Georgia Institute of Technology

IACT Tutorial

Back of the envelope

Fermi Summer School 2012

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Can my favorite source be detected with VERITAS?

A spectrum extrapolated from Fermi data
can the tail be measured with VERITAS?

Taking M82 as an example

1. Is the source visible?

Declination -> is the source visible at all?

Source culminates at min Zenith angle:
abs(Obs.Latitude-Source declination)

Observable if zenith angle at culmination is < 60 degrees

Right ascension –>
what time of year does the source culminates at midnight

0 hours RA $\longleftrightarrow$ October

+2 hours in RA each month

M82	R.A.:	09 55 52.7 (hh mm ss)
	Dec.:	+69 40 46 (dd mm ss)

VERITAS latitude 32 degrees North

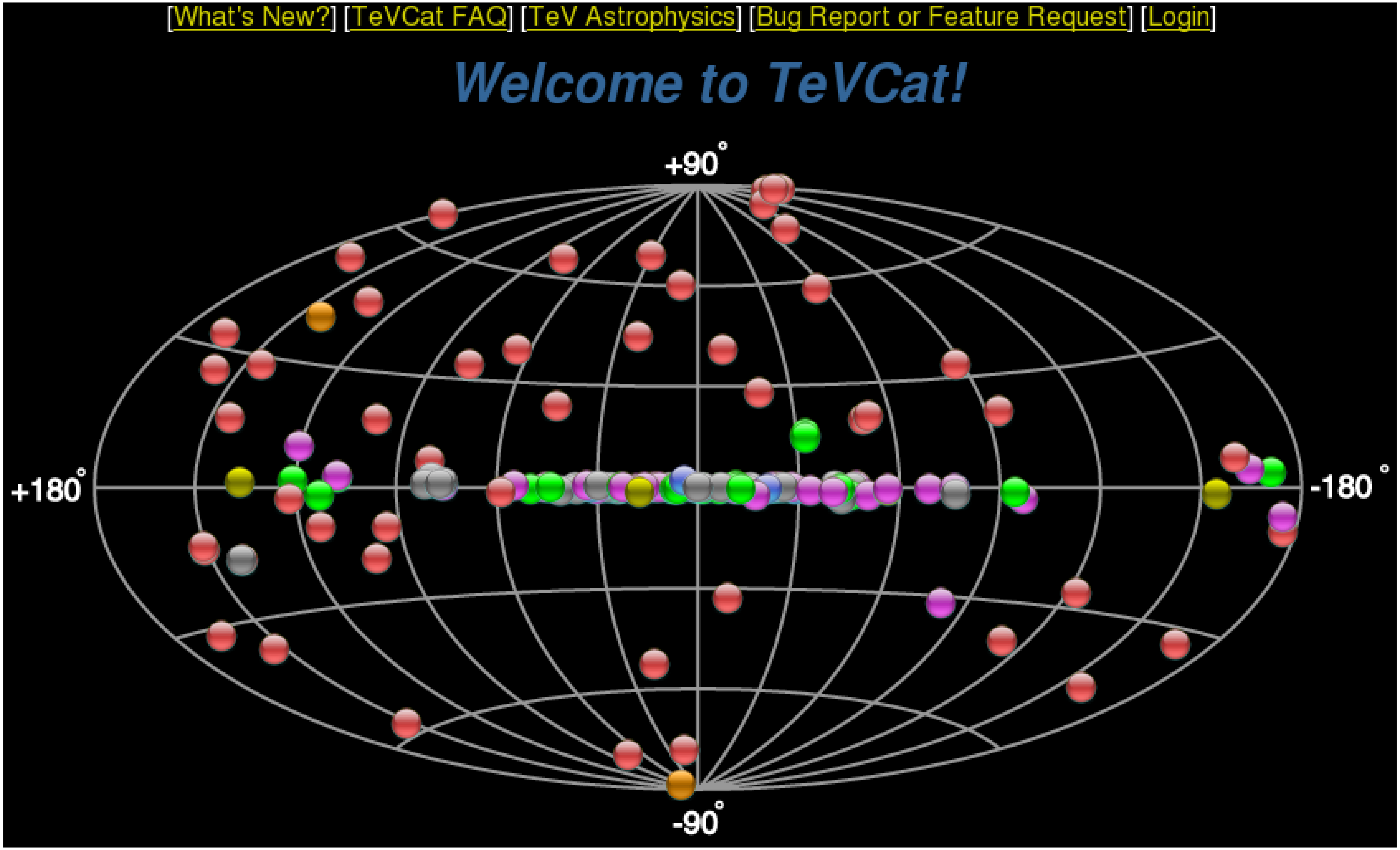
Culmination at 38 degree Zenith angle

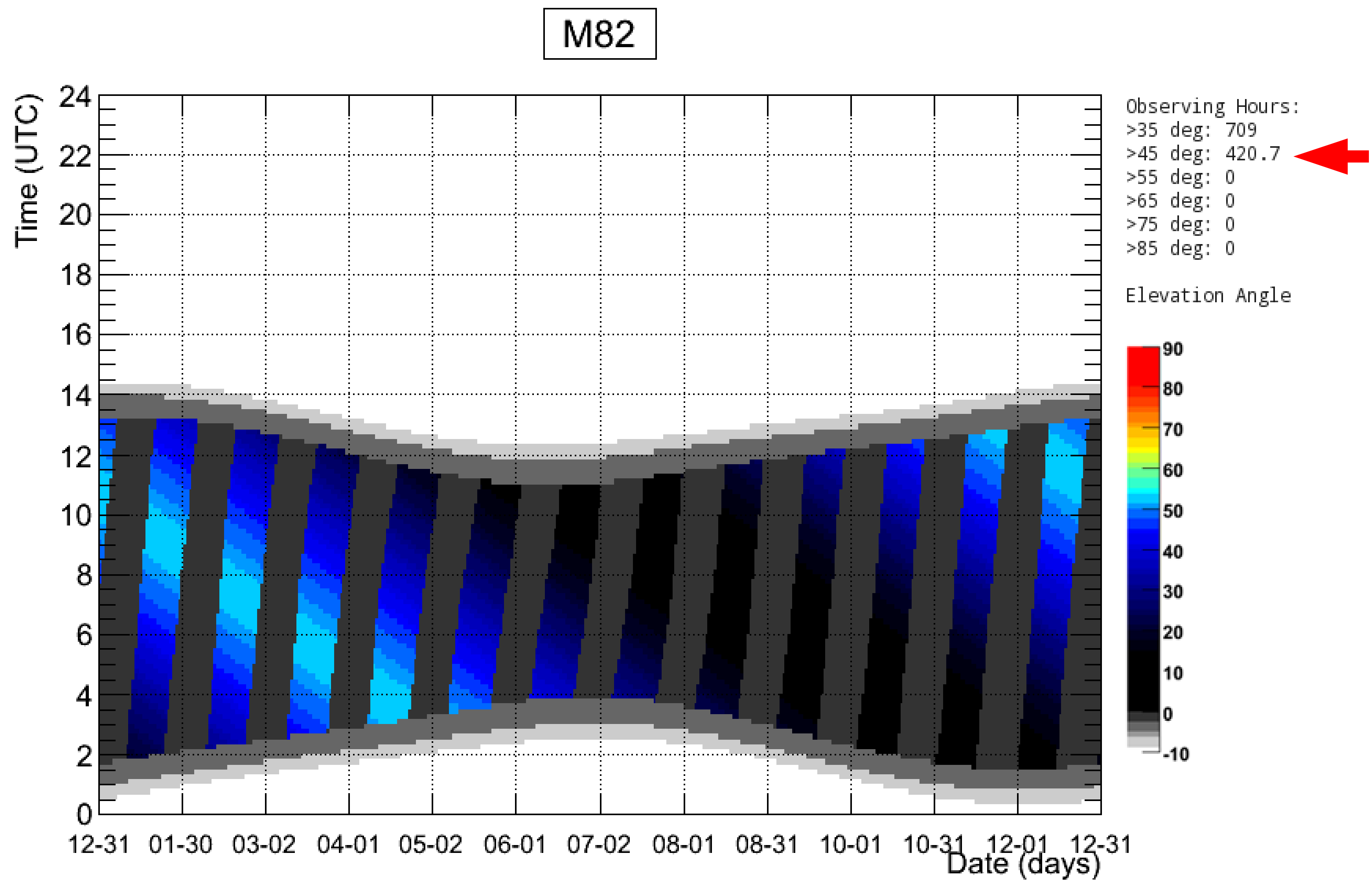
Best observability (culmination at midnight local)

