Gamma Ray Observation with Tibet AS γ Experiment

--- Past Results and Upgrading Project ---

Zhaoyang Feng, IHEP, CAS, China

For the Tibet AS γ Collaboration

~ Contents ~

- What we have done
- Tibet III + MD project
  - Gamma ray point source sensitivity
  - Cosmic ray electron and DM electron sensitivity

Tibet MD: Tibet underground Muon Detector array

THE 2nd WORKSHOP OF AIR SHOWER DETECTION AT HIGH ALTITUDES

17-19 February 2011

The Tibet ASγ Collaboration

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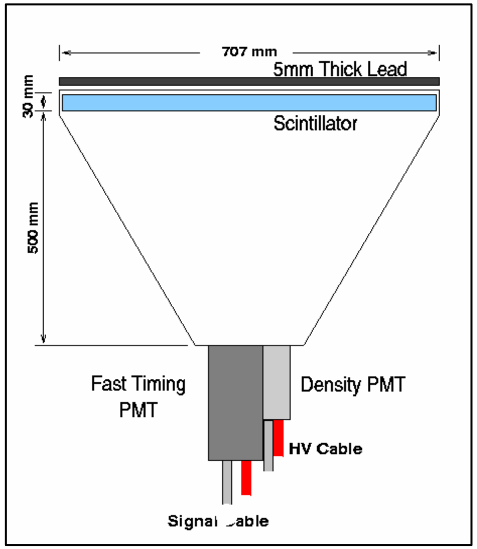
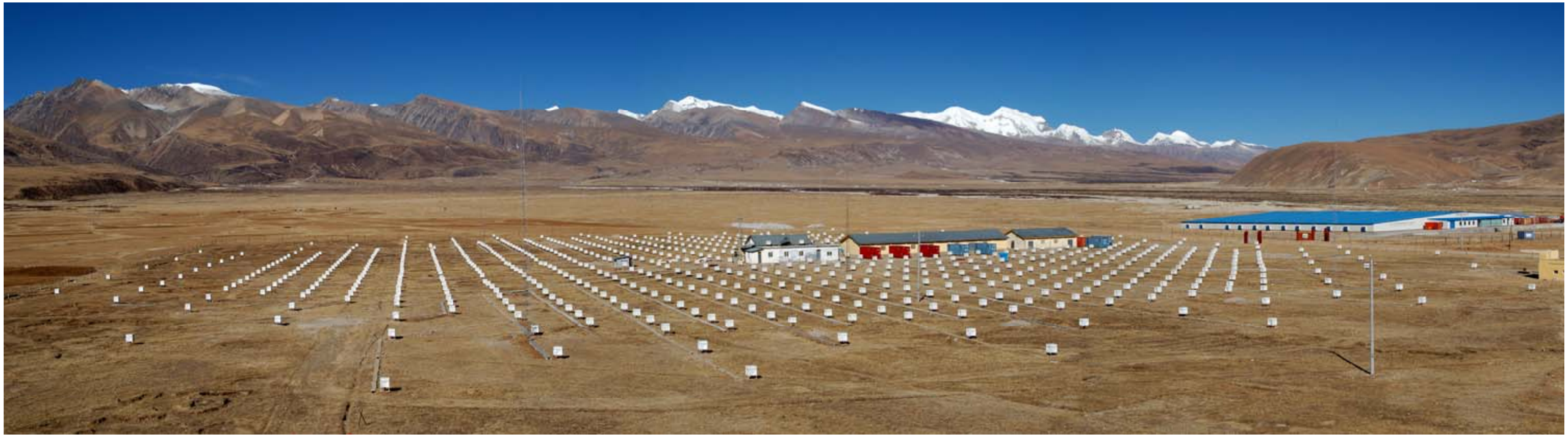
Tibet AS γ Experiment

Tibet China (90.522°E, 30.102°N) 4300 m a.s.l., since 1989

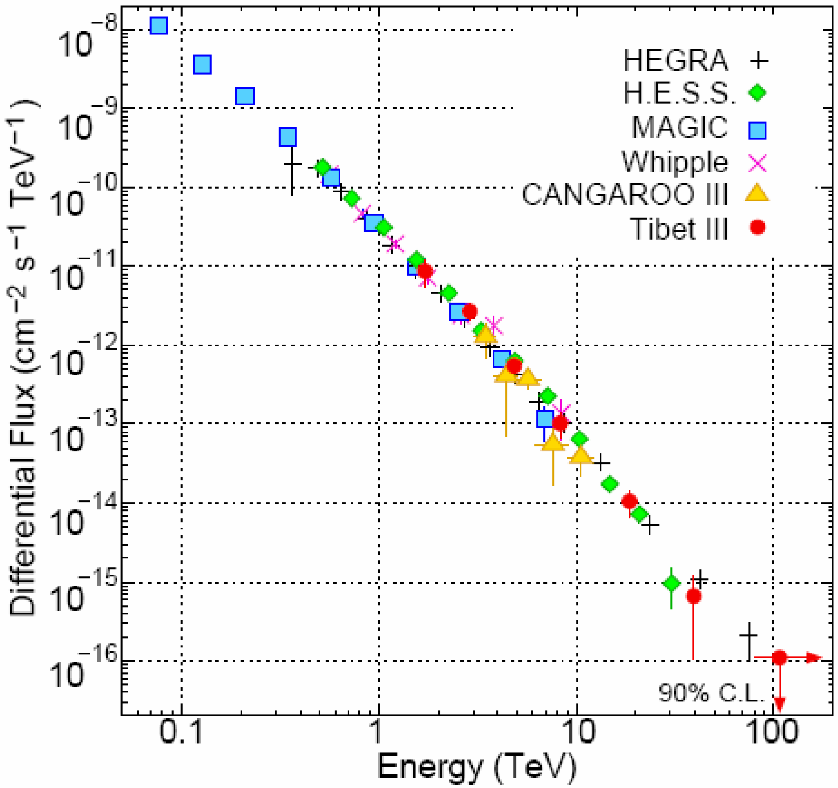
Number of Scinti. Det.	0.5 m^2 x 789
Angular Resolution for gamma rays	~0.9 deg.@3 TeV ~0.5 deg.@10 TeV ~0.2 deg.@100 TeV
Energy Resolution for gamma rays	~100% @3 TeV ~60% @10 TeV ~40% @100 TeV
F.O.V.	~2 sr

Effective Area for AS ~37,000 m^2

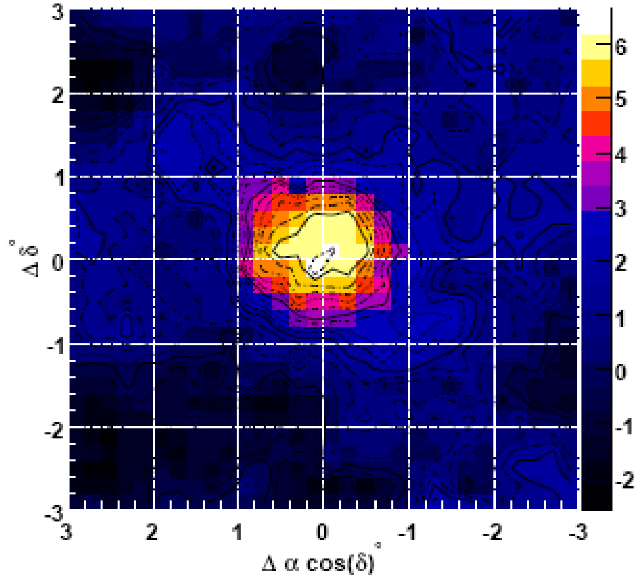




Energy Spectrum of Gamma Rays from Crab Nebula



ApJ, **525**, L93-L96 (1999)
ApJ, 692, 61 (2009)



Consistent with other observations using IACTs

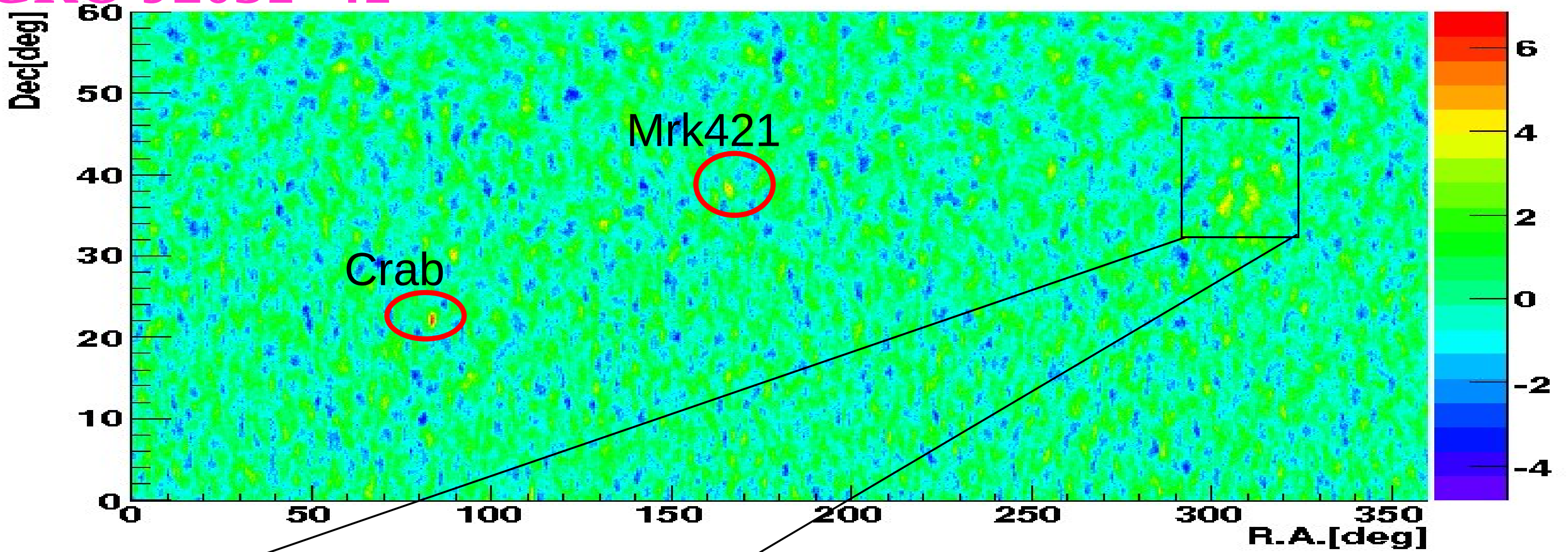
Other point source:

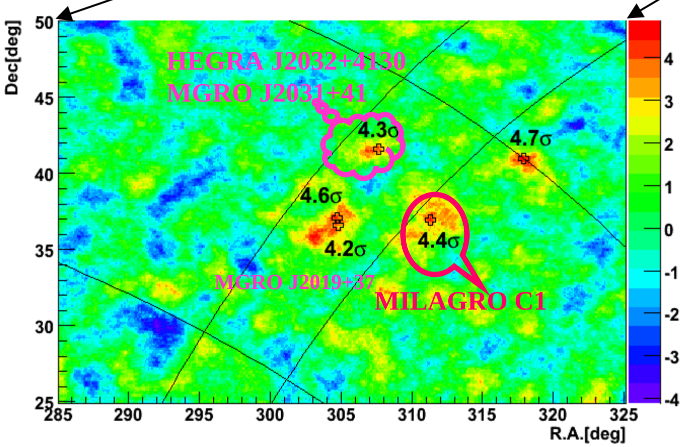
- Flare of Mrk501 ApJ, **532**, 302-307 (2000)
- Flare of Mrk421 ApJ, **598**, 242-249 (2003)

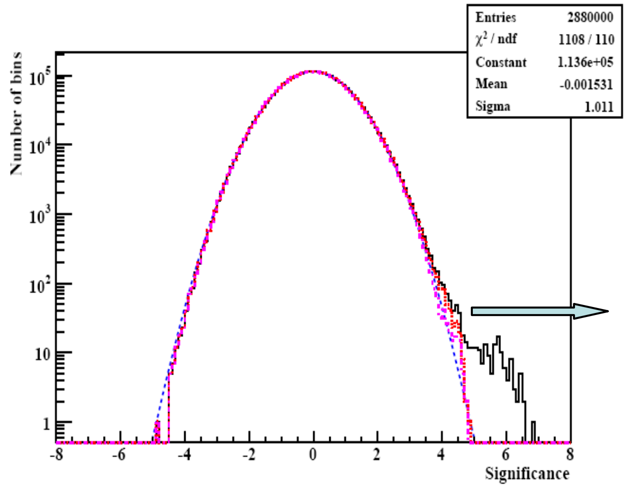
Northern Sky Survey & Cygnus Region

MGRO J2019+37
MGRO J2031+41

—Smooth radius is optimal angular resolution(0.99 °) considering the extension 0.32 ° of MGRO J2019+37







Solid line--all sky;
Dashed line-gaus fit;
Dotted line-without Mrk421 and Crab;
Dot-dashed line-without Mrk421,Crab and MGRO J2019+37;

