Search for Dark matter in the sky in the Fermi and Pamela era

Aldo Morselli  
INFN Roma Tor Vergata

Seul Konkuk University, 27 August 2009

Extended Workshop on DM, LHC and Cosmology  
17 Aug - 12 Sept 2009 at KIAS

The KIAS-KAIST-YITP Joint Workshop  
27 Aug - 4 Sept, 2009 at KIAS
Neutralino WIMPs

Assume $\chi$ present in the galactic halo

- $\chi$ is its own antiparticle $\Rightarrow$ can annihilate in galactic halo producing gamma-rays, antiprotons, positrons….
- Antimatter not produced in large quantities through standard processes (secondary production through $p + p \rightarrow$ anti $p + X$)
- So, any extra contribution from exotic sources ($\chi \chi$ annihilation) is an interesting signature

- ie: $\chi \chi \rightarrow$ anti $p + X$
- Produced from (e.g.) $\chi \chi \rightarrow q / g /$ gauge boson / Higgs boson and subsequent decay and/or hadronisation.
Antiproton/proton ratio 1997

Caprice coll.
Astrophysics Journal,
487, 415, 1997
MASS  Matter Antimatter Space Spectrometer

GAS CHERENKOV

MAGNET

TOF

TRACKING SYSTEM

TOF

CALORIMETER

1 m
PAMELA

Payload for Antimatter Matter Exploration and Light Nuclei Astrophysics

In orbit on June 15, 2006, on board of the DK1 satellite by a Soyuz rocket from the Bajkonour launch site.

First switch-on on June 21 2006

From July 11 Pamela is in continuous data taking mode
Pamela

Separating p from e⁻
• ~ 3 years from PAMELA launch

• Launched in orbit on June 15, 2006, on board of the DK1 satellite by a Soyuz rocket from the Bajkonour cosmodrom.
Antiproton-Proton Ratio

- PAMELA data, Nature [arxiv:0810.4994]
Antiproton-Proton Ratio

\[ \frac{\text{antiproton}}{\text{proton}} \]

- PAMELA data arxiv:0810.4994

Diffuse and Convection Propagation Model
Upper and lower bounds
A.Lionetto, A.Morselli, V.Zdravkovic
PAMELA antiprotons and WIMP Detection

PAMELA allowed region for a boost factor 10

PAMELA excluded region for a boost factor 10

no electroweak symmetry breaking

$tg(\beta) = 55, \text{sign}(\mu) = +1$
PAMELA antiprotons and WIMP Detection

\[ \tan(\beta) = 55, \ sign(\mu) = +1 \]

PAMELA allowed region for a boost factor 10

PAMELA excluded region for a boost factor 10

WMAP 3 allowed region (95% C.L.)

no electroweak symmetry breaking
larger values of $\tan(\beta)$ gives larger signals both in antiprotons and gammas
Antiproton-Proton Ratio

Diffuse and Convention Propagation Model
Upper and lower bounds
A.Lionetto, A.Morselli, V.Zdravkovic

• PAMELA data arxiv:0810.4994
Propagation Equation for Cosmic Rays

\[ \frac{\partial \psi (r, p, t)}{\partial t} = q(r, p) + \nabla \cdot (D_{xx} \nabla \psi - \mathbf{V} \psi) + \frac{\partial}{\partial p} p^2 D_{pp} \frac{\partial}{\partial p} \frac{1}{p^2} \psi \]

- convection velocity field that corresponds to galactic wind and it has a cylindrical symmetry, as the geometry of the galaxy. It’s z-component is the only one different from zero and increases linearly with the distance from the galactic plane
- loss term: fragmentation
- diffusion coefficient is function of rigidity
- loss term: radioactive decay
- diffusion coefficient in the impulse space, quasi-linear MHD: \( D_{pp}(D_{xx}, v_A) \)
- primary spectra injection index \( dq(p)/dp \propto p^{-\gamma} \)

implemented in Galprop (Strong & Moskalenko, available on the Web) [astro-ph/0502406]
Comparison between the cosmic rays and the Solar System element composition, both relative to Carbon.
Enveloping curves of all the good fits of the experimental B/C data

Dashed line: Best fit

**DR**: diffusion + reacceleration

**DC**: diffusion + convection

In DC model problem with the ACE data at low energy

A.Lionetto, A.Morselli, V.Zdravkovic
Enveloping curves of all the good fits of the experimental B/C data

