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

Antarctic Impulse Transient Antenna (ANITA) Experiment

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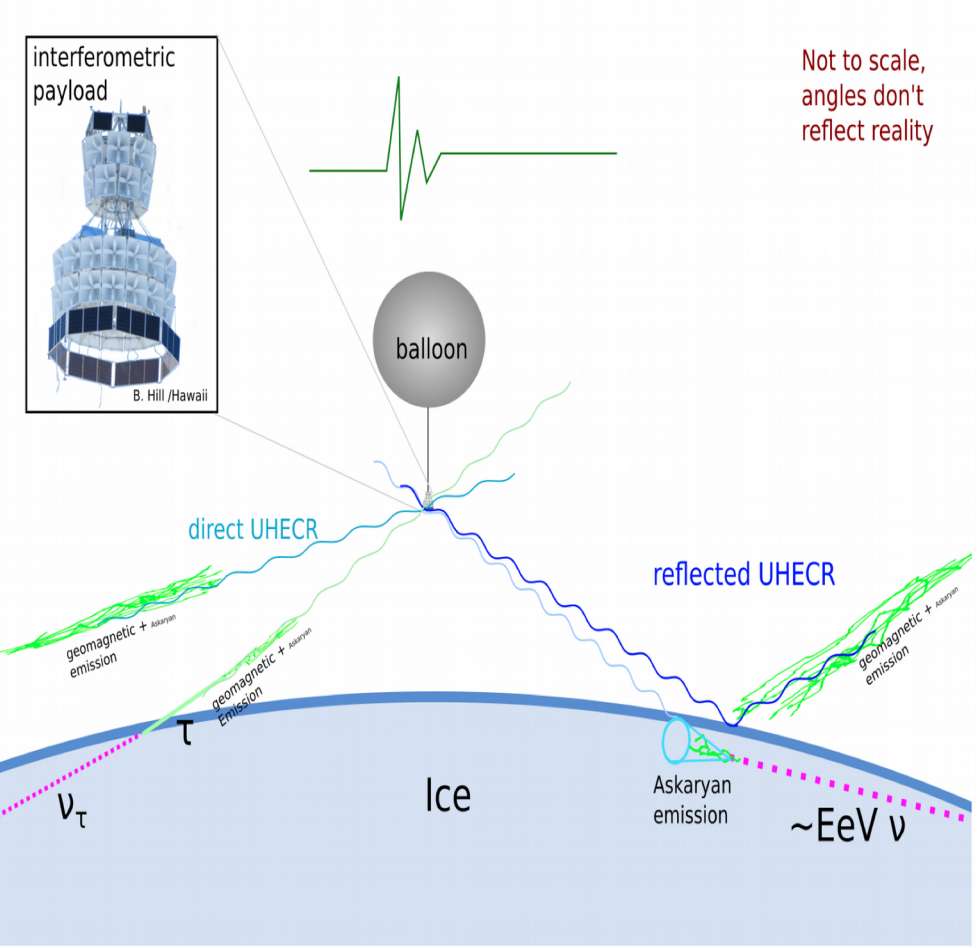

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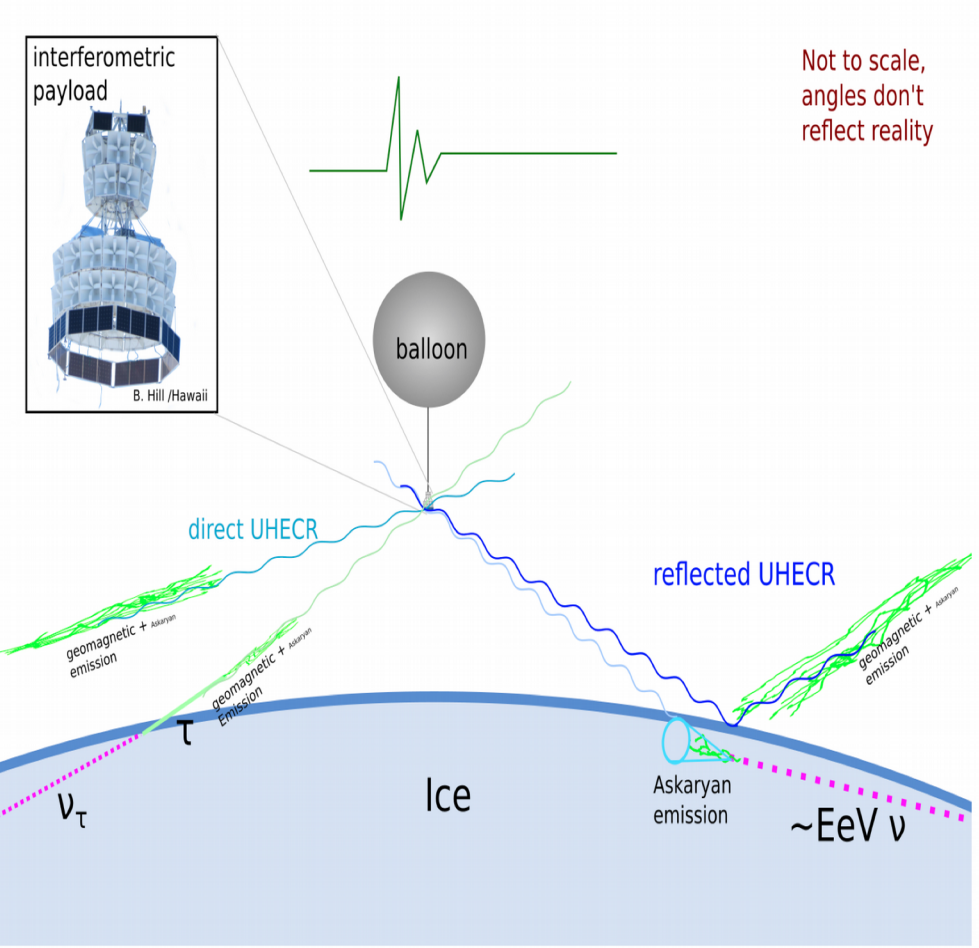

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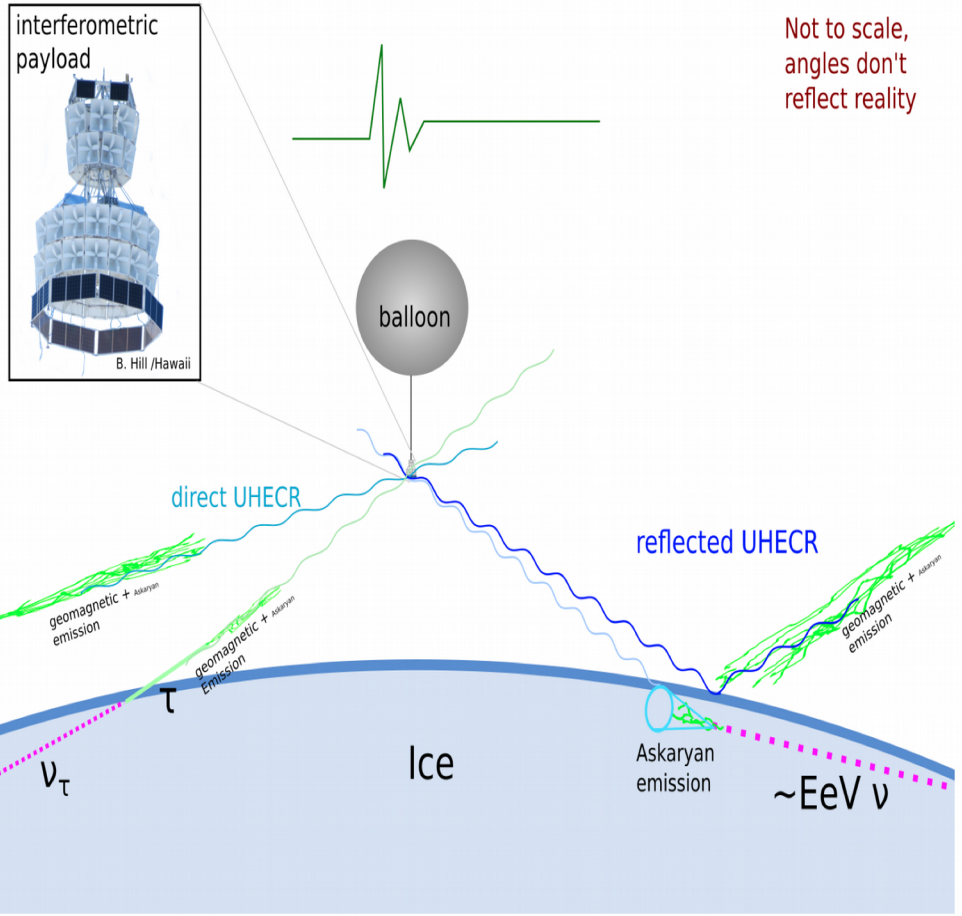

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Lat., Lon.[1]	-82.6559, 17.2842	-81.39856, 129.01626
Altitude	2.56 km	2.75 km
Ice depth	3.53 km	3.22 km
El., Az.	$-27.4 \pm 0.3°, 159.62 \pm 0.7°$	$-35.0 \pm 0.3°, 61.41 \pm 0.7°$
RA, Dec[2]	282.14064, +20.33043	50.78203, +38.65498
E_{shower}[3]	0.6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

[1] Latitude, Longitude of the estimated ground position of the event.
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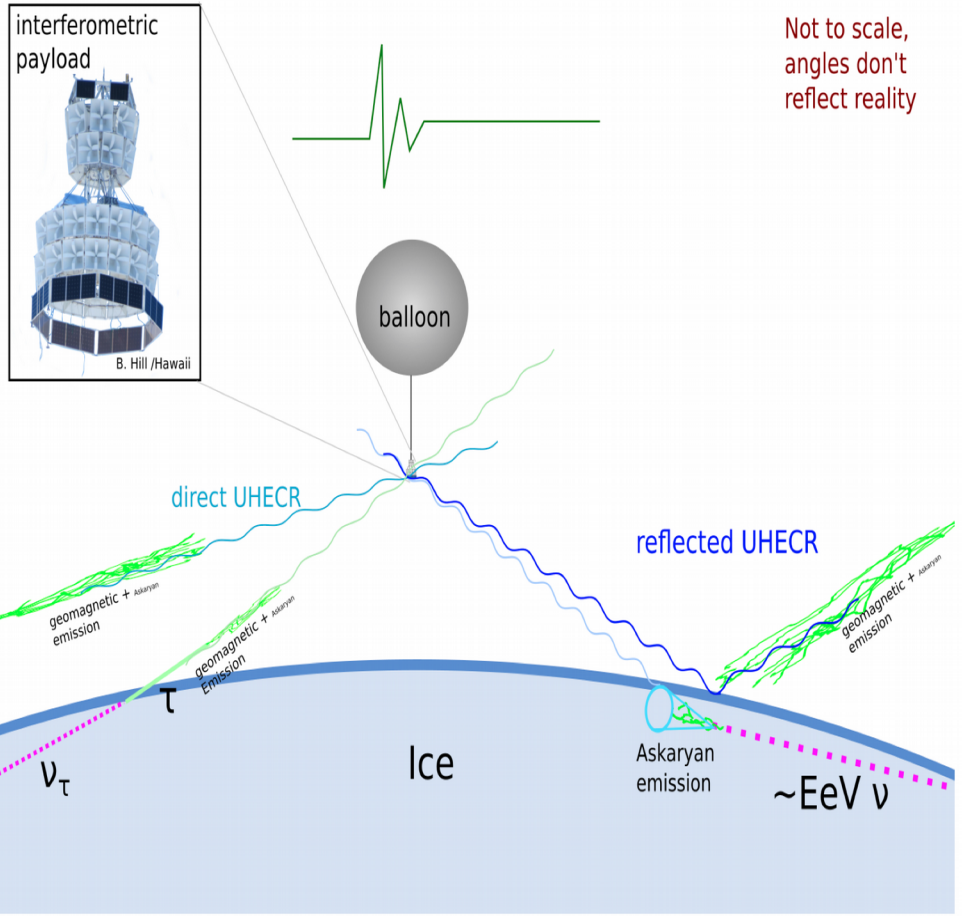

