

Beyond-Standard Model Physics with TAMBO

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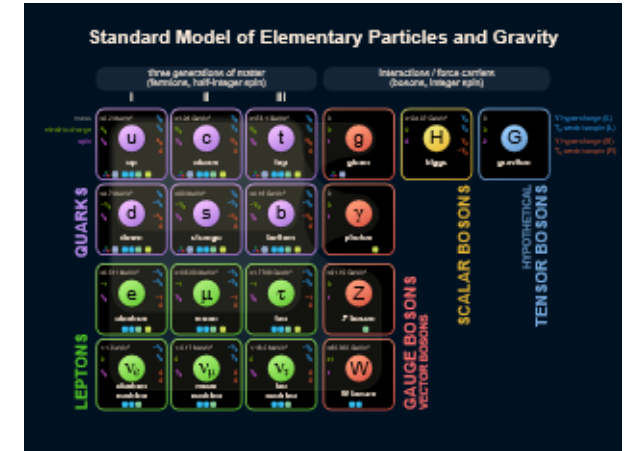
Outline

- Why consider beyond-SM physics at all? And why at TAMBO?
- A birds-eye view of previous BSM work on astrophysical neutrinos (necessarily incomplete).
- A few examples - what has been done previously, and what could or could not be done with TAMBO.



Why Consider beyond-Standard Model Physics at all?

- Unresolved puzzles in Standard Model. For example:
 - Neutrino mass mechanism?
 - Why are neutrino masses so small / why the mixing angles?
 - Nature of dark matter / any connection w/ neutrino physics?
- High-energy astrophysical neutrinos can probe energy scales inaccessible at accelerator experiments.

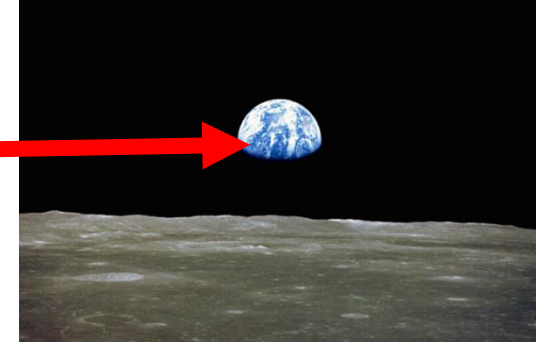


How could BSM physics affect observations of astro neutrinos?



Modifying
spectrum or rate
at source.

Modifying
spectrum during
propagation.



Modifying
spectrum at
detection, or
anomalous
detector signal.

- Many works look at one or more of these in relation to e.g. IceCube data.

For instance: Bustamante, Rosenstrom, Shalgar, Tamborra arXiv:2001.04994; Esteban, Gago, Gonzalez-Garcia, Zapata arXiv:2605.13955; Esteban, Pandey, Brdar, Beacom arXiv:2107.13568; Maitra, Arguelles, Dev, Martinez-Soler, Sen arXiv:2605.19723; Palomares-Ruiz, Vincent, Mena arXiv:1502.02649;

Which types of models are most relevant to TAMBO?

Can affect flavor ratio
(see Mauricio's talk).

Modifying
spectrum or rate
at source.

Typically affects spectrum,
so harder to do with few
signal events.

Modifying
spectrum during
propagation.

However, probably
computationally cheaper
than other category –
sensitivity and data can be
analyzed by appropriate
reweighting of MC.

Anomalous events (either
rate or morphology) can still
stand out easily with low
event rate.

