Systematic Uncertainties in Cosmic Ray Energies Measured by the Auger Fluorescence Detectors

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Contents

Abstract ix

Statement of Originality xi

Acknowledgements xiii

List of Figures xxviii

List of Tables xxx

1 Introduction 1

2 Cosmic Rays 3
   2.1 Energy Spectrum 4
   2.2 Composition 10
   2.3 Origin of UHECR 15
      2.3.1 Fermi Acceleration 15
      2.3.2 Astrophysical Sources 18
      2.3.3 Propagation 19
      2.3.4 Energy losses and GZK processes 20
   2.4 Anisotropy 23

3 Physics of Extensive Air Showers 25
   3.1 Heitler Model 25
   3.2 Hadronic component 27
3.3 Electromagnetic component 27
3.4 Muon component 29
3.5 Longitudinal Profile 30
3.6 Fluorescence Light 31
  3.6.1 Electron excitation and radiative de-excitation 32
3.7 Cherenkov Light 36
3.8 Detection Techniques 38
  3.8.1 Surface Array Detectors 38
  3.8.2 Fluorescence Detectors 38
  3.8.3 Initial Experiments 39
    3.8.3.1 The Fly’s Eye experiment 40
    3.8.3.2 The HiRes experiment 40
    3.8.3.3 Telescope Array 40
    3.8.3.4 ASHRA 41
    3.8.3.5 JEM-EUSO 41
  3.8.4 Radio Detectors 41

4 Pierre Auger Observatory 43
  4.1 Surface Detector System 43
    4.1.1 Surface Detector Energy Calibration 45
  4.2 Fluorescence Detector System 50
    4.2.1 Fluorescence Detector Calibration 51
      4.2.1.1 Absolute Calibration 52
      4.2.1.2 Relative Calibration 52
  4.3 Auger South Enhancements 53
    4.3.1 HEAT 54
    4.3.2 AMIGA 55
    4.3.3 AERA 56
  4.4 Auger North 56
    4.4.1 Physics Motivation and Potential 57
    4.4.2 Site Configuration 59

5 Results from the Pierre Auger Observatory 63
  5.1 Energy Spectra 63
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1.1 Surface detector spectrum</td>
<td>64</td>
</tr>
<tr>
<td>5.1.2 Hybrid spectrum</td>
<td>65</td>
</tr>
<tr>
<td>5.1.3 Combined spectrum</td>
<td>65</td>
</tr>
<tr>
<td>5.1.4 Systematic Uncertainties</td>
<td>66</td>
</tr>
<tr>
<td>5.2 Composition Studies</td>
<td>67</td>
</tr>
<tr>
<td>5.2.1 Neutrino and Photon Limits</td>
<td>69</td>
</tr>
<tr>
<td>5.3 Anisotropy</td>
<td>72</td>
</tr>
<tr>
<td>5.3.1 Statistical Significance</td>
<td>72</td>
</tr>
<tr>
<td>5.3.2 Posteriori Analysis</td>
<td>75</td>
</tr>
<tr>
<td>5.4 Astrophysical Models</td>
<td>76</td>
</tr>
<tr>
<td>5.5 Conclusion</td>
<td>77</td>
</tr>
<tr>
<td>6 Vapour pressure dependence of the Air Fluorescence Yield</td>
<td>79</td>
</tr>
<tr>
<td>6.1 Air Fluorescence Yield</td>
<td>80</td>
</tr>
<tr>
<td>6.2 Atmospheric Profiles</td>
<td>81</td>
</tr>
<tr>
<td>6.3 Atmospheric Monitoring</td>
<td>82</td>
</tr>
<tr>
<td>6.3.1 Weather Stations</td>
<td>83</td>
</tr>
<tr>
<td>6.3.2 Cloud Cameras</td>
<td>83</td>
</tr>
<tr>
<td>6.3.3 Infra-red Vertical Cloud Monitor</td>
<td>86</td>
</tr>
<tr>
<td>6.3.4 LIDAR</td>
<td>86</td>
</tr>
<tr>
<td>6.3.5 Central and eXtreme Laser Facilities</td>
<td>89</td>
</tr>
<tr>
<td>6.4 Collisional quenching by water vapour</td>
<td>89</td>
</tr>
<tr>
<td>6.4.1 Measurement of quenching parameters</td>
<td>90</td>
</tr>
<tr>
<td>6.5 Vapour Pressure Profiles</td>
<td>91</td>
</tr>
<tr>
<td>6.6 Seasonal Profiles</td>
<td>92</td>
</tr>
<tr>
<td>6.6.1 Implementing the correction</td>
<td>93</td>
</tr>
<tr>
<td>6.6.2 Shift in reconstructed parameters</td>
<td>93</td>
</tr>
<tr>
<td>6.6.3 Uncertainties in seasonal profiles</td>
<td>94</td>
</tr>
<tr>
<td>6.7 Cloud Cover</td>
<td>97</td>
</tr>
<tr>
<td>6.7.1 Identifying Overcast Days</td>
<td>97</td>
</tr>
<tr>
<td>6.7.2 Statistics</td>
<td>97</td>
</tr>
<tr>
<td>6.8 Comparing ‘Cloudy’ and ‘Clear’ Seasonal Profiles</td>
<td>99</td>
</tr>
<tr>
<td>6.9 Discarding Day-time launches</td>
<td>102</td>
</tr>
</tbody>
</table>
6.10 Creating Monthly Profiles
   6.10.1 Moving boxcar profile 105
   6.10.2 Shift in reconstructed parameters 105
   6.10.3 Uncertainties in monthly profiles 106

