TenTen: A new IACT Array for Multi-TeV Gamma-Ray Astronomy

Gavin Rowell ***, Roger Clay, Greg Thornton, Victor Stamatescu***

(University of Adelaide)

Searching for PeV CR Accelerators
Adelaide Dec 2006

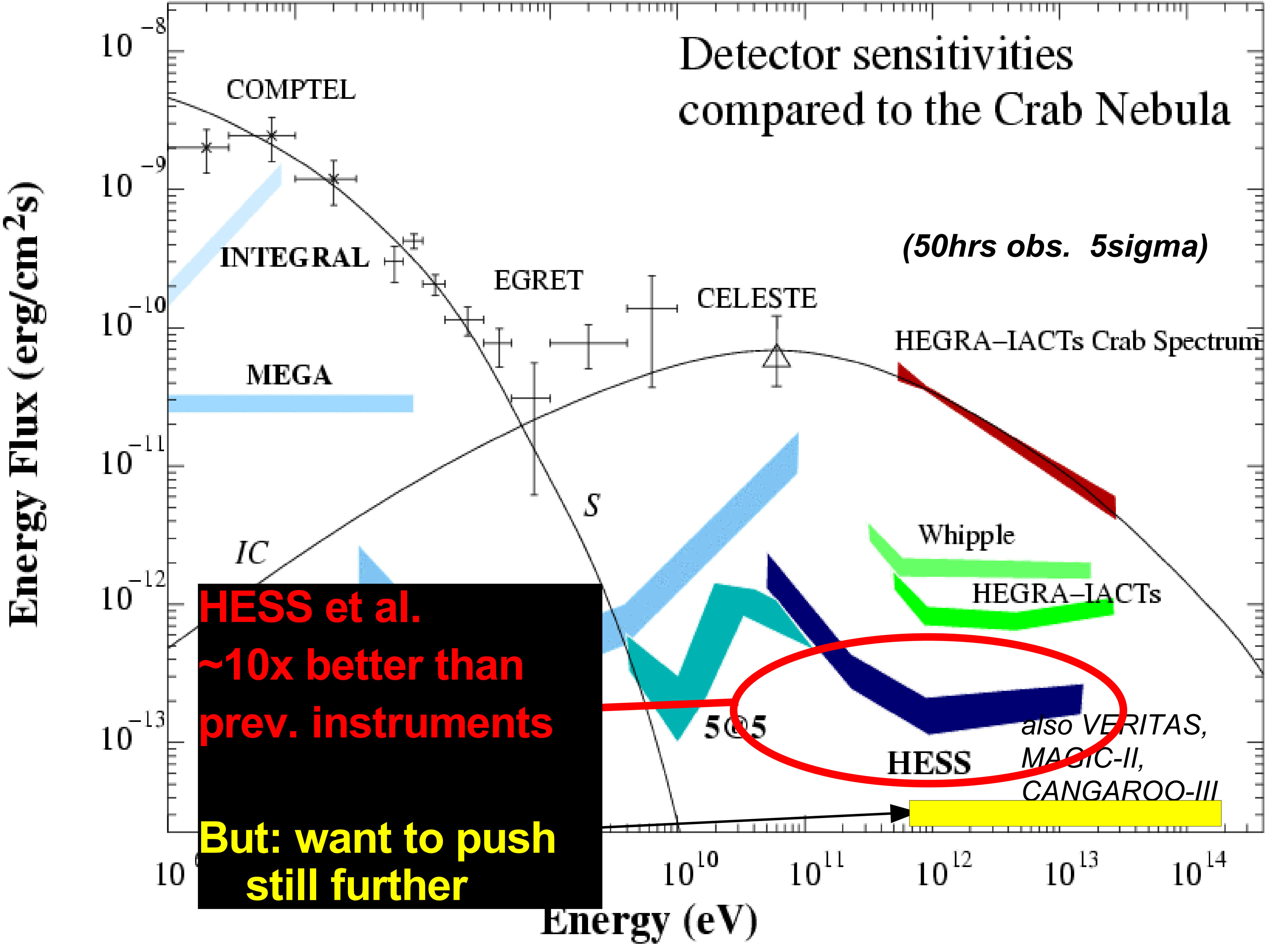
Conclusions & Lessons from HESS et al.

- Hard spectra (harder than $E^{-2.4}$) for the majority of Galactic TeV sources.
- No clear sign of cutoffs above 10 TeV so far in many
- Require > 50 hrs observation to reach >50 TeV gamma energies
- Require > 50 hrs observations to probe extended sources < 0.05 Crab
- 0.1 TeV instruments have packed observation programmes

- Still want to search for Particle PeVatrons (the knee and beyond)
- PeV CR Acceleration much less well understood cf. Multi-TeV energies but present results are providing clues.

Along with current future efforts to lower the energy threshold and improve the sensitivity of instruments (eg. HESS-II, MAGIC-II..)

There is great potential and a niche for Gamma Ray telescopes optimised for the E> 1 TeV regime.


Detector sensitivities
compared to the Crab Nebula
(50hrs obs. 5sigma)
COMPTEL
INTEGRAL
EGRET
CELESTE
MEGA
HEGRA–IACTs Crab Spectrum
S
IC
Whipple
HEGRA–IACTs
5@5
HESS
also VERITAS,
MAGIC-II,
CANGAROO-III
HESS et al.
~10x better than
prev. instruments
But: want to push
still further
Energy Flux (erg/cm²s)
Energy (eV)
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{10}
10^{11}
10^{12}
10^{13}
10^{14}

The *TenTen* Concept: for Multi-TeV Gamma Ray Astronomy

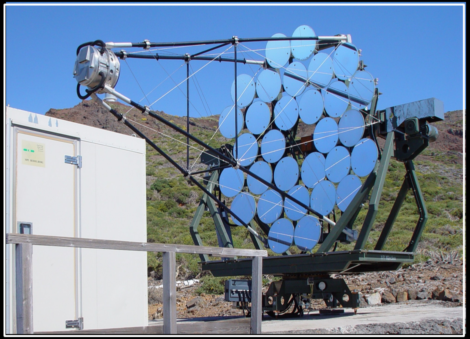
Requirements (compared to HESS)

Based on simulation studies

Plyasheshnikov et al. (2000)

Each telescope:

- **Smaller mirror area/size (~10-30 m^2) HESS ~100 m^2**
- **Larger camera field of view (6°-10°) HESS ~5°**
- **Larger telescope spacing (L >200 m) HESS 120 m**



HEGRA IACT

System Telescope

Desired Effective collecting area:

10 km^2 at 10 >TeV ---> *'TenTen'* project

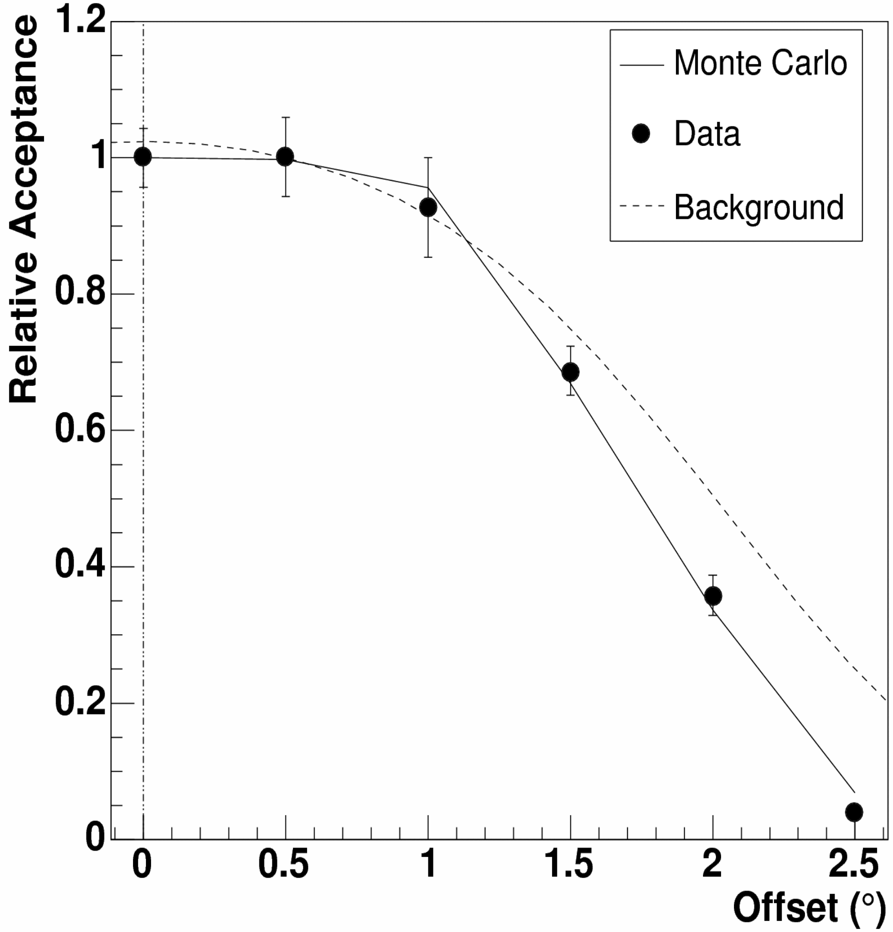
and >1km^2 at ~1 TeV

Sites: **Sea-level altitude maybe favourable**

--> Australian sites.

Large FoV: Why?

HESS: Gamma acceptance vs. off-axis dist.

