Enhancing LArTPC BSM search capabilities with low-energy signals

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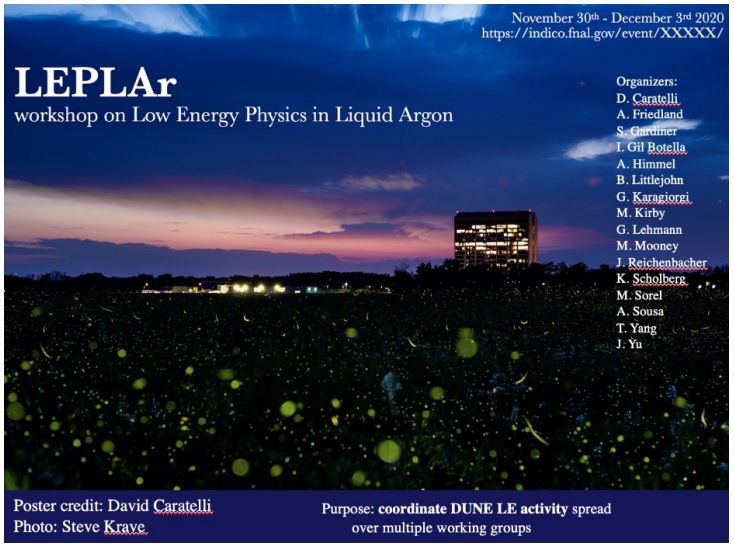
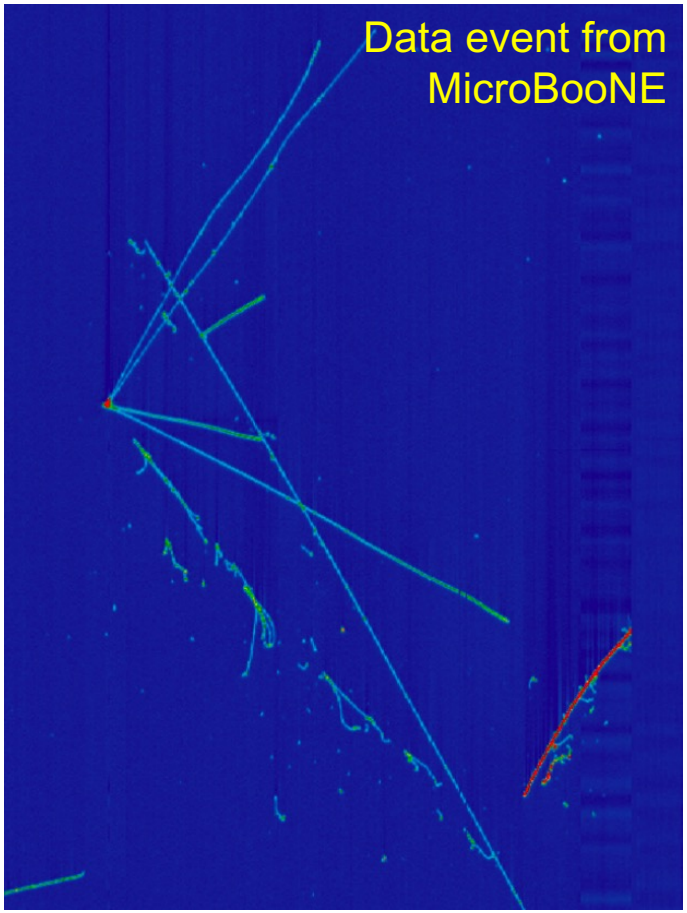
Introduction

- LArTPC reconstruction has mostly focused on resolving features at higher energies: ~50 MeV to GeVs
- Relatively less attention given to *low energies* (~MeV-scale)
- **L**ow **E**nergy **P**hysics in Neutrino **LAr**TPCs (LEPLAr)
  - Coordinating DUNE-centric LE activity spread over multiple working groups
  - Workshop in 2020; white paper in progress

