Predictions of the **Diffuse Galactic Neutrino Flux** in Light of New Milagro Data

Based on the work by:

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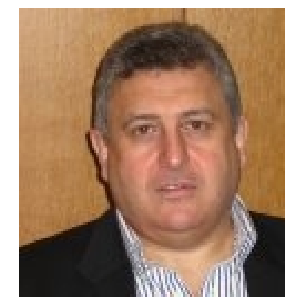
by...

A. Taylor

S. Gabici

R. White



S. Casanova

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Aims

Why a Galactic diffuse ν-flux exists

pp interactions overview

Previous calculations

Relevant energy range for KM3NeT

Observed γ-ray fluxes

A Crab sized flux!

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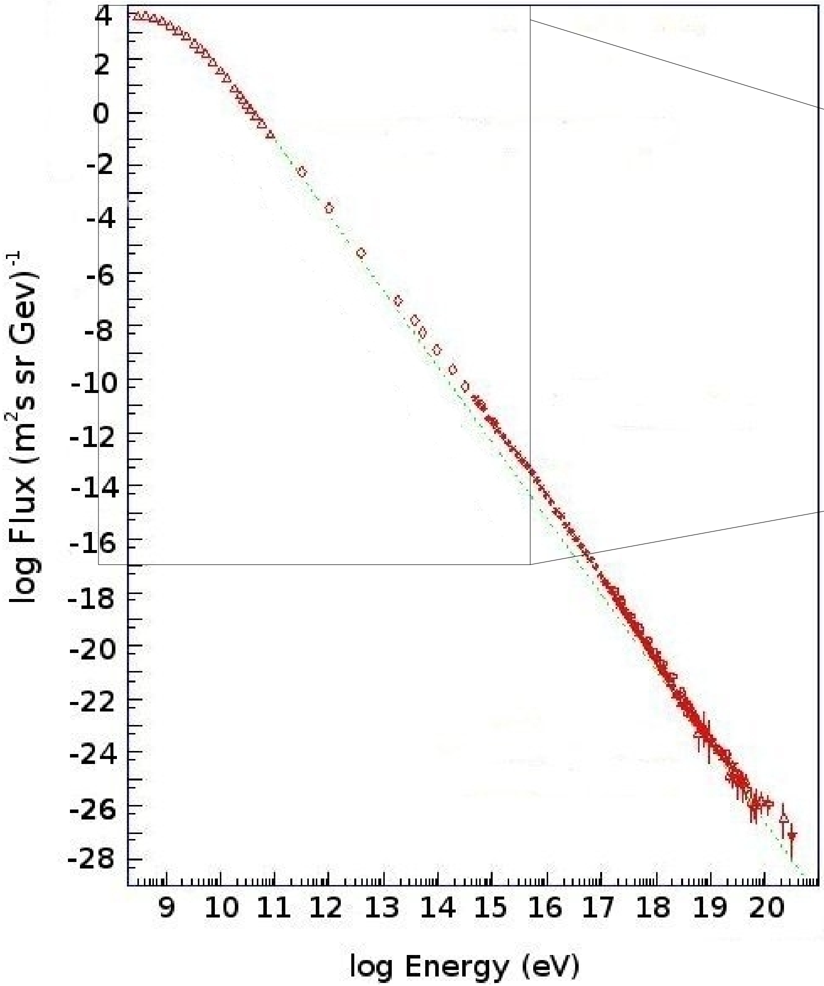
The Cosmic Ray Flux



cosmic rays which may interact with Galactic matter before leaving the Galaxy (diffuse on sub-Galactic scales in μG fields)

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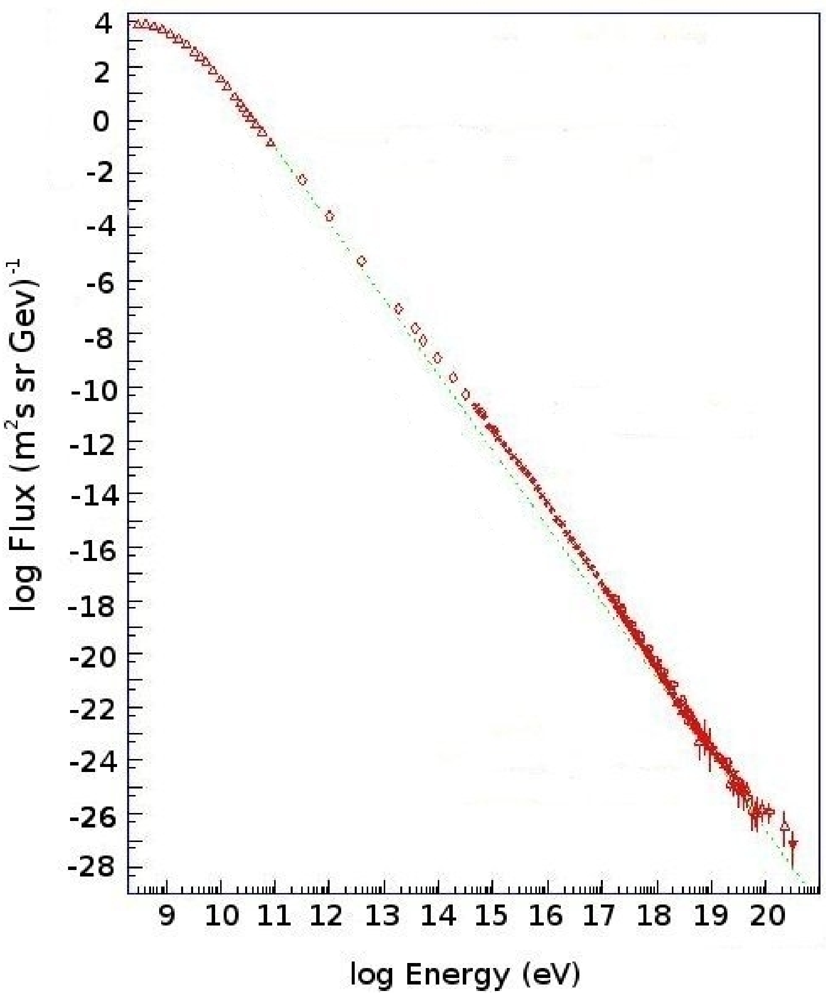
The Cosmic Ray Flux



Galactic cosmic rays require a source power output of ~10^{41} erg s^{-1}

Most EGRET GeV sources have power outputs ~10^{34} (Crab@1 kpc)-10^{36} erg s^{-1}

- ie. ~10^5-10^7 Galactic cosmic ray sources

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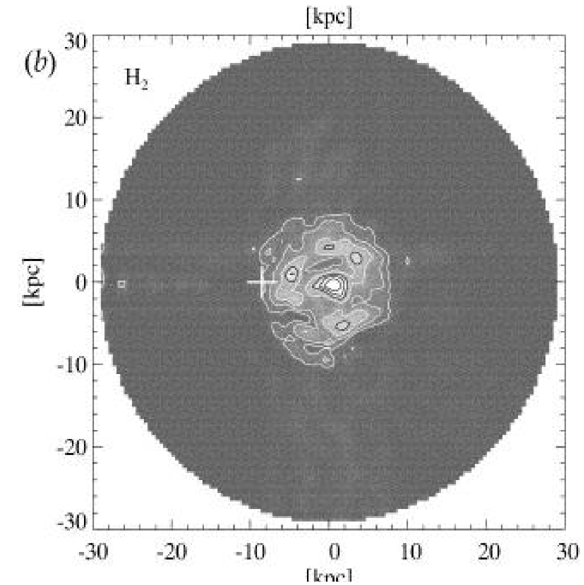
Galactic Matter Distribution

plot:(Hunter *et al.* 1997)
data: (Dame et al.)

