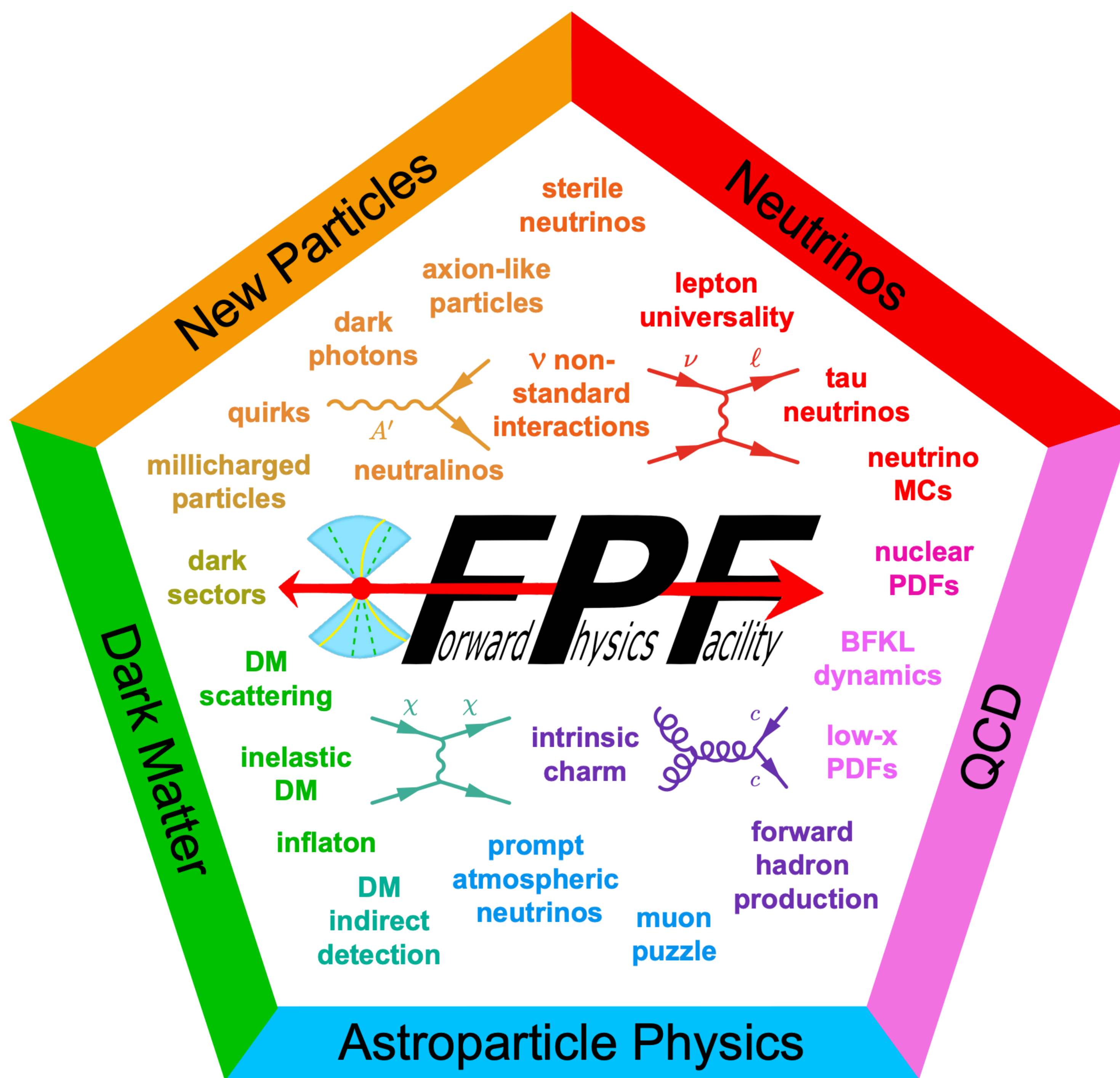
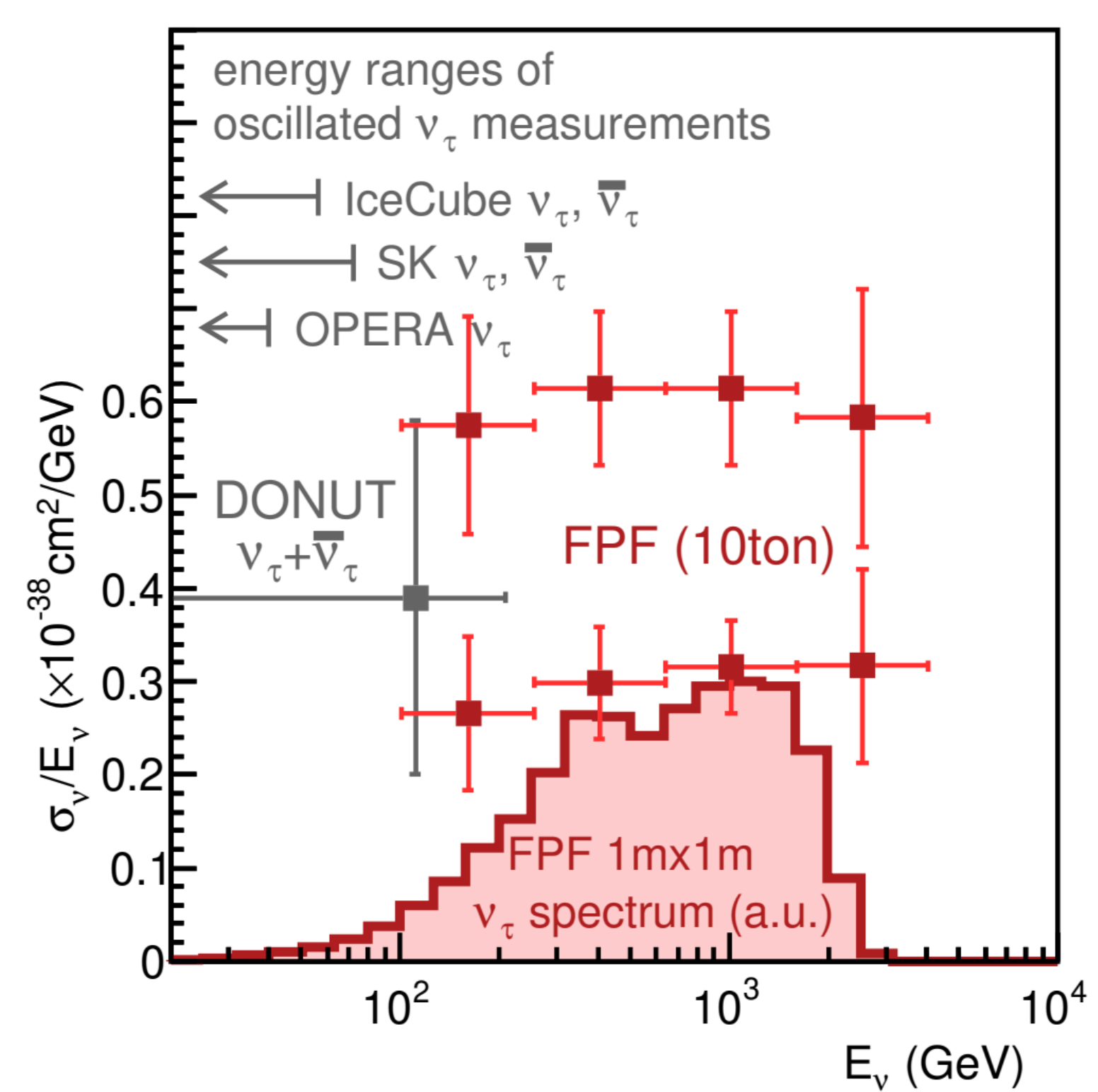
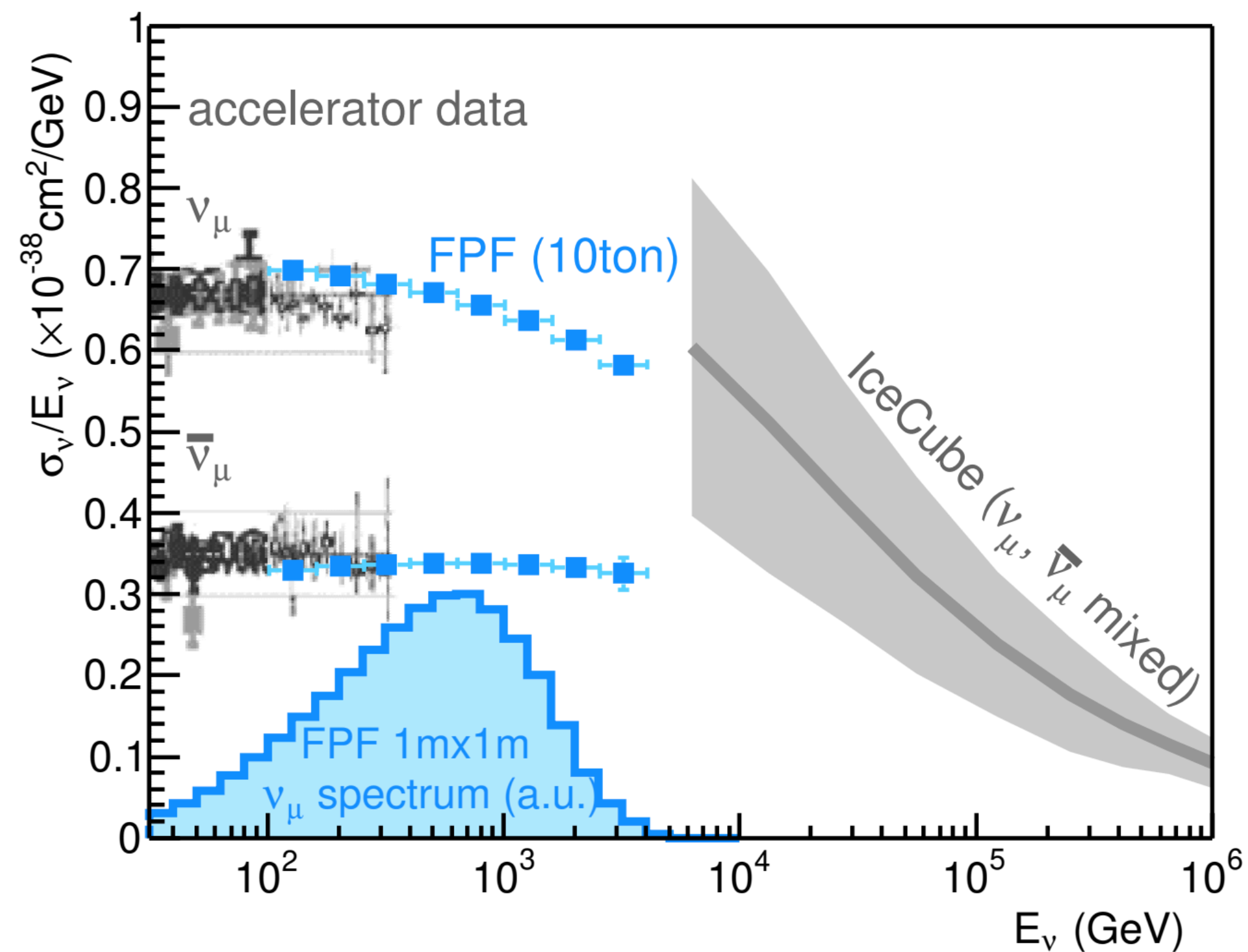
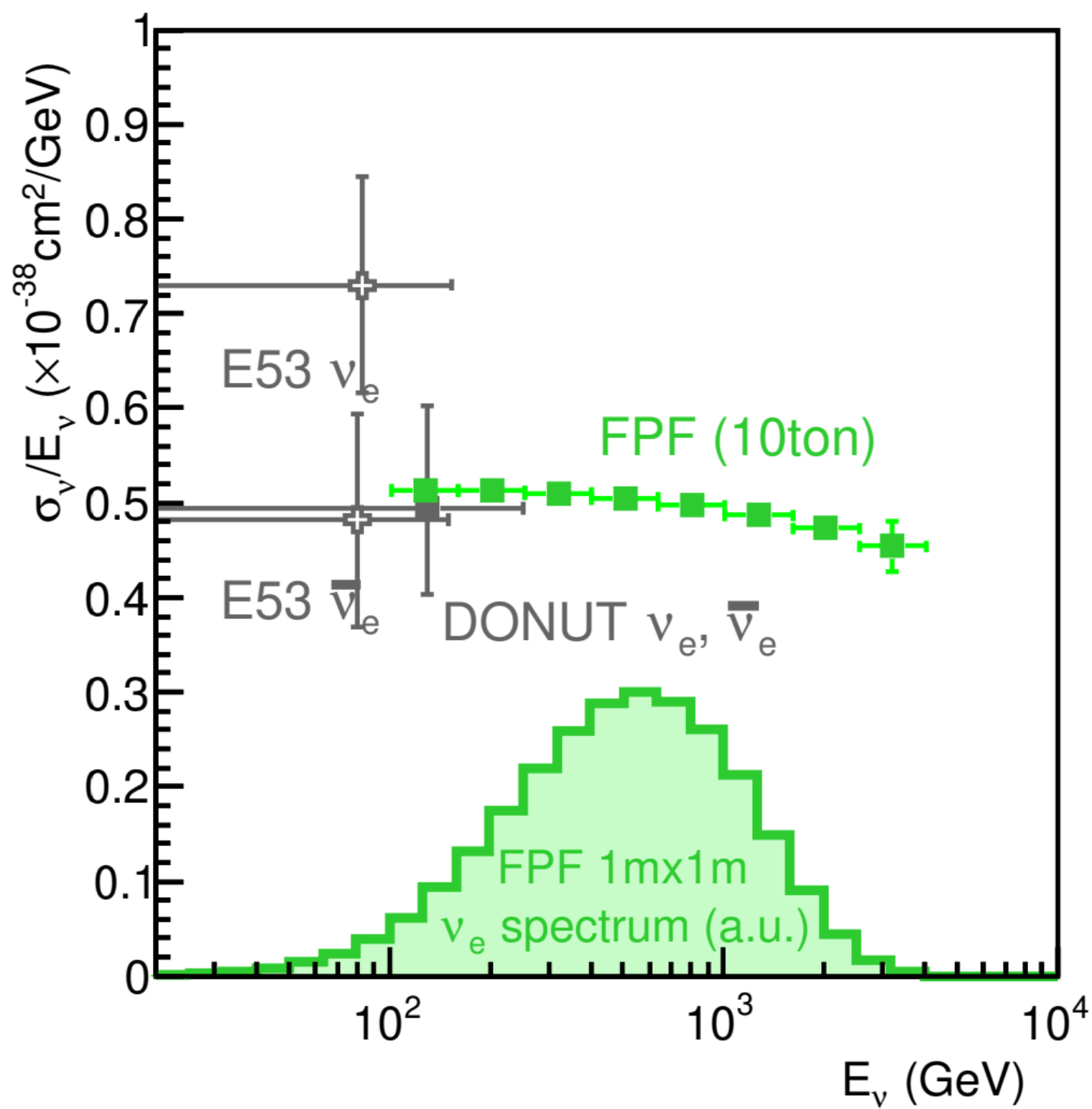


