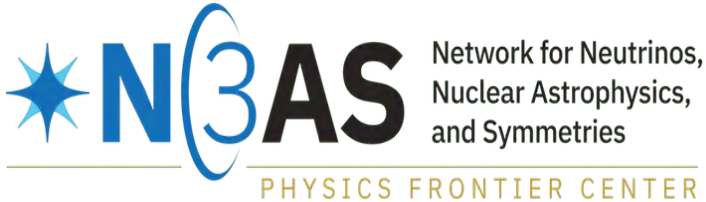
Search for dark matter using diffuse gamma rays discovered by Tibet AS_γ

Tarak Nath Maity

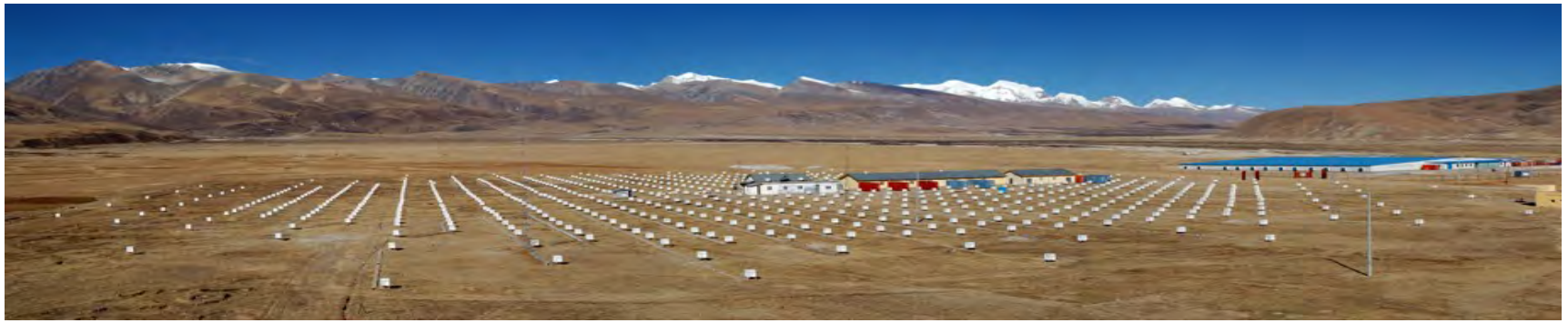
Centre for High Energy Physics (CHEP)
Indian Institute of Science, Bangalore

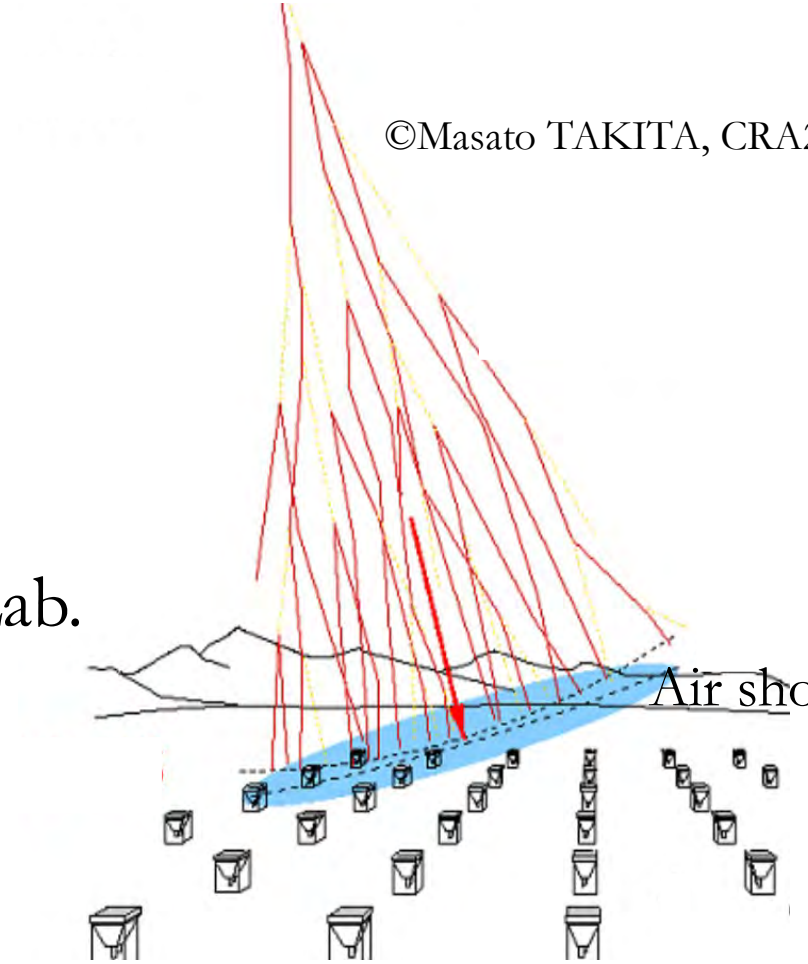
Based on

TNM, A K Saha, A Dubey, R Laha 2105.05680 PRD(Letter)



Tibet ASγ





- ✔ 4300 m above sea level
- ✔ Effective area: ~10% Berkeley Nat. Lab.
- ✔ No. of scintillator detectors: 597
- ✔ Each having area 0.5 m^2

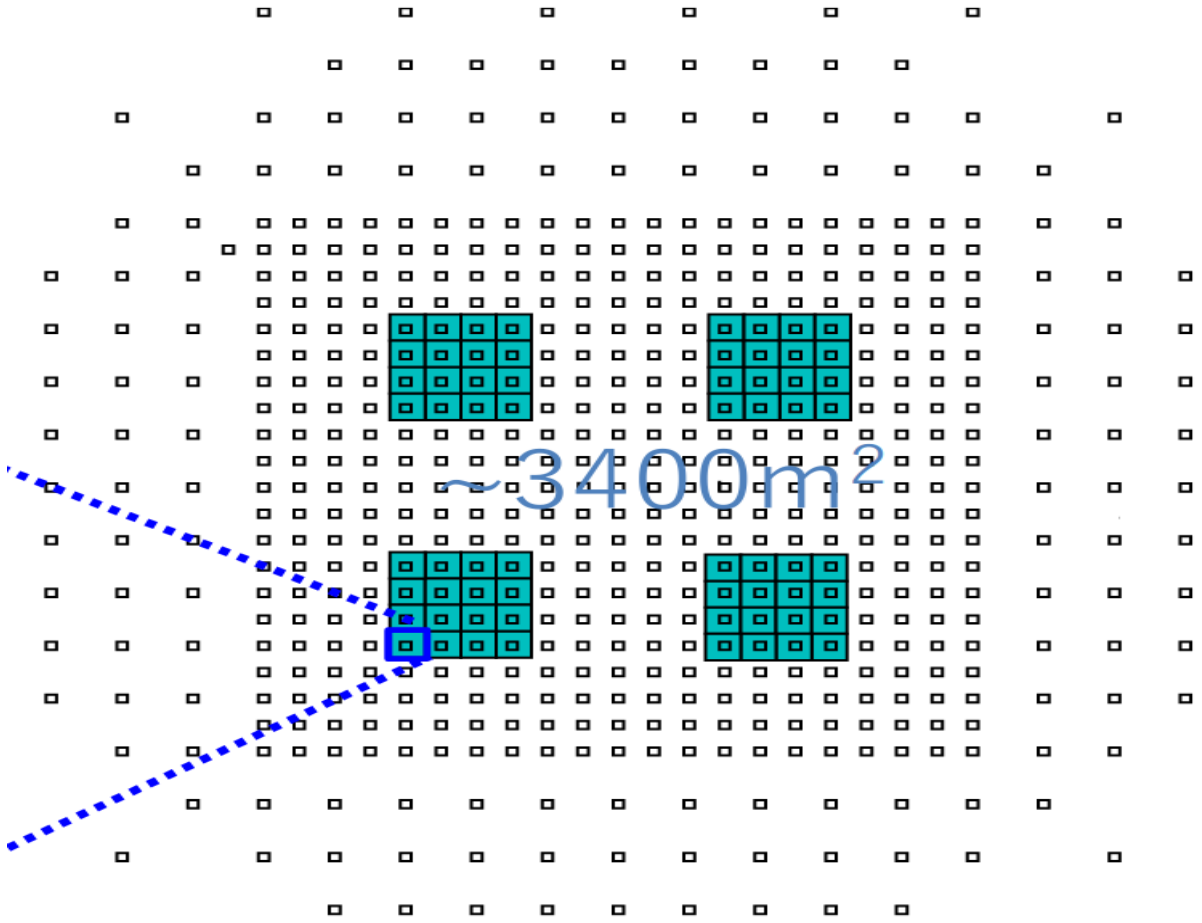
Amenomori et al 2104.05181 PRL

Tibet AS+MD

✔2.4m underground

✔ Hybridize with muon detector.

