# Cross Calibration of the H.E.S.S. Telescopes

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H.E.S.S.

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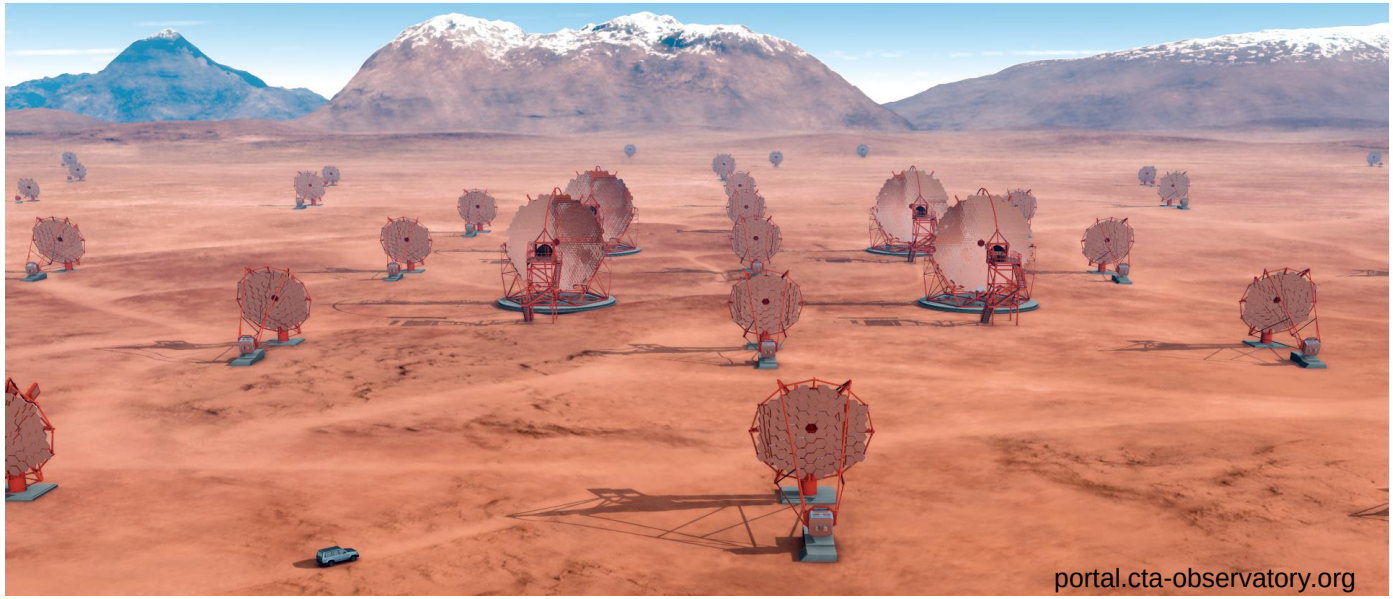
# H.E.S.S. – Imaging Atmospheric Cherenkov Telescopes

- Ground based Cherenkov telescopes
- Located in Namibia
- Phase I: array of four equal telescopes (108 m² mirror area)
- Phase II: first light 2012; fifth telescope in center of the existing array (614 m² mirror area)

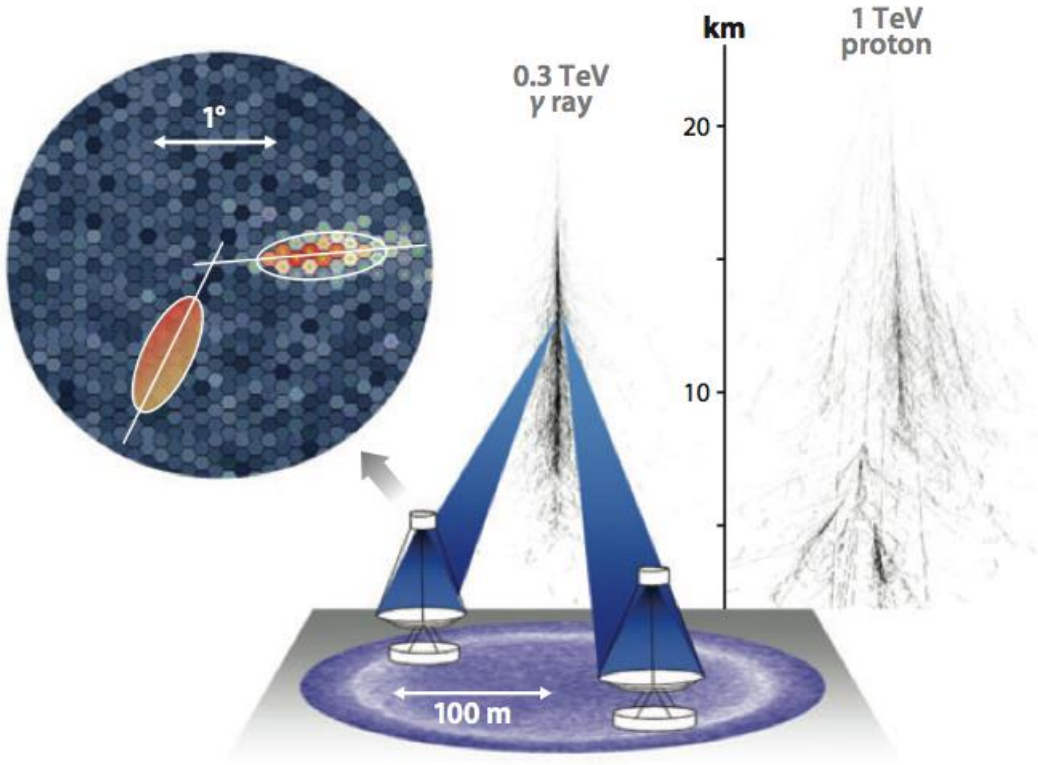
# CTA – The Next Big Step in γ Ray Astronomy

