Sterile Neutrino and Dipole Portal Explanations of the MiniBooNE Excess

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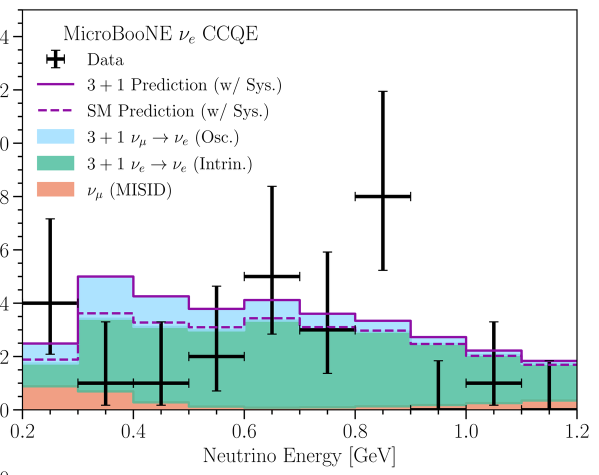
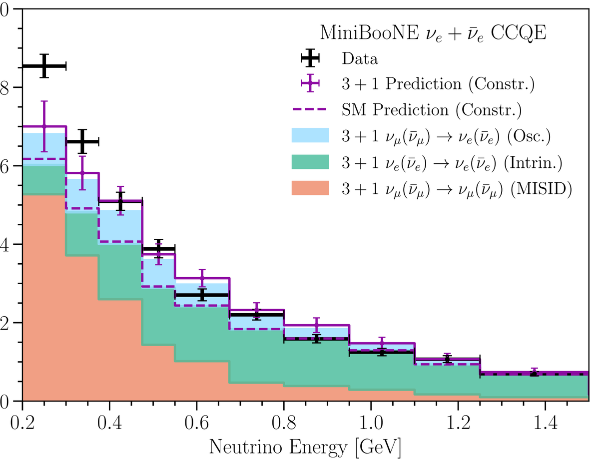
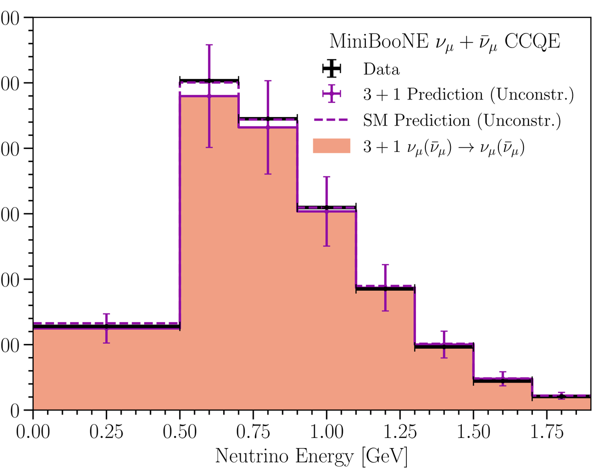
The MiniBooNE Excess and Sterile Neutrinos

- The simplest explanation of the LSND $\bar{\nu}_e$-like excess and MiniBooNE electron-like excess invokes oscillations involving an eV-scale sterile neutrino
- Recent MicroBooNE results [1] have disfavored a generic excess of electron neutrinos in the Booster Neutrino Beam, but do not rule out MiniBooNE's allowed region in oscillation parameter space [2, 3]
- The MiniBooNE collaboration has recently performed a combined 3+1 fit using MiniBooNE data and the MicroBooNE CCQE result [2]



