

Absolute Calibration of PMTs with Rayleigh Scattered Laser light

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Abstract

We report on the results from calibrating photo-multiplier tubes (PMTs) absolutely. Obtaining the quantum efficiency measurements of PMTs to better than 10% is very difficult, but this level of accuracy is necessary to make an absolute measurement of cosmic ray air shower fluorescence yield. As a calibration light source we use Rayleigh scattered photons. This gives a low enough energy to measure the single photo electron spectrum for the PMT with same accuracy as the calibrated energy probe.

1. Introduction

- I.) Motivation for experiment
 - a.) Connection with ultra-high energy cosmic rays
 - b.) Current Fluorescence experiments
 - 1.) Auger
 - 2.) Telescope Array
 - c.) Similar calibration experiments and results
 - 1.) [1]
 - 2.) [2]

2. Experimental Design

- I.) Description of experimental set up/Overall Design
 - 1.) Scatter-box set up
 - i.) Fig. ?? Diagram of scatter box (!CURRENT SET-UP)
 - ii.) Fig. ?? PMT set-up with integration sphere. (!NEEDS COMPLETION)
- II.) Components
 - a.) Laser
 - 1.) Laser energy stability
 - i.) Fig. 1 Histogram of example beam energy $\sigma \sim 2\%$
 - b.) Energy Probes
 - 1.) High energy probe (calibrated to 5%)
 - 2.) Low energy silicon probe (calibrated to 5%)

3. Yield Predictions

- I.) Monte Carlo
 - c.) Monte Carlo of Dector set-up
 - 1.) Monte carlo simulation of geometry
 - i.) Fig. 2 example of 100 rays.
- II.) Rayleigh Yield for probe set up
- III.) Rayleigh Yield for PMT set up

4. Measurement of Rayleigh Scattered light

- I.) Measurement of Rayleigh Scattered light using Si-Probe.
 - a.) Fig. 5 10 cm from beam, expect value of $\sim 84\mu J$ from monte carlo.
 - b.) Fig. 6 7.75 cm from beam, expect value of $\sim 126\mu J$ from monte carlo.
 - c.) Fig. ?? Linear correlation with beam energy
 - d.) Fig. ?? $1/r^2$ correlation with distance

5. Calibration of PMTs

!NEEDS COMPLETION

- I.) Calibration of PMT
 - a.) Measurement of energy and efficiency

6. Conclusion

We measure accurately the energy of our laser using a high-sensitivity probe. The Rayleigh scattering cross section, a well known value, is then used to calculate the number of photons arriving at a PMT for given geometry. We have measured, with the use of these Rayleigh scattered photons as our source, the single photo-electron spectrum of PMTs. From this measurement we are able to find the quantum efficiency of the PMTs to better than 10%. This method is validated through measurements of Rayleigh scattered light made using a high-sensitivity, calibrated Si-probe.

This set-up will be used for in situ calibration during test beam measurements or air fluorescence. By including periodic calibration measurements we expect to obtain an absolute measurement of air fluorescence yield to better than 10%.

References

- [1] H. Tokuno, et al., Proc. 29th ICRC (Pune) 8, 221-224 (2005)
- [2] C. Field, et al. SLAC-PUB-12928, (2007)

Beam Energy

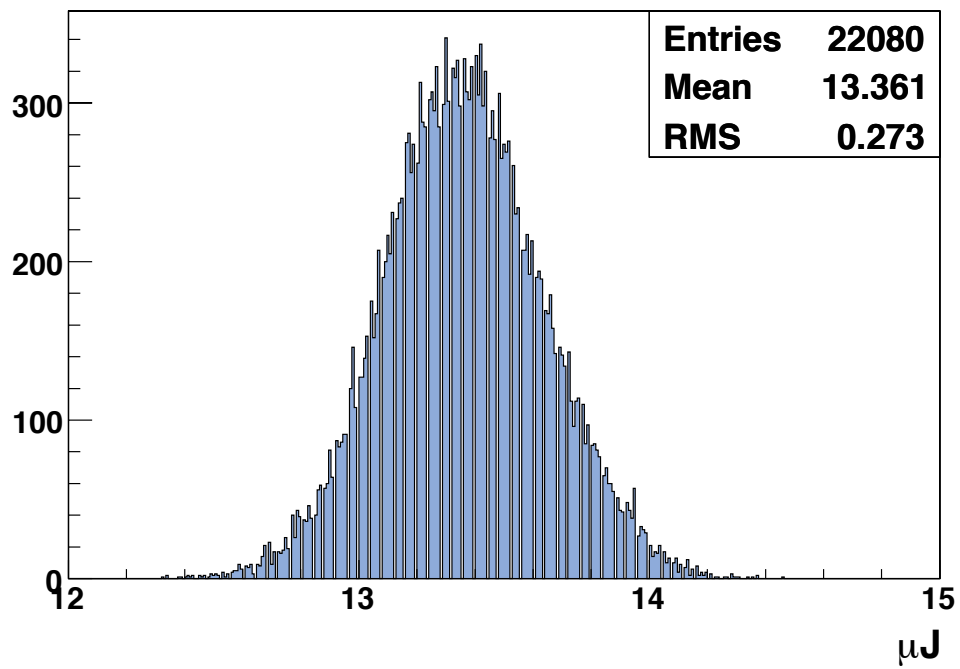


Figure 1: Histogram of energy of laser with a $1\mu\text{m}$ pinhole beam mask.

