DSNB Decay Notes 6/26

Miller MacDonald

DSNB ν decay (IO):

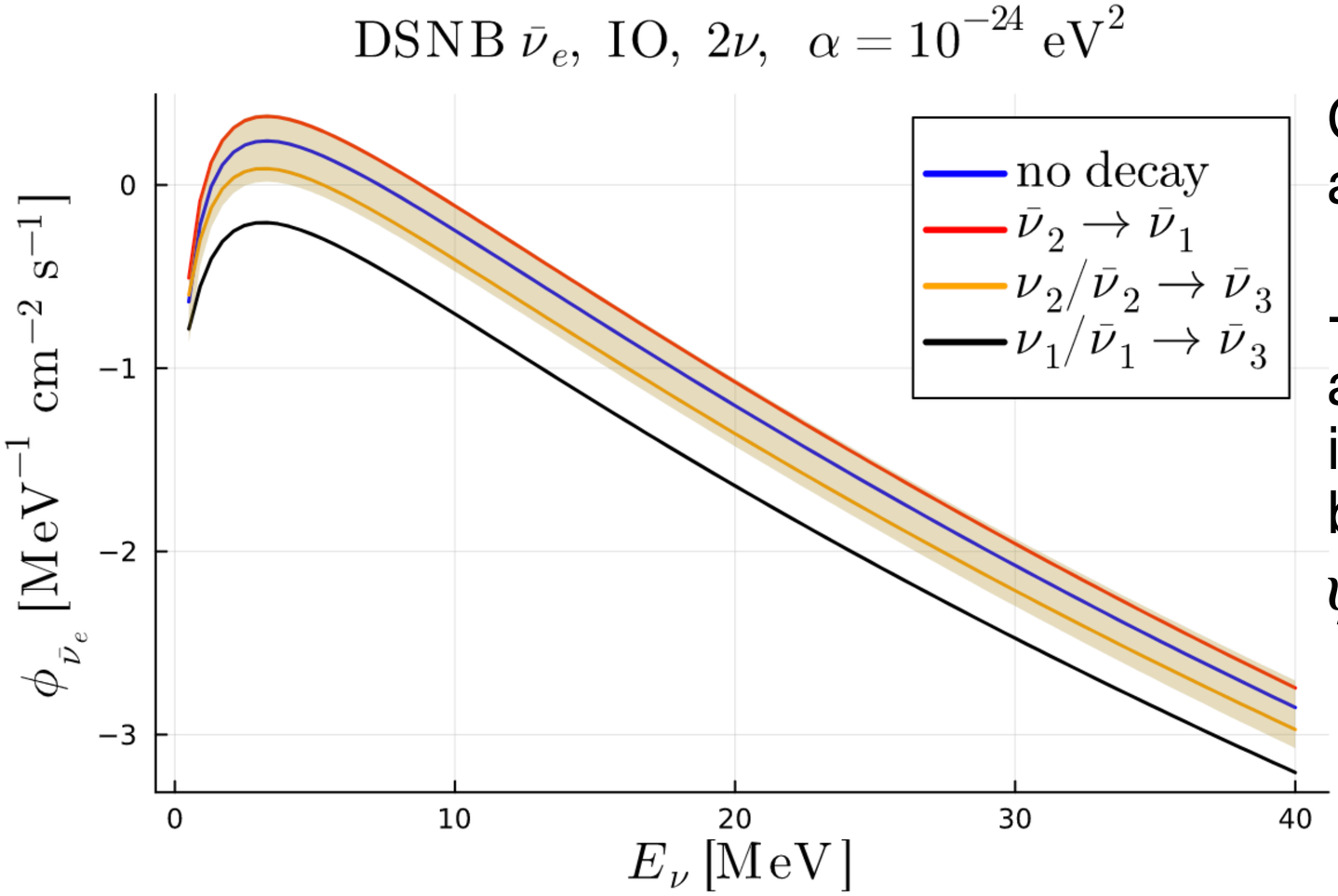
We (for now) assume $m_{\nu_3} \simeq 0$, so m_ν / m_{ν_1} and m_{ν_3} can be approximated as strongly hierarchical and m_{ν_2} and m_{ν_1} can be approximated as quasidegenerate

Can think of $\alpha_i = 10^{-24}\ \mathrm{eV}^2$ as almost **complete decay** of that mass state and $\alpha_i = 10^{-26}\ \mathrm{eV}^2$ as **partial decay**

DSNB ν decay (IO): 2ν picture

Three choices: $\bar{\nu}_2 \to \bar{\nu}_1, \nu_2/\bar{\nu}_2 \to \bar{\nu}_3, \nu_1/\bar{\nu}_1 \to \bar{\nu}_3$

Branching ratios not free!