6.11 Including the effect of temperature dependent collisional cross-sections into the fluorescence yield 110
   6.11.1 Shift in reconstructed parameters 110
   6.11.2 Overall changes to Reconstruction of Hybrid Showers 114

6.12 Techniques for reducing uncertainties on Vapour Pressure Profiles 114
   6.12.1 Re-scaling monthly models 114
   6.12.2 Using sky temperature measurements 122

6.13 Conclusion 125

7 Residual light
   7.1 Lateral Width 127
   7.2 Atmospheric Transmittance 129
      7.2.1 Rayleigh Scattering 129
      7.2.2 Aerosol Scattering 130
      7.2.3 Absorption 132
   7.3 Multiple Scattering of Fluorescence Light 132
   7.4 Residual halo 135
   7.5 Fractional Increase 137
   7.6 Search for Correlation 138
      7.6.1 Selection Criteria 138
      7.6.2 Initial Search for Correlations 139
      7.6.3 Method required for further study 145
   7.7 Shower age correlation 145
      7.7.1 Creating correlation coefficients dependent on angular acceptance 145
   7.8 Scattering probability correlation 149
   7.9 Final Parametrisation 153
   7.10 Implementation into Offline 156
   7.11 Results 156
8 Lateral Distribution Function

8.1 Spot Reconstruction Method
8.2 Spot Model
  8.2.1 Optical Spot
  8.2.2 Lateral Width of Shower
  8.2.3 Mercedes Correction
8.3 Investigation of the spot model
  8.3.1 CORSIKA
  8.3.2 Particle Thinning
  8.3.3 Calculation of Energy Deposit
    8.3.3.1 Ionisation by tracked particles
    8.3.3.2 Below the energy threshold
8.4 Previous Parametrisation of the LDF
  8.4.1 Energy and Composition Dependence
  8.4.2 Zenith Angle Dependence
8.5 Extending to larger ages
8.6 Checking Universality of Correction
  8.6.1 Composition and energy independence down to $10^{17}$eV
8.7 Comparing with past parametrisation
8.8 Conclusions

9 Conclusion

A Monthly vapour pressure profiles
Abstract

This work investigates the processes used to reconstruct extensive air showers induced in the atmosphere by ultra high energy cosmic rays. It contributes to the efforts of the Pierre Auger Collaboration, whose members are working to solve many mysteries behind the phenomenon of these particles. Specifically my work has focused on the use of the Pierre Auger Observatory’s fluorescence detectors to determine cosmic ray energies. I have investigated ways to reduce the systematic uncertainties involved in the reconstruction process.

To accurately reconstruct an extensive air shower in order to determine properties of the primary cosmic ray, we need to be able to model how the atmosphere will affect its production and propagation. A precise knowledge of how to interpret the signals received at our detectors is also needed. Inaccurate models or incorrect assumptions may lead to large errors in the shape and magnitude of the true energy spectrum of the cosmic rays which we observe at Earth. We wish to use the information that we gather from this experiment about the energy spectrum, anisotropy and composition of cosmic rays to help locate and study sources, and the acceleration mechanisms that produce their incredible energies. If we are inaccurately reconstructing these extensive air showers then this could lead to incorrect theories being developed. The systematic uncertainties that I have investigated and are presented in my thesis are:

- An unexplained halo of light around the shower track at the fluorescence detector which led me to develop a parameterisation for singly scattered Cherenkov light that we receive at the fluorescence detectors. This parameterisation is a function of
shower evolution, distance to the shower, scattering probability and angular distance from the tracks centre.

- Uncertainty in the nitrogen fluorescence yield due to the humidity dependence of collisional quenching. To take this dependence into account I constructed monthly vapour pressure profiles using data acquired from radiosonde launches conducted above the Pierre Auger Observatory. As the fluorescence detectors are unable to detect air showers on overcast days, launches conducted in overcast conditions were identified and excluded, using infra-red cloud camera data and sky temperature measurements. Methods to reduce the uncertainty on the vapour pressure profiles uncertainties were also investigated.