Molecular Gas Target

molecular gas



$$n = n_0 e^{-\left(\frac{R}{R_{H_2}}\right)}$$ where $n_0 = 4\ \mathrm{cm}^{-3}$, $R_{H2} = 2.6$ kpc

(Misiriotis *et al.* 2006)- inferred using CO measurements and the $\mathbf{X}_{\mathbf{factor}}$ relation

(possible enhancement)

existence of a density enhancement of $n_p \sim 10^4\ \mathrm{cm}^{-3}$ in central 200 pc (containing 10% of all H_2) should be noted

Interactions of Cosmic Ray Protons with Galactic Gas (Hydrogen):

Proton-Pion Production (threshold)-

$$p+p\rightarrow p+p+\pi^0$$

$$E_p^{th}=\frac{\left[(2m_p+m_\pi)^2-2m_p^2\right]}{2m_p}\sim 1.23\ \text{GeV}$$

note- threshold value is in lab frame

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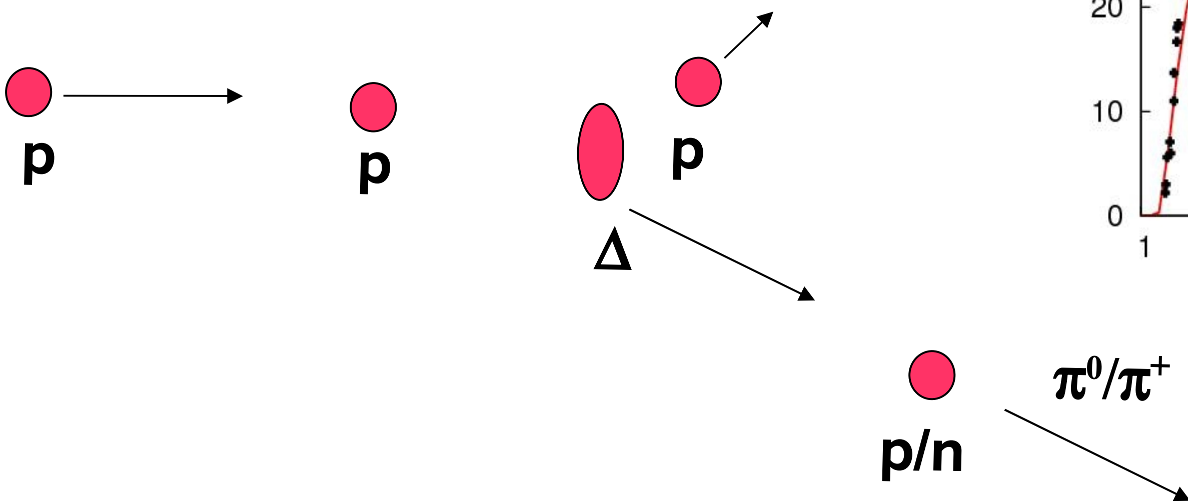
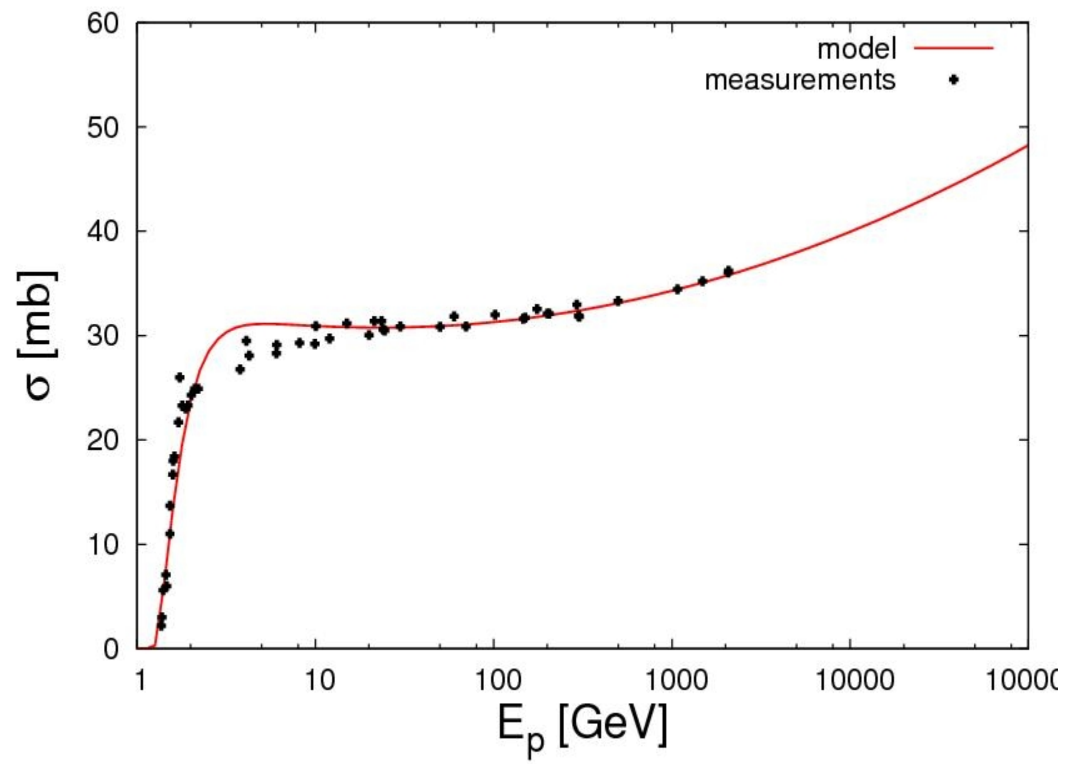
Cosmic Ray Proton-Pion Production

Low Energies (Delta resonance approximation)-

For E_{proton}>1.23 GeV





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Previous Approaches to the Problem

Assume a single diffusion coefficient for the whole Galaxy

$$D(E) = D(E_0)\left(\frac{E}{E_0}\right)^{-\delta}$$

Choose a source distribution (eg. for SNR)-

$$\frac{dN}{dR}(R) = \frac{dN}{dR}(R_0)\left(\frac{R}{R_o}\right)^{1.7} e^{-3.3\left(\frac{R}{R_o}\right)}$$

and injection spectrum-

$$\frac{dN}{dE}(E) = \frac{dN}{dE}(E_0)\left(\frac{E}{E_0}\right)^{-\alpha}$$

Find the steady state solution to the energy transport equation for protons, which lose energy through pp interactions, ignoring adiabatic losses

Use the local cosmic ray flux to normalise the global cosmic ray injection rate for the Galaxy

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....however

The interstellar medium is far from homogeneous so steady state cosmic ray distribution through the Galaxy may not be meaningful

The diffusion coefficient most likely DOES vary strongly spatially (SNR sources require low value diffusion coefficients to accelerate cosmic rays to high energies)

Low energy cosmic ray measurements, from which we determine the diffusion coefficient, may well be effected by the existence of a local Supperbubble

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At What Energy is KM3NeT Best Suited for ν Detection?

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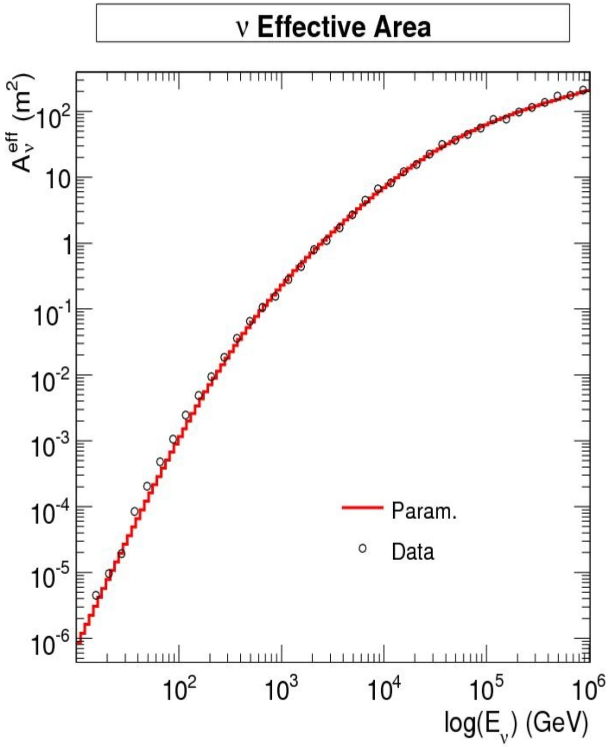
Flux Detection with KM3NeT



Using the fiducial source flux,

$$\frac{dN}{dE}(E)=\frac{dN}{dE}(E_0)\left(\frac{E}{E_0}\right)^{-\alpha} e^{\frac{-E}{E_{max}}}$$

