Observations of the isotropic diffuse gamma-ray emission with the Fermi Large Area Telescope

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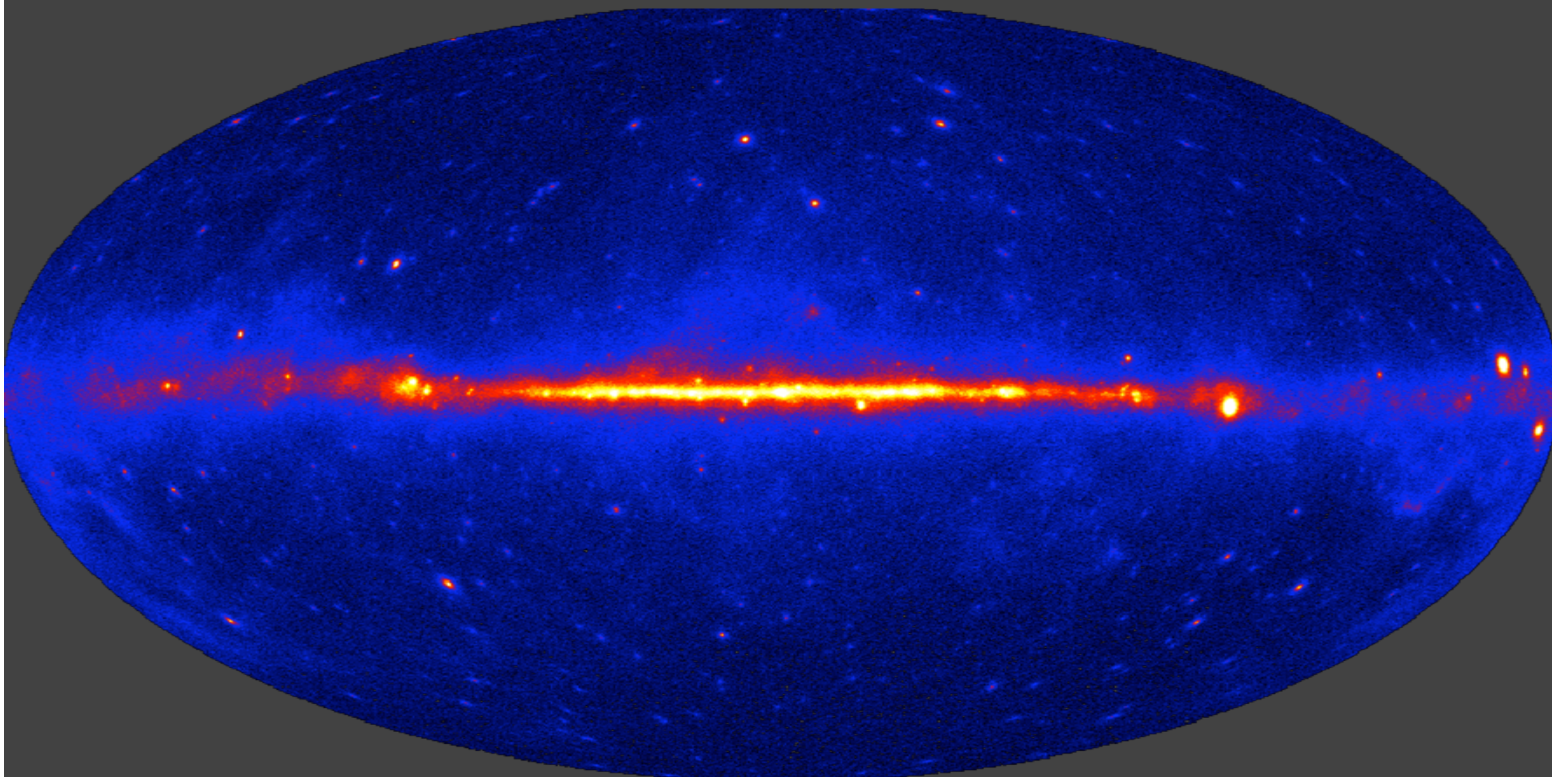
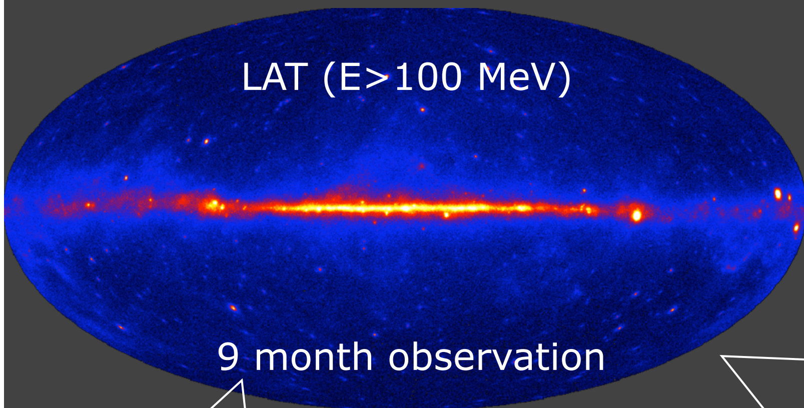


Main contributions to the Fermi gamma-ray sky

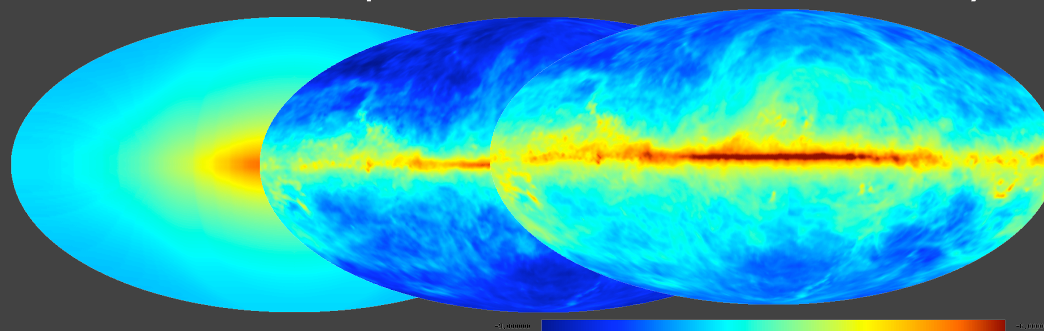


Galactic diffuse emission

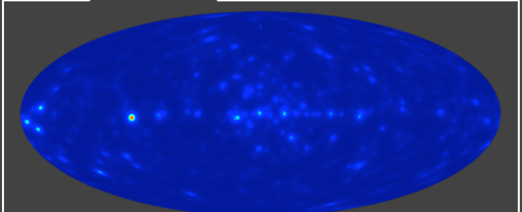
(CR interactions with the interstellar medium)