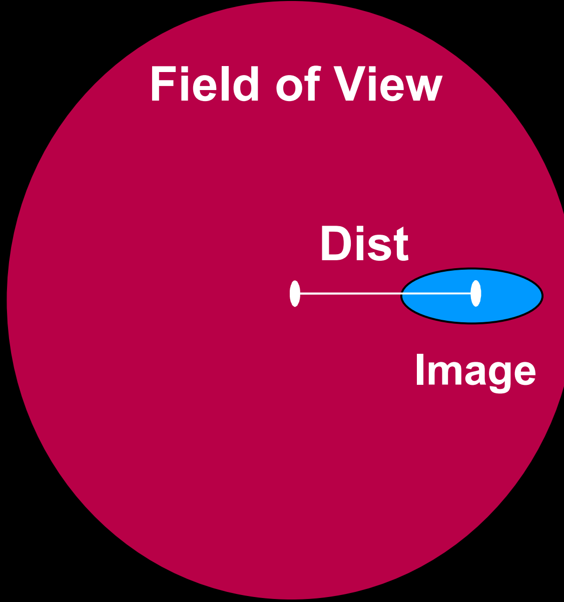


5.0 deg diameter HESS FoV

--> FWHM ~ 4.0 deg

Flat response 2.0 deg diam

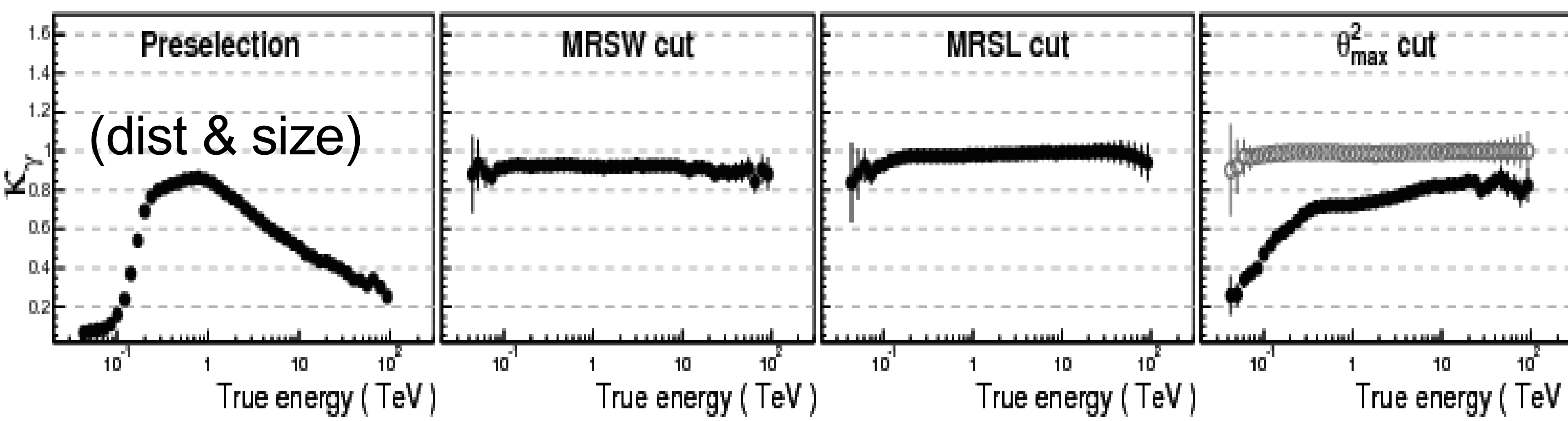
Large FoV: Why?



Require 'Dist' cut to avoid edge effects.

HESS Gamma efficiencies for various cuts

D.Berge PhD thesis



Dist <= 2.0deg ----- image shape ----- direction

size>80 pe.

Necessary distance cut limits efficiency at higher energies

Large FoV: Why?

D.Berge PhD thesis

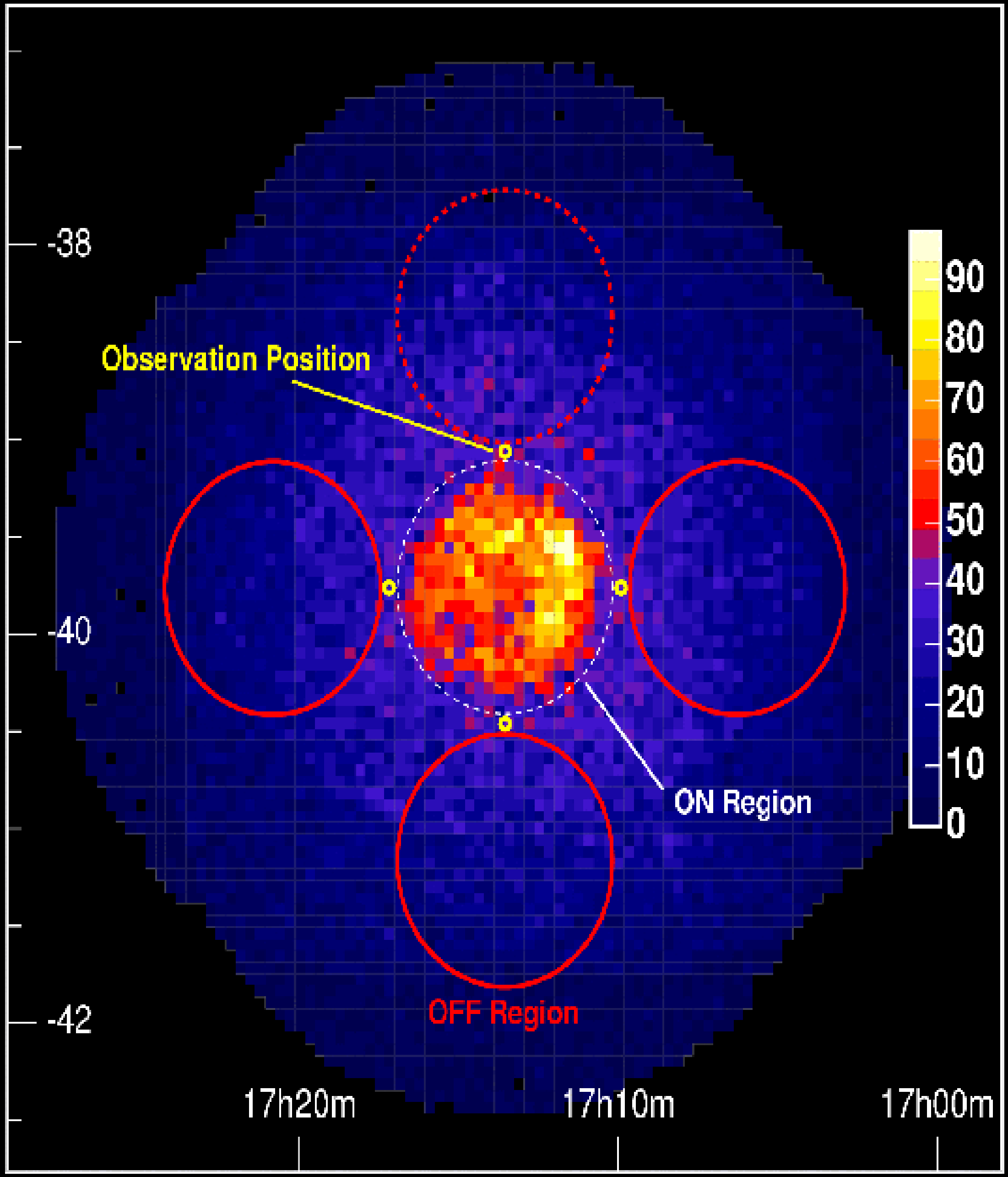
<u>Background estimates for spectra in extended source studies.</u>

Require event sample matched to ON source (same off-axis position)

1 deg source
 (eg. RXJ1713-3946)

--> require 2 deg flat FoV

Many other TeV sources in this category!



Large FoV & Better TeV sensitivity .Why?

