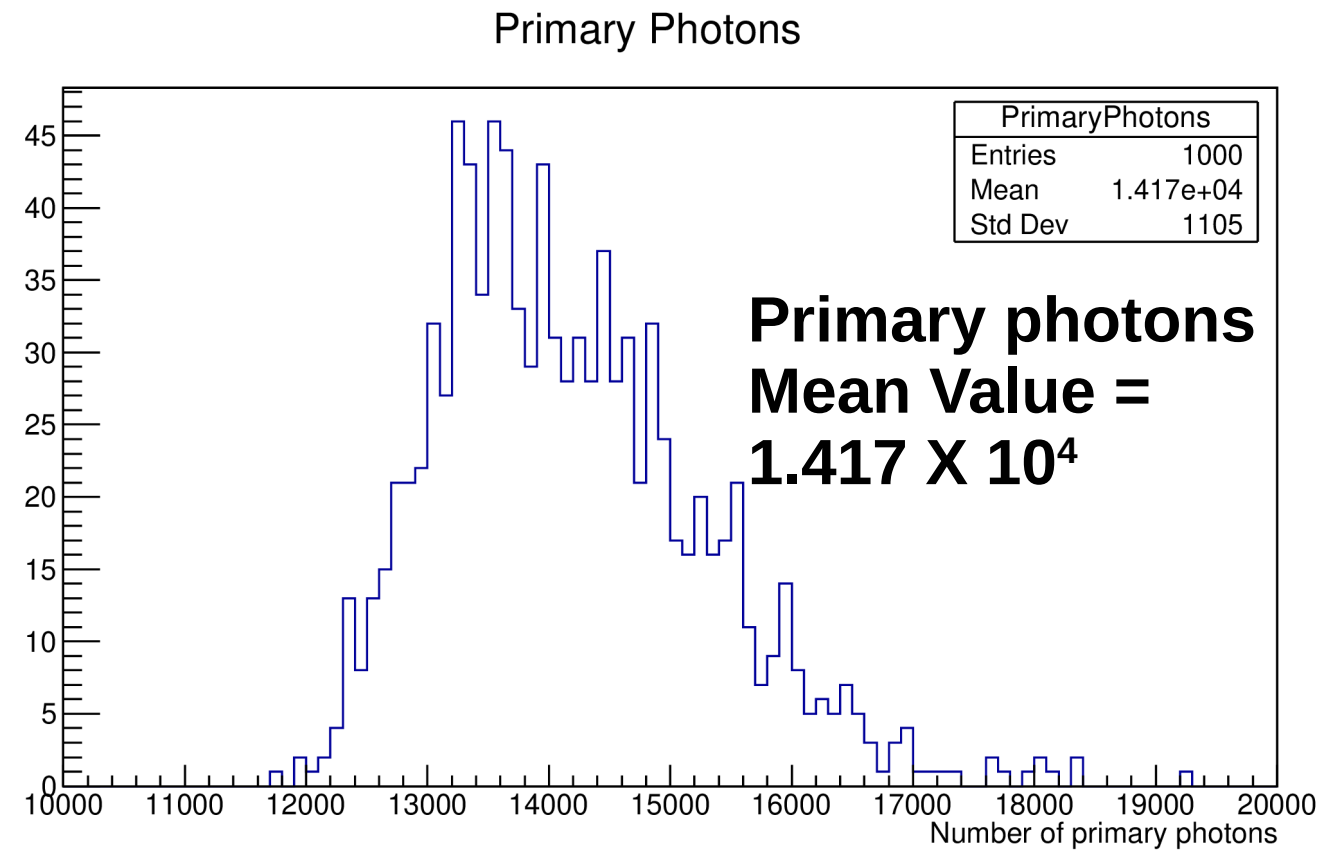
Photons at SiPM0 - Left



Ratio between photons at the SiPM right and left



NUMBER OF PHOTONS - Geometry 1

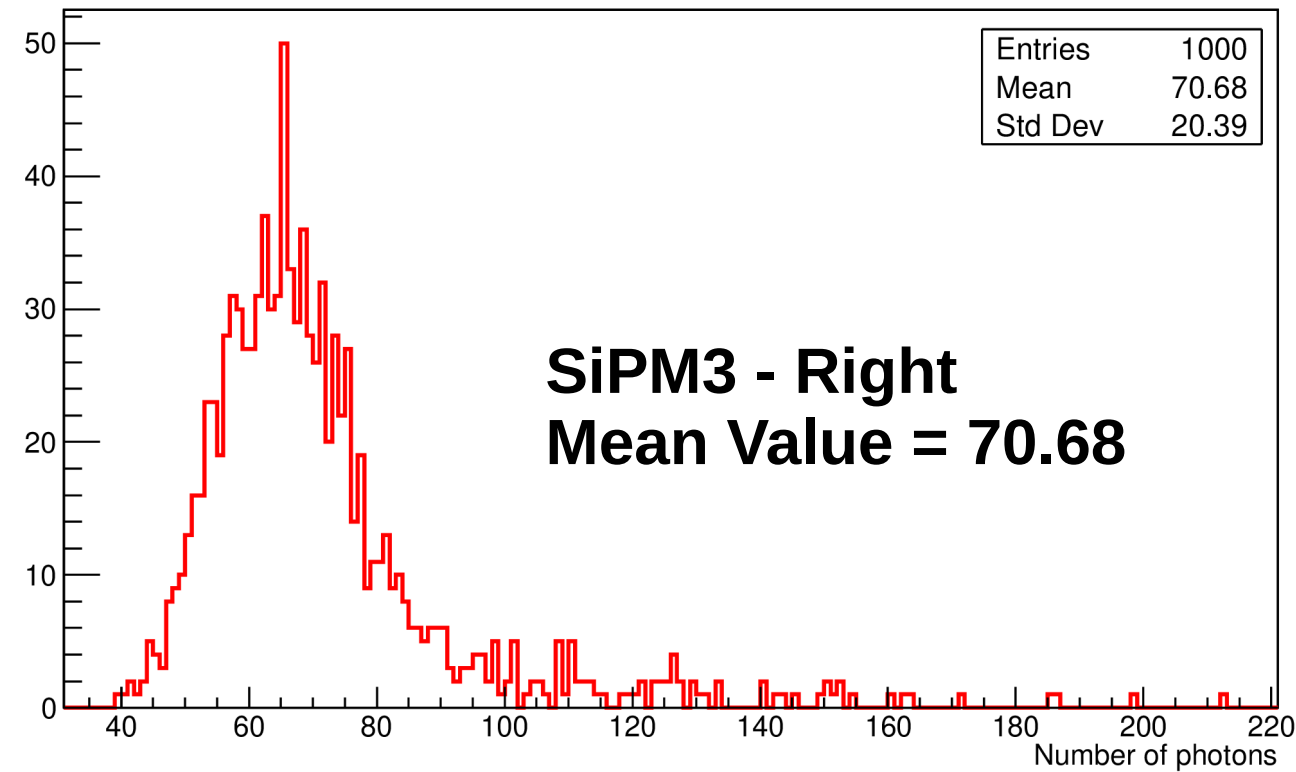


Total number of photons (Primary + Delta) = 20986

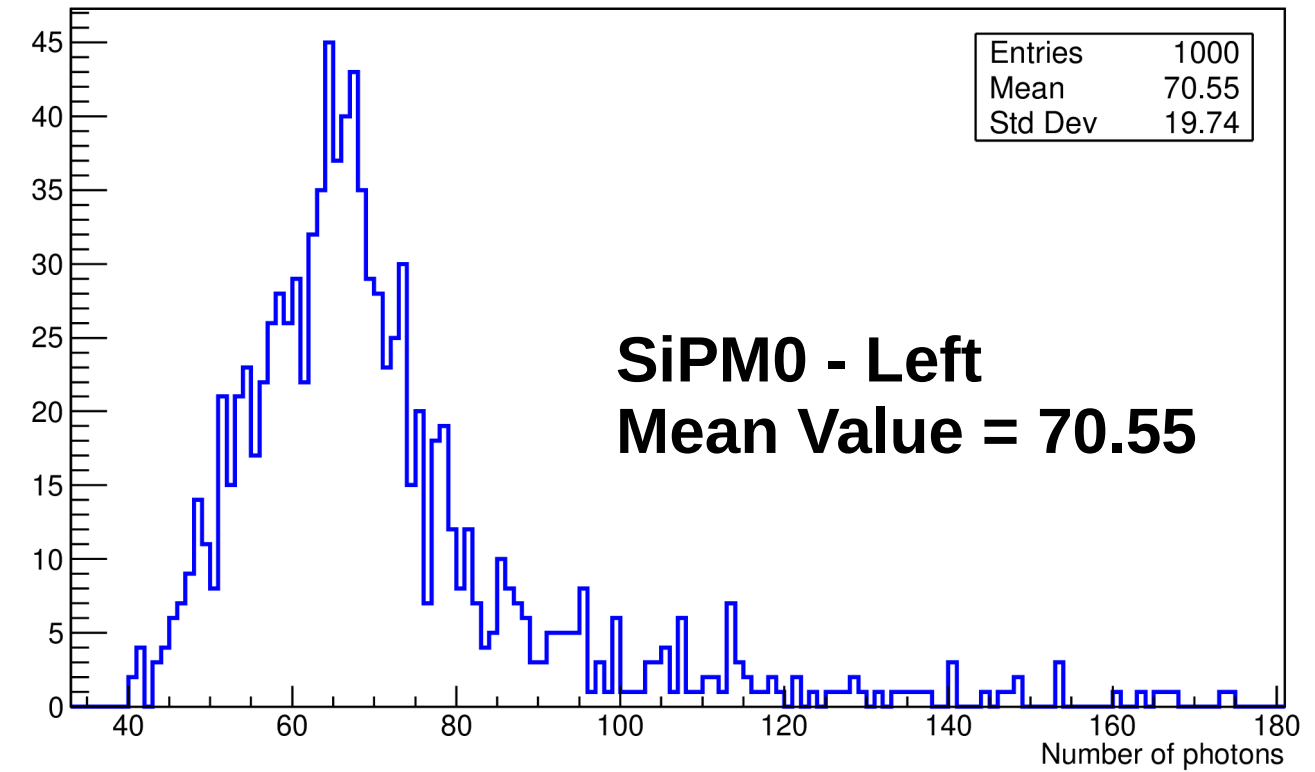
$$\frac{\text{Photons at the SiPMs}}{\text{Total number of photons}} = 1.2\% \pm 0.1\%$$

NUMBER OF PHOTONS - Geometry 2

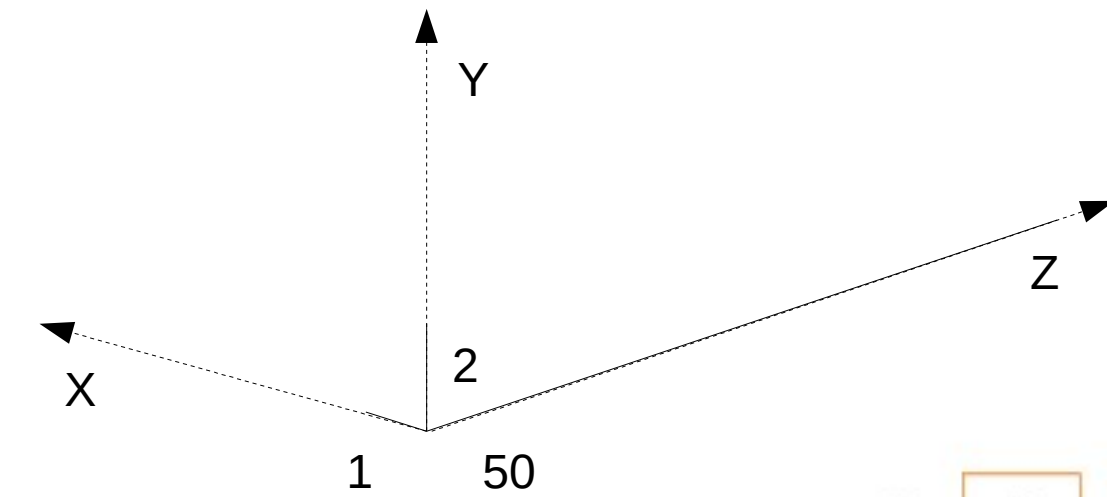
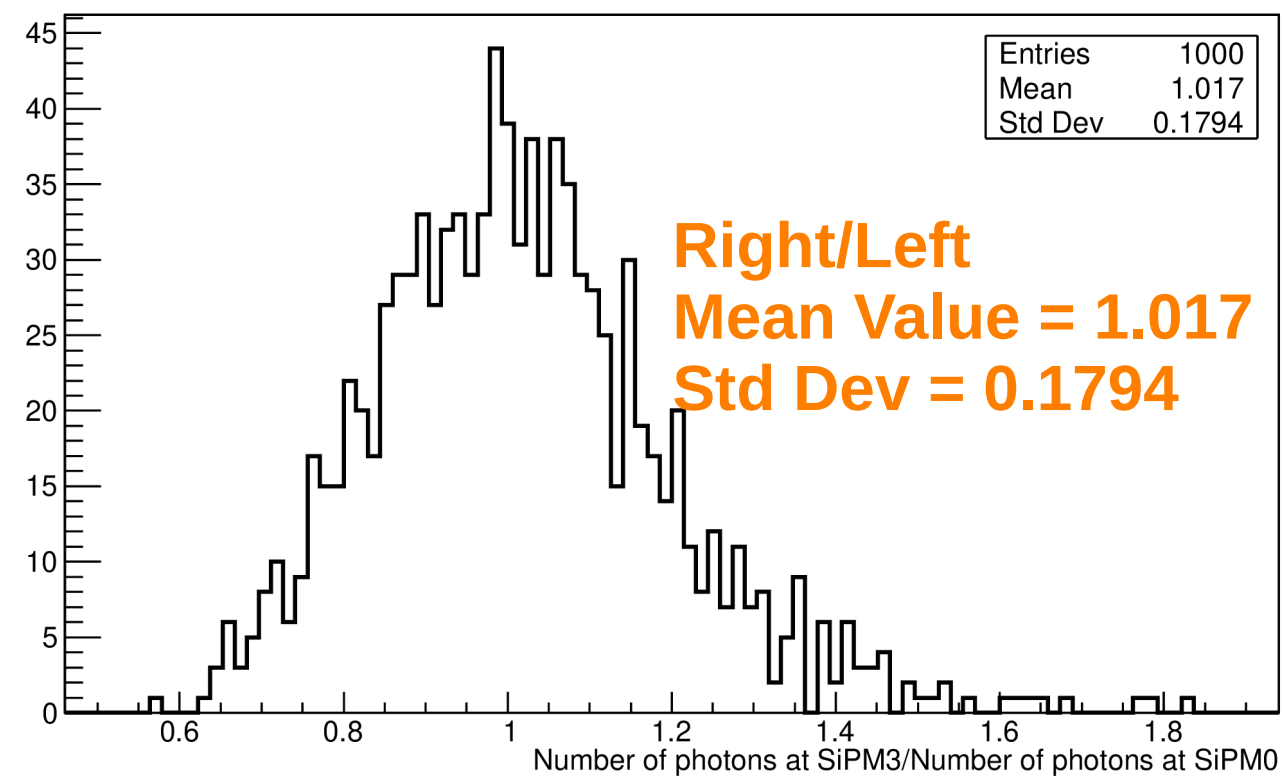
Photons at the SiPM3 - Right



