

# Neutrinos from Dark Matter Annihilation in the Sun in Models with a Hidden Sector

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# Capture and Annihilation

$$\frac{dN}{dt} = \Gamma_{\text{capt}} - 2\Gamma_{\text{ann}}$$

$$\Gamma_{\text{ann}} = \frac{\Gamma_{\text{capt}}}{2} \tanh^2\left(\frac{t}{\tau}\right)$$

- $\tau = 1/\sqrt{\Gamma_{\text{capt}} C_{\text{ann}}}$  - equilibration timescale
- $C_{\text{ann}} = \langle \sigma v \rangle \left( \frac{G_N M_{\text{DM}} \rho_{\odot}}{3T_{\odot}} \right)^{3/2}$

# DM Portals

- Scalar Portal

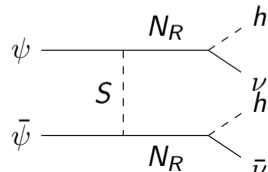
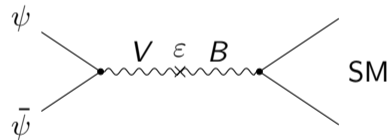
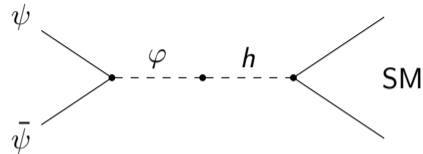
$$\mathcal{L} = \frac{1}{2}(\partial_\mu \varphi)^2 - \frac{1}{2}m_\varphi^2 \varphi^2 + \bar{\psi}(i\not{\partial} - m_\psi - \lambda_\varphi \varphi)\psi - \lambda_1 v \varphi (H^\dagger H - \frac{v^2}{2}) - \lambda_2 \varphi^2 (H^\dagger H - \frac{v^2}{2}) - V(\varphi)$$

- Vector Portal

$$\mathcal{L} = -\frac{1}{4}V_{\mu\nu}^2 + \frac{1}{2}m_V^2 V^2 - \frac{\varepsilon}{2}V_{\mu\nu}B^{\mu\nu} + \bar{\psi}(i\not{\partial} - m_\psi - e'\gamma^\mu V_\mu)\psi$$

- Neutrino Portal

$$\mathcal{L} = \frac{1}{2}(\partial_\mu S)^2 - \frac{1}{2}m_S^2 S^2 + \bar{\psi}(i\not{\partial} - m_\psi)\psi + \bar{N}_R i\not{\partial} N_R - (\frac{1}{2}m_N \bar{N}_R N_R^c + Y_N \bar{L} \tilde{H} N_R + Y_\psi S \bar{\psi} N_R + h.c.) - \lambda S^2 (H^\dagger H - \frac{v^2}{2})$$

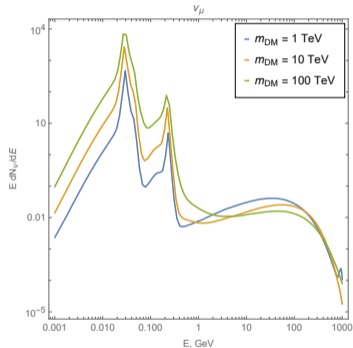
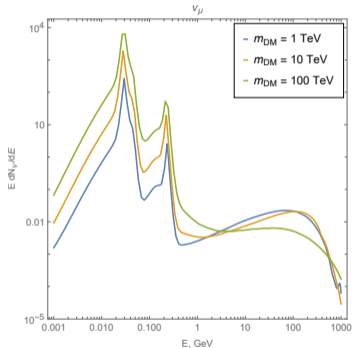
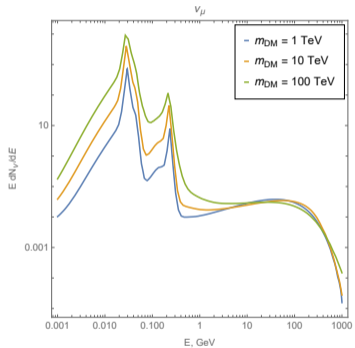


