# The **gamma signal** events: Gamma/Hadron separation et al..

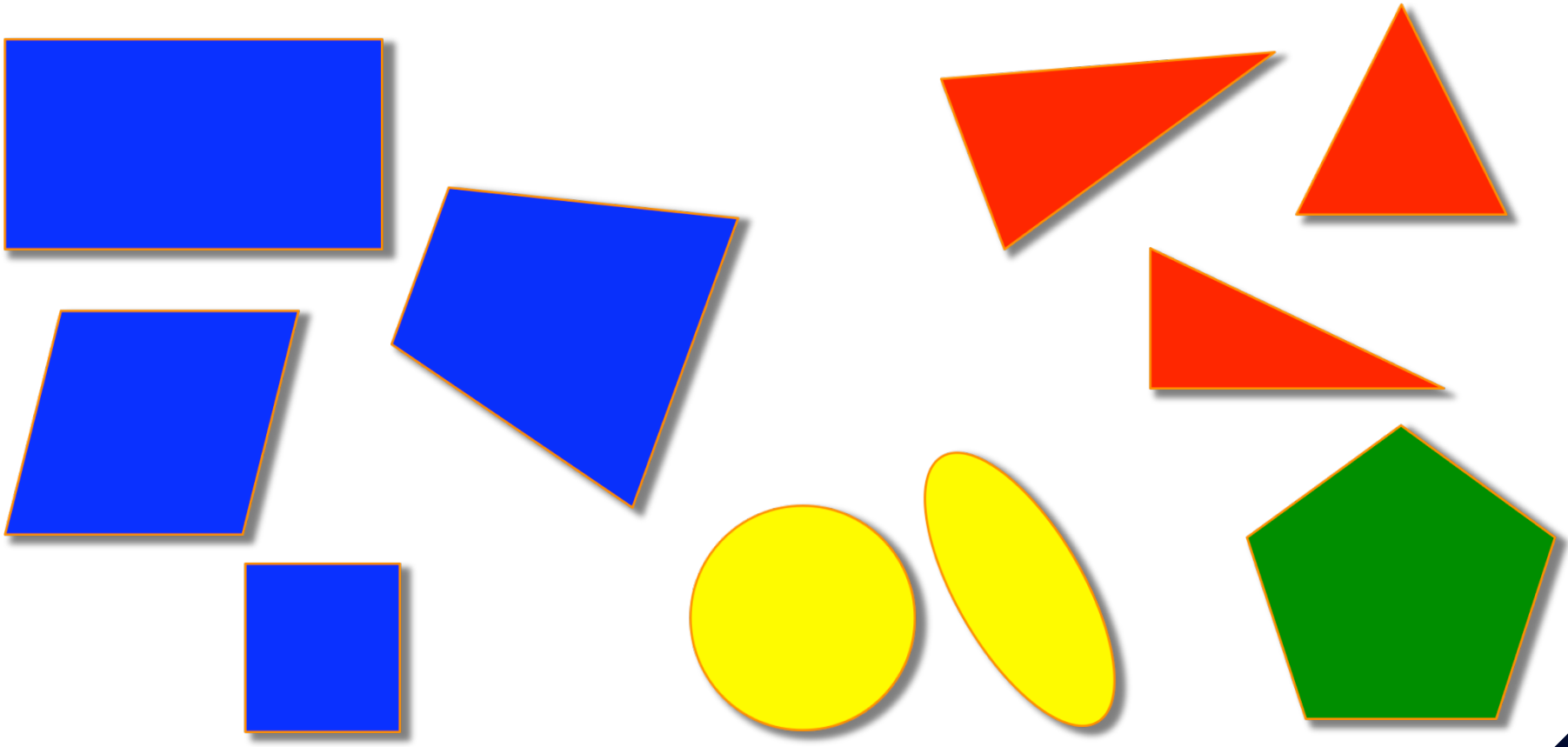
Villi Scalzotto – MAGIC outreach summer school - 2009

# Resume

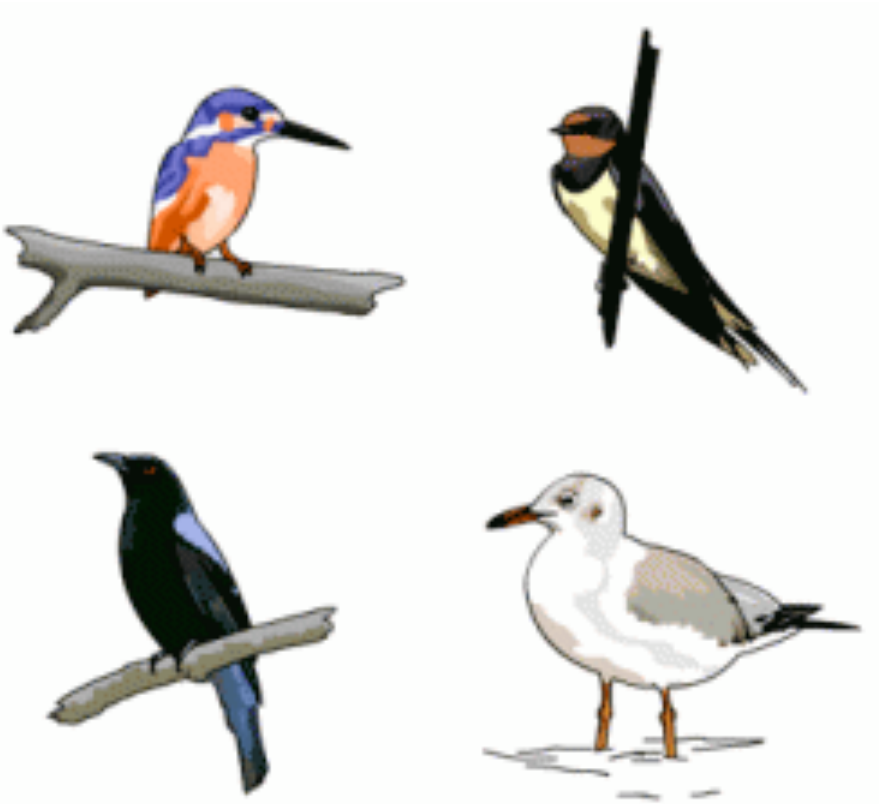
- So: you realized you were not able to select your gammas directly by your eyes.
- Why??
- If we want to ask the help of your pc, we need to define properly what's the definition of a general object, you need to recognize with respect to some other.