✔ Muon with energy greater than 1 GeV

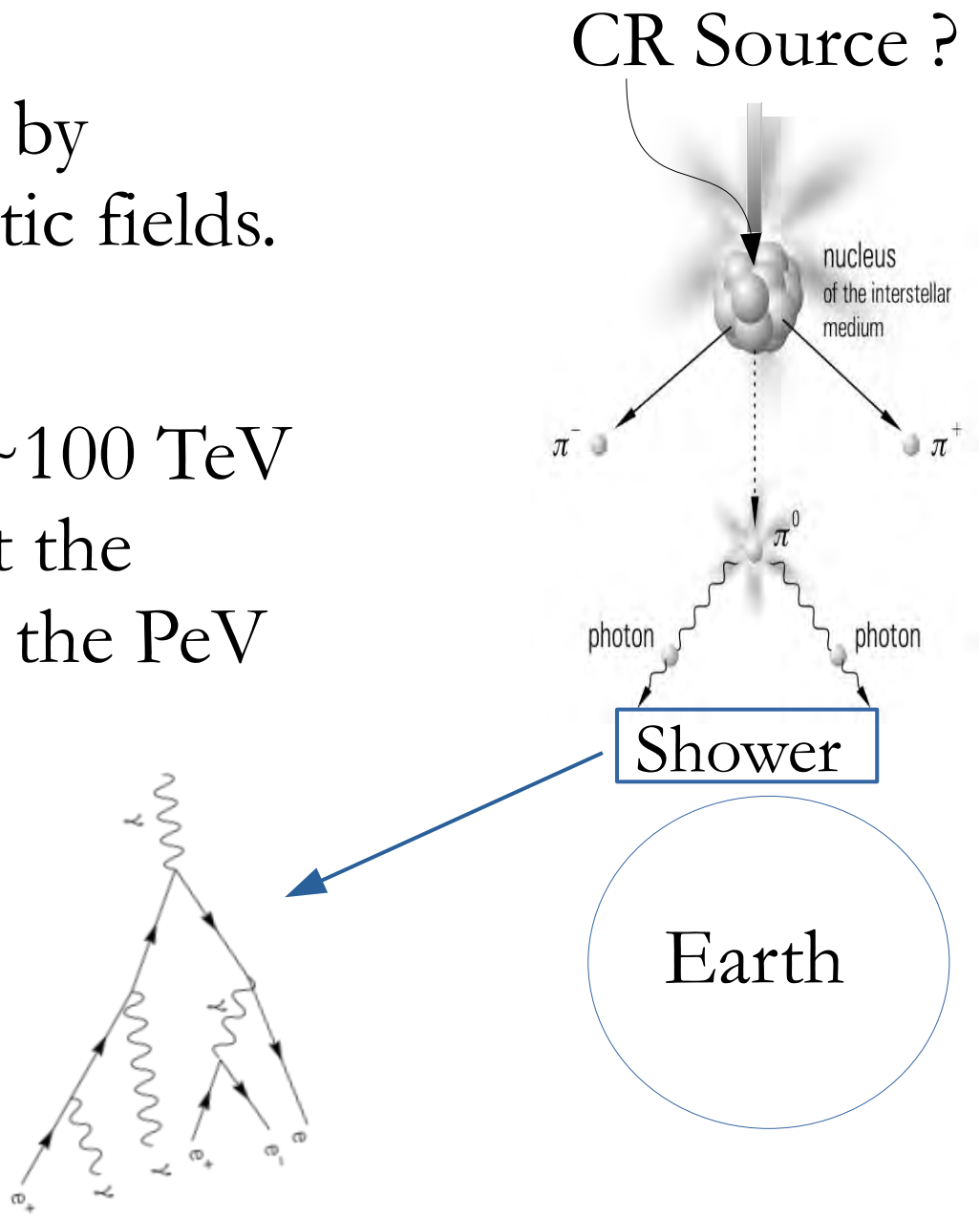


Livetime: 719 days from February 2014 to May 2017

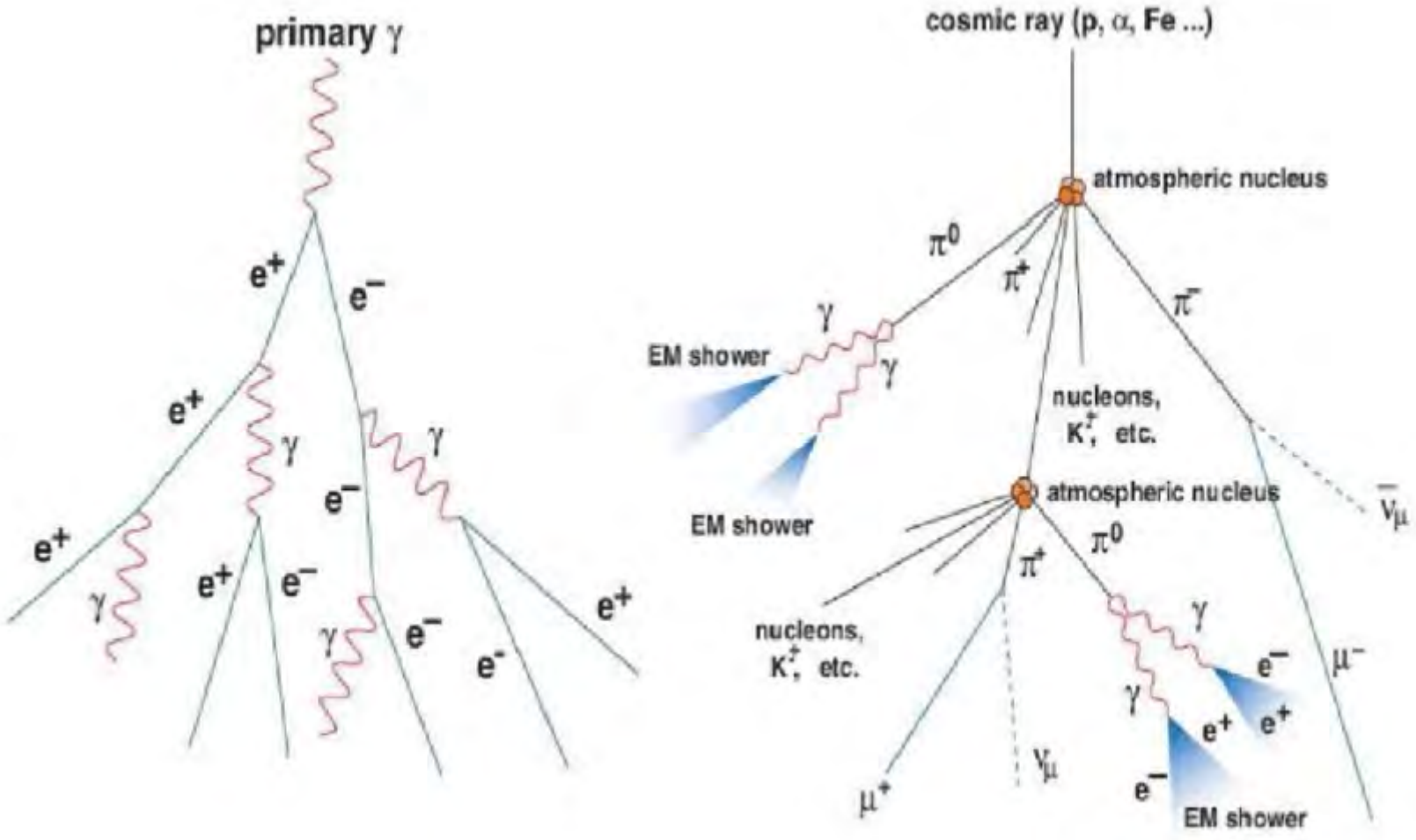
Muon detector: gamma and cosmic ray (CR) discrimination

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.

