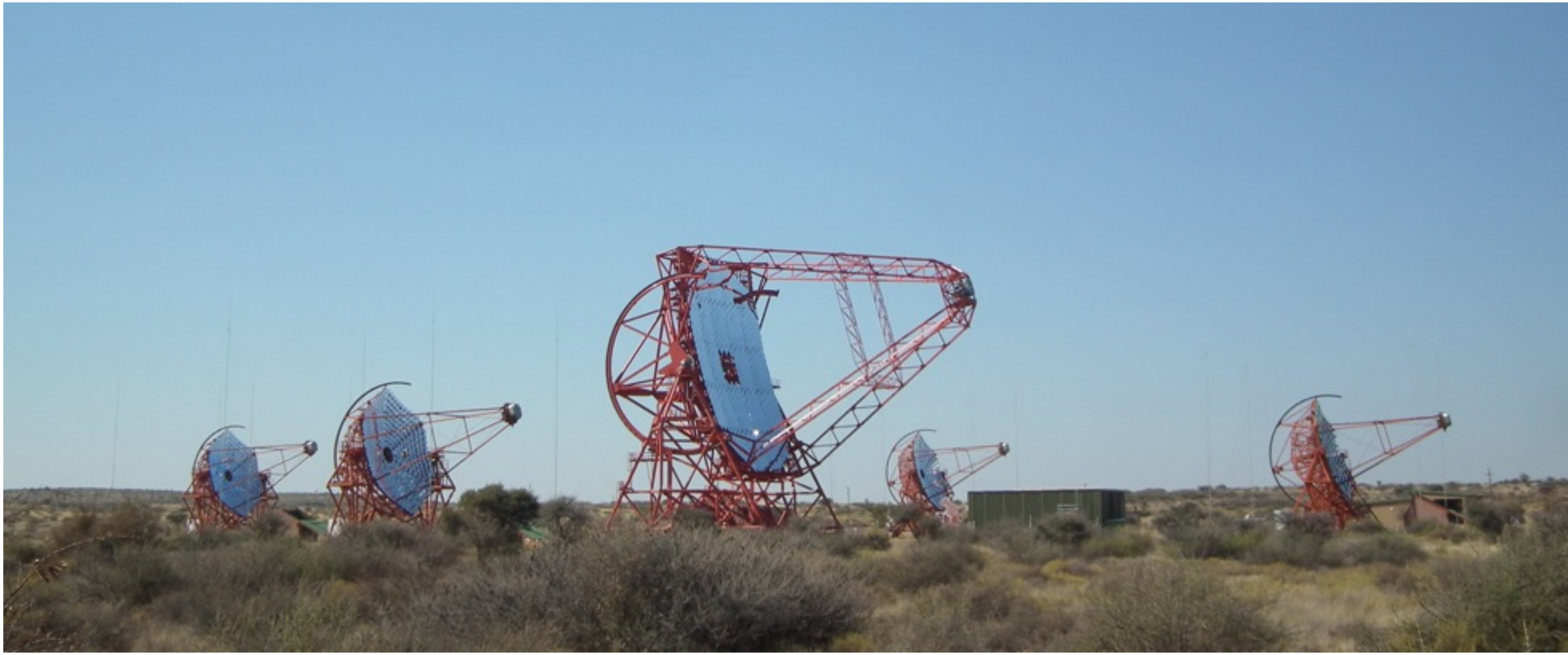


ImPACT: A MC Template based analysis for IACTs

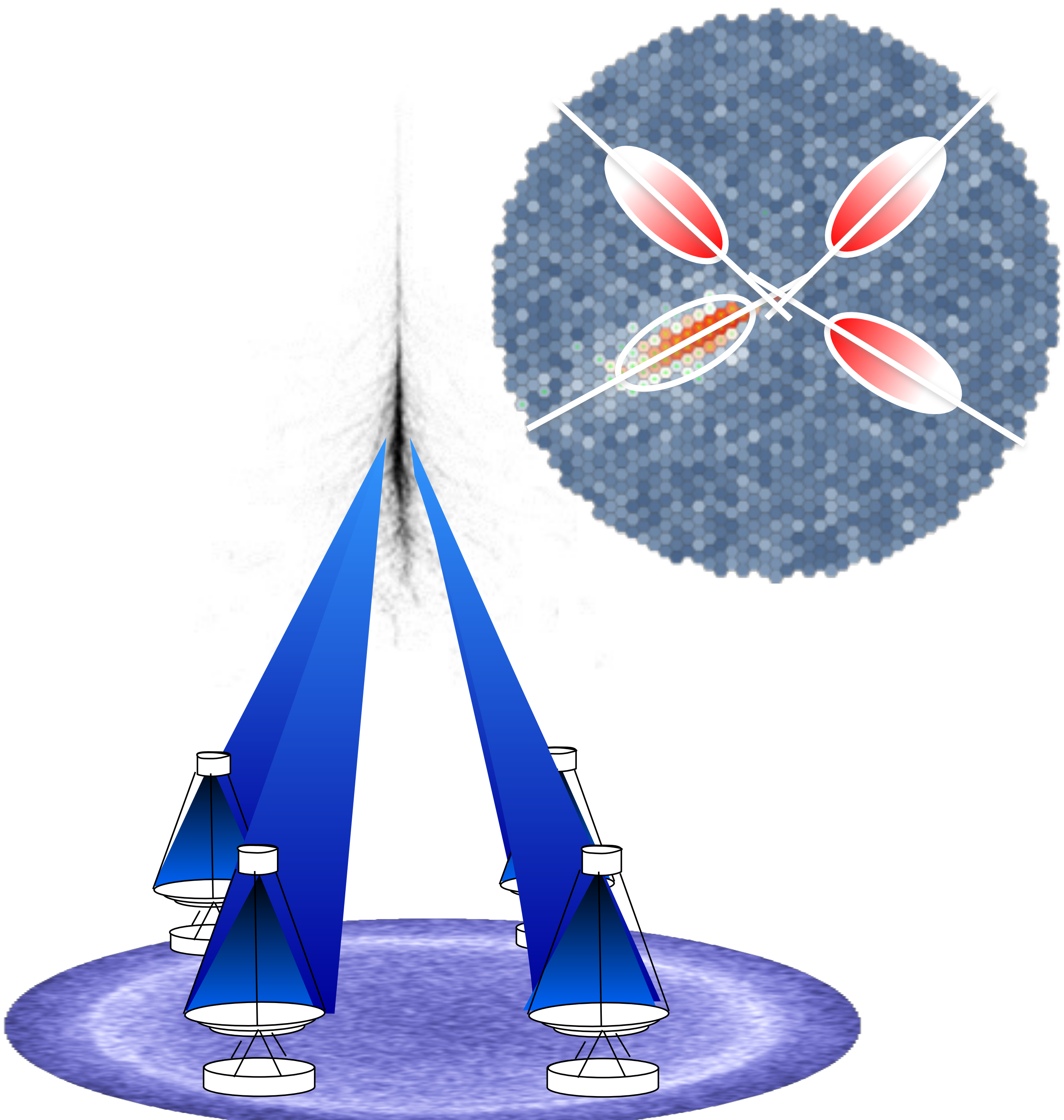
R D Parsons & J A Hinton

Parsons & Hinton,
Astroparticle physics 56, 26, 2014

MAX-PLANCK-INSTITUT FÜR KERNPHYSIK

H.E.S.S.