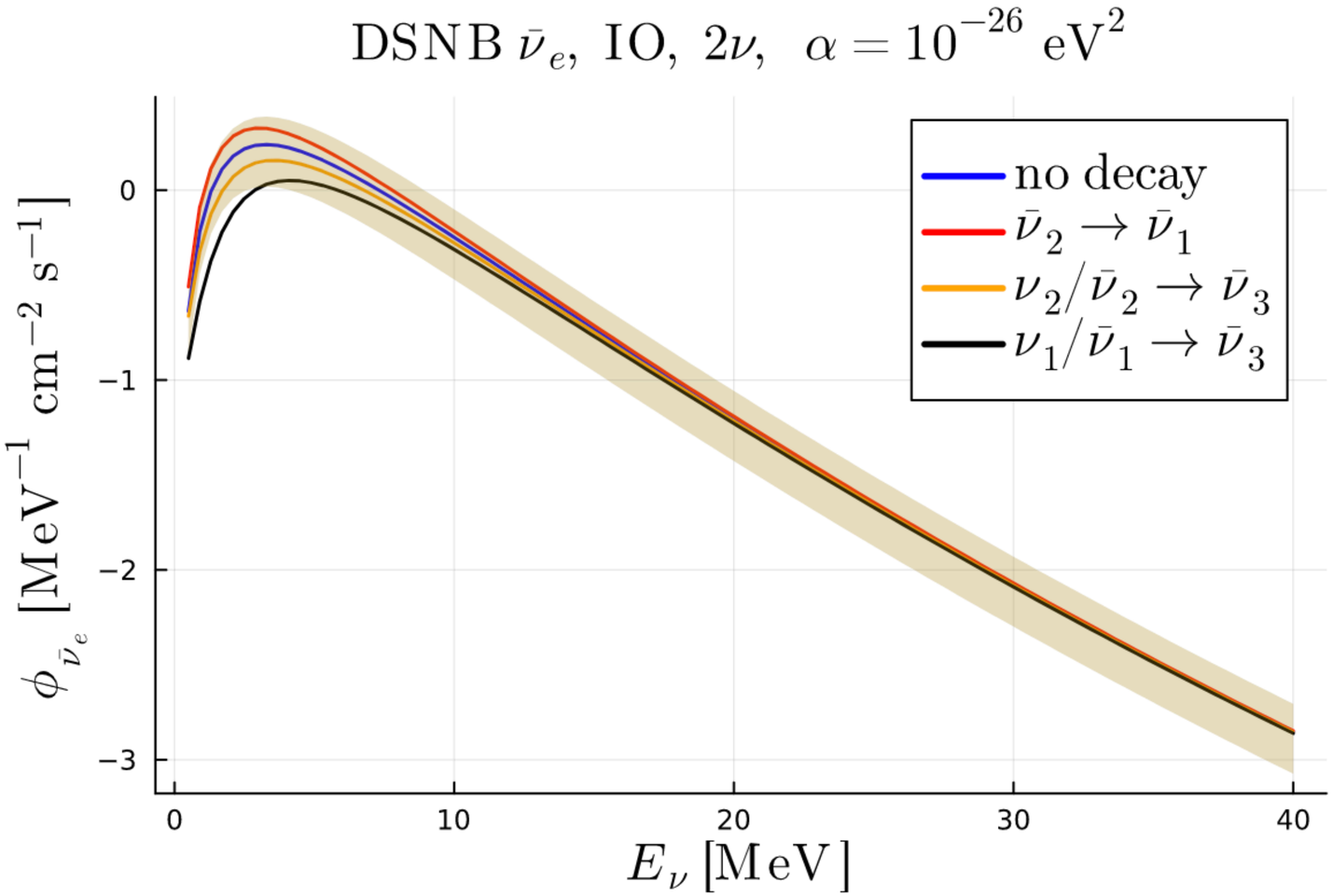
Complete decay results in roughly just a normalization change to the flux

- for $\bar{\nu}_2 \to \bar{\nu}_1$ in particular, this is almost exactly a 33% normalization increase (no spectral change), because the energy spectrum $\psi_{\nu_j \to \nu_i, \mathrm{QD}}(E_j, E_i) = \delta(E_j - E_i)$

DSNB ν decay (IO): 2ν picture

Three choices: $\bar{\nu}_2 \to \bar{\nu}_1, \nu_2/\bar{\nu}_2 \to \bar{\nu}_3, \nu_1/\bar{\nu}_1 \to \bar{\nu}_3$

Branching ratios not free!



Partial decay case isn't all that interesting lol

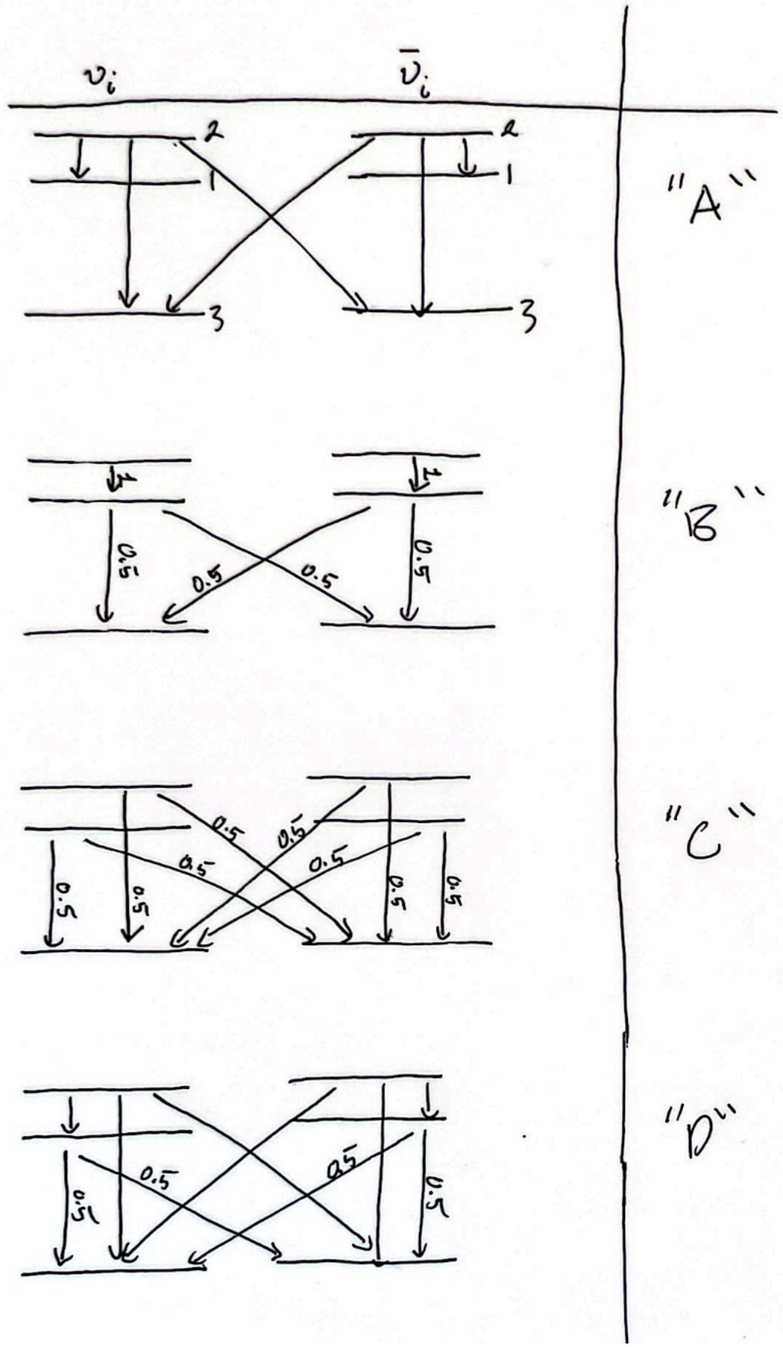
DSNB ν decay (IO): 3ν picture, it gets messier now

