Recent results from MicroBooNE

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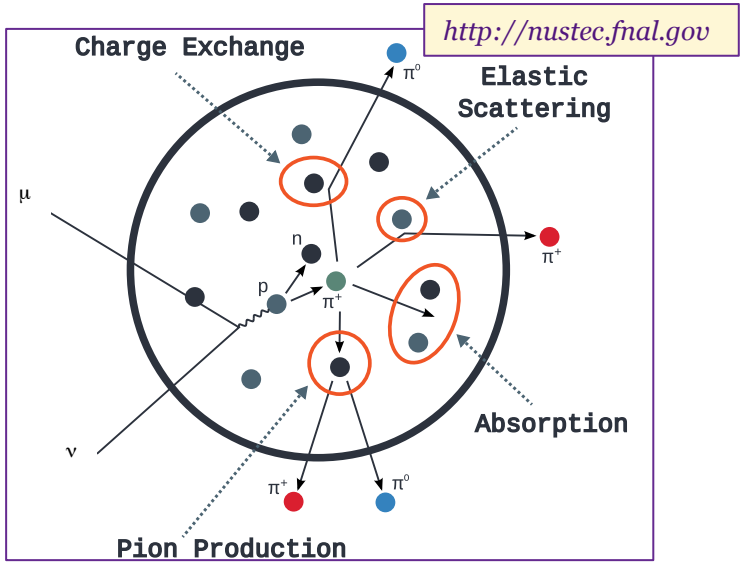
Outline:
Latest results, from the past year

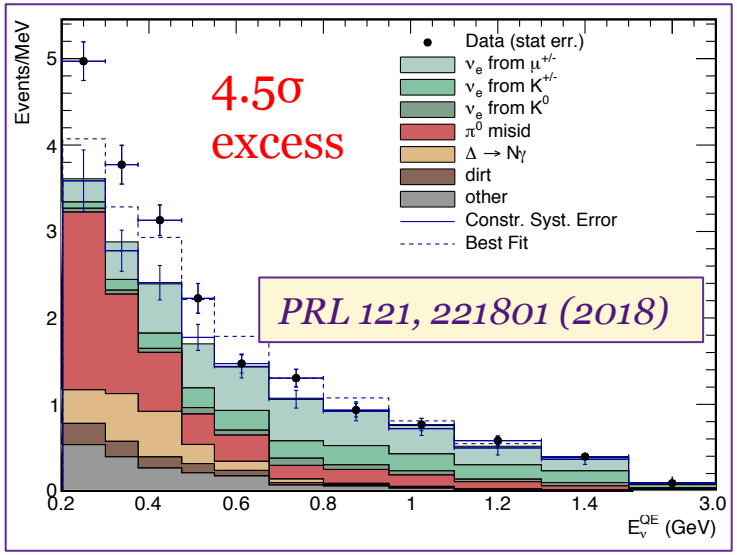
- Cross section measurements
- Progress on MiniBooNE anomaly
- Prospects for 2019

* on behalf of the MicroBooNE Collaboration

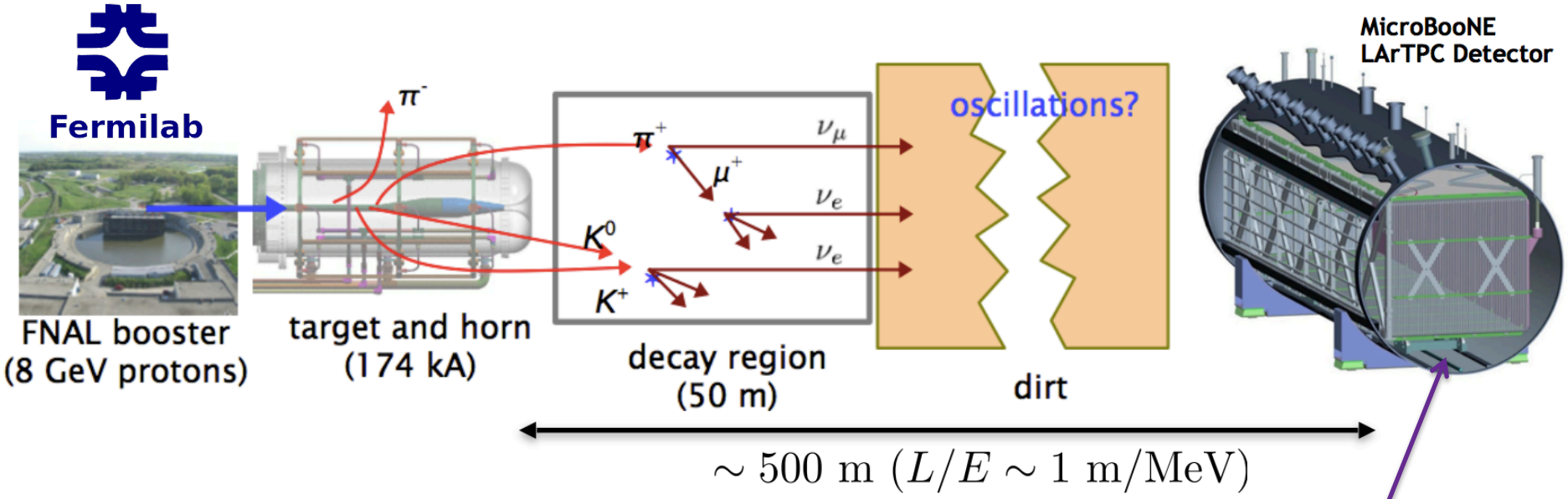
Goals of the experiment

- Study performance of liquid argon time projection chamber technology
  - **See talk by Christopher Barnes**
- Measure neutrino interaction **cross sections** on argon
- Make definitive statement about nature of MiniBooNE **low energy excess**
- Search for **exotic** beam-related or astrophysical phenomena



