$\chi arov$: a tool for neutrino flux generation from WIMPs

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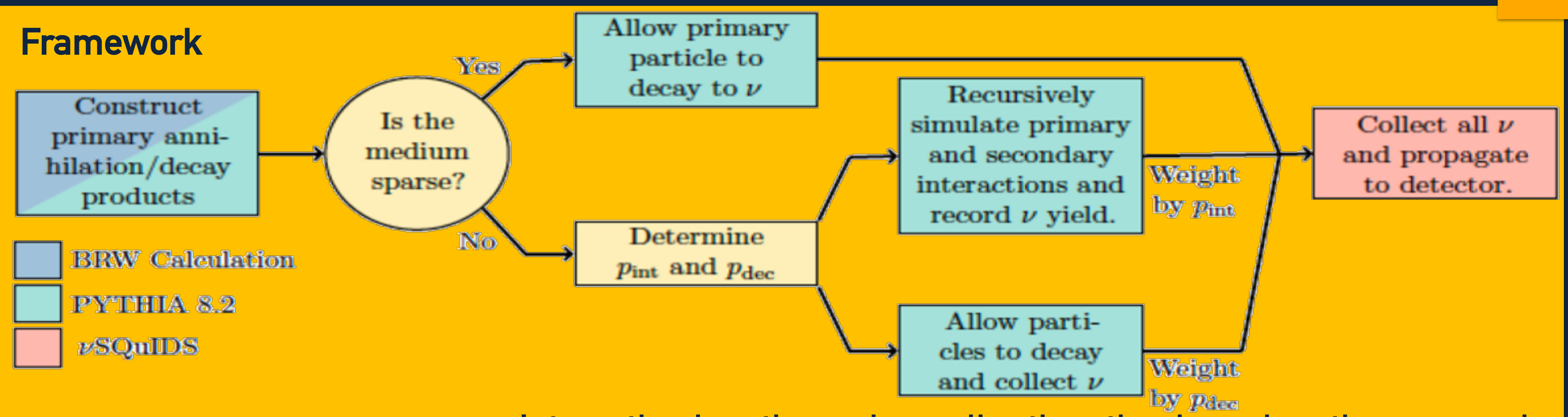
$\chi arov$ is a new flexible tool to generate neutrino fluxes aiming for searches of WIMP annihilation/decay from both Halos and dense sources like the Sun and the Earth. This package is coupled to a new calculation of electroweak interactions [1] which includes processes missing in PYTHIA [2]. Besides the standard case, it also includes the possibility of a secluded dark matter sector which introduces a long-lived mediator. We want to have an organized and comprehensive software flexible for users to compute neutrino flux for different goals.

Introduction

- Indirect detection which detects Standard Model (SM) particles produced by dark matter annihilation/decay is an important piece of current approaches searching for the dark matter.
- Stable particles from astrophysical sources are messengers of these indirect signals.
- Among messengers used in indirect searches for dark matter, neutrinos are special as they are neutral, light, and seldom interact. These unique properties give them advantages in astrophysical studies: they are advantageous over cosmic rays as they can point back to their sources and win over gamma rays as they can exit environments of large matter and radiation densities. It is important to have a tool to generate the fluxes efficiently and accurately.

Production

Framework



Add electroweak (EW) treatment which is missing in PYTHIA after the mass reaches the EW scale.

- Interaction length much smaller than the decay length, same as in vacuum. Interaction length comparable to the decay length, weight whether the particle decays or interacts.
- Long-lived particles can be stopped or absorbed completely in dense environments. , e.g. pions, kaons, muons, neutrons.