(10hr/2hr + October)%12 = March

1. Is the source visible to VERITAS

http://tevcat.uchicago.edu/

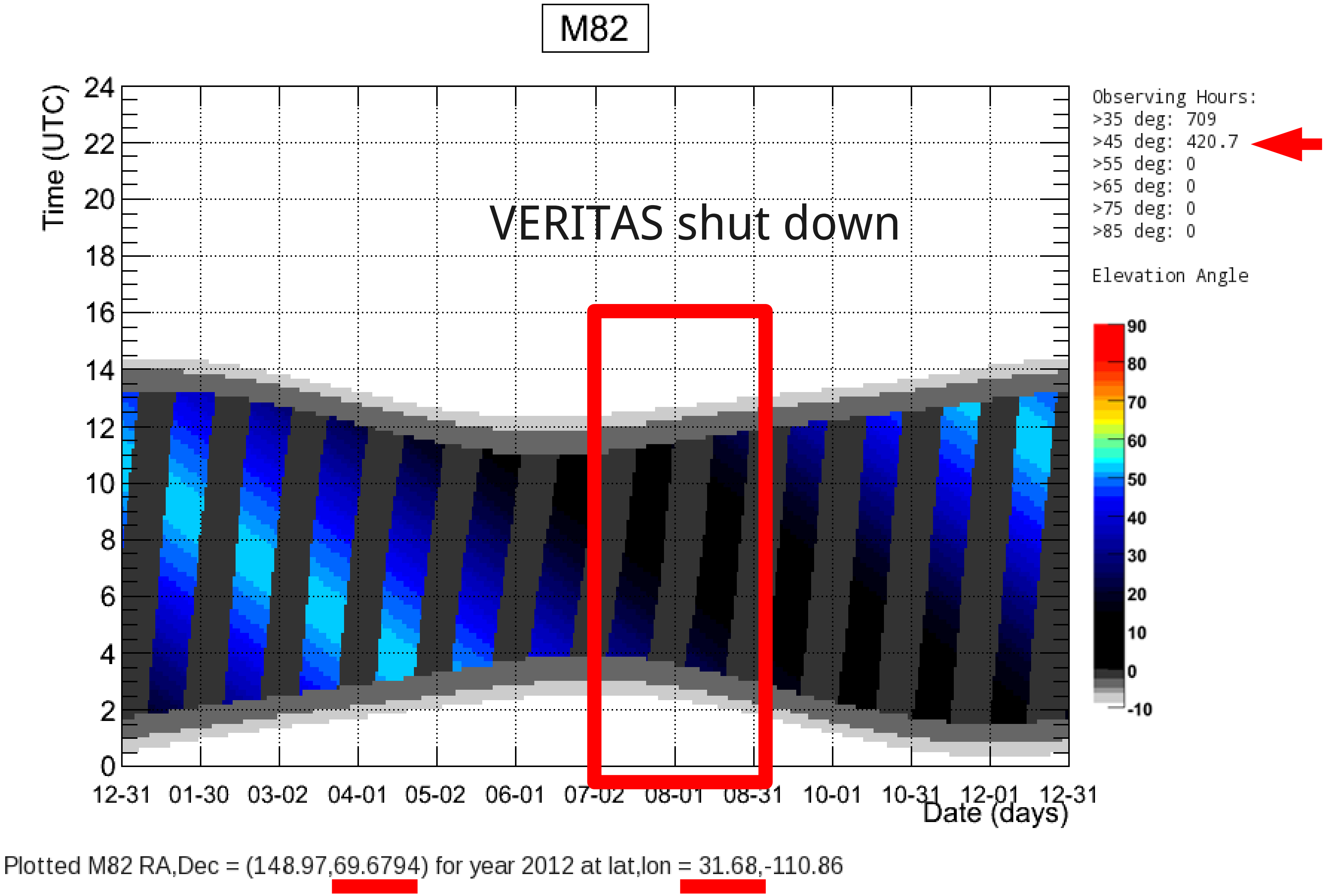




Plotted M82 RA,Dec = (148.97,69.6794) for year 2012 at lat,lon = 31.68,-110.86

Source culminates at a Zenith angle of 70-32=38 degrees

Visible from December to May



Source culminates at a Zenith angle of 70-32=38 degrees

Visible from December to May

A source is flaring can we observe right now?

