Studies in the atmospheric monitoring at the Pierre Auger Observatory using the upgraded Central Laser Facility

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Laser Test-beams at the Pierre Auger Observatory

- Observatory studies Ultra High Energy Cosmic Rays (UHECR) using a hybrid technique:
  - A Fluorescence Detector (FD) (27 telescopes distributed at 4 sites)
  - A Surface Detector (1660 stations spread over ~3000 km^2)
- Unbiased FD reconstruction needs atmospheric monitoring
- Two "laser test beams" provide laser pulses at energies equivalent to a 50 EeV air shower

Central Laser Facility (CLF)

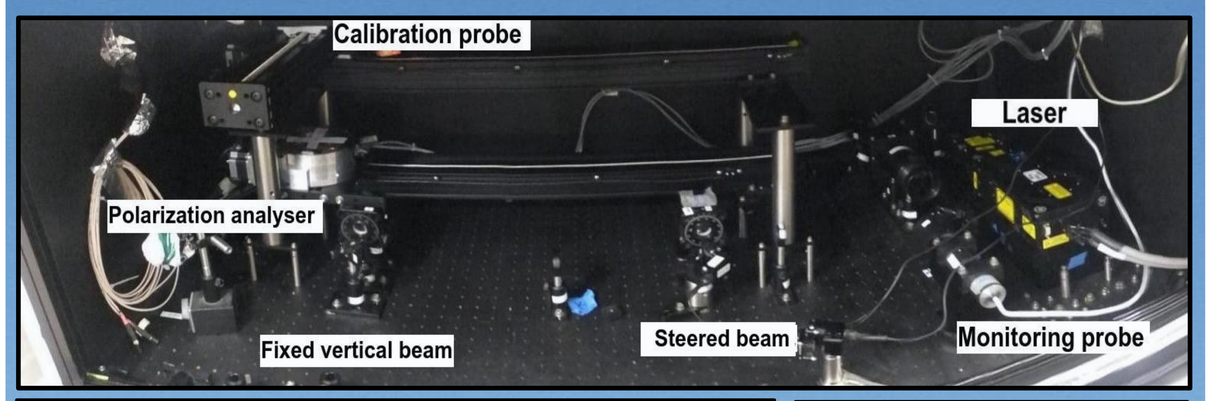
eXtreme Laser Facility (XLF)

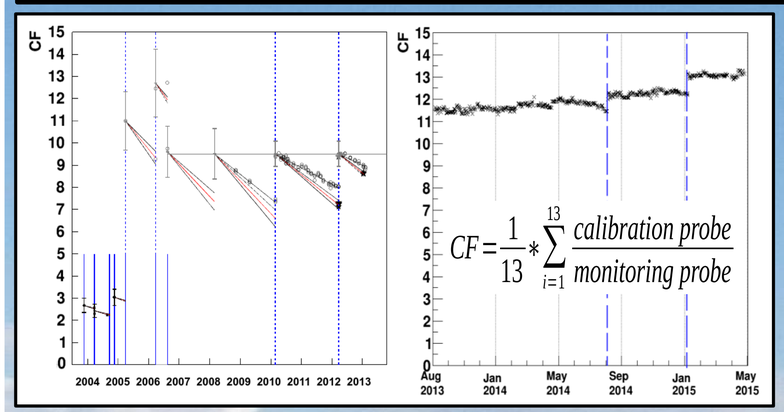
The CLF upgrade

- Includes a back scatter Raman LIDAR
- Solid state laser controlled with improved GPS system
- Better sealed 40 ft container with a 2000 liter thermal reservoir
- A robotic system for automatic energy and polarization calibrations
- Laser facilities are automatically operated and remotely programmed

