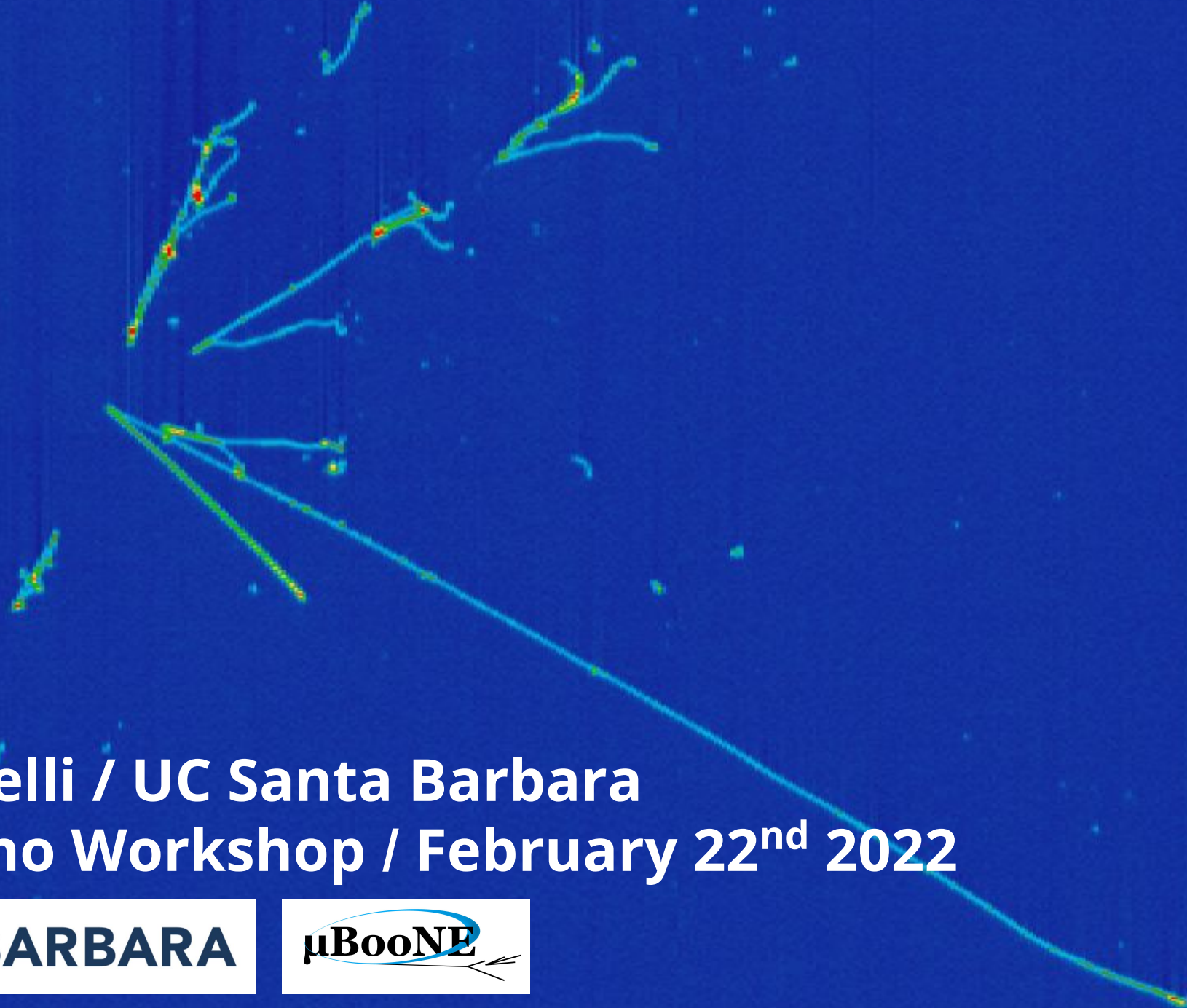


First Results from MicroBooNE's Low Energy Excess Search

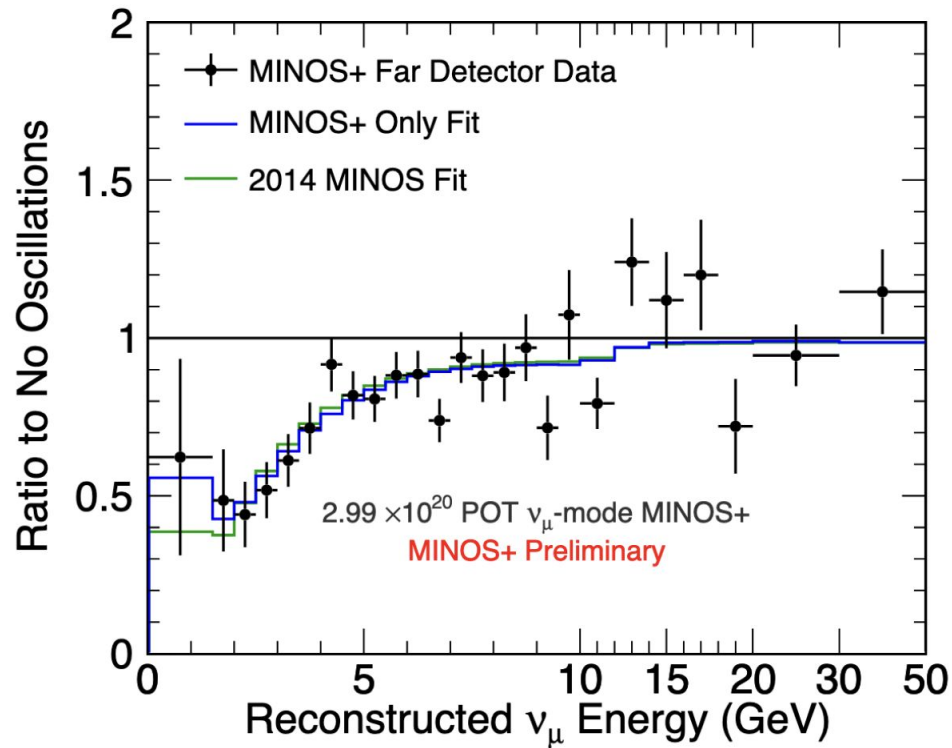


David Caratelli / UC Santa Barbara
KITP Neutrino Workshop / February 22nd 2022

UC SANTA BARBARA



Neutrino Oscillations

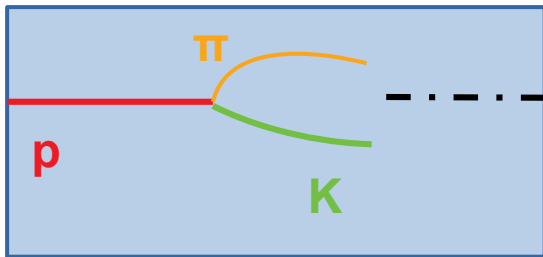


Freq. Of oscillation.
Choose L, E appropriate for Δm^2 .

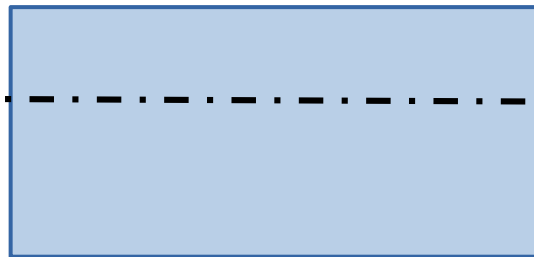
$$P_{\nu_\mu \rightarrow \nu_e} \approx \sin^2(2\theta) \sin^2\left(\frac{\Delta m^2 L}{4E}\right)$$

sets amplitude of oscillation.
large \rightarrow "easy" to detect.

neutrino source

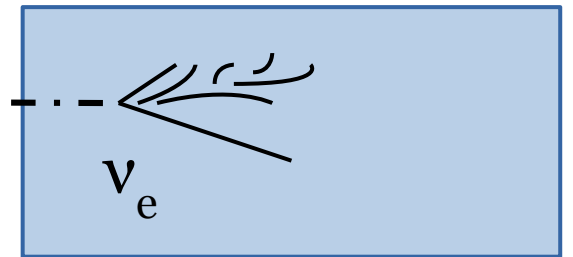


near detector



"control sample"

far detector



oscillated flux

Short-Baseline Neutrino Anomalies

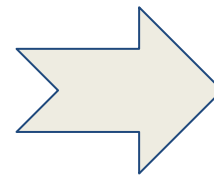
Freq. Of oscillation.
Choose L, E appropriate for Δm^2 .

$$P_{\nu_\mu \rightarrow \nu_e} \approx \sin^2(2\theta) \sin^2\left(\frac{\Delta m^2 L}{4E}\right)$$

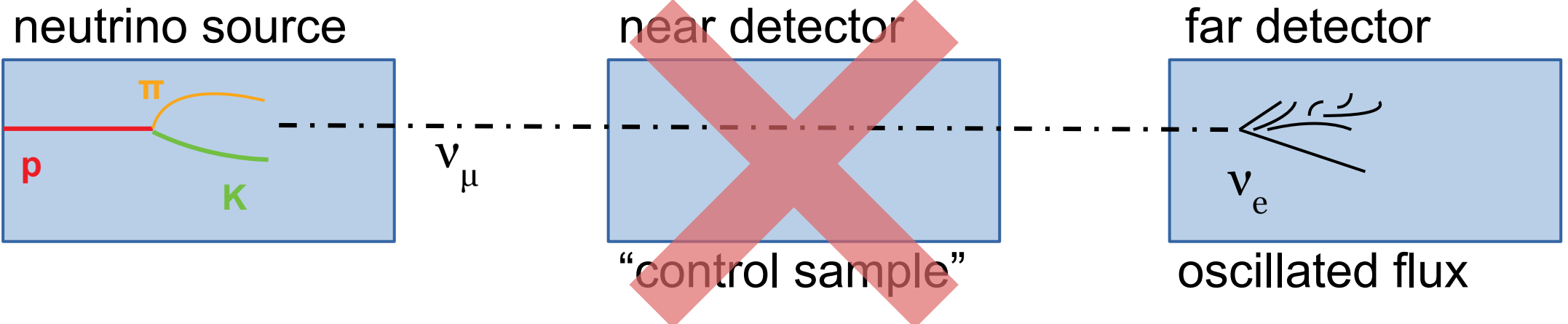
sets amplitude of oscillation.
large \rightarrow "easy" to detect.

Lack of "near detector" \rightarrow larger uncertainty on predicted neutrino rate

- flux uncertainties
- ν cross-section systematics

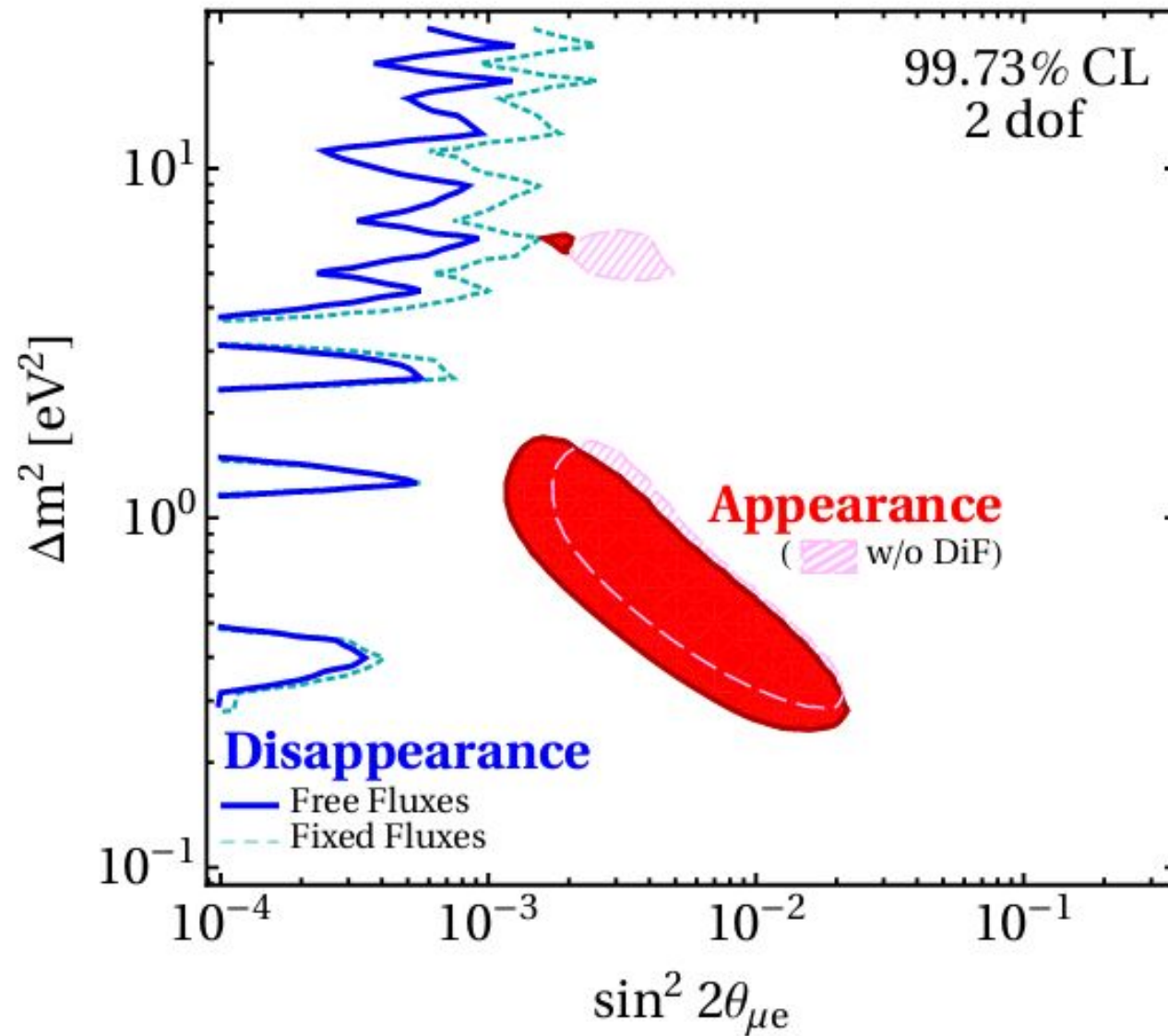


both boil down to
nuclear physics



eV Sterile Neutrinos?

Dentler M, et al. *JHEP* 08:010 (2018)

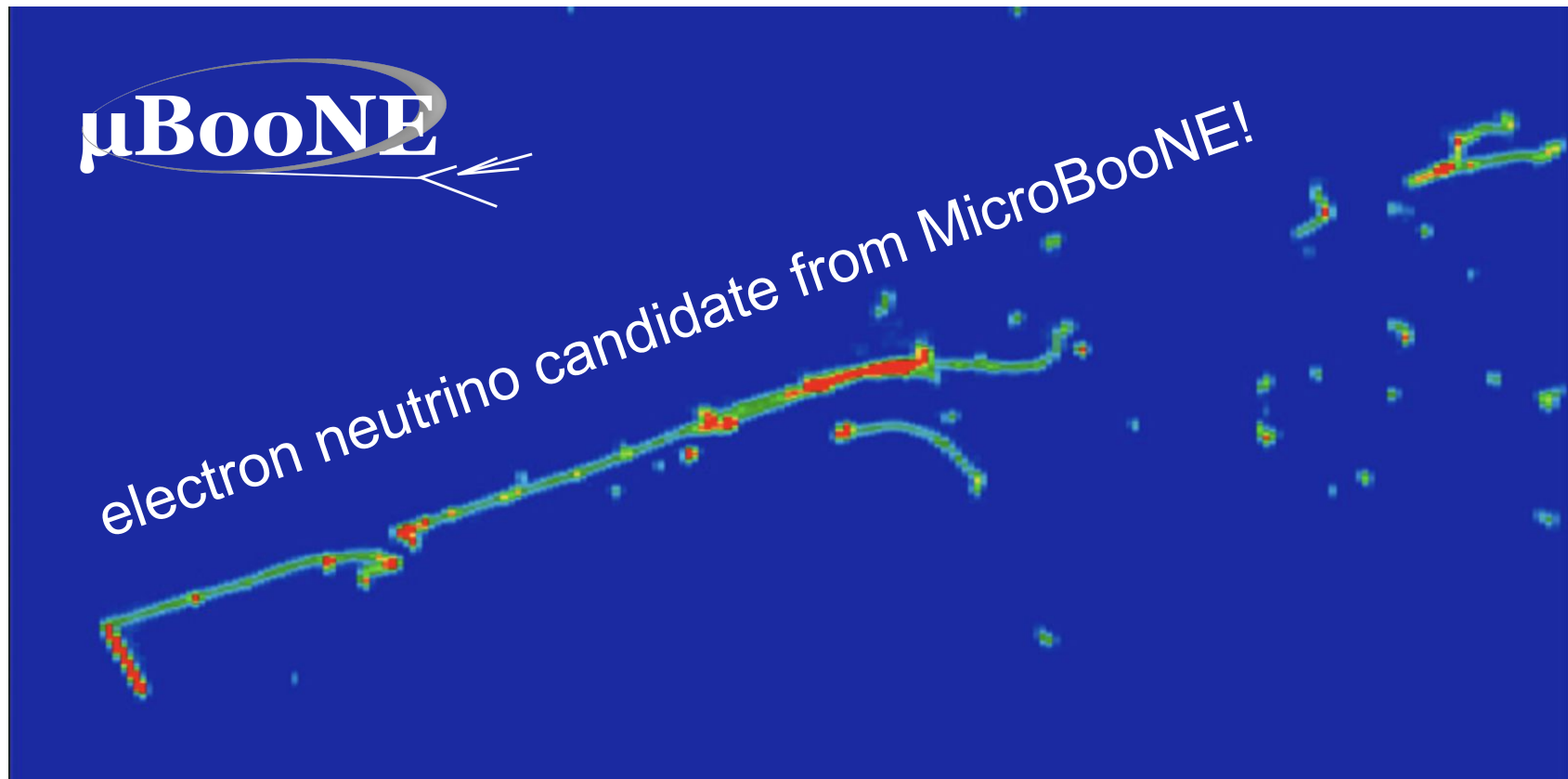


eV sterile neutrinos: an unclear picture...

New Results from MicroBooNE

Many recent results which directly tie to this question.

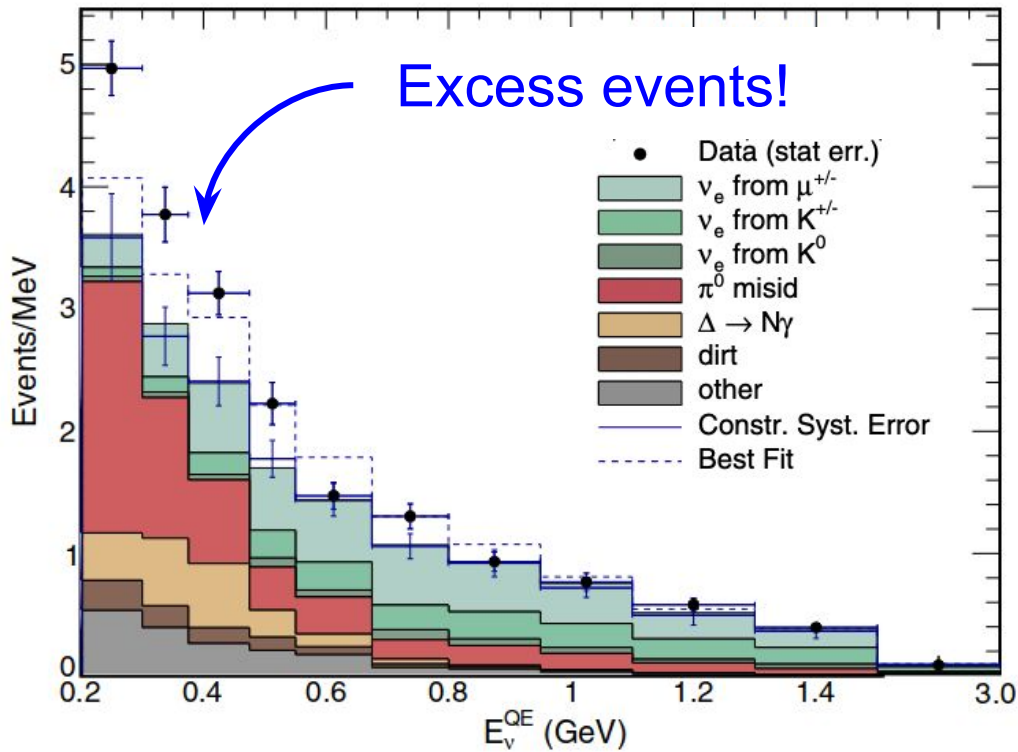
This talk will highlight recent results from MicroBooNE.



eV sterile neutrinos: a **changing** landscape...