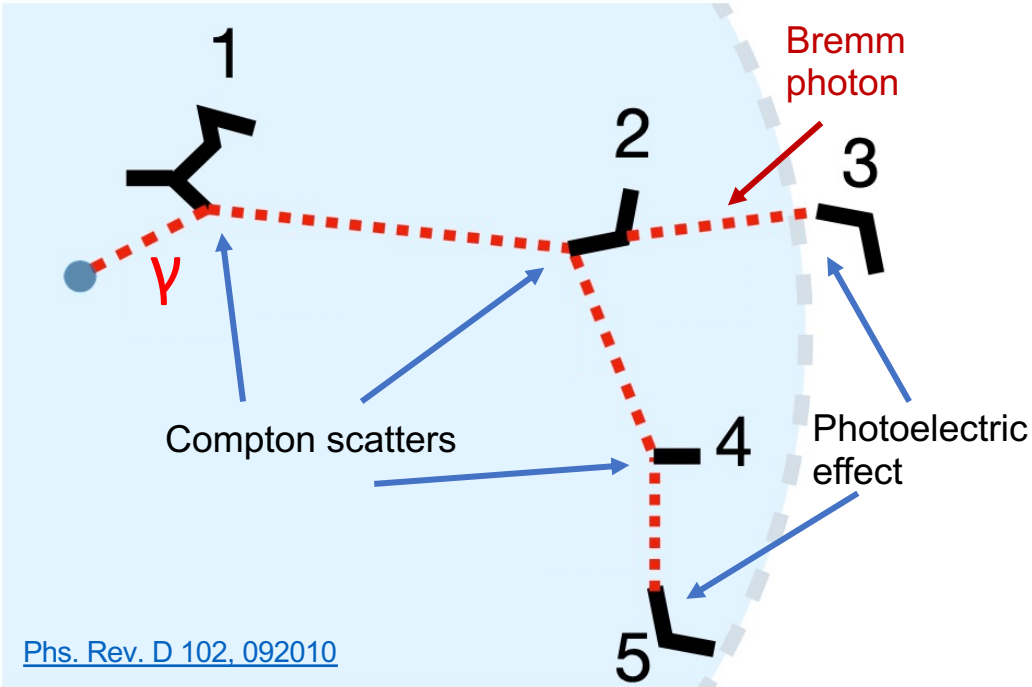


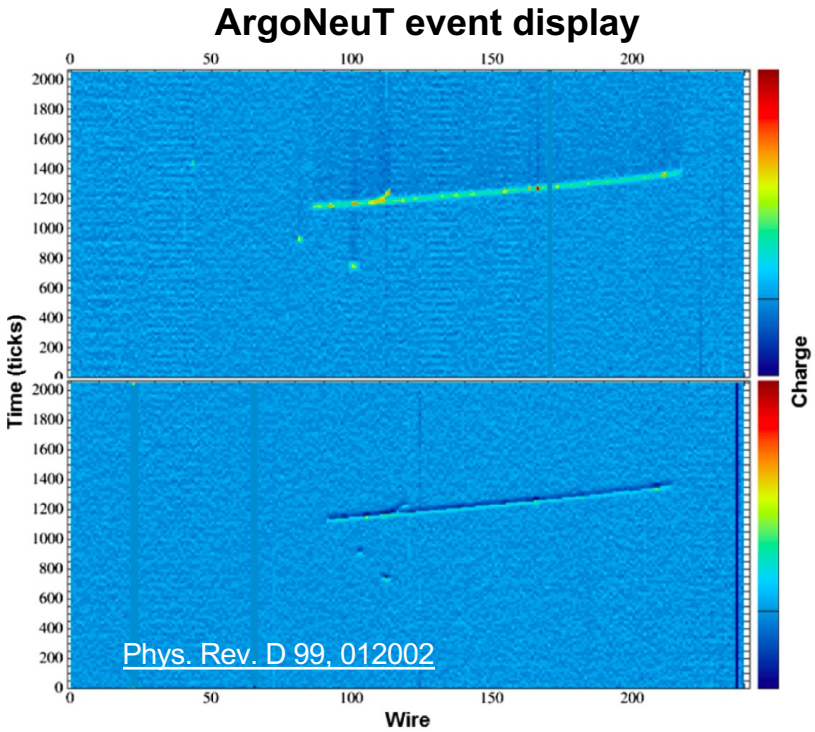


What is a "blip"?

