Application of an analysis method based on a semi-analytical shower model to the first H.E.S.S. telescope

The 28th International Cosmic Ray Conference

Mathieu de Naurois, LPNHE *Paris University VI/VII*

- The H.E.S.S. experiment
- Principles
- Application to the Crab Nebula & PKS2155-304 observations

The H.E.S.S. Experiment

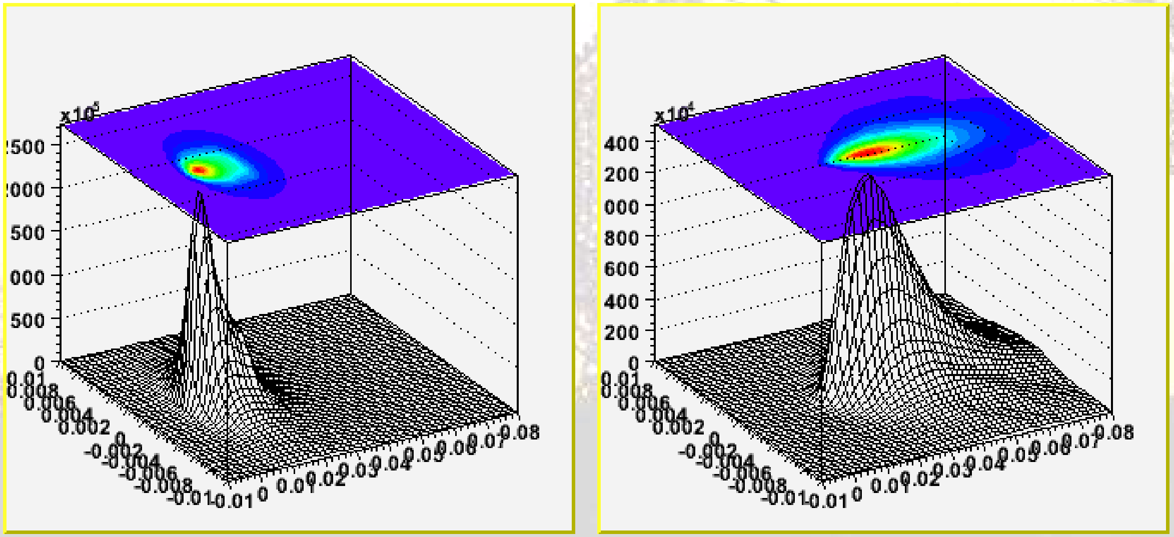
- 4 Cerenkov Imaging Telescopes
  - 107 m^2 dish, 960 pixel fast camera
  - 2 telescopes operational (system completed early 2004)
  - stereoscopic observations started
- Current official analysis :
  Hillas parameters (moments), with box cuts
  (Conor Masterson's talk – OG 2.2.3)

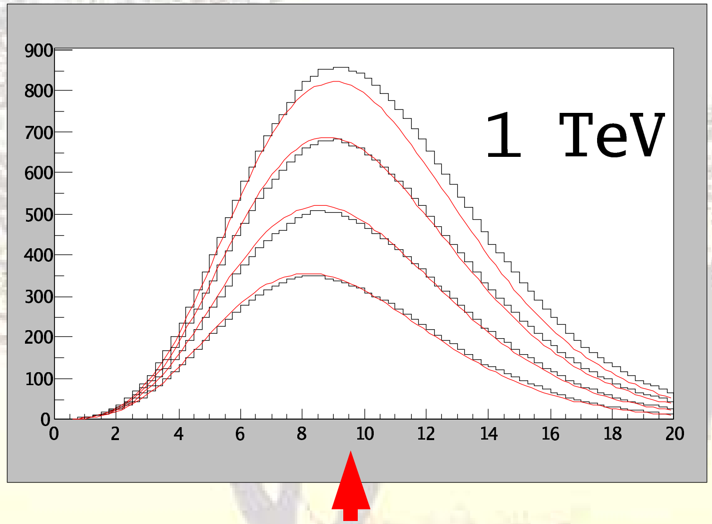
Principles

- Derived from the CAT analysis (Le Bohec *et al*)
- Use a model to describe the shower images in the camera
  - analytical expression of shower development, cross sections, lateral & angular distribution of particles in shower,... (some distributions adjusted on the simulation)
  - multi-dimension numerical integration gives the average shower
- Fit the actual images to the model with a log-likelihood
  - gives an intrinsic rejection variable (likelihood)
  - gives energy & impact point estimations
- Only single telescope analysis so far

