An R-parity Violating Supersymmetric Explanation of the EeV Events at ANITA

Yicong Sui
Washington University in St. Louis

In collaboration with Jack Collins and Bhupal Dev,
arXiv:1810.xxxxx

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Antarctic Impulse Transient Antenna (ANITA) Experiment

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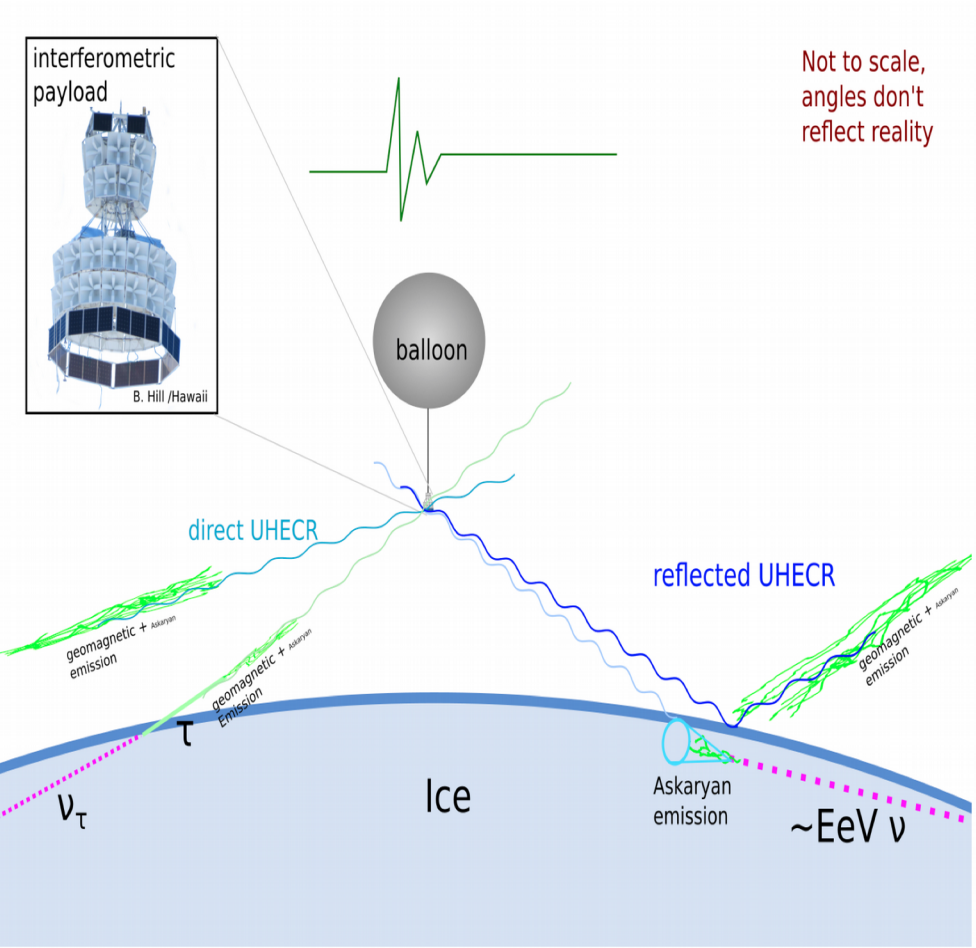

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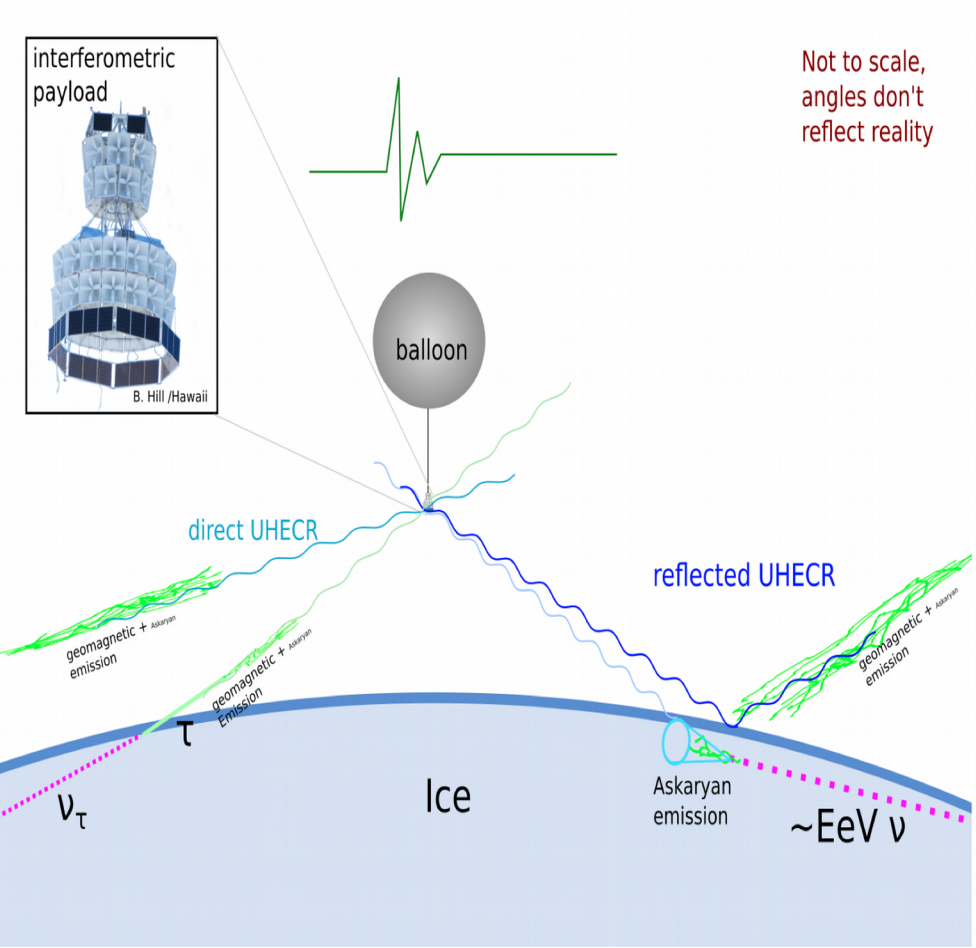

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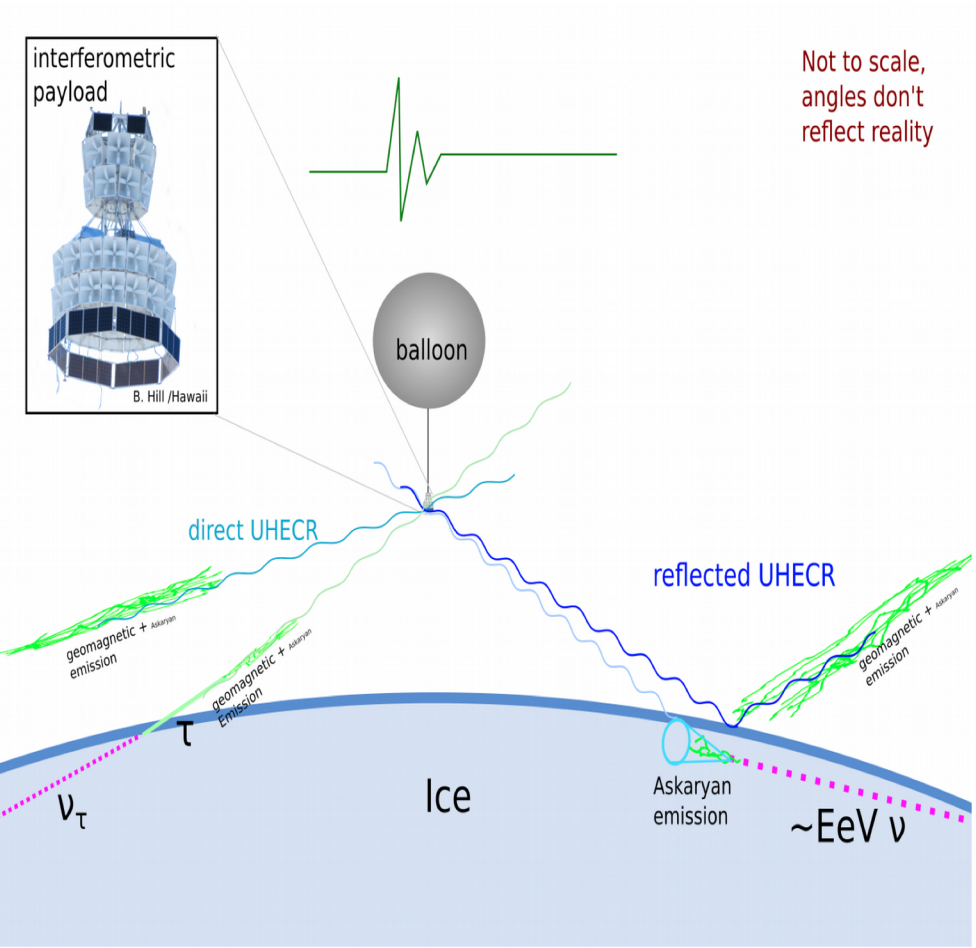

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Lat., Lon.[1]	-82.6559, 17.2842	-81.39856, 129.01626
Altitude	2.56 km	2.75 km
Ice depth	3.53 km	3.22 km
El., Az.	$-27.4 \pm 0.3°, 159.62 \pm 0.7°$	$-35.0 \pm 0.3°, 61.41 \pm 0.7°$
RA, Dec[2]	282.14064, +20.33043	50.78203, +38.65498
E_{shower}[3]	0.6 ± 0.4 EeV	$0.56^{+0.3}_{-0.2}$ EeV

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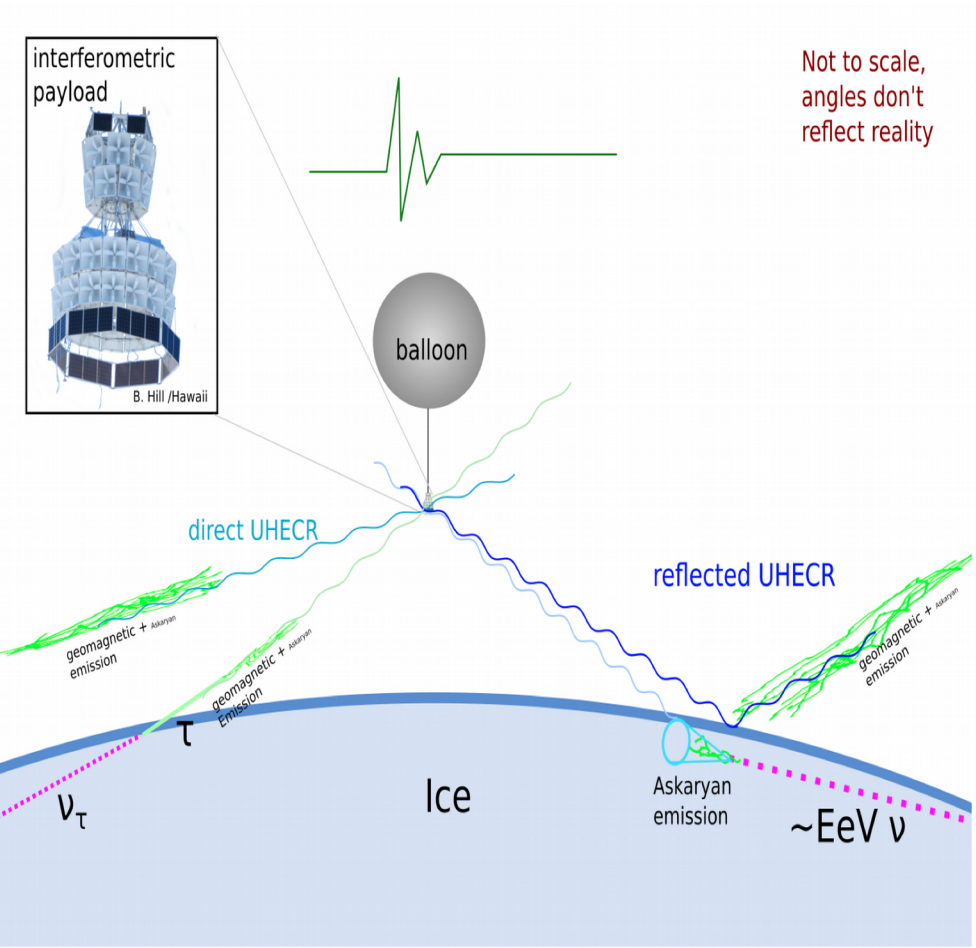

