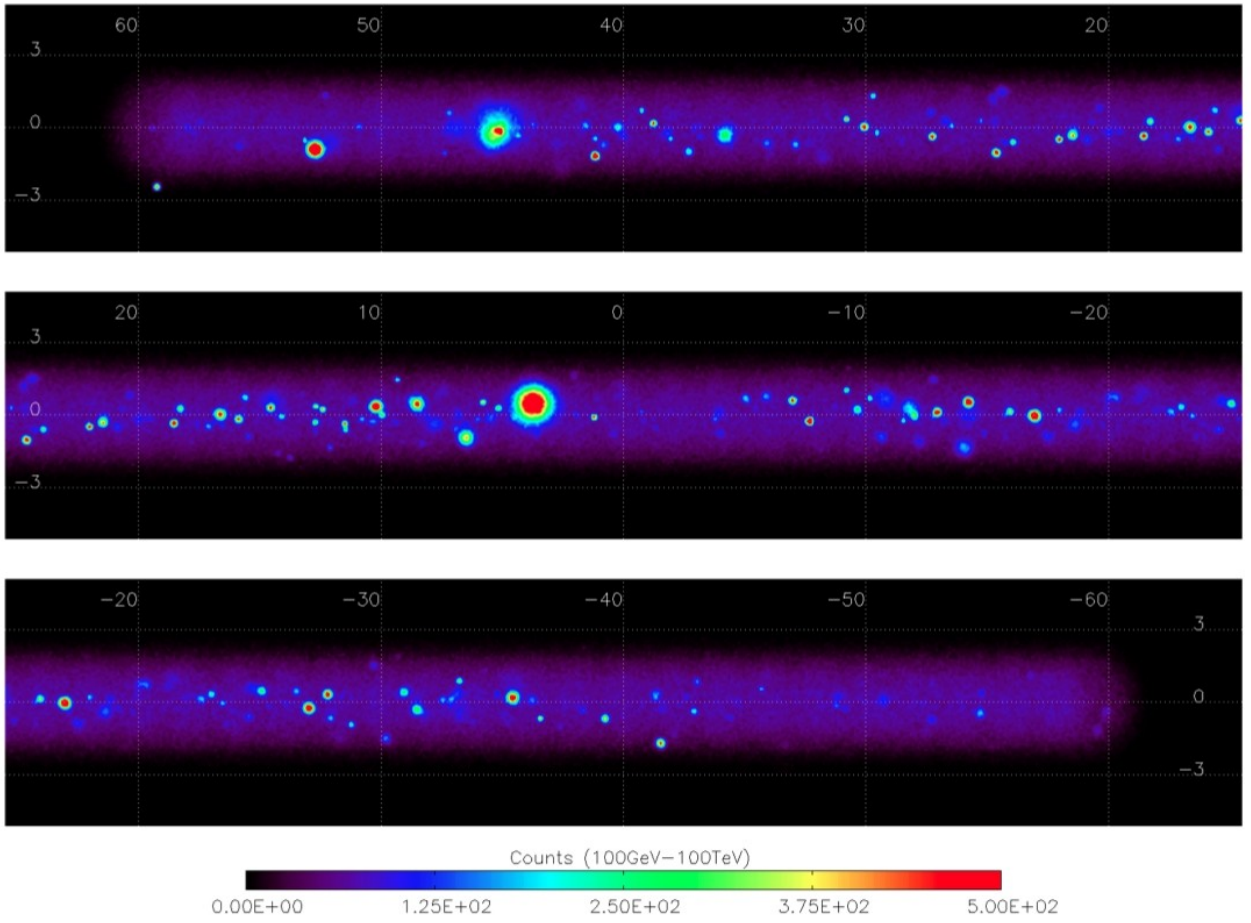
GammaLib and ctools

Status and recent developments



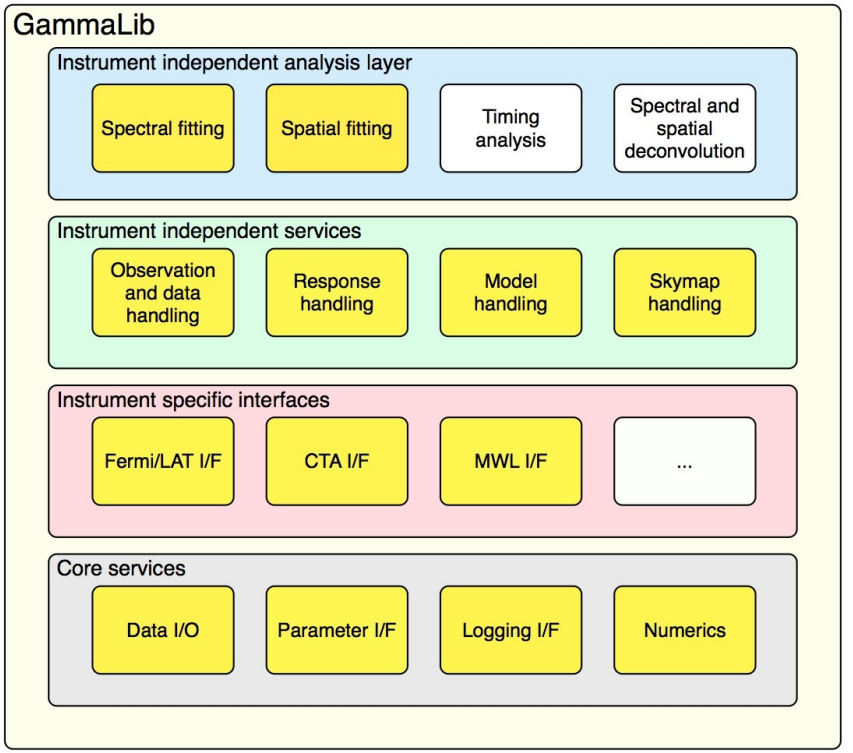
Jürgen Knödlseder (IRAP, Toulouse)

What is GammaLib, what are the ctools?

GammaLib

A versatile toolbox for high-level analysis of astronomical gamma-ray data

- Open source C++ library for analysis of astronomical gamma-ray data
- Developed @ IRAP since 2006
- Available at http://gammalib.sourceforge.net
- Latest release: GammaLib-00-04-12
- Reference: arXiv::1110.6418



Organisation of GammaLib in layers and modules.

ctools

cherenkov telescope array

- ftools prototypes for CTA data analysis
- Based on GammaLib
- Available at http://cta.irap.omp.eu/ctools
- Latest release: ctools-00-03-00
- Comprises so far:
  ctobssim – CTA observation simulation
  ctselect – Event selection
  ctbin – Event binning
  ctlike – Maximum likelihood fitting (unbinned & binned)

What is new since the Toulouse meeting?

