New BSM Results from MicroBooNE

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University of Manchester
for the MicroBooNE Collaboration

FIPs 2022
17- 21 October 2022, CERN
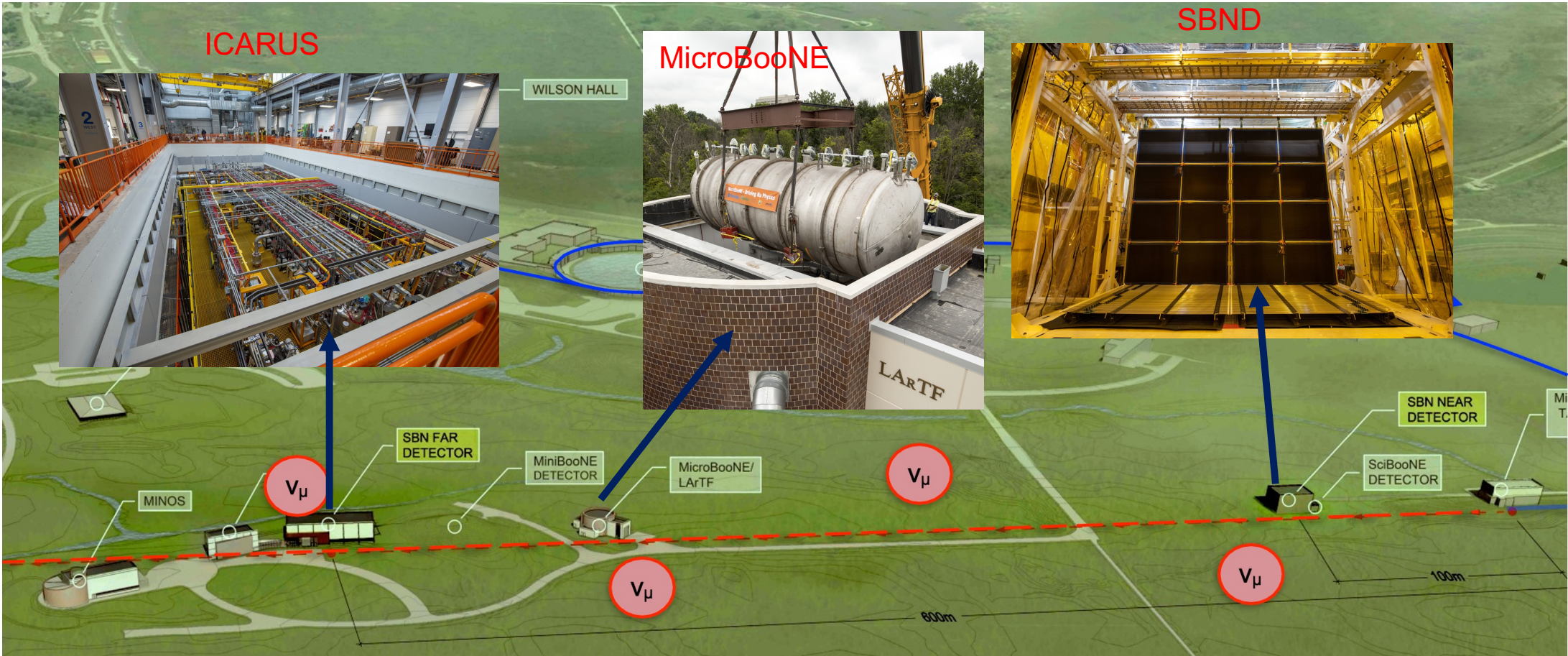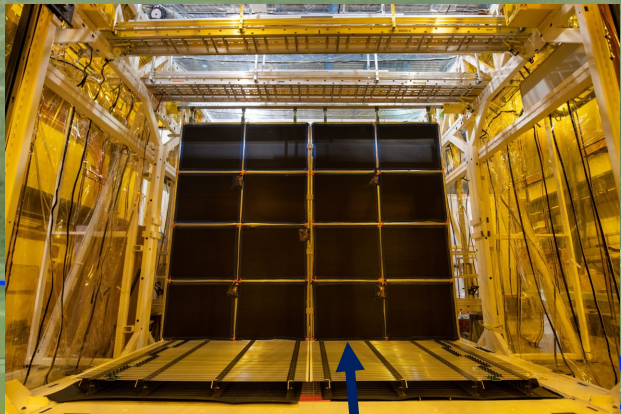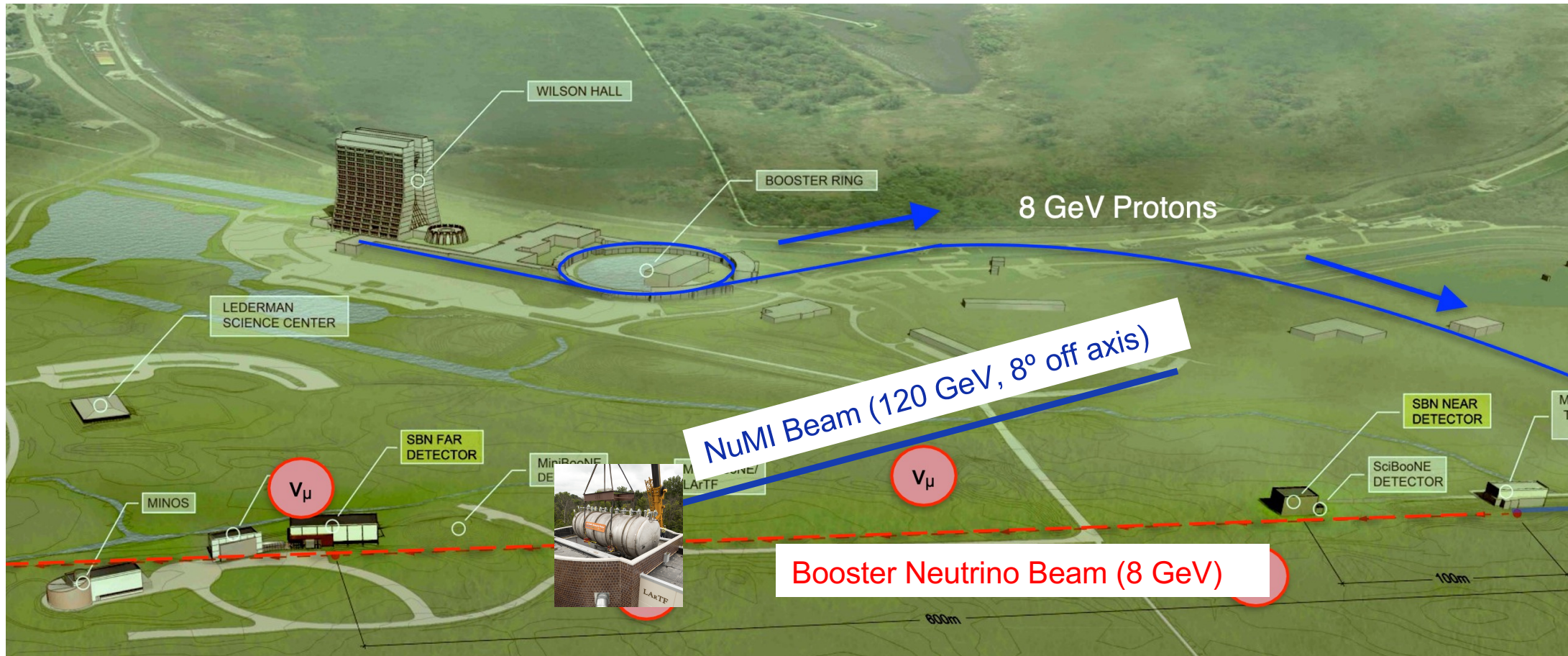
Short-baseline programme

