Advances in analysis with Paris-MVA

Work in progress

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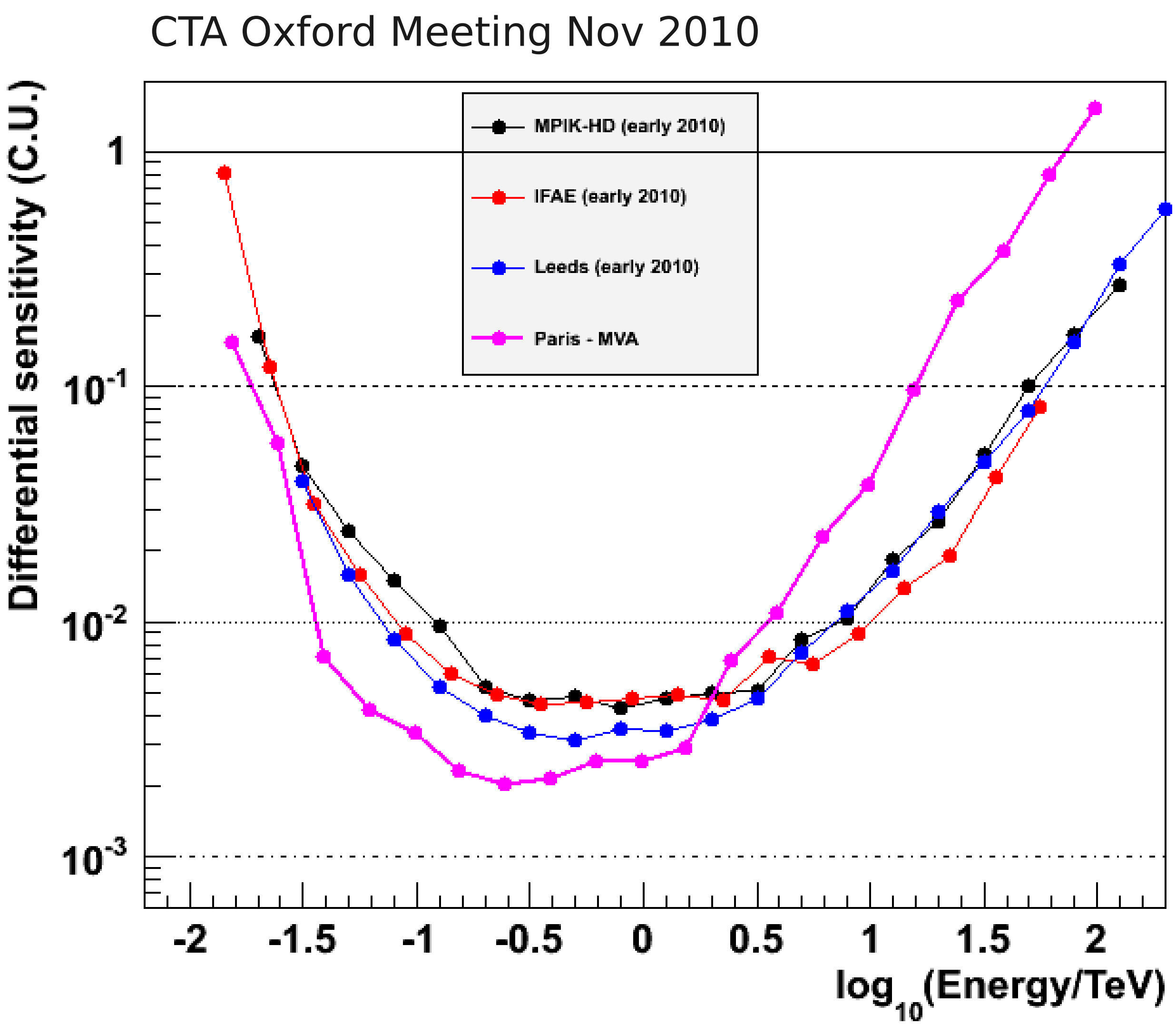
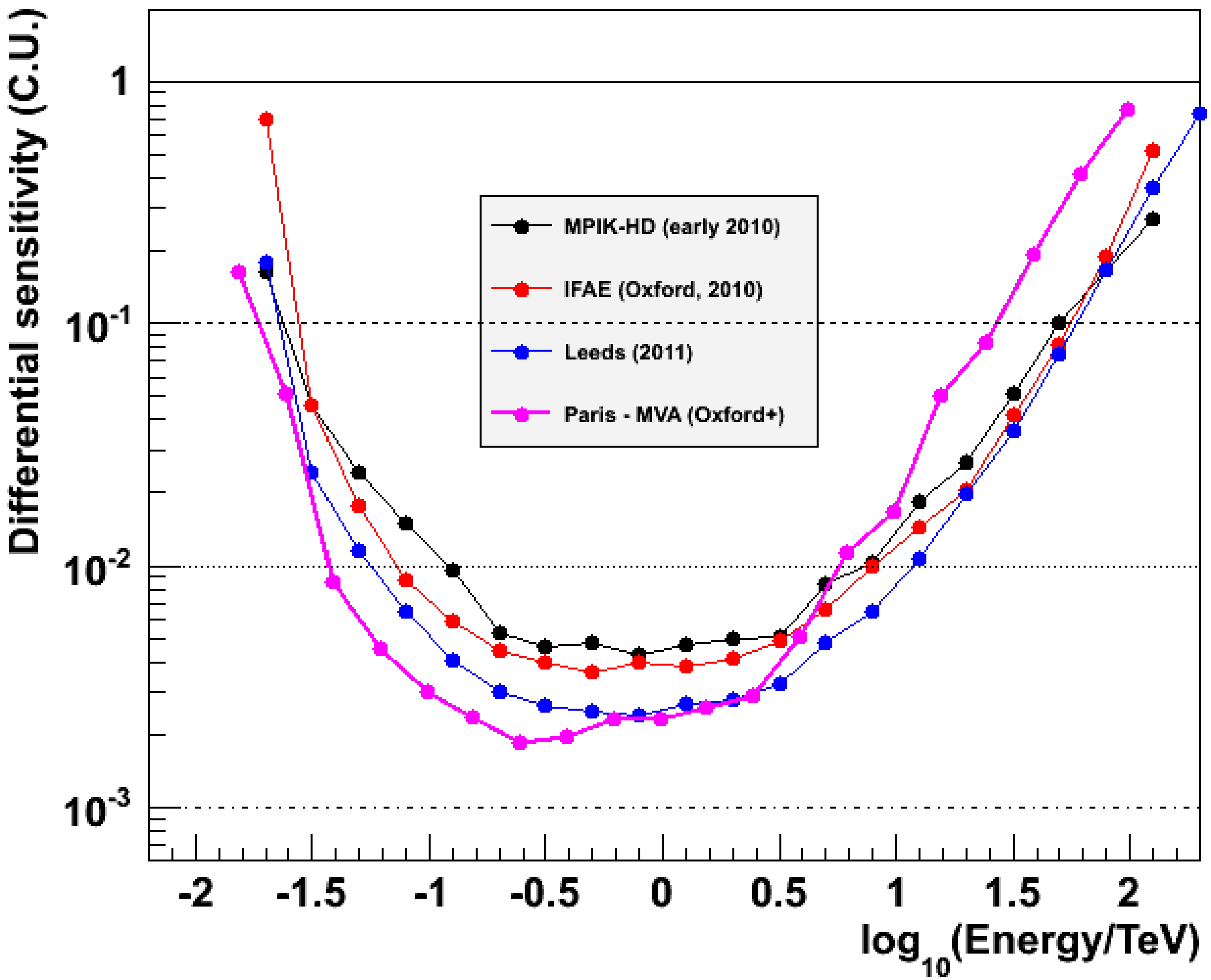
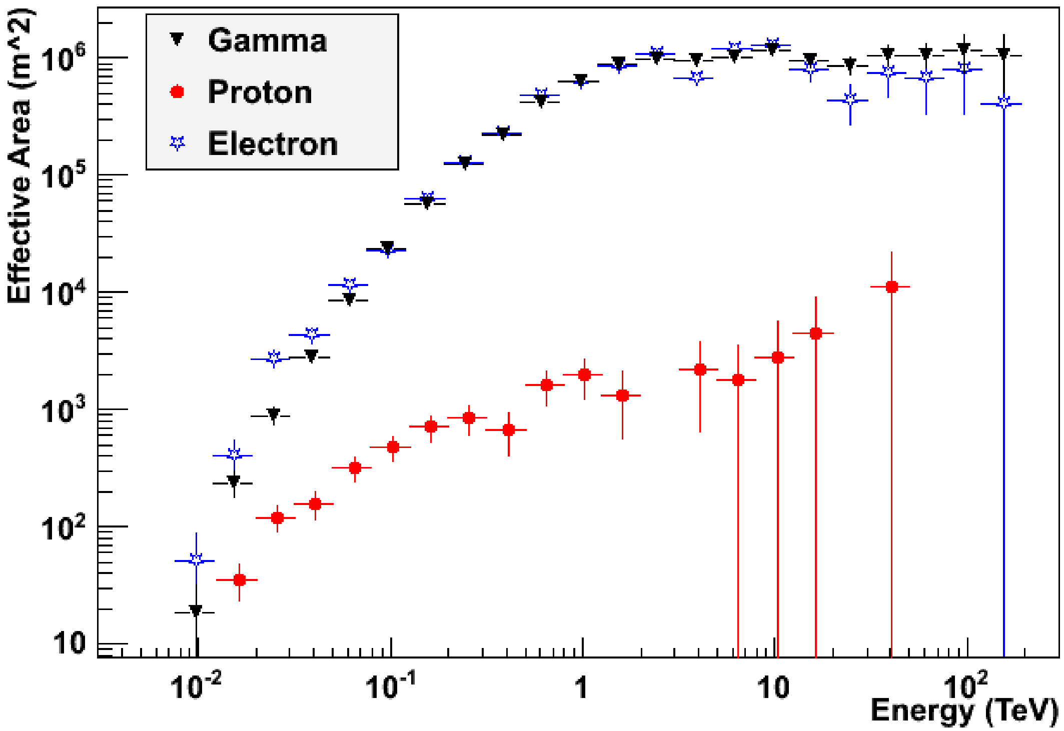
Sensitivity for array 'E' presented in Oxford