Neutrino Anomalies: MiniBooNE

MiniBooNE, PRL **121**, 221801 (2018)



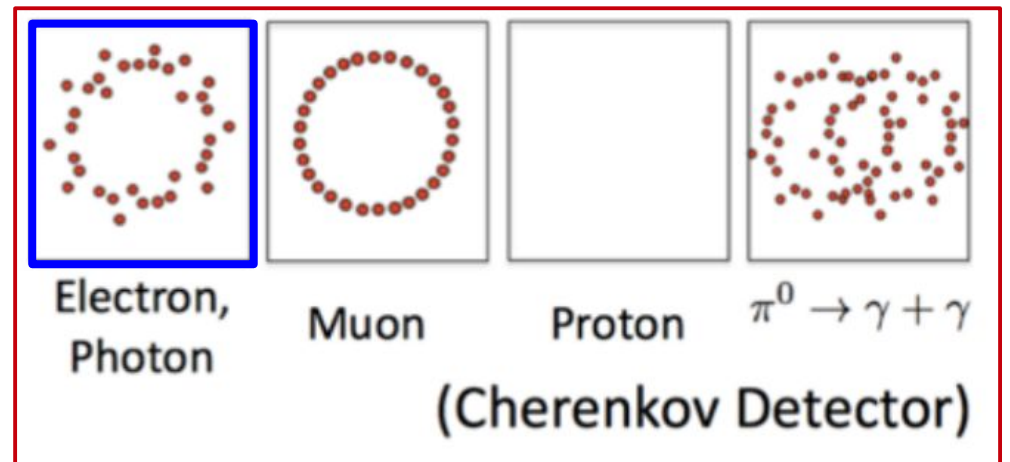
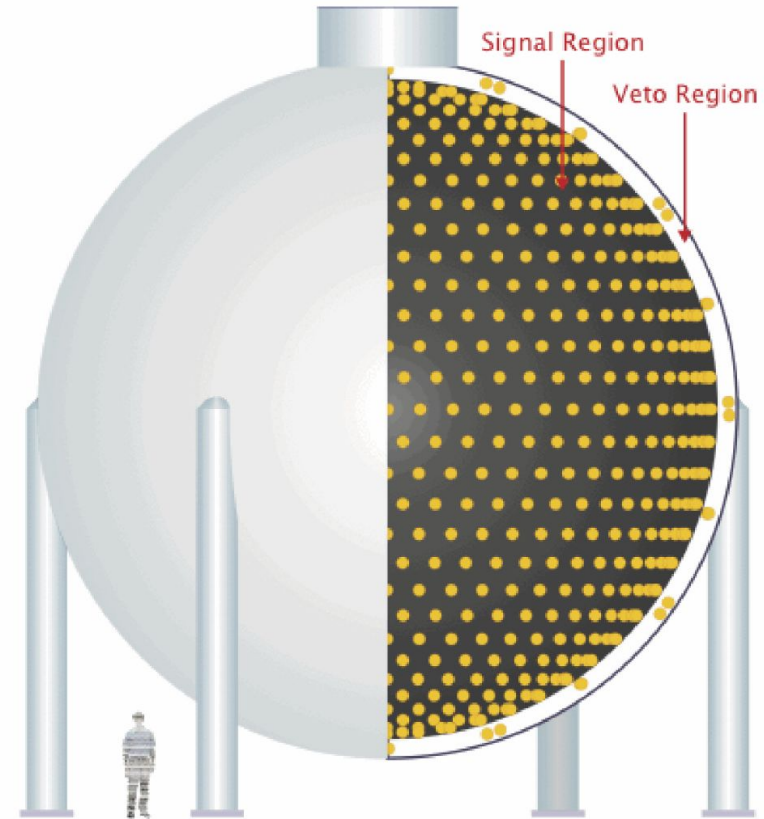
Excess events!

$O(100s)$ MeV

“Low-Energy-Excess” EM activity in detector.

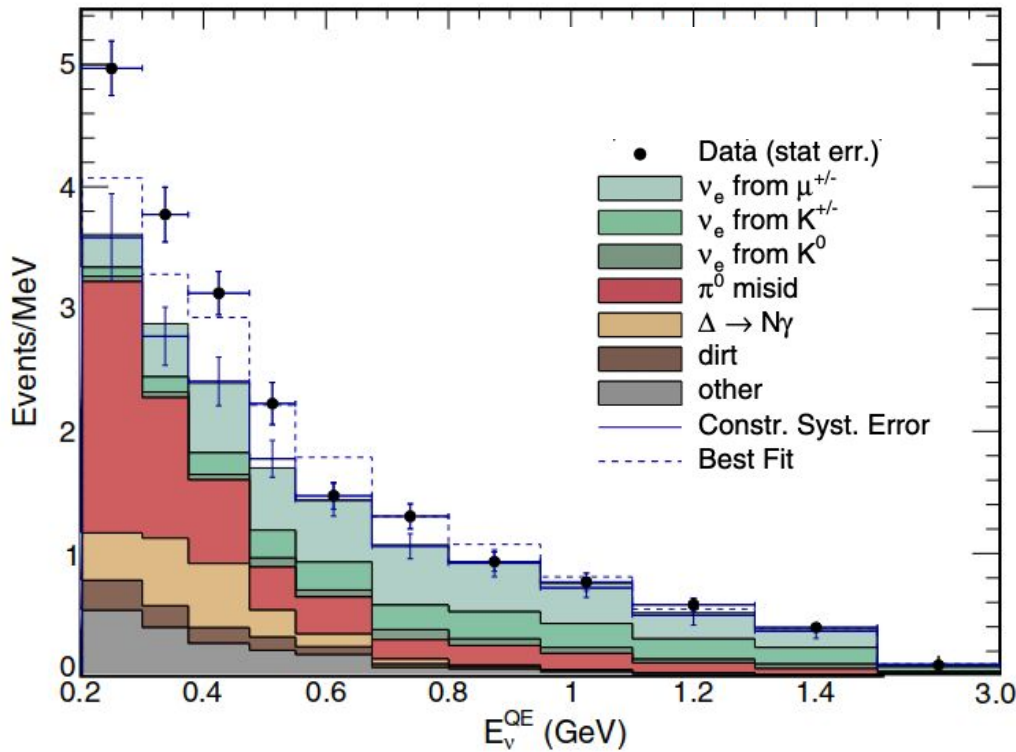
4.5 σ significance.

Cannot distinguish electrons from photons.



MiniBooNE as eV-scale Sterile Neutrinos

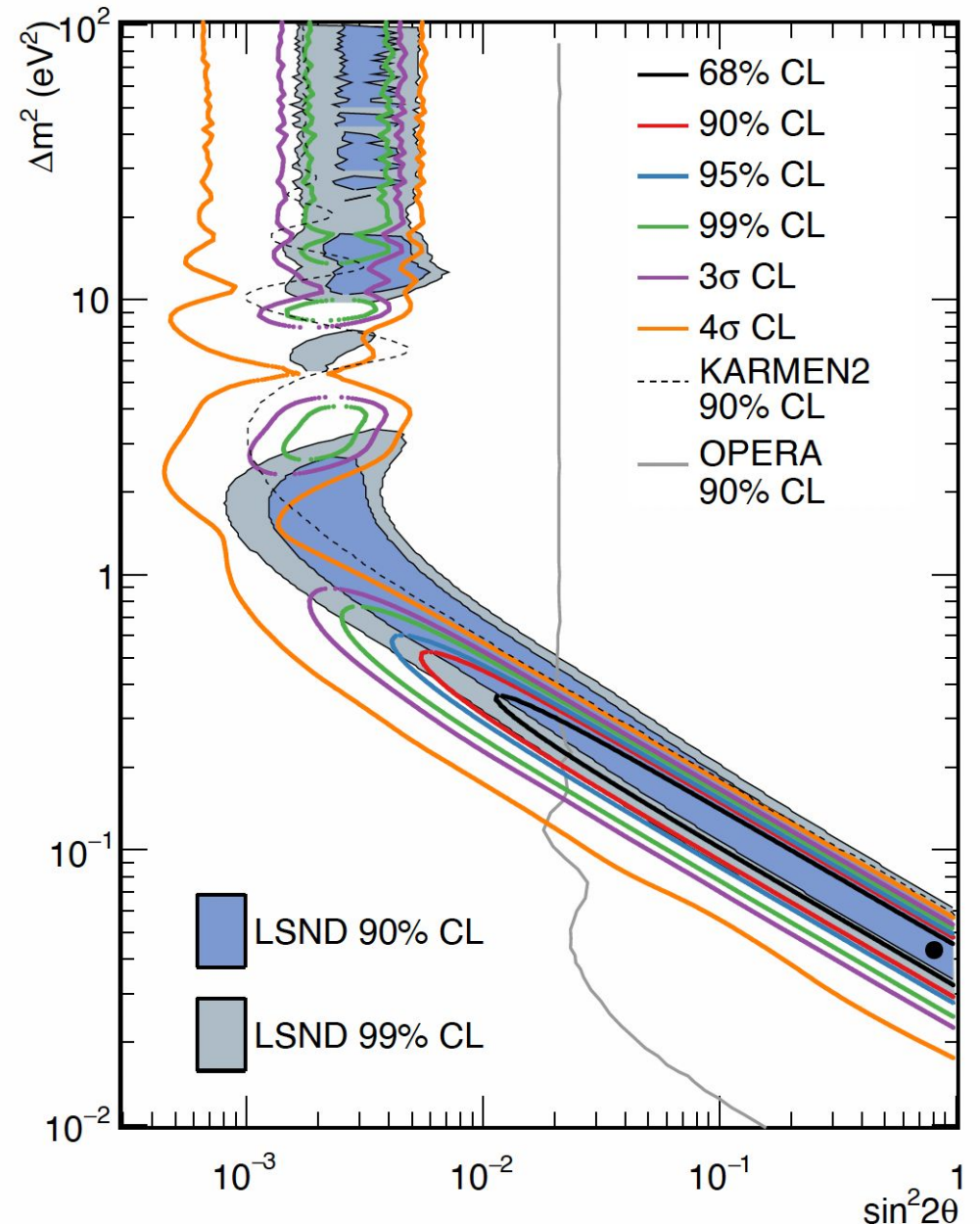
MiniBooNE, PRL **121**, 221801 (2018)



MiniBooNE's result a key motivation for eV-scale sterile neutrino searches.

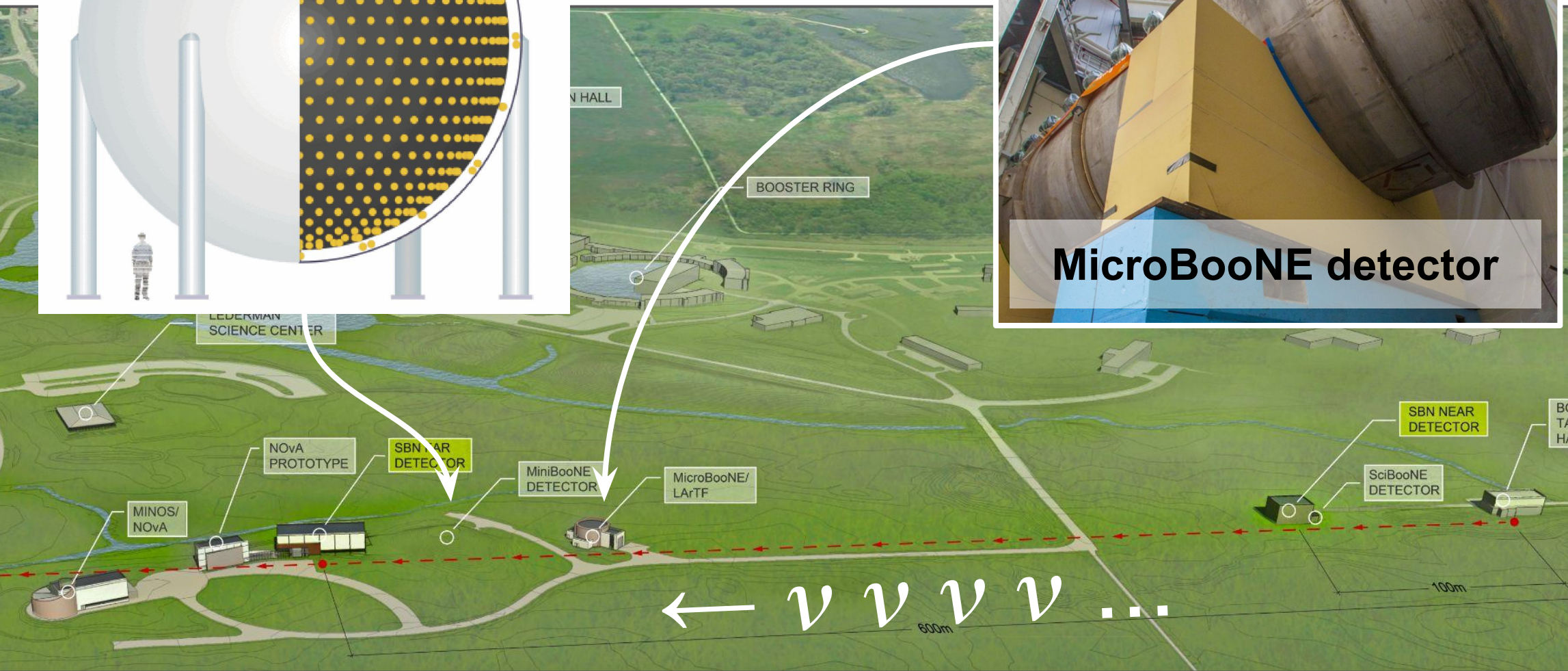
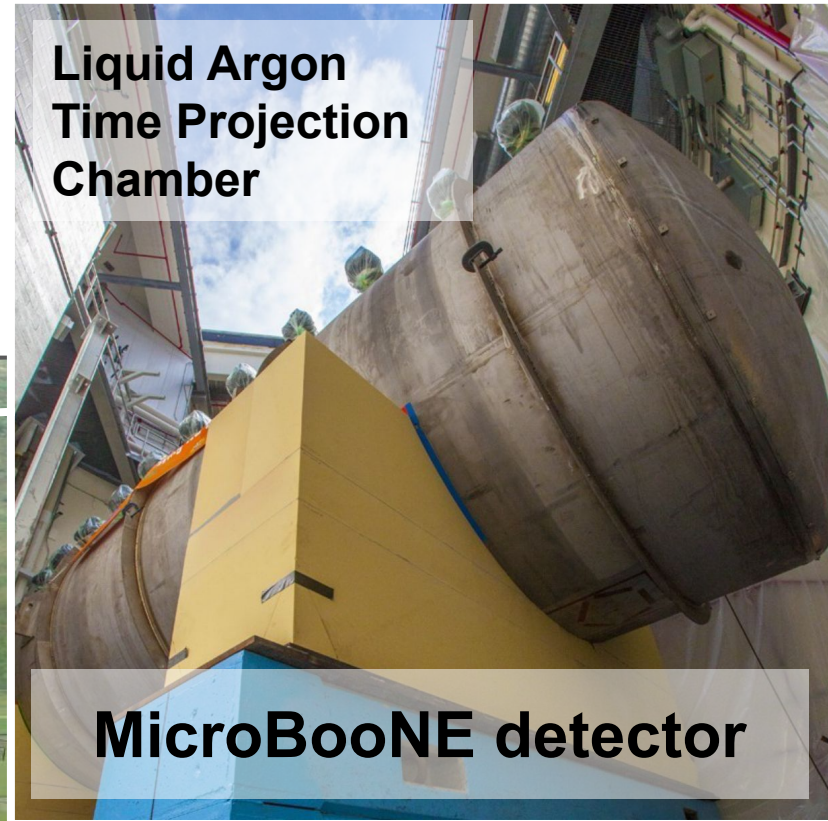
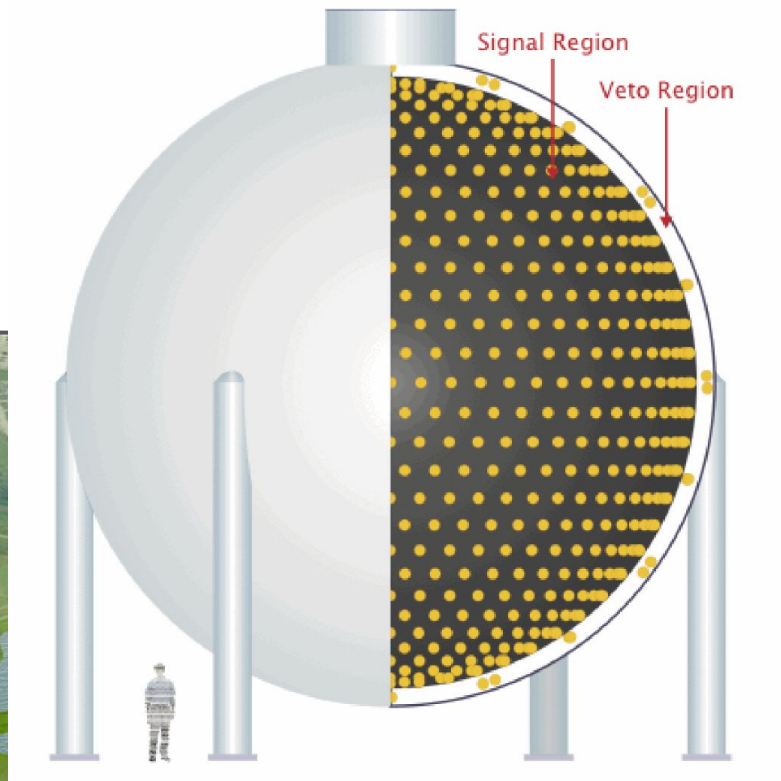
Motivation arises from interpretation of excess as "extra" oscillated electron neutrinos.

MiniBooNE, Phys. Rev. D 103, 052002 (2021)

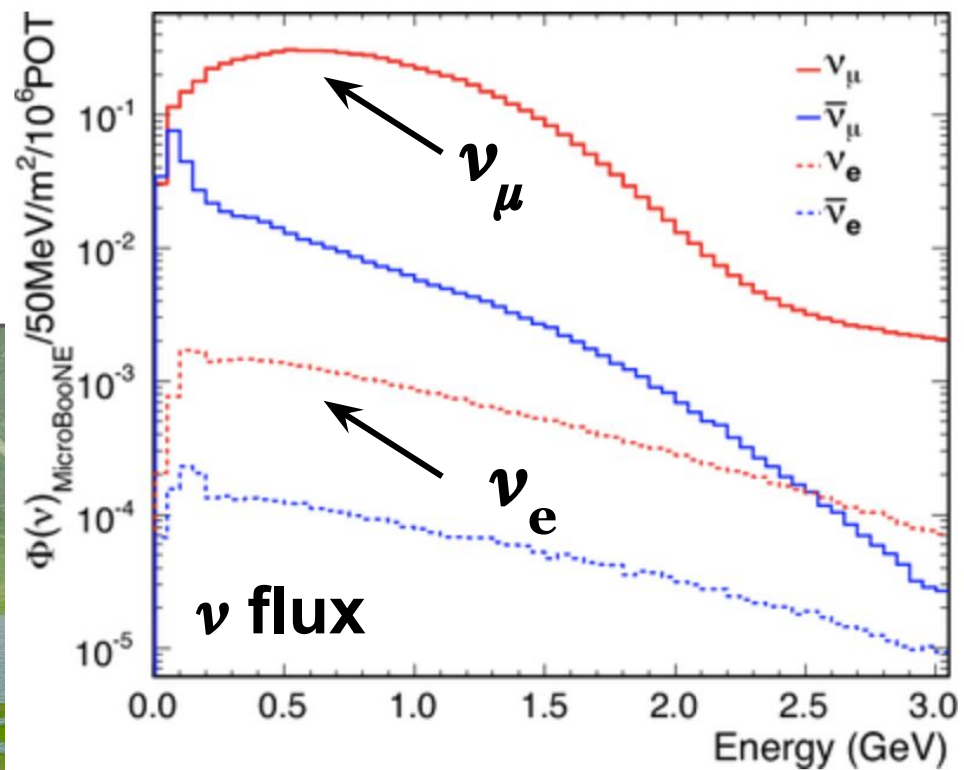


↓ active neutrinos are down here....