ICARUS

MicroBooNE

SBND

WILSON HALL

LArTF

MINOS

SBN FAR DETECTOR

V_μ

MiniBooNE DETECTOR

MicroBooNE/ LArTF

V_μ

SBN NEAR DETECTOR
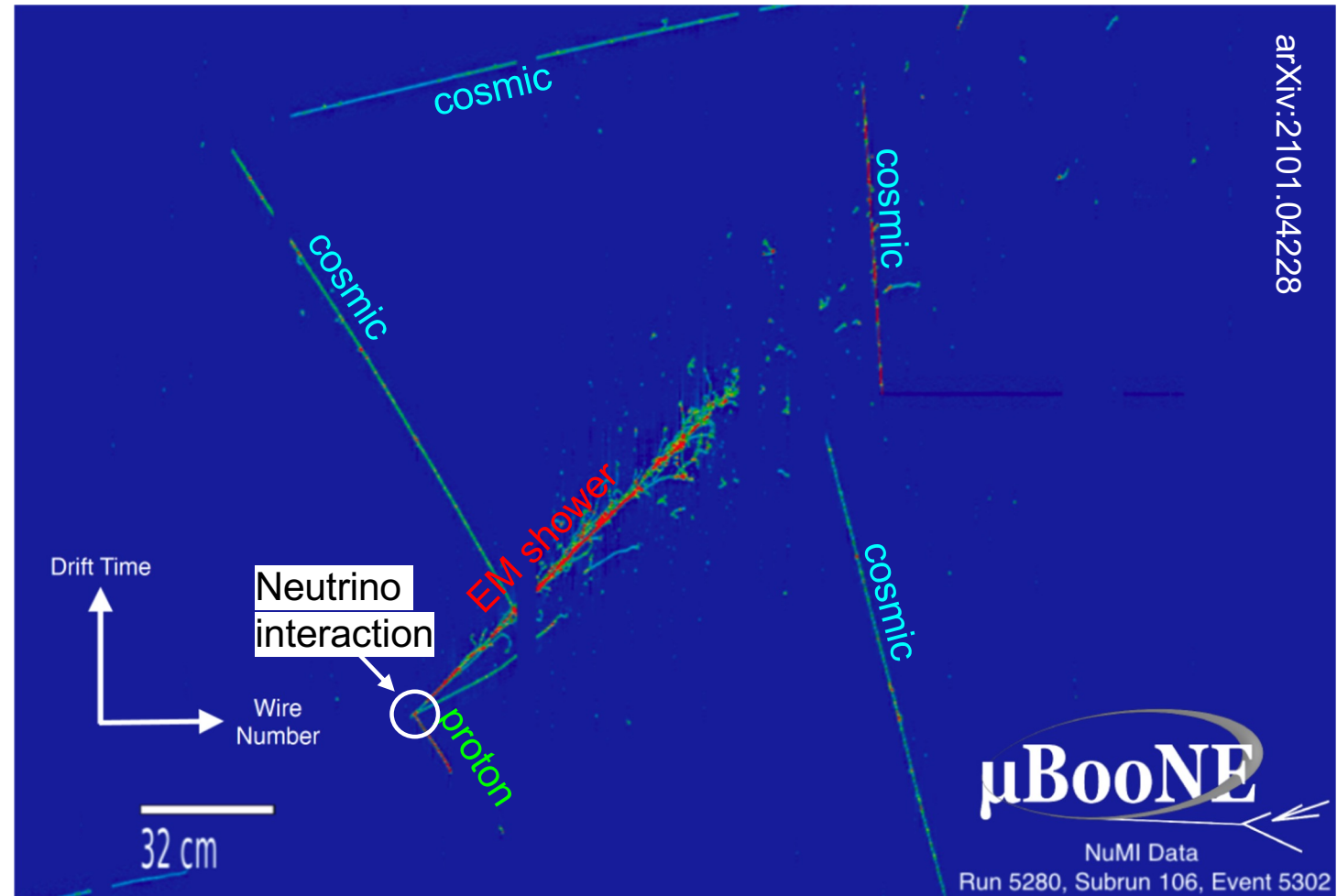
SciBooNE DETECTOR

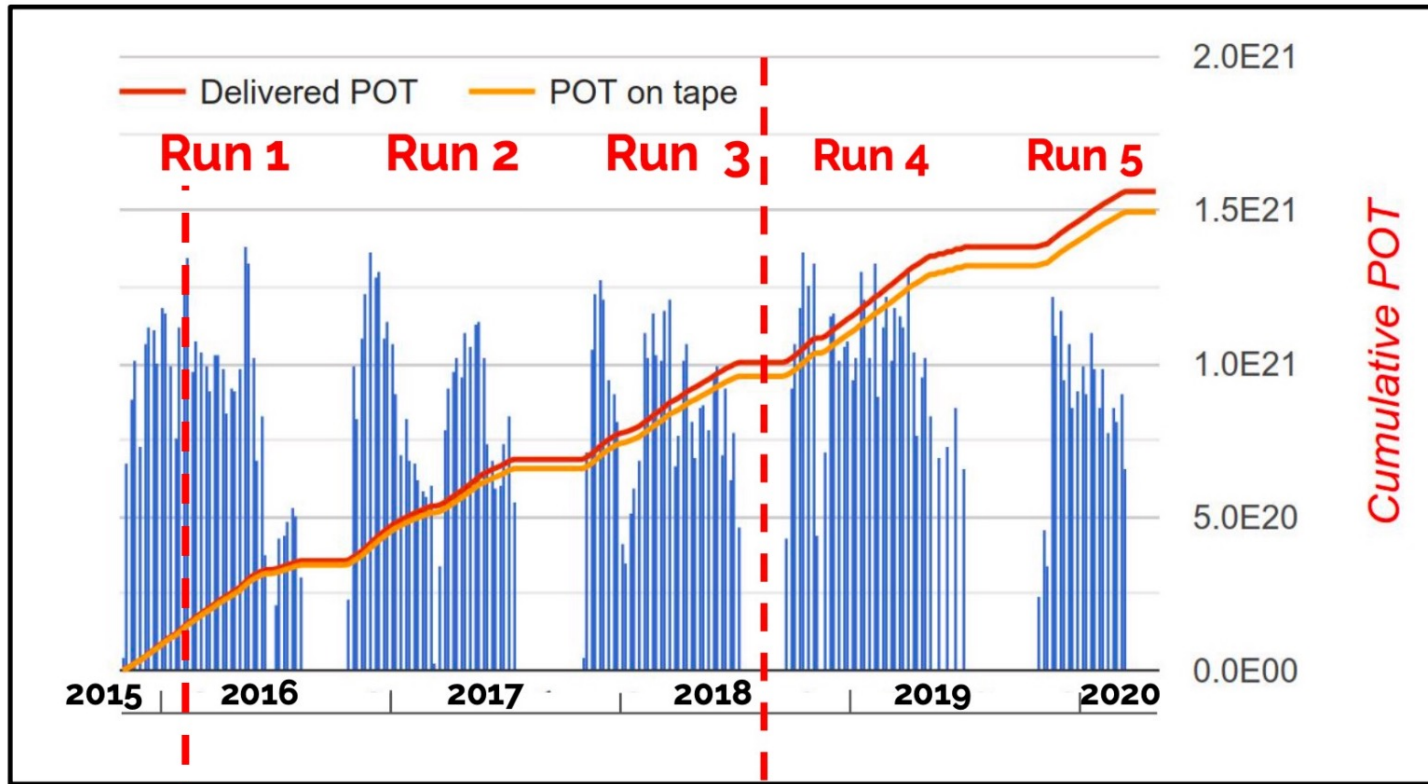V_μ

V_μ

100m

800m

One experiment – two beams

LArTPC – a powerful technique

- Few mm resolution.
- Excellent energy measurement.
- Excellent e-γ separation.
- Particle identification through dE/dx, range,..
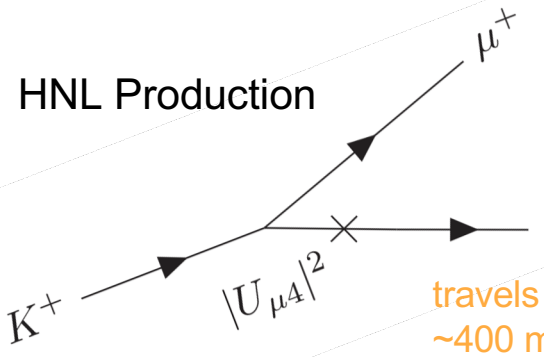- Timing through scintillation light.