Where,

$$\frac{dN}{dE}(E_0)=10^{-11}\,\mathrm{TeV}^{-1}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$$

$$\approx 1\ \mathrm{Crab}(E_0=1\,\mathrm{TeV})$$

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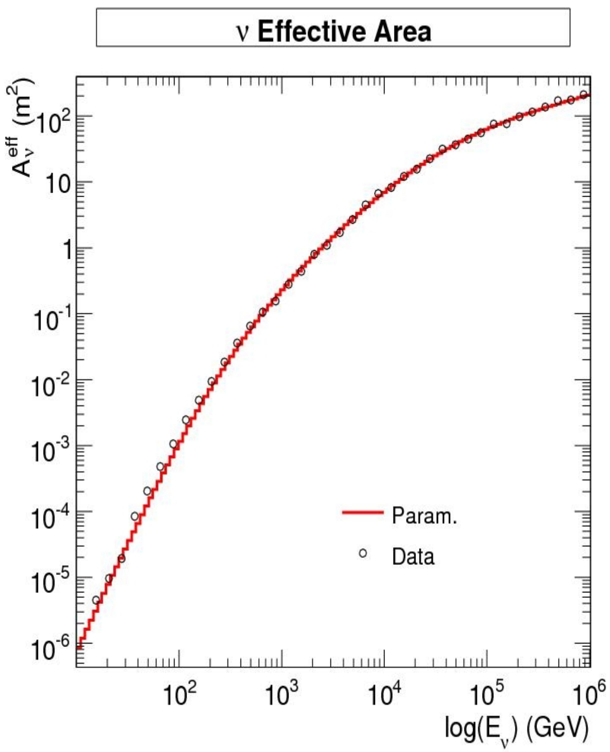
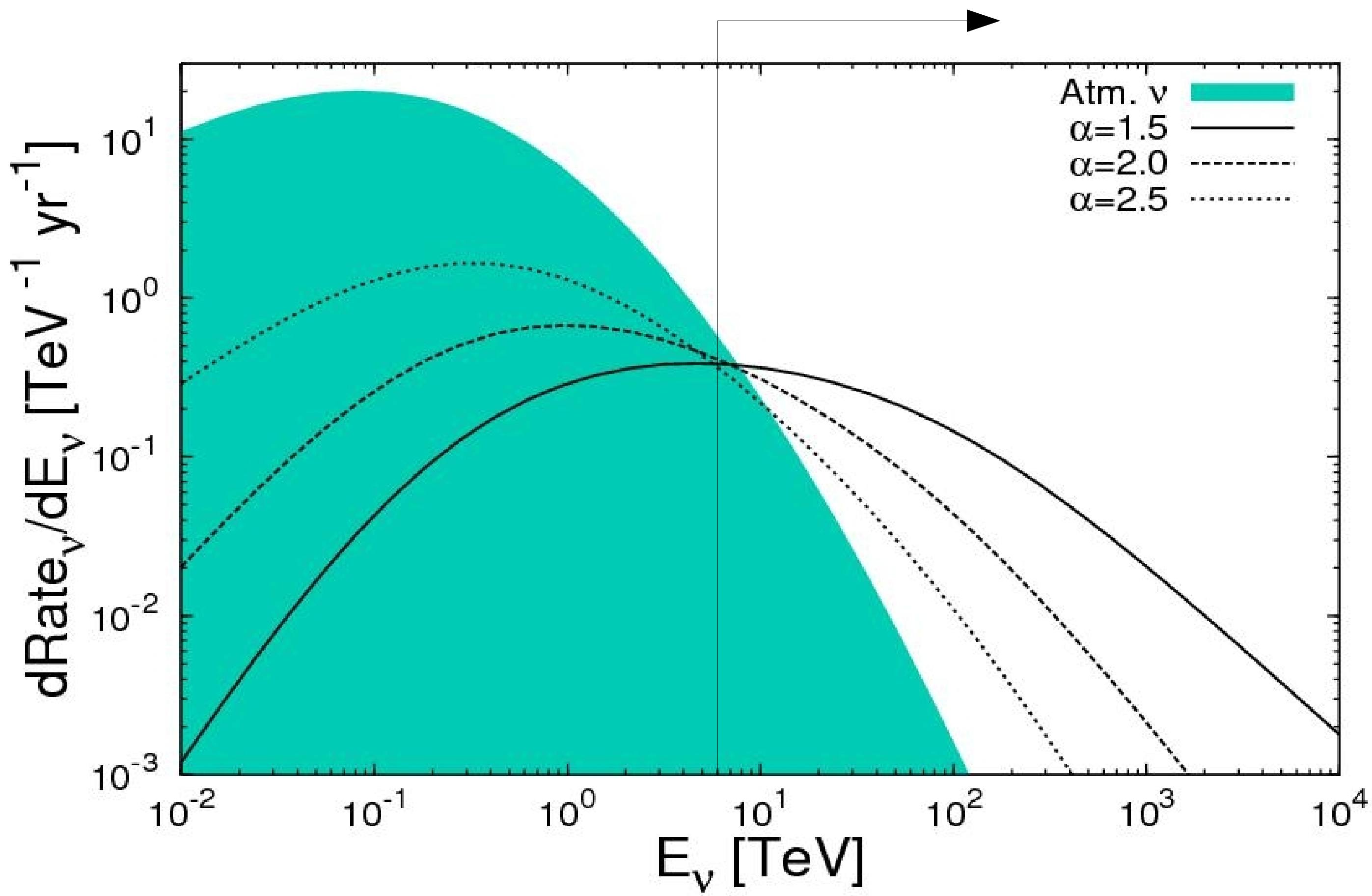
Flux Detection with KM3NeT

KM3NeT is a multi **TeV- PeV** ν detector





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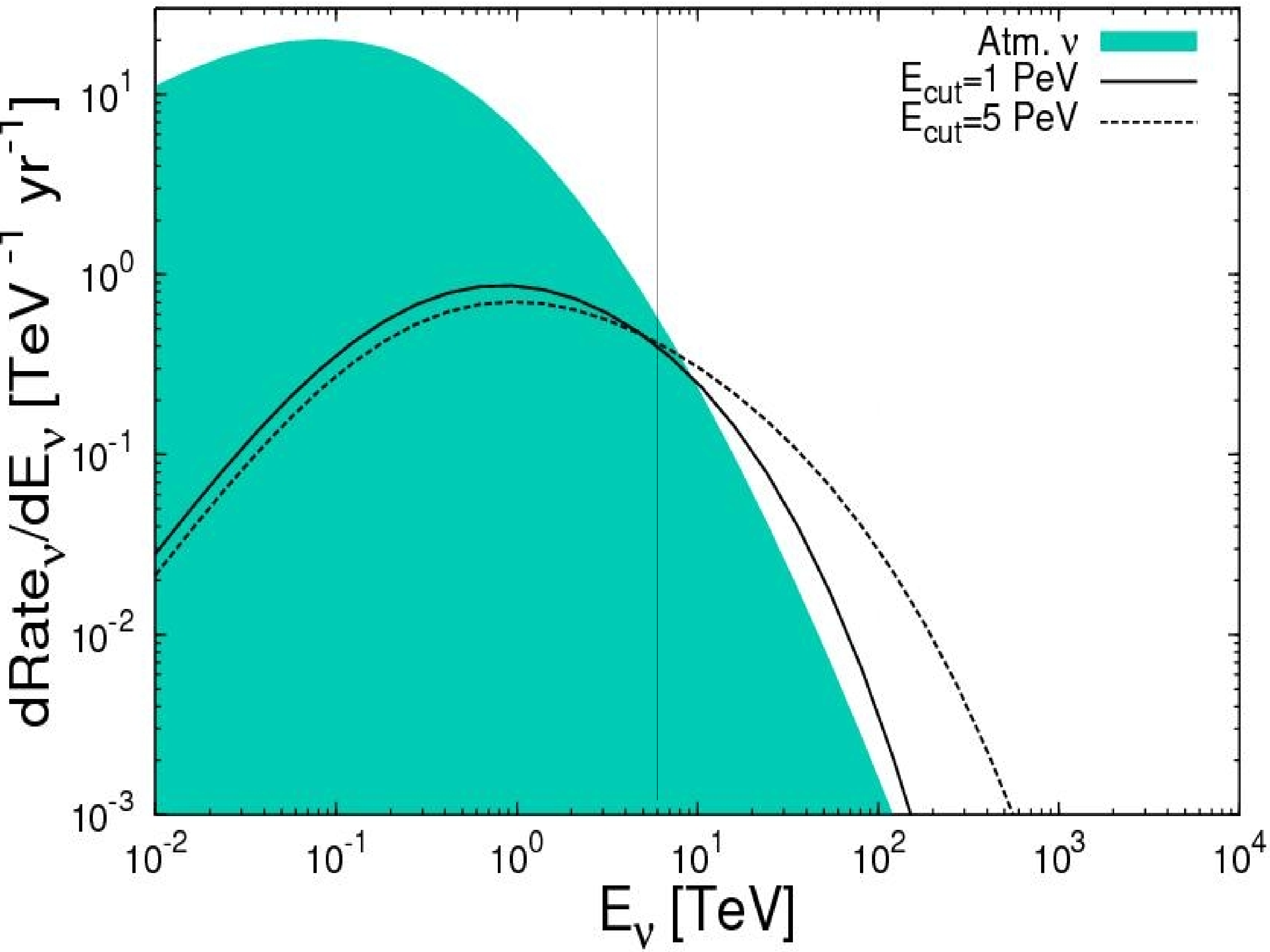
Flux Detection with KM3NeT