MGRO J1908+06

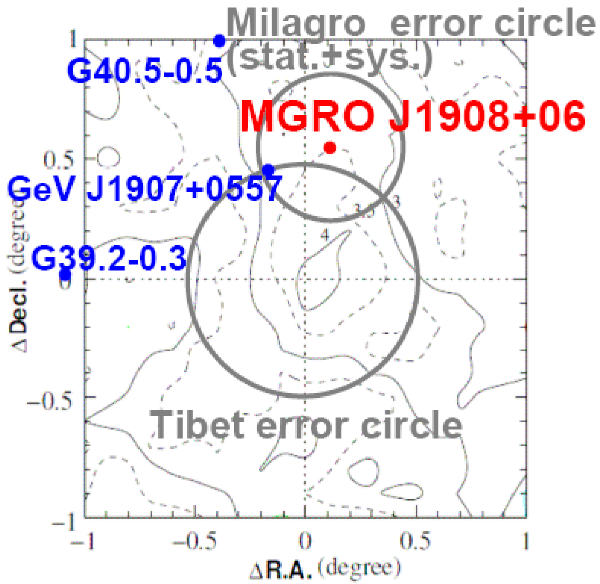


Figure 1. The significance for an event excess as a function of right ascension and declination in a 1° × 1° region with the position [R.A. = 287.1°, decl. = 5.5° (J2000)] in the center observed between 2000 October and 2001 September. For the each bin, the significance is calculated for the area of 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 γ :
marginal excess
~4.4 σ (pre-trial)

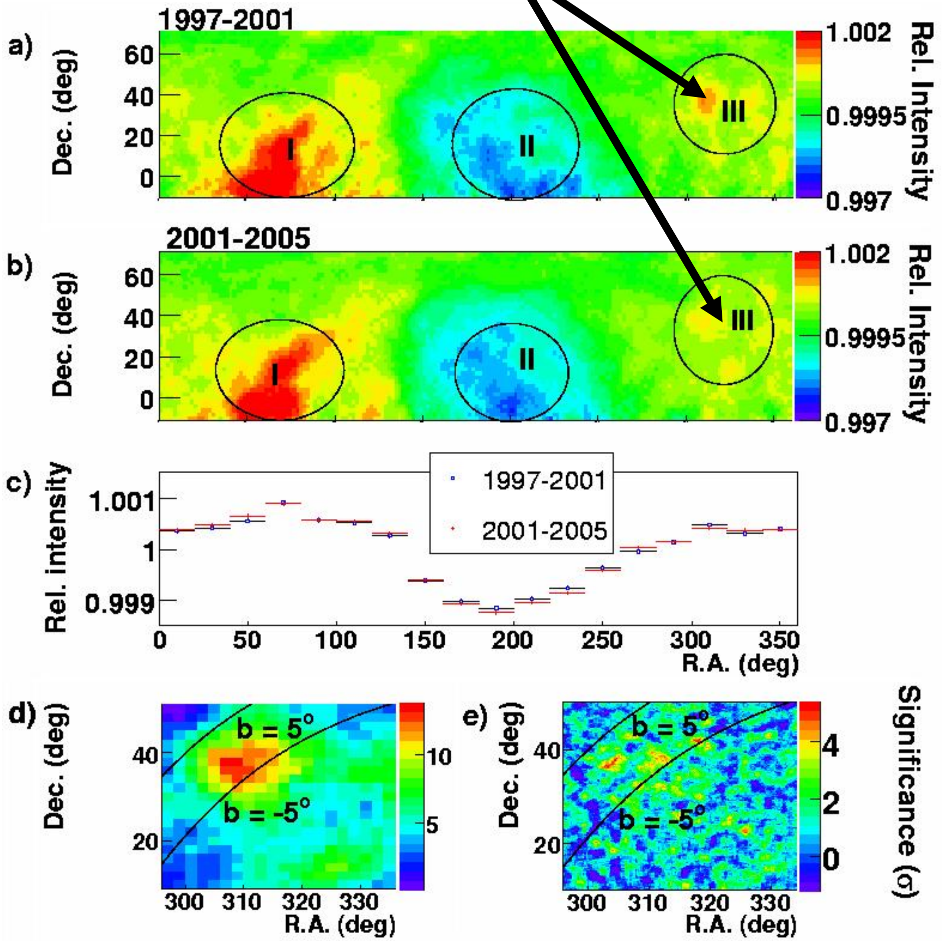
Subsequently
Milagro:
clear excess(~7.4 σ)

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)

New Anisotropy Component and Corotation Evidence of the GCR (Science 314(2006)439-443)

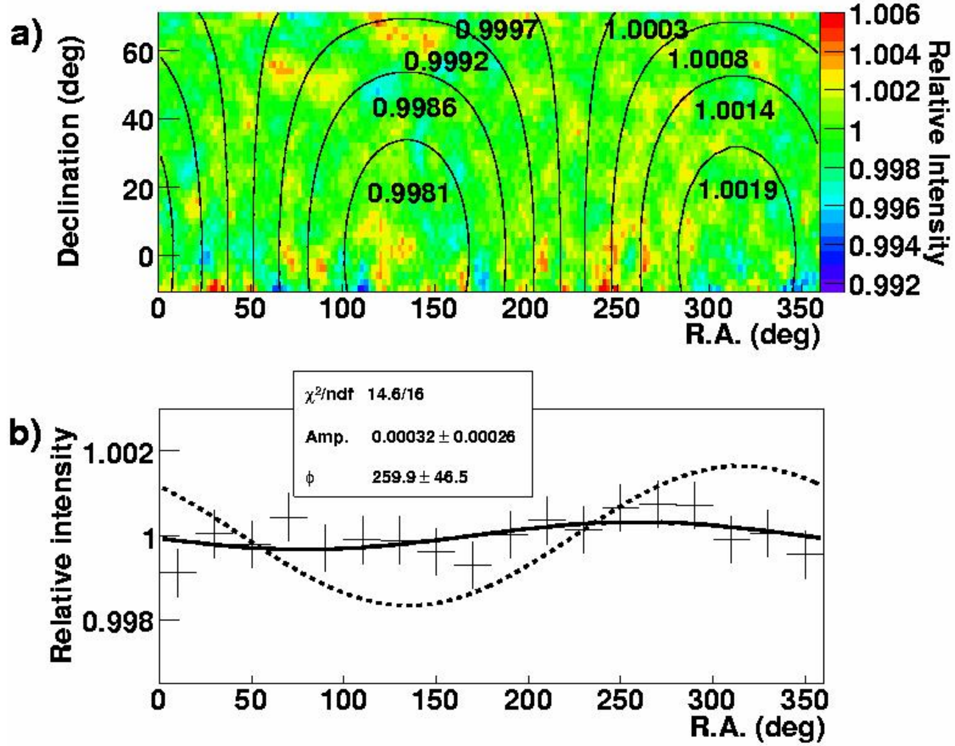
Celestial Intensity map (E~3TeV)

New anisotropy component



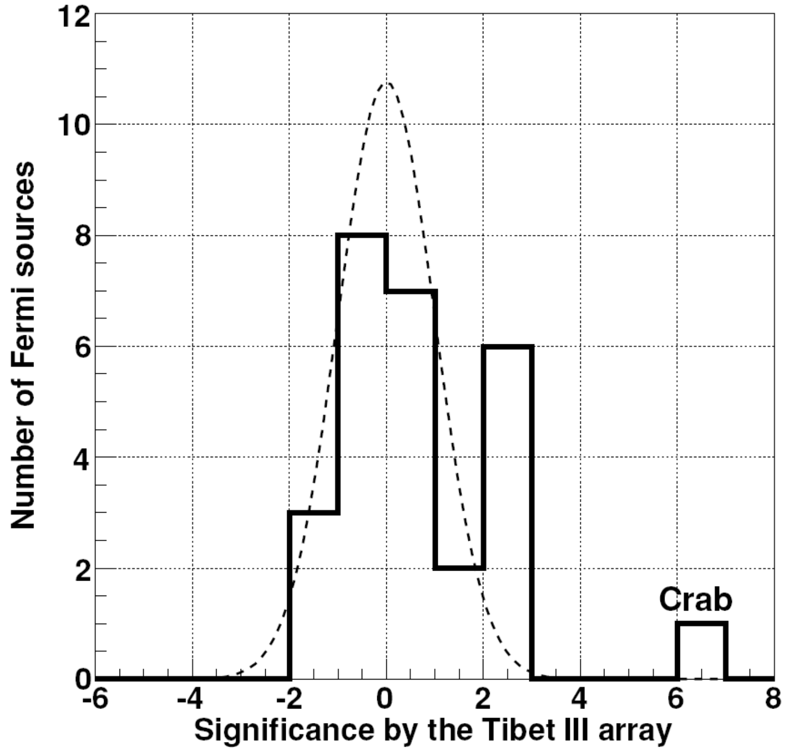
Intensity @ E~300TeV

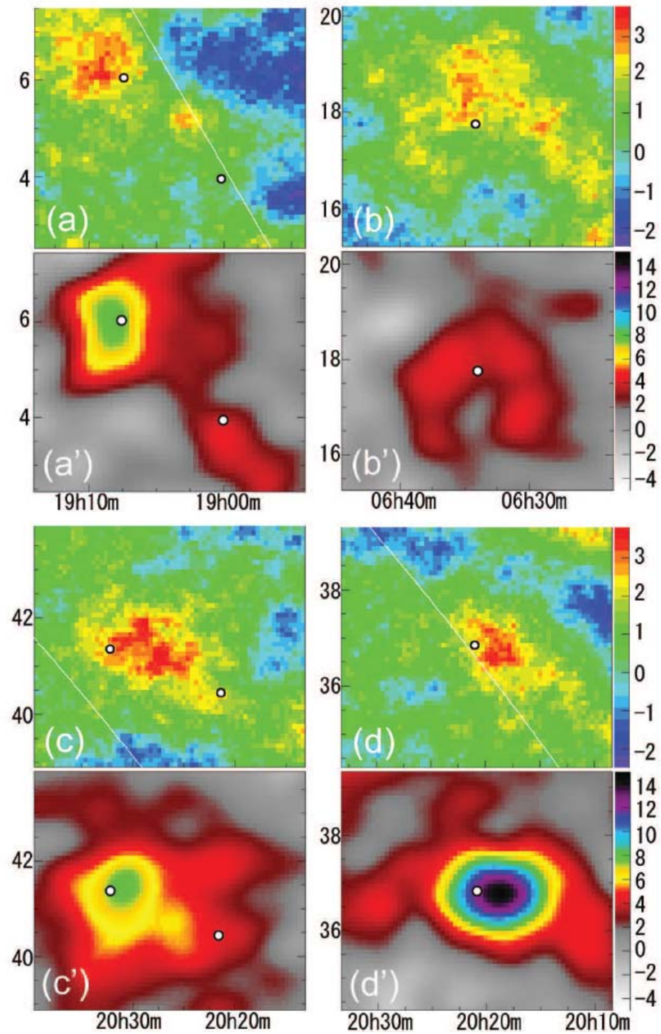
Amp=0.16% w/o corotation;
Observation: 0.03%±0.03%.



Observation of TeV Gamma Rays From the Early 27 Fermi Bright Galactic Source

ApJ, 709:L6–L10, 2010





7 sources ⩾2 sigma

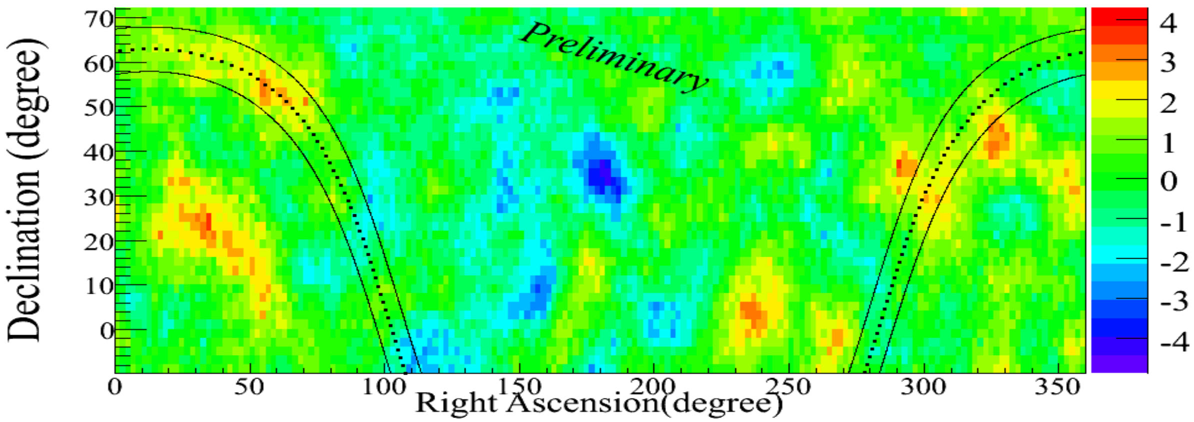
0.61 expected

Result on γ Emission at 100TeV without Having MUON Detector

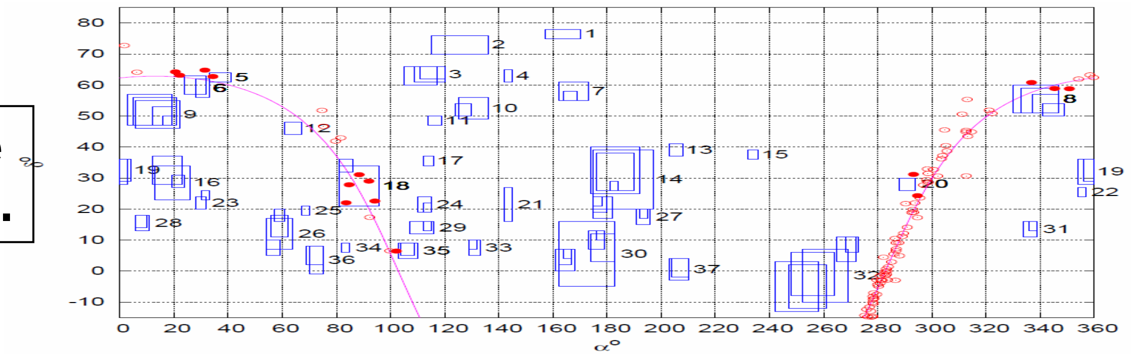
(Zhaoyang Feng et al, ICRC2009)

Upper：Hints of 100TeV γ emission?