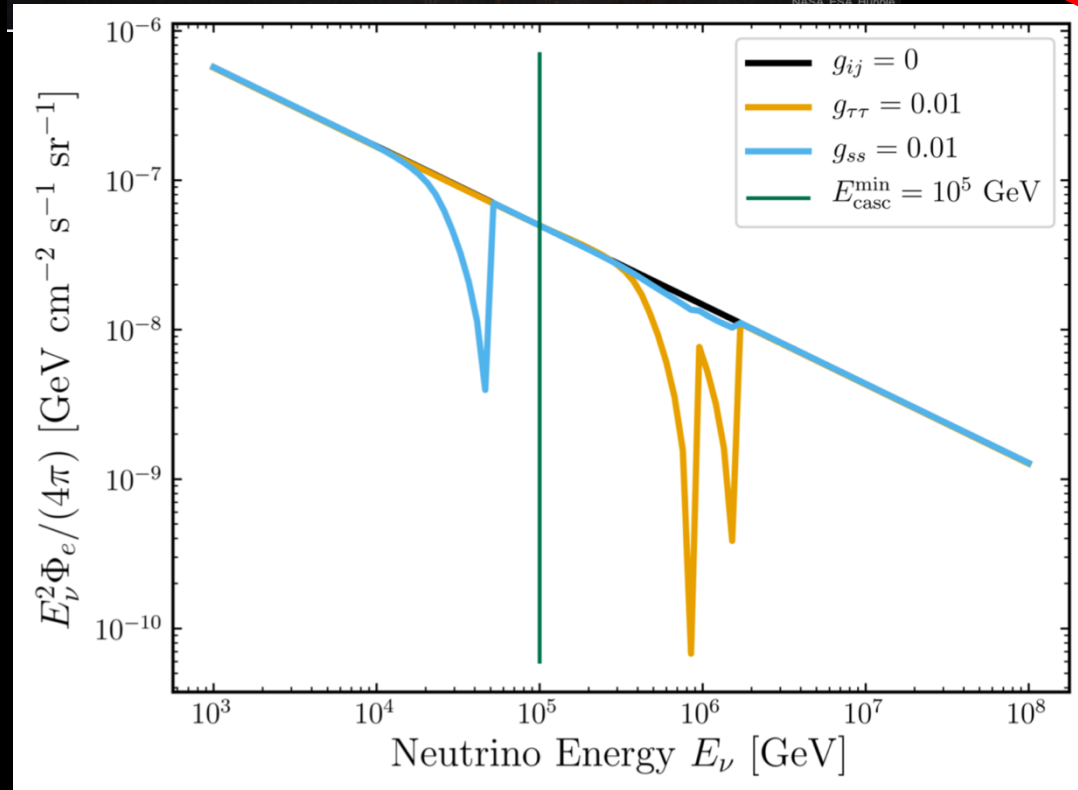
Modifying
spectrum at
detection, or
anomalous
detector signal.

But would require more in-
depth analysis beyond
reweighting MC.

Neutrino Self-Interactions

Scattering off of relic neutrinos would affect the flux spectrum at Earth.

$$E_R = m_\phi^2 / (2m_\nu)$$

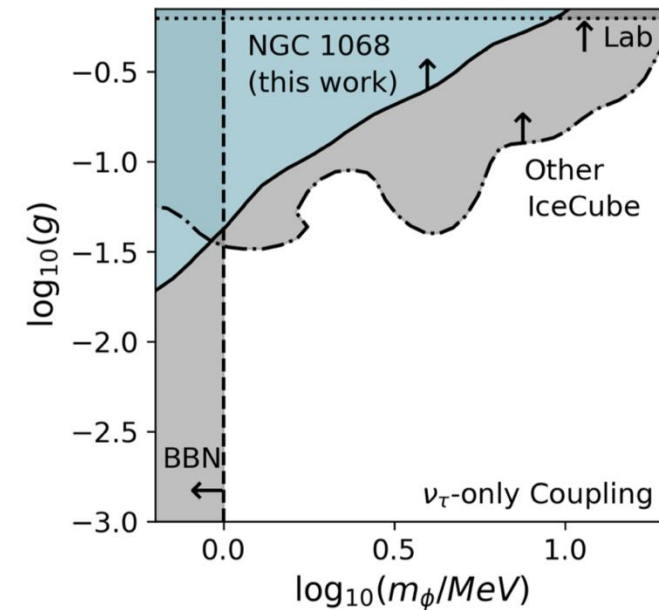
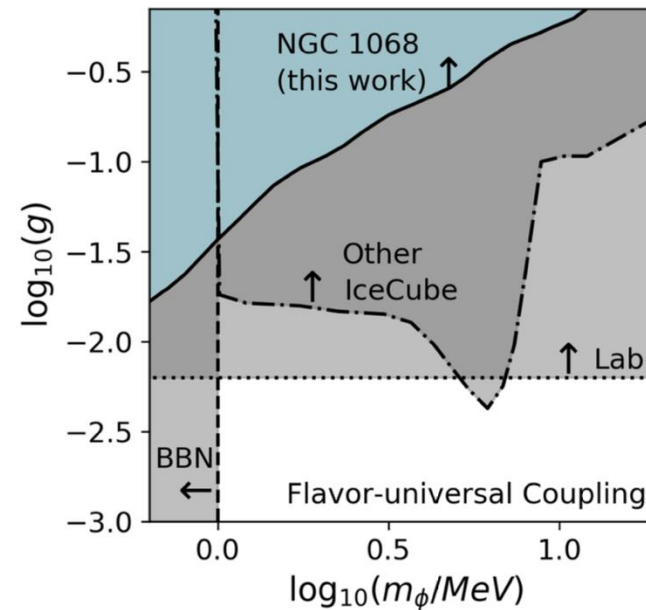
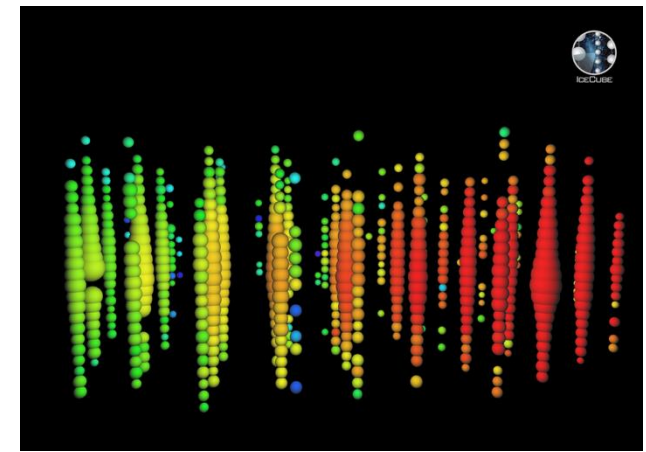
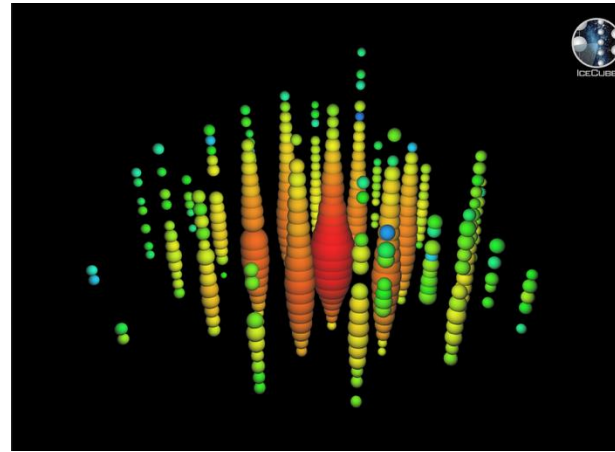


