

Gamma-ray Observation with the Tibet AS γ Experiment

--- Recent Results and Future Plan ---

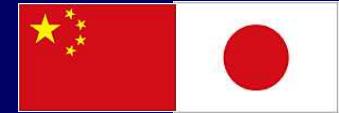
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TeV Particle Astrophysics 2007, 30 August 2007, Venice, Italy



The Tibet AS γ Collaboration



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□ Summary

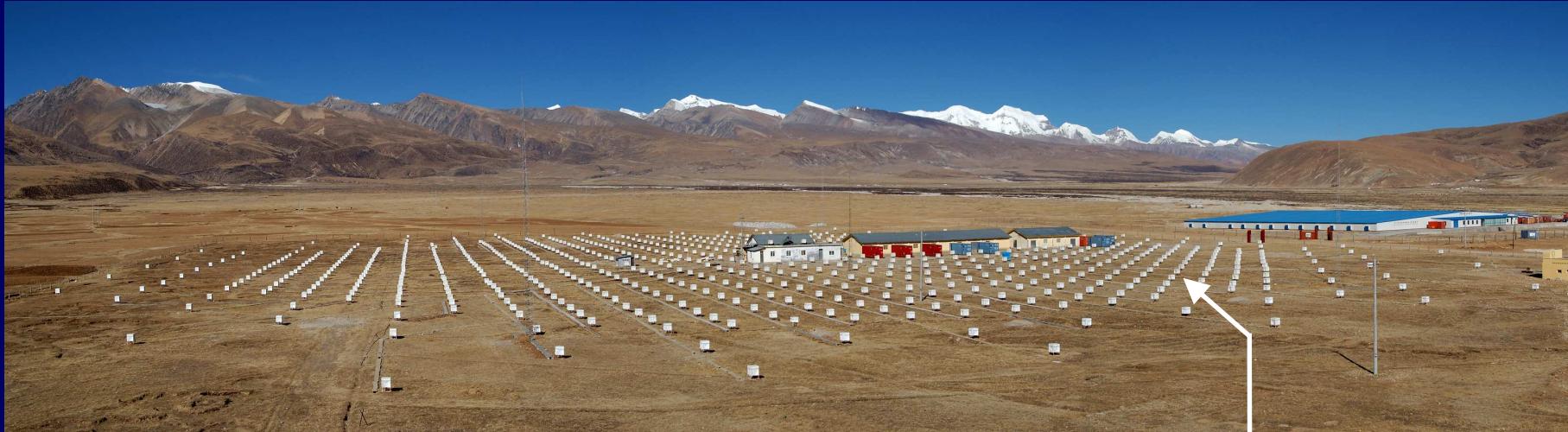
Yangbajing Cosmic Ray Observatory



Yangbajing (羊八井), Tibet, CHINA

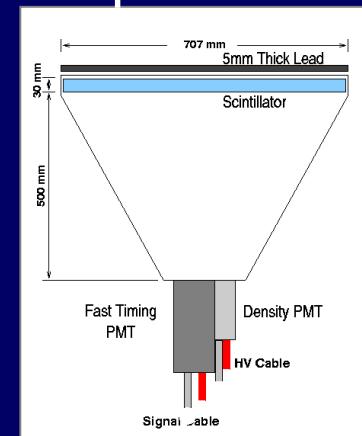
90°52'22"E, 30°10'2"N, 4,300 m a.s.l. (606g/cm²)

Tibet Air Shower (AS) Array

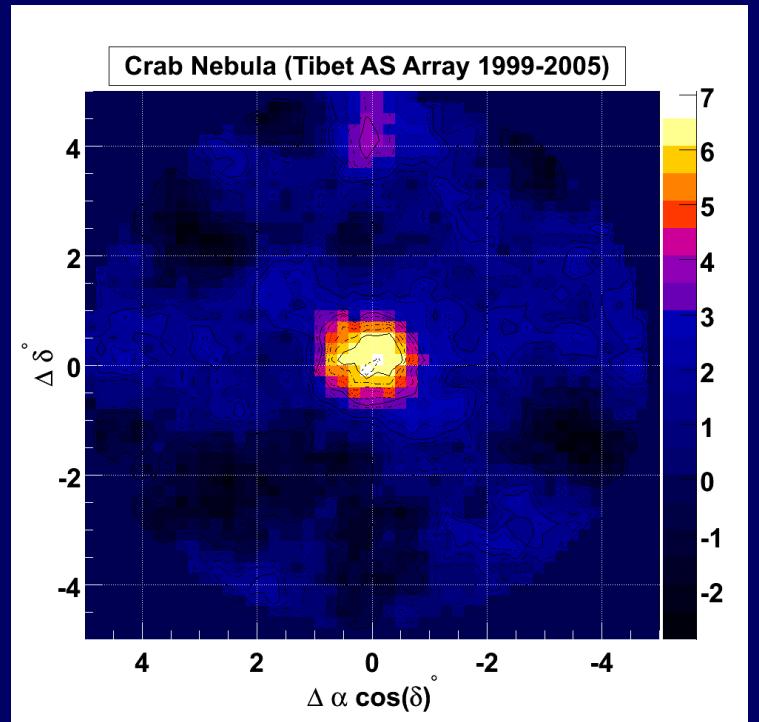
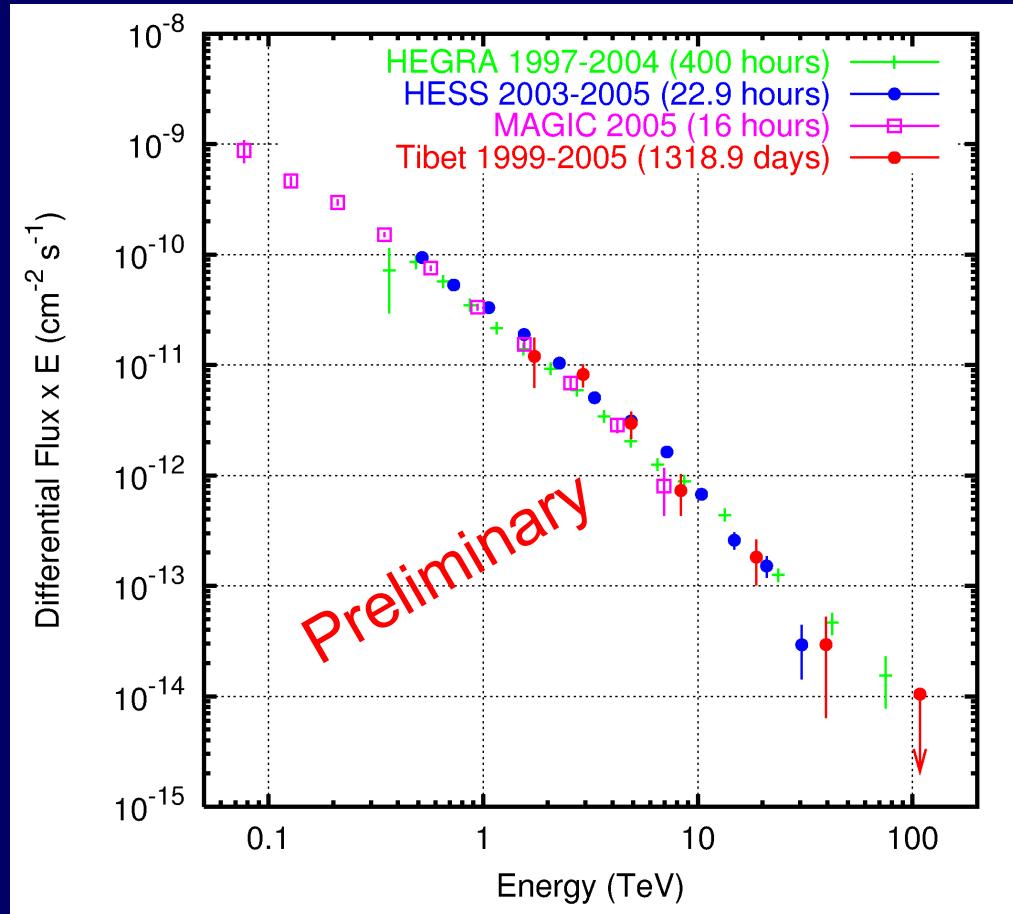