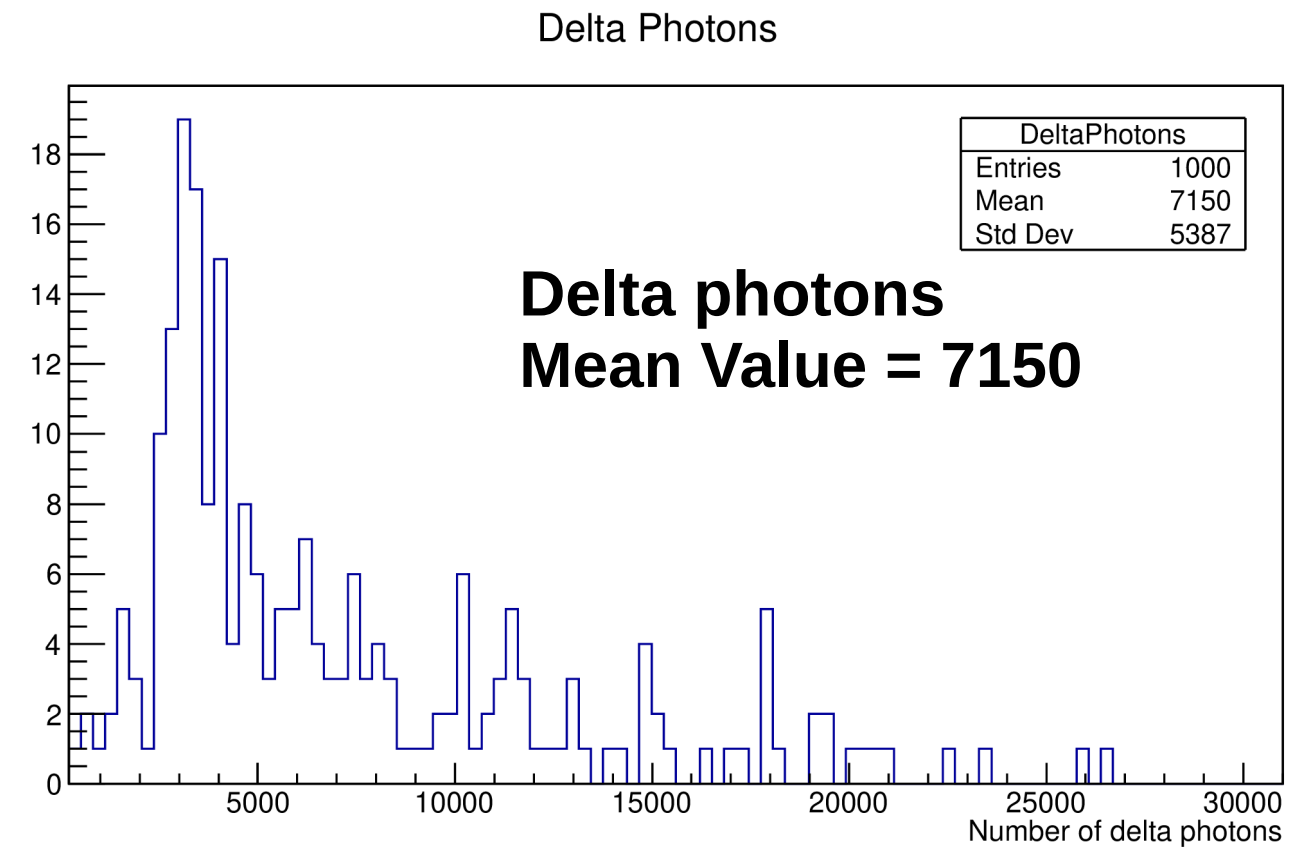
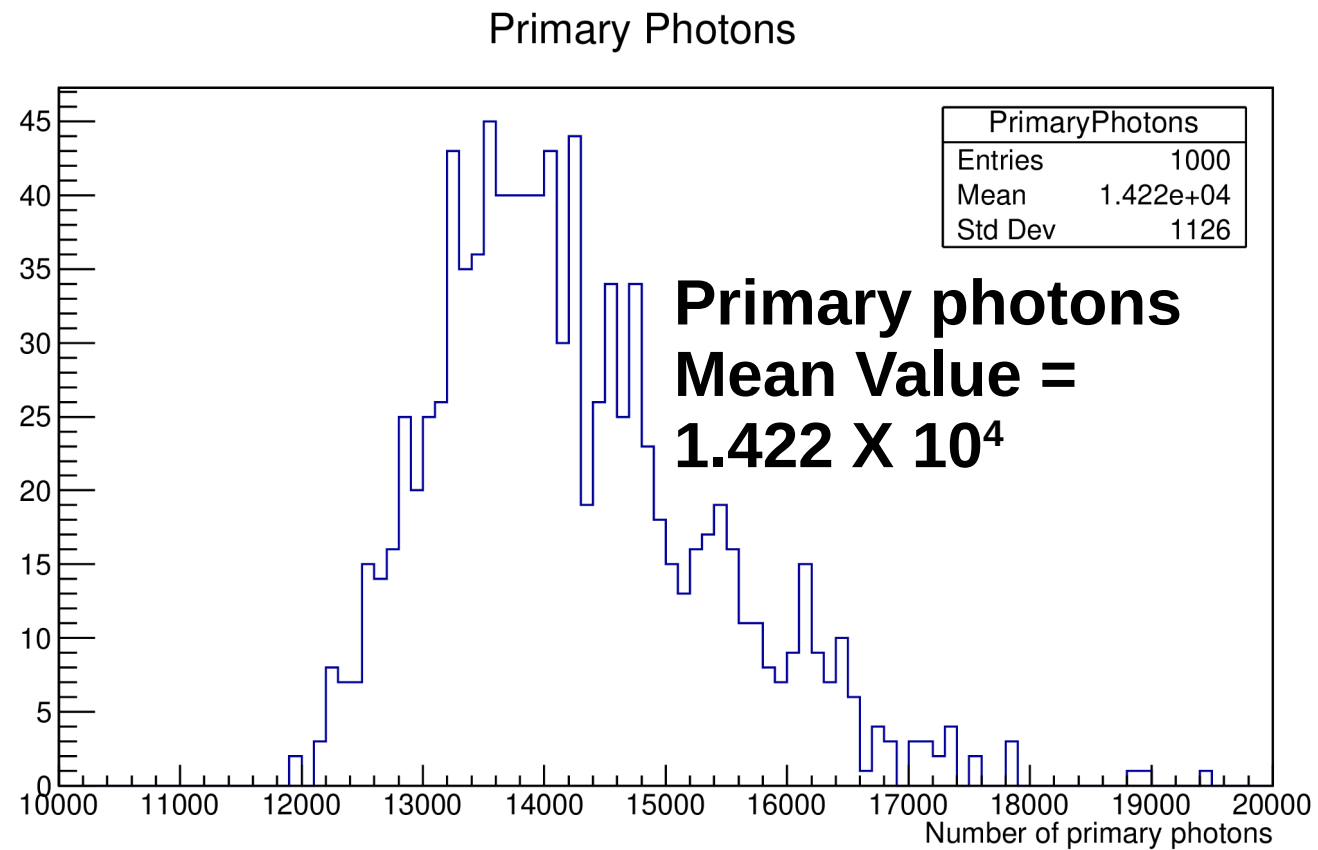
Photons at SiPM0 - Left



Ratio between photons at the SiPMs right and left



NUMBER OF PHOTONS - Geometry 2

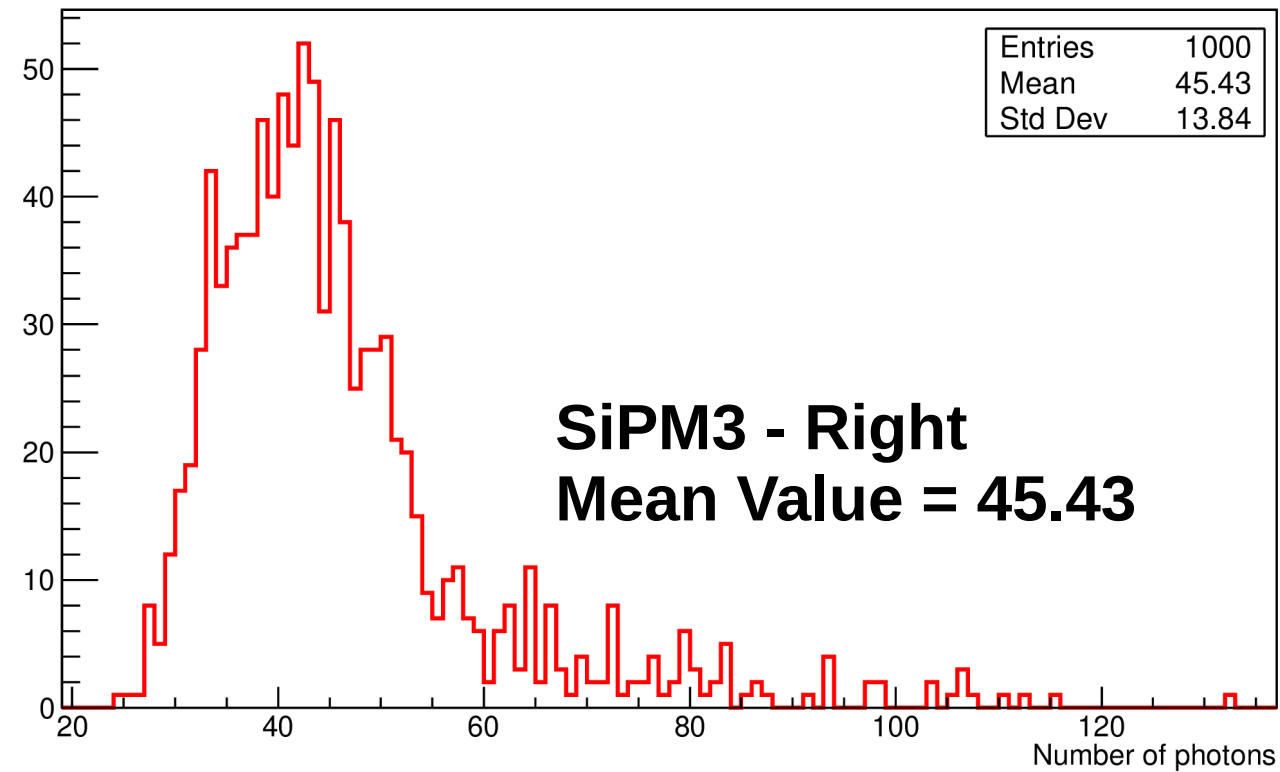


Total number of photons (Primary + Delta) = 21370

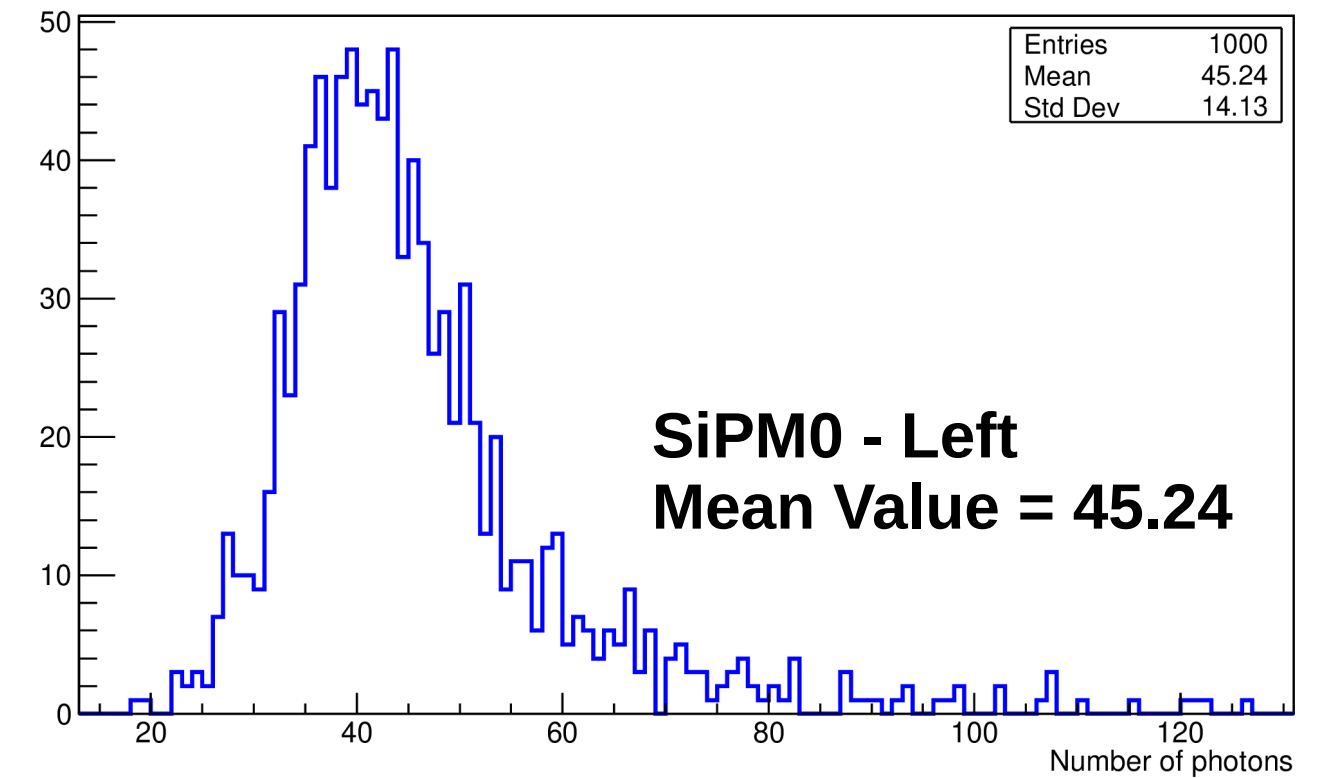
$$\frac{\text{Photons at the SiPMs}}{\text{Total number of photons}} = 0.6\% \pm 0.1\%$$

