

# Searching for Beyond the Standard Model Physics with MicroBooNE

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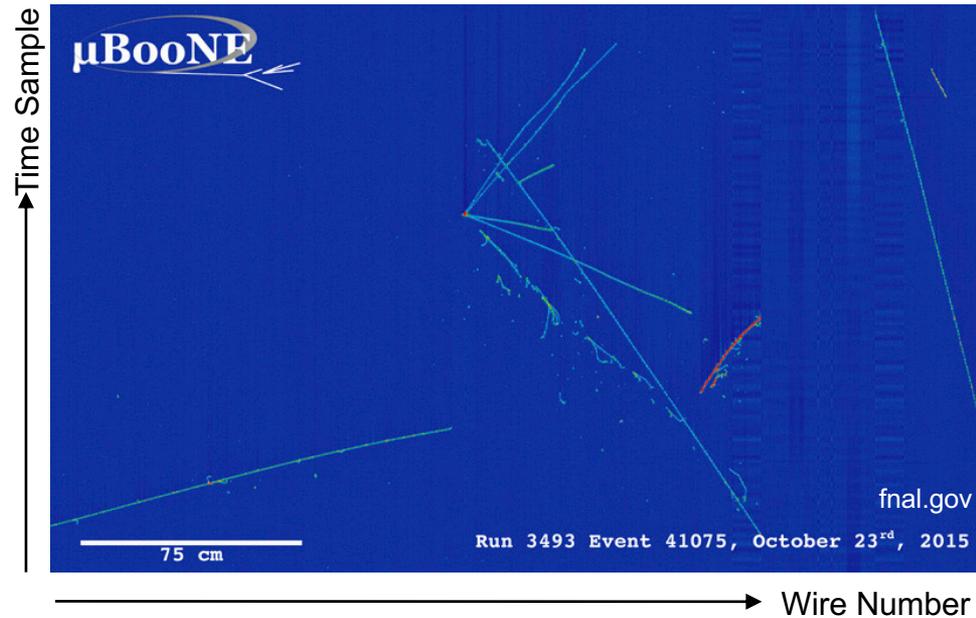
For the MicroBooNE Collaboration

Snowmass Joint Workshop on New Physics Opportunities with Neutrino Experiments

# LArTPC Technology

- LArTPCs offer excellent spatial resolution.
  - 3 mm for MicroBooNE
- As well as excellent calorimetry
- Electron-gamma separation
  - See Mark Ross-Lonergan's talk
- Low detection thresholds
- LArTPCs are an excellent choice for Beyond the Standard Model studies.

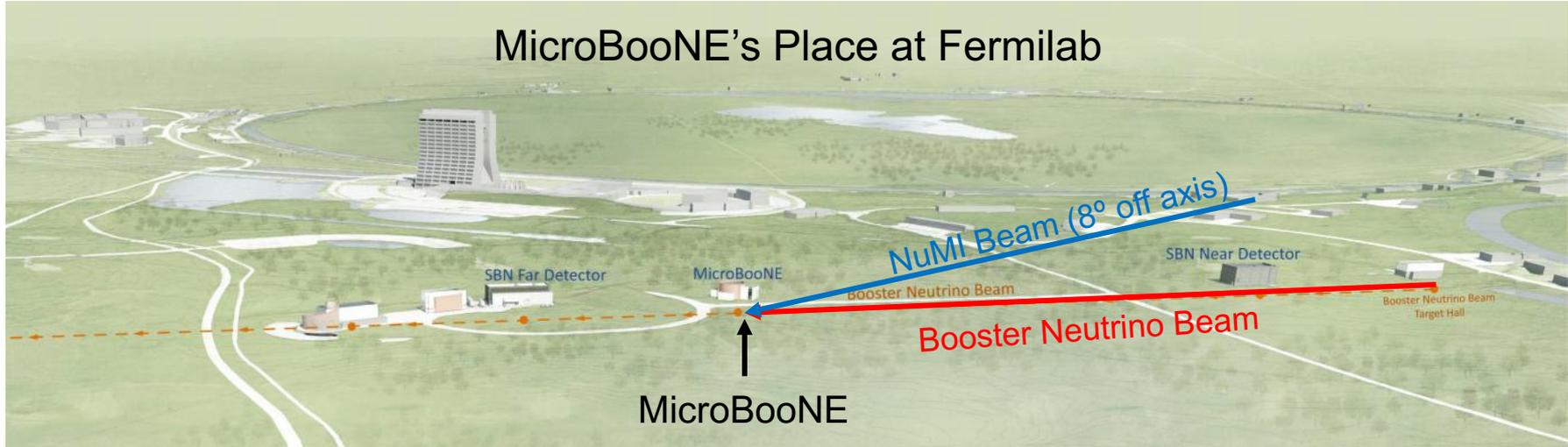
MicroBooNE Event Display



This presentation will explore some of these BSM studies in MicroBooNE.