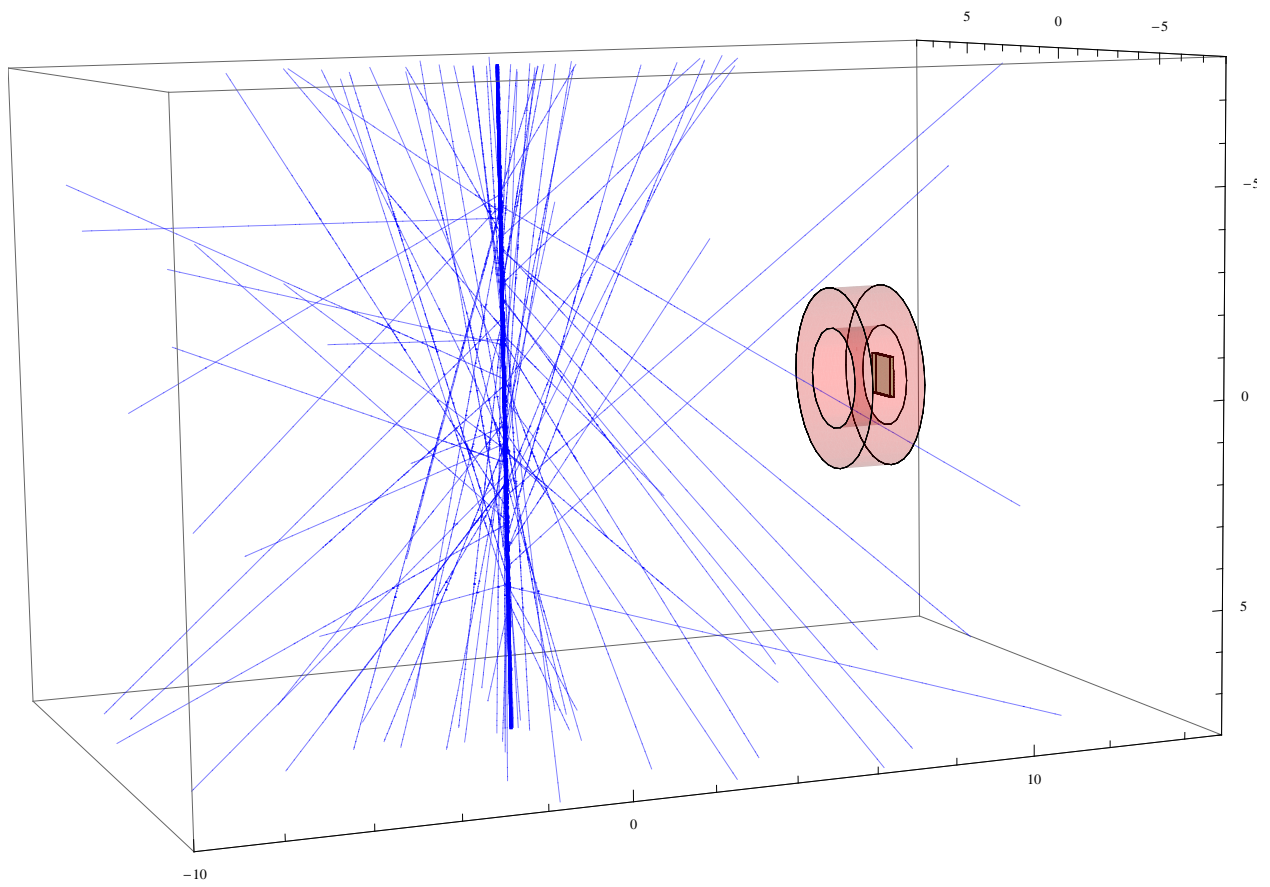


Figure 2: 100 ray graphical representation of monte carlo simulation for Rayleigh scattering. Green square is representation of Si-probe, and red cylinder is shielding around probe. $1 + \cos^2 \theta$ factor in cross section gives preference to on-axis scattering.

