Atmospheric Monitoring Systems of the Auger Southern Observatory

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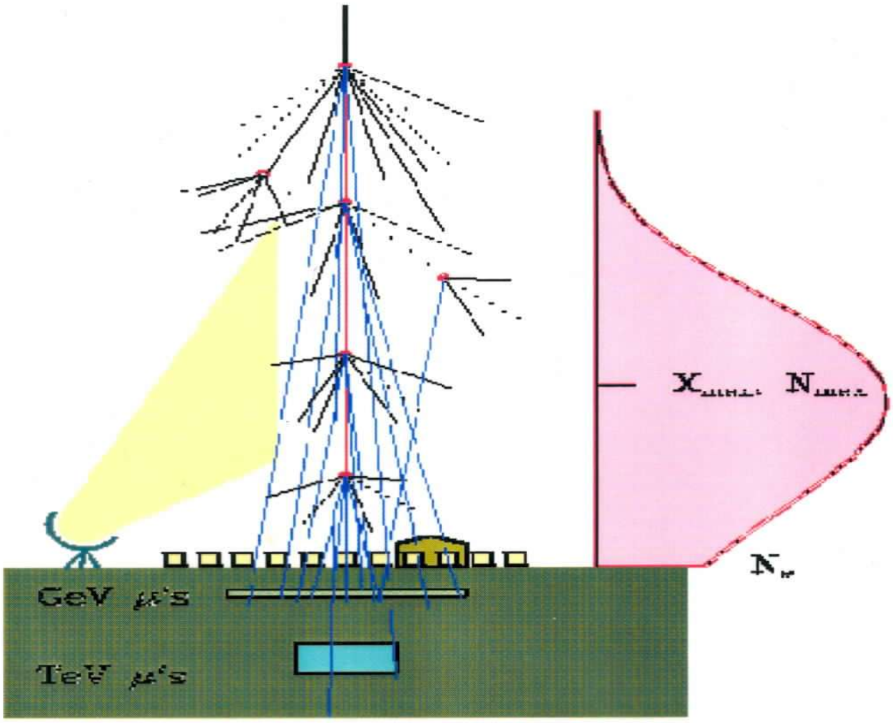
1. Why does Auger need *Atmospheric Monitoring*?
2. Atmospheric issues for Auger
3. Where is the *grammage*?
4. Wavelength acceptance of Fluorescence Detectors (FDs)
5. FD motivated atmospheric monitoring
6. Some (Auger) atmospheric monitoring issues
7. Are there broader interests?

1: Why does Auger need *Atmospheric monitoring*?

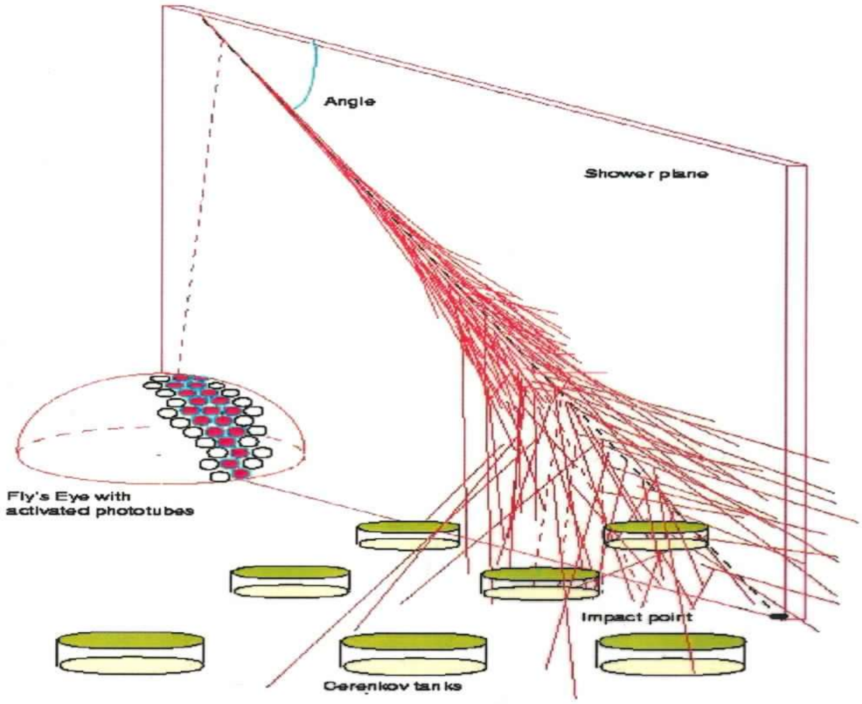


Schematic of air shower measurements

- 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_{max}**
  2. the readout system: $\sim$ 50**ppm of shower energy is re-emitted as N_2 fluorescence light providing a *calorimetric* measurement of the shower energy**