- Two sites with over 100 telescopes in three different sizes
- Good calibration of the array is even more important and needed

→ Inter and cross calibration



# H.E.S.S. Detection Principle

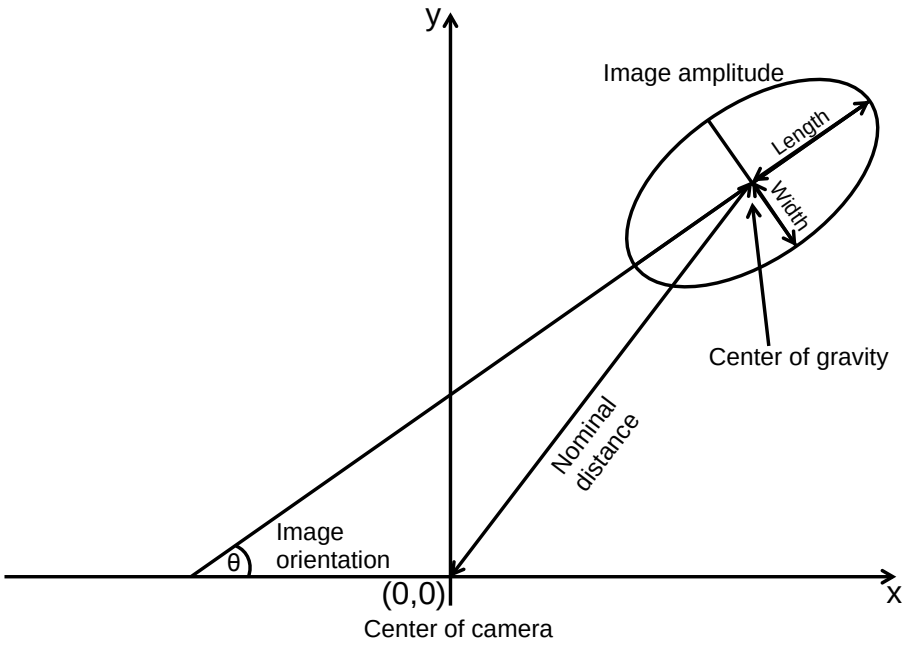



- γ rays
- Induce particle showers in atmosphere
- Particles emit Cherenkov light
- Light is detected by telescopes