# Definition of "anything"…

- In geometry, for example, it is clear and exhaustive:



# How do you recognize a bird??



**Let's discuss together!**

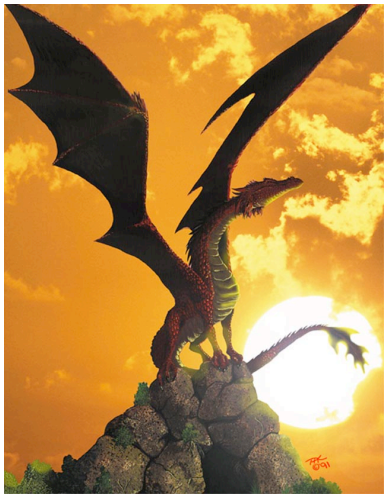
# Let's search for a variable defining it…

2 legs

it flies

a pecker

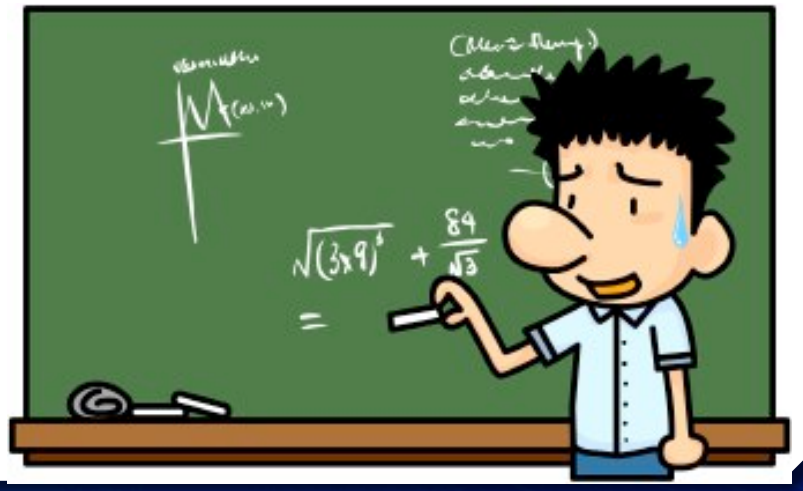
2 wings



We need to find
a best variable,
Let's call it 'birdness'!
???? HOW ????

# The idea

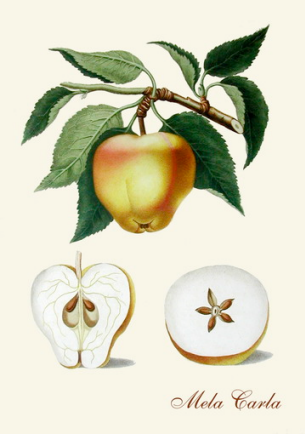
- We don't want a high precision, since the real life is not precise! ;-) Otherwise we will find only "ideal" birds!
- We use the possibility to GUESS, instead of answering a question only when you are 100% sure… like at school!!!
- **BUT you need a (very long) training/experience!!!**



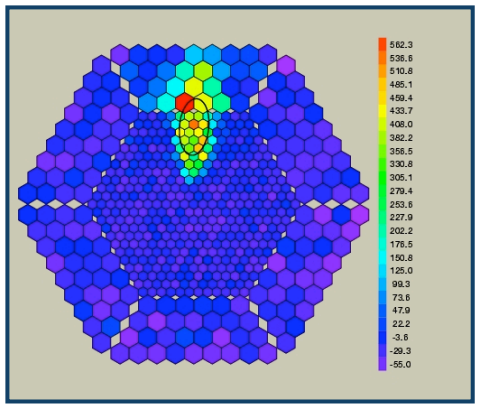
# The idea → How ?

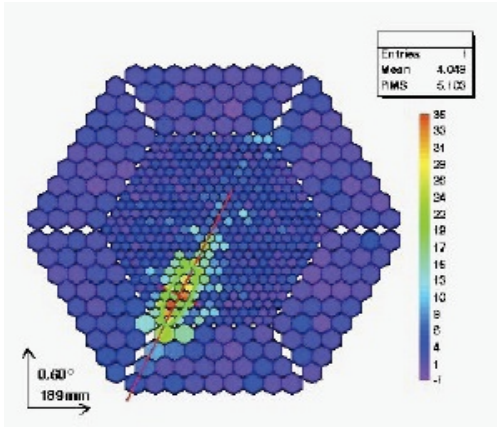
- We create an algorithm
- Let's allow the pc "to be wrong!"
- We realize a training session, where the pc "learn" to recognize. Each time we say it: "Good!" ..if it's ok, or "Bad!" ..in case it's wrong.
- We need a lot of CPU power, and of time. But mostly during the training!!!
- Some other techniques uses the same principle (neural nets, likelihood)

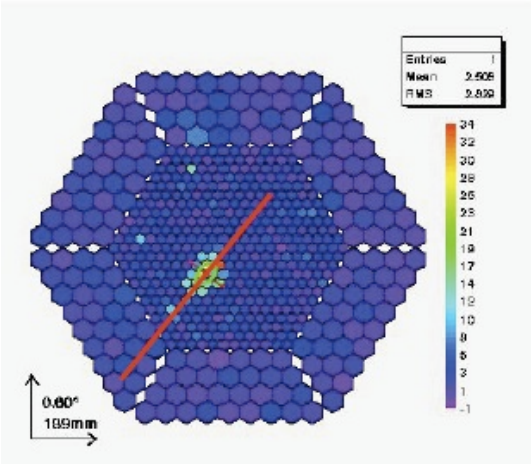
# “Apple/Pear separation”