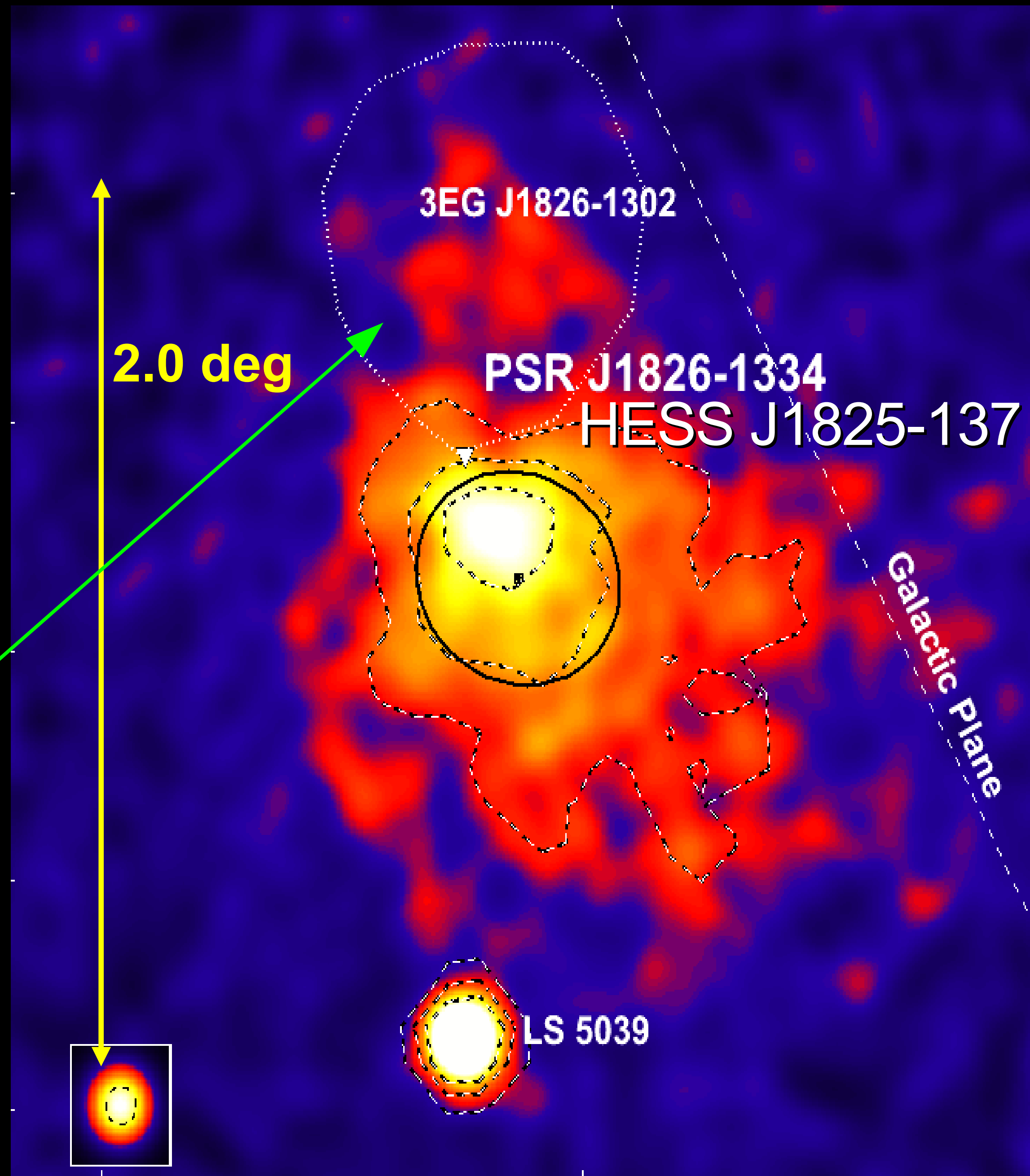
Complex source structures & strengths

- extended & pointlike
- strong & weak

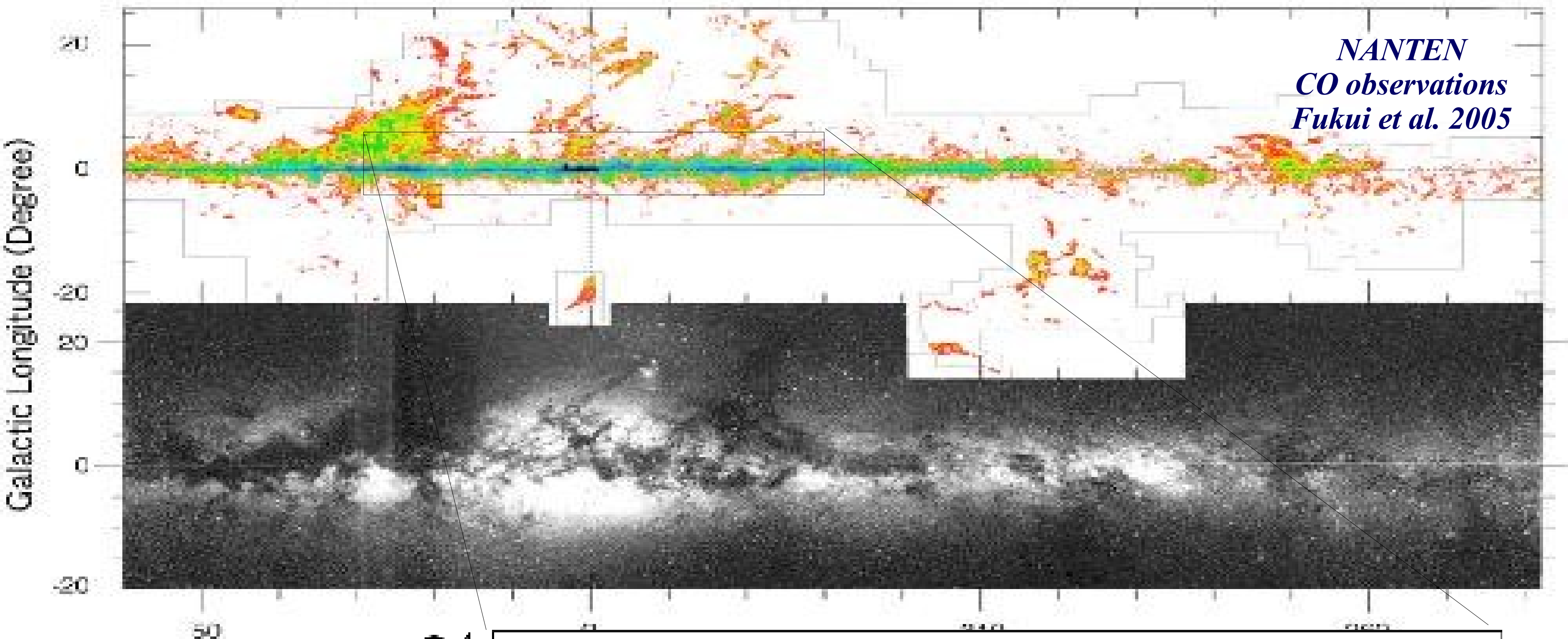
HESS J1825-137
Field after ~60 hrs observation

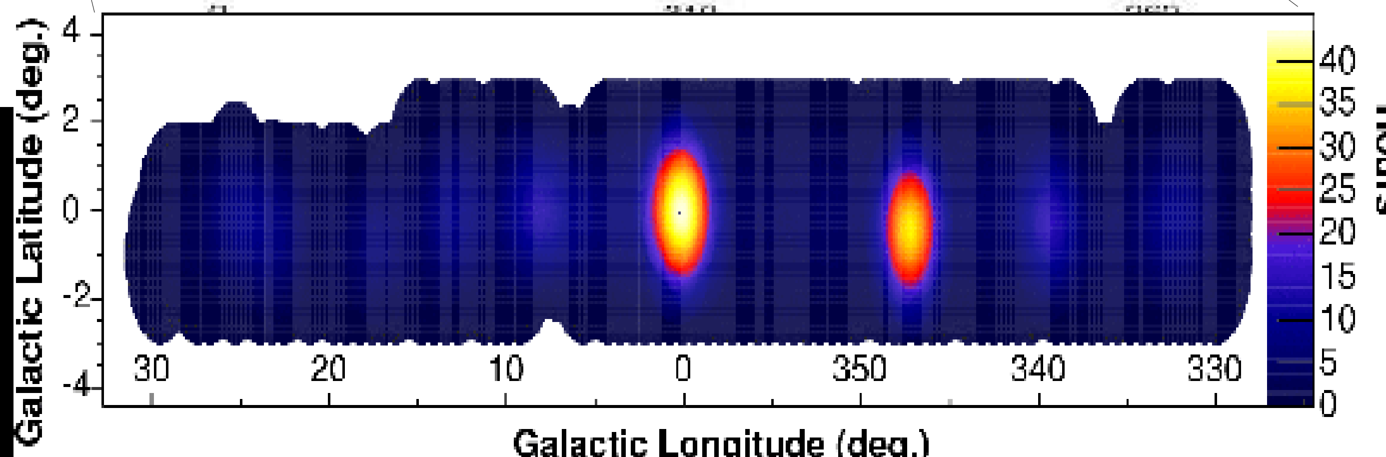
New, weak source appears

HESS cannot study this source any further



As we probe deeper --> might expect TeV gamma-ray sources to mimic galactic gas structures (scale ~few deg)





HESS effective exposure for inner Gal. Plane (2004)

Simulation Study

- **Investigate performance of:**
  Cell of 5 telescopes:

--> extrapolate to many Cells

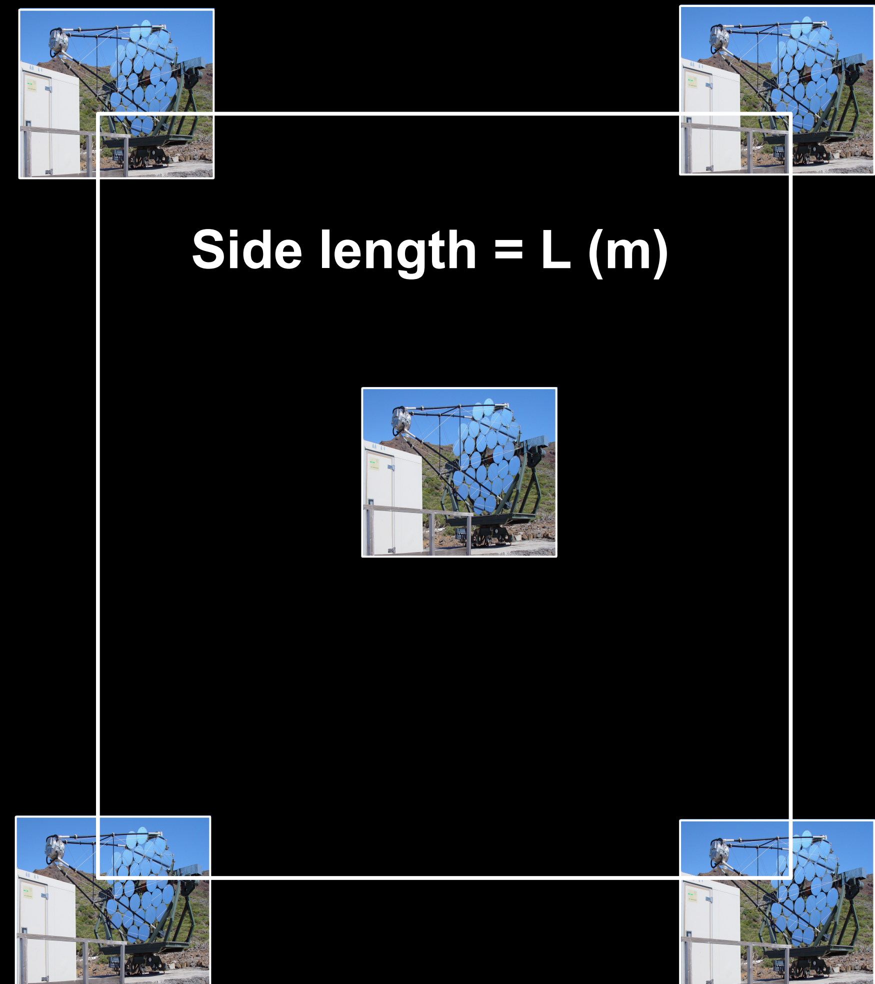
Site altitude 200m a.s.l

- **eg. Cell of 4 tels on a square of side**
  L = 200, 300, 500 metres

+ central telescope (for lower energies)