Portal  $\rightarrow$  Branching Ratios  $\rightarrow$  Neutrino Spectra

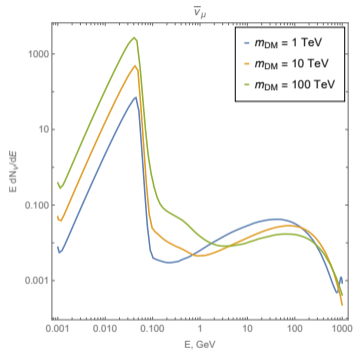
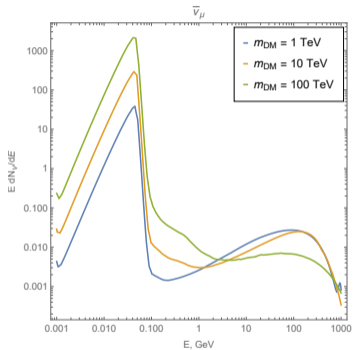
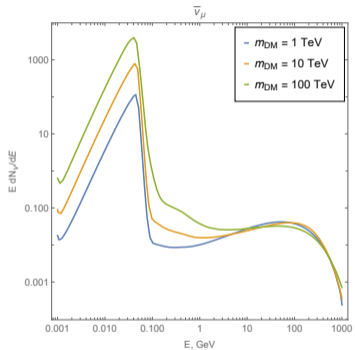
Portal	Annihilation Channels
Scalar Portal	$b\bar{b}, t\bar{t}, W^+W^-, ZZ, hh$
Vector Portal	$f\bar{f}, hh$
Neutrino Portal	$\nu\bar{\nu} + hh$

- P. Baratella, M. Cirelli, A. Hektor, J. Pata, M. Piibeleht, A. Strumia, "PPPC 4 DM : A Poor Particle Physicist Cookbook for Neutrinos from DM annihilations in the Sun", arXiv 1312.6408, JCAP 1403 (2014) 053

# $\nu_\mu$ Spectra



# $\tilde{\nu}_\mu$ Spectra



# Annihilation Rate

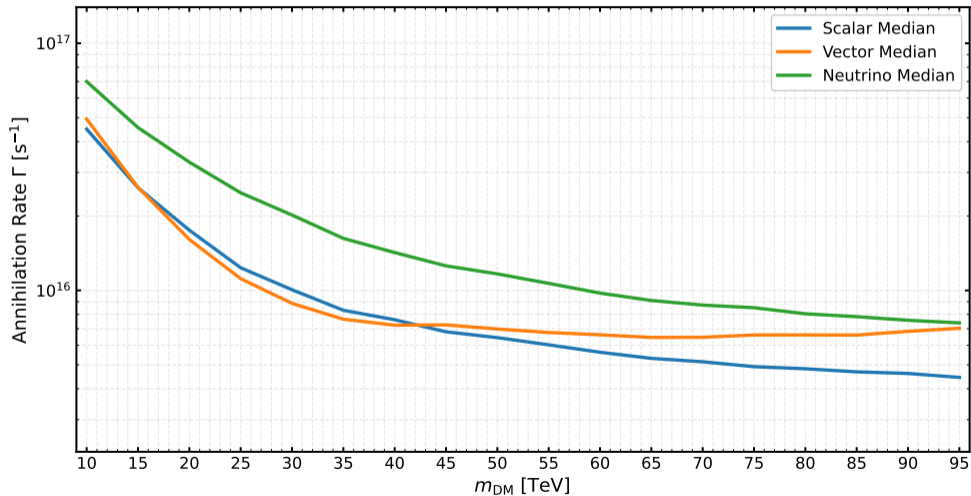
$$\ell(\Gamma) = \sum_{i=1}^N [M_i \cdot \ln(S_i(\Gamma) + B_i) - (S_i(\Gamma) + B_i) - \ln(M_i!)]$$

$$B_i = \int_{E_i}^{E_{i+1}} \frac{d\Phi_b}{dE} \Delta\Omega A_{\text{eff}} t dE$$

$$S_i = \int_{E_i}^{E_{i+1}} \frac{d\Phi_s}{dE} A_{\text{eff}} t dE = \frac{\Gamma}{4\pi^2 d^2} \int_{E_i}^{E_{i+1}} \frac{dN_s}{dE} A_{\text{eff}} t dE$$