- Shower reconstruction

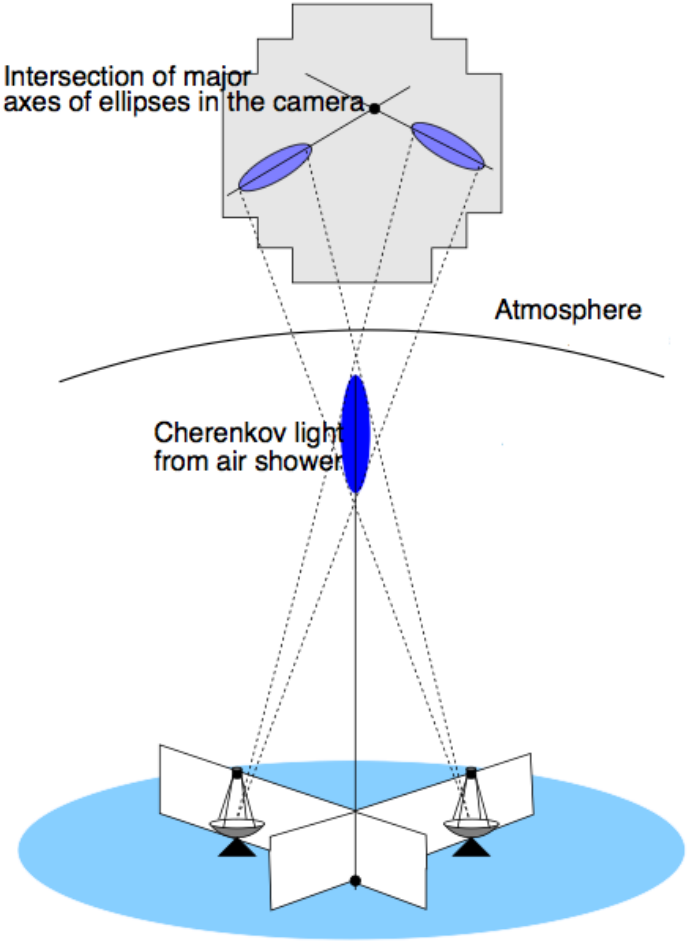
Hinton, J. & Hofmann, W. 2009, ARA&A, 47, 523

# Shower Image Parametrization – Hillas Parameters



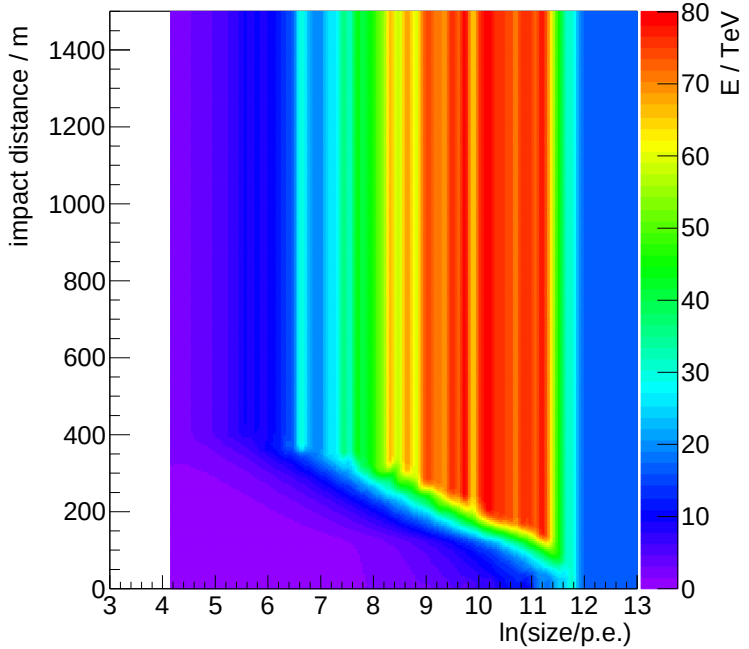

- Approximate with elliptical shape
- Determine parameters:
  - Size / image amplitude
  - Length & width
  - Center of gravity
  - Image orientation
  - Nominal distance

# Stereo Reconstruction of Shower



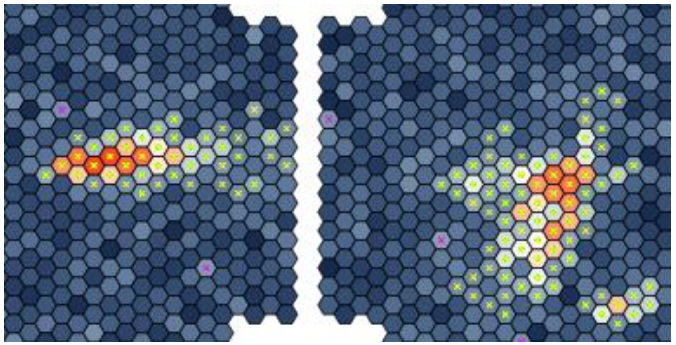

Funk, S. 2005, PhD thesis, University Of Heidelberg

- Selection cuts on Hillas parameters
- Reconstruction of shower direction and impact point
- Energy reconstruction through lookup tables



# Event Selection

- Consider only $\gamma$ like events, eliminate hadronic events
  → Investigate shape of image in camera
  → Compare width and length of approximated elliptical shape



Bernloehr, K. 2008, Astropart.Phys., 30, 149

Further cuts:

- Image amplitude per telescope > 80 p.e. / 100 p.e.
- Reconstructed energy > 200 GeV
- Distance center of gravity & center of camera < 1.75° / 1.0°
- Squared angle shower direction & gamma source < 0.35

