A search for dark matter using sub-PeV gamma-rays observed by Tibet AS$_\gamma$

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Based on

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2105.05680

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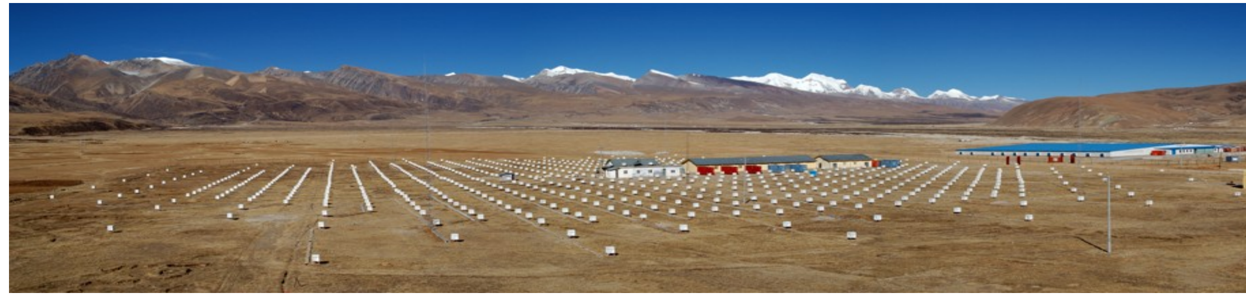
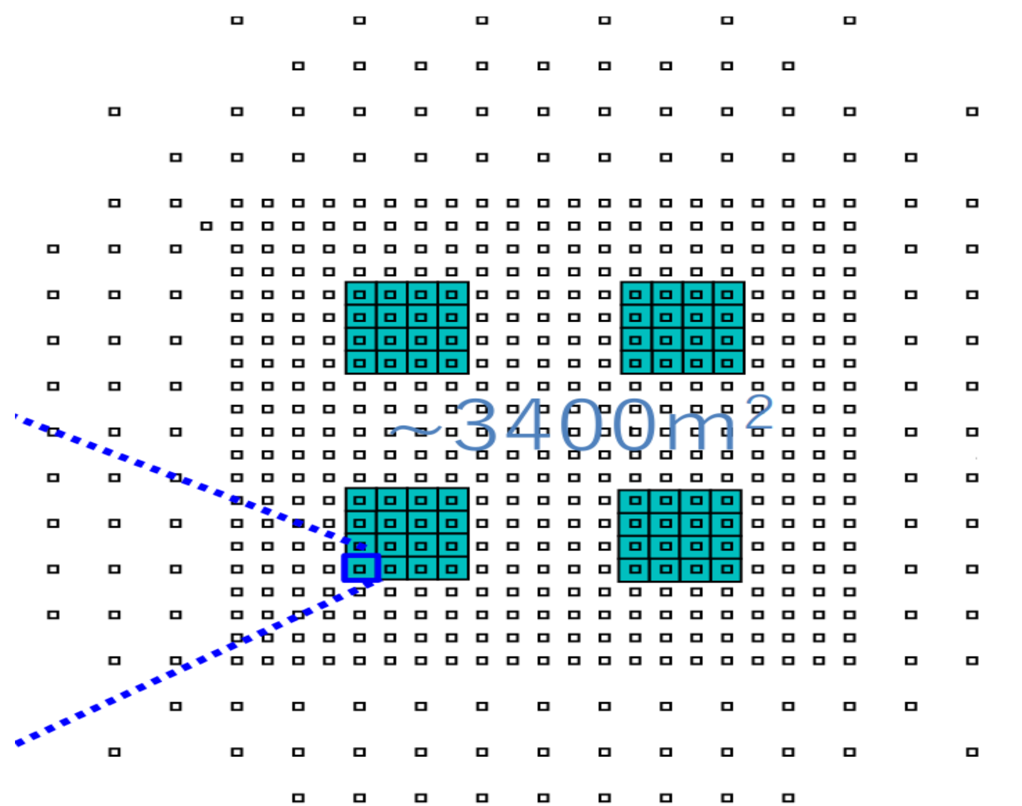
Tibet AS+MD



- ✔ Area: ~1.5 Eiffel tower
- ✔ Hybridize with muon detector.
- ✔ 2.4 m underground
- ✔ Muon with energy greater than 1 GeV



Livetime: 719 days from February 2014 to May 2017

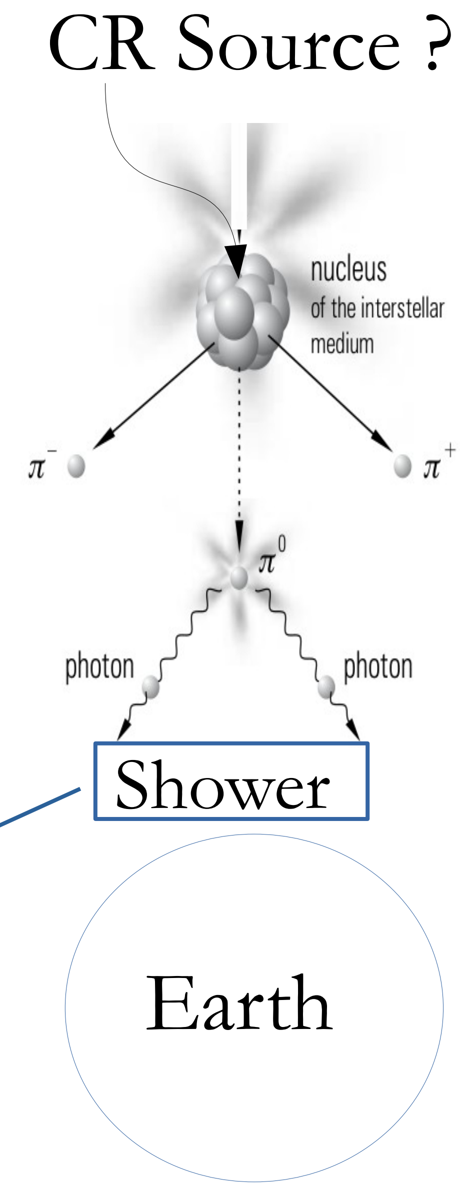
Muon detector: gamma and cosmic ray (CR) discrimination

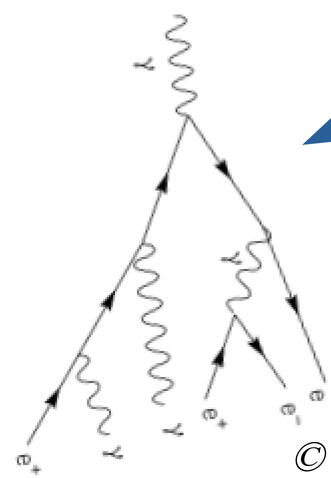
Amenomori et al 2104.05181 PRL

What is it observing?

✔Are not deflected by interstellar magnetic fields.

✔ Observation of ~100 TeV gamma ray predict the Galactic origin of the PeV cosmic ray.





