Atmospheric Monitoring Systems of the Auger Southern Observatory

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1. Why does Auger need Atmospheric Monitoring?
2. Atmospheric issues for Auger
3. Where is the grammage?
4. Wavelength acceptance of Fluorescence Detectors (FDs)
5. FD motivated atmospheric monitoring
6. Some (Auger) atmospheric monitoring issues
7. Are there broader interests?
1: Why does Auger need *Atmospheric monitoring*?

Schematic of air shower measurements

- Cosmic rays are *observed* as extensive air showers in the earth’s atmosphere
- The atmosphere is:
  1. the showering medium: **composition of primary cosmic rays is related to depth of shower maximum, \( X_{\text{max}} \)**
  2. the readout system: \( \sim 50\text{ppm of shower energy is re-emitted as } N_2 \text{ fluorescence light providing a calorimetric measurement of the shower energy} \)**
2: Atmospheric issues for Auger

Detection method

- Surface Detector (SD): where is the grammage?
- Fluorescence detector (FD) (additionally):
  1. air fluorescence yield (efficiency VS T and P)
  2. light transmission
  3. light multiple scattering correction
  4. scattered Cherenkov background into fluorescence signal
  5. atmospheric inhomogeneities: clouds, fog, smoke ...
3: Where is the *grammage*?

High precision weather stations monitor $T$ and $P$ at each Auger fluorescence site.

- Most of the air shower is within the troposphere
- Weather stations, plus the adiabatic and/or seasonal models, provide a 0$^{th}$ vertical profile of $T$ and $P$ and thus the relation between shower depth in $gm/cm^2$ and elevation in meters
- Radiosonde flights show significant variations...
4: Wavelength acceptance of Fluorescence Detectors

![Fluorescence Detector Efficiency VS Wavelength](image)

**Piece-by-piece estimate of Auger FD efficiency VS wavelength.**

- Major N$_2$ fluorescence lines at 314/316nm, 337nm, 354/358nm, 376/381nm, 391nm, and 400/406nm
- Rayleigh scattering ($\Lambda(360\text{nm}) \approx 18.5\text{km}$) weights spectrum to longer wavelength lines for distant showers
- Frequency tripled YAG (335nm) near middle of the FD wavelength acceptance
5: FD motivated atmospheric monitoring

Ordered by importance ...

- *clouds*:
  1. cloud monitors: (4) steerable IR cameras
  2. shoot-the-shower: (4) steerable LIDARs and IR cameras immediately after a “big” shower

- *transmission corrections* ... depend on total (light) scattering cross sections:
  1. aerosols: (4) steerable LIDARs, central laser facility (CLF) vertical laser, (3) horizontal attenuation length (HAM) monitors, star monitor
  2. molecular: (5?) weather stations, radiosonde balloons
  3. ozone: – SUGGESTIONS?

- *multiple scattering* and *air Cherenkov corrections* ... depend on differential (light) scattering cross sections:
  1. Definitions: \( \frac{d\sigma(\varepsilon,\Lambda)}{d\Omega} = \sigma \cdot \frac{1}{\sigma} \cdot \frac{1}{\Lambda} \cdot \frac{1}{\sigma} \) where \( \Lambda(z, 355\text{nm}) \) is the extinction length (from transmission corrections) and \( \frac{1}{\sigma} \) is the phase function
  2. aerosol phase function: (2) APF light sources
  3. molecular phase function: Rayleigh scattering
Specifications

- Raytheon 2000B OEM digital IR camera
- 320 x 240 pixels  $(0.15^\circ)$
  FOV = 46° x 35°
- spectral range 7-14 µm
  (matches cloud spectrum)
- 12 bit resolution
- maximum frame rate 30 Hz
Implementation
6: Some (Auger) atmospheric monitoring issues ...

- “Ground” level measurements monitor (aerosol) wavelength dependence:
  
  1. HAM systems monitor $\Lambda^a$ at 365nm, 405nm, 436nm and 542nm
  2. APF sources monitor aerosol $\frac{1}{\sigma} \frac{d\sigma}{d\Omega}$ at $\sim$ 330nm, 360nm and 390nm

  **but how do we extrapolate to heights above “ground” level?**

- Large number of atmospheric monitoring experiments:
  
  1. Can all of the hardware be maintained (and kept calibrated)?
  2. Can all of the cross checks be implemented and then maintained?
  3. Should some measurements be done differently?
Proposed Layout of Completed HAM System
3 Lamp / Receiver Systems.

Los Leones to Coihéco (HAM 1 prototype) 44.5 km
Coihéco to Los Morados (HAM 2) 57.4 km
Coihéco to Norte (HAM 3) 45 km
General Equipment Configuration for Receiver and Lamp.

Receiver System

Lamp System

50 Km
Wavelength Correlations (2001-2002 HAM Data)

L404 vs L365 (aer)

L436 vs L365 (aer)

L542 vs L365 (aer)

L542 vs L436 (aer)
UV Att Lengths (2001-2002 HAM Data)

- **ID**: 100
- **Entries**: 288
- **Mean**: 12.35
- **RMS**: 3.021

**Tot. Att Length 365 nm**

- **ID**: 200
- **Entries**: 246
- **Mean**: 37.51
- **RMS**: 21.05

**Aerosol Att Length 365 nm**
7: Are there broader interests?

- To what extent are the Auger atmospheric data of interest to a broader community?

1. The Auger monitoring covers an area of perhaps 75km × 75km
2. Communications infra-structure would allow for additional atmospheric monitoring ...
3. Some restrictions exist on (laser) wavelengths and intensities ...