Tibet China (90.522°E , 30.102°N) 4300 m a.s.l.

<input type="checkbox"/> Number of Scinti. Detectors	$0.5 \text{ m}^2 \times 789$
<input type="checkbox"/> Effective Area for AS	$\sim 37,000 \text{ m}^2$
<input type="checkbox"/> Energy region	$\sim \text{TeV} - 100 \text{ PeV}$
<input type="checkbox"/> Angular Resolution (for Gamma 1ry)	$\sim 0.4^{\circ} @ 10 \text{ TeV}$ $\sim 0.2^{\circ} @ 100 \text{ TeV}$
<input type="checkbox"/> Energy Resolution (for Gamma 1ry)	$\sim 70\% @ 10 \text{ TeV}$ $\sim 40\% @ 100 \text{ TeV}$
<input type="checkbox"/> Pointing Error	$< 0.01^{\circ}$
<input type="checkbox"/> Absolute Energy Error	$\sim 10\%$
<input type="checkbox"/> F.O.V.	$\sim 2 \text{ sr}$

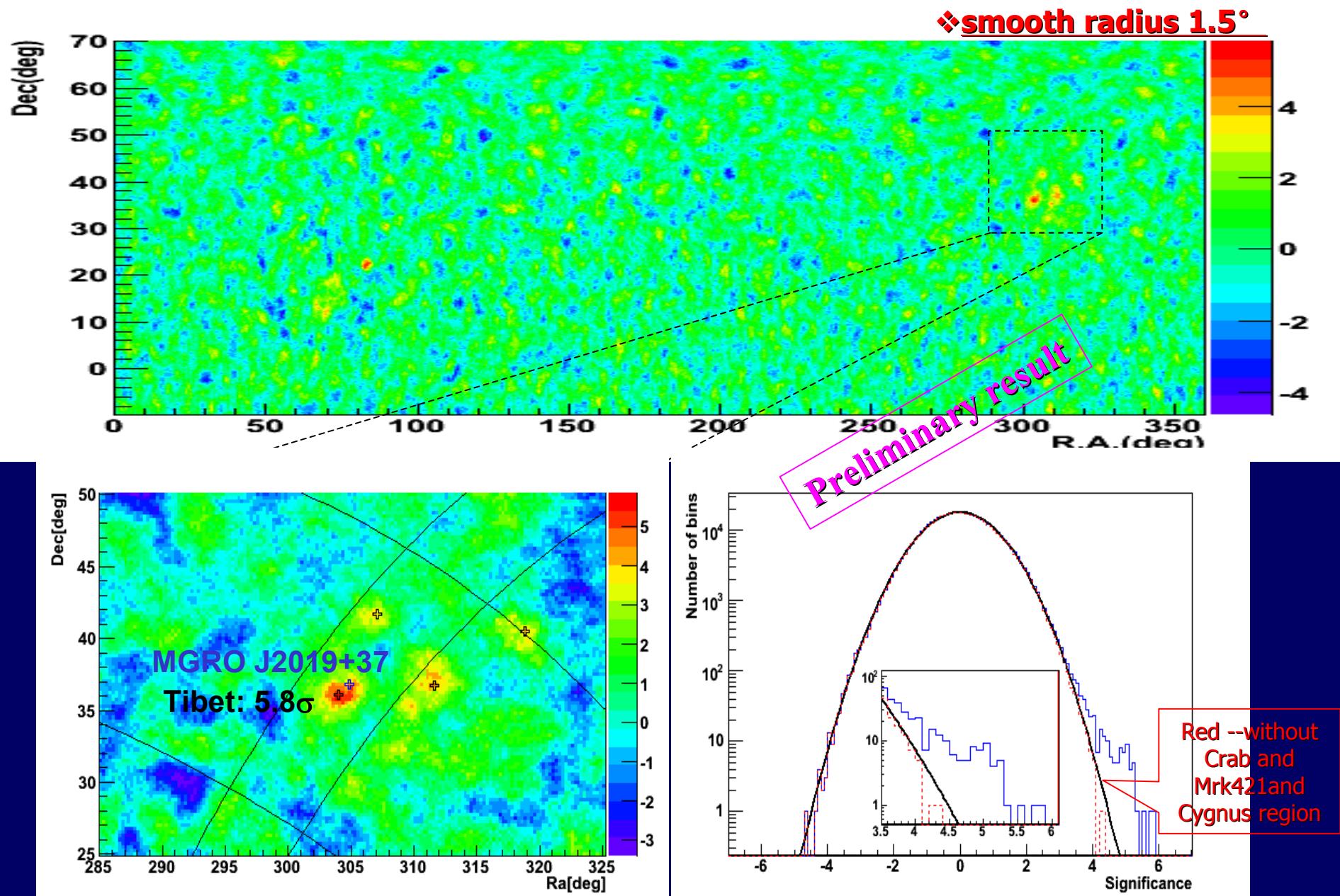


Energy Spectrum of Gamma rays from Crab Nebula

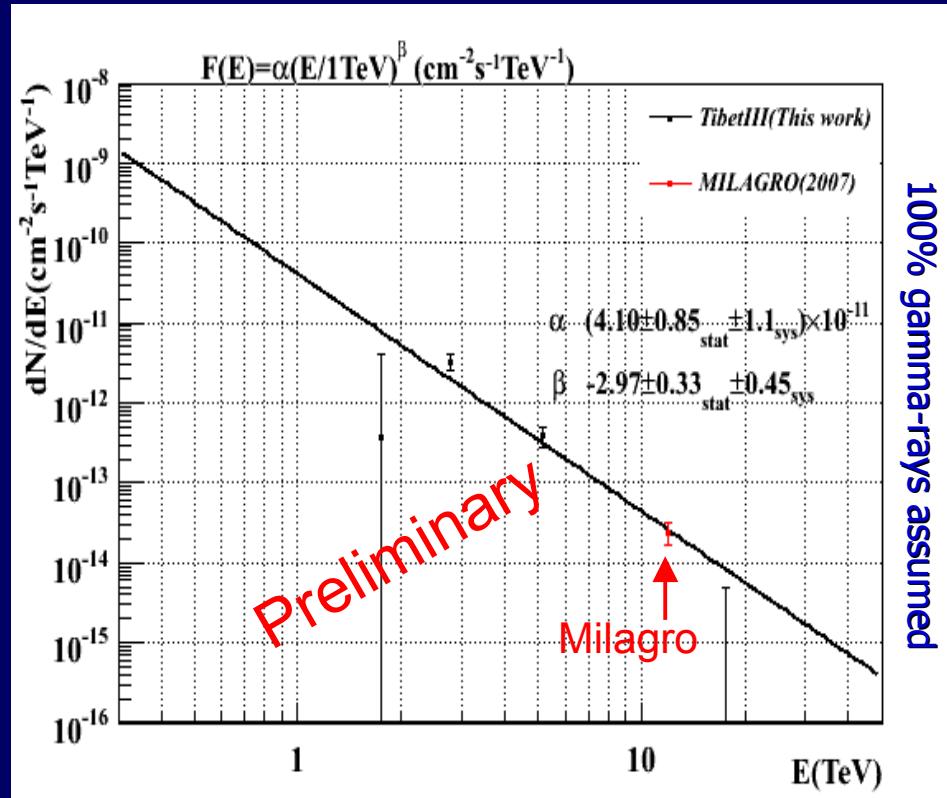


Consistent with other
observations using IACT

Northern Sky Survey & Cygnus Region



MGRO J2019+37 Energy Spectrum



Tibet AS has no ability for