Let's label general cases:

- "A": $\bar{\nu}_2 \to \bar{\nu}_1$, $\nu_2/\bar{\nu}_2 \to \bar{\nu}_3$ allowed (BRs not fixed)
  - For the following plots I've picked $B(\nu_2/\bar{\nu}_2 \to \bar{\nu}_3) = 1/4$, $B(\bar{\nu}_2 \to \bar{\nu}_1) = 1/2$
- "B": $\bar{\nu}_2 \to \bar{\nu}_1$, $\nu_1/\bar{\nu}_1 \to \bar{\nu}_3$ allowed (BRs fixed)
- "C": $\nu_2/\bar{\nu}_2 \to \bar{\nu}_3$, $\nu_1/\bar{\nu}_1 \to \bar{\nu}_3$ allowed (BRs fixed)
- "D": $\bar{\nu}_2 \to \bar{\nu}_1$, $\nu_2/\bar{\nu}_2 \to \bar{\nu}_3$, $\nu_1/\bar{\nu}_1 \to \bar{\nu}_3$ allowed (i.e. everything) (BRs not fixed)
  - We can pick out a "democratic" case that's used in Fogli et al. (2004) and Iváñez-Bastalleros and Volpe (2023): $B(\nu_2/\bar{\nu}_2 \to \bar{\nu}_3) = B(\bar{\nu}_2 \to \bar{\nu}_1) = 1/3$

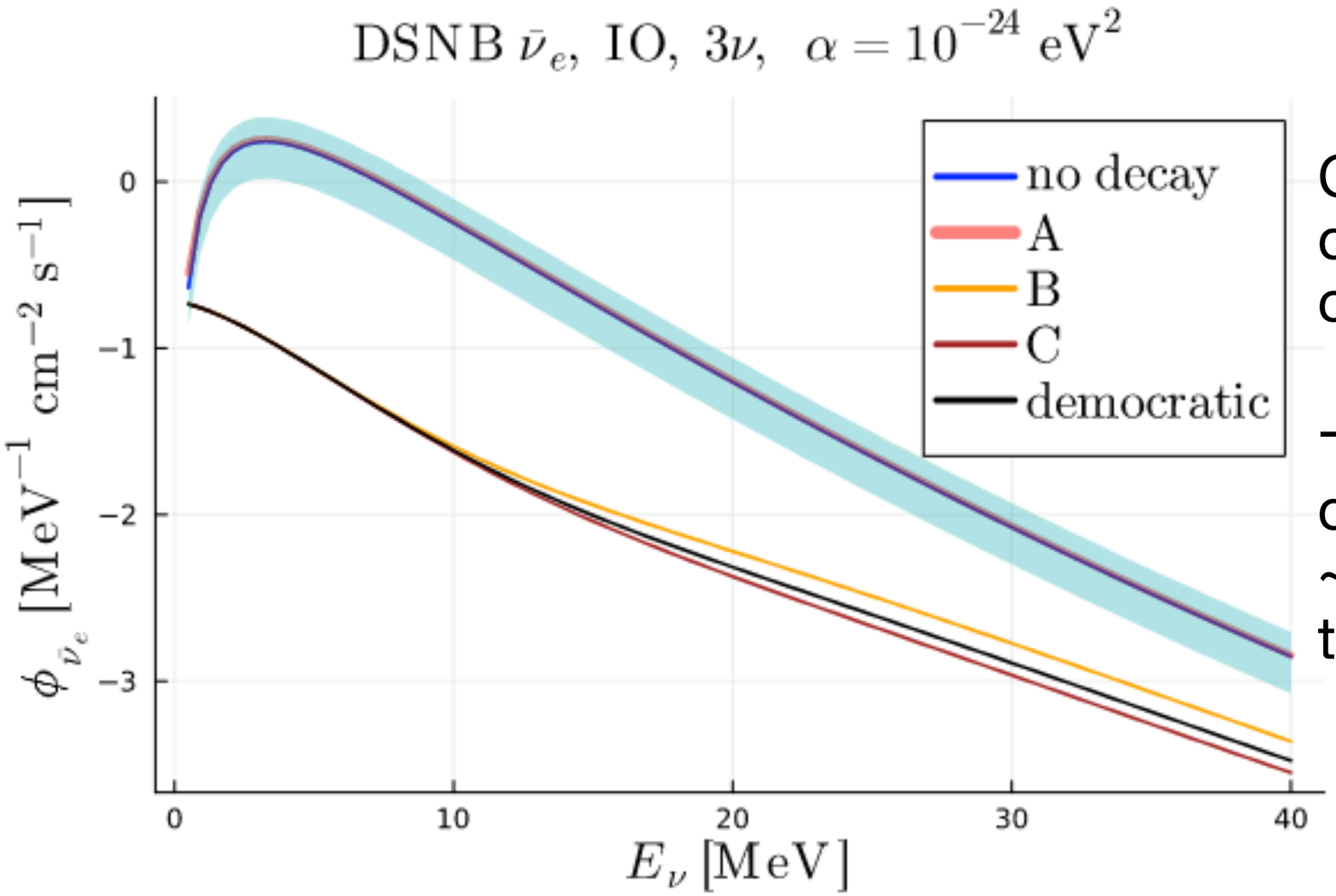
DSNB ν decay (IO): 3ν picture

Fixed branching ratios are labeled with their values, free branching ratios are left unlabeled



