RENCONTRES DE MORIOND
50
since 1966

ULB

A Search for Mono-energetic Neutrinos from Dark Matter Decay

Chaïmae EL AISATI

51st Rencontres de Moriond EW 2016

[Based on: 1506.02657,
in collaboration w/ M. Gustafsson and T. Hambye]

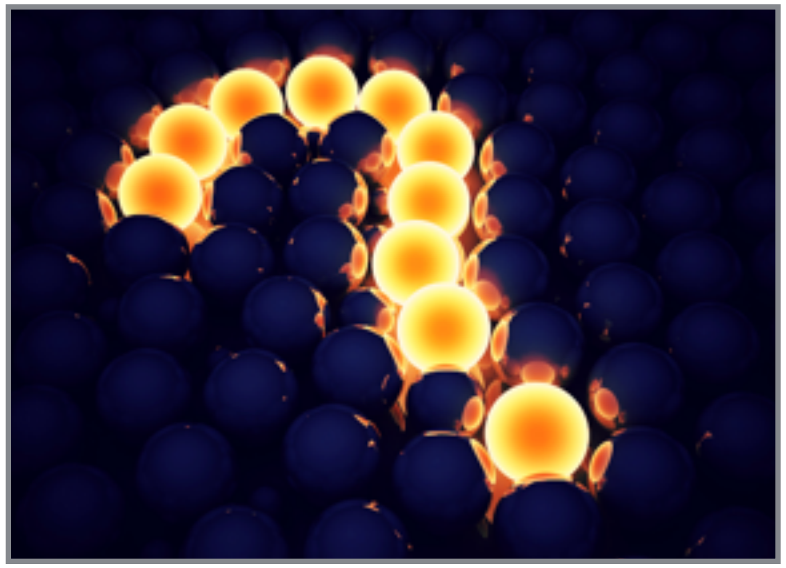
fnrs
FREEDOM TO RESEARCH

Outline

- Motivation
- The analysis
- Results

Motivation

Gravitational evidences for DM do $\exists$ at all scales.



But, identify DM <=> Need to probe signals:

- Collider searches (mono-jet, mono-lepton events)
- Direct detection (Xenon, LUX, CDMS, ...)
- Indirect detection (<=> anomalies in CR fluxes)

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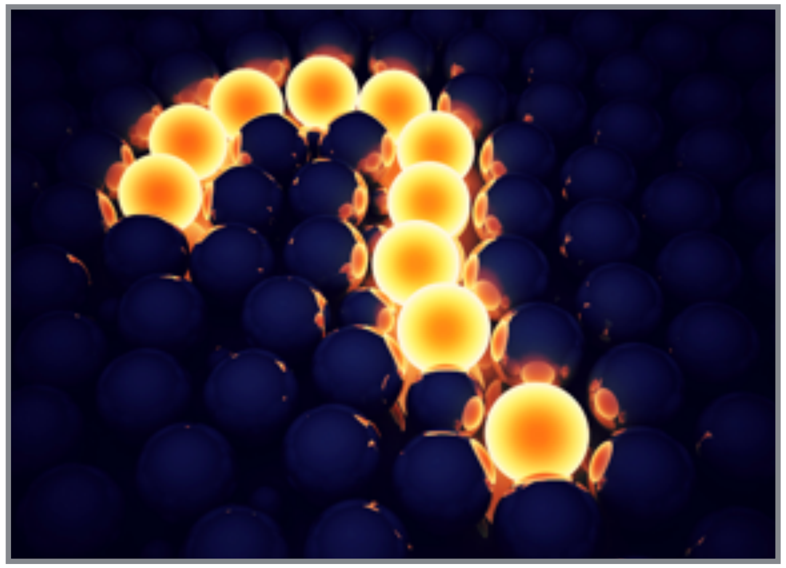

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γ, ν : features basically unaltered, allow to point back to sources (interesting for searches in objects that are known to be DM-dominated).

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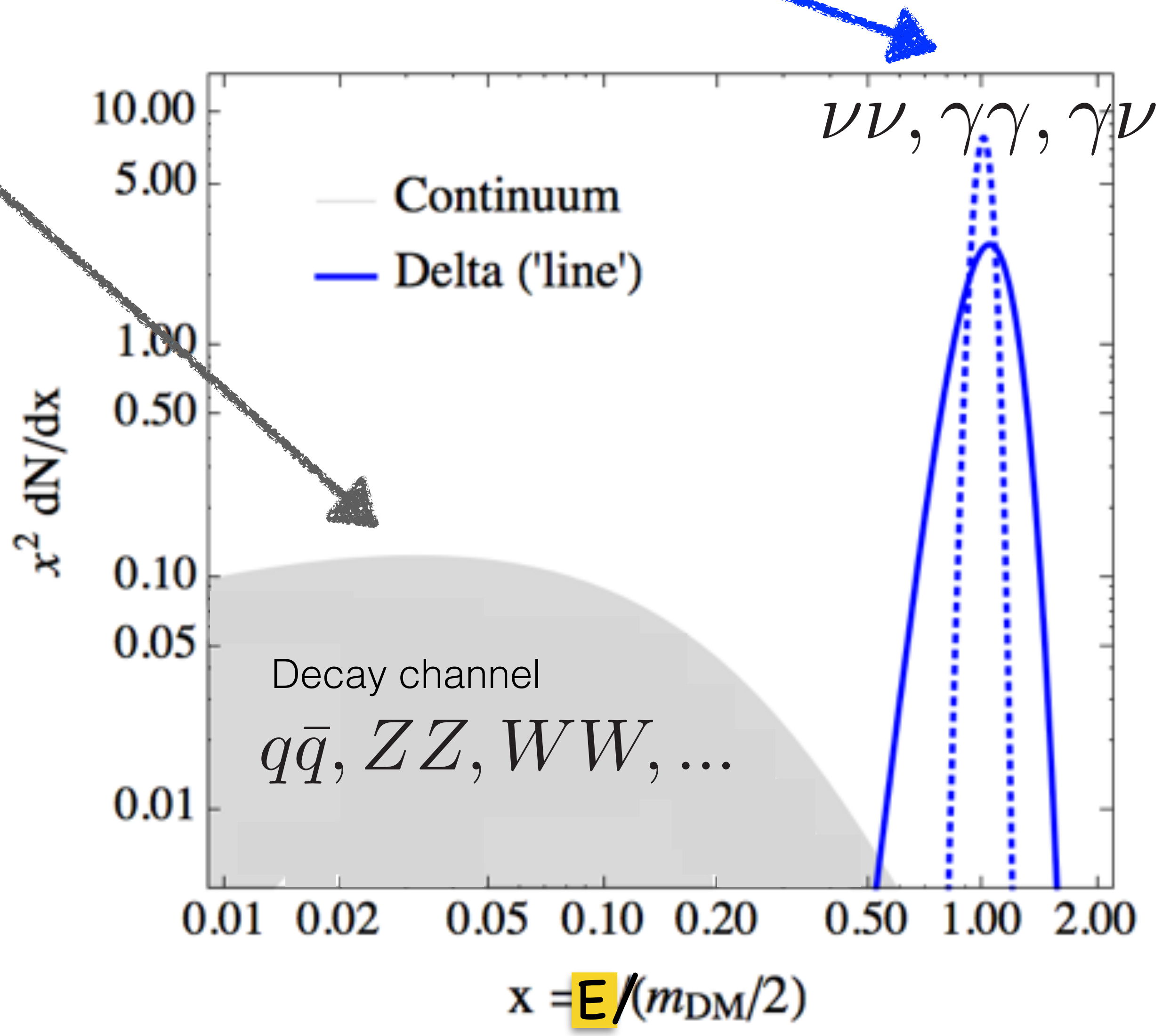
1. Broad excess

