Atmospheric Monitoring and Analysis for H.E.S.S.

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OUTLINE:

- **Introduction to H.E.S.S.**
- **Atmospheric monitoring**
- **Atmospheric considerations**
- **Atmospheric analysis**
  - radiosonde analysis
  - ceilometer analysis and application
  - lidar analysis and application
- **Conclusions and future activities**

Introduction to H.E.S.S.

- **energy range >100GeV**
- **arid highlands, altitude 1800m, desert dust aerosols**

Atmospheric monitoring

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- **H.E.S.S. telescopes**
- **radiometers**
  - 4 line of sight (i.e. 1 per telescope)
  - 1 scanning radiometer
- **ceilometer**
- **transmissometer**
- **weather station**
- **optical telescope (1m diameter)**
- **2 single scattering lidars**

Radiometers (KT 19.82 mkII)

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- infrared radiometers
- spectral range 8-14 μm
- fov = 2 degrees
- temperature range -100C to +3000C (50->6,500,000 W/m^2)
- temperature resolution 0.03C
- response time 5ms to 10 minutes depending on resolution required

http://www.heitroncs.com/

Ceilometer (Vaisala CT25K)

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- operational 2002 - 2007, λ = 905 nm, range < 7.5 km
- does not calculate atmospheric transmission

Atmospheric monitoring (3)

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lidar specifications:

• Wavelength:	355nm	355nm, 532nm, 1064nm
• Frequency:	10Hz	10Hz
• Pulse Width:	5ns	4ns
• Energy/Pulse:	20mJ	65mJ
• Range:	15km	25km
• Resolution:	1.5m	1.5m
• Operator:	Durham (Leosphere)	Montpellier

Atmospheric considerations

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For IACT's atmospheric quality affects shower development and Cherenkov yield in two ways:

- the vertical profile of the atmospheric density and hence refractive index of the air
  - variation is seasonal
  - effects mid-latitudes worse than the tropics
  - profile can be measured using radiosondes

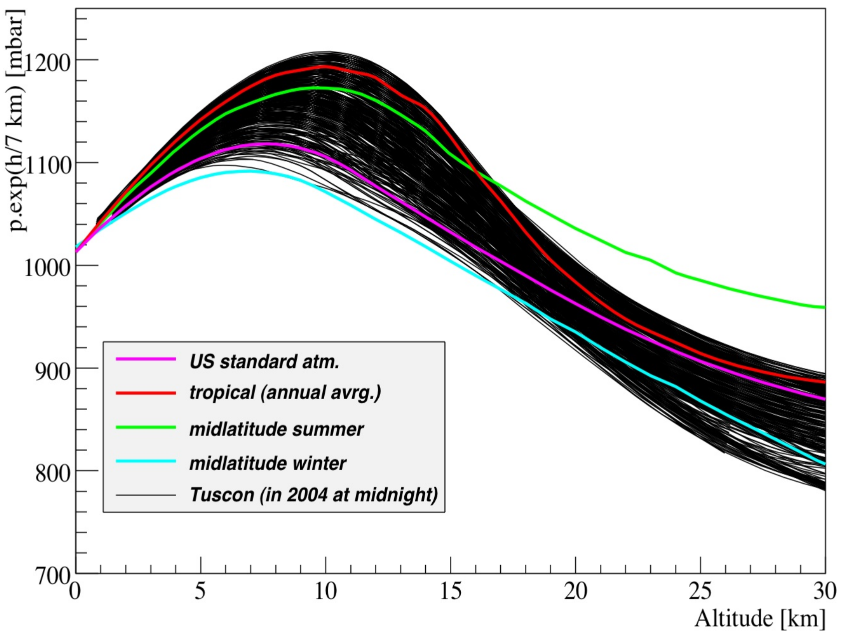
production of Cherenkov light

- through Rayleigh & Mie scattering of the Cherenkov light
  - lowers the brightness of an image
  - using a lidar measurment
  - possible to derive the probability of transmission