Reconstruction in IACTs



In order to perform any astronomy we need to use IACT camera images to determine the properties primary gamma-ray

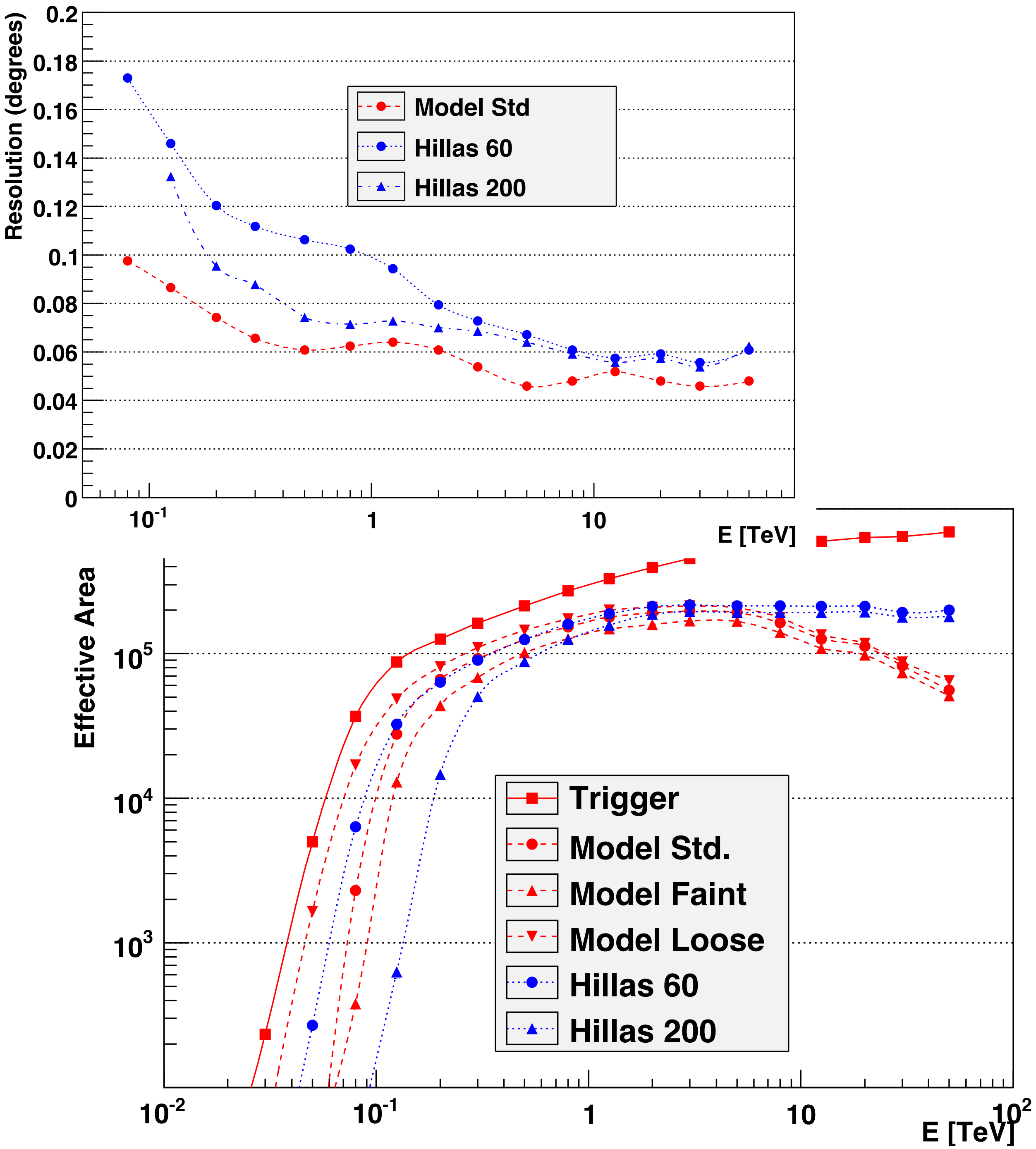
Typically this is done using Hillas parameters (first and second image moments)

Image axes are intersected in a common frame to determine the source position

Similar procedure used in ground frame

Energy determine using image amplitudes and distance from shower core

Template Based analysis



There is however clearly more information available in the shower images than just these moments

Instead of parameterising images we can try fitting the full shower image with an expected image template

This approach has been used before (LeBohec et al 1998, de Naurois et al, 2009)

Both these implementations fit shower images with the predictions of a semi-analytical model

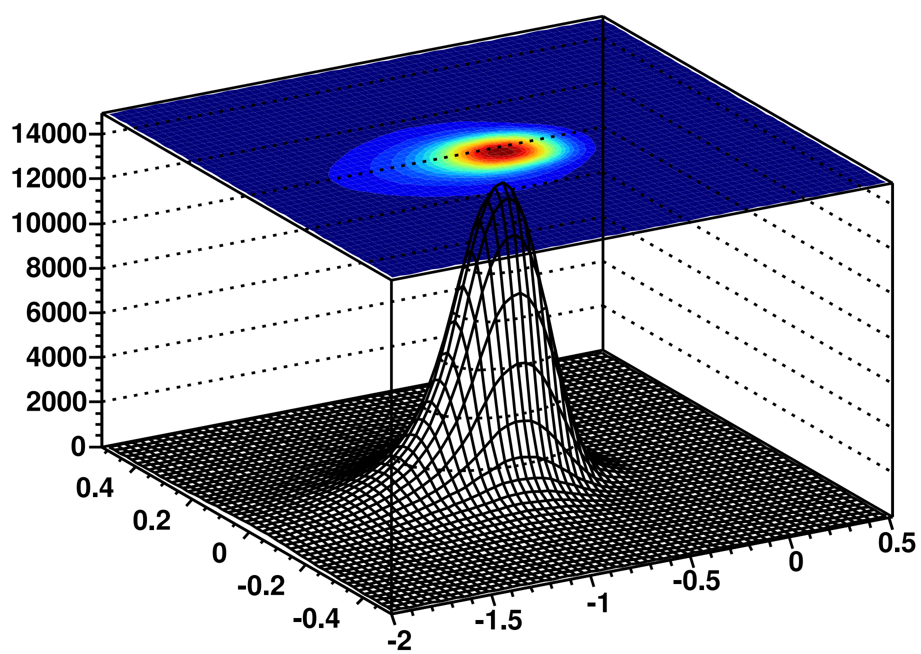
Result in large improvements in performance