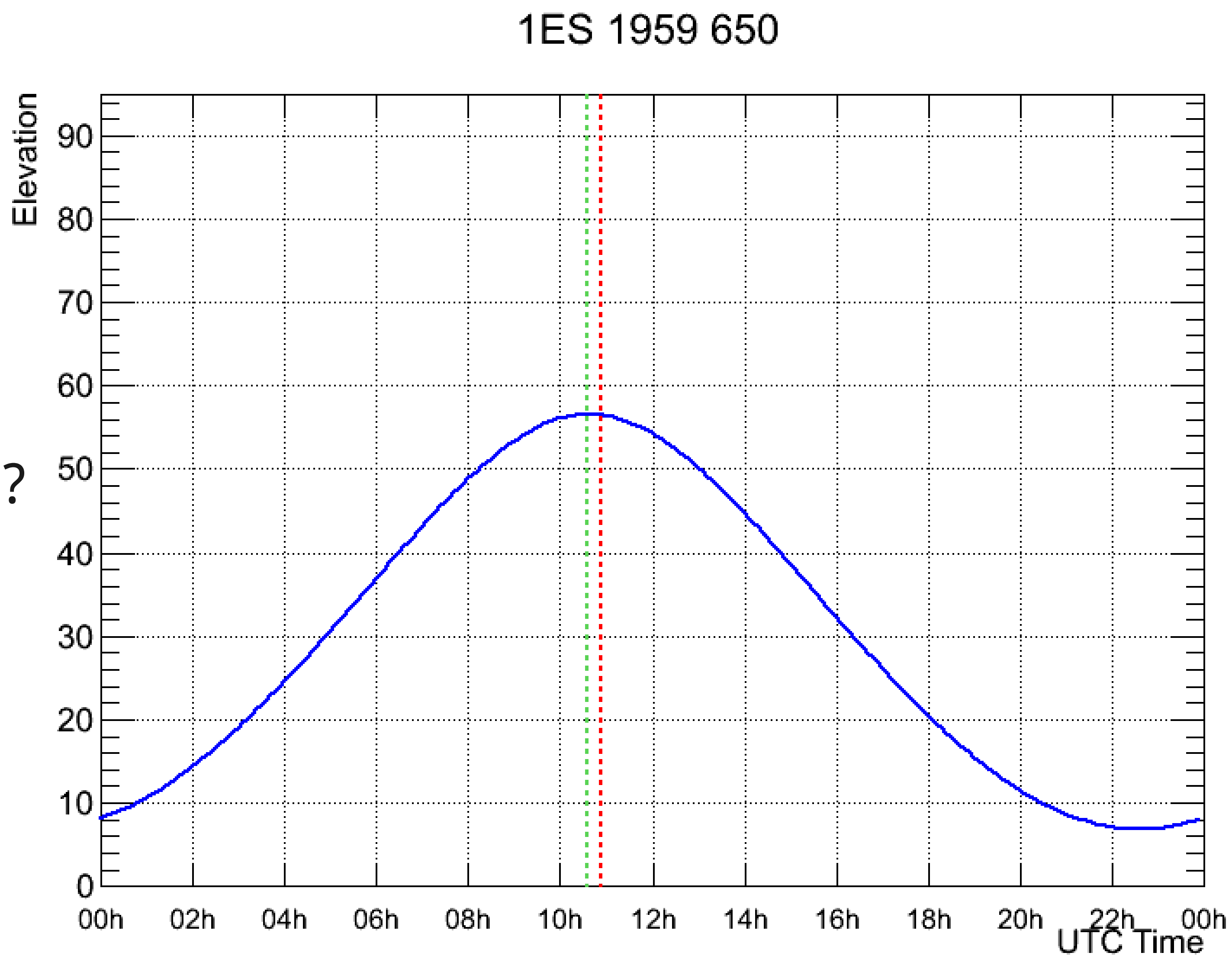
Visibility for VERITAS

today

What is going on?

Sun set/rise

Moon set/rise



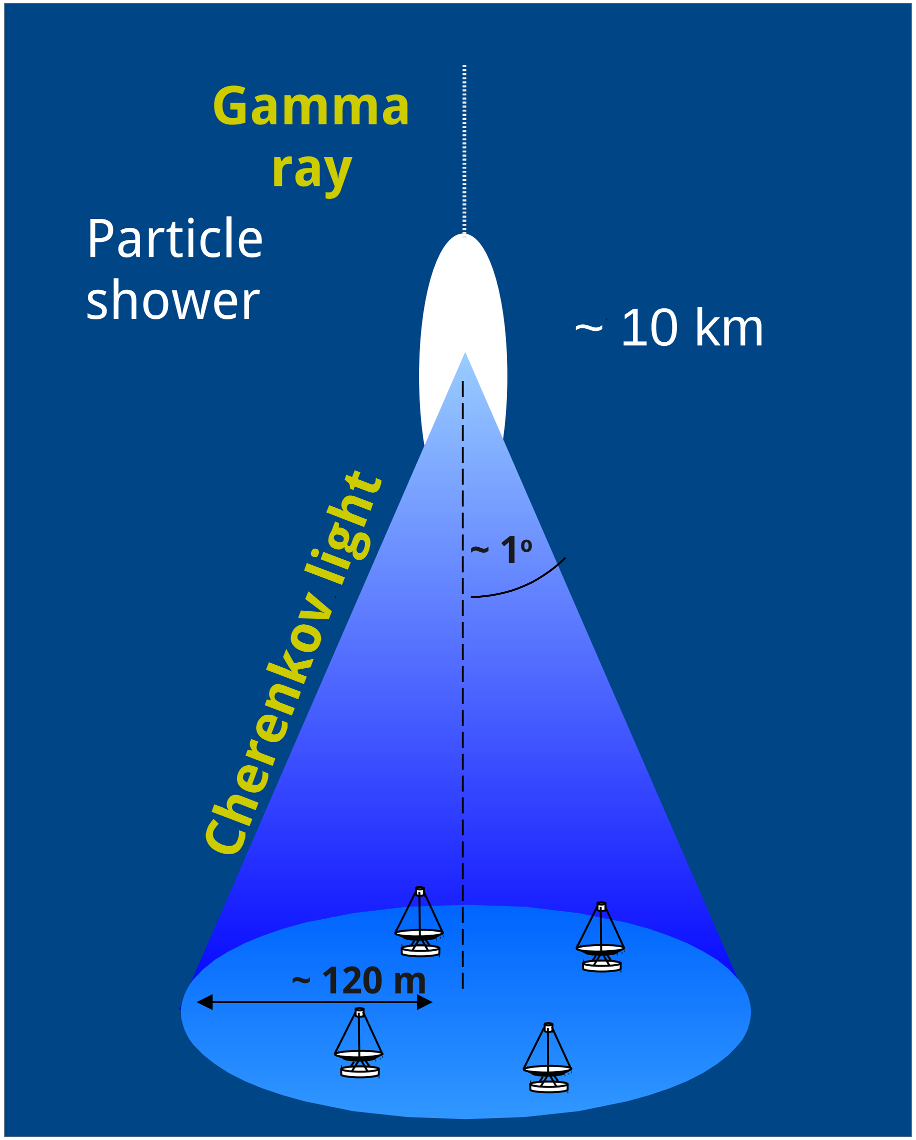
Plotted 1ES 1959 650 RA,Dec = (299.999,65.1486) for date (dd-mm-yy) 2-6-2012 (MJD= 56080) at lat,lon = 31.68,-110.86
Nominal Times (rough guesses) Start: 10:35, Stop : 10:53, dT ~ 00:17

What is the energy threshold?