DSNB ν decay (IO): 3ν picture

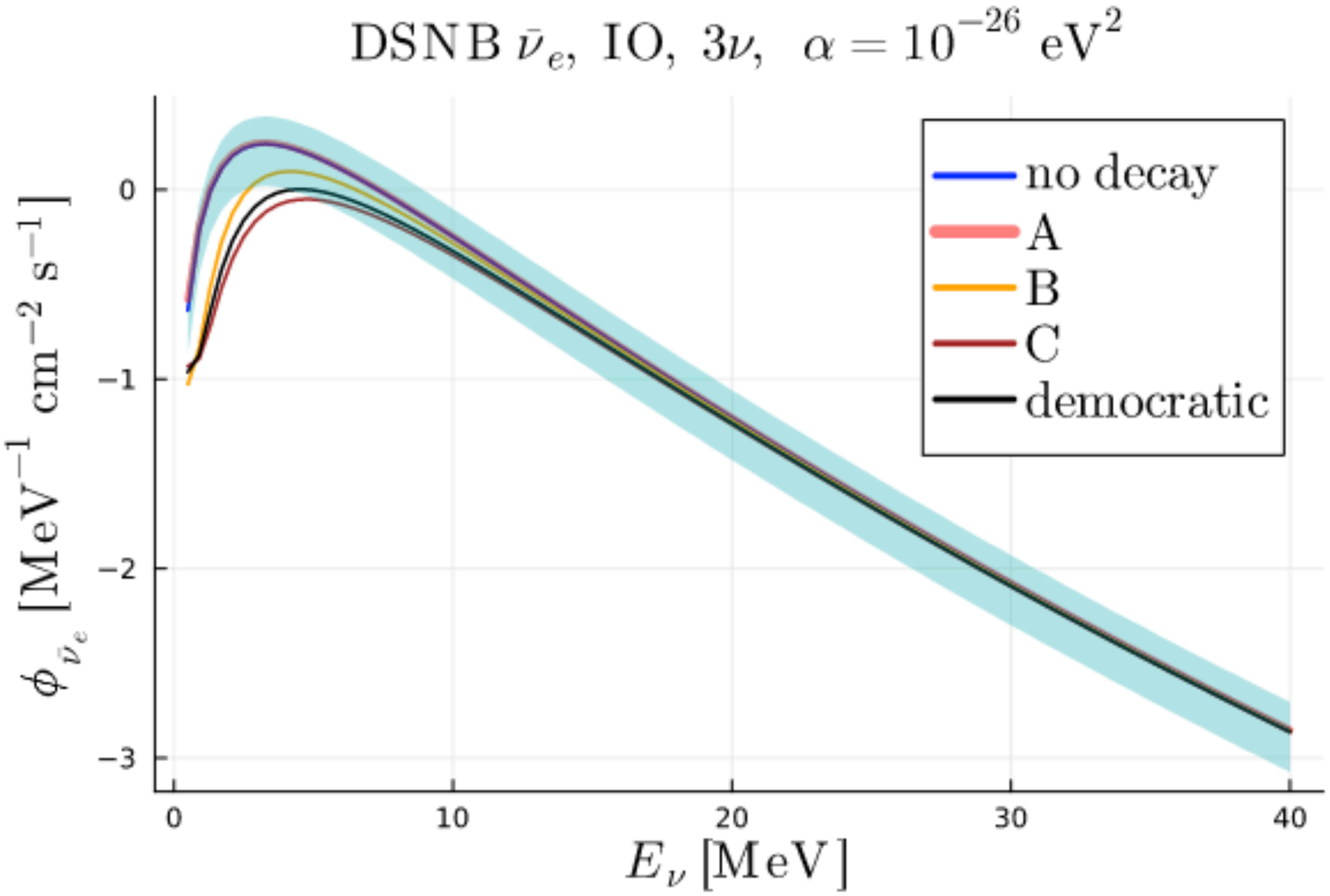
Let's first consider when $\alpha_1 = \alpha_2$, complete decay:



Case A yields an almost completely degenerate signal to the no decay case!

- Complete $\nu_2 \rightarrow \nu_3$ gives a ~1/3 decrease, complete $\nu_2 \rightarrow \nu_1$ gives a ~1/3 increase, for this choice of BR they cancel out

