Propagation of CR electrons and the interpretation of diffuse _-rays

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GLAST Workshop, Rome, 17 Sept 2003

with Igor Moskalenko & Olaf Reimer

* What's new in interpretation of EGRET diffuse g-rays

* origin of the GeV excess

* => implications for CR electrons

* New extragalactic spectrum

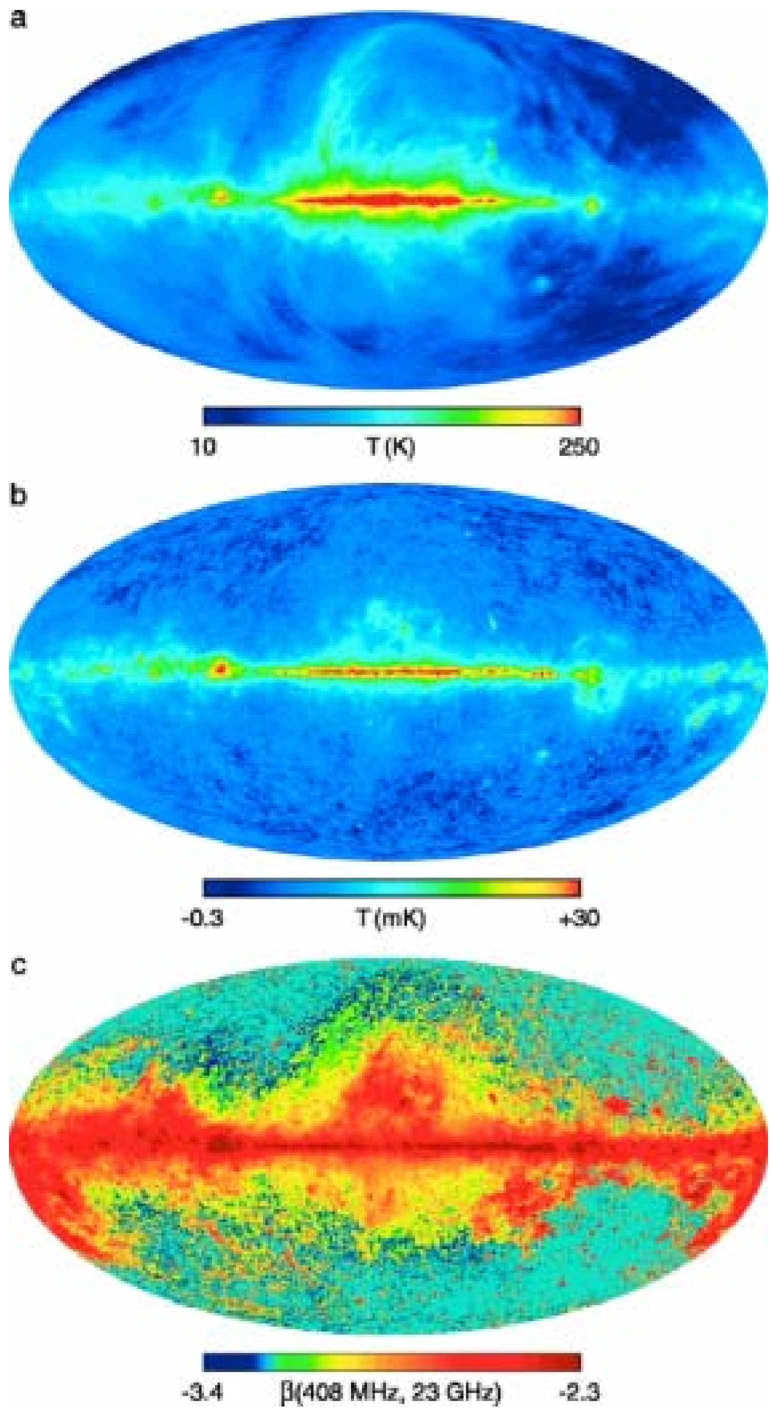
Direct evidence for
Galactic electrons

WMAP will provide
constraints on
electron propagation

(WMAP23-94 Ghz)

Bennett et al. (2003)
ApJS 148, 97

Spectral steepening:
evidence
for electron propagation
from disk to halo
Excellent data for testing
electron propagation models

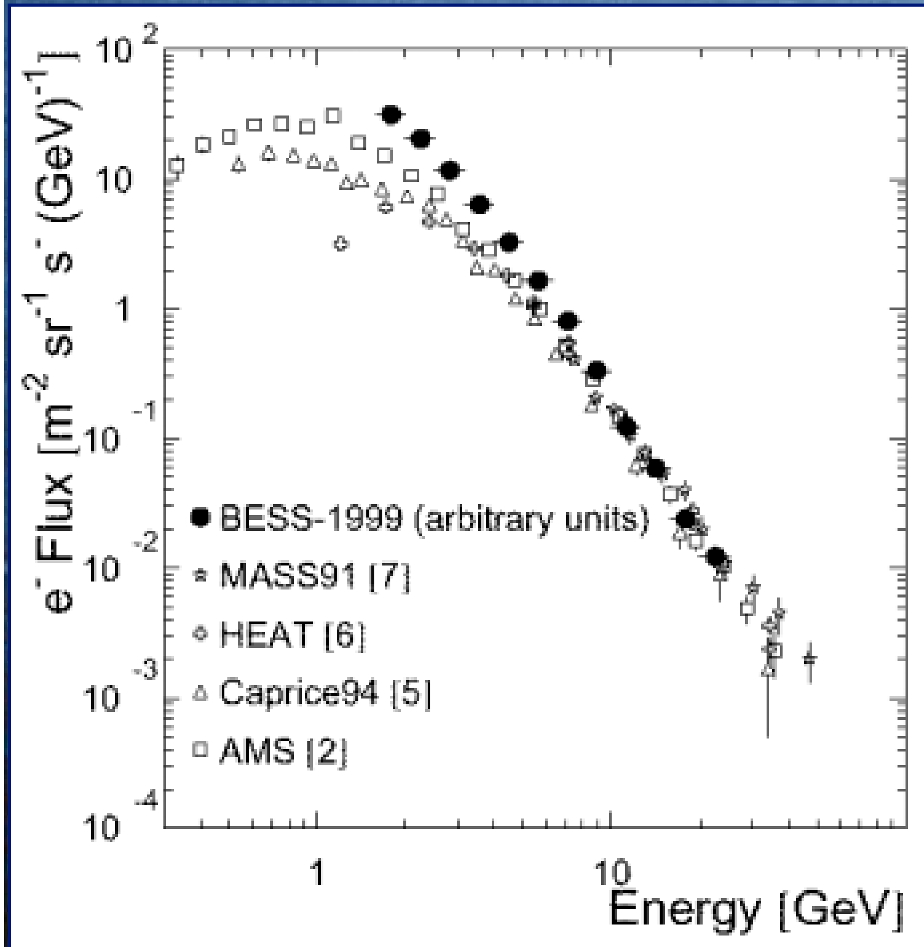


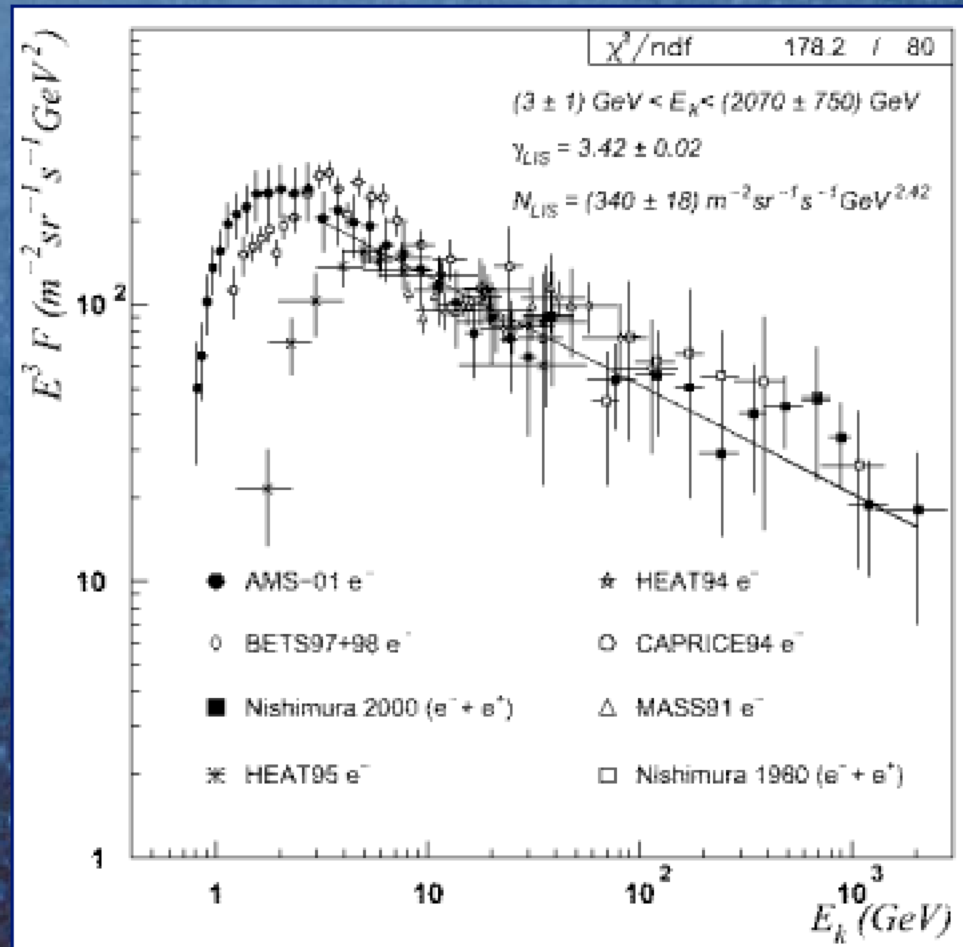
408 Mhz Haslam

23 GHz WMAP

408 MHz/23 Ghz
spectral index

Direct electron measurements





Hams et al. ICRC2003

BESS 1999 (arb units) ICRC 2003

Casadei, ICRC 2003

normalized at 20 GeV

Still uncertainty in absolute fluxes even at 1-10 GeV !

Computing diffuse g-rays

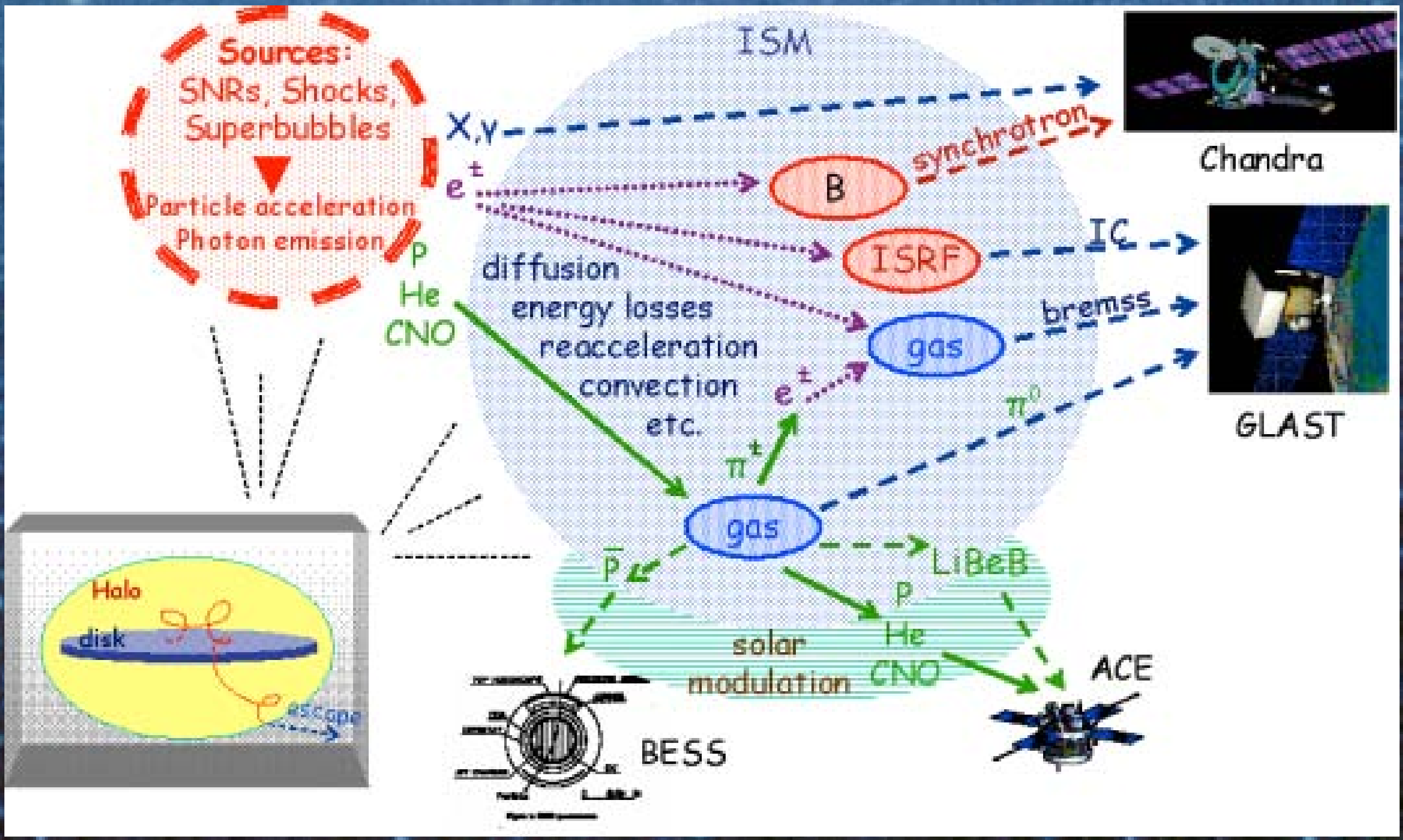
galprop model

2D / 3D / equilibrium / time dependent, stochastic sources

CR propagation: primary, secondary, e^+, p^- etc.