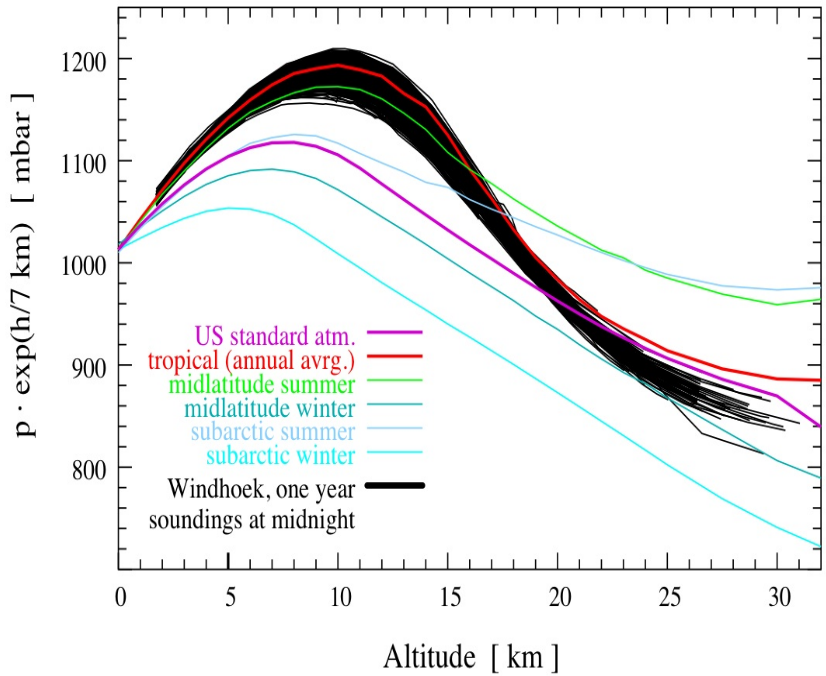
loss of Cherenkov light

Radiosonde analysis

Tucson 2007 (VERITAS)



Windhoek 2007 (H.E.S.S.)

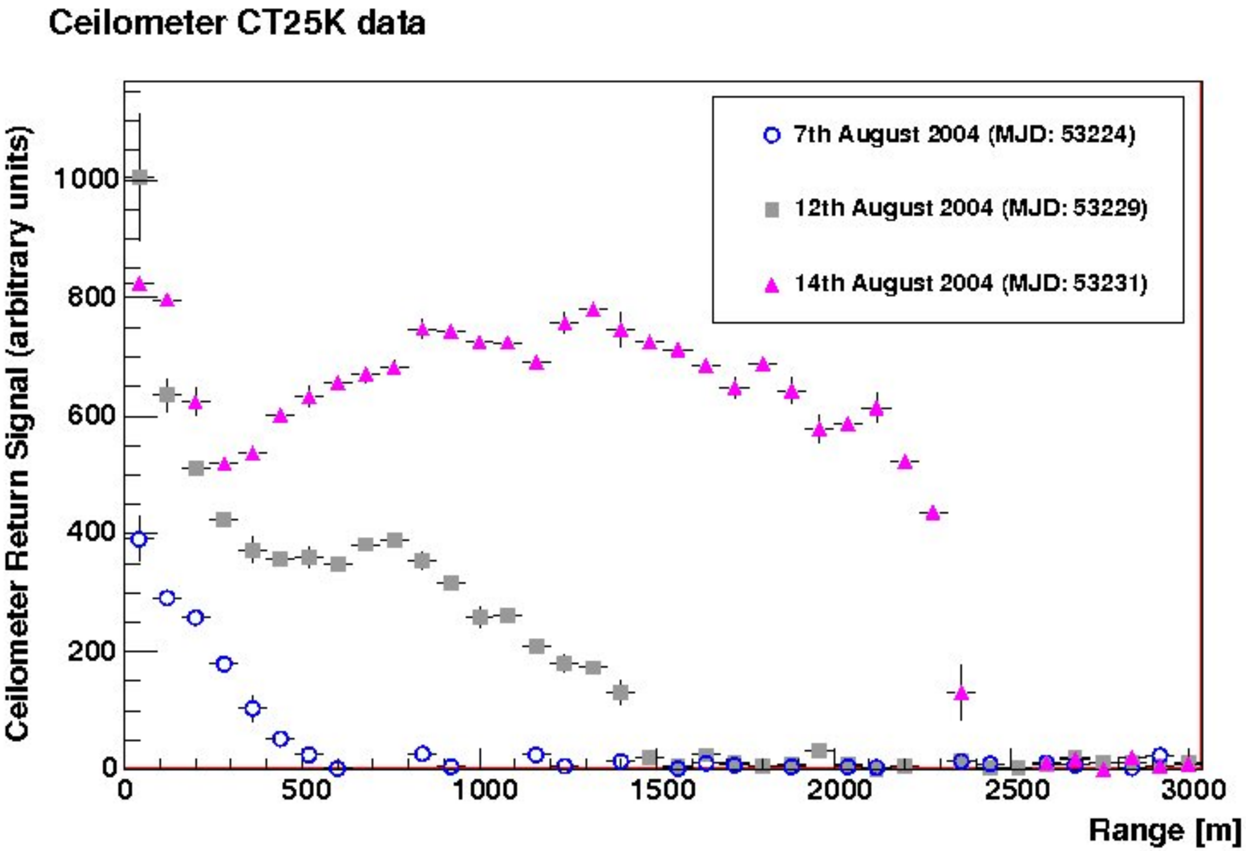


- there is a big difference in the seasonal variation between sites
- see Sam Nolan's talk