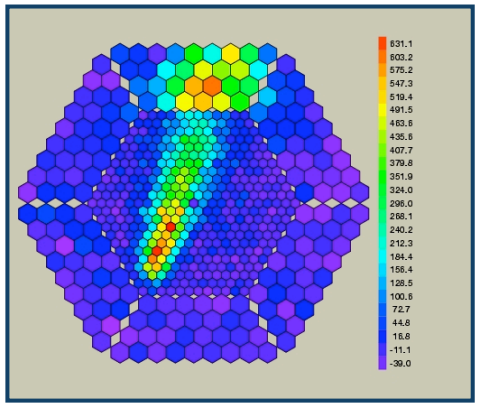

# Gamma/hadron separation

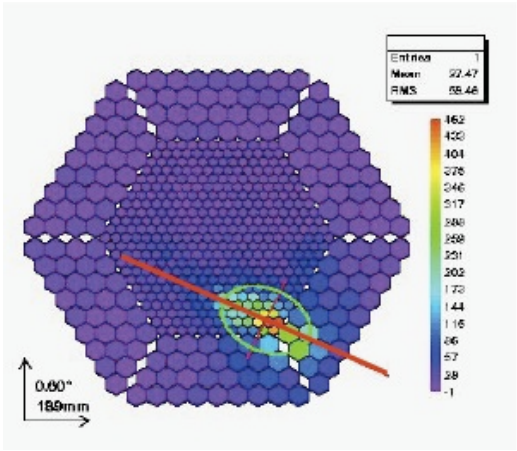


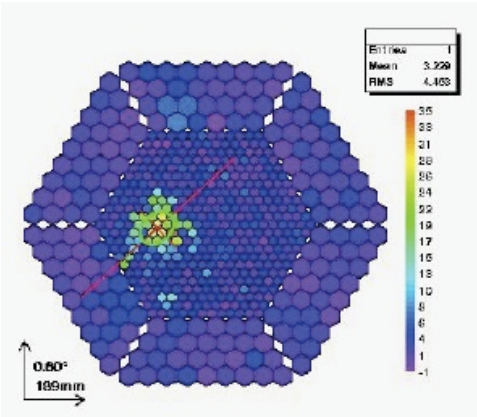




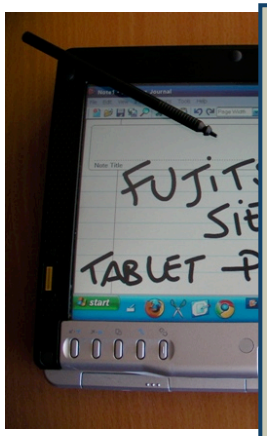
At low energy, harder and harder…!