- Uncertainty in the methods used to interpret the light seen by the fluorescence detectors. When comparing two methods, I found that they differed in their approach to take into account the lateral shower width at large shower ages. This was because the initial parameterisation was only constructed up to shower ages of 1.2. I used the simulation package CORSIKA to check whether the original parameterisation was still valid at ages up to 1.5, and to check its validity down to primary particle energies of $10^{17}$eV.

In addressing these systematic uncertainties, we now have a better understanding of the light that we receive at the Fluorescence Detectors, and of how to collect this light for use in reconstructing extensive air showers to determine the cosmic ray energy spectrum, cosmic ray composition and their arrival directions.
Statement of Originality

I, Vanessa Catherine Holmes certify that this work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. I give consent to this copy of my thesis, when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968. I also give permission for the digital version of my thesis to be made available on the web, via the University’s digital research repository, the Library catalogue and also through web search engines, unless permission has been granted by the University to restrict access for a period of time.

Signature : 

Student : Vanessa Catherine Holmes

Date : 27/09/2011
Acknowlegdements

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List of Figures

2.1 Observed energy spectrum of primary cosmic rays, measured by many different experiments as listed in the legend [5].

2.2 Cosmic ray spectrum [6]. The cosmic ray flux is scaled with $E^{2.7}$ to emphasise the characteristic features. The knee at about $3 \times 10^{15}$ eV and the ankle around $5 \times 10^{18}$ eV can be observed. Furthermore a suppression in the flux around $10^{20}$ eV is visible in the spectra of HiRes and Auger.

2.3 Cosmic-ray energy spectrum for five groups of elements as reconstructed by the KASCADE experiment using the hadronic interaction models: Right: QGSJET 01, and Left: SIBYLL 2.1 to interpret the measured data[9]

2.4 Here we have the energy spectra from HiRes1 and HiRes2 monocular, and from AGASA. The solid line represents a best fit to the HiRes data. Not only is the AGASA data systematically higher, it doesn’t indicate a suppression in flux at the highest energies. Figure from [14].

2.5 Compilation of data on depth of maximum as a function of energy from different experiments compared with predictions for different models [15].

2.6 The mean values of $X_{max}$ and the RMS of $X_{max}$ for proton, He, N and Fe calculated using hadronic interaction models SIBYLL 2.1, QGJET II and QGJET01. Figure from [17].

2.7 Propagated spectra, $\Phi(E) E^3$, for a mixed extragalactic cosmic ray source composition, compared with the HiRes monocular data and the Akeno/AGASA data. In both cases the source spectrum has a power law index of $\alpha = 2.3$, and the ankle corresponds to the transition from the galactic to the extragalactic component [17].
2.8 Same as Figure 2.7, for a pure proton extra galactic cosmic ray source. The injection spectral index is $\alpha = 2.6$ for the HiRes data (left) and $\alpha = 2.7$ for the Akeno AGASA data (right). Two different propagated spectra and the corresponding inferred galactic cosmic ray component are shown, for an injection spectrum either with or without a low energy cut [17].

2.9 Left: Contribution of different elements to the propagated mixed composition spectrum. The GZK suppression can be seen at $10^{19}$ eV for He and $2 \times 10^{19}$ eV for the CNO group. The dotted line shows the contribution of the secondary low mass nuclei (protons and He) resulting from the photodissociation of heavier nuclei. That contribution is responsible for the bump in the spectrum at $5 \times 10^{19}$ eV. Right: Propagated spectra are shown for different values of the maximum proton energy, $E_{\text{max}}(p) = 10^a$ eV, with $a = 19.5, 20.0, 20.2$ and 20.5 [17].

2.10 Left: second order Fermi acceleration mechanism occurring in a moving magnetised cloud. Right: first order Fermi acceleration occurring in strong plane shocks [19].

2.11 Hillas plot showing the size (radius L) and magnetic field strength (B) of possible UHECR sources. Lines indicating the minimum values of L and B required to accelerate protons and iron to $10^{20}$ eV are indicated in the figure. Any objects below these lines are not capable of accelerating these particles to ultra-high energies [23].

2.12 The attenuation length of proton, iron, and gamma-ray primaries in the microwave, infrared, and radio background radiations as a function of energy. Proton 1 is from Yoshida and Teshima [25] and proton 2 from Protheroe and Johnson [26]. Results from Rachen and Biermann [27] and Berezinsky and Grigoreva [28] lie between protons 1 and 2. That of iron is from Stecker and Salamon [29]. That of gamma rays in the total low-energy photon background down to kHz frequencies is shown by the dot-dashed curve from Bhattacharjee and Sigl [30]. Figure comes from [20].