Injection -- diffusion -- convection-- energy-loss – reacceleration

_-rays : using HI, CO, interstellar radiation field



Electrons: propagation complex due to rapid losses

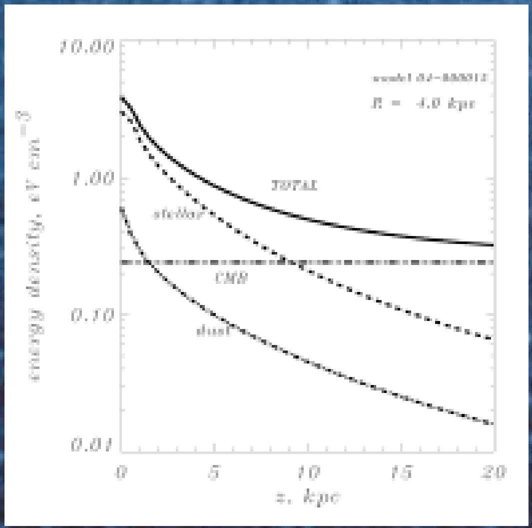
Interstellar radiation field not well enough known

can improve with e.g. WMAP data

big project, but required for GLAST-quality data

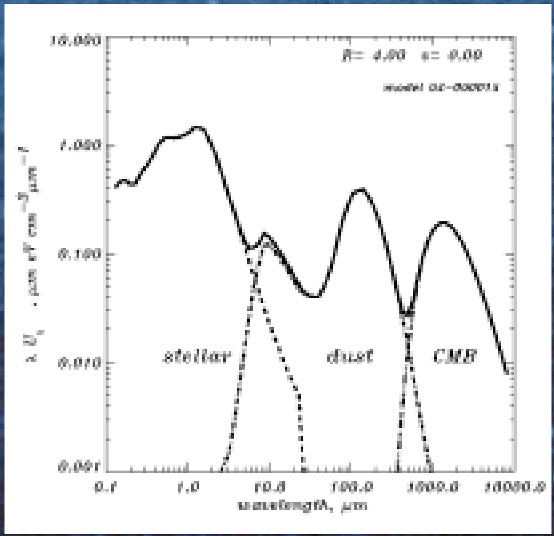
Interstellar radiation field

eV cm^{-3}

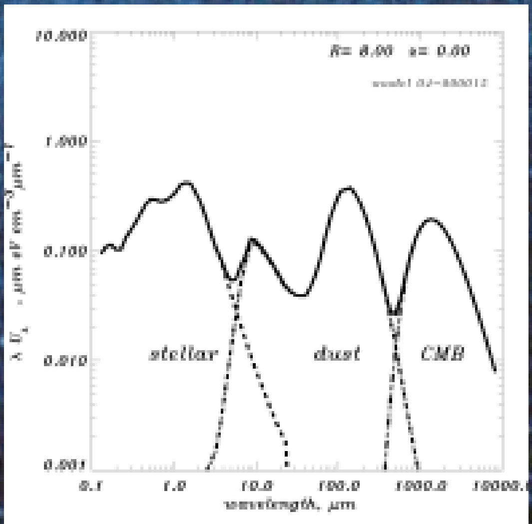


R kpc

R = 4 kpc



R= 8 kpc



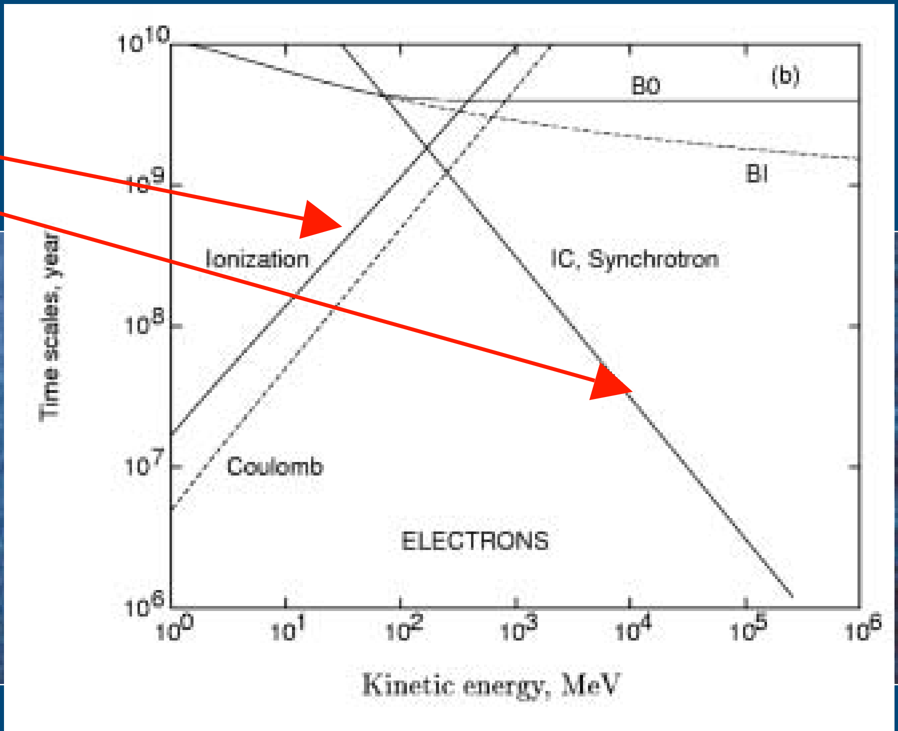
Local electron spectrum may not be good guide

Time-dependent model needed.

Electron energy losses large at low and high energy

< 100 MeV ionization

> 1 GeV inverse Compton, synchrotron



_- rays from

bremsstrahlung < 1 GeV, less than originally thought

minor role?

$E_{electron} \sim E_{gamma}$ 10-1000 MeV,

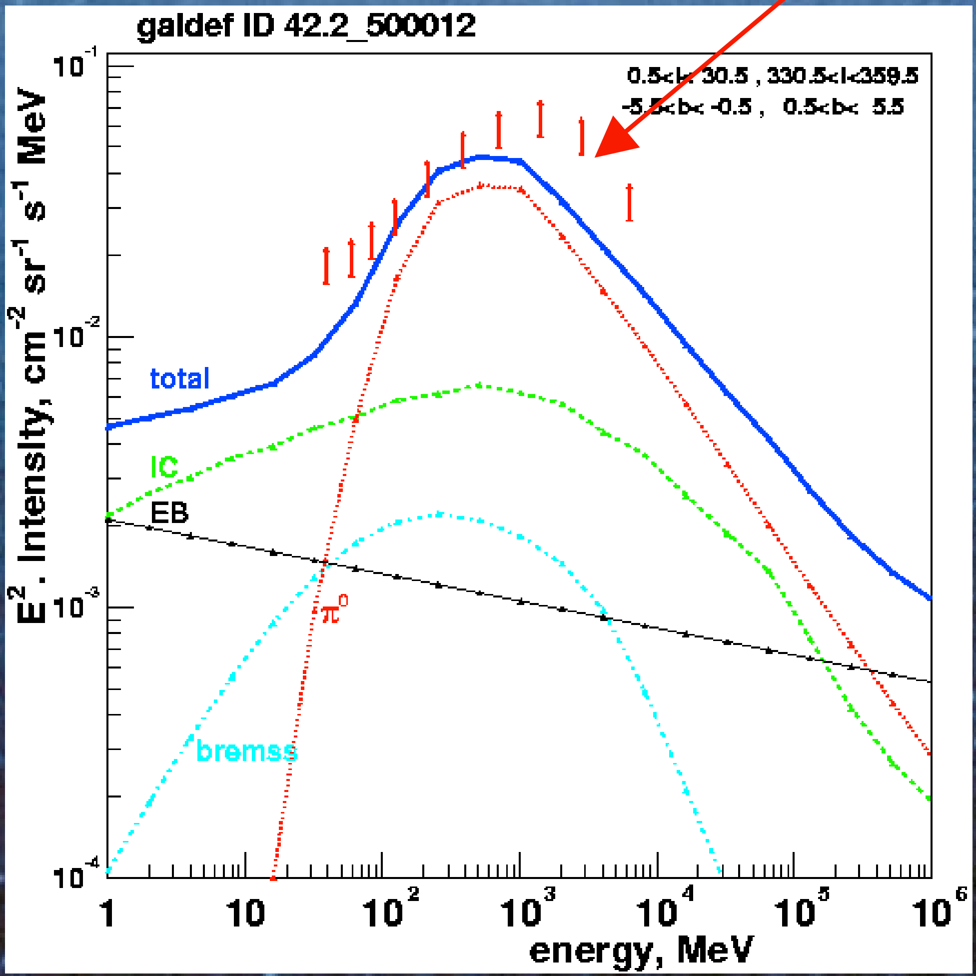
hard to observe – solar modulation

true situation at low energies very uncertain

Normal electron spectrum leads to well-known discrepancy (GeV excess)

Is it the CR spectrum or could it be due to sources

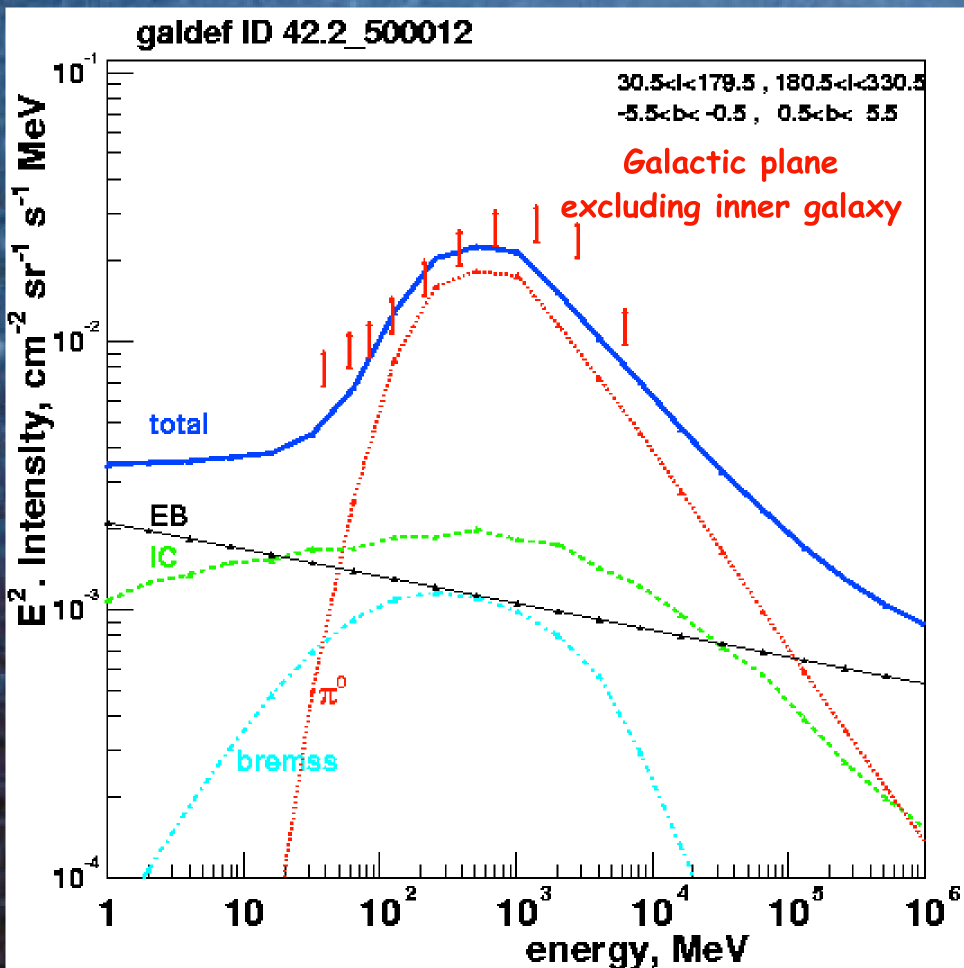
(e.g. SNR show the hard particle injection spectrum)