arXiv:2101.04228

cosmic
cosmic
cosmic
cosmic

EM shower

Drift Time

Neutrino interaction

Wire Number

proton

32 cm

µBooNE

NuMI Data
Run 5280, Subrun 106, Event 5302

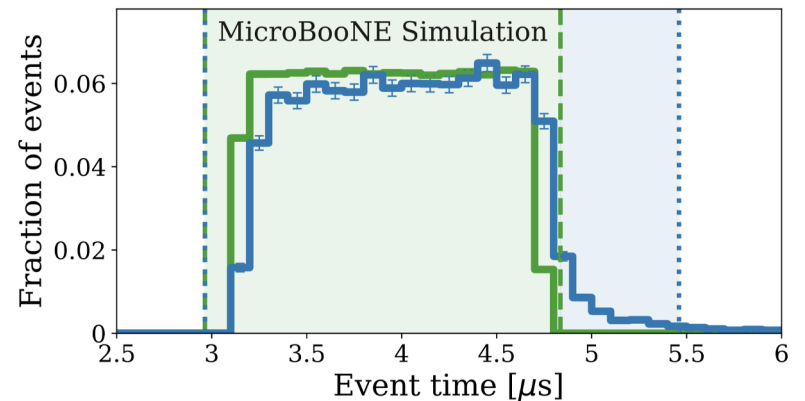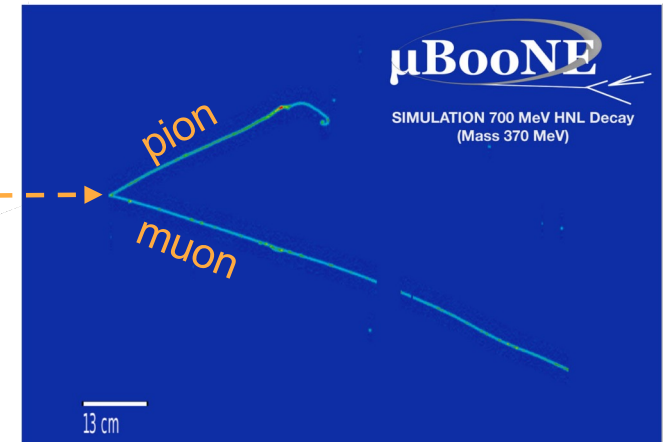MANCHESTER 1824

µBooNE   4

MicroBooNE data set

Results in this talk (~50 % of total)

Heavy Neutral Leptons

- Introduced in several talks.

- We are sensitive to HNLs with masses <500 MeV.

- Final states: electrons, muons, pions.

- First analysis based on dedicated "late trigger" window.
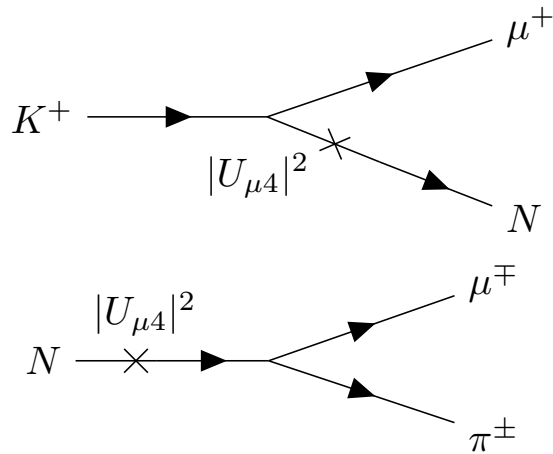
- Excludes neutrino background from beam.

HNL Production

travels ~400 m

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

μBooNE
SIMULATION 700 MeV HNL Decay (Mass 370 MeV)

pion

muon

13 cm

MicroBooNE Simulation

Fraction of events

Event time [μs]
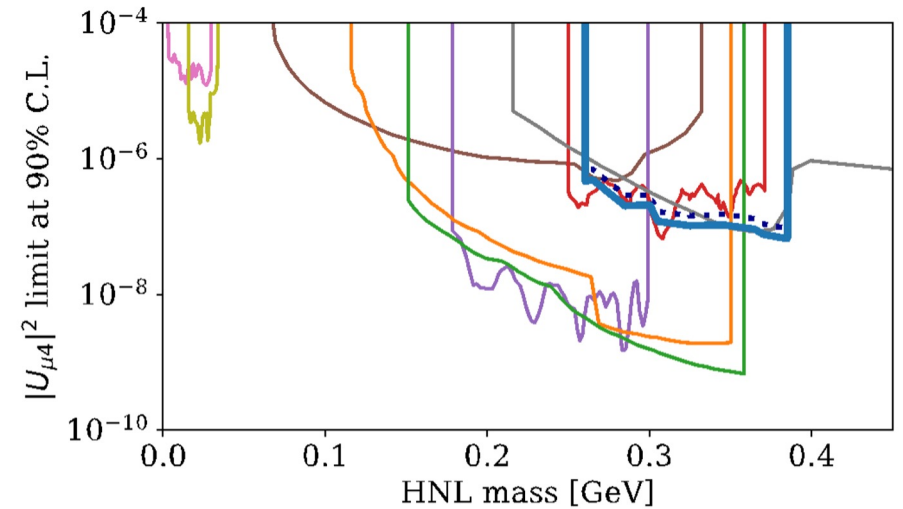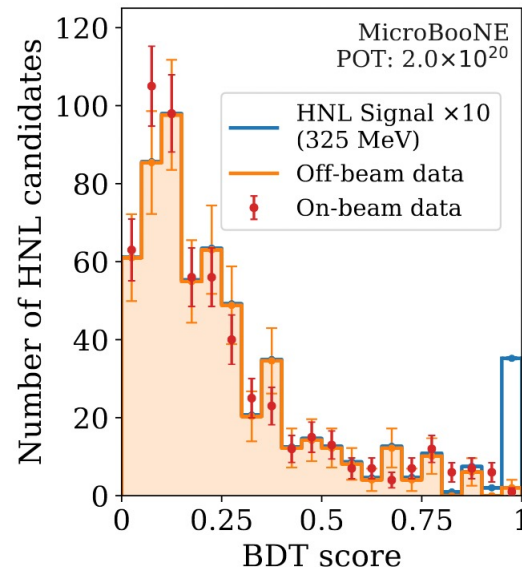
— BNB neutrinos   --- BNB Trigger window
— HNL (365 MeV)   ⋯ HNL Trigger window