Lots of people have thought about this;
Starting w/ Kolb & Turner re: SN 1987a

← From work w/ Cyril Creque-Sarbinowski & Marc Kamionkowski
CCS, JH, MK, Phys. Rev. D 103, 023527, arXiv:2005.05332

Neutrino Self-Interactions

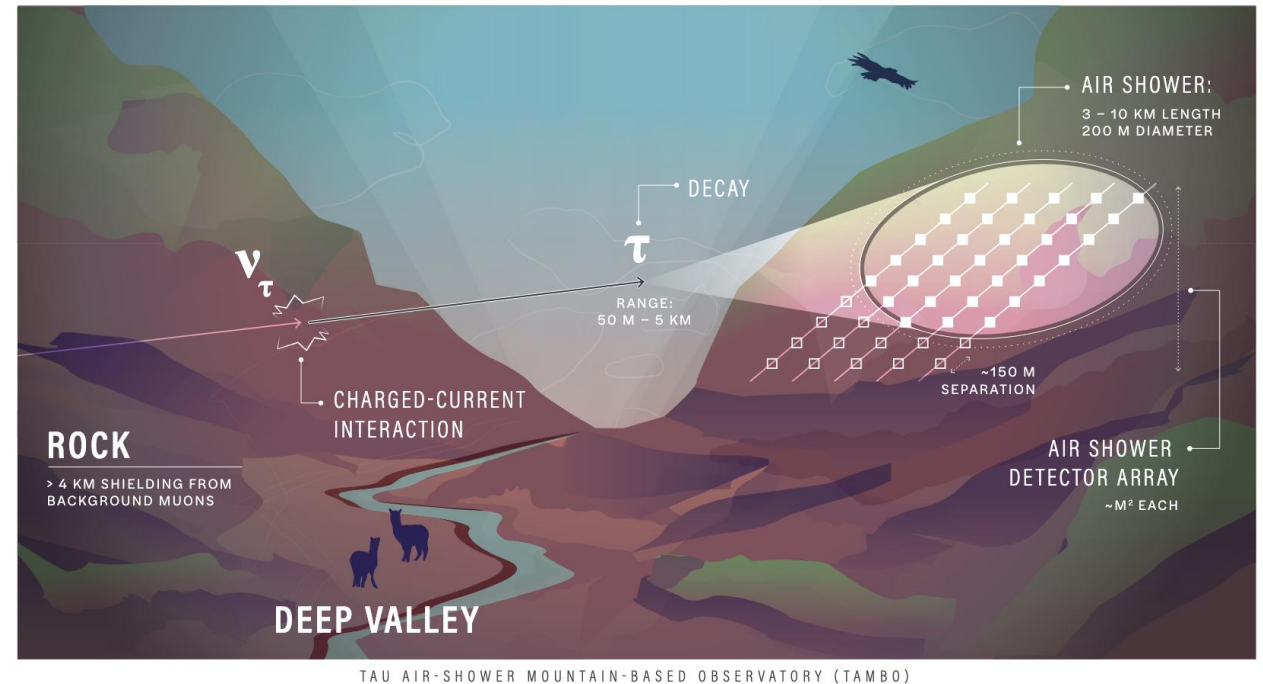
- Point sources:
 - Known (hopefully) distance.
 - Track events have better pointing but worse knowledge of neutrino energy.
 - Many background events.
- Diffuse flux:
 - Unknown source distance – have to make assumptions about source distribution.
 - Mix of track and cascades – cascade events have better knowledge of neutrino energy.