Automatic (energy + polarization) calibration

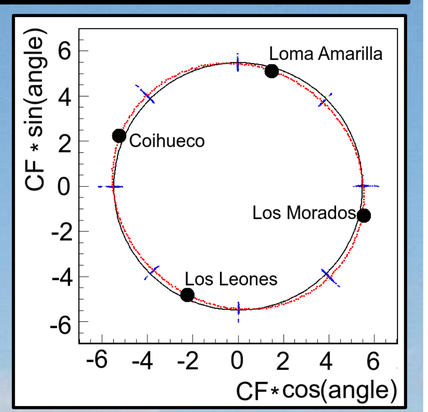
- Pre-upgraded CLF needed manual energy measurements
- New system measures the absolute laser energy and provide a Calibration Factor (CF) on a daily basis
- New system measures the polarization of the beam





CF PRE-UPGRADE

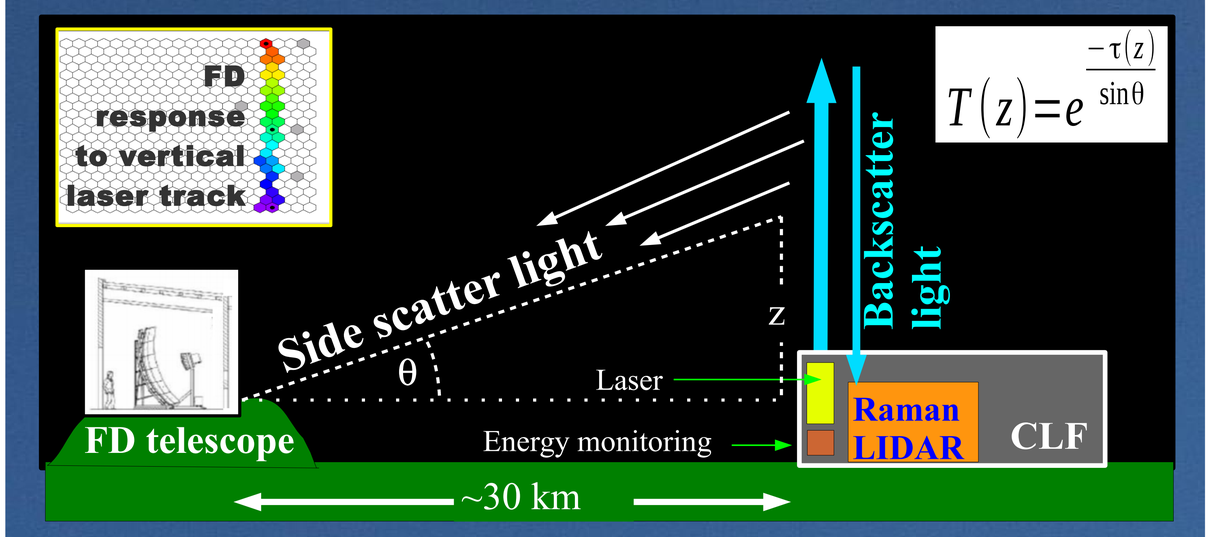
CF POST-UPGRADE



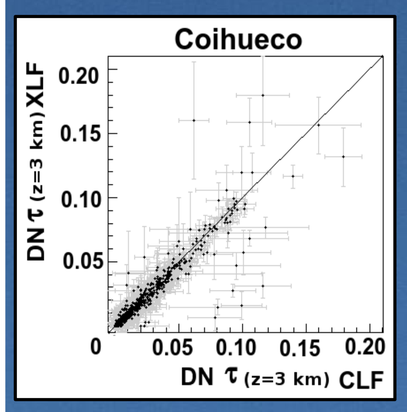
POLARIZATION

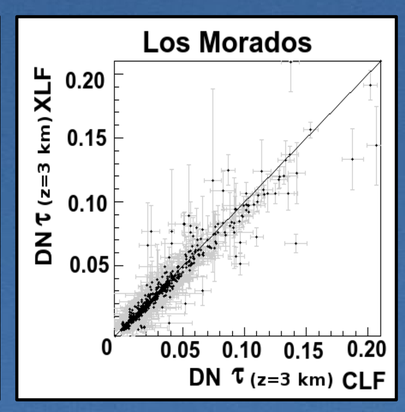
Vertical aerosol optical depth τ(z,t) measurements

