ParisAnalysis

Flexible analysis chain for Hillas, Model, 3D Model

Mathieu de Naurois, LPNHE - CNRS/*Paris University VI/VII*
denauroi@in2p3.fr

- 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/*

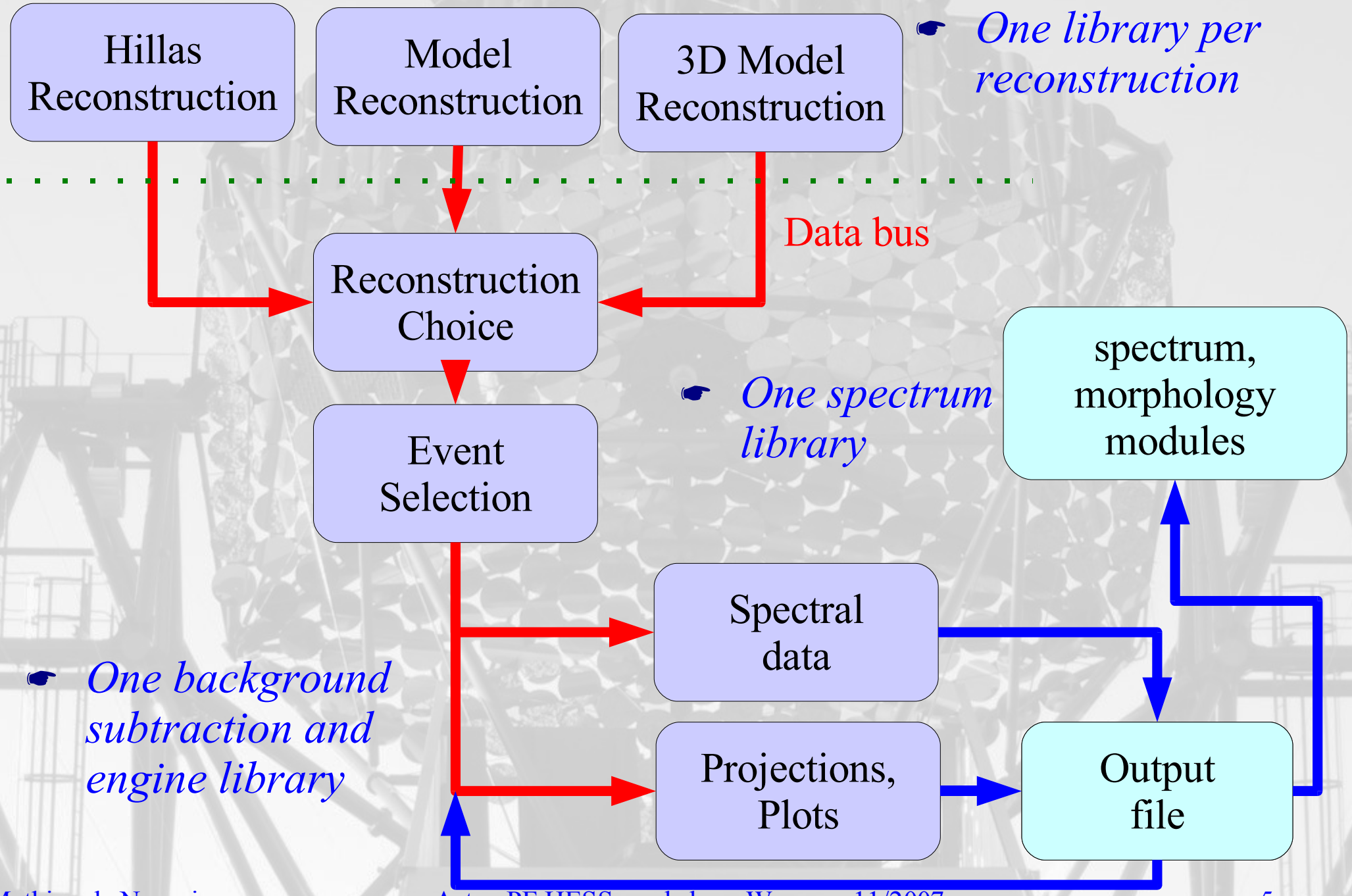
Overall organization – user interface

- *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)*

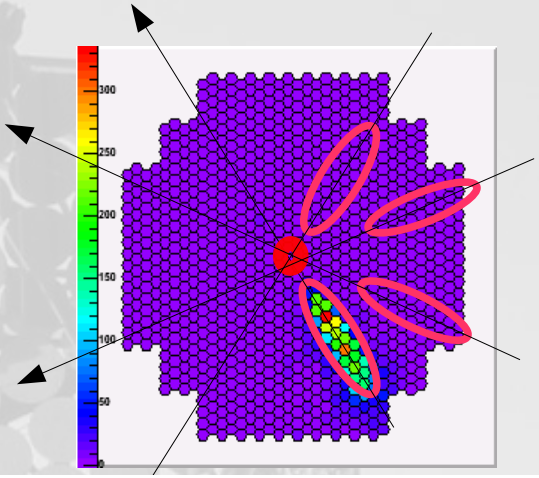
- *Results saved in an output file for later use*

Overall organization - Scheme

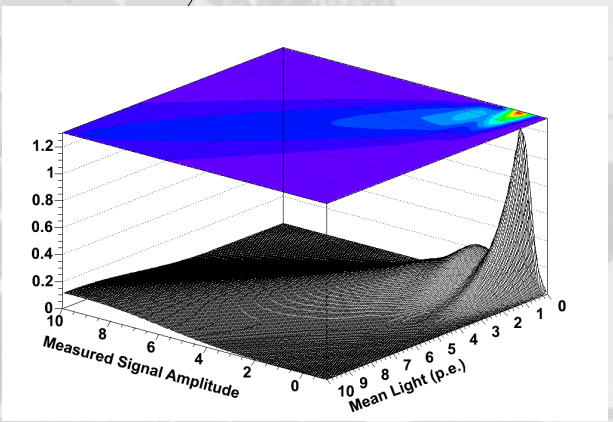


Available reconstructions

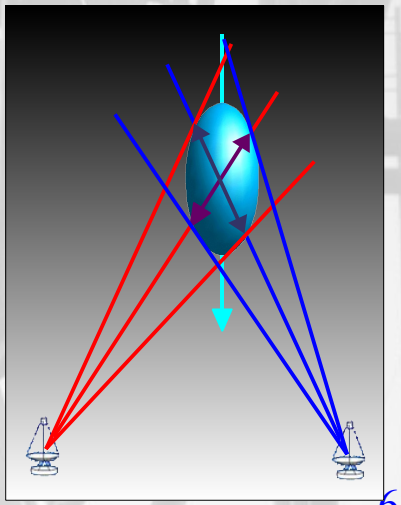
- *Hillas*
  - *Elliptical images, geometrical reconstruction of direction and impact, lookup table, image cleaning*



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



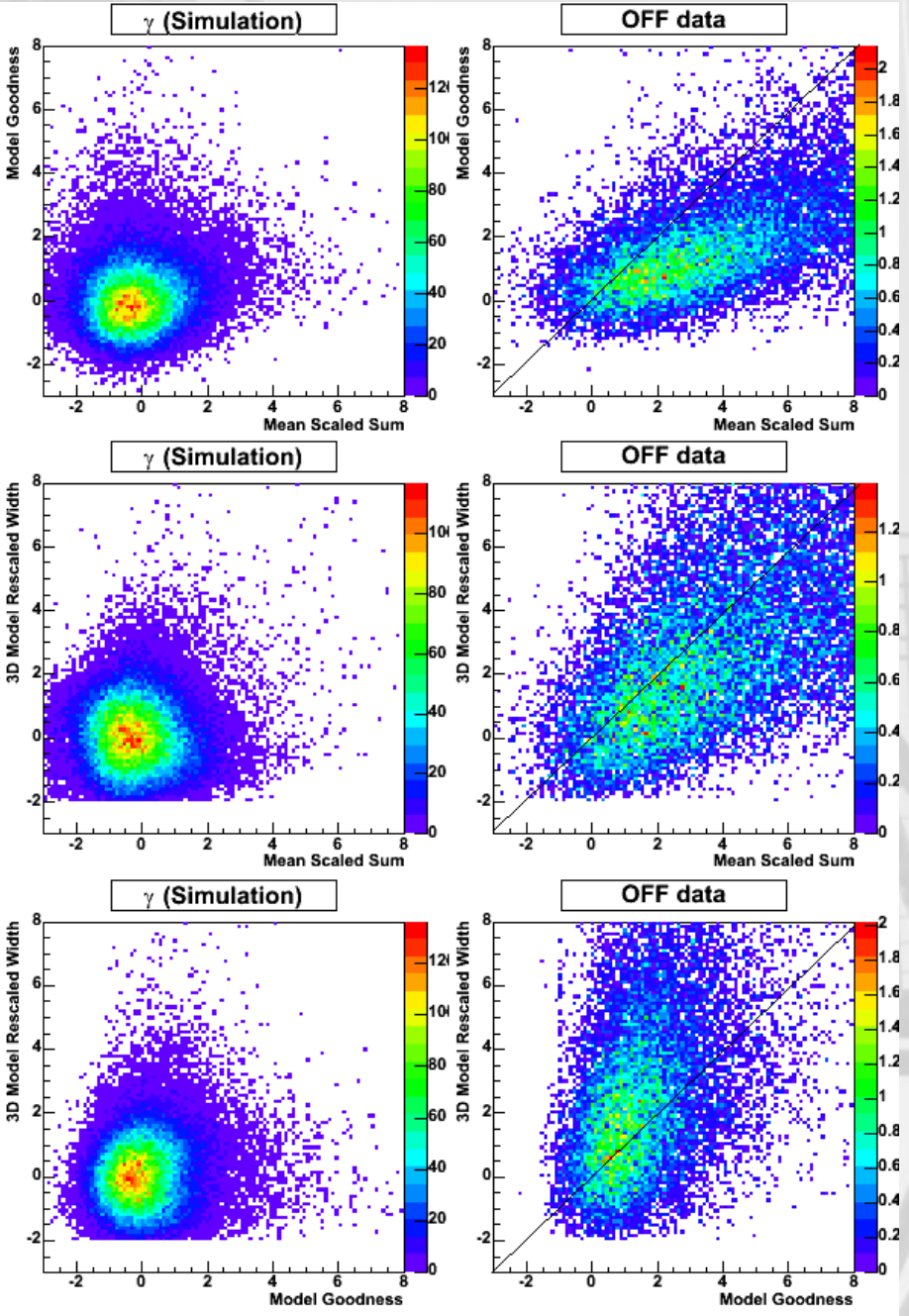
- *3D Model*
  - *3D Gaussian photosphere in the atmosphere, 8 parameters fit combining telescopes*



- *Any combination of them*

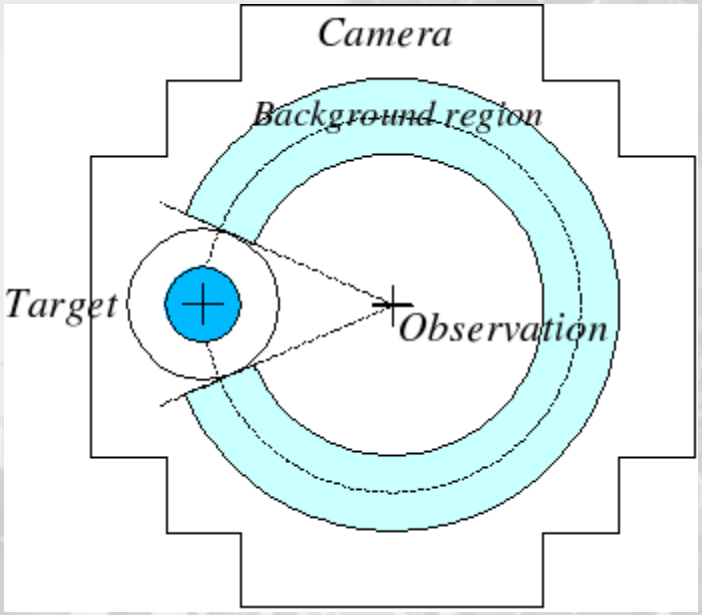
Why three reconstructions?

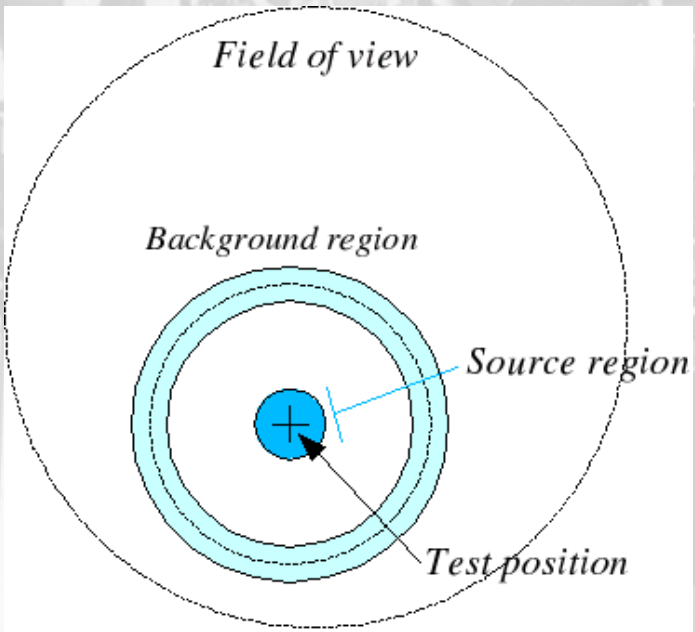
- *Almost no correlation between discriminating variables (for γ's)*
- *Different information used:*
  - *Hillas:*
    - Correlation between telescopes not used
    - Scaled cuts ⇒ most frequent showers
  - *Model*
    - Correlation used
    - Shower fluctuations not used except first interaction point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



