



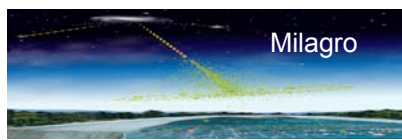
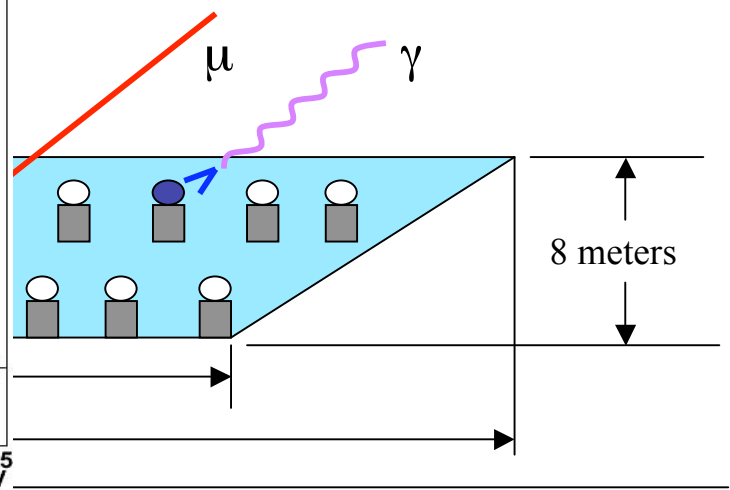
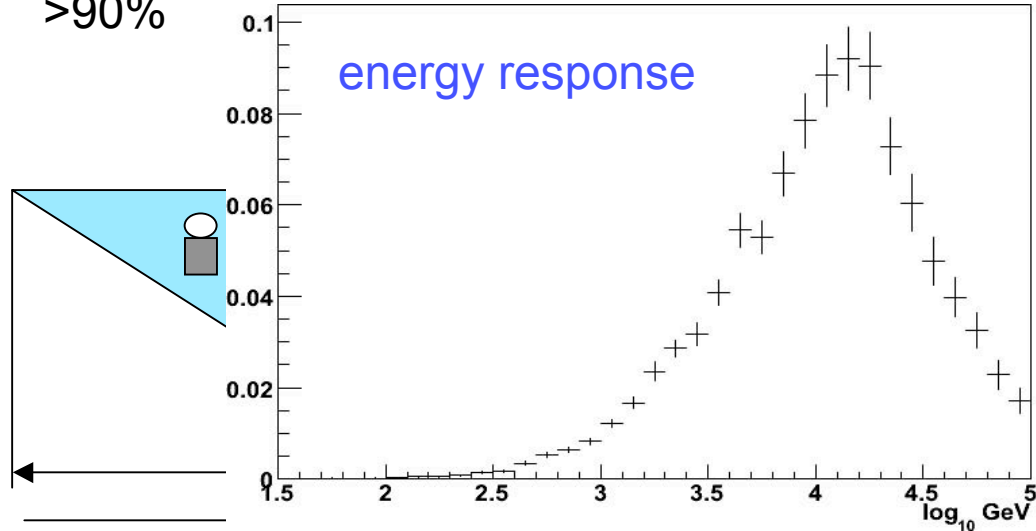
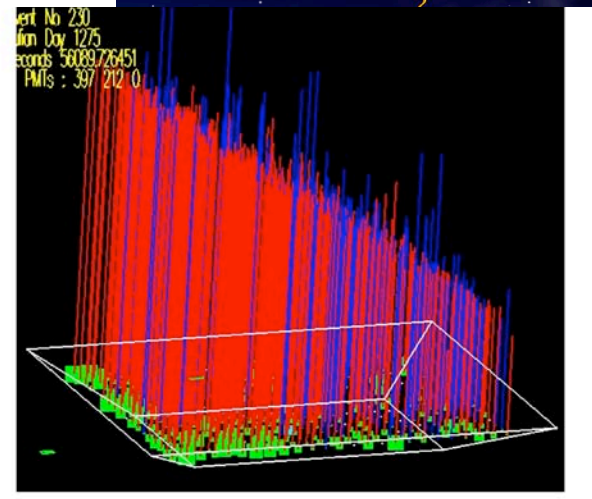
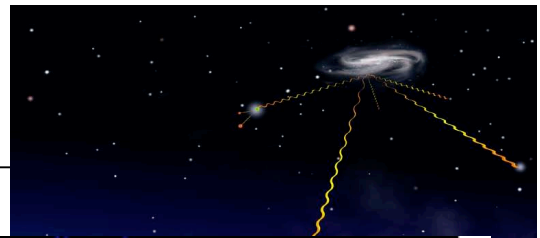
# Survey of the Galactic Plane at 12 TeV with Milagro and the Discovery of MGRO J1909+06 and MGRO J2033+42