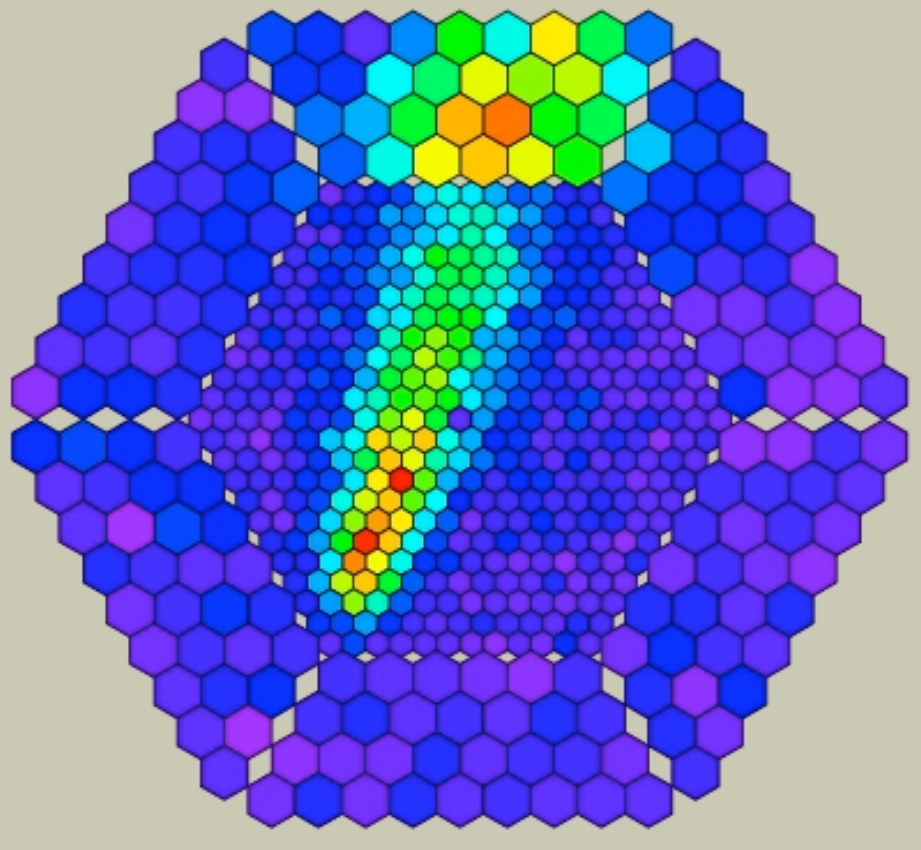
# Applications

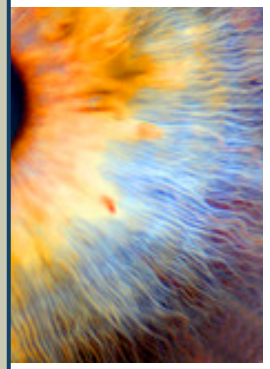


HandWritin

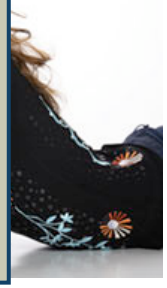
License Pla

## Gamma astronomy (MAGIC)



Speech

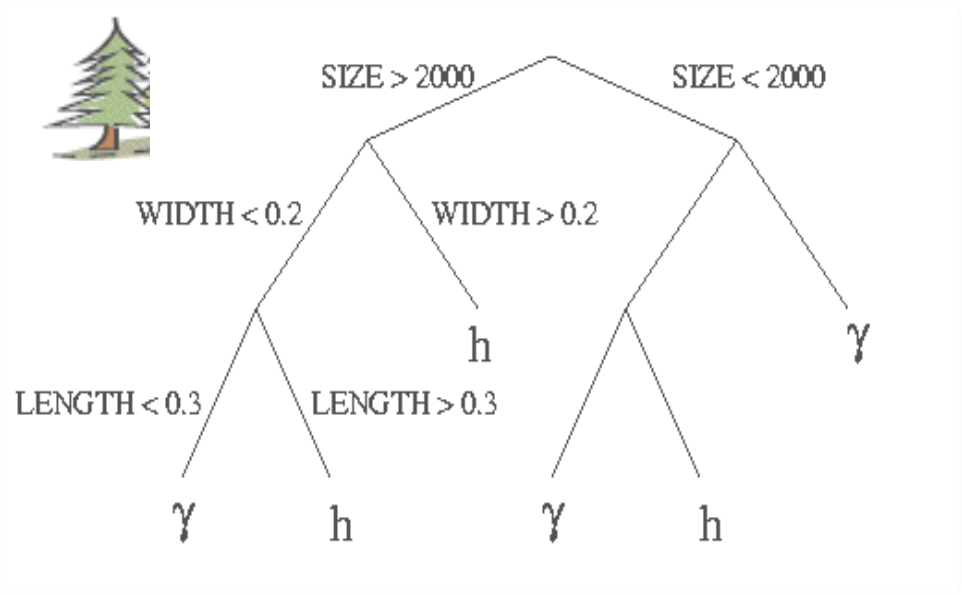


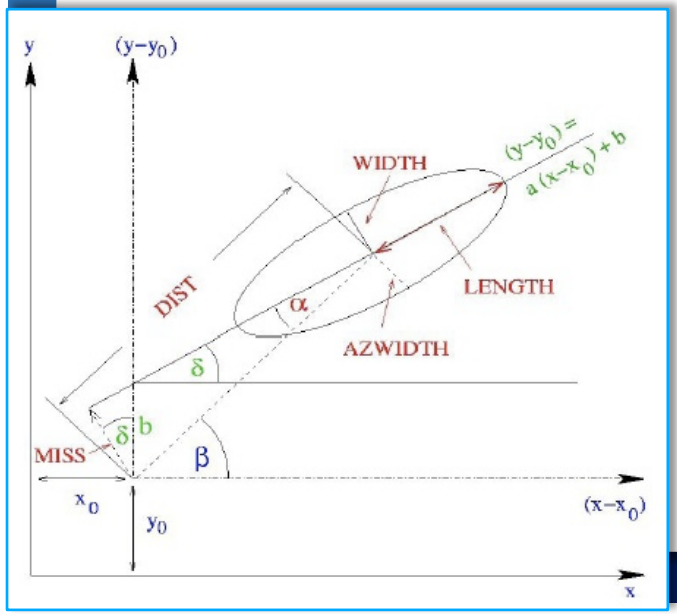
# Not only mimicry…

# Random forest: the Hadronness

- **No parametrization**
- **Use of "decision trees", built by training samples of events of known kind**
- **Combination of parameters and their correlations can be taken into account**
- **It tags each event with a "hadronicity coefficient", spanning from 0 (gamma-like event) to 1 (hadron-like event)**

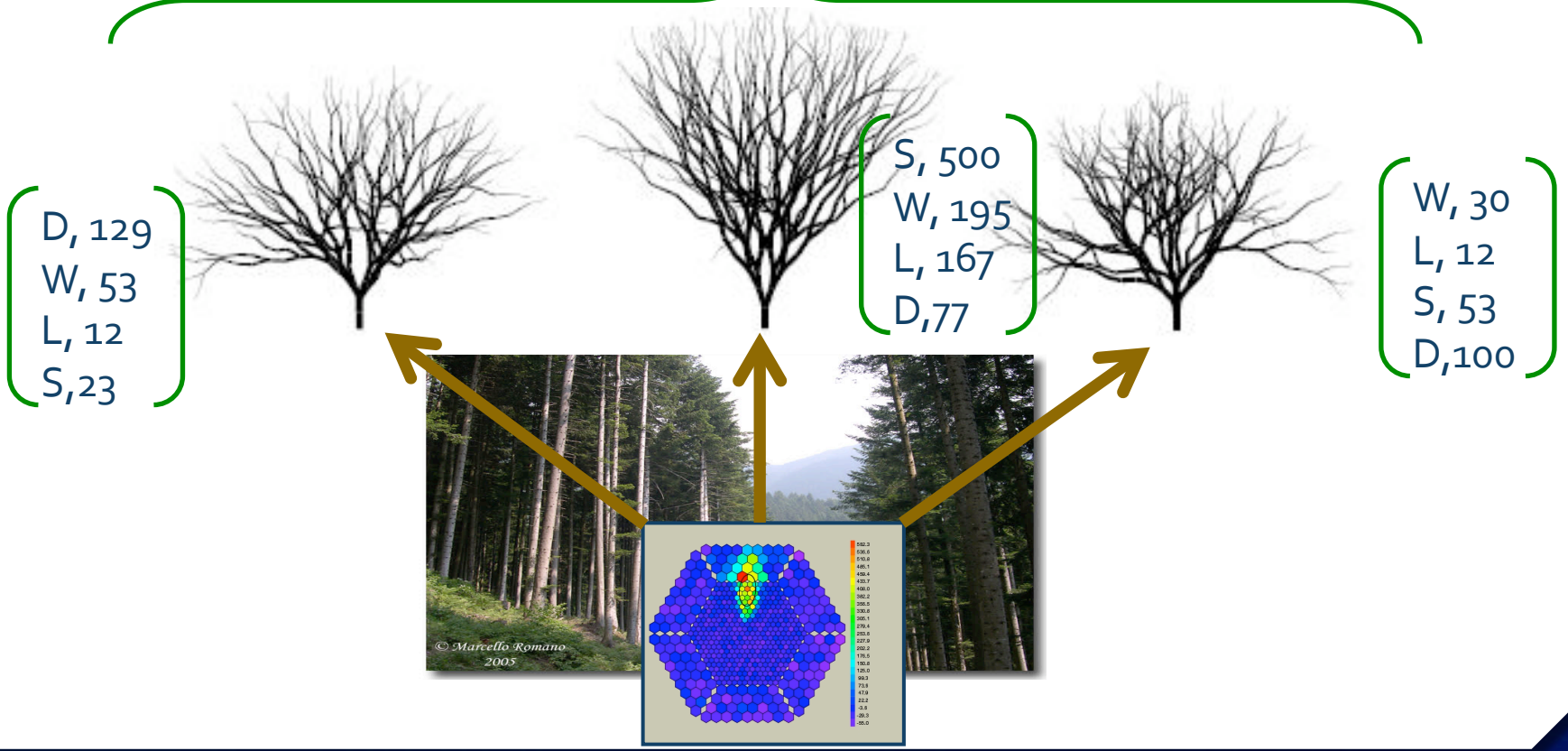
Gamma event selection is based on the use of Random Forest (RF) classification method by the information lead from image parameters




# Random forest: the Hadronness

$$\text{Hadronness} = \sum_{tree} h_{tree}$$



# Remember: the system is not perfect!

- Improvements in the analysis
- Often this means more cpu power and more statistic (that is … more and more "books" to be studied by your pc!)
- Our brain is still more clever than software

example of a captcha used in the web against hacking

- …but drastically slower!

