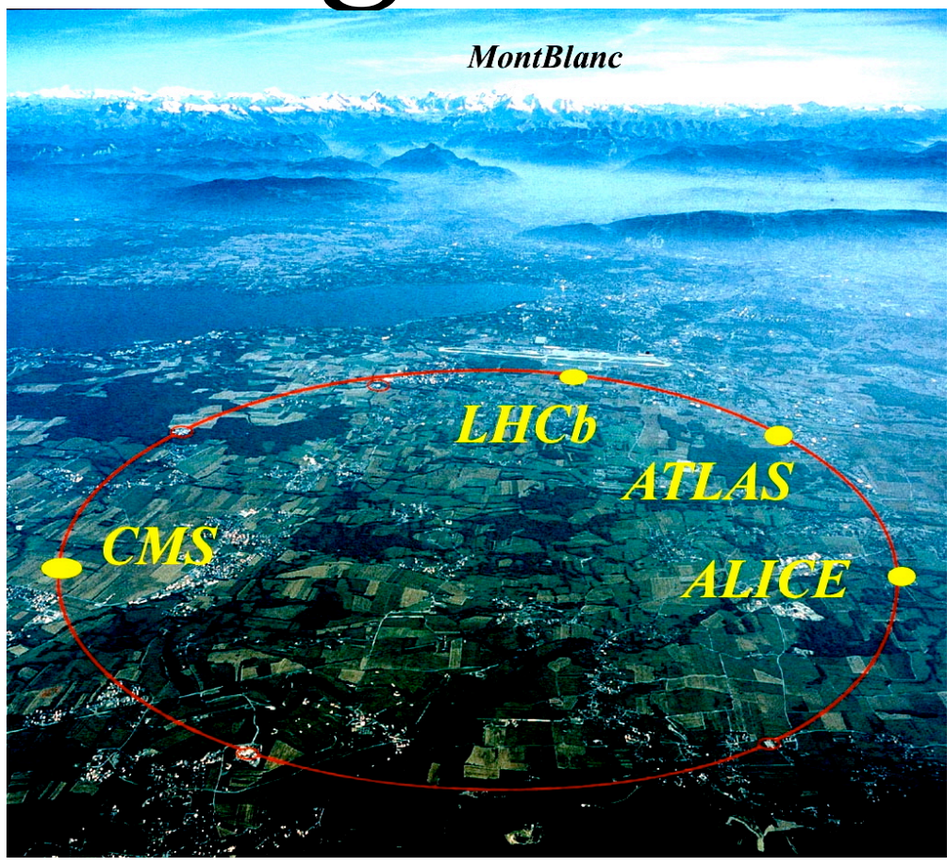
Decaying Dark Matter as a probe of Unification

Asimina Arvanitaki
LBNL-UCB

in collaboration with
Savas Dimopoulos
Sergei Dubovsky
Peter Graham
Roni Harnik
Surjeet Rajendran

The Age of Data

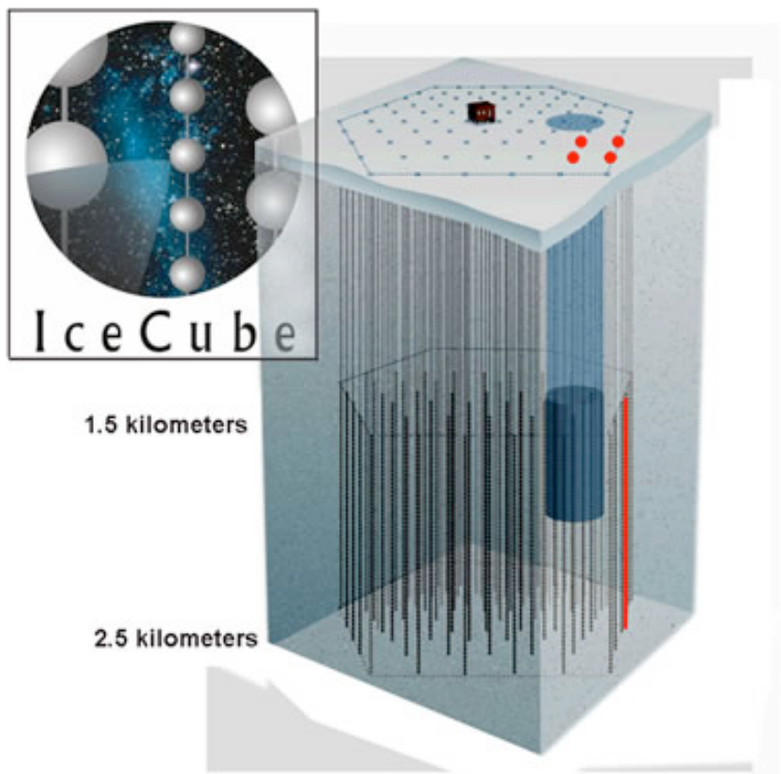
PAMELA



Fermi (GLAST)

ATIC

HESS



IceCube

The Hierarchy problem

Why is gravity so weak?