Inverse Compton

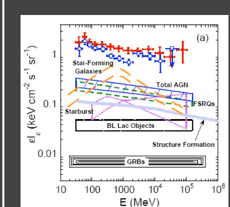
π^0-decay



Bremsstrahlung

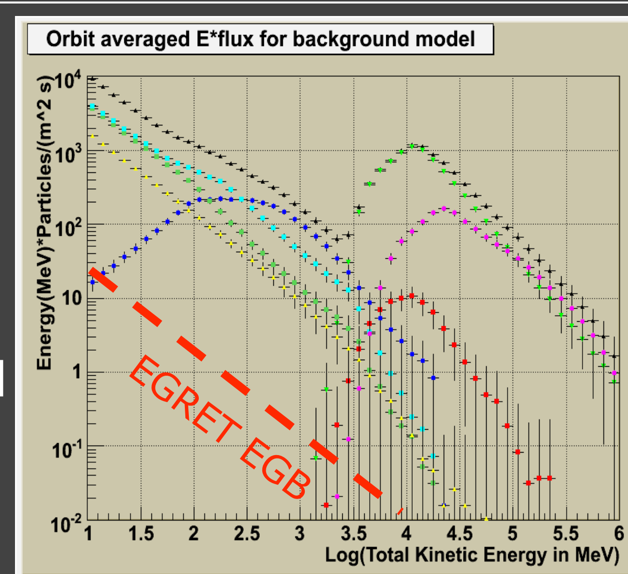


Resolved sources

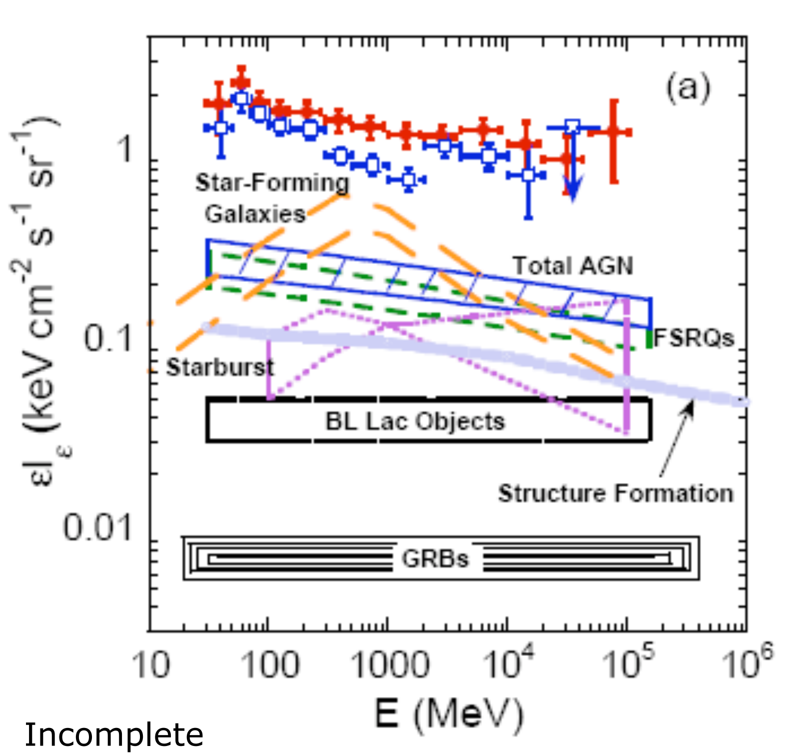


Isotropic diffuse emission

- Residual cosmic rays surviving background rejection filters
- misreconstructed γ-rays from the earth albedo



The isotropic diffuse gamma-ray emission



Incomplete collection of model predictions (Dermer, 2007)

❑ Isotropic diffuse flux contribution from unresolved sources depends on LAT point source sensitivity