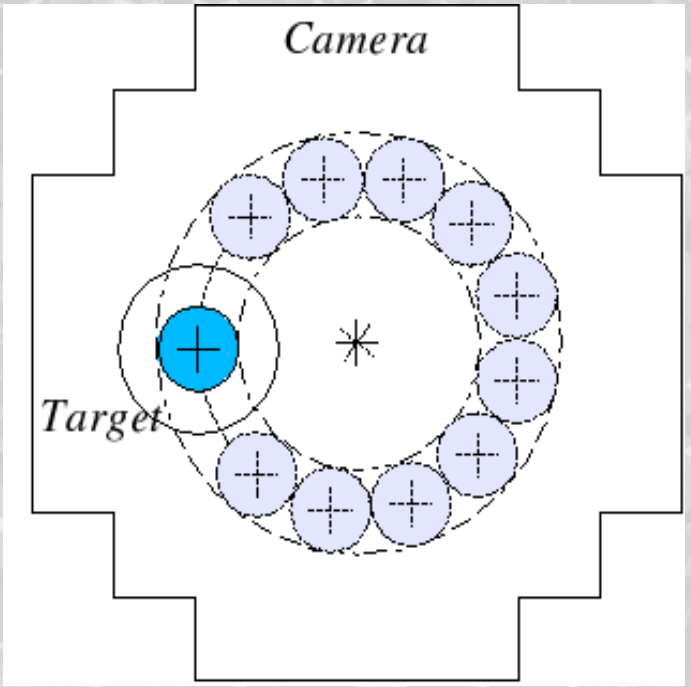
Subtraction techniques

Ring background

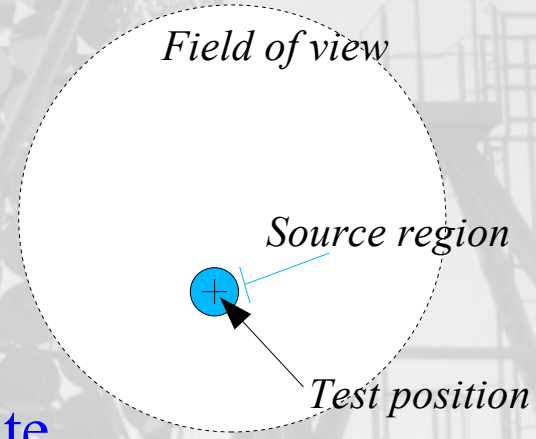


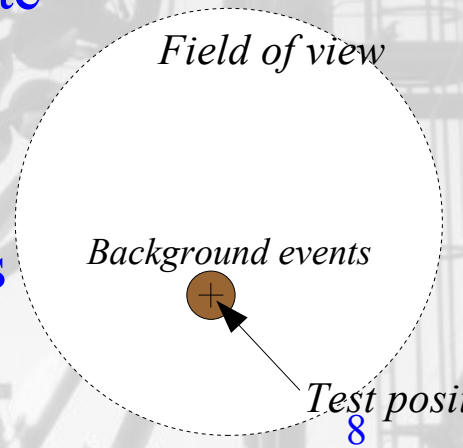


Multiple off, ON-OFF



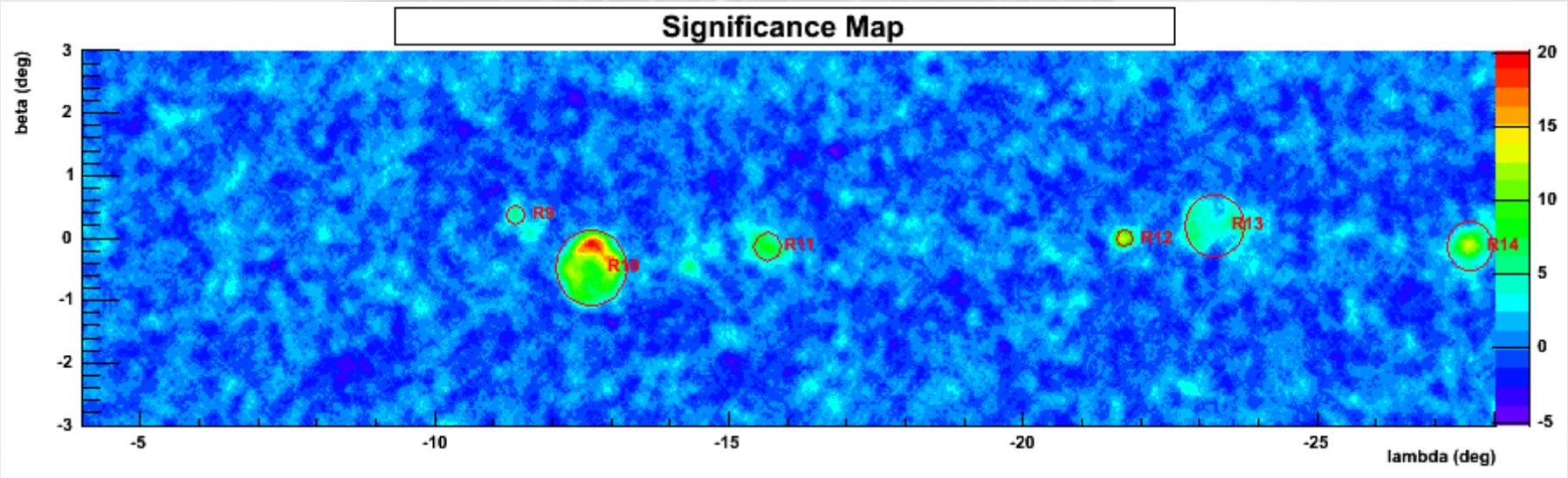
Template Model





+ More elaborate techniques (Weighting Method)

Excluded regions

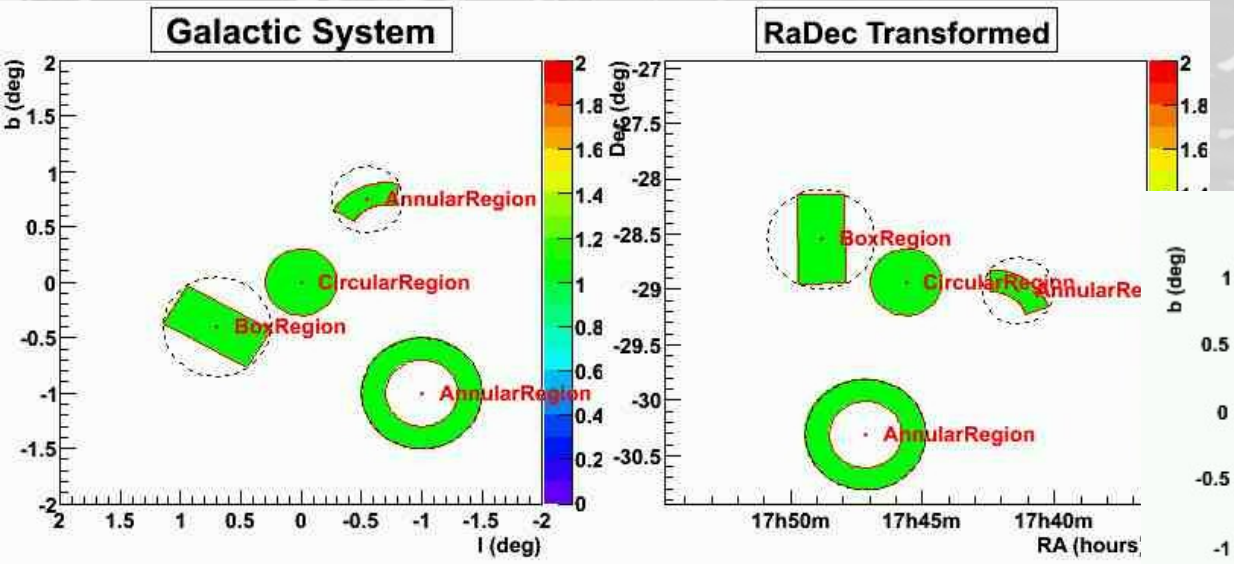


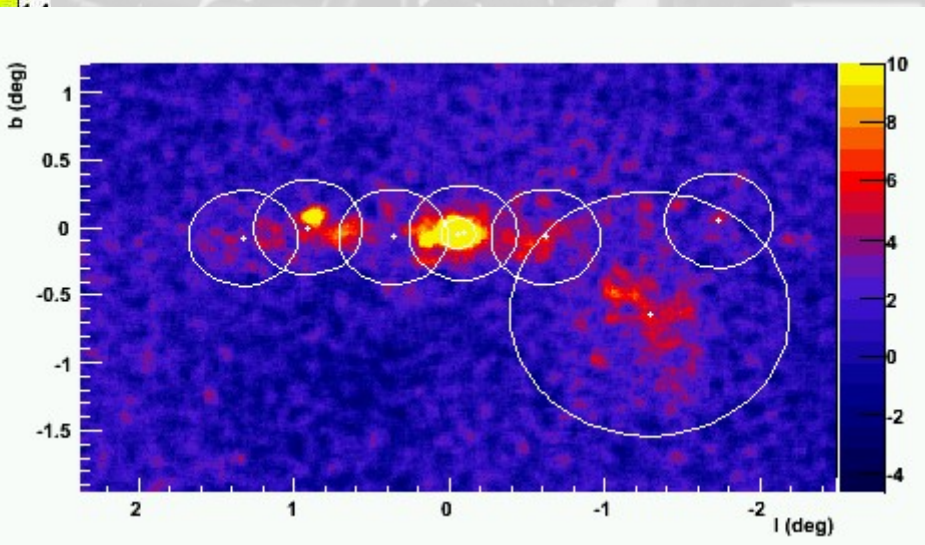
- *For most background substraction techniques, background taken from the same event population (γ like)*
- *Background contamination by γ's induces and underestimation of signal and produces a deficit around sources*
- *⇒ Excluded regions need to be defined around intense sources*

Arbitrary shape regions

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*

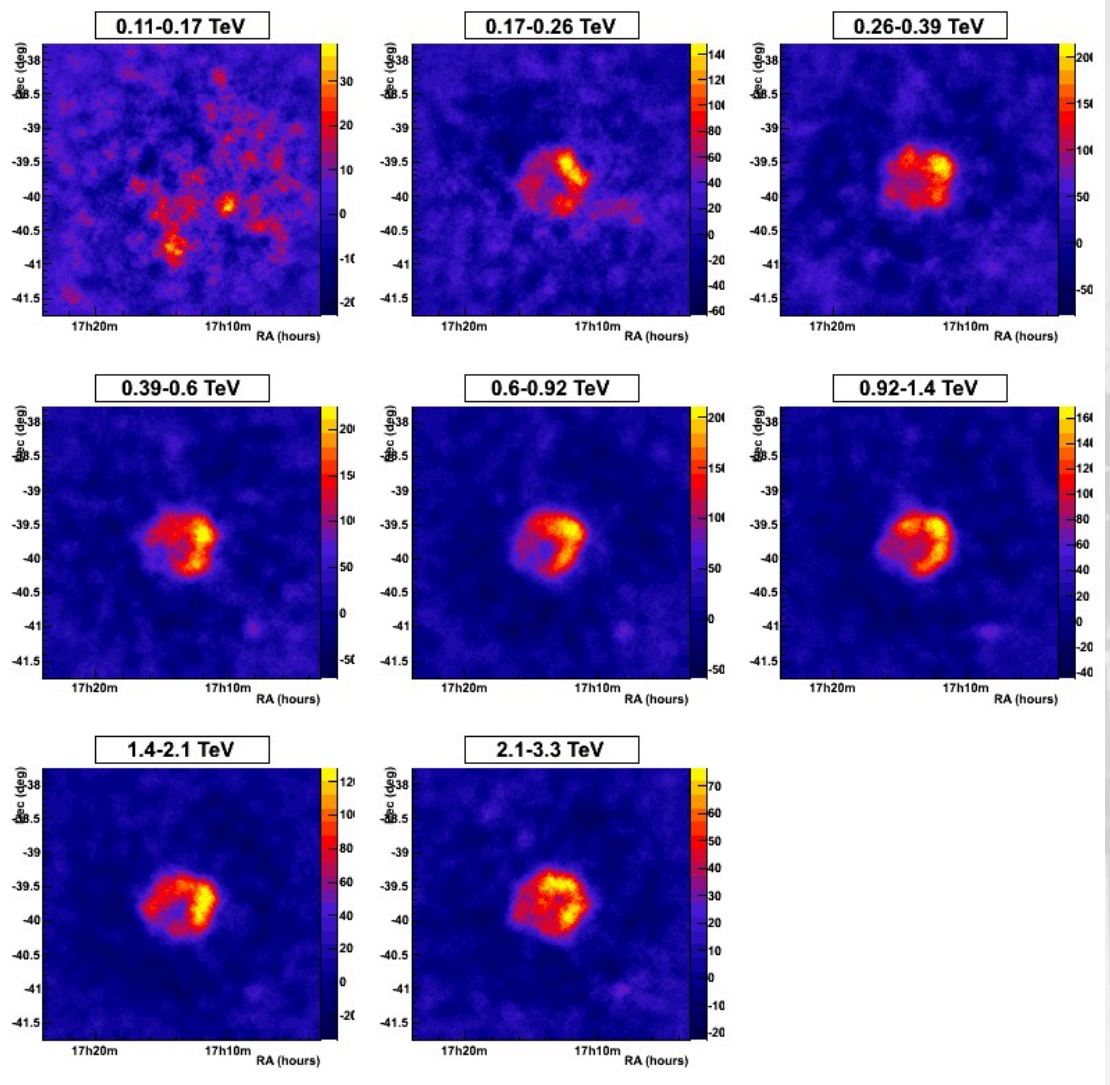
Sliced-Analysis

http://lpnp90.in2p3.fr/~denauroi/protected/Doc/parisanalysis/group__ParisAnalysis__SlicedAnalysis.html

- *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

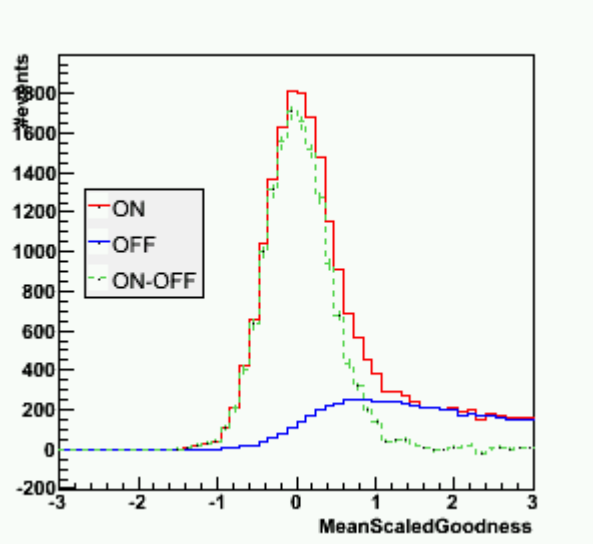
- *Can do maps in energy (or something else) slices*



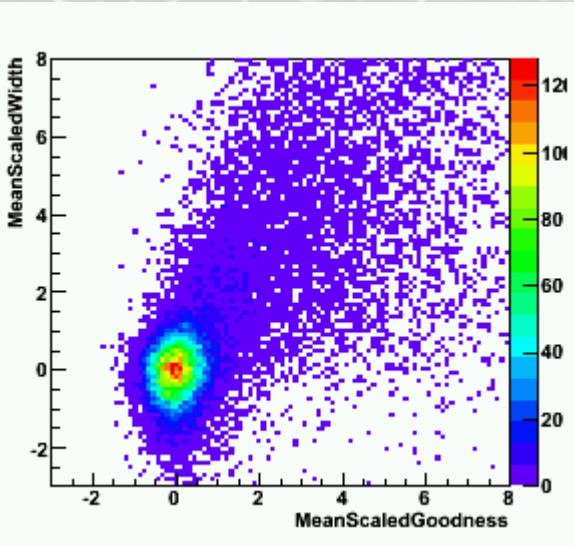
Plot engine

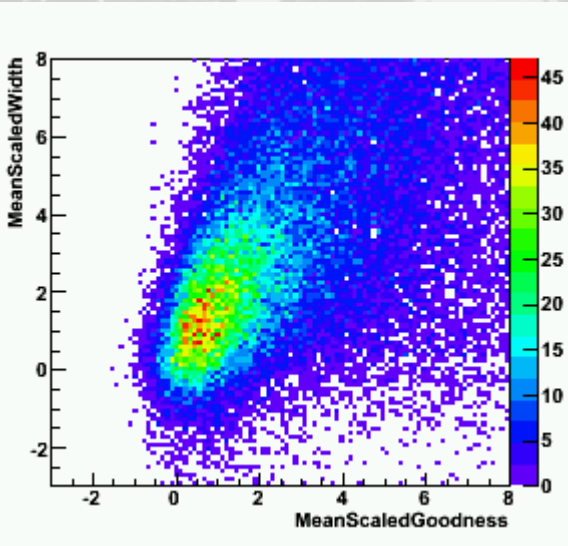
- *Any information available in the data bus can be displayed easily*

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



- *Various display types available*
  - *1D Plots*
  - *2D Plots (⇒ correlation studies)*
  - *Correlation plots*
  - *ScaledPlot (mean and rms of one variable versus 2 others)*
  - *SkyPlot*
- *Plots saved in the result file*

