MicroBooNE in 10 Minutes

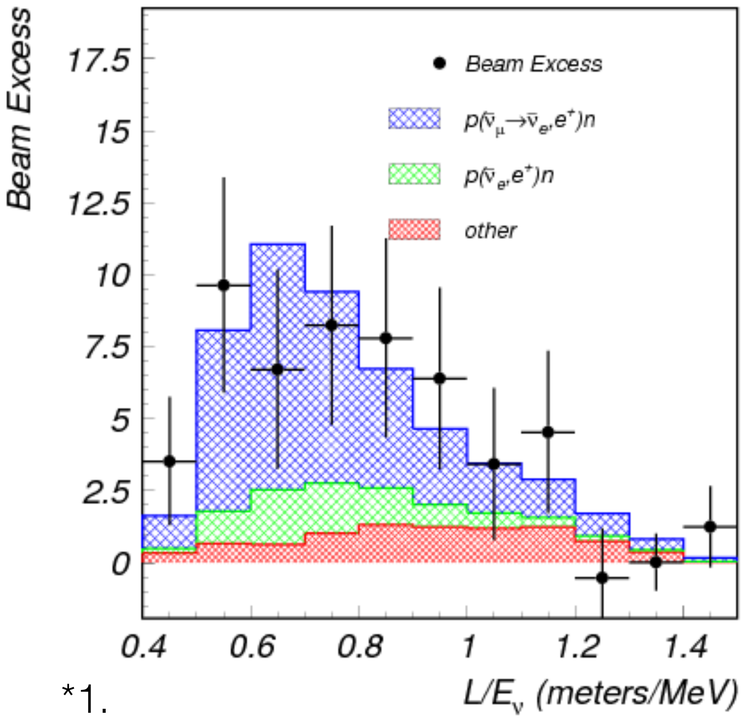
FNAL New Perspectives

Colton Hill, on behalf of the MicroBooNE Collaboration

June 18 2018

MANCHESTER 1824
The University of Manchester

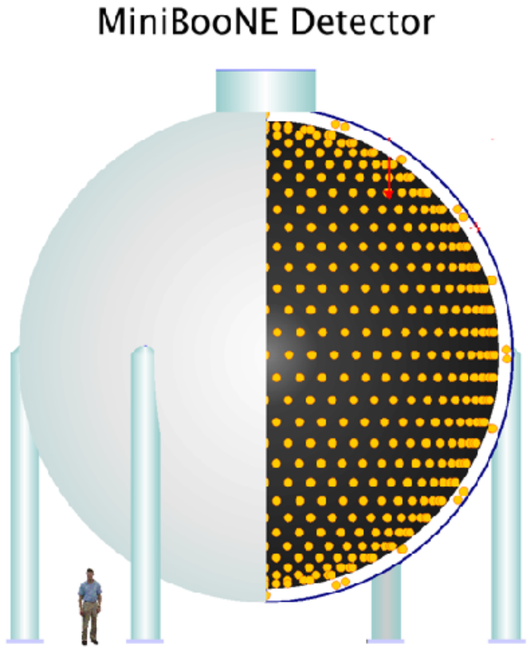
µBooNE

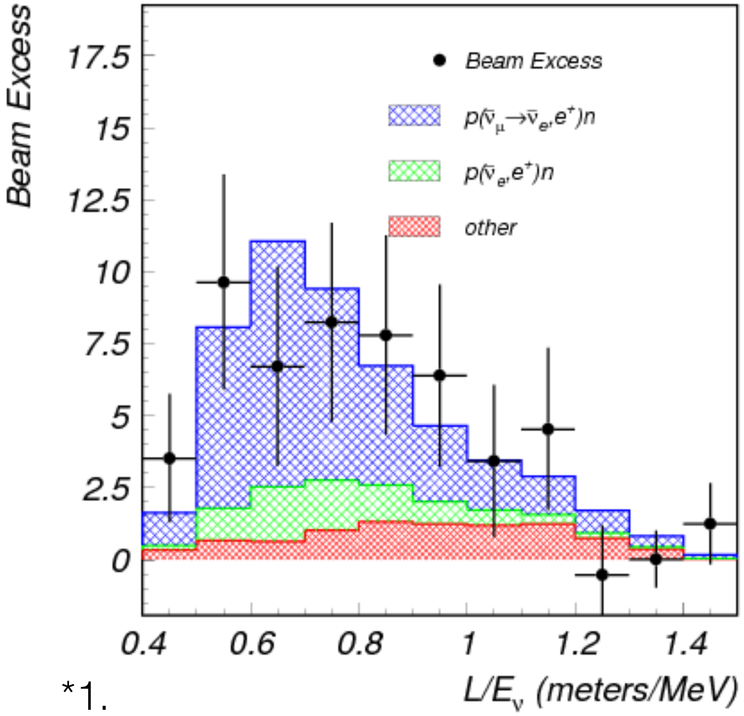


*1.

- LSND (1993)
- Sees excess of anti-ν_e.

*1. Annu. Rev. Nucl. Part. Sci. 63, 45 (2013)





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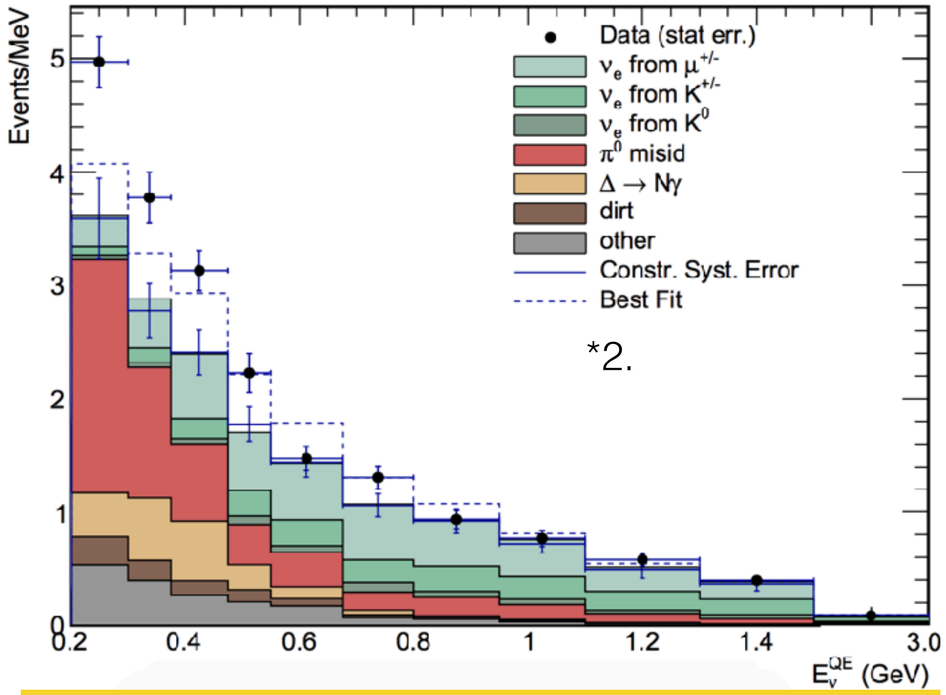

*2.

- LSND (1993)
- Sees excess of anti-ν_e.
- MiniBooNE (2002) - investigate LSND anomaly.
- Also sees accelerator-based excess of low energy electron neutrinos.
- Recent results reaffirm the need for further study.

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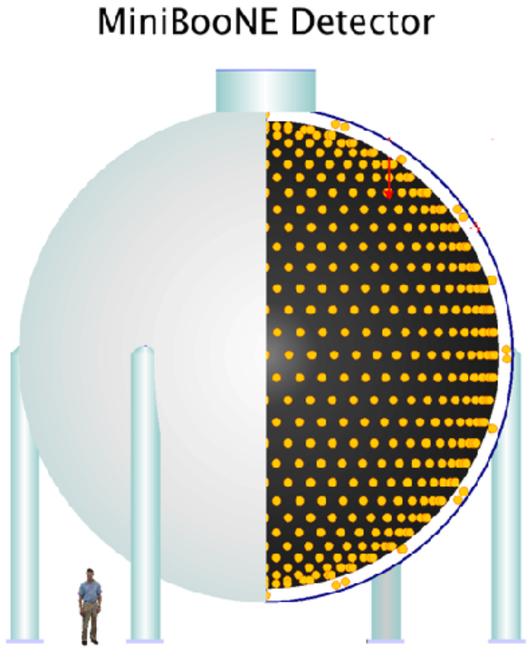
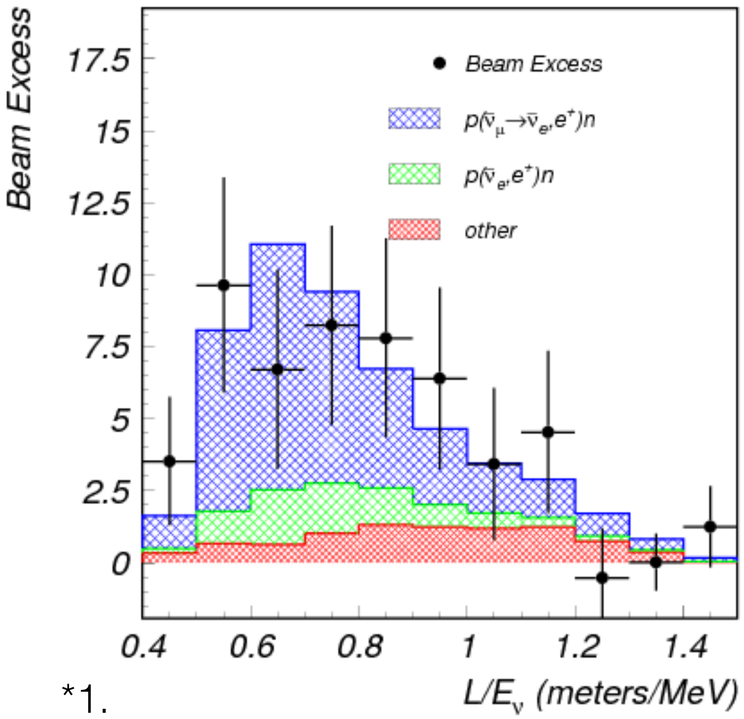
*2. FERMILAB-PUB-18-219, LA-UR-18-24586





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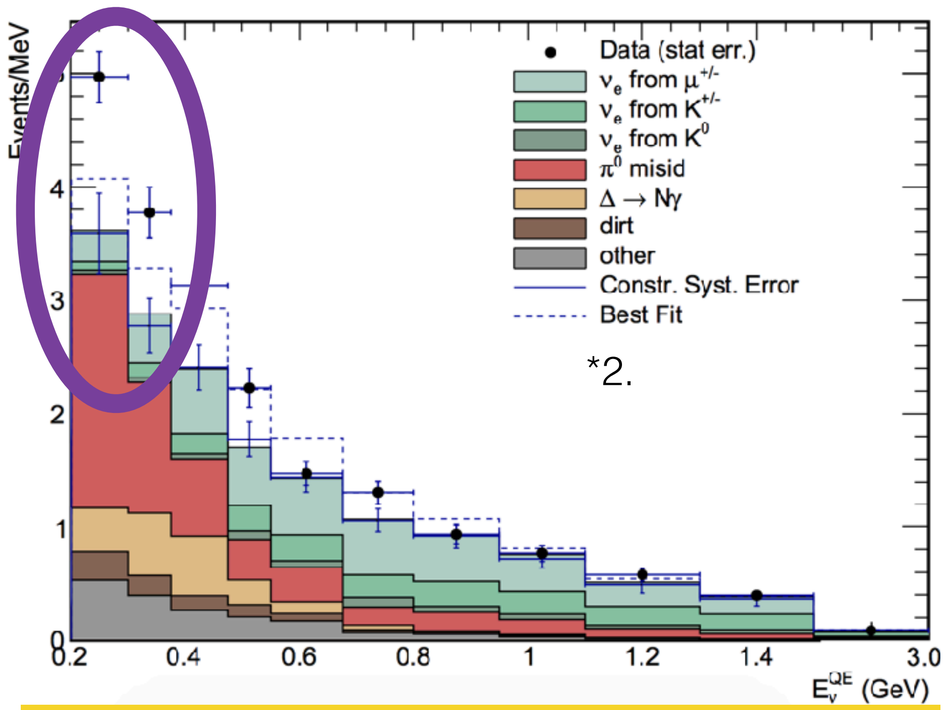

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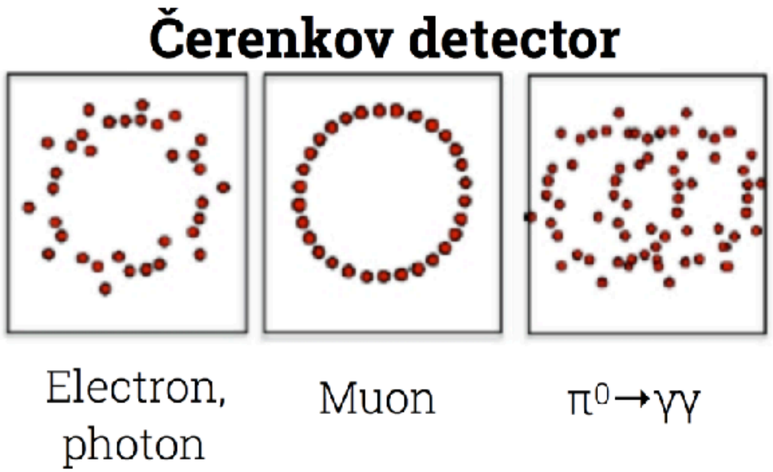
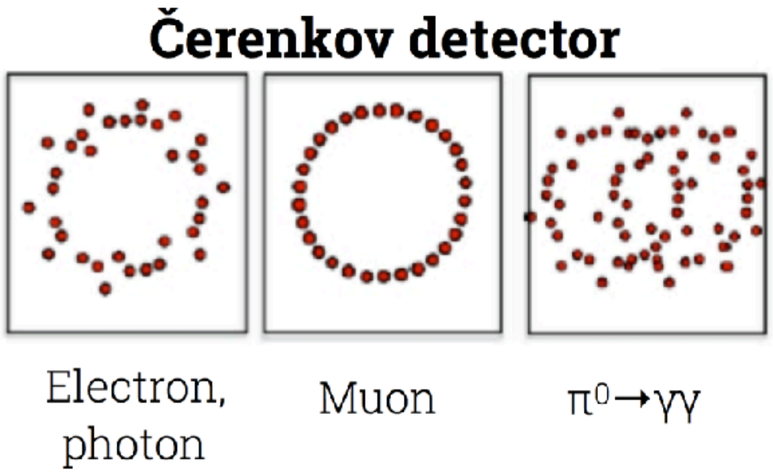
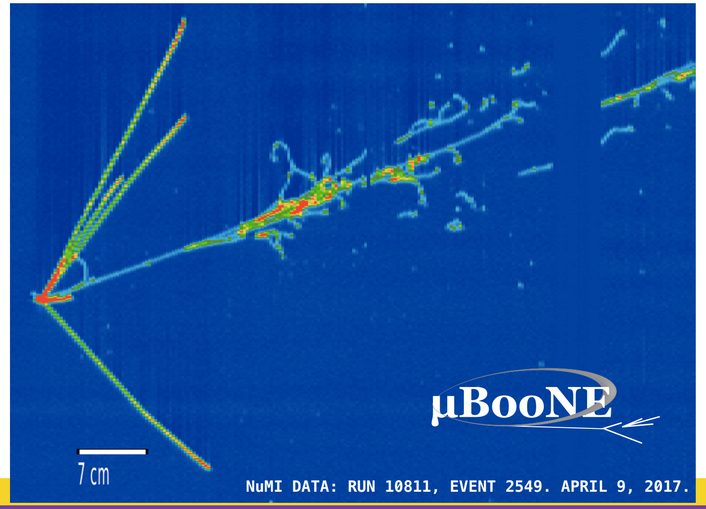
- Why use liquid argon to investigate this anomaly?

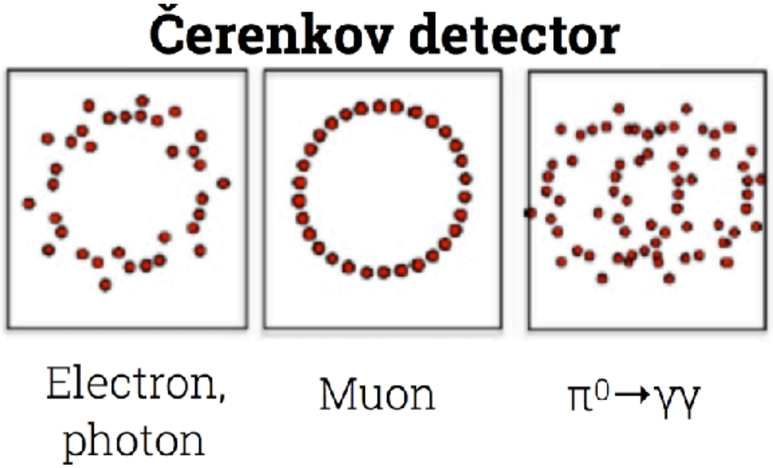


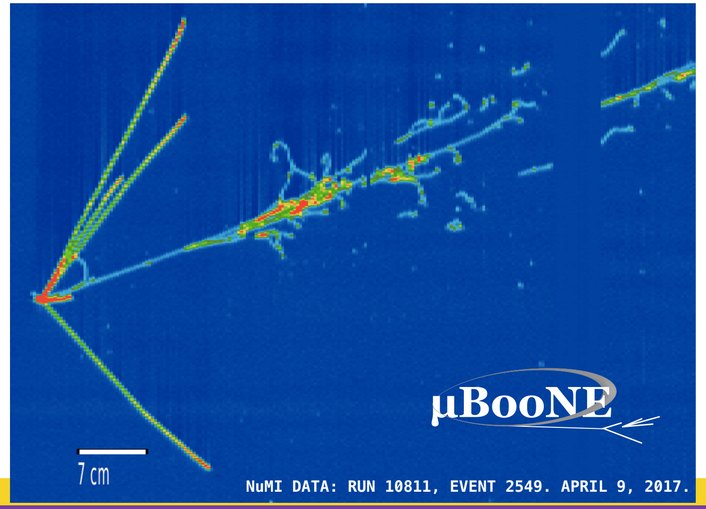
- Why use liquid argon to investigate this anomaly?
- Liquid argon detectors have high spatial resolution and calorimetric information.

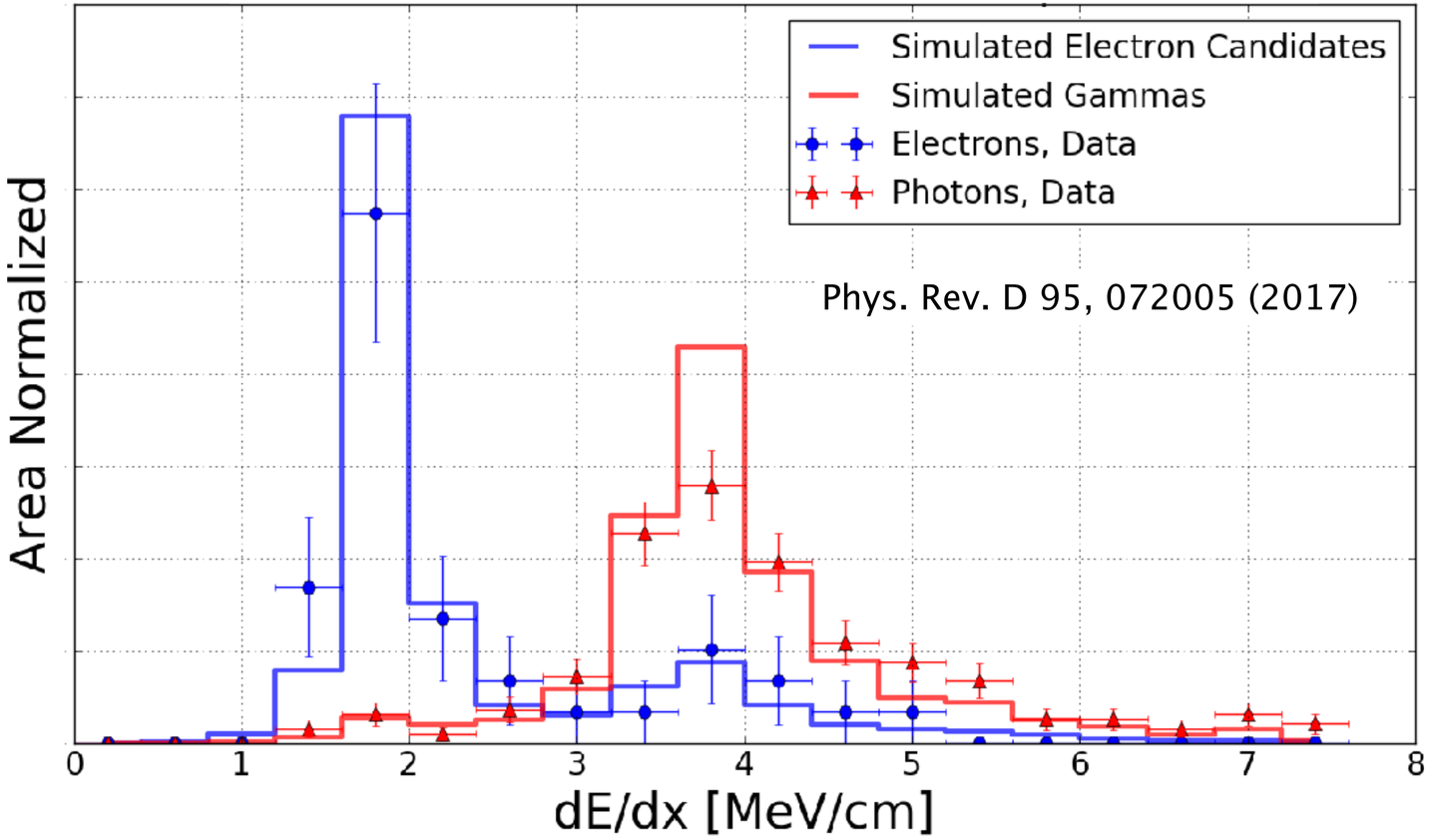




- Why use liquid argon to investigate this anomaly?
- Liquid argon detectors have high spatial resolution and calorimetric information.
- Using dE/dx liquid argon detectors can separate electrons and photons.







- Argoneut - 0.3 tons LAr.