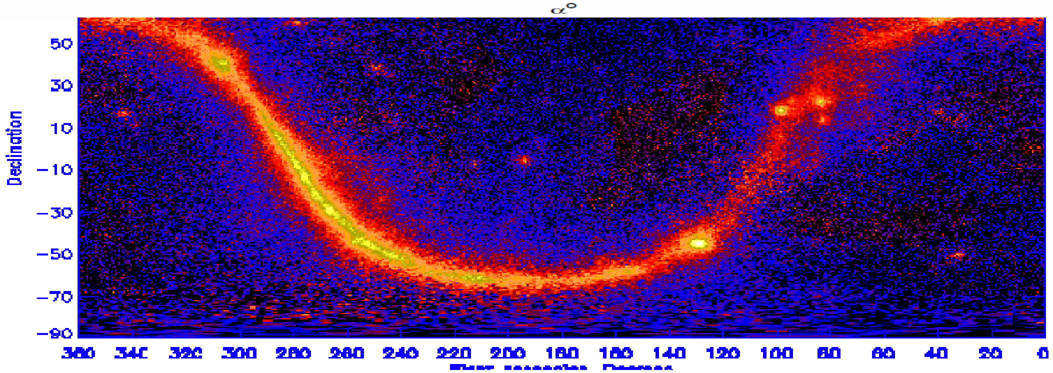
TibetMD would answer this question



Middle : EAS-1000 prototype array from 100TeV to 10 PeV.



Lower: γ ray observation by satellite experiment EGRET at GeV energy.



The Tibet AS γ Experiment,

- Crab, Mrk501 , Mrk421 observed
- marginal excess of three Milagro sources.
- Possible diffuse γ-ray signal from Cygnus region
- Hints of 100TeV γ emission

But

No new significant TeV γ-ray point source discovered

Advantages and disadvantage

- High altitude
- High duty cycle
- large FOV
- Big area

But

Poor ability for γ /p discrimination

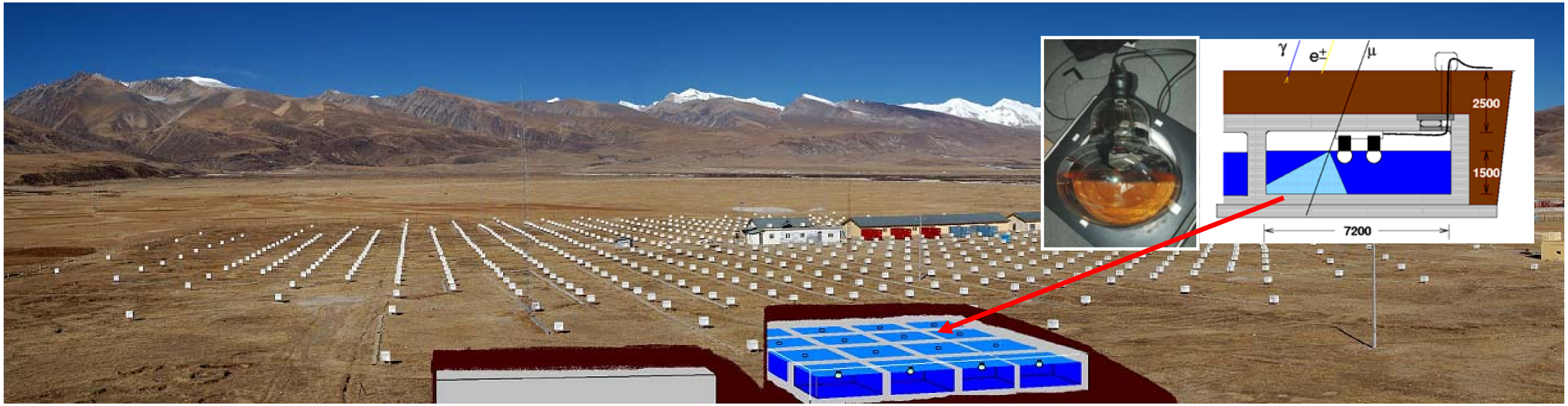
Future

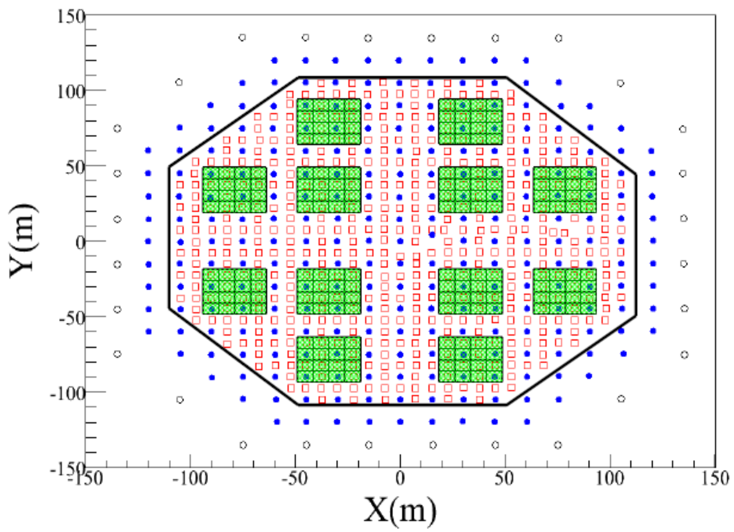
TibetMD: Improve ability for γ /p discrimination

- 100 TeV-region gamma ray astronomy
- Knee physics (combining YAC, see Dr. Huang Jing's talk at this afternoon.)

Tibet MD：10,000m^2 underground Muon Detector

Measuring muon number in air shower





MD array

--- 12 x 16 =192 muon detectors (~10,000 m^2)

--- 2.5m underground (~515g/cm^2, ~19X_0)

Each muon detector

--- Water pool, made of concrete

--- 7.2m x 7.2m x 1.5m depth

--- 20" inch PMT x 2 (HAMAMATSU R3600)

Threshold

--- 1 GeV for Vertical Muon

Tibet MD： 10,000m² underground Muon Detector

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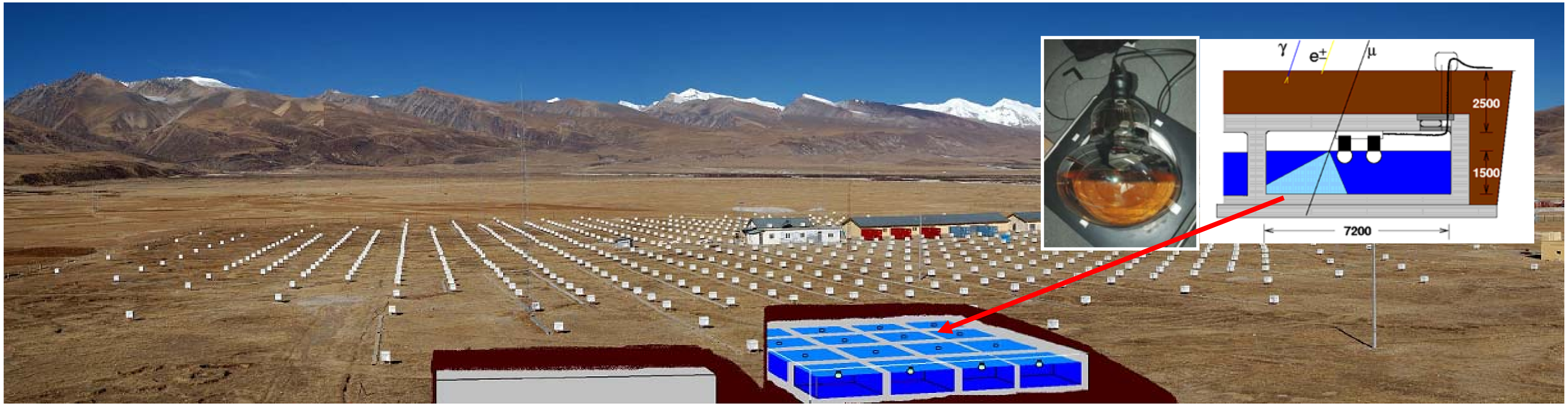

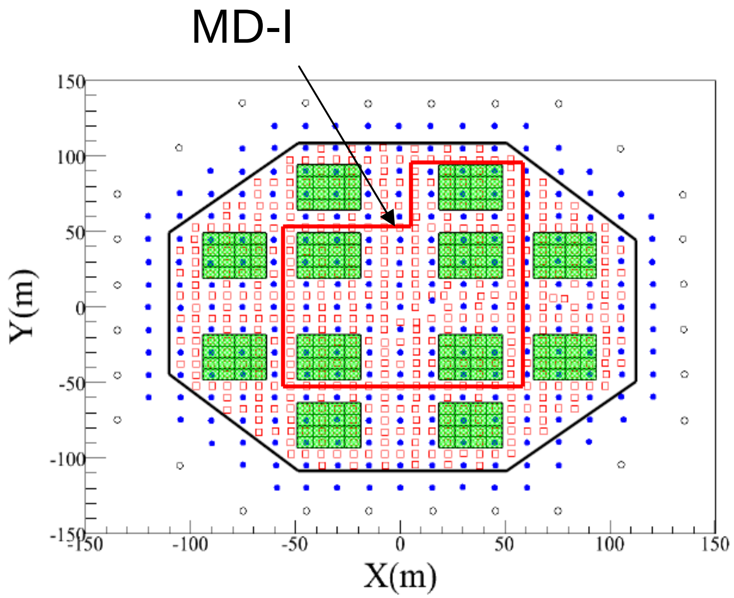

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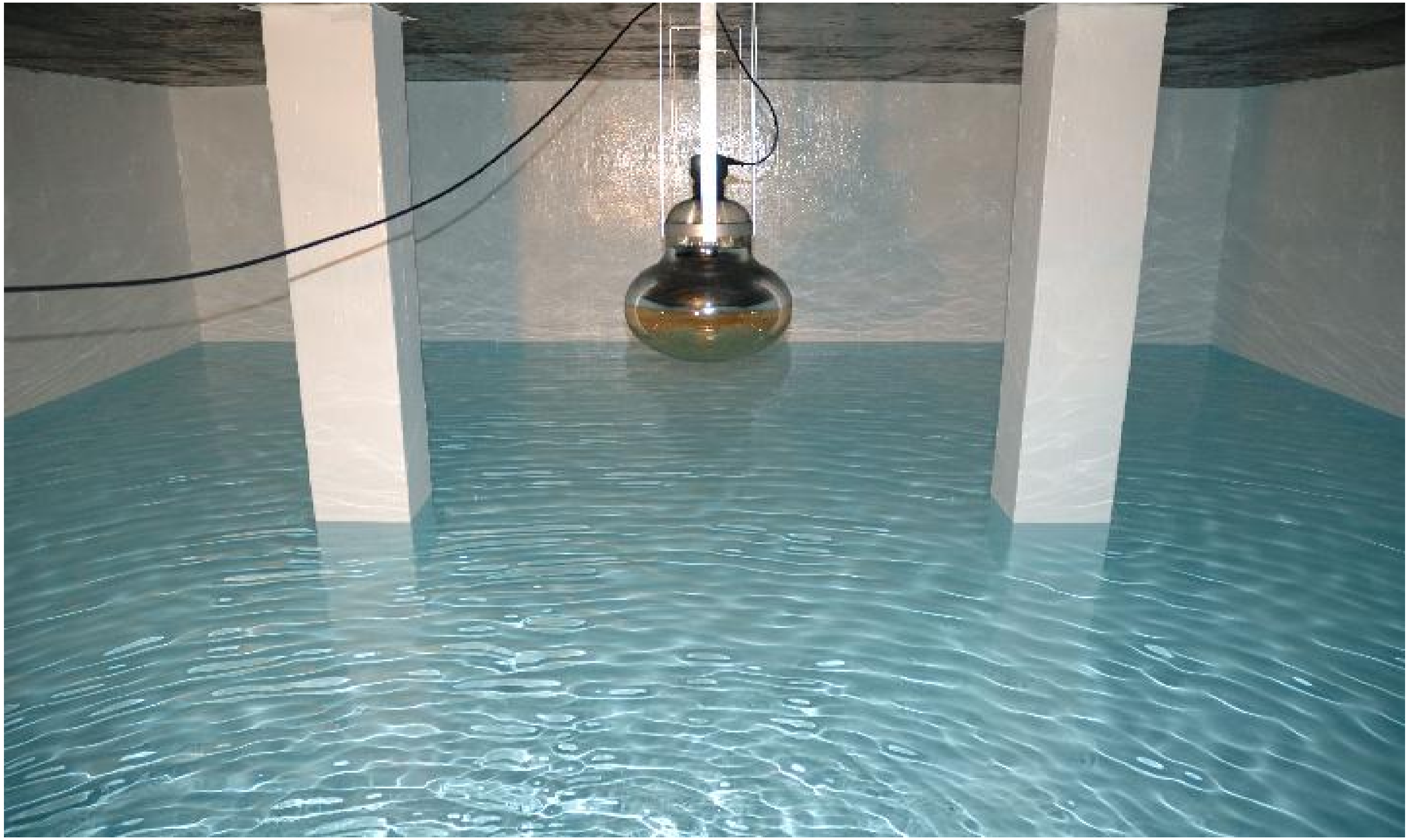
Inside View of MD Prototype@2007