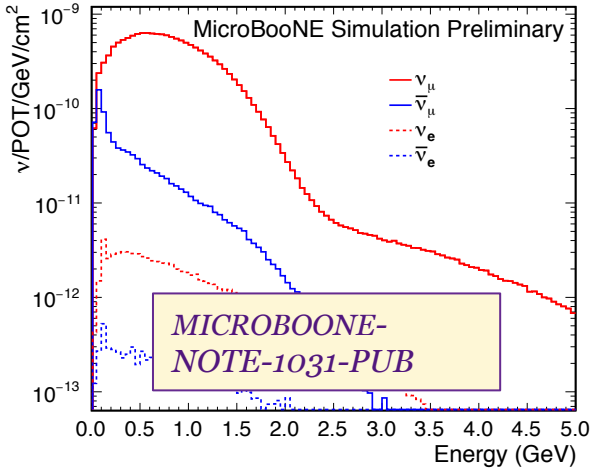


Booster Neutrino Beam



12×10^{20} POT delivered since 2015

– approved for 13.2×10^{20} POT

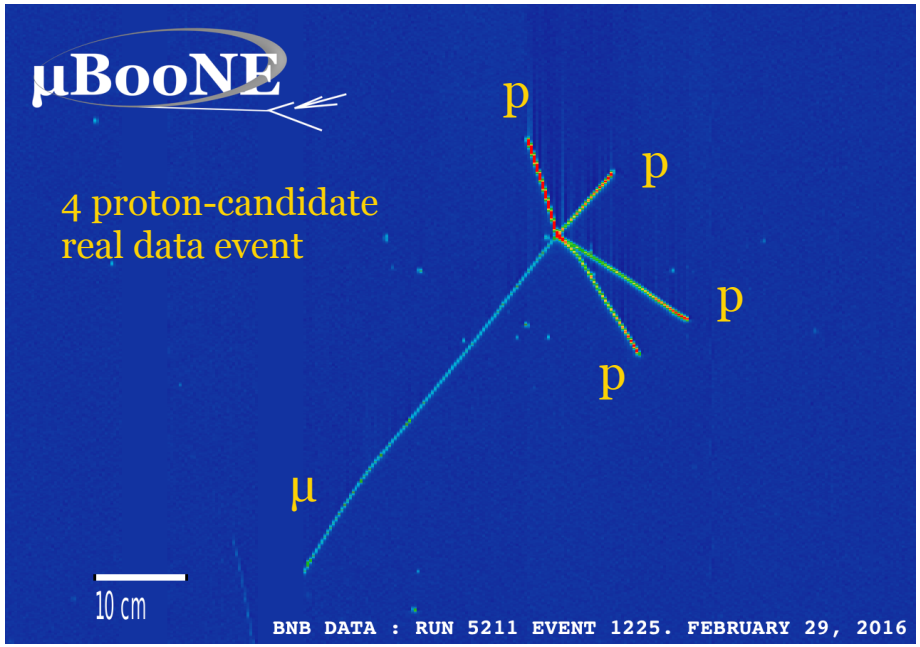


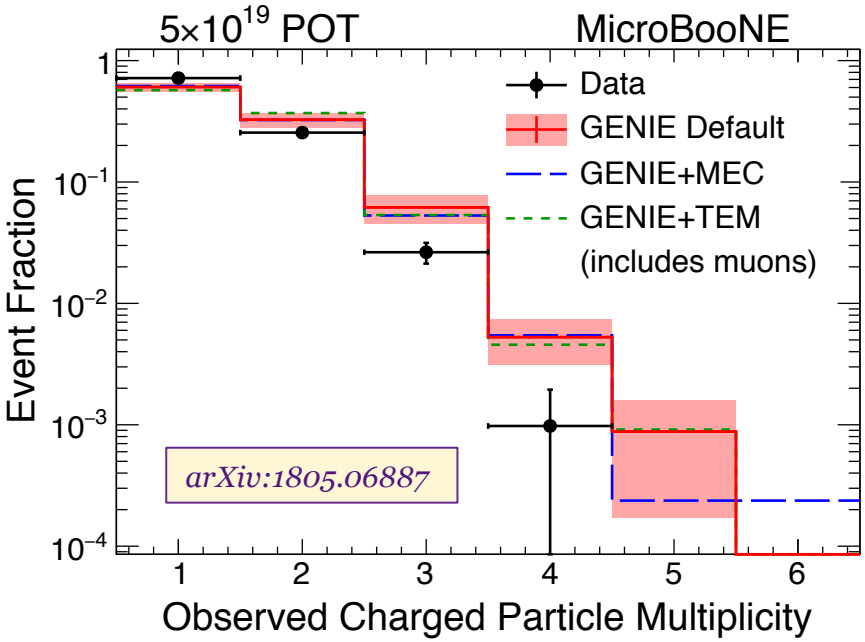
See Christopher's talk for details on detector, calibration, and detector physics

Surface detector – large cosmic ray background. Cosmic rejection paper: **arXiv:1812.05679**

Charged particle multiplicity

- LArTPCs have excellent spatial resolution of charged tracks
  - High-multiplicity exclusive cross section measurements
- Charged particle multiplicity agrees with GENIE [1] generator at 2σ level; data favours lower multiplicities

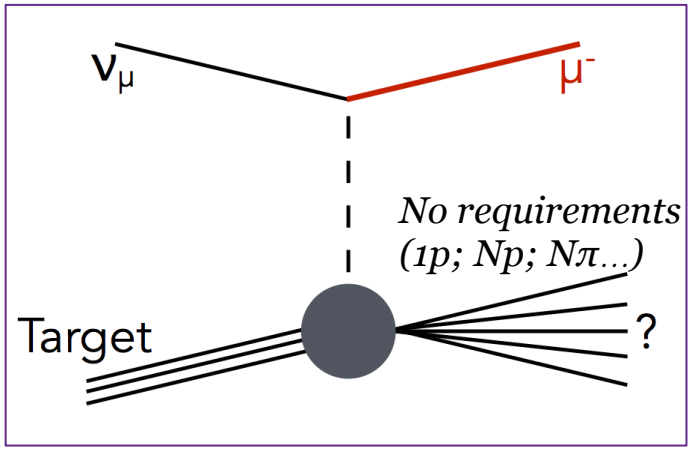




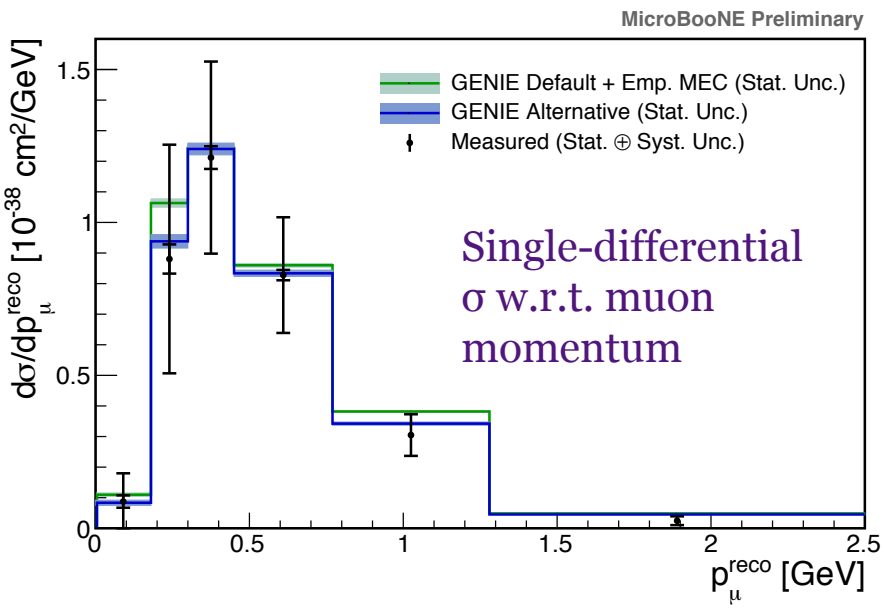
[1] http://genie-mc.org/

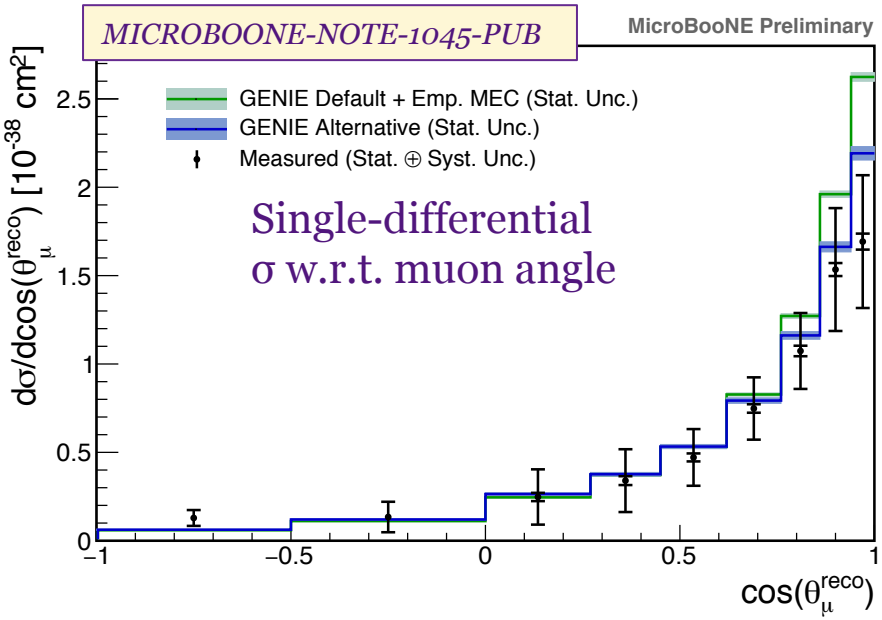
ν_μ-Ar CC-inclusive cross section

- Signal: μ + X
- First year data only (so far)
- Largest ever sample of muon neutrinos on argon
- Double differential cross sections will also be produced