DSNB ν decay (IO): 3ν picture

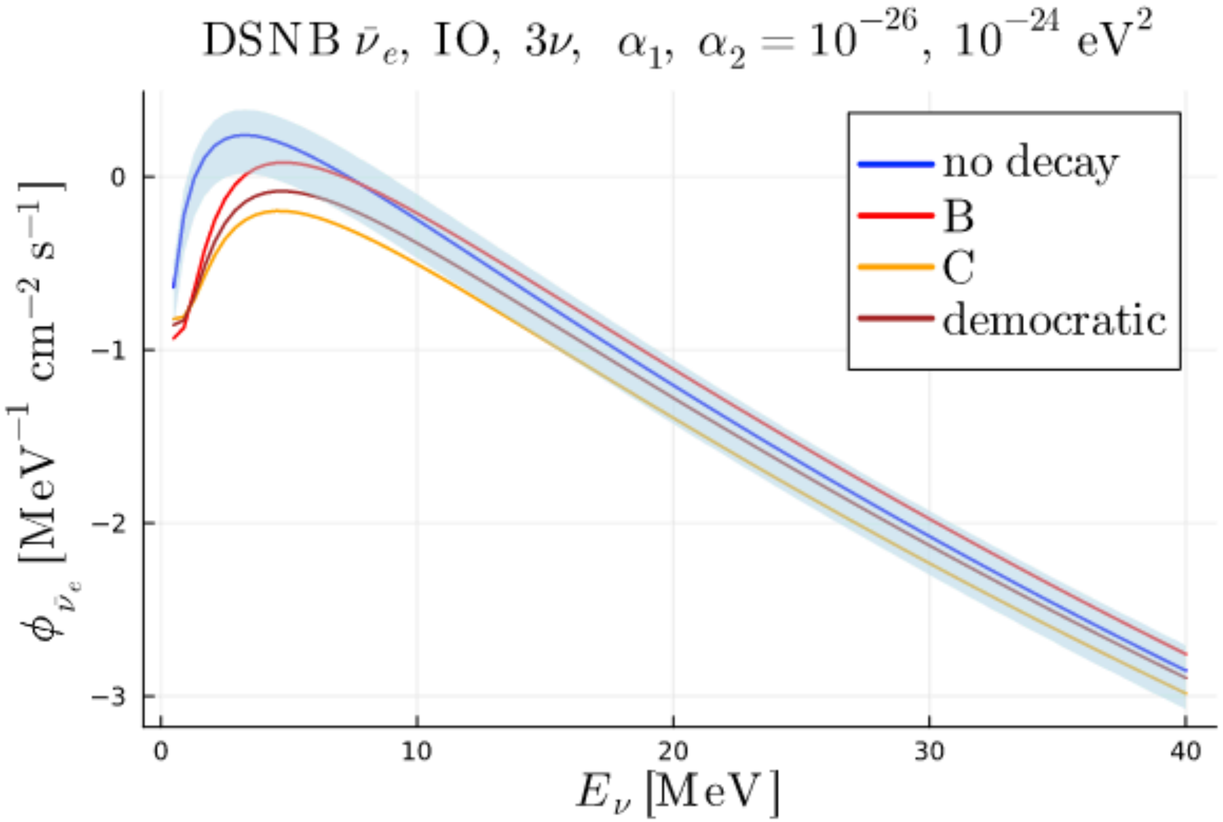


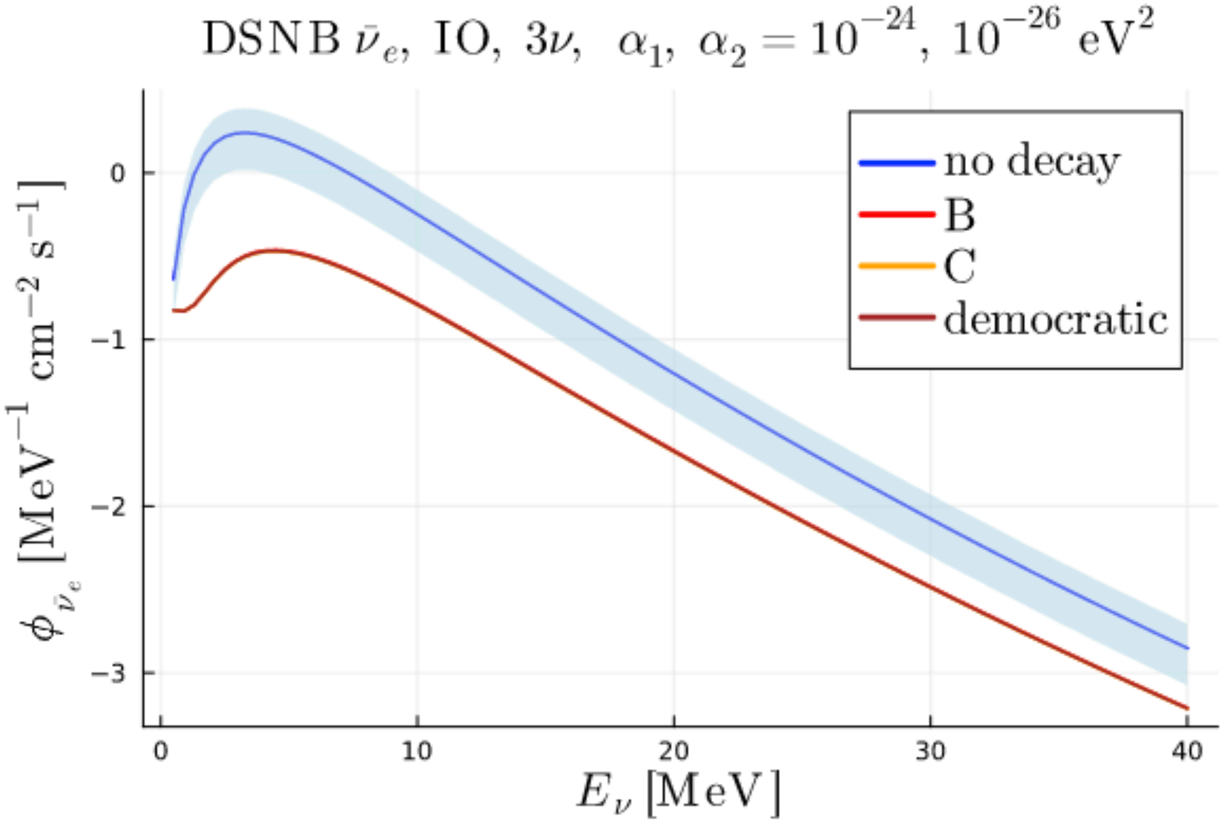
Partial decay case is again not that interesting