Semi-analytical model difficult to fit at high energies

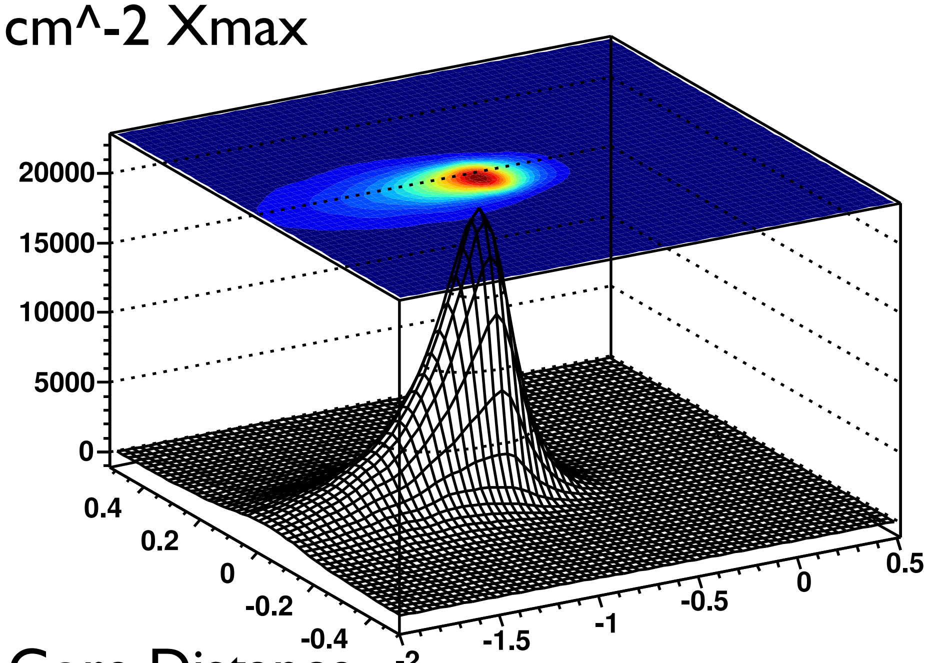
Requires tuning to different telescope types

Images from de Naurois et al 2009

Image Template Generation



100m Core Distance
300 g cm^-2 Xmax



100m Core Distance
400 g cm^-2 Xmax

Use MC simulations instead of semi analytical model to generate the templates

Naturally accounts for instrumental + environmental effects

- Atmospheric absorption
- Magnetic fields
- Telescope PSF
- Camera Readout

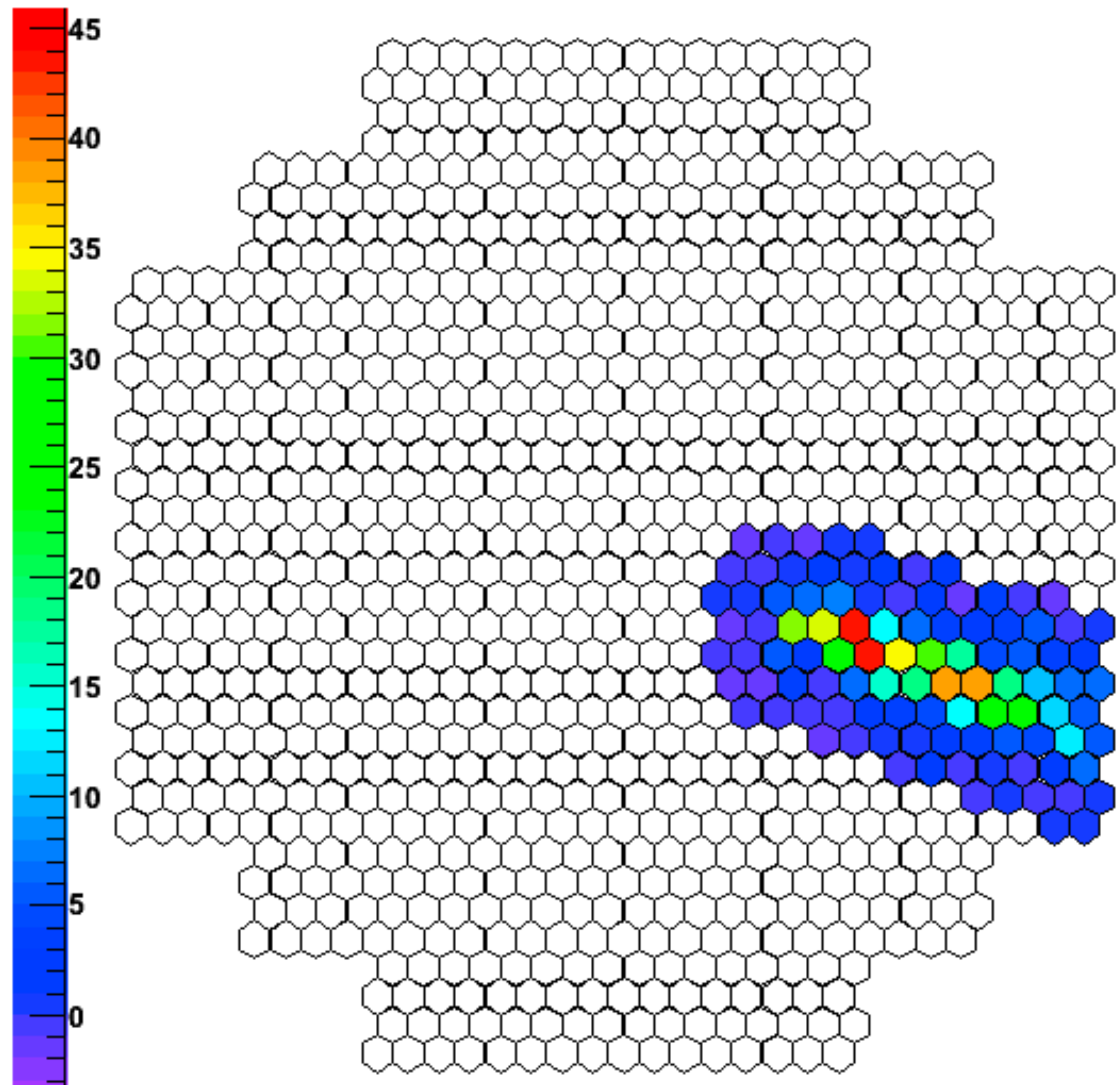
High energy gamma-rays can be well understood

Need to create a library of image templates for all possible shower parameters

Cover full range of zenith angle, azimuth angle, impact distance, energy and X_{max}

Fitting Technique

Take extended camera image
(cleaned image + 2 extra rows)