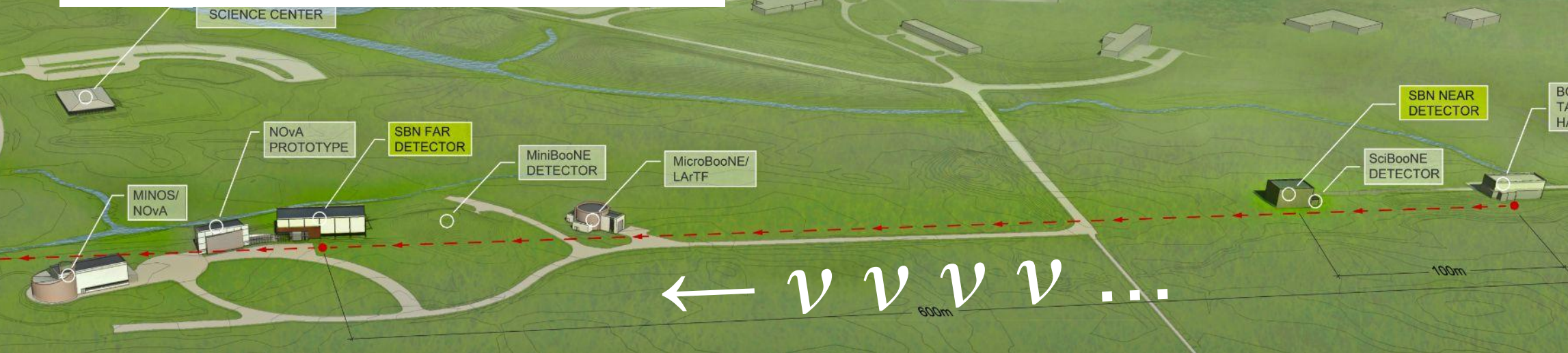
The MicroBooNE Experiment



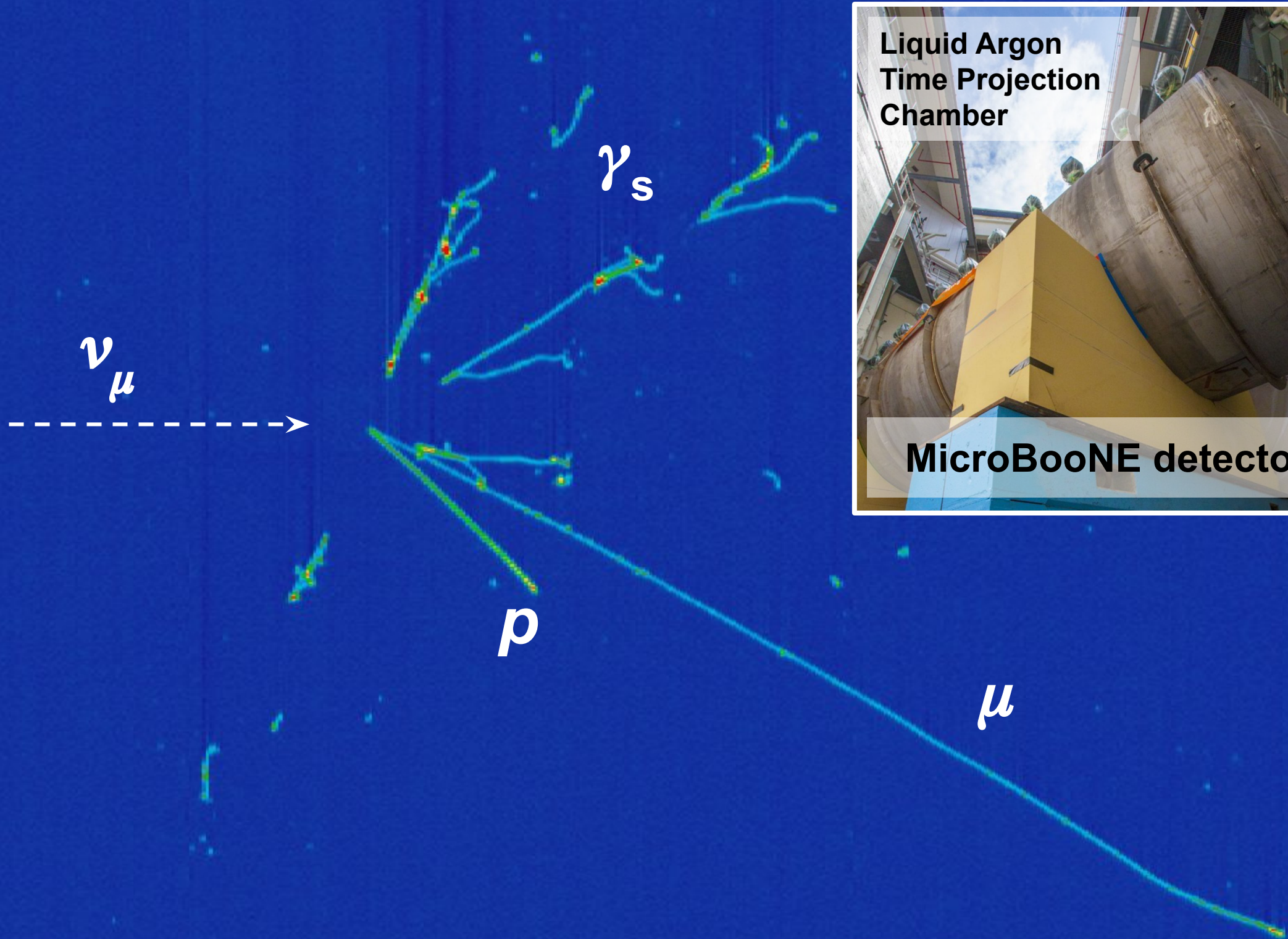
The Booster Neutrino Beamline @ Fermilab



- 99% ν_{μ} / 1% ν_e beam composition
- O(1) GeV neutrino energy
- ~400 meter baseline
- one neutrino interaction per minute @ μB



The MicroBooNE Experiment

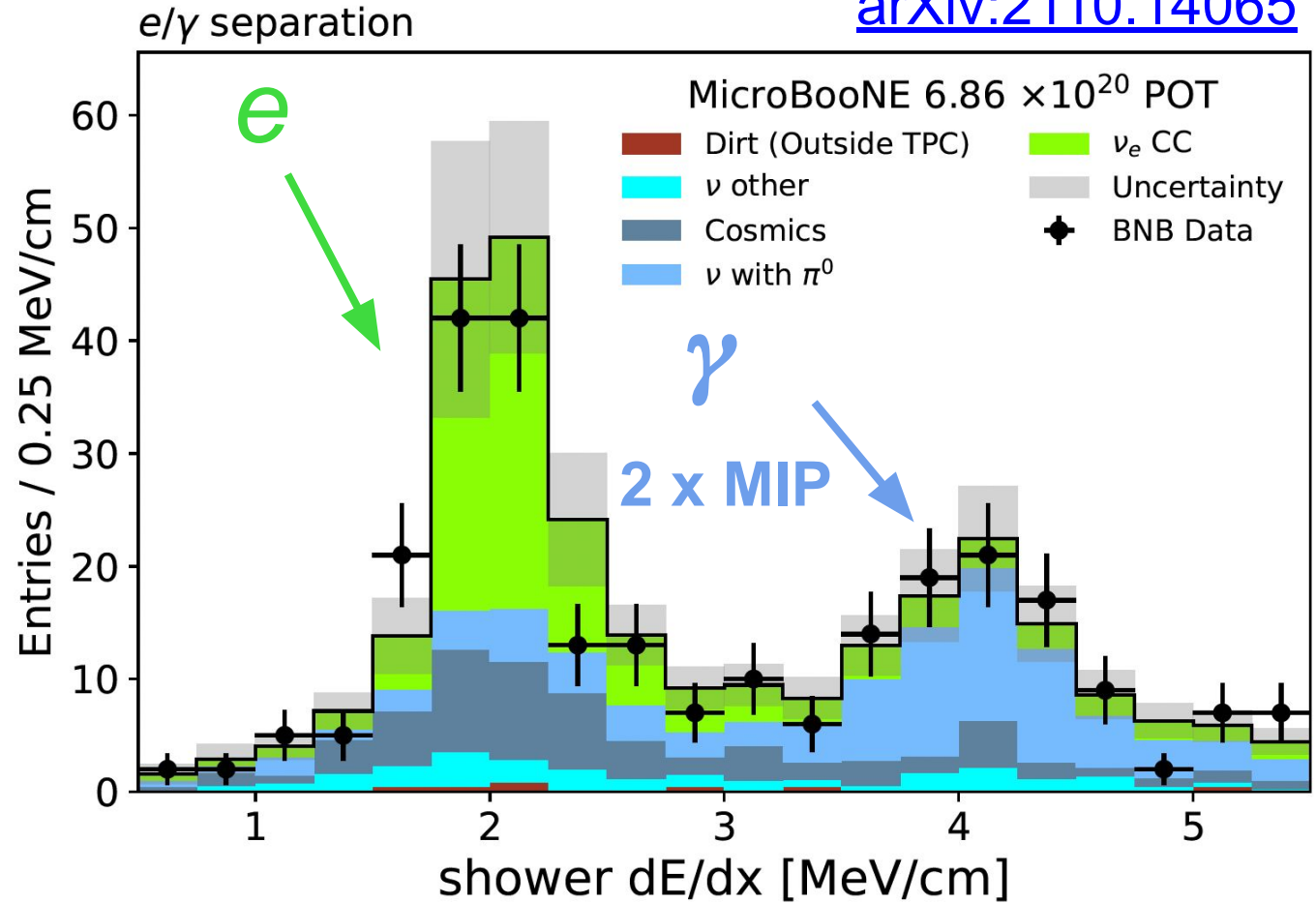
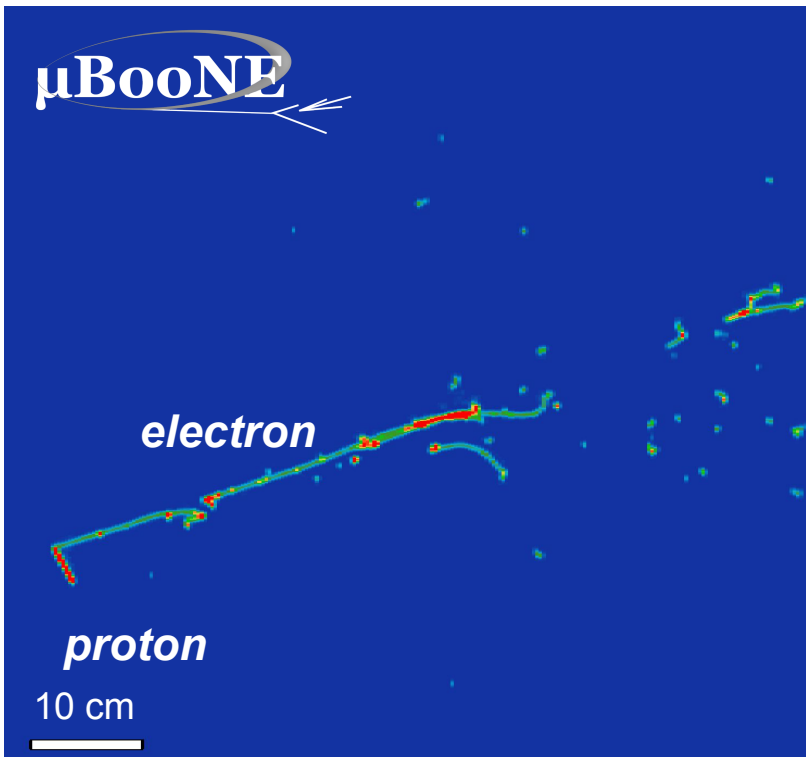
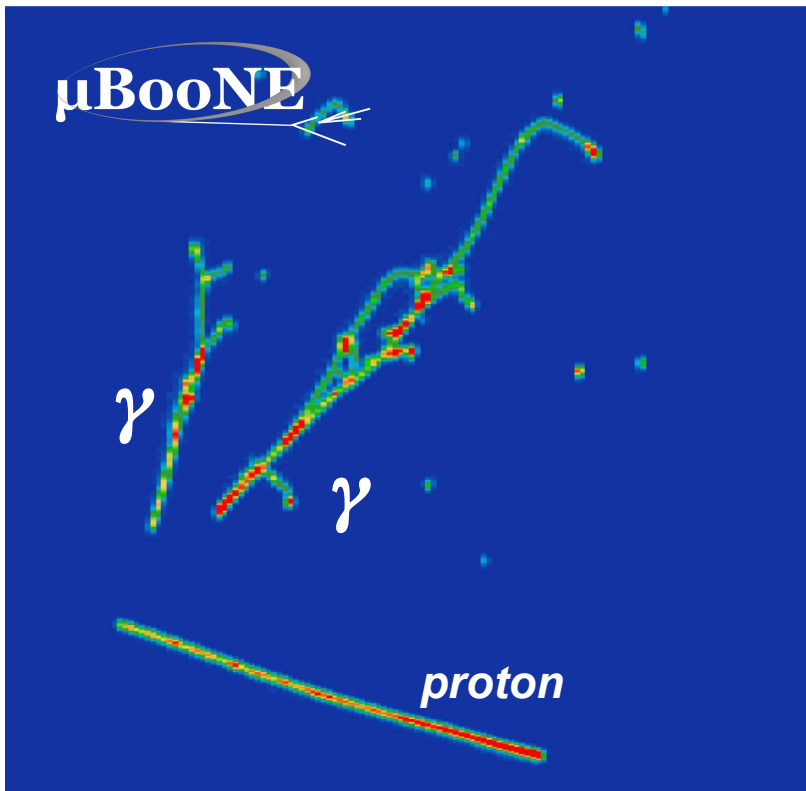


Liquid Argon
Time Projection
Chamber

MicroBooNE detector

e/ γ separation

[arXiv:2110.14065](https://arxiv.org/abs/2110.14065)

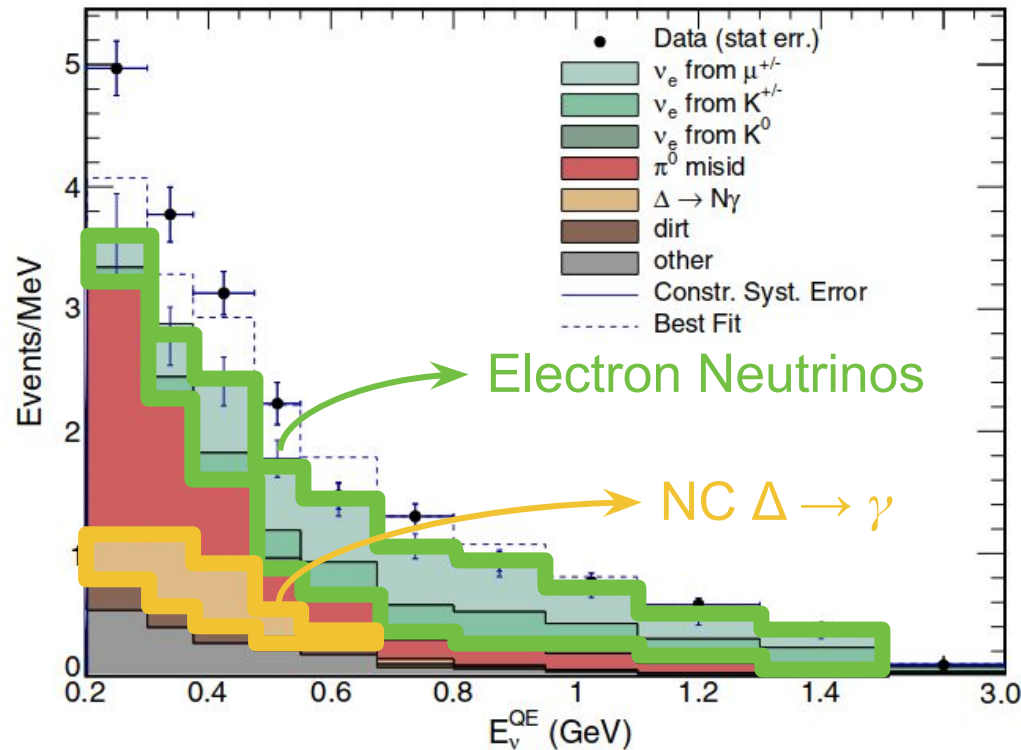


Can separate **electron** and **photon** showers

→ address the nature of MiniBooNE's excess

MicroBooNE Low-Energy-Excess Search

MiniBooNE, PRL **121**, 221801 (2018)



Investigated two key hypotheses for MiniBooNE excess:

$NC \Delta \rightarrow \gamma$
SM background

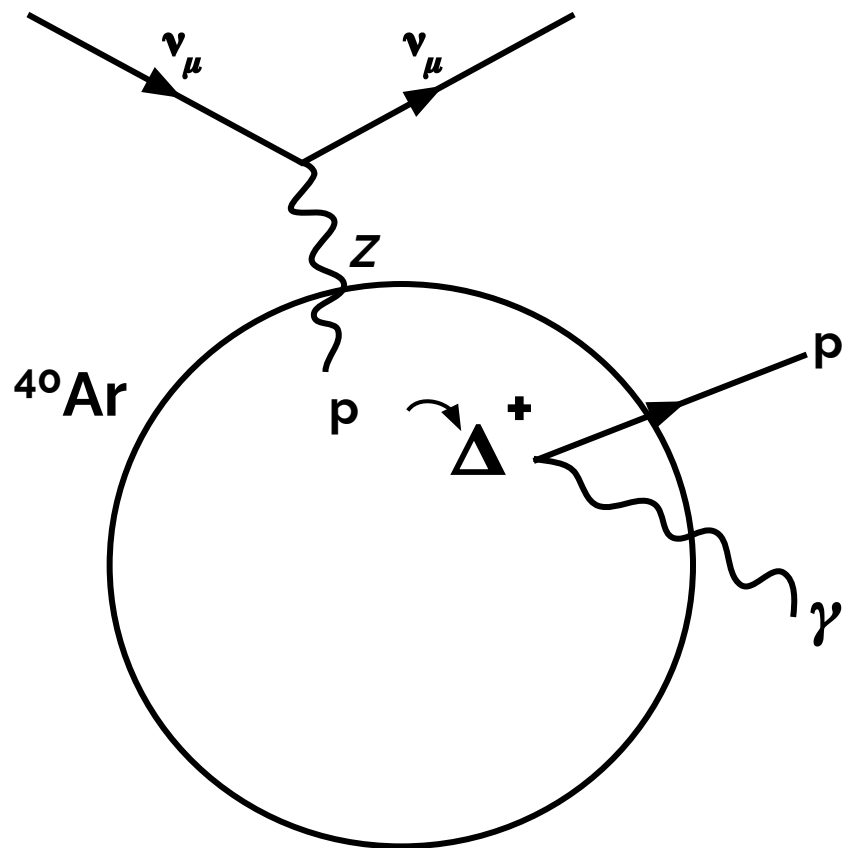
Electron Neutrinos
eV steriles?

Both leading hypotheses for source of anomaly.

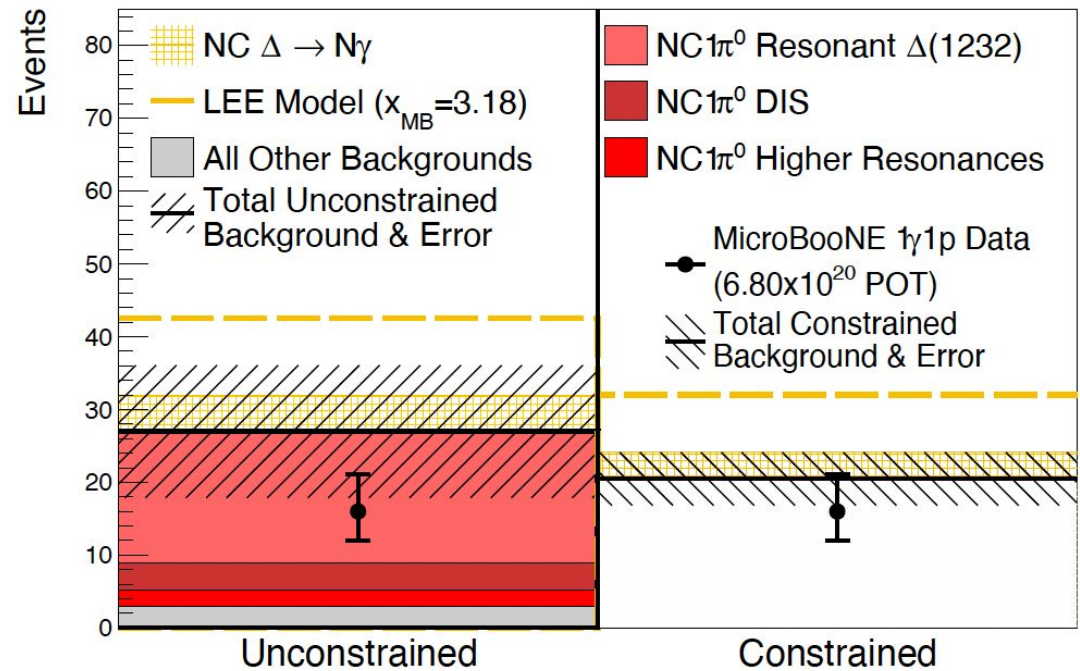
NC $\Delta \rightarrow \gamma$ Analysis

NC $\Delta \rightarrow \gamma$ background looked with interest from community.

