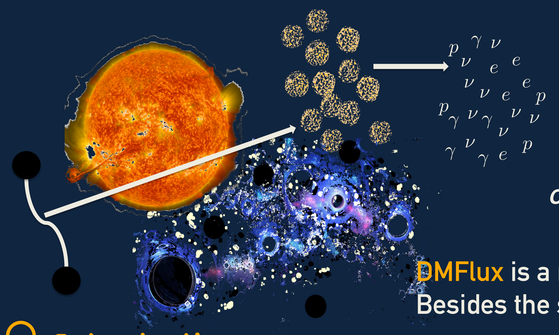
DMFlux: a tool for neutrino flux generation from dark matter annihilation and decay



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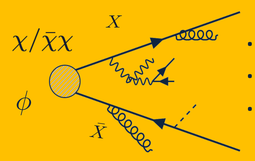
DMFlux is a new flexible tool to generate neutrino fluxes aiming for searches of dark matter annihilation/decay from both Halos and dense sources dependent on PYTHIA and nuSQuIDs. Besides the standard case, DMFlux also includes the possibility of a secluded dark matter sector which introduces a long-lived mediator.

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 unlike gamma rays can exit environments of large matter and radiation densities. It is important to have a tool to generate the fluxes efficiently and accurately.

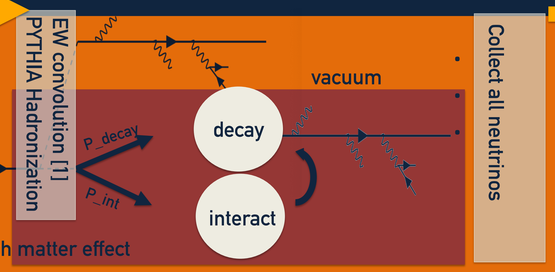
Production

Initial state radiation with EW correction

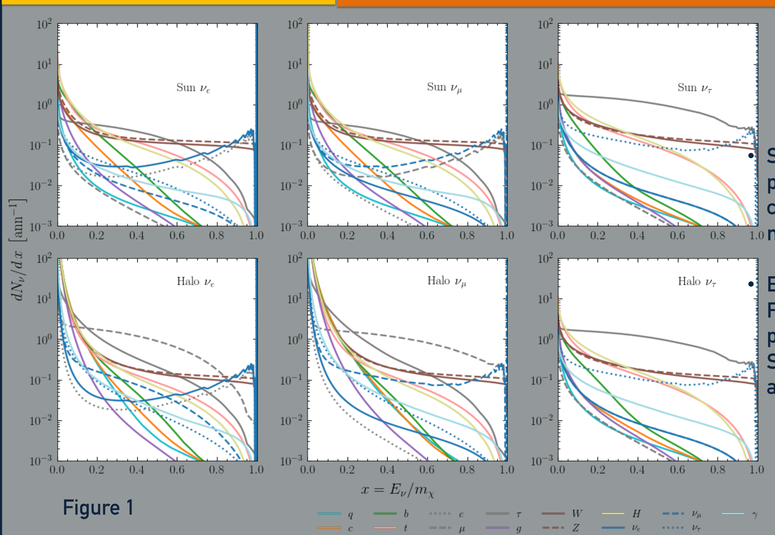


Add electroweak (EW) treatment which is missing in PYTHIA after the mass reaches the EW scale. The correction used is from [1].

Collect all particles and feed to PYTHIA[2]



- 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, e.g. c/b mesons.
- Long-lived particles are stopped or absorbed completely, e.g. pions, kaons.



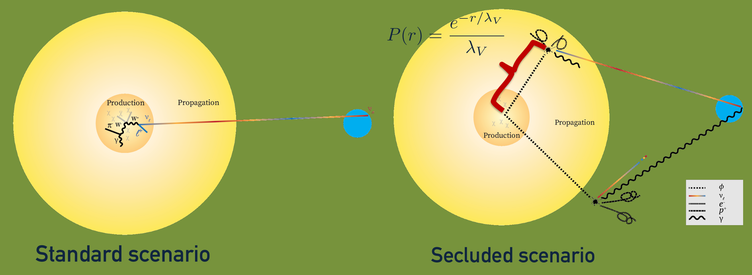
Self-annihilation spectra at production of different channels when the dark matter mass is 10 TeV.