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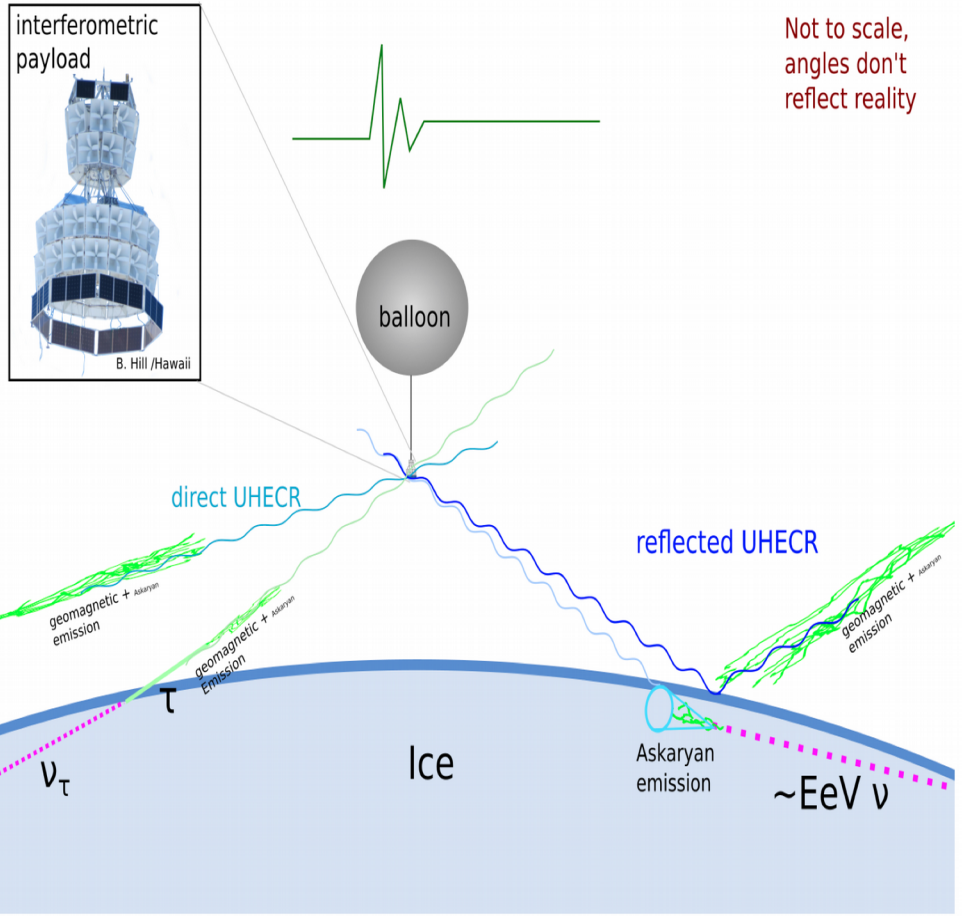

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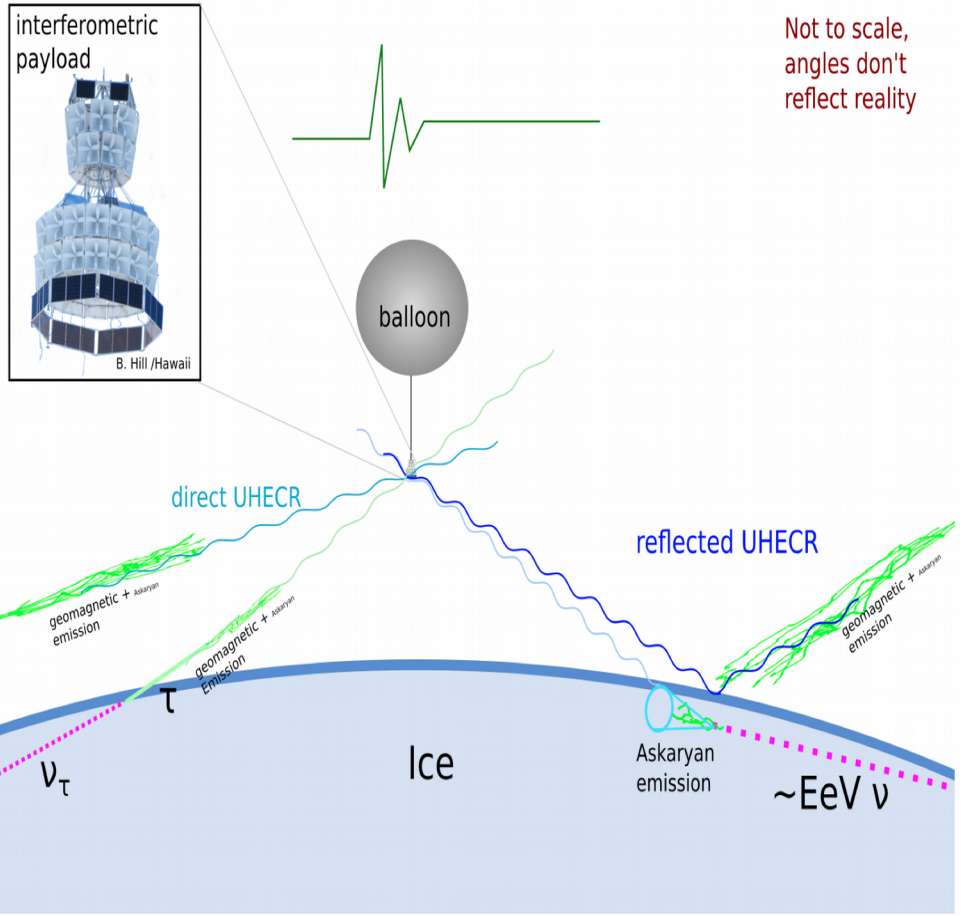

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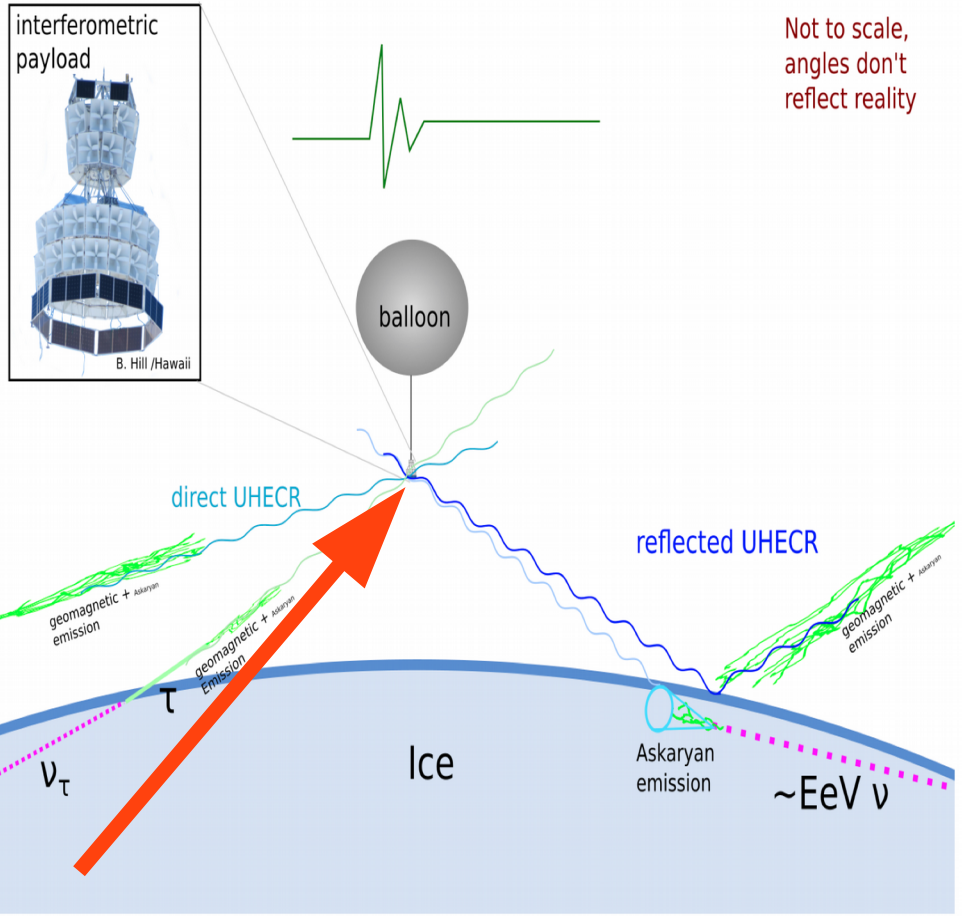

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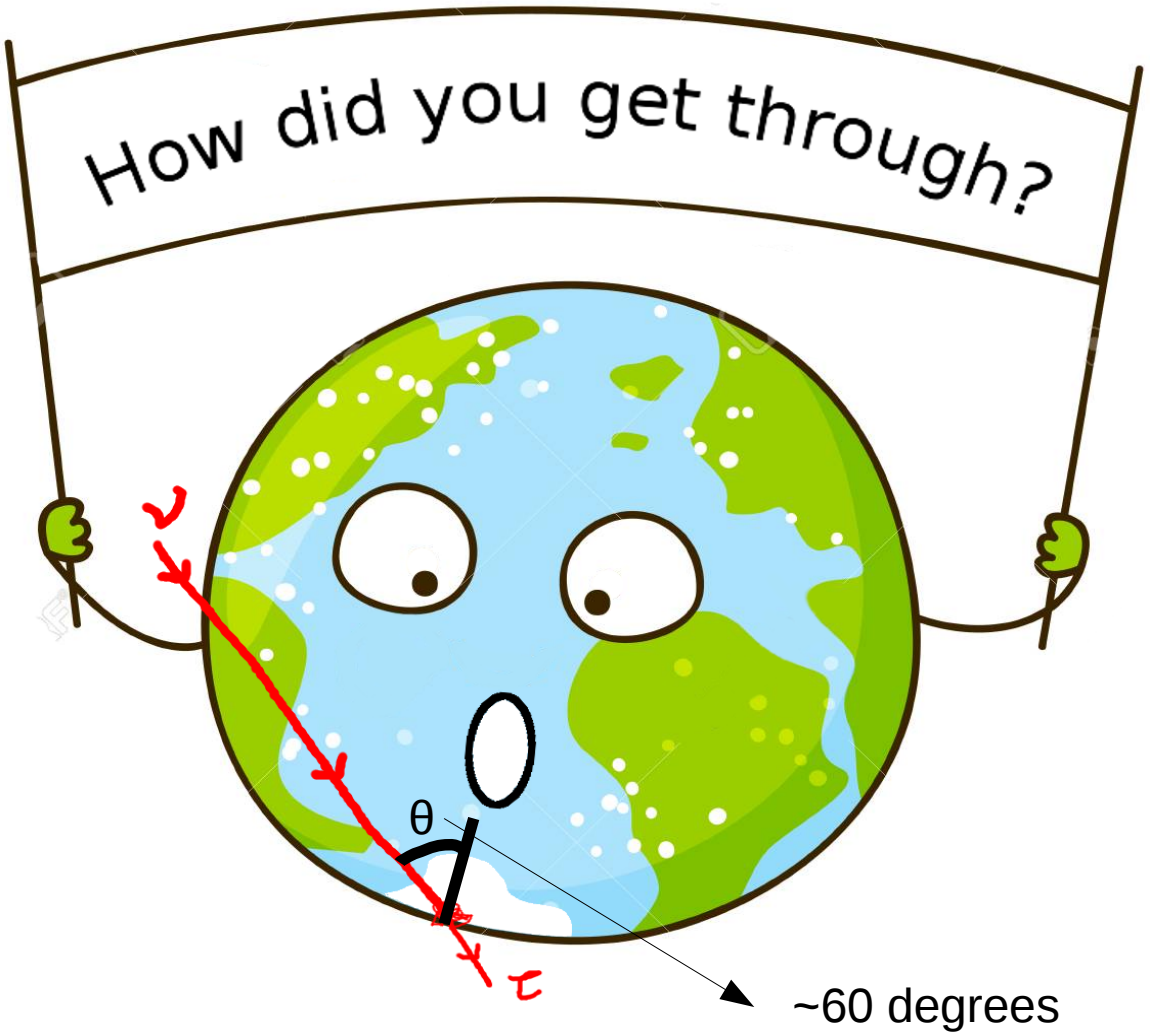