Background Facing Away From Beam

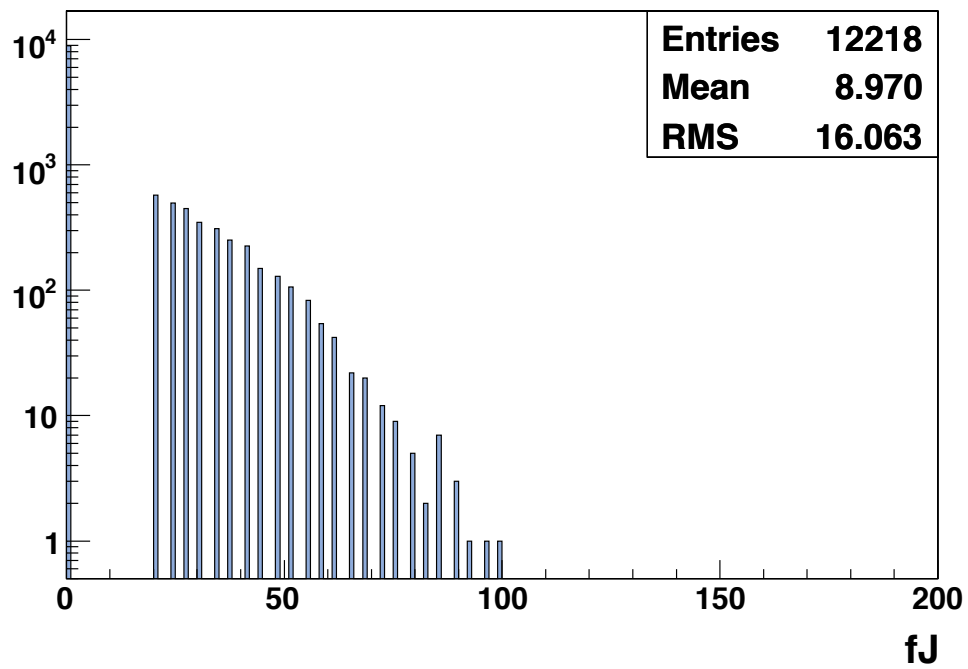


Figure 3: Histogram of measured background energy. Probe is oriented directly away from beam. Laser has a $1\mu\text{m}$ pinhole beam mask with an energy of $13.6\mu\text{J}$.

Background Facing Beam

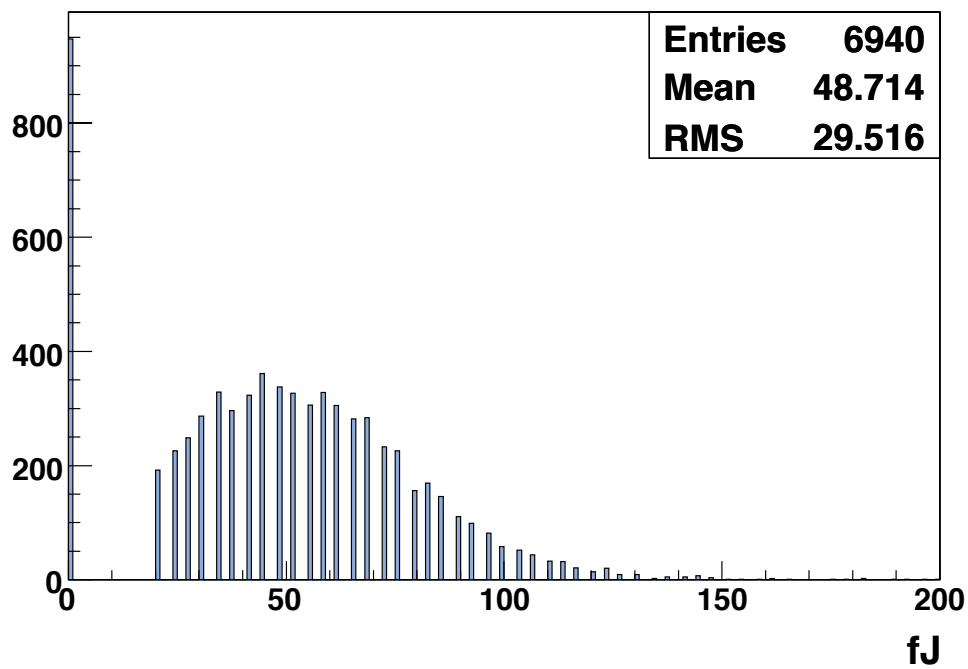


Figure 4: Histogram of measured background energy. Probe is oriented toward beam, but lowered 4cm below beam level. Laser has a $1\mu\text{m}$ pinhole beam mask with an energy of $13.6\mu\text{J}$. Additional power above background seen in Fig. 3 is Rayleigh scattered light measured off-axis.