The cutoff energy of the ν source is of crucial importance to whether the flux is detectable

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So 10 TeV-PeV γ–Rays are of Most Relevance for Potentially Detectable ν–Flux Calculations

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...but first a look at GeV γ-Rays

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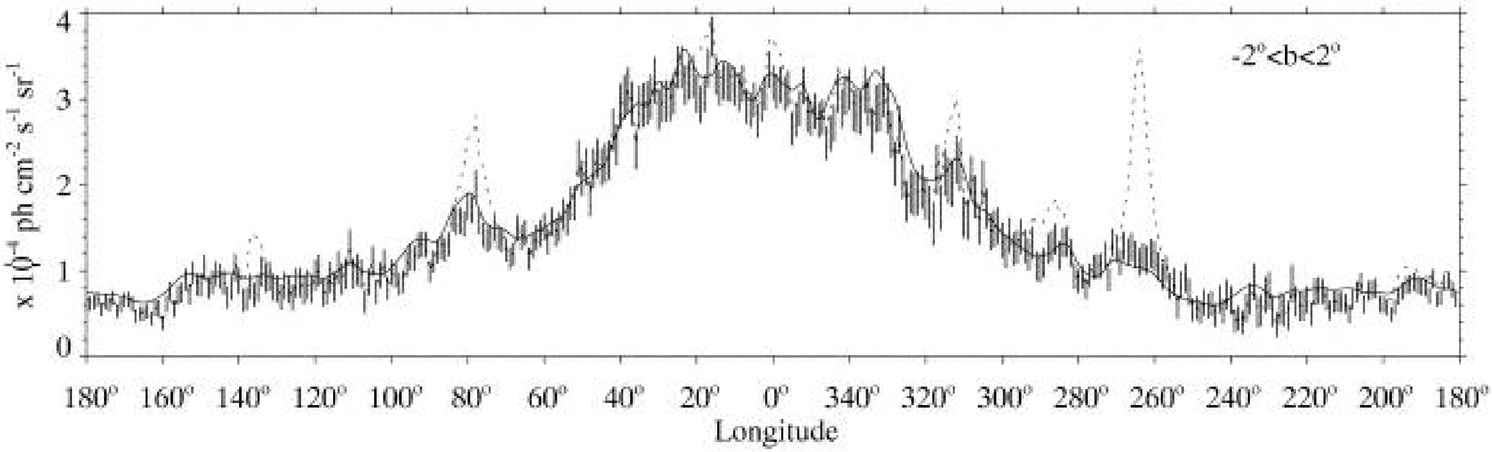
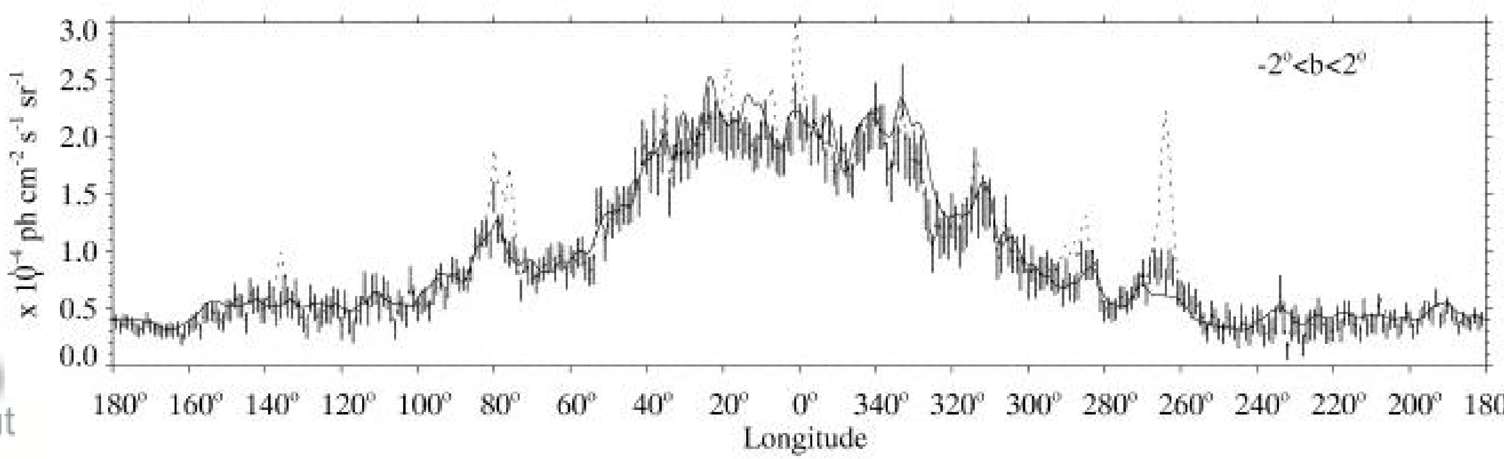
The EGRET Observations

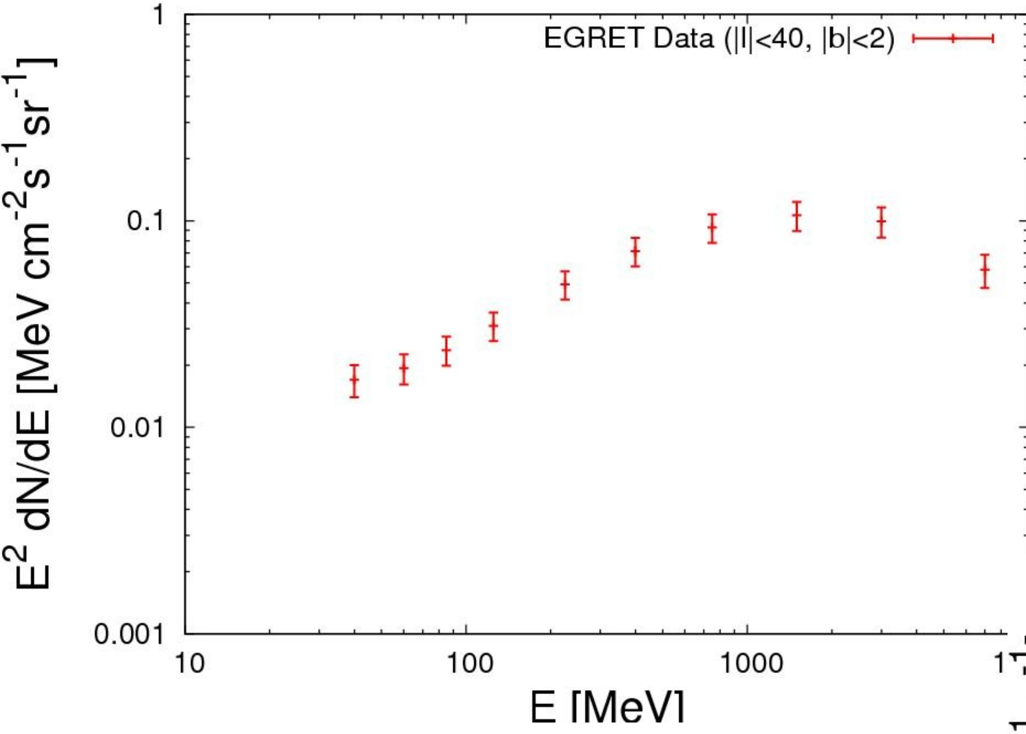
Spatial Distribution of EGRET Signal (100-300 MeV)-