HEGRA IACT-System philosophy

may not be optimal but fine for first-order studies



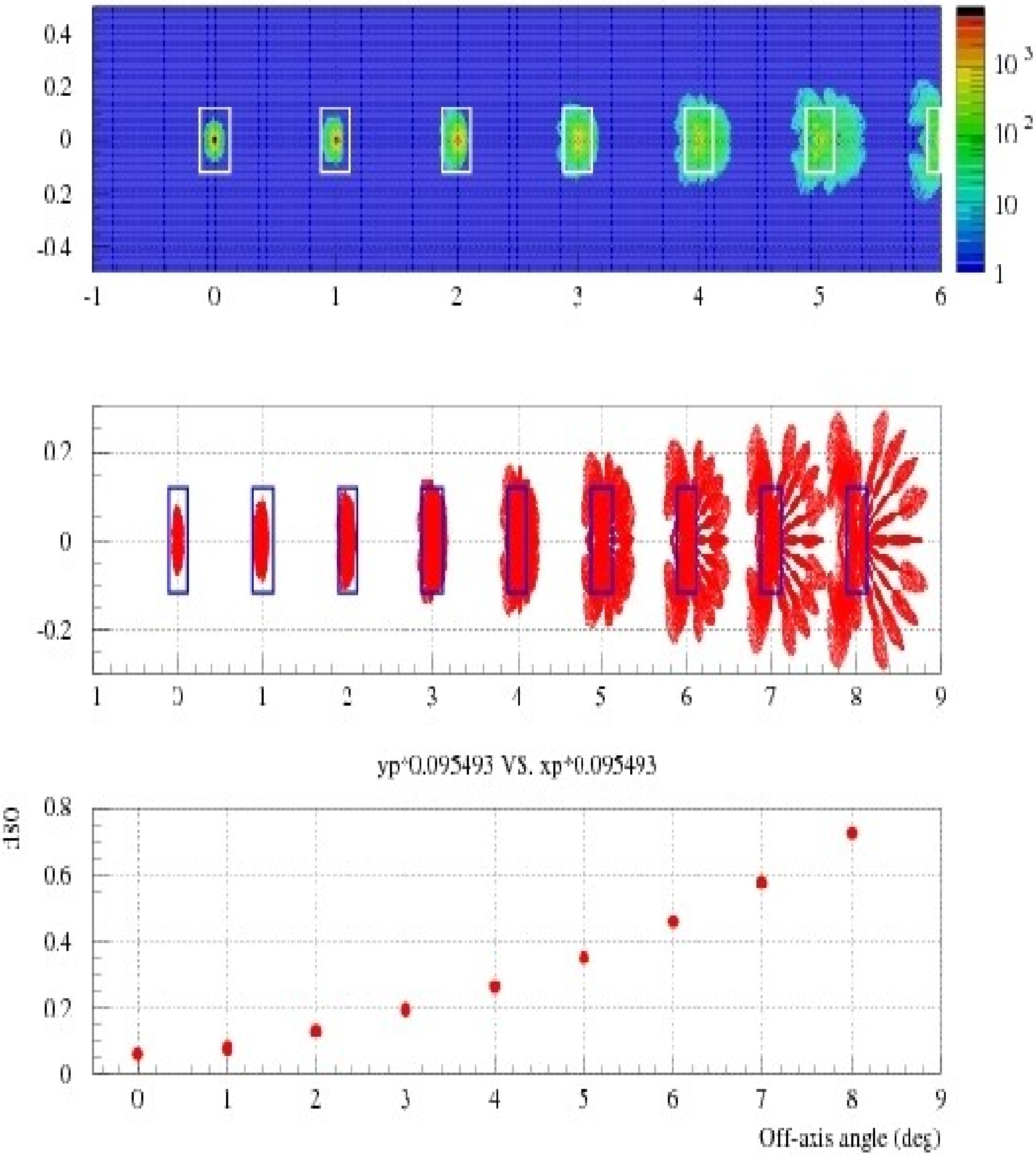
Mirror Optics

f/1.5 Elliptic dish shape
δ=5.0, r=0.85f
(Schliesser et al 2005 Astro.Part Phys. 24, 382)

with mirror canting (on-axis rays at focus)

tessellation ratio 0.1 = mirror / dish

Eg. Pixel size 0.24 deg (white box)
d80 : diameter containing 80% of light
8 deg FoV possible



Simulation Study

corsika v6.204 EAS simulations

30deg zenith angle gammas,protons 1-10, 10-100 TeV

sim_telarray tel simulation from K. Bernlohr

HESS–like electronics setup

(comparator, 20ns (F)ADC gate width....1-2ns rise/fall, ray-tracing)

6 metre diam mirror f/1.5 23.8 m^2

12 p.e. @ 2 pix near-neighbour 0.25deg pix x 1024 8.2 deg FOV

60 p.e. image SIZE

dist < 3.5 deg

4 metre diam mirror f/1.5 10.6 m^2

8 p.e. @ 2 pix near-neighbour 0.25deg pix x 1024

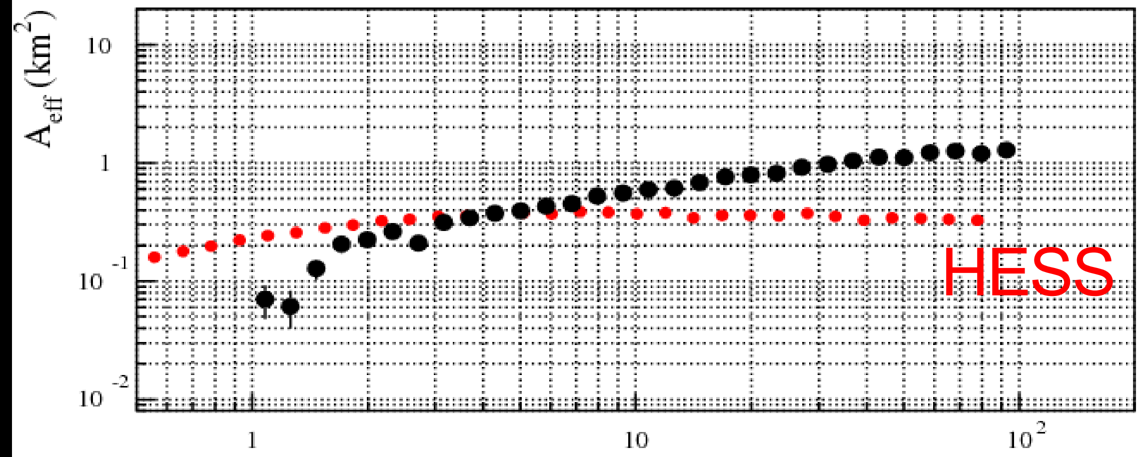
40 p.e. image SIZE

dist < 3.5 deg

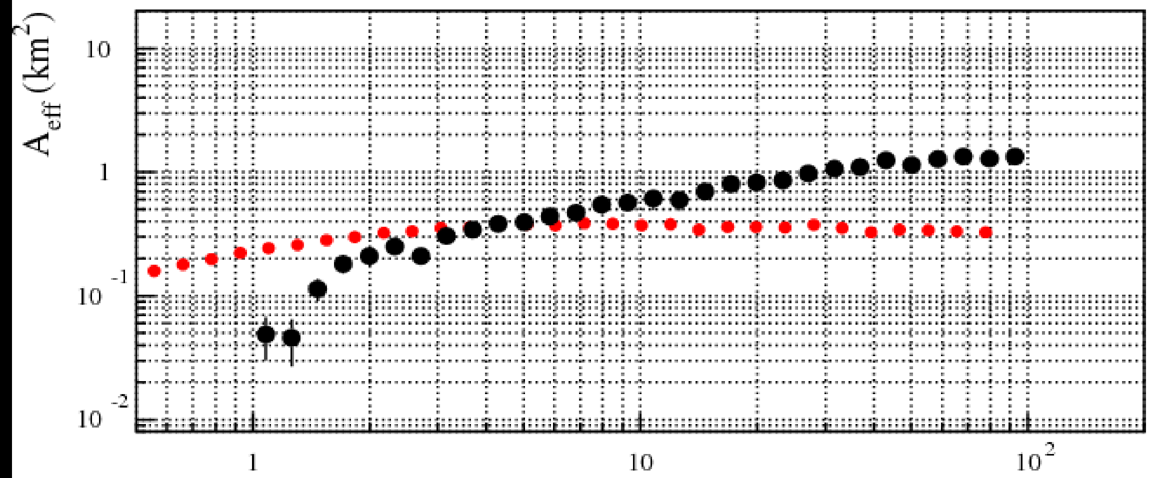
all cases *ntels >= 2 (stereo analysis)*

