# Comparing MicroBooNE Low Energy Excess Analyses

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## 1. Low Energy Excess (LEE) and MiniBooNE experiment

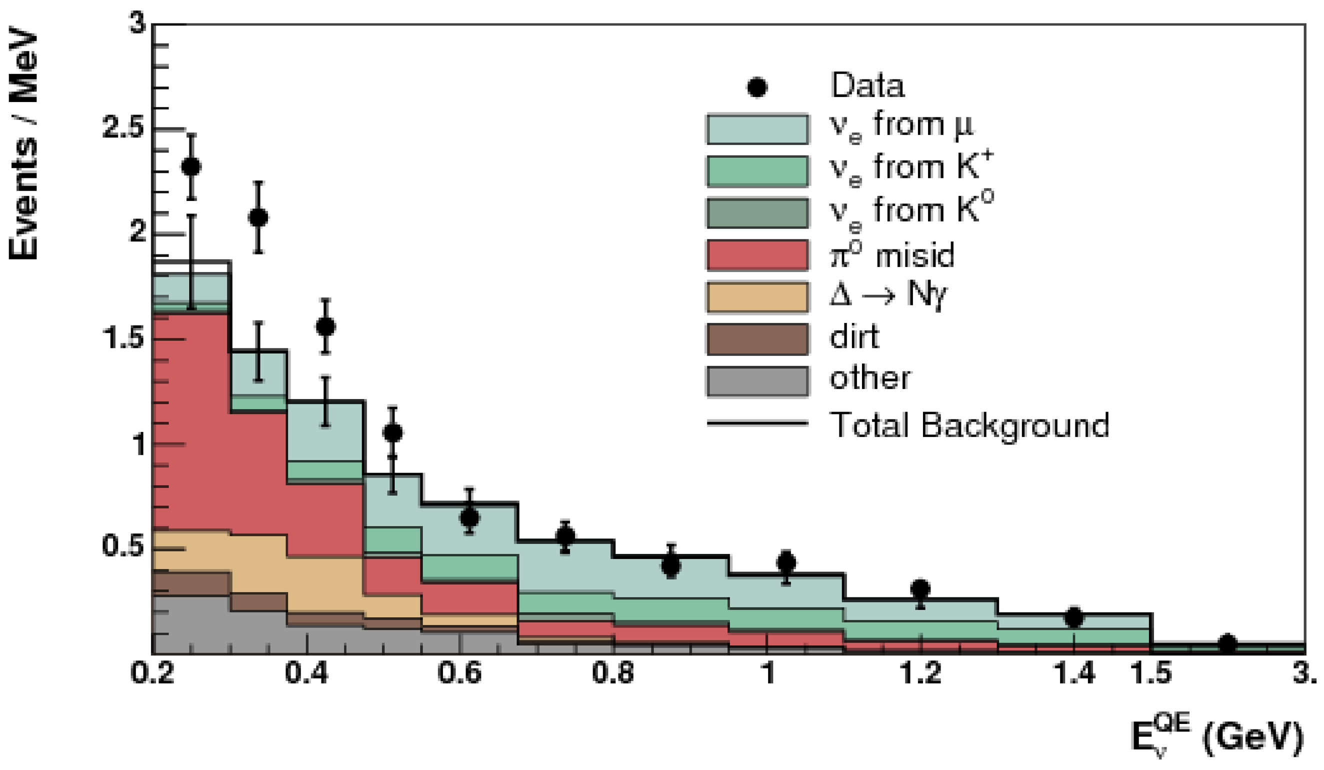



Figure 1: Black dots are electron-like events measured by MiniBooNE as a function of neutrino energies $E_\nu^{QE}$ and coloured histograms are the predictions. The noticeable discrepancy between data and predictions at the low energy region is called LEE [1].

- The excess of electron-like events in a $\nu_\mu$ beam was observed by MiniBooNE [1] as shown in Figure 1 and LSND.
- Possible explanations include:
  - Neutrino decay.
  - Sterile neutrino: 3+1 and 3+n.
  - Misidentifying photon as electron.
- Equipped with a Cerenkov light detector, it was difficult for MiniBooNE to distinguish photons from electrons.

