Exploring Physics Beyond the Standard Model with MicroBooNE

David Marsden

University of Manchester

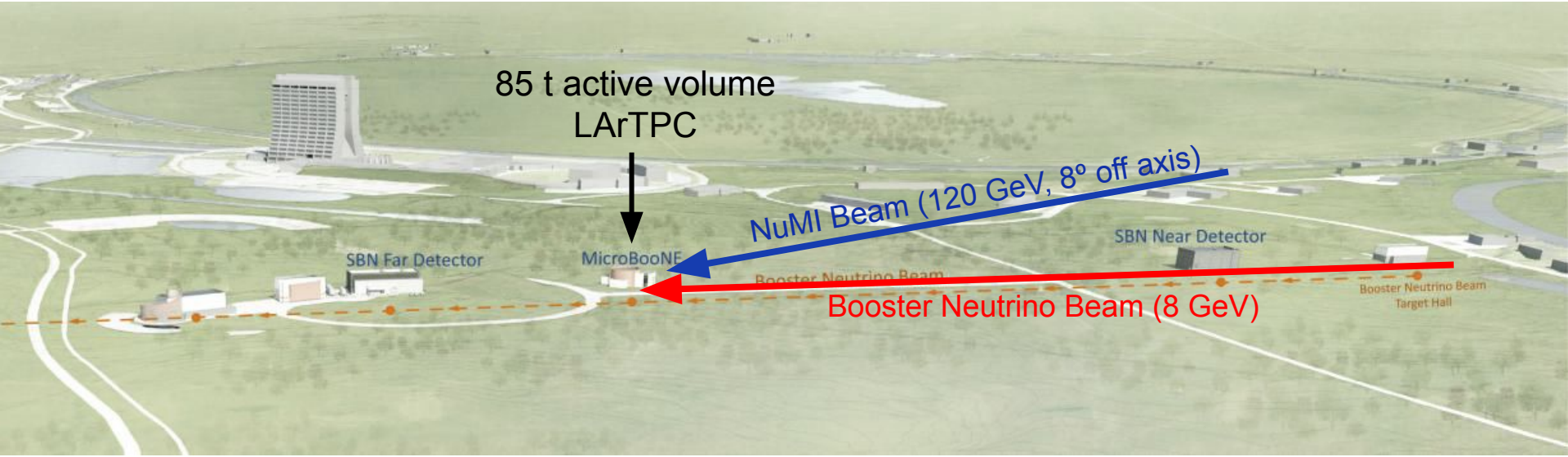
For the MicroBooNE Collaboration

ICHEP 2022

MANCHESTER 1824
The University of Manchester

μBooNE

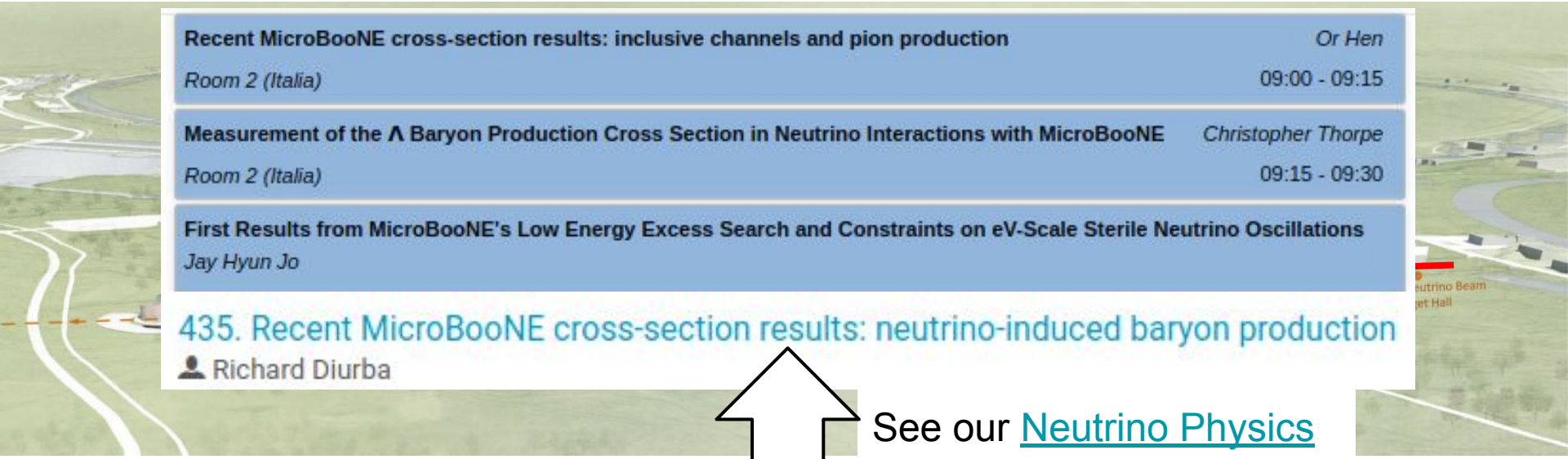
MicroBooNE



Experiment objectives:

