

# ParisAnalysis

## Flexible analysis chain for Hillas, Model, 3D Model

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- ☞ Architecture
- ☞ Summary of available algorithms
- ☞ Plot engine
- ☞ Installation & Documentation
- ☞ Customization
- ☞ Further development

# What is ParisAnalysis ?

- *Flexible and configurable analysis chain for HESS*
- *Separate background subtractions methods from subtractions algorithms and projections*
- *Unified schema for spectrum, lightcurve, ... determination, independently from reconstruction*
- *Be able to cross-correlate and compare reconstructions at all levels: combined discriminating variable, event-by-event reconstruction, ...*
- *Flexible display engine: can virtually display any information, in many different forms (1D, 2D, Correlation, Sky View,...)*
- *Fully customizable without recompilation: algorithm replacement, new reconstruction methods,... using external plugged-in modules*
- *Fully documented*

<http://lpnp90.in2p3.fr/~denauroi/protected/Doc/parisanalysis/>

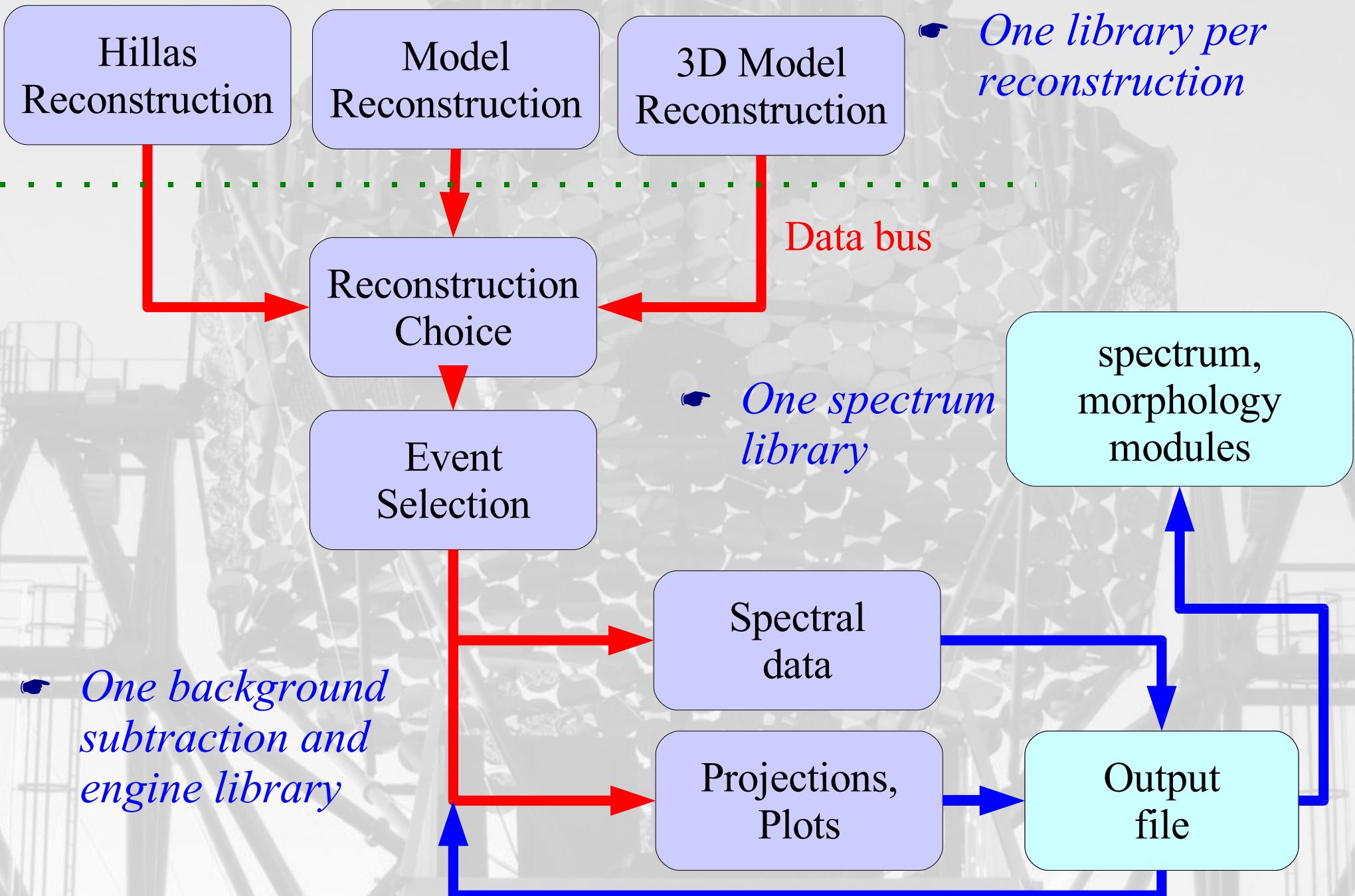
# Overall organization - Data Bus

- ☛ *ParisAnalysis is based on a data-bus concept*
  - ☛ *Generic class (ParisAnalysis::EventFlag) holding event properties*
  - ☛ *Filled by many input, incl. the selected reconstruction*
  - ☛ *Background subtraction algorithms, spectrum, morphology use only the data bus*
- ☛ *Based on Sash (HESS Software framework)*
  - ☛ *Data classes and algorithms separated*
    - ☛ Sash::MonitorBase base class for persistent classes
    - ☛ Sash::Maker base class for algorithms
  - ☛ *Information transport done with Folder's, containing data classes and passed to algorithms in a standardized way*
- ☛ *See Sash's Tutorial for an introduction:*  
<http://lpnp90.in2p3.fr/~denauroi/protected/Doc/sash/>

# Overall organization – user interface

- ☛ *Code compiled in shared libraries*
- ☛ *User configuration using ROOT scripting mode:*
  - ☛ *C scripts loaded in ROOT for analysis configuration*
  - ☛ *More flexible than any ASCII configuration file loaded by any analysis configuration parser*
- ☛ *Script functions precompiled in a scripting library*
- ☛ *Graphical user interface (for standard analyzes) in preparation (not yet available)*
- ☛ *Results saved in an output file for later use*

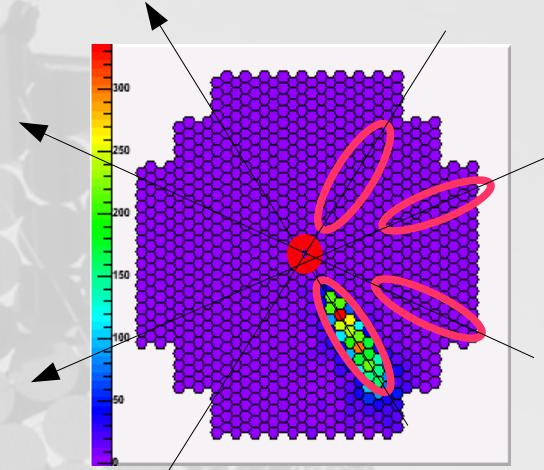
# Overall organization - Scheme



# Available reconstructions

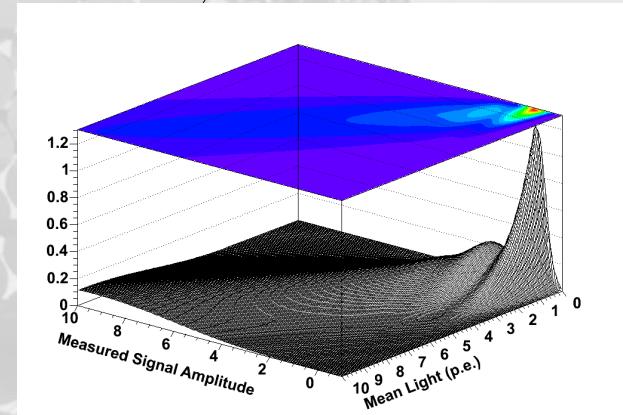
- *Hillas*

- *Elliptical images, geometrical reconstruction of direction and impact, lookup table, image cleaning*



- *Model*

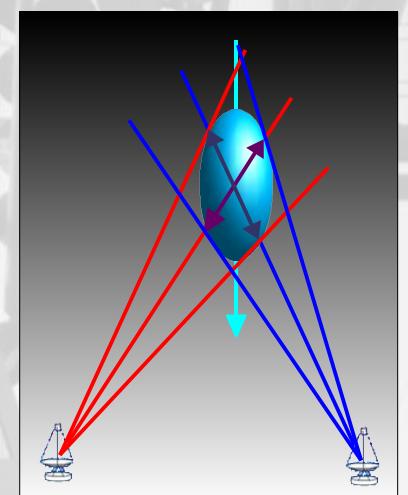
- *Brute force fit of images to precalculated templates, full NSB treatment*



- *3D Model*

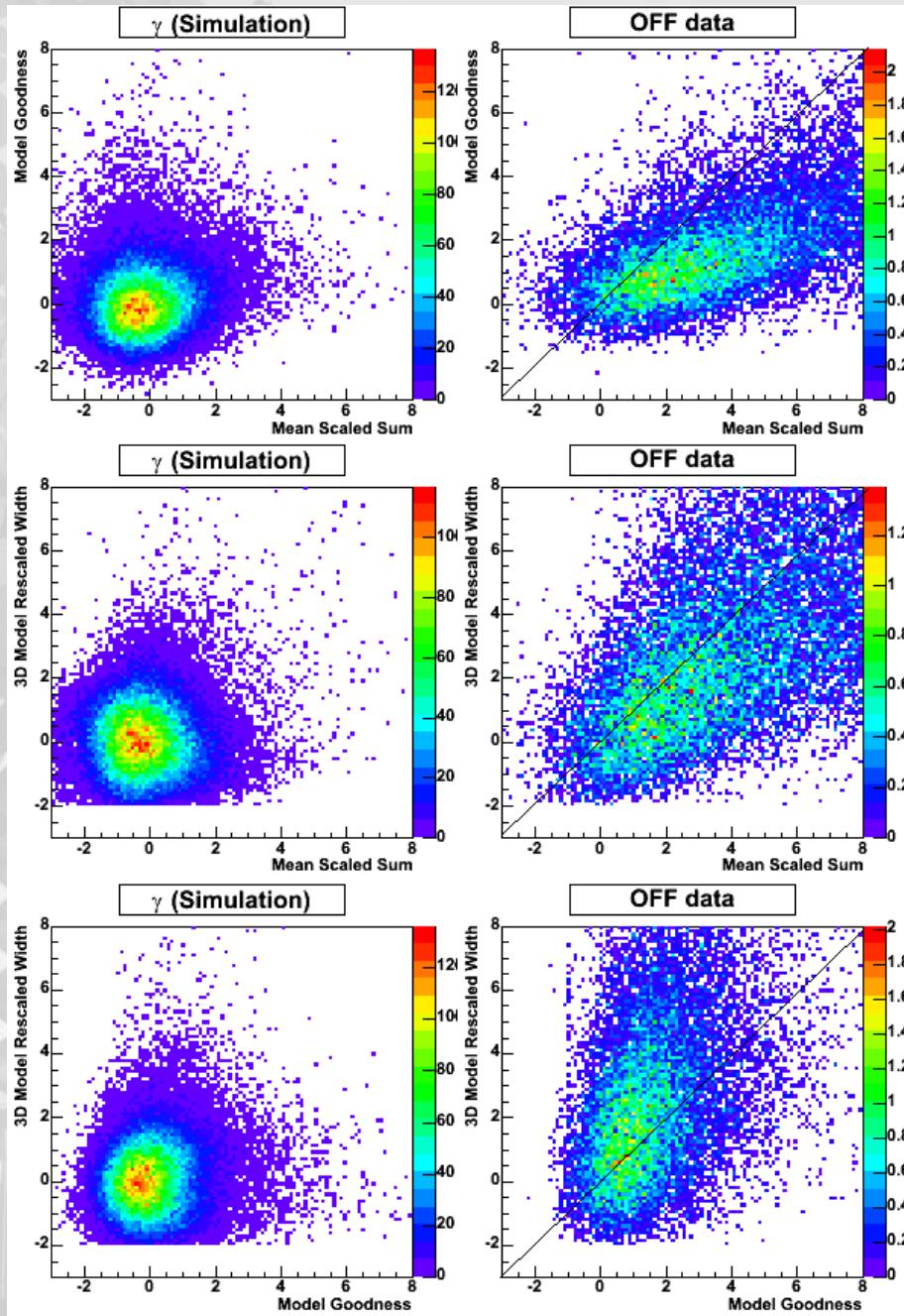
- *3D Gaussian photosphere in the atmosphere, 8 parameters fit combining telescopes*

- *Any combination of them*



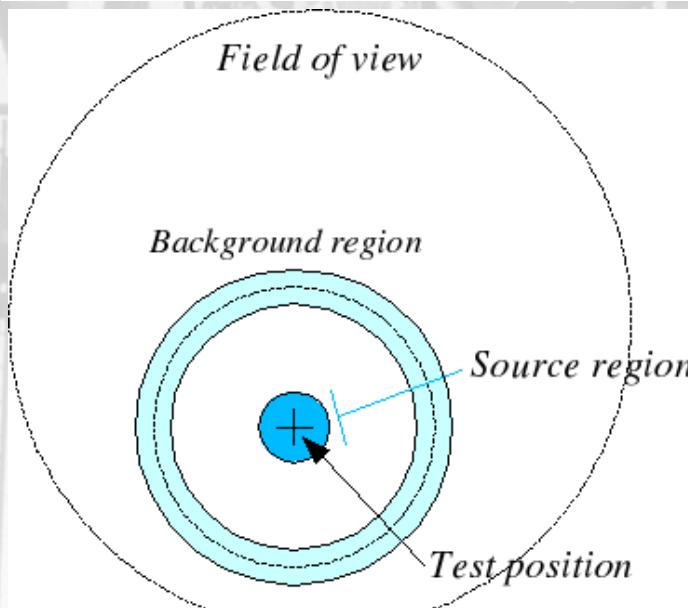
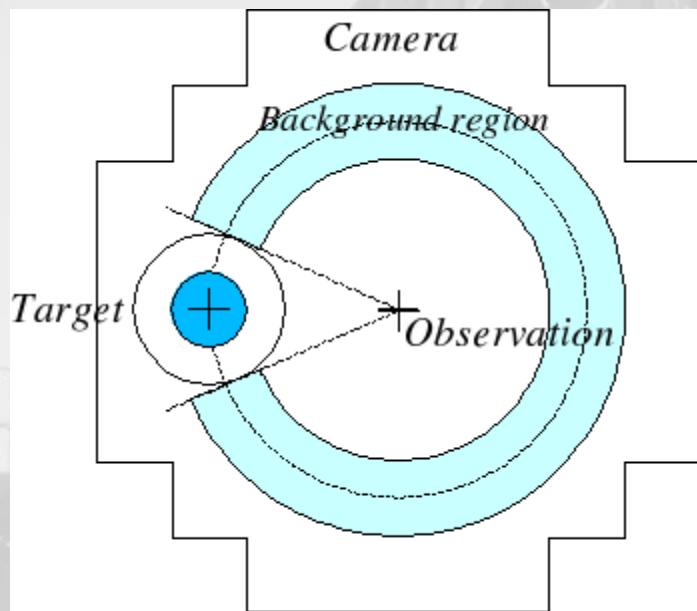
# Why three reconstructions?