2. Sharp features



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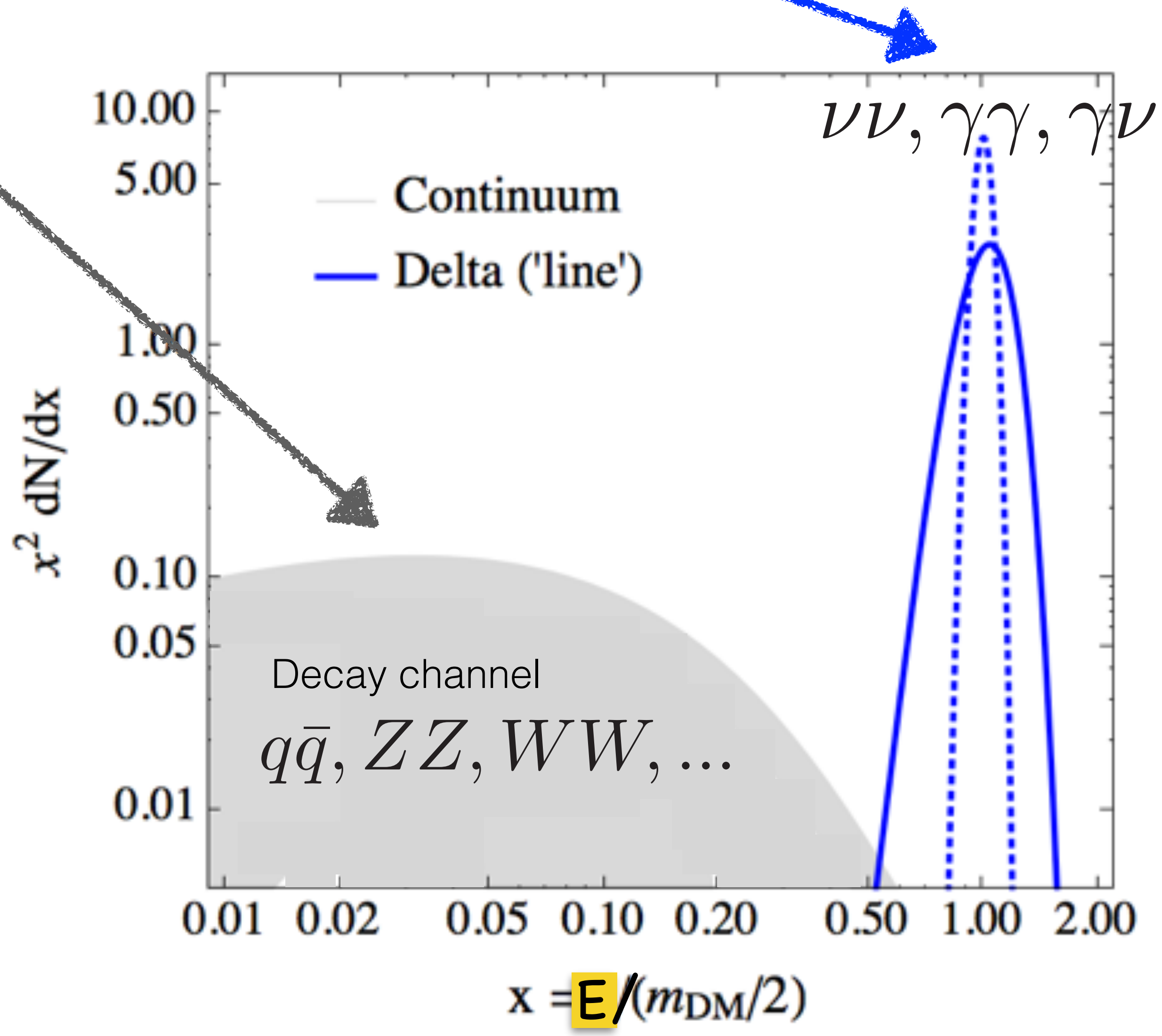

Sharp spectral features, cannot be explained by astrophysical background.

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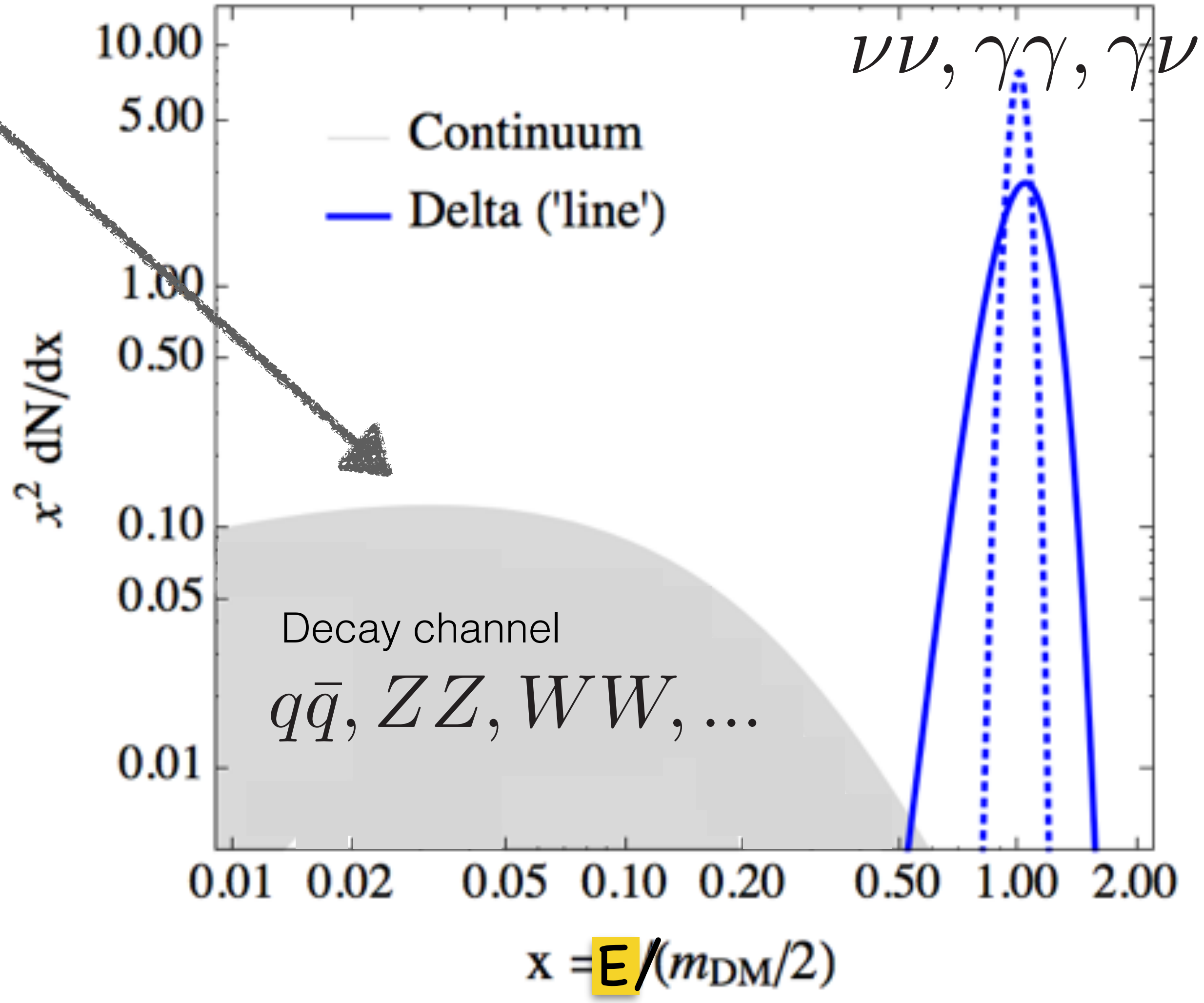
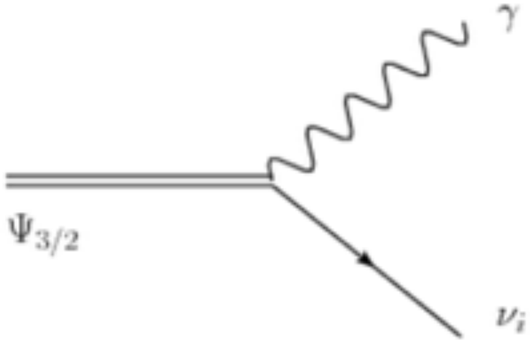
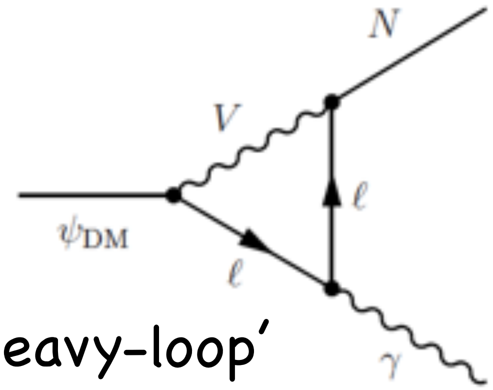