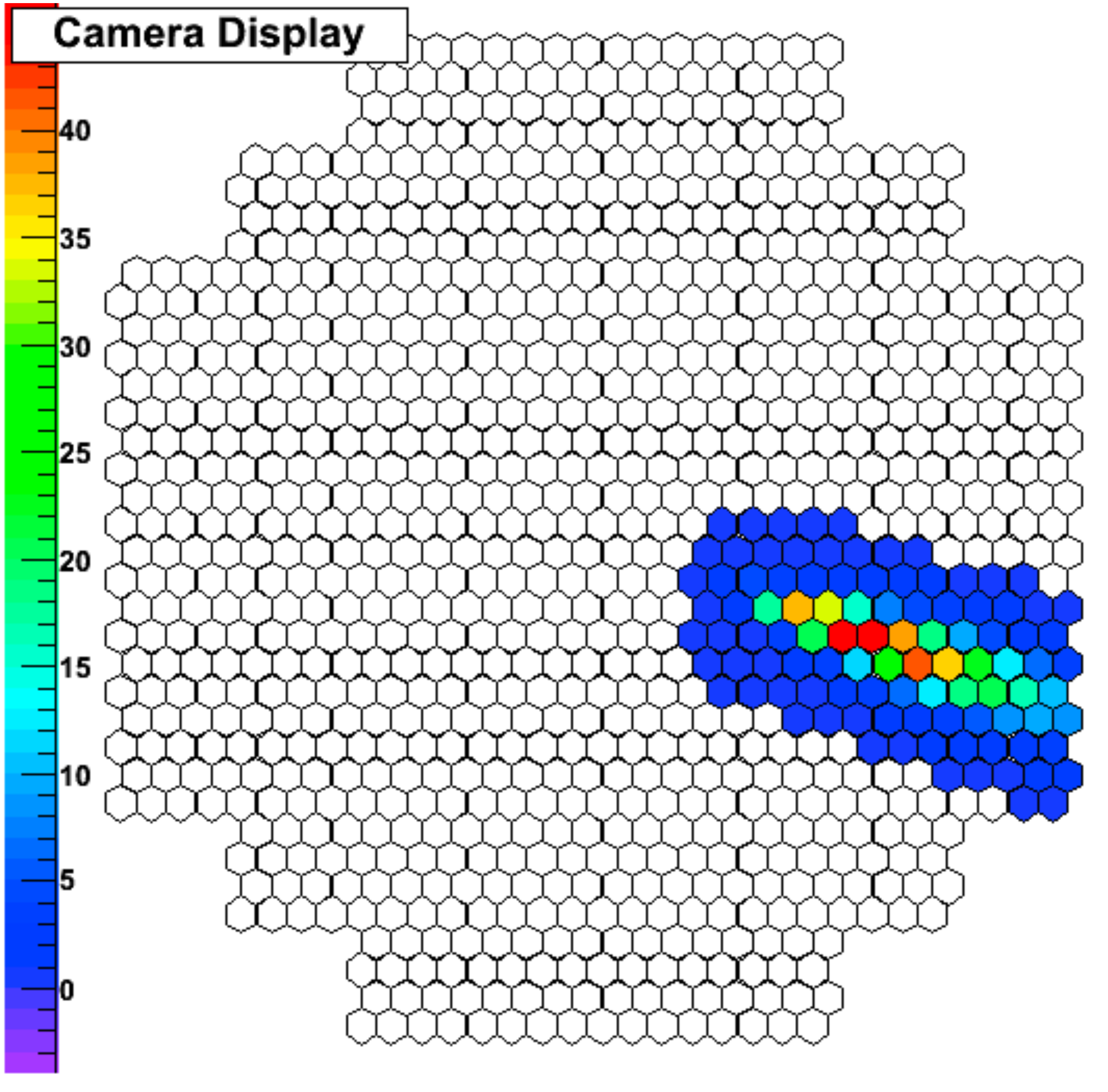


Fitting Technique

Take extended camera image (cleaned image + 2 extra rows)

Generate expected camera image using the image library at the trial position

Interpolate between simulated templates



Fitting Technique

Take extended camera image (cleaned image + 2 extra rows)

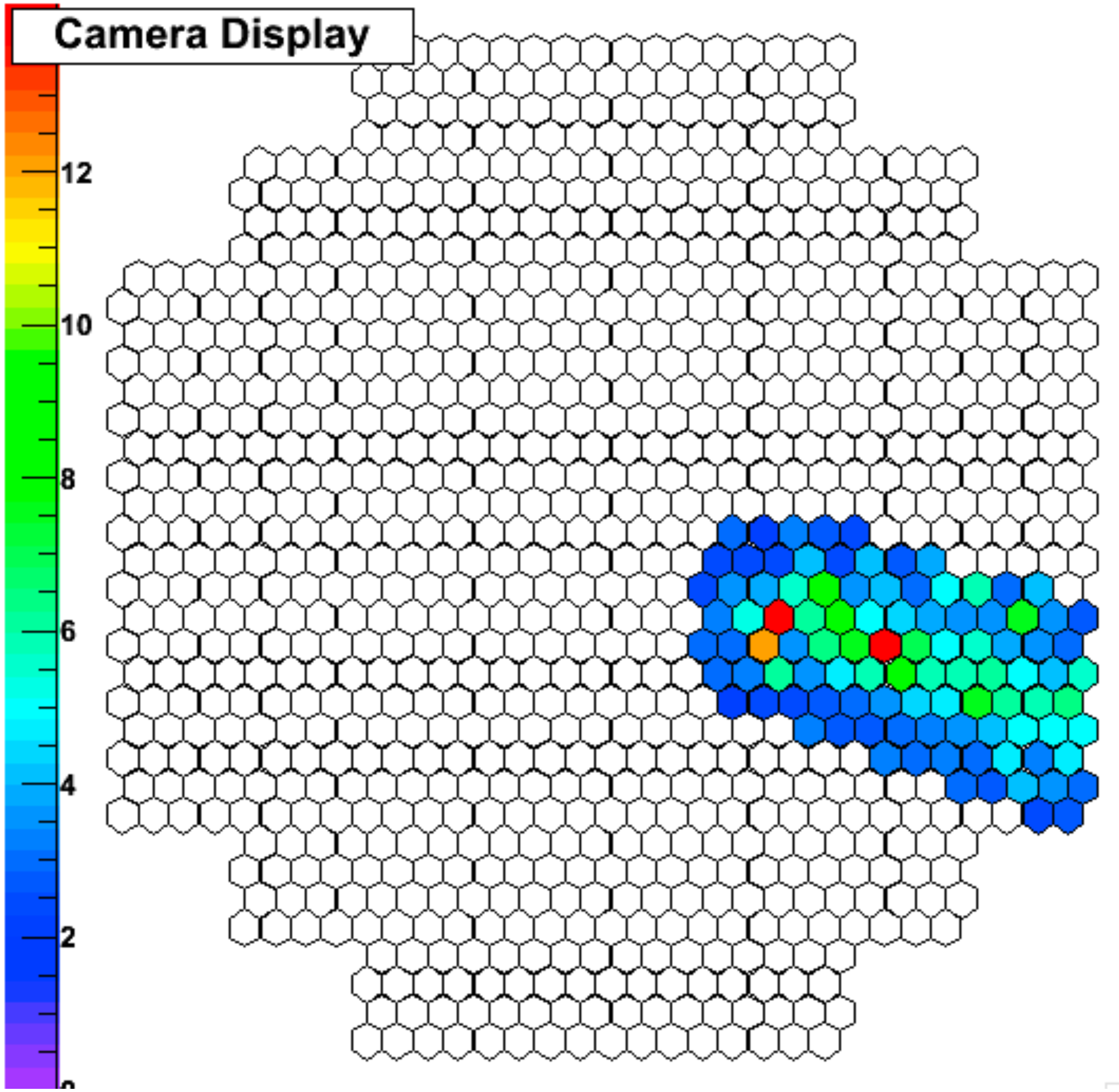
Generate expected camera image using the image library at the trial position