Dashed line: Best fit

**DR**: diffusion + reacceleration  
**DC**: diffusion + convection

\[
\chi^2 = \frac{1}{N-1} \sum_{n} \frac{1}{(\sigma_n^{B/C})^2} \left( \Phi_{n, \text{exp}}^{B/C} - \Phi_{n, \text{teo}}^{B/C} \right)^2
\]

- \( \sigma_n^{B/C} \) = statistical errors for N = 46 experimental points

A. Lionetto, A. Morselli, V. Zdravkovic  
Proton spectra: Upper and lower bounds of due to the uncertainties of propagation parameters

A. Lionetto, A. Morselli, V. Zdravkovic
Helium spectra: Upper and lower bounds due to the uncertainties of propagation parameters.
Prim/Sec consistency check

(Sc+Ti+V)/Fe Ratio that corresponds to the best fit of B/C;

Phi = 325 MV
Cosmic Ray Electron propagation models

They generally assume:

\[ N_e(E) \propto E^{-\gamma_0} \]

- Power-law source spectrum

- Power-law diffusion coefficient
  \[ D = D_0 \left( \frac{E}{E_0} \right)^{-\delta} \]
  (normalised to match CR nuclear data)

- Continuous source distribution in the Galactic Disk

For \( E > 10 \text{ GeV} \) solar modulation, re-acceleration, convection have negligible effects. Only synchrotron and IC energy losses matter.

Under those conditions:

\[ N_e(E) \propto E^{-\left( \gamma_0 + \frac{\delta}{2} + \frac{1}{2} \right)} \]

This is only for illustrative purposes. All models here have been computed with GALPROP accounting for all effects!!

See http://galprop.stanford.edu/web_galprop/galprop_home.html
The situation before 2008
Electron + positron spectrum

Data were compatible with conventional large-scale Galactic models of CRs tuned to fit gamma-ray data and other observables.
The conventional GALPROP model with
\[ \gamma_0 = 2.54 \ (\delta = 0.33) \]
gives a satisfactory description of those data

• PAMELA data arxiv:0810.4994
2008: Results from ATIC and HESS

Data clearly call for major changes to the conventional model:
Nearby sources (e.g. pulsar) or dark matter annihilation/decay models have been proposed to explain those data.
2009: PAMELA results

$e^+/(e^+ + e^-) \propto E^{-\gamma_p + \gamma_0 - \delta}$

$\gamma_p$: proton source power-index

It improves only adopting very soft electron spectra (high $\gamma_0$)

conventional GALPROP model
$\gamma_0 = 2.54 \ (\delta = 0.33)$

Secondary positrons only!

E < 10 Gev, probably solar modulation effect
some articles about the positron excess

1. arXiv:0901.3474 Cosmic Ray Positrons from Cosmic Strings Robert Brandenberger, Yi-Fu Cai, Wei Xue, Xinmin Zhang
2. arXiv:0901.2556 Positrons and antiprotons from inert doublet model dark matter Emmanuel Nezri, Michel H.G. Tytgat, Gilles Vertongen
3. arXiv:0901.1520 On the cosmic electron/positron excesses and the knee of the cosmic rays - a key to the 50 years' puzzle? Hong-Bo Hu, Qiang Yuan, Bo Wang, Chao Fan, Jian-Li Zhang, Xiao-Jun Bi
14. arXiv:0810.4846 Possible causes of a rise with energy of the cosmic ray positron fraction Pasquale Dario Serpico
17. arXiv:0810.1527 Pulsars as the Sources of High Energy Cosmic Ray Positrons Dan Hooper, Pasquale Blasi, Pasquale Dario Serpico
19. arXiv:0809.2601 Two dark matter components in N_{DM}MSSM and dark matter extension of the minimal supersymmetric standard model and the high energy positron spectrum in PAMELA/HEAT data Ji-Haeng Huh, Jihn E. Kim, Bumseok Kyae
23. arXiv:0808.3867 Minimal Dark Matter predictions and the PAMELA positron excess Marco Cirelli, Alessandro Strumia
~ 1 year from Fermi launch
11 June 2008
The Galactic Diffuse Emission

- Spectra shown for mid-latitude range → GeV excess in this region of the sky is not confirmed.
- Sources are not subtracted but are a minor component.
- LAT errors are dominated by systematic uncertainties and are currently estimated to be ~10% → this is preliminary.
EGRET GeV excess was not observed ⇒ Conventional models (based on the locally measured CR fluxes) can be used