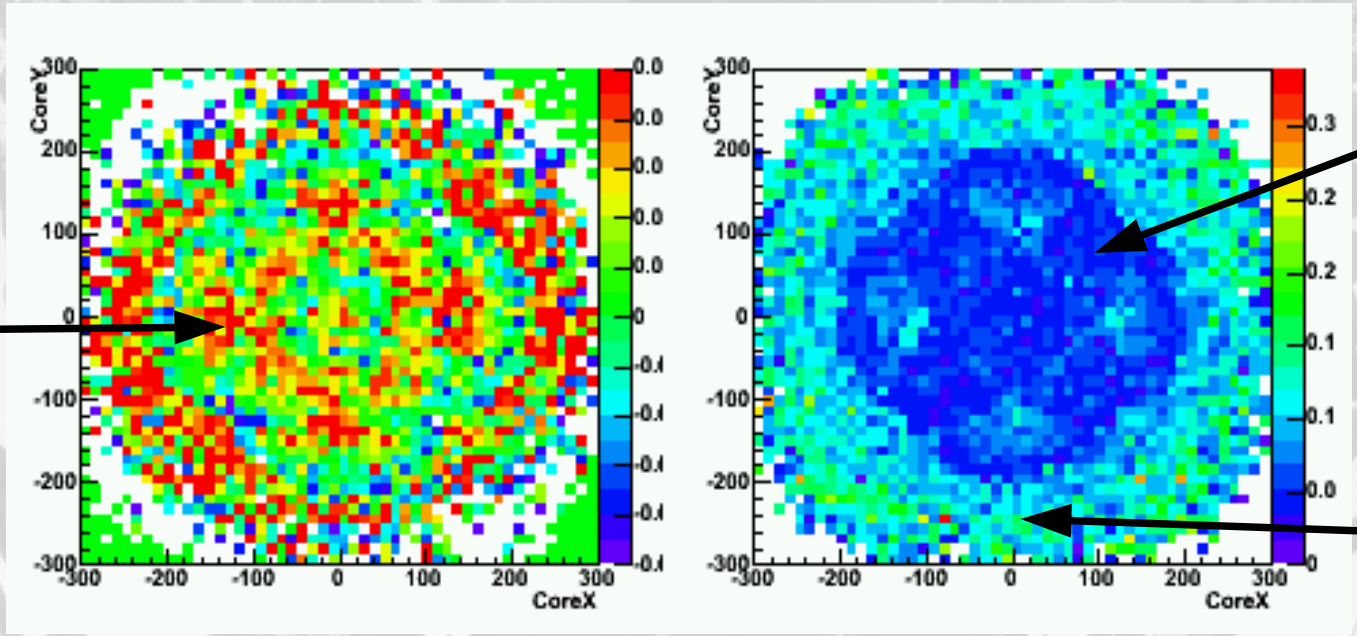




Plot example – Scaled plot

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

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



+5% energy bias

Resolution ~ 7%

Resolution > 10%

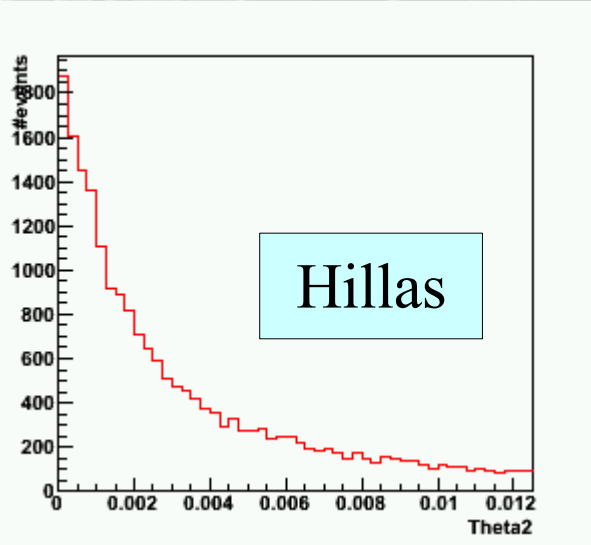
Average

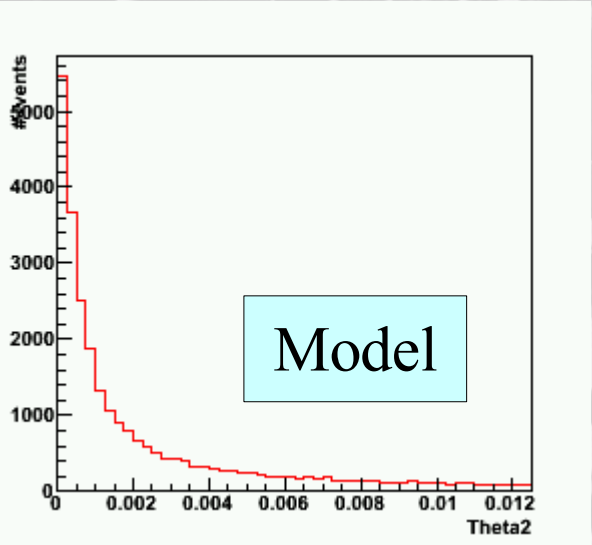
Sigma

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");
```

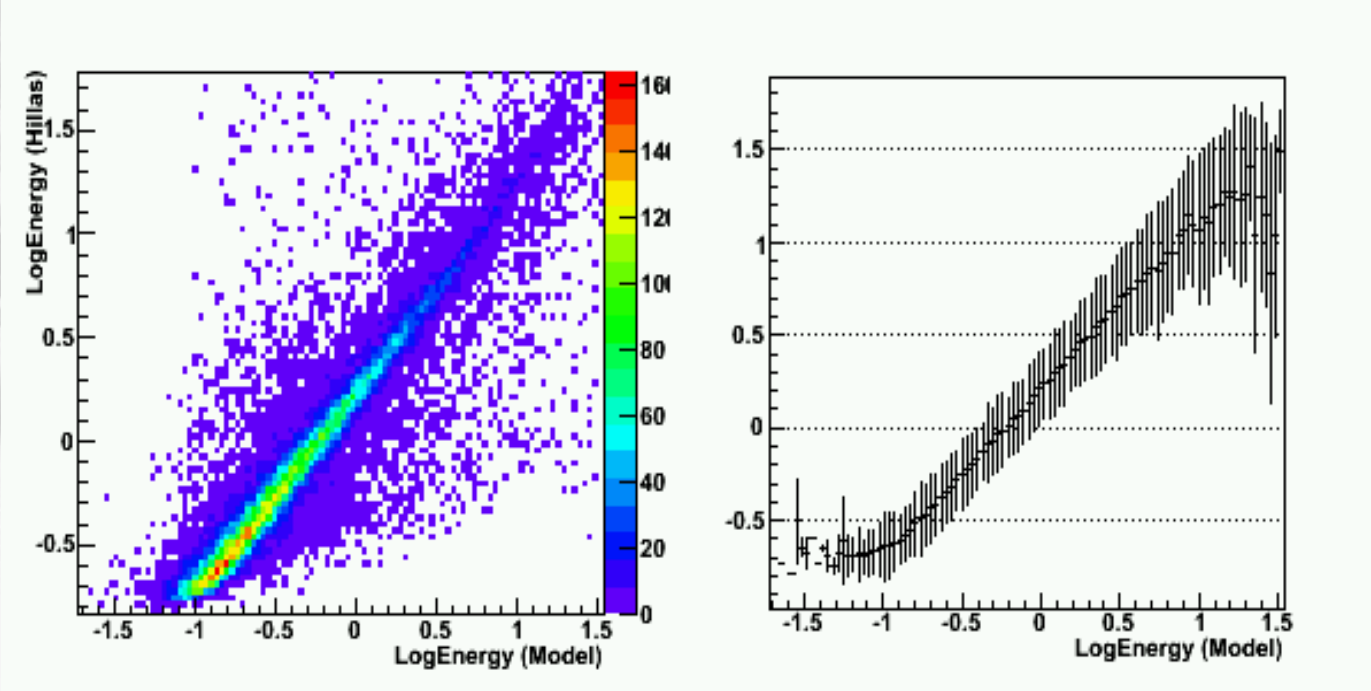




Plot example – Reconstructions correlations

- *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

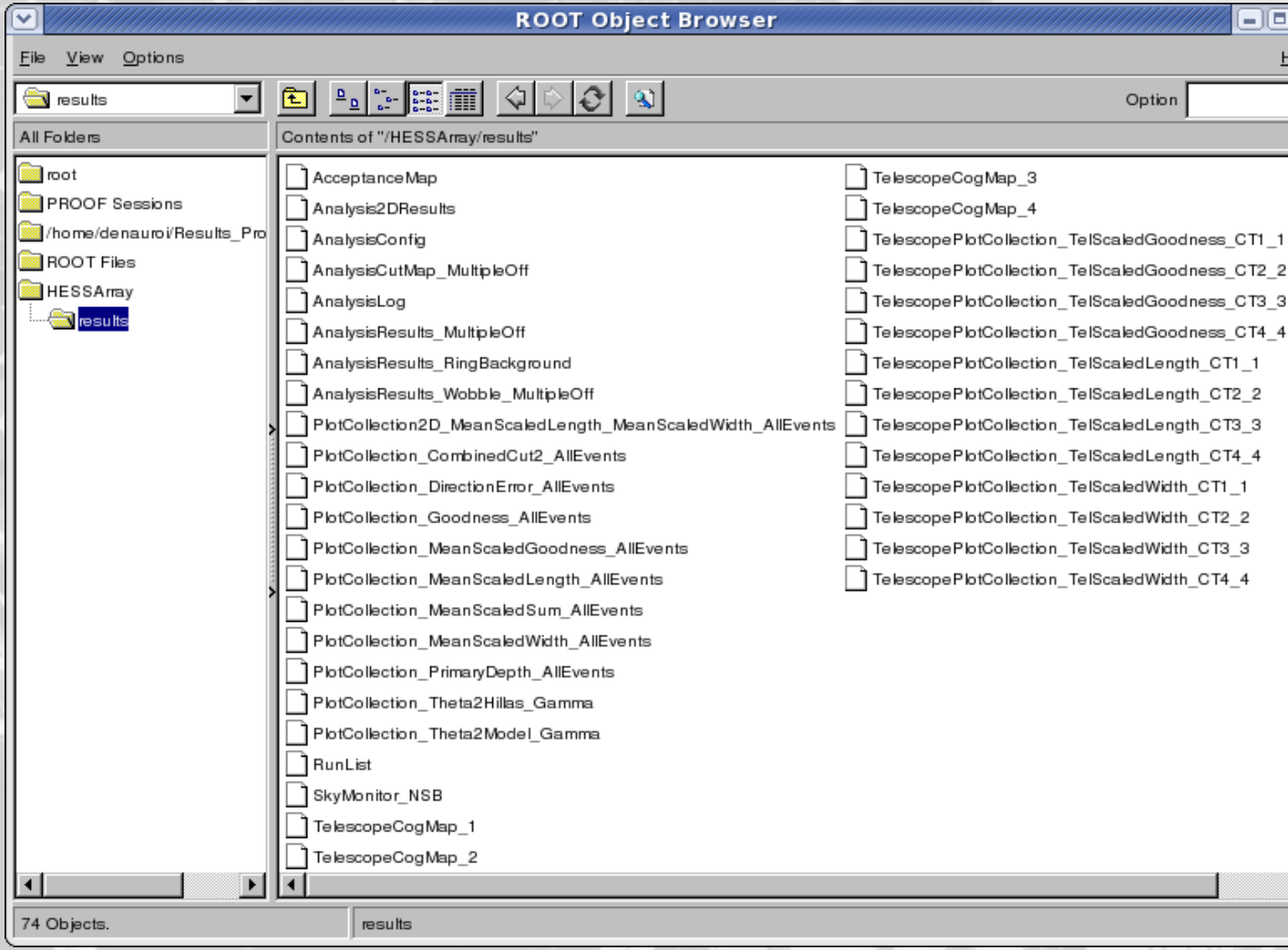
Optional Cuts

Go

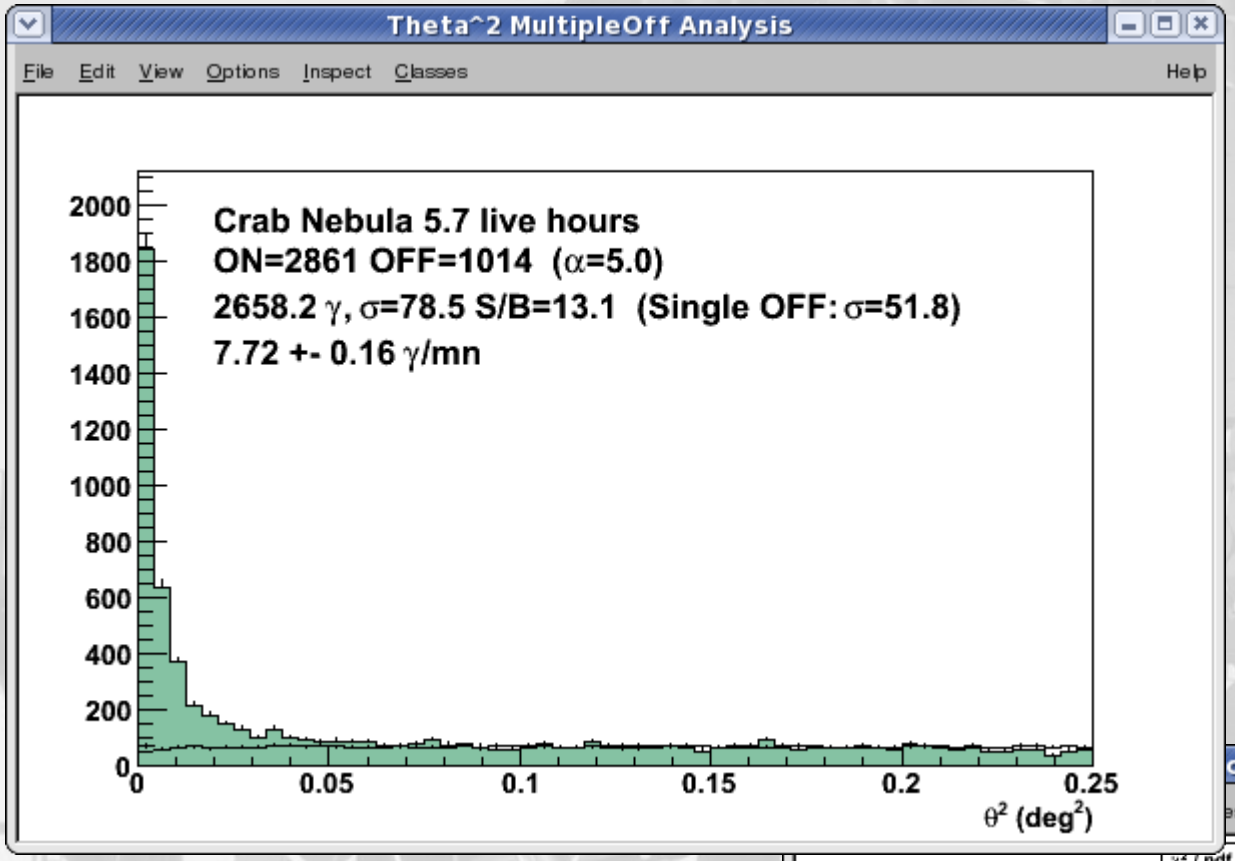
```
...
  // Model Plots
  add_plot("PrimaryDepth",20,-1,6);
  add_plot("MeanScaledGoodness",330,-3,30);
  add_telescope_plot("TelScaledGoodness");
  add_plot("Goodness",330,-3,30);
  add_plot("DirectionError",50,0,0.002);

  // 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

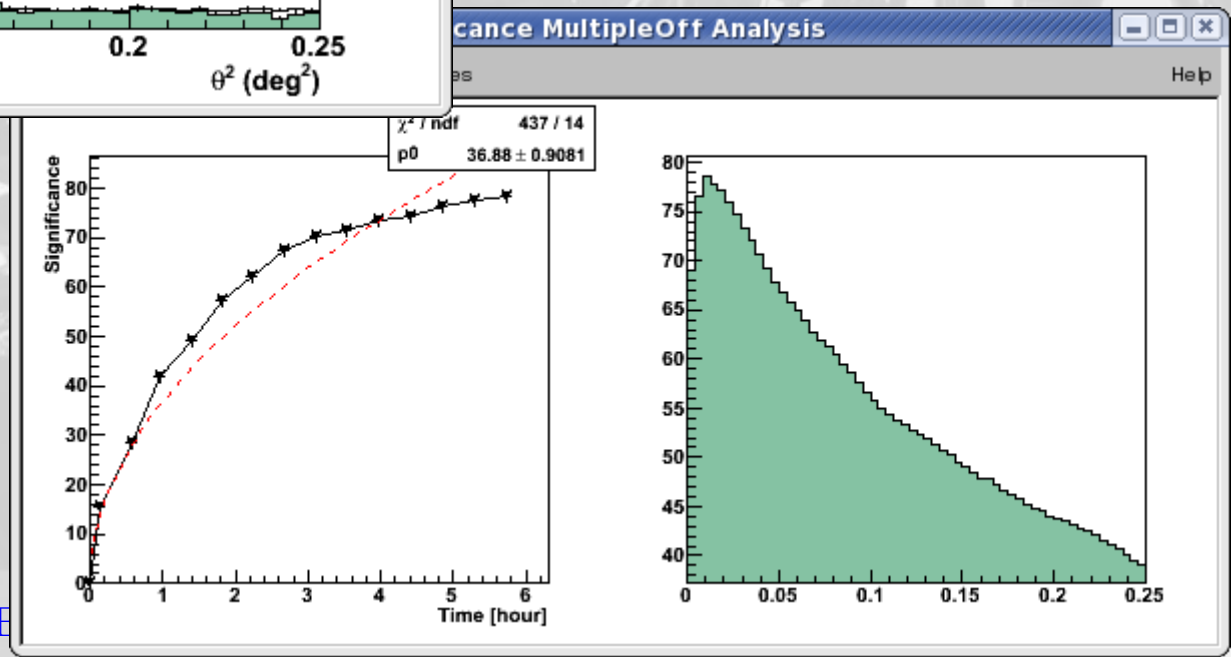
- *Output file "Results_Crab_Combined_Prod16.root"*
- *Many objects produced:*
  - *AnalysisConfig*
  - *AnalysisResults*
  - *Analysis2DResults*
  - *AcceptanceMap*
  - *AnalysisLog*
  - *RunList*
  - *Plots*
  - *SkyMonitor_NSB*



