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Gamma-ray, neutrino and antiproton fluxes from TeV Dark Matter at the Galactic Center

Viviana Gammaldi

Universidad Complutense Madrid

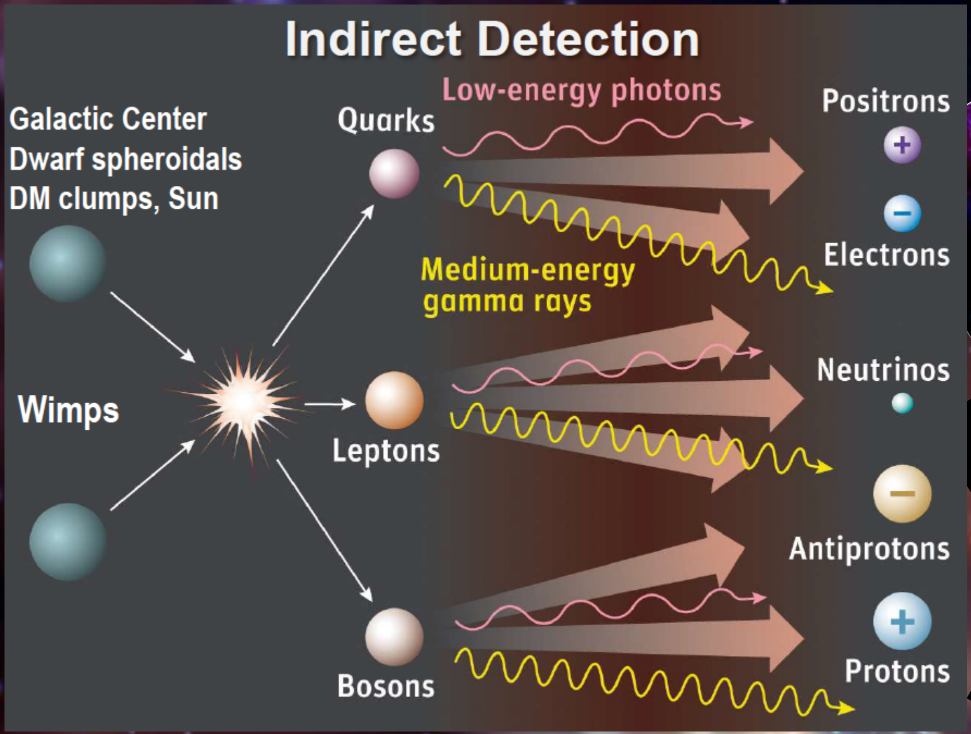
Multidark Group

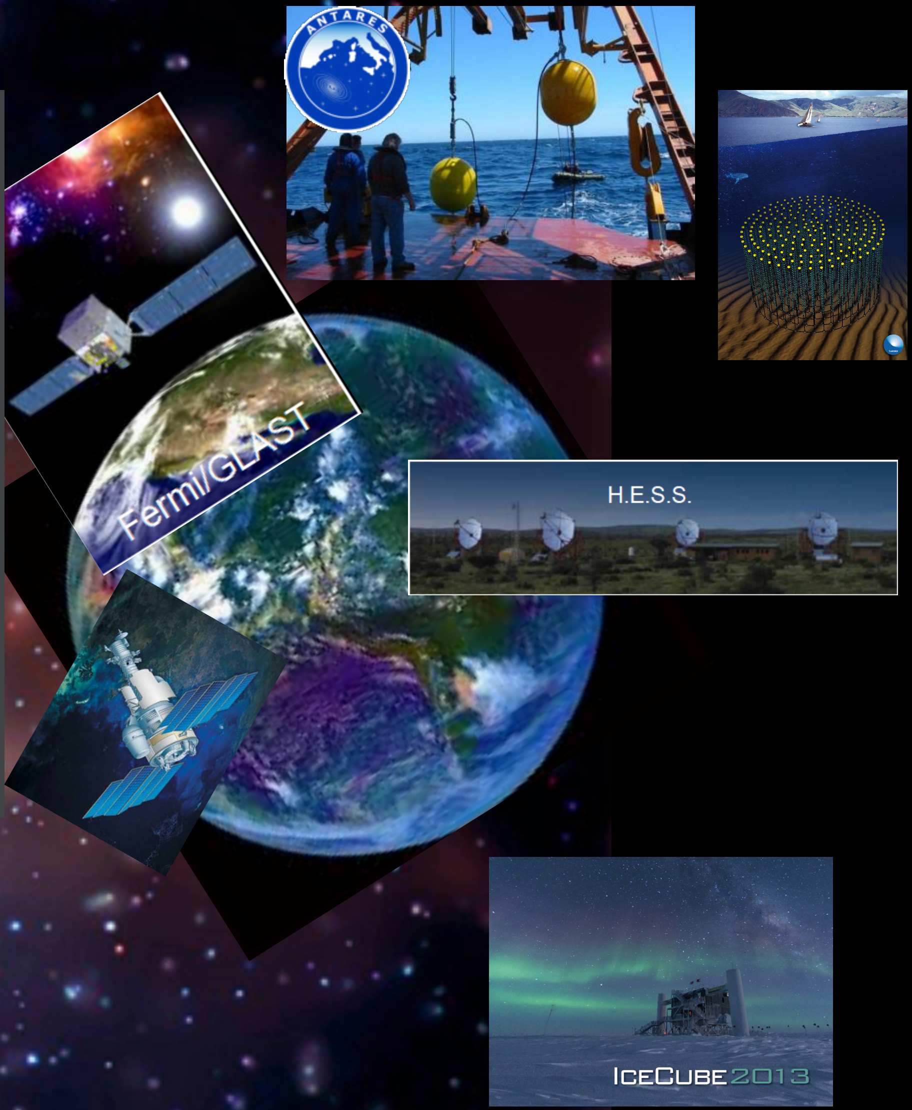
J. A. R Cembranos, V. G., A. L. Maroto [arXiv:1204.0655v1], PRD 86, 103506 (2012); [arXiv:1302.6871v2][astro-ph.CO], JCAP04 (2013) 051, [arXiv:1403.6018], PRD 90, 043004 (2014); , A. de la Cruz-Dombriz, R. A. Lineros [arXiv:1404.2067] TAUP 2013 Proceedings, JHEP 1309 (2013) 077, arXiv:1305.2124v3 [hep-ph]

Outline

- Dark Matter (DM) Indirect search
- The Galactic Center (GC):
  - Gamma-rays
  - Neutrinos
  - Antiprotons
- Conclusion

Indirect search





Indirect search

Cosmic-ray fluxes at the Earth from DM annihilating or decay in Galactic sources depend by the Standard Model (SM) secondary particle of interest.

Gamma-rays: $$\frac{d\Phi_\gamma}{dE} = \sum_{a=1}^{2} \sum_{i}^{\text{channels}} \frac{\zeta_i^{(a)}}{a} \cdot \frac{dN_i^{(\gamma)}}{dE} \cdot \frac{\Delta\Omega \left\langle J_{(a)} \right\rangle_{\Delta\Omega}}{4\pi M^a}$$

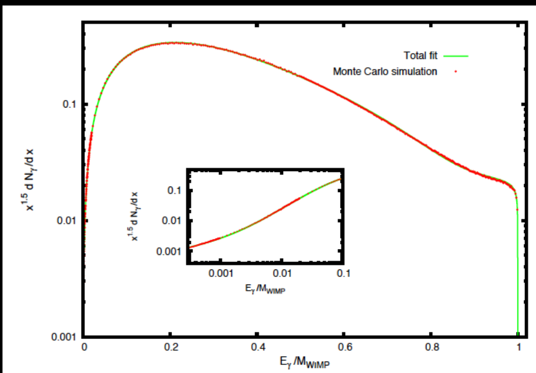
Neutrinos: $$\frac{d\Phi_{\nu_f}}{dE} = \sum_{p=1}^{3} \sum_{a=1}^{2} \sum_{i}^{\text{channels}} P_{fp} \cdot \frac{\zeta_i^{(a,\nu_p)}}{a} \frac{dN_i^{(\nu_p)}}{dE} \cdot \frac{\Delta\Omega \left\langle J_{(a)} \right\rangle_{\Delta\Omega}}{4\pi M^a}$$

Antiprotons: $$\frac{\mathrm{d}\Phi_{\bar{p}}}{\mathrm{d}E_{\bar{p}}} = \sum_{a=1}^{2} \sum_{i}^{\text{channels}} \frac{\zeta_i^{(a)}}{a} \frac{\mathrm{d}N_i^{(\bar{p})}}{\mathrm{d}E_{\bar{p}}} \cdot \frac{v_{\bar{p}}}{4\pi} \left(\frac{\rho_\odot}{M}\right)^a R_{(a)}(E_{\bar{p}})$$

Indirect search: simulations

Secondary particle fluxes are simulated by Monte Carlo events generator software such as PYTHIA or HERWIG.

An example: gamma-ray spectra for 1 TeV DM annihilating into tau$^+$tau$^-$ by PYTHIA 6.4 .



(c) Photon spectrum for $M = 1000\,\mathrm{GeV}$ for $\tau^+\tau^-$ channel.

Pythia 6.4 all channels fitting function here:

J.A.R. Cembranos, A. de la Cruz-Dombriz, A. Dobado, R.A. Lineros, A. L. Maroto, Phys.Rev. D 83, 083507(2011), arXiv:1012.4473 [hep-ph] arXiv: 1011.2137 [hep-ph] ArXiv:1009.4936 [hep-ph]

Comparison between gamma rays simulated fluxes in different softwares here:

J.A.R. Cembranos, A. de la Cruz-Dombriz, V.G., R.A. Lineros, A. L. Maroto, JHEP 1309 (2013) 077, arXiv:1305.2124v3 [hep-ph]

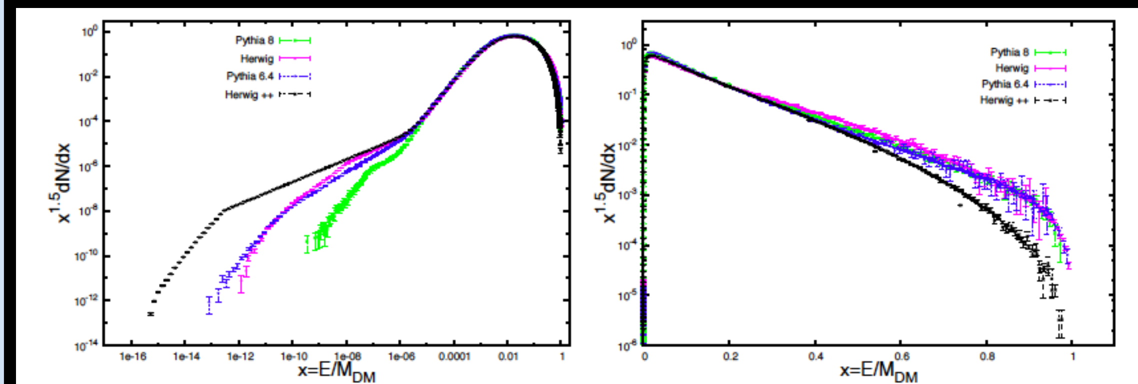
$$\frac{\zeta_i^{(a)}}{a} \cdot \frac{dN_i^{(\gamma)}}{dE} \cdot \frac{\Delta\Omega \left\langle J_{(a)} \right\rangle_{\Delta\Omega}}{4\pi M^a}$$

$$P_{fp} \cdot \frac{\zeta_i^{(a,\nu_p)}}{a} \frac{dN_i^{(\nu_p)}}{dE} \cdot \frac{\Delta\Omega \left\langle J_{(a)} \right\rangle_{\Delta\Omega}}{4\pi M^a}$$

$$\frac{\mathrm{d}N_i^{(\bar{p})}}{\mathrm{d}E_{\bar{p}}} \cdot \frac{v_{\bar{p}}}{4\pi} \left(\frac{\rho_\odot}{M}\right)^a R_{(a)}(E_{\bar{p}})$$

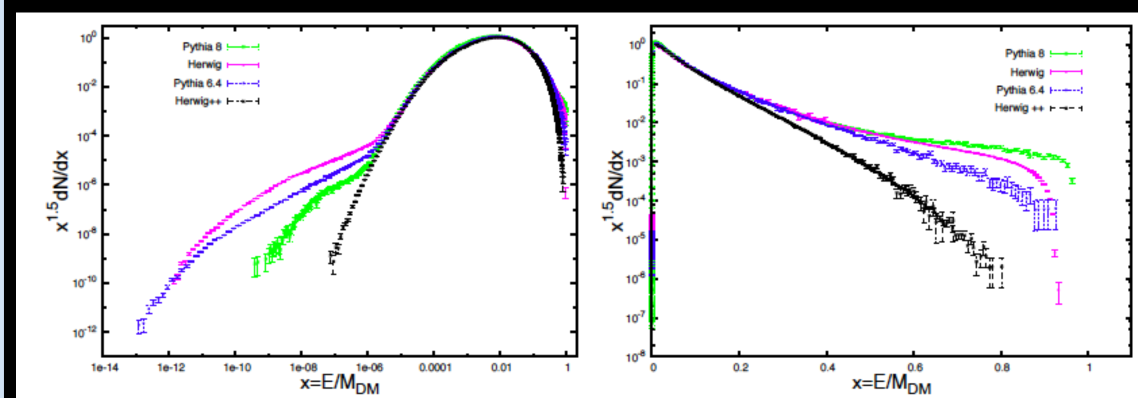
Indirect search: simulations

Simulation in PYTHIA 6.4 and HERWIG (Fortran) and PYTHIA 8 and HERWIG++ (C++):



m_{DM}=1 TeV
W^+W^- annihilation channel

Package	Bremsstrahlung
PYTHIA 6.4	Implemented
PYTHIA 8	Implemented
HERWIG	Partially implemented
HERWIG++	Not implemented



m_{DM}=1 TeV
top-antitop annihilation channel

J.A.R. Cembranos, A. de la Cruz-Dombriz, V.G., R.A. Lineros, A. L. Maroto, JHEP 1309 (2013) 077, arXiv:1305.2124v3 [hep-ph]

Indirect search: DM annihilation/decay

a=1 $\zeta^{(1)} = \Gamma$

a=2 $\zeta^{(2)} = \langle\sigma v\rangle$

They depend by the DM theoretical model.

For model independent analysis we use the cosmological thermal value for $\zeta^{(2)}$:

$$\langle \sigma v \rangle = 3 \cdot 10^{-26}\ \mathrm{cm^3 s^{-1}}$$

The final flux power-dependence by the DM mass and density distribution is also affected.

els $\frac{\zeta_i^{(a)}}{a} \cdot \frac{dN_i^{(\gamma)}}{dE} \cdot \frac{\Delta\Omega \langle J_{(a)} \rangle_{\Delta\Omega}}{4\pi M^a}$

nels $P_{fp} \cdot \frac{\zeta_i^{(a,\nu_p)}}{a} \frac{dN_i^{(\nu_p)}}{dE} \cdot \frac{\Delta\Omega \langle J_{(a)} \rangle_{\Delta\Omega}}{4\pi M^a}$

s $\frac{\zeta_i^{(a)}}{a} \frac{\mathrm{d}N_i^{(\bar{p})}}{\mathrm{d}E_{\bar{p}}} \cdot \frac{v_{\bar{p}}}{4\pi} \left(\frac{\rho_\odot}{M}\right)^a R_{(a)}(E_{\bar{p}})$

Indirect search: astrophysical factor

Astrophysical factor encode the physics of DM distribution and particles propagation.

For gamma-rays and neutrinos:

$$\langle J_{(a)} \rangle = \frac{1}{\Delta\Omega} \int_{\Delta\Omega} \mathrm{d}\Omega \int_0^{l_{max}(\Psi)} \rho^a[r(l)] dl(\Psi)$$

depends by the DM distribution and the devise angular resolution and effective area.

