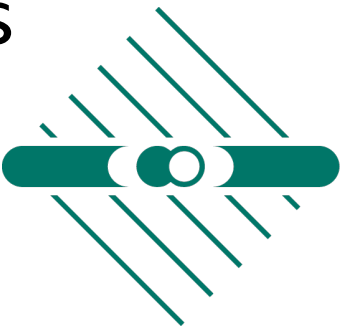
Atmospheric Monitoring With H.E.S.S.

Joachim Hahn, Raquel de los Reyes



Outline

- The H.E.S.S. instrument
- Monitoring Devices on site
- Data Quality Selection
- Smart Scheduling
- Data Correction

The H.E.S.S. Instrument

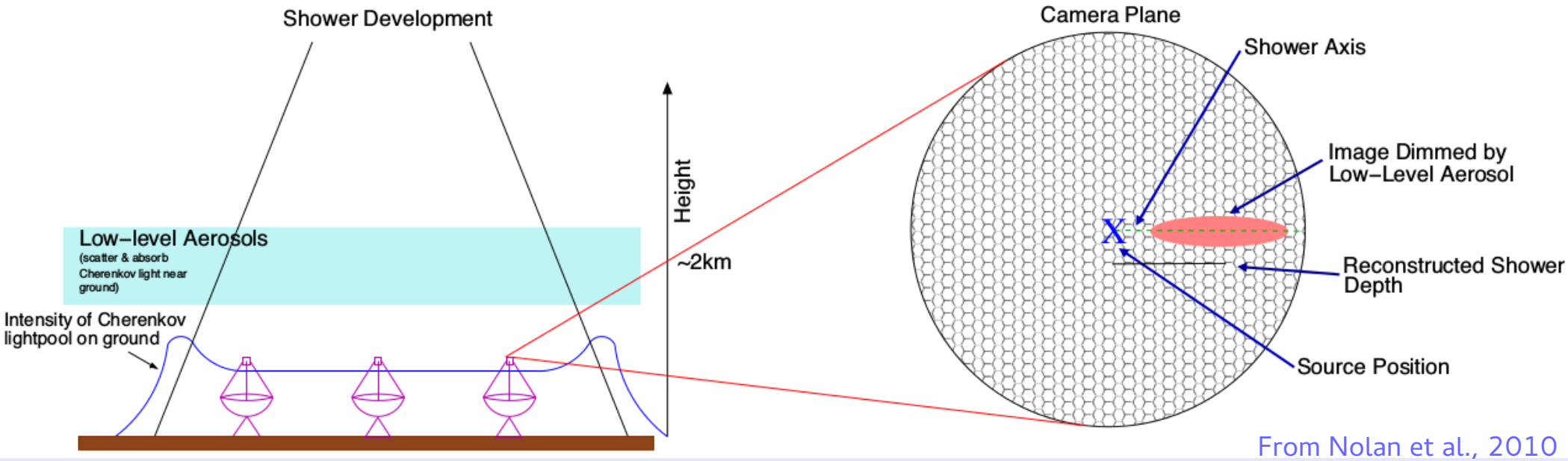
The H.E.S.S. Instrument

- H.E.S.S. phase I telescopes
  - 12m diameter
  - 5° field of view
  - Energy threshold ~100 GeV
  - 0.1° angular resolution
  - ~20% energy resolution

The H.E.S.S. Instrument

- H.E.S.S. phase I telescopes
  - 12m diameter
  - 5° field of view
  - Energy threshold ~100 GeV
  - 0.1° angular resolution
  - ~20% energy resolution
- H.E.S.S. phase II telescope
  - 28m telescope
  - 3.2° field of view
  - Energy threshold ~ 30GeV
  - Fast slewing speed (important for transients)
  - Mono or stereo mode

Impact of atmospheric absorbers



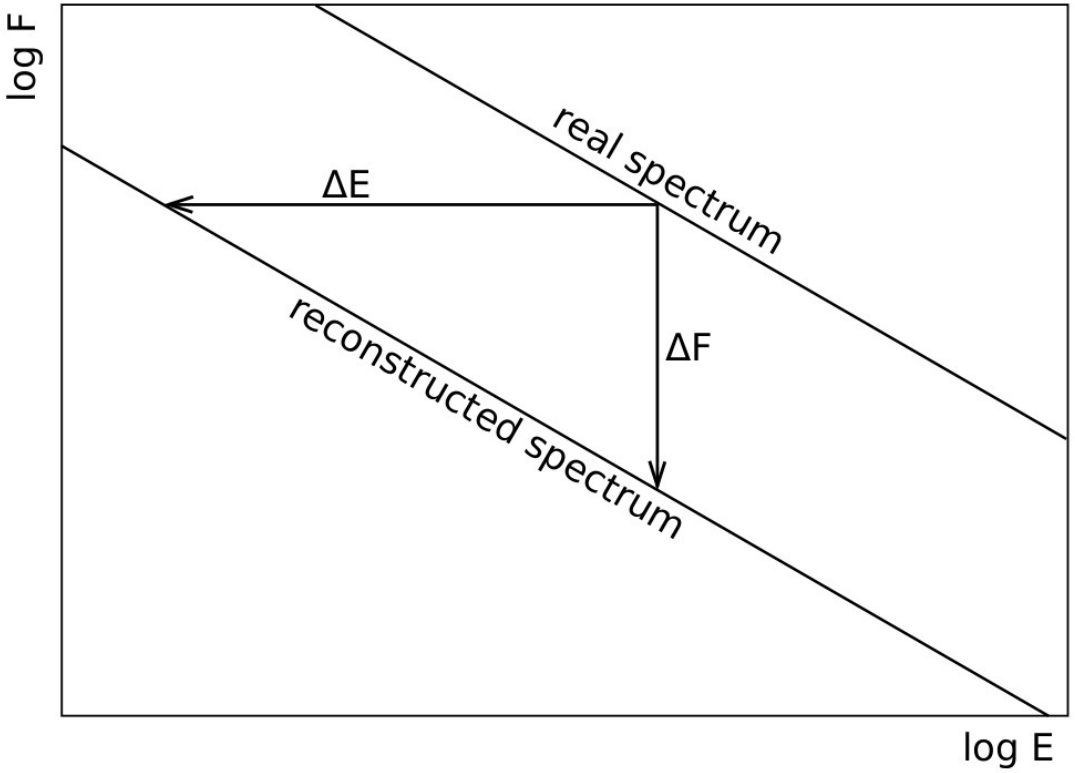
From Nolan et al., 2010

- Gamma-rays: Cherenkov light intensity proportional to primary energy

-> Reconstruction: $E_{reco} \sim N_{ph}$

-> Light-attenuation by atmospheric absorbers leads to downwards bias in E_{reco}

The H.E.S.S. Instrument



- Downwards bias in reconstructed energy
  -> Downwards bias in reconstructed flux
  -> Excess of particles at the low energ end
  -> slight spectral softening

Monitoring devices on site

Atmospheric Monitoring With H.E.S.S.

Monitoring devices on site

- Normal weather station
  - Precipation
  - Wind speed
  - Humidity
  - Air Pressure

Atmospheric Monitoring With H.E.S.S.

Monitoring devices on site

- 5 Radiometers
  - 4 instruments mounted on the telescope structure, pointing in observational direction
  - λ = 8-14µm, 2° field-of-view
  - Allows detection of clouds
  - aerosol load measurement

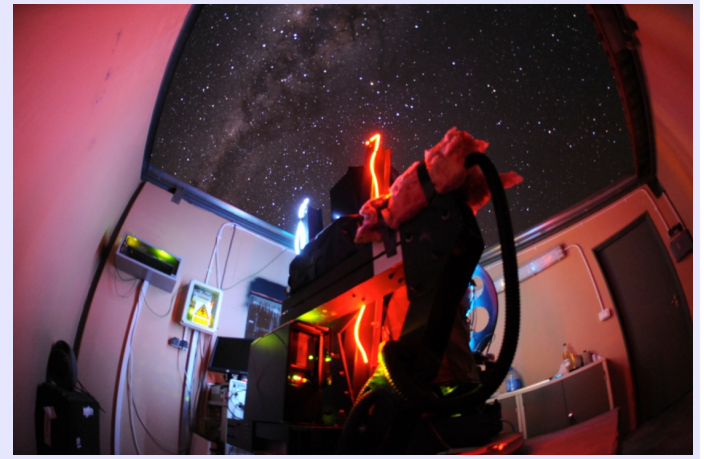
→ **See Michael's talk!**

Atmospheric Monitoring With H.E.S.S.

Monitoring devices on site

- Scanning Radiometer
  - Same Type as the telescope-mounted ones
  - Round-turn every ~30min
  - Cloud monitoring, also smart scheduling

Monitoring devices on site



- LIDAR
  - 60cm diameter primary parabolic mirror
  - 532nm,355nm @ 10Hz
  - Records atmospheric profiles in between runs

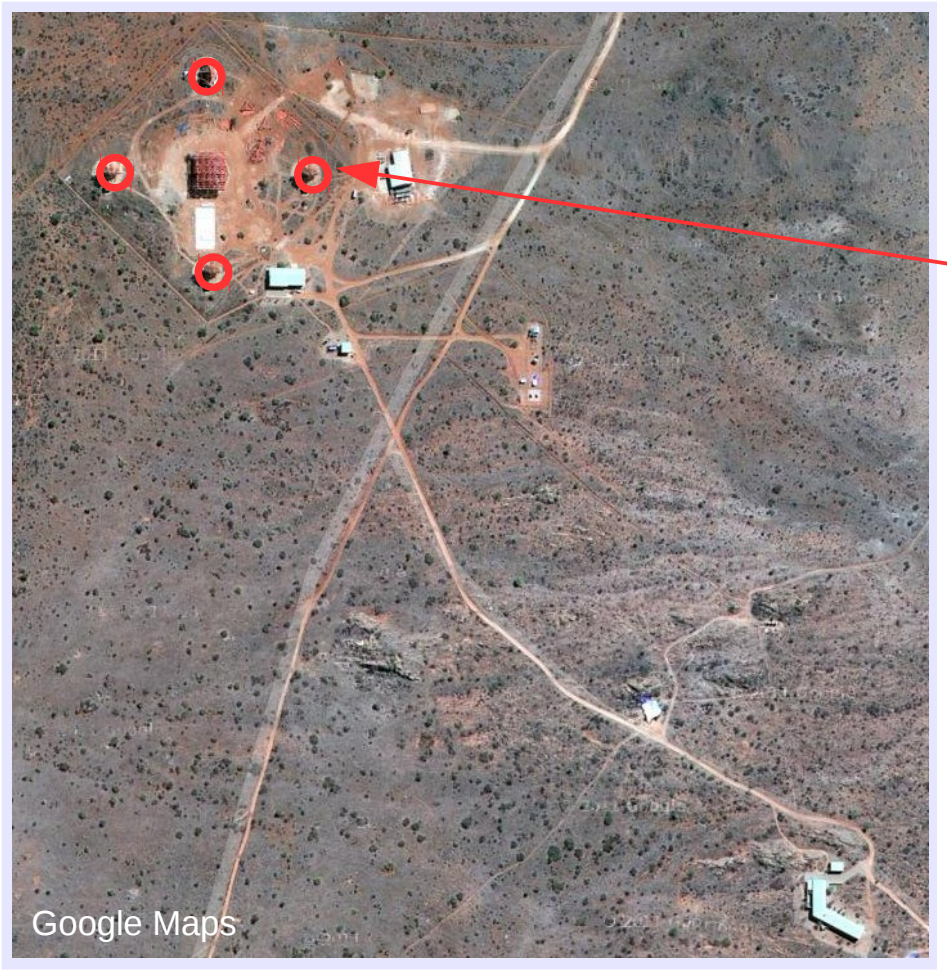
→ **See George's talk!**

Monitoring devices on site

- ATOM All Sky Camera
  - 180° field of view
  - Images every 3 min
  - Cloud monitoring