# Cross Calibration – General Principle

Important telescope parameters: image amplitude & energy

→ Investigate calibration by comparing the reconstructed parameters

- Careful event selection
- Compare parameters (size & energy) of telescope pairs *(i,j)*

$$a_{ij}^{x} = \frac{x_i - x_j}{x_i + x_j}$$

- Calculate different asymmetries of telescope pairings

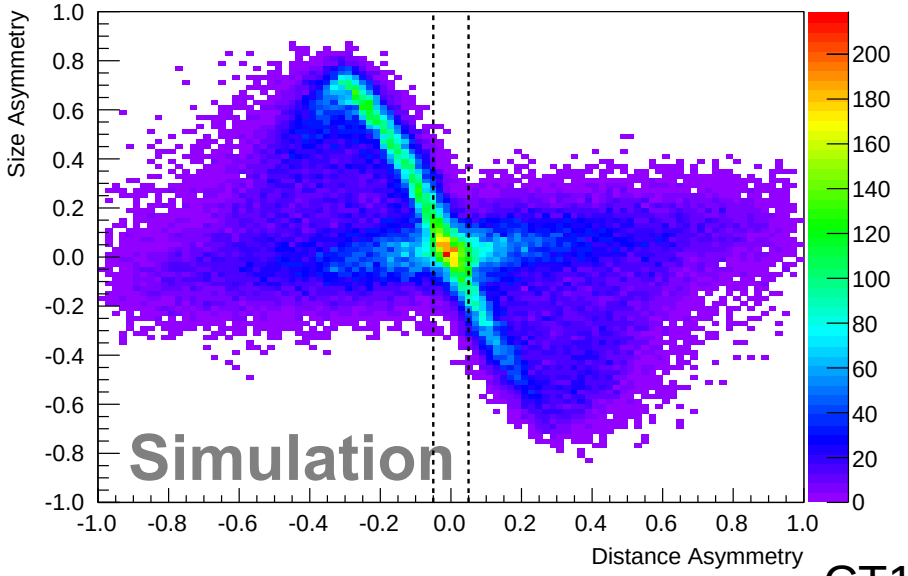
→ Investigate asymmetries of telescopes among each other, their temporal evolution and results of different analysis chains

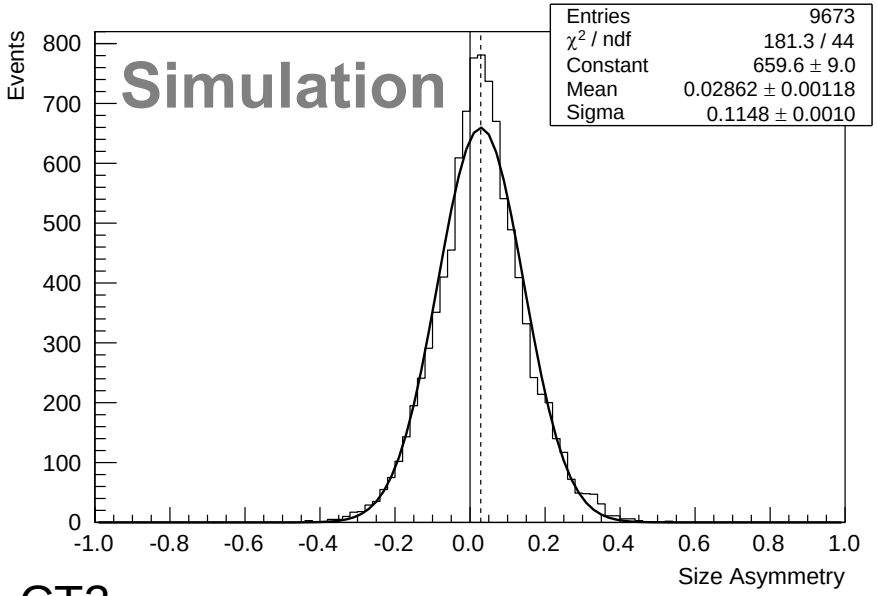
# Size-Distance Asymmetry

$$a_s = \frac{s_i - s_j}{s_i + s_j} \qquad a_d = \frac{d_i - d_j}{d_i + d_j}$$

- Asymmetry in size und distance (impact point & telescope position)
- Apply cuts on both considered telescopes
- Cut on distance asymmetry: $|a_d| < 0.05$

