Measurement of the Inclusive Electron Antineutrino Cross-Section on Argon Using the MicroBooNE Detector

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On behalf of the MicroBooNE Collaboration

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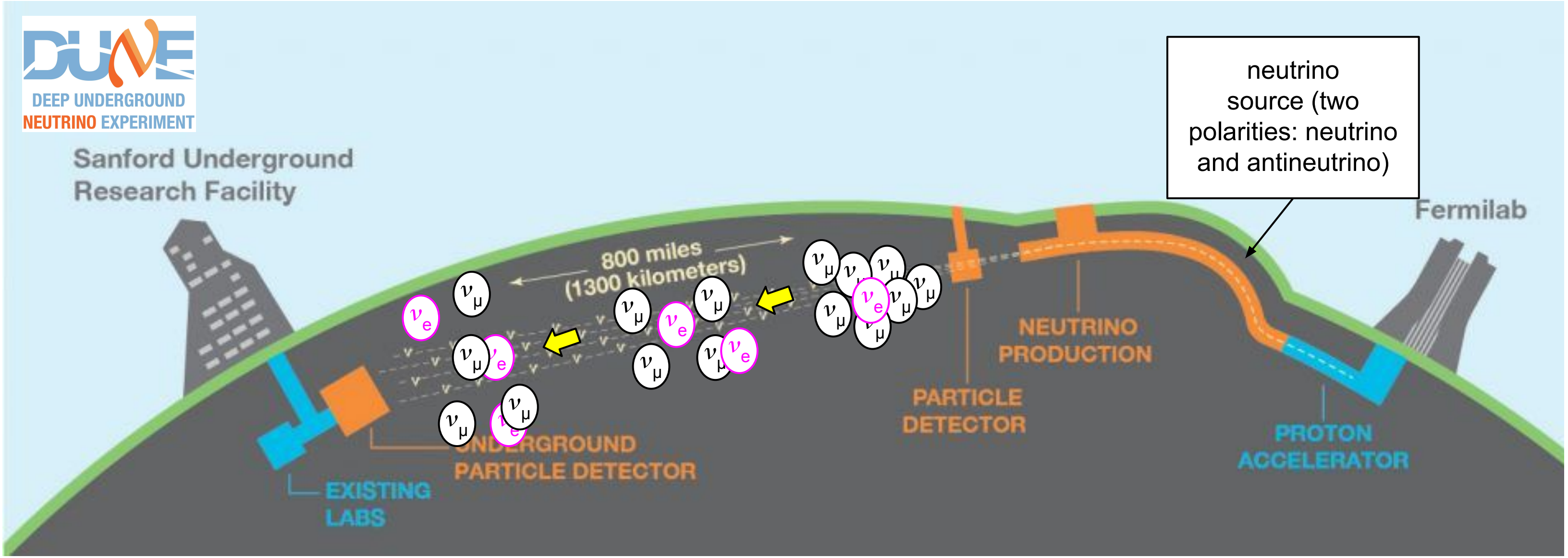
Why is measuring ν_e and $\bar{\nu}_e$ important?

Current and future long-baseline neutrino oscillation experiments measure ν_e appearance in a ν_μ beam



To measure the CP violation in the lepton sector

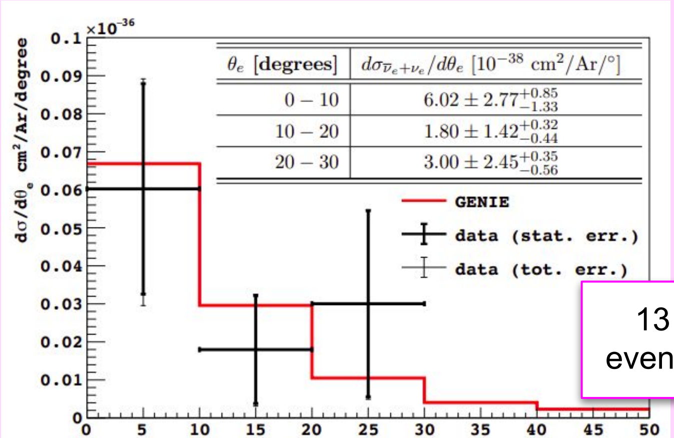
both $\nu_\mu \to \nu_e$ and $\bar{\nu}_\mu \to \bar{\nu}_e$ are necessary

$$\mathcal{A}_{CP} = \frac{P(\nu_\mu \to \nu_e) - P(\bar{\nu}_\mu \to \bar{\nu}_e)}{P(\nu_\mu \to \nu_e) + P(\bar{\nu}_\mu \to \bar{\nu}_e)}$$

ν_e cross-section measurements

There are only 8 ν_eCC cross-section measurements to date:

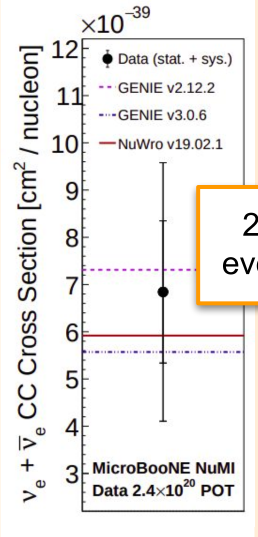
- Non-LAr target (x5): MINERνA (2016), T2K (2014, 2015, 2020), and Gargamelle (1978)
- LAr target (x3): **MicroBooNE (2021, 2021)**, ArgoNeuT (2020)



θ_e [degrees]	$d\sigma_{\bar{\nu}_e+\nu_e}/d\theta_e$ [10^{-38} cm²/Ar/°]
0 – 10	$6.02 \pm 2.77^{+0.85}_{-1.33}$
10 – 20	$1.80 \pm 1.42^{+0.32}_{-0.44}$
20 – 30	$3.00 \pm 2.45^{+0.35}_{-0.56}$

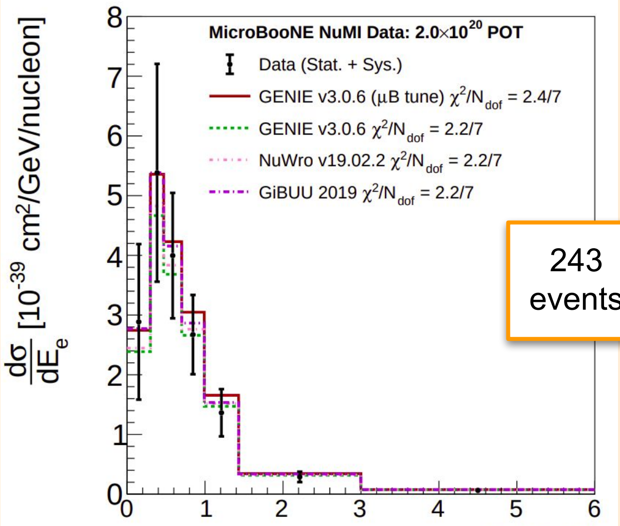
13 events

Phys. Rev. D 102,011101(R) (2020)