Investigate MiniBooNE Low Energy Excess	Cross section measurements	LArTPC detector physics, R&D

MicroBooNE



See our Neutrino Physics talks + poster from Friday

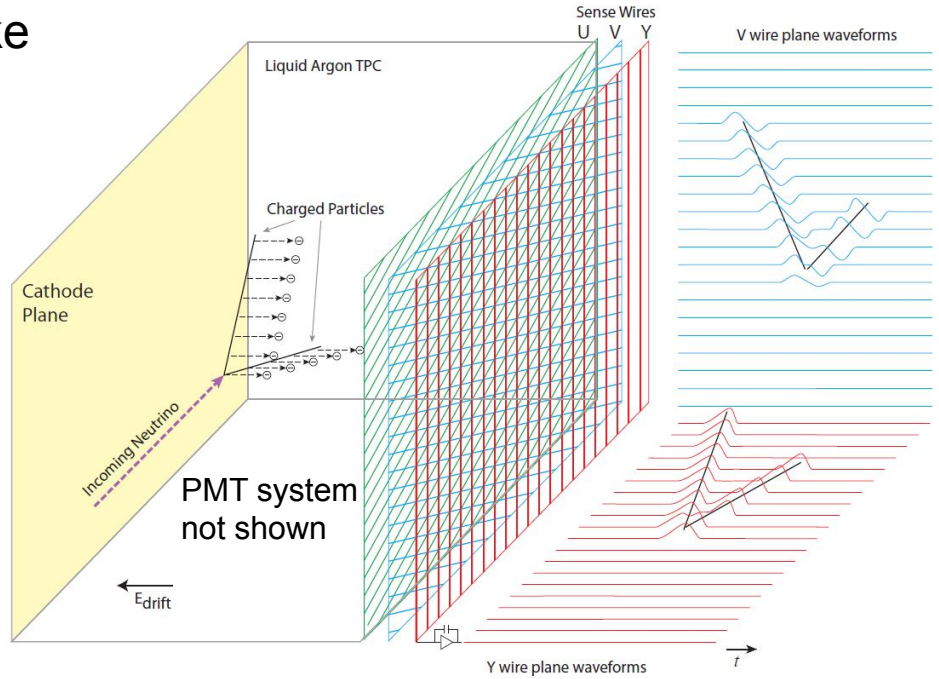
Experiment objectives:

- Investigate MiniBooNE Low Energy Excess
- Cross section measurements
- LArTPC detector physics, R&D