The conventional model with
\[ \gamma_0 = 2.54 \ (\delta = 0.33) \]
gives a satisfactory description of Fermi-LAT gamma-ray data

Conventional model are weakly affected by small changes in the electron spectrum.
2009: Fermi-LAT diffuse gamma-ray spectrum first measurements

$0^\circ \leq l \leq 360^\circ, 10^\circ \leq |b| \leq 20^\circ$

Fermi LAT data

Total

$10^{-2}$

$10^{-4}$

$10^2$ $10^3$ $10^4$

$E_\gamma$ (MeV)

PRELIMINARY

Konkuk University, August 27 2009
Aldo Morselli, INFN Roma Tor Vergata
Gamma-ray spectrum for an example of gravitino dark matter decay in the mid-latitude range

- $10^0 \leq |b| \leq 20^0$
Although the feature @~600 GeV measured by ATIC is not confirmed
Some changes are still needed respect to the pre-Fermi conventional model
Elements of a pair-conversion telescope

- photons materialize into matter-antimatter pairs:
  \[ E_\gamma \rightarrow m_e c^2 + m_e c^2 \]

- electron and positron carry information about the direction, energy and polarization of the \( \gamma \)-ray
How Fermi LAT detects gamma rays

4 x 4 array of identical towers with:
- Precision Si-strip tracker (TKR)
  - With W converter foils
- Hodoscopic CsI calorimeter (CAL)
- DAQ and Power supply box

An anticoincidence detector around the telescope distinguishes gamma-rays from charged particles.

Conversion ($\gamma$ in $e^+/e^-$) in W foils

Incoming direction reconstruction by tracking the charged particles

Energy measurement with e.m. calorimeter
The LAT sensitivity extends to higher energies (> 300 GeV) than that of any previous space-based gamma-ray mission, opening the unexplored energy range above 30 GeV. The energy range of the LAT will overlap those of the next generation ground-based TeV gamma-ray instruments, allowing for inter-calibration between the LAT and these instruments.
Simulated Fermi LAT exposure for five years of all-sky scanning at 100 GeV

- 2.0E+11 cm² s
- 2.1E+11 cm² s
- 2.2E+11 cm² s
- 2.3E+11 cm² s
- 2.4E+11 cm² s
- 2.5E+11 cm² s
How Fermi LAT detects electrons

Trigger and downlink

- LAT triggers on (almost) every particle that crosses the LAT
  - ~ 2.2 kHz trigger rate
- On board processing removes many charged particles events
  - But keeps events with more that 20 GeV of deposited energy in the CAL
  - ~ 400 Hz downlink rate
- Only ~1 Hz are good γ-rays

Electron identification

- The challenge is identifying the good electrons among the proton background
  - Rejection power of $10^3 - 10^4$ required
  - Can not separate electrons from positrons

Incoming Electron

ACD identifies charged particles

Main track pointing to the hit ACD tile

Same tracking and energy reconstruction algorithms used for γ-rays
Event topology

A candidate electron
(recon energy 844 GeV)

- TKR: clean main track with extra-clusters very close to the track
- CAL: clean EM shower profile, not fully contained
- ACD: few hits in conjunction with the track

A candidate hadron
(raw energy > 800 GeV)

- TKR: small number of extra clusters around main track
- CAL: large and asymmetric shower profile
- ACD: large energy deposit per tile
Energy reconstruction

Reconstruction of the most probable value for the event energy:
- based on calibration of the response of each of 1536 calorimeter crystals
- energy reconstruction is optimized for each event
- calorimeter imaging capability is heavily used for fitting shower profile
- tested at CERN beams up to 280 GeV with the LAT Calibration Unit

Very good agreement between shower profile in beam test data (red) and Monte Carlo (black)
Fermi LAT Energy resolution for electrons

Full width $\Delta E/E$

Energy (GeV)

LAT 95%
LAT 68%
Beam Test MC 68% (60°)
Beam Test Data 68% (60°)
Beam Test MC 68% (0°)
Beam Test Data 68% (0°)
)}
Models 0 and 1 account for CR re-acceleration in the ISM, while 2 is a plain-diffusion model. All models assume $\gamma_0 = 1.6$ below 4 GeV.