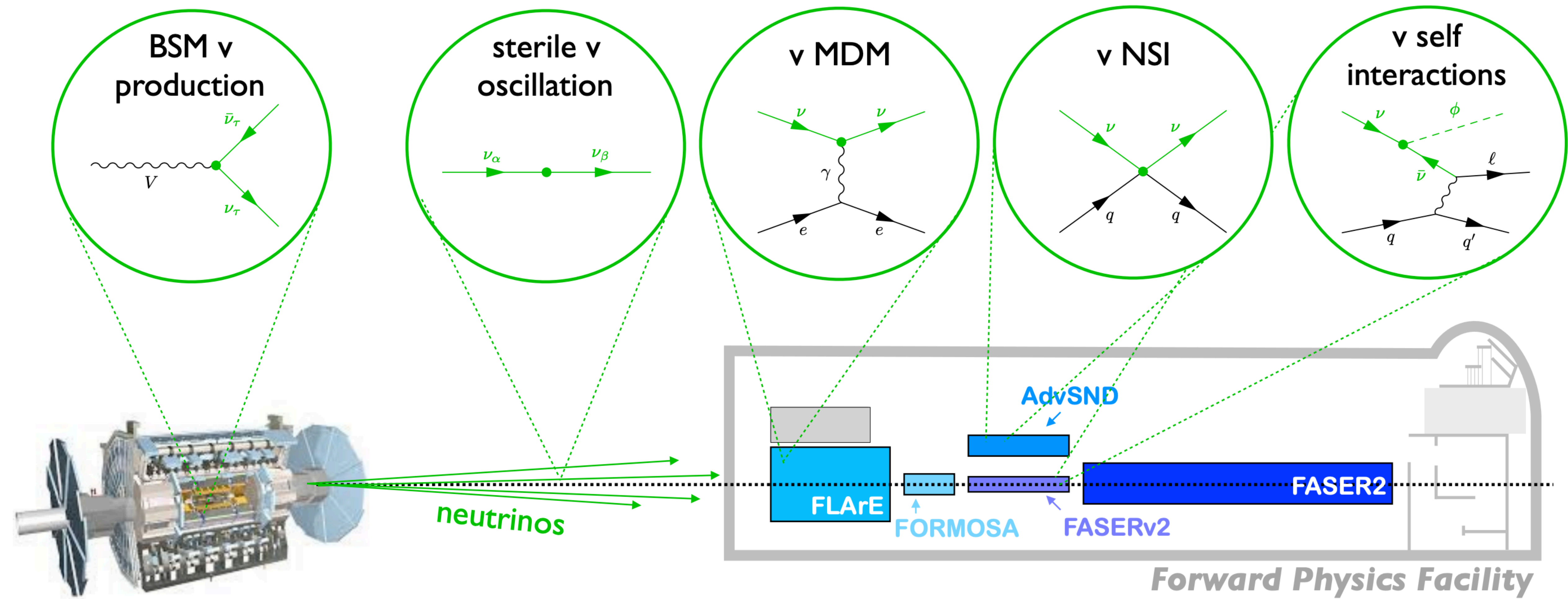
BSM Physics Opportunities

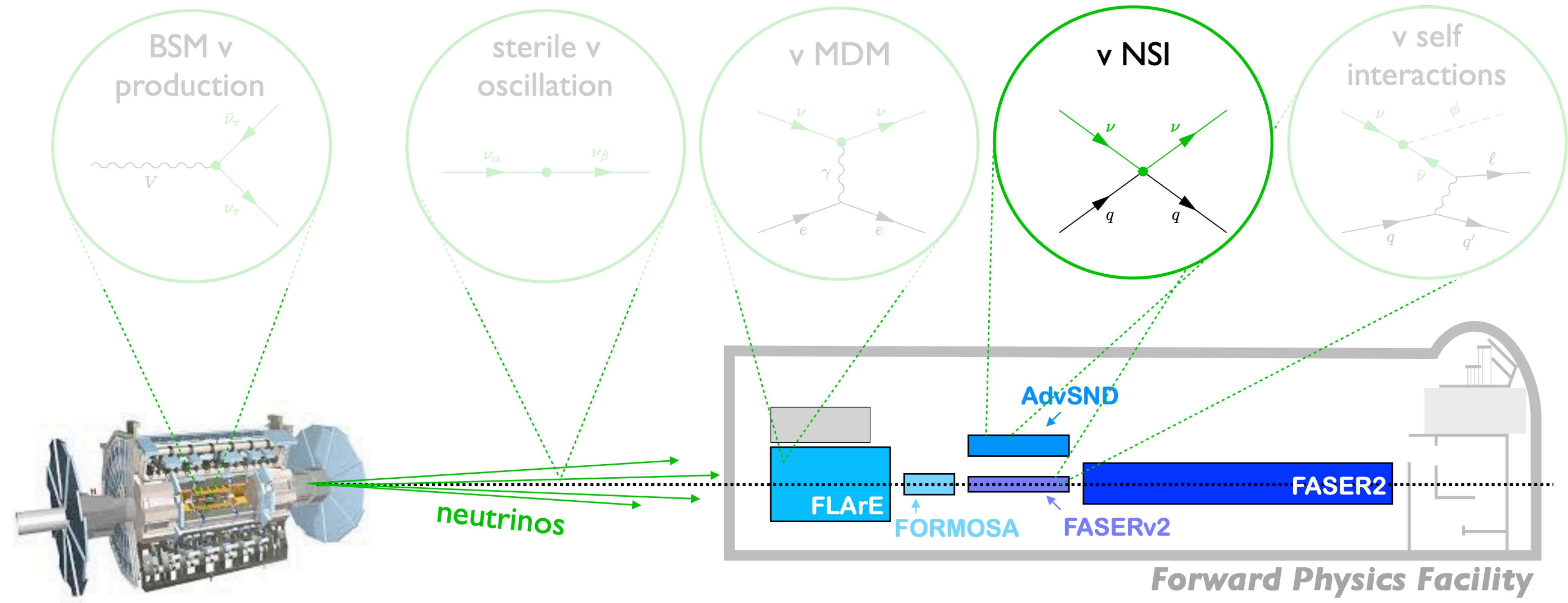
with LHC Neutrino Beams

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FPF Theory Workshop, 17th Sept., 2023
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Scattering with New EFT Operators