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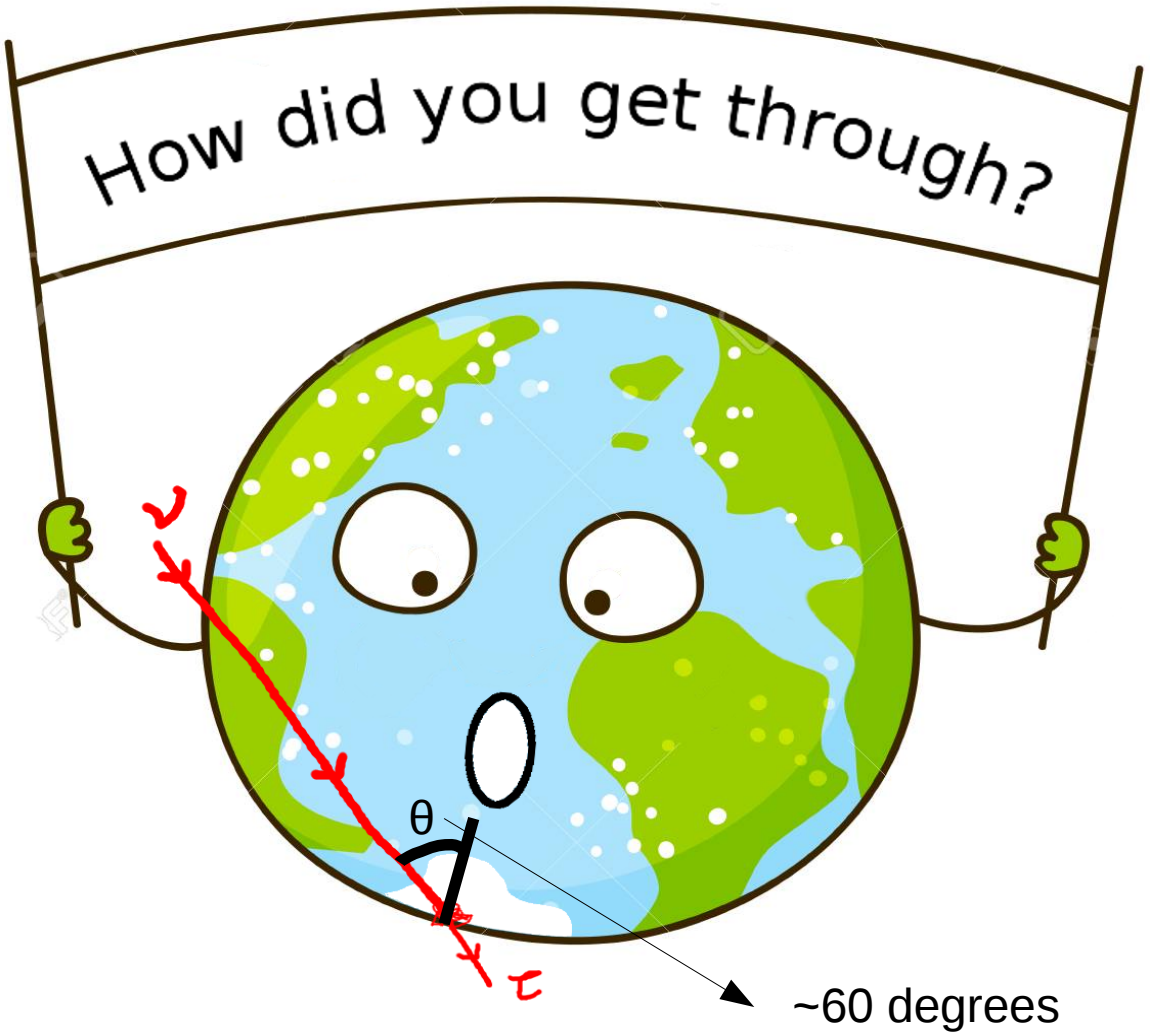

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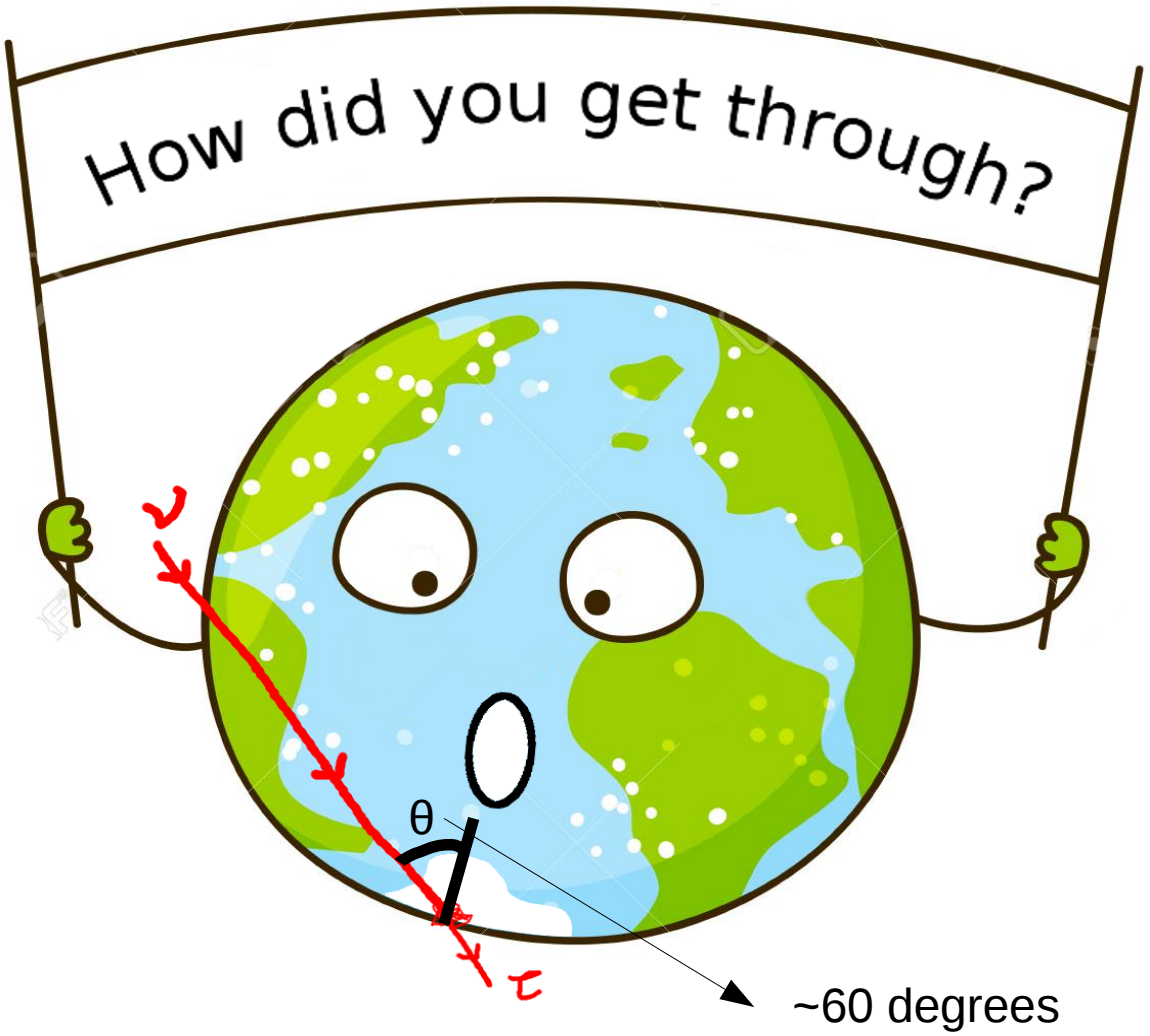

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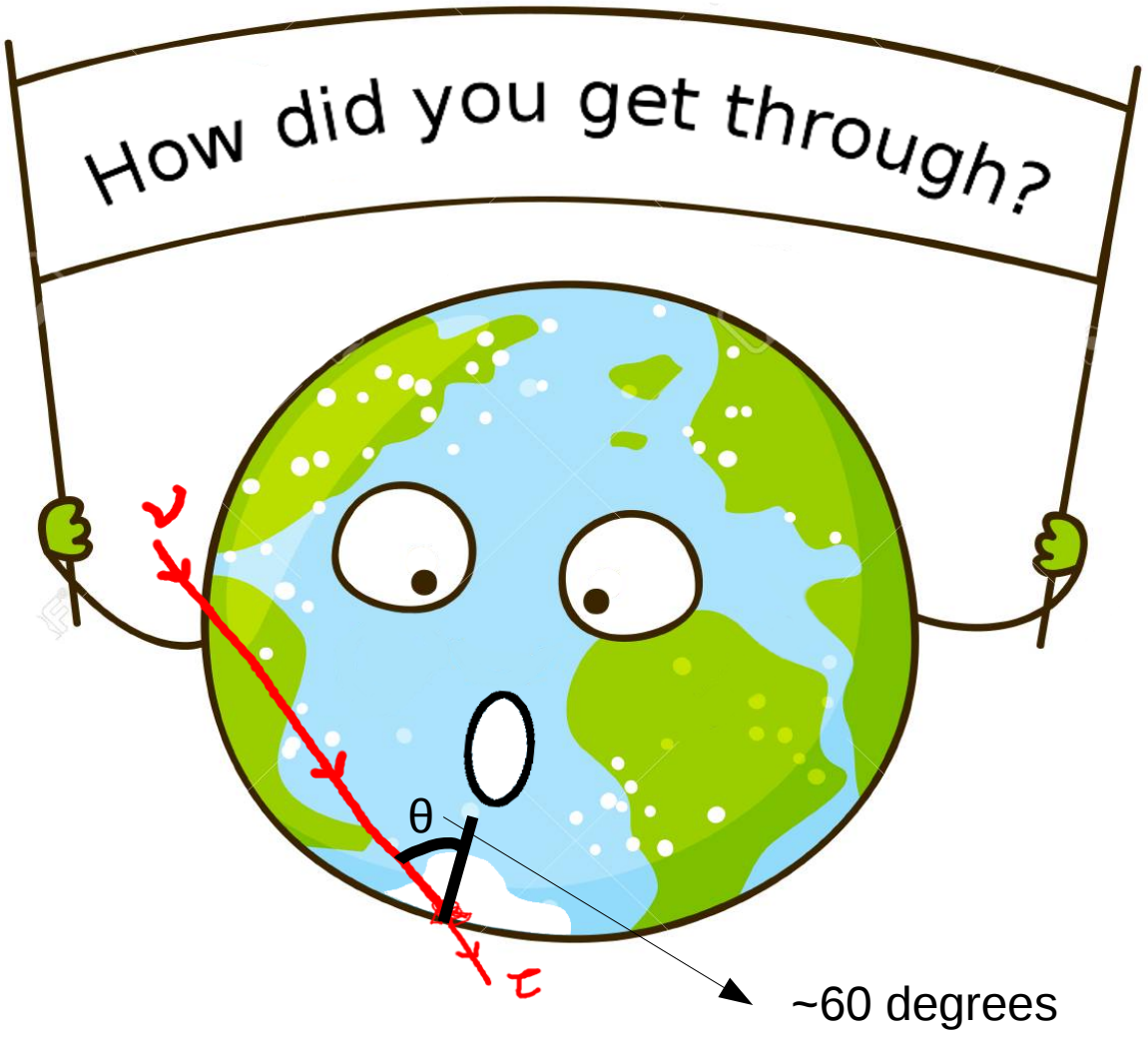

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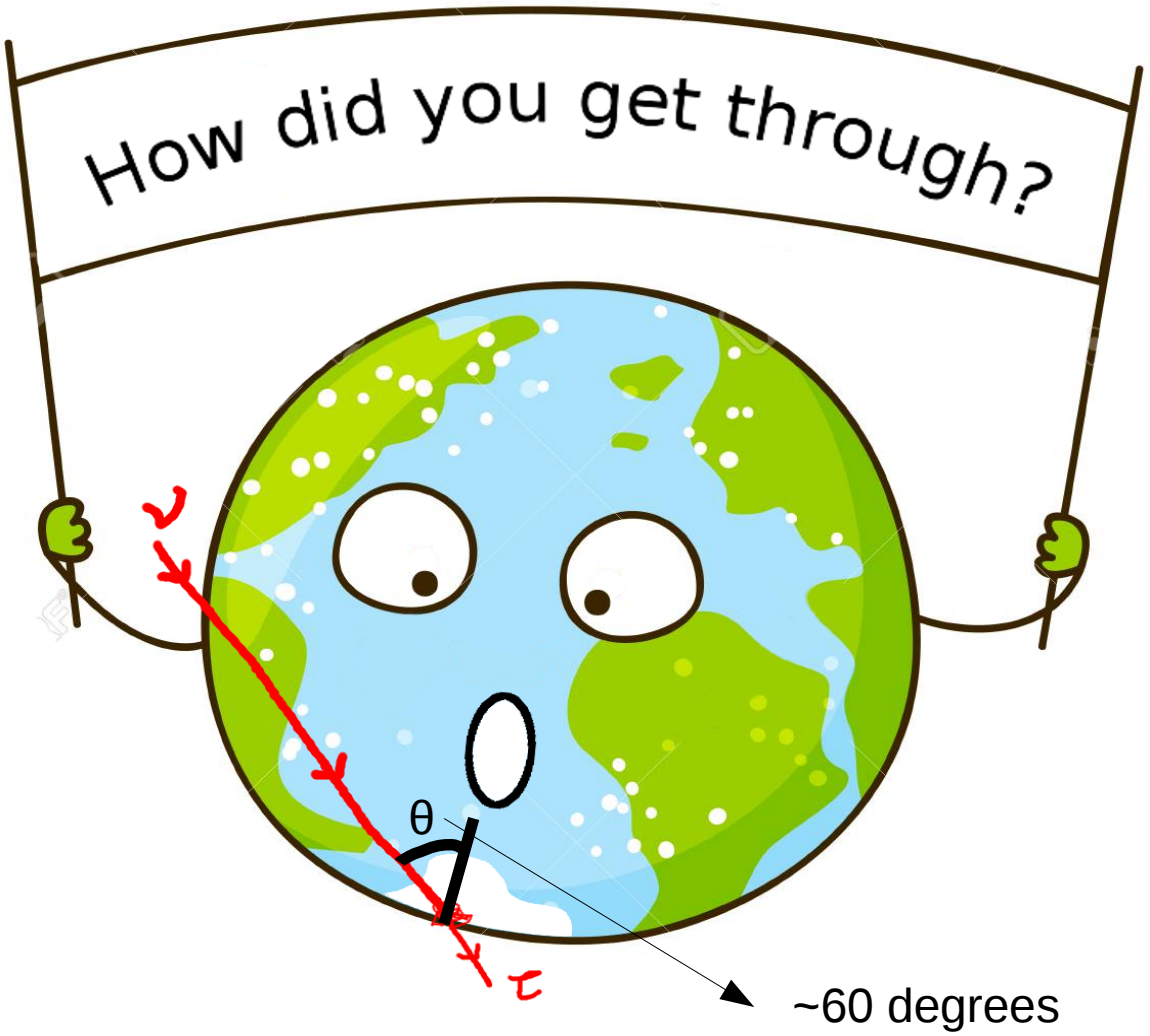