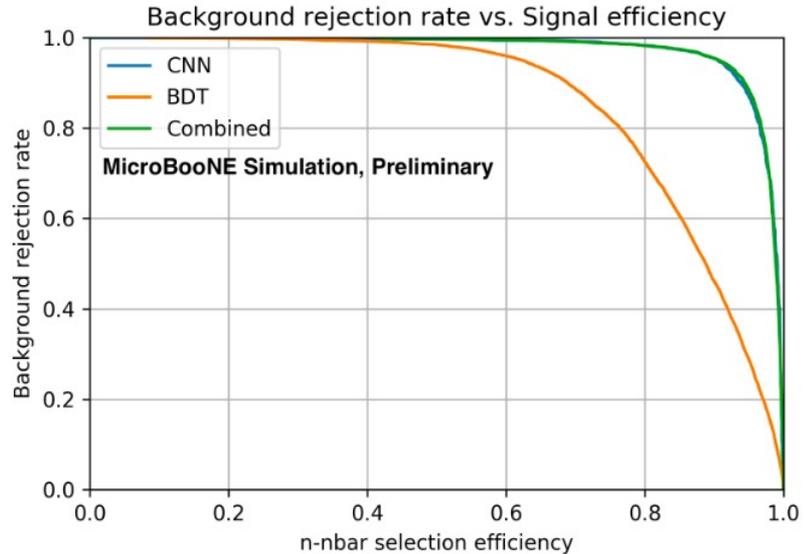
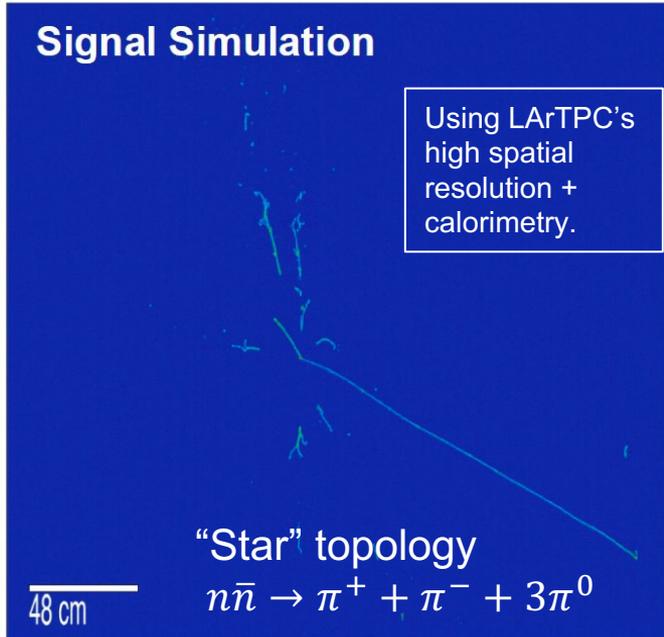
# MicroBooNE

- 85-ton active mass Liquid Argon Time Projection Chamber (LArTPC)
- On-axis to the Booster Neutrino Beam at Fermilab (8 GeV protons)
- Off-axis to the Neutrinos at the Main Injector beam (120 GeV protons)
- Two beams = lots of BSM physics opportunities



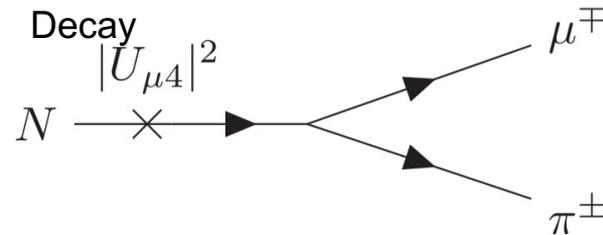
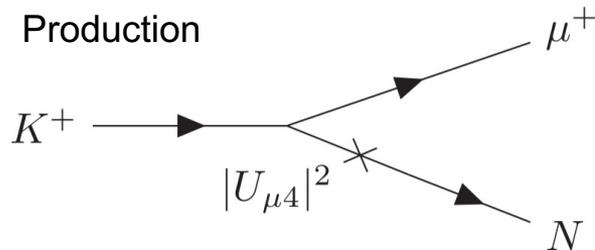
# Neutron-Antineutron Oscillation