# Annihilation Rate

KM3NeT Comparison of Portal Medians

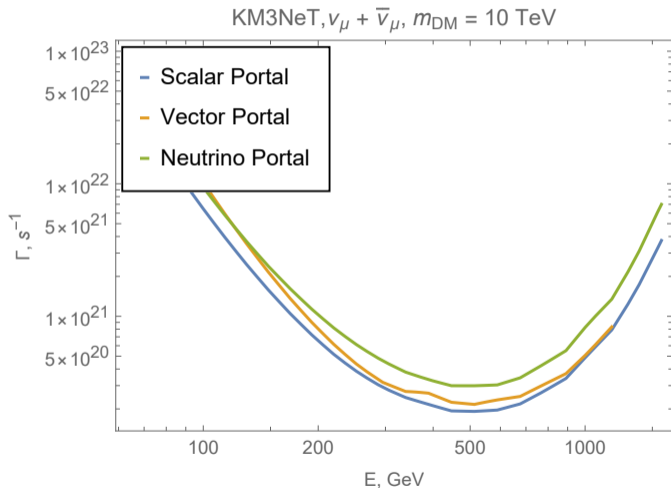


# Portal Comparison

$$\frac{N_s(E)}{\sqrt{N_b(E)}} = k \Rightarrow \Gamma = \Gamma(E)$$

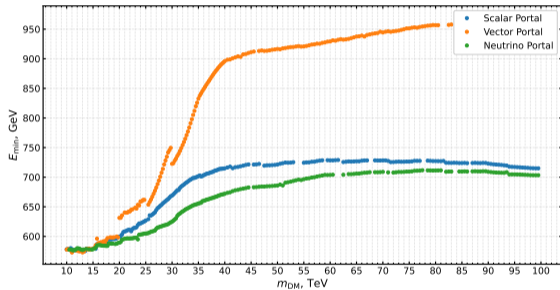
$$N_b(E) = \frac{d\Phi_b}{dE} \Delta E A_{eff} \Delta\Omega t$$

$$\begin{aligned} N_s(E) &= \frac{d\Phi_s}{dE} \Delta E A_{eff} t = \\ &= \frac{\Gamma}{4\pi d^2} \frac{dN_s}{dE} \Delta E A_{eff} t \end{aligned}$$

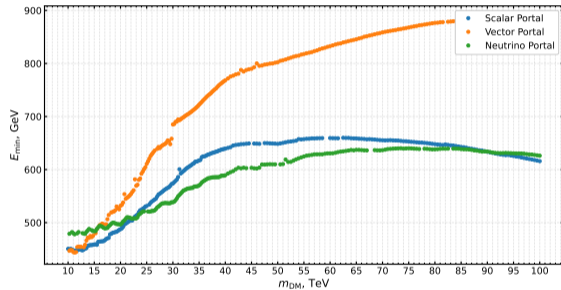


# Portal Comparison

KM: Portal Comparison



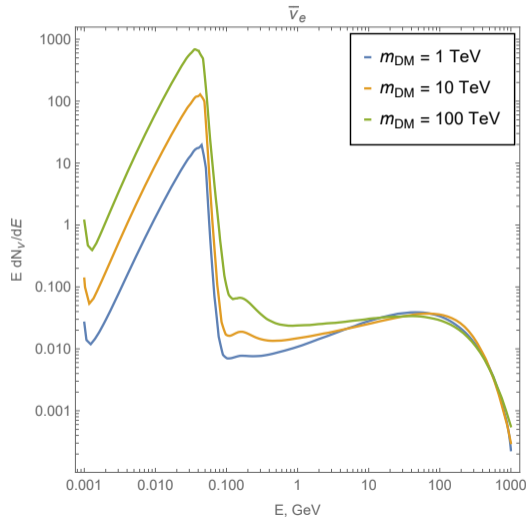
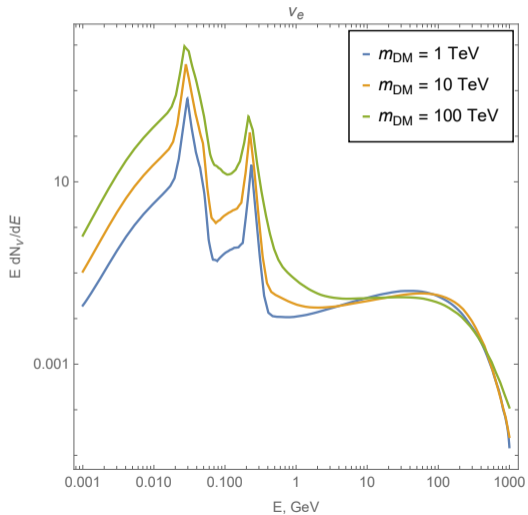
IC86: Portal Comparison



