

# Recent Astro-Particle & Exotic Physics results from MicroBooNE

David Marsden  
University of Manchester  
For the MicroBooNE Collaboration

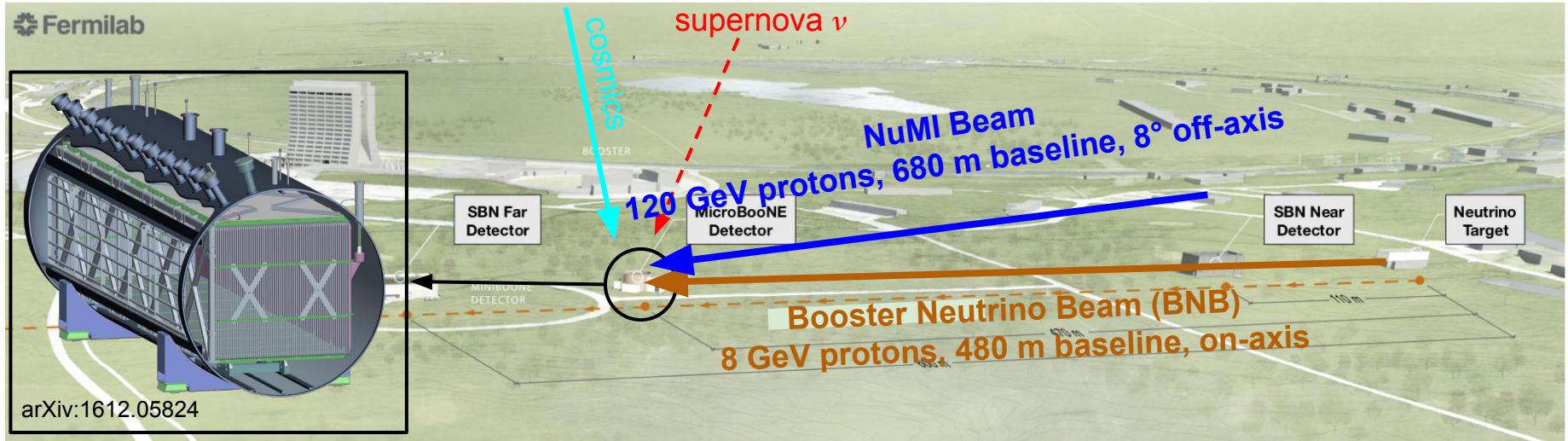
SUSY 2021

MANCHESTER  
1824

The University of Manchester



# MicroBooNE introduction



Experiment objectives:

Investigate MiniBooNE Low Energy Excess

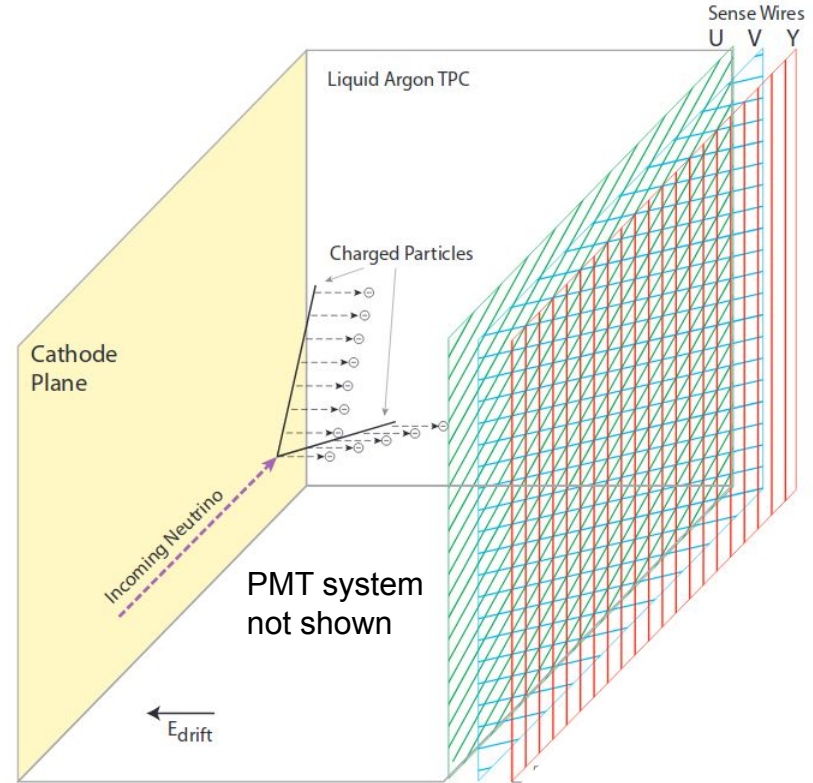
Cross section measurements

LArTPC detector physics, R&D

Also many diverse topics in astroparticle and exotic physics, which can be explored with MicroBooNE - what we'll look at now