2.13 Significance map showing 4 $\sigma$ excess (see $\sigma$ scale on right hand side of figure) near the direction of the Galactic Centre. Near the direction of the anti-Galactic centre, a 3.7$\sigma$ deficit is seen by AGASA [35].
3.1 (a) shows an electromagnetic cascade, and (b) shows a hadronic induced shower (not to scale) [38].
3.2 Longitudinal profile of the highest energy shower detected by the Fly's Eye experiment. The reconstructed energy was $3 \times 10^{20}\text{eV}$ [44].
3.3 Molecular levels of $N_2$ and $N_2^+$. The broad arrows represent the main transitions (1N and 2P systems) [47].
3.4 Air fluorescence spectrum resulting from excitation of air molecules by 3 MeV electrons at 800 hPa, as measured by the AIRFLY Collaboration [48].
3.5 Total cross sections for the excitation of the electronic states $C^3\Pi_u$ and $B^2\Sigma_u^+$ versus electron energy [49].
3.6 Illustration of the production of Cherenkov light about the particles axis.
3.7 Expected cumulative exposure of JEM-EUSO in Linsley units (1 Linsley = 1 km$^2$sr yr). Evolution of exposure by other retired and running EECR observatories are also shown for comparison. Figure from [61].

4.1 A map of the Pierre Auger Observatory in Argentina. Each water Cherenkov tank is represented by a black dot. The array is surrounded by the four fluorescence stations as shown. The fields of view of the 24 telescopes are indicated by the blue lines.
4.2 Schematic view of a surface detector unit. The tank is equipped with a solar panel, battery, GPS unit and a radio transceiver.
4.3 Lateral distribution: filled circles represent recorded signals. The fitted value $S(1000)$ is marked with a cross. Figure from [67].
4.4 Derived attenuation curve, $\text{CIC}(\theta)$, fitted with a quadratic function.
4.5 Left: Correlation between $\log(S_{38})$ and $\log(E_{FD})$ for the 795 hybrid events used in the fit. The line represents the best fit. Right: Fractional difference between the calorimetric energy, $E_{FD}$, and the energy estimate of the surface detector, $E$, obtained by the calibration curve, for the 795 selected events. The results are a mean of $0.02 \pm 0.01$ and a RMS of $0.17 \pm 0.01$ [67].
4.6 The two segmentation configurations of the FD mirrors. Left: 60 hexagonal glass mirror segments. Right: 36 rectangular mirror segments [68].
4.7 Schematic of the Fluorescence Detector with the drum attached to the aperture [68].
4.8 The cosmic ray energy spectrum as measured by a range of experiments. The energy ranges covered by the Auger South baseline (BL) design, and the added enhancements AMIGA and HEAT are shown [72].

4.9 Illustration showing detector bias to showers coming towards the detector [73].

4.10 This image shows the layout of the enhancements with respect to the current array. The white radial lines from the FD Coihueco illustrate the current telescope fields of view, and the black lines show the fields of view of the high elevation telescopes. The grey and white dots represent the 433 m and 750 m detector spacings respectively and the black dots are the positions of the current detectors [74].

4.11 Illustration of the proposed Auger North site.

4.12 Surface Detector grid configuration for Auger North. The top three rows of tanks show the standard configuration and the bottom three rows illustrate the infill configuration.

5.1 Energy spectrum derived from surface detector data calibrated with fluorescence measurements. Only statistical uncertainties are shown [78].

5.2 Energy spectrum derived from hybrid data. Only statistical error bars are shown [78].

5.3 The fractional difference between the combined energy spectrum of the PAO and a spectrum of the form $E^{-2.6}$. Data from the HiRes instrument [82, 83], are shown for comparison [78].

5.4 Left: Mean depth of shower maximum as a function of shower energy. Right: Mean RMS of depth of shower maximum as a function of energy. Both figures have predicted values for these quantities from a range of different hadronic interaction models [84].
5.5 Limits at 90% CL for each flavor of diffuse UHE neutrino fluxes assuming a proportion of 1:1:1 due to neutrino oscillations. The Auger limits are given using the most pessimistic case of the systematics (solid lines). For the integral, the limit that would be obtained in the most optimistic scenario of systematics is also shown (dashed line). The shaded area corresponds to the allowed region of expected GZK neutrino fluxes computed under different assumptions [87, 88, 89, 90]. The limits from the other experiments shown above are discussed further in [85].

5.6 Upper limits on the photon fraction in the integral cosmic-ray flux for different experiments: AGASA (A1, A2) [91, 92], AGASA–Yakutsk (AY) [93], Yakutsk (Y) [94], Haverah Park (HP) [95, 96]. In black are the limits from the Auger surface detector (Auger SD) [97], and in blue are the limits above 2, 3, 5, and 10 EeV (Auger HYB) derived in [98]. The shaded region shows the expected GZK photon fraction as derived in [99]. Lines indicate predictions from top–down models, see [100, 101, 102].