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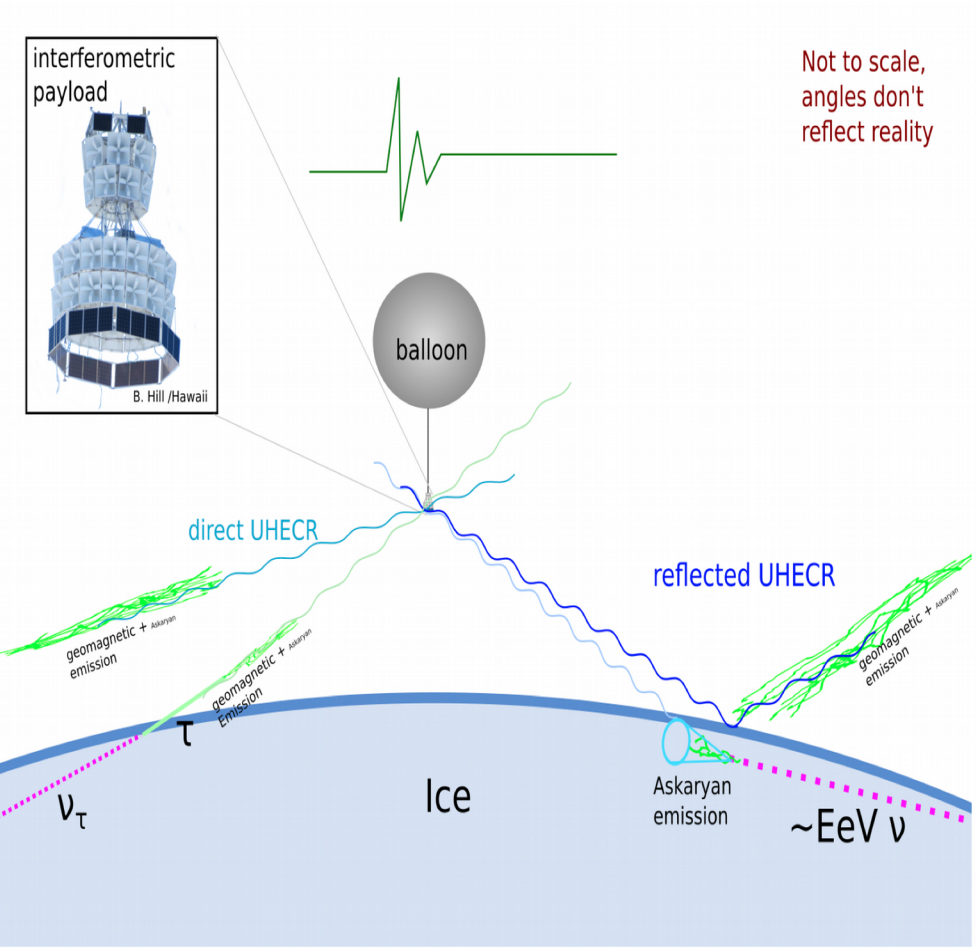

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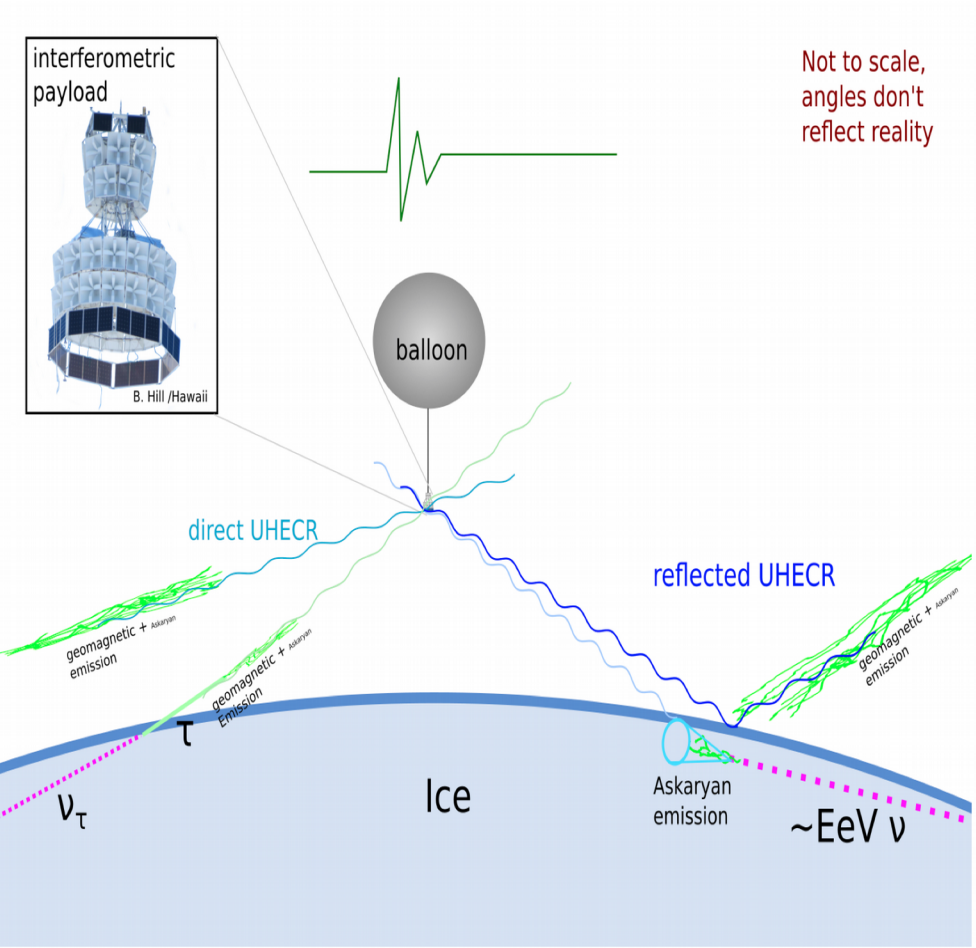

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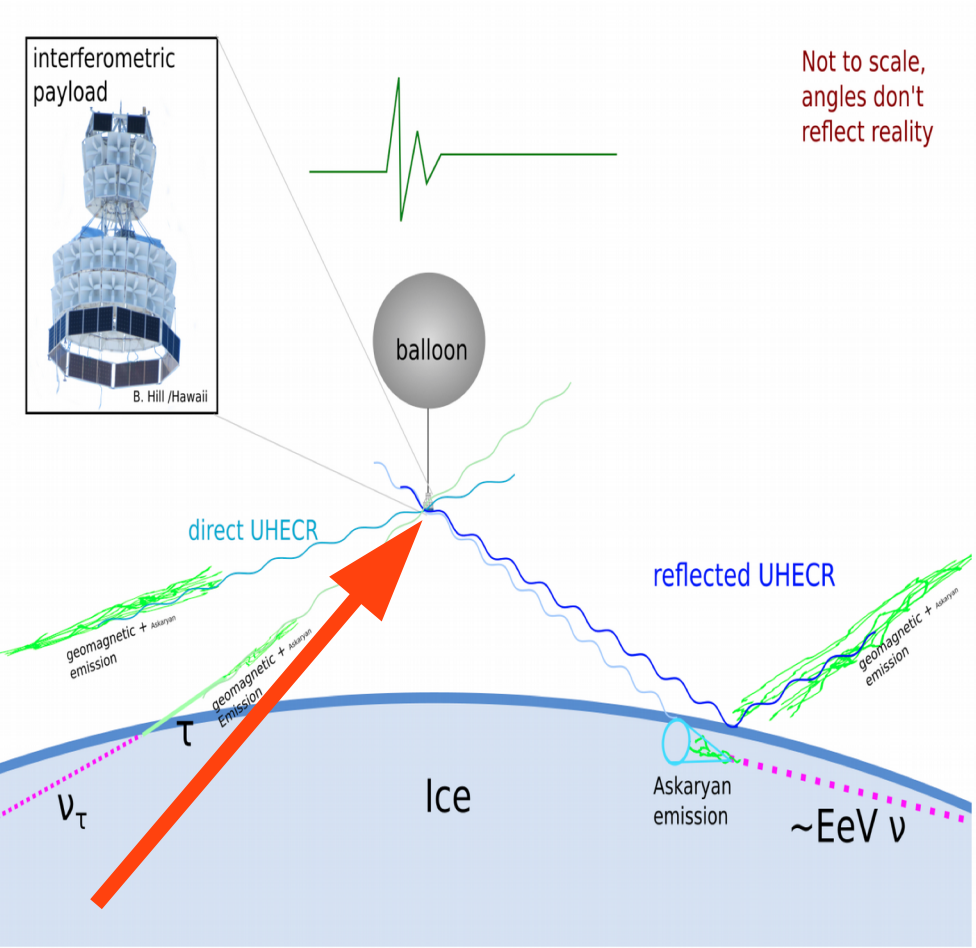

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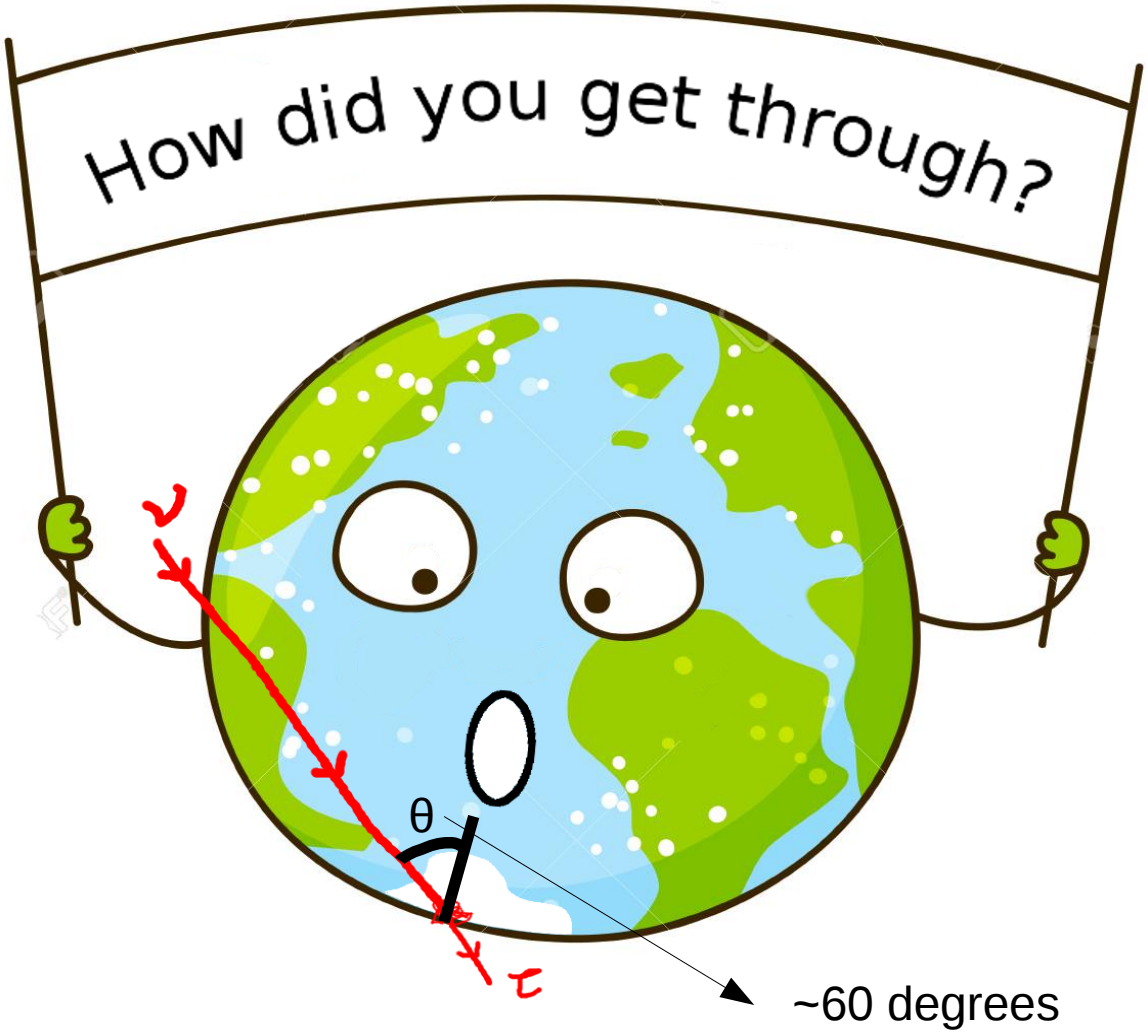

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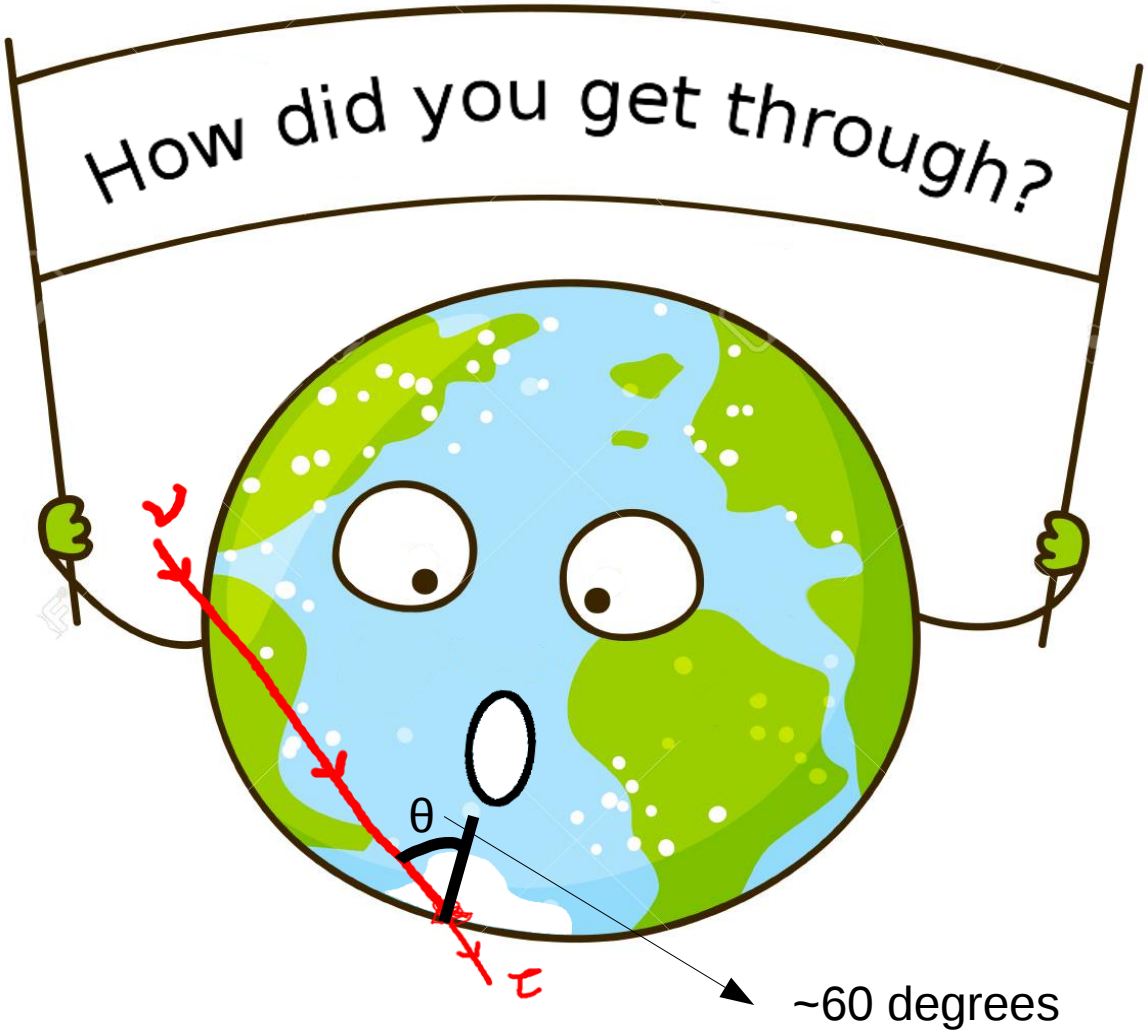