  → Only events, with impact points equidistant to both telescopes



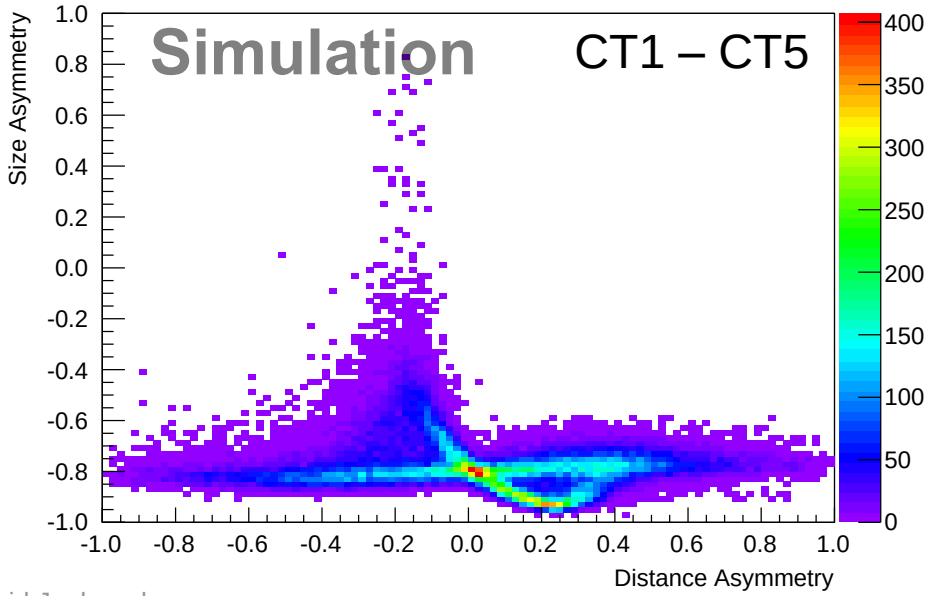

CT1 – CT2

# Size-Distance Asymmetry

$$a_s = \frac{s_i - s_j}{s_i + s_j} \qquad a_d = \frac{d_i - d_j}{d_i + d_j}$$

- Asymmetry in size und distance (impact point & telescope position)
- Apply cuts on both considered telescopes
- Cut on distance asymmetry: $a_d < |0.05|$

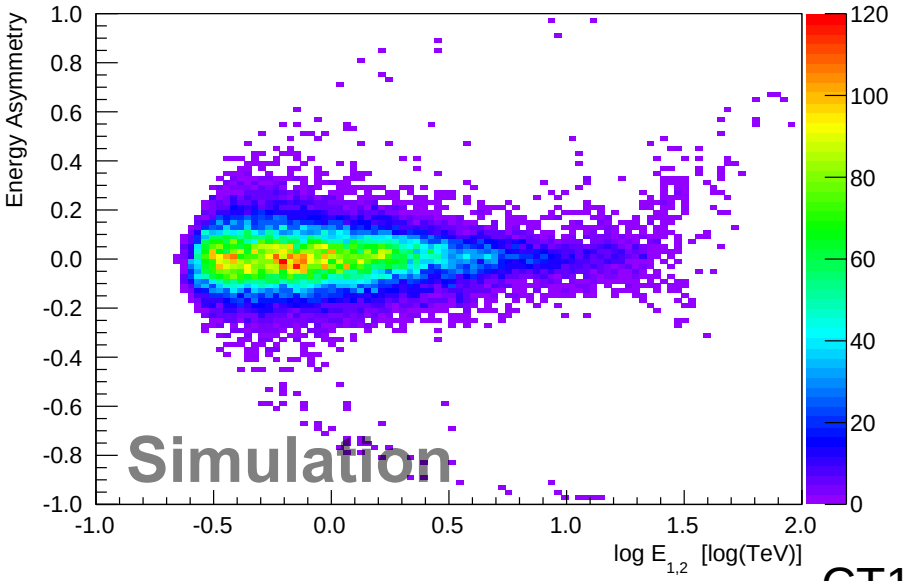
  → Only events, with impact points equidistant to both telescopes
- Disadvantage: not suitable for telescopes of different size