Model generation

- Originally developed by the CAT collaboration
- Good agreement with Kaskade simulation
  - Small mismatch (15%) at large impact parameters
- Generated for E ∈ [50 GeV, 20 TeV] and impact distances up to 400 m





Number of electrons above 10, 20, 40 & 80 MeV as function of thickness (in rad. length)

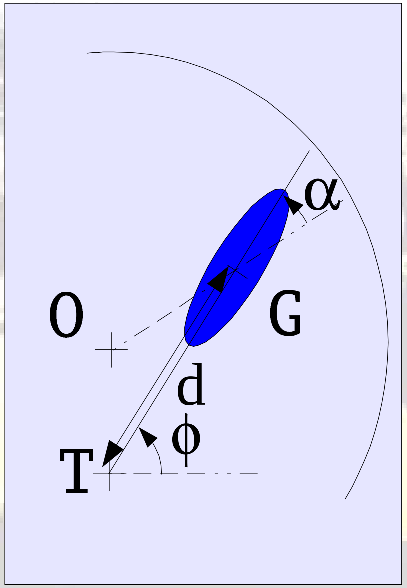
Fit procedure

- Log likelihood fit
  - Probability density function of pixel amplitude is a convolution of:
    - Poisson distribution of number of photoelectrons
    - Gaussian distribution for PMT resolution

$$f(x,\mu)=\sum_{n}\frac{\mu^{n}e^{-\mu}}{n!\sqrt{2\pi(\sigma_{p}^{2}+n^{2}\sigma_{\gamma}^{2})}}\exp\left(\frac{-(x-n)^{2}}{2(\sigma_{p}^{2}+n^{2}\sigma_{\gamma}^{2})}\right)$$

$$\sigma_{p}=Pedestal\ width(NSB+electronic\ noise)$$

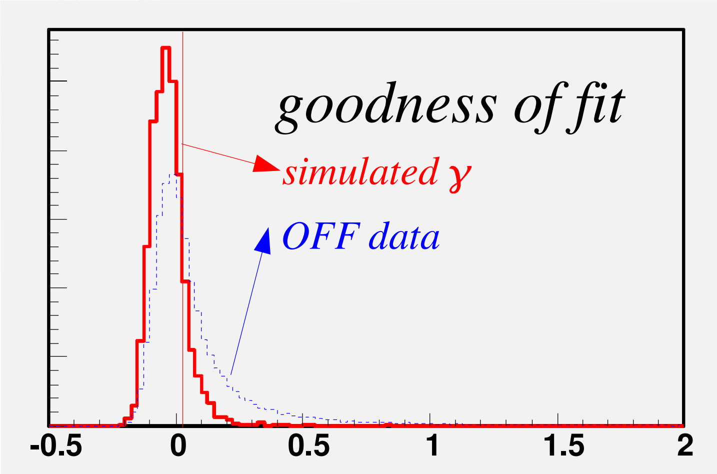
$$\sigma_{s}=PMT\ resolution$$

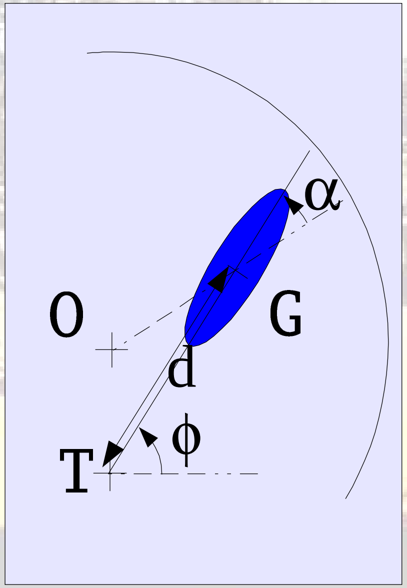


- All pixels included (shower tails taken into account) except non-operational pixels
- Actual NSB on each pixel included in the likelihood
- 4 parameter fit (primary energy. impact distance, azimuthal angle, α angle)