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for the Milagro Collaboration, Andrew Strong, Igor Moskalenko  
GLAST Symposium  
February 5-8, 2007

see Aous Abdo's plenary session talk and Gary Walker's poster for more details

# How Does Milagro Work?

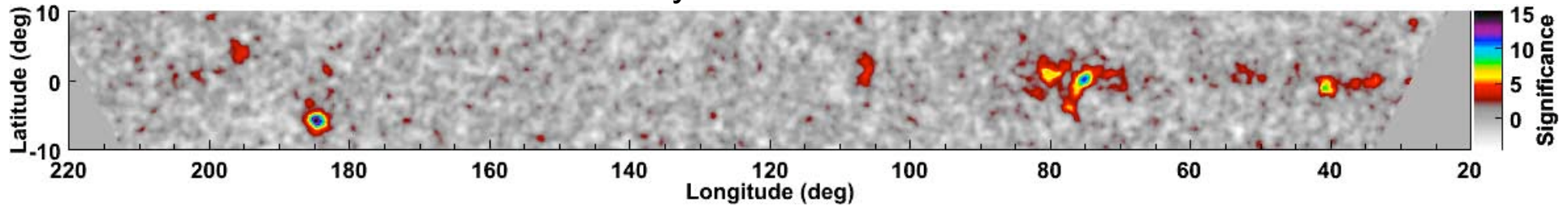
- Detect Particles in Extensive Air Showers from Cherenkov light created in 60m x 80 m x 8m pond containing filtered water
- Reconstruct shower direction to  $\sim 0.5^\circ$  from the time different PMTs are hit
- 1700 Hz trigger rate mostly due to Extensive Air Showers created by cosmic rays
- Field of view is  $\sim 2$  sr and the average duty factor is  $>90\%$



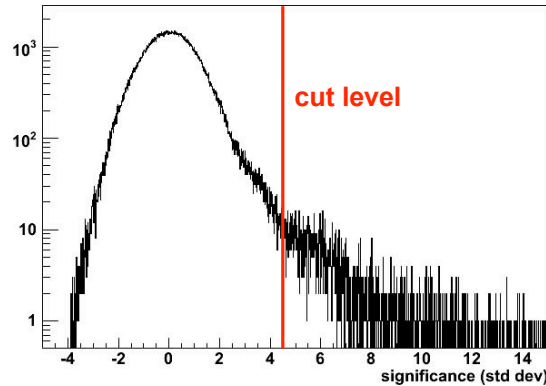
Curtis Lansdell  
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# >4.5 $\sigma$ Regions in the Galaxy

6 years of data

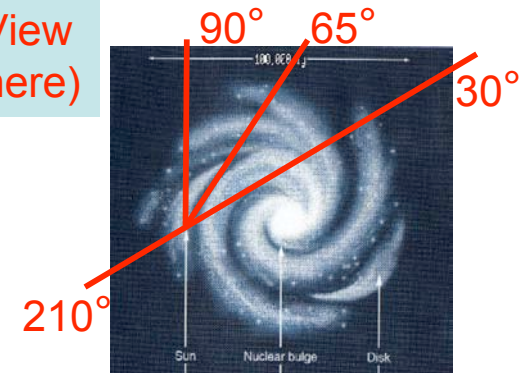


Distribution of Excesses in the Galactic Plane



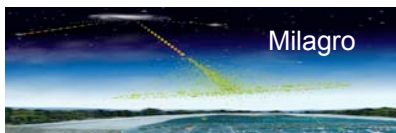
Milagro's Field of View  
(Northern Hemisphere)

Milagro sees the Galactic plane  
from longitude  $\sim 30^\circ$  to  $\sim 220^\circ$



