A DM Interpretation of the MiniBooNE Excess and Its Implications in CEvNS Experiments

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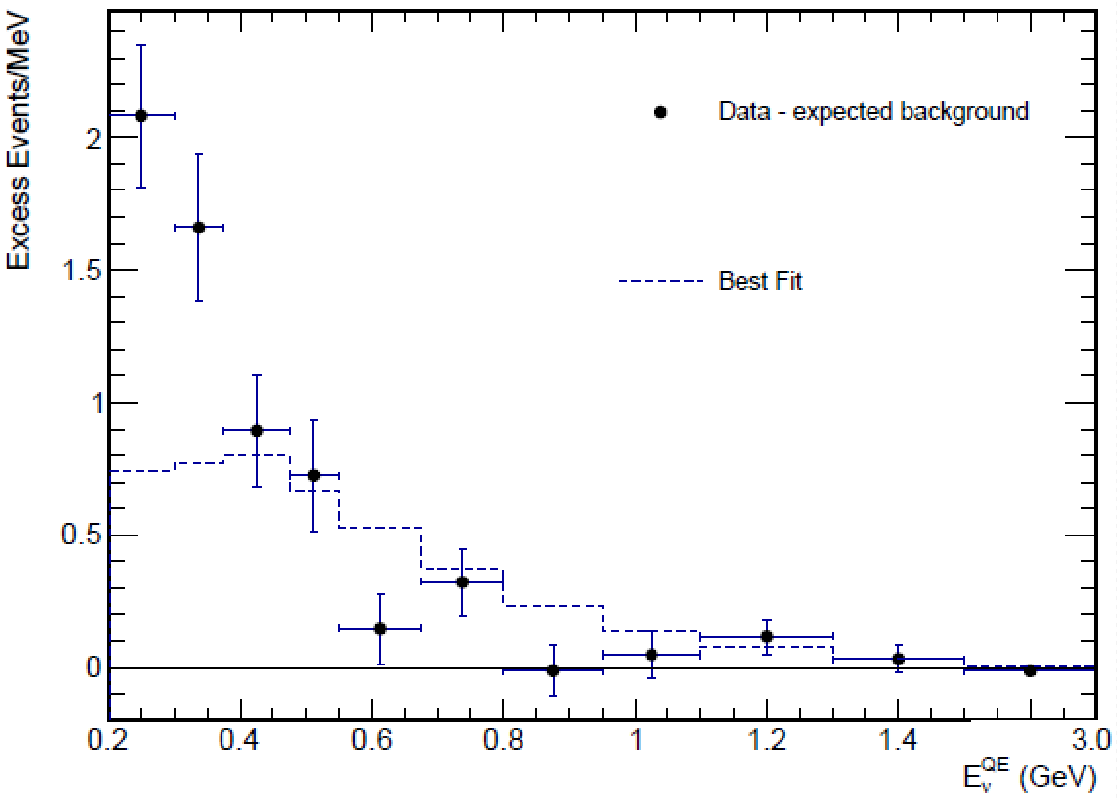
Magnificent CEvNS, October 7th, 2021

In collaboration with Bhaskar Dutta, Adrian Thompson, Remington Thornton, Richard Van de Water, to appear soon