NUMBER OF PHOTONS - Geometry 3

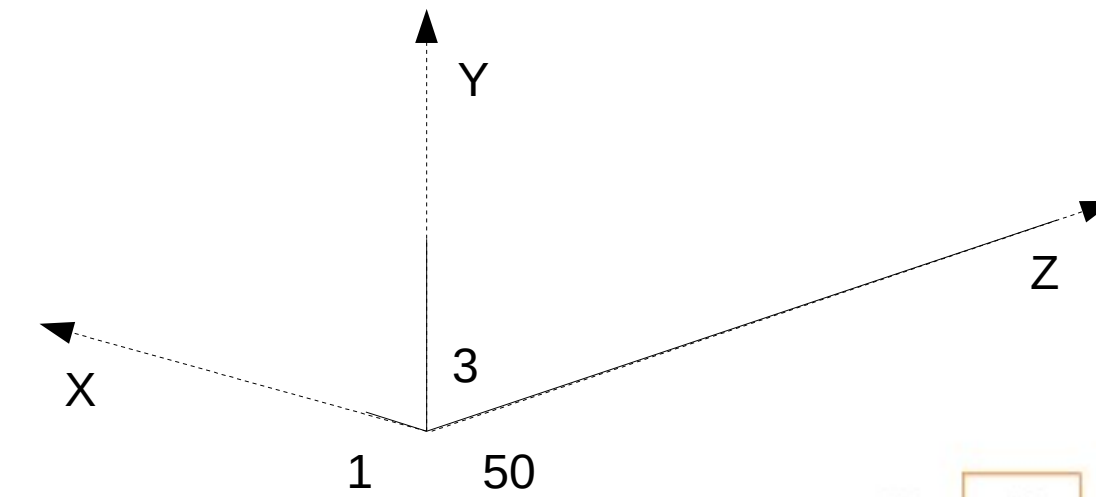
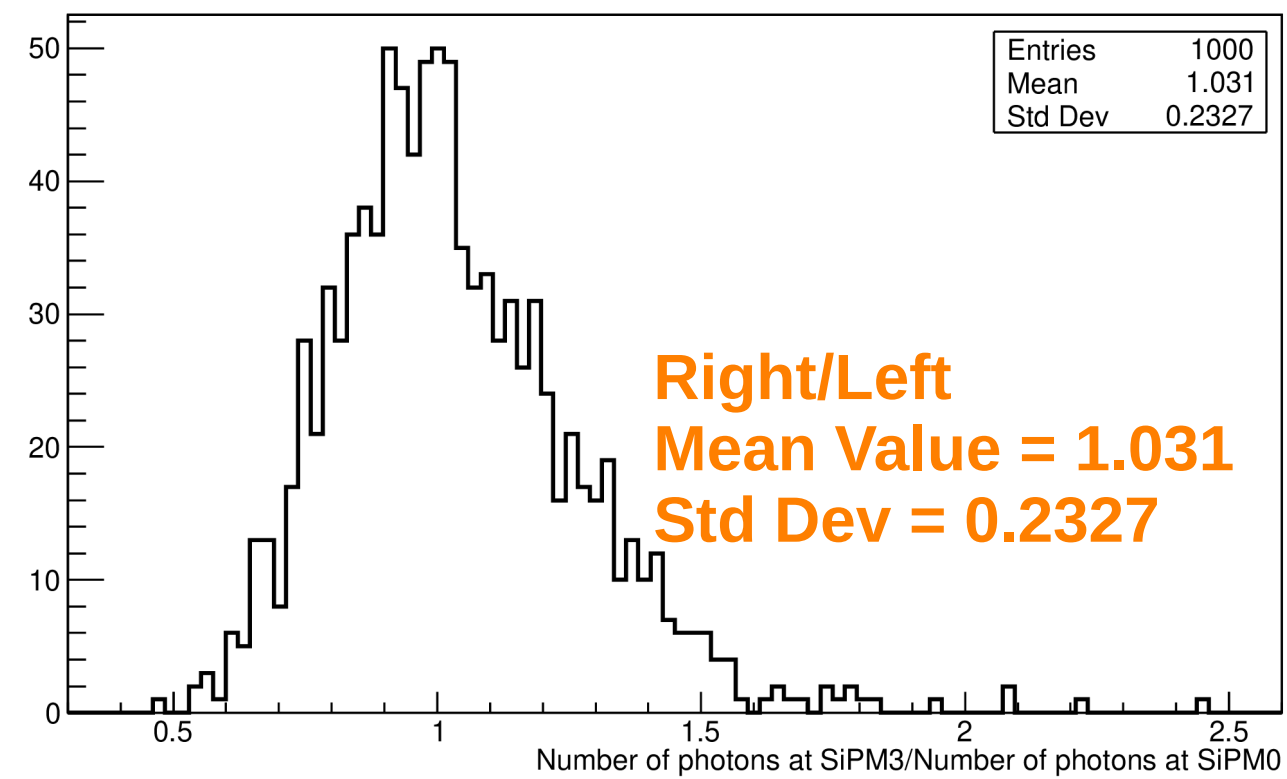
Photons at the SiPM3 - Right



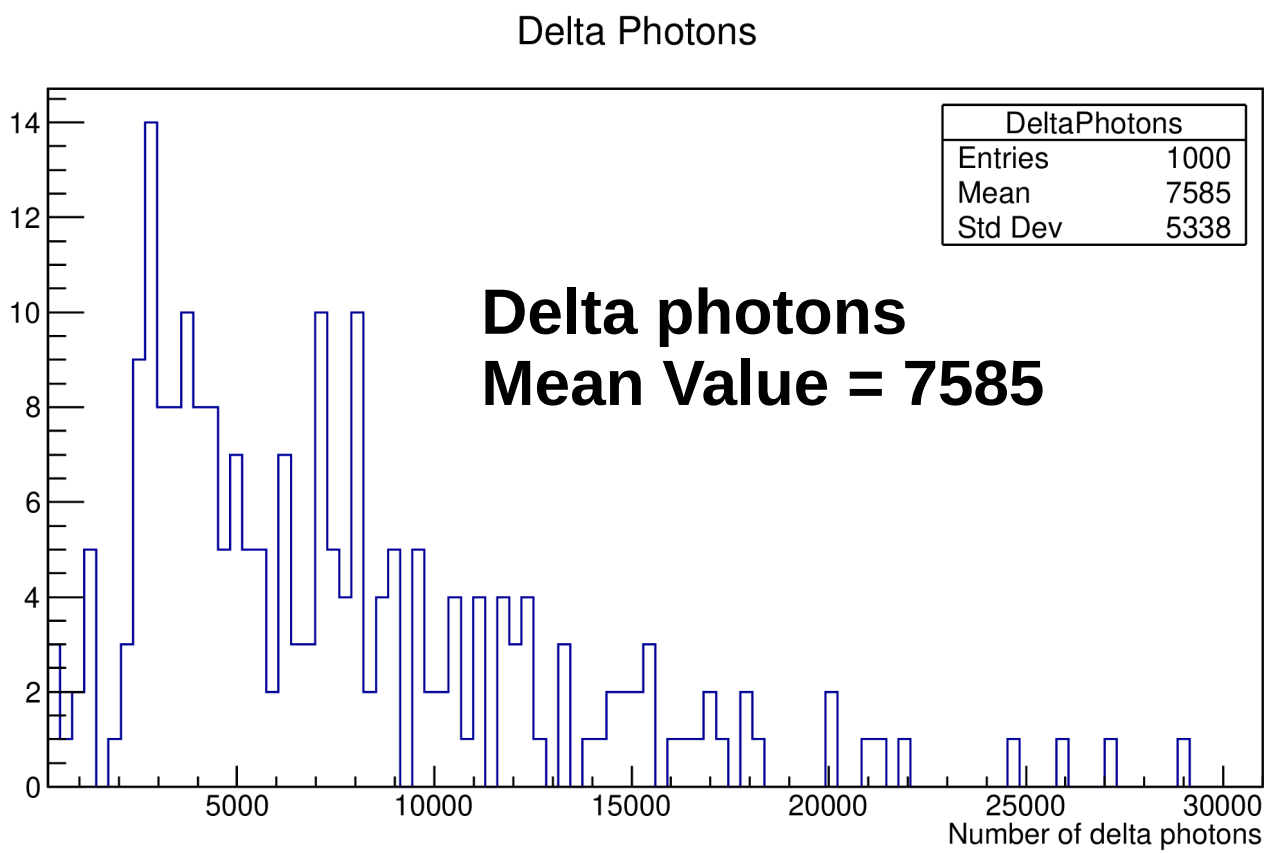
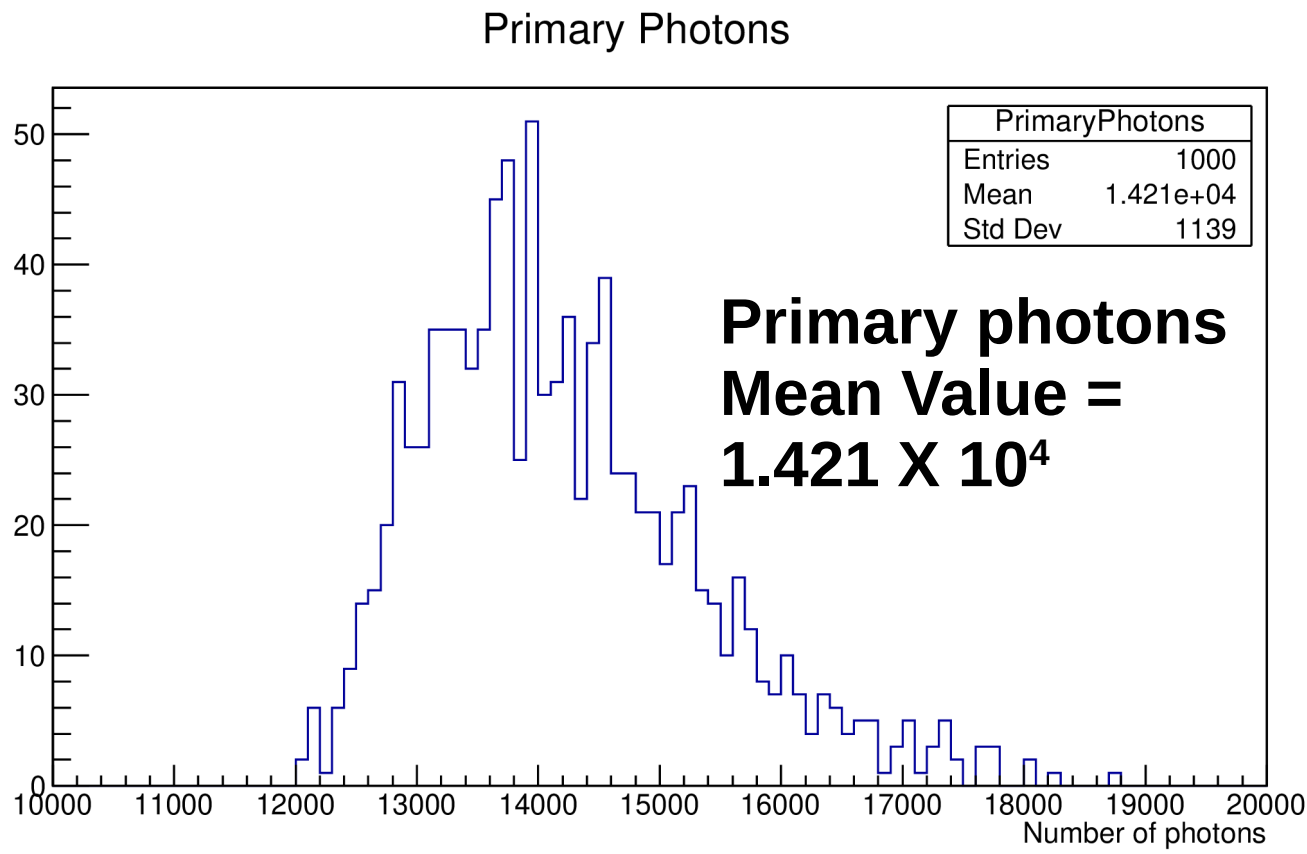
Photons at the SiPM0 - Left



Ratio between photons at the SiPM right and left



NUMBER OF PHOTONS - Geometry 3



Total number of photons (Primary + Delta) = 21795

$$\frac{\text{Photons at the SiPMs}}{\text{Total number of photons}} = 0.4\% \pm 0.1\%$$

COMPARISON

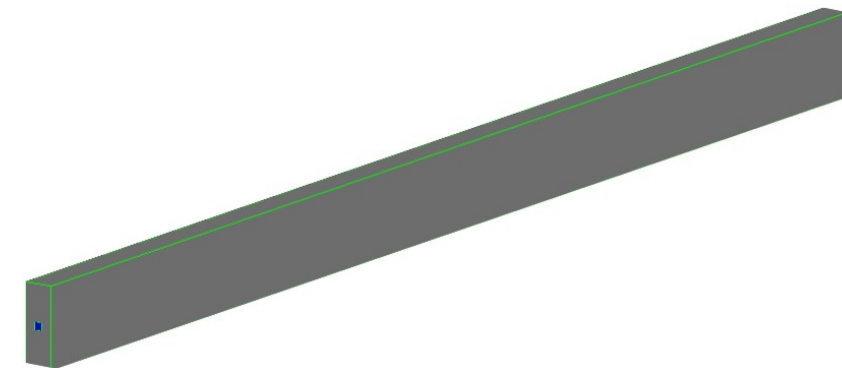
Geometry	N of photons at SiPM0 - Left	N of photons at SiPM3 - Right	Total N of photons	SiPM_Right / SiPM_Left	Photons in SiPMs / Total N photons
1	132.9	132.5	20986	1.01 ± 0.13	$1.26\% \pm 0.08\%$
2	70.68	70.55	21370	1.02 ± 0.18	$0.66\% \pm 0.06\%$
3	45.43	45.24	21795	1.03 ± 0.23	$0.42\% \pm 0.04\%$