- *Almost no correlation between discriminating variables (for  $\gamma$ 's)*
- *Different information used:*
  - *Hillas:*
    - Correlation between telescopes not used
    - Scaled cuts  $\Rightarrow$  most frequent showers
  - *Model*
    - Correlation used
    - Shower fluctuations not used except first interaction point
    - Chooses showers most like the model  $\neq$  most frequent
  - *3D Model*
    - Correlation used
    - Some part of fluctuations used (in reconstruction, but not in selection)
- *Combination improves sensitivity*

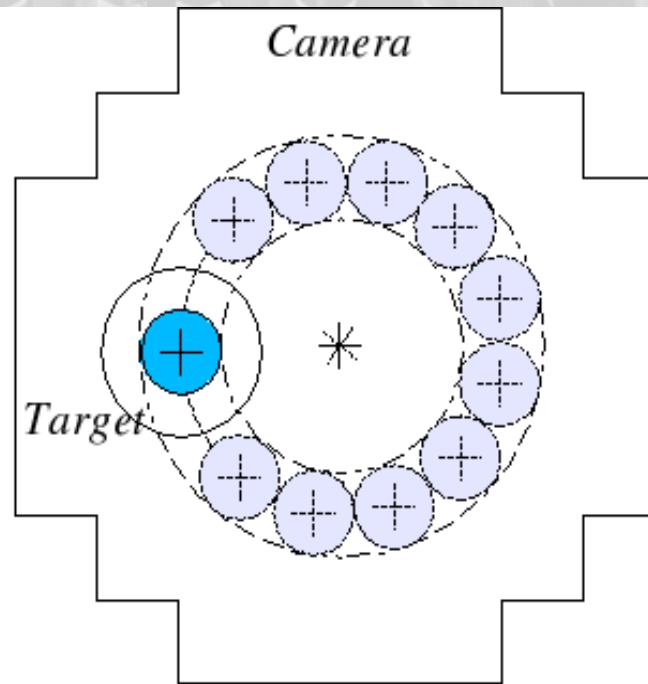


# Subtraction techniques

## Ring background

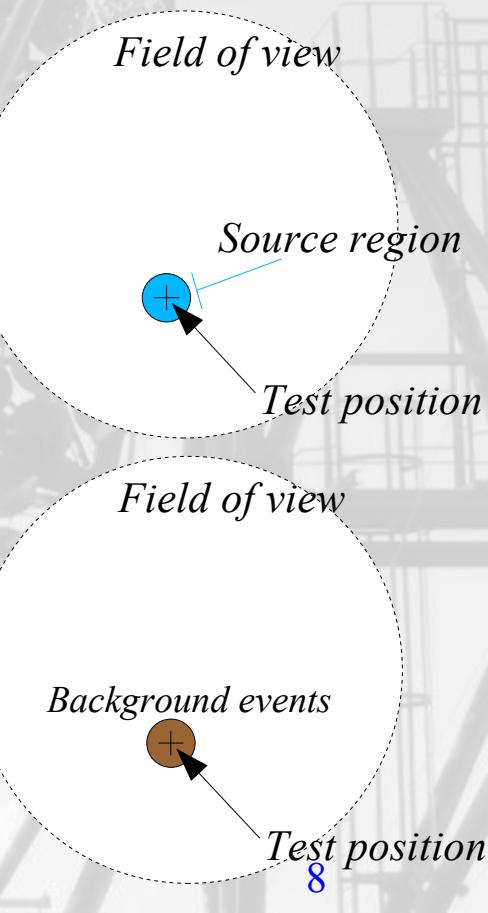


## Multiple off, ON-OFF

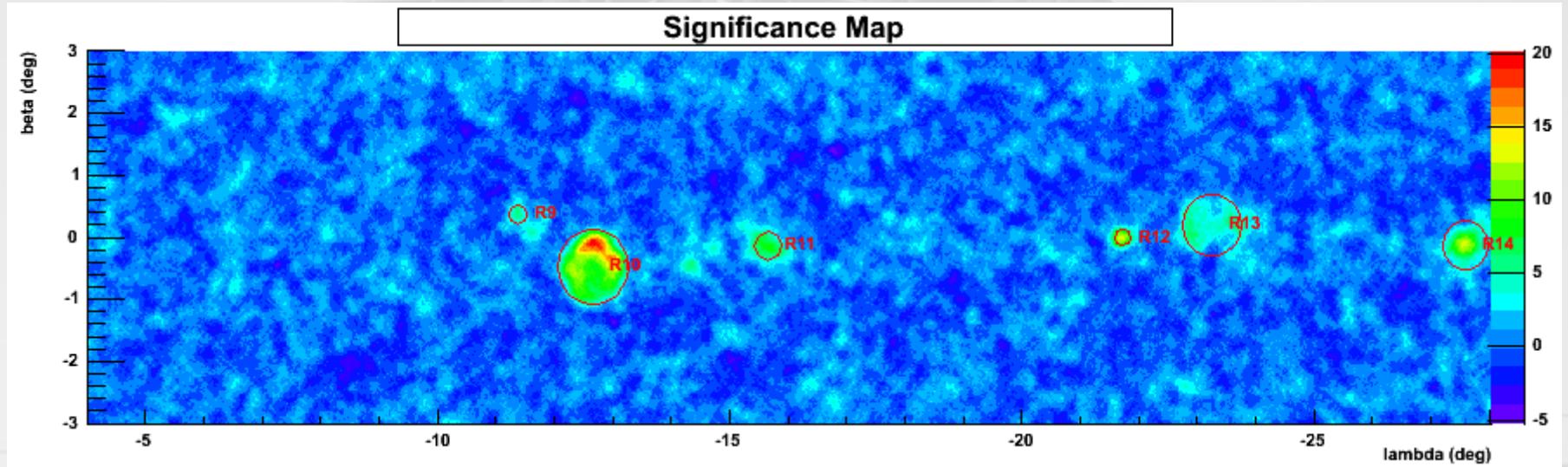


## Template Model

+ More elaborate techniques  
(Weighting Method)



# Excluded regions



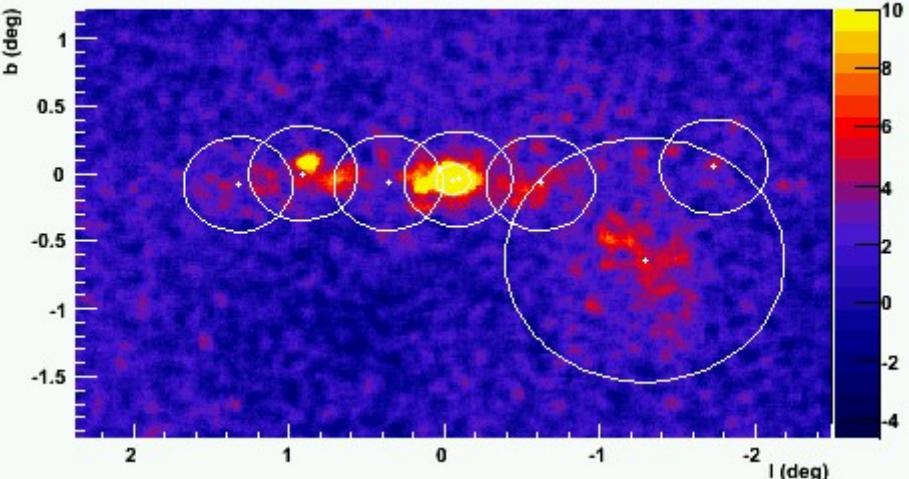
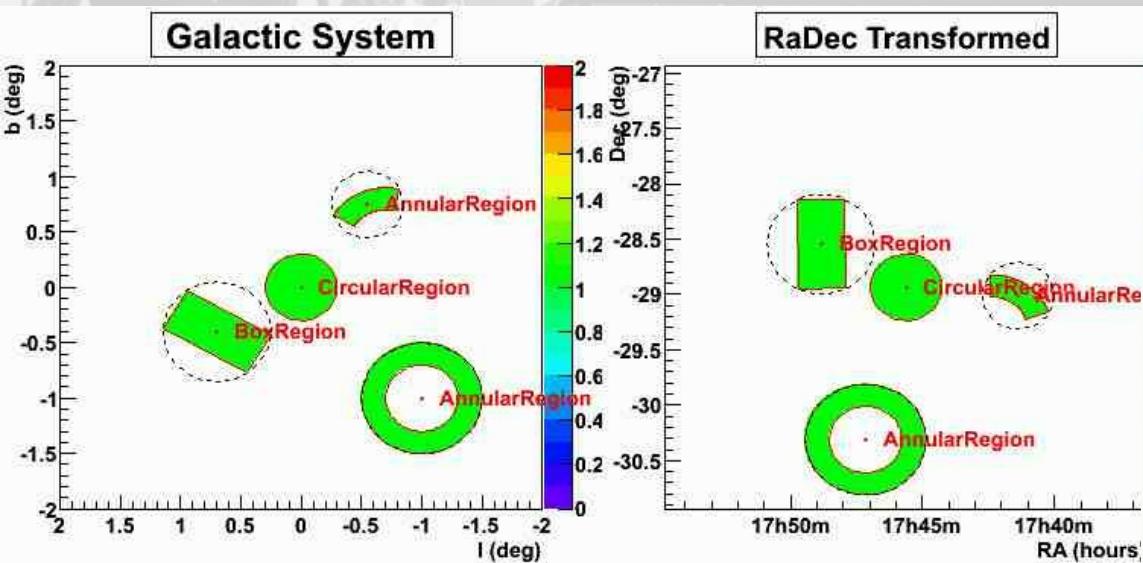
- For most background subtraction techniques, background taken from the same event population ( $\gamma$  like)
- Background contamination by  $\gamma$ 's induces and underestimation of signal and produces a deficit around sources
- $\Rightarrow$  Excluded regions need to be defined around intense sources

# Arbitrary shape regions

[http://lpnp90.in2p3.fr/~denauroi/protected/Doc/parisananalysis/group\\_\\_ParisAnalysis\\_\\_ArbitraryShapes.html](http://lpnp90.in2p3.fr/~denauroi/protected/Doc/parisanalysis/group__ParisAnalysis__ArbitraryShapes.html)

- *Base class ParisAnalysis::AnalysisRegion*

- *ParisAnalysis::BoxRegion, ParisAnalysis::CircularRegion et ParisAnalysis::AnnularRegion available, other shapes possible*
- *Used by almost all background subtraction algorithms*
- *Can be plotted SkyHistogram2D*
- *Can overlap each other*



script *tests/test\_regions.C*

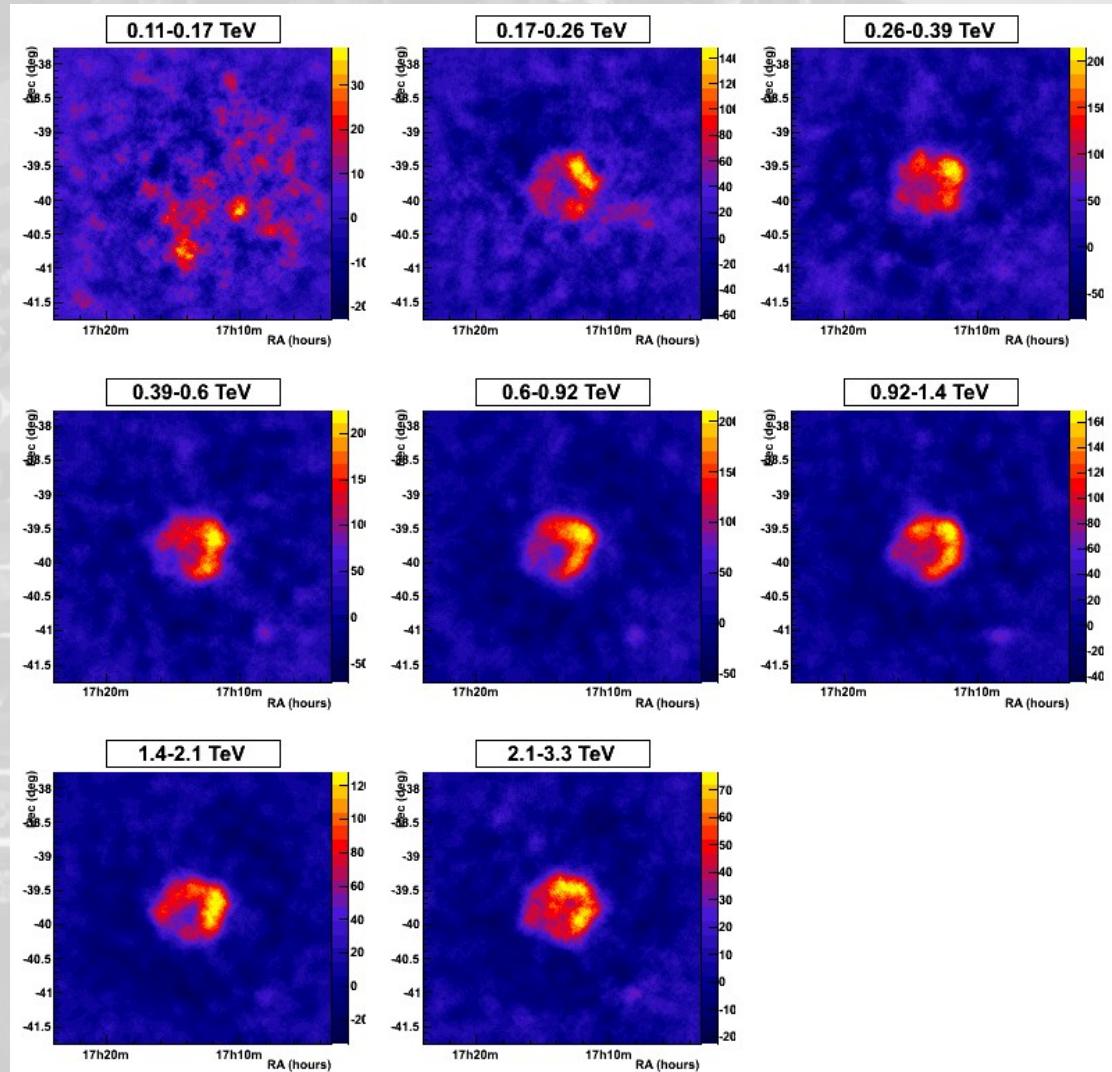
# Sliced-Analysis

[http://lpnp90.in2p3.fr/~denauroi/protected/Doc/parisanalysis/group\\_\\_ParisAnalysis\\_\\_SlicedAnalysis.html](http://lpnp90.in2p3.fr/~denauroi/protected/Doc/parisanalysis/group__ParisAnalysis__SlicedAnalysis.html)

- ☛ *Can split an analysis in “slices”*
  - ☛ *One result file per slice*
  - ☛ *"Slices" merged "offline"*
    - ☛ *Excess and significance map calculation*
    - ☛ *Plots, Histograms summation*
    - ☛ *Merging of spectral data*
    - ☛ *One can easily add new data to an existing analysis (e.g. Galactic Scan)*
  - ☛ *Fully documented tutorial on Sgr A\**

