Electron Neutrino Selection in MicroBooNE

Wouter Van De Pontseele – On behalf of the MicroBooNE collaboration

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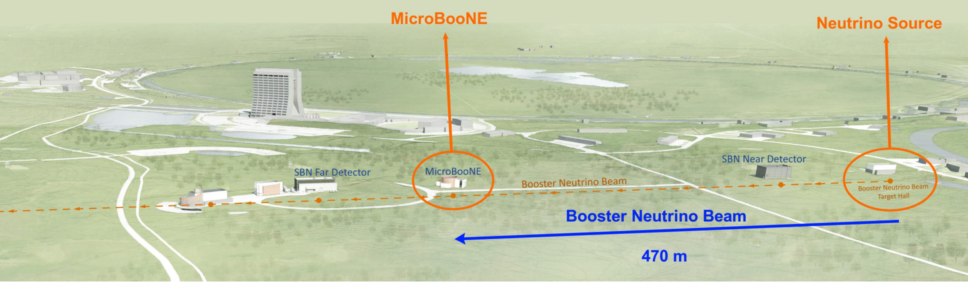
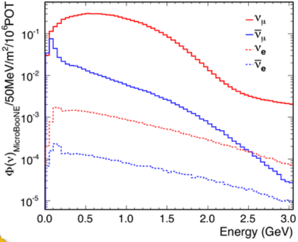
University of Oxford, Harvard University

