cherenkov telescope array

the observatory for ground-based gamma-ray astronomy

AtmoHEAD

Influence of cloud altitude and optical depth on CTA-N performance

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Outline

- **Influence of atmospheric transmission on the quality of data observed with Cherenkov Telescopes**
- **Simulation of clouds with MODTRAN**
- **Effects of cloud altitude and optical depth**
- **Preliminary MC simulations for CTA-N with sim_telarray**

Motivation

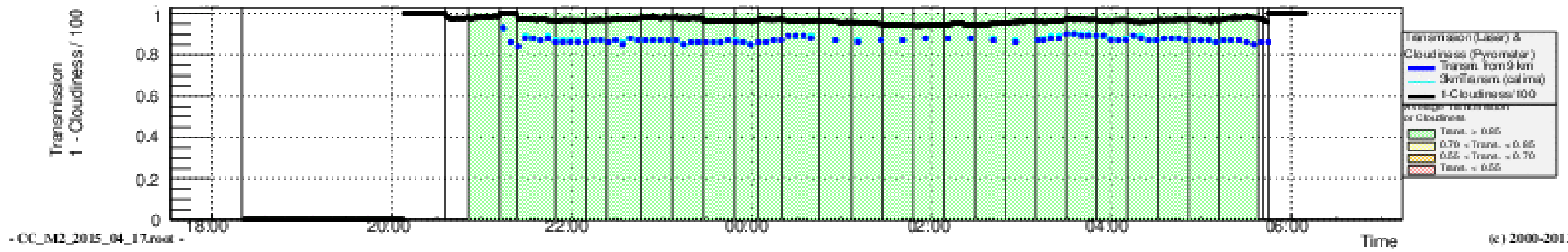
- Clouds and dust in the atmosphere affect observations with Cherenkov telescopes in dependence with energy
- Different energy thresholds needed for observations of different source types, redshifts and activity states
- Measurements of atmospheric transmission with MAGIC LIDAR at La Palma show that up to 30% of observing time can be gained by applying proper corrections
- Adaptive (dynamic) observation scheduling with CTA

Experience in MAGIC

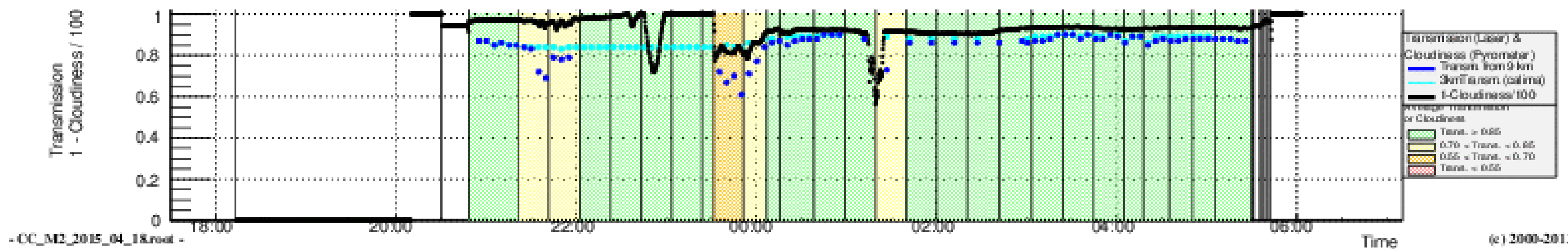
- Atmospheric transmission measured at LA Palma using LIDAR (532 nm)
- Testing of the effects on Crab Nebula data
- Observations checked for different ranges of transmission at 9 km (cirrus clouds) and 3 km (calima)
- Data quality check
- Future plan: applying “Adaptive Scheduling” for different types of targets

MAGIC – atmospheric transmission

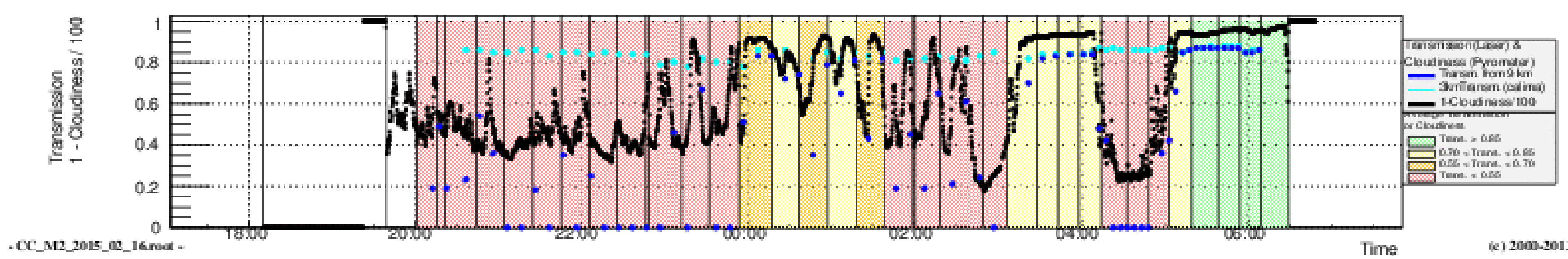
Perfect weather: no corrections



Easy corrections possible



Very variable atmosphere



Measuring atmospheric transmission in CTA

- **Instruments used for adaptive scheduling:**
  - All-Sky-Camera (ASC) – map of sky cloud coverage
  - Ceilometer (1064 nm) – cloud height
- **Instruments used for data correction:**
  - Raman lidars
  - FRAMs (large FOV optical telescopes)
- **Auxiliary instruments and methods:**
  - UVscope
  - CTA weather stations
  - Weather forecasts (external)
  - Calculate Cherenkov Transparency coefficient (CTC) – after the observations

Parameters for the simulations

cherenkov telescope array

- **Proposal for the gamma-ray simulation campaign for the CTA-N** (Gaug, Prouza, Vrastil)**, 2017**
- **Height of cloud base from 3000 m to 13000 m above ground level (steps of 2000 m)**
- **Total AOD: 0.05, 0.1, 0.2, 0.3, 0.5, 0.7**
- **Zenith: 20°, Azimuth: 180°, Standard Wobble, Slope: -2.0, Observatory level: 2147 m**

Simulations with MODTRAN

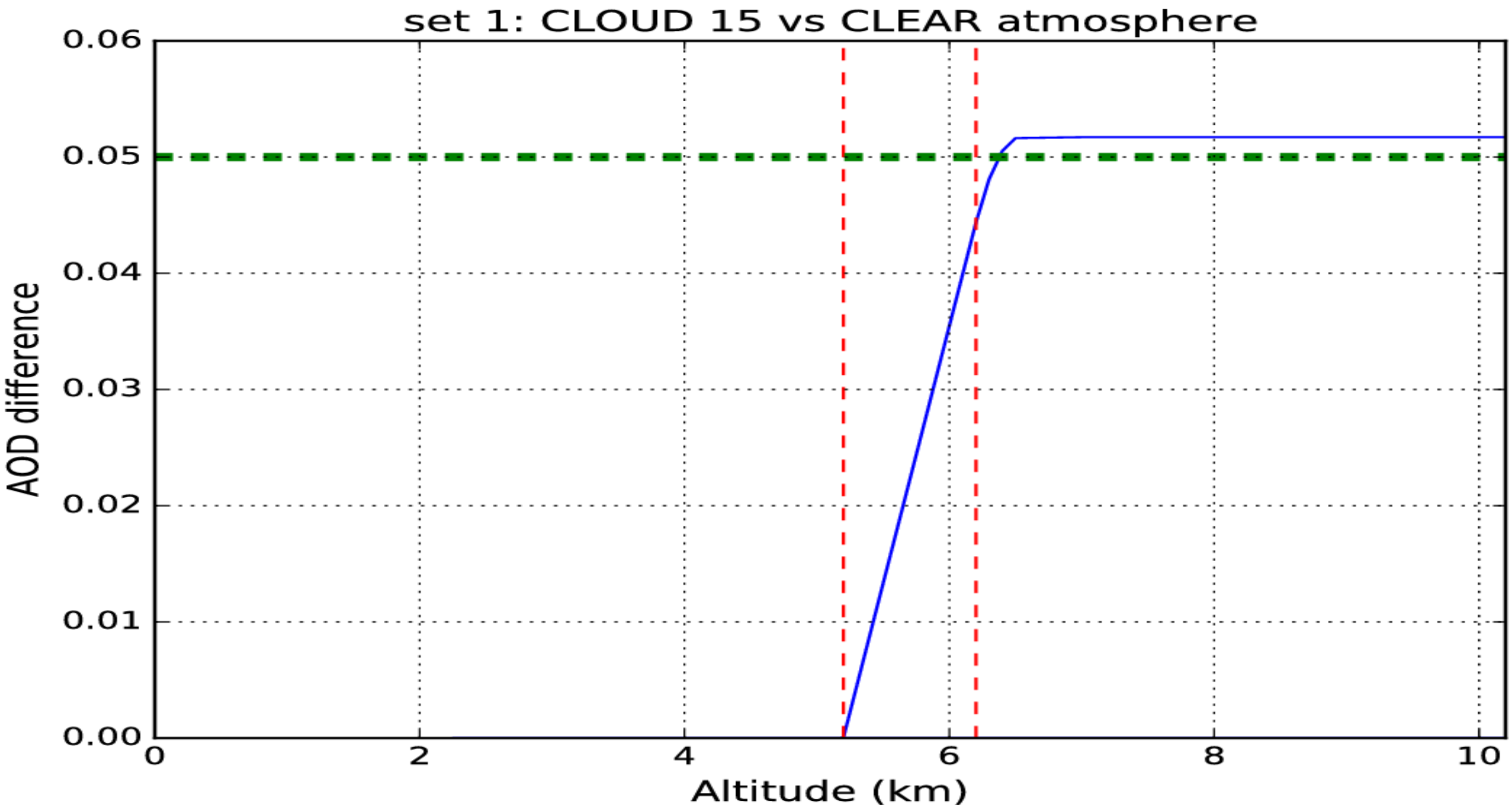
- *MODerate resolution atmospheric TRANsmission*
- Standard moderate spectral resolution radiative transport model
- **Version 5.2.2**
- Installed and used at **warp.zeuthen.desy.de**
- Wavelengths range: **203 nm to 999 nm** (step 1 nm)
- Atmospheric model: **6** (US Standard Atmosphere)
- Extinction model: **10** (desert extinction)
- Zenith angle: **0.0°**
- Ground altitude: **2147 m**