Analysis Results

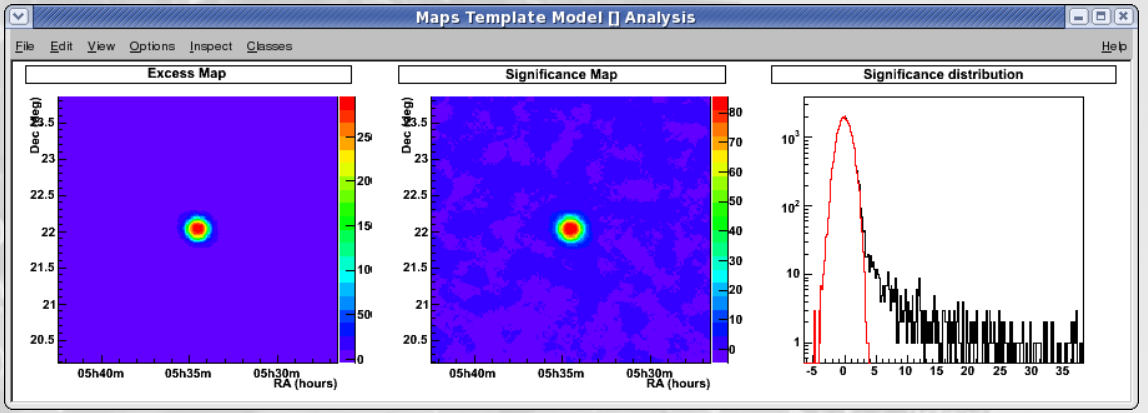


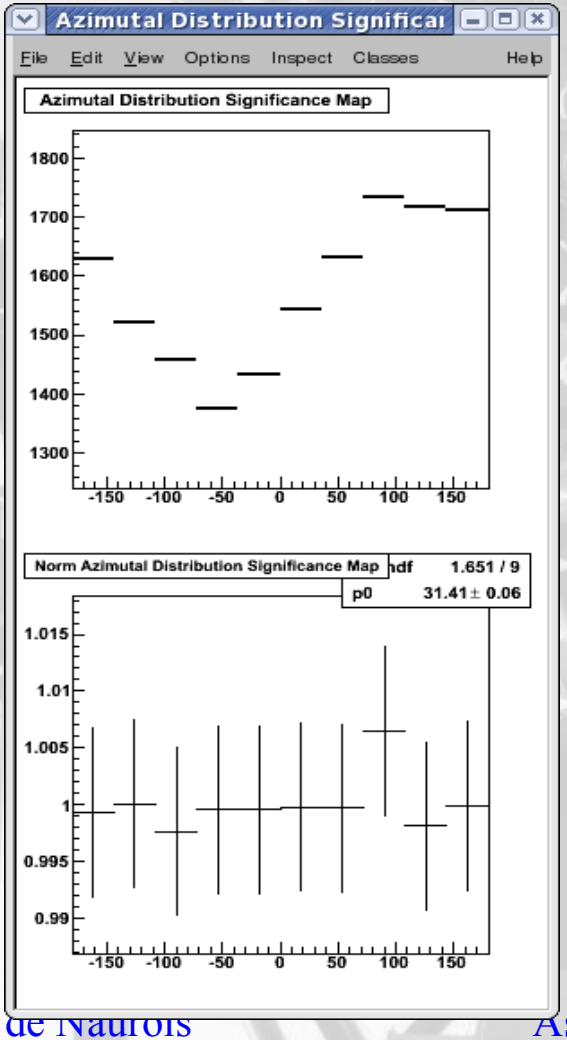
- *θ^2 plot*
- *Sig. Over time*

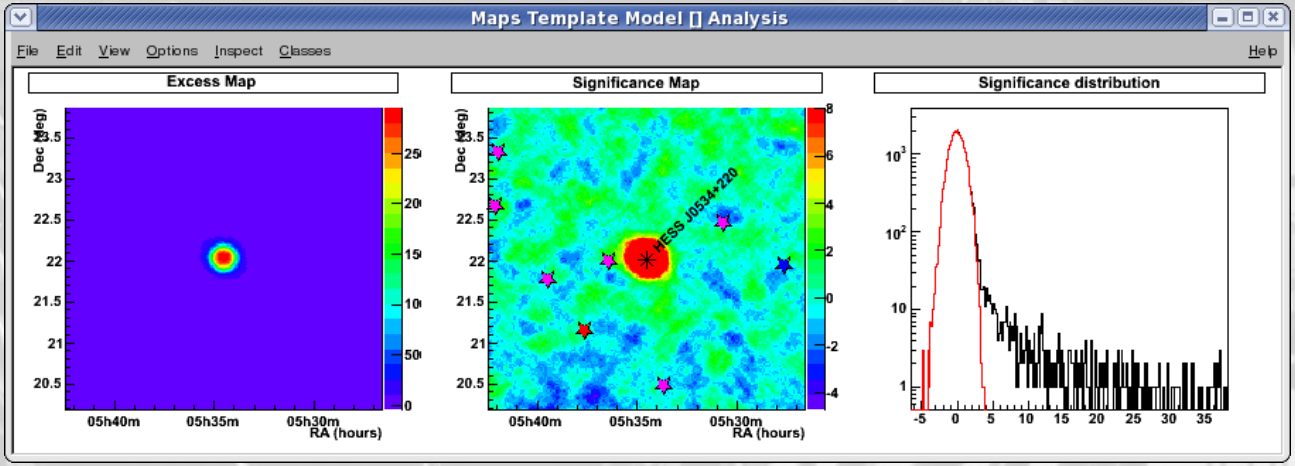


Analysis2DResults

- *Sky Maps*
- *Projections*

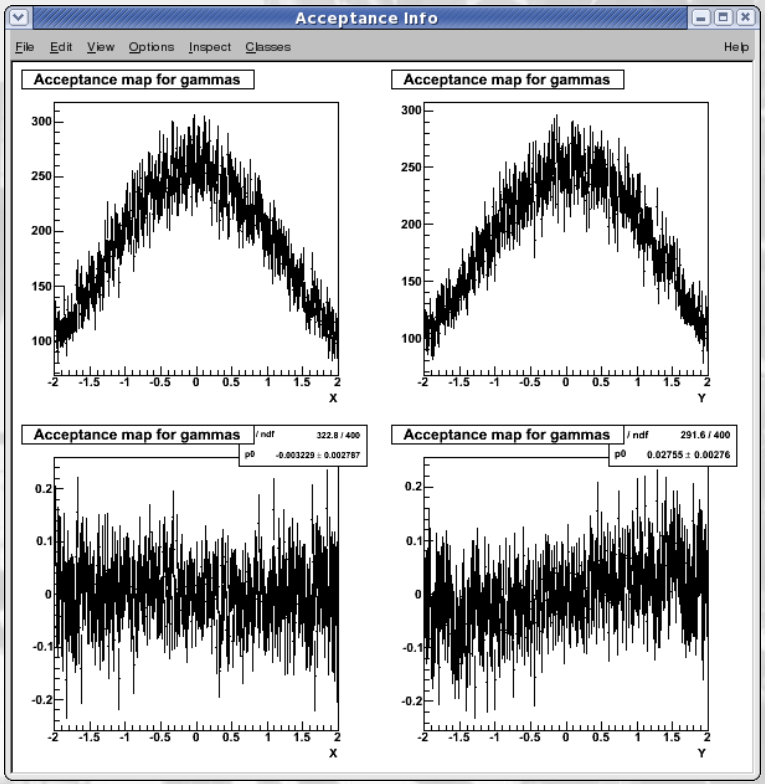


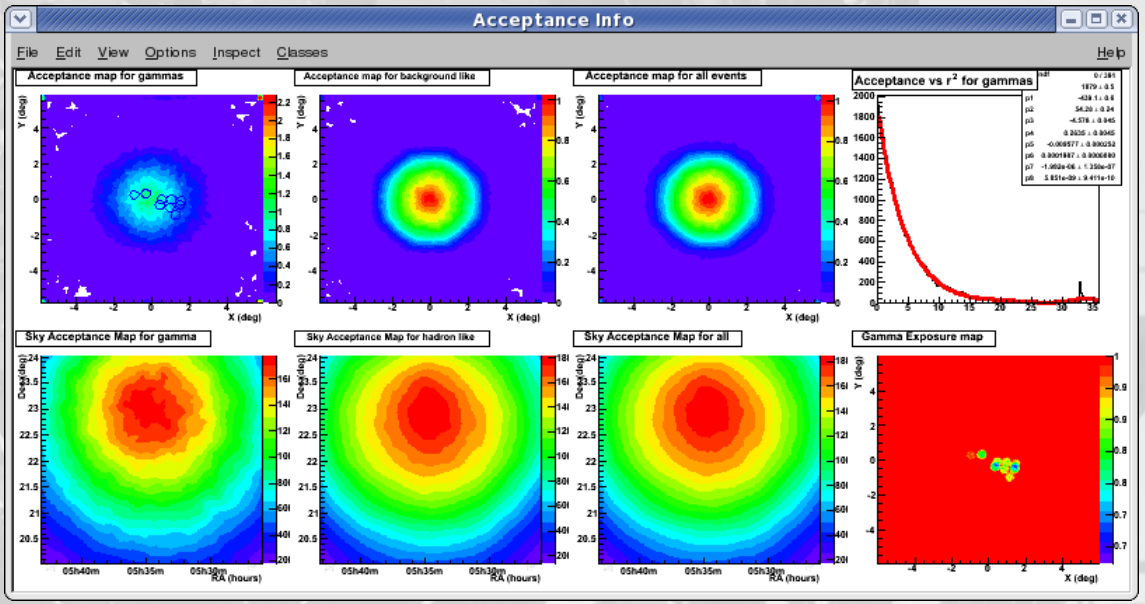


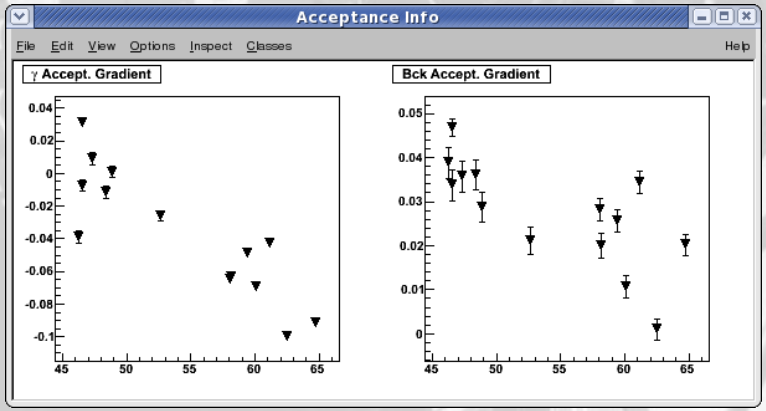


AcceptanceMap

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

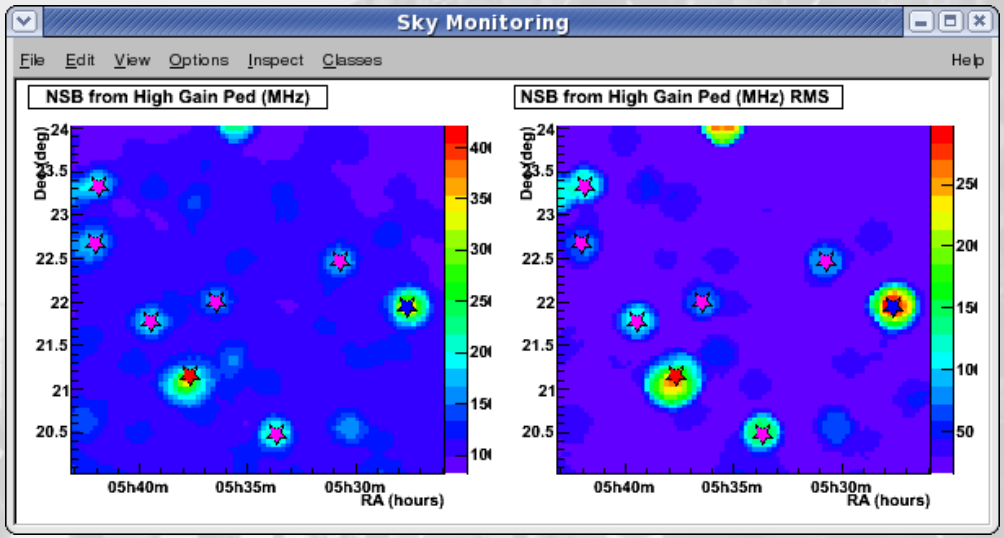


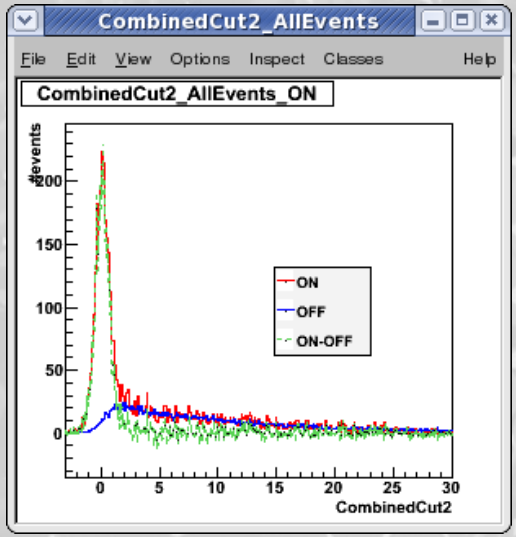


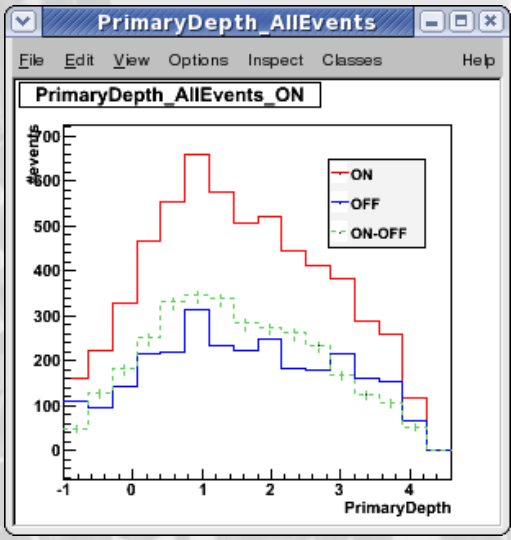


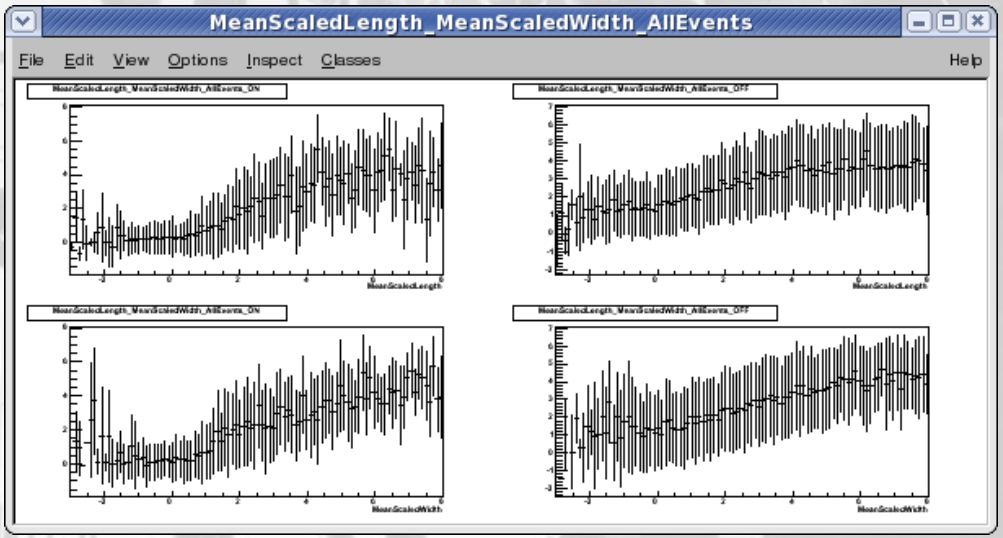
Plot Collections

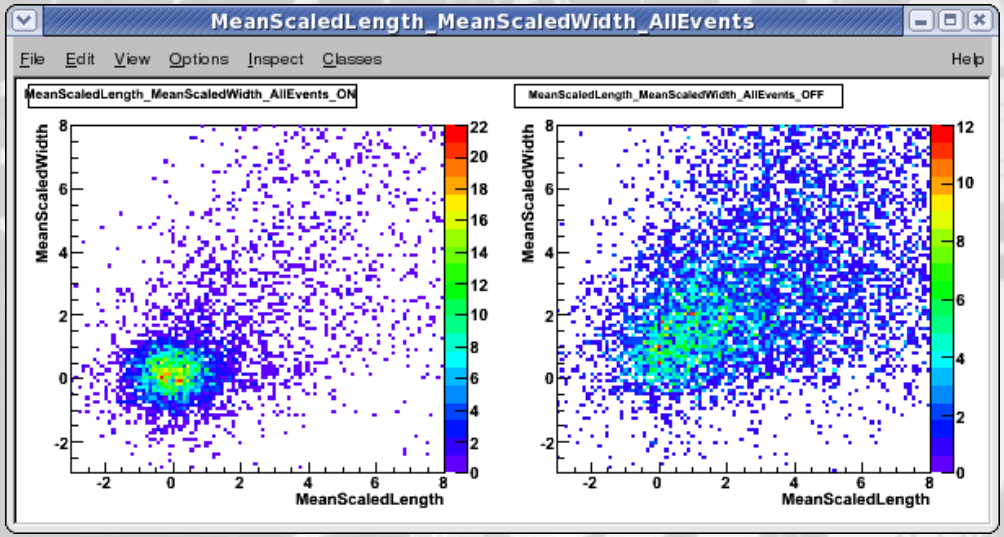
- *All plots (one object per plot)*