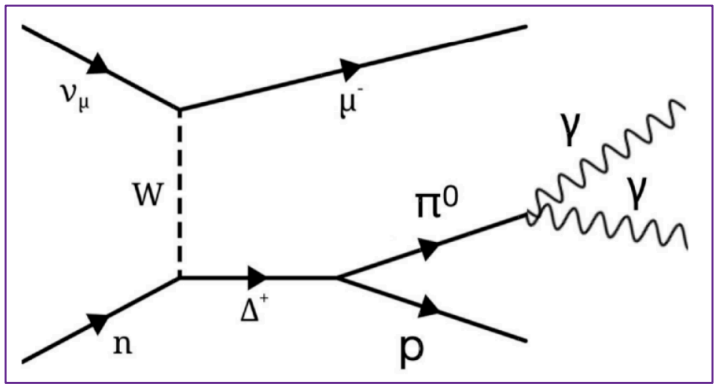


σ=0.76 ±0.01 (st.) ±0.19 (sys.) ×10^{-38} cm²/n





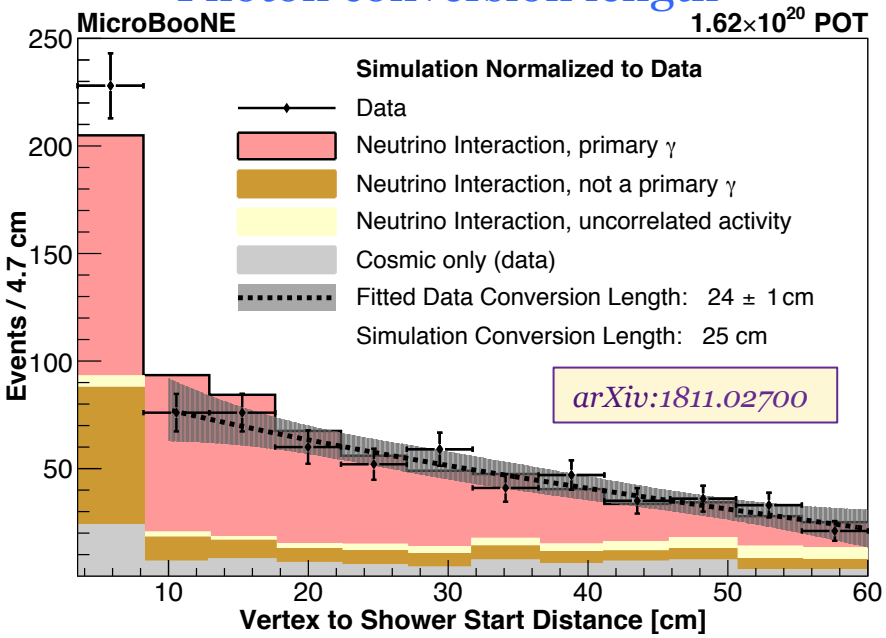
CC neutral pion production



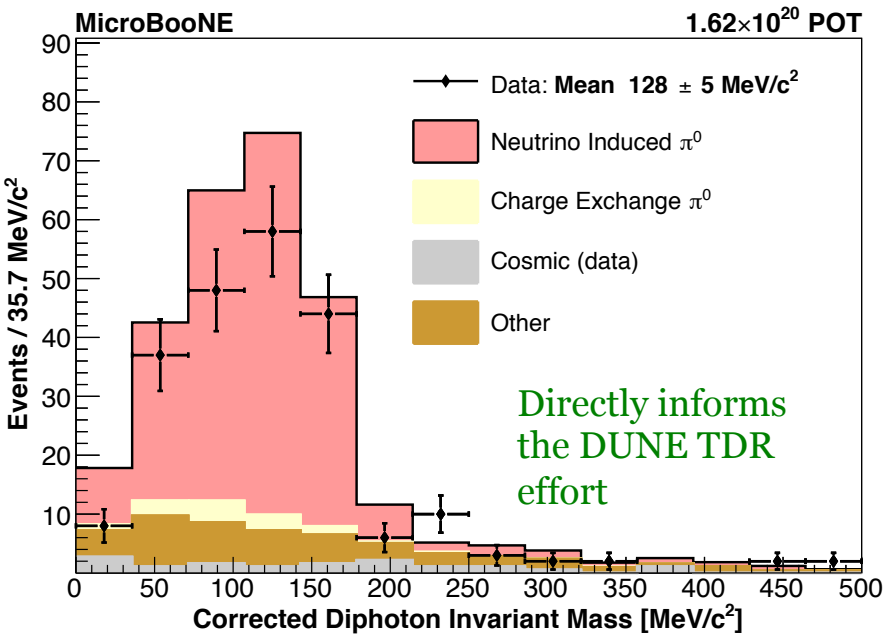
- Signal: $\mu + \pi^0 + X$
- MicroBooNE's first PRL submission
- First π^0 cross section on argon to use fully automated reconstruction