MODTRAN output

- For each wavelength and each altitude MODTRAN produced a single number: **transparency**
- Final output is a large table of transparencies in a text file (default filename extension is M5)
- We use our **own Python code** to transform a table of transparencies (M5 file) into a table of atmospheric optical depths (AOD; .dat file) appropriate as input for sim_telarray

Selected check plots

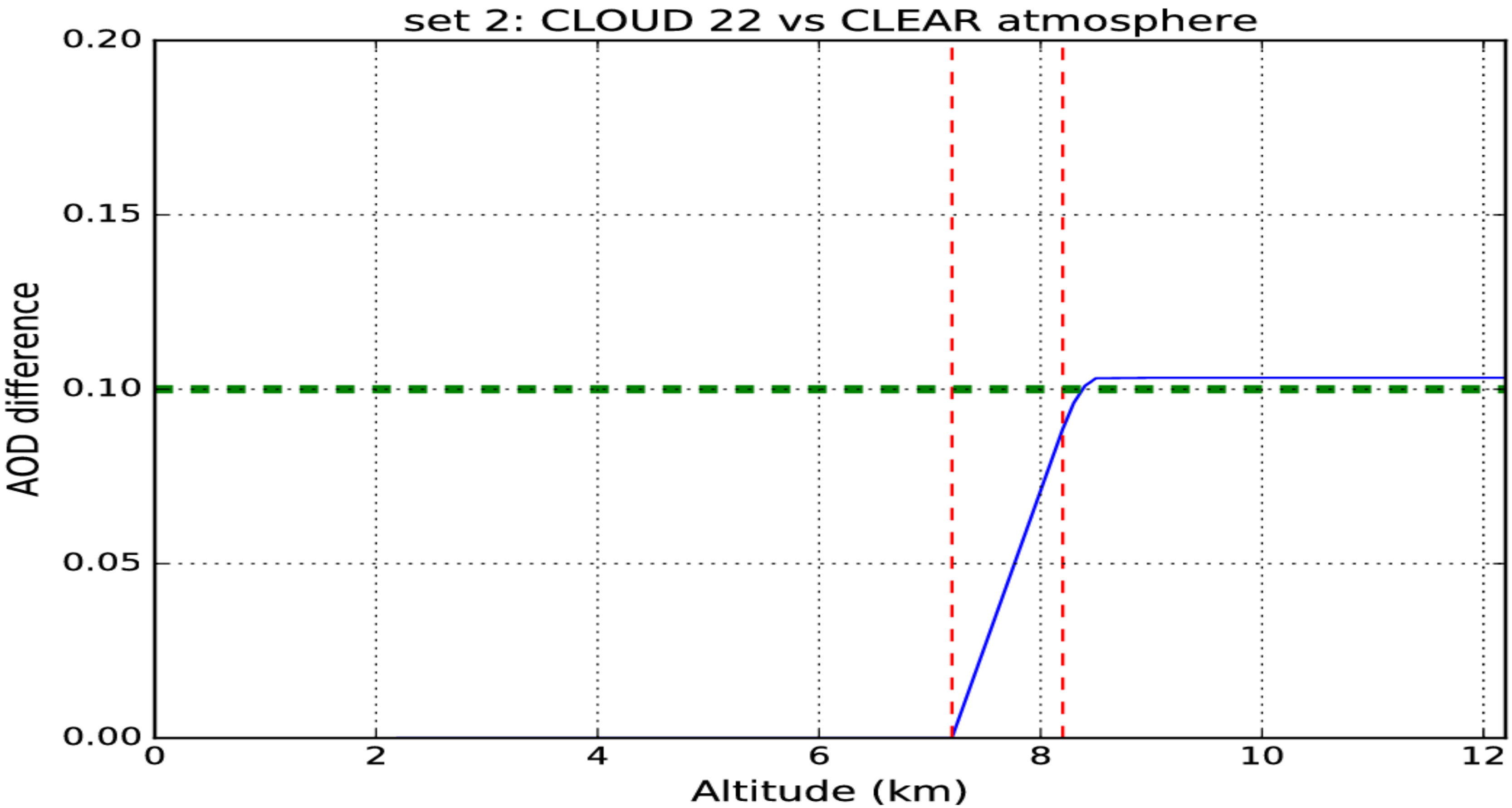
AOD difference of cloudy and clear atmosphere **Vs Altitude**



SET1 (total AOD **0.05**); **#15** (height of cloud base **3 km** a.g.l.)

Selected check plots

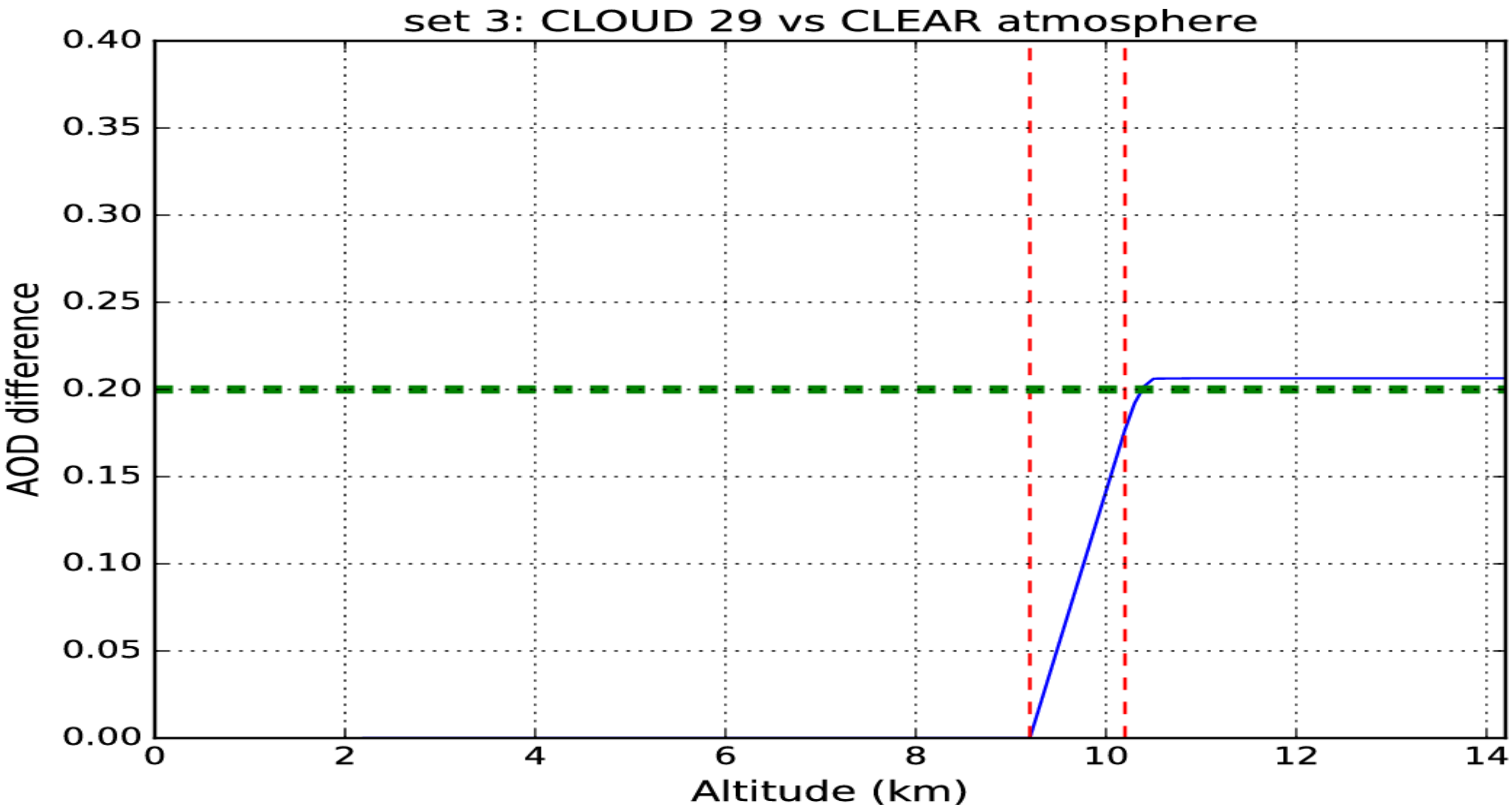
AOD difference of cloudy and clear atmosphere **Vs Altitude**



SET2 (total AOD **0.1**); **#22** (height of cloud base **5 km** a.g.l.)