Peak of the differential trigger rate distribution

= Source spectrum multiplied with effective area

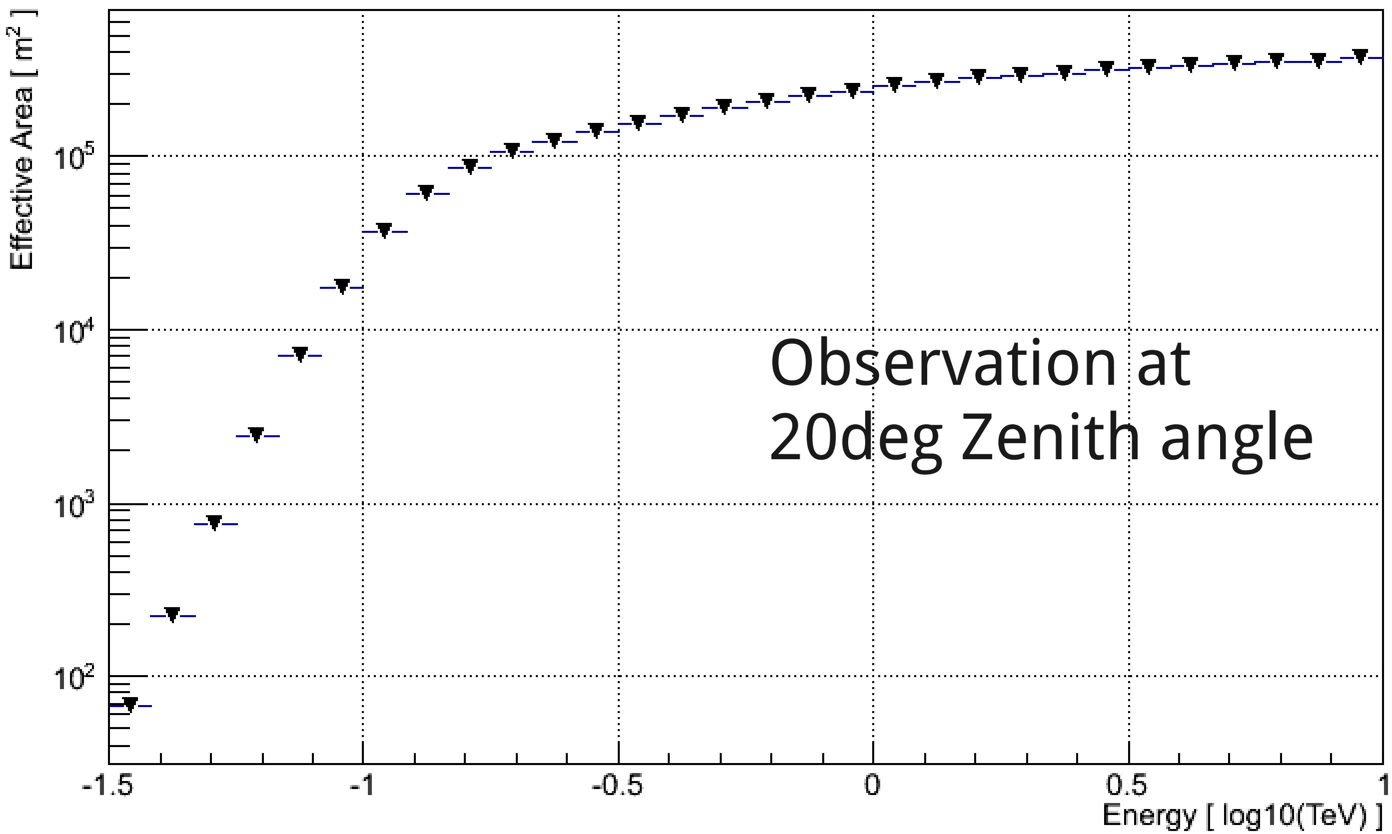
$$\mathrm{F}(E) \times A(E) = \mathrm{TriggerRate}(E)$$



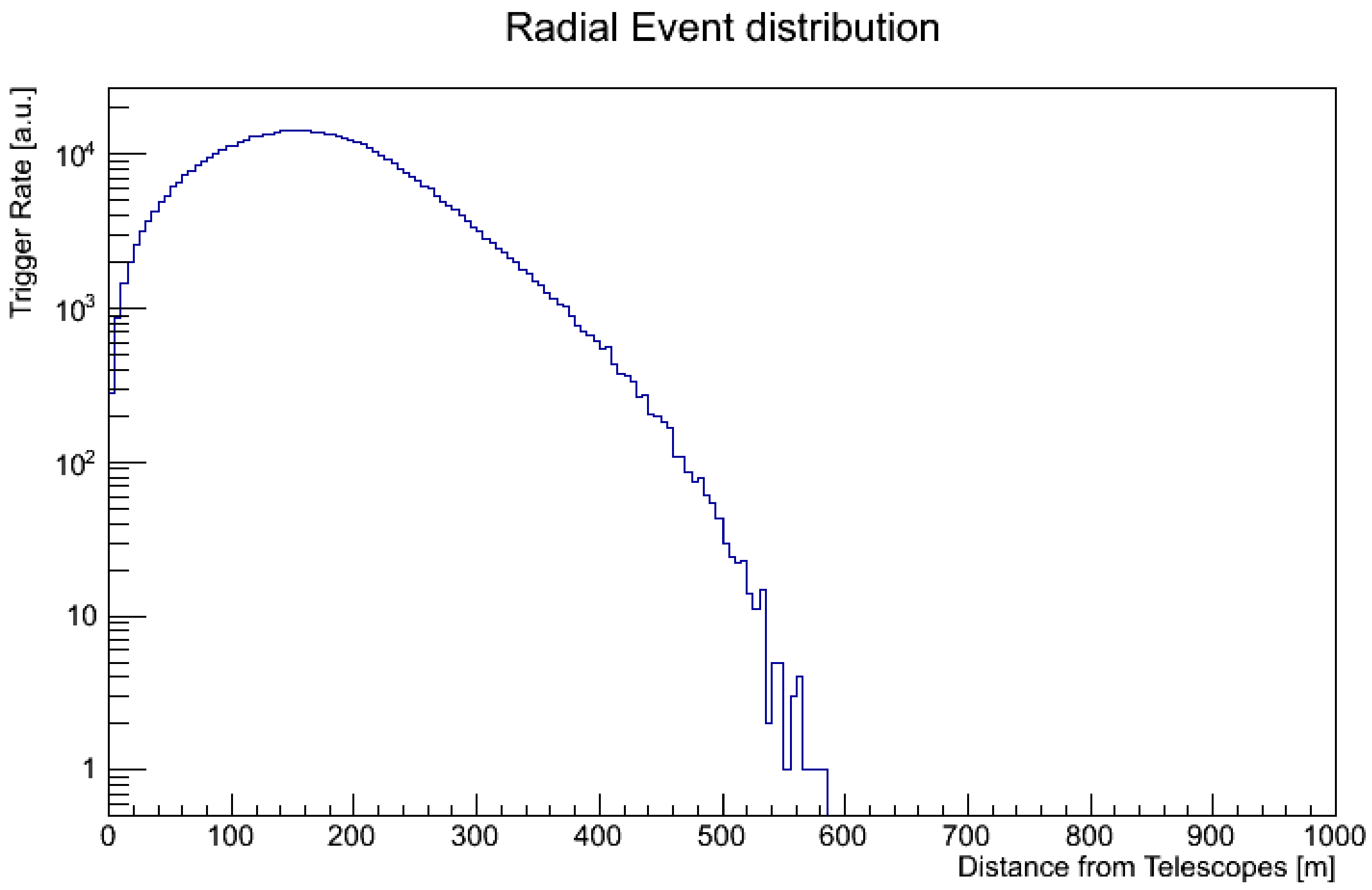
Effective area is not determined by the size of the telescope but the size of the Cherenkov photon light pool on ground

Effective Area

Effective area = area over which gamma-rays are being simulated
X number of triggered events/total number of simulated events