σ=1.94 ±0.16 (st.) ±0.60 (sys.) $\times 10^{-38}$cm²/Ar

Photon conversion length

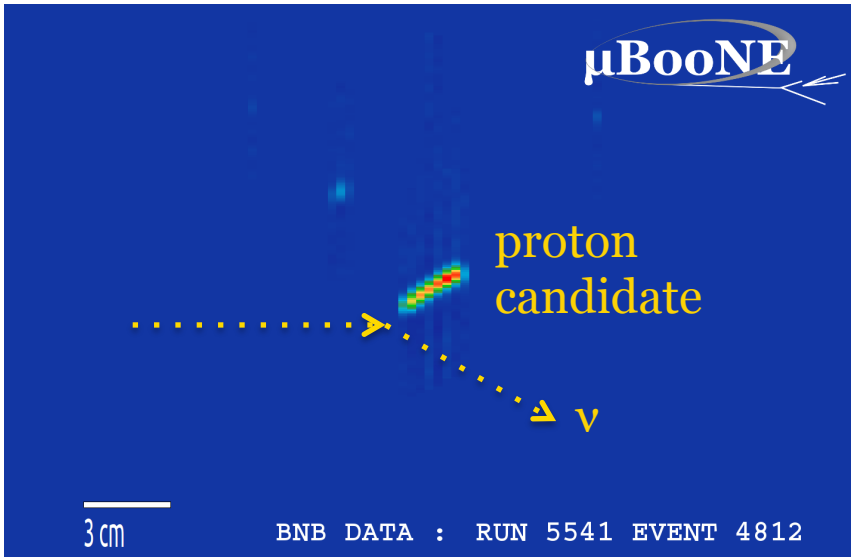


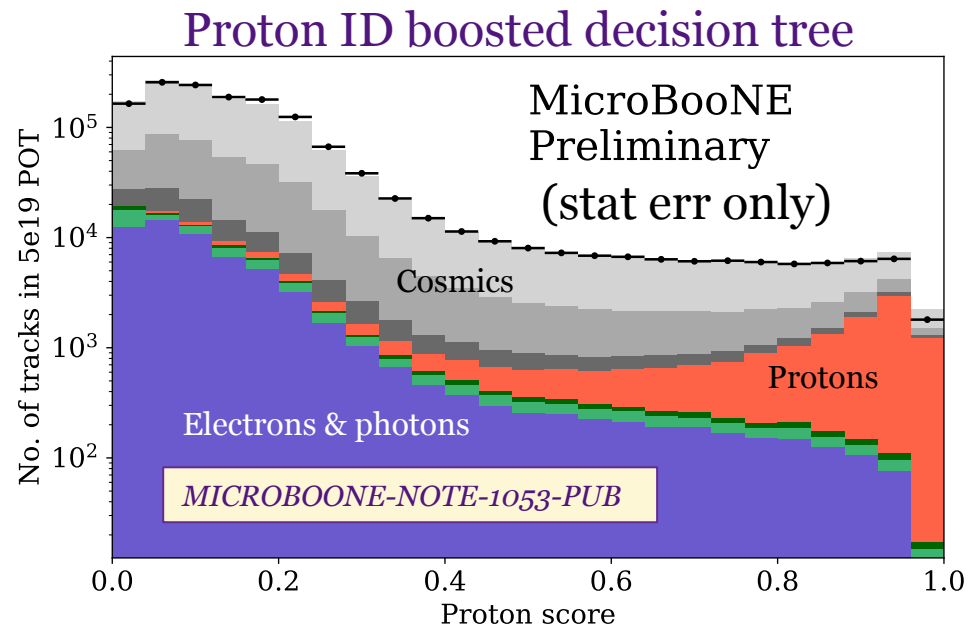
π^0 mass reconstruction



Directly informs the DUNE TDR effort

Neutral current elastic scattering





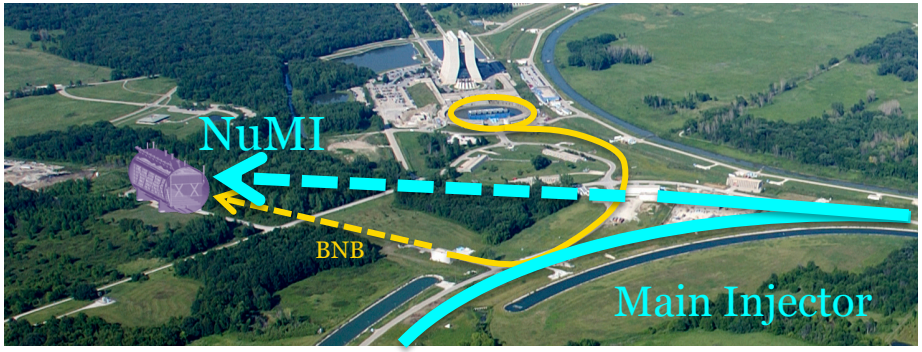
- Signal is isolated single protons
- Can extract the strange axial form factor of nucleus
  - Predicted to be zero
  - 1980's experiments hinted at a non-zero value

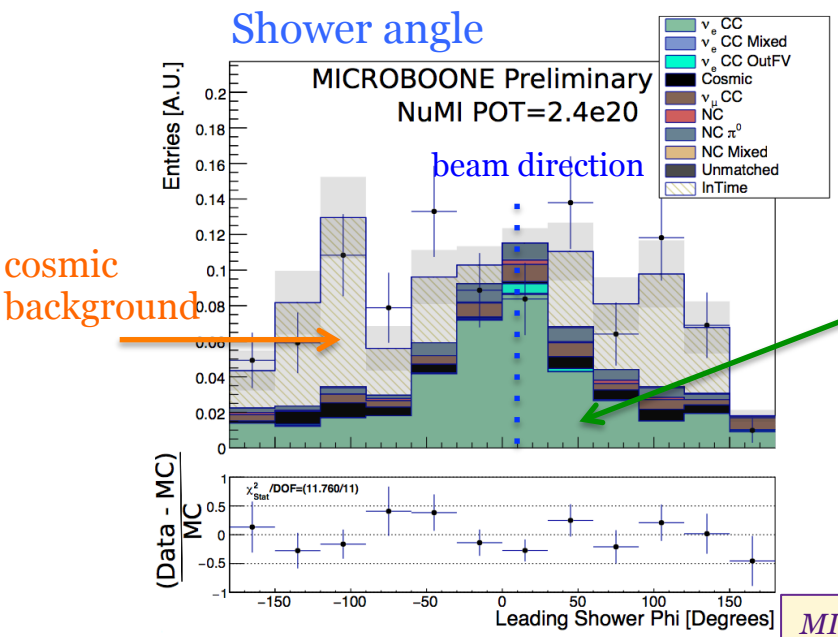
$$d\sigma_{NC}(\mathbf{x}) = f_0(d\sigma_{CC}, \mathbf{x}) + g_A^s f_1(d\sigma_{CC}, \mathbf{x}) + {g_A^s}^2 f_2(d\sigma_{CC}, \mathbf{x})$$

strange quark contribution to axial form factor

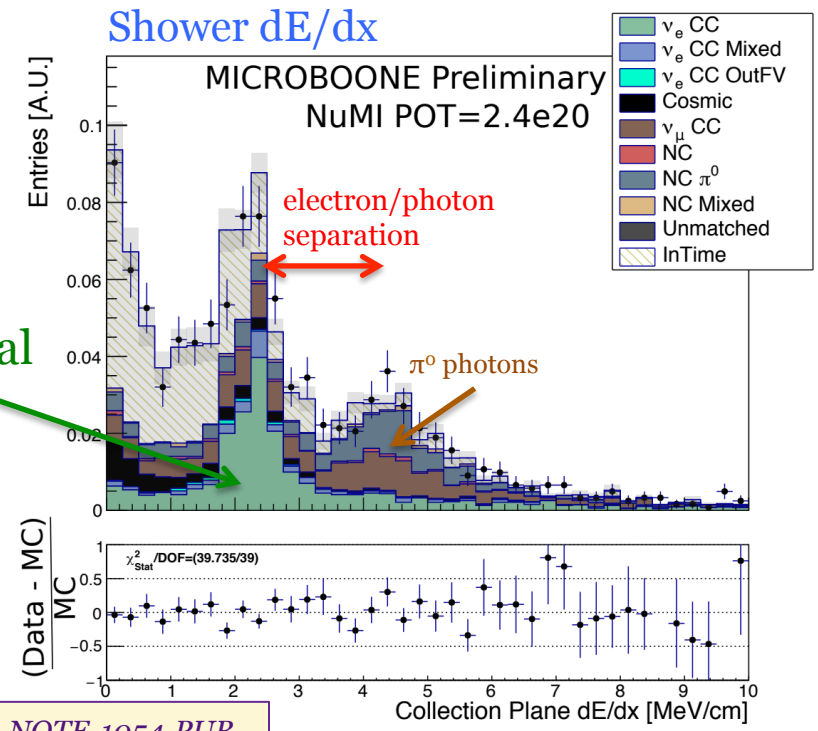
ν_e-Ar CC-inclusive cross section

- MicroBooNE sits at 8° off-axis to NuMI beam
  - Enhanced ν_e:ν_μ flux ratio compared to BNB
  - Data is unblinded
- Will be first ever measurement of this cross section on argon