Is this responsible for MiniBooNE's excess? Excess consistent with x3 flat scaling.



[arXiv:2110.00409](https://arxiv.org/abs/2110.00409)



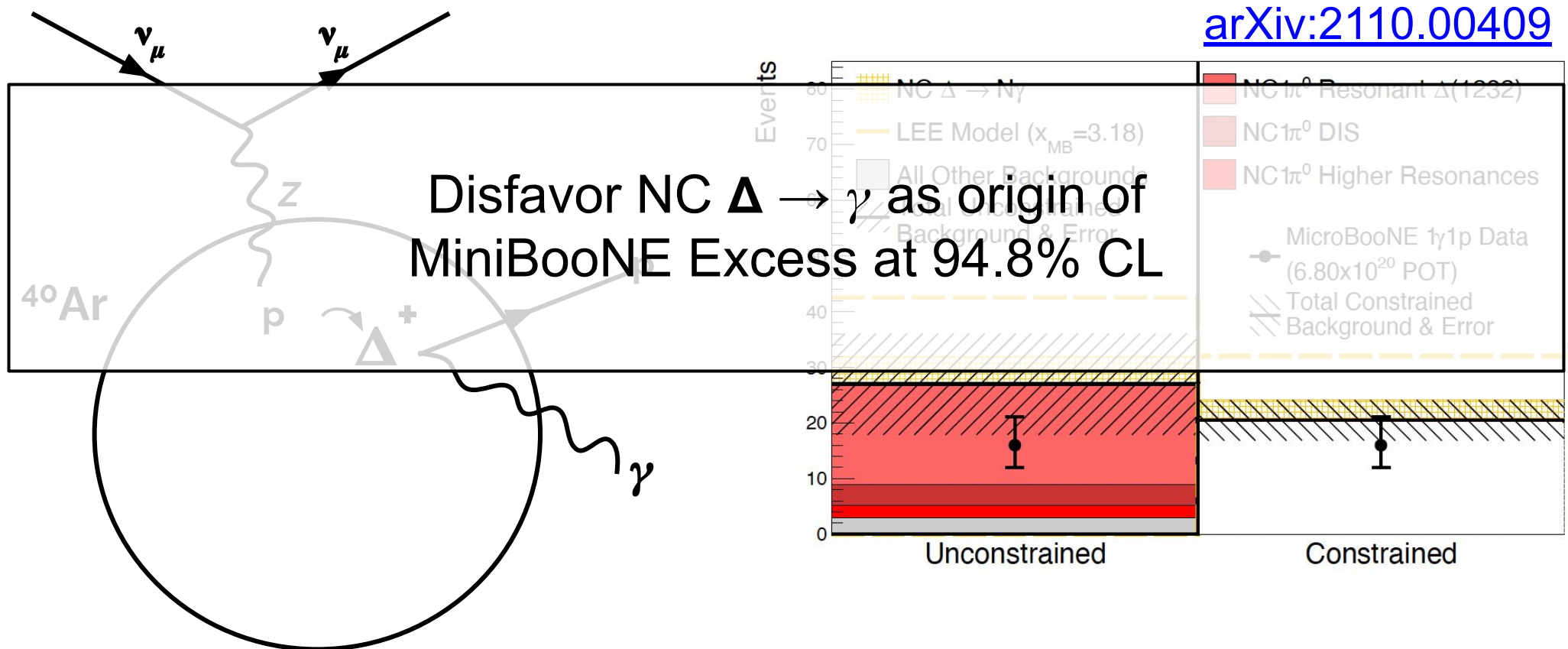
[arXiv:2110.00409](https://arxiv.org/abs/2110.00409) (submitted to PRL)

Search for Neutrino-Induced Neutral Current Δ Radiative Decay in MicroBooNE and a First Test of the MiniBooNE Low Energy Excess Under a Single-Photon Hypothesis

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[arXiv:2110.00409](https://arxiv.org/abs/2110.00409) (submitted to PRL)

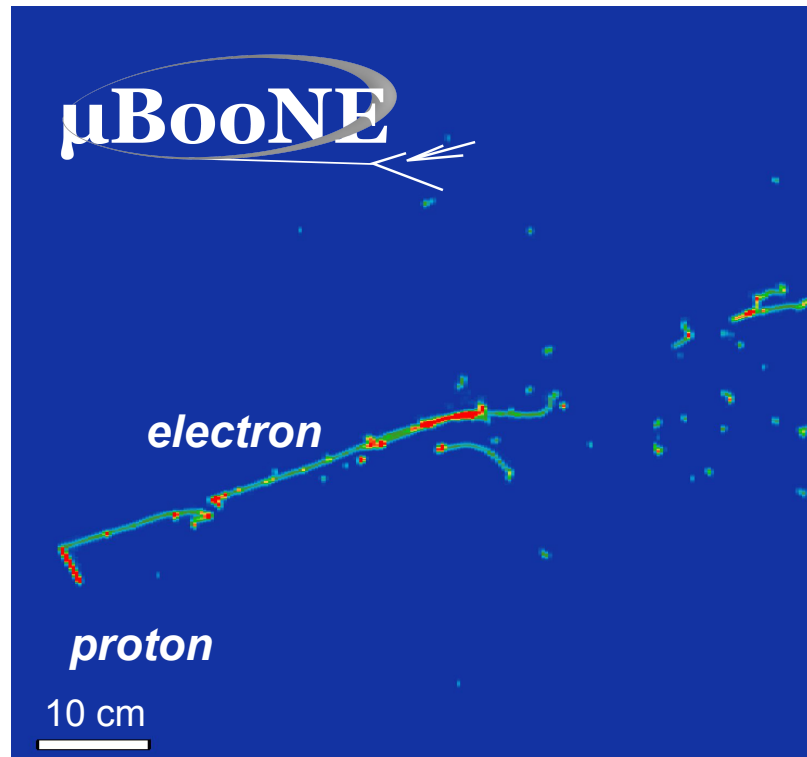
Search for Neutrino-Induced Neutral Current Δ Radiative Decay in MicroBooNE and a First Test of the MiniBooNE Low Energy Excess Under a Single-Photon Hypothesis

ν_e Analyses

MiniBooNE conceived to search for eV sterile neutrinos as follow-up to LSND.

Electron-like nature of excess would support hypothesis that MiniBooNE saw appearance of electron neutrinos in a muon neutrino beam.

MicroBooNE can test the electron-neutrino hypothesis for the MiniBooNE excess.



[arXiv:2110.13978](https://arxiv.org/abs/2110.13978)

Search for an anomalous excess of inclusive charged-current ν_e interactions in the MicroBooNE experiment using Wire-Cell reconstruction

P. Abratenko,²³ R. An,¹⁴ J. Anthony,⁴ L. Arellano,¹⁴ J. Asadi,²² A. Ashkenazi,²⁰ S. Balasubramanian,¹¹ B. Baller,¹¹ C. Barnes,²⁰ G. Barr,²³ V. Basque,¹⁴ L. Bathe-Peters,¹⁴ O. Benevides Rodrigues,²⁰ S. Berkman,¹¹ A. Bhandari,¹⁸ A. Bhat,²⁹ M. Bishai,² A. Blake,¹⁶ T. Bolton,¹³ J. Y. Book,¹³ L. Camilleri,³ D. Caratelli,¹¹ I. Caro Terrazas,⁸ F. Cavanna,¹¹ G. Cerati,¹¹ Y. Chen,¹¹ D. Cianci,³ J. M. Conrad,¹⁰ M. Convery,²⁰ L. Cooper-Troendle,²⁶ J. I. Crespo-Anadón,⁵ M. Del Tutto,¹¹ S. R. Dennis,⁴ P. Detje,⁴ A. Deviti,¹⁶ R. Durba,²¹ R. Durrill,¹⁴ K. Duffy,¹¹ S. Dytman,²⁴ B. Eberly,²⁸ A. Ereditato,¹ J. J. Evans,¹⁸ R. Fine,¹⁷ G. A. Horton-Smith,¹⁵ A. Hourani,²¹ J. H. Jo,²⁶ R. A. Johnson,⁷ Y.-J. Jwa,² D. K. Kallek,² D. K. Kishore,¹¹ I. Kreslo,¹ I. Lepkova,²¹ C. McInnis,¹⁹ D. M. Meade,¹⁵ T. L. Moore,¹³ L. Mora Lepin,¹⁹ J. Mossauer,²⁹ M. Murphy,²⁴ D. Naples,²⁴ A. Navrer-Agasson,¹⁸ M. Nebot-Guinot,¹⁰ R. K. Neely,¹³ D. A. Newmark,¹⁷ J. Nowak,¹⁹ M. Nunes,²⁰ O. Palamara,¹¹ V. Paolone,²⁴ A. Papadopoulos,¹⁹ V. Papavasiliou,²² S. F. Pate,²² N. Patel,¹⁶ A. Paudel,¹² Z. Pavlovic,¹² E. Piasetzky,²⁰ I. D. Ponce-Pinto,²⁶ S. Prince,¹³ X. Qian,⁷ J. L. Raaf,¹¹ V. Radzka,² A. Rafique,¹⁵ M. Reggiani-Guzzo,¹⁸ L. Ren,²² L. C. J. Rice,²⁴ L. Rochester,²⁶ J. Rodriguez Rondon,²⁷ M. Ross-Louergan,²⁶ R. Russell,²⁰ G. Scavini,²⁰ D. W. Schmitz,¹⁹ A. Schukraft,¹¹ W. Seligman,² M. H. Shaevitz,² R. Sharankov,²³ J. Shi,¹ J. Sinclair,¹ A. Smith,⁴ E. L. Snider,¹¹ M. Soderberg,²³ S. Söldner-Rembold,¹⁸ P. Spentzorakis,¹¹ J. Spitz,²⁹ M. Stancari,¹¹ J. St. John,¹¹ T. K. Sutton,⁸ S. Sword-Fehlig,²² A. M. Szele,¹⁰ W. Tang,³¹ K. Terao,²⁶ C. Thorpe,¹⁶ D. Totani,¹³ M. Toups,¹¹ Y.-T. Tsai,²⁰ M. A. Uchida,⁴ T. Usher,²⁶ W. Van De Pottsele,²³ B. Viren,² M. H. Wei,² Z. Williams,²² S. Wolbers,¹¹ T. Wongjirad,³³ M. Wospakrik,¹¹ K. Wresilo,⁴ N. Wright,¹⁹ E. Yandel,³ T. Yang,¹¹ G. Yarbrough,²¹ L. E. Yates,¹⁹ H. W. Yu,² G. P. Zeller,¹¹ J. Zemanina,¹¹ and C. Zhang²

ν_e inclusive PRD

0.14054v2 [hep-ex] 30 Oct 2021

[arXiv:2110.14080](https://arxiv.org/abs/2110.14080)

Search for an anomalous excess of charged-current quasi-elastic ν_e interactions with the MicroBooNE experiment using Deep-Learning-based reconstruction

P. Abratenko,²³ R. An,¹⁴ J. Anthony,⁴ L. Arellano,¹⁴ J. Asadi,²² A. Ashkenazi,²⁰ S. Balasubramanian,¹¹ B. Baller,¹¹ C. Barnes,²⁰ G. Barr,²³ V. Basque,¹⁴ L. Bathe-Peters,¹⁴ O. Benevides Rodrigues,²⁰ S. Berkman,¹¹ A. Bhandari,¹⁸ A. Bhat,²⁹ M. Bishai,² A. Blake,¹⁶ T. Bolton,¹³ J. Y. Book,¹³ L. Camilleri,³ D. Caratelli,¹¹ I. Caro Terrazas,⁸ F. Cavanna,¹¹ G. Cerati,¹¹ Y. Chen,¹¹ D. Cianci,³ G. H. Collins,¹⁰ J. M. Conrad,¹⁰ M. Convery,²⁰ L. Cooper-Troendle,²⁶ J. I. Crespo-Anadón,⁵ M. Del Tutto,¹¹ S. R. Dennis,⁴ P. Detje,⁴ A. Deviti,¹⁶ R. Durba,²¹ R. Durrill,¹⁴ K. Duffy,¹¹ S. Dytman,²⁴ B. Eberly,²⁸ A. Ereditato,¹ J. J. Evans,¹⁸ R. Fine,¹⁷ G. A. Horton-Smith,¹⁵ R. S. Fitzpatrick,²⁰ B. T. Fleming,²⁶ N. Foppiani,¹³ D. Franco,²⁶ A. P. Furnasinski,²¹ D. Garcia-Gomez,¹² S. Gardner,¹⁹ G. S. Gollapinni,¹⁹ O. Goodwin,¹⁹ E. Grammelini,¹¹ P. Green,¹⁸ H. Greenlee,¹¹ W. Gu,² R. Guenther,¹² P. Guzowski,¹⁶ I. Hagaman,²⁰ O. Hen,¹⁶ C. Hilgenberg,²¹ G. A. Horton-Smith,¹⁵ A. Hourani,²¹ J. H. Jo,²⁶ R. A. Johnson,⁷ Y.-J. Jwa,² D. K. Kallek,² D. K. Kishore,¹¹ I. Kreslo,¹ I. Lepkova,²¹ C. McInnis,¹⁹ D. M. Meade,¹⁵ T. L. Moore,¹³ L. Mora Lepin,¹⁹ J. Mossauer,²⁹ M. Murphy,²⁴ D. Naples,²⁴ A. Navrer-Agasson,¹⁸ M. Nebot-Guinot,¹⁰ R. K. Neely,¹³ D. A. Newmark,¹⁷ J. Nowak,¹⁹ M. Nunes,²⁰ O. Palamara,¹¹ V. Paolone,²⁴ A. Papadopoulos,¹⁹ V. Papavasiliou,²² S. F. Pate,²² N. Patel,¹⁶ A. Paudel,¹² Z. Pavlovic,¹² E. Piasetzky,²⁰ I. D. Ponce-Pinto,²⁶ S. Prince,¹³ X. Qian,⁷ J. L. Raaf,¹¹ V. Radzka,² A. Rafique,¹⁵ M. Reggiani-Guzzo,¹⁸ L. Ren,²² L. C. J. Rice,²⁴ L. Rochester,²⁶ J. Rodriguez Rondon,²⁷ M. Ross-Louergan,²⁶ R. Russell,²⁰ G. Scavini,²⁰ D. W. Schmitz,¹⁹ A. Schukraft,¹¹ W. Seligman,² M. H. Shaevitz,² R. Sharankov,²³ J. Shi,¹ J. Sinclair,¹ A. Smith,⁴ E. L. Snider,¹¹ M. Soderberg,²³ S. Söldner-Rembold,¹⁸ P. Spentzorakis,¹¹ J. Spitz,²⁹ M. Stancari,¹¹ J. St. John,¹¹ T. K. Sutton,⁸ S. Sword-Fehlig,²² A. M. Szele,¹⁰ W. Tang,³¹ K. Terao,²⁶ C. Thorpe,¹⁶ D. Totani,¹³ M. Toups,¹¹ Y.-T. Tsai,²⁰ M. A. Uchida,⁴ T. Usher,²⁶ W. Van De Pottsele,²³ B. Viren,² M. H. Wei,² Z. Williams,²² S. Wolbers,¹¹ T. Wongjirad,³³ M. Wospakrik,¹¹ K. Wresilo,⁴ N. Wright,¹⁹ W. Wu,¹¹ E. Yandel,³ T. Yang,¹¹ G. Yarbrough,²¹ L. E. Yates,¹⁹ H. W. Yu,² G. P. Zeller,¹¹ J. Zemanina,¹¹ and C. Zhang²

ν_e QE PRD

0.14054v2 [hep-ex] 30 Oct 2021

Search for an Excess of Electron Neutrino Interactions in MicroBooNE Using Multiple Final State Topologies

P. Abratenko,²³ R. An,¹⁴ J. Anthony,⁴ L. Arellano,¹⁴ J. Asadi,²² A. Ashkenazi,²⁰ S. Balasubramanian,¹¹ B. Baller,¹¹ C. Barnes,²⁰ G. Barr,²³ V. Basque,¹⁴ L. Bathe-Peters,¹⁴ O. Benevides Rodrigues,²⁰ S. Berkman,¹¹ A. Bhandari,¹⁸ A. Bhat,²⁹ M. Bishai,² A. Blake,¹⁶ T. Bolton,¹³ J. Y. Book,¹³ L. Camilleri,³ D. Caratelli,¹¹ I. Caro Terrazas,⁸ F. Cavanna,¹¹ G. Cerati,¹¹ Y. Chen,¹¹ D. Cianci,³ J. M. Conrad,¹⁰ M. Convery,²⁰ L. Cooper-Troendle,²⁶ J. I. Crespo-Anadón,⁵ M. Del Tutto,¹¹ S. R. Dennis,⁴ P. Detje,⁴ A. Deviti,¹⁶ R. Durba,²¹ R. Durrill,¹⁴ K. Duffy,¹¹ S. Dytman,²⁴ B. Eberly,²⁸ A. Ereditato,¹ L. Escudero Sanchez,⁴ J. J. Evans,¹⁸ R. Fine,¹⁷ G. A. Horton-Smith,¹⁵ A. Hourani,²¹ J. H. Jo,²⁶ R. A. Johnson,⁷ Y.-J. Jwa,² D. K. Kallek,² D. K. Kishore,¹¹ I. Kreslo,¹ I. Lepkova,²¹ C. McInnis,¹⁹ D. M. Meade,¹⁵ T. L. Moore,¹³ L. Mora Lepin,¹⁹ J. Mossauer,²⁹ M. Murphy,²⁴ D. Naples,²⁴ A. Navrer-Agasson,¹⁸ M. Nebot-Guinot,¹⁰ R. K. Neely,¹³ D. A. Newmark,¹⁷ J. Nowak,¹⁹ M. Nunes,²⁰ O. Palamara,¹¹ V. Paolone,²⁴ A. Papadopoulos,¹⁹ V. Papavasiliou,²² S. F. Pate,²² N. Patel,¹⁶ A. Paudel,¹² Z. Pavlovic,¹² E. Piasetzky,²⁰ I. D. Ponce-Pinto,²⁶ S. Prince,¹³ X. Qian,⁷ J. L. Raaf,¹¹ V. Radzka,² A. Rafique,¹⁵ M. Reggiani-Guzzo,¹⁸ L. Ren,²² L. C. J. Rice,²⁴ L. Rochester,²⁶ J. Rodriguez Rondon,²⁷ M. Ross-Louergan,²⁶ R. Russell,²⁰ D. W. Schmitz,¹⁹ A. Schukraft,¹¹ W. Seligman,² M. H. Shaevitz,² R. Sharankov,²³ J. Shi,¹ J. Sinclair,¹ A. Smith,⁴ E. L. Snider,¹¹ M. Soderberg,²³ S. Söldner-Rembold,¹⁸ P. Spentzorakis,¹¹ J. Spitz,²⁹ M. Stancari,¹¹ J. St. John,¹¹ T. K. Sutton,⁸ S. Sword-Fehlig,²² A. M. Szele,¹⁰ W. Tang,³¹ K. Terao,²⁶ M. Thomson,⁴ C. Thorpe,¹⁶ D. Totani,¹³ M. Toups,¹¹ Y.-T. Tsai,²⁰ M. A. Uchida,⁴ T. Usher,²⁶ W. Van De Pottsele,²³ B. Viren,² M. H. Wei,² Z. Williams,²² S. Wolbers,¹¹ T. Wongjirad,³³ M. Wospakrik,¹¹ K. Wresilo,⁴ N. Wright,¹⁹ W. Wu,¹¹ E. Yandel,³ T. Yang,¹¹ G. Yarbrough,²¹ L. E. Yates,¹⁹ H. W. Yu,² G. P. Zeller,¹¹ J. Zemanina,¹¹ and C. Zhang²

ν_e PRL

0.14054v2 [hep-ex] 29 Oct 2021

Search for an anomalous excess of charged-current ν_e interactions without pions in the final state with the MicroBooNE experiment