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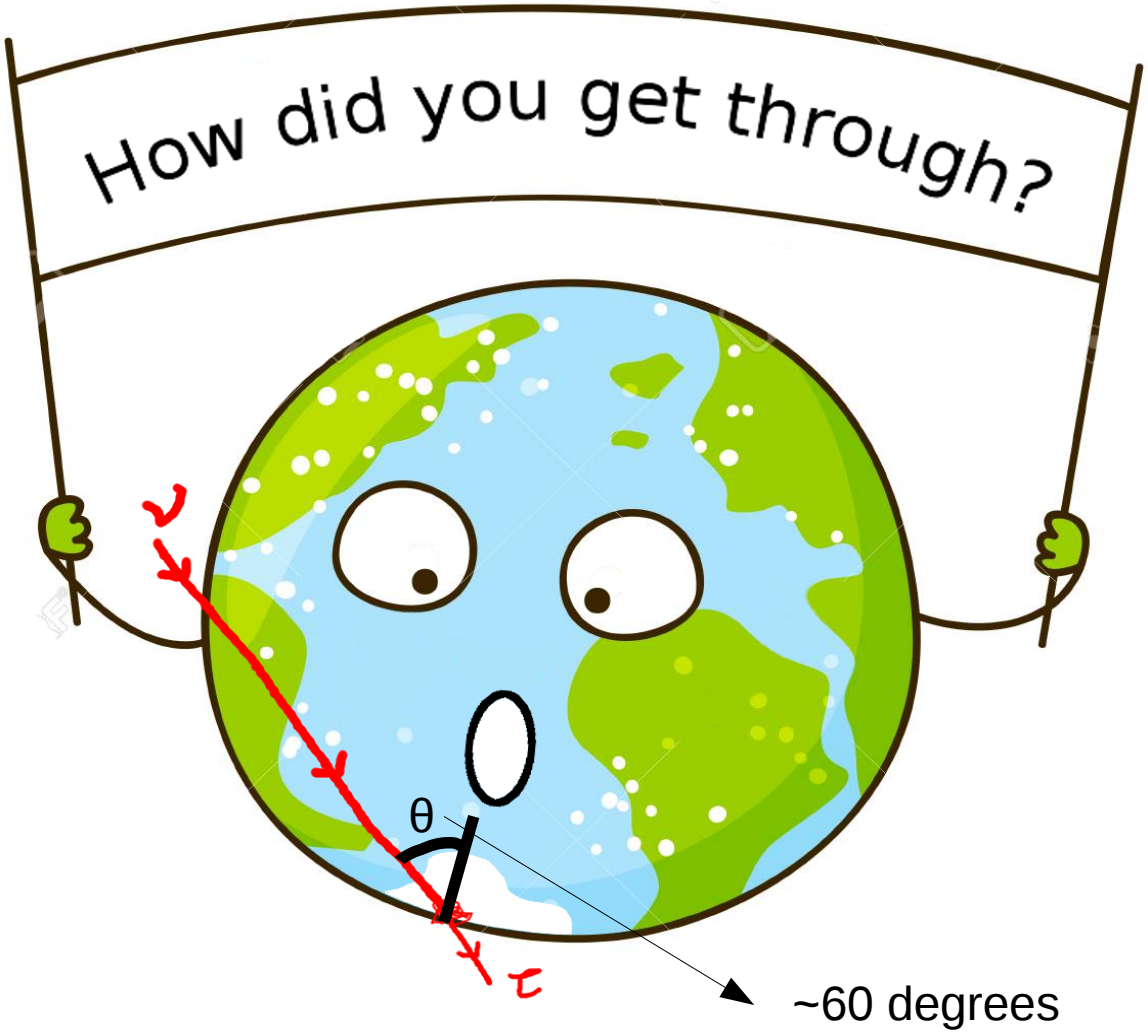

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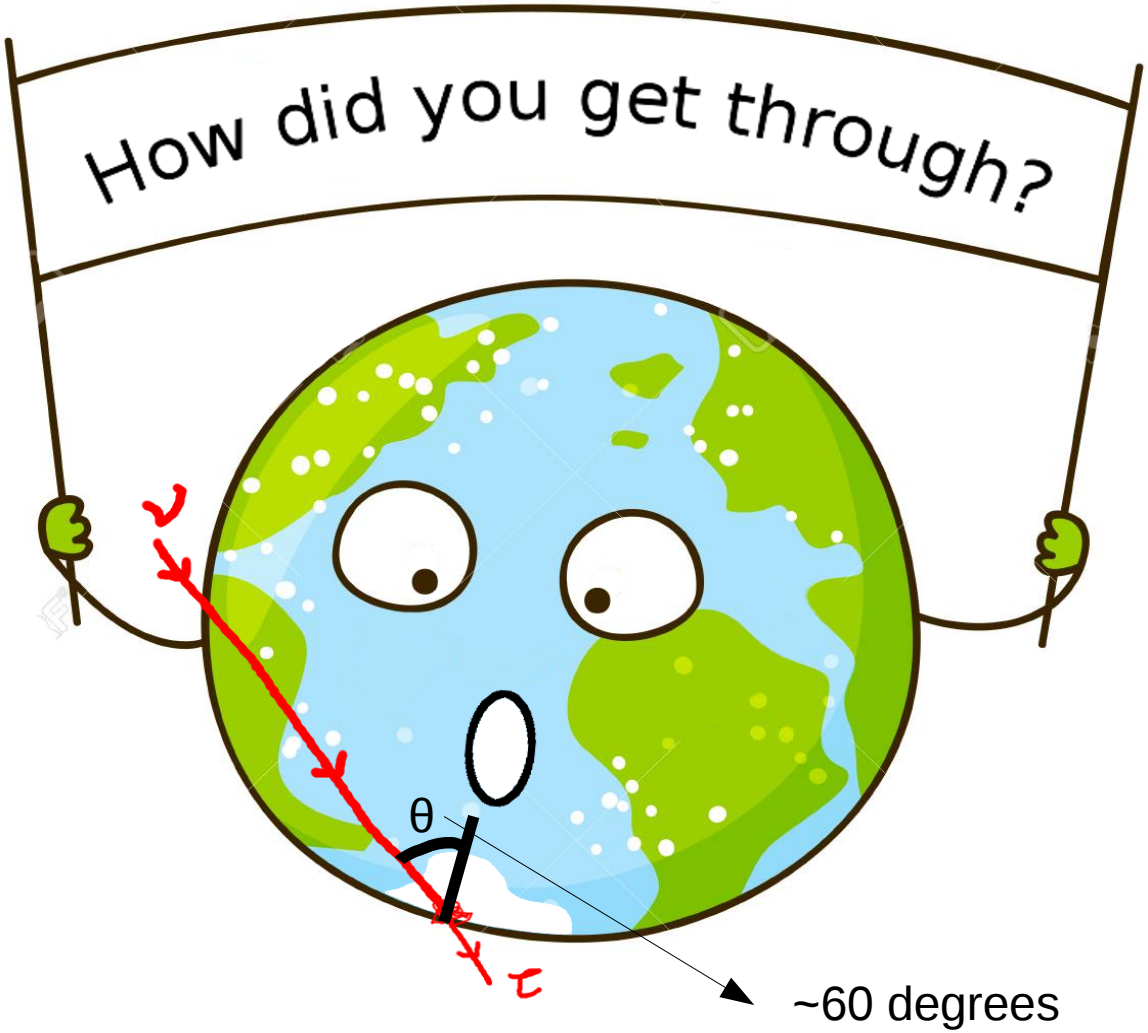

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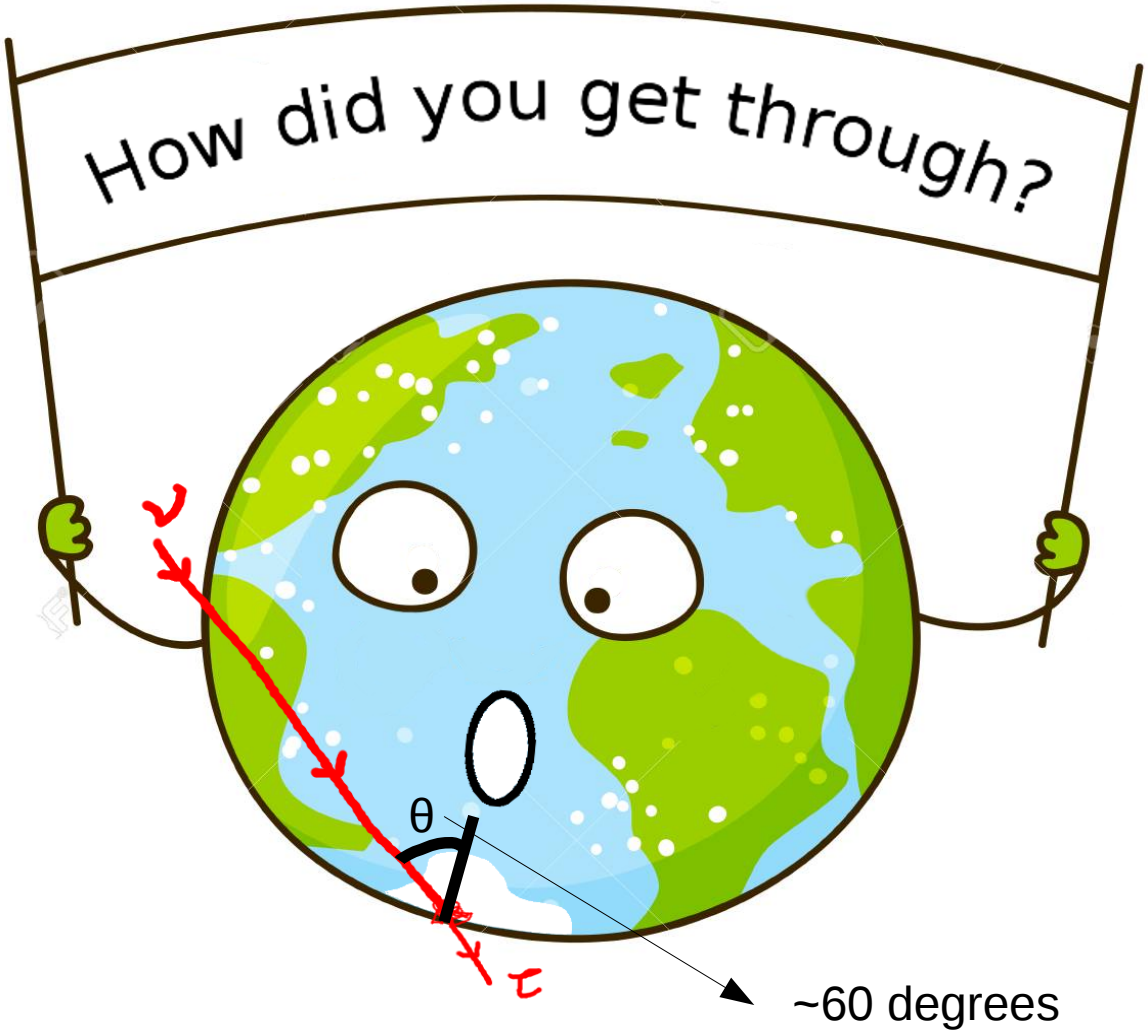