Interpolate between simulated templates

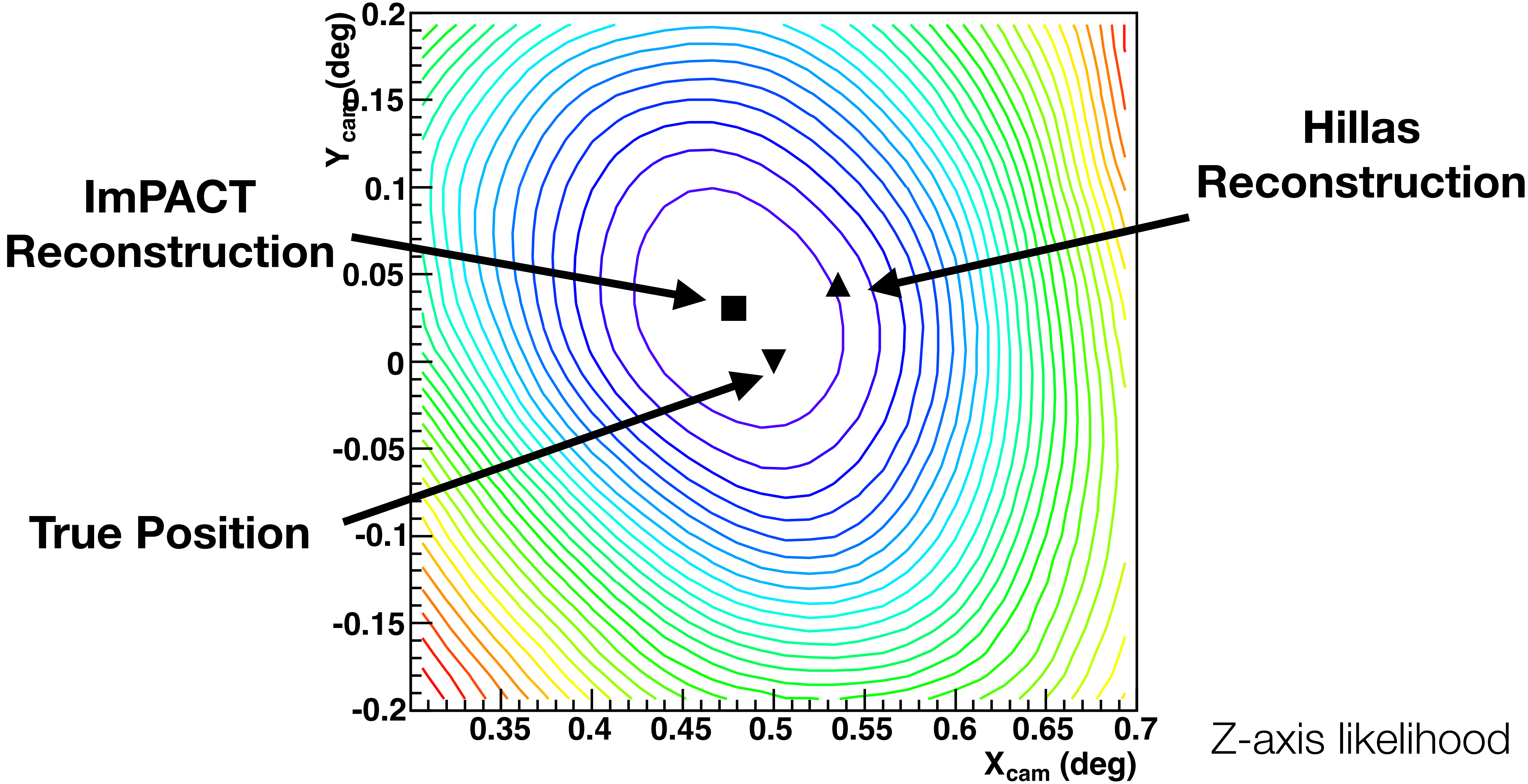
Calculate likelihood that expectation fits data (de Naurois, 2009)

Sum likelihood over all pixels in all telescopes

Perform 6 dimensional fit (source position, ground position, energy and Xmax)