→ **See Felix' talk!**

Monitoring devices on site



- H.E.S.S. phase I telescopes
  - Use the trigger rates to estimate air transparency
    -> Able to detect clouds & aerosols
  - Used in DQ monitoring

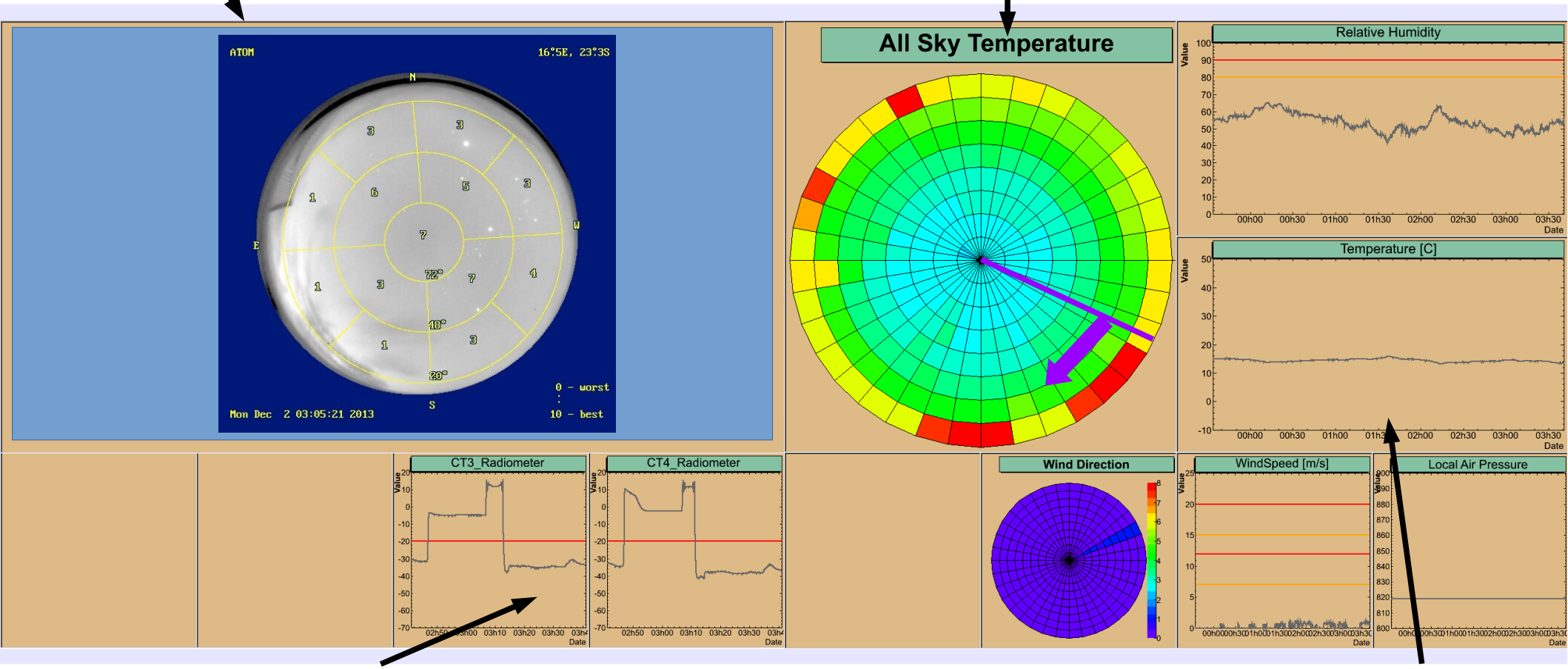
Atmospheric Monitoring With H.E.S.S.

The H.E.S.S. Instrument

Meanwhile in the Control Room...

All-Sky Camera

Scanning Radiometer



Radiometers

Weather Station

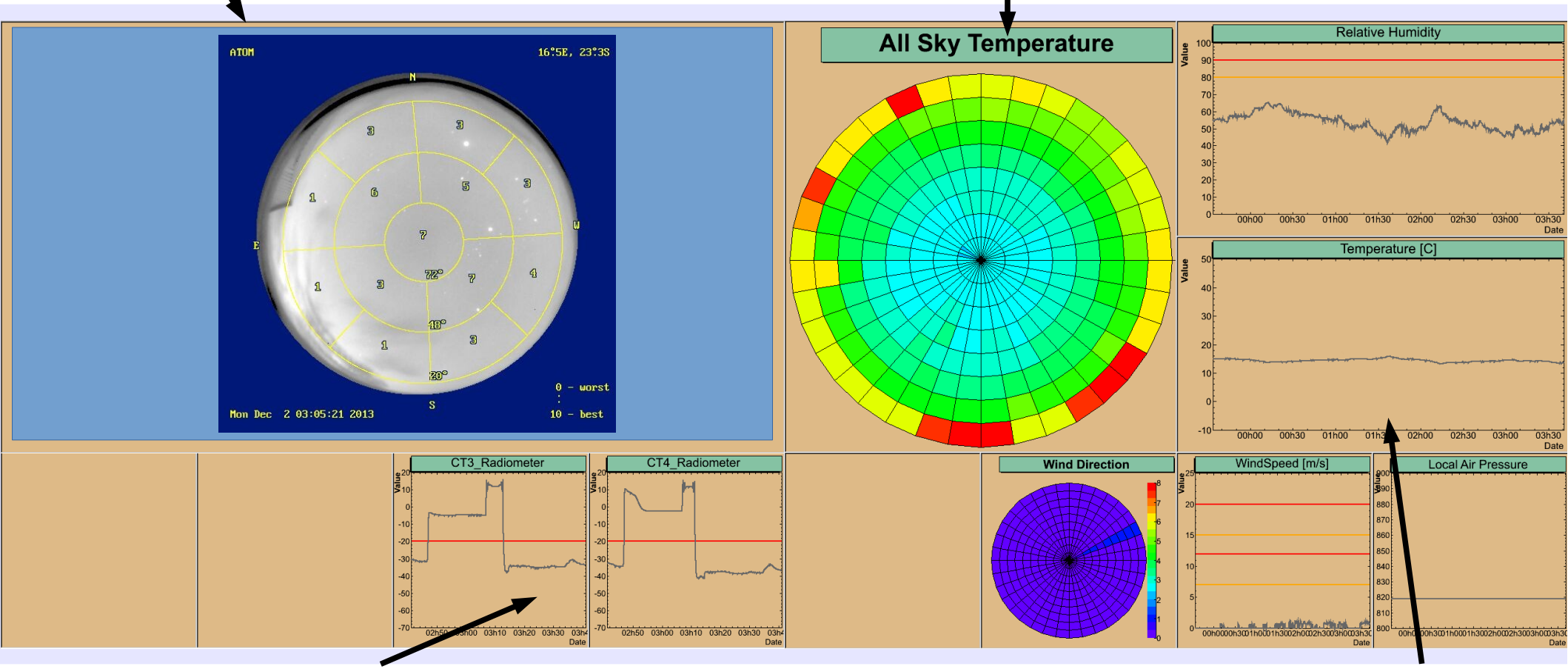
The H.E.S.S. Instrument

Meanwhile in the Control Room...

Scanning Radiometer

All-Sky Camera

Clouds approaching?



Radiometers

Weather Station

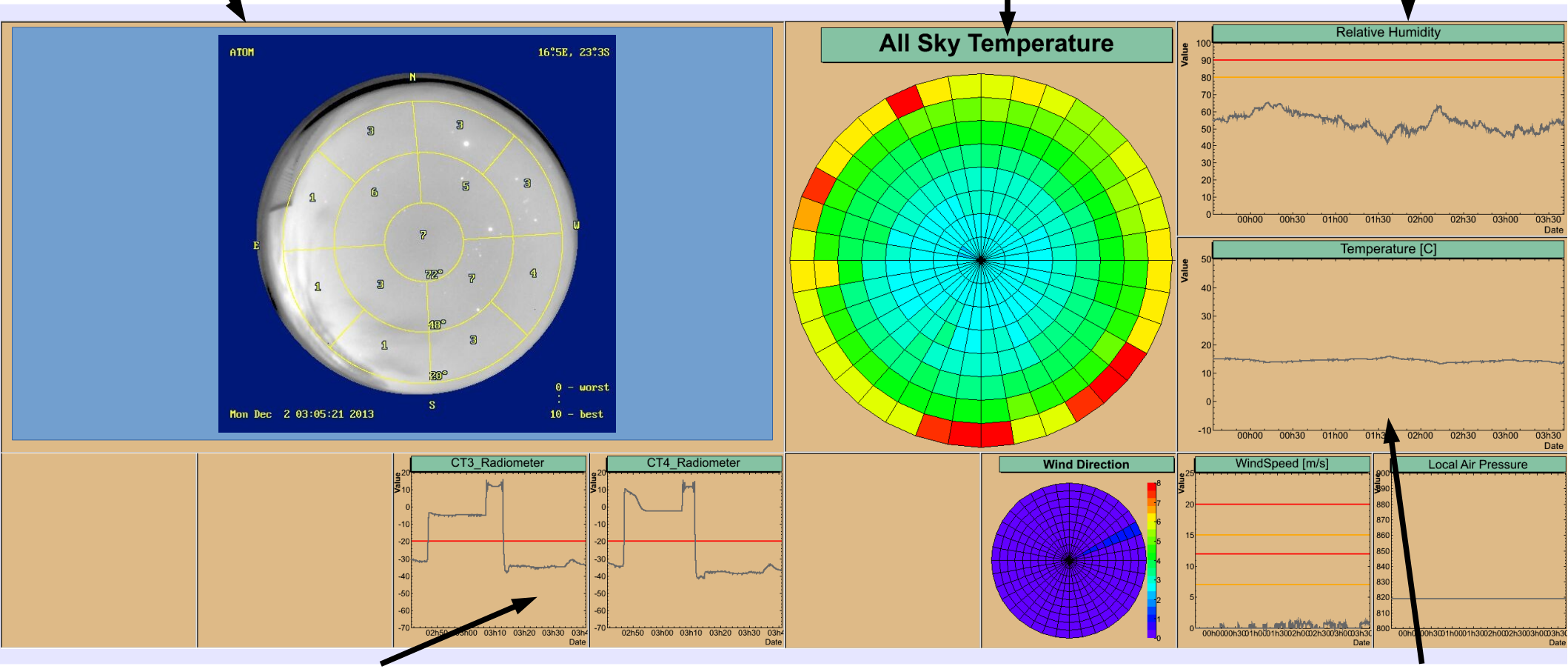
The H.E.S.S. Instrument

Meanwhile in the Control Room...