Sensitivity for array 'E' after correction of the sensitivity calculation



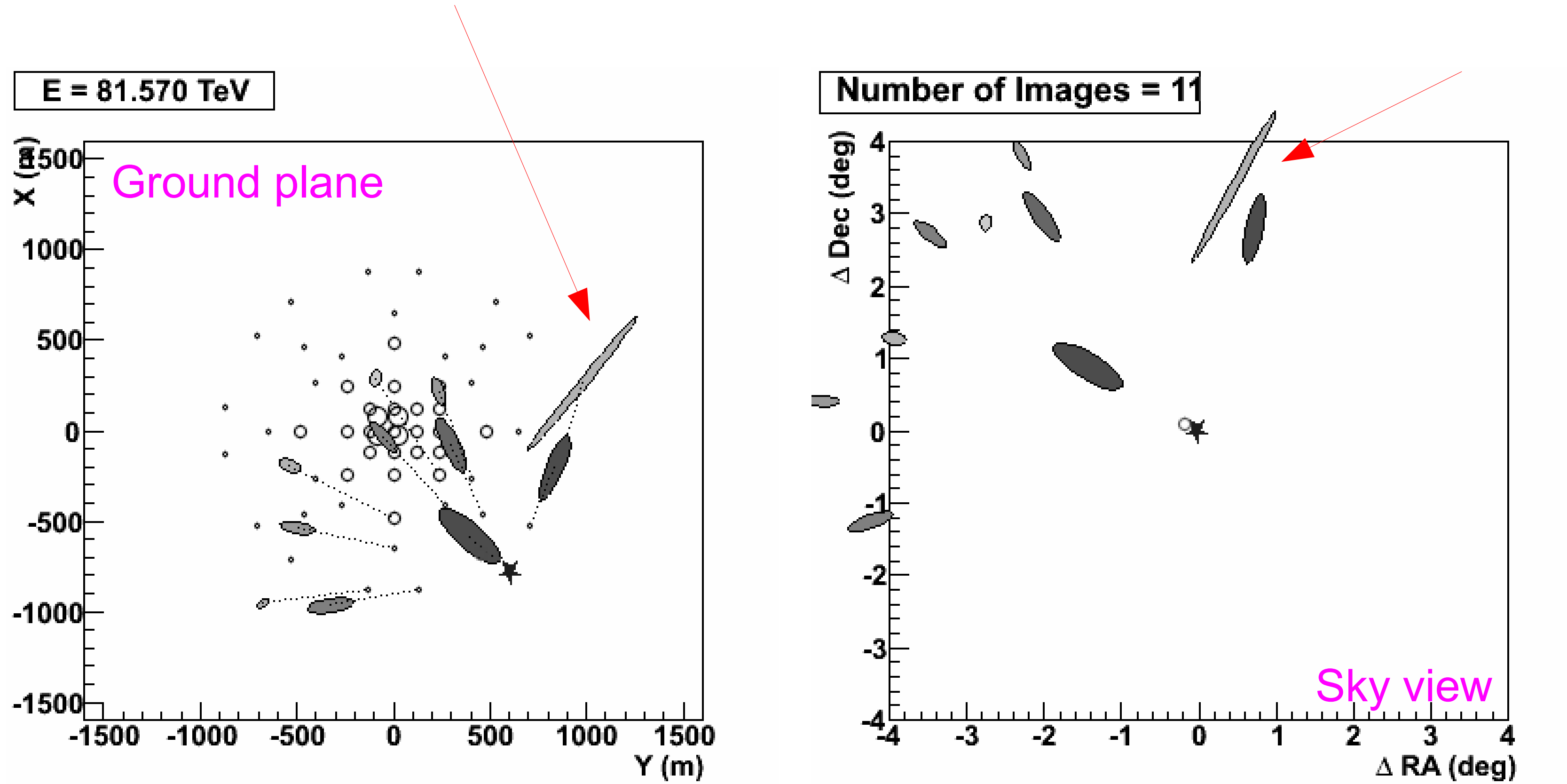
CTA Oxford Meeting Nov 2010



- The effective area remains flat after few TeV
- Other Hillas-based analyses do not show the same behaviour
- Problem with the 3D-Model convergence at E > few TeV
- Conclusion :

→ Start a deep investigation into the problem

First example at E ~ 80 TeV

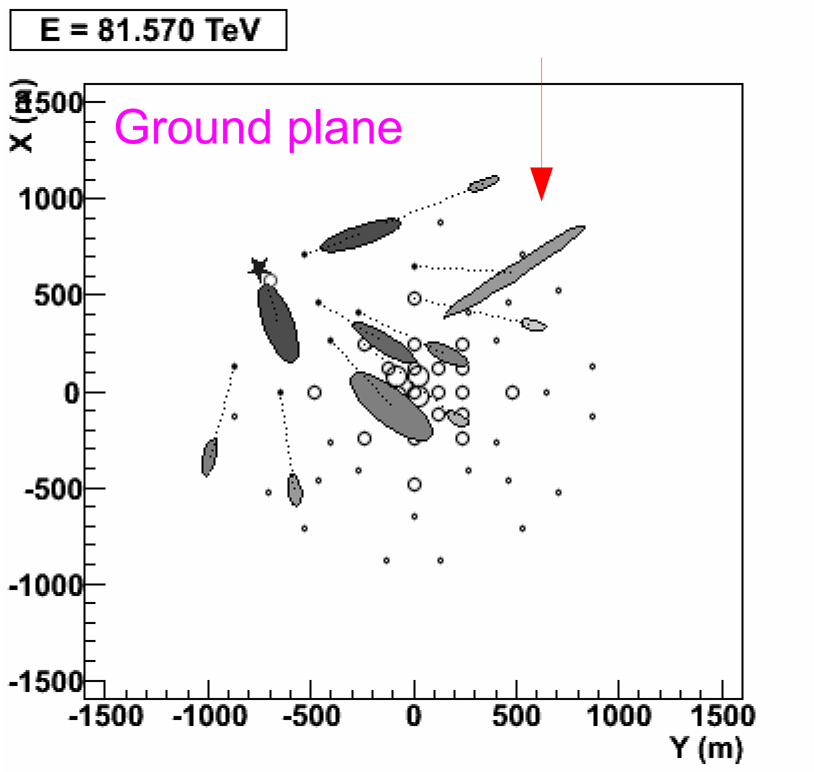


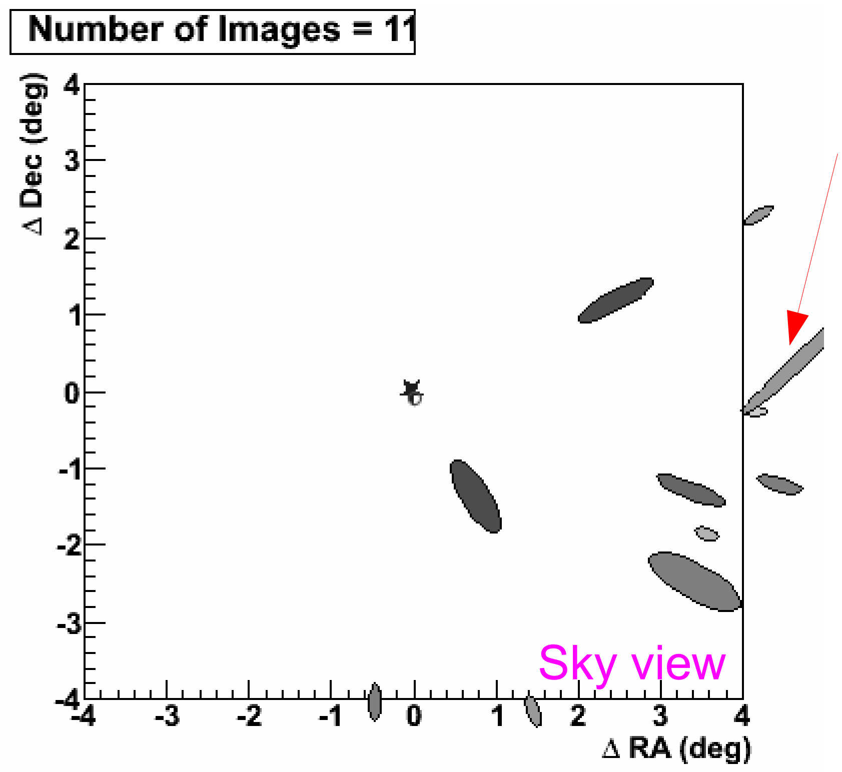
Event with no reason not to converge:

high multiplicity and impact point just at the edge of the array.

BUT one image looking longer and not pointing in the same direction of other images

Second example at E ~ 80 TeV





- 13 clusters passing standard image cleaning

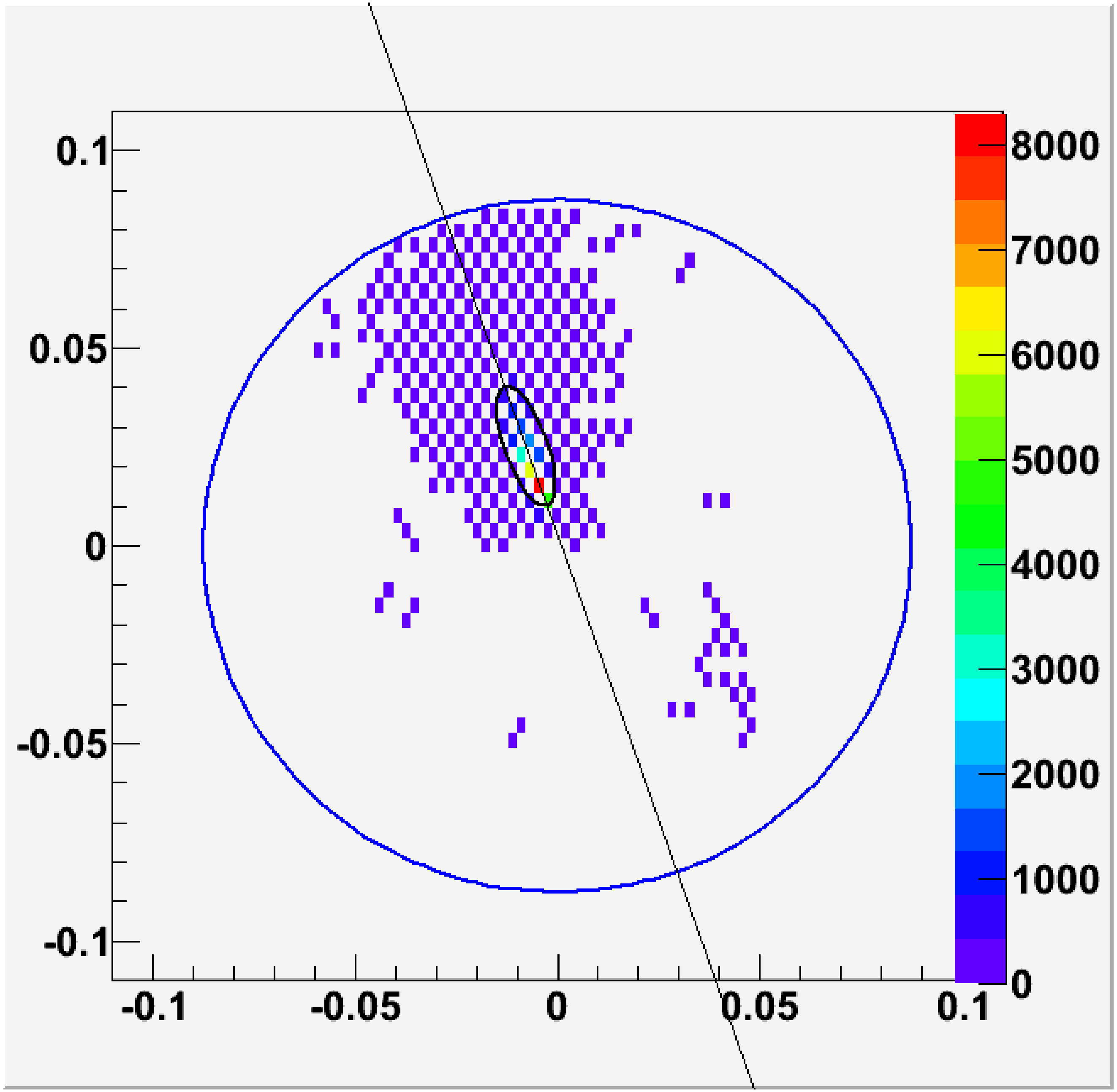
- **Solution (I) :**

Consider only the biggest cluster of the image for Hillas-based geometrical reconstruction