For antiprotons:

Is the solution of the diffusion equation that depends by the DM distribution and diffusion model.

$$\cdot \frac{\Delta\Omega \langle J_{(a)} \rangle_{\Delta\Omega}}{4\pi M^a}$$

$$\frac{(\nu_p)}{E} \cdot \frac{\Delta\Omega \langle J_{(a)} \rangle_{\Delta\Omega}}{4\pi M^a}$$

$$\left(\frac{\rho_\odot}{M}\right)^a R_{(a)}(E_{\bar{p}})$$

Galactic Center

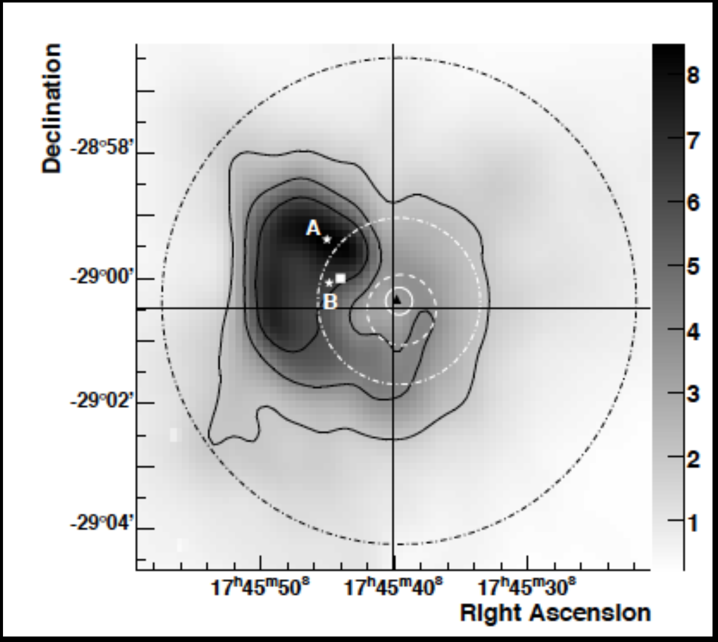
- Possible DM distribution close to the Earth but embedded in a very complex region due to the presence of multiplies sources.

- Multiplies sources observed (Radio flux, Sgr A* black hole, SNR Sgr A East, pulsar candidate, gamma emission).

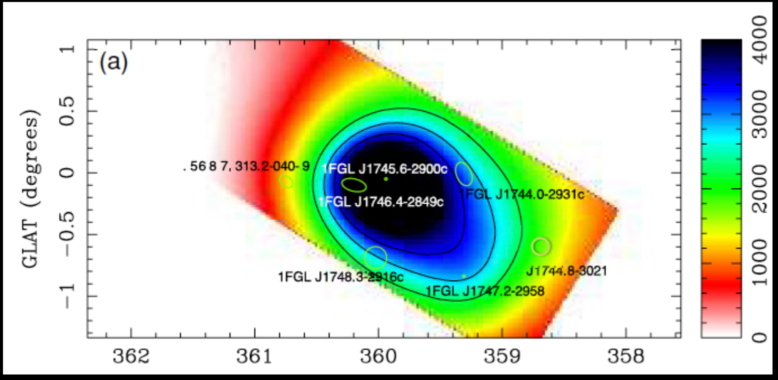
- Variability in Radio and X,

but not in gamma flux

HESS J1745-290



1FGL J1745.6-2900c

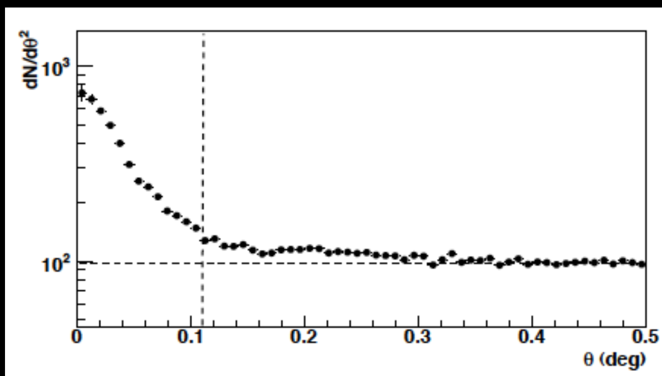


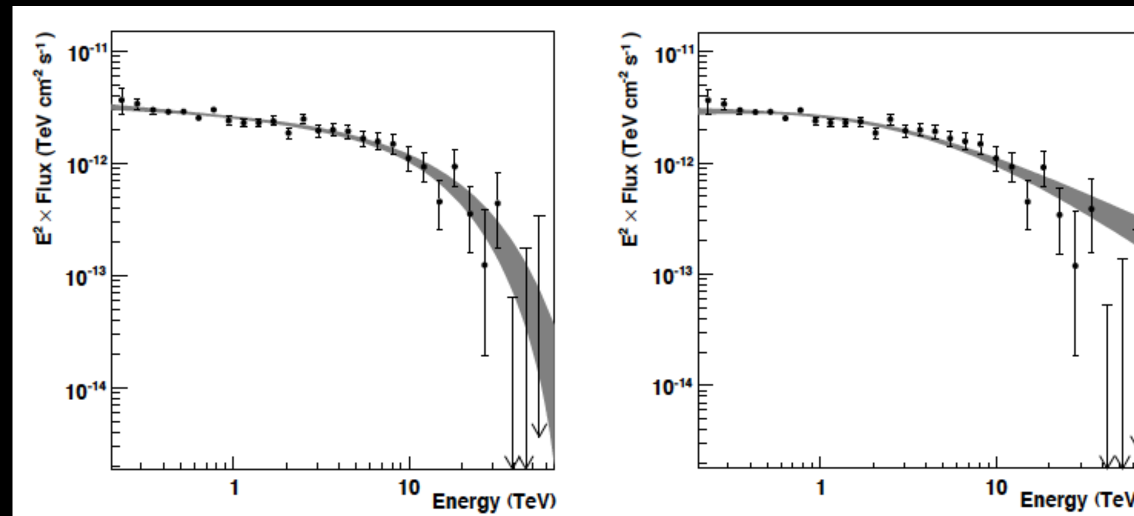
Gamma-rays from the Galactic Center

By HESS:

270 GeV-70 TeV

Θ < 0.1°

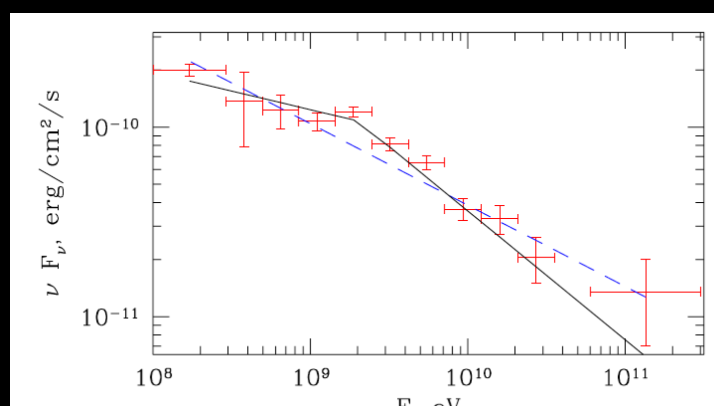




F. Aharonian et al. A&A 503, 817-825 (2009) F. Prada et al. Phys. Rev. Lett. 95, 241301 (2004)

By Fermi-LAT:

100 MeV-300 GeV



$$E > E_{br}$$

$$\chi^2/d.o.f. = 0.81$$

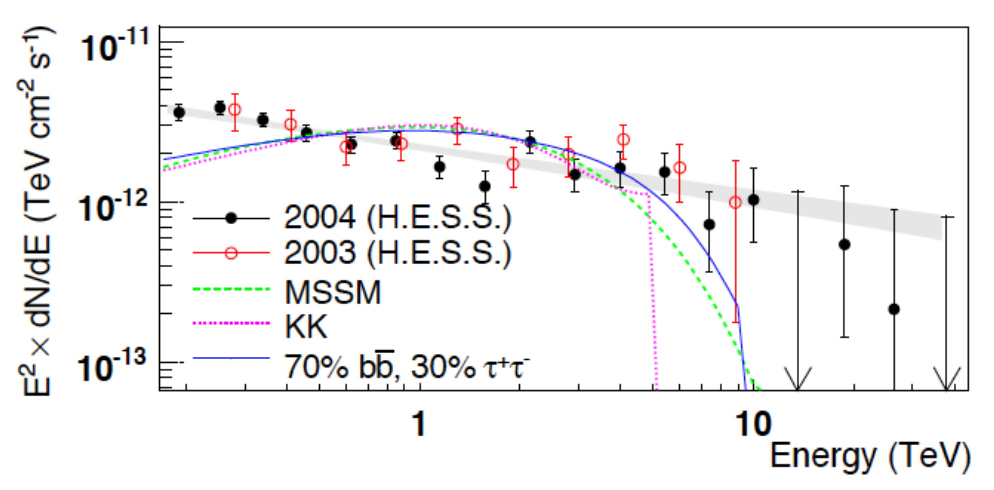
$$\Gamma = 2.68 \pm 0.05$$

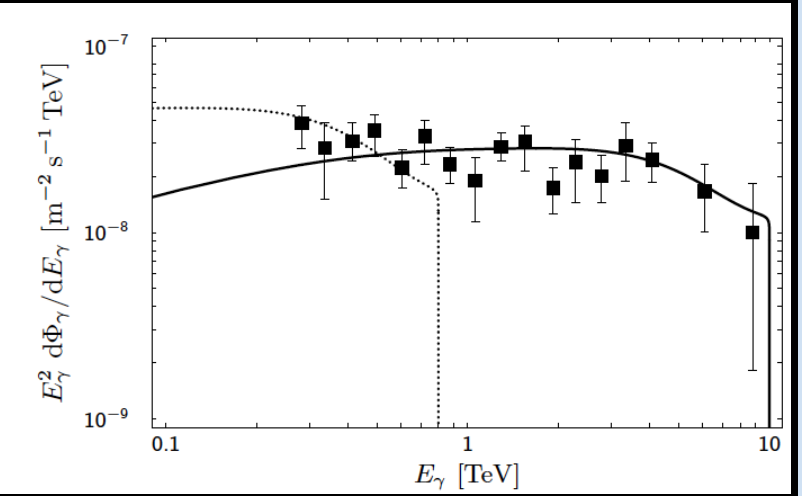
M. Cherenyakova et al. ApJ 726, 60 (2011)

Gamma-rays from the Galactic Center

Previous fits are not able to justify HESS signal in gamma-rays as DM signal without take into account a background contribution.

F. Aharonian et al. arXiv: astrp-ph/0610509v2 (2006) L. Bergstöm et al. arXiv:astro-ph/0410359v2(2005)





Gamma-rays from the Galactic Center

Background component: $$\frac{d\Phi_{Bg}}{dE} = B^2 \cdot \left(\frac{E}{\mathrm{GeV}}\right)^{-\Gamma}$$

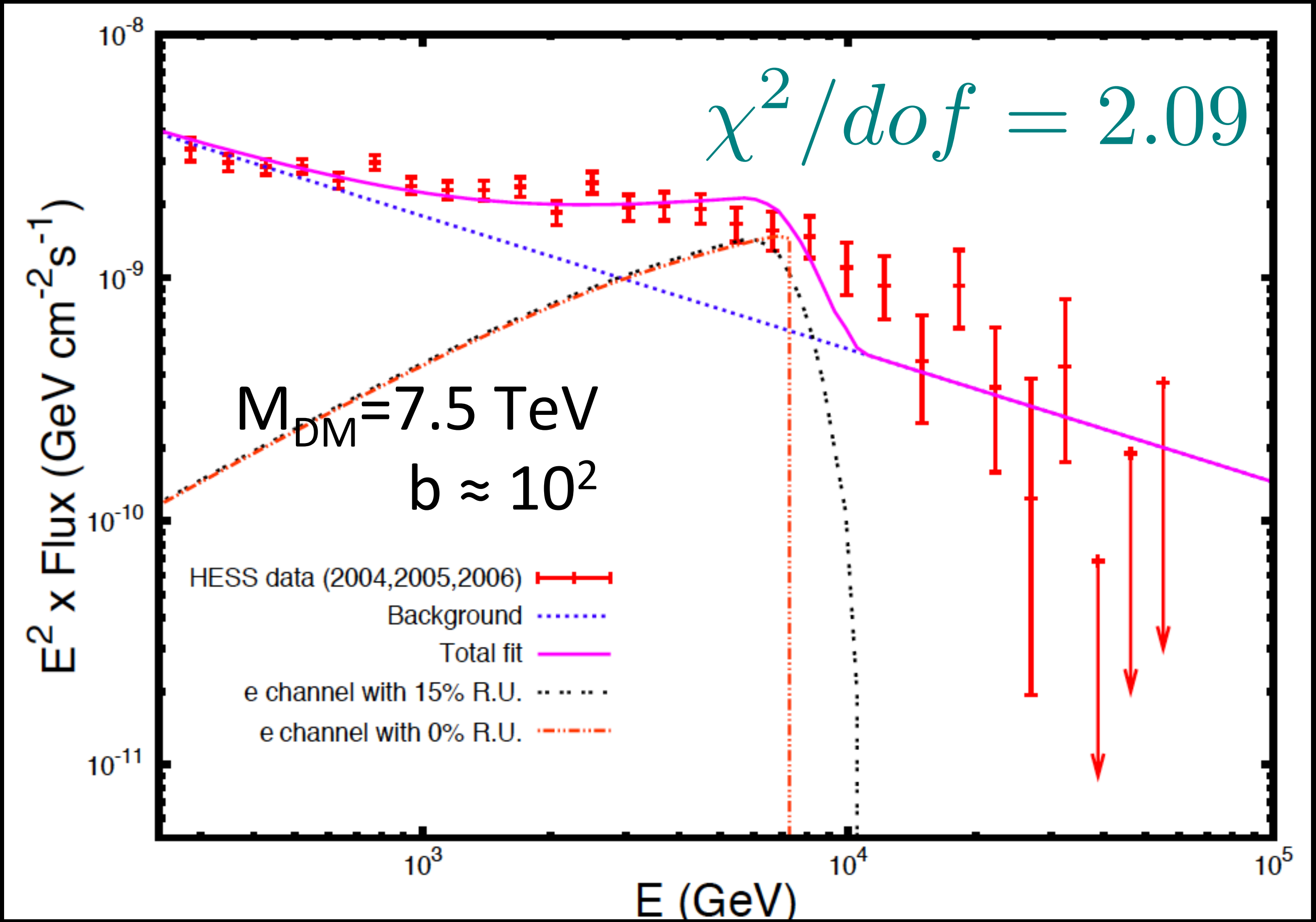
$$\frac{d\Phi_{Tot}}{dE} = \frac{d\Phi_{Bg}}{dE} + \frac{d\Phi_{DM}}{dE}$$