Also many opportunities for **BSM studies** - this talk

LArTPC Technology

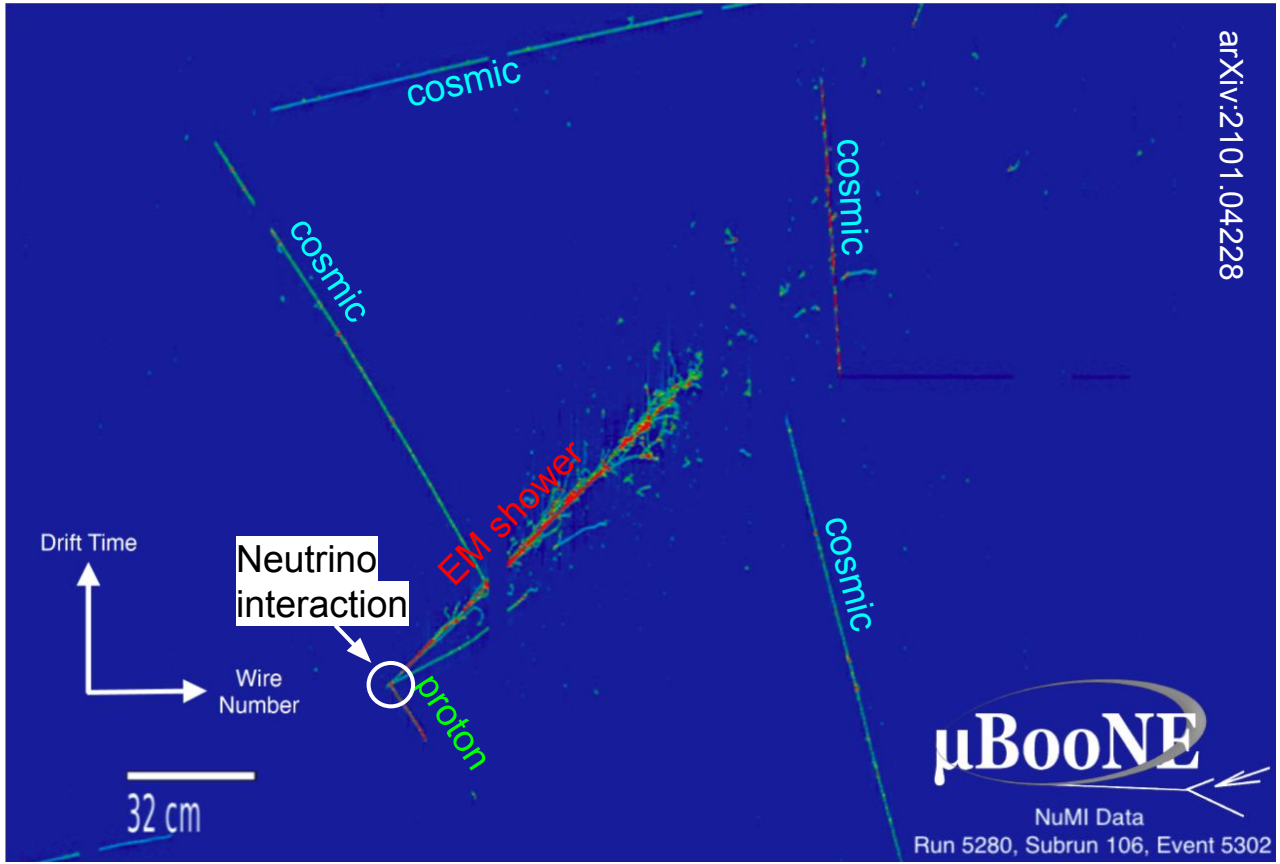
- Scintillation and ionisation signals used to produce bubble chamber like images of events
- Offers excellent spatial resolution
  - 3 mm in MicroBooNE
- Excellent calorimetry and low thresholds
  - 100 keV for EM single hits
  - 300 MeV for protons



JINST 12 (2017) 09, P09014

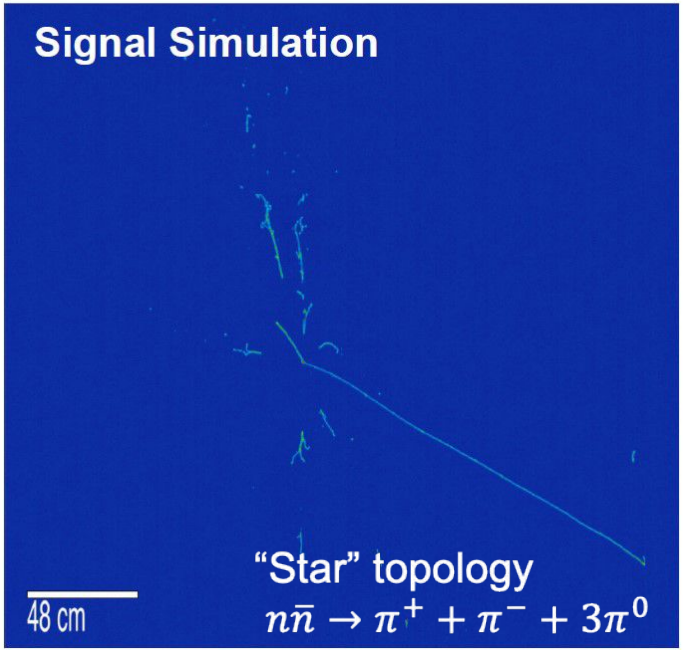
LArTPC - Event Display

- Allows for powerful particle identification
- We can detect:
  - Cosmic ray muons O(1-10 GeV)
  - Beam neutrino interactions O(GeV)
  - **Anomalous final states - new physics!**