Gamma/Hadron separation



Assuming 100% of the excess
is caused by gamma rays



Not inconsistent with Milagro
flux

➤ Milagro flux is $E^2 dN/dE = (3.49 \pm 0.47_{\text{stat}} \pm 1.05_{\text{sys}}) \times 10^{-12} \text{TeV cm}^{-2} \text{s}^{-1}$ from 3x3 square degree bin centered on the location of Hotspot $(304.83^\circ, 36.83^\circ)$ at 12TeV, assuming a differential source spectrum of $E^{-2.6}$ (reference : ApJ658:2007).

MGRO J1908+06

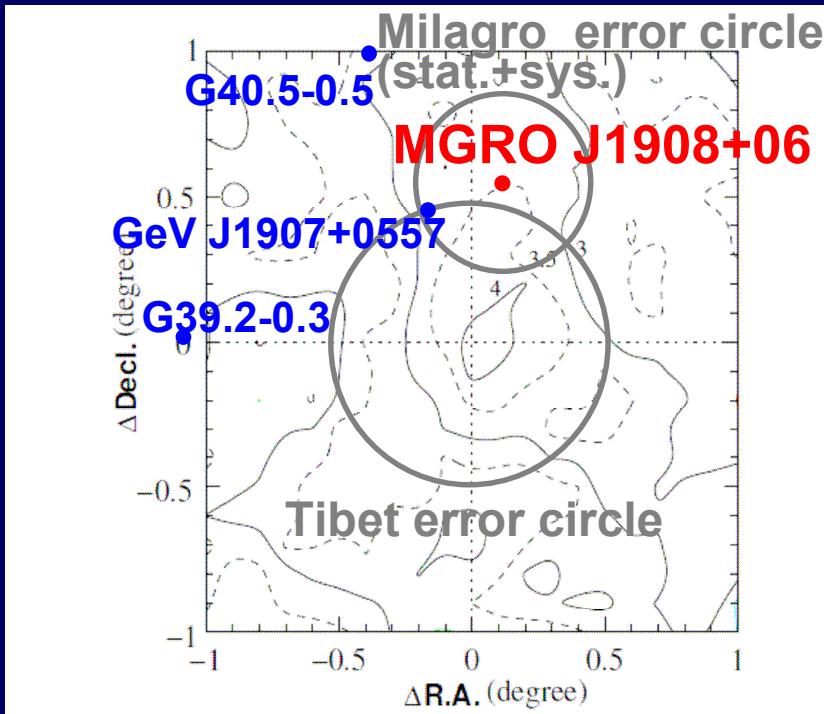


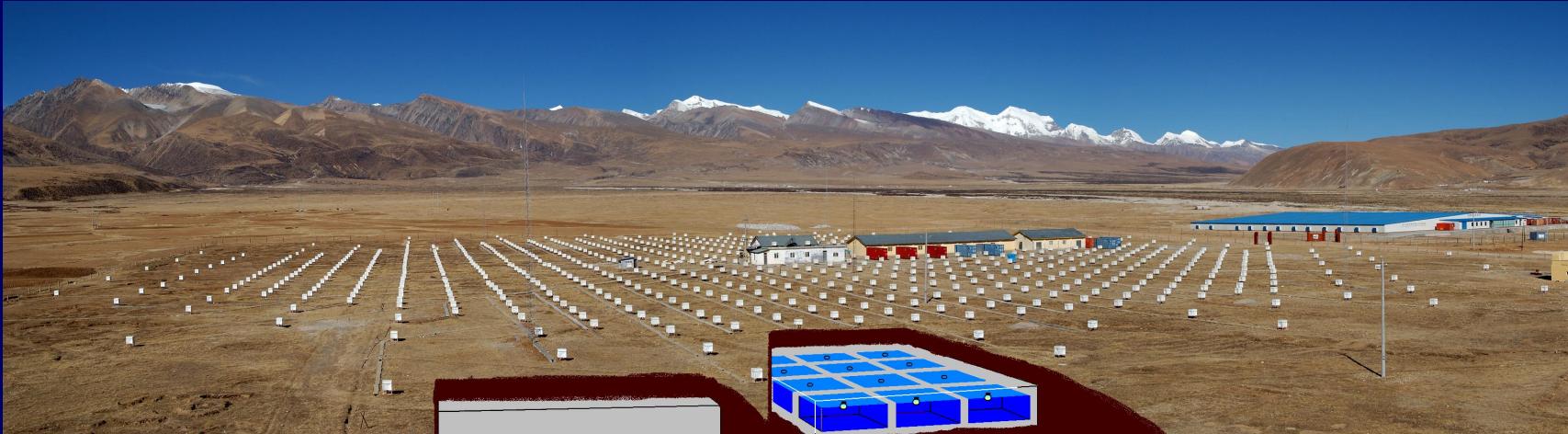
Figure 1. The significance for an event excess as a function of right ascension and declination in a $1^\circ \times 1^\circ$ region with the position [R.A. = 287.1° , decl. = 5.5° (J2000)] in the center observed between 2000 October and 2001 September. For each bin, the significance is calculated for the area of the circle with radius 1.4° and the bin center as the central point. The contour lines are drawn with a step of 0.5σ .