(which is used as first guess for the Model3D minimization)

- **Solution (II) :**

Cut the telescope if it has more than 3 clusters in the 3D-model



Telescope far from the impact point

• 2 clusters passing
standard image cleaning

• **Second solution** :

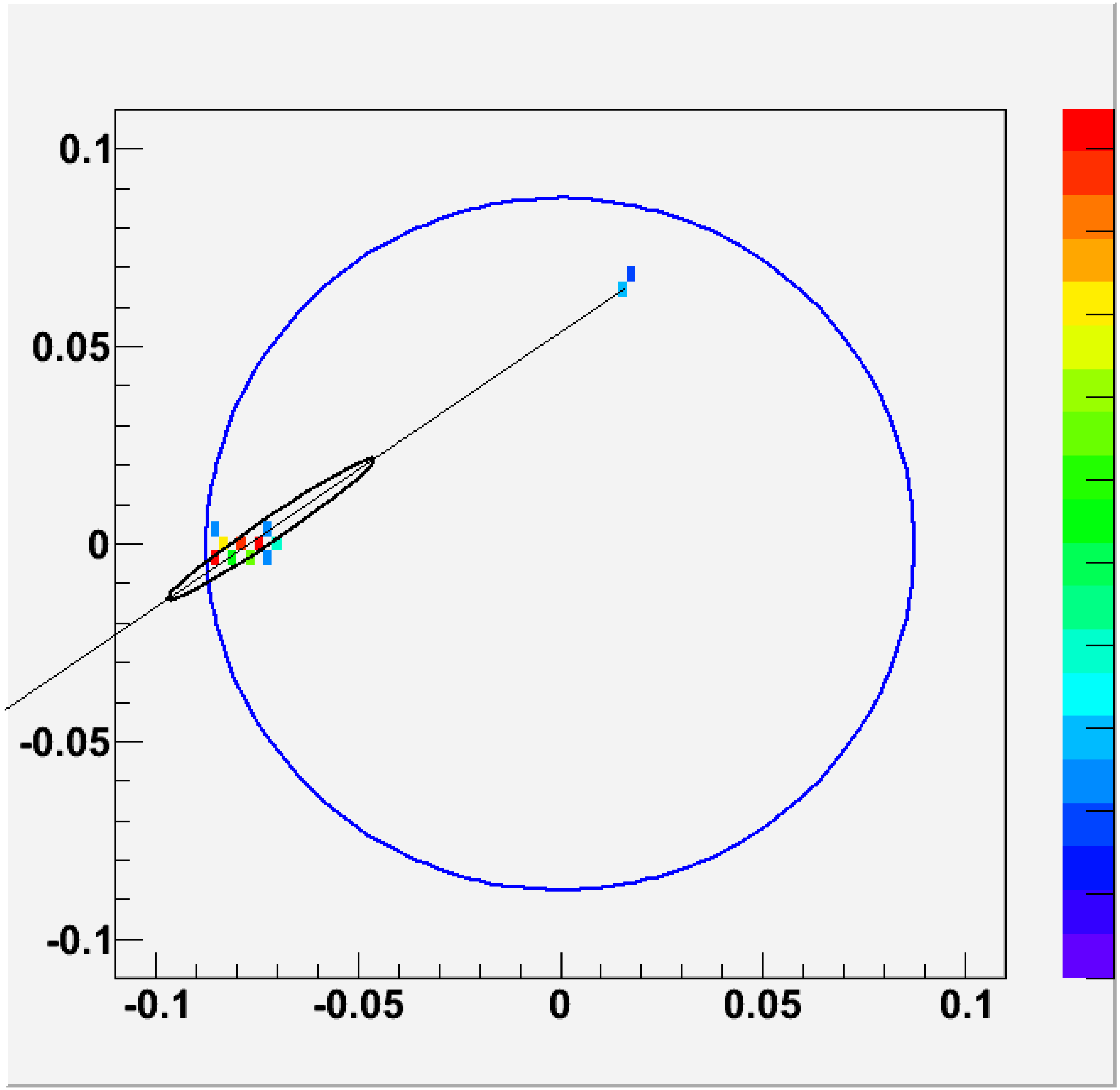
cut the second cluster
by a selection based on:

charge > 30 p.e.

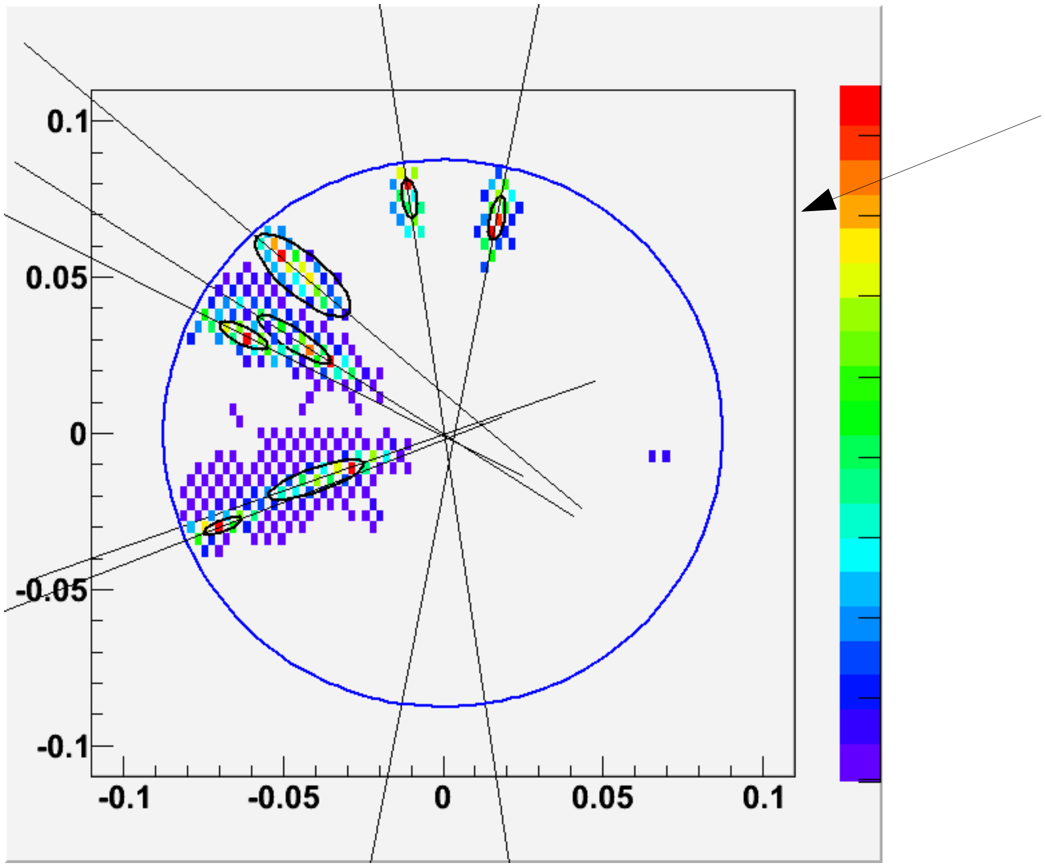
barycentre + length > …

for Hillas-based geometrical reconstruction
to improve the first guess for the Model3D minimization

In 3D-model
apply the charge criterion

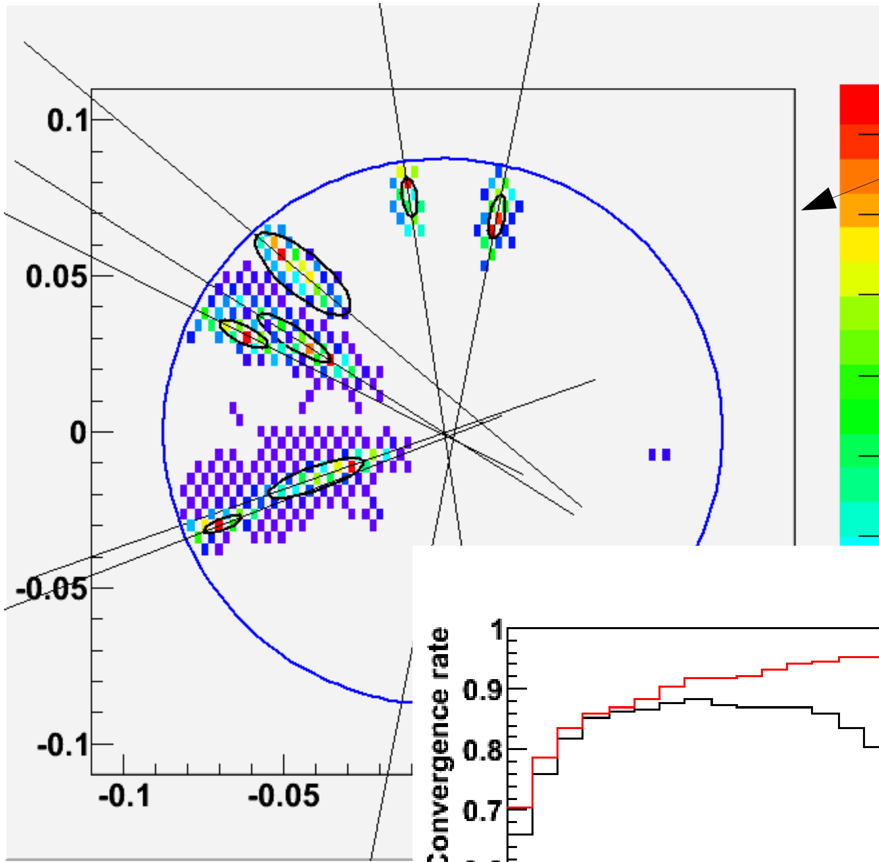


Effect of the improvement on the 3D-model convergence rate



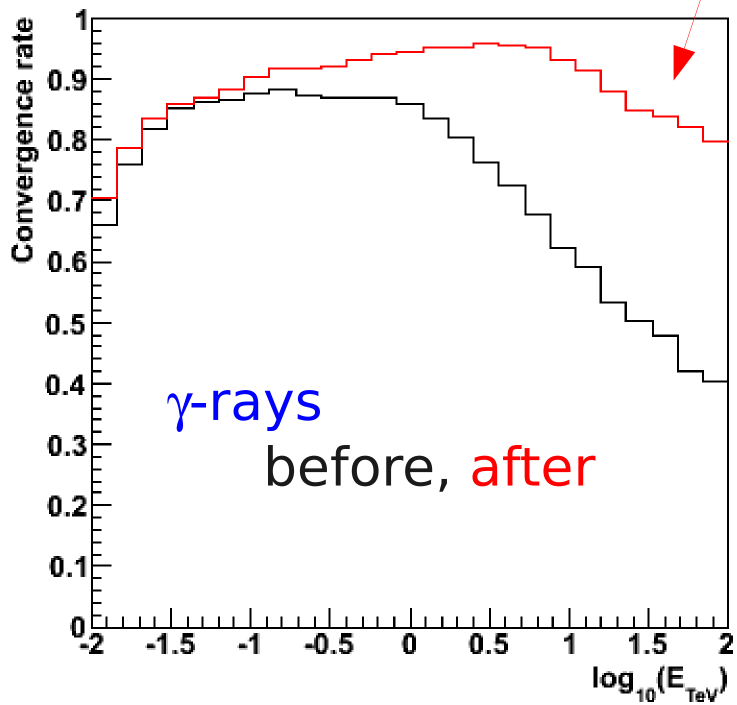
- Final selected images
  after cleaning improvement
- Hillas-based first guess
  closer to the true value