MiniBooNE Low Energy Excess

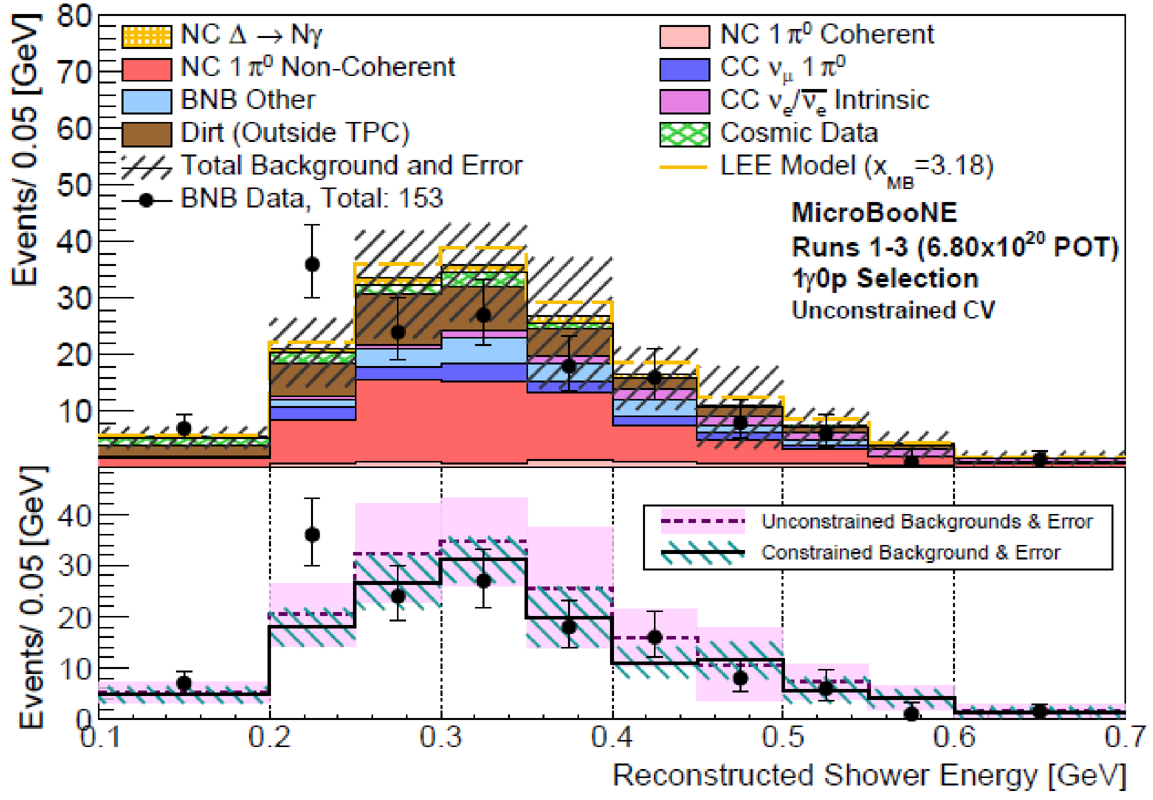


[MiniBooNE Collaboration, arXiv:2006.16883]

- An observational motivation of new physics (4.8σ)
- Numerous explanations, mostly involving neutrino-sector new physics [Karagiorgi, Djurcic, Conrad, Shaevitz, Sorel (2009); Collin, Arguelles, Conrad, Shaevitz (2016); Giunti, Lavender (2011); Gariazzo, Giunti, Lavender, Li (2017); Kopp, Maltoni, Schwetz (2011); Doring, Pas, Sicking, Weiler (2018); Dutta, Ghosh, Li (2020), and many more]
- Interpretations with dark-sector new physics (mostly coming from neutral mesons) less favored because off-target mode measurements [MiniBooNE DM Collaboration, arXiv:1807.06137] show null signal.

We propose an idea of reinstating the dark-sector scenarios for the MB excess (see also Adrian Thompson's talk).

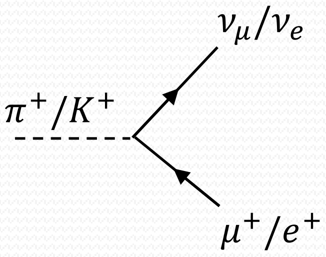
Recent MicroBooNE Result and MiniBooNE Excess



[MicroBooNE Collaboration, arXiv:2006.16883]

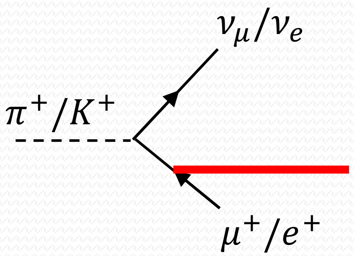
- The recent MicroBooNE result constrains NC $\Delta \to N\gamma$ event rates more stringently, supporting that the MB excess requires a new physics interpretation!
- The MicroBooNE data may not be sensitive enough to the MB excess, yet, because of (~3 times) smaller POTs, (~8 times) smaller detector volume, (~5 – 6 times) smaller efficiency.

