New Physics at MicroBooNE

Mark Ross-Lonergan

On behalf of the MicroBooNE Collaboration

NOW 2024, Otranto, Italy

September 4th 2024

μBooNE

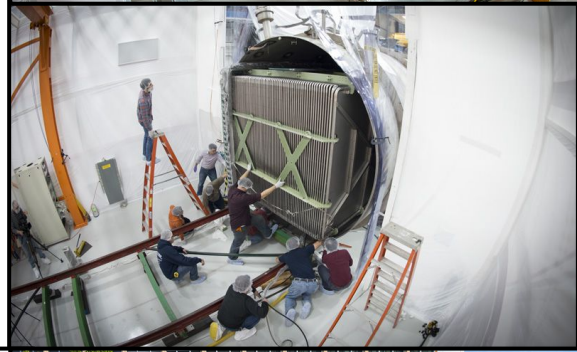
Los Alamos NATIONAL LABORATORY

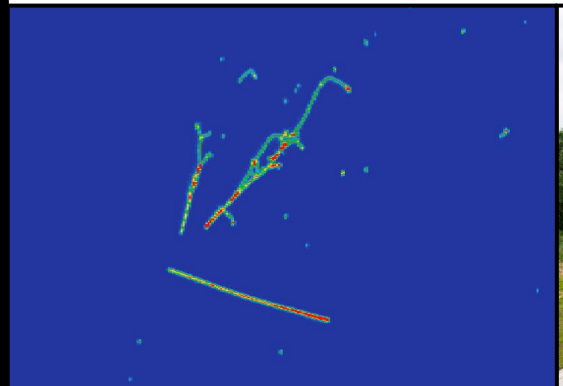
Fermilab

The MicroBooNE LArTPC Experiment

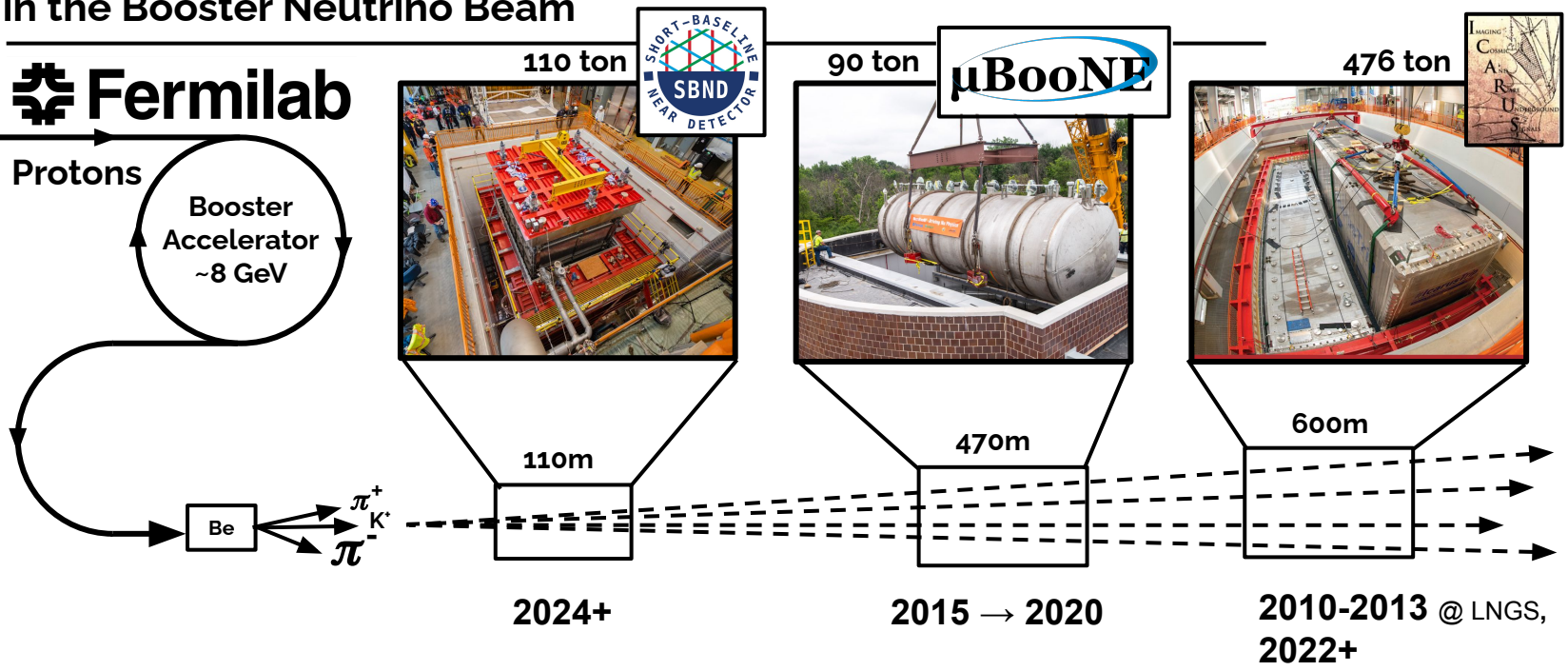
The **world's longest running** Liquid Argon Time Projection Chamber (LArTPC) in a neutrino beam

Collected data for five years from 2015 to 2020, amassing the **largest sample of neutrino interactions on argon in the world**





Experiments in the Booster Neutrino Beam



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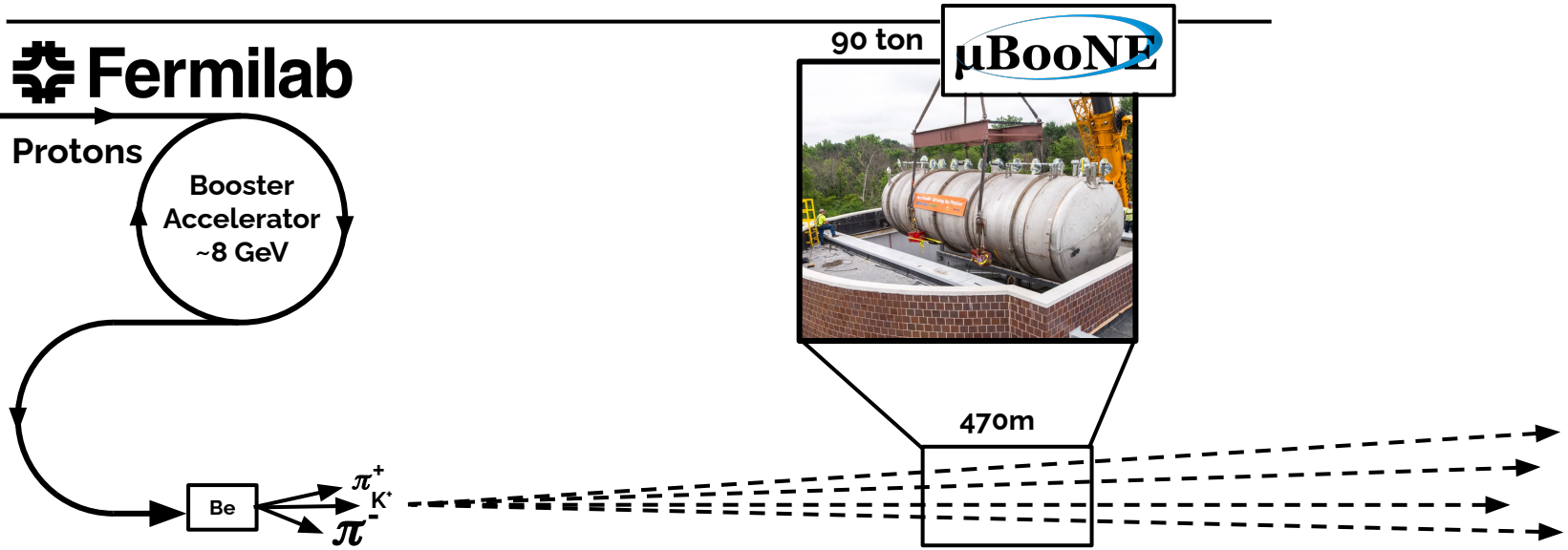
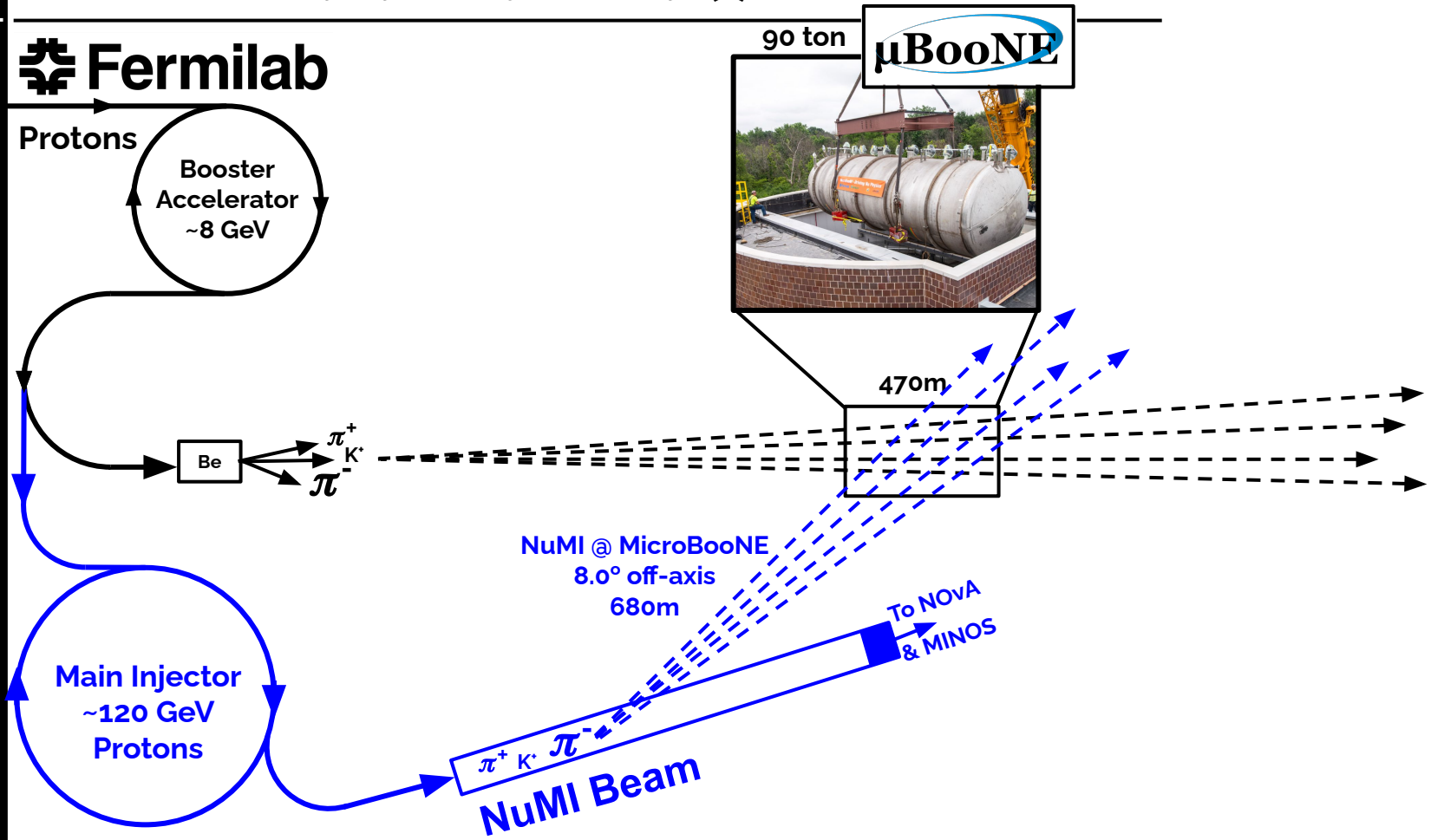


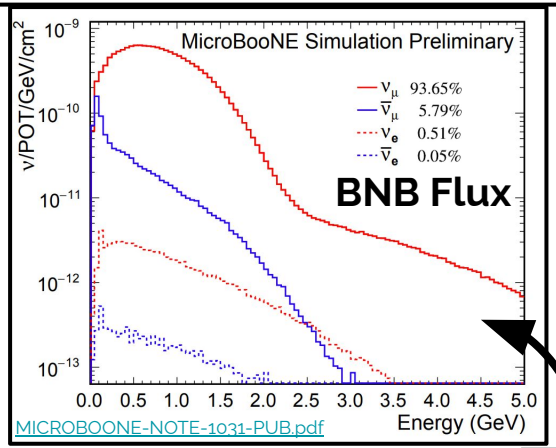
Experiments in the Booster *and NuMI* Neutrino Beam(s)



Fermilab

Protons

Booster Accelerator ~8 GeV



0.55% $\nu_e/\bar{\nu}_e$

Be

π^+ K$^+$ π^-

NuMI @ MicroBooNE
8.0° off-axis
680m

To NOvA & MINOS

Main Injector ~120 GeV Protons

π^+ K$^+$ π^-

NuMI Beam

Neutrino Fluxes at MicroBooNE

Fermilab

Protons

Booster Accelerator ~8 GeV

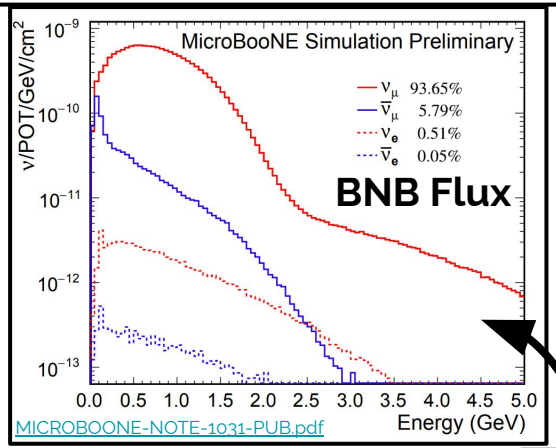
Be

π^+ K$^+$ π^-

Main Injector ~120 GeV Protons

NuMI @ MicroBooNE
8.0° off-axis
680m

NuMI Beam



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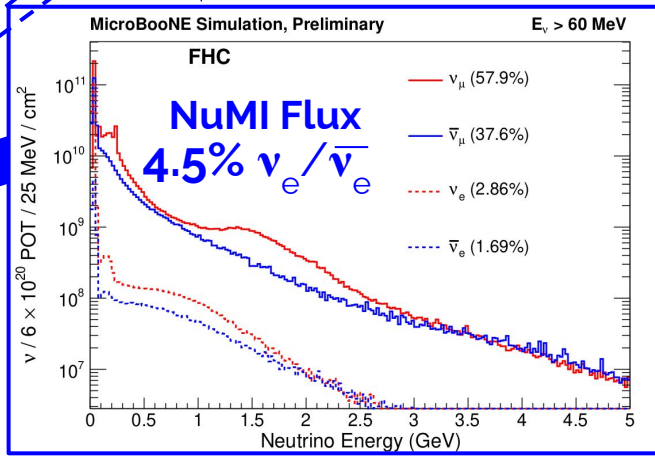
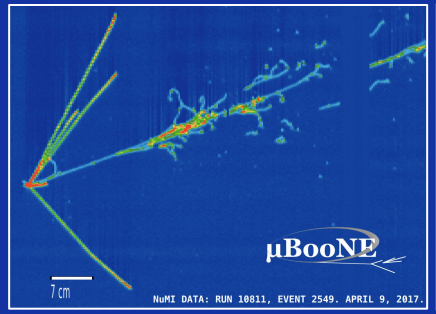
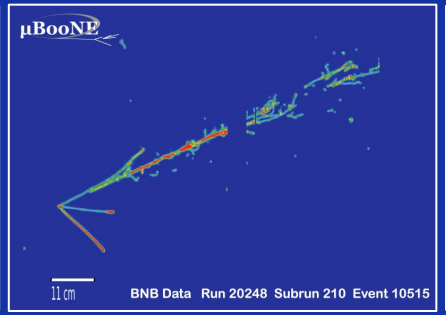


Liquid Argon Time Projection Chamber Detector Technology

Extremely effective **Particle ID capabilities**





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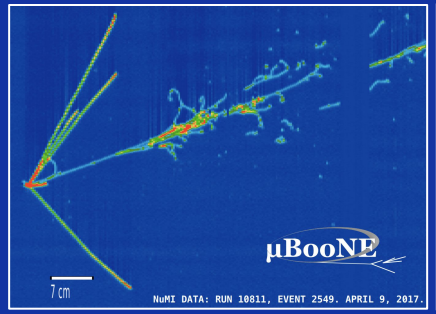
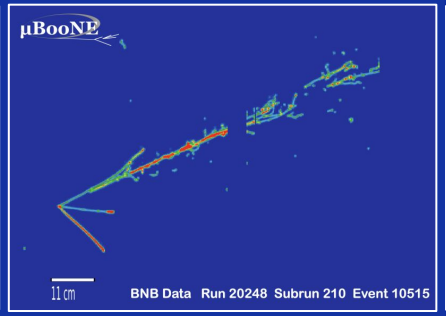
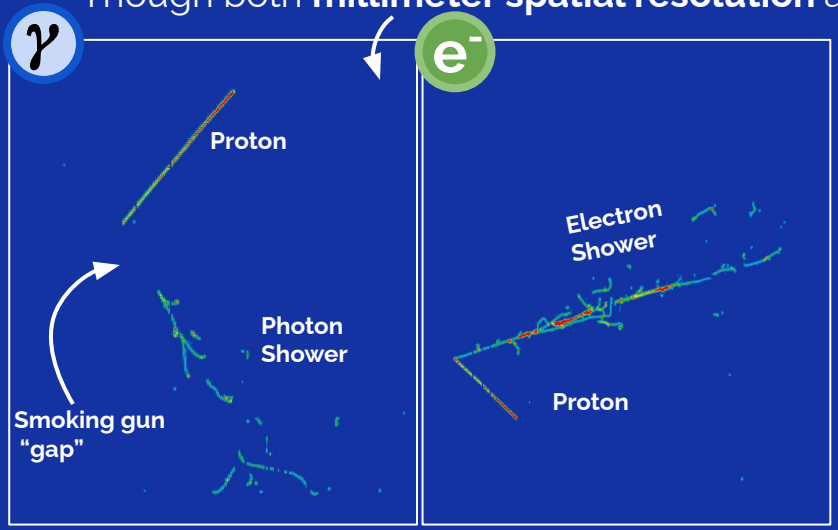
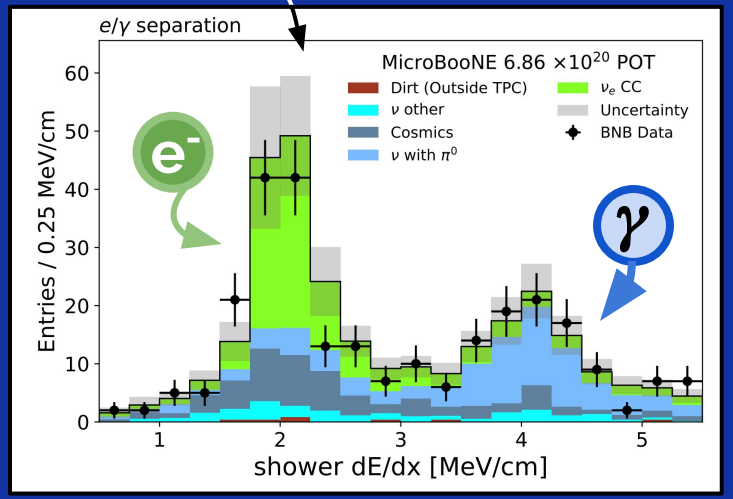


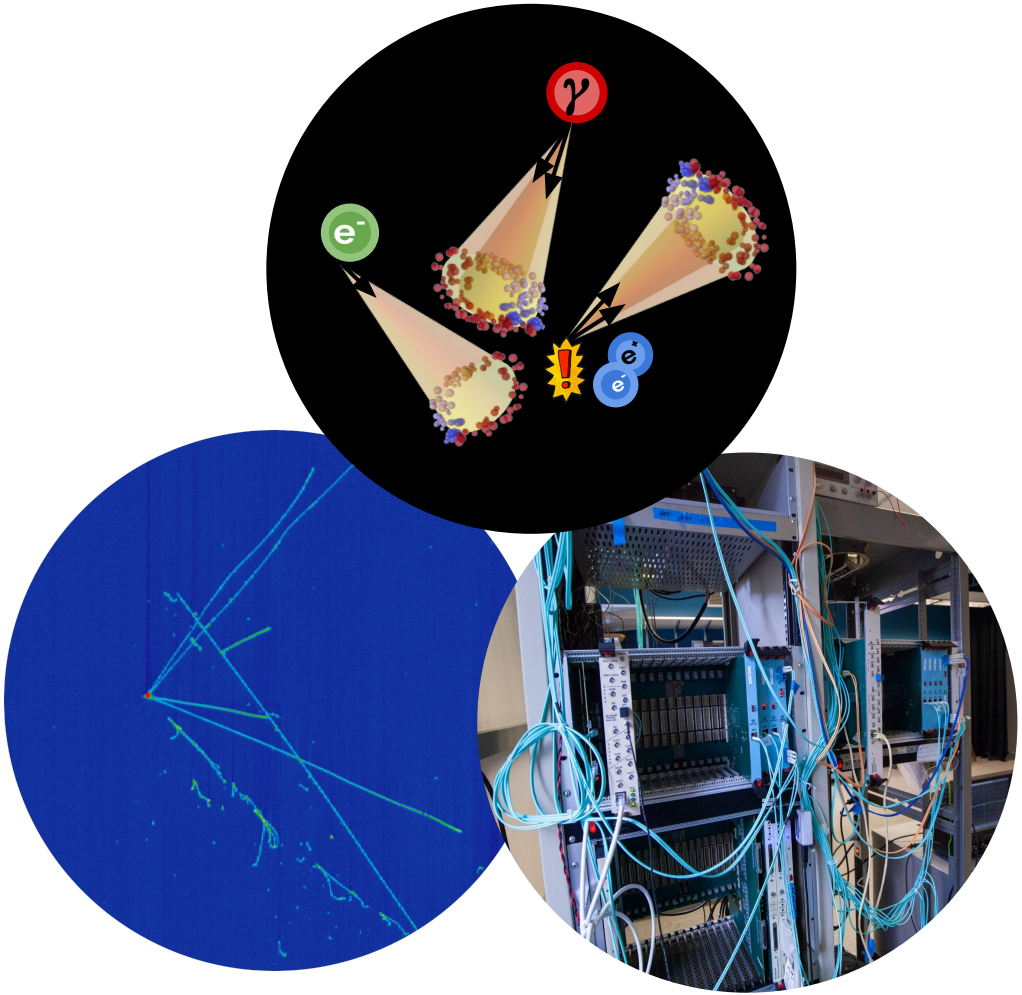


Strong **photon** ↔ **electron** **separation**
Though both **millimeter spatial resolution** and **Calorimetry**





The Physics Goals of MicroBooNE



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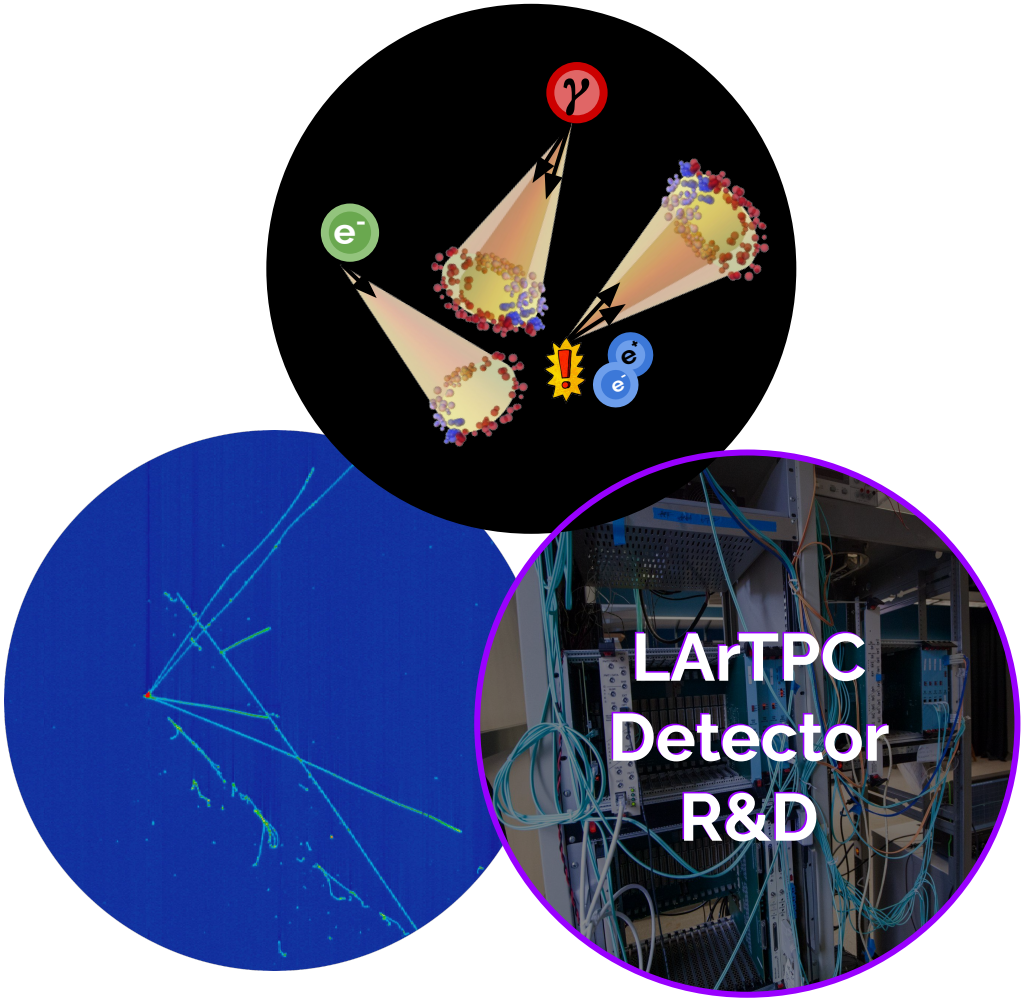