$$\begin{aligned} \mathcal{L}_{\text{WEFT}} \supset & -\frac{2V_{jk}}{v^2} \left\{ [\mathbf{1} + \epsilon_L^{jk}]_{\alpha\beta} (\bar{u}^j \gamma^\mu P_L d^k) (\bar{\ell}_\alpha \gamma_\mu P_L \nu_\beta) + [\epsilon_R^{jk}]_{\alpha\beta} (\bar{u}^j \gamma^\mu P_R d^k) (\bar{\ell}_\alpha \gamma_\mu P_L \nu_\beta) \right. \\ & + \frac{1}{2} [\epsilon_S^{jk}]_{\alpha\beta} (\bar{u}^j d^k) (\bar{\ell}_\alpha P_L \nu_\beta) - \frac{1}{2} [\epsilon_P^{jk}]_{\alpha\beta} (\bar{u}^j \gamma_5 d^k) (\bar{\ell}_\alpha P_L \nu_\beta) \\ & \left. + \frac{1}{4} [\epsilon_T^{jk}]_{\alpha\beta} (\bar{u}^j \sigma^{\mu\nu} P_L d^k) (\bar{\ell}_\alpha \sigma_{\mu\nu} P_L \nu_\beta) + \text{h.c.} \right\}. \end{aligned}$$

New four-fermion operators induce

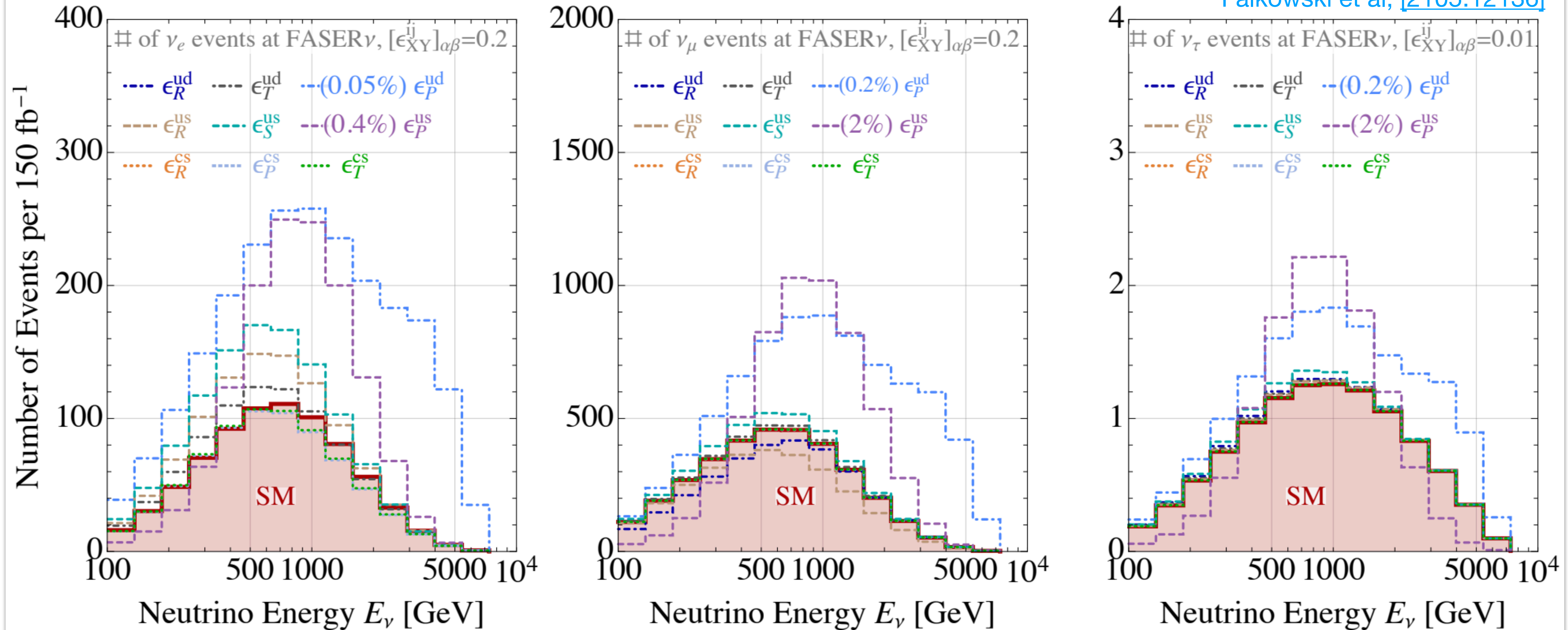
- (a) additional production of neutrinos from meson decays and
- (b) new contributions to scattering in detectors.

$$\begin{aligned} \tilde{P}_{\alpha\beta}^S(E_\nu)_{L=0} \simeq & \delta_{\alpha\beta} + 2 \sum_{X,j,k} p_{XL,\alpha}^{S,jk} [\epsilon_X^{jk}]_{\alpha\alpha} \delta_{\alpha\beta} + 2 \sum_{j,k} d_{LL,\alpha}^{jk} [\epsilon_L^{jk}]_{\beta\beta} \delta_{\alpha\beta} \\ & + \sum_{X,Y,j,k} \left[p_{XY,\alpha}^{S,jk} [\epsilon_X^{jk}]_{\alpha\beta} [\epsilon_Y^{jk}]_{\alpha\beta} + d_{XY,\beta}^{jk} [\epsilon_X^{jk}]_{\beta\alpha} [\epsilon_Y^{jk}]_{\beta\alpha} \right]. \end{aligned}$$

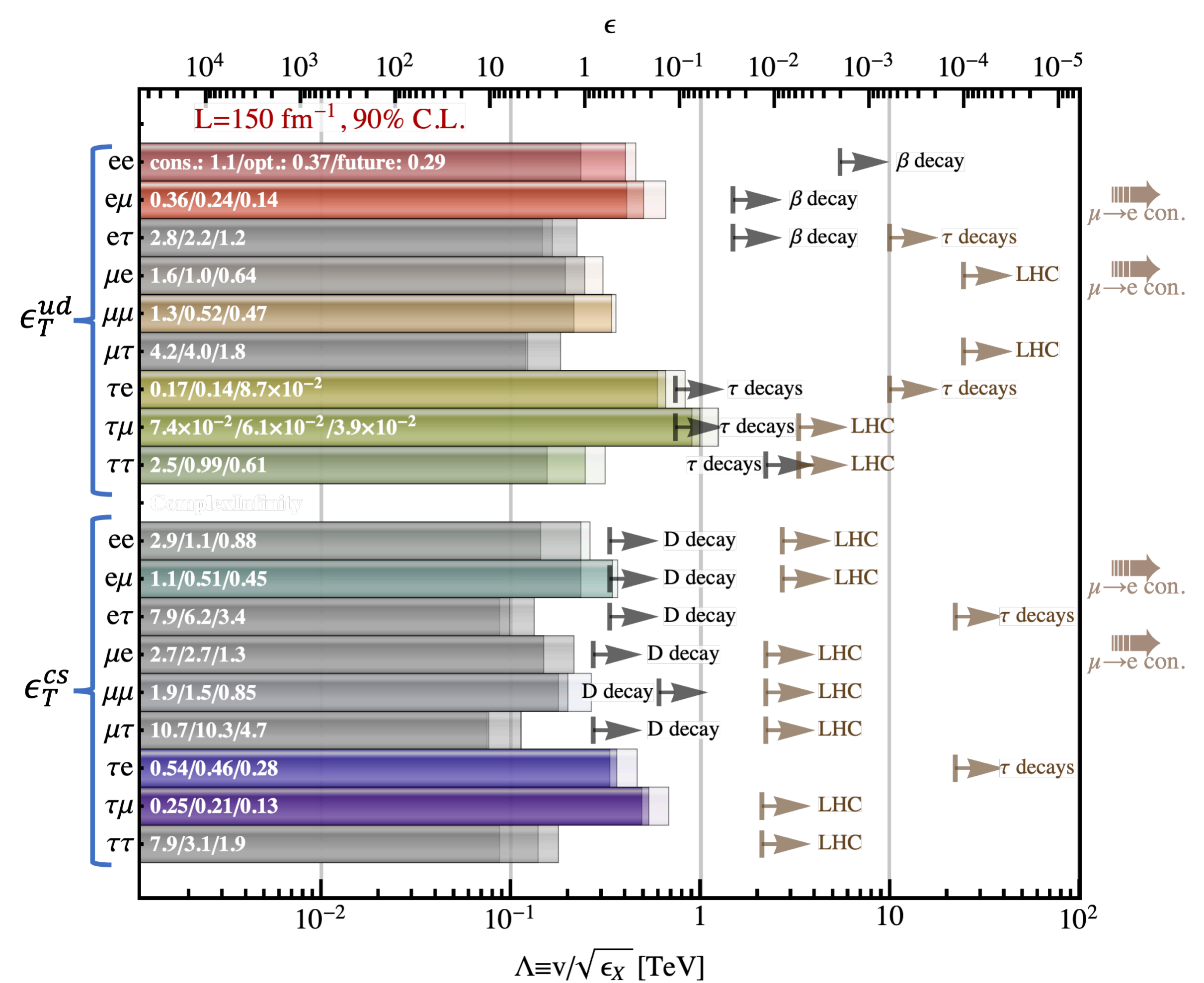
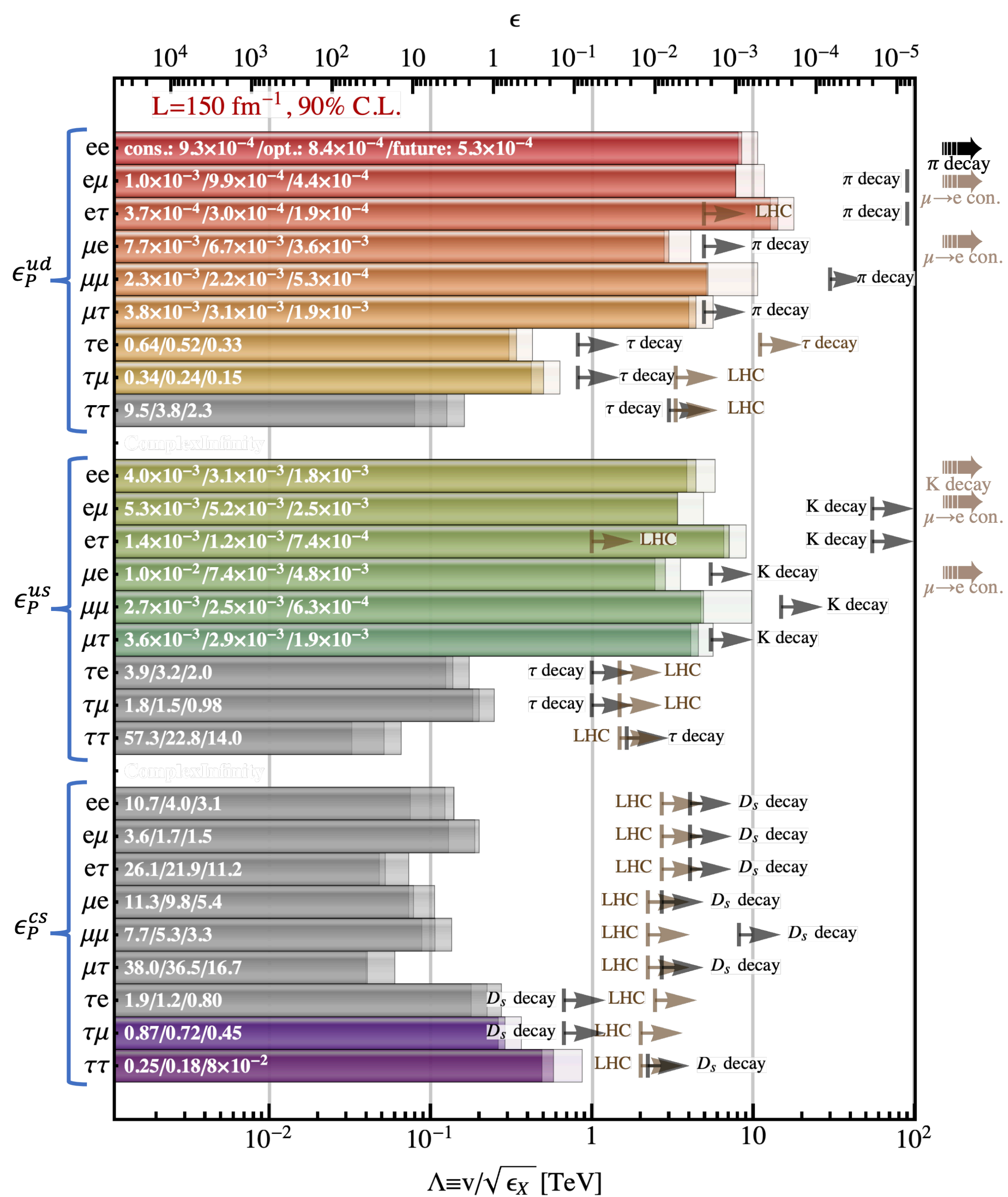
Effective probability (quadratic in Wilson coefficients) capturing these new-physics effects.