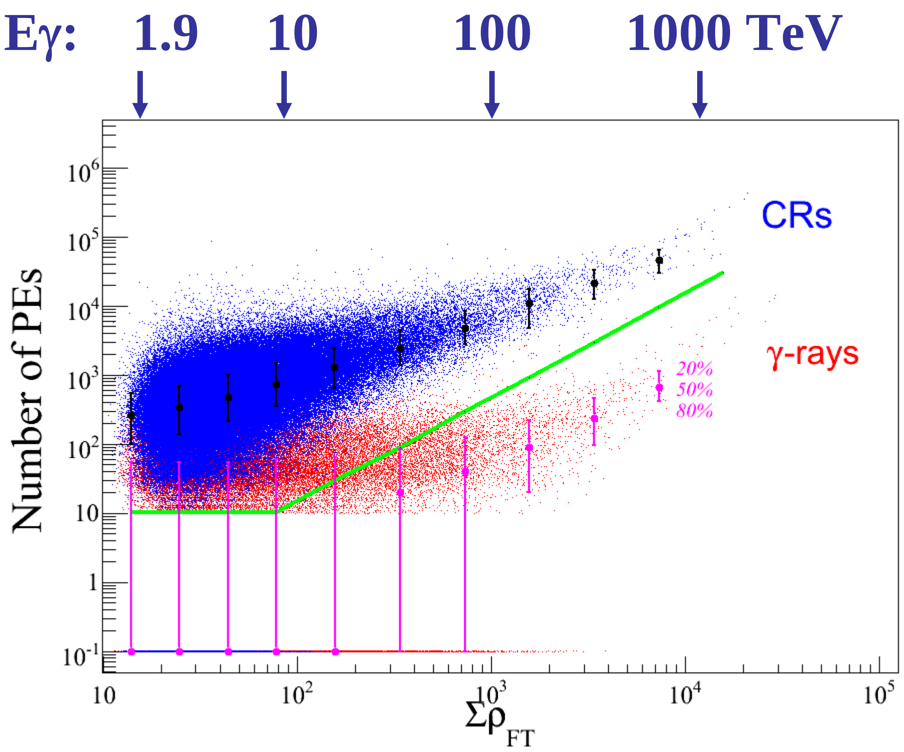
Number of muons vs. Shower Size (Simulation) (full-scale)

$\Sigma\rho_{FT}$:Sum of particle density of all scintillation det.

$\propto$ **Shower Size （a measure of energy）**

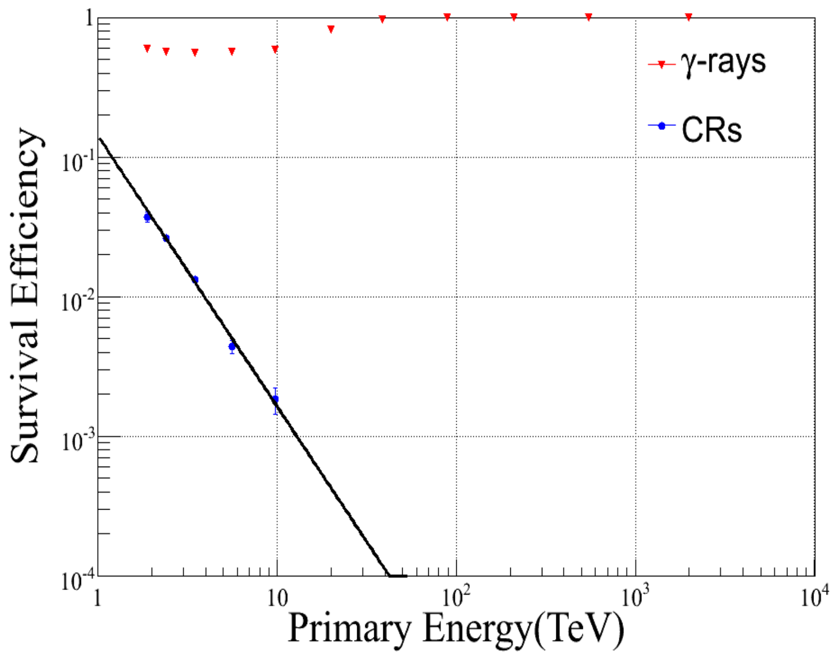
ΣN_{PE} :Sum of photoelectrons of all muon det.

$\propto$ **the number of muons in air showers**

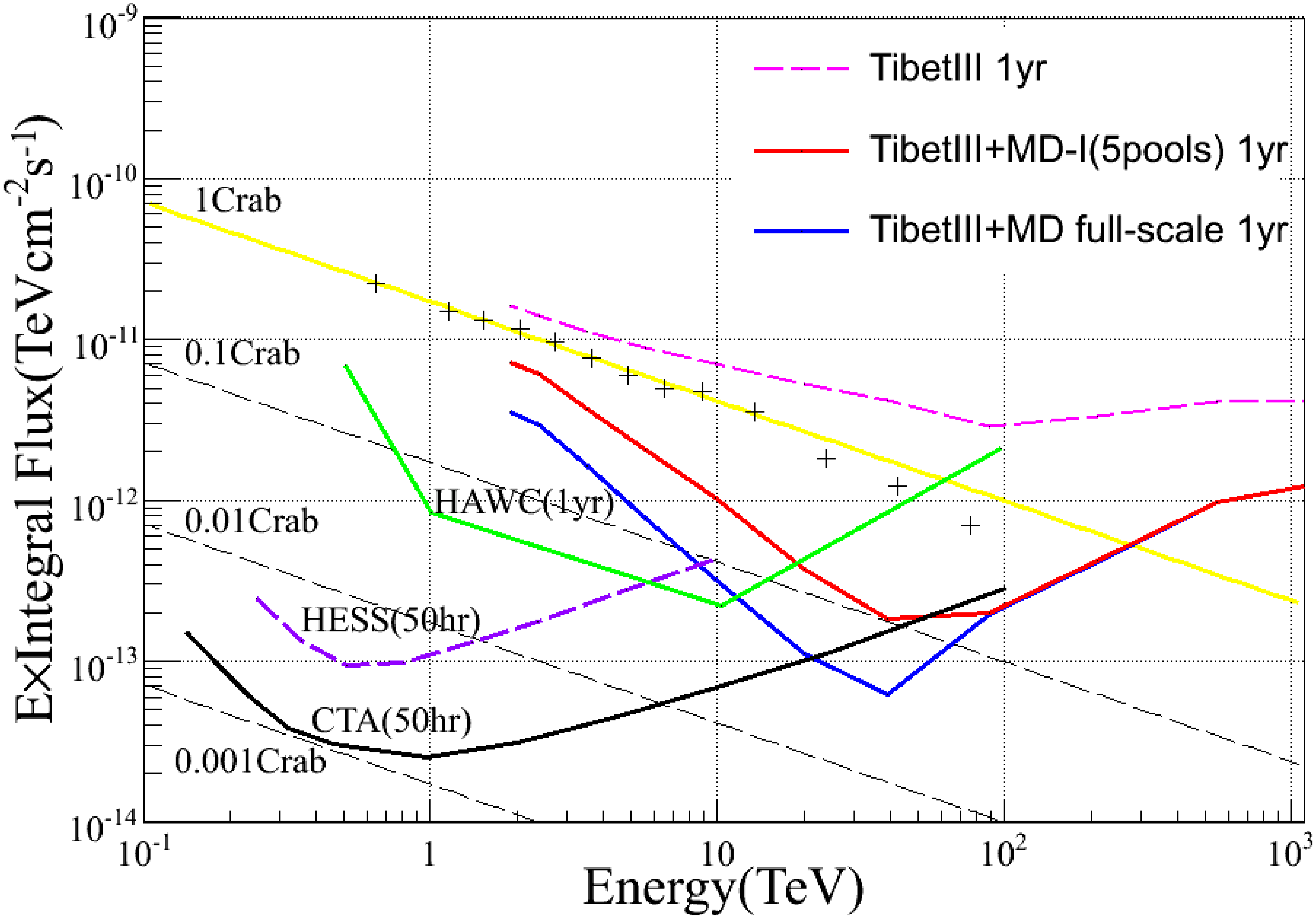


Survival Efficiency (Simulation)

Energy	1.9TeV	10 TeV	100 TeV
ΣN_{PE} cut value	10PEs	~30 PEs	~910 PEs
BG rejection	95.4%	~99.7%	>~99.99%
γ survival	59%	~61%	~99%
Sensitivity	2.8 ftimes improved	~11 times improved	BG free



5σ or 10 ev. Sensitivity to Point-like Gamma-ray Source(Crab)



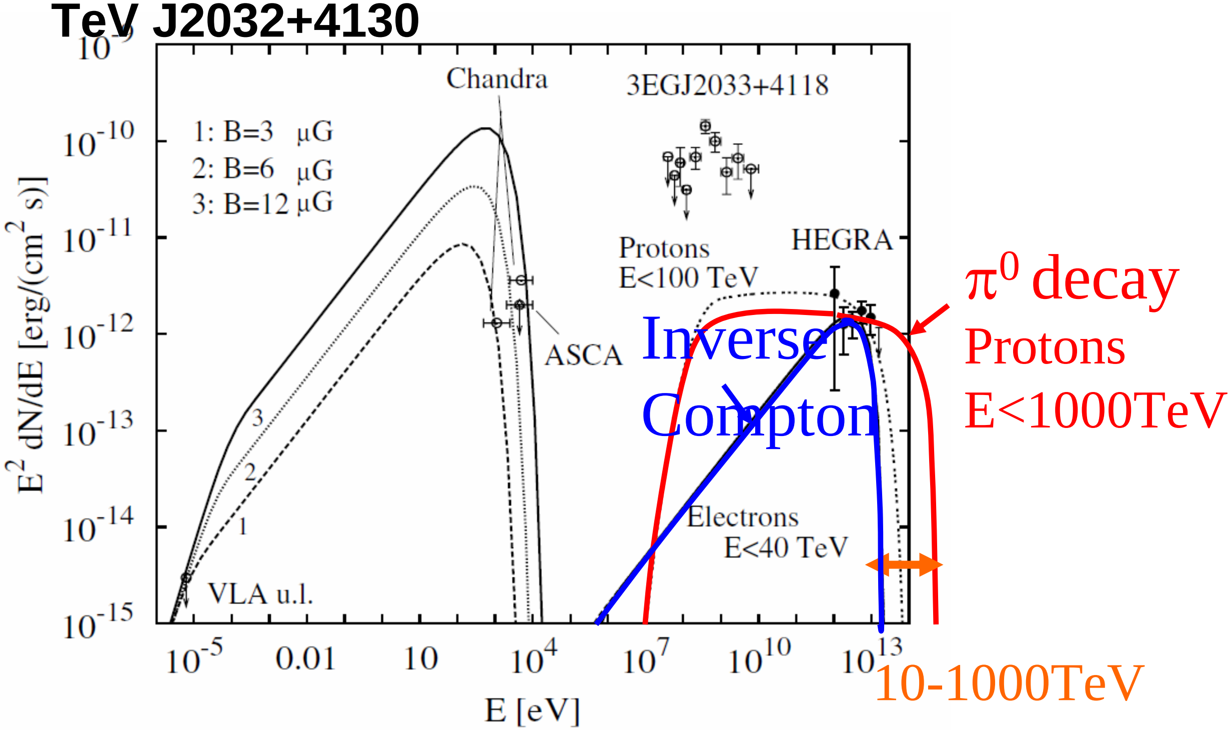
Origin of Cosmic Rays – A Fundamental Problem.

Where do galactic cosmic rays under the knee region come from?

leptonic VS hadronic origin of gamma-ray emission from celestial source?

Multi-wavelength Observation

TeV J2032+4130



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

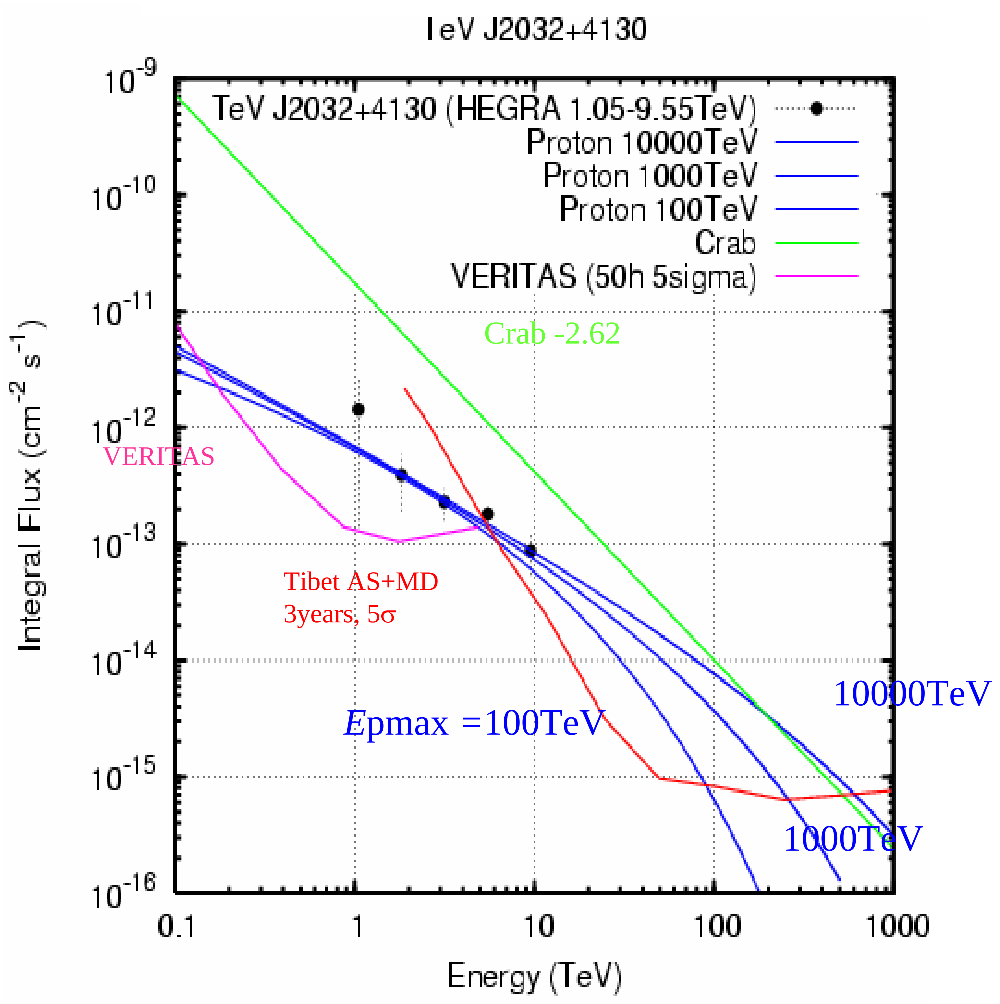
- **synchrotron radiation and Klein-Nishima effect** **greatly suppress the 100TeV gamma ray radiation of electron by IC process.**
- **100 TeV Gamma Ray— hadronic origin:** **the decay of secondary π^0 from interaction of the VHE CRs with the ambient gas**

Origin of Cosmic Rays – A Fundamental Problem.