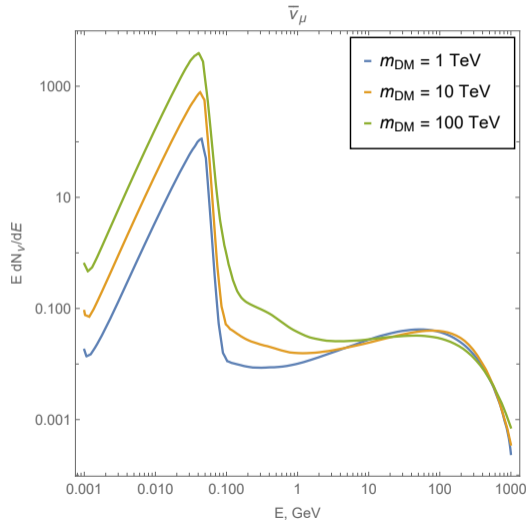
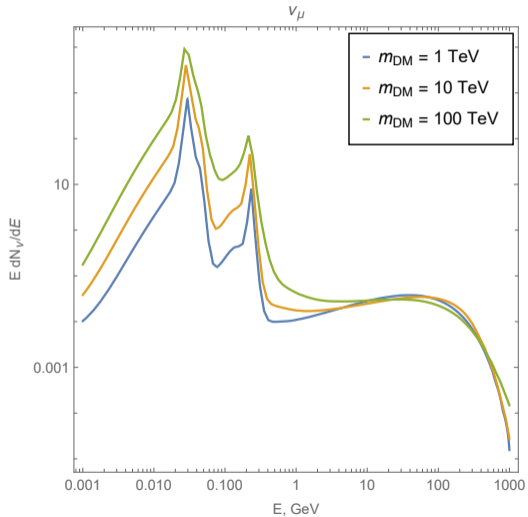
# Conclusion

- Neutrino spectra were obtained for different portals
- Upper limits on the dark matter annihilation rate were derived
- The potential for distinguishing annihilation portals and determining the dark matter mass was investigated

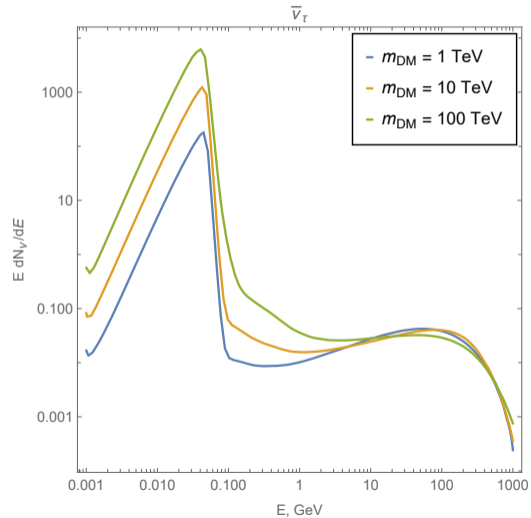
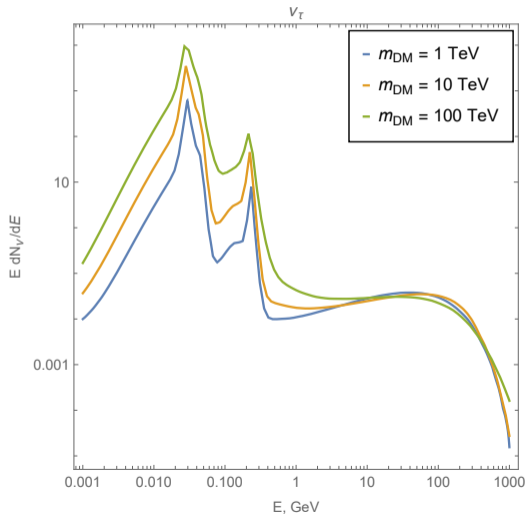
# Scalar Portal, $\nu_e$



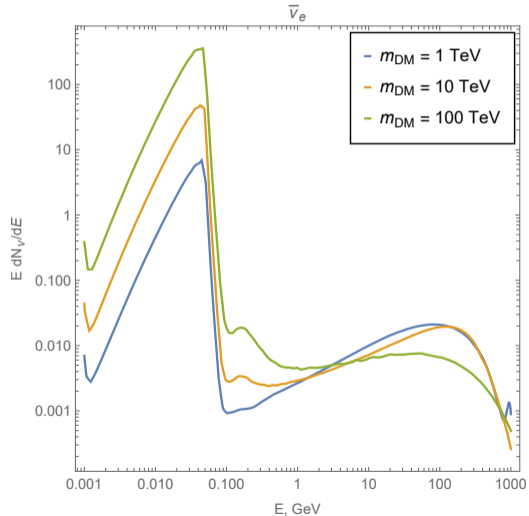
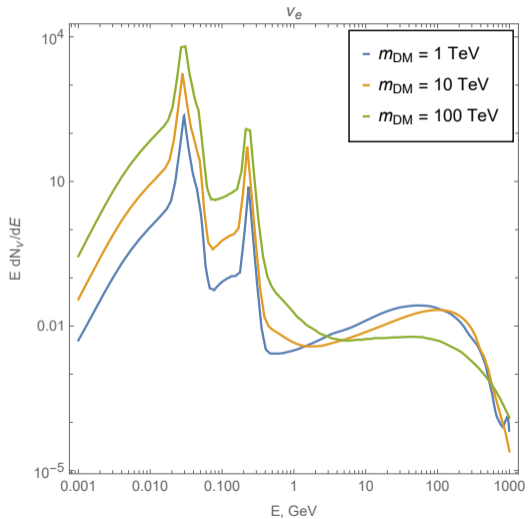
# Scalar Portal, $\nu_\mu$