→ Contribution expected to decrease with LAT observation time

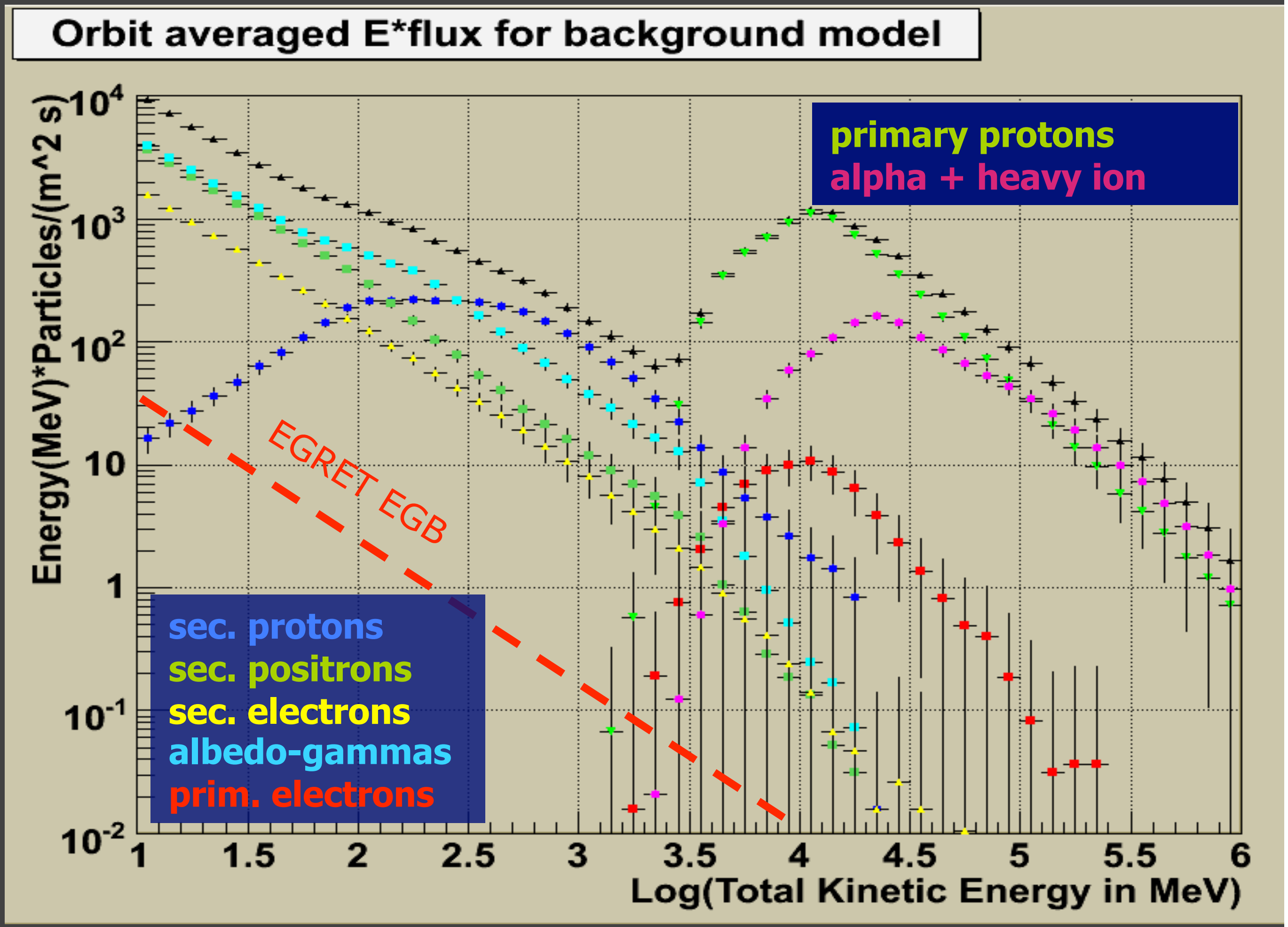
Potential contributions to the isotropic diffuse continuum gamma-ray emission in the LAT energy range (100 MeV-300 GeV):

❑ unresolved point sources
- Active galactic nuclei (see talk by M. Ajello)
- Star-forming galaxies
- Gamma-ray bursts

❑ diffuse emission processes
- UHE cosmic-ray interactions with the Extragalactic Background Light
- Structure formation
- large Galactic electron halo
- WIMP annihilation

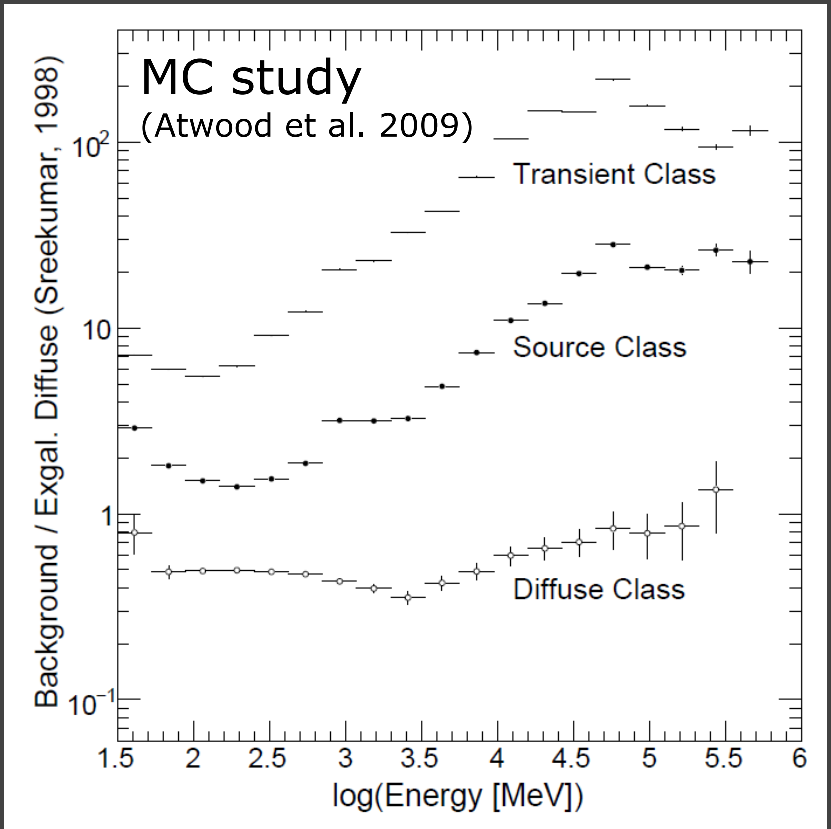
Cosmic-ray background

- Primary cosmic-rays + secondary CR produced in earth atmosphere
- Charged and neutral cosmic-rays outnumber celestial gamma-rays by many orders of magnitude
- CR contamination strongly suppressed by Anti-coincidence detector (ACD) veto and multivariate analysis of event properties



- Residual CR produce unstructured, quasi-isotropic background (after sufficient observation time)