- $\gamma_0 = 2.54 \; (\delta = 0.33)$
- $\gamma_0 = 2.42 \; (\delta = 0.33 \; \text{ - with reacceleration}): \text{ red line}$
- $\gamma_0 = 2.33 \; (\delta = 0.6 \; \text{ - plain diffusion}): \text{ blue line}$
Numerical models of propagation of CR electrons can be tuned to fit Fermi data assuming an *harder injection index*:

- Problems: These tuned models are in tension with low-energy and HESS data (no big problems with gamma-ray data - *work in progress*)
Fermi & HESS data vs the conventional _pre-Fermi_ model

\[ \gamma_0 = 2.54 \ (\delta = 0.33) \]

cutoff in the CRE source spectrum or breakdown of the source spatial continuity?
Electron and positron spectra derived from Fermi and Pamela

Flux, $J E^3$, $m^{-2} s^{-1} sr^{-1} GeV^2$

- $\alpha = -3.1$
- $\alpha = -3.17$
- $\alpha = -3.25$

- Fermi $e^+ + e^-$
- Electrons derived
- Positrons derived

Energy, GeV

Konkuk University, August 27 2009
Aldo Morselli, INFN Roma Tor Vergata
Primary electrons in Cosmic Rays

Letters

Observation of the Cosmic Ray Electron-Positron Ratio
from 100 Mev to 3 bev in 1964

R. C. Hartman and Peter Meyer

Enrico Fermi Institute for Nuclear Studies and Department of Physics
University of Chicago, Chicago, Illinois

R. H. Hildebrand

Argonne National Laboratory and University of Chicago
Chicago, Illinois

Now, ~45 years later
PAMELA excess in positron fraction
and Fermi results on the electron+positron spectrum
unavoidably testifies the presence of primary positrons in CRs
which are the sources of the primary positrons?
Pulsars as sources of $e^{-/+}$ pairs

e$^\pm$ pairs are produced in the magnetosphere and accelerated by the electric fields and/or the pulsar wind.

Crab Pulsar Wind Nebula (PWN)
Pulsars as sources of $e^{-/+}$ pairs
not a new idea

- A. Boulares APJ 342 (1989) 807-813
The CRE spectrum accounting for nearby pulsars (d < 1 kpc)

This particular model assumes:
- 40% e\pm conversion efficiency for each pulsar
- pulsar spectral index $\Gamma = 1.7$  
  $E_{\text{cut}} = 1 \text{ TeV}$  .  
  Delay = 60 kyr

Rescaled conventional pre-Fermi GCRE model by 0.95 @ 100 GeV
$\gamma_0 = 2.54 \ (\delta = 0.33 )$

Analytically computed spectra using the same diffusion param. as for the GCRE model

[arXiv:0905.0636]
the positron ratio accounting for nearby pulsars (d < 1 kpc)
What if we randomly vary the pulsar parameters relevant for e+e- production?

(injection spectrum, e+e- production efficiency, PWN “trapping” time)

Under reasonable assumptions, electron/positron emission from pulsars offers a viable interpretation of Fermi CRE data which is also consistent with the HESS and Pamela results.

[arXiv:0905.0636]
The Pulsing $\gamma$-ray Sky

16 Gamma-Ray Pulsars Through Blind Frequency Searches
Science 325 (5942), 840-844
A Population of Gamma-Ray Millisecond Pulsars Seen with Fermi
Science 325 (5942), 848-852

(14 August 2009)
**Pulsars**

1. On purely energetic grounds they work (relatively large efficiency)

2. On the basis of the spectrum, it is not clear
   1. The spectra of PWN show relatively flat spectra of pairs at low energies but we do not understand what it is
   2. The general spectra (acceleration at the termination shock) are too steep

The biggest problem is that of escape of particles from the pulsar
   1. Even if acceleration works, pairs have to survive losses
   2. And in order to escape they have to cross other two shocks

New Fermi data on pulsars will help to constrain the pulsar models
 Contribution from nearby KNOWN young SNRs: Geminga, Monogem, Vela LoopI and Cygnus Loop

Primary arm electrons
Primary disk electrons with nearby sources excluded
secondary positrons

Piran, Shaviv, Nakar
astro-ph/0902.0376
astro-ph/0905.0904
• Positrons created as secondary products of hadronic interactions inside the sources
• Secondary production takes place in the same region where cosmic rays are being accelerated