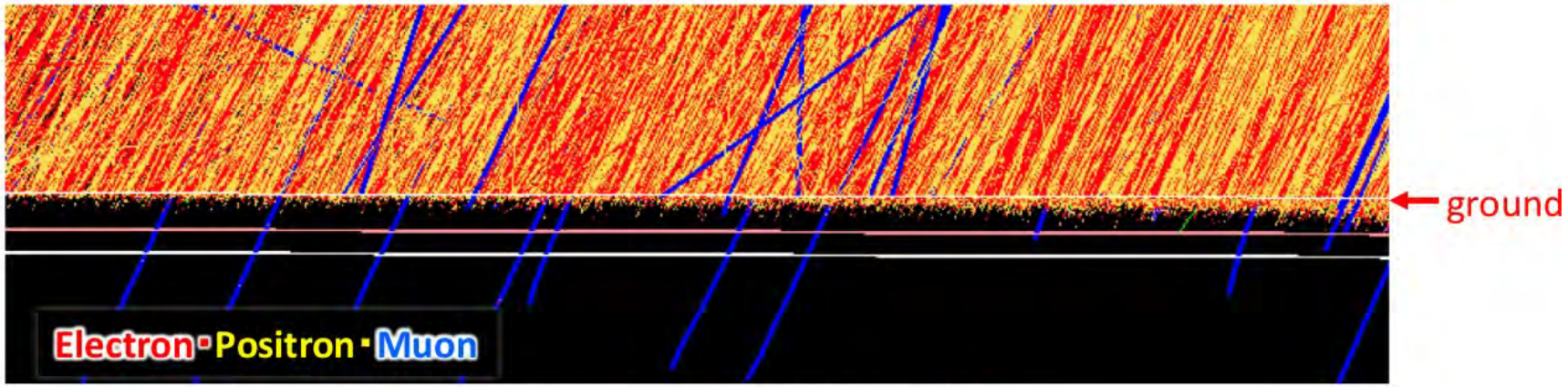


How? Photon and Proton Shower

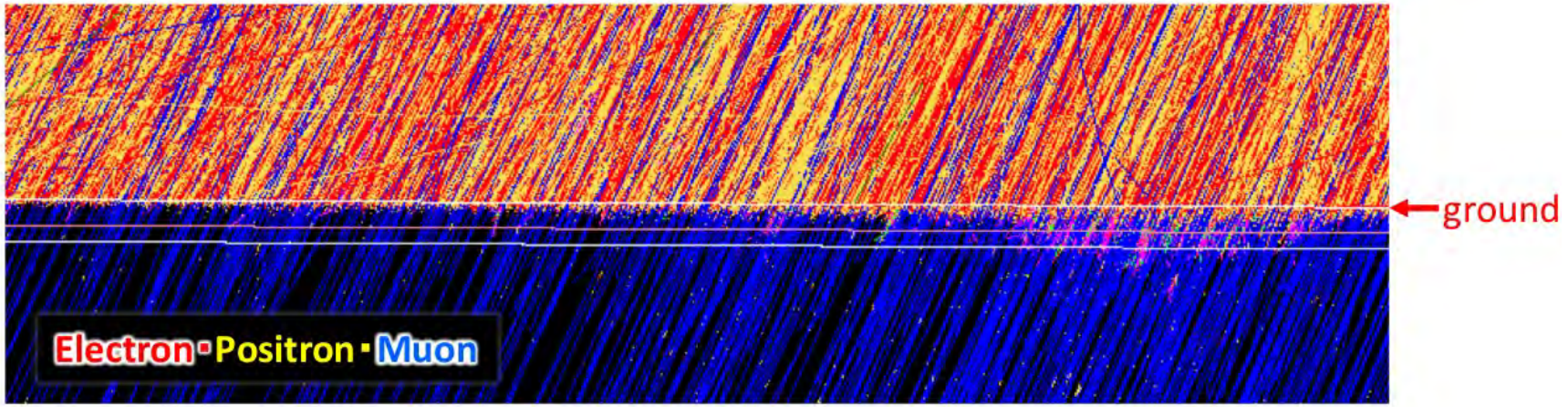


Occasional γ-p interaction gives rises shower similar to hadronic shower

Photon and Proton Shower

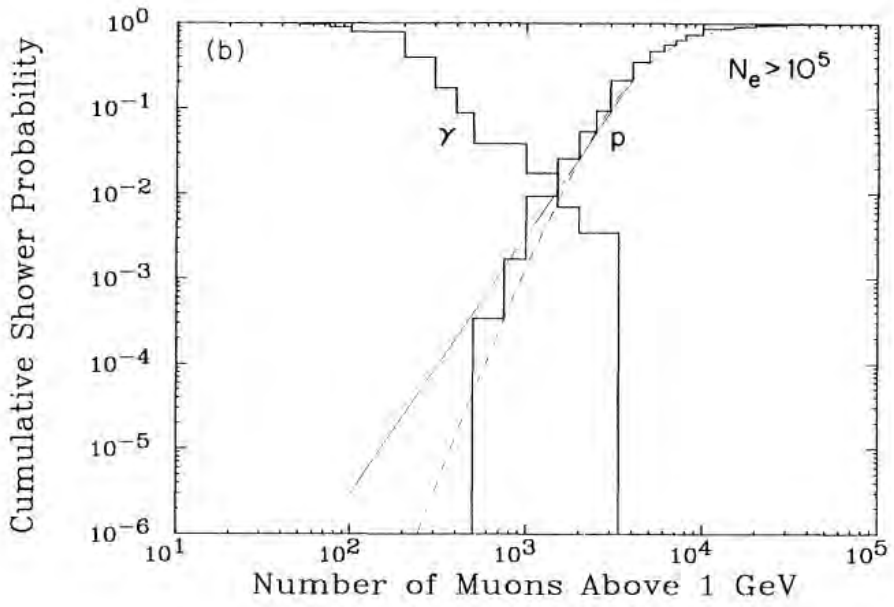


200TeV Gamma-ray induced AS



200TeV Proton induced AS

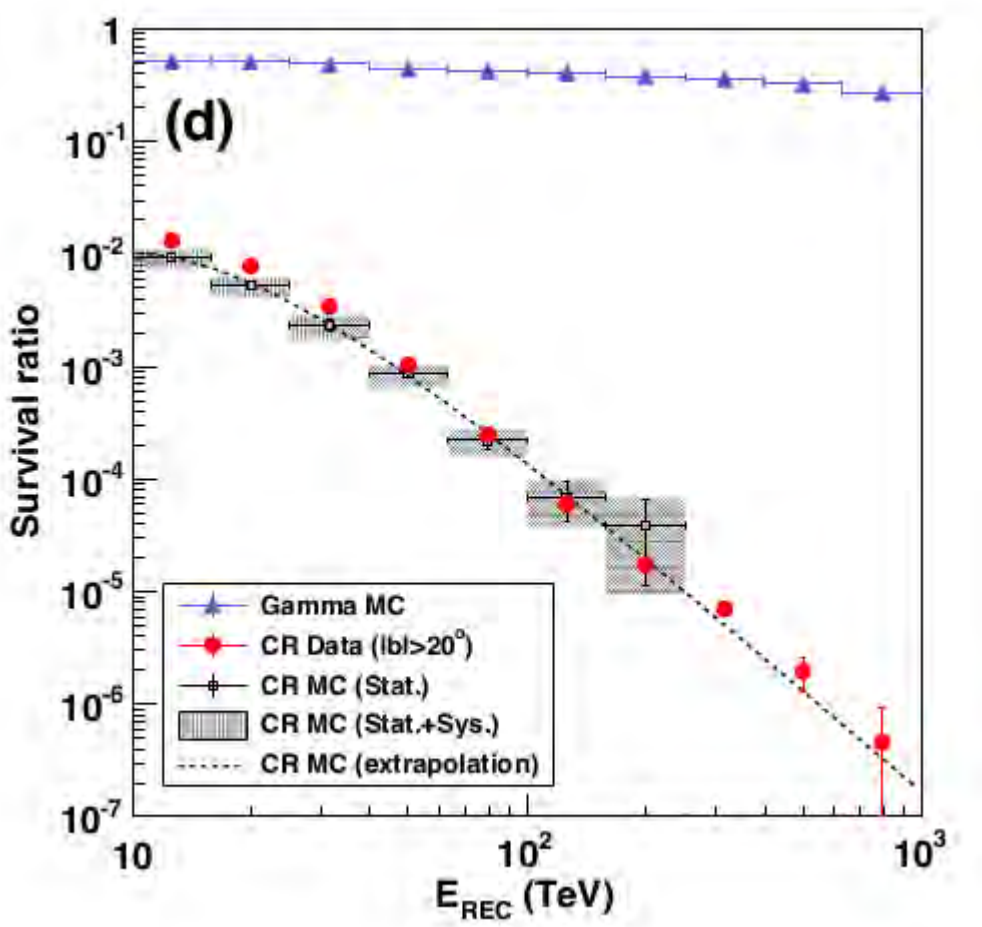
Photon Proton Shower: Tibet ASγ



	$N_\mu < 75$	$N_\mu < 100$	$N_\mu < 200$	$N_\mu < 300$
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}