214 events

Phys. Rev. D 104.05202 (2021)



243 events

Phys. Rev. D 105, L051102 (2022)

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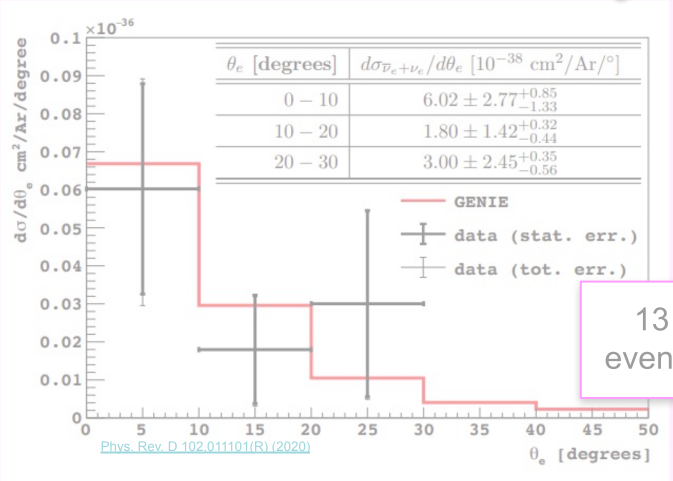
All of them are **inclusive electron neutrino + antineutrino** cross-sections on argon. But separate $\nu_\mu \rightarrow \nu_e$ and $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ oscillation measurements are crucial to achieving the DUNE Physics Goals.



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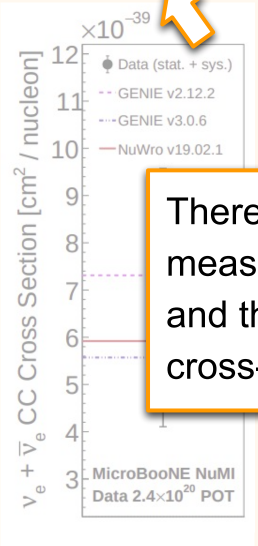
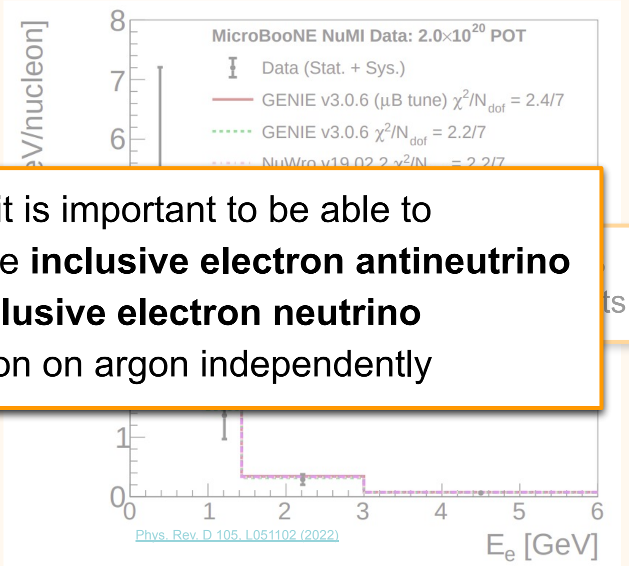


Phys. Rev. D 104.05202 (2021)



Phys. Rev. D 105, L051102 (2022)

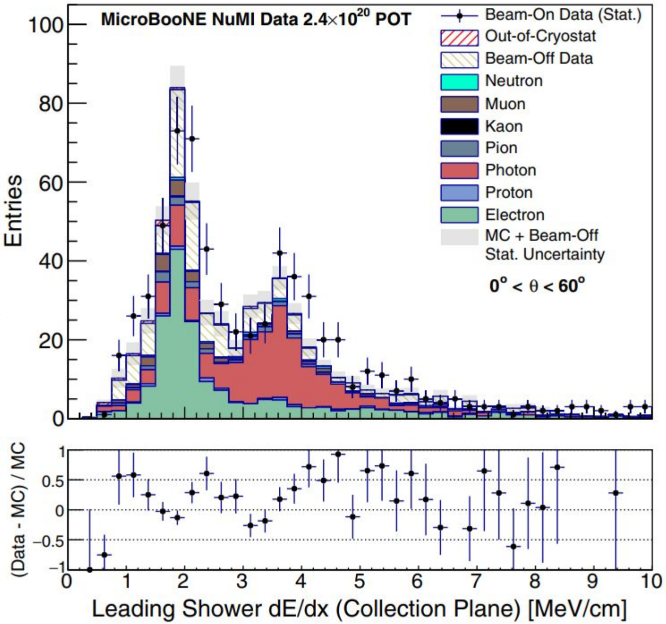
Therefore, it is important to be able to measure the **inclusive electron antineutrino** and the **inclusive electron neutrino** cross-section on argon independently

The MicroBooNE Detector

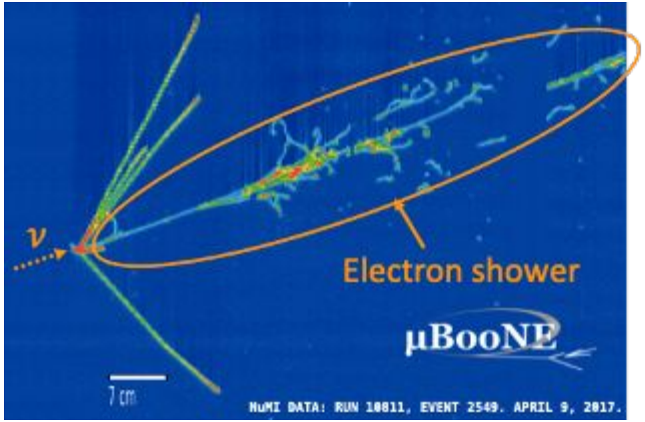
see Chris Thorpe's talk

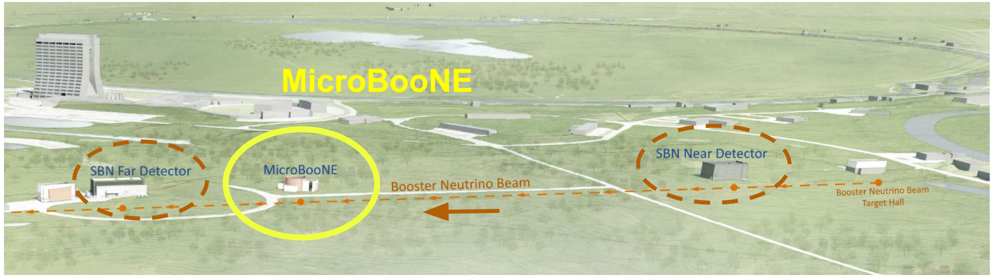
The MicroBooNE detector is one of the three Liquid Argon Time Projection (LArTPC) of the SBN Program at Fermilab, US