Heavy Neutral Leptons

Focused on these production and decay channels:
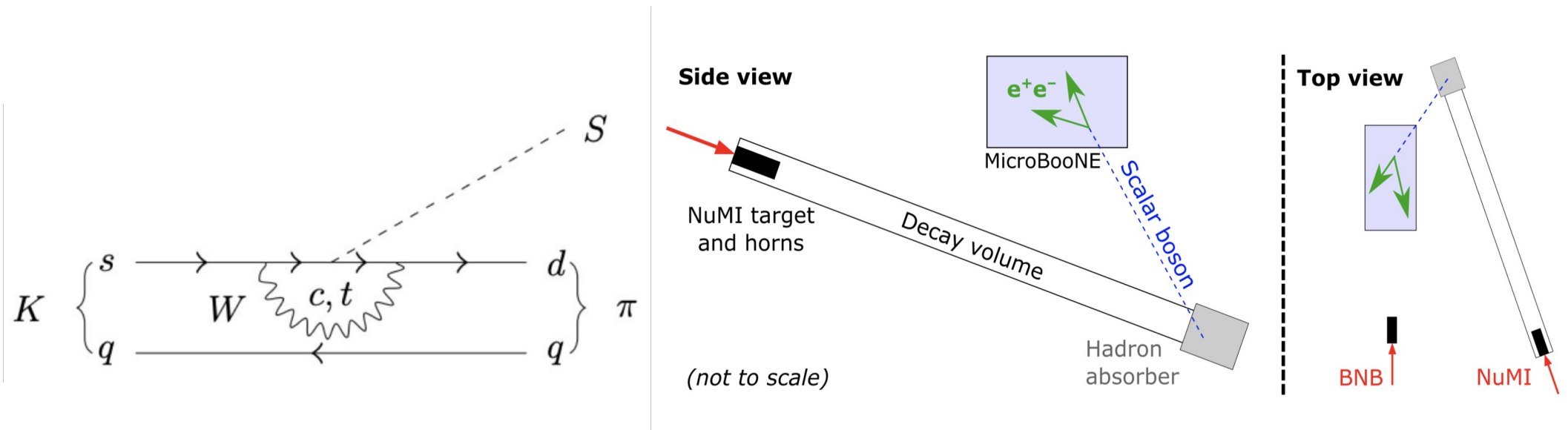
BDT to search in mass range 260 – 385 MeV

Higgs Portal Scalars

- Dark scalar that mixes with the Higgs boson

- Decays into l^+l^- or $\pi^+\pi^-$

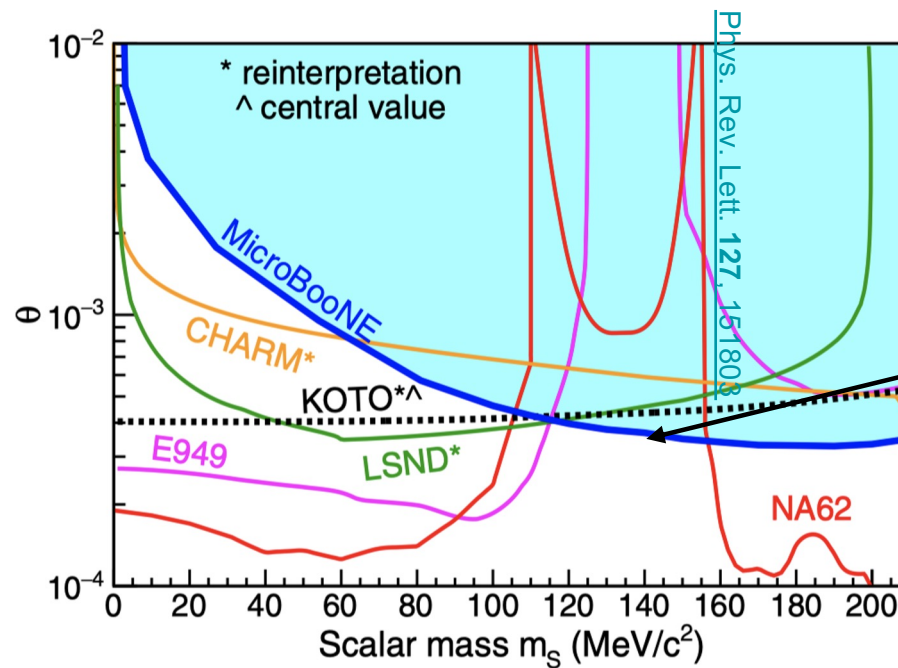- Using kaons decaying at rest in the NuMI beam dump