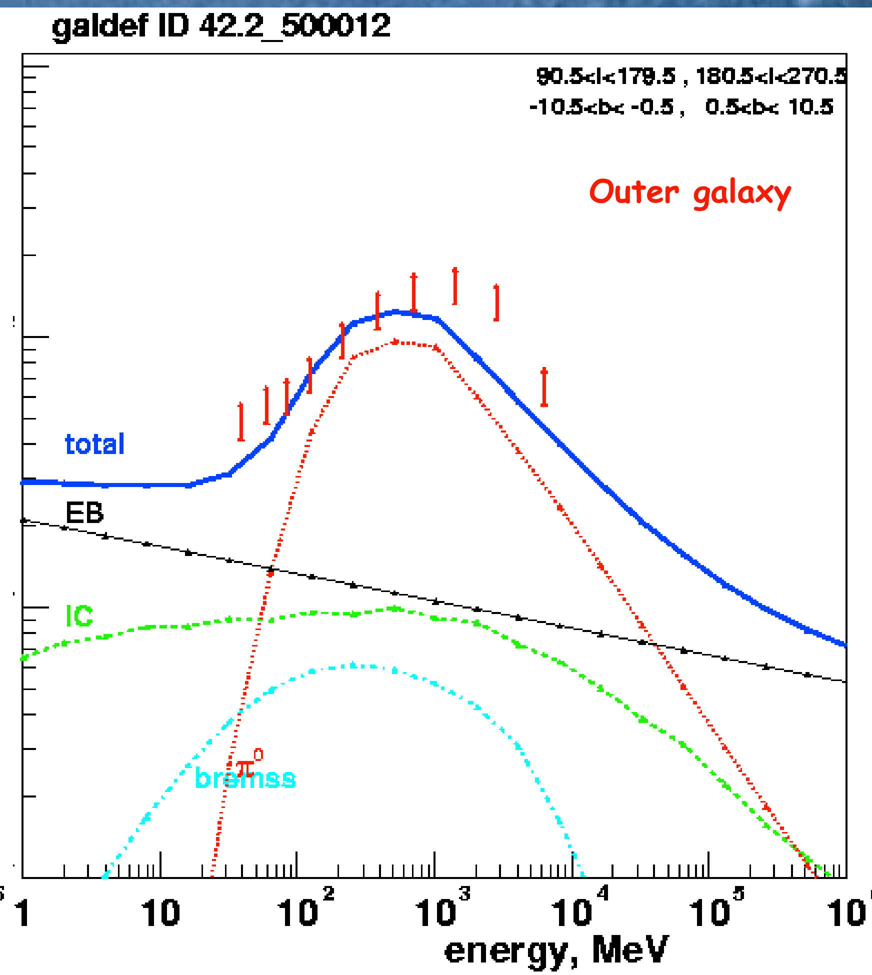


Strong, Moskalenko, Reimer
ICRC 2003
astroph/0306346

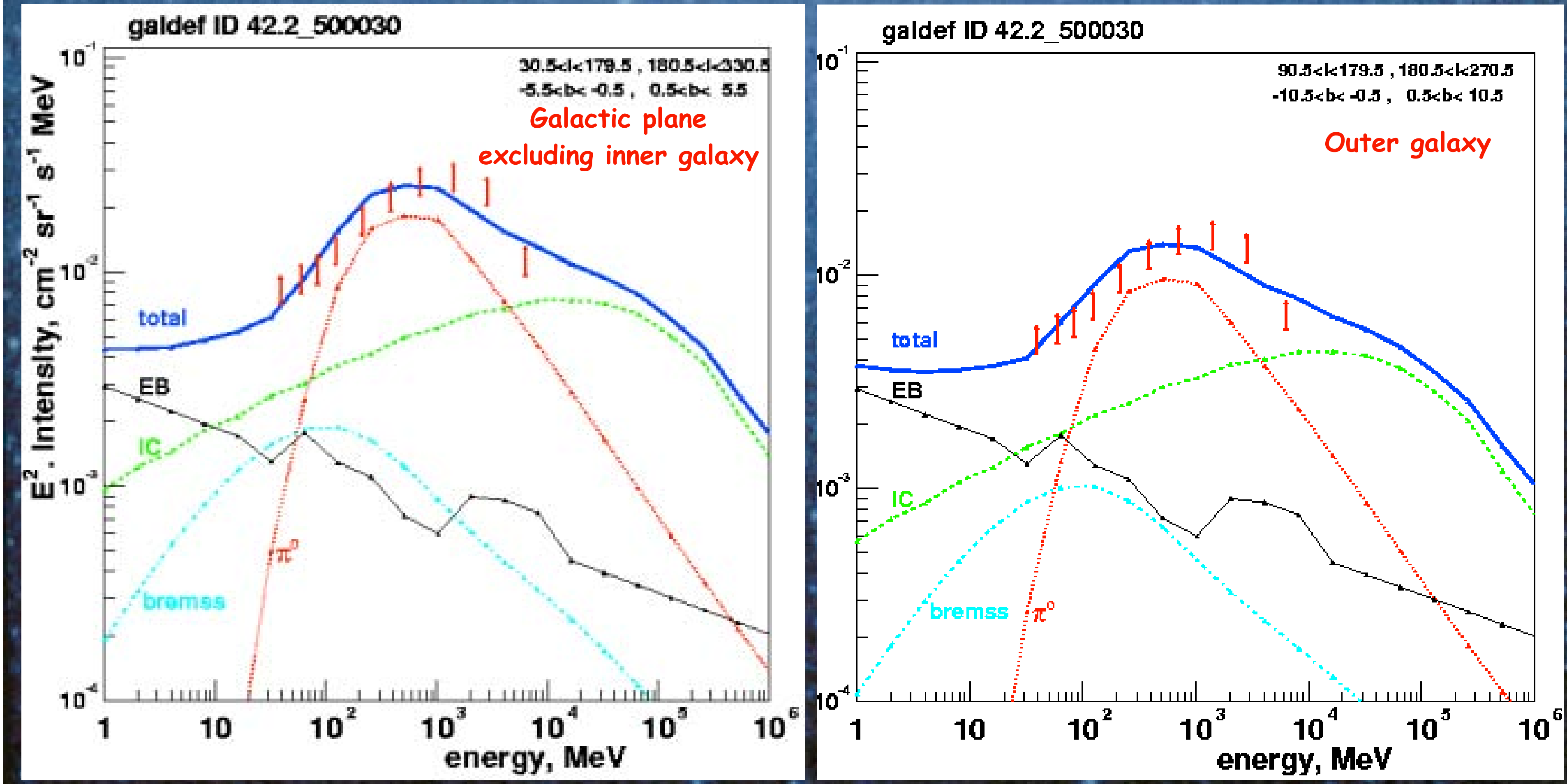
Hard proton spectrum ? : excluded using secondary positrons, antiprotons!

Excess present *also in outer Galaxy and high latitudes*
-> source hypothesis unlikely -> **need hard electron spectrum**

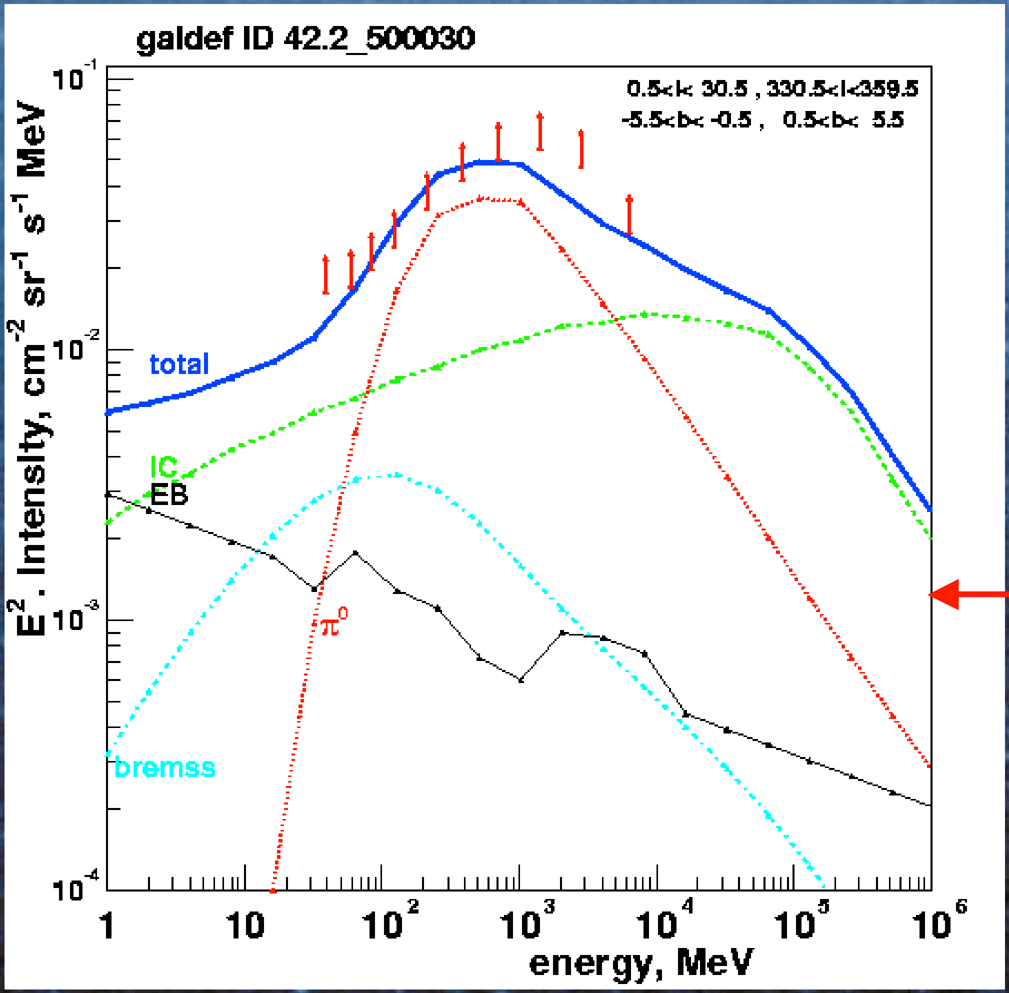




Hard electron injection spectrum improves fit and away from inner Galaxy is satisfactory



Hard electron injection spectrum ($E^{-1.9}$)can improve fit but still require another component for inner Galaxy (SNR ?)