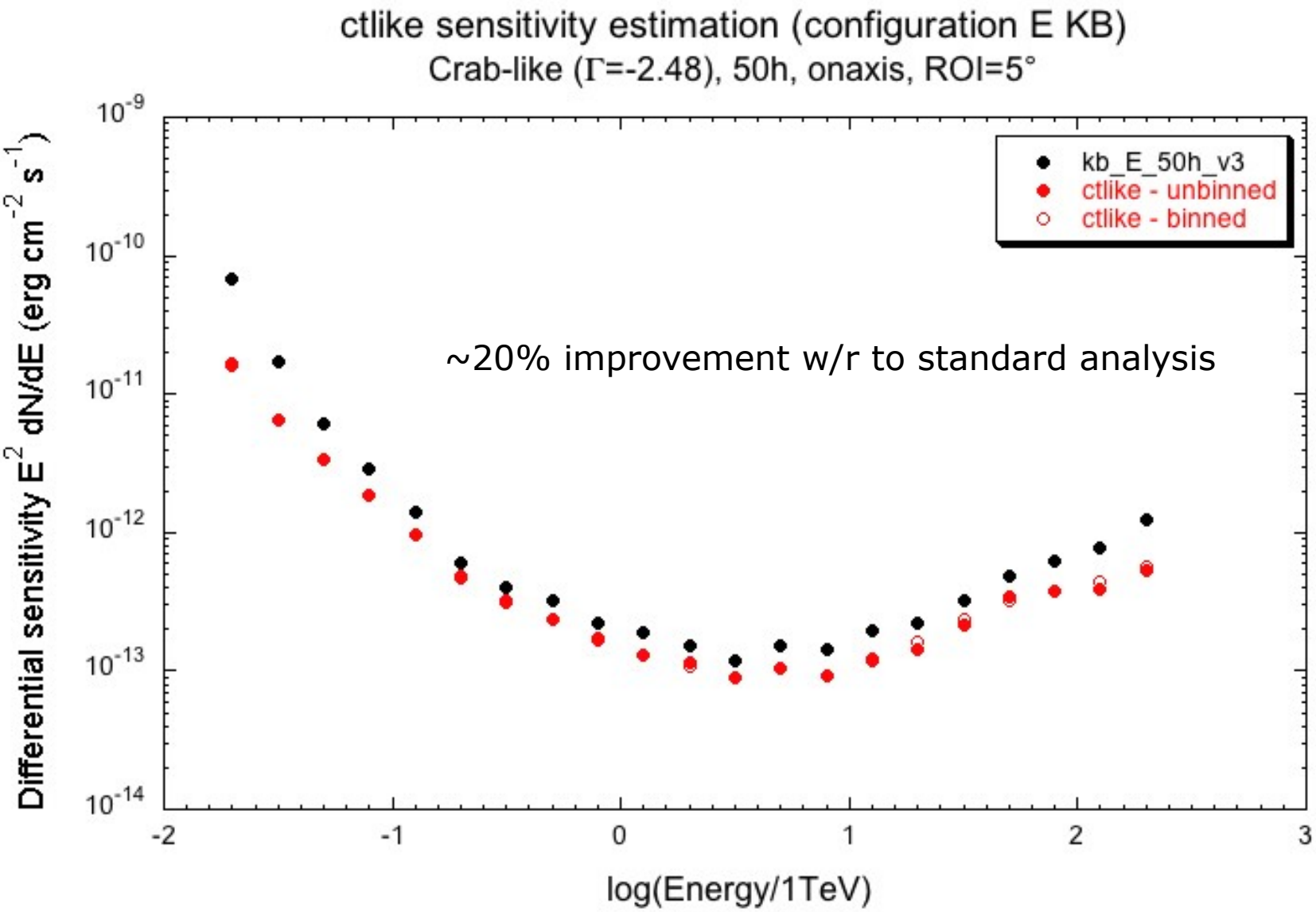
Software developments

- Implement offset angle dependence in CTA response
- Improve World Coordinate System support for skymap projections
- Improve cross-platform compatibility (Mac OS X, Linux, FreeBSD, openSolaris)
- First binary package for Mac OS X
- Code consolidation & bug fixes

Software validation and applications

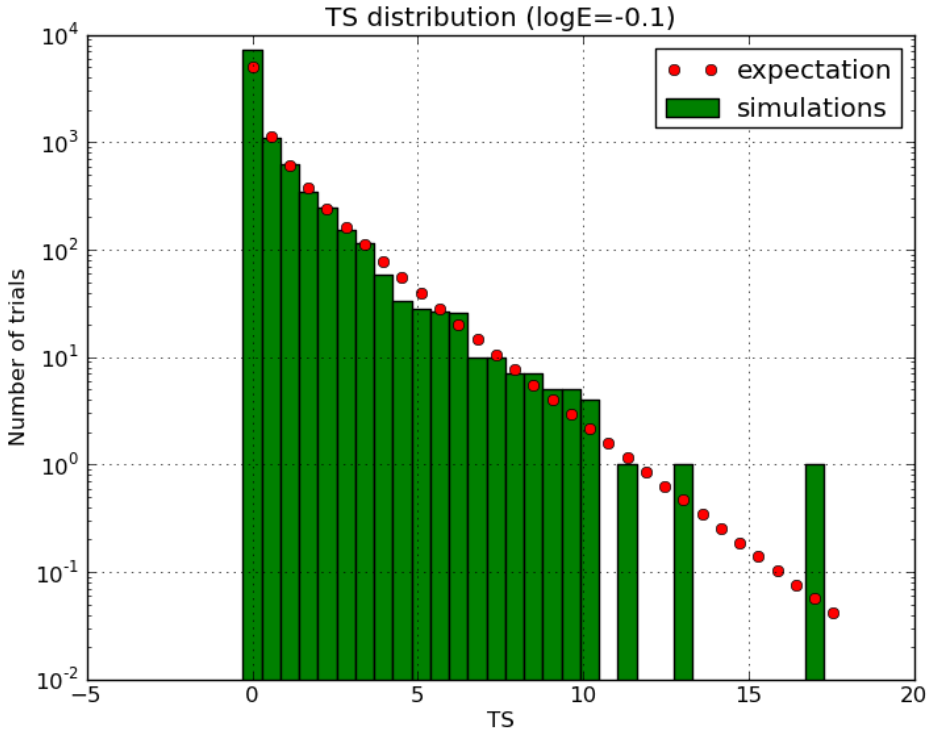
- CTA sensitivity studies
- CTA survey capabilities
- First H.E.S.S. Data analysis

ctlike-based CTA sensitivity

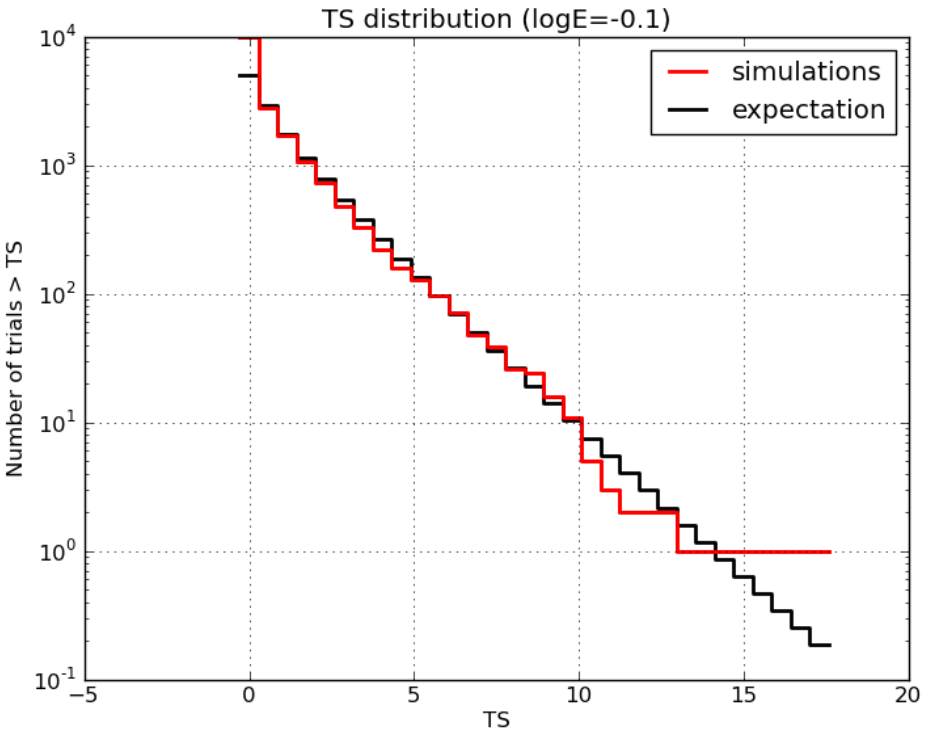


$$TS = 2 \times (\ln L_{\text{source}} - \ln L_{\text{no source}}) = 25$$

Does TS=25 correspond to 5σ?