Ceilometer Analysis (1)

- used ceilometer to locate boundary-layer
- simulated cosmic-rays to match real trigger-rate by increasing aerosol component
- generated lookup-tables from matched atmosphere
- applied these to real contemporaneous Crab data
- applied these to real contemporaneous AGN PKS2155-304 data

Ceilometer analysis (2)

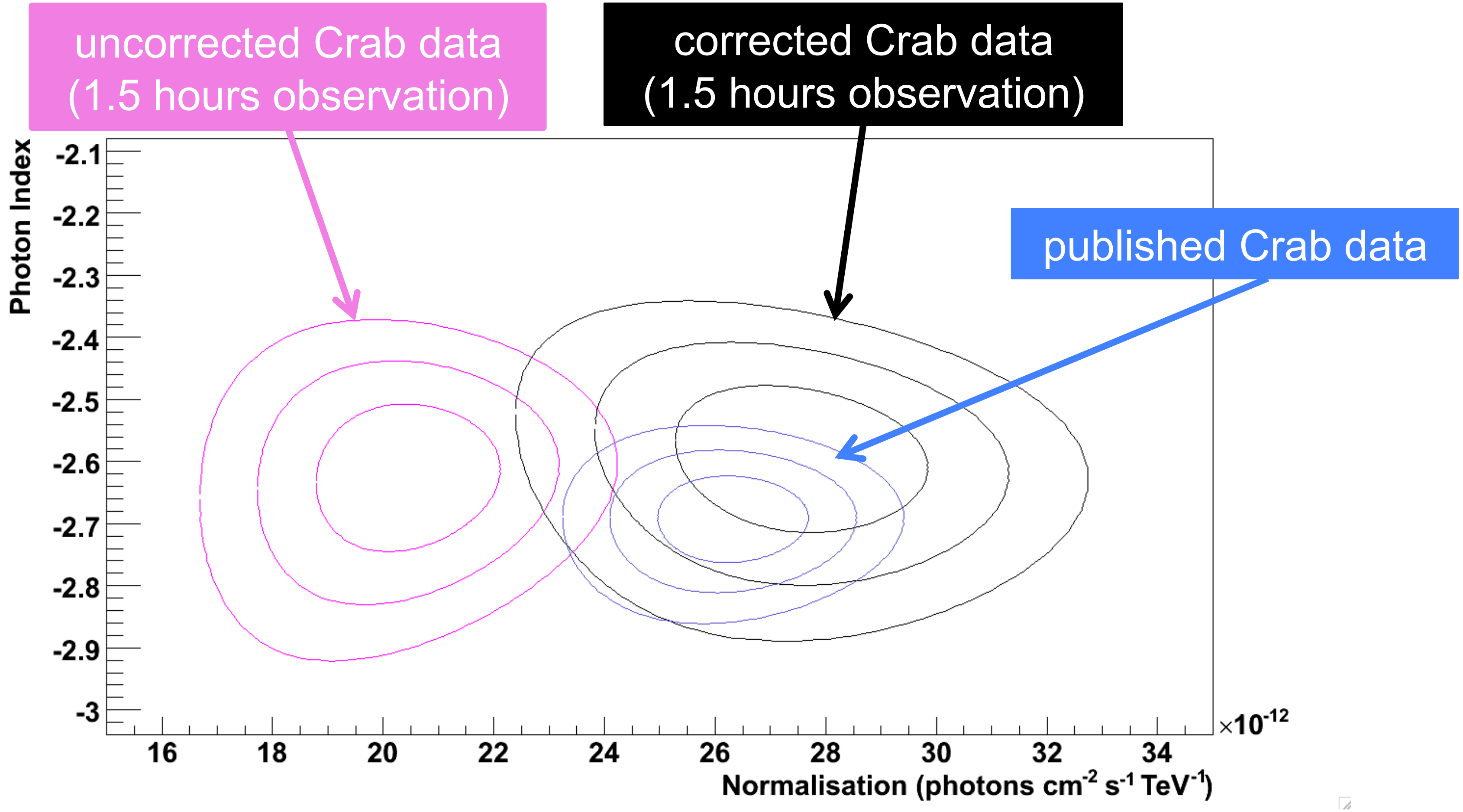


- boundary layer
- increased ceilometer return => increased aerosol density

Ceilometer analysis (3)