$$\frac{M_{\text{weak}}}{M_{\text{Planck}}} \sim 10^{-16}$$

New physics at the TeV scale

Supersymmetry: New particles at the TeV scale

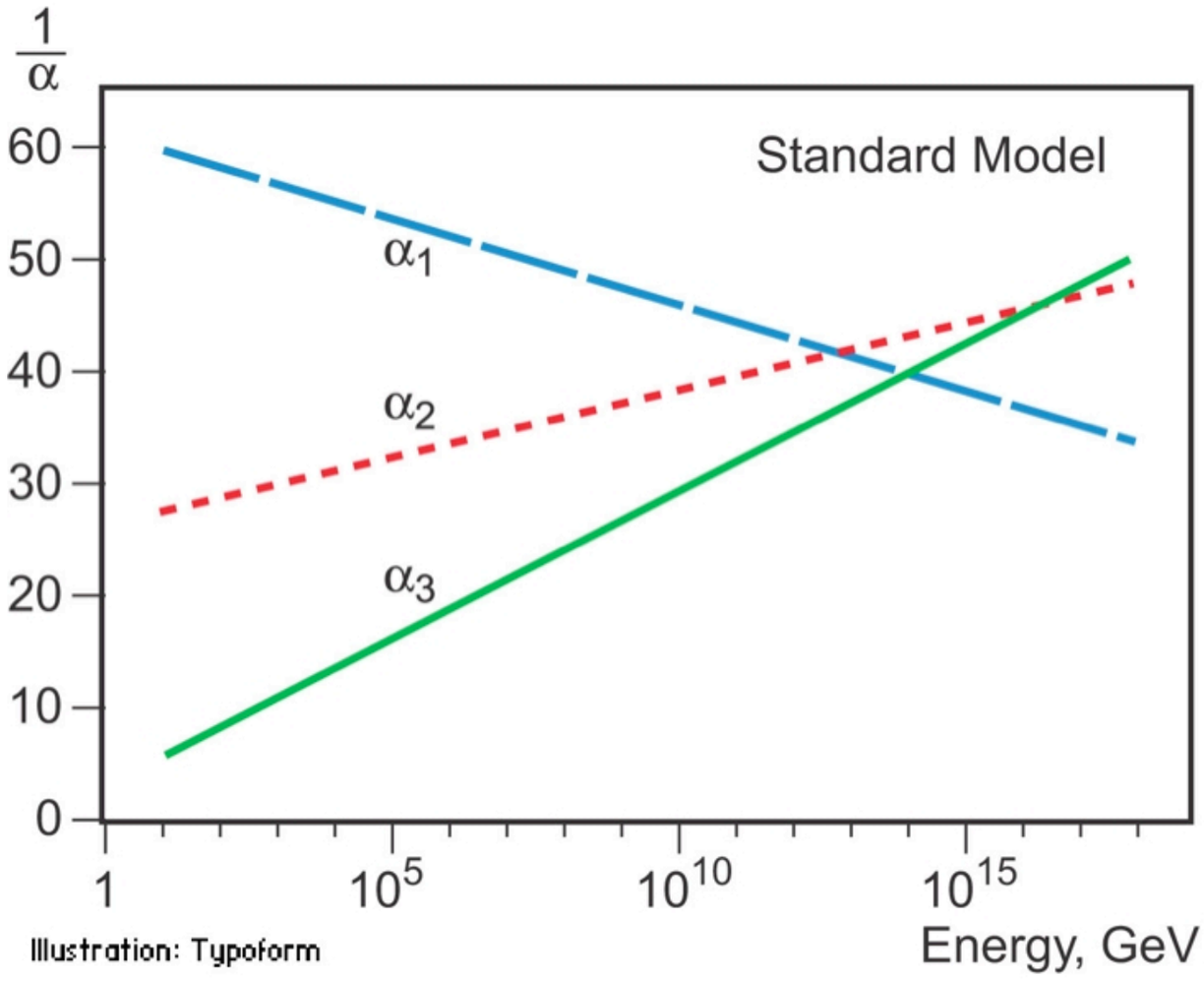
Dimopoulos, Georgi (81)

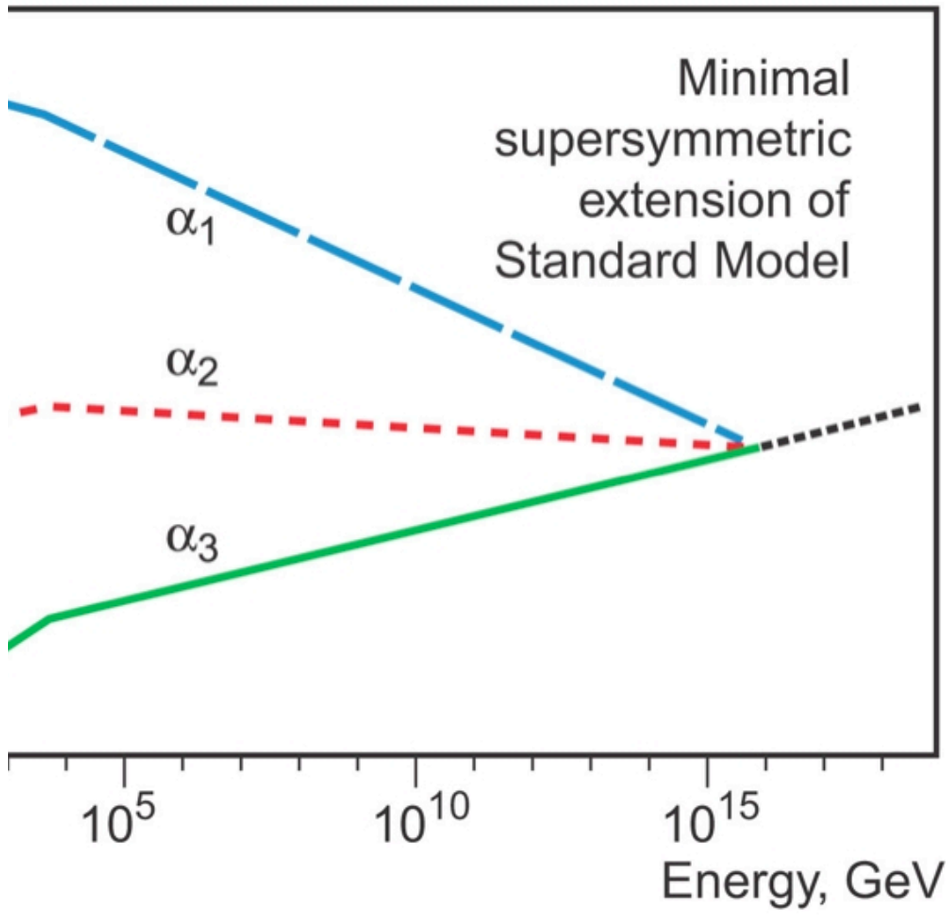
Dimopoulos, Raby, Wilczek (81)

Lightest Supersymmetric Particle:

TeV mass Dark Matter candidate with calculable abundance

Supersymmetric Unification

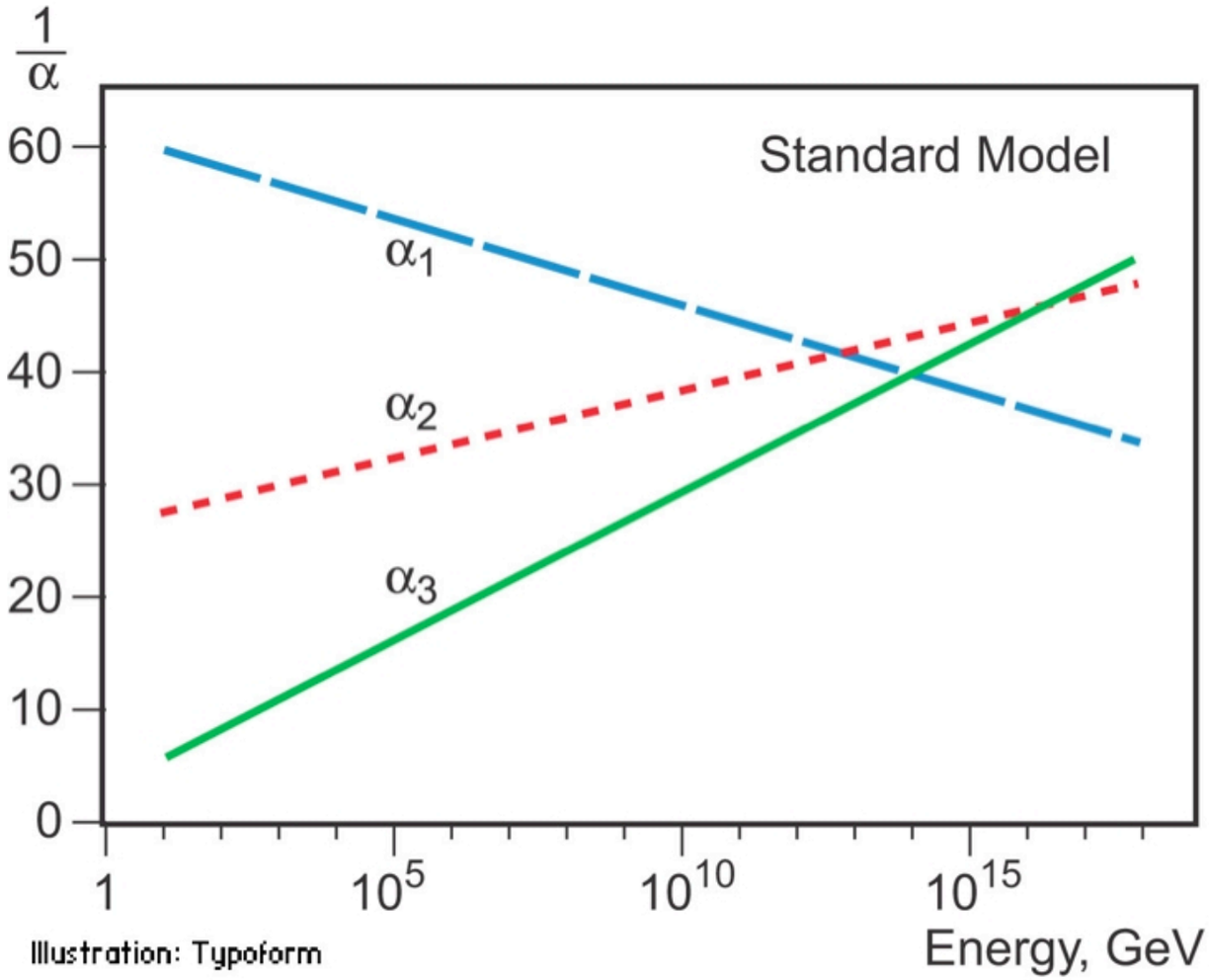


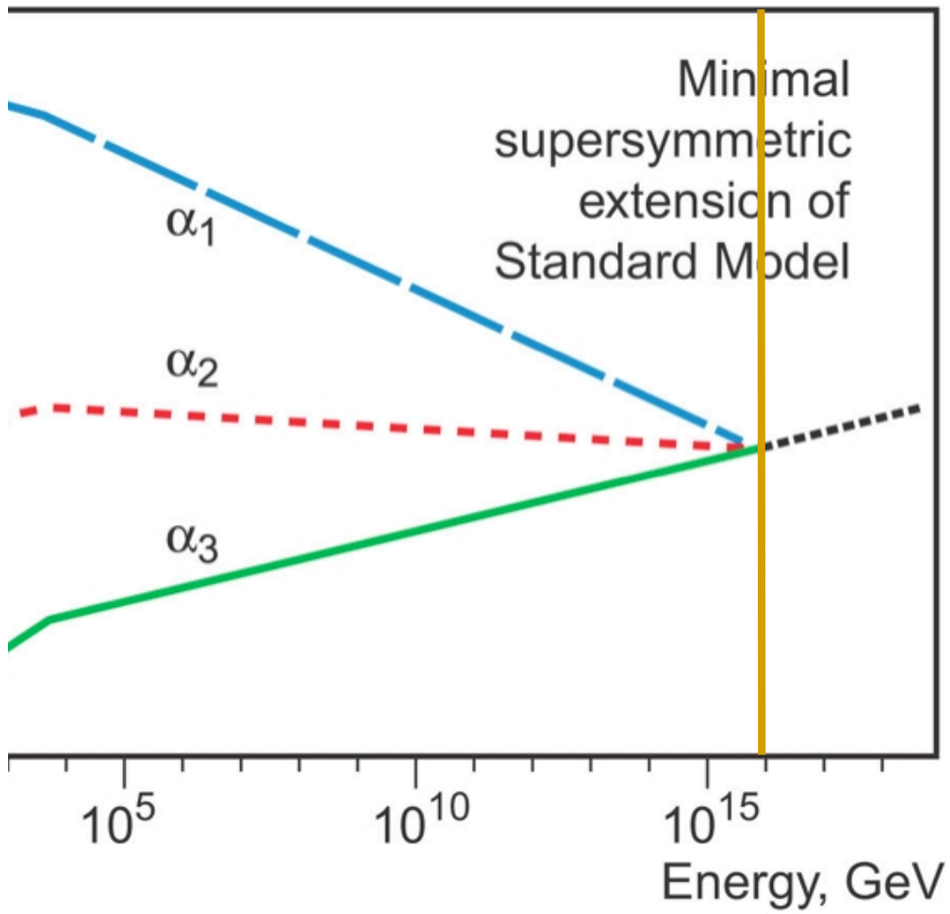


Experimentally verified with the measurement of $\sin^2\theta_W$ in the early 1990's

Supersymmetric Unification

10^{16} GeV





Experimentally verified with the measurement of $\sin^2\theta_W$ in the early 1990's

New physics at the GUT scale

Just as the proton decays...

Anything not forbidden is obligatory

If TeV Dark Matter decays
through dimension 6 GUT operators:

$$8\pi \frac{(\text{GUT scale})^4}{(1\ \text{TeV})^5} \sim 10^{27}\ \text{sec}$$

Limits on decaying Dark Matter

Decay channel	γ-rays EGRET	Galactic γ-rays HESS	antiprotons PAMELA	positrons PAMELA	neutrinos Super-K, Frejus AMANDA
$q\overline{q}$	4×10^{25} s	–	10^{27} s	–	–
e^+e^-	8×10^{22} s	2×10^{22} s (K)	10^{24} s	2×10^{25} s	3×10^{21} s
$\mu^+\mu^-$	8×10^{22} s	2×10^{22} s (K)	10^{24} s	2×10^{25} s	3×10^{24} s
$\tau^+\tau^-$	10^{25} s	10^{22} s (K)	10^{24} s	10^{25} s	3×10^{24} s
WW	3×10^{25} s	–	3×10^{26} s	4×10^{25} s	8×10^{23} s
$\gamma\gamma$	10^{22-25} s	2×10^{24} s (K) 5×10^{25} s (NFW)	2×10^{25} s	8×10^{23} s	–
$\nu\overline{\nu}$	8×10^{22} s	–	10^{24} s	10^{23} s	10^{25} s

Outline

- 10^{27} sec: Dark Matter decay possibilities
- Signals in current experiments
- Predictions

Dark Matter decays

Minimal Model: SUSY with R-parity violation

A few possibilities

There is no R-parity but another symmetry

Bento, Hall, Ross (87)

$$\int d^2\theta \frac{DDDLL}{M^2_{\rm GUT}}$$

decays to quarks and leptons

R-parity is broken with SUSY breaking

$$\frac{m^2_{\rm SUSY}}{M^2_{\rm GUT}} \tilde{\ell} \ell \mathrm{e}$$

decays to leptons

Dark Matter decays

Dark Matter is a new singlet particle
that couples only through dim-6 GUT operators