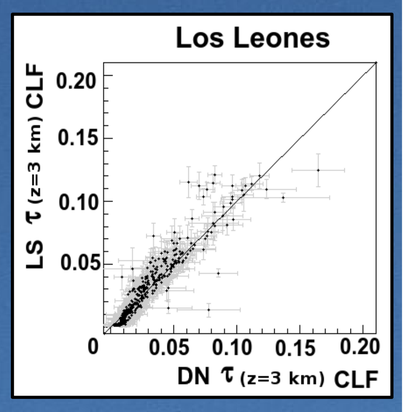
- FD measures τ(z,t) using the scattered light from the laser facilities
- Atmospheric transmission (T) can be described in terms of τ(z,t)



- Side scatter method for τ(z,t) measurements:
  - Data Normalized (DN) analysis compares FD laser tracks against a reference one obtained during a night free of aerosols
  - Laser Simulation (LS) analysis compares FD laser tracks against a set of simulated responses with different atmospheric parameters
- τ(z,t) values fill a atmospheric database for use in FD reconstructions





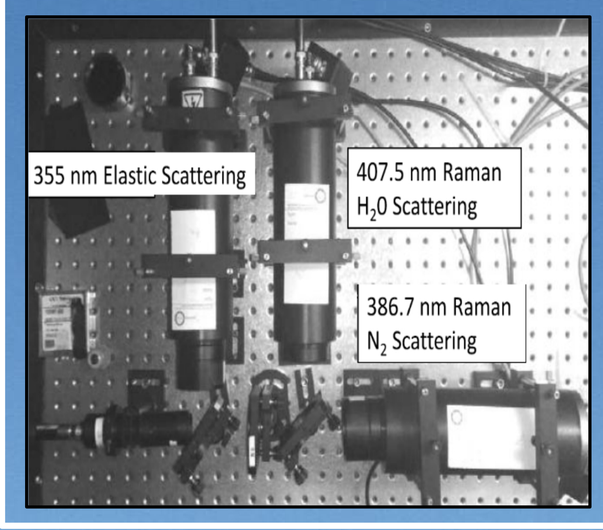


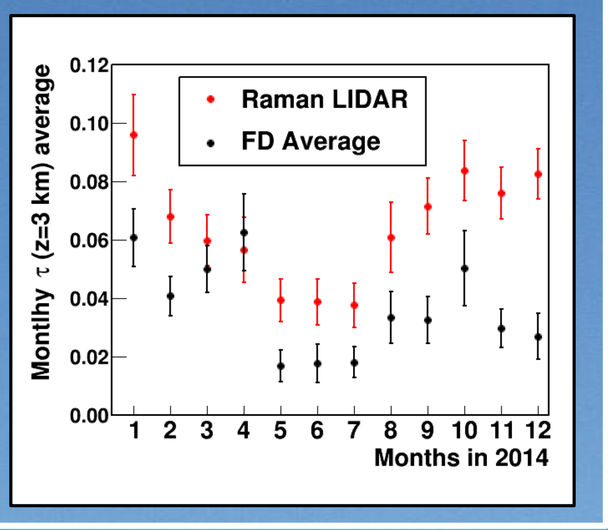
Same analysis, different laser source

Different analysis, same laser source

The Raman LIDAR receiver at the CLF

- Independent method for τ(z,t) measurements
- One elastic channel, two Raman channels (see photo below)
- N_2 Raman Scattering provides a known "atmospheric mirror"
- Preliminary Raman measurements show higher τ(z=3km) than FD side scattering measurements
- Seasonal variations are observed





Conclusions

- τ(z,t) is a critical parameter to accurately measure the energy and composition of UHECR
- The CLF upgrade has been completed, including the first Raman LIDAR at a UHECR observatory
- The Auger Observatory now has two independent methods to measure τ(z,t): the side scattering method and the Raman method
- One year of Raman data collection, two measurements per night
- Differences between the measurements are being evaluated, including the systematic uncertainties and possible physics implications

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