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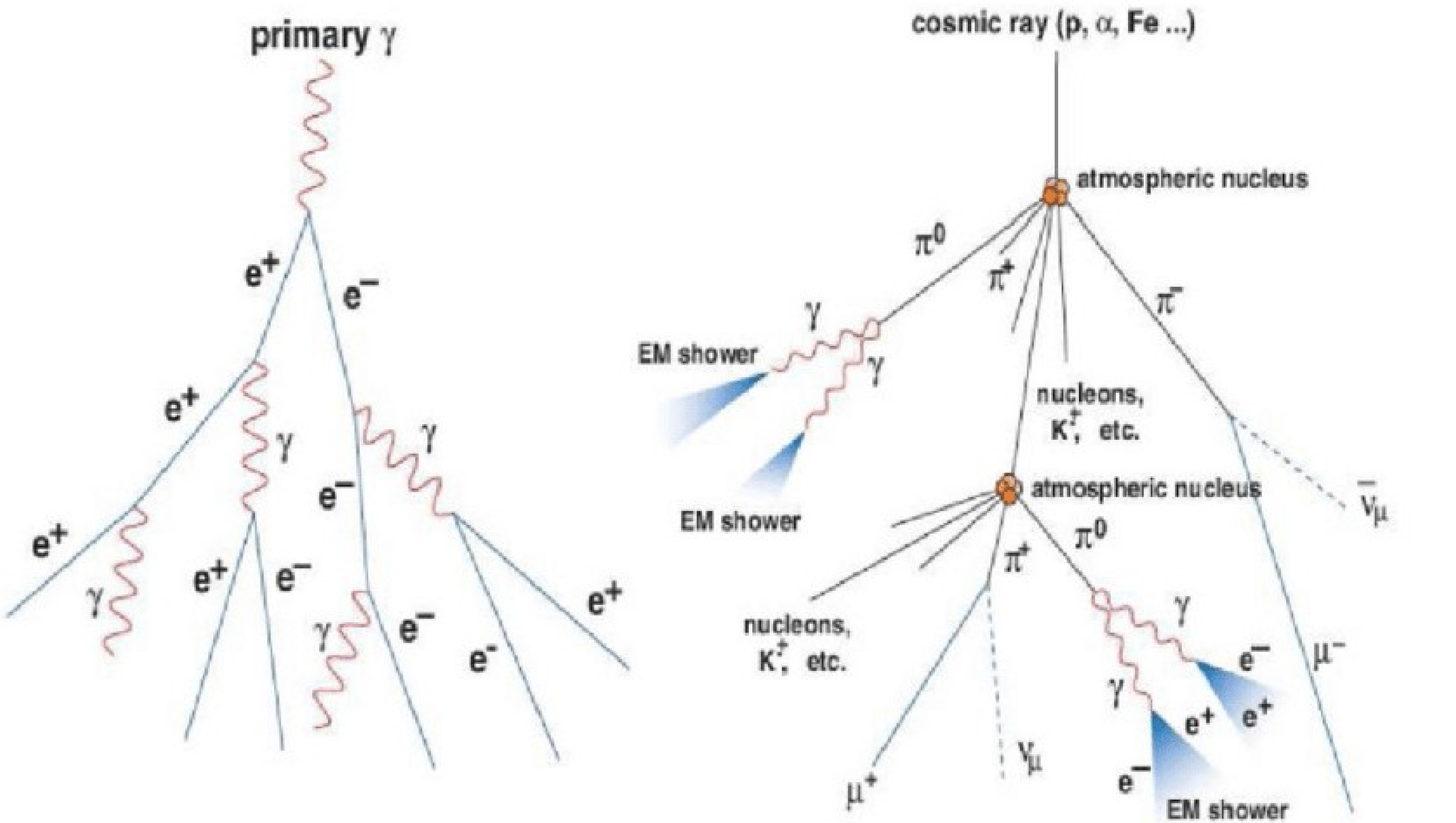
How? Photon and Proton Shower



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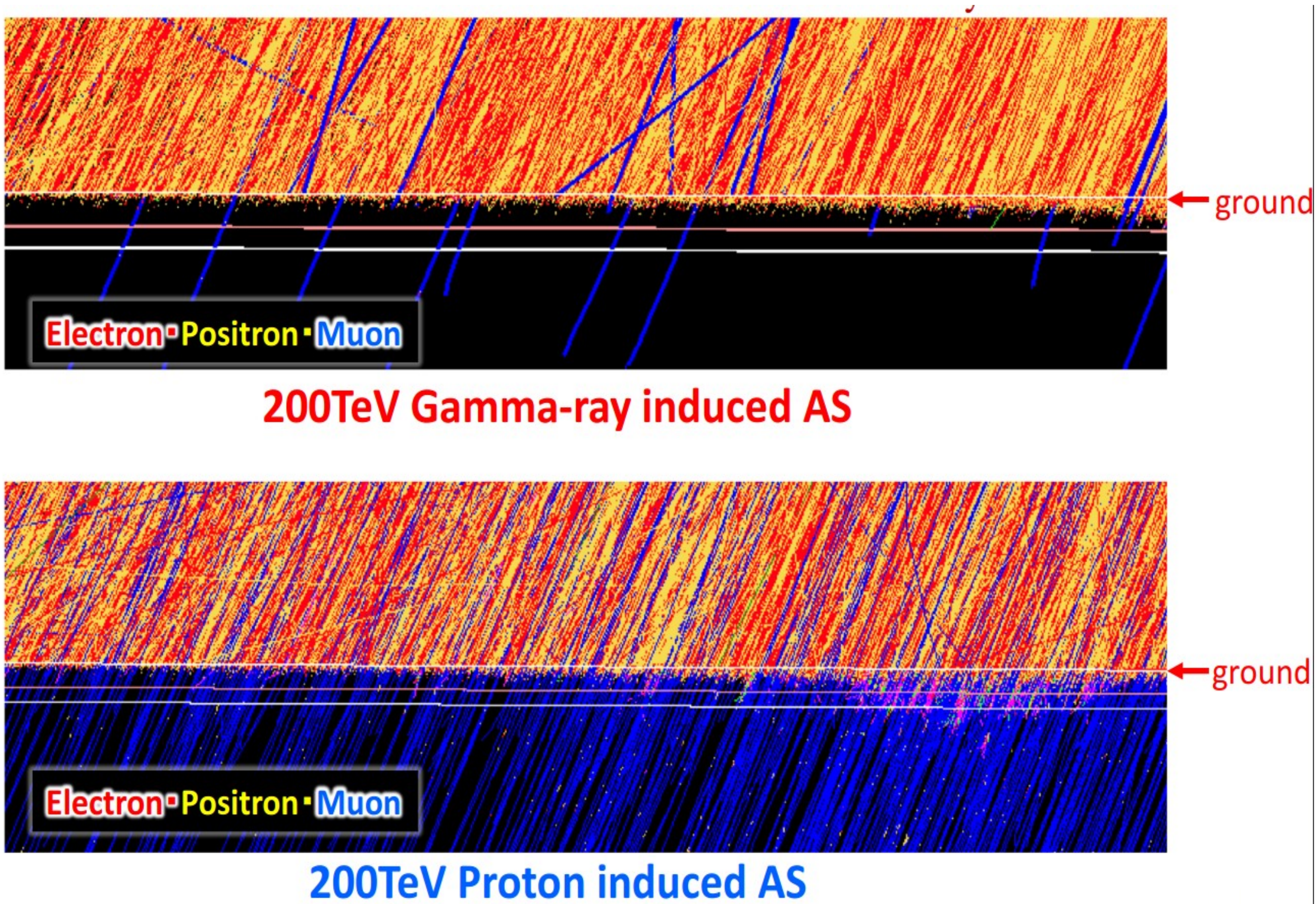
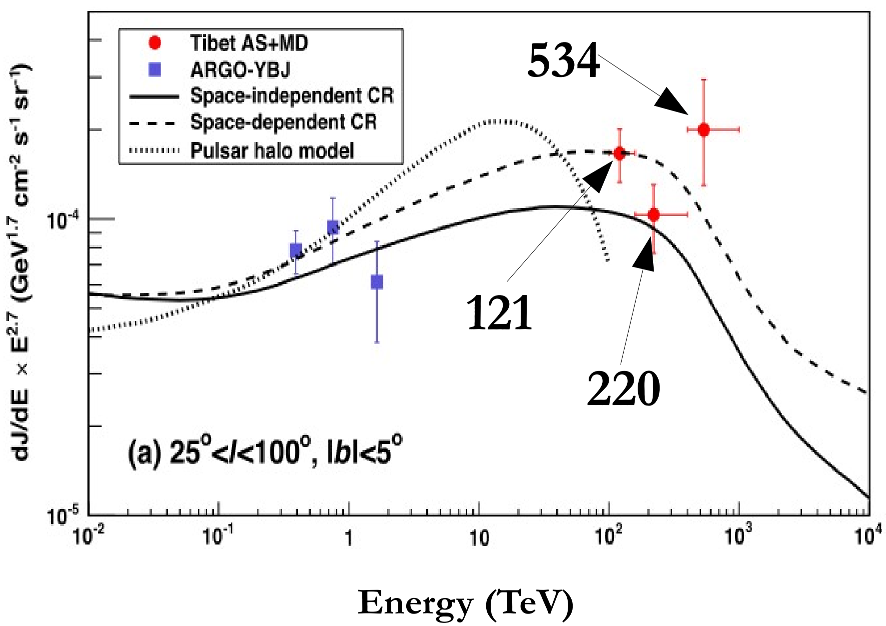
Occasional γ-p interaction gives rises shower similar to hadronic shower