5.7 Celestial sphere in galactic coordinates showing arrival directions of the 27 highest energy events detected by Auger with \( E > 57 \, \text{EeV} \). These events are depicted by circles of radius 3.1°. 472 AGN from the VCV catalogue within 75 Mpc are represented by red crosses. The blue region defines the field of view of the Auger southern observatory with deeper blue regions indicating areas of higher exposure. The solid curve marks the boundary of this field of view, defined by a zenith angle of 60°. The location of Centaurus A, the closest AGN, is marked with a white star. Two of the 27 events are within 3° of this marker. The super-galactic plane is indicated by the dashed curve, and it represents a region where a large number of nearby AGN are concentrated.
5.8 Monitoring the correlation signal. Left: The sequential analysis of cosmic rays with energy greater than 55 EeV arriving after 27 May, 2006. The likelihood ratio $\log_{10} R$ for the data is plotted in black circles. Events that arrive within $A_{\text{max}} = 3.1^\circ$ of an AGN with maximum redshift $z_{\text{max}} = 0.018$ result in an up-tick of this line. Values above the area shaded in blue have less than 1% chance probability to arise from an isotropic distribution ($p_{\text{iso}} = 0.21$). Right: The most likely value of the binomial parameter $p_{\text{data}} = k/N$ is plotted with black circles as a function of time. The 1$\sigma$ and 2$\sigma$ uncertainties in the observed value are shaded. The horizontal dashed line shows the isotropic value $p_{\text{iso}} = 0.21$. The current estimate of the signal is $0.38 \pm 0.07$. In both plots, events to the left of the dashed vertical line correspond to period II of Table I and those to the right, collected after [1], correspond to period III.[104]

5.9 The distribution of angular separations between the 58 events with $E > 55$ EeV and the closest AGN in the VCV catalogue within 75 Mpc. Left: The cumulative number of events as a function of angular distance. The 68% confidence intervals for the isotropic expectation is shaded blue. Right: The histogram of events as a function of angular distance. The 13 events with galactic latitudes $|b| < 12^\circ$ are shown with hatching. The average isotropic expectation is shaded brown.[104].

5.10 Left: The cumulative number of events with $E > 55$ EeV as a function of angular distance from Cen A. The average isotropic expectation with approximate 68% confidence intervals is shaded blue. Right: The histogram of events as a function of angular distance from Cen A. The average isotropic expectation is shaded brown.[104].

5.11 The combined energy spectrum compared with several astrophysical models assuming a pure composition of protons (red lines) or iron (blue line), a power-law injection spectrum following $E^{-\beta}$ and a maximum energy of $E_{\text{max}} = 10^{20.5}$ eV. The cosmological evolution of the source luminosity is given by $(z+1)^m$. The black line shows the fit used to determine the spectral features.[78].
6.1 Top: Raw infra-red image of the sky above the ground array in the field of view of one of the FD sites. Middle: Processed image in which each pixel is assigned black (no cloud) or white (cloud). Bottom: Middle image overlayed onto the cameras at the FD, where the shade of grey represents the fraction of the pixel contaminated by cloud.

6.2 Coihueco infrared cloud camera images at the beginning of a radiosonde launch, local time 21:35 17/08/2006. The entire field of view is shown. The bright band along the bottom of the images in the top row is the horizon. The images on the top row are the raw images, and the bottom row shows the analysis of the images directly above them. This analysis was performed by PACMan, image processing software developed by Michael Winnick for the collaboration, that determines whether a pixel contains cloud. The white corresponds to cloud, and black to clear sky. The sky appears to be completely clear.

6.3 Coihueco infrared cloud camera images near the beginning of a radiosonde launch, local time 06:40 21/04/2007. The sky appears to be completely overcast.

6.4 This shows the readings from the vertical cloud monitor. The uncompensated temperature is the one that gives us an indication of the cloud cover above the site. It appears to be clear until 0500 hrs UT, and then by 0900 hrs UT the sky is overcast. The readings lose all meaning after the sun appears overhead as the infra-red pixel saturates. This can be seen from 1200 hrs UT onwards.

6.5 Data from a radiosonde launch conducted on 21/04/2007 at 0625 hrs. Both a peak in the relative humidity and a temperature inversion are observed at the same height.

6.6 Top: Seasonal vapour pressure profiles constructed using data from night-time radiosonde launches conducted over the southern Pierre Auger Observatory. The error bars represent one standard deviation in the mean. The numbers next to the seasons in the legend correspond to the number of launches used to create each profile. Bottom: The standard deviations from the top figure, plotted as a function of height. These are large near the ground, especially in the summer and autumn seasons (\(\sim 50\%\)).
6.7 Histograms of the relative shifts in energy for 3927 events spread out over the four seasons. The largest average shift was that for Summer, but the highest shift in energy here was for an event in Autumn.