4 free parameters:

$$B, \Gamma, A, M$$

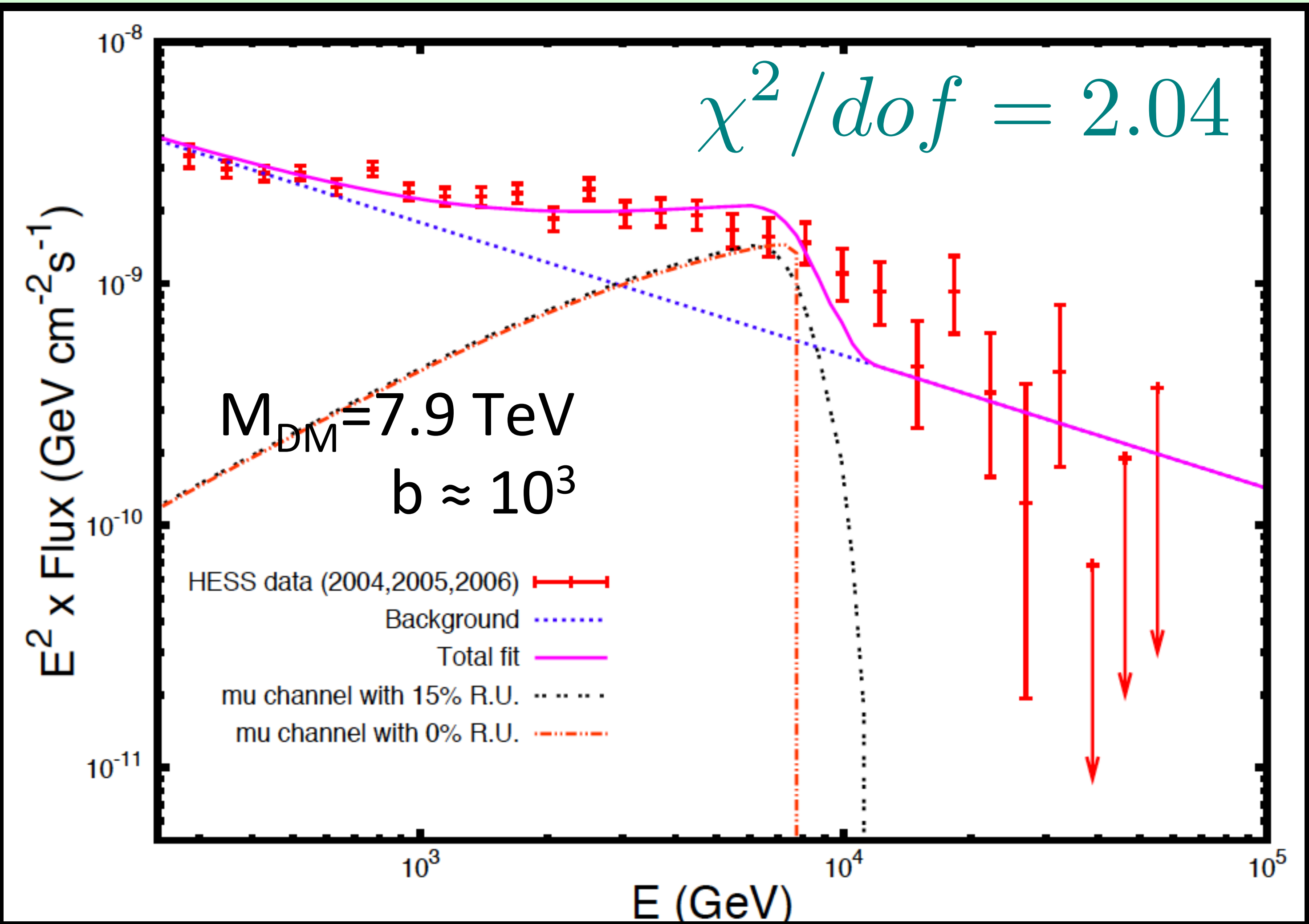
DM contribution: $$\frac{\mathrm{d}\,\Phi_{\mathrm{DM}}}{\mathrm{d}\,E} = \sum_i \frac{\langle \sigma_i v \rangle}{2} \frac{\mathrm{d}\,N_i}{\mathrm{d}\,E} \times \underbrace{\frac{\Delta\Omega \, \langle J_{(2)} \rangle_{\Delta\Omega}}{4\pi M^2}}_{A}$$

e^+e^- channel



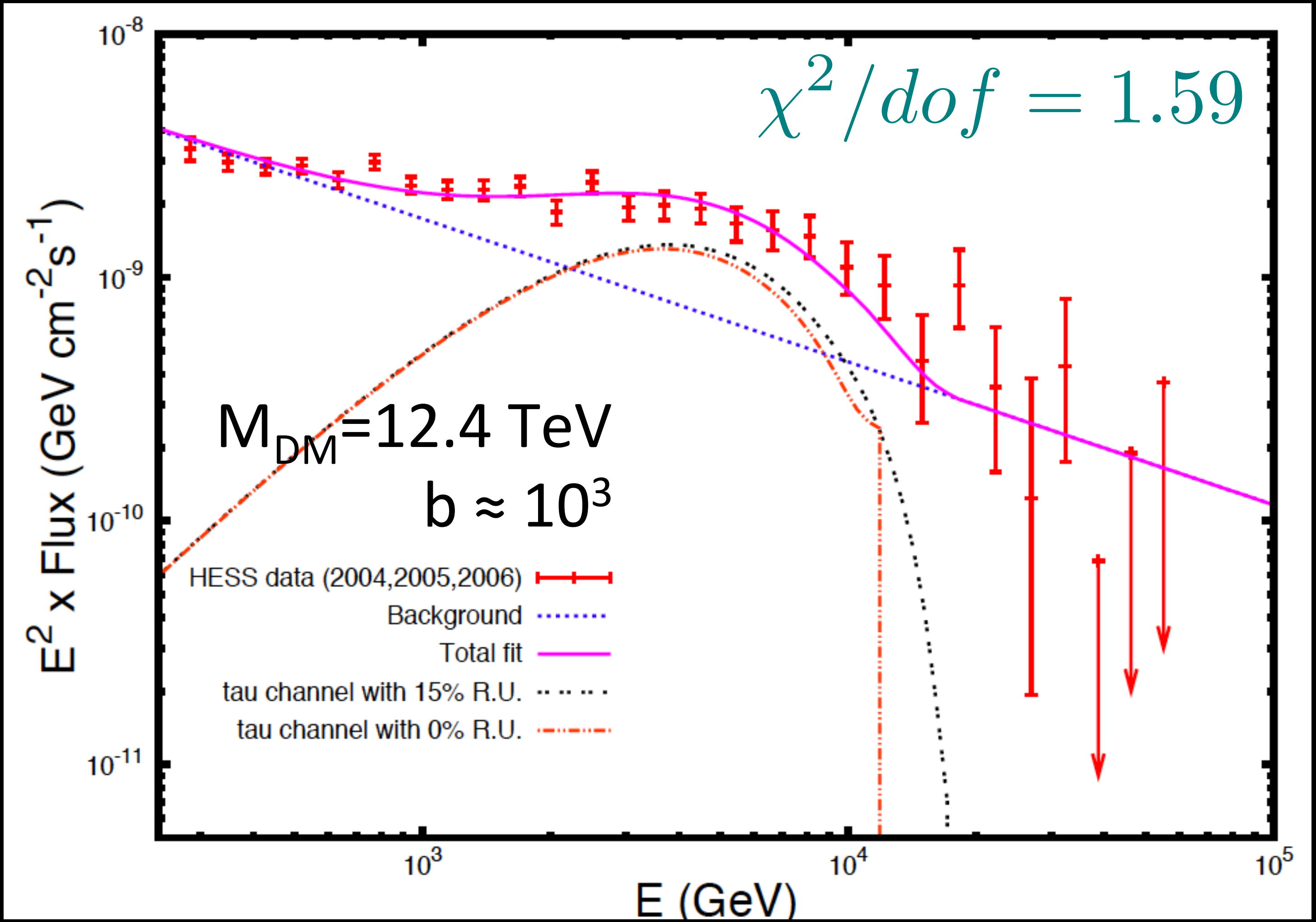
J. A. R Cembranos, V. G., A. L. Maroto arXiv [1204.0655v1], PRD 86, 103506 (2012); [arXiv:1302.6871v2][astro-ph.CO], JCAP04 (2013) 051

$\mu^+\mu^-$ channel



J. A. R Cembranos, V. G., A. L. Maroto arXiv [1204.0655v1], PRD 86, 103506 (2012); [arXiv:1302.6871v2][astro-ph.CO], JCAP04 (2013) 051

$tau^{+}tau^{-}$ channel



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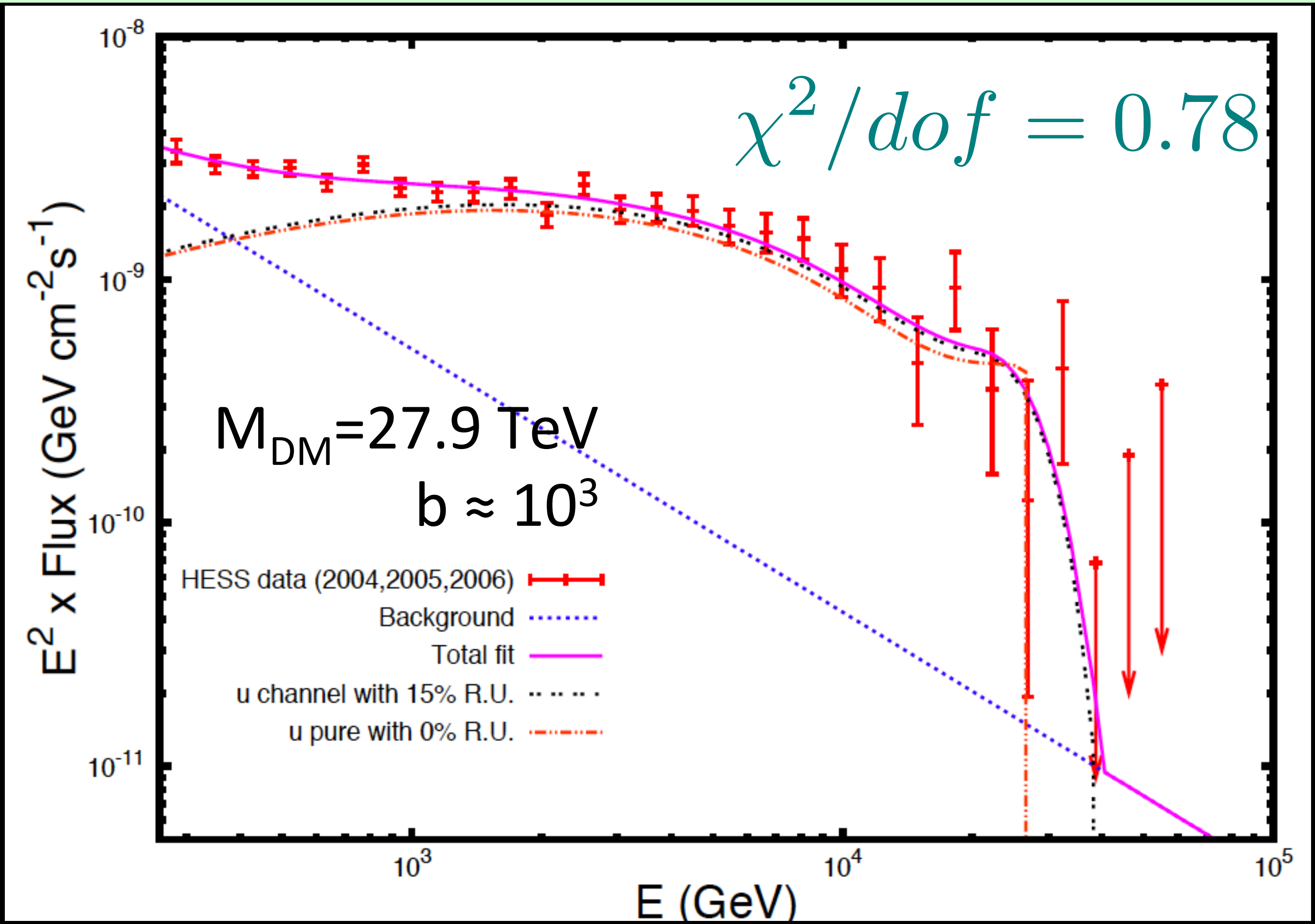
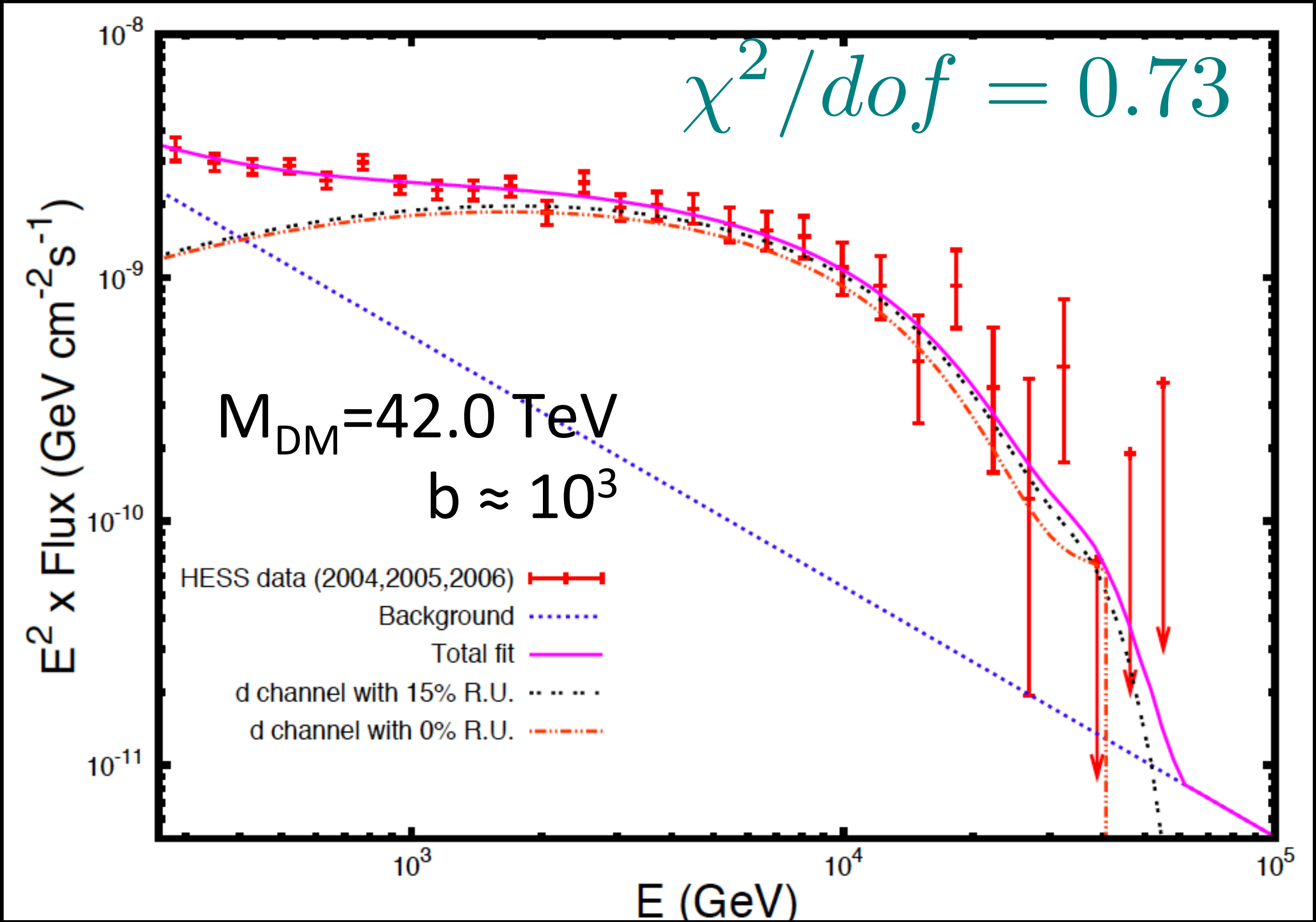
u-ubar channel