differential distribution

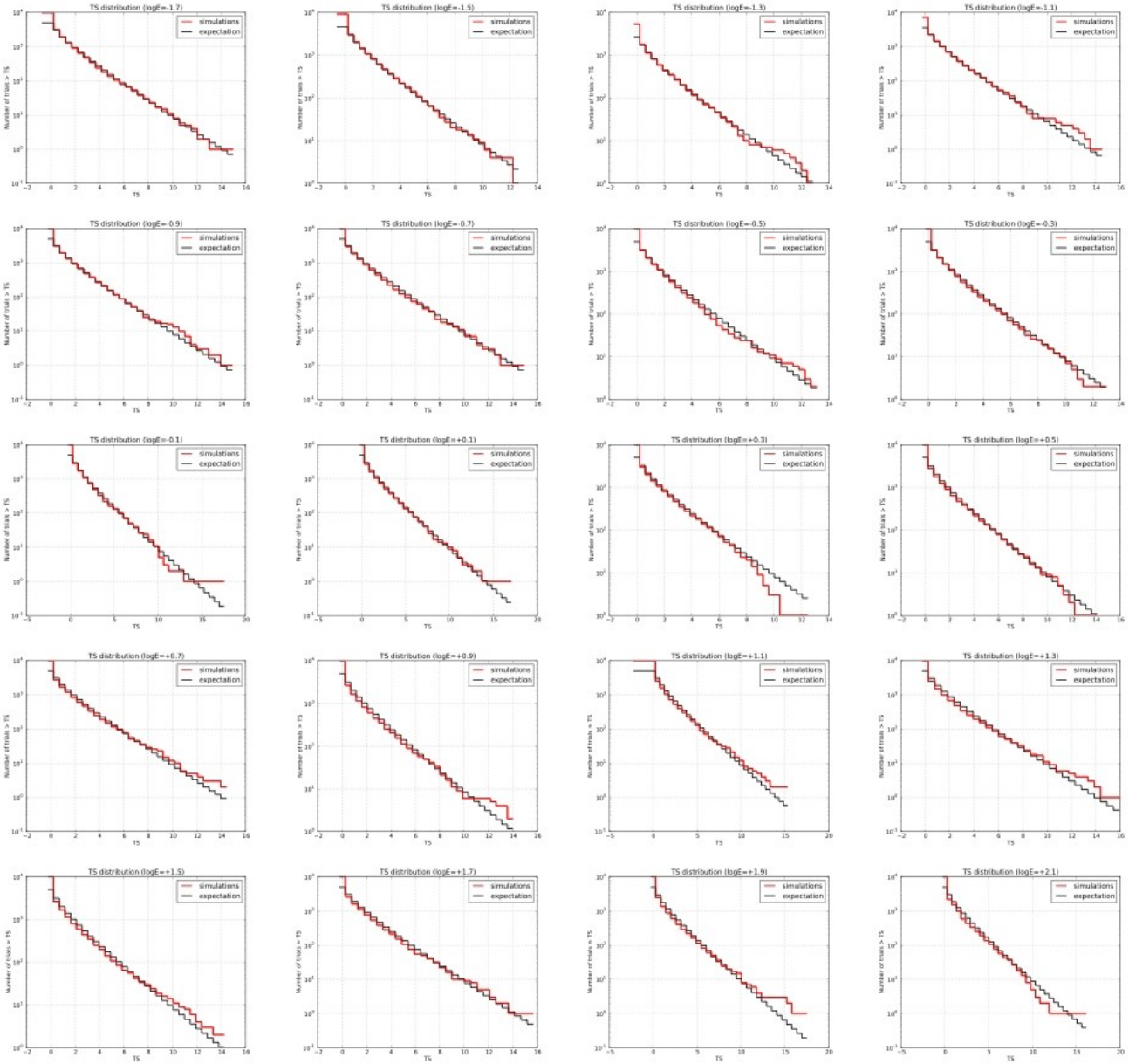


cumulative distribution

Comparison of simulations to Wilk's theorem (Chi2 with 1 d.o.f.)

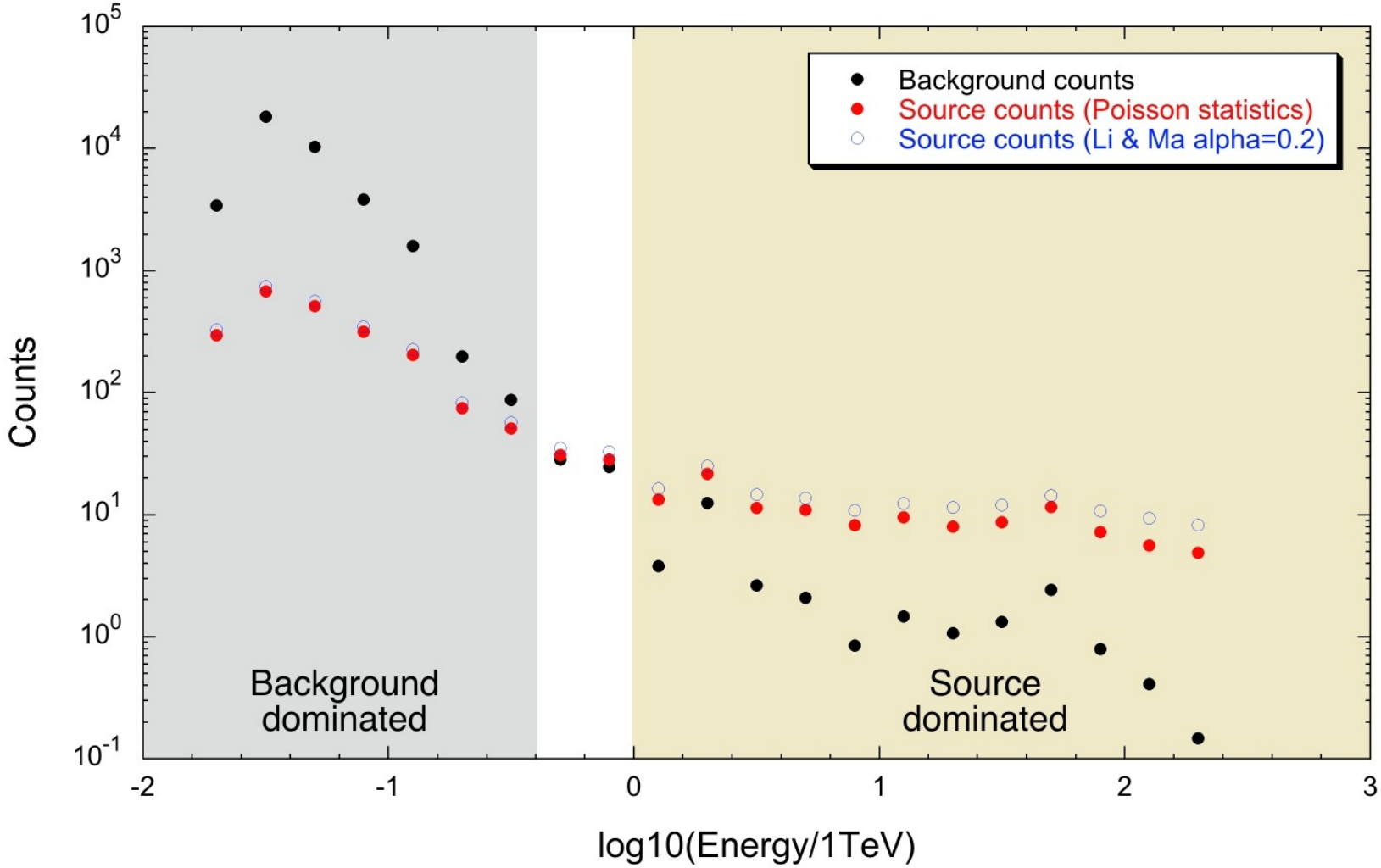
- 10000 *ctobssim* Monte Carlo simulations of empty fields
- 50 hours exposure, configuration E (Konrad's files)
- *ctlike* fit (onaxis Crab-like point source + background model)

Does TS=25 correspond to 5σ?



Simulated TS distribution follows reasonably well Wilk's theorem for all energy bins