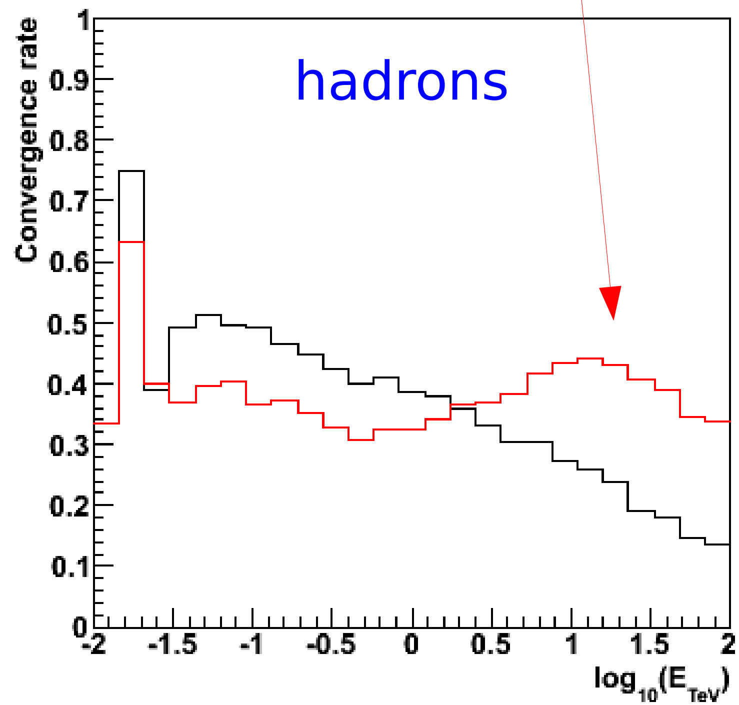
Effect of the improvement on the 3D-model convergence rate



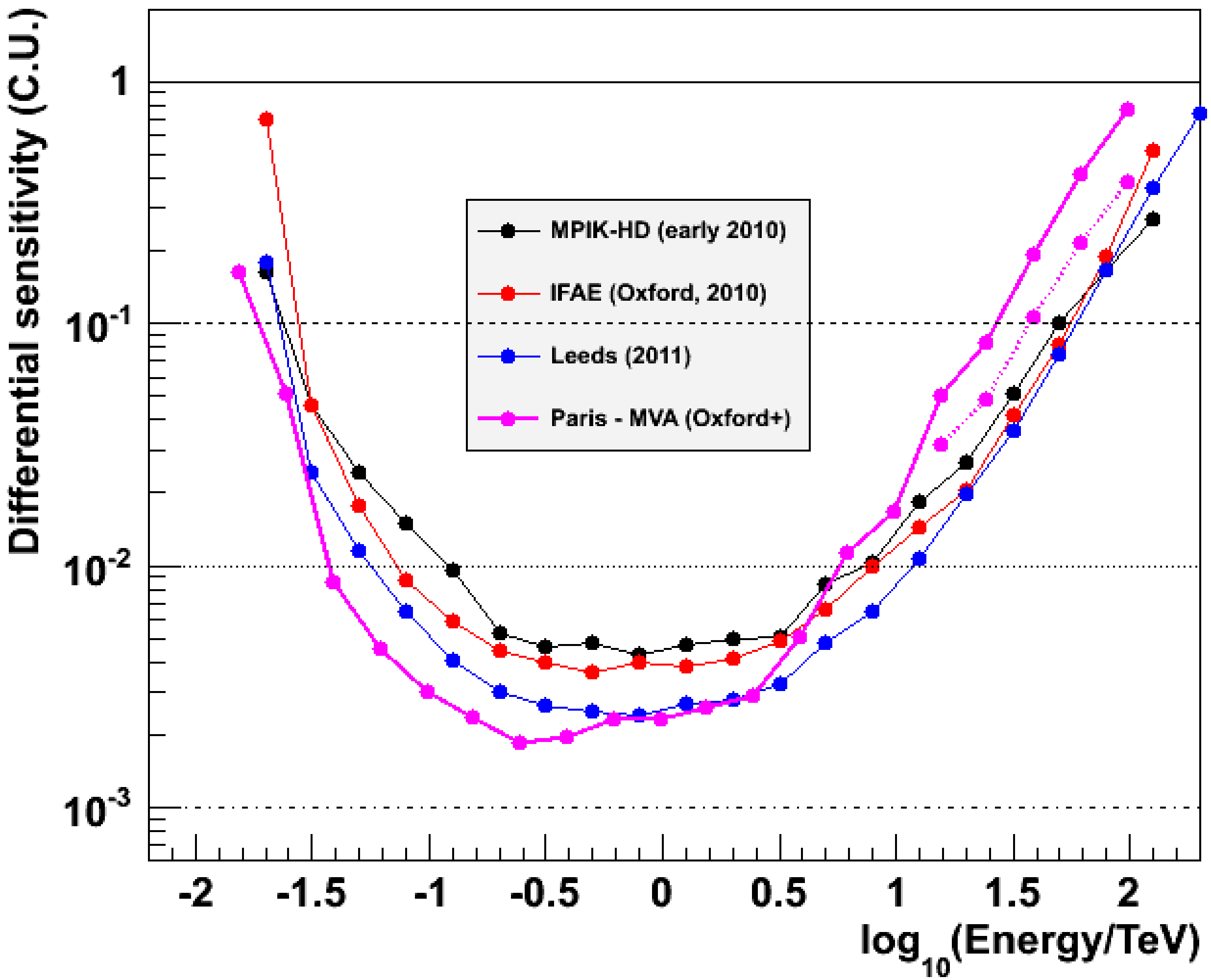
- Final selected images after cleaning improvement
- Hillas-based first guess closer to the true value

- Net effect on the convergence rate





Sensitivity for array 'E' with 3D-model improvement



Multi-variate analysis based on the 8 parameters

Training data sample:

MC: 1 zenith angle (20°)
on-axis

Bkg: Proton & electrons

27 bins:

1 in Zenith

9 in 3D-Model Nphot

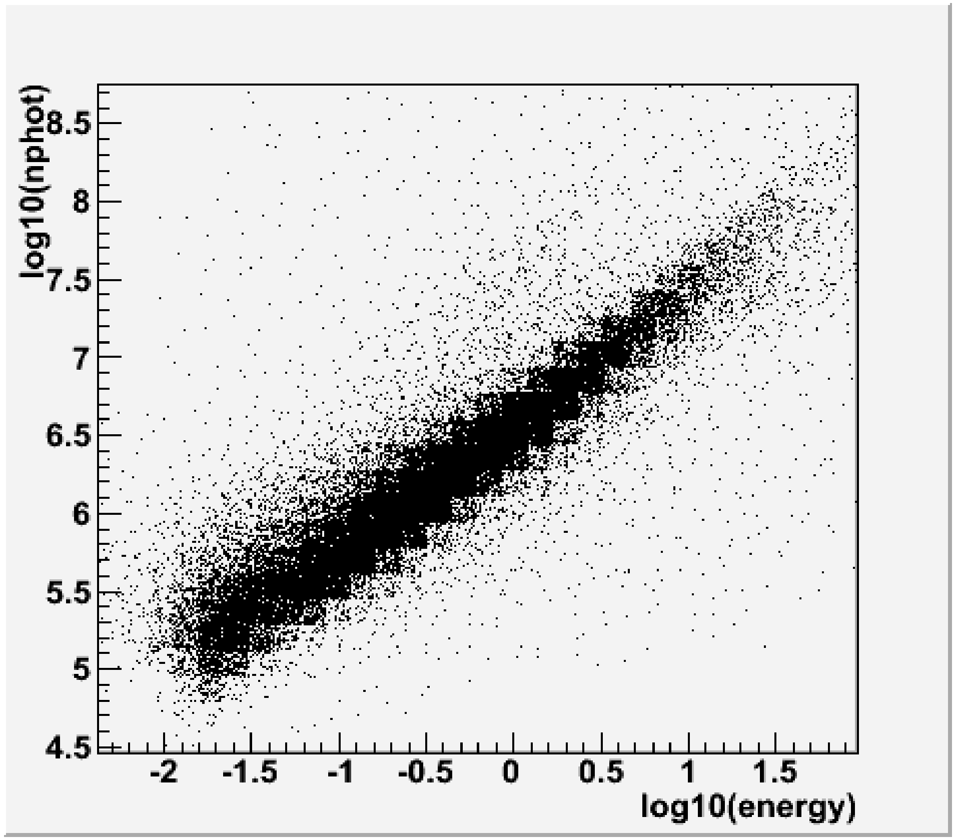
3 bins in multiplicity

→ 2 tel-events

→ 3-5 tel-events

→ 6-60 tel-events

Use Nphot bins rather than Energy with this relation

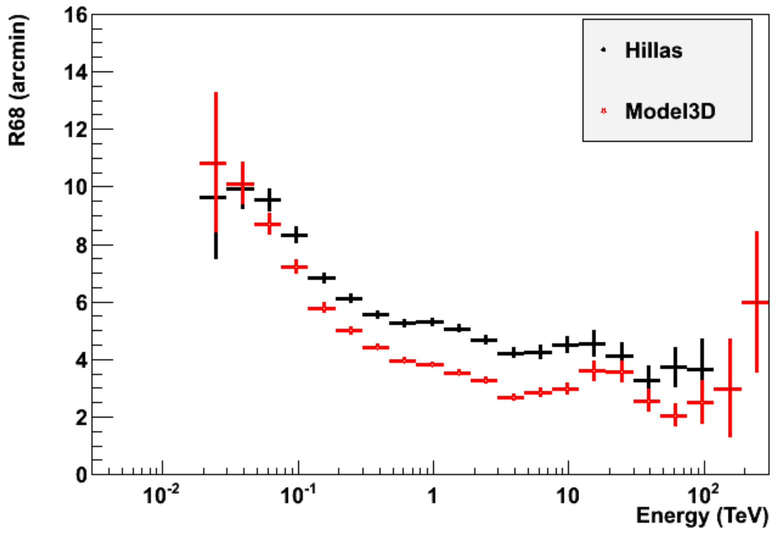


Bin	$\log_{10}$(nphot)	Energy (TeV)
0	0.01 - 5.8	0.003 - 0.1
1	5.8 - 6.18	0.1 - 0.3
2	6.18 - 6.35	0.3 - 0.5
3	6.35 - 6.59	0.5 - 1
4	6.59 - 6.82	1 - 2
5	6.82 - 7.132	2 - 5
6	7.132 - 7.3	5 - 10
7	7.3 - 8.1	10 - 50
8	8.1 - 10	50 - 1000