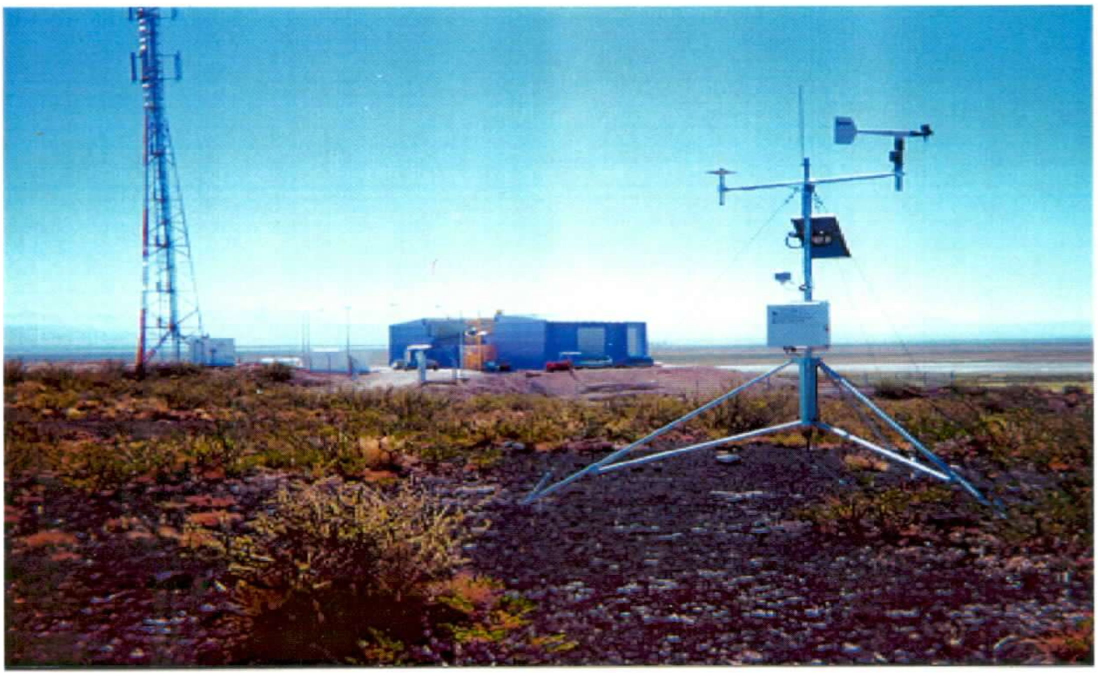
2: Atmospheric issues for Auger

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 ...

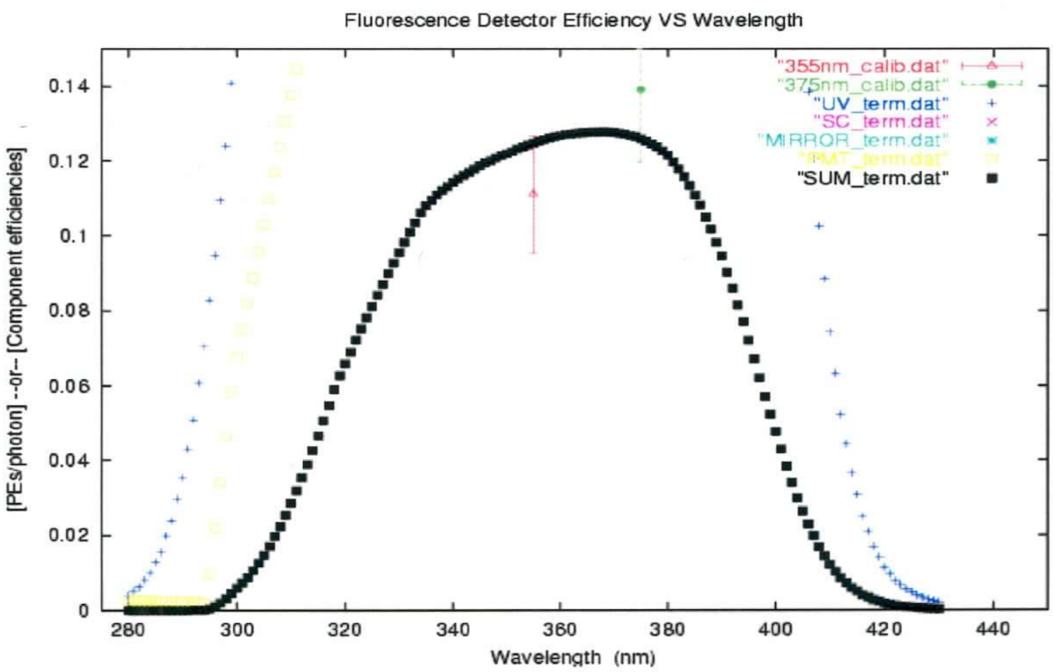
3: Where is the *grammage*?



