Search for Gamma Rays from LKP Dark Matter in the UED framework with GLAST

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on behalf of GLAST DM & Exotic Physics WG

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KK Dark Matter in (minimal) UED

SM in $D = 5$ with 1 compactified extra-dimension (over $S^1/\mathbb{Z}_2$ with S^1 radius R)

Every SM field (bulk field) possess a KK tower

1-loop level computation shows that the LKP is well approximated by the first KK mode of the hypercharge gauge boson $B^{(1)}$[a]

[a] Reference papers: Bergstrom et al. **Phys.Rev.Lett.94:131301,2005**, Servant, Tait **Nucl.Phys.B650:391-419,2003**

Limit from Relic Density and Colliders

WMAP results $\Omega_{CDM}h^2 = 0.12 \pm 0.02$

$\Downarrow$

0.5 TeV$\lesssim m_{B^{(1)}} \lesssim 1$ TeV

(depending from the coannihilation channels)

Collider measurements of EW observables

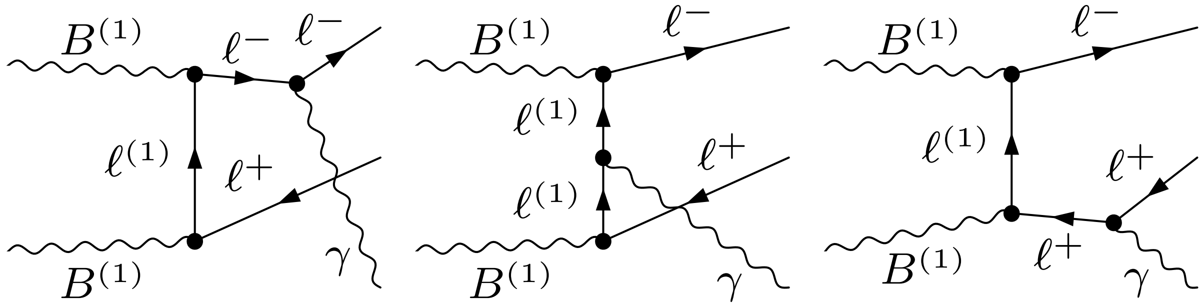
$\Downarrow$

$R^{-1} \gtrsim 0.3$ TeV

Unlike the supersymmetric case charged lepton production is not helicity suppressed and it is the dominant annihilation channel for masses $\lesssim 0.5$ TeV.

Gamma Rays from LKP

Tree level Feynman diagrams $B^{(1)}B^{(1)} \rightarrow l^+ l^- \gamma$



Differential photon multiplicity well approximated by

$$\frac{dN_\gamma^l}{dx} \simeq \frac{\alpha}{\pi} \frac{(x^2 - 2x + 2)}{x} \ln \left[\frac{m_{B^{(1)}}^2}{m_l^2} (1 - x) \right] \quad (1)$$

with $x \equiv E_\gamma / m_{B^{(1)}}$

Gamma Rays from LKP

Total number of photons per $B^{(1)}B^{(1)}$ annihilation

$$\frac{dN_\gamma^{tot}}{dx} \equiv \sum_i k_i \frac{dN_\gamma^i}{dx} \quad (2)$$

where the sum is over all processes that contribute to primary and secondary gamma rays with k_i the corresponding branching ratio.

In the following analysis we have considered both the primary and secondary γ-ray production

LKP Branching Ratios

We assume the branching ratios computed in Servant, Tait (agree with Bergstrom et al)

Channel	Branching Ratio
quark pairs	35%
charged lepton pairs	59%
neutrino pairs	4%
Higgs bosons	2%

dominant annihilation channel

Secondary Contribution

Hadronization and/or fragmentation of $q\bar{q}$ final states

We include semihadronic decays of τ leptons (fairly hard spectrum) Fornengo et al **Phys.Rev.D70:103529,2004**

$\Downarrow$

parametrization of $dN_\gamma^{q,\tau}/dx$ for
a center of mass energy ~ 1 TeV.

We neglect gauge and Higgs bosons final states.

