Explaining the MiniBooNE Excess Through a Mixed Model of Oscillation and Decay

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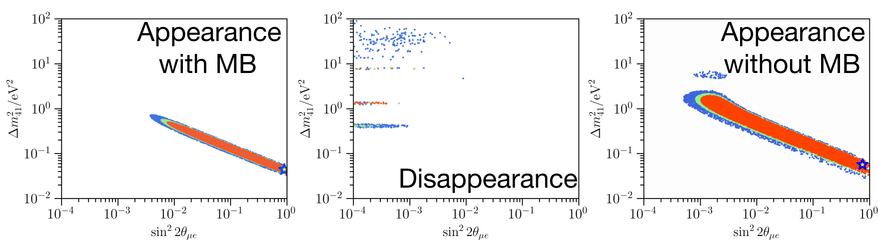
MiniBooNE and the 3+1 Model

- The most common explanation of the MiniBooNE (MB) electron-like excess invokes oscillations involving an eV-scale sterile neutrino
- This sterile neutrino is not consistent with global experimental data—removing MB from the global fits reduces tension between appearance and disappearance results

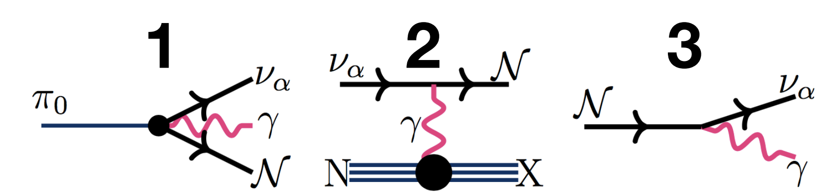


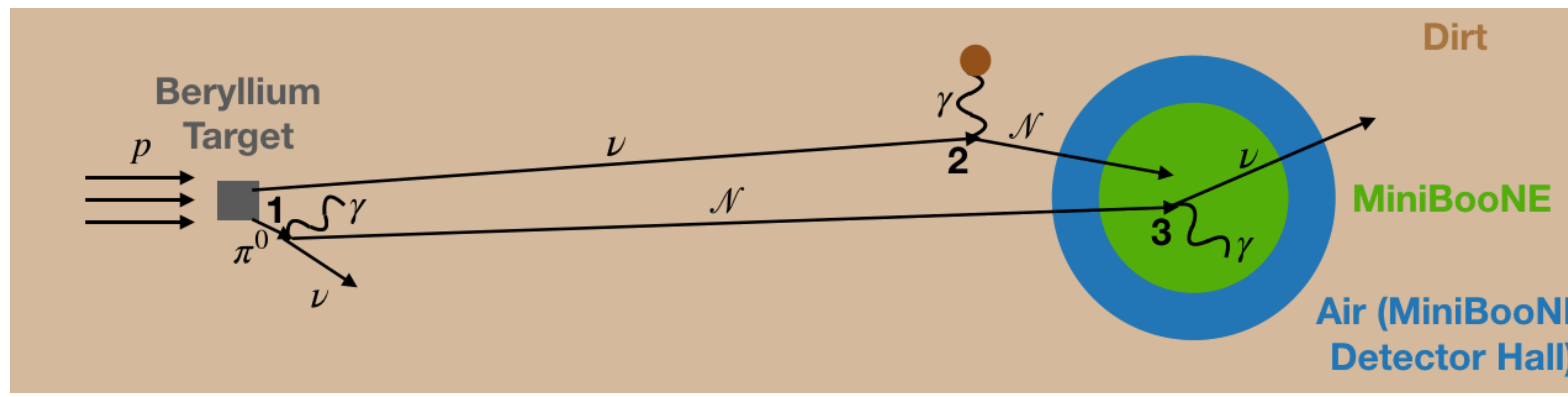
$$p_{\mathrm{PG}} = \begin{cases} 8\times10^{-7}\,(4.8\sigma) & \text{w/ MiniBooNE} \\ 7\times10^{-3}\,(2.5\sigma) & \text{w/o MiniBooNE} \end{cases}$$

The HNL Dipole Model

- Adds a small coupling between heavy neutral leptons (HNLs), active neutrinos, and photons
- HNL decays to photons inside MB will mimic a charged-current electron neutrino signal
- We have simulated the expected HNL decay rate in MB for different dipole couplings and HNL masses

$$\mathcal{L} \supset \mathcal{L}_{SM} + \sum_{j=1}^{3} \bar{\mathcal{N}}_j (i\partial\!\!\!/ - M_j)\mathcal{N}_j + \sum_{i=1}^{3} (d_{i,j}\bar{\nu}_i \sigma_{\mu\nu} F^{\mu\nu} \mathcal{N}_j + h.c.)$$