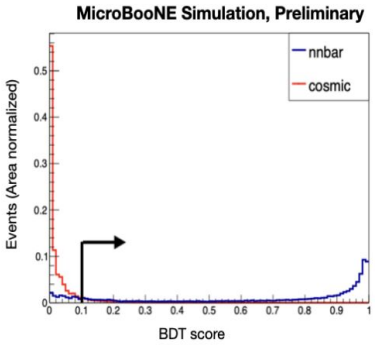
Neutron-Antineutron Oscillation

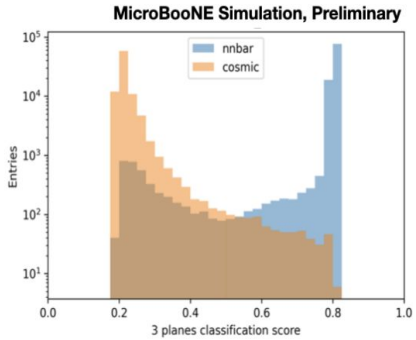
- n spontaneously transforms into $\bar{n}$, a baryon-number violating process
- First search for this process in a LArTPC
- Useful input for DUNE

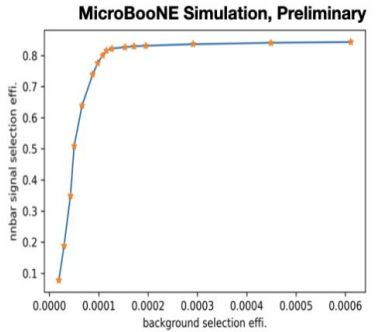


Y. Jwa, ICHEP 2020

Developed novel machine learning techniques (CNN, BDT) to efficiently select signal



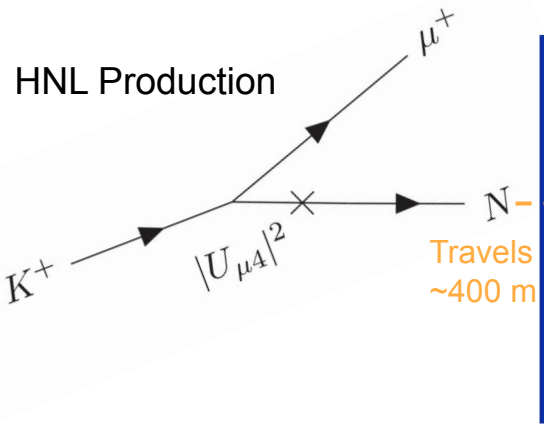


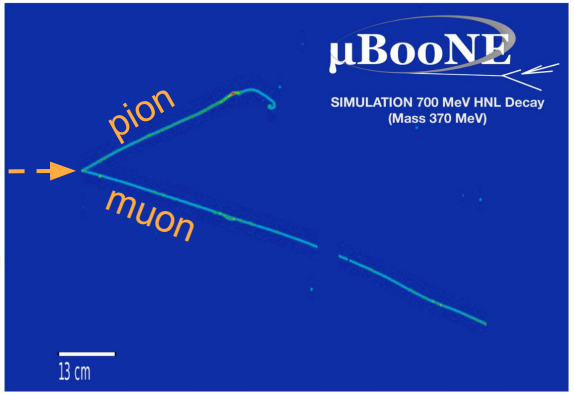


MICROBOONE-NOTE-1093-PUB , MICROBOONE-NOTE-1113-PUB

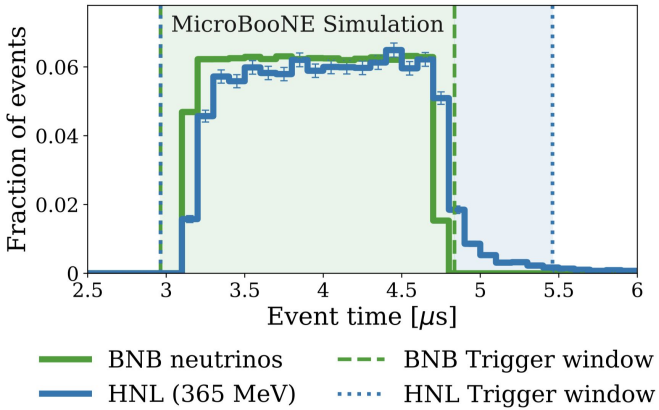
Heavy Neutral Leptons

- O(100 MeV) mass neutral leptons
- Mix with SM neutrinos via extended PMNS matrix elements
- Search for weak decays inside MicroBooNE
- Developed specific BNB “late trigger” window
  - Excludes beam neutrino background