Rayleigh Energy (10cm)

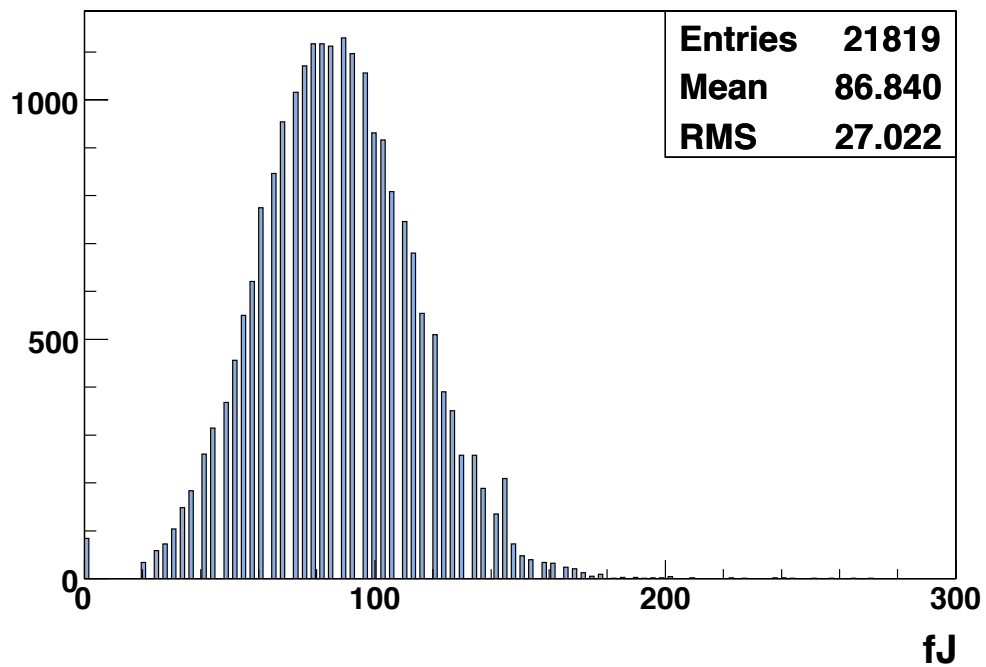


Figure 5: Rayleigh scattering measured directly at a distance of 10cm from beamline. Laser has a $1\mu m$ pinhole beam mask with an energy of $13.6\mu J$.

Rayleigh Energy (7.75cm)

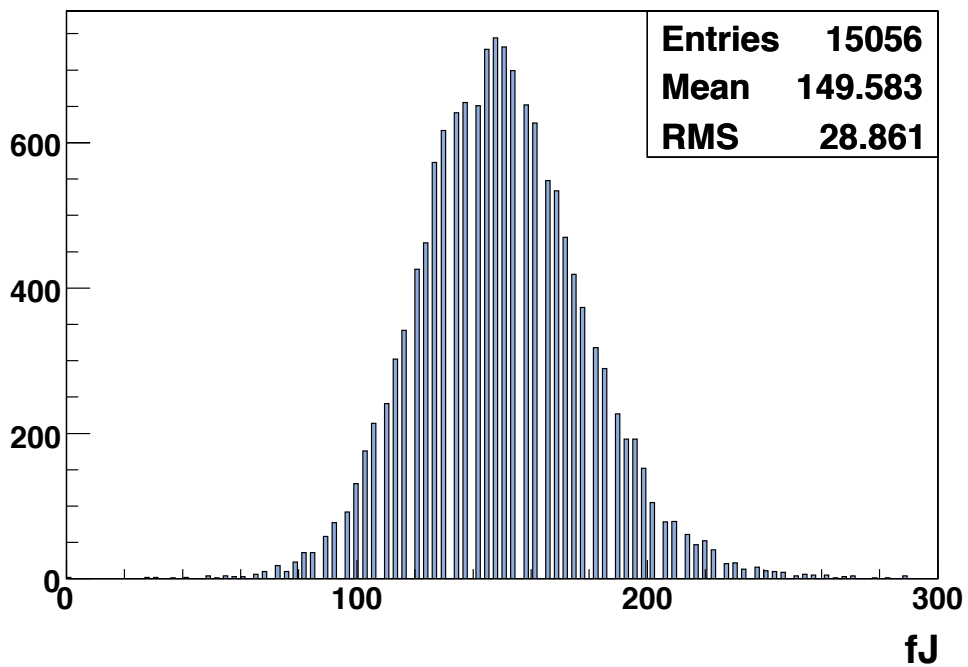


Figure 6: Rayleigh scattering measured directly at a distance of 7.75cm from beamline. Laser has a $1\mu\text{m}$ pinhole beam mask with an energy of $13.6\mu\text{J}$.