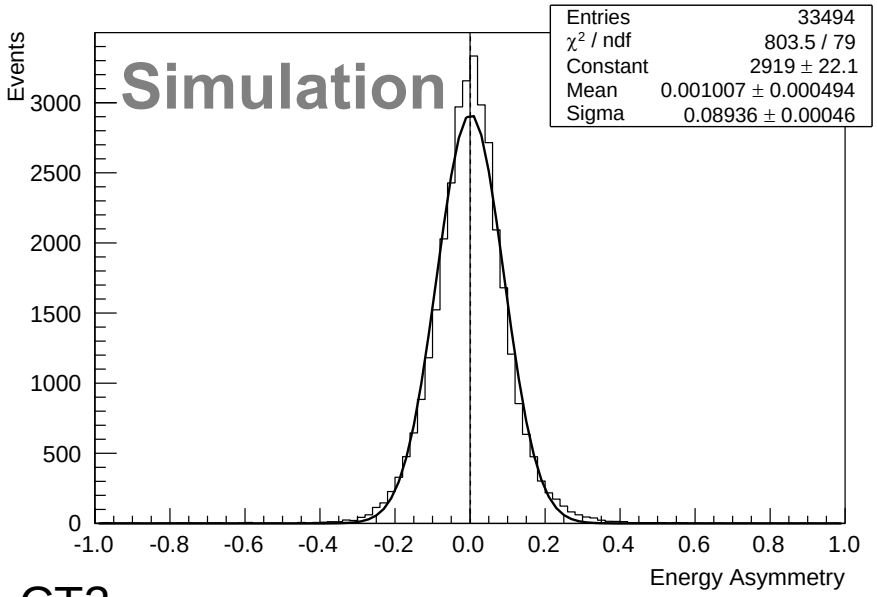


# Energy Asymmetry

$$a_E = \frac{E_i - E_j}{E_i + E_j}$$

- Similar approach as before
- Change cuts: apply them on all four telescopes
  & remove distance cut



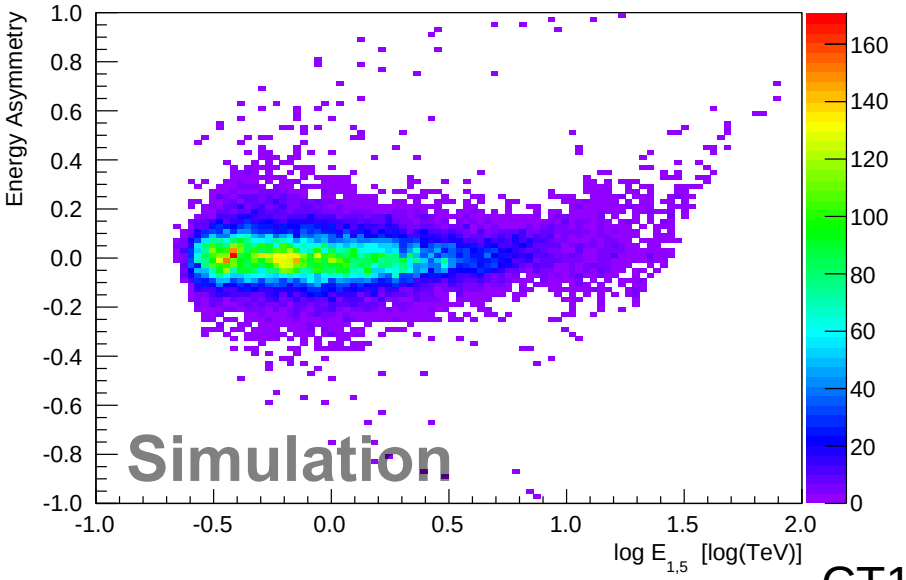



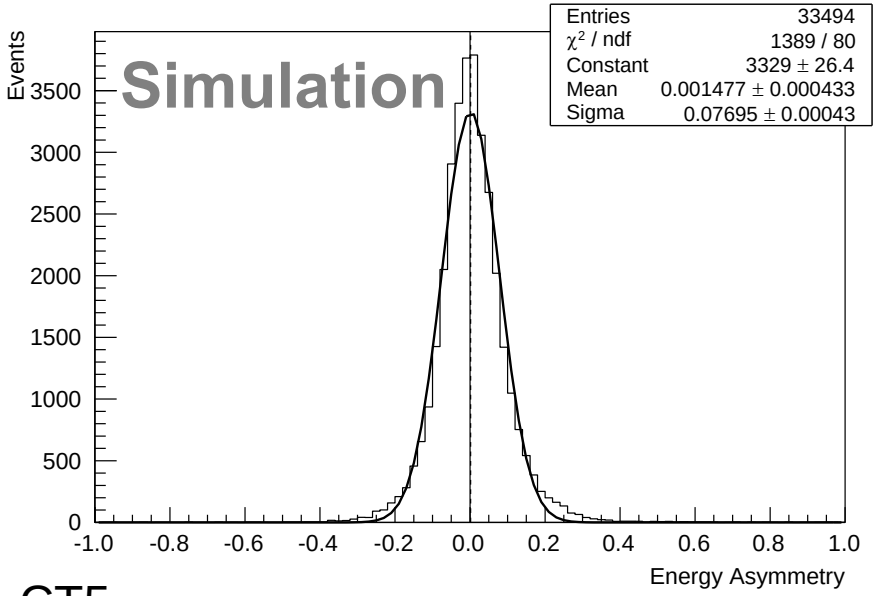

CT1 – CT2

# Energy Asymmetry

$$a_E = \frac{E_i - E_j}{E_i + E_j}$$

- Similar approach as before
- Change cuts: apply them on all four telescopes
  & remove distance cut
- Advantage: also usable with telescopes of different size