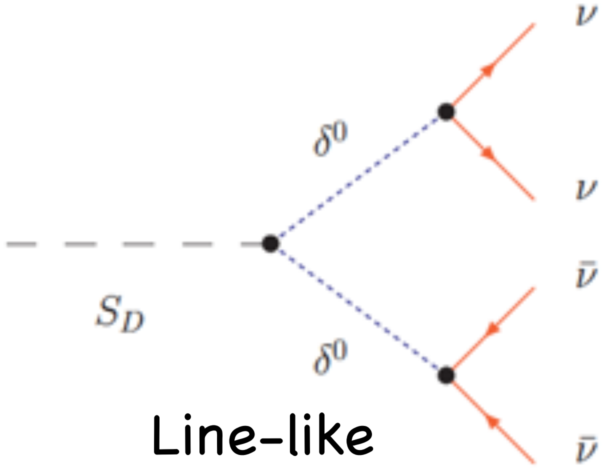


Gravitino decay



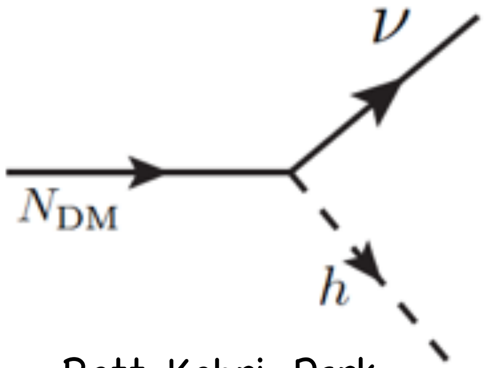
‘Heavy-loop’

Garny, Ibarra, Tran, Weniger
1011.3786



Line-like

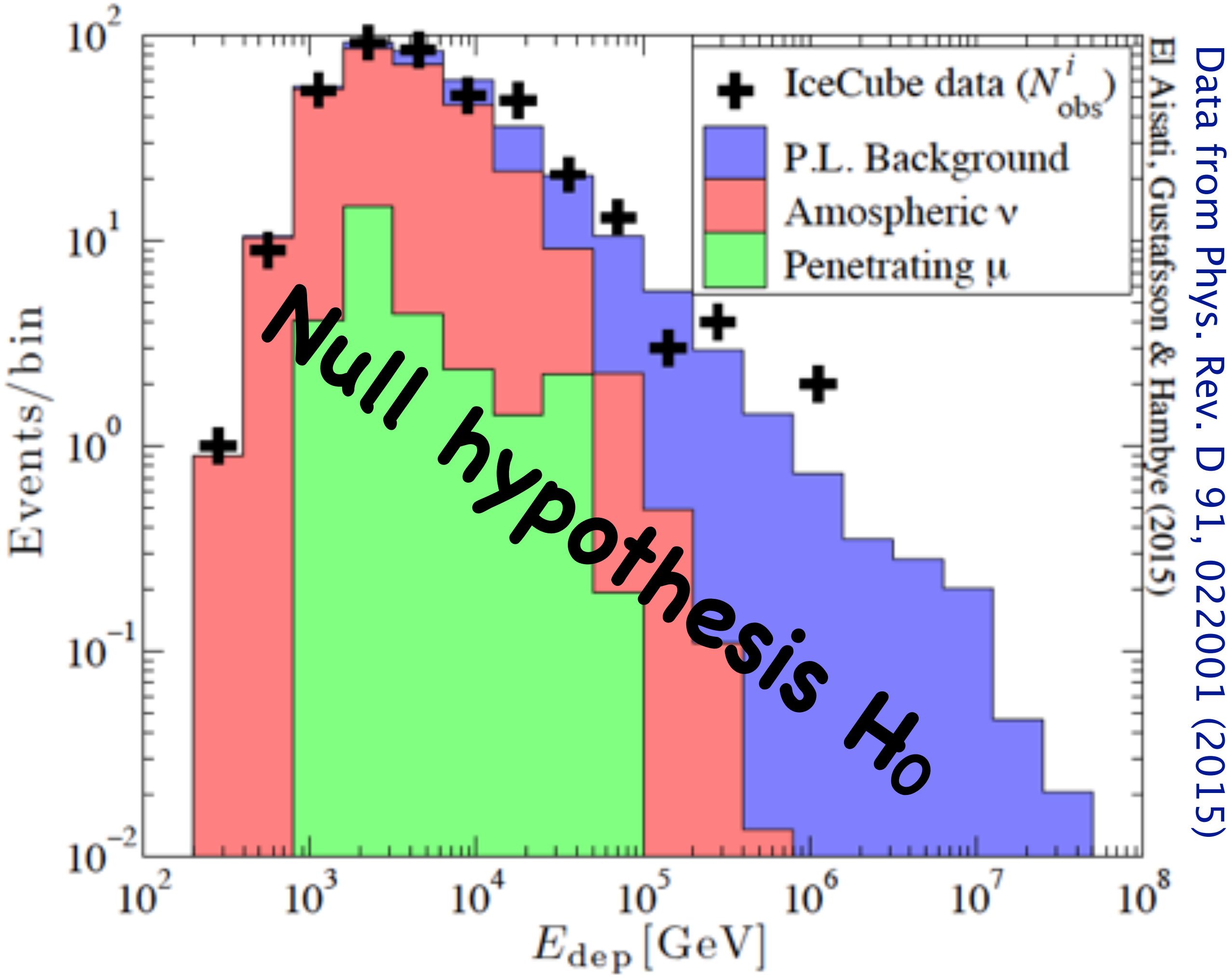
Guo, Wu Zhou,
PRD 81, 075014 (2010)



Rott, Kohri, Park
1408.4575

The Analysis

= Search for sharp spectral features from DM decay in neutrino data



Data from Phys. Rev. D 91, 022001 (2015)

- Test of the signal hypothesis **H_1** against the null hypothesis **H_0**, using a LLH procedure, fitting **energy** spectra:

$$\mathrm{TS} = 2\ln\frac{\mathcal{L}(n_{\rm sig} = n_{\rm sig,best})}{\mathcal{L}(n_{\rm sig} = 0)}$$