Scattering with New EFT Operators

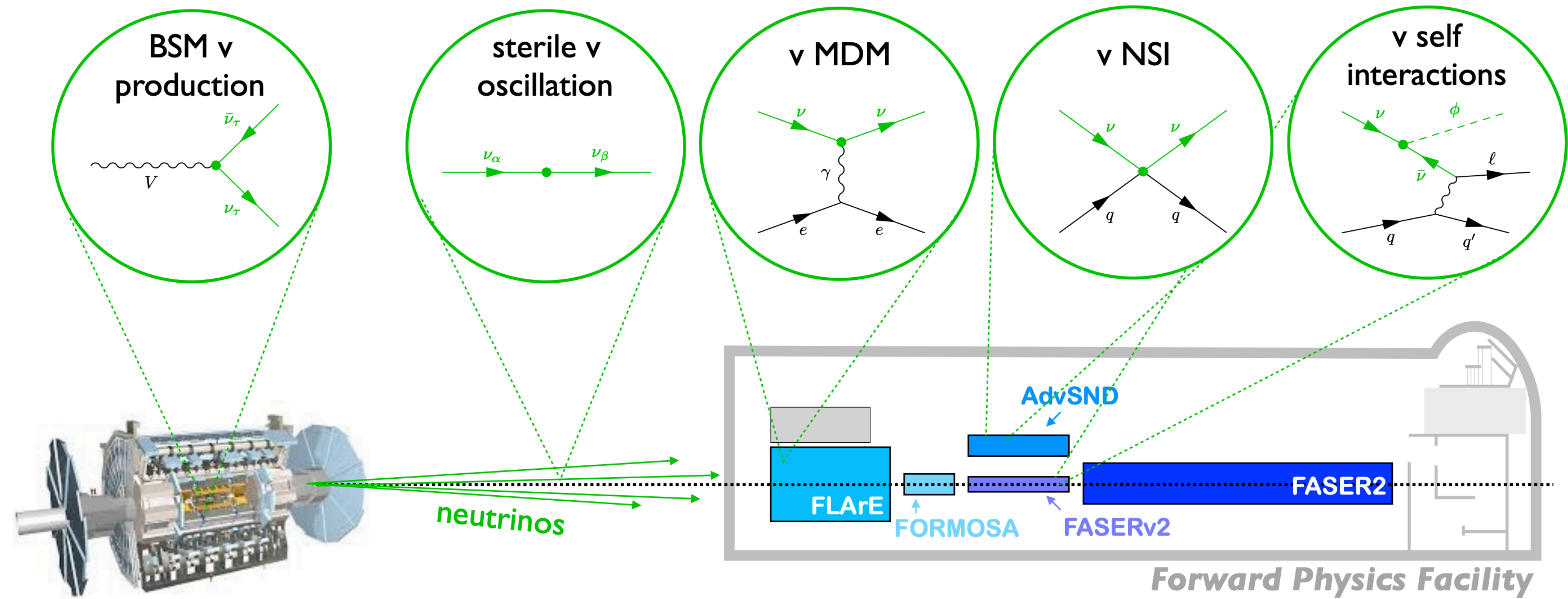
Falkowski et al, [2105.12136]

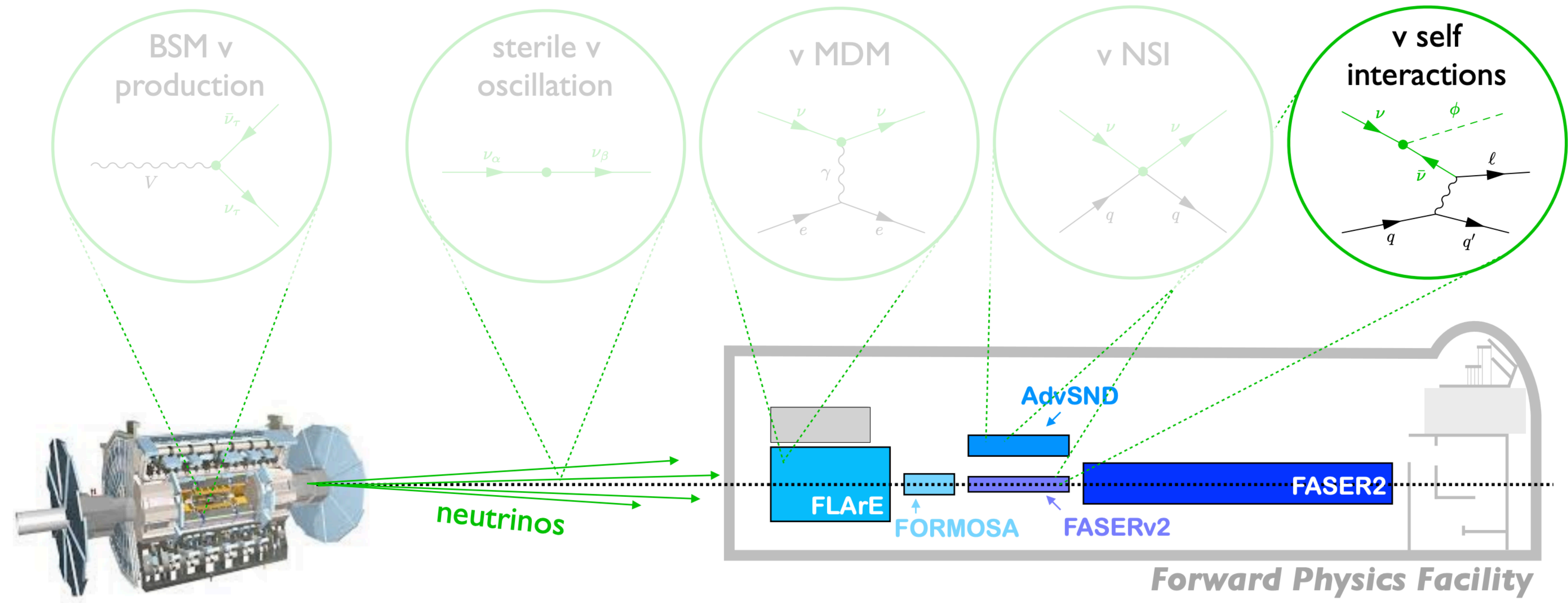


- Goal: utilize a precise measurement of event rate (and shape) to constrain Wilson coefficients, compared against orthogonal probes