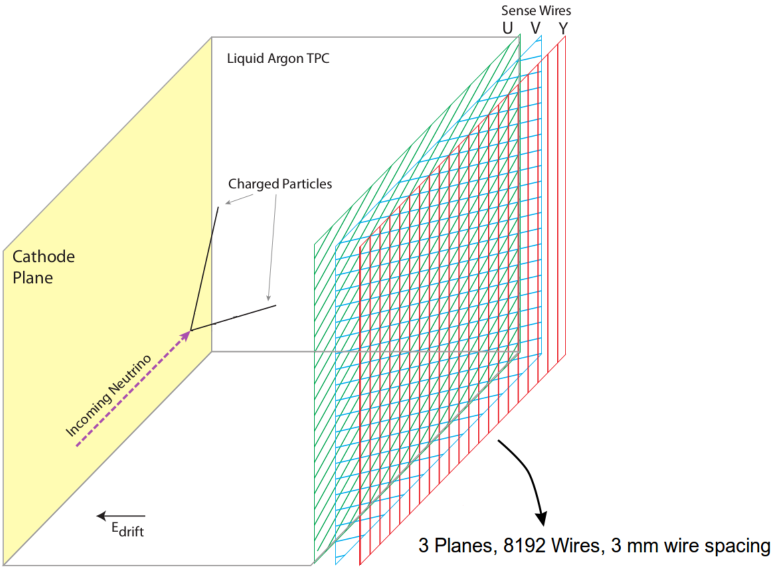


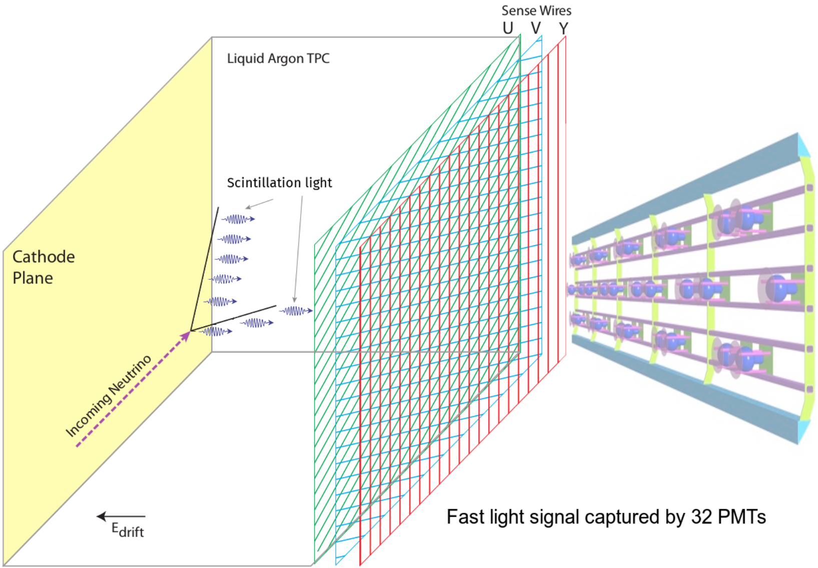
Physics goals

- Liquid Argon Time Projection Chamber (LArTPC) **R&D**.
- Adress electromagnetic **low-energy excess** observed by MiniBooNE.
- **Cross-section** measurements on argon.
- First step in the **Fermilab short baseline neutrino program.**

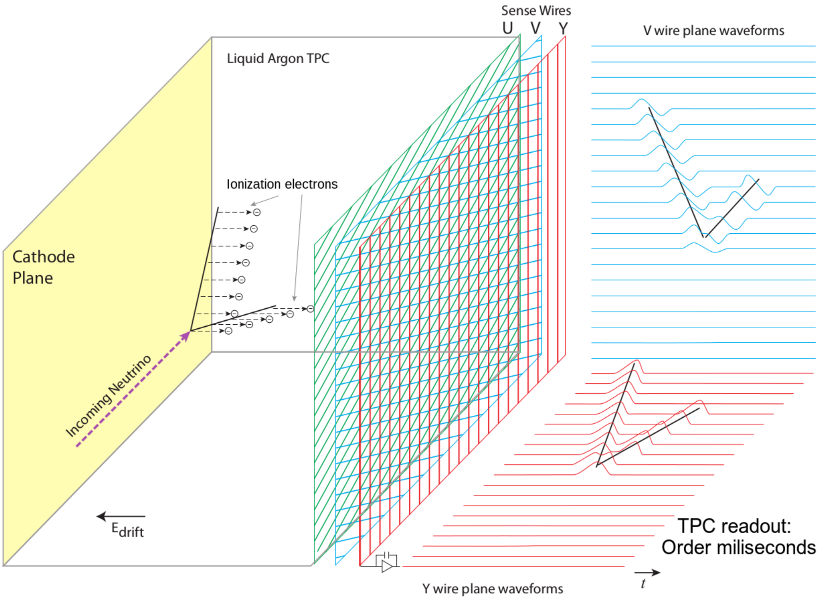


Liquid Argon Time Projection Chamber

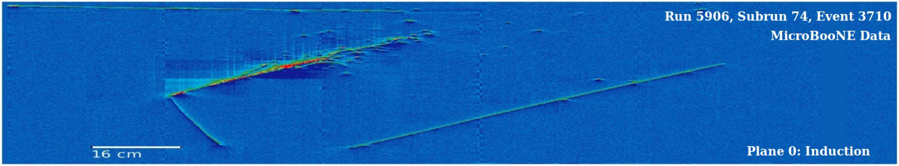


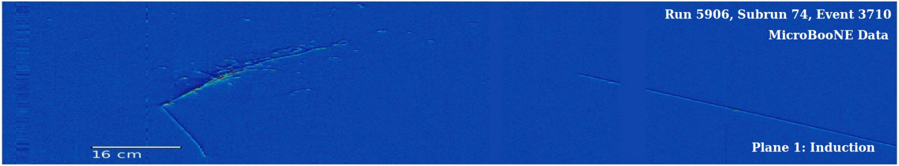

Sense Wires
U V Y
Liquid Argon TPC
Scintillation light
Cathode Plane
Incoming Neutrino
E_{drift}
Fast light signal captured by 32 PMTs