Effective Areas
6 metre dish

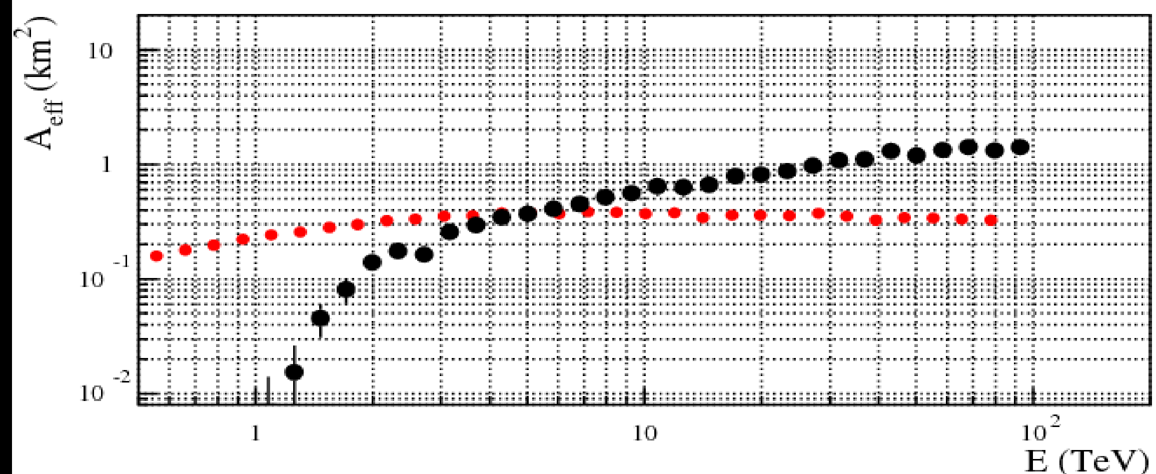
L=200m



L=300m



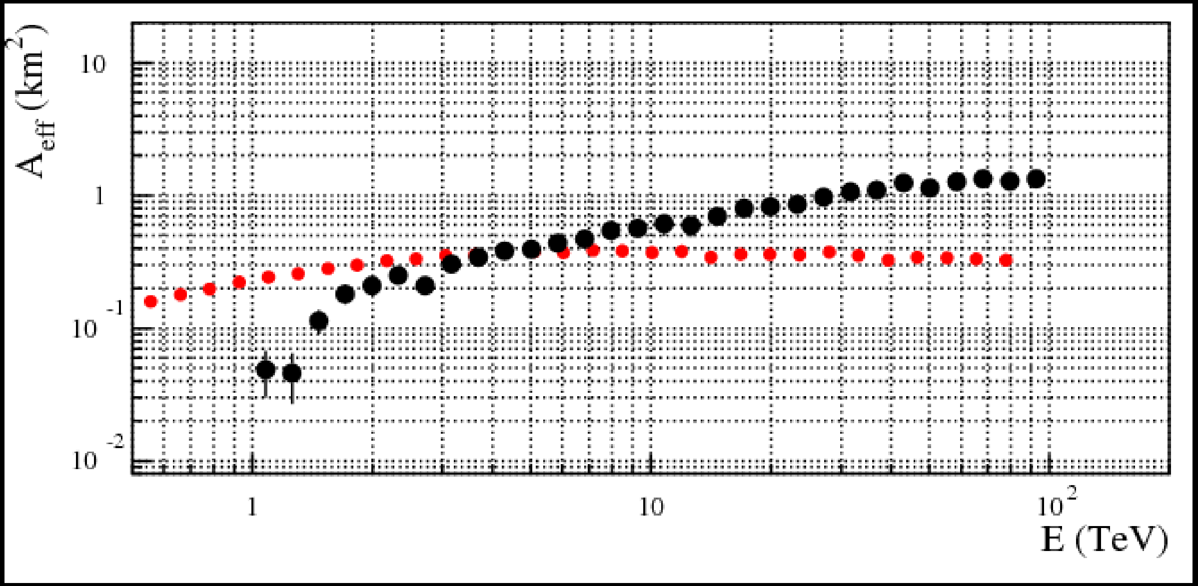
L=500m



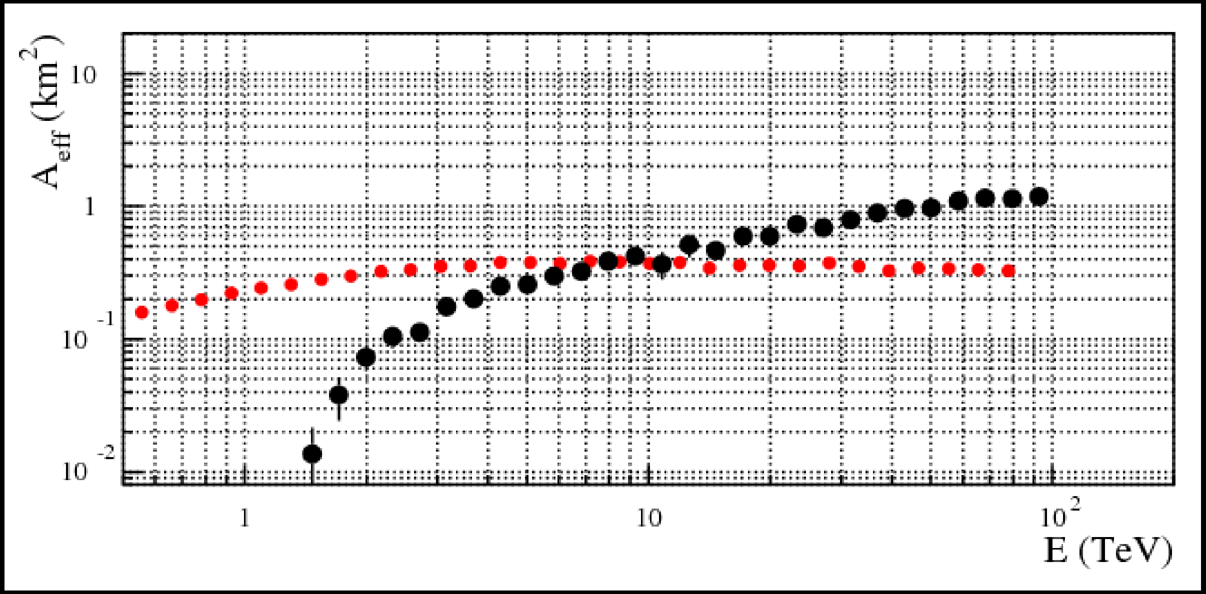
HESS – Aeff after size & dist cuts

Effective Areas

6 metre dish
L=300m



4 metre dish
L=300m



True
Shower 'Core'
6 metre dish

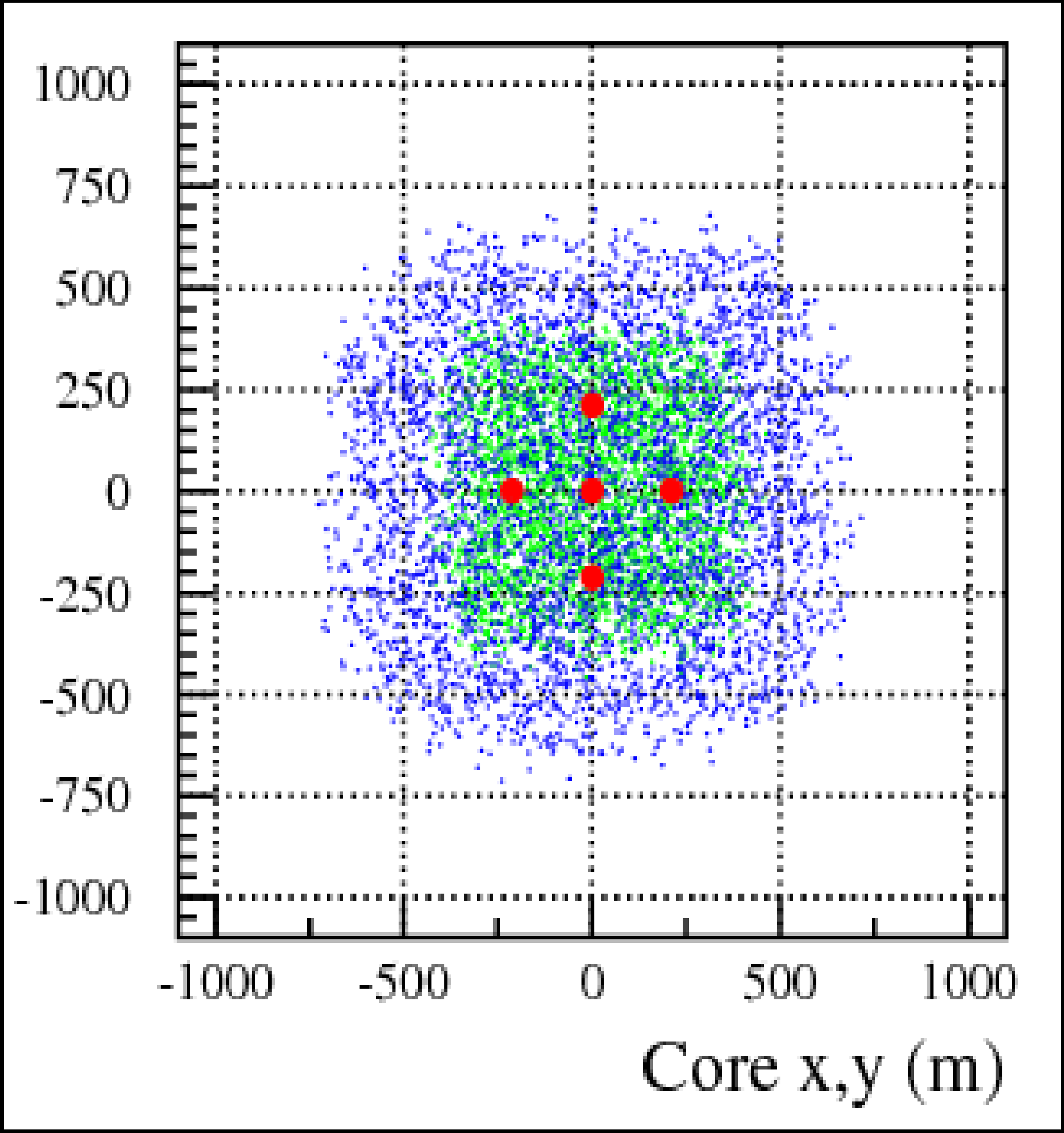
L=300m

Telescope positions

Energy 1-10 TeV

Energy 10-100 TeV

Core resolution
RMS <20 metres