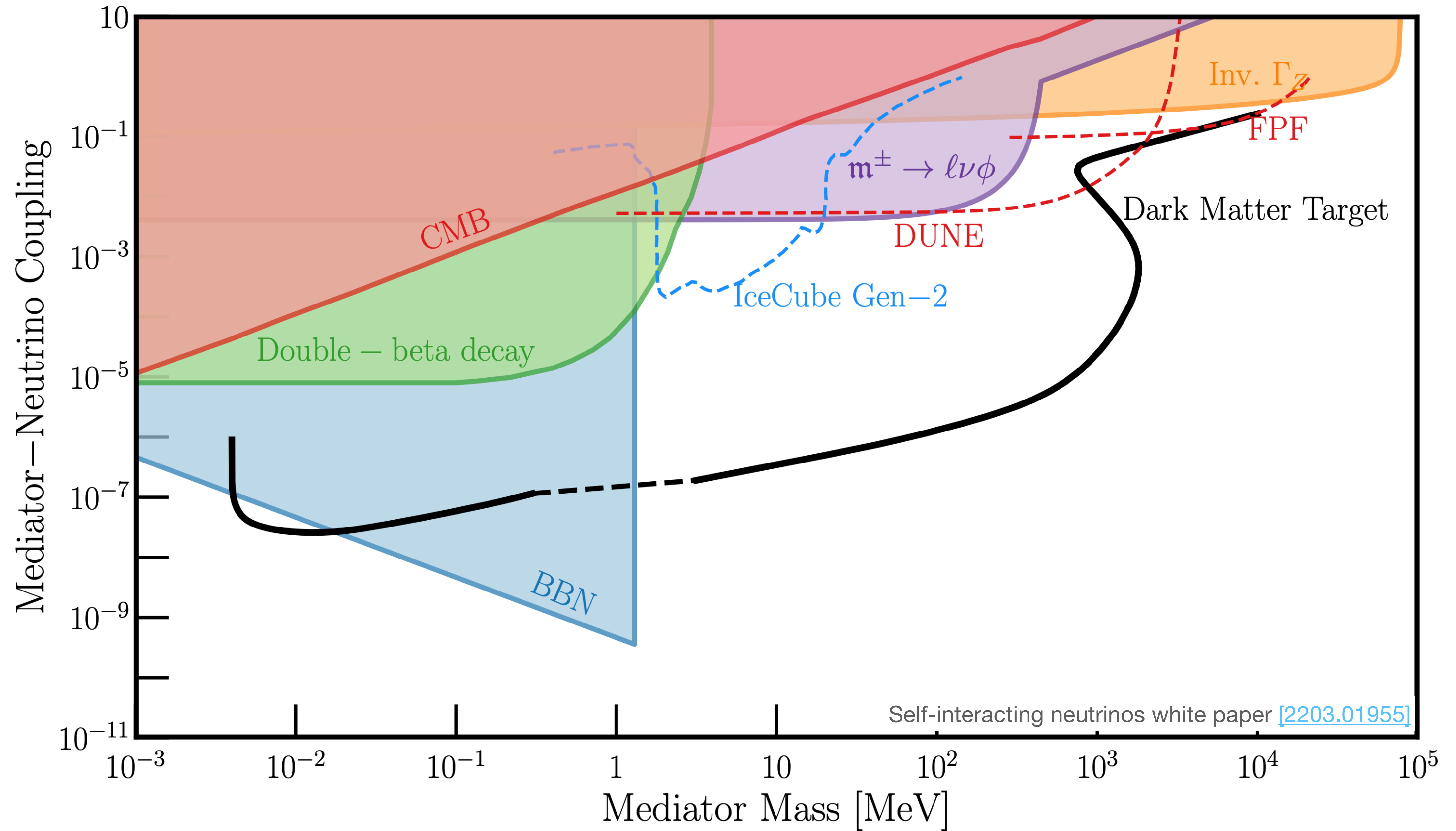


See Falkowski et al, [2105.12136] for RH, scalar couplings, discussion of complementarity of these and other constraints.

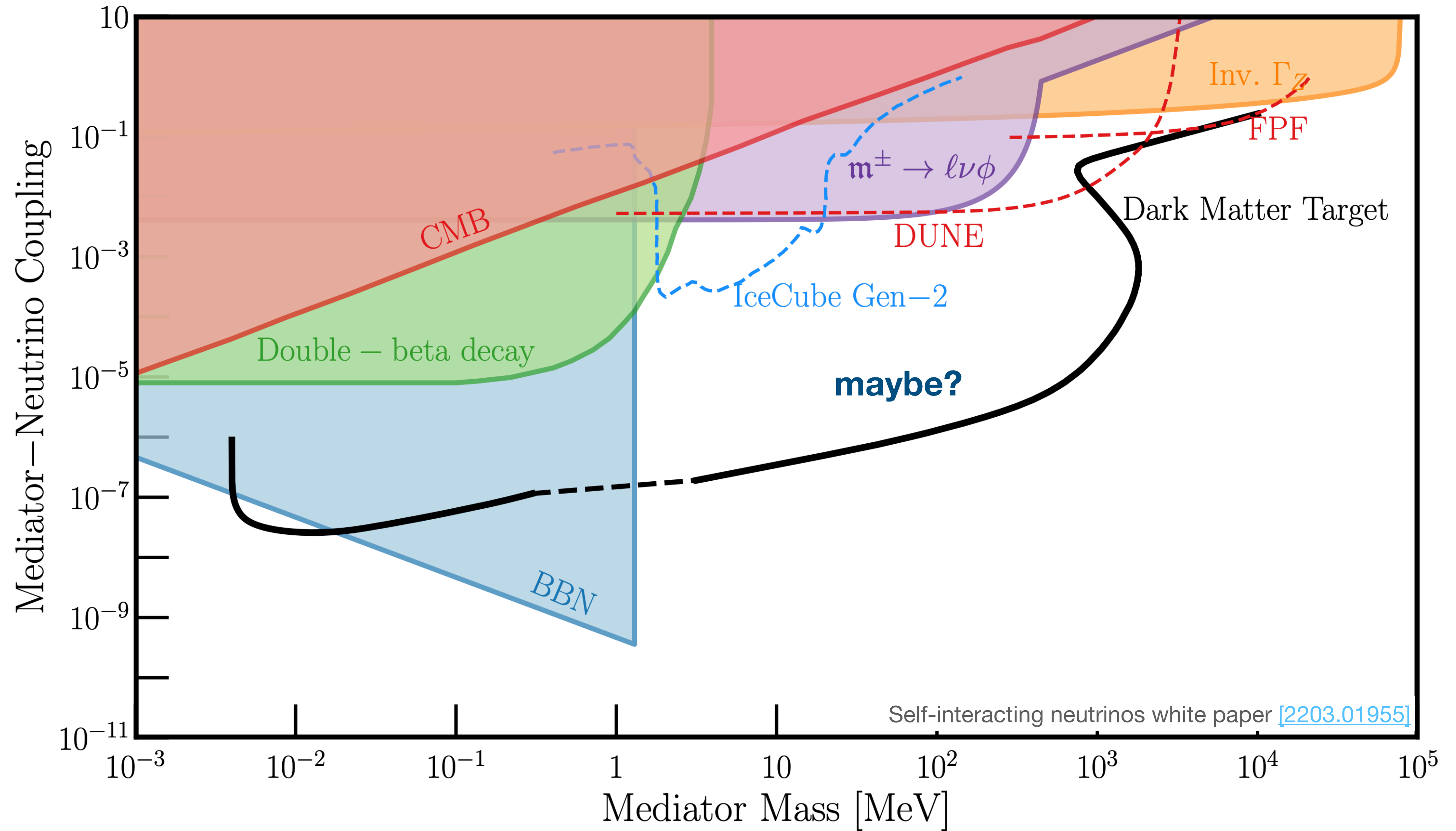




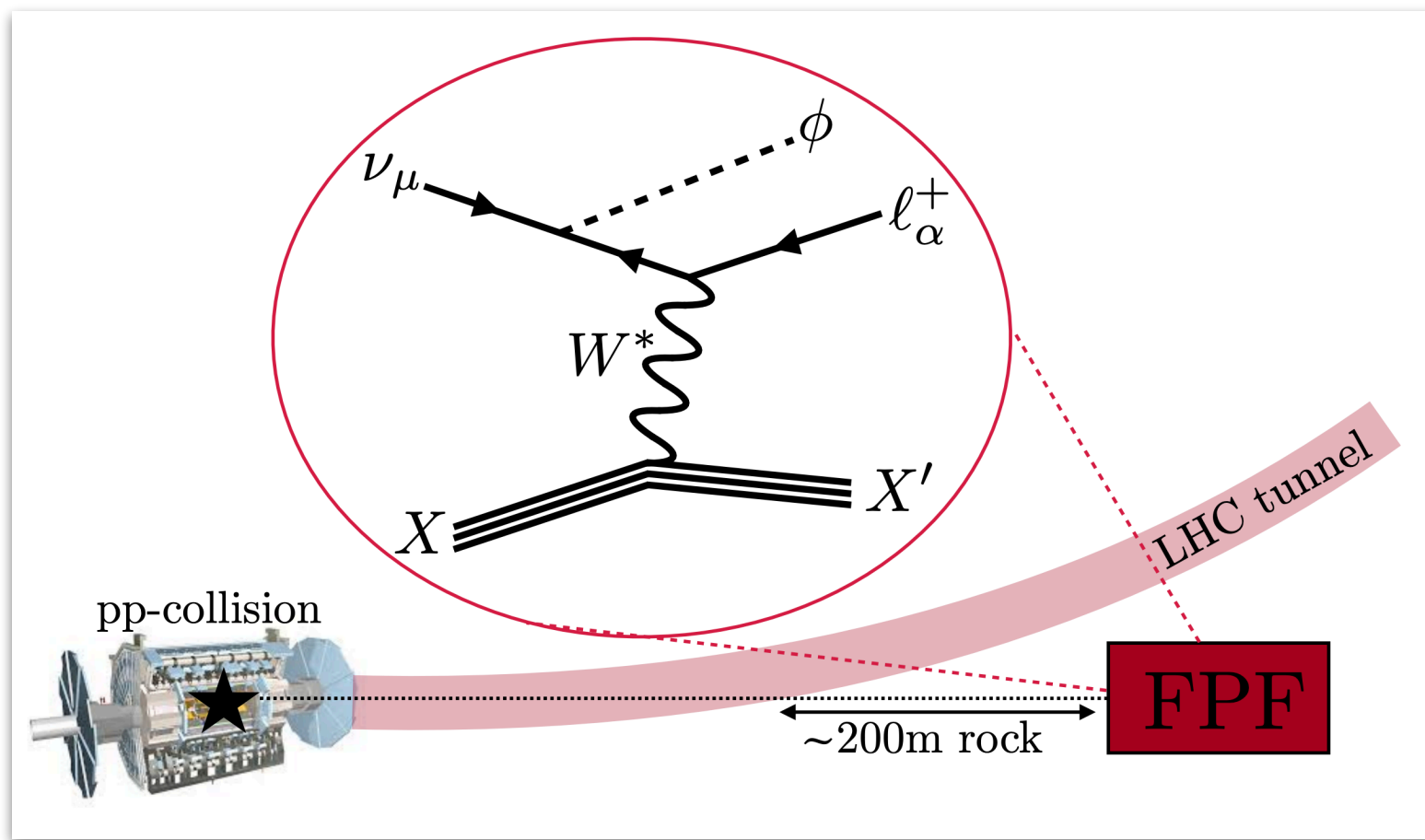
Could neutrinos have sizable self-interactions?