New scheme for enhanced discrimination

- Discrimination presented in Oxford:
  27 bins;
  9 bins in nphot (energy) x
  3 bins in multiplicity
- Mixed multiplicity:
  Large, Medium, Small
- New cut scheme:
  bins with specialized multiplicity to attempt to further enhance discrimination at all energies (but especially at < 100 GeV)
- Larger number of bins:
  54 bins;
  9 bins in nphot (energy) x
  6 sets of multiplicities
- Aim of this work:
  - enhance the sensitivity in general
  - enhance the PSF by tuning the relative contribution of events having different multiplicity

- First tests not enhancing the sensitivity presented in Oxford
- Other important point: θ2 cut as a function of energy
- Large gain expected thanks to the enhanced PSF of the 3D-model



Conclusions

- Corrected the calculation of the sensitivity
  → high energy performance
  better than that presented in Oxford

- Working on the optimization of the reconstruction methods (Geometrical Hillas-based & 3D-model) for an enhanced performance at E > TeV

- Working on the optimization of the bins in multiplicity for an enhanced γ-ray/hadron discrimination depending on a definition of the telescope multiplicity by type of telescope

- Aim: as for H.E.S.S. have different configurations for different spectral indexes;
  - For AGN physics, enhance the detection of lower energy events triggering the Large telescopes in the core of the array; larger PSF
  - For Galactic plane observations, enhance the detection in MST and SST array; good PSF

We're working … so expect new results for next Collaboration meeting

Backup from Oxford

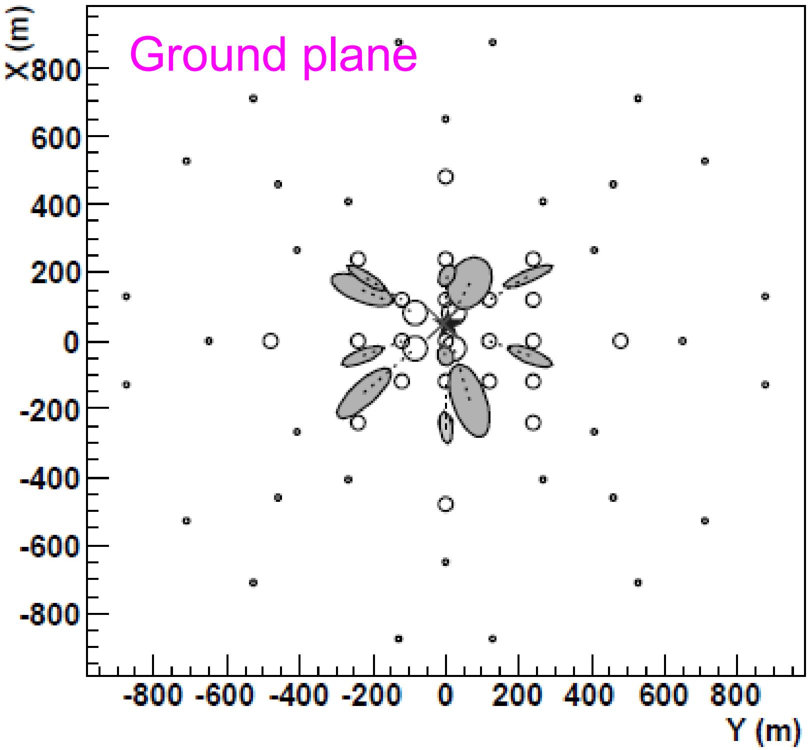
- Multi-variate discrimination
  - based on Boosted Decision Trees
  - careful testing of decision tree design (depth, pruning etc.)
  - training for large range
    - in Zenith angle
    - In Energy/Nphot
    - in event multiplicity
  - Definition of cuts using pre-defined energy dependent γ-ray efficiencies

Choice of parameters:

- Avoid correlated parameters
  - Test for correlations, exclude params
- Not based on goodness-of-fit
  - Since need excellent understanding of detector for g-o-f
- Three new parameters, gain of 20% in discrimination for HESS

- Hillas (5/7 p.e. image cleaning)

E = 0.260 TeV



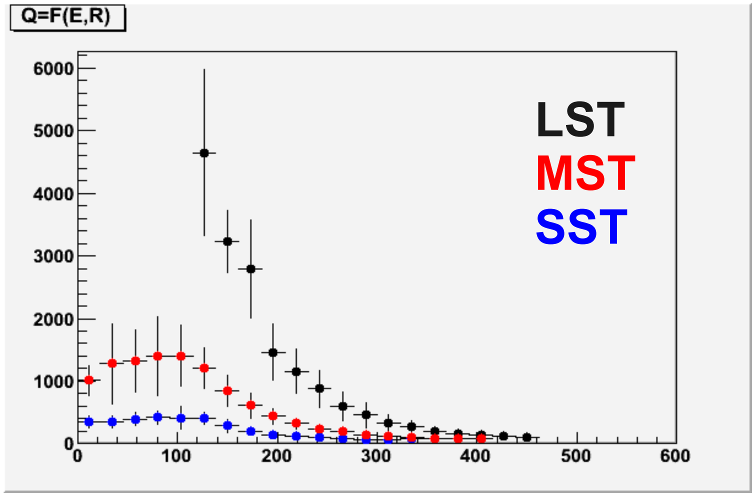
« 3D-Model »

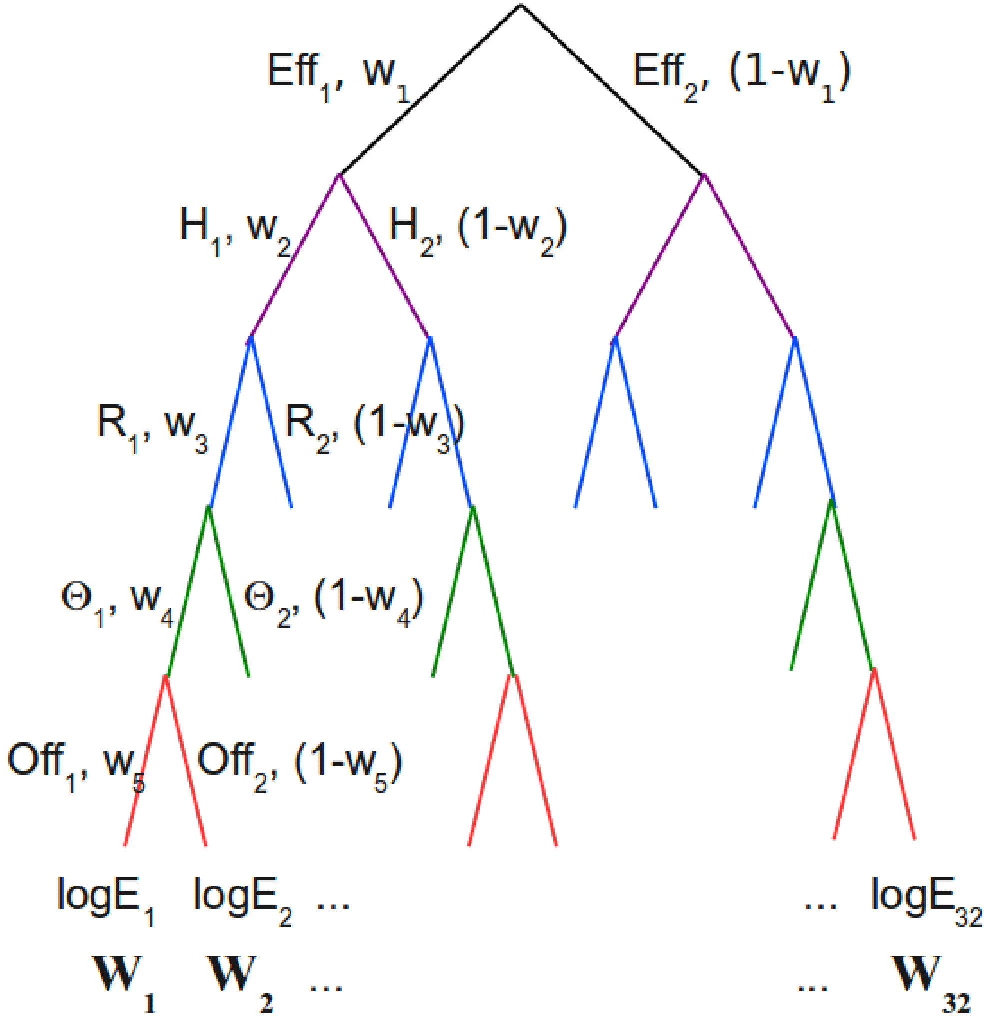
- 3D model of the Cherenkov photosphere (Nphot photons)
- Maximum likelihood method to reproduce the model charge expectations on the pixels

Lemoine-Goumard et al.

Astropart. Phys. 25 (2006) 195-211

Fitted width of the shower and its associated error and normalised depth at maximum used in the new analysis





- New method of calculating the energy of the shower (Oak)
- Pre-define charge profiles vs. impact parameter
  based on simulations
- Evaluation of energy
  through weighted tree
- Independent of MVA: compatible with standard Hillas analysis, 3D-model events

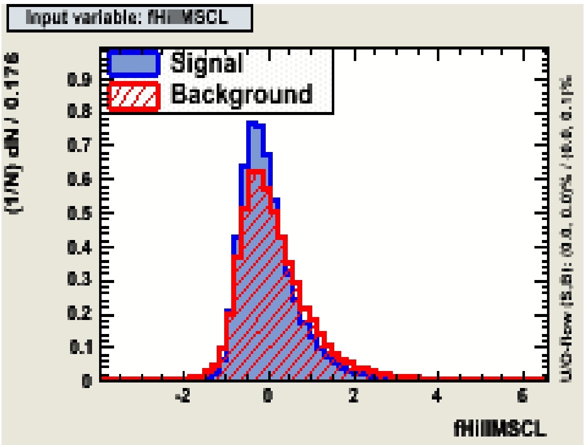
$$E_{event} = \frac{1}{Q_{tot}} \sum_{i=1}^{N_{Tels}} [q_{Tel_i} \cdot E_{Tel_i}]$$

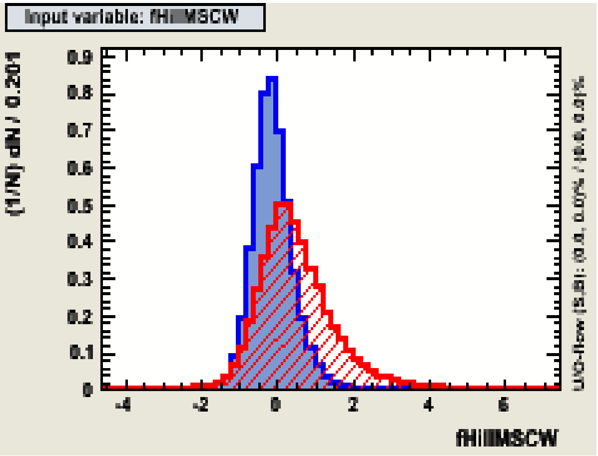
For CTA : Resolution 10% at 1 TeV
Bias 0% at 1 TeV after simple cuts