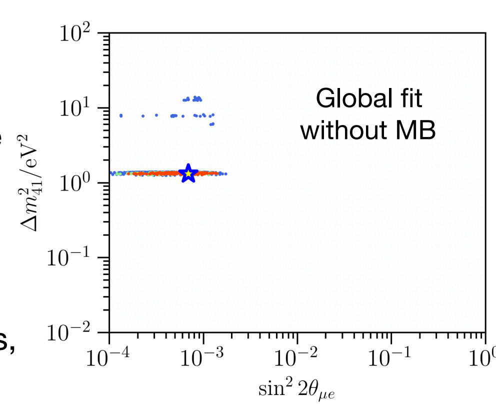
MiniBooNE Fit Results

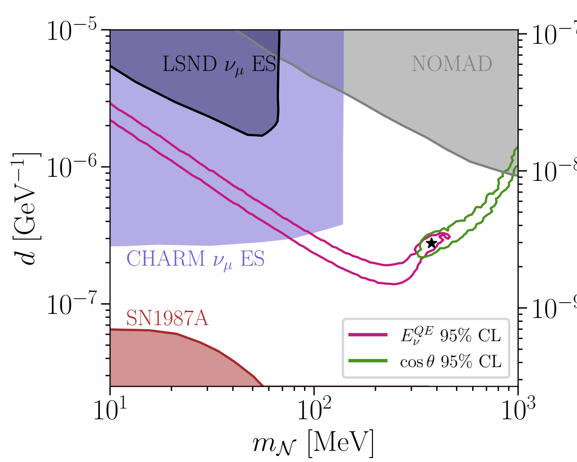
- We first determine the eV-scale oscillation parameters from a global fit to ν_e appearance (without MB) and $\nu_{\mu/e}$ disappearance data:

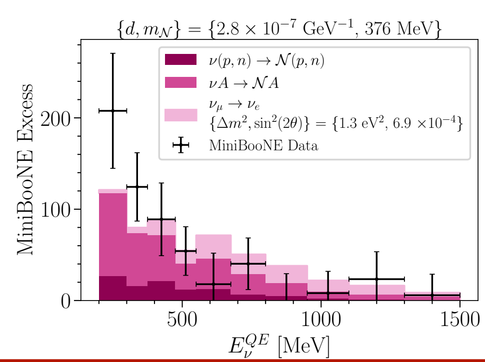
$$\Delta m^2 = 1.3\,\mathrm{eV}^2 \qquad \sin^2(2\theta_{\mu e}) = 6.9\times10^{-4}$$

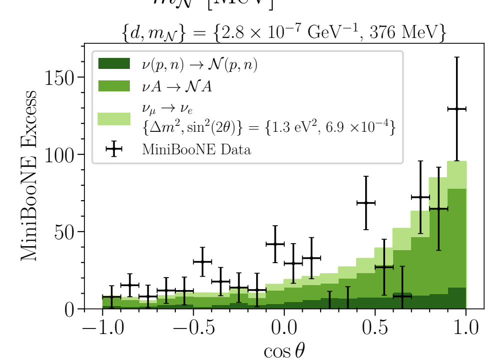
- We then subtract this oscillation contribution from the MB data and fit the remaining excess, in both the energy (systematic + statistical error) and angular (statistical error only) distributions, to the HNL dipole model

Parameters	χ^2/dof			
$(\sin^2 2\theta, d, m_{\mathcal{N}})$	$3+1+\mathcal{N}$		$3+1$	
	E_ν^{QE}	$\cos\theta$	E_ν^{QE}	$\cos\theta$
(0.30, 3.1, 376)	5.7/8	32.1/18	30.5/10	86.4/20
(0.69, 2.8, 376)	7.9/8	31.4/18	27.3/10	71.8/20
(2.00, 5.6, 35)	20.2/8	36.7/18	27.6/10	40.8/20
(0, 0, 0)	34.1/10	99.4/20	same	same









Conclusion

- Removing MB from the 3+1 global fit relieves tension between appearance and disappearance channels
- The combination of oscillations from the 3+1 fit with dipole-mediated HNL decays gives a good fit to the energy and angular distributions of the MB excess
- This results in a highly predictive HNL dipole model which evades existing experimental limits but can be tested by future experiments

Acknowledgements

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