Dark-Sector Particles Sourced by Charged Mesons

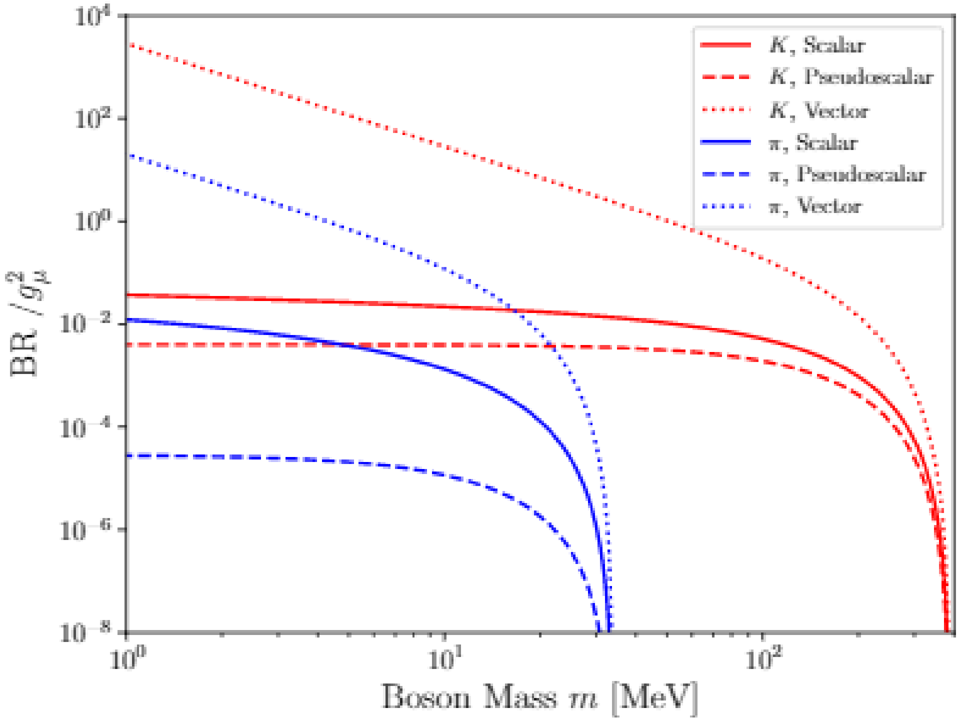


Suppressed by a "wrong" helicity assignment

vs



scalar, pseudoscalar, vector etc

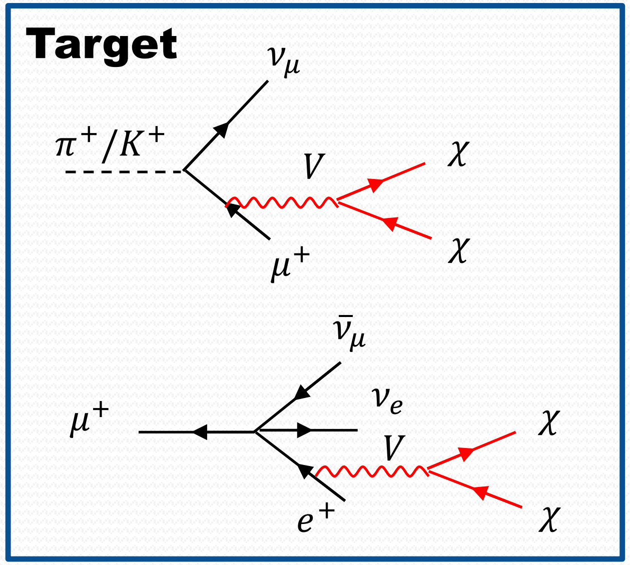


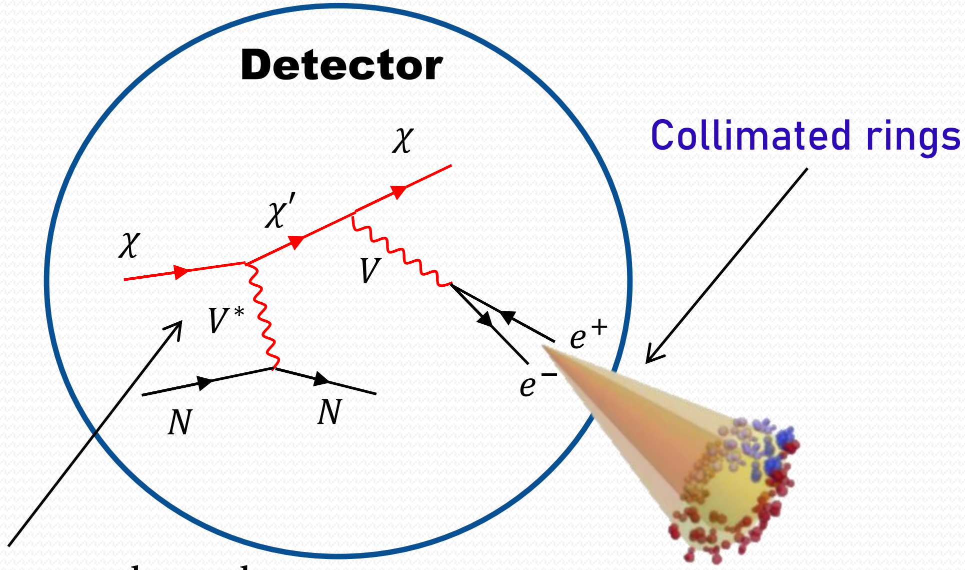
By adding the third particle, the helicity suppression can be evaded, i.e., 3-body decays can be hugely enhanced. The decay to a massive vector is even more enhanced due to the longitudinal polarization. [e.g., Carlson, Rislow, arXiv:1206.3587]