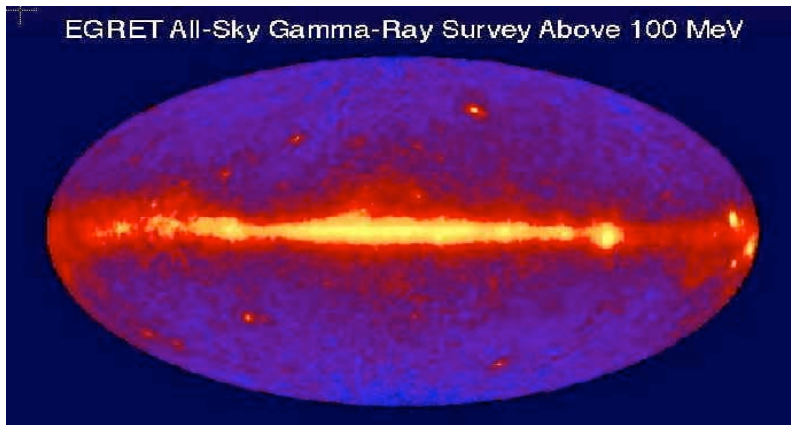
- 7 regions  $>4.5\sigma$

– Expect 0.2 spots  $>4.5\sigma$  in  $l \in [30^\circ, 216^\circ]$ ,  $b \in [-5^\circ, 5^\circ]$

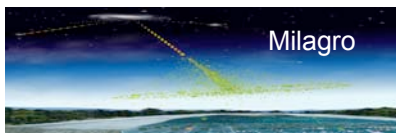


# Diffuse Emission from the Galactic Plane

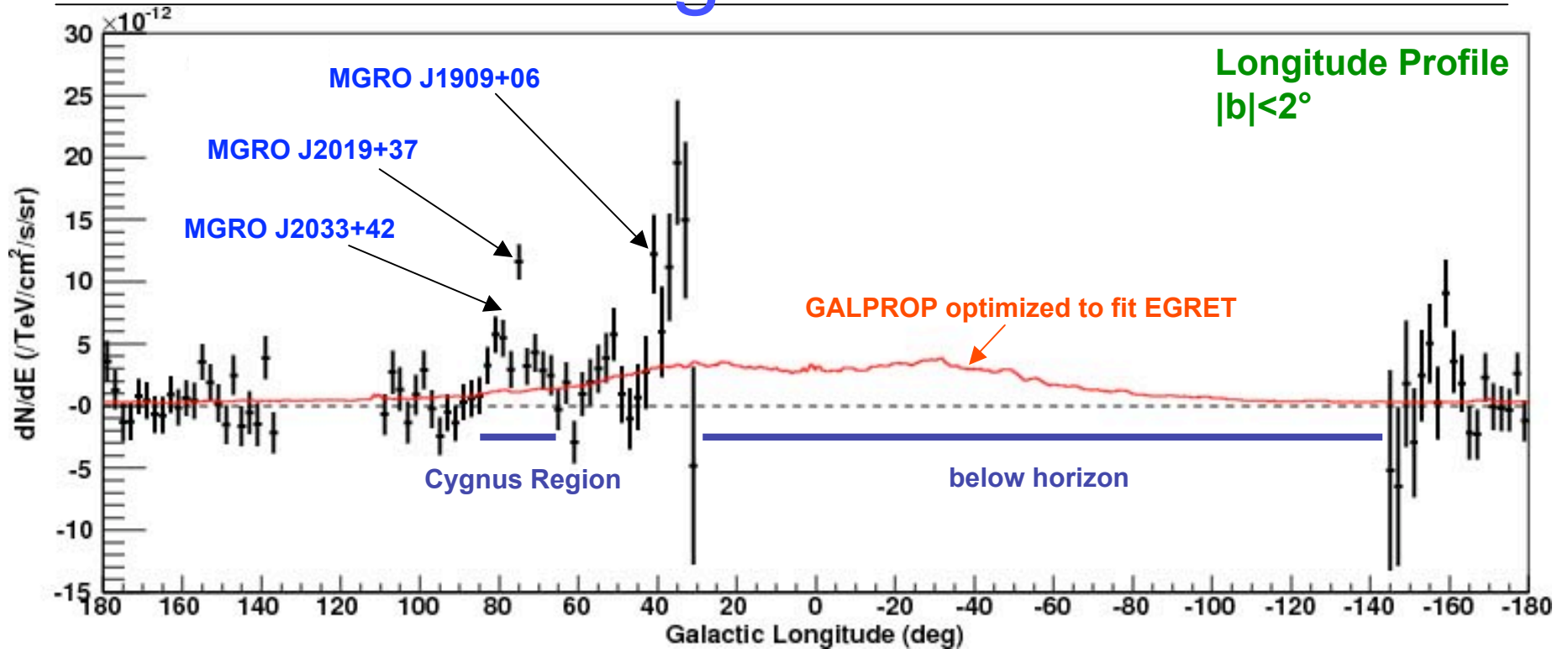
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- EGRET observations to 20 GeV indicate a GeV excess
  - Is there an excess at TeV energies?
- Gamma rays can measure cosmic ray flux elsewhere by observing cosmic ray interactions that produce  $\gamma$  rays
  - Proton + matter interactions
  - Inverse Compton scattering
- See Aous Abdo's talk about the Cygnus Region