All the numbers in the table are average values

Geometry 1: $(x, y, z) = (1, 1, 50)$ cm

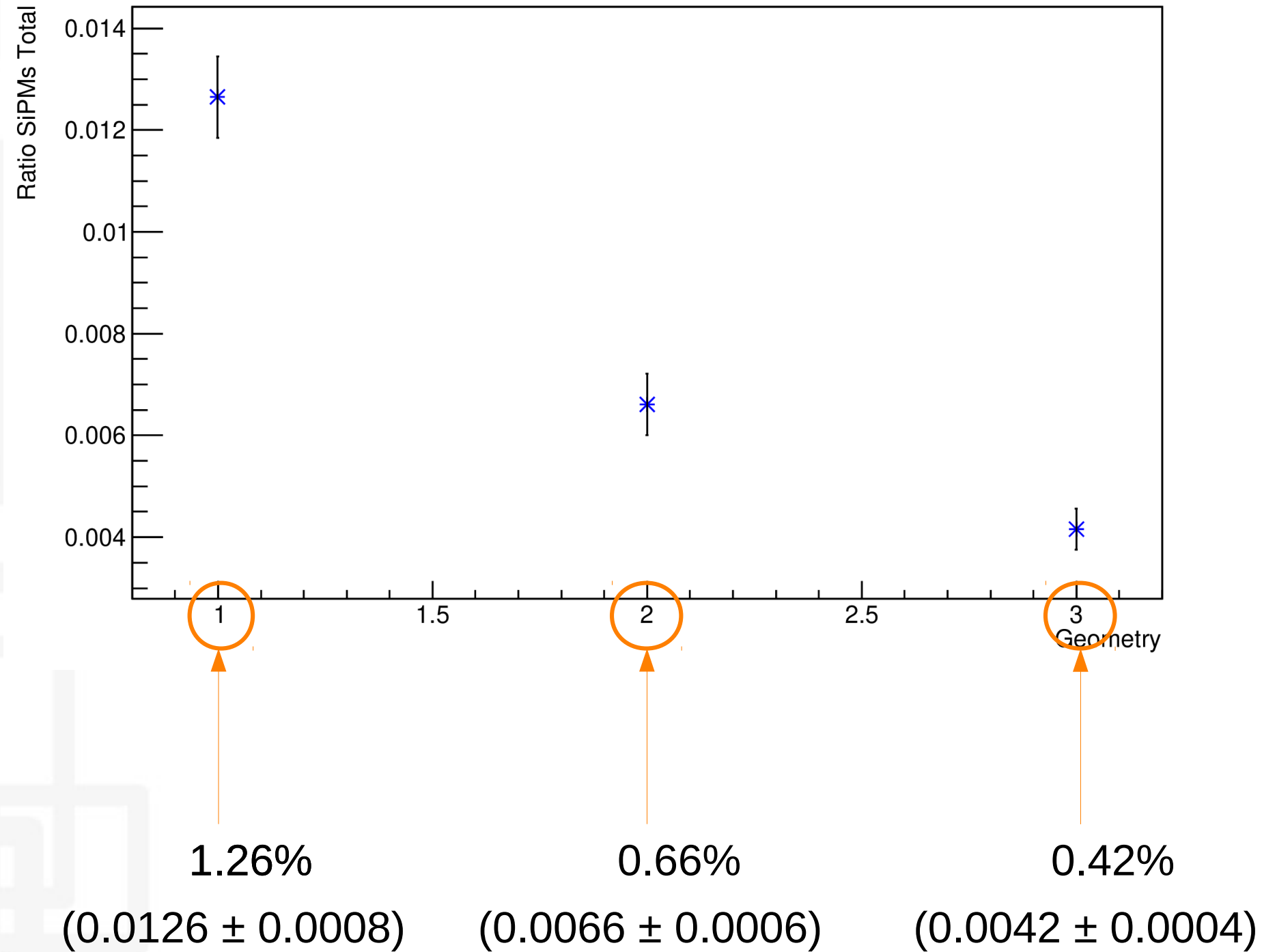
Geometry 2: $(x, y, z) = (1, 2, 50)$ cm

Geometry 3: $(x, y, z) = (1, 3, 50)$ cm



COMPARISON

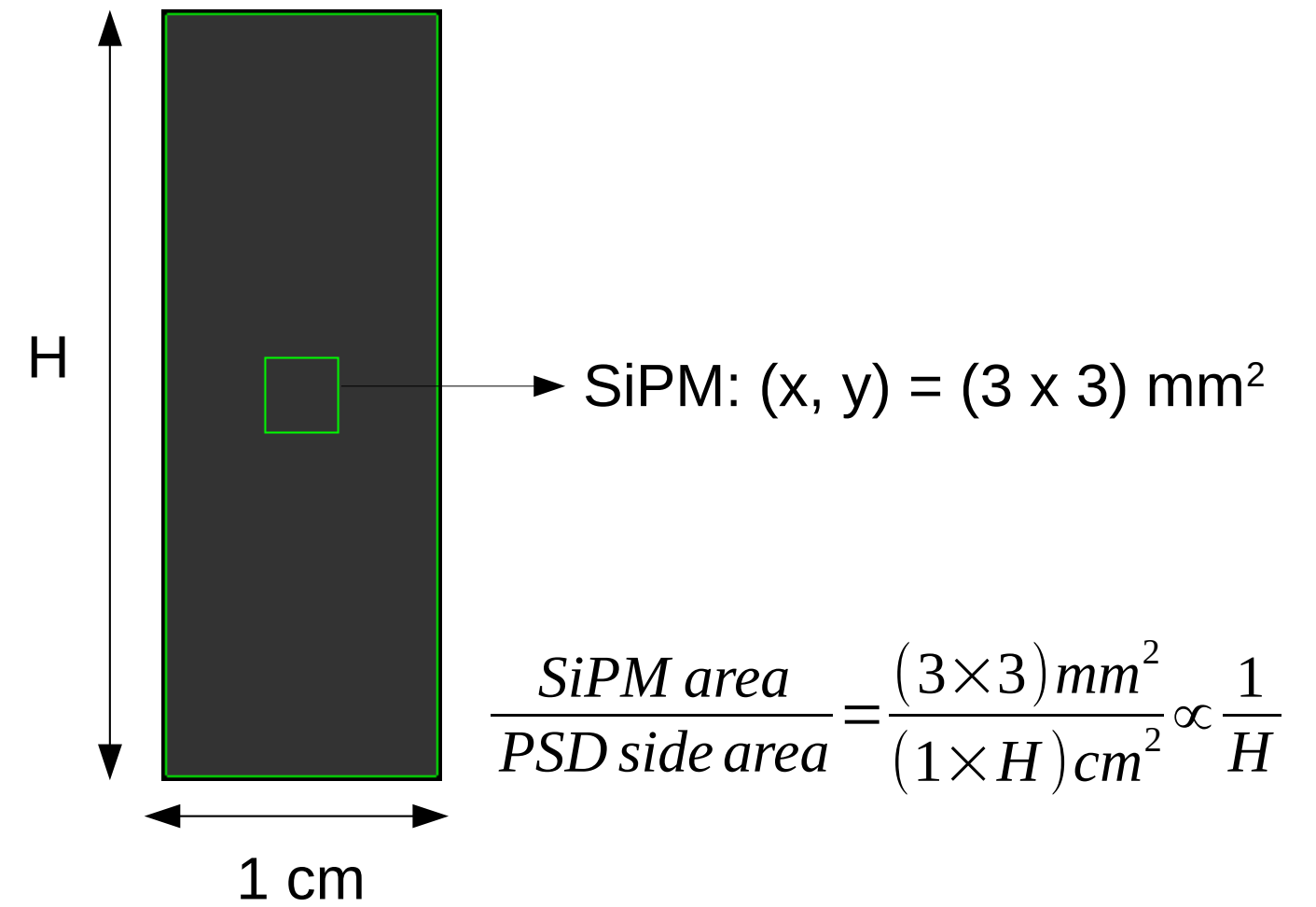
Number of photons - Ratio SiPMs Total



Geometry 1: (x, y, z) = (1, 1, 50) cm

Geometry 2: (x, y, z) = (1, 2, 50) cm

Geometry 3: (x, y, z) = (1, 3, 50) cm



A POSSIBLE IMPROVEMENT

The main difference between the studied geometries is in the collection of the light by the SiPMs

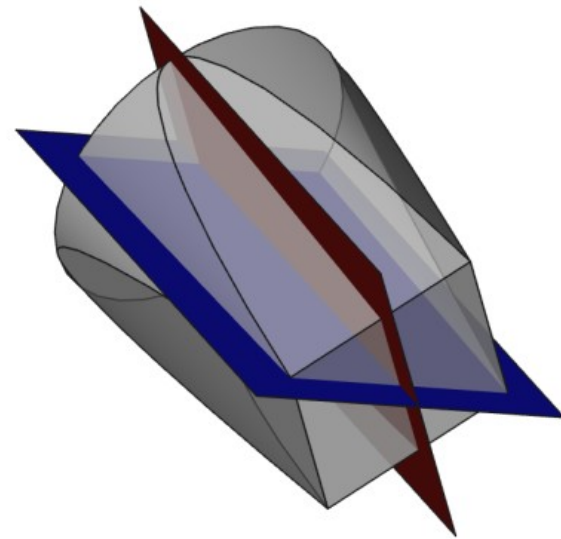
We might shape the bar ends in such a way to enhance photon' collection

Test will be done using this code

Light guide 1:

Regular pyramid + Cone

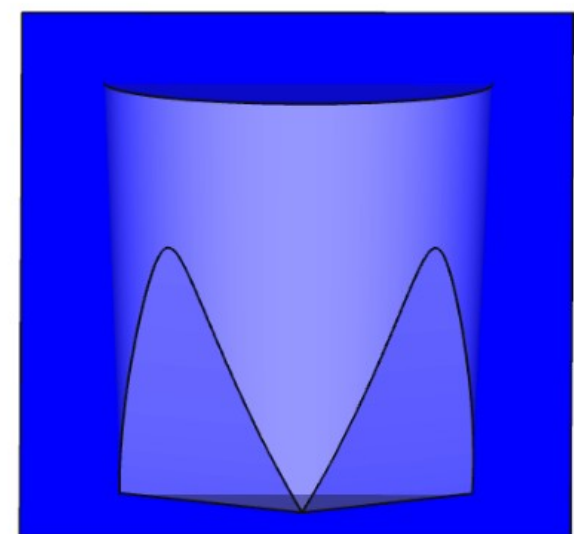
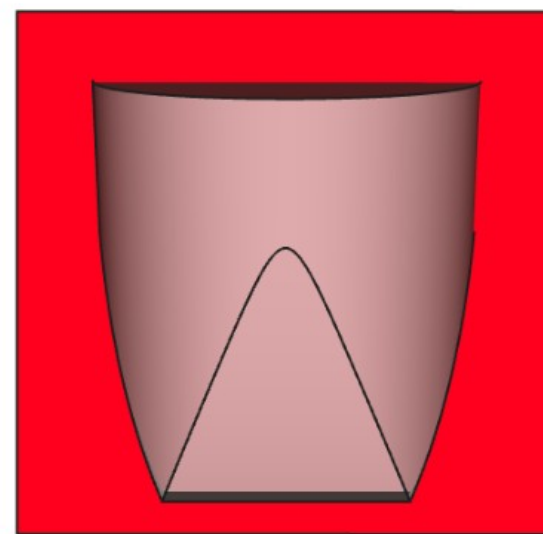
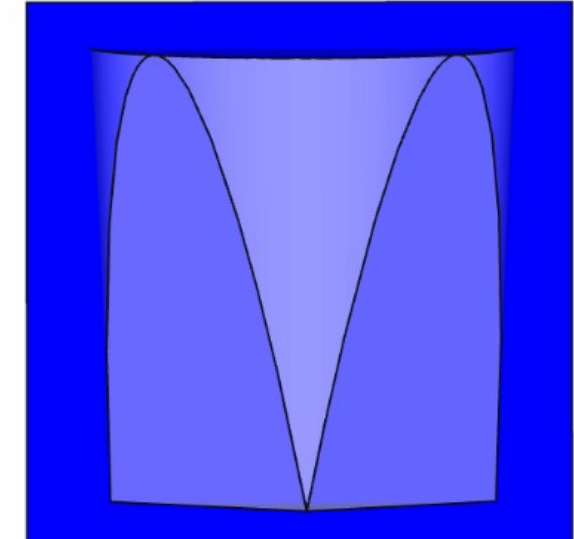
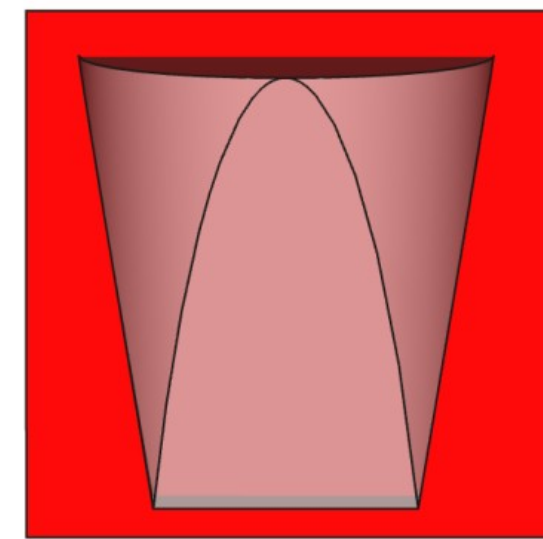
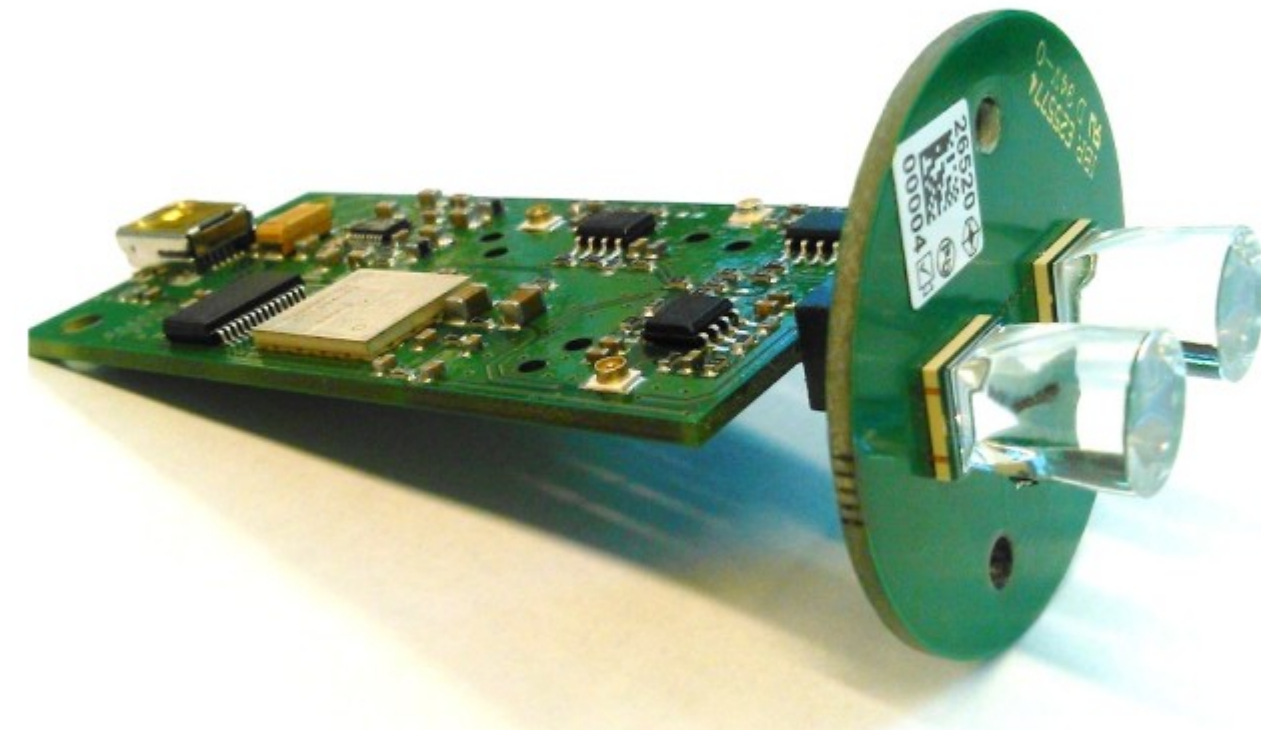
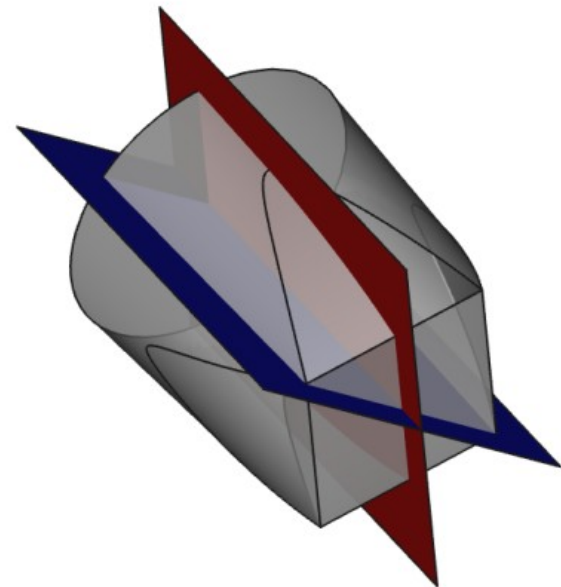
All surface contours follow straight lines