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



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 ($\Lambda(360nm) \approx$ 18.5km) 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?

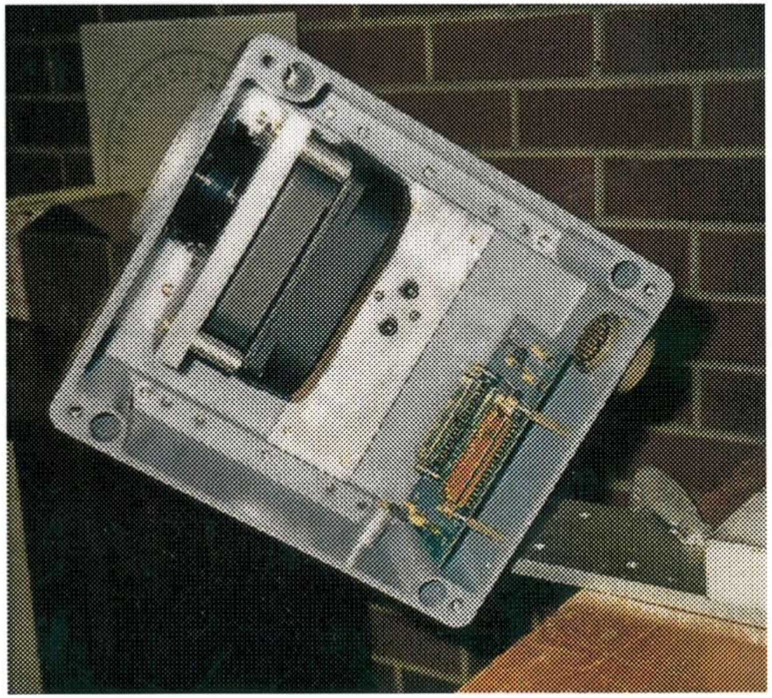
- *multiple scattering* and *air Cherenkov corrections* ... depend on differential (light) scattering cross sections:
  1. Definitions: $\frac{d\sigma(z,\lambda)}{d\Omega} = \sigma \cdot \frac{1}{\sigma}\frac{d\sigma}{d\Omega} \propto \frac{1}{\Lambda} \cdot \frac{1}{\sigma}\frac{d\sigma}{d\Omega}$ where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