A few possibilities

Exchange of GUT scale gauge bosons

$$\int d^4\theta \frac{S S^\dagger 10 10^\dagger}{M_{\rm GUT}^2} \qquad \int d^4\theta \frac{S^\dagger 10_f H_u^\dagger \bar{5}_f}{M_{\rm GUT}^2}$$

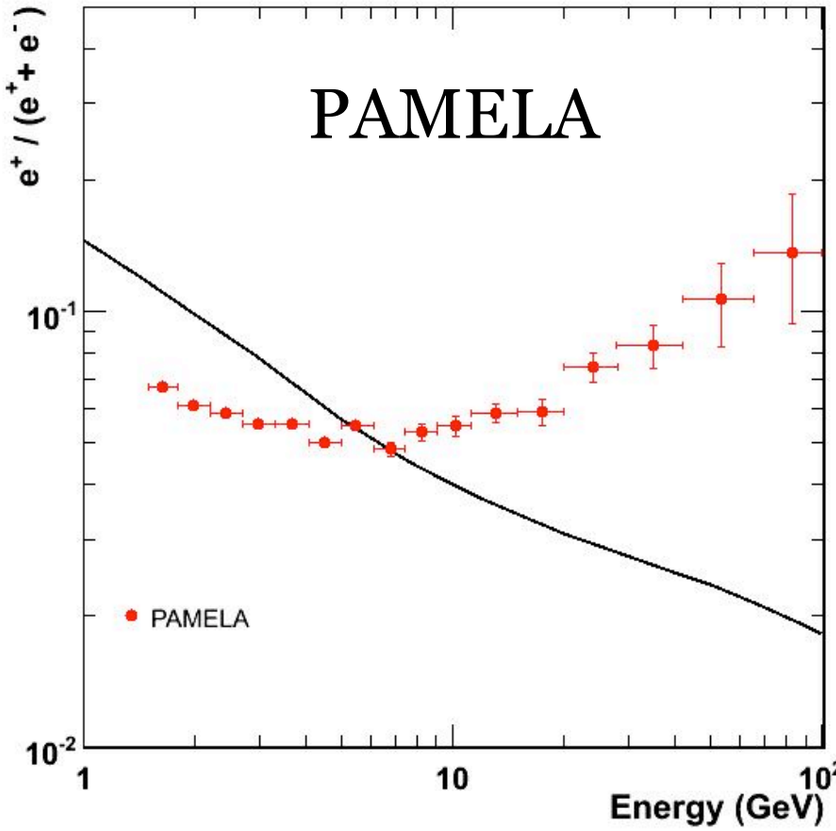
decays to quarks or leptons

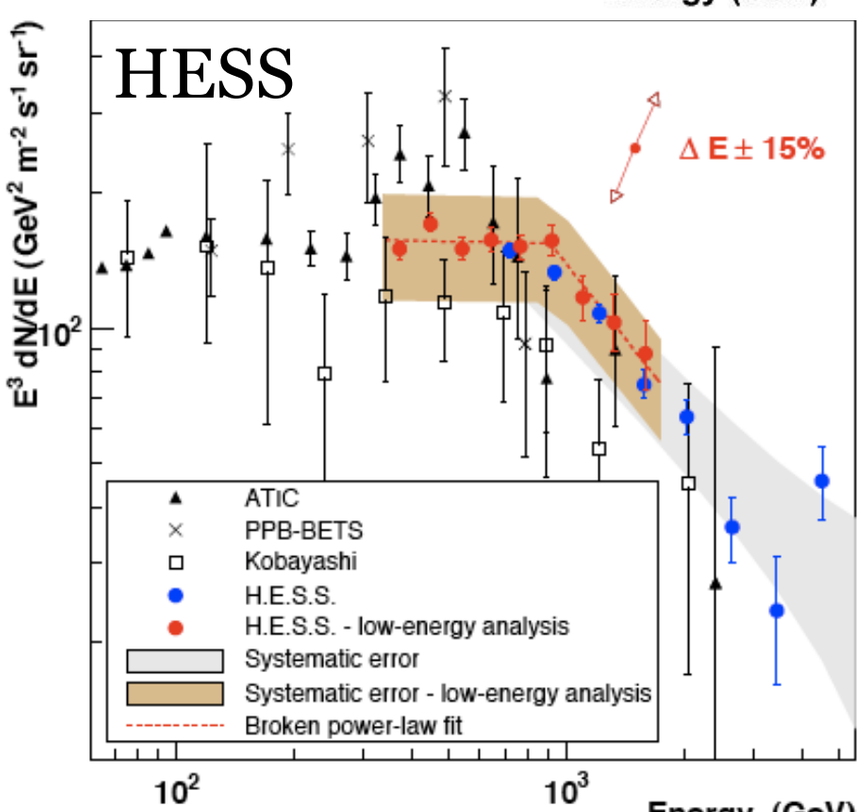
GUT scale “axions”

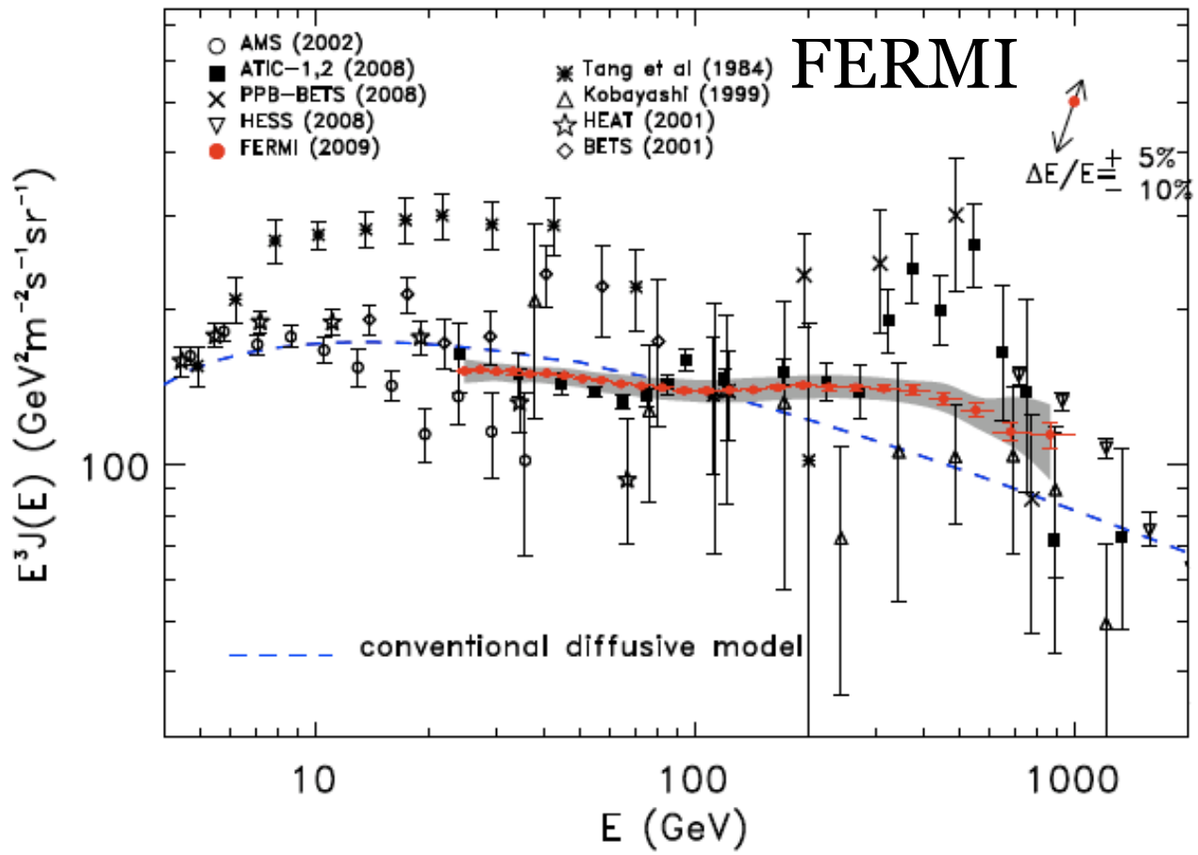
$$\int d^2\theta \frac{S^2 W_\alpha W^\alpha}{M_{\rm GUT}^2}$$