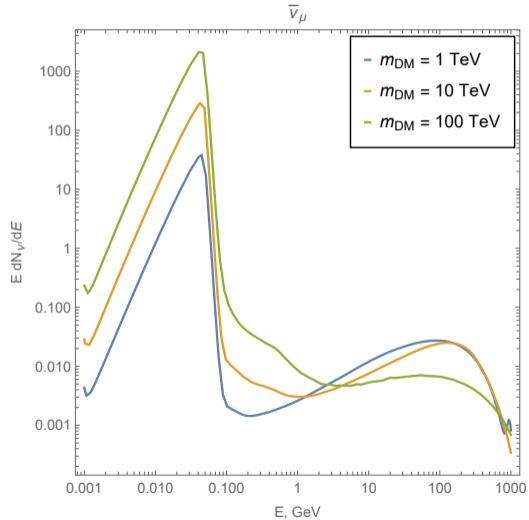
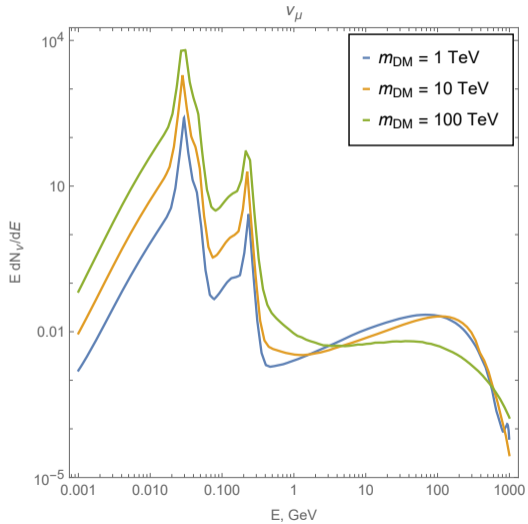
# Scalar Portal, $\nu_\tau$



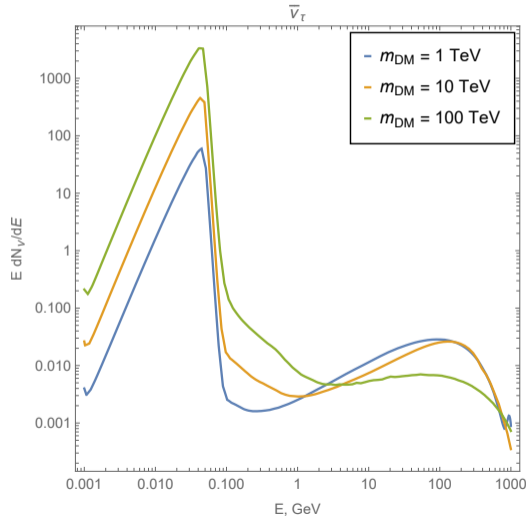
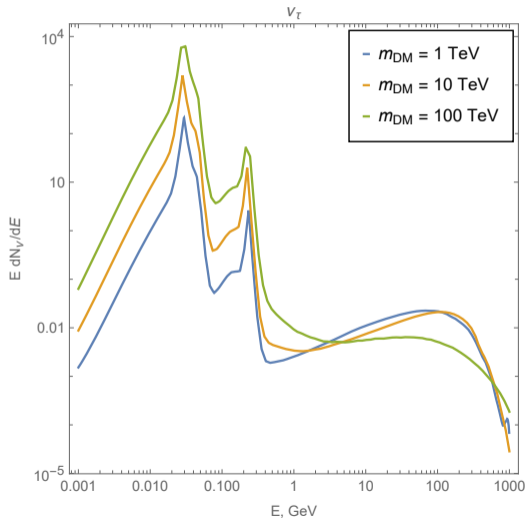
# Vector Portal, $\nu_e$