- Compact, spatially isolated, *point-like* ionization clusters from low-energy electrons (< ~5 MeV) and protons

- Rich physics information contained in blips
  - But challenging to reconstruct





BSM searches in LArTPCs

- Several LArTPC-based BSM searches benefit from low-energy blips
  - Millicharged particles
  - SM neutrino trident anomalies
  - Heavy neutral lepton (HNL) decays
  - Dark Higgs decays
  - Dark neutrinos

BSM searches in LArTPCs:
millicharged particles

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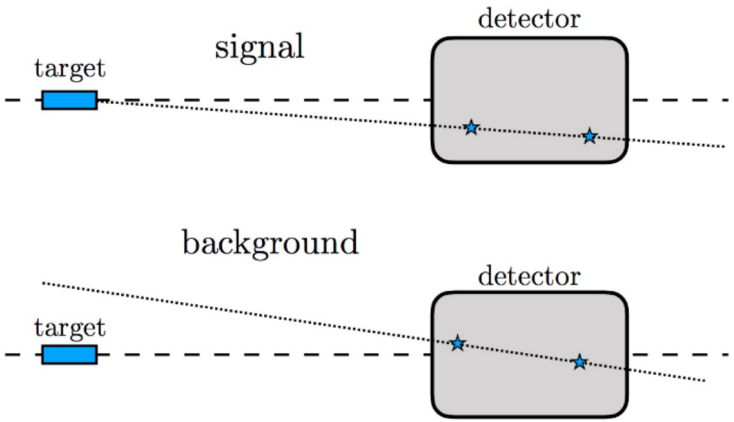
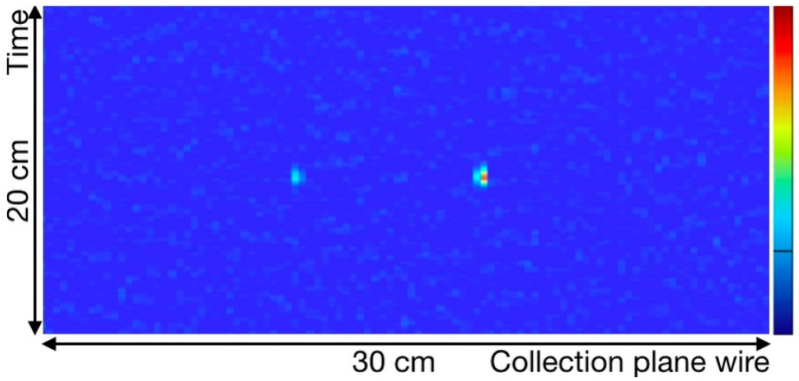
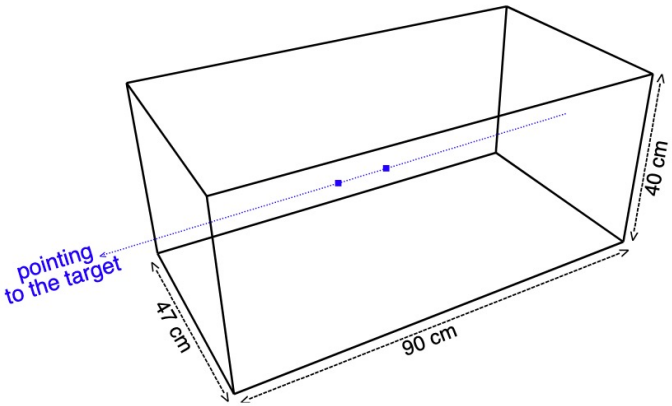


ArgoNeuT searched for blips pointing back to NUMI target





Phys. Rev. Lett 124, 131801

BSM searches in LArTPCs:
tridents, HNL, dark Higgs

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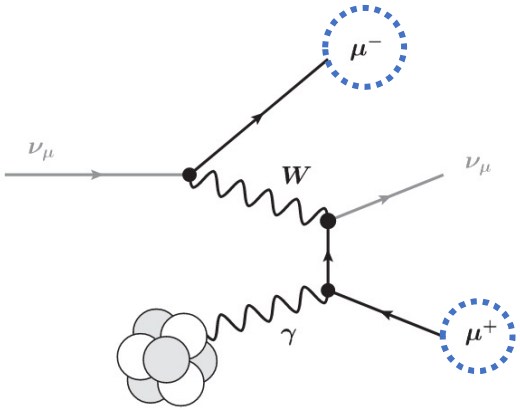
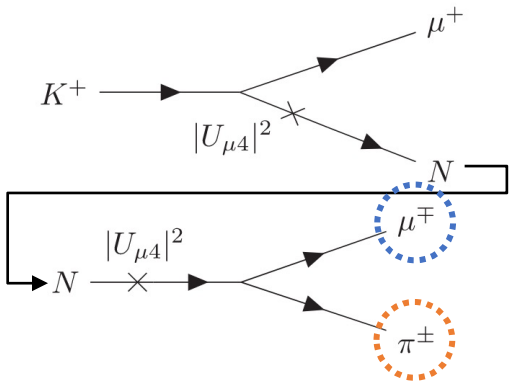
Di-lepton-like signatures