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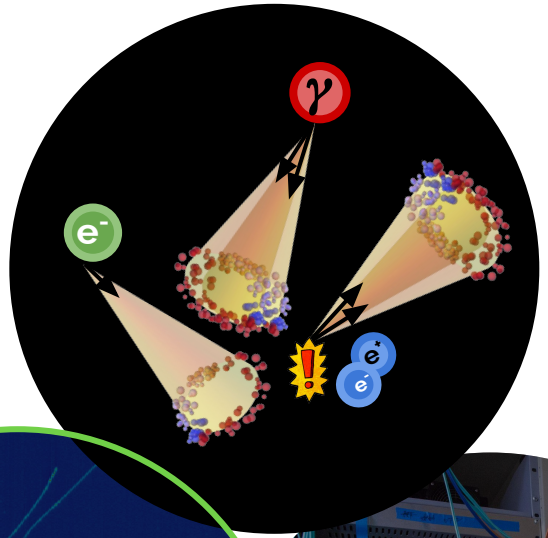
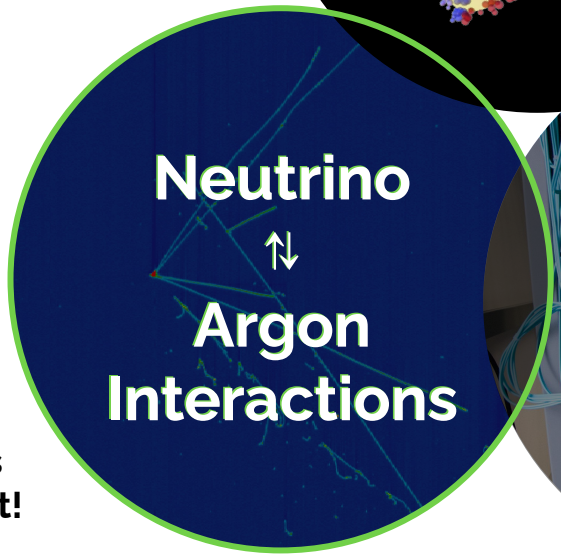
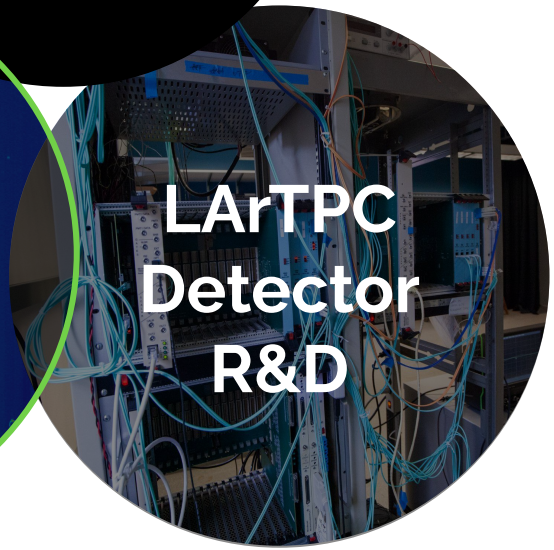


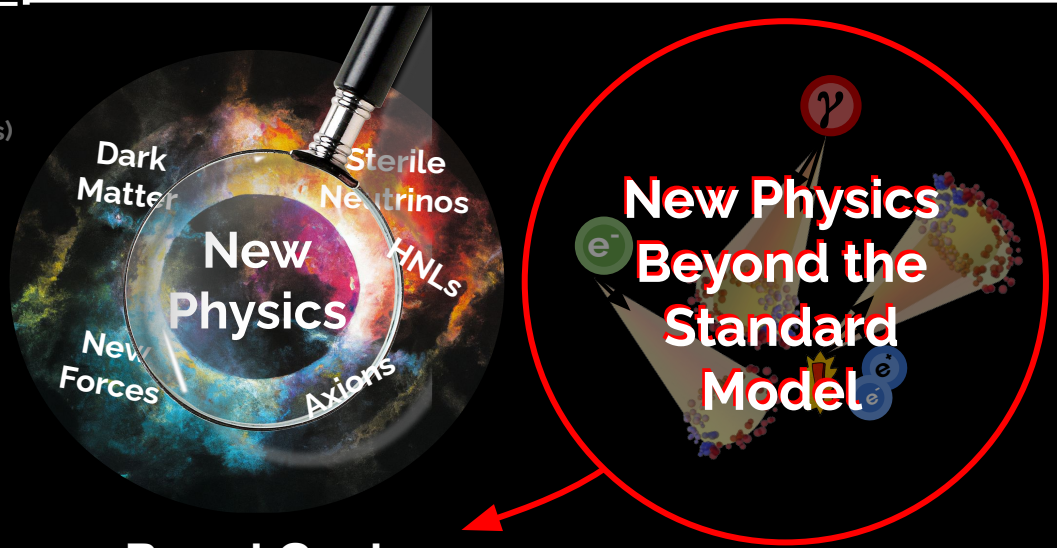




See J. Nowak's talk on Sat!

The Physics Goals of MicroBooNE

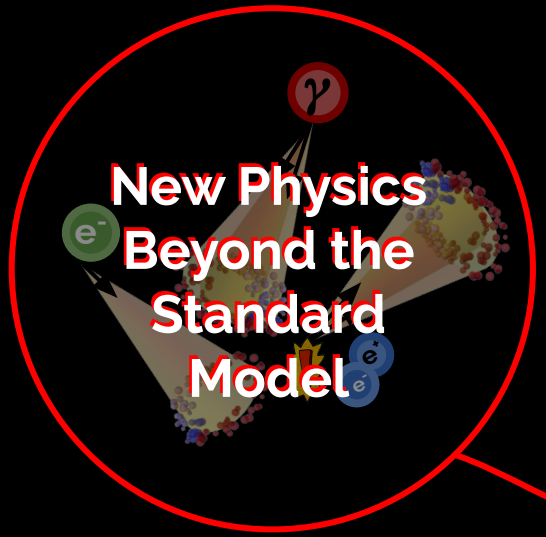
The Physics Goals of MicroBooNE

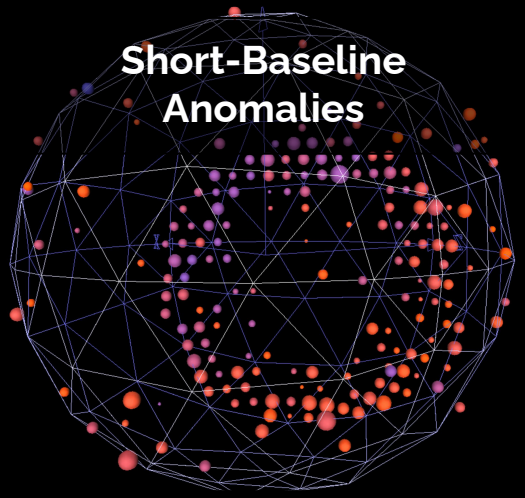


Broad Goals

Broadly speaking, MicroBooNE aims to probe all forms of "Beyond the Standard Model" **(BSM) new physics** it is sensitive to.

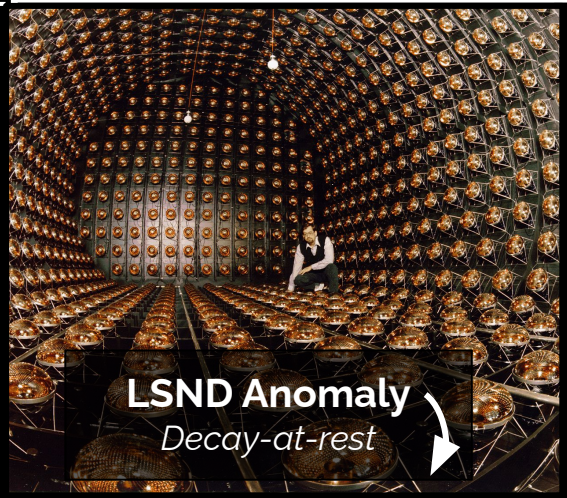
The Physics Goals of MicroBooNE

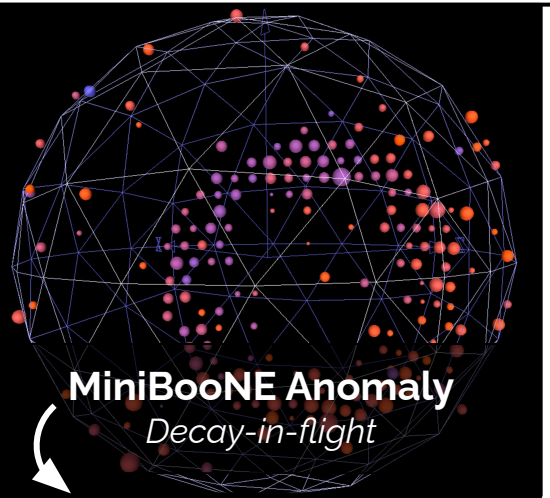


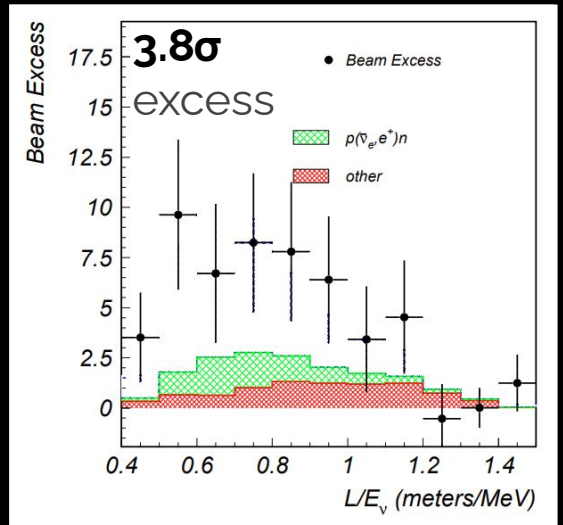


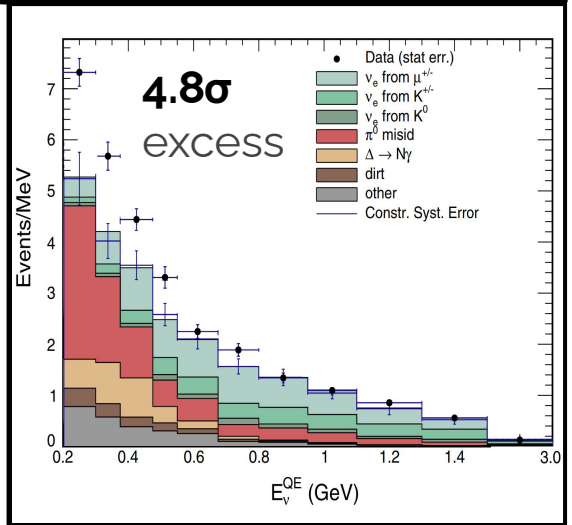
Specific Goals

The Short Baseline Anomalies

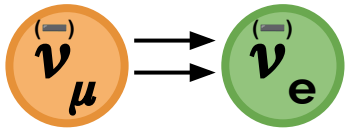






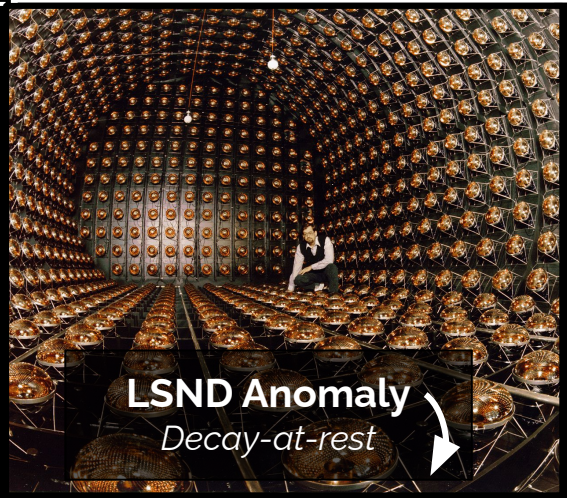


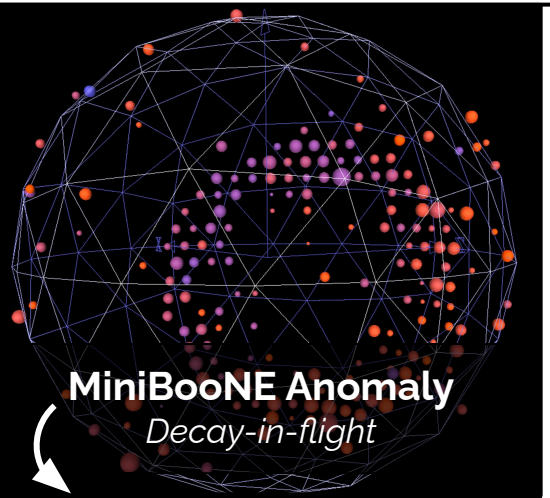
Observed excess of electron like events in a

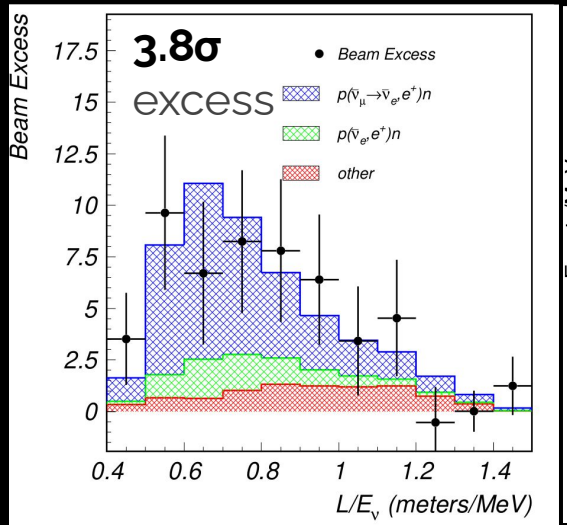


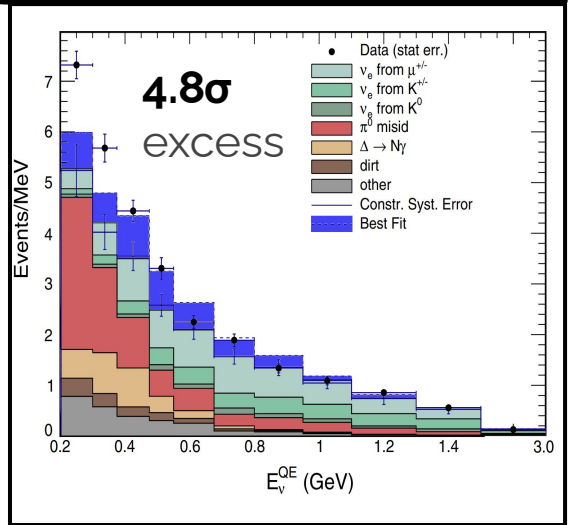
experiment

The Short Baseline Anomalies









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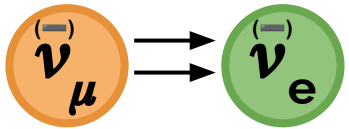
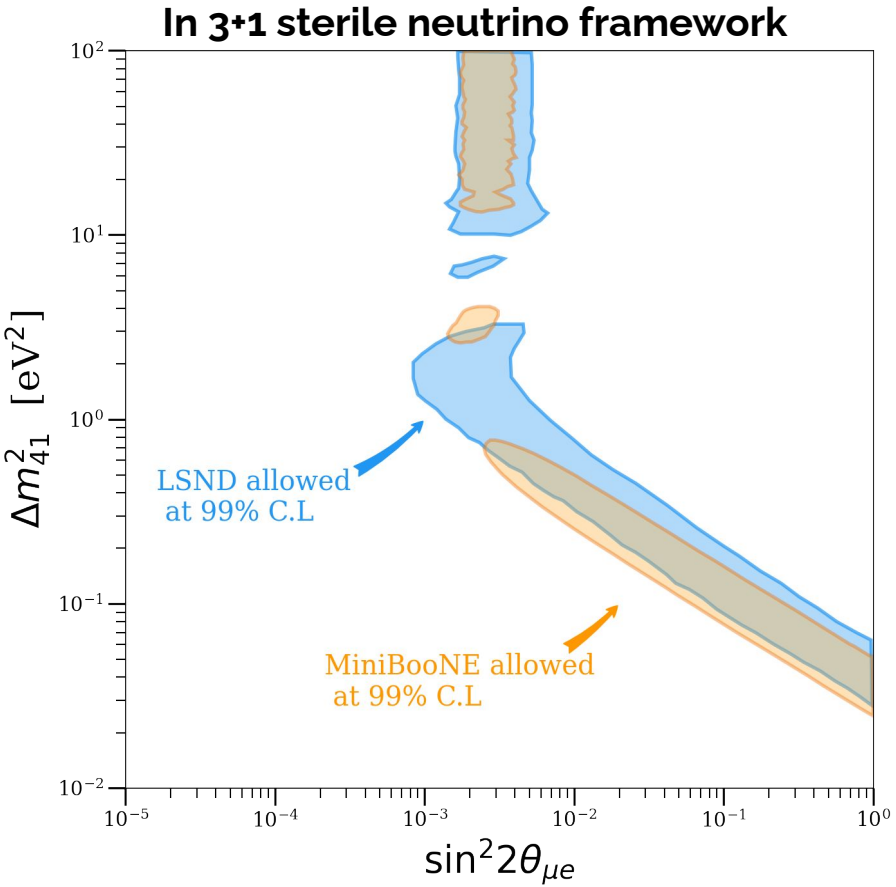


experiment.

Individually consistent with **~1 eV² scale sterile neutrino** oscillations



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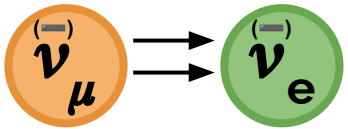
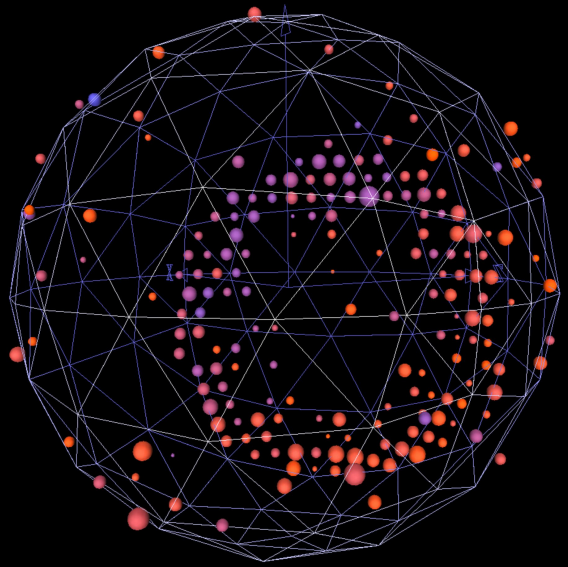


experiment.

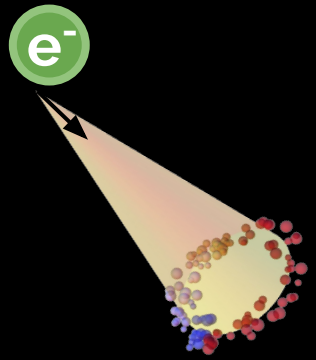
Individually consistent with **~1 eV² scale sterile neutrino** oscillations

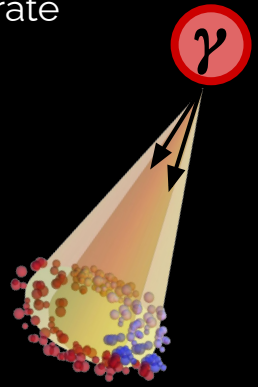
Particular focus on MiniBooNE



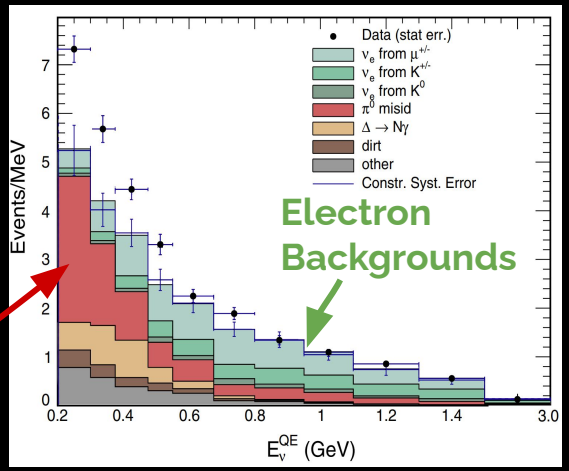
Cherenkov ring event in MiniBooNE

MiniBooNE could't separate **electrons** from **photons**





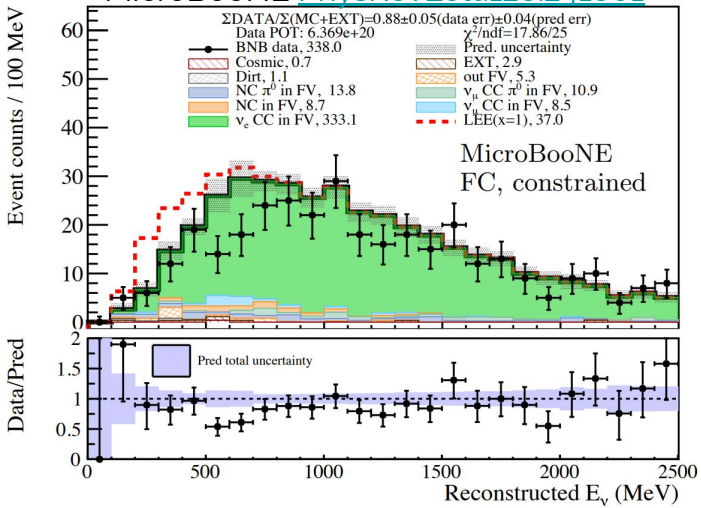
pair-production $\rightarrow e^+e^-$



First Results (2021) Quick Recap

Electron Search

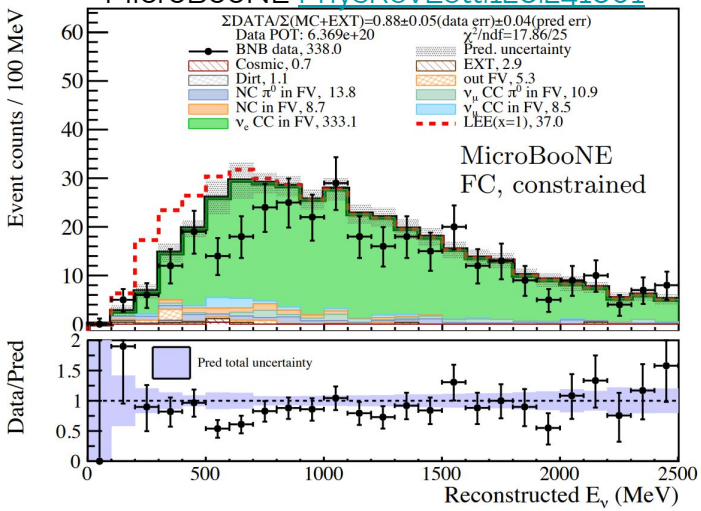
MicroBooNE PhysRevLett.128.241801



- Looking for overall excess in electron data consistent with an **increase in intrinsic ν_e rates**
- Generic search. **No excess observed**
- ***NOT*** a sterile neutrino search

Electron Search

MicroBooNE PhysRevLett.128.241801



- Looking for overall excess in electron data consistent with an **increase in intrinsic ν_e rates**
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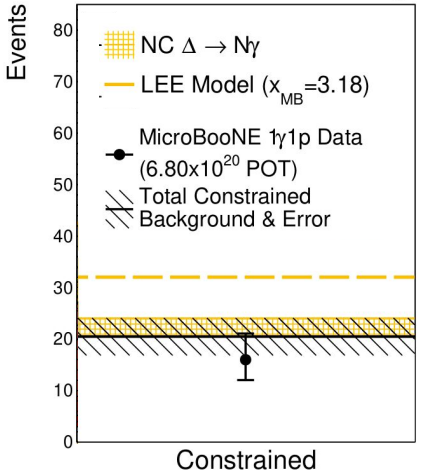
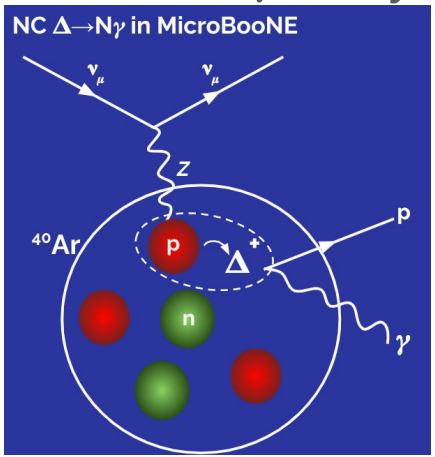
Photon Search

Search for enhanced **NC $\Delta \rightarrow N\gamma$ decay**

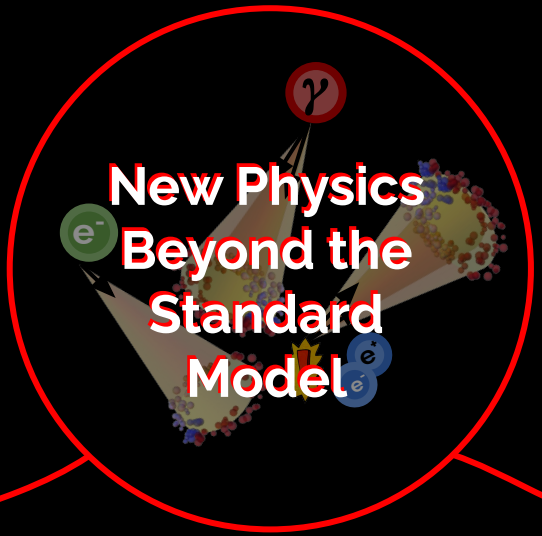


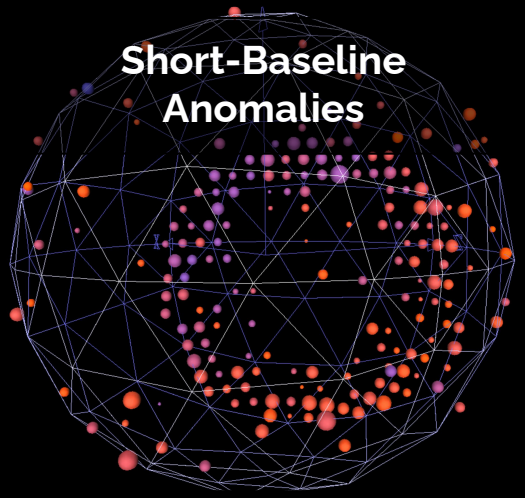


- **No evidence** for an enhanced rate of single-photons from **NC $\Delta \rightarrow N\gamma$ decay**
- Disfavors NC $\Delta \rightarrow N\gamma$ backgrounds as a sole source of the MiniBooNE excess at **94.8% C.L**