- Has collected 5 years of data from 2015 to 2020
- Largest $\nu_e + \bar{\nu}_e$ dataset on argon to date
- Electron/photon discrimination
- Good shower/track separation



Phys. Rev. D 104, 052002



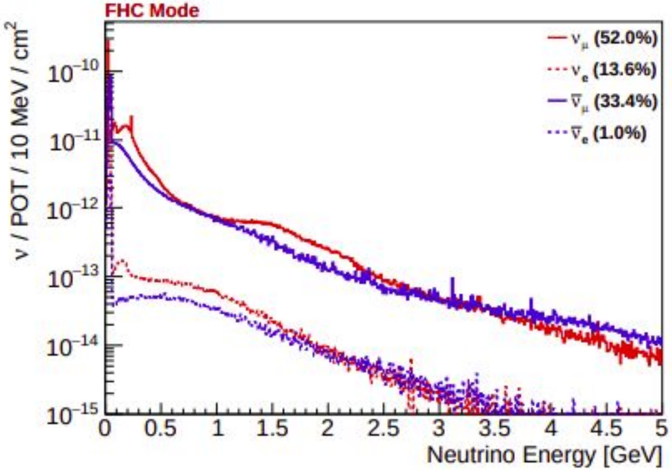


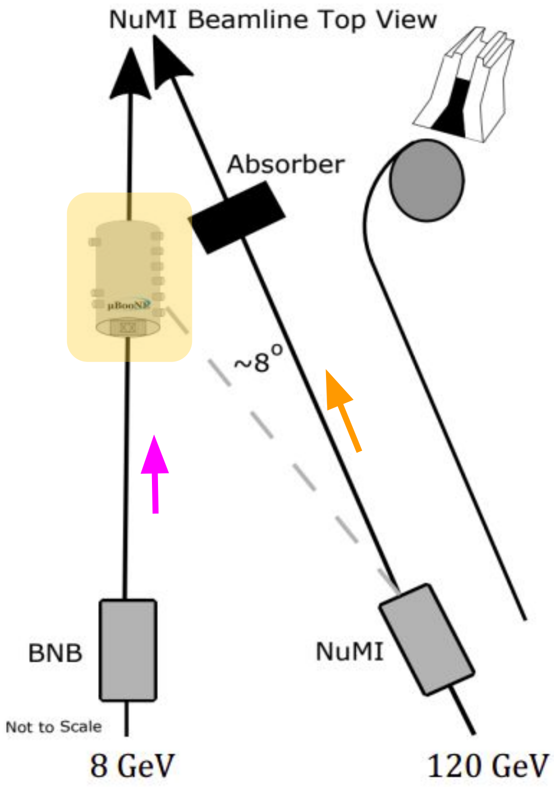
The NuMI Beam

MicroBooNE is:

- On-axis to the Booster Neutrino Beam (BNB) and
- **Off-axis to the Neutrino in the Main Injector (NuMI) beam**

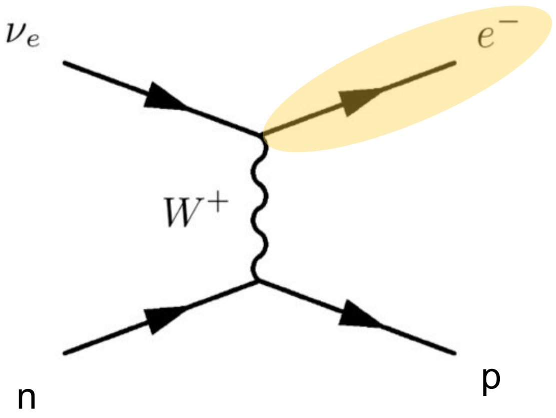
NuMI has a significant component of electron antineutrinos

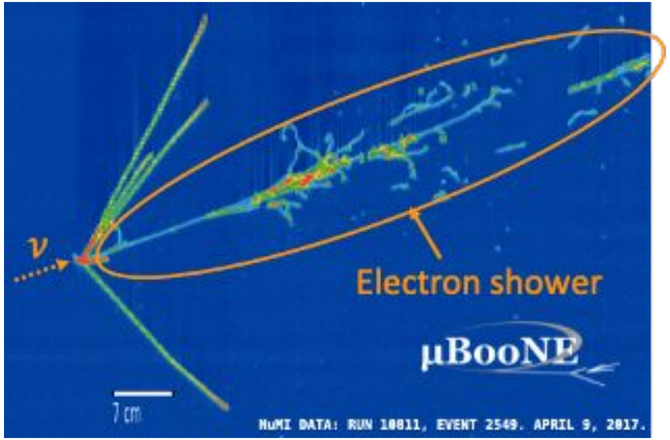


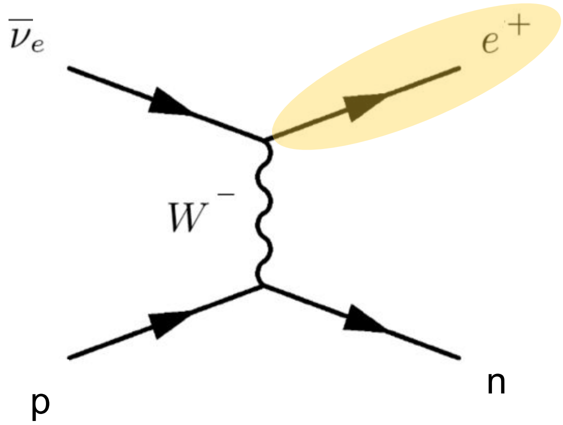


What are we measuring?