JMH, 2307.02381 + upcoming work w/ student
 “Other IC” curve from Bustamante et al, 2001.04994

How could TAMBO help?

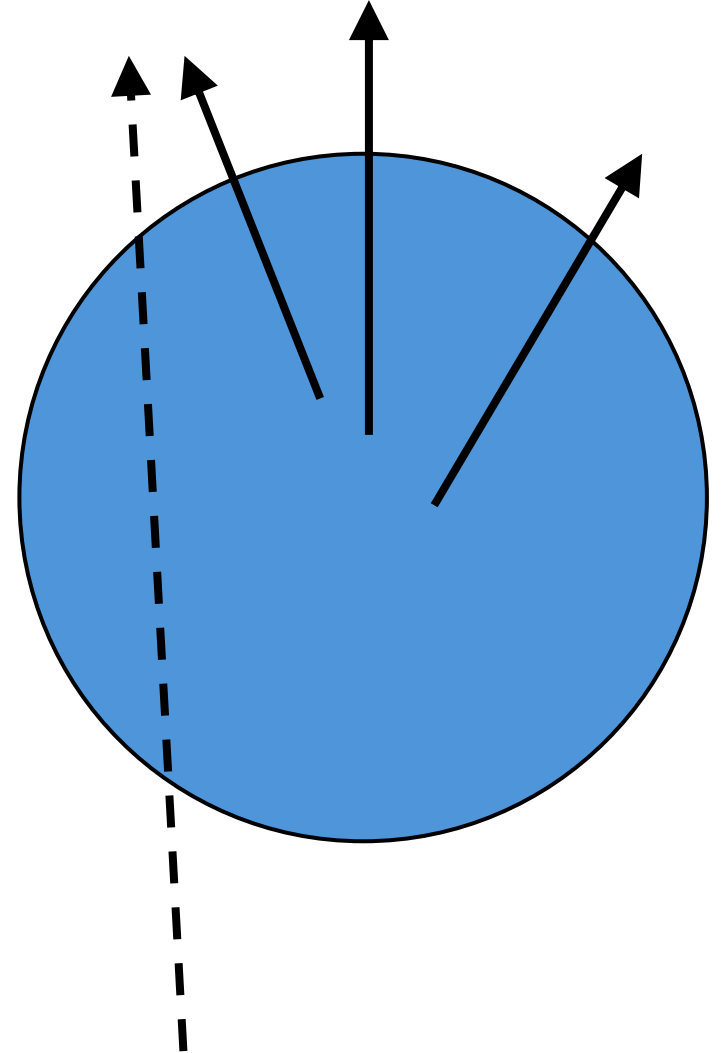
- In a vacuum:
 - Low statistics, but e.g. a single event much higher than PeV, in coincidence with flaring blazar, could potentially still add constraints.
- In connection with other data:
 - TAMBO can help identify other point sources (see Ali's talk) --> there could be observed events which we are not currently using due to low significance of source.
 - Additional events beyond energies observed by IceCube add significance in a parameter space region that hasn't been touched.



Understanding constraints from individual TAMBO events should be doable with just re-weighting Monte Carlo results from TamboSim.

Other Models

- Anomalous Earth-emerging particles – e.g. from ideas proposed in response to ANITA anomalous events.
 - Lower backgrounds
- New physics that affects the signature observed by TAMBO, e.g. air shower development.
 - Could be more uniquely suited to TAMBO capabilities with lower backgrounds and higher energy.
 - Analysis and detection requires more in-depth simulation and trigger work.



Summary

- There are many BSM models, and how they affect TAMBO observations depends quite a bit on how the new physics comes into play.
- There is also a worthwhile consideration about TAMBO's specific sensitivity to some model, versus its value in identifying point sources in connection with data from other experiments.
- In the case of distorted neutrino spectra, even a few TAMBO events could potentially be useful – worth investigating further.

Model dependence of diffuse flux analysis