ν_e signal

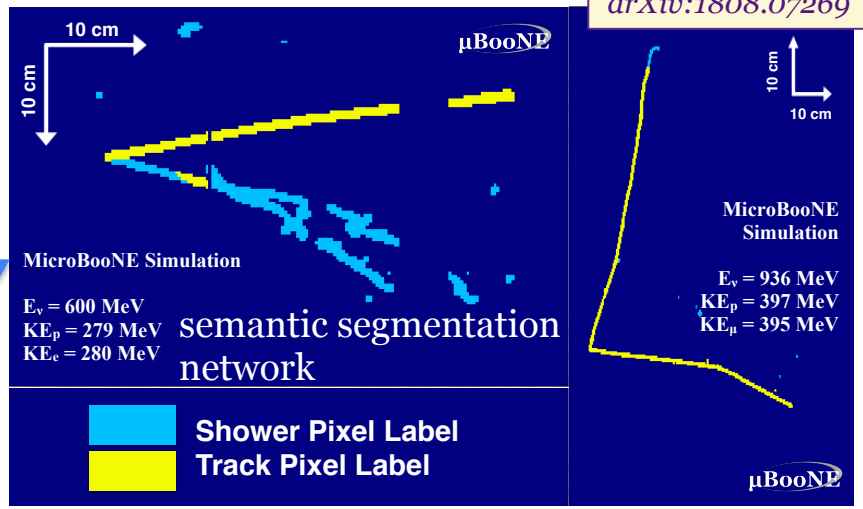


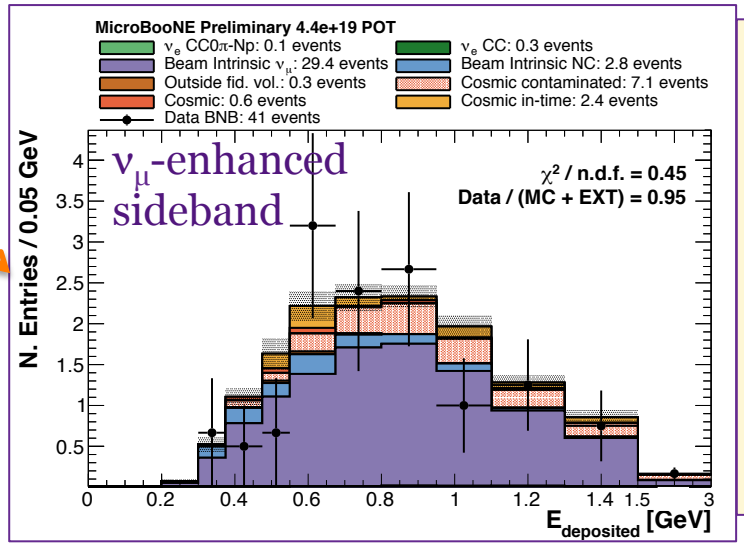
MICROBOONE-NOTE-1054-PUB

Towards a Low Energy Excess search

- Three independent analyses tackling the MiniBooNE LEE ν_e appearance hypothesis:
  - Deep learning methods [1]
  - Pandora pattern recognition [2]
  - Wire-cell 3D hit reconstruction [3]
  - Inclusive & exclusive (1e1p) channels
- Sensitivities being finalised before unblinding

arXiv:1808.07269





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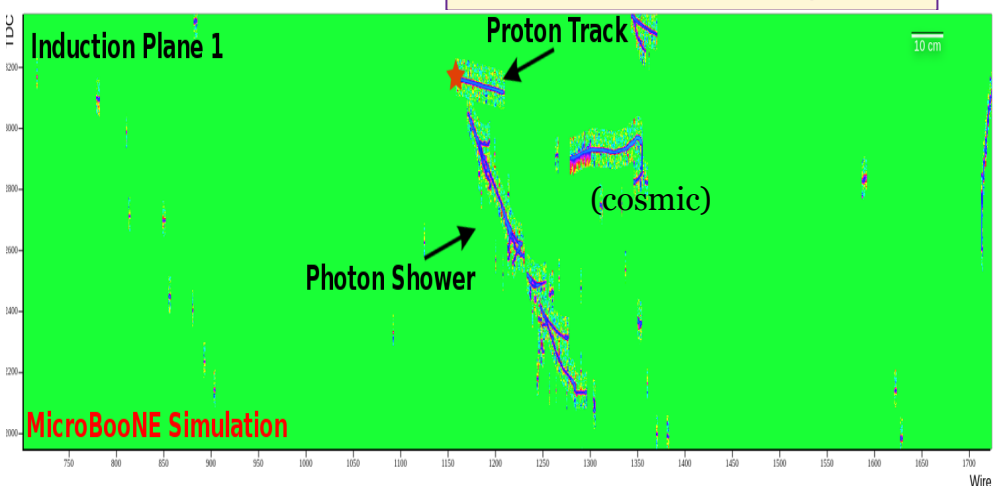
[1] arXiv:1808.07269 *(accepted by PRD)* [2] Eur. Phys. J. C78 (2018) 1, 82 [3] https://www.phy.bnl.gov/wire-cell/

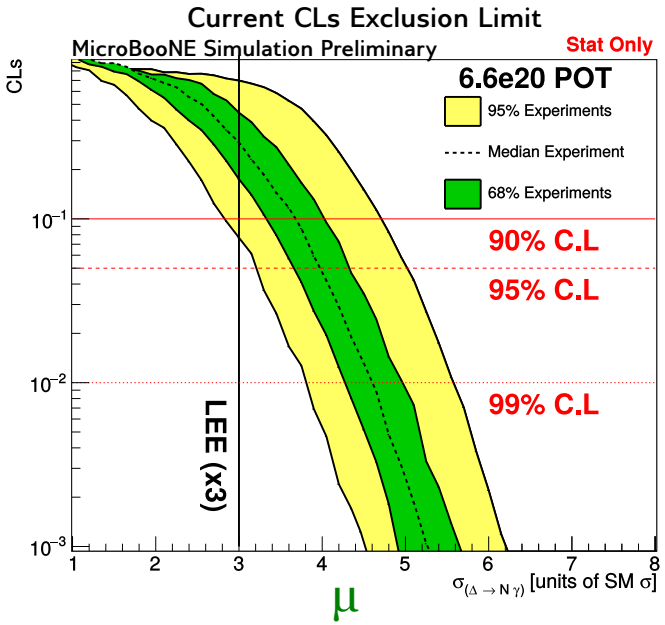
Single photon search

- Photon hypothesis of LEE also being adressed
  - Radiative decay of NC-produced Δ: production cross section scaling (μ) by 3 could explain the MiniBooNE excess
  - Best experimental limit so far (NOMAD): μ < O(10)
- Transitioning towards using a hybrid of Pandora and Deep Learning techniques