Cuts

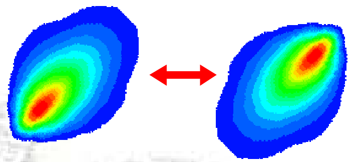
- Use an analytical approximation of the likelihood mean and RMS --> goodness of fit variable
- Cut on (Image Length)/(Image Amplitude) : kills single muons
- Cut on (Image Width)/log(Image Amplitude)
- Cut on "Distance offset" OG-TG (variable orthogonal to α) : select showers possibly originating from the center of the FOV



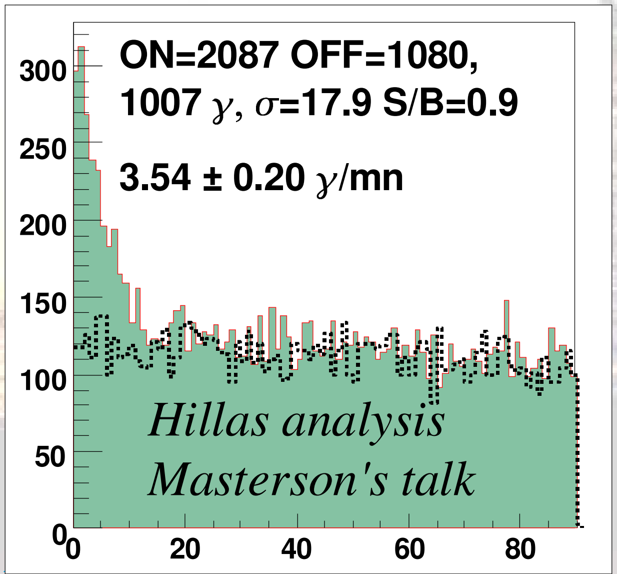


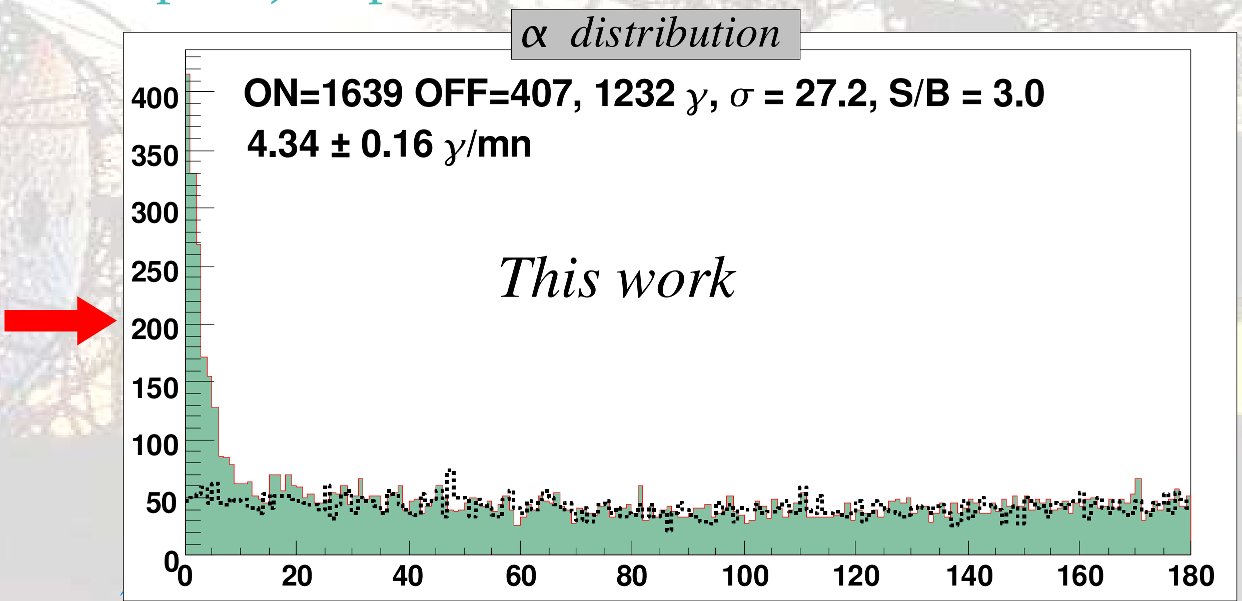
Results (Crab Nebula)