3 TeV cutoff in electron injection

Milagro

20°< l <100°

Milagro, inner Galaxy

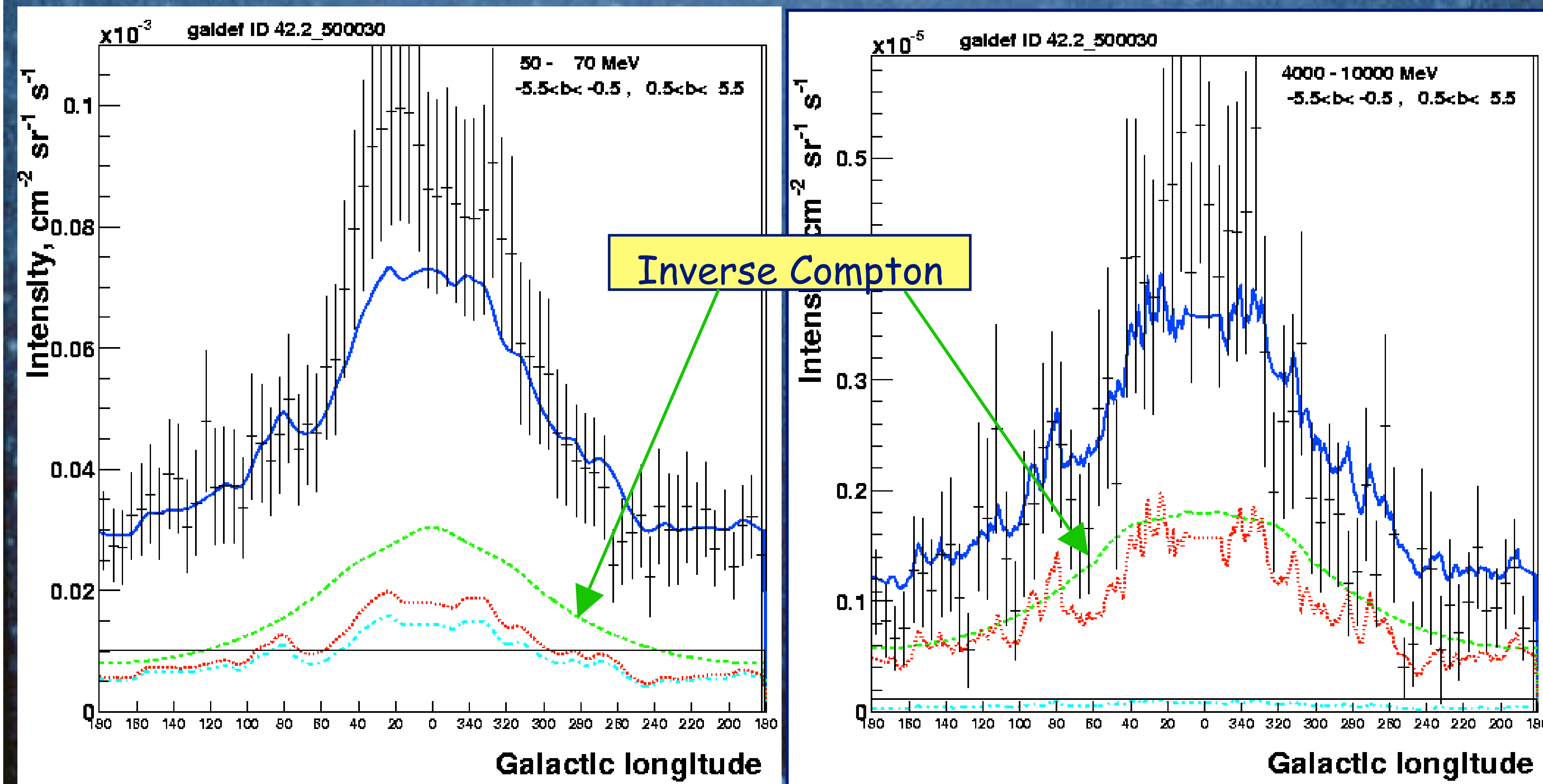
Fleysher 28th ICRC 2003

8 +- 3.3 10^{-10} cm^{-2} sr^{-1} s^{-1} > 1 TeV for $E^{-2.63}$

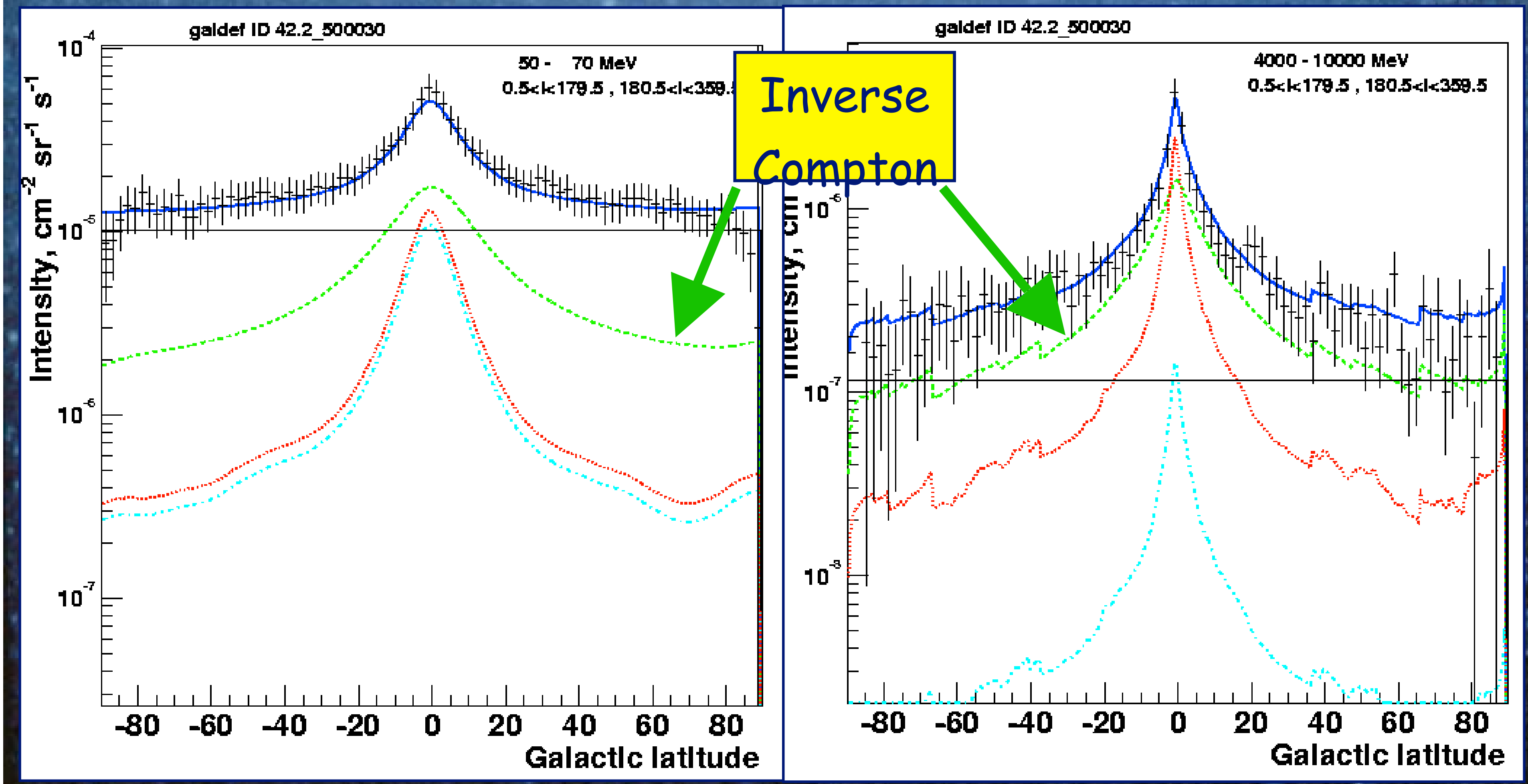
Need cutoff in electrons at few TeV to avoid too much IC

In this scenario, inverse Compton *dominates* at low energies and equals π°-decay at high energies

Testable by GLAST



Latitude distribution can distinguish inverse Compton (also effect on estimates of extragalactic background)

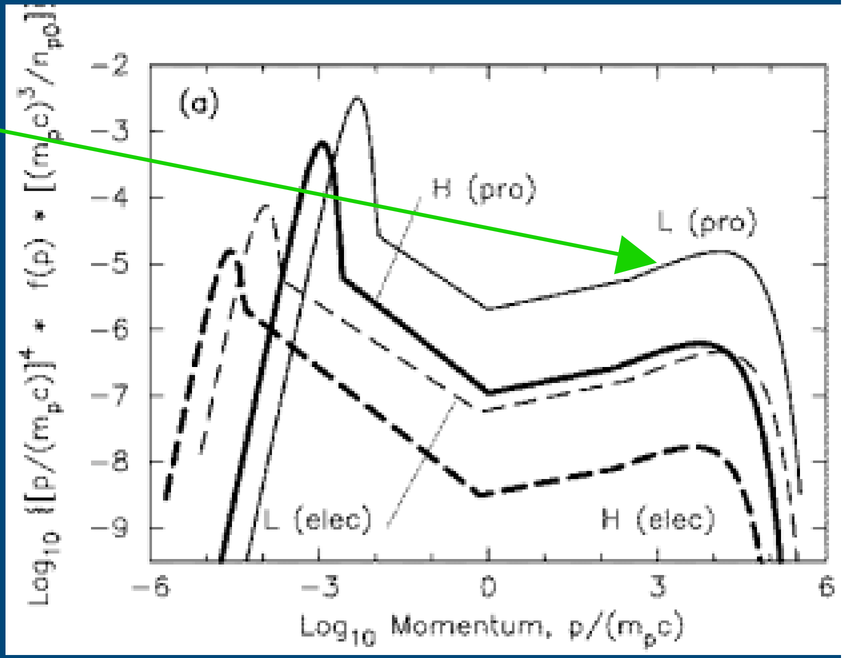


SNR Electron spectra from non-linear shock models by Ellison et al. 2000 ApJ 540, 292:

hard spectrum to ~ TeV

with TeV cutoff

as required by diffuse _-rays!