Light guide 2:

Winston pyramid + Cone

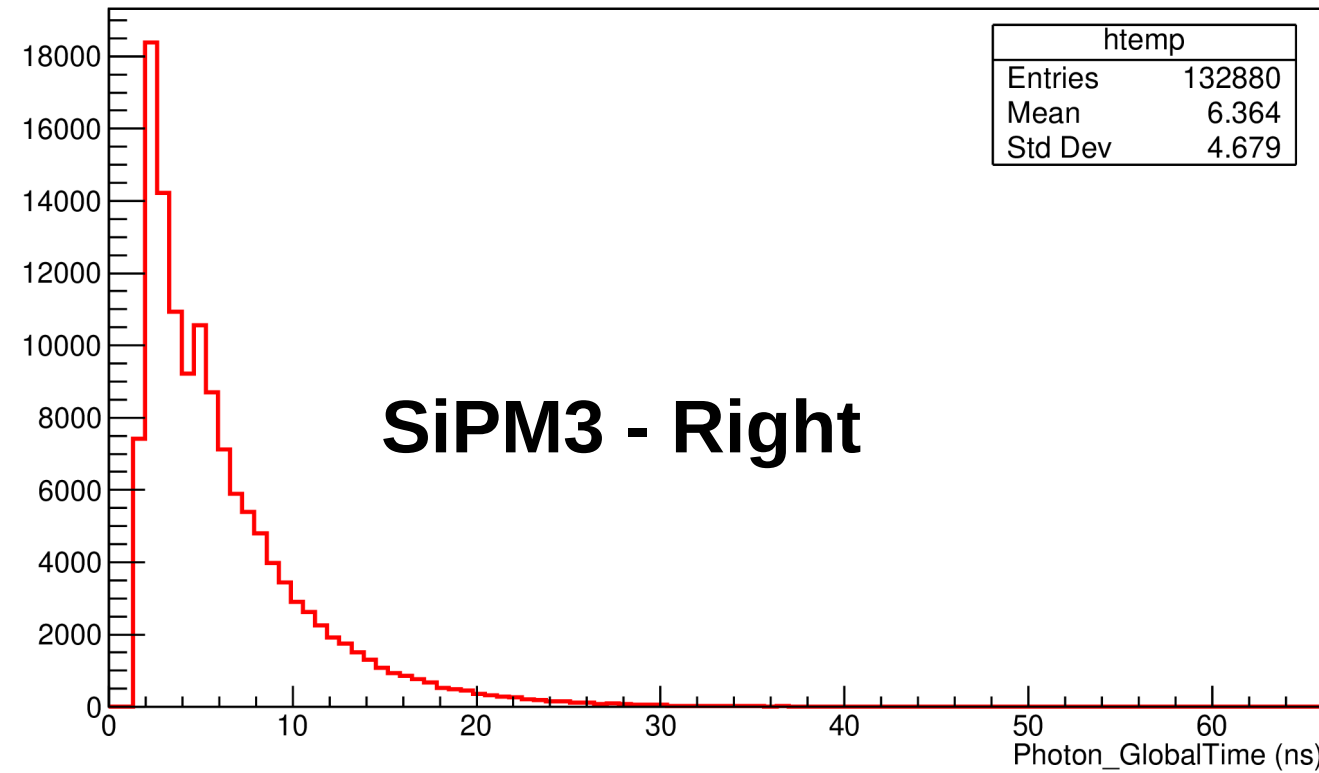
Parabolically shaped surface contours



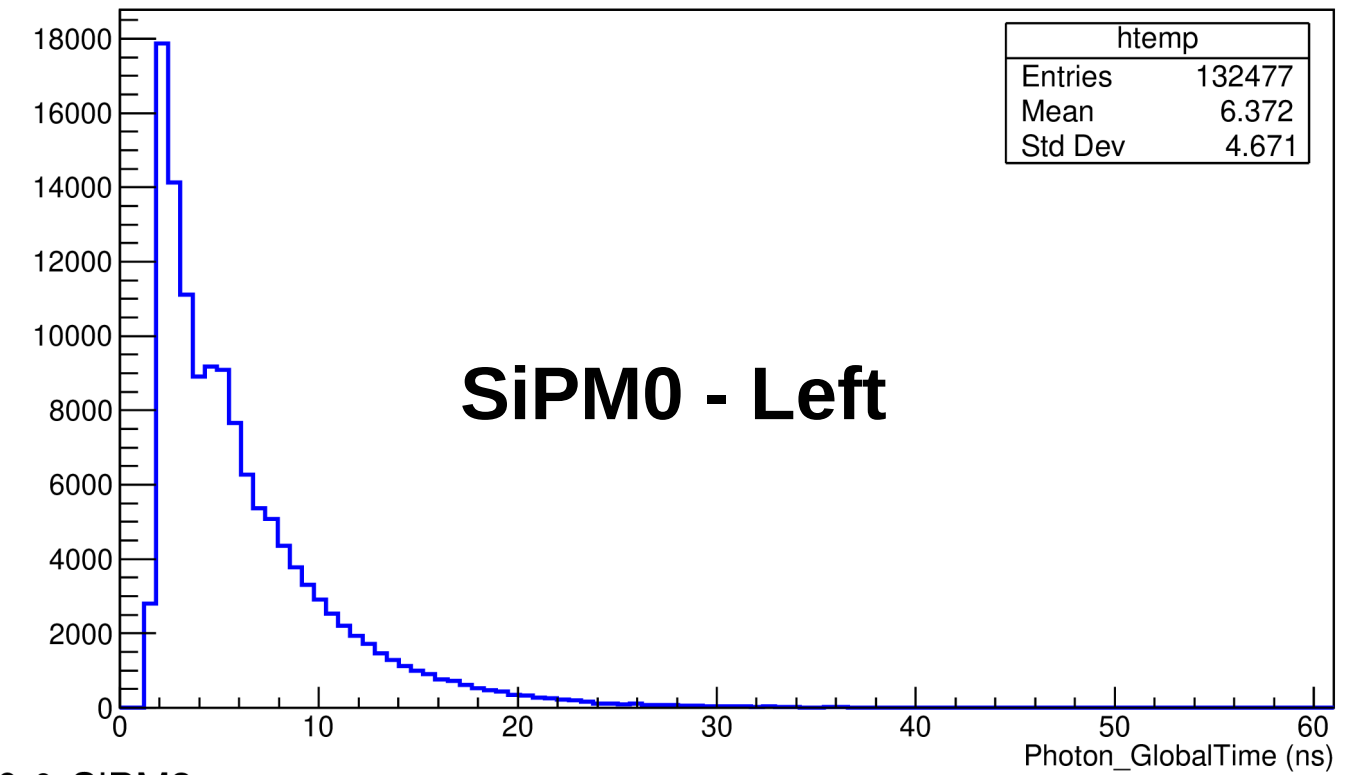
Propagation time of the photons - Geometry 1

Time interval between the production of the primary particle and the absorption of the photon