decays to photons

The electron-positron excess





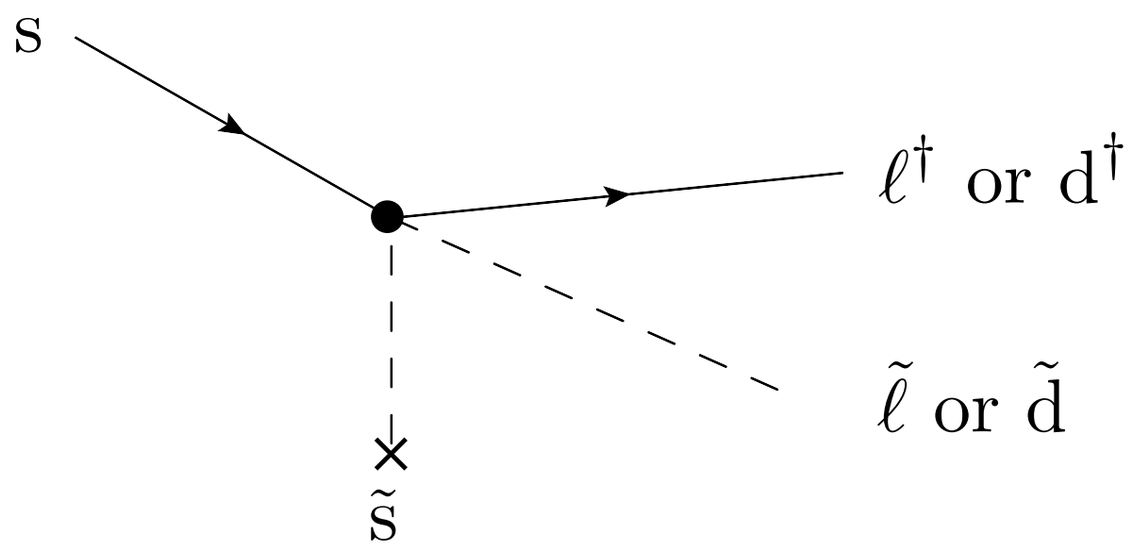


No antiproton excess
No photon excess

The excesses explained by DM decay

The DM is a singlet and
decays through GUT scale gauge bosons (flavor universal)
or through other particles (flavor non-universal)