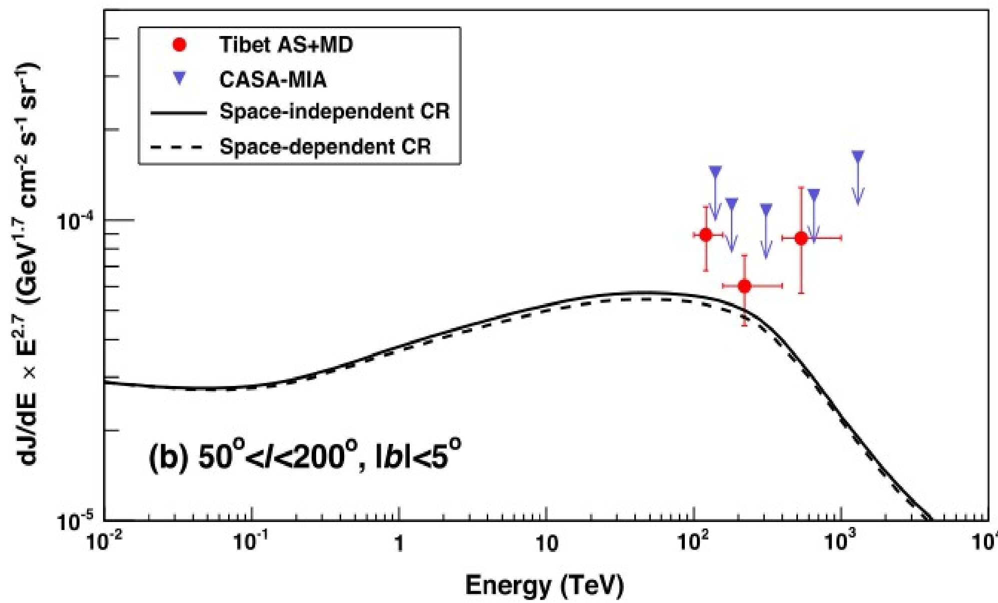
How? Photon and Proton Shower



✔ After muon cut,~99.9% CR rejection & ~90% gamma efficiency @100 TeV

Result: Observed Flux





✔ **First detection of sub-PeV diffuse gamma rays.**

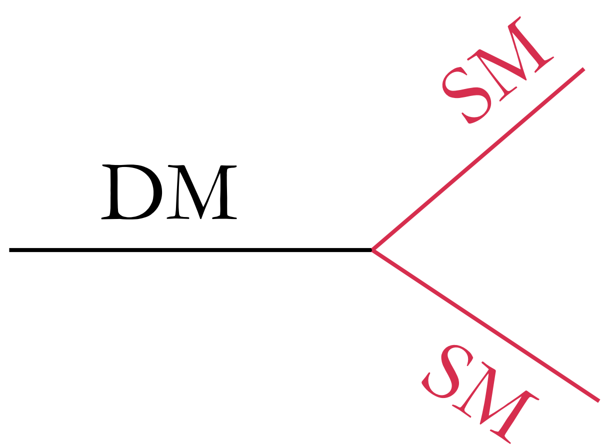
✔ Space dependent and space independent cosmic ray model seems to fit well with data, proposed in 1804.10116

✔ Several recent proposals e.g., see 2104.09491, 2104.03729, 2104.05609

Amenomori et al 2104.05181 PRL

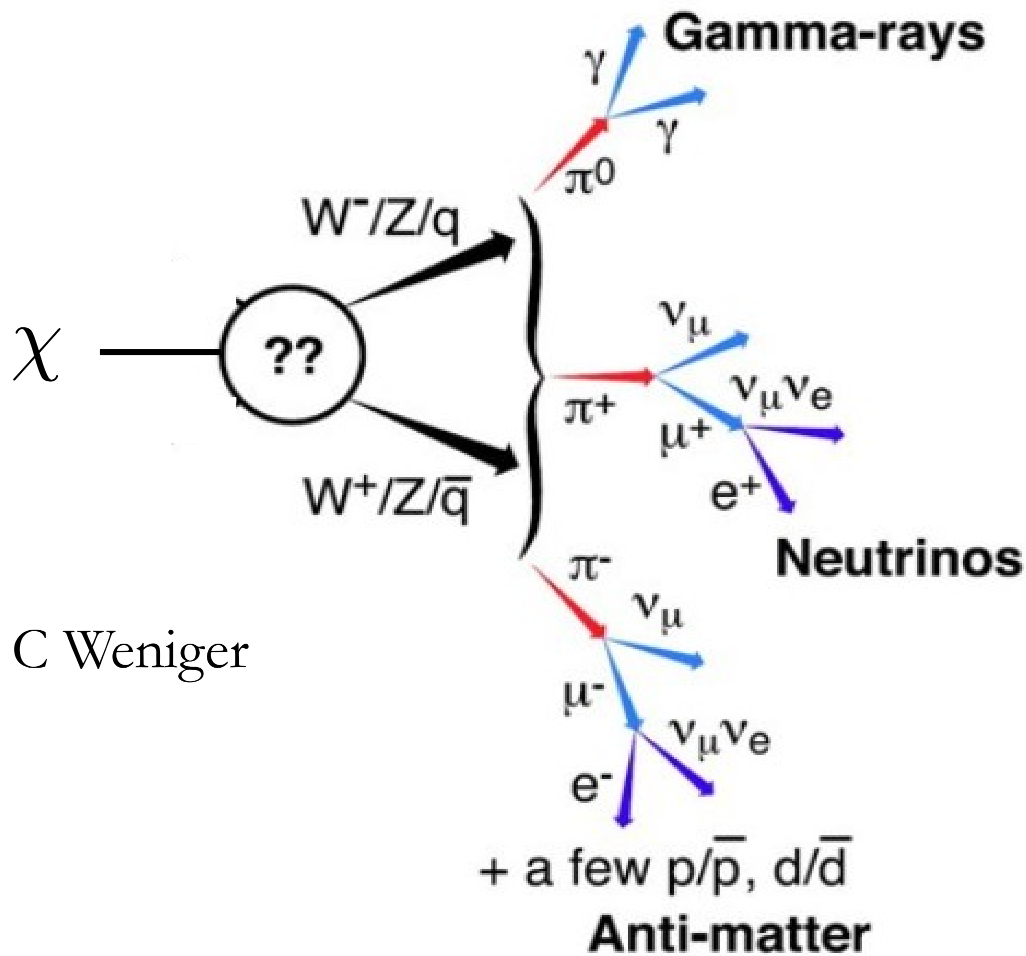
What are we doing?