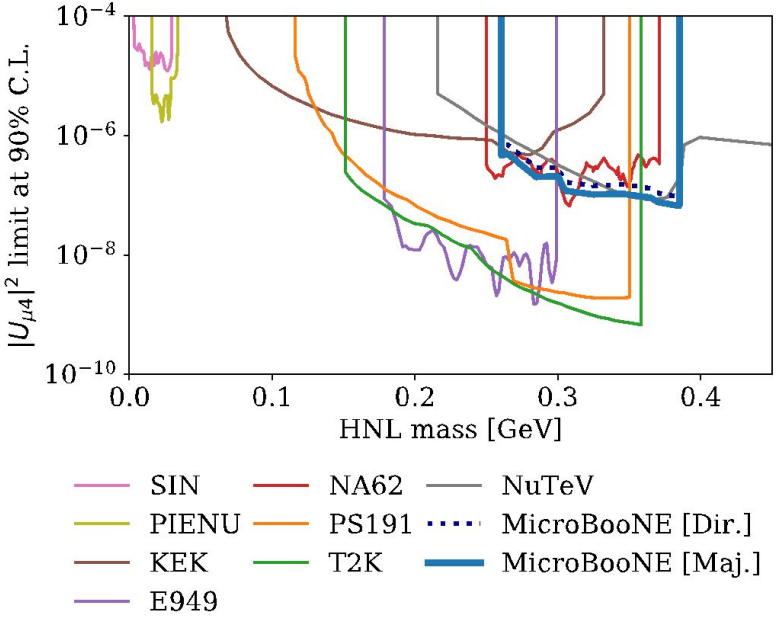


Phys. Rev. D **101**, 052001

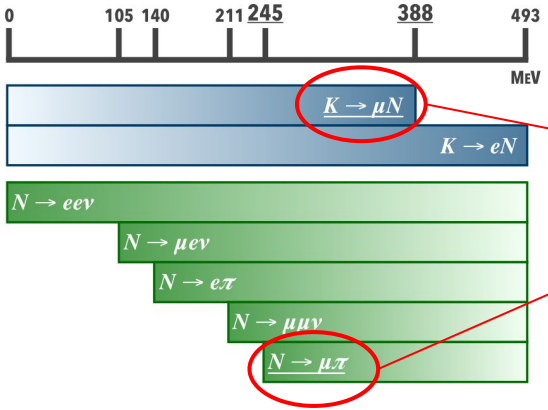


Heavy Neutral Leptons Result

- We used a BDT to search for HNLs with masses of 260 – 385 MeV
- Set a competitive limit with only a fraction of our dataset
- **New** MicroBooNE search surpasses this limit (coming up)



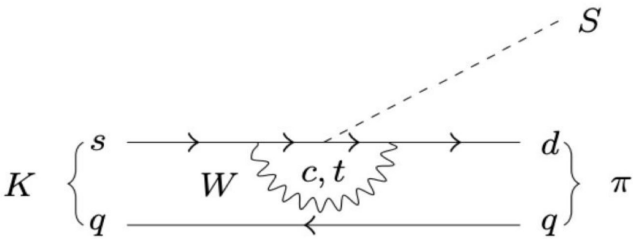
Phys. Rev. D **101**, 052001

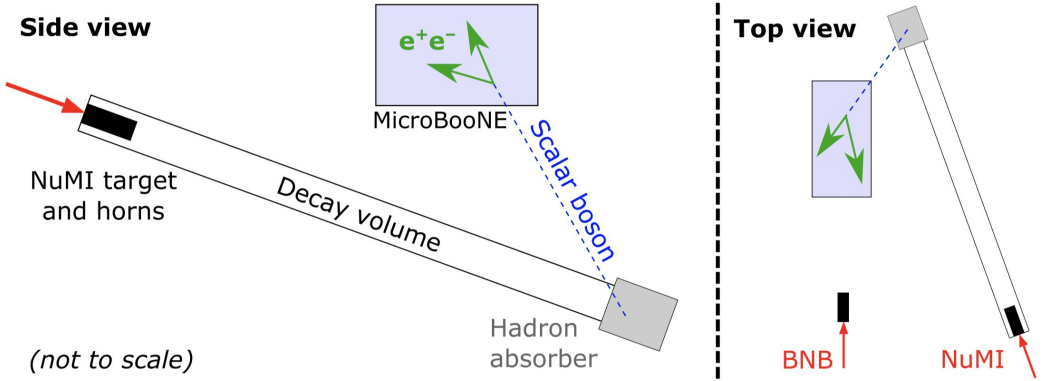


Focused on these production and decay channels

Higgs Portal Scalars

- Dark scalar which mixes with the Higgs
- Decays into l^+l^- or $\pi^+\pi^-$
- We performed a search using Kaons decaying at rest in the **NuMI beam dump**