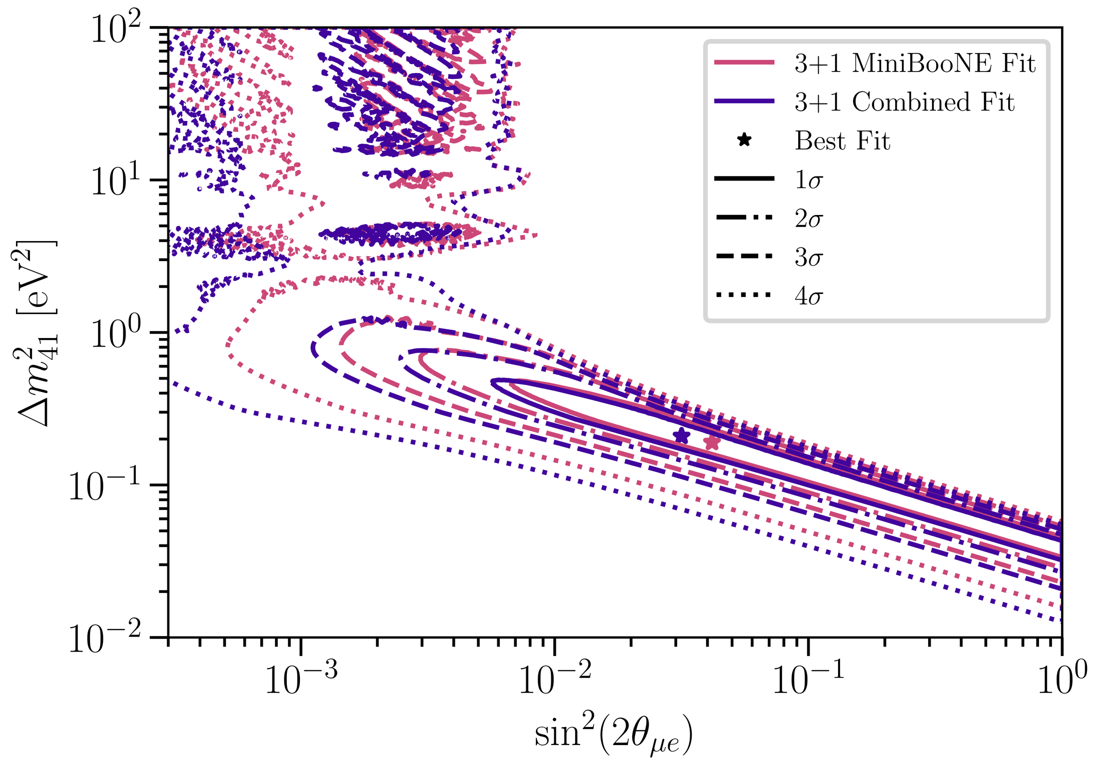




$$P(\nu_\mu \to \nu_X) = 4|U_{\mu 4}|^2(1-|U_{\mu 4}|^2)\sin^2\left(\frac{\Delta m^2_{41}L}{E}\right)$$

$$P(\nu_e \to \nu_X) = 4|U_{e4}|^2(1-|U_{e4}|^2)\sin^2\left(\frac{\Delta m^2_{41}L}{E}\right)$$

$$P(\nu_\mu \to \nu_e) = 4|U_{e4}|^2|U_{\mu 4}|^2\sin^2\left(\frac{\Delta m^2_{41}L}{E}\right)$$



The inclusion of the MicroBooNE CCQE data does not appreciably change the allowed regions in 3+1 parameter space

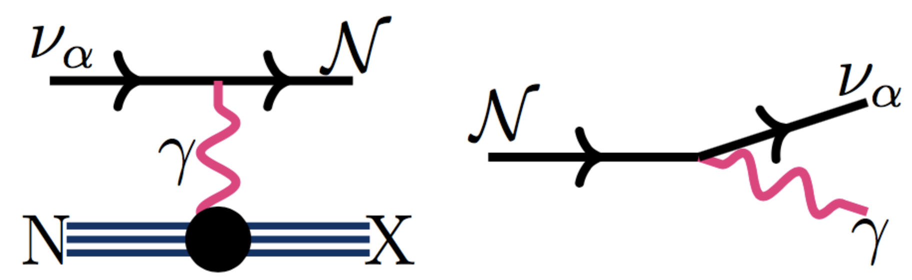
- Even so, an eV-scale sterile neutrino is not able to explain the lowest energy and most forward parts of the MiniBooNE excess.
- Additionally, removing MiniBooNE reduces tension in global 3+1 oscillation fits by $\sim 2\sigma$ [4]

$$p_{\text{PG}} = \begin{cases} 8 \times 10^{-7}\,(4.8\sigma) & \text{w/ MiniBooNE} \\ 7 \times 10^{-3}\,(2.5\sigma) & \text{w/o MiniBooNE} \end{cases}$$