Continuum Gamma Ray Flux

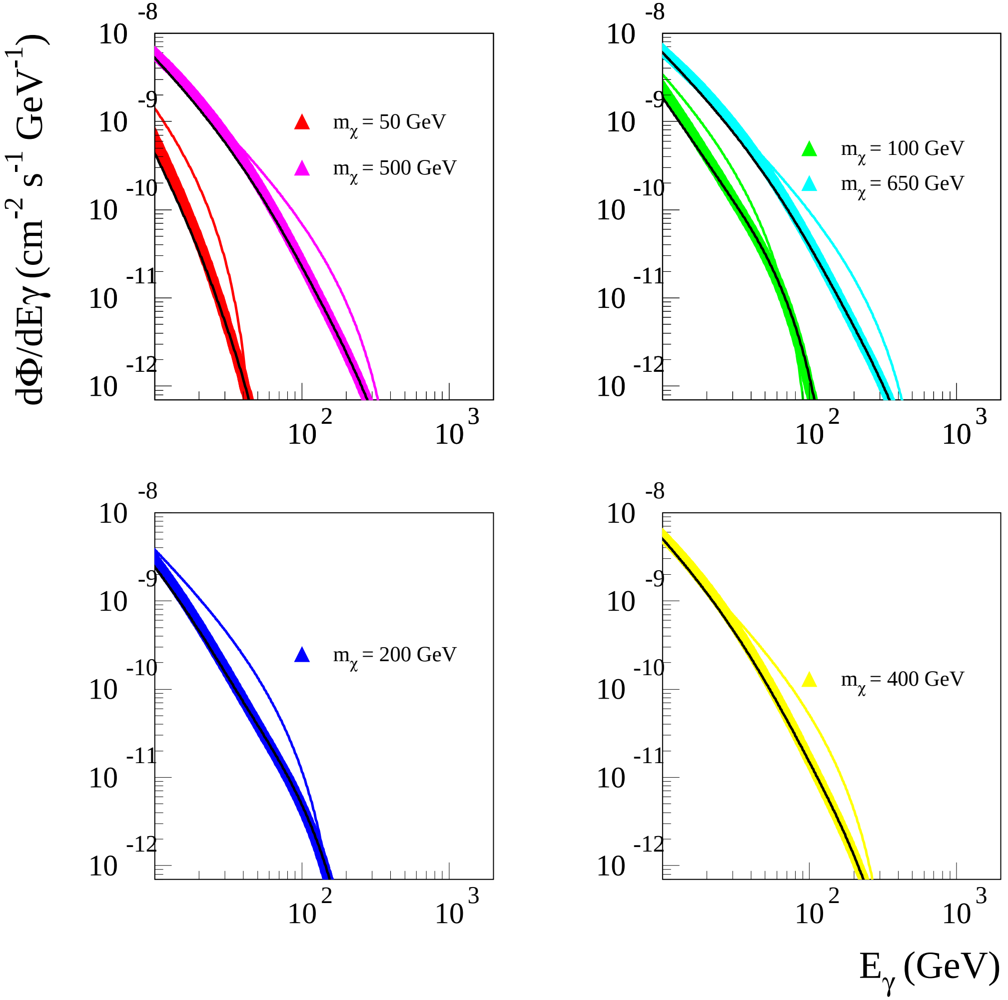
We assume a NFW profile with a boost factor b.

The differential γ-ray flux from the GC is

$$E_\gamma^2 \frac{d\Phi_\gamma(\Delta\Omega)}{dE_\gamma} \simeq 3.5 \cdot 10^{-8} x^2 \frac{dN_\gamma^{tot}}{dx} \left(\frac{\sigma_{tot} v}{3 \cdot 10^{-26}\ \mathrm{cm}^3 \mathrm{s}^{-1}}\right) \times \left(\frac{0.8\mathrm{TeV}}{m_{B^{(1)}}}\right) \langle J_{GC} \rangle_{\Delta\Omega}\ \mathrm{m}^{-2}\mathrm{s}^{-1}\mathrm{TeV} \quad (3)$$