- Crab Nebula, 4.73 live hours
  - Significance increased from 18 σ to 27 σ (8.1 -> 12.5 $\sigma/\sqrt{hour}$)
  - γ efficiency increased by 20 %
  - Signal/Background ratio increased by a factor of 3 (better hadron rejection $\epsilon_h = 1.3 \cdot 10^{-4}$) -> good for faint sources
  - α distribution flat up to 180° instead of 90° (Take the image orientation into account)



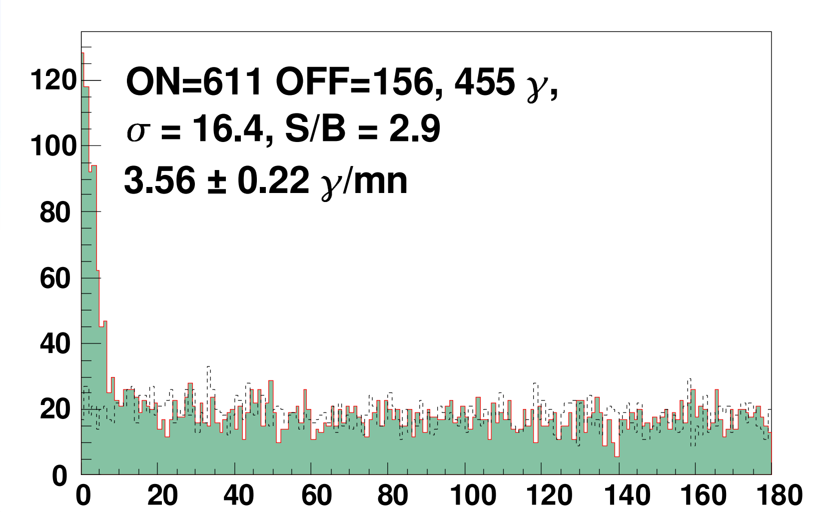
  - α resolution (FWHM of peak) improved from 3° to 2.15°



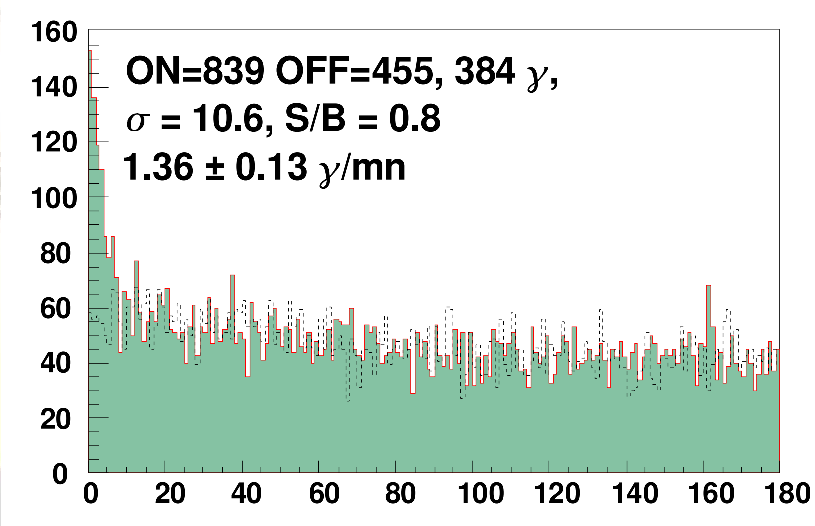


Results (PKS2155-304)

- See Djannati's talk (OG 2.3.5) for Hillas analysis
- July 2002, 2.14 live hours
  - 3.56 γ/mn
  - 16.4 σ instead of 11 σ