MICROBOONE-NOTE-1041-PUB

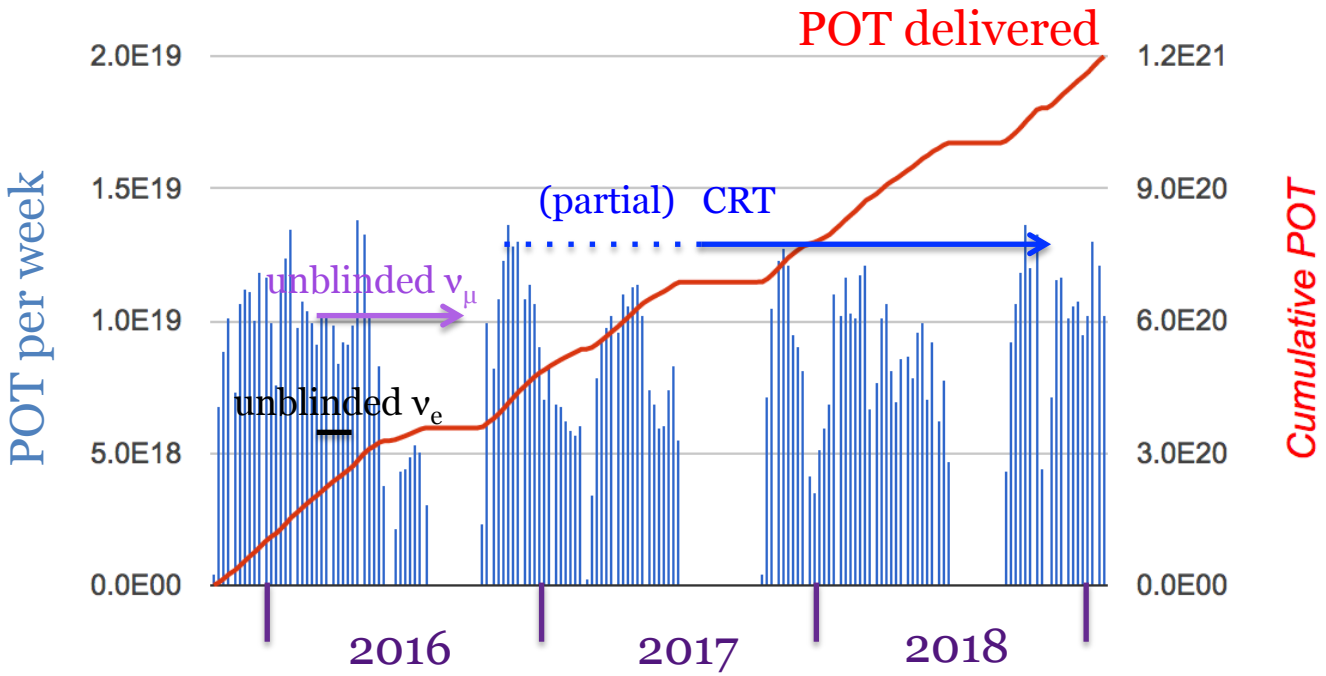


sensitivity [half-dataset]

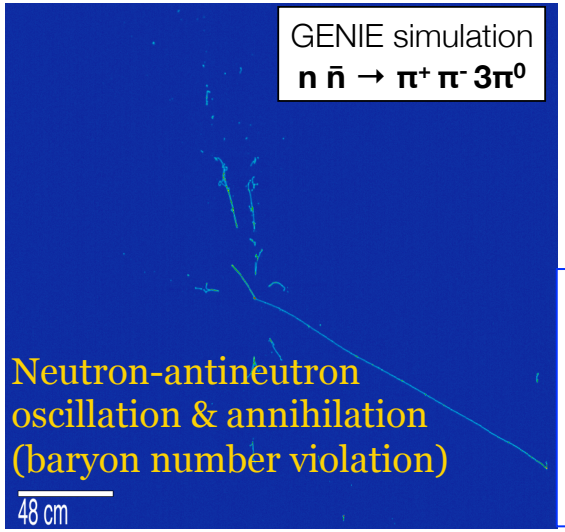


LEE prospects for 2019

- Final sensitivities in preparation; exploiting novel signal processing and 2D deconvolution implemented over past year
  - JINST 13 P07006 & P07007 (2018)
- We have only fully unblinded 5% of the full dataset so far
- Results produced so far are only with first-year data
  - Cosmic Ray Tagger (CRT) installed during second year of running, will help to reduce backgrounds

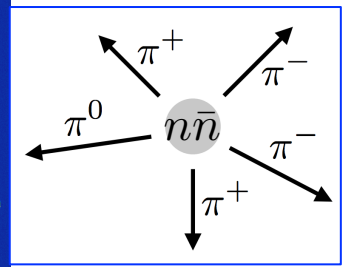


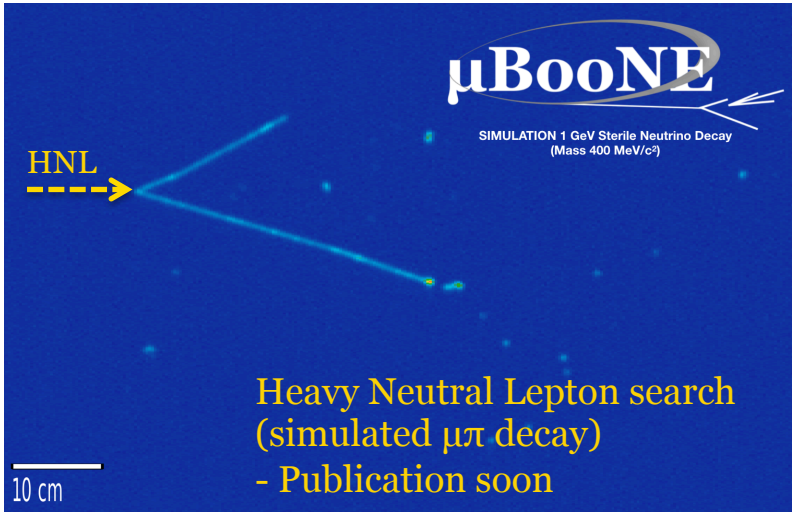
Astroparticle and Exotics



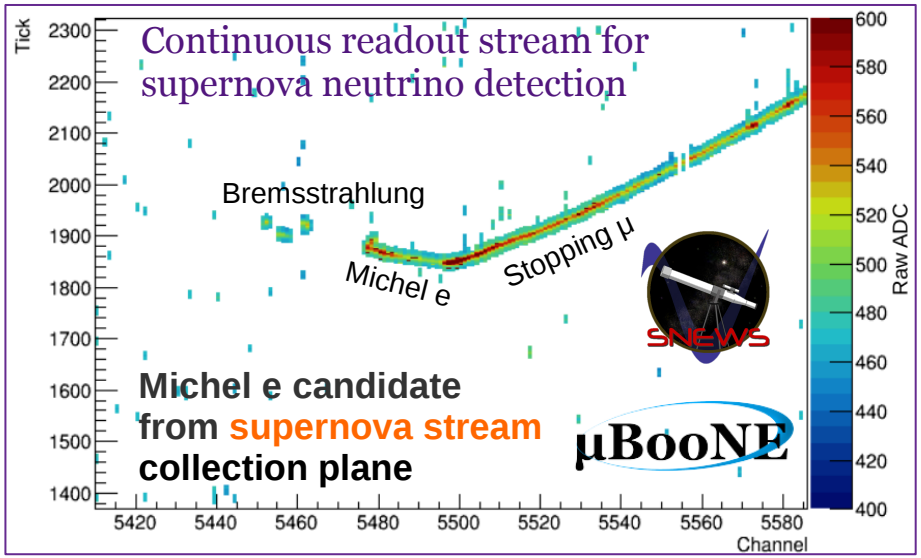
Neutron-antineutron oscillation & annihilation (baryon number violation)

Rich program of non-beam-neutrino physics, including:

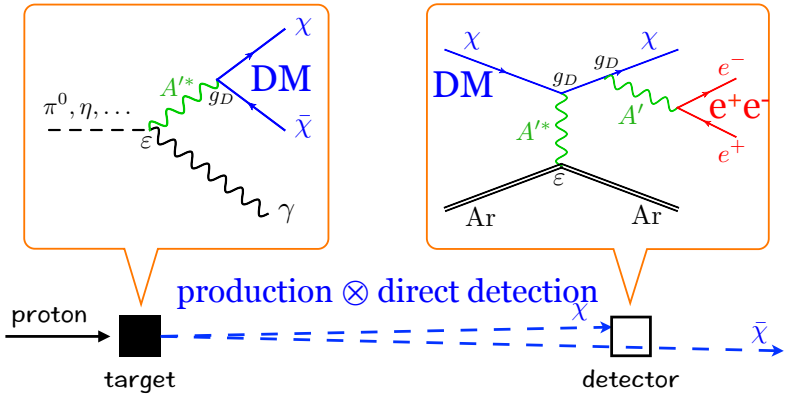




Heavy Neutral Lepton search (simulated μπ decay)
- Publication soon



JHEP (2019) 2019:1

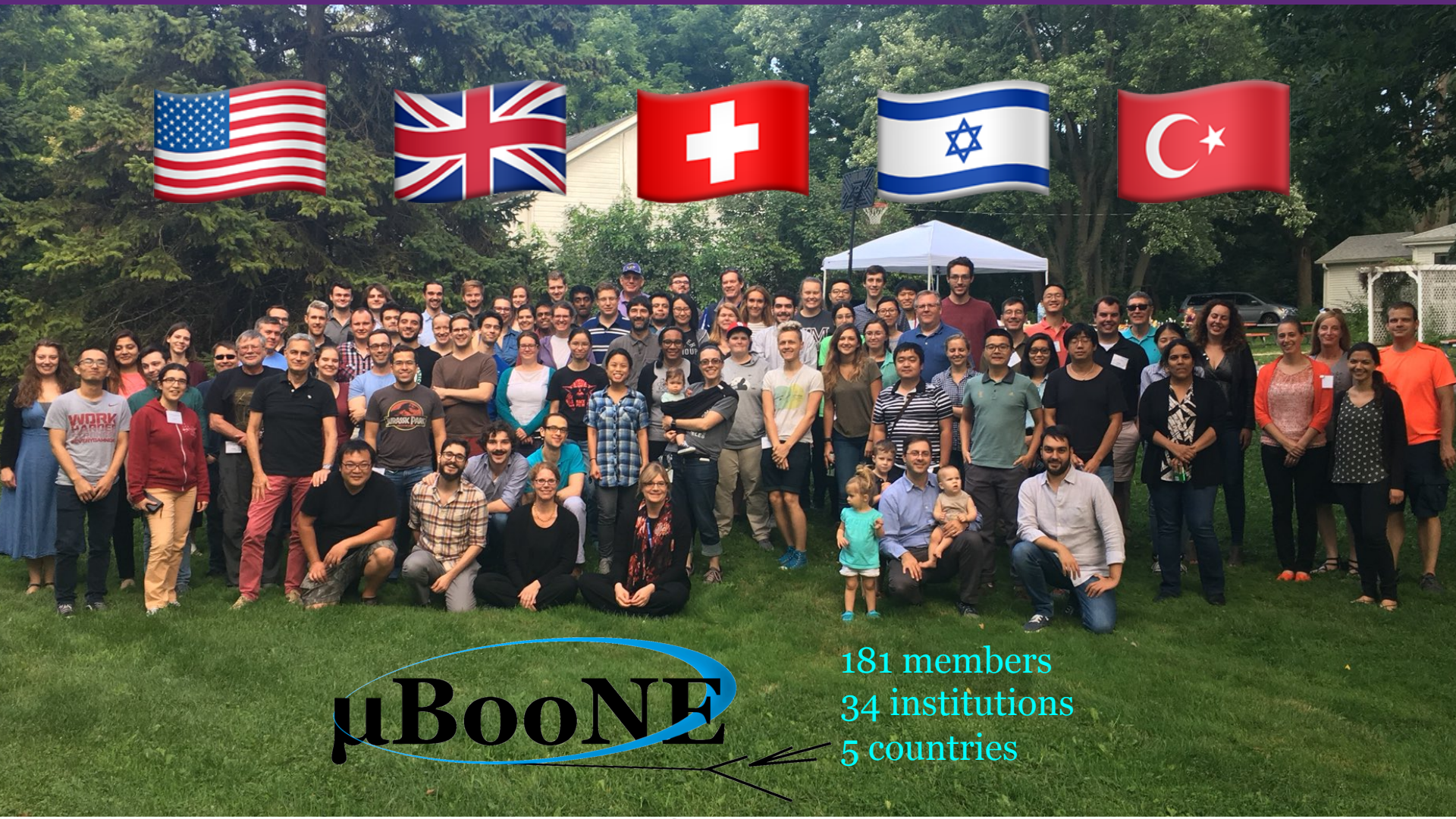


Dark photons coupled to neutrinos or dark matter

PRL 121, 241801 (2018)
arXiv:1808.02915

Summary

- Large physics output from the experiment in 2018
  - 2 papers on cross sections
  - 5 papers on signal processing, reconstruction & cosmic rejection
  - 15 public notes
- Many more results due in 2019
  - Low Energy Excess analysis
  - At least 3 cross section publications
  - Heavy Neutral Lepton search
- Watch this space!



Fermilab U.S. DEPARTMENT OF ENERGY Office of Science NSF FNSNF SWISS NATIONAL SCIENCE FOUNDATION Science & Technology Facilities Council THE ROYAL SOCIETY