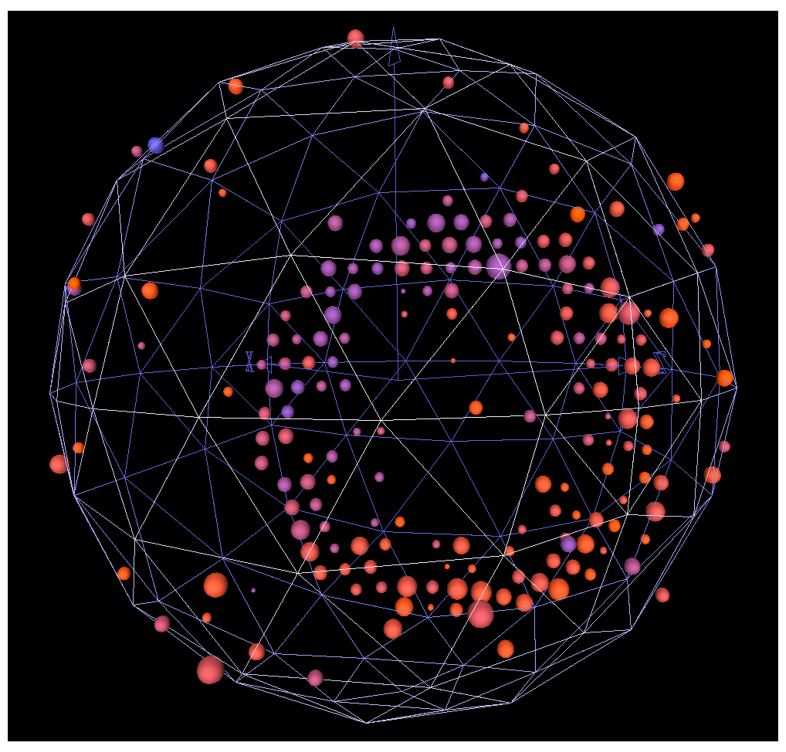


Figure 2: Event display of an electromagnetic shower from MiniBooNE [2].

## 2. Micro Booster Neutrino Experiment (MicroBooNE)

- MicroBooNE is designed to investigate the LEE using a Liquid Argon Time Projection Chamber (LArTPC) →
- A LArTPC can easily distinguish photons and electrons as shown in Figure 5.

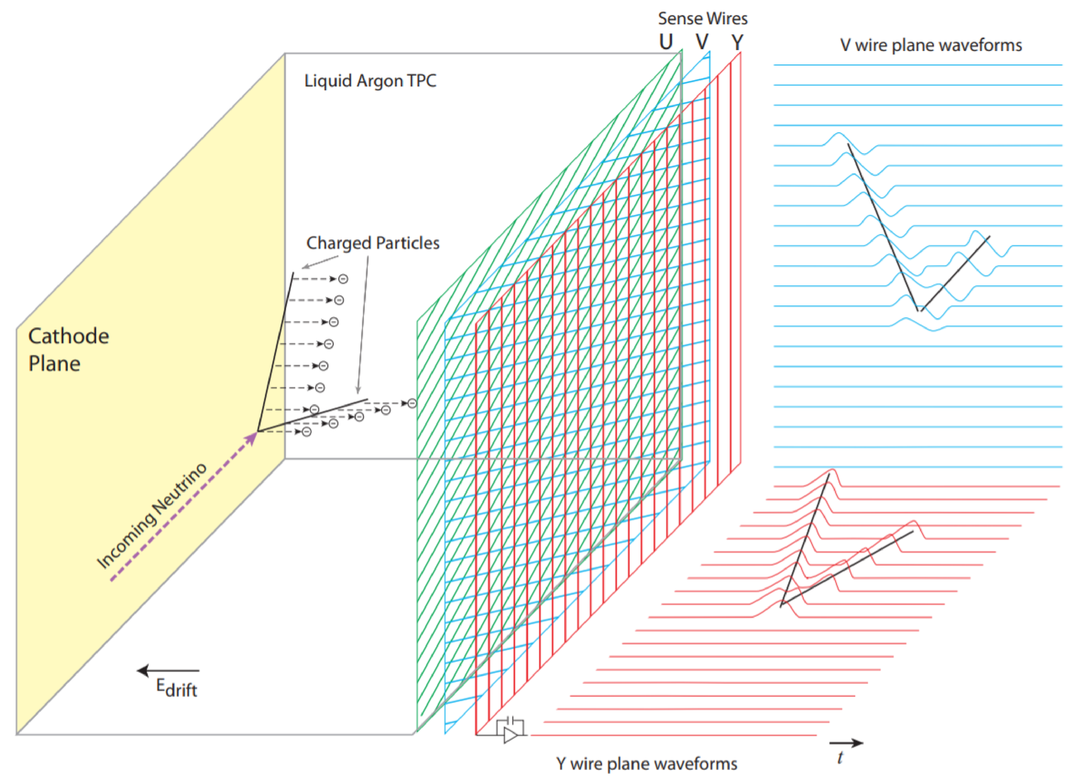