Data selection for the analysis of the isotropic flux



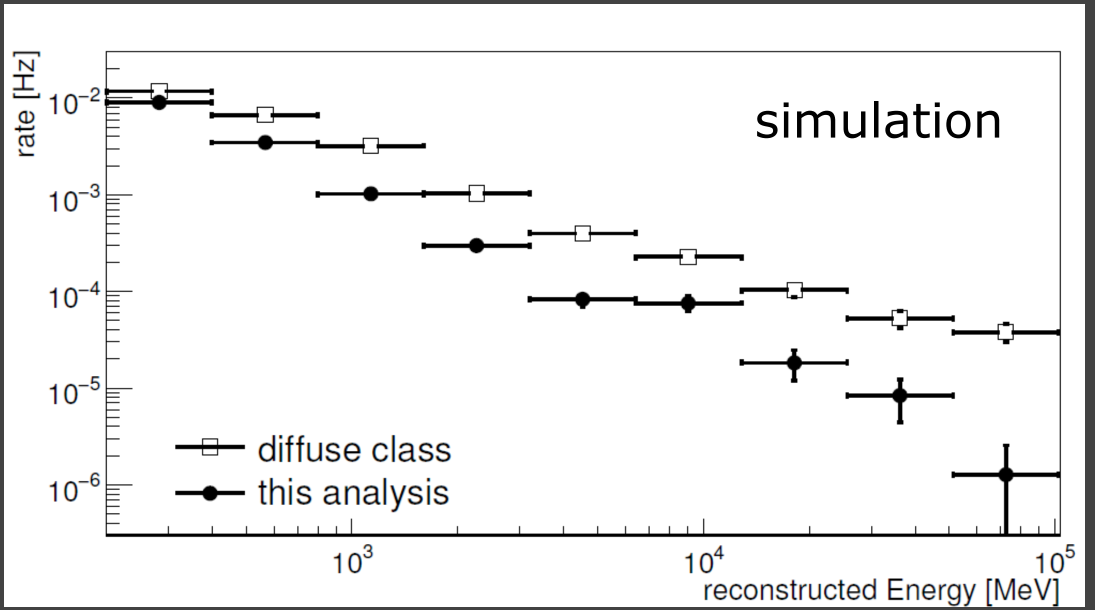
- LAT standard event classes:

Event class	Background contamination
transient	<~ 100 x EGRET EGB flux
source	<~ 20 x EGRET EGB flux
diffuse	<~ 1 x EGRET EGB flux

- 3 event classes defined in standard LAT event selection
- LAT isotropic flux expected to be below EGRET level (factor »10 improvement in point source sensitivity)
- LAT on-orbit background higher than predicted from pre-launch model
- More stringent background rejection developed for this analysis
- Event parameters used:
  - Shower shape in Calorimeter
  - Charge deposit in Silicon tracker
  - Gamma-ray probability from classification analysis
  - Distance of particle track from LAT corners

Performance of the dedicated event selection

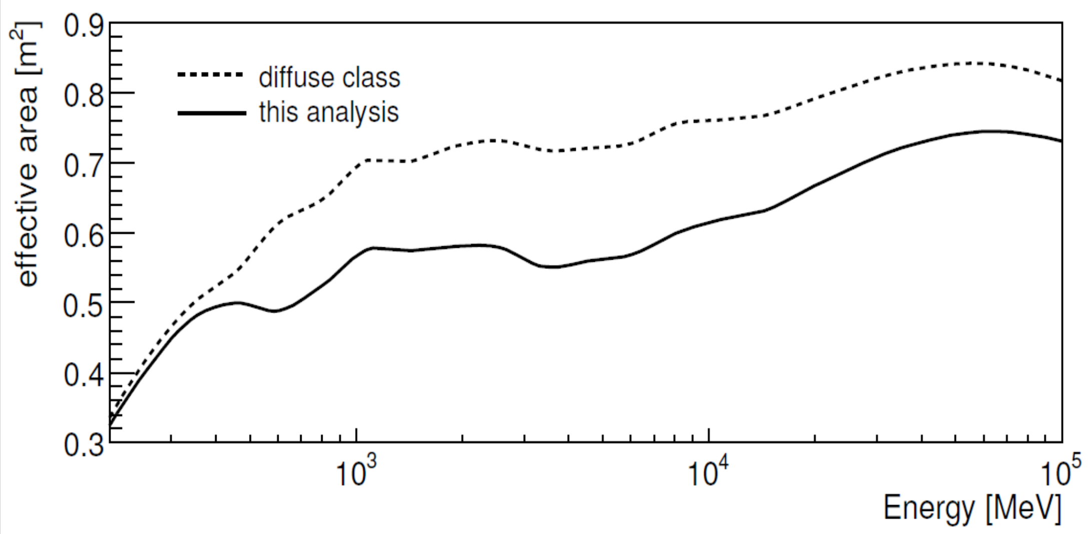
- Improved residual background suppression compared to diffuse class



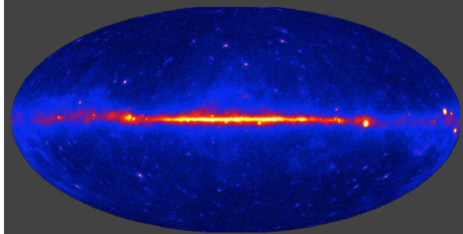
- Improved agreement between simulation and data from rejection of hadronic shower and heavy ions

  Uncertainty: +50%/-30%

- Retained effective area for γ-rays



Analysis technique



LAT sky

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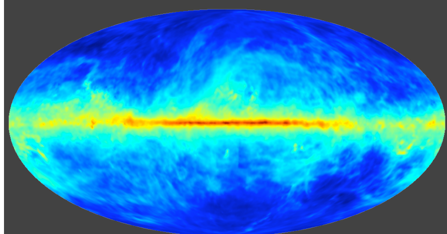
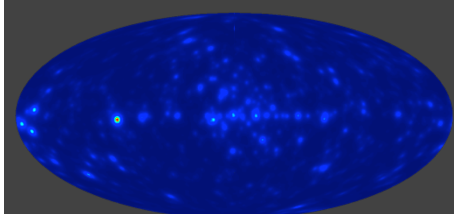


gal. diffuse

+



point sources

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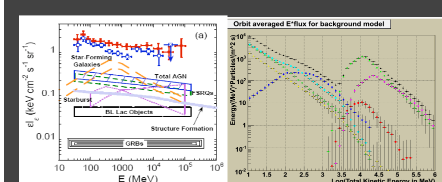