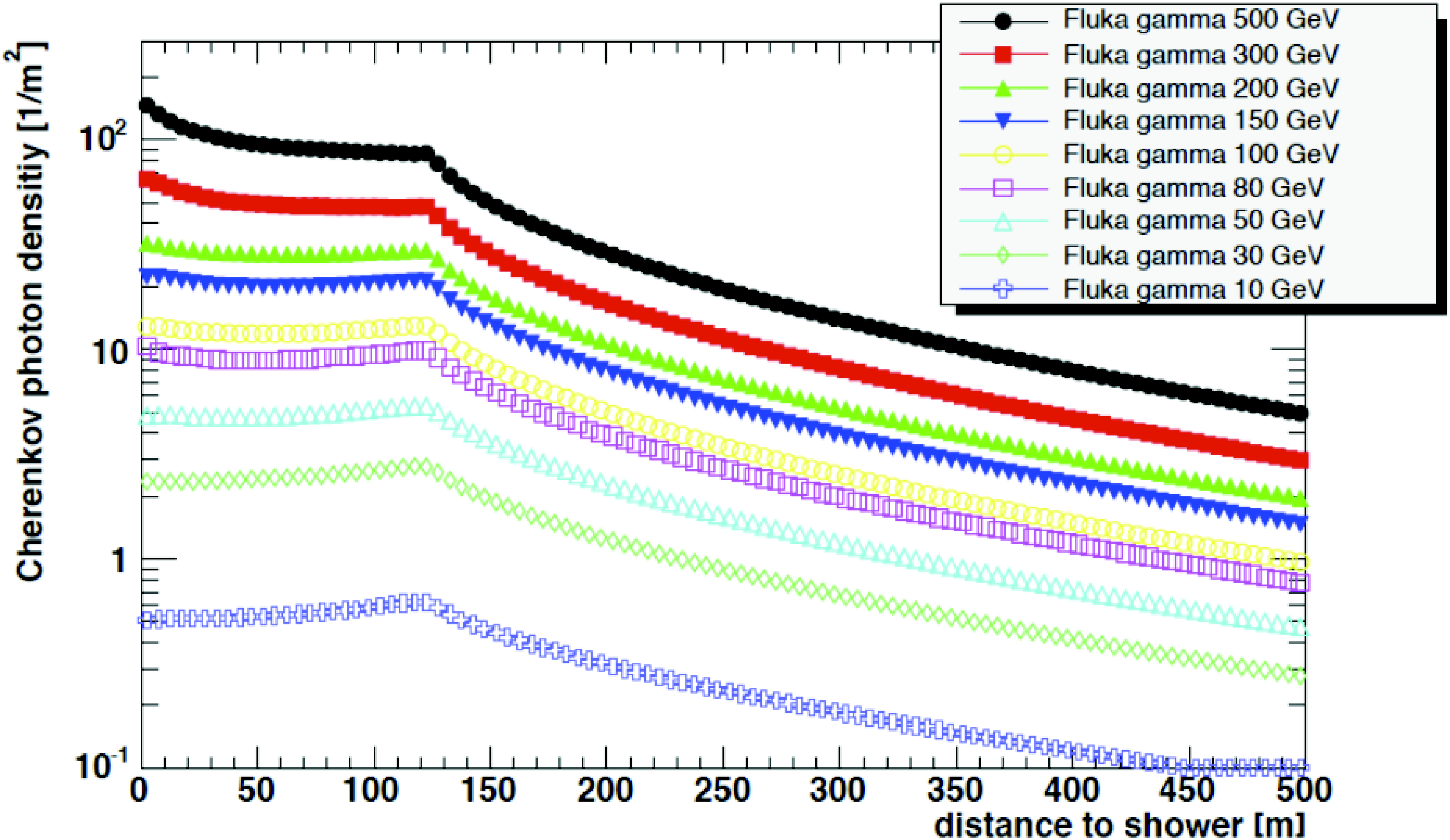


Gamma-ray showers simulated with impact points up to 750 m away from the telescopes



No photon beyond 600 m triggers telescopes

Cherenkov photon density on ground



Threshold Energy

Table 1
Results of Maximum Likelihood Analyses of M82 and NGC 253

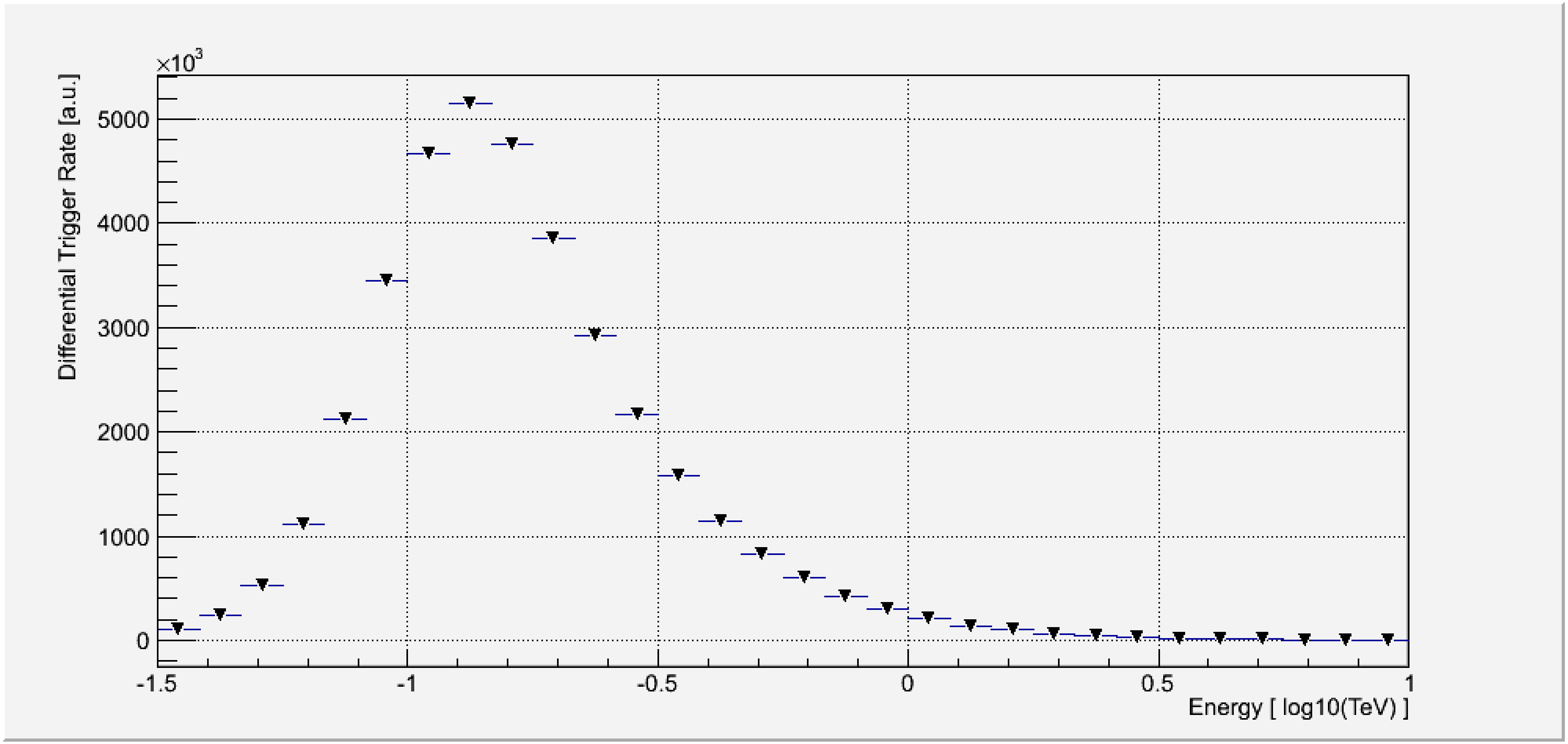
Galaxy	R.A.[a] (deg)	Decl.[a] (deg)	r_{95}[a] (deg)	$F(>100\ \mathrm{MeV})$[b] (10^{-8} ph cm^{-2} s^{-1})	Photon Index[b]	Significance[c]
M82	149.06	69.64	0.11	$1.6 \pm 0.5_{\mathrm{stat}} \pm 0.3_{\mathrm{sys}}$	$2.2 \pm 0.2_{\mathrm{stat}} \pm 0.05_{\mathrm{sys}}$	6.8
NGC 253	11.79	−25.21	0.14	$0.6 \pm 0.4_{\mathrm{stat}} \pm 0.4_{\mathrm{sys}}$	$1.95 \pm 0.4_{\mathrm{stat}} \pm 0.05_{\mathrm{sys}}$	4.8