# LArTPCs introduction

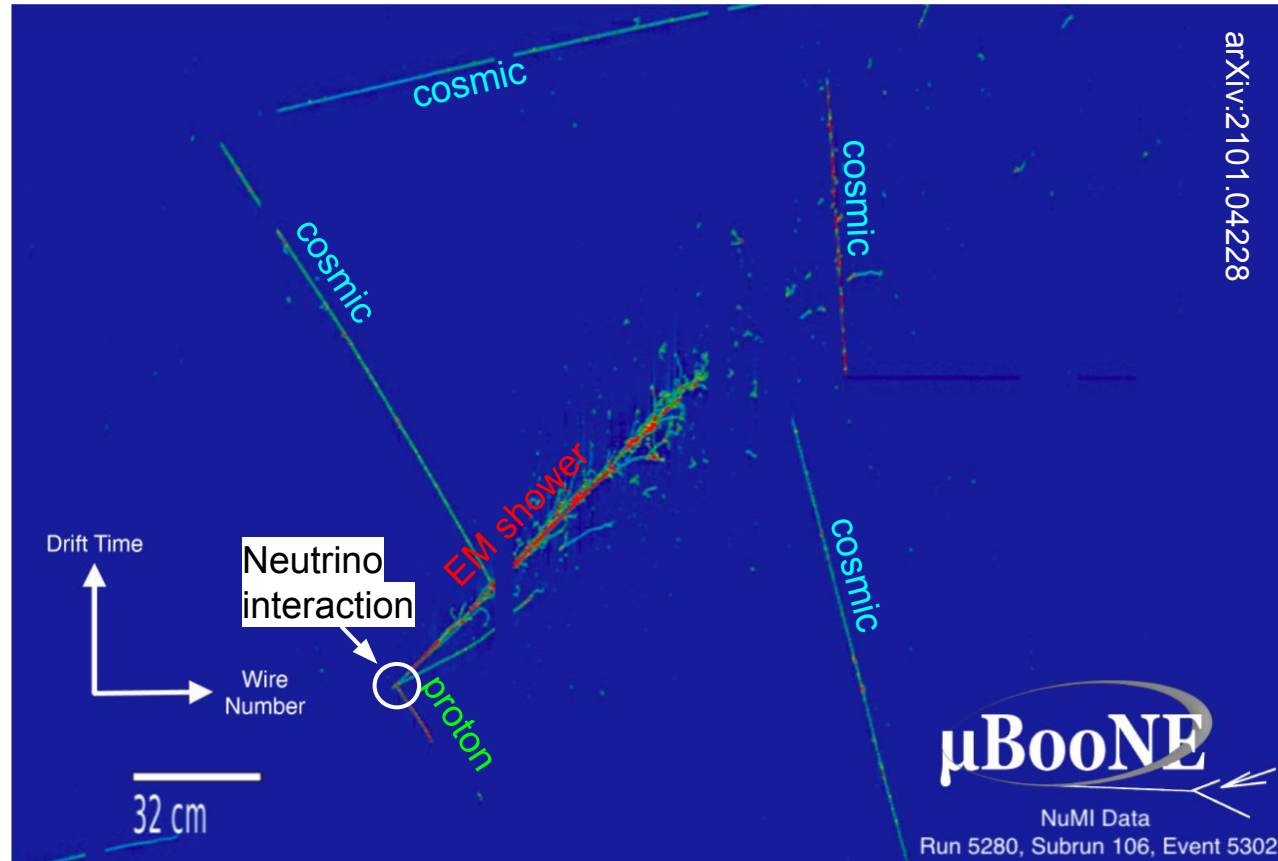
- Scintillation and ionisation signals used to produce bubble chamber like images of events
- Offers excellent spatial resolution
  - 3 mm in MicroBooNE
- Excellent calorimetry and low thresholds
  - 100 keV for electrons
  - 20 MeV for protons



