APF Light Sources for the Auger Southern Observatory

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Abstract

The air fluorescence signal from extensive air showers includes backgrounds from scattered Cherenkov light and from multiple scattered light. The dominant limitations in estimating, and thus correcting for, these backgrounds come from uncertainties in the aerosol attenuation length and in the aerosol differential scattering cross section. This paper discusses dedicated light sources used to measure the aerosol differential scattering cross section every hour during Auger fluorescence data taking.

1. Introduction

The light from an extensive air shower includes an isotropic air fluorescence signal plus Cherenkov light (mostly in a few degree cone centered on the air shower axis [1]). Through scattering of the Cherenkov light in the air, some of the Cherenkov light appears as a background in the fluorescence data. The fraction of Cherenkov light scattered on aerosols depends on the aerosol attenuation length (related to the aerosol total cross section). The fraction scattered into a given direction depends additionally on the aerosol phase function (APF): *i.e.* the normalized aerosol differential scattering cross section. To minimize direct Cherenkov light in the fluorescence signal, fluorescence detectors typically view showers at angles $> 20^\circ$ (from the shower axis). Thus the APF needs to be known for scattering angles $\gtrsim 20^\circ$.

The observed light from an extensive air shower will also include a contribution of multiple scattered light. This will be true for the air fluorescence signal and for the Cherenkov background light. To make this correction, it is most important to know the aerosol phase function at forward scattering angles where Mie dominates Rayleigh scattering.

As the aerosol phase function is *a priori* unknown and varies in time, the Auger experiment includes dedicated "APF" light sources to measure the aerosol phase function every hour during Auger fluorescence data taking. The APF light sources provide a near-horizontal, pulsed light beam directed across the field of view of a near-by fluorescence detector [14]. As Auger fluorescence detectors view

pp. 873–876

Fig. 1. Three light sources are shown facing the UV transmitting window. The white enclosure (on shelf) contains the solar power regulator and storage battery.

$\sim 180^\circ$ in azimuth, even a fixed direction light beam will allow the aerosol phase function to be measured over most of the range of scattering angles.

This paper describes the design of the first APF light sources. These have been installed ~ 1.3km southwest of the Coihueco fluorescence detector.

2. APF light sources

The Auger fluorescence detectors measure fluorescence light over the wavelength range 300nm $\lesssim \lambda \lesssim$ 420nm [9]. To exploit this capability, the APF light source includes three separate light sources at $\sim$ 330nm, 360nm and 390nm. Three sources provide experimental cross checks as well as the potential to measure wavelength variations in the aerosol phase function.

Each light source includes a broad-band xenon flash lamp source [12], an interference filter [3] to select the desired wavelength and a $f_{/1.7}$ Fresnel lens [7] to form a parallel beam with $\lesssim$5mrad divergence. The xenon flash lamps were chosen because of their excellent stability in intensity and pulse shape [9]. CVI filters were selected because of their high energy density damage threshold. Two inch diameter filters were selected so they could be mounted well forward of the xenon light source. Both choices were necessitated because the light sources will occasionally focus the sun (at low angle to the horizon) back through the optics. The optical components were assembled on commercial hex-cell panels [13] using optical table parts [15]. A photograph of the three sources is shown in Fig. 1.

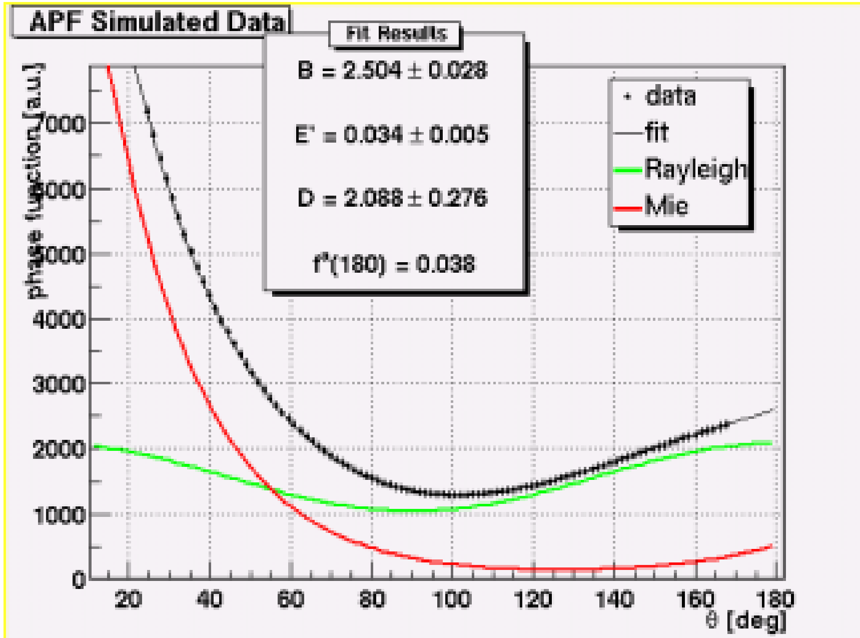

Fig. 2. Simulated Coihueco fluorescence detector telescope signal from the 360nm APF light beam. The curves are from a fit of Rayleigh and Mie scattering to the simulated data using the 3-parameter model.

The sources are mounted in a refurbished 20-foot shipping container [11]. The light beams exit through a UV transmitting window [4]. One light source is enabled at any given time. Computer control is at the Coihueco fluorescence detector building. A serial radio link [16] connects the computer to a commercial ADC/relay system [6] at the light source. When the lights are not operating only the radio link and ADC board are powered. In this mode the current draw is only ~ 0.2A at 12V. Each hour during fluorescence data taking the computer controlled ADC/relay system enables a 1Hz GPS pulser [2], a 12V to 24V inverter to power the xenon flash lamps and then sequentially enables one light source at a time to provide light pulses in the field of view of the Coihueco fluorescence telescopes. The eight 8-bit ADCs monitor the correct operation of the relay-switched components. Solar panels [5] provide 12V power.

3. Simulated signals

The simulated light signal at the Coihueco fluorescence detector is shown in Fig. 2. The source intensity (4μJ/pulse), the aerosol horizontal attenuation length (20km), the fluorescence telescope efficiency (0.125 PEs/photon) and night sky background (21.25 PEs/m^2/μsec) match measured quantities. The intensity *versus* scattering angle (θ) is compared with a prediction of Rayleigh plus Mie scattering. The total Rayleigh scattering probability is based on air density from Auger weather station pressure and temperature measurements. The total Mie scattering probability is based on Auger horizontal attenuation length [8] and backscattered LIDAR [10] measurements. The Mie scattering phase function is modeled with 2-parameters:

$$f^a(\mu) = \frac{1-g^2}{4\pi}\left(\frac{1}{(1+g^2-2g\mu)^{3/2}} + f\frac{3\mu^2-1}{2(1+g^2)^{3/2}}\right)$$

where $\mu = cos(\theta)$ or with 3-parameters:

$$f^a(\theta) = \frac{1}{2\pi}\left(\frac{e^{-B\theta} + E'e^{-D(\pi-\theta)}}{(\frac{1+e^{-B\pi}}{1+B^2}) + \frac{E'(1+e^{-D\pi})}{1+D^2}}\right)$$

4. References

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