P. Abratenko,²³ R. An,¹⁴ J. Anthony,⁴ L. Arellano,¹⁴ J. Asadi,²² A. Ashkenazi,²⁰ S. Balasubramanian,¹¹ B. Baller,¹¹ C. Barnes,²⁰ G. Barr,²³ V. Basque,¹⁴ L. Bathe-Peters,¹⁴ O. Benevides Rodrigues,²⁰ S. Berkman,¹¹ A. Bhandari,¹⁸ A. Bhat,²⁹ M. Bishai,² A. Blake,¹⁶ T. Bolton,¹³ J. Y. Book,¹³ L. Camilleri,³ D. Caratelli,¹¹ I. Caro Terrazas,⁸ F. Cavanna,¹¹ G. Cerati,¹¹ Y. Chen,¹¹ D. Cianci,³ J. M. Conrad,¹⁰ M. Convery,²⁰ L. Cooper-Troendle,²⁶ J. I. Crespo-Anadón,⁵ M. Del Tutto,¹¹ S. R. Dennis,⁴ P. Detje,⁴ A. Deviti,¹⁶ R. Durba,²¹ R. Durrill,¹⁴ K. Duffy,¹¹ S. Dytman,²⁴ B. Eberly,²⁸ A. Ereditato,¹ L. Escudero Sanchez,⁴ J. J. Evans,¹⁸ R. Fine,¹⁷ G. A. Horton-Smith,¹⁵ R. S. Fitzpatrick,²⁰ B. T. Fleming,²⁶ N. Foppiani,¹³ D. Franco,²⁶ A. P. Furnasinski,²¹ D. Garcia-Gomez,¹² S. Gardner,¹⁹ G. S. Gollapinni,¹⁹ O. Goodwin,¹⁹ E. Grammelini,¹¹ P. Green,¹⁸ H. Greenlee,¹¹ W. Gu,² R. Guenther,¹² P. Guzowski,¹⁶ I. Hagaman,²⁰ O. Hen,¹⁶ C. Hilgenberg,²¹ G. A. Horton-Smith,¹⁵ A. Hourani,²¹ R. Hav²⁶ C. James,¹¹ X. Ji,² L. Junez,²¹ J. H. Jo,²⁶ R. A. Johnson,⁷ Y.-J. Jwa,² D. K. Kallek,² D. K. Kishore,¹¹ I. Kreslo,¹ I. Lepkova,²¹ C. McInnis,¹⁹ D. M. Meade,¹⁵ T. L. Moore,¹³ L. Mora Lepin,¹⁹ J. Mossauer,²⁹ M. Murphy,²⁴ D. Naples,²⁴ A. Navrer-Agasson,¹⁸ M. Nebot-Guinot,¹⁰ R. K. Neely,¹³ D. A. Newmark,¹⁷ J. Nowak,¹⁹ M. Nunes,²⁰ O. Palamara,¹¹ V. Paolone,²⁴ A. Papadopoulos,¹⁹ V. Papavasiliou,²² S. F. Pate,²² N. Patel,¹⁶ A. Paudel,¹² Z. Pavlovic,¹² E. Piasetzky,²⁰ I. D. Ponce-Pinto,²⁶ S. Prince,¹³ X. Qian,⁷ J. L. Raaf,¹¹ V. Radzka,² A. Rafique,¹⁵ M. Reggiani-Guzzo,¹⁸ L. Ren,²² L. C. J. Rice,²⁴ L. Rochester,²⁶ J. Rodriguez Rondon,²⁷ M. Ross-Louergan,²⁶ G. Scavini,²⁰ D. W. Schmitz,¹⁹ A. Schukraft,¹¹ W. Seligman,² M. H. Shaevitz,² R. Sharankov,²³ J. Shi,¹ J. Sinclair,¹ A. Smith,⁴ E. L. Snider,¹¹ M. Soderberg,²³ S. Söldner-Rembold,¹⁸ P. Spentzorakis,¹¹ J. Spitz,²⁹ M. Stancari,¹¹ J. St. John,¹¹ T. K. Sutton,⁸ S. Sword-Fehlig,²² A. M. Szele,¹⁰ W. Tang,³¹ K. Terao,²⁶ M. Thomson,⁴ C. Thorpe,¹⁶ D. Totani,¹³ M. Toups,¹¹ Y.-T. Tsai,²⁰ M. A. Uchida,⁴ T. Usher,²⁶ W. Van De Pottsele,²³ B. Viren,² M. H. Wei,² Z. Williams,²² S. Wolbers,¹¹ T. Wongjirad,³³ M. Wospakrik,¹¹ K. Wresilo,⁴ N. Wright,¹⁹ W. Wu,¹¹ E. Yandel,³ T. Yang,¹¹ G. Yarbrough,²¹ L. E. Yates,¹⁹ H. W. Yu,² G. P. Zeller,¹¹ J. Zemanina,¹¹ and C. Zhang²

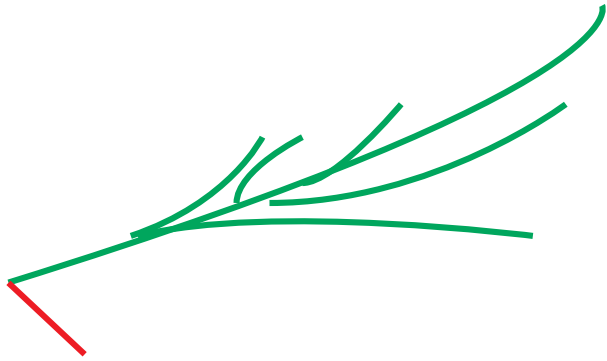
ν_e pionless PRD

0.14054v2 [hep-ex] 29 Oct 2021

[arXiv:2110.14054](https://arxiv.org/abs/2110.14054)

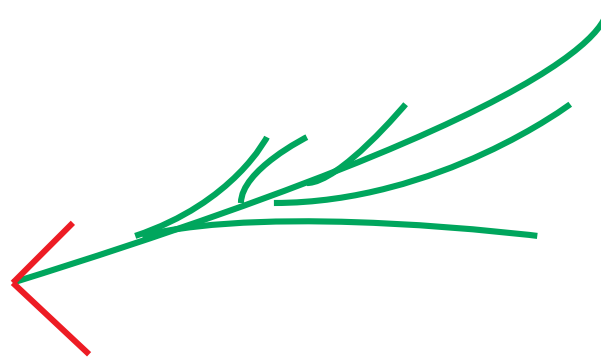
[arXiv:2110.14065](https://arxiv.org/abs/2110.14065)

ν_e Analyses



1e1p0 π : QE-like

[arXiv:2110.14080](https://arxiv.org/abs/2110.14080)



1eXp0 π : pionless

[arXiv:2110.14065](https://arxiv.org/abs/2110.14065)



1eX : inclusive

[arXiv:2110.13978](https://arxiv.org/abs/2110.13978)

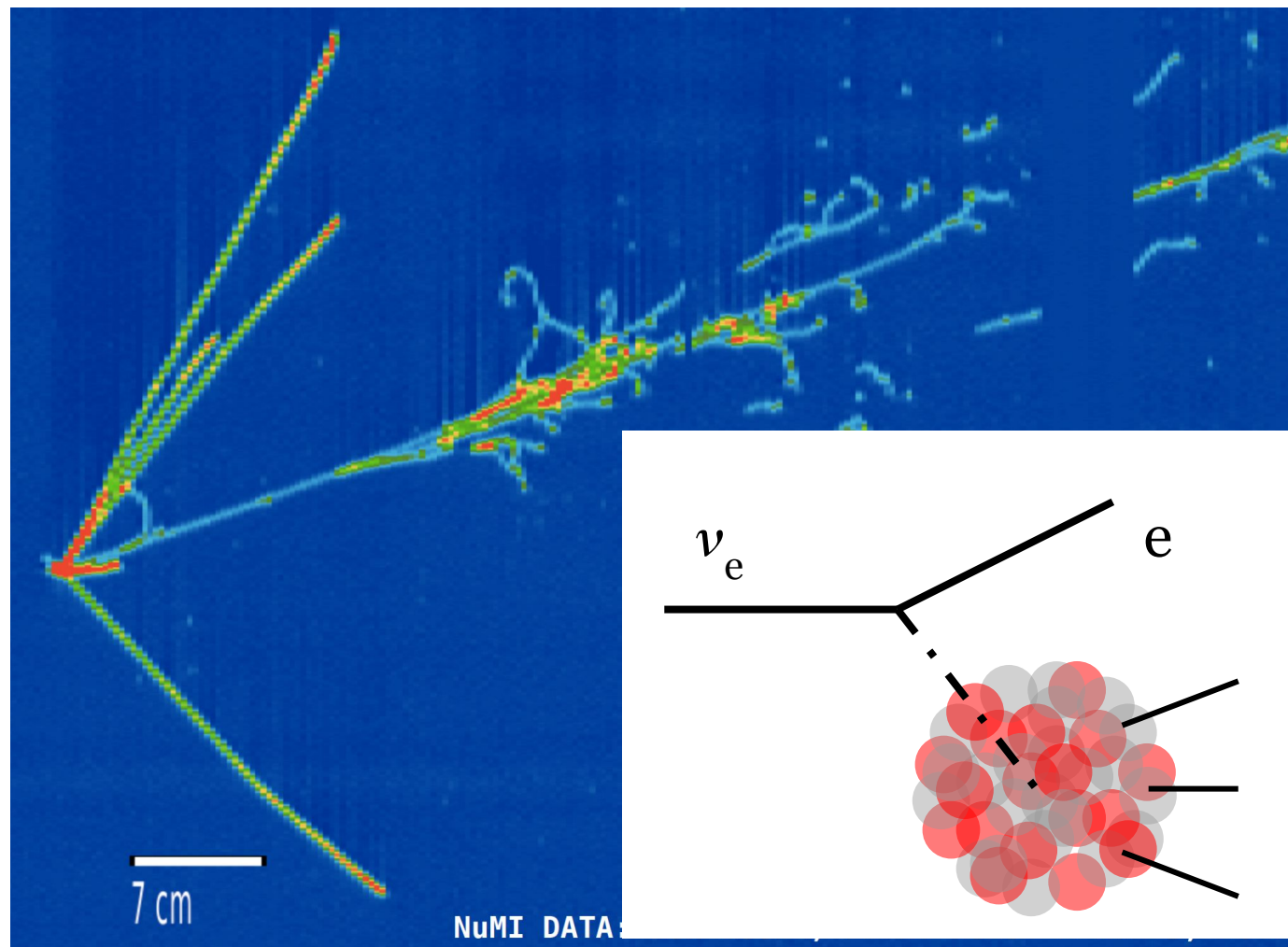
Three independent & blind analyses:

1. Different reconstruction techniques
→ LArTPC technology
2. Different final-states
→ different interaction modes & FSI
→ new physics may lurk in different channels.

Neutrino Interactions

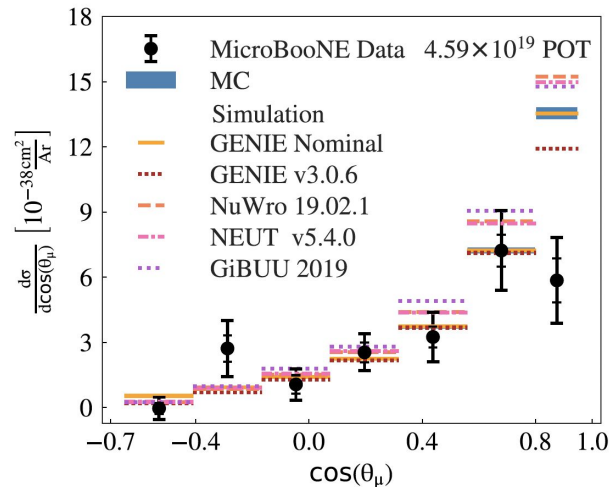
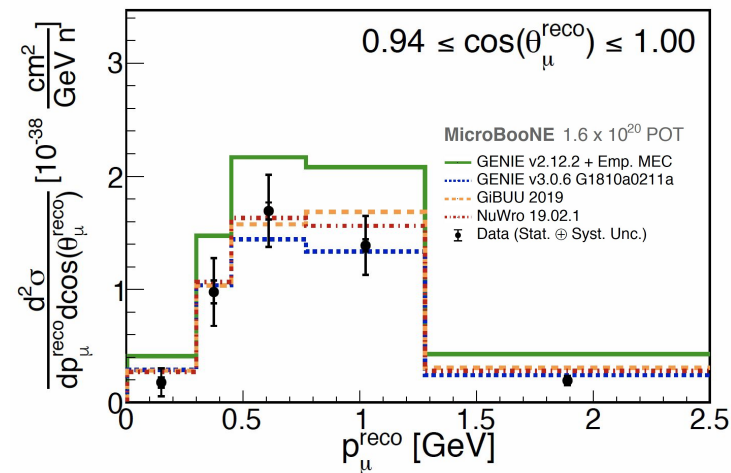
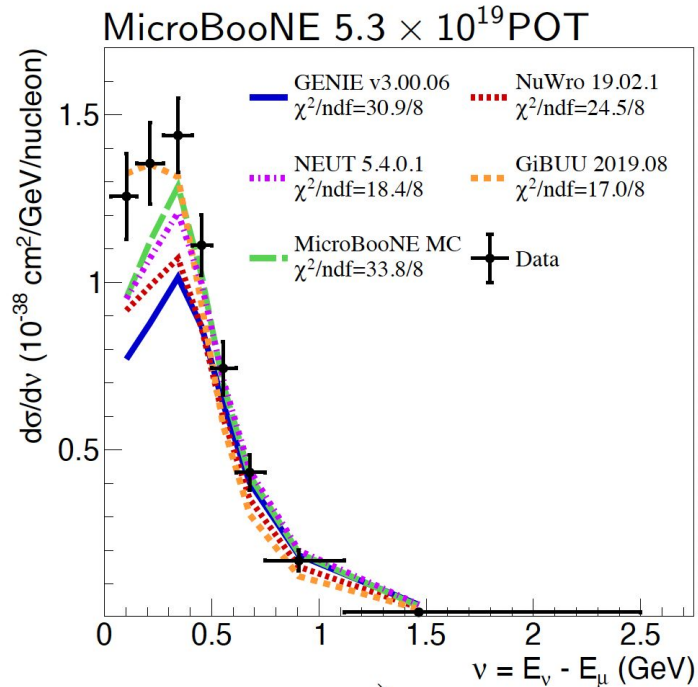
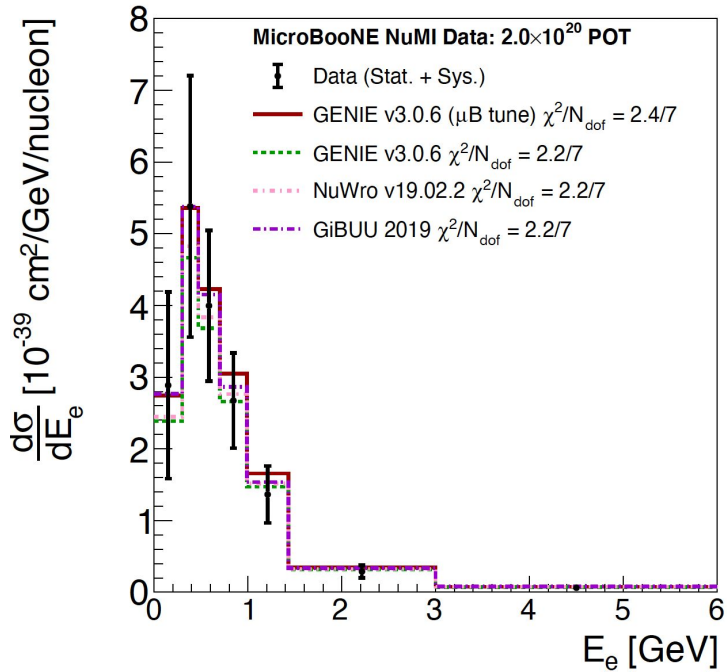
Neutrino interactions on argon target lead to complex final-states.

Rate and final-state observables need to be modeled accurately to carry out this analysis.



high energy electron neutrino interaction candidate with large track multiplicity

MicroBooNE's Cross-Section Program



MicroBooNE xsec measurements:

ν CC $Np0\pi$ [1D differential]
Phys.Rev.D 102 (2020) 11, 112013

ν CCQE-like [1D differential]
Phys.Rev.Lett. 125 (2020) 20, 201803

ν CC inclusive [2D differential]
Phys.Rev.Lett. 123 (2019) 13, 131801

ν CC π^0 [integrated]
Phys.Rev.D 99 (2019) 9, 091102

ν_e CC [inclusive]
Phys.Rev.D 104 (2021) 5, 052002

ν_e CC [1D differential]
 arXiv:2109.06832 [submitted PRL]

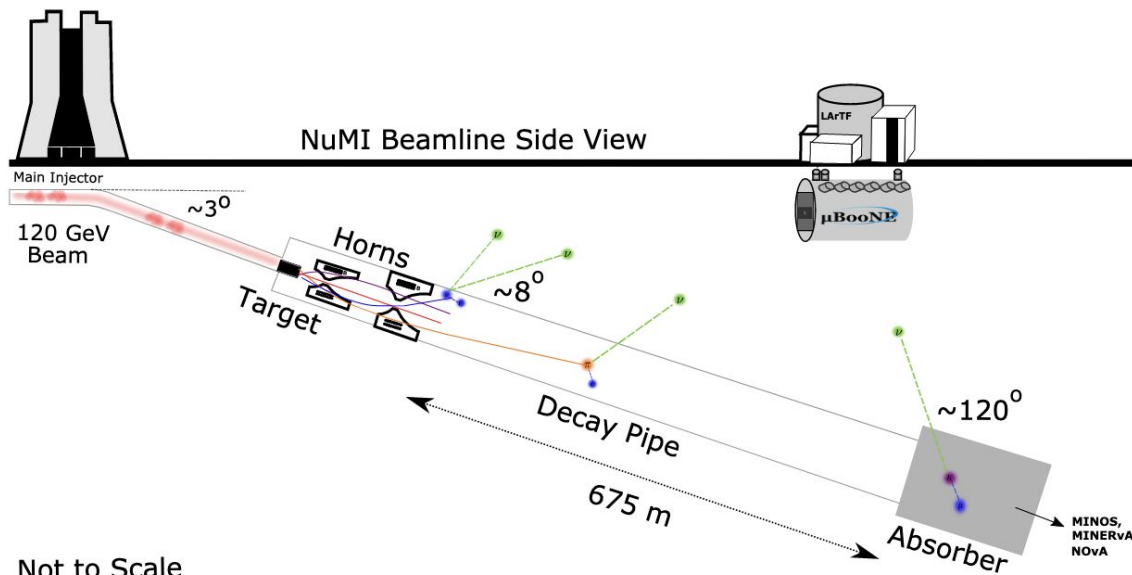
ν_{μ} CC inclusive [1D differential]
 arXiv:2110.14023 [submitted PRL]