A Dark Matter Interpretation for the MiniBooNE Excess

$$-\mathcal{L}_{V,\mathrm{int}} \supset e(\epsilon_1 V_{1,\mu} + \epsilon_2 V_{2,\mu})J^{\mu}_{\mathrm{EM}} + (g_1 V_{1,\mu} + g_2 V_{2,\mu})J^{\mu}_{D} + (g'_1 V_{1,\mu} + g'_2 V_{2,\mu})J'^{\mu}_{D}$$

[See Adrian Thompson's talk for (pseudo)scalar scenarios]



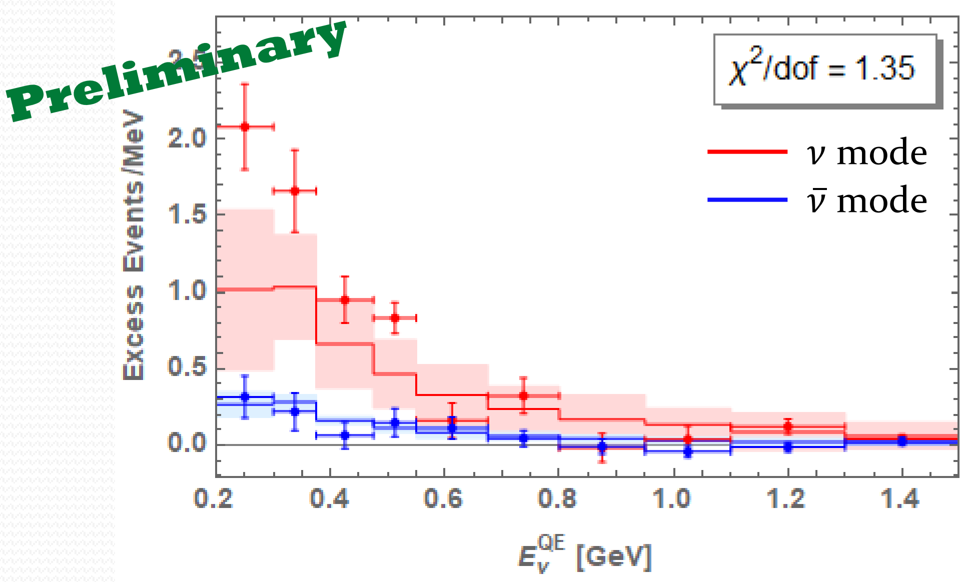


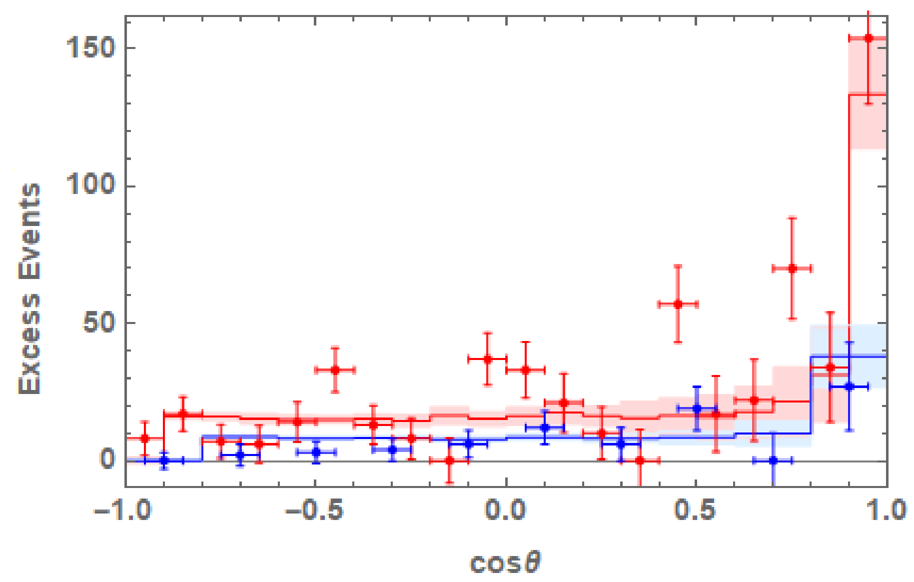
BR($V \to 2\chi$):BR($V \to 2e$) = 50%: 50% for illustration

Scattering may happen through an exchange of a different mediator.