MicroBooNE Phys.Rev.Lett. 128 11, 111801

The Physics Goals of MicroBooNE

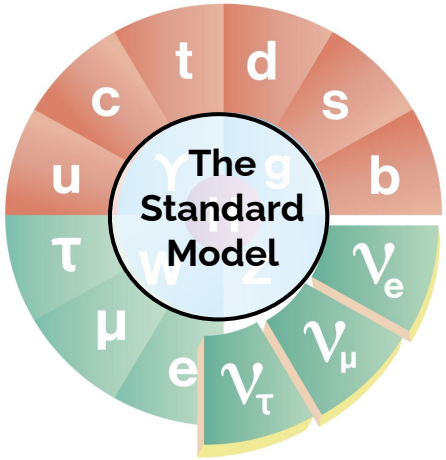


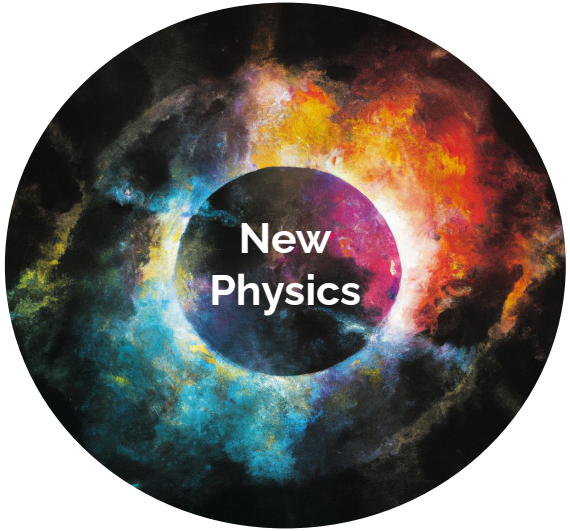


Broad Goals

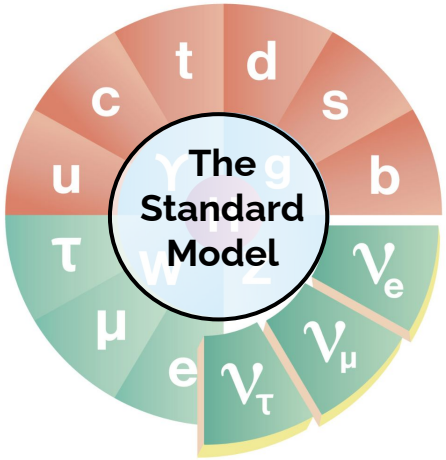
Specific Goals

New Physics





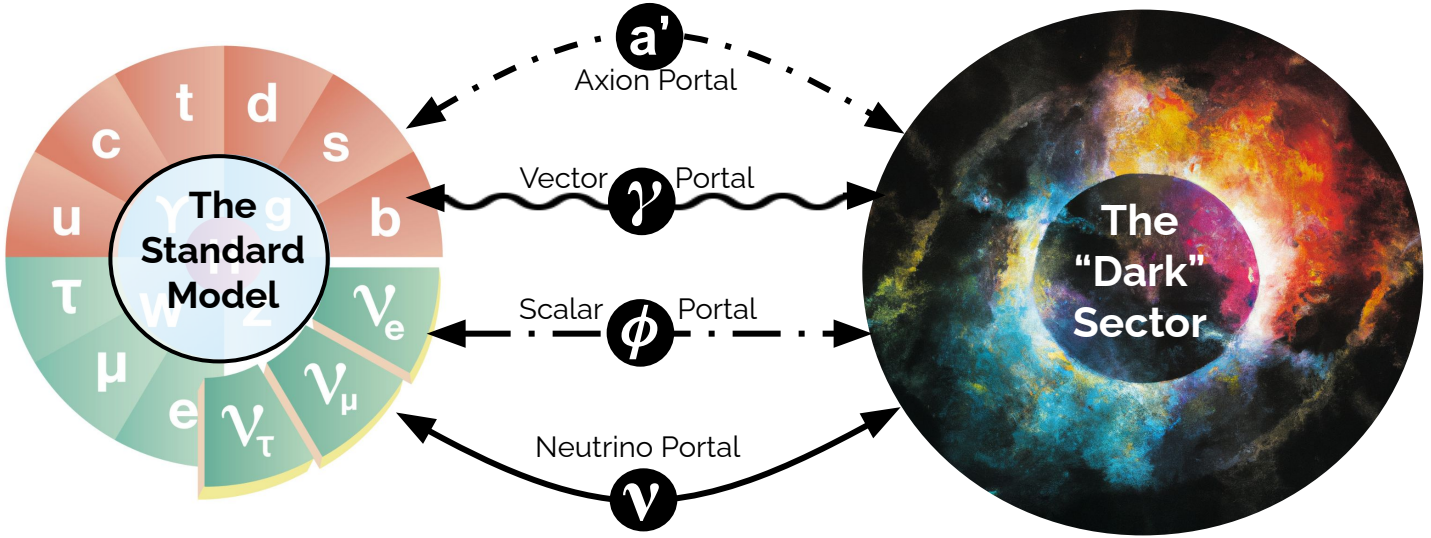
The ‘Dark’ Sector’



- Rich particle content
  - Dark matter candidate(s)
  - Sterile Neutrinos
  - Axions
  - + ….
- New Forces and Interactions

} Rich & Complex phenomenology

Portals to the 'Dark Sector'



ν Neutrino Portal

$$\mathcal{L} \supset -y^{\alpha} L_{\alpha} H N + \text{h.c.}$$

ϕ Scalar Portal

$$\mathcal{L} \supset (A\,S + \lambda\,S^2)\,H^{\dagger}H$$

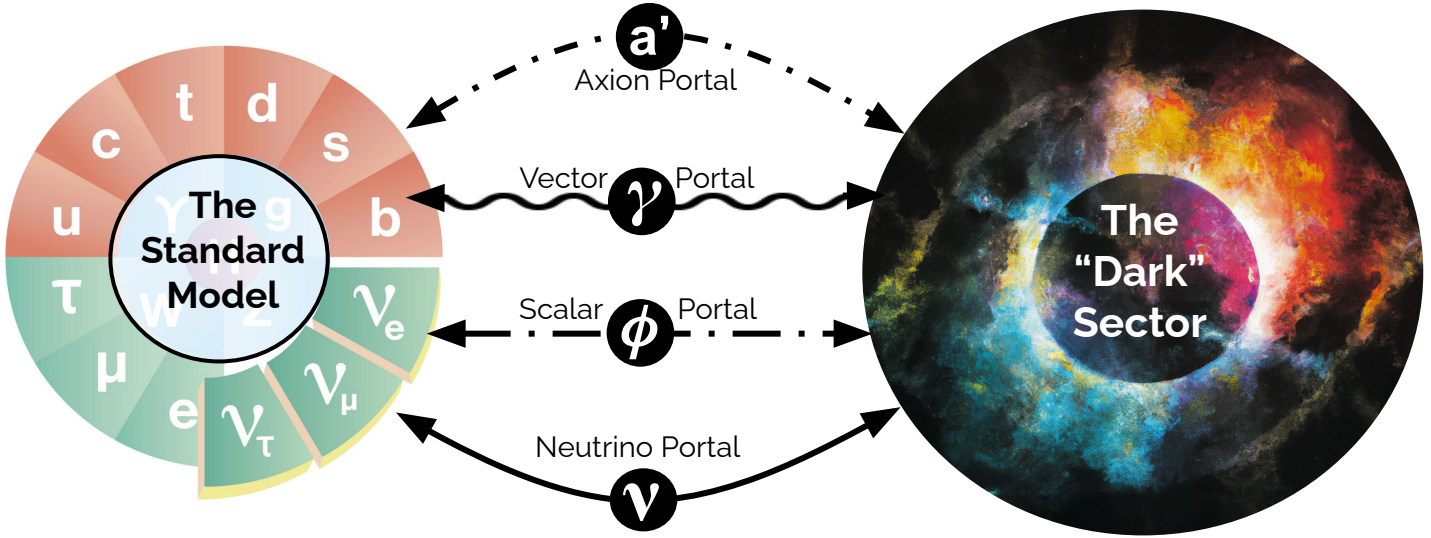
γ Vector Portal

$$\mathcal{L} \supset \epsilon F'_{\mu\nu} B^{\mu\nu}$$

a' Axion Portal

$$\mathcal{L} \supset c_{GG} \frac{\alpha_s}{4\pi} \frac{a}{f} G^a_{\mu\nu} \widetilde{G}^{a,\,\mu\nu}$$

Portals to the 'Dark Sector'



Neutrino Portal

$\mathcal{L} \supset -y^{\alpha} L_{\alpha} H N + \text{h.c.}$

- Light 3+1 sterile Neutrino
- Heavy Neutral Leptons

Scalar Portal

$\mathcal{L} \supset (A\,S + \lambda\,S^2)\,H^{\dagger}H$

- Higgs Portal Scalars

Vector Portal

$\mathcal{L} \supset \epsilon F'_{\mu\nu} B^{\mu\nu}$

- Light Dark Matter
- Millicharged Particles

Axion Portal

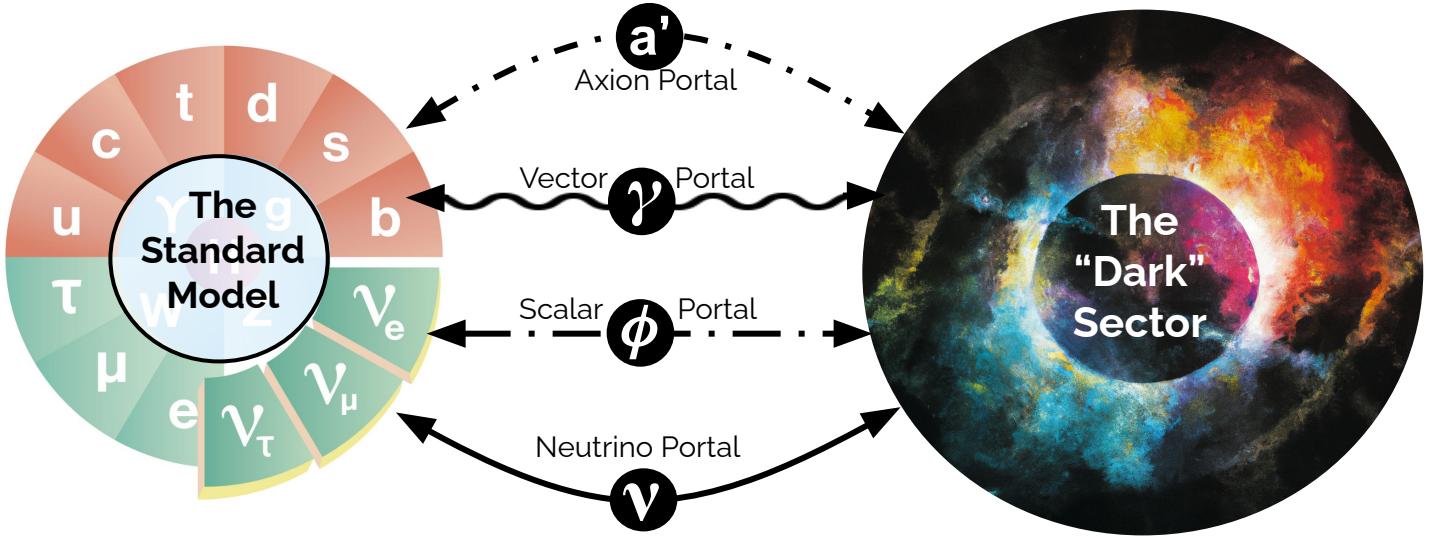
$\mathcal{L} \supset c_{GG} \frac{\alpha_s}{4\pi} \frac{a}{f} G^{a}_{\mu\nu} \widetilde{G}^{a,\mu\nu}$

- Heavy QCD Axions

A plethora of new physics detectable at MicroBooNE!

Portals to the 'Dark Sector'

*Possible Short-Baseline Anomaly Solution



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$\mathcal{L} \supset -y^{\alpha} L_{\alpha} H N + \text{h.c.}$

- ***Light 3+1 sterile Neutrino****
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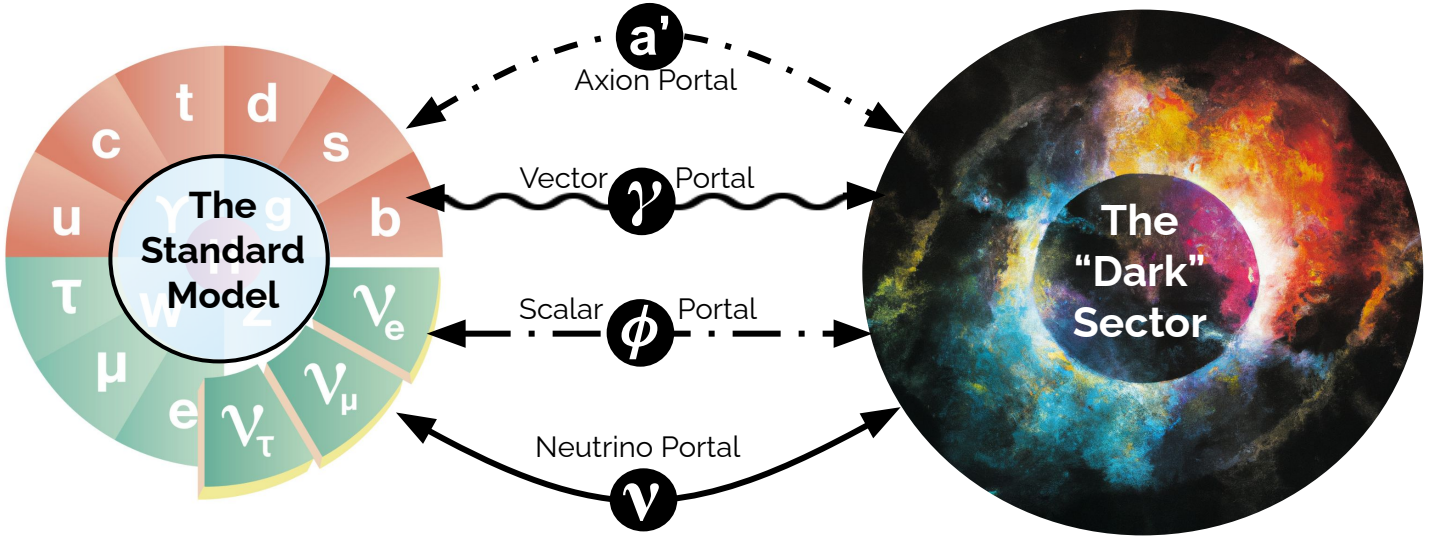
Portals to the 'Dark Sector'

*Possible Short-Baseline Anomaly Solution



ν Neutrino Portal

$\mathcal{L} \supset -y^{\alpha} L_{\alpha} H N + \text{h.c.}$

- ***Light 3+1 sterile Neutrino****
- Heavy Neutral Leptons

ϕ Scalar Portal

$\mathcal{L} \supset (A\,S + \lambda\,S^2)\,H^{\dagger}H$

- Higgs Portal Scalars

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- Light Dark Matter
- Millicharged Particles

a' Axion Portal

$\mathcal{L} \supset c_{GG} \frac{\alpha_s}{4\pi} \frac{a}{f} G^a_{\mu\nu} \widetilde{G}^{a,\mu\nu}$

- Heavy QCD Axions

A plethora of new physics detectable at MicroBooNE!

Portal: Light 3+1 Oscillating Sterile Neutrino

3x3 active mixing

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \\ \nu_s \end{pmatrix} = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} & U_{e4} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} & U_{\mu 4} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} & U_{\tau 4} \\ U_{s1} & U_{s2} & U_{s3} & U_{s4} \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \\ \nu_4 \end{pmatrix}$$

Full 4x4 including sterile mixing

If sterile state is light < O(10 eV)

$$P(\nu_\mu \to \nu_e) = \sin^2 2\theta_{\mu e} \sin^2 \left(\frac{\Delta m^2_{14} L}{4E_\nu} \right)$$

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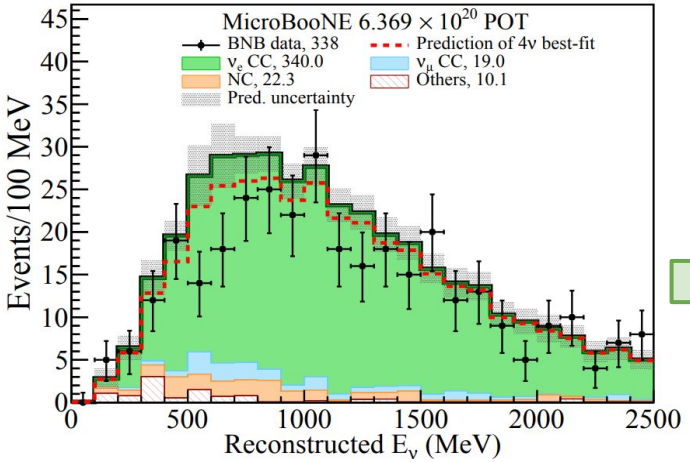
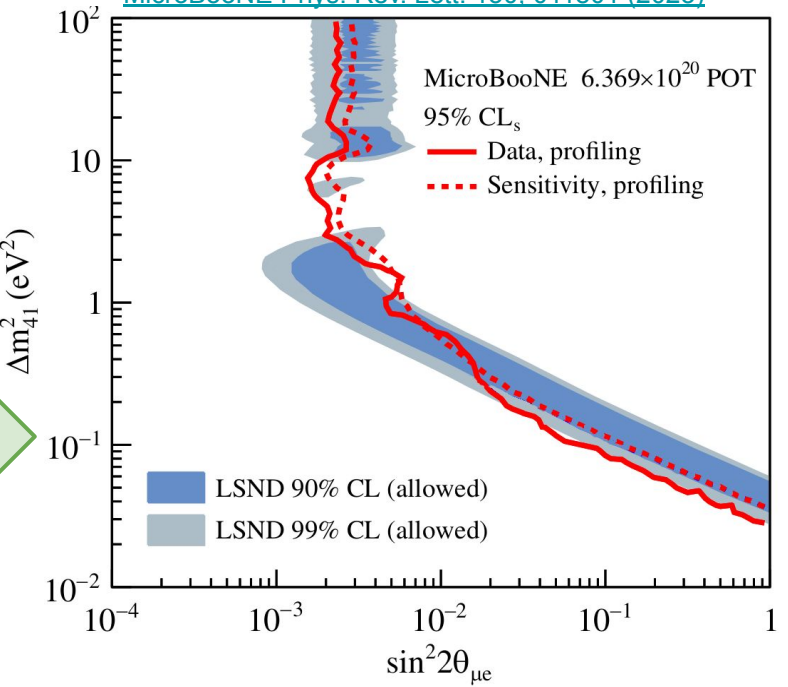


MicroBooNE Phys. Rev. Lett. 130, 011801 (2023)



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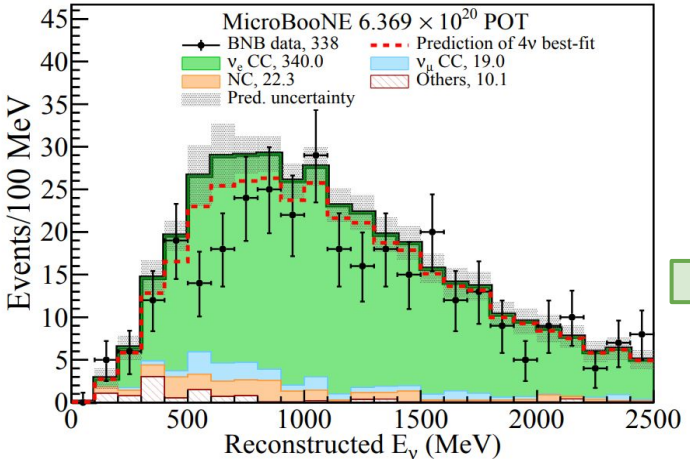
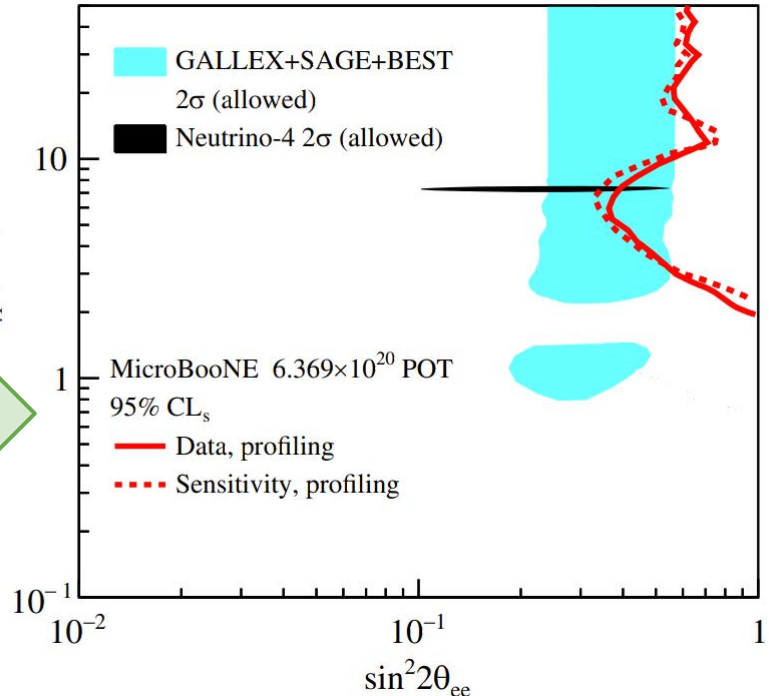
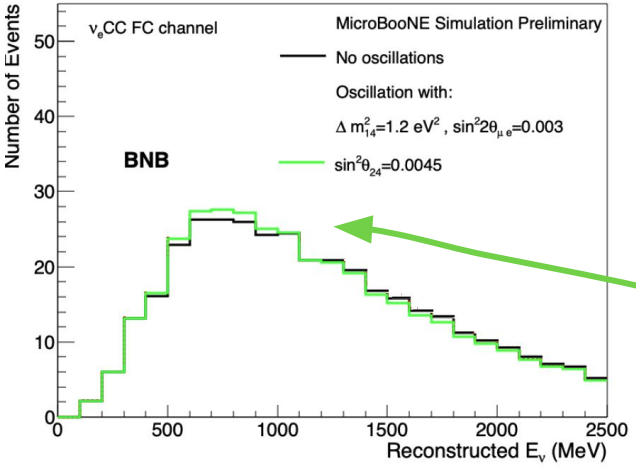
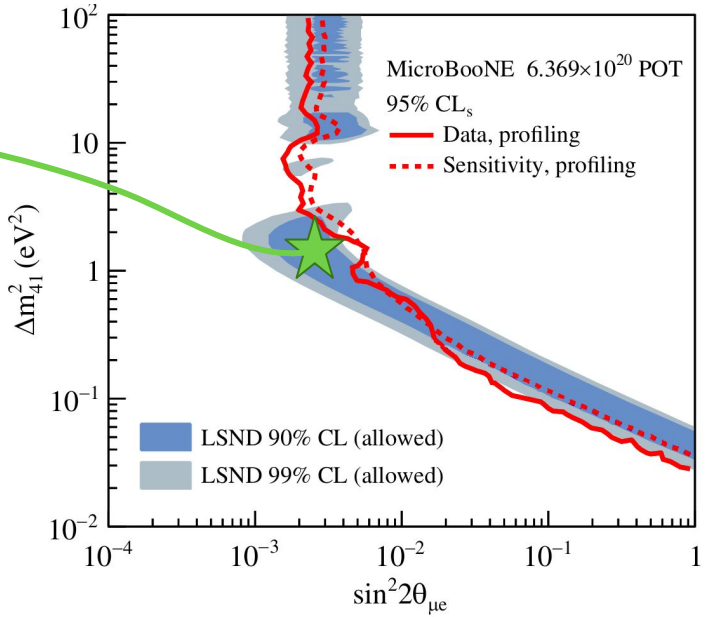




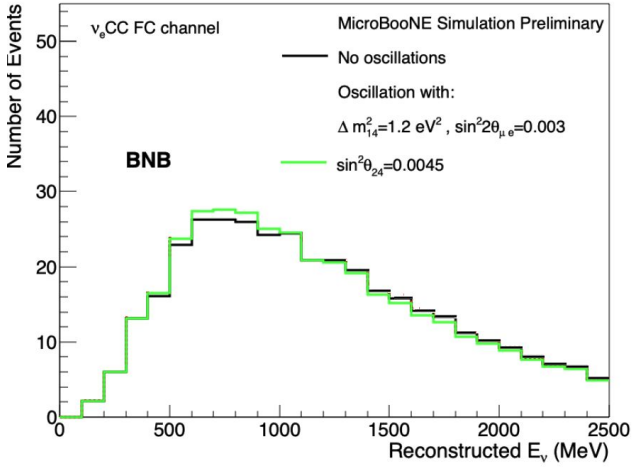


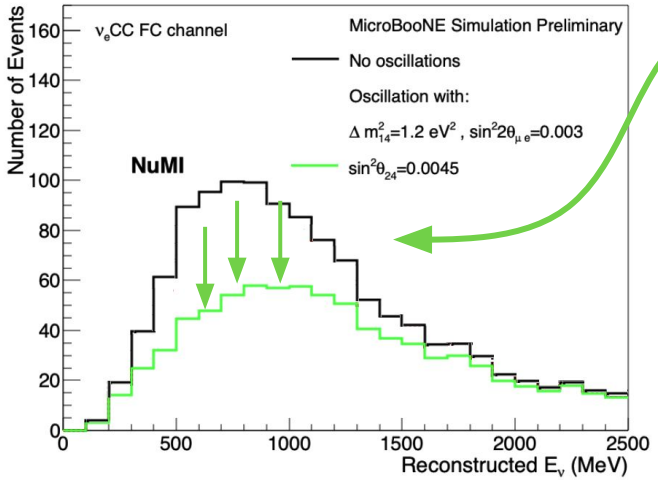
ν_e disappearance *cancels* $\nu_\mu \rightarrow \nu_e$ appearance

Ratio of ν_μ / ν_e in BNB ~ 200



MICROBOONE-NOTE-1132-PUB





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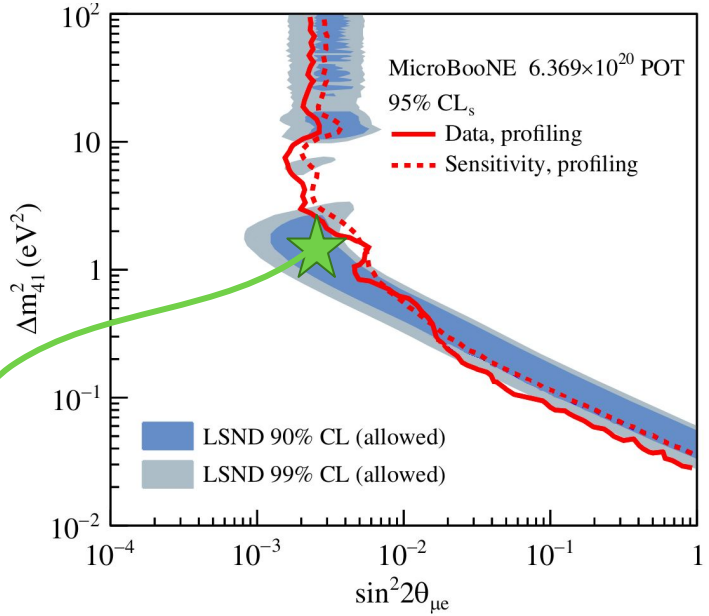


For same point in NuMI huge effect is observed.

