MicroBooNE Neutrino Master Class Status

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(for MicroBooNE)

Where are we now?

- Discussion on developing a MicroBooNE master class started roughly around October 2016, good progress since then
- **We have been discussing broadly three elements for the Master Class:**
  - Developing Physics tasks → need to define this first to nail down all other details
  - Event displays tools
  - Prepare Data/Monte Carlo files
- **Current plan:** Design the masterclass in such a way that we teach students both detector level physics and neutrino beam physics — and how former impacts the latter.
  - Use Booster Neutrino Beam (BNB) neutrino data events from MicroBooNE (which include both cosmic and neutrino events by default)

Some ideas in development

- **The detector physics: Electron lifetime measurement (tells us about argon purity)**

  — Argon purity is a fundamental operational requirement for LArTPCs. If purity is bad, you cannot do physics and you will see obvious effects in your data.

- **The neutrino (BNB) physics: charged particle multiplicity measurement & related physics**

  — One of the current challenges of neutrino experiments is understanding how neutrino interacts with a nucleus, especially with dense targets like argon since they present a complicated environment and impact oscillation measurements. This task will show students how well the data and models used in MC (e.g. GENIE or NuWro) agree **(need to make this more accessible to students, for example implement energy mass conservation or calculate incoming neutrino energy etc. - still under works)**

- **But, both of these tasks are connected!**

  — For example, provide students with high and low purity samples to see the connection

What will the students learn?

- Goals of the proposed physics task:
  - Learn how to differentiate **Charged current (CC) vs Neutral current (NC) interactions**
  - Learn how to **identify various particles** (muons, electrons, gammas, neutral pions, protons, charged pions, and other)
  - Learn how to **identify and reject cosmic tracks** in the detector
  - Learn how to **identify a neutrino interaction vertex**
  - Learn how to **produce charged particle multiplicity distribution for CC events and perform related physics**
  - Learn how to **extract electron lifetime (attenuation)** from event displays

- Interpretation of results will give them some understanding of
  - Challenges in identifying interaction types, particle types, reconstruction issues, cosmic rejection challenges, and vertex identification challenges
  - How does the multiplicity distributions b/n data and MC compare
  - How to quantify the electron attenuation and impurity content in the detector
  - In what ways impurities in argon can impact a given physics measurement