Selected check plots

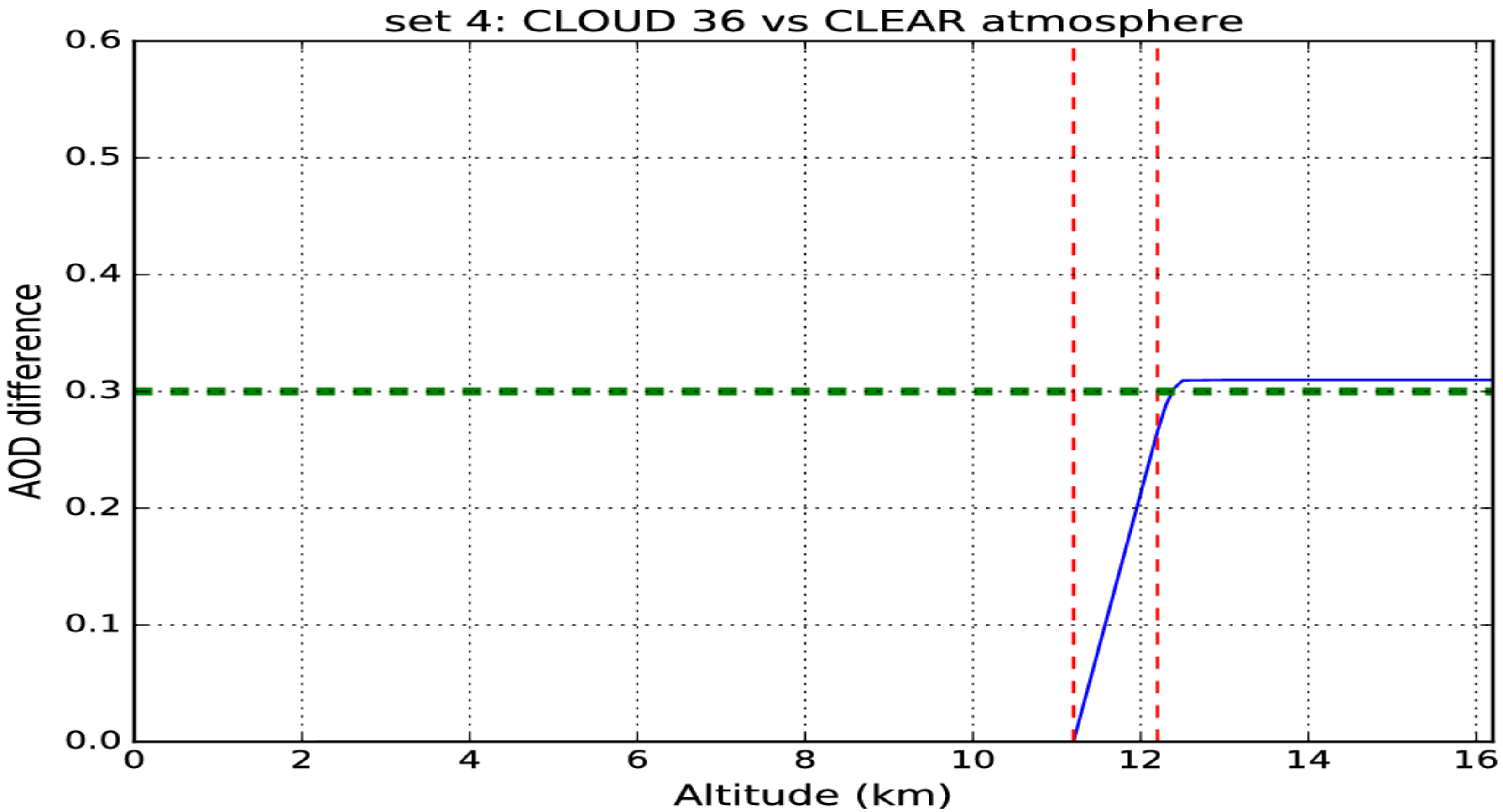
AOD difference of cloudy and clear atmosphere **Vs Altitude**



SET3 (total AOD **0.2**); **#29** (height of cloud base **7 km** a.g.l.)

Selected check plots

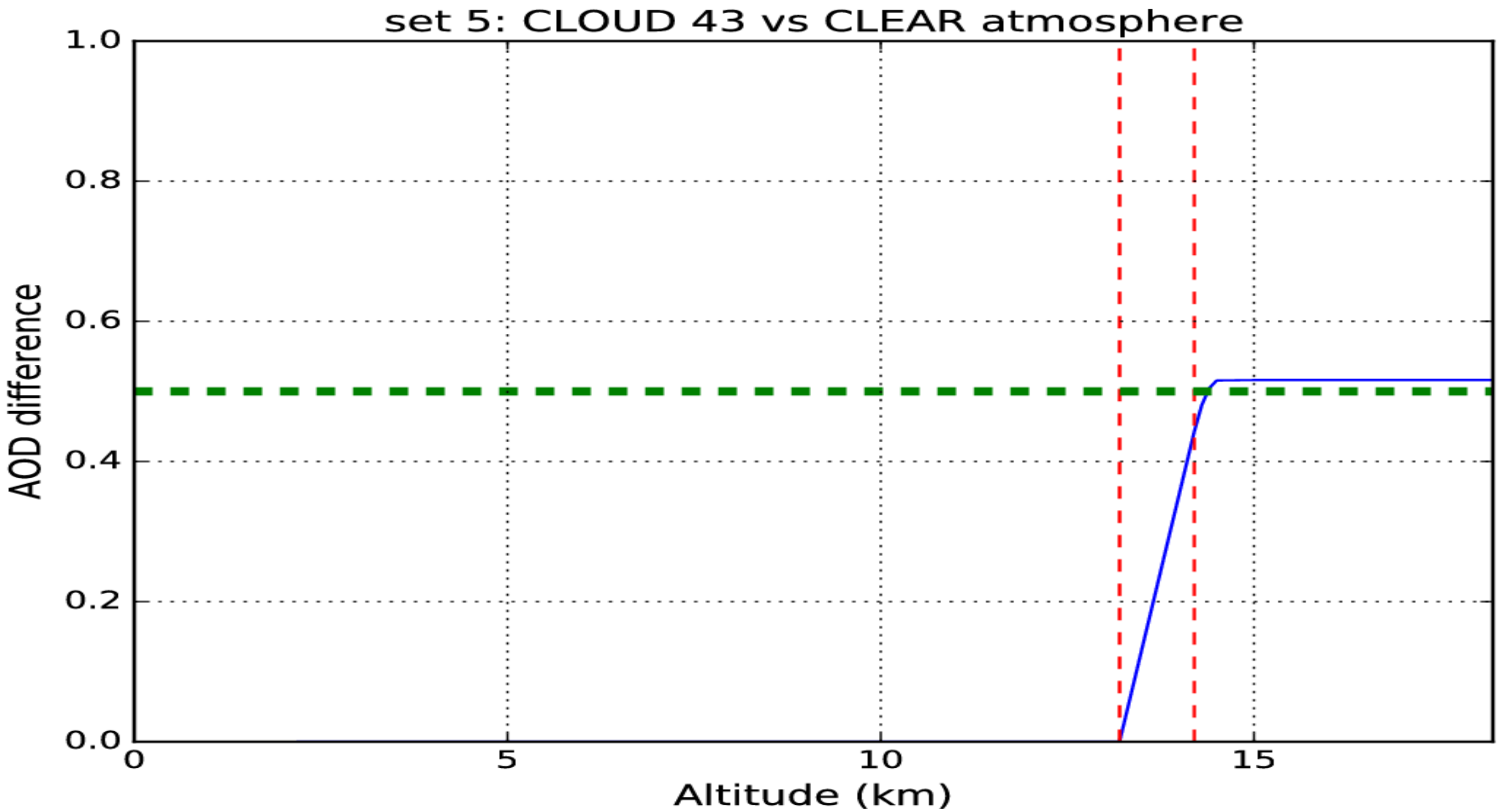
AOD difference of cloudy and clear atmosphere **Vs Altitude**



SET4 (total AOD **0.3**); **#36** (height of cloud base **9 km** a.g.l.)