Goal: inclusive measurement of the electron antineutrino cross-section







Due to the absence of magnetic fields, LArTPCs are not able to distinguish a charged particle from its antiparticle. But neutrino-nucleus interactions can provide us with a way to tell them apart.

Strategy

$\nu_e + \bar{\nu}_e$ selection

Set of selection cuts that selects electron neutrino and electron antineutrino events, and removes most of the background

ν_e versus $\bar{\nu}_e$

Develop a BDT to distinguish electron-neutrino from electron-antineutrino events

Measure the Cross-Section

Perform the likelihood fit on simulation to data to extract the cross-section for ν_e and $\bar{\nu}_e$ (ongoing)

In this talk

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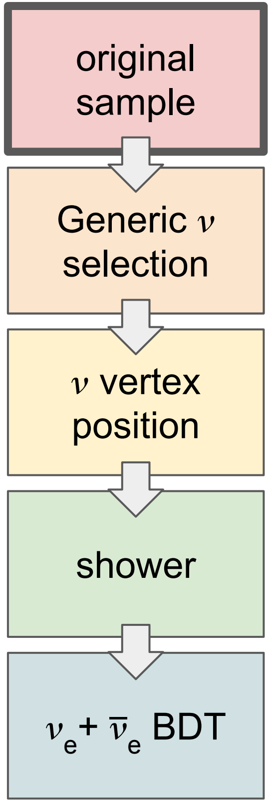
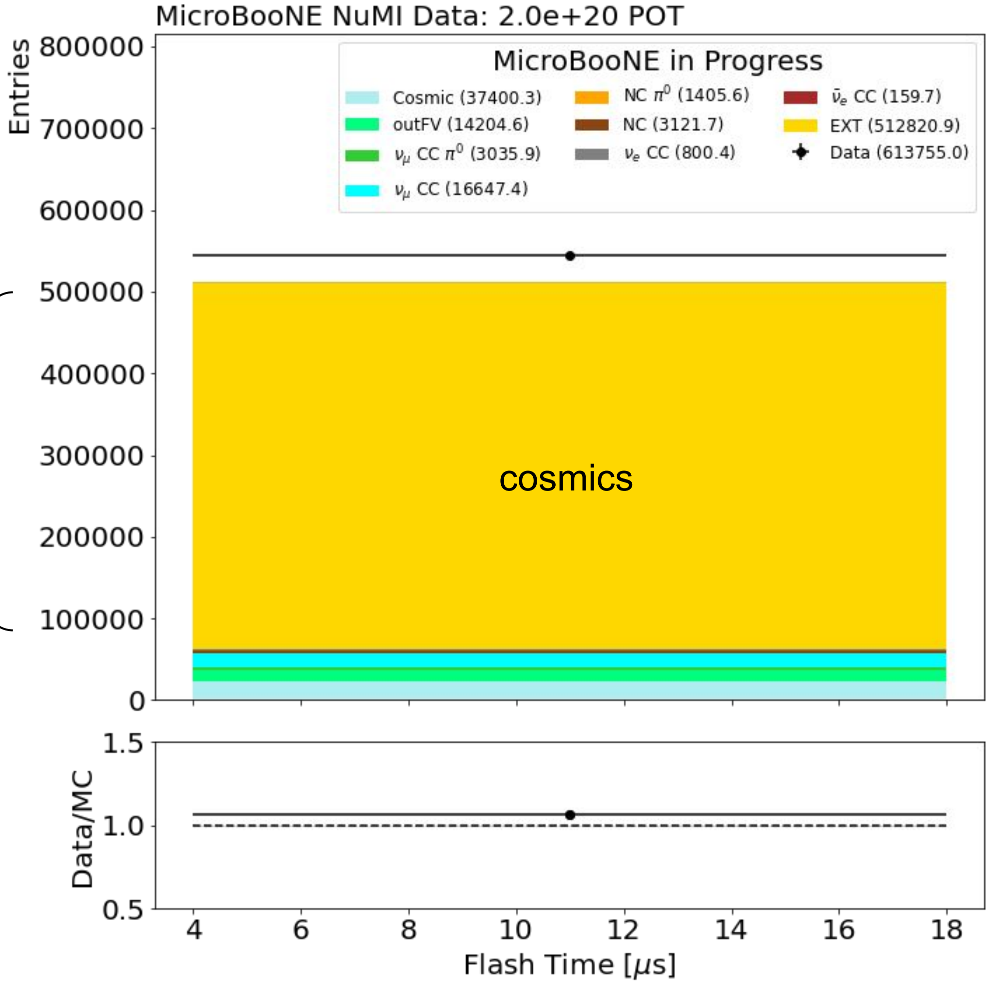
$\nu_e + \overline{\nu}_e$ selection