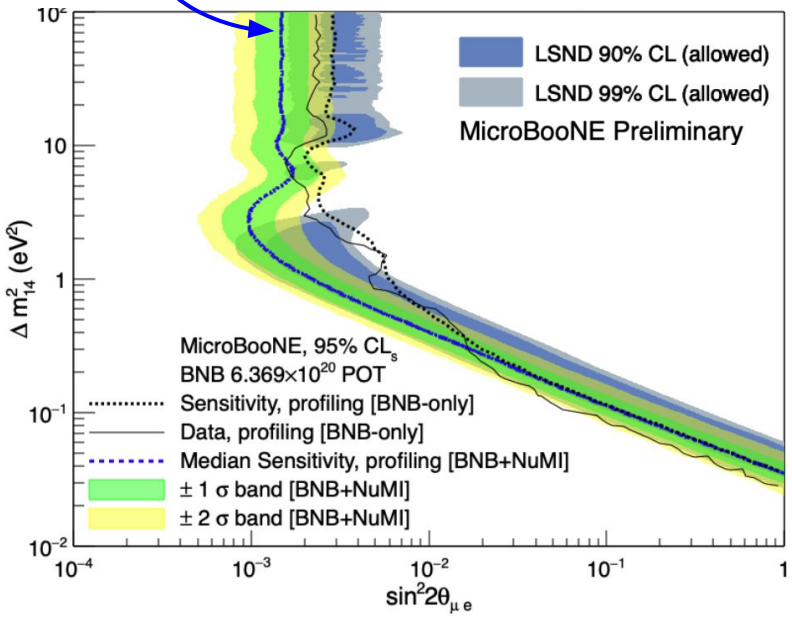
Ratio of ν_μ / ν_e in NuMI ~ 25

NuMI can break the degeneracy!

MICROBOONE-NOTE-1132-PUB

BNB+NuMI Sensitivities

BNB Only Result



BNB: 6.369 x 10^{20} POT
NuMI: 10.54 x10^{20} POT

Note: Note statistics is *NOT* the driving force behind improvement.

MICROBOONE-NOTE-1132-PUB

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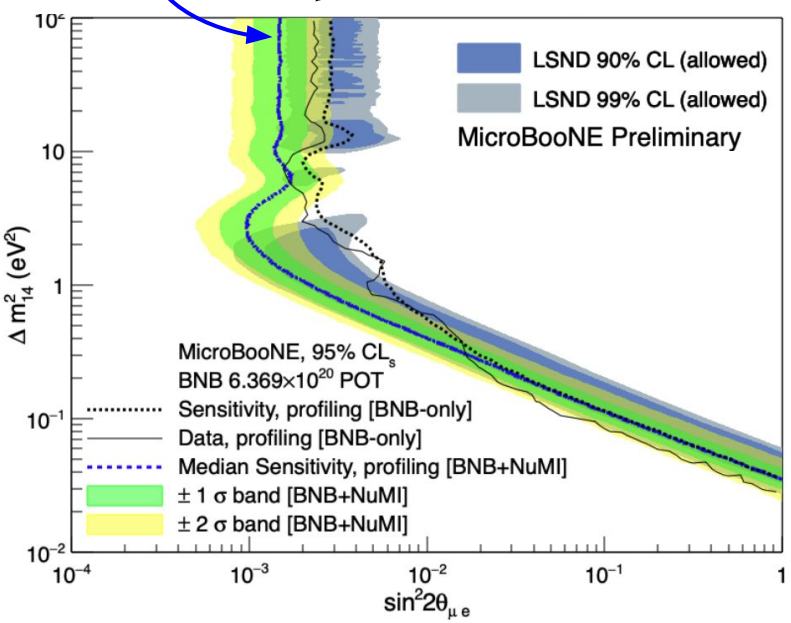

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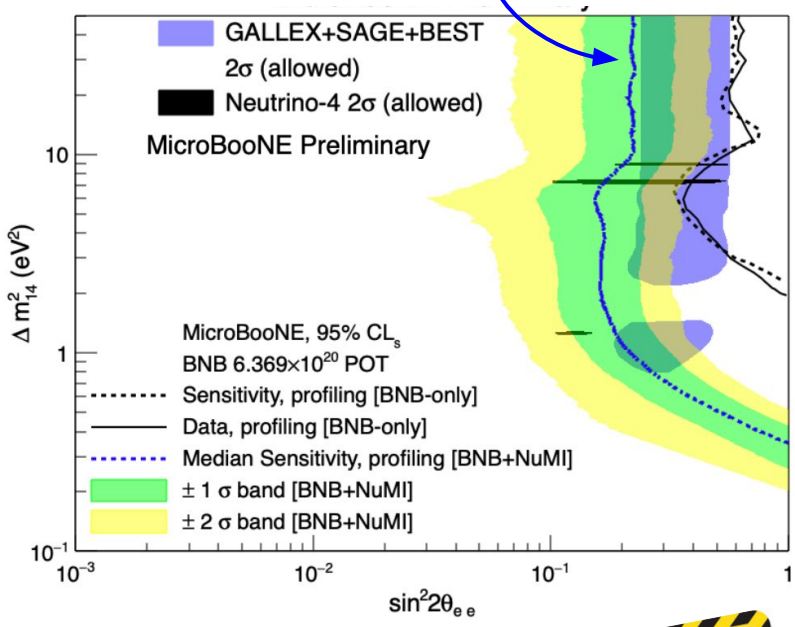

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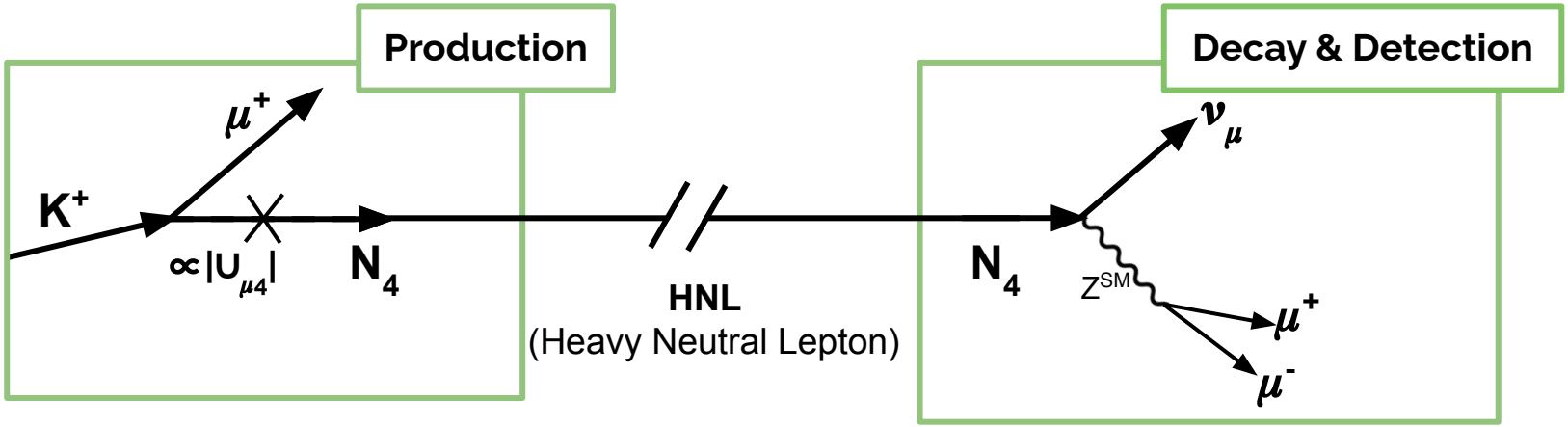
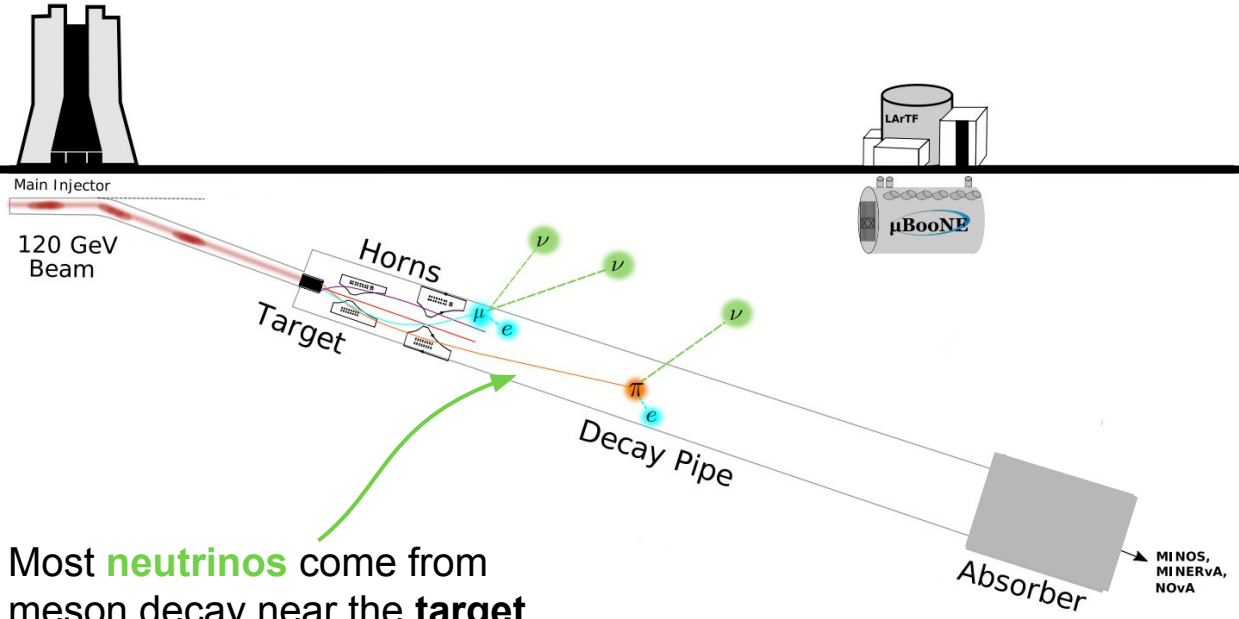
Full 4x4 including sterile mixing

If the sterile state is **too heavy** to undergo oscillations, can still be produced in meson decays alongside neutrinos.



Portal: Heavy Neutral Leptons from NuMI Absorber



Most **neutrinos** come from meson decay near the **target and decay pipe**

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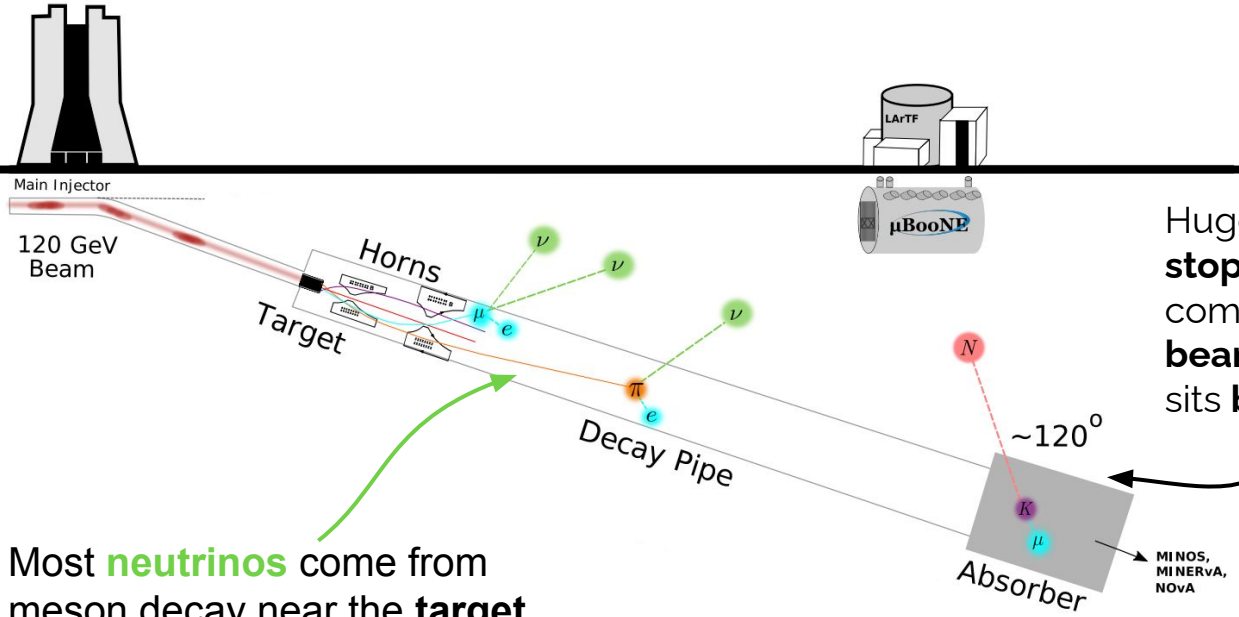


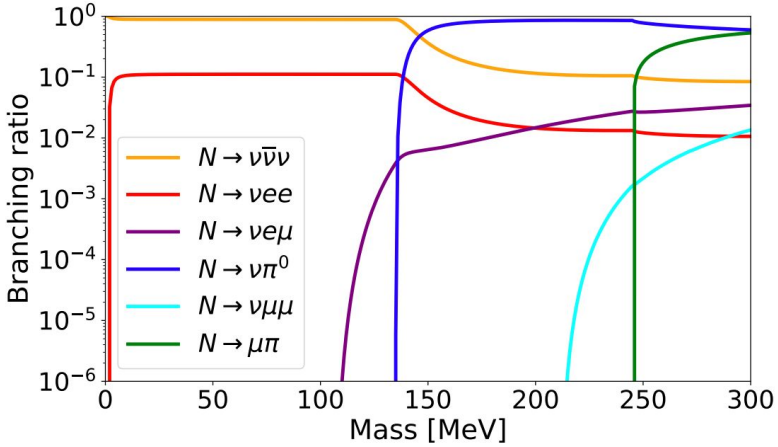
Most **neutrinos** come from meson decay near the **target and decay pipe**

Huge number of **stopped Kaon** decays coming from the **NuMI beam absorber,** which sits **below MicroBooNE**

Search for long lived **Heavy Neutral Leptons** from here!

Portal: Heavy Neutral Lepton decay signatures

Depending on the mass of the HNL, various visible decays are detectable in MicroBooNE



Phys. Rev. D 106, 092006 (2022)

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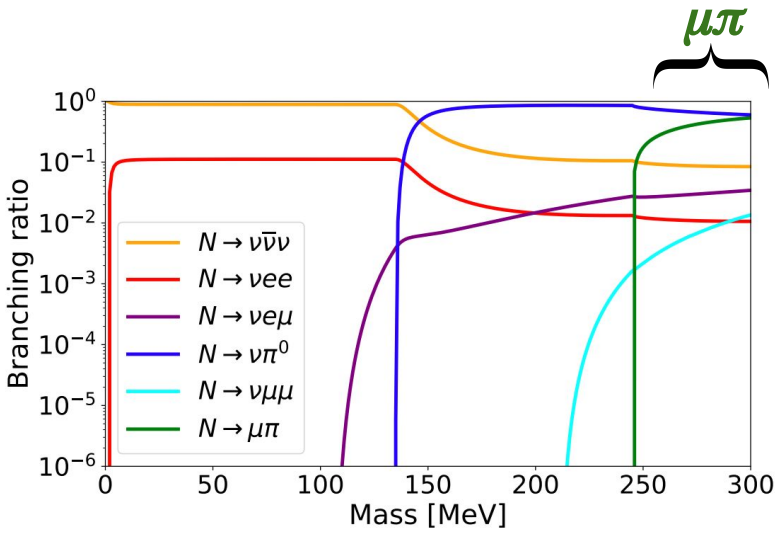
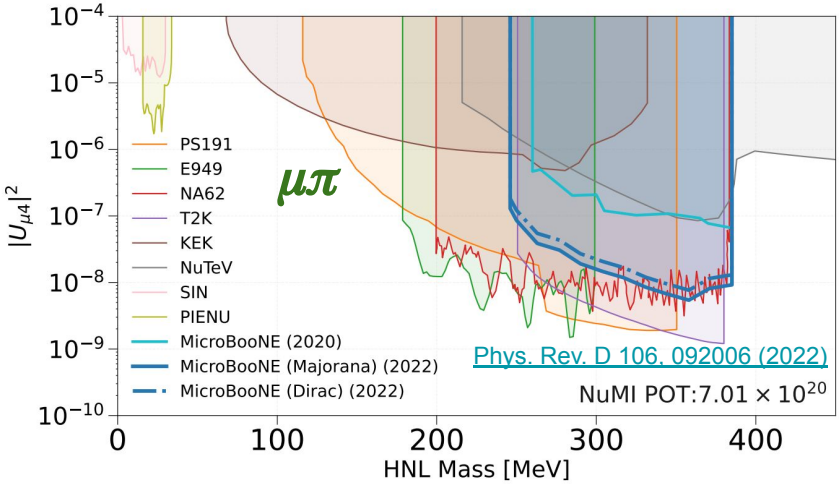
No observed signal, we place 90% CL exclusion limits





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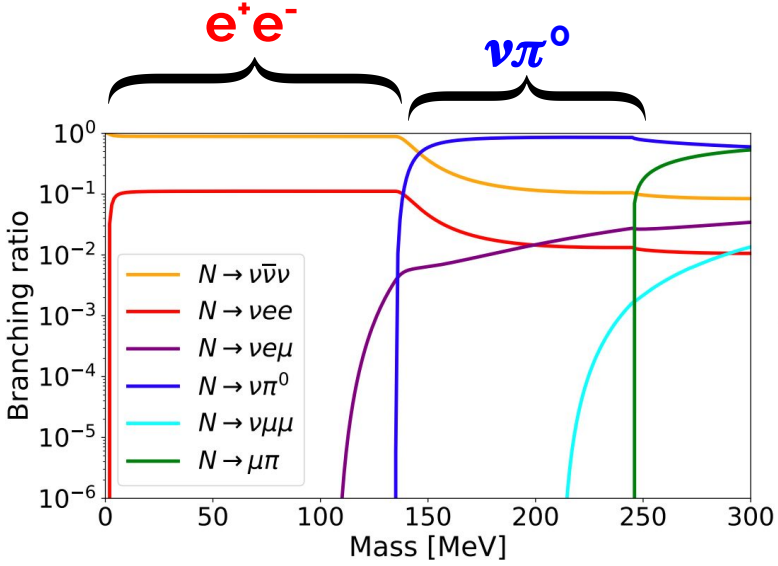

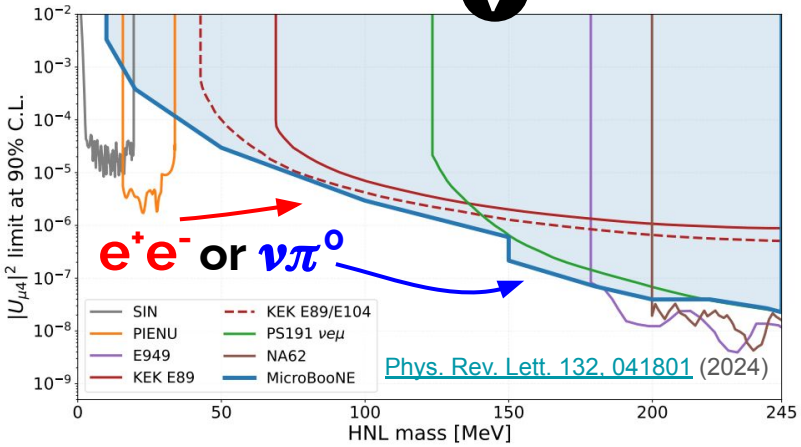

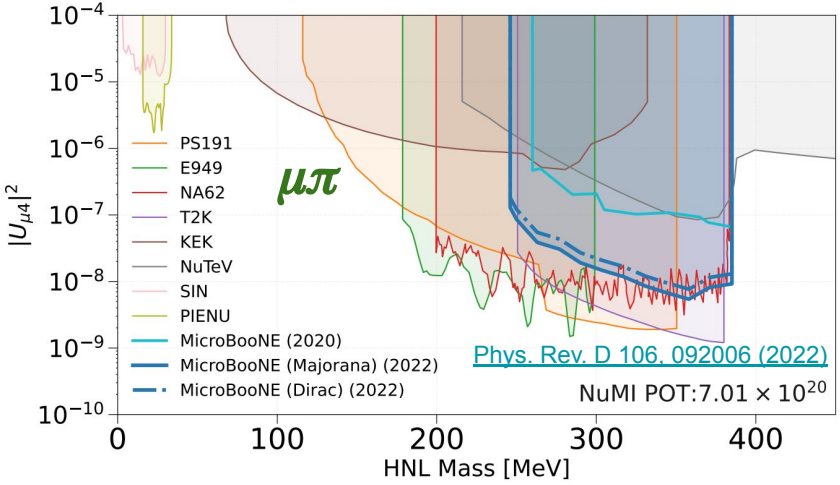

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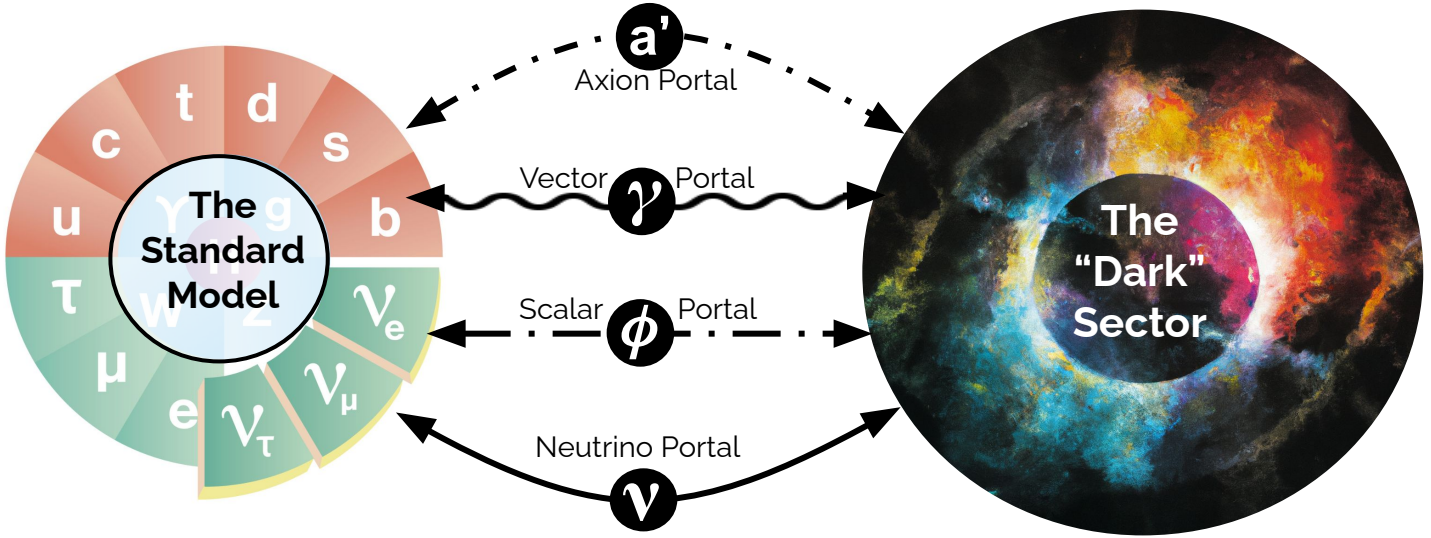

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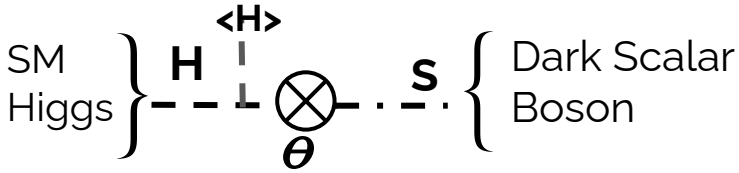
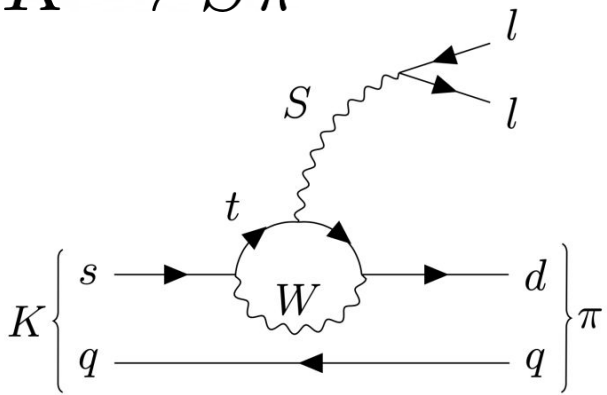
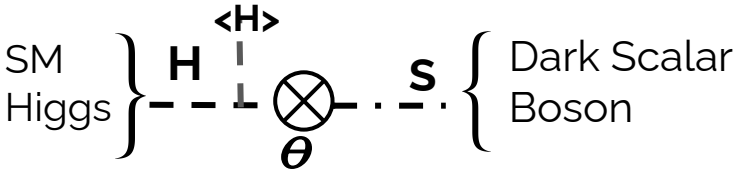


Higgs portal scalars also **produced** in charged kaon decays

$$K \to S\pi$$



Use stopped kaon decay from **NuMI absorber** again



Due to portal to SM via the higgs, **Decay** is extremely strongly dependent on daughter mass

$$\Gamma(S \to \ell^+\ell^-) = \theta^2 \frac{m_\ell^2 m_S}{8\pi v^2}\left(1 - \frac{4m_\ell^2}{m_S^2}\right)^{3/2}$$

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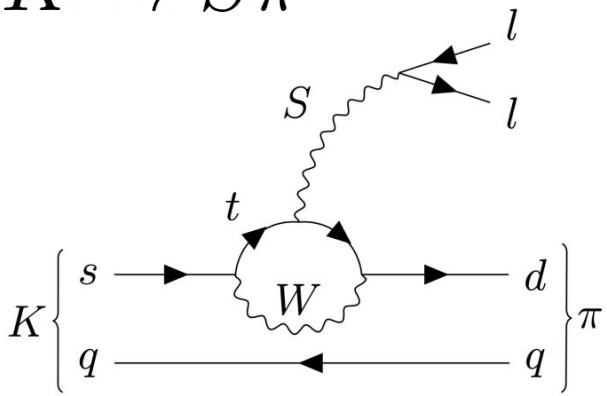