- MicroBooNE is developing techniques to search for neutron-antineutron oscillation, a baryon-number violating process.
- Using a convolutional neural network to identify signal
- Useful input for DUNE



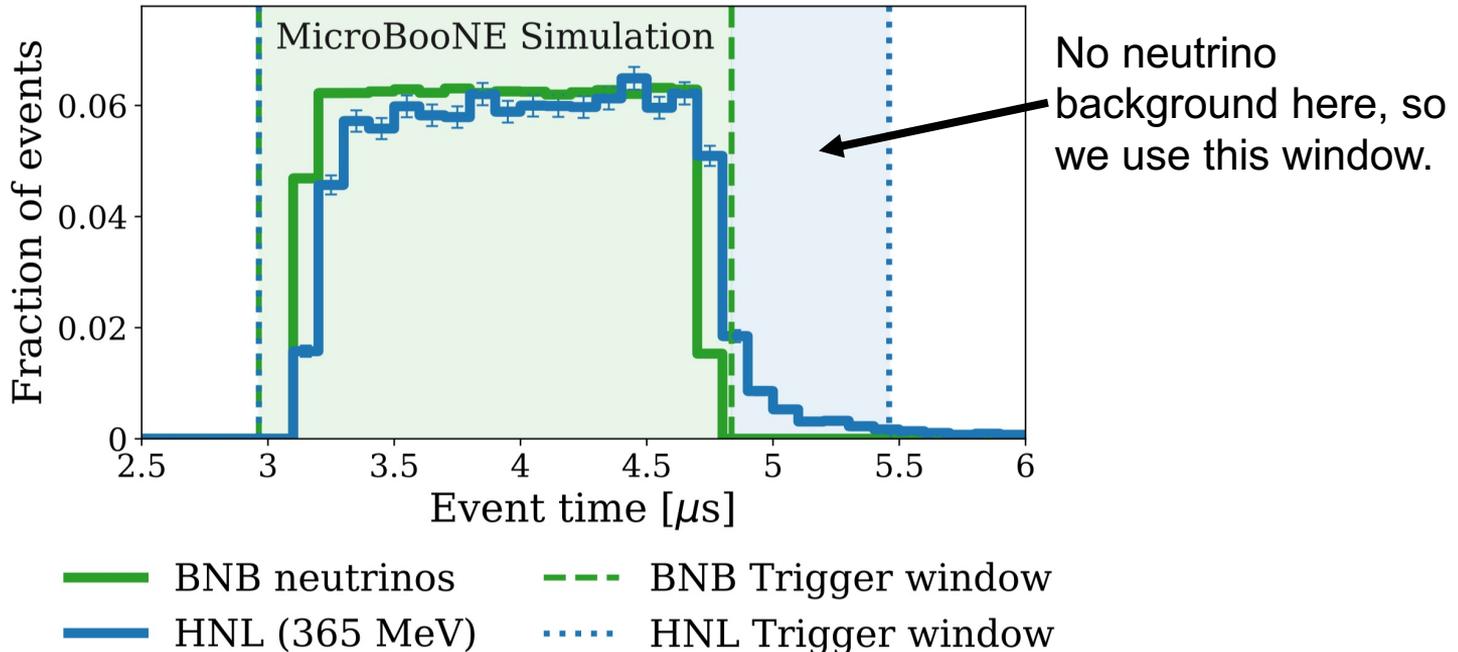
# Heavy Neutral Leptons

- Like neutrinos, but more massive
- Arise from extending the PMNS matrix
  - We will assume  $|U_{e4}|^2 = |U_{\tau 4}|^2 = 0$ .
- Production and decay via SM gauge interactions
- Can be produced in fixed-target setups from charged kaon and pion decay
  - Here we only consider production from  $K^+ \rightarrow \mu^+ + N$  ( $N = \text{HNL}$ ) from the BNB.
- Decay via  $N \rightarrow \mu^+ + \pi^-$  or  $N \rightarrow \mu^- + \pi^+$