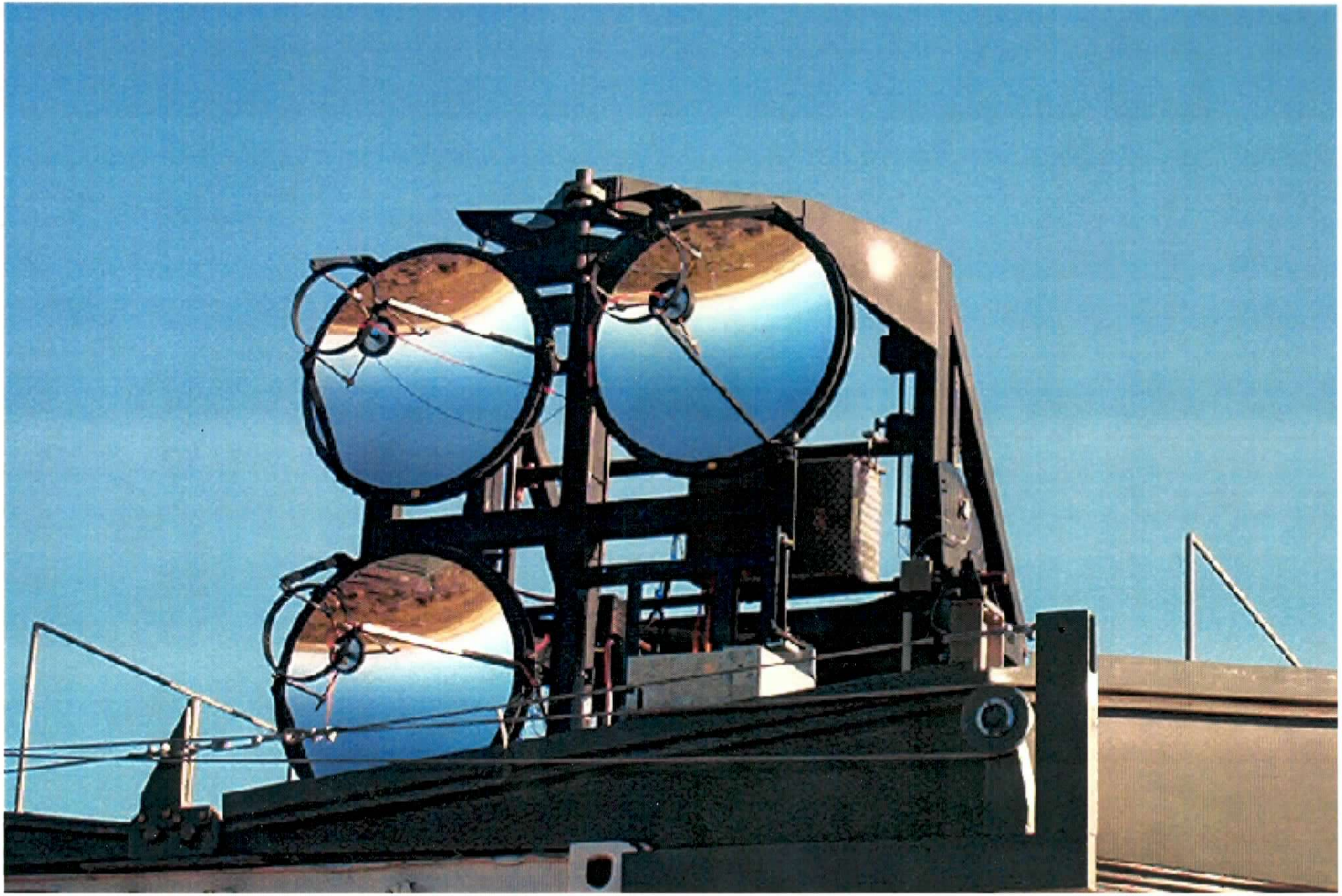
Specifications

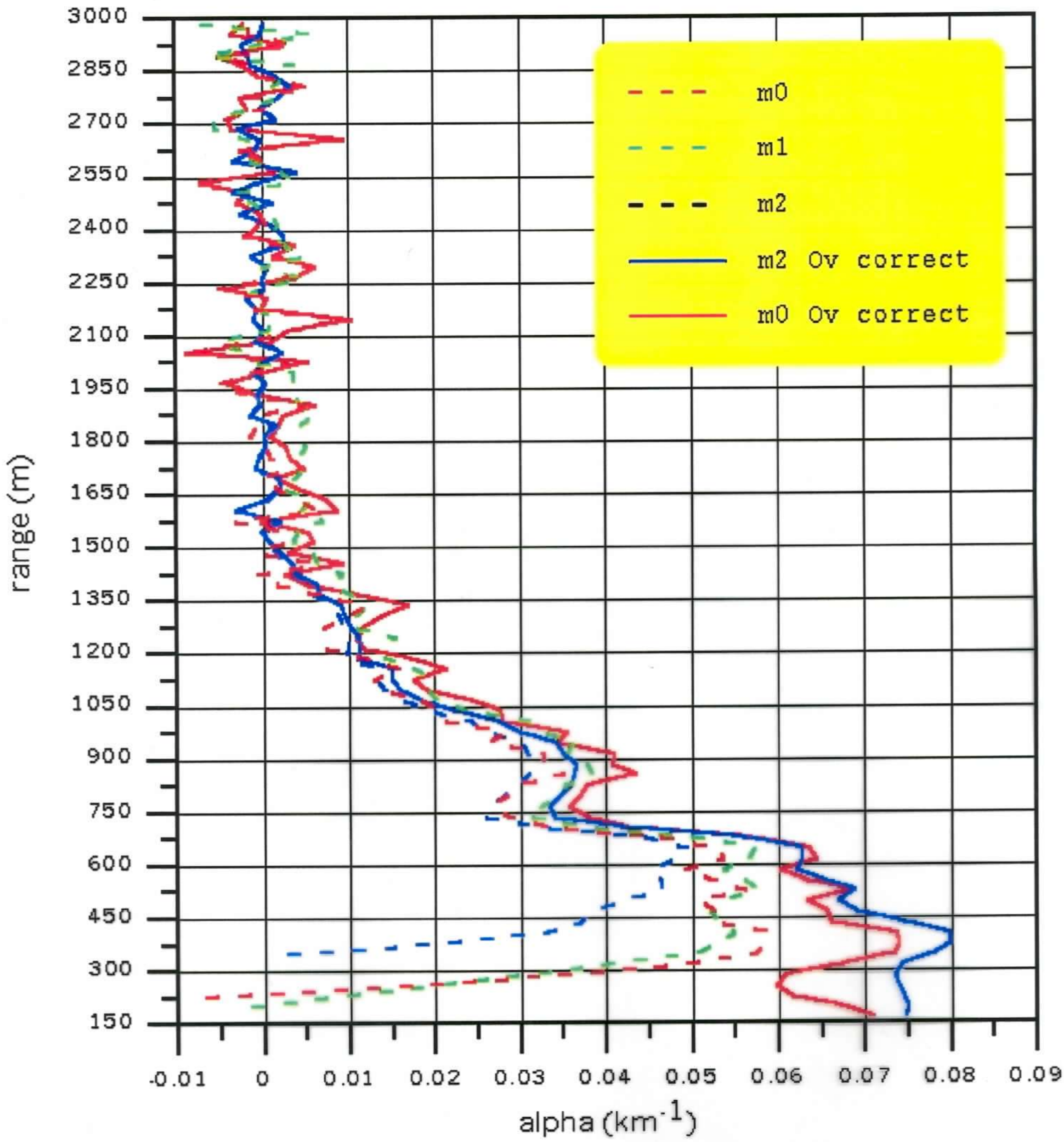
- Raytheon 2000B OEM digital IR camera
- 320 x 240 pixels (0.15°) FOV = 46° x 35°
- spectral range 7-14 μm (matches cloud spectrum)
- 12 bit resolution
- maximum frame rate 30 Hz