Observed Flux: Whether this observation could be used for detection of dark matter?



Decaying DM: gamma-ray spectrum

$$\frac{dN_\gamma}{dE_\gamma}$$



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PPPC

1012.4515

HDMSpectra

2007.15001

Decaying DM + Background < Data

DM Flux

$$\frac{d^2\phi_\gamma}{dE_\gamma d\Omega}(E_\gamma) = \frac{1}{\Delta\Omega} \int_{\Delta\Omega} d\Omega \frac{1}{4\pi m_\chi \tau_\chi} \frac{dN_\gamma}{dE_\gamma}(E_\gamma) \int_0^{s_{\max}} \rho_\chi(s,b,l)\, e^{-\tau_{\gamma\gamma}(E_\gamma,s,b,\ell)} ds$$

$\rho_\chi(s,b,l)$ → NFW

$e^{-\tau_{\gamma\gamma}(E_\gamma,s,b,\ell)}$ → Attenuation

Background

Different cosmic ray models:
- Space dependent CR, 1804.10116
- Space independent CR, 1804.10116
- Hybrid gamma-model, 2104.09491

Data

TABLE S2. Galactic diffuse gamma-ray fluxes measured by the Tibet AS+MD array.

Energy bin (TeV)	Representative E (TeV)	Flux ($25^\circ < l < 100^\circ, \lvert b\rvert < 5^\circ$) ($\mathrm{TeV^{-1}\ cm^{-2}\ s^{-1}\ sr^{-1}}$)	Flux ($50^\circ < l < 200^\circ, \lvert b\rvert < 5^\circ$) ($\mathrm{TeV^{-1}\ cm^{-2}\ s^{-1}\ sr^{-1}}$)
100 – 158	121	$(3.16 \pm 0.64) \times 10^{-15}$	$(1.69 \pm 0.41) \times 10^{-15}$
158 – 398	220	$(3.88 \pm 1.00) \times 10^{-16}$	$(2.27 \pm 0.60) \times 10^{-16}$
398 – 1000	534	$(6.86\ ^{+3.30}_{-2.40}) \times 10^{-17}$	$(2.99\ ^{+1.40}_{-1.02}) \times 10^{-17}$

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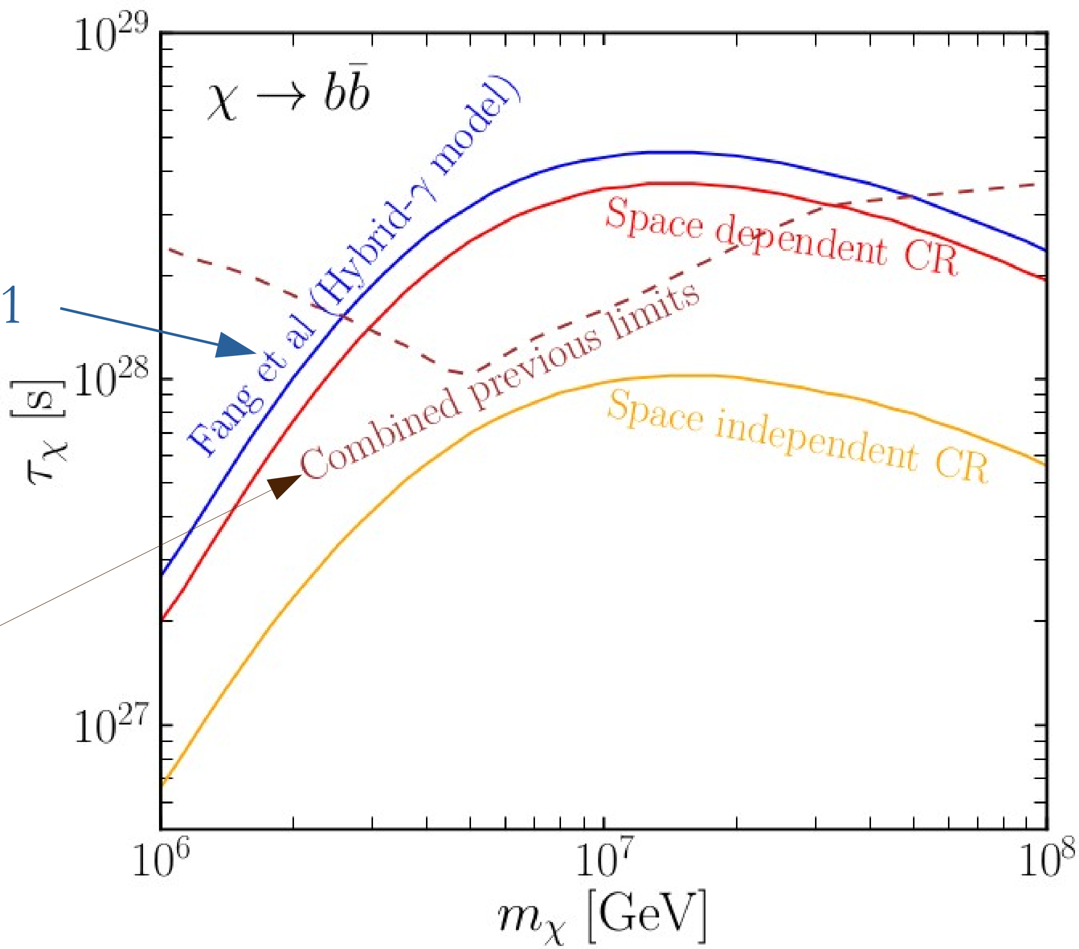
Decaying DM: Limits

✔ We have done a χ^2 analysis to set the limits.