$$\int d^4\theta \frac{S S^\dagger \bar{5}_f \bar{5}_f^\dagger}{M_{\rm GUT}^2}$$

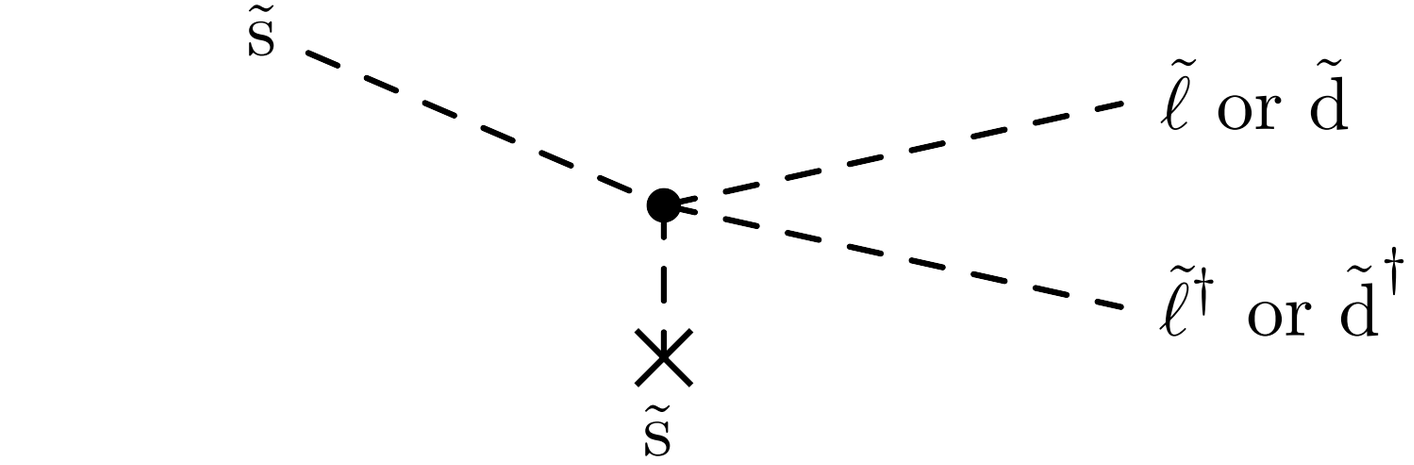


Squarks are heavier than sleptons
Decays to leptons kinematically favorable

The excesses explained by DM decay

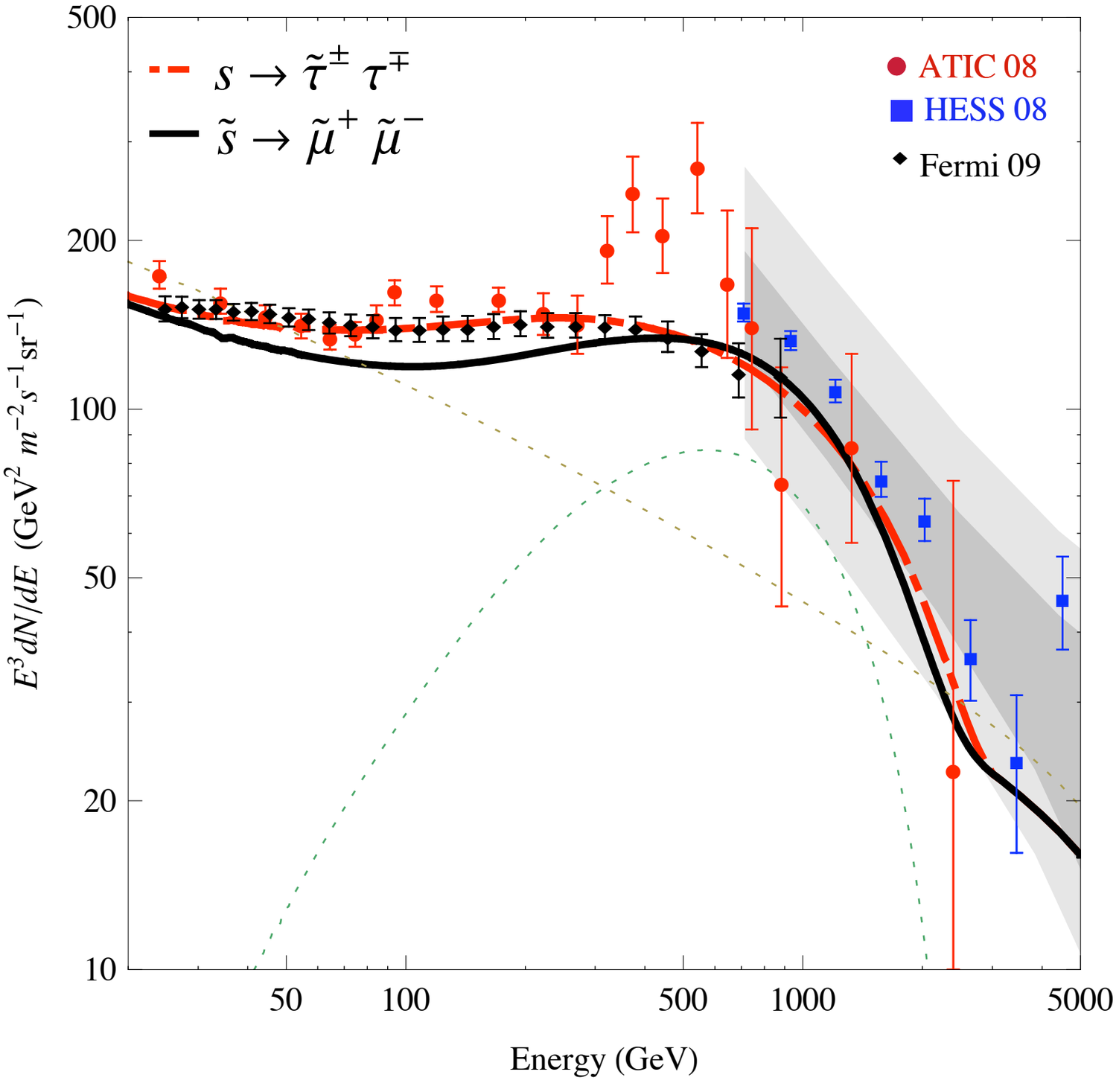
Part of the DM can also be scalar singlet