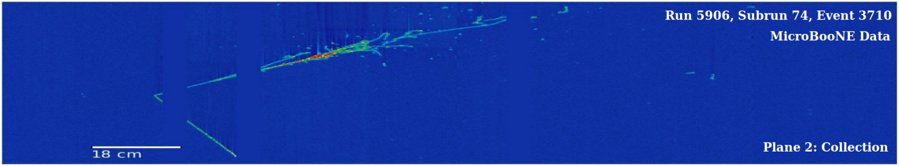
Liquid Argon Time Projection Chamber



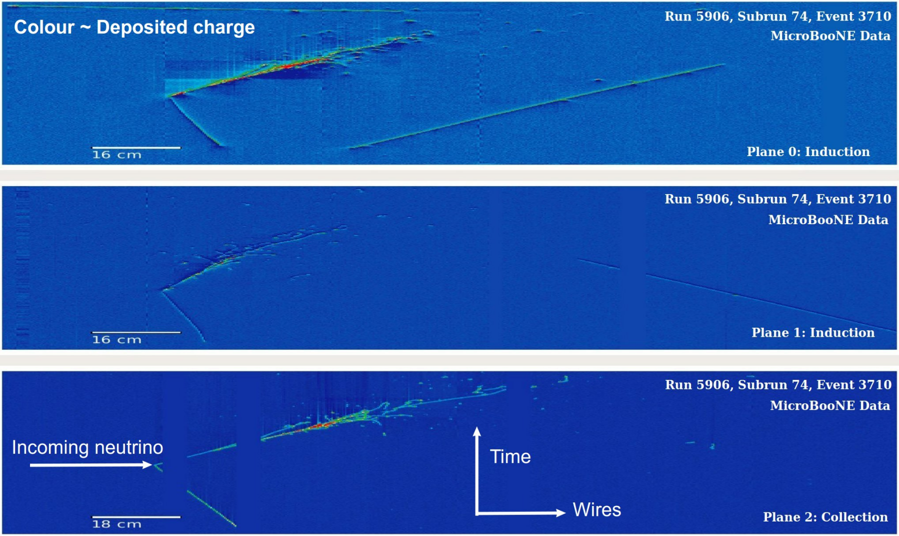
MicroBooNE Data Event



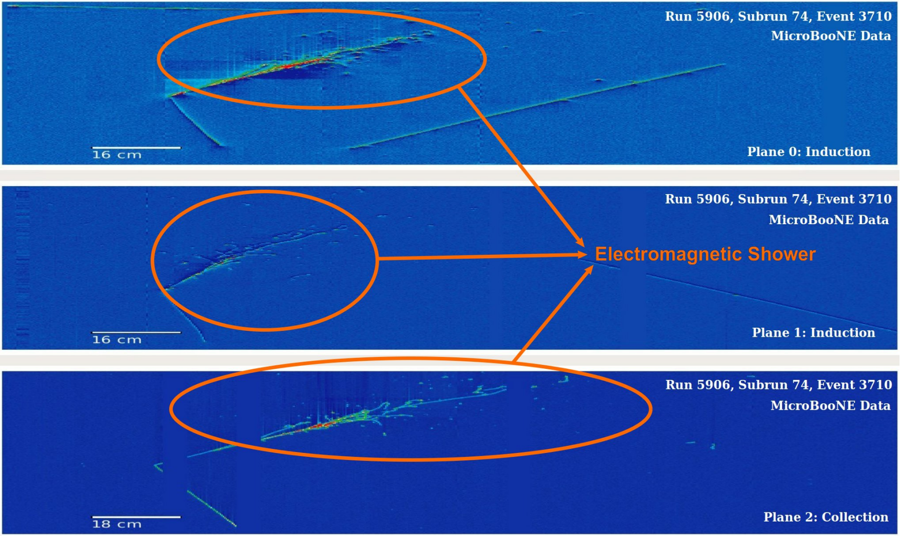


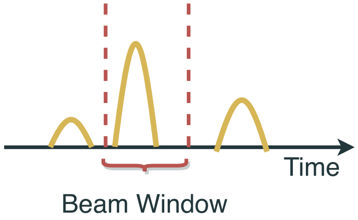


MicroBooNE Data Event



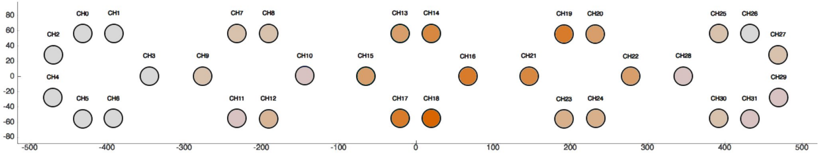
MicroBooNE Data Event



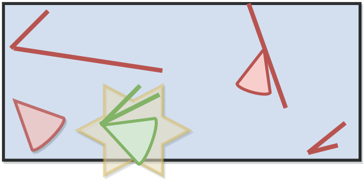


Flash selection

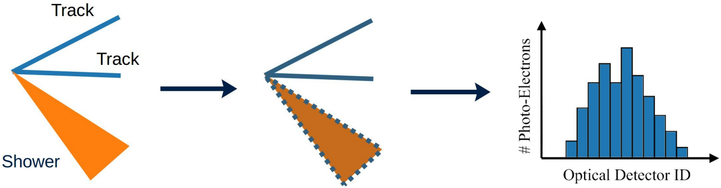
- Reconstruct a ***Flash* coincident with the neutrino beam**.
- Contains a **PMT photo-electron spectrum** corresponding to an interaction in the TPC.



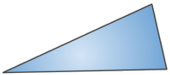
Pandora reconstruction framework creates multiple candidate interactions in the TPC. Only a neutrino interaction will likely coincide with the flash inside the beam window.



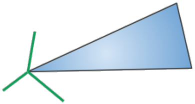
For all candidates, a **flash hypothesis** is created and **compared with the optical flash**.



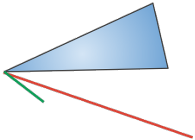
1. Only one electron: ν_e CC 0π $0p$
   - Significant contribution at low energy.
   - No vertex activity.