Standard model ν trident

Phys. Rev. D 100, 115029

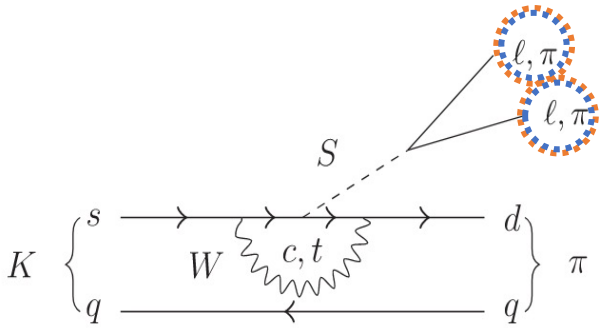
Opposite charged leptons
No hadronic activity



HNL production via mixing in K^+ meson decay

Phys. Rev. D 101, 052001

Pion + muon pair
No hadronic activity



Heavy scalar / Higgs production via kaon decay

Phys. Rev. D 100, 115039

Pion pair OR muon pair
No hadronic activity

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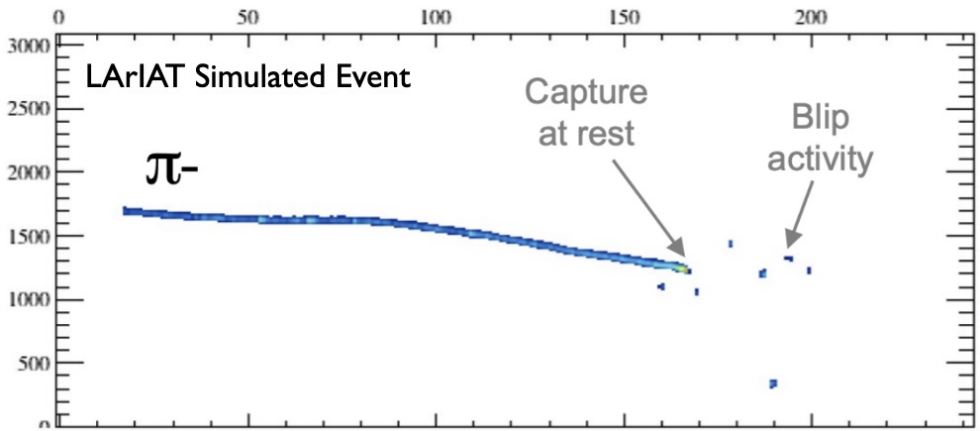
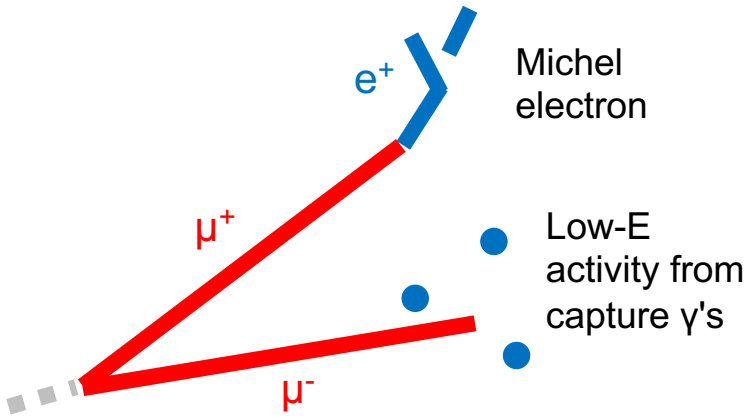
π and μ tracks look similar, but MeV-scale activity near their endpoints can allow for some level of discrimination