# Slices Maps

- Can do maps in energy (or something else) slices



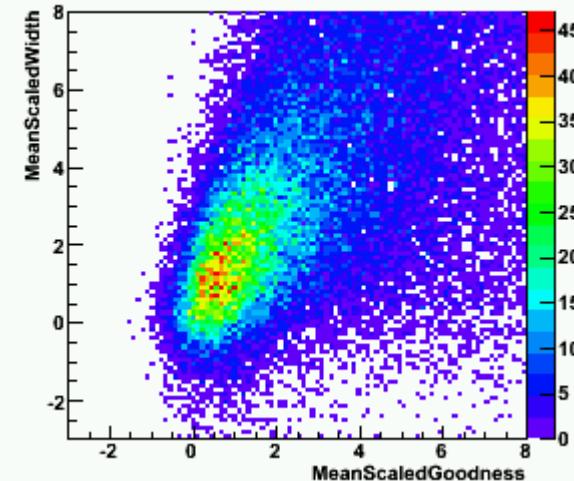
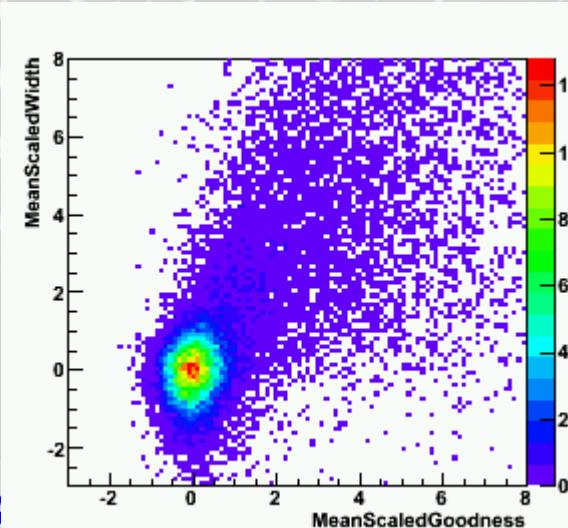
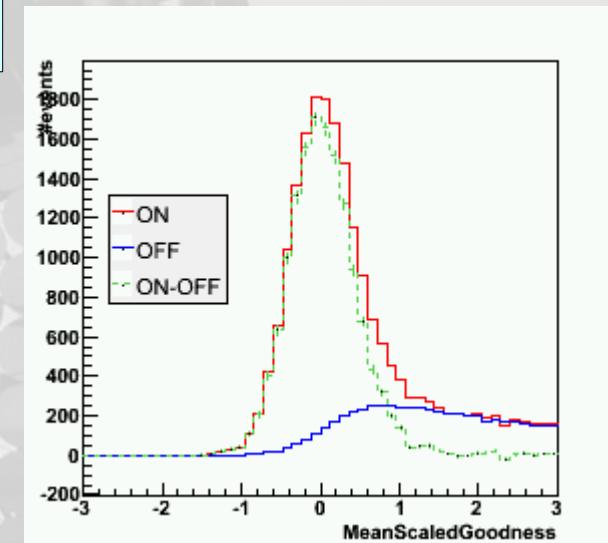
# Plot engine

- Any information available in the data bus can be displayed easily

```
add_plot("MeanScaledGoodness",50,3,3,GammaCandidate);
```

- Various display types available

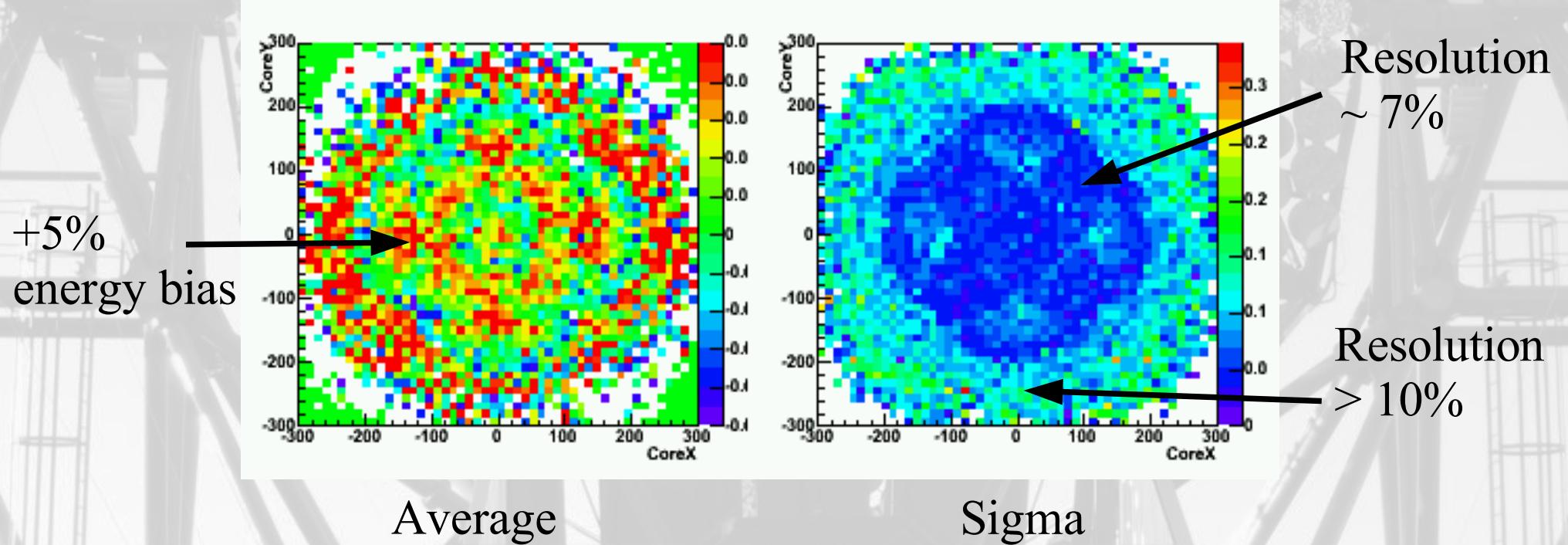
- 1D Plots
- 2D Plots ( $\Rightarrow$  correlation studies)
- Correlation plots
- ScaledPlot (mean and rms of one variable versus 2 others)
- SkyPlot
- Plots saved in the result file



# Plot example – Scaled plot

- *Energy Bias as function of shower impact on the ground*

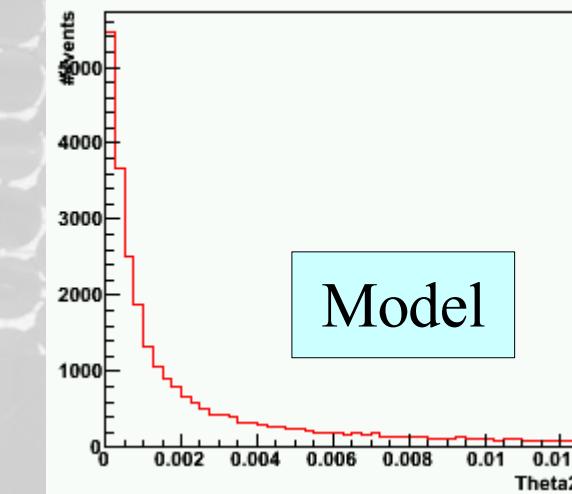
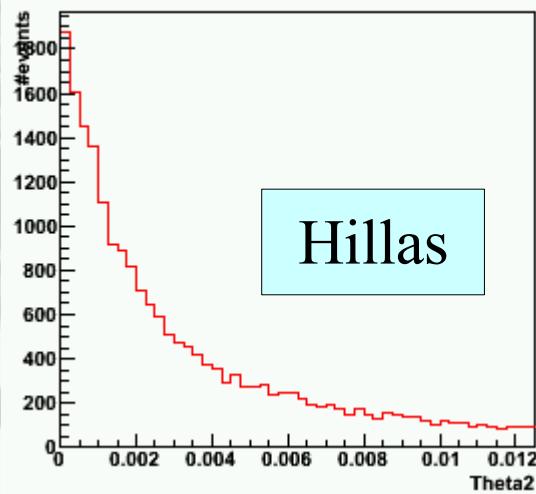
```
add_scaled_plot("GroundCoreX","GroundCoreY","EnergyDiff",50,-300,300,50,-300,300,  
GammaCandidate)
```



# Plot example – Reconstruction comparison

- *One data bus per reconstruction, plus one common bus*
  - *One variable can be available for several reconstructions at the same time*
  - *One can specify which “instance” to use*

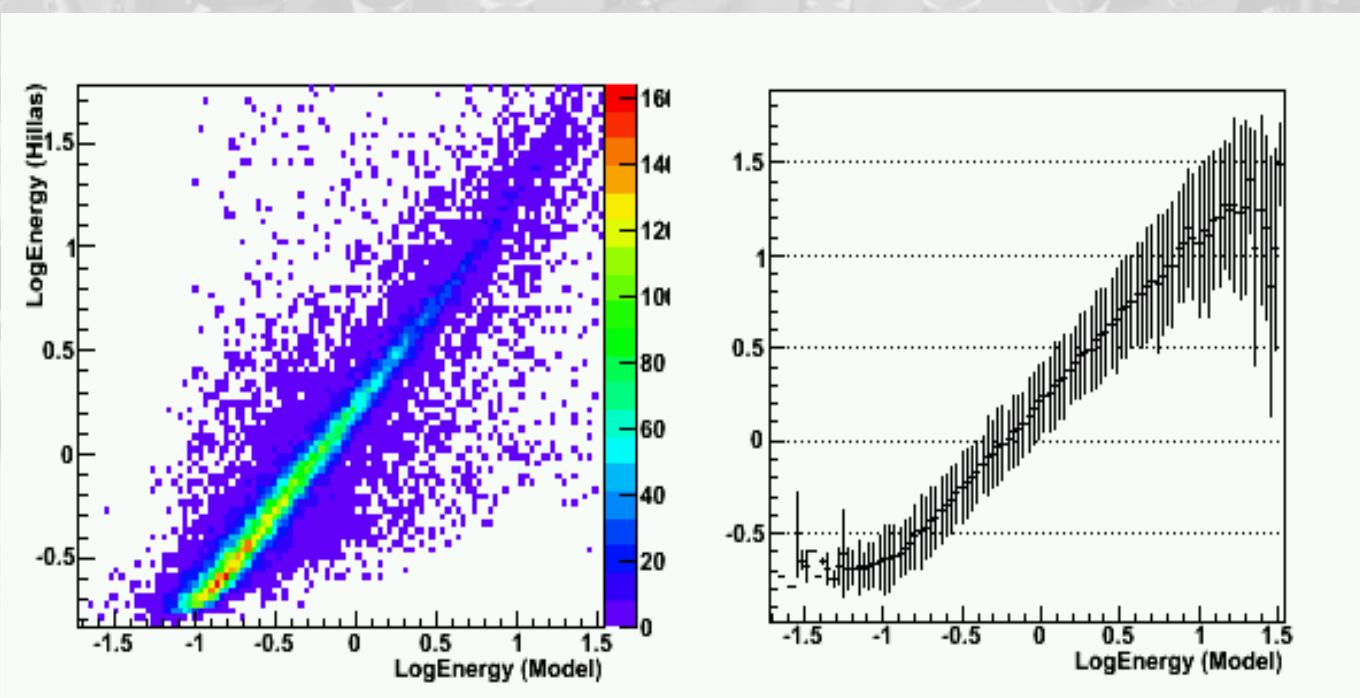
```
add_plot("Theta2",50,0,0.025,GammaCandidate,"Hillas");
add_plot("Theta2",50,0,0.025,GammaCandidate,"Model");
```



# Plot example – Reconstructions correlations

- Can easily compare different reconstructions:

```
add_plot("LogEnergy","LogEnergy",GammaCandidate,"Model","Hillas");
```



Correlation between 'hillas' energy and 'model' energy

# Analysis example

- *root make\_crab\_combined\_example.C:*
- *Combined Hillas/Model analysis on the Crab*

DST configuration {

Spectral data {

Background Subtractions {

```
void make_crab_combined_example()
{
    use_combined_analysis();

    // Use Model DSTs
    set_dst_type(mModel);
    set_dst_version("Model_Deconvoluted_Prod16");
    // 5/10 Cleaning for Hillas
    set_hillas_name("Clean510");

    // To save the data needed to produce a spectrum
    save_spectrum_data(true);

    // To generate a ring background theta^2
    use_ring_background(true);
    // To generate significance maps
    use_ring_backgroundmap(true);
    // To generate a theta^2 with 5 OFF control regions
    use_multipleoff_background(true);
    // To use a template model
    use_template_background(true);
```