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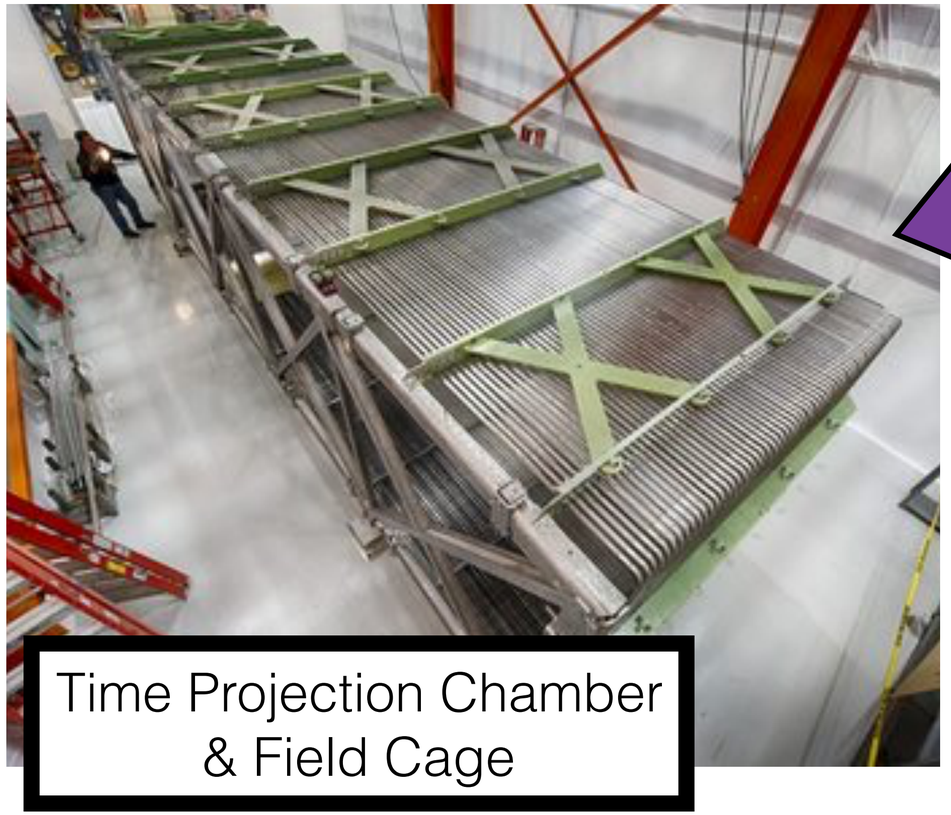
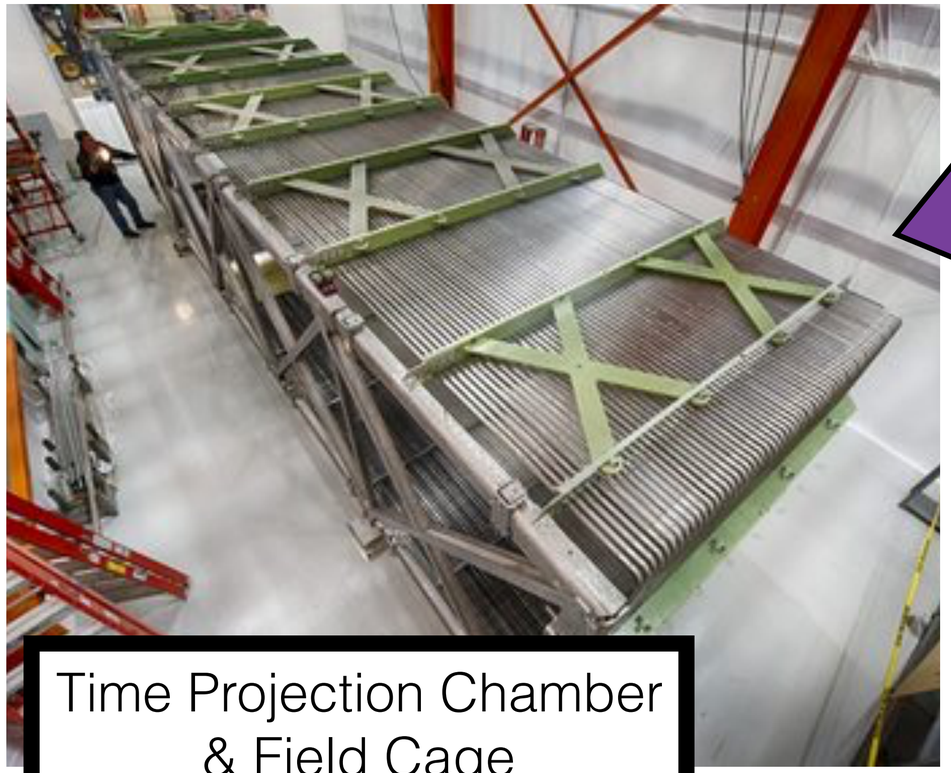
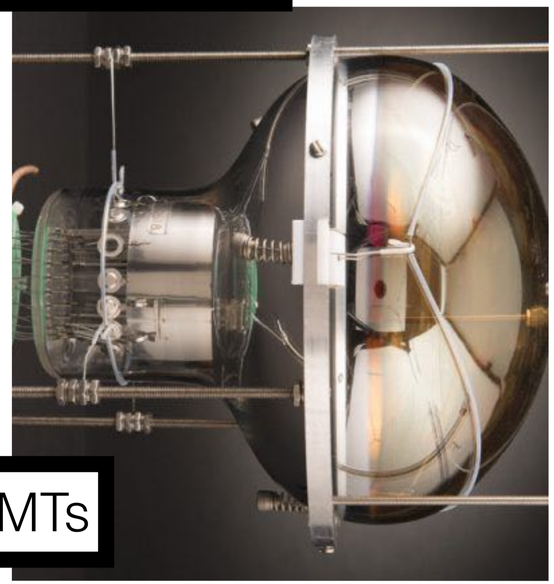
- MicroBooNE - 170 tons LAr.



- Field cage cathode is held at -70 kV.
- Time Projection Chamber (TPC) composed of 3 wire planes (8256 total wires) to collect ionisation charge.

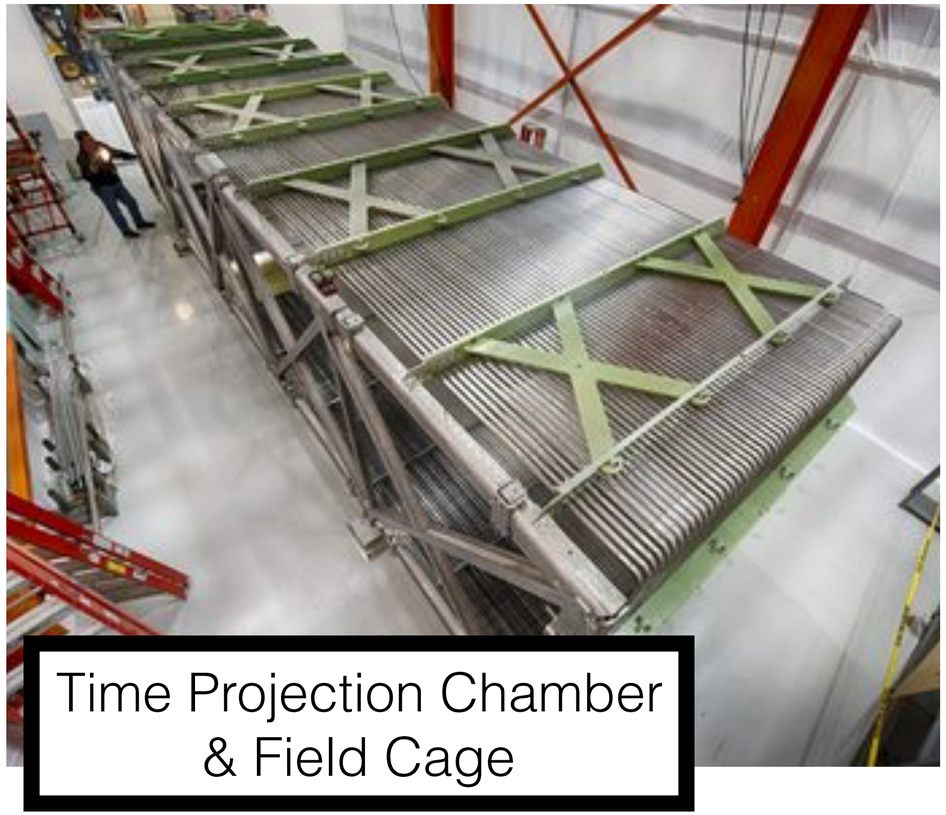


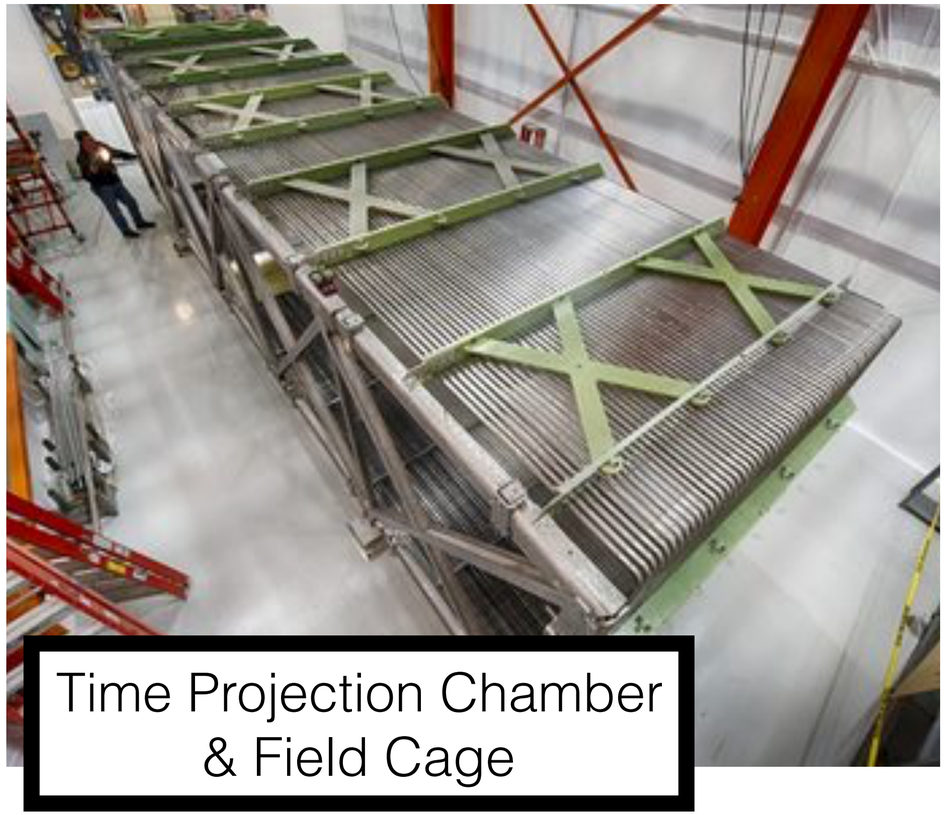
Time Projection Chamber & Field Cage

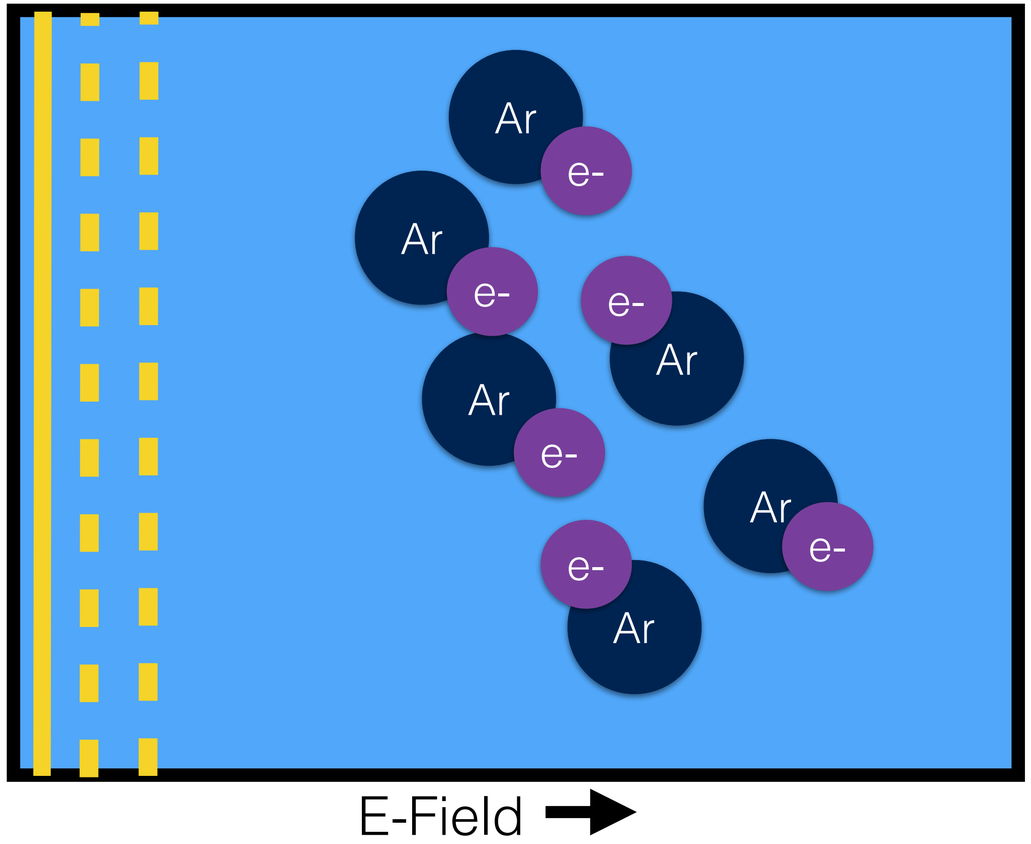


Array of 32 PMTs

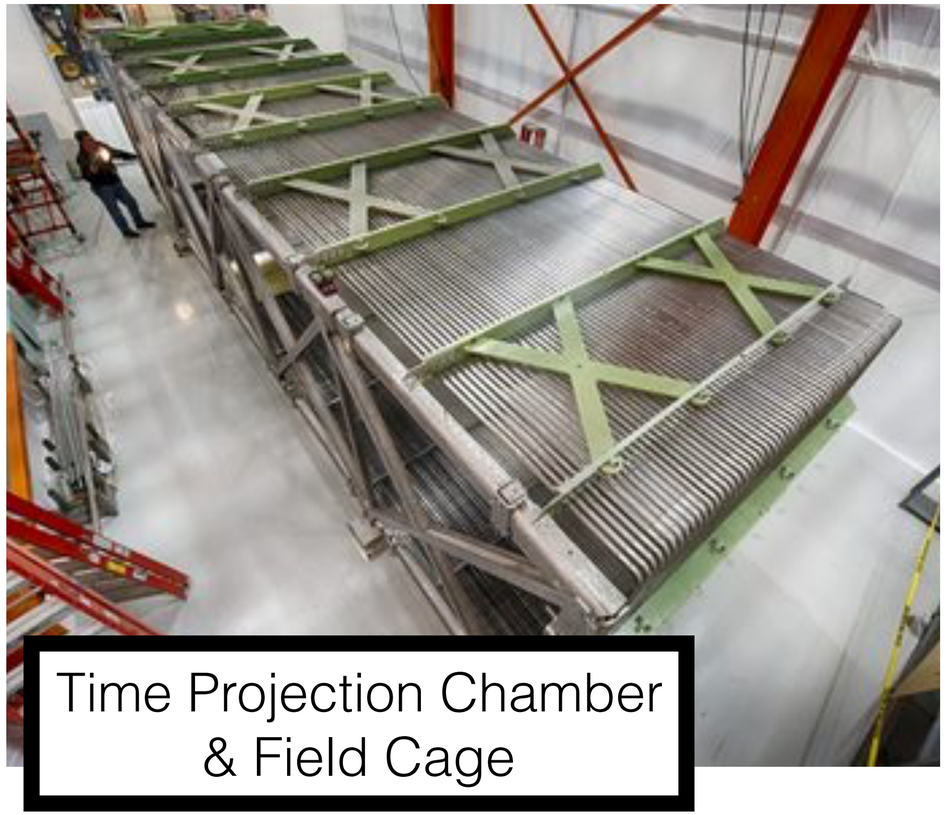
- Field cage cathode is held at -70 kV.
- Time Projection Chamber (TPC) composed of 3 wire planes (8256 total wires) to collect ionisation charge.
- LAr Scintillation light collected on PMT array.

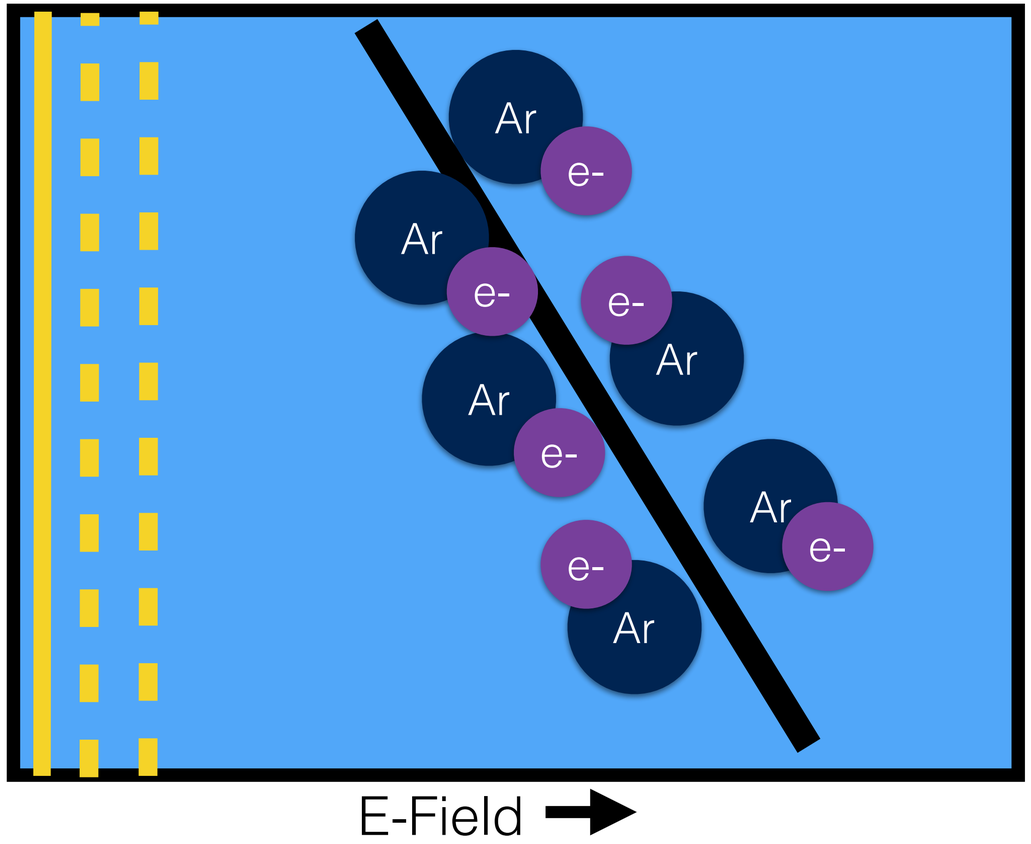

Time Projection Chamber
& Field Cage



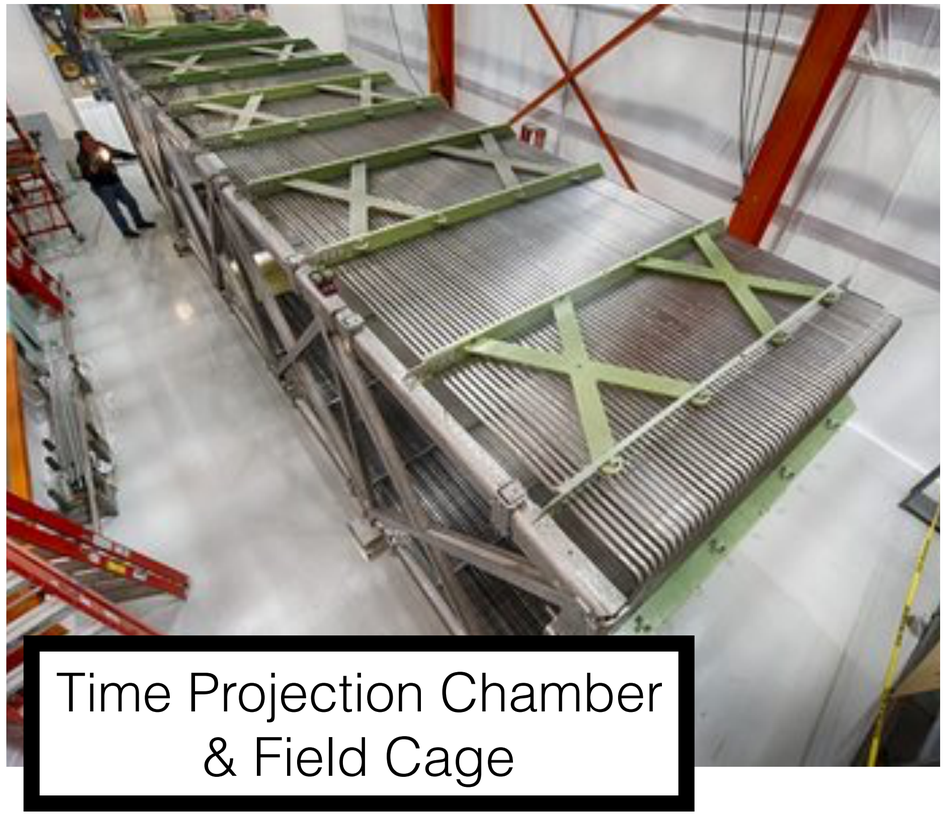


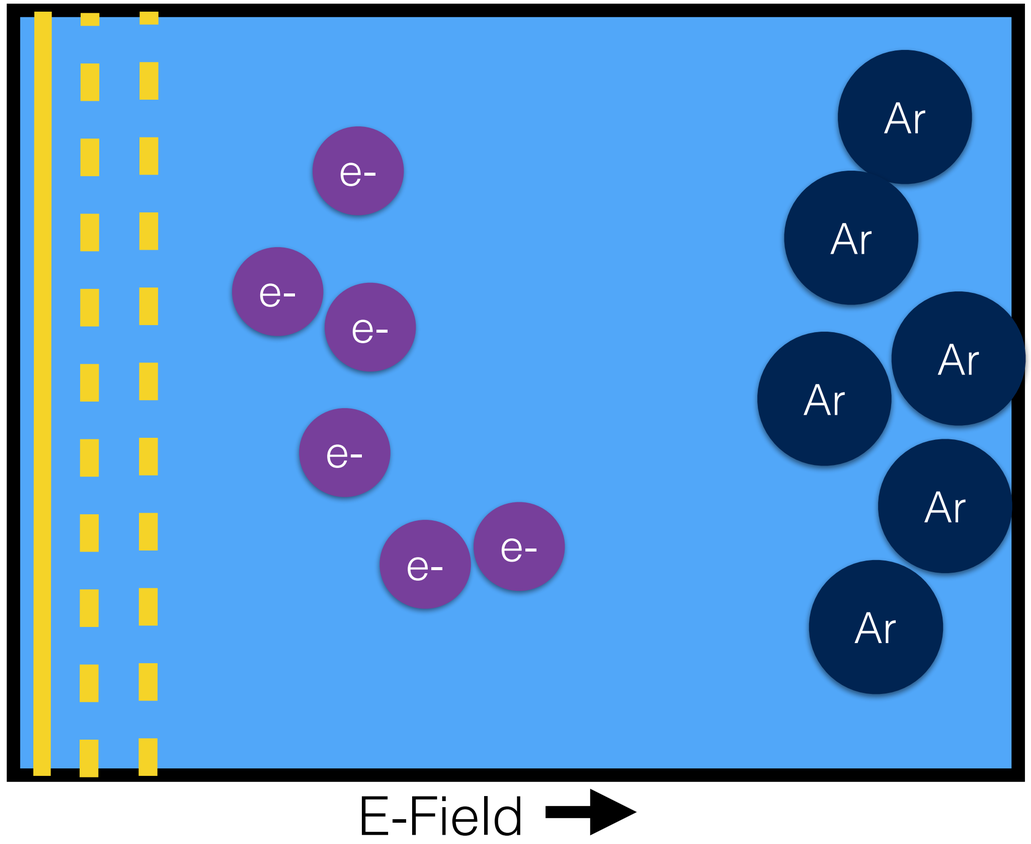
- Detector volume, composed of argon atoms is held at high voltage.



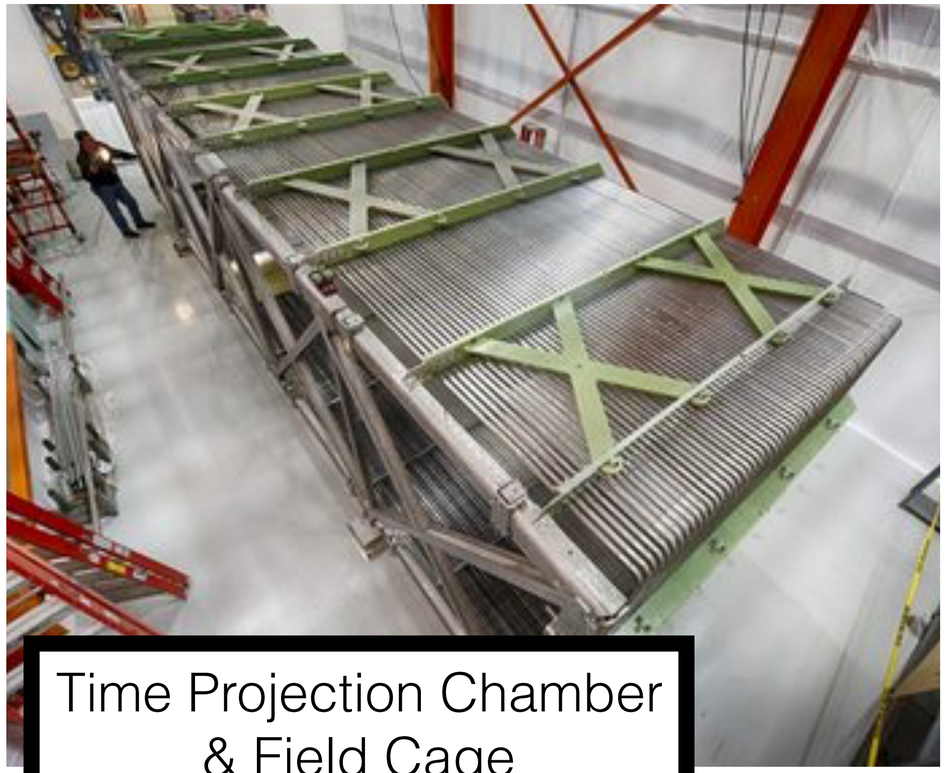


- Detector volume, composed of argon atoms is held at high voltage.
- Charged particles passing through volume ionise the atoms.