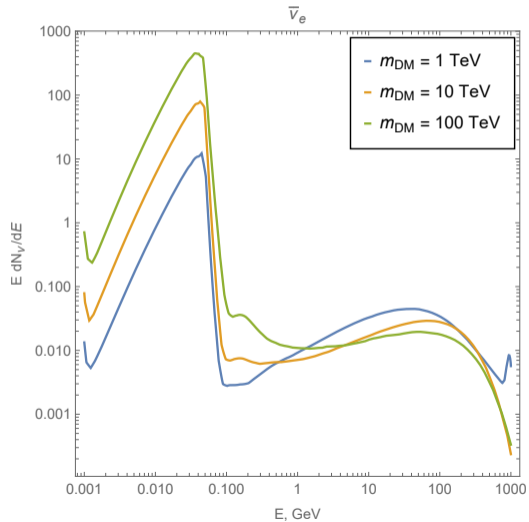
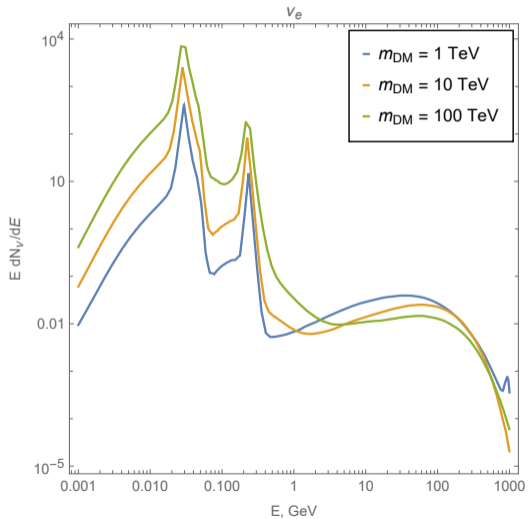
# Vector Portal, $\nu_\mu$



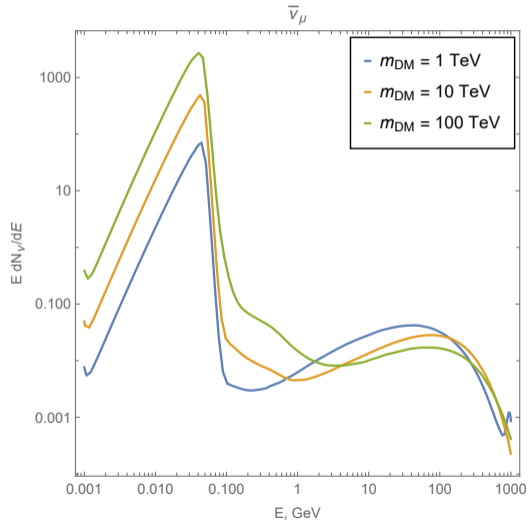
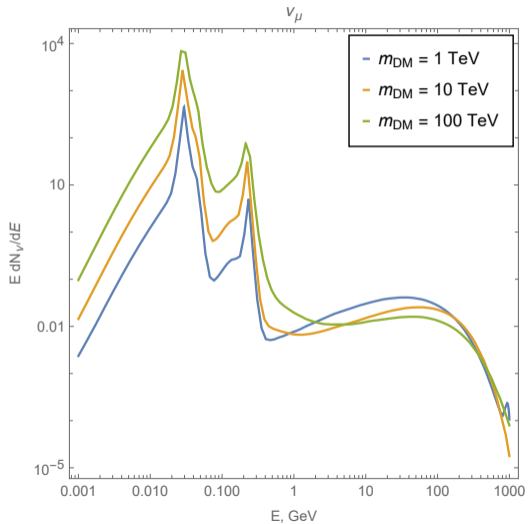
# Vector Portal, $\nu_\tau$



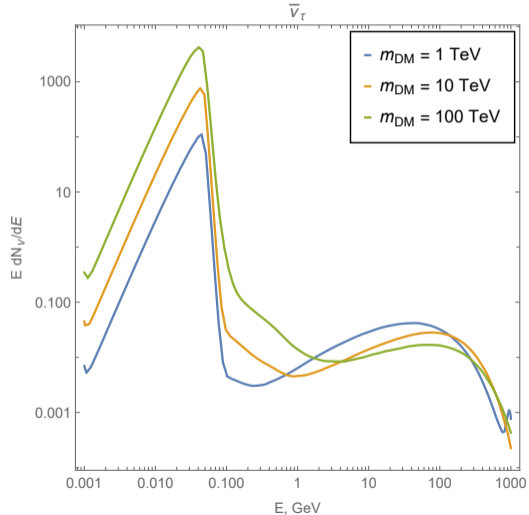
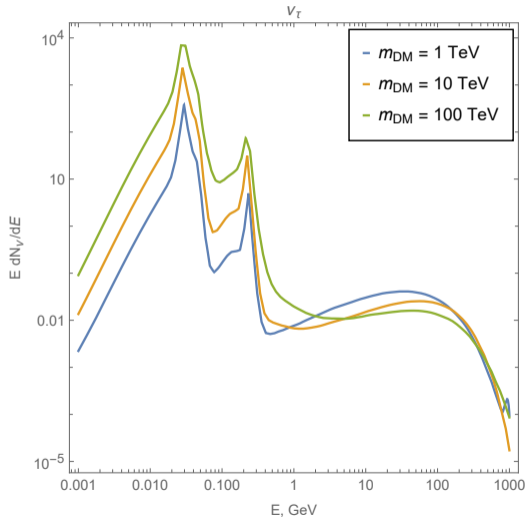
# Neutrino Portal, $\nu_e$