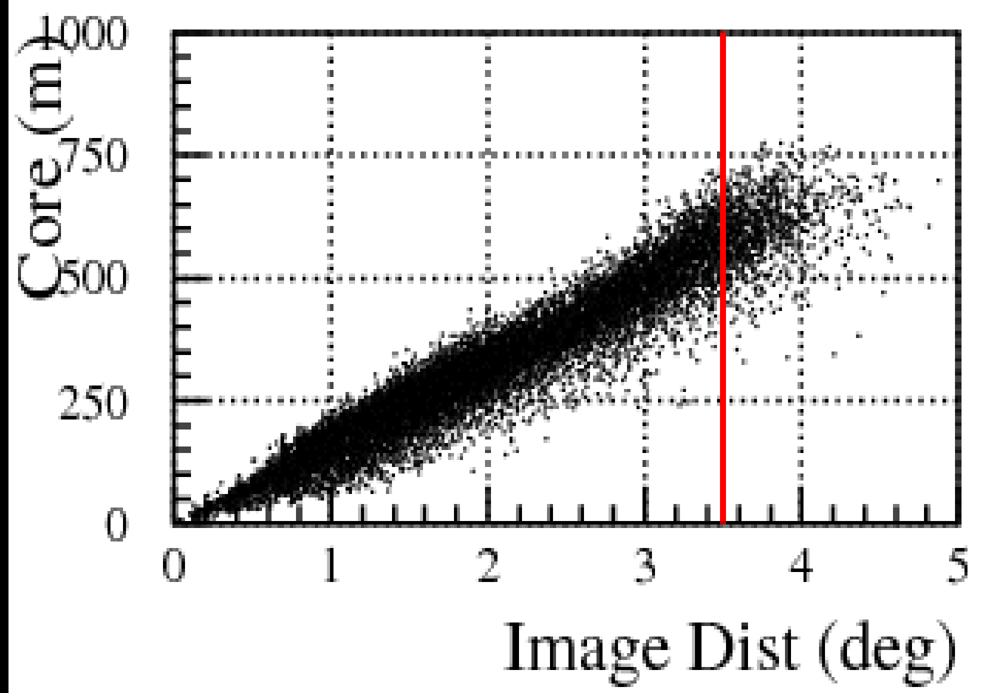


<u>Core vs. Dist</u>

<u>6 metre dish</u>

L=300m

dist <= 3.5 deg

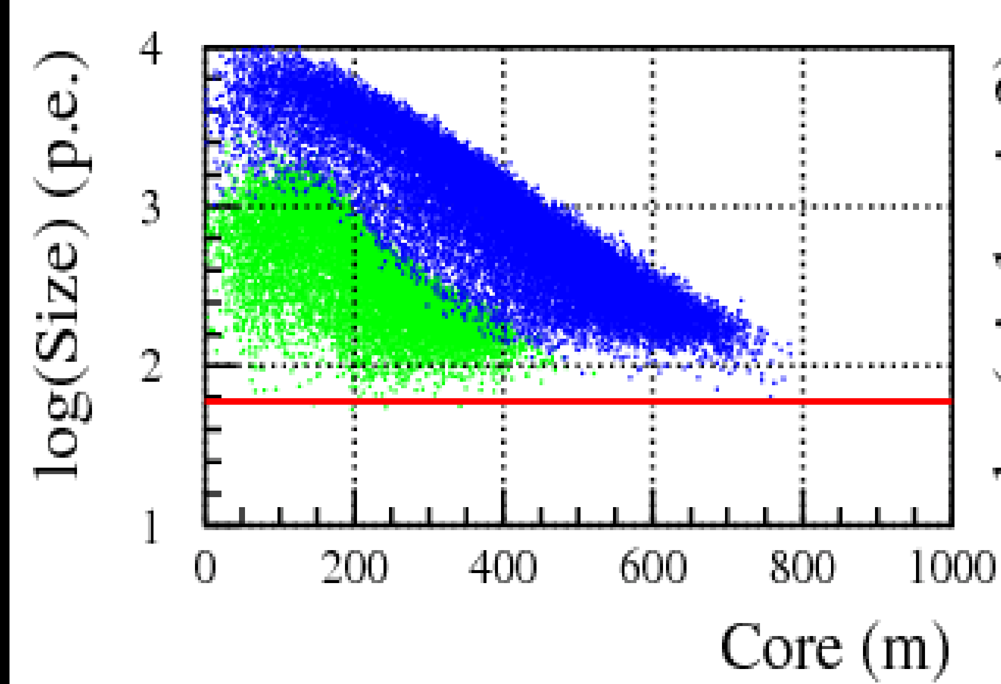


<u>log(Image Size) vs. Core</u>

size >= 60 p.e.

Energy 1-10 TeV

Energy 10-100 TeV



Energy Resolution

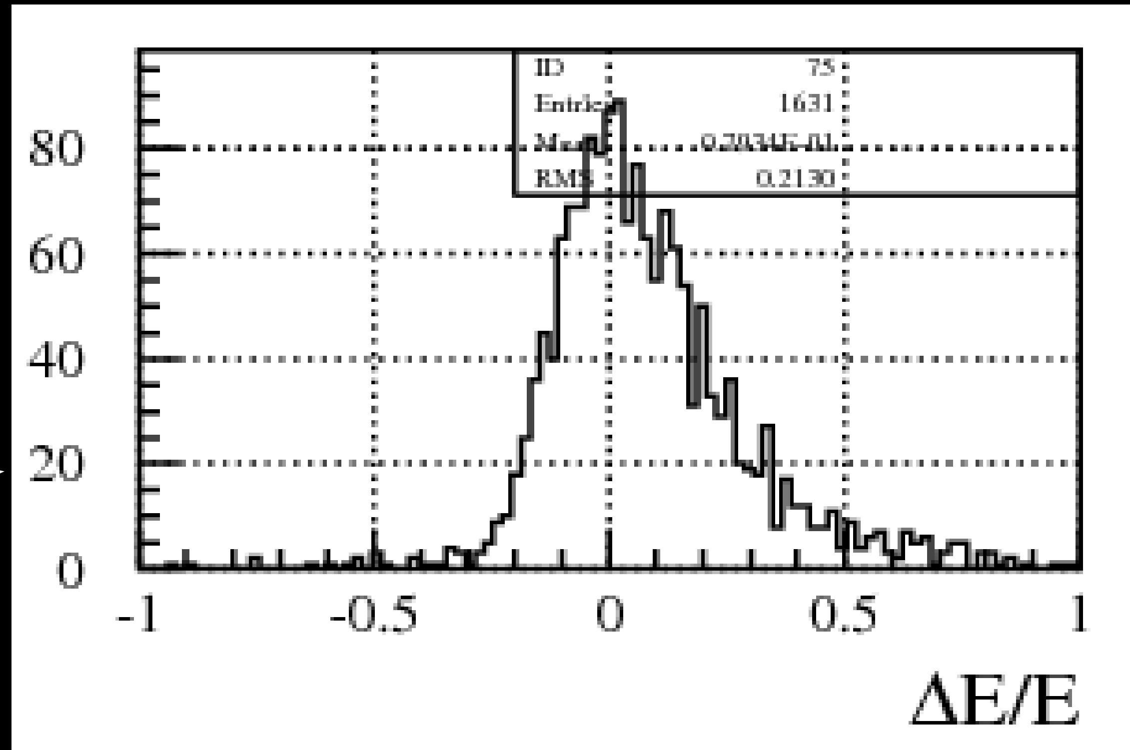
6 metre dish
L=300m

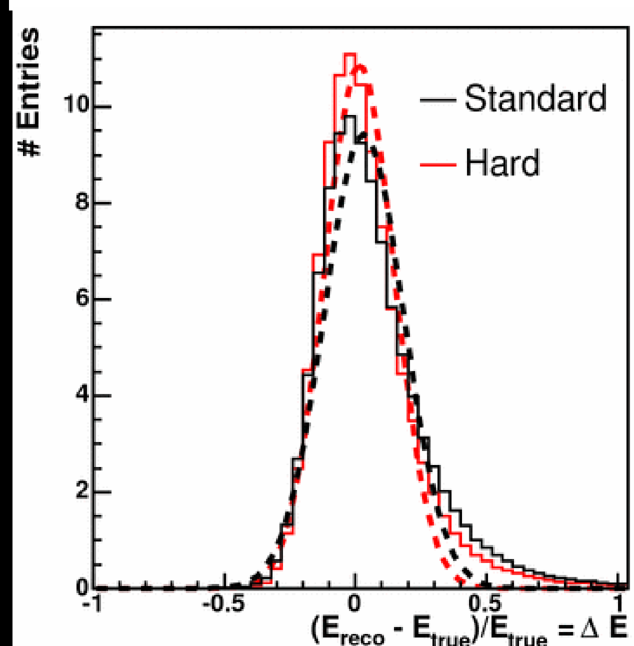
From 1 to 100 TeV
RMS ~20-25%
all evts

+ve bias 'tail' for
threshold events

as for HEGRA,
HESS....