isotropic

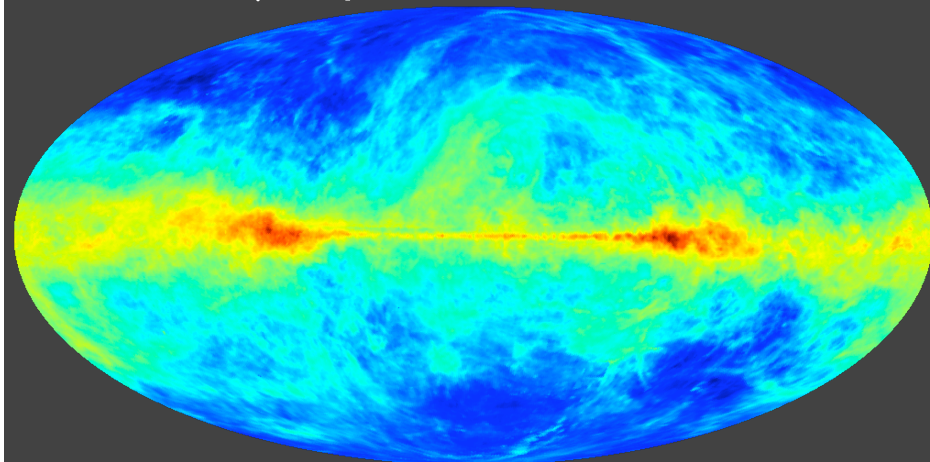
- **Pixel-by-pixel max. likelihood fit** of |b|>10º sky
  - equal-area pixels with ~ 0.8 deg^2 (HEALPIX grid)
  - sky-model compared to LAT data
  - point source /diffuse intensities fitted simultaneously
  - 9 independent energy bins, 200 MeV - 100 GeV
  - 10 month of LAT data, 19 Ms observation time

- **Sky model:**
  - Maps of Galactic foreground γ-rays considering individually contributions from IC and local HI
  - Individual spectra of TS>200 (~>14σ) point sources from LAT catalog
  - Map of weak sources from LAT catalog
  - Solar IC and Disk emission
  - Spectrum of isotropic component

- **Subtraction of residual background** (derived from Monte Carlo simulation) from isotropic component

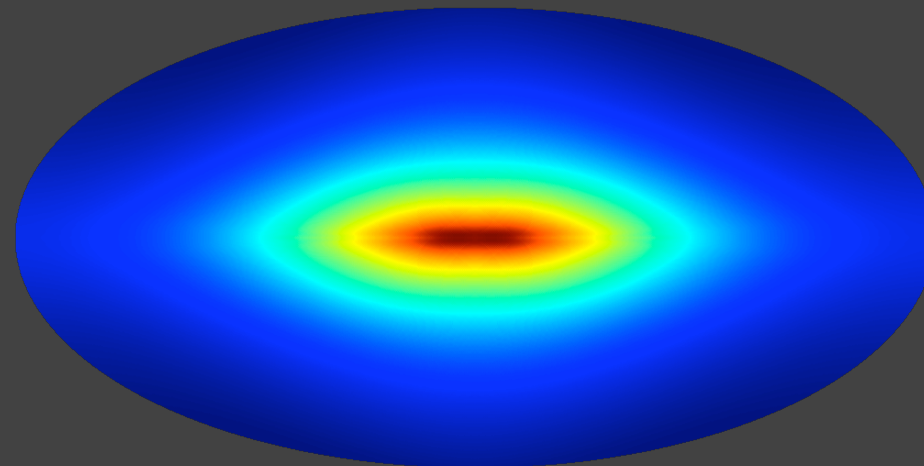
Model of the Galactic foreground

γ-ray emission model



HI (7.5kpc < r < 9.5kpc)