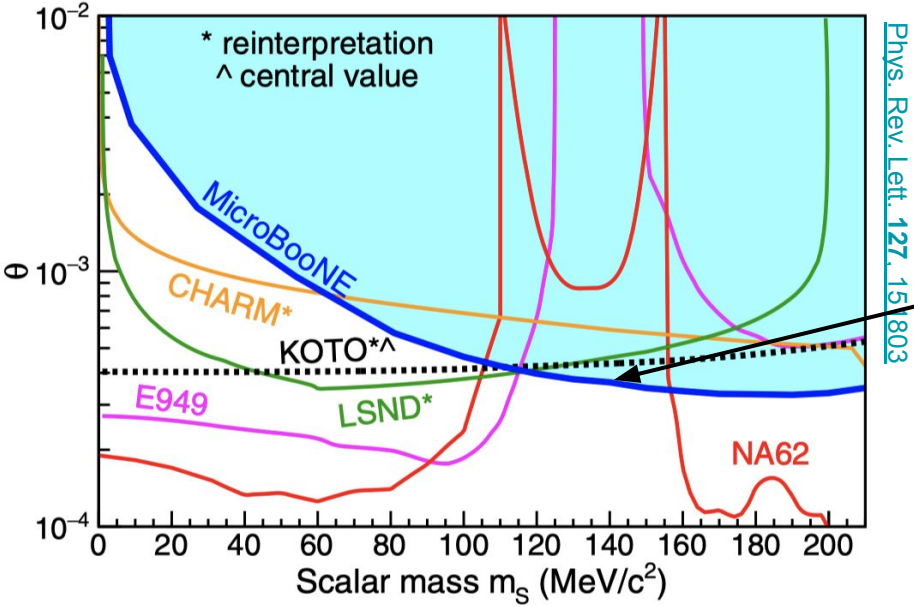




Phys. Rev. Lett. **127**, 151803

Higgs Portal Scalars Result

- We used a BDT to search for the $S \rightarrow e^+ + e^-$ decay
- One event passes all cuts, consistent with background
  - Background expectation: 1.9 ± 0.8
- Rules out HPS contribution to initial KOTO measurement



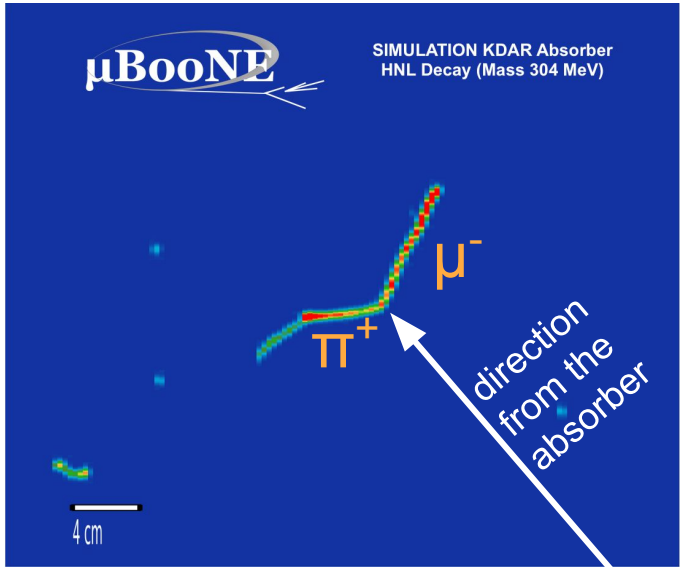
Phys. Rev. Lett. 127, 151803

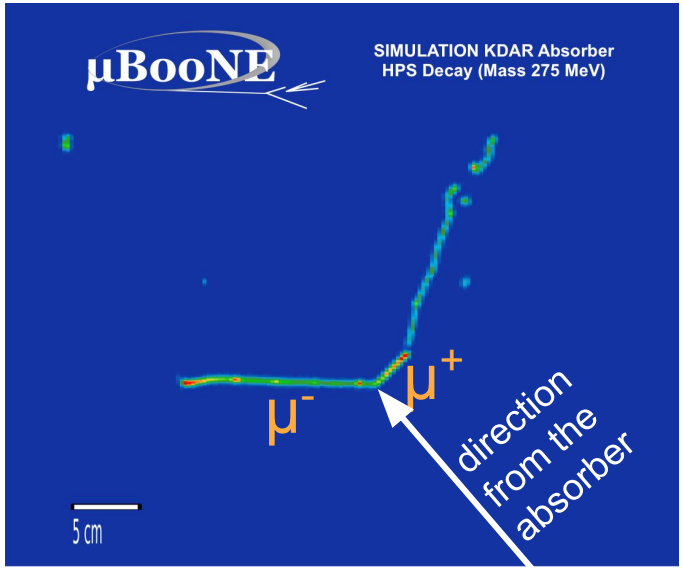
World leading limit in this region!