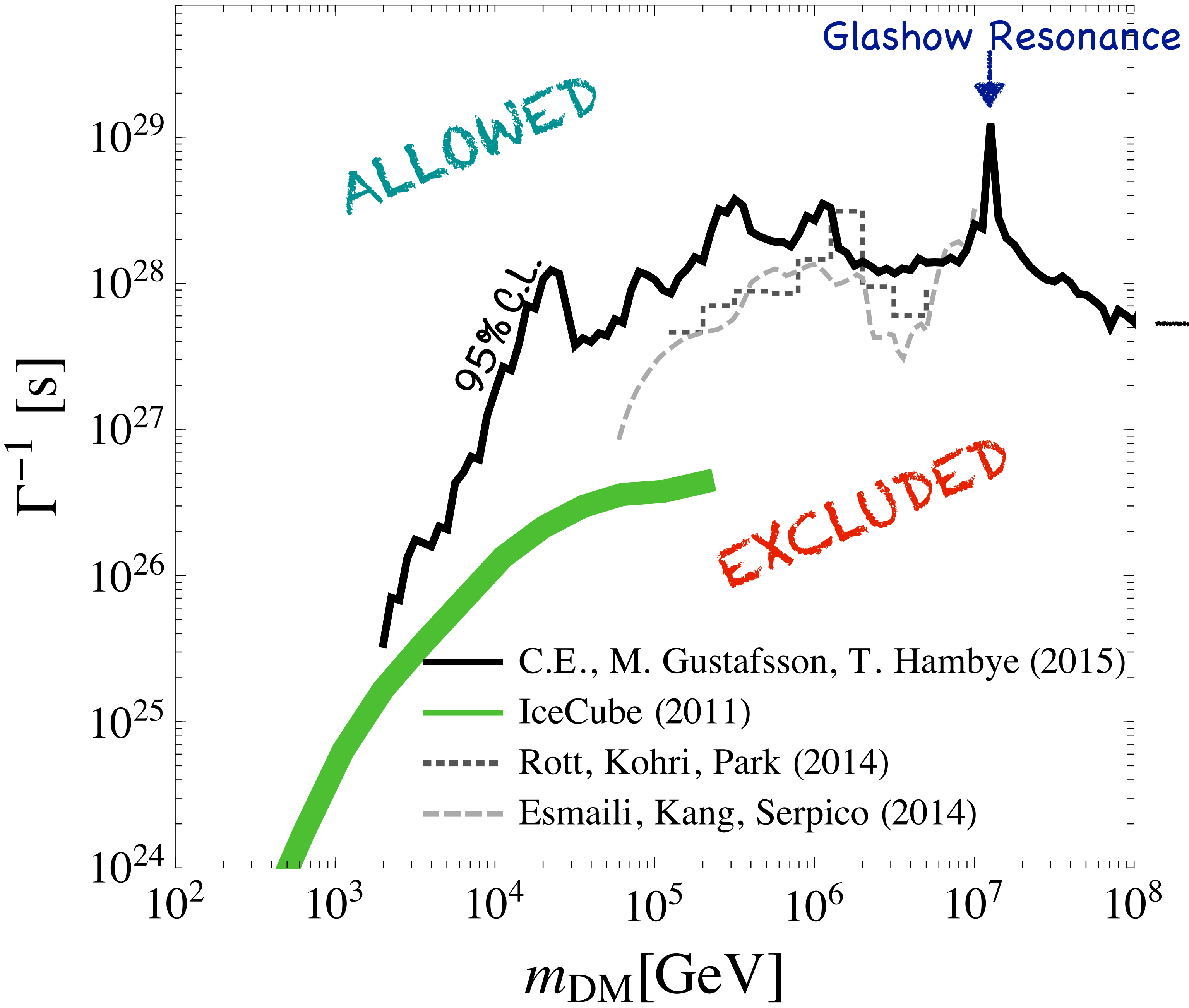
H_1

H_0

- $\sqrt{\mathrm{TS}}$ = significance (in #'s of σ) for rejecting **H_0** in favour of **H_1** .

Results

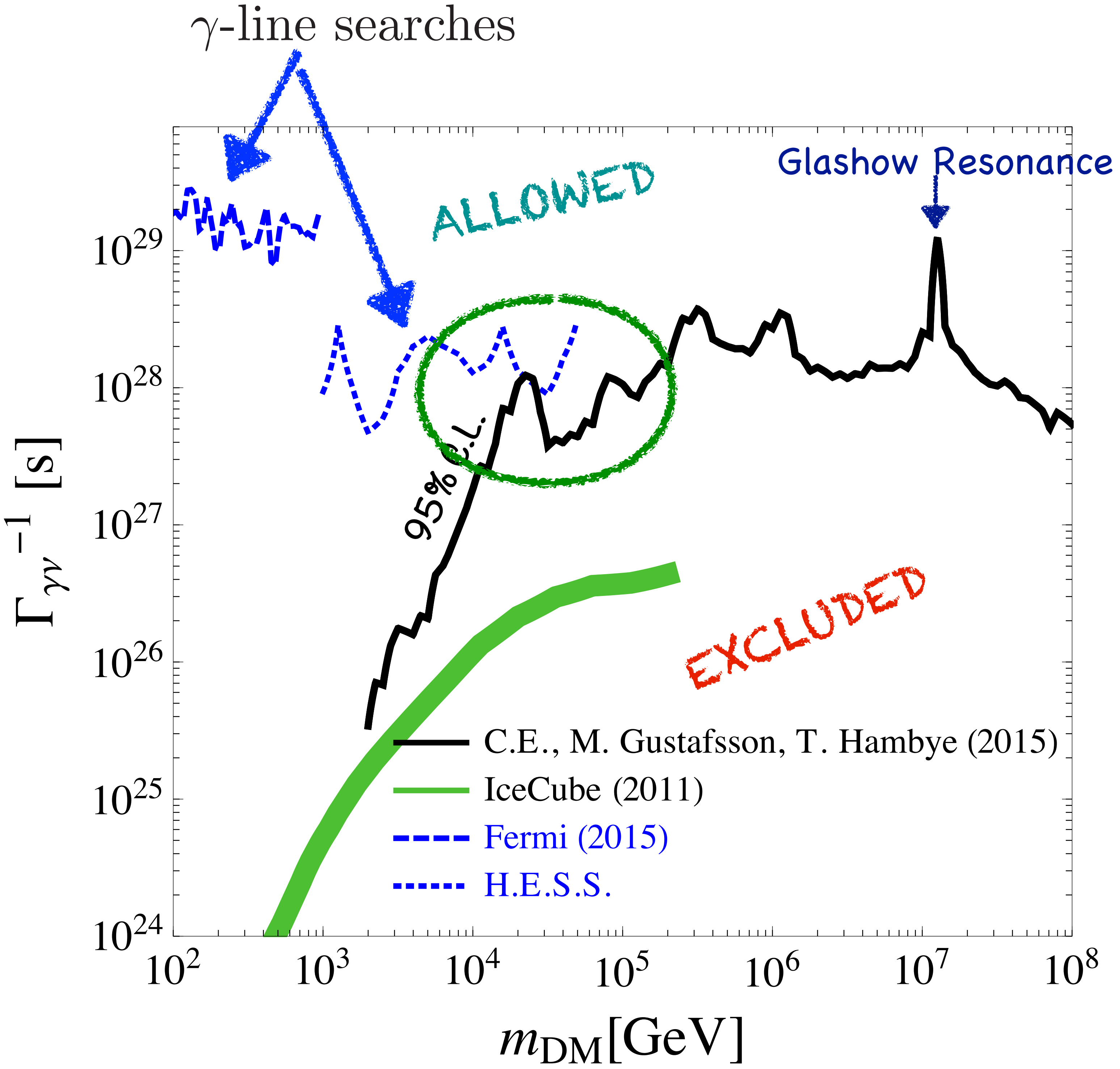
- Line and few other sharp features tested at different DM masses along w/ different flavour compositions
- No significant hint for a signal found in the data (<3σ locally)
- => Limits derived on the DM lifetime :