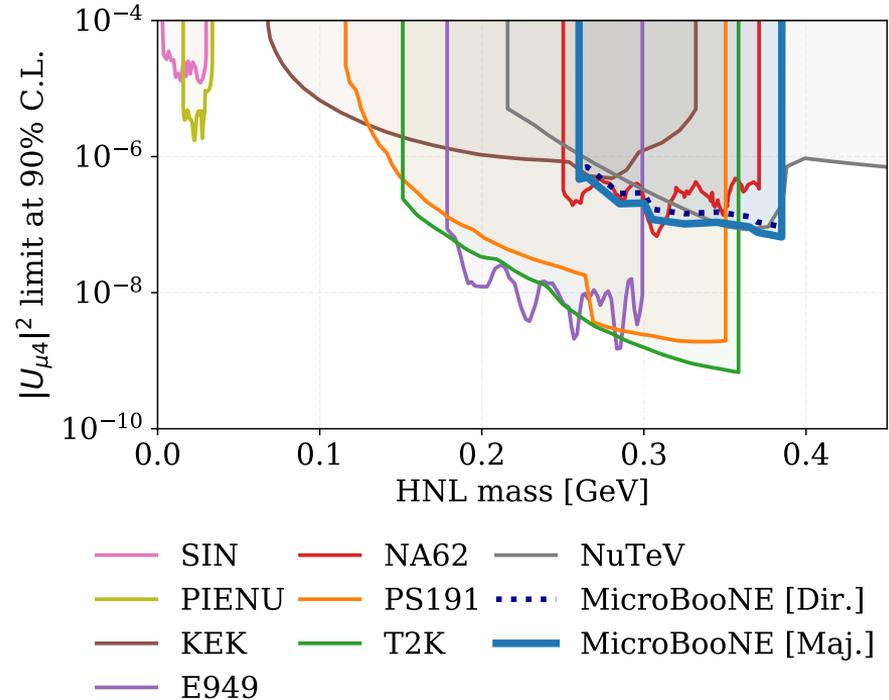
# Searching for HNLs

- HNLs will take on average longer than neutrinos to get to MicroBooNE.
- A special trigger was developed, looking after the BNB beam window.



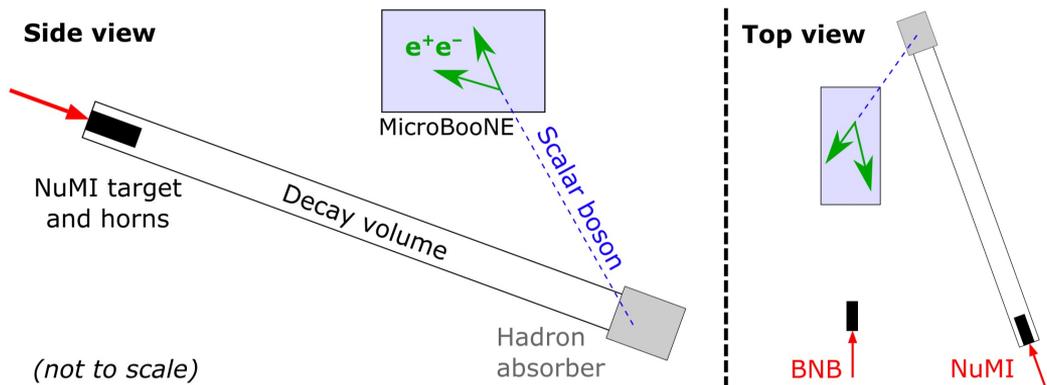
# HNL Results

- We used a BDT to search for HNLs with masses of 260 – 385 MeV.
- We set limits on HNLs with  $K \rightarrow \mu + N$  production and  $N \rightarrow \mu + \pi$  decay.
  - [Published in PRD](#)
- Currently exploring more production and decay modes.



# Higgs Portal Scalars

- Dark scalar which mixes with the Higgs
- Decays into  $l^+l^-$  or  $\pi^+\pi^-$
- Search motivated in response to KOTO's initial results.
- We perform a search using Kaons decaying at rest in the NuMI beam dump.