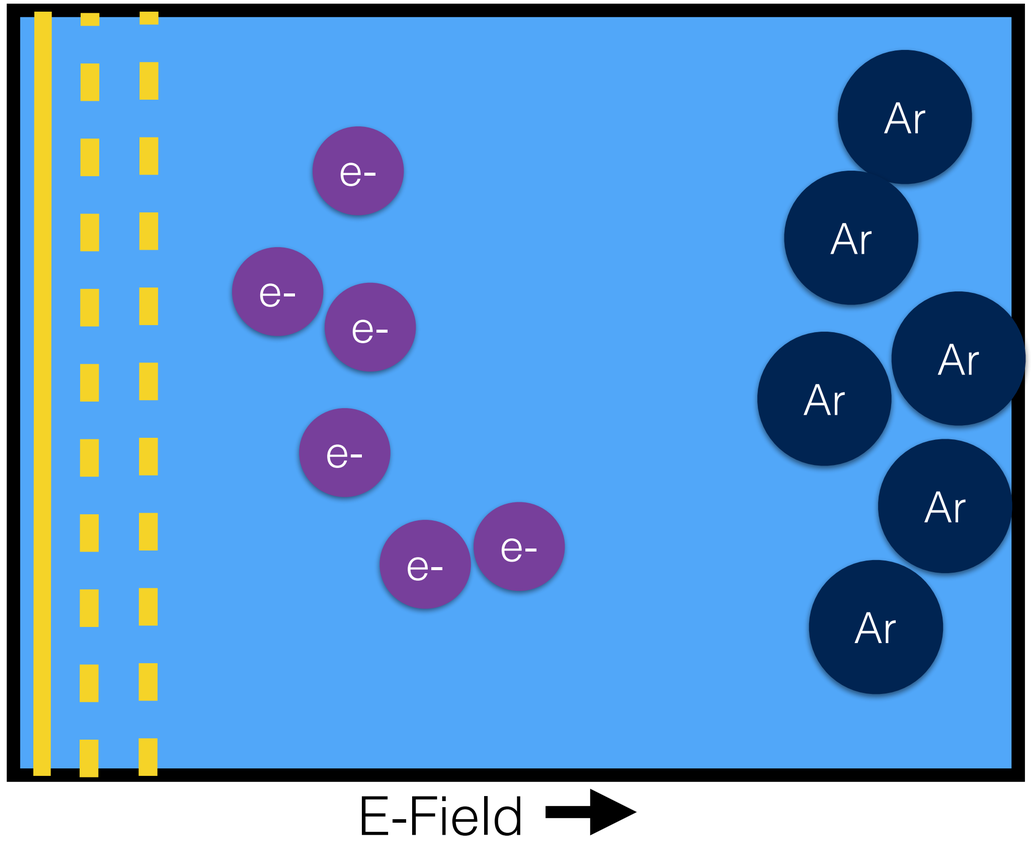


- Detector volume, composed of argon atoms is held at high voltage.
- Charged particles passing through volume ionise the atoms.
- Groups of electrons and Ar ions drift to edges of the field cage.

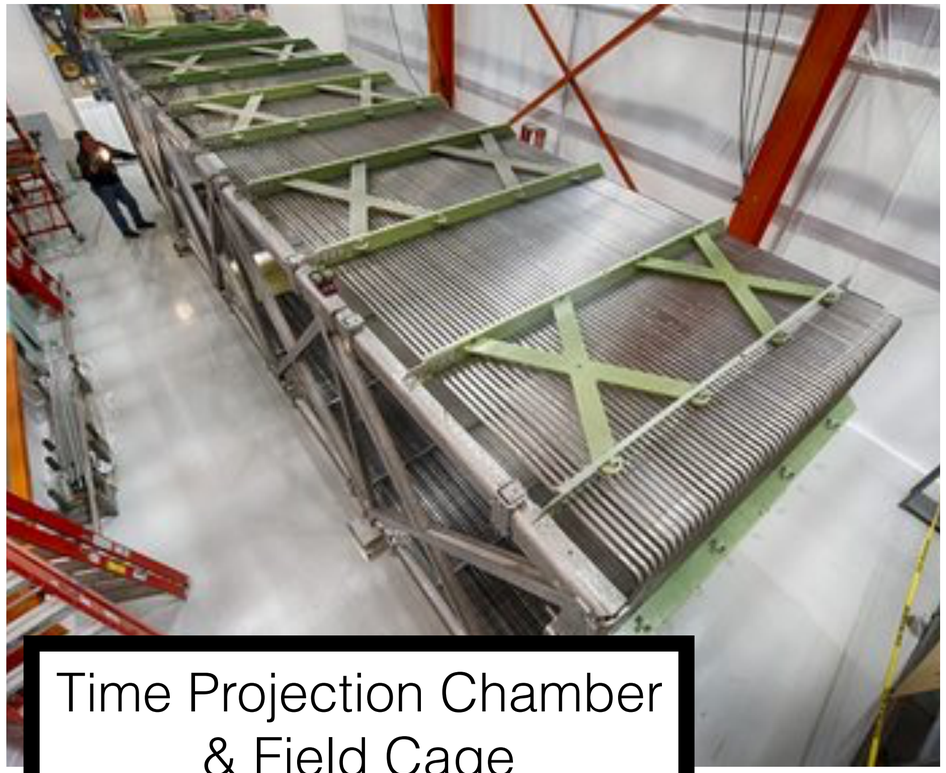


Time Projection Chamber & Field Cage

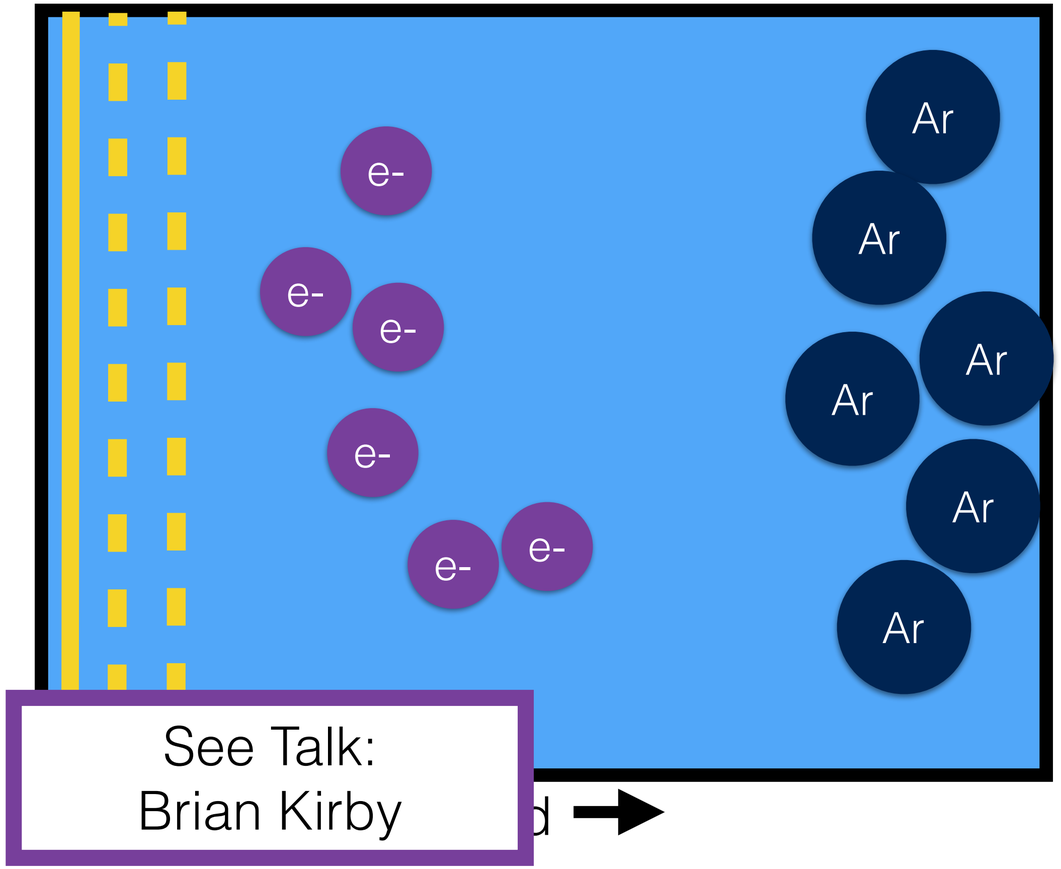
Read-out Wire Planes



- Detector volume, composed of argon atoms is held at high voltage.
- Charged particles passing through volume ionise the atoms.
- Groups of electrons and Ar ions drift to edges of the field cage.
- Electrons are read-out by the wire-planes.



Time Projection Chamber & Field Cage



See Talk: Brian Kirby

Read-out Wire Planes

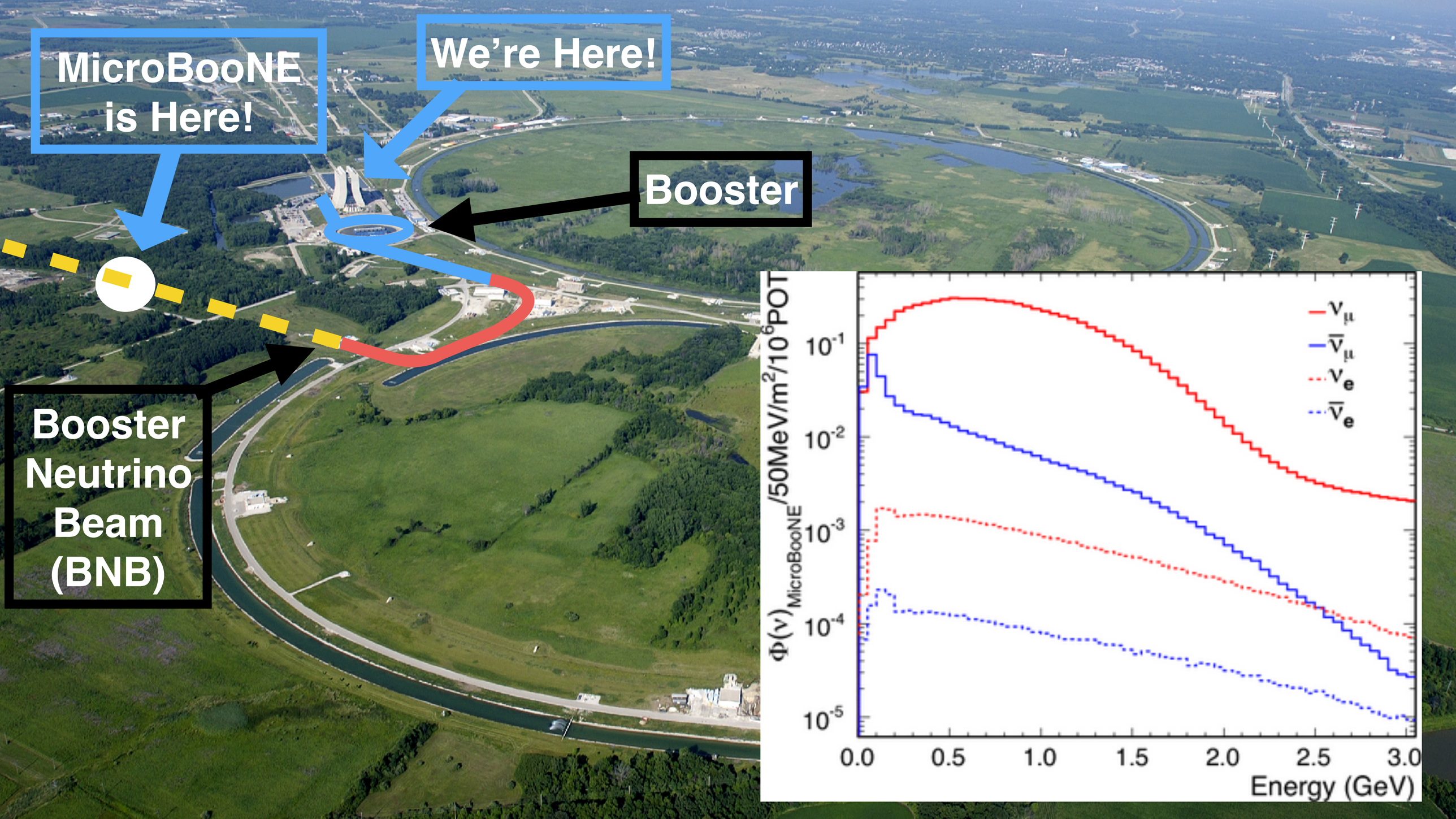
- Detector volume, composed of argon atoms is held at high voltage.
- Charged particles passing through volume ionise the atoms.
- Groups of electrons and Ar ions drift to edges of the field cage.
- Electrons are read-out by the wire-planes.

We're Here!

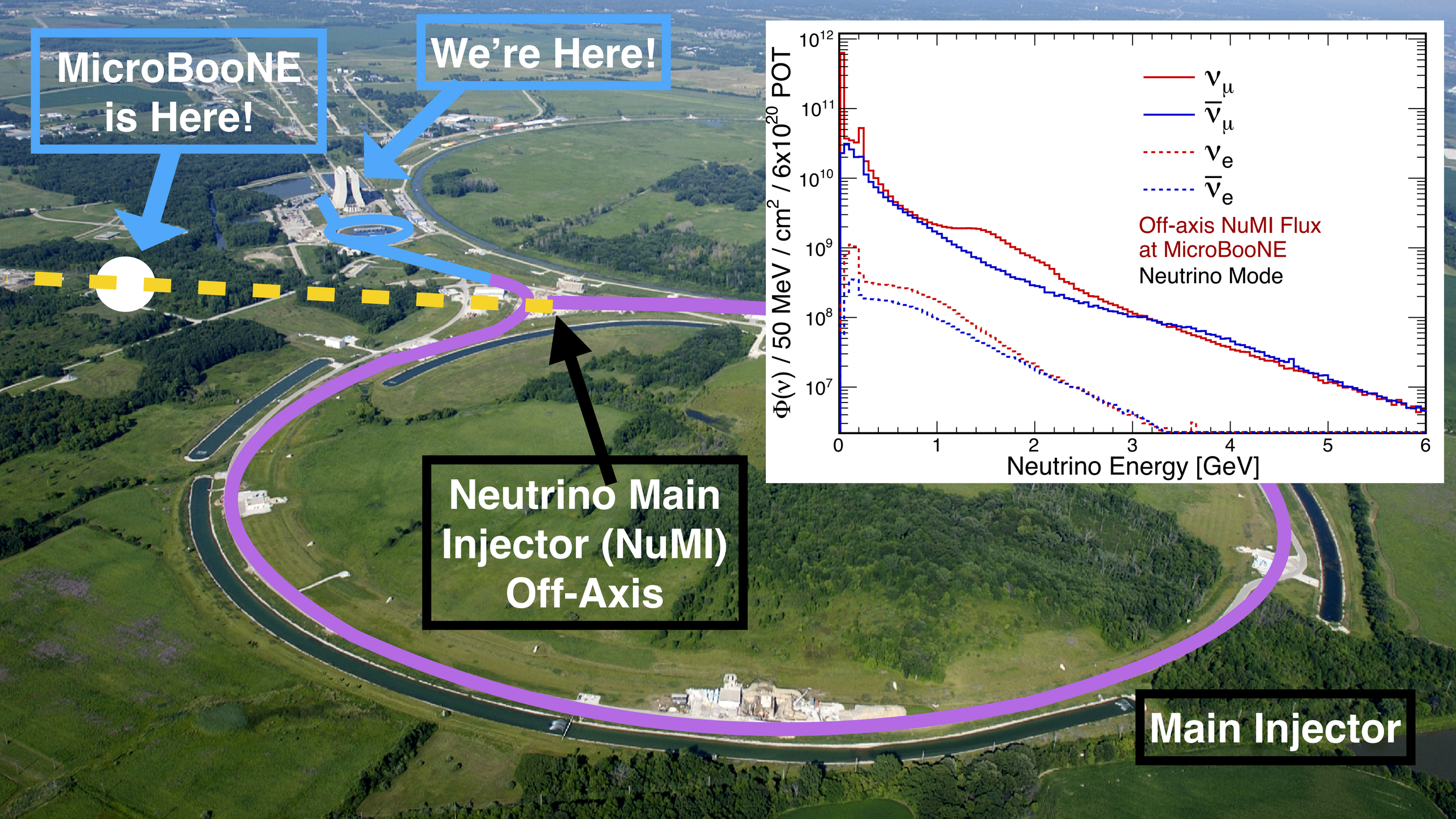
MicroBooNE is Here!
We're Here!

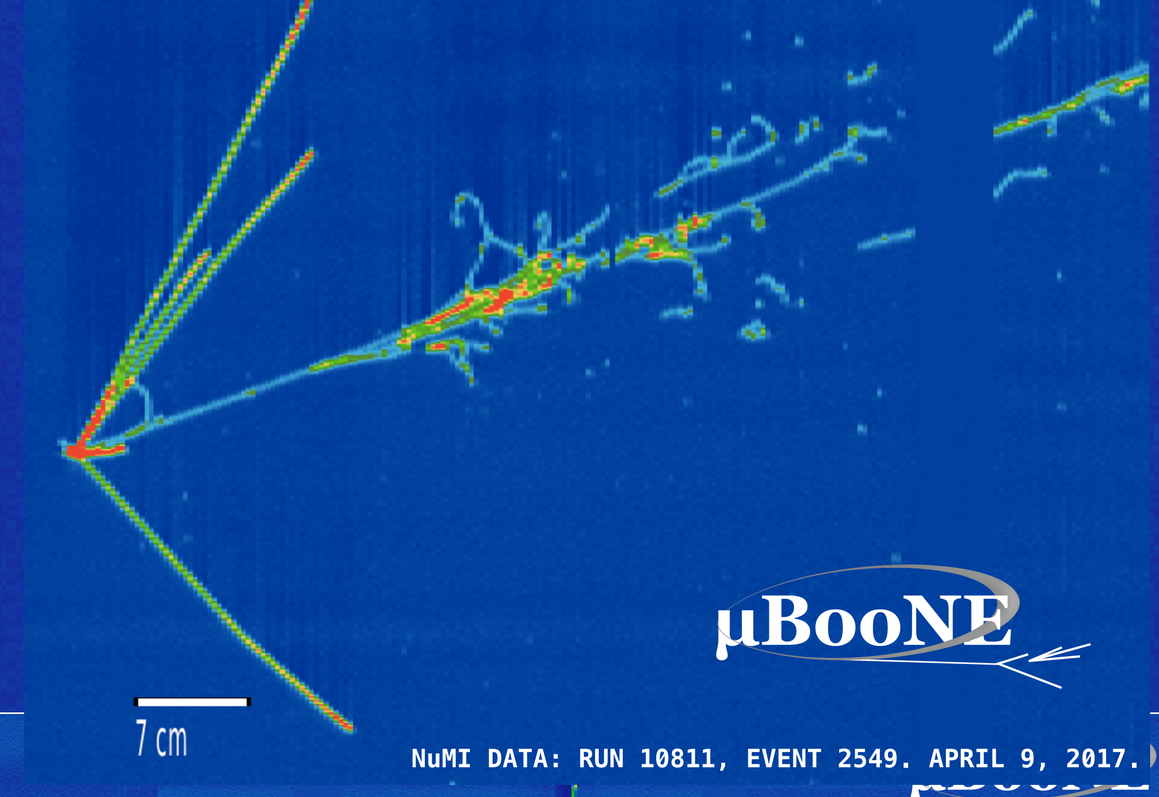
MicroBooNE is Here!
We're Here!
Booster

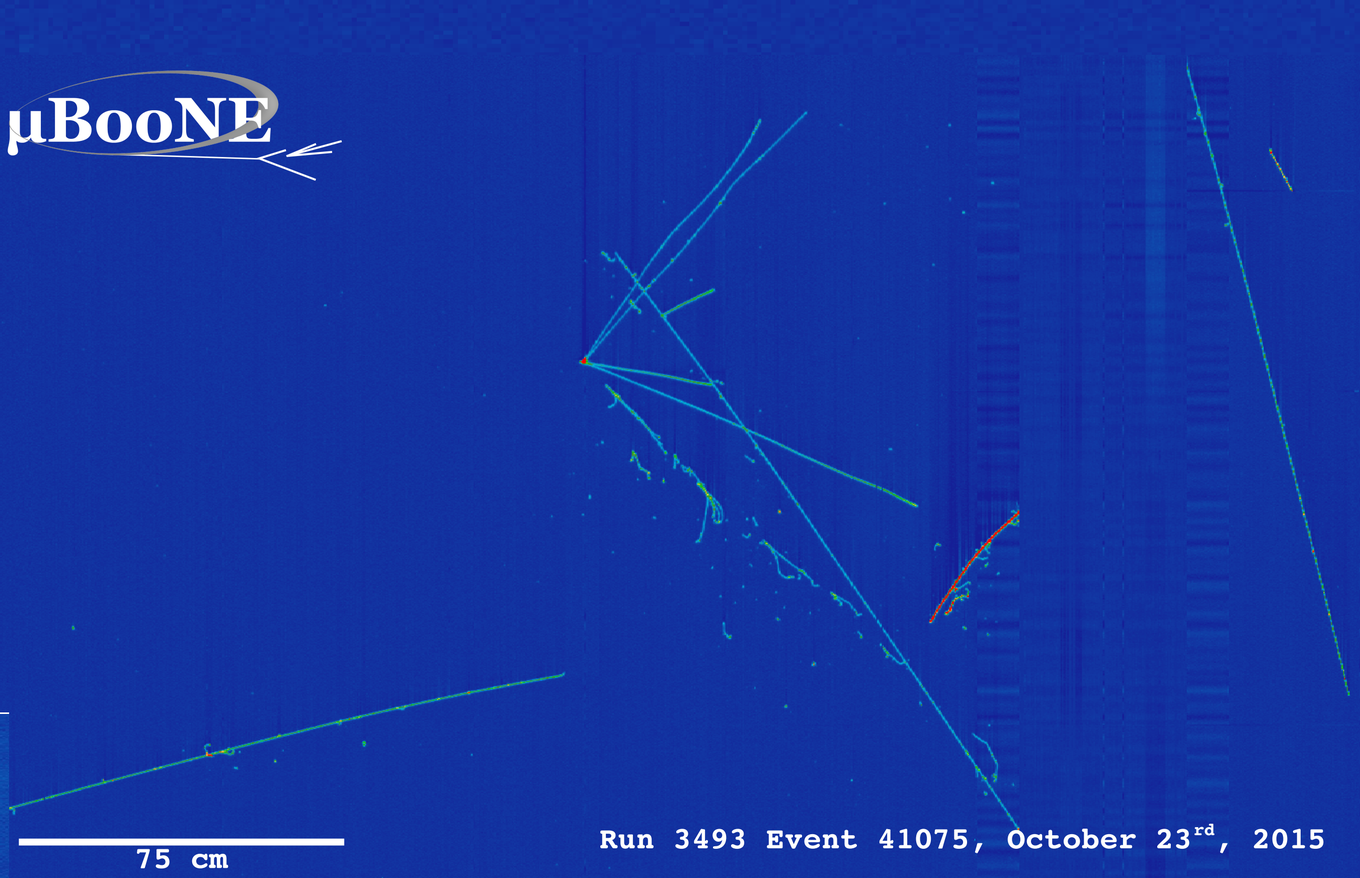
MicroBooNE is Here!
We're Here!
Booster
Booster Neutrino Beam (BNB)