Tibet AS:
marginal excess
 $\sim 4.4\sigma$ (pre-trial)

Subsequently
Milagro:
clear excess
(MGRO J1908+06)

J.L. Zhang for the Tibet AS γ Collaboration,
28th ICRC, vol. 4, pp 2405 - 2408 (2003)
Amenomori et al., 29th ICRC, vol. 4,
pp 93 - 96 (2005)
Amenomori et.al, ApJ 633, 1005 (2005)

Tibet AS+MD project



7.2m x 7.2m x 1.5m depth Water pool

20"φ PMT x 2 (HAMAMATSU R3600)

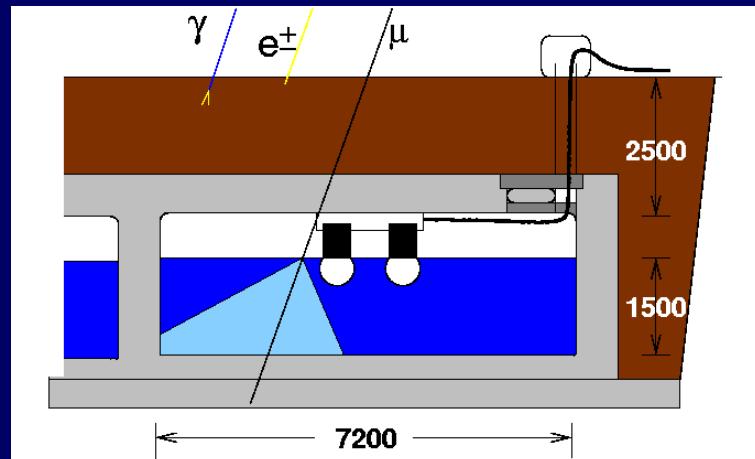
Underground 2.5m ($\sim 515\text{g/cm}^2 \sim 19X_0$)

Material:

- Reinforced concrete
- White waterproof paint

192 detectors

Total 9950 m²



Counting the number of muons accompanying an air shower

→ Gamma/Hadron separation

Tibet AS+MD Simulation

□ Air Shower Generation - Corsika Ver.6.204

CR: 0.3TeV-10PeV, Crab Orbit

Chemical components

Interaction model: QGSJET01c

Gamma: 0.3TeV-10PeV, Crab Orbit
 $E^{-2.6}$

Core position:

Throw randomly within 300 m radius

□ Scintillation det. (Tibet AS) - Epics UV8.00

Estimate energy, direction, core position, ...

□ Soil + Cherenkov det. (Tibet MD) - GEANT4 8.0

Reflectance at walls 70%

Att. length ~40m@400nm

(Dependant on wave length)

Quantum Eff. ~20%@400nm

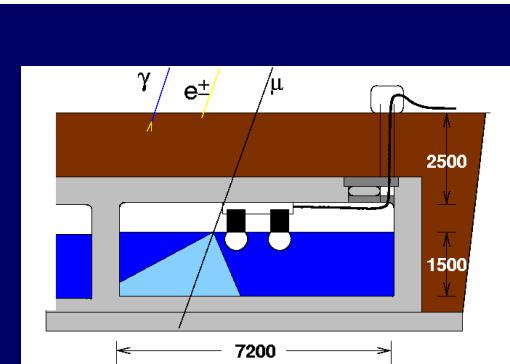
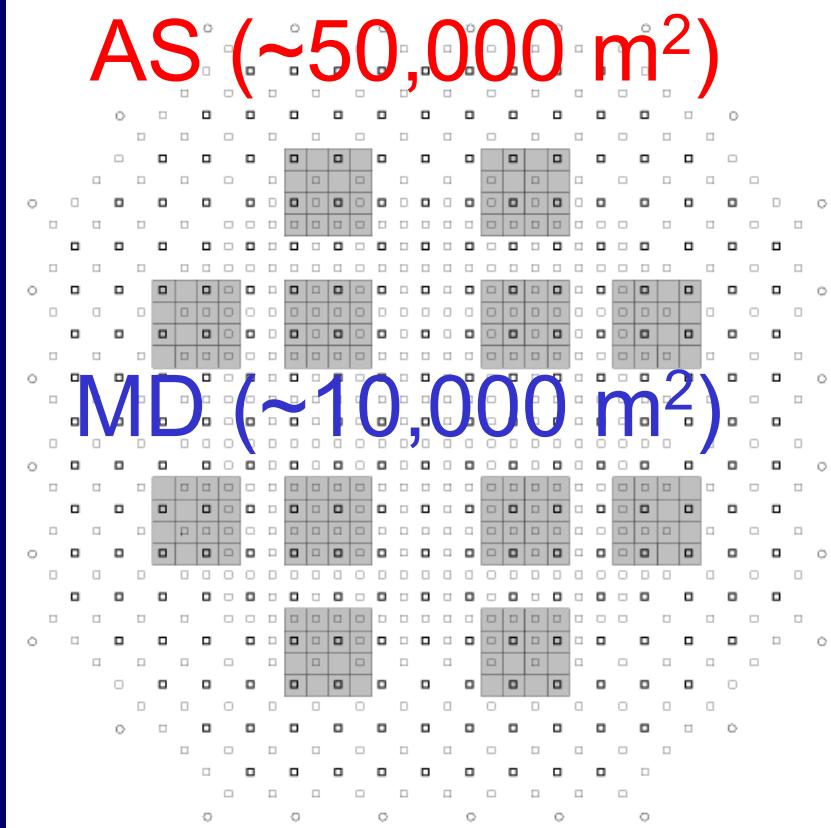
(Dependant on wave length)

□ Accidental muons

300 Hz/m² x 9950 m² x 200 ns

= ~0.6 muons/an air shower

(Poisson noise distribution)