Fitting Technique

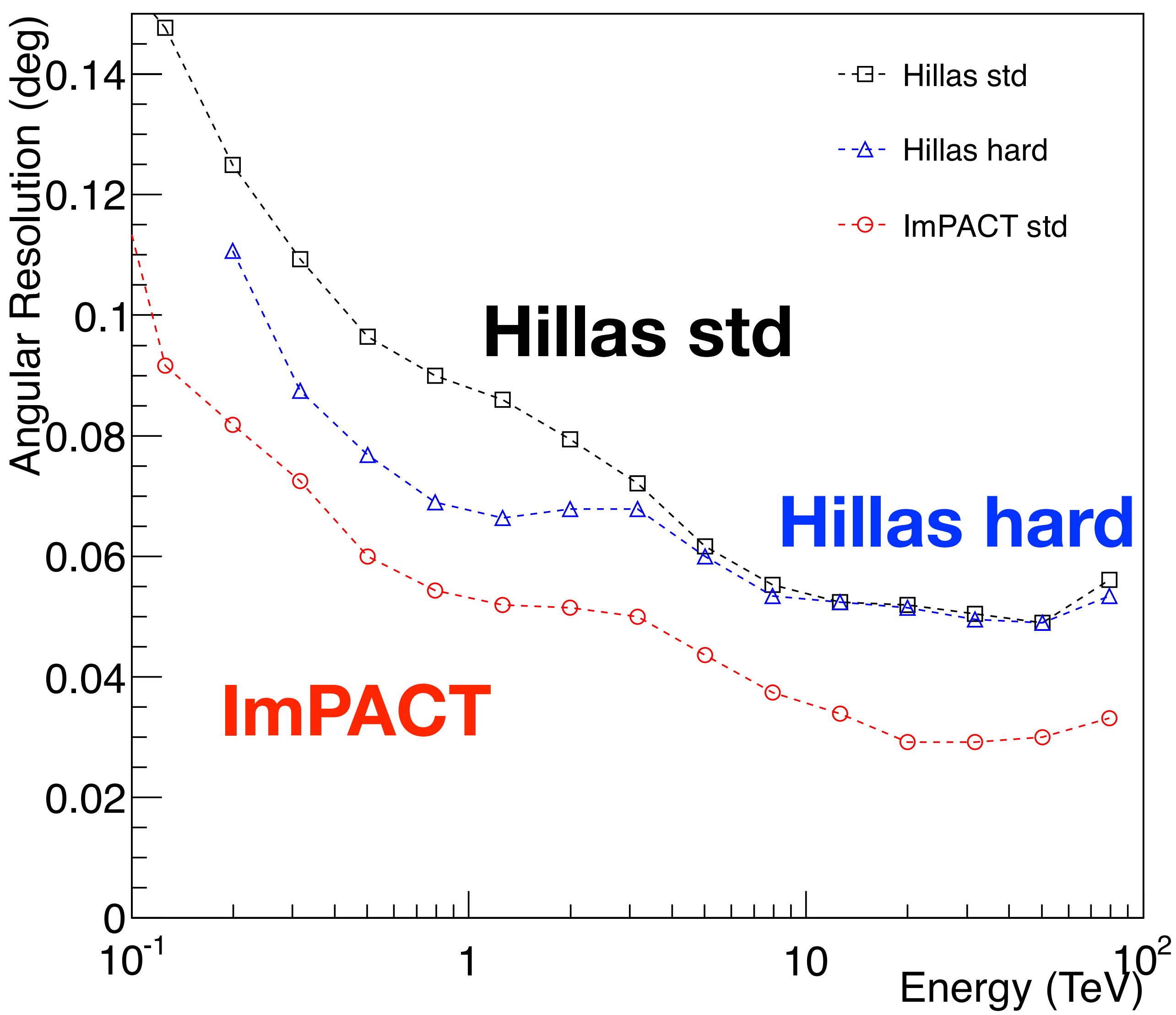


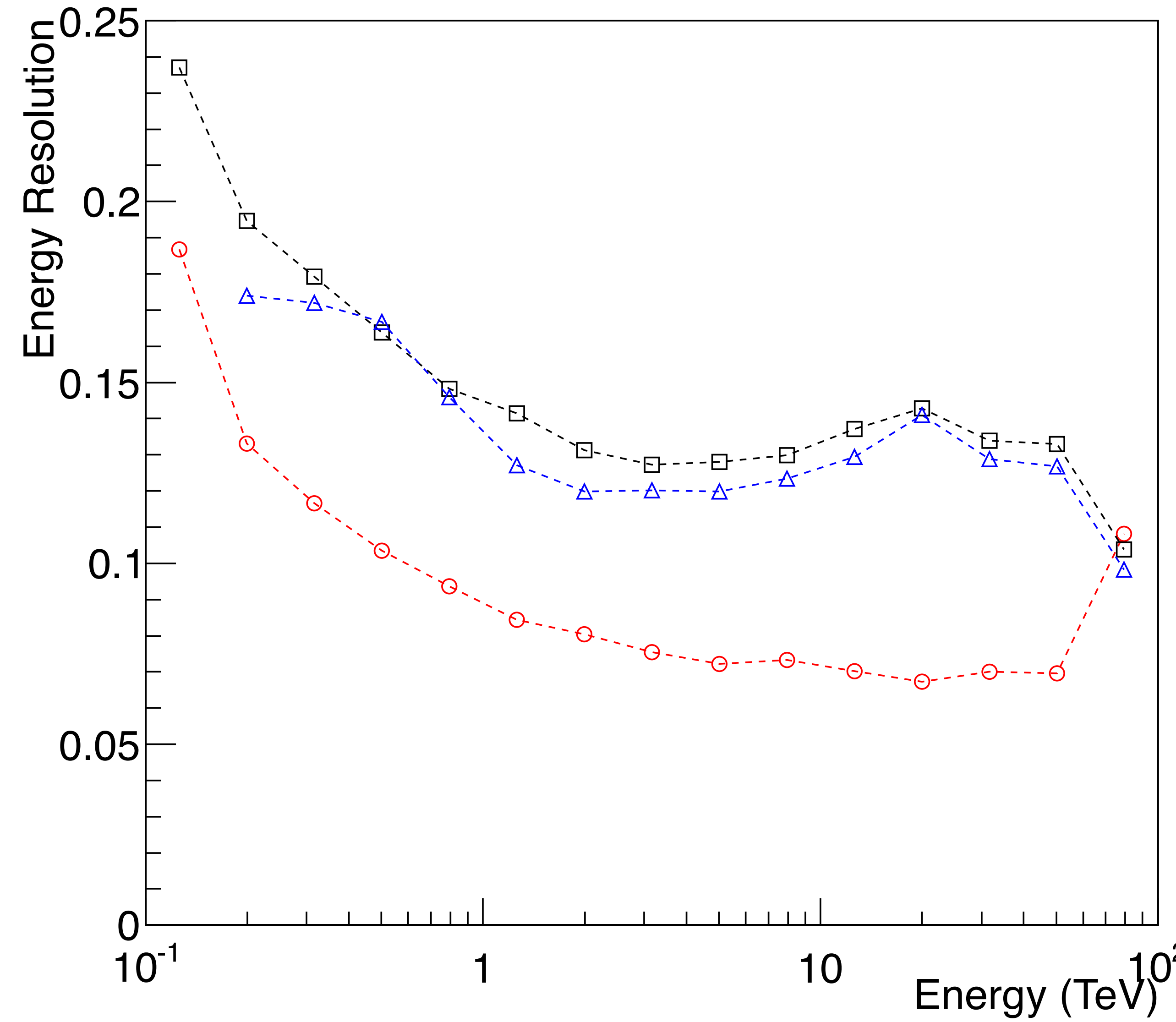
Z-axis likelihood

Performance

	Amp (p.e.)	Theta
Hillas std	60	0.0125
Hillas hard	160	0.01
ImPACT	60	0.005

Simulations of the HESS I array (4 x 12m)