Selected check plots

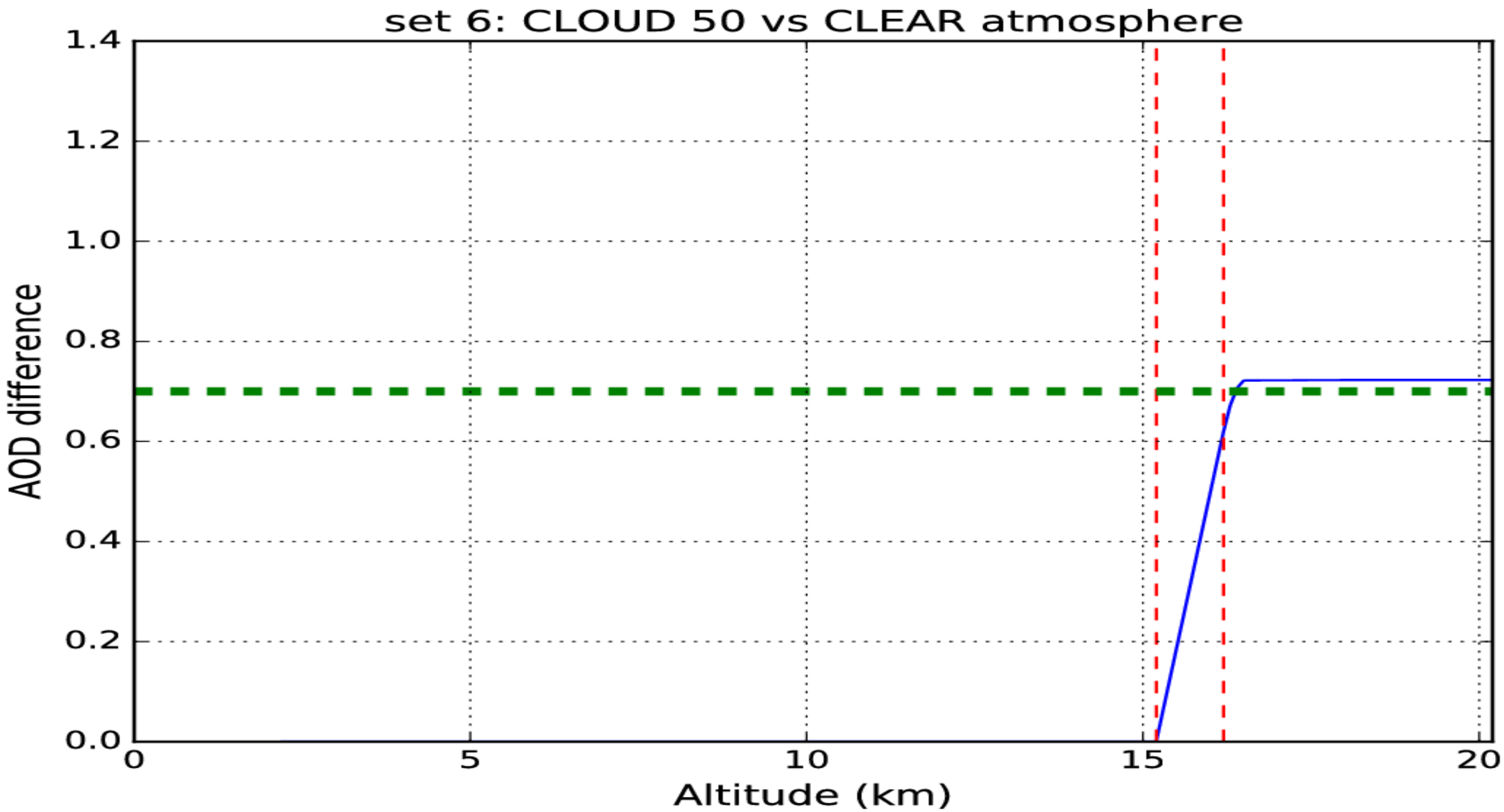
AOD difference of cloudy and clear atmosphere **Vs Altitude**



SET5 (total AOD **0.5**); **#43** (height of cloud base **11 km** a.g.l.)

Selected check plots

AOD difference of cloudy and clear atmosphere **Vs Altitude**

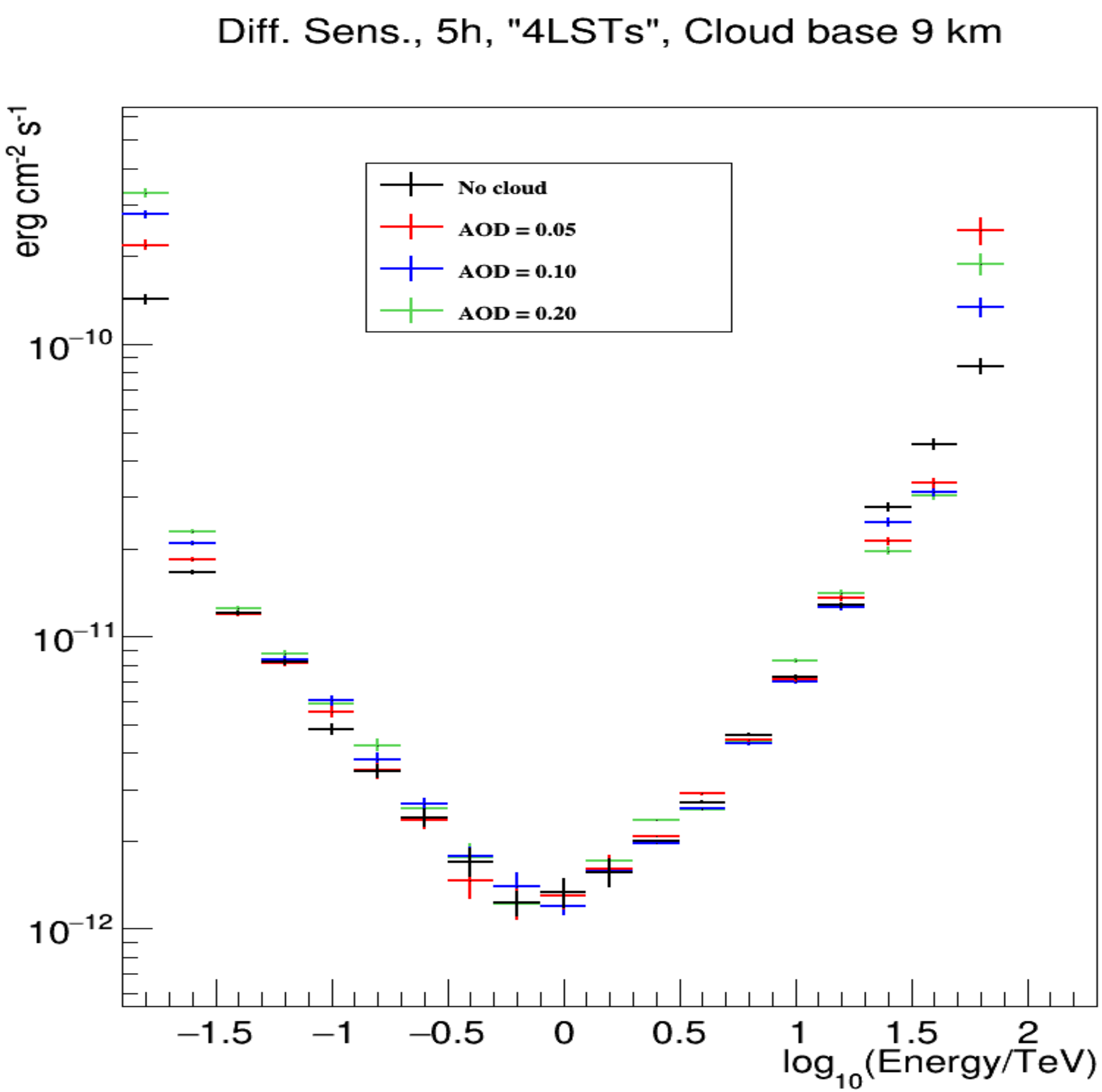


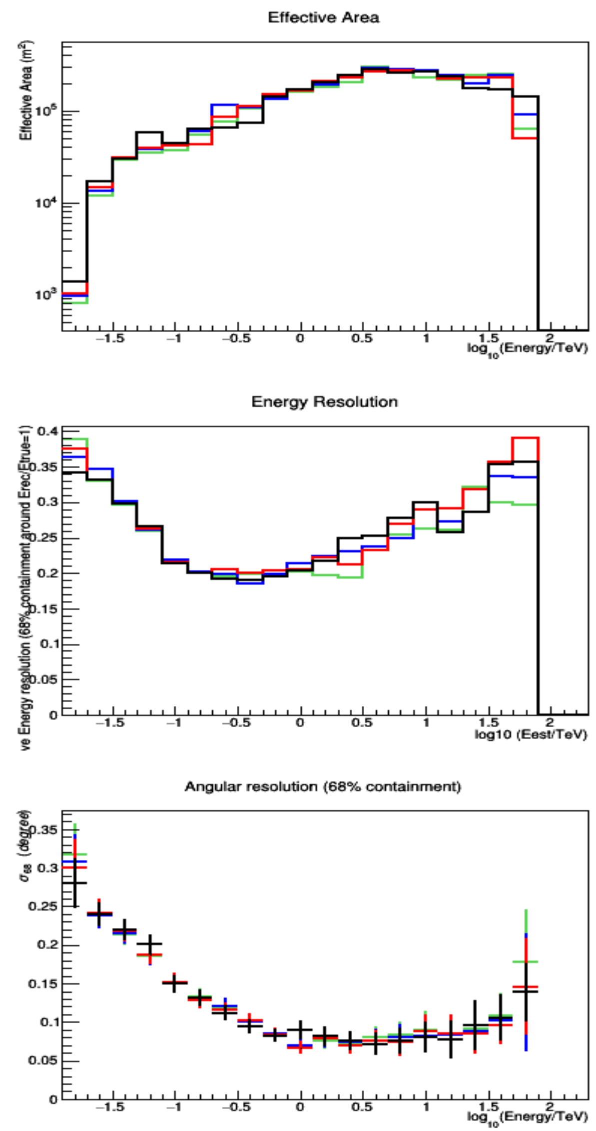
SET6 (total AOD **0.7**); **#50** (height of cloud base **13 km** a.g.l.)