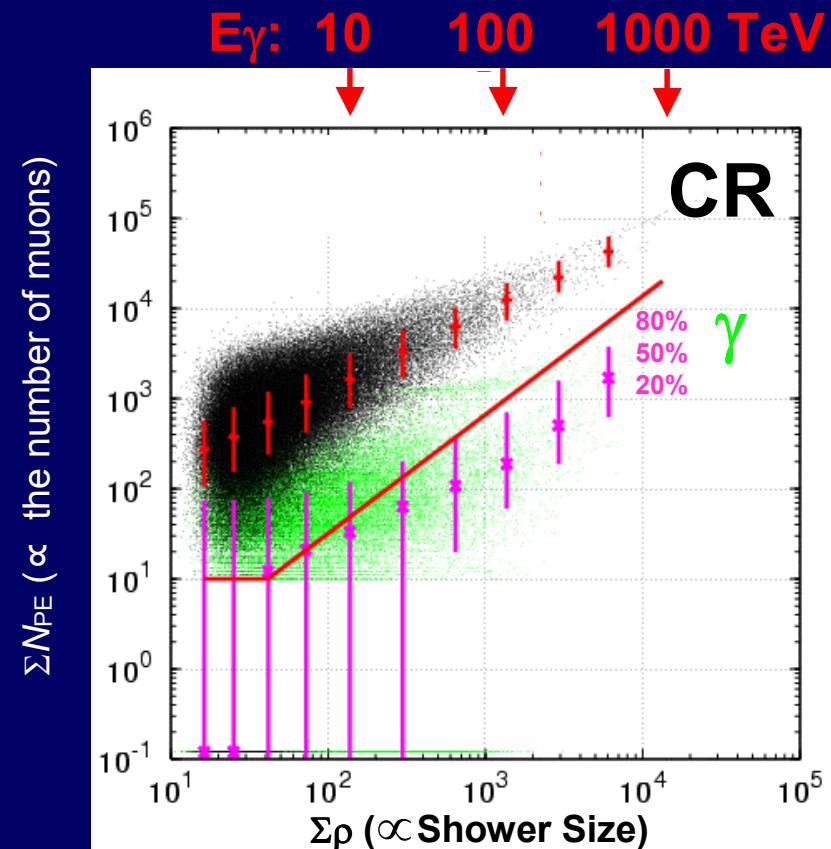


Number of muons vs. Shower Size (Simulation)

$\Sigma\rho$: Sum of particle density by all scintillation det.
 \propto air shower size

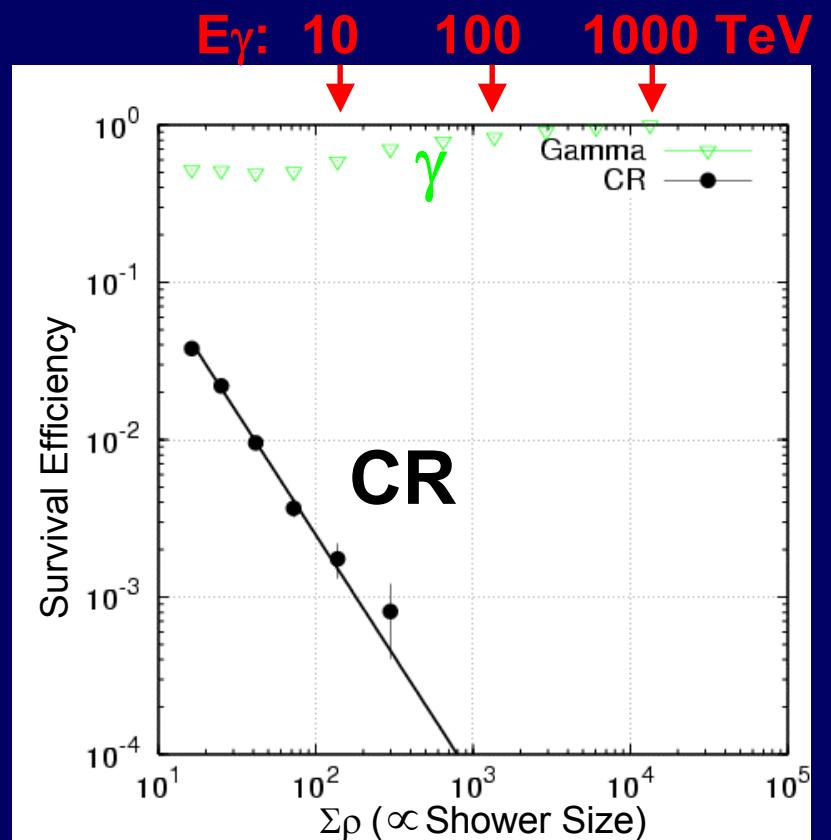
ΣN_{PE} : Sum of photoelectrons by all muon det.

\propto the number of muons in air shower



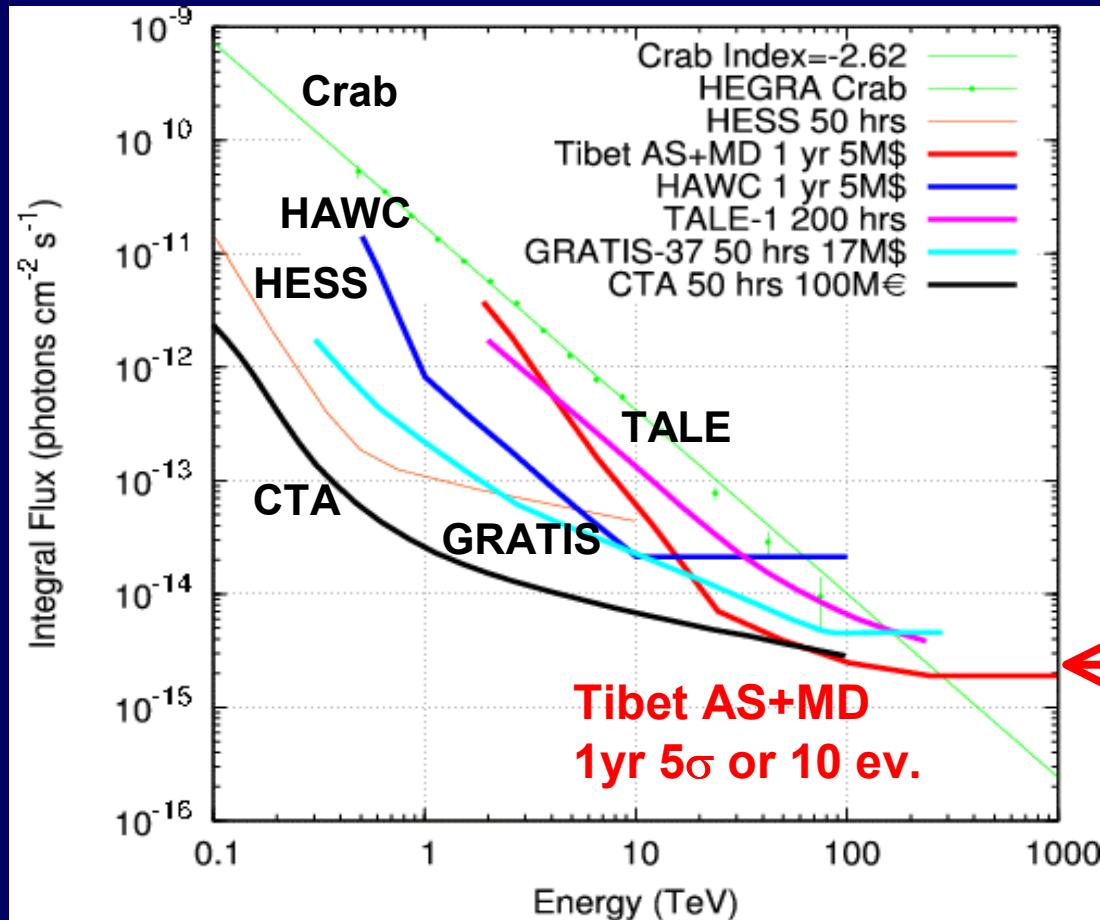
Survival Efficiency (Simulation)