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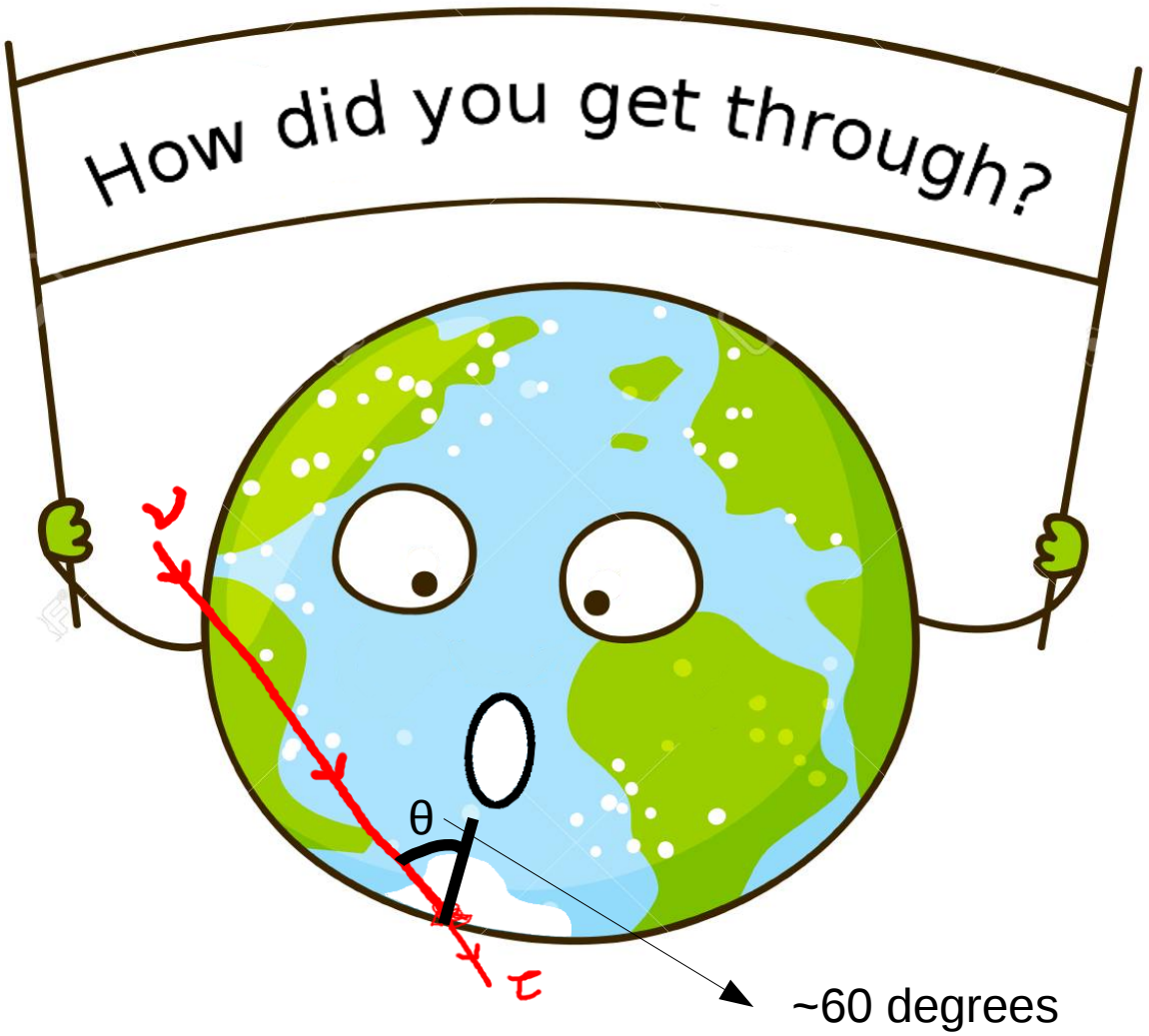

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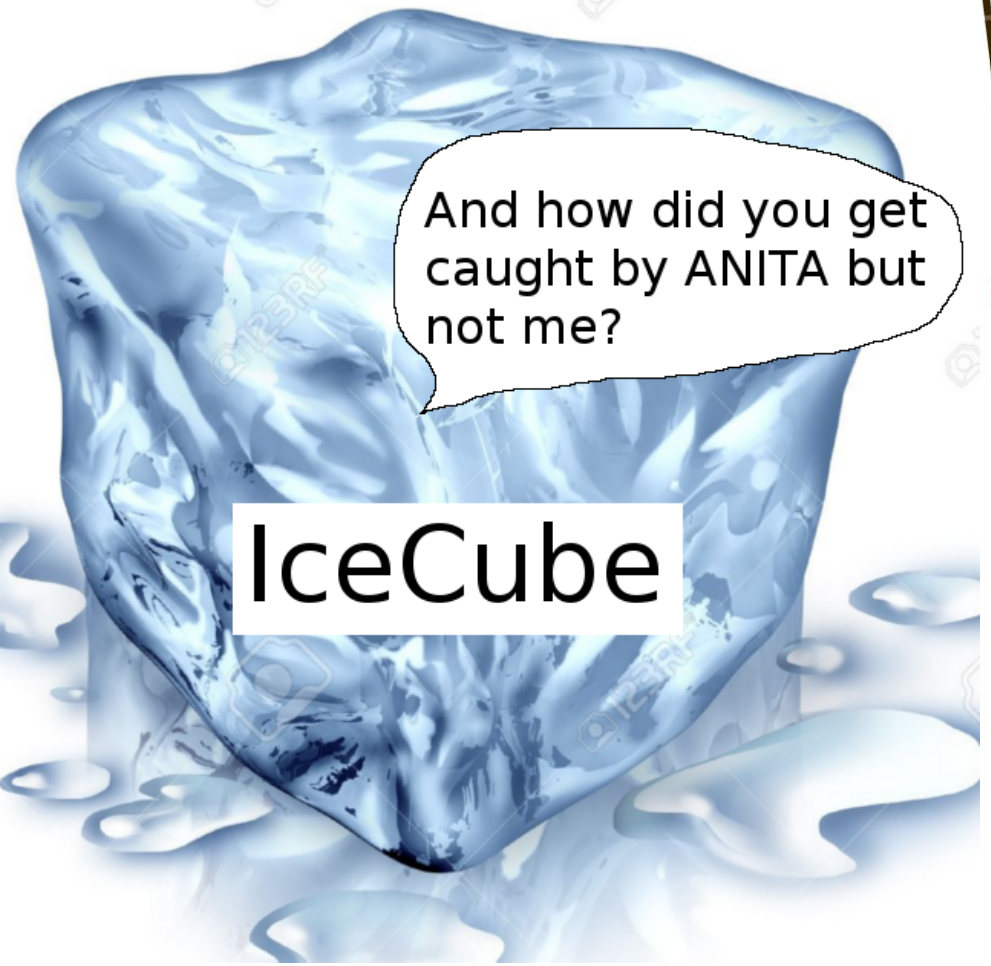

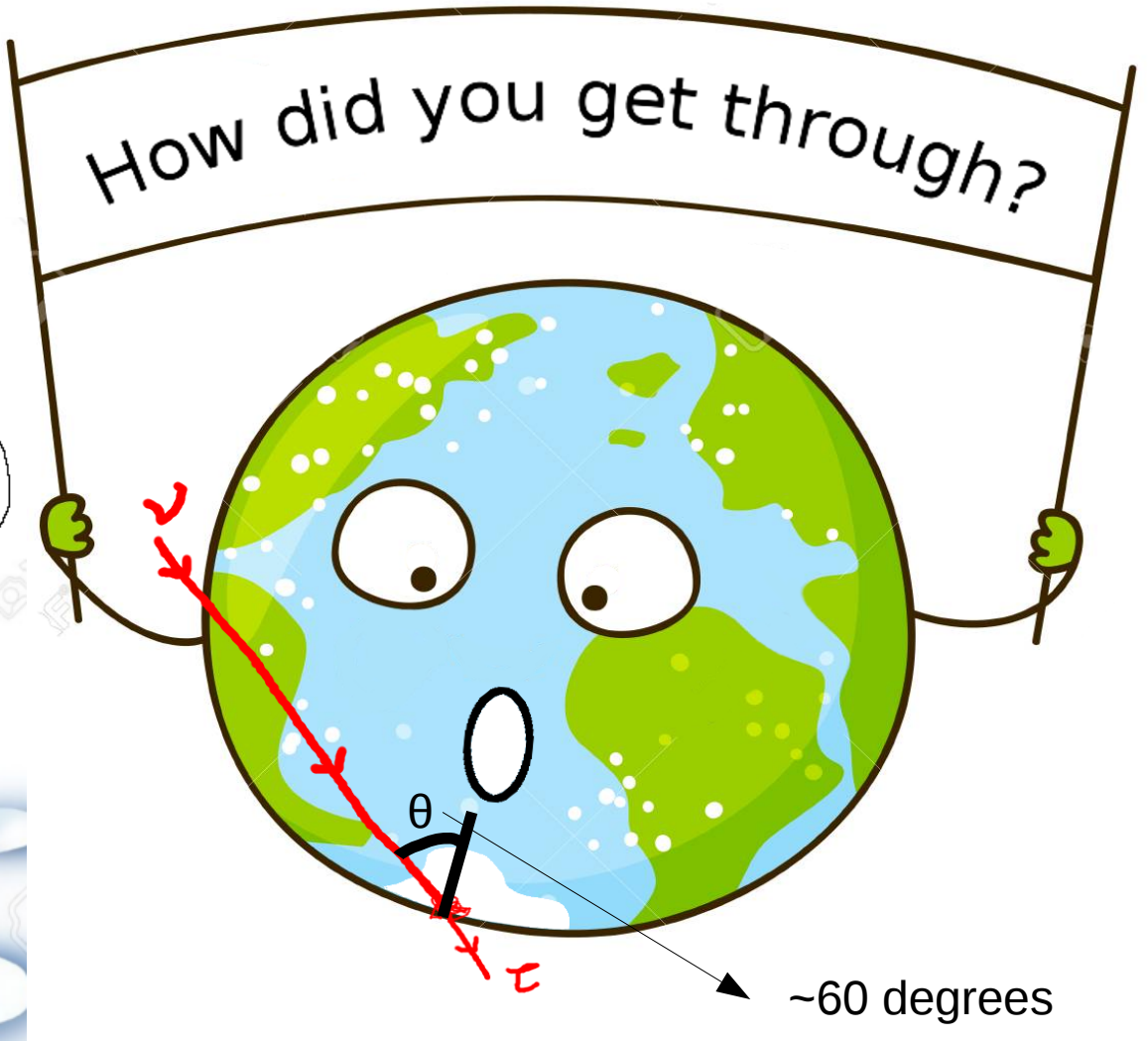

Some plausible scenarios:

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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)

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

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Abstract

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- Dark matter inside Earth Explanation

Upgoing ANITA events as evidence of the CPT symmetric universe

Luis A. Anchordoqui,[1,2,3] Vernon Barger,[4] John G. Learned,[5] Danny Marfatia,[5] and Thomas J. Weiler[6]

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[2] *Department of Physics, Graduate Center, City University of New York, NY 10016, USA*
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[5] *Department of Physics & Astronomy, University of Hawaii at Manoa, Honolulu, HI 96822, USA*
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We explain the two upgoing ultra-high energy shower events observed by ANITA as arising from the decay in the Earth's interior of the quasi-stable dark matter candidate in the CPT symmetric universe. The dark matter particle is a 480 PeV right-handed neutrino that decays into a Higgs boson and a light Majorana neutrino. The latter interacts in the Earth's crust to produce a τ lepton that in turn initiates an atmospheric upgoing shower. The fact that both events emerge at the same angle from the Antarctic ice-cap suggests an atypical dark matter density distribution in the Earth.