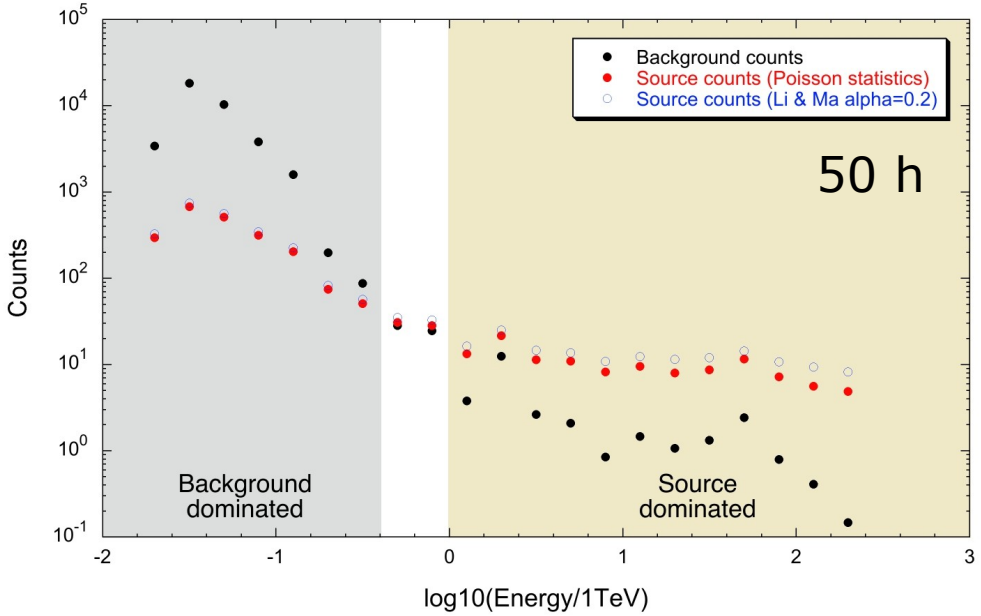
A word about counting statistics

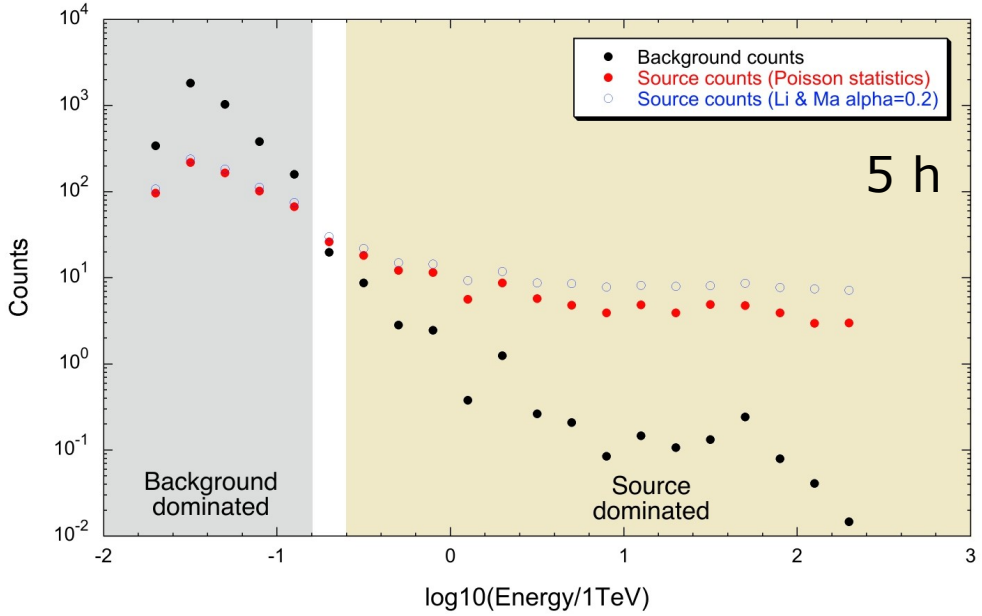


How many source counts are required for a 5σ detection?

- 50 hours exposure, configuration E (Konrad's files)
- Background counts in r80 confinement radius (<1 at high energies)
- Source counts from Poisson statistics

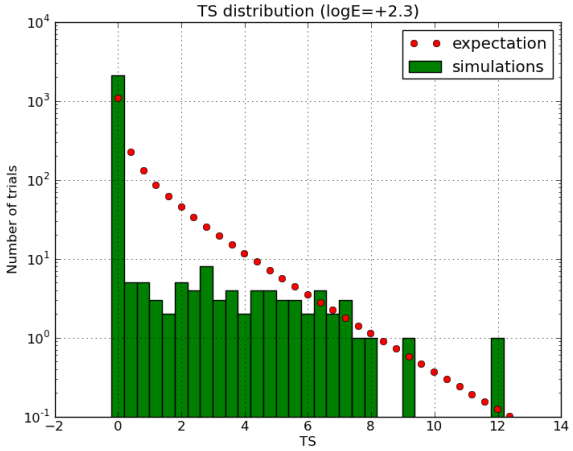
Another word about counting statistics

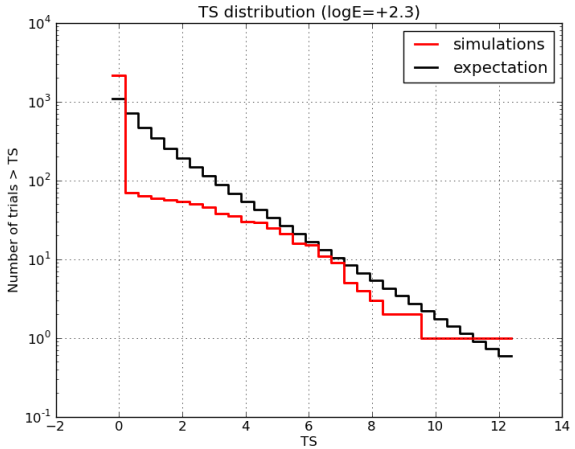




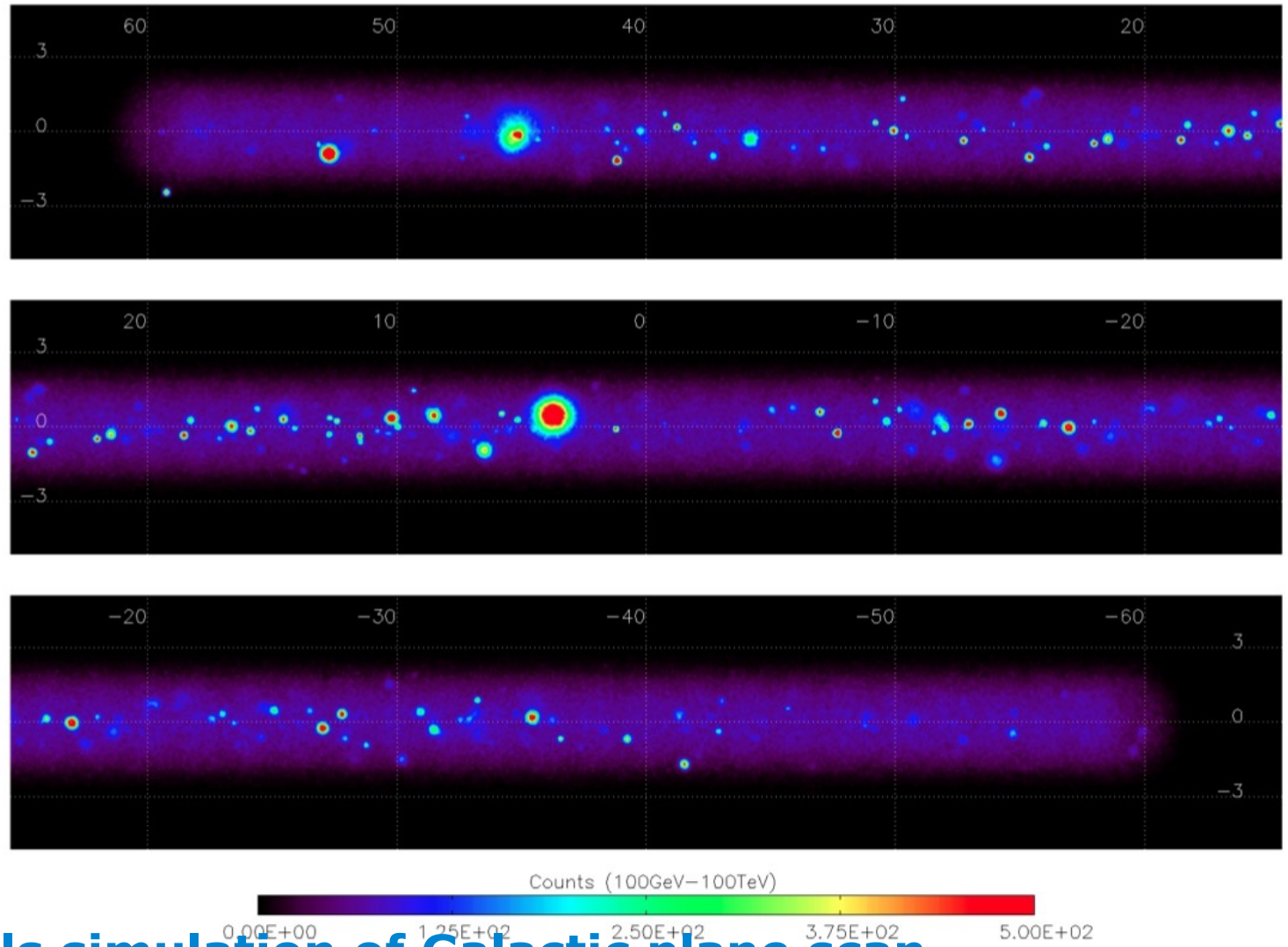
How about shorter exposures?