Preliminary results of MC simulations

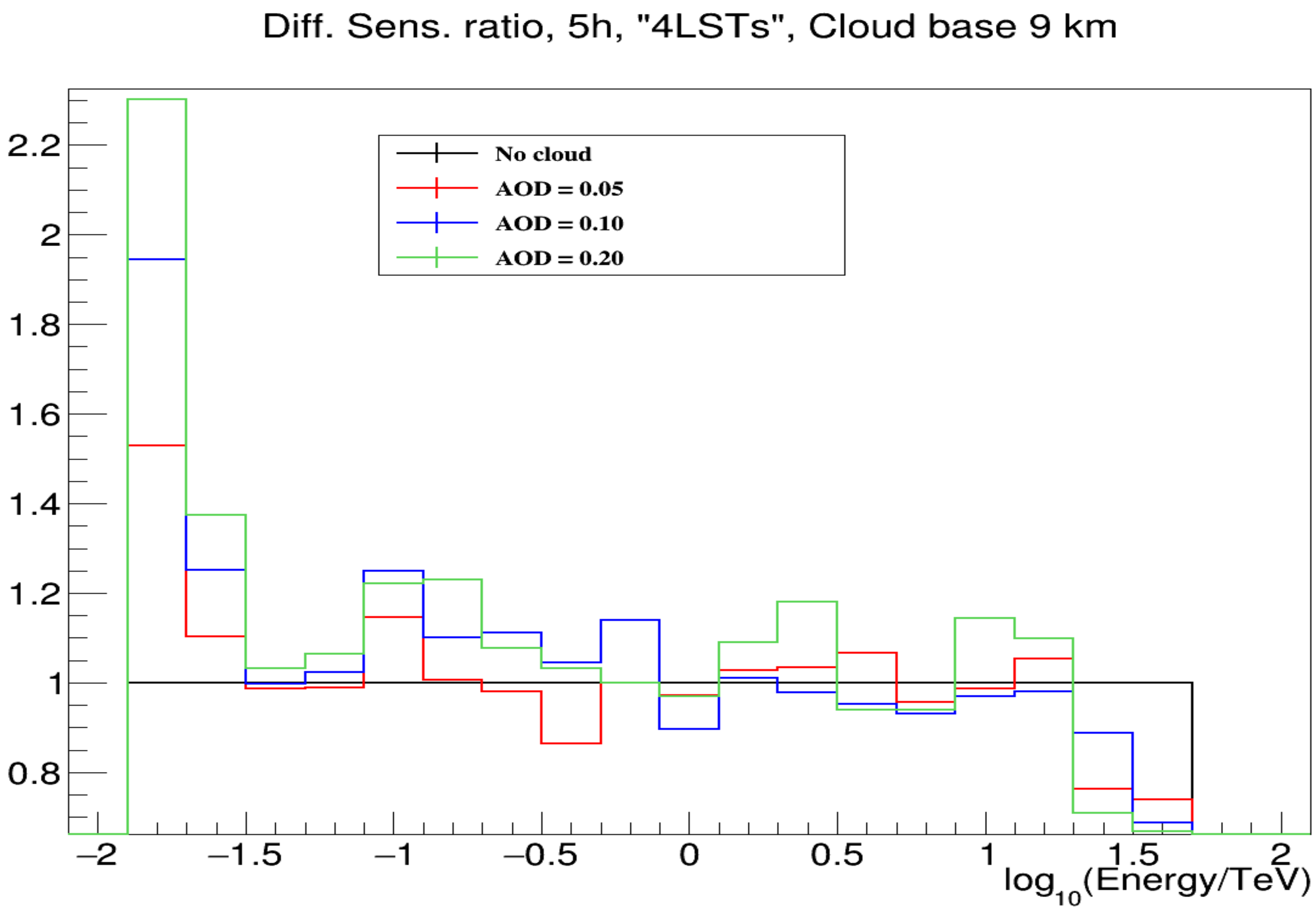
- Supercomputer “Bura” (University of Rijeka)
- In order to test the analysis chain, we produce preliminary MC simulations using sim_telarray with low statistics (**γ: 1971975, e: 83202, p: 212931**)
- Zenith: 20°, Azimuth: 180°, Standard Wobble, Slope: -2.0, Observatory level: 2147 m
- “MAGIC” style analysis (by A. Moralejo at al.)
- First analysis with 4 LSTs (we expect the effects on sensitivity to be most significant at low energies)