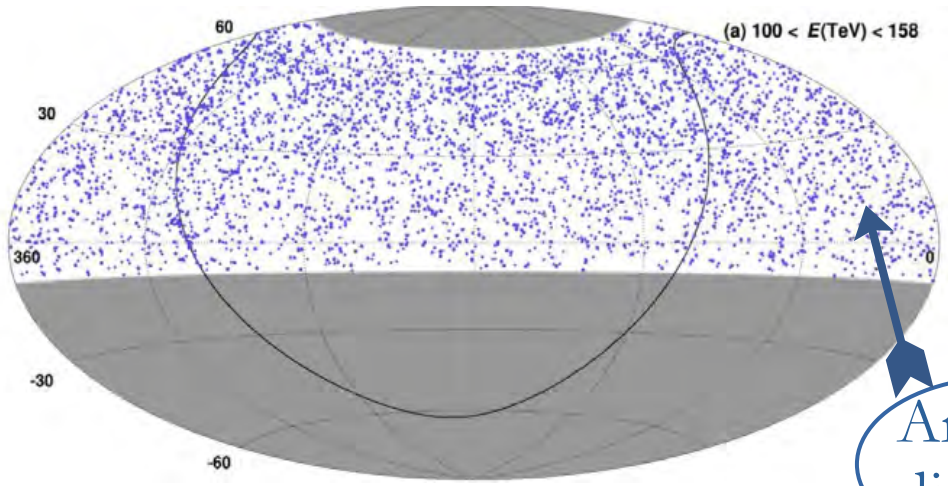
Gaisser et al PRD '91

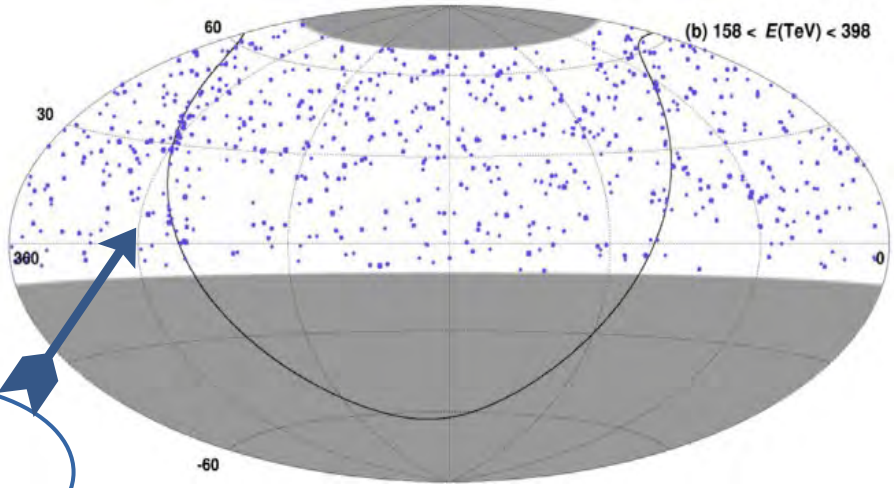
After muon cut



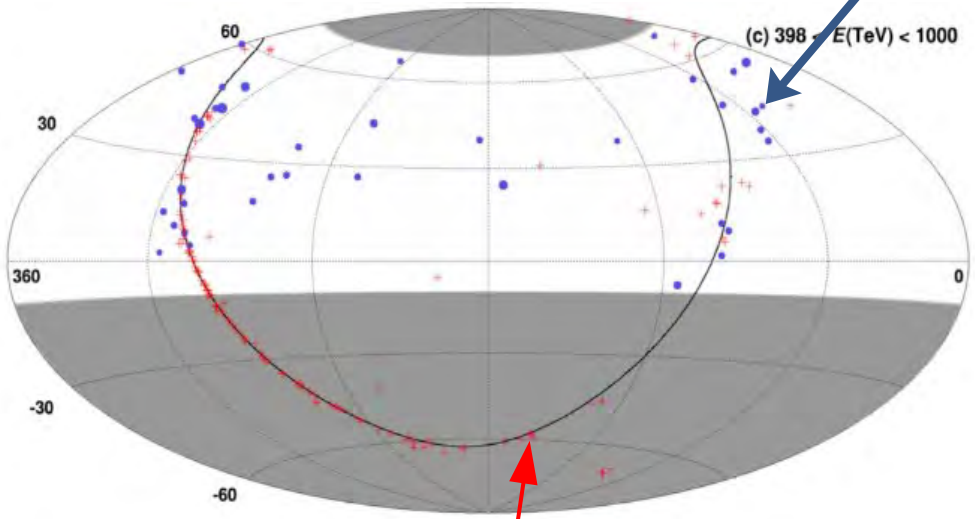
Amenomori et al 2104.05181 PRL

Result: Tibet ASγ

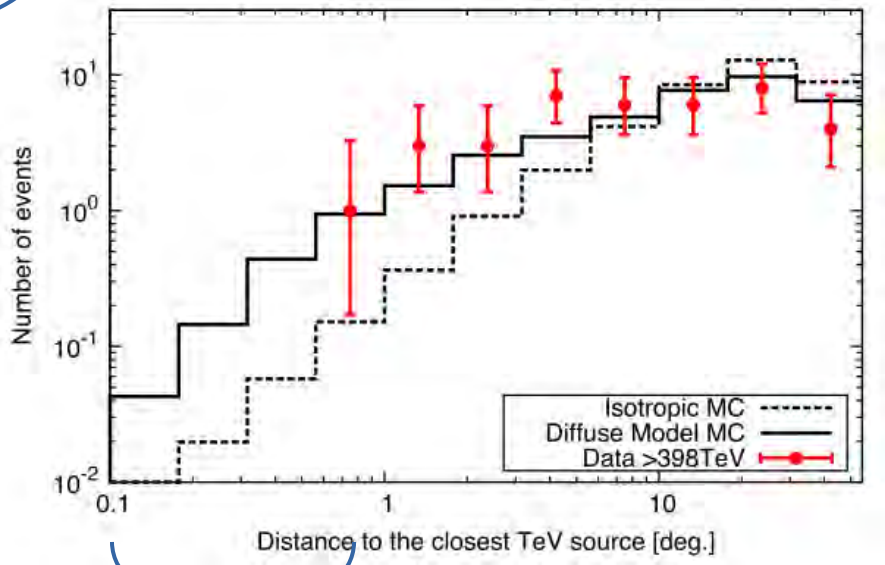




Arrival direction

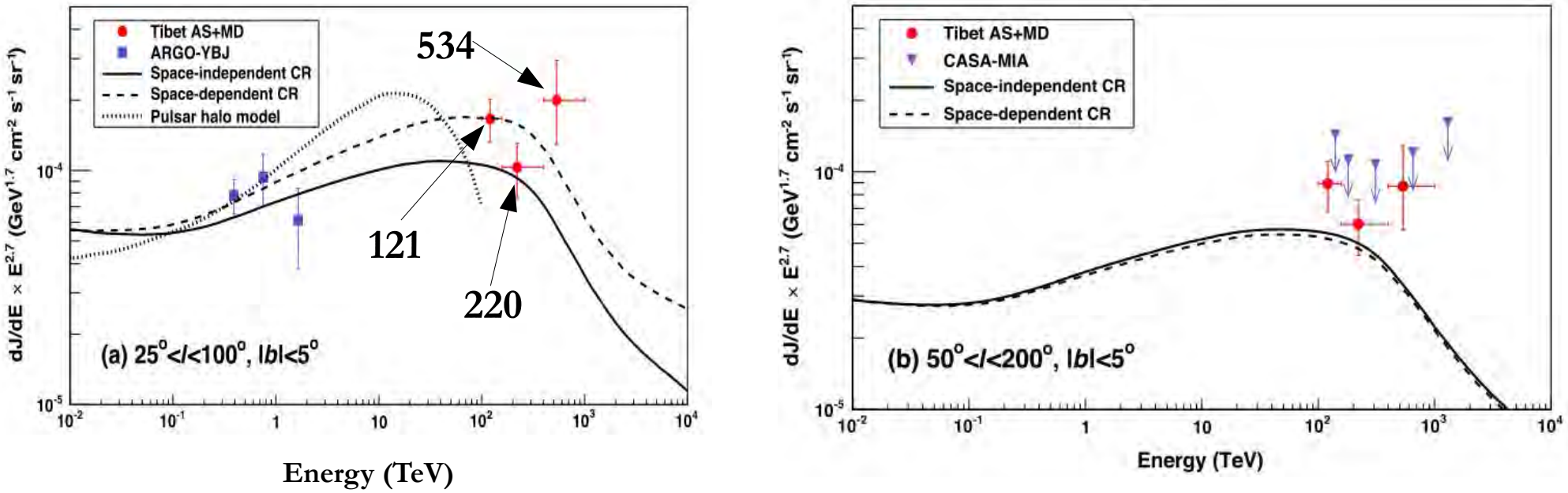