# Analysis Example

Plots

Output file name,  
run list

Primary Cut

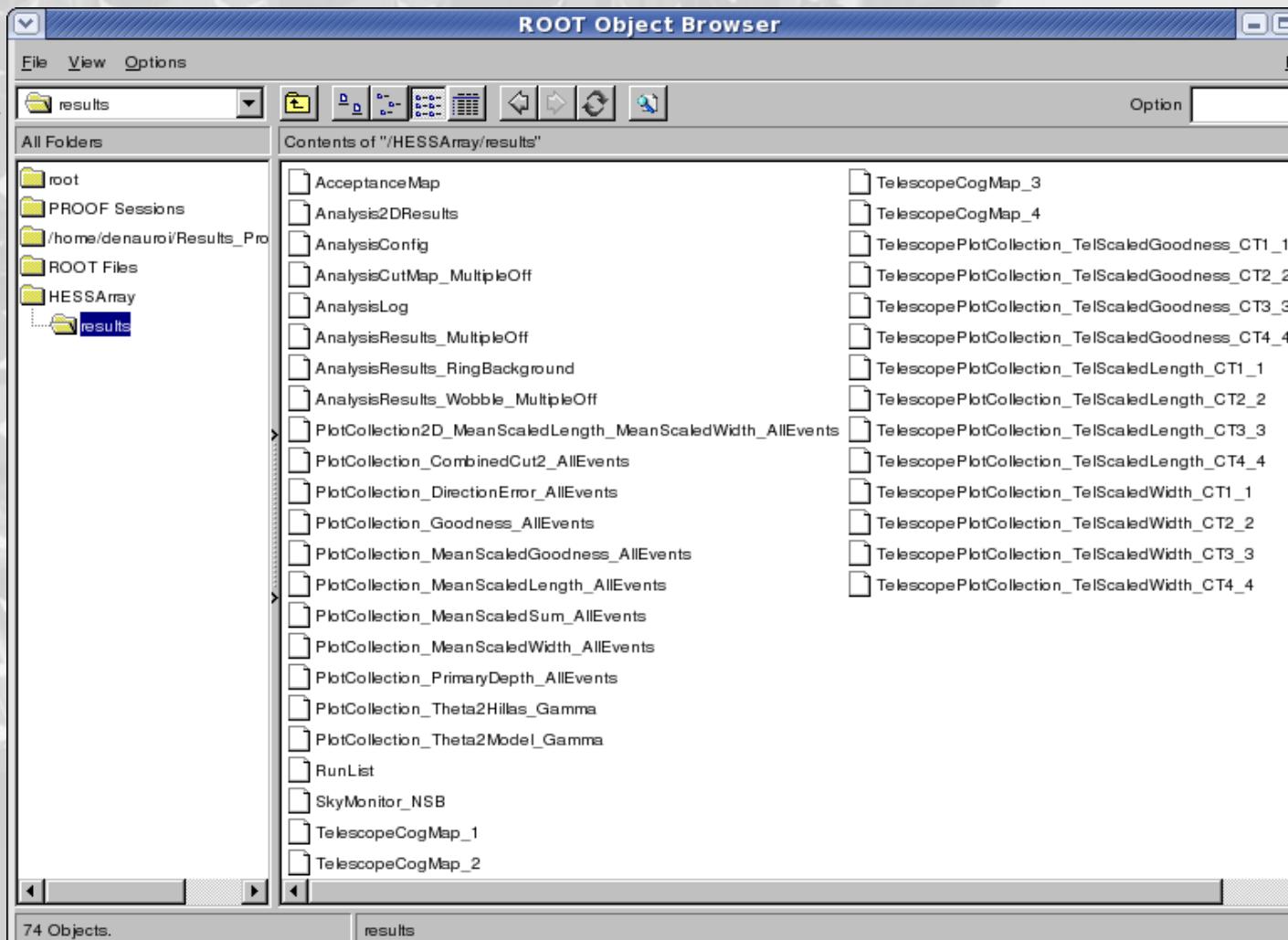
Optional Cuts

Go

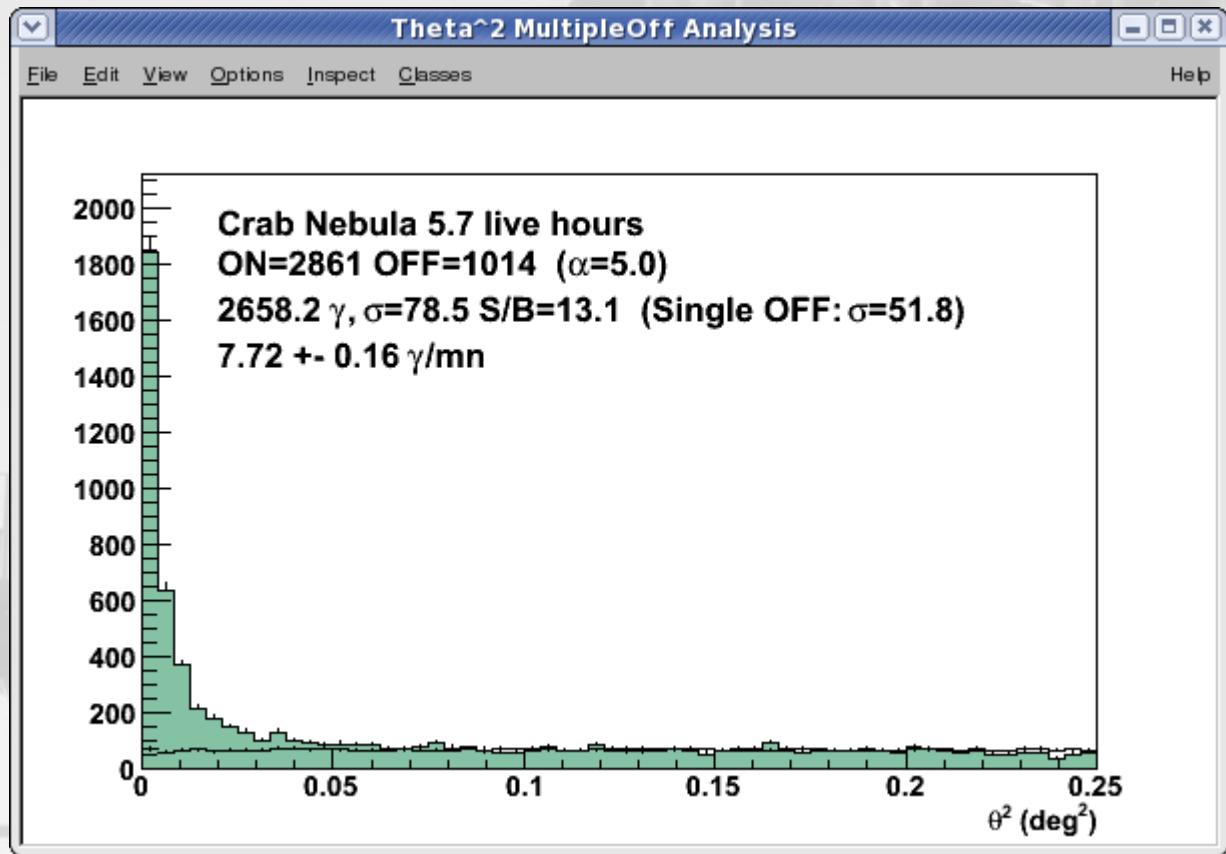
```
...  
// Model Plots  
add_plot("PrimaryDepth",20,-1,6);  
add_plot("MeanScaledGoodness",330,-3,30);  
add_telescope_plot("TelScaledGoodness");  
add_plot("Goodness",330,-3,30);  
add_plot("DirectionError",50,0,0.002);  
  
// Set the name of the analysis  
set_chain_name("Crab_Combined_Prod16");  
// Use a list of run from the DB  
read_list("crab_II");  
  
// Set name of cut variable  
set_cutname("CombinedCut2");  
// Set a charge cut at 60 pe  
set_chargemin(60);  
// Primary depth range  
set_maxdepth(4);  
set_mindepth(-1);  
// Nominal distance 2.5 degrees  
set_maxnomdistance(2.5);  
  
run_analysis(-999,0.9,0.0125);
```

# What is produced

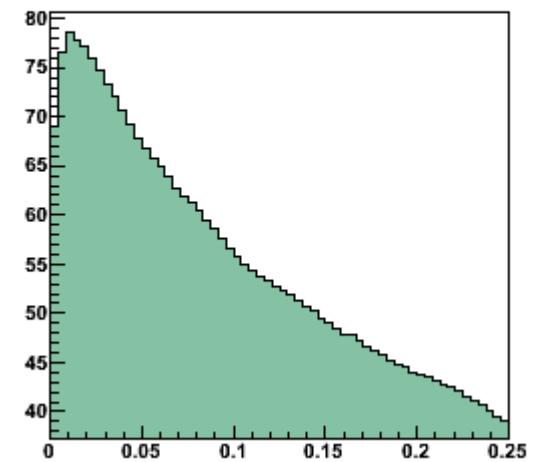
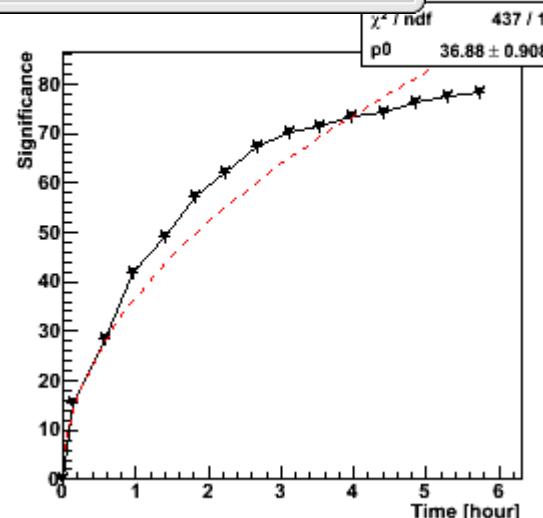
- Output file “*Results\_Crab\_Combined\_Prod16.root*”
- Many objects produced:
  - *AnalysisConfig*
  - *AnalysisResults*
  - *Analysis2DResults*
  - *AcceptanceMap*
  - *AnalysisLog*
  - *RunList*
  - *Plots*
  - *SkyMonitor\_NSB*



# Analysis Results

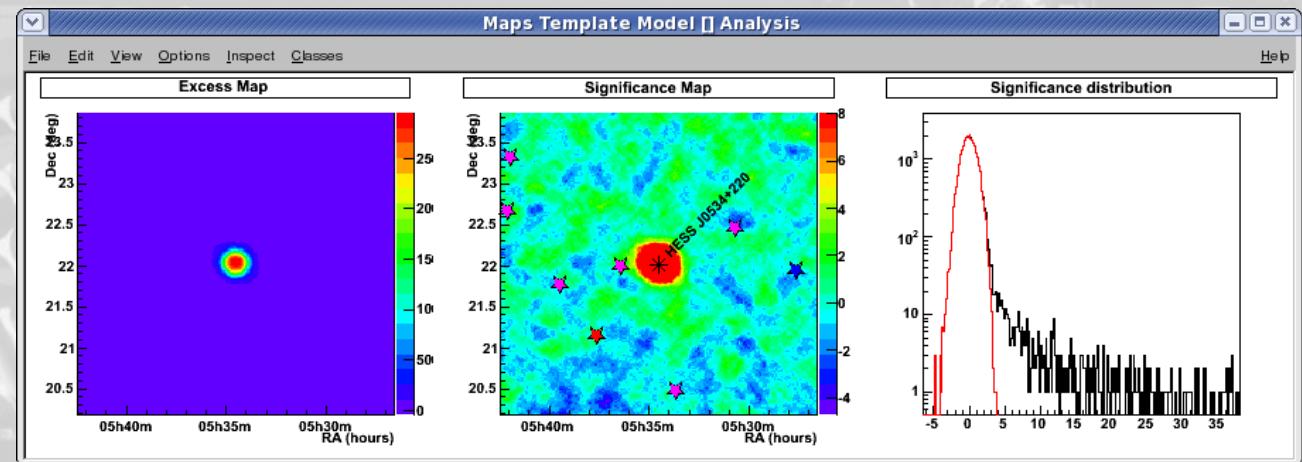
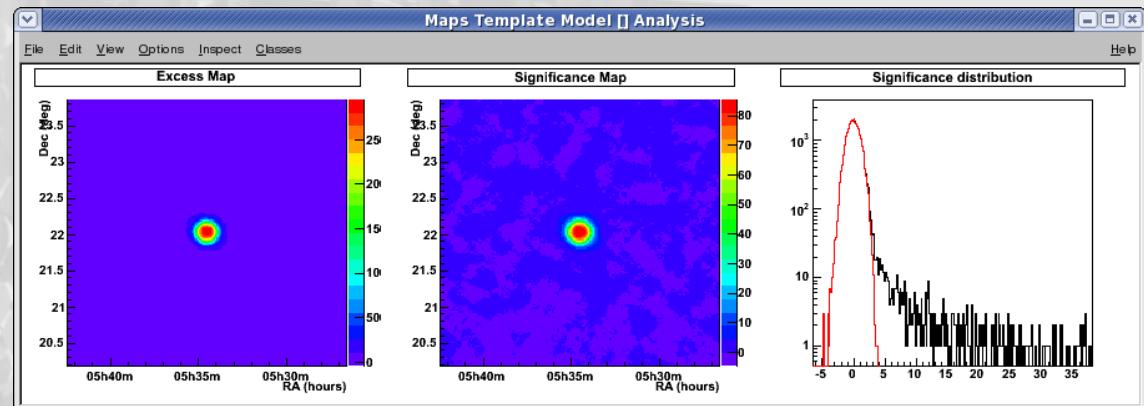
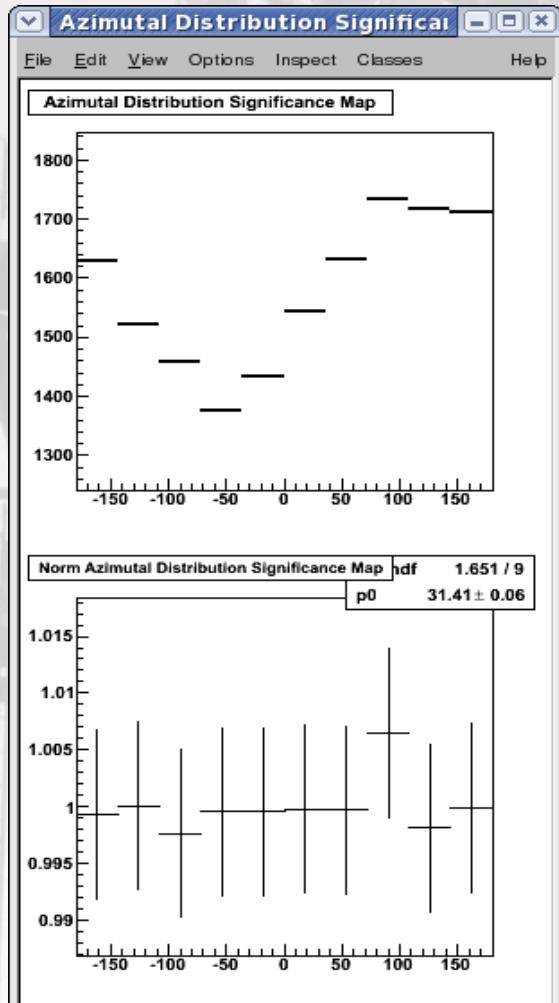


- θ<sup>2</sup> plot
- Sig. Over time



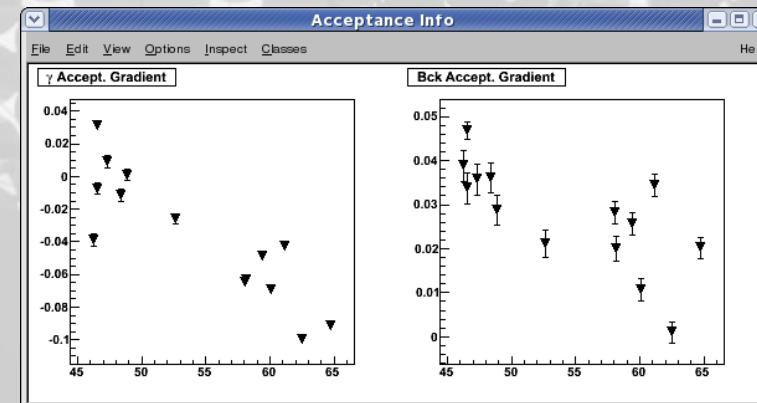
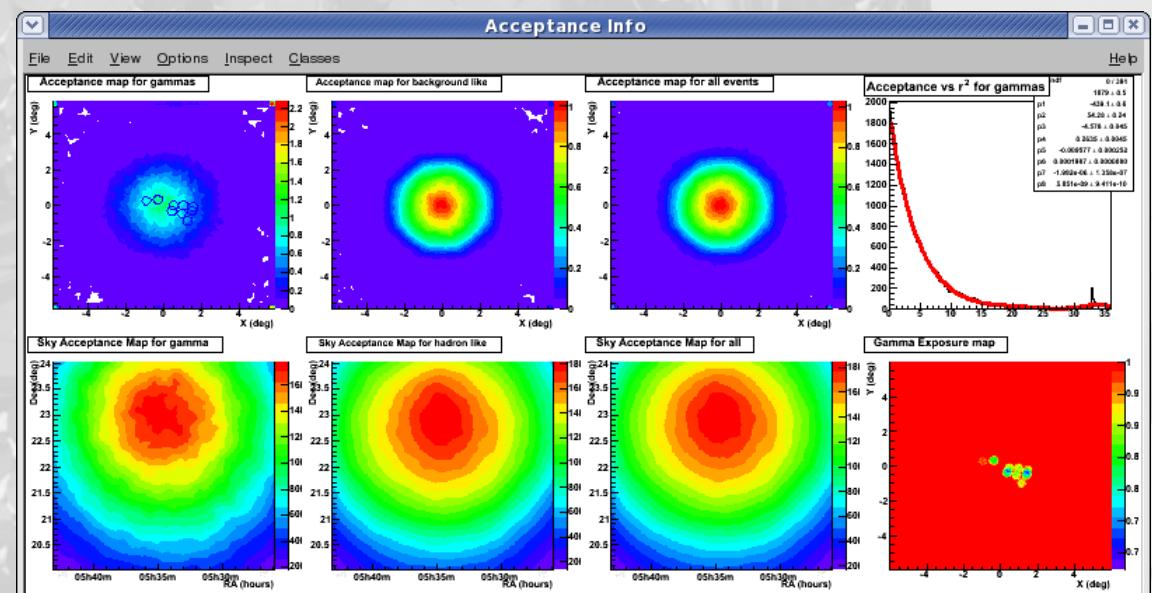
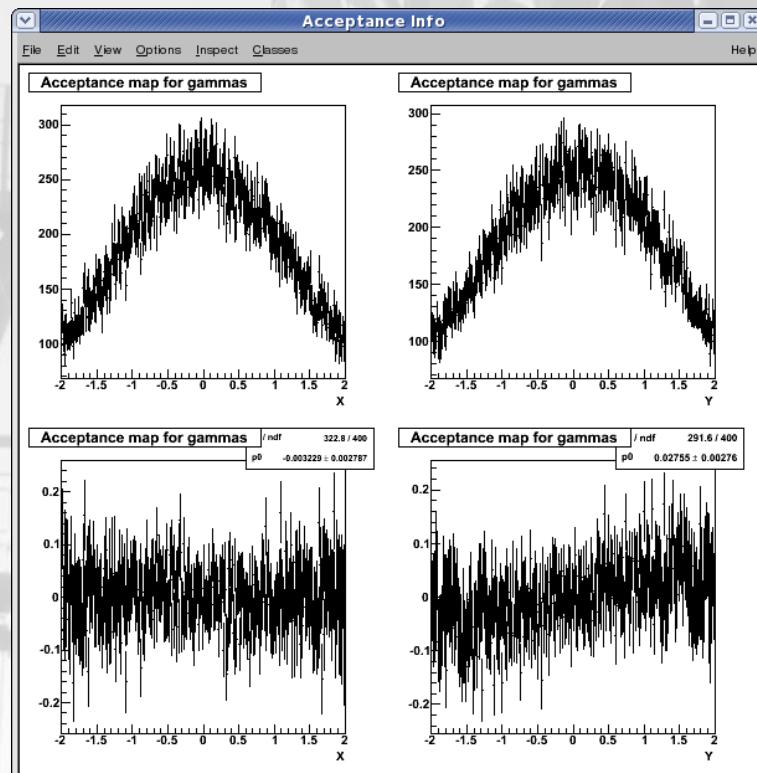
# Analysis2DResults

