Calibration results of the first two H.E.S.S. telescopes

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Muons

Gamma-like
Calibration coefficients

To provide data analysis for physics we need on short time-scales:

- Conversion factor between ADC and photo-electron (p.e.)
- Correction of camera inhomogeneities
- Pedestal position and excluded pixels

we also use muon images to monitor the detector and check our calibrations

i.e.,

Classical Calibration
Calibration coefficients

Calibration of the detection system:
  atmosphere, mirror, Winston cones, PMTs, and electronics
Classical methods - Calibration runs

- ADC to photo-electron conversion factor using a LED system
  
  * ADC counts to photo-electron conversion factor using a LED system

  ![](CTD5_High_Gain_Charge.png)

  - 80 ADC counts = 1 pe
  - Fit with a sum of Gaussians

- Flat Fielding
  
  - Correction factor for each pixel
  - Uniform response of the camera
  - Detection of a damaged pixel (excessive illumination)

  ![](Flat_Field_Distribution.png)

  - Flat-Field coefficients

  Leroy Nicolas, HESS Calibration results, 28th ICRC Tsukuba Japan,
Classical method - In data runs

- Pedestal position determined every minute in presence of Night Sky Background
  
- Night Sky Background determination using High Voltage Current information from the PMTs

- Excluded Pixels
  HV Off
  HV unstable stars, highly-illuminated pixels

- ~4% of the pixels per run are excluded from the analysis

Leroy Nicolas, HESS Calibration results, 28th ICRC Tsukuba Japan, August
Muons from hadronic showers are also very useful for calibration purposes

- Cherenkov emission of a single particle
- Muons represent half of the trigger rate (~150Hz) in single-telescope trigger configuration
- Unique calibration tool providing information on the whole detection system with a real Cherenkov spectrum
- Validation of detector simulation
Geometry of Cherenkov emission from a muon

> complete ring in the camera (~1Hz)

\[ x, y : \text{ring centre in the camera} \]
\[ R : \text{ring radius} \]
\[ \epsilon : \text{total collection efficiency} \]
\[ \rho : \text{impact parameter} \]
\[ \sigma : \text{ring width} \]
\[ \phi_{\text{max}} : \text{azimuth of the maximum in intensity} \]

\[ \theta_c \] is the Cherenkov angle, i.e., the ring radius in the camera

\[ \epsilon \] is the conversion factor between p.e. and photons

\[ 200 \ \text{nm} < \lambda < 700 \ \text{nm} \]

For each pixel, we determine \( \epsilon \) from

\[ I(\phi) \propto \sin(2\theta_c)D(\phi)\epsilon \]
Reconstruction

Intensity vs. Radius (real data)

Conversion factor and MC

Conversion factor between Photon and photo-electron

Distribution for one run

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Simulations

Data

provides a good modelling of the detector in simulations
- Monitoring of the telescopes

Average conversion factor between 200 and 700 nm as a function of time

- Flat Fielding with muons using fit residuals per pixel

- Small shift in efficiency for CT3
- Same behaviour between CT2 and CT3
  - Atmospheric effects?

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Conclusions

- H·E·S·S· uses different independent methods of calibration
  - Classical methods with LEDs and laser systems
  - Muon ring images in data

- Allow a realistic calibration of our detector simulation

- Monitoring of each detector performance at the few percent level

- Accurate correction on flat-fielding

- Muons also provide information for selection of good-quality runs