Spatial Distribution of EGRET Signal (300-1000 MeV)-

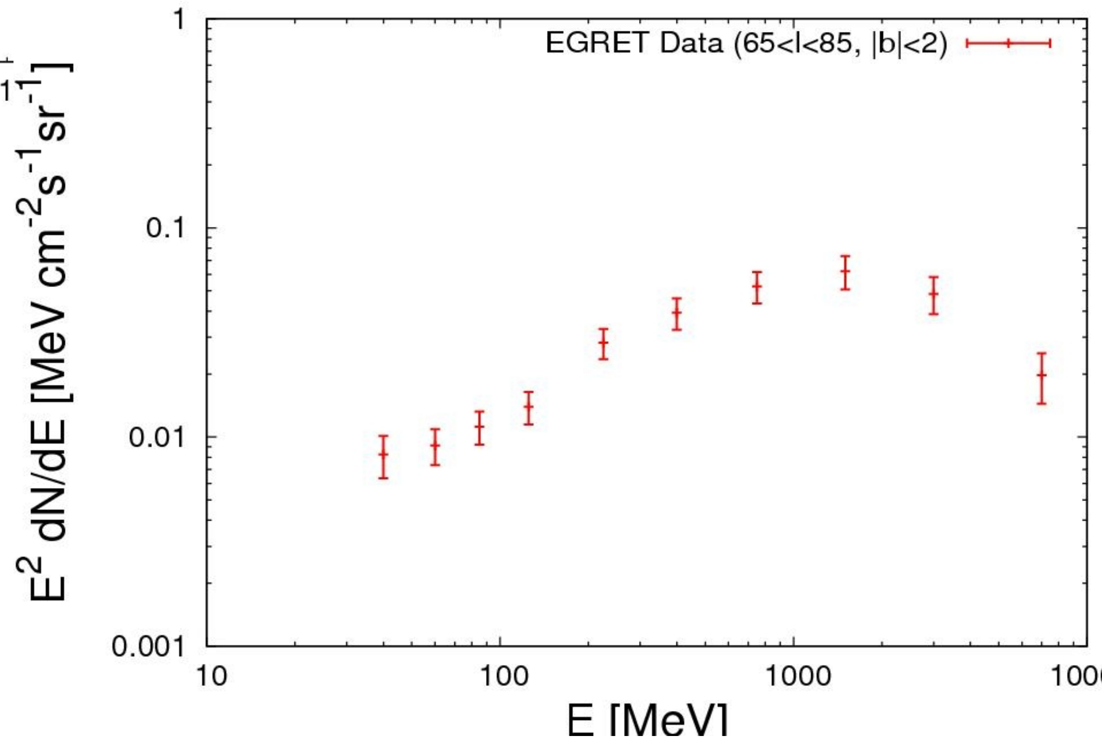


The EGRET Observations



our selected Galactic plane region (**|l| < 40°**)

Cygnus region (**30° < l < 65°**)



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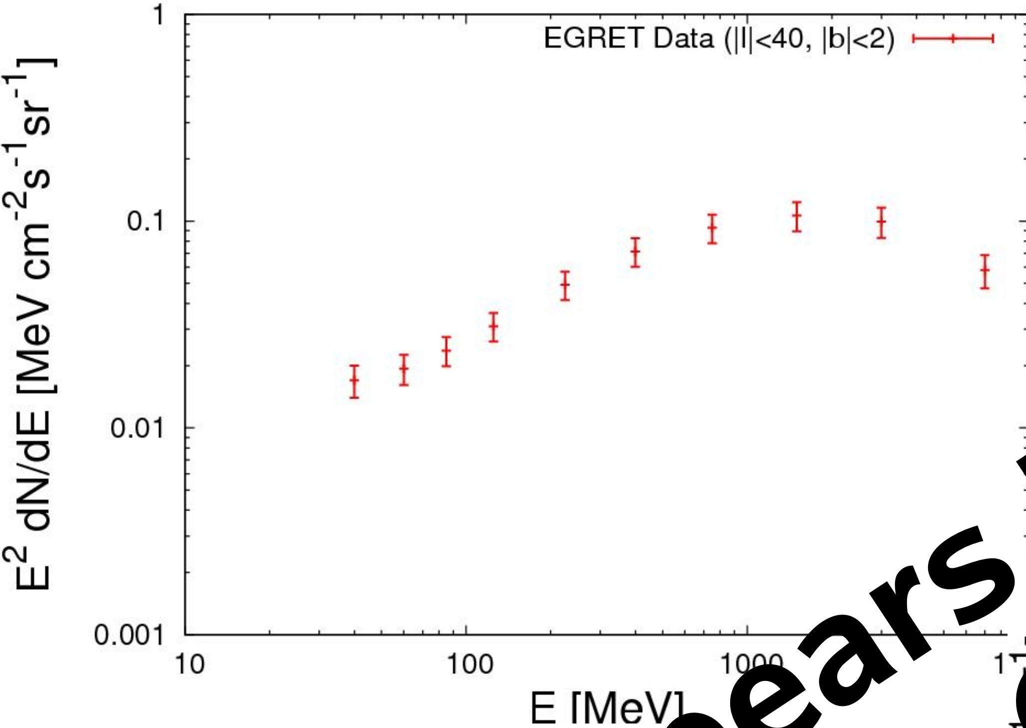
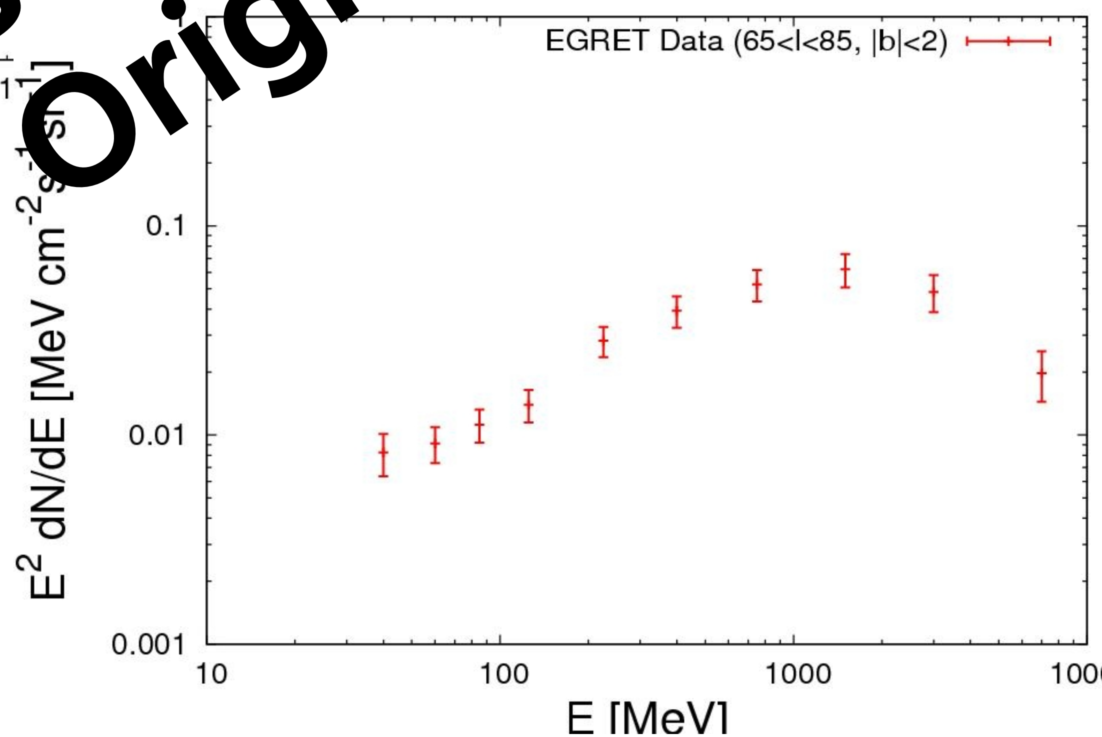
The EGRET Observations



our selected Galactic plane region (|l|<40º)

Cygnus region (30º<l<65º)



Appears Hadronic in Origin

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..and now to the more relevant TeV γ-Rays