All-Sky Camera

Scanning Radiometer

Humidity too high? ->Condensation!



Radiometers

Weather Station

Atmospheric Monitoring With H.E.S.S.

The H.E.S.S. Instrument

Meanwhile in the Control Room...

All-Sky Camera

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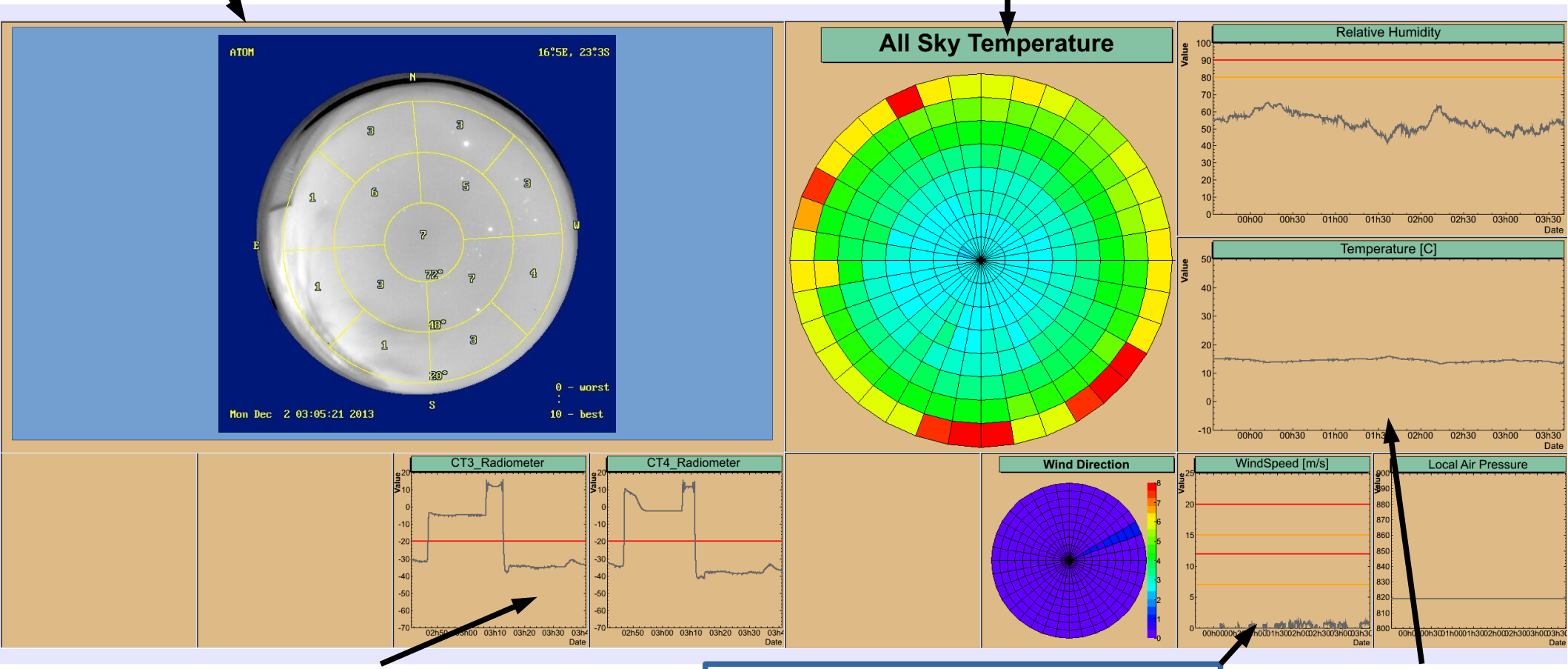


Radiometers

Wind? ->Structural damage!

Weather Station

Application

Data Quality Selection

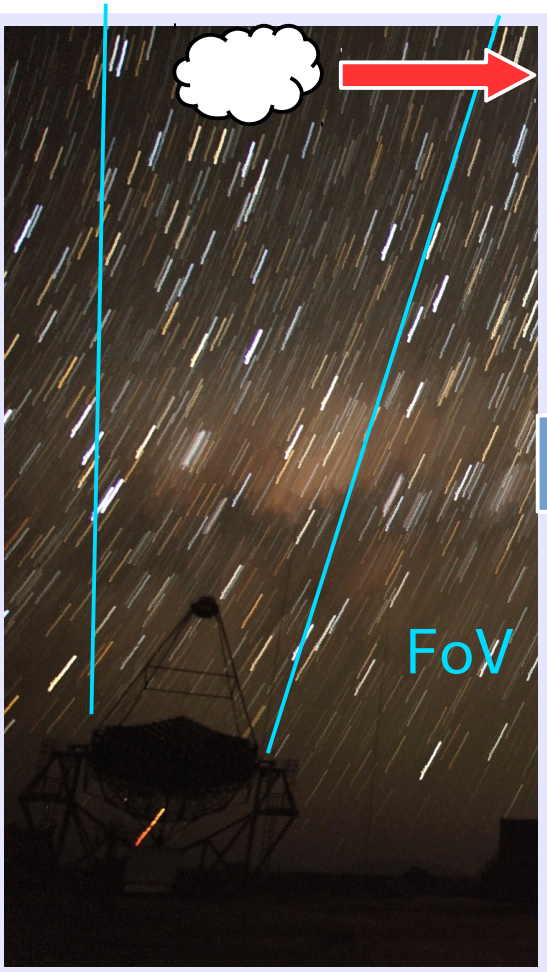
Application – Data Quality Selection

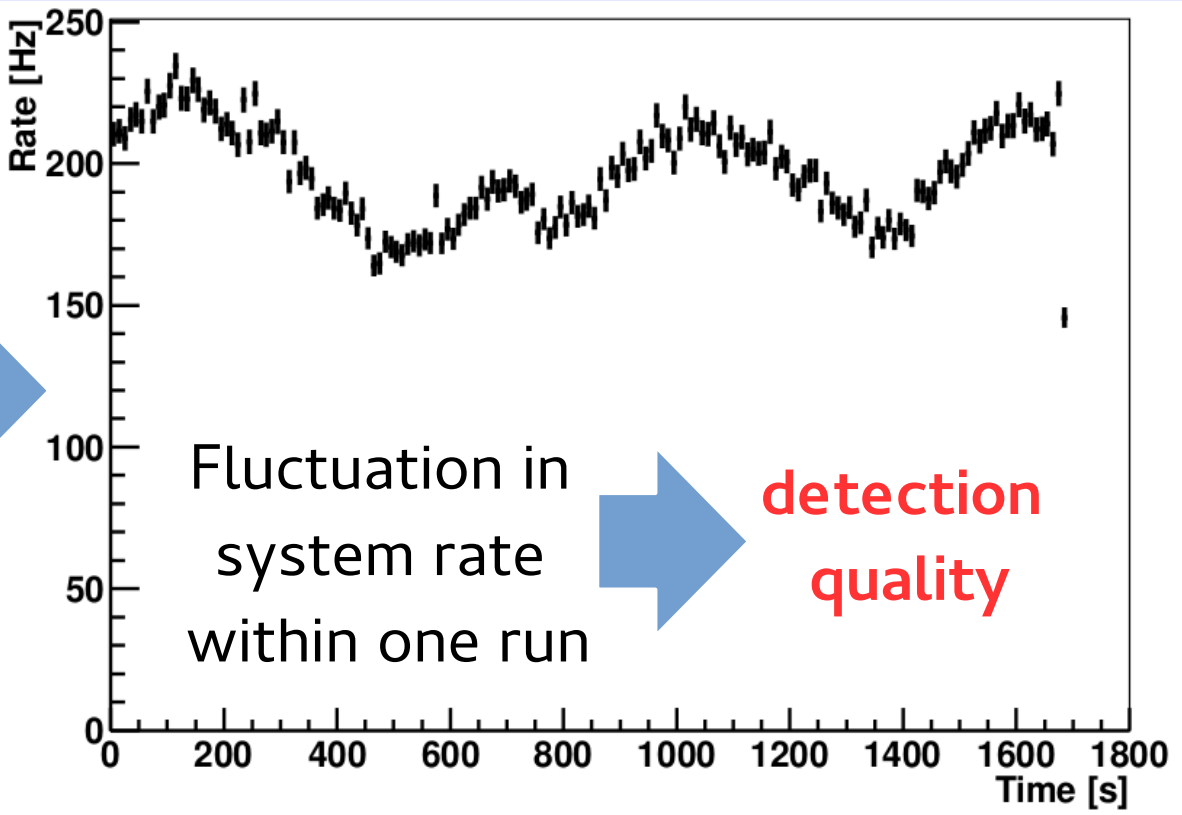
- In H.E.S.S., we classify our data in 2 quality categories:
  - **Detection** quality, hardware works fine, but atmosphere-induced energy biases are possible
    -> sufficient for source *detection*
  - **Spectral** quality, where data selection additionally guarantees limited systematics due to atmospheric effects
    -> required for *spectral reconstruction*

Application – Data Quality Selection

Detect sources in the presence

- Small – medium sized clouds





Application – Data Quality Selection

Detect sources in the presence of

- Aerosol layers, large scale and dilute clouds

Cherenkov Transparency Coefficient (CTC)

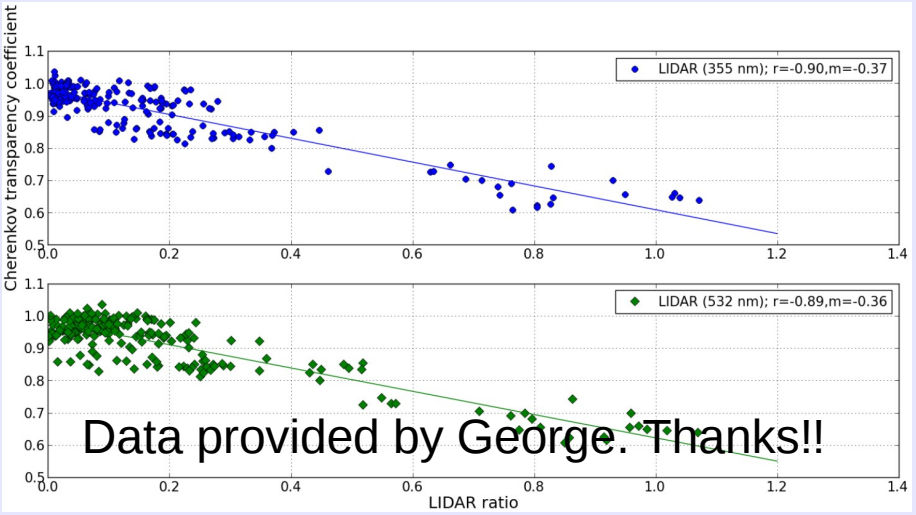
$$T \equiv \frac{1}{N \cdot k_N} \sum_i \frac{R_i^{\frac{1}{1.7-\Delta}}}{\mu_i \cdot g_i}$$