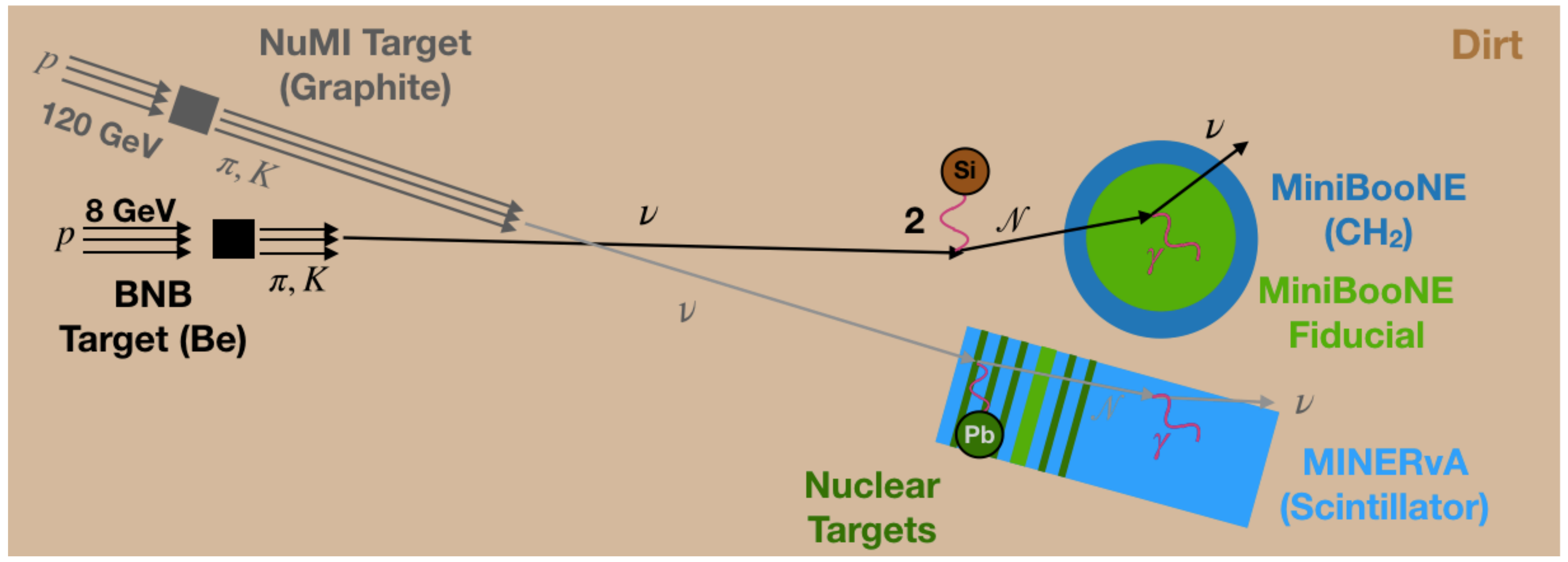
- This motivates the study of more exotic BSM models in addition to standard 3+1 oscillations