--> Therefore secondary positron have a very flat spectrum, which is responsible, after propagation in the Galaxy, for the observed positron excess

Blasi, arXiv:0903.2794
Predictions for the CRE spectrum from two specific dark matter models

$spectrum should be folded with the Fermi energy resolution$
Pure $e^+e^-$ Models

The dark matter pair annihilation always yields a pair of monochromatic $e^+e^-$, with injection energies equal to the mass of the annihilating dark matter particle.
**Lepto-philic Models**

Here we assume a democratic dark matter pair-annihilation branching ratio into each charged lepton species: 1/3 into $e^+e^-$, 1/3 into $\mu^+\mu^-$ and 1/3 into $\tau^+\tau^-$. Here too antiprotons are not produced in dark matter pair annihilation.
Super-heavy Models (ann. in gauge bosons)

Super-heavy dark matter models: antiprotons can be suppressed below the PAMELA measured flux if the dark matter particle is heavy (i.e. in the multi-TeV mass range), and pair annihilates e.g. in weak interaction gauge bosons. Models with super-heavy dark matter can have the right thermal relic abundance, e.g. in the context of the minimal supersymmetric extension of the Standard Model.
electron + positron expected anisotropy in the directions of Monogem and Geminga
Measurement of anisotropies: statistics

**Statistical limit for the integral anisotropy set by**

\[
\delta = \frac{\sqrt{2}N_\sigma}{\sqrt{N_{\text{events}}}}
\]

- Poor sensitivity below 20 GeV (on board filter).
- The plot includes all the instrument effects:
  - Energy-dependent effective geometry factor;
  - Instrumental dead time and duty cycle, On board filter.
- Room for improvements with a better event selection!
The Fermi-LAT Cosmic ray Electron spectrum is shown in the graph. The spectrum is plotted against energy, with different lines and error bars representing different models:

- \( \gamma_0 = 2.42 \) (with reacceleration) represented by the red line.
- \( \gamma_0 = 2.33 \) (plain diffusion) represented by the blue line.

The energy range is indicated from 100 GeV to 400 GeV.
Where should we look for Dark Matter with FERMI?

- Galactic center
- Galactic satellites
- Galactic halo
- Extra-galactic
## How the GLAST-LAT* telescope could help to disentangle the Dark Matter puzzle?

<table>
<thead>
<tr>
<th>Search Technique</th>
<th>advantages</th>
<th>challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Galactic center</td>
<td>Good Statistics</td>
<td>Source confusion/Diffuse background</td>
</tr>
<tr>
<td>Satellites, Subhalos, Point Sources</td>
<td>Low background, Good source id</td>
<td>Low statistics</td>
</tr>
<tr>
<td>Milky Way halo</td>
<td>Large statistics</td>
<td>Galactic diffuse background</td>
</tr>
<tr>
<td>Extra-galactic</td>
<td>Large Statistics</td>
<td>Astrophysics, galactic diffuse background</td>
</tr>
<tr>
<td>Spectral lines</td>
<td>No astrophysical uncertainties, good source id</td>
<td>Low statistics</td>
</tr>
</tbody>
</table>
EGRET data & Susy models

Annihilation channel $W^+W^-$
$M_\chi = 80.3$ GeV

\[ N_b = 1.82 \times 10^{21} \]
\[ N_\chi = 8.51 \times 10^4 \]

Typical $N_\chi$ values:
- NFW: $N_\chi = 10^4$
- Moore: $N_\chi = 9 \times 10^6$
- Isotermal: $N_\chi = 3 \times 10^1$

~2 degrees around the galactic center

A.Morselli, A. Lionetto, A. Cesarini, F. Fucito, P. Ullio, astro-ph/0211327
Fermi Expectation & Susy models

~2 degrees around the galactic center, 2 years data

Annihilation channel $W^+W^-$  
$M_\chi = 80$ GeV

$N_b = 1.82 \times 10^{21}$
$N_\chi = 8.51 \times 10^4$

Typical $N_\chi$ values:
NFW: $N_\chi = 10^4$
Moore: $N_\chi = 9 \times 10^6$
Isothermal: $N_\chi = 3 \times 10^1$

Differential yield for each annihilation channel

$\gamma$ yield per annihilation

$t - t\bar{t}$
$b - b\bar{b}$
$W - W$
$\tau - \tau$

Secondary $\pi^0$ component (arbitrarily rescaled)