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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

Derek B. Fox,[1,2,3] Steinn Sigurdsson,[1,3] Sarah Shandera,[4,5,2] Peter Mészáros,[1,4,2,3] Kohta Murase,[4,1,3] Miguel Mostafá,[4,1,3] and Stephane Coutu[4,1,3]
[1] *Department of Astronomy & Astrophysics, 525 Davey Lab, Penn State University, University Park, PA 16802, USA*
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[4] *Department of Physics, 104 Davey Lab, Penn State University, University Park, PA 16802, USA*
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(Dated: September 26, 2018)

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Upgoing ANITA events as evidence of the CPT symmetric universe

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

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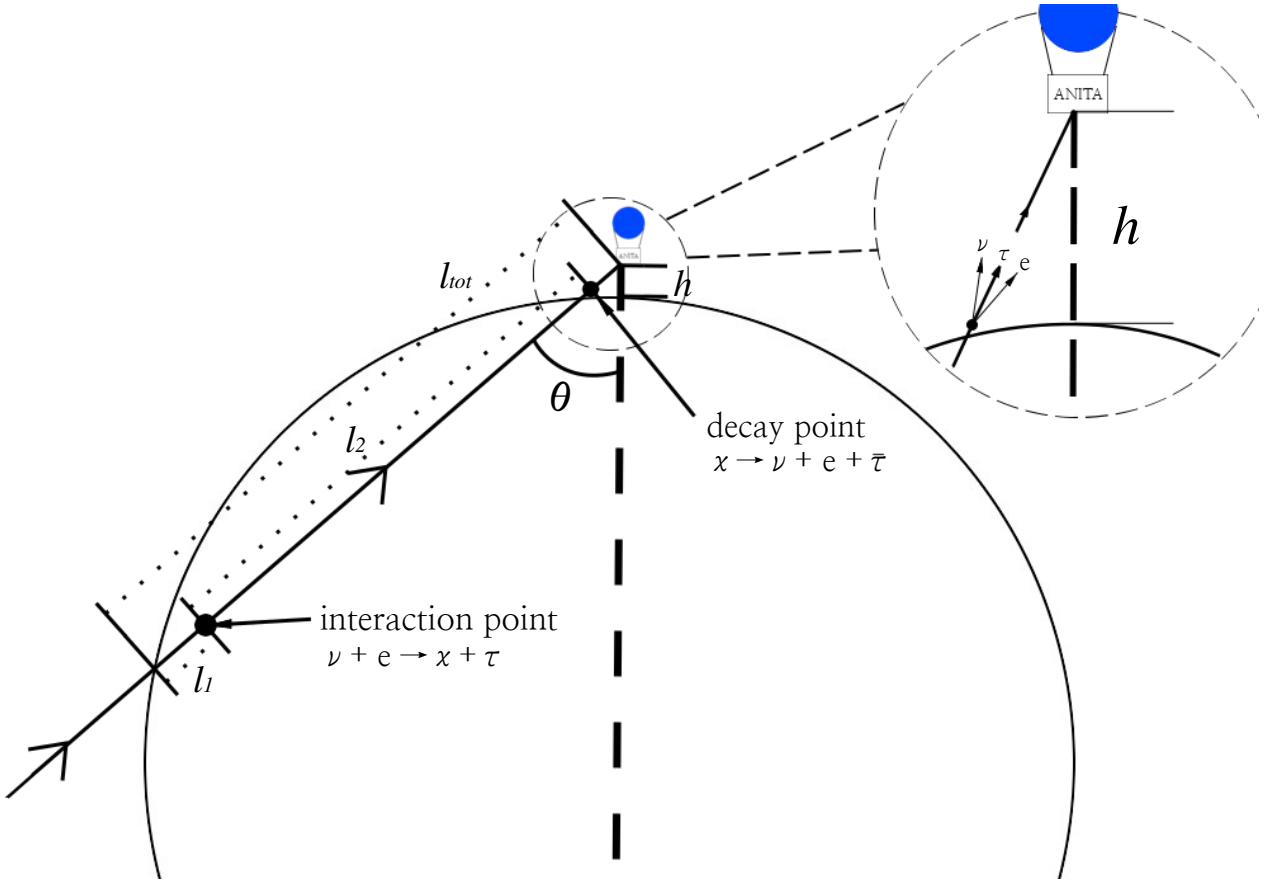

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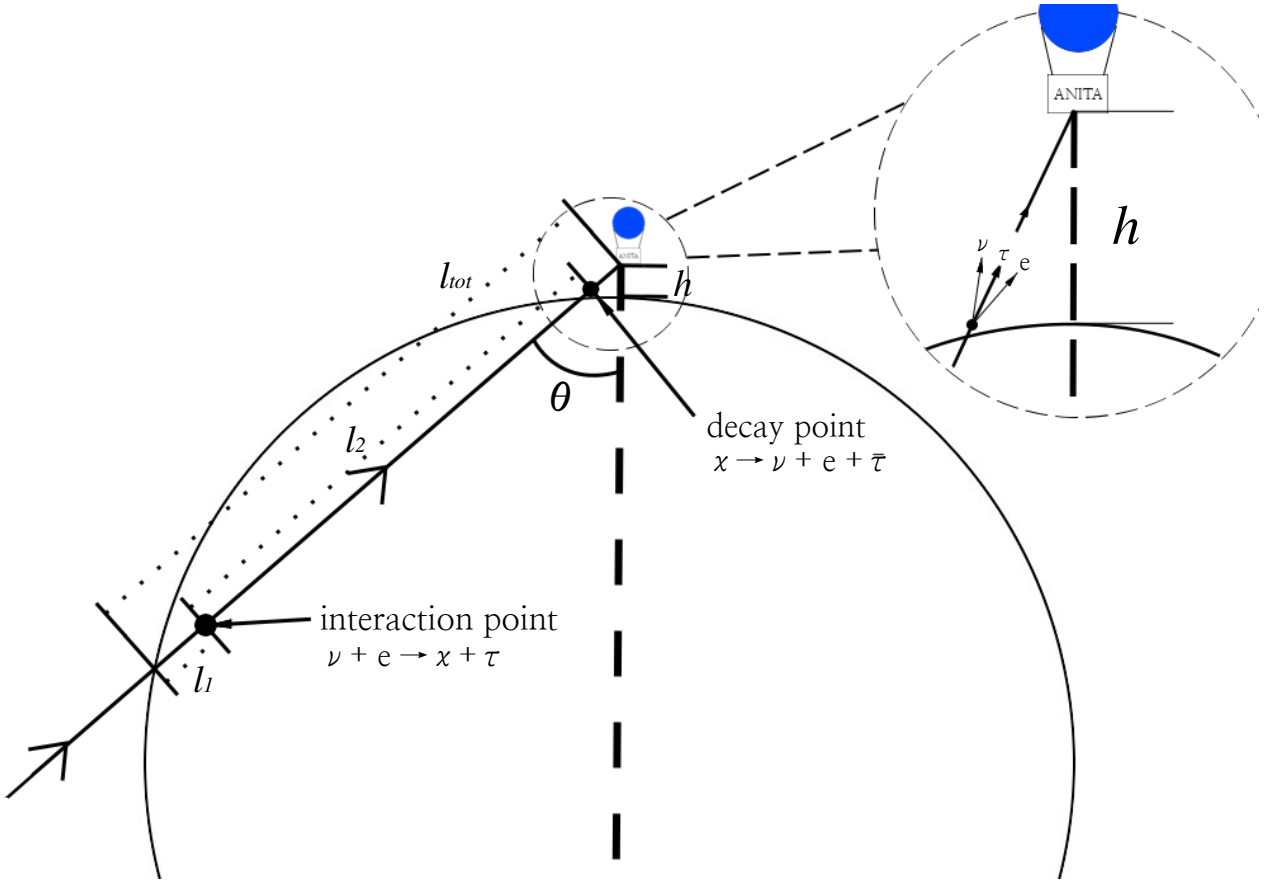

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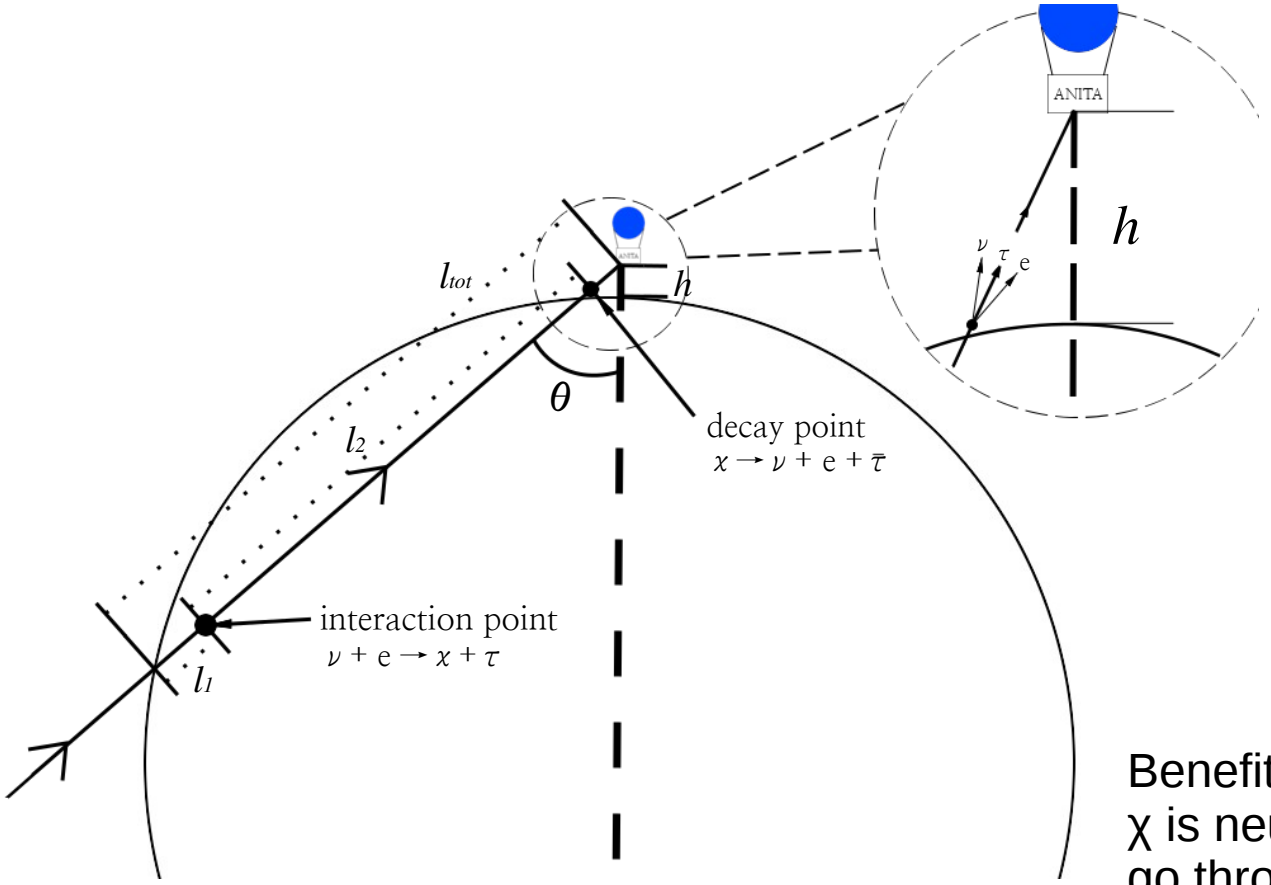