AOD dependence

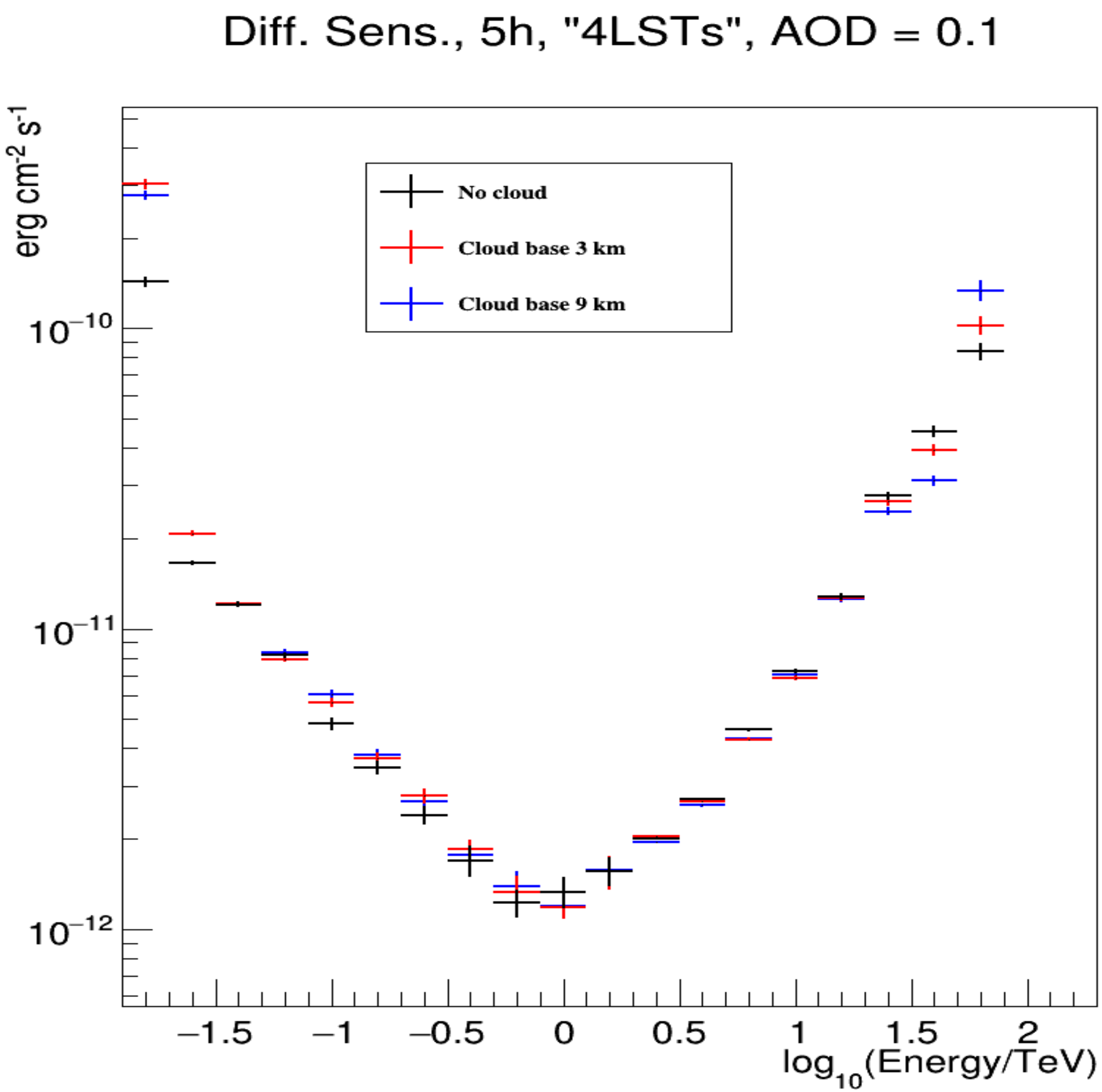


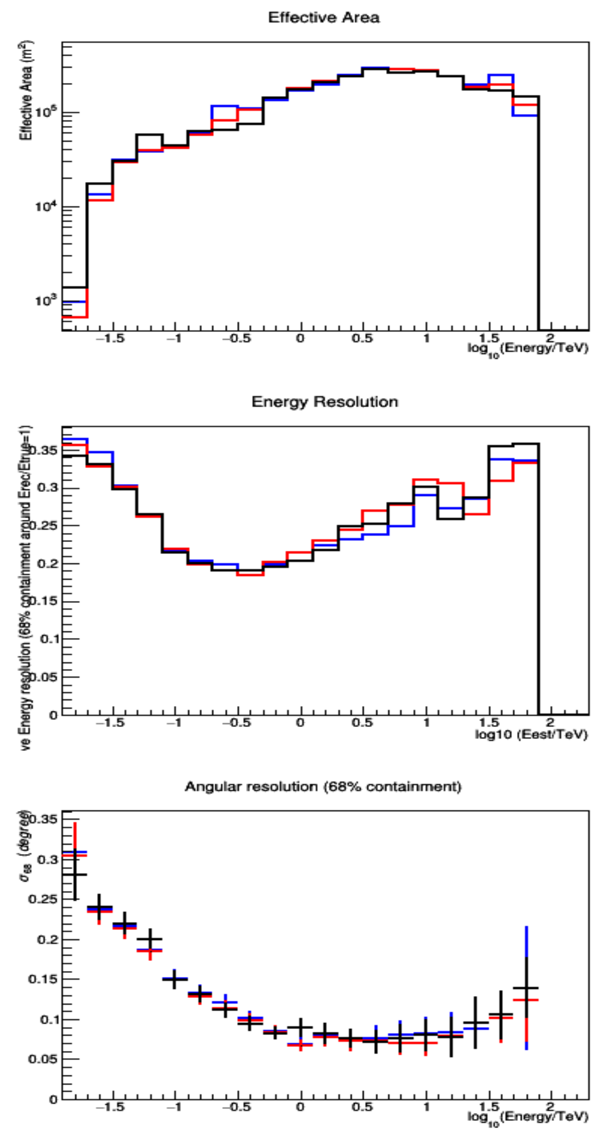


AOD dependence

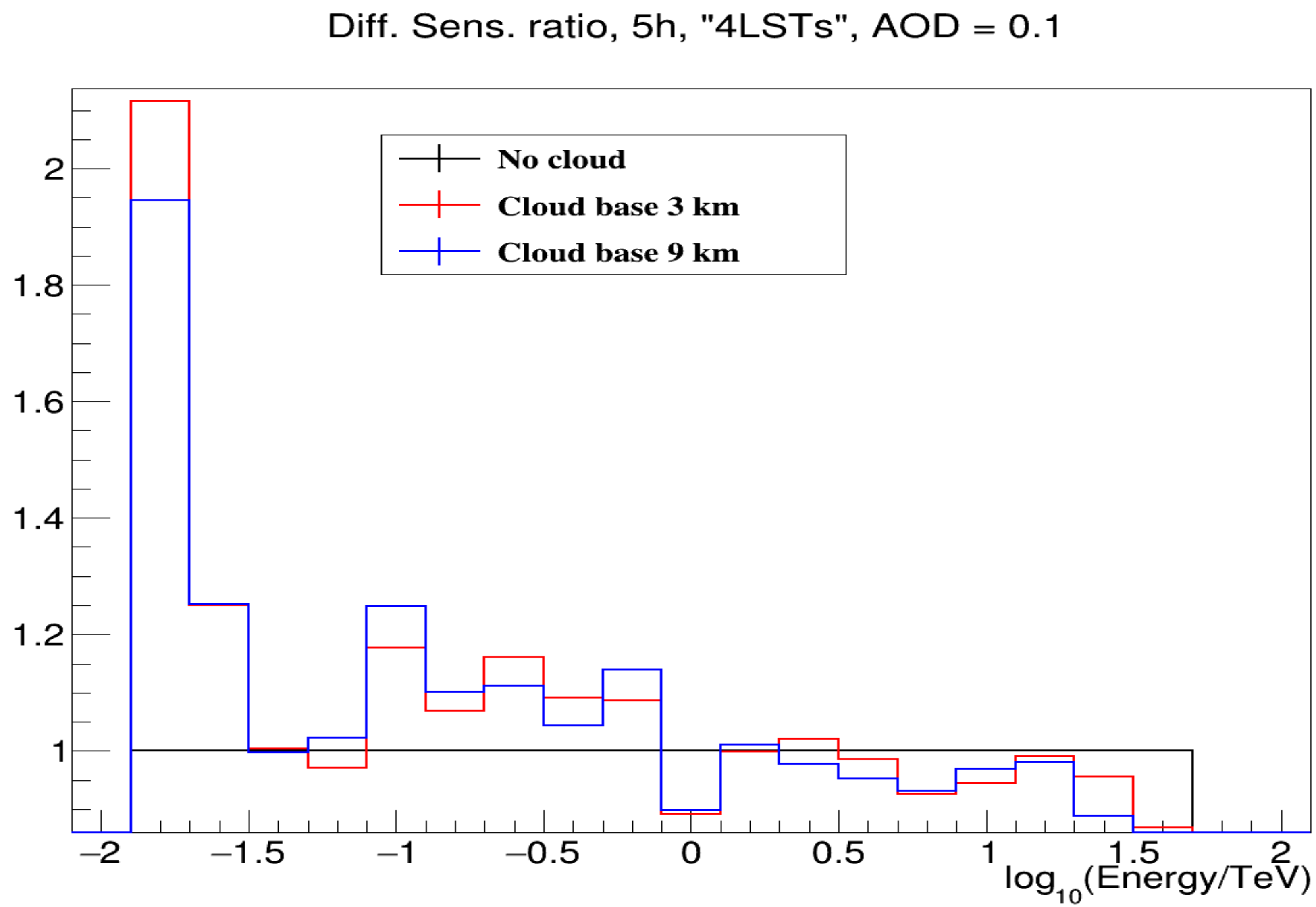


Cloud altitude dependence





Cloud altitude dependence

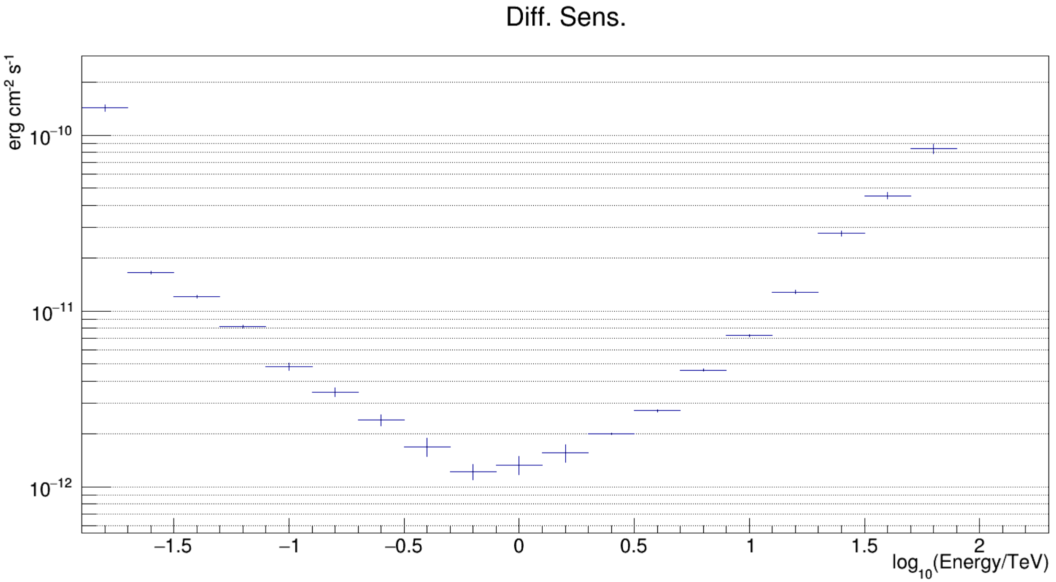


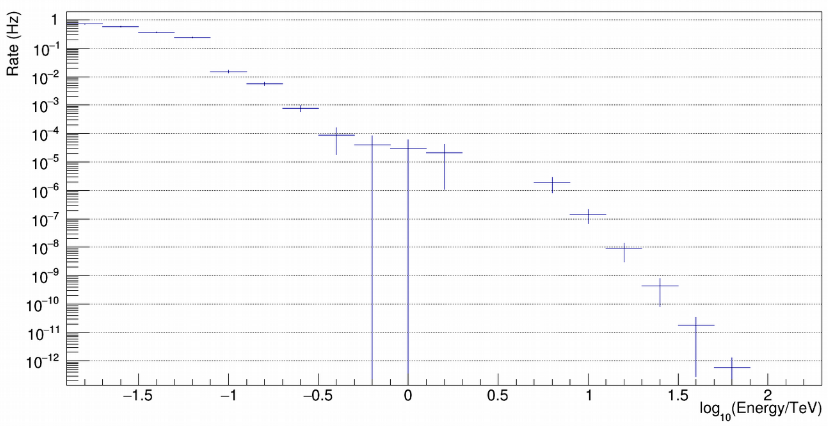
Conclusions and future plans

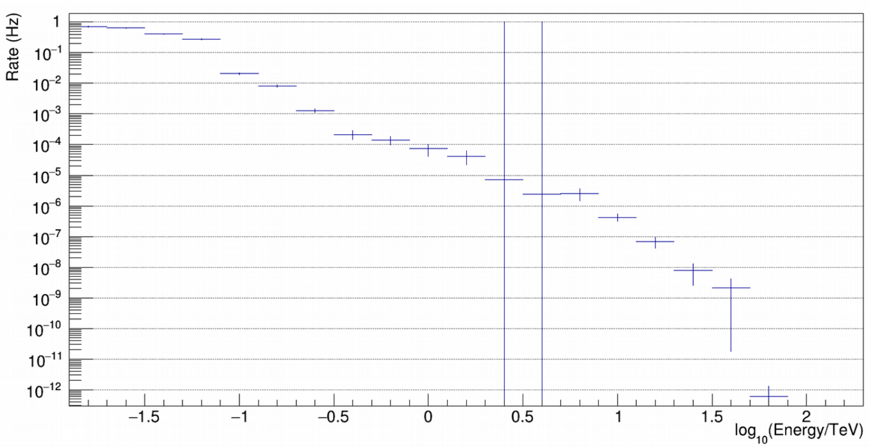
- Effects of clouds are visible at low energies (even with low statistics)
- Simulation and analysis chain have been tested for the purpose of this study
- Input parameters for sim_telarray need to be adjusted for CTA-N in order to improve statistics
- Work on energy reconstruction bias is ongoing
- Full production for complete Prod3 CTA-N array with better statistics is expected soon (~months)

Backup slides

Test MC simulations (low statistics): 4 LSTs at CTA-N without clouds







Supercomputer “Bura” – University of Rijeka, Croatia

- Operational since **2016**
- Multiprocessor: 2 nodes (256 processor cores and 6 TB of shared memory each)
- Cluster: 288 computing nodes with 6912 processor cores (each node has 24 cores and 64GB of RAM). In addition there are 4 nodes with graphical processing units (GPU) suitable for highly parallel applications

- 1 PB of data storage space (plus additional 2.5 PB for archiving on the tape drives)
- Achieved performance is 233.56 TFLOPS

List of altitudes (in km)

2.197 2.247 2.347 2.447 2.647 2.847 3.147 3.647
4.147 4.500 5.000 5.500 6.000 7.000 8.000 9.000
10.000 11.000 12.000 13.000 14.000 15.000 16.000
18.000 20.000 22.000 24.000 26.000 28.000 30.000
32.500 35.000 37.500 40.000 45.000 50.000 60.000
70.000 80.000 100.000

Extended list of altitudes (in km)

E.g. cloud thickness 1.0 km; height of cloud base **9.2 km a.s.l.**; fine grid (step 100 m) between 9.0 km a.s.l. and 10.5 km a.s.l.