Could neutrinos have sizable self-interactions?

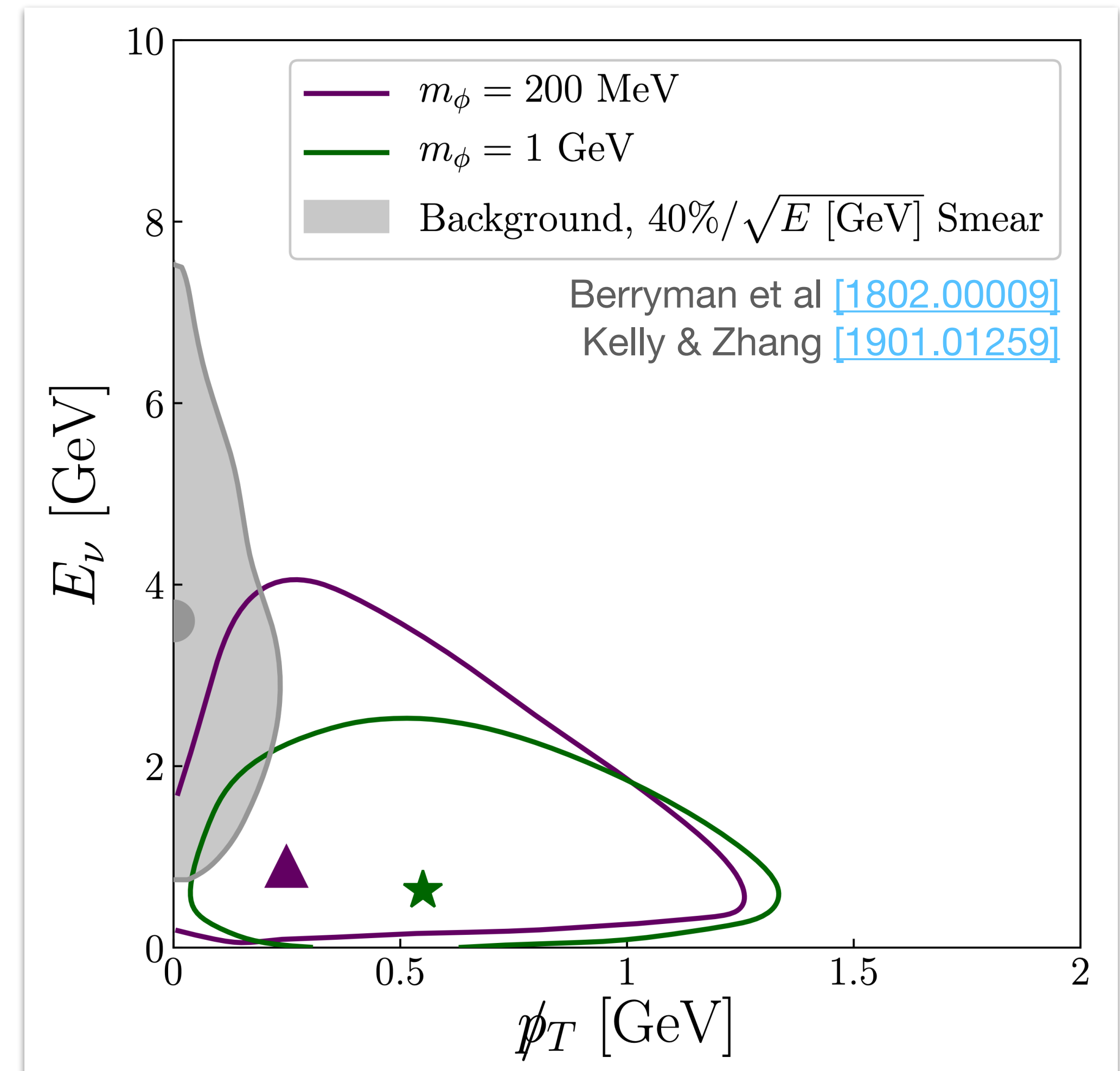


Neutrinophilic Dark Matter at the FPF

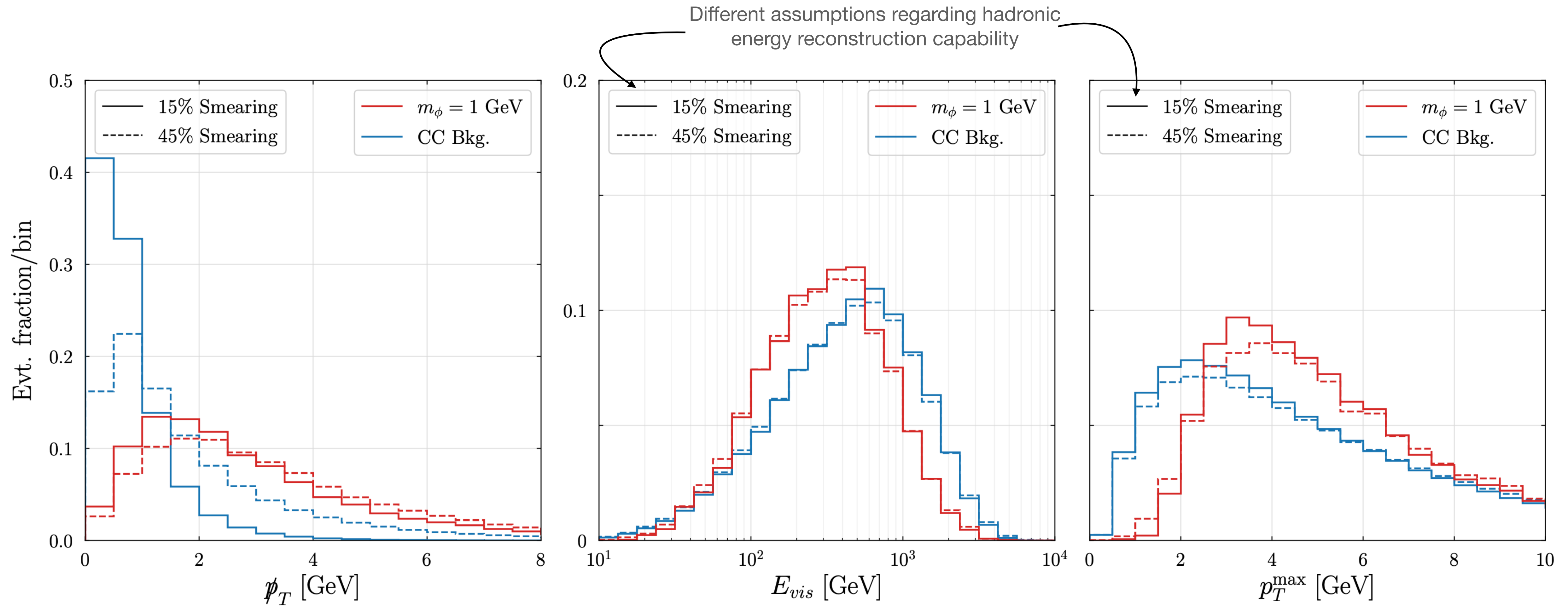


New mediator (possibly connected to DM) can be emitted in neutrino scattering, leading to signatures with large missing transverse momentum.