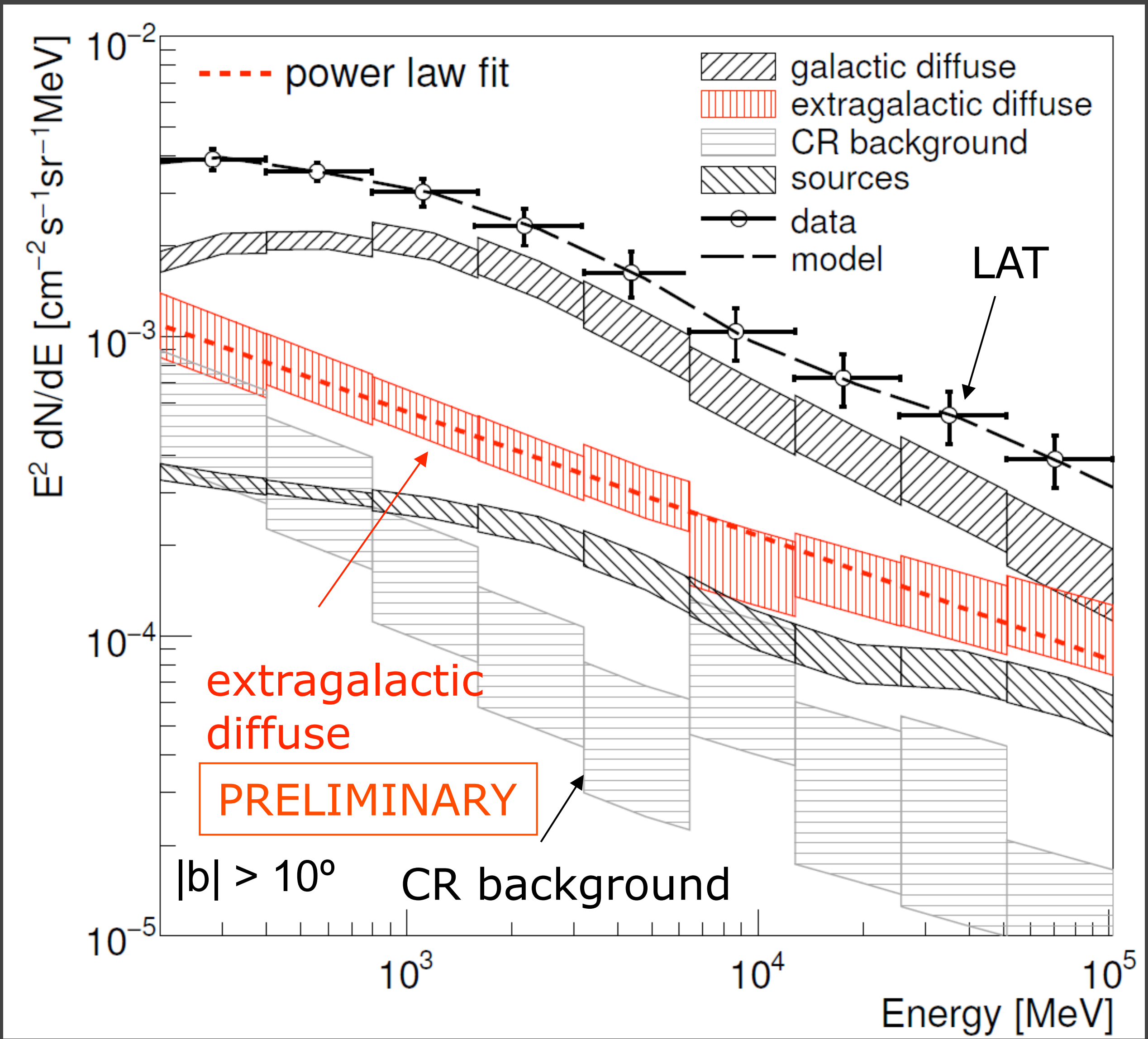
γ-ray emission model



Inverse Compton scattering

- Diffuse gamma-ray emission of Galaxy modeled using GALPROP
- Spectra of dominant high-latitude components fit to LAT data:
  - Inverse Compton emission (isotropic ISRF approximation)
  - Bremsstrahlung and π^0-decay from CR interactions with local (7.5kpc < r < 9.5kpc) atomic hydrogen (HI)
- HI column density estimated from 21-cm observations and E(B-V) magnitudes of reddening
- 4 kpc electron halo size for Inverse Compton component (2kpc - 10kpc tested)

The LAT isotropic diffuse flux (200 MeV – 100 GeV)



error bars / bands:
statistical error + LAT effective area uncertainty + residual background contamination uncertainty

- Spectrum can be fitted by power law:
  $\gamma = 2.41 +/- 0.05$
- Flux above 100 MeV:
  $F_{100} = 1.03 +/- 0.17 \times 10^{-5}$ cm^{-2} s^{-1} sr^{-1}
  (extrapolated)
- Foreground modeling uncertainty not included in error bands

Systematic uncertainties from foreground modeling

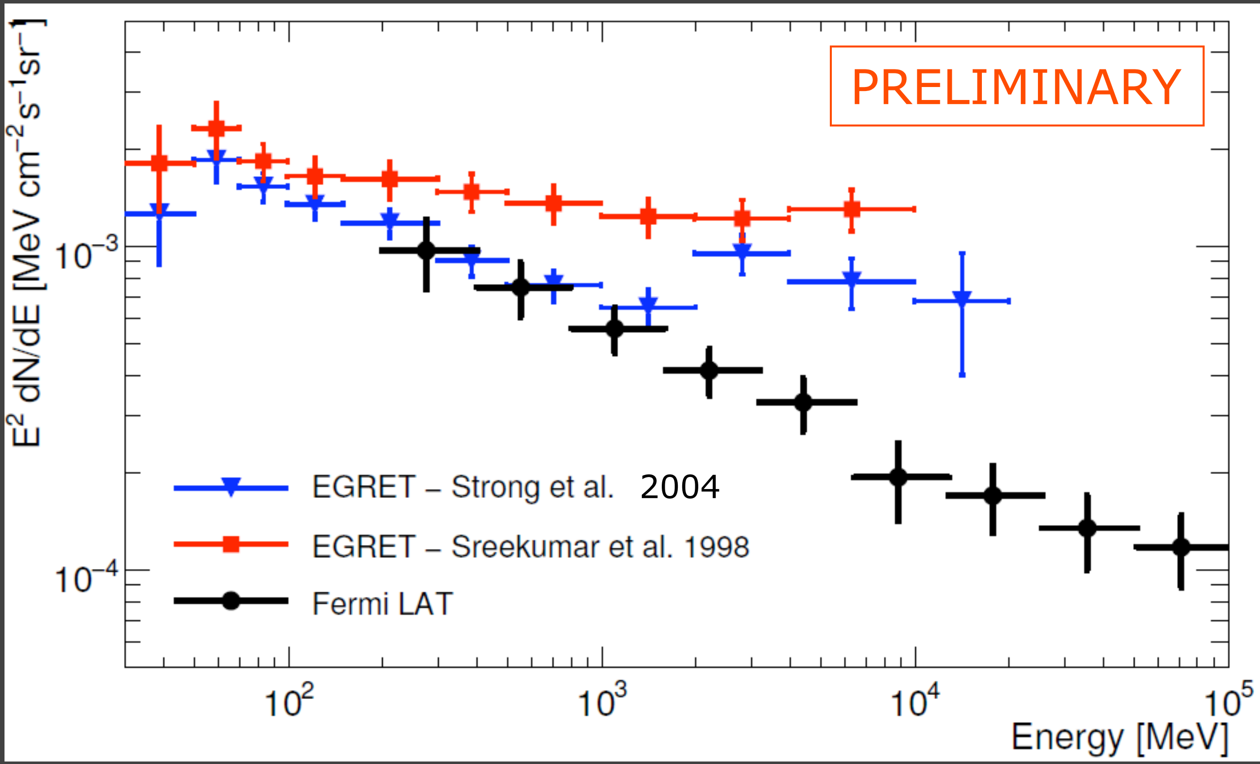
- RMS of residual map (averaged over 13.4 deg^2 bins) is 8.2%,
  3.3 % expected from statistics
- Residuals show some correlation to structures seen in the galactic foreground emission
  → Foreground model is not perfect.