2.197 2.247 2.347 2.447 2.647 2.847 3.147 3.647 4.147 4.500 5.000 5.500 6.000 7.000 8.000 **9.000 9.100 9.200 9.300 9.400 9.500 9.600 9.700 9.800 9.900 10.000 10.100 10.200 10.300 10.400 10.500** 11.000 12.000 13.000 14.000 15.000 16.000 18.000 20.000 22.000 24.000 26.000 28.000 30.000 32.500 35.000 37.500 40.000 45.000 50.000 60.000 70.000 80.000 100.000

MODTRAN simulations

SET1

cloud thickness 1.0 km

total optical depth **0.05**

simulation number	height of cloud base a.s.l. (km)
15	**5.2**
16	**7.2**
17	**9.2**
18	**11.2**
19	**13.2**
20	**15.2**

MODTRAN simulations

SET2

cloud thickness 1.0 km

total optical depth **0.1**

simulation number	height of cloud base a.s.l. (km)
21	**5.2**
22	**7.2**
23	**9.2**
24	**11.2**
25	**13.2**
26	**15.2**

MODTRAN simulations

SET3
cloud thickness 1.0 km
total optical depth **0.2**

simulation number	height of cloud base a.s.l. (km)
27	**5.2**
28	**7.2**
29	**9.2**
30	**11.2**
31	**13.2**
32	**15.2**

MODTRAN simulations

SET4
cloud thickness 1.0 km
total optical depth **0.3**

simulation number	height of cloud base a.s.l. (km)
33	**5.2**
34	**7.2**
35	**9.2**
36	**11.2**
37	**13.2**
38	**15.2**

MODTRAN simulations

SET5
cloud thickness 1.0 km
total optical depth **0.5**

simulation number	height of cloud base a.s.l. (km)
39	**5.2**
40	**7.2**
41	**9.2**
42	**11.2**
43	**13.2**
44	**15.2**

MODTRAN simulations

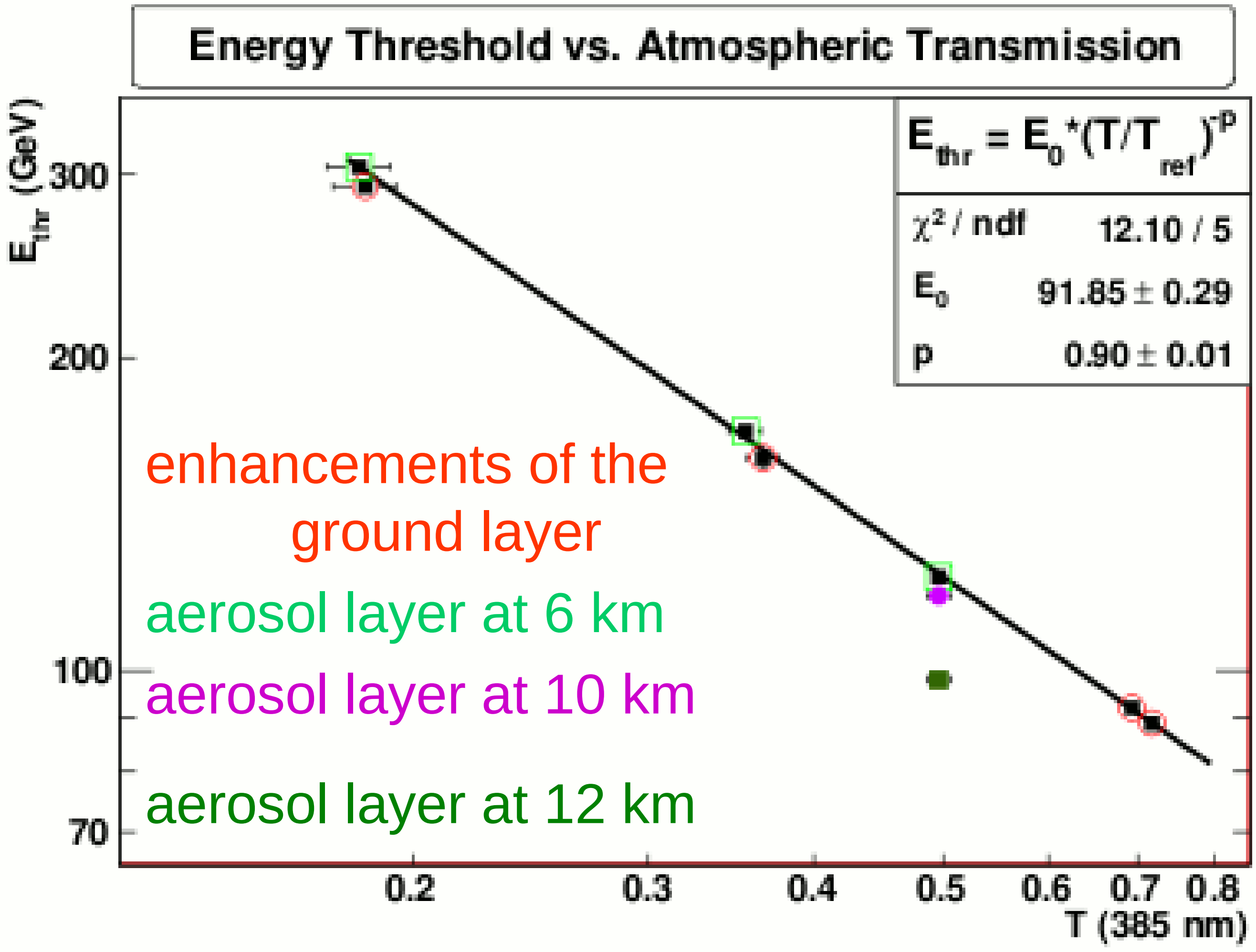
SET6

cloud thickness 1.0 km

total optical depth **0.7**

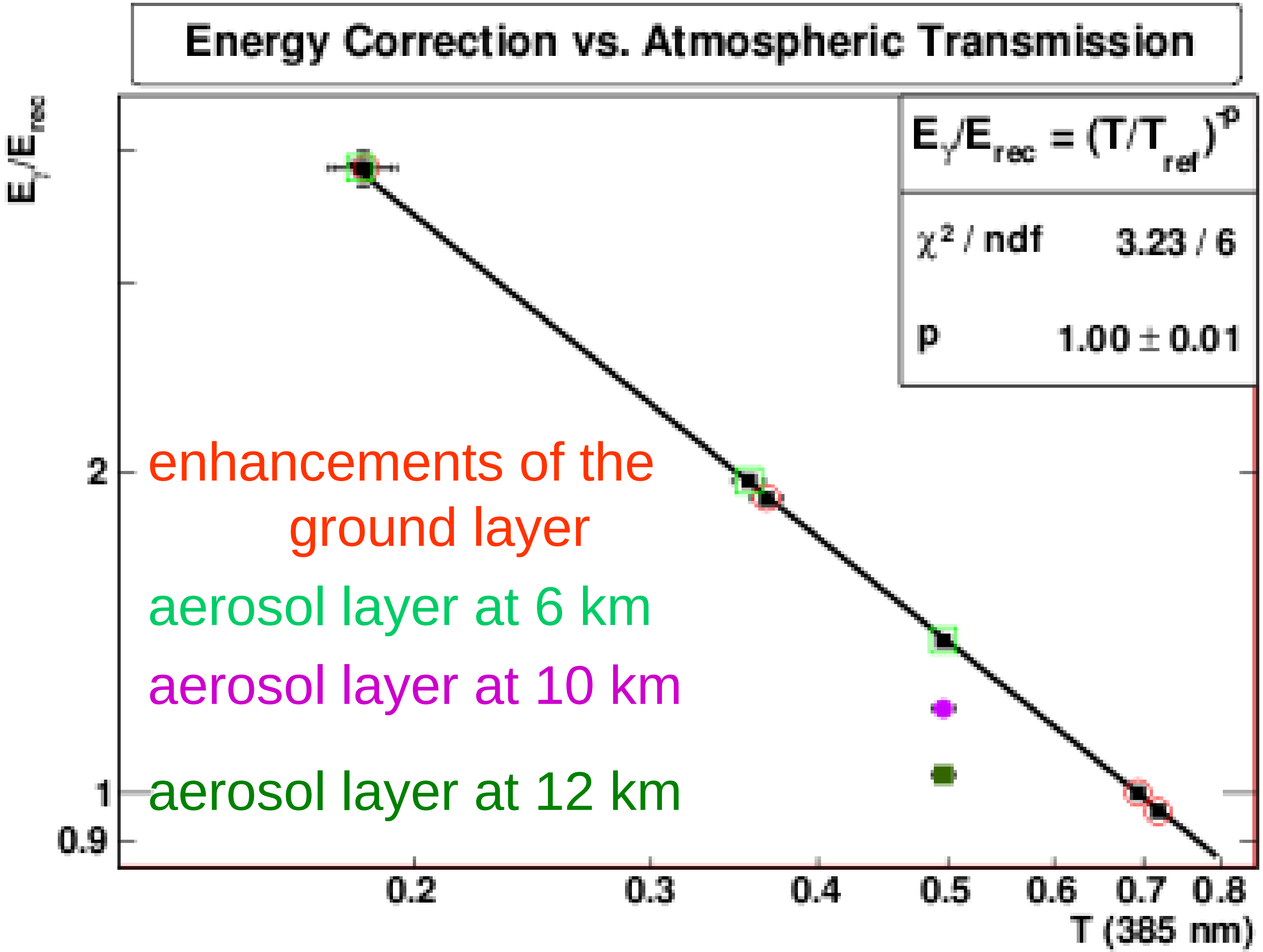
simulation number	height of cloud base a.s.l. (km)
45	**5.2**
46	**7.2**
47	**9.2**
48	**11.2**
49	**13.2**
50	**15.2**