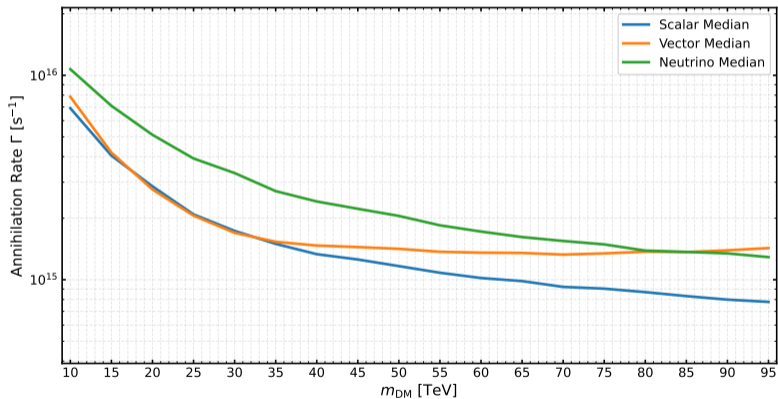
# Neutrino Portal, $\nu_\mu$



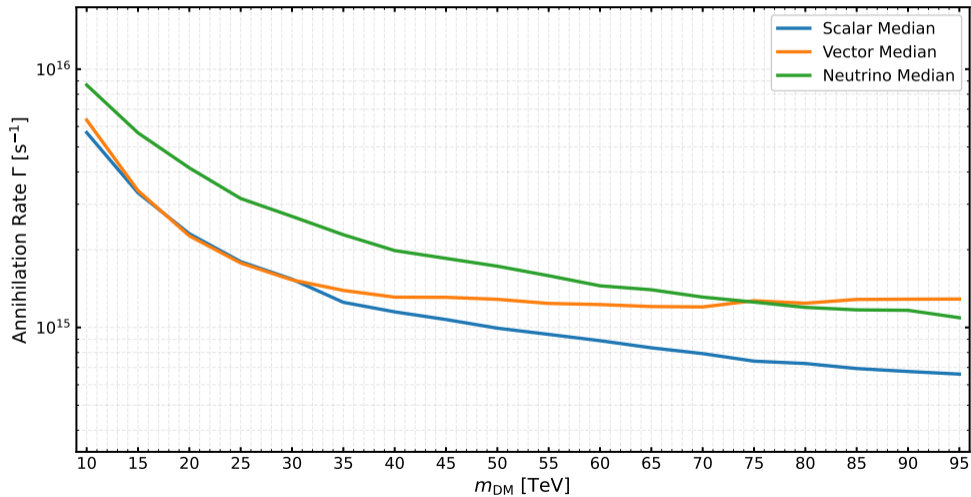
# Neutrino Portal, $\nu_\tau$



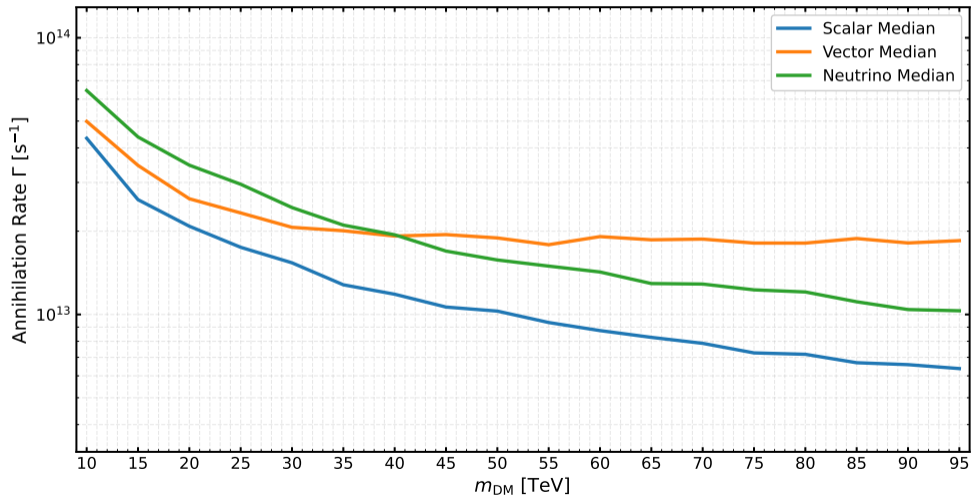
IC86 Comparison of Portal Medians



## DeepCore Comparison of Portal Medians

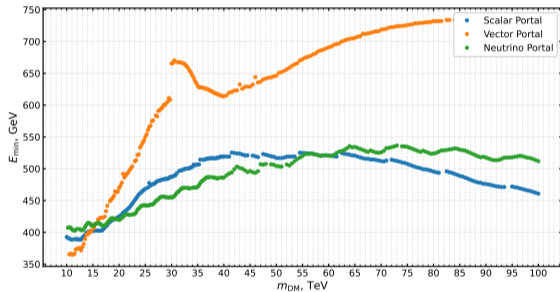


## SuperK Comparison of Portal Medians

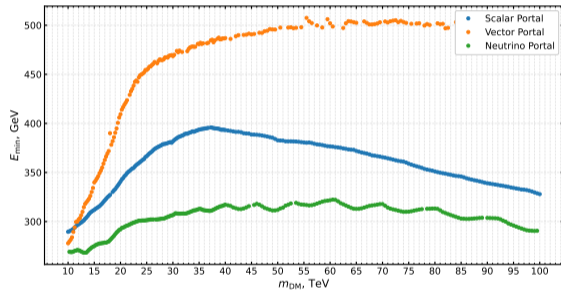


# Portal Comparison

DC: Portal Comparison