- σ_{tot} total annihilation rate for $B^{(1)}$
- $\langle J_{GC} \rangle_{\Delta\Omega} = 0.13 \cdot 10^5\, b$ for $\Delta\Omega = 10^{-5}$ sr
- for KK DM $\sigma_{tot} v \simeq 3 \cdot 10^{-26}\ \mathrm{cm}^3\ \mathrm{s}^{-1}$

Flux from Secondary Contribution



Different approximations

- Tasitsiomi, Olinto

Phys.Rev.D66:083006,2002

- DarkSUSY

- Fornengo et al

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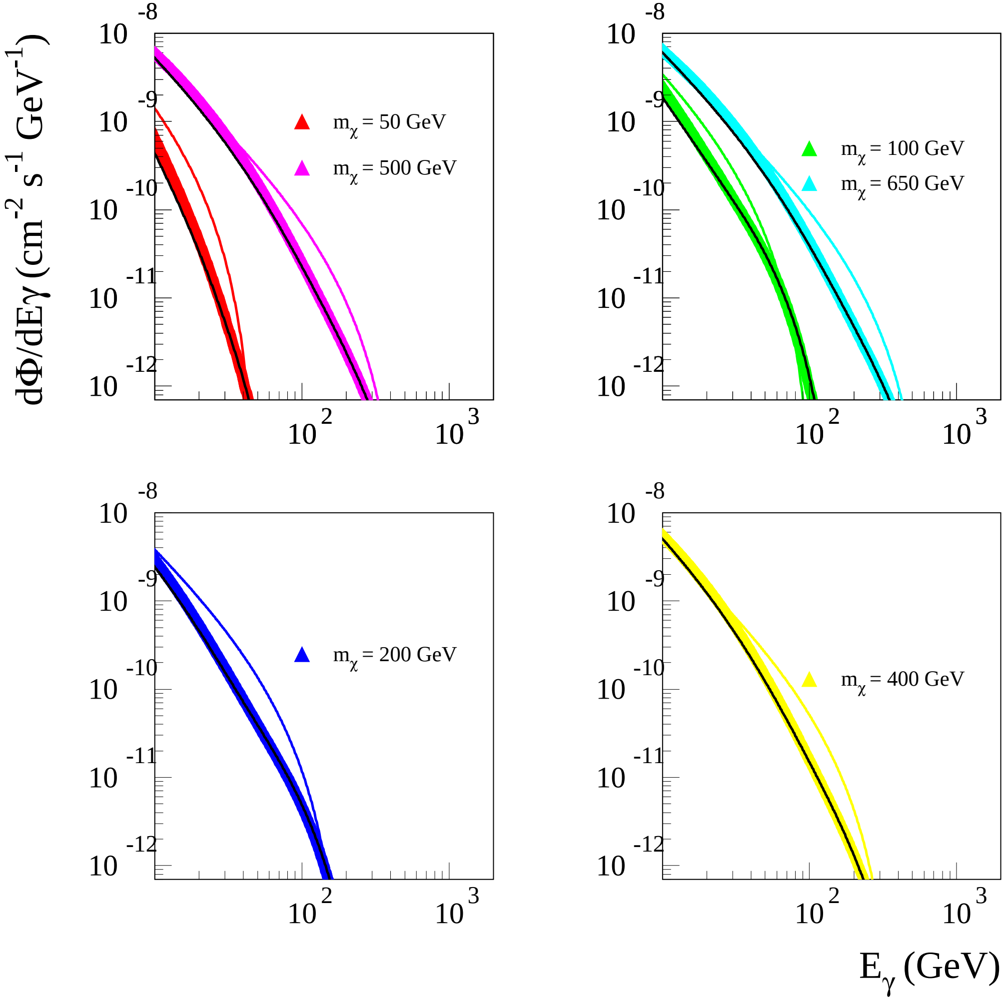