Where do galactic cosmic rays under the knee region come from?

leptonic VS hadronic origin of gamma-ray emission from celestial source?

Multi-wavelength Observation



- **100TeV gamma ray----** A new window in electromagnetic wave observation
- **Observation of 100TeV----** greatly improve our knowledge to the question: where is the origin of CR?

<u>Very preliminary from now on</u>

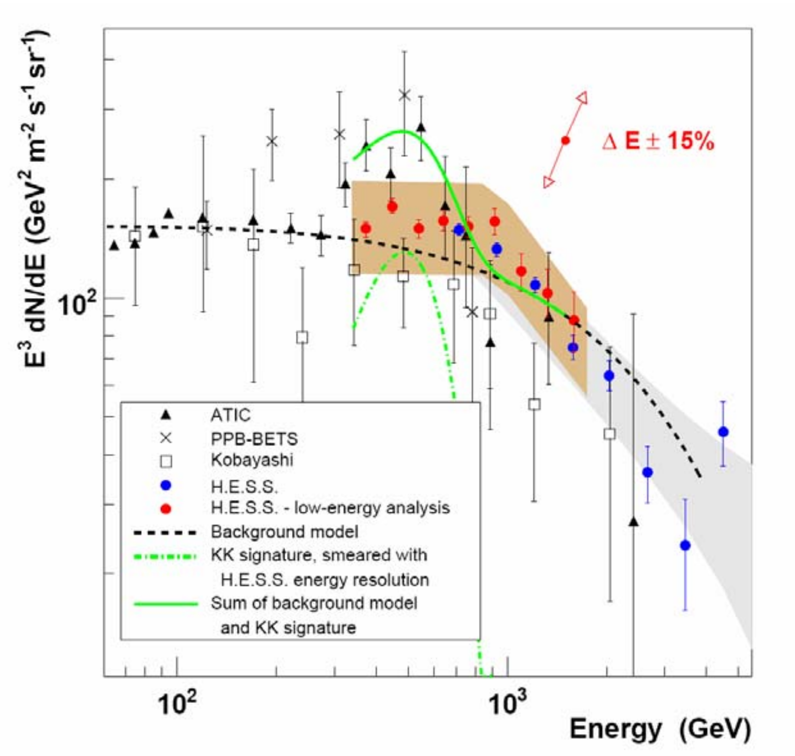
Let's see

Multi-TeV - 100 TeV cosmic ray electron and DM electron detection by

Tibet-III + MD

Peaks in electron spectrum

- Dark Matter signal
- Cosmic ray propagation effect
- Nearby pulsar production
- CRs(knee)+ γ -> $e^+ e^-$ （H.B.Hu et al)

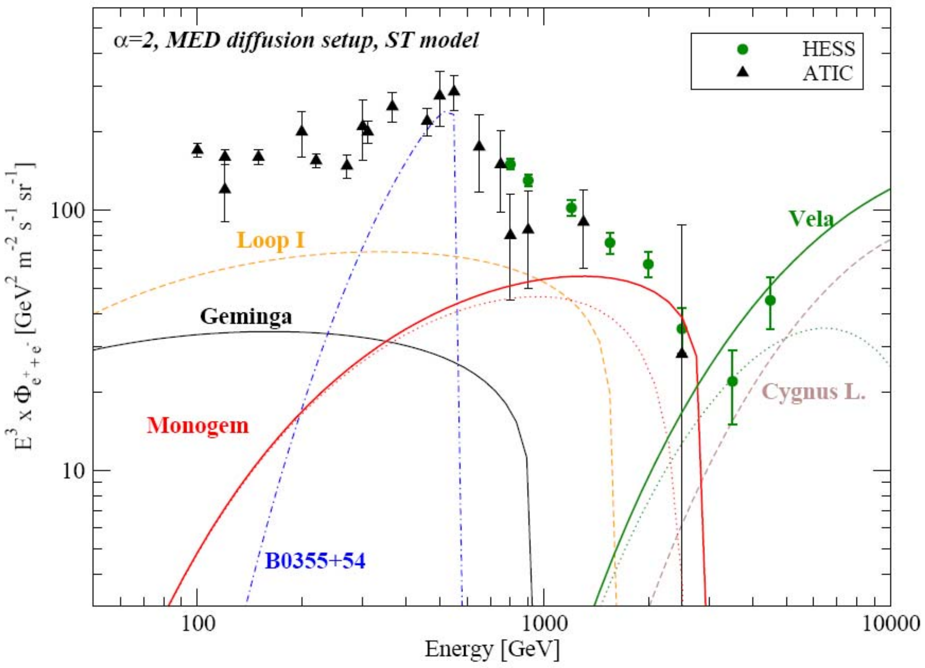


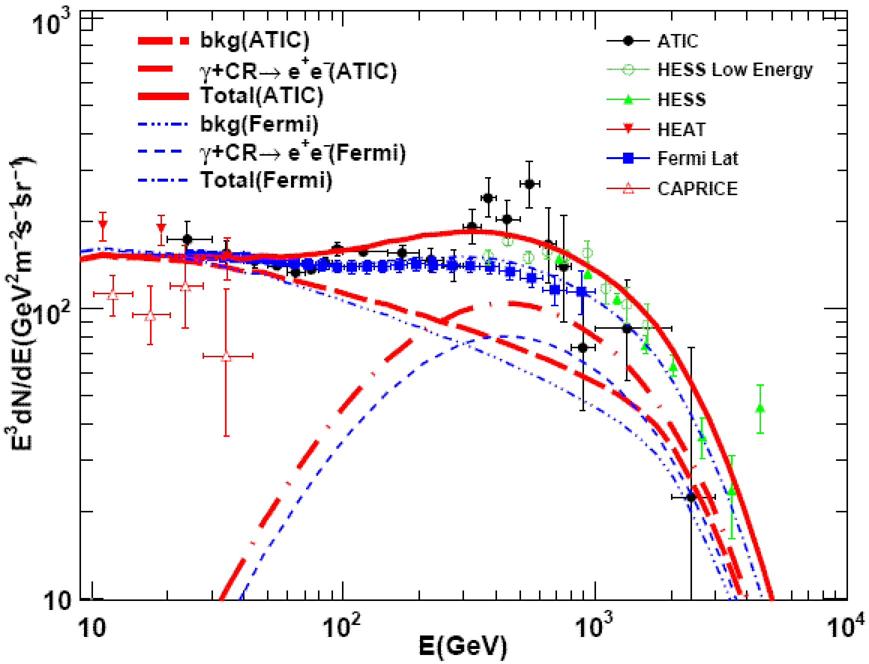
Peaks in electron spectrum

Pulsar Production **VS** CRs(knee)+ γ -> $e^+ e^-$ Production

arXiv:0812.4457

ApJ 700:L170–L173, 2009





Electron spectrum@>Multi-TeV: sensitive in testing the models

Detection of Cosmic Ray Electron and Electron Generated by Dark Matter

MC study:

Cosmic ray electron:

extrapolation of electron spectrum measured by HESS

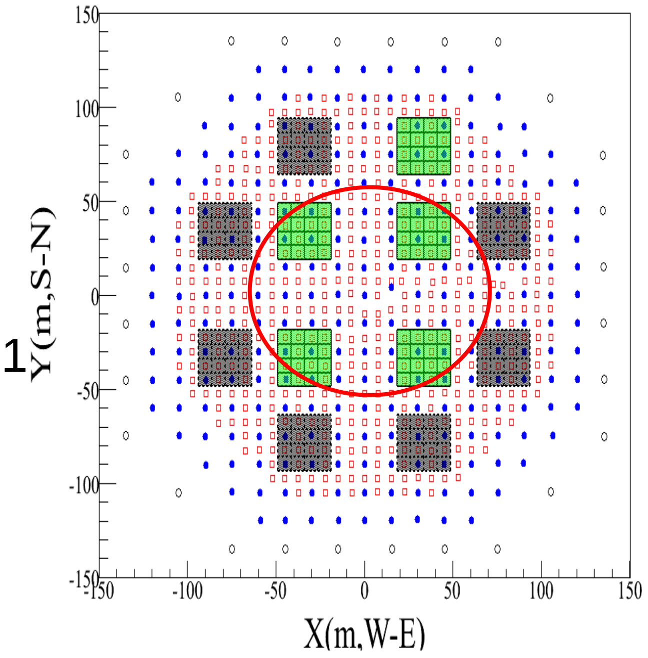
Electron generated by DM :

1） Calculated in a model independent way

2） χχ -> e+ e- , Natural Scale: <σ v> = 3*10-26cm-3s-1

3） Einasto distribution, only considering the main halo

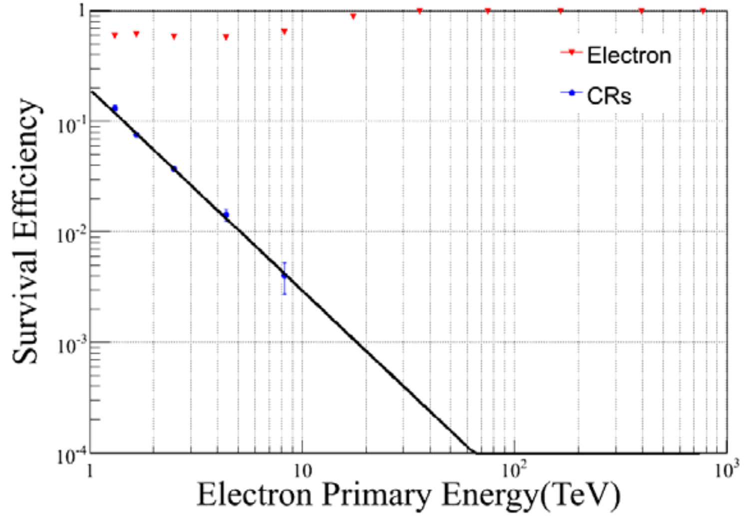
4） Considering transportation in Galaxy（GALPROP）



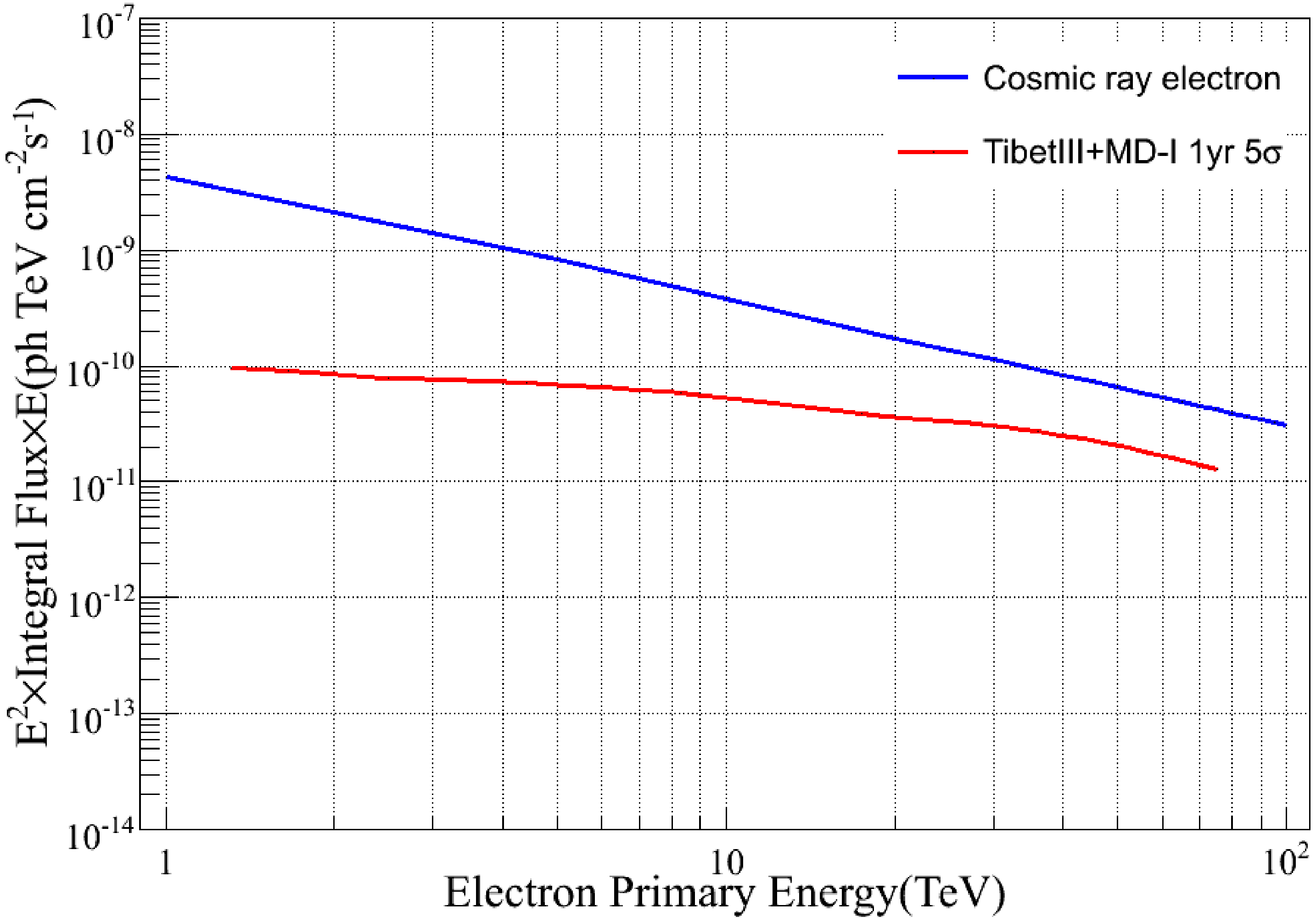
With MD-I (5 pools),

Data selection to get maximum S/B ratio:

- R<50m
- Zenith angle<25°（secTheta<1.1)



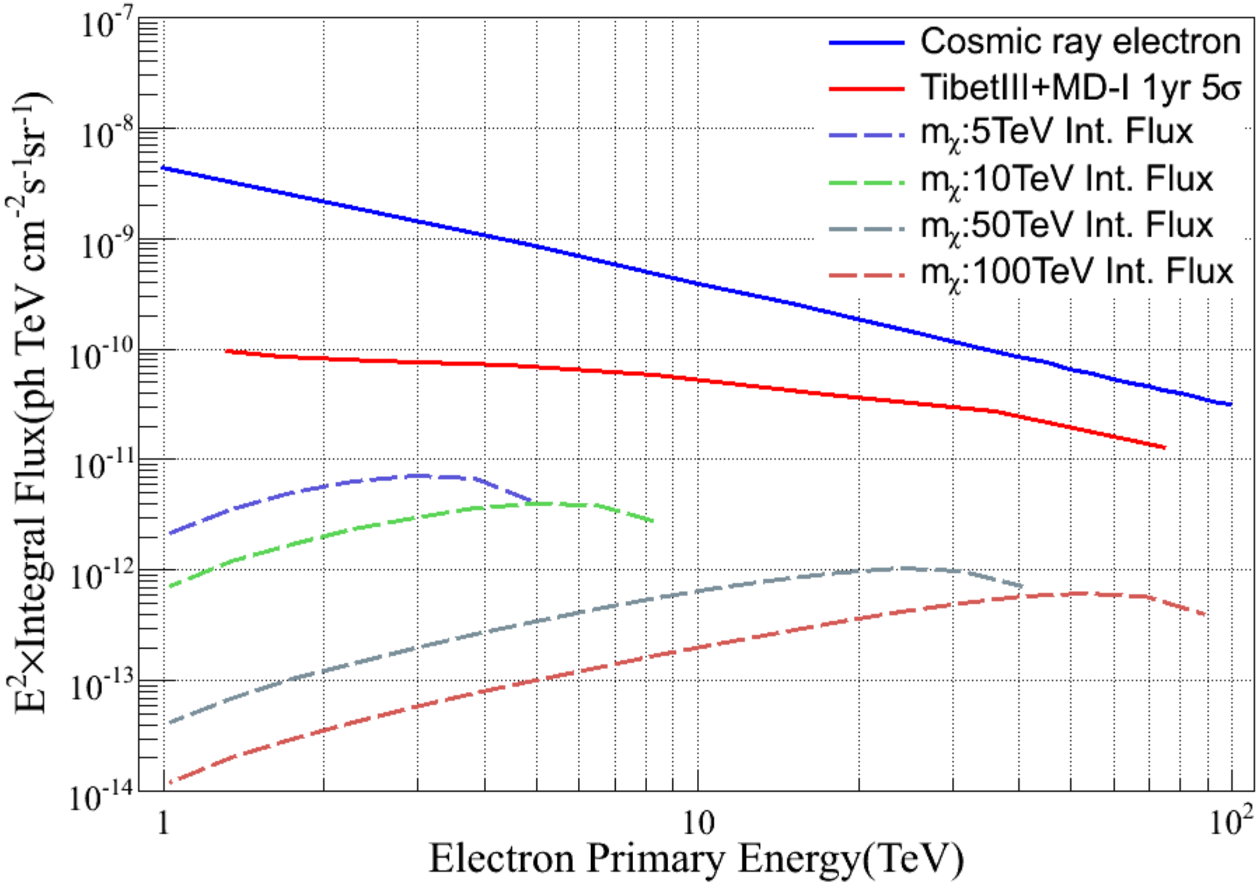
Sensitivity for Cosmic Ray Electron



Sensitivity for Indirect Detection of DM

Cosmic ray electron

VS electron fluxes from DM annihilation



Summary

- **Tibet AS γ Experiment has been successfully operated since 1989**
  Crab, Mrk501 , Mrk421 observed
  Marginal excess of three Milagro sources.
  Possible diffuse gamma-ray signal from Cygnus region
  Hints of 100TeV γ emission

- **Tibet III + MD: 10000 m^2 underground Muon Detector**

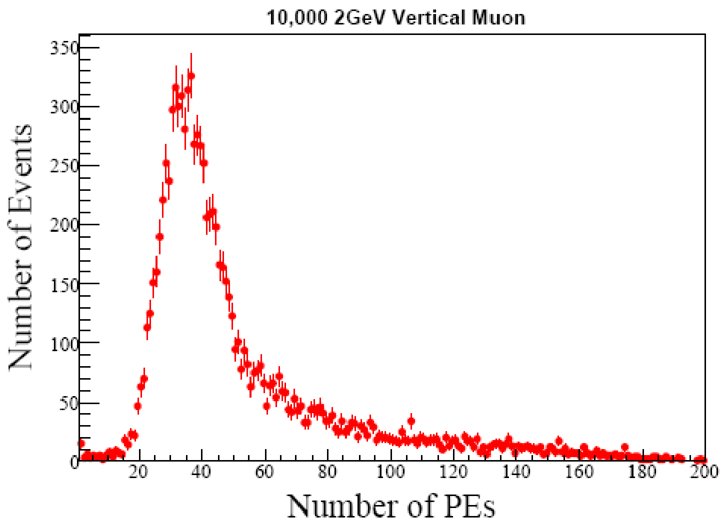
Gamma ray point source: Sensitivity is 5-20% Crab @ 10-100 TeV (full-scale)
or 10%-20% Crab @ 10-100 TeV (MD-I, 5 pools)

Cosmic ray electron: Would be detected in high significance
Sensitive in testing the models related to the astrophysics origin of e+/e- excesses

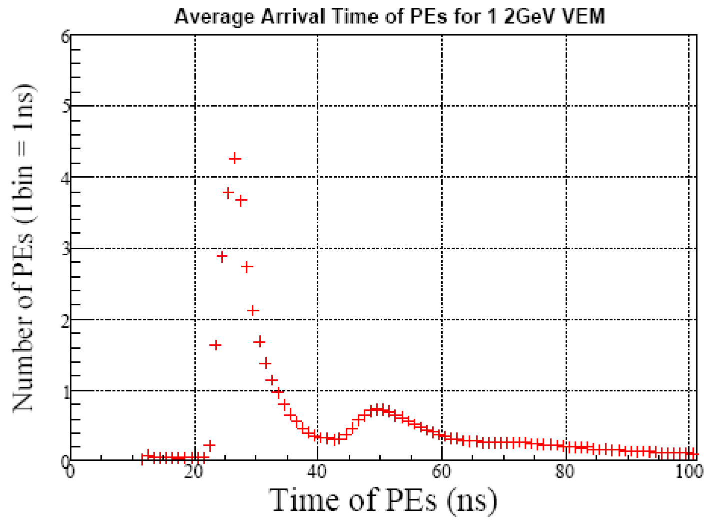
DM electron: Could be detected by TibetIII+MD, If it follows the
DM models used to explain the ATIC and PAMELA excess.

- **Status**
  MD-I (5 pools) were constructed in 2010
  Setting up the MD detectors and resuming data taking in this year

Thanks for your attention!



10,000 2GeV Vertical Muon
Number of Events
Number of PEs



Average Arrival Time of PEs for 1 2GeV VEM
Number of PEs (1bin = 1ns)
Time of PEs (ns)