... and many more in the pipeline

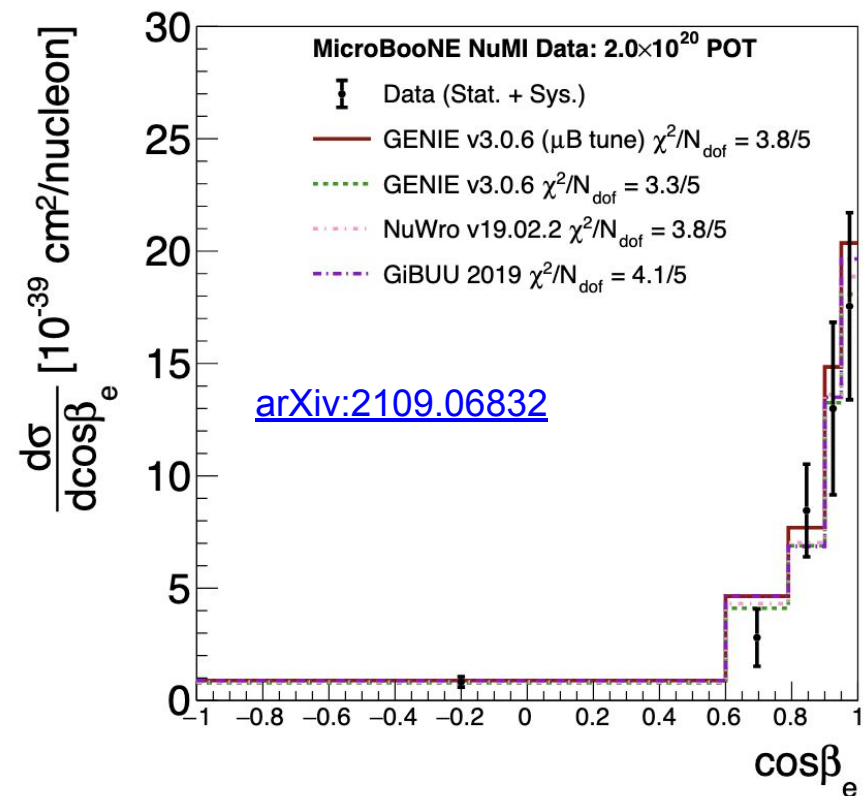
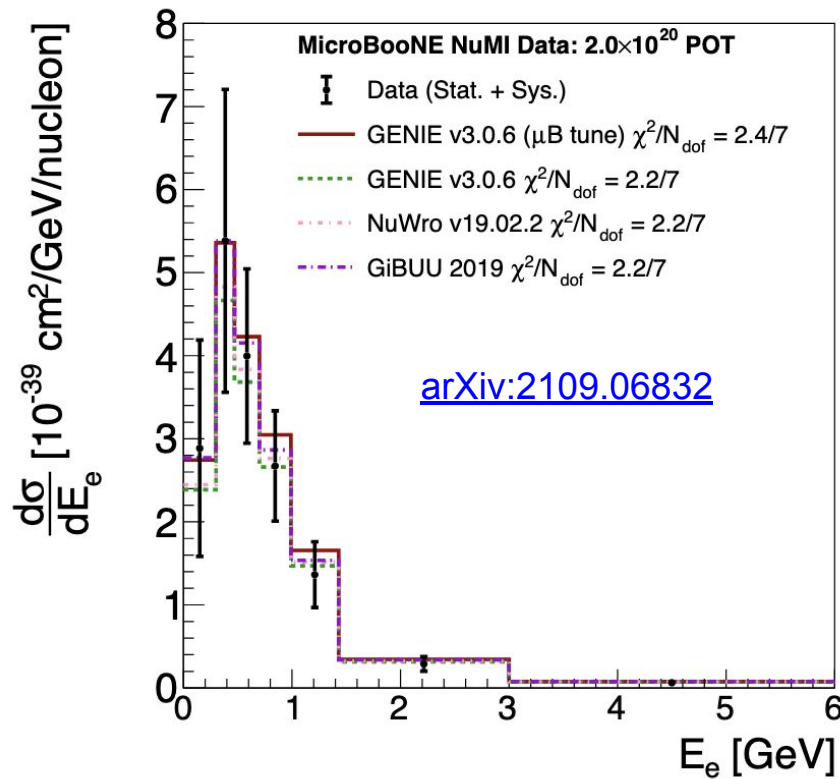
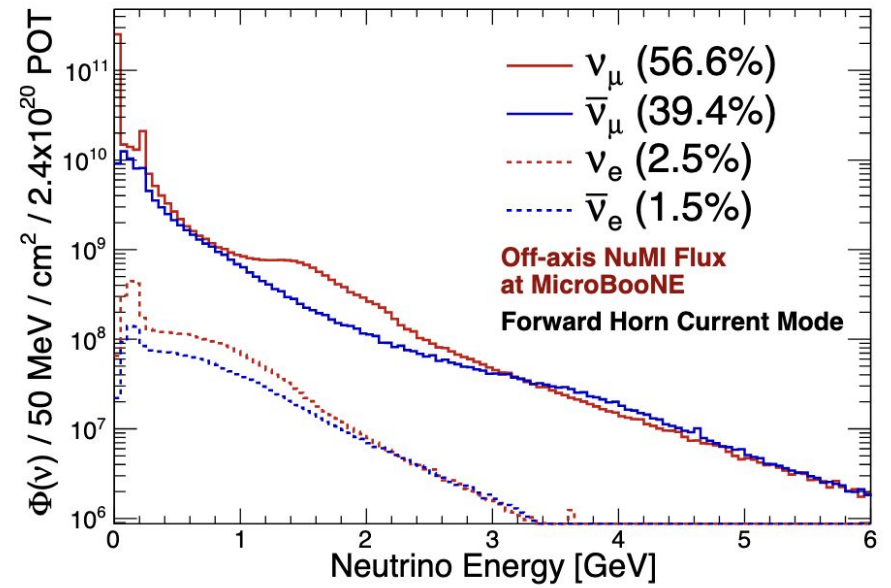
Extensive xsec program performing high-statistics measurements of neutrino interactions on argon for the first time.

Help improve our understanding and modeling of ν -Ar interactions for our own physics program and for the broader neutrino community.

Electron Neutrino Cross-Sections with NuMI



Not to Scale



Neutrino Interaction Model and Tune

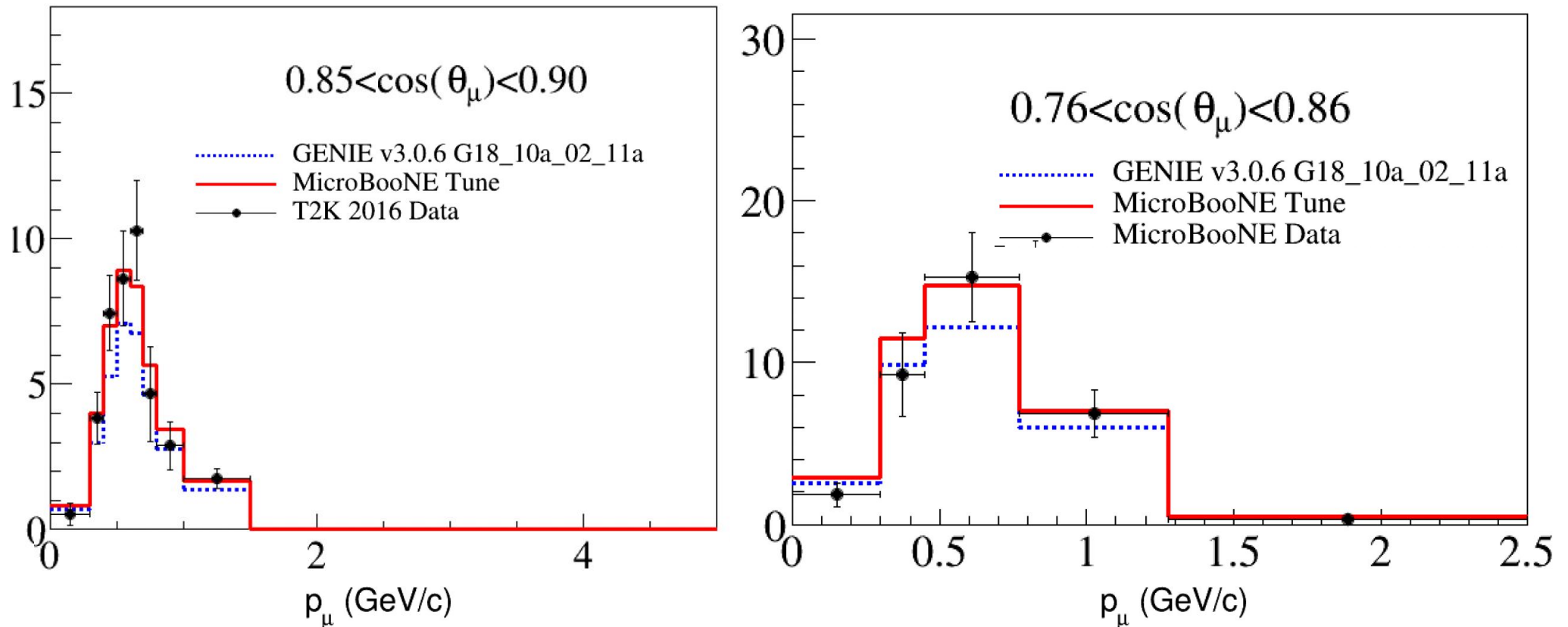
Utilize the GENIE neutrino interaction generator.

GENIE v3 for choice of model.

Tuned to external data: T2K $CC0\pi$ cross-section data.

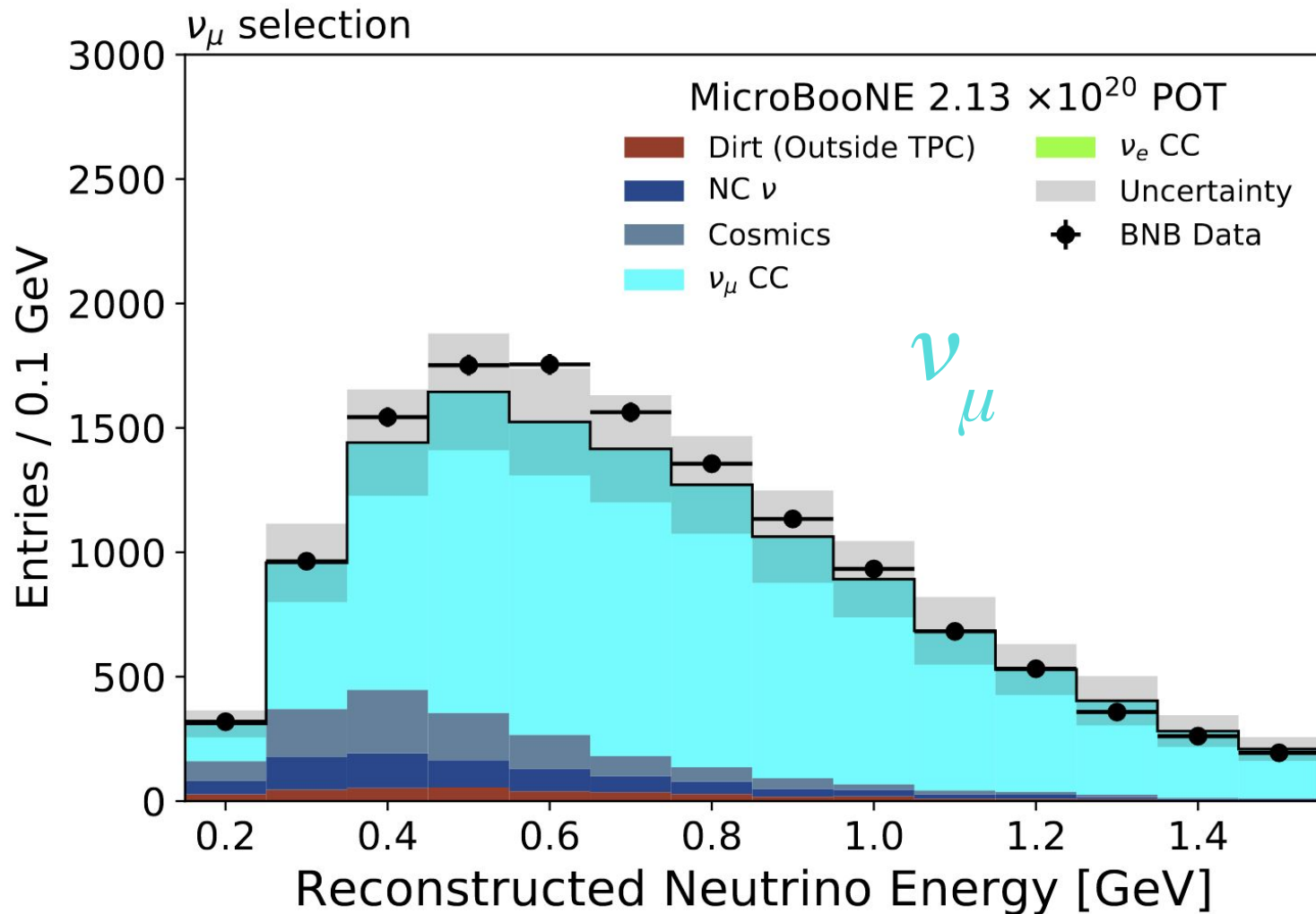
- O(GeV) energy beam, similar flux as BNB

4-parameter fit for CCQE and MEC processes



“New Theory-driven GENIE Tune for MicroBooNE” [arXiv:2110.14028](https://arxiv.org/abs/2110.14028)

In-Situ Data-Driven Constraint

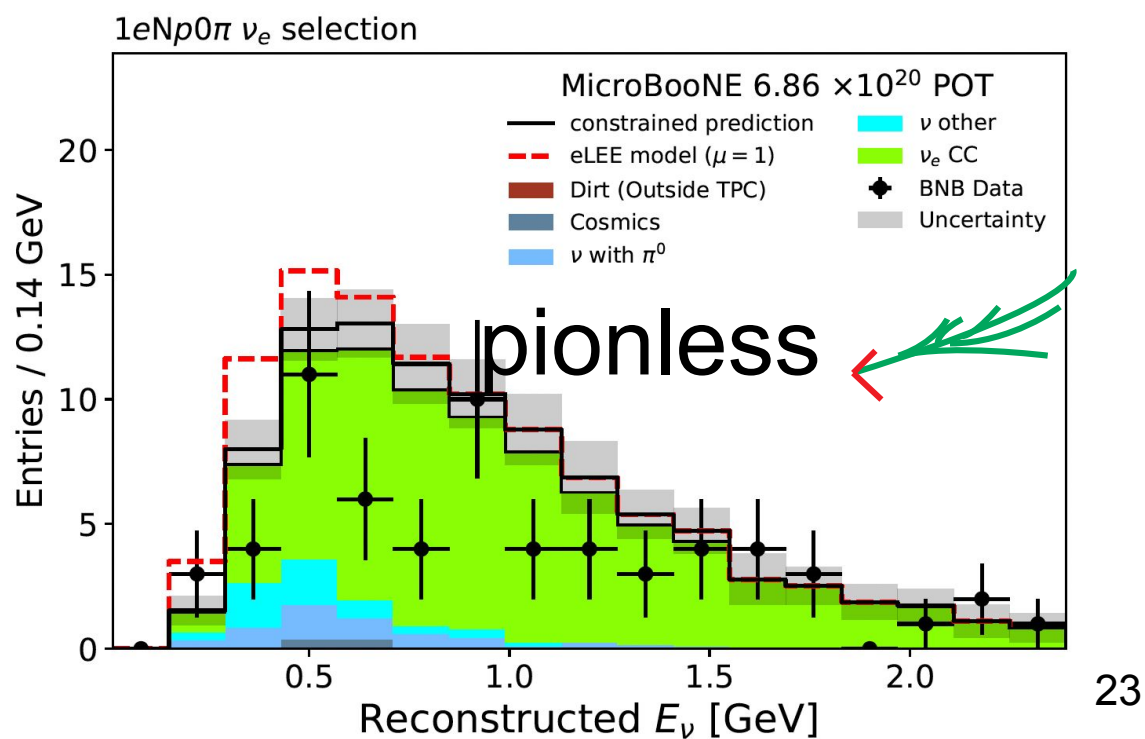
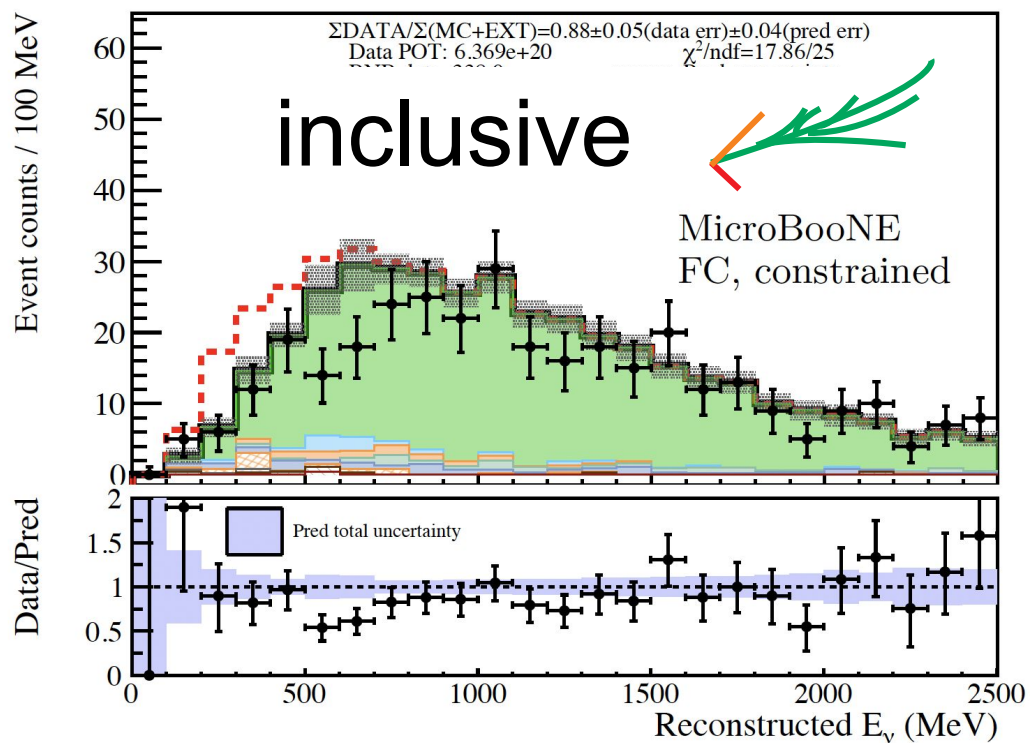
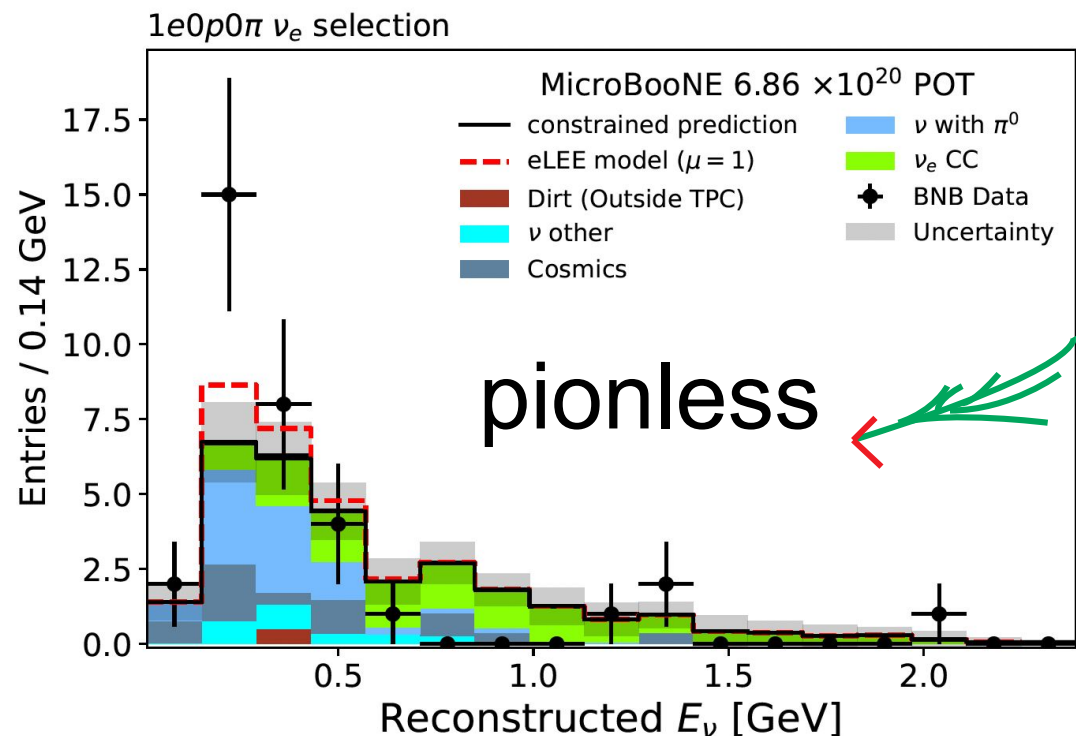
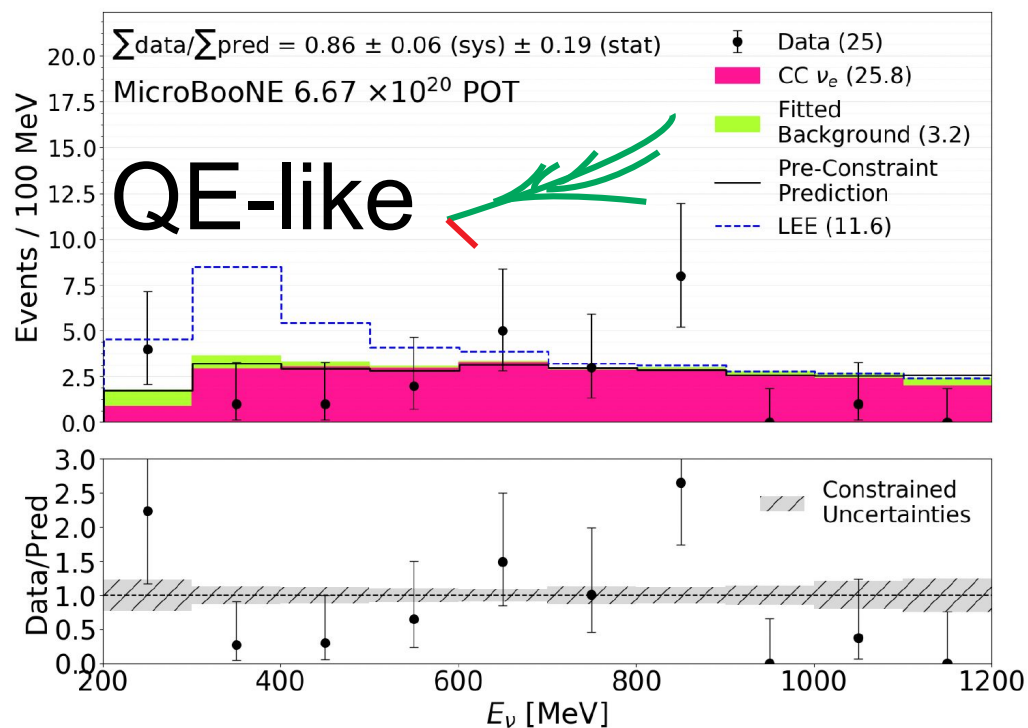


ν_μ CC constraint sample for electron analysis

High statistics ν_μ : same flux and xsec model as backgrounds and ν_e .