Selected γ/hadron discrimination variables

Hillas-based
discrimination parameters

$$\mathrm{MSCL} = \frac{1}{\mathrm{N_{Tels}}} \sum_{i=1}^{\mathrm{N_{Tels}}} \frac{\ell_i - \overline{\ell}_{q,x}}{\sigma_{\ell,q,x}}; \quad \mathrm{MSCW} = \frac{1}{\mathrm{N_{Tels}}} \sum_{i=1}^{\mathrm{N_{Tels}}} \frac{w_i - \overline{w}_{q,x}}{\sigma_{w,q,x}}$$

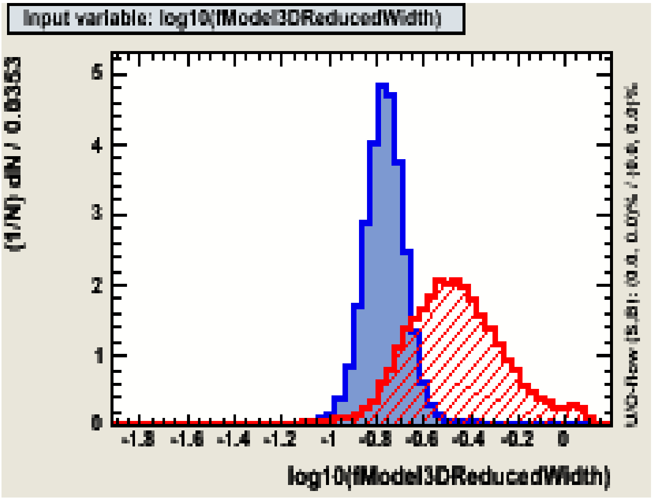




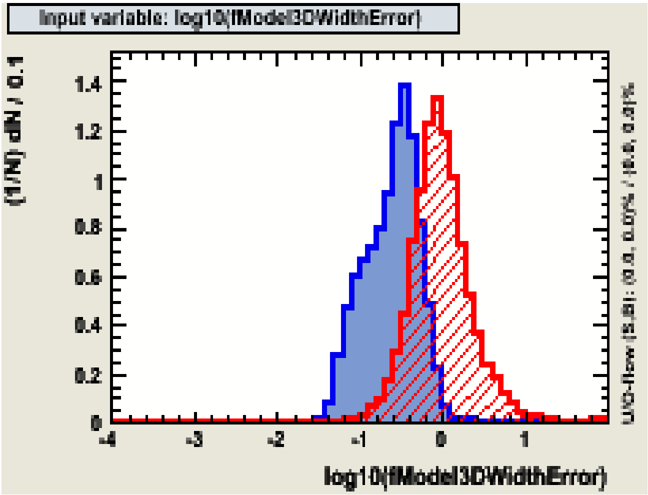
γ-rays vs. **background**

3D-model based

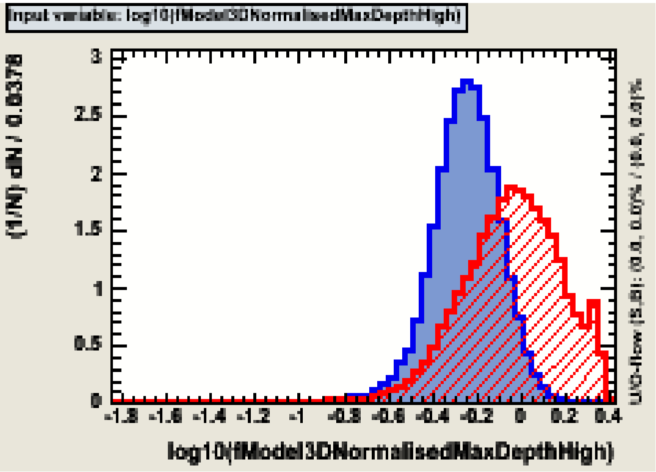
Reduced Width



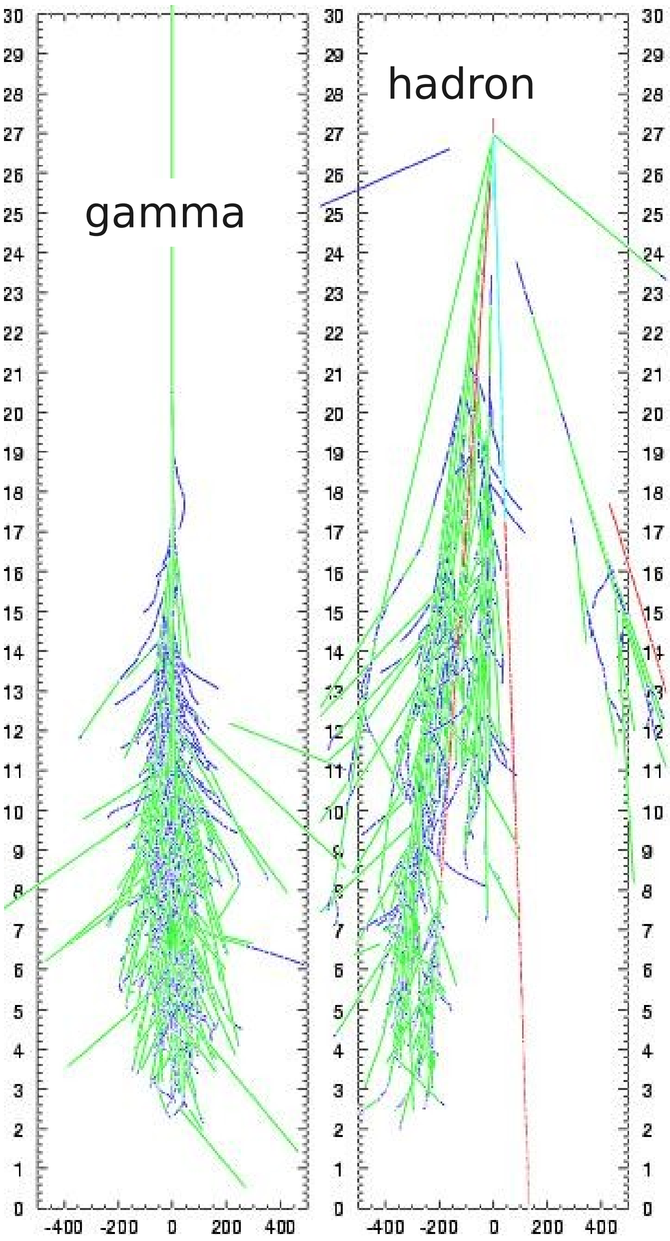
Error on Width



Depth of Shower Max



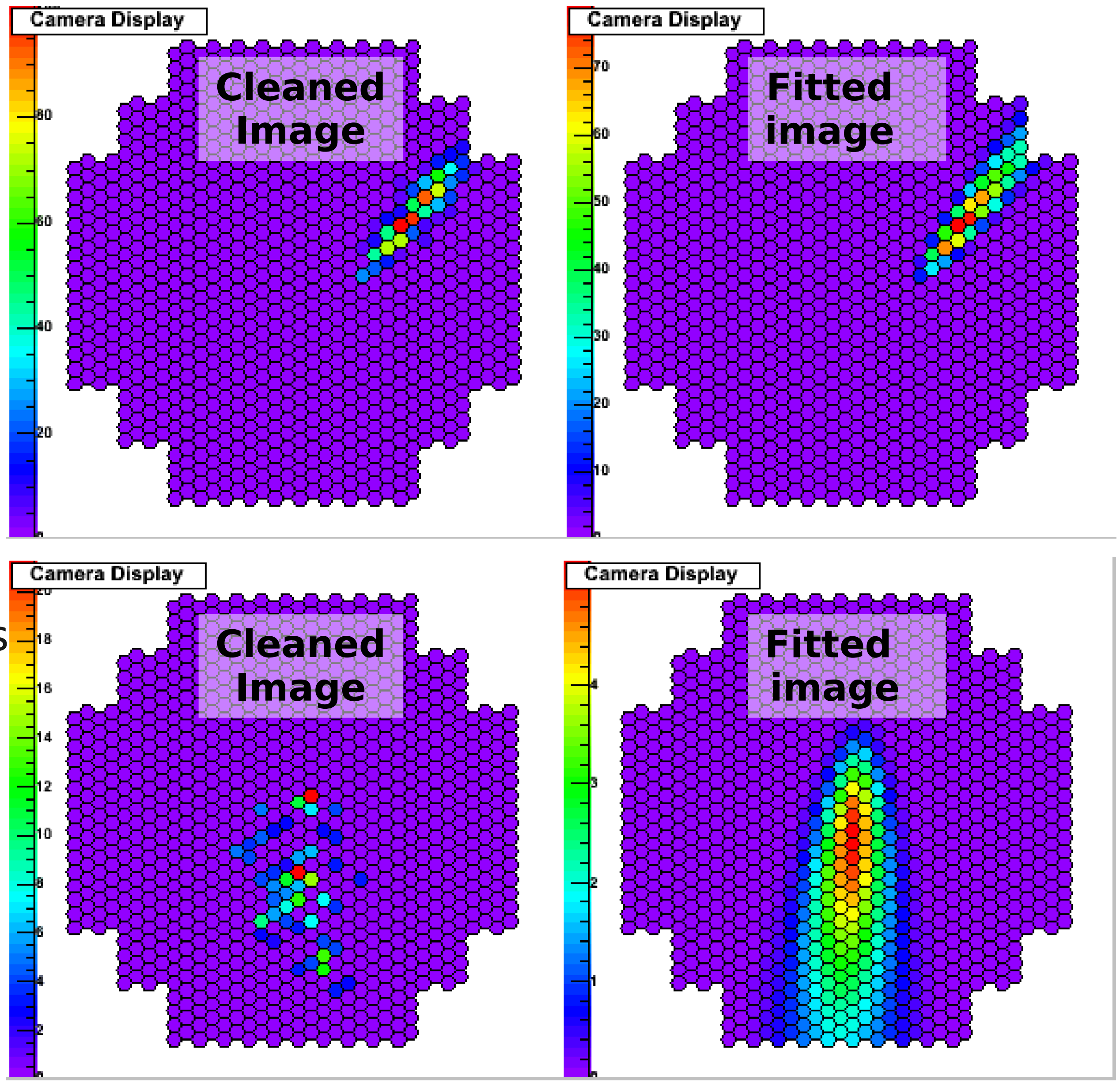
- Due to differences in the shower development, we can take advantage of the azimutal symmetry of the gamma ray shower versus the asymmetry of the proton shower
- The fit of a hadronic shower with a gamma-ray model (Model3D) gives incoherences that can be exploited
- By using the information of the images predicted by the Model3D minimisation
- If a good fit is found
  - predicted images are close to those detected
- If a bad fit is found
  - predicted images are different with respect to those detected