- Sky Maps
- Projections



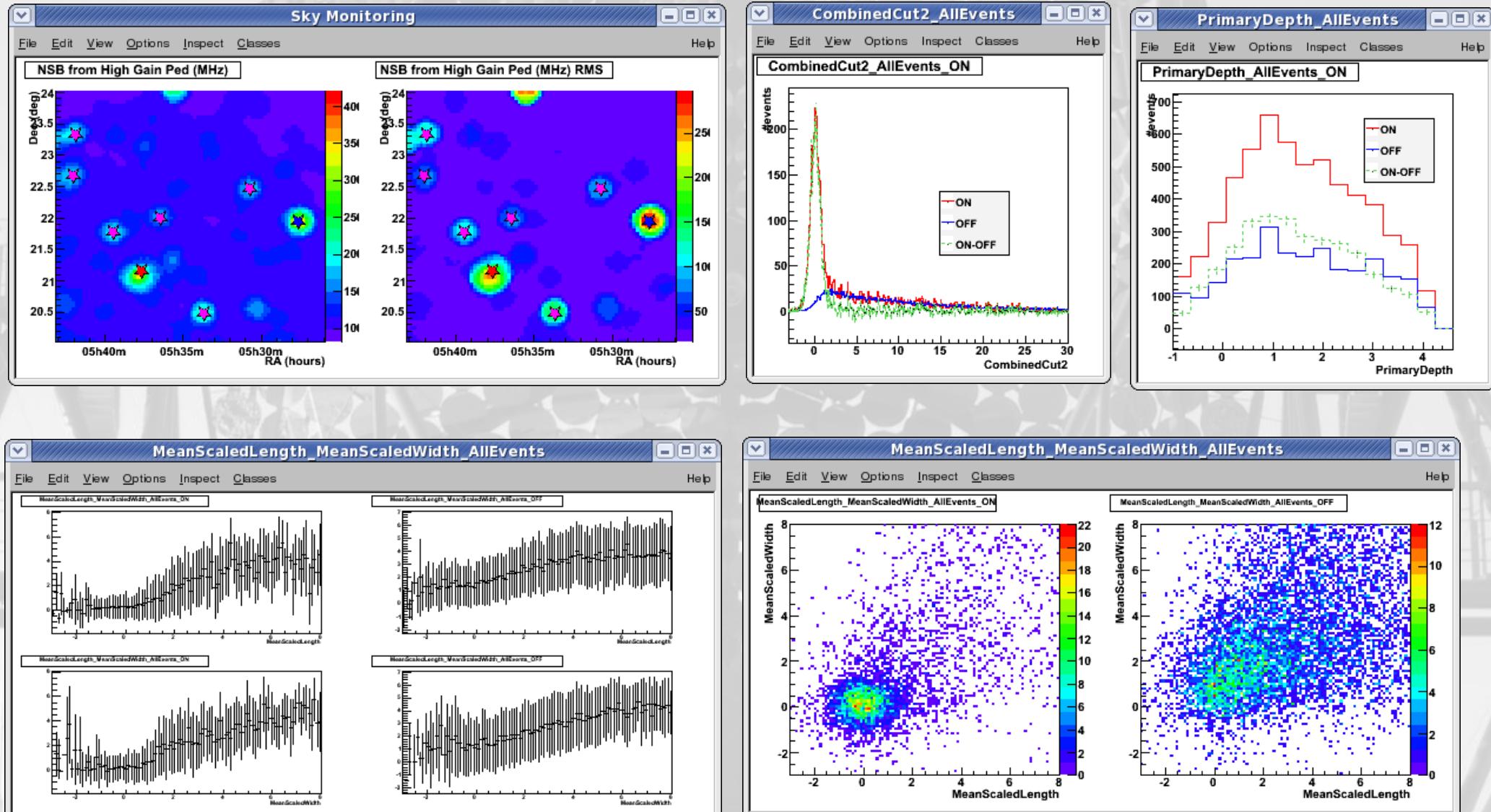
# AcceptanceMap

- Acceptance, Exposure in the camera and on the sky
- Zenith angle dependance,..
- Radial acceptance



# Plot Collections

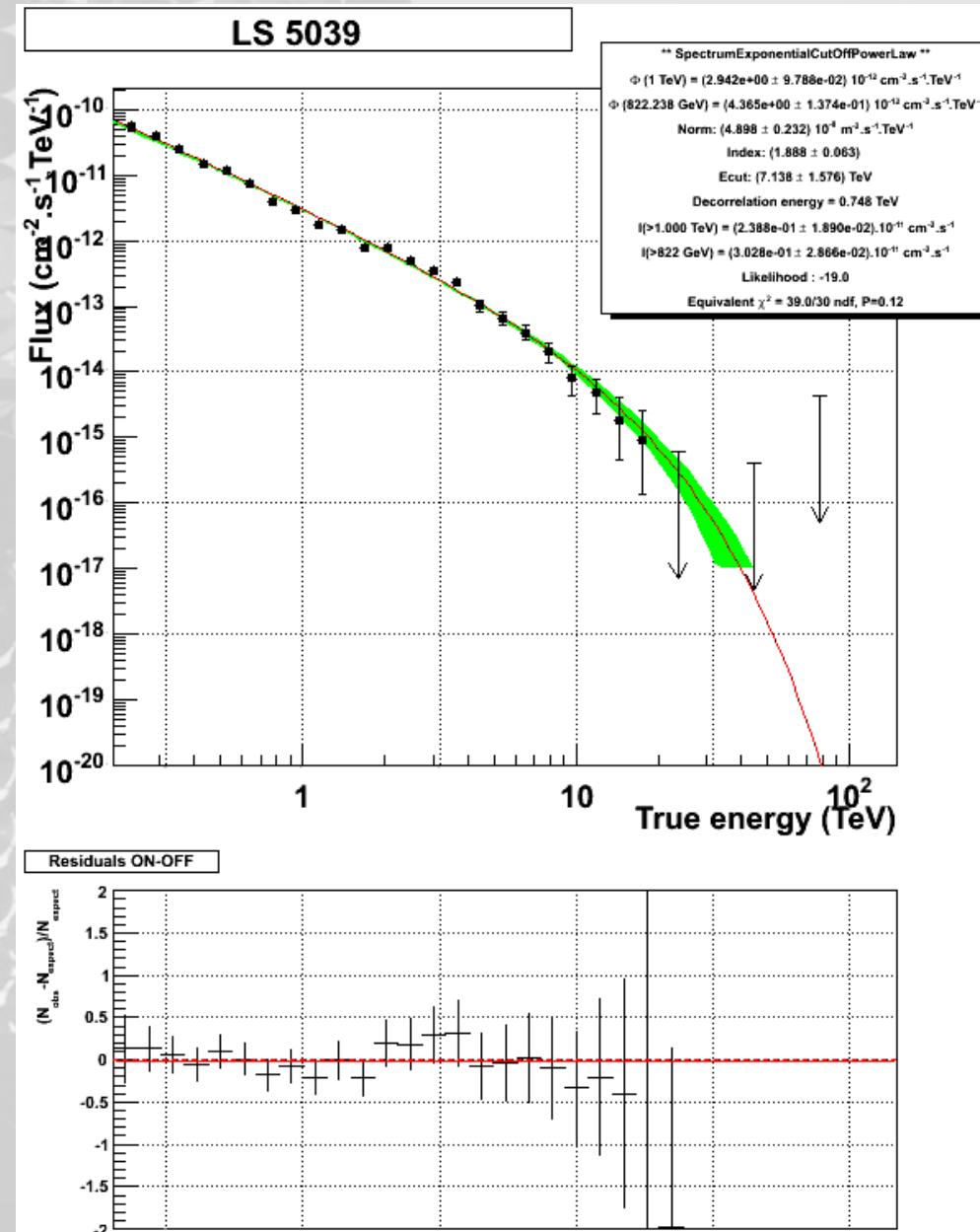
☛ All plots (one object per plot)



# Spectrum module

## Spectrum, lightcurves, ...

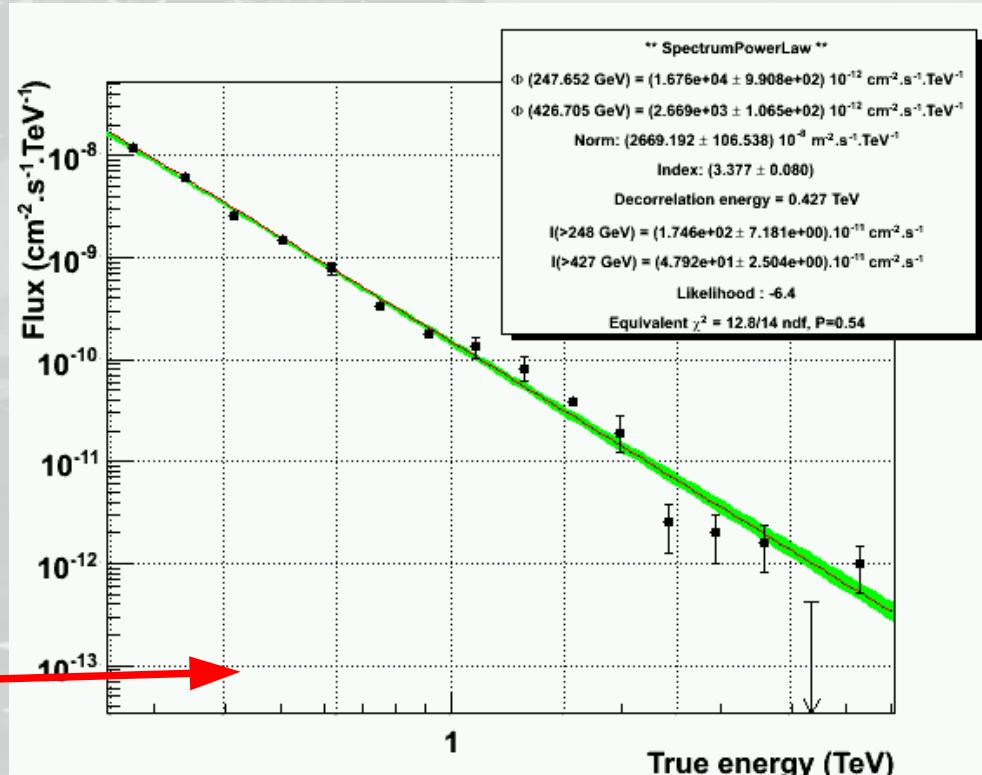
- Forward folding technique (See Santiago's talk)
- Completely independent from the reconstruction technique
  - Works with combined variable, user variable, ... without recompilation
  - Many spectral shape available: Power Law, Broken Power Law, Curved Power Law, Power Law with cutoff, Annihilation lines
  - Can combine several shapes (Power Law + Annihilation lines,...)



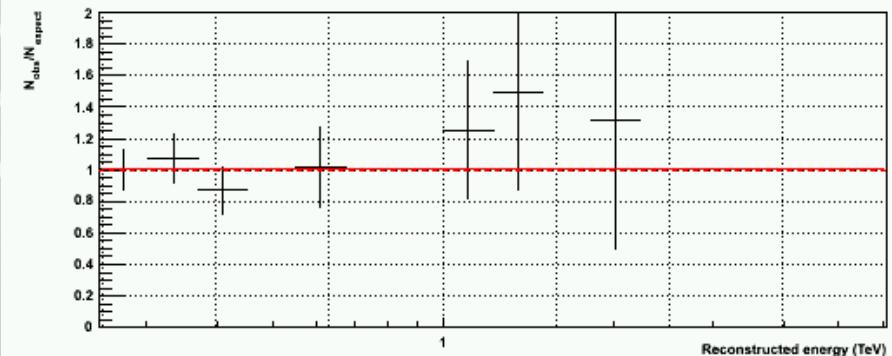
# Short time-scale spectra



```
set_time_range(53944.039,53944.044)
FitSpectrum("PKS2155...")
```

