The first cross-calibration of Imaging Atmospheric Cherenkov Telescopes with a UAV-based airborne calibration platform

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Cross-calibration of IACTs

- Optical efficiencies of Cherenkov telescopes degrade due to weathering effects → Regular cross-calibration of telescopes in array necessary
- So far done mostly using atmospheric muons
- CTA: Unprecedented accuracy and sensitivity [1]
- Ameliorated cross-calibration also considering wavelength dependent degradation necessary
- Here: Novel cross-calibration method based on an UAV emitting 4ns light pulses with 400nm wavelength flying above H.E.S.S. array [2]
- First cross-calibration of Cherenkov telescopes with a single light source

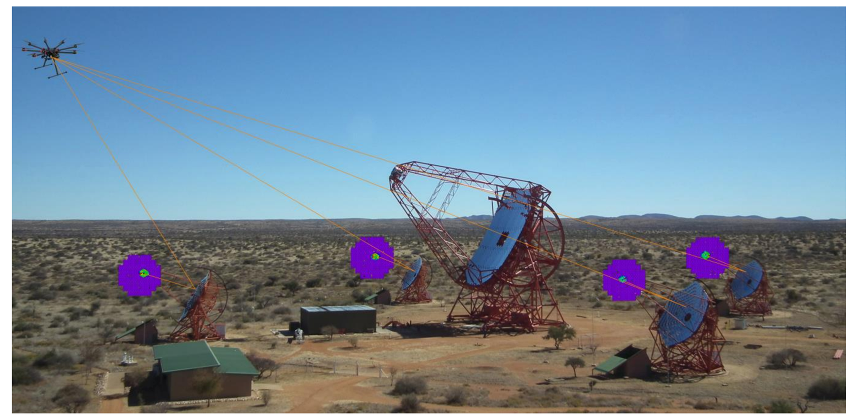


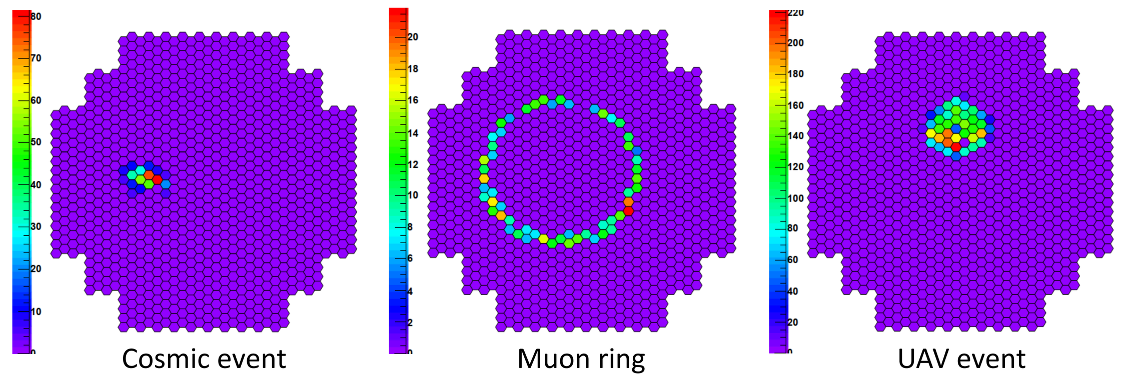
Image from [3]

Test campaign

- In May 2018 at the H.E.S.S. site
- UAV with pulsed LED positioned 200m above take-off point 800m south-east of array centre
- Two successful runs with about 350 UAV events recorded in the four smaller H.E.S.S. telescopes in each run