HNL and HPS Search

ICHEP exclusive

- Using kaons decaying at rest in **NuMI beam dump** to set new limits for MicroBooNE
- These HNLs and HPS would enter the detector at a specific angle and for a given mass would be mono-energetic
- Both decays produce similar two-track topology

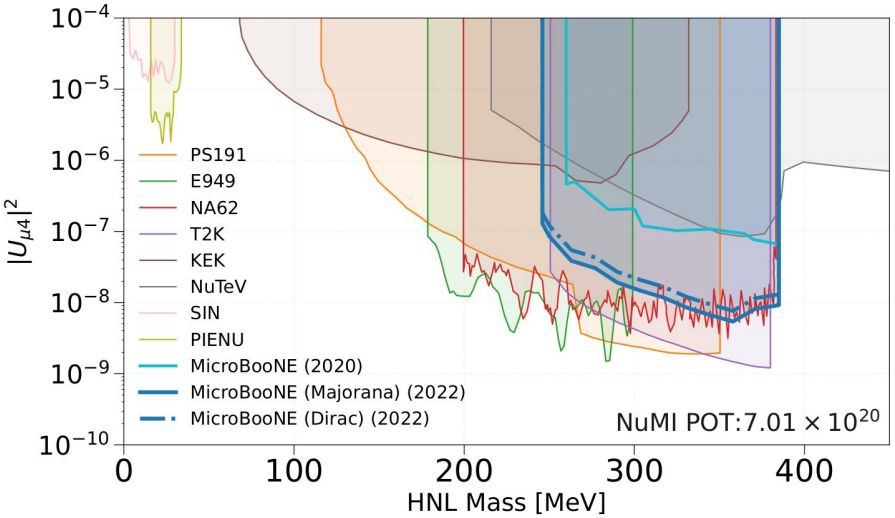


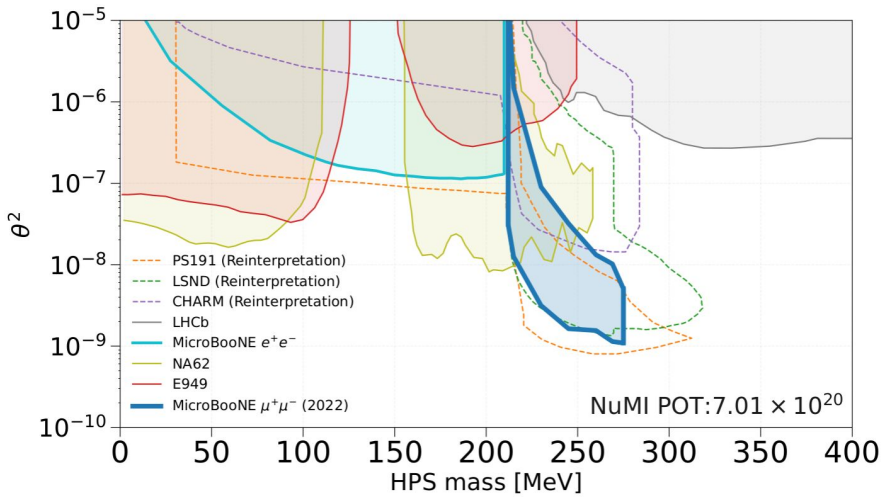


HNL and HPS Search

ICHEP exclusive

- Performed a BDT analysis on a range of signal masses
- Obtained an order of magnitude improvement on previous MicroBooNE HNL limit
- First constraints from a dedicated experimental search for this range of HPS parameters