Higgs Portal Scalars

- We use 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 events
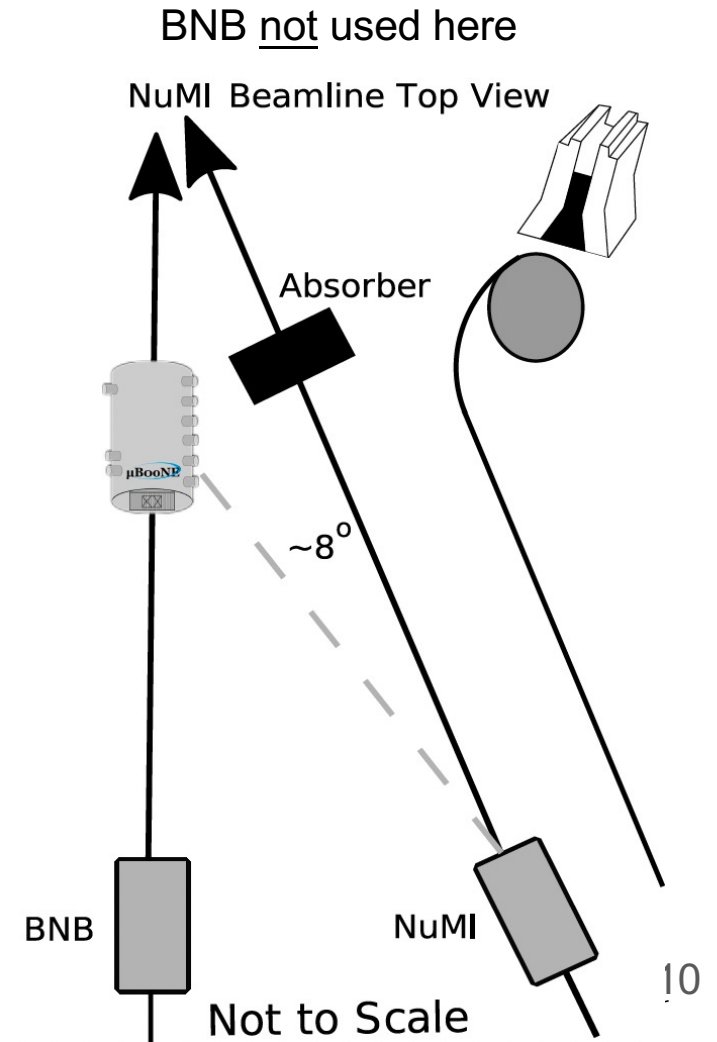
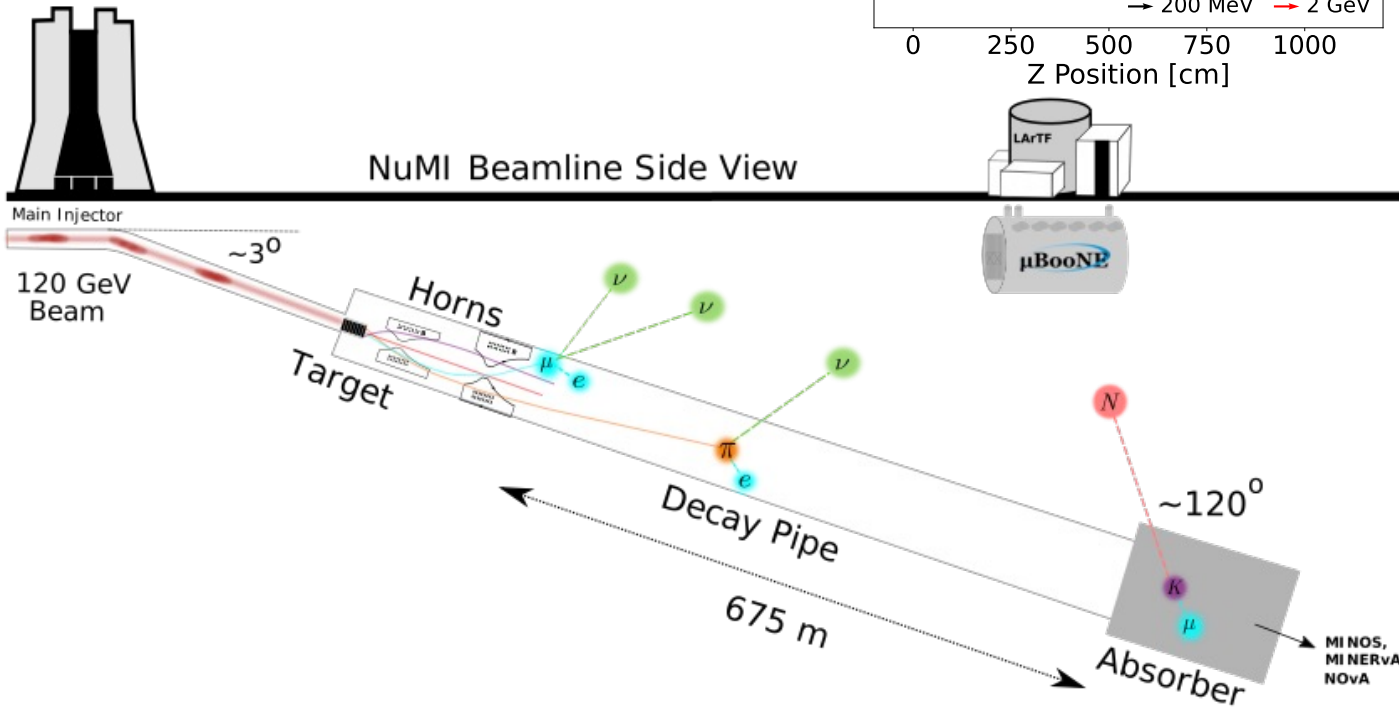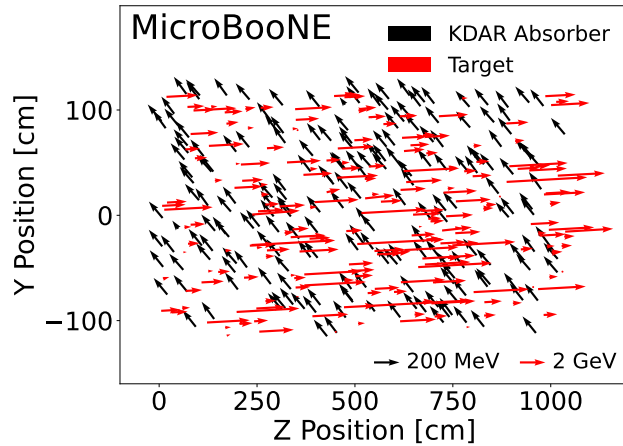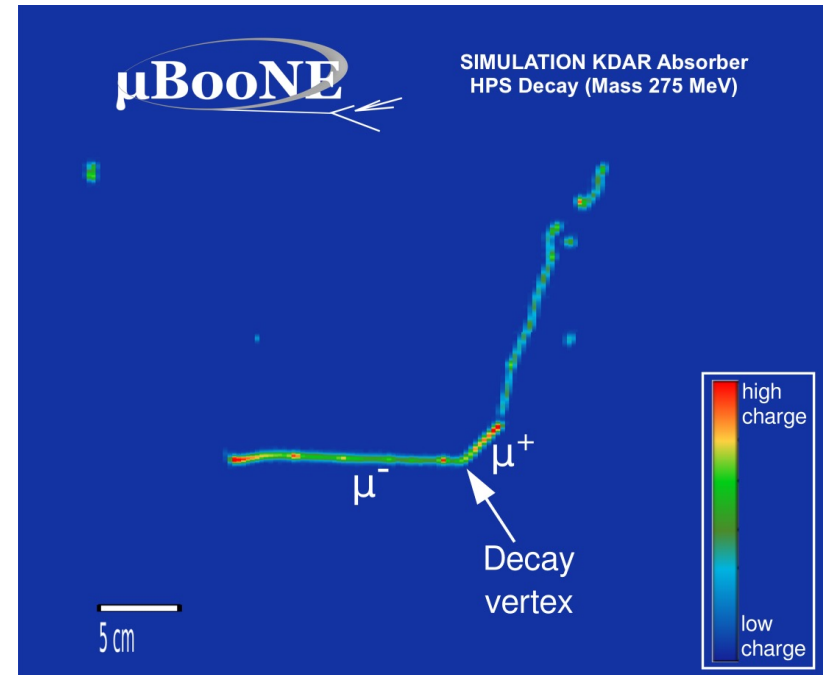- Rules out HPS contribution to initial KOTO measurement