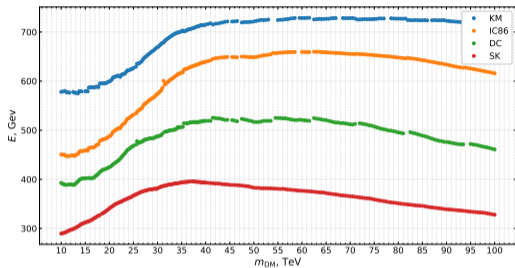


SK: Portal Comparison

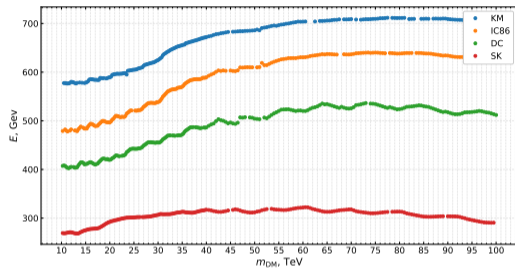


# Portal Comparison

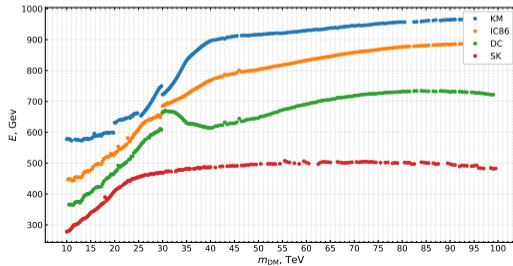
Scalar Portal: All Detectors



Neutrino Portal: All Detectors

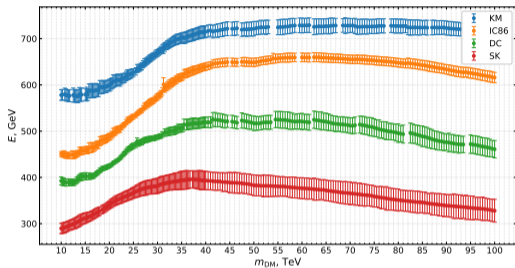


Vector Portal: All Detectors

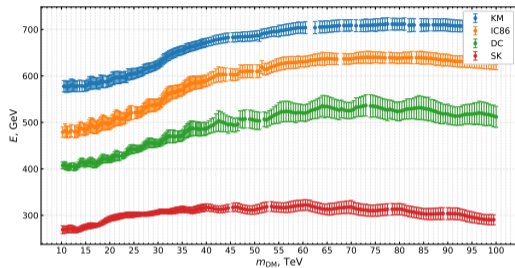


# Portal Comparison with Errors

Scalar Portal: All Detectors



Neutrino Portal: All Detectors



Vector Portal: All Detectors