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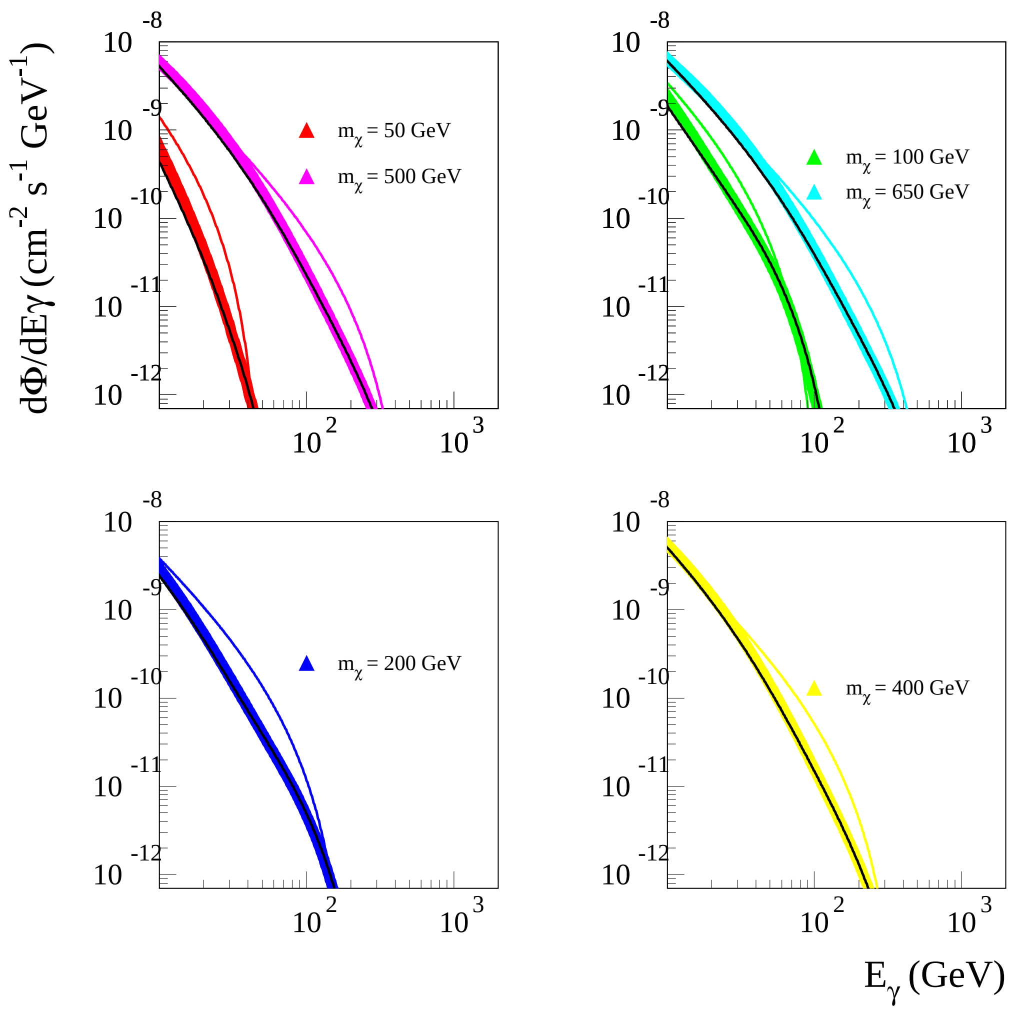