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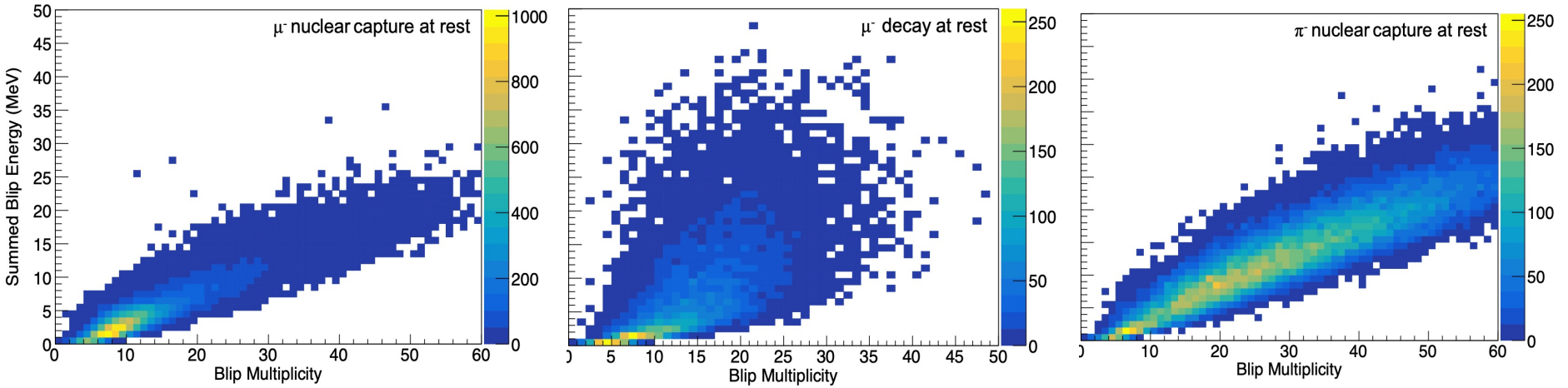
Simple blip energy/multiplicity cuts
- Enable π^- capture-at-rest (CAR) samples with statistically enhanced purity

Radius	N_{blip}	E_{blip}	E_{vert}	μ CAR	μ Decay	π CAR
30 cm	> 7	–	–	52%	65%	85%
30 cm	–	$\geqslant 4$ MeV	–	33%	47%	77%
30 cm	> 7	$\geqslant 4$ MeV	–	30%	42%	75%
60 cm	> 14	–	–	34%	46%	85%
60 cm	–	$\geqslant 8$ MeV	–	22%	44%	78%
60 cm	> 14	$\geqslant 8$ MeV	–	21%	33%	77%
60 cm	–	–	> 5 MeV	18%	0%	74%
60 cm	> 14	$\geqslant 8$ MeV	> 5 MeV	6.3%	0%	53%

TABLE IV. Selection efficiency for various blip activity and vertex activity cuts for μ^- captures at rest (CAR), decaying μ^-, and π^- CAR. The vertex region is defined by a 5 mm radius sphere centered at the particle's decay or capture point; only blips found outside of this region are considered.

Phs. Rev. D 102, 092010



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BSM searches in LArTPCs:
dark neutrinos

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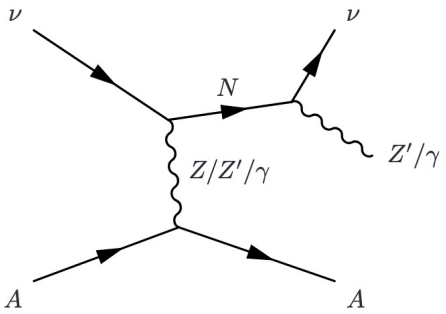
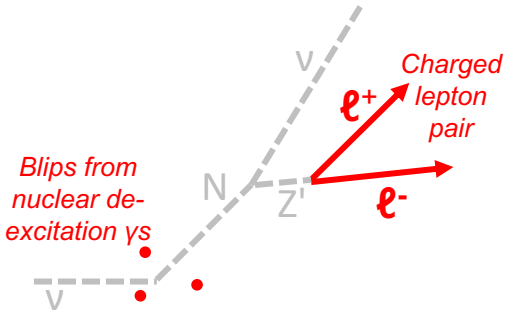
Up-scattered dark neutrino



Feynman diagram



LArTPC topological signature

Two displaced vertices
- Lepton pair
- De-exciting nucleus surrounded by blip activity