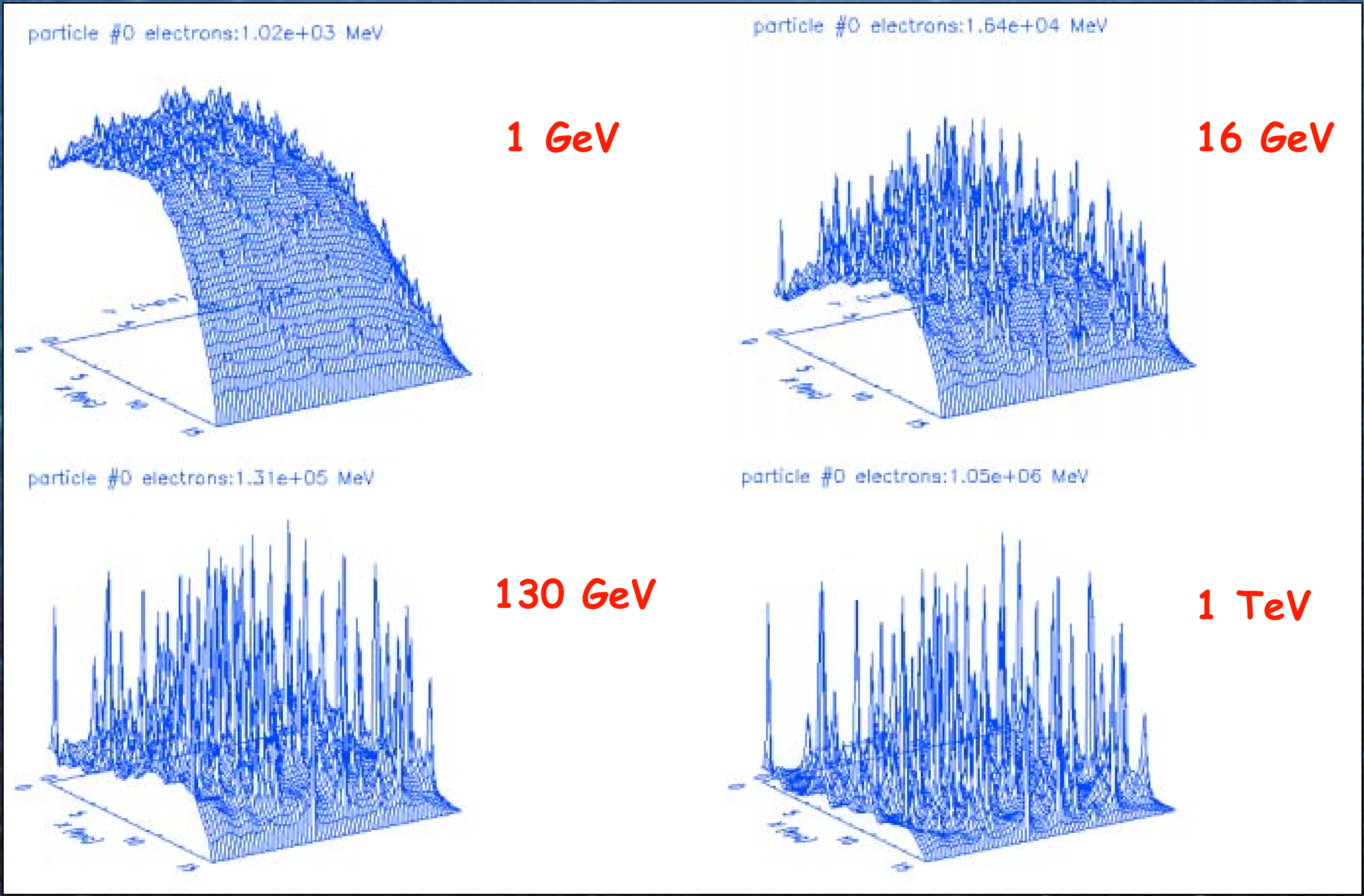
NB

this is spectrum in SNR,

but

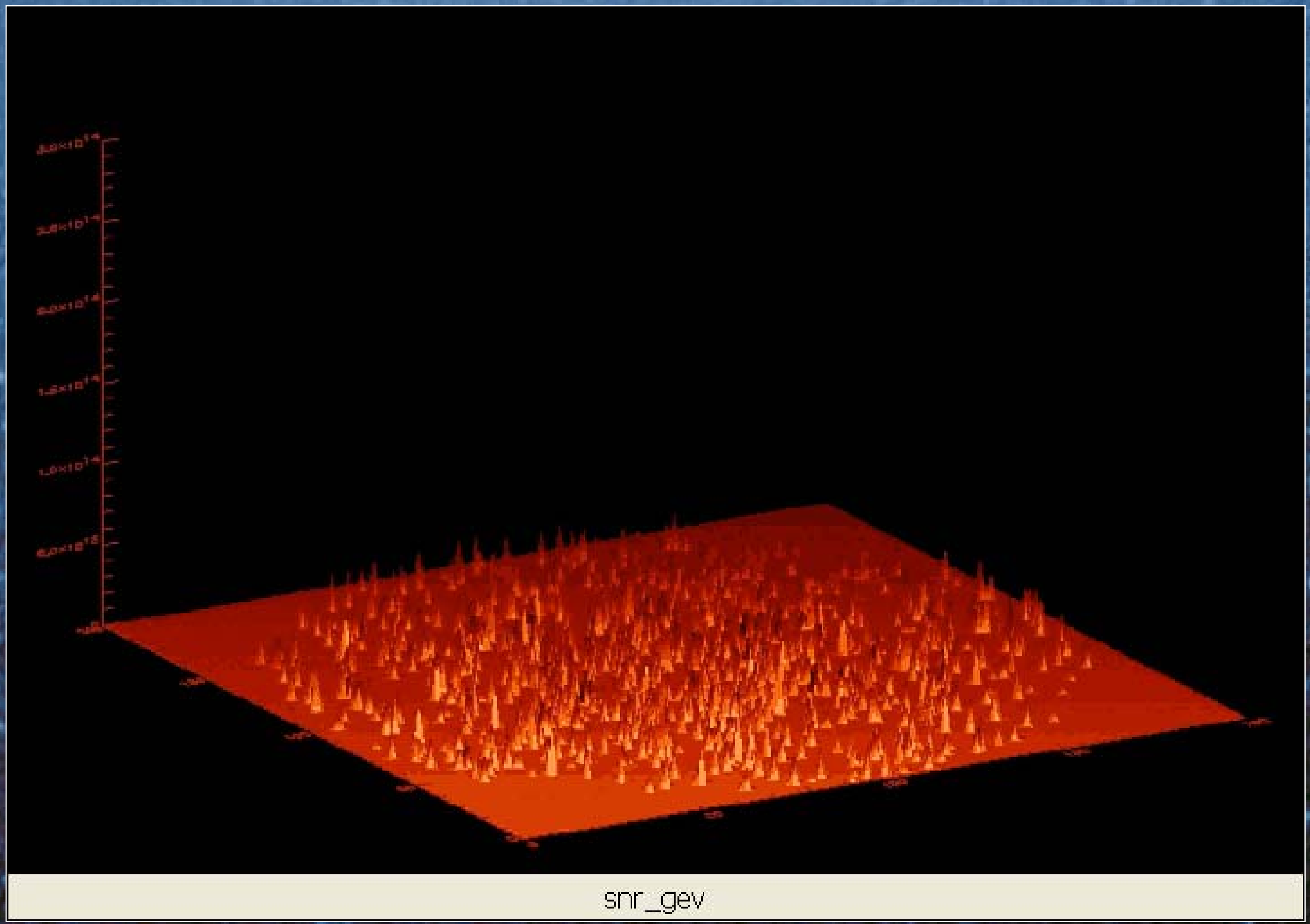
what is spectrum of escaping electrons which give diffuse _-rays?