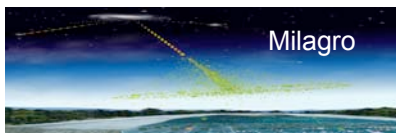


# Galactic Longitude Flux Profile

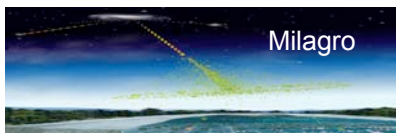
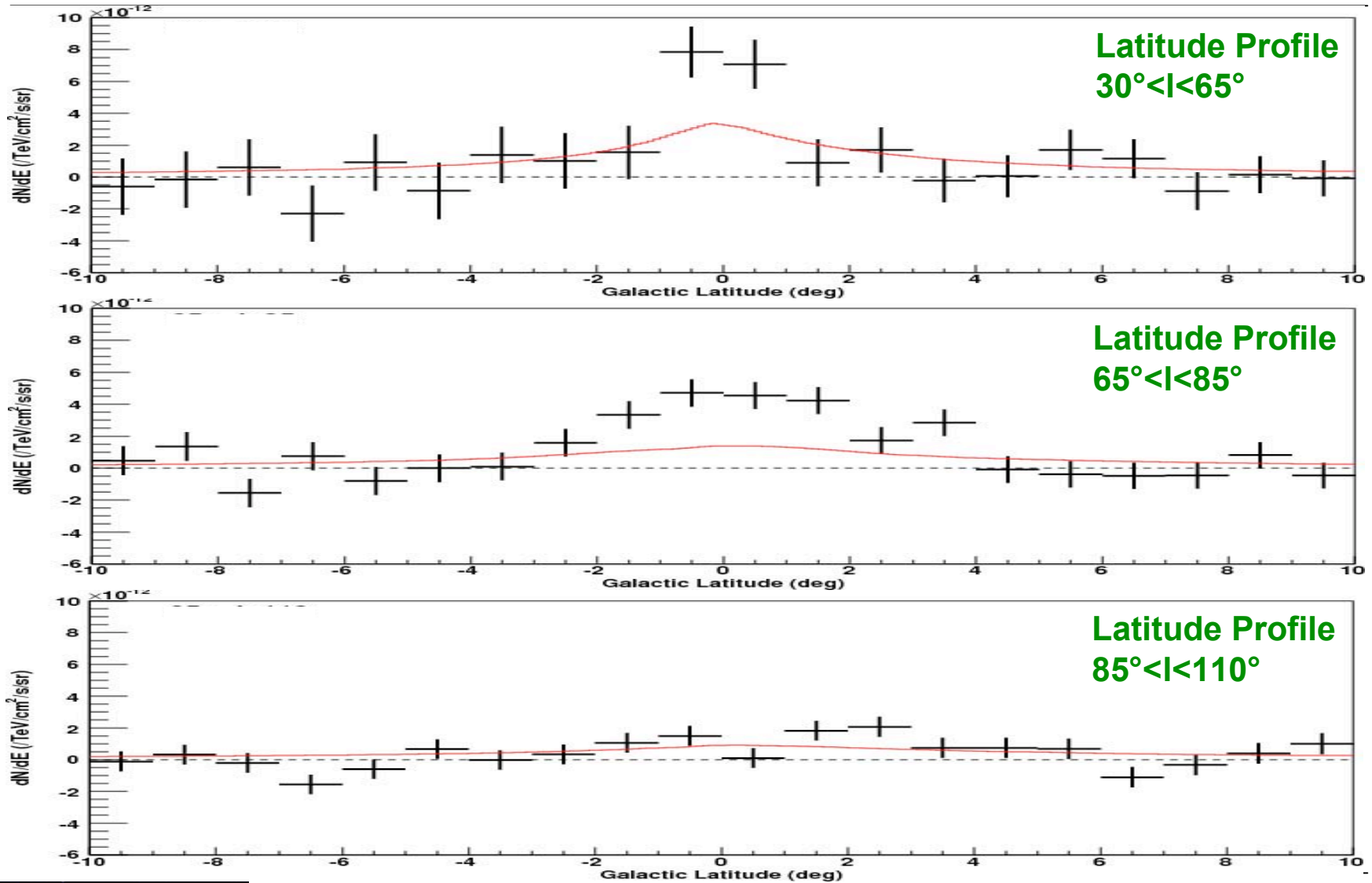