$$\int d^4\theta \frac{S S^\dagger \bar{5}_f \bar{5}_f^\dagger}{M_{\rm GUT}^2}$$



Decays to leptons are helicity suppressed

The excesses explained by DM decay



m_{DM} = 6 TeV

$m_{\tilde{\tau}}$ = 200 GeV

m_{LSP} = 100 GeV

$\tau = 6 \times 10^{25}$ s

m_{DM} = 8 TeV

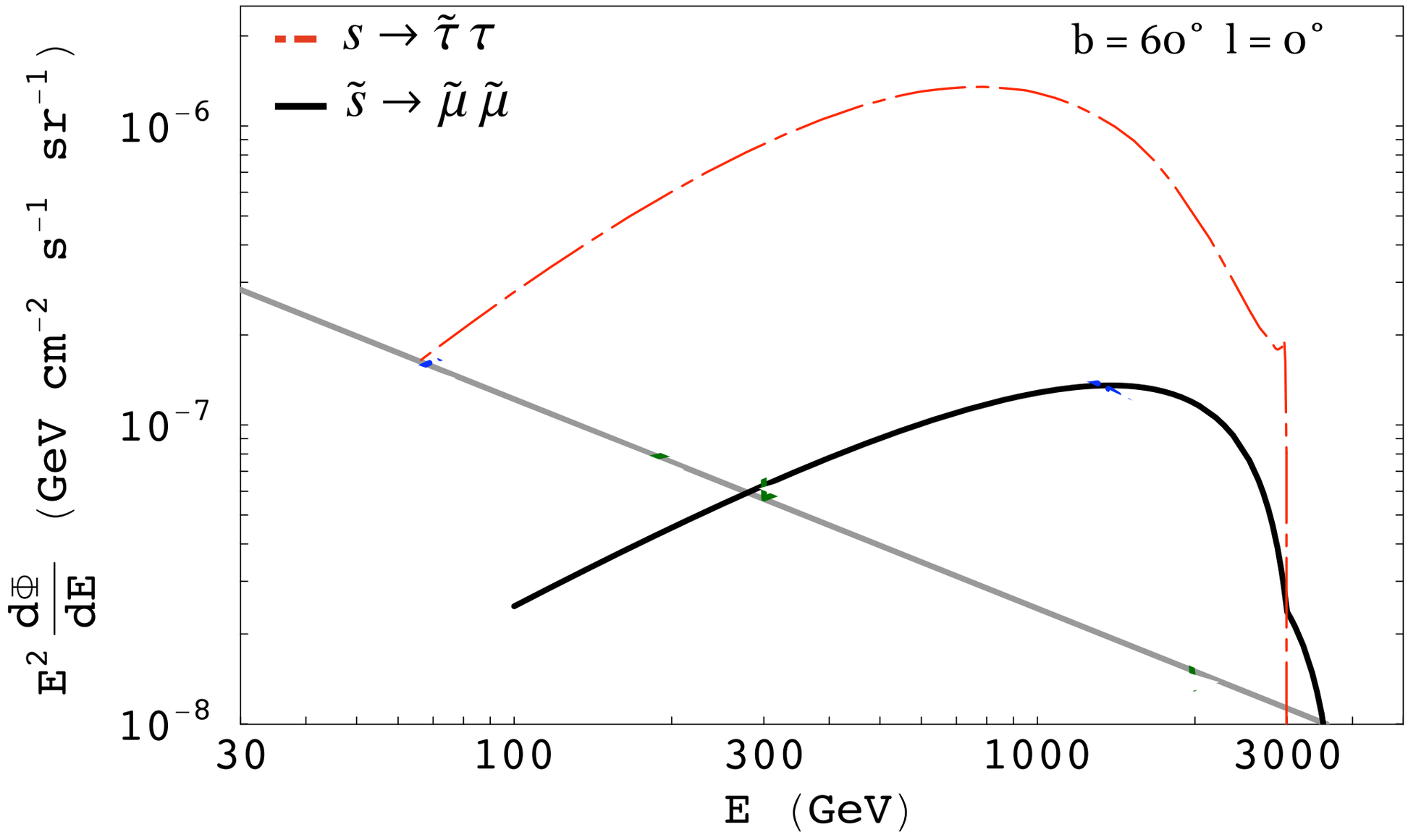
$m_{\tilde{\mu}}$ = 260 GeV

m_{LSP} = 130 GeV

$\tau = 1.2 \times 10^{26}$ s

Photon Flux in Fermi

Looking for Dark Matter decays off the galactic plane

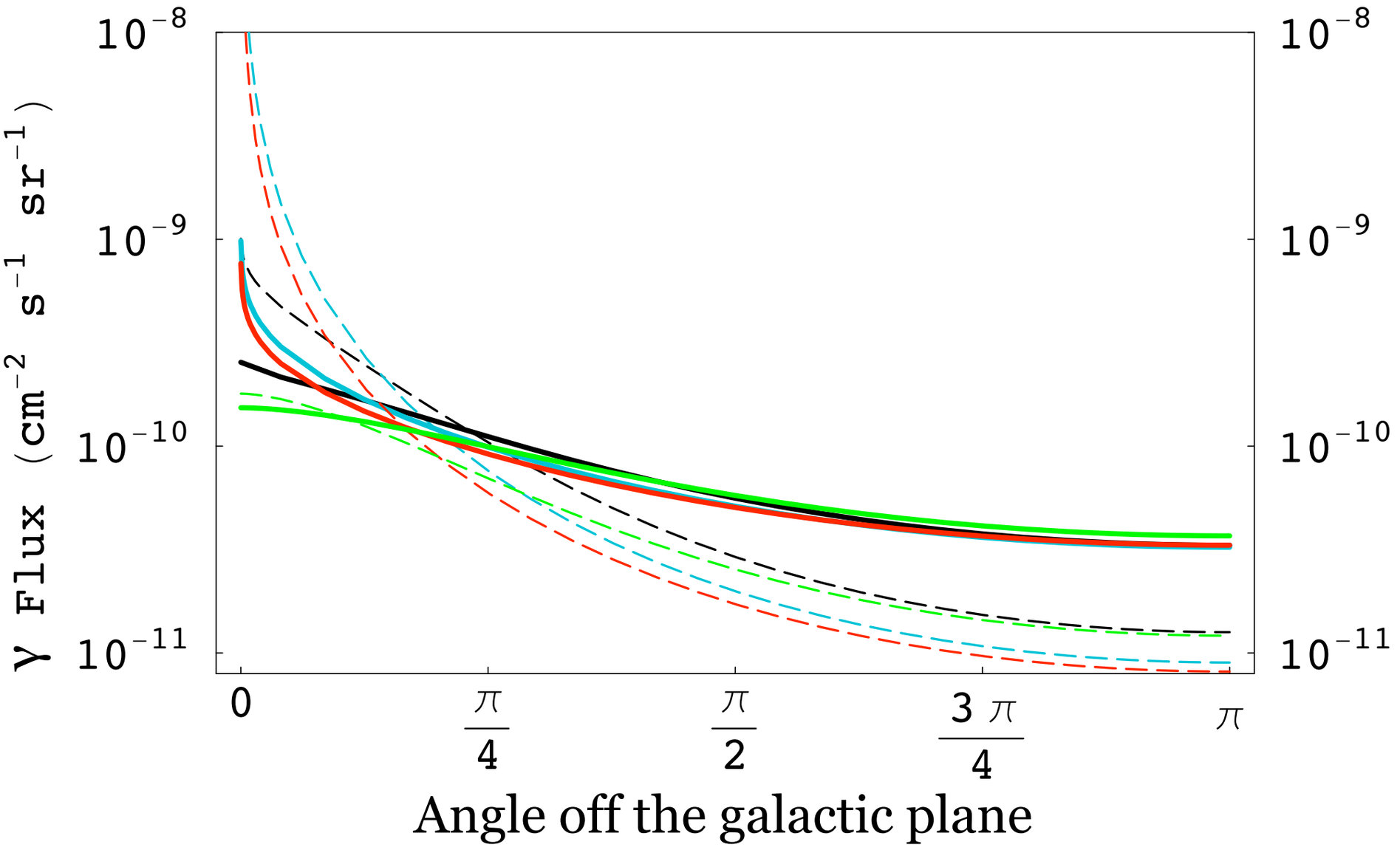


Models with similar electron spectra have different photon spectra

Decays vs Annihilations

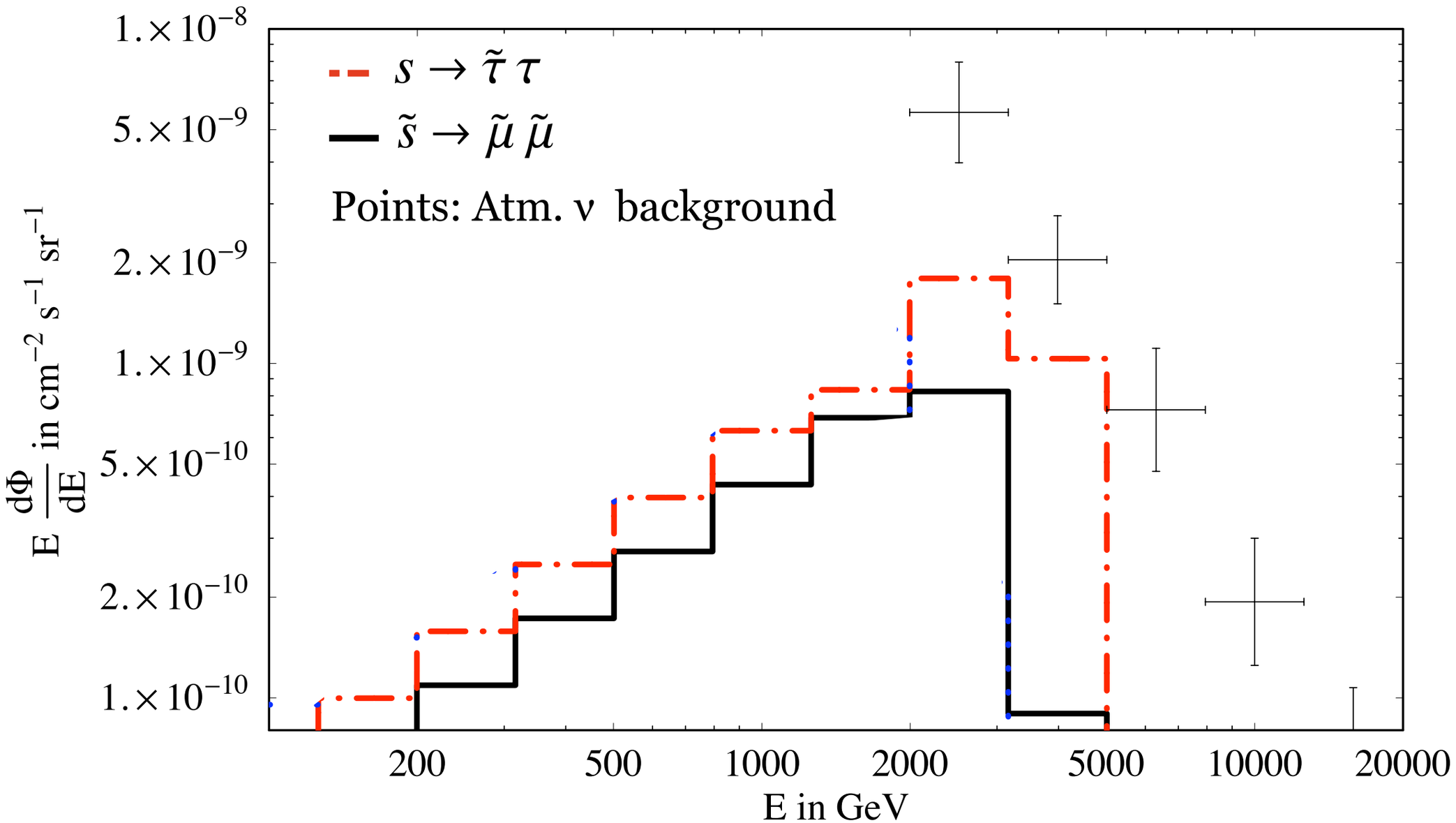
Decay rate ~ DM density $\tau \sim 10^{28}$ sec