Implementation

PIERRE
AUGER
OBSERVATORY






m0
m1
m2
m2 Ov correct
m0 Ov correct
range (m)
alpha (km-1)
3000
2850
2700
2550
2400
2250
2100
1950
1800
1650
1500
1350
1200
1050
900
750
600
450
300
150
-0.01
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09

6: Some (Auger) atmospheric monitoring issues ...

- "Ground" level measurements monitor (aerosol) wavelength dependence:
  1. HAM systems monitor Λ^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

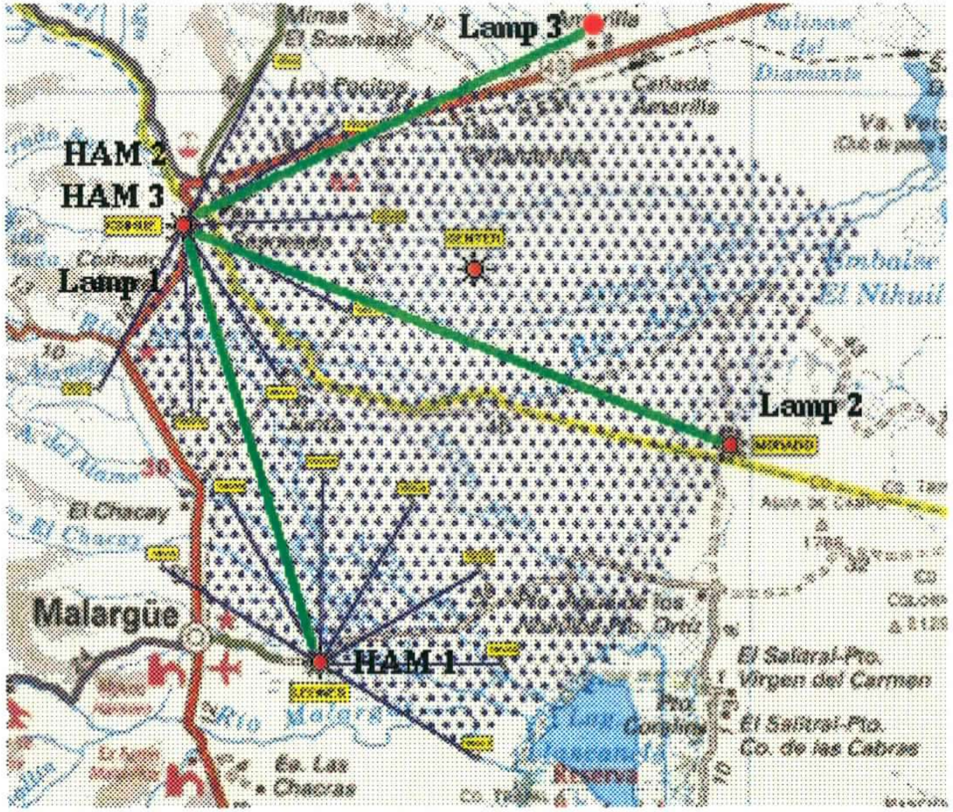
  but how do we extrapolate to heights above "ground" level?

