The LIDAR Systems for Atmospheric Monitoring in AUGER

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A LIDAR network is being built for the measurement and online monitoring of the atmospheric optical parameters, which play a central role in the energy measurement of ultra high energy cosmic rays (UHECR). Four LIDAR systems, each one equipped by a Nd:YAG UV laser and 3 parabolic mirrors with PMTs for the detection of the backscatter photons, are scheduled to be installed in the proximity of the four fluorescence detectors (FD) of the Pierre Auger Observatory (Malargüe, Argentina). In this paper a report describing hardware components, commissioning and shooting strategies of the LIDAR systems is given.

1. Atmospheric monitoring in Auger

The Pierre Auger Observatory will study UHECR's using two complementary techniques: muon detection at ground level, and atmospheric fluorescence. The fluorescence detector (FD) substantially uses our atmosphere as a calorimeter, to detect the EM component of the cosmic air showers. Given the variability of its parameters, atmospheric monitoring is crucial[1] for our understanding of the energy corrections. A multifold plan of attack [2] is therefore in preparation to get the most thorough understanding of the atmospheric conditions on site. A central role will be played by four LIDAR stations, located at approximately 150 m from each FD site.

The first system has been installed by the FD South Site (Los Leones) in March 2002. It started taking data soon after, to test its impact on the FD activity, define optimal running conditions, and implement controls for full remote operation. Installation of the second system, by the FD West Site (Coihueco) has started in April 2003, and will be completed during the current austral winter. An identical LIDAR setup [3] is also mounted at the Pino Torinese Astronomical Observatory, near Torino, to test possible upgrades.

Figure 1. The LIDAR setup in Los Leones.

2. The LIDAR telescopes

The workhorse of such system will be four fully steerable alt-altazimuthal frames built in 1993 for the EAS-TOP [4] experiment. Each mount is equipped with a UV laser source and 3 parabolical glass mirrors. These mirrors are aluminum coated, have 0.8 m diameter, and $f/0.5$. Mirrors' axes were aligned within 0.1° to the UV laser source.

Two DC servomotors steer the frame axes to speeds up to 2°/s; active feedback is provided by relative encoders. The absolute pointing direction is known with 0.2° accuracy. The whole setup, mounted on a 20' container (as shown in Fig.1), is protected by a fully retractable motorized cover, custom built by a local company. Both frame steering and cover movements are controlled by the MC-204 motion controller, made by Control Techniques, which allows full remote operation of the system, via Ethernet.

The LIDAR shooting activity will follow two schemes: (1) a continuous sky scan on a $\sim 50°$ cone around the zenith direction, outside the FD field of view; and (2) a shoot-the-shower fast sweep of the sky region where an interesting event has been spotted by the FD. A Linux PC, connected via serial ports to all the sub-components, controls the whole system. A GPSY module [5] provides the trigger to the laser source, with a fixed delay with respect to the GPS clock. The NdYAG flashlamp pumped laser source emits 5 ns pulses at λ=355 nm, at a repetition rate up to 20 Hz. Pulse energy is limited to 0.1 mJ, to match the PMT and DAQ dynamic range. The current source is planned to be replaced by a diode pumped YAG laser, to raise the repetition rate above 1 kHz.

The backscattered UV light is focused by each mirror on a Hamamatsu R7400 PMT. To suppress sky background, we use a UG-1 filter with 60% transmittance at 355 nm, FWHM=50 nm. The PMT signals are digitized by a LICEL transient recorder TR40-160 with 12 bit resolution, 40 MHz sampling rate, 16k trace length. The LICEL can be also operated in single photon counting mode at 250 Mhz. Each raw Lidar event from 3 PMTs will be 300 kb wide.

3. Data Analysis

The backscattered power observed at the PMT from distance R is given by the LIDAR equation

$$P(R) = K\frac{\beta(R)}{R^2}e^{-2\tau(R)}$$

where $\beta(R)$ is the backscattering coefficient and the optical depth $\tau(R) = \int_0^R \alpha(r)dr$ is the integral of the extinction coefficient $\alpha(r)$ along the path. Both quantities depend linearly on the density of scattering centers, and are sums of aerosol and molecular contributions: $\alpha(R) = \alpha_{mol}(R) + \alpha_{aer}(R), \beta(R) = \beta_{mol}(R) + \beta_{aer}(R)$.

The molecular contribution can be evaluated with standard models, knowing pressure and temperature vs height from atmospheric measurements. The extraction of the aerosol coefficients from the Lidar equation uses either Klett's [6] or Fernald's [7] inversion algorithms to extract α and β from Lidar shots at a given polar angle θ. Both methods need a priori assumptions on the molecular vs. aerosol parameters functional relation. As an alternative, in case of smooth horizontal variation of atmospheric patterns, a multiangle inversion technique can be used [8], which fully exploits the steering capabilities of Auger Lidar systems. The optical depth $\tau(R)$ is then used to calculate the atmospheric light transmission coefficient T$\sim e^{-\tau(R)}$, to correct the cosmic ray shower energy measurement.

4. Acknowledgments

The authors wish to warmly thank all the staff of the Auger Observatory, as well as D.Melo, A.Risi, M.Santander, A.Tonachini for their contribution to the installation of the two LIDAR systems in Los Leones and Coihueco.

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