JINST 12 (2017) 09, P09014

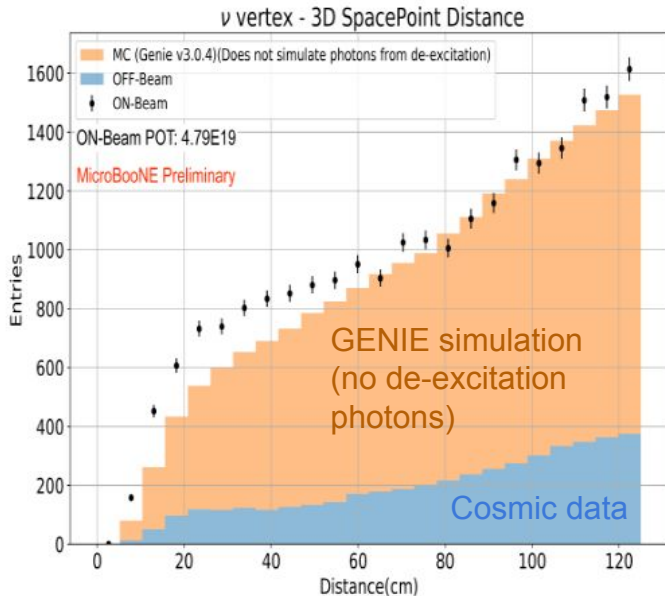
# LArTPCs introduction - Event display

- Allows for powerful particle identification
- We can detect:
  - Cosmic ray muons  $O(1-10 \text{ GeV})$
  - Beam neutrino interactions  $O(\text{GeV})$
  - Supernova neutrinos  $O(10 \text{ MeV})$
  - Anomalous final states - new physics!

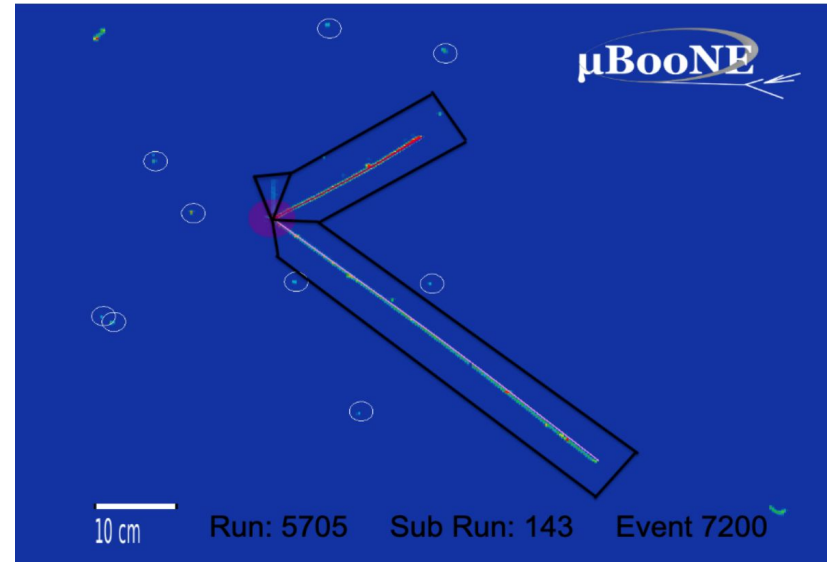


# MeV Scale reconstruction

- MeV scale event reconstruction is important for many low energy studies
- Used “blips” of ionisation from low-energy gammas