Quantity designed to isolate atmospheric contributions to decreased trigger rate

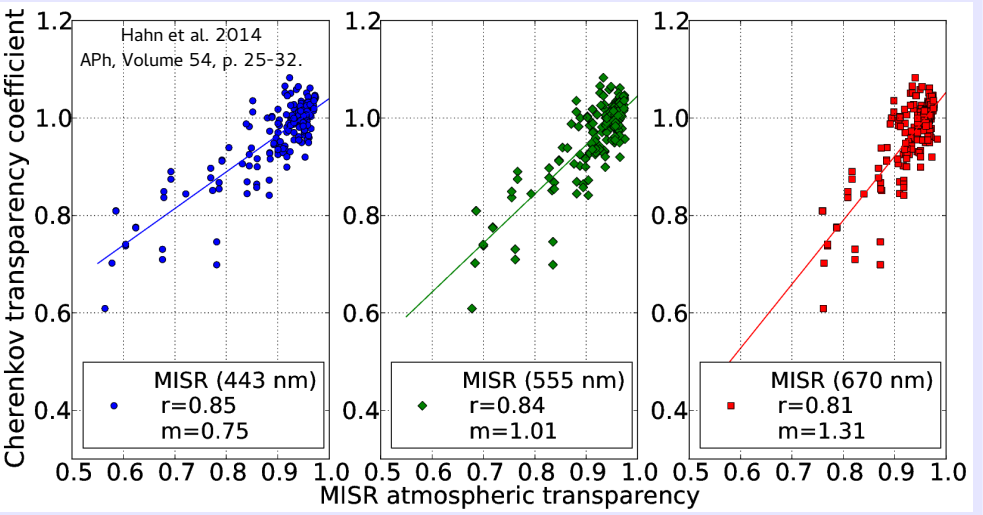
Application – Data Quality Selection

Detect sources in the presence of

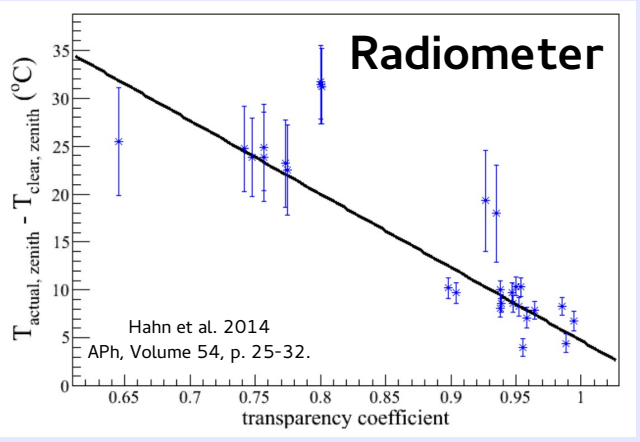
- Aerosol layers, large scale and dilute clouds



LIDAR



Satellite (MISR)



Application – Data Quality Selection

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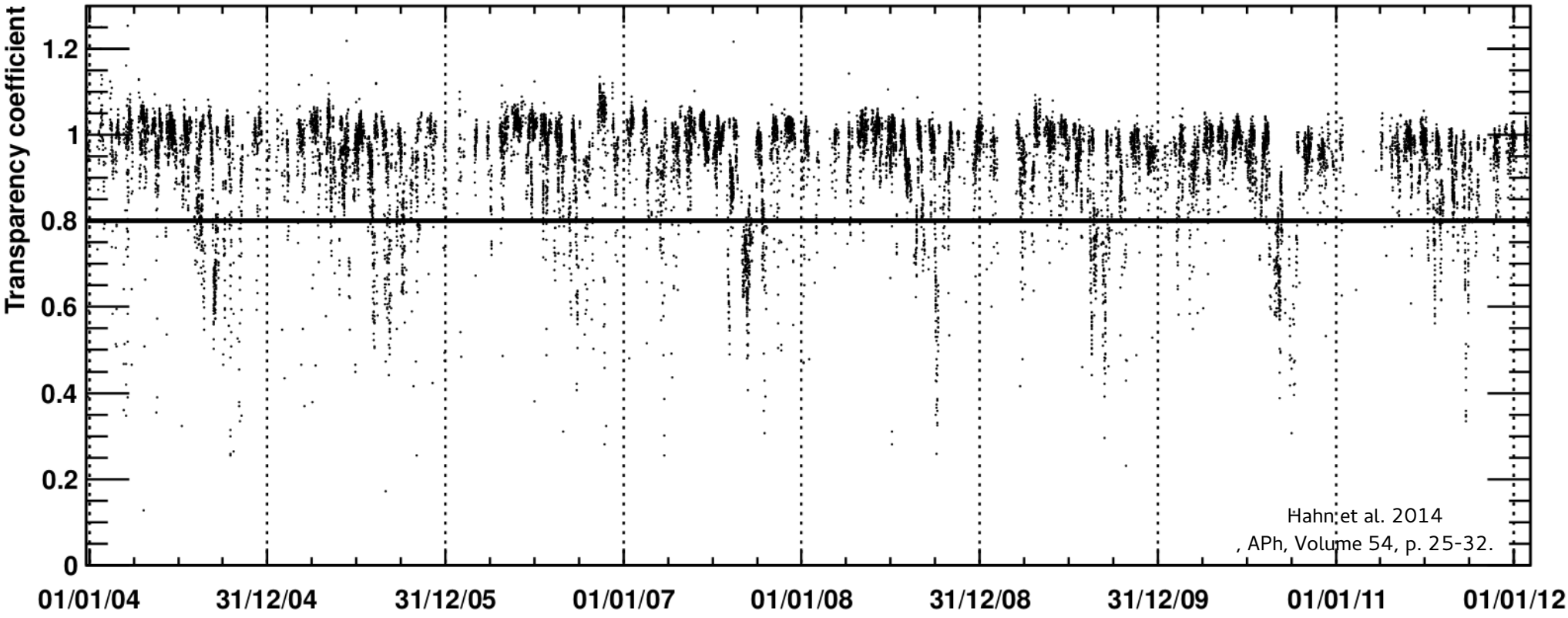

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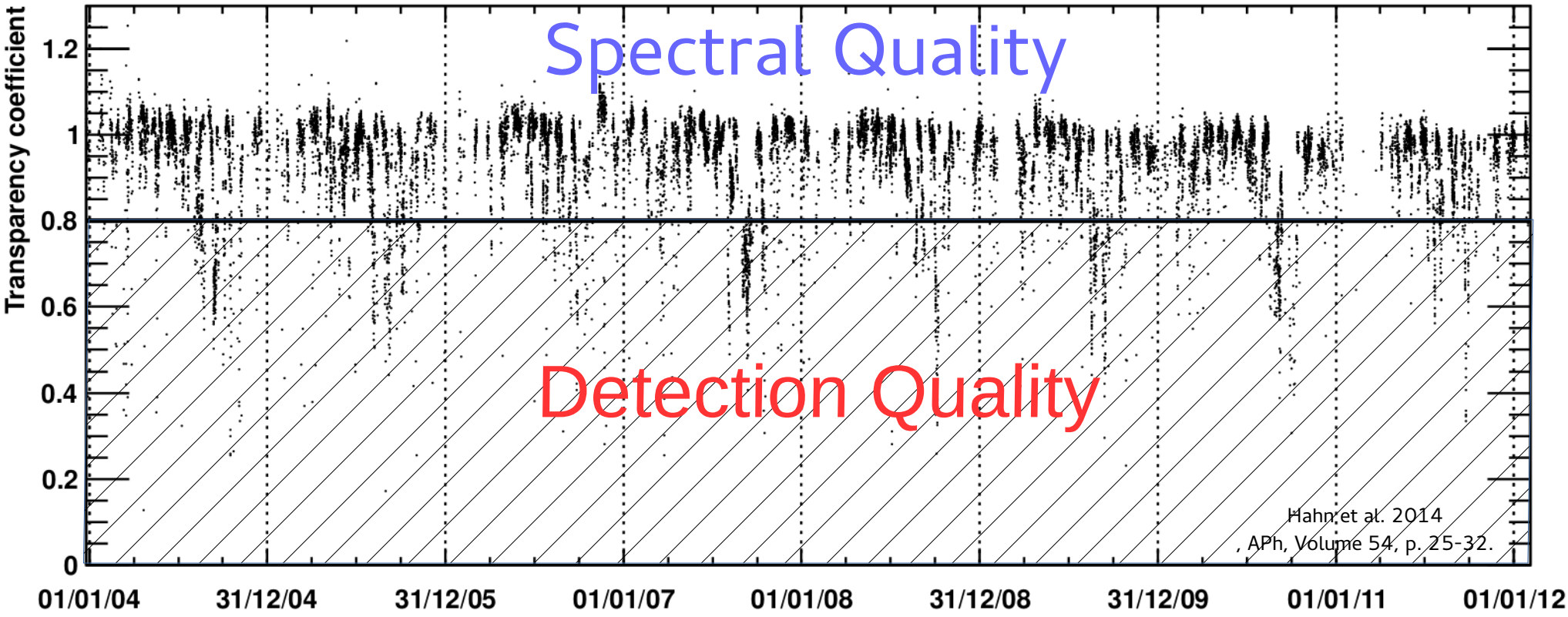