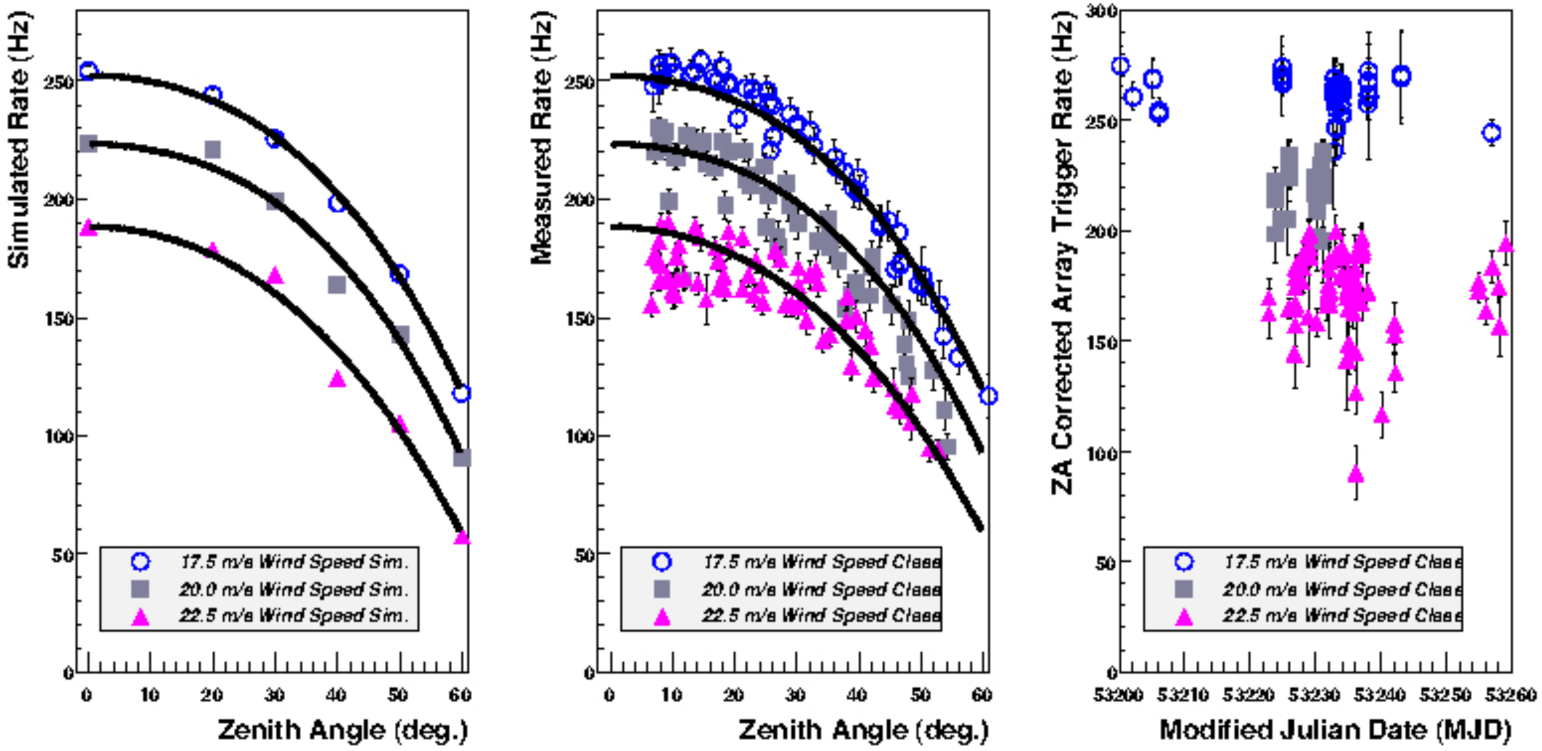
- **without correction**
  - telescope images look dimmer
  - and events reconstructed incorrectly to a lower energy than their intrinsic value
- **constrained the boundary-layer using ceilometer measurements**
- **constructed an atmospheric model to match the cosmic-ray background**
- **extracted the gamma-ray spectra from gamma-ray simulations created with these atmospheric models that include an increased low-level aerosol density**