MicroBooNE is a surface LArTPC ⇒ large cosmic contamination



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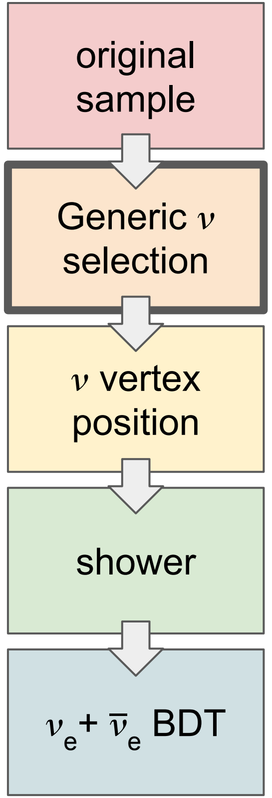
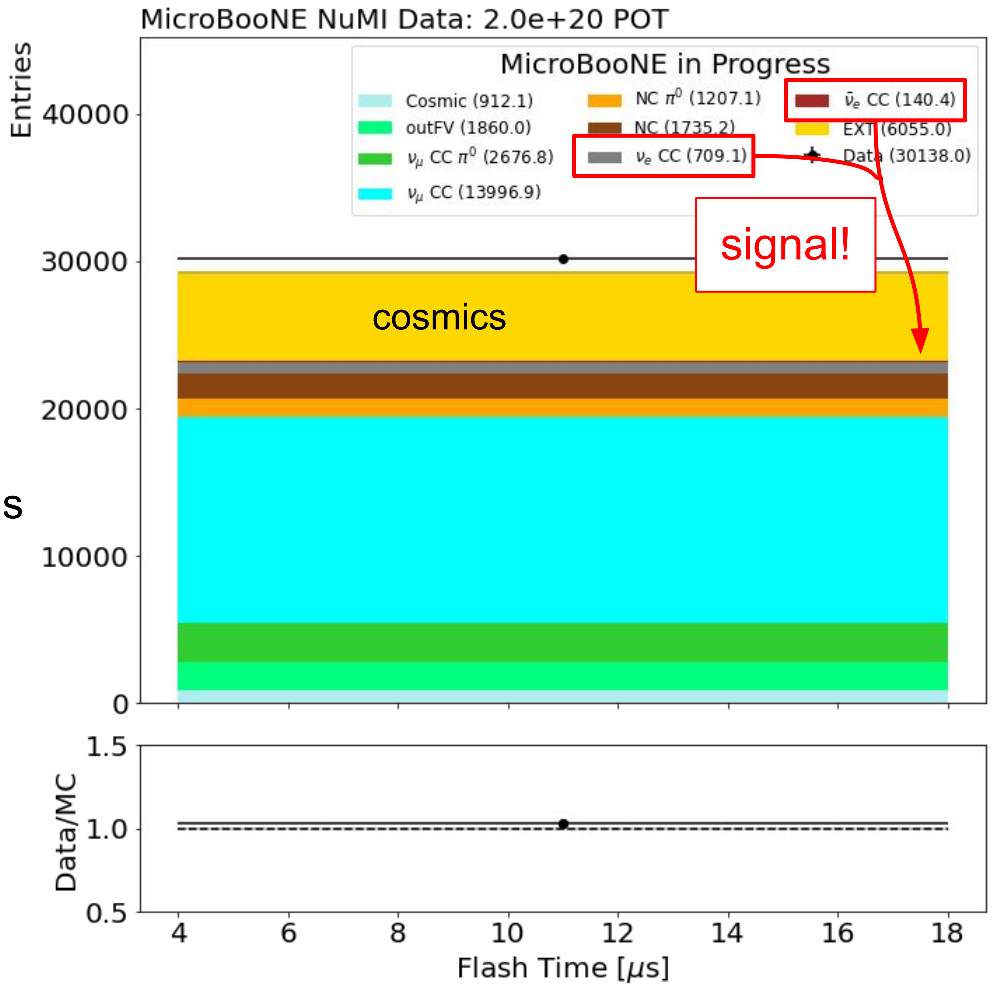


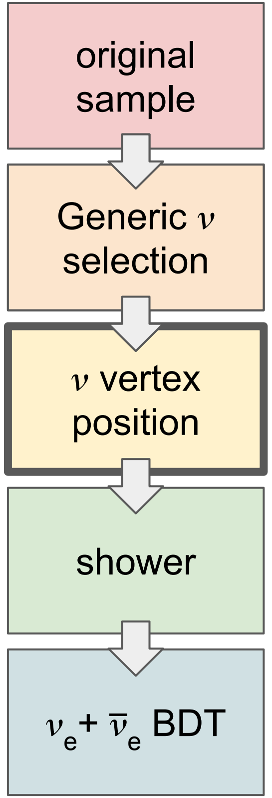
Cosmic ray rejection

~98% of the cosmic ray background is rejected at this stage

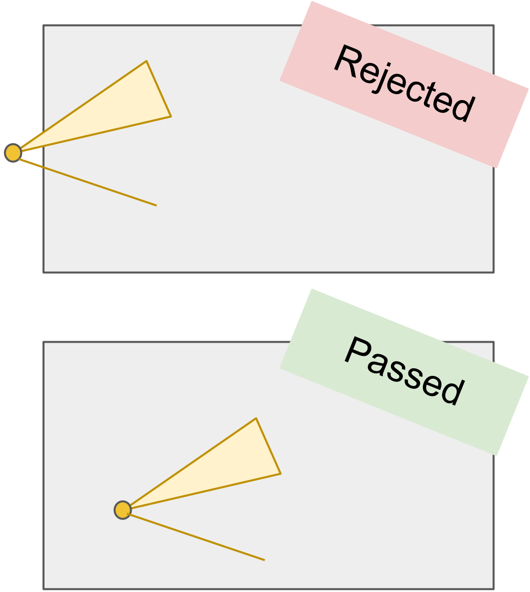
No specific requirements regarding the nature of the neutrino