Application

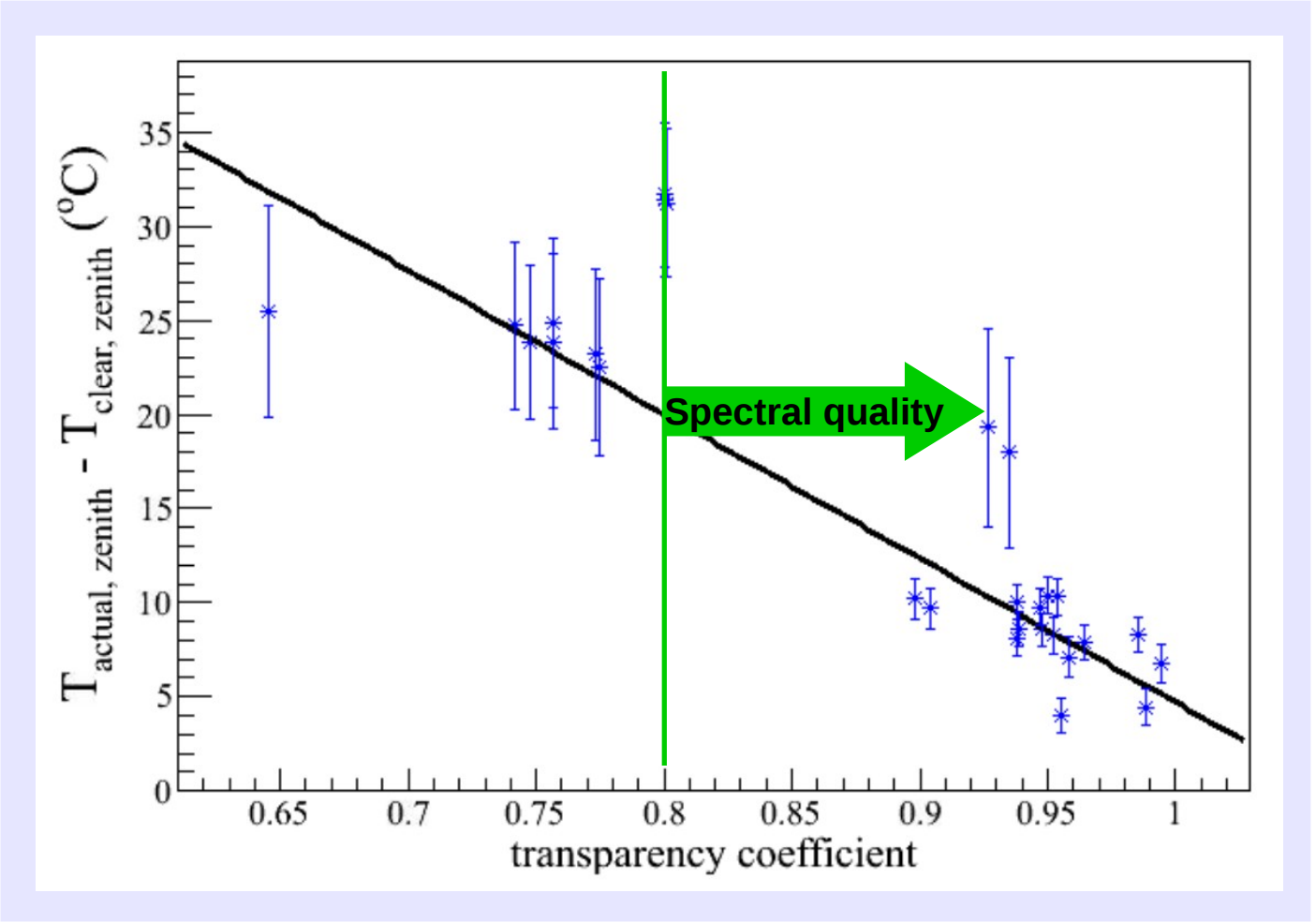
Smart Scheduling

Application – Smart Scheduling

- Not all observations require the best atmospheric conditions, e.g. source detections
  - Take this into account in observation planning
  - Different observation schedules
- Radiometer is continuously taking data during observations
  - Use this data to switch between schedules
- Corresponding mechanism is implemented
  - currently being investigated and tested with H.E.S.S.

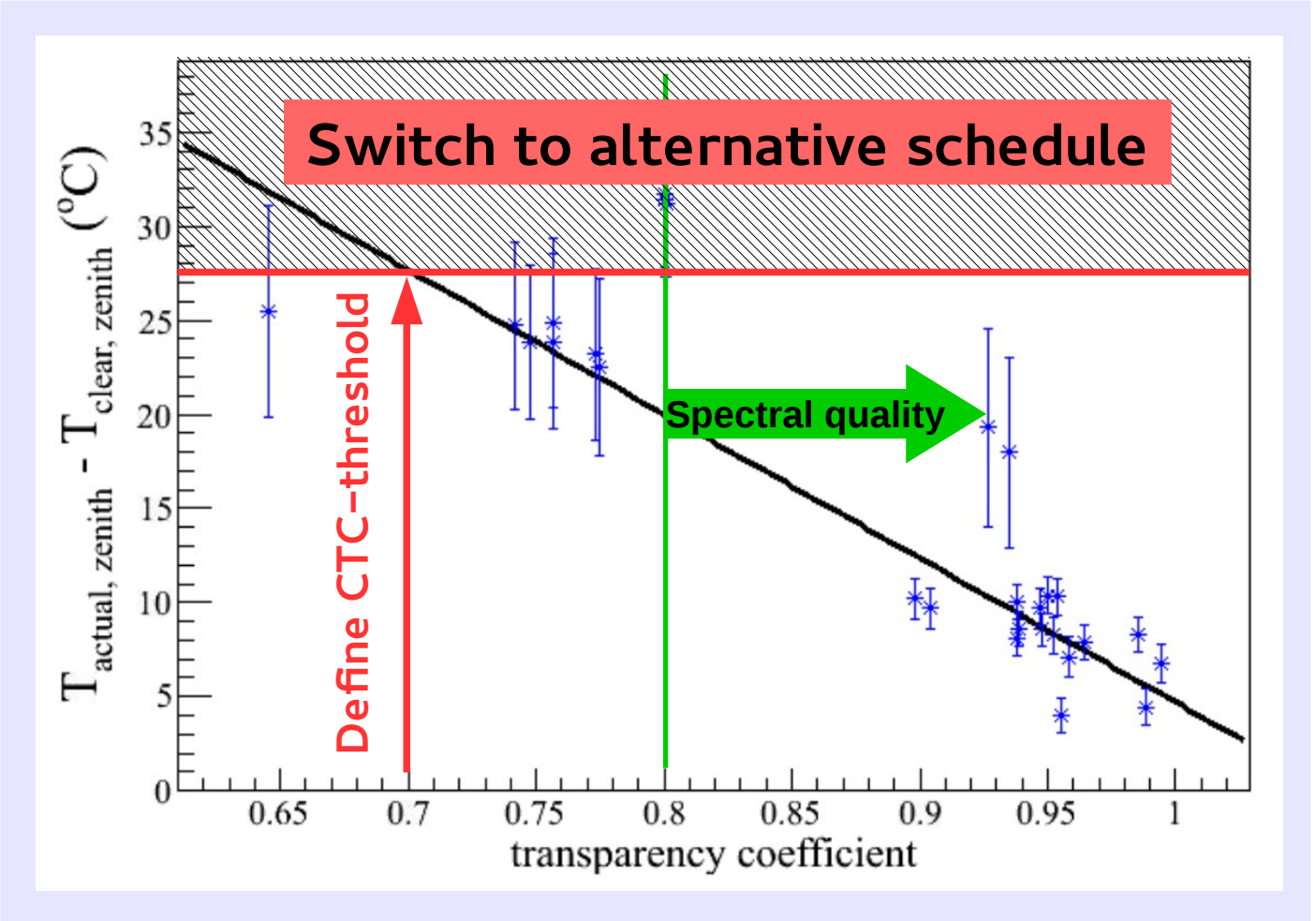
Application – Smart Scheduling

Use the correlation CTC-Sky Temperature



Application – Smart Scheduling

Use the correlation CTC-Sky Temperature



Application – Smart Scheduling

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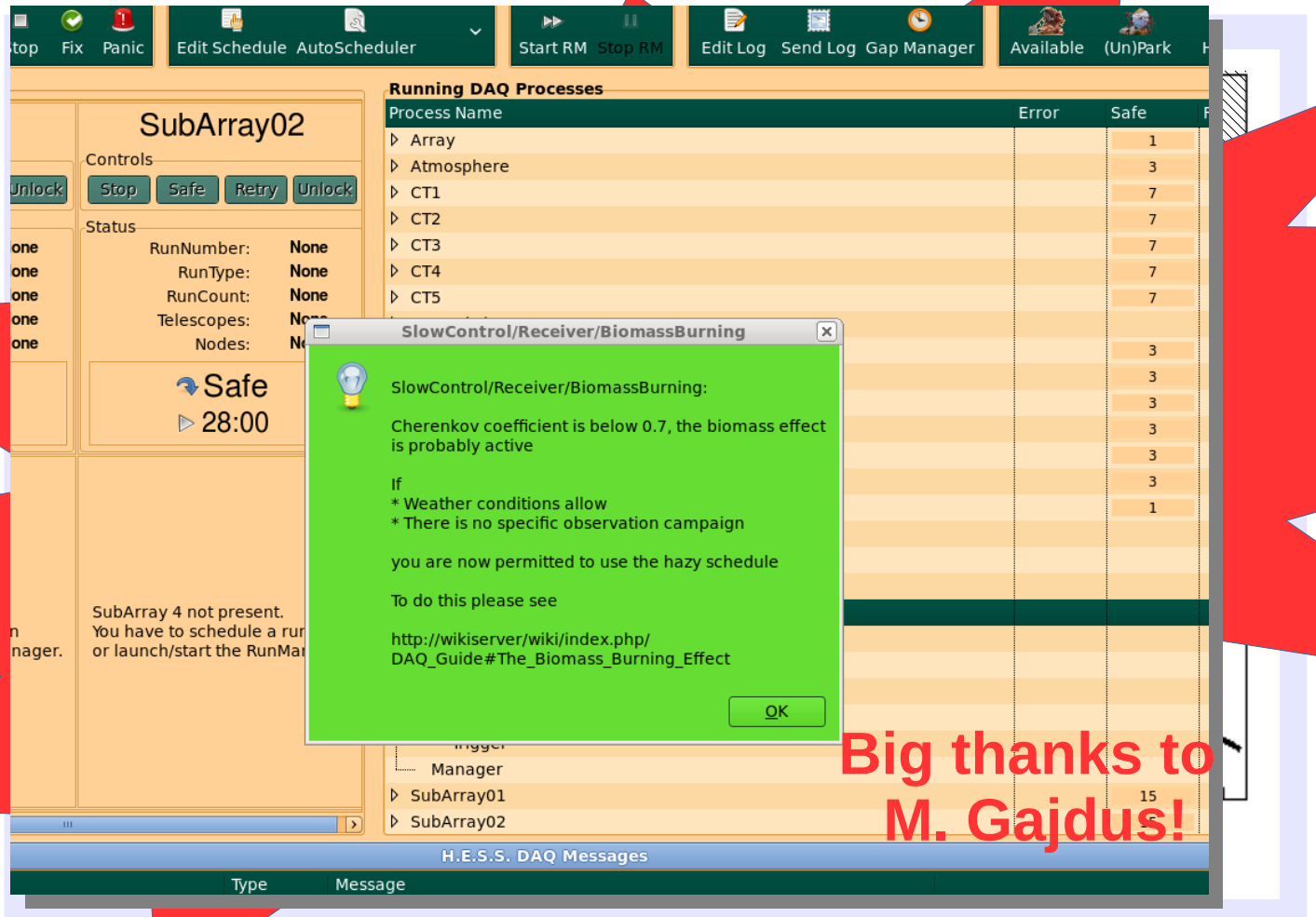


Big thanks to M. Gajdus!