Energy	10 TeV	100TeV
ΣN_{PE} cut value	~ 30 PEs	~ 700 PEs
BG rejection	$\sim 99.8\%$	$> \sim 99.99\%$
γ survival	$\sim 60\%$	$\sim 85\%$
Sensitivity	~ 15 times	BG free improved



Sensitivity to Point-like Gamma-ray Sources

5 σ or 10 ev. sensitivity in 1yr or 50 hours



Sensitivity

5-20% Crab @ 10-100 TeV

>15 TeV

Surpass existing IACTs

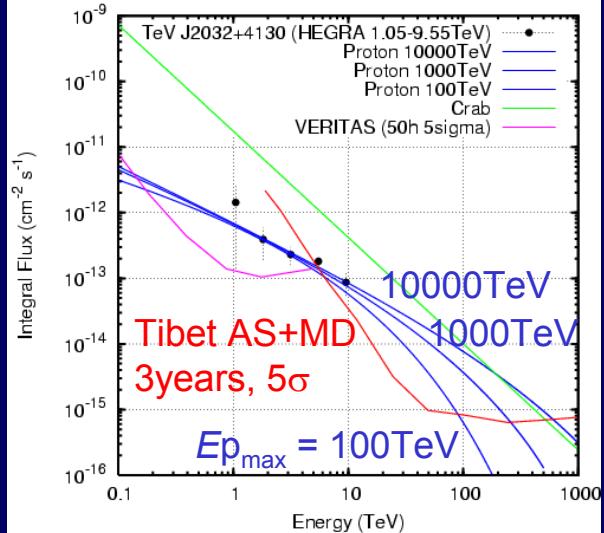
>40 TeV

Surpass future plans of IACTs

Background free
10 gamma-ray events
sensitivity

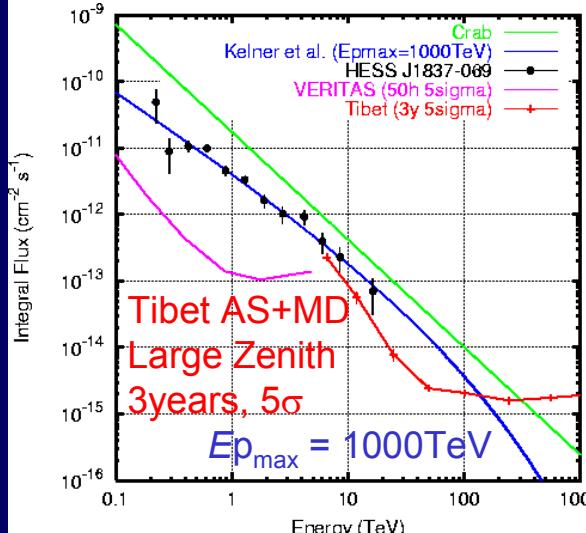
Known Galactic Sources in the Northern Sky

TeV J2032+4130



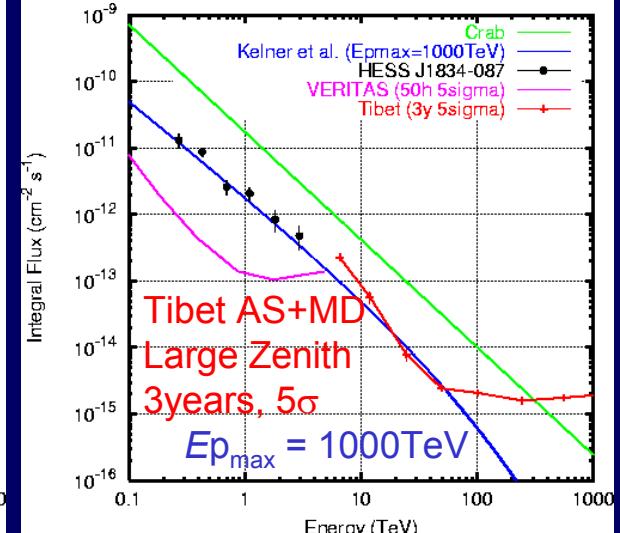
Aharonian et al, A&A, 431, 197 (2005)

HESS J1837-069



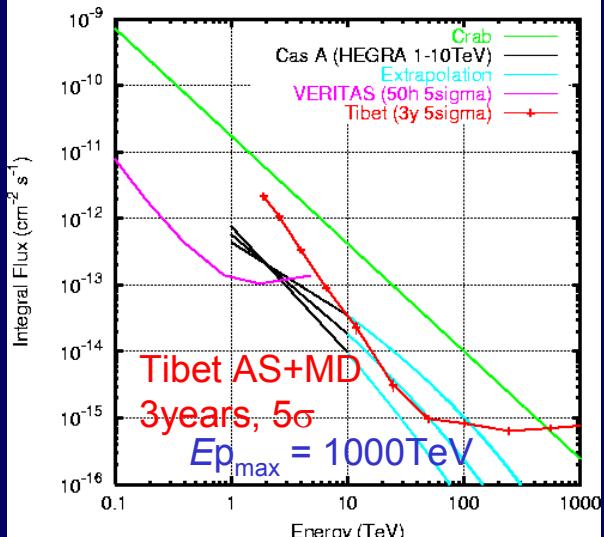
Aharonian et al, ApJ, 636, 777 (2006)

HESS J1834-087



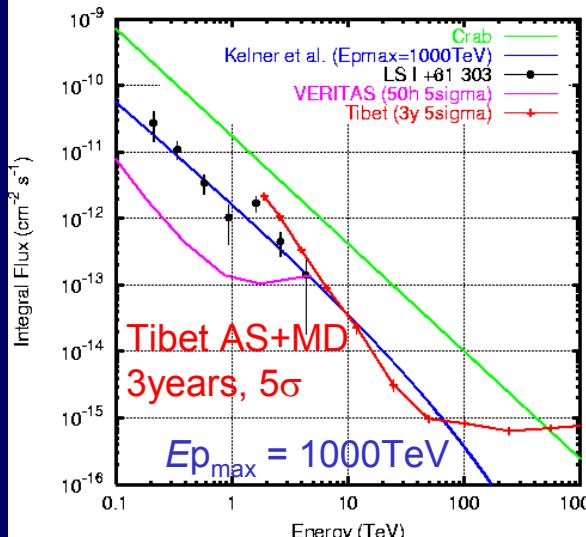
Aharonian et al, ApJ, 636, 777 (2006)

Cas A



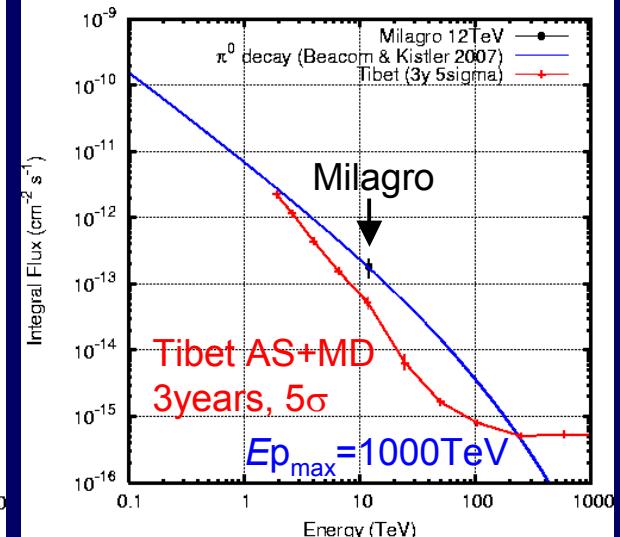
Aharonian et al, A&A, 370, 112 (2001)

LSI +61 303



Albert et al, Science, 312, 1771 (2006)

MGRO J2019+37



Beacom et al, astro-ph/070175 (2007)

How many new sources?