Crab spectrum



- technique results in a better fit
- proof of principle

Matching cosmic-ray triggers



- 3 distinct atmospheric classes can be identified for observations of AGN PKS 2155-304 during August 2004

Energy spectra (PKS 2155-304)

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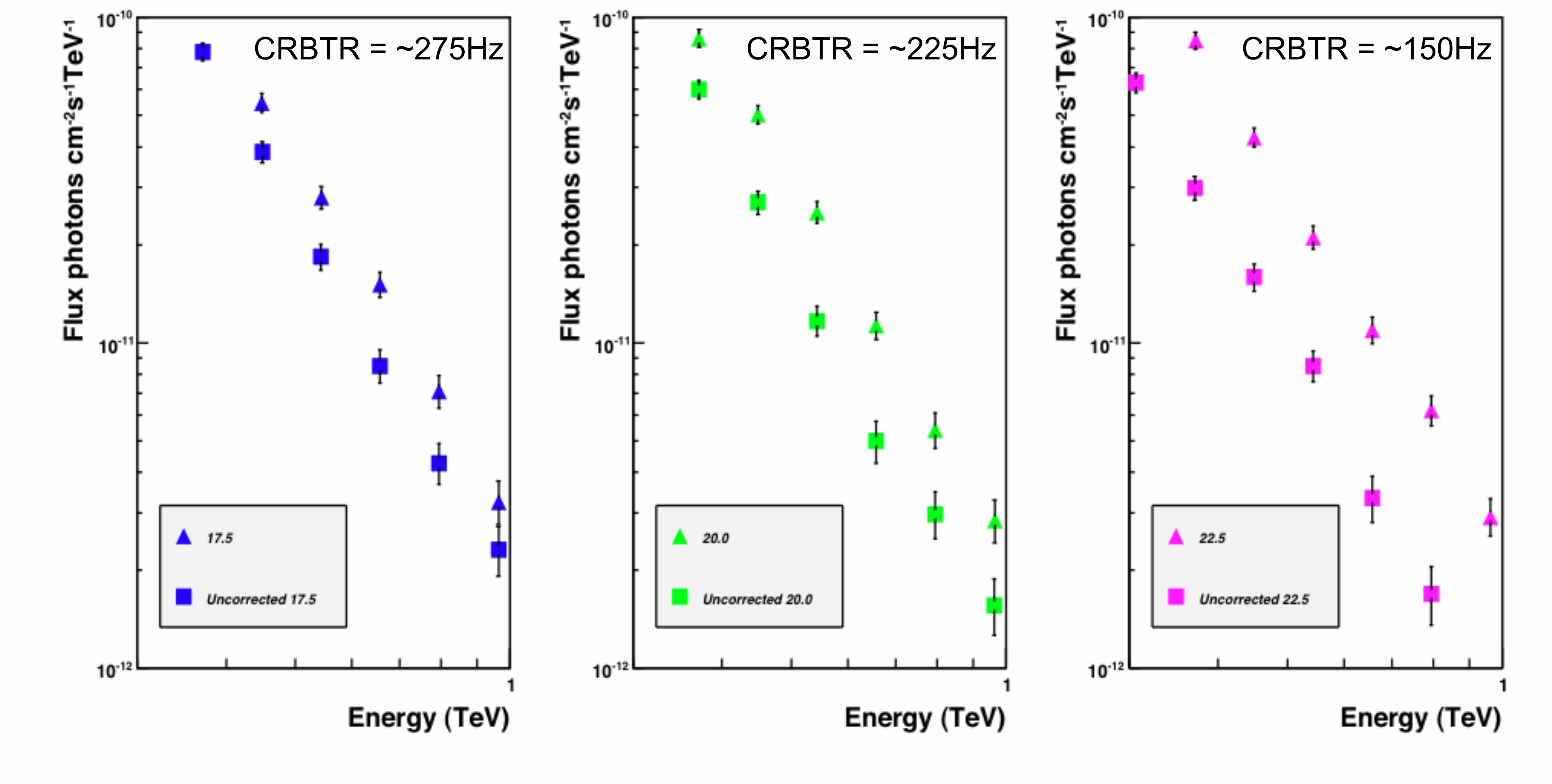

- uncorrected (squares) and corrected (triangles) data between 300GeV and 1TeV
- statistical errors above 1TeV

Lidar analysis

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- conducted atmospheric measurements with single-scattering lidar
- constructed atmospheric model to match lidar measurements
- generated lookup-tables from matched atmosphere
- applied these to (non-contemporaneous) real Crab data

Lidar analysis (2)

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lidar analysis techniques implemented:

- **Klett Method -** Klett.J.D Applied Optics 20(2):211-220 (1981)
- **Fernald Method –** Fernald.F.G Applied Optics 23(5):652-653 (1984)
- **Multi-angle Method –** Filipčič,A et al. Astroparticle Physics 18:501-512 (2003)

- **assumptions**
- **lidar range**
- **large systematic uncertainties**
- **2 unknowns 1 measurement**

need to derive probability of transmission for the Cherenkov spectrum

Lidar analysis (3)

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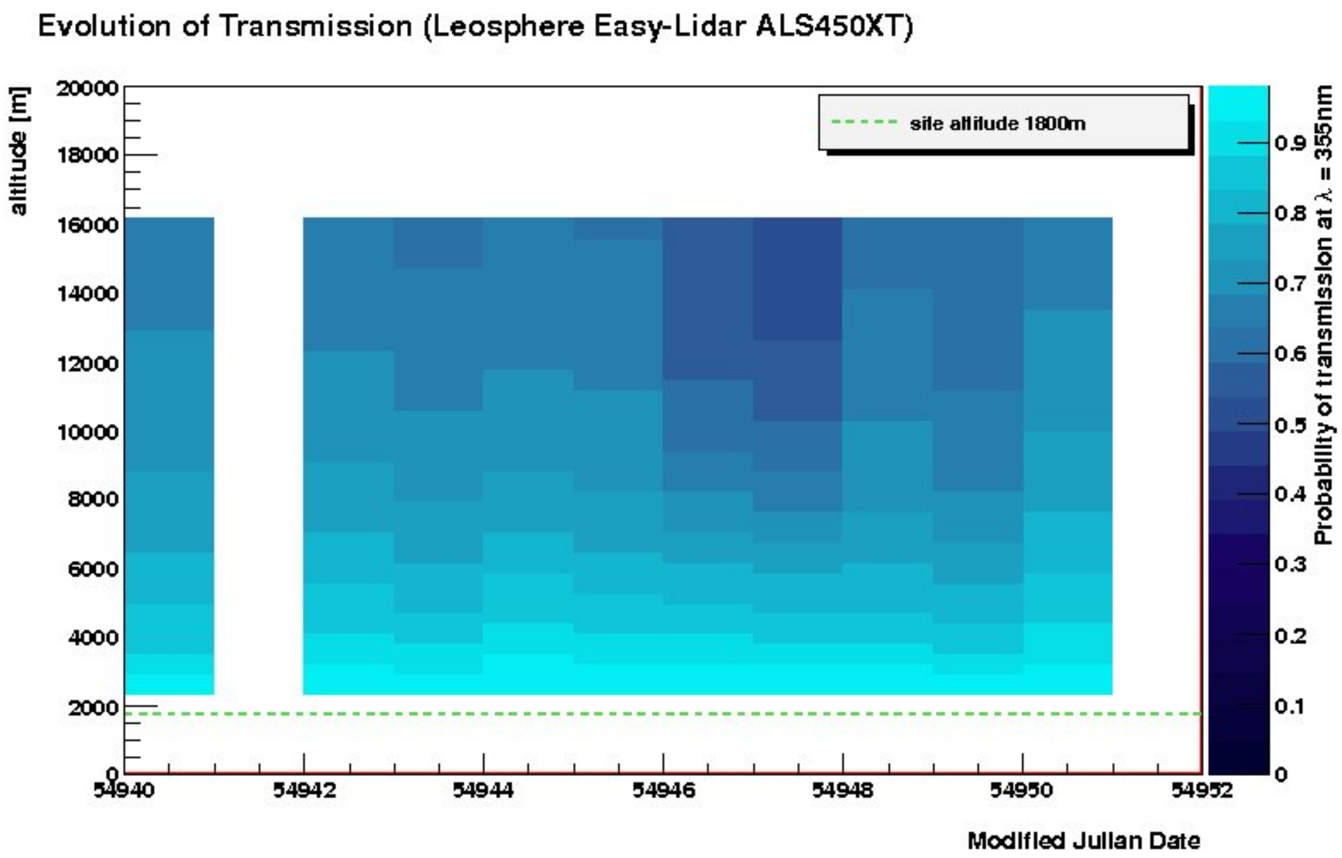
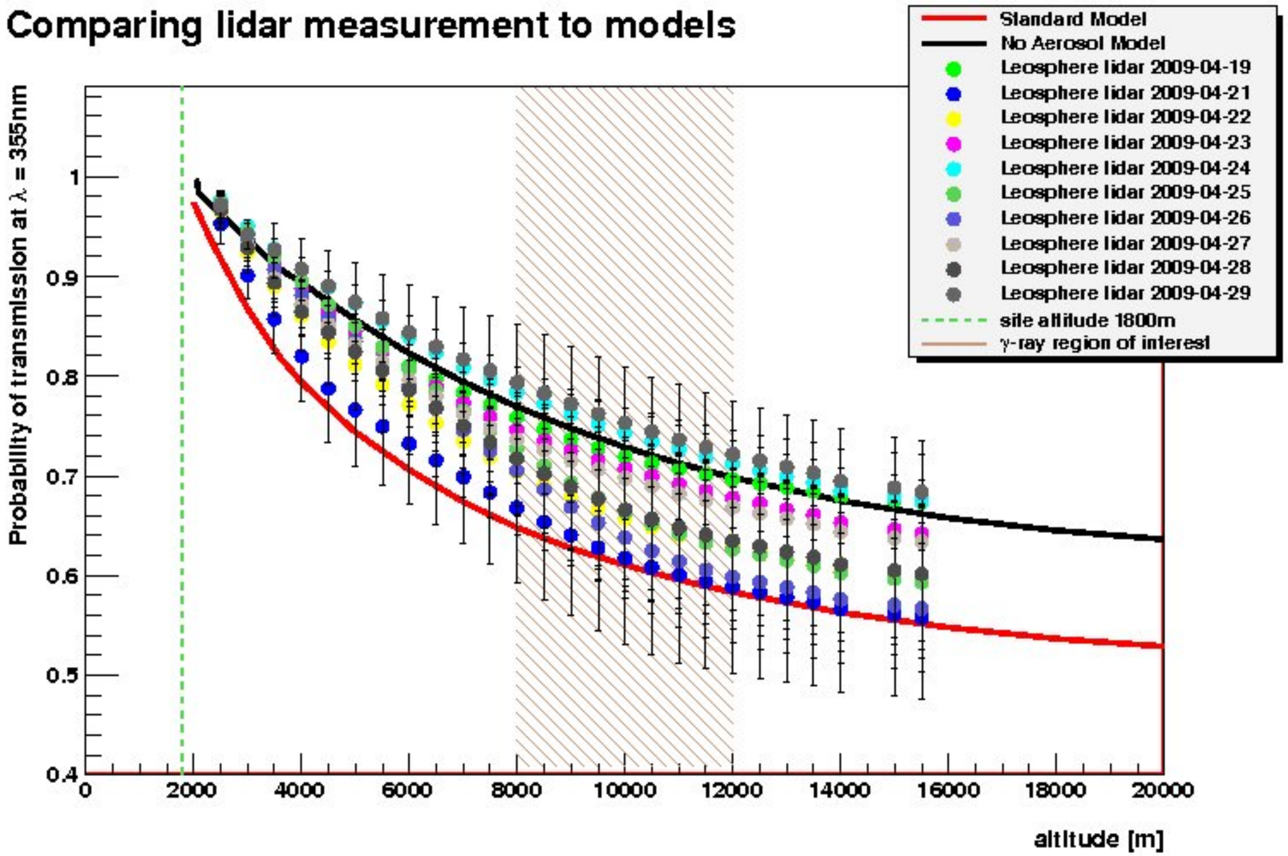