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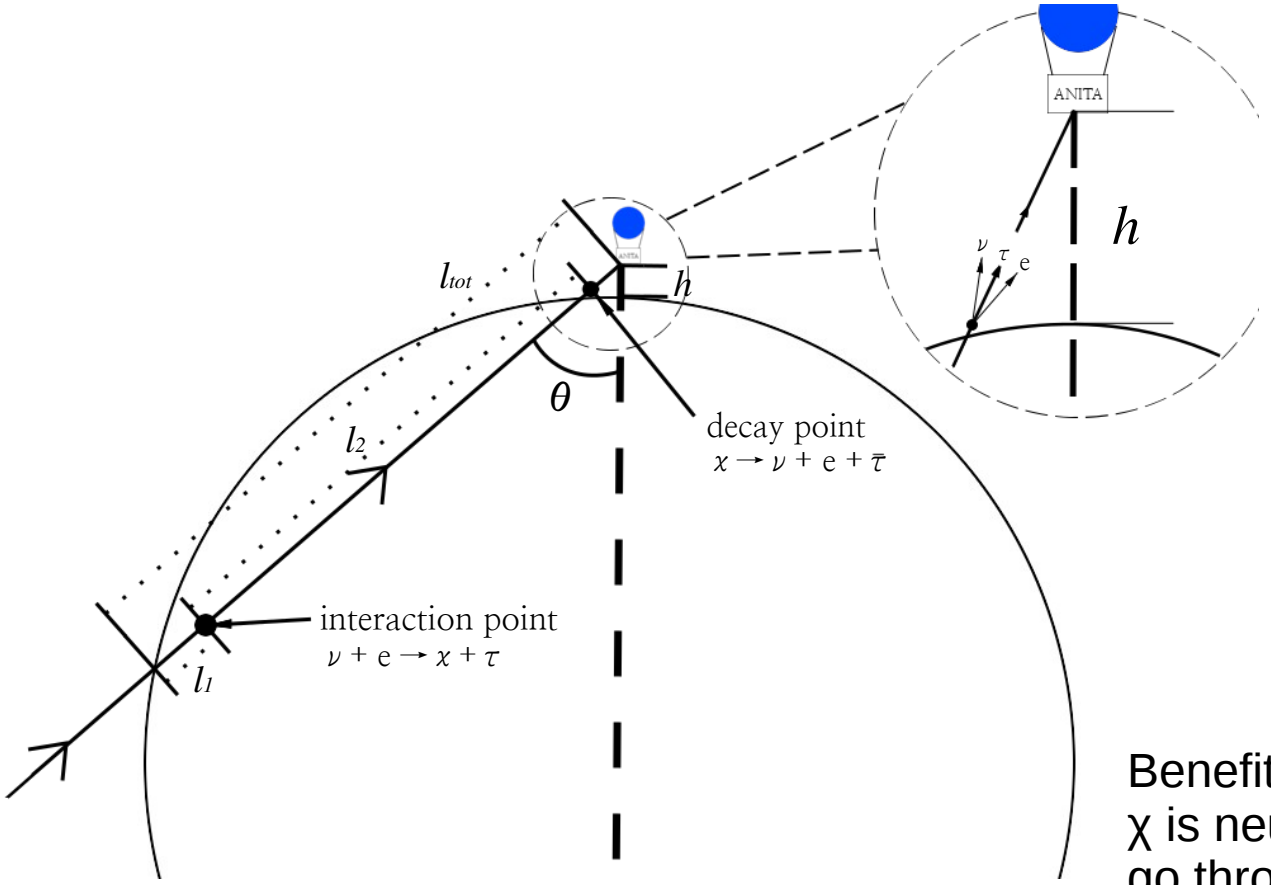

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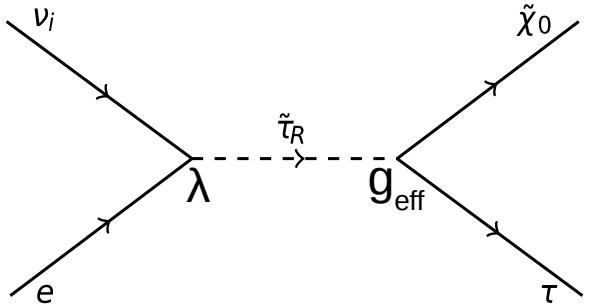

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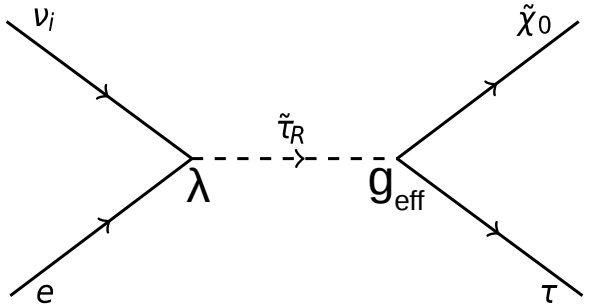

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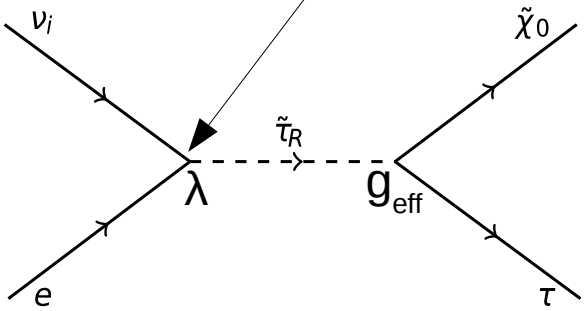

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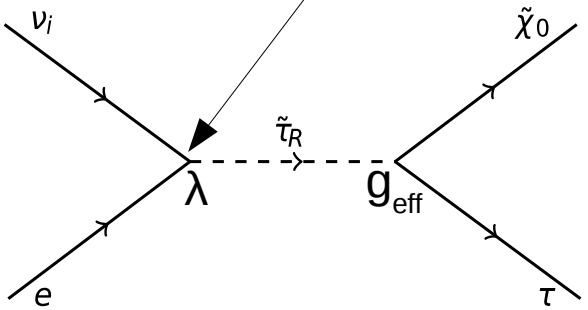

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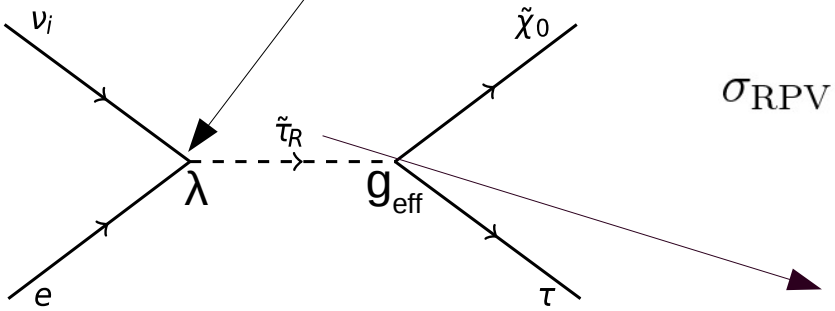

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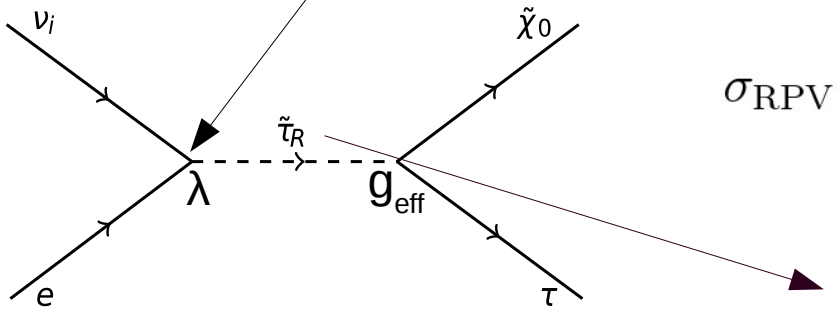

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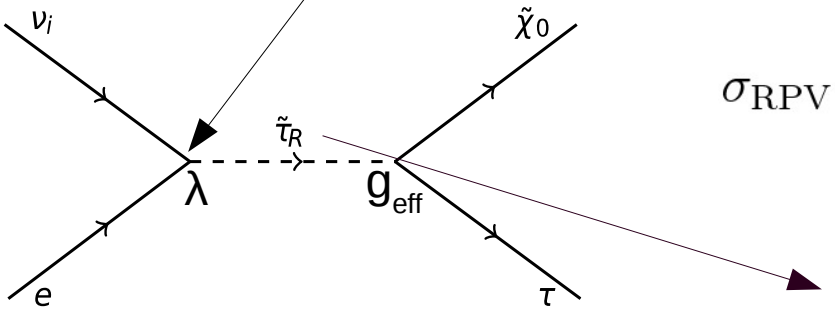
$$W_{RPV} = \lambda_{ijk} L^i L^j \bar{E}^k + \lambda'_{ijk} L^i Q^j \bar{D}^k + \lambda''_{ijk} \bar{U}^i \bar{D}^j \bar{D}^k$$



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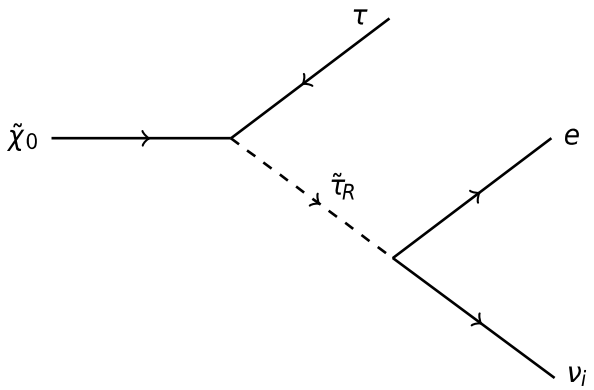
@ resonance, naturally enhancing the cross section

- χ decay



Interaction and Decay

- SUSY RPV term

M. Carena, D. Choudhury, S. Lola, C. Quigg, Hep-ph/9804380;
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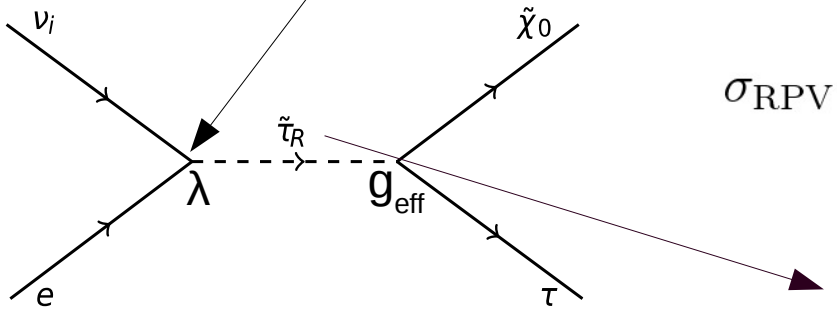

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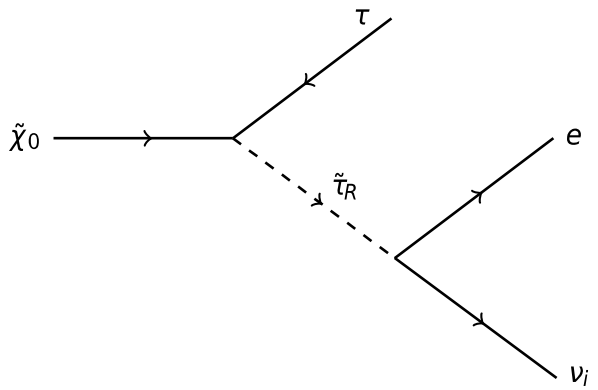

$$\Gamma(\chi \to \tau e \nu) \sim \frac{3\alpha\lambda^2_{i31}}{128\pi^2} \frac{\mathrm{M}^5_{\chi}}{\mathrm{M}^4_{\tilde{\tau}}}$$

Possible sources of ANITA events

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- Isotropic source : GZK~ $10^{-25}\ (\mathrm{GeV}\cdot\mathrm{cm}^2\cdot\mathrm{s}\cdot\mathrm{sr})^{-1}$

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A test for GZK based on ANITA events

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For any general NP process assuming GZK flux:

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$$\mathrm{N_{exp}} > 0.046$$