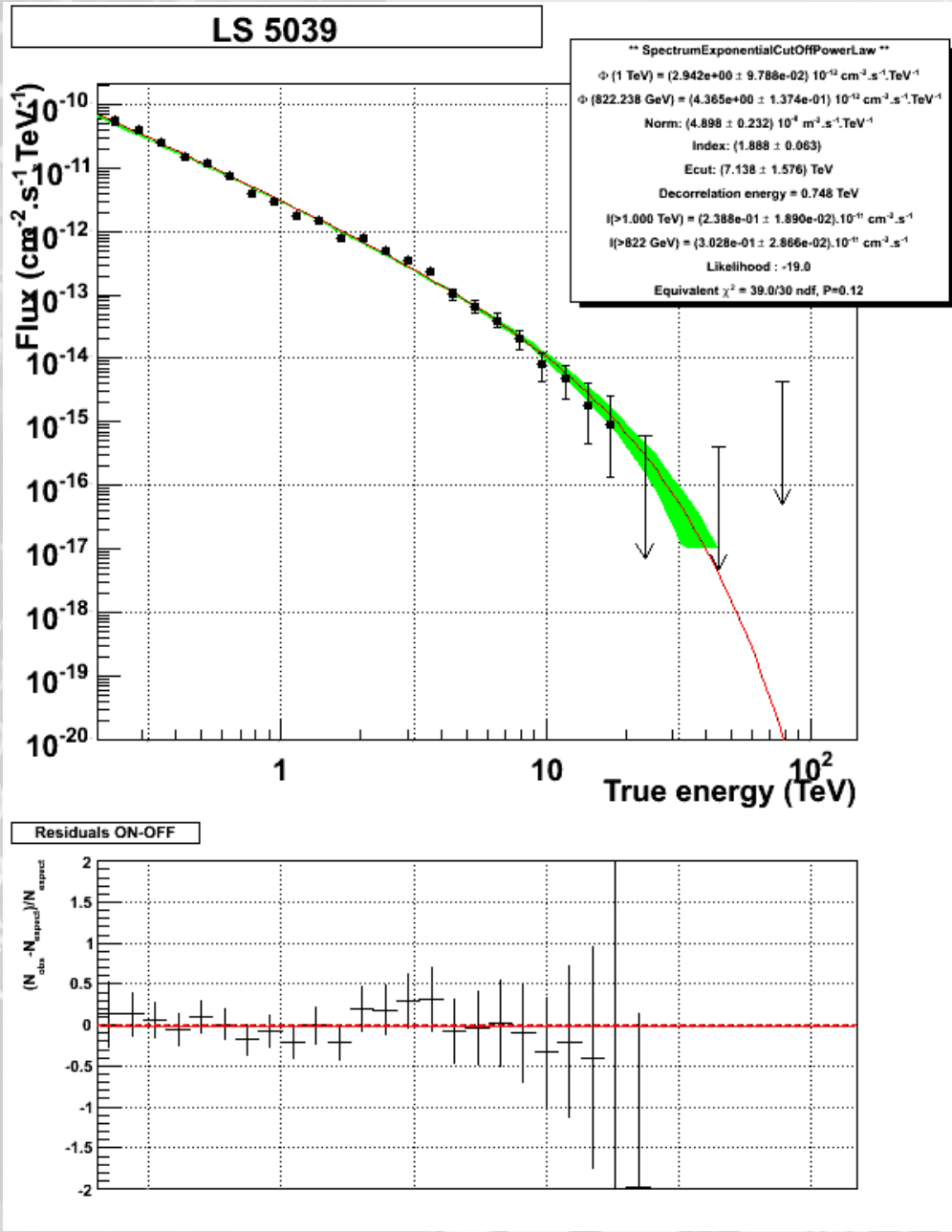




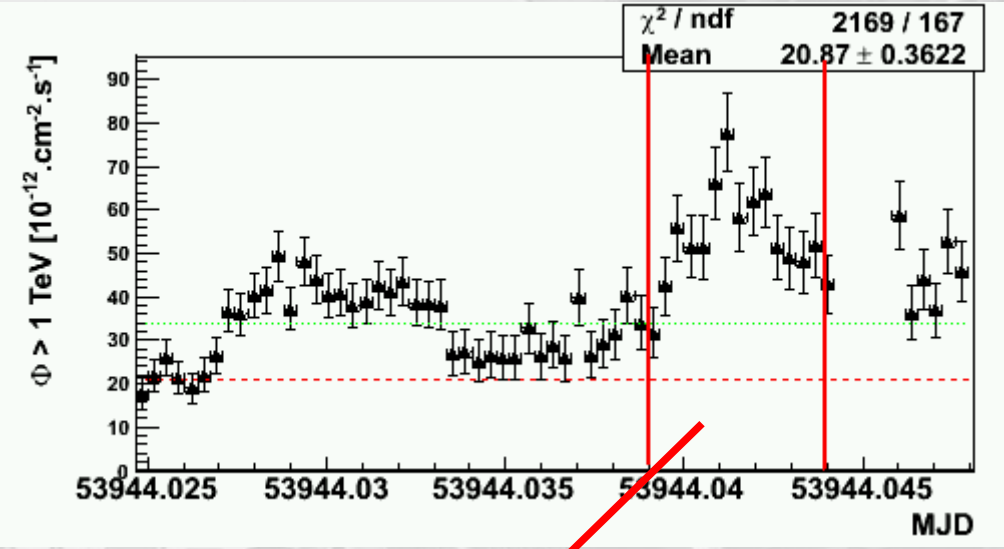


Spectrum module
Spectrum, lightcurves, ...

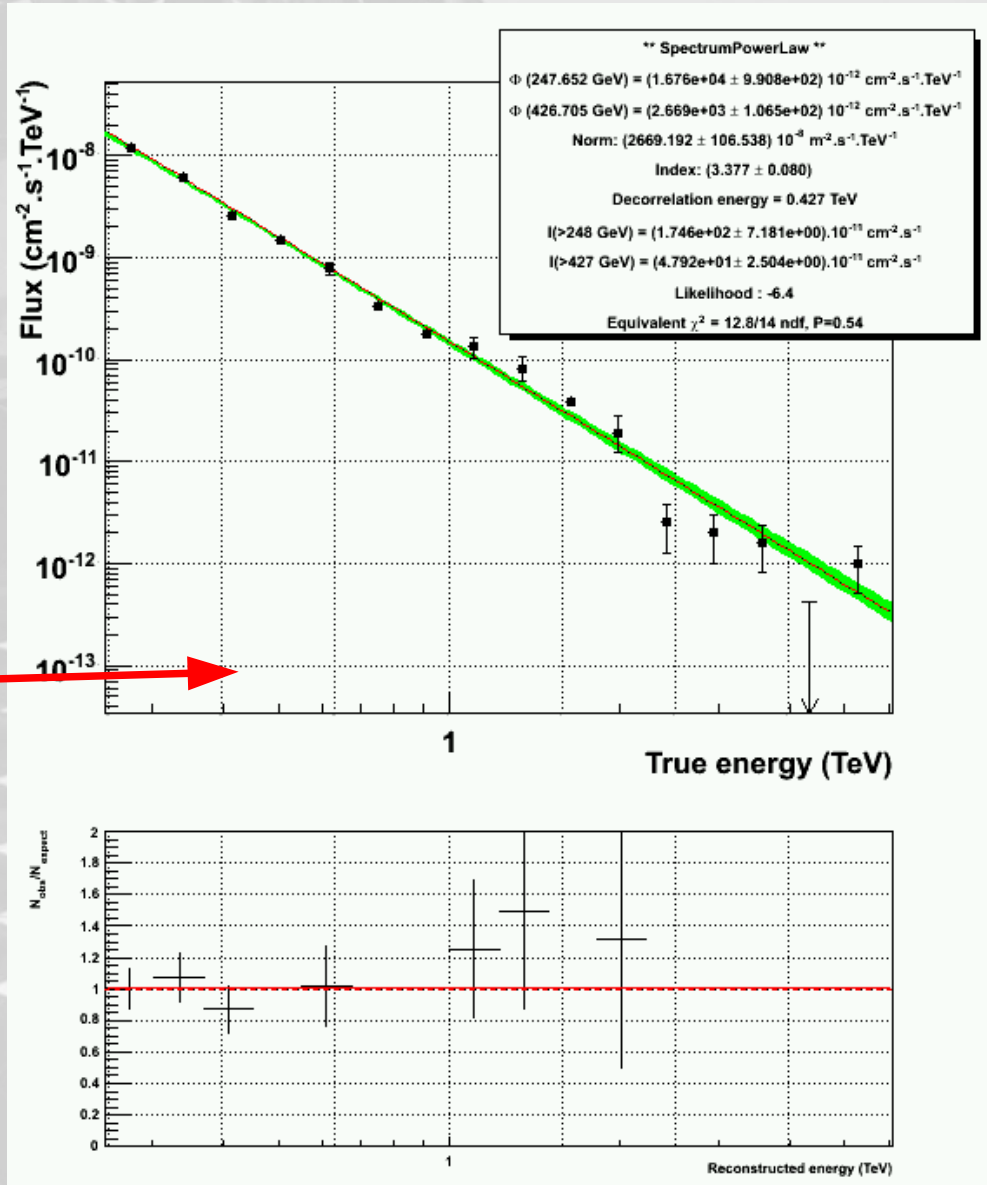
- *Forward folding technique (See Santiago's talk)*
- *Completely independent from the reconstruction technique*
  - *Works with combined variable, user variable, ... without recompilation*
  - *Many spectral shape available: Power Law, Broken Power Law, Curved Power Law, Power Law with cutoff, Annihilation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



Short time-scale spectra



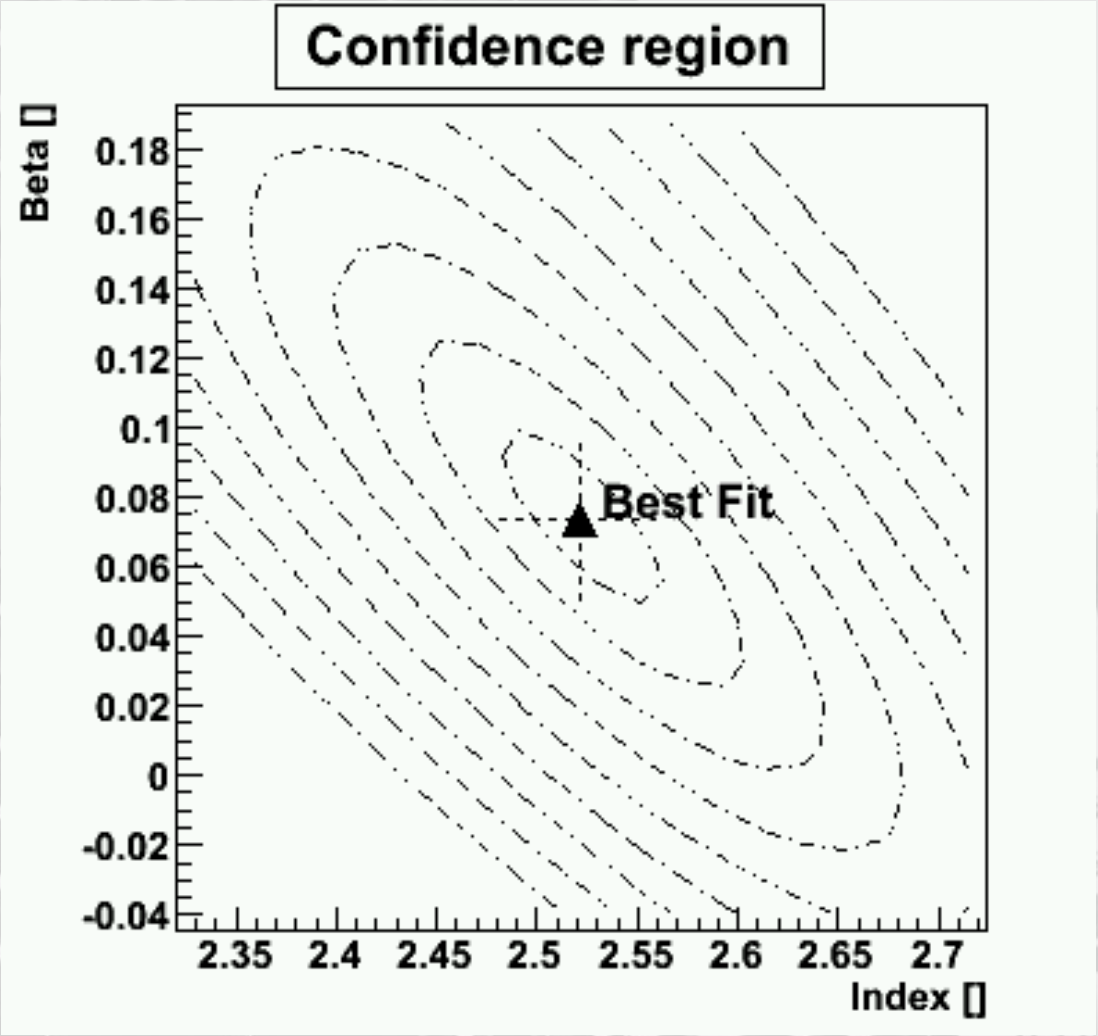

```
set_time_range(53944.039,53944.044)
FitSpectrum("PKS2155...")
```