Data analysis

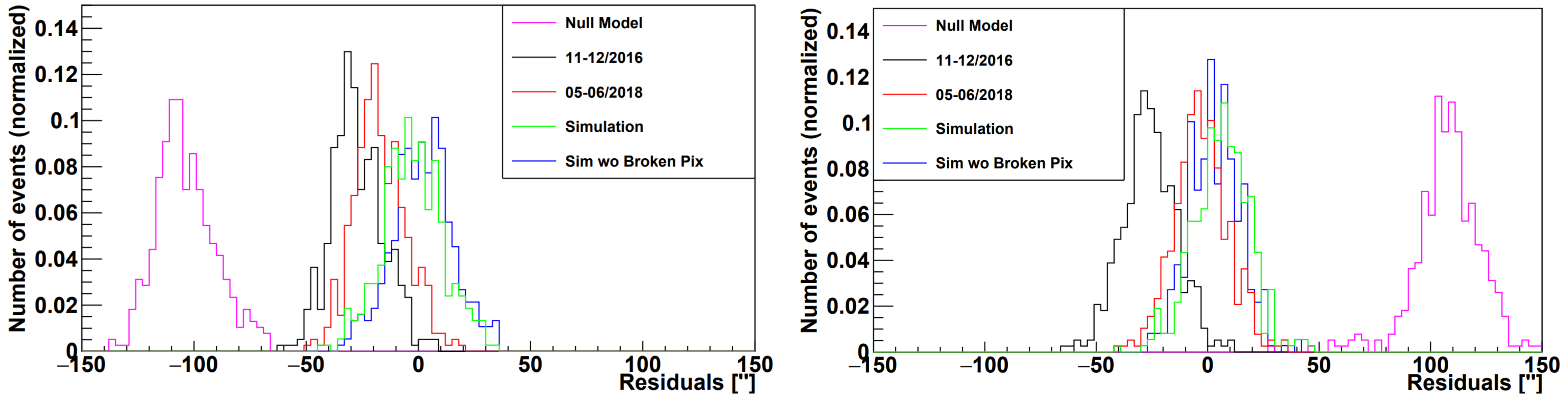
1. Event selection



   - UAV event if event recorded in 3 or 4 telescopes
   - Cosmic event if event recorded in 1 or 2 telescopes
   - No cosmic event misidentified as UAV event
2. Determination of UAV position
   - By triangulation in camera field of view
   - Statistical uncertainty: 50cm ∥ to pointing, 5cm ⊥ to pointing (12.3" angular uncertainty)
   - Systematic uncertainties from comparison with UAV GPS: At least 5cm (⊥) respectively 1.1m (||); at most 8m (⊥ & ||)
3. Cross-calibration of telescopes
   - From pure geometrical considerations: $I \propto \frac{1}{d^2} + O\left(\frac{1}{d^4}\right)$, with I total intensity recorded in telescope and d the distance of the UAV to the telescope mirror plane
   - Verified by MC simulation: Small correction for atmospheric absorption necessary
   - Relative efficiency of telescope i: $\epsilon_\mathrm{i} = \frac{(\mathrm{Id}^2 C)_\mathrm{i}}{<(\mathrm{Id}^2 C)_\mathrm{j}>}$, with C correction factor close to 1 for atmospheric absorption and $O\left(\frac{1}{d^4}\right)$ term