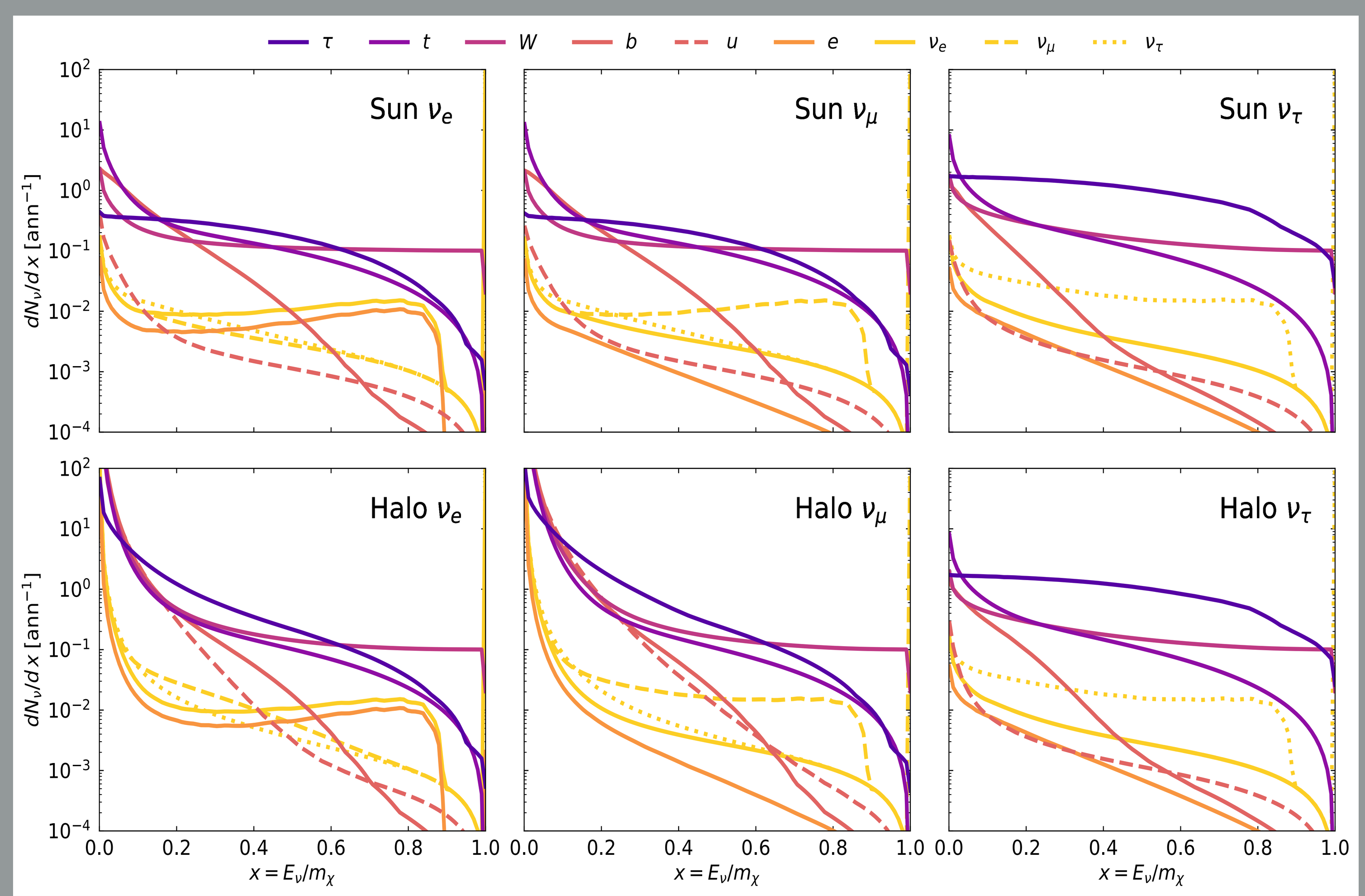


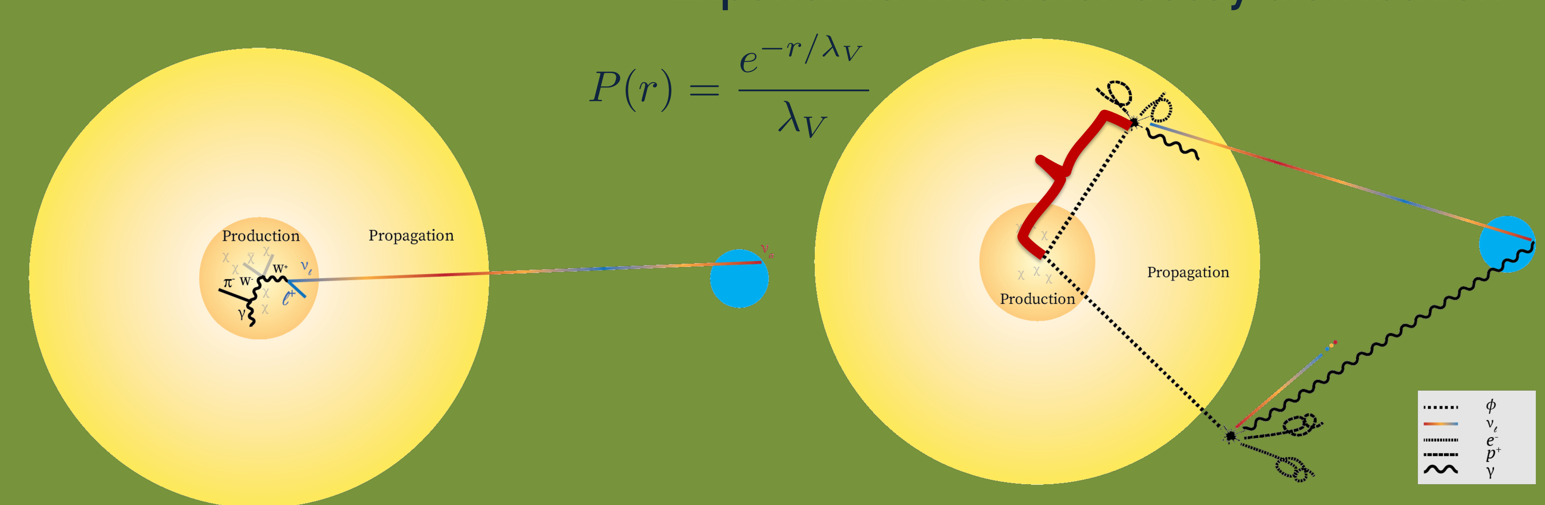
Figure 1

- Self-annihilation spectra at production of several channels when the dark matter mass is 1 TeV.
- EW corrections and polarization averaged states are included. For the case of Sun, production is assumed at the Sun center. Interactions and absorptions at production are included.

Propagation

Exponential mediator decay distribution

$$P(r) = \frac{e^{-r/\lambda_V}}{\lambda_V}$$



Standard scenario
Both annihilation and SM particle production happen at the central region.

Secluded scenario
Annihilation happens at the central region while SM particles are produced somewhere else.

- nuSQuIDs is an efficient solver of the neutrino propagation equation both in vacuum and in a given medium.
- In matter, chemical composition is considered to account for fractions of protons and neutrons. Isoscaler approximation, which assumes equal number of protons and neutrons is also applicable.
- **$\chi arov$** is also flexible to propagate external input of spectra at production, as well as read external cross section files for neutrino interactions.