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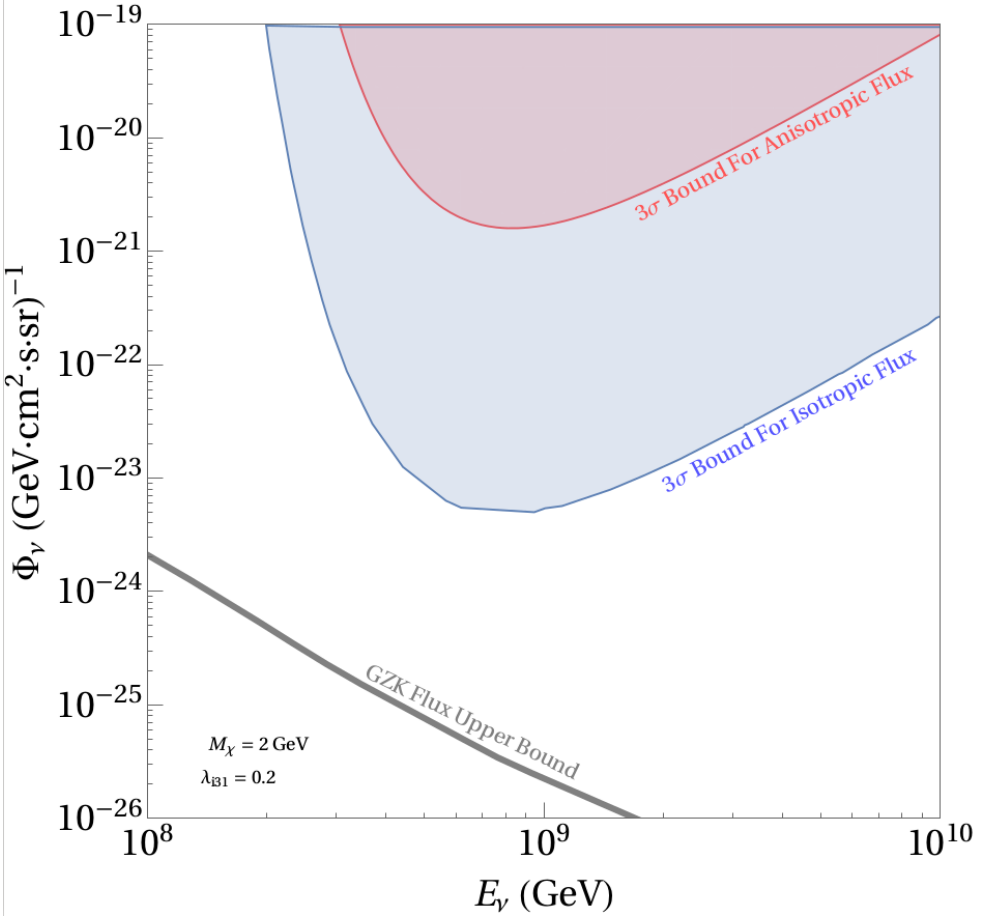

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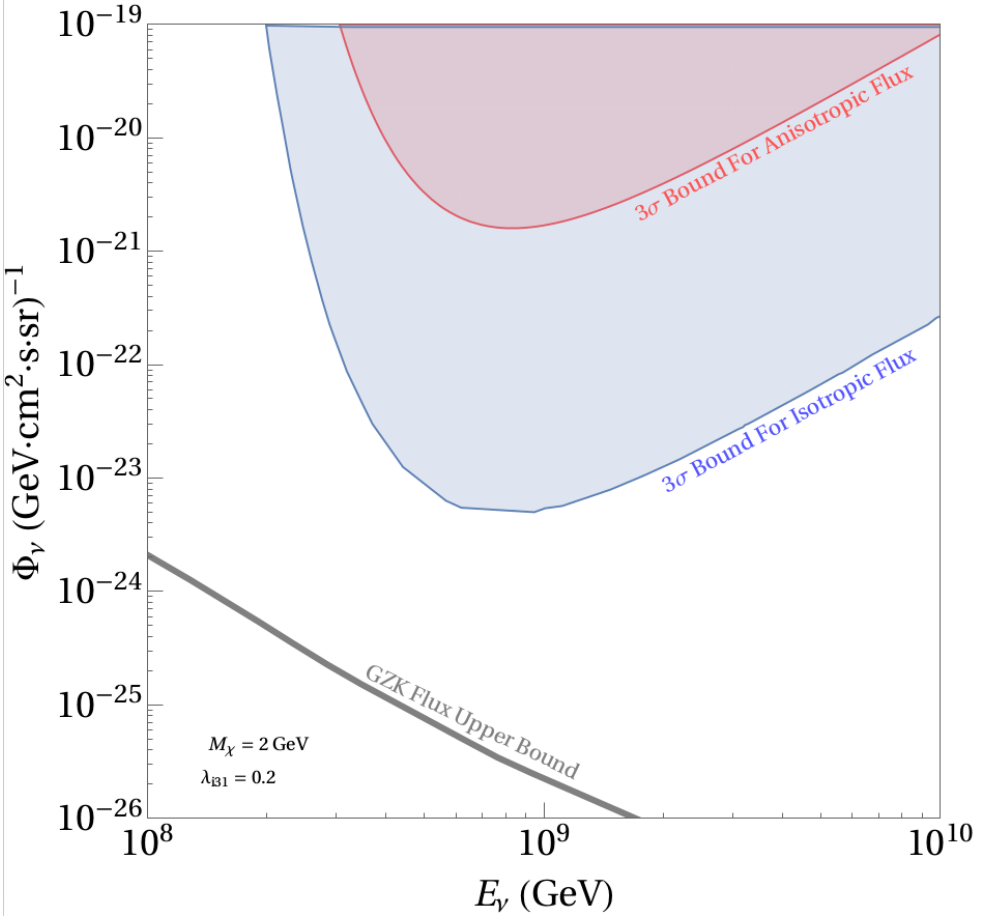

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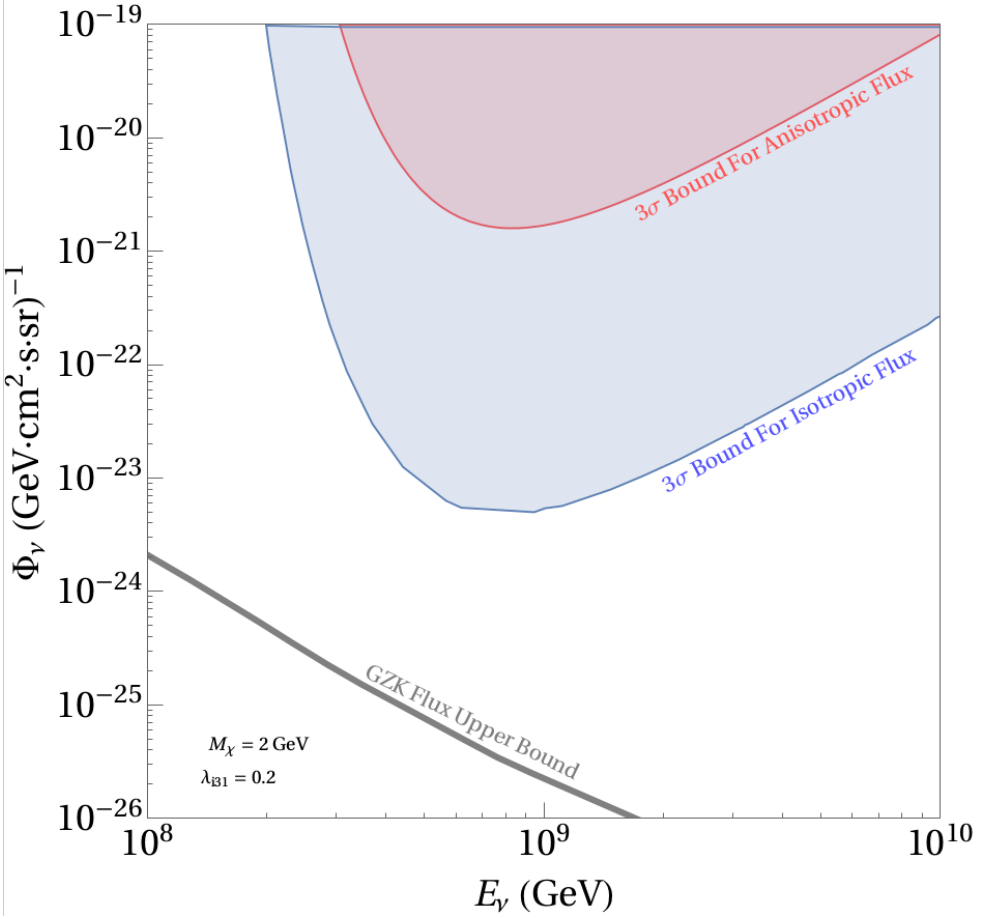

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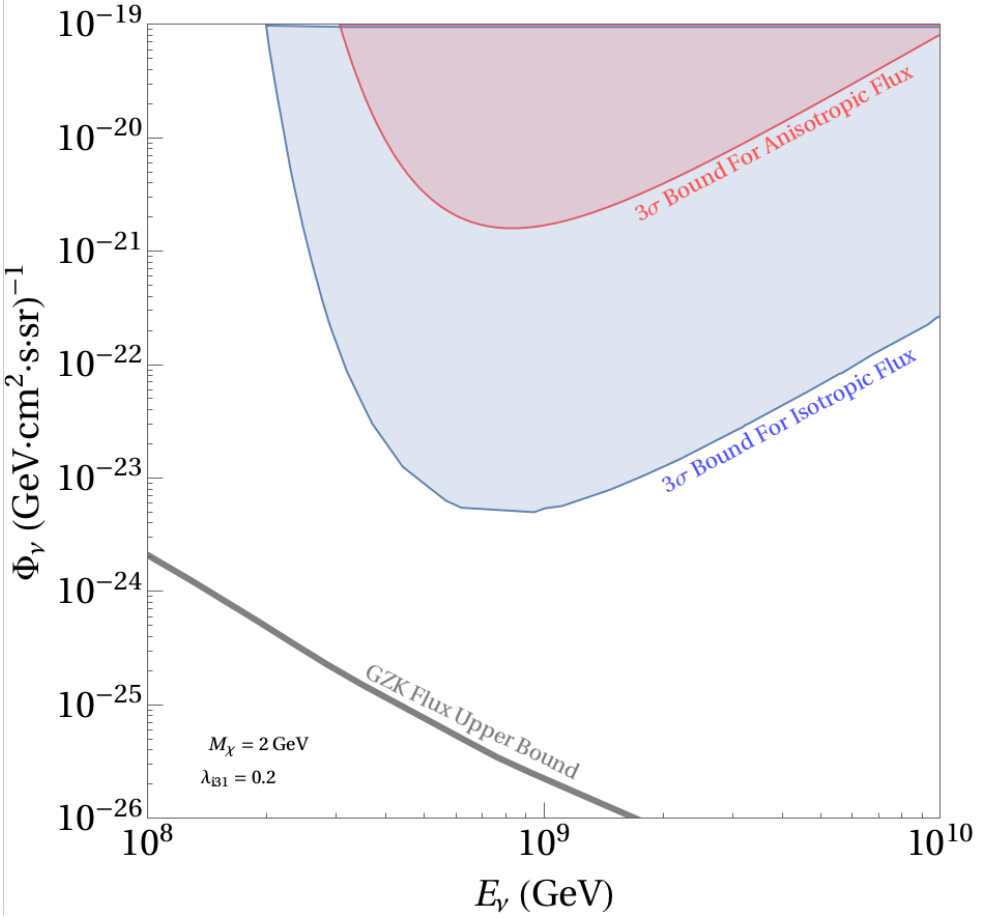
Provide a larger flux and a more direction-focused beam.



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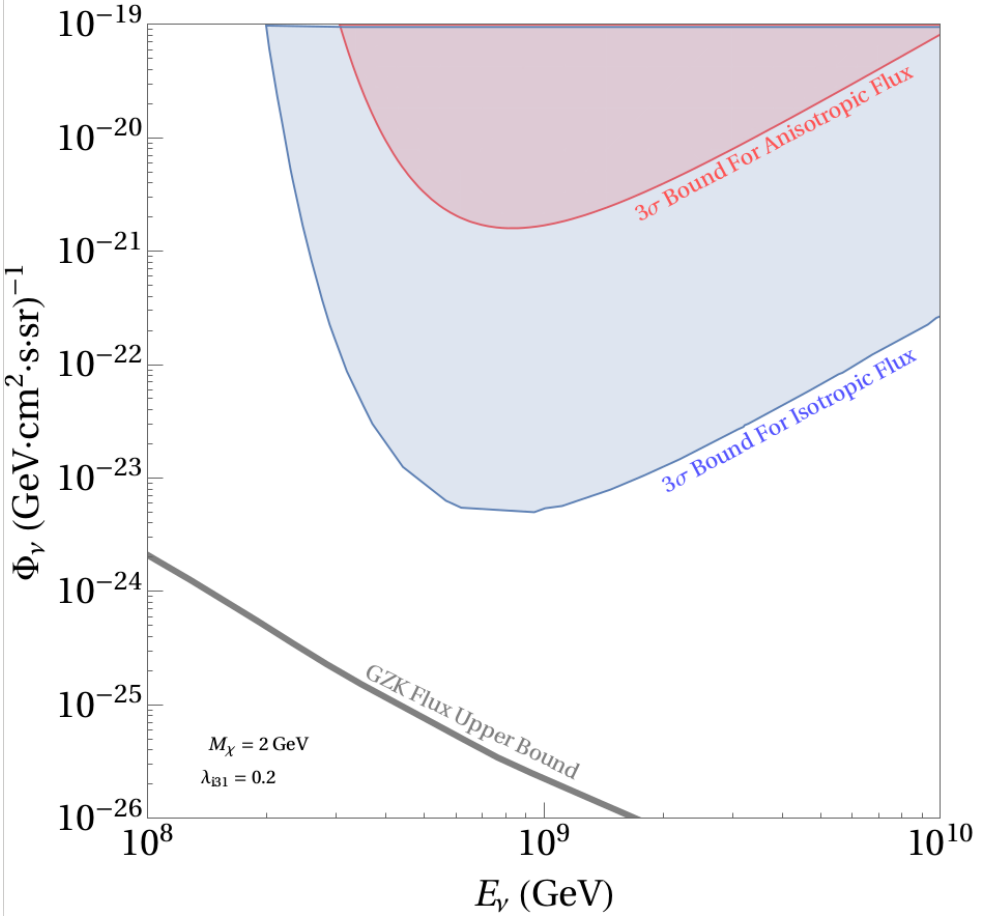
Provide a larger flux and a more direction-focused beam.