WIMP mass = 200 GeV

Differential yield for $b\bar{b}$

\[ \gamma \text{ yield per annihilation} \times (50\,\text{GeV}/\text{Mchi})^2 \]

Model independent results for the GC

after the Fermi
Galactic Diffuse
Emission data

5 years of
operations, truncated NFW

updated from arXiv:0806.2911

above 3σ EGRET observation

detectable by GLAST

Not detectable by GLAST

a) channel $b\bar{b}$ at 3σ, NFW profile
after the Fermi Galactic Diffuse Emission data

Model independent results for the Sagittarius Dwarf

channel $bb$ at $3\,\sigma$, Moore profile

Not detectable by Fermi
detectable by Fermi

above EGRET observation

$\langle \sigma v \rangle \left(10^{-26}\text{ cm}^3\text{s}^{-1}\right)$

$m_{\text{Wimp}}$ (GeV/c$^2$)

updated from arXiv:0806.2911
Crosses mark source locations, in Galactic coordinates.
205 Preliminary LAT Bright Sources -

Some Information

• EGRET on the Compton Observatory found fewer than 30 sources above 10 $\sigma$ in its lifetime.

• Typical 95% error radius is less than 10 arcmin. For the brightest sources, it is less than 3 arcmin. Improvements are expected.

• About 1/3 of the sources show definite evidence of variability.

• More than 30 pulsars are identified by gamma-ray pulsations.

• Over half the sources are associated positionally with blazars. Some of these are firmly identified as blazars by correlated multiwavelength variability.

• Over 40 sources have no obvious associations with known gamma-ray emitting types of astrophysical objects.
A galactic dark matter halo

Detecting dark matter substructure with Fermi
z=11.9
800 x 600 physical kpc

Diemand, Kuhlen, Madau 2006

A galactic dark matter halo
Dwarf spheroidal galaxies (dSph): promising targets for DM detection
Dwarf spheroidal galaxies (dSph) : promising targets for DM detection

- dSphs are the most DM dominated systems known in the Universe with very high M/L ratios (M/L ~ 10^2 - 2000).
- Many of them (at least 6) closer than 100 kpc to the GC (e.g. Draco, Umi, Sagittarius and new SDSS dwarfs).
- SDSS [only 1/4 of the sky covered] already double the number of dSphs these last years.
- Most of them are expected to be free from any other astrophysical gamma source.

✔ Low content in gas and dust.
Dwarf Spheroidal Galaxies upper-limits

Fermi-LAT 3-months data preliminary results

Preliminary
Annihilation cross-section upper-limits in Dwarf Spheroidal Galaxies

Fermi-LAT 9-months

Preliminary
Inverse Compton Emission and Diffusion in Dwarfs

- We expect significant IC gamma-ray emission for high mass WIMP models annihilating to leptonic final states.
- The IC flux depends strongly on the uncertain/unknown diffusion of cosmic rays in dwarfs.
- We assume a simple diffusion model similar to what is found for the Milky Way
  \[ D(E) = D_0 E^{1/3} \text{ with } D_0 = 10^{28} \text{ cm}^2/\text{s} \]
  (only galaxy with measurements, scaling to dwarfs ??)
Combined constraints for Final State Radiation (FSR) plus IC with reference diffusion model $D_0 = 10^{28}$ cm$^2$/s
Cluster of Galaxies: muon antimuon final state

Fornax and Coma clusters: NFW, no substructure

50% of mass in substructure

Combined constraints for Final State Radiation (FSR) plus IC

Preliminary
The LAT isotropic diffuse flux (200 MeV - 100 GeV)

Low galactic latitudes
- Galactic diffuse flux (from fit)
- Total point source contribution (from fit)
- Isotropic diffuse emission (isotropic component from fit, residual CR background subtracted)
- Power law fit to isotropic diffuse emission with index $\gamma = 2.45$

High galactic latitudes
- Galactic diffuse flux (from fit)
- Total point source contribution (from fit)
- Isotropic diffuse emission (isotropic component from fit, residual CR background subtracted)
- Power law fit to isotropic diffuse emission with index $\gamma = 2.45$

Galactic poles
- Galactic diffuse flux (from fit)
- Total point source contribution (from fit)
- Isotropic diffuse emission (isotropic component from fit, residual CR background subtracted)
- Power law fit to isotropic diffuse emission with index $\gamma = 2.45$