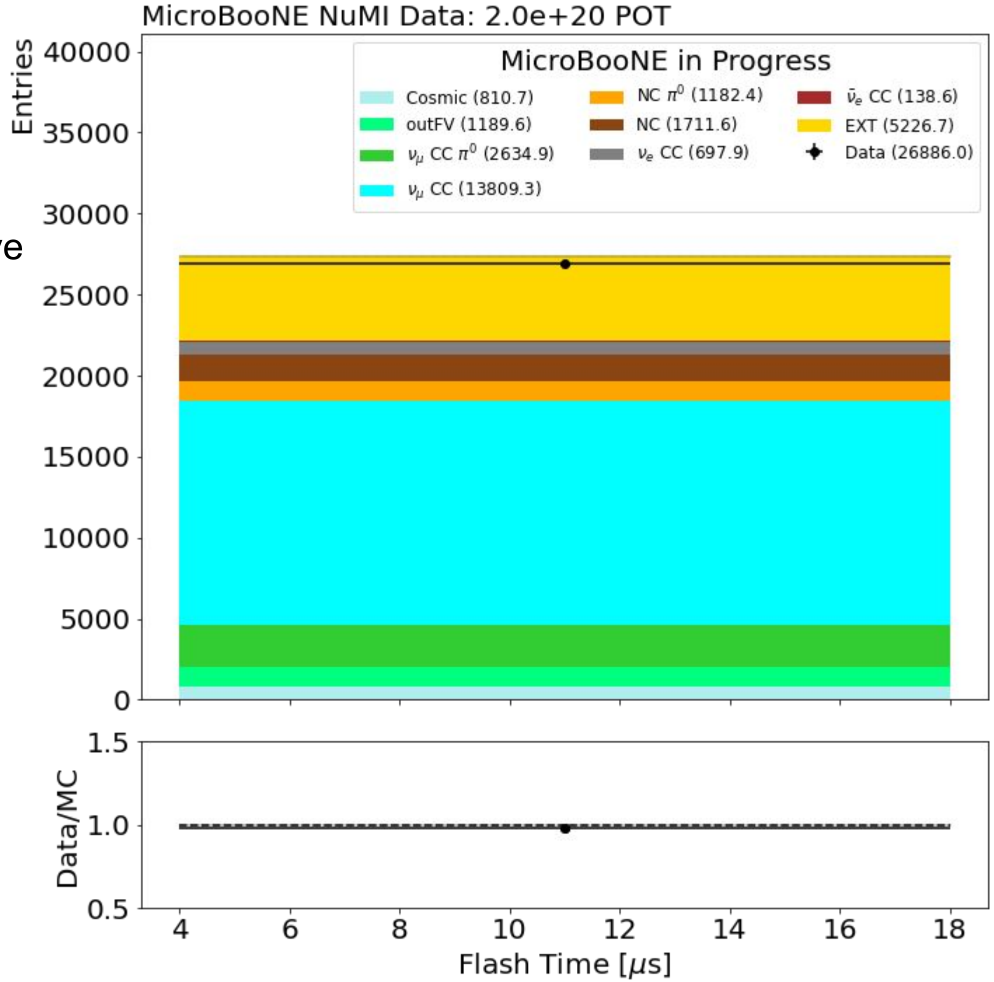


$\nu_e + \overline{\nu}_e$ selection

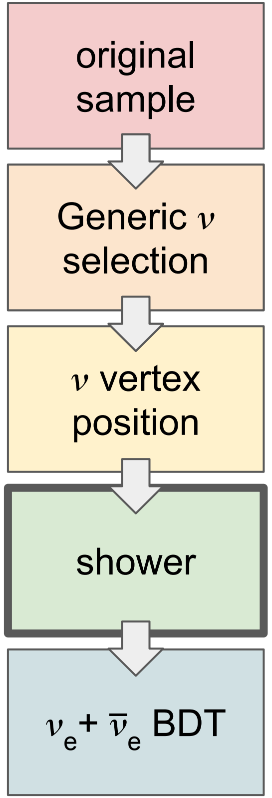


Neutrino vertex within the active volume of the detector

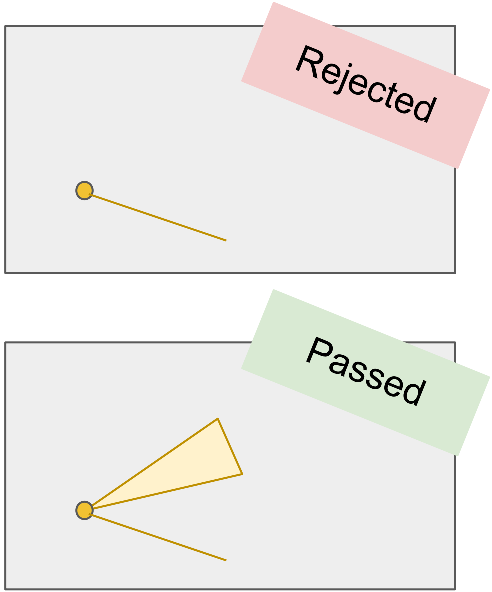


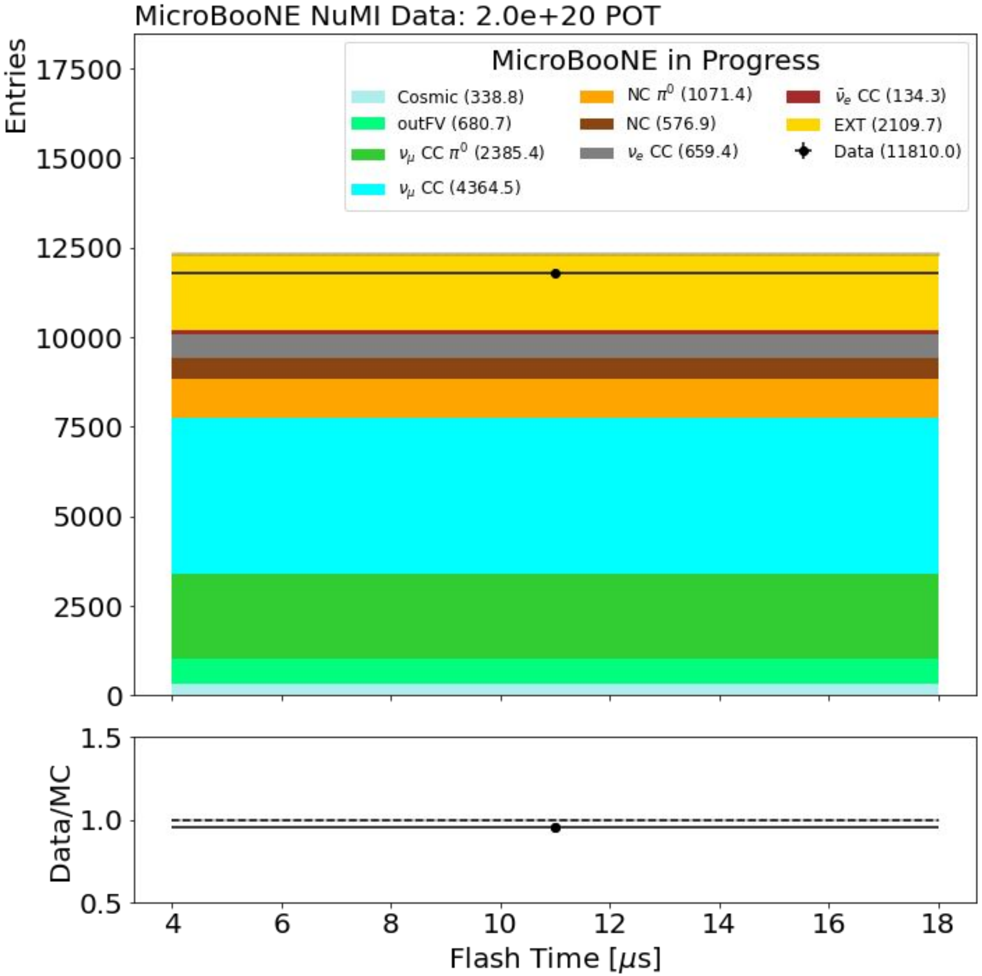


$\nu_e + \bar{\nu}_e$ selection

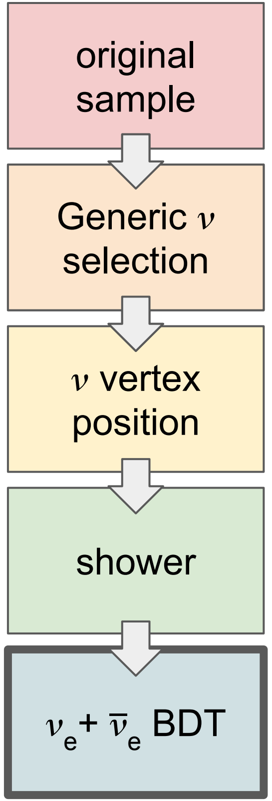


The interaction must produce at least one shower





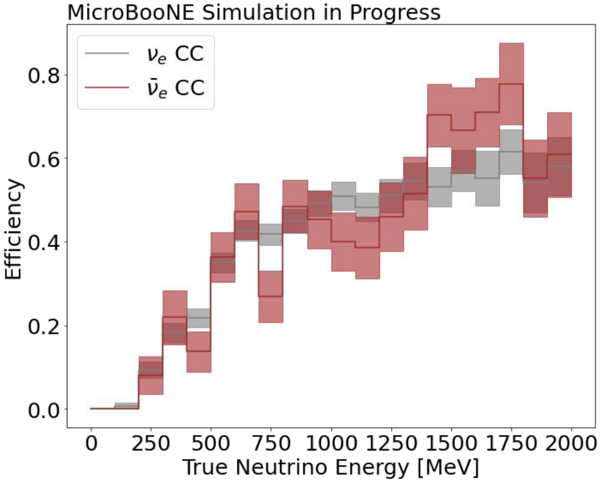
$\nu_e + \bar{\nu}_e$ selection