Potential power in detecting the electrons from nearby pulsar

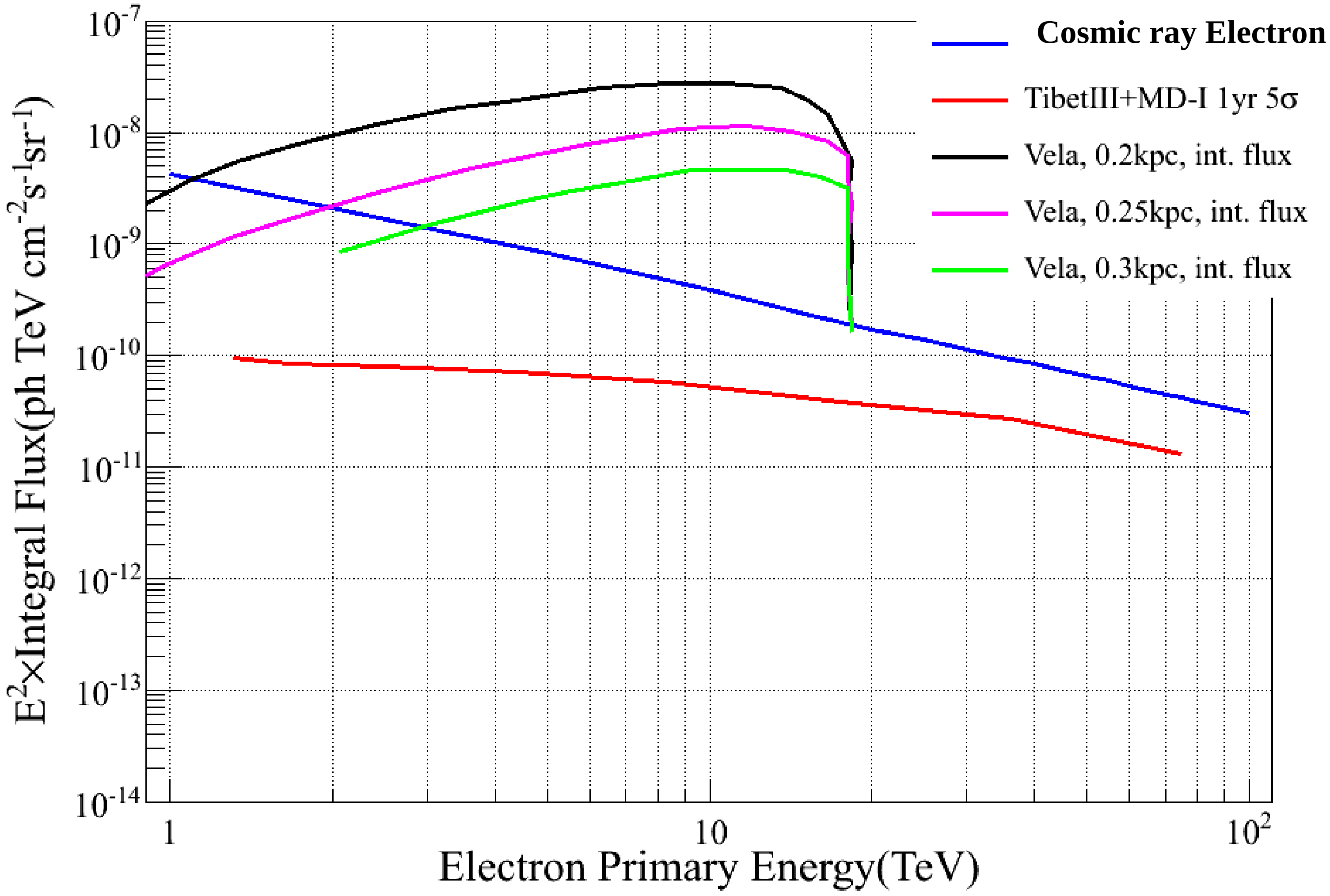


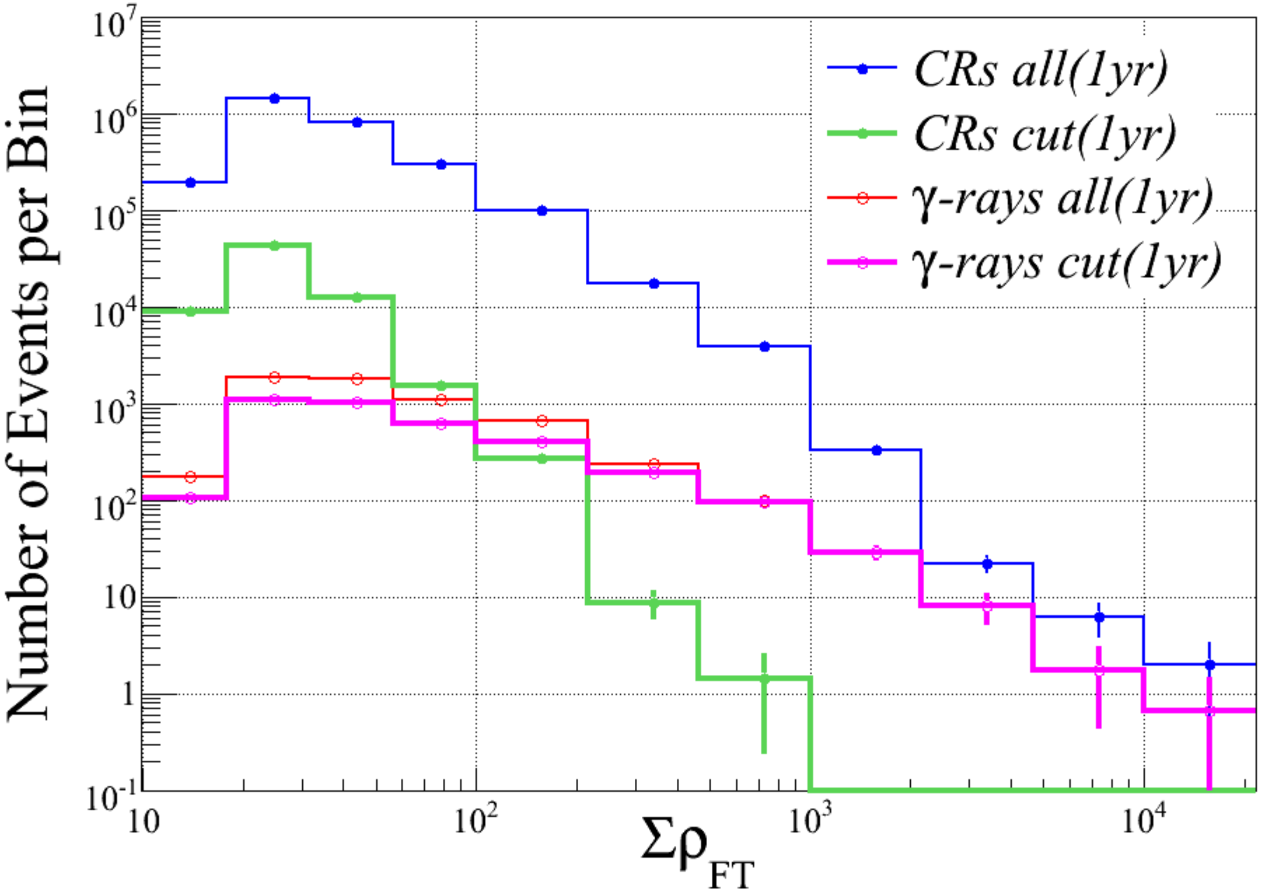
Table 1
Summary of the Tibet-III Array Observations of the *Fermi* Sources

Fermi LAT Source (0FGL)	Class	R.A. (deg)	Decl. (deg)	Tibet-III Signi. (σ)	Milagro[a] Signi. (σ)	Source Associations
J0030.3+0450	PSR	7.600	4.848	1.7	−1.7	
J0357.5+3205	PSR[b]	59.388	32.084	−1.7	−0.1	
J0534.6+2201	PSR	83.653	22.022	6.9	17.2	Crab
J0617.4+2234	SNR	94.356	22.568	0.2	3.0	IC 443
J0631.8+1034	PSR	97.955	10.570	0.3	3.7	
J0633.5+0634	PSR[b]	98.387	6.578	2.4	1.4	
J0634.0+1745	PSR	98.503	17.760	2.2	3.5	Geminga
J0643.2+0858		100.823	8.983	−1.2	0.3	
J1830.3+0617		277.583	6.287	−0.2	0.2	
J1836.2+5924	PSR[b]	279.056	59.406	−0.3	−0.9	
J1855.9+0126	SNR	283.985	1.435	0.7	2.2	W44
J1900.0+0356		285.009	3.946	1.0	3.6	
J1907.5+0602	PSR[b]	286.894	6.034	2.4	7.4	MGRO J1908+06
						HESS J1908+063
J1911.0+0905	SNR	287.761	9.087	1.7	1.5	G43.3 − 0.2
J1923.0+1411	SNR	290.768	14.191	−0.3	3.4	W51
						HESS J1923+141
J1953.2+3249	PSR	298.325	32.818	−0.0	0.0	
J1954.4+2838	SNR	298.614	28.649	0.6	4.3	G65.1+0.6
J1958.1+2848	PSR[b]	299.531	28.803	0.1	4.0	
J2001.0+4352		300.272	43.871	−0.5	−0.9	
J2020.8+3649	PSR	305.223	36.830	2.2	12.4	MGRO J2019+37
J2021.5+4026	PSR[b]	305.398	40.439	2.2	4.2	
J2027.5+3334		306.882	33.574	−0.3	−0.2	
J2032.2+4122	PSR[b]	308.058	41.376	2.4	7.6	TeV J2032+4130
						MGRO J2031+41
J2055.5+2540		313.895	25.673	−0.0	−0.0	
J2110.8+4608		317.702	46.137	0.3	1.1	
J2214.8+3002		333.705	30.049	−1.0	0.6	
J2302.9+4443		345.746	44.723	−0.0	−0.6	
LAT PSR J2238+59[c]	PSR[b]	339.561	59.080	2.5	4.7	

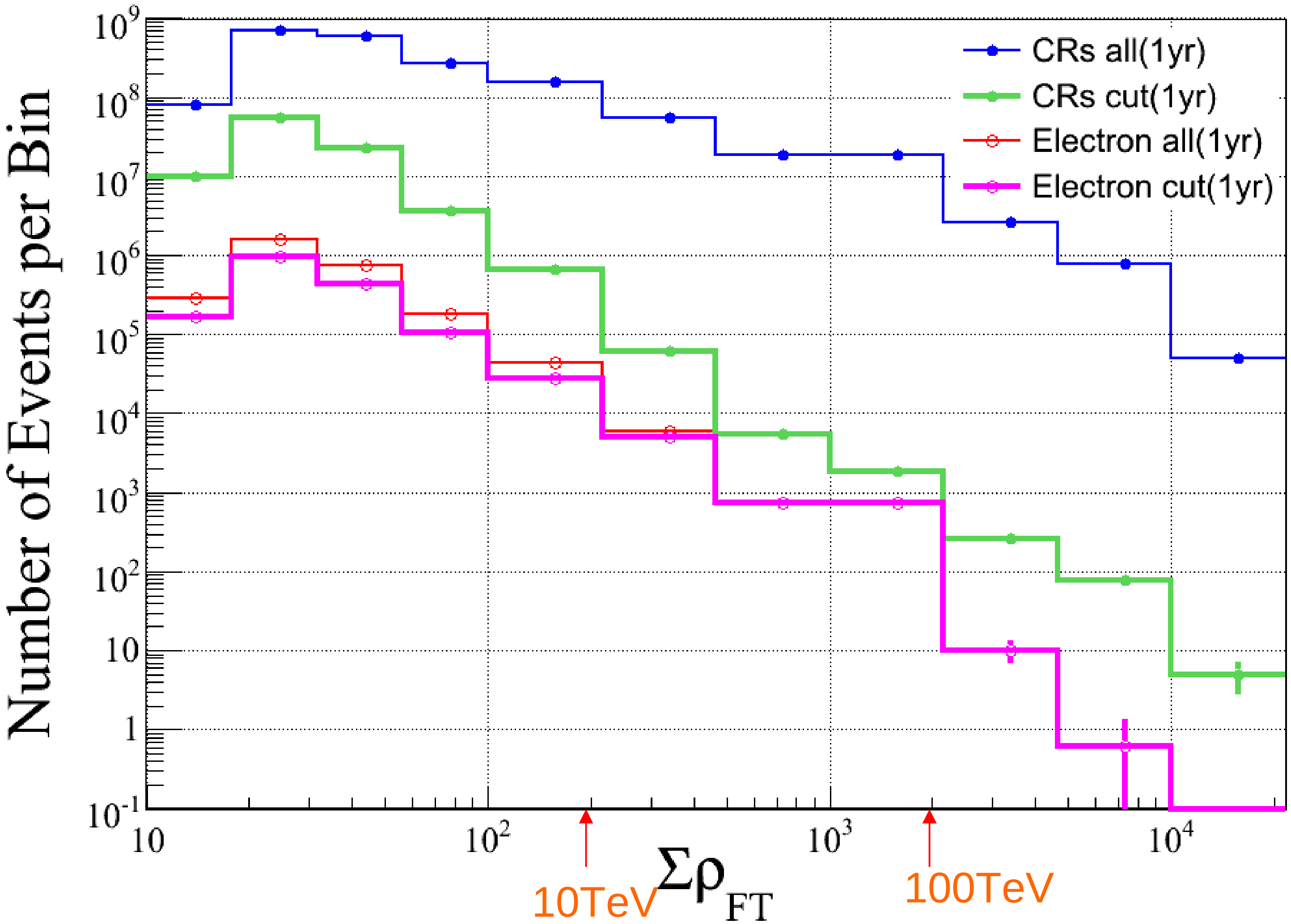
Crab, full scale

E_{CR}: 4.0 5.0 7.0 11.1 19 39 80 184 348 900 TeV

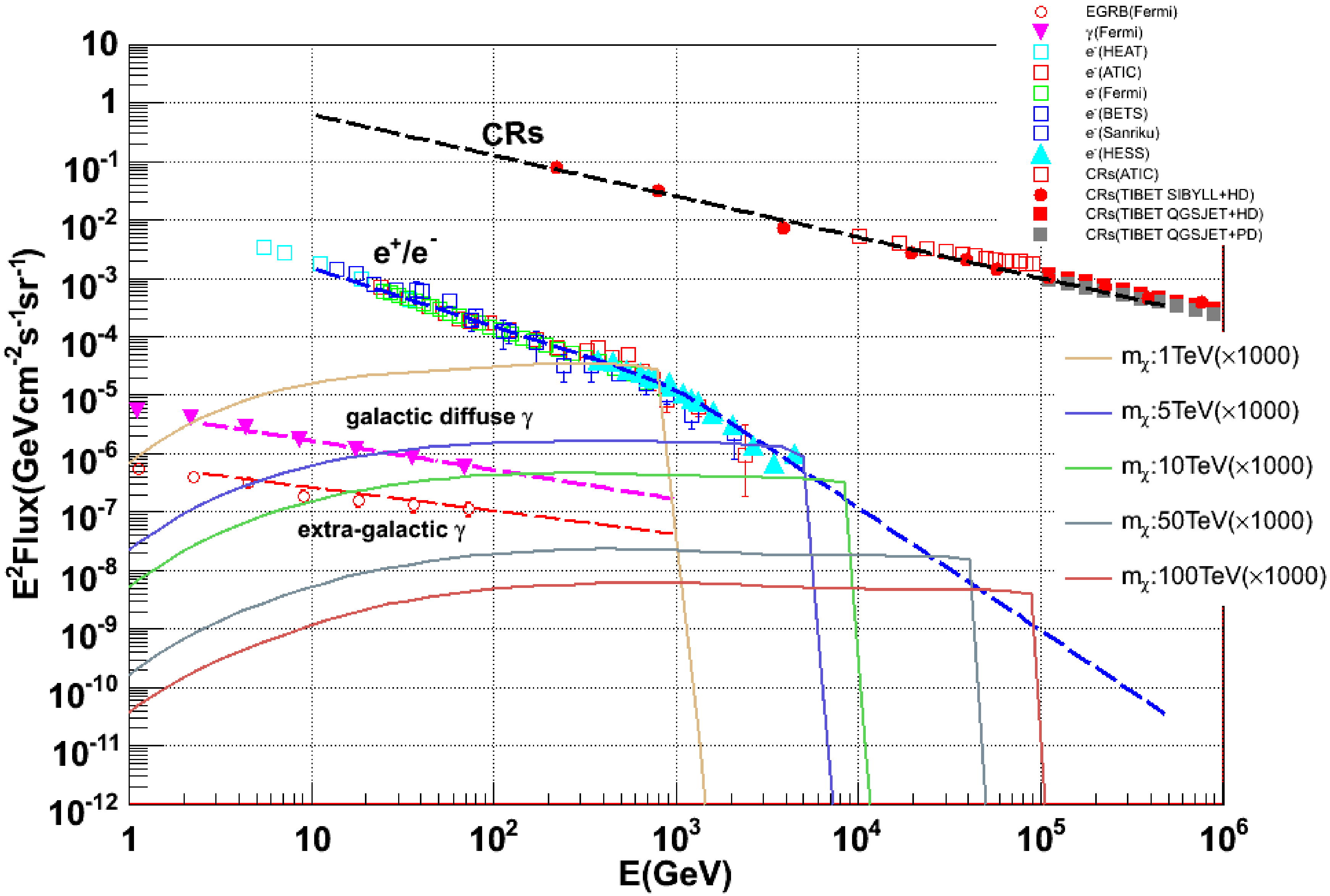
E_{γ} : 1.9 2.4 3.5 5.6 9.8 20 39 89 210 550 TeV