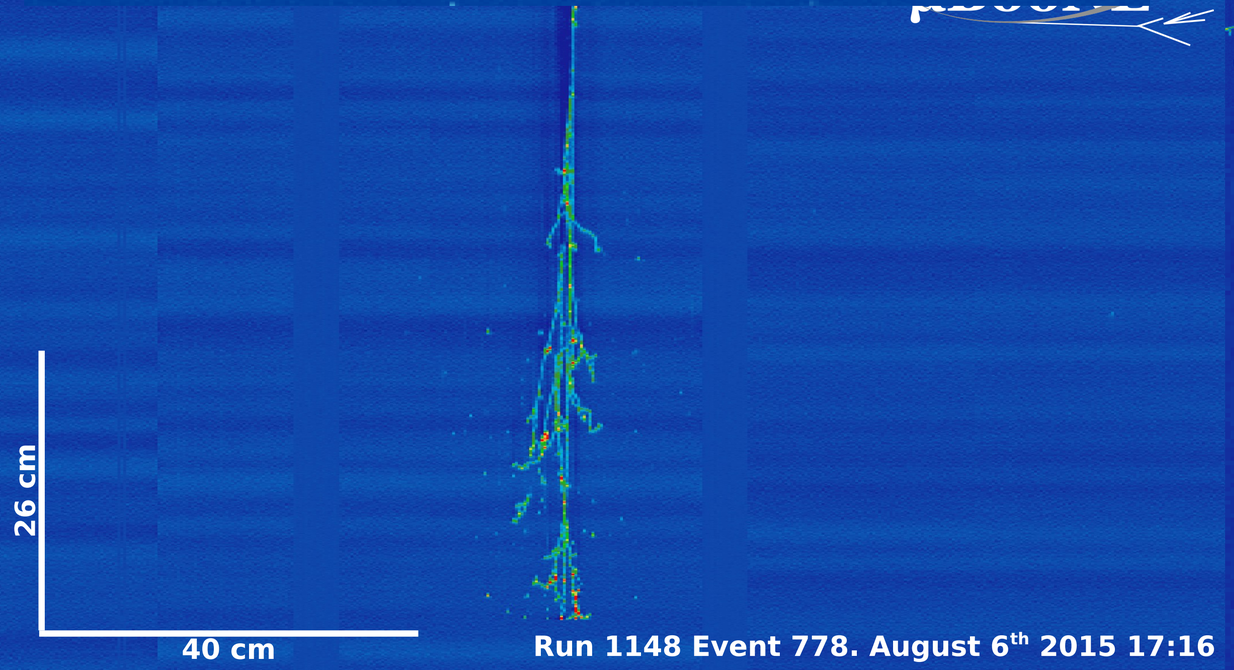

MicroBooNE is Here!
We're Here!
Booster
Booster Neutrino Beam (BNB)
$\Phi(\nu)_{MicroBooNE}/50MeV/m^2/10^6POT$
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Energy (GeV)
ν_μ
$\bar{\nu}_\mu$
ν_e
$\bar{\nu}_e$

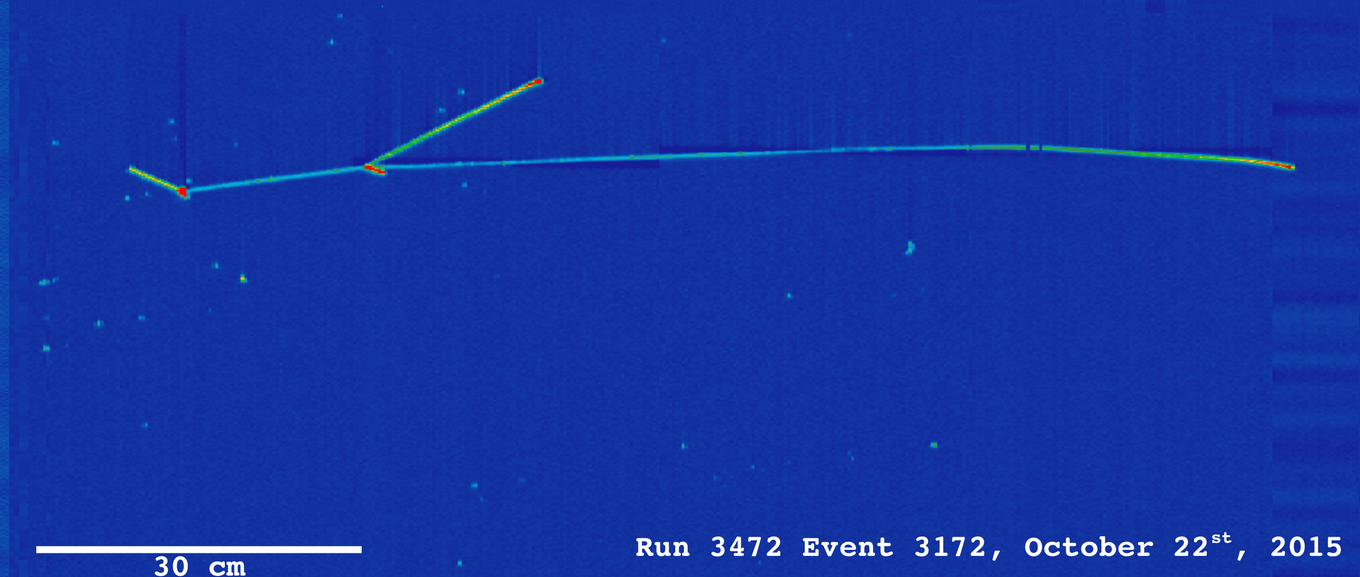
MicroBooNE is Here!
We're Here!
Neutrino Main Injector (NuMI) Off-Axis
Main Injector


MicroBooNE is Here!
We're Here!
Neutrino Main Injector (NuMI) Off-Axis
Main Injector
$\Phi(\nu)$ / 50 MeV / cm^2 / 6x10^{20} POT
10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
0
1
2
3
4
5
6
Neutrino Energy [GeV]
ν_μ
$\bar{\nu}_\mu$
ν_e
$\bar{\nu}_e$
Off-axis NuMI Flux at MicroBooNE
Neutrino Mode

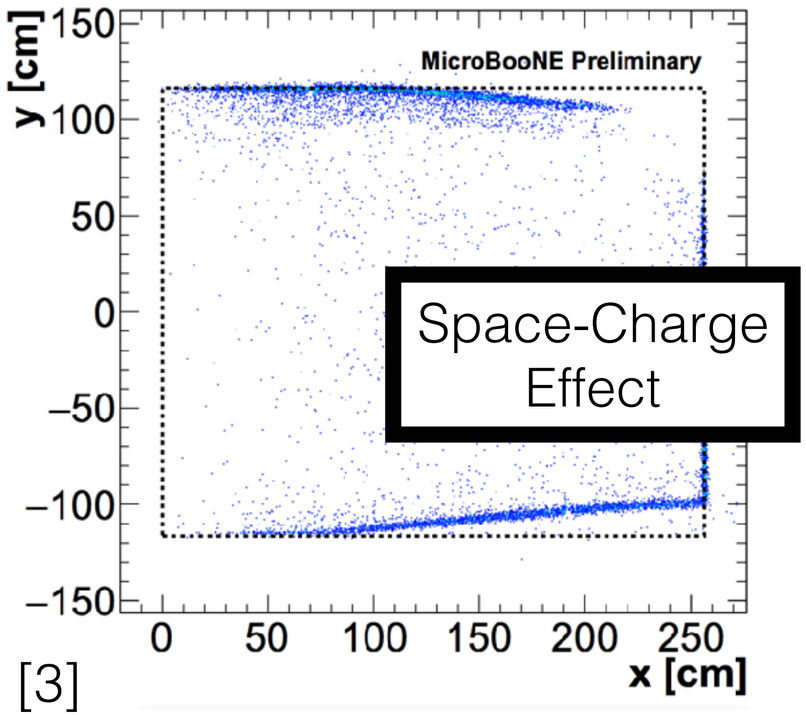

μBooNE
7 cm
NuMI DATA: RUN 10811, EVENT 2549. APRIL 9, 2017.


μBooNE
75 cm
Run 3493 Event 41075, October 23rd, 2015

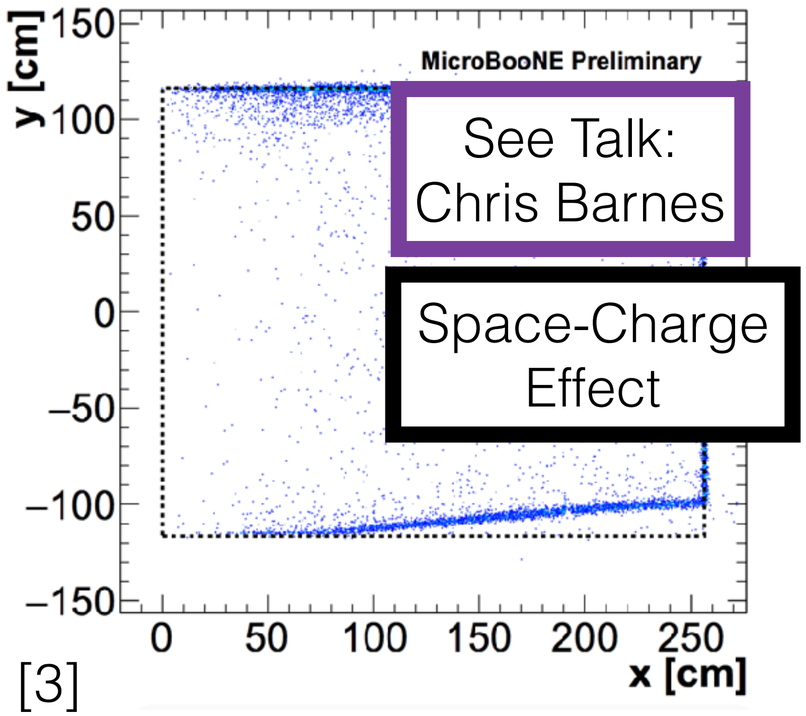

26 cm
40 cm
Run 1148 Event 778. August 6th 2015 17:16


30 cm
Run 3472 Event 3172, October 22st, 2015

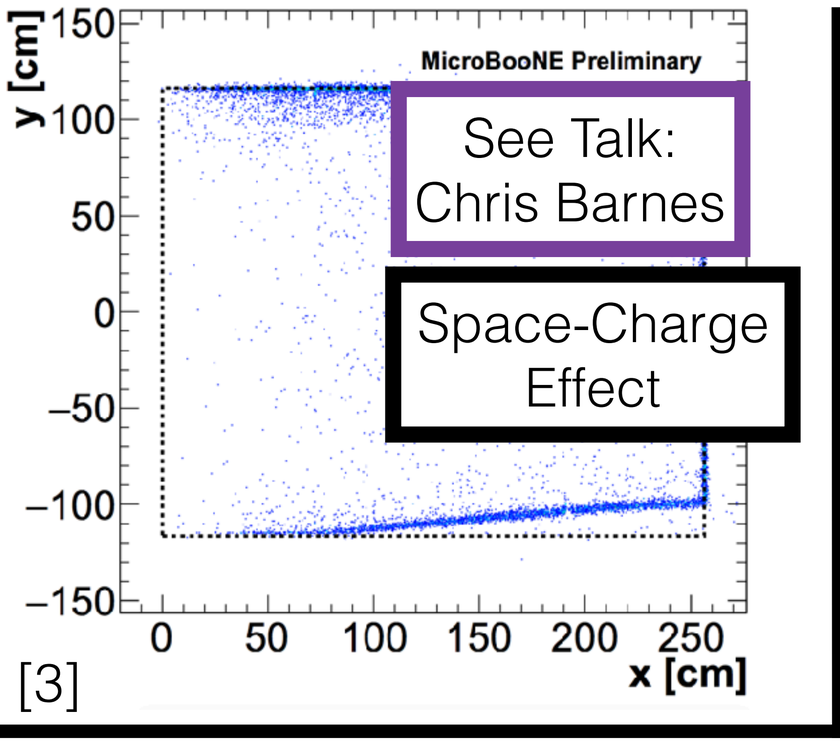
- MicroBooNE has been collecting data since October 2015.
- We have a rich and varied physics program:
  - Neutrino-argon interactions and cross sections.
  - LArTPC R&D.
  - Short-baseline neutrino oscillation searches.
  - Astro-particle / exotics searches.
- These results are extremely useful for future LArTPCs (SBN, DUNE).

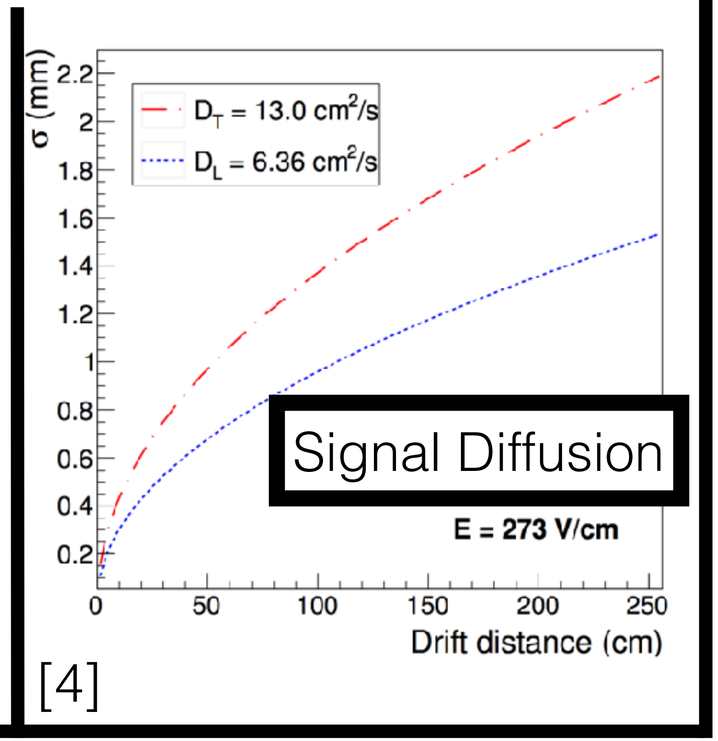

MicroBooNE Preliminary
y [cm]
150
100
50
0
−50
−100
−150
0
50
100
150
200
250
x [cm]
Space-Charge Effect

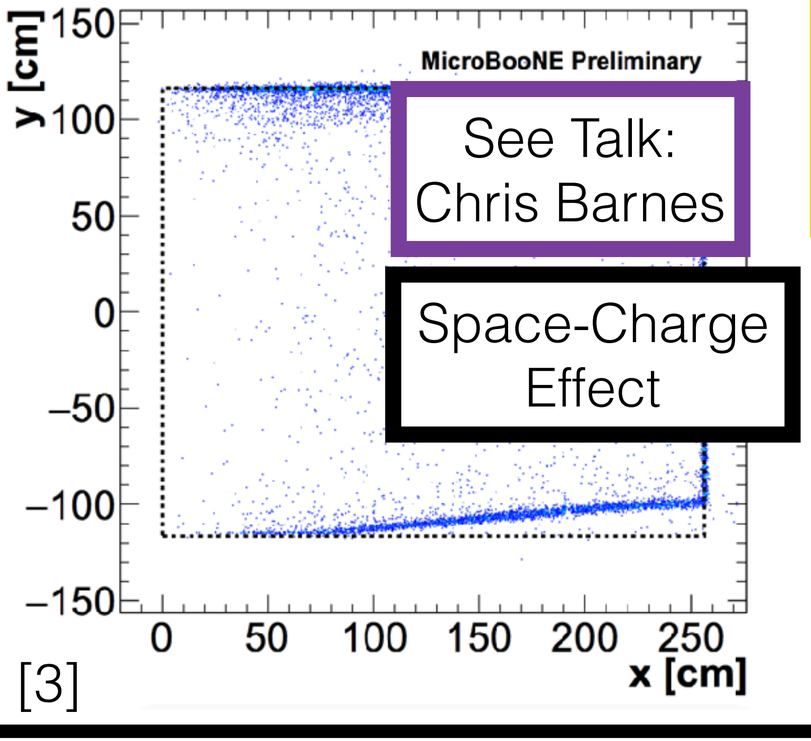
[3]

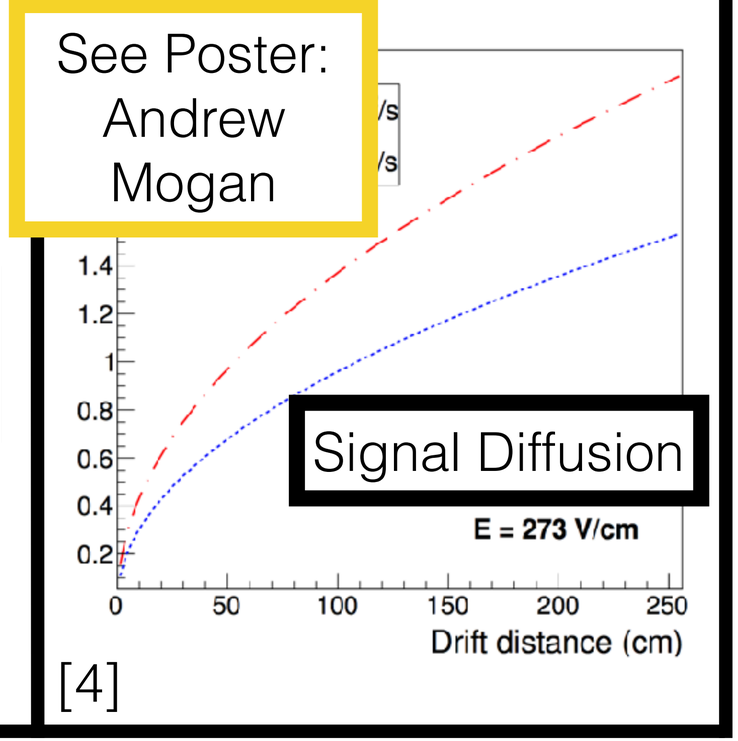

MicroBooNE Preliminary
y [cm]
150
100
50
0
−50
−100
−150
0
50
100
150
200
250
x [cm]
See Talk:
Chris Barnes
Space-Charge
Effect

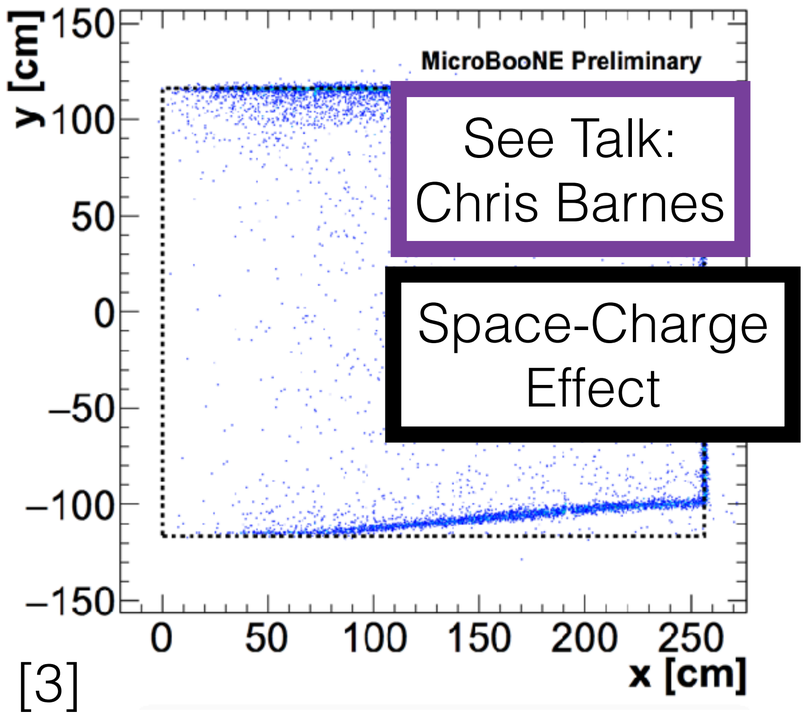
[3]


MicroBooNE Preliminary
y [cm]
x [cm]
150
100
50
0
−50
−100
−150
0
50
100
150
200
250
See Talk:
Chris Barnes
Space-Charge
Effect
[3]


σ (mm)
Drift distance (cm)
D_T = 13.0 cm²/s
D_L = 6.36 cm²/s
E = 273 V/cm
Signal Diffusion
[4]


MicroBooNE Preliminary
y [cm]
x [cm]
150
100
50
0
−50
−100
−150
0
50
100
150
200
250
See Talk:
Chris Barnes
Space-Charge
Effect
[3]


See Poster:
Andrew
Mogan
1.4
1.2
1
0.8
0.6
0.4
0.2
0
50
100
150
200
250
Drift distance (cm)
E = 273 V/cm
Signal Diffusion
[4]


MicroBooNE Preliminary
y [cm]
x [cm]
150
100
50
0
−50
−100
−150
0
50
100
150
200
250
See Talk:
Chris Barnes
Space-Charge
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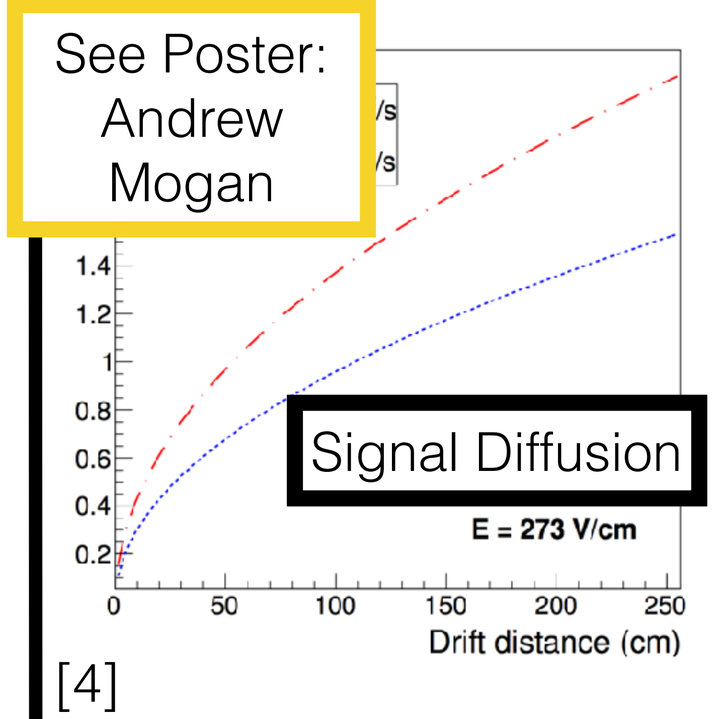
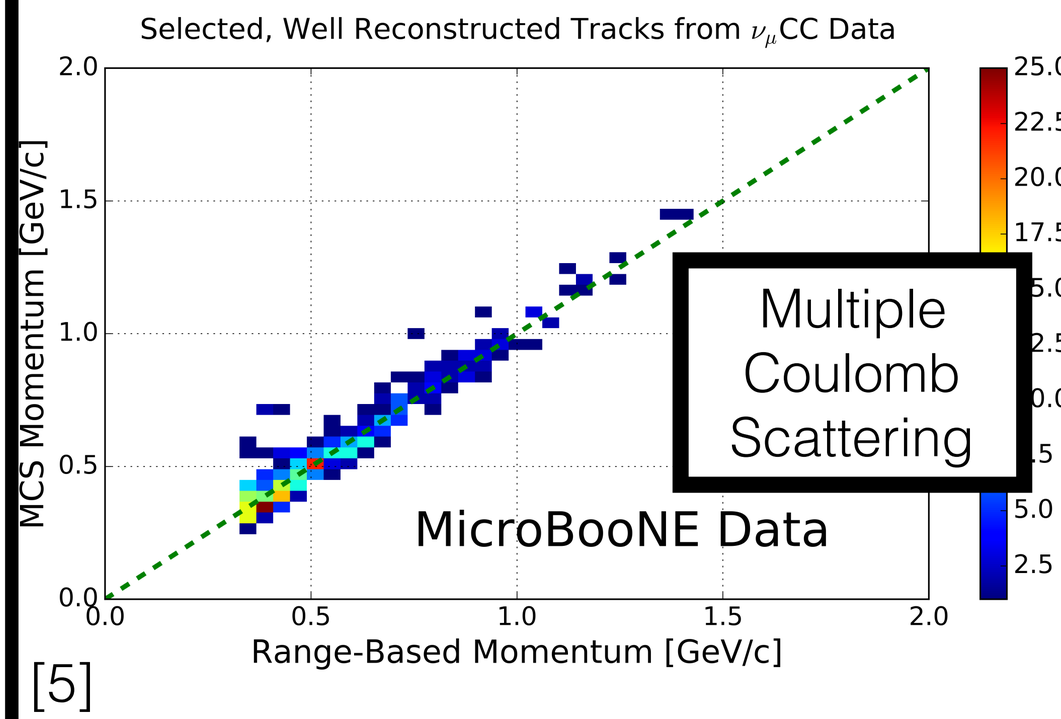
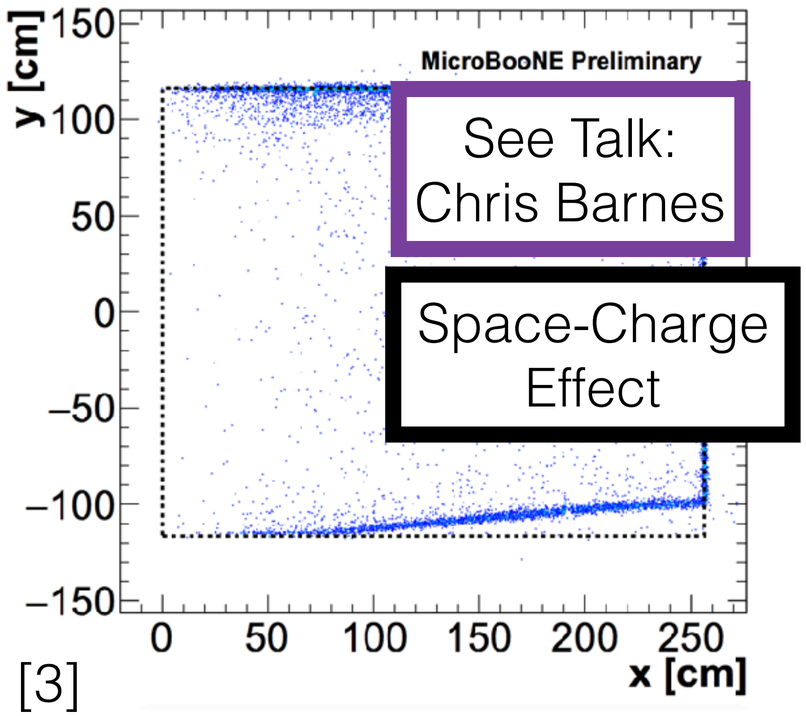