nuSQuIDs [3] for propagation

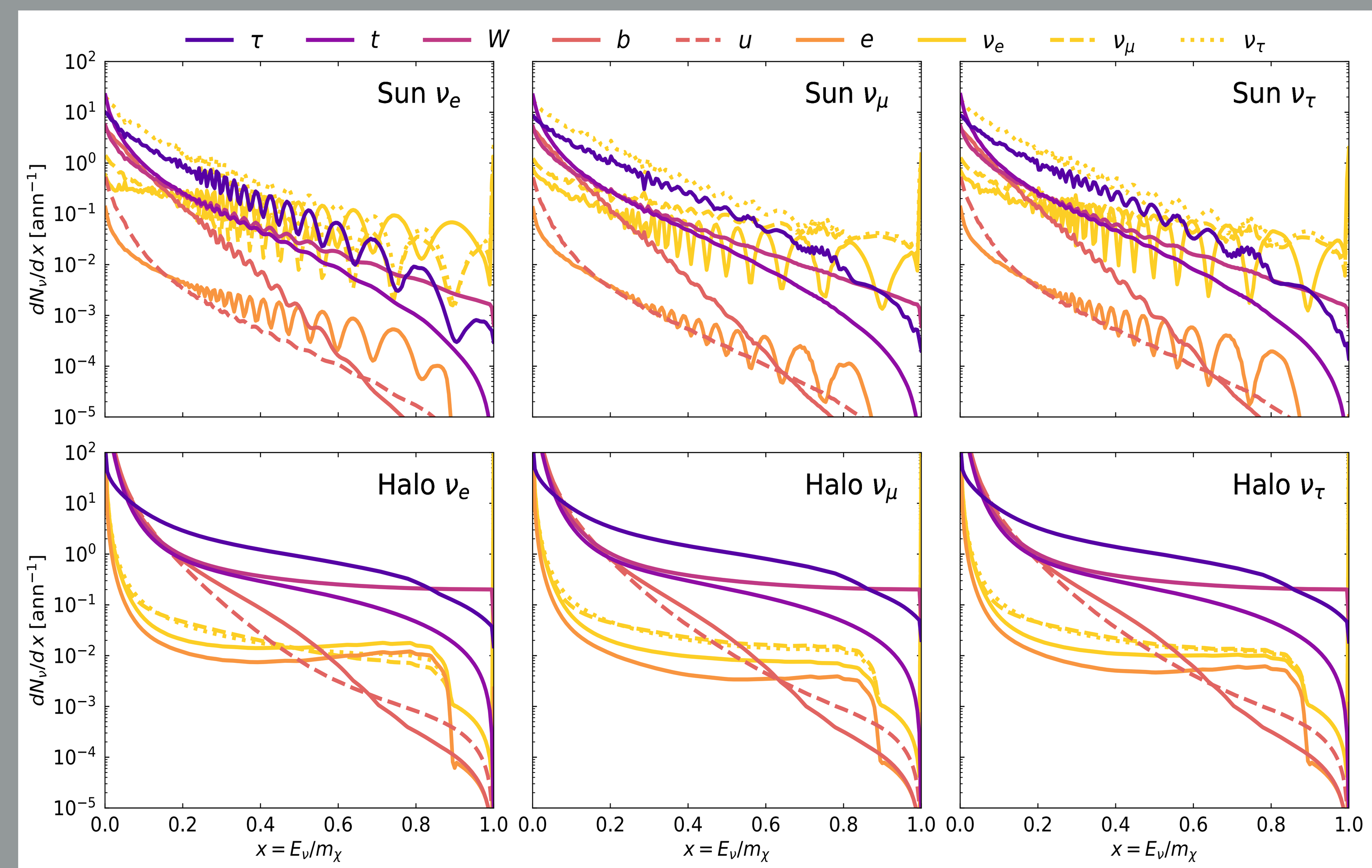


Figure 2

- Annihilation spectra for the standard scenario at detector after propagation of different channels when the dark matter mass is 1 TeV.
- The spectra for neutrinos from the Sun have zenith angle 30 degree. When $m_\chi \gtrsim 10$ TeV there is large attenuation of neutrinos in Sun, like other messengers.