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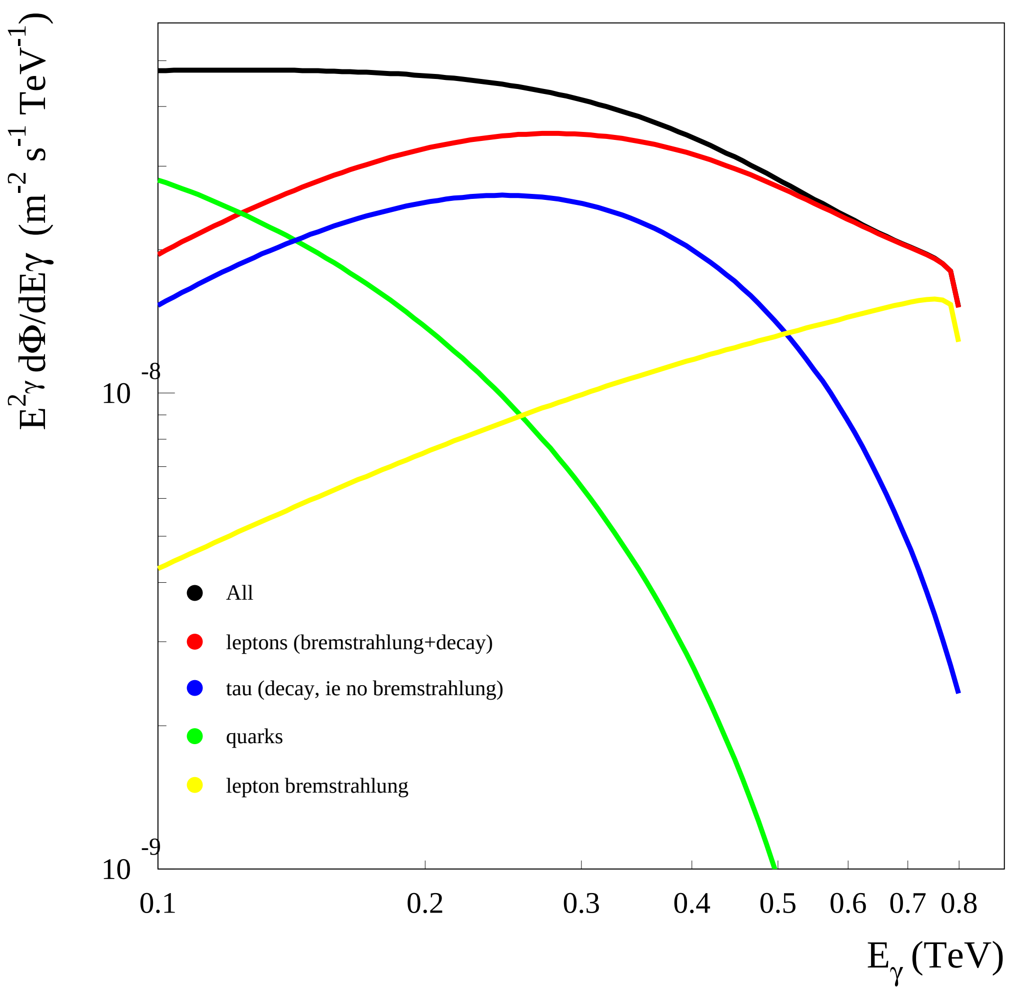
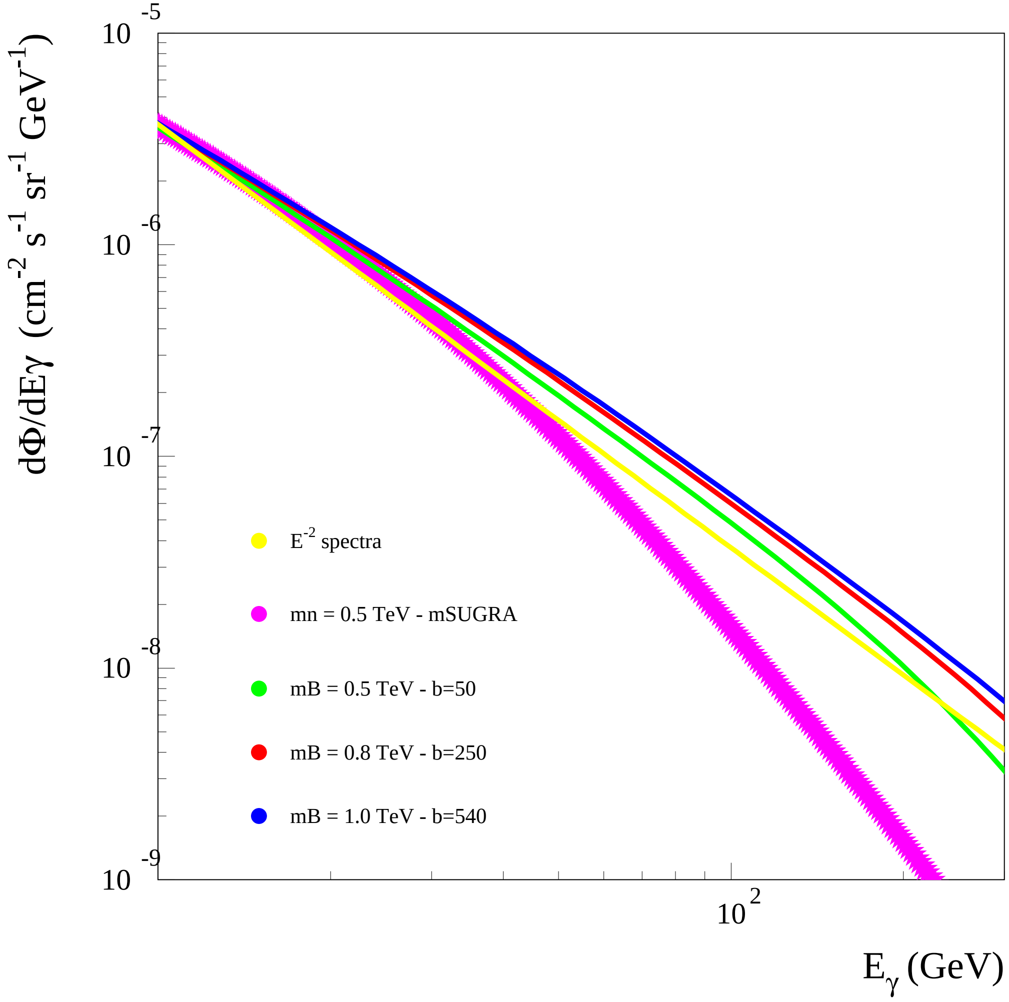
Our results are for $m_{B^{(1)}} = 0.5,\ 0.8,\ 1$ TeV