EW correction is included. For the case of Sun, production is assumed at the Sun center, interactions and absorptions are included.

Figure 1

Propagation

Exponential mediator decay distribution



Standard scenario

Both annihilation and SM particles 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.
- DMFlux 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

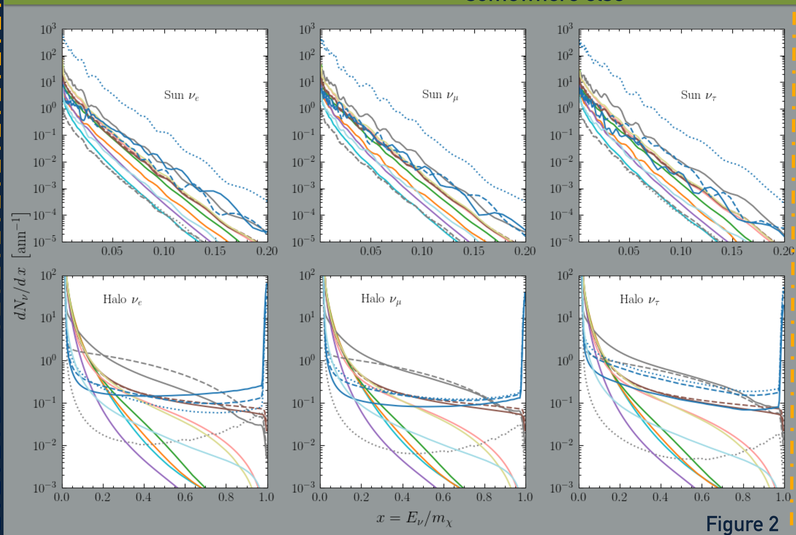
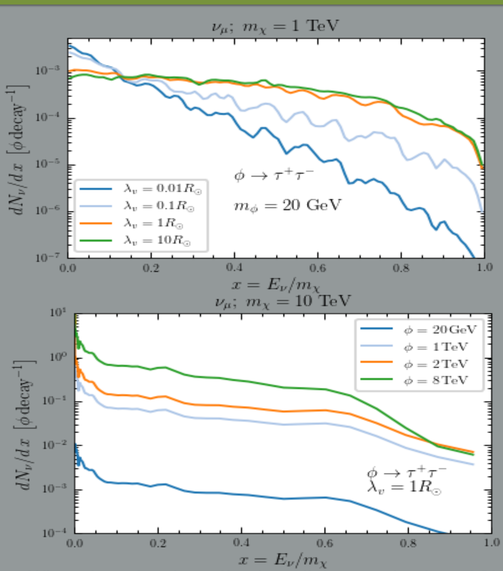


Figure 2

- Self-annihilation spectra for the standard scenario at detector after propagation of different channels when the dark matter mass is 10 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.
- The spectra for dark matter Halo have zenith angle 180 degree.



Spectra of self-annihilation with a long-lived mediator with varying decay length and mediator mass at 1 AU. Here, an 1D approximation is made considering the mediator is boosted, which only includes collimated particles.

Figure 3

- When there is a long-lived mediator, production of SM particles is no longer concentrated at the the center of the dense object but has an exponential distribution along the track.
- 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
- Propagation is done using Nu-Fit 4.1 oscillation parameters with CP phase equal to 0.
- Used for IceCube new solar DM analysis (see poster 626)

References

[1] C. Bauer, N. Rodd, B. Webber. In preparation.
[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
[4] Esteban, Ivan, et al. *Journal of High Energy Physics* 2019.1 (2019): 106 http://www.nu-fit.org

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Release coming soon…