World leading limit in this region!
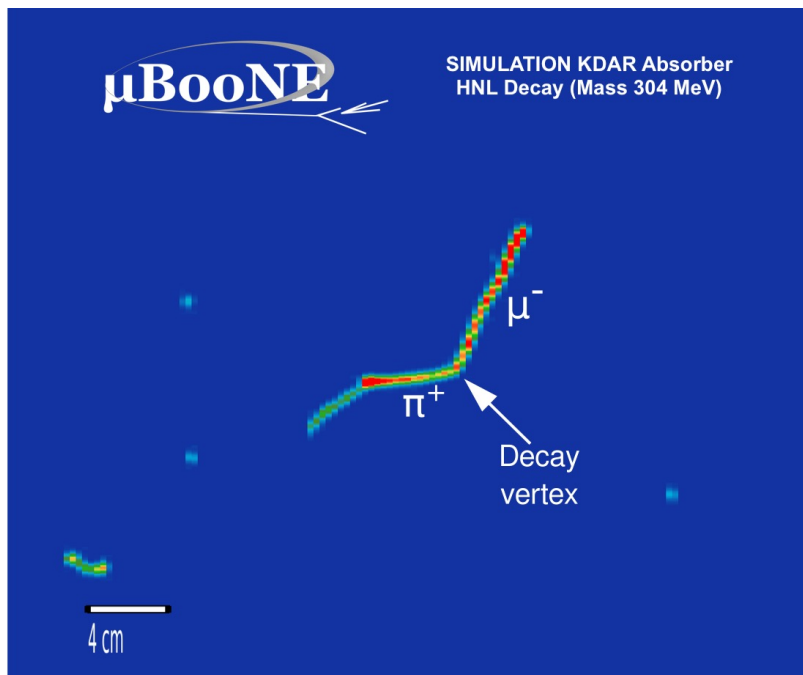
- HNLs (or HPS) enter the detector from the absorber.
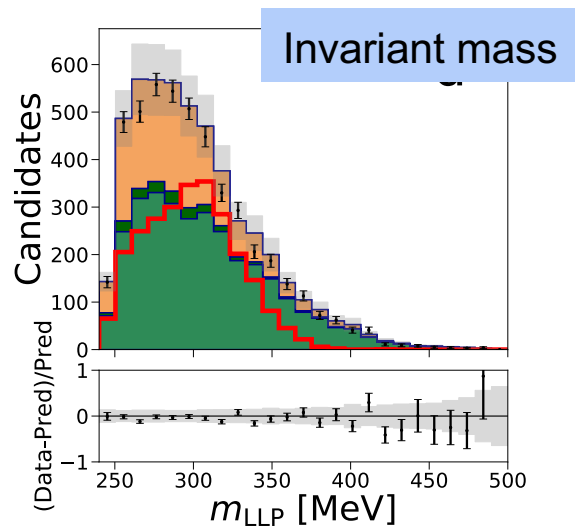- Angular information helps to discriminate signal from neutrino beam background.
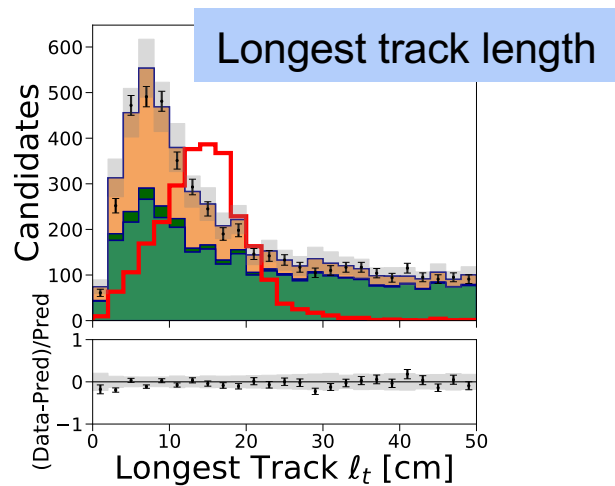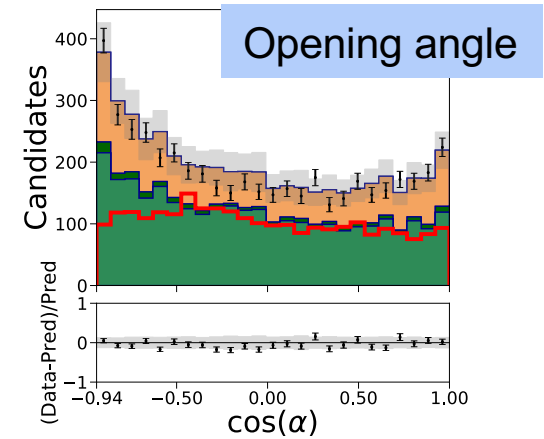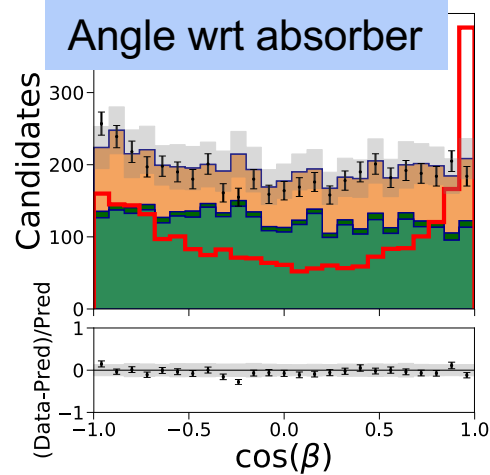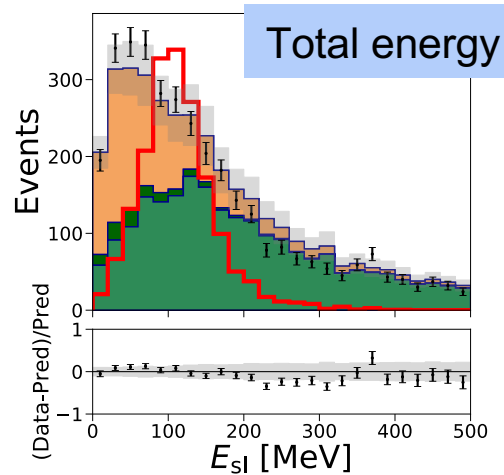
New HNL and HPS search

- As kaon decays at rest, HNL is mono-energetic for given mass.
- HNL and HPS decays produce similar two-track topology – one search strategy.
- Full simulation of beam, HNL/HPS production and decay kinematics, detector.

μBooNE SIMULATION KDAR Absorber
HNL Decay (Mass 304 MeV)

μ⁻
π⁺
Decay vertex
4 cm

μBooNE SIMULATION KDAR Absorber
HPS Decay (Mass 275 MeV)

μ⁻ μ⁺
Decay vertex
5 cm

high charge

low charge
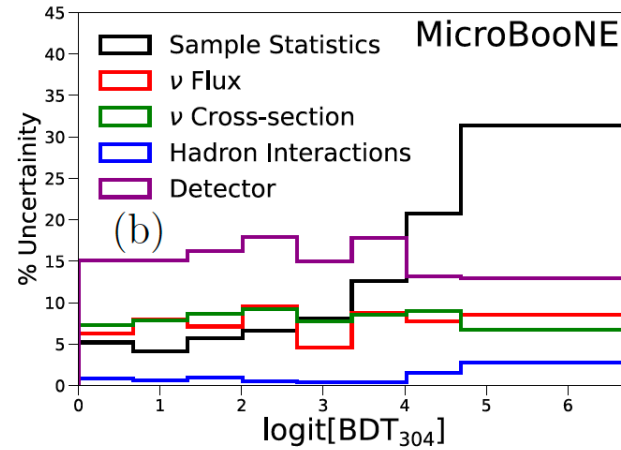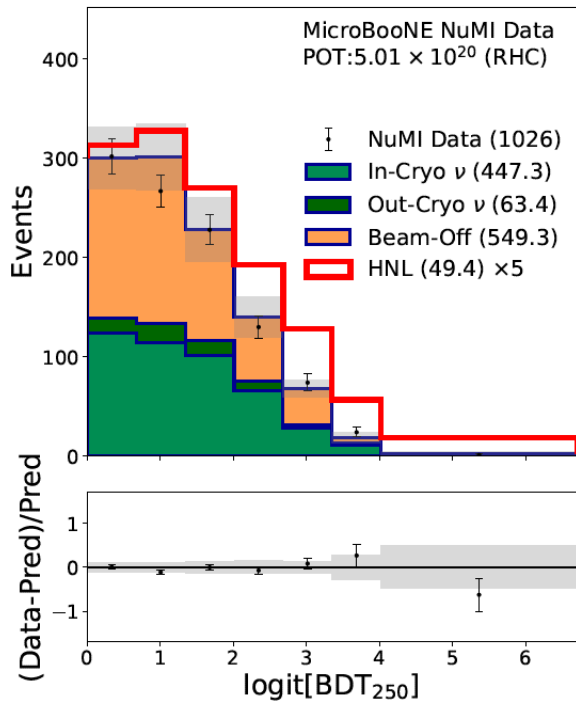
Signal and background kinematics

MicroBooNE NuMI Data
POT: 5.01×10^{20} (RHC)

| NuMI Data
In-Cryo ν
Beam-Off
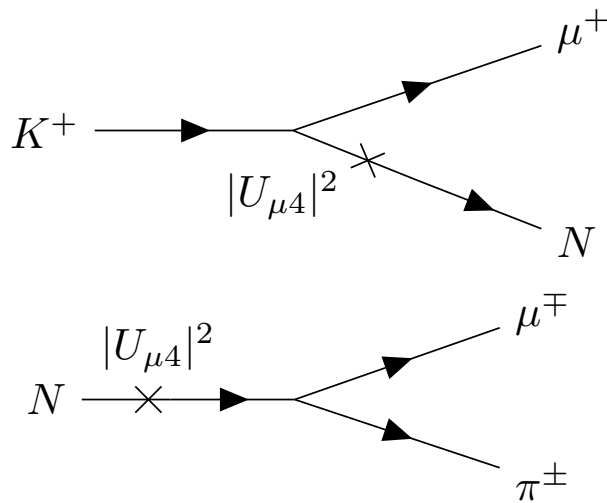Out-Cryo ν
HNL ($m_{HNL} = 304$ MeV)