See Poster:
Andrew
Mogan
Signal Diffusion
E = 273 V/cm
Drift distance (cm)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
50
100
150
200
250
[4]


Selected, Well Reconstructed Tracks from ν_μCC Data
MCS Momentum [GeV/c]
Range-Based Momentum [GeV/c]
2.0
1.5
1.0
0.5
0.0
Multiple
Coulomb
Scattering
MicroBooNE Data
[5]


MicroBooNE Preliminary
y [cm]
x [cm]
See Talk:
Chris Barnes
Space-Charge
Effect
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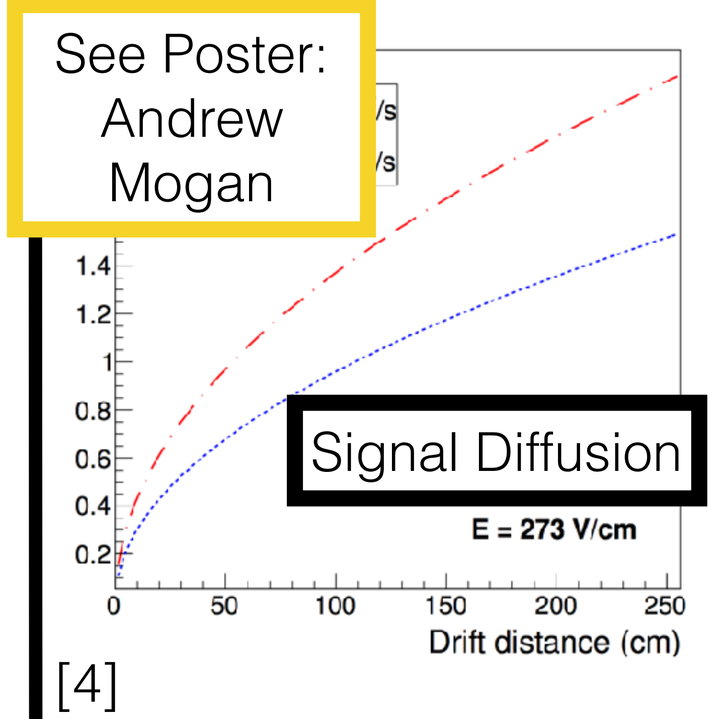
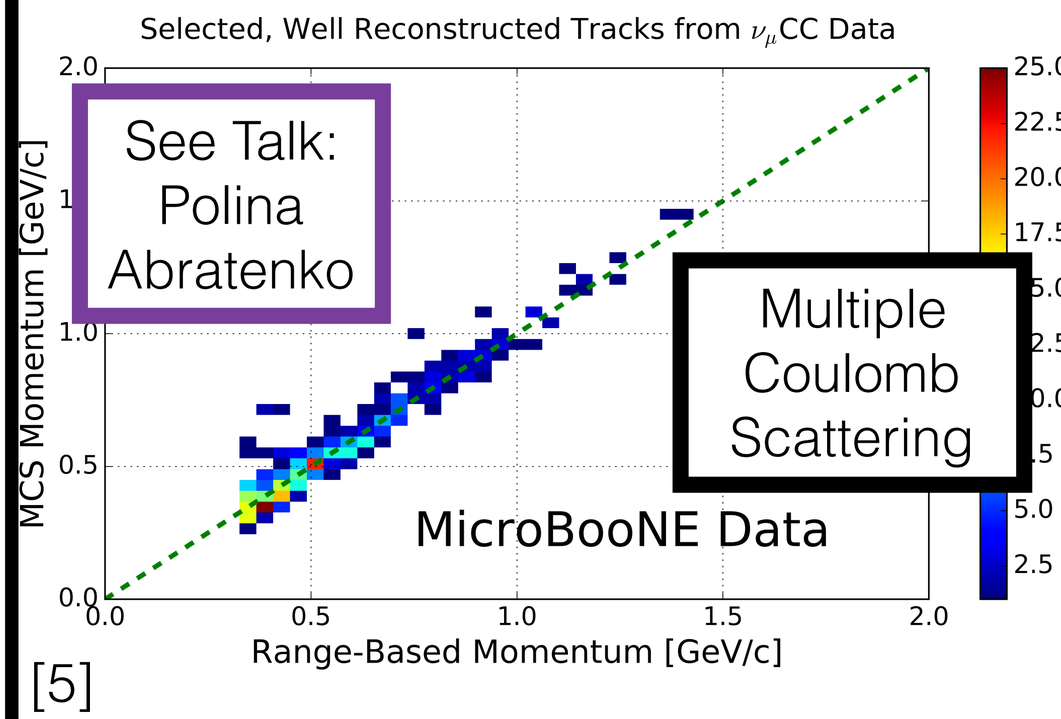

See Poster:
Andrew
Mogan
Signal Diffusion
E = 273 V/cm
Drift distance (cm)
[4]


Selected, Well Reconstructed Tracks from ν_μCC Data
See Talk:
Polina
Abratenko
Multiple
Coulomb
Scattering
MicroBooNE Data
MCS Momentum [GeV/c]
Range-Based Momentum [GeV/c]
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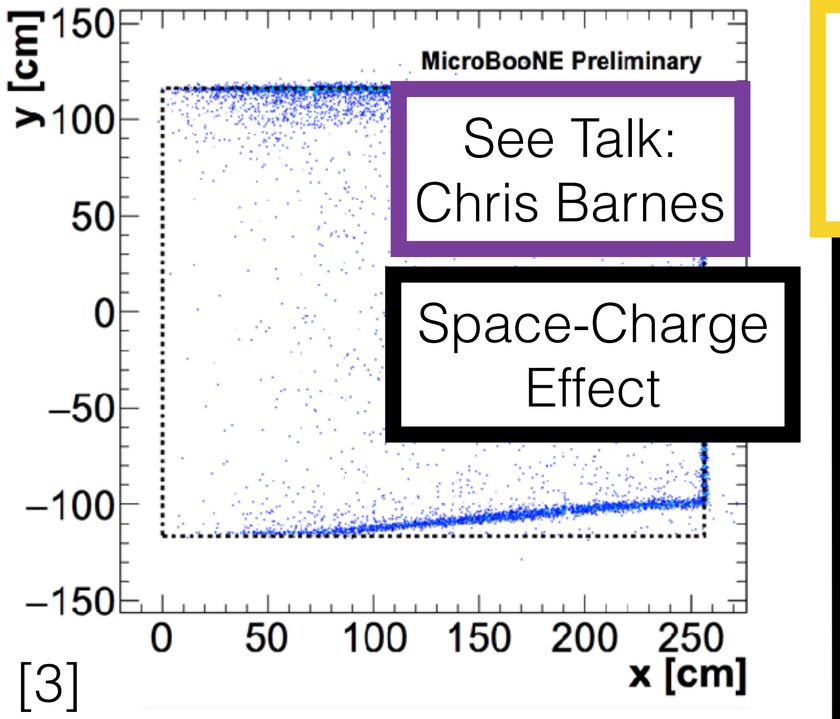
MicroBooNE Preliminary
y [cm]
x [cm]
See Talk:
Chris Barnes
Space-Charge
Effect

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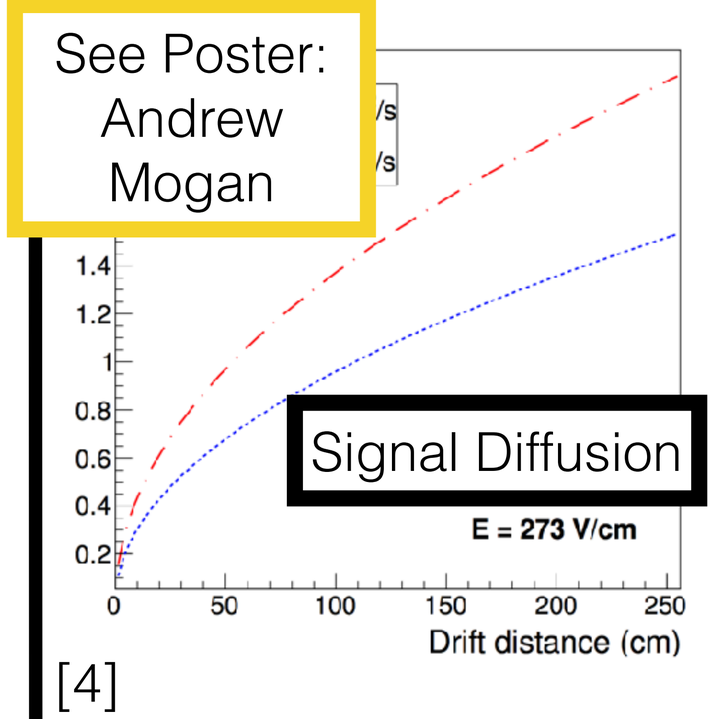
See Poster:
Andrew
Mogan
Signal Diffusion
E = 273 V/cm
Drift distance (cm)

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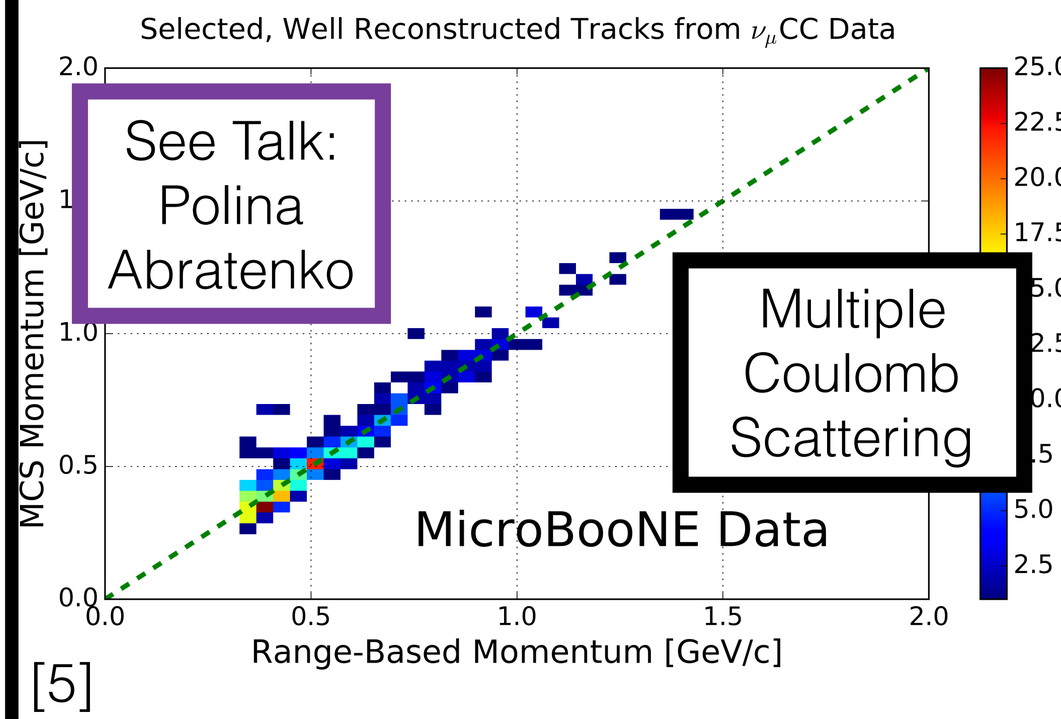
Selected, Well Reconstructed Tracks from ν_μCC Data
See Talk:
Polina
Abratenko
Multiple
Coulomb
Scattering
MicroBooNE Data
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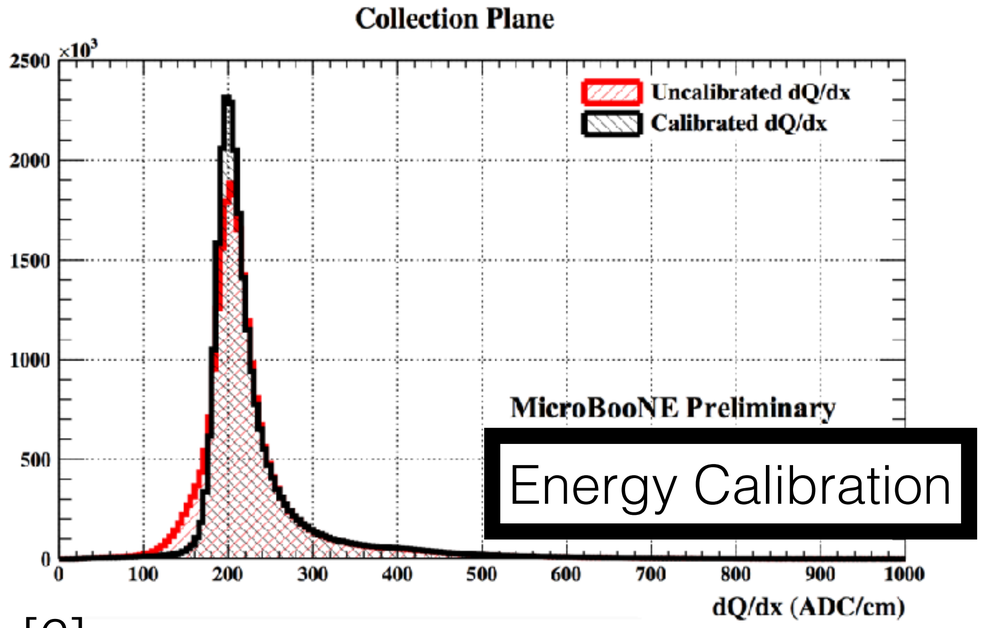
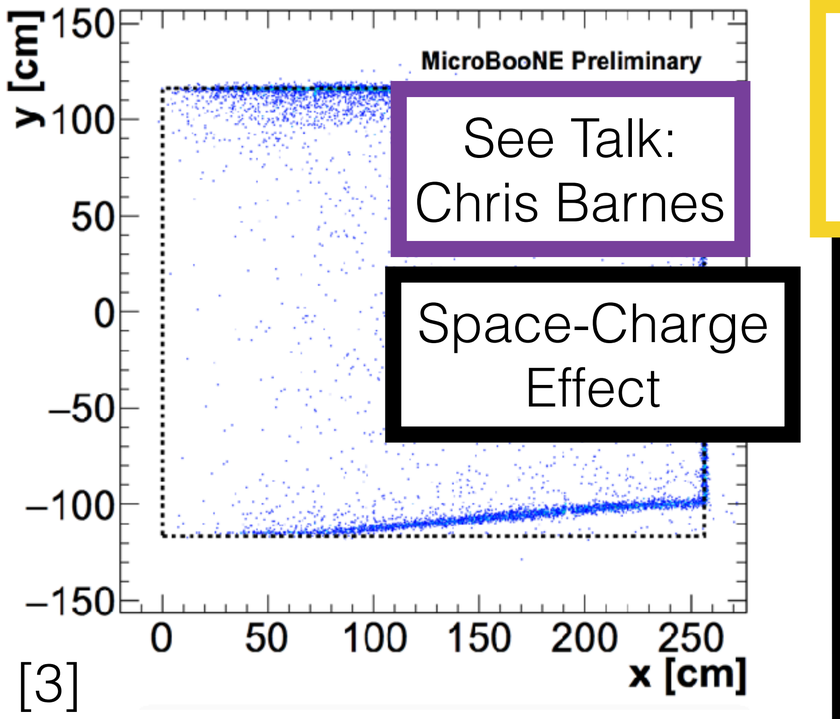
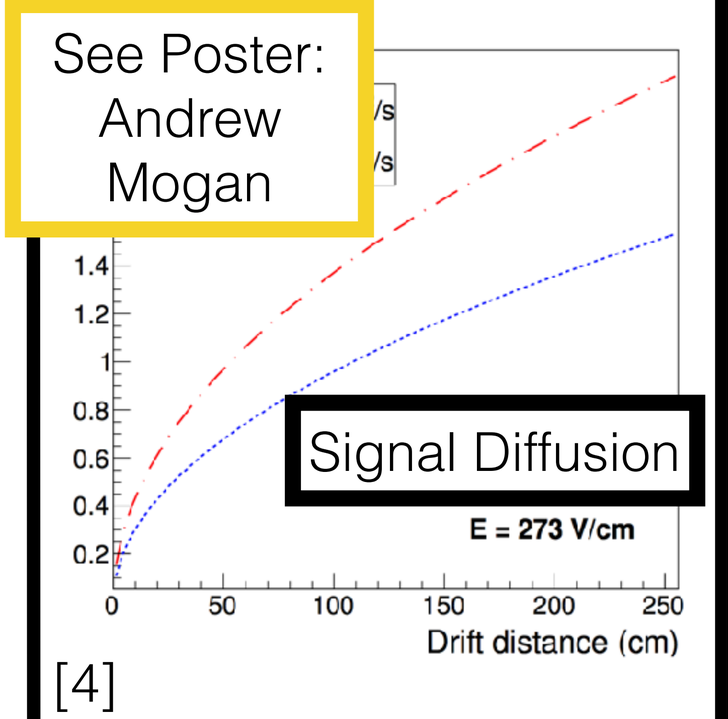
[5]


Collection Plane
Uncalibrated dQ/dx
Calibrated dQ/dx
MicroBooNE Preliminary
Energy Calibration
dQ/dx (ADC/cm)

[6]


MicroBooNE Preliminary
y [cm]
x [cm]
See Talk:
Chris Barnes
Space-Charge
Effect

[3]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Signal Diffusion
E = 273 V/cm
Drift distance (cm)

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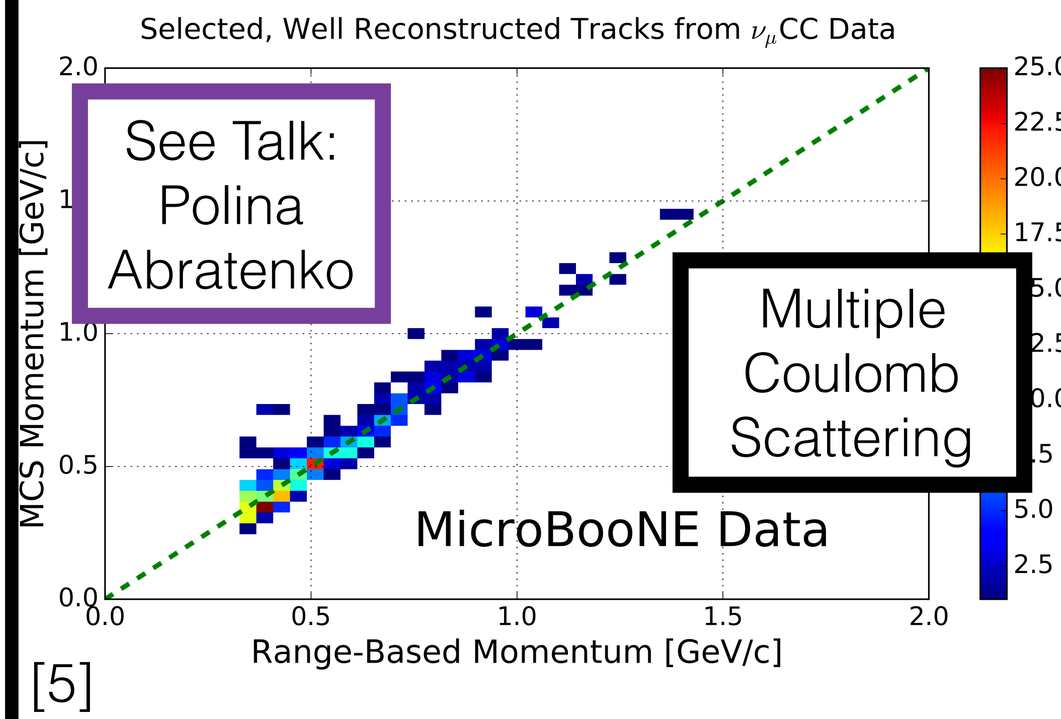
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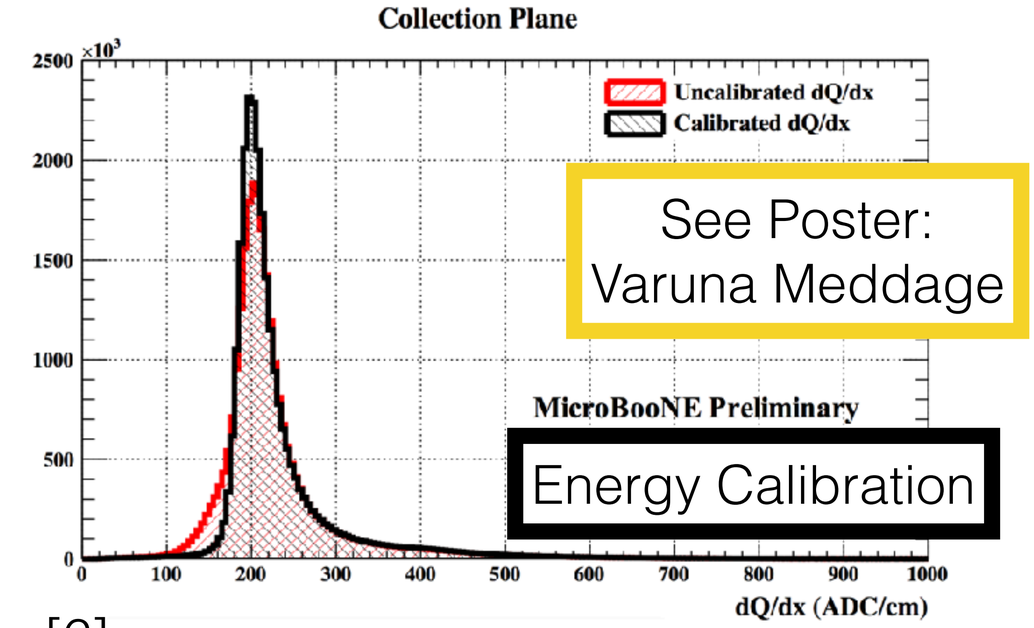
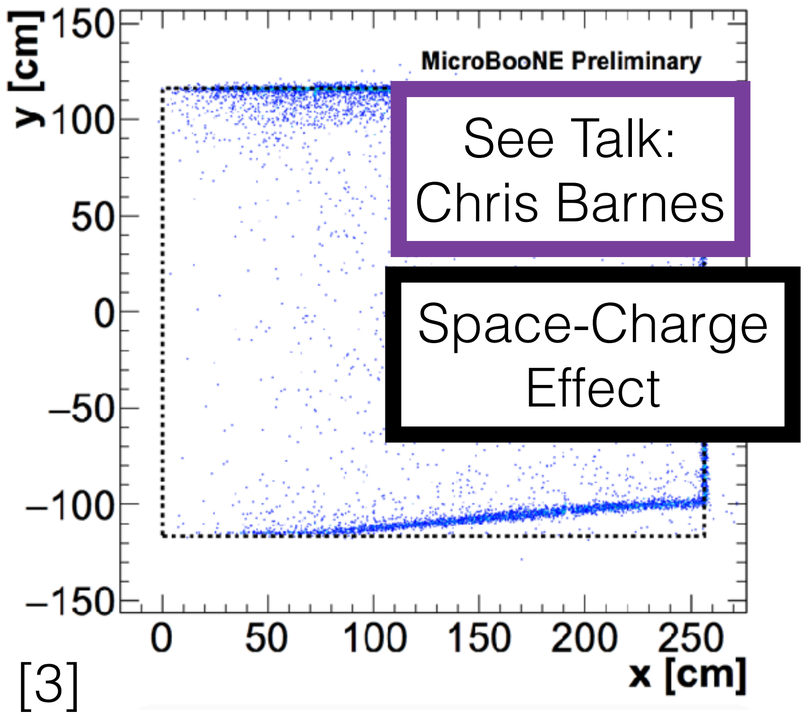
[5]