   - Hard to distinguish from single photon.



2. Additional protons: ν_e CC 0π Np
   - Vertex activity reduces backgrounds.
   - Protons might be below reconstruction threshold.

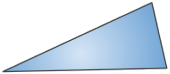


3. Additional protons and/or pions: ν_e CC $M\pi$ Np
   - Important for more energetic neutrino interactions, $\mathcal{O}(1\,\text{GeV})$ and higher
   - Typically more complex events with a lot of vertex activity.

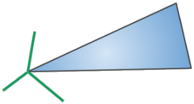


TPC Topology: ν_e charged current final states

1. Only one electron: ν_e $CC\ 0\pi\ 0p$
    - Significant contribution at low energy.
    - No vertex activity.
    - Hard to distinguish from single photon.



2. Additional protons: ν_e $CC\ 0\pi\ Np$
    - Vertex activity reduces backgrounds.
    - Protons might be below reconstruction threshold.
    - Require one shower and at least one track.



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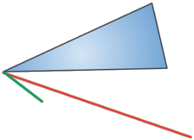
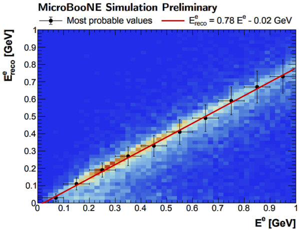
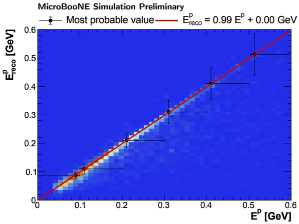