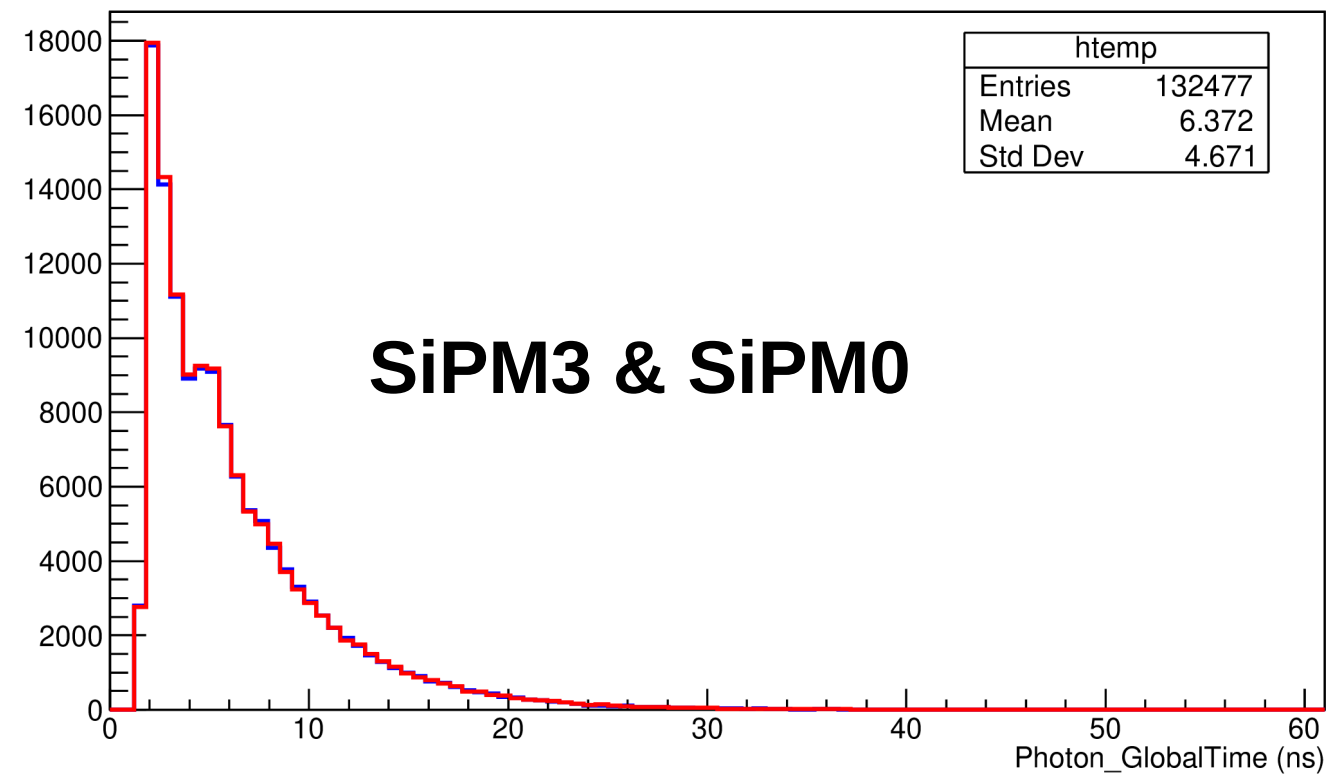
Photon_GlobalTime - SiPM3



Photon_GlobalTime - SiPM0

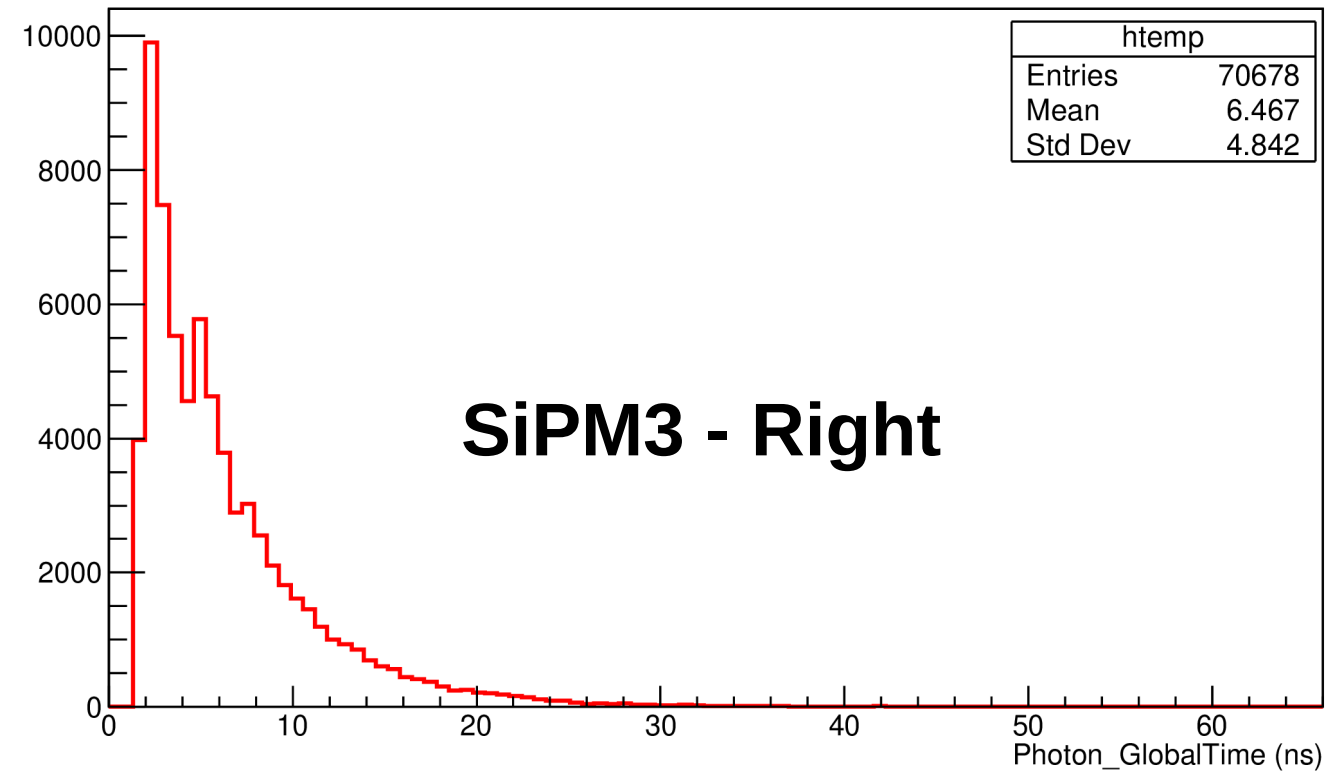


Photon_GlobalTime - SiPM0 & SiPM3

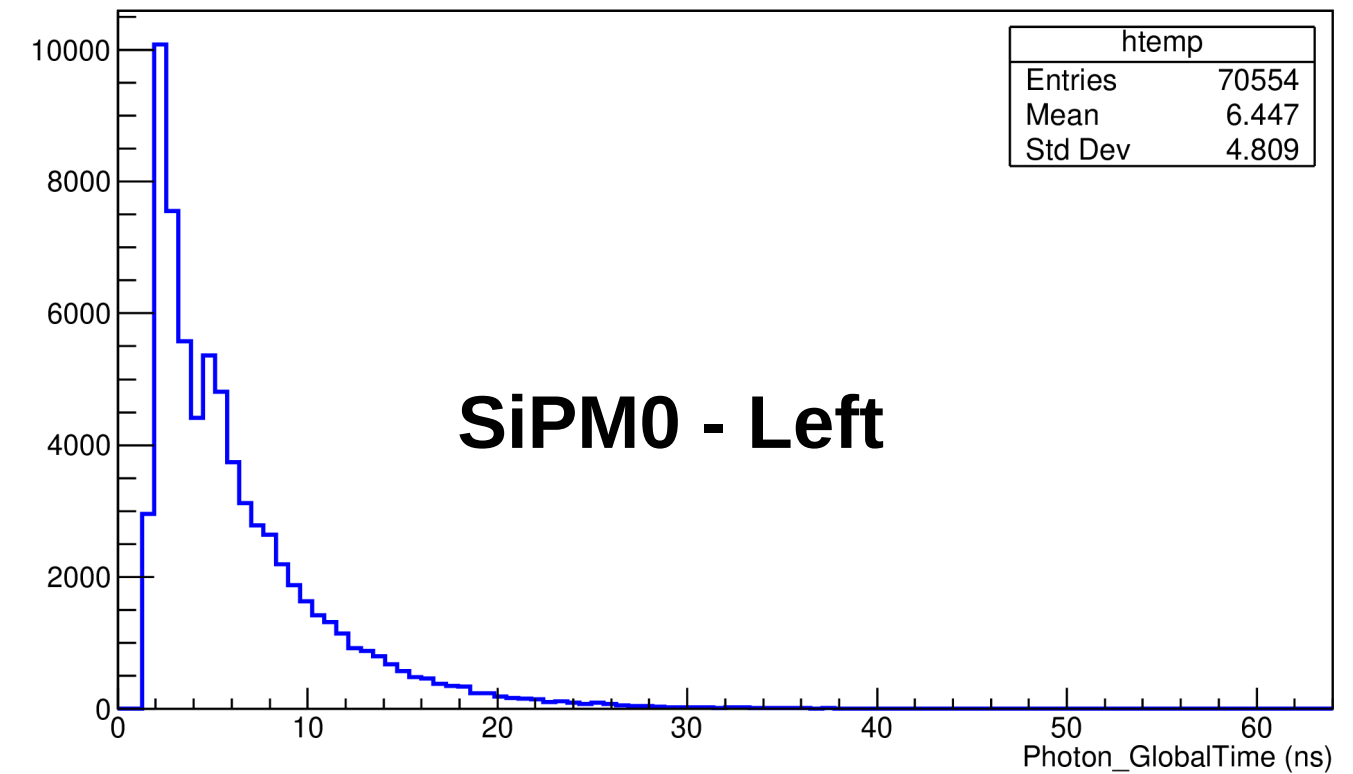


Propagation time of the photons - Geometry 2

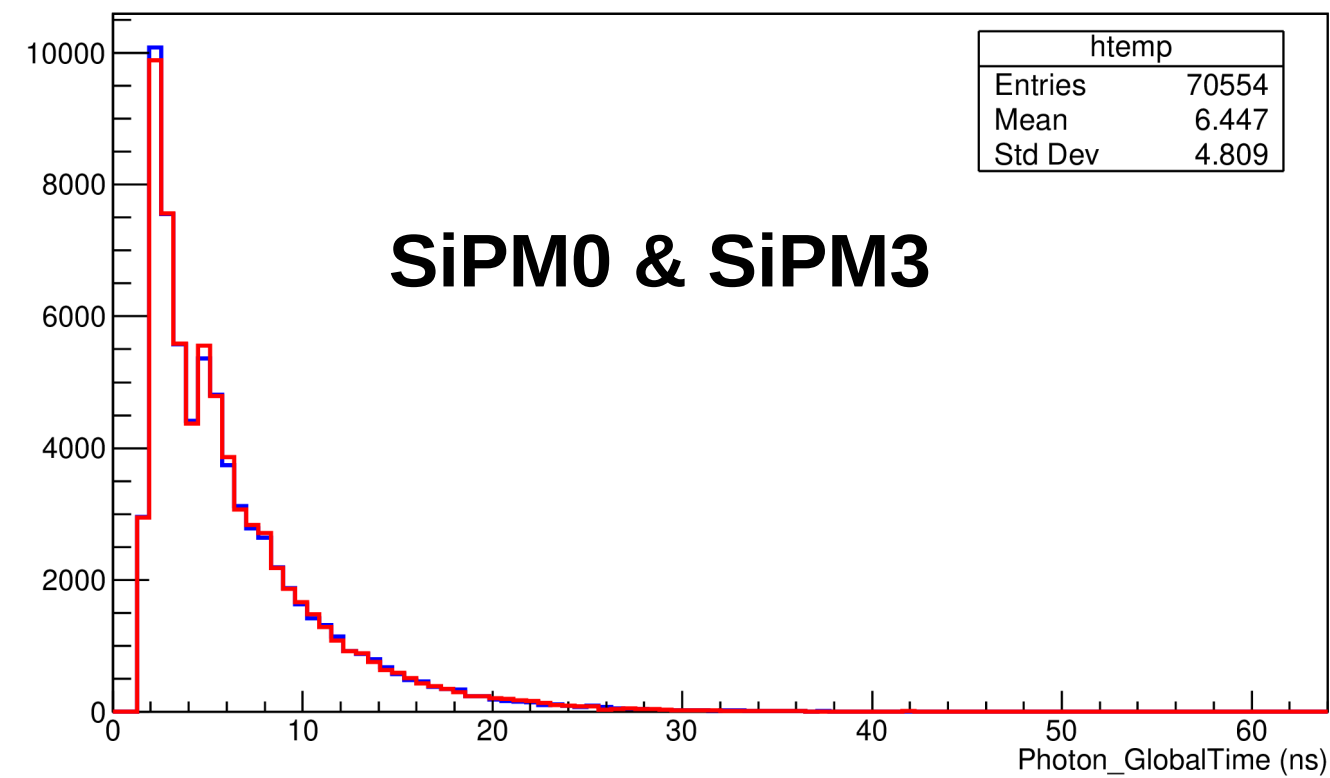
Photon_GlobalTime - SiPM3



Photon_GlobalTime - SiPM0

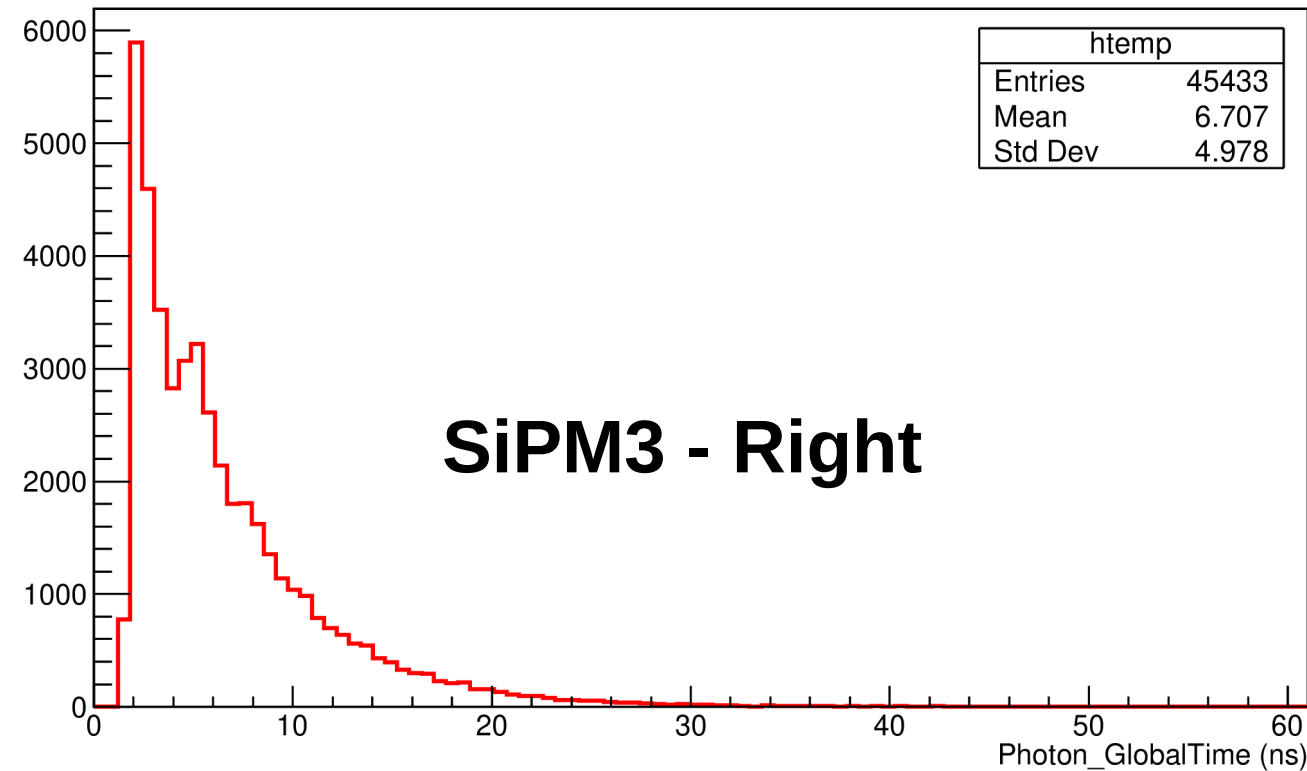


Photon_GlobalTime - SiPM0 & SiPM3

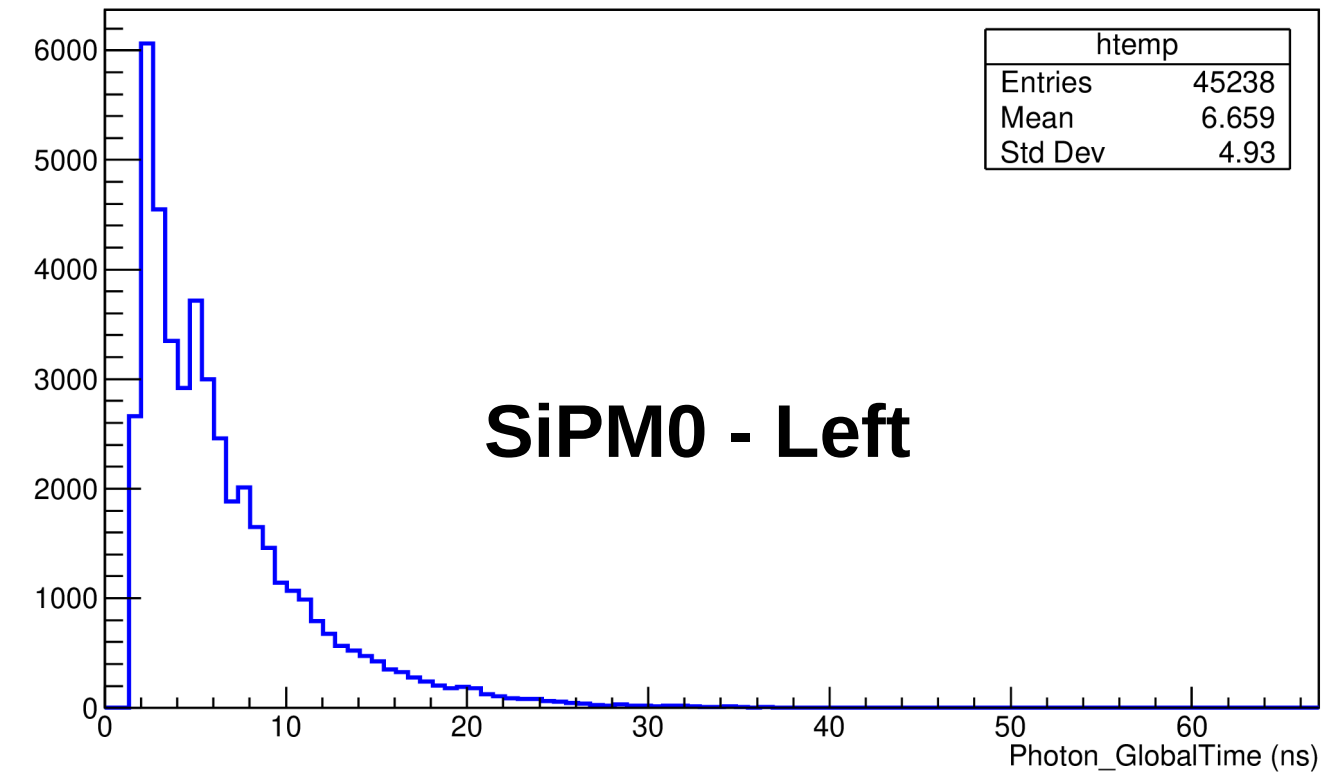


Propagation time of the photons - Geometry 3

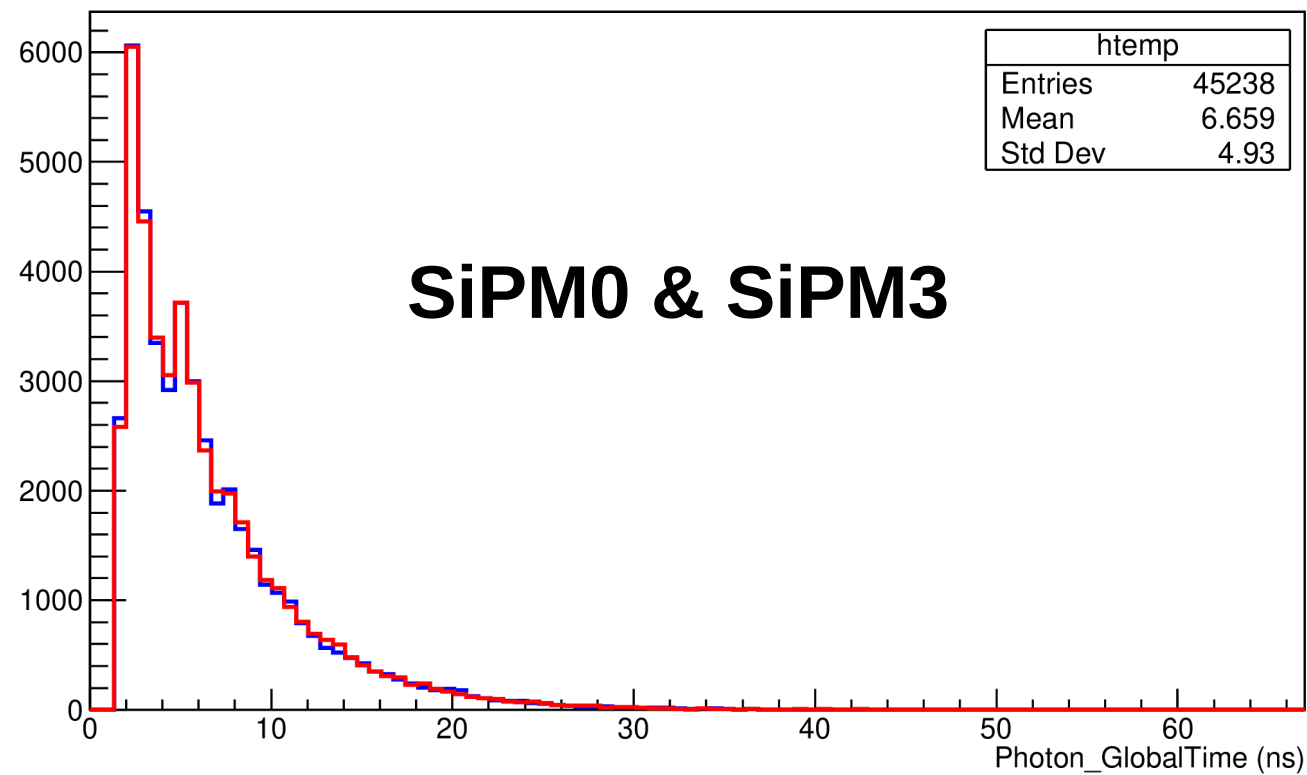
Photon_GlobalTime - SiPM3



Photon_GlobalTime - SiPM0



Photon_GlobalTime - SiPM0 & SiPM3



No significant difference in the propagation time between different geometries

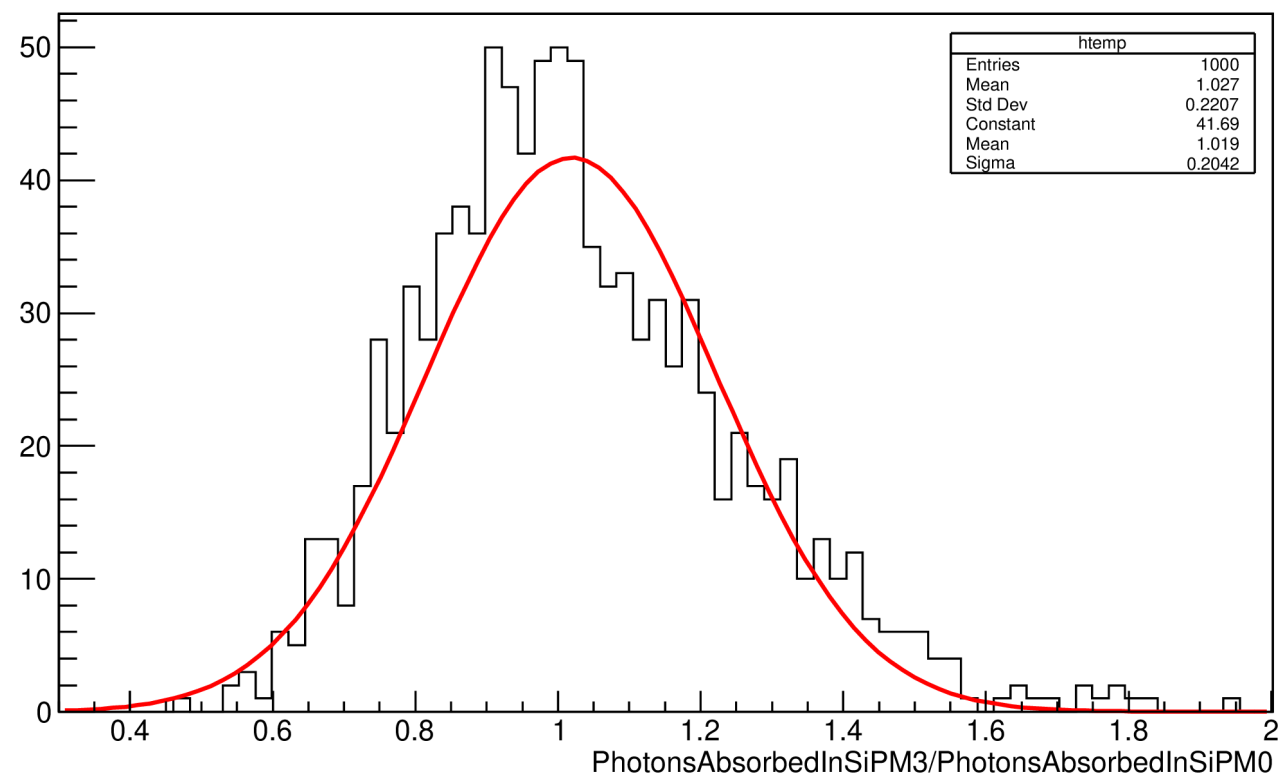
Conclusions & Future prospects

- 1) Three PSD geometries studied. Main difference in the collection of the light by the SiPMs. In order to collect more photons a light guide could be installed on each end of the bar. A simulation will be done to explore this possibility.
- 2) Results of this work obtained considering cosmic ray muons crossing the bar, consistent with the tests that we are performing at Gran Sasso National Laboratory (LNGS).
Next step: simulation of the response of the bar to particles coming from accelerated beams, and particles with $z > 1$.
- 3) The obtained results will be used as a crosscheck for the test performed in the laboratory (ONGOING).
- 4) Additional simulations with different number of SiPMs, geometries and scintillating materials.