MICROBOONE-NOTE 1076-PUB



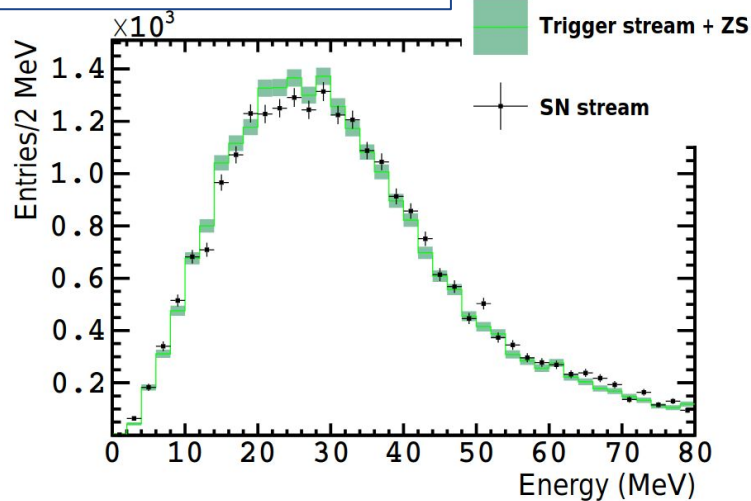
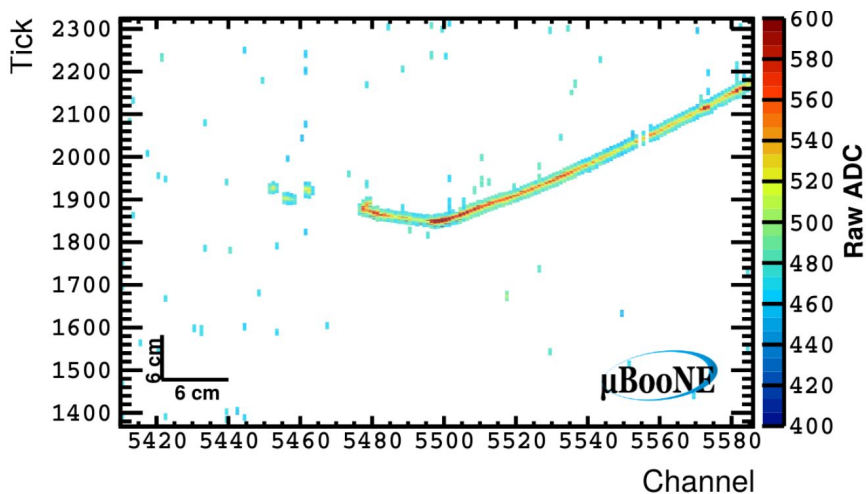
Applications:  
Supernova neutrino reconstruction  
Muon/pion separation  
Some BSM searches e.g. millicharged particles

# Continuous readout for supernova neutrino detection

- Detecting a supernova neutrino burst requires continuous data readout (33GB/s raw data from MicroBooNE)
- Pioneered a system to zero-suppress and compress data
- Evaluated performance by looking at reconstruction of Michel electrons