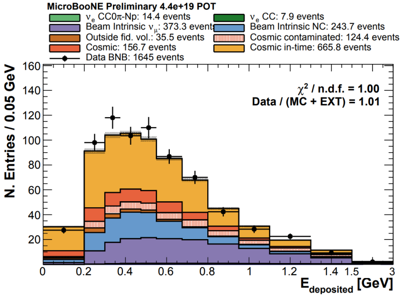
Electron Energy



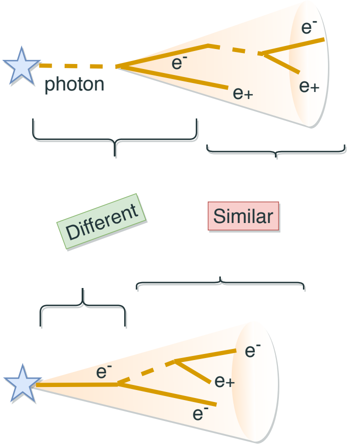
Proton Energy



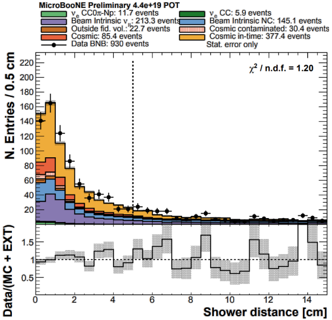
1. The **electron** energy is measured using the collected charge.
2. The **proton** energy is calculated using the reconstructed track length and the stopping power in liquid argon.
3. The reconstructed energy spectrum after pre-selection for ν_e $CC\ 0\pi\ Np$ candidates is the **electron and proton sum**:

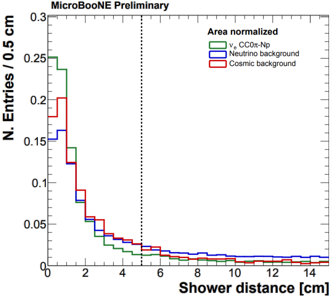


Photon shower:
displaced vertex and ~4 MeV/cm at start

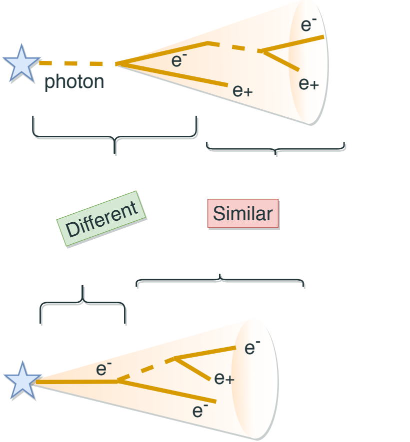


Electron shower:
vertex at interaction and ~2 MeV/cm at start

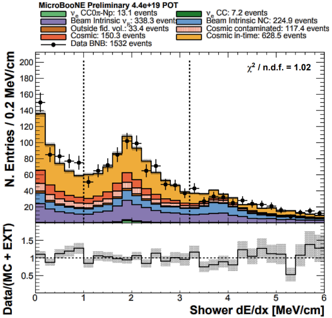


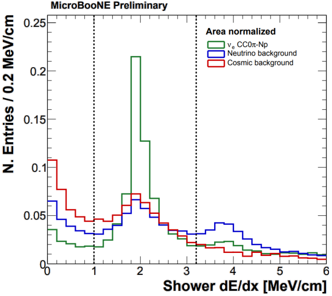


Photon shower:
displaced vertex and ~4 MeV/cm at start



Electron shower:
vertex at interaction and ~2 MeV/cm at start

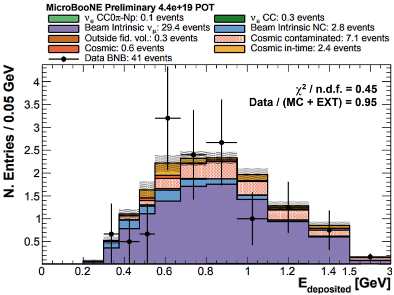




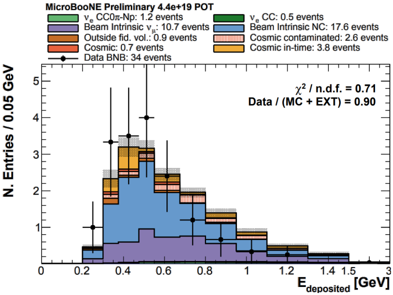
Some cuts useful to select ν_e $CC\ 0\pi\ Np$ events can be inverted or modified

- Explore orthogonal regions of the phase-space.
- Study important background events.
- Demonstrate data/MC agreement.