Annihilation rate ~ (DM density)^2 $\sigma\upsilon \sim 10^{-26}$ cm^3/sec



Neutrino Flux in IceCube

Whatever produces electrons may also produce neutrinos



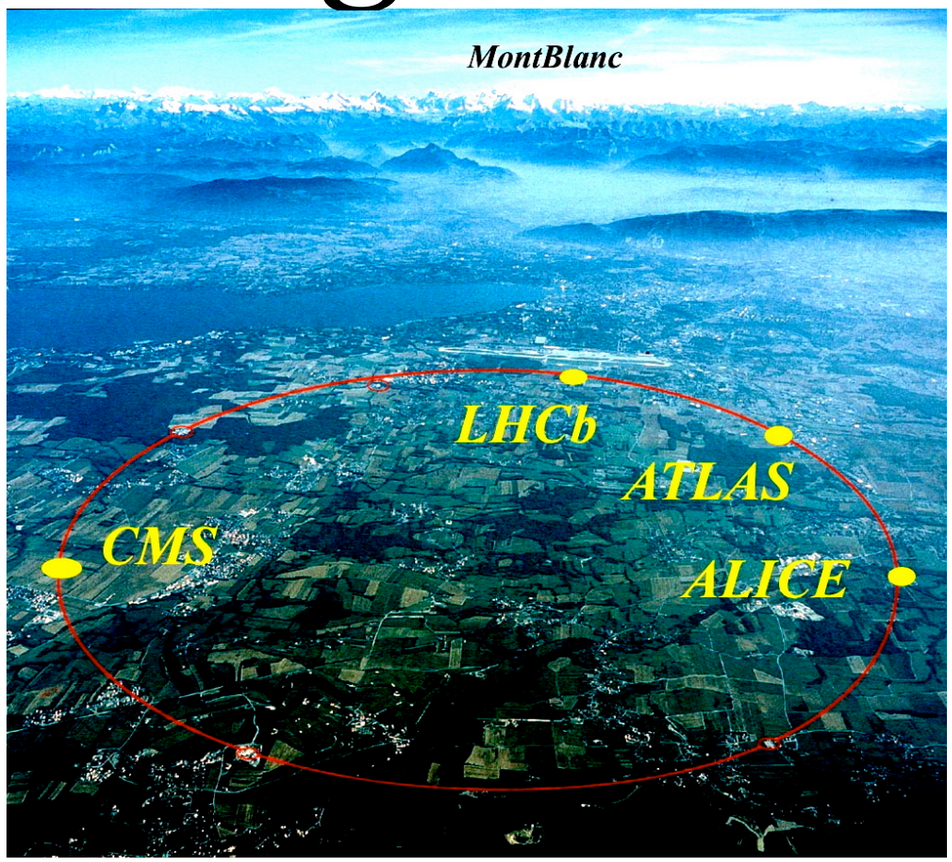
Conclusions

- Decays: signals of new physics at the TeV and GUT scale

- DM Decays at 10^{27} sec: Signals at current cosmic ray experiments
  - Can explain current PAMELA and Fermi-Hess excesses
  - Predictions for Fermi and IceCube

The Age of Data

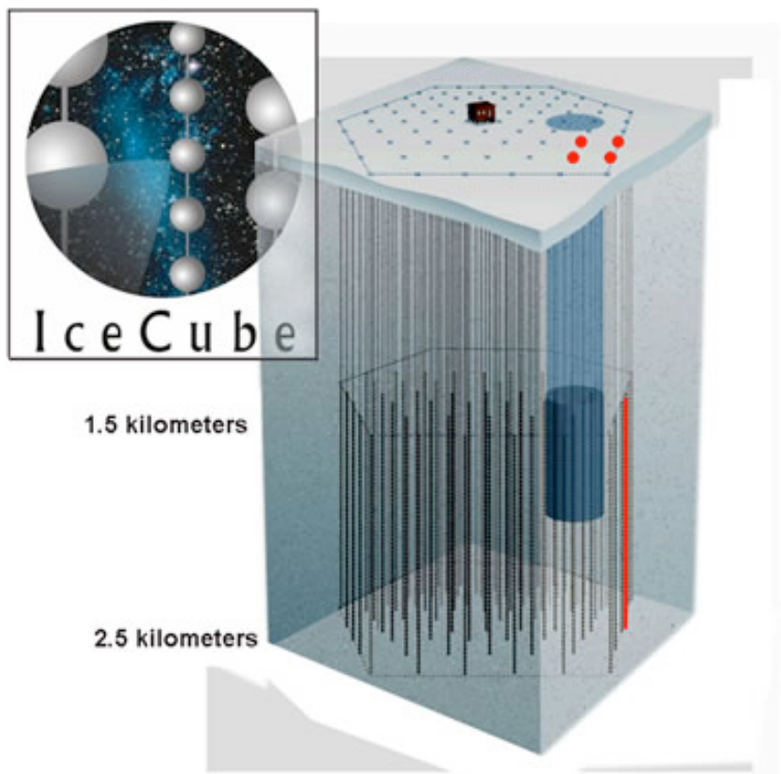
PAMELA



Fermi (GLAST)

ATIC

HESS



IceCube