Electron, 1yr operation

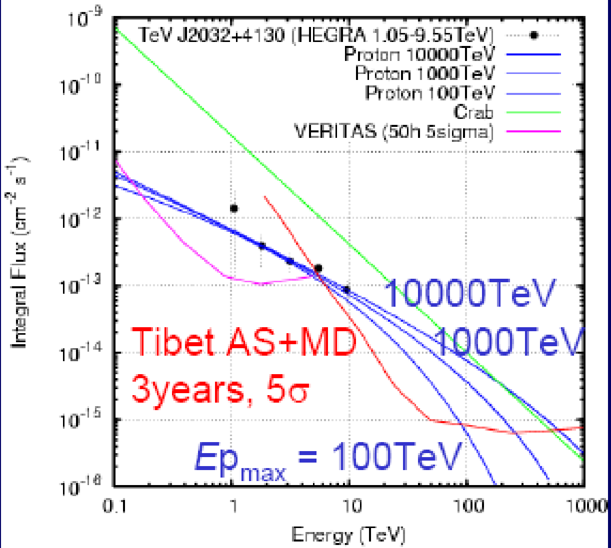


Signal and background of electron



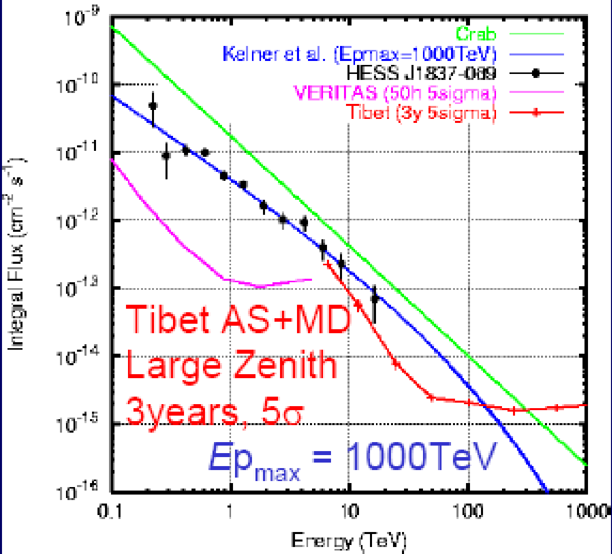
Known Galactic Sources in the Northern Sky

TeV J2032+4130



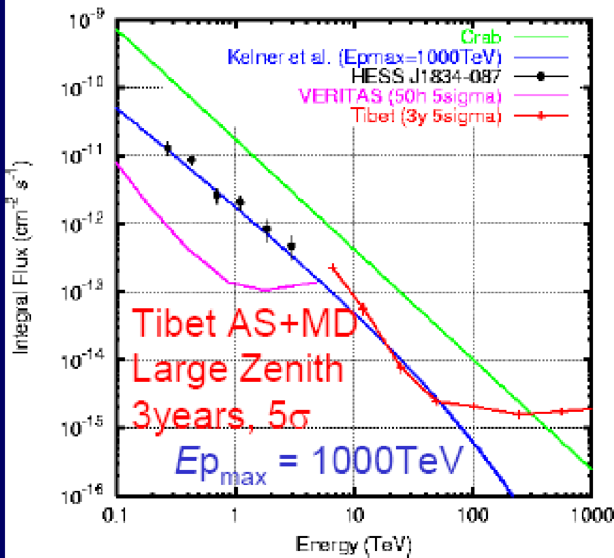
Aharonian et al, A&A, 431, 197 (2005)

HESS J1837-069



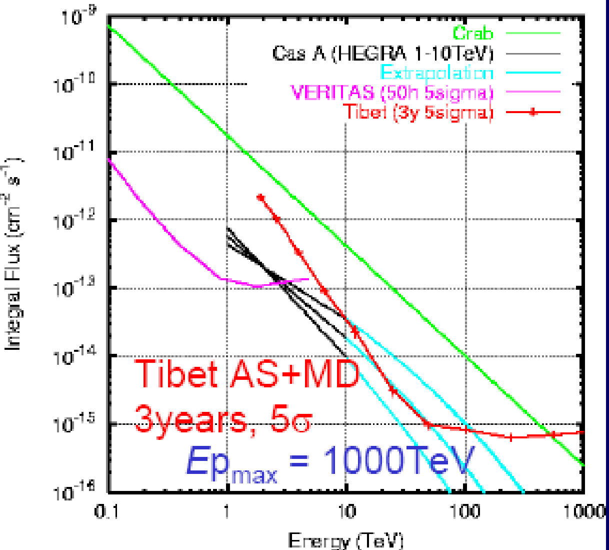
Aharonian et al, ApJ, 636, 777 (2006)

HESS J1834-087



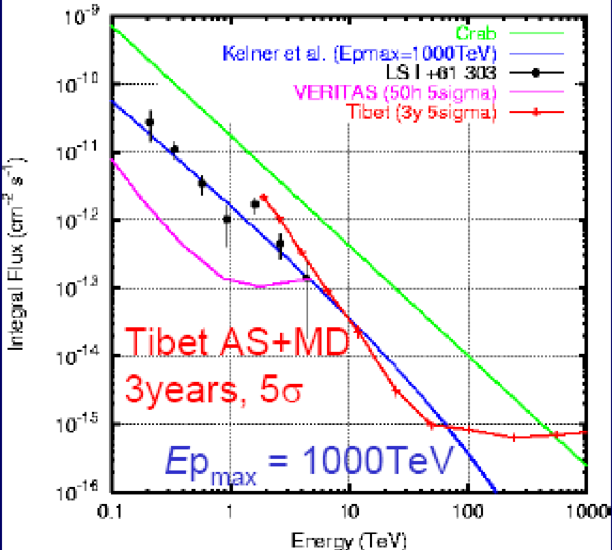
Aharonian et al, ApJ, 636, 777 (2006)

Cas A



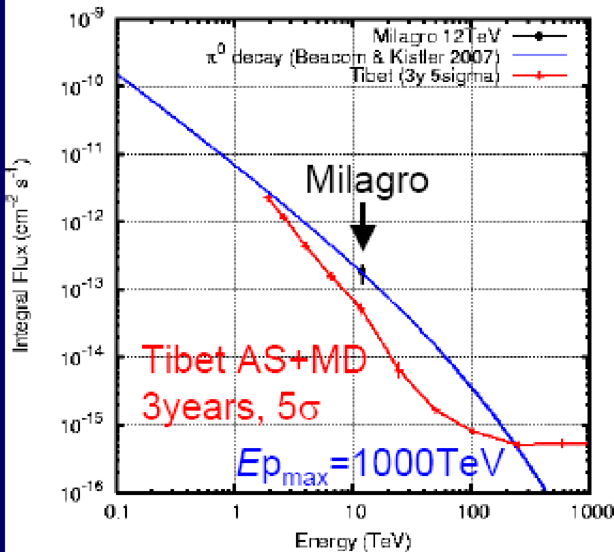
Aharonian et al. A&A, 370, 112 (2001)

LSI +61 303



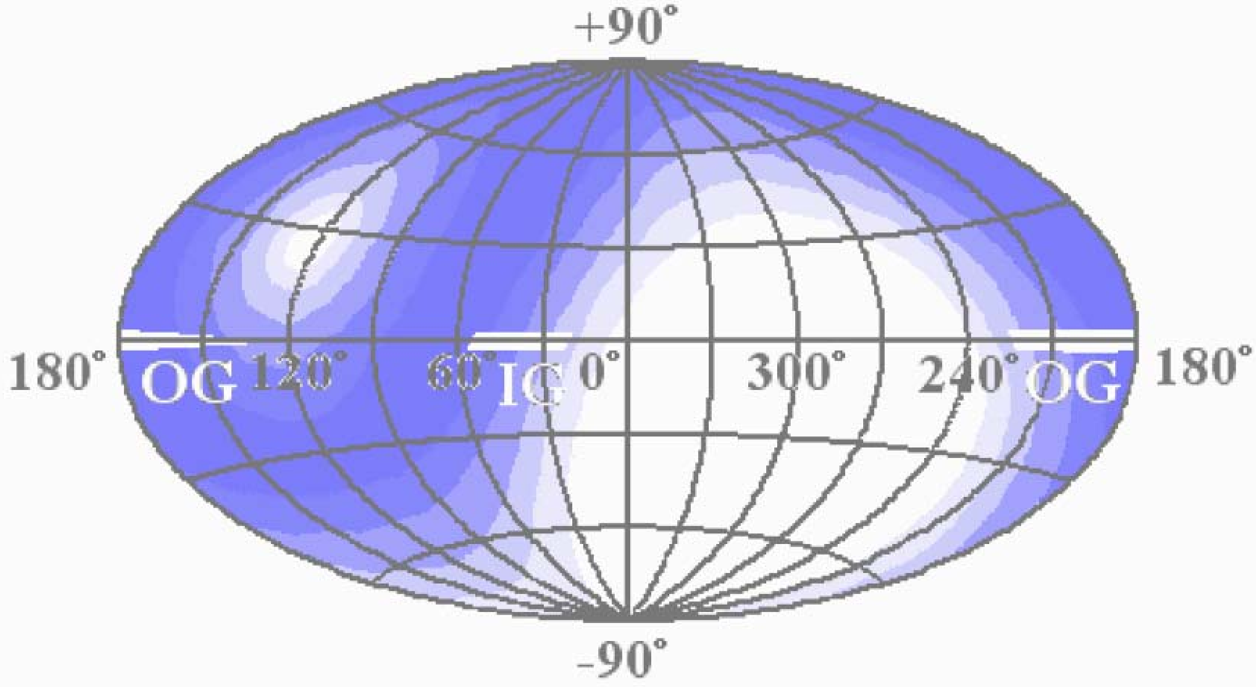
Albert et al. Science, 312, 1771 (2006)

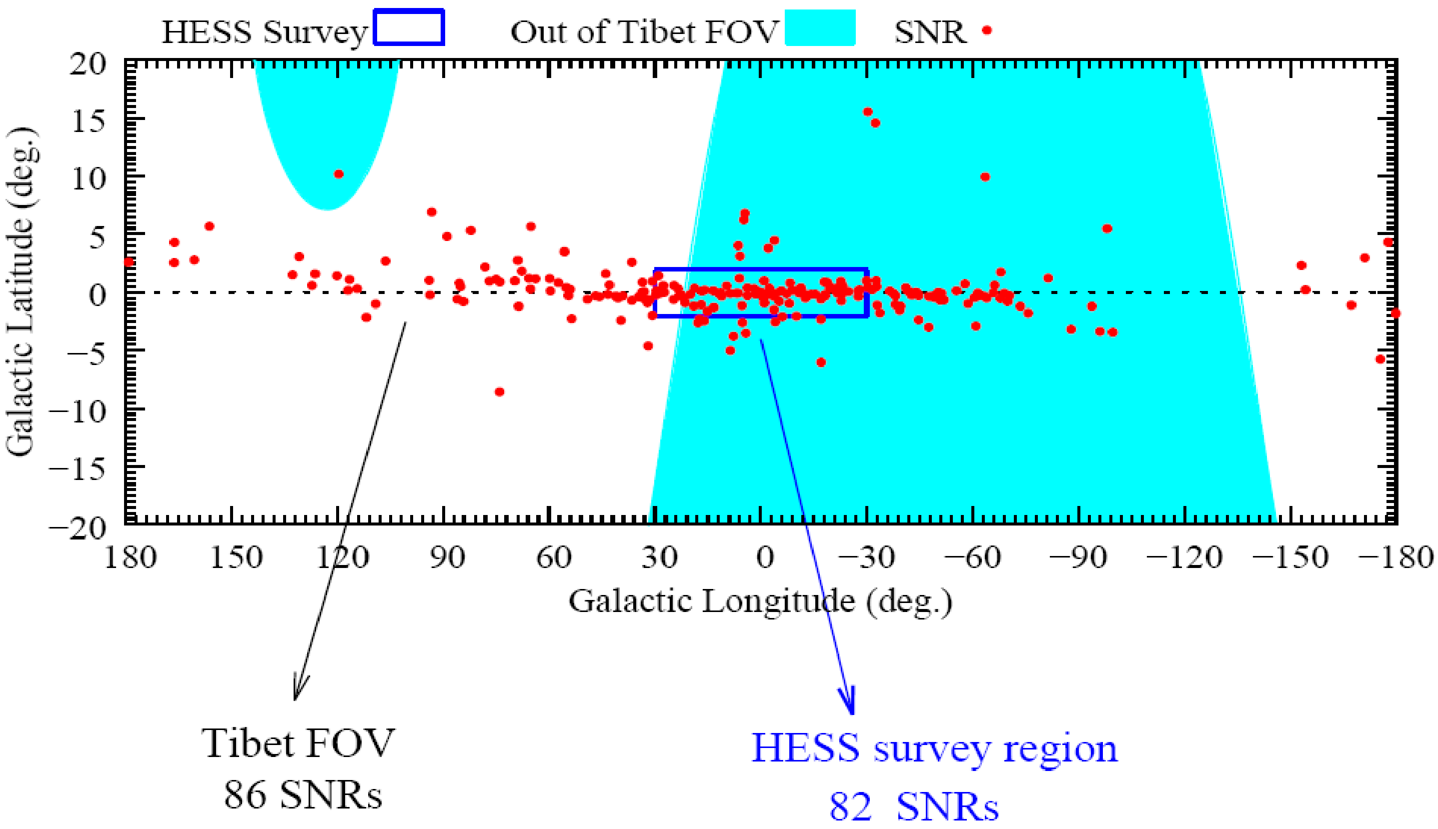
MGRO J2019+37



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

Exposure map for the Tibet-III array




HESS Survey
Out of Tibet FOV
SNR
Galactic Latitude (deg.)
Galactic Longitude (deg.)
20
15
10
5
0
−5
−10
−15
−20
180
150
120
90
60
30
0
−30
−60
−90
−120
−150
−180
Tibet FOV
86 SNRs
HESS survey region
82 SNRs