Known TeV sources



Diffuse gamma ray event

Observed Flux

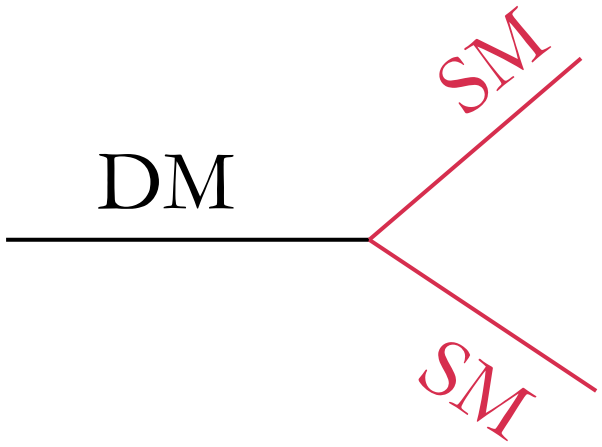


✔ **First detection of sub-PeV diffuse gamma rays.**

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

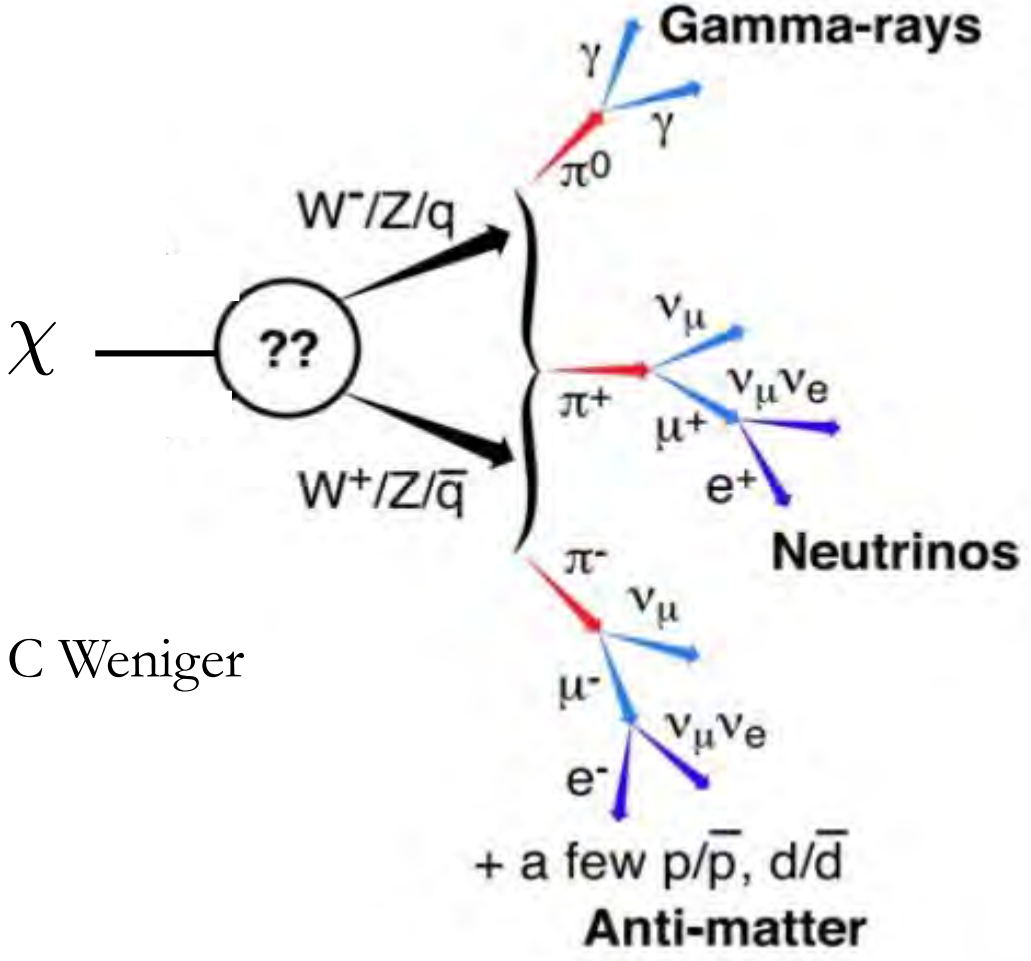
✔ Several recent proposals e.g., see 2104.09491, 2104.03729, 2104.05609