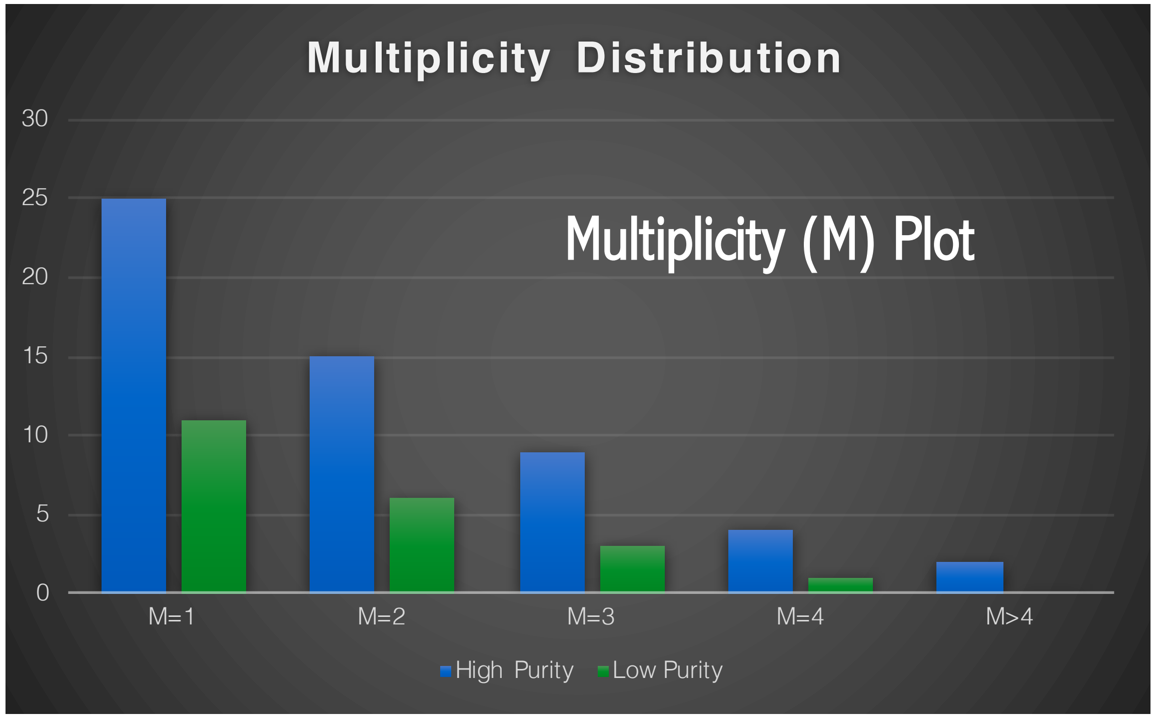
Example work flow

- **Start with a high and low purity BNB datasets** and tabulate the items shown in the table below

Dataset Used	Electron Lifetime (ms)	No. of tracks per event	CC events	NC events	No. of muons	No. of protons	No. of electrons	No. of gammas	No. of neutral Pions	No. of charged pions	Other
High Purity Data											
MC (GENIE)											
Low Purity Data											

Charged Track Multiplicity (M) Table

Dataset Used	M=1	M=2	M=3	M=4	M>4
High Purity Data					
MC (GENIE)					
Low Purity Data					



How many events would we need?

- 50 events per 2 students → about 3000 MicroBooNE BNB data events would be a good start assuming 50 to 60 students. This can very well raise to 6000 events if we want to do 100 events per student group.

Current Plan

- Like we discussed before, there are broadly three elements to the Master Class:
  - Defining Physics tasks
  - Event displays tools
  - Prepare Data/Monte Carlo files as needed

Browsable, 3D images, interactive, can show hits charge/time/energy deposited information

- Current plan: Design the masterclass in such a way that we teach students both detector level physics and neutrino beam physics — and how they are connected.
  - BNB data events which include cosmic tracks by default will suffice for our needs
  - For MC, we need BNB + cosmics simulation.

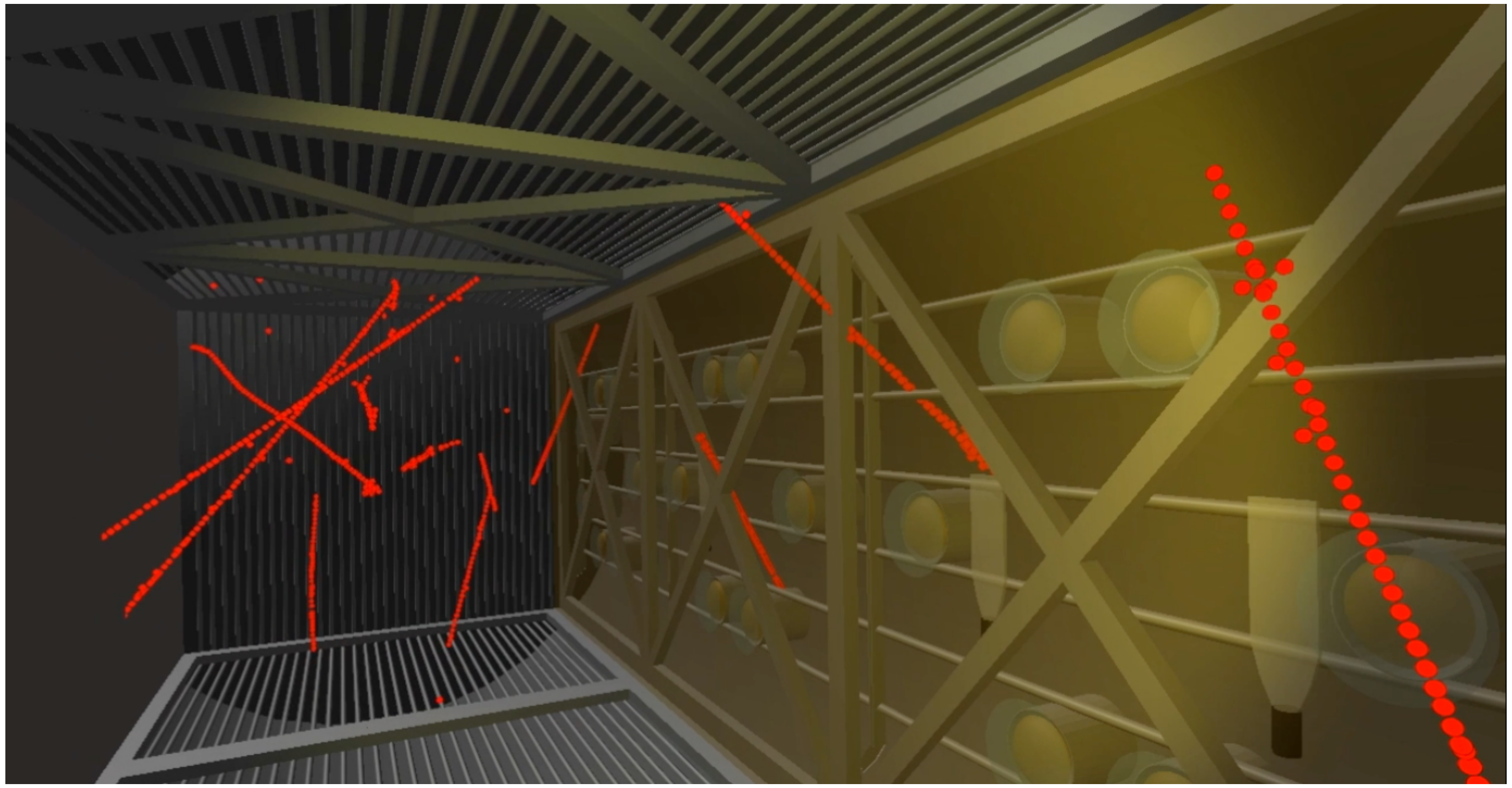
The following four displays were explored