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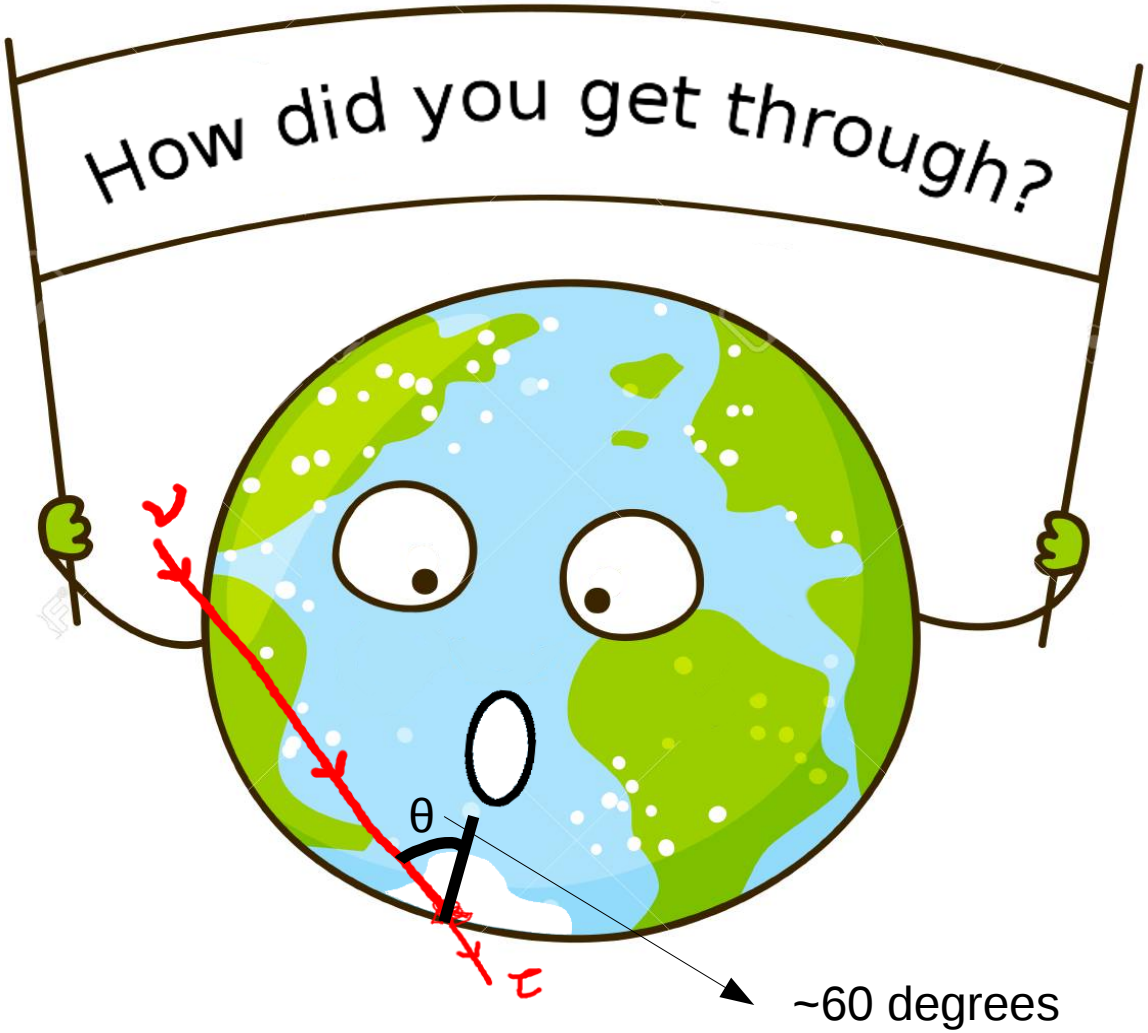

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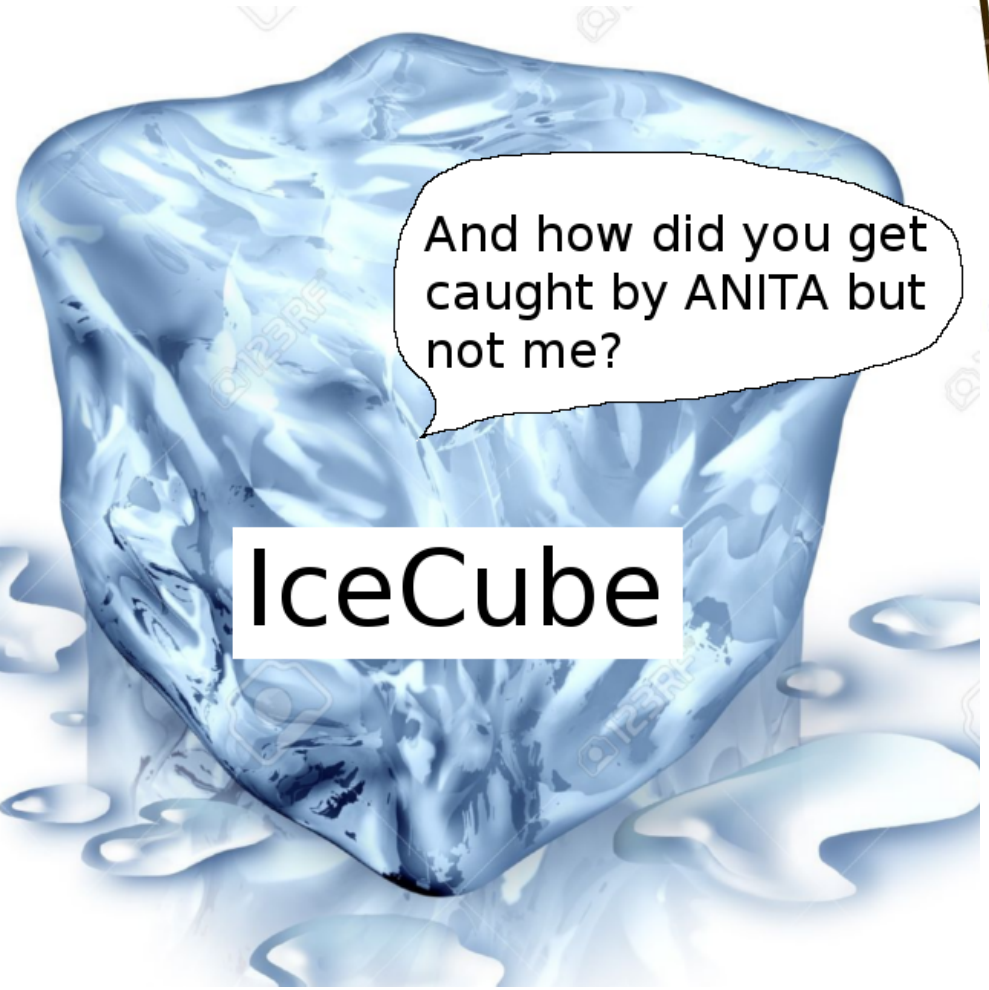

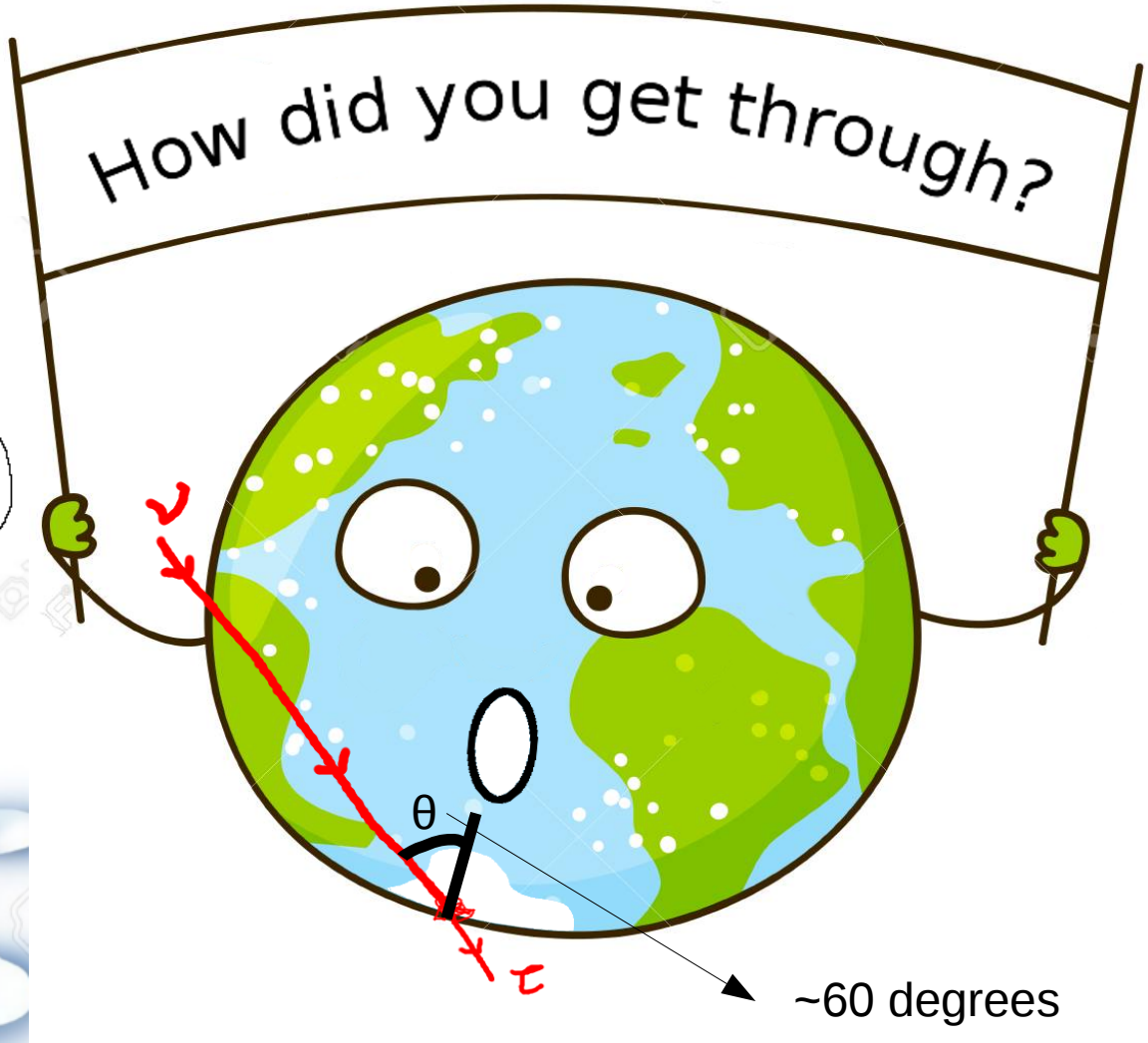

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A Sterile Neutrino Origin for the Upward Directed Cosmic Ray Shower Detected by ANITA

John F. Cherry[1] and Ian M. Shoemaker[1]

[1] *Department of Physics, University of South Dakota, Vermillion, SD 57069, USA*[*]

(Dated: 2/5/18)

The ANITA balloon experiment has observed an $\sim$ EeV cascade event at an angle below the horizon that renders any Standard Model (SM) interpretation unlikely as the Earth is significantly opaque to all SM particles at such energies. In this paper, we study a sterile neutrino interpretation of this event, calculating the angular event distribution of cascades and the relative sensitivities of several experiments to a cascade initiated by an EeV sterile neutrino. We find that ANITA is uniquely sensitive to this type of upward directed cascade signal and canonical ultrahigh energy cosmic ray (UHECR) models can produce a reprocessed EeV sterile neutrino flux at sufficient levels to accommodate the ANITA event.

PACS numbers: 13.15.+g, 14.60.St, 14.60.Pq, 98.70.Sa

Sterile neutrinos as a possible explanation for the upward air shower events at ANITA

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Abstract

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Upgoing ANITA events as evidence of the CPT symmetric universe

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[2] *Department of Physics, Graduate Center, City University of New York, NY 10016, USA*

[3] *Department of Astrophysics, American Museum of Natural History, NY 10024, USA*

[4] *Department of Physics, University of Wisconsin, Madison, WI 53706, USA*

[5] *Department of Physics & Astronomy, University of Hawaii at Manoa, Honolulu, HI 96822, USA*

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- stau Explanation

On ANITA's sensitivity to long-lived, charged massive particles

Amy Connolly[a], Patrick Allison[a], Oindree Banerjee[a]

[a] *Dept. of Physics, Center for Cosmology and AstroParticle Physics, Ohio State Univ., Columbus, OH 43210.*

Abstract

We propose that the Antarctic Impulsive Transient Antenna (ANITA) can serve as a detector for long-lived, charged particles, through its measurement of extensive air showers from secondary leptons. To test this on an example model, we simulate the production of staus inside the earth from interactions between ultra-high energy neutrinos and nuclei. We propose that results of ANITA searches for upgoing air showers can be interpreted in terms of constraints on long-lived, charged massive particles (CHAMPs) and consider a supersymmetric partner of the tau lepton, the stau, as an example of such a particle. Exploring the parameter space in stau mass and lifetimes, we find that the stau properties that lead to an observable signal in ANITA are highly energy dependent. At $10^{18.5}$ eV, we find that the best constraints on the

The ANITA Anomalous Events as Signatures of a Beyond Standard Model Particle, and Supporting Observations from IceCube

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(Dated: September 26, 2018)