- (1) Validate neutrino rate modeling.
- (2) Constrain uncertainties on prediction \rightarrow reduction of $\frac{1}{2}$.

Electron Neutrino Energy Spectra



ν_e Results Summary

Results indicate no electron neutrino excess in data

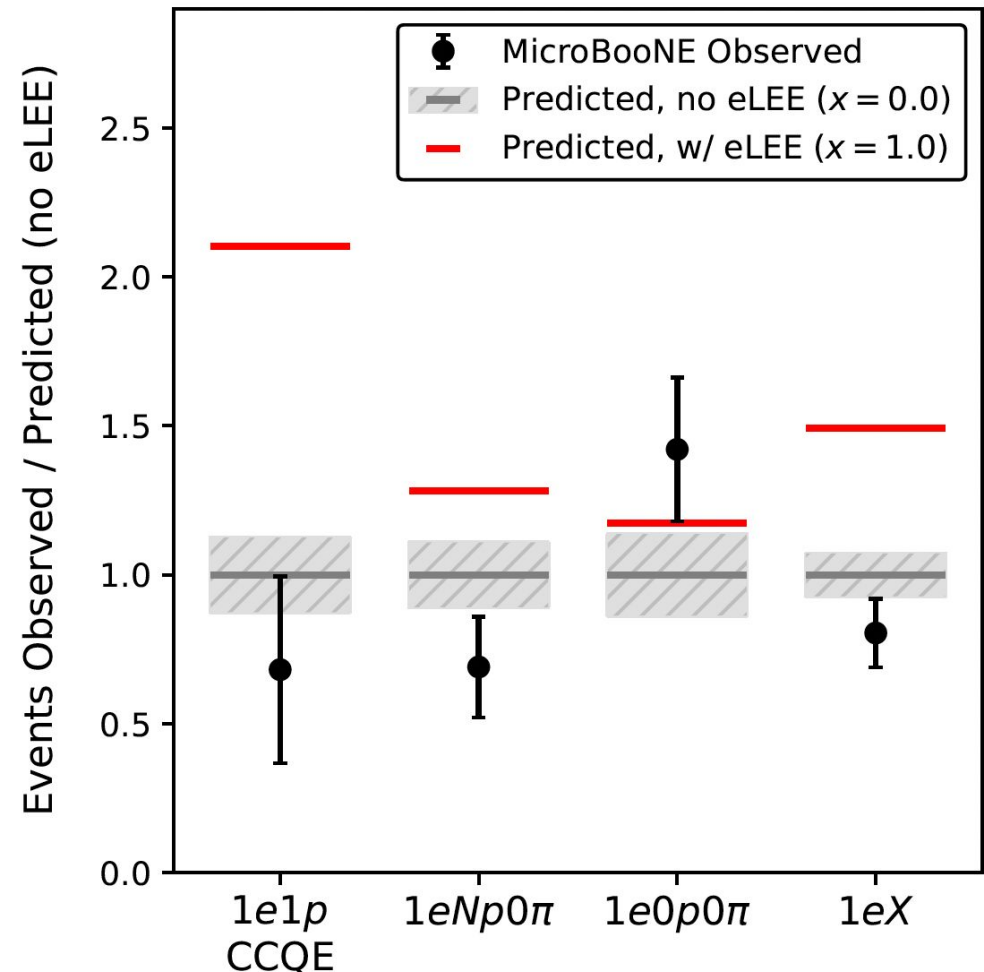
- Consistent across analyses
- CL varies from 97% to $>3\sigma$

Overall observe slight deficit of electron neutrinos relative to prediction in ν_e dominated selections.

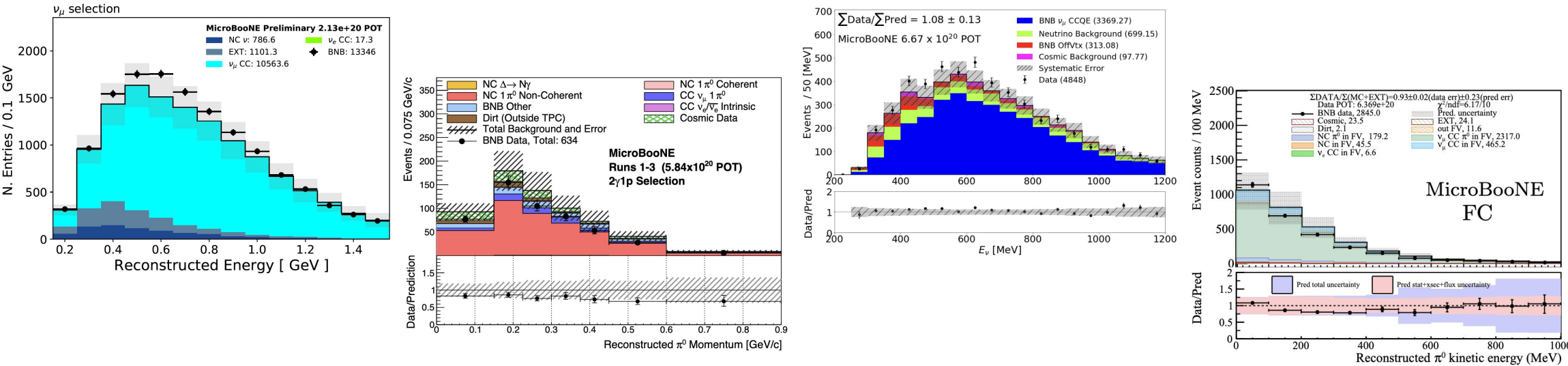
$1e0p0\pi$ channel has slight excess.

- Low sensitivity, consistent with prediction
- Single shower measurement, γ dominated prediction.

[arXiv:2110.14054](https://arxiv.org/abs/2110.14054)

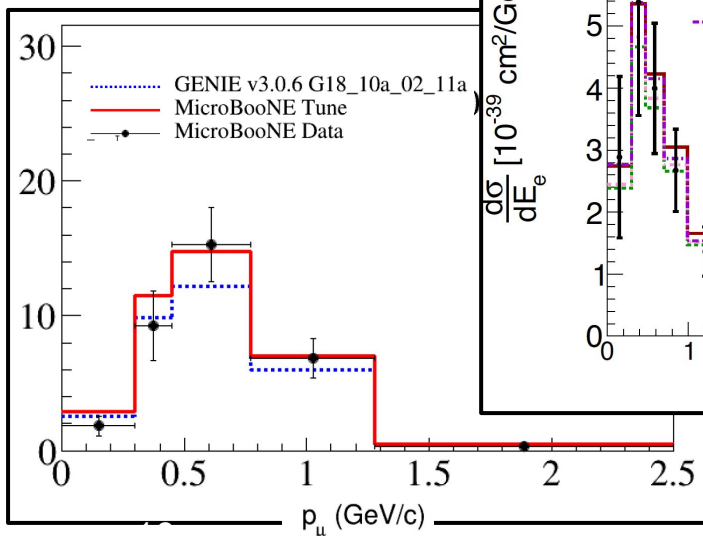


A Milestone Beyond the Analysis Results...

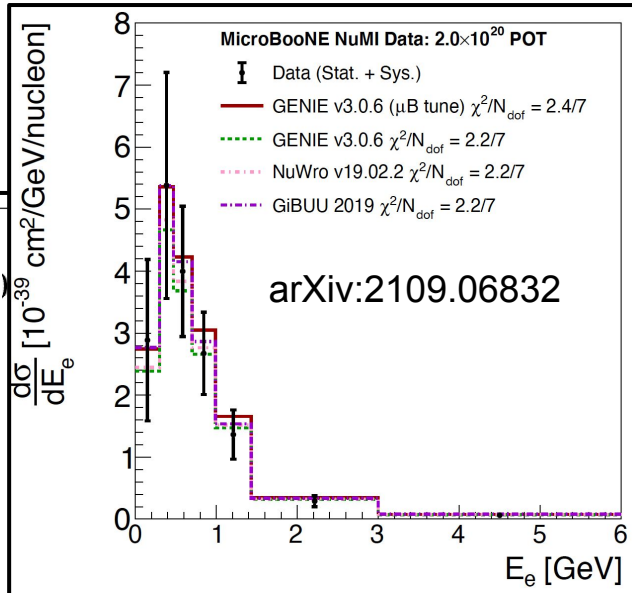


data-driven background constraints throughout these analyses

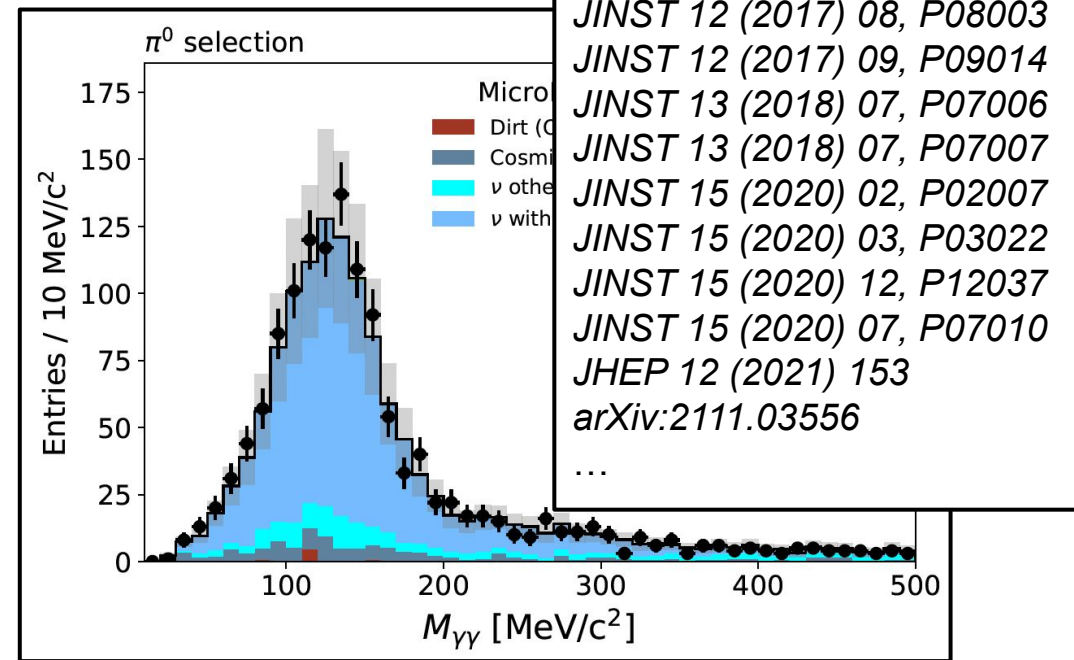
[arXiv2110.14028](https://arxiv.org/abs/2110.14028)



[arXiv:2109.06832](https://arxiv.org/abs/2109.06832)



multiple rounds of XSEC measurements



JINST 12 (2017) 08, P08003
 JINST 12 (2017) 09, P09014
 JINST 13 (2018) 07, P07006
 JINST 13 (2018) 07, P07007
 JINST 15 (2020) 02, P02007
 JINST 15 (2020) 03, P03022
 JINST 15 (2020) 12, P12037
 JINST 15 (2020) 07, P07010
 JHEP 12 (2021) 153
 arXiv:2111.03556
 ...

years of LArTPC analysis development...



The Road Ahead

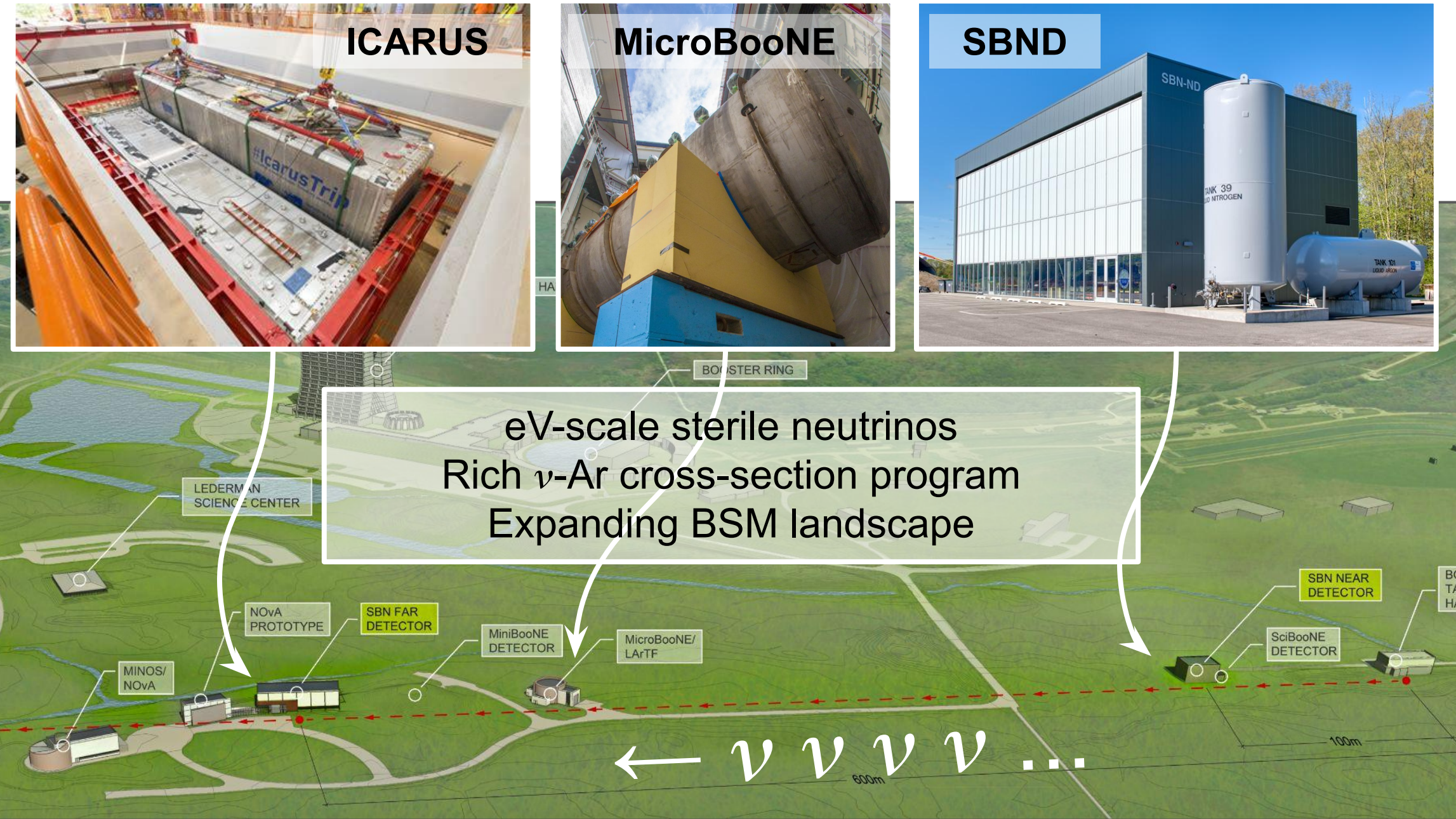
Short-Baseline Neutrino (SBN) Program

ICARUS

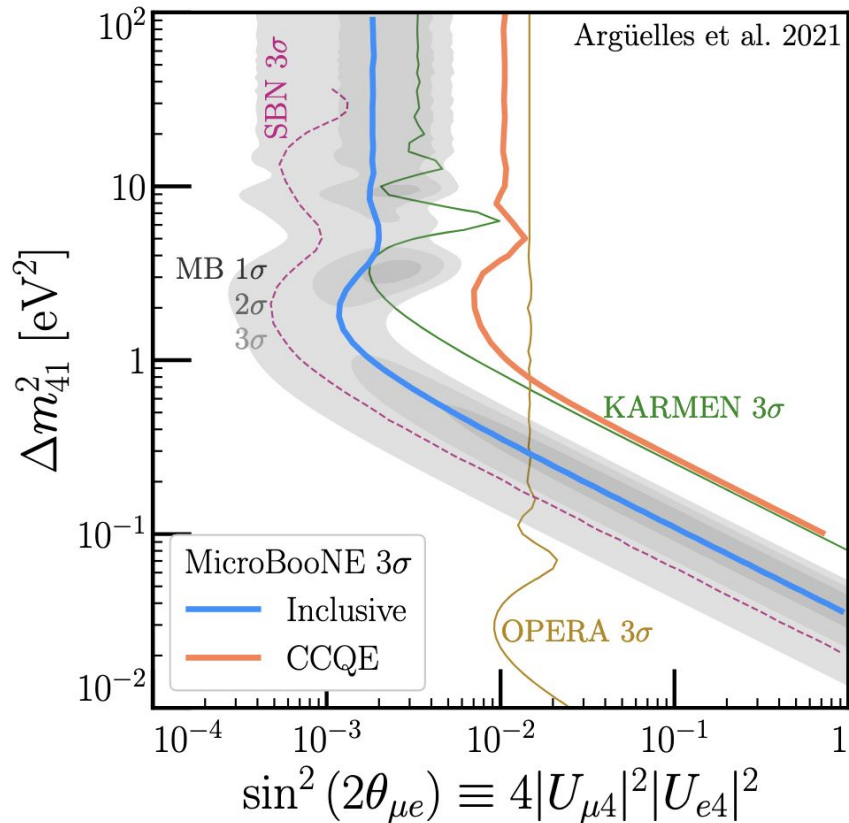
MicroBooNE

SBND

eV-scale sterile neutrinos
Rich ν -Ar cross-section program
Expanding BSM landscape

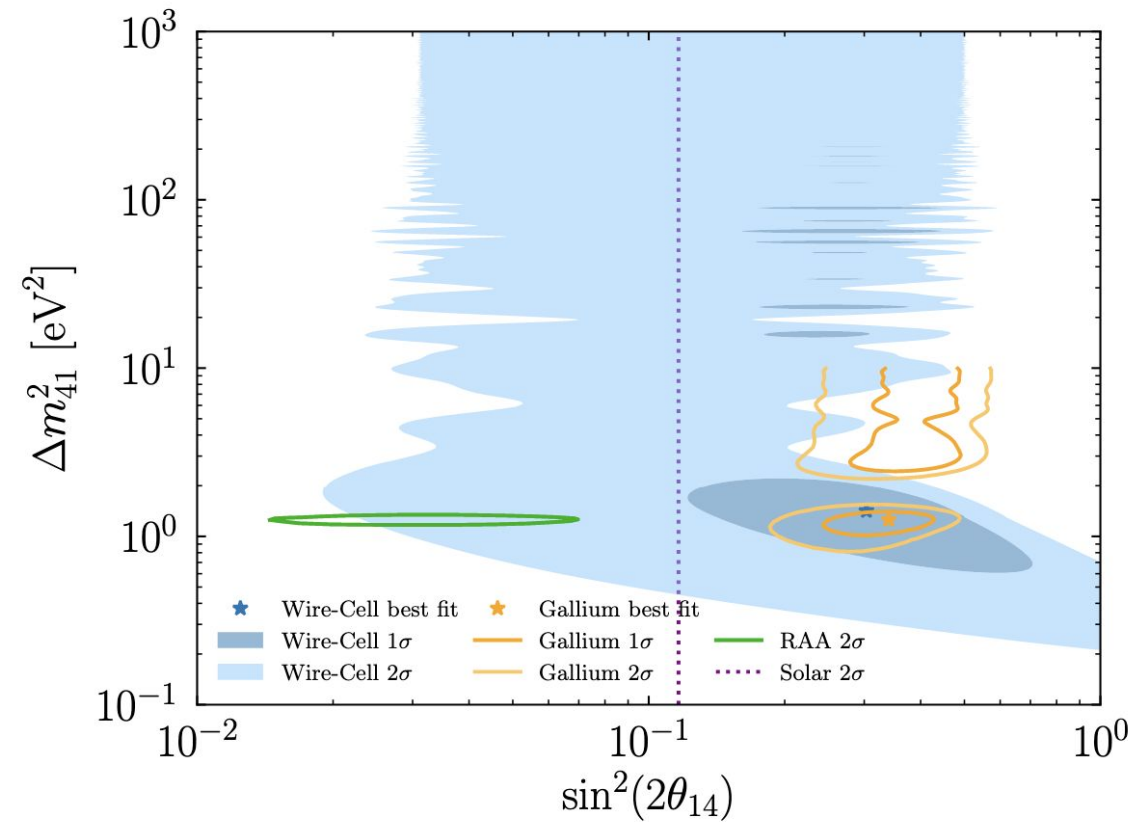


MicroBooNE's Result Under 3+1 Hypothesis



[arXiv:2111.10359](https://arxiv.org/abs/2111.10359)