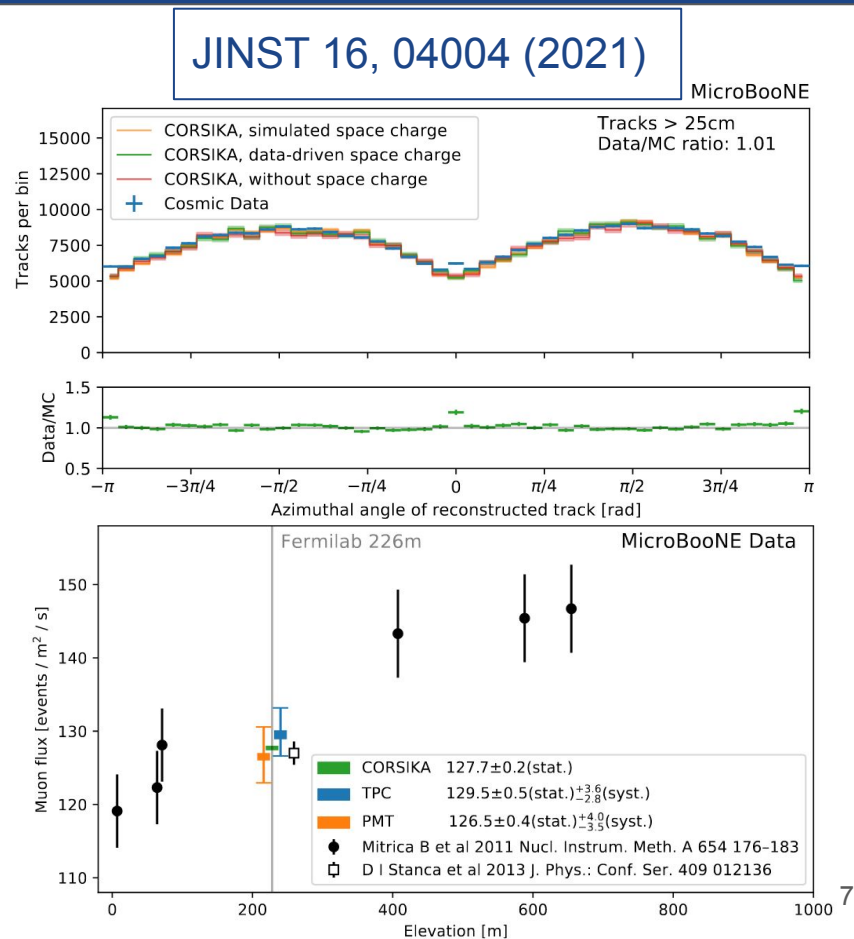
JINST 16 (2021) 02, P02008

Event Display after zero suppression



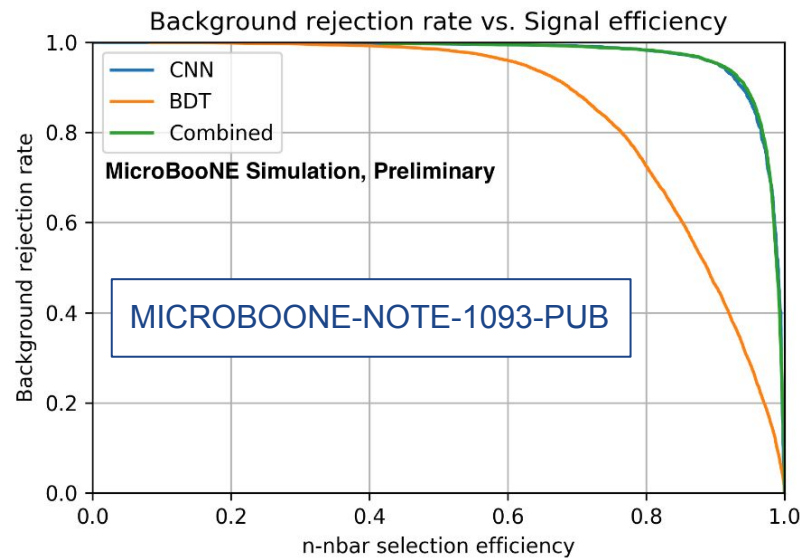
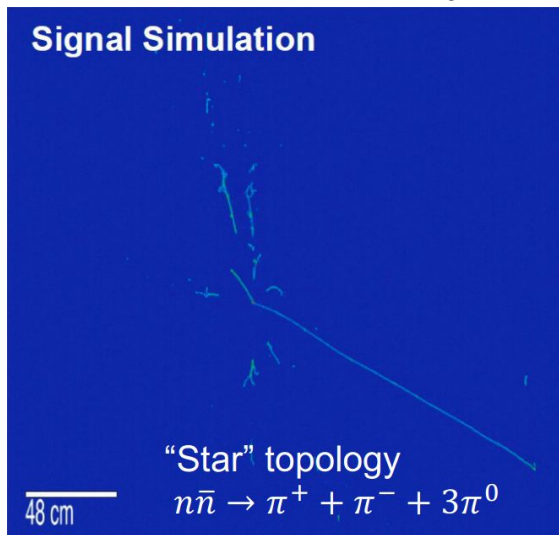
# Cosmic ray measurement

- Used MicroBooNE data to measure the rate of cosmic ray muons at the surface at Fermilab
- Found good agreement with a CORSIKA simulation
- Useful for tuning cosmic simulation and as an input for future experiments at Fermilab, including SBN program and DUNE