eg. HESS





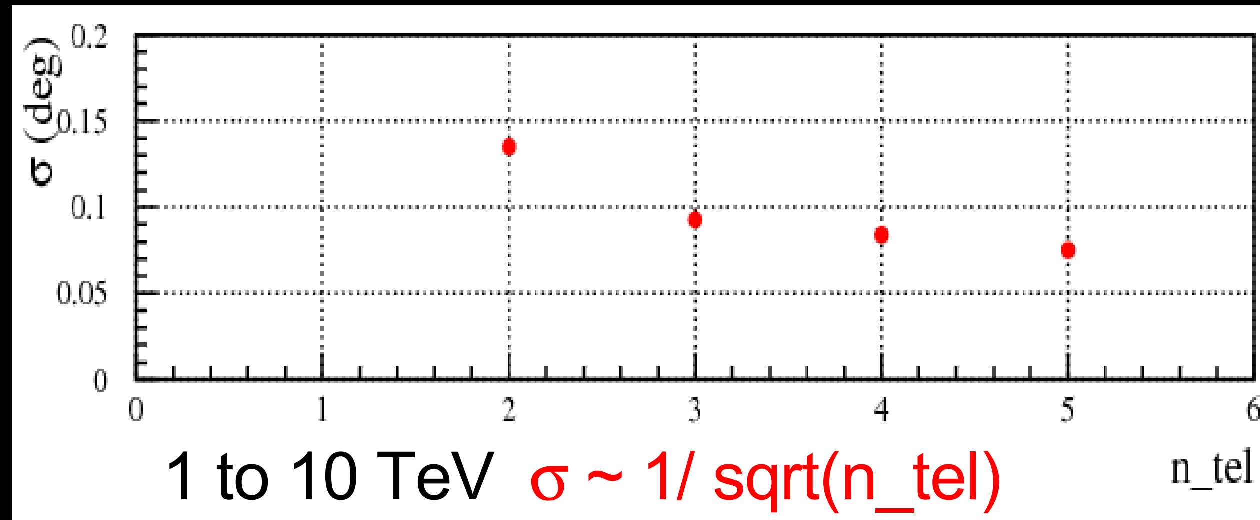
Angular Resolution vs. ntel

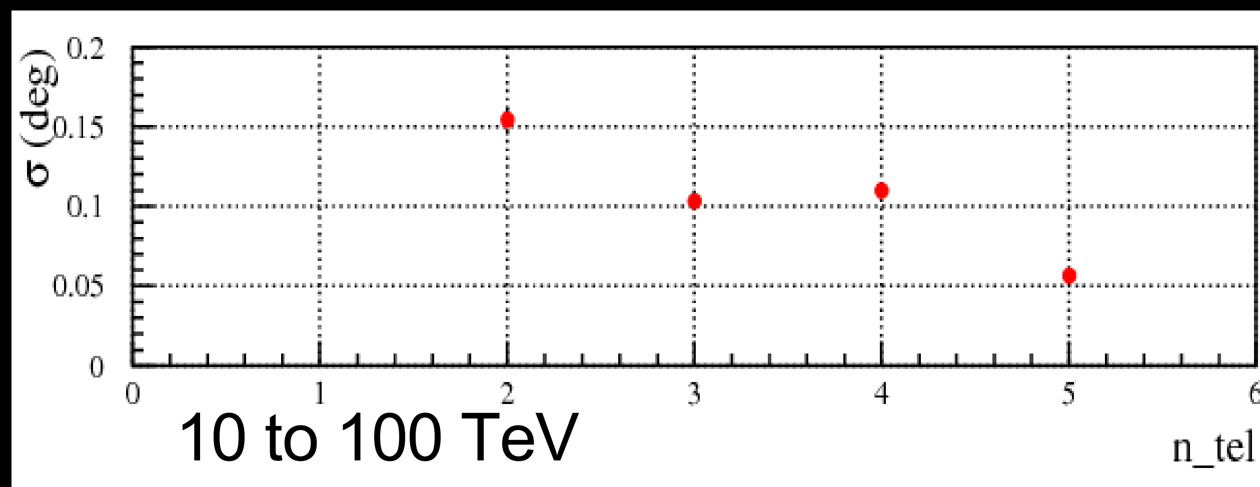
evts 29% 41 16 14

6 metre dish
L=300m

Gaussian profile
σ = std.dev

optimal 4-5 tels





higher fraction of
ntel=5 events.

few arcmins
v.similar to HEGRA, HESS

evts 21% 28 13 38

CR Background Rejection

Use 'classic' stereo parameter

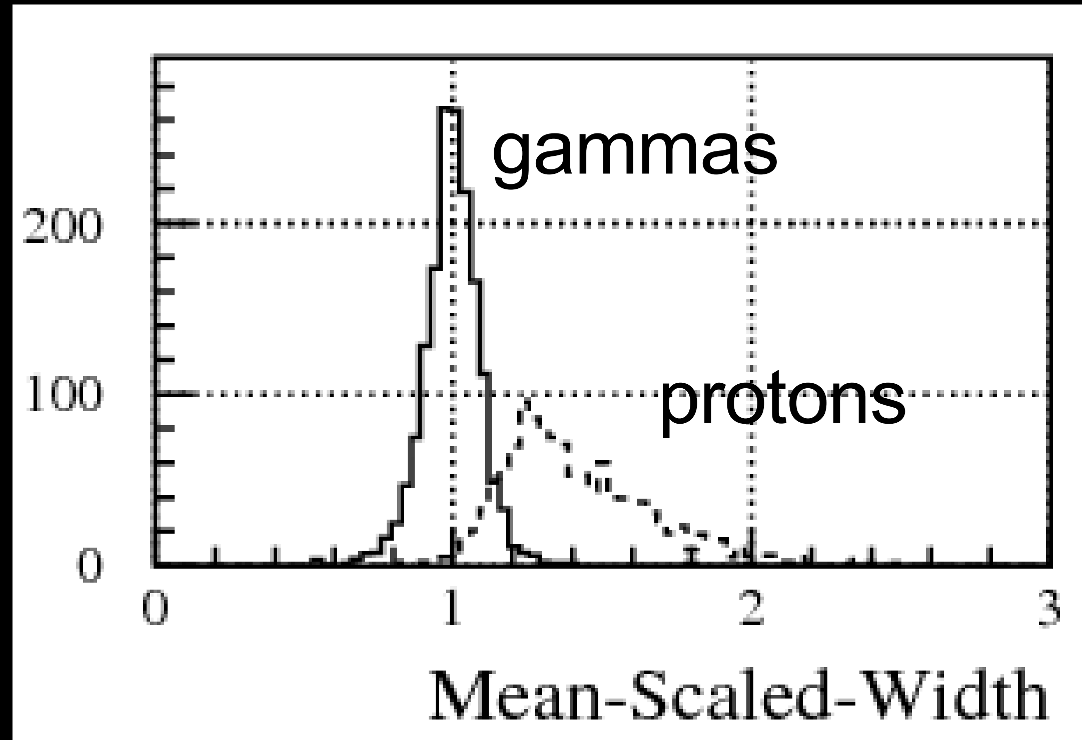
Mean-Scaled-Width

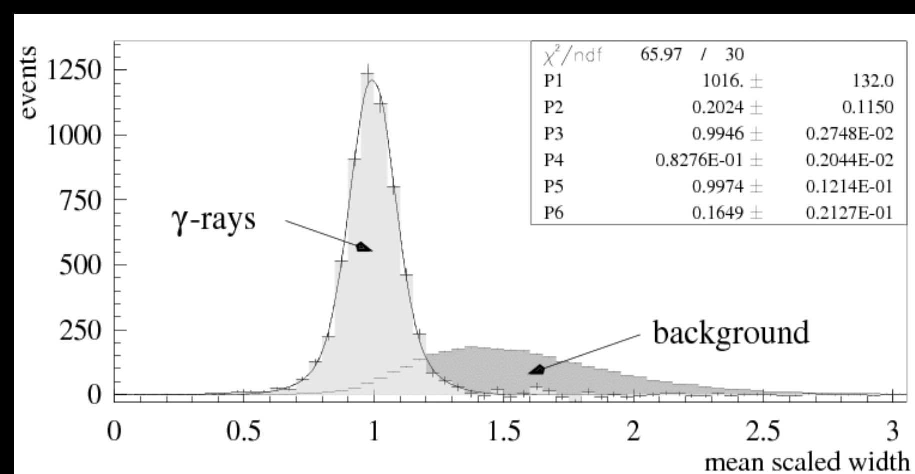
msw < 1.1

accept ~85% gam
~5% protons

v. similar to HEGRA

Puehlhofer et al 2003

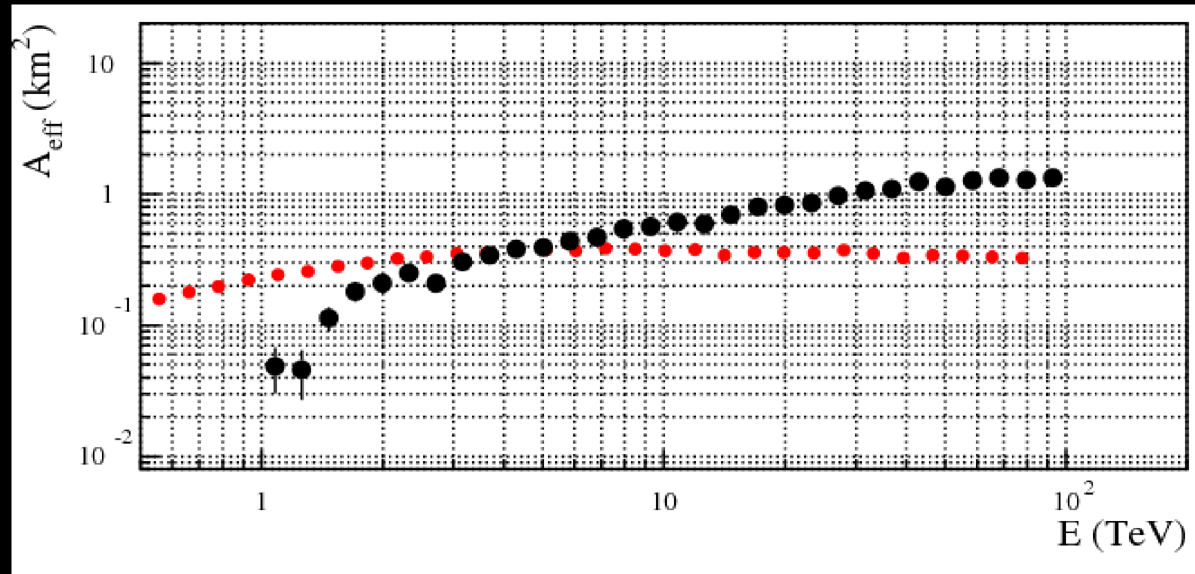




Check Altitude of Site

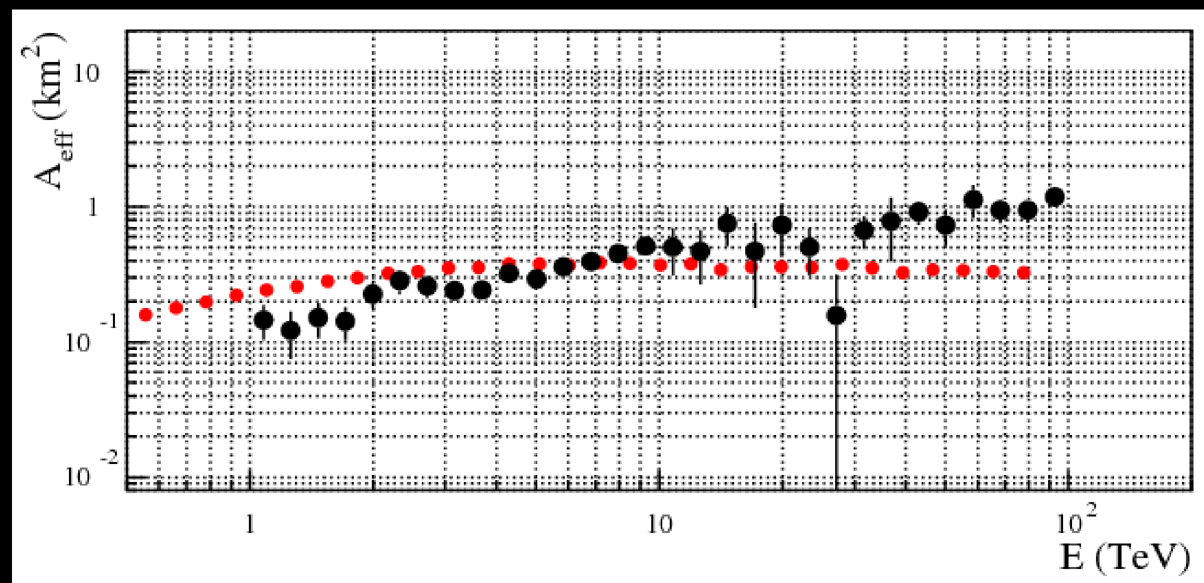
6 metre dish
L=300m

200m a.s.l.