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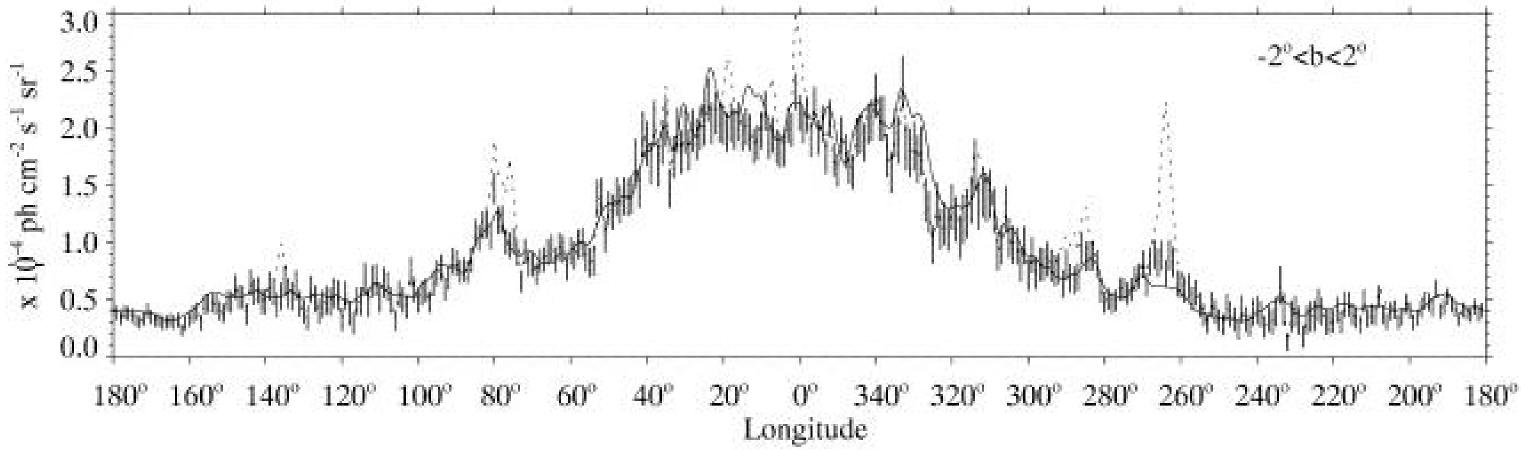
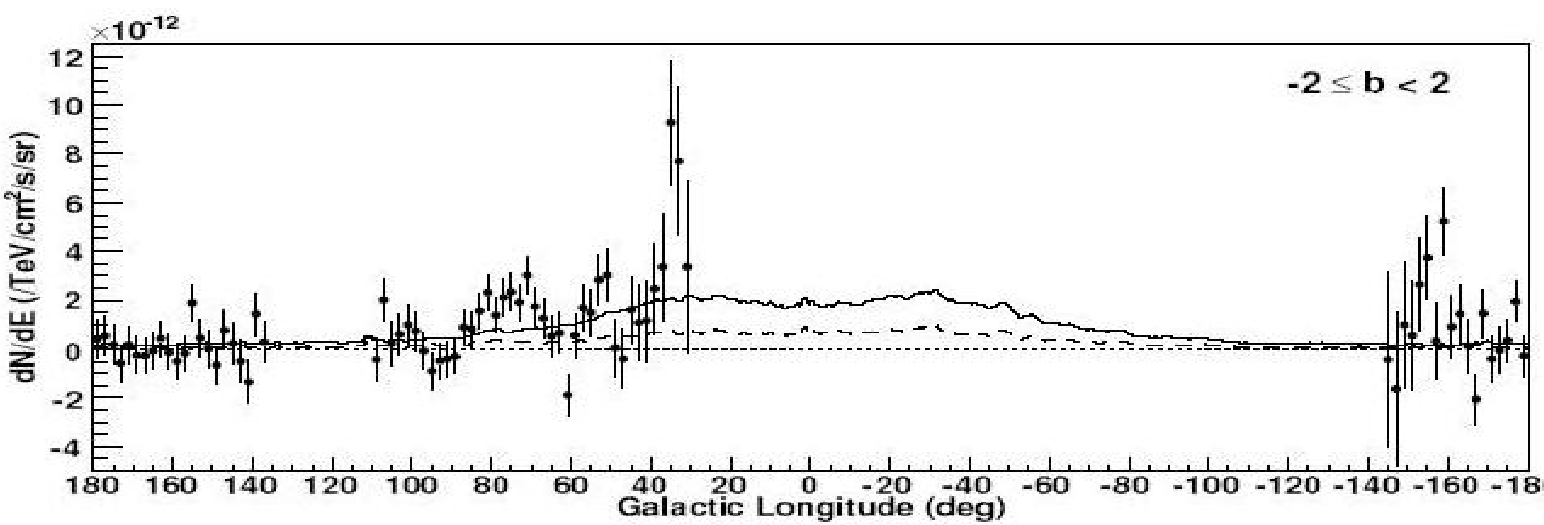
The Milagro Observations

Spatial Distribution of EGRET Signal (300-1000 MeV)-



Spatial Distribution of Milagro Signal (~15 TeV ???)-



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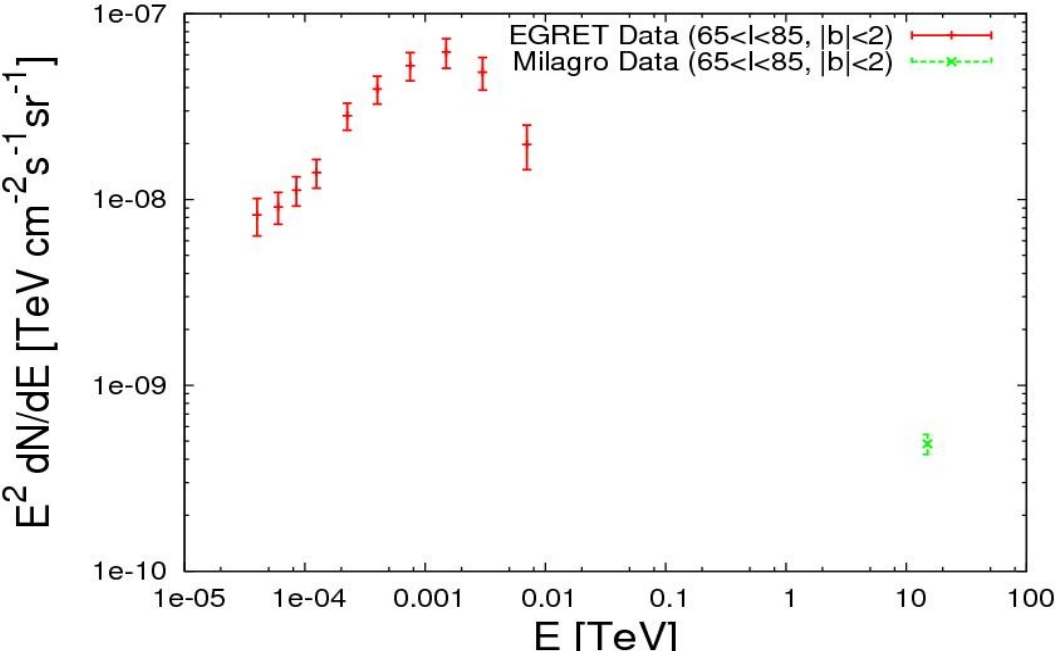
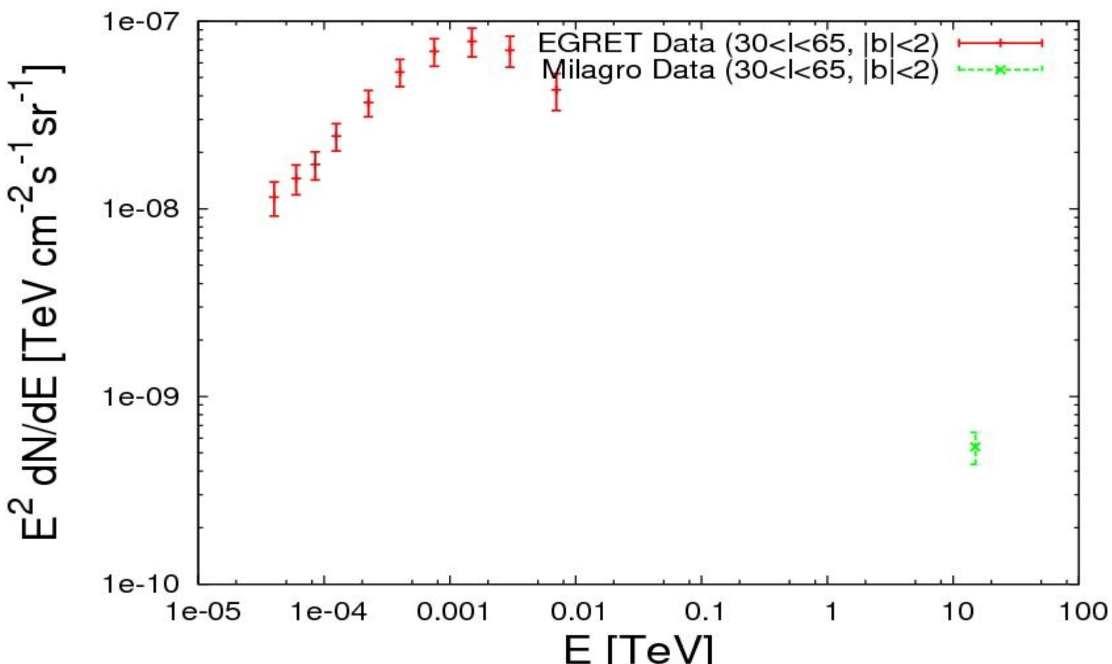
The Milagro Observations