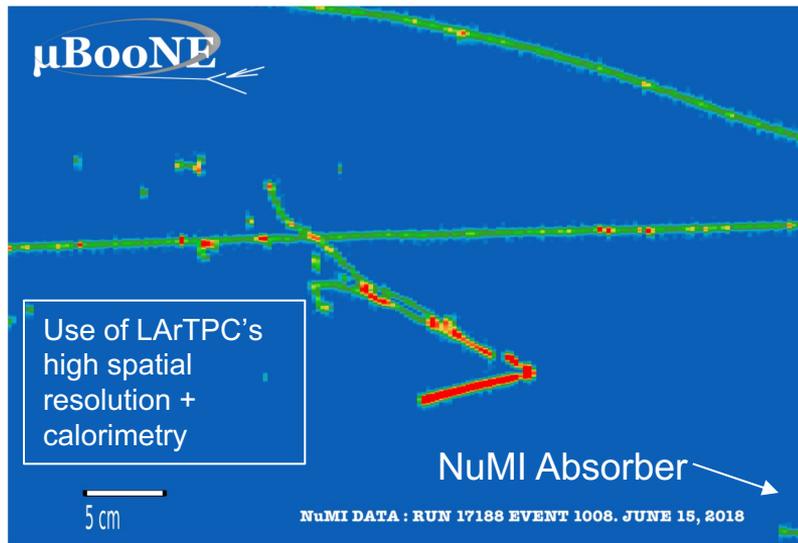


[Phys. Rev. Lett. 127, 151803](#)

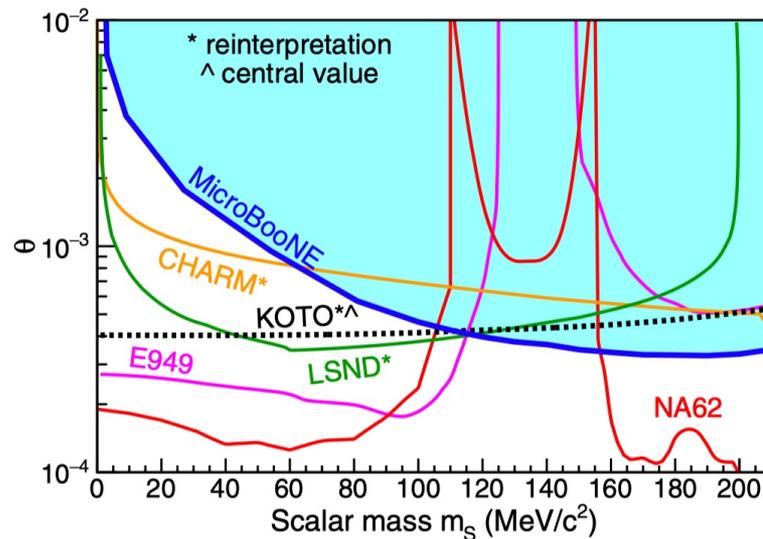
# Higgs Portal Scalars

- We used a BDT to search for the  $S \rightarrow e^+ + e^-$  decay.
- One event passes all cuts, consistent with background.
  - Background expectation:  $2 \pm 1$
- Rules out HPS contribution to KOTO experiment