# Neutron-antineutron oscillation

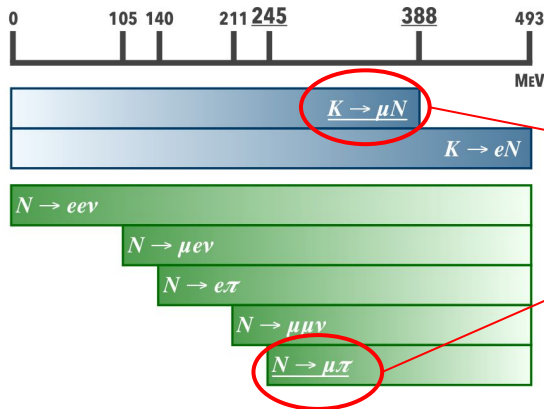
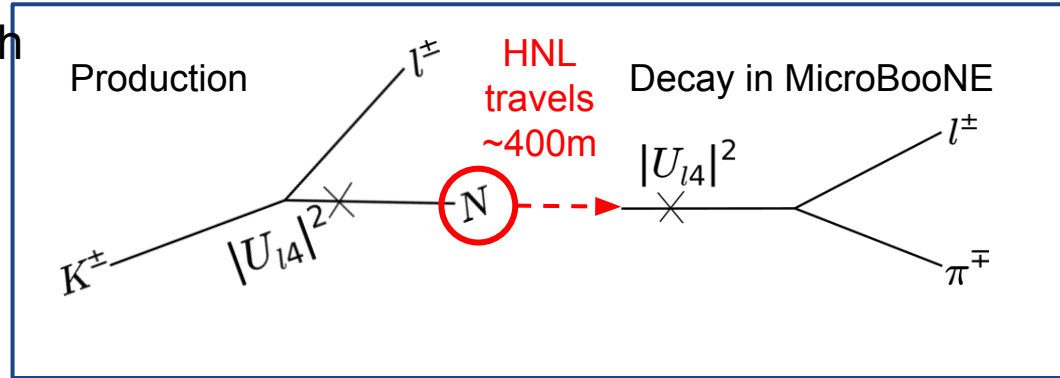
- Searched for this baryon-number violating process in argon
- Trained a Convolutional Neural Network (CNN) to identify signal over cosmic-induced background
- MicroBooNE will not have competitive sensitivity but have pioneered techniques which may be used in DUNE





# Heavy Neutral Leptons

- Searches for neutral leptons with mass  $O(100 \text{ MeV})$
- Produced via mass mixing with SM neutrinos with extended PMNS element  $|U_{l4}|$
- Could decay inside MicroBooNE

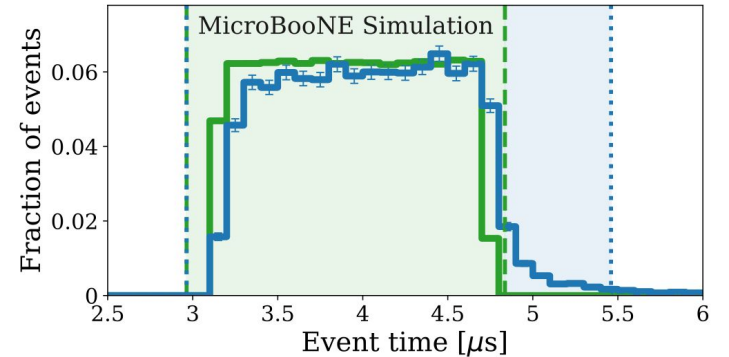


Focusing on these production and decay channels gives a mass range of 245-388 MeV

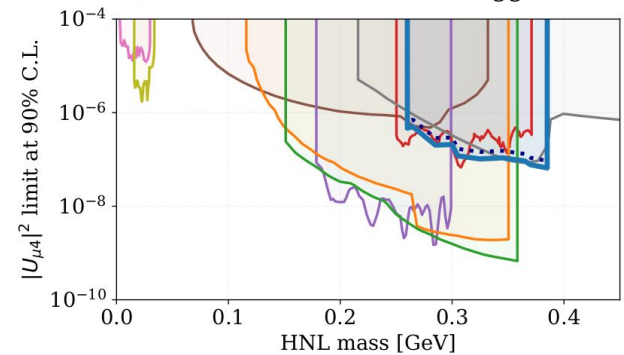
# Heavy Neutral Leptons

Phys.Rev.D101, 052001 (2020)

- First HNL search using a LArTPC
- Developed a “late window” trigger specifically for this analysis
  - Effectively eliminates in-beam neutrino events which would be background
- Looked for decays to muon+pion to set a limit on HNL mixing element  $|U_{\mu 4}|$
- No excess discovered