Gamma Ray Flux Contributions



Total flux contribution from LKP of $m_{B^{(1)}} = 0.8$ TeV and with a boost factor $b = 200$

Spectral Shapes



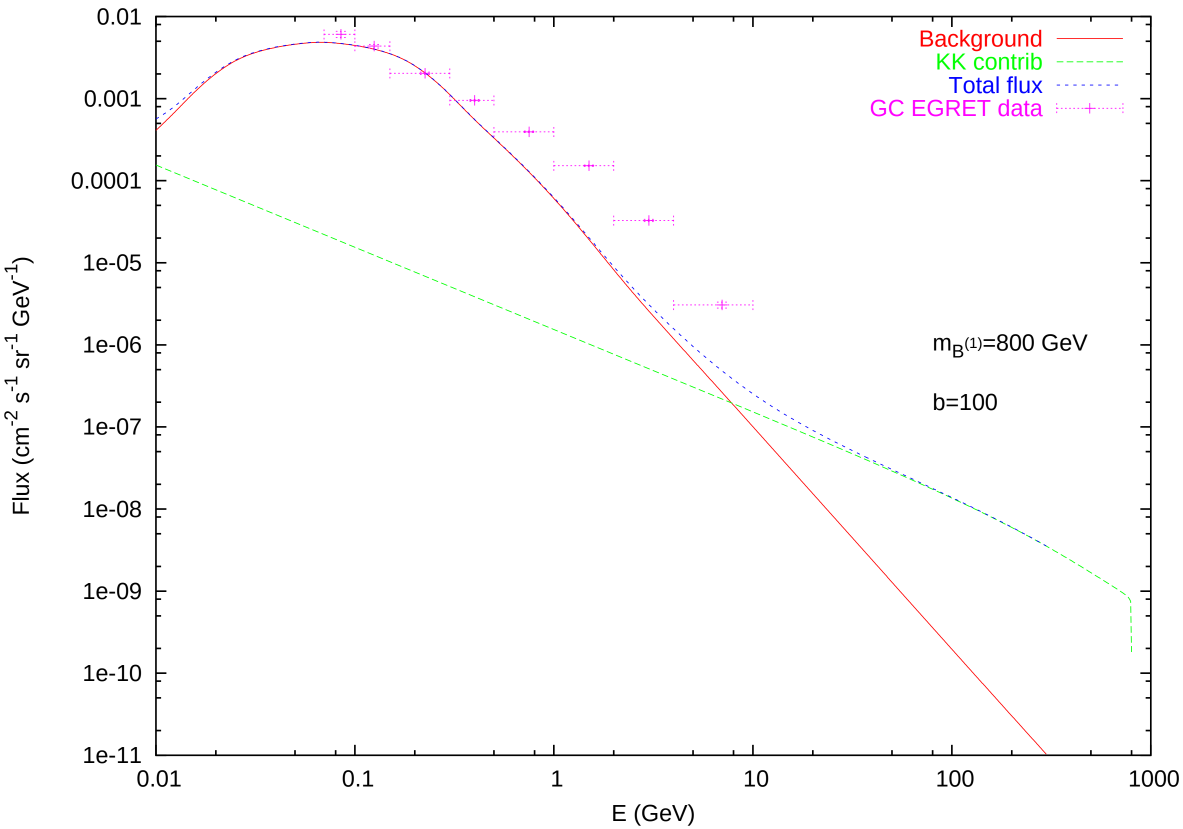
Comparison between different spectral shapes