DSNB ν decay (IO): 3ν picture

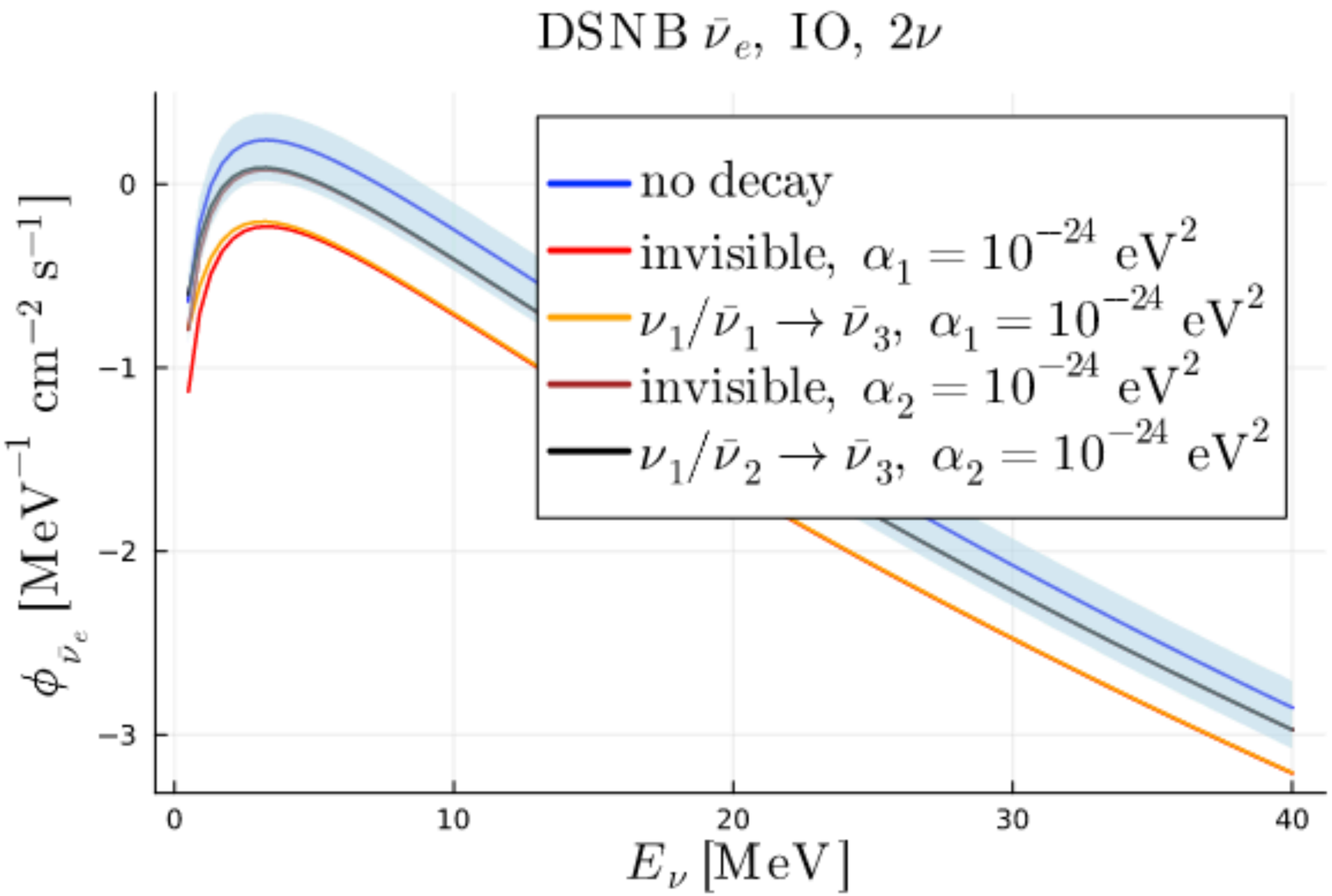
What if we made one of the mass states almost fully decay while having the other only partially decay?

Very dependent on which state does what… if ν_1 fully decays, near degenerate signals, while if ν_2 fully decays, significant differences