2104.09491



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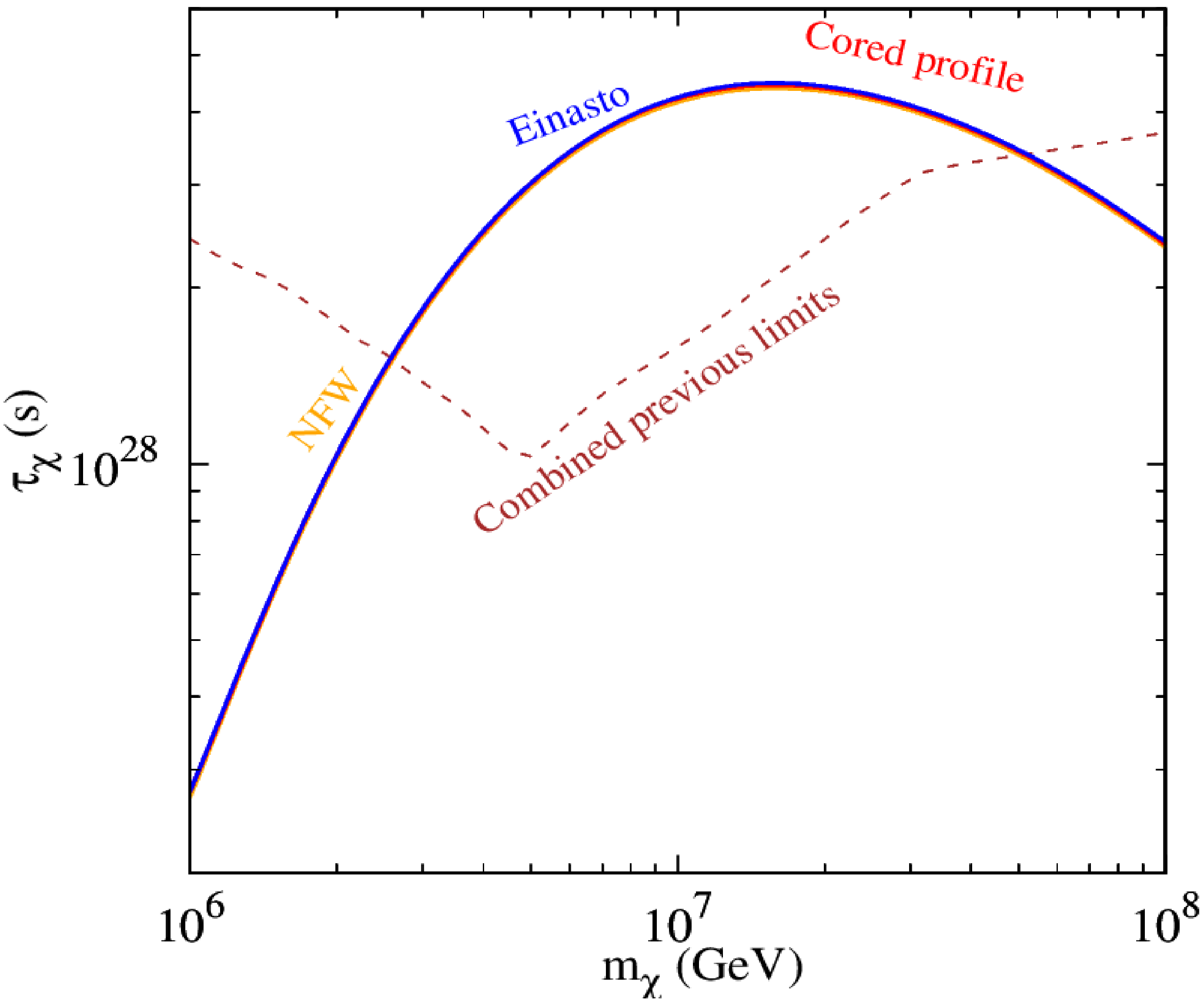
1612.05638, 1907.11222, 1907.11671

Related work: 2105.01826

Decaying DM Limits: DM profile



@ Our limits are robust.

Conclusion

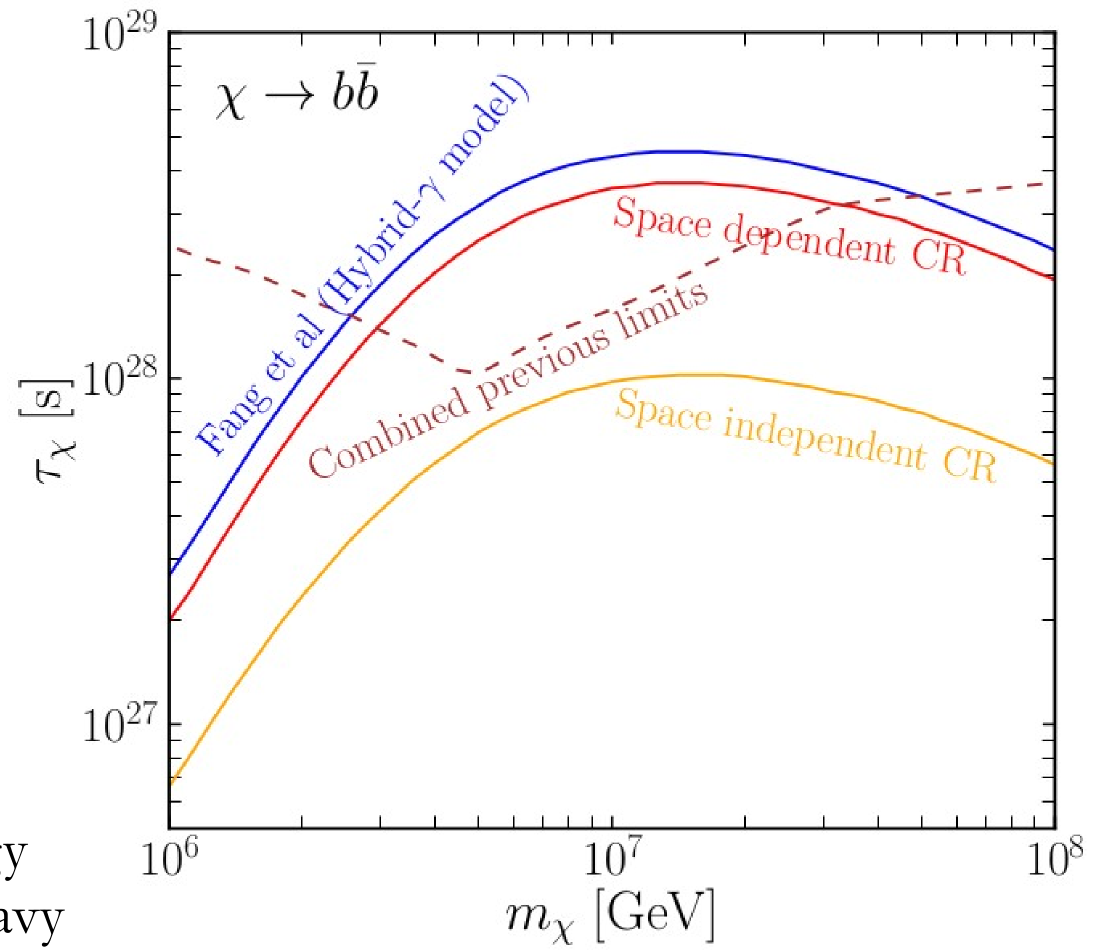
✔ Recently, Tibet AS$_\gamma$ collaboration has discovered the first sub-PeV diffuse gamma-rays from the MW Galactic disk.