- **lidar wavelength λ = 355nm**
- **10 days, 19th – 29th April 2009**

Lidar analysis (4)



- average transmission falls between 2 models
- MODTRAN desert model (red line) and no-aerosol model (black line)

Lidar analysis (5)

- systematic errors are big and are not included
- looked at the difference between 2 different MODTRAN models which lidar data spans.
- constructed gamma-ray lookup-tables based on these models
- analyzed Crab data as if it were being observed to see effect

Crab spectrum

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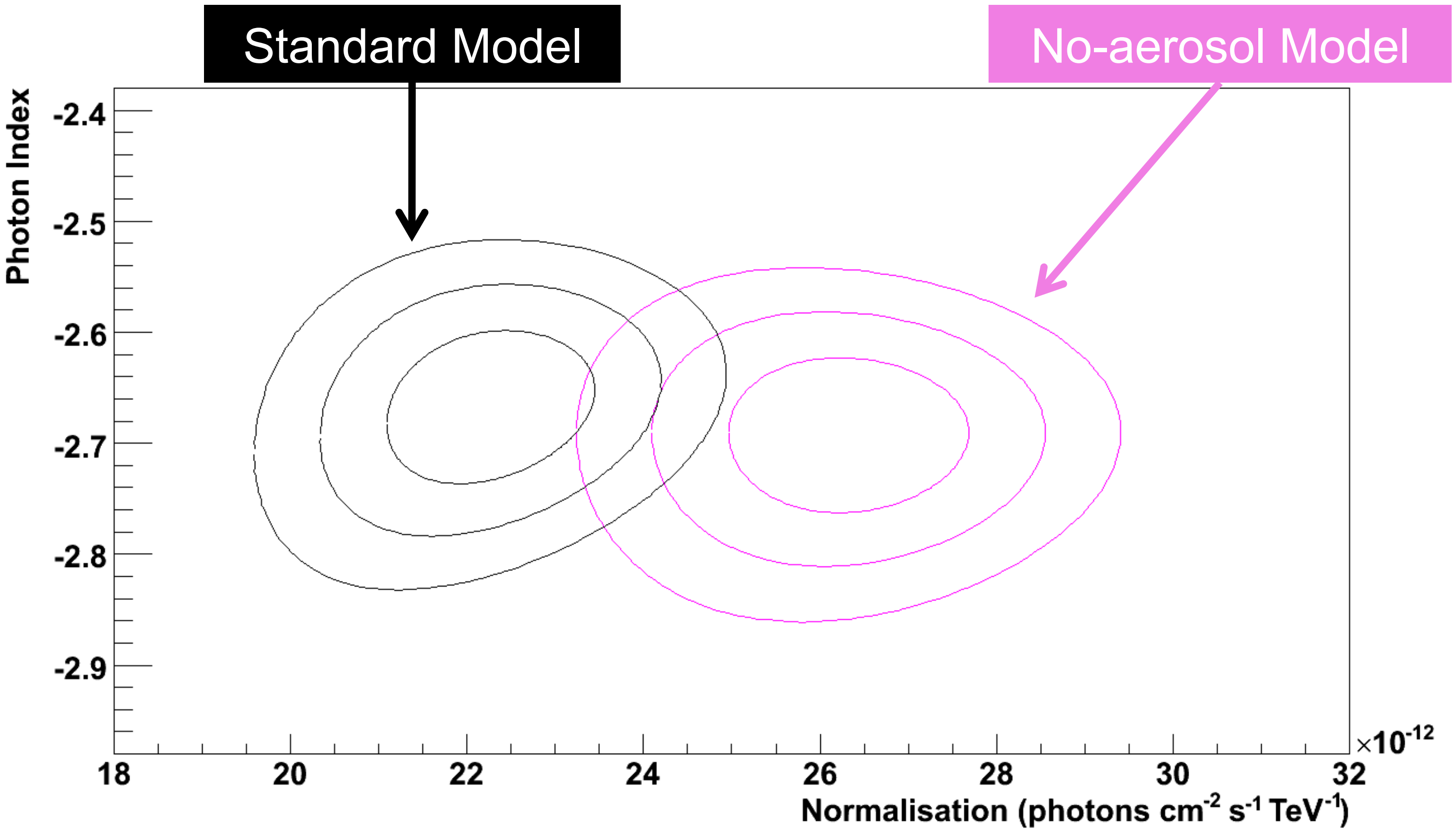

- change in reconstructed Crab flux of ~ 15%

Conclusions

- **ceilometer analysis**
  - used ceilometer measurements as well as simulated versus real cosmic-ray rates to constrain atmospheric model
  - able to correct Crab data providing ‘proof of principle’
  - applied technique to non-constant flux source PKS 2155-304

- **lidar analysis**
  - derived transmissions from lidar measurements
  - used to constrain atmospheric model
  - systematic errors ignored
  - change in reconstructed Crab flux of ~ 15%

- **Need a better measurement of atmospheric transmission (independent of telescope)**

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Detailed Studies of Atmospheric Calibration in Imaging Cherenkov Astronomy

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Abstract

The current generation of Imaging Atmospheric Cherenkov telescopes are allowing the sky to be probed with greater sensitivity than ever before in the energy range around and above 100 GeV. To minimise the systematic errors on derived fluxes a full calibration of the atmospheric properties is important given the calorimetric nature of the technique. In this paper we discuss an approach to address this problem by using a ceilometer co-pointed with the H.E.S.S. telescopes and present the results of the application of this method to a set of observational data taken on the active galactic nucleus (AGN) PKS 2155-304 in 2004.

Keywords: Gamma-ray, IACT, Cherenkov, H.E.S.S., Atmospheric calibration

Future Activities

- **Montpellier lidar analysis**
- **back catalogue of ceilometer study**
- **development of these methods for CTA**