# Random forest: Hadronness

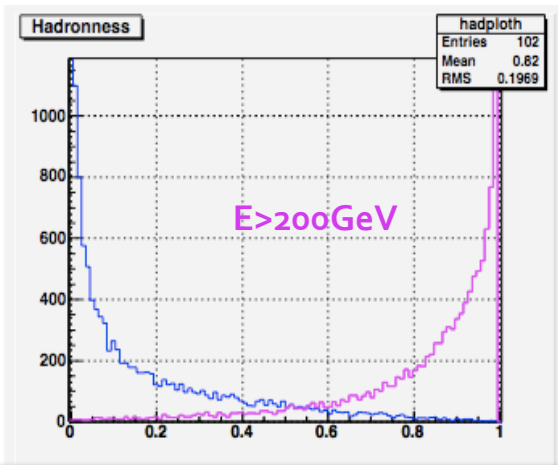
To measure the gamma/hadron separation,
a scalar value is defined:

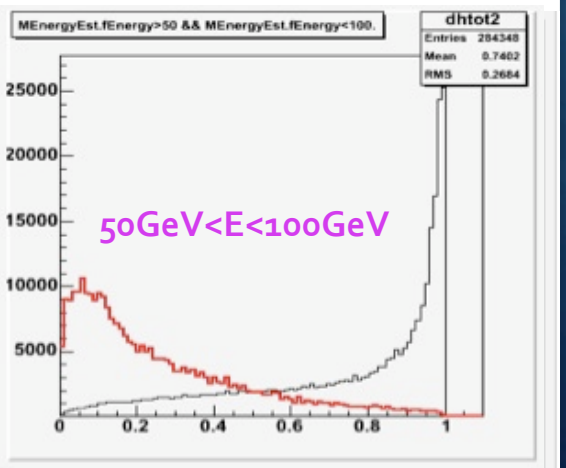
$$Q = \frac{\epsilon_\gamma}{\sqrt{\epsilon_h}}$$

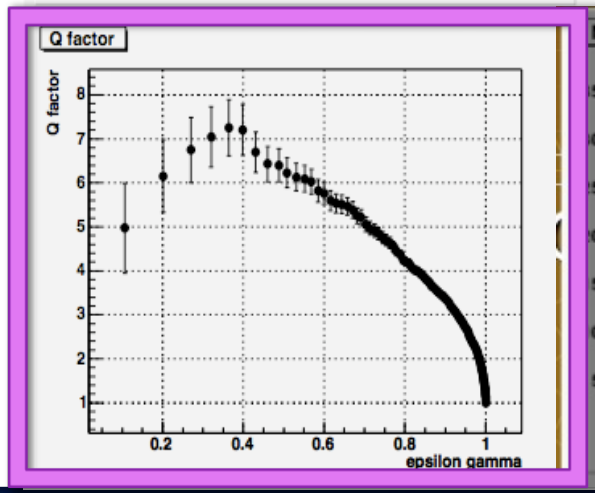
$$\epsilon_{\gamma,h} = \frac{\#_{\gamma,h}\ \text{after cuts}}{\#_{\gamma,h}\ \text{before cuts}}$$

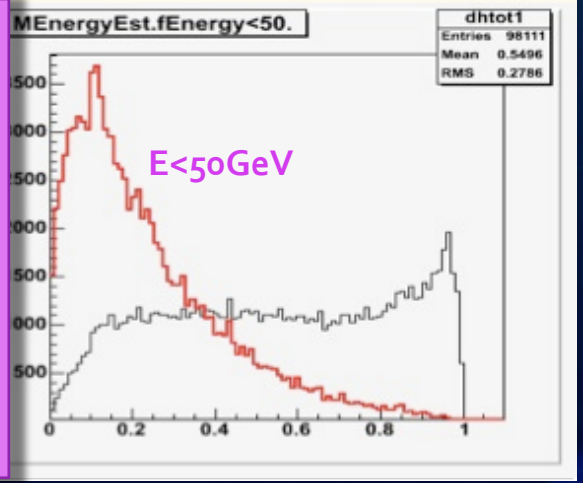
The higher the Q factor,
the better the gamma/hadron separation

**0 < Hadronness < 1**



# End of the γ/h-sep session

We have quite arrived to the end!

BTW: how much difficult do you think it would be to separate these two kinds of fruit?

# Observations and signal detection

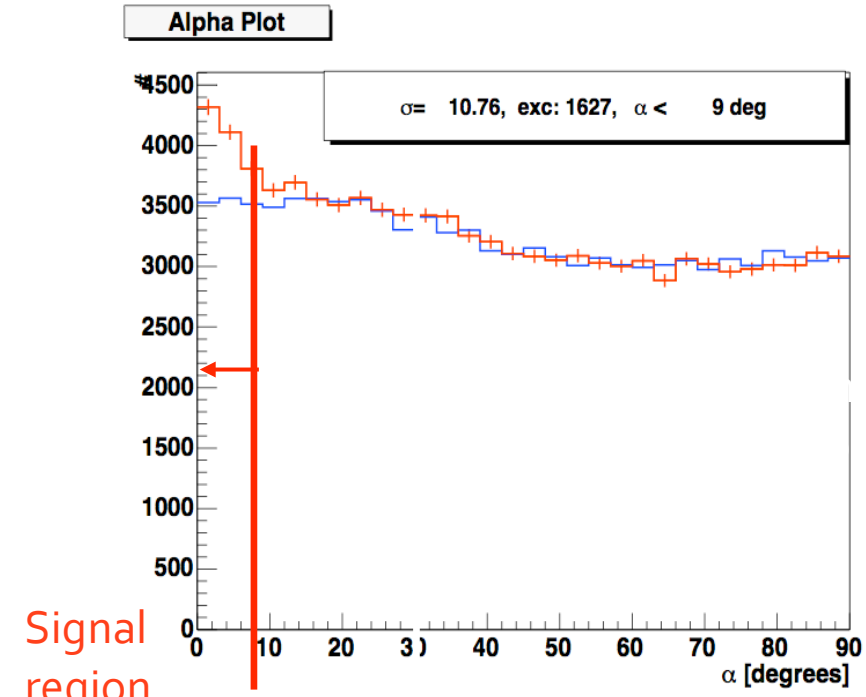
For each source, two kind of observation:

- ON : data taking pointing toward the source
- OFF: data taking in a portion of the sky with similar conditions, but with no gamma source

Alpha distribution for On and Off used to detect the signal

Detection defined as a signal found with significance (Li&Ma formula) equal to 5

On/Off normalization by the tail of Alpha distribution



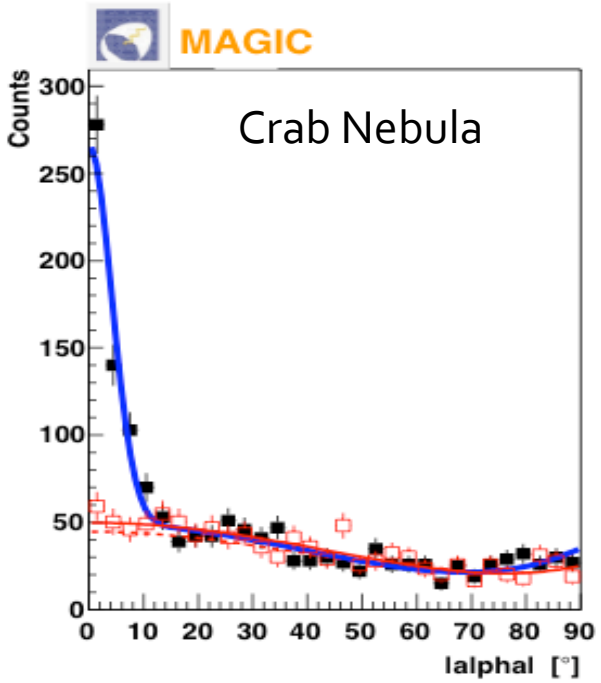

Signal region

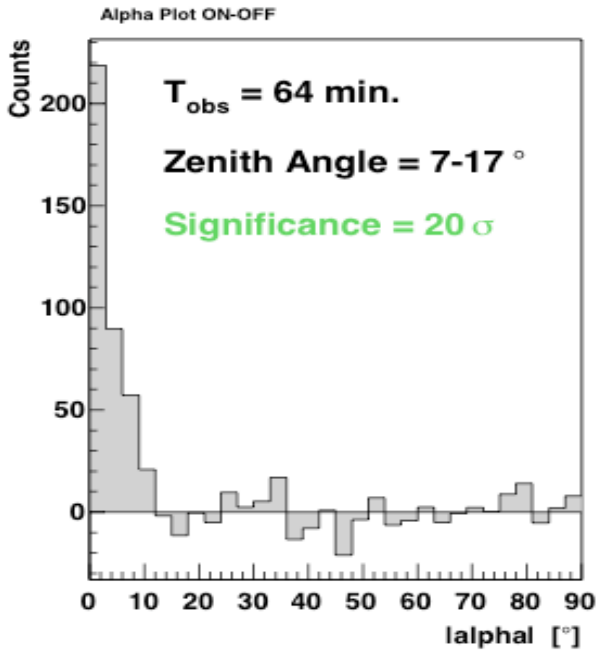
# Crab: the standard candle

Strong steady source of GeV/TeV gamma rays (Whipple '89)

=> Standard candle to test performance Cherenkov Telescopes

- Explosion observed in 1054 A.D.
- Distance 2 kpc

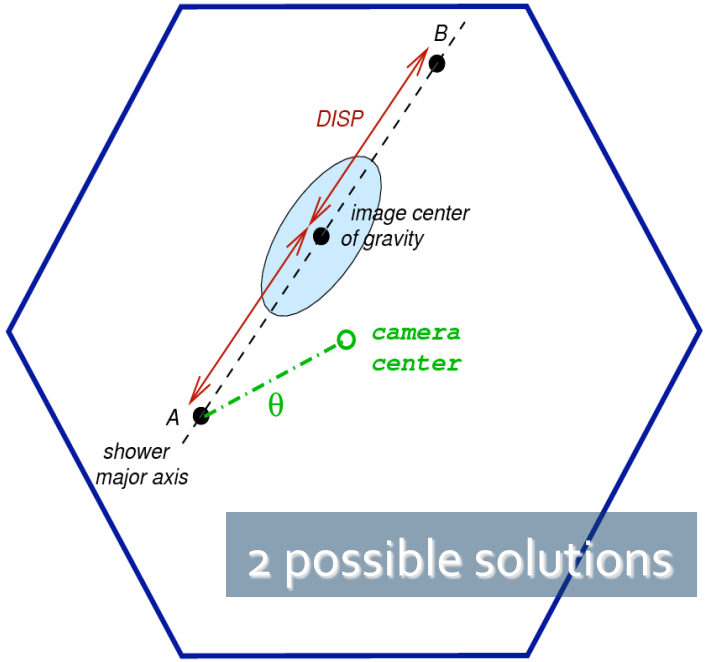


# Source Position reconstruction

## (DISP method)

- **Angular Resolution: 0.1°**




2 possible solutions

$$\mathrm{Disp} = \mathrm{A(Size)} + \mathrm{B(Size)}\frac{\mathrm{Width}}{\mathrm{Length} + \eta(\mathrm{Size}) \cdot \mathrm{Leakage}}$$

Theta: (Estimated SrcPos - Nominal SrcPos)