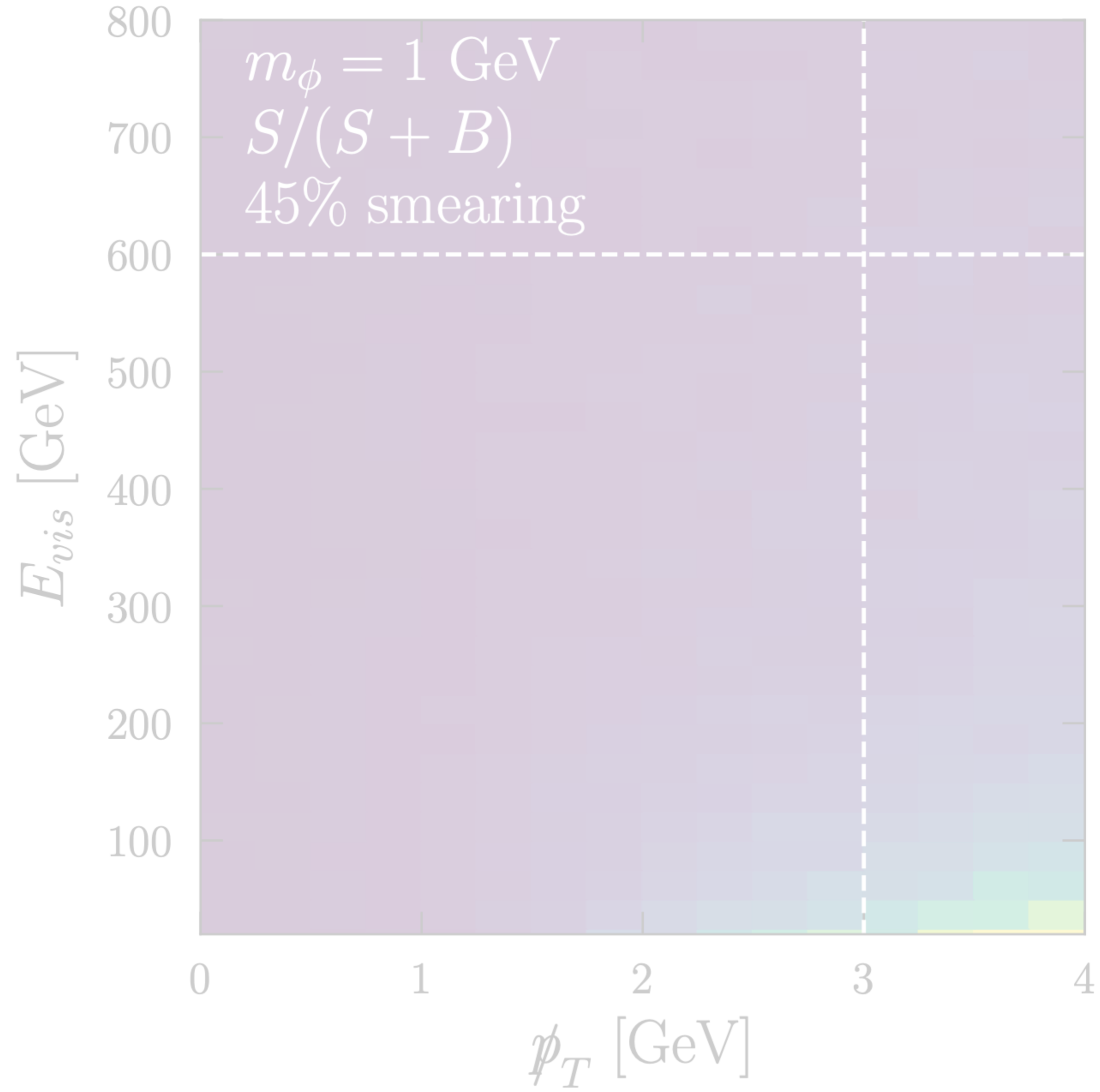
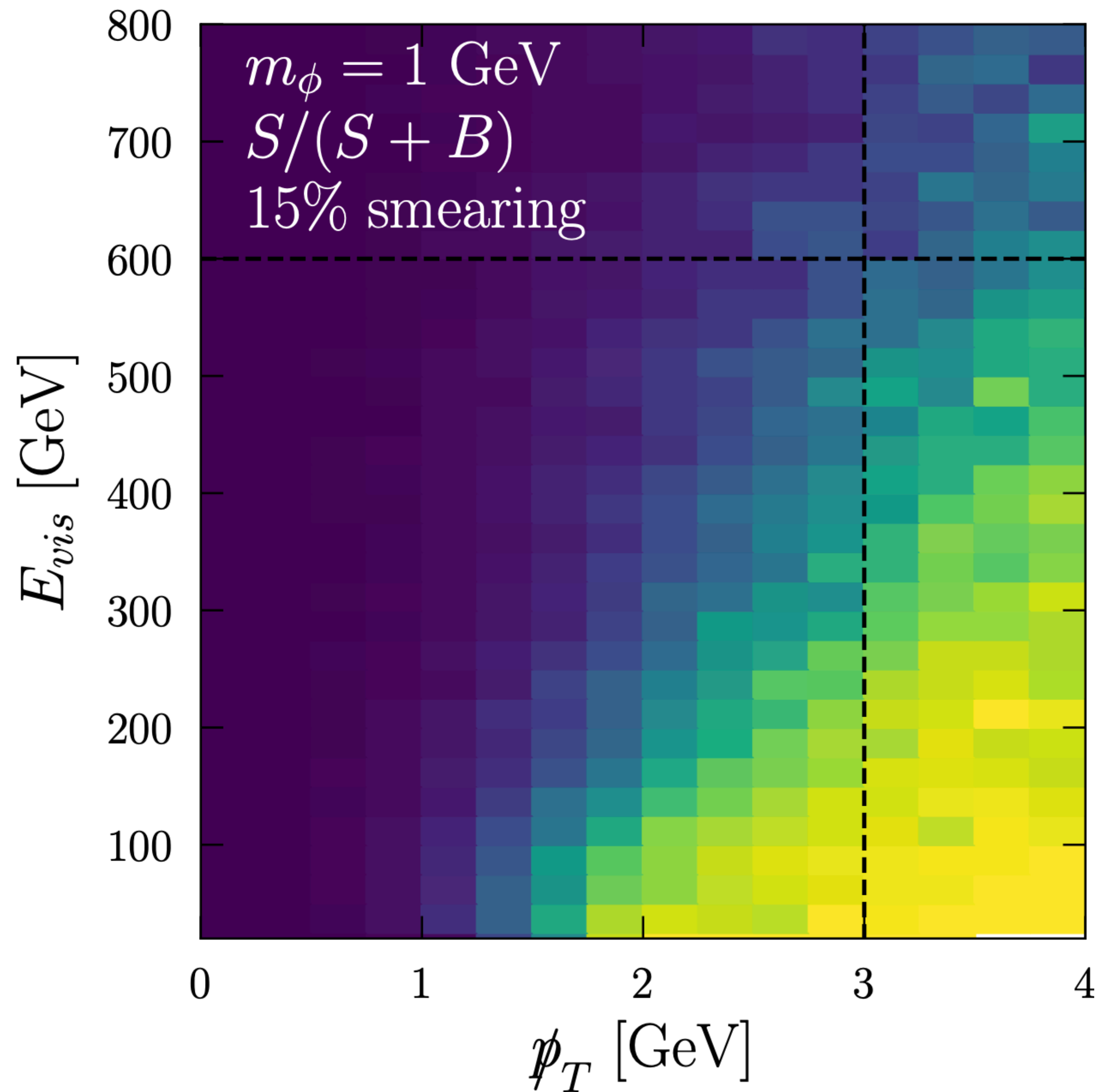
Figure considering the DUNE beam/near detector (lower beam energy), but same message persists.



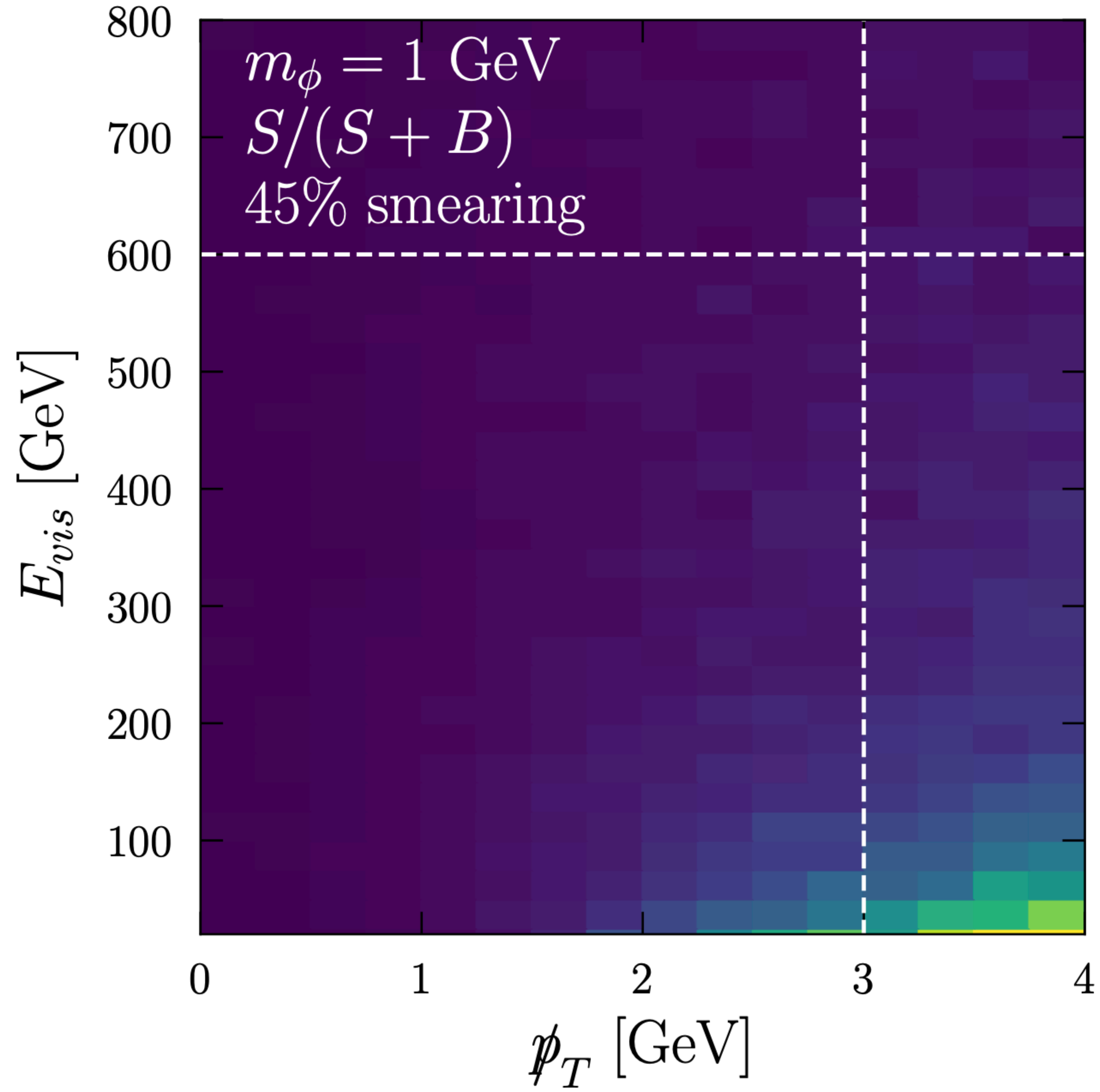
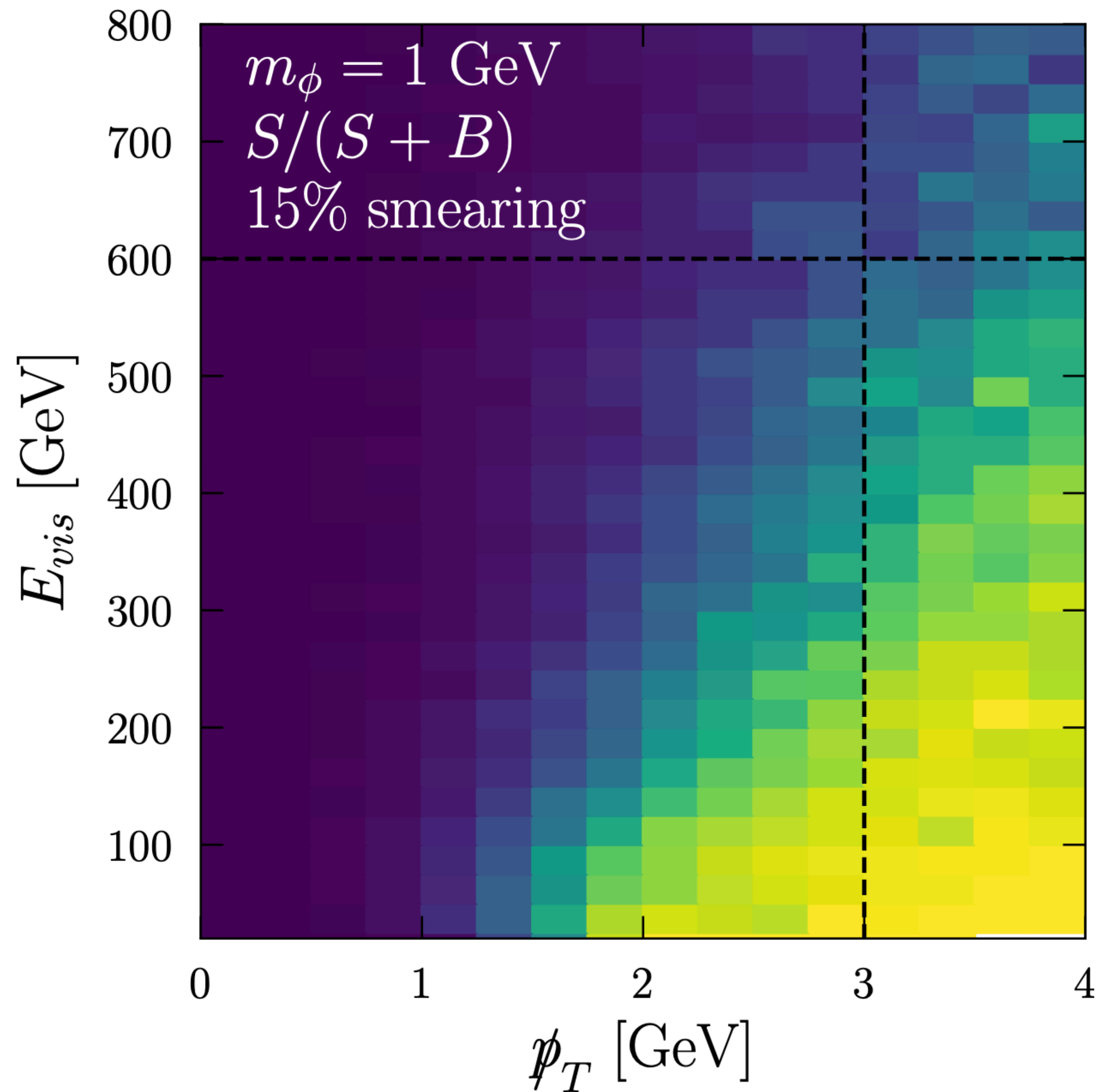
Event Distributions in a FLArE-like Detector