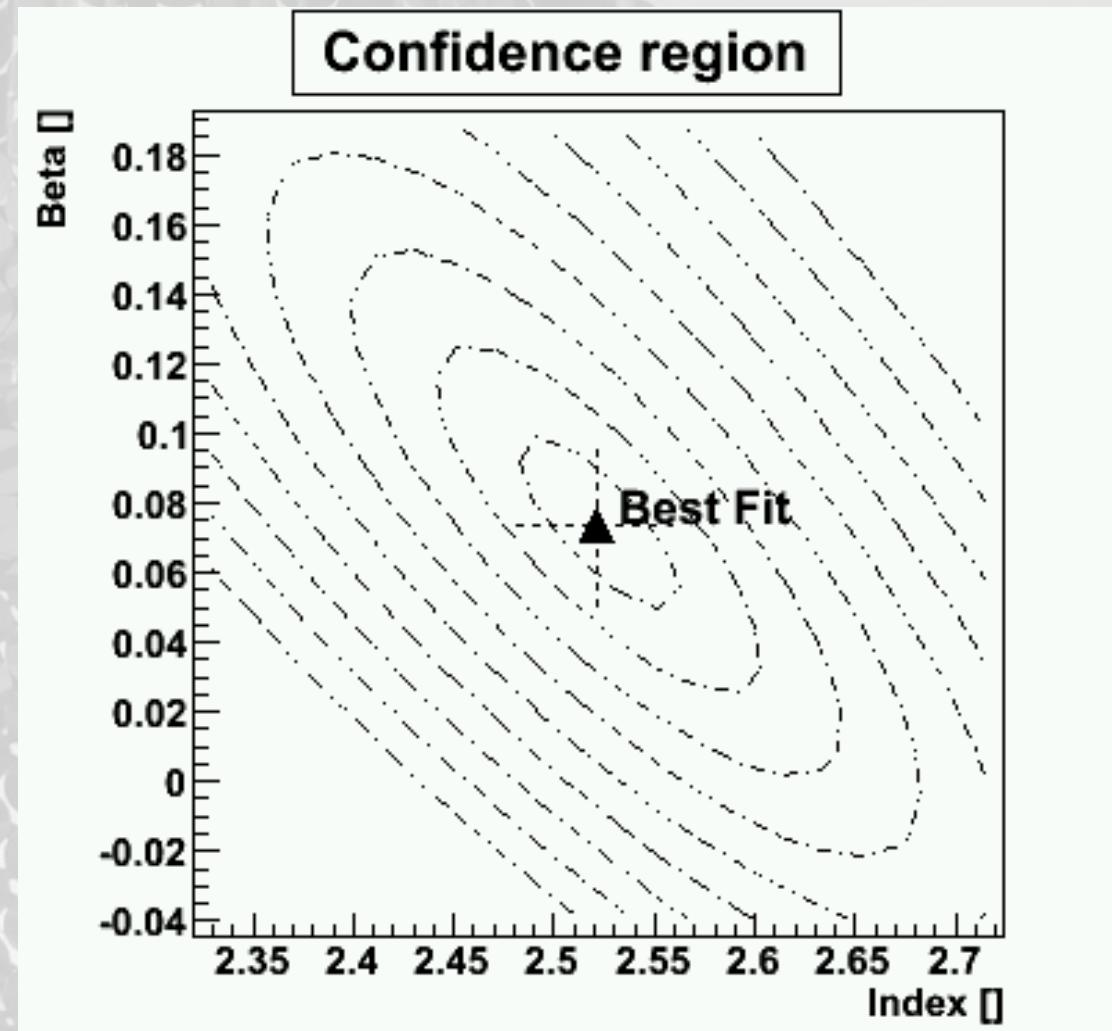


- Can select a subset of events (time, phase,...) without rerunning analysis



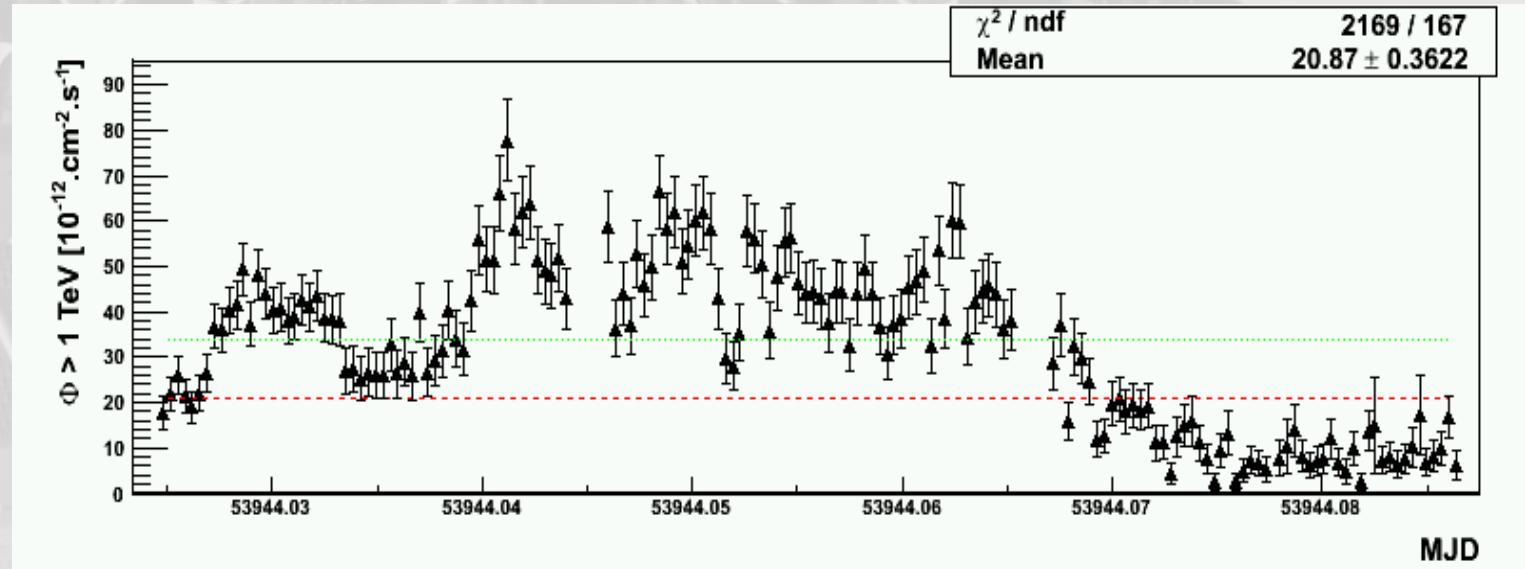
# Confidence regions

- *Spectrum parameters confidence region:*
  - Here Crab curvature vs spectral index



# LightCurves

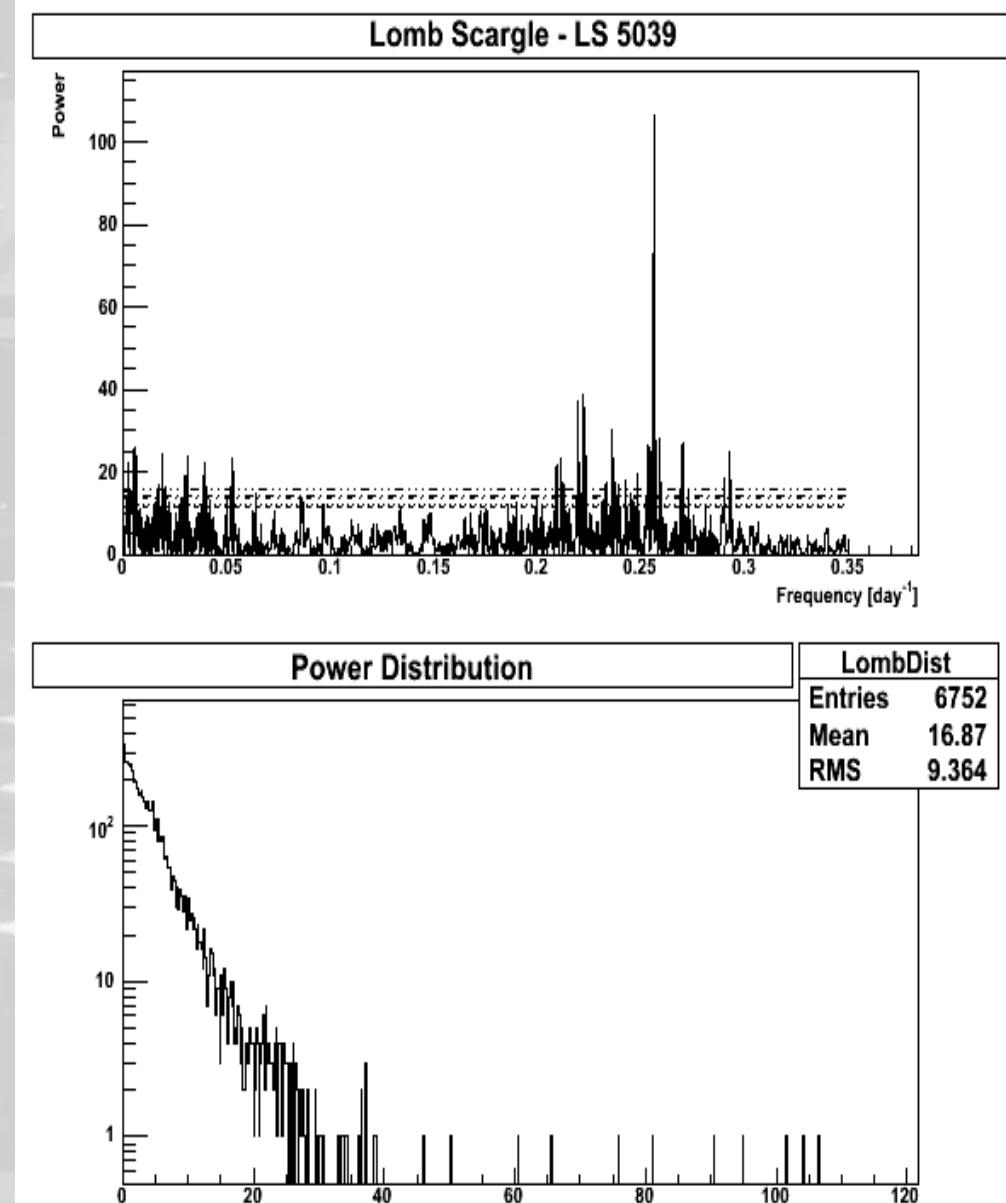
- Run-by-run, night-by-night
- Arbitrary time-slice lightcurves



- Several lightcurve determination techniques:
  - Event-base acceptance weighted,
  - Using spectrum shape assumption,
  - ...
- Other lightcurve types: CR rate, hardness ratio, spectrum parameters lightcurve (i.e. Spectral index vs time)

# Periodicity

- *Periodicity search algorithms (Lomb-Scargle)*
  - Orbital period subtraction
  - Chance prob. Estimation using bootstrap / MC
  - Folded lightcurves,
  - ...

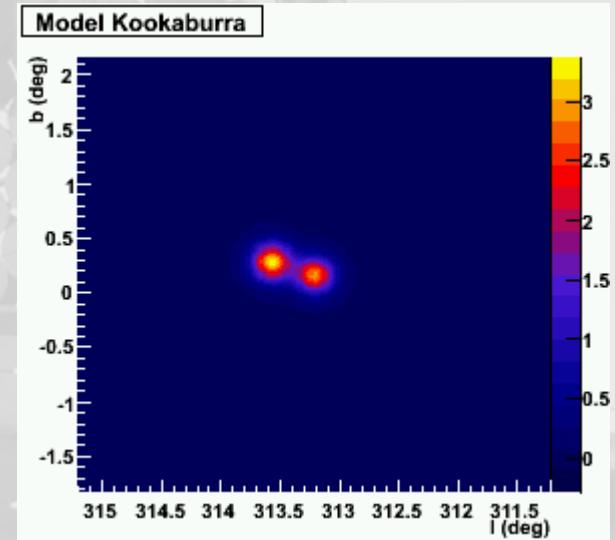
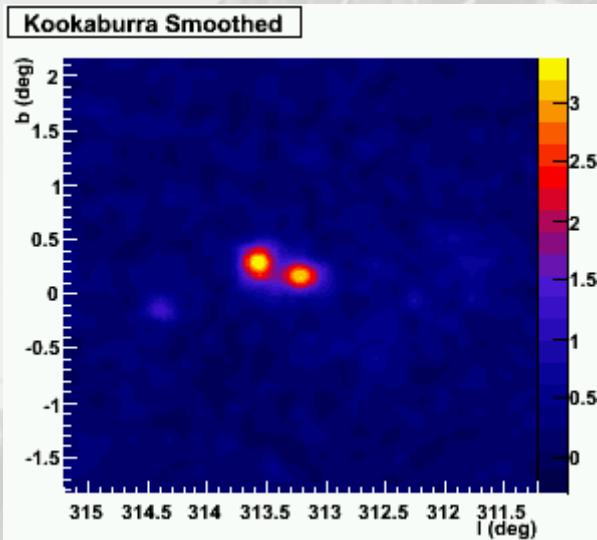


# Morphology module

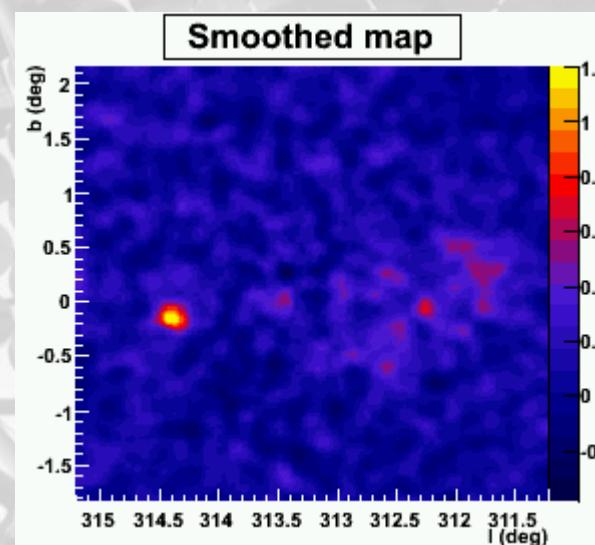
- ☛ *Forward folding technique applied to morphological studies*
  - ☛ *Derive intrinsic source size (or other parameters) (or upper limit)*
  - ☛ *Source position determination*
  - ☛ *Map smoothing (using actual Psf)*
  - ☛ *Source subtraction*
  - ☛ ...
- ☛ *Also fully documented*