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

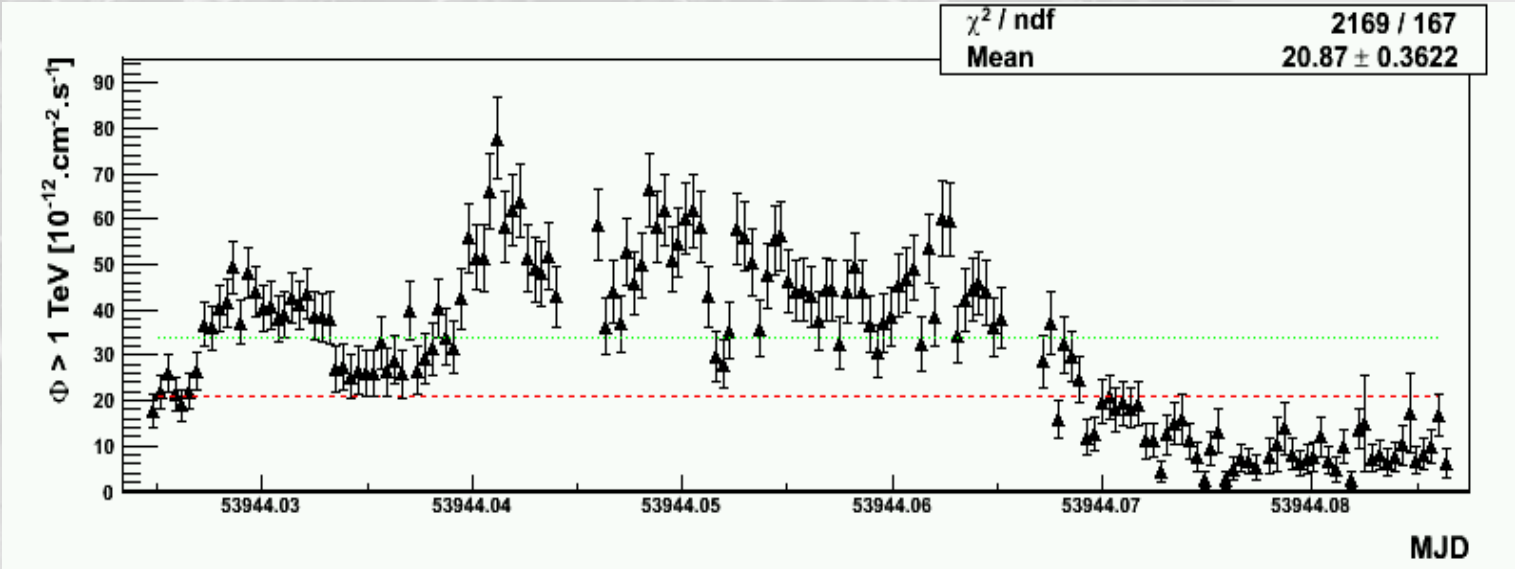
Confidence regions

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



LightCurves

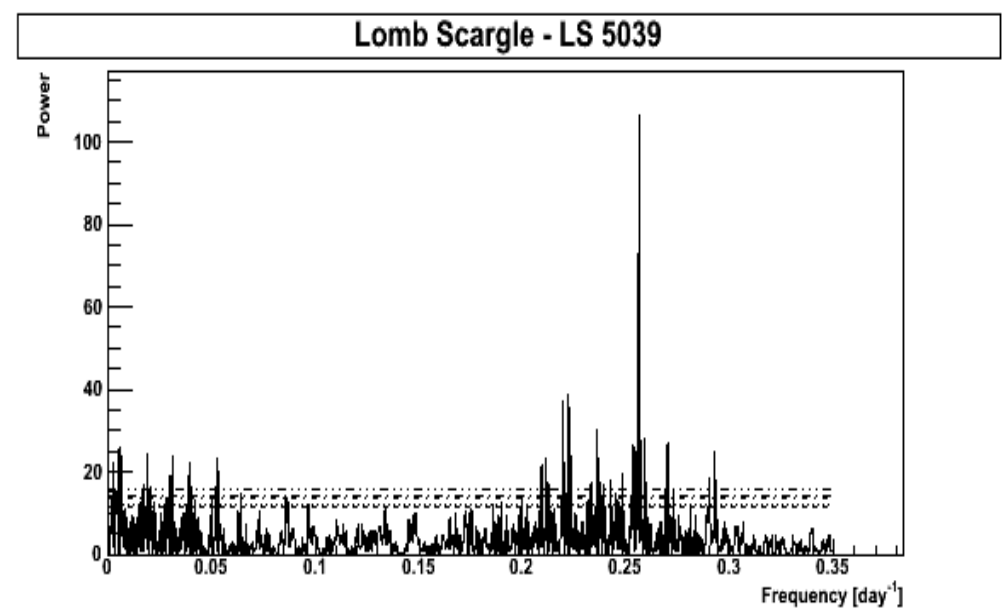
- *Run-by-run, night-by-night*
- *Arbitrary time-slice lightcurves*

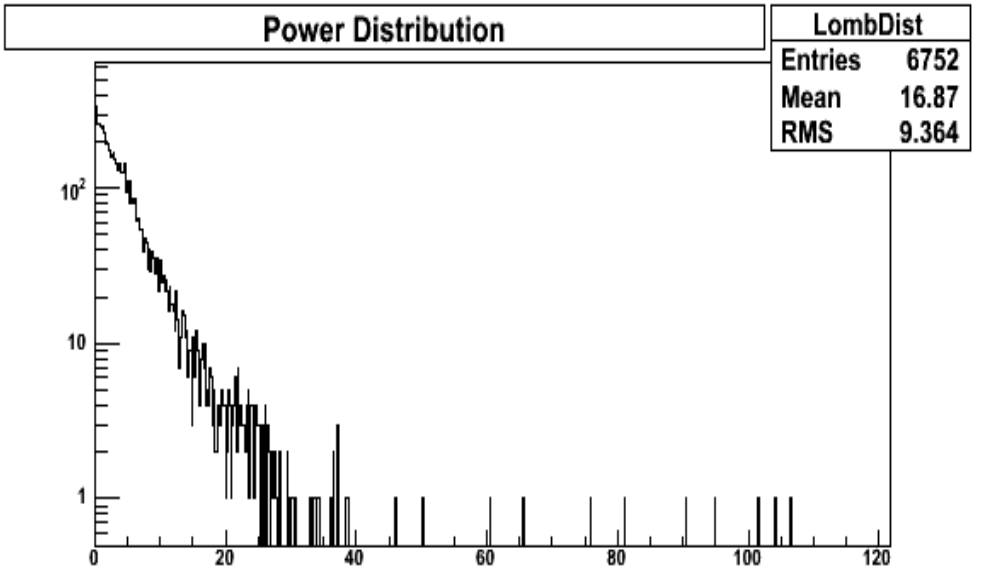


- *Several lightcurve determination techniques:*
  - *Event-base acceptance weighted,*
  - *Using spectrum shape assumption,*
  - *…*
- *Other lightcurve types: CR rate, hardness ratio, spectrum parameters lightcurve (i.e. Spectral index vs time)*

Periodicity

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



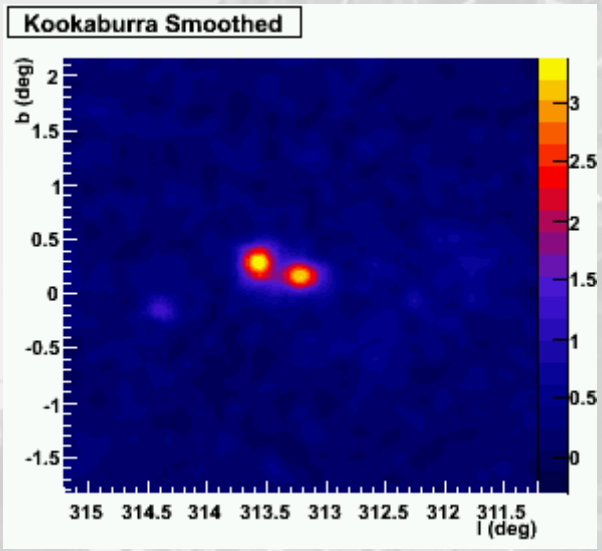


Morphology module

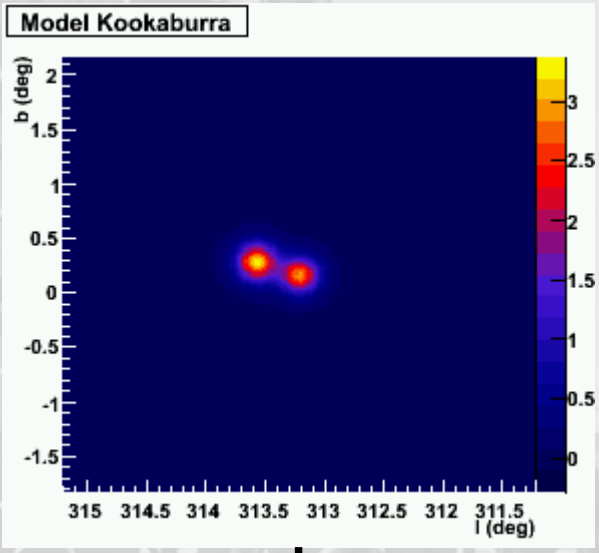
- *Forward folding technique applied to morphological studies*
  - *Derive intrinsic source size (or other parameters) (or upper limit)*
  - *Source position determination*
  - *Map smoothing (using actual Psf)*
  - *Source subtraction*
  - *...*
- *Also fully documented*

Morphology example – Source subtraction

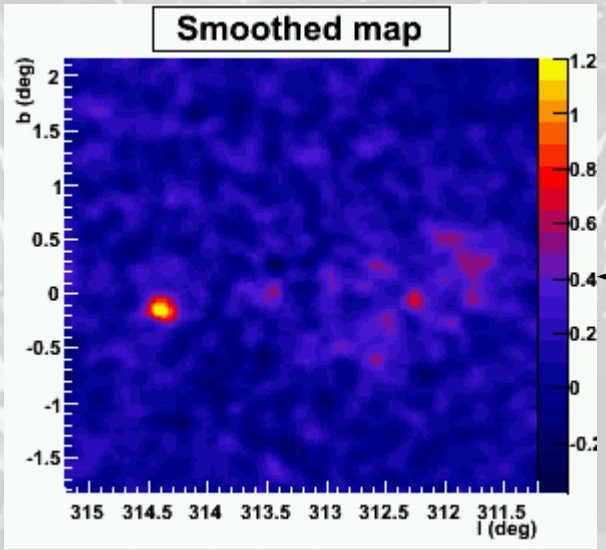
- *Kookabura region's smoothed map*



Fit of 2 point-like sources



Subtraction of the 2 sources

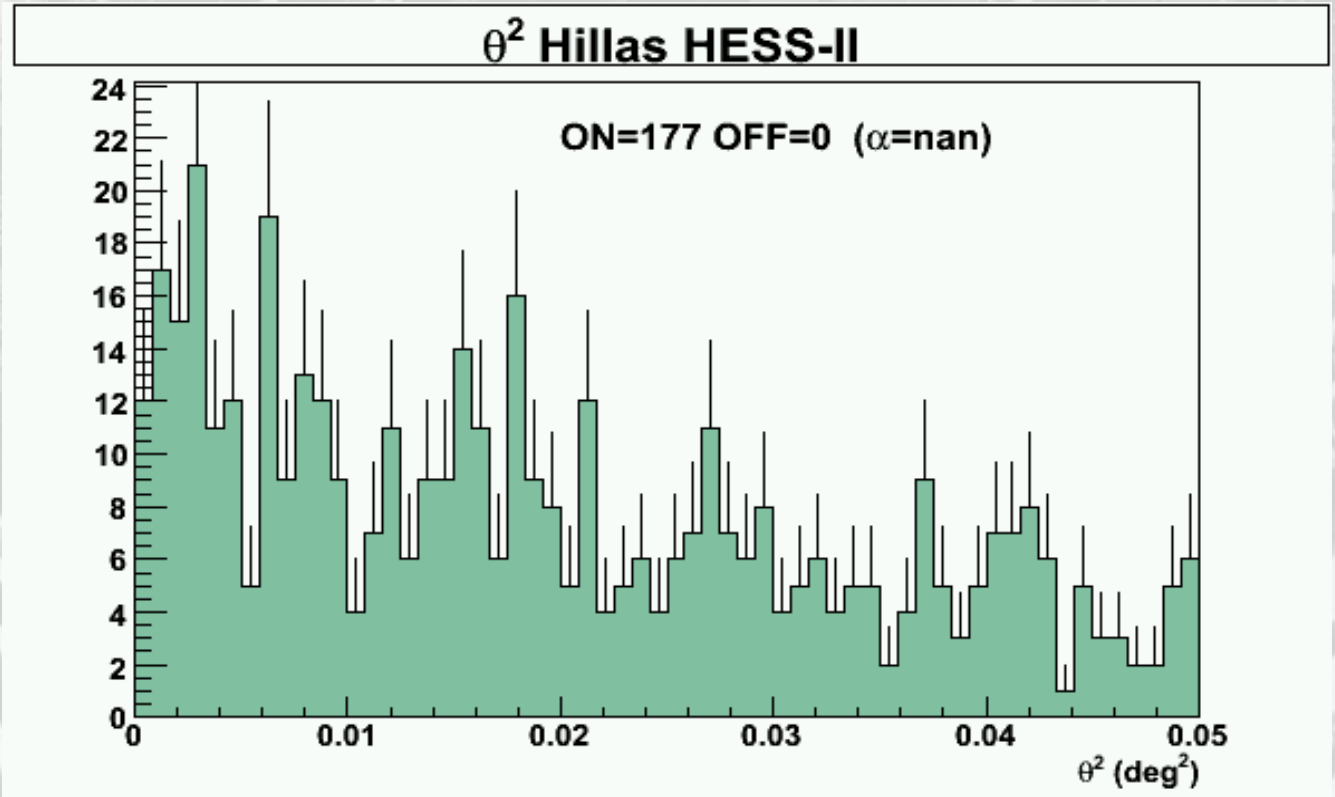


ParisAnalysis customization

- *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 (Xeff), using Model and Hillas Pdfs for simulated γ and real off data*
  - *Base for user developments*
- *muDST output module (for Sash independent analysis)*
  - *See Nukri's talke*