- 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?

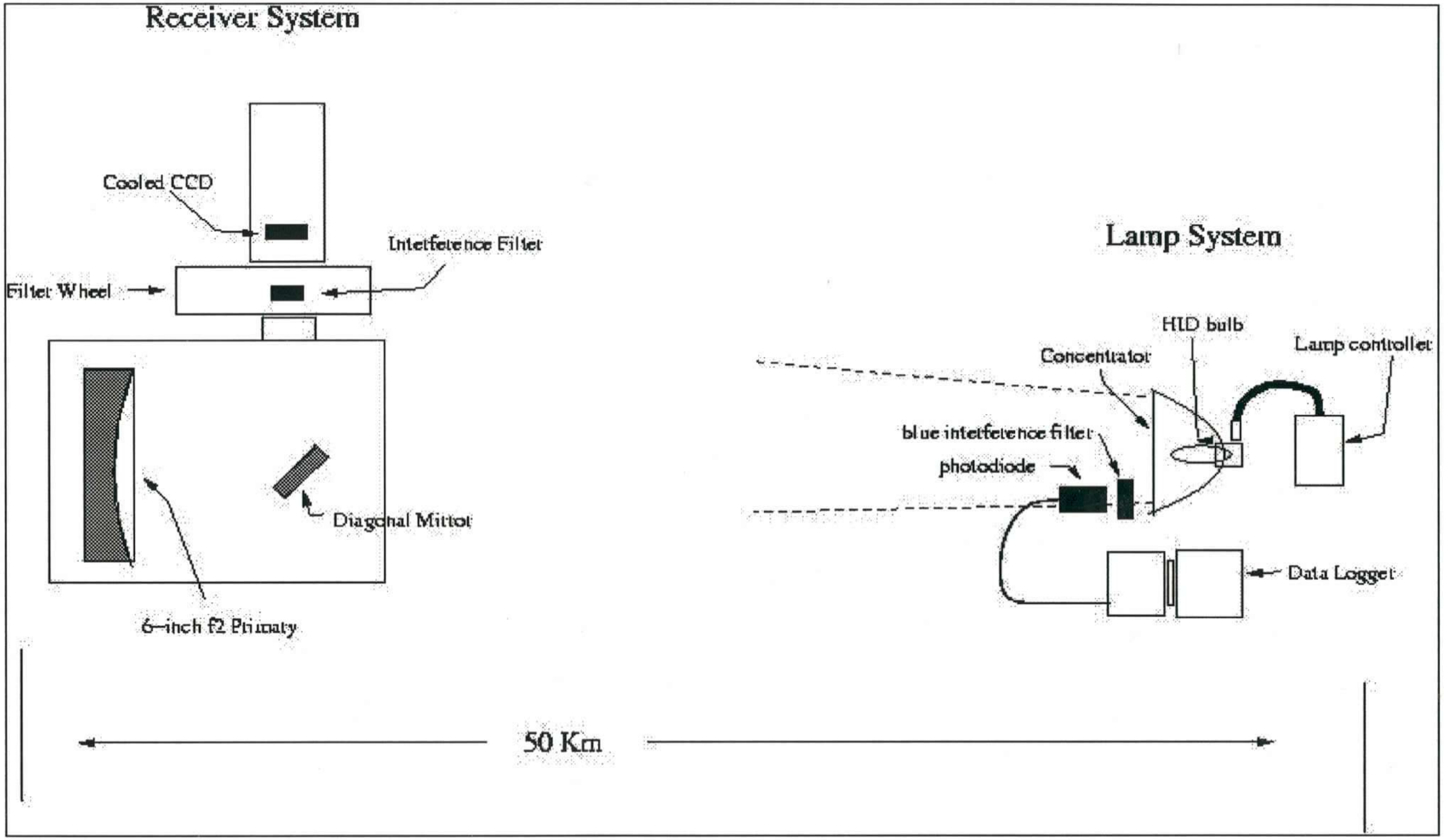
Proposed Layout of Completed HAM System

3 Lamp / Receiver Systems.