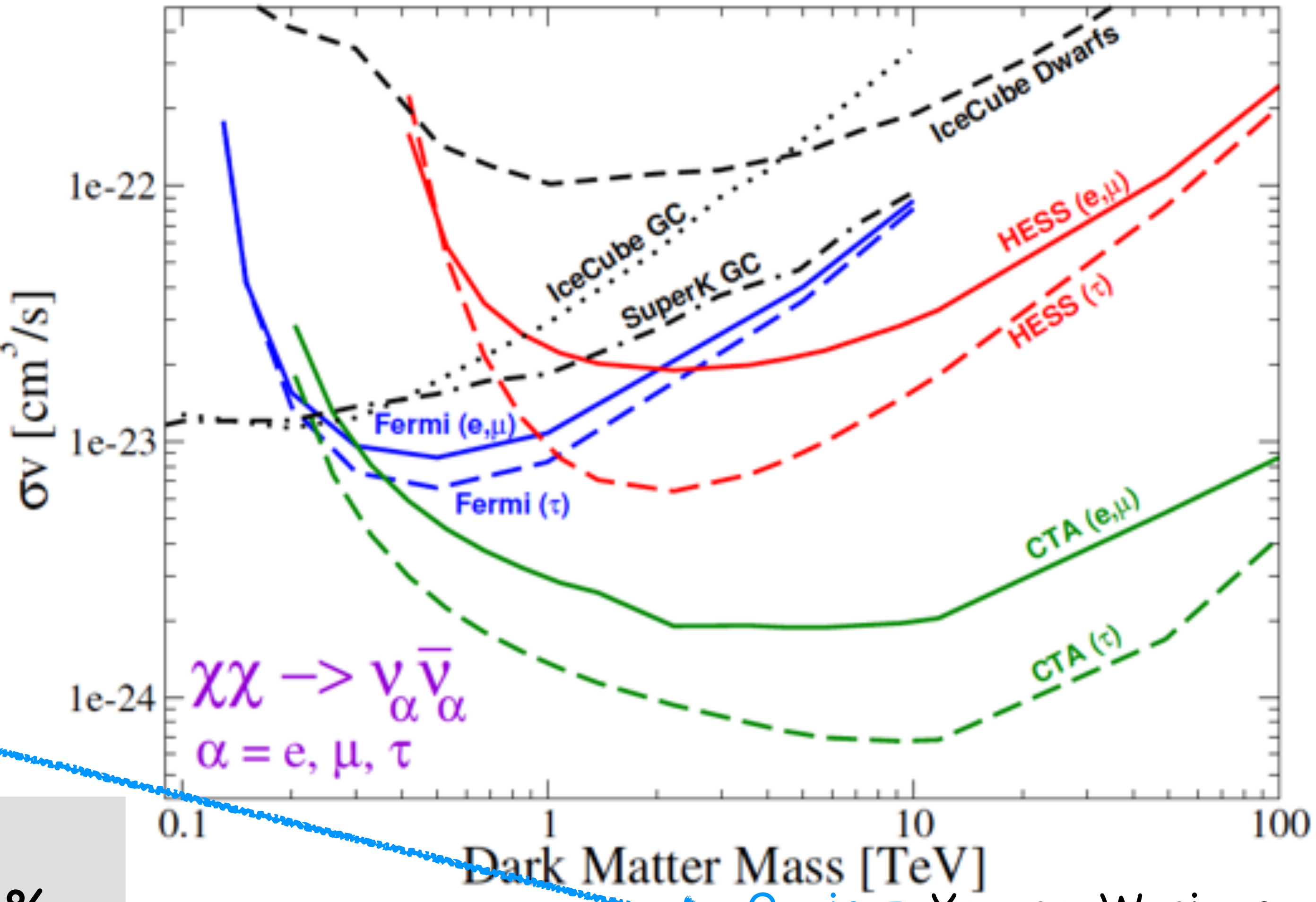
line, 'democratic' flavour composition

Results

- Higher sensitivity than in gamma-ray line searches above 50 TeV masses



Few words on radiative corrections...



1st talk of the day

Energy resolutions:
Fermi-LAT, HESS: 10-15%
IceCube: 15% (cascade-like)

Queiroz, Yaguna, Weniger
1602.05966

Joined project with IceCube in order to optimise sharp feature searches (e.g. by including **energy** in the fits) and further improve sensitivities using neutrinos as messengers.

¡Thank you for your attention!

Backup Slides

DM Flux Computation

$$N^i_{\mathrm{model}} \quad \propto \quad A^{e,\mu,\tau}_{\mathrm{eff}} \times \Phi_{\mathrm{model}}$$

Flux predicted
by your model

$$\Phi_{\mathrm{signal}} \qquad + \qquad \Phi_{\mathrm{bkg}}$$

(DM)

Everything else :
Atmospheric neutrinos, muons,
astrophysical source,…

$$\frac{\mathrm{d}\phi_{\mathrm{h}\alpha}}{\mathrm{d}E_\nu \mathrm{d}\Omega}(b,l) = \frac{1}{4\pi\, m_{\mathrm{DM}}\, \tau_{\mathrm{DM}}} \frac{\mathrm{d}N}{\mathrm{d}E_\nu} \int_{\mathrm{l.o.s.}} \mathrm{d}s\ \rho_{\mathrm{h}}[r(s,\psi[b,l])]$$

(halo, **anisotropic**)

$\propto$ ‘J-factor’

$+$

$$\frac{\mathrm{d}\phi_{\mathrm{eg}}}{\mathrm{d}E_\nu d\Omega} = \frac{\Omega_{\mathrm{DM}}\rho_{\mathrm{c}}}{4\pi m_{\mathrm{DM}}\tau_{\mathrm{DM}}} \int_0^\infty \mathrm{d}z\, \frac{c}{H(z)}\, \frac{\mathrm{d}N}{\mathrm{d}E}\Big|_{E=E_\nu(1+z)}$$

(Extra-Gal., **isotropic**)

Particle physics
dependent factors

Convolution with the detector's response function

$$\frac{\mathrm{d}N_\alpha}{\mathrm{d}E_\nu\,\mathrm{d}\Omega\,\mathrm{d}E'\,\mathrm{d}\cos\theta'\,\mathrm{d}\phi'} = \frac{\mathrm{d}(\phi_\mathrm{h}+\phi_\mathrm{eg})_\alpha}{\mathrm{d}E_\nu\,\mathrm{d}\Omega} \cdot A_{\mathrm{eff},\alpha} \cdot T \cdot D_{\mathrm{eff},\alpha}$$

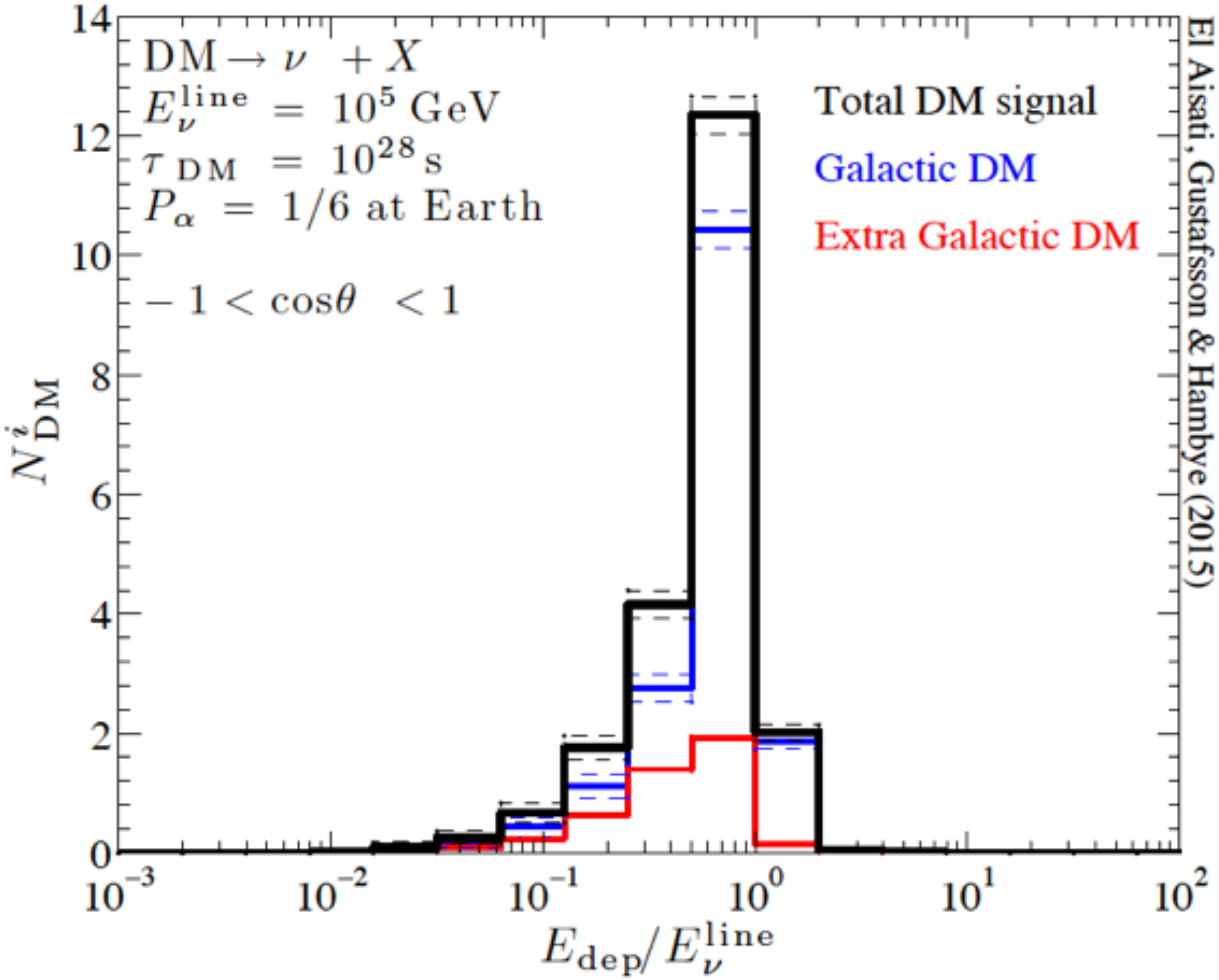
with $\alpha \in \{e, \mu, \tau, \bar{e}, \bar{\mu}, \bar{\tau}\}$
T the exposure time
E_ν the ‘true’ energy variable
Ω solid angle
$D_{\mathrm{eff},\alpha}$ the dispersion function
E' the ‘reconstructed’ energy variable
(θ', ϕ') solid angle.