The hunt for new discriminant variables

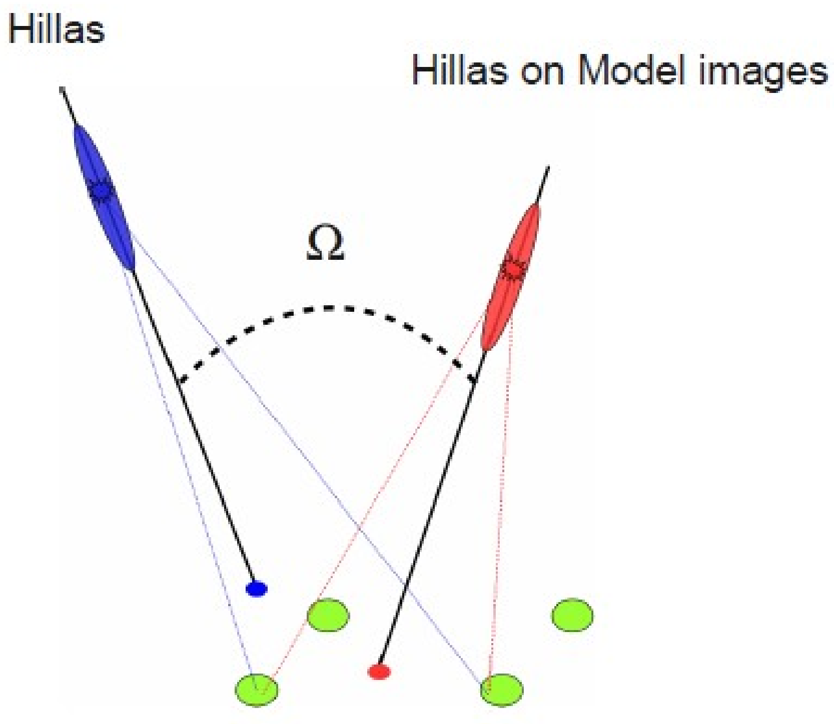
- The images predicted by the 3D-model minimization can be used to reconstruct a new set of Hillas parameters (*HillasOnModel*)
- The main axis direction of these new ellipses can be used to reconstruct a new shower direction, and so define a new discriminant parameter
- The charge of the fitted images can also be input to the energy reconstruction algorithm, and so define two new discriminant parameters

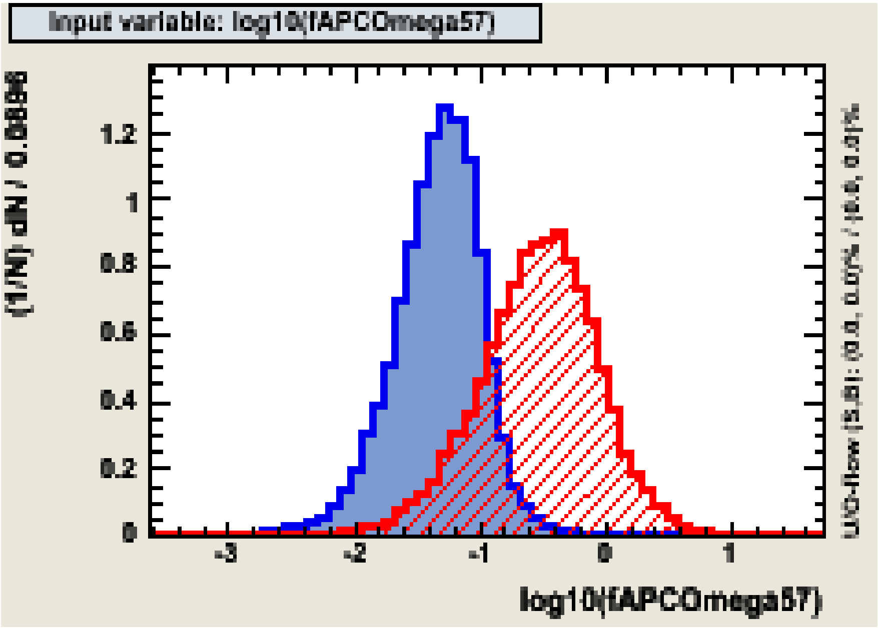
Simulated γ ray



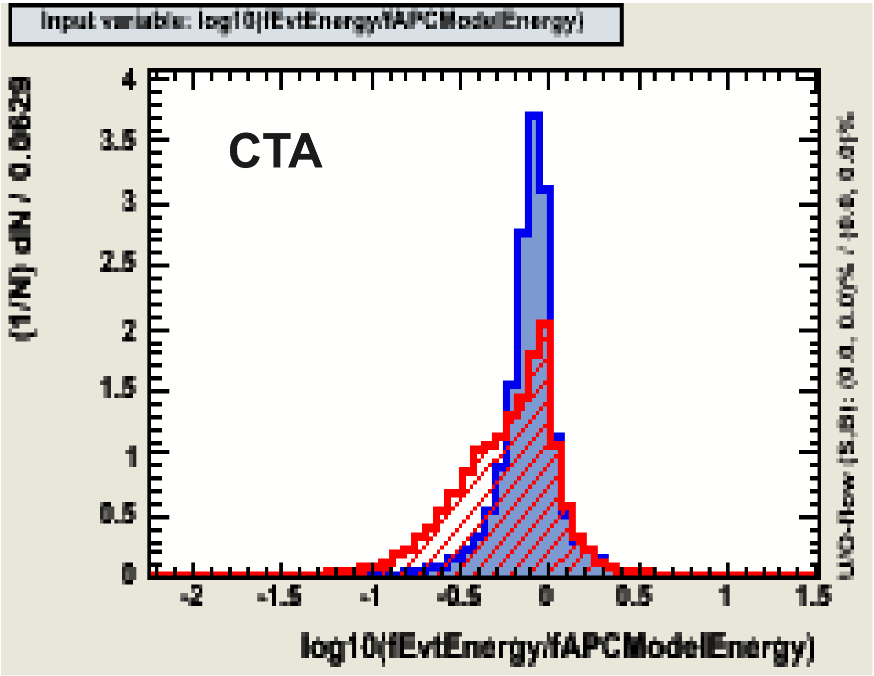
Real hadron

New γ/hadron discrimination variables (#1)

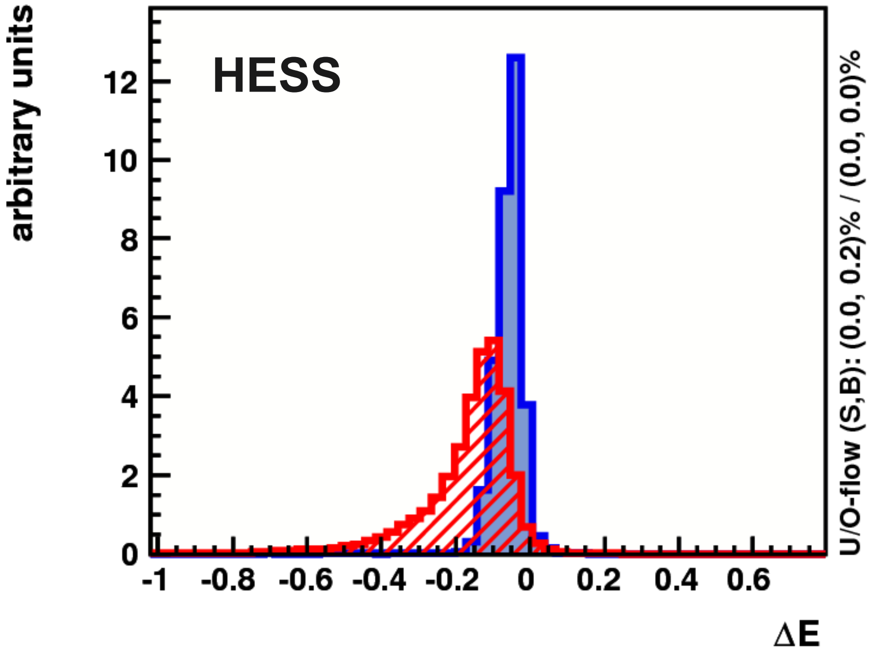




$$R_E = \log_{10}\left[\frac{E_{Hillas}}{E_{HillasOnModel}}\right]$$

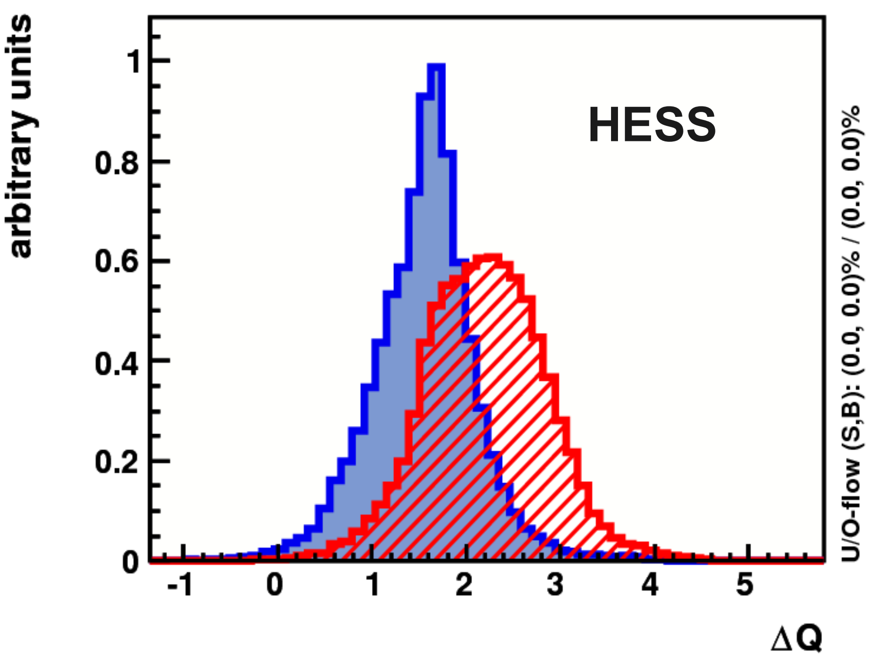


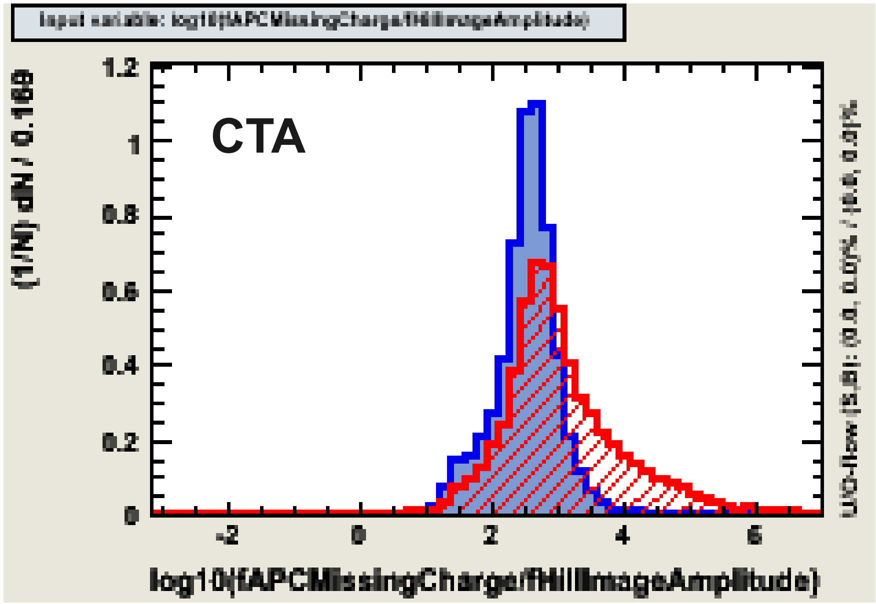
R_E



Knowing the energy E_{Hillas},
reverse the Oak procedure
to “predict” the expected image charges in each telescope

$$\Delta Q = \frac{1}{Q_{tot}} \sum_{i=1}^{N_{Tels}} \left[q_{exp} - q_{det}\right]^2$$