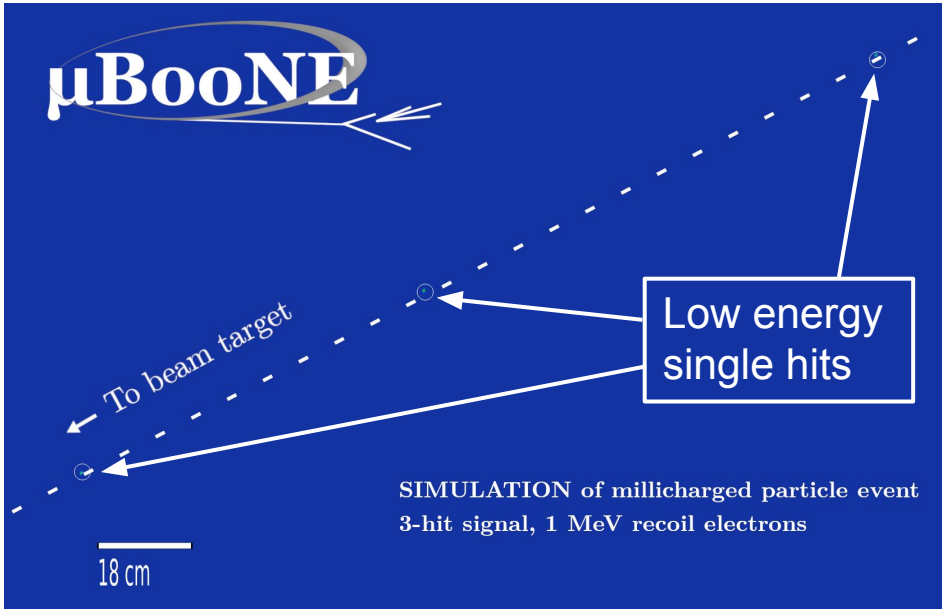


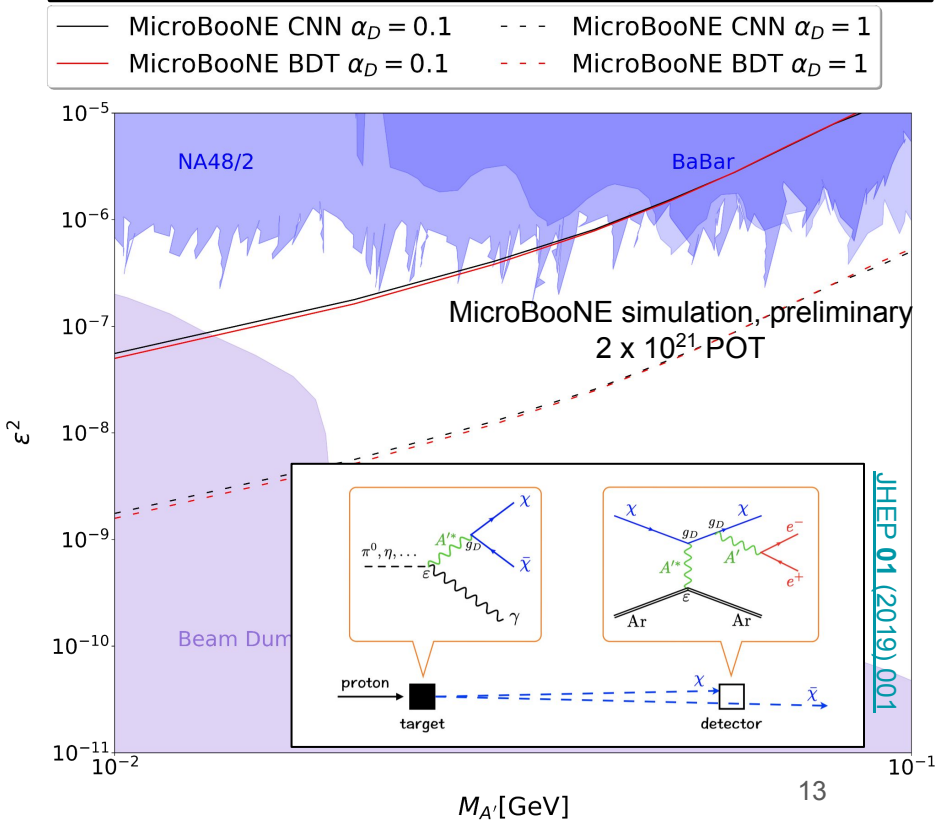


What Else Are We Working On?

- Other HNL decay channels
- e^+e^- models to explain LEE
- Dark Tridents
- Millicharged particles

See “Sensitivity of the MicroBooNE experiment to the dark trident interaction” poster





Summary

- MicroBooNE has demonstrated that we can use LArTPCs to perform world leading BSM searches
- This presentation has highlighted four such studies.
  - Neutron-antineutron oscillation
  - Heavy neutral leptons
  - Higgs portal scalars
  - New HPS + HNL search
- 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!