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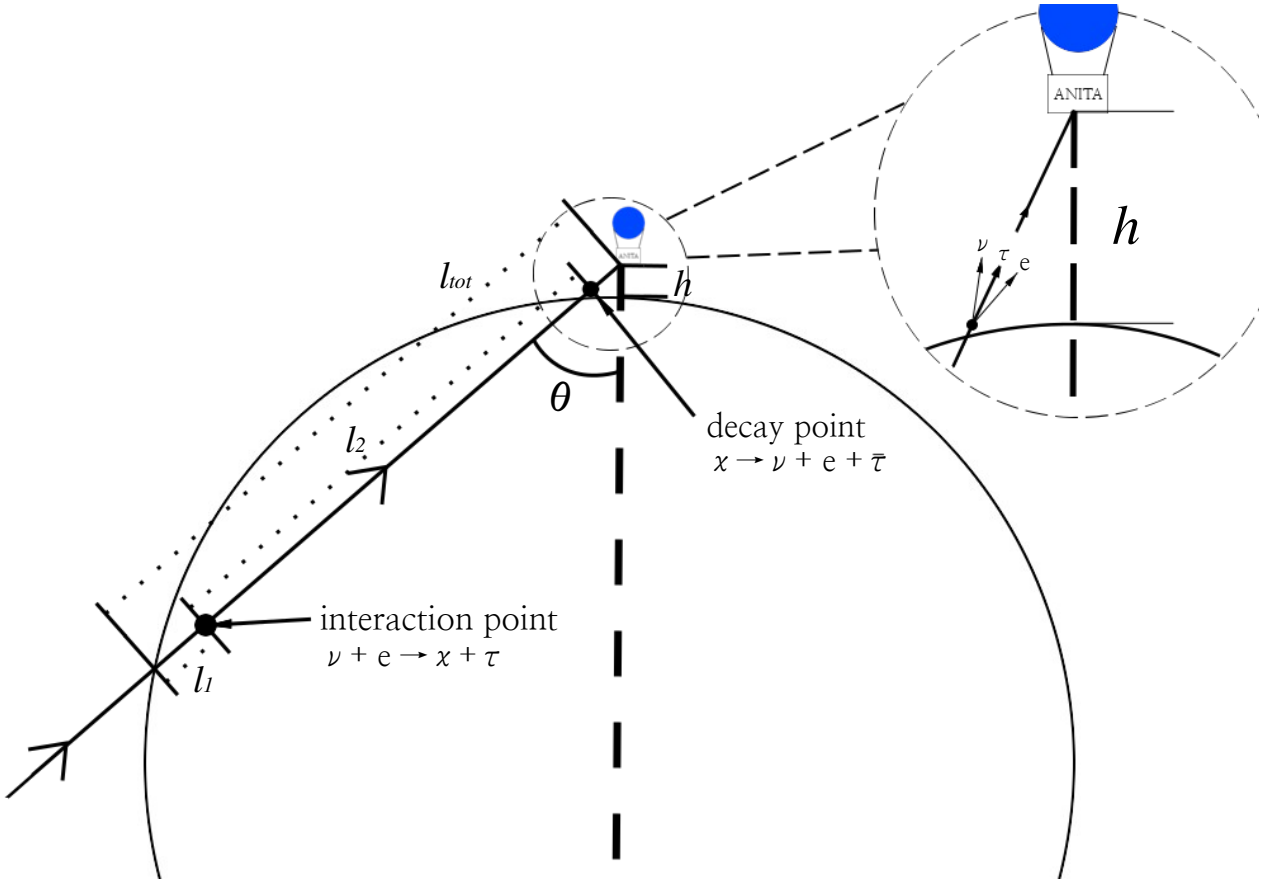

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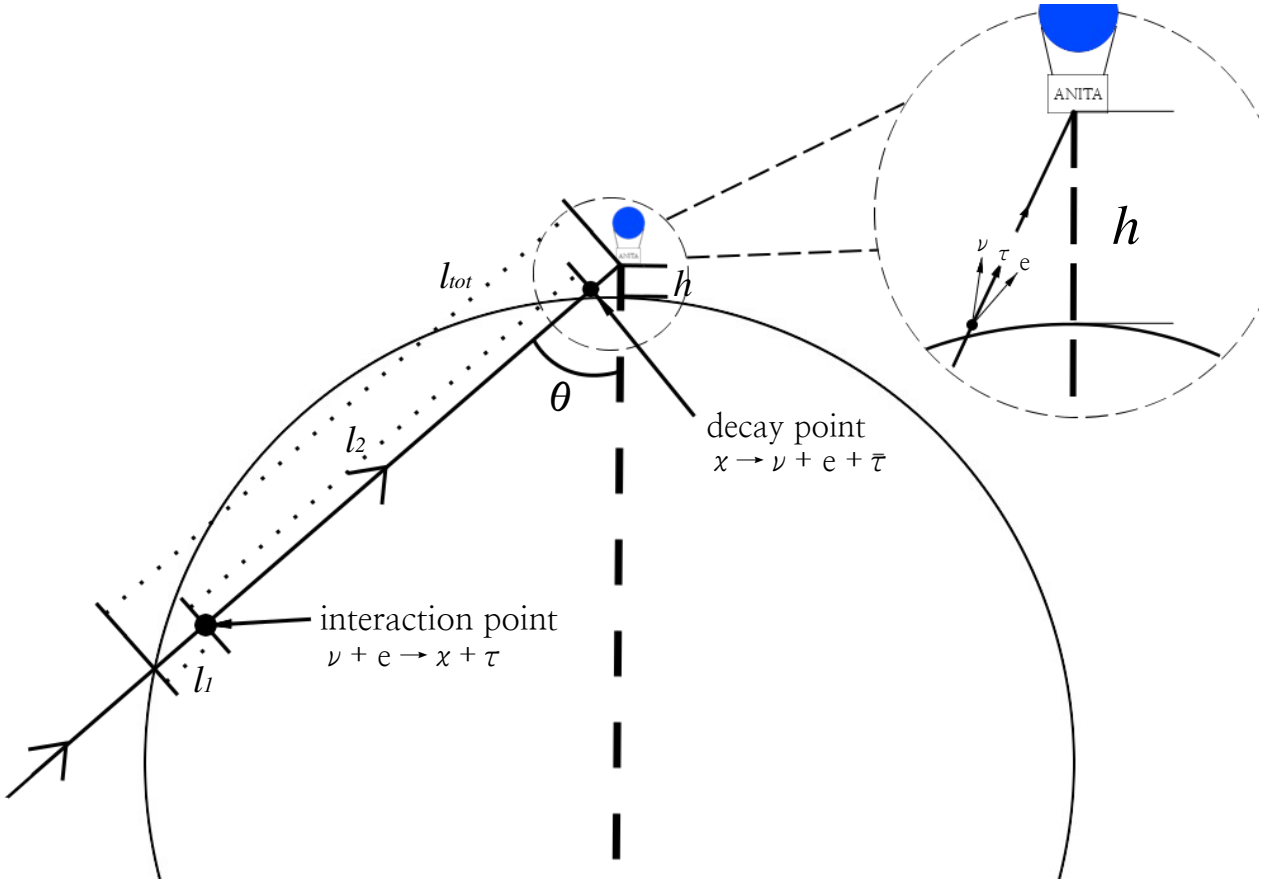

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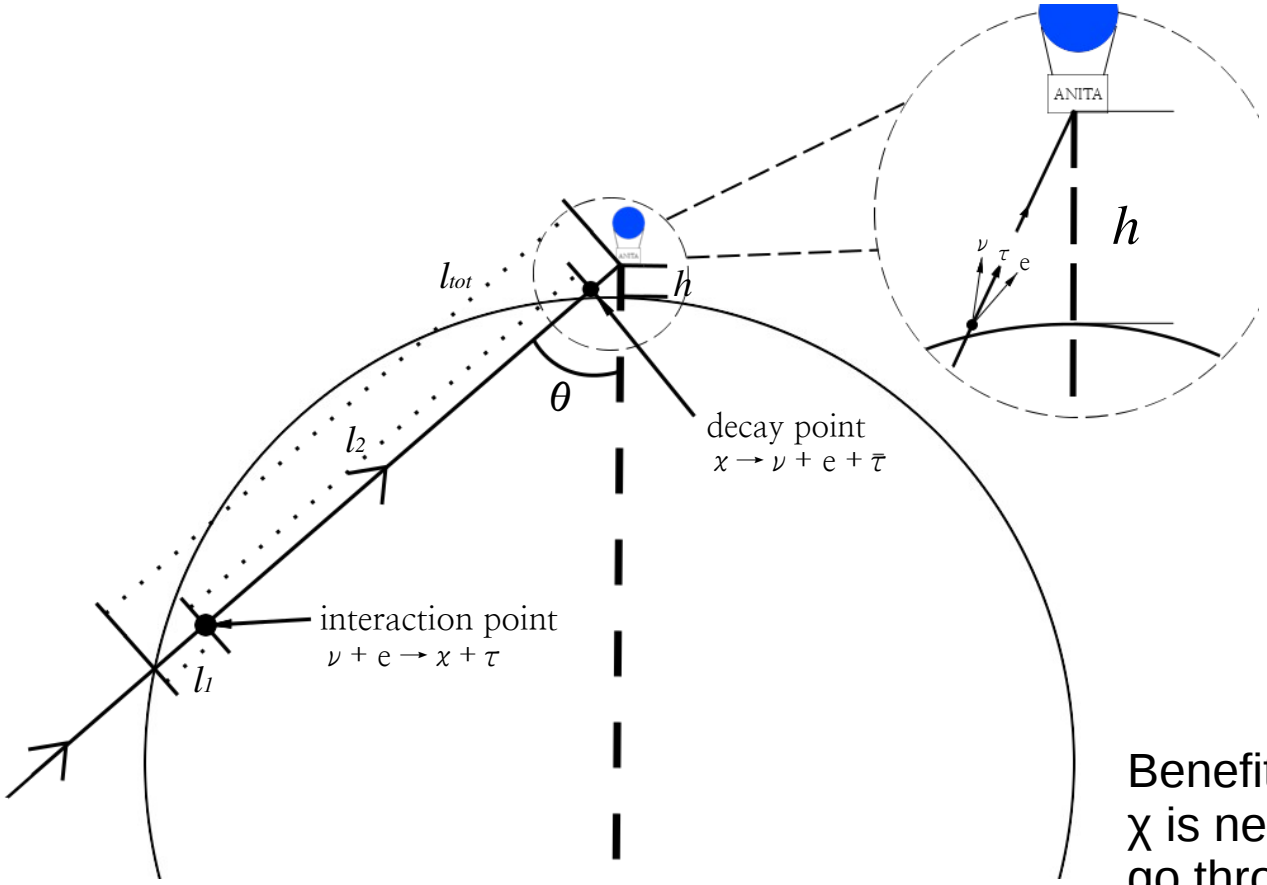

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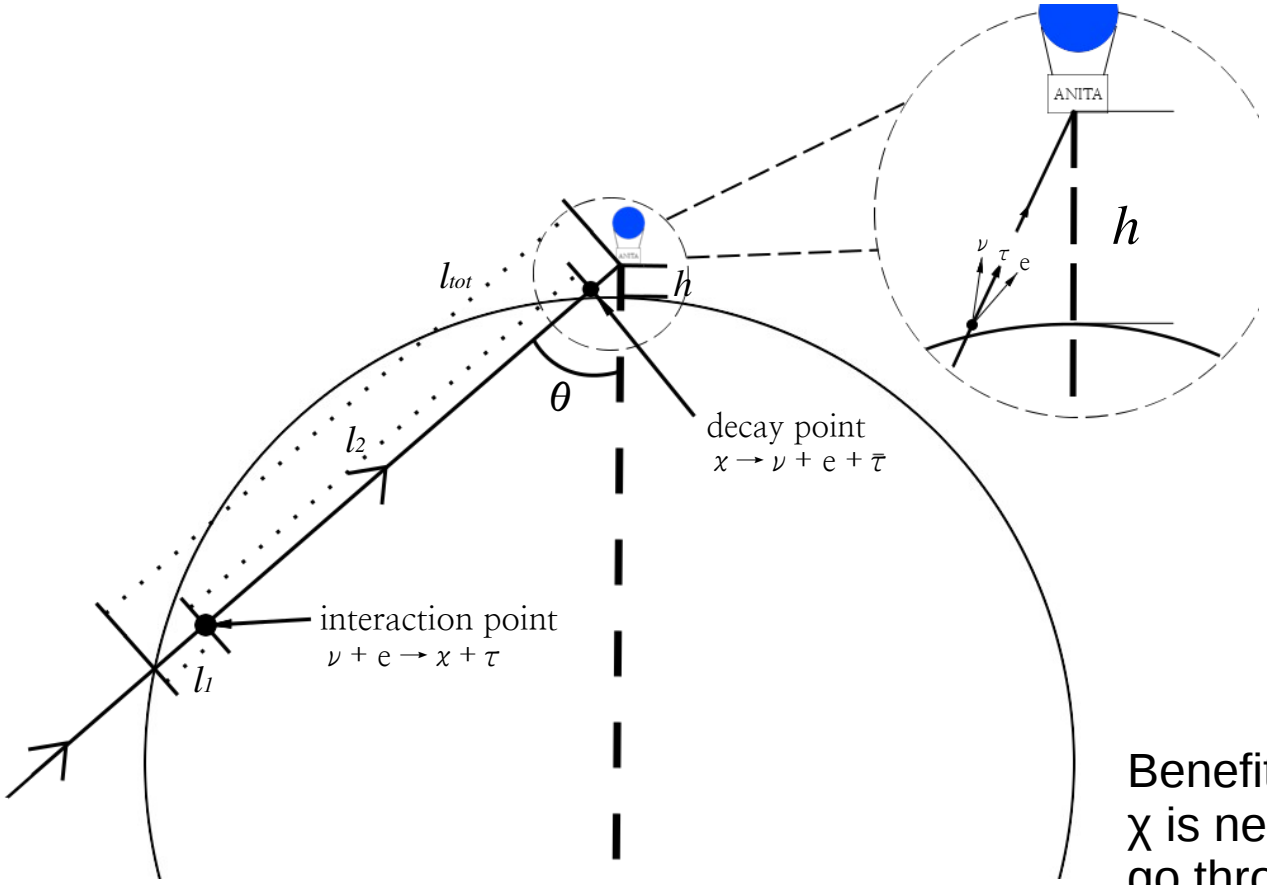