- Impact of foreground model variations on derived EGB intensity studied:

Flux in band	200 MeV – 400 MeV	1.6 GeV - 3.2 GeV	51 GeV – 102 GeV
Extragalactic	**2.4 +/- 0.6**	**12.7 +/- 2.1**	**11.1 +/- 2.9**
HI column density	+0.1 / -0.3	+0.1 / -3.6	+0.1 / -1.1
Halo size + IC	+0.1 / -0.3	+0.1 / -1.8	+2.9 / -0.5
CR propagation model	+0.1 / -0.3	+0.1 / -0.8	+3.0 / -0.1
Subregions of |b|>10	+0.2 / -0.3	+1.9 / -2.1	+2.7 / -0.9
	x 10^{-6} cm^{-2} s^{-1} sr^{-1}	x 10^{-8} cm^{-2} s^{-1} sr^{-1}	x 10^{-10} cm^{-2} s^{-1} sr^{-1}

- Table items are NOT independent and cannot be added to provide overall modeling uncertainty

Comparison with EGRET results



- Considerably steeper than the EGRET spectrum by Sreekumar et al.
- No spectral features around a few GeV seen in re-analysis by Strong et al.

	Flux, E>100 MeV	spectral index
LAT (this analysis)	**1.03 +/- 0.17**	**2.41 +/- 0.05**
EGRET (Sreekumar et al., 1998)	1.45 +/- 0.05	2.13 +/- 0.03
EGRET (Strong et al. 2004)	1.11 +/- 0.10	
LAT + resolved sources below EGRET sensitivity	1.19 +/- 0.18	2.37 +/- 0.05
	x 10^{-5} cm^{-2} s^{-1} sr^{-1}	

Summary

- A new low-background data selection was developed to obtain a measurement of the EGB. This data selection will be made public with the next update of the Fermi event classification.
- The EGB found by the LAT is compatible with a simple power law of index 2.41+/-0.05 between 200 MeV and 100 GeV.
- It is softer than the EGRET spectrum and does not show distinctive peaks (compared at EGRET sensitivity level).
- ~ 15% of the EGRET EGB is resolved into sources by the LAT.
- From Blazar population study: ~20%-30% of LAT EGB is due to unresolved Blazars (see M. Ajello's talk).
- Ongoing work to extend the energy range and reduce systematic uncertainties of this measurement.

Cosmic Ray background in data and simulation

- Sample A: events classified as γ-rays by on-board filters, |b|>45 deg
- Sample B: events accepted in medium purity ("source"), but rejected in high purity ("diffuse") standard event class, |b|>45 deg

Both samples are strongly dominated by CR background !