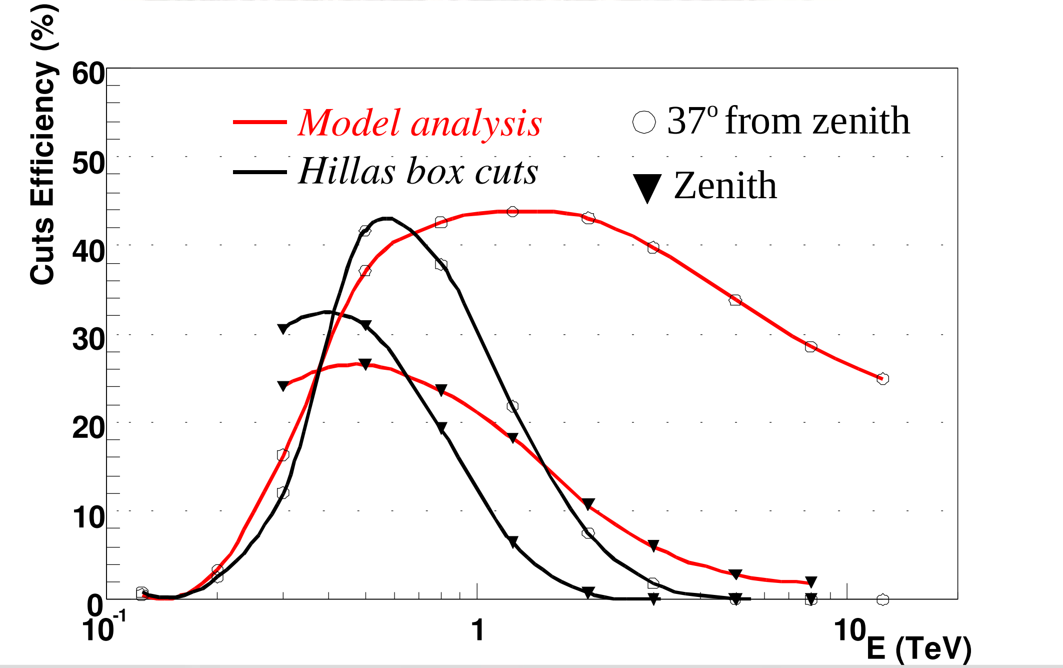


- October 2002, 4.71 live hours
  - Softer emission: 1.36 γ/mn
  - 10.6 σ instead of 6.6 σ



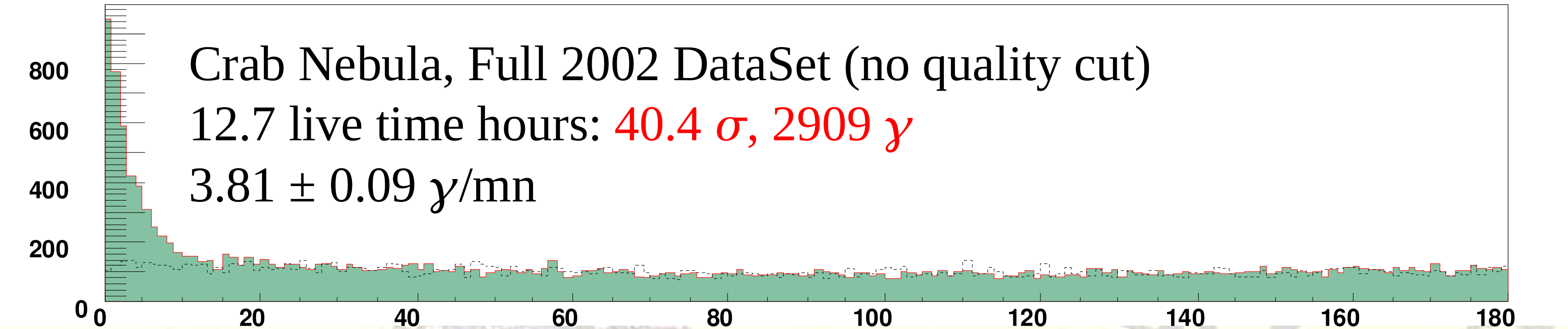
Efficency/Resolution

- Rather flat efficiency over a wide energy range (flatter than Hillas box cut)
- Currently optimized for non-zero zenith angle
- Energy resolution: about 20% from 500 GeV to 20 TeV, but rather large energy-dependent bias due to incorrect timing handling in the model
  -> to be treated in next generation



Conclusion

- New Analysis method
  - Better gamma efficiency, better hadron rejection, better alpha resolution
    - ⇨ very powerful for faint sources
  - Rather flat efficency
  - Less sensitive to non-operational pixels (unbiased)
  - But much slower and much more complicated to use



  - Easily extendable to stereo analysis
  - Promising results for energy reconstruction, to be investigated further