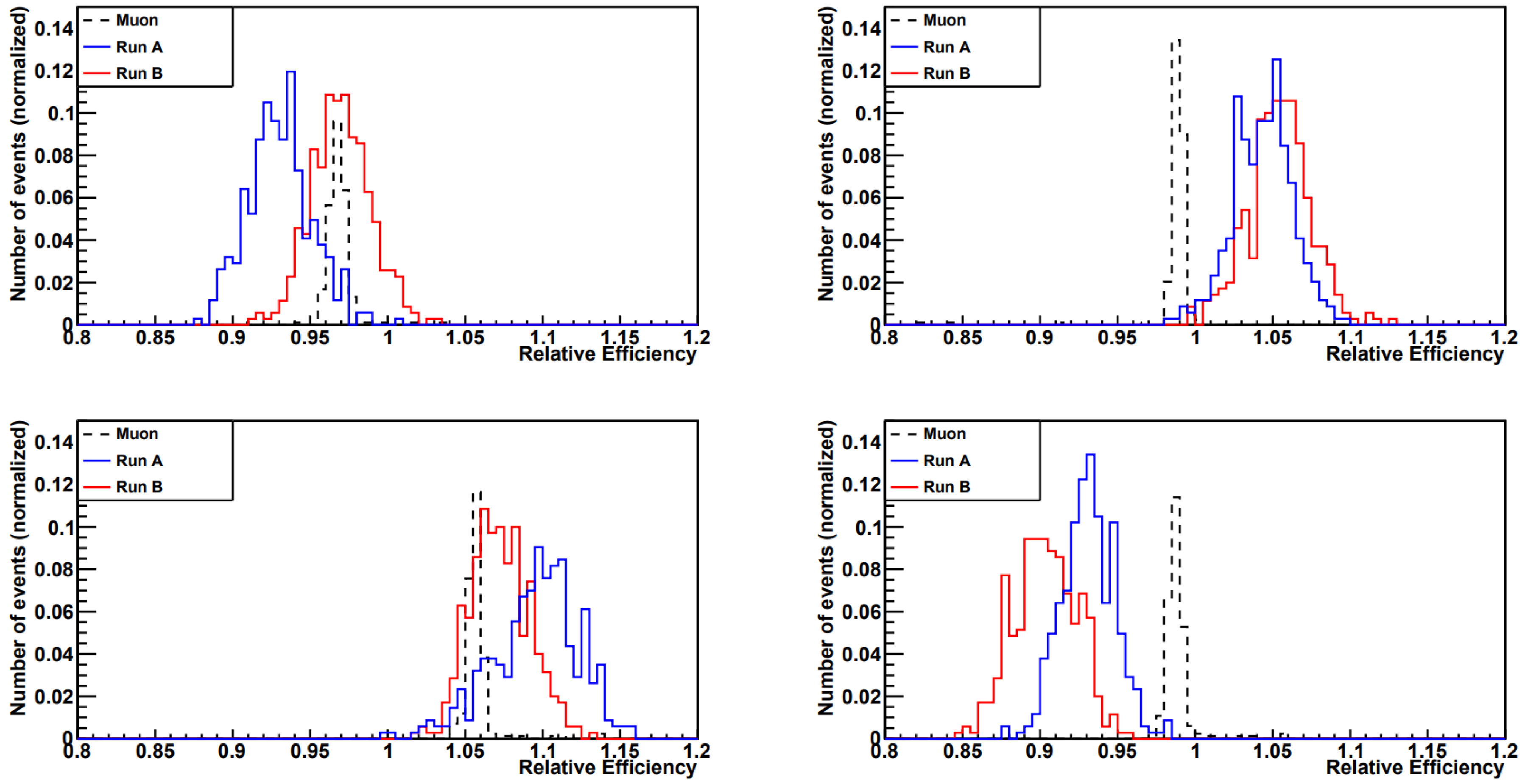
Pointing corrections

- Pointing of IACTs evolves with time due to mechanical deformations of the telescope structure → leads to mispointings → usually corrected with pointing models regularly determined by comparing measured position of stars with their nominal position
- Mispointings → shift of position of centre of gravity in camera → higher residuals in triangulation of position determination
- UAV data allows to determine best pointing model when comparing pointing models from different epochs → Allows verification of pointing models
- No room for improvement of pointing models left with UAV data as best pointing model reduces residual size to the level that non-operational camera pixels start dominating their size
- Amelioration would need better recovery of non-operational camera pixels
- Residuals obtained with most up-to-date pointing model similar to uncertainty in pointing obtained with other methods → UAV already now achieves similar accuracy



Comparison of distribution of residuals on the centre of gravity for different pointing models on top for Run A and on bottom for run B: Violet: No pointing corrections at all, Black: One and half a year old pointing corrections (at data taking), Red: Contemporaneous pointing corrections, Green: MC simulation with non-operational pixels, Blue: MC simulation without non-operational pixels

Cross-calibration results



- Event-by-event relative efficiencies for 2 UAV runs compared to run-by-run muon efficiencies over whole observation period
- Deviation of relative efficiency between runs: 3.1% (taken in different night)
- Deviation of relative efficiencies between UAV & muon calibration: 5.5% and 6.3% respectively for the 2 runs

Future plans

- Inclusion of the large H.E.S.S. telescope (CT5) to do a cross-calibration of different telescope types
- Increase number of configurations and scan camera field of view to reduce systematic uncertainties
- Wavelength dependent cross-calibration
- Atmospheric monitoring by mounting meteorological devices on the UAV

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