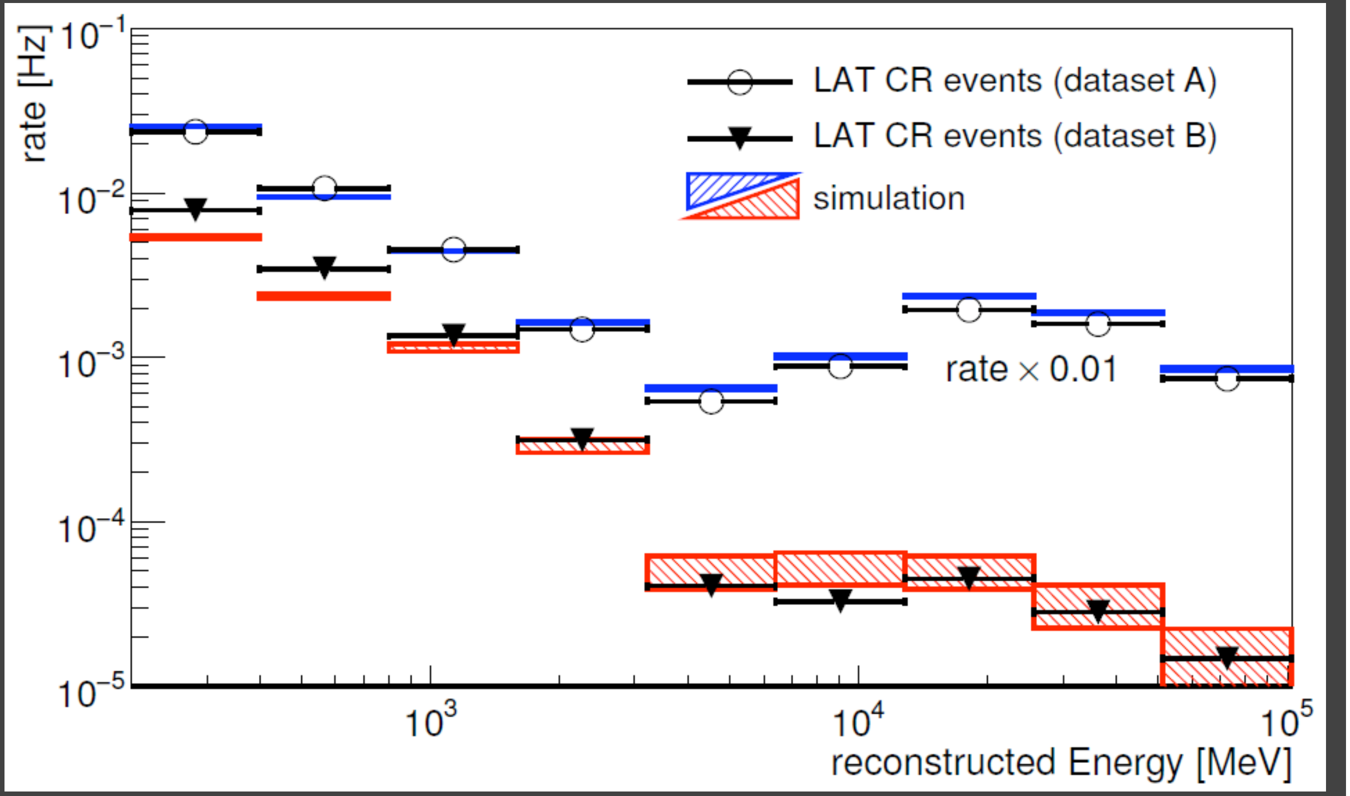
Sample A → bulk of the CR background

Sample B → extreme tails of CR distribution which mimic γ-rays

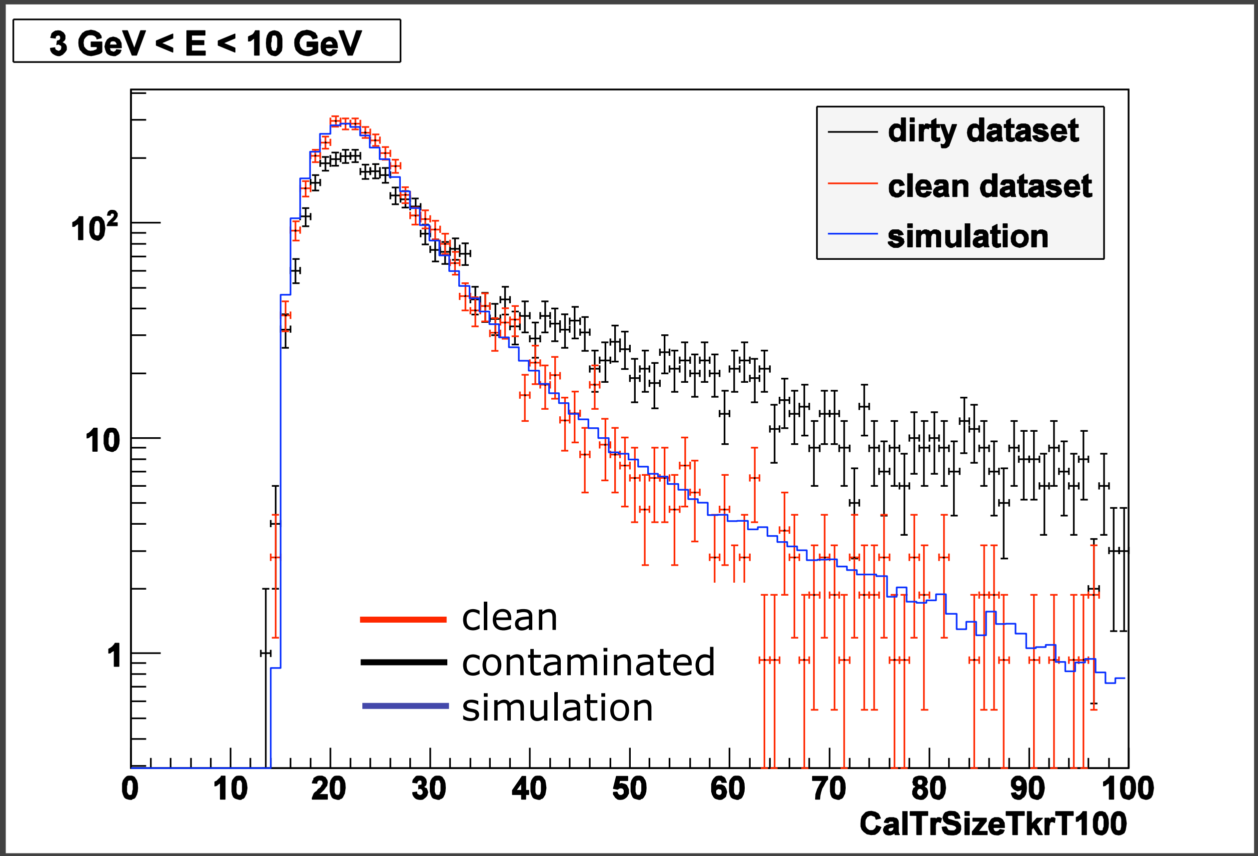
+ shower shape and charge deposit cuts

Tails of the CR distribution agree within +50%/- 30%

→ uncertainty of the CR background for this analysis



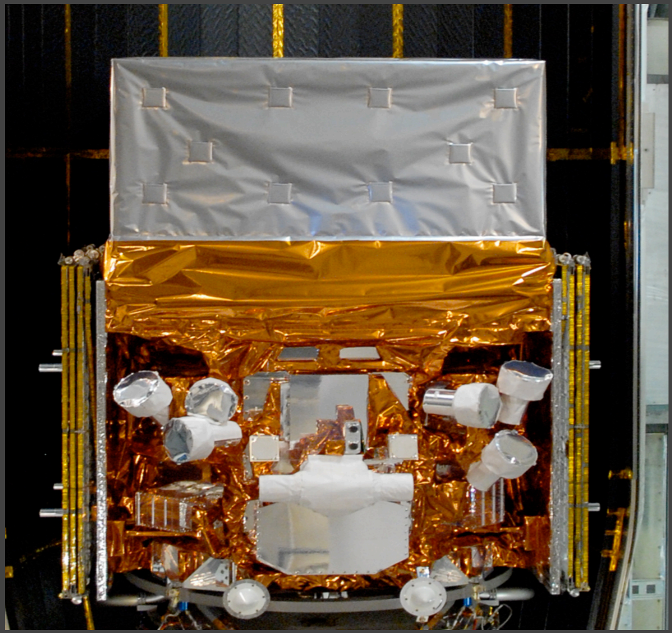
Data selection for the analysis of the isotropic diffuse background



- Example for improved background rejection: Transverse shower size in Calorimeter
  - clean dataset (observations with high γ-ray flux, low CR flux)
  - contaminated dataset (observations with low γ-ray flux, high CR flux)
  - predicted distribution from LAT simulation

The Fermi Large Area Telescope

- Energy range: 100 MeV – 300 GeV
- Peak effective area: > 8000 cm^2 (standard event selection)
- Field of view: 2.4 sr
- Point source sensitivity (>100 MeV): $3 \times 10^{-9}\ cm^{-2}\ s^{-1}$
- No consumables onboard LAT → Steady response over time expected



- Standard operation in 'sky survey' mode allows almost flat exposure of the sky