- VENu phone app (Marco) ✔
- ARGO browser-based (Nathaniel) ✔
- BEE browser based (BNL group) ✘
- LArlite event display (Corey, Yale) ✘

Decision to go with VENu and ARGO

VENu Event Display Tool

Website: http://venu.physics.ox.ac.uk



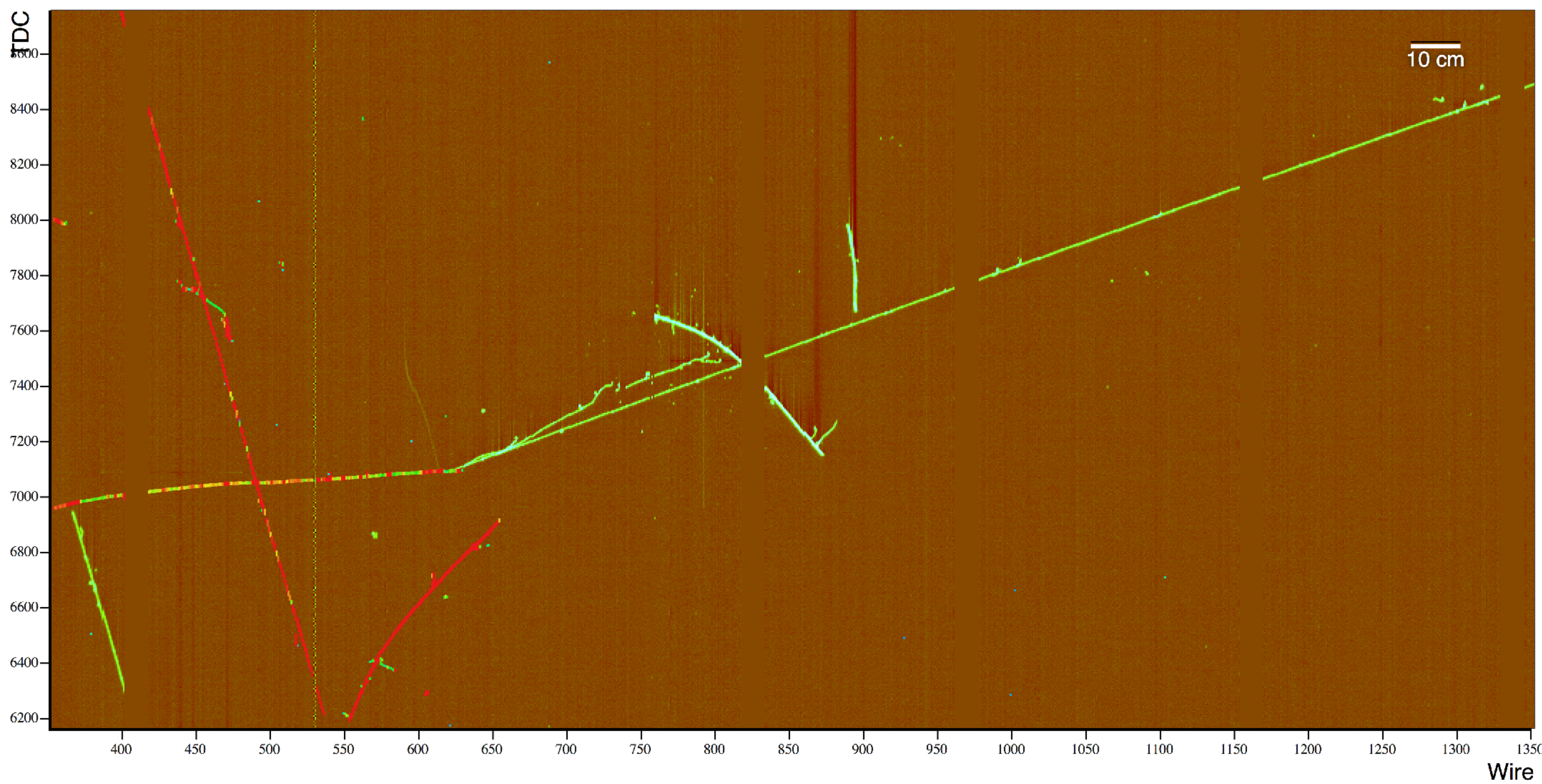
- A great interactive event display app, available for both Android and iOS
- Built in 3D and is designed to exhibit both virtual and augmented reality features (e.g. use with google cardboards)
- Can browse MicroBooNE events directly
- Provides both learning and gaming mode