Application

Data Correction

Application – Data Correction

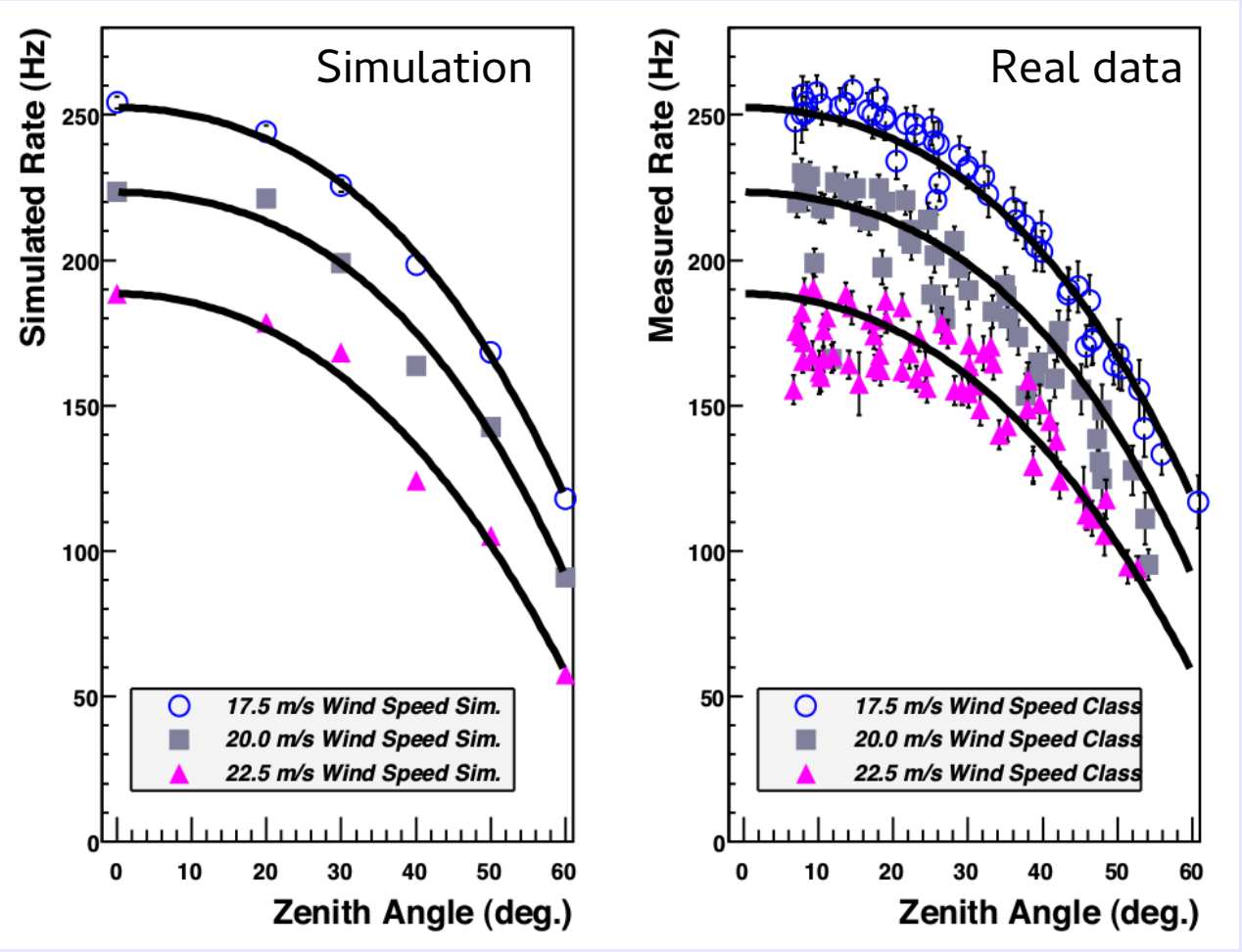
Detailed study by Nolan, Pühlhofer and Rulten

(2010, APh, Volume 34, Issue 5, p. 304-313.)

- Aim: Recovery of important data on PKS2155-304 recorded during bad weather and a MWL campaign
- Method: Atmospheric simulations for adverse conditions(haze) using MODTRAN, use results in standard H.E.S.S. analysis

Application – Data Correction

Compare simulated BG rate data under different assumed atmospheric conditions to observation until there is a match

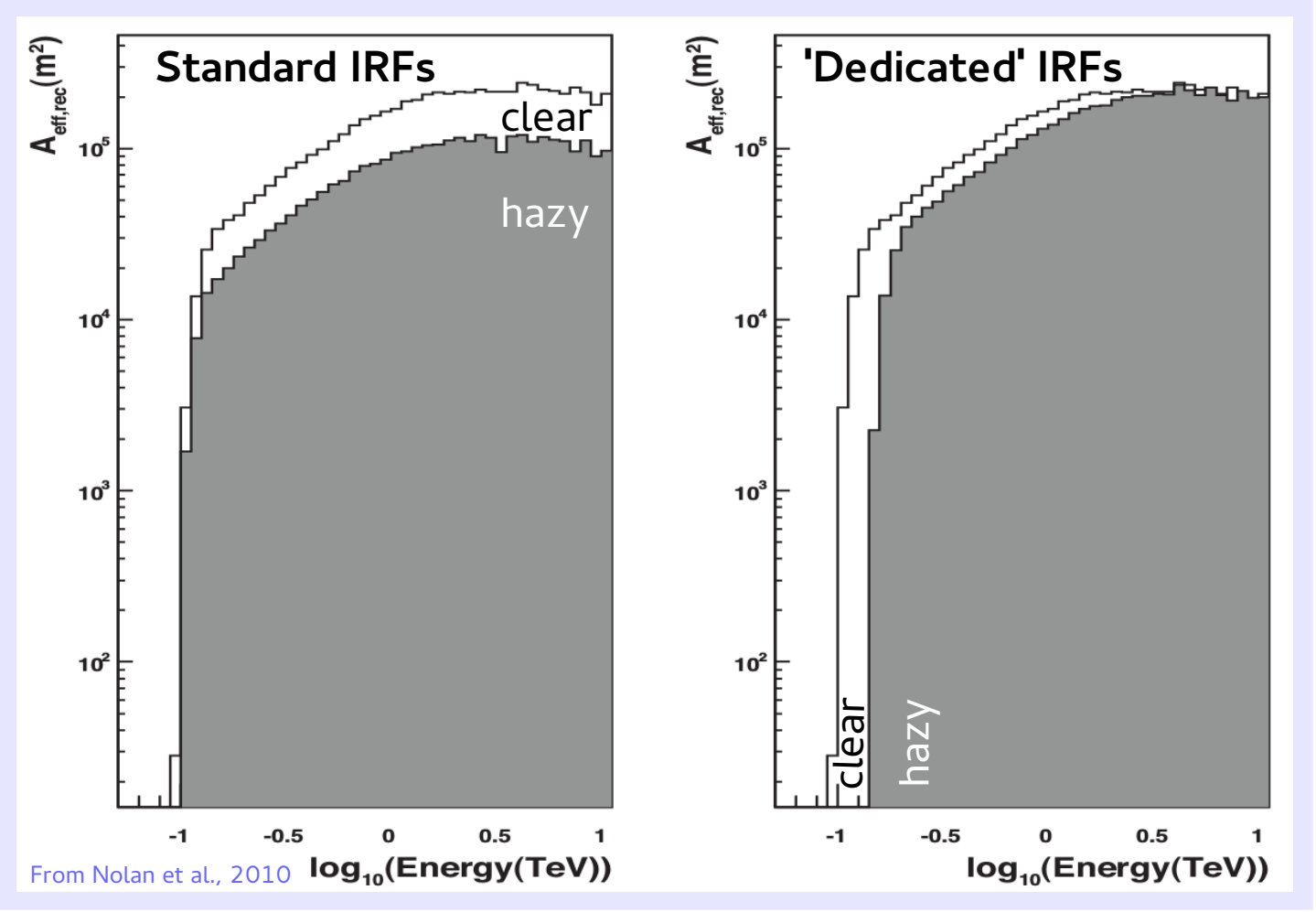


Models match real data!
-> Create correct IRFs for analysis

From Nolan et al., 2010

Application – Data Correction

Allows to reconstruct proper energies -> proper effective areas



From Nolan et al., 2010

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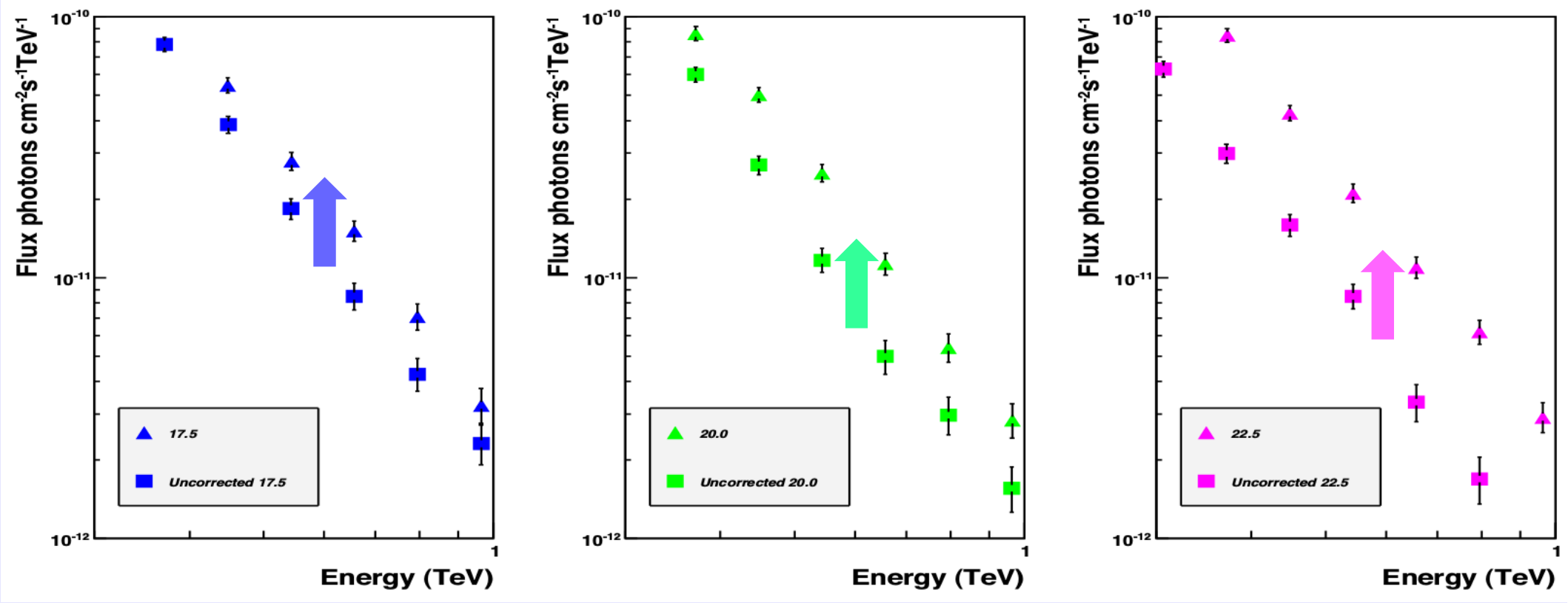
Application – Data Correction

Reconstruct unbiased spectra!