- Shorter exposures are more source dominated
- Wilk's theorem breaks down for small count statistics (reason: zero counts in r80)





CTA survey studies (PHYS paper)



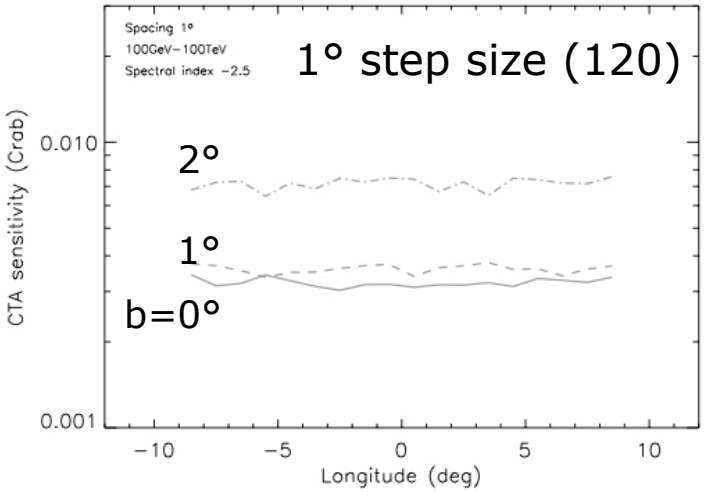
Simulation by Pierrick Martin

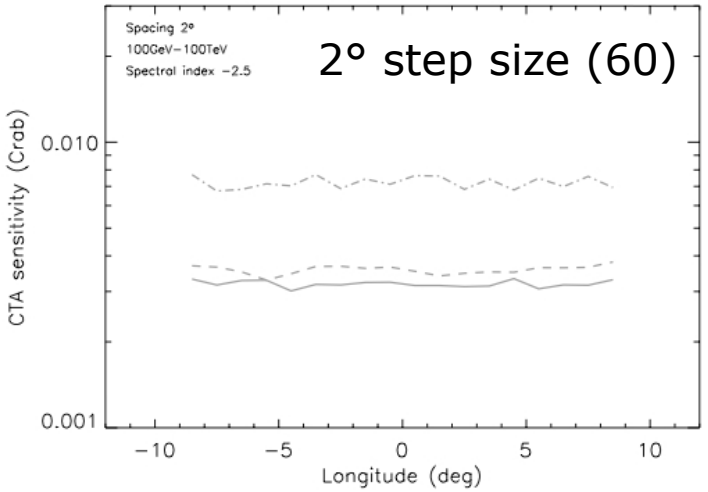
Dubus et al. (submitted)

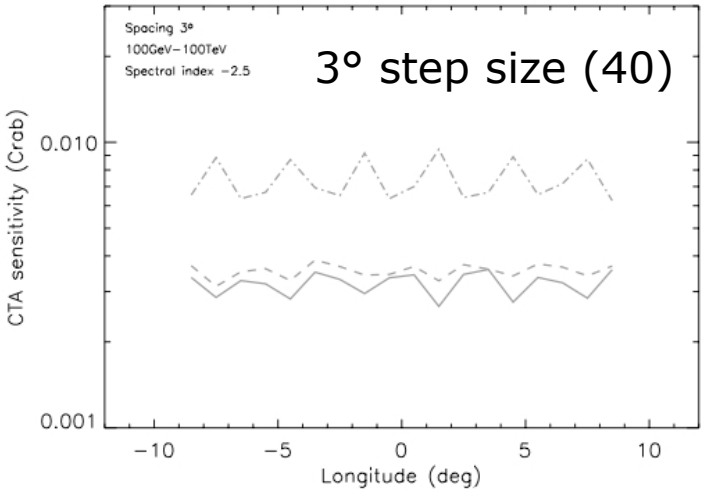
ctools simulation of Galactic plane scan

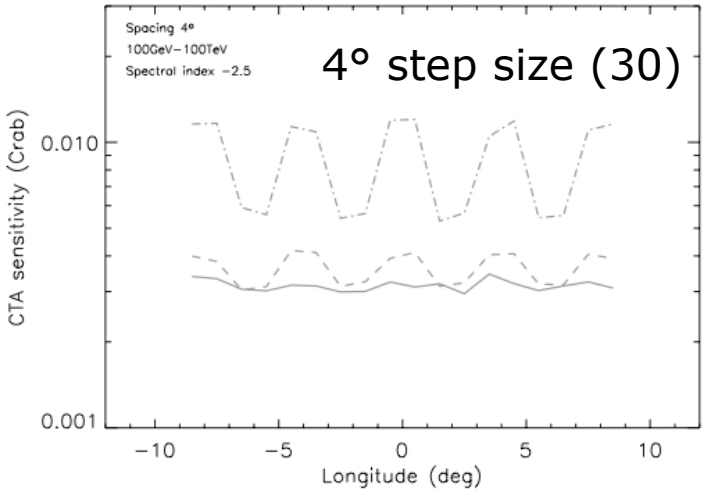
- 240 hours total exposure, *ctobssim* & *ctbin*
- PWN only
- Source confusion will be an issue for CTA (at least in the Galactic plane)

CTA survey strategy optimisation









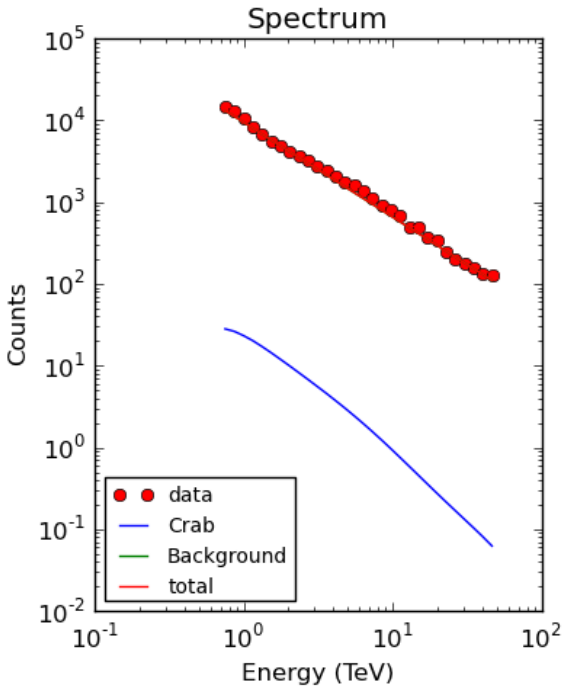
Simulations by Pierrick Martin

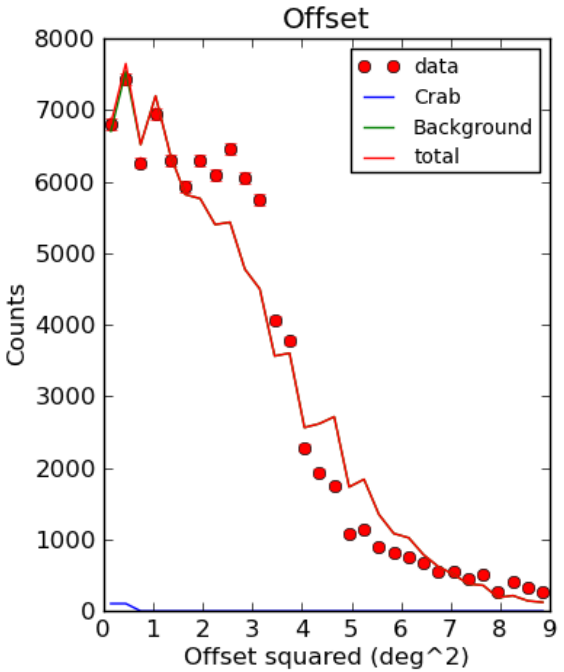
Dubus et al. (submitted)

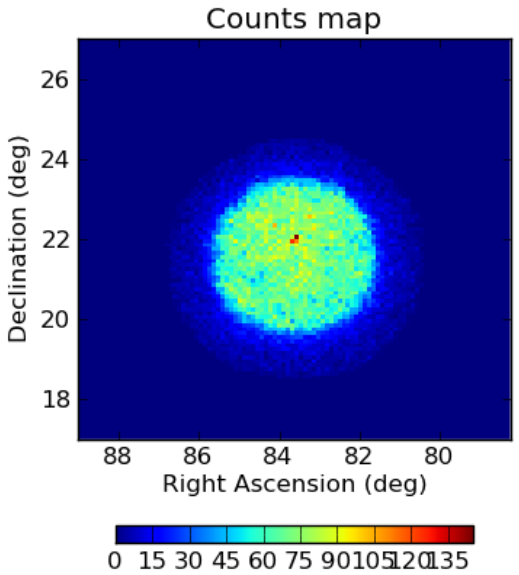
Impact of survey step size on sensitivity