CT1 – CT5

# Thank you
# for your attention!

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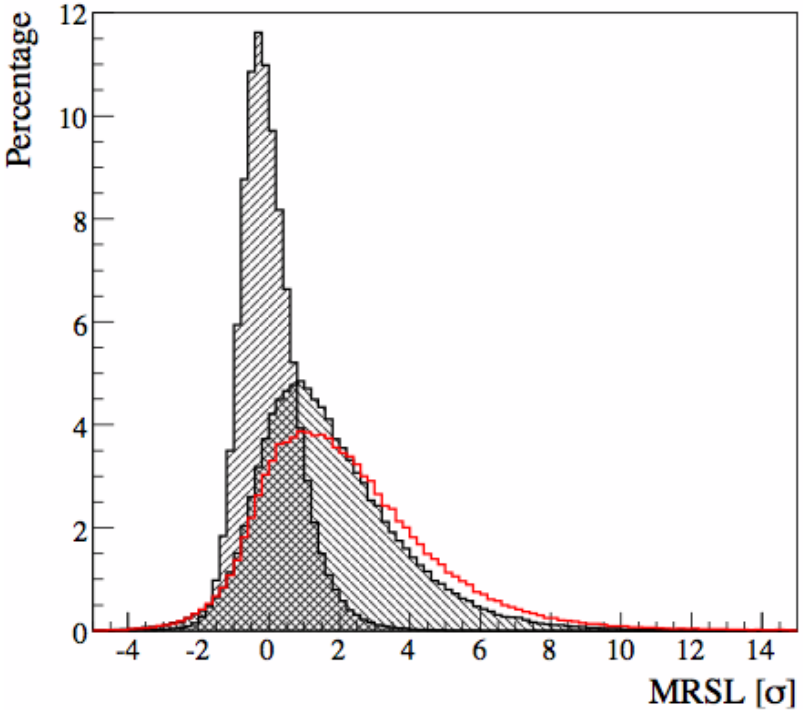
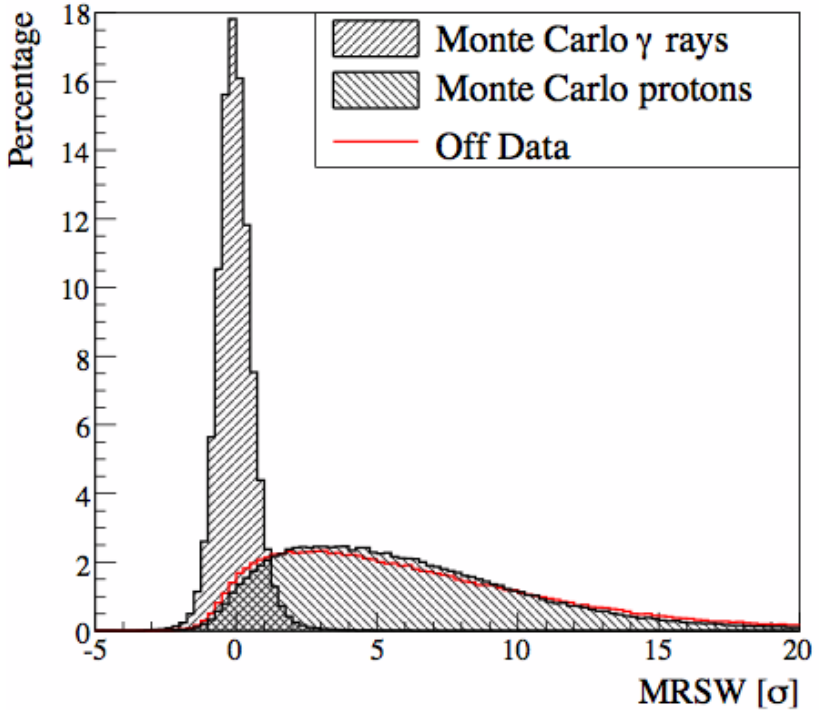
# Back-up slides