$$\mathrm{F}(E) \cdot A(E) = \mathrm{TriggerRate}(E)$$

$$N E^{-\alpha} \cdot A(E) = N\, R'(E)$$

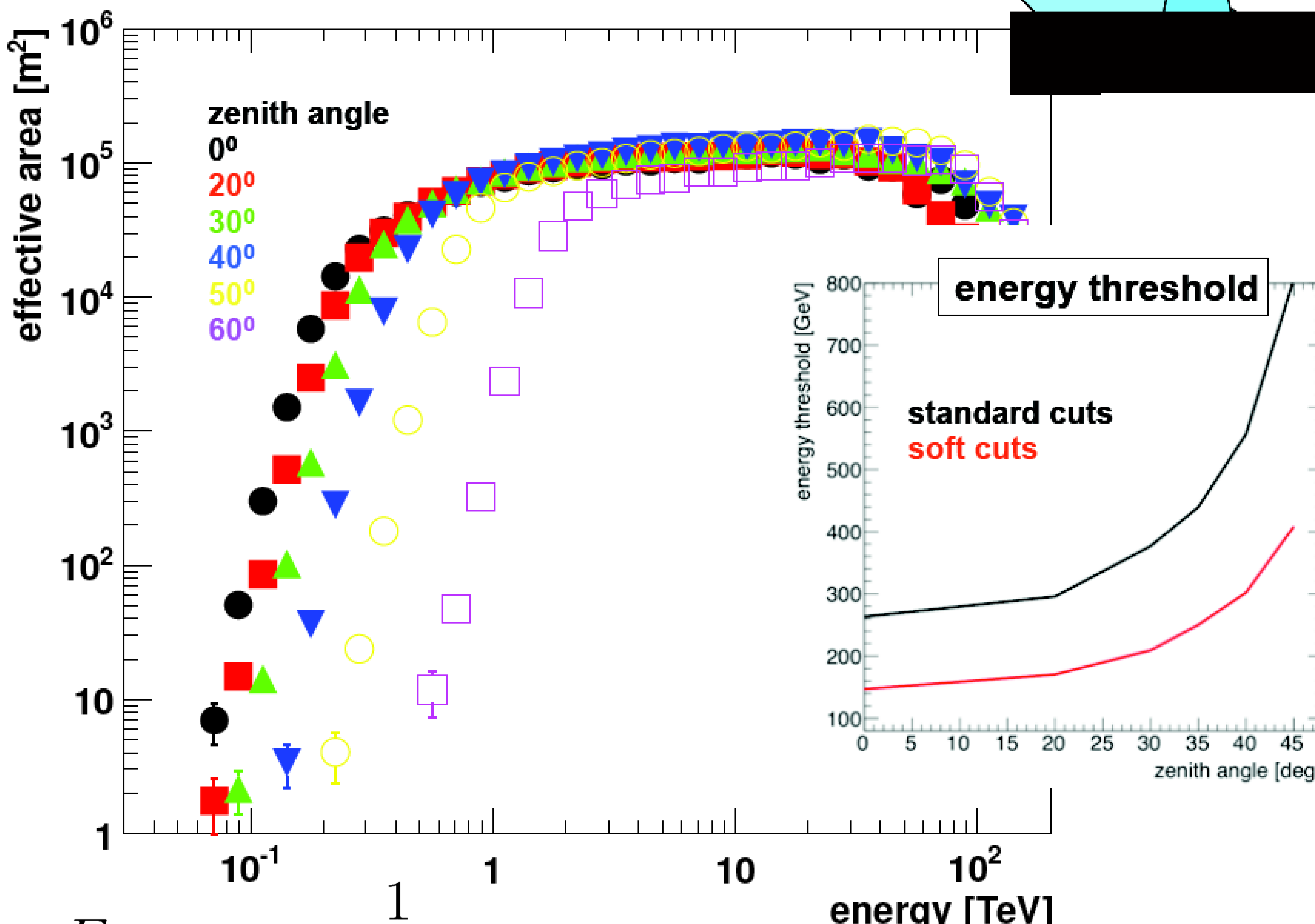
Strong dependence on photon index

Rate distribution (@ Trigger)