21 BDT Input variables

μBooNE   12

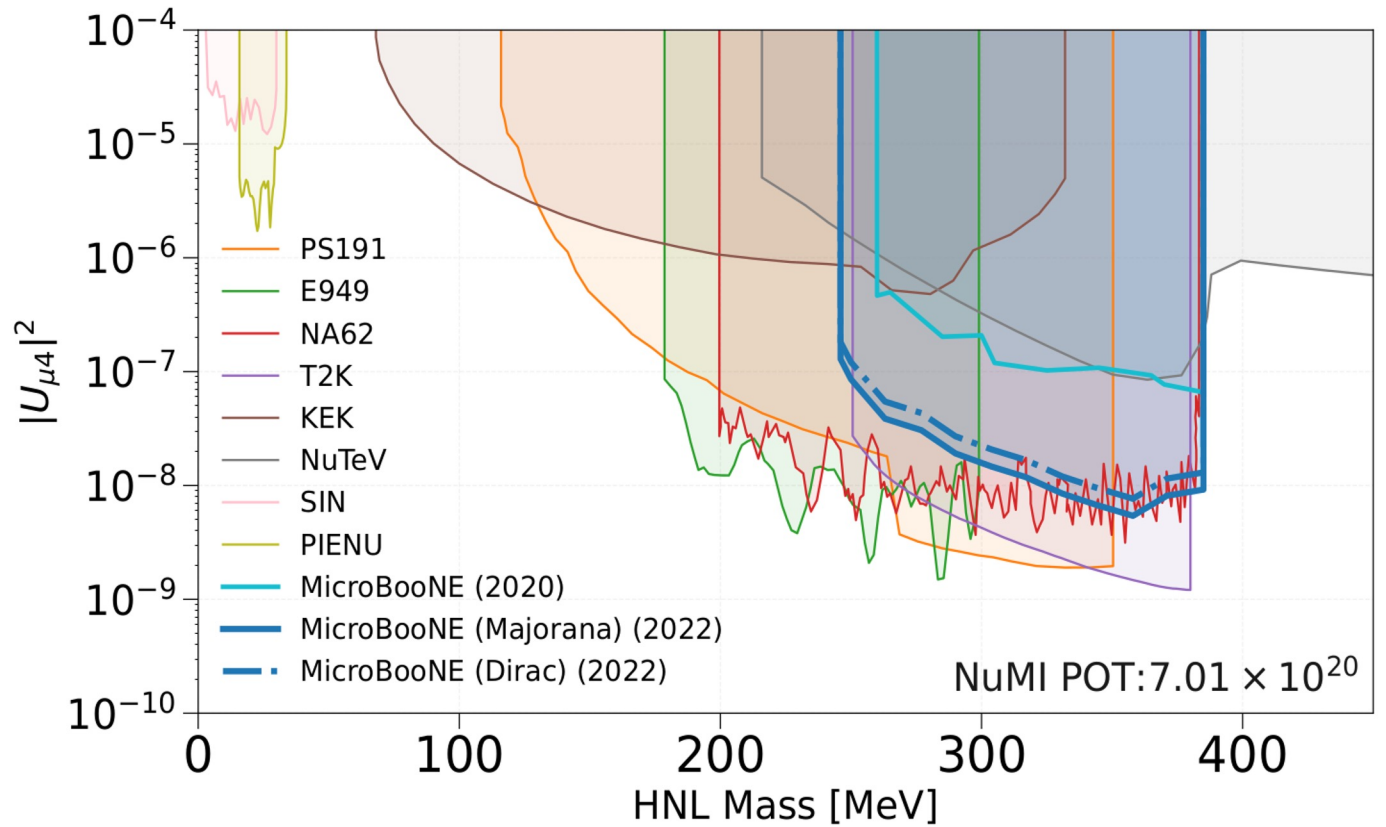# BDT output + Systematics → Limit
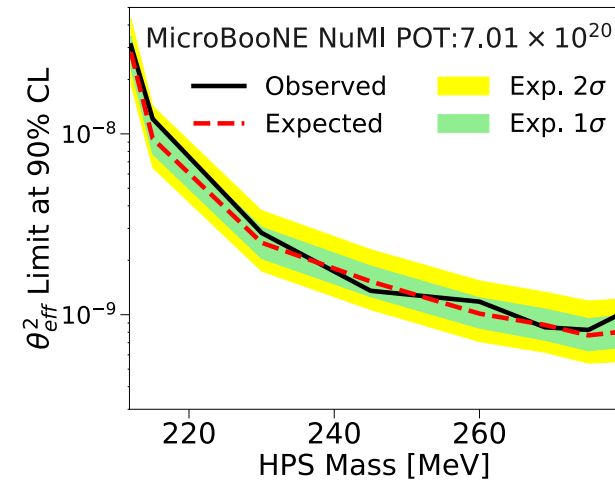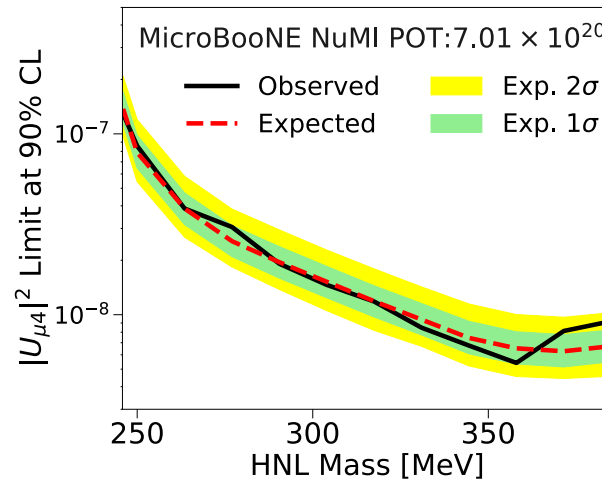
HNL result

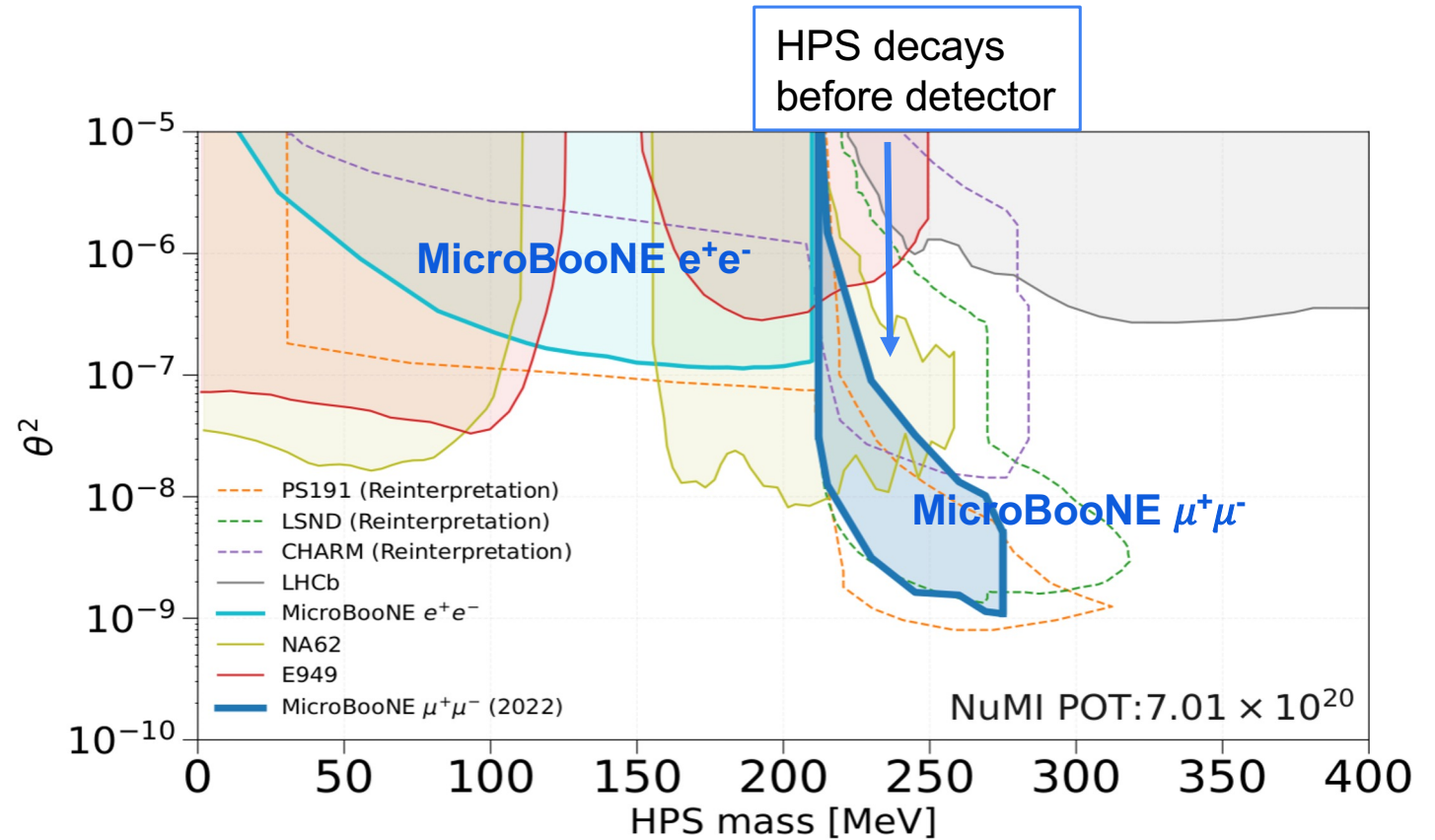Order of magnitude improvement on previous MicroBooNE HNL limit
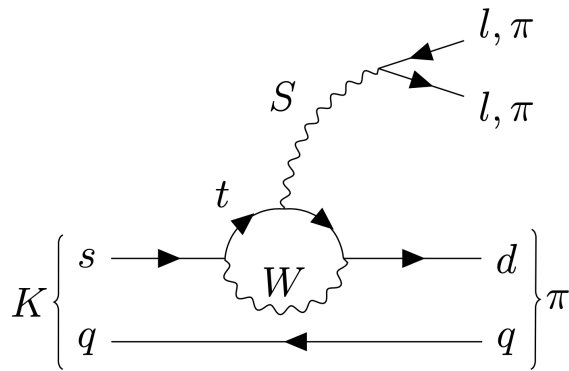