✔ Data broadly agrees with prior theoretical expectations

✔ We study the impact of this discovery on PeV scale decaying DM

✔ We find that data provides strongest bound on most of the final states

➔ Near future data of these high-energy gamma-rays can be used to discover heavy decaying DM.



email: tarak.maity.physics@gmail.com

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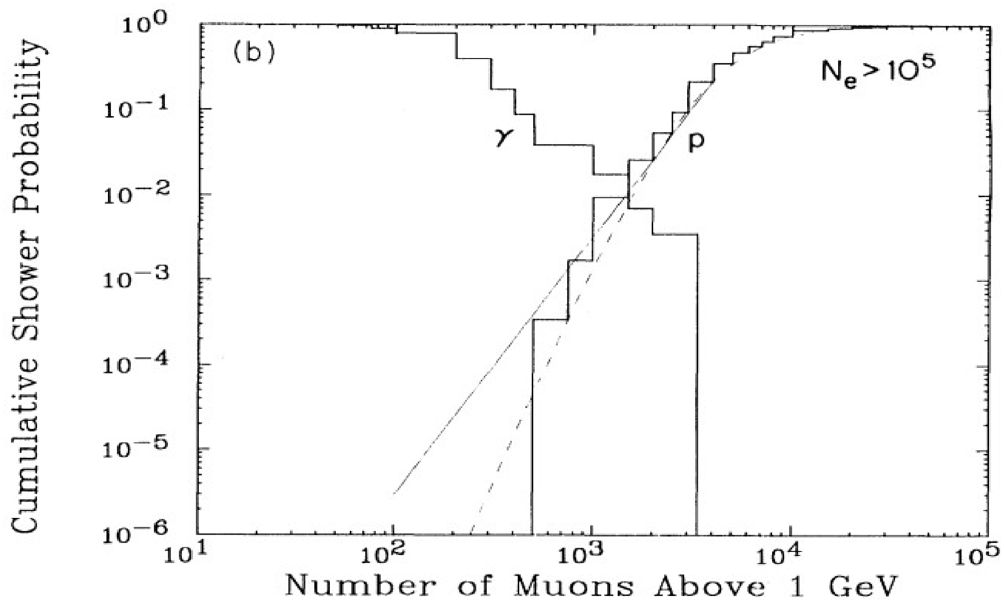
Thank you

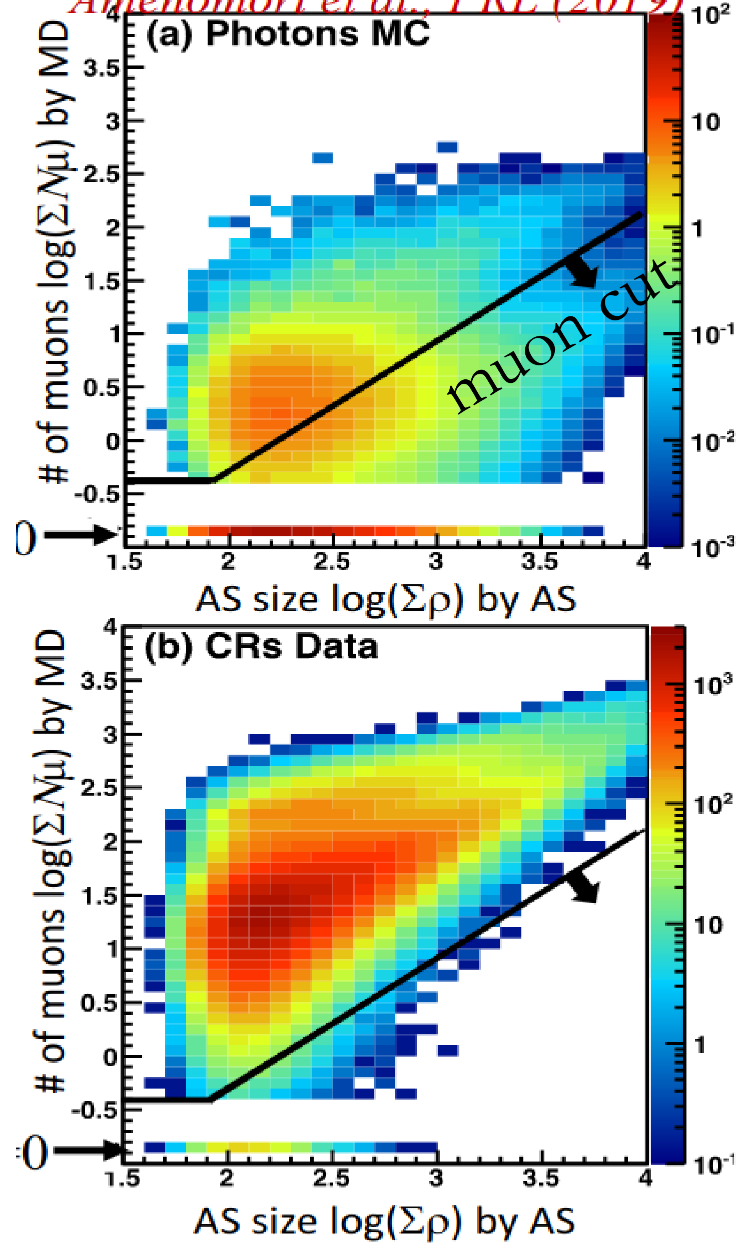
Photon Proton Shower: Tibet AS_γ



	$N_\mu < 75$	$N_\mu < 100$	$N_\mu < 200$	$N_\mu < 300$
Percentage of γ-ray signals retained	10%	20%	60%	83%
Level of cosmic-ray background				
Solid line fit	10^{-5}	1.5×10^{-5}	4×10^{-5}	10^{-4}
Dashed line fit	$<10^{-7}$	10^{-7}	6.6×10^{-7}	4×10^{-6}

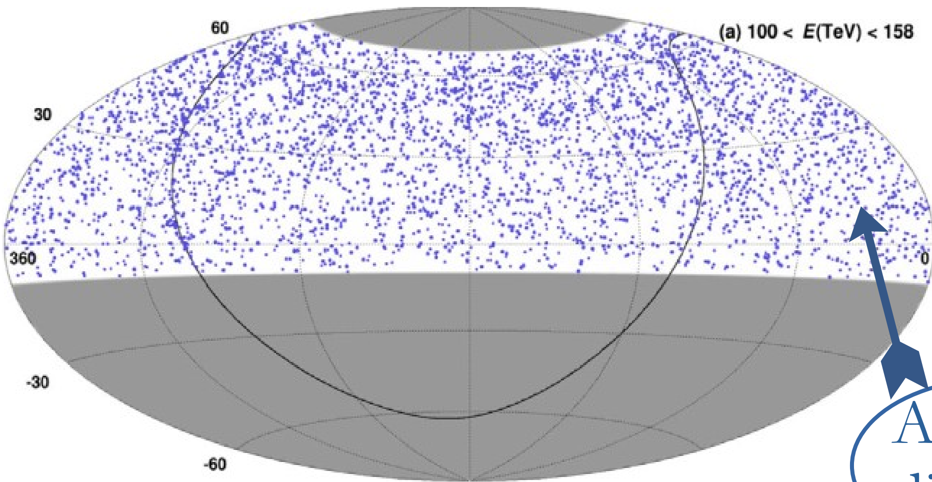
Gaisser et al PRD 91'