Collection Plane
Uncalibrated dQ/dx
Calibrated dQ/dx
See Poster:
Varuna Meddage
MicroBooNE Preliminary
Energy Calibration
dQ/dx (ADC/cm)

[6]



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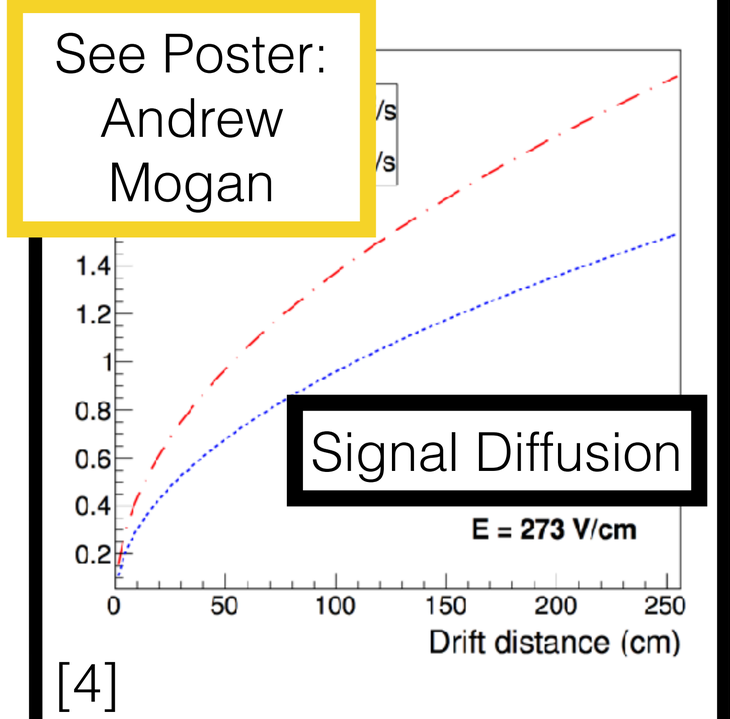

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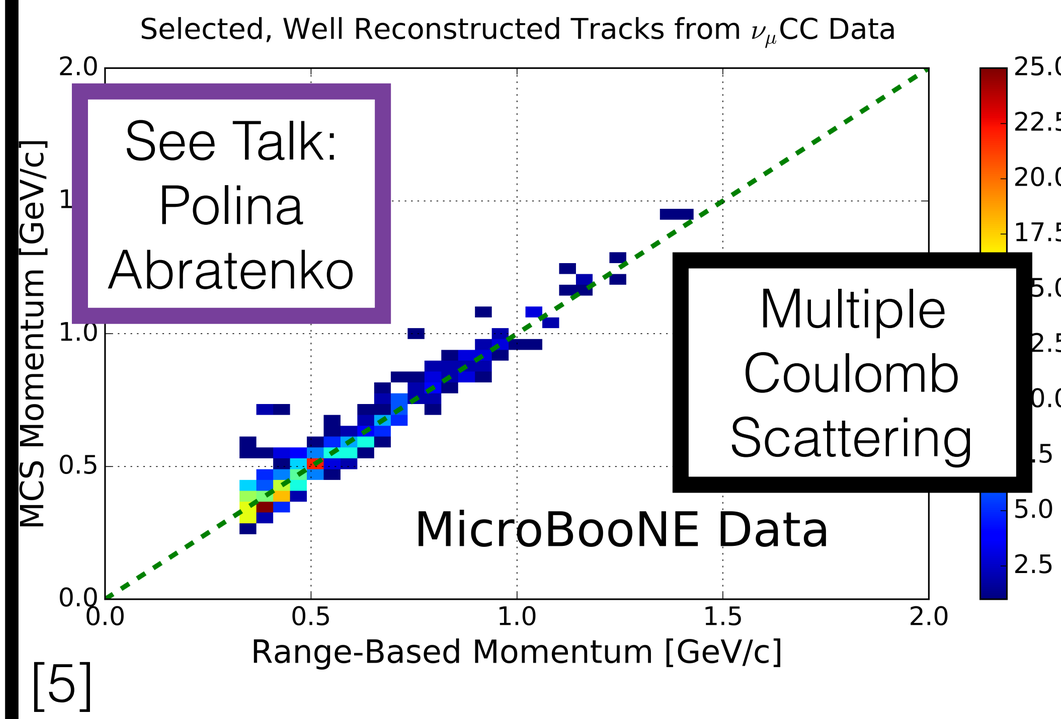

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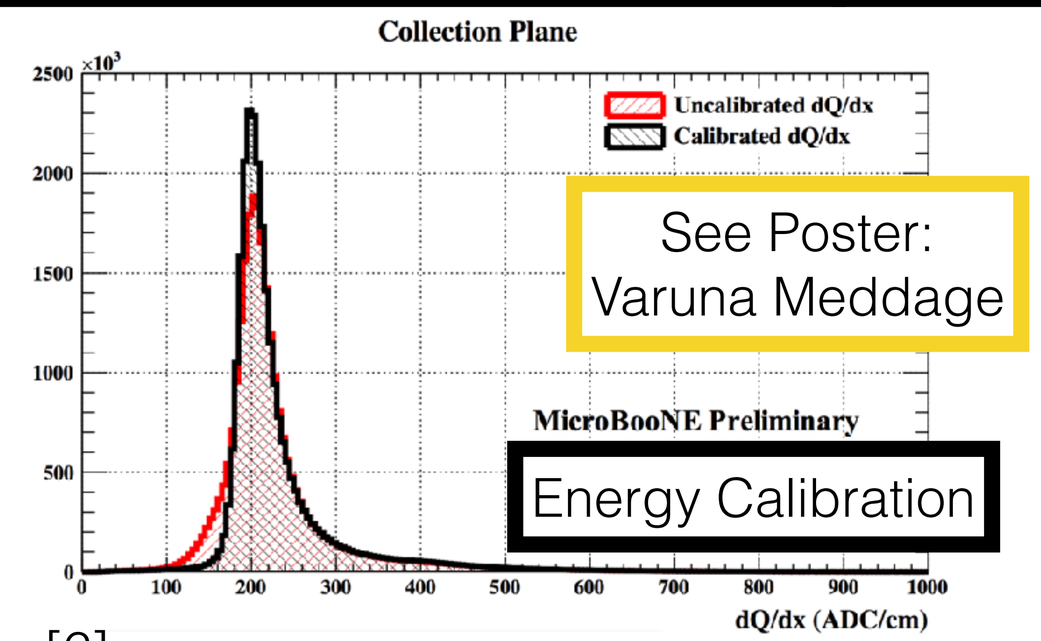

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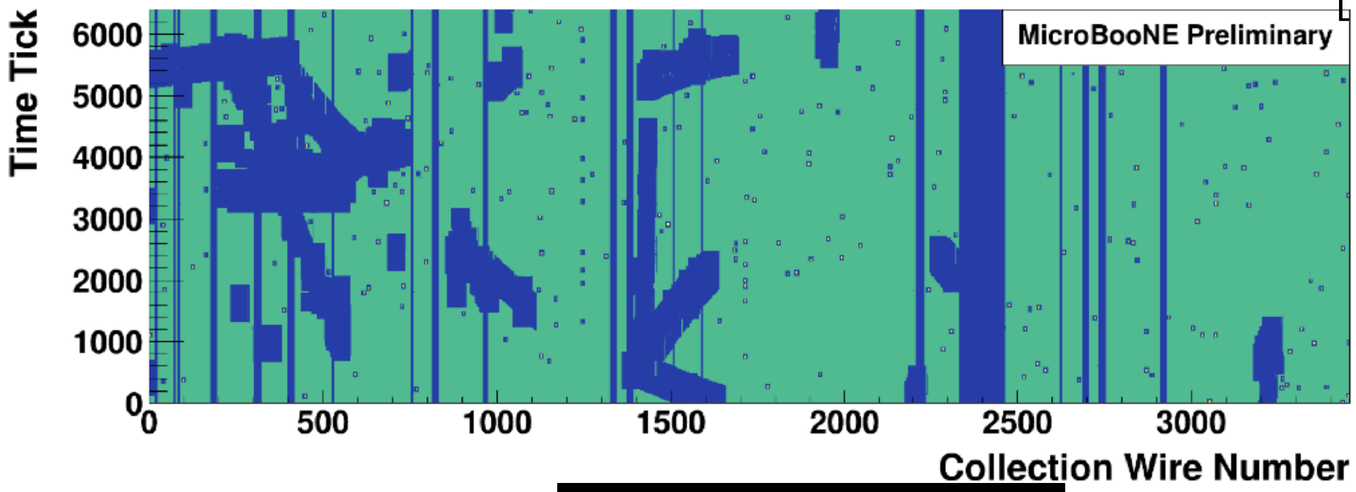
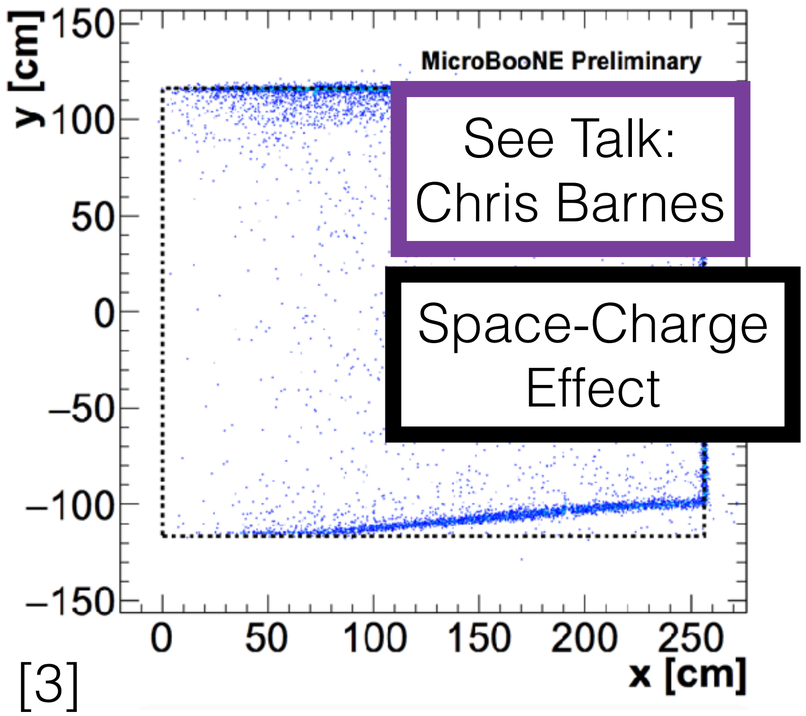
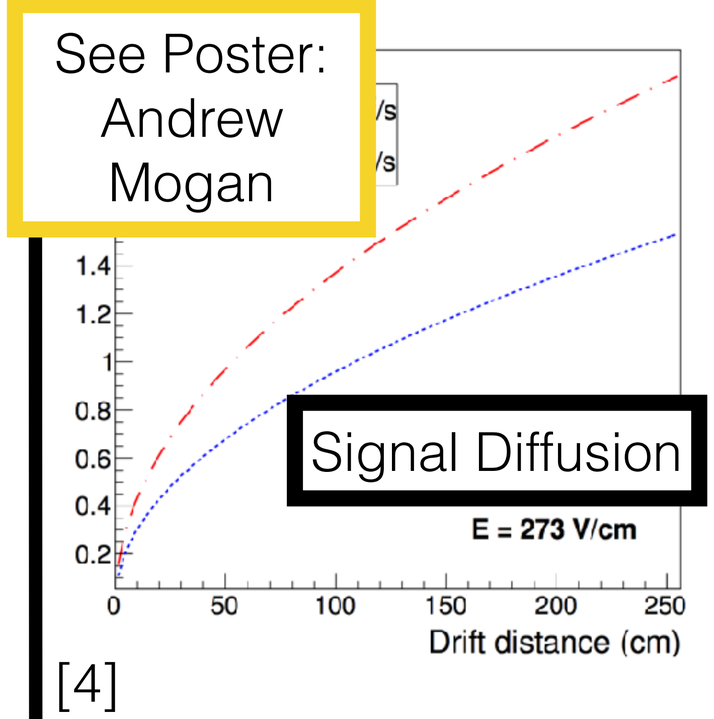


Ar39 Contaminants


MicroBooNE Preliminary
y [cm]
x [cm]
See Talk:
Chris Barnes
Space-Charge
Effect
[3]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Mogan
Signal Diffusion
E = 273 V/cm
Drift distance (cm)
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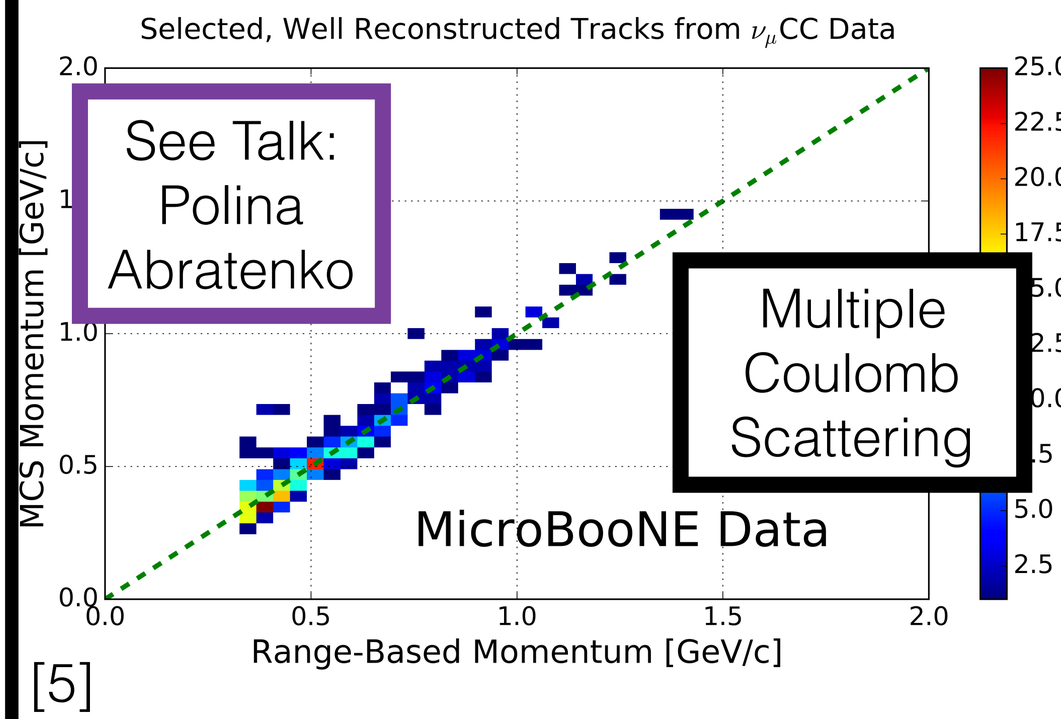
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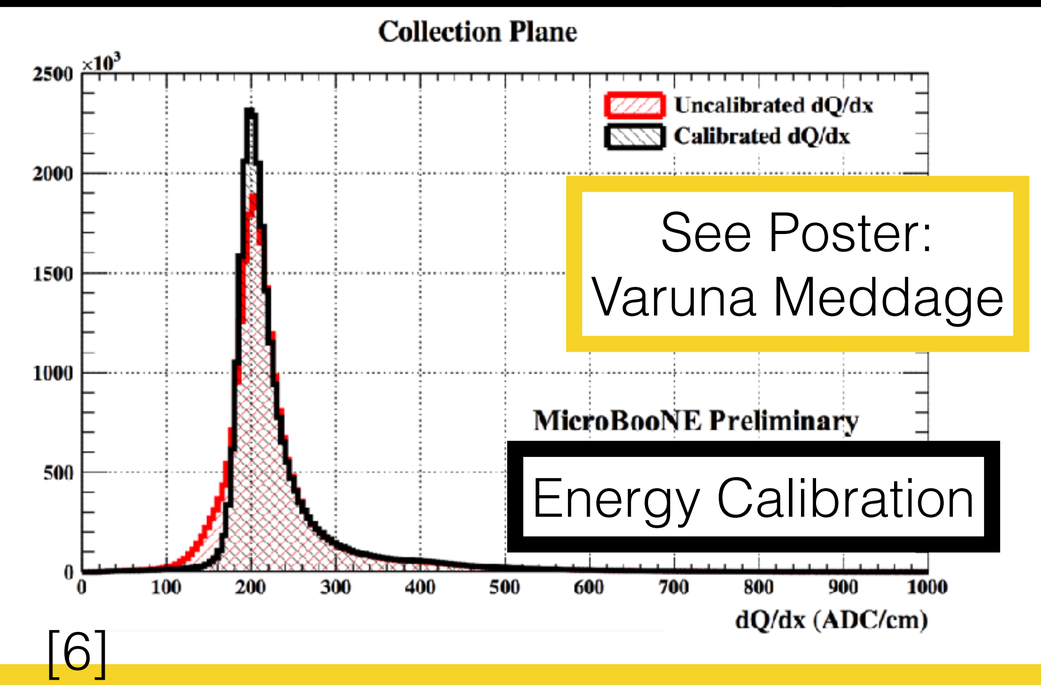
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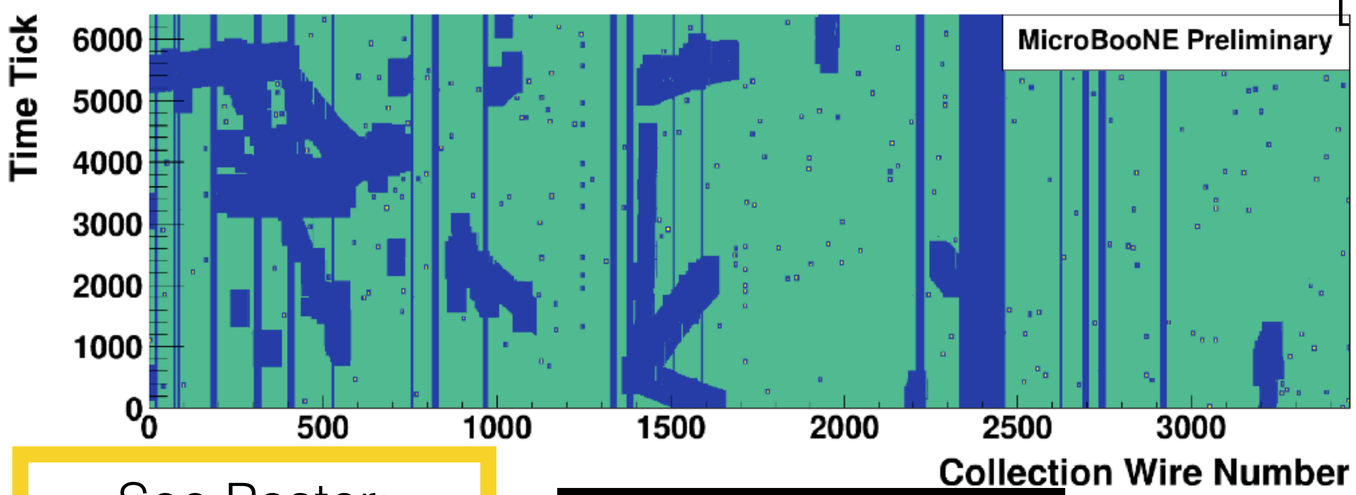
Uncalibrated dQ/dx
Calibrated dQ/dx
See Poster:
Varuna Meddage
MicroBooNE Preliminary
Energy Calibration
dQ/dx (ADC/cm)
[6]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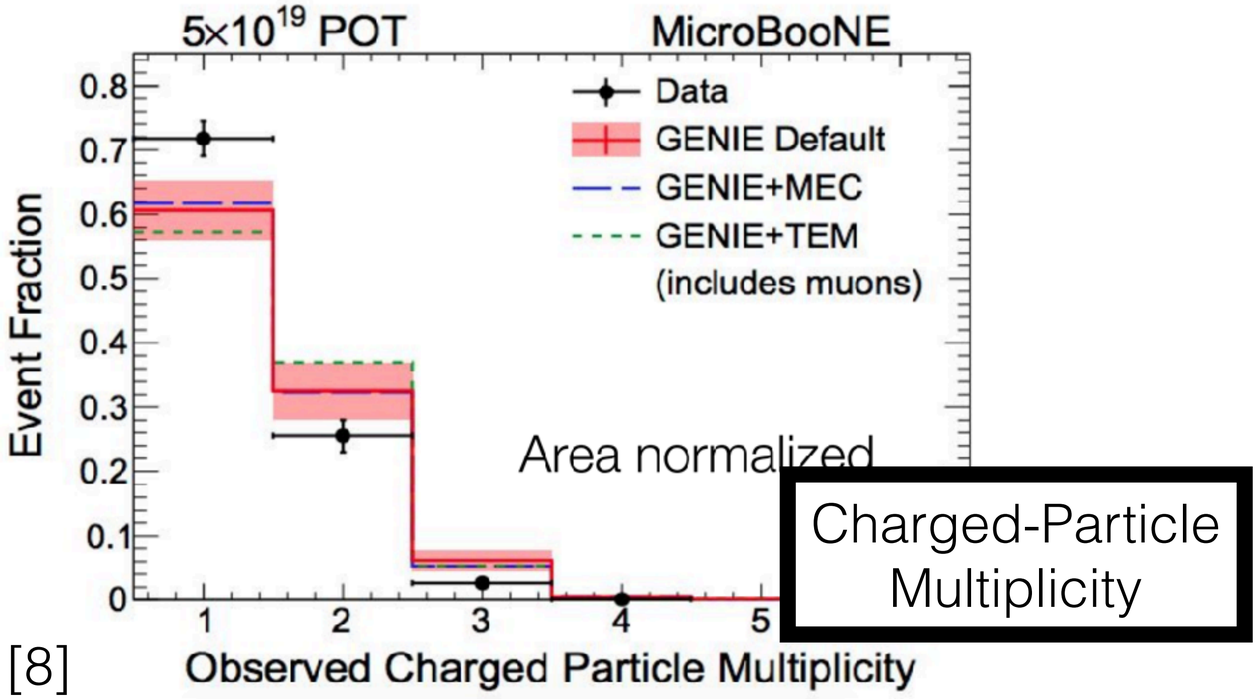
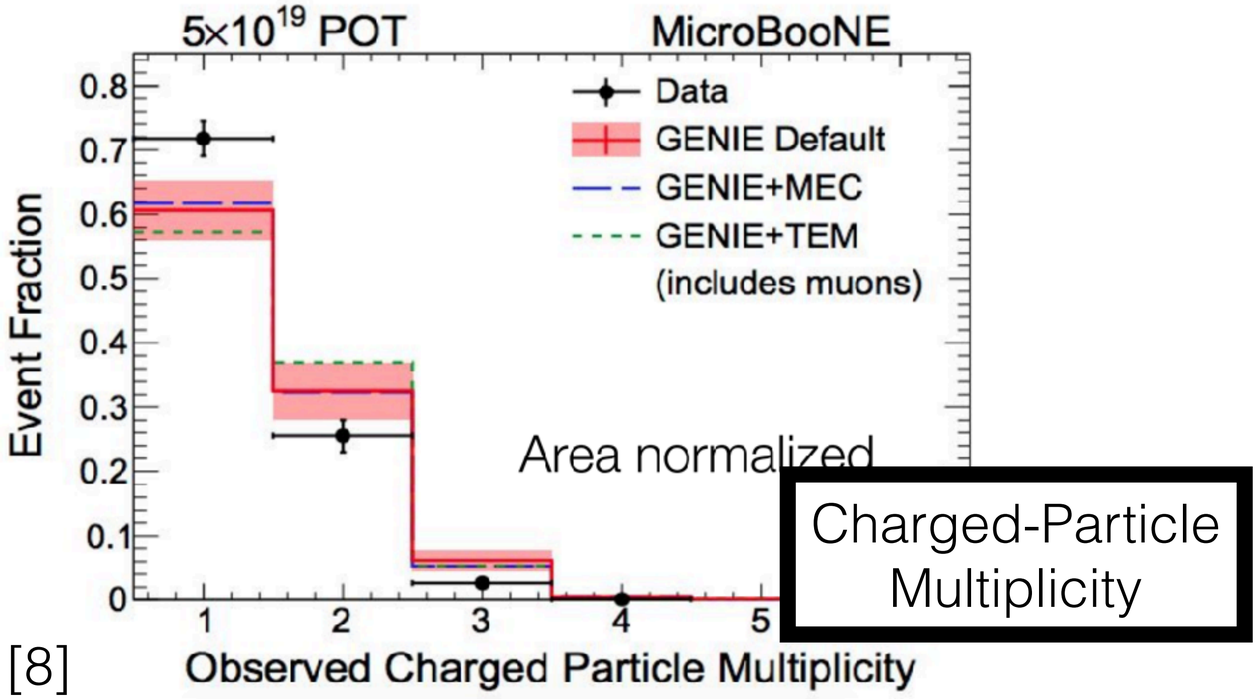
MicroBooNE Preliminary
Time Tick
Collection Wire Number
See Poster:
Alexander Flesher
Ar39 Contaminants