Flavour composition

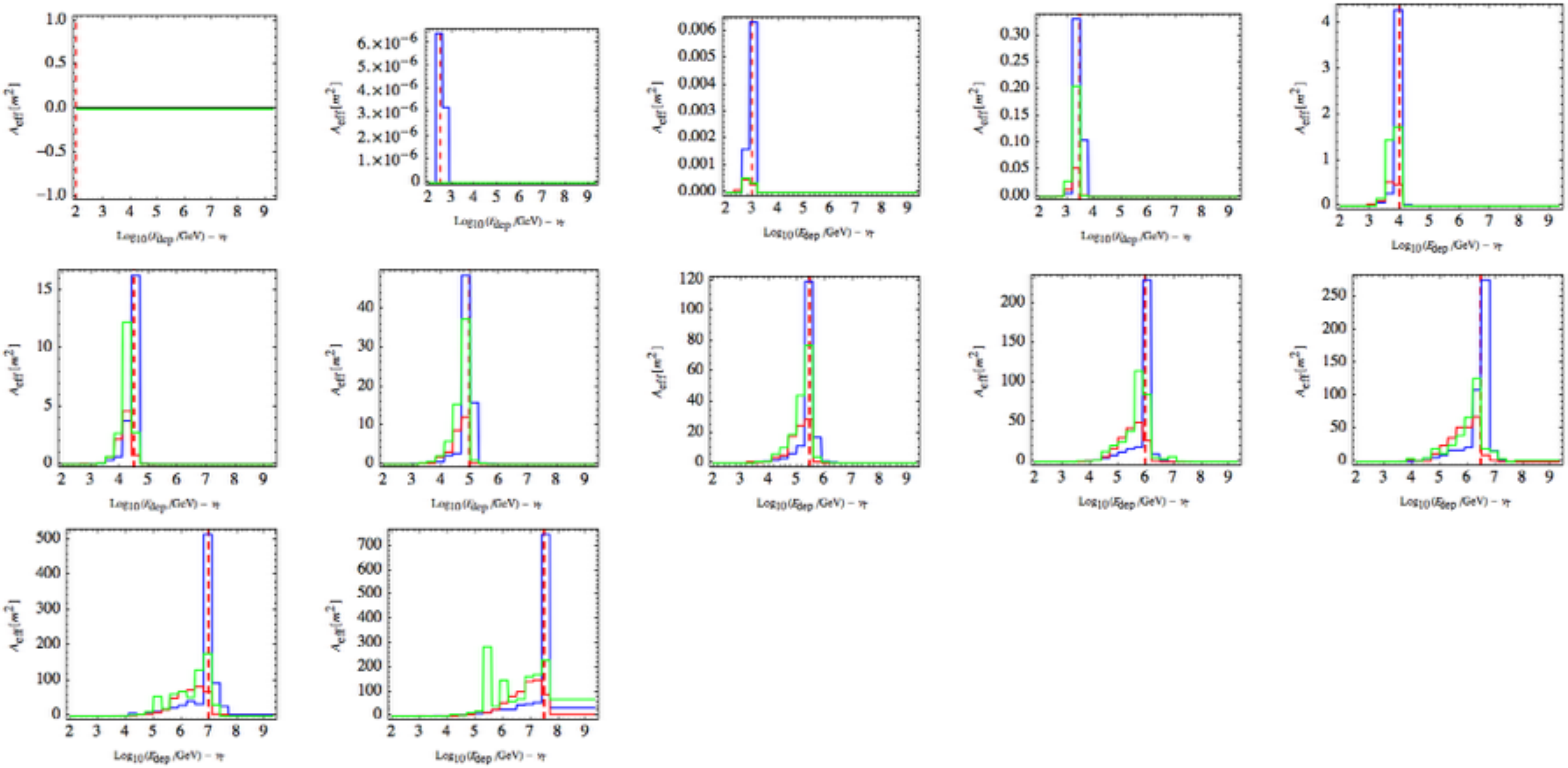
and then integrate

$$N^i_\mathrm{DM}(m_\mathrm{DM}, \tau_\mathrm{DM}) = \int_{\Delta_i E'} \mathrm{d}E' \int_{\Delta\theta'(t)} \mathrm{d}\cos\theta' \int_{\Delta\phi'(t)} \mathrm{d}\phi' \int \mathrm{d}E \int_{4\pi} \mathrm{d}\Omega \sum_{\substack{\alpha=e,\mu,\tau,\\ \bar{e},\bar{\mu},\bar{\tau}}} P_\alpha \frac{\mathrm{d}N_\alpha}{\mathrm{d}E_\nu\,\mathrm{d}\Omega\,\mathrm{d}E'\,\mathrm{d}\cos\theta'\,\mathrm{d}\phi'}$$