6 metre dish
L=300m

1800m a.s.l



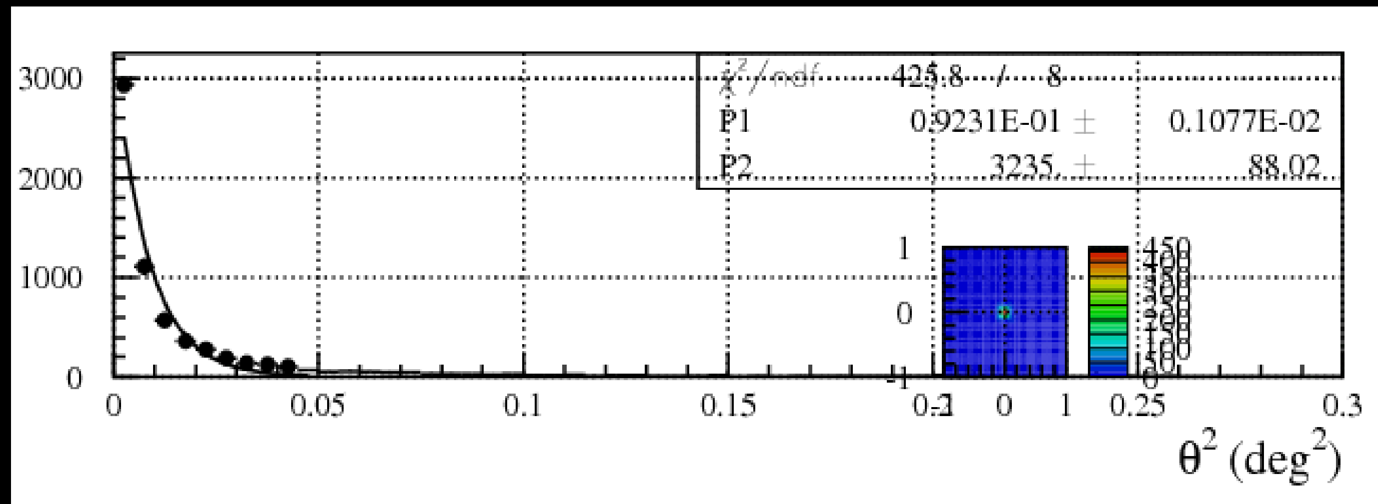
- some (~20%) improvement for E> few TeV at 200m
- lower threshold at 1800m (limit = 1 TeV here!)

Different Pixel Sizes

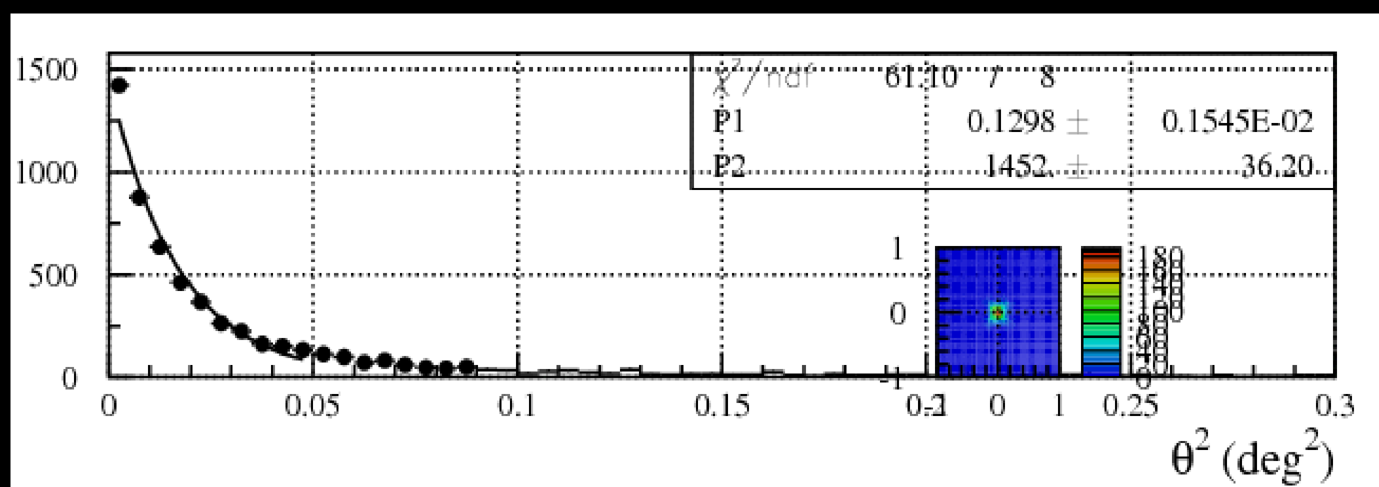
6 metre dish

L=300m

0.25 deg x
1024 pixels



0.35 deg x
484 pixels



19pe @ 2pix trigger
Aeff v. similar to
1024 camera

Multiple Cells

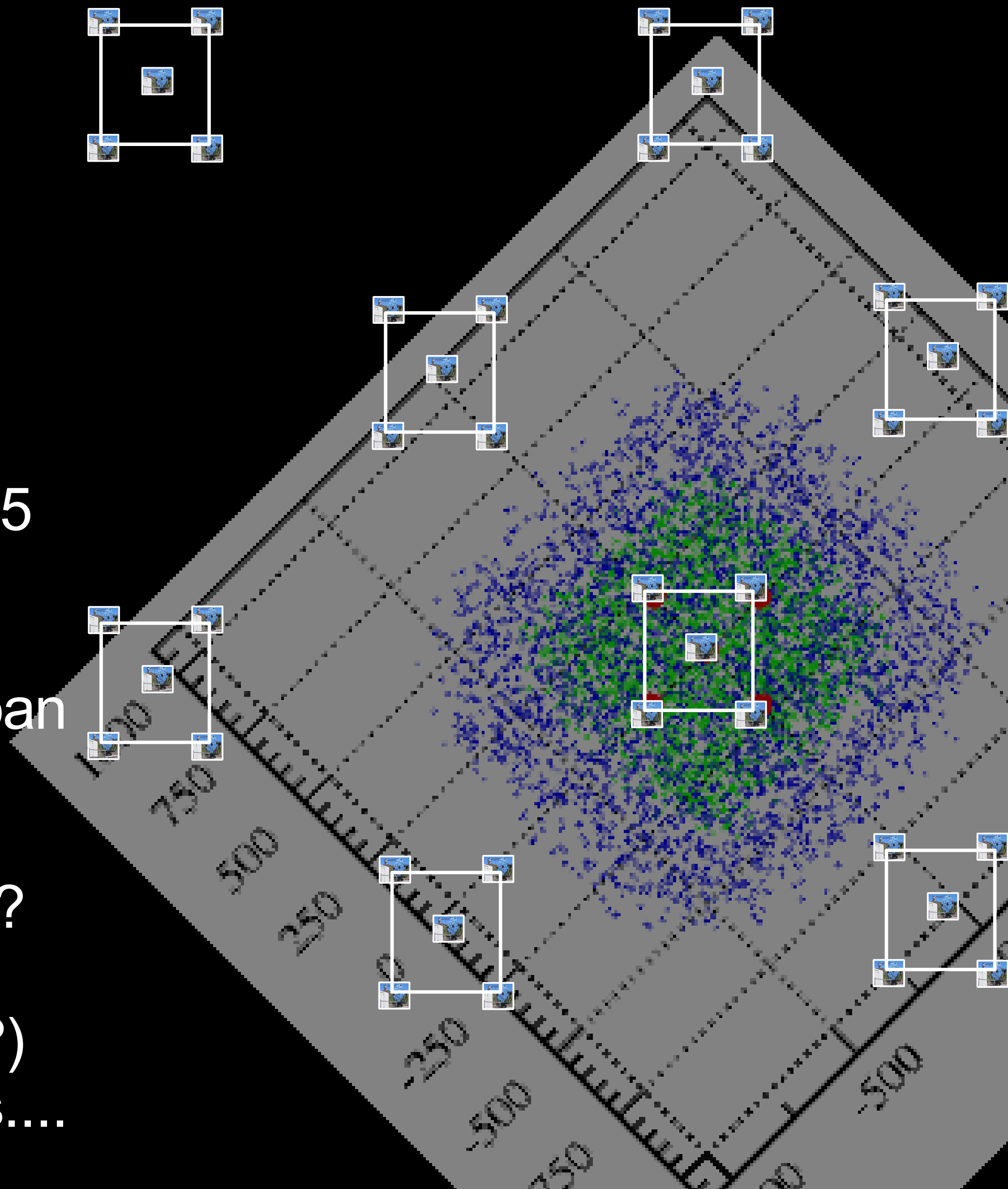
Cell Concept

- 1-10 TeV
  Lower energy events contained within single cell. Optimal ntel ~ 4 to 5

- 10-100 TeV
  Higher energy events span several cells.

Aeff ~ n x Aeff (1 Cell) ...?

Intercell spacing (~1 km?) optimised via simulations....



The *TenTen* Concept: Summary

<u>5-telescope Cell - 300 m spacing   6metre dishes   200m a.s.l.</u>

Area ~ HESS at 2 TeV   ~0.2 km^2

~ fewxHESS at 10 TeV   ~0.6 km^2

~ >5xHESS at 100 TeV   ~1 km^2

Ang, Energy resolution similar to HEGRA, HESS: - confirms earlier studies Plyasheshnikov et al. (2000)

Extend to 10 or more cells aiming for 10 km^2 at 10 TeV

<u>Guaranteed Success:</u>

- Technical: No serious innovation required. Use established ideas

- Astrophysics motivation is clear

- Can be done NOW!

<u>Rough Cost:</u> ~$0.5M to $1M per telescope   (~70% camera, ~30% tel)