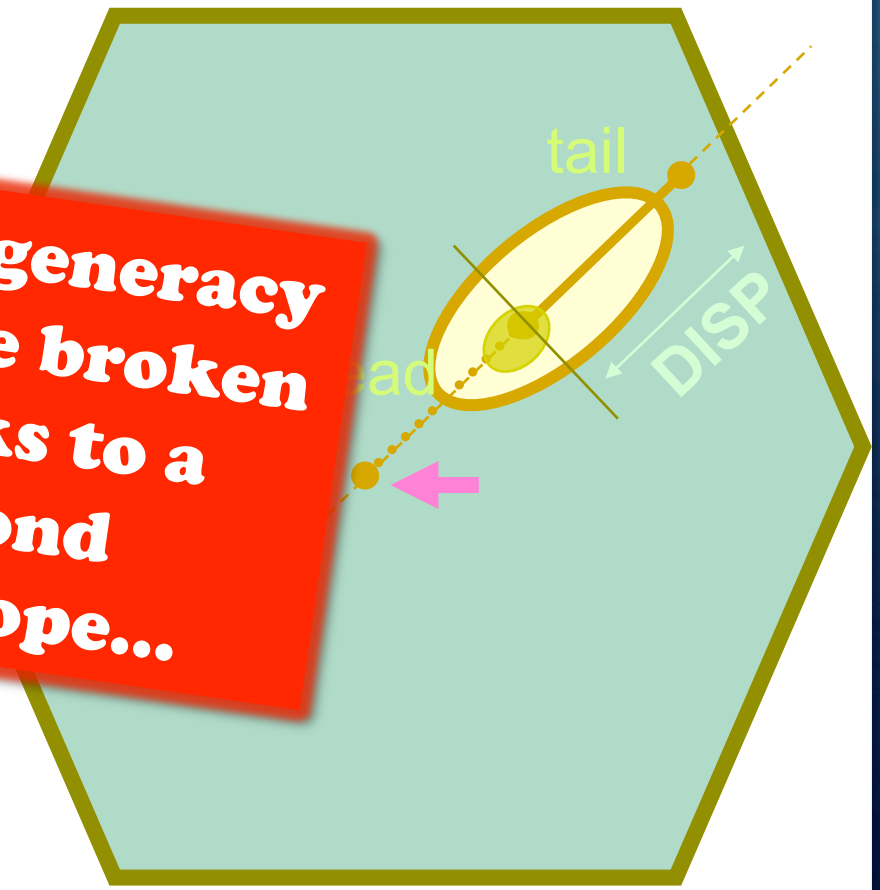
Useful also for extended sources

# Head-tail discrimination

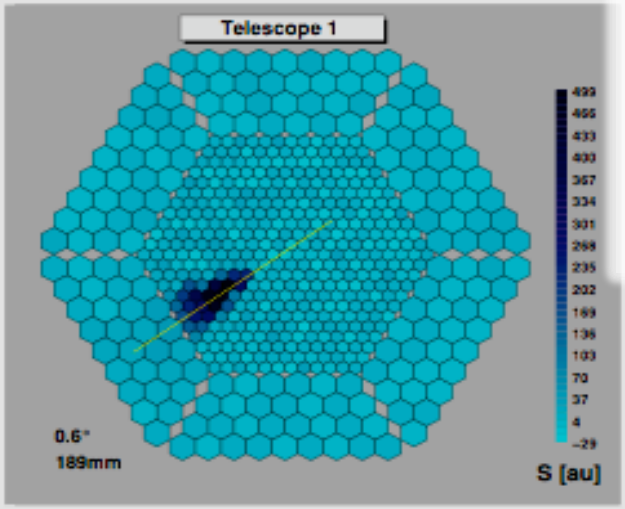
Differences in image shape: l
asymmetry

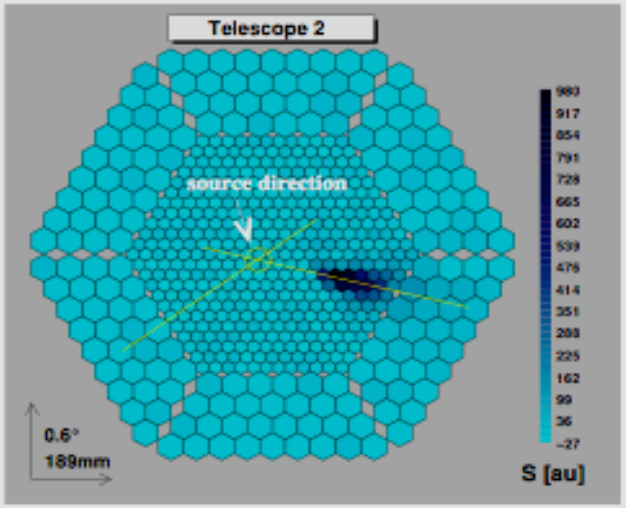
Head Tail asymmetry h
disentangle
the degeneration in the sou
lead by *DISP met*
(2 possible solutions)