- Flux calculations assume a Crab spectrum (-2.62)
- 3 sources detected, **MGRO J1909+06**, <sup>1</sup>**MGRO J2019+37**, and **MGRO J2033+42**

<sup>1</sup> Abdo *et al.*, arXiv:astro-ph/0611691, submitted to ApJ Letters



# Galactic Latitude Flux Profiles



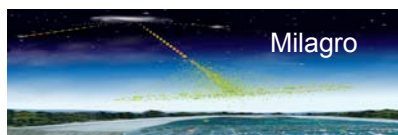
# Galactic Plane Fluxes

object	position box (deg) $ b  < 2$	<sup>1</sup> significance (std deviations)	<sup>2</sup> flux ( $\times 10^{-12}$ ) (/TeV/cm <sup>2</sup> /s/sr)	GALPROP ( $\times 10^{-12}$ ) (/TeV/cm <sup>2</sup> /s/sr)
Galactic Plane	30<l<110	7.5	3.0±0.4 <sub>stat</sub>	1.6
	30<l<65	4.8	4.3±0.9 <sub>stat</sub>	2.5
	65<l<85	8.4	4.2±0.5 <sub>stat</sub>	1.2
	85<l<110	--	<1.1 (95% CL)	0.7
	136<l<216	--	<1.1 (95% CL)	0.3

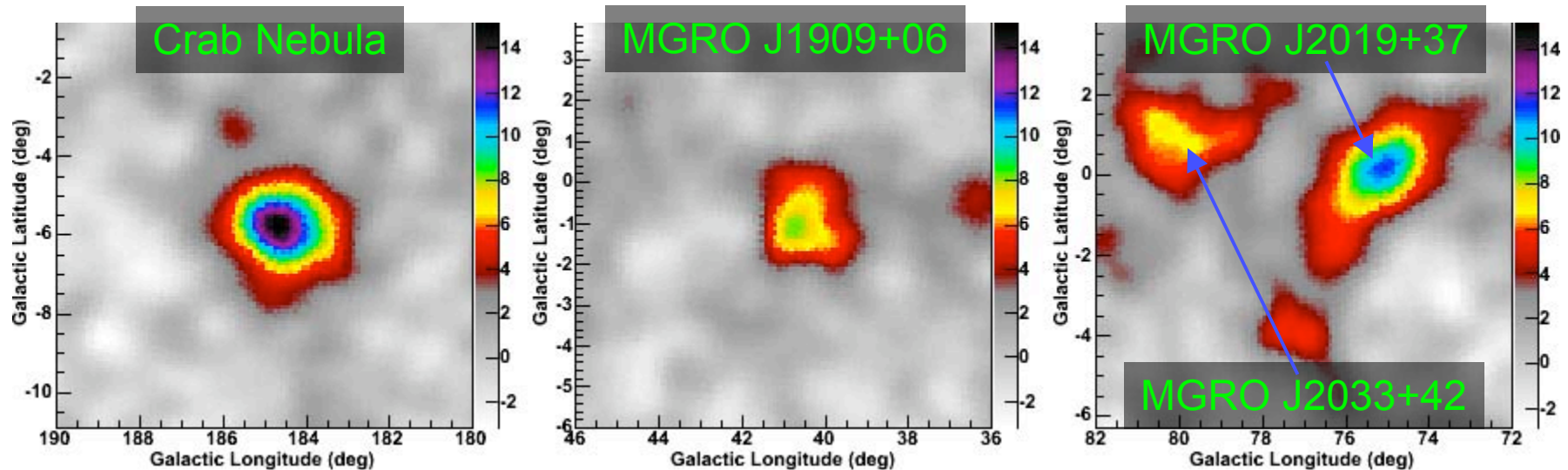
<sup>1</sup> pre-trials significance

<sup>2</sup> add 30% systematic error to fluxes

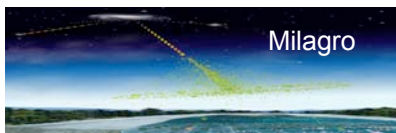
- 30% systematic error is applied
  - Crab flux is consistent with HEGRA measured flux
  - But the trigger rate is higher than expected from the cosmic-ray flux
- A significant excess over GALPROP is seen for 30°<l<85° regions