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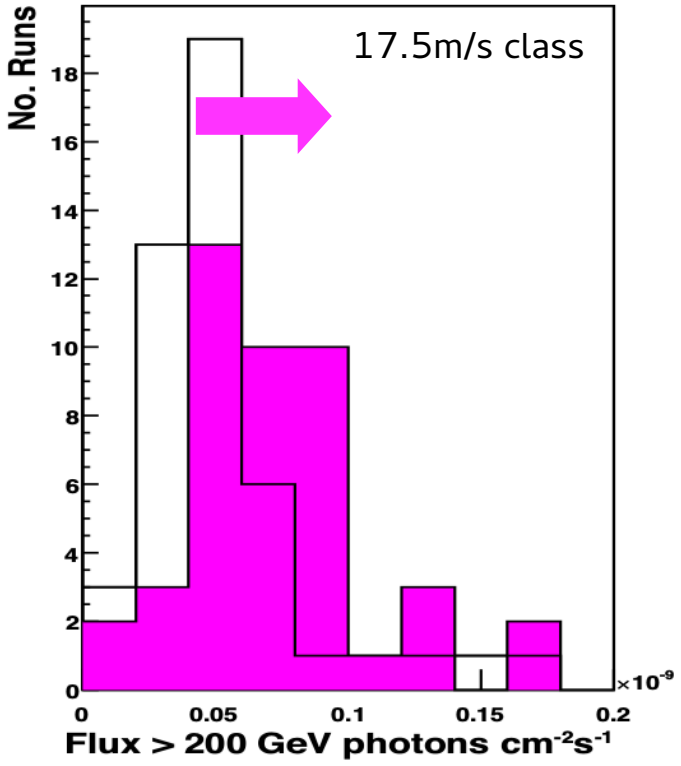
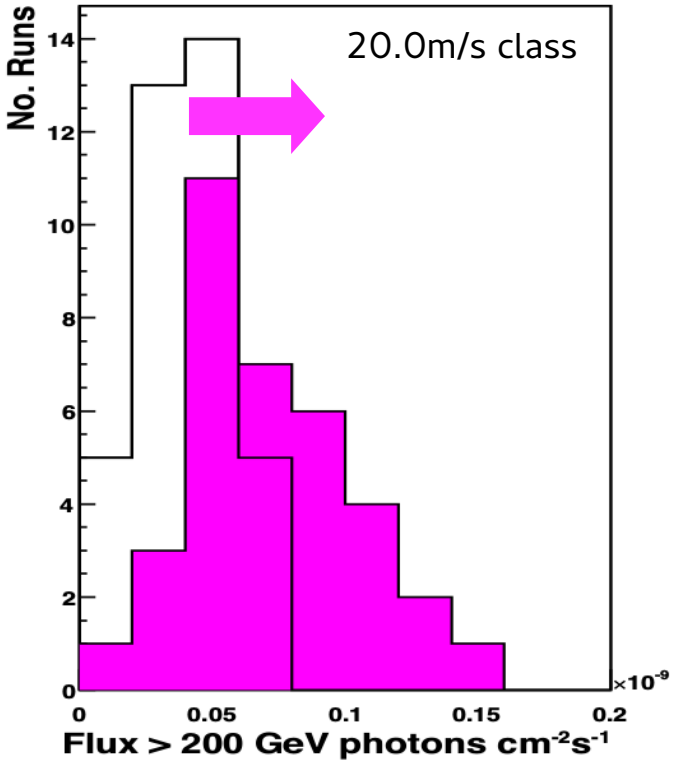
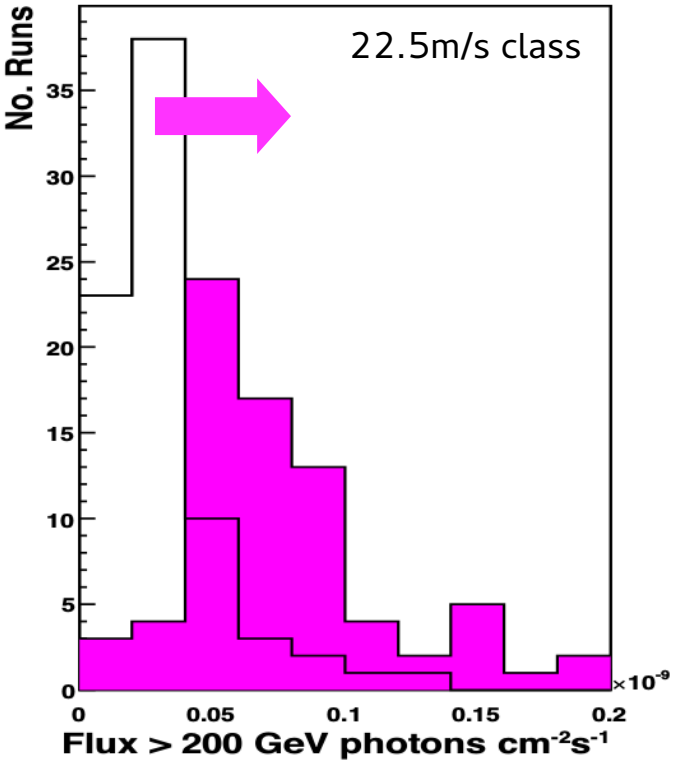
Atmospheric Monitoring With H.E.S.S.

Application – Data Correction

Reconstruct unbiased spectra!







Per-run integrated flux

From Nolan et al., 2010

Application – Data Correction

First attempts using the CTC

Simplifying assumptions:

- $E_{reco,hazy} = E_{reco,clear} * f(CTC,\theta)$
- $E_{thr,hazy} = E_{thr,clear} / f(CTC,\theta)$

with $f(CTC) = pow(CTC, 1/\cos\theta)$
and θ=zenith angle

Application – Data Correction

First attempts using the CTC

observed

desired

Simplifying assumptions:

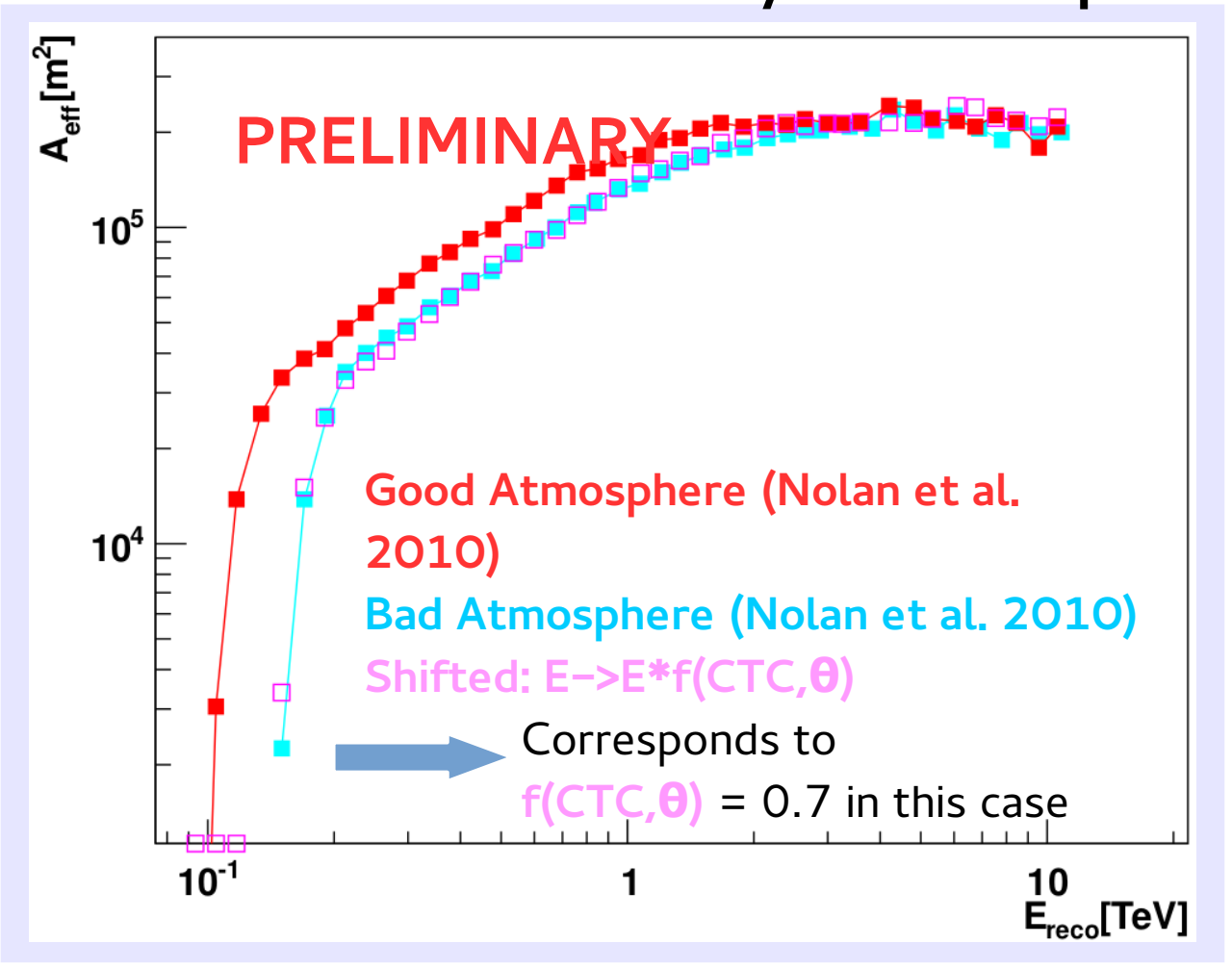
- $E_{reco,hazy} = E_{reco,clear} * f(CTC,\theta)$
- $E_{thr,hazy} = E_{thr,clear} / f(CTC,\theta)$