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



Decaying DM: gamma-ray spectrum

$$\frac{dN}{dE}$$



© C Weniger

PPPC

Cirelli et al 1012.4515

HDMSpectra

Bauer et al 2007.15001

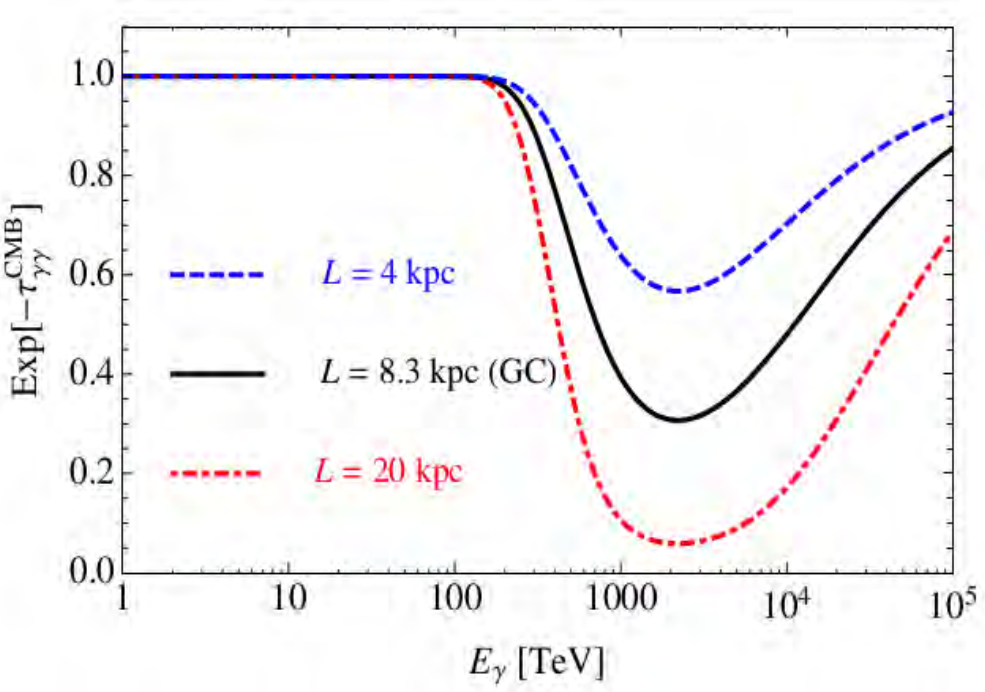
Decaying DM: Attenuation

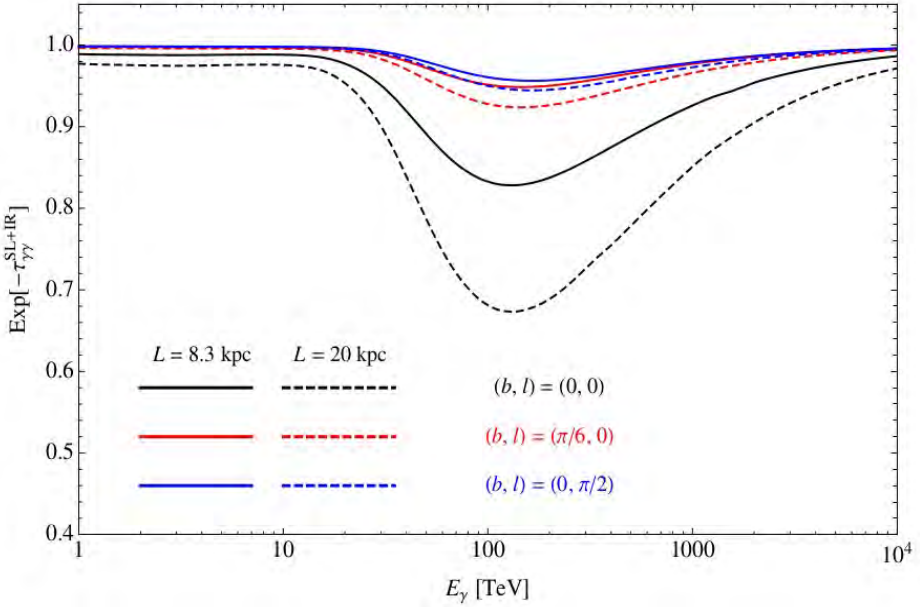
Pair production: $\gamma + \gamma_b \to e^+ e^-$

γ_b { CMB, Starlight, Infrared }

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.

Esmaili, Serpico 1505.06486

Decaying DM + Background < Data

DM Flux

$$\frac{d^2\phi_\gamma}{dE_\gamma d\Omega}(E_\gamma) = \frac{1}{\Delta\Omega}\int_{\Delta\Omega} d\Omega \frac{1}{4\pi m_\chi \tau_\chi}\frac{dN_\gamma}{dE_\gamma}(E_\gamma)$$

$$\int_0^{s_{\rm max}} \rho_\chi(s,b,l)\, e^{-\tau_{\gamma\gamma}(E_\gamma,s,b,\ell)} ds$$

$\rho_\chi(s,b,l)$ → 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

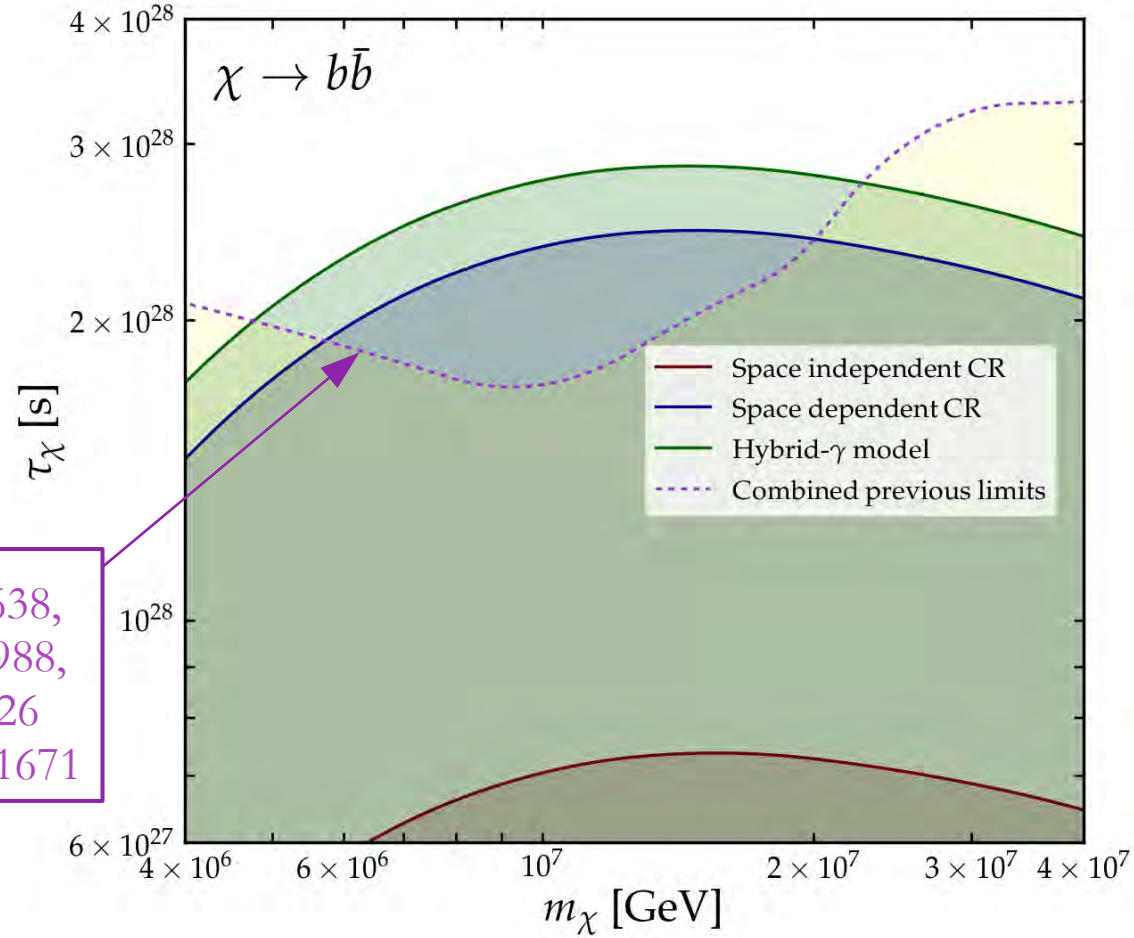
TABLE S2. Galactic diffuse gamma-ray fluxes measured by the Tibet AS+MD array.