Effect of stochastic SNR on electron distribution

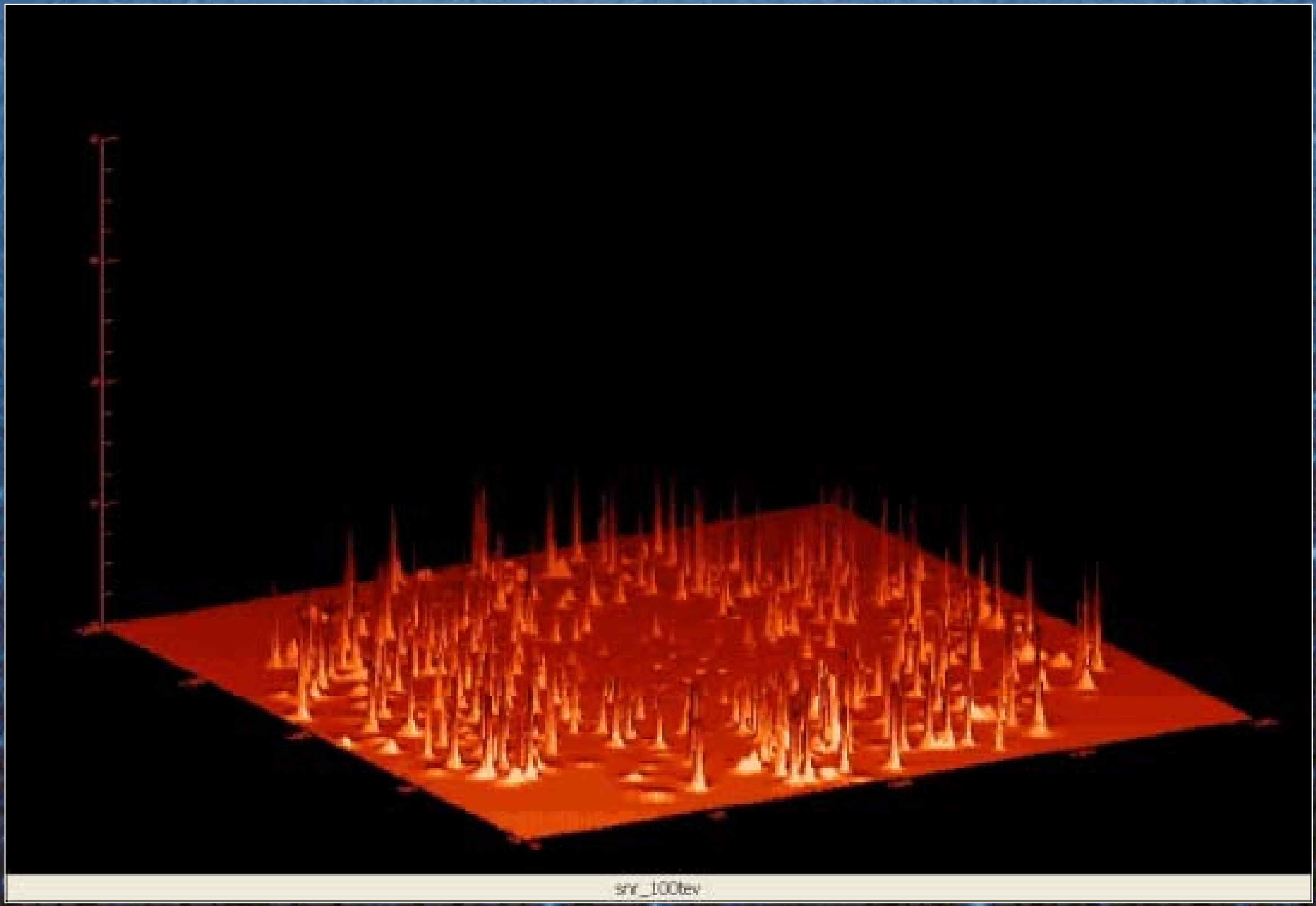


Strong & Moskalenko ICRC2001

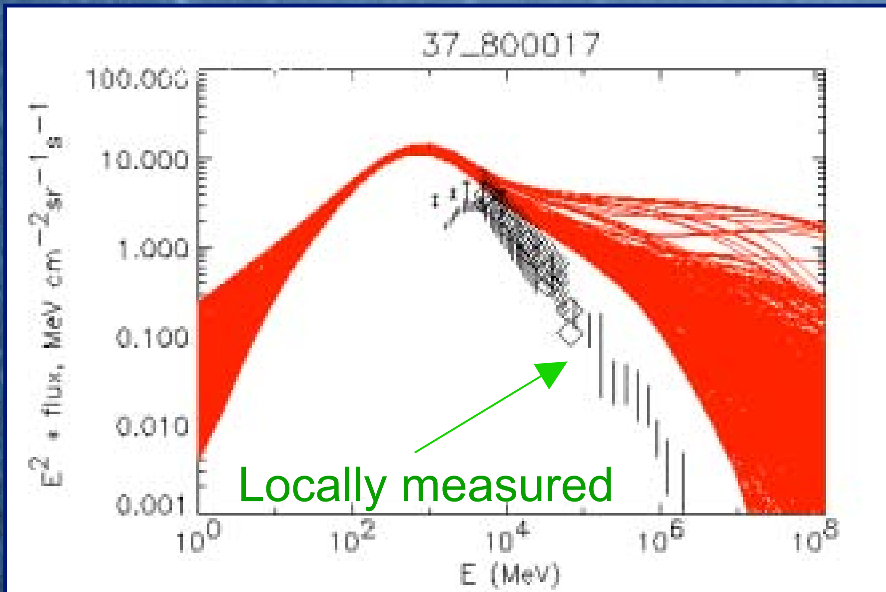
1 GeV electrons
S. Swordy

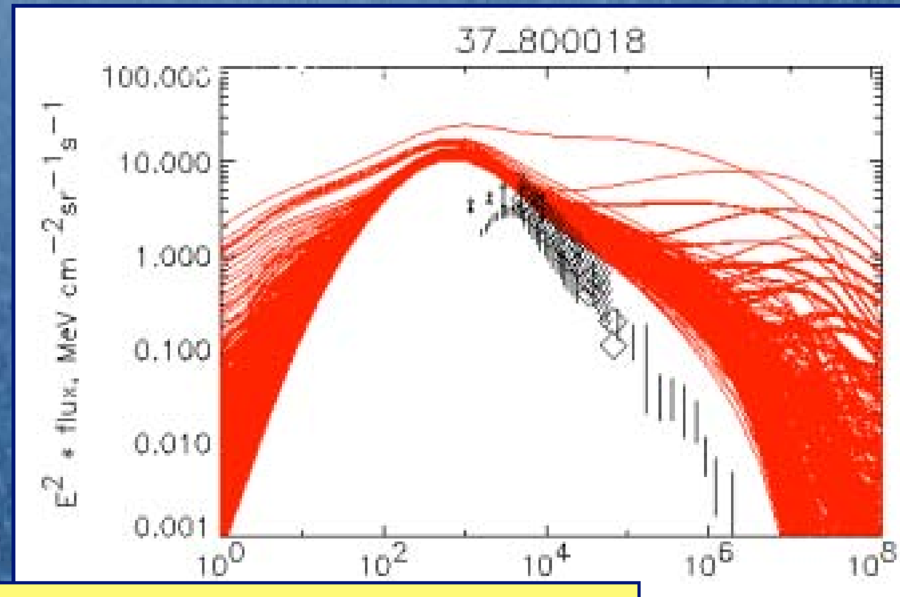


100 TeV electrons
S. Swordy

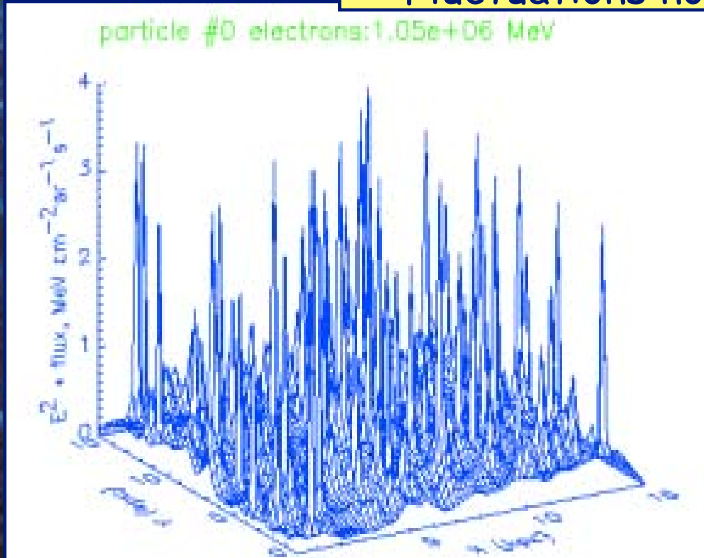


Electron spectrum fluctuates with position



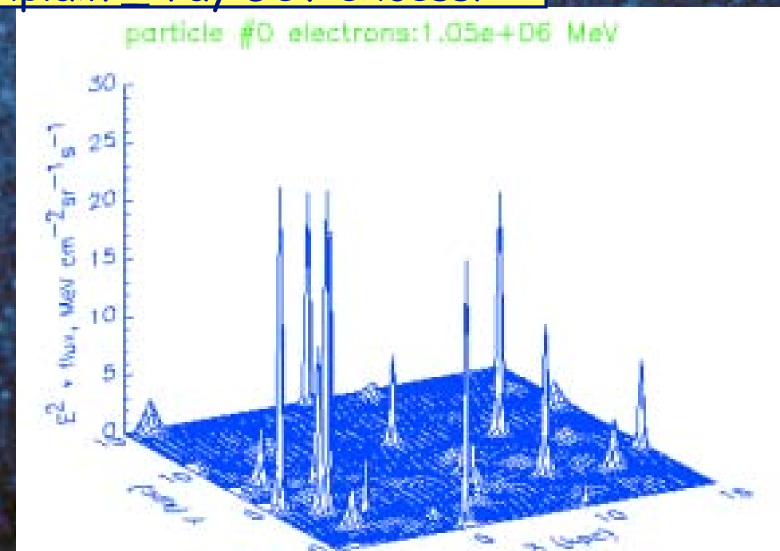


Fluctuations not enough to explain _-ray GeV excess!



High rate $1/10^4$ yr/kpc^3

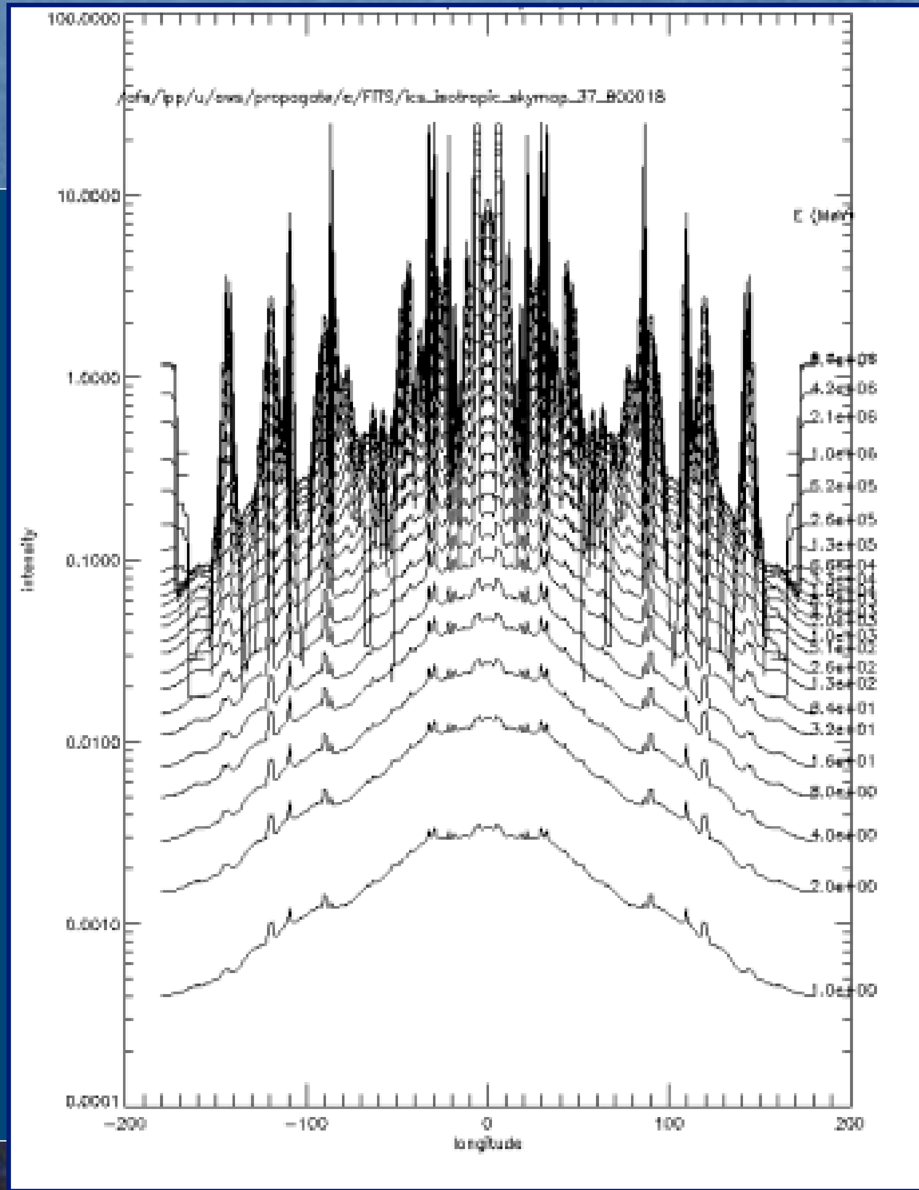
Depending on SN rate



Low rate $1/10^5$ yr/kpc^3

Inverse Compton shows fluctuations reflecting stochastic SNR

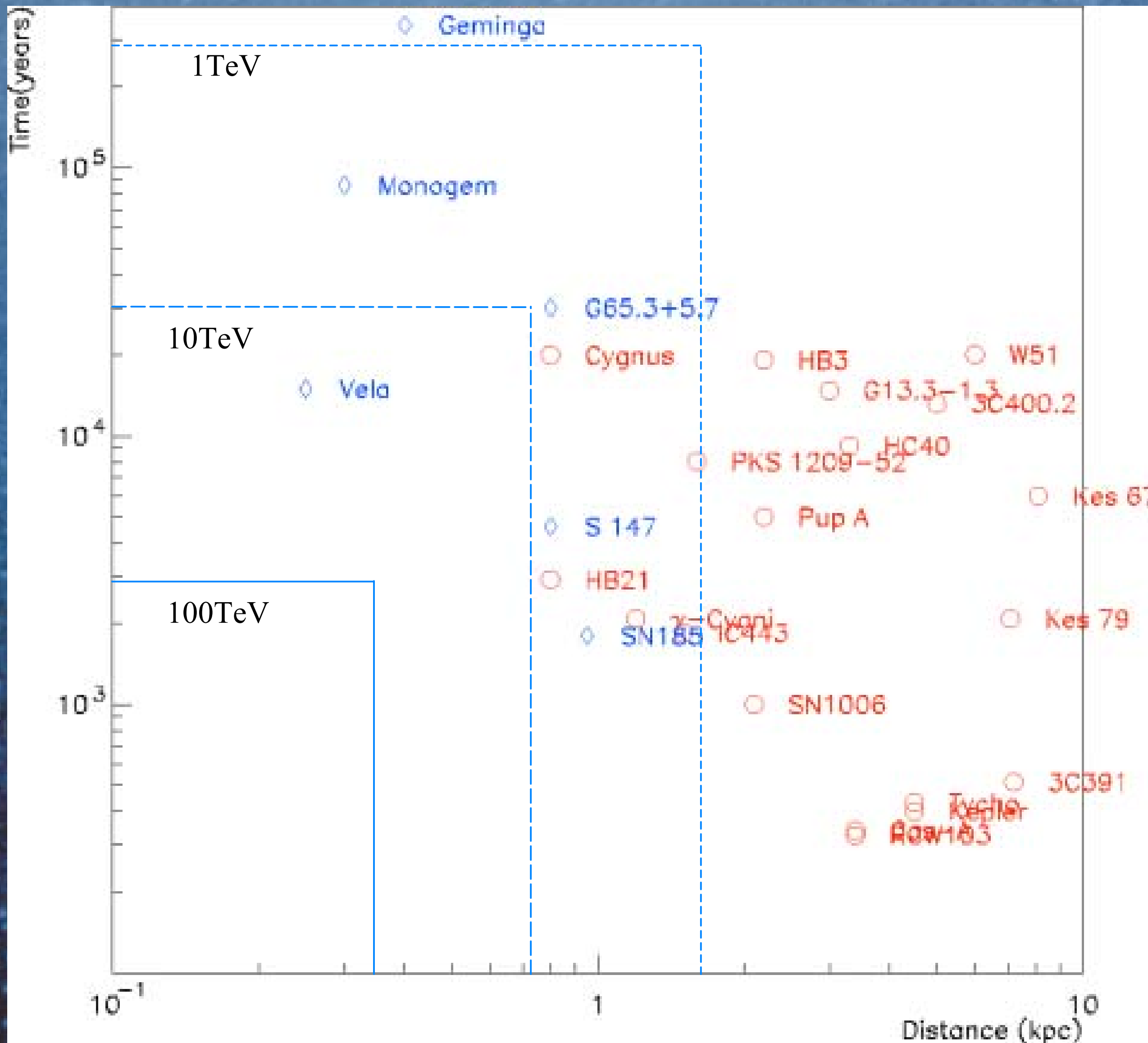
Should be detectable by GLAST



1 TeV

1 GeV

Swordy, ICRC 2003



RED Shell-type (D. Green)