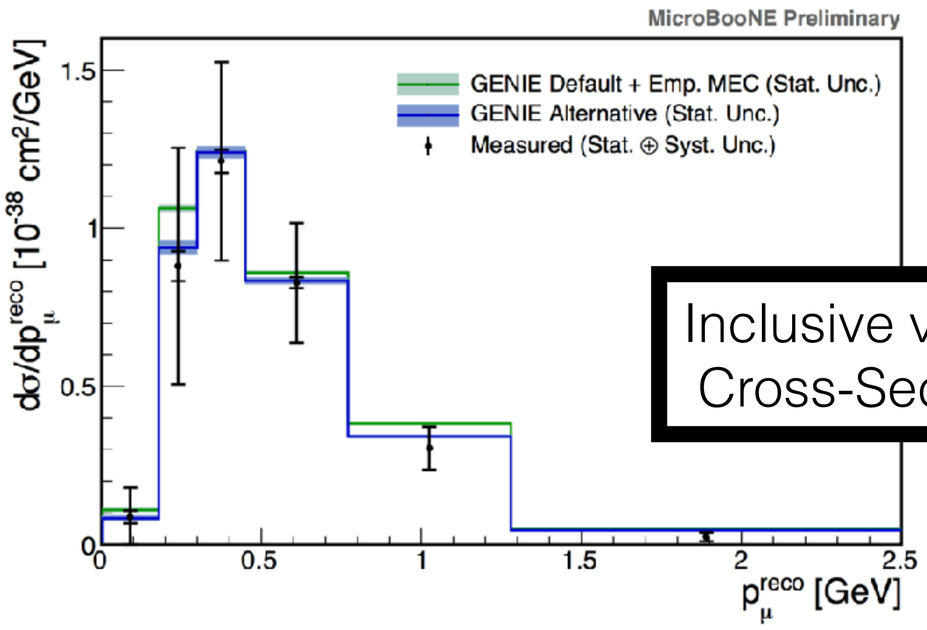
Charged-Particle Multiplicity

[8]



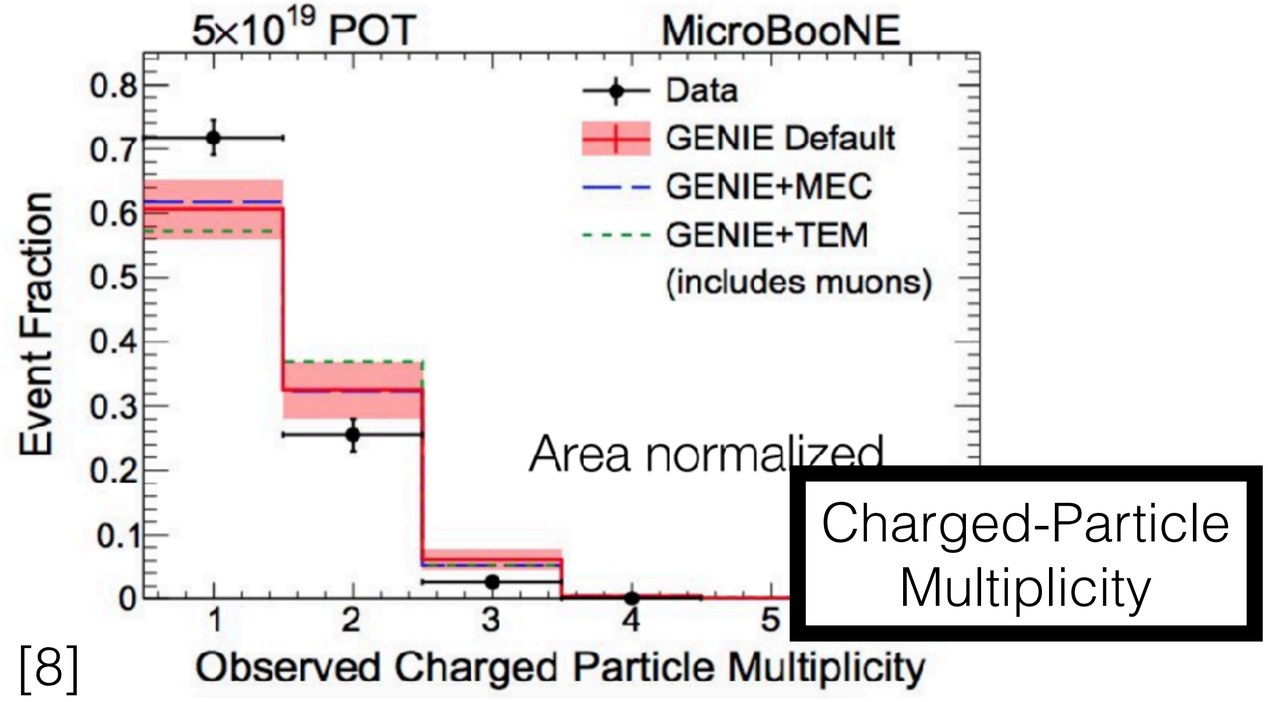
Charged-Particle Multiplicity

[8]

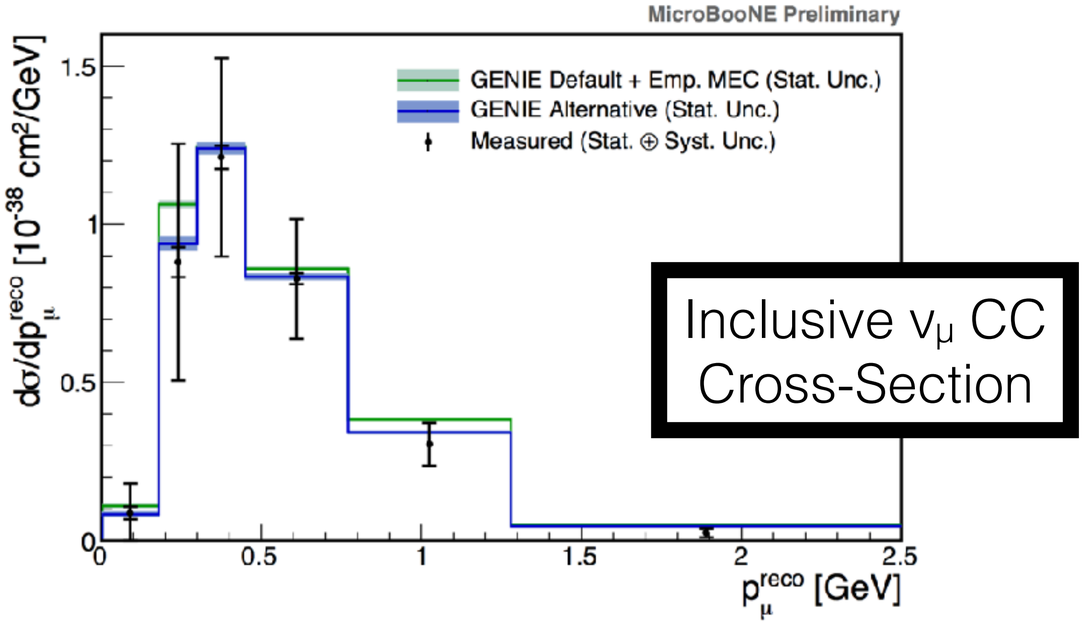


Inclusive ν_μ CC Cross-Section

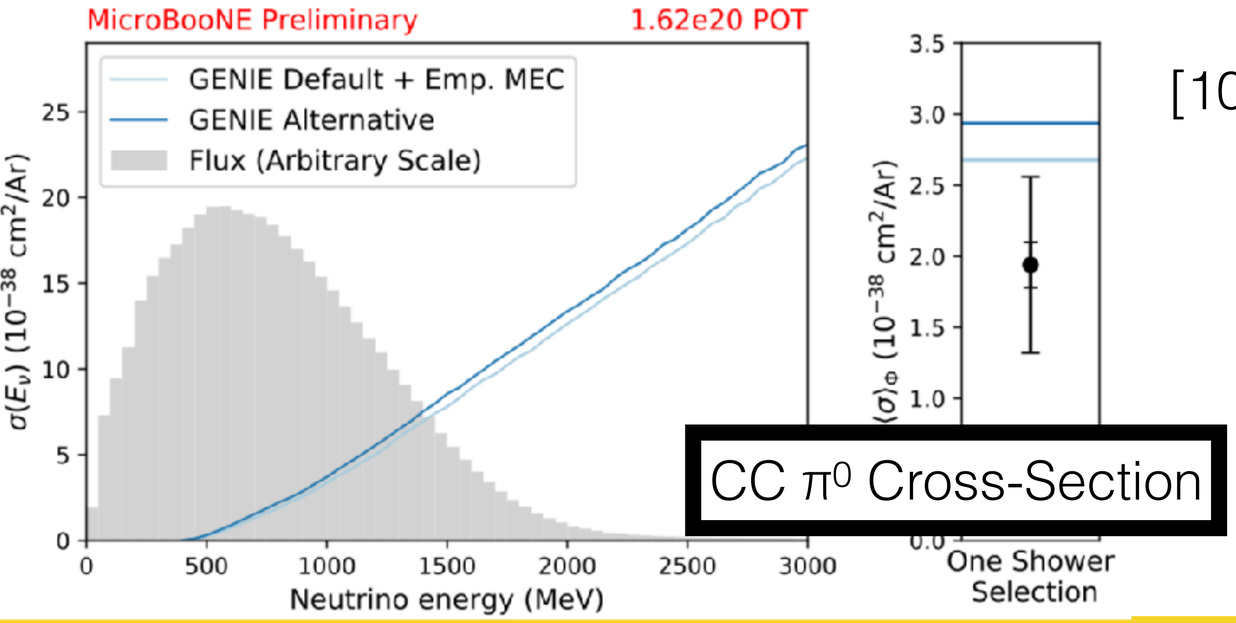
[9]


5×10^19 POT
MicroBooNE
Data
GENIE Default
GENIE+MEC
GENIE+TEM
(includes muons)
Event Fraction
Area normalized
Observed Charged Particle Multiplicity
Charged-Particle Multiplicity

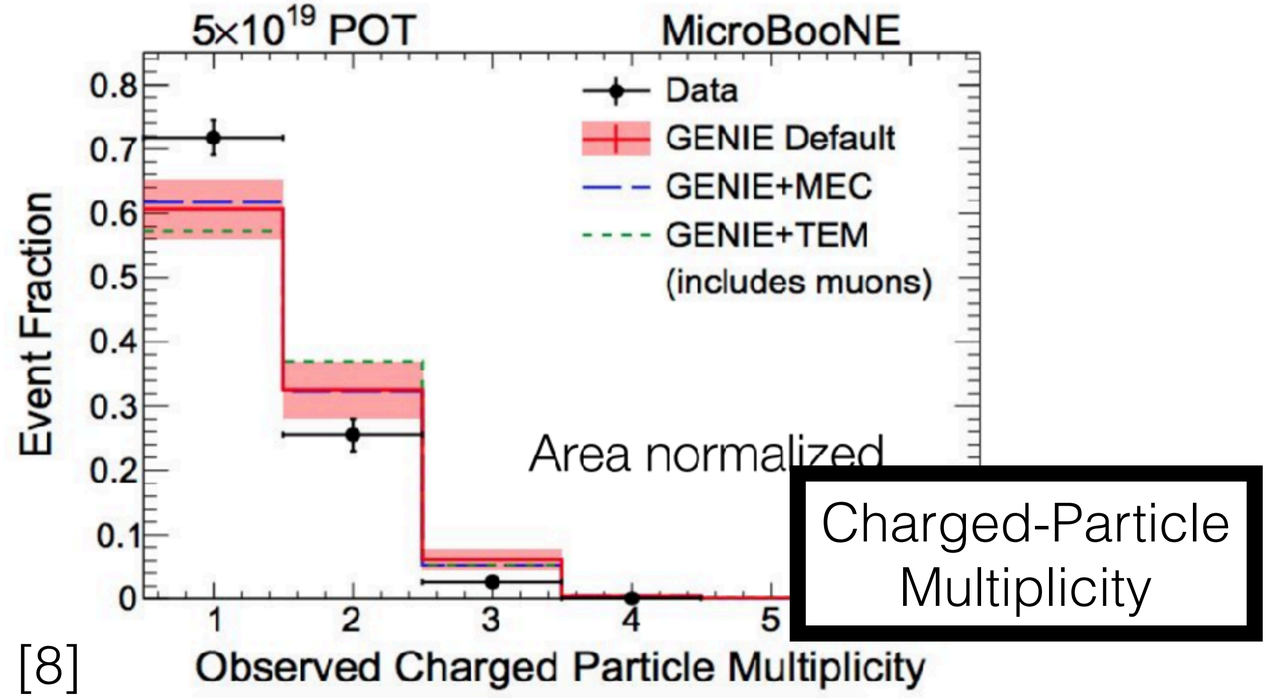
[8]


MicroBooNE Preliminary
GENIE Default + Emp. MEC (Stat. Unc.)
GENIE Alternative (Stat. Unc.)
Measured (Stat. ⊕ Syst. Unc.)
dσ/dp_μ^reco [10^-38 cm²/GeV]
p_μ^reco [GeV]
Inclusive νμ CC Cross-Section

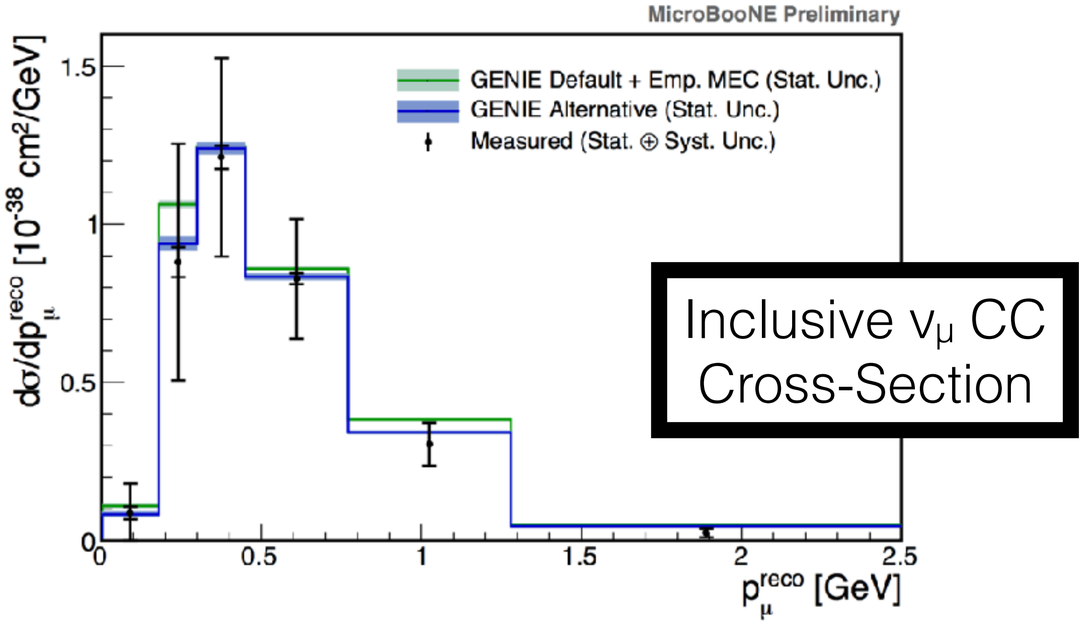
[9]


MicroBooNE Preliminary
1.62e20 POT
GENIE Default + Emp. MEC
GENIE Alternative
Flux (Arbitrary Scale)
σ(E_ν) (10^-38 cm²/Ar)
Neutrino energy (MeV)
⟨σ⟩_Φ (10^-38 cm²/Ar)
One Shower Selection
CC π⁰ Cross-Section

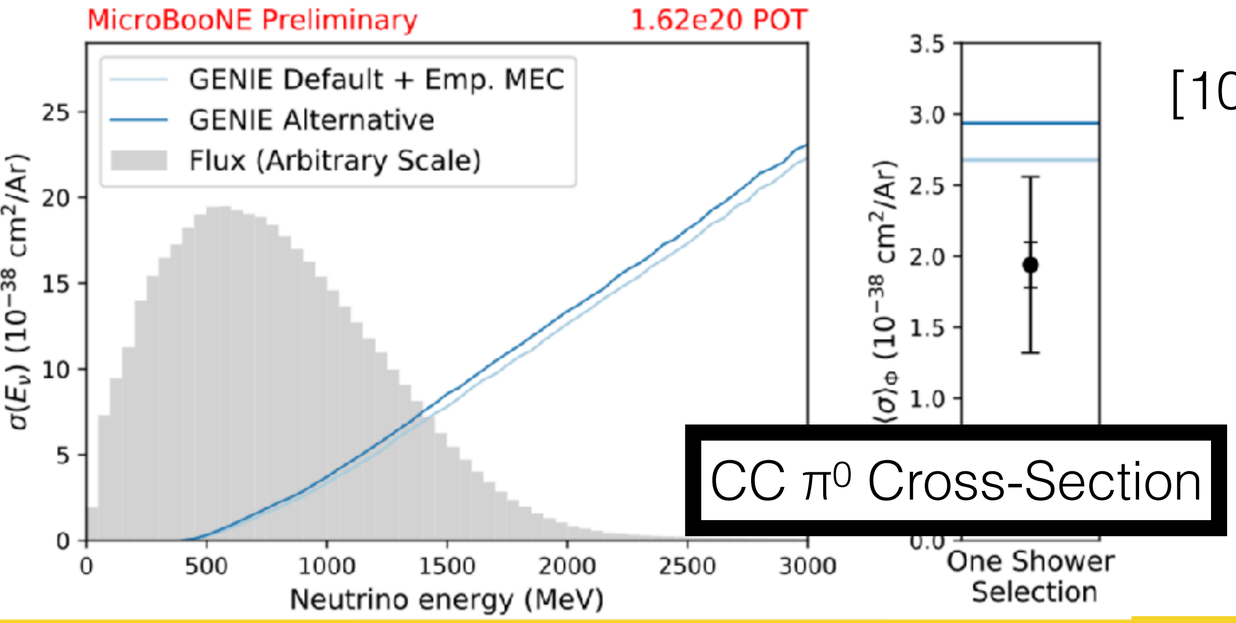
[10]


5×10^19 POT
MicroBooNE
Data
GENIE Default
GENIE+MEC
GENIE+TEM
(includes muons)
Area normalized
Event Fraction
Observed Charged Particle Multiplicity
Charged-Particle Multiplicity

[8]

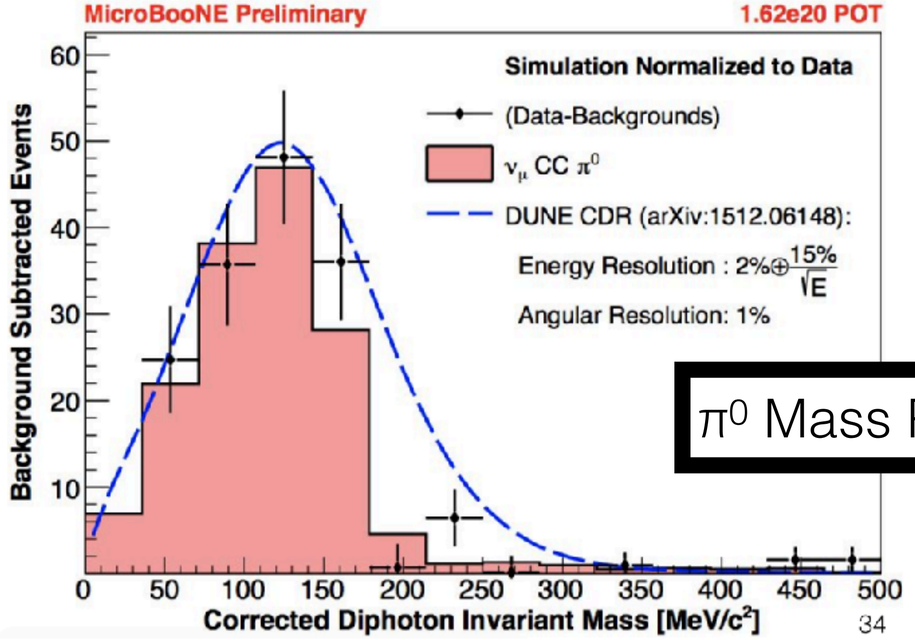

MicroBooNE Preliminary
GENIE Default + Emp. MEC (Stat. Unc.)
GENIE Alternative (Stat. Unc.)
Measured (Stat. ⊕ Syst. Unc.)
dσ/dp_μ^reco [10^-38 cm²/GeV]
p_μ^reco [GeV]
Inclusive νμ CC Cross-Section

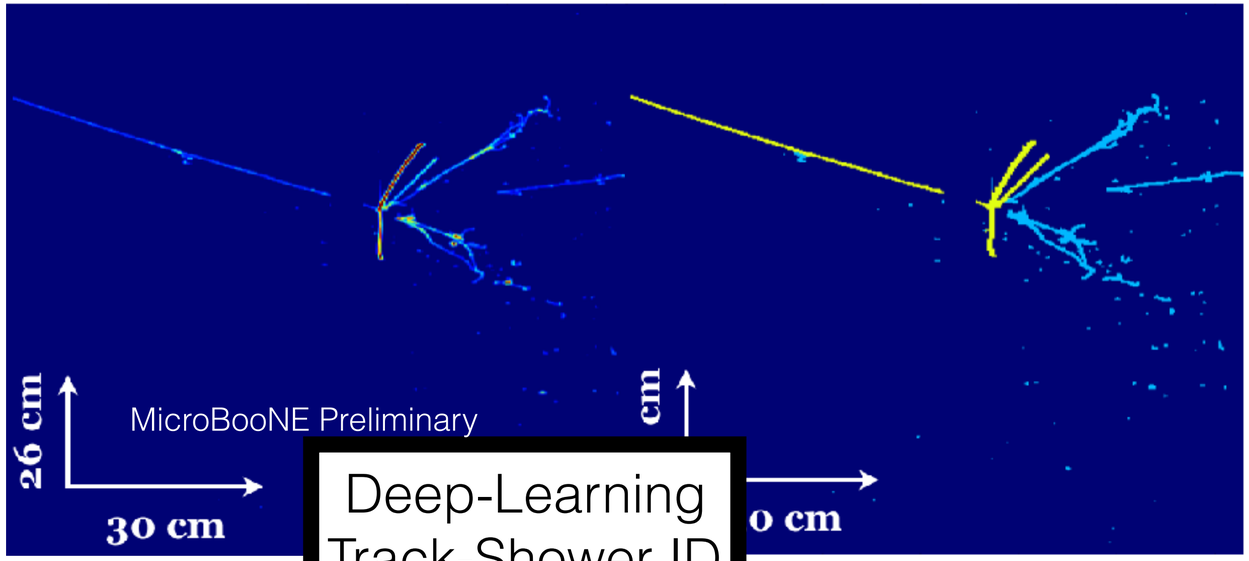
[9]


MicroBooNE Preliminary
1.62e20 POT
GENIE Default + Emp. MEC
GENIE Alternative
Flux (Arbitrary Scale)
σ(E_ν) (10^-38 cm²/Ar)
Neutrino energy (MeV)
⟨σ⟩_Φ (10^-38 cm²/Ar)
One Shower Selection
CC π0 Cross-Section

[10]