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Cosmic Ray Proton Fluxes Considered

$$\frac{dN}{dE}(E)=\frac{dN}{dE}(E_0)\frac{\left(\frac{E}{E_0}\right)^{-\alpha}}{1+\left(\frac{E}{E_*}\right)^{\delta}}e^{-\left(\frac{E}{E_{cut}}\right)} \quad \text{(1)}$$

$$E_*=GeV$$
$$E_0=TeV$$
$$E_{cut}=PeV$$

$$\frac{dN}{dE}(E)=\frac{dN}{dE}(E_0)\left(\frac{E}{E_0}\right)^{-\alpha}e^{-\left(\frac{E}{E_{cut}}\right)} \quad \text{(2)}$$

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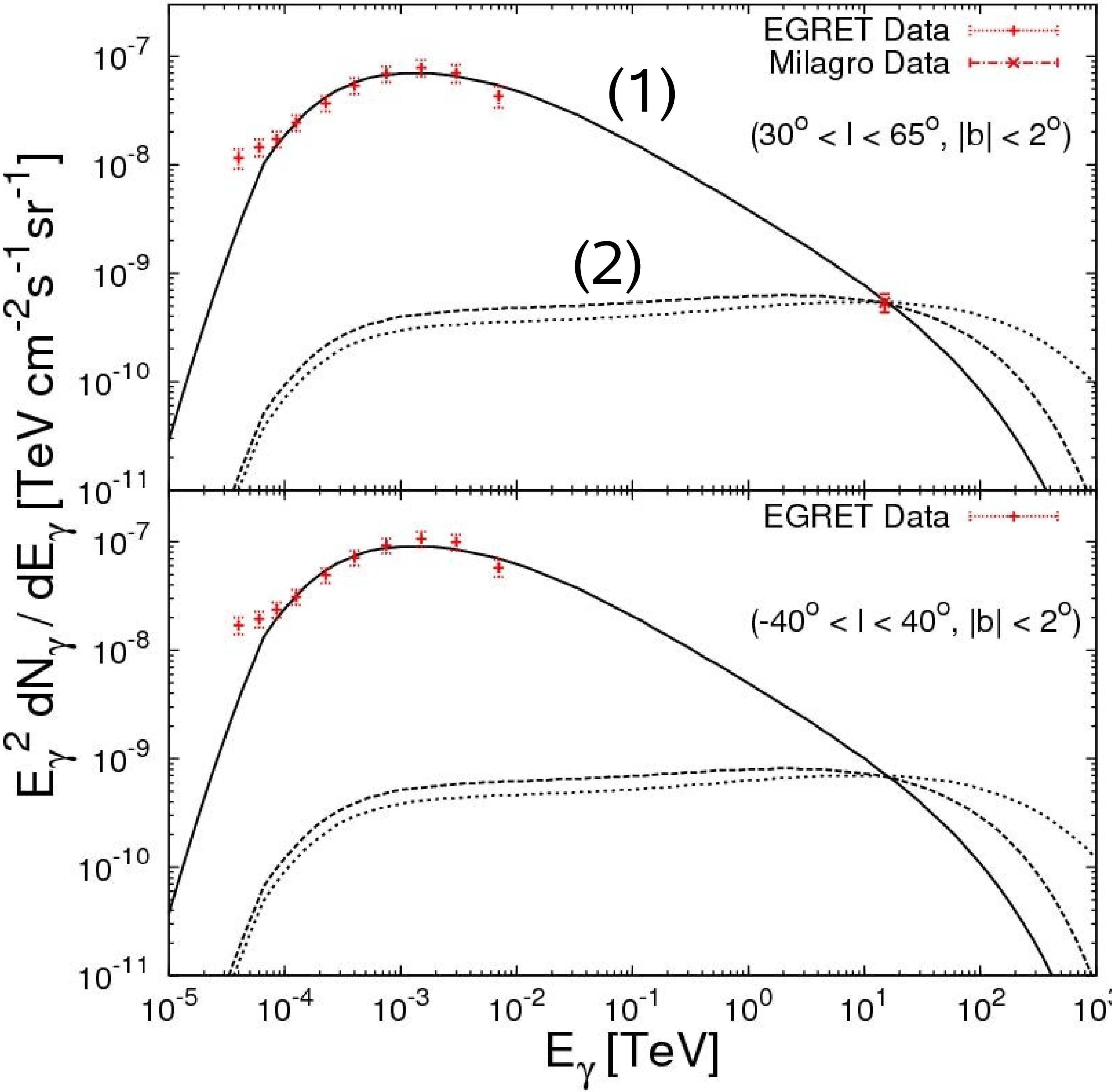
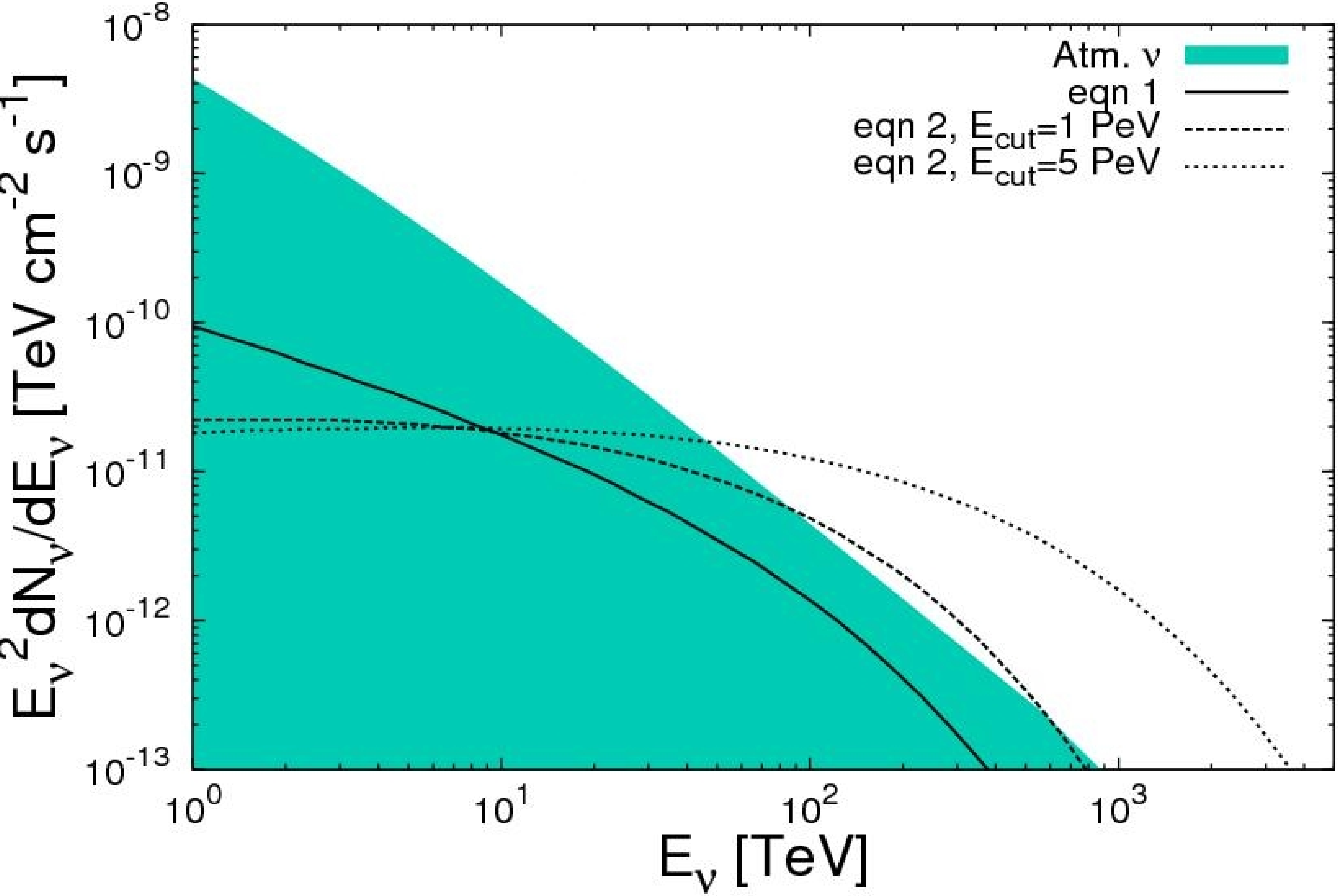
Fits to the Data



A Crab-Size ν–Flux!