# Galactic TeV Sources



- Milagro detects 3 TeV sources in the Galactic plane
  - MGRO J1909+06 at  $8.2\sigma$  ( $>6.5\sigma$  post-trials)
  - MGRO J2019+37 at  $11.3\sigma$  ( $>10.2\sigma$  post-trials)
  - MGRO J2033+42 at  $7.1\sigma$  ( $>5.2\sigma$  post-trials)



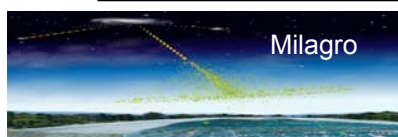


# “Hot Spot” Fluxes

object	<sup>1</sup> position (l, b)	<sup>2</sup> significance (std deviations)	<sup>3</sup> flux ( $\times 10^{-14}$ ) (/TeV/cm <sup>2</sup> /s)
Crab	$-175.4 \pm 0.1_{\text{stat}}$ , $-5.7 \pm 0.1_{\text{stat}}$	15.2	$4.8 \pm 0.5_{\text{stat}}$
MGRO J2019+37	$75.1 \pm 0.1_{\text{stat}}$ , $0.3 \pm 0.1_{\text{stat}}$	11.3	$2.4 \pm 0.4_{\text{stat}}$
MGRO J1909+06	$40.5 \pm 0.1_{\text{stat}}$ , $-1.0 \pm 0.1_{\text{stat}}$	8.2	$4.1 \pm 0.9_{\text{stat}}$
MGRO J2033+42	$80.4 \pm 0.4_{\text{stat}}$ , $1.0 \pm 0.3_{\text{stat}}$	7.1	$1.7 \pm 0.4_{\text{stat}}$
	$76.3 \pm 0.1_{\text{stat}}$ , $-1.9 \pm 0.2_{\text{stat}}$	5.8	$0.9 \pm 0.2_{\text{stat}}$
	$77.2 \pm 0.2_{\text{stat}}$ , $-4.0 \pm 0.2_{\text{stat}}$	5.6	$1.2 \pm 0.2_{\text{stat}}$
	$34.1 \pm 0.3_{\text{stat}}$ , $0.0 \pm 0.2_{\text{stat}}$	5.1	$5.5 \pm 1.4_{\text{stat}}$
	$106.4 \pm 0.5_{\text{stat}}$ , $1.7 \pm 0.8_{\text{stat}}$	4.5	$1.0 \pm 0.4_{\text{stat}}$

<sup>1</sup> add 0.3° systematic error to positions    <sup>2</sup> pre-trials significance    <sup>3</sup> add 30% systematic error to fluxes

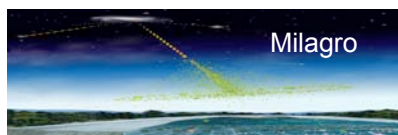
- Sources in the Cygnus Region
  - MGRO J2019+37 is coincident with EGRET 3EG J2016+3657 and 3EG J2021+3716
  - MGRO J2033+42 is coincident with HEGRA TeV 2032+4130 ( $dN/dE = (0.5 \pm 0.2) \times 10^{-14}$  /TeV/cm<sup>2</sup>/s) and EGRET 3EG J2033+4118



# Summary

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- TeV sources discovered in the Galactic plane
  - MGRO J1909+06 with  $>6.5\sigma$  post-trials
  - MGRO J2019+37 with  $>10.2\sigma$  post-trials
  - MGRO J2033+42 with  $>5.2\sigma$  post-trials
- 7 interesting spots in the Galactic plane at TeV energies
  - Expect 0.2 spots above  $4.5\sigma$  by chance
  - Observe 7, all within longitude =  $[30^\circ, 110^\circ]$ 
    - 4 spots in the Cygnus Region (includes MGRO J2019+37 and MGRO J2033+42) – see Aous Abdo's plenary session talk tomorrow
  - $(44 \pm 9_{\text{stat}})\%$  of the total flux in the Galactic plane as seen with Milagro is contained in these spots
  - GALPROP fit to EGRET gives  $\sim 50\text{-}70\%$  of the total Milagro flux in the plane in the same field of view



# TeV $\gamma$ Rays: New Window for the Sky