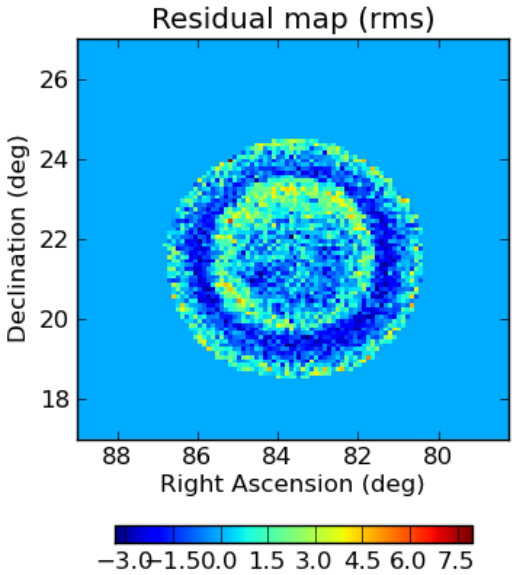
- 240 hours total exposure, *ctobssim, ctselect, ctlike (unbinned)*
- 2° step size presents a good compromise between homogeneity and number of pointings (3 mCrab for |b| < 1°)

Towards 1DC – First analysis of H.E.S.S. data





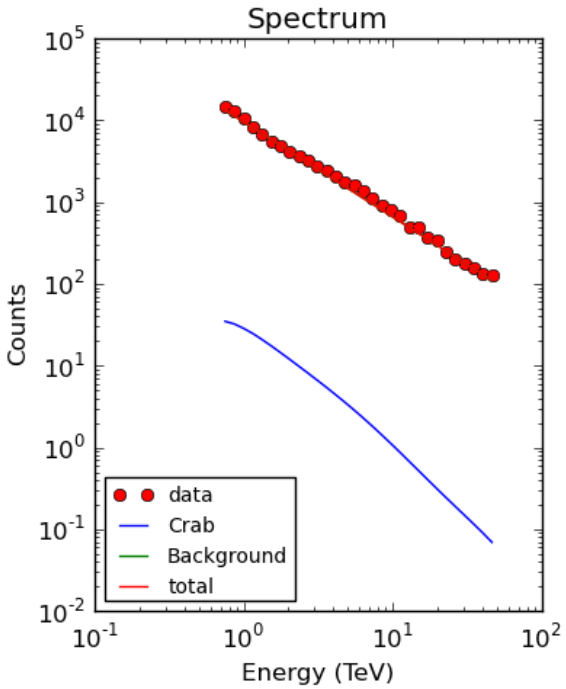


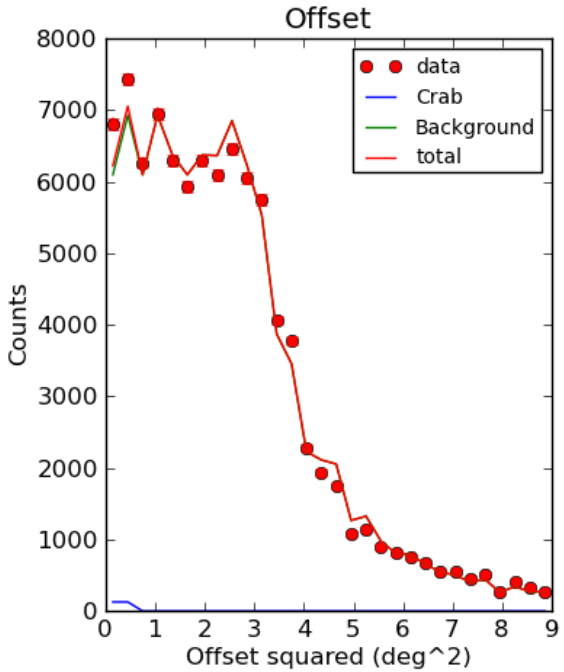


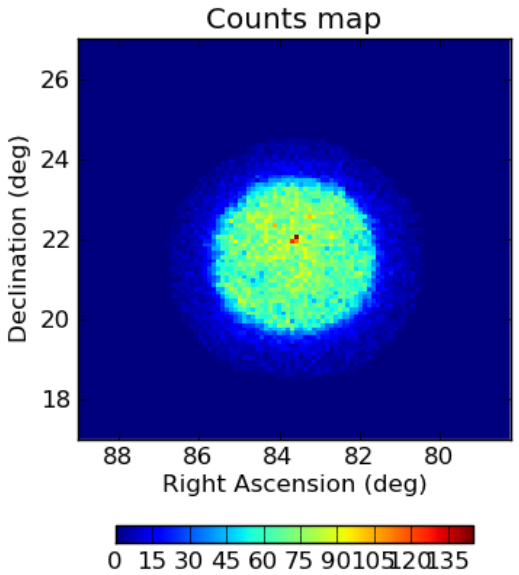
H.E.S.S. Crab observation

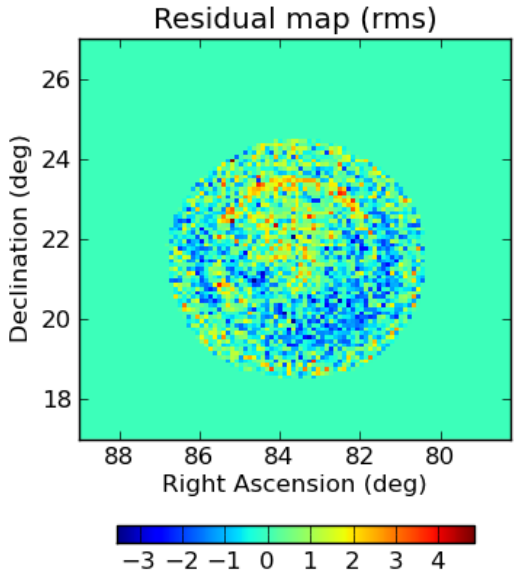
- Single run (28 min)
- 0.7-50 TeV, θ<3°
- Radial acceptance model:
  Gaussian in θ^2
  Power law in energy
- Crab model:
  Power law
- Use of appropriate ARF
- Only fake PSF so far
- No background supression

Towards 1DC – First analysis of H.E.S.S. data









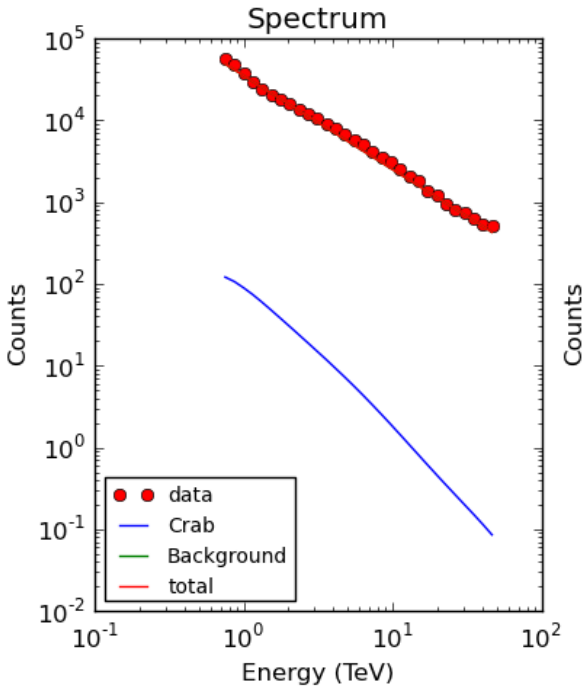
H.E.S.S. Crab observation

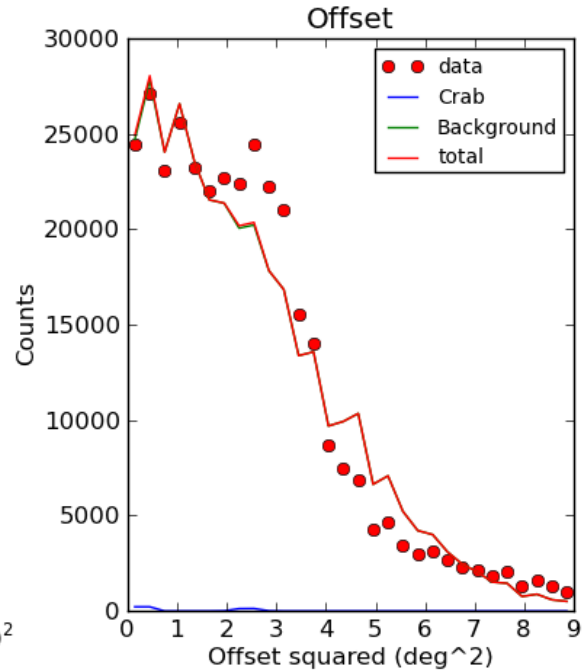
- Single run (28 min)
- 0.7-50 TeV, θ<3°
- Radial acceptance model:

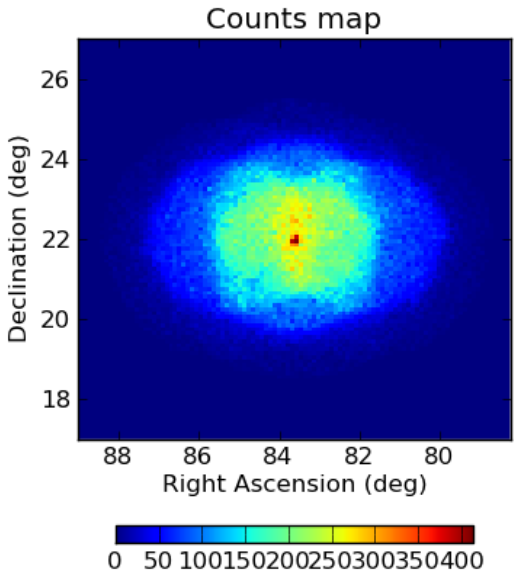
$$\left(1+\left(\frac{\theta}{p_0}\right)^{p_1}\right)^{-\frac{p_2}{p_1}}$$

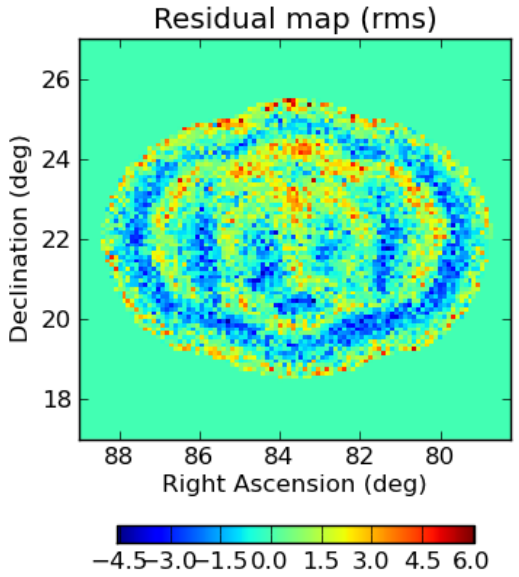
  Power law in energy
- Crab model:
  Power law
- Use of appropriate ARF
- Only fake PSF so far
- No hadron subtraction

Towards 1DC – First analysis of H.E.S.S. data







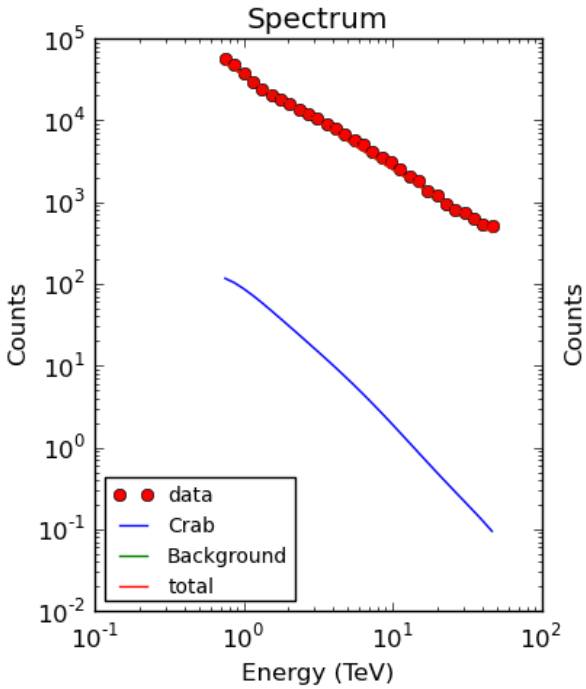


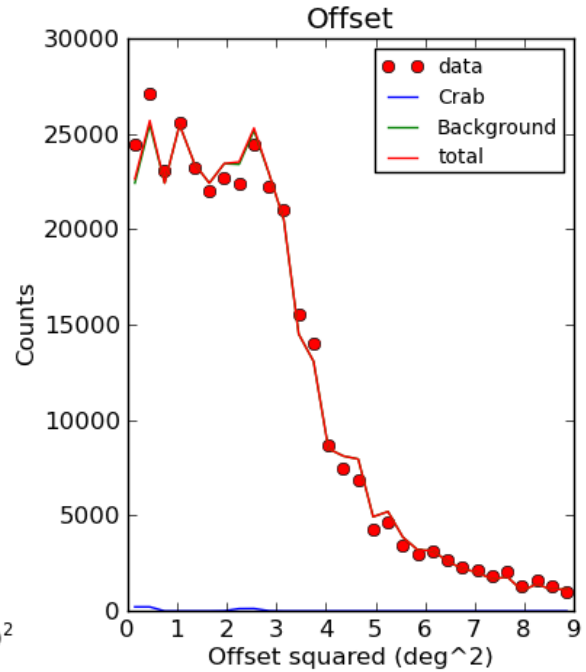
H.E.S.S. Crab observation

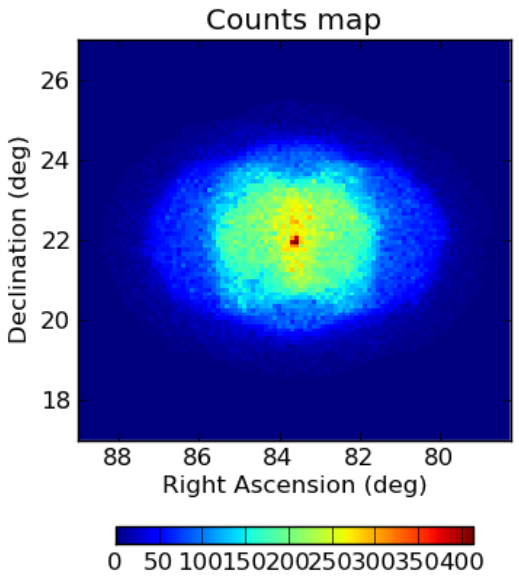
- 4 runs (112 min)
- 0.7-50 TeV, θ<3°
- Radial acceptance model:
  Gaussian in θ^2
  Power law in energy
- Crab model:
  Power law
- Use of appropriate ARF
- Only fake PSF so far
- No background supression

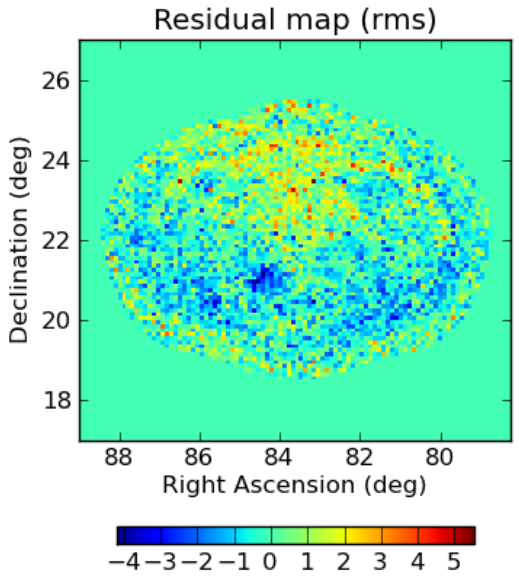
Note: Data for runs are not added; every event is treated individually using the proper ARF for each run.