Energy Threshold



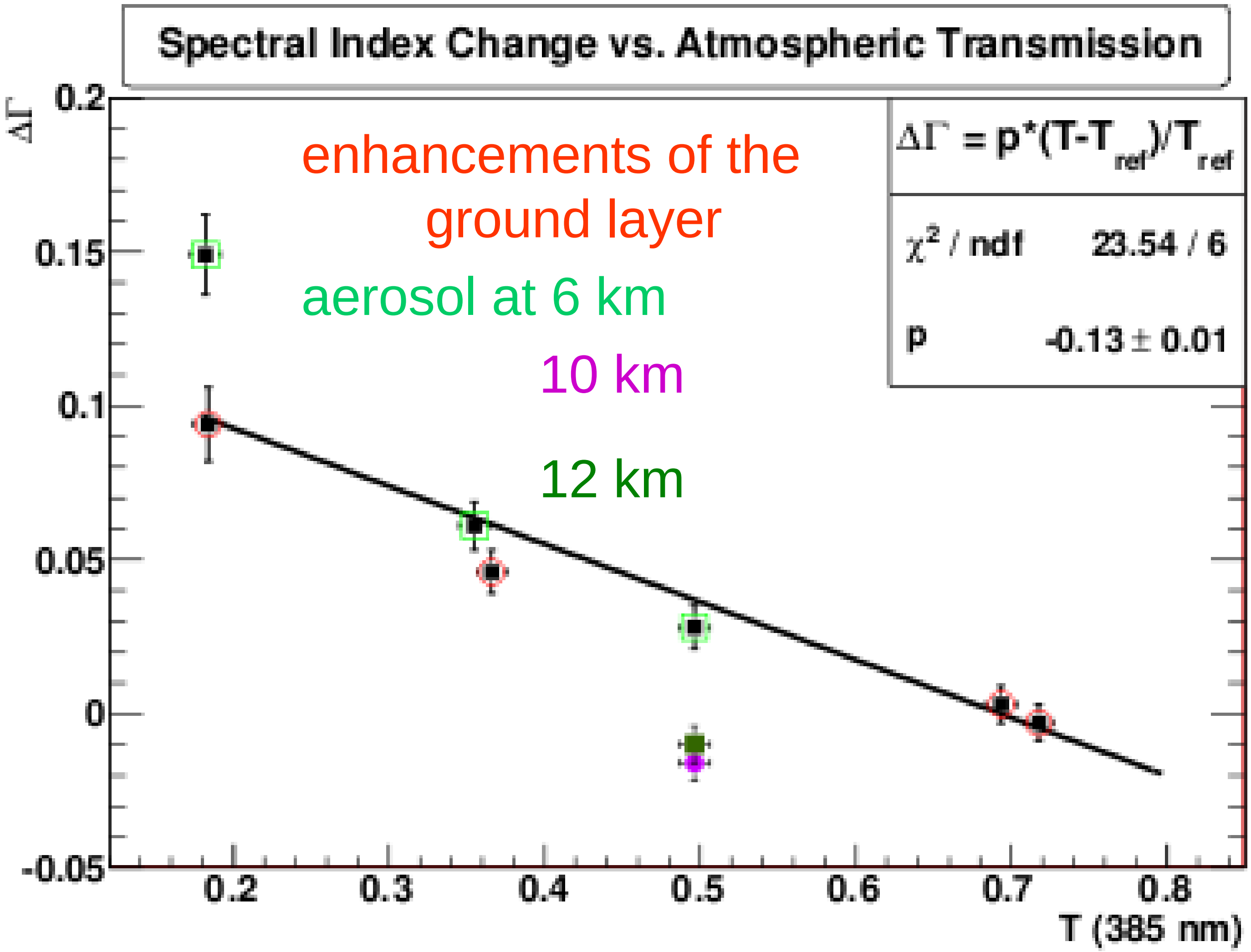
Garrido, Gaug, Font, Moralejo (MAGIC Coll.), 2014

Energy correction



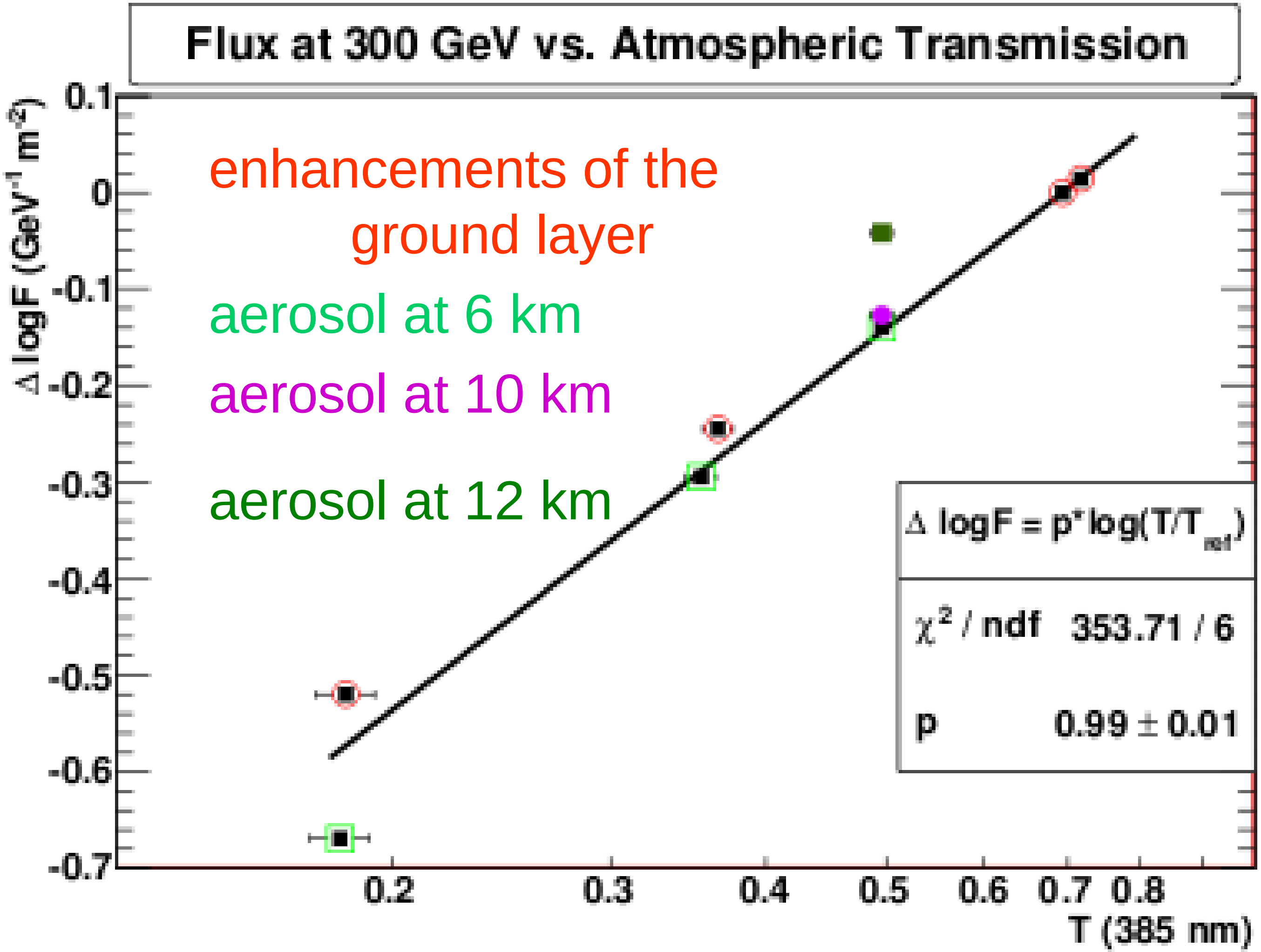
Garrido, Gaug, Font, Moralejo (MAGIC Coll.), 2014

Spectral index change



Garrido, Gaug, Font, Moralejo (MAGIC Coll.), 2014

Flux at 300 GeV



Garrido, Gaug, Font, Moralejo (MAGIC Coll.), 2014