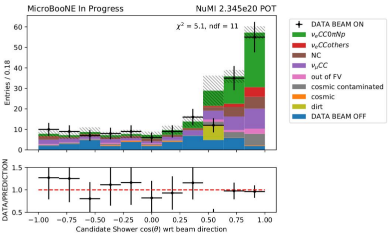
ν_μ CC - enhanced

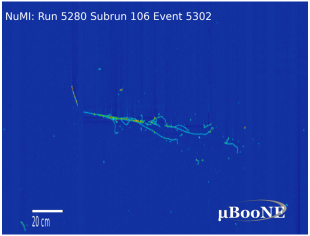


ν NC π^0 - enhanced



1. First **cross-section measurements** submitted for PRL publication:
   - ν_μ CC Inclusive — MICROBOONE-NOTE-1045-PUB
   - ν_μ CC π^0 — MICROBOONE-NOTE-1032-PUB
2. Strong demonstration of the **low-energy-excess analysis strategies**:
   - **Electron-like search with BNB** — **MICROBOONE-NOTE-1045-PUB**
   - Photon-like search with BNB: — MICROBOONE-NOTE-1041-PUB
   - Deep learning based electron-like search with BNB — MICROBOONE-NOTE-1042-PUB
   - Electron-like selection using the NUMI off-axis beam — MICROBOONE-NOTE-1054-PUB





- MicroBooNE just passed **3.5 years of stable data-taking**, over 1.1×10^{21} protons-on-target collected.
- **Demonstrated low-energy excess strategy** on unblinded data-set corresponding to 4.4×10^{19} protons-on-target
  1. **Optical pre-selection** rejecting cosmic background.
  2. **TPC topology** to select ν_e *CC*.
  3. **Calorimetry** for particle-identification and energy reconstruction.

Selection on improved Monte Carlo in progress

New results expected soon!

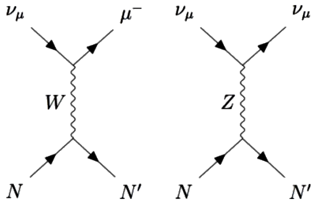
Thank you!
& Back-up slides

Neutrino interactions in MicroBooNE

The data shown here is an **unblinded sample** collected by the detector between February and April 2016. It corresponds to an exposure of 4.4×10^{19} protonsontarget of the booster neutrino beam.

Typical neutrino energy $\mathcal{O}(1\,\mathrm{GeV})$, in this energy range, the neutrino interacts with the argon nuclei. This happens dominantly through quasi-elastic or meson-exchange processes. They can be split up in:

1. **Charged current interactions**
    - Production of a lepton.
    - Distinguish different flavours.
2. **Neutral current interactions**
    - No lepton, exited nucleus.
    - Identical for all neutrino flavours.



For the the verification of the electron hypothesis of MiniBooNE's low-energy excess, we are only interested in ν_e CC interactions.

MiniBooNE and the low-energy excess

1. **LSND experiment** at Los Alamos observed excess of anti-electron neutrino events in the anti-muon neutrino beam.

2. **MiniBooNE experiment**
   - Booster Neutrino Beam, 500 m.
   - Filled with 800 ton of pure mineral oil.
   - muons: clear filled Cerenkov rings.
   - e/γ: Fuzzy Cerenkov rings.
   - After 15 years of running: neutrino mode: (381.2 ± 85.2) excess (4.5σ).