Energy bin (TeV)	Representative E (TeV)	Flux ($25^\circ < l < 100^\circ, \lvert b\rvert < 5^\circ$) (TeV^{-1} cm^{-2} s^{-1} sr^{-1})	Flux ($50^\circ < l < 200^\circ, \lvert b\rvert < 5^\circ$) (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	$(6.86\ ^{+3.30}_{-2.40}) \times 10^{-17}$	$(2.99\ ^{+1.40}_{-1.02}) \times 10^{-17}$

Amenomori et al 2104.05181 PRL

Decaying DM: Limits

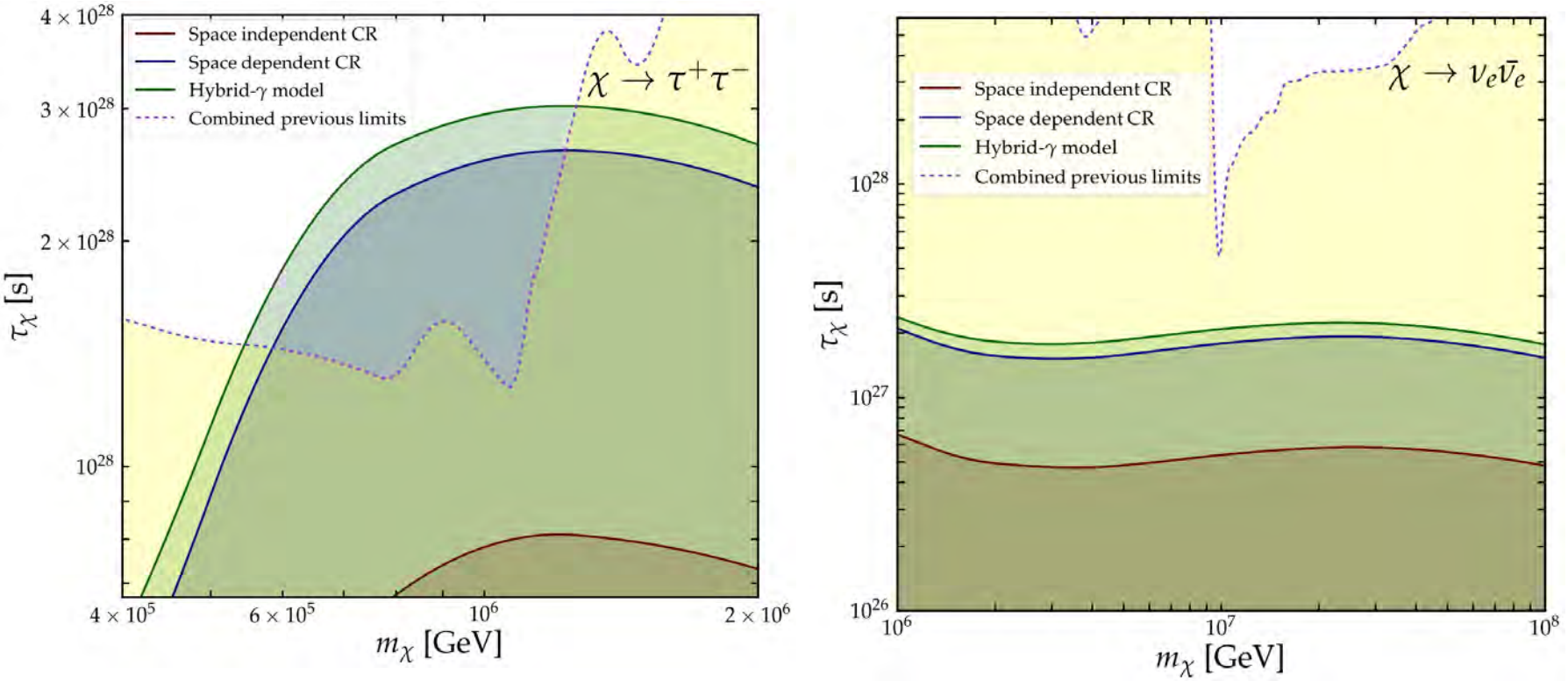
✔ We have done a χ^2 analysis to set the limits.



Cohen et al 1612.05638,
Blanco et al 1811.05988,
Bhatt. et al 1903.12626
Ishiwata et al 1907.11671

TNM, Saha, Dubey, Laha 2105.05680 PRD(Letter)