SUPPLEMENTARY SLIDES

ν_μ CC inclusive cross section

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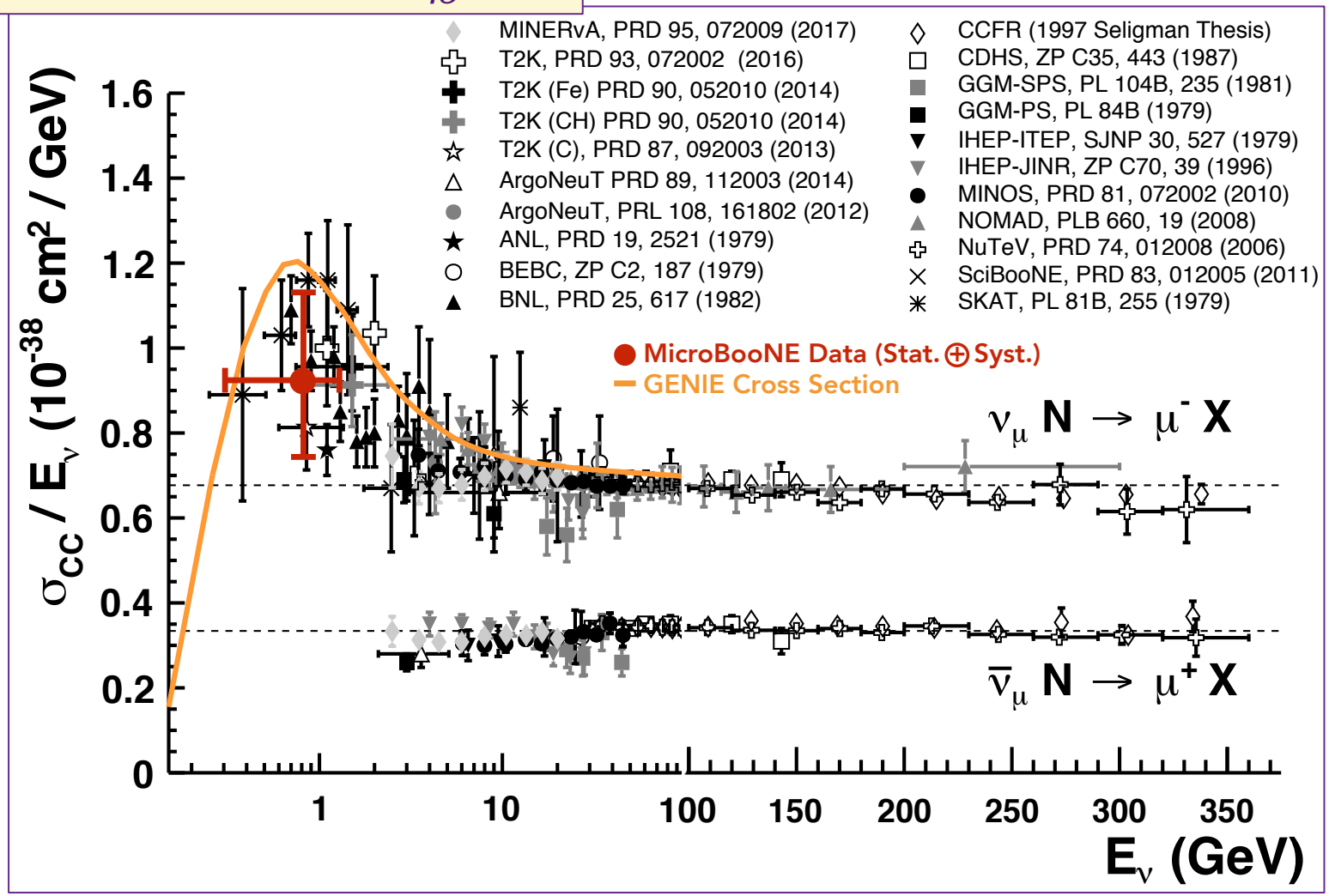
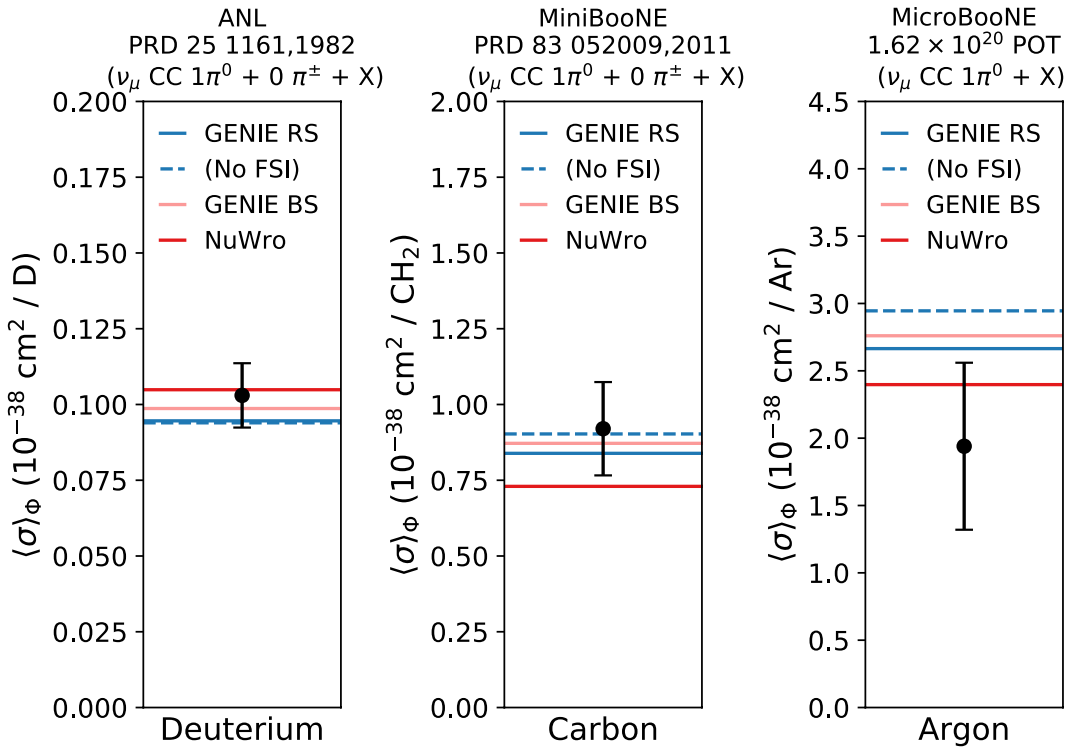


CC neutral pion production

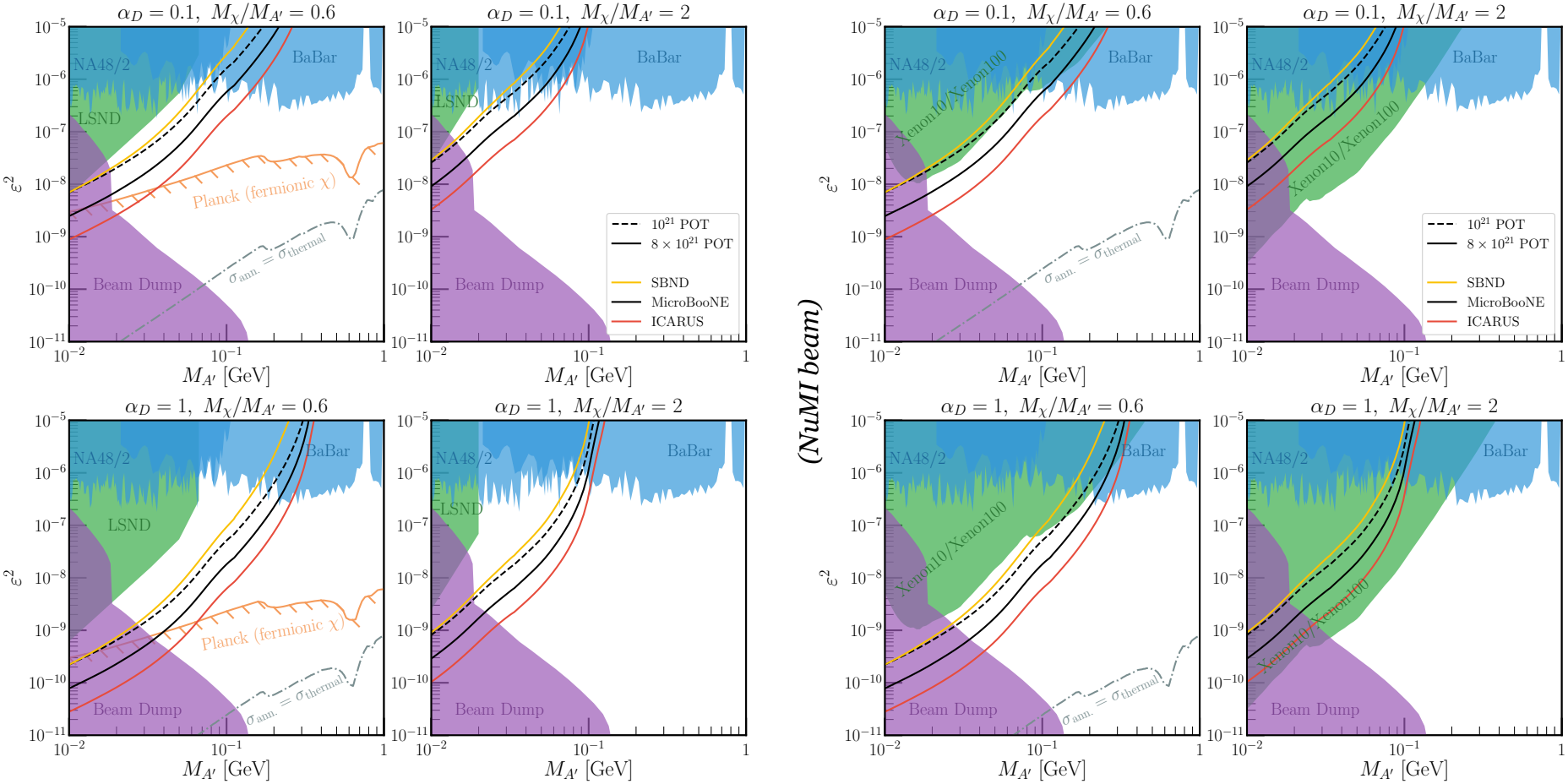
arXiv:1811.02700



MicroBooNE measurement

“Dark Tridents” in MicroBooNE

de Gouvêa, Fox, Harnik, Kelly, Zhang – J. High Energ. Phys. (2019) 2019: 1.



symmetric DM

asymmetric DM

MicroBooNE sensitivity: Black line