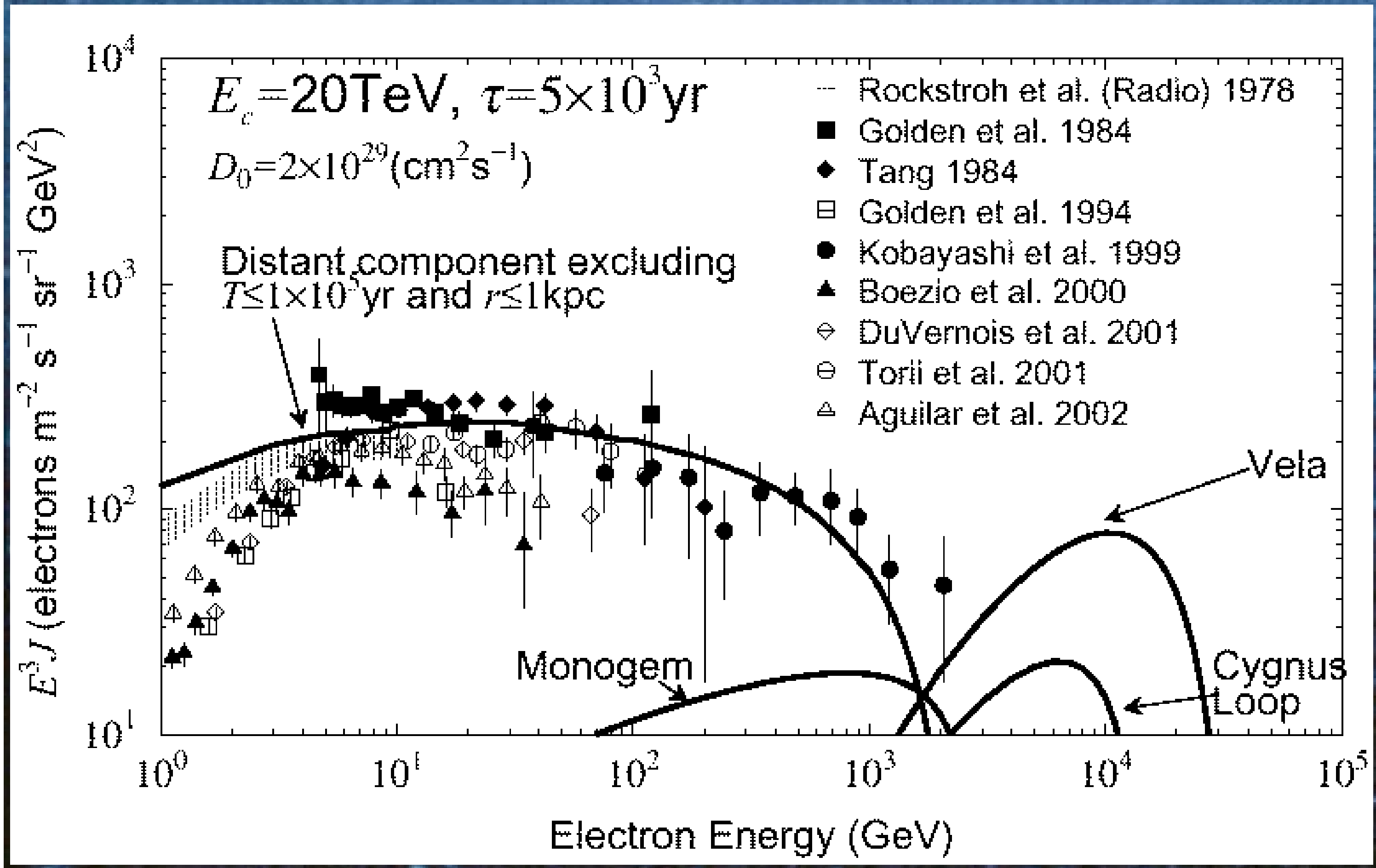
BLUE Plerion-type (Kobayashi et al.)

Electrons from nearby/recent SNR

$r \sim \sqrt{Dt}$ $D \sim E^{0.3\text{-}0.6}$ $dE/dt \sim E^2$

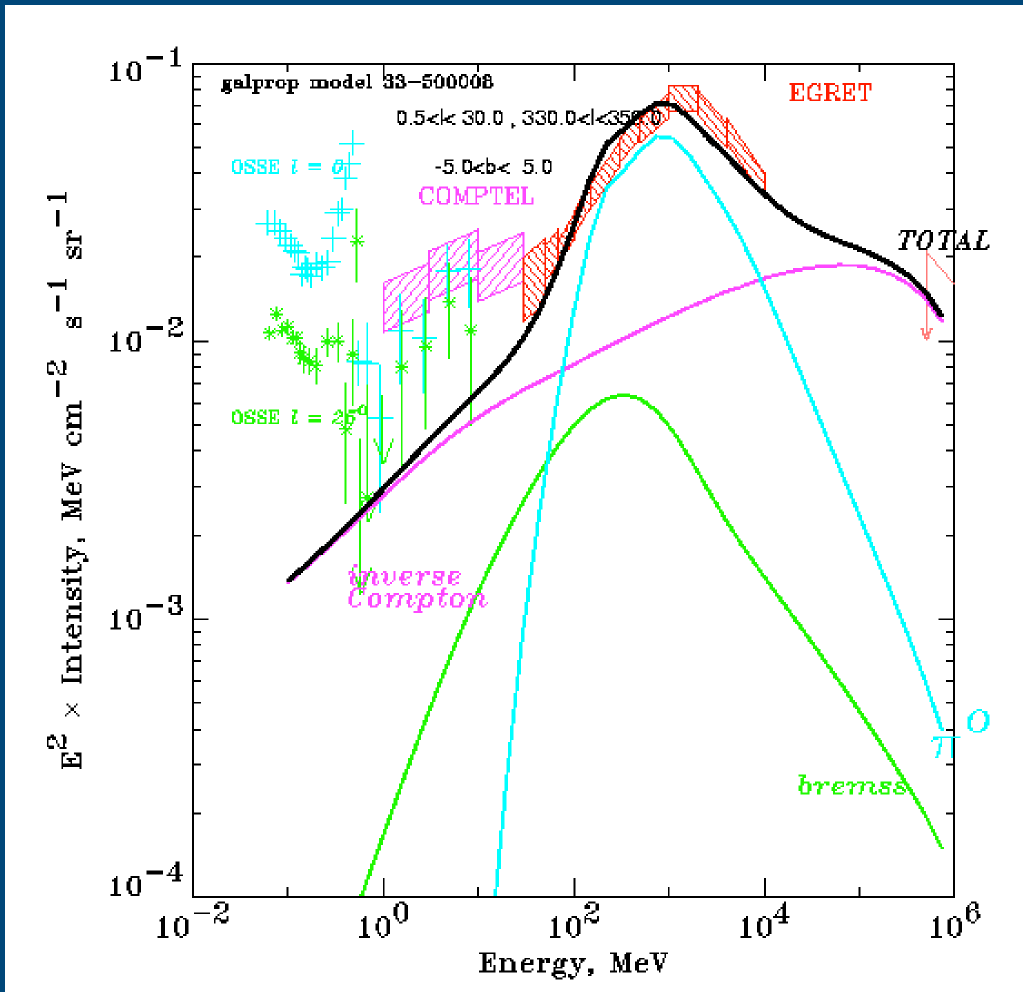
For SNR younger than 10^5 yr only >TeV electrons have reached us even for distance 300 pc. Cutoff by energy losses.

Only Vela, Monogem, Cygnus Loop may give individual signature.



Yoshida
ICRC 2003
Kobayashi
astroph/0308470

LOW ENERGIES < 30 MeV



Electron energy losses large

< 100 MeV ionization

_- rays from bremsstrahlung < 1 GeV, less than originally thought -minor role?

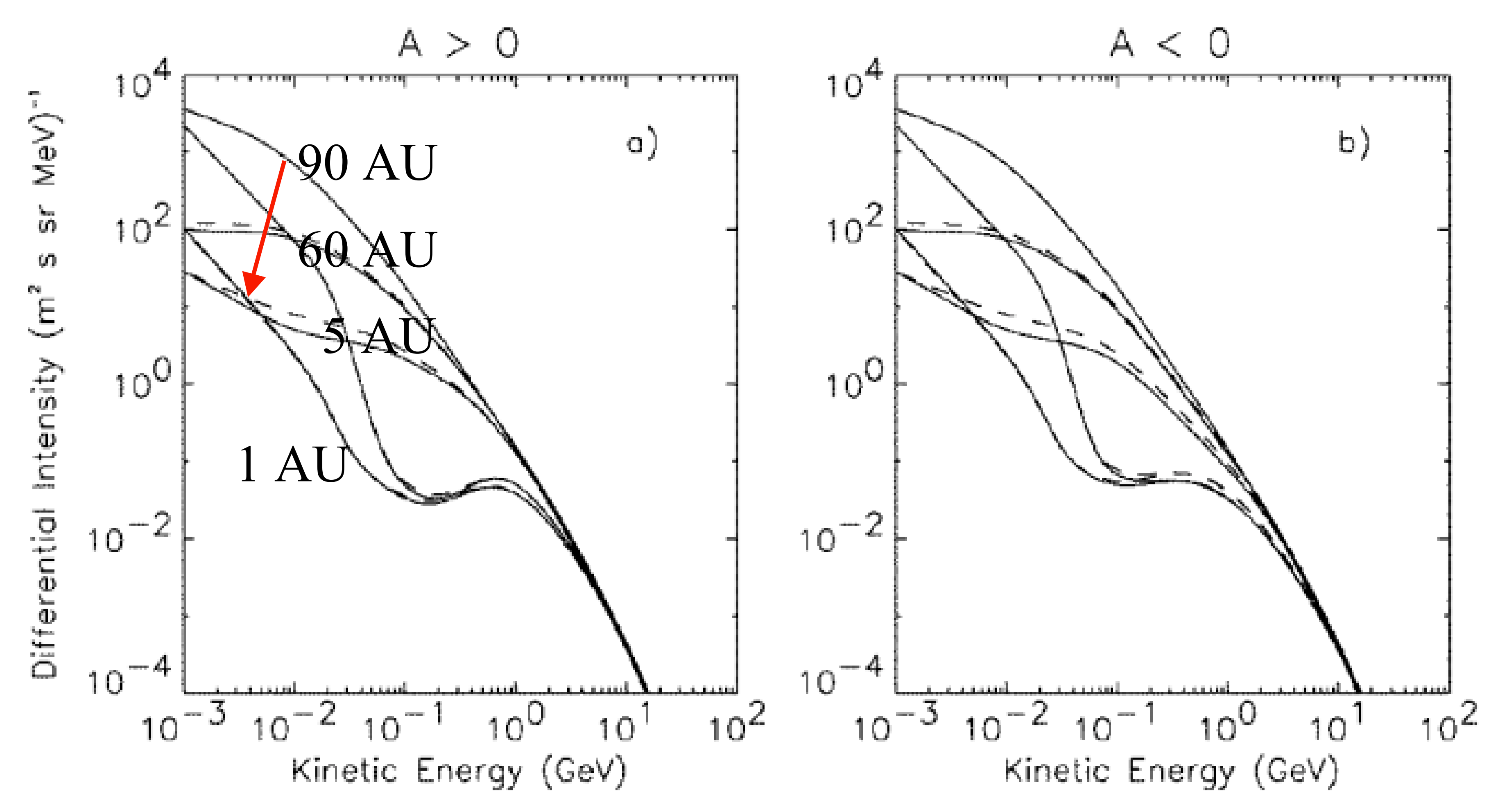
$E_{electron} \sim E_{gamma}$ 10-1000 MeV, hard to observe – solar modulation