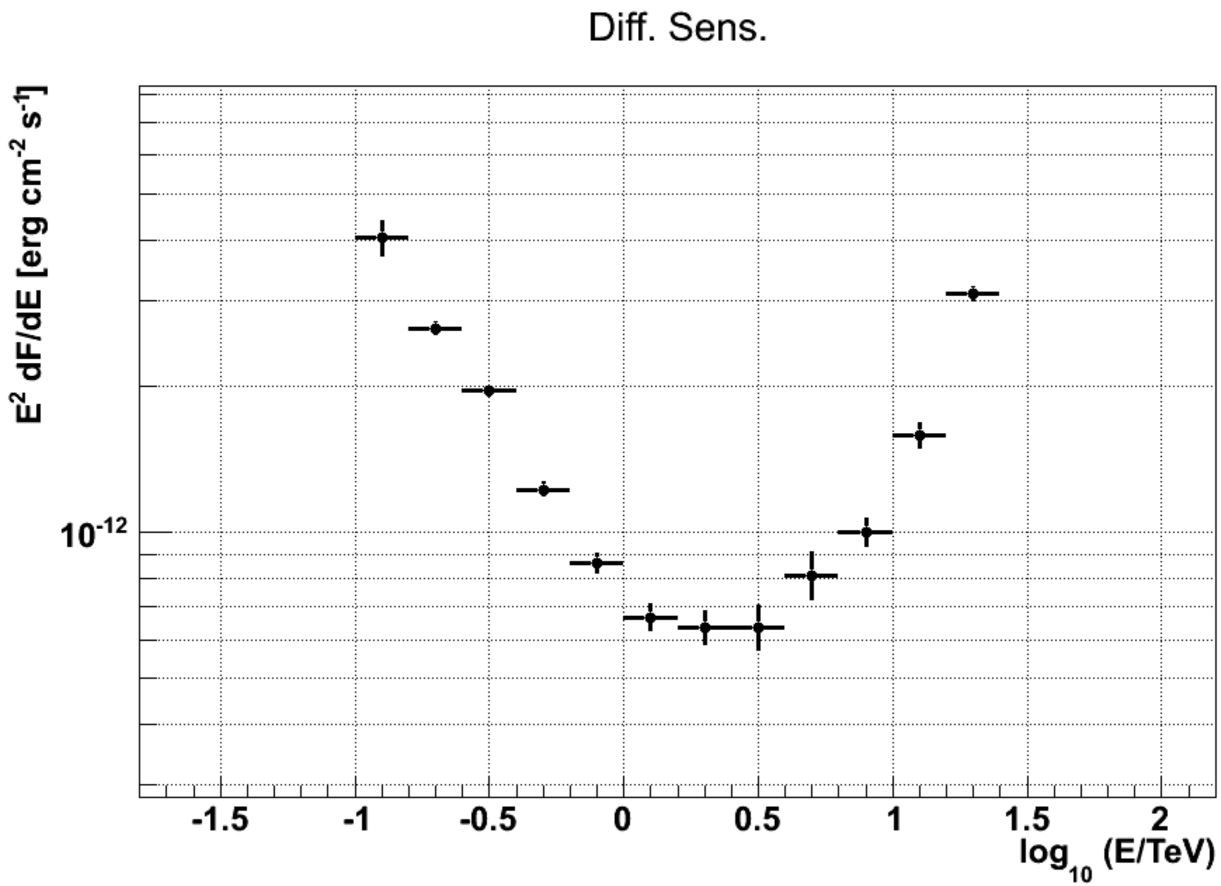
For a photon index of -2.2

Effective Areas



$$E_{\mathrm{Thr}} \propto \frac{1}{\cos(\mathrm{ZA})^{2.7}}$$

Differential Sensitivity



Flux that gives 5 sigma excess in energy bin after 50 hours for an observation at 20 deg

For spectral reconstruction need 3 sigma excess in each bin

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Need flux in E^2 dN/dE and in erg/cm^2/s

For spectral reconstruction need 3 sigma excess in each bin

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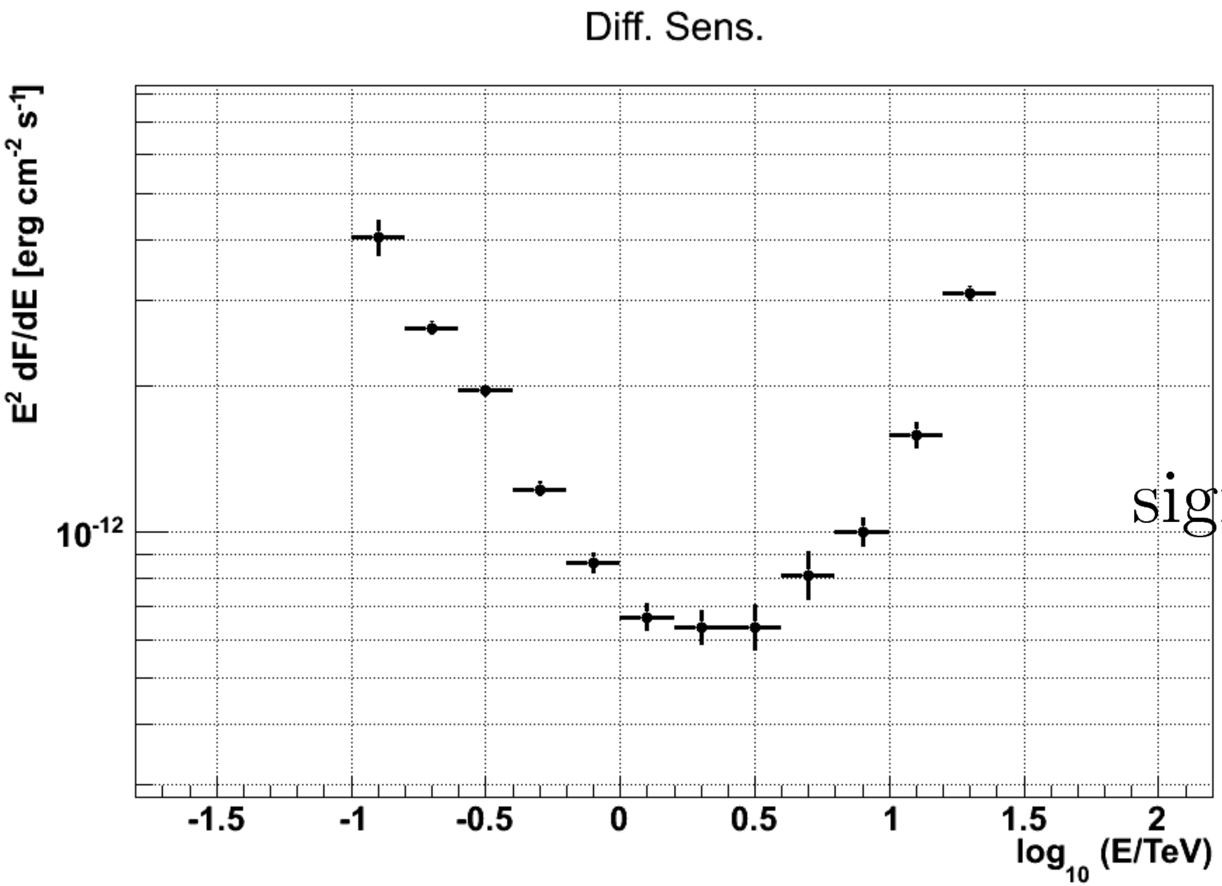
$$E^2 \frac{dN}{dE} = 5.15 \cdot 10^{-12} E^{-0.2} erg/cm^2/s$$



Background limited regime

$$\text{significance} \propto \text{Flux} \times \sqrt{time}$$

@ 1 TeV & 20deg zenith: sensitivity ~$6.5 \cdot 10^{-13}$

Going from 20 deg to 40 deg -> shift in energy scale 1.7

1 TeV => 1.7 TeV

$6.5 \cdot 10^{-13}$ erg/cm^2/s=> $(1.7/1.0)^2\ 6.5 \cdot 10^{-13} = 1.9 \cdot 10^{-12}$ erg/cm^2/s

$$E^2 \frac{dN}{dE} = 5.15 \cdot 10^{-12} (1700)^{-0.2} erg/cm^2/s$$

$= 1.16\ 10^{-12}$ erg $/cm^2/s$

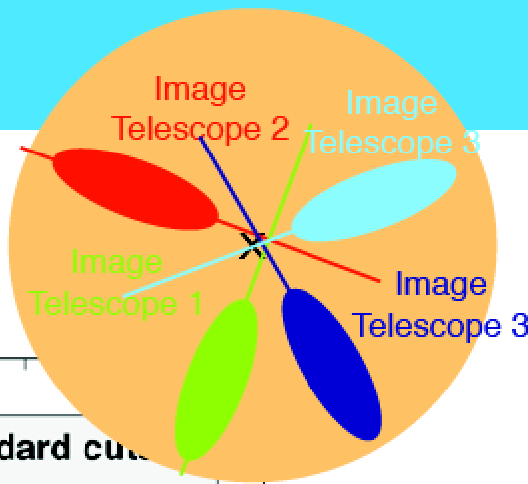
$$\text{significance} = \frac{F_{\text{expolated}}}{F_{5\sigma \text{ in } 50 \text{ hrs}}} \cdot \sqrt{\frac{t}{50\,hrs}} \cdot 5\sigma$$