with f(CTC) = pow(CTC, 1/cos θ)
and θ=zenith angle

Application – Data Correction

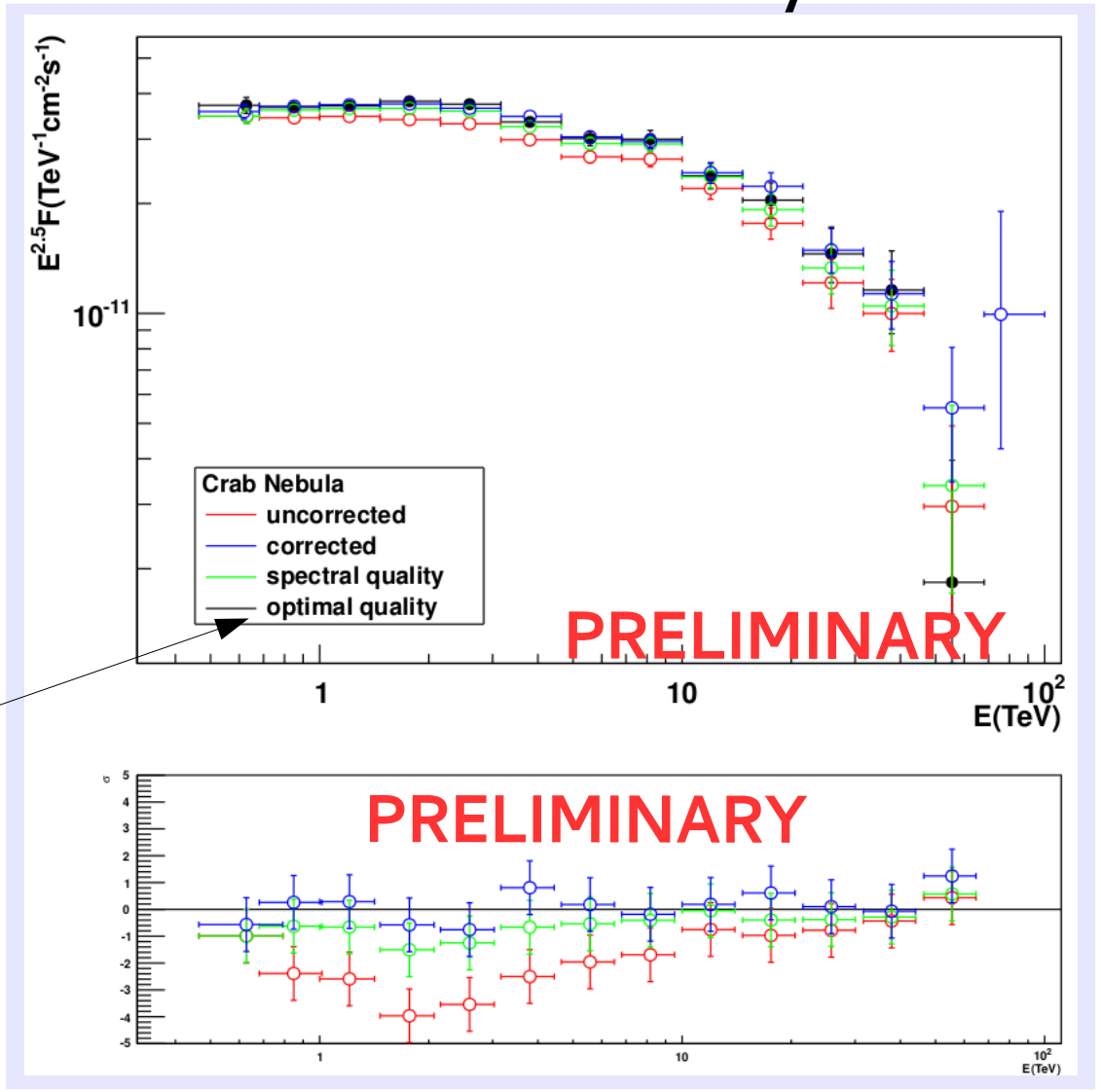
First attempts using the CTC

Effective areas for hazy atmosphere



Application – Data Correction

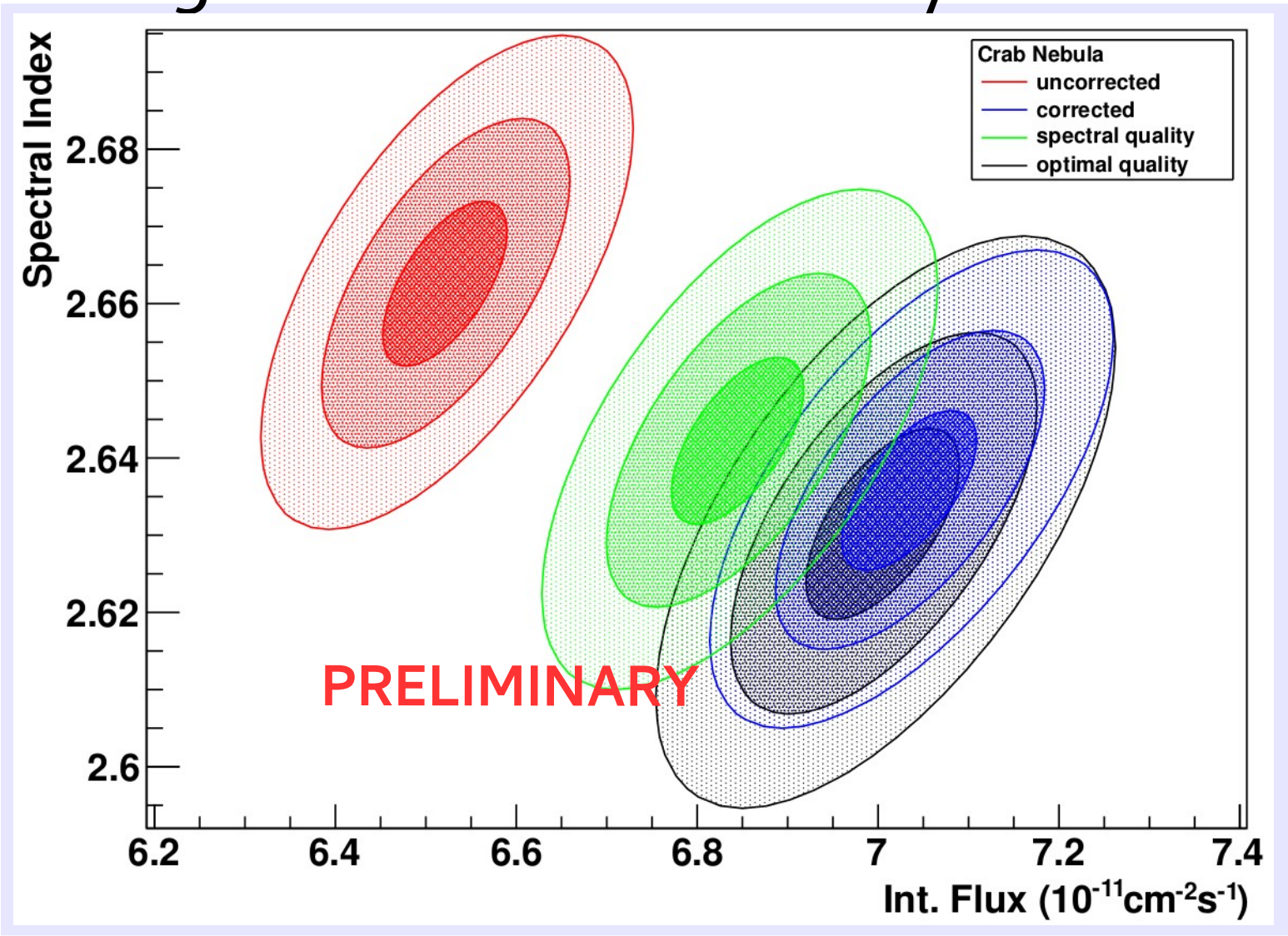
Using the CTC: Preliminary results



(0.95 < CTC < 1.05)

Application – Data Correction

Using the CTC: Preliminary results



Summary

- Atmospheric attenuation leads to biased shower reconstruction in the IACT method
  -> Important source of systematic effects
- Several monitoring devices are in place at the H.E.S.S. site, from Radiometers to LIDAR
- Data quality selection uses Cherenkov telescope trigger rates + CTC
- Smart scheduling (work in progress) applies Radiometer data + CTC
- Data correction:
  - Succesfully performed for PKS2155-304 observations using Ceilometer data and atmosphere simulations
  - First attempts to use the CTC (work in progress)
- Future CTA will have more stringent criteria on systematics

  -> Good understanding of on-site atmosphere will be essential

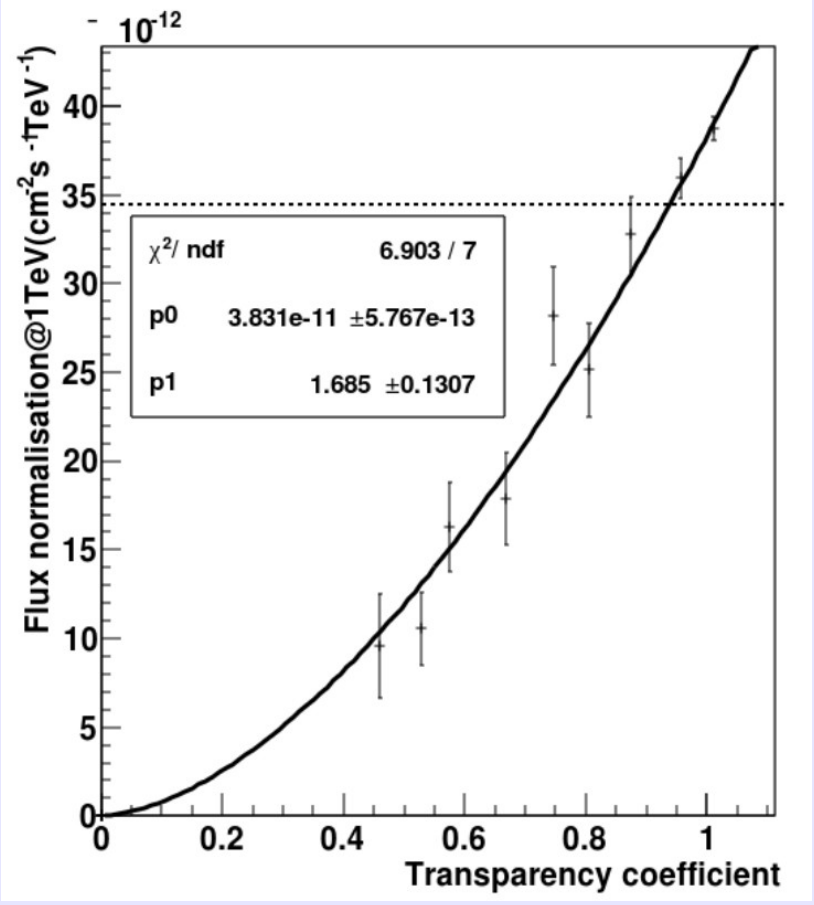
Atmospheric Monitoring With H.E.S.S.

Additional Slides

Application – Data Quality Selection

Detect sources in the presence of

- Aerosol layers, large scale and dilute clouds



Cut value chosen to limit relative flux variations to less than 20%