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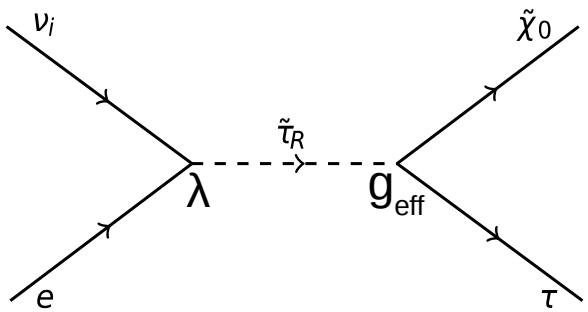

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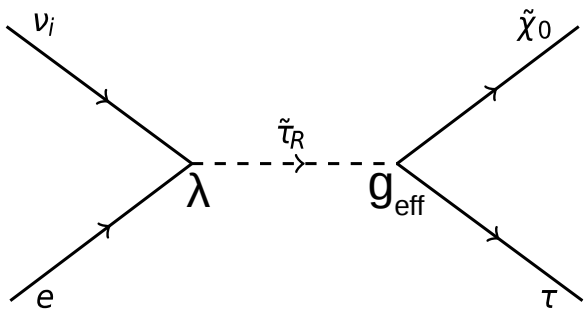

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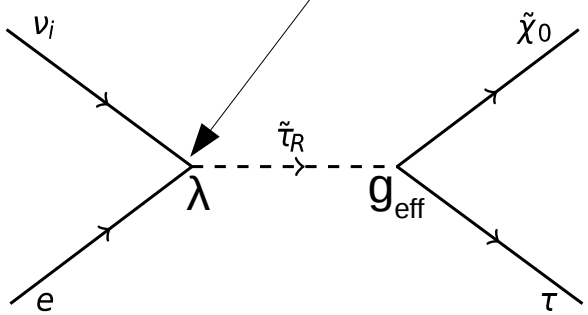

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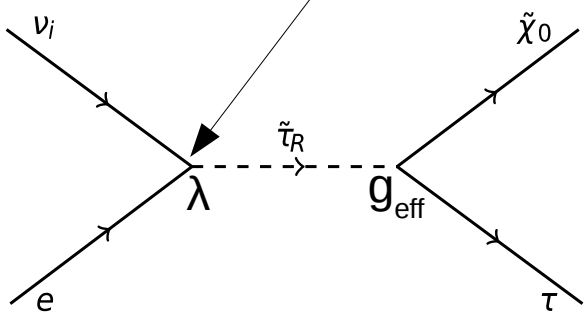

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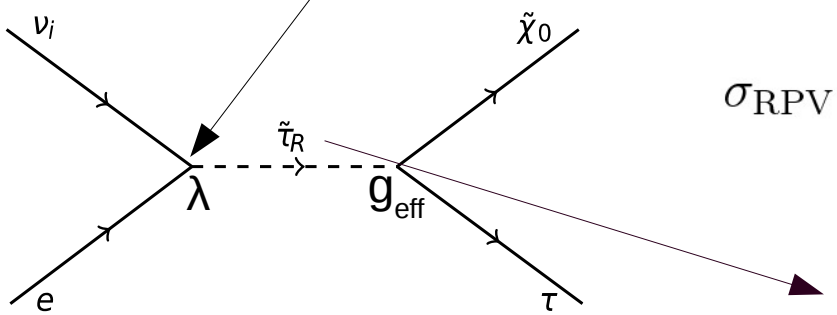

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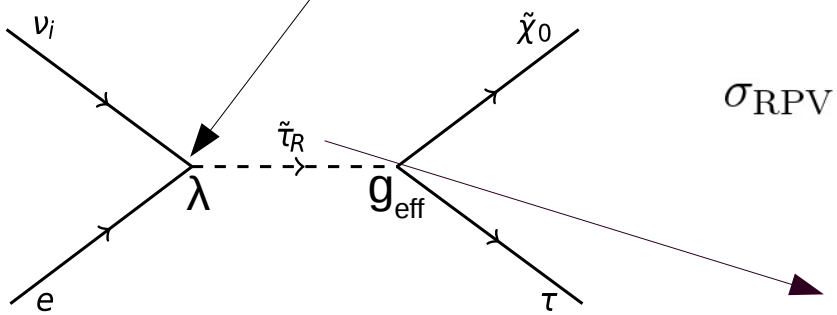

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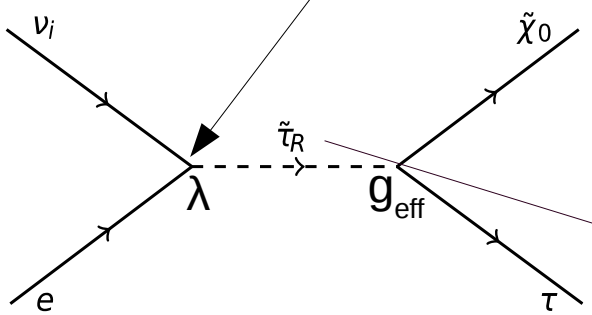
$$W_{RPV} = \lambda_{ijk} L^i L^j \bar{E}^k + \lambda'_{ijk} L^i Q^j \bar{D}^k + \lambda''_{ijk} \bar{U}^i \bar{D}^j \bar{D}^k$$



$$\sigma_{\rm RPV} = \frac{8\pi}{M^2_{\tilde{\tau}}} {\rm Br}[\tilde{\tau} \to \nu + {\rm e}] \cdot {\rm Br}[\tilde{\tau} \to \chi + \tau]$$
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@ resonance, naturally enhancing the cross section

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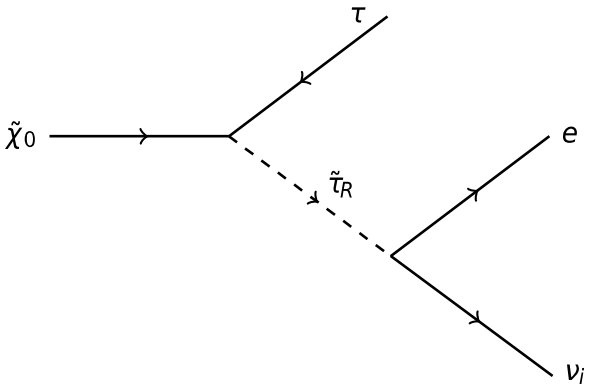

Interaction and Decay

- SUSY RPV term

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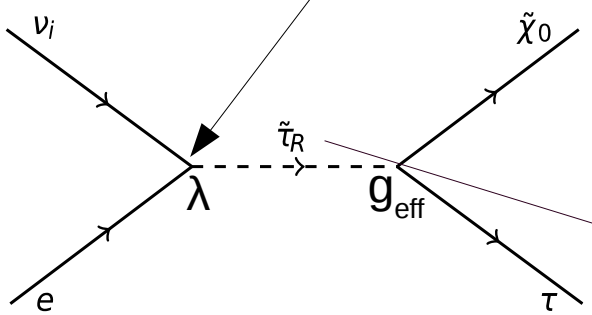

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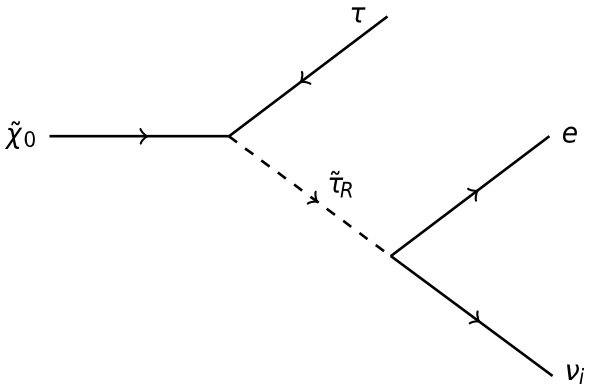

$$\Gamma(\chi \to \tau e \nu) \sim \frac{3\alpha\lambda^2_{i31}}{128\pi^2} \frac{M^5_\chi}{M^4_{\tilde{\tau}}}$$

Possible sources of ANITA events

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$$\sim 0.19$$

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$$[0.315, 12.68]$$

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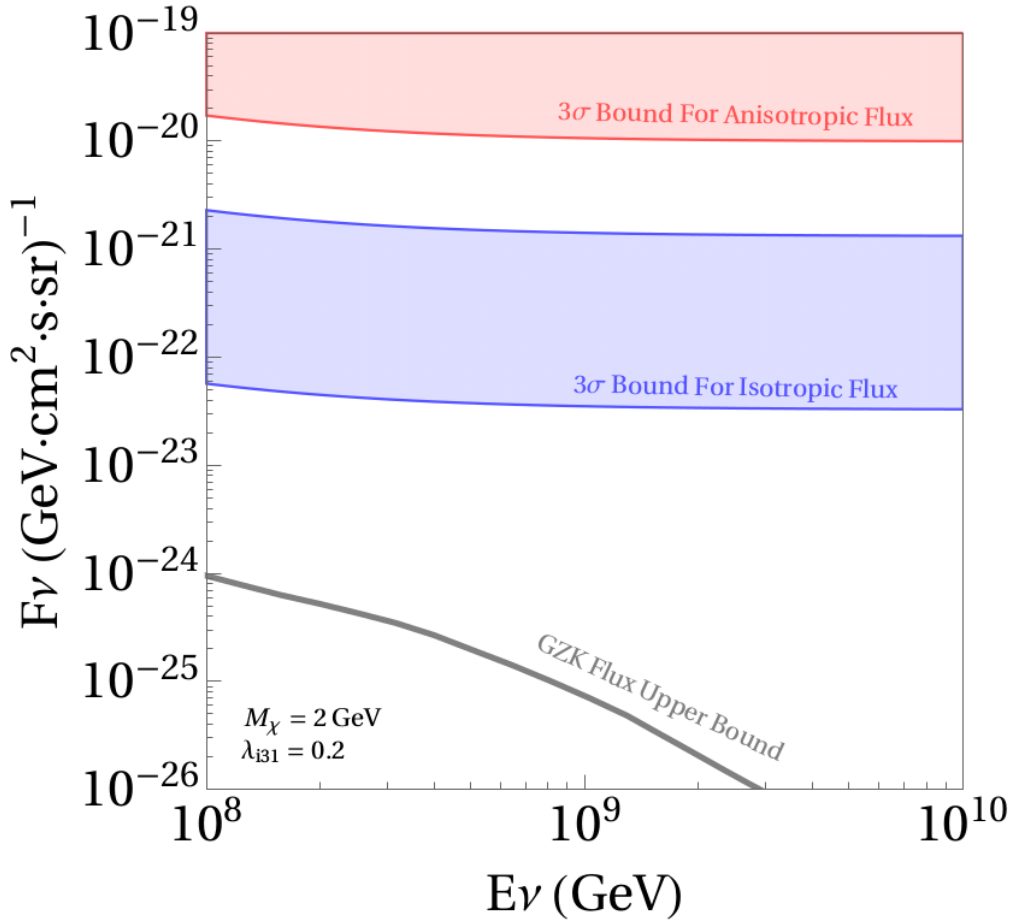

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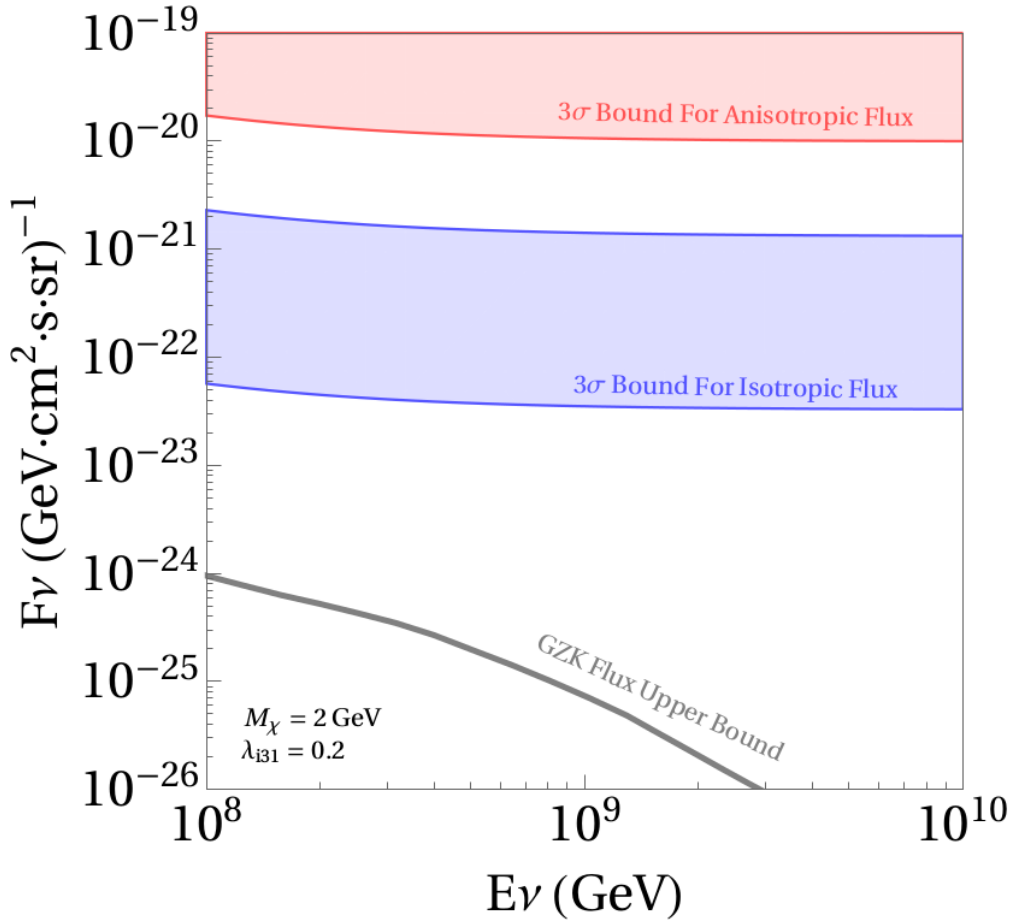