ΔQ

Multi-variate analysis based on the 8 parameters

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on-axis
Bkg: Proton & electrons

Use Nphot bins rather than Energy
with this relation

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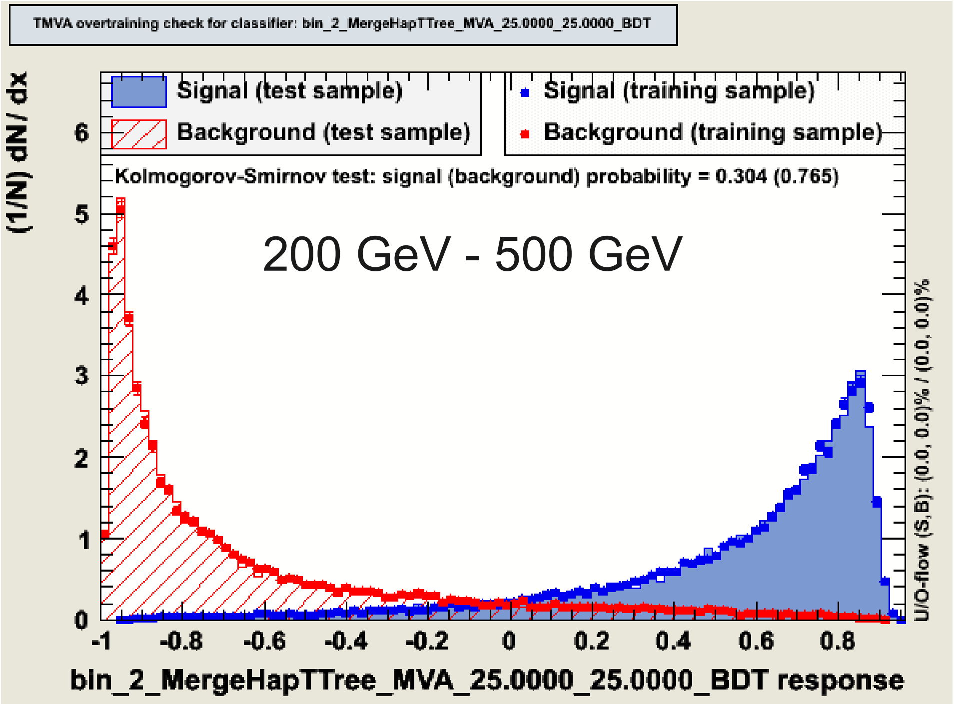
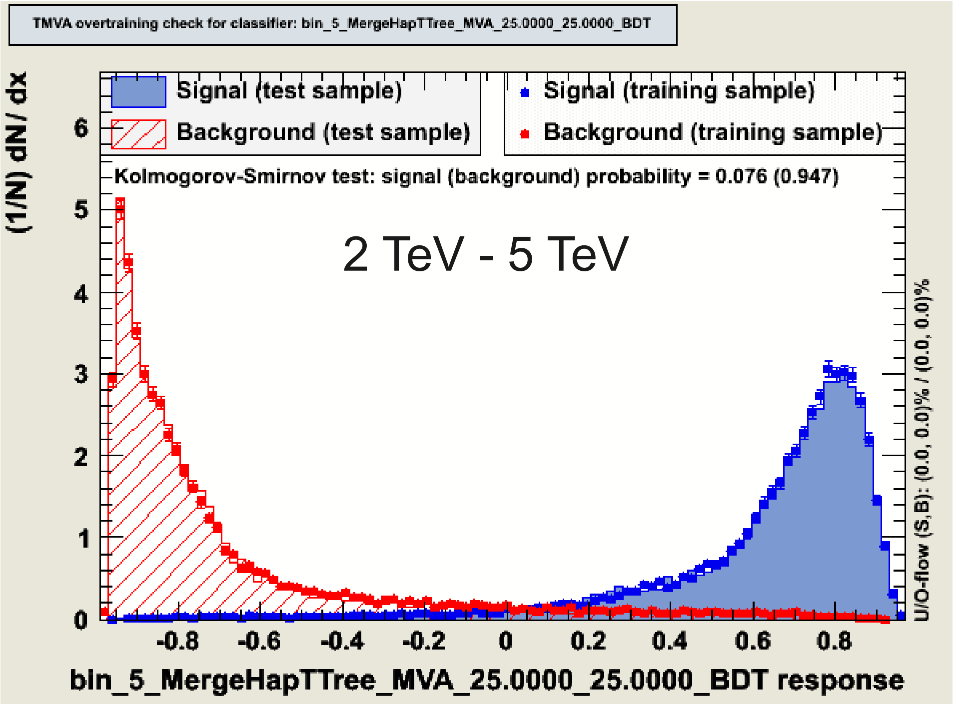
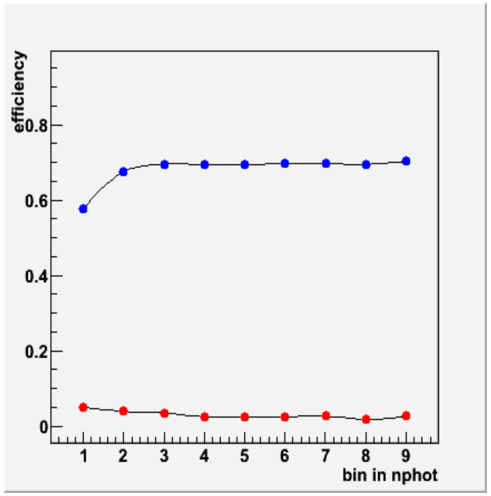
Example of BDT classifier performance

γ-rays vs. **background**





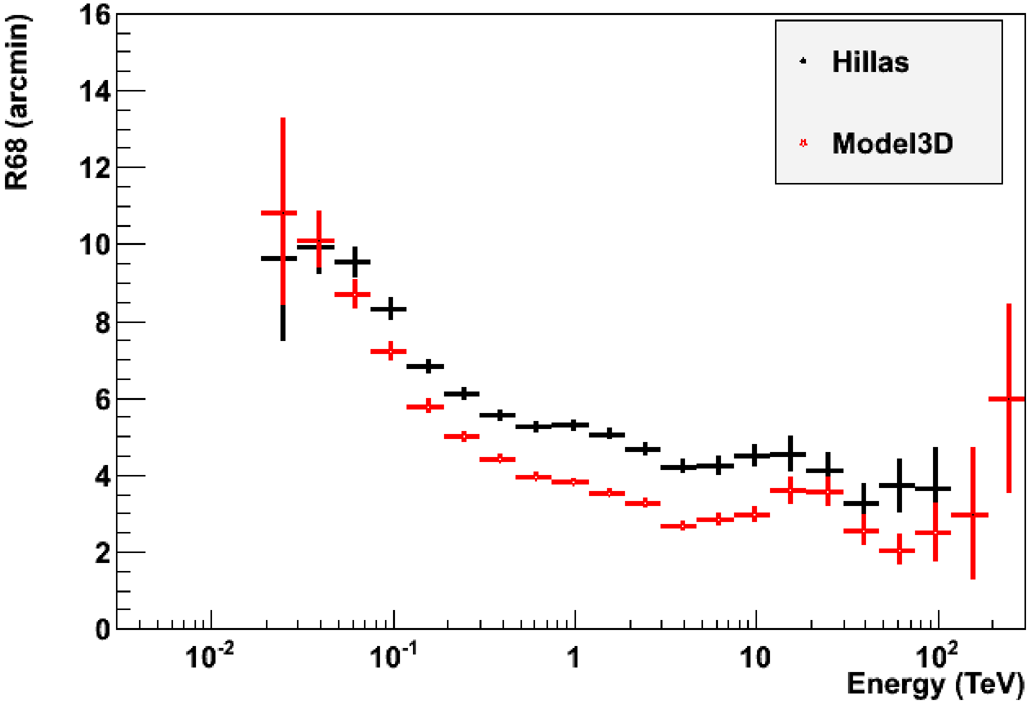
Given BDT variable definition, use these predefined γ-ray efficiencies, rising smoothly in Nphot, to set the cut level (giving corresponding hadron efficiencies)



70% γ

5% → 1% bkg

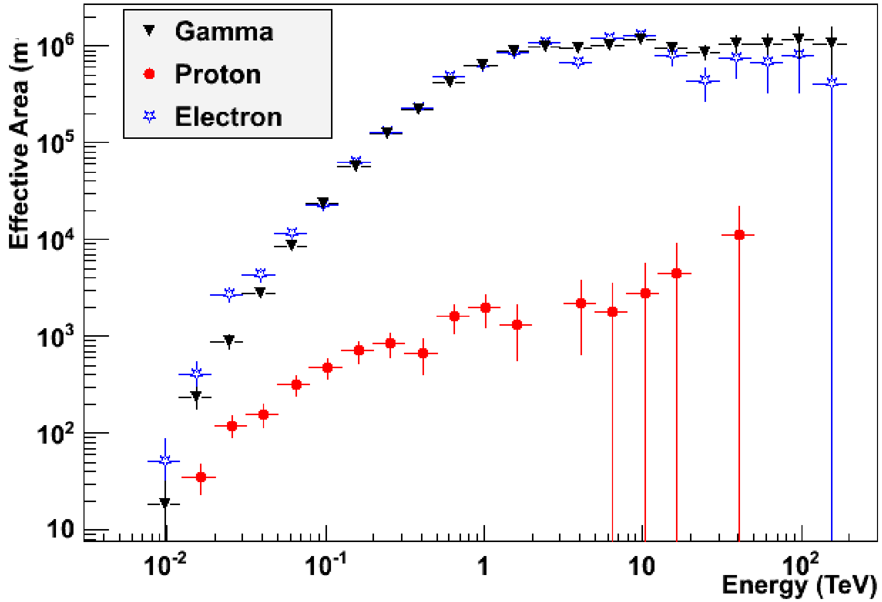
Instrument response functions for point source analysis



PSF > 200 GeV

→ 3.8 arcmin

Effective area after θ^2 cut →



Sensitivity for array 'E'

Conclusions

- Method developed for HESS weakest sources
- Easily adapted to CTA
- Dramatic increase of the sensitivity at energies < TeV
- Further work needed for the higher energies

Thanks for your attention!