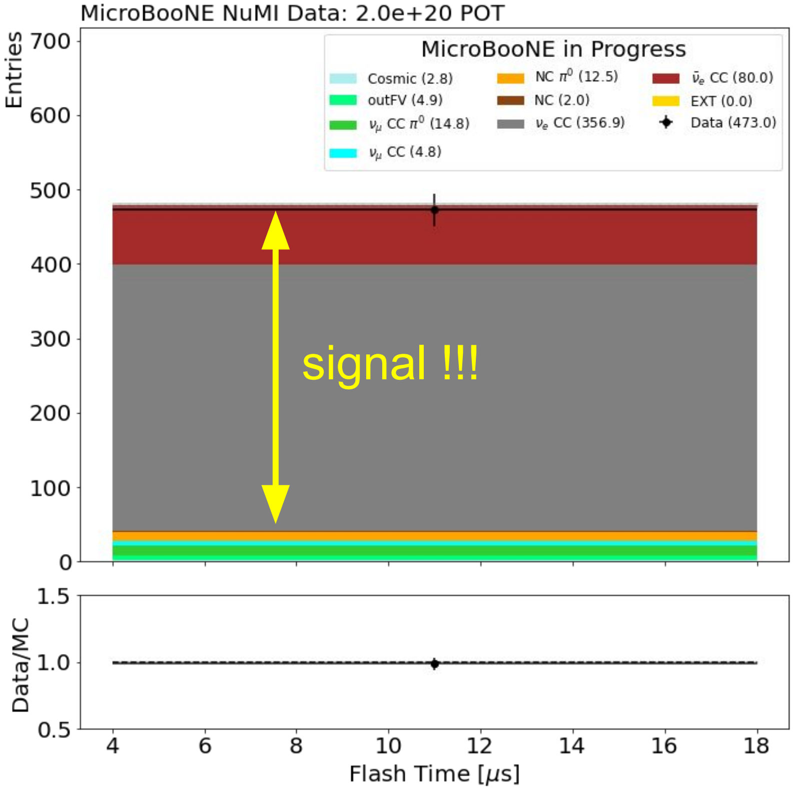


BDT selection focused on selecting $\boldsymbol{\nu_e + \bar{\nu}_e}$ (developed for the LEE inclusive selection)
arXiv 2110.13978

Overall purity of ~90%

473 $\nu_e + \bar{\nu}_e$ candidates in data





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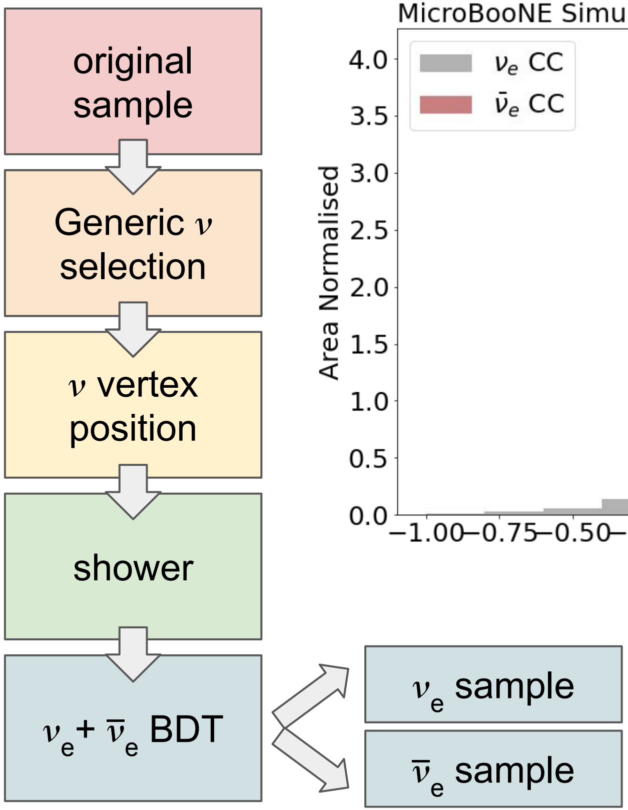
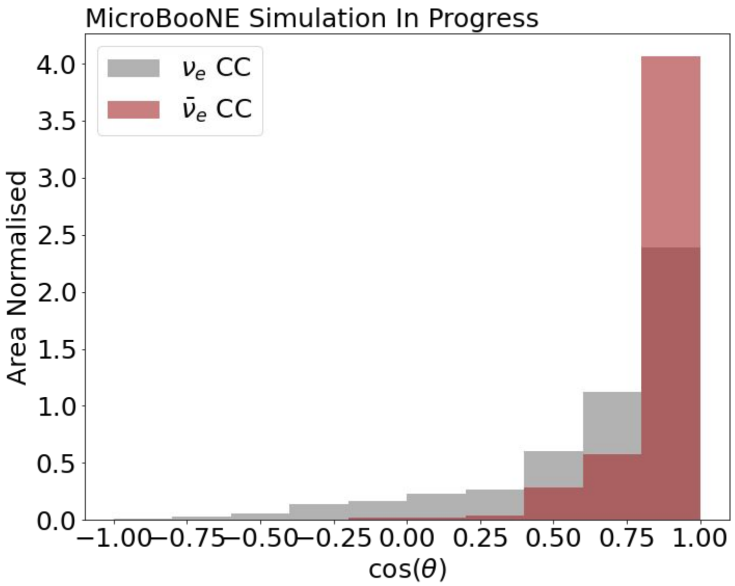
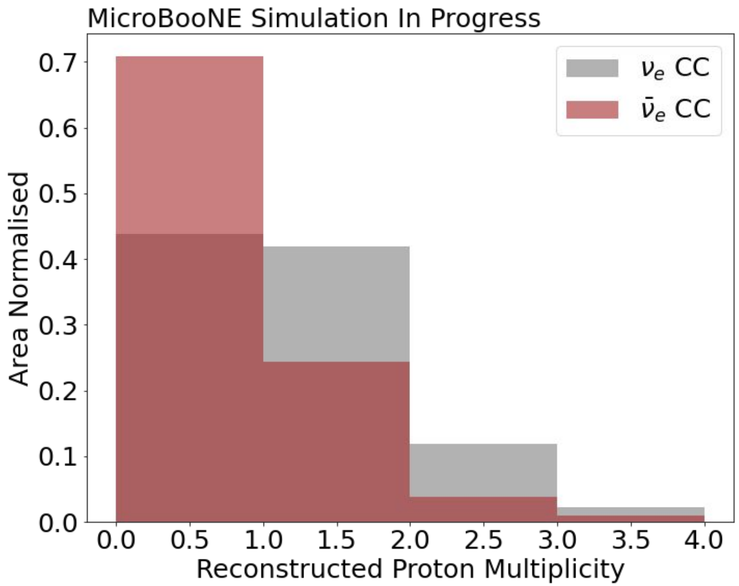
ν_e *versus* $\bar{\nu}_e$ selection