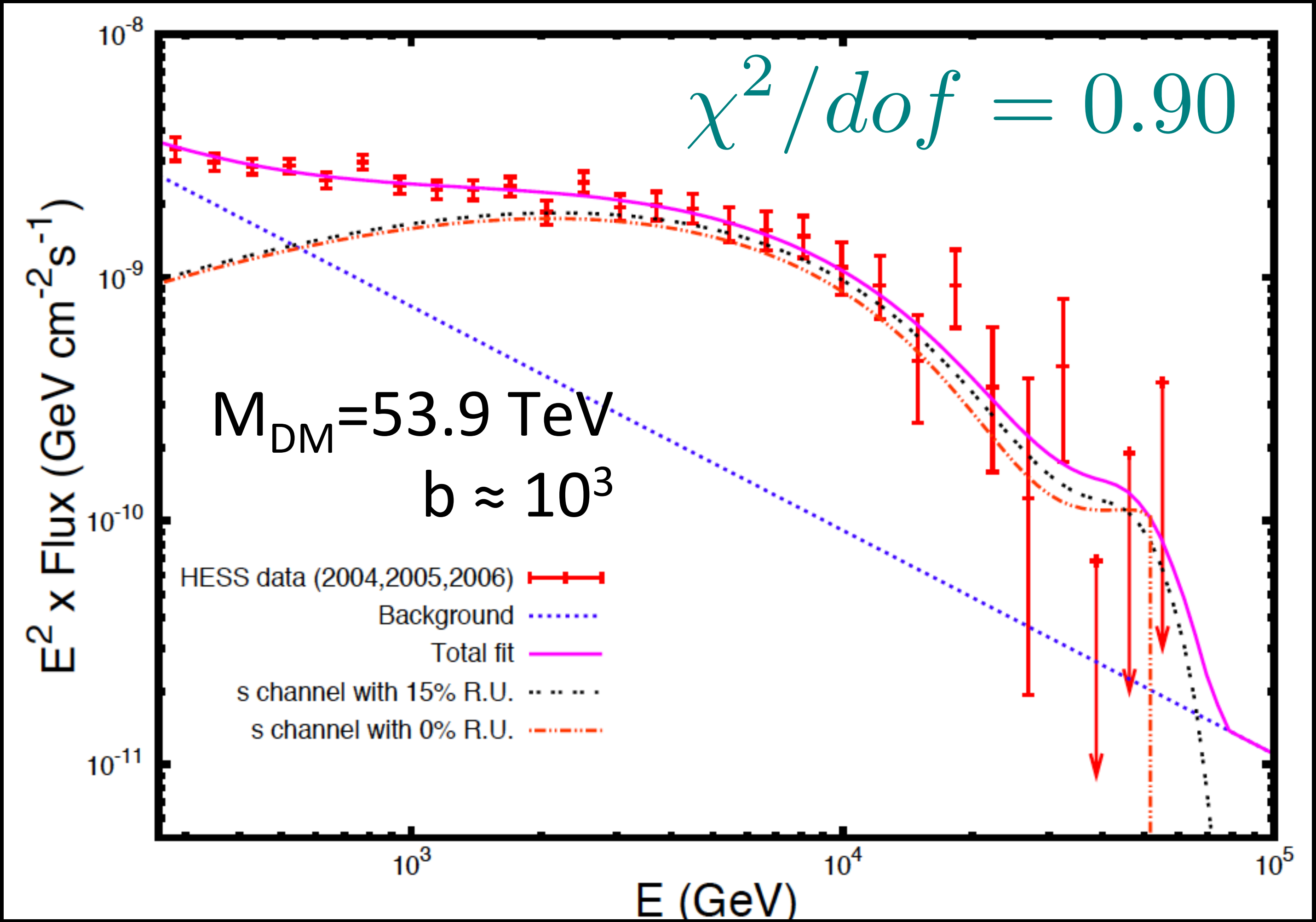
J. A. R Cembranos, V. G., A. L. Maroto arXiv [1204.0655v1], PRD 86, 103506 (2012); [arXiv:1302.6871v2][astro-ph.CO], JCAP04 (2013) 051

d-dbar channel



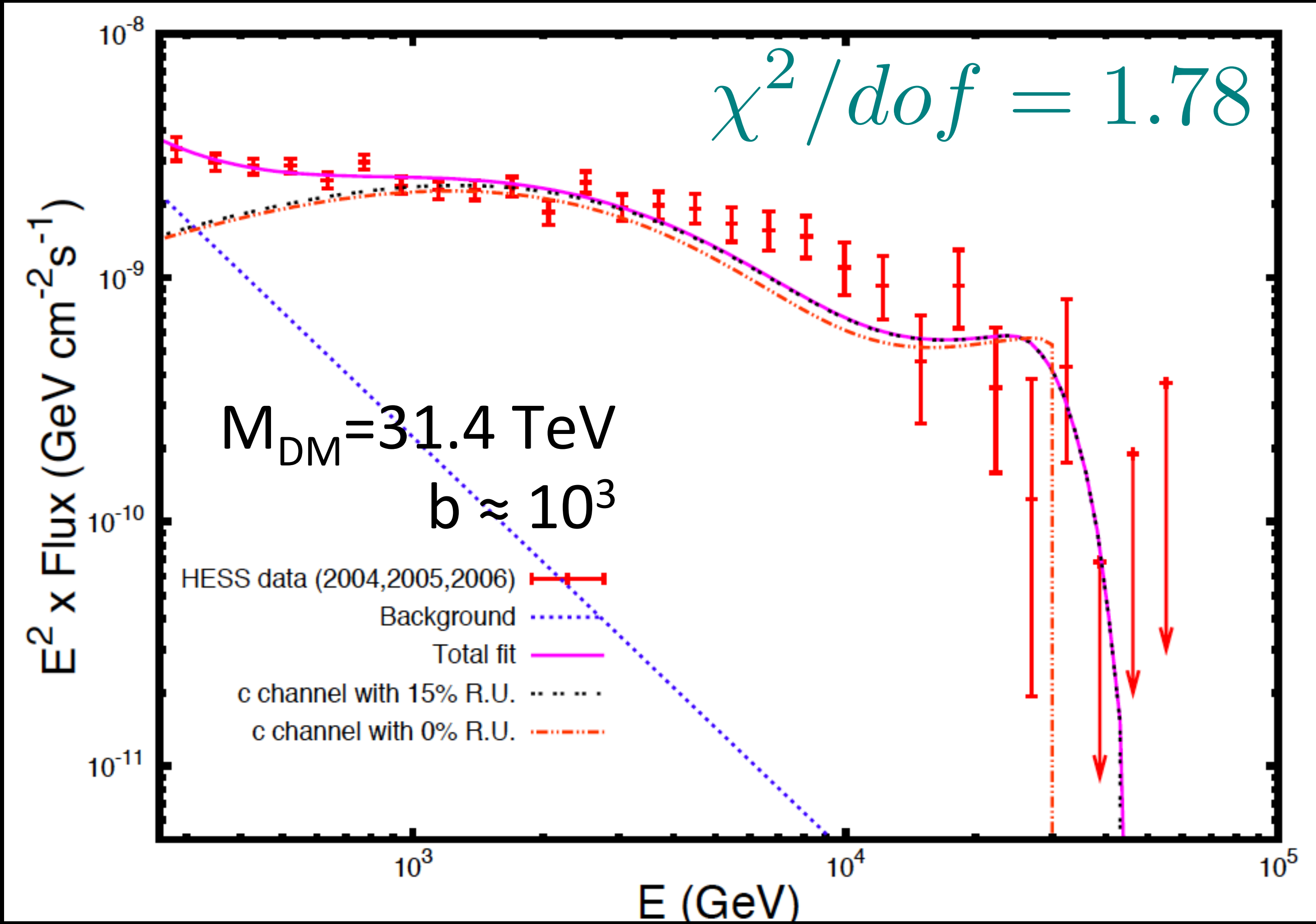
J. A. R Cembranos, V. G., A. L. Maroto arXiv [1204.0655v1], PRD 86, 103506 (2012); [arXiv:1302.6871v2][astro-ph.CO], JCAP04 (2013) 051

s-sbar channel



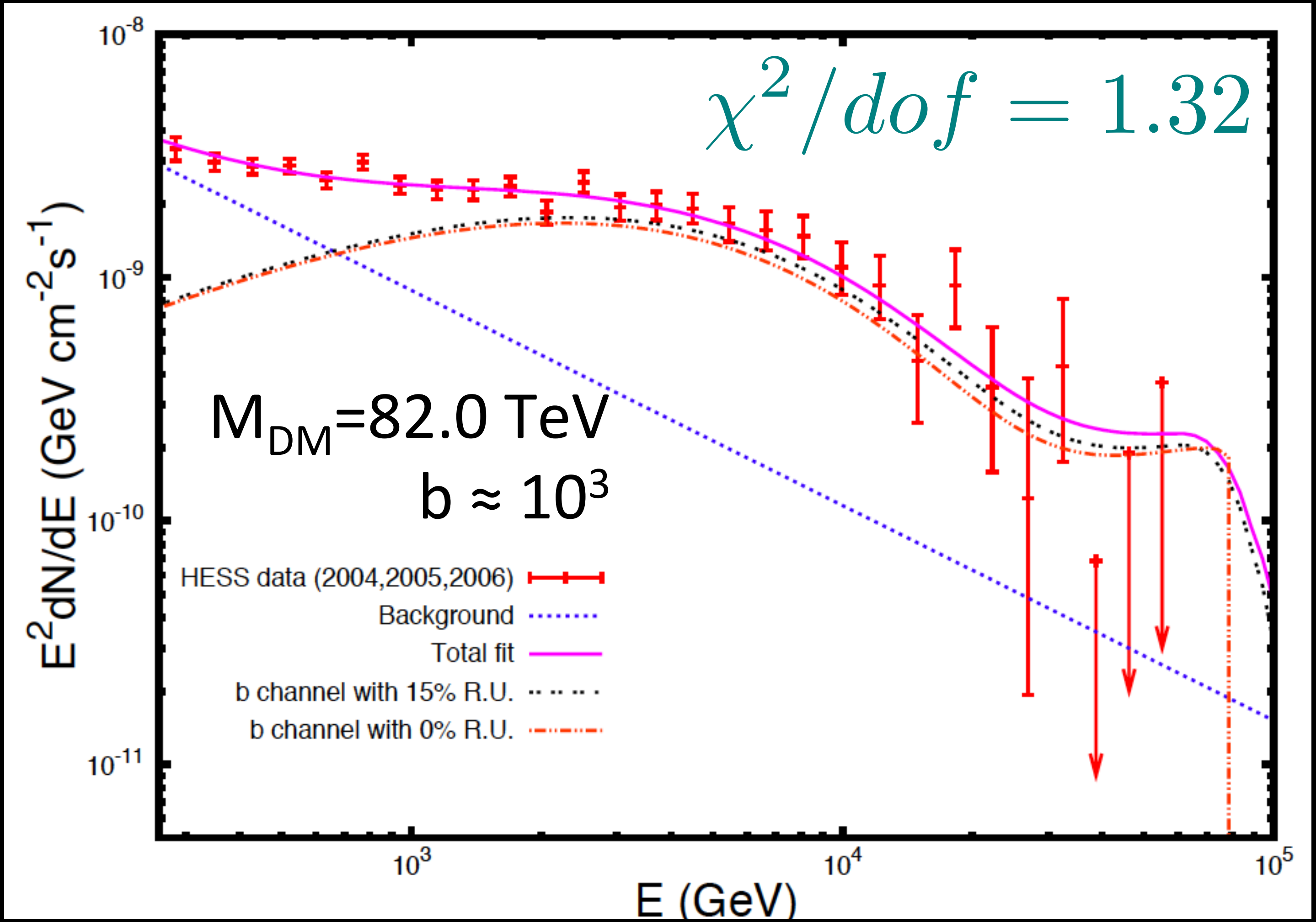
J. A. R Cembranos, V. G., A. L. Maroto arXiv [1204.0655v1], PRD 86, 103506 (2012); [arXiv:1302.6871v2][astro-ph.CO], JCAP04 (2013) 051

c-cbar channel



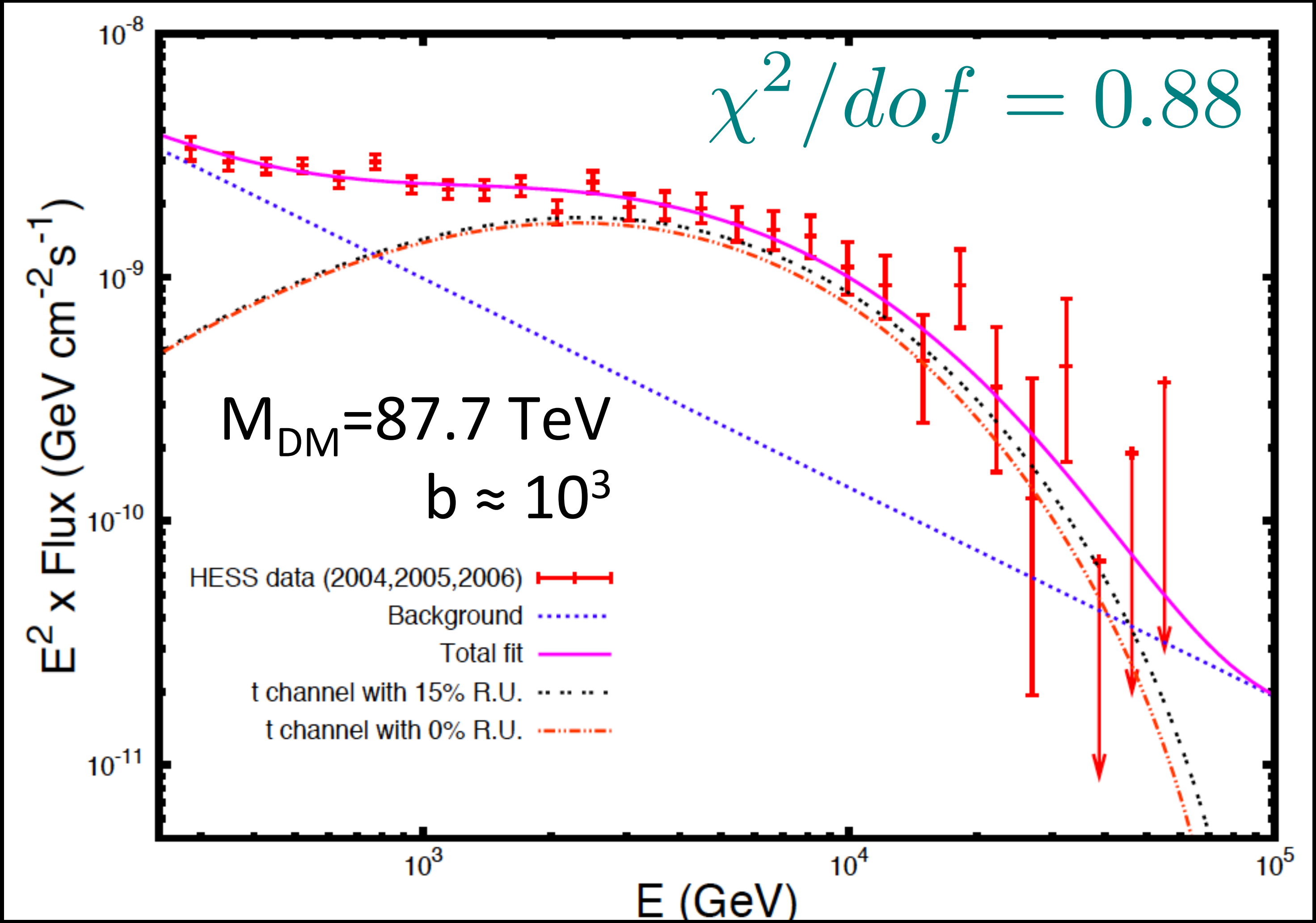
J. A. R Cembranos, V. G., A. L. Maroto arXiv [1204.0655v1], PRD 86, 103506 (2012); [arXiv:1302.6871v2][astro-ph.CO], JCAP04 (2013) 051