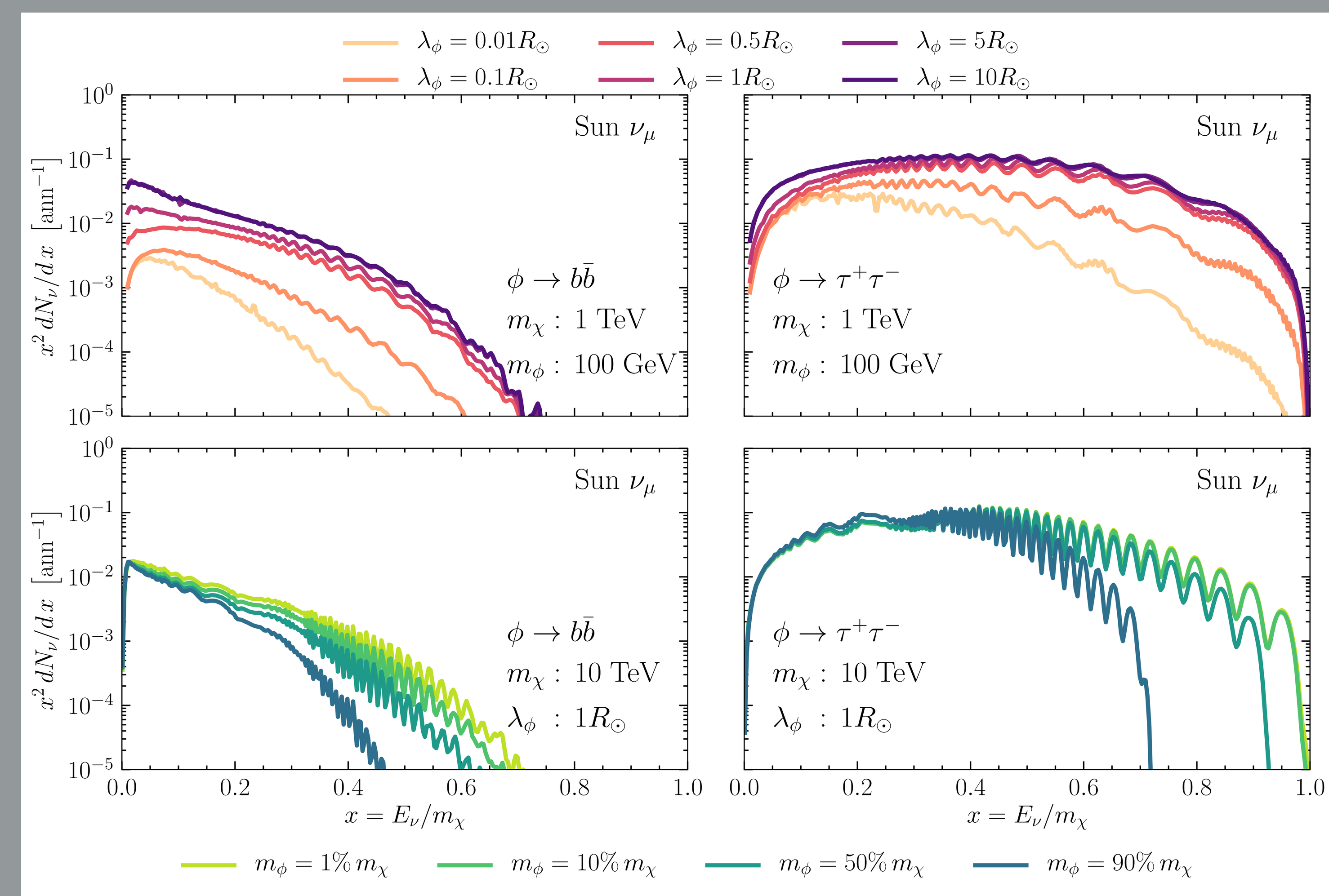


Figure 3

- Spectra of self-annihilation with a long-lived mediator with varying decay length and mediator mass at 1 AU.
- As the lifetime of the mediator increases, an enhanced signal can be obtained for less propagation in dense matter which introduces attenuation.

Notes

- PYTHIA version 8240
- nuFIT 5.0 oscillation parameters are used for plots shown here.

References

[1] C. Bauer, N. Rodd, B. Webber. *arXiv:2007.15001*
[2] T. Sjöstrand., et al. *Computer physics communications* 191 (2015): 159-177.
[3] A. Argüelles, J. Salvado, and C. Weaver. https://github.com/arguelles/nuSQuIDS