- VENu currently cannot handle providing hit information, charge and timing information that would be needed to do physics analysis – will be available for a future iteration
- However, VENu will make an excellent introductory tool for students to get started with neutirnos, experience MicroBooNE in 3D etc. so, we plan to use it for this purpose

ARGO event display

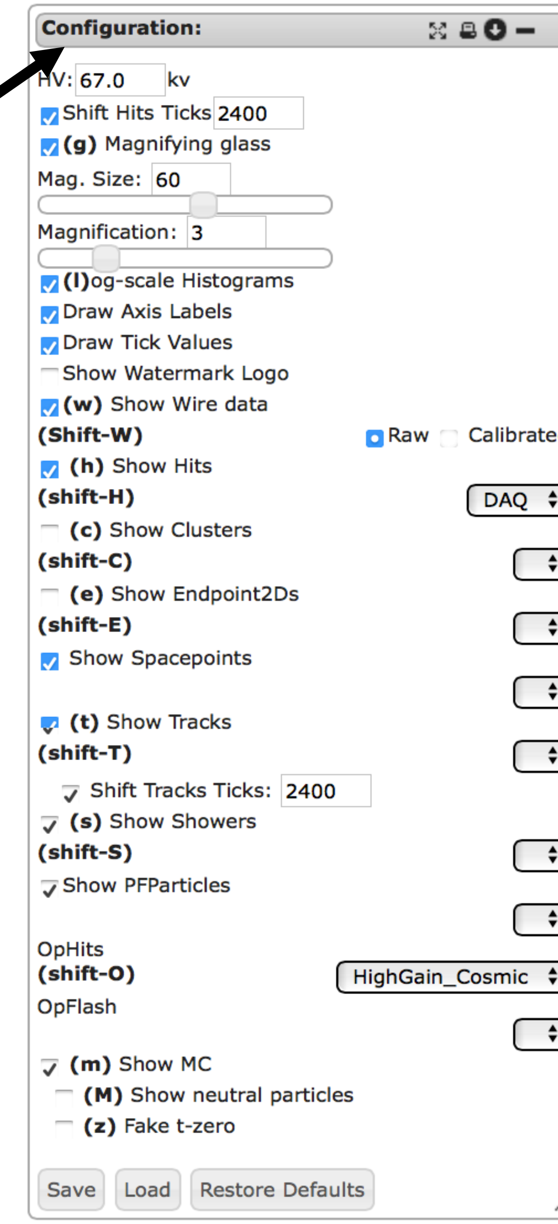
Website: http://argo-microboone.fnal.gov

Example ARGO event display for Plane 2



Has a lot of options to configure what gets displayed. Very user friendly.

Nathaniel actively maintains this page



A simplified version of ARGO used by MINERvA masterclasses, Nathaniel has agreed to provide a similar version for MicroBooNE

Access data directly from uboone discs