BACKUP

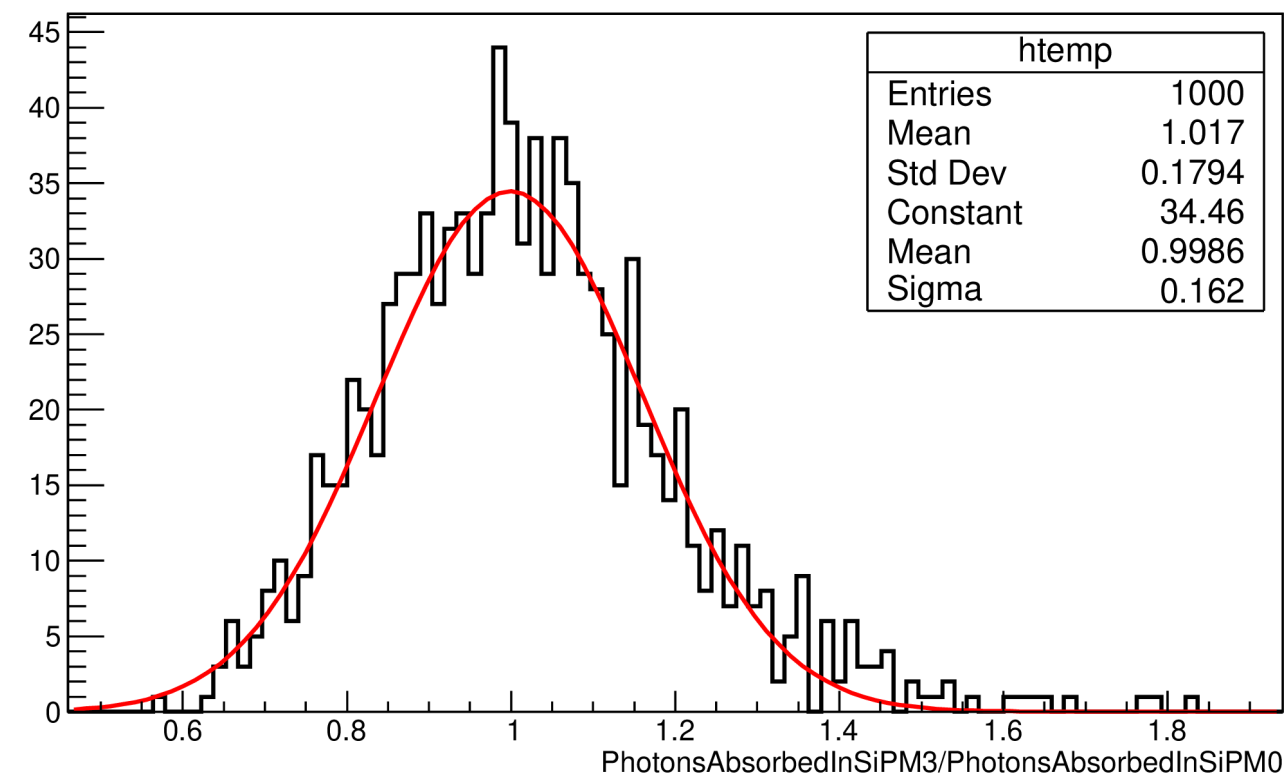
Geometry 1

PhotonsAbsorbedInSiPM3/PhotonsAbsorbedInSiPM0



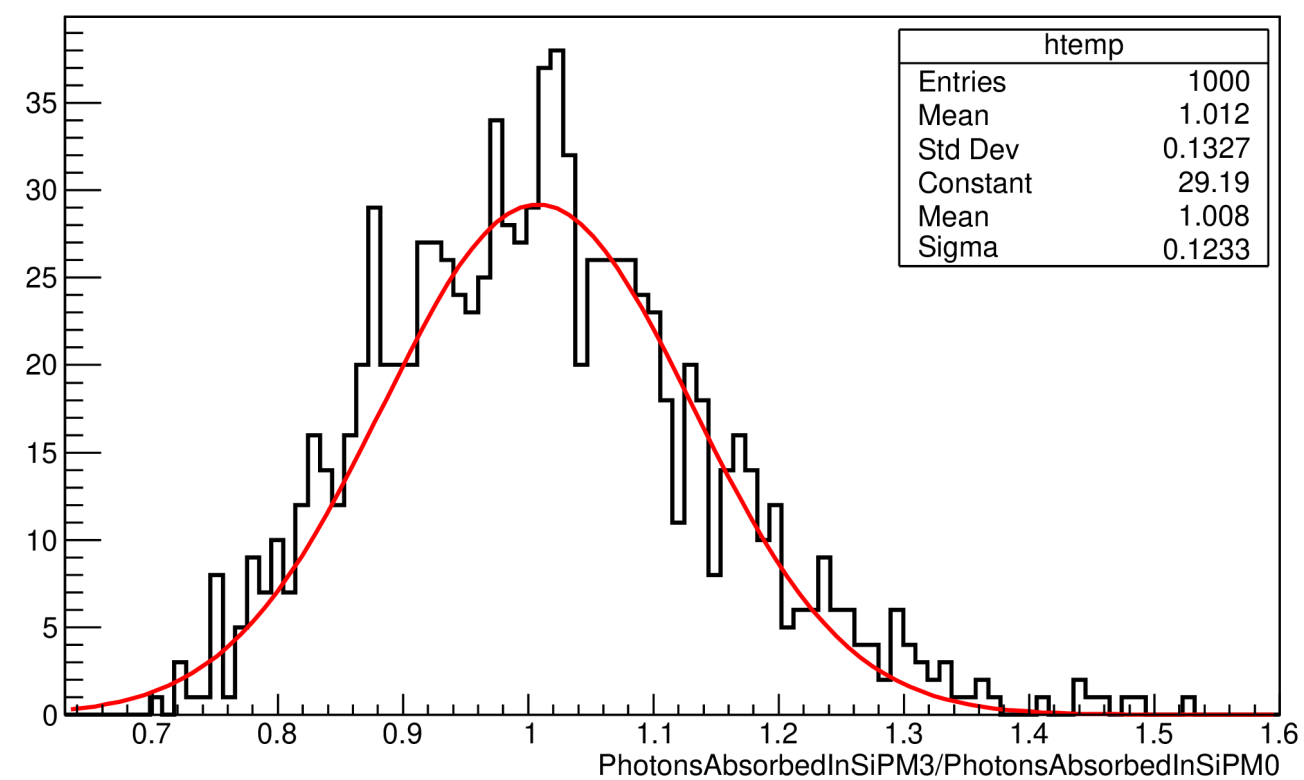
Geometry 2

PhotonsAbsorbedInSiPM3/PhotonsAbsorbedInSiPM0



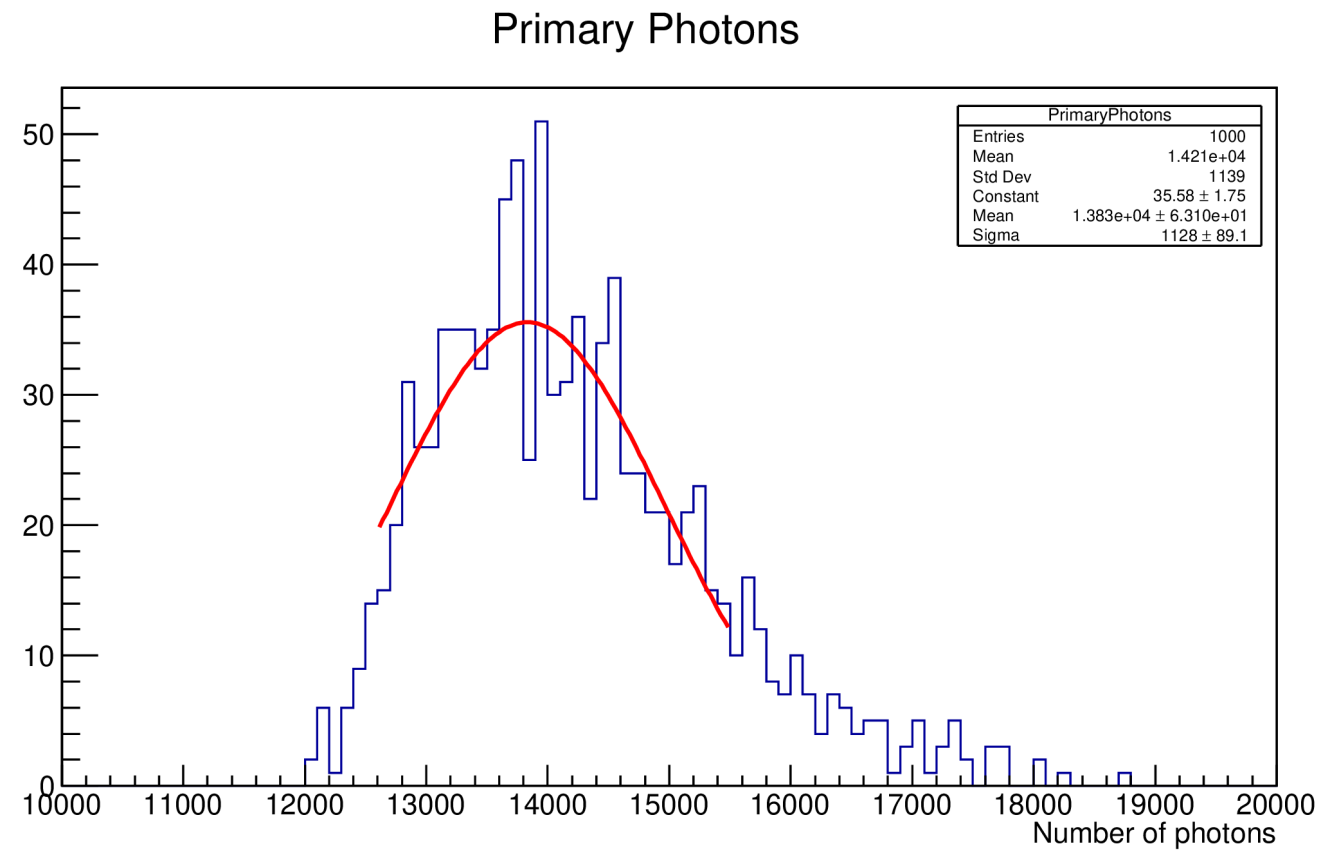
Geometry 3

PhotonsAbsorbedInSiPM3/PhotonsAbsorbedInSiPM0

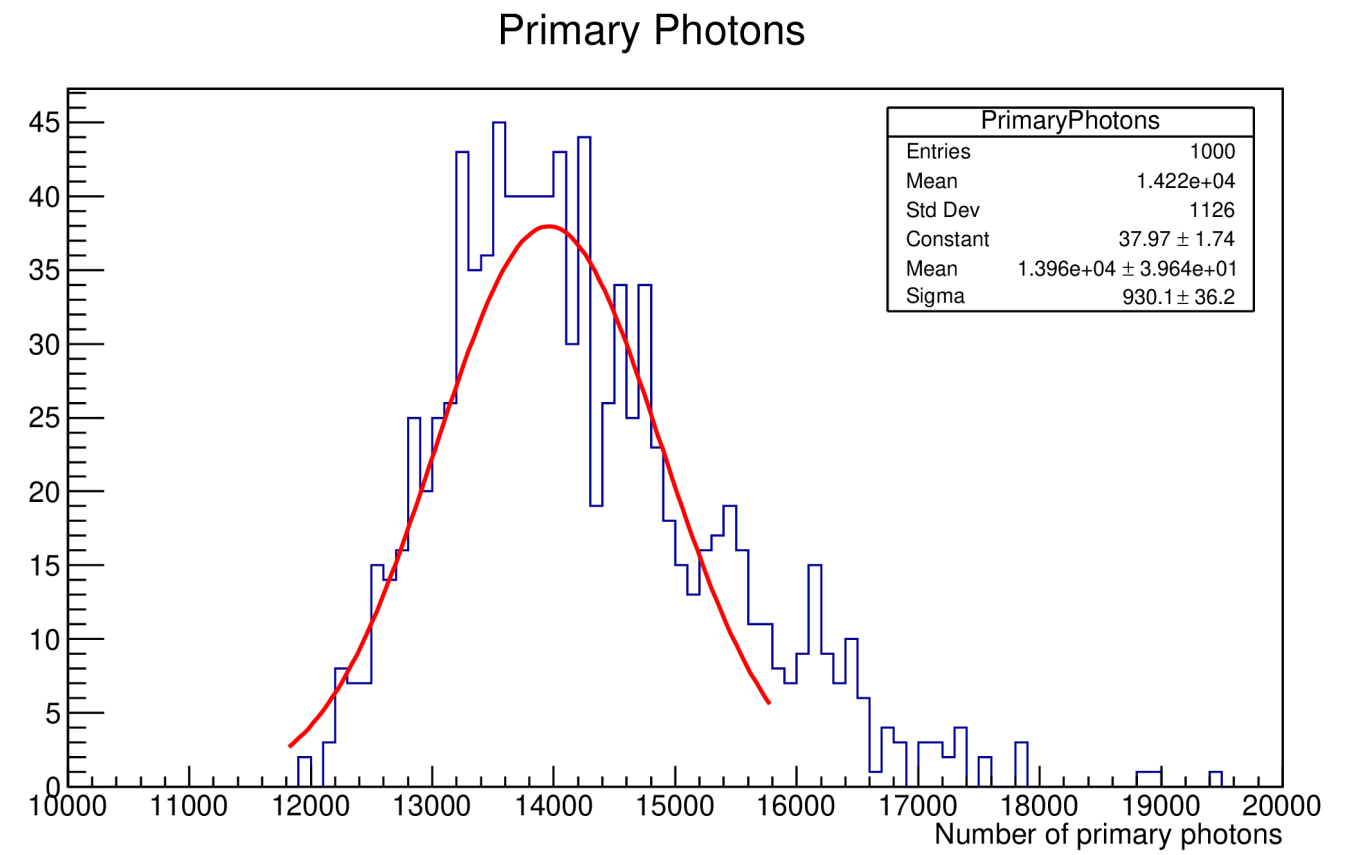


BACKUP

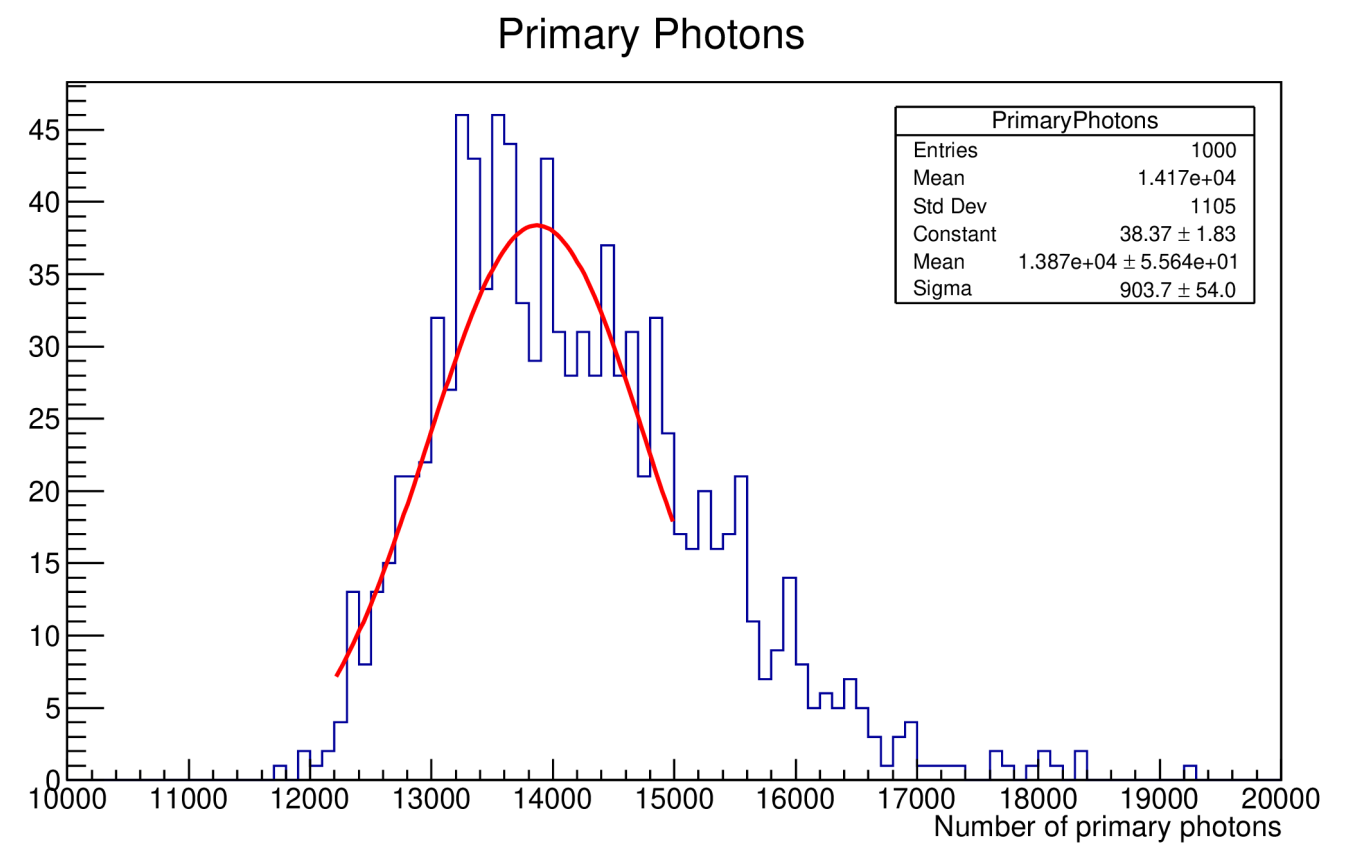
Geometry 1



Geometry 2

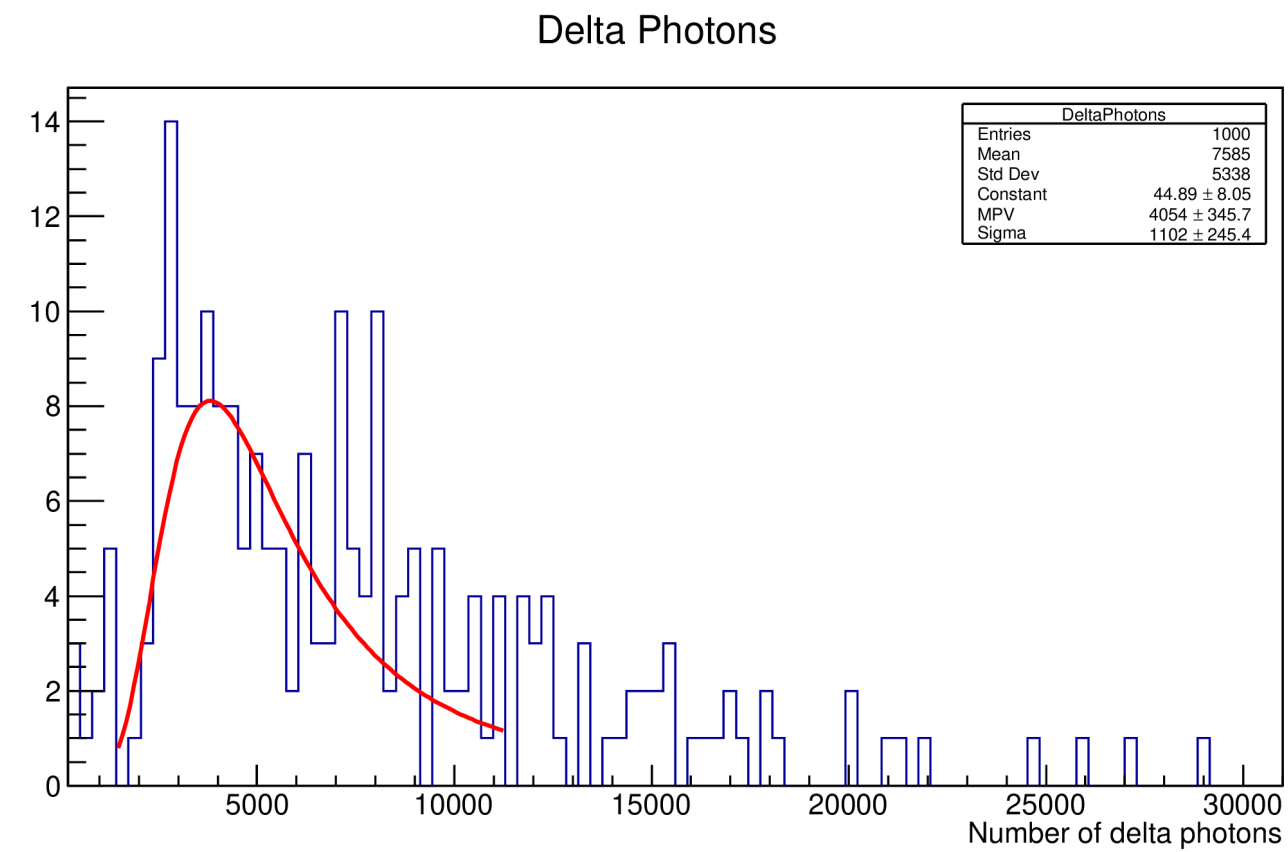


Geometry 3

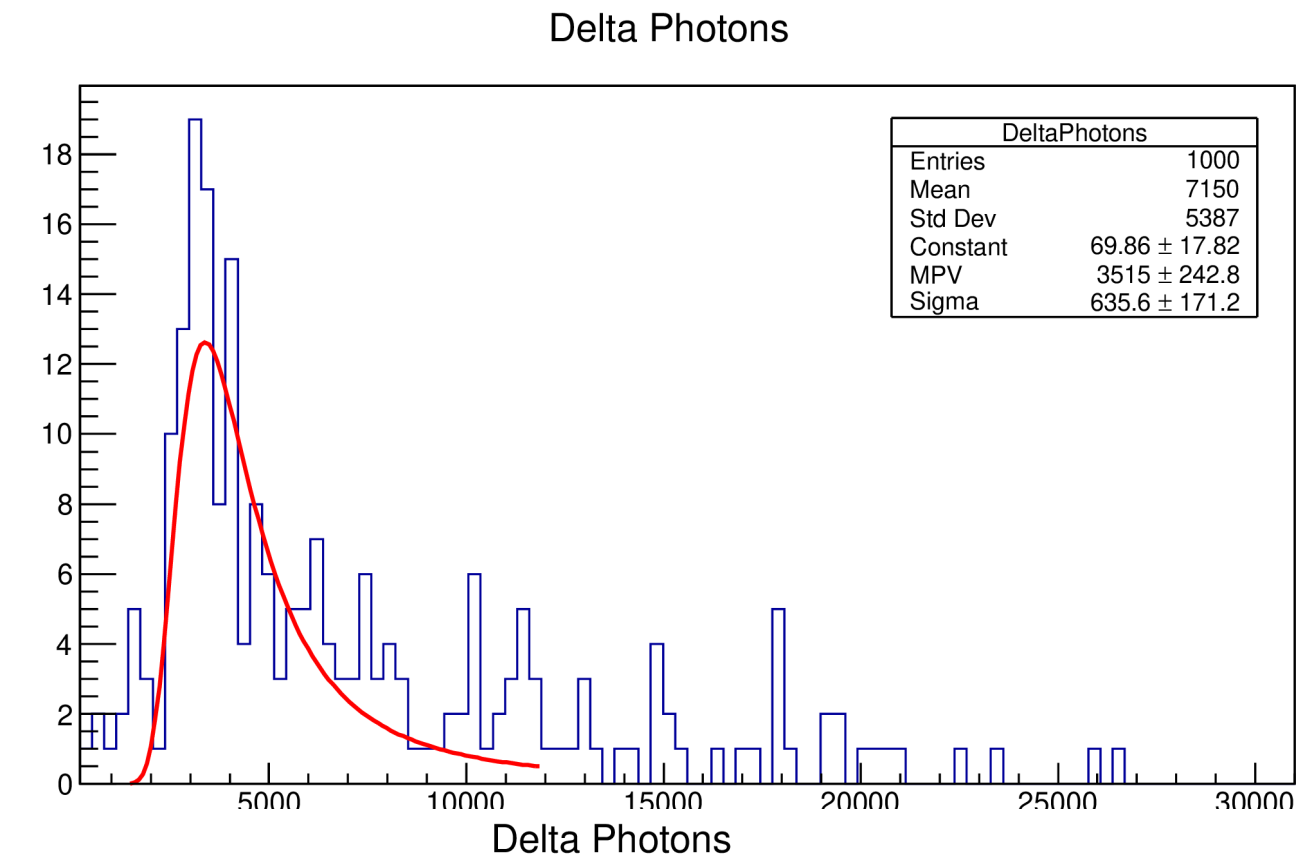


BACKUP

Geometry 1



Geometry 2



Geometry 3