primary and secondary contribution

mSUGRA
vs
LKP

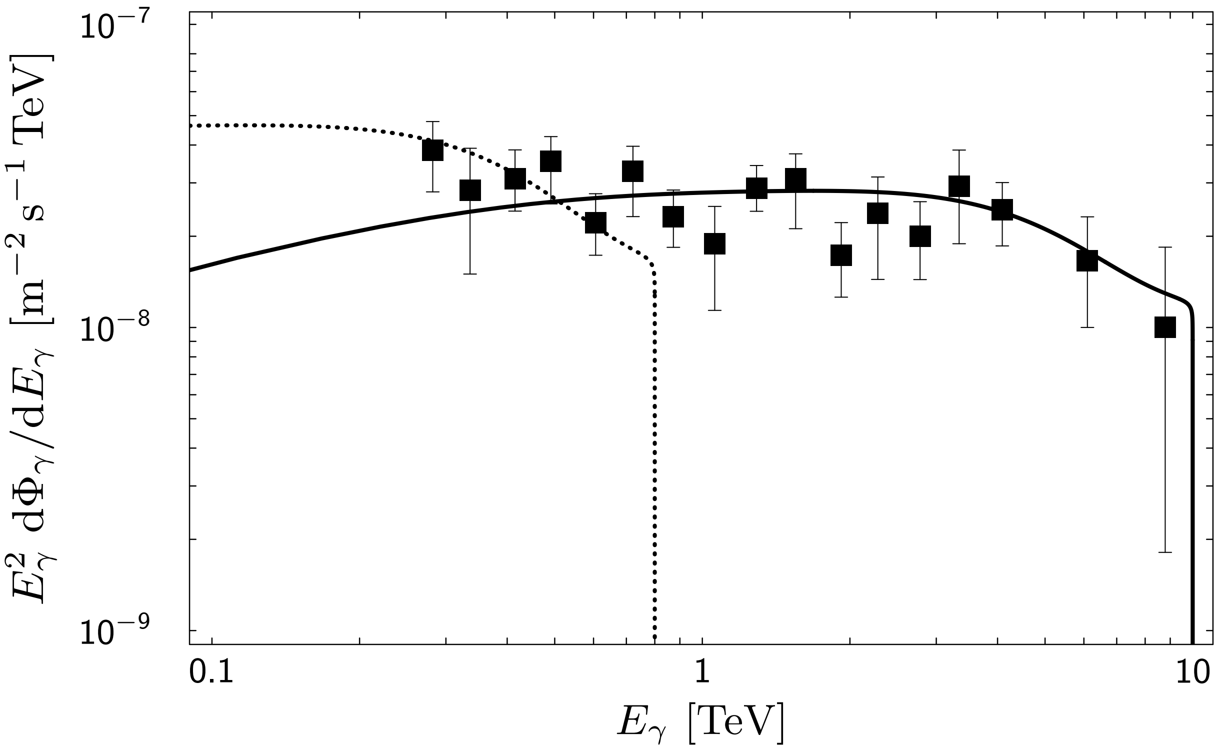
Gamma from LKP in the GLAST range

Differential flux from the GC does not violate EGRET data



Bonus: HESS data

The same model of the previous slide (dashed line) is able to fit the HESS data[a] up to energies $\simeq m_{B^{(1)}}$ with $b \simeq 100$