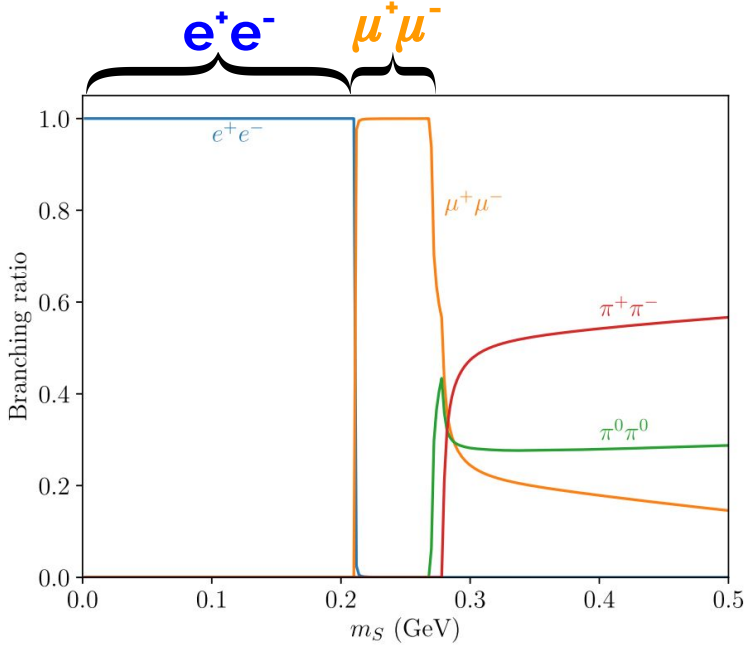

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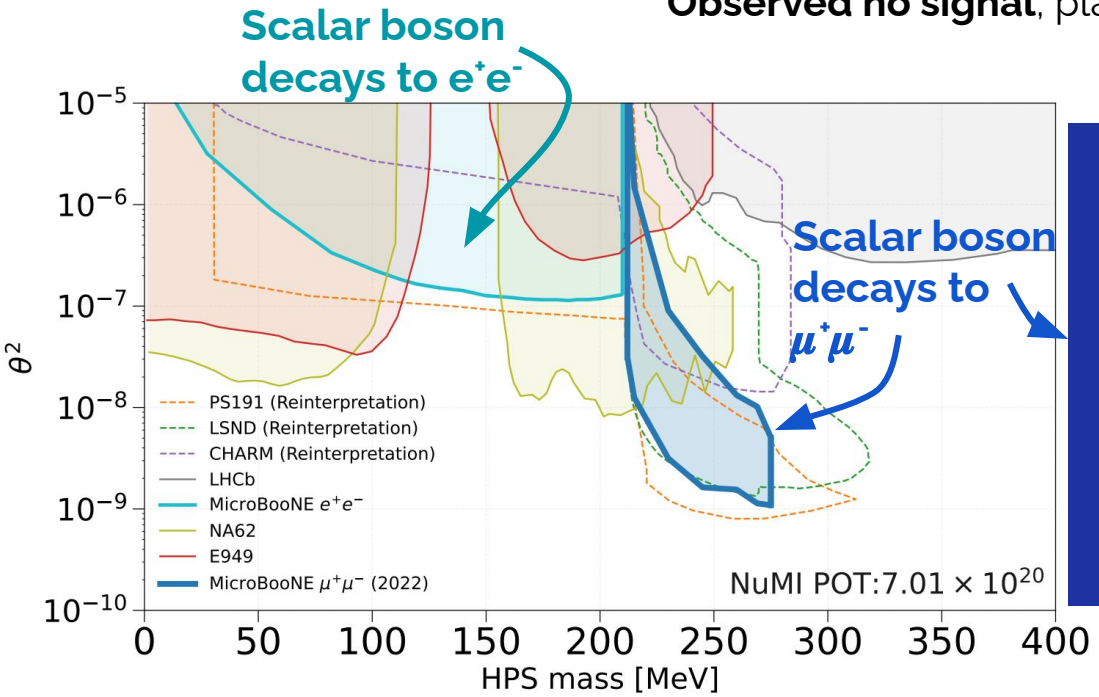

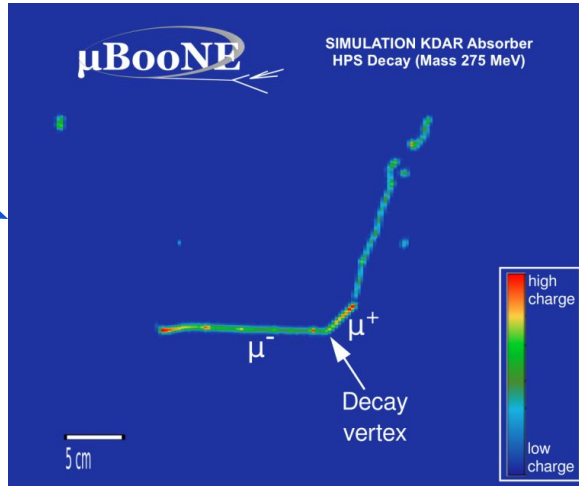

MicroBooNE e^+e^- HPS result Phys. Rev. Lett. 127, 151803 (2021)
MicroBooNE $\mu^+\mu^-$ HPS result Phys. Rev. D 106, 092006 (2022)

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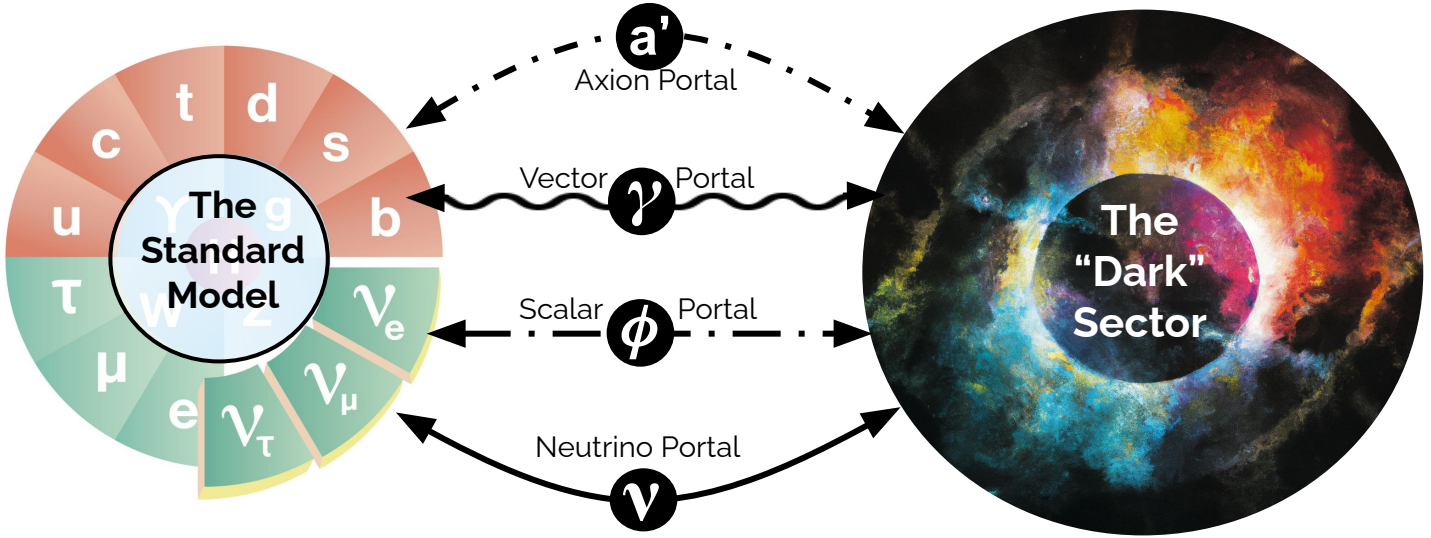

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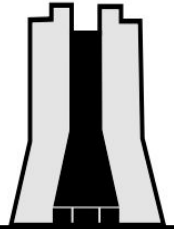
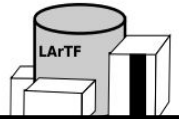
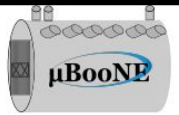
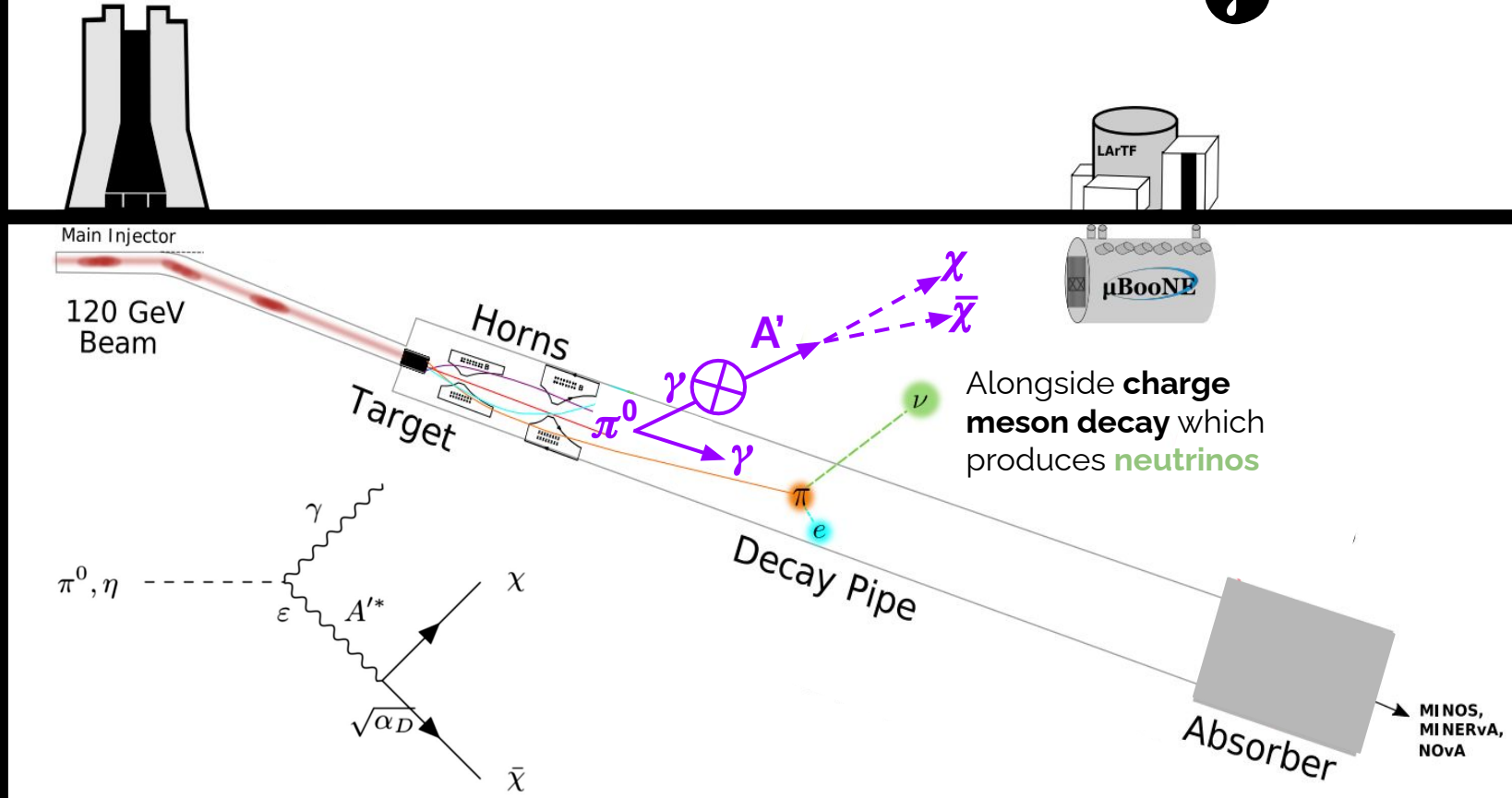




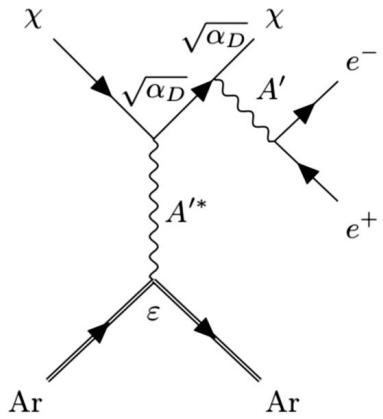


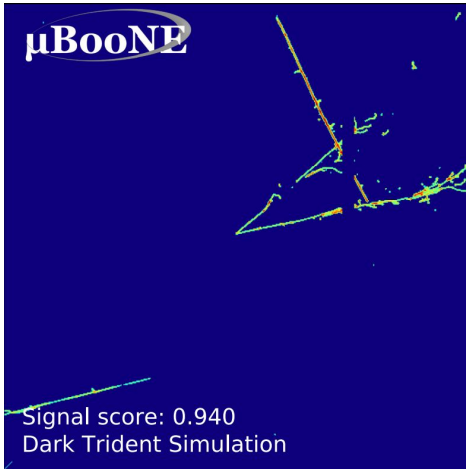
Alongside **charge meson decay** which produces **neutrinos**



Produce a beam of **light dark matter particles (χ)** via an intermediate **dark photon (A')**

This light dark matter is then detected in MicroBooNE when it scatters of Argon leaving a visible **e+e- pair**, so called **Dark Trident production**





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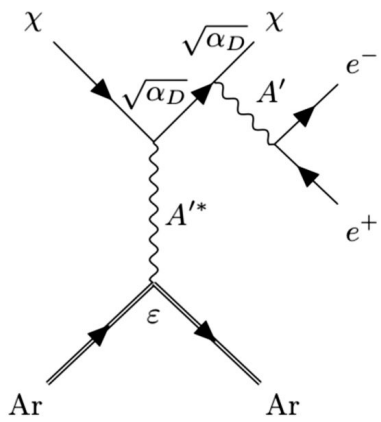
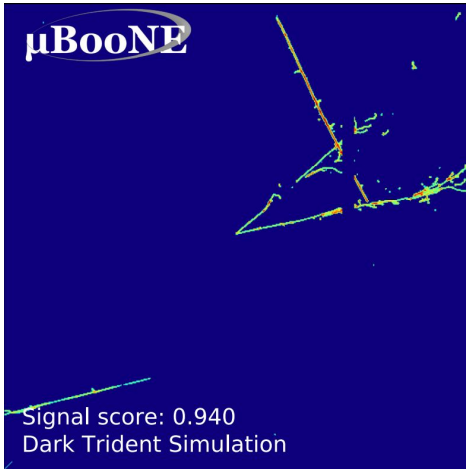
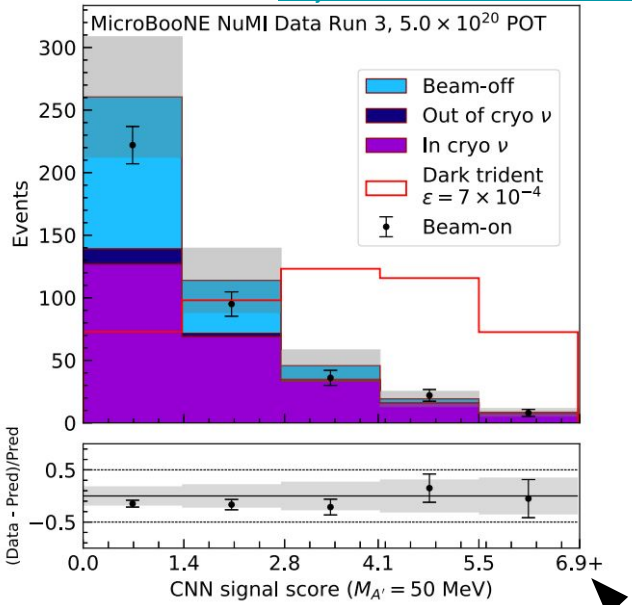




MicroBooNE: Phys. Rev. Lett. 132, 241801

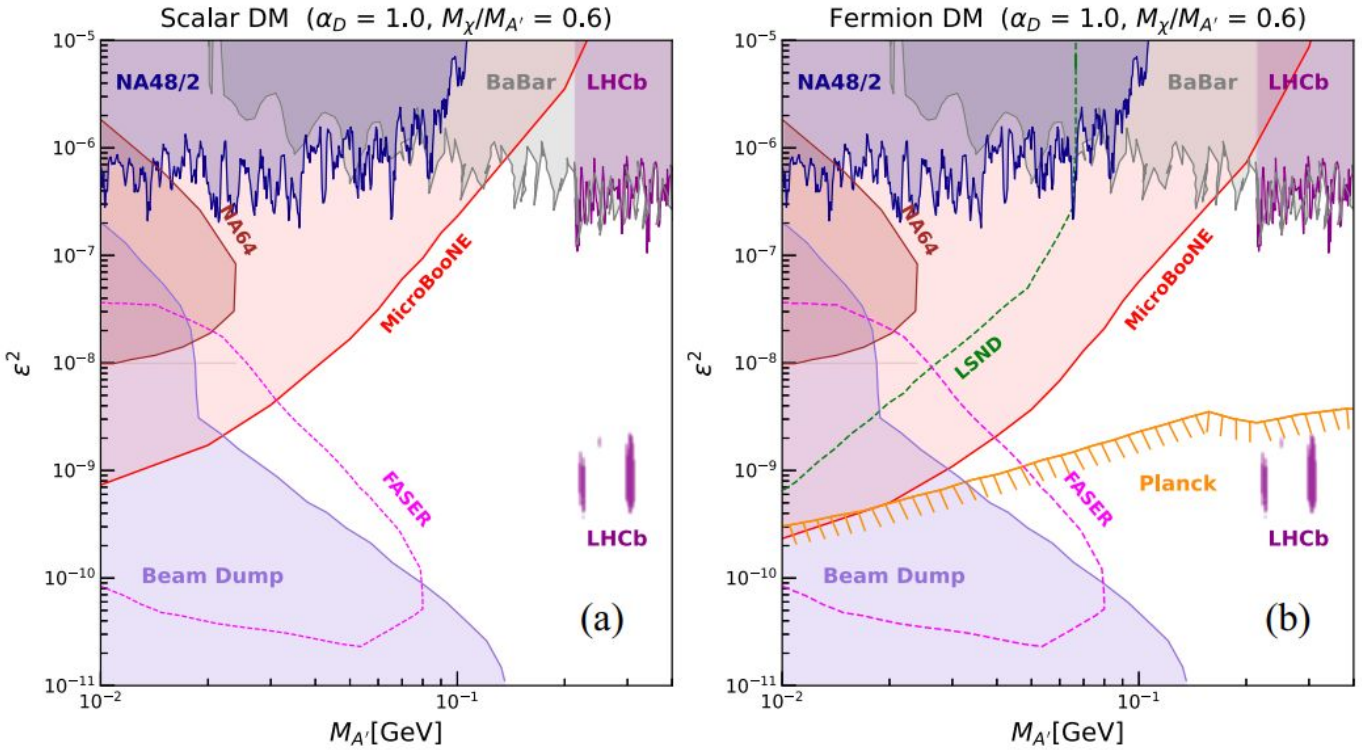


Developed a **convolutional neural net** (CNN) trained on images of dark tridents and neutrino backgrounds.

- **> 99% background rejection** with a **(27–30)% signal efficiency**

Good agreement observed with background only. Shown here for a **Dark photon of mass 50 MeV**

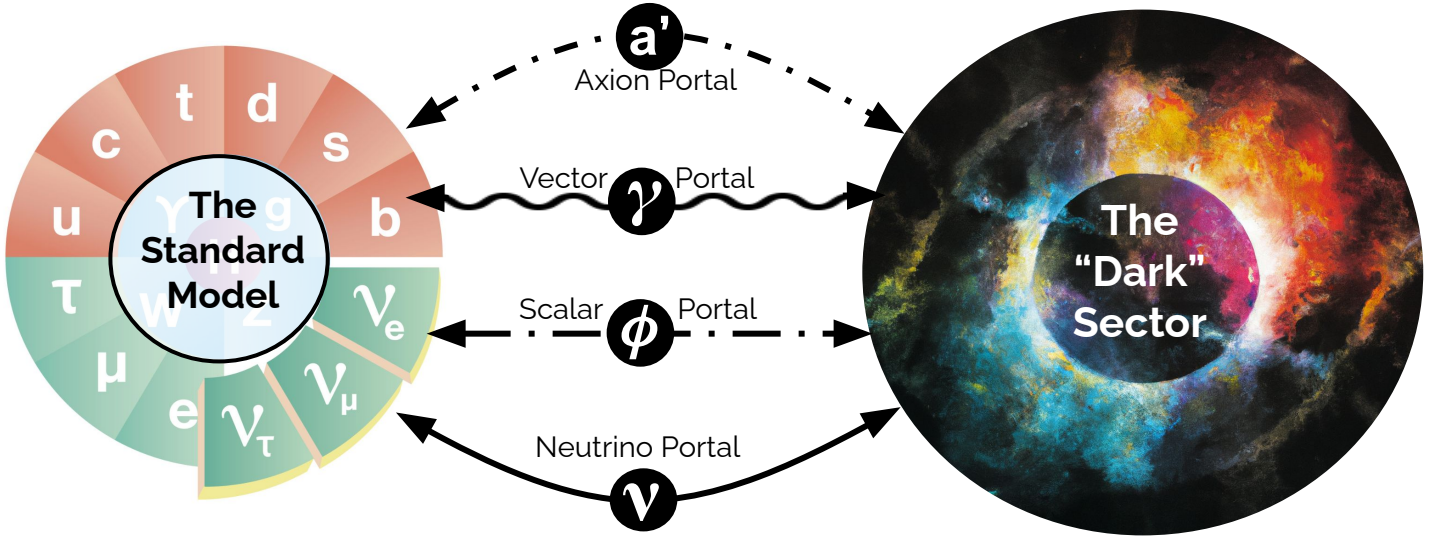
World leading **exclusion limits** from MicroBooNE



Uses **BdNMC** (deNiverville, Chen, Pospelov, Ritz)
https://github.com/pgdeniverville/BdNMC

MicroBooNE Light Dark Matter:
Phys. Rev. Lett. 132, 241801

Portals to the 'Dark Sector'



ν Neutrino Portal

$\mathcal{L} \supset -y^{\alpha} L_{\alpha} H N + \text{h.c.}$

- Light 3+1 sterile Neutrino
- Heavy Neutral Leptons

ϕ Scalar Portal

$\mathcal{L} \supset (A\,S + \lambda\,S^2)\,H^{\dagger}H$

- Higgs Portal Scalars

γ Vector Portal

$\mathcal{L} \supset \epsilon F'_{\mu\nu} B^{\mu\nu}$

- Light Dark Matter
- Millicharged Particles

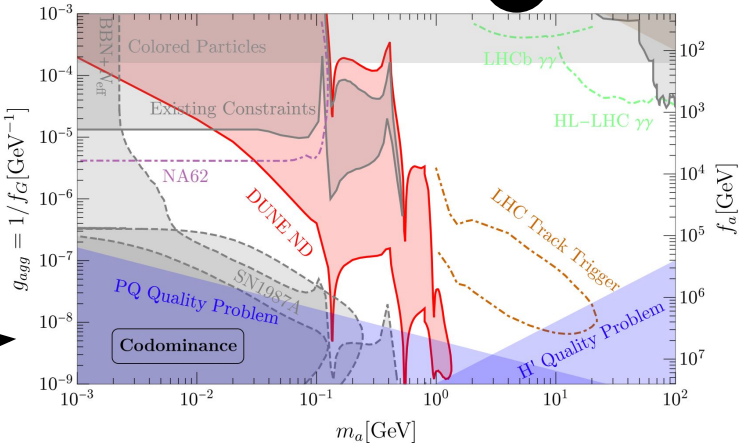
a' Axion Portal

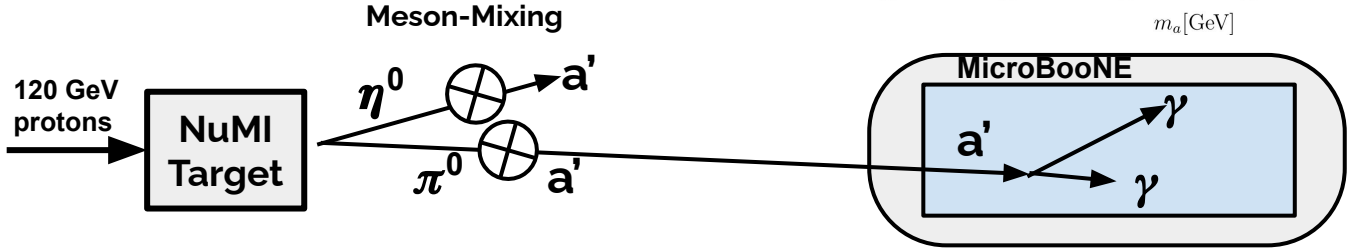
$\mathcal{L} \supset c_{GG} \frac{\alpha_s}{4\pi} \frac{a}{f} G^a_{\mu\nu} \widetilde{G}^{a,\,\mu\nu}$

- Heavy QCD Axions

(or Axion-Like Particle) Portal: Heavy QCD Axions

Motivated by K. Kelly, S. Kumar, Z.Liu "*Heavy Axion Opportunities at the DUNE Near Detector*" PhysRevD. 103 095002 (2021)



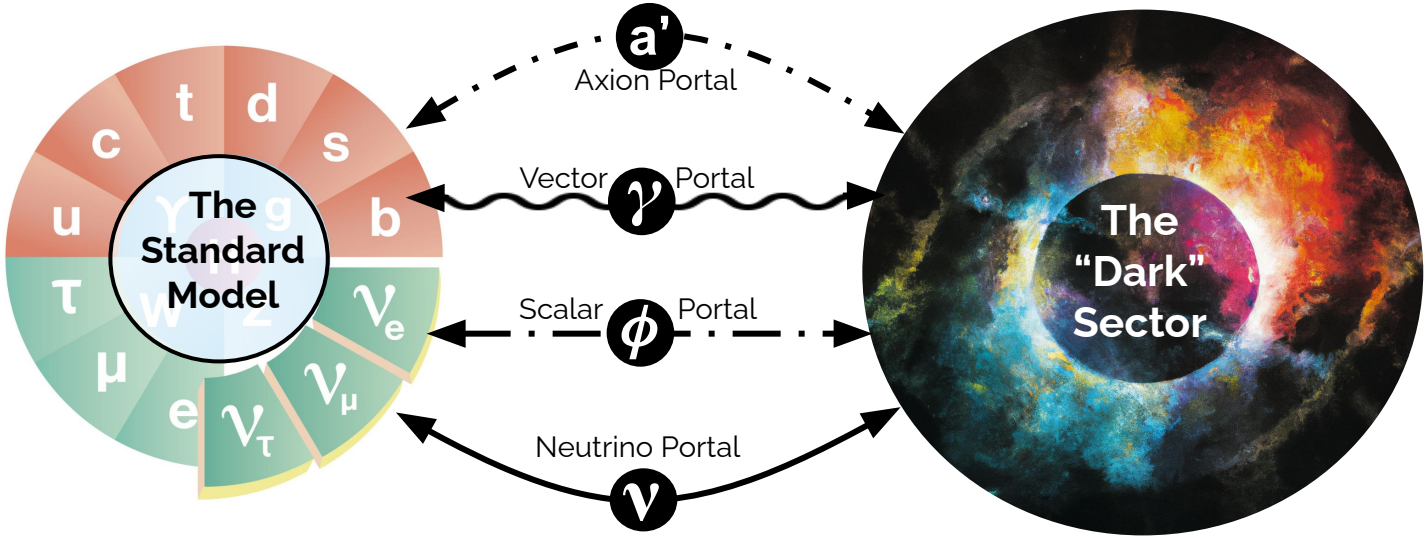


Will be MicroBooNE's first ***di-photon*** BSM search!