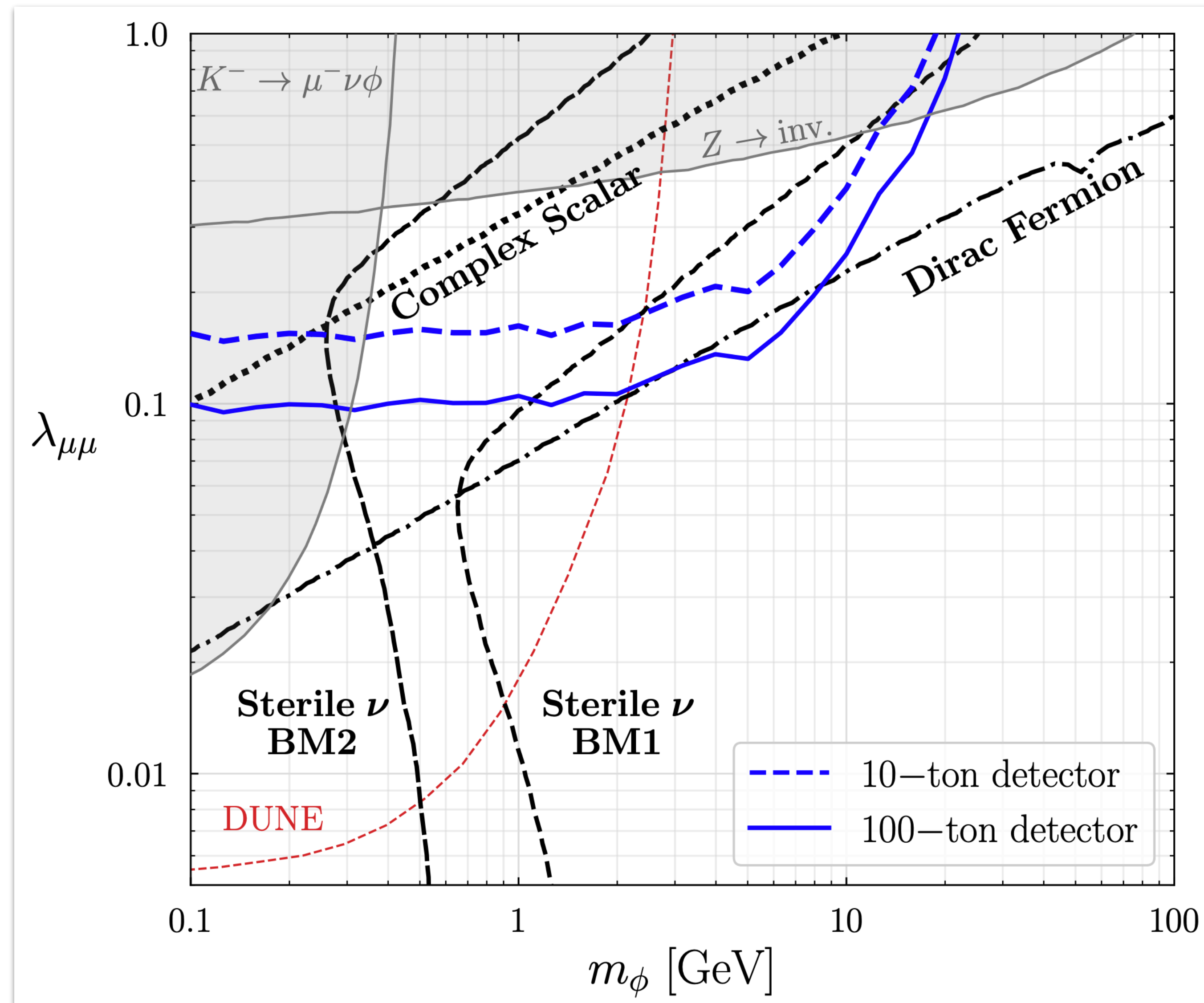
Signal/Background Optimization



Signal/Background Optimization



Sensitivity Reach at FLArE



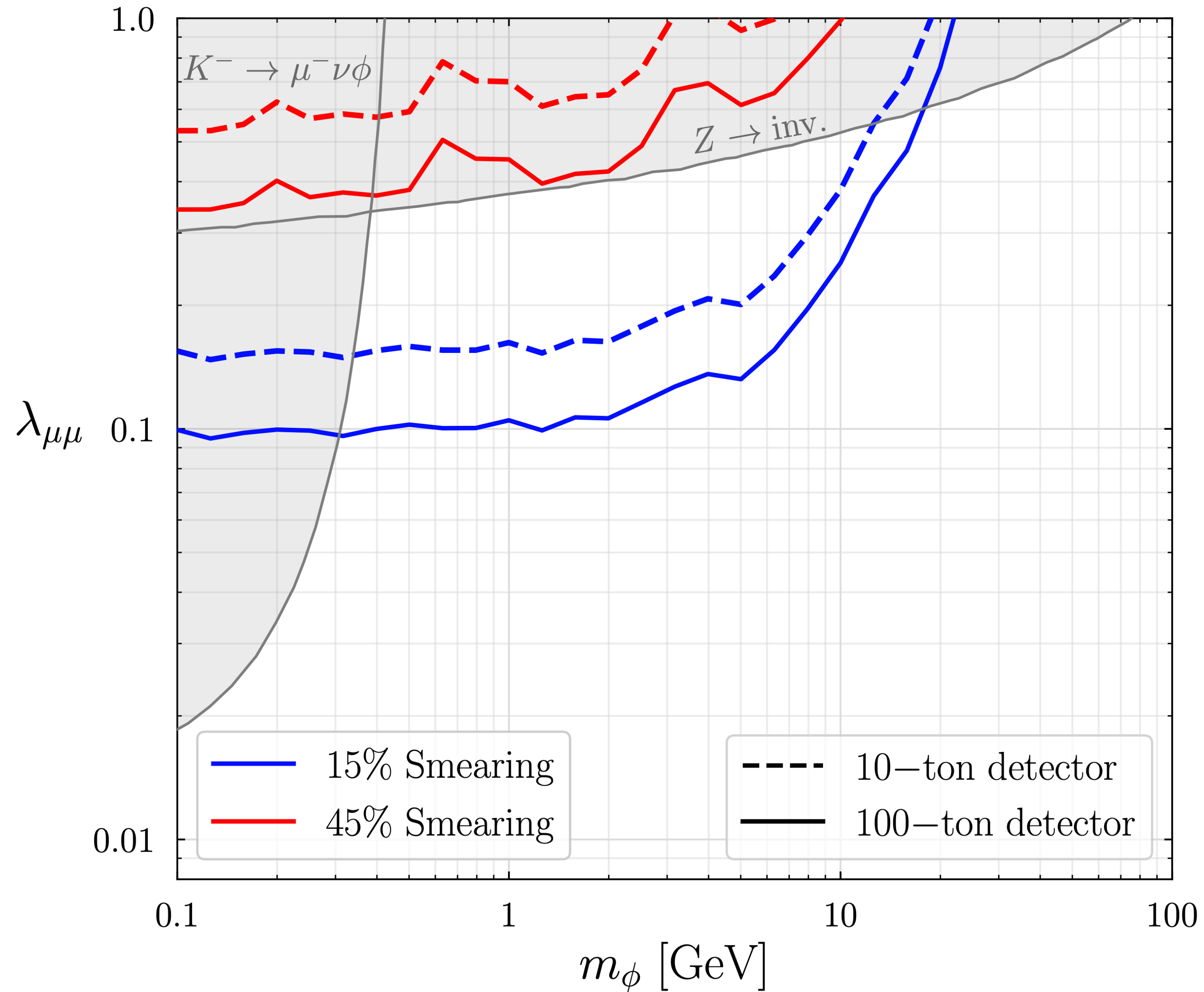
See backup slides for comparison with 45% hadronic smearing case, projections for $\lambda_{\mu\tau}$ coupling.

Wrap-up

- ✦ Many new-physics models predict modifications to neutrino rates at FPF.
- ✦ Some modify the flux, some modify the cross section, some both.
- ✦ Can introduce novel kinematical signatures in many cases that the FPF detectors (depending on type) can exploit).
- ✦ More exciting work to come!

Backup Slides

Hadronic Energy Reconstruction Impact



Coupling to Tau Neutrinos