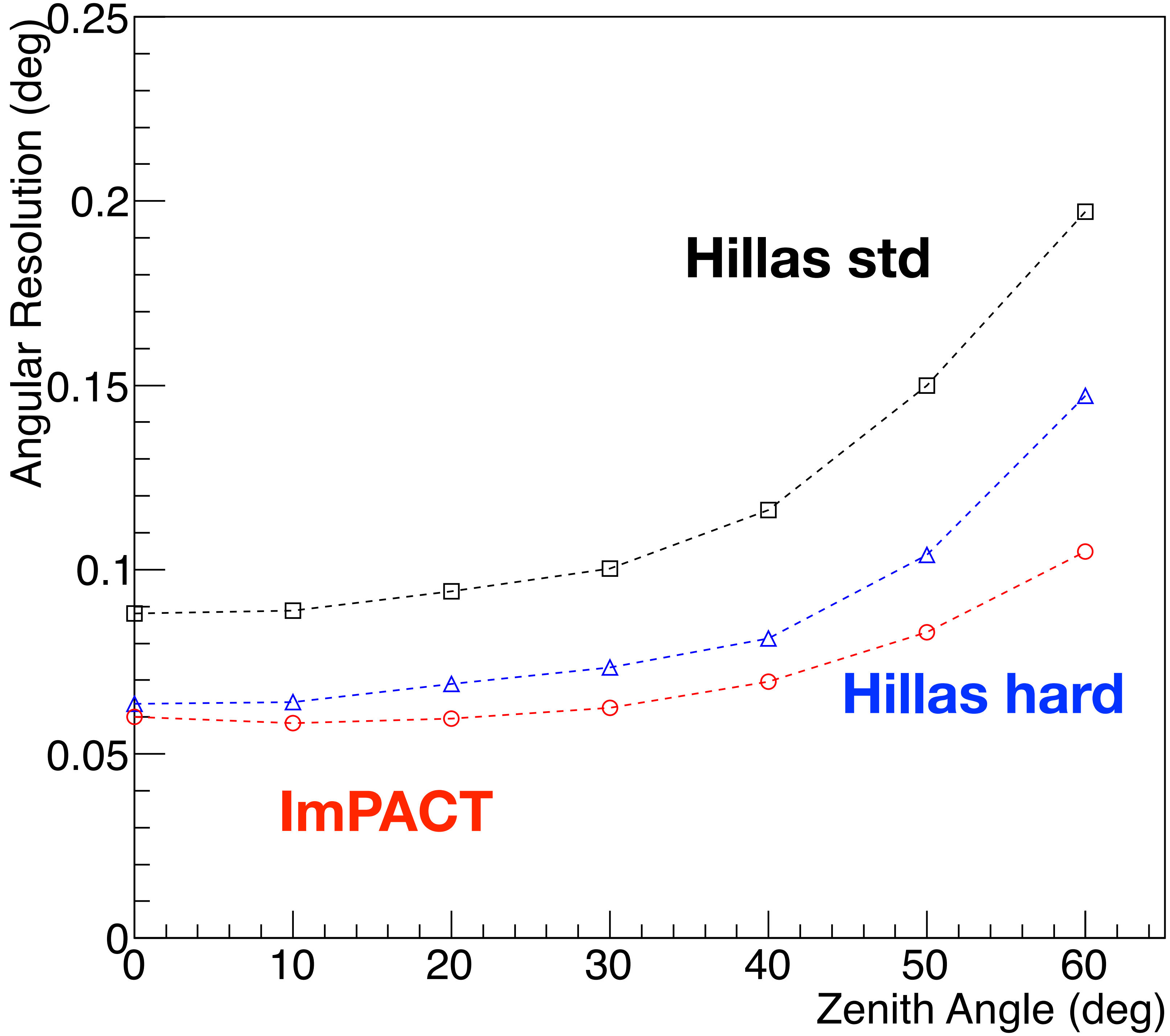
68 % event containment radius

RMS of energy distribution (ΔE/E)