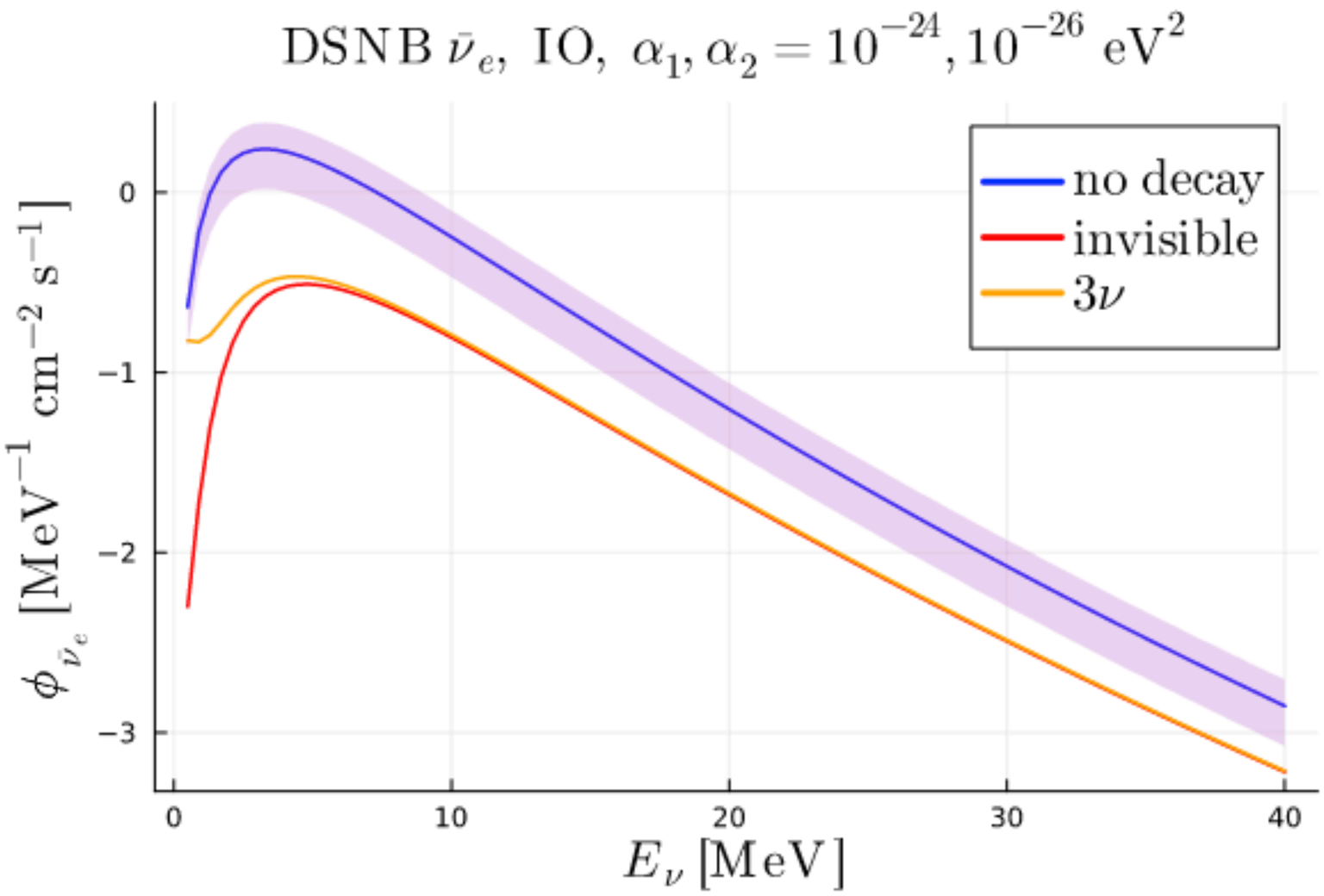


DSNB ν decay (IO): Interesting degeneracies



As expected, 2ν decays into ν_3 are degenerate with invisible decays of the given heavier mass state

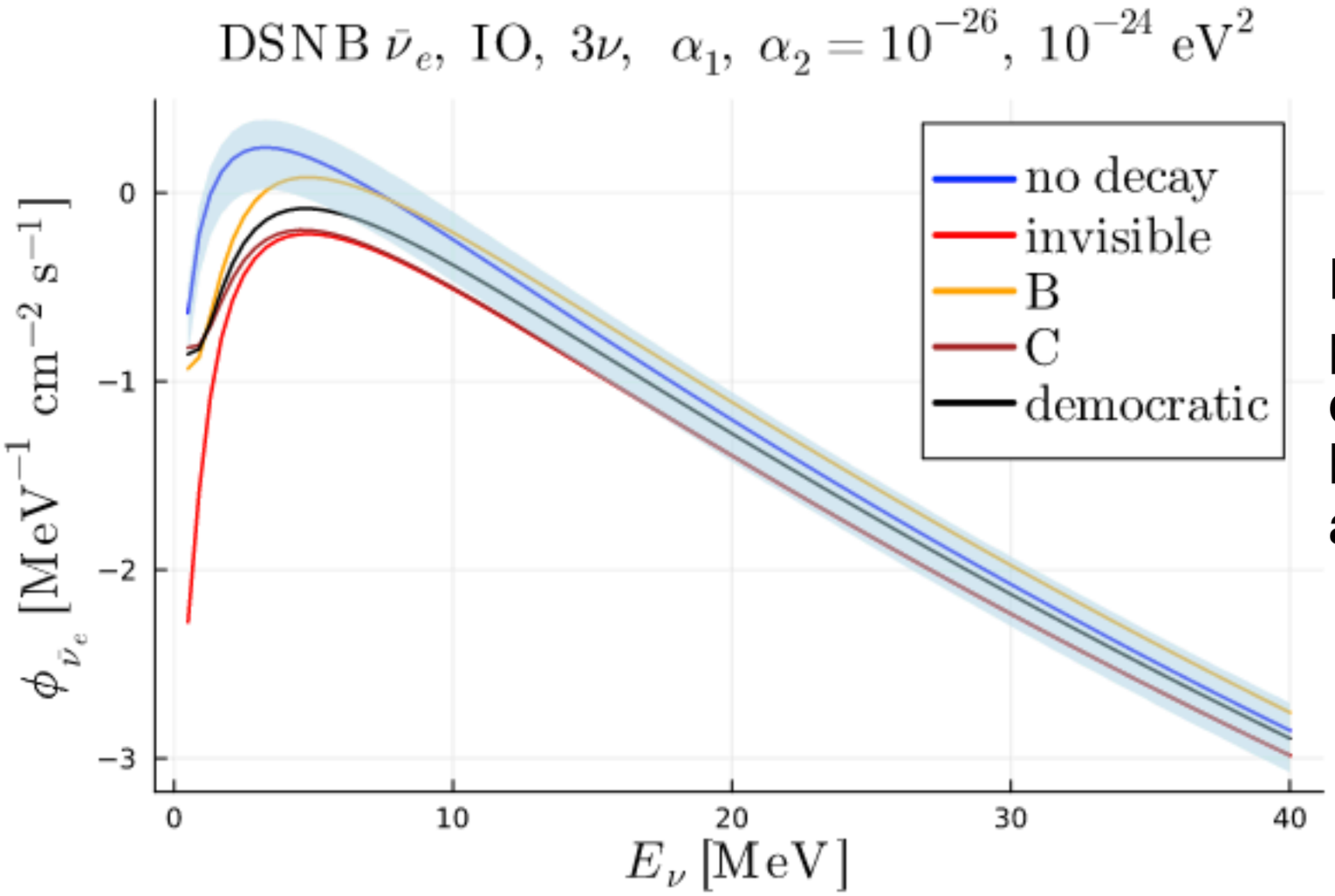
DSNB ν decay (IO): Interesting degeneracies