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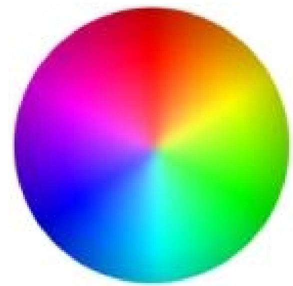
Extra Slides



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A Phenomenological Look at a Hadronic Origin

15 TeV photons either came from ~100 TeV electrons or ~100 TeV protons

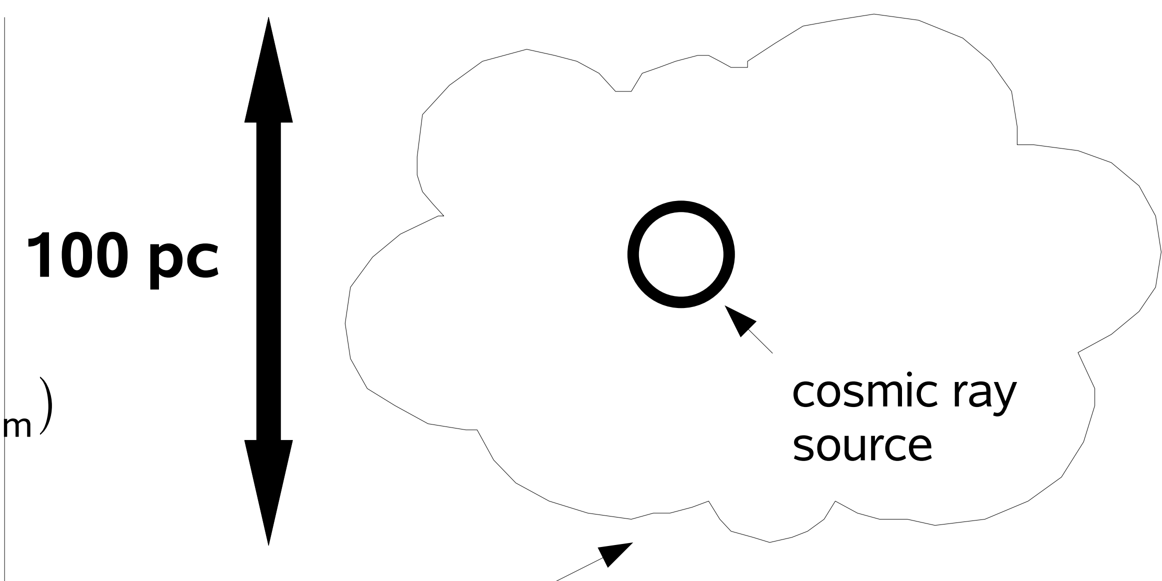
The loss lengths of these two populations (both presumably accelerated by the source) are in the ratio $(1/n_\gamma \sigma_T):(1/n_p \sigma_{pp})=1:1000$

$$\sigma_{pp} \approx 35\,\mathrm{mb}$$

$$\tau_{pp} = \frac{1}{n \sigma_{pp}} \sim 10^6\,\mathrm{yrs}$$

$$D(100\,\mathrm{TeV}) = 10^{28}\,\mathrm{cm}^2\,\mathrm{s}^{-1}\,(\sim 10\,D_{\mathrm{Bohm}})$$

$$l_p^{loss} \approx 1\,kpc \qquad l_e^{loss} \approx pc$$



molecular cloud (n_p~10 cm^3)

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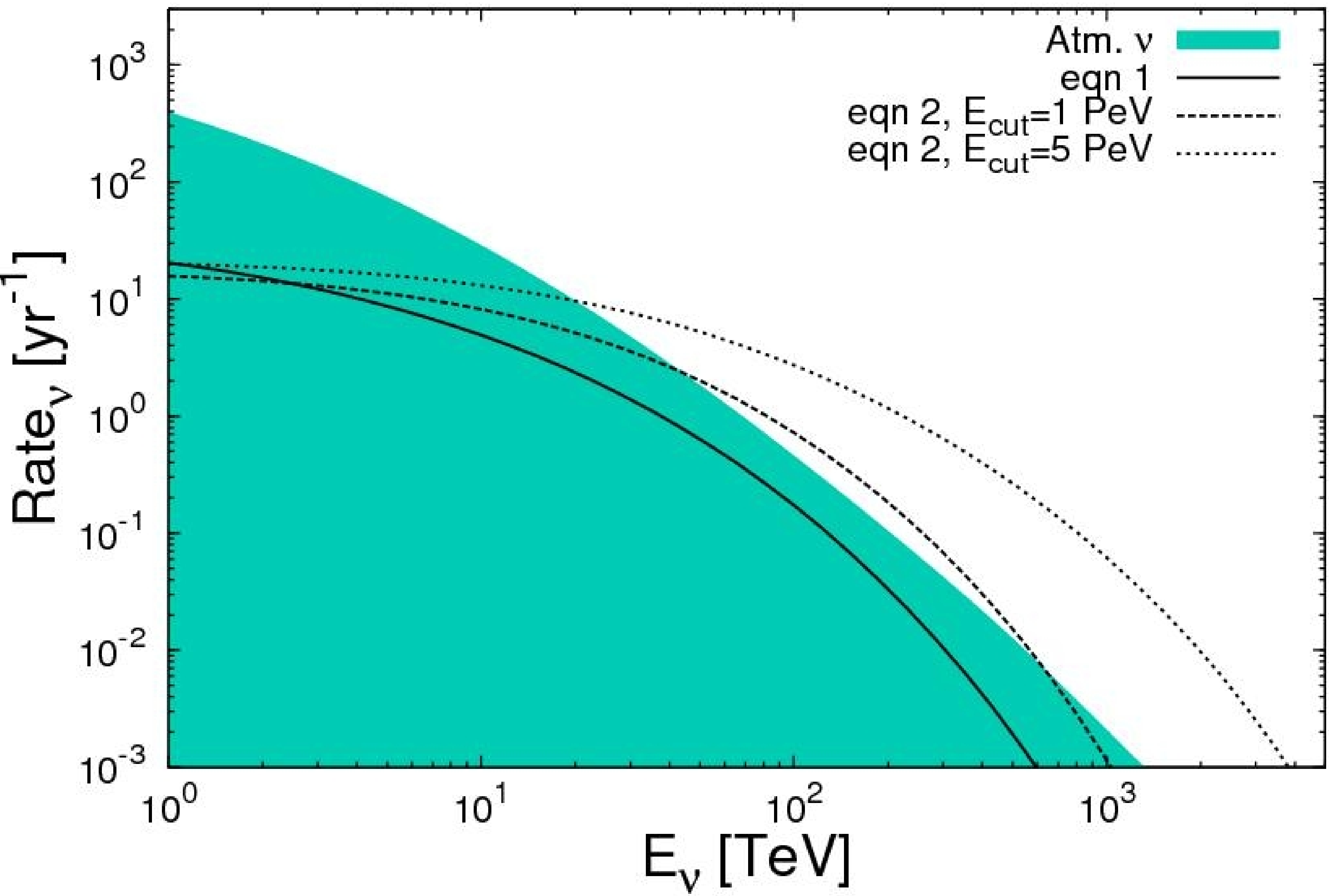

Atm. ν
eqn 1
eqn 2, E_cut=1 PeV
eqn 2, E_cut=5 PeV
Rate_ν [yr^-1]
E_ν [TeV]
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3
10^0
10^1
10^2
10^3

The Anti-Proton Flux Constraint

A large π^{0} production rate predicts a correspondingly large anti-proton flux

However, BESS measurements have only been done up to 50 GeV

Forthcoming PAMELA observations should provide anti-proton measurements up to several 100 GeV

However, the anti-proton flux in the ~TeV energy region remains unmeasured

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