6.8 The Summer clear and the Summer overcast relative humidity and vapour pressure profiles, plotted with the complete Summer seasonal profile, which includes clear, overcast and undetermined profiles. The relative humidity is shown in the top plot and the vapour pressure is shown in the bottom plot. The numbers next to the profile names in the legends indicate how many individual launches were used to create each average profile. It can be clearly seen that the relative humidity and vapour pressure profiles depend on whether the conditions are clear or overcast.

6.9 The magnitude of the standard deviations of the summer clear and overcast relative humidity and vapour pressure profiles, plotted with those of the complete seasonal profiles, which includes data from launches classified as clear, overcast or undetermined. The uncertainty in the relative humidity is shown in the top plot and the uncertainty in the vapour pressure is shown in the bottom plot.

6.10 Left: All relative humidity readings from the weather station at the Los Leones fluorescence detector site from March 2006, grouped into one hour blocks. Right: The value of the vapour pressure [hPa] calculated from the temperature and relative humidity readings using equations 6.9 and 6.10. Weather station readings are taken every 5 minutes. A definite daily trend can be seen here.

6.11 Here the monthly vapour pressure models created using the moving boxcar method are shown. The number of launches used to create each profile can be found in Table 6.7.

6.12 Here the magnitude of the standard deviations on the monthly vapour pressure models presented in Figure 6.11 are shown. The number of launches used to create each profile can be found in Table 6.7.

6.13 The change in the reconstructed energy and depth of shower maximum of 3780 events, as the result of taking temperature into account in the quenching calculations.
6.14 The change in the reconstructed energies of 3780 events as a function of energy. The band containing approximately 90% of the data is indicated by the red and blue markers which are the mean values plus or minus two standard deviations.

6.15 The change in the reconstructed depth of shower maximum of 3780 events as a function of energy. The band containing approximately 90% of the data is indicated by the red and blue markers which are the mean values plus or minus two standard deviations.

6.16 The difference in the measurements of vapour pressure at the weather station located at Los Leones compared to that in the middle of the array at the CLF. There is no systematic difference between measurements at the two sites.

6.17 This figure shows the uncertainty in vapour pressure calculations as a function of temperature for 100% relative humidity. This is calculated using the instrumental uncertainty in weather station measurements listed in table 6.2, and equations 6.9 and 6.10 for the vapour pressure.

6.18 Comparing the standard deviations from the original monthly profiles for January, February, March and April, with the same profiles normalised to the ground.

6.19 Comparing the standard deviations from the original monthly profiles for May, June, July and August, with the same profiles normalised to the ground.

6.20 Comparing the standard deviations from the original monthly profiles for September, October, November and December, with the same profiles normalised to the ground.

6.21 Plotted here is the Maghrabi factor for 38 launches plotted against the square-root of the vapour pressure at ground multiplied by the scale height of vapour pressure measured by each individual launch. Nights classified as clear are represented by squares, patchy cloud by triangles and overcast by crosses.

6.22 Plotted here is the Maghrabi factor for launches conducted on nights determined to be clear, plotted against the square-root of the vapour pressure at the ground multiplied by the scale height of vapour pressure determined for each individual launch.
7.1 Geometry of an EAS as seen by the fluorescence detector. Photons which arrive simultaneously at the FD originate from surface S.\cite{124}  

7.2 This illustration shows the scattering of photons by particles of different sizes. The term 'Mie scattering' is an alternate name for aerosol scattering in the case of spherical aerosols. The relative size of the arrows is meant to indicate the weights of the scattering directions. The larger the size of the scatterer, the stronger the forward scattering of the photons.  

7.3 The relative shift in energy as a function of energy, resulting from correcting for multiply scattered fluorescence light as parametrised in Eq. 7.7. The average effect is a small reduction of the shower energy, which has an energy dependence.  

7.4 The absolute shift in depth of shower maximum $X_{\text{max}}$ as a function of energy, resulting from correcting for multiply scattered fluorescence light as parametrised in Eq. 7.7. The average effect is a small reduction of the depth of shower maximum.  

7.5 Illustration of a shower track (in green) across a FD camera. The red circles are centred on the spot center for a given time step, and the radius of each circle is the angular acceptance angle $\zeta$.  

7.6 Integrated signal and signal to noise as a function of the angular acceptance angle $\zeta$. The dashed vertical line indicates the angle at which the signal to noise optimises plus the $0.2^\circ$ safety margin. The dashed horizontal lines indicate the integrated signal at $\zeta_{\text{best}}$ and at $4.0^\circ$.  