**This degeneracy could be broken thanks to a second telescope...**



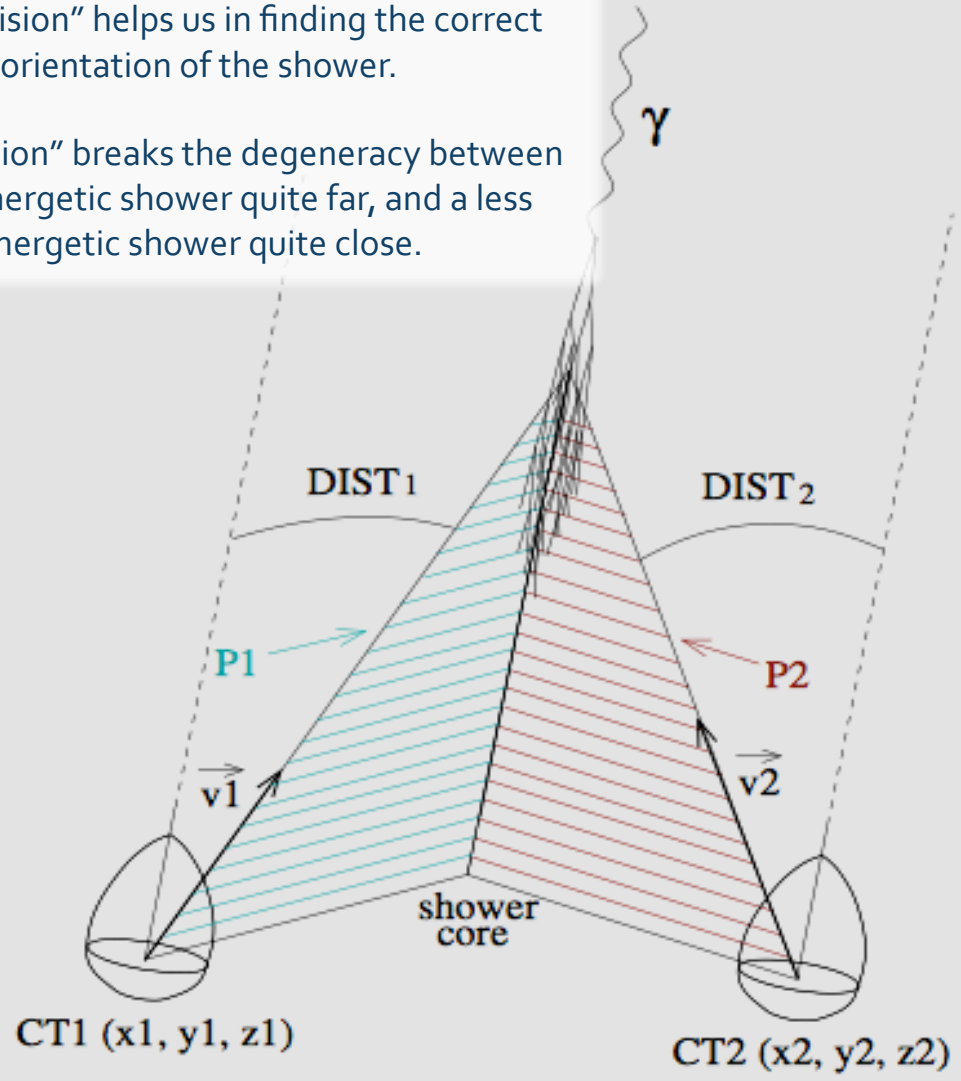
# Working in stereo mode



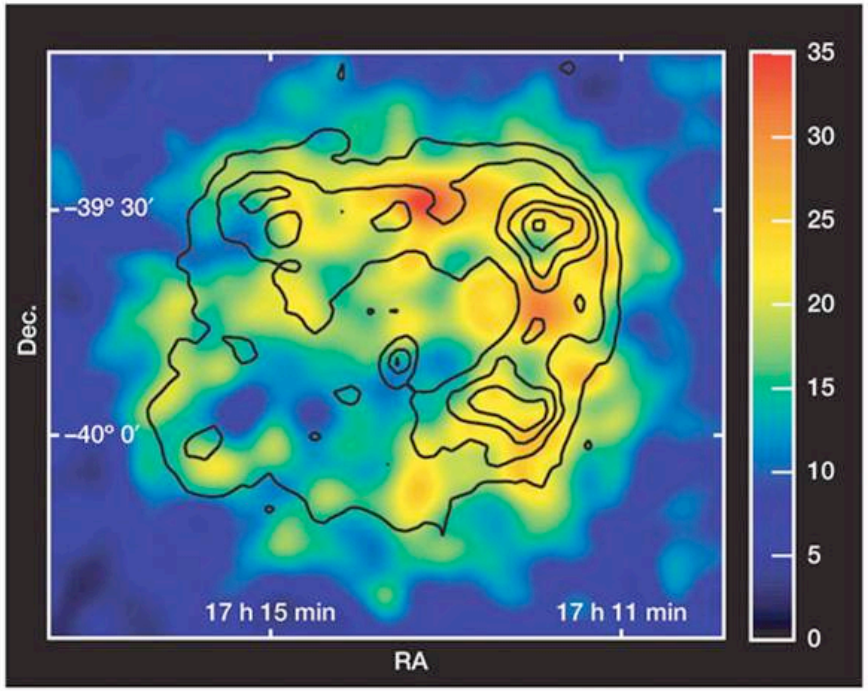




Stereo "vision" helps us in finding the correct orientation of the shower.

Stereo "vision" breaks the degeneracy between a high energetic shower quite far, and a less energetic shower quite close.



# What does the stereoscopy change?



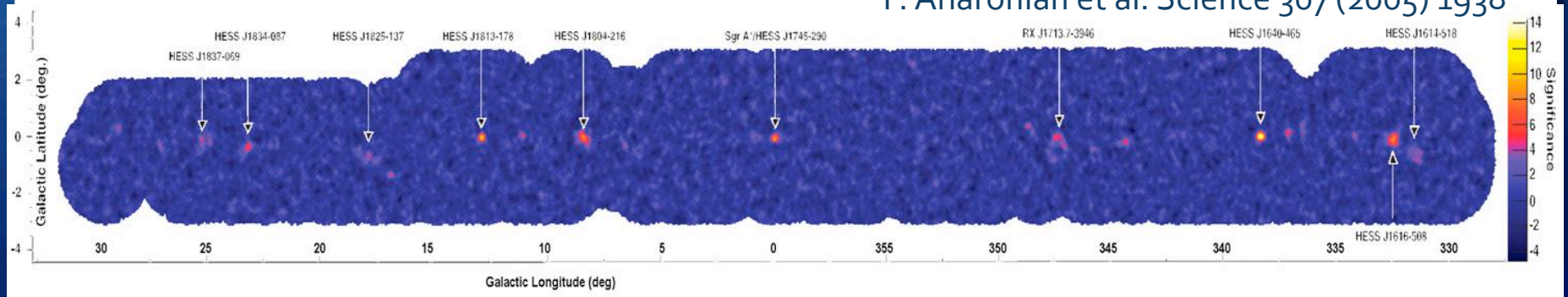

Higher resolution → Structures of gamma sources will become visible!

like
RX J1713.7-3946 (Gamma image by HESS)

Galactic Plane Survey by HESS

Many new galactic sources !!!

F. Aharonian et al. Science 307 (2005) 1938



# The stereo system

Just to give you an idea of what the stereo system

would change…

This could be the difference….


(see next slide with 1 eye or 2 eyes properly combining the information coming by each single eye…. ;-) )


EINSTEIN
MAGIC STEREO!!!
MAGIC
MAGIC