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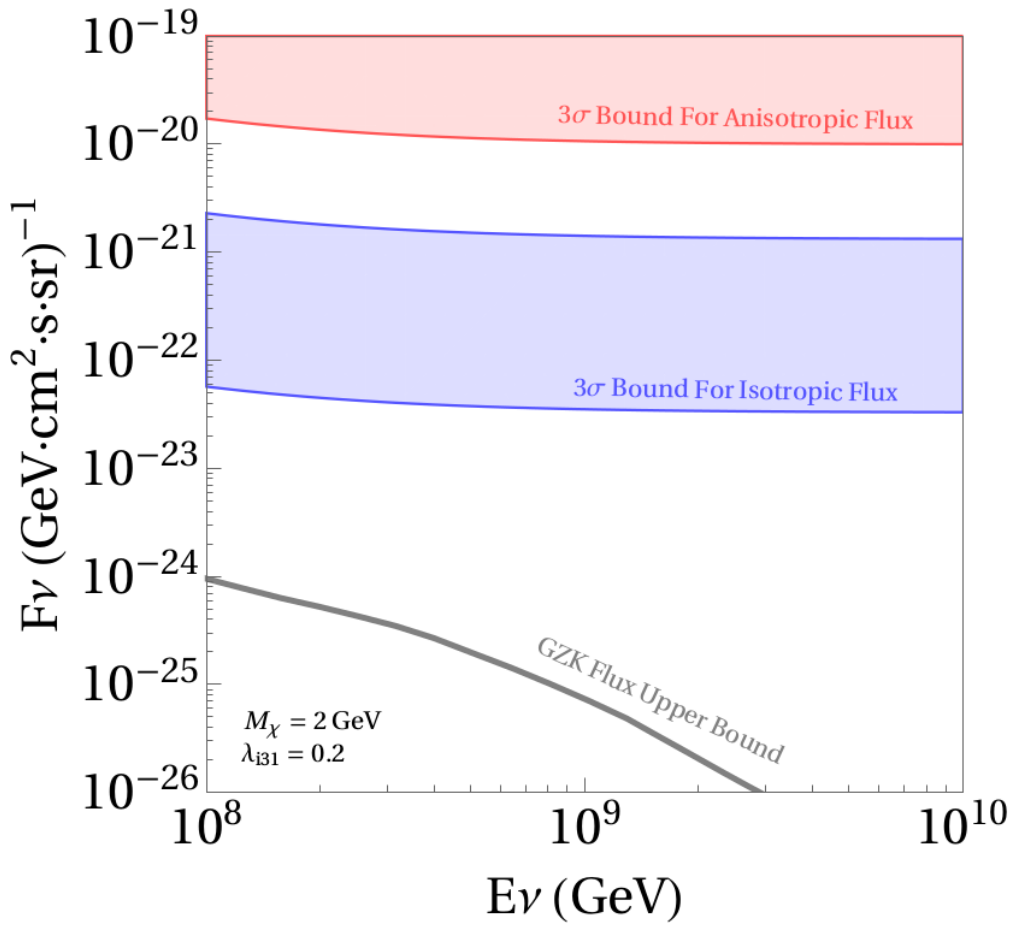

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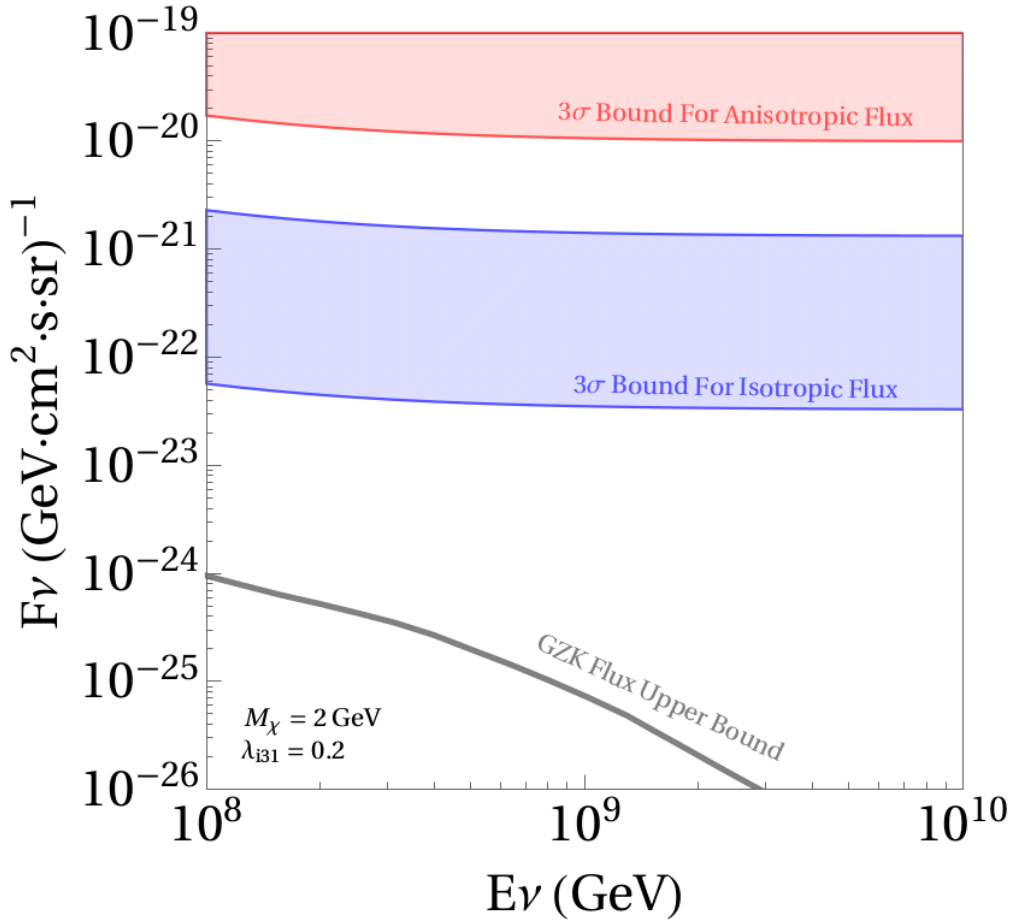
Provide a larger flux and a more direction-focused beam.



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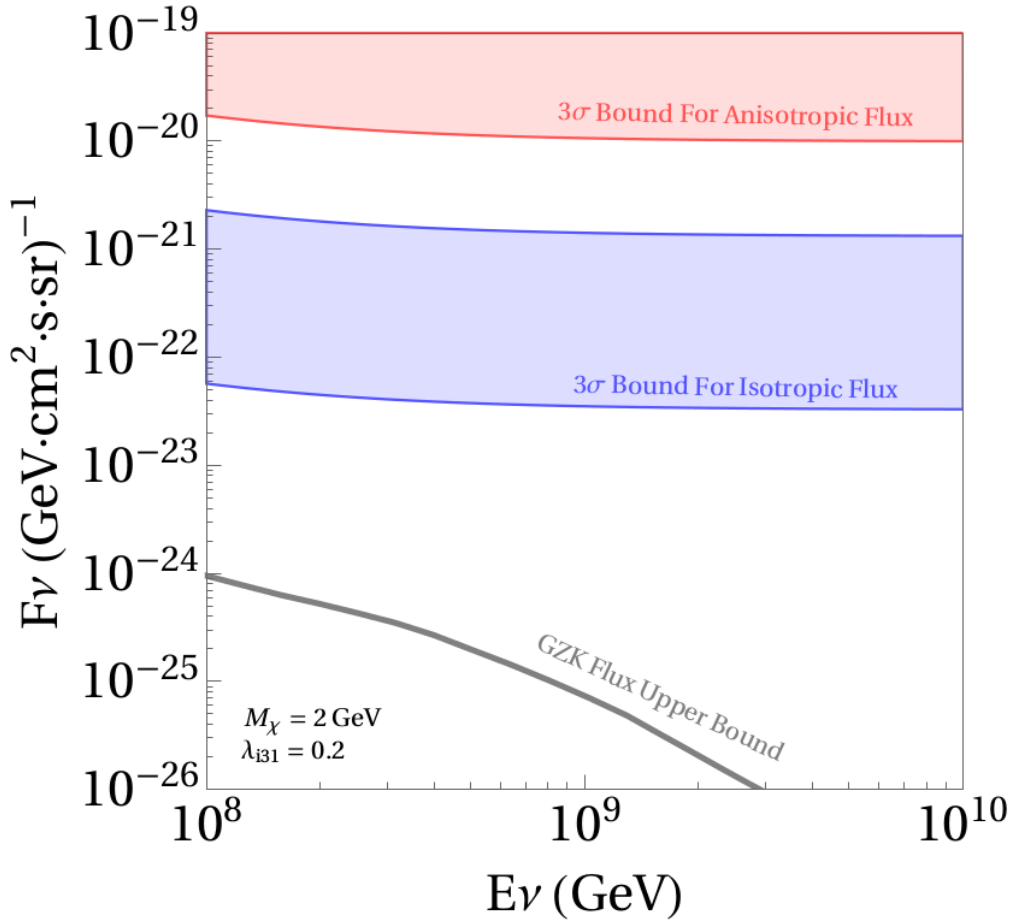

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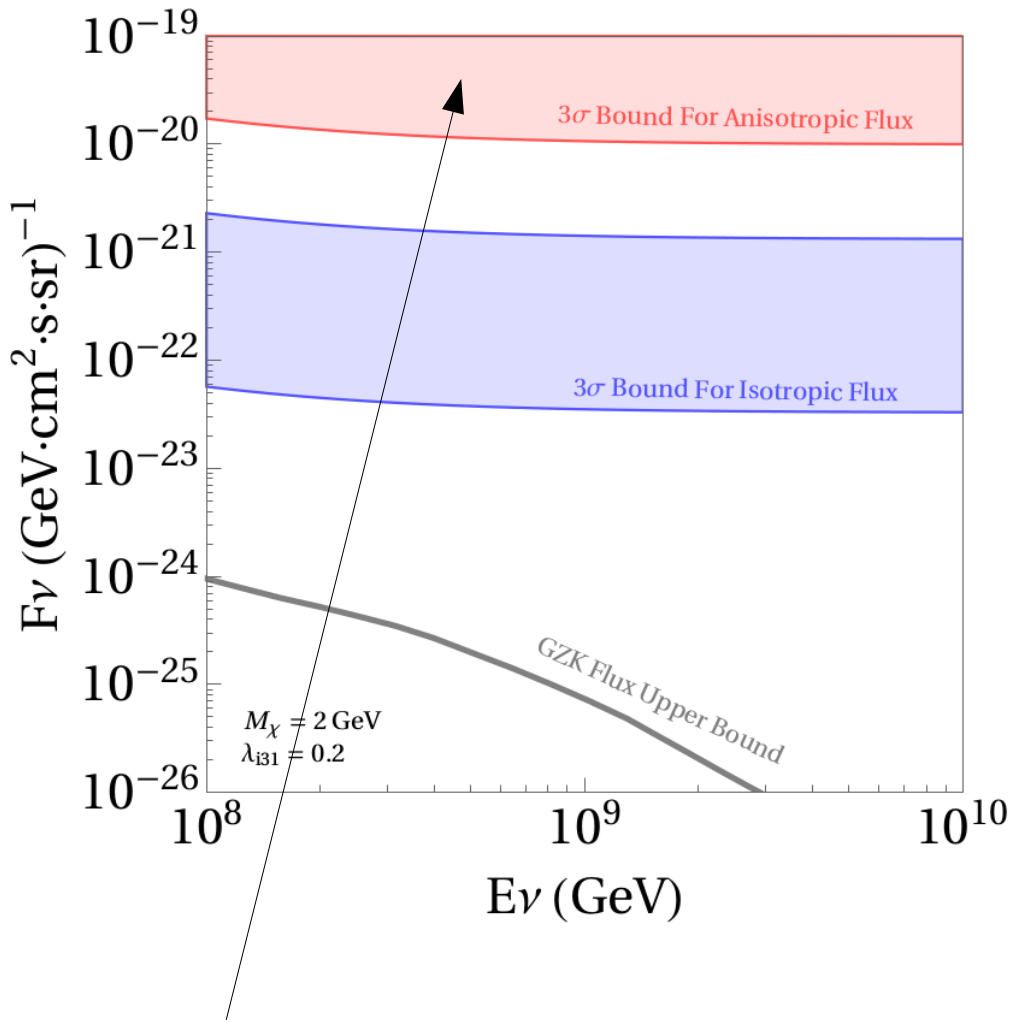

IceCube Collaboration 1609.04981

AGN flux: $\sim 10^{-20}\ (\mathrm{GeV}\cdot\mathrm{cm}^2\cdot\mathrm{s}\cdot\mathrm{sr})^{-1}$

Results

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$$\mathrm{N} = \langle \mathrm{A_{eff}} \cdot \Delta\Omega \rangle \cdot \Delta\mathrm{E} \cdot \mathrm{T} \cdot \mathrm{F}_\nu \in [0.315, 12.68] \longrightarrow$$ Event Constraint

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$$\tau_\chi \sim 0.219 \pm 0.051 \text{ ns}$$ → Geometry Constraint