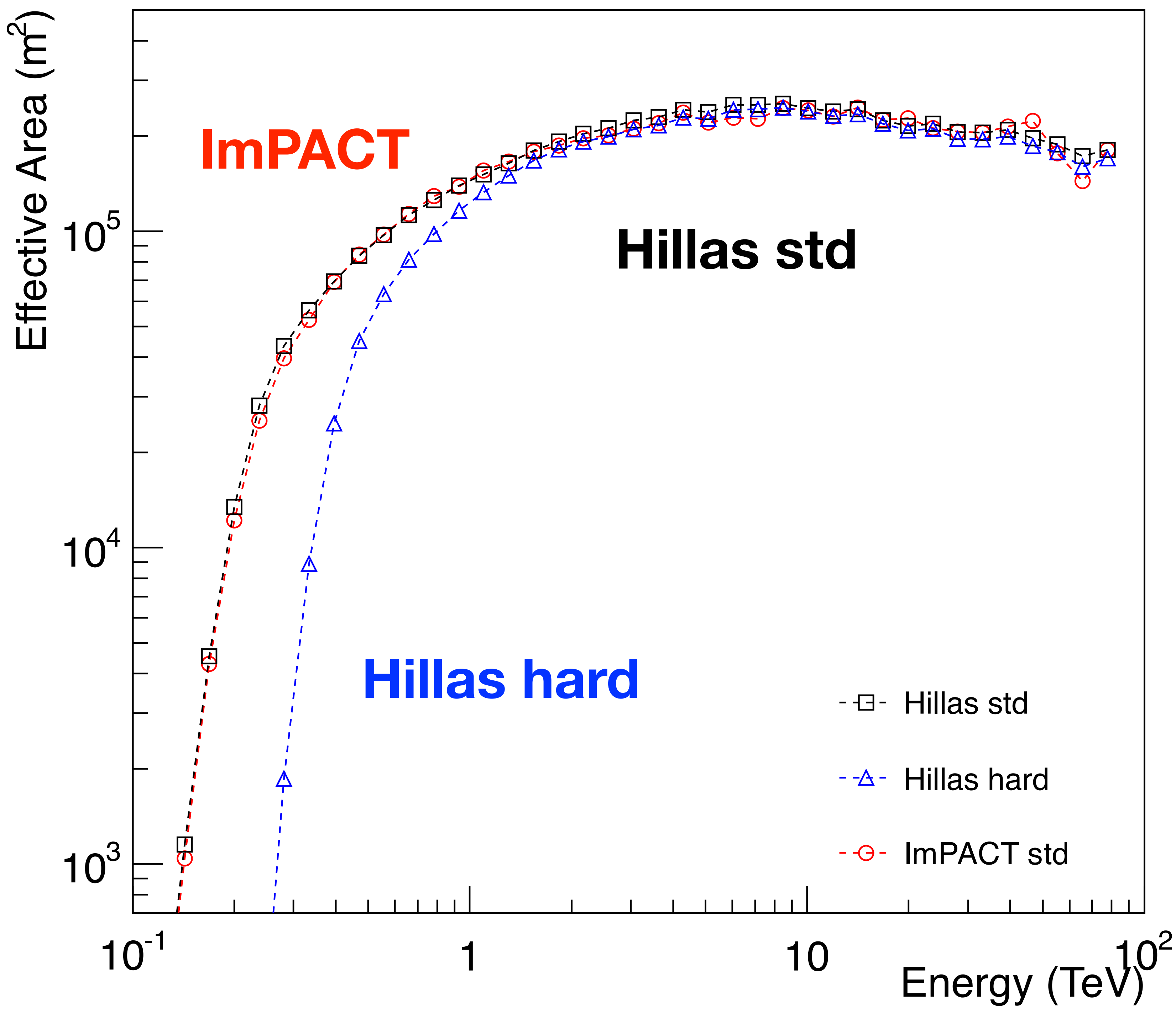
Performance

68 % event
containment radius

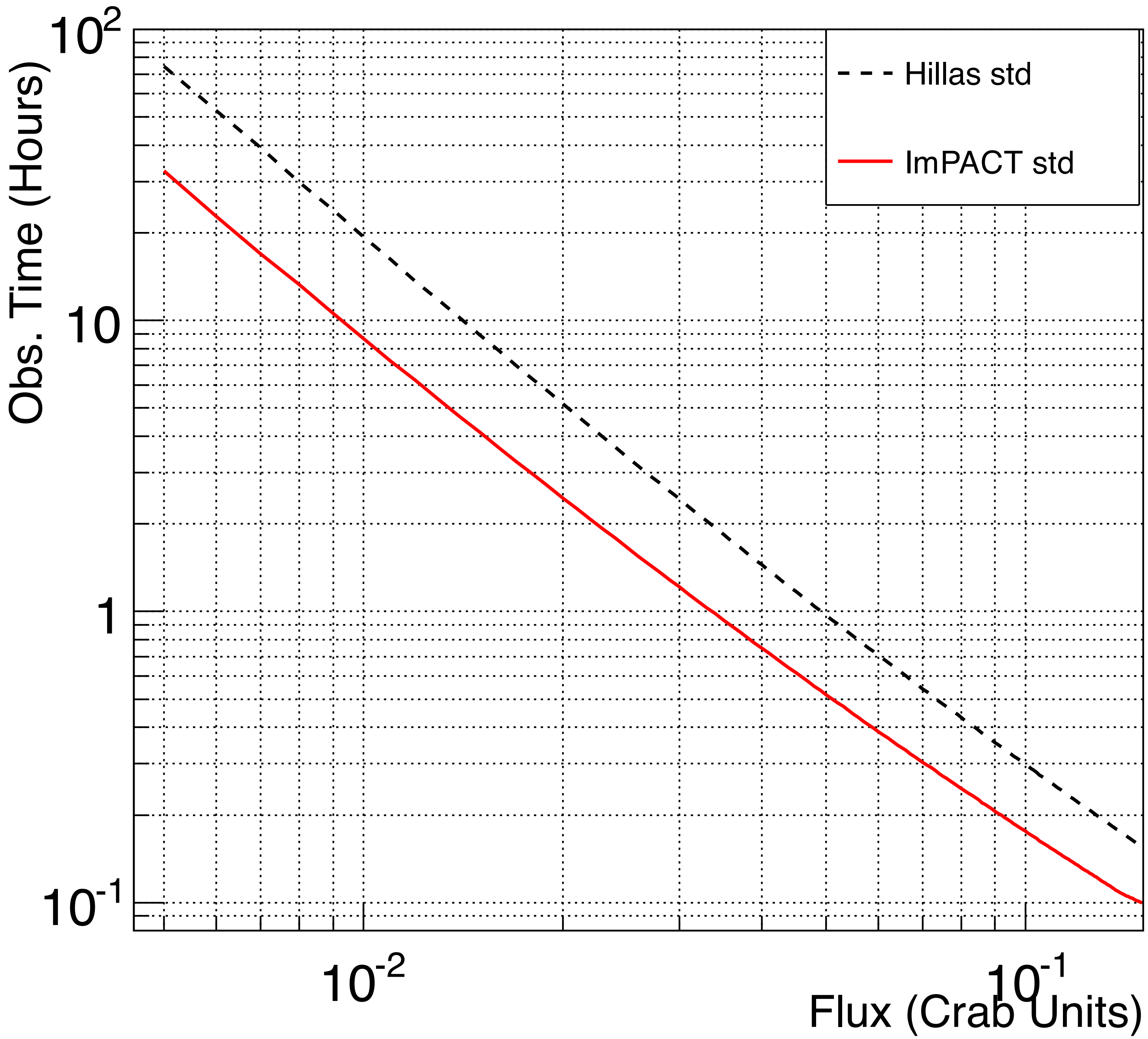
E^{-2} source



Performance (Collection Area)



Sensitivity



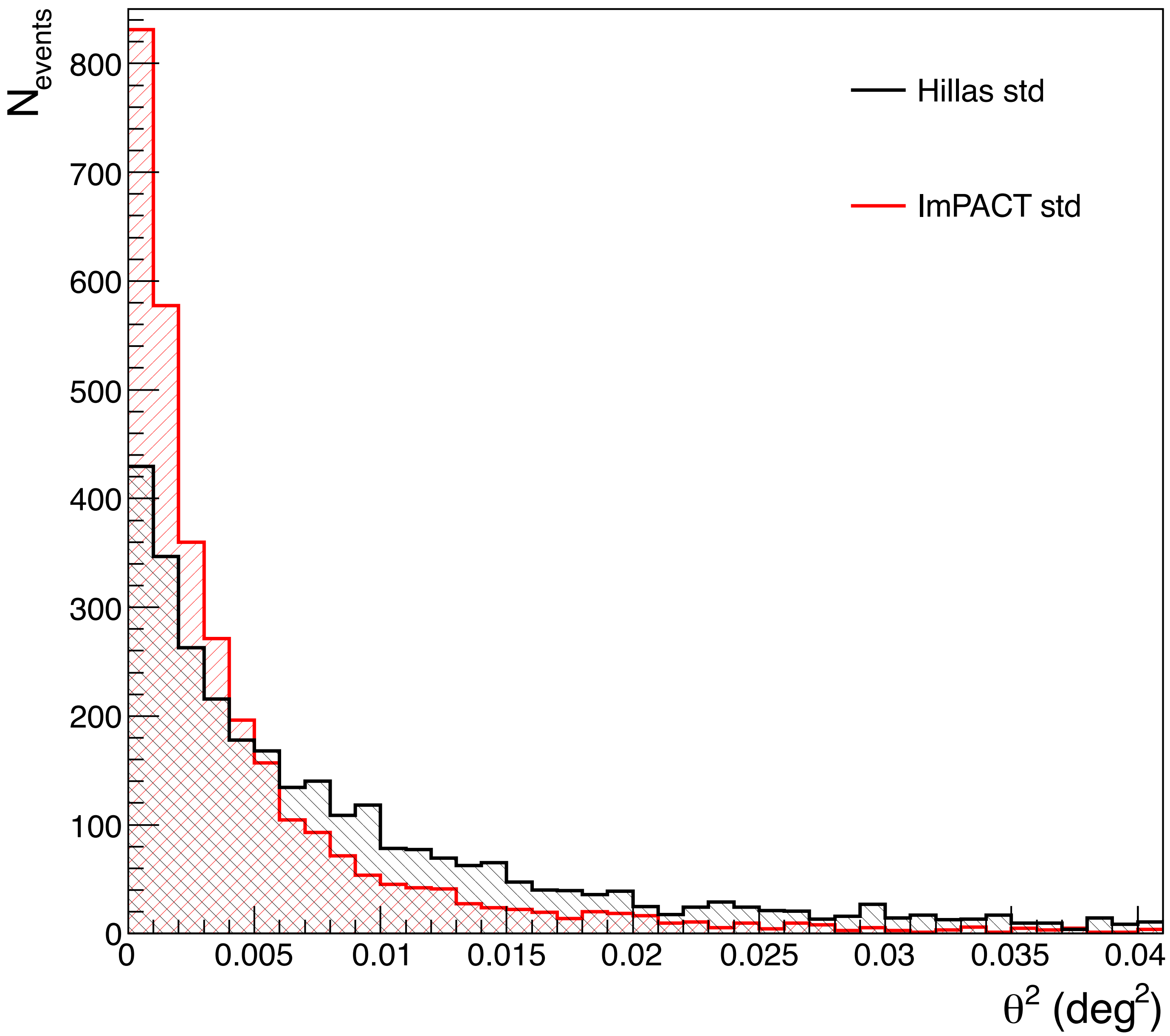
Observation time required to see a Crab Nebula like source ($E^{-2.6}$) at 5 sigma

ImPACT observation time for a 1% Crab source half that of Hillas analysis

Improved angular resolution means we can use a smaller source integration region

Less background integrated

Data Analysis



Aharohnian et al, 2006

Test analysis on 1 run (30 mins) of PKS 2155-305 flaring data (July 2006)

Brightest object ever seen in VHE gamma-rays

Significant improvement in PSF is obvious

	Non	α Noff	Sig	Ang
Hillas Std	2290	11.9	109	0.1
ImPACT Std	2279	4.4	127	0.067

Conclusions

Event reconstruction using Hillas parameters provides acceptable angular resolution in IACT arrays, however far more information is available for event reconstruction

Template fitting methods have already shown large improvements in performance by fitting a semi-analytical shower model

The accuracy of this model is limited at high energies

We present a new method of template generation, directly from MC simulations (ImPACT)

Impact produces large increases in array performance at all energies, maintains very similar collection area to Hillas approach

Tests on HESS data show similarly large increases in performance

Similar performance to semi-analytical fits at low energy, large gains above 5 TeV

A simple and accurate method of event reconstruction, very useful for next generation arrays!

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Thanks to the HESS collaboration for allowing me the use of HESS data

Thank you for your attention