Majorana and Dirac HNLs

https://arxiv.org/abs/2207.03840

Higgs Portal Scalar Result

First constraints from a dedicated experimental search in this parameter range.
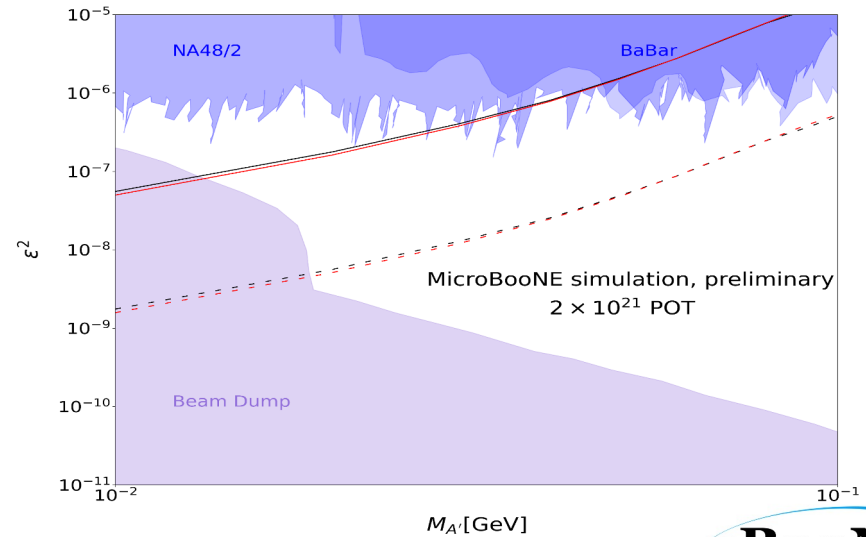
What else are we working on?

- Several HNL decay channels
- Models to explain low-energy excess (MiniBooNE)
- Neutron-antineutron oscillations
- Dark tridents
- Milli-charged particles

SIMULATION of millicharged particle event
3-hit signal, 1 MeV recoil electrons

18 cm
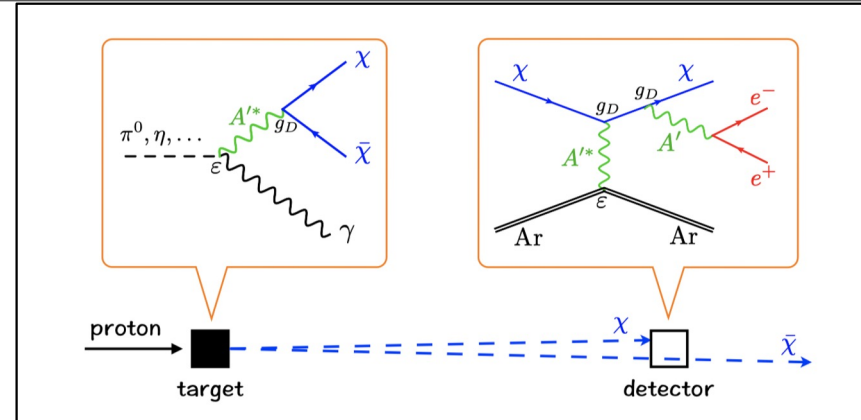
MicroBooNE CNN $\alpha_D = 0.1$ — MicroBooNE CNN $\alpha_D = 1$
MicroBooNE BDT $\alpha_D = 0.1$ — MicroBooNE BDT $\alpha_D = 1$

NA48/2   BaBar

ε^2

MicroBooNE simulation, preliminary
2×10^{21} POT

Beam Dump

$M_{A'}$[GeV]

JHEP 01 (2019) 001
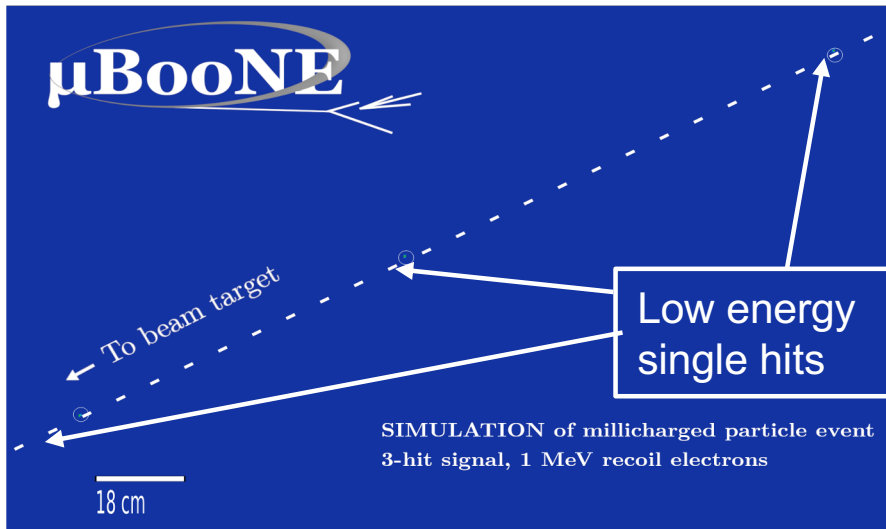
Summary

- BSM searches are one of three pillars of MicroBooNE's physics programme (in addition to cross sections, low-energy excess).
- New 3+1 light sterile neutrino result this week on https://arxiv.org/abs/2210.10216
- New BSM results published on
  - Heavy neutral leptons
  - Higgs portal scalars
- More search results to be released soon.
- Important to perform full experimental analysis of data.
- Need support tor BSM generators.