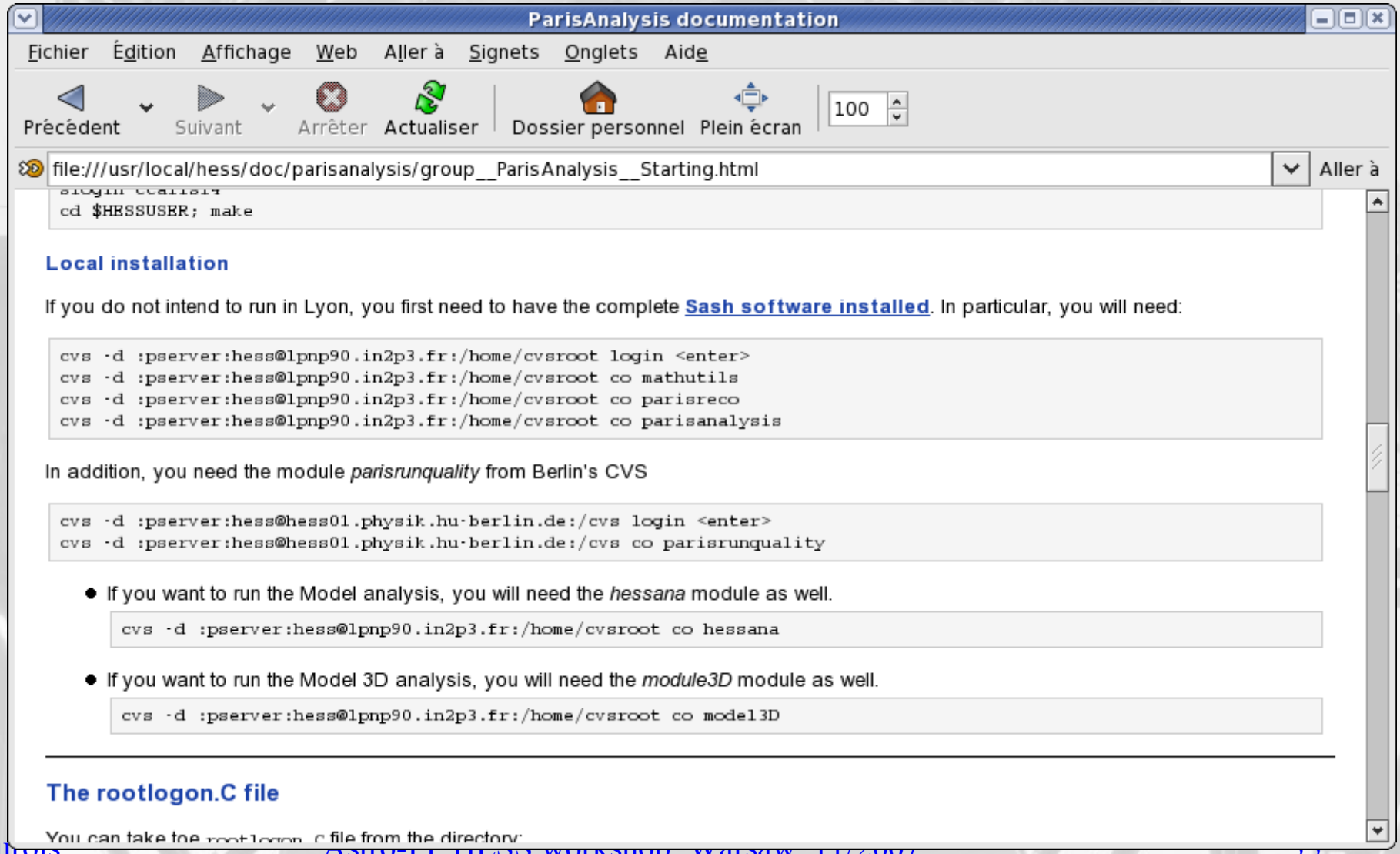
HESS-II capabilities

- *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

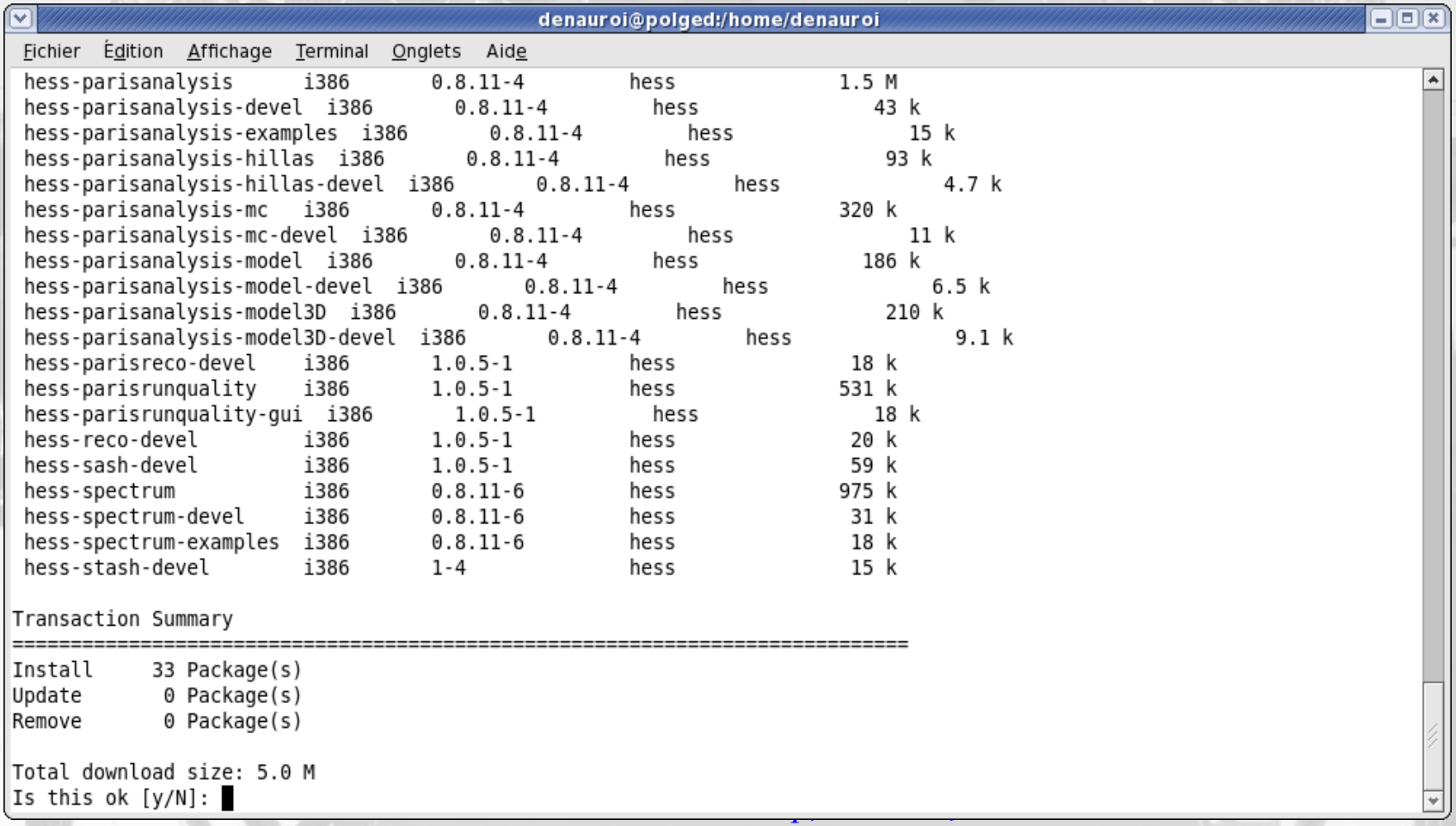
- *Central installation in Lyon ($THRONG_DIR)*
- *Installation procedure fully documented*



Yum installation

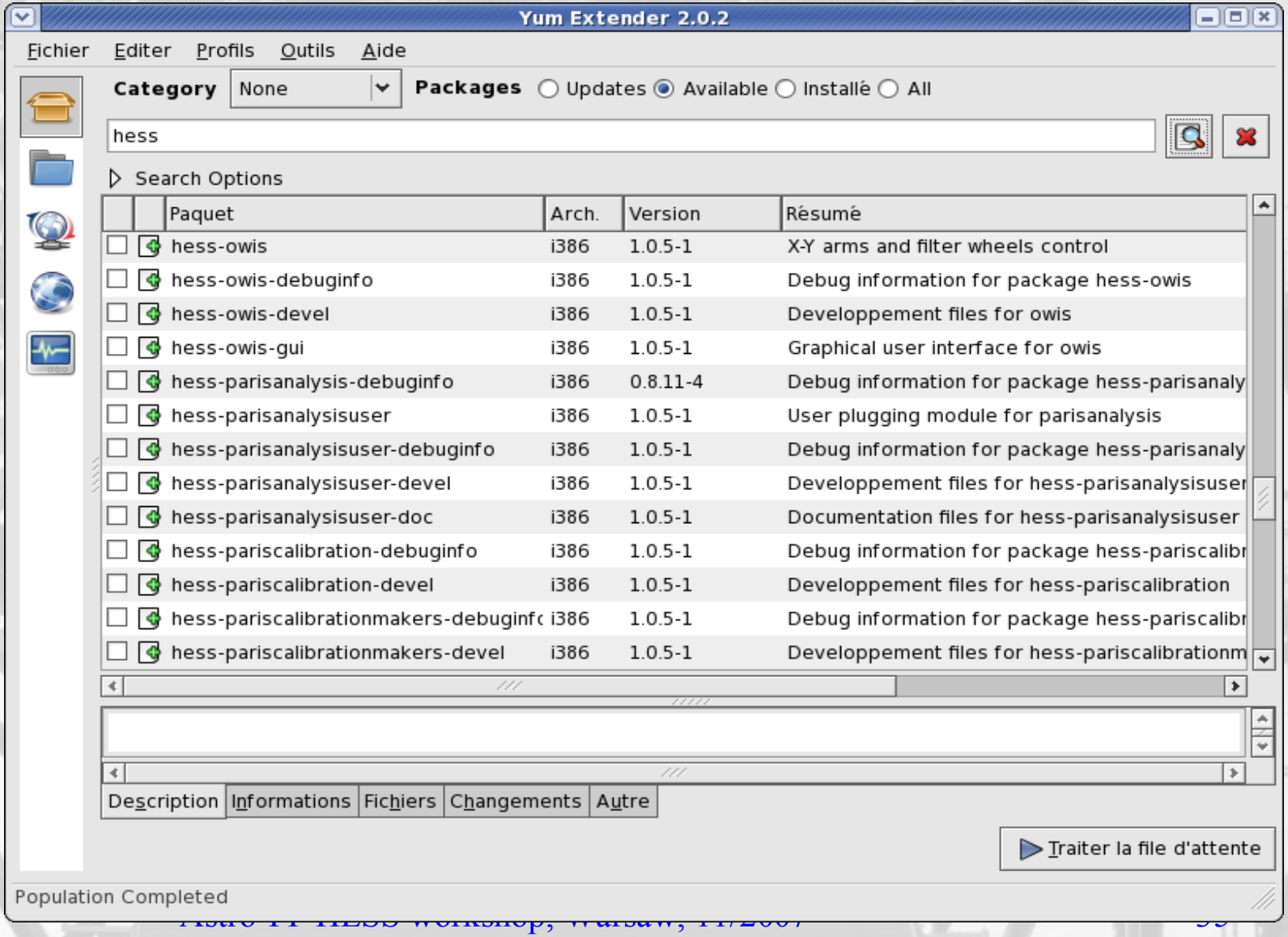
- *Yum repository (standard Redhat/Fedora/Ubuntu/...) available for Fedora 6 and Fedora 7 (SL4 will be added)*
  - *http://lpnp90.in2p3.fr/~hess/Software/For_Fedora6/hess-release-6-4.noarch.rpm*
  - *http://lpnp90.in2p3.fr/~hess/Software/For_Fedora7/hess-release-7-4.noarch.rpm*

> yum install hess-parisanalysis-full



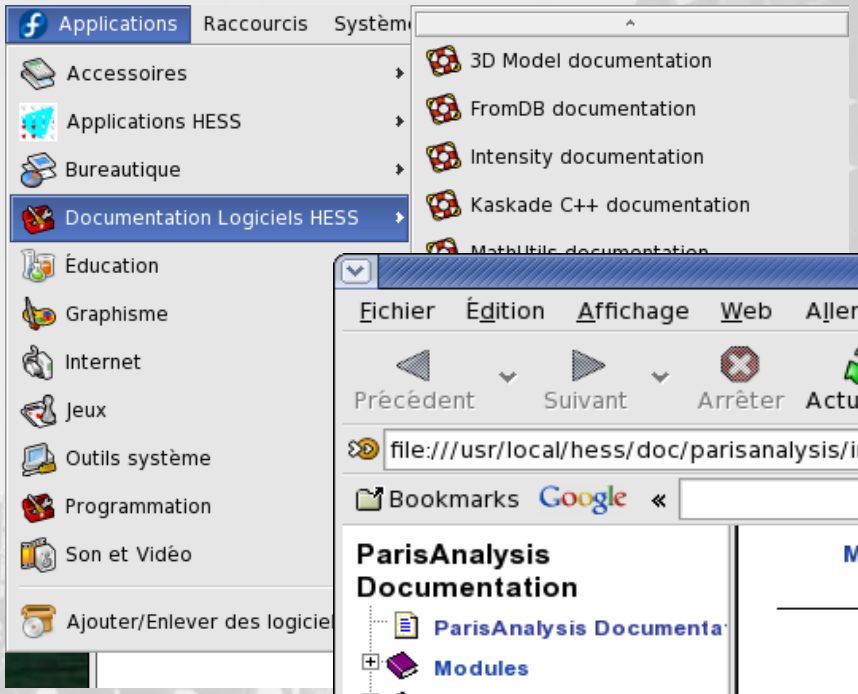
Yum installation (2)

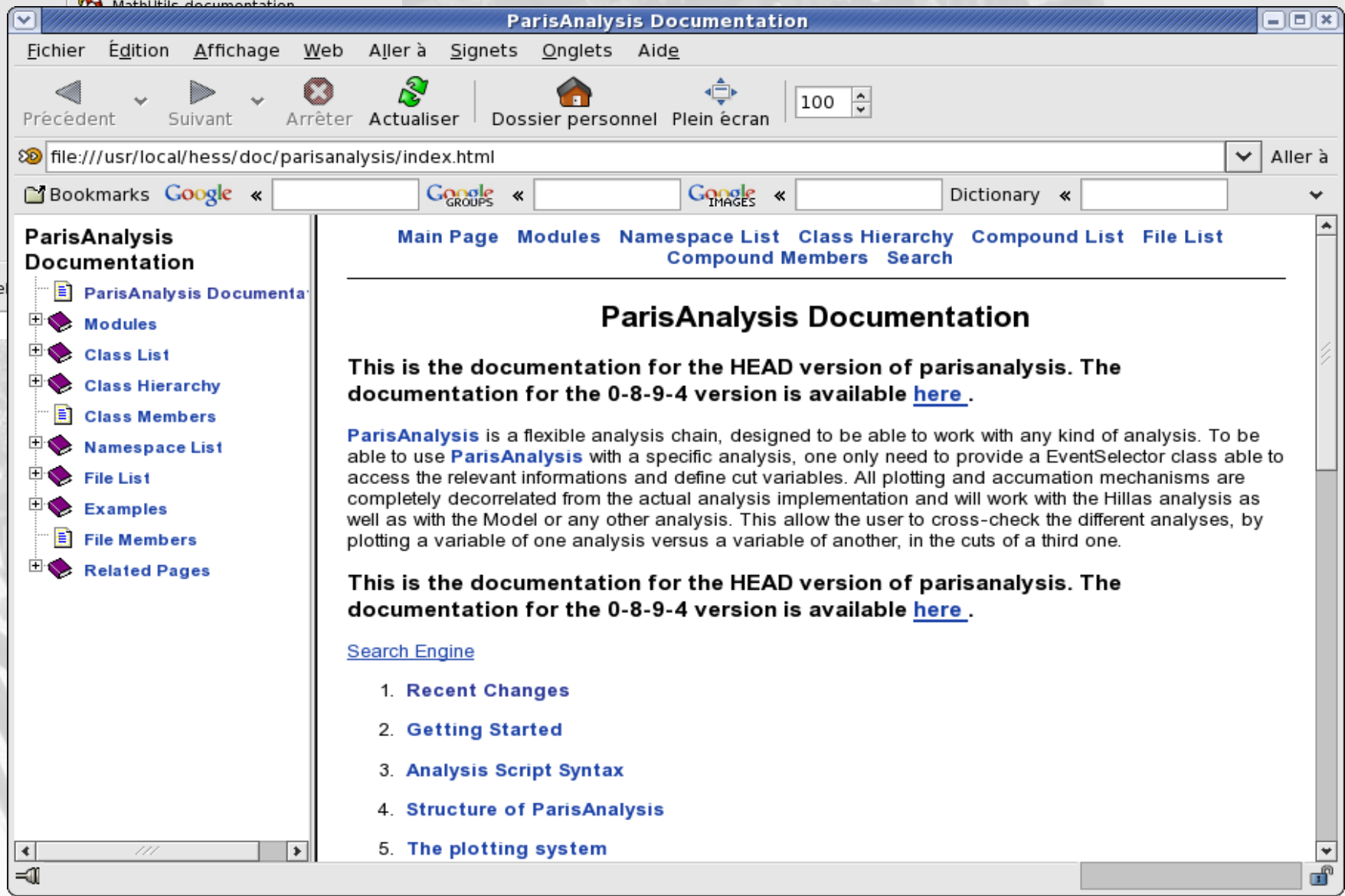
- *Package installation with yumex*
  - *Dependencies handled properly*
  - *Stay up-to-date easily, no compilation*