C. A. Argüelles et al.



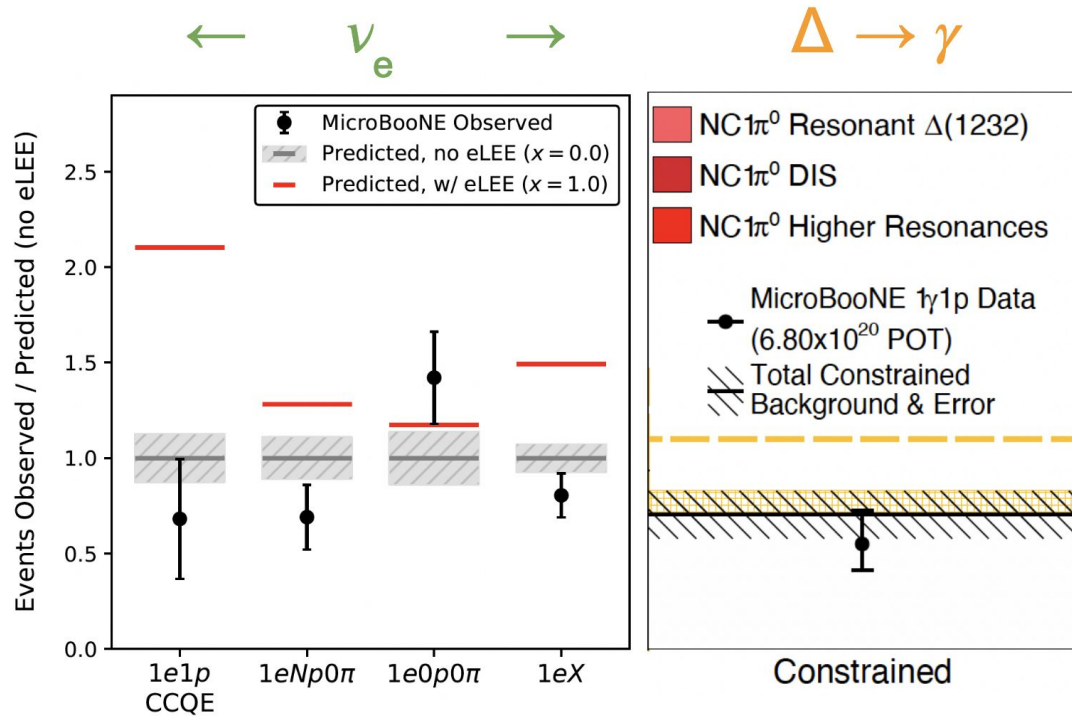
[arXiv:2111.05793](https://arxiv.org/abs/2111.05793)

Peter Denton, BNL

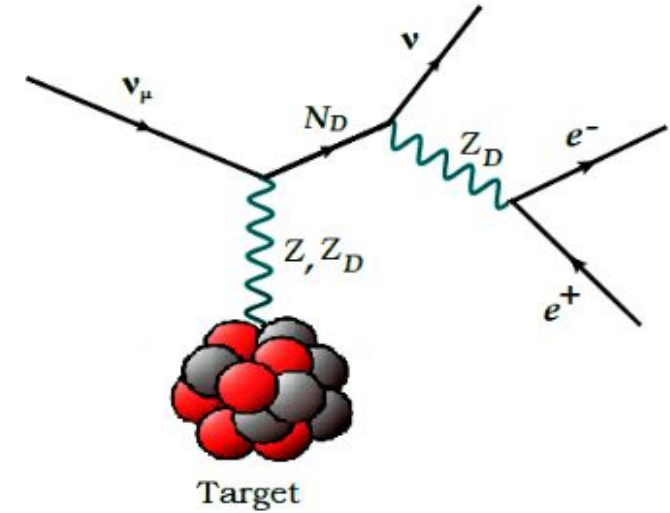
What does MicroBooNE's result say about eV-scale Sterile Neutrino models in 3+1 scenario?

Active interest from theory community. We are catching up...

MicroBooNE's BSM Program



E. Bertuzzo et al., PRL **121** 241801 (2018)

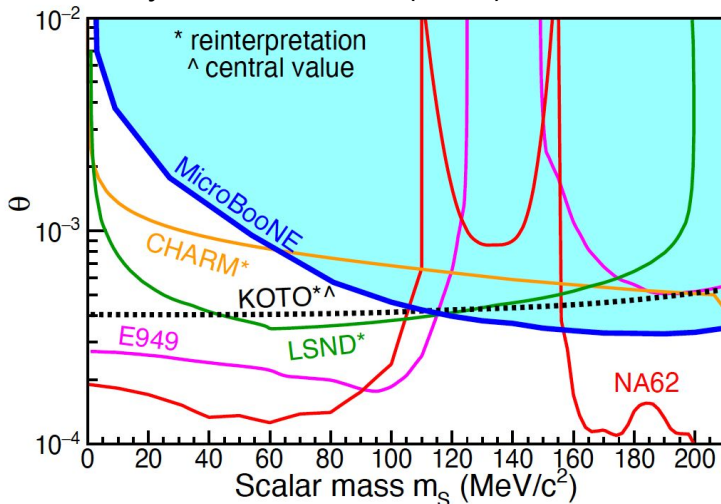


e^+e^- / Inclusive γ search

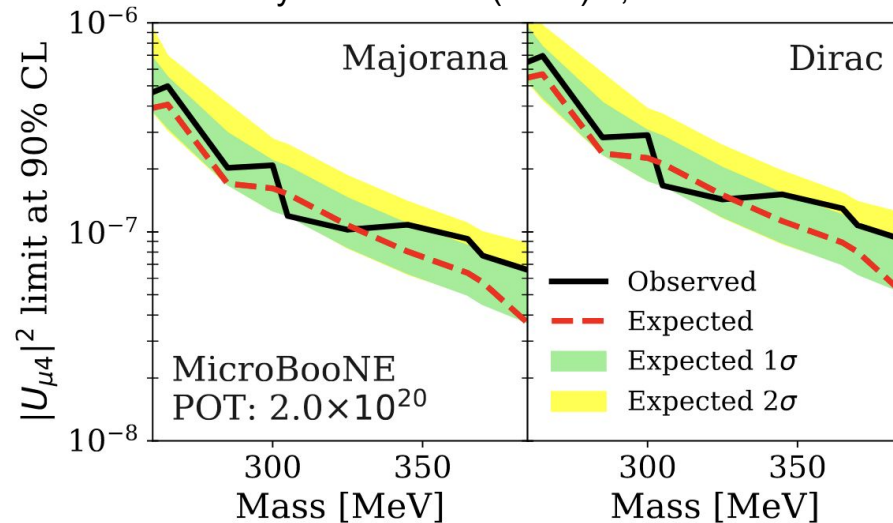
← *Current Results...*

...in the works! →

Phys.Rev.Lett. 127 (2021) 15, 151803

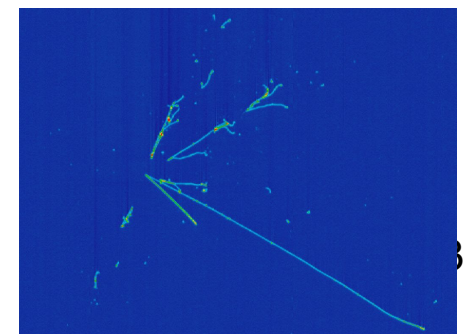
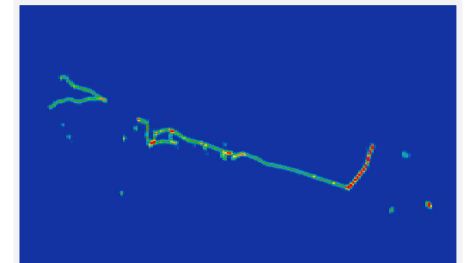
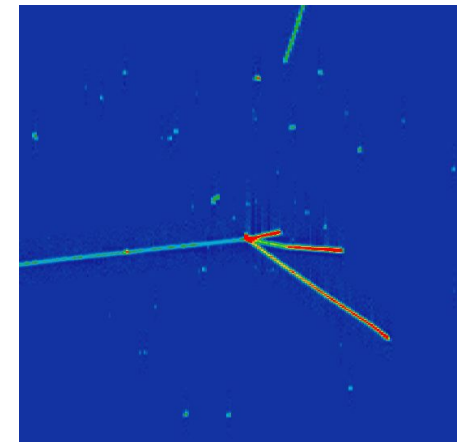
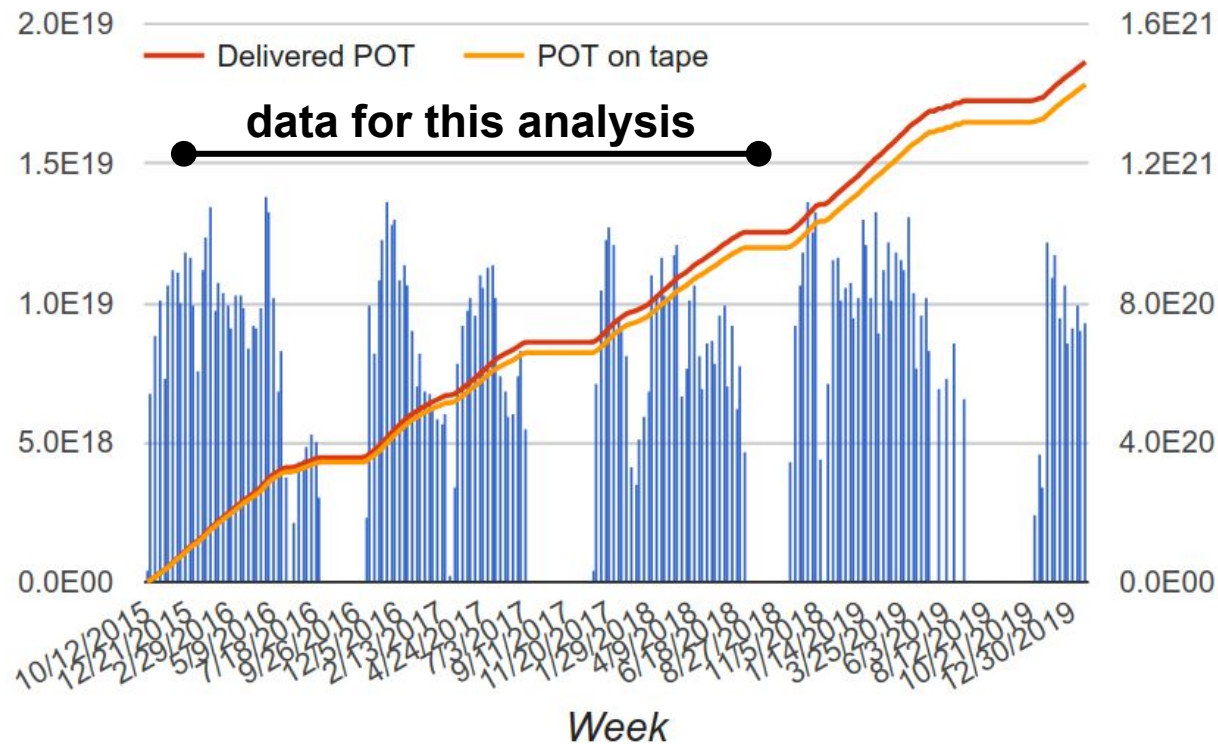
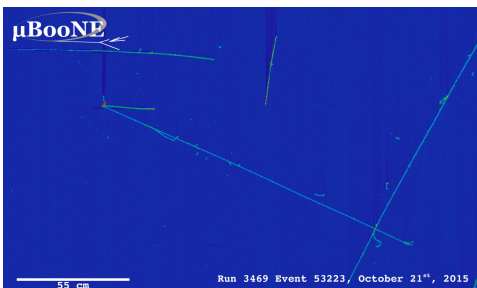
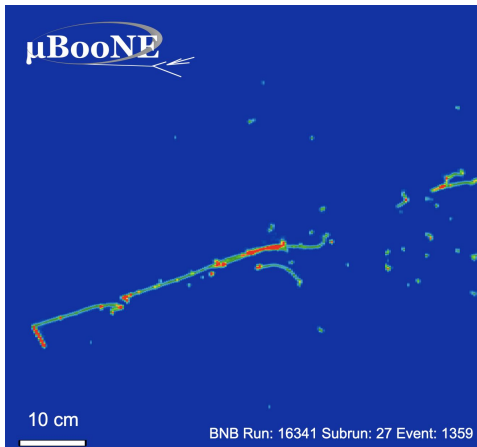
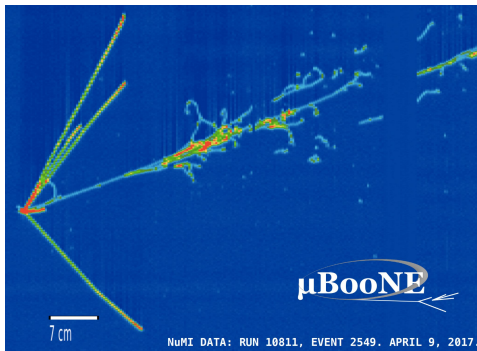
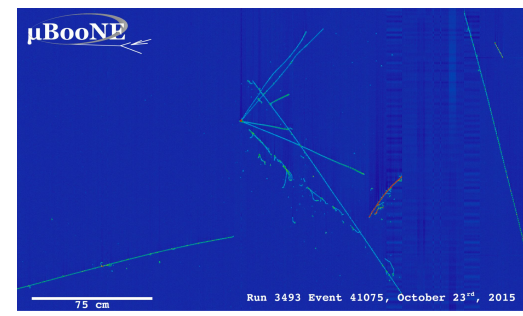
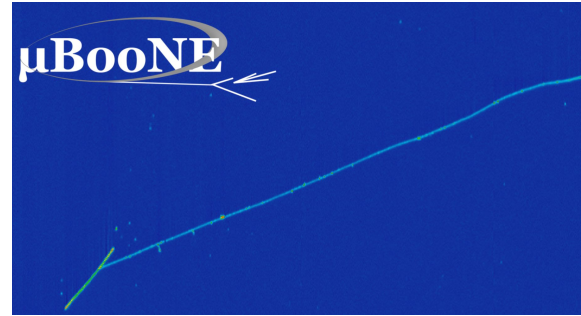
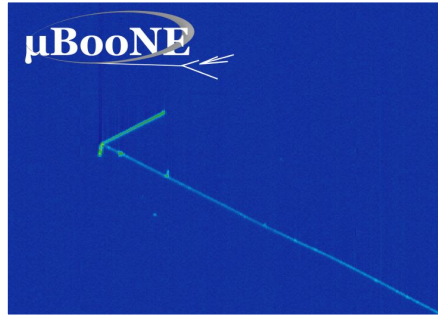
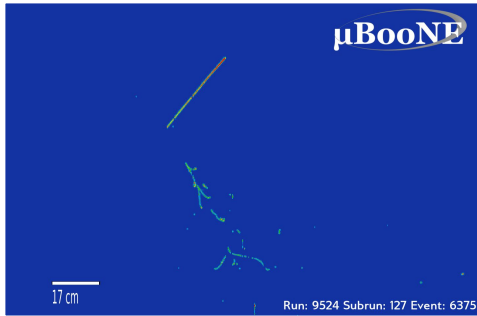


Phys.Rev.D 101 (2020) 5, 052001



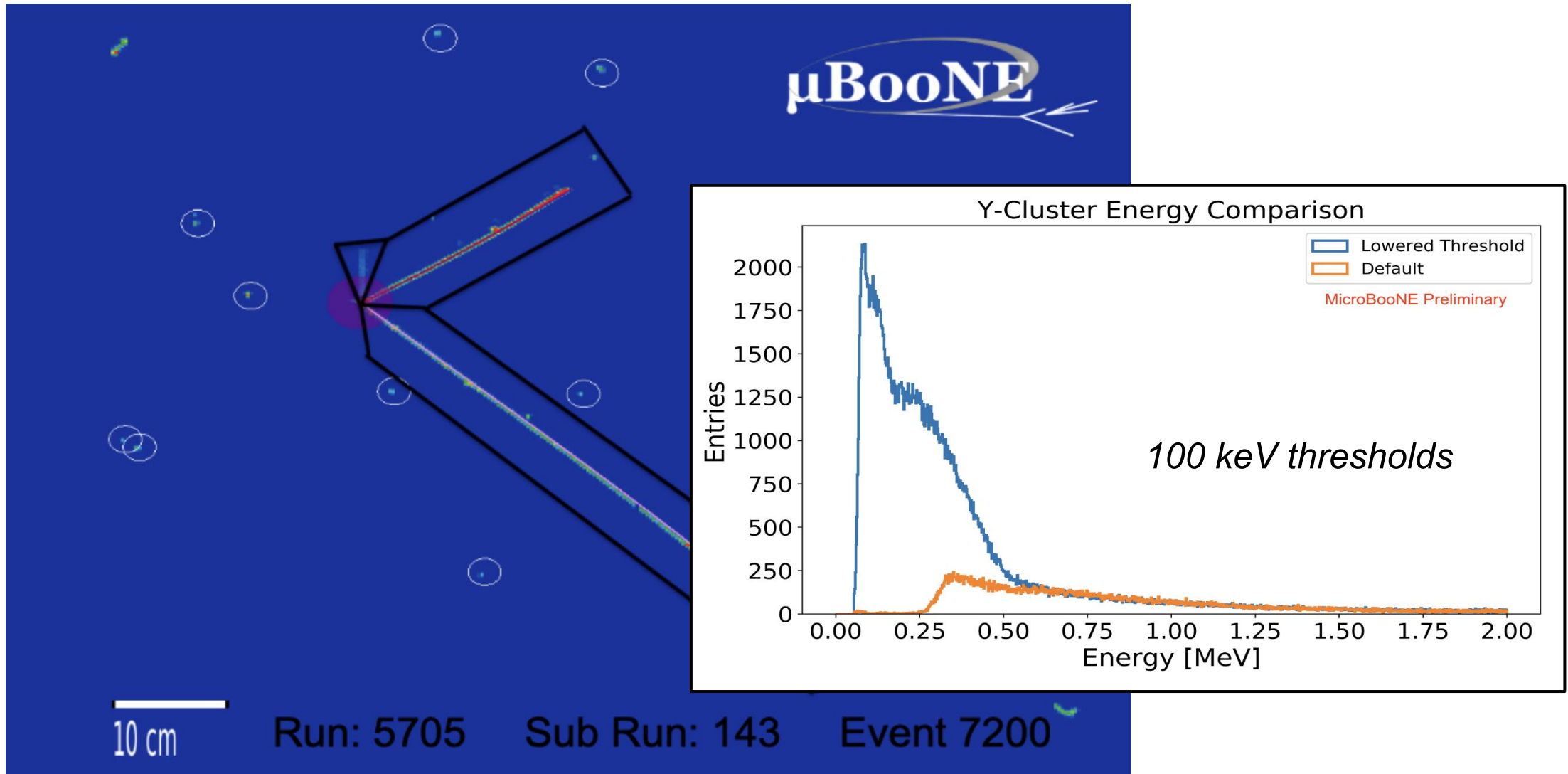
...and more to come!

MicroBooNE Data Set



- Longest running large-scale LArTPC to date.
- Dataset of 500k ν - Ar interactions!

MeV-scale Physics @ MicroBooNE



Reconstruction and Potential for MeV-Scale Physics in MicroBooNE

sub-MeV thresholds and meter-scale volumes

[MICROBOONE-NOTE-1076](#)

Summary

MicroBooNE has followed-up on one of the most intriguing puzzles in neutrino physics.

- see no excess of $\text{NC } \Delta \rightarrow \gamma$ or **Electron Neutrinos** in Booster Neutrino Beamline.

Demonstrated power of LArTPC technology for precision measurements.

- Foundational for the broader LArTPC program

Exciting new chapter ahead!

- double the data from MicroBooNE, new measurements actively being pursued.
- Expanded reach with SBN program.