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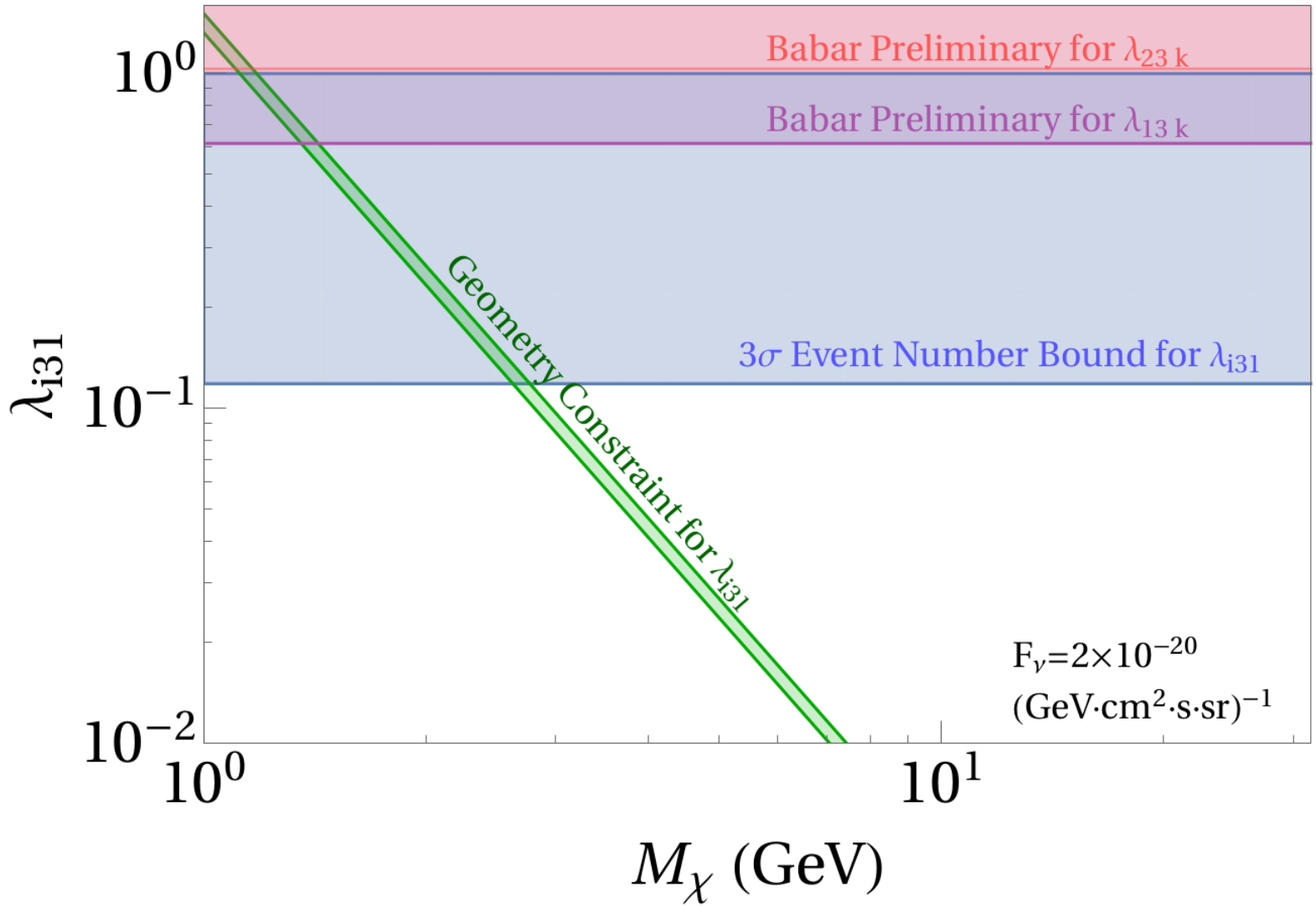

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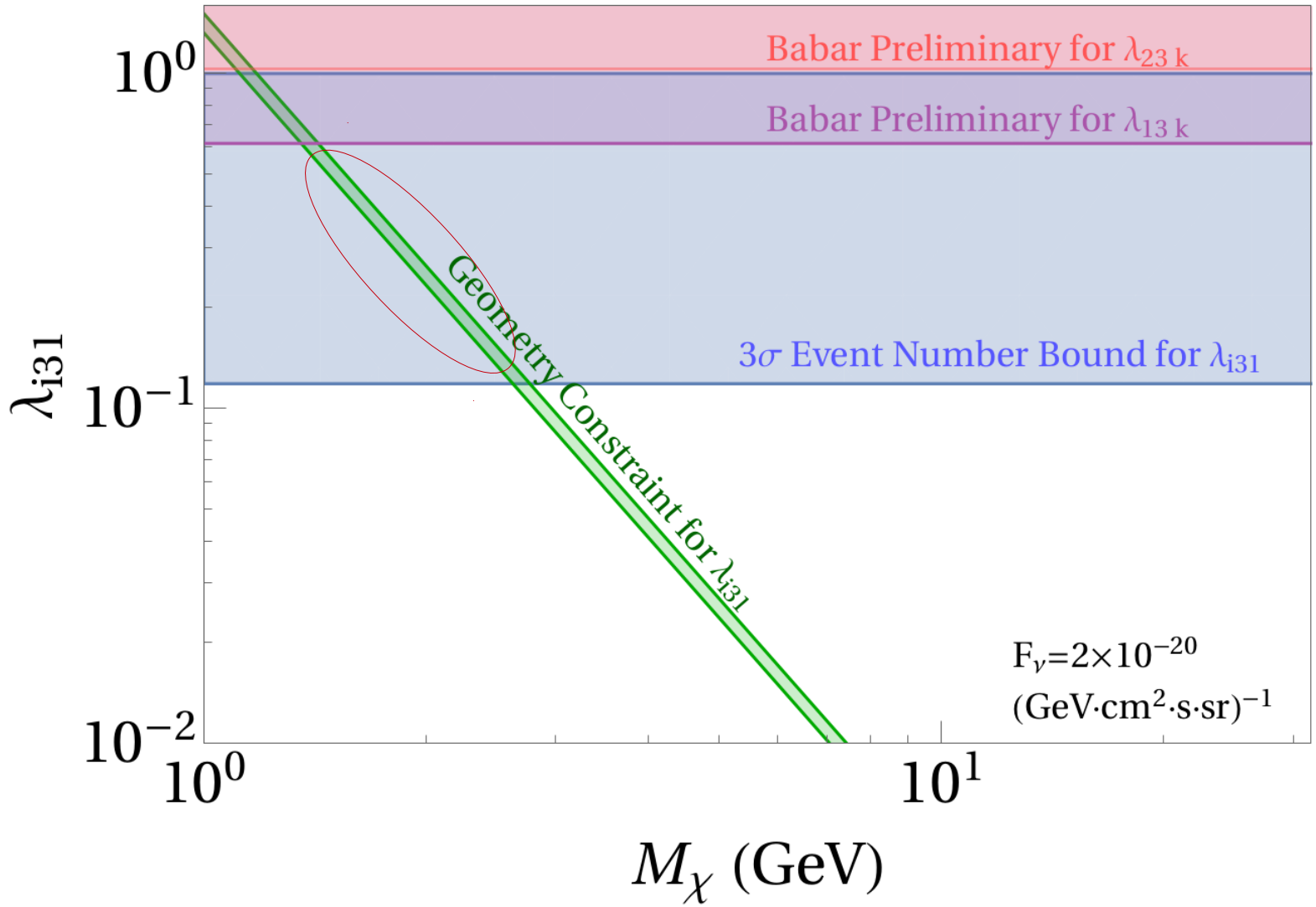


Conclusion

- We propose that bino χ in RPV SUSY could be a suitable interpretation for ANITA events.
- χ should be long-lived with $\tau_\chi \sim 0.219 \pm 0.051 \text{ ns}$ with mass around a few GeV, with LLE coupling λ ~ 0.2.
- Isotropic source (GZK) cannot provide enough events to fit ANITA observation.
- Anisotropic/transient source could fit ANITA data while being consistent with IceCube.
- Should be testable in the near future.

Thank you !

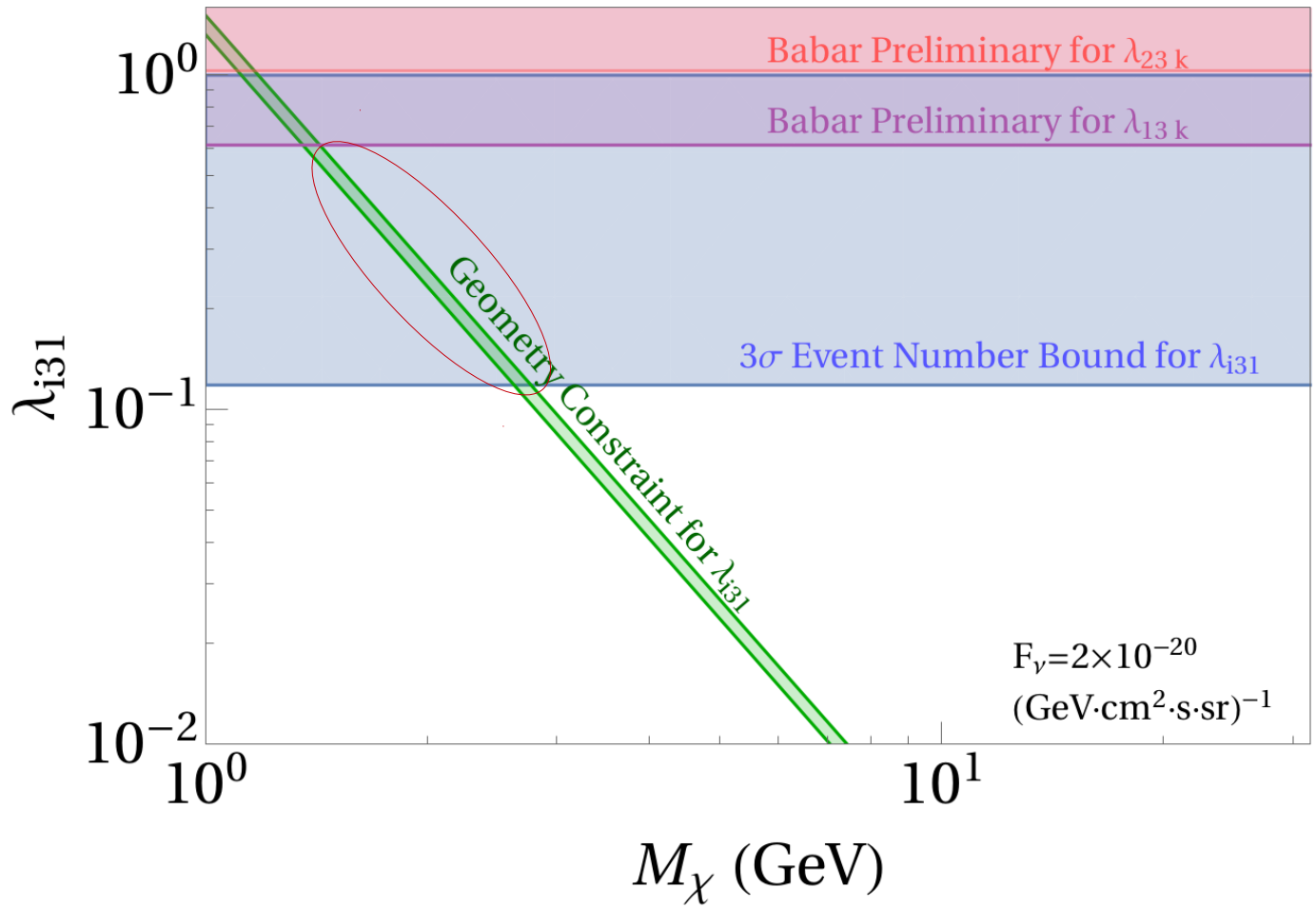
$$N = \langle A_{\rm eff} \cdot \Delta\Omega \rangle \cdot \Delta E \cdot T \cdot F_\nu$$

Anisotropic sources

$$[0.315, 12.68]$$

Event Constraint

$$\langle A_{\rm eff} \cdot \Delta\Omega \rangle \equiv \int d\Omega \, \sin[\theta] \frac{(\ell_{\rm tot} - l_1 - l_2)^2 \; \theta_c^2 \; \pi}{\cos[\theta]} \int_0^{\ell_{\rm tot}[\theta]} \frac{dl_1}{\ell_{\rm bsm}} \cdot e^{-l_1\left(\frac{1}{\ell_{\rm bsm}} + \frac{1}{\ell_{\rm sm}}\right)} \int_{\ell_{\rm tot}[\theta] - {\rm d}[\theta] - l_1}^{\ell_{\rm tot}[\theta] - l_1} \frac{dl_2}{\ell_{\rm decay}} e^{-\frac{l_2}{\ell_{\rm decay}}}$$



Geometry Constraint

$$\tau_\chi \sim 0.219 \pm 0.051 \text{ ns}$$

$$\Gamma(\chi \to \tau e \nu) \sim \frac{3\alpha\lambda^2}{128\pi^2} \frac{M_\chi^5}{M_{\rm SUSY}^4}$$

- Report ANITA events again with some details: upgoing, none phase reflection→ meaning those are events coming from Earth.
- Explain why SM neutrino cannot past through Earth in such angle; and the effective area comparison between IceCube and ANITA and their results contradiction
- Ideas of BSM of getting around such stuff by Cherry, Huang, Dark matter people, stau people. Still has some IceCube contradiction
- To solve IceCube contradiction, we propose our model (cartoon explanation), such model requires we have bino particle with certain interaction
- This interaction could be provide by RPV SUSY and the bino being LSP particle
  ---------- some introduction of the theory
- Possible sources of ANITA events and rough estimate shows that GZK cannot be the source for the events
- Setting up favored region for parameters: Geometry constraint and Events fitting constraint calculation
- Showing such constraints
- conclude