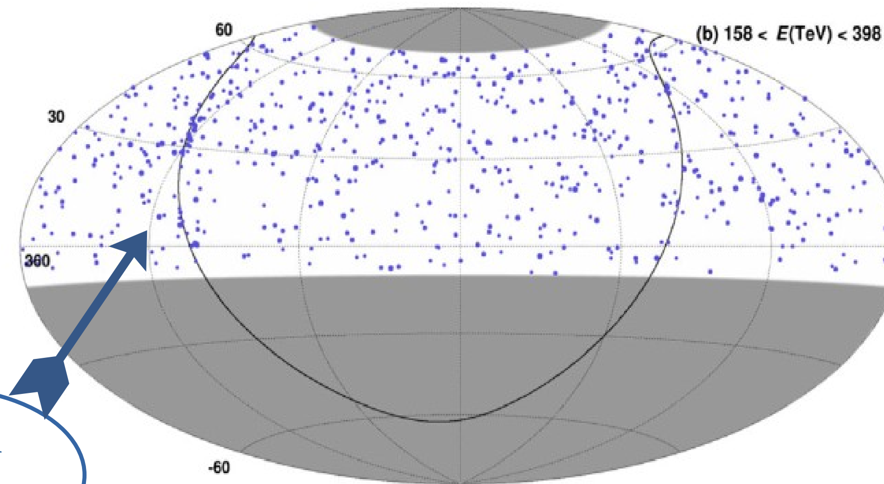
Amenomori et al., PRL (2019)



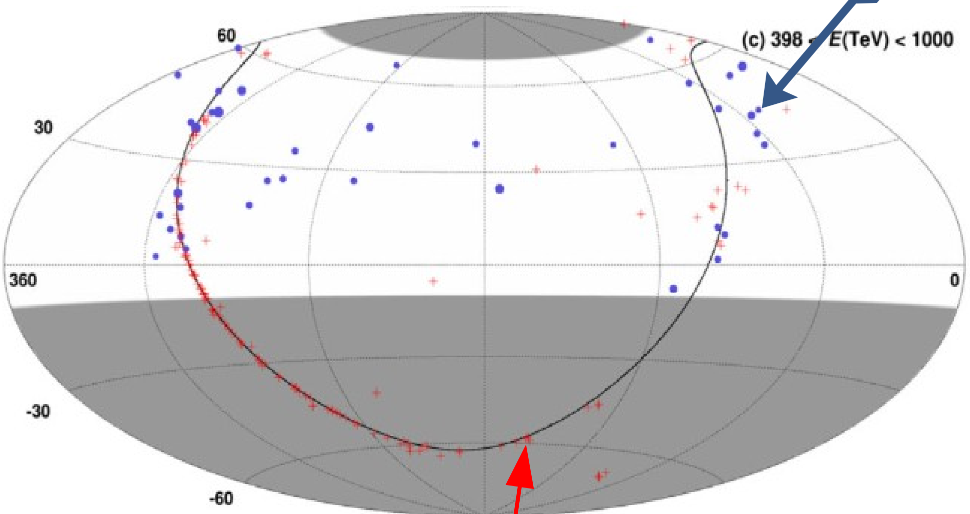
✔After muon cut,~99.9% CR rejection & ~90% gamma efficiency @100 TeV

Tibet AS$_\gamma$

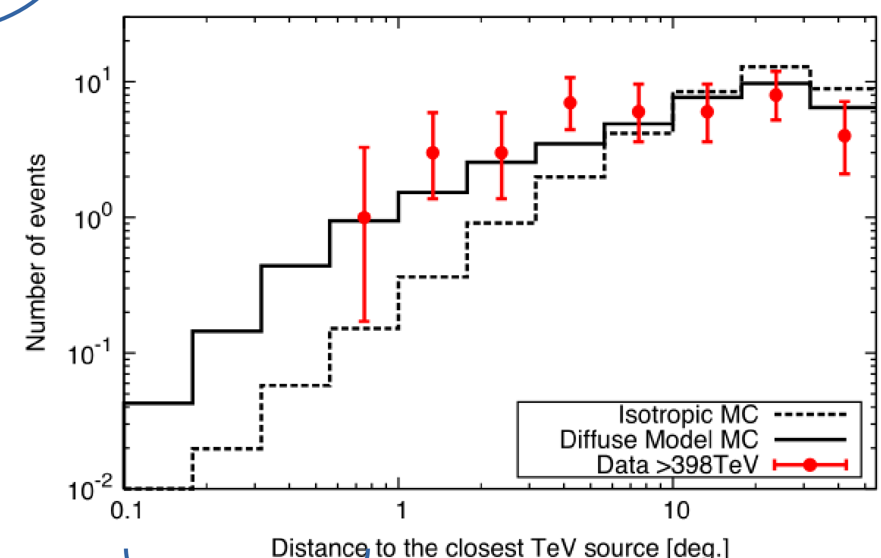




Arrival direction



Known TeV sources



Diffuse gamma ray event

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Decaying DM: Attenuation

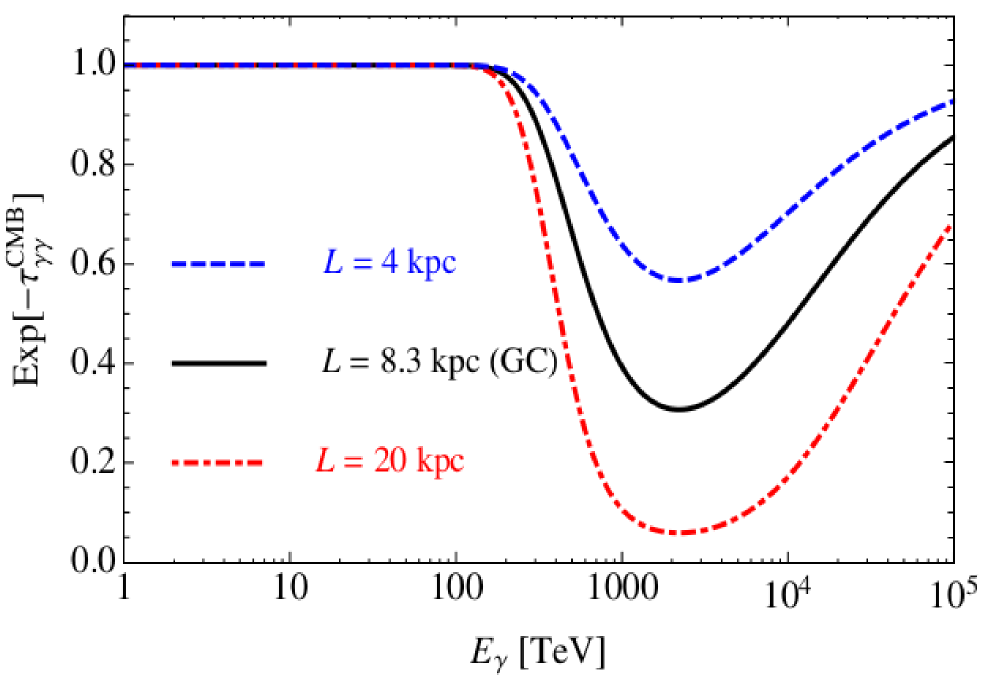
Pair production: $\gamma + \gamma_b \to e^+ e^-$

$\gamma_b \begin{cases} \text{CMB} \\ \text{Starlight} \\ \text{Infrared} \end{cases}$