Errors = statistical + instrumental + systematic (added in quadrature)

Data model/model

Error bars / bands:
- statistical error + LAT effective area uncertainty + residual background contamination uncertainty
Main contributions to the Fermi gamma-ray sky

- **Lat (E>100 MeV)**
  - 9 month observation

- **Resolved sources**

- **Galactic diffuse emission**
  - (CR interactions with the interstellar medium)
  - Inverse Compton
  - $\pi^0$-decay

- **Bremsstrahlung**

- **Isotropic diffuse emission**

- **Resolved sources**
  - Residual cosmic rays surviving background rejection filters
  - Misreconstructed $\gamma$-rays from the earth albedo
Inverse Compton
SED of the isotropic diffuse emission (1 keV-100 GeV)

LAT error bars = statistical + instrumental systematic (added in quadrature)

uncertainties from galactic diffuse model not included
extragalactic gamma-ray spectrum

Buchmuller et al, arXiv:0906.1187

600 GeV gravitino decay
25 of August: Fermi Data are public

We are pleased to announce that the LAT level-1 data products (photon event lists and associated auxiliary files needed for analysis) are now available for public download through the FSSC web site.

http://fermi.gsfc.nasa.gov/ssc

This data release contains information on individual LAT gamma-ray candidate events and will allow detailed studies of the temporal, spatial and spectral behavior of high energy gamma-ray sources. The current analysis software release can also be obtained from the FSSC web site (follow the "data analysis" link).

http://fermi.gsfc.nasa.gov/ssc/data/
New Data is Forthcoming

Electron Spectrum:

- **PAMELA & FERMI (GLAST)** (taking data in space);
- **ATIC-4** (had successful balloon flight, under analysis);
- **CREST** (new balloon payload under development);
- **AMS-02** (launch date TBD);
- **CALET** (proposed for ISS);
- **ECAL** (proposed balloon experiment).

<table>
<thead>
<tr>
<th>Mission</th>
<th>Upper Energy (TeV)</th>
<th>Collecting Power (m²sr)</th>
<th>Calorimeter Thickness (X₀)</th>
<th>Energy Resolution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CALET</td>
<td>20</td>
<td>0.75</td>
<td>30.8</td>
<td>&lt; 3 (over 100 GeV)</td>
</tr>
<tr>
<td>PAMELA</td>
<td>0.25 (spectrometer)</td>
<td>0.0022</td>
<td>16.3</td>
<td>5.5 (300 GeV)</td>
</tr>
<tr>
<td></td>
<td>2 (calorimeter)</td>
<td>0.04</td>
<td></td>
<td>12 (300 GeV)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16 (1TeV)</td>
</tr>
<tr>
<td>GLAST</td>
<td>0.7</td>
<td>2.1 (100 GeV)</td>
<td>8.3</td>
<td>6 (100 GeV)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.7 (700 GeV)</td>
<td></td>
<td>16 (700 GeV)</td>
</tr>
<tr>
<td>AMS-02</td>
<td>0.66 (spectrometer)</td>
<td>0.5</td>
<td>16.0</td>
<td>&lt; 3 (over 100 GeV)</td>
</tr>
<tr>
<td></td>
<td>1 (calorimeter)</td>
<td>0.06 (100 GeV)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 0.04 (1 TeV)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Positron / Electron Separation:** **PAMELA & AMS-02**
the positron ratio

e^+/(e^+ + e^-)

E (GeV)

HEAT 94+95
CAPRICE 94
AMS 01
PAMELA 08
Conclusion:

The CRE spectrum measured by Fermi-LAT is significantly harder than previously thought on the basis of previous data.

Adopting the presence of an extra $e^\pm$ primary component with $\sim 2.4$ spectral index and $E_{\text{cut}} \sim 1$ TeV allow to consistently interpret Fermi-LAT CRE data (improving the fit), HESS and PAMELA.

Such extra-component can be originated by pulsars for a reasonable choice of relevant parameters:
- or by annihilating dark matter for model with $M_{\text{DM}} \approx 1$ TeV

• Improved analysis and complementary observations
• ($\text{CRE anisotropy}$, spectrum and angular distribution of diffuse $\gamma$, DM sources search in $\gamma$) are required to possibly discriminate the right scenario.

In September 2009 Fermi data will be open to the community. You are all invited to join!

thank you for the attention!