Aharonian et al, ApJ, 636, 777 (2006)

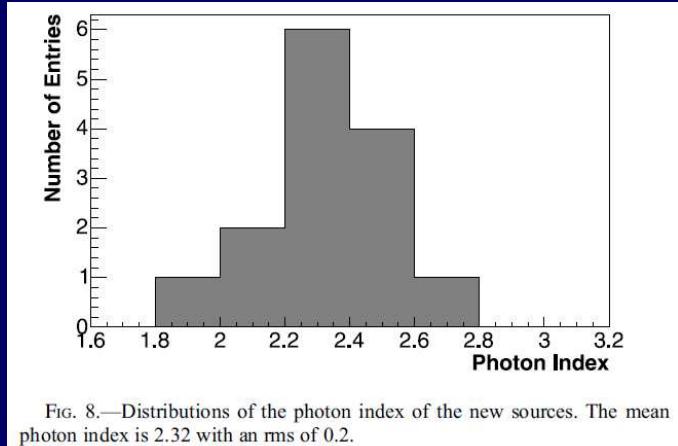
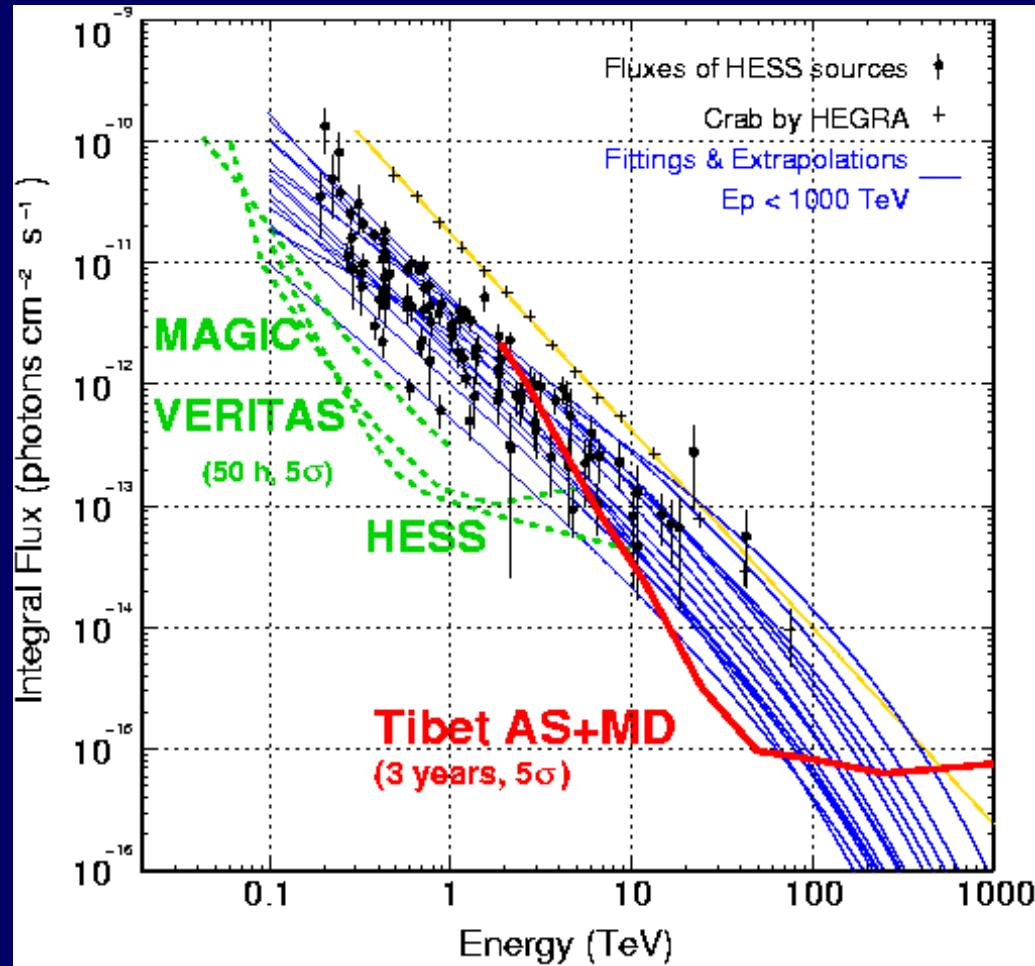
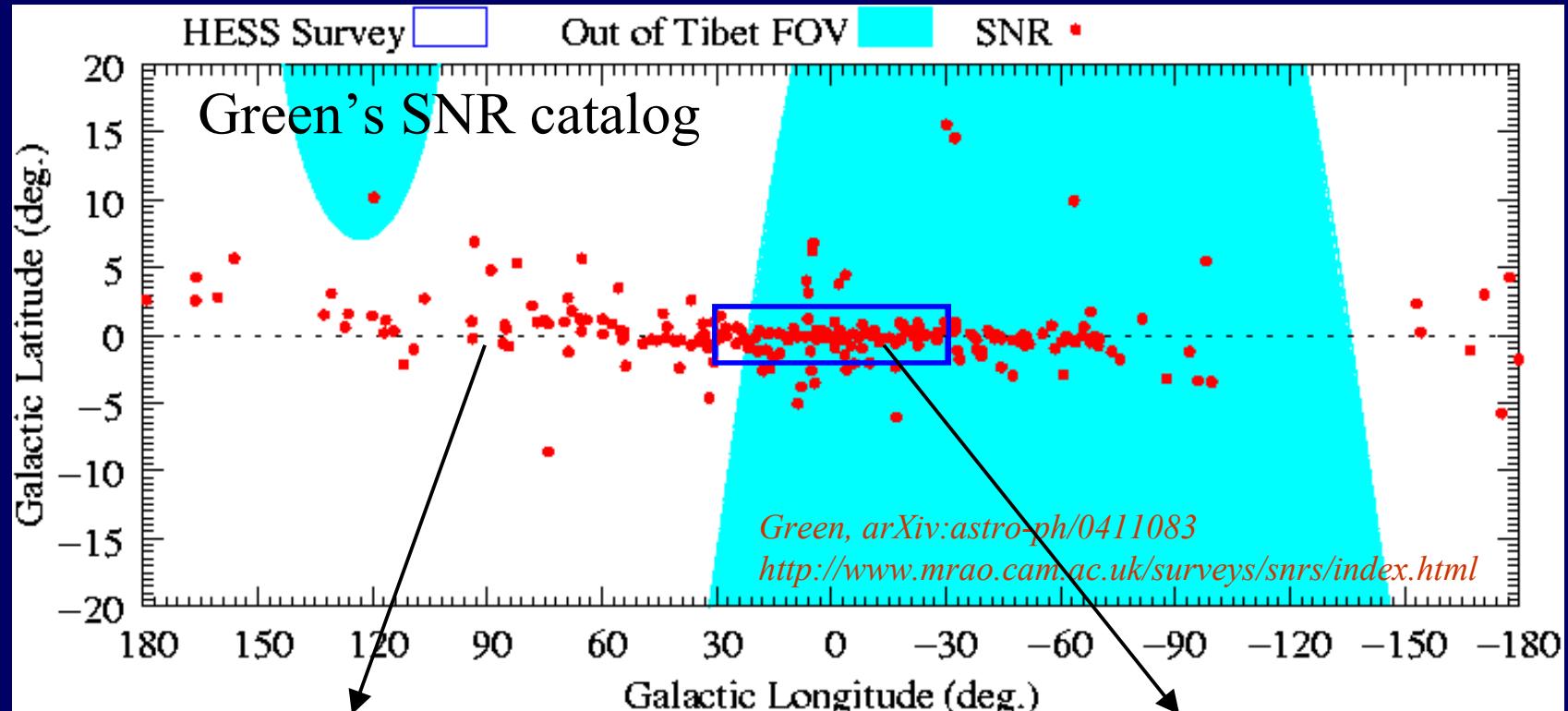