Here, 3ν would be B, C, or democratic—all degenerate with invisible decay (with same decay parameters)

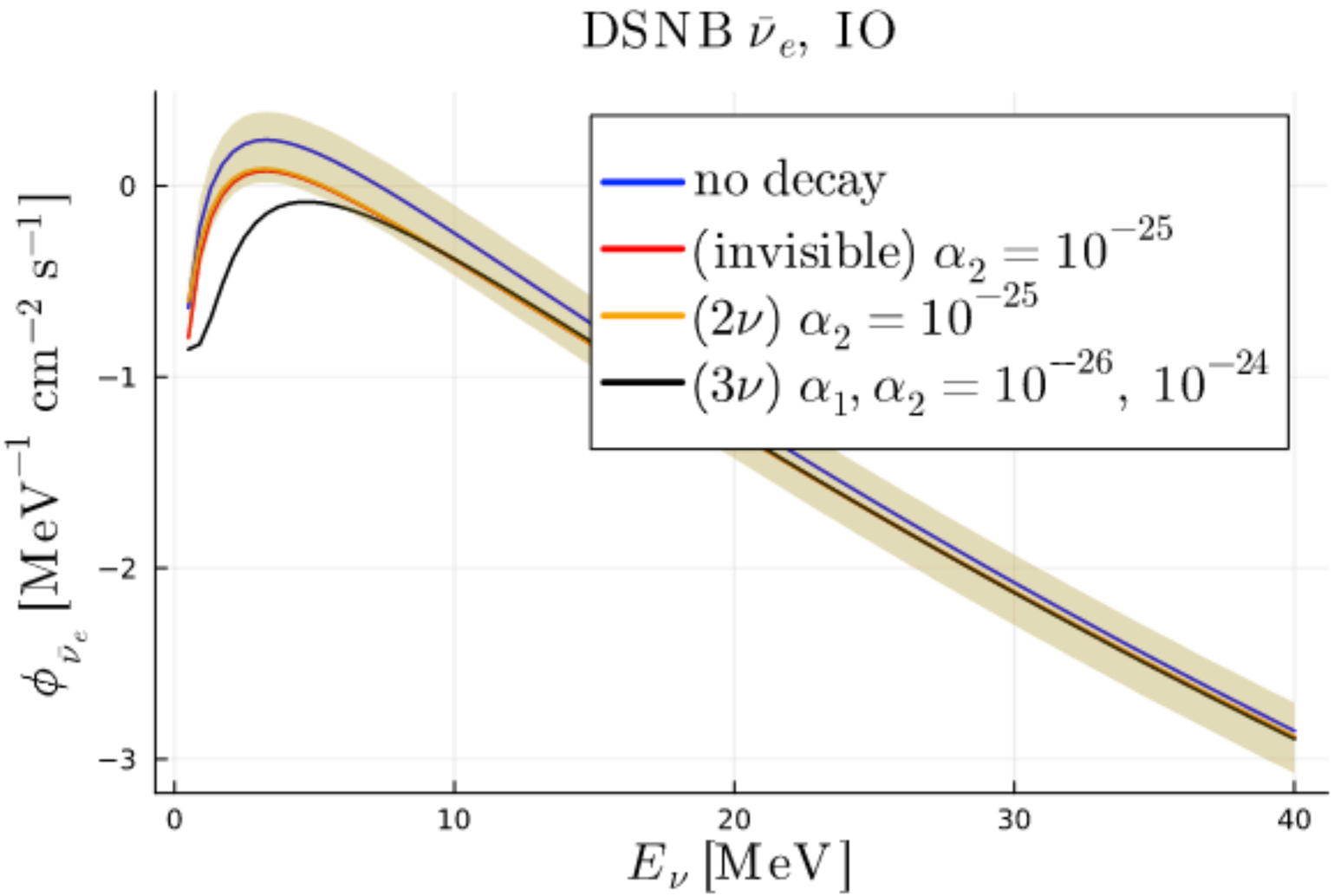
Note: Case A will never be fully degenerate with non-trivial invisible decay

DSNB ν decay (IO): Interesting degeneracies



If we let ν_2 fully decay and ν_1 only partially decay, C is still degenerate with invisible decay, but B and democratic are not anymore

DSNB ν decay (IO): Interesting degeneracies



Here's an interesting case where the 3ν (democratic) scenario for one set of decay parameters is degenerate with both 2ν and invisible scenarios for a different set of decay parameters

General thoughts + takeaways

Plenty of rich phenomenology even in these relatively model-agnostic explorations

Plenty of degeneracies both within the 3ν framework, between $3\nu - 2\nu$ – invisible, between all of these decay scenarios and no-decay signal

Still need to test out different black hole fractions to see how the spectral distortions from that play with the distortions from visible decays

Still need to examine the NO case: I think that in general the phenomenology is a little less varying (i.e. every decay scenario results in a flux increase)

- Maybe there's some degeneracy between the few IO flux increase cases (the pileups in "B" scenarios) and NO decays?