interstellar spectrum at low energies

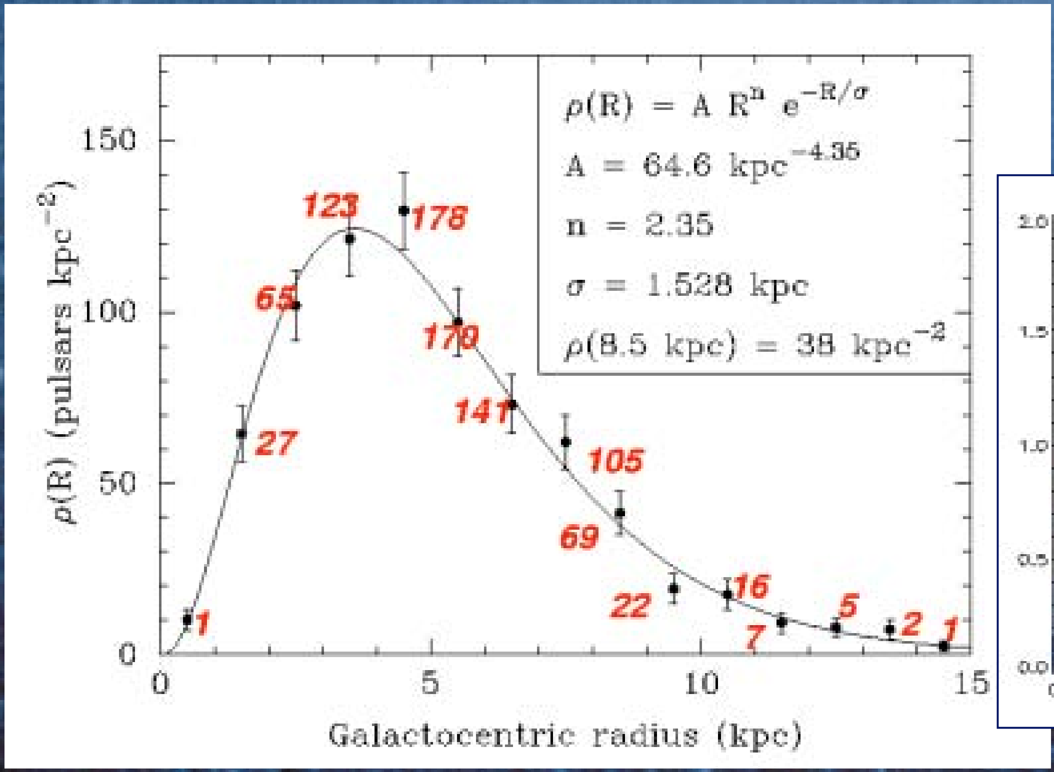
very uncertain

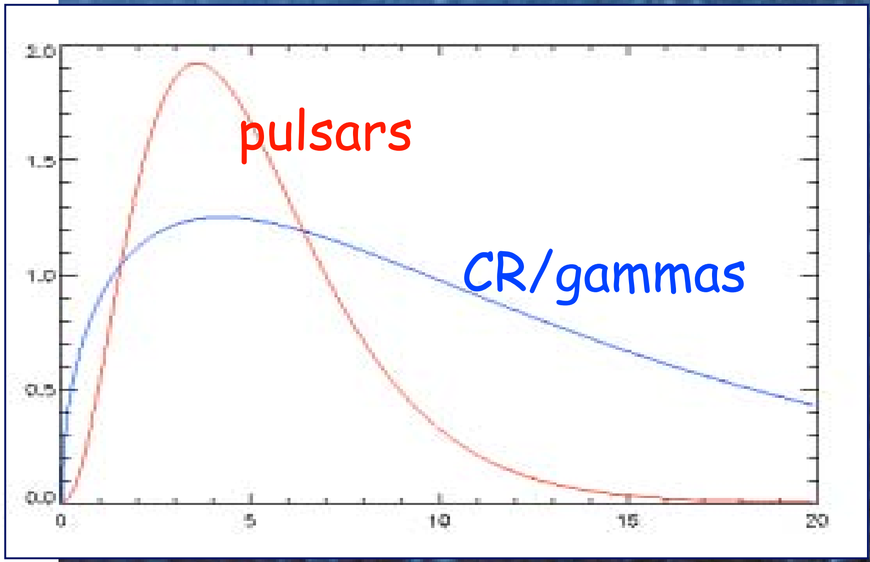
Below 100 MeV not clear if CR or source population

Solar modulation of electrons: Computed electron spectra (Galactic + Jovian) for Ulysses Ferreira et al. 2003 ApJ 594, 552



Pulsar distribution: Lorimer IAU 218, (2004) astroph/0308501
914 pulsars



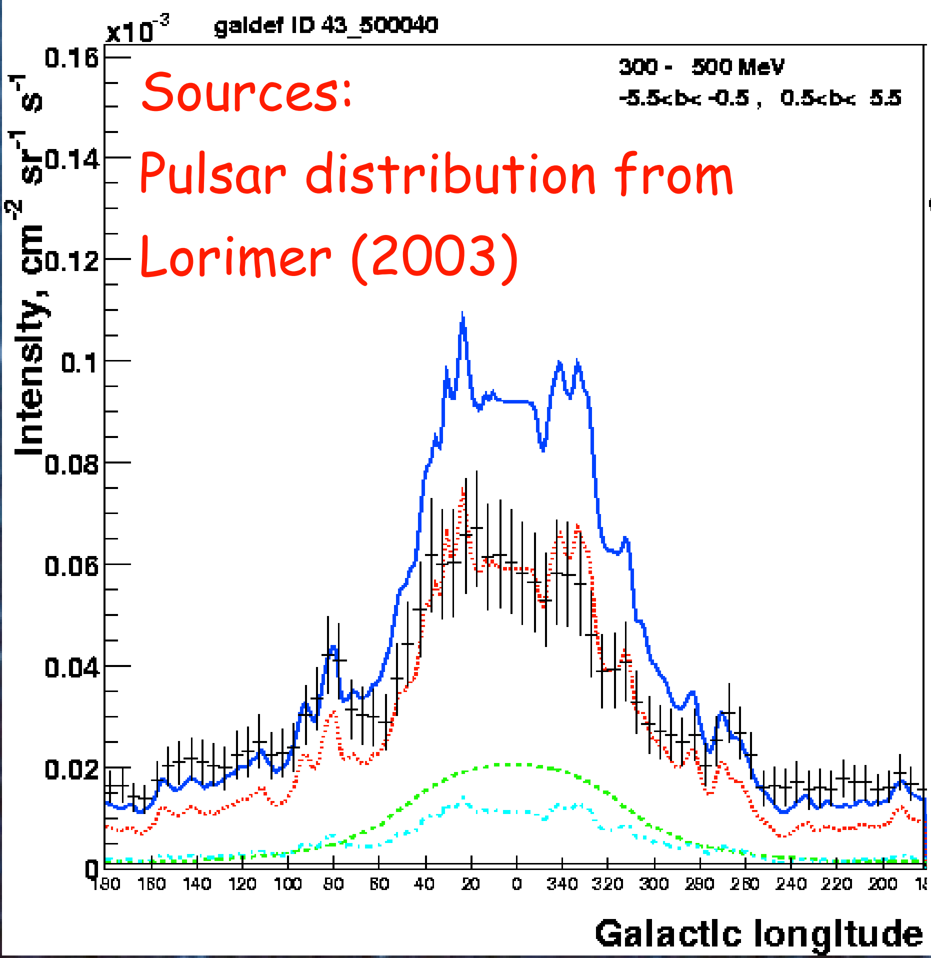


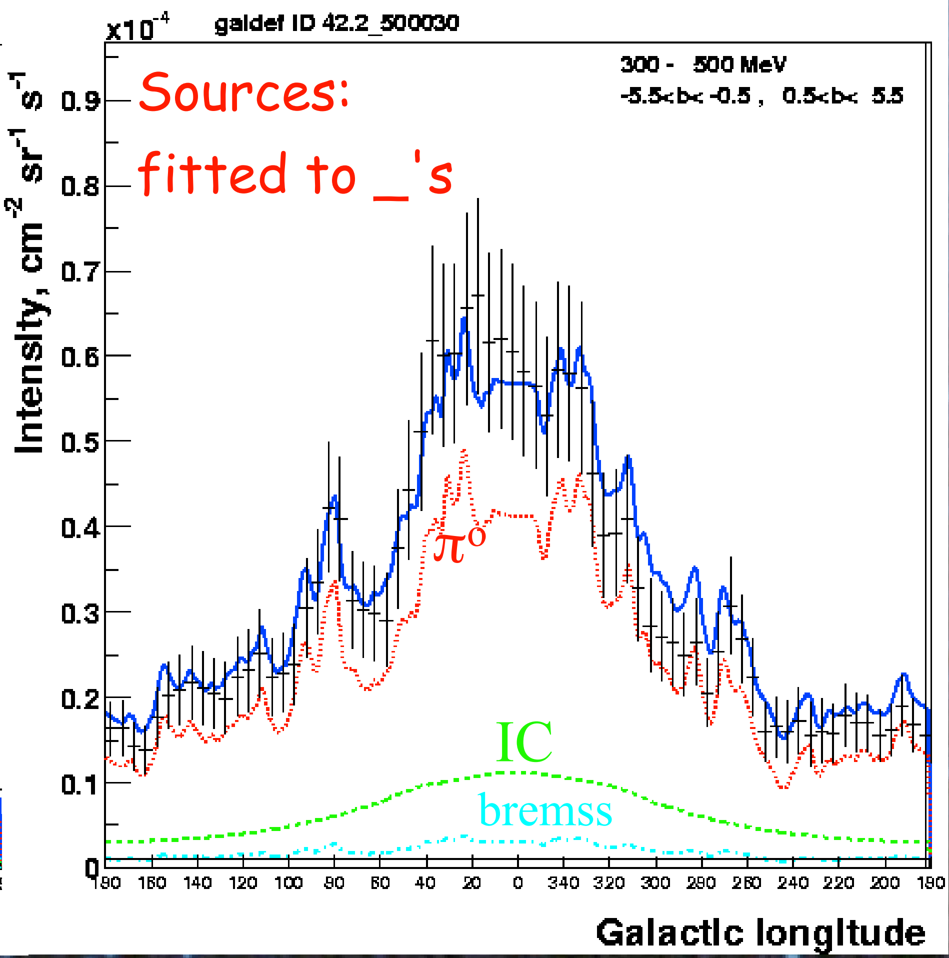
Pulsars max/solar = 3.3 cf. gammas ~ 1

Better determined than SNR.

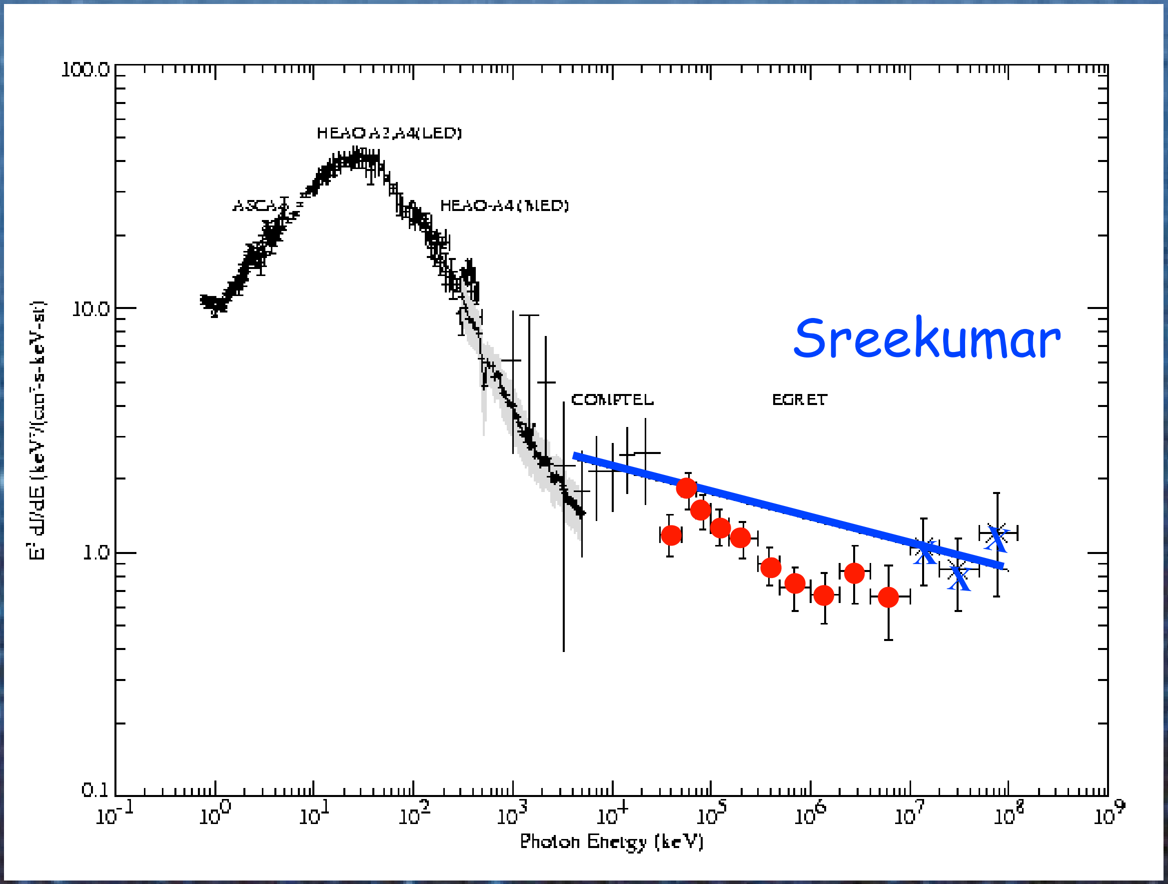
The classical gradient problem for SNR origin is still with us!

Gamma-ray longitude profiles 300-500 MeV





New estimate of extragalactic diffuse spectrum in EGRET range using *galprop* model of Galactic emission



Strong Moskalenko Reimer 2003
28th ICRC astroph/0306345

Difference mainly due to larger Galactic inverse Compton emission


GLAST Workshop, Roma, 17 Sept. 2003
END