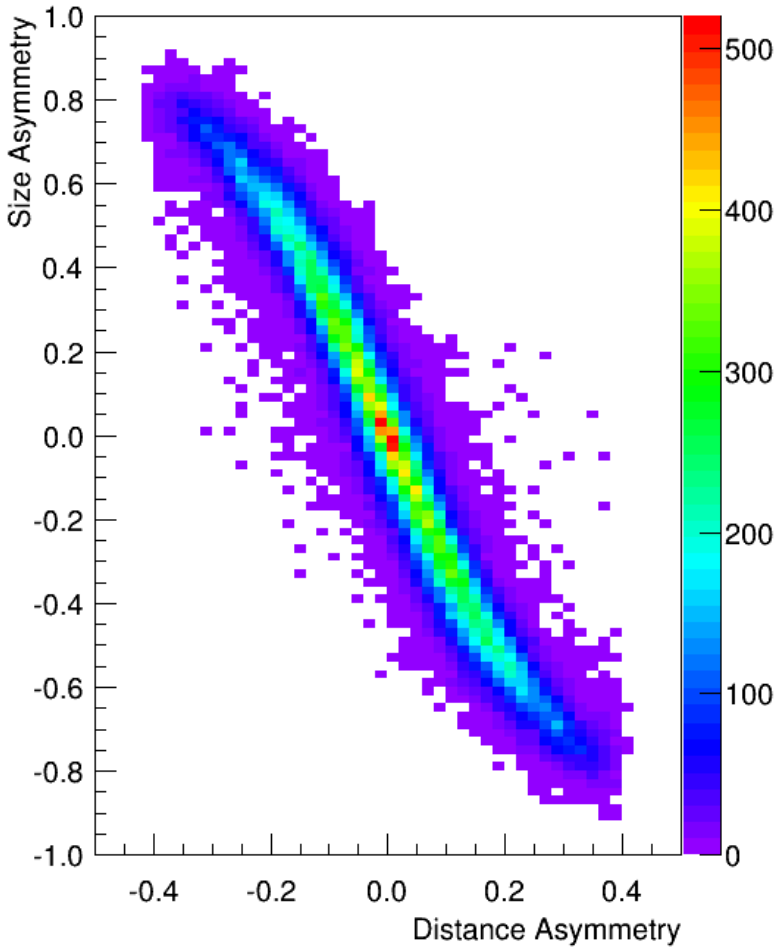
# Gamma – Hadron Unterscheidung

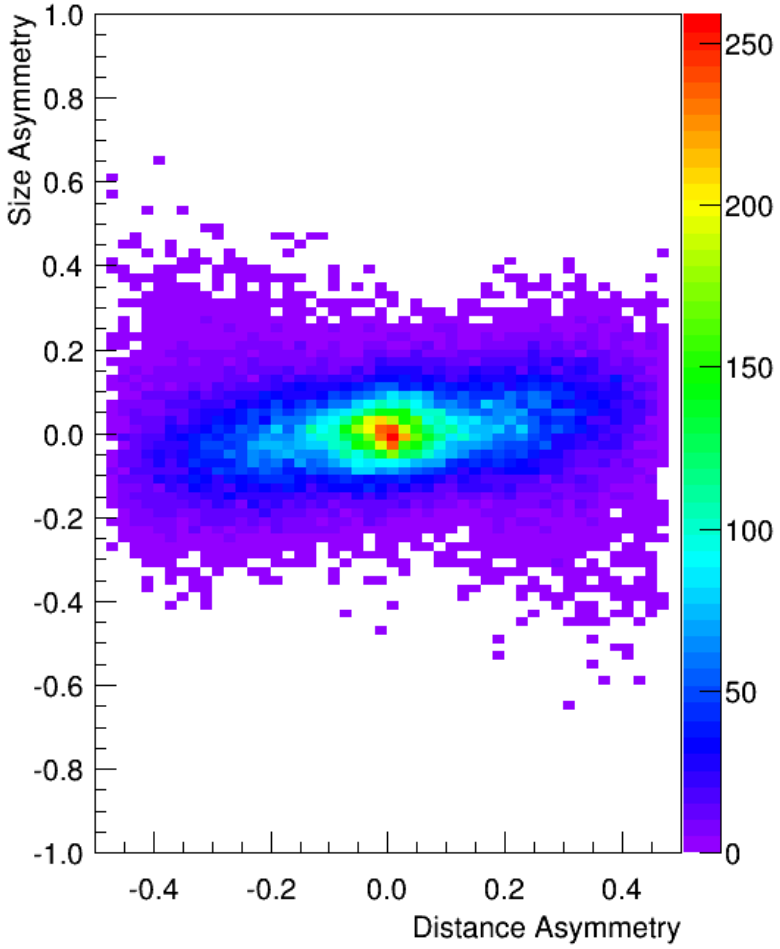



$$MRSW_i = \frac{\sum_i \omega_i \cdot RSW_i}{\sum_i \omega_i} \; ; \qquad RSW_i = \frac{W_i - \langle W_i \rangle}{\sigma_i} \; , \omega_i = \frac{\langle W_i \rangle^2}{\sigma_i^2}$$

# Shape of Size Distance Asymmetry



# Shape of Size Distance Asymmetry