Systematic Effects in the Measurement of Vertical Aerosol Profiles at the Pierre Auger Observatory

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Abstract

The Pierre Auger Observatory, located on the high plains of western Argentina, is the result of an international effort to measure the properties of the highest energy cosmic rays with an unprecedented level of precision and statistical significance. The Pierre Auger Observatory is a hybrid detector, consisting of a surface array detecting shower particles reaching ground level, as well as a fluorescence detector which observes the longitudinal development of showers in the atmosphere. One of the distinct advantages of using a hybrid method to detect cosmic ray air showers is that events detected and reconstructed by the fluorescence detector can be used to calibrate the energy determination of the nearly 100% duty cycle surface detector. As such, the fluorescence detector sets the energy scale of the entire Observatory, and it is essential that its energy determination and associated uncertainties are well understood.

In this thesis we investigate a number of systematic uncertainties in the determination of the aerosol loading in the atmosphere above the Observatory. Accurate knowledge of the vertical distribution of aerosols at the Auger site is essential for the accurate reconstruction of shower energy deposit profiles using the fluorescence technique. In this work we focus on three independent systematic effects that have a non-negligible impact on the reconstructed aerosol loading above the Observatory: the determination of nights on which the atmosphere is completely aerosol free, the aerosol scattering of light out of a vertically directed laser beam, and the multiple scattering of that laser light on molecules and aerosol particles on its way to the detector.

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Nomenclature

$\tau_{a,A}$	Vertical aerosol optical depth
τ_{aer}	Vertical aerosol optical depth
H_A	Aerosol atmosphere scale height
H_M	Molecular atmosphere scale height
L_A	Aerosol horizontal attenuation length at ground level
L_M	Molecular horizontal attenuation length at sea level
APF	Aerosol phase function
Auger	The Pierre Auger Observatory
CLF	Central laser facility
DN	Data Normalized
FRAM	Photometric robotic attenuation monitor
HAM	Horizontal attenuation monitor
HEAT	High-elevation Auger telescopes
LS	Laser Simulation
MS	Multiple scattering
TA	The Telescope Array experiment
UHECRs	Ultra-high energy cosmic rays
VAOD	Vertical aerosol optical depth
XLF	Extreme laser facility