FIG. 8.—Distributions of the photon index of the new sources. The mean photon index is 2.32 with an rms of 0.2.

Induces are harder

(If Tibet AS+MD is constructed at southern hemisphere)
Most of new HESS sources detectable by Tibet AS+MD

Expectation of the number of SNR-like sources in the Northern Sky



Tibet F.O.V. region
86 SNRs

~14 discoverable?? (SNR-like)
optimistic value?
But, could not be 0?

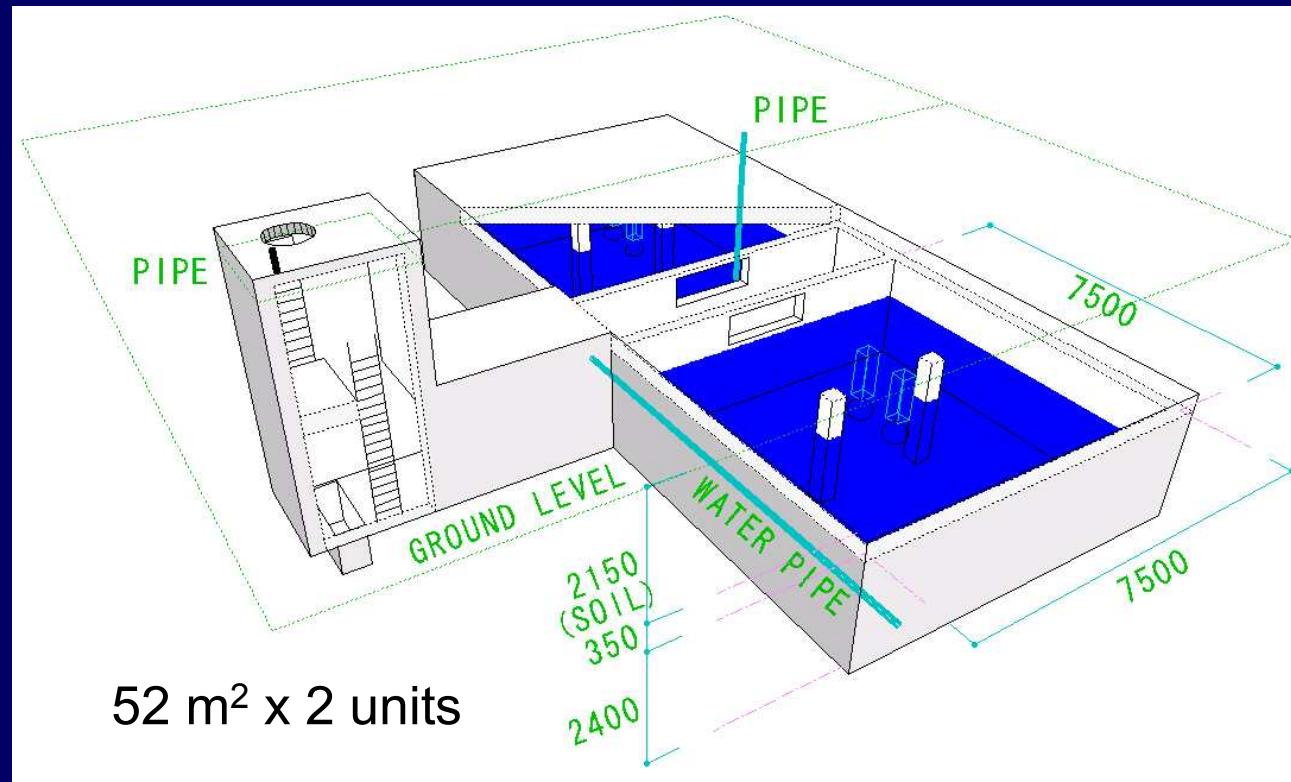
HESS survey region
82 SNRs

14 discovered (SNR-like)
Aharonian et al, ApJ, 636, 777 (2006)

Cost Estimation

Items		Unit Price (USD)	Quantity	Price (USD)
PMT	20“ ϕ PMT	5,000	384	1.9M
Electronics	ADC, TDC, HV, Cable etc.	1,000	384	0.4M
Water Pool	Construction and Waterproof	250/m ²	10,000m ²	2.5M
Water Purification	MF filter			0.2M
Others				+ α
Total				5M + α

Test MD



Construction	start	1 st September 2007
	complete	end of November 2007

- Feasibility study of construction
- Compare with simulation
- Search for 1000 TeV Gamma rays

Summary

- Performance of Tibet Air Shower Array:

Angular Resolution	0.2° @100TeV
Energy Resolution	~40% @100TeV
Systematic Pointing Error	< 0.01°
Absolute Energy Error	~10%
- Crab Nebula: Energy spectrum observed by Tibet AS is consistent with other observations using IACTs.
- MGRO J2019+37: Tibet flux is not inconsistent with Milagro results, if we assume 100% of the excess is caused by gamma rays.
- MGRO J1908+06: Marginal excess was found.
- Tibet AS+MD: 10000 m² Water Cherenkov Muon Detector Sensitivity is 5-20% Crab @ 10-100 TeV.
- Construction of test MD (52 m² x 2) will start 1st September 2007.

Thank you!