[a] see Bergstrom et al

Preliminary GLAST Sensitivity

We simulated a 1 year map of the sky with a NFW profile ($b \sim 100$)

for a LKP with $m_{B^{(1)}} = 500$ GeV

The total integrated flux is given by

$$\Phi_\gamma \left(\Delta\Omega, E_\gamma > E_{thrs}\right) = 3.4 \cdot 10^{-8} \, N_\gamma \left(\frac{1\,\mathrm{TeV}}{m_{B^{(1)}}}\right) \langle J_{GC} \rangle_{\Delta\Omega} \ \mathrm{m}^{-2}\mathrm{s}^{-1} \quad (4)$$

For $E_{thrs} = 10$ GeV and $\Delta\Omega = 0.21$ sr we obtain

$$\Phi_\gamma \left(\Delta\Omega, E_\gamma > E_{thrs}\right) = 1.2\, 10^{-3} \ \mathrm{m}^{-2}\mathrm{s}^{-1} \quad (5)$$

Counting photons in a circle of 30deg we got 18σ significance

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$$\Phi_\gamma \left(\Delta\Omega, E_\gamma > E_{thrs}\right) = 1.2\, 10^{-3}\ \mathrm{m}^{-2}\mathrm{s}^{-1} \qquad (7)$$

Counting photons in a circle of 30deg we got 18σ significance

5σ significance $\Rightarrow \Phi_\gamma \left(\Delta\Omega, E_\gamma > E_{thrs}\right) = 3.2\, 10^{-4}\ \mathrm{m}^{-2}\mathrm{s}^{-1}$

Conclusions

- Our (preliminary) computation indicates that, in the energy range $E_\gamma > 10$ GeV, GLAST could detect γ-rays from KK DM with "moderate" boost factors
- Spectral shape is quite distinctive $\sim E_\gamma^{-2}$
- (Possible) connection with the HESS data
- But this result strongly depends from the background model
(need of a precise estimate)

Backup Slides

Continuum Gamma Ray Flux

Differential flux for $m_{B^{(1)}} = 0.8$ TeV and
$\sigma_{tot} v \simeq 3 \cdot 10^{-26}\ \mathrm{cm}^3\ \mathrm{s}^{-1}$

$$\frac{1}{\Delta\Omega} \frac{d\Phi_\gamma}{dE_\gamma} = 3.5 \cdot 10^{-9} \frac{1}{m^2_{B^{(1)}}} \frac{dN^{tot}_\gamma}{dx} \langle J_{GC} \rangle_{\Delta\Omega} \tag{8}$$

in unit of $\mathrm{cm}^{-2}\ \mathrm{s}^{-1}\ \mathrm{GeV}^{-1}\ \mathrm{sr}^{-1}$ and where

$$\langle J_{GC} \rangle_{\Delta\Omega} = 0.13 \cdot 10^5\, b \tag{9}$$

for $\Delta\Omega = 10^{-5}$ sr. b is a boost factor (deviations from a pure NFW)

EGRET Limit

We checked our models against EGRET limits

(Re)Normalizing the KK flux to a region of ~ 1.5 deg around the GC we have (in the worst case)

$$\frac{1}{\Delta\Omega}\frac{d\Phi_\gamma}{dE_\gamma} = 2\,10^{-7}\mathrm{cm}^{-2}\ \mathrm{s}^{-1}\ \mathrm{GeV}^{-1}\ \mathrm{sr}^{-1} \tag{10}$$

that is about 15 times lower than the EGRET upper bounds.