b-bbar channel



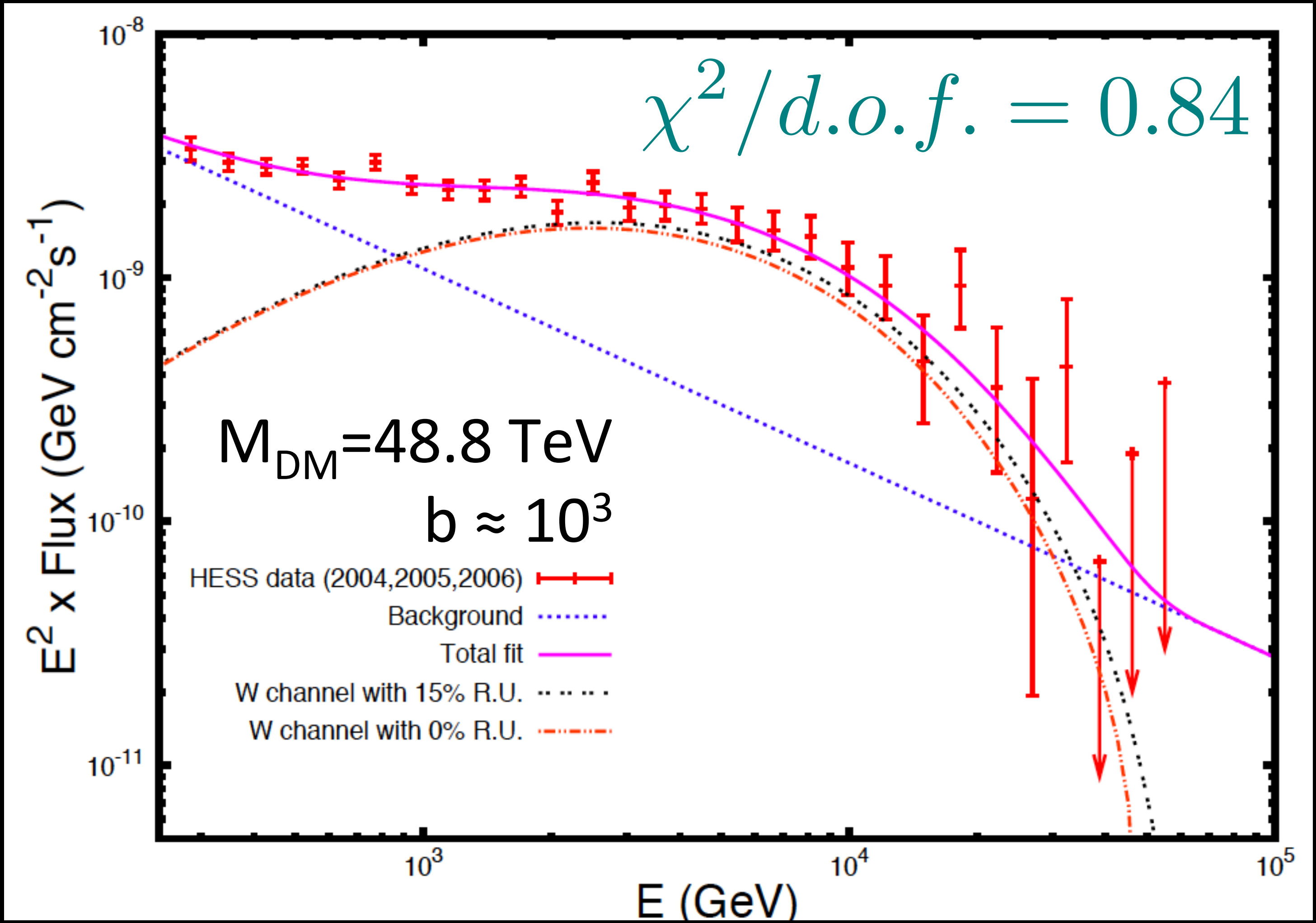
J. A. R Cembranos, V. G., A. L. Maroto arXiv [1204.0655v1], PRD 86, 103506 (2012); [arXiv:1302.6871v2][astro-ph.CO], JCAP04 (2013) 051

t-tbar channel



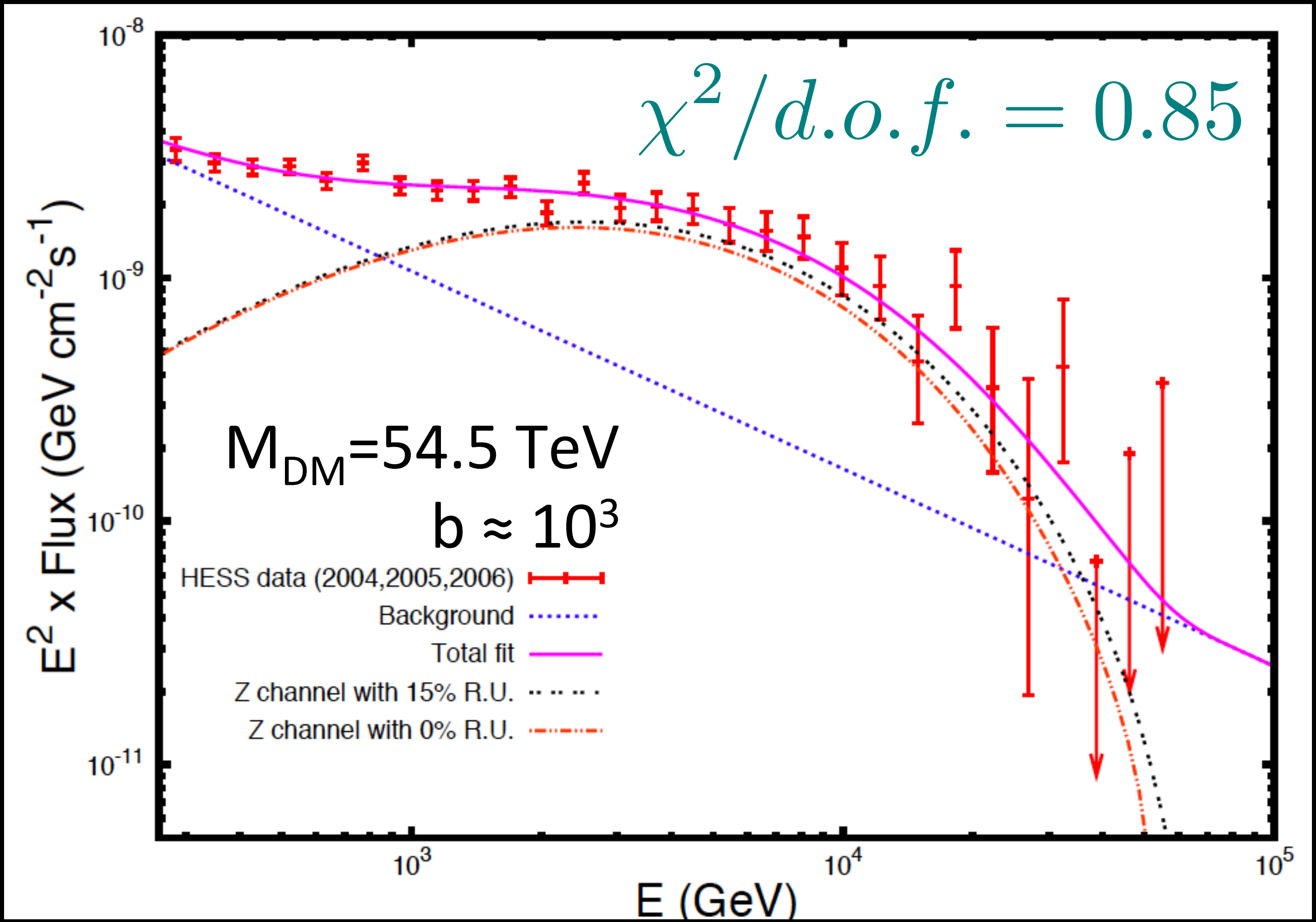
J. A. R Cembranos, V. G., A. L. Maroto arXiv [1204.0655v1], PRD 86, 103506 (2012); [arXiv:1302.6871v2][astro-ph.CO], JCAP04 (2013) 051

W^+W^- channel



J. A. R Cembranos, V. G., A. L. Maroto arXiv [1204.0655v1], PRD 86, 103506 (2012); [arXiv:1302.6871v2][astro-ph.CO], JCAP04 (2013) 051

ZZ channel



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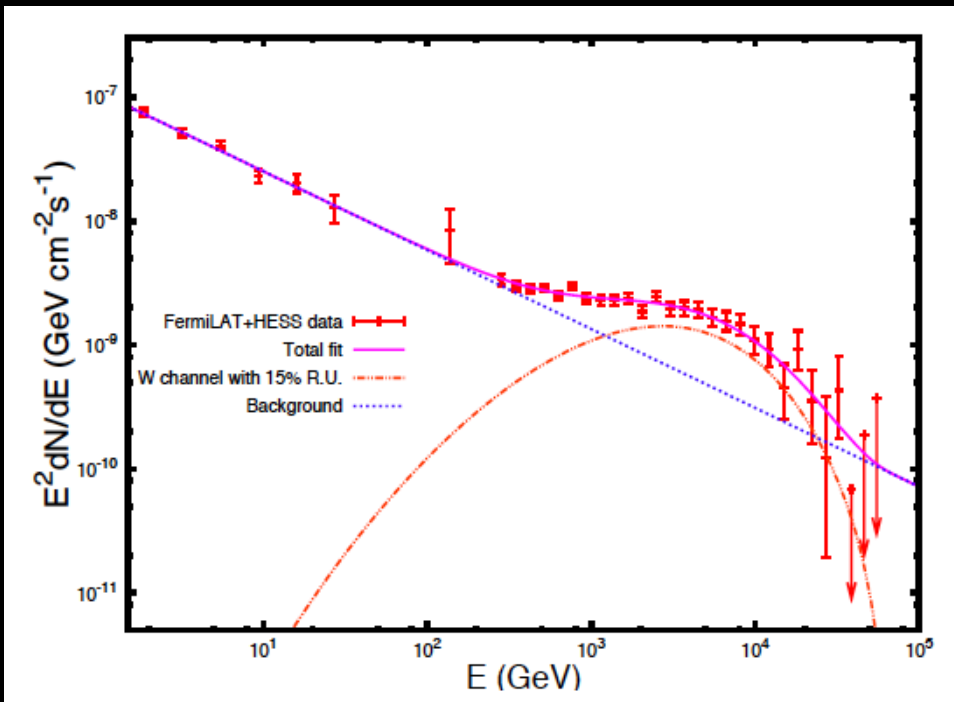
Gamma-rays from the Galactic Center



M_{DM}>10 TeV

Boost factor =$\langle J\rangle/\langle J\rangle_{NFW} \approx 10^3$

Bg compatible with Fermi-LAT

(Fermi-LAT Data)	W^+W^-
M	51.7 ± 5.2
A	4.44 ± 0.34
B	3.29 ± 1.03
Γ	2.63 ± 0.02
$\chi^2/\,\mathrm{dof}$	0.75

J. A. R Cembranos, V. G., A. L. Maroto arXiv [1204.0655v1], PRD 86, 103506 (2012); [arXiv:1302.6871v2][astro-ph.CO], JCAP04 (2013) 051

Gamma-rays from the Galactic Center

Channel	M (TeV)	$A\,(10^{-7}\,\mathrm{cm}^{-1}\mathrm{s}^{-1/2})$	$B\,(10^{-4}\,\mathrm{GeV}^{-1/2}\mathrm{cm}^{-1}\mathrm{s}^{-1/2})$	Γ	χ^2/dof	$\Delta\chi^2$	b
e^+e^-	7.51 ± 0.11	8.12 ± 0.73	2.78 ± 0.79	2.55 ± 0.06	2.09	32.6	111 ± 20
$\mu^+\mu^-$	7.89 ± 0.21	21.2 ± 1.92	2.81 ± 0.53	2.55 ± 0.06	2.04	31.4	837 ± 158
$\tau^+\tau^-$	12.4 ± 1.3	7.78 ± 0.69	3.17 ± 0.62	2.59 ± 0.06	1.59	20.6	278 ± 76
$u\bar{u}$	27.9 ± 1.8	6.51 ± 0.46	9.52 ± 9.47	3.08 ± 0.35	0.78	1.2	987 ± 189
$d\bar{d}$	42.0 ± 4.4	4.88 ± 0.48	8.26 ± 7.86	3.03 ± 0.34	0.73	0.0	1257 ± 361
$s\bar{s}$	53.9 ± 6.2	4.85 ± 0.57	6.59 ± 5.43	2.92 ± 0.29	0.90	4.1	2045 ± 672
$c\bar{c}$	31.4 ± 6.0	6.90 ± 1.06	53.0 ± 157	3.70 ± 1.07	1.78	25.0	1404 ± 689
$b\bar{b}$	82.0 ± 12.8	3.69 ± 0.61	6.27 ± 6.07	2.88 ± 0.35	1.32	14.2	2739 ± 1246
$t\bar{t}$	87.7 ± 8.2	3.68 ± 0.34	6.07 ± 3.34	2.86 ± 0.19	0.88	3.6	3116 ± 820
W^+W^-	48.8 ± 4.3	4.98 ± 0.40	5.18 ± 2.23	2.80 ± 0.15	0.84	2.6	1767 ± 419
ZZ	54.5 ± 4.9	4.73 ± 0.40	5.38 ± 2.45	2.81 ± 0.16	0.85	2.9	1988 ± 491

$$A^2 = \frac{\langle \sigma v \rangle \, \Delta\Omega \, \langle J_{(2)} \rangle_{\Delta\Omega}}{8\pi M^2} \qquad \langle \sigma v \rangle = 3 \cdot 10^{-26}\ \mathrm{cm}^3 \mathrm{s}^{-1} \qquad \Delta\Omega \simeq 10^{-5}$$

$$b \equiv \langle J_{(2)} \rangle / \langle J_{(2)}^{\mathrm{NFW}} \rangle \qquad \langle J_{(2)}^{\mathrm{NFW}} \rangle \simeq 280 \cdot 10^{23}\ \mathrm{GeV}^2 \mathrm{cm}^{-5}$$

J. A. R Cembranos, V. G., A. L. Maroto arXiv [1204.0655v1], [Phy. Rev. D 85, 043505] ; [arXiv: 1302.6871v2][astro-ph.CO], JCAP04 (2013) 051

Neutrinos from the Galactic Center

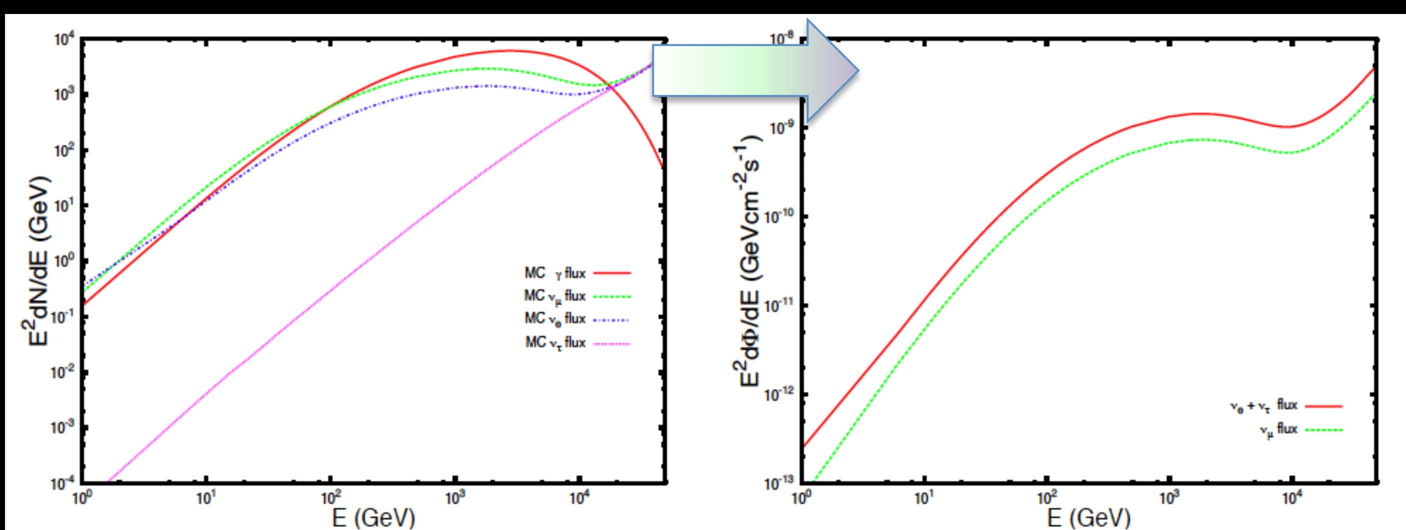
$$\frac{d\Phi_{\nu_f}}{dE} = \sum_{p=1}^{3}\sum_{a=1}^{2}\sum_{i}^{\text{channels}} \boxed{P_{fp}} \cdot \frac{\zeta_i^{(a,\nu_p)}}{a}\frac{dN_i^{(\nu_p)}}{dE}\cdot\frac{\Delta\Omega\,\langle J_{(a)}\rangle_{\Delta\Omega}}{4\pi M^a}$$

1. W^+W^- boson channel parameters from gamma-rays fit:

$M_{DM} \approx 50$ TeV

Neutrinos flux at the Earth needs to account for:

2. neutrino oscillation



3. detector different (in)sensitivity to neutrinos flavors and antineutrinos

J. A. R Cembranos, V. G., A. L. Maroto arXiv [1403.6018], PRD 90, 043004 (2014); [arXiv:1404.2067]TAUP 2013 Proceedings

Neutrinos from the Galactic Center

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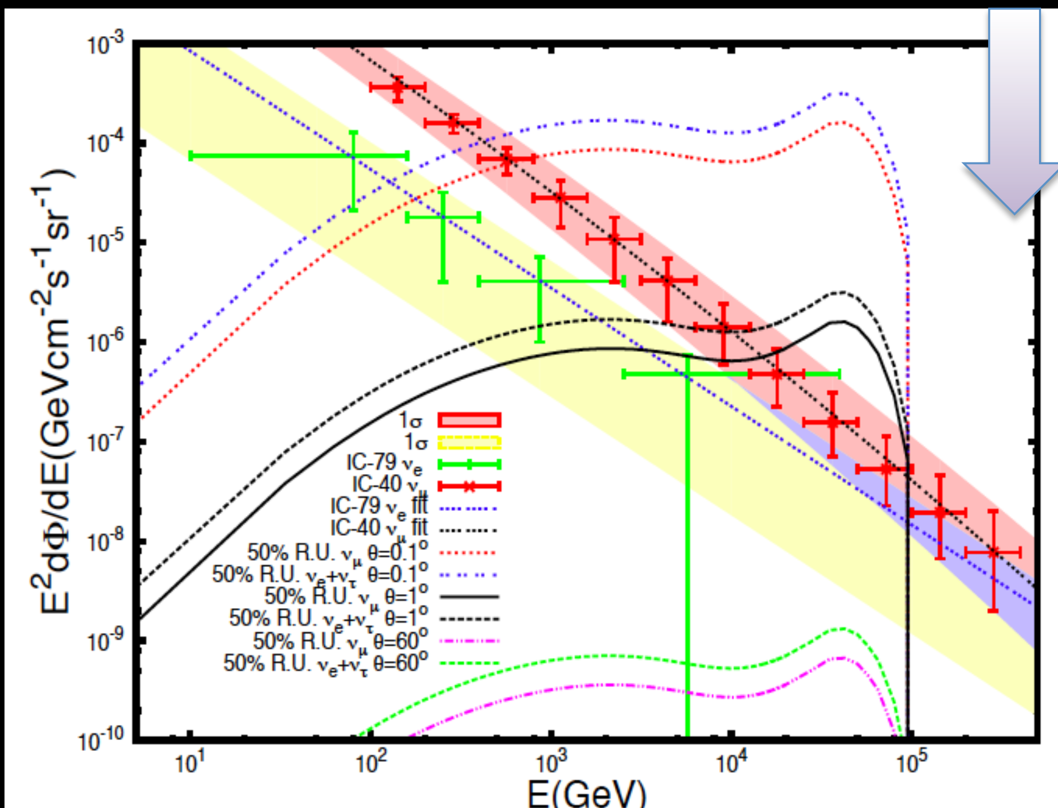
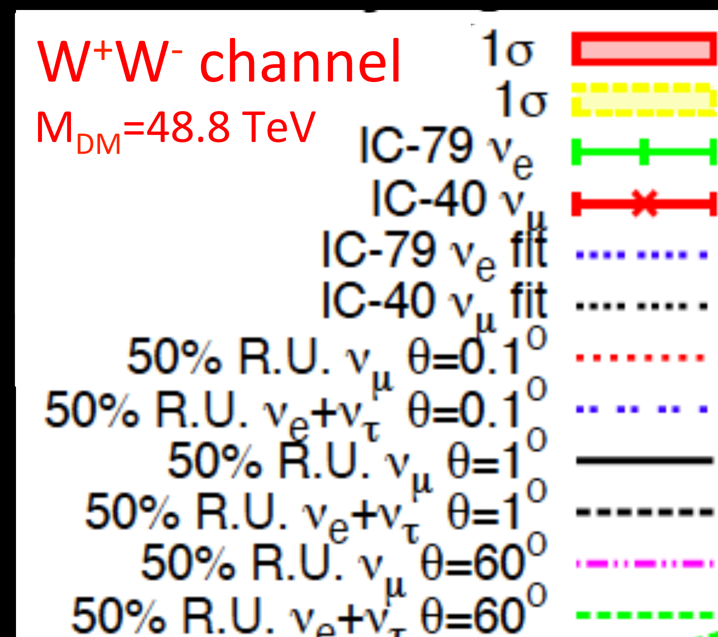


$$\Delta\Omega = 2\pi(1-\cos\theta)$$



J. A. R Cembranos, V. G., A. L. Maroto arXiv [1403.6018],PRD 90, 043004 (2014); [arXiv:1404.2067]TAUP 2013 Proceedings

Neutrinos from the Galactic Center

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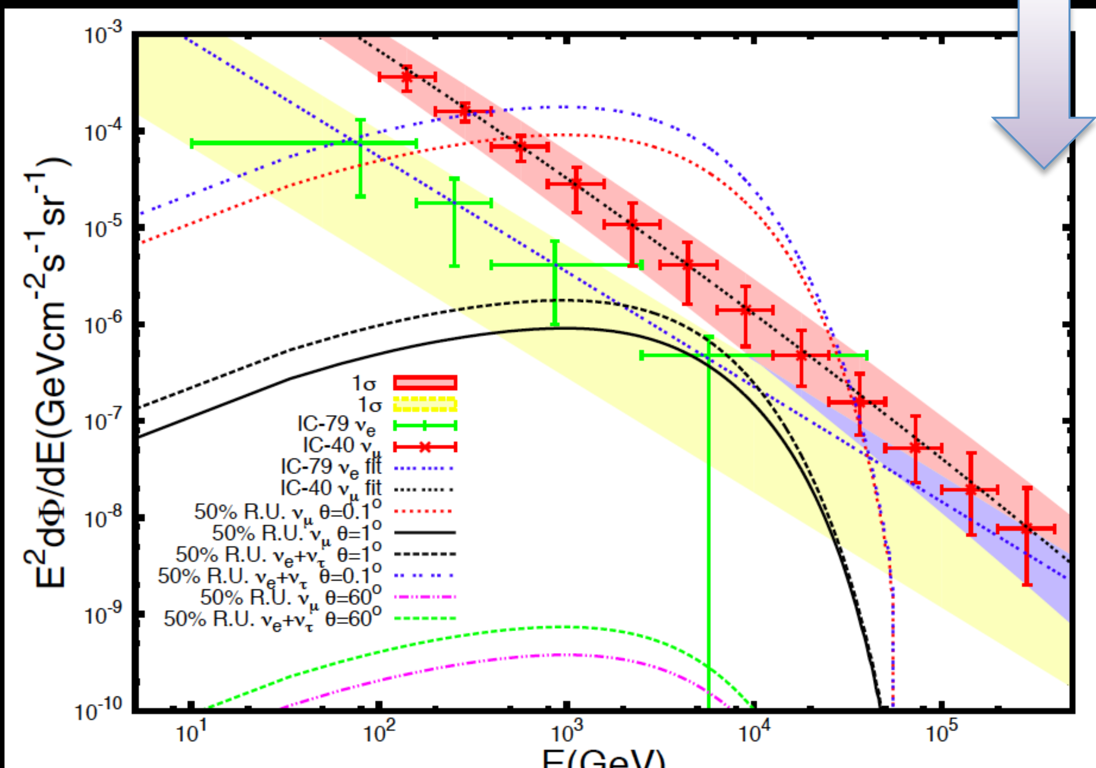
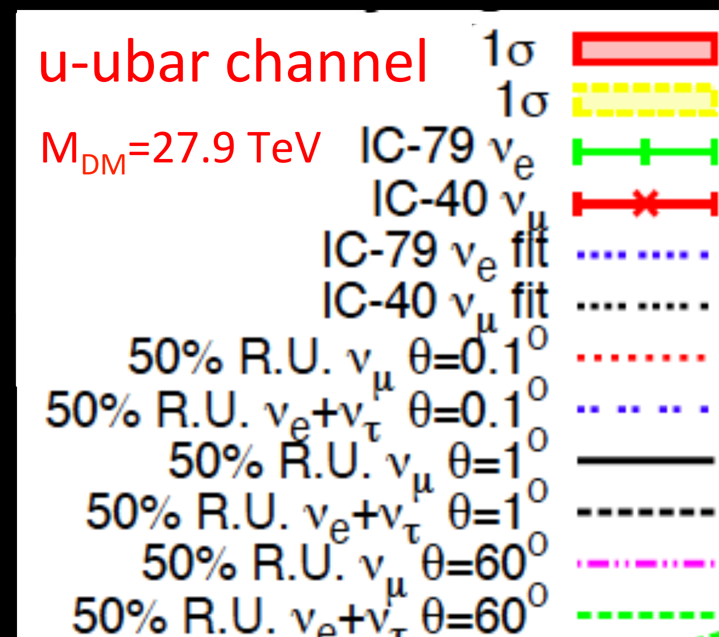


$$\Delta\Omega = 2\pi(1-\cos\theta)$$



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Neutrinos from the Galactic Center

$$\chi_{\nu_i} = \frac{\Phi_{\nu_i}\sqrt{A_{\rm eff}\, t_{\rm exp}\, \Delta\Omega}}{\sqrt{\Phi_{\nu_i} + \Phi_{\nu_i}^{\rm Atm}}} = 5\,(3,\, 2)$$

$$N_{\nu_f}^{t_{exp}} = \int_{E^{\nu}_{\rm min}}^{\infty} dE_{\nu}\; \frac{d\Phi_{\nu_f}}{dE} \times A_{\rm eff}\, t_{\rm exp}$$

Effective Area and Resolution Angle depend on:

- Energy range;
- Neutrino flavor and background;
- Position of the source with respect to the detector (Northern or Southern sky);
- Number of strings in the configuration of observation.

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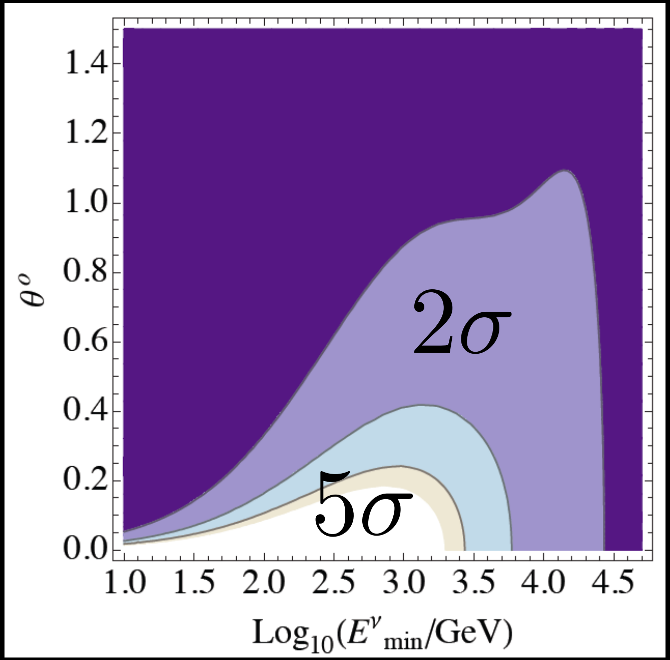
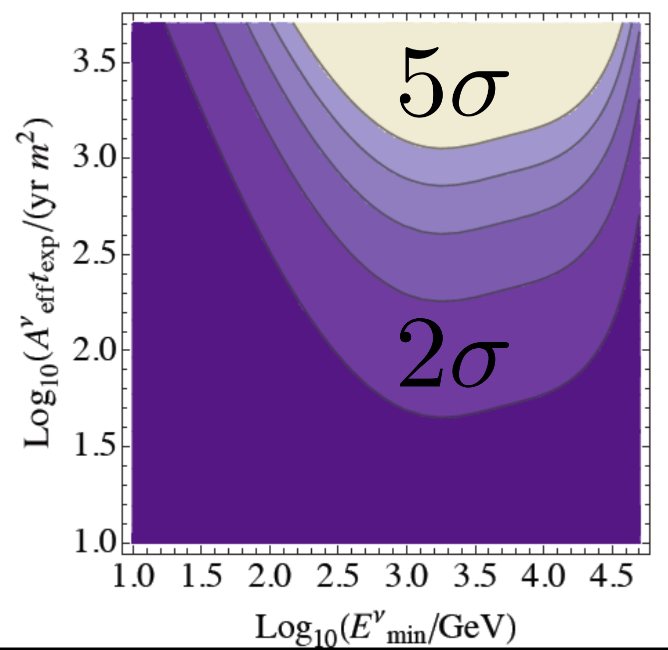
Neutrinos from the Galactic Center

$$A f = A_{\rm eff} \times t_{\rm exp} = 100\,{\rm m}^2\,{\rm yr}$$

$$\theta = 0.6^\circ$$





W^+W^- channel, with $\theta = 0.6^o$, $E_{min} \approx 1$ TeV and 5 years we need:

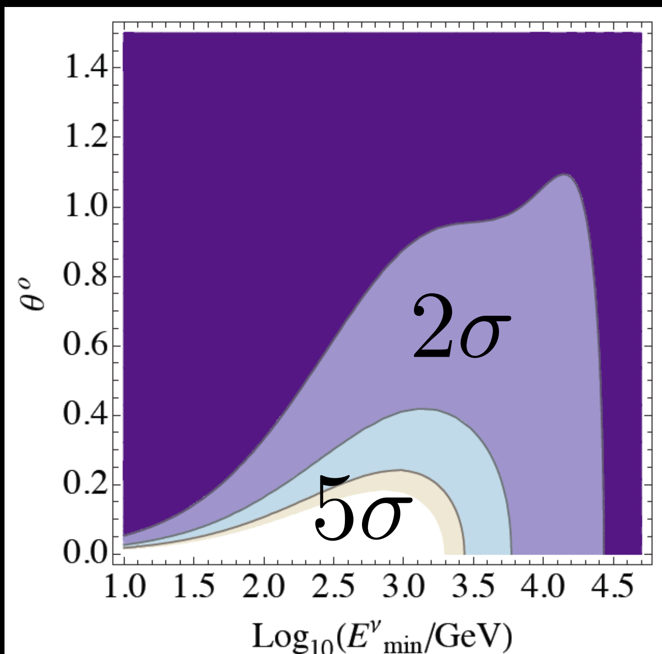
$A_{eff} \approx 40\ m^2$ to get ≈2σ signal;

$A_{eff} \approx 200\ m^2$ to get a ≈5σ signal;

J. A. R Cembranos, V. G., A. L. Maroto arXiv [1403.6018] , PRD 90, 043004 (2014); [arXiv:1404.2067]TAUP 2013 Proceedings

Neutrinos from the Galactic Center

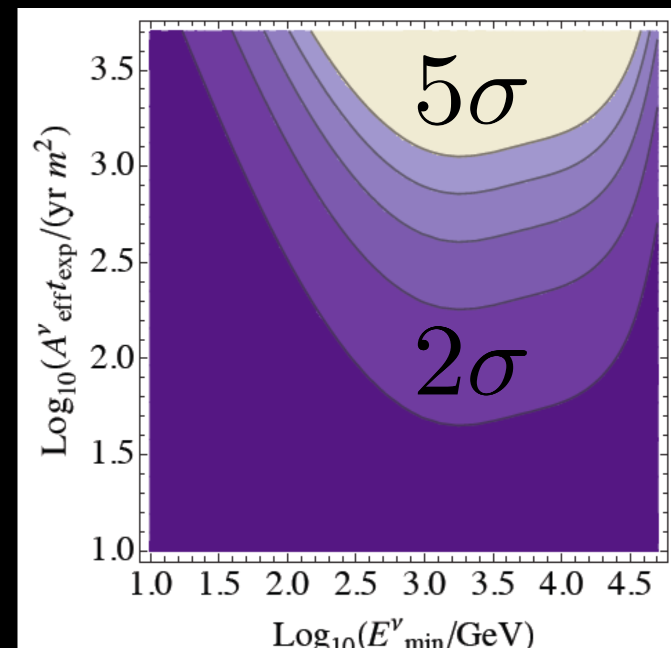
$$Af = A_{\rm eff} \times t_{\rm exp} = 100\,{\rm m}^2\,{\rm yr} \qquad \theta = 0.6^\circ$$



<u>Example:</u>

IC-79 ν_μ
Southern Sky at
≈ 30-100 TeV:

A_{eff} ≈ 5-20 m^2
θ ≥ 0.5º;