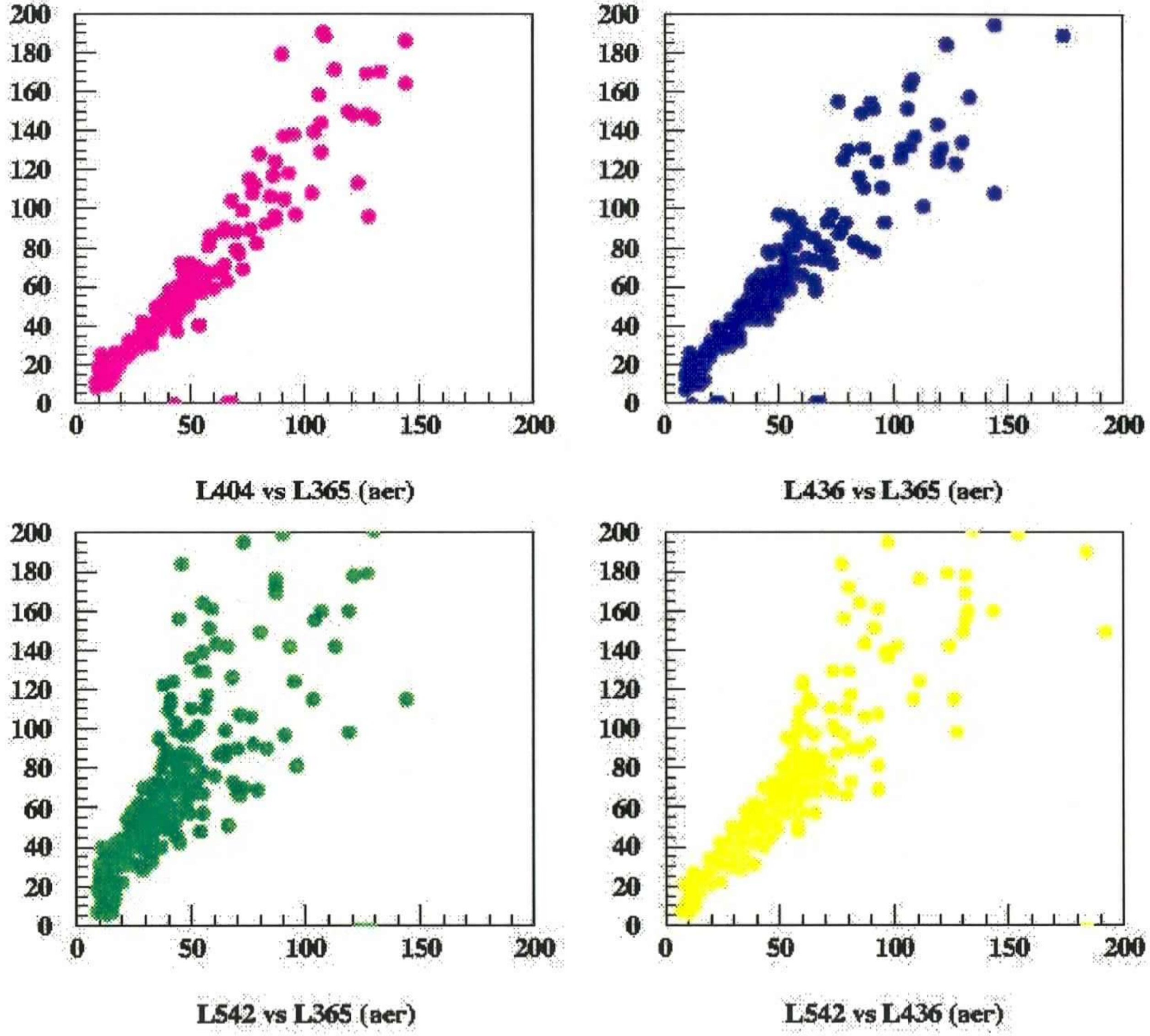
Los Leones to Coiheco	(HAM 1 prototype)	44.5 km
Coihueco to Los Morados	(HAM 2)	57.4 km
Coihueco to Norte	(HAM 3)	45 km