# Morphology example – Source subtraction

- *Kookabura region's smoothed map*



Fit of 2 point-like sources



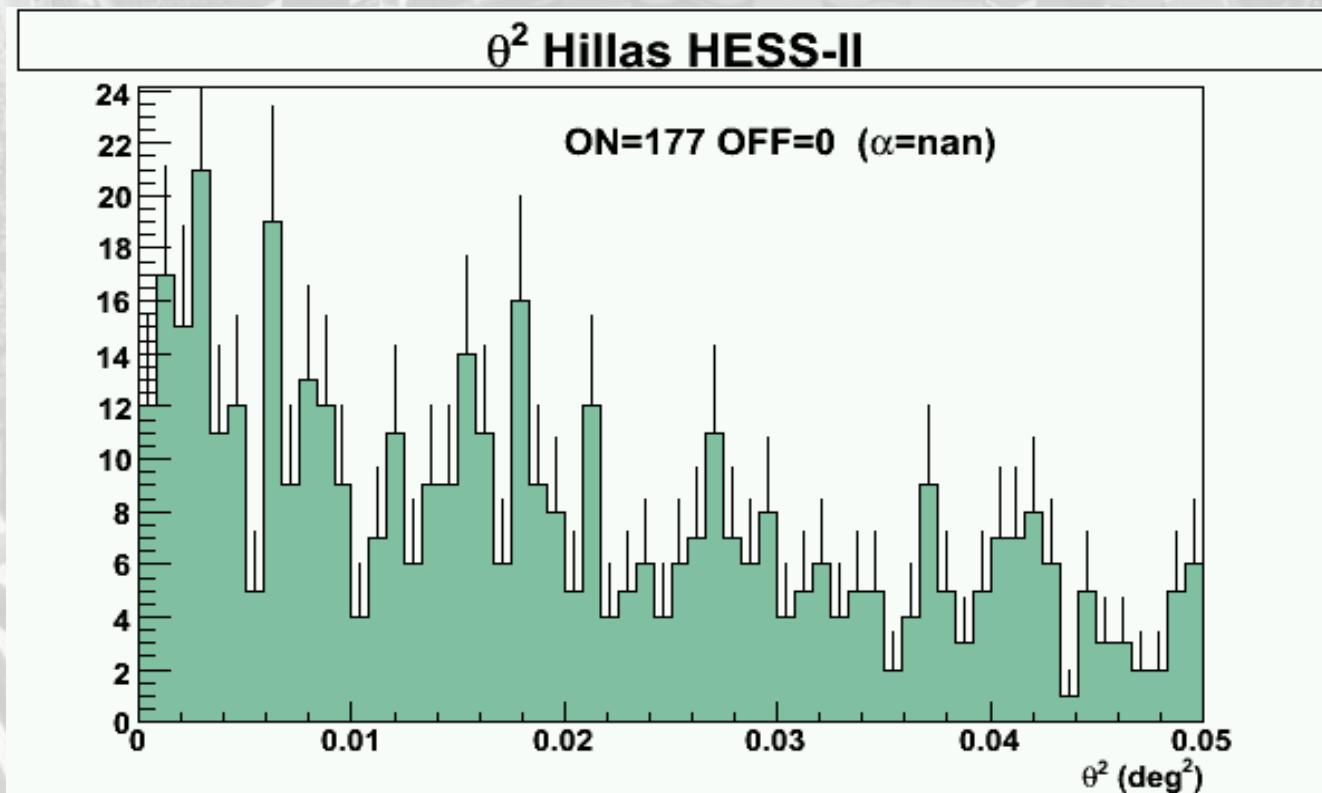
Subtraction of the 2 sources

# ParisAnalysis customization

- ☛ *Basic idea - Plugins:*
  - ☛ *Any element in the analysis can be replaced by a user version*
    - ☛ Without recompiling parisanalysis
    - ☛ Using external plugins modules
    - ☛ Keeping the overall consistency with spectrum determination,...
  - ☛ *One can easily design and use new selection variables, investigate new ideas,...*
- ☛ *Complete tutorial (parisanalysisuser model)*
  - ☛ *New selection variable ( $X_{eff}$ ), using Model and Hillas Pdfs for simulated  $\gamma$  and real off data*
  - ☛ *Base for user developments*
- ☛ *muDST output module (for Sash independent analysis)*
  - ☛ *See Nukri's talk*

# HESS-II capabilities

- ☛ *Parisanalysis almost ready for HESS-II*
  - ☛ *Different treatment of different type telescopes (different cuts, different scaled tables,...)*
  - ☛ *Model and 3D Model analyses not yet completely ready for HESS-II*



# Installation - I

- ☛ *Central installation in Lyon (\$THRONG\_DIR)*
- ☛ *Installation procedure fully documented*

**ParisAnalysis documentation**

Fichier Édition Affichage Web Aller à Signets Onglets Aide

Précédent Suivant Arrêter Actualiser Dossier personnel Plein écran 100

file:///usr/local/hess/doc/parisanalysis/group\_\_ParisAnalysis\_\_Starting.html

Aller à

```
cd $HESSUSER; make
```

**Local installation**

If you do not intend to run in Lyon, you first need to have the complete [Sash software installed](#). In particular, you will need:

```
cvs -d :pserver:hess@lpnp90.in2p3.fr:/home/cvsroot login <enter>
cvs -d :pserver:hess@lpnp90.in2p3.fr:/home/cvsroot co mathutils
cvs -d :pserver:hess@lpnp90.in2p3.fr:/home/cvsroot co parisreco
cvs -d :pserver:hess@lpnp90.in2p3.fr:/home/cvsroot co parisanalysis
```

In addition, you need the module *parisrunquality* from Berlin's CVS

```
cvs -d :pserver:hess@hess01.physik.hu-berlin.de:/cvs login <enter>
cvs -d :pserver:hess@hess01.physik.hu-berlin.de:/cvs co parisrunquality
```

- If you want to run the Model analysis, you will need the *hessana* module as well.  

```
cvs -d :pserver:hess@lpnp90.in2p3.fr:/home/cvsroot co hessana
```
- If you want to run the Model 3D analysis, you will need the *module3D* module as well.  

```
cvs -d :pserver:hess@lpnp90.in2p3.fr:/home/cvsroot co module3D
```

---

**The rootlogon.C file**

You can take the *rootlogon.C* file from the directory:

Asroot@HESS WORKSHOP, Warsaw, 11/2007

# Yum installation

- *Yum repository (standard Redhat/Fedora/Ubuntu/...) available for Fedora 6 and Fedora 7 (SL4 will be added)*
  - [http://lpnp90.in2p3.fr/~hess/Software/For\\_Fedora6/hess-release-6-4.noarch.rpm](http://lpnp90.in2p3.fr/~hess/Software/For_Fedora6/hess-release-6-4.noarch.rpm)
  - [http://lpnp90.in2p3.fr/~hess/Software/For\\_Fedora7/hess-release-7-4.noarch.rpm](http://lpnp90.in2p3.fr/~hess/Software/For_Fedora7/hess-release-7-4.noarch.rpm)

> yum install hess-parisanalysis-full

```
denuroi@polged:/home/denuroi
Fichier Édition Affichage Terminal Onglets Aide
hess-parisanalysis i386 0.8.11-4 hess 1.5 M
hess-parisanalysis-devel i386 0.8.11-4 hess 43 k
hess-parisanalysis-examples i386 0.8.11-4 hess 15 k
hess-parisanalysis-hillas i386 0.8.11-4 hess 93 k
hess-parisanalysis-hillas-devel i386 0.8.11-4 hess 4.7 k
hess-parisanalysis-mc i386 0.8.11-4 hess 320 k
hess-parisanalysis-mc-devel i386 0.8.11-4 hess 11 k
hess-parisanalysis-model i386 0.8.11-4 hess 186 k
hess-parisanalysis-model-devel i386 0.8.11-4 hess 6.5 k
hess-parisanalysis-model3D i386 0.8.11-4 hess 210 k
hess-parisanalysis-model3D-devel i386 0.8.11-4 hess 9.1 k
hess-parisreco-devel i386 1.0.5-1 hess 18 k
hess-parisrunquality i386 1.0.5-1 hess 531 k
hess-parisrunquality-gui i386 1.0.5-1 hess 18 k
hess-reco-devel i386 1.0.5-1 hess 20 k
hess-sash-devel i386 1.0.5-1 hess 59 k
hess-spectrum i386 0.8.11-6 hess 975 k
hess-spectrum-devel i386 0.8.11-6 hess 31 k
hess-spectrum-examples i386 0.8.11-6 hess 18 k
hess-stash-devel i386 1-4 hess 15 k

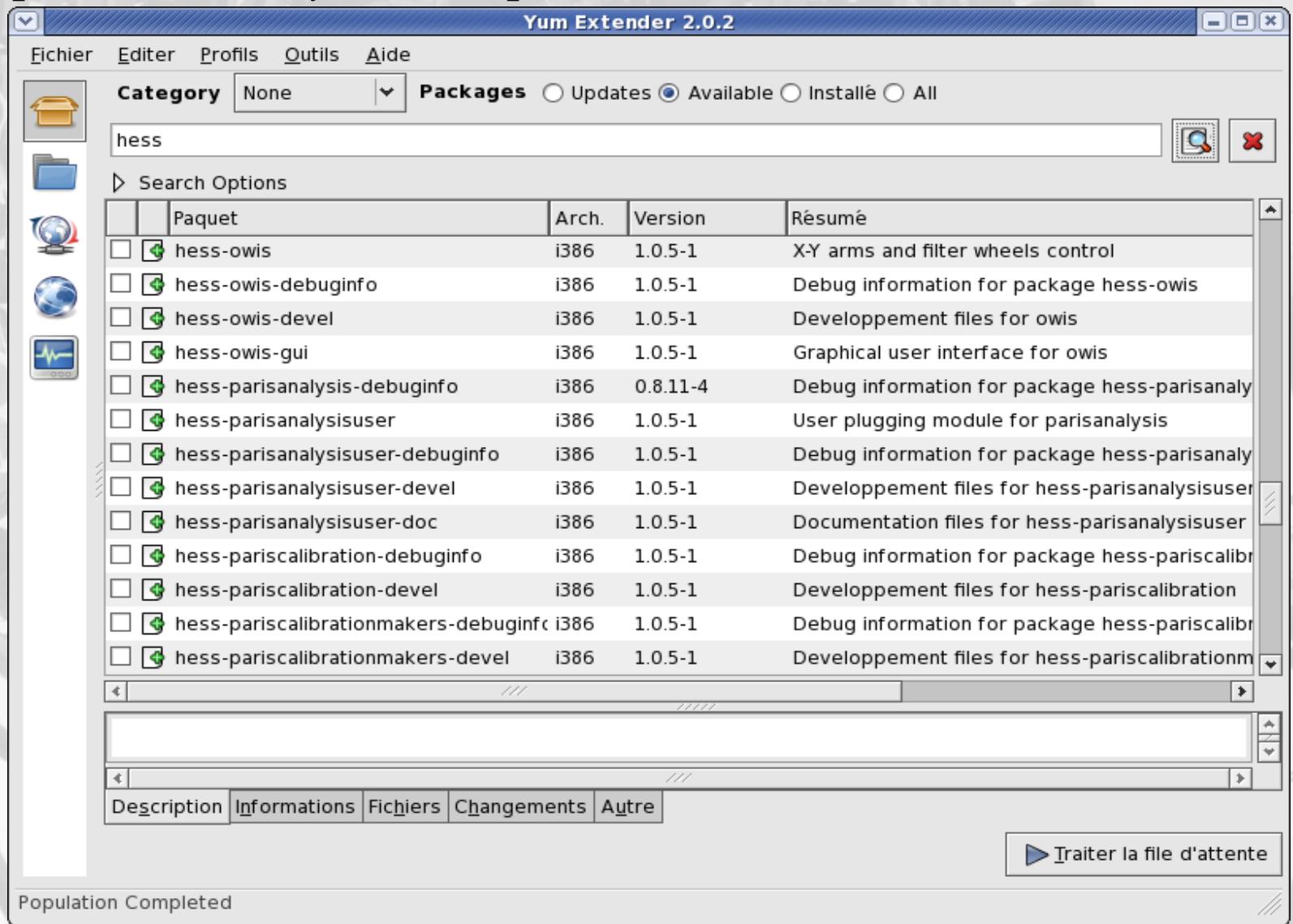
Transaction Summary
=====
Install 33 Package(s)
Update 0 Package(s)
Remove 0 Package(s)

Total download size: 5.0 M
Is this ok [y/N]:
```

# Yum installation (2)

## • Package installation with yumex

- Dependencies handled properly
- Stay up-to-date easily, no compilation



# Desktop integration

The screenshot shows a desktop interface with a sidebar containing various application icons and labels. The main window is titled "ParisAnalysis Documentation" and displays a documentation page for the ParisAnalysis library.

**Application menu:** The sidebar includes a "Documentation Logiciels HESS" section which contains links to "3D Model documentation", "FromDB documentation", "Intensity documentation", "Kaskade C++ documentation", and "MathUtilis documentation".

**Documentation menu:** The main window has a menu bar with "Fichier", "Édition", "Affichage", "Web", "Aller à", "Signets", "Onglets", and "Aide". Below the menu bar is a toolbar with buttons for "Précédent", "Suivant", "Arrêter", "Actualiser", "Dossier personnel", and "Plein écran". The status bar at the bottom shows zoom levels from 100 to 1500.

**Content:** The main content area shows the "ParisAnalysis Documentation" page. It features a navigation sidebar on the left with links to "ParisAnalysis Documentation", "Modules", "Class List", "Class Hierarchy", "Class Members", "Namespace List", "File List", "Examples", "File Members", and "Related Pages". The main content area includes a header with "Main Page", "Modules", "Namespace List", "Class Hierarchy", "Compound List", "File List", "Compound Members", and "Search" links. Below the header is a large heading "ParisAnalysis Documentation" and a text block stating: "This is the documentation for the HEAD version of parisanalysis. The documentation for the 0-8-9-4 version is available [here](#)". Further down, another text block states: "This is the documentation for the HEAD version of parisanalysis. The documentation for the 0-8-9-4 version is available [here](#)". At the bottom, there is a "Search Engine" section with a list of links:

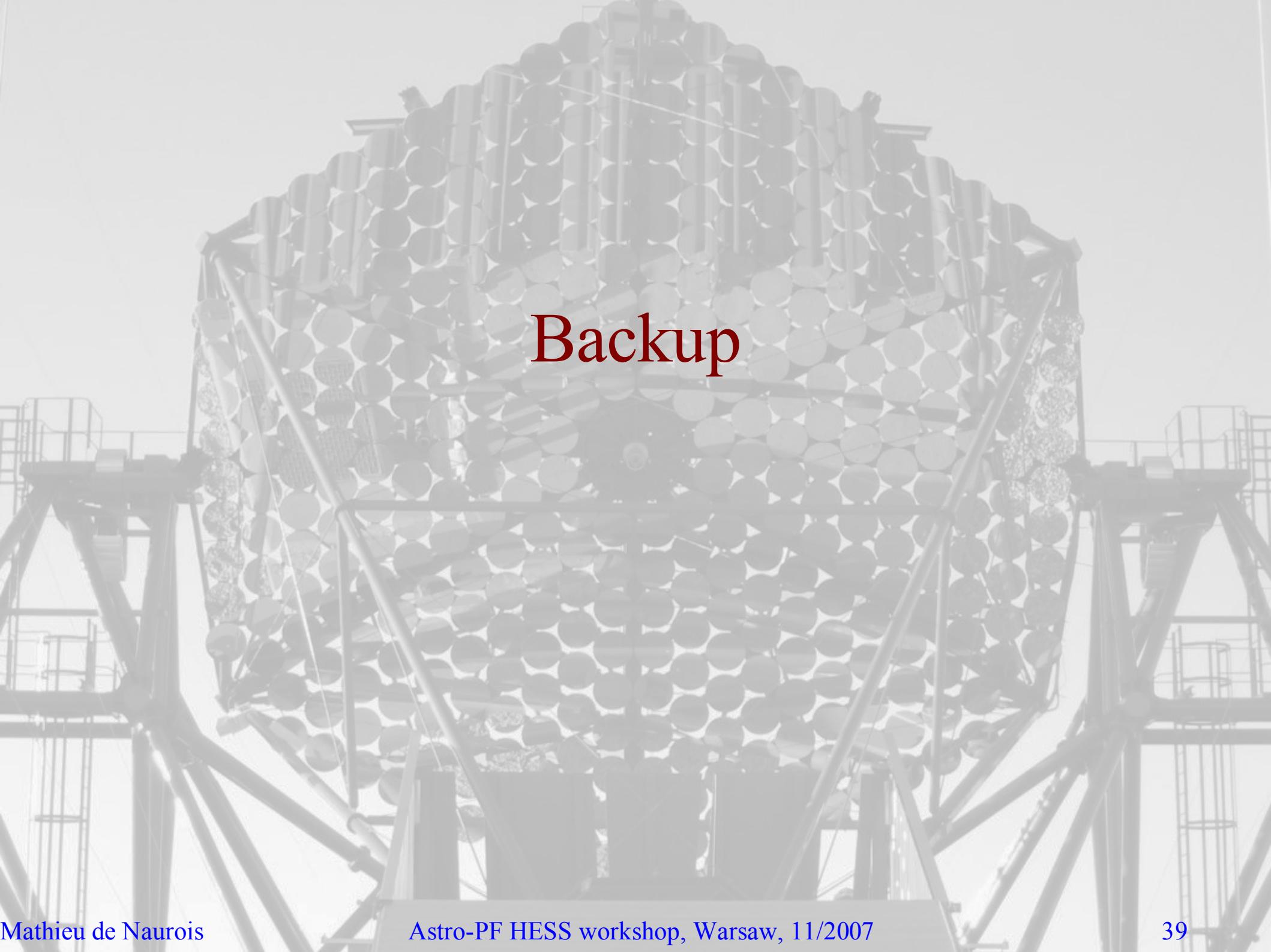
1. [Recent Changes](#)
2. [Getting Started](#)
3. [Analysis Script Syntax](#)
4. [Structure of ParisAnalysis](#)
5. [The plotting system](#)

# Summary

- ☛ *Hillas, Model, 3D Model reconstruction*
- ☛ *Cross-comparison and combination of reconstructions*
- ☛ *Standard background subtraction, using several acceptance calculation algorithms*
- ☛ *Arbitrary region shapes*
- ☛ *Sliced analysis with offline merging*
- ☛ *Evolved plotting engine*
- ☛ *Fully customizable, plugin capabilities*
- ☛ *Rich spectral/lightcurve determination module*
- ☛ *Morphological studies*
- ☛ *Easy installation*
- ☛ *Graphical User Interface in development*
- ☛ *Development framework for new analyzes ideas*
- ☛ ...