Example of DM signal

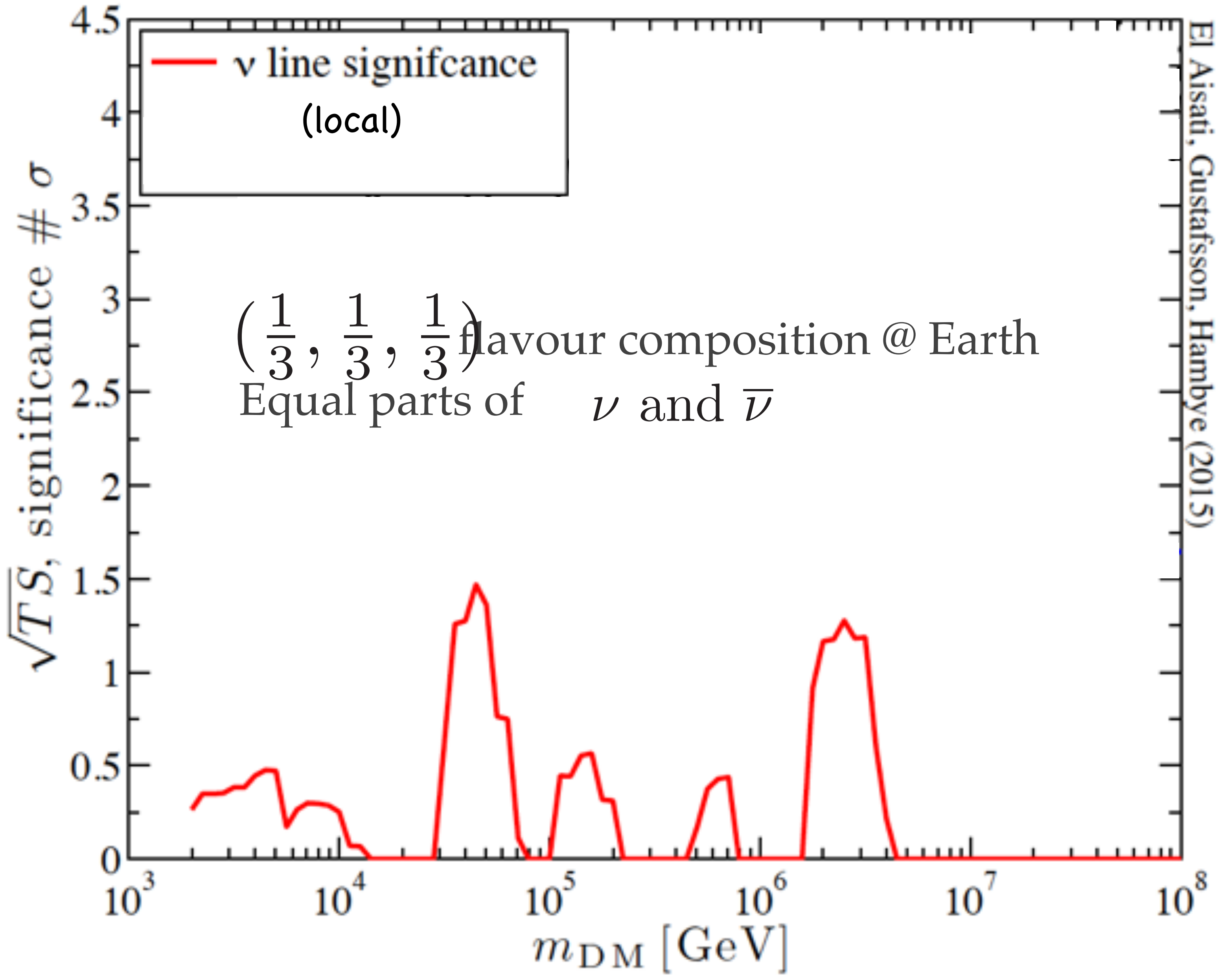


Reconstruction of lines @ different energies



Blue: e-neutrinos
Green: mu-neutrinos
Red: Tau-neutrinos

Significance plot



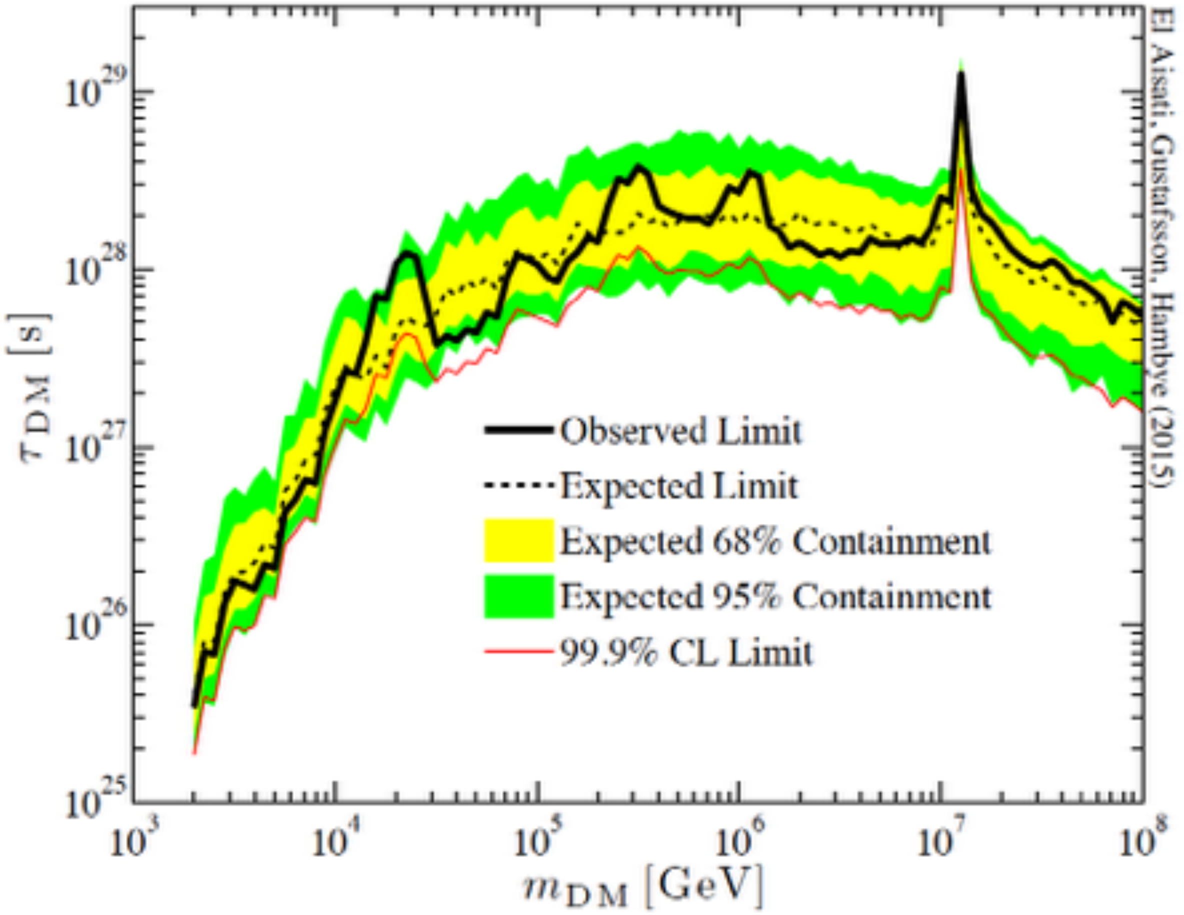
Maximal TS =2.9 found for 100% $\nu_{\rm e}$ composition @ Earth and DM mass of 45 TeV.

Deriving limits

$$\mathrm{TS} = 2\ln\frac{\mathcal{L}(n_{\mathrm{sig}} = n_{\mathrm{sig,best}}, \hat{\theta})}{\mathcal{L}(n_{\mathrm{sig}} = n_{\mathrm{limit}}, \hat{\hat{\theta}})}$$

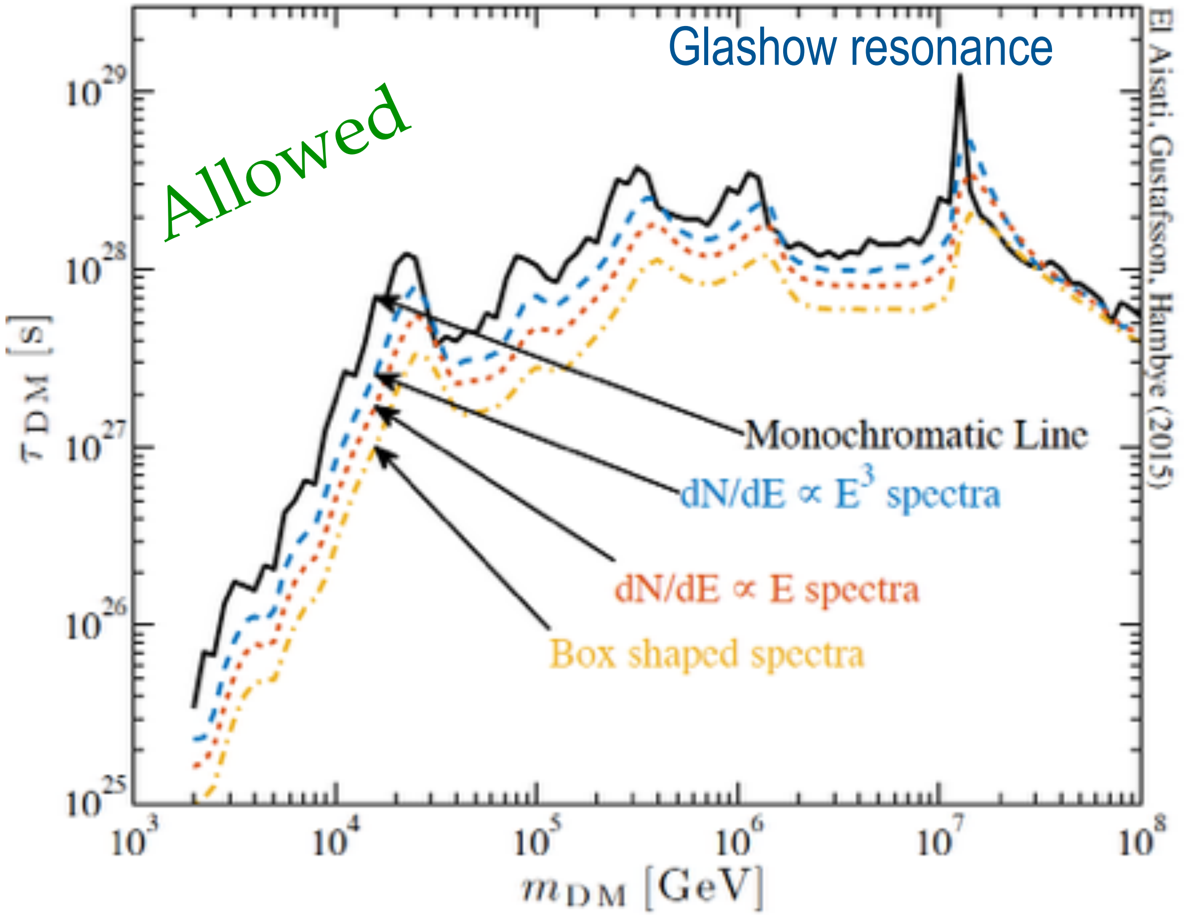
(Profile Likelihood)

Keep DM lifetimes
that give TS < 2.71 (95% C.L.)