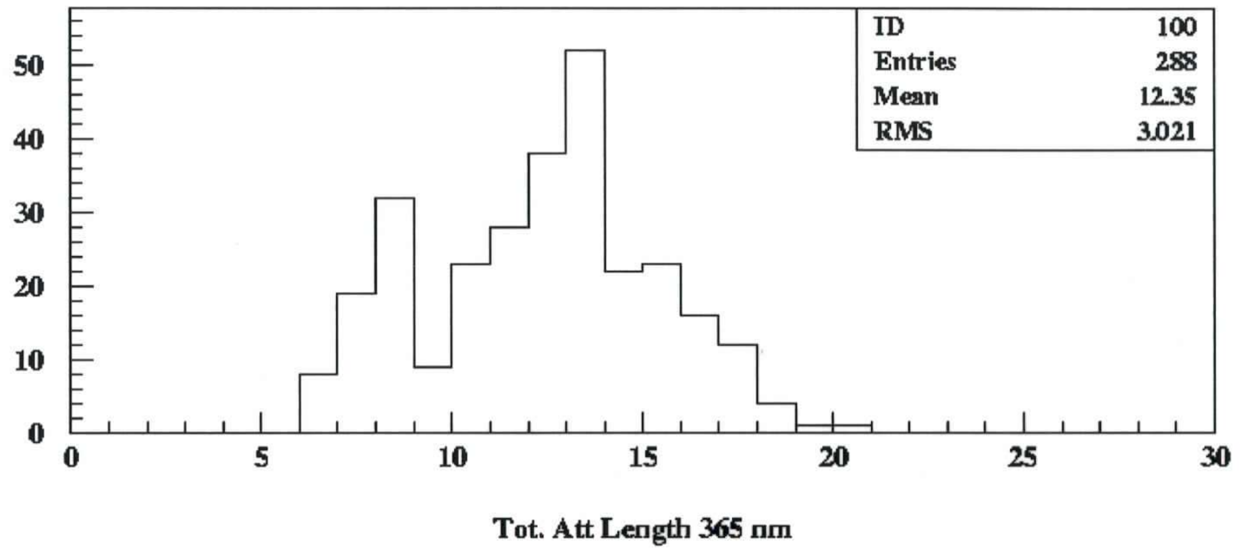
General Equipment Configuration for Receiver and Lamp.

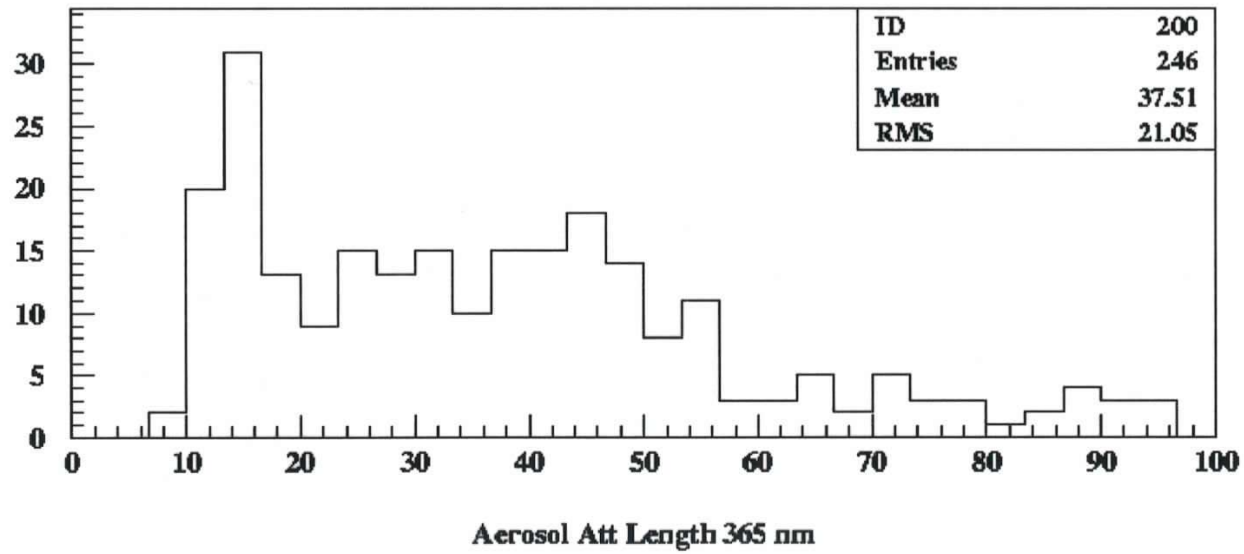


Wavelength Correlations (2001-2002 HAM Data)



UV Att Lengths (2001-2002 HAM Data)





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 ...