7.7 This plot shows the integrated signal as a function of $\zeta$. The integrated signal before the lateral width and multiple scattering of fluorescence corrections are applied, is shown in blue, and after the corrections have been applied is shown in pink. The dashed lines show that past $\zeta_{\text{best}} = 1.0^\circ$, there is still a 7.4% increase in the integrated signal once the corrections have been applied.  

7.8 Illustration showing the bias that the field of view imposes on the average shower ages viewed by the Fluorescence Detectors. For the two shower axes shown here, the closer shower would have a larger average shower age in the field of view than the more distant shower.
7.9 Histograms showing the fractional increase calculated for 90 bright showers in four regions across the camera. The mean fractional increase is largest in pixels within the lowest 8 degrees of the shower, and decreases moving up the camera.

7.10 Histograms showing the values of angular distance (in degrees) from the shower track that optimises the signal to noise, calculated for 90 bright showers in four regions across the camera. On average, $\zeta$ is largest for the lowest track segment, and decreases as the track segments get higher on the camera.

7.11 The plot on the left shows the fractional increase between $\zeta_{\text{best}}$ and 4.0° vs. the zenith angle of the shower for the lowest 8° of elevation. The error bars in the right plot were calculated using equation 7.9. On the right is the maximum age $s_{\text{max}}(X)$ viewed by the lowest 8° of the camera vs. the zenith angle of the shower.

7.12 This is the same data from figure 7.11, but with the fractional increase plotted against maximum age viewed by the camera within the lowest 8° of elevation.

7.13 Exponential fits to the fractional increase between $\zeta$ and 4.0° as a function of shower age, for eight different values of $\zeta$ ranging from 1.0 to 1.7. Corrections for fluorescence lateral width and multiple scattering have already been applied.

7.14 Exponential fits to the fractional increase between $\zeta$ and 4.0° as a function of shower age, for eight different values of $\zeta$ ranging from 1.8 to 2.5.

7.15 The Cherenkov yield as a function of wavelength for the fluorescence detectors’ range of sensitivity.

7.16 The fluorescence detector efficiency as a function of wavelength. This is a combination of mirror reflectivity, optical filter transmission and PMT quantum efficiency.

7.17 The fluorescence detector efficiency multiplied by the Cherenkov spectrum displayed in figure 7.15, as a function of wavelength. This is roughly flat between 330nm and 380nm.
7.18 The fractional increase between $\zeta$ and 4.0° plotted against the product of $\frac{\alpha(1+\cos^2\xi)}{d}e^{s(x)(1.915c+1.613)}$, for $\zeta$ equal to 1.2°, 1.4°, 1.6° and 1.8°. A(s) and B(s) are the fits to the fractional increase as a function of age from section 7.7.1.

7.19 The value of the parameter $D$ from the equation 7.13, for $\zeta \in [1.1, 2.5]$. The error bars are from the uncertainty in the linear fit. The black solid line is a power law, described by Eq. 7.14.

7.20 The value of the parameter $E$ from the equation 7.13, for $\zeta \in [1.1, 2.5]$. The error bars are from the uncertainty in the linear fit.

7.21 Left: Histogram of the fractional shifts in energy due to the correction for the Cherenkov halo. Right: Histogram of the absolute shifts in depth of shower maximum.

7.22 Relative shift in reconstructed shower energy as a function of energy, from applying this correction for the scattered Cherenkov light.

7.23 Shift in the reconstructed depth of shower maximum as a function of energy.

8.1 The number of 370 nm equivalent photons as a function of angular distance from the shower track. This is the sum of the light from every 100 ns time step in over 6000 bright events. The crosses represent the shower data, and the solid black line is the spot model prediction of the light distribution. The individual components of the model; the direct fluorescence, multiply scattered fluorescence, direct Cherenkov and scattered Cherenkov are also indicated by the other solid lines. The figure was produced using data and code obtained via private communication [145].

8.2 The green line represents the average distribution of direct fluorescence light from the shower data, and the red line is the spot model's prediction of that distribution. The four plots correspond to data from 4 different shower age brackets. Top right: 1.1–1.2, Top Left: 1.2–1.3, Bottom Right: 1.3–1.4, and Bottom left 1.4–1.5.

8.3 The fraction of light between 1.4° and 4.0°, for ages 0.6 to 1.4, from the spot model's prediction of the fluorescence compared to the data from over 6000 high quality events. The red squares represent the data halo, and the blue diamonds represent the spot model's prediction of the halo.
8.4 The fraction of light between 1.4° and 4.0° as a function of shower distance, from the spot model's prediction of the fluorescence compared to data from over 6000 high quality events. The red squares represent the data halo, and the blue diamonds represent the spot model prediction of the halo.

8.5 The difference between the fraction of light between 1.4° and 4.0° as a function of shower age as calculated from the spot model prediction of the fluorescence and from the data for over 6000 high quality events.