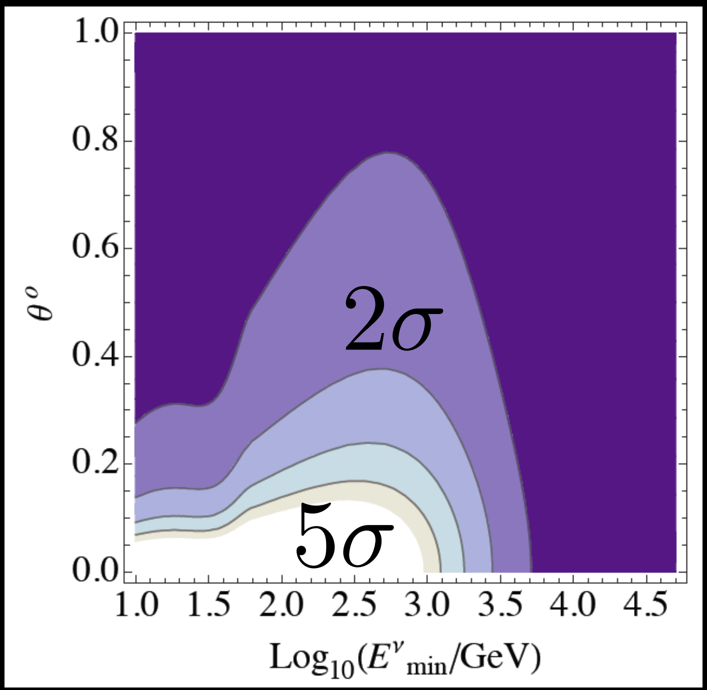
W^+W^- channel, with θ = 0.6º, E_{min}≈ 1 TeV and 5 years we need:
A_{eff} ≈ 40 m^2 to get ≈2σ signal;
A_{eff} ≈ 200 m^2 to get a ≈5σ signal;

J. A. R Cembranos, V. G., A. L. Maroto arXiv [1403.6018] , PRD 90, 043004 (2014); [arXiv:1404.2067]TAUP 2013 Proceedings

Neutrinos from the Galactic Center

$$Af = A_{\rm eff} \times t_{\rm exp} = 100\,{\rm m}^2\,{\rm yr}$$

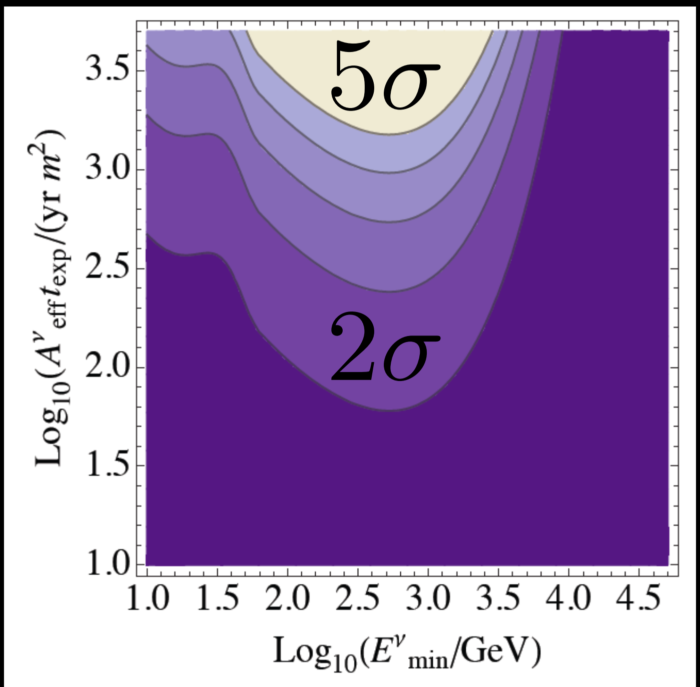
$$\theta = 0.6^\circ$$



<u>Example:</u>

IC-79 ν_μ Southern Sky at ≈ 30-100 TeV:

$A_{\rm eff}$ ≈ 5-20 m^2
θ ≥ 0.5º;



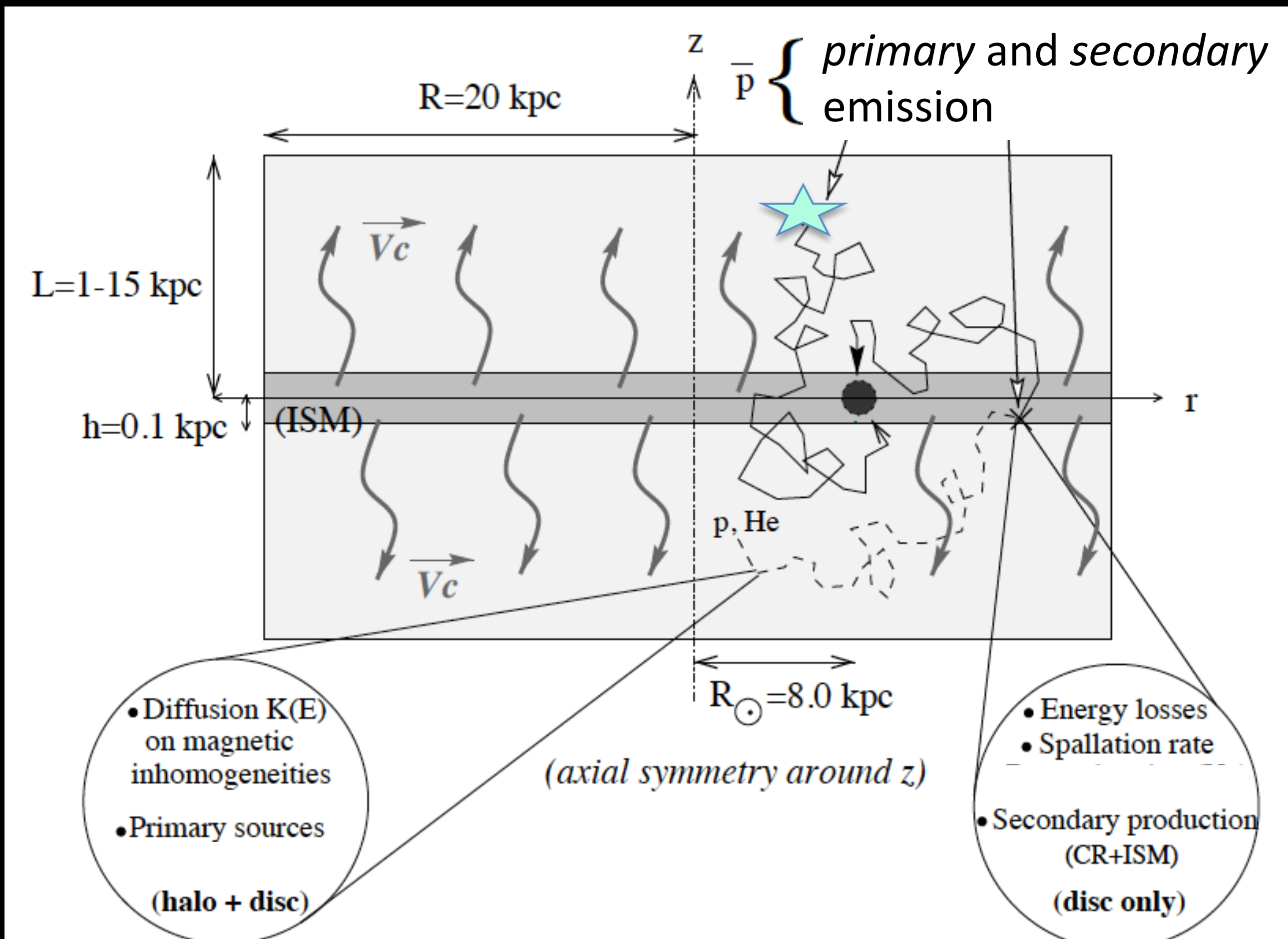
uubar channel, with θ = 0.6º, E_{min}≈ 1 TeV and 5 years we need:

Aeff ≈ 63 m^2 to get ≈2σ signal;

Aeff ≈ 400 m^2 to get a ≈5σ signal;

J. A. R Cembranos, V. G., A. L. Maroto arXiv [1403.6018, PRD 90, 043004 (2014); [arXiv:1404.2067]TAUP 2013 Proceedings

Antiprotons from the Galactic Center



- V_c convective velocity
- $K(E_{\bar{p}})$ pure diffusion
- p-$\bar{p}$ annihilations (secondary) and ISM interactions (tertiary)
- $Q(E_{\bar{p}}, x, t)$ is the primary source

A&A 388, 676-687 (2002) Barrau et al. , arXiv:0112486v2

Antiprotons from the Galactic Center

$$\frac{\partial}{\partial t}\frac{dN_{\bar{p}}}{dE_{\bar{p}}} - K(E_{\bar{p}})\cdot\nabla^2\frac{dN_{\bar{p}}}{dE_{\bar{p}}} + \frac{\partial}{\partial z}\left(sign(z)\frac{dN_{\bar{p}}}{dE_{\bar{p}}}V_c\right) = \hat{Q} - 2h\delta(z)\Gamma_{inel}\frac{dN_{\bar{p}}}{dE_{\bar{p}}}$$

≈ 0

The anti-proton differential flux at the Top of the Atmosphere (TOA) is the solution of the diffusion equation for steady state condition:

$$\frac{\mathrm{d}\Phi_{\bar{p}}}{\mathrm{d}E_{\bar{p}}} = \sum_{a=1}^{2}\sum_{i}^{\text{channels}} \frac{\zeta^{(a)}}{a}\frac{\mathrm{d}N_i^{(a,\bar{p})}}{\mathrm{d}E_{\bar{p}}}\cdot\frac{v_{\bar{p}}}{4\pi}\left(\frac{\rho_\odot}{M}\right)^a R_{(a)}(E_{\bar{p}})$$

$$R(E_{\bar{p}}) = \sum_{m=1}^{\infty} J_0\left(\zeta_m\frac{r_\odot}{R}\right)\exp\left[-\frac{V_cL}{2K\left(E_{\bar{p}}\right)}\right]\frac{\Pi_m\left(L\right)}{A_m\sinh\left(S_mL/2\right)}$$

- $R(E_{\bar{p}})$ encode all the astrophysics of spatial production and propagation and $\Pi(L)$ depends by the DM distribution.

Antiprotons from the Galactic Center

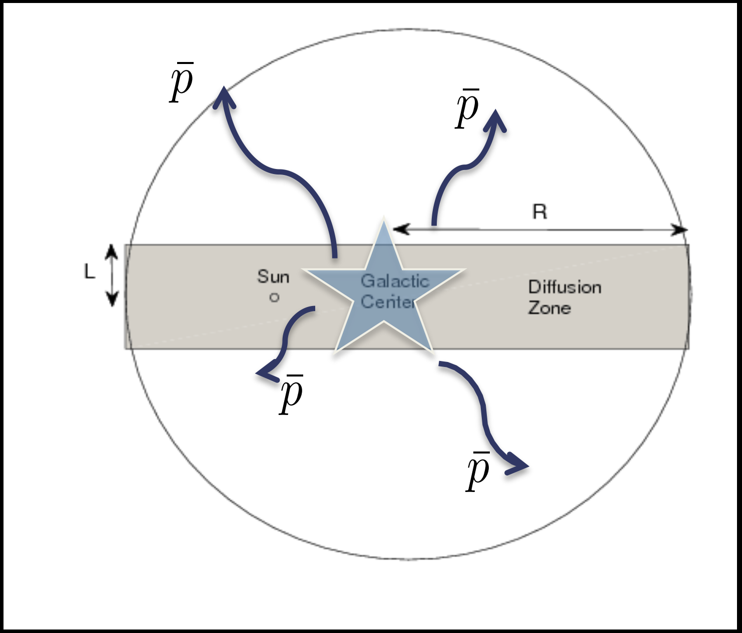
The anti-protons point-like production and their propagation is described by :

$$R^{\delta}(E_{\bar{p}}) = \frac{2}{R^2}\sum_{m=1}^{\infty}\frac{J_0\left(\zeta_1 \frac{r_\odot}{R}\right)}{A_m J_1^2(\zeta_m)} \times Const$$

$$A_m(E_{\bar{p}}) = 2h\Gamma_{inel} + V_c + K(E_{\bar{p}}) S_m \coth[S_m L/2]$$

$$K(E_{\bar{p}}) = K_0 \beta (p/GeV)^{\delta}$$

Model	δ	K_0 [kpc^2/Myr]	V_c [km/s]	L [kpc]
MIN	0.85	0.0016	13.5	1
MED	0.70	0.0112	12	4
MAX	0.46	0.0765	5	15



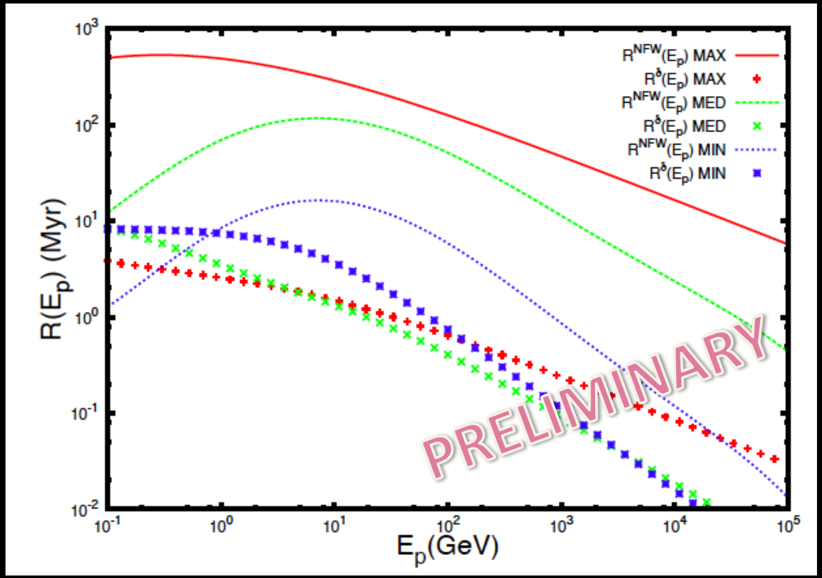
Where the new constant volume needs to be determined.

Antiprotons from the Galactic Center

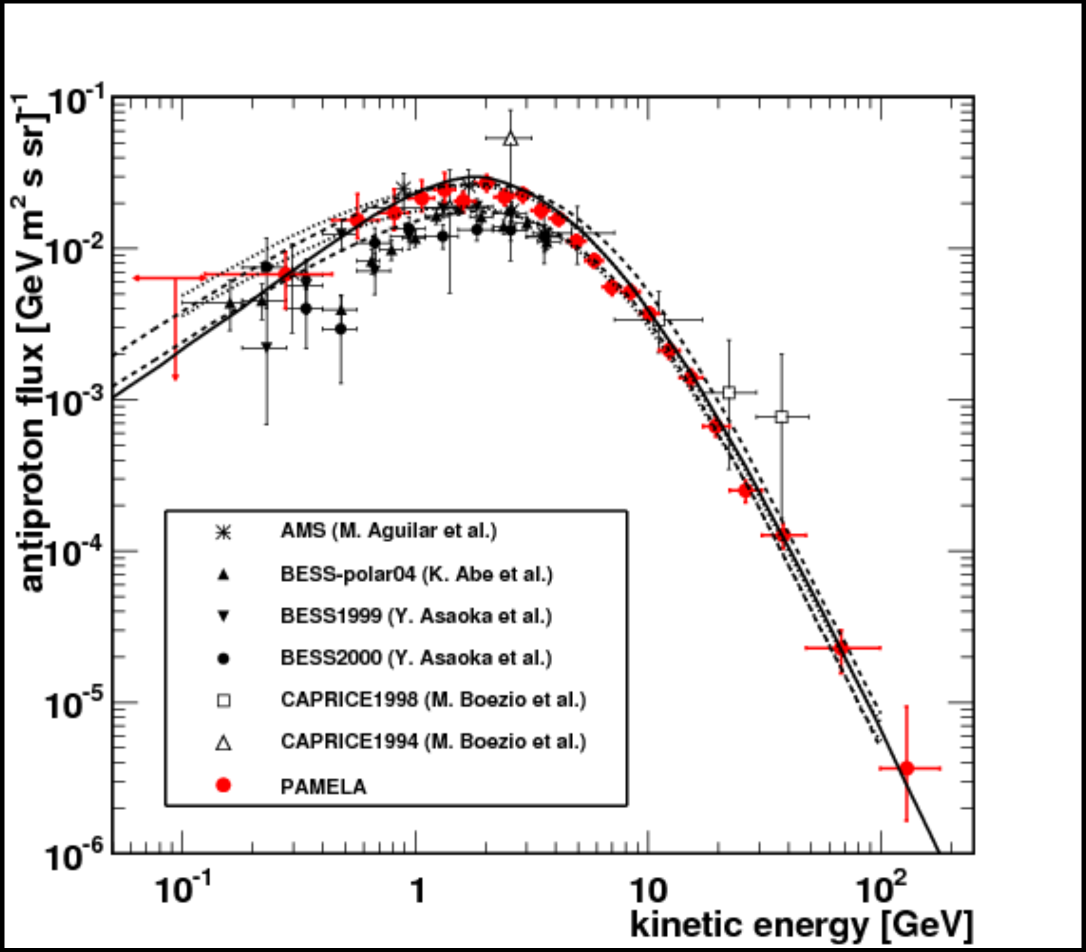
To determine the new constant, we refer to the astrophysical factor for "not charged" particles:

$$\langle J_a \rangle = \frac{1}{\Delta\Omega} \int_{\Delta\Omega} \mathrm{d}\Omega \int_0^{l_{max}(\Psi)} \rho^a[r(l)]dl(\Psi) \qquad \left(\frac{\rho(r,0)}{\rho\odot}\right)^2 \simeq C_2 \times \delta^{(3)}(\vec{r})$$

$$C_2 = Const \times 2\pi = \langle J \rangle_{\Delta\Omega}^{NFW} \Delta\Omega_{HESS} \left(\frac{D_\odot}{\rho_\odot}\right)^2 \approx \quad 2.13 \times 10^{60} m^3 \mathrm{sr}$$



PAMELA antiproton data



- Compatible with antiproton *secondary* emission
- Any astroparticles source needs to be compatible with such antiproton flux.