# HAP vs ParisAnalysis

- *HAP is a new development, parisanalysis is in production since 2 years*
- *Parisanalysis is more complex, but more powerful*
  - Fully customizable
  - More complex algorithms (Weighting Backgound, 2D Acceptance calculation,...)
  - Powerful display engine
  - Access to all variables using the data bus concept
  - ...
- *Parisanalysis is also a framework for developing new analyses*



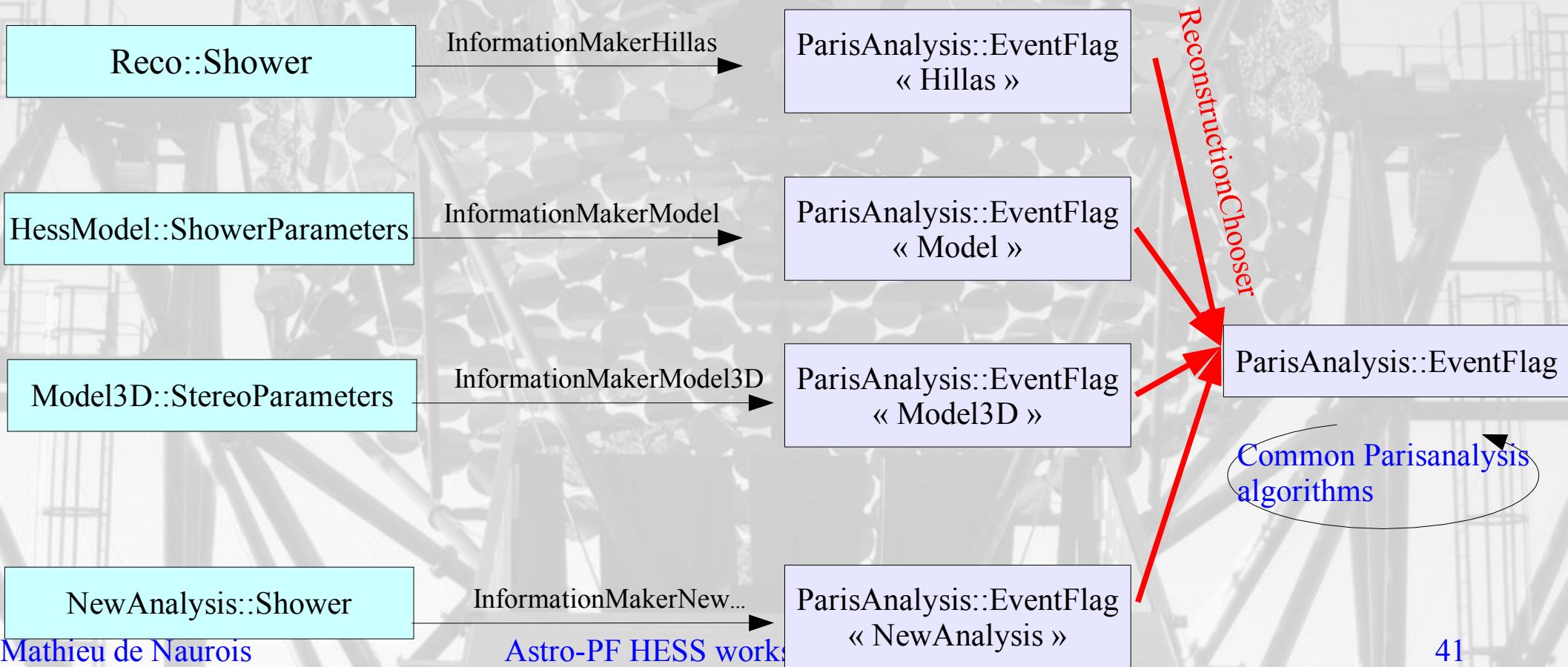
# Backup

# Résumé : types de soustraction de fond

Nom	Spectre	Cartes	Commentaires
Ring Background	OUI	OUI	Spectre: Ne marche que pour les petites sources, non centrées dans la caméra, suppose une symétrie azimuthale Cartes: Nécessite de bien définir toutes les régions d'exclusion pour éviter un déficit autour des sources
Multiple Off Regions	OUI	NON	Spectre: On peut forcer le nombre de régions OFF à 1 -> MirroredBackgroundMaker. Accepte aussi des runs ON et OFFs
On – Off	OUI	OUI	Nécessite une liste de runs alternant ON et OFF avec mêmes angles zenithaux. Fonctionne pour des sources étendues et/ou centrés
Template Model	NON ?	OUI	Pas de reconstruction spectrale pour le moment. Fonctionne bien avec des sources étendues. Sensibilité aux variations de conditions locales ? (NSB, ???)
Weighting Method	NON	OUI	Idem Template Model + Calibration de la variable discriminante
Full Background	OUI	NON	En cours de développement, utilise toute la stat disponible pour la reconstruction spectrale. Exploite les runs ON, OFF, et wobble

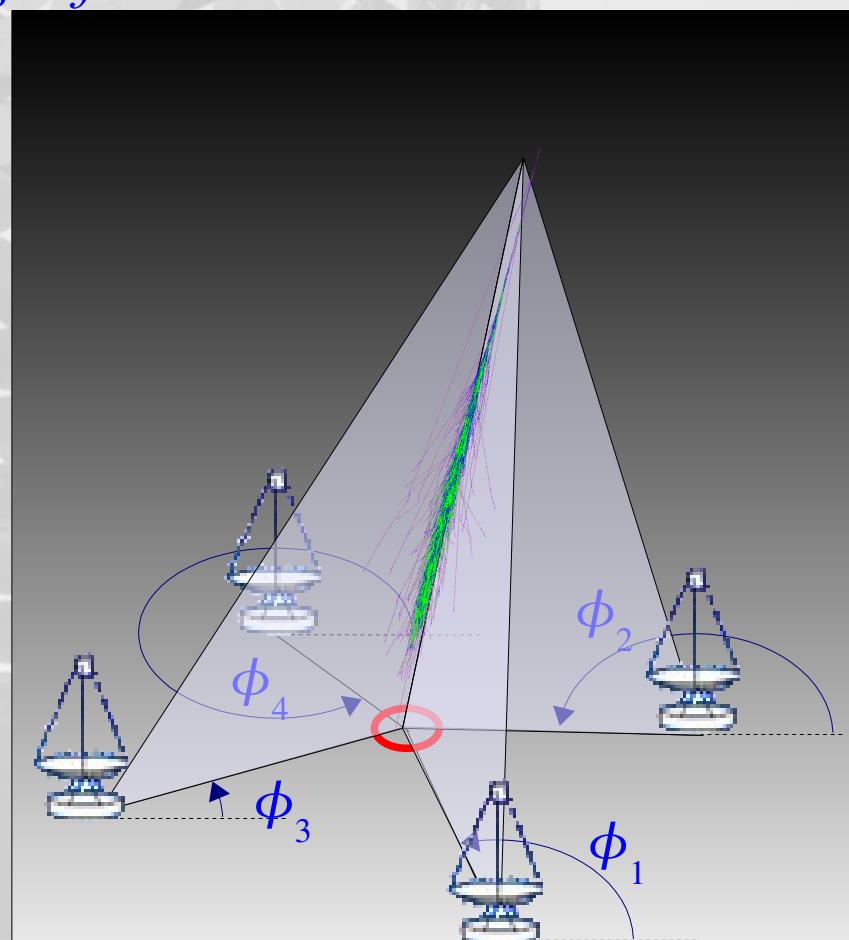
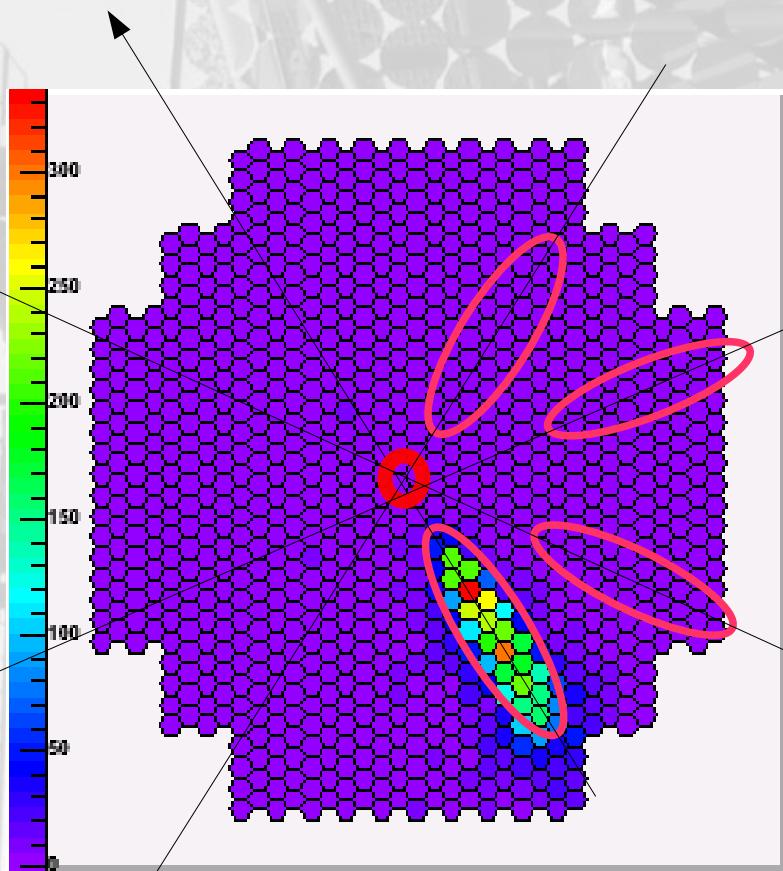
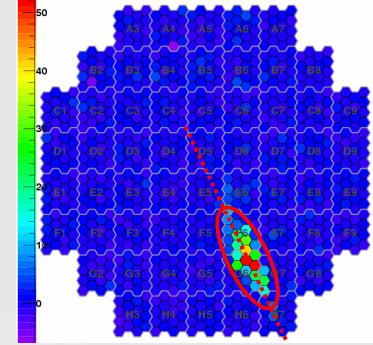
# Reconstruction Selection

- One data bus (`ParisAnalysis::EventFlags`) filled by a `ParisAnalysis::InformationMaker` specific to each reconstruction
- `ParisAnalysis::ReconstructionChooser` chooses the appropriate reconstruction and fills the unnamed data bus (`ParisAnalysis::EventFlags`)
- Additional makers may compute combined variables for later use



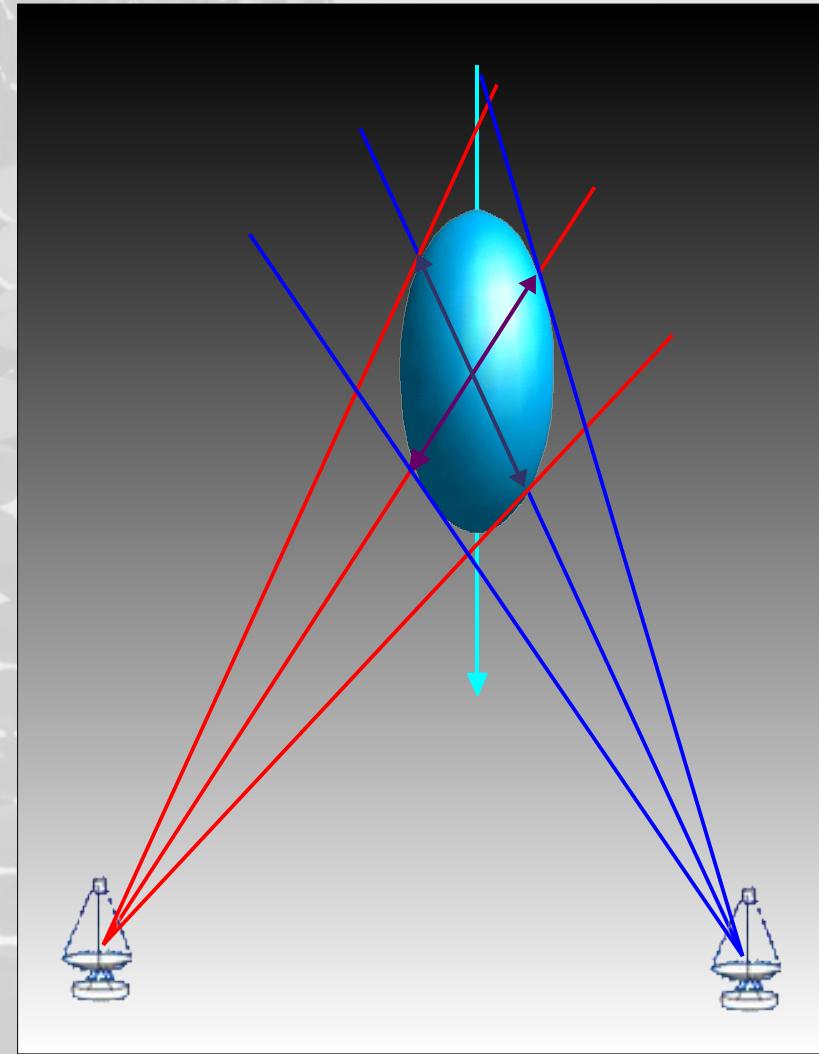
# Reconstruction - Hillas

- *Elliptical fit of camera images*
- *Geometric reconstruction of direction and impact*
- *Lookup tables for energy reconstruction*
- *Mean Scaled Width / Mean Scaled Length for discrimination*



# Reconstruction – 3D Model

- *Ellipsoid Photosphere*
- *Simultaneous fit of all telescope data*
- *Use of lookup tables for energie determination (from ellipsoid luminosity)*
- *Discrimination base on ellipsoid width*



# Reconstruction - Model

- ☛ *Log-likelihood comparison of actual images with pre-calculated template*
- ☛ *Fit directly provides shower parameters + uncertainties:*
  - ☛ *Direction, Impact, Energy, and depth of first interaction*
  - ☛ *Goodness of fit provides discrimination*