Towards 1DC – First analysis of H.E.S.S. data









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- Radial acceptance model:

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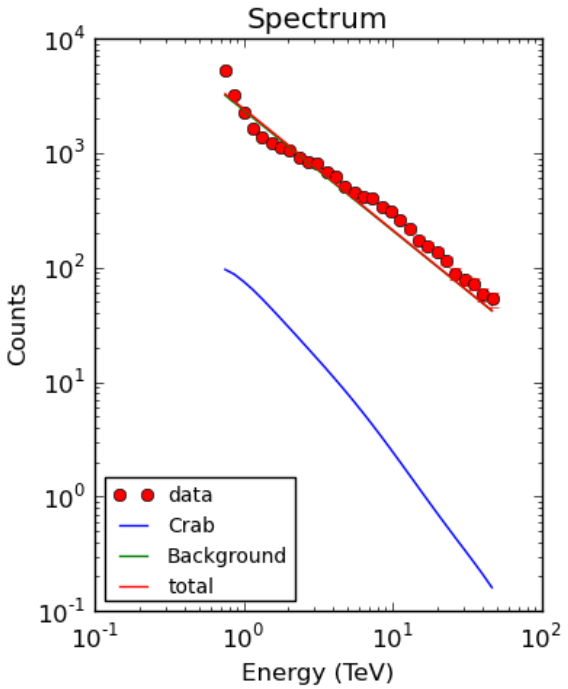
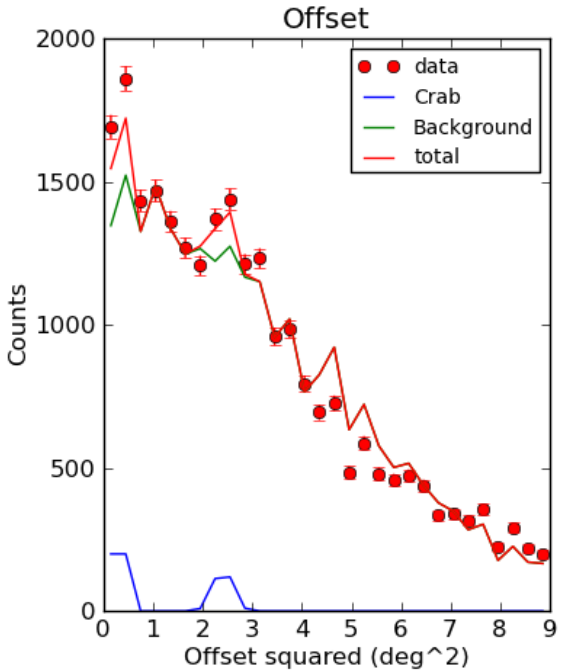
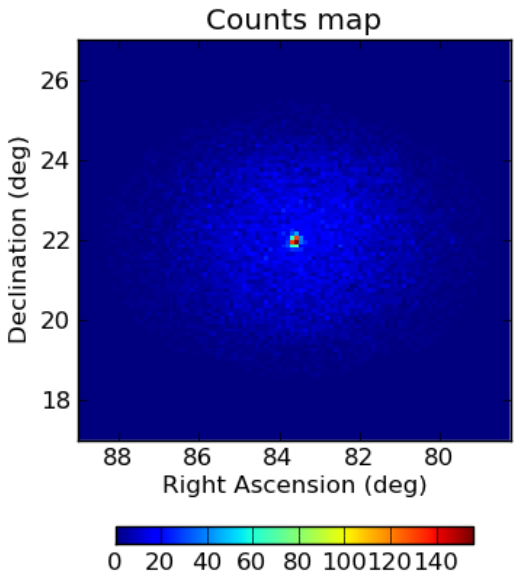
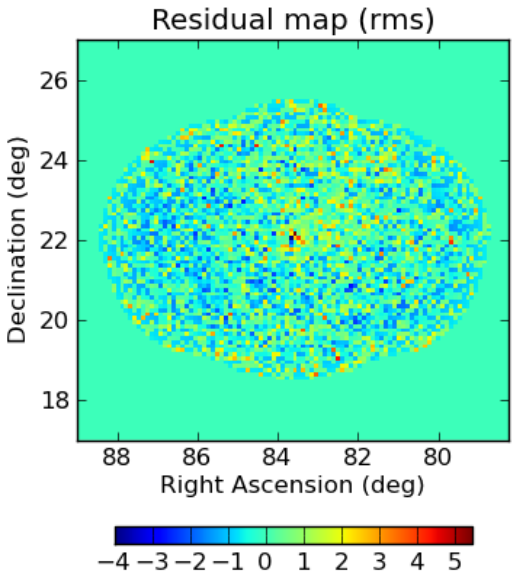
  Power law in energy
- Crab model:
  Power law
- Use of appropriate ARF
- Only fake PSF so far
- No background supression

Towards 1DC – First analysis of H.E.S.S. data









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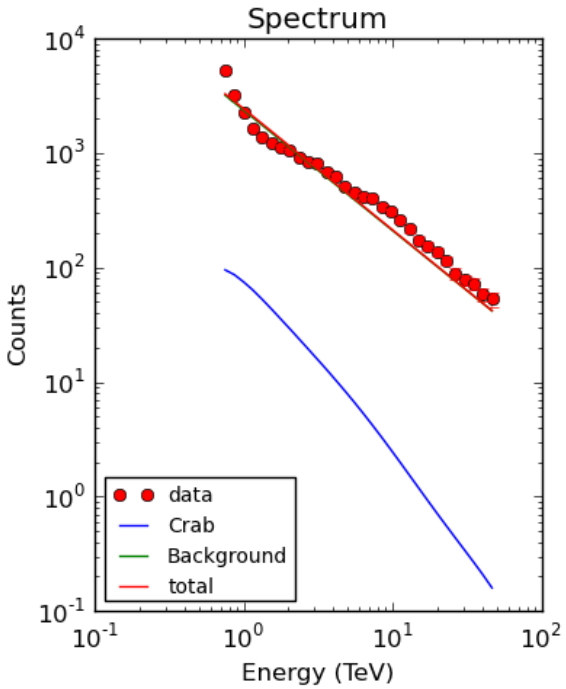

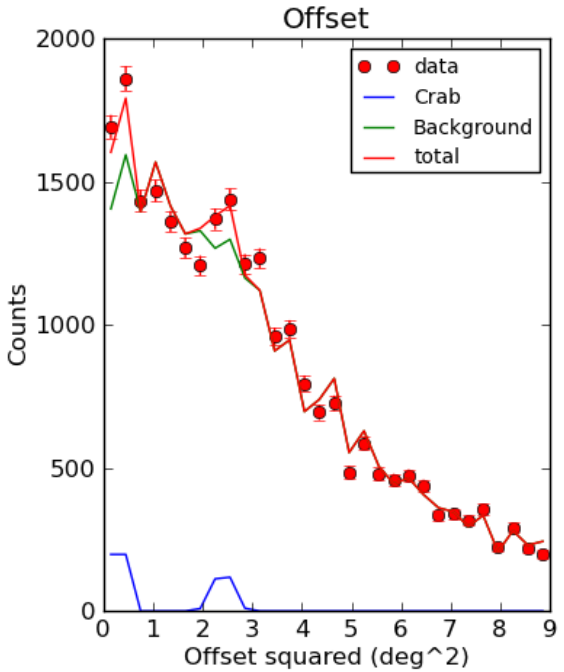

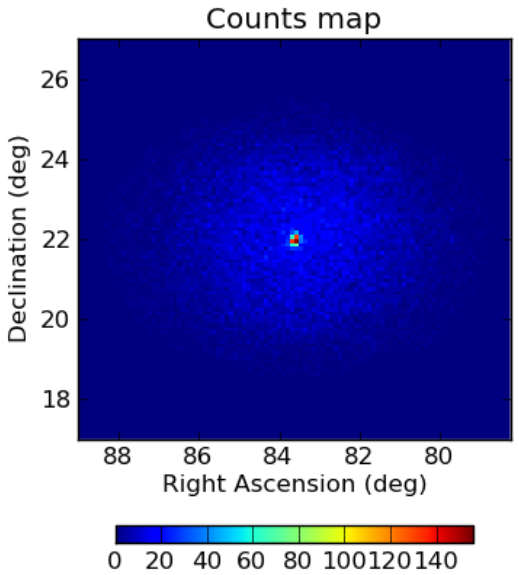

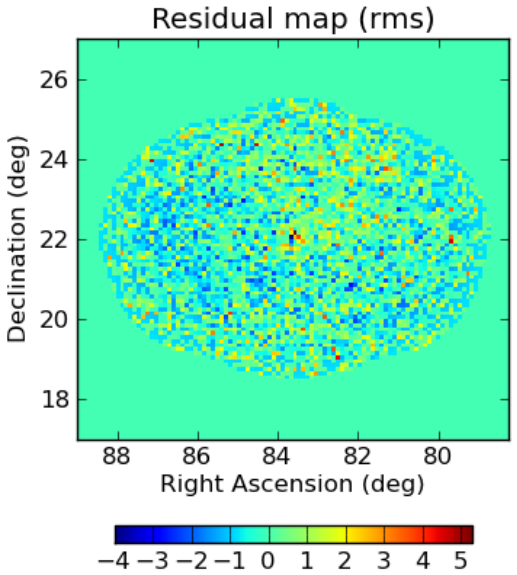

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  Power law in energy
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Next steps

Software developments

- 1DC readiness (adapt tools to agreed data and response formats)
- Enhance the ctools suite (sky mapping, background modelling)

Software distribution

- Provide binary distributions for common Linux platforms
- ctools/GammaLib in a virtual machine?
- ctools/GammaLib on the Grid?

Development infrastructure

- Setup multi-platform continuous build system (Jenkins)
- Provide community development services (SVN, Forge)