Candidate Event



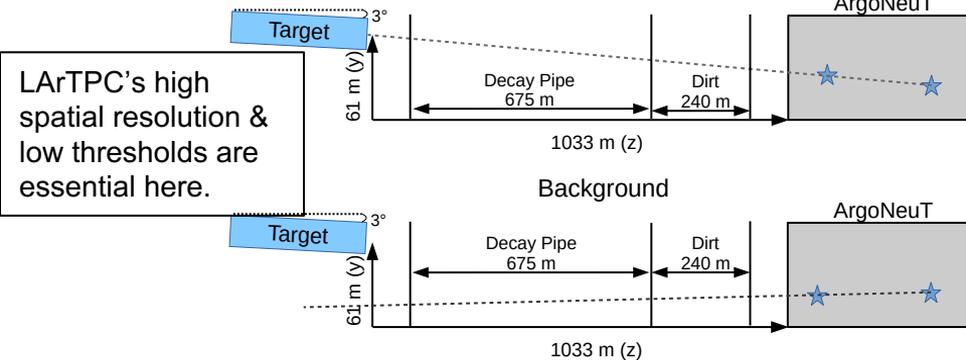
MicroBooNE's Limits



# What Else Are We Working On?

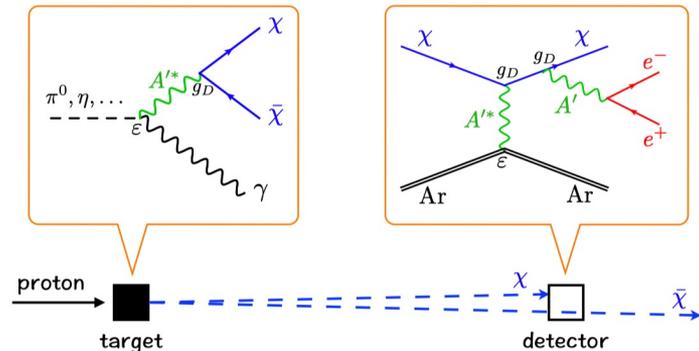
- Other sources of heavy neutral leptons
  - KDAR from NuMI absorber
- Millicharged particles
  - LArTPCs have already been used for such a search.
- Dark Tridents
  - Beam produced dark matter scatters and produces an  $e^+e^-$  trident.

## Millicharged Particle Signal & Background



[Phys. Rev. Lett. 124, 131801](#)

## Dark Trident Production & Detection



[JHEP 01 \(2019\) 001](#)

# Summary

- MicroBooNE has demonstrated that one can use LArTPCs to preform world leading BSM searches
- This presentation has highlighted three such studies.
  - Neutron-antineutron oscillation
  - Heavy neutral leptons
  - Higgs portal scalars
- MicroBooNE continues to look for evidence of exotic new physics.
  - If you have an idea of something we should search for, get in touch!
- New results coming soon!

arXiv:1911.10545v2 [hep-ex] 12 Feb 2020

FERMILAB-PUB-19-581-ND

Search for heavy neutral leptons decaying into muon-pion pairs in the MicroBooNE detector

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Search for a Higgs Portal Scalar Decaying to Electron-Positron Pairs in the MicroBooNE Detector

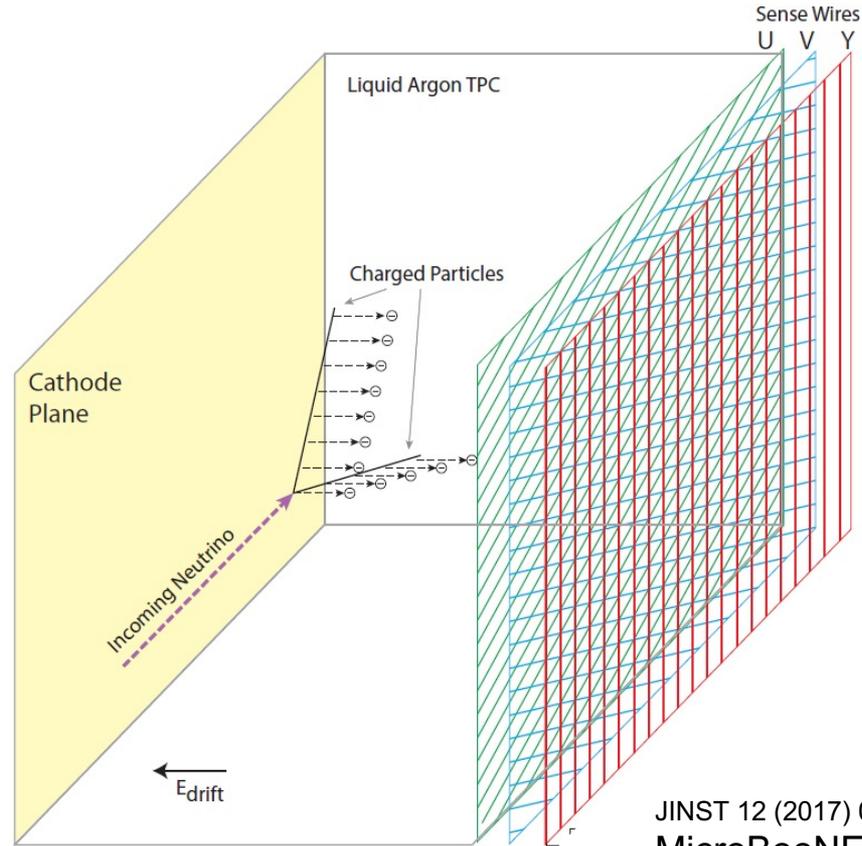
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# LArTPC Technology



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MicroBooNE's PMTs are not shown.