8.6 (A) shows the integral of energy deposit at s=1.0, for iron and proton vertical showers at 10^{19} eV and 10^{20} eV, as a function of distance from the shower axis. (B) is the same plot, but with the distance from the shower axis in Molière radii units [125].

8.7 (A) Integral of energy deposit density over radius versus distance from the shower axis for vertical and inclined (θ = 45°) proton showers. (B) The integral profile measured in Molière units. The profiles are shown for 10 EeV showers at s=1 [125].

8.8 Values of parameters a(s) and b(s), obtained based on integral of CORSIKA energy deposit density for vertical proton showers of energy 10 EeV [125].

8.9 Functions a(s) and b(s) plotted for s(X) ∈ [0.2, 1.6]. The black line at s(X) = 1.2 indicates the limit of the Gora parametrisation.

8.10 The integral of the lateral energy deposit as a function of distance from the shower axis in Molière radius units. The profiles are averages for different age ranges as indicated. The primary particles were iron nuclei with an energy of 10^{17} eV.

8.11 The integral of the lateral energy deposit as a function of distance from the shower axis in Molière radius units. The profiles are averages for different energies and compositions within the age range of s(X) ∈ [0.975, 1.000].

8.12 The integral of the lateral energy deposit as a function of distance from the shower axis in Molière radius units. The profiles are averages for different energies and compositions within the age range of s(X) ∈ [1.175, 1.200].

8.13 The integral of the lateral energy deposit as a function of distance from the shower axis in Molière radius units. The profiles are averages for different energies and compositions within the age range of s(X) ∈ [1.275, 1.300].
8.14 The parameter $a$ as a function of shower age. The blue data points represent the results of my fits to the integral energy deposit, and the red markers represent the corresponding value obtained from Gora’s parametrisation.

8.15 The parameter $b$ as a function of shower age. The blue data points represent the results of my fits to the fraction energy deposit, and the red markers represent the corresponding value obtained from Gora’s parametrisation.

A.1 Monthly vapour pressure profiles for January and February. The error bars represent one standard deviation around the mean.

A.2 Monthly vapour pressure profiles for March and April. The error bars represent one standard deviation around the mean.

A.3 Monthly vapour pressure profiles for May and June. The error bars represent one standard deviation around the mean.

A.4 Monthly vapour pressure profiles for July and August. The error bars represent one standard deviation around the mean.

A.5 Monthly vapour pressure profiles for September and October. The error bars represent one standard deviation around the mean.

A.6 Monthly vapour pressure profiles for November and December. The error bars represent one standard deviation around the mean.
List of Tables

4.1 Comparison of the southern and proposed northern Pierre Auger sites. The energy ranges for the efficiency refer to iron and proton primaries respectively. 59

5.1 Systematic uncertainties in the energy measurement of hybrid events. 68

6.1 Atmospheric parameters measured by the radiosondes as well as their accuracy and range [108]. 82

6.2 Atmospheric parameters measured by the weather stations as well as their accuracy and range [109]. 83

6.3 Measurement of water vapour collisional quenching pressure $p'_{H_2O}$ for each of the molecular electronic-vibrational excited state emission bands by the AIRFLY Collaboration [105]. 91

6.4 Lists of the average shifts in the reconstructed shower energies and $X_{max}$, as well as the RMS of these distributions. These shifts are the result of using the seasonal vapour pressure profiles created in section 6.6, to calculate the effect of including the vapour pressure dependence in the fluorescence yield calculation for 3927 high quality events. 94

6.5 The number of radiosonde launches conducted on nights determined to be clear or overcast from each season, as well as the number which remain undetermined. 98

6.6 Average monthly values of ground-level vapour pressure, for both day-time and night-time, as measured by the Los Leones weather station over 2005 and 2006. The night-time vapour pressure is larger between September and April, and smaller between May and August inclusive. 103
6.7 Number of launches available from each month after overcast launches have been removed. Also shown are the number of launches used to create each monthly model using the boxcar method.

6.8 Average shifts in energy and $X_{\text{max}}$, as well as the RMS of the distributions, as the result of using the monthly vapour pressure models in the event reconstruction. The shifts are with respect to not using the humidity correction.

6.9 Measurement of temperature dependence parameters for a selected group of air fluorescence bands by the AIRFLY Collaboration[105].

6.10 The uncertainty in the vapour pressure at the ground for each month, calculated by adding the RMS of the lateral homogeneity to the instrumental uncertainty in measuring the vapour pressure at the ground. The average temperatures and the relative humidities were calculated using data from 2004 - 2008, from between 00:00 UTC and 09:59 UTC.

6.11 The average scale height $\bar{H}$ [km] found by fitting an exponential to each individual vapour pressure profile used in creating the monthly models. The uncertainty in the scale height is the RMS of the launches used to calculate these averages. The third column presents the relative uncertainties.