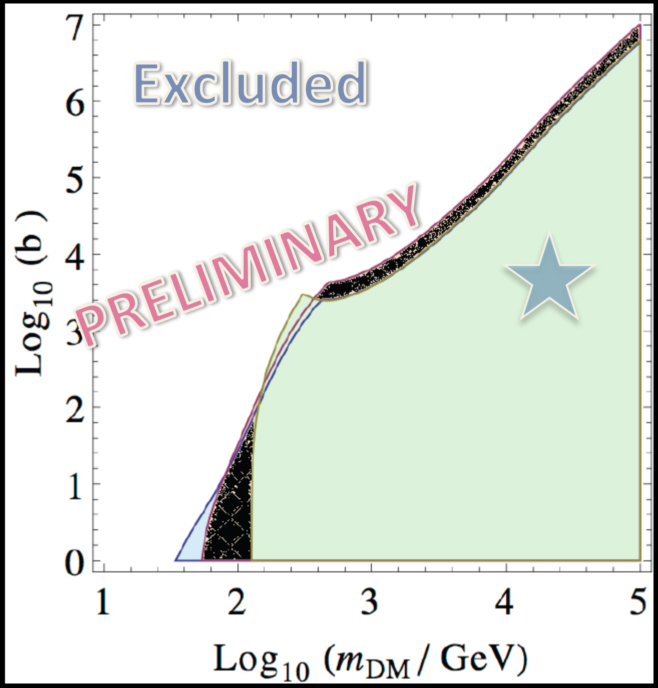
Phys. Rev. Lett. 105, 121101 – Adriani et al. arXiv:1007.0821v1

Antiprotons from the Galactic Center

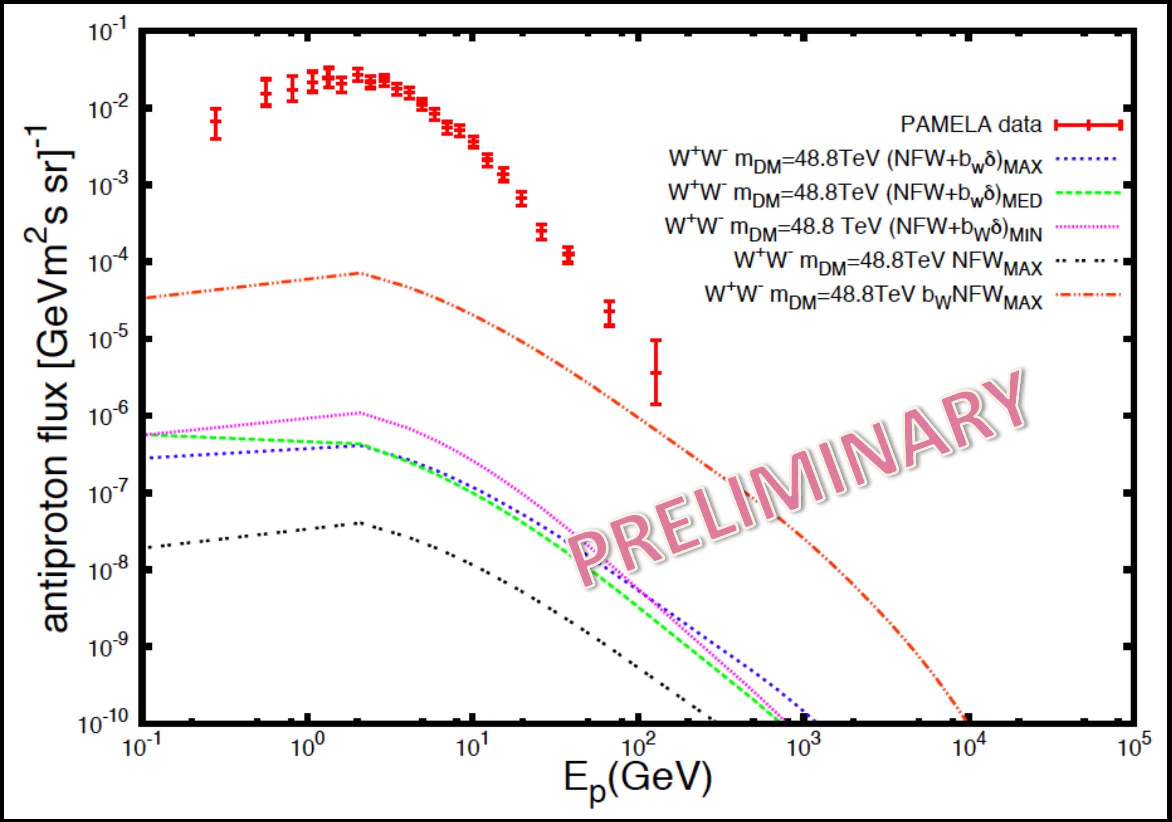
$$\frac{d\Phi_{\bar{p}}}{dE_{\bar{p}}} = \frac{v_{\bar{p}}}{4\pi}\frac{1}{2}\left(\frac{\rho_\odot}{m_{DM}}\right)^2 \sum_j \langle\sigma v\rangle_j \frac{dN^j_{\bar{p}}}{dE_{\bar{p}}}\left(b^j_{NFW} \times R^{NFW}(E_{\bar{p}}) + b^j_\delta \times C_1 \times R^\delta(E_{\bar{p}})\right)$$

MIN | MED | MAX

$b^W{}_{NFW}=1$



W^+W^- channel M_{DM}=48.8 TeV



Conclusions

- gamma-ray HESS data of the J1745-290 point-like source in the GC is well fitted by heavy 48.8 TeV DM annihilating into boson and some quark-antiquarks channels, with 10^3 boost factor (possible uncertainty due to the choice of the Monte Carlo event generation software).

- Fermi-LAT gamma-rays data from the same region are compatible with a power-law background component.

- Next generation of neutrino experiment with implemented effective area and angular resolution will set more constraints on such DM hypothesis.

- PAMELA antiprotons data are compatible with a NFW TeV DM distribution with a 10^3 enhancement factor at the GC.

¡Thank you!

PYTHIA vs HERWIG

Fortran Code: PYTHIA 6.4 and HERWIG

C++ Code: PYTHIA 8 and HERWIG++

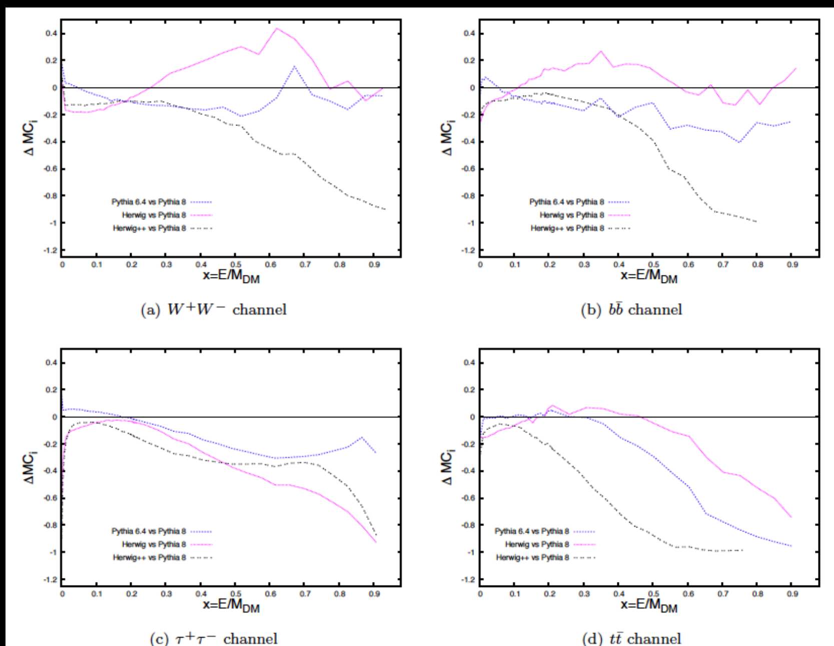
Intrinsic differences:

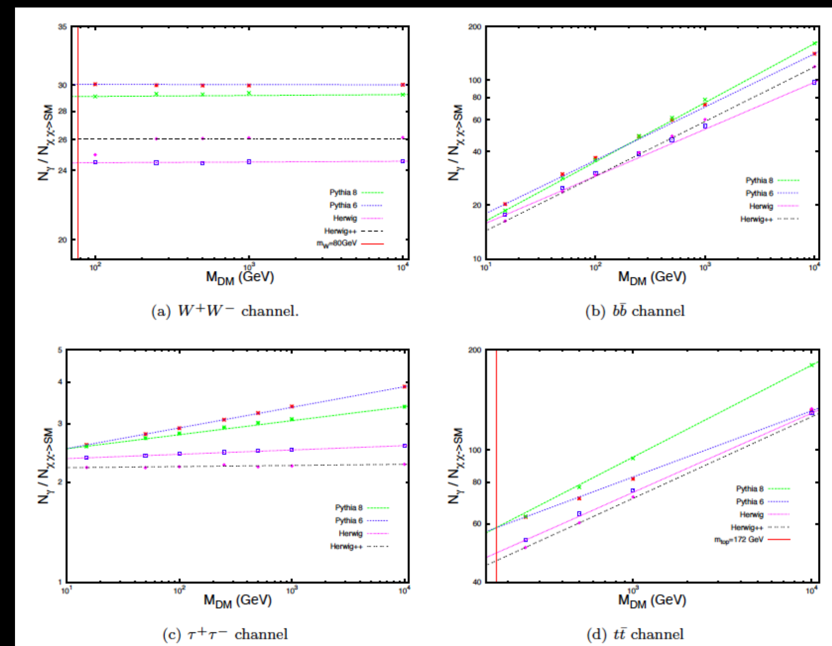
1. Parton Shower Evolution Variable
2. Hadronization Model (String in PYTHIAs o Cluster in HERWIGs)
3. QED Final State Radiation: 2->2 EW Processes and Bremsstrahlung (there is no gamma-rays production in HERWIG++ from DM -> e^+e^-, $\mu^+\mu^-$ lepton channels):
4. Top decay

J.A.R. Cembranos, A. de la Cruz-Dombriz, V.G., R.A. Lineros, A. L. Maroto, JHEP 1309 (2013) 077, arXiv:1305.2124v3 [hep-ph]

Indirect search: simulations

Implications to WIMPs phenomenology

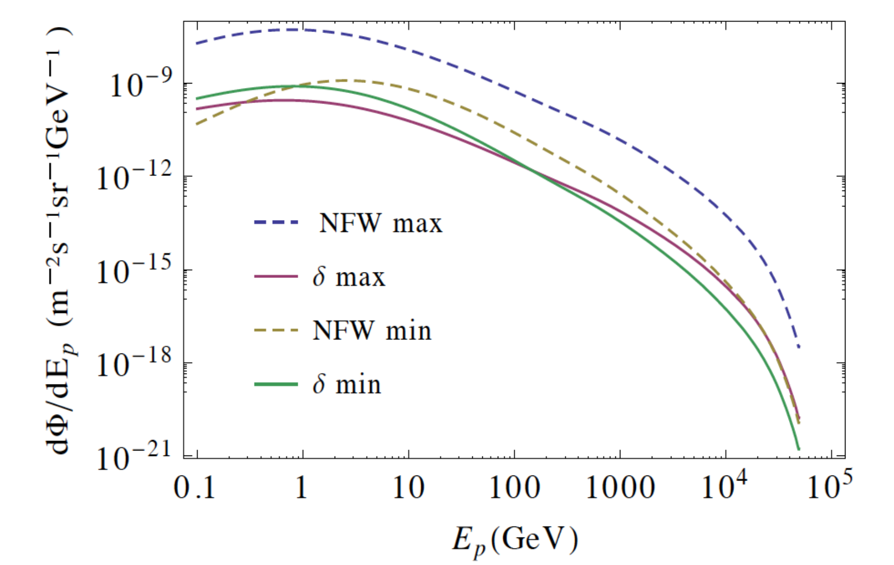




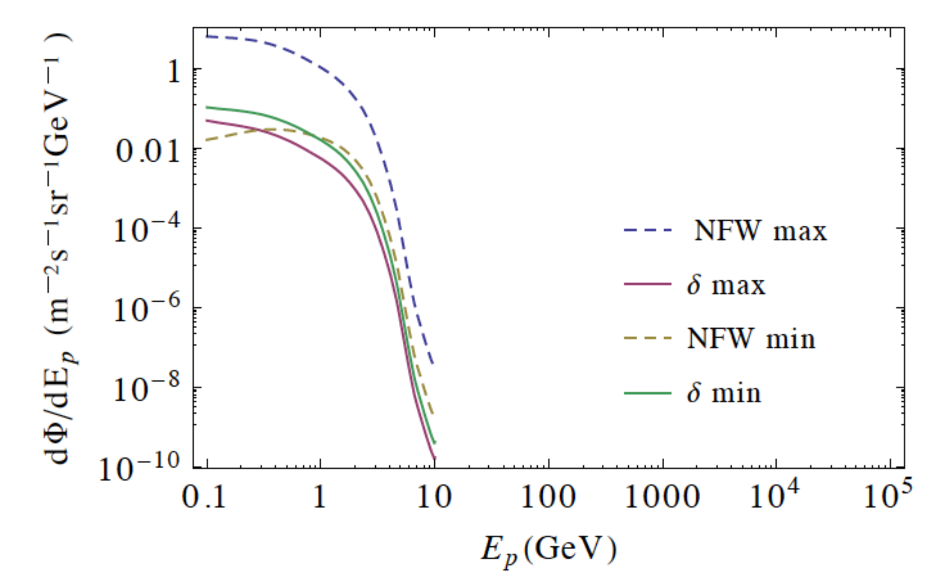
$$\Delta MC_i = \frac{MC_i - \text{PYTHIA 8}}{\text{PYTHIA 8}} \qquad \frac{N_\gamma}{N_{\chi\chi\rightarrow SM}} \simeq a\cdot\left(\frac{M}{1\,\text{GeV}}\right)^b$$

J.A.R. Cembranos, A. de la Cruz-Dombriz, V.G., R.A. Lineros, A. L. Maroto, JHEP 1309 (2013) 077, arXiv:1305.2124v3 [hep-ph]

Antiproton flux after diffusion



m_{DM}=48.8 TeV



m_{DM}=10 GeV