BSM searches in LArTPCs:
distinguishing from ν-CC

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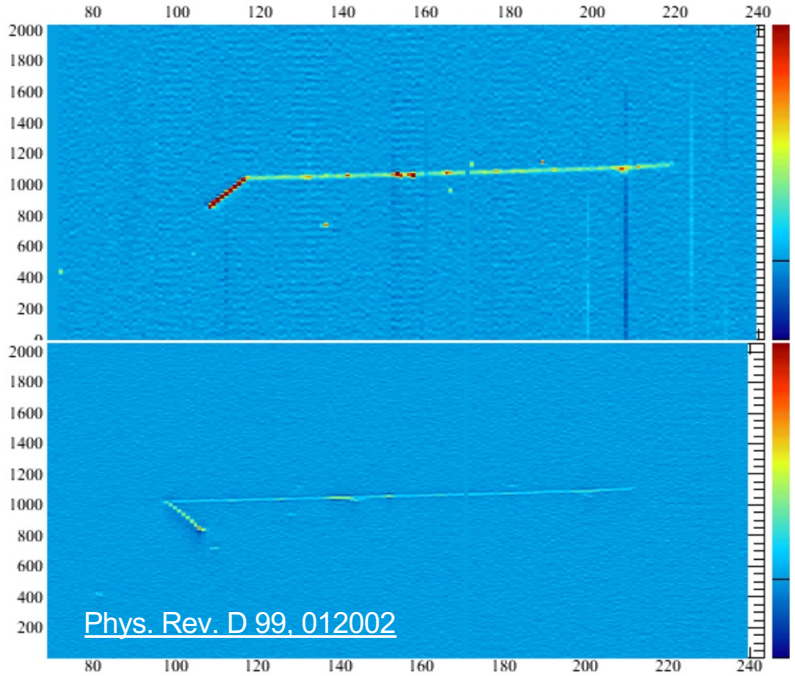
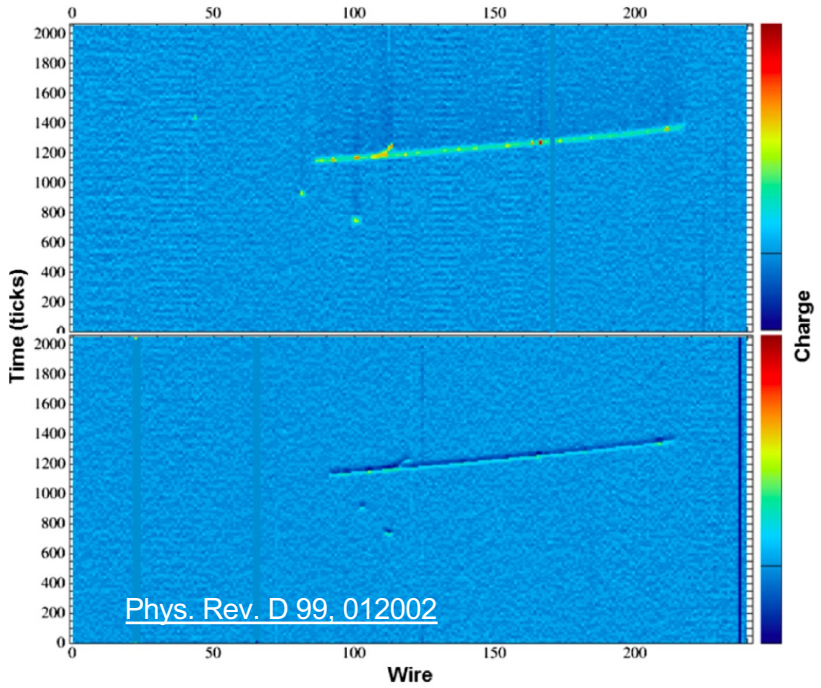
Hidden sector physics (HNL, dark photons, dark Higgs) need *not* include large momentum transfer to Ar nucleus.

Blips can distinguish BG ν-CC interactions by ID'ing hadronic activity
- 1π1μ final-states from ν_μ-CC





Summary

- MeV-scale blips have a wide variety of benefits
- Outlined here were several BSM topologies that benefit from effective blip reconstruction
- **Efforts in extending reconstruction capabilities down to the MeV-scale are critical for maximizing the physics reach of DUNE and other large LArTPCs**