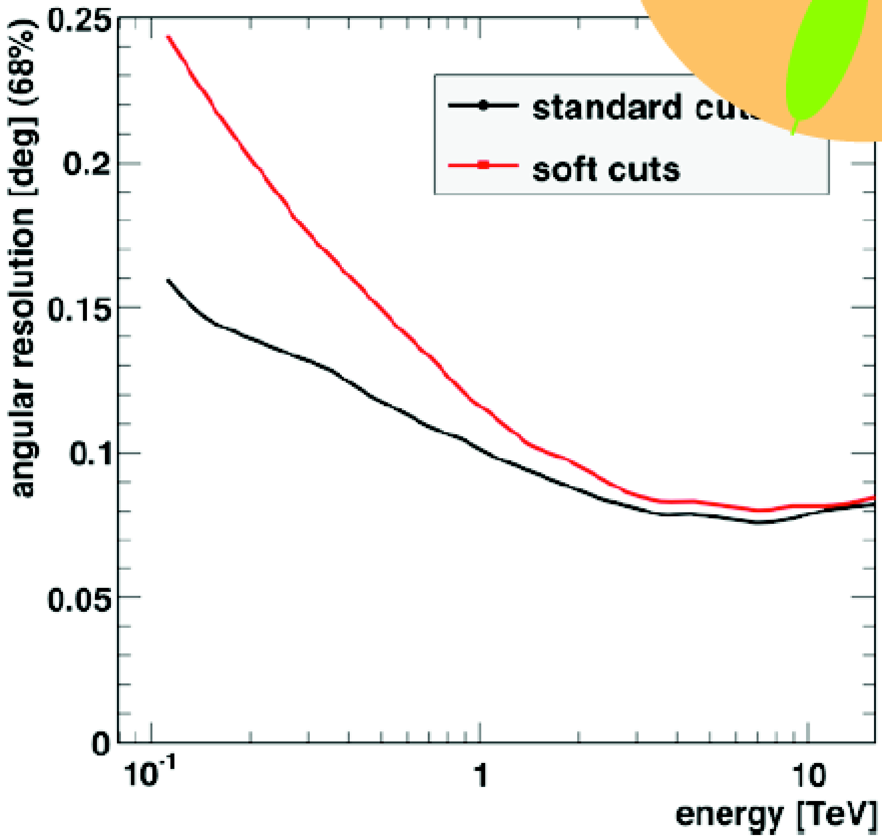
Observation Time to obtain 3sigma @ 1700 GeV:

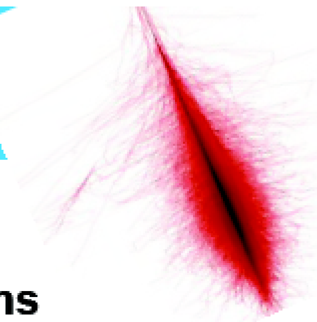
~ 50 hours

Note that this is only a rough estimate,
which gives you a ball park number

Angular Resolution







Limitations

lateral spread of shower (multiple scattering)

gamma-ray collection efficiency

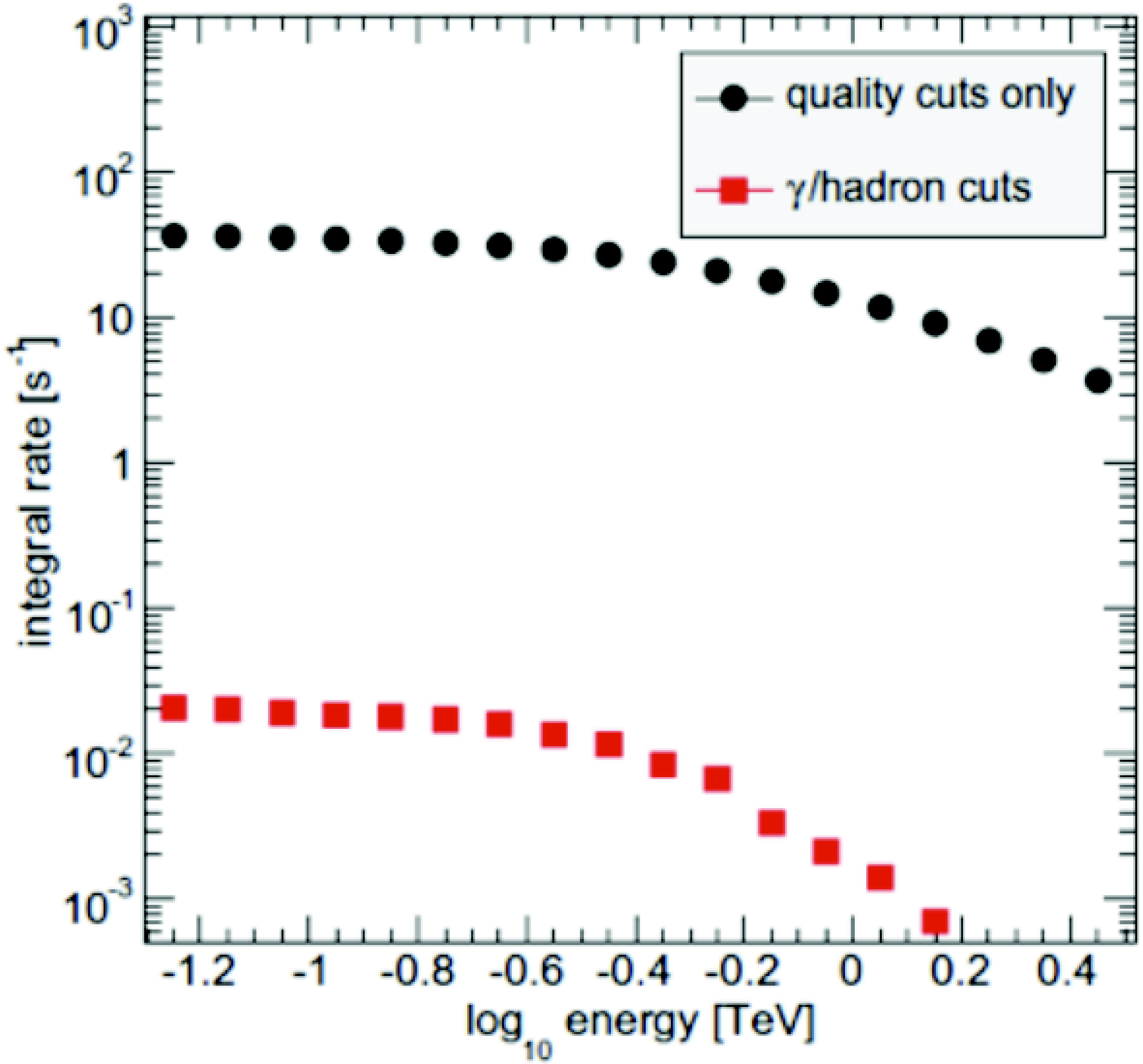
geomagnetic field

number of telescopes

array geometry

optical point spread function

pixel size



quality cuts only
γ/hadron cuts
integral rate [s-1]
log10 energy [TeV]
10^3
10^2
10
1
10^-1
10^-2
10^-3
-1.2
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4