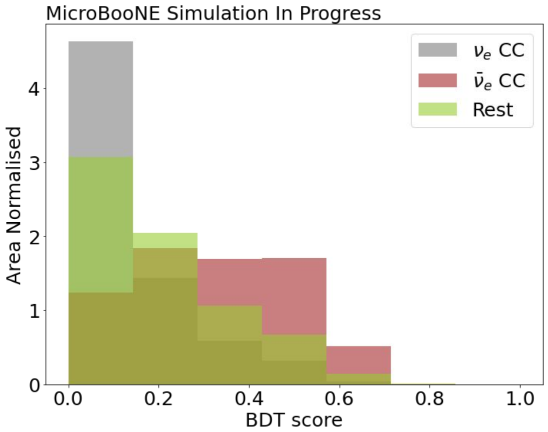


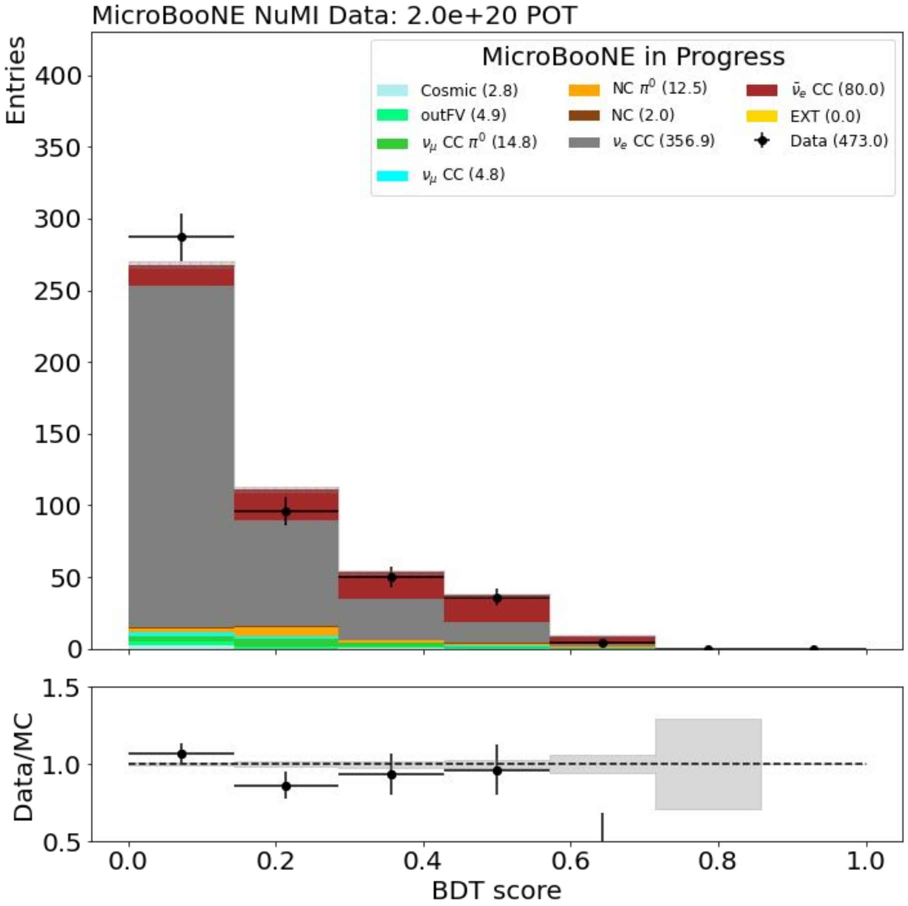
Kinematic variables (such as cosθ and proton multiplicity, above) which can provide separation between ν_e and $\bar{\nu}_e$ are then used to develop a second BDT → **Model dependent measurement**

ν_e versus $\bar{\nu}_e$ BDT

The area normalised distribution of the BDT score peaks towards larger values for signal ($\bar{\nu}_e$CC) and towards 0 for background (ν_eCC + rest)

Different shapes allow to apply the likelihood fit to data to extract the cross-section (currently ongoing stage of my analysis)





Conclusions and summary

- Showed the $\nu_e + \overline{\nu}_e$ CC selection that results in a 90% pure sample with similar efficiency for ν_e and $\overline{\nu}_e$
- Developed a BDT to distinguish ν_eCC and $\overline{\nu}_e$CC interactions that resulted in a BDT score distribution with different shapes for signal and background
- A likelihood fit to data will be performed to extract the cross-section
- This will be the **first** ever measurement of $\overline{\nu}_e$ **on argon**

Thank you for your attention!