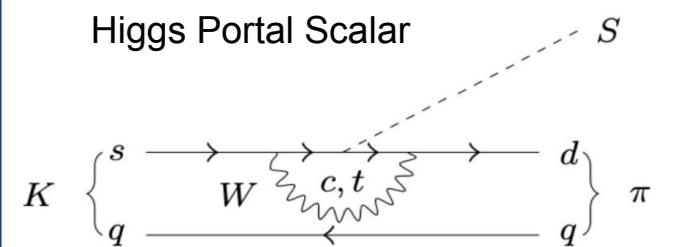
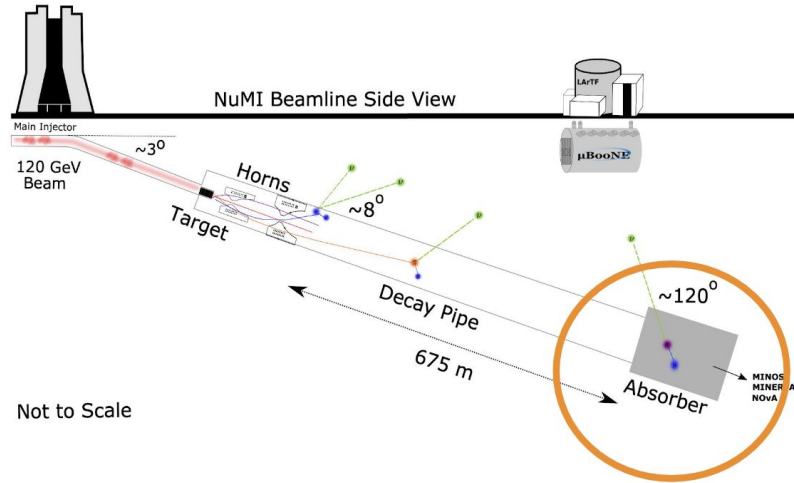
— BNB neutrinos      - - - BNB Trigger window  
— HNL (365 MeV)      ····· HNL Trigger window



— SIN      — NA62      — NuTeV  
— PIENU      — PS191      ····· MicroBooNE [Dir.]  
— KEK      — T2K      — MicroBooNE [Maj.]  
— E949

# Heavy Neutral Leptons Further Work

- Using Kaons decaying at rest from NuMI to set a new limit for MicroBooNE
- These HNLs would enter the detector at a large angle and would be mono-energetic
- Simultaneously looking for similar Higgs Portal Scalar decays ( $\mu^+\mu^-$  or  $\pi^+\pi^-$ )
- Also exploring other decay channels to probe different mass ranges of HNL

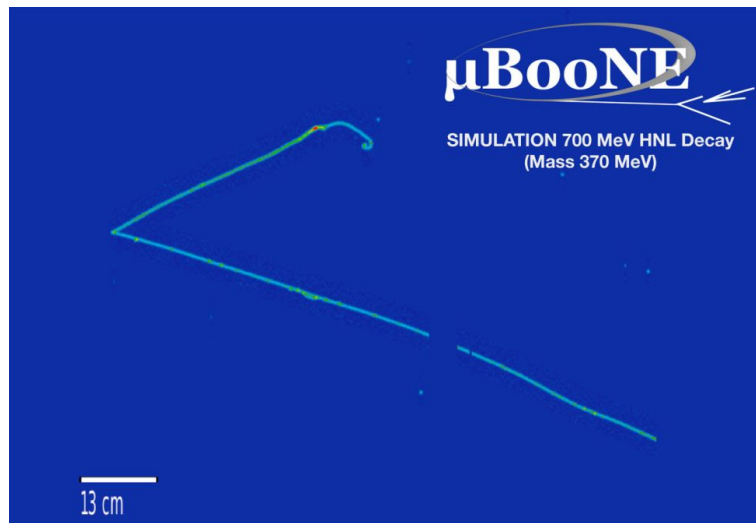


See Pawel Guzowski's talk "Search for Higgs portal scalar decaying in MicroBooNE" for more



# Summary

- MicroBooNE is performing a variety of astroparticle and exotic physics searches in addition to other primary physics studies
- Recent exciting results include:
  - Supernova continuous readout ([JINST 16, 02, P02008 \(2021\)](#))
  - MeV Scale Physics ([MICROBOONE-NOTE 1076-PUB](#))
  - Cosmic ray rate measurement ([JINST 16, 04004 \(2021\)](#))
  - Neutron-antineutron oscillation analysis ([MICROBOONE-NOTE-1093-PUB](#))
  - Searches for heavy neutral leptons ([Phys.Rev.D101, 052001 \(2020\)](#)) and Higgs portal scalars ([arXiv:2106.00568](#))
- Many more results to come!



Simulated Heavy Neutral Lepton decay in MicroBooNE

# Backup

# Millicharged Particles

- Particles with a fraction of electric charge, potential dark matter candidates
- Could scatter off atomic electrons and cause “blips” of ionisation in LAr
  - MeV scale reconstruction useful
- Previous search in much smaller LArTPC ArgoNeuT, MicroBooNE could improve limits