Desktop integration

- *Application menu*
- *Documentation menu*



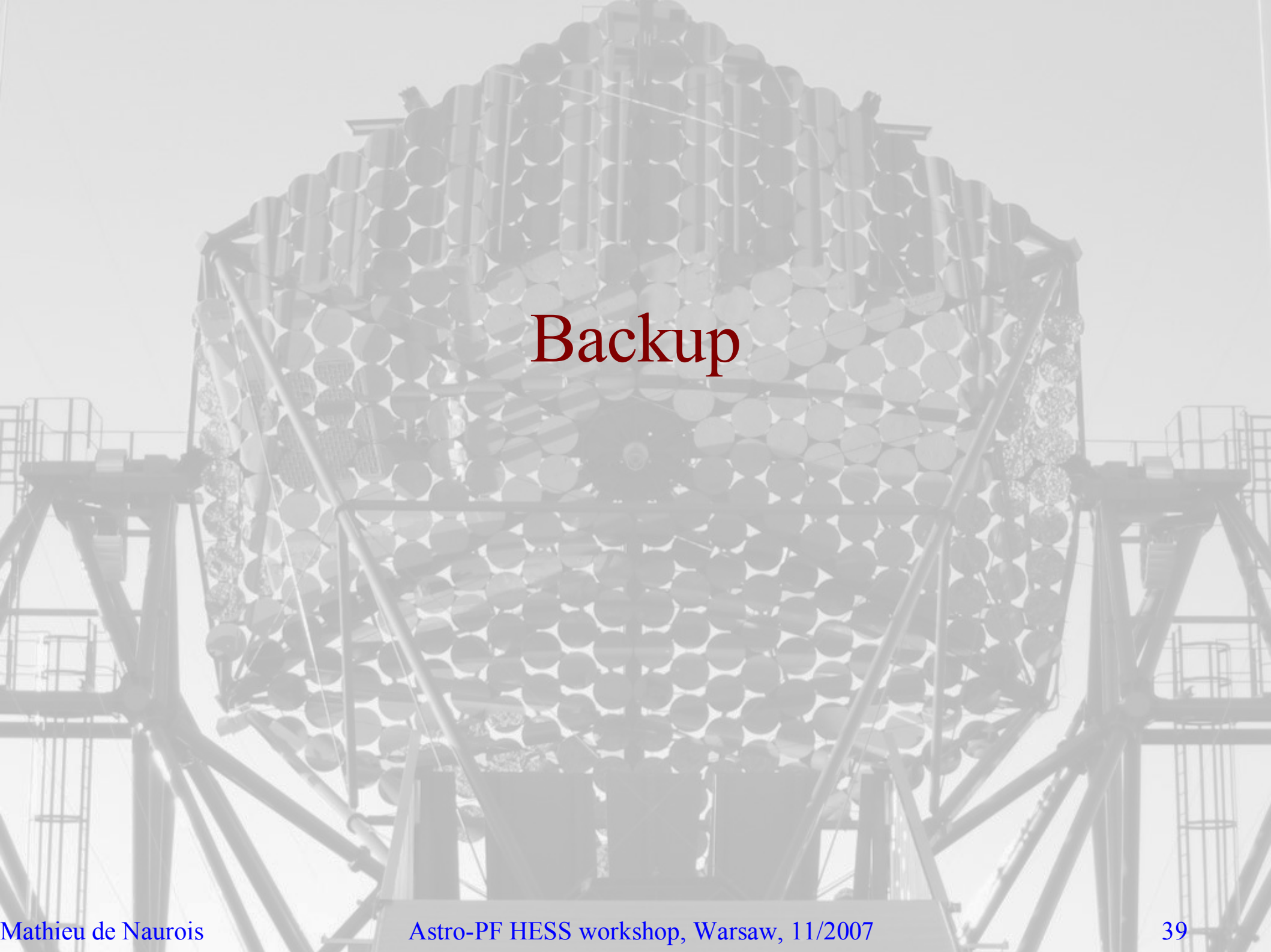


Summary

- *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*



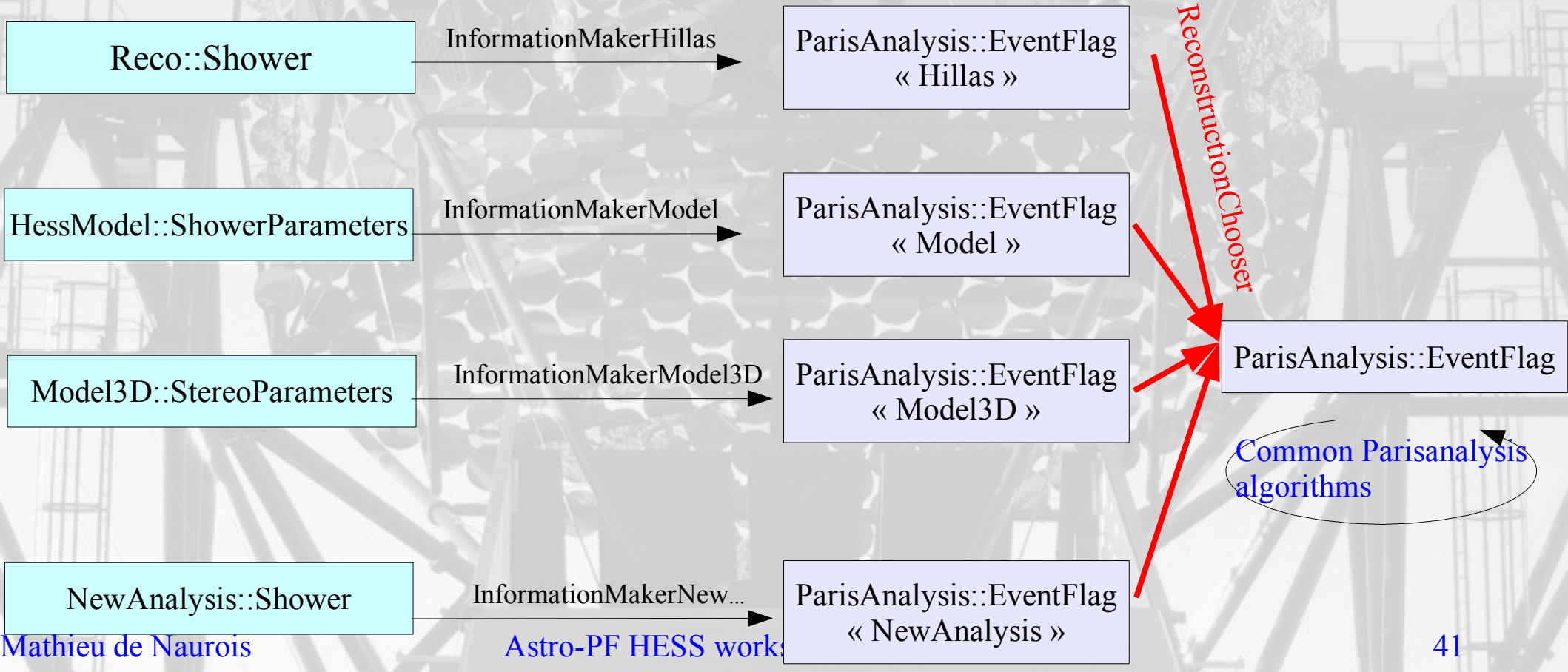
Backup

Résumé : types de soustraction de fond

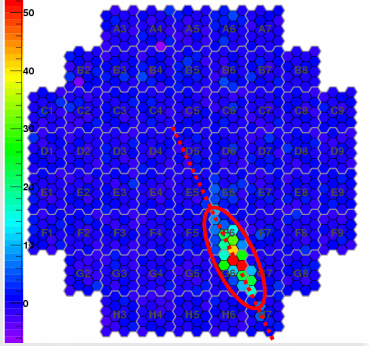
Nom	Spectre	Cartes	Commentaires
Ring Background	OUI	OUI	Spectre: Ne marche que pour les petites sources, non centrées dans la caméra, suppose une symétrie azimuthale Cartes: Nécessite de bien définir toutes les régions d'exclusion pour éviter un déficit autour des sources
Multiple Off Regions	OUI	NON	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

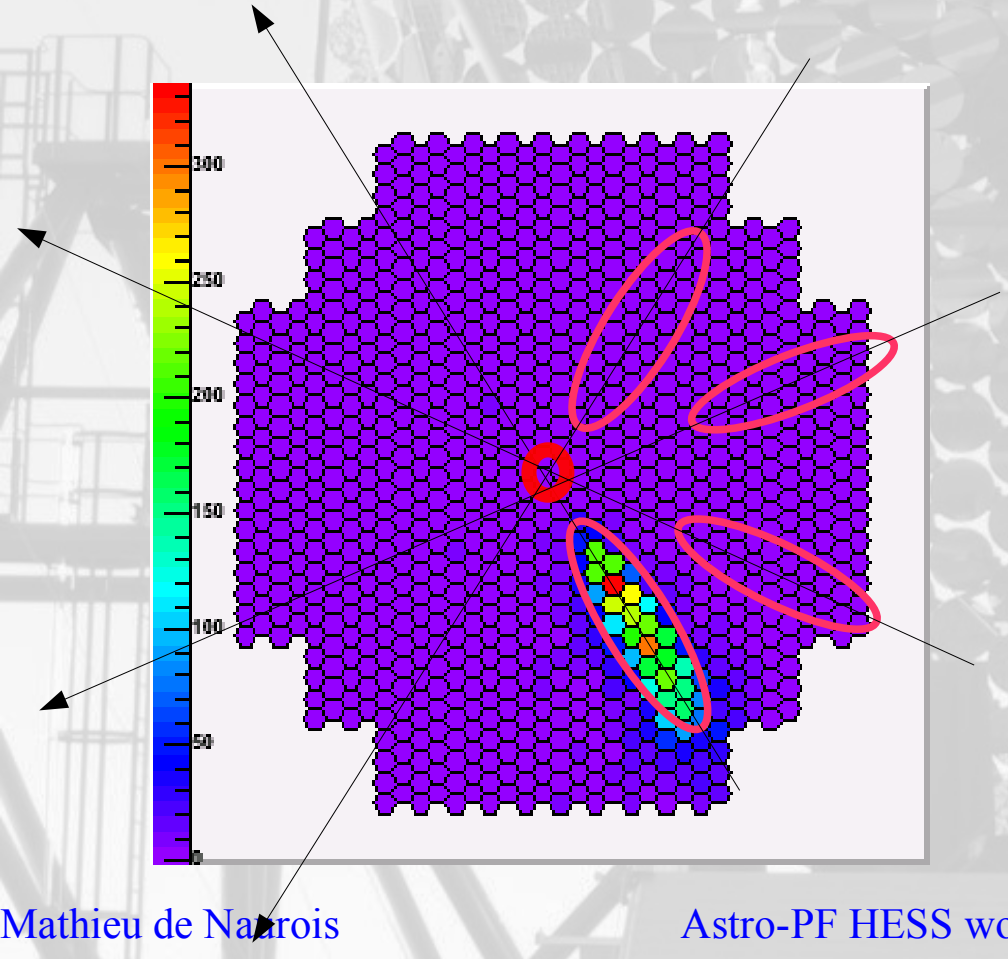
- *One data bus (ParisAnalysis::EventFlags) filled by a ParisAnalysis::InformationMaker specific to each reconstruction*
- *ParisAnalysis::ReconstructionChooser chooses the appropriate reconstruction and fills the unnamed data bus (ParisAnalysis::EventFlags)*
- *Additional makers may compute combined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

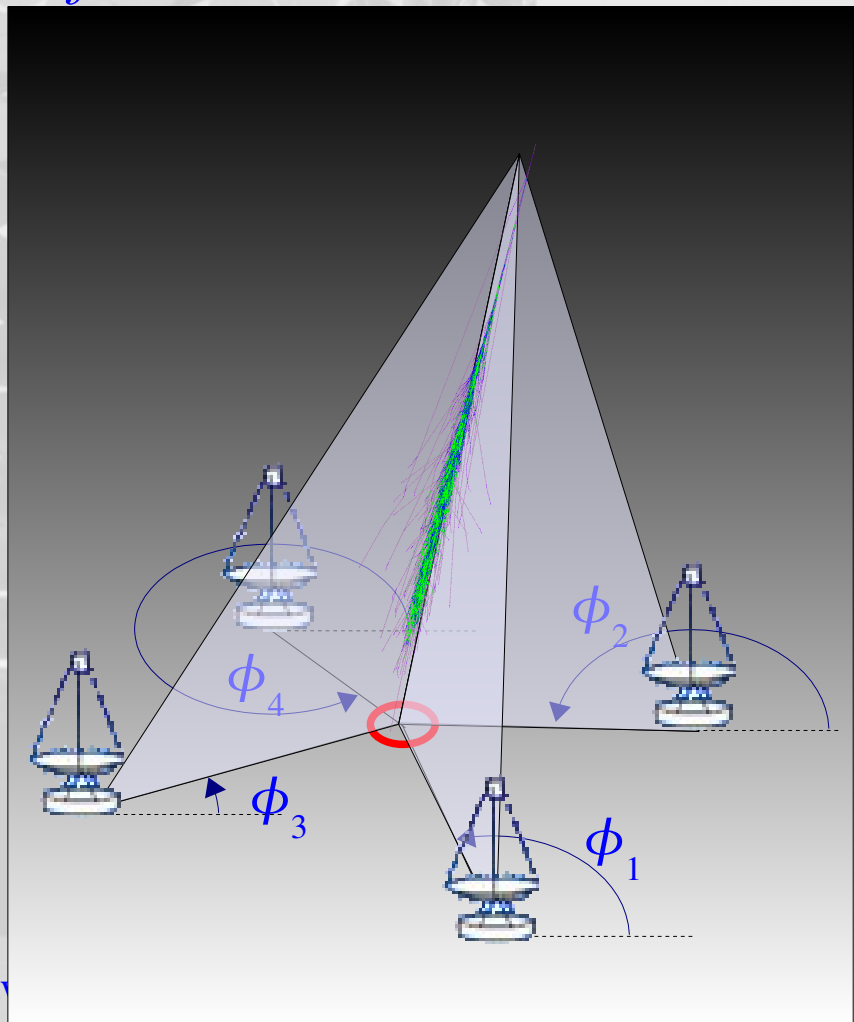


Reconstruction - Hillas



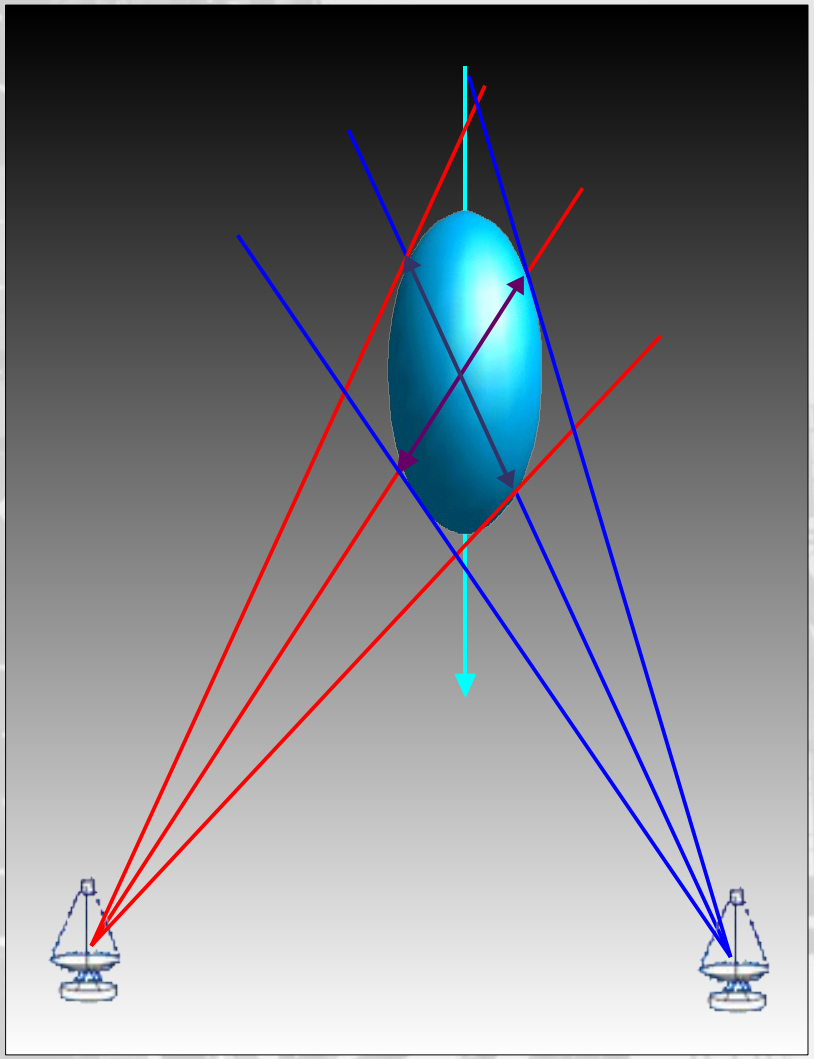
- *Elliptical fit of camera images*
- *Geometric reconstruction of direction and impact*
- *Lookup tables for energy reconstruction*
- *Mean Scaled Width / Mean Scaled Length for discrimination*





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*