- Neutral meson contributions are small as they are **not focused** and their decays involve **no BR enhancement**.

Example Fit

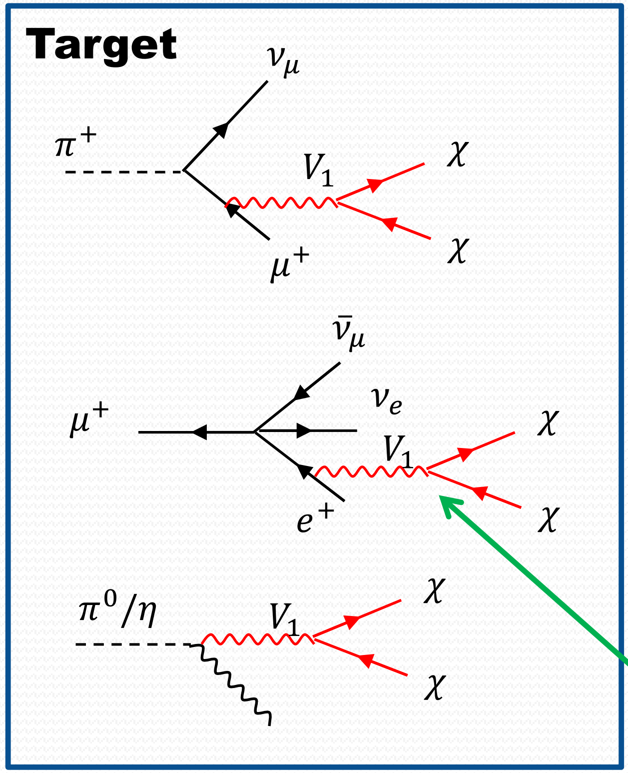




$m_{V_1} = 30$ MeV, $m_{V_2} = 200$ MeV, $m_\chi = 14$ MeV, $m_{\chi'} = 220$ MeV, $\epsilon_1\epsilon_2 = (4 \times 10^{-4})^2$

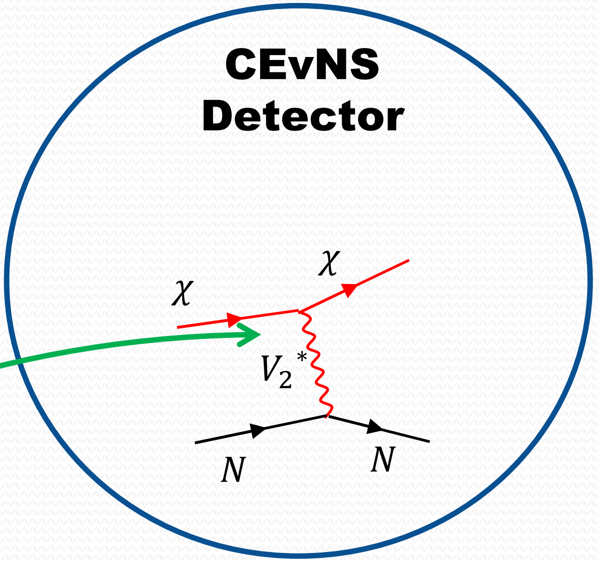
- The best-fit parameters are consistent with various limits including limits for (in)visibly decaying dark photons, limits for the exotic decays of charged π^+/K^+, and the MiniBooNE off-target mode (~30 times smaller POTs) measurement
- We have found equally good fits in the single-mediator scenario.

Predictions for CEvNS Experiments



Subdominant because the resulting χ flux is not focused, but isotropic.

→ Conventional neutral meson channels are important.



This dark-sector coupling is as small as $\sim\epsilon_1$ to have 50%:50% BRs.

This dark-sector coupling in the double-mediator scenario can be large enough for CEvNS experiments to observe MB signal events.

- Moreover, more energetic beam based experiments, e.g., JSNS², can be sensitive to signals coming from the decay of kaons.

Conclusions

- The MiniBooNE excess can be explained by dark-sector scenarios, using three-body decays of charged mesons that are focused by the horn system.
- CEvNS experiments can test new physics scenarios of explaining the MiniBooNE excess.