Allows for **invariant mass peak searches** over **large NC π^0 backgrounds**

Portals to the 'Dark Sector'

*Possible Short-Baseline Anomaly Solution



ν Neutrino Portal
- ***Light 3+1 sterile Neutrino****
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a' Axion Portal
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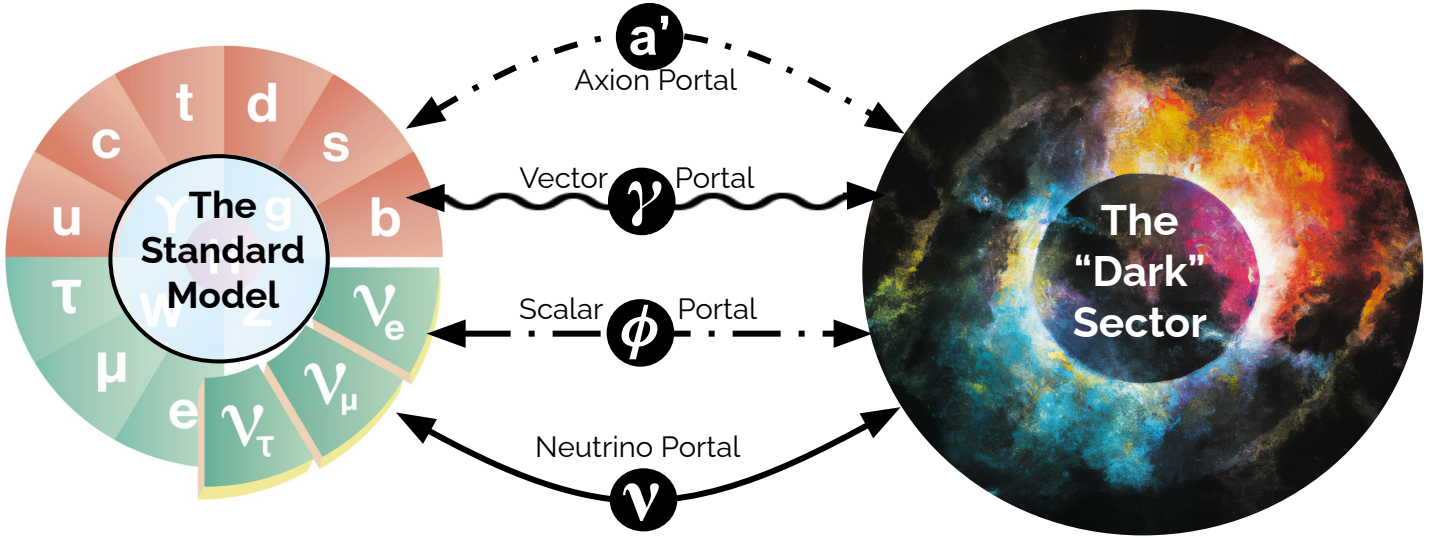
Not many explanations of Short-baseline anomalies yet. What if our new physics **is more complex than minimal portals?**

Portals to the 'Dark Sector'

*Possible Short-Baseline Anomaly Solution



Neutrino Portal
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Vector Portal
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Axion Portal
- Heavy QCD Axions

Combined or Non-Minimal Portals
- *Dark Neutrino Upscattering**

Casting a wide net!
- Generic Electron Searches*
- Inclusive Single-Photon Searches*

Portals to the 'Dark Sector'

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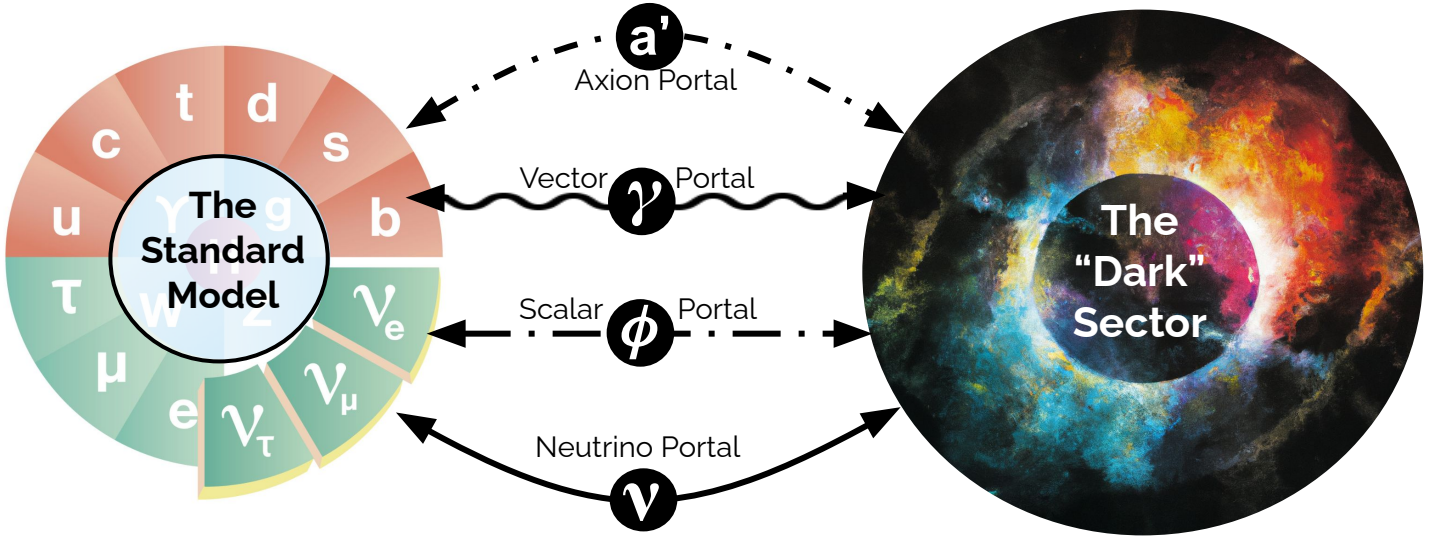

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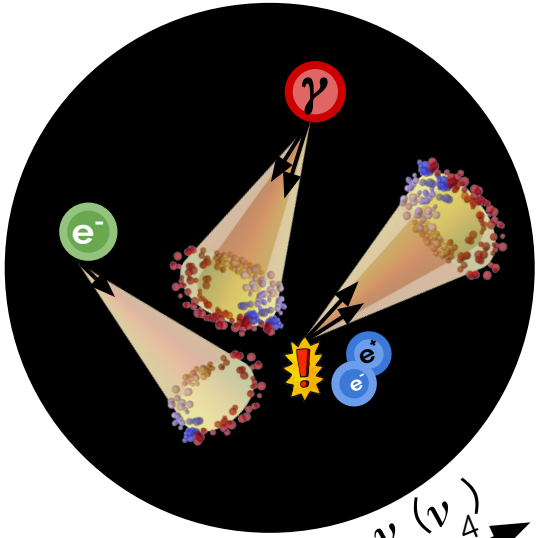
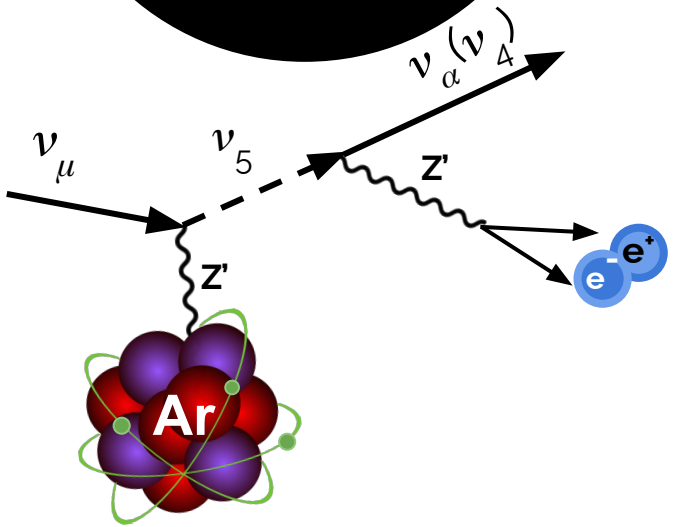
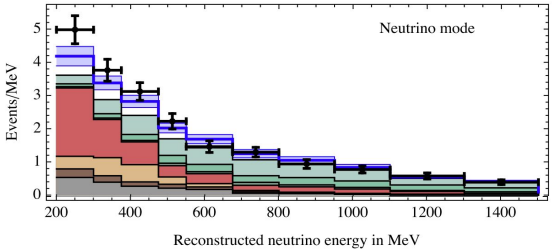
Non-Minimal Portal Example: Dark Neutrino Portal

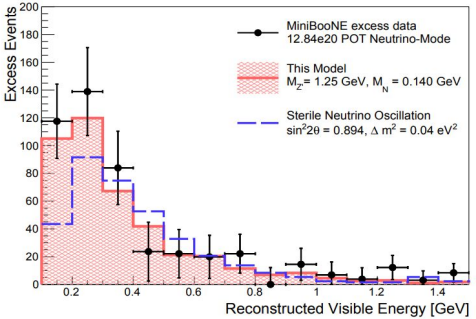




Models began life as alternative explanations to **MiniBooNE anomaly** via exotic production of **e^+e^- pairs**



E. Bertuzzo, S. Jana, P. Machado, R. Funchal
Phys. Rev. Lett. 121, 241801



P. Ballett, S. Pascoli, M. RL PhysRevD.99.071701

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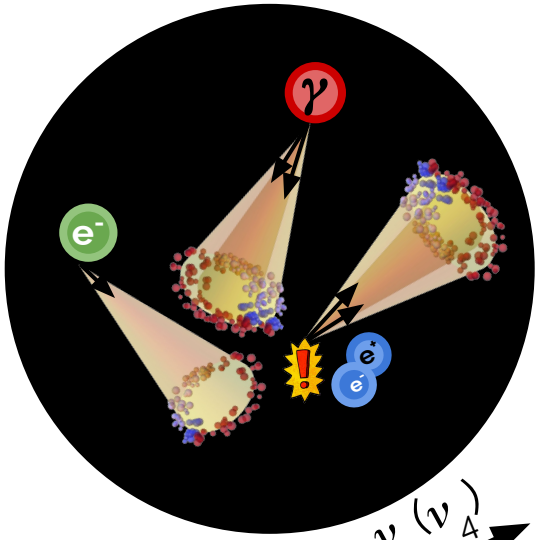

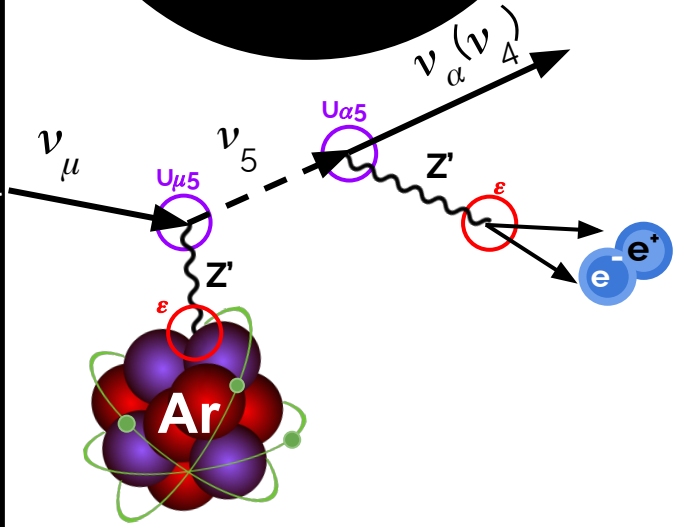

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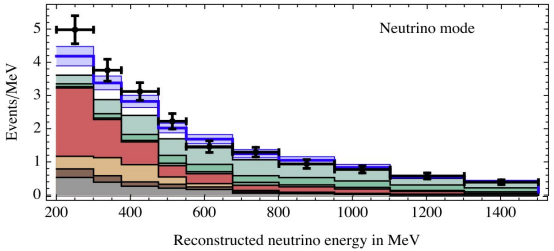

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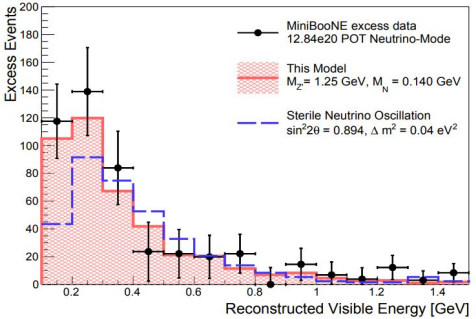


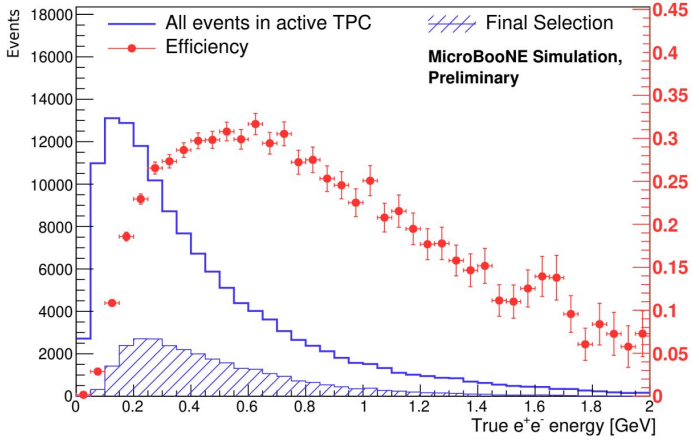
P. Ballett, S. Pascoli, M. RL PhysRevD.99.071701

One or more **heavy sterile neutrinos**, charged under a new **dark U(1)'**

Upscattering produces ν_5 via **neutrino portal**, with scattering and **visible decay via vector portal** mediated by dark gauge boson **Z'**

Non-Minimal Portal Example: Dark Neutrino Portal

MicroBooNE has developed multiple analyses to probe this class of models using both Wire-Cell and Pandora Reconstruction frameworks



Signal efficiencies **up to 30%** across model phase space show significant enhancement over first generation photon results, **~O(5%)**

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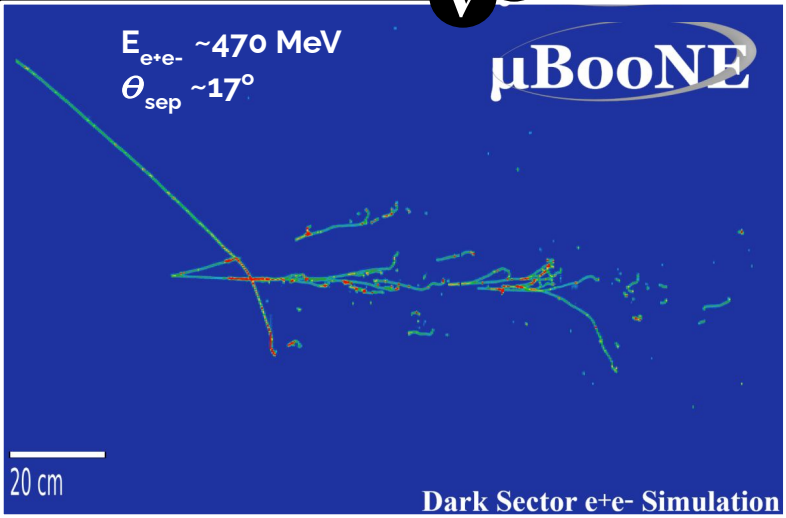
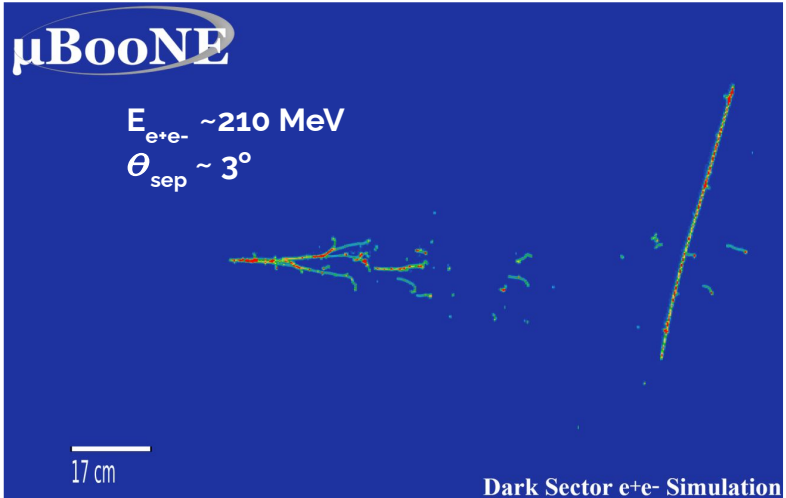
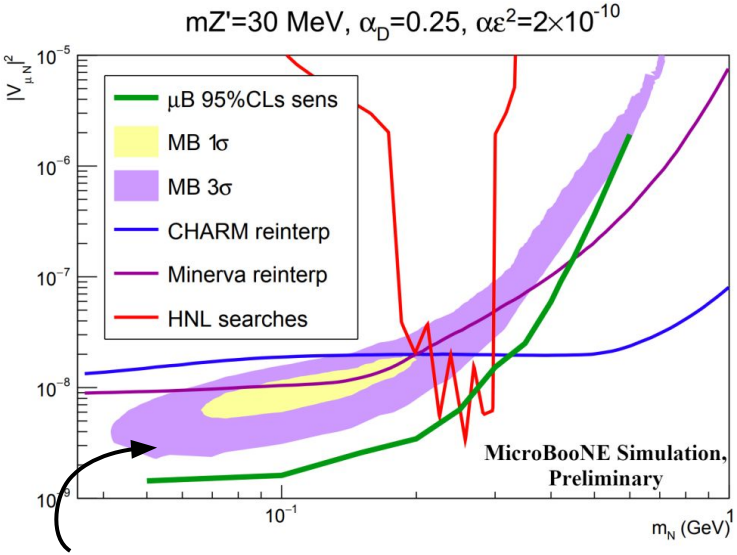




Non-Minimal Portal Example: Dark Neutrino Portal

One Heavy Sterile



MiniBooNE allowed region from
E. Bertuzzo, S. Jana, P. Machado, R. Funchal
Phys. Rev. Lett. 121, 241801

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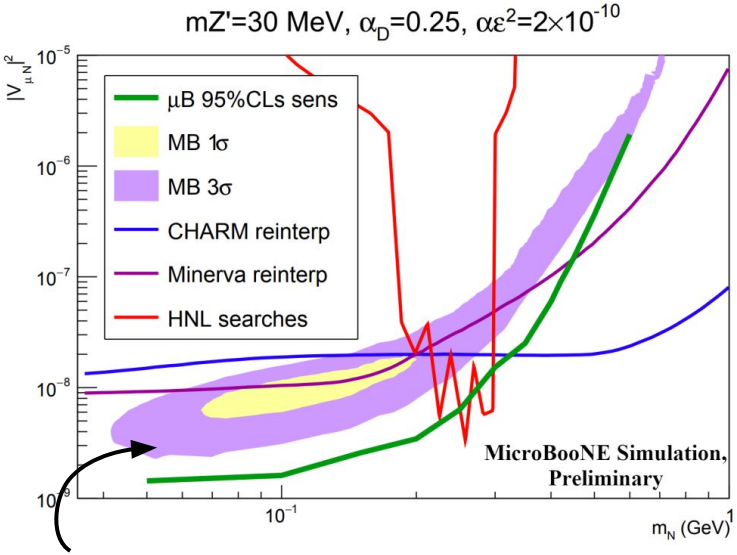

MiniBooNE allowed region from
E. Bertuzzo, S. Jana, P. Machado, R. Funchal
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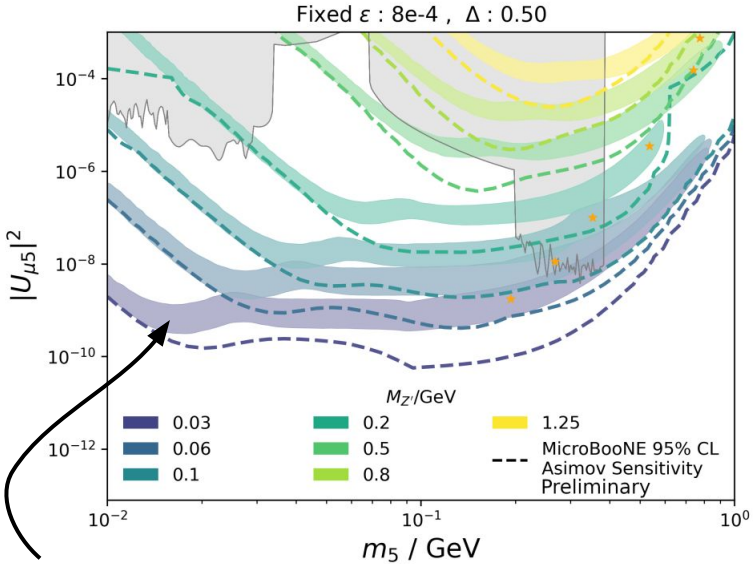
Multiple Steriles States

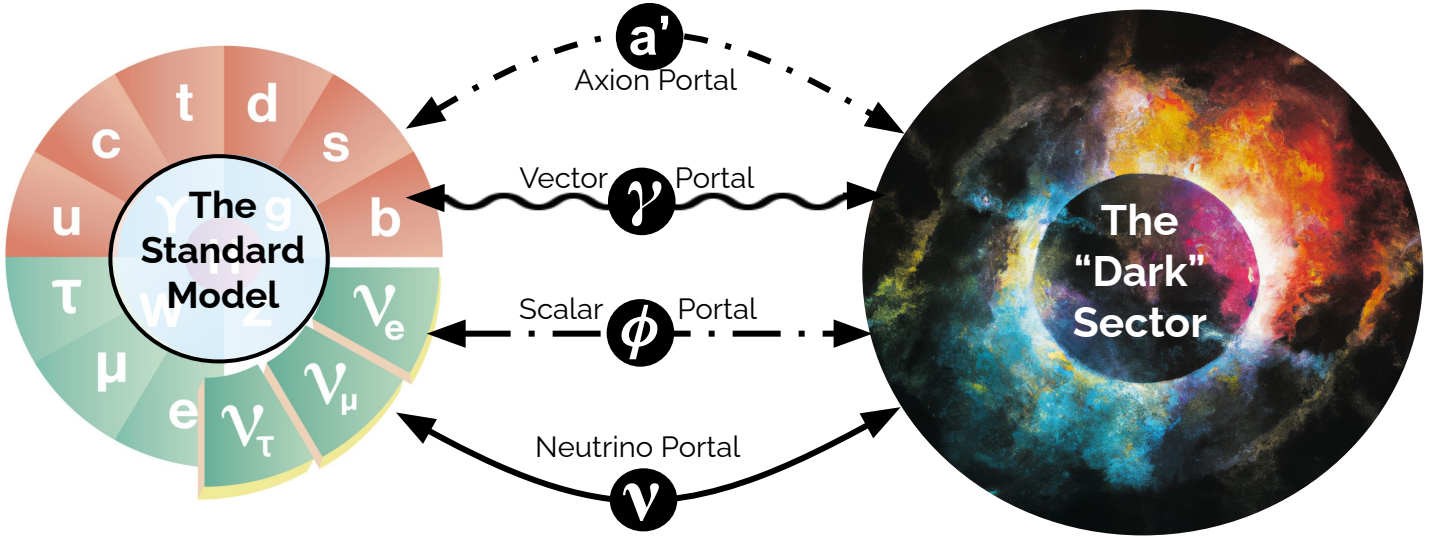


MiniBooNE allowed regions from
A. Abdullahi, J. Hoefken, M. Hostert, D. Massaro, S. Pascoli *arXiv:2308.02543*

MICROBOONE-NOTE-1124-PUB.pdf

Portals to the 'Dark Sector'

*Possible Short-Baseline Anomaly Solution



Neutrino Portal
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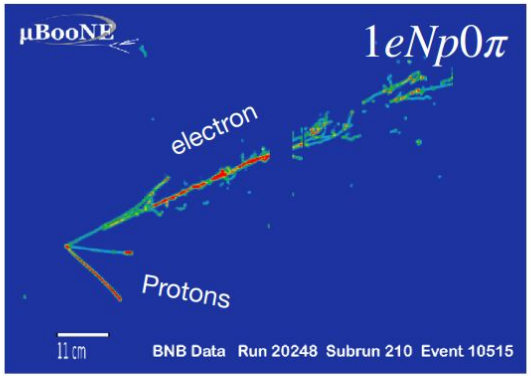
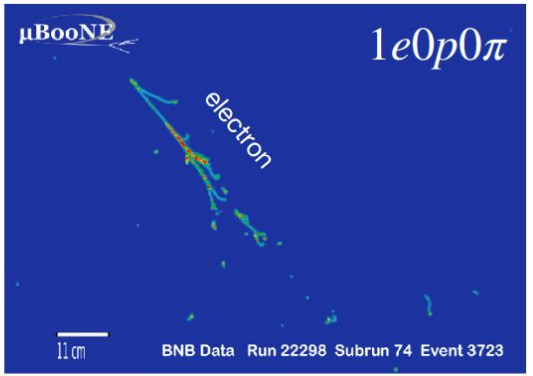
Combined or Non-Minimal Portals
- *Dark Neutrino Upscattering**