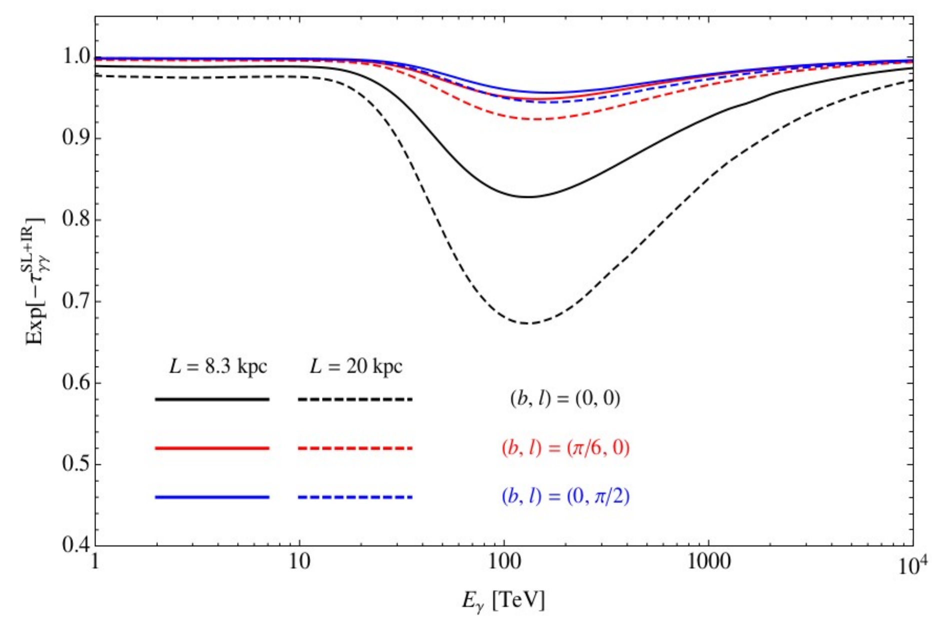
$\text{Attenuation} \sim e^{(-L/\lambda)}$

Mean free path $\lambda = 1/n_b \sigma_{\gamma\gamma}$

CMB



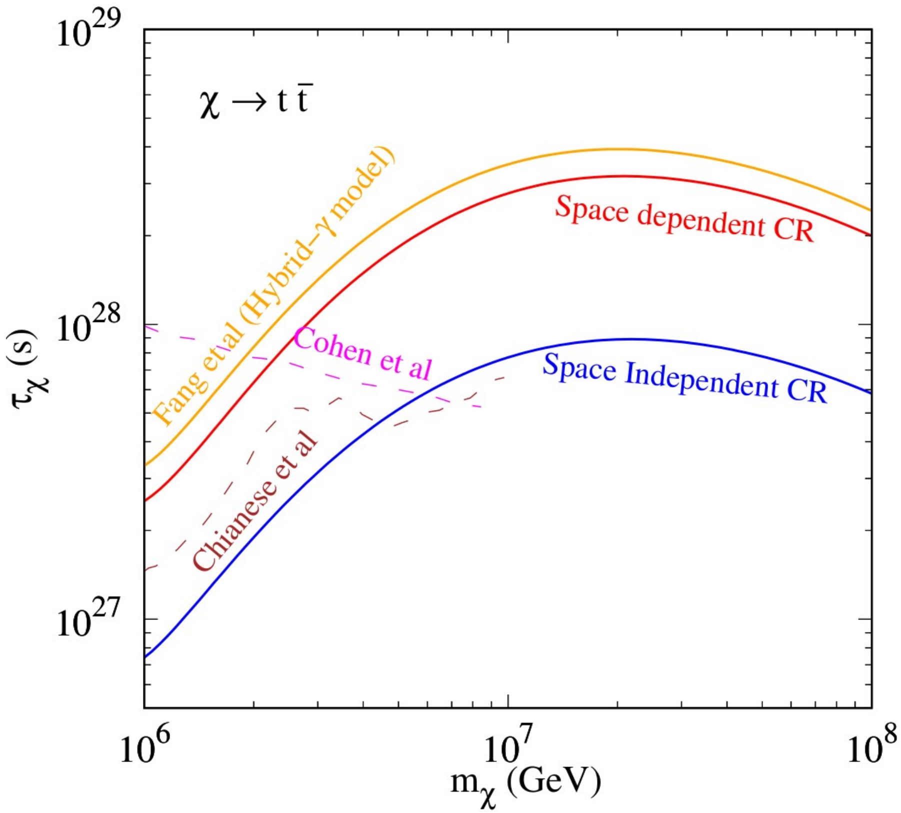
SL+IR

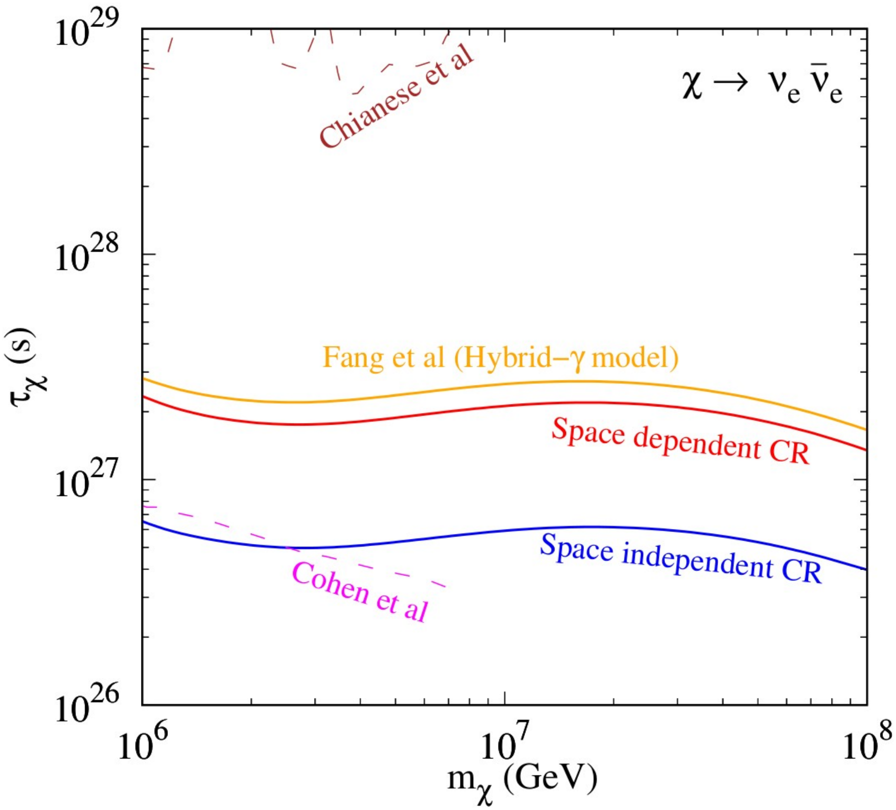


@ A 100 TeV photon must originate from our galaxy.

1505.06486

Decaying DM: Limits





- ✔ For some of the channels (e.g., $t\bar{t}$) our bounds are stronger than previous limits.
- ✔ For some of the channels (e.g., $\nu\bar{\nu}$) our bounds are not as strong as previous limits.

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