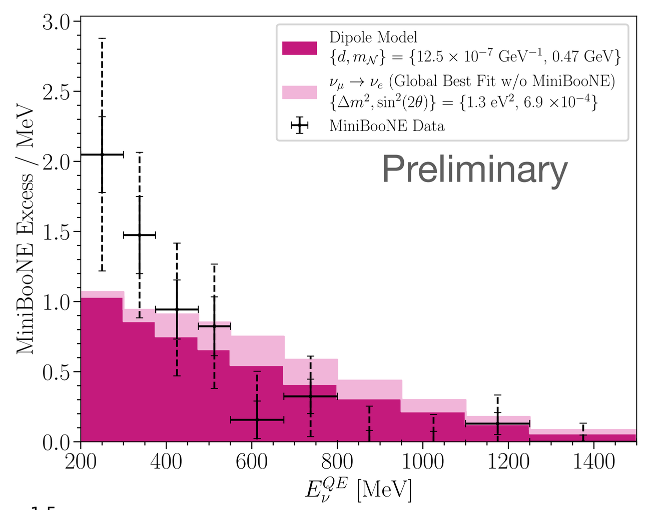
The Dipole Portal Model

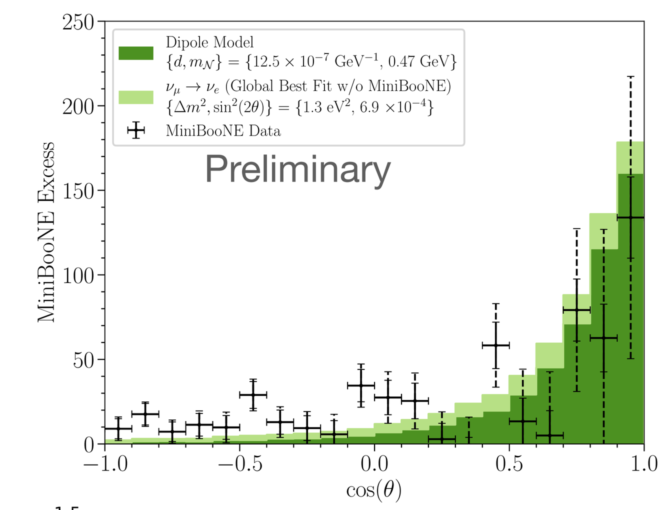
$$\mathscr{L} \supset d_{\mu N}\overline{\nu_\mu}\sigma_{\rho\sigma}F^{\rho\sigma}\mathcal{N}_R + \text{h.c.}$$

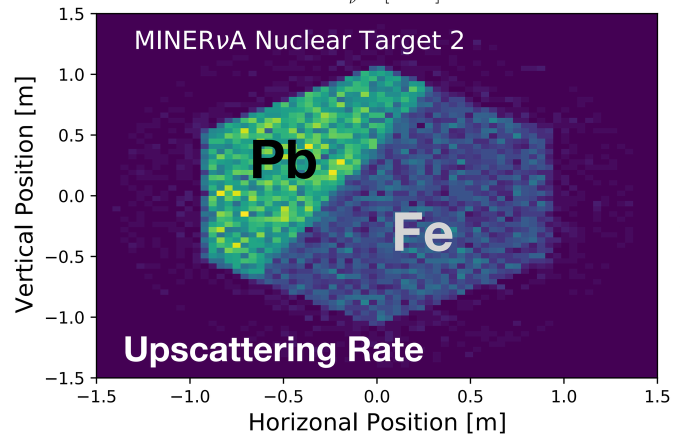


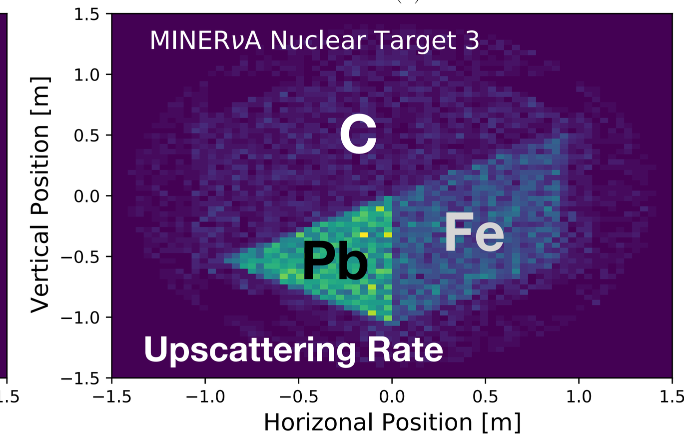
- To accommodate the remaining MiniBooNE excess, we consider the addition of a dipole-coupled heavy neutral lepton (HNL)
- MINERvA elastic scattering measurements [5] are also sensitive to HNL decays to photons
  - NuMI energies are too large to be sensitive to oscillations
- Use LeptonInjector [6] to simulate HNL production and decay