Casting a wide net!
- Generic Electron Searches*
- Inclusive Single-Photon Searches*

Generic selections formed the backbone of the first MicroBooNE electron LEE results





Highlight an **update to the pionless ν_e selection**

- Same topology as MiniBooNE
- This update is the first analysis from MicroBooNE to use **all five runs of data**
  - **6.8×10^{20} → 11.1×10^{20} POT** of BNB data
- Based on MicroBooNE (2022) PhysRevD 105 112004 but with several updates in addition to extra data

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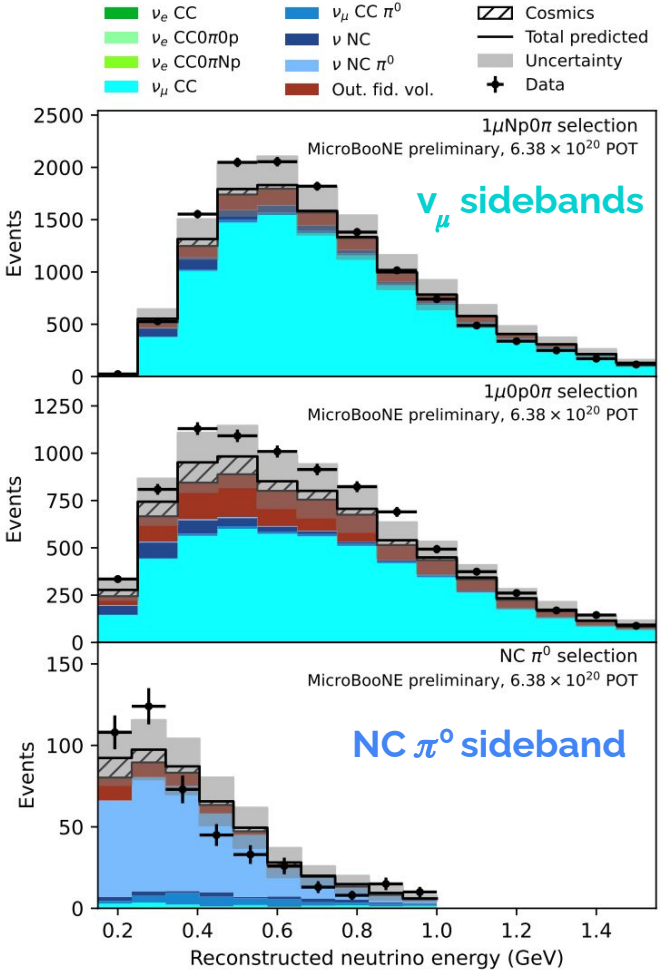
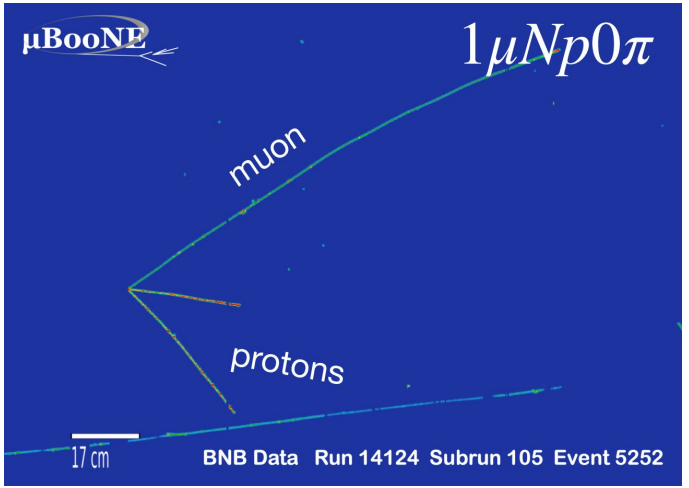
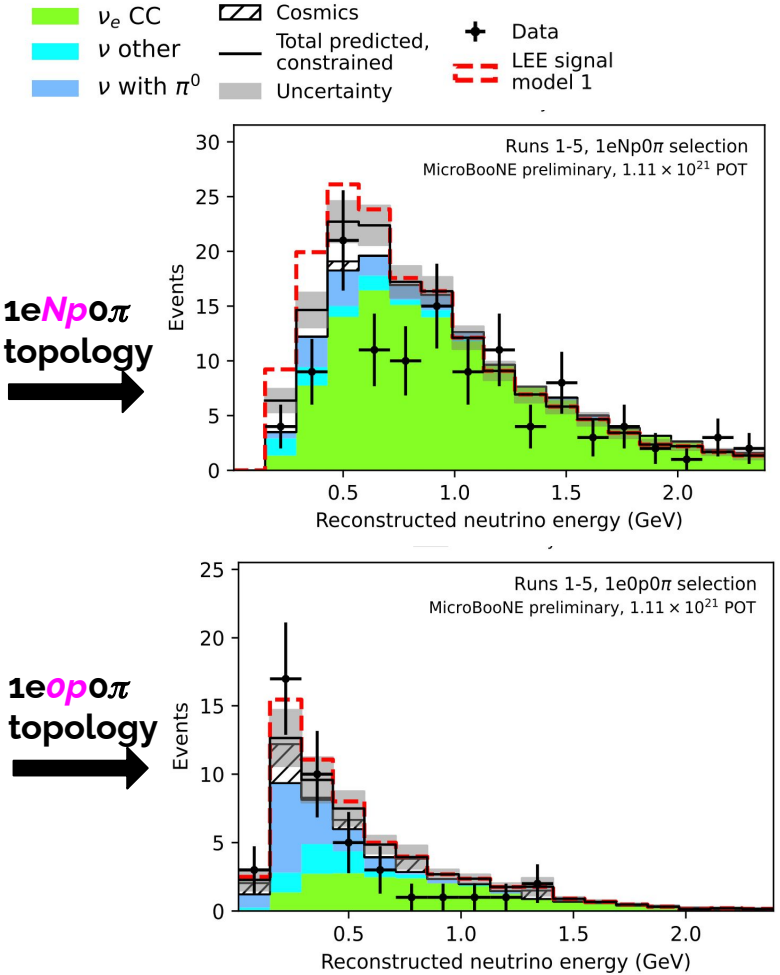


Updated ν_μ **sidebands** to better constrain intrinsic ν_e

Inclusion of a **NC π^0 sideband** a particularly important background for 1e0p0π



MICROBOONE-NOTE-1127-PUB



- Data in overall agreement with **intrinsic ν_e flux** prediction.

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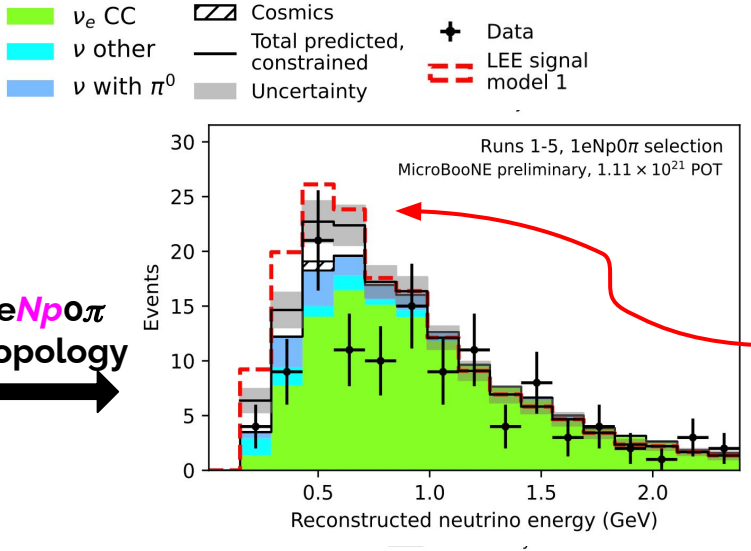
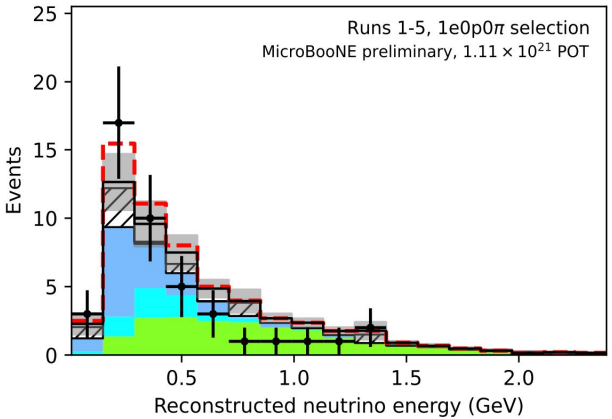
Generic Selections: Electron

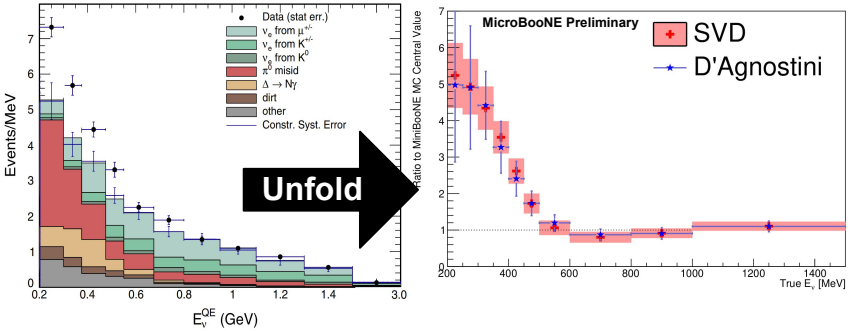


1e*Np*0π topology



1e*0p*0π topology

- Data in overall agreement with **intrinsic ν_e flux** prediction.
- Although selection is *model independent*, want to test **neutrino energy dependent ν_e rate scaling** as possible MiniBooNE explanation



- Rule out **excess model** @ 99.5% CL in **Np** & **0p** combined channels.

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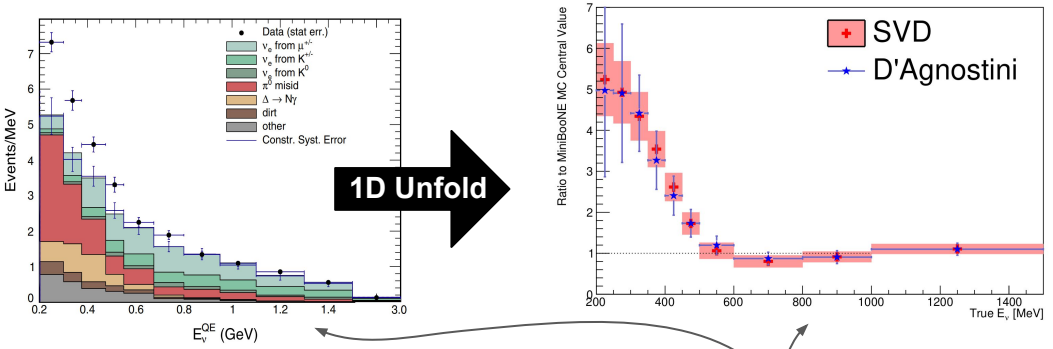
Generic Selections: Electron



Neither MiniBooNE nor MicroBooNE measures **neutrino energy directly**

MICROBOONE-NOTE-1127-PUB

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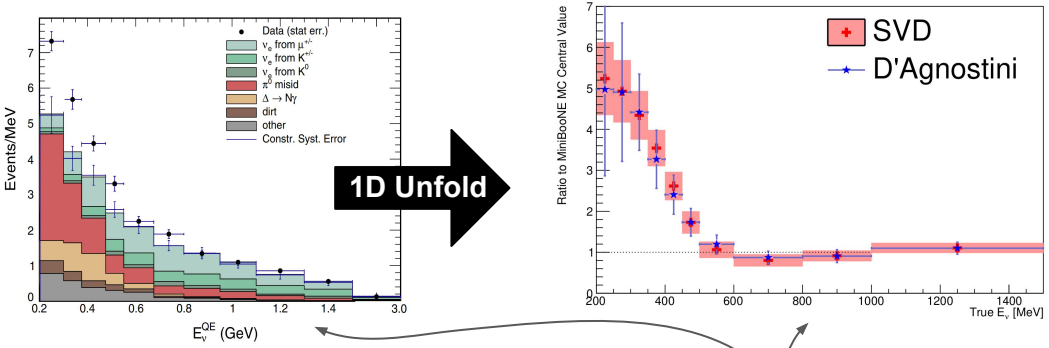

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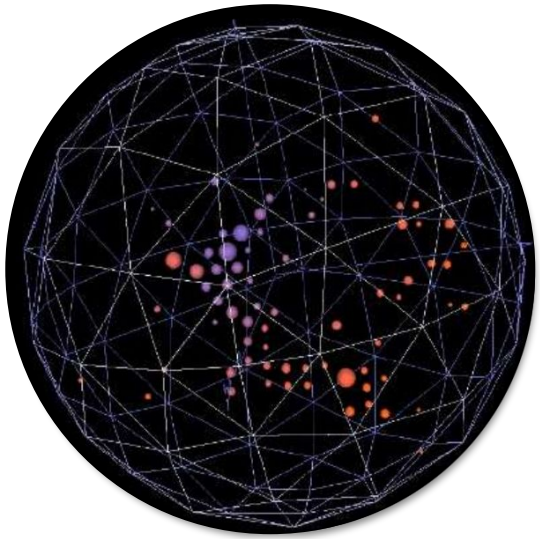
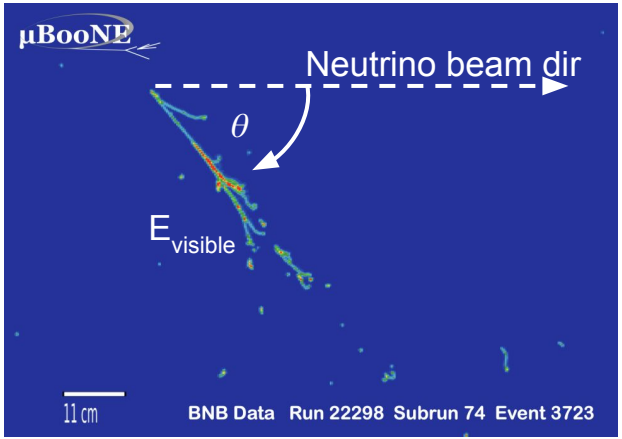


Instead we reconstruct

- The **direction**
- The **visible energy**

of the **observed shower**



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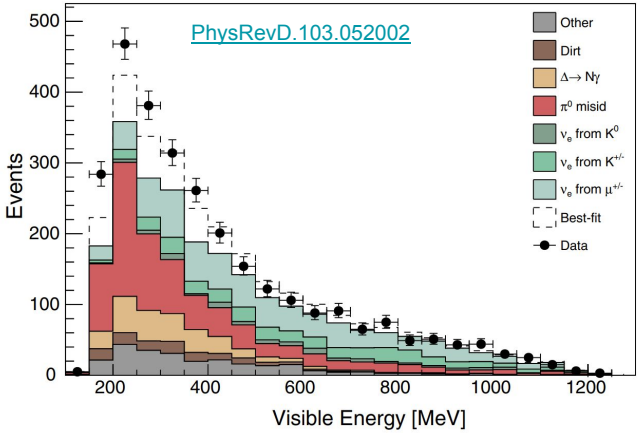
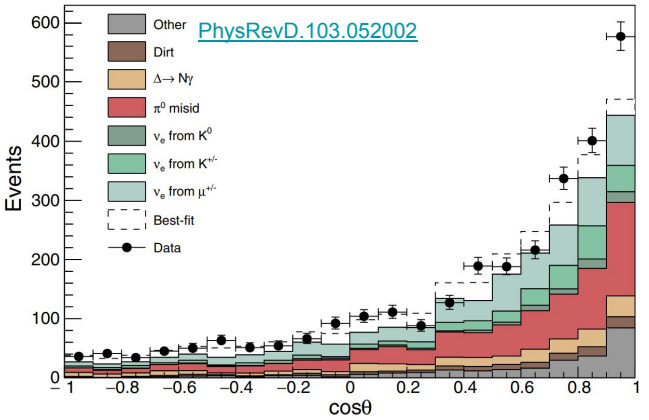
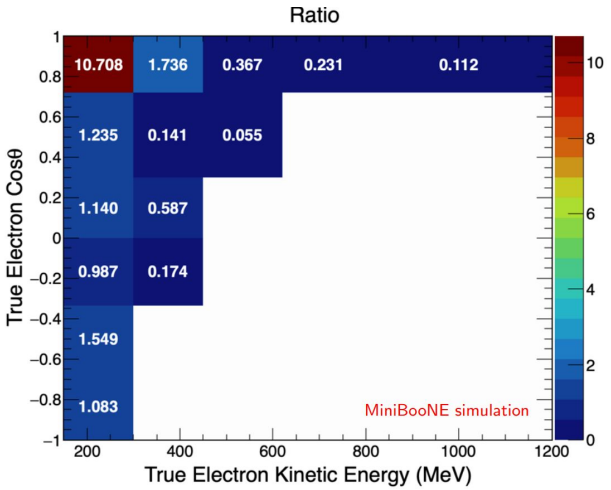




2D Unfolding



A new model based on
2D shower kinematics

MICROBOONE-NOTE-1127-PUB

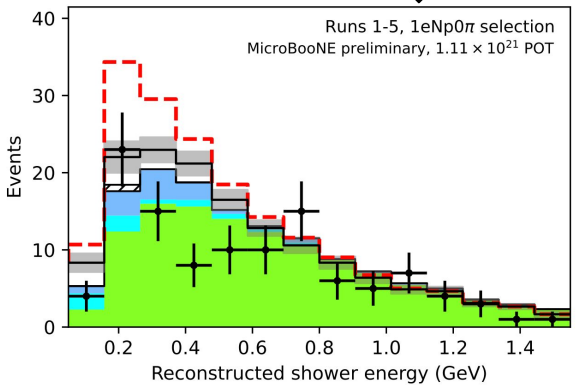
Generic Selections: Electron

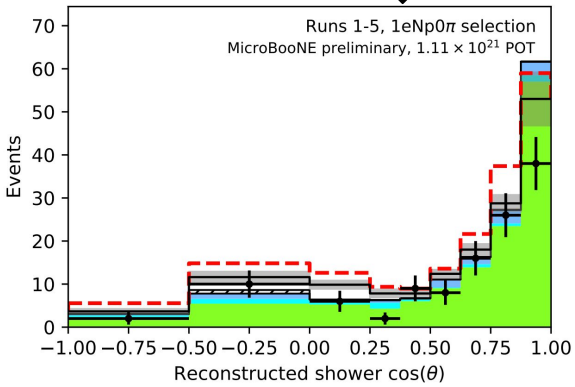
ν_e CC
ν other
ν with π^0
Cosmics
Total predicted, constrained
Uncertainty
Data
LEE signal model 2

A new model based on **2D shower kinematics**

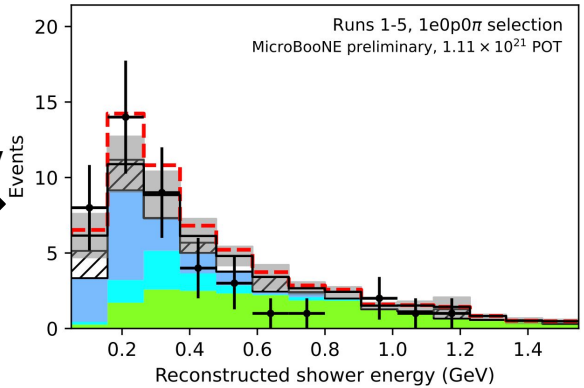
Shower Energy ↓ | **Shower Angle** ↓

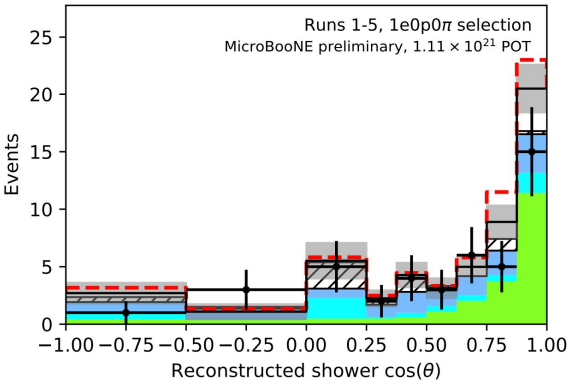
1e*Np*0π topology →





1e*op*0π topology →





MICROBOONE-NOTE-1127-PUB

ν_e CC
ν other
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Cosmics
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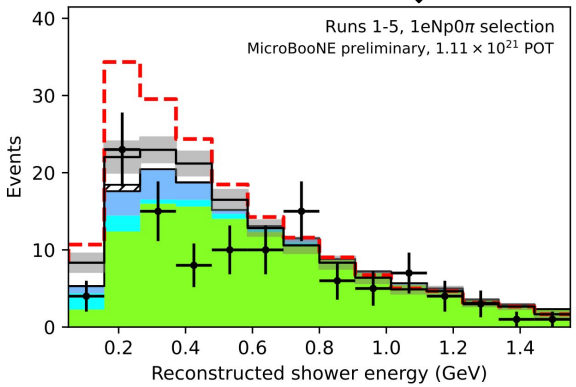
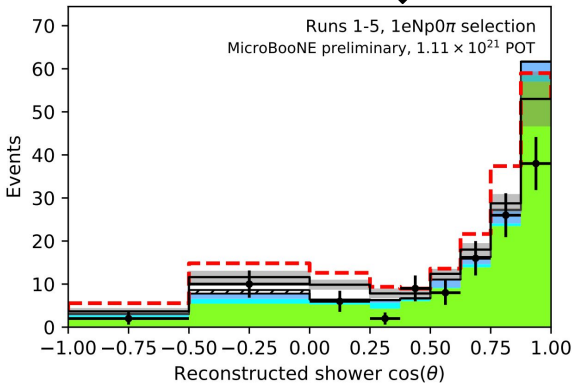
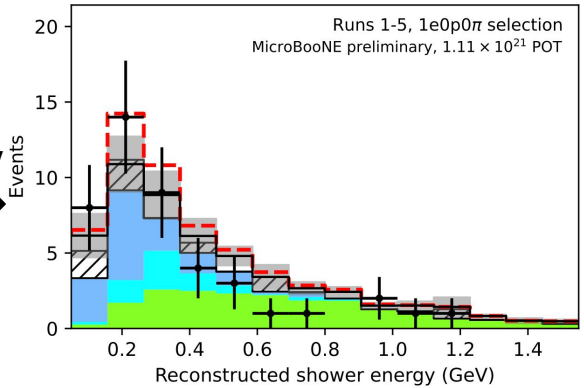
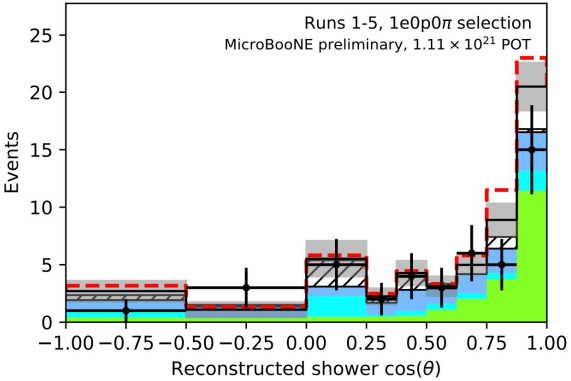




1e*0p*0π topology →

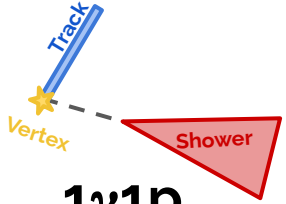




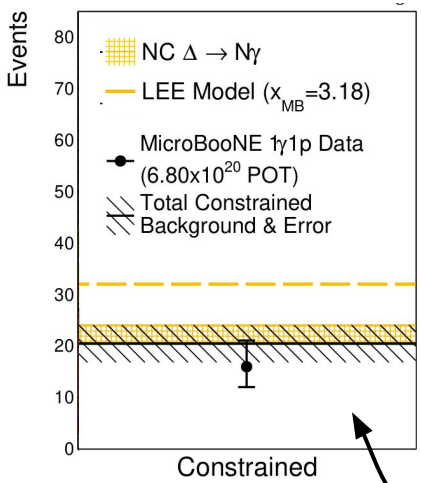
Combined Np & 0p channels: exclude **this model** at > 99.9% CL

MICROBOONE-NOTE-1127-PUB

In contrast, MicroBooNE's first generation photon analysis was ***not*** **a generic or model independent result**, it was specific to **NC Δ Radiative decay**



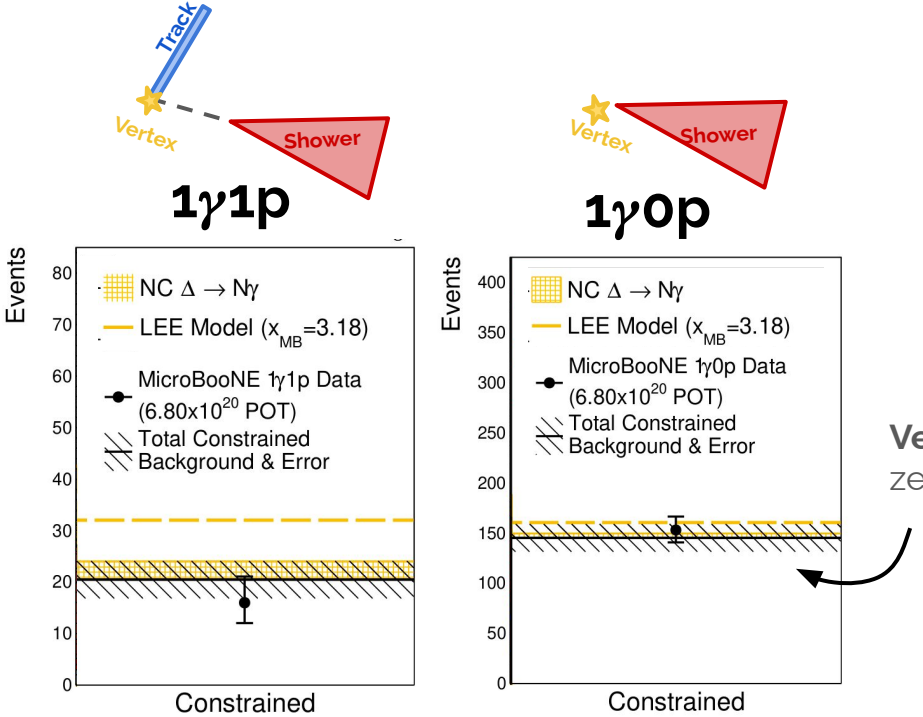
1γ1p



Power comes mostly from 1γ1p selection

MicroBooNE: Phys. Rev. Lett. **128**, 111801 (2022)