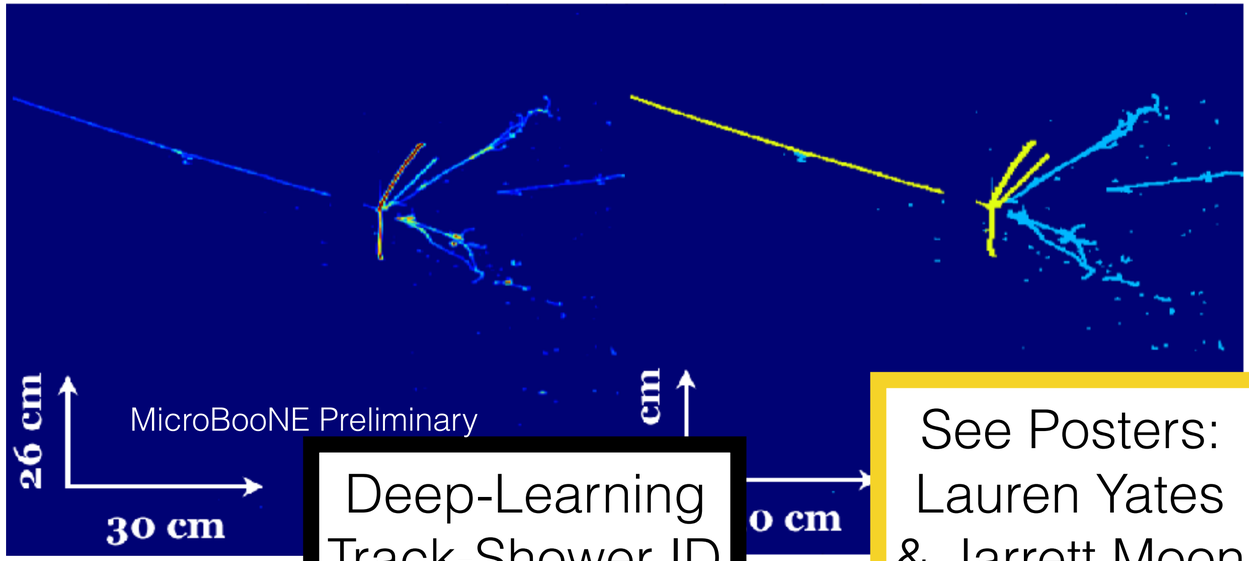
[11]


MicroBooNE Preliminary
1.62e20 POT
Simulation Normalized to Data
(Data-Backgrounds)
νμ CC π0
DUNE CDR (arXiv:1512.06148):
Energy Resolution : 2%⊕15%/√E
Angular Resolution: 1%
Background Subtracted Events
Corrected Diphoton Invariant Mass [MeV/c²]
π0 Mass Peak



Deep-Learning Track-Shower ID

[12]



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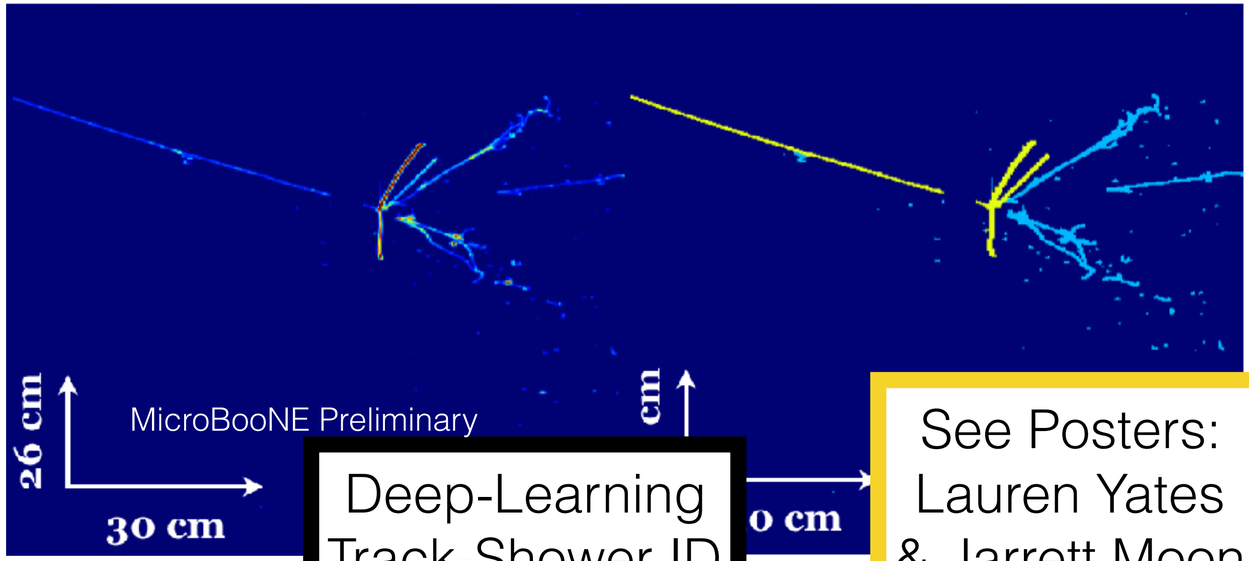
Deep-Learning Track-Shower ID

See Posters: Lauren Yates & Jarrett Moon



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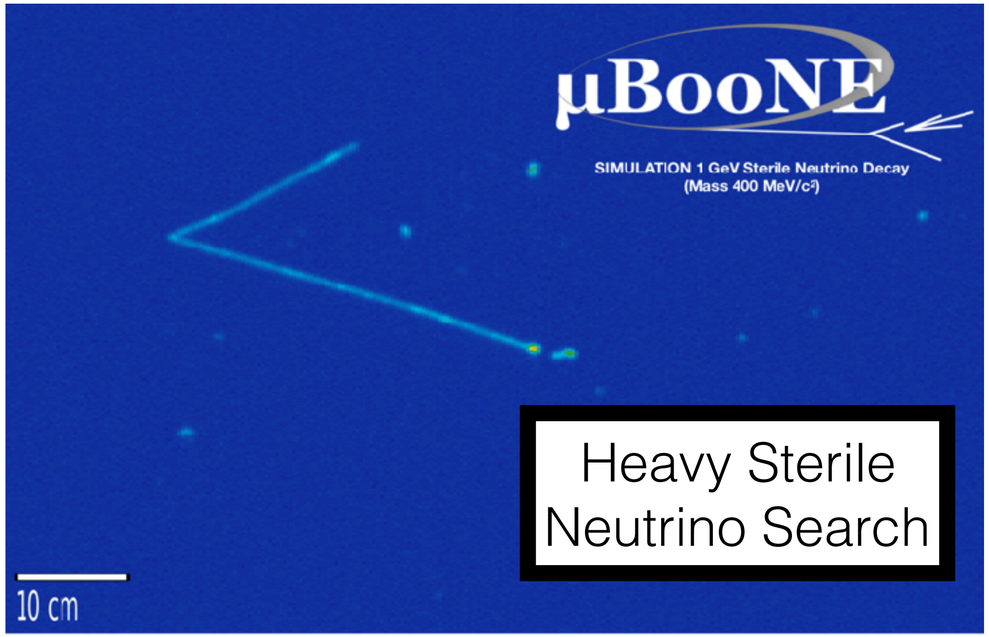
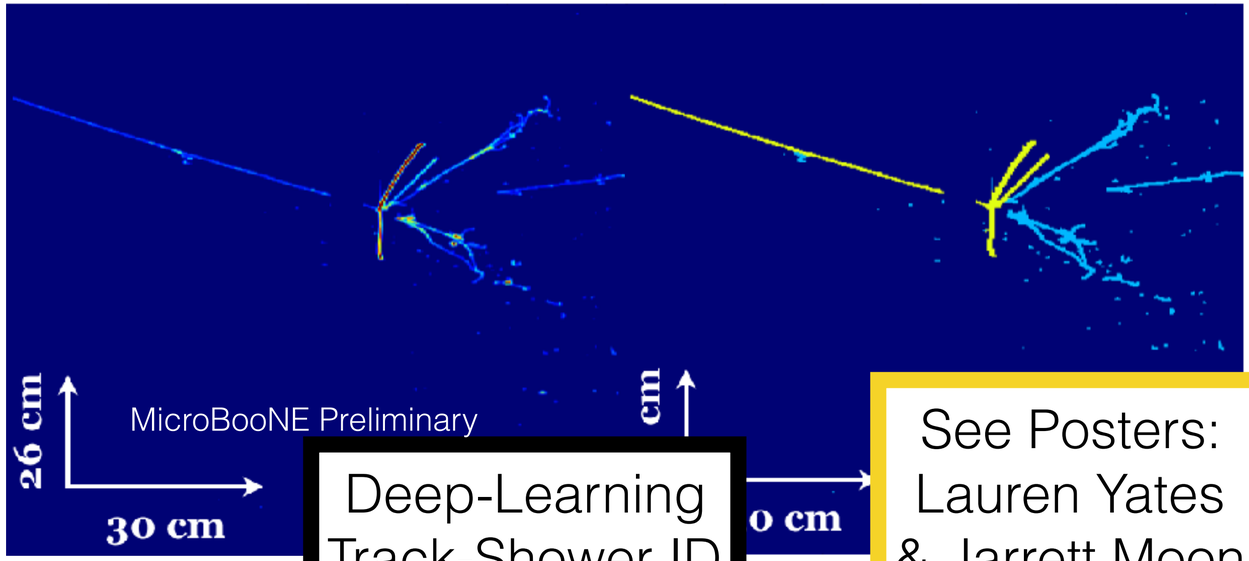
Deep-Learning Track-Shower ID

See Posters: Lauren Yates & Jarrett Moon

[13]



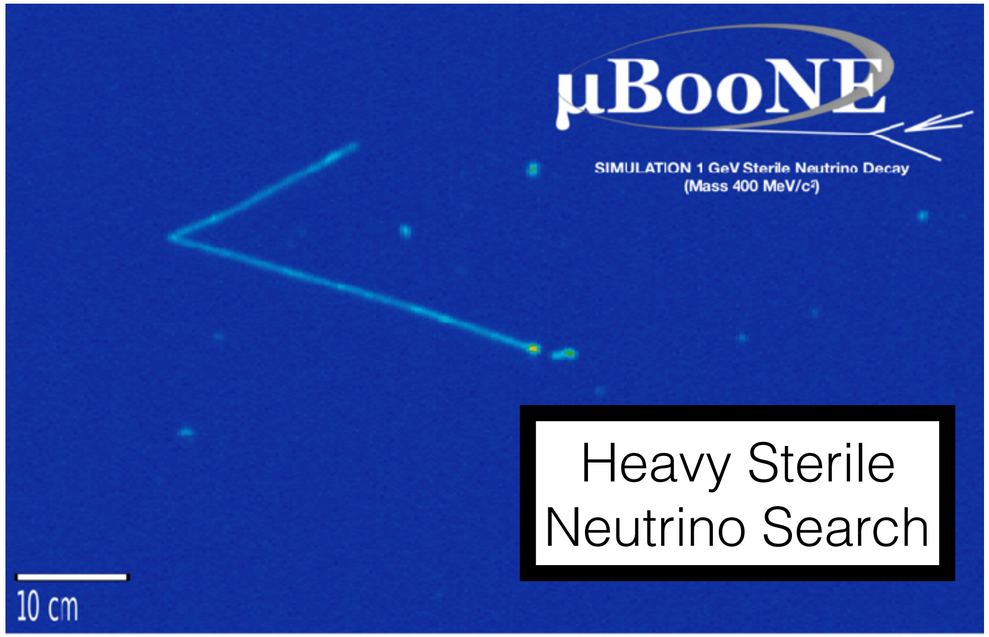
Heavy Sterile Neutrino Search



Deep-Learning Track-Shower ID

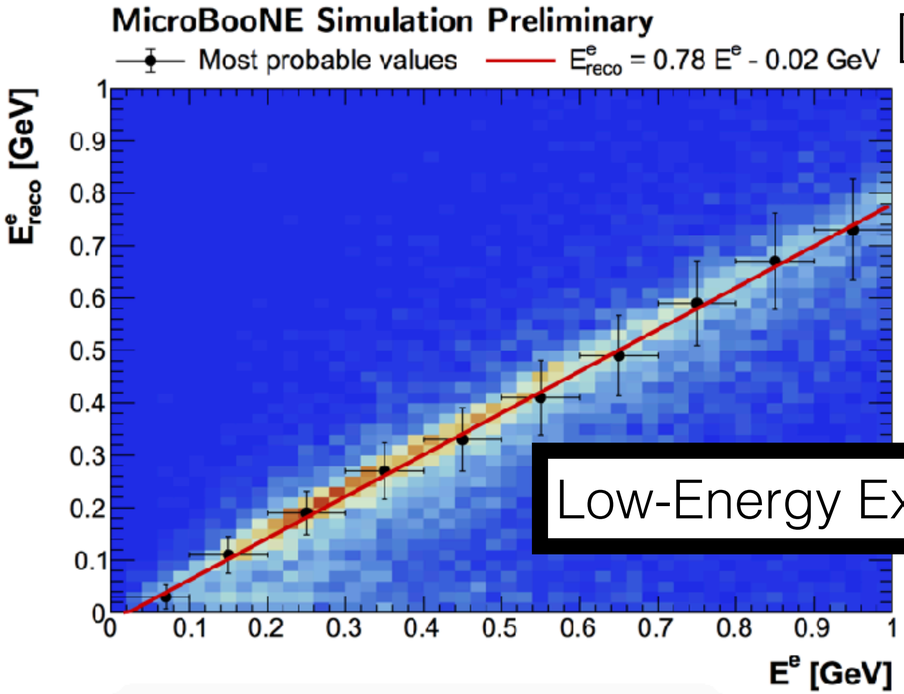
See Posters: Lauren Yates & Jarrett Moon

[12]



Heavy Sterile Neutrino Search

[13]



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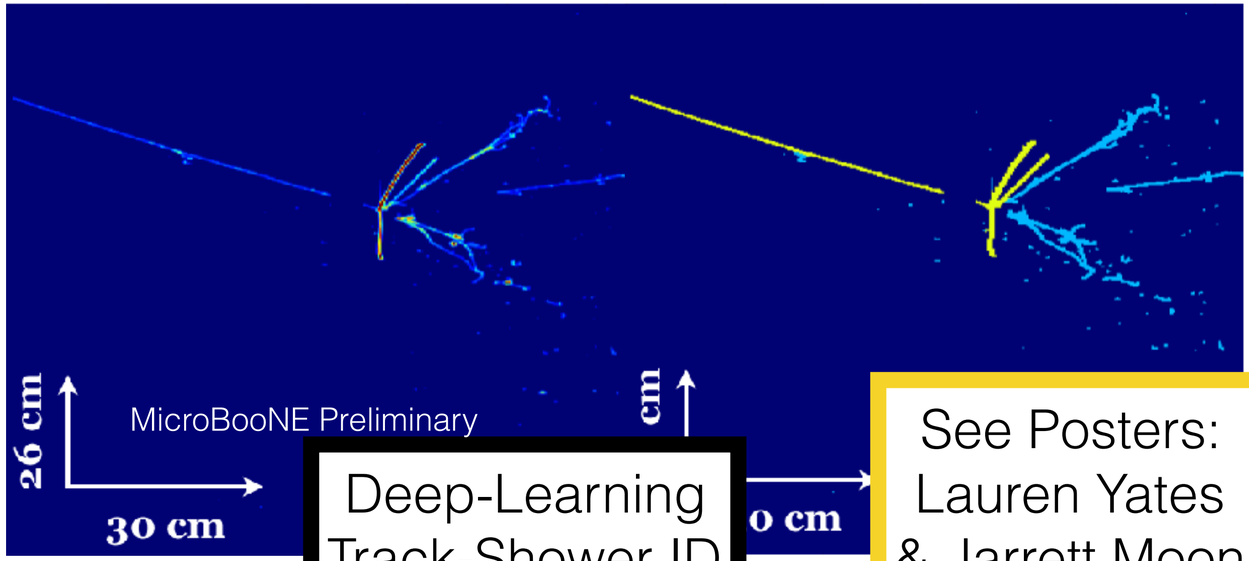
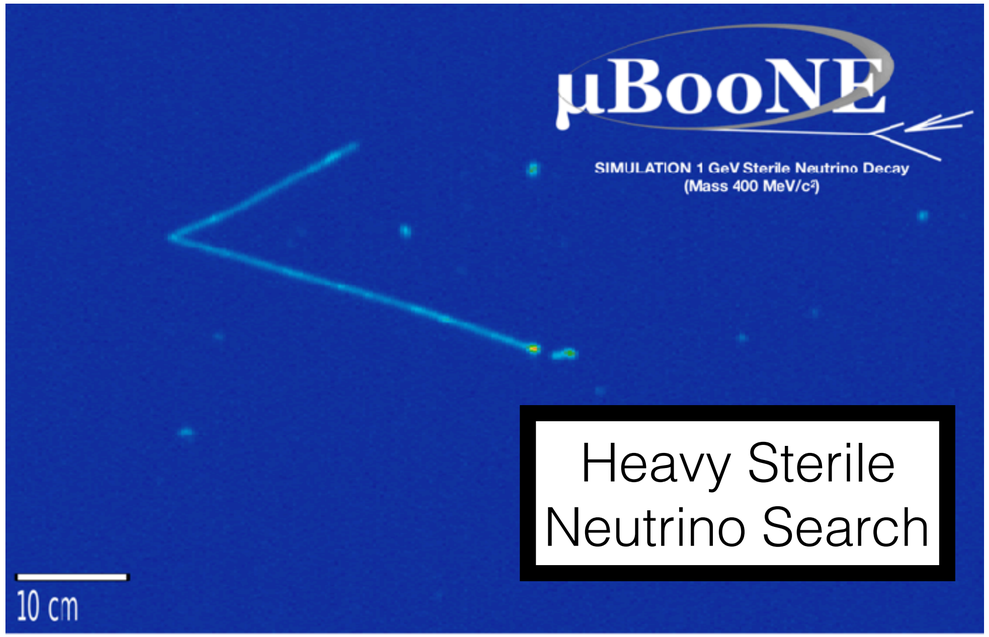
Low-Energy Excess Search



[12]

Deep-Learning Track-Shower ID

See Posters: Lauren Yates & Jarrett Moon



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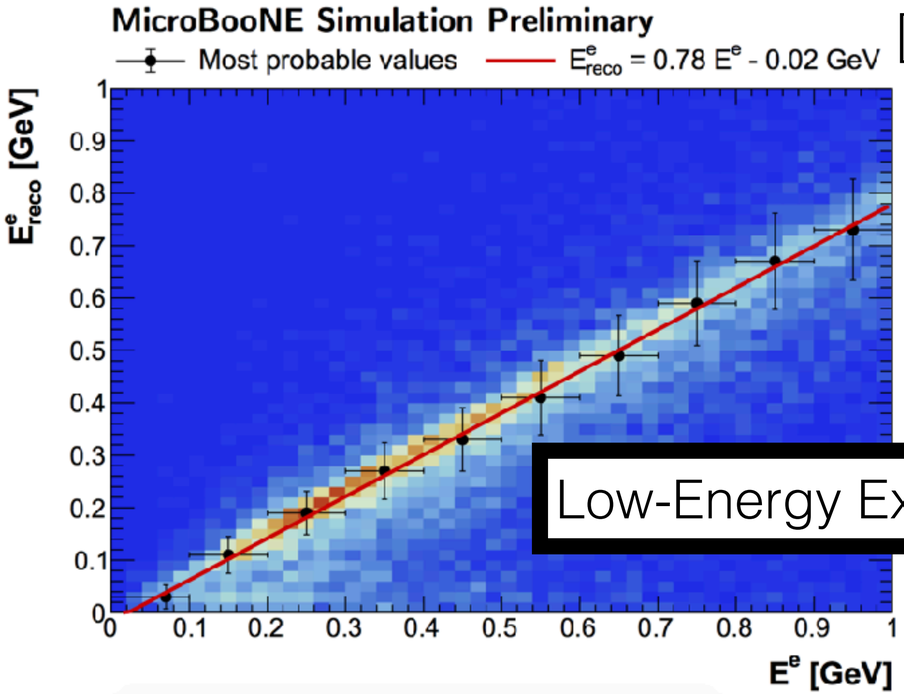
Heavy Sterile Neutrino Search



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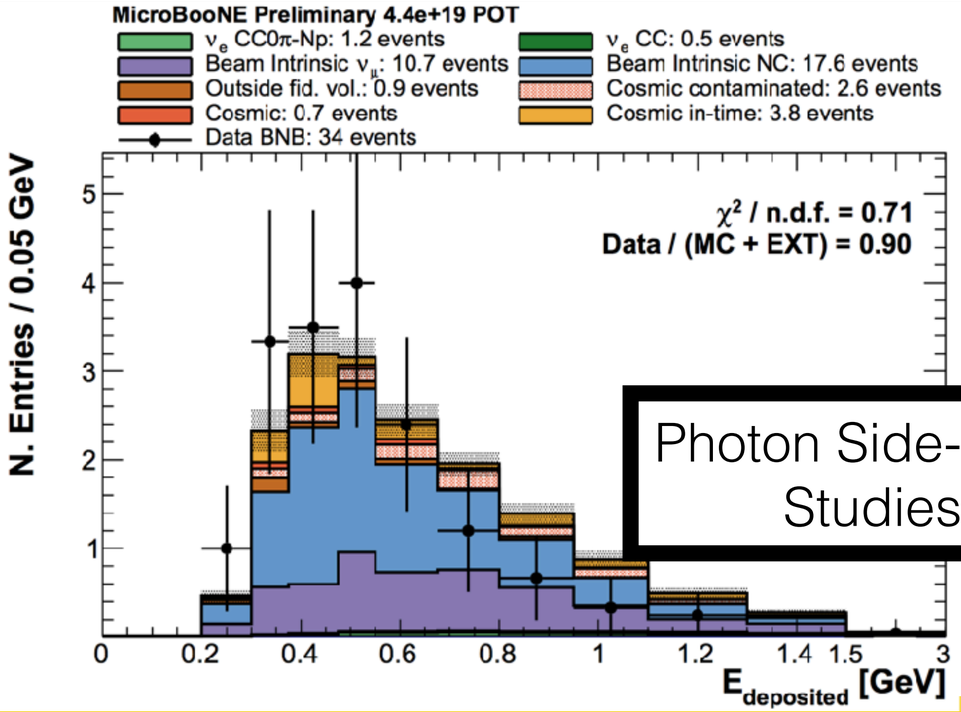
Low-Energy Excess Search



[15]

Photon Side-Band Studies

- MicroBooNE is working very hard to produce excellent results including:
  - Fully understanding complexities of LArTPC operations.
  - Characterising neutrino interactions and nuclear effects.
  - Carefully assessing the results seen from LSND/MiniBooNE.
  - Investigating exotic and astrophysical interactions, like Supernova neutrinos and heavy sterile neutrinos.
- Public Notes and Publications: http://microboone.fnal.gov/documents-publications/

Thank You!
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About Fermilab
KOVAL

New Perspectives Talks:

- ***Cold Electronics and Signal Processing*** *in the MicroBooNE LArTPC* - Brian Kirby
- *Evaluating the Performance of* ***Multiple Coulomb Scattering*** *Based Momentum Reconstruction with MicroBooNE Data* - Polina Abratenko
- *Testing a Neutrino Event Generator against* ***Electron Scattering Data*** - Afroditi Papadopoulou
- *Studying Track Distortions From the* ***Space Charge Effect*** *at MicroBooNE* - Chris Barnes

Users Meeting Posters:

- *Study of Reconstructed* ***Ar-39*** *Beta Decays in the MicroBooNE LArTPC* - Alex Flesher
- ***Detector Calibration*** *using through going and stopping muons in the MicroBooNE LArTPC* - Varuna Meddage
- *Towards a Measurement of Longitudinal* ***Electron Diffusion*** *in the MicroBooNE LArTPC* - Andrew Mogan
- *Systematic Uncertainties for MicroBooNE's* ***Deep-Learning****-Based Low-Energy Excess Analysis* - Lauren Yates
- *Hunting Muon Neutrinos in MicroBooNE with* ***Deep Learning*** *Techniques* - Jarrett Moon

References:

- [3] MICROBOONE-NOTE-1018-PUB
- [4] Based on empirical model
- [5] JINST 12 (2017) no.10, P10010
- [6] MICROBOONE-NOTE-1048-PUB
- [7] MICROBOONE-NOTE-1050-PUB
- [8] FERMILAB-PUB-18-077-ND
- [9] MICROBOONE-NOTE-1045-PUB
- [10] MICROBOONE–NOTE–1032–PUB
- [11] MICROBOONE–NOTE–1032–PUB
- [12] (In-Preparation) Deep Neural Network for Pixel-Level Track/Shower Separation
- [13] https://microboone-exp.fnal.gov/public/approved_plots/Event_Displays.html
- [14] MICROBOONE-NOTE-1038-PUB
- [15] MICROBOONE-NOTE-1038-PUB