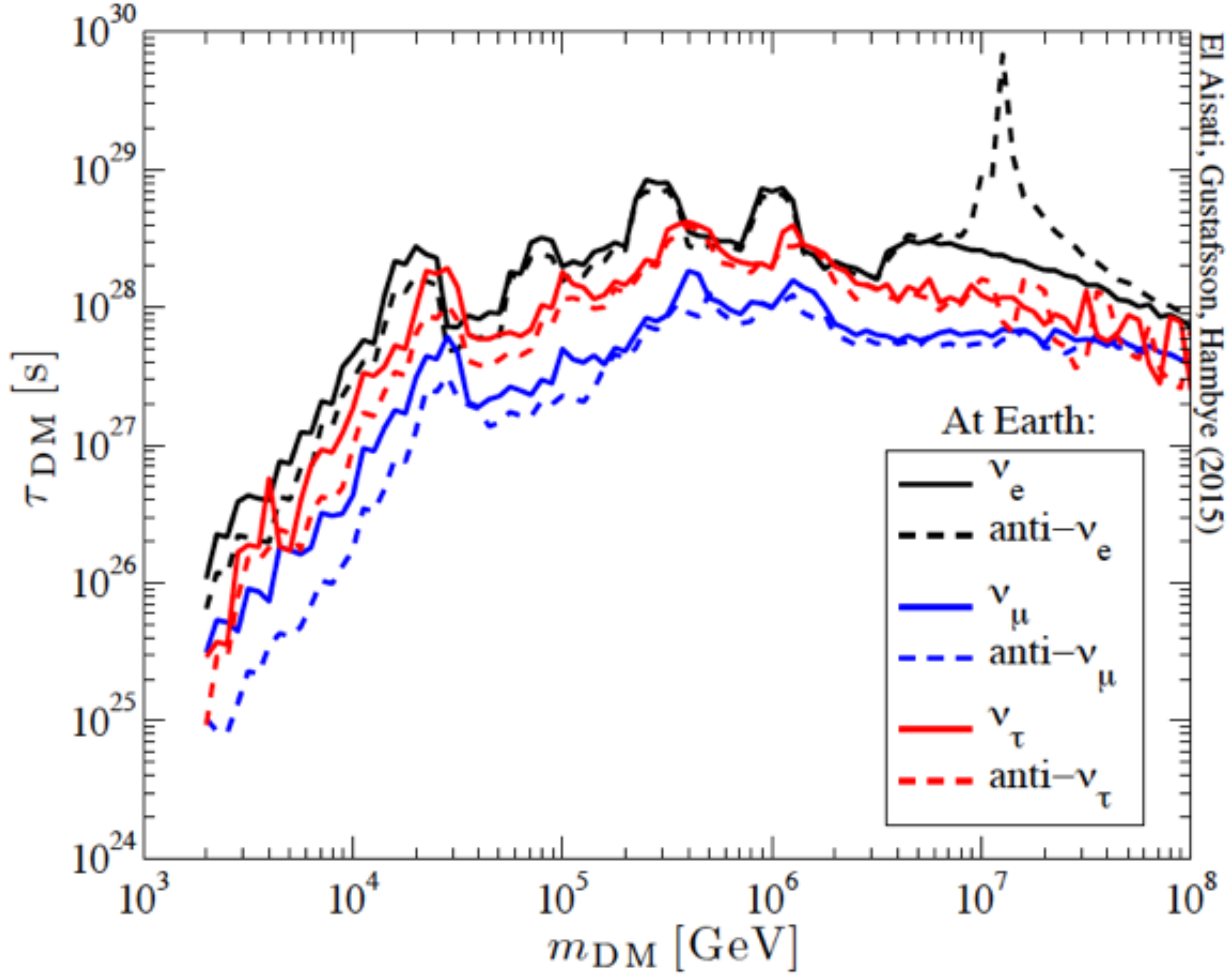
El Aisati, Gustafsson, Hambye (2015)

$$\frac{\mathrm{d}N}{\mathrm{d}E} = \frac{2^{n+1}(n+1)}{m_{\mathrm{DM}}}\left(\frac{E}{m_{\mathrm{DM}}}\right)^{n}\Theta(m_{\mathrm{DM}} - 2E)$$



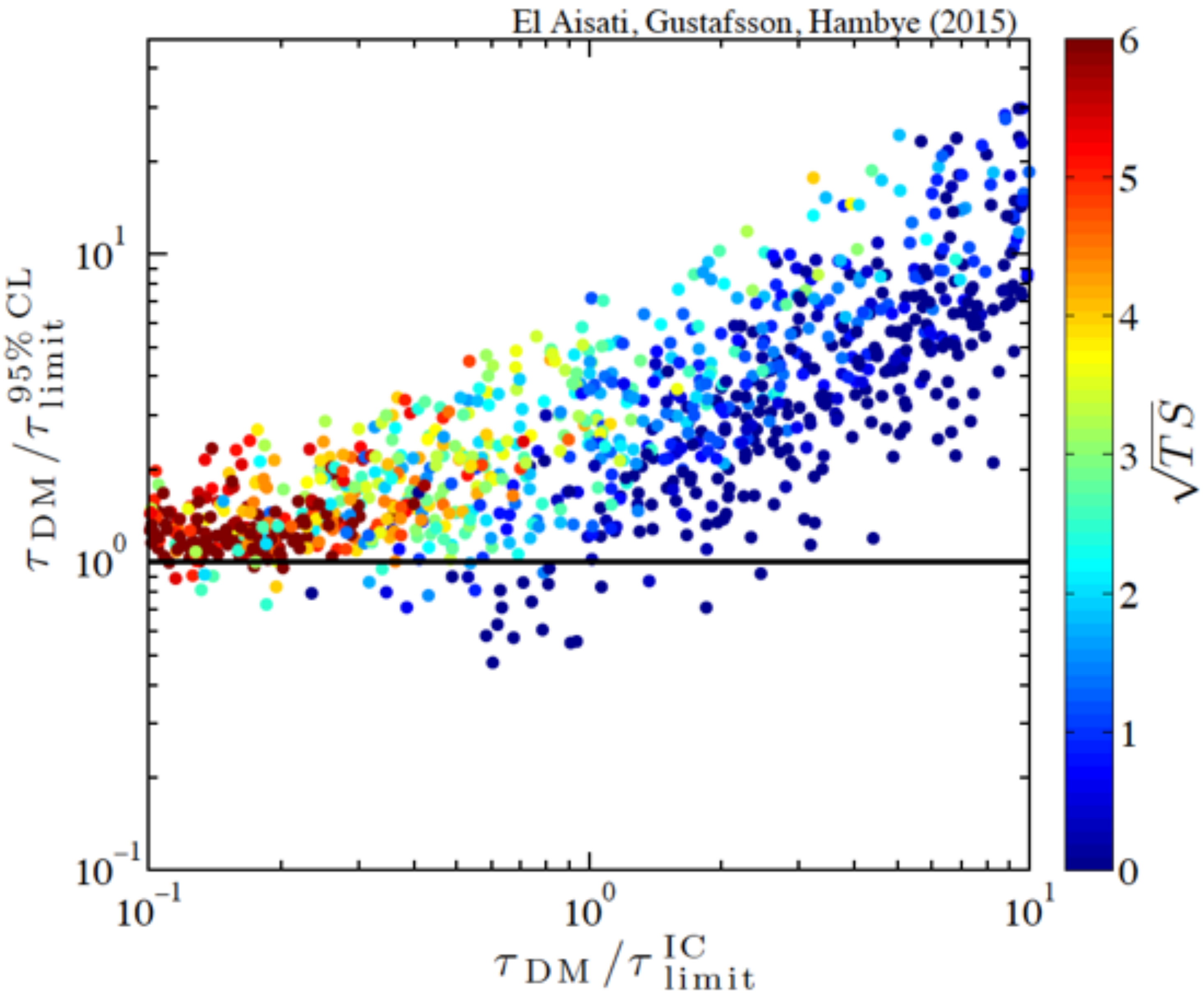
El Aisati, Gustafsson, Hambye (2015)

Limits (nu/nubar/flavour compositions)



El Aisati, Gustafsson, Hambye (2015)

Statistical coverage



Coverage = 93%
101 masses tested