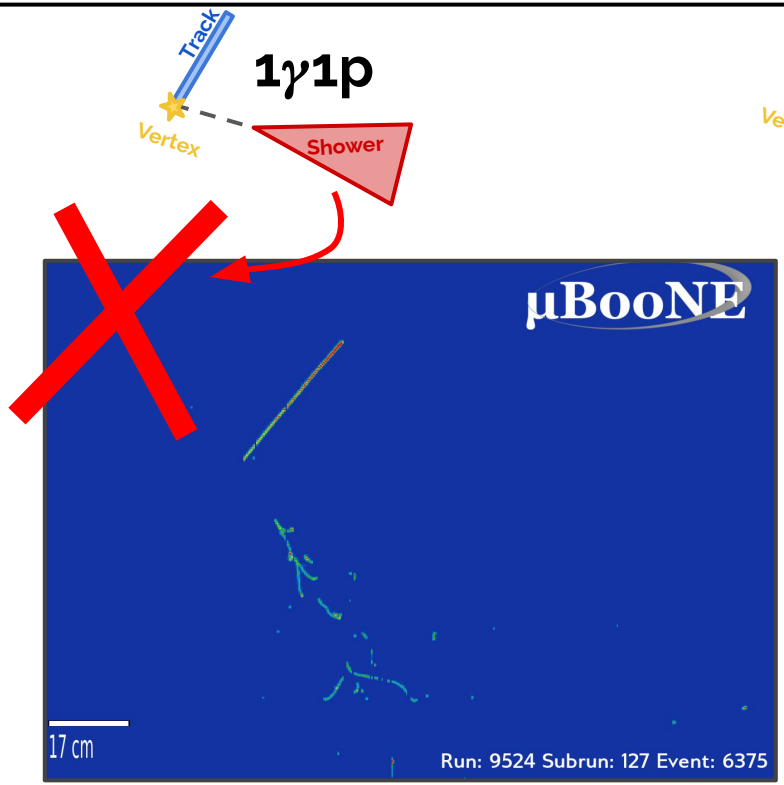
In contrast, MicroBooNE's first generation photon analysis was ***not*** **a generic or model independent result**, it was specific to **NC Δ Radiative decay**

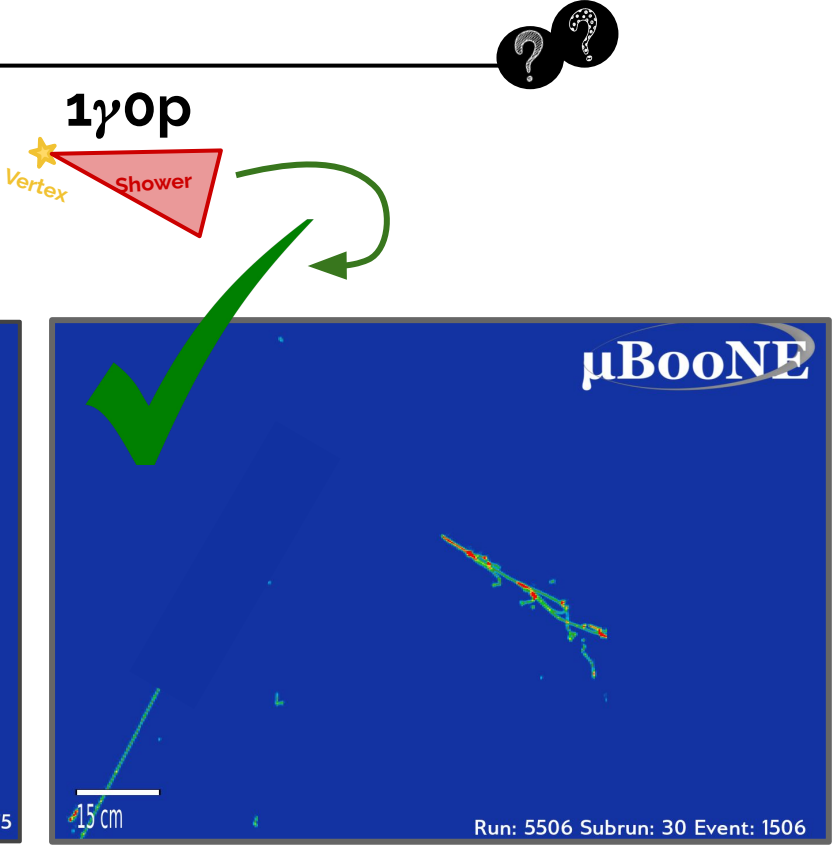


Very little sensitivity in the zero-proton sample

MicroBooNE: Phys. Rev. Lett. **128**, 111801 (2022)

Generic Selections: Photon





Heavily Constrained

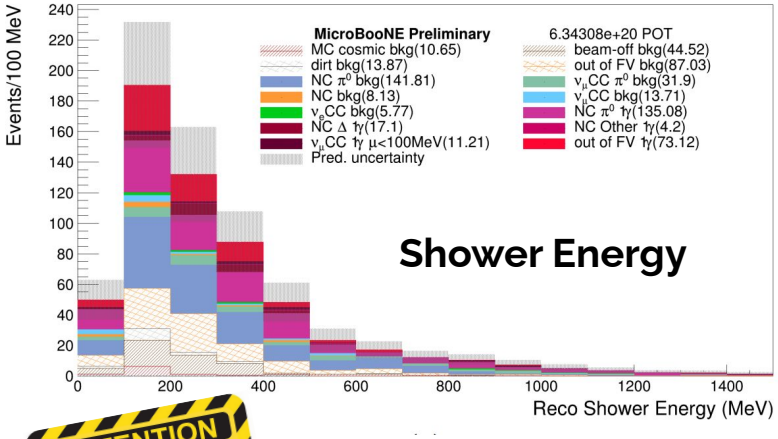
Currently Allowed, Need further probes…

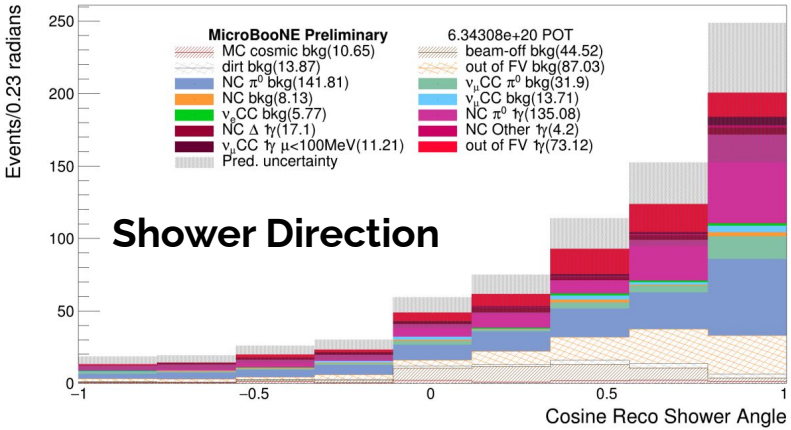
MicroBooNE: Phys. Rev. Lett. **128**, 111801 (2022)

An **inclusive single-photon selection** has been developed using the Wire-Cell reconstruction framework.

Aim to **cast a wide net** to capture any potential photon anomaly, especially in 0-proton events

Expect **O(600)** events in final selections, with a purity of **~40%** and single-shower efficiency of **7%**





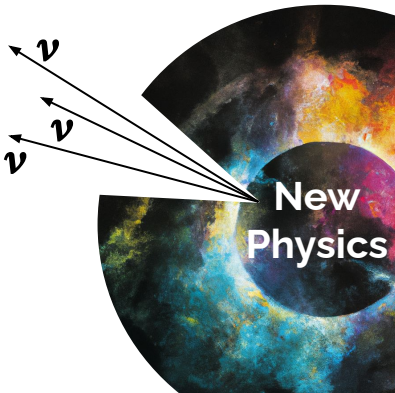
MicroBooNE Inclusive Single-Photon: MICROBOONE-NOTE-1125-PUB

Conclusions and Summary

- Combination of powerful **dual beam neutrino sources** and **LArTPC detector technology** provides MicroBooNE with the tools to probe a wide array of BSM **Dark Sector Physics**
  - **World-leading limits on some low-mass BSM particles**
  - Beginning to explore the **rich world of non-minimal portals** with upcoming dark-neutrino **e+e- analysis**

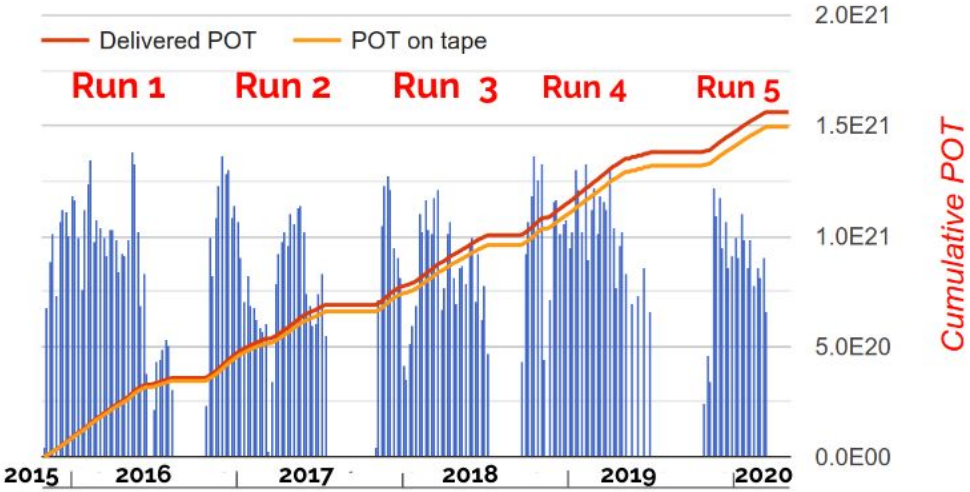
- Novel **"Dual-Beam" 3+1 sterile neutrino search** will continue to weigh in on 3+1 interpretation of the **short-baseline anomalies**, alongside first full dataset **electron analyses**

- New **inclusive single-photon** results coming soon, with many more **full 5-year dataset analyses to follow!**




Thank You
μBooNE
Los Alamos
NATIONAL LABORATORY
Fermilab

Since turning on in 2015, MicroBooNE has amassed the **largest sample of neutrino interactions on argon in the world**

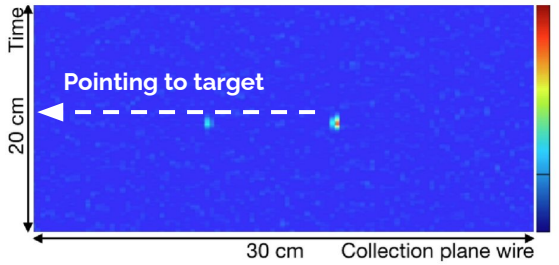


Particles (χ) with a **fraction of the electron charge, εe** .

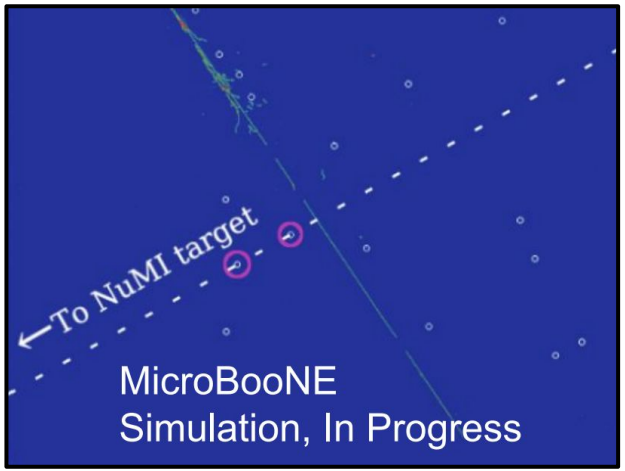
$$\mathcal{L}_{mCP} = i\bar{\chi}\left(\partial\!\!\!/ - i\epsilon e B\!\!\!/ + M_{mCP}\right)\chi$$

While millicharged particles can studied in isolation without a dark sector, this fractional charge could come from **vector portal kinetic mixing ε**

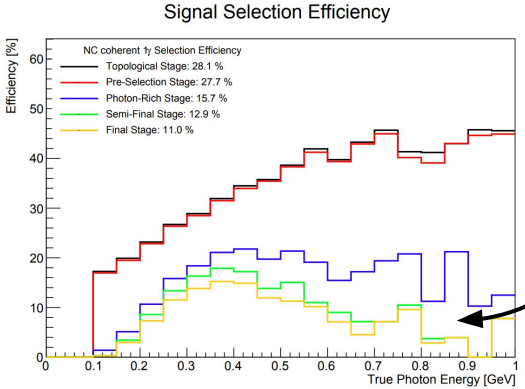
ArgoNeuT: PhysRevLett.124.131801



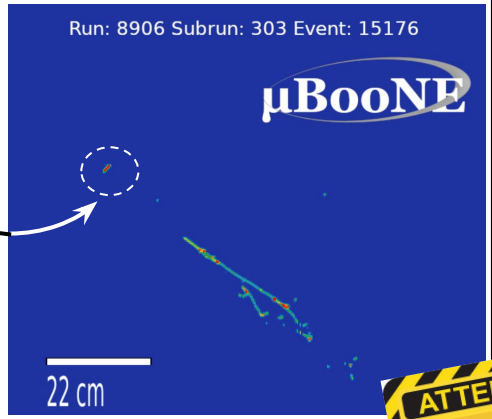
Methods pioneered by **ArgoNeuT** for LArTPC's, with analysis now ongoing in **MicroBooNE**



Coherent Photon Production



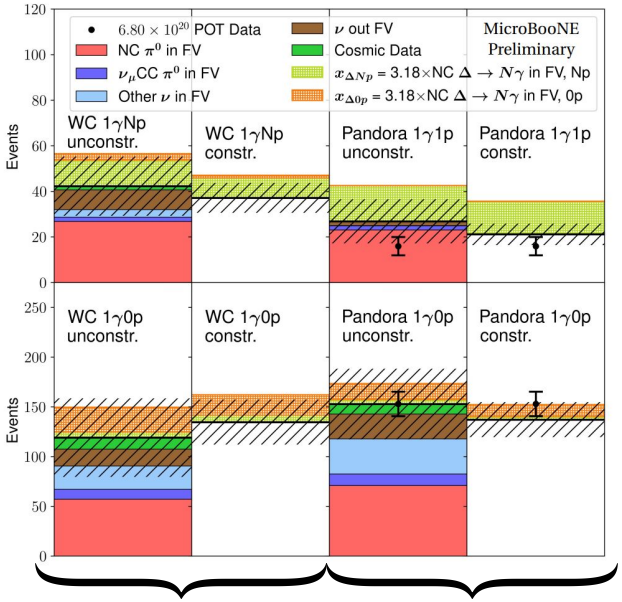
Targeting specific topology leads to higher efficiency



Example of Proton "Stub" This analysis aims to remove

MICROBOONE-NOTE-1131-PUB

Updated NC Δ→Nγ (Delta Radiative)

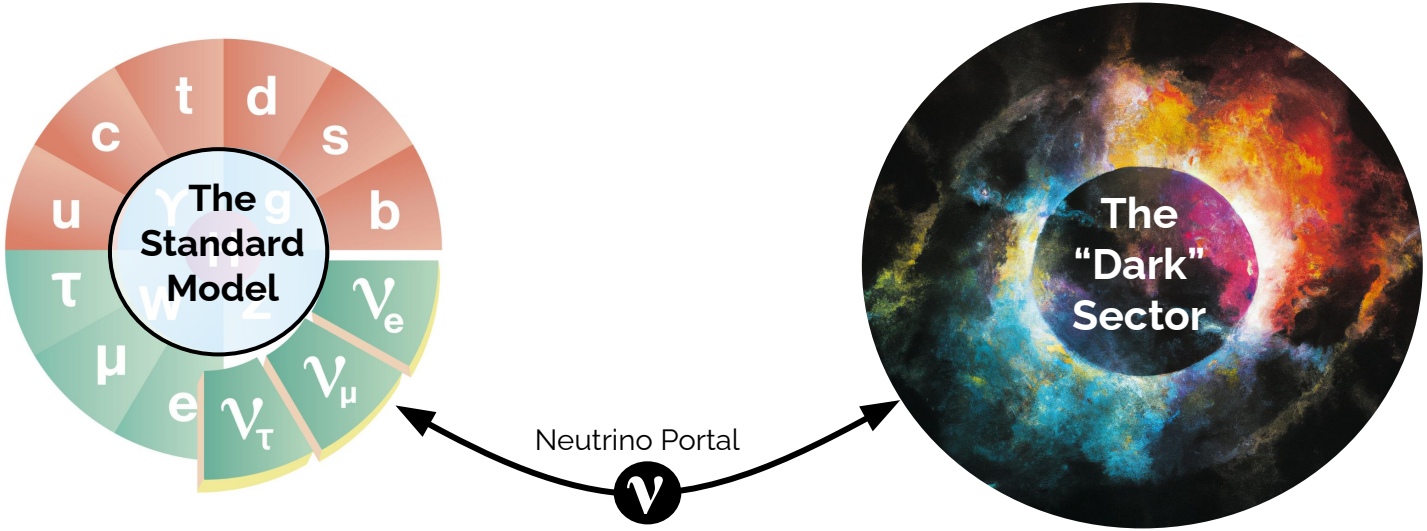


New Wire-Cell Selections

1st generation NC Δ→Nγ Results (Pandora)

MICROBOONE-NOTE-1126-PUB

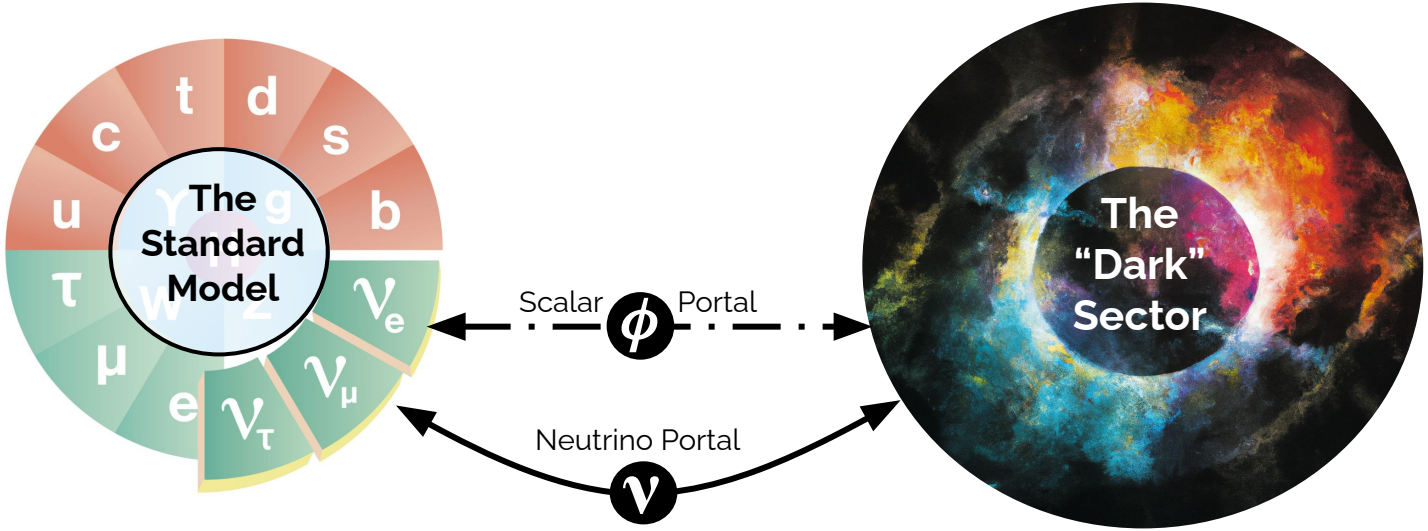
Portals to the 'Dark Sector'



ν Neutrino Portal

$$\mathcal{L} \supset -y^{\alpha} L_{\alpha} H N + \text{h.c.}$$

Portals to the 'Dark Sector'



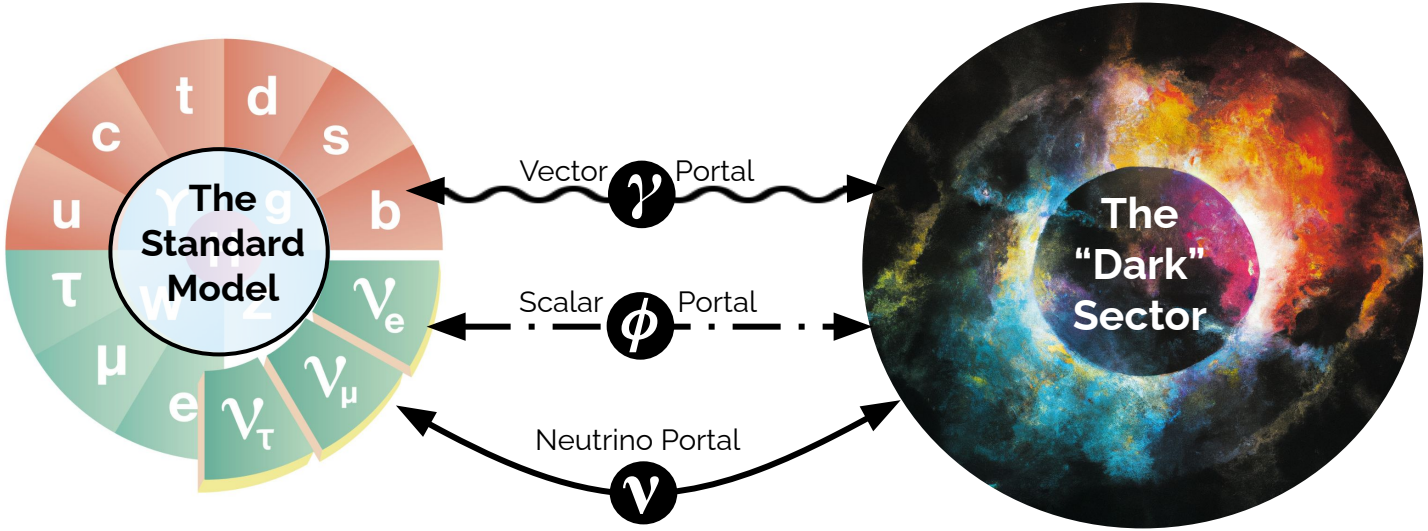
Neutrino Portal

$$\mathcal{L} \supset -y^{\alpha} L_{\alpha} H N + \text{h.c.}$$

Scalar Portal

$$\mathcal{L} \supset (A\,S + \lambda\,S^2)\,H^{\dagger}H$$

Portals to the 'Dark Sector'



ν Neutrino Portal

$$\mathcal{L} \supset -y^{\alpha} L_{\alpha} H N + \text{h.c.}$$

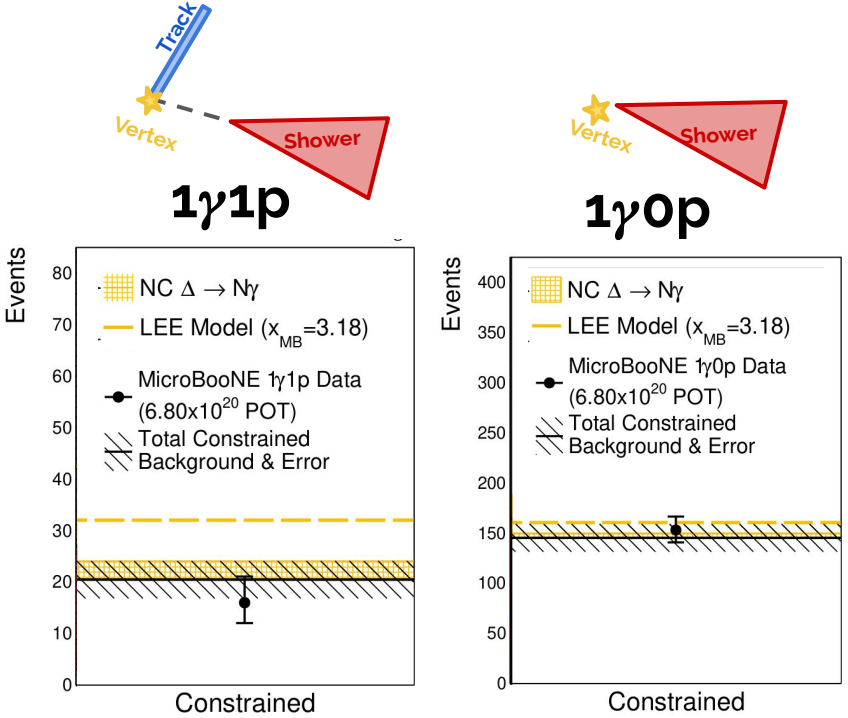
ϕ Scalar Portal

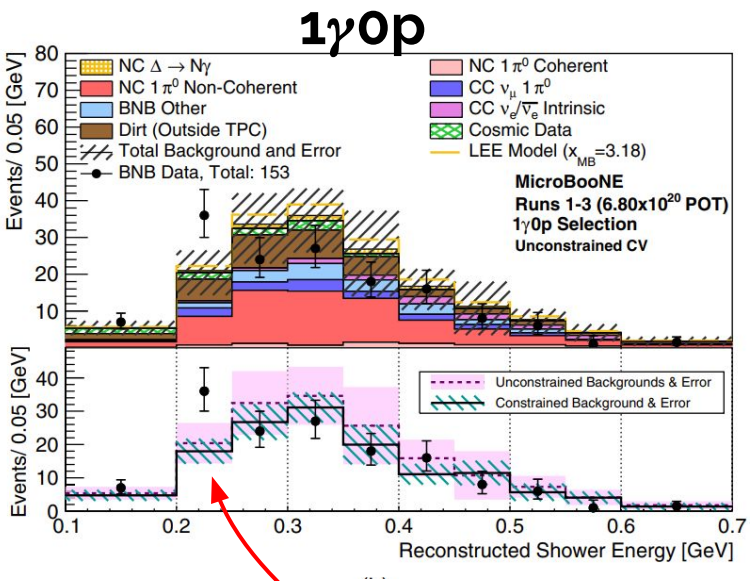
$$\mathcal{L} \supset (A\,S + \lambda\,S^2)\,H^{\dagger}H$$

γ Vector Portal

$$\mathcal{L} \supset \epsilon F'_{\mu\nu} B^{\mu\nu}$$

In contrast, MicroBooNE's first generation photon analysis was ***not*** **a generic or model independent result**, it was specific to **NC Δ Radiative decay**





In fact very mild excess at lower energy in the **1γ0p** selection.

MicroBooNE: Phys. Rev. Lett. **128**, 111801 (2022)