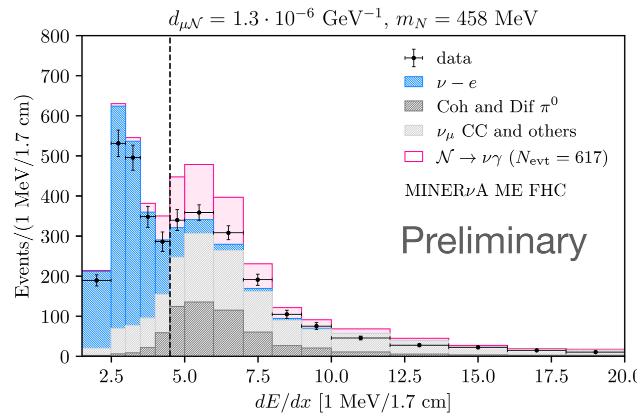


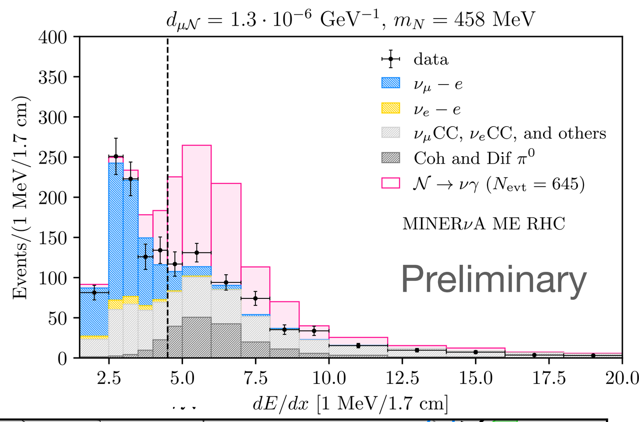


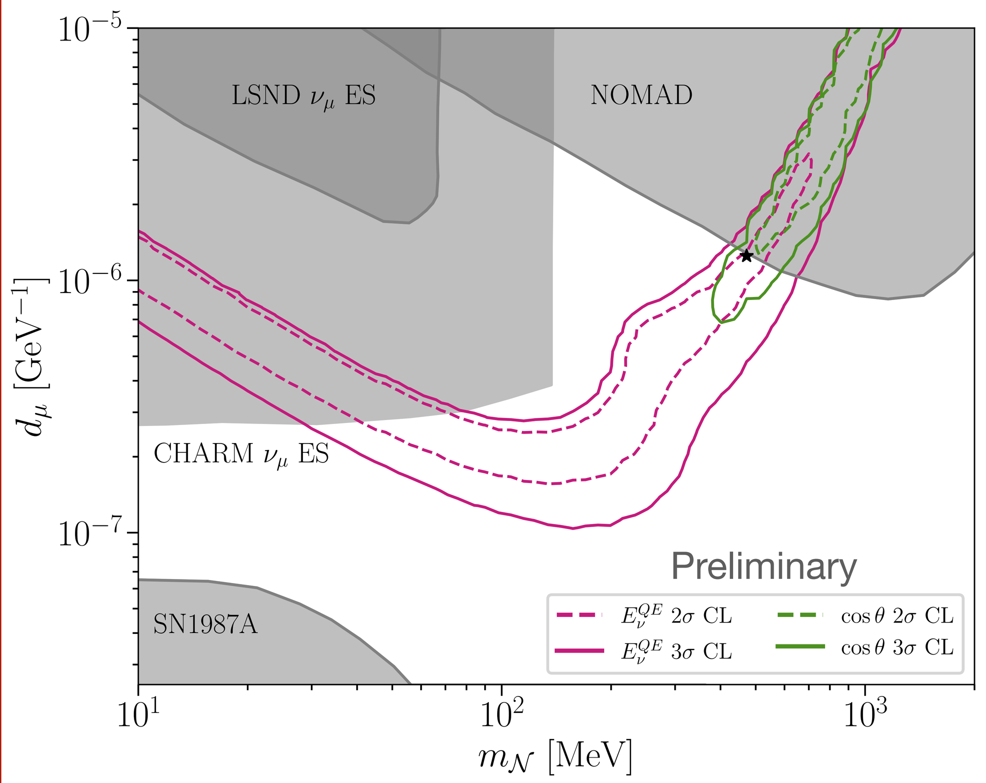


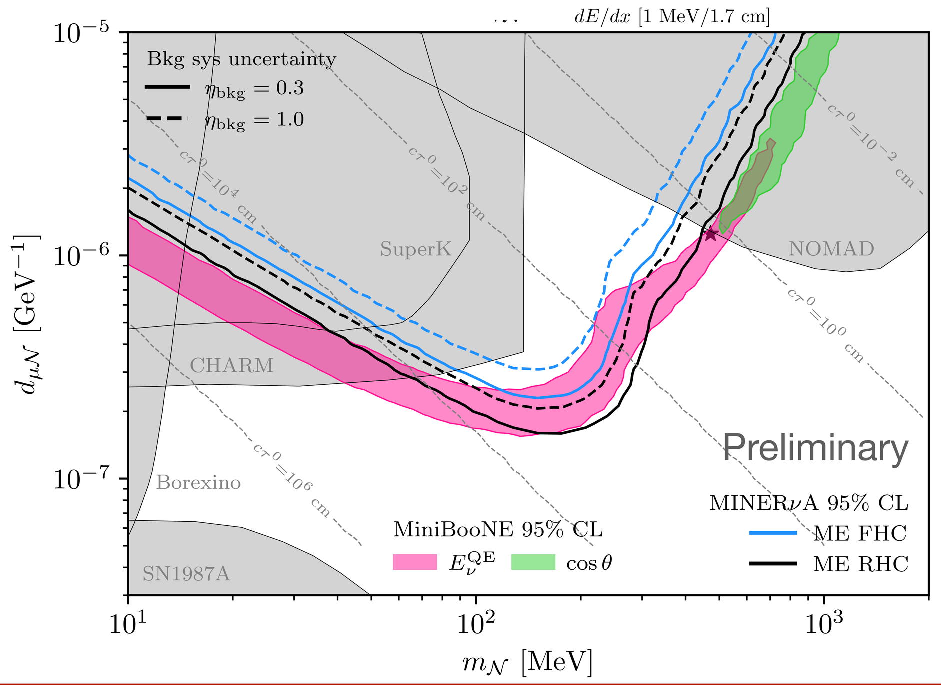
Dipole Fit Results

- Energy and angular distributions of the MiniBooNE excess prefer different regions of dipole parameter space
- Allowed regions for each distribution overlap at the 2σ level
- MINERvA elastic scattering data places stringent limits on the MiniBooNE preferred regions









Conclusions

- The recent MicroBooNE results do not rule out the MiniBooNE preferred region in 3+1 parameter space
- The addition of a dipole-coupled HNL can alleviate tension in 3+1 global fits while retaining a reasonable explanation of the MiniBooNE excess
- MINERvA elastic scattering measurements place constraints on MiniBooNE preferred region in dipole parameter space; however, allowed regions still remain at the 2σ-3σ level
- Most stringent constraints come from the unpublished antineutrino analysis

References and Acknowledgements

[1] MicroBooNE Collaboration. 2110.14054 (2021)
[2] MiniBooNE Collaboration. 2201.01724 (2022)
[3] Argüelles et al. 2111.10359 (2021)
[4] Vergani et al. Phys. Rev. D 104, 095005 (2021)
[5] MINERvA Collaboration. Phys. Rev. D 100, 092001 (2019)
[6] See Austin Schneider's poster

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