Transient source could make IceCube observation time advantage irrelevant.



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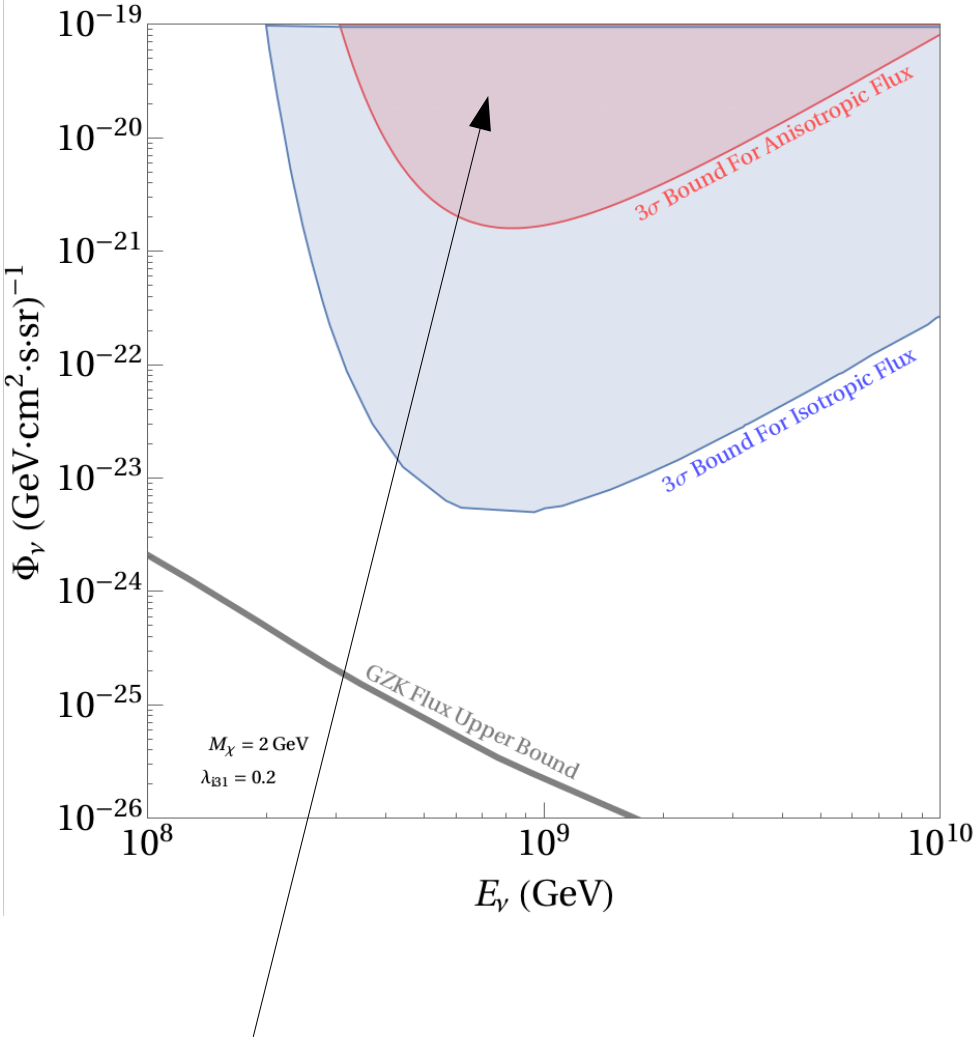

IceCube Collaberation 1609.04981

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

Results

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$$\mathrm{N} = \langle \mathrm{A_{eff}} \cdot \Delta\Omega \rangle \cdot \Delta\mathrm{E} \cdot \mathrm{T} \cdot \Phi_{\nu} \;\&\; \mathrm{N_{exp}} > 0.046 \longrightarrow$$ Event Constraint

Results

$$N = \langle A_{eff} \cdot \Delta\Omega \rangle \cdot \Delta E \cdot T \cdot \Phi_\nu \;\&\; N_{exp} > 0.046 \longrightarrow$$ Event Constraint

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

Results

$$N = \langle A_{eff} \cdot \Delta\Omega \rangle \cdot \Delta E \cdot T \cdot \Phi_\nu \;\&\; N_{exp} > 0.046$$ → Event Constraint

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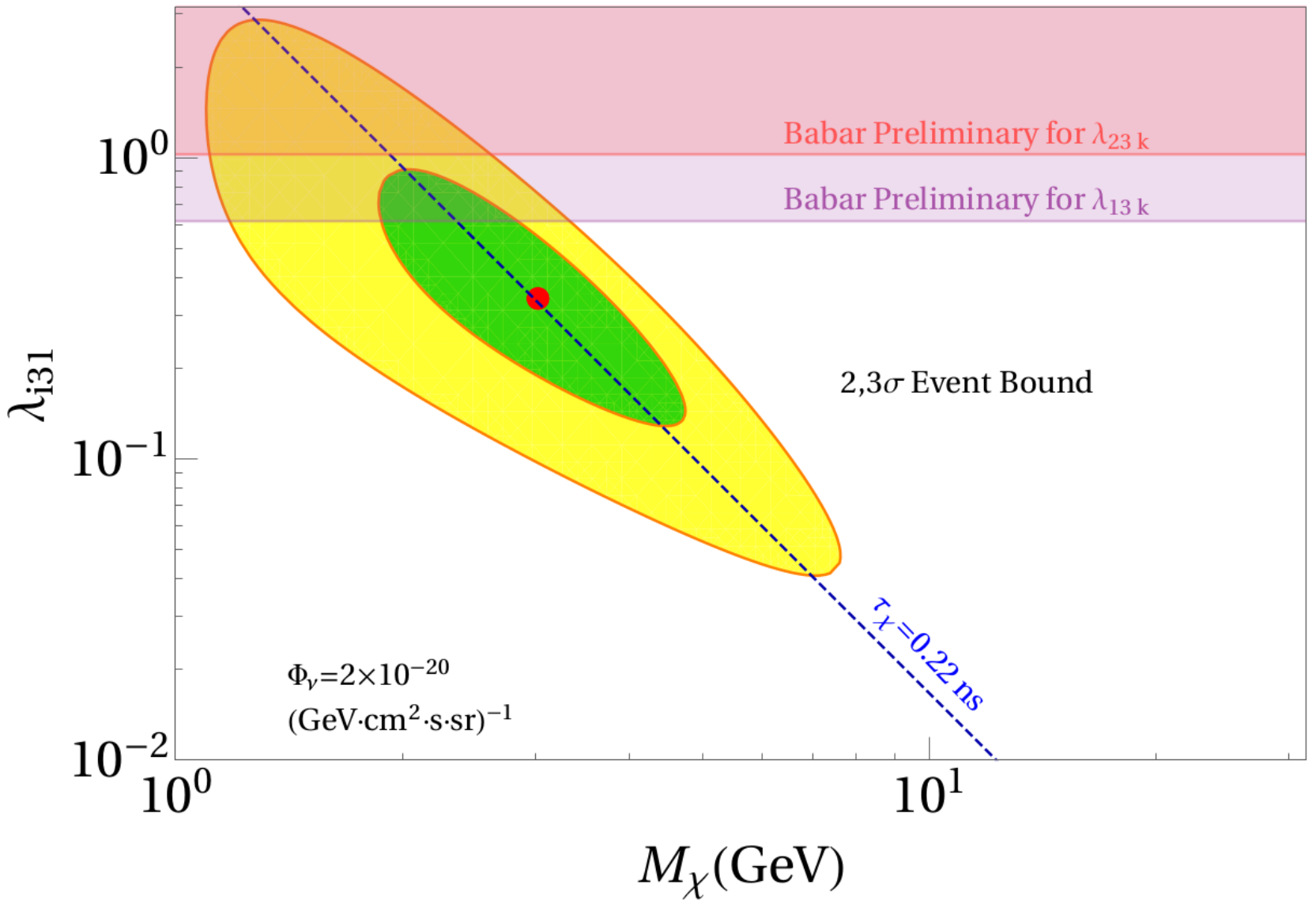


Conclusion

- We propose that bino χ in RPV SUSY could be a suitable interpretation for ANITA events.
- χ should be long-lived with $\tau_\chi \sim 0.219 \pm 0.051$ 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 !

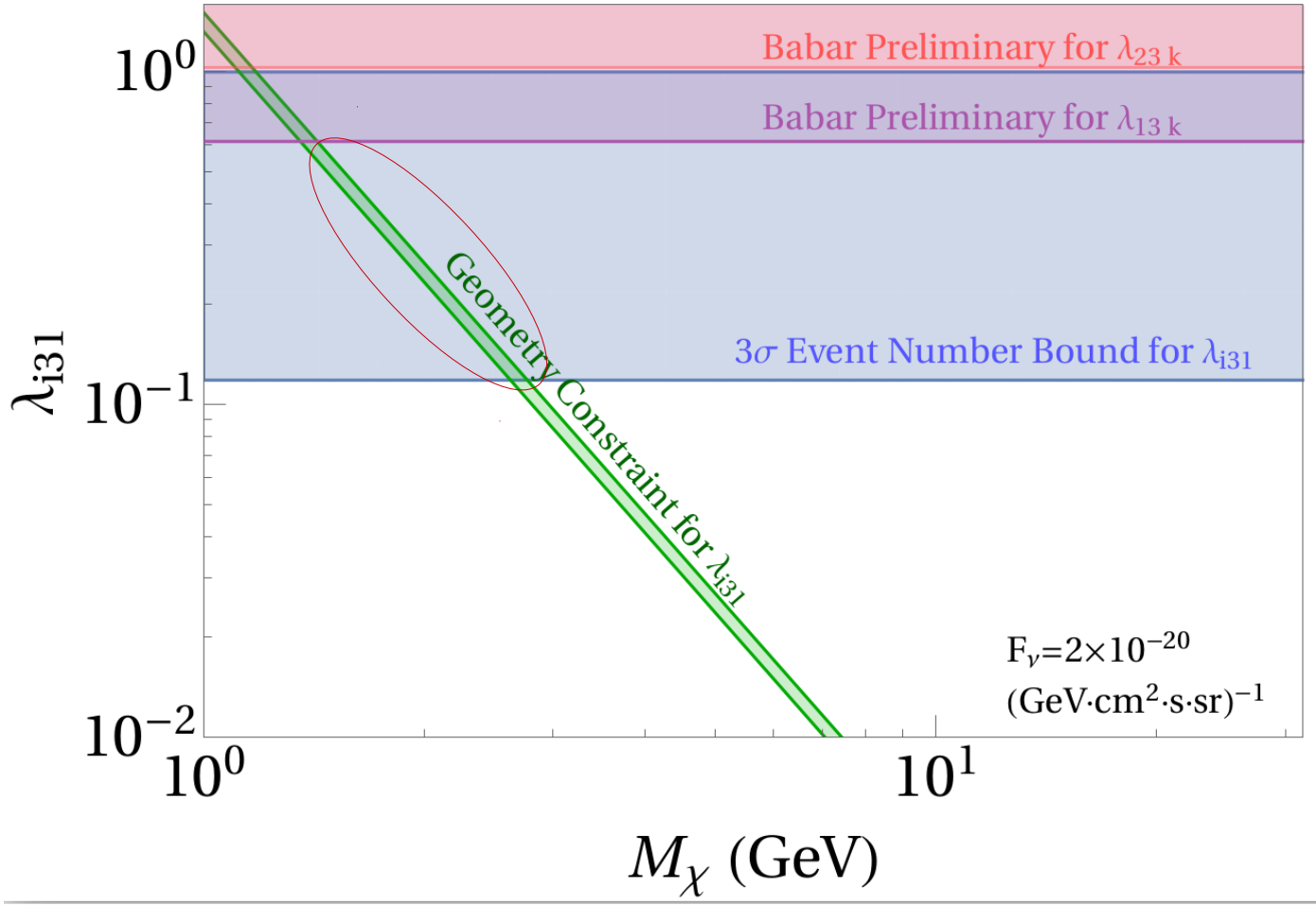
$$N = \langle A_{\text{eff}} \cdot \Delta\Omega \rangle \cdot \Delta E \cdot T \cdot F_\nu$$

→ Anisotropic sources

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

$[0.315, 12.68]$

Event Constraint



Geometry Constraint

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

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

- 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