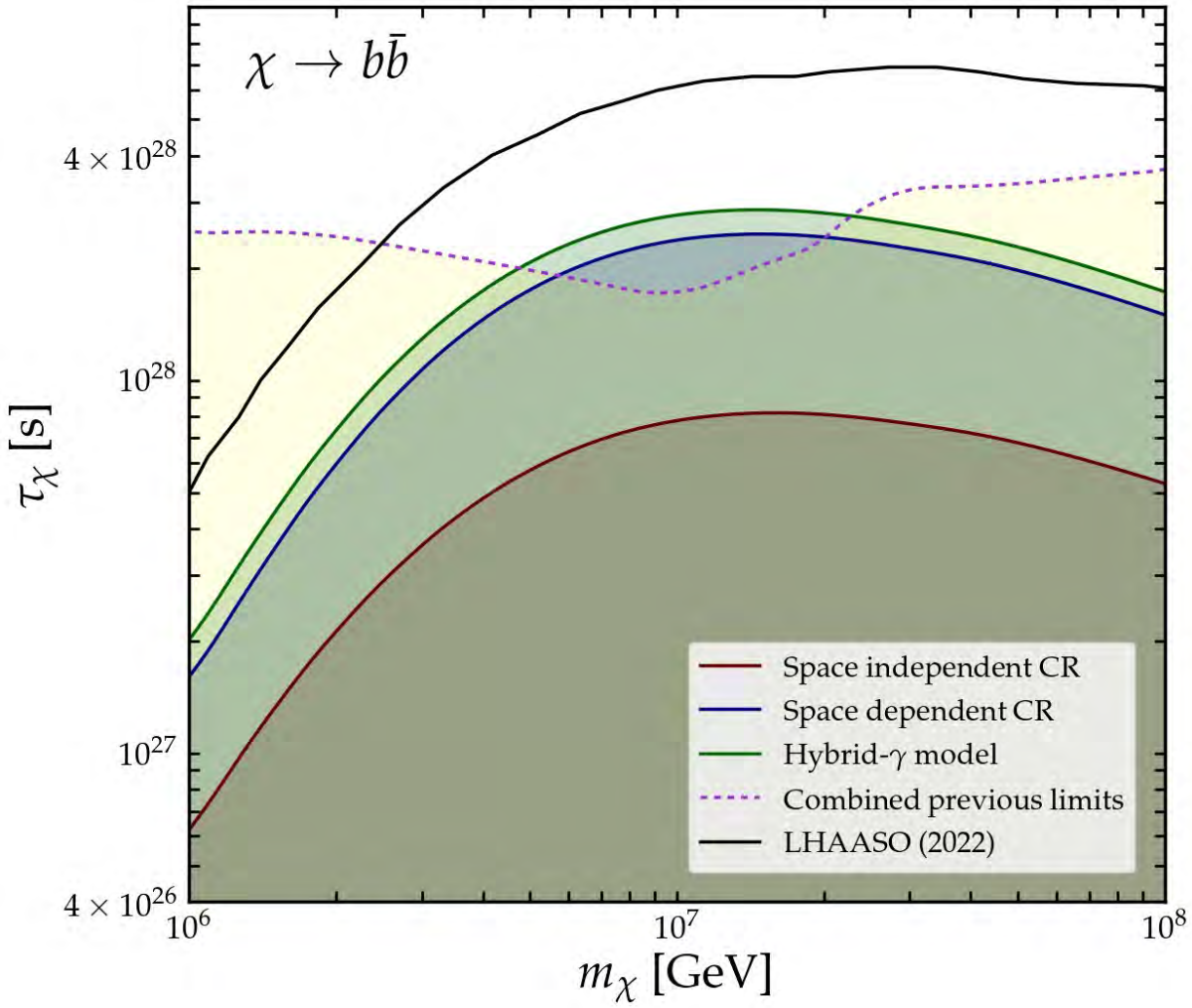
Decaying DM: Limits



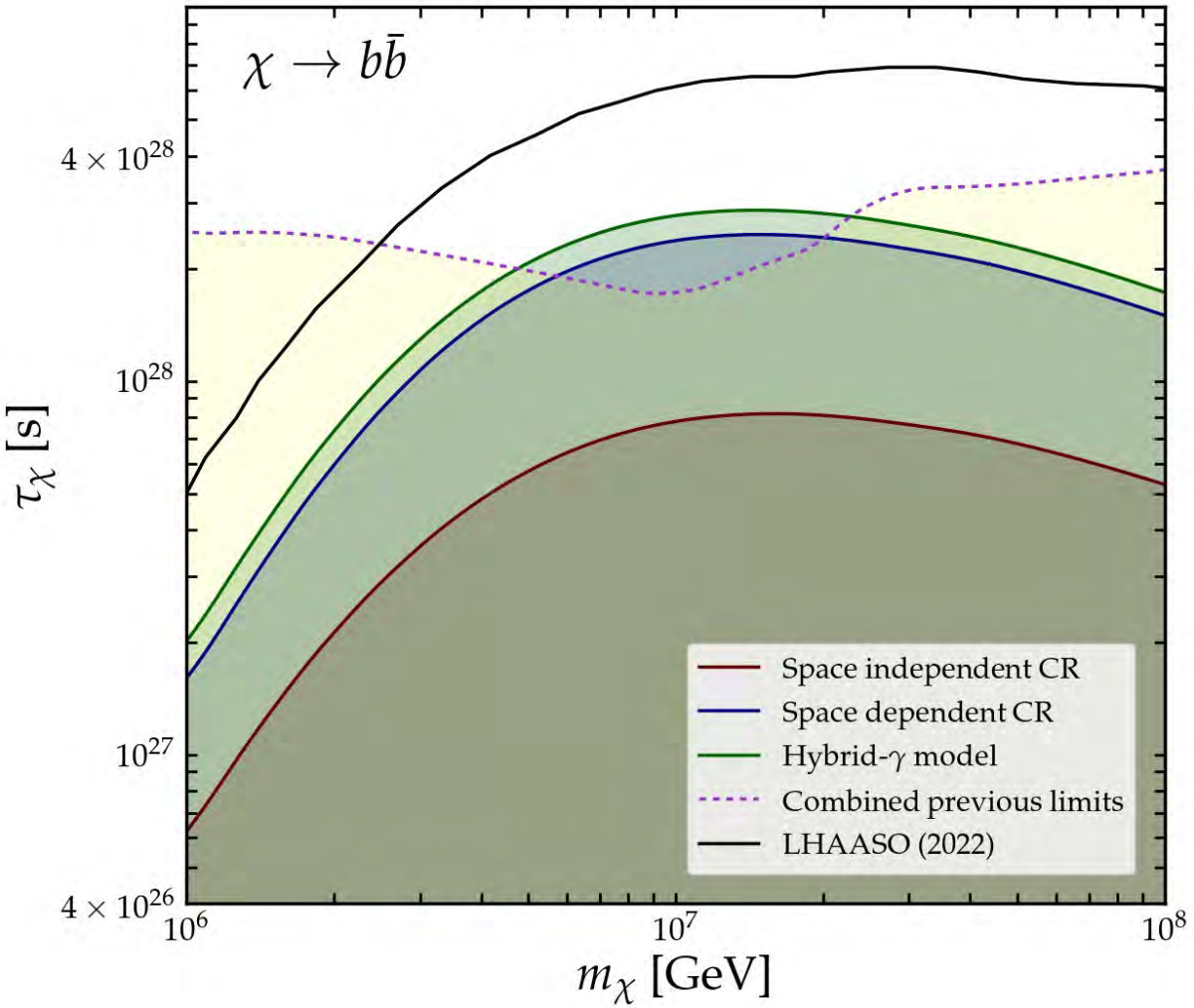
- ✔ For most of the channels (except first two generations of leptons) our bounds are stronger than previous limits.
- ✔ Our limits are robust, does not depend on choice of DM density profile.

TNM, Saha, Dubey, Laha 2105.05680 PRD(Letter)

An update!


$\chi \to b\bar{b}$
4×10^{28}
10^{28}
10^{27}
4×10^{26}
τ_χ [s]
10^6
10^7
10^8
m_χ [GeV]
Space independent CR
Space dependent CR
Hybrid-γ model
Combined previous limits
LHAASO (2022)

An interesting update!



Shows that the field is growing rapidly and it is interesting!

Conclusion

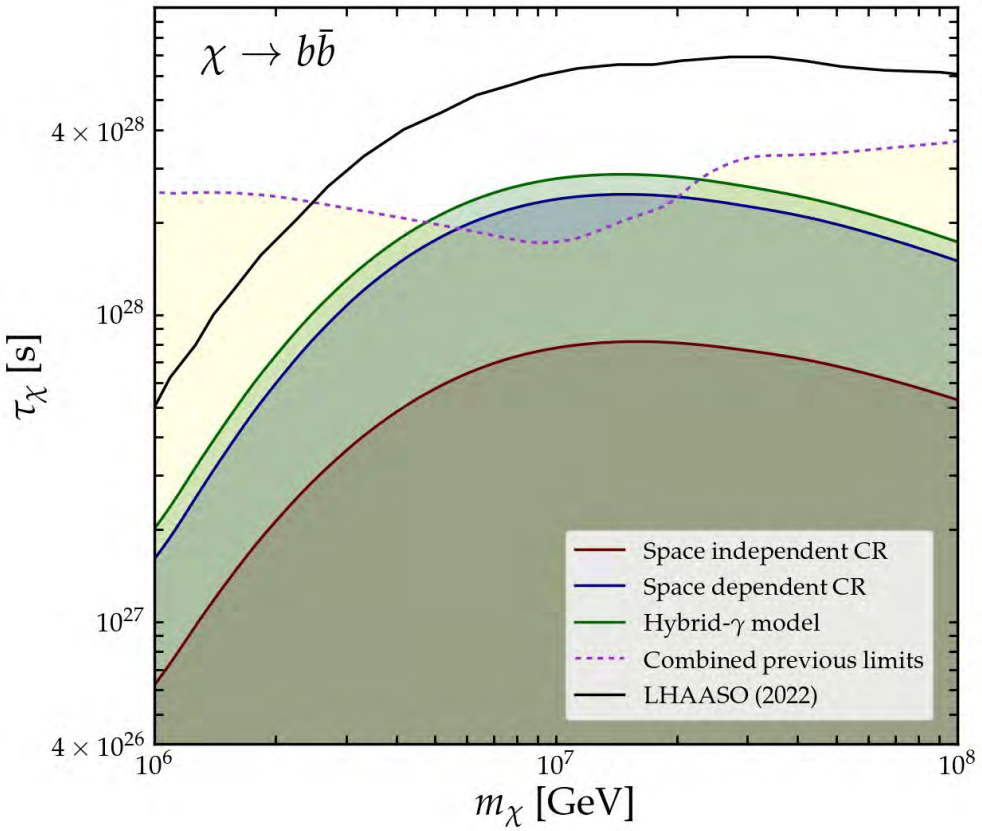
✔ Recently, Tibet AS$_\gamma$ collaboration has discovered the first sub-PeV diffuse gamma-rays from the MW Galactic disk.

✔ Data broadly agrees with prior theoretical expectations

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

✔ For most of the channels (except first two generations of leptons) we obtained stronger bound.

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



TNM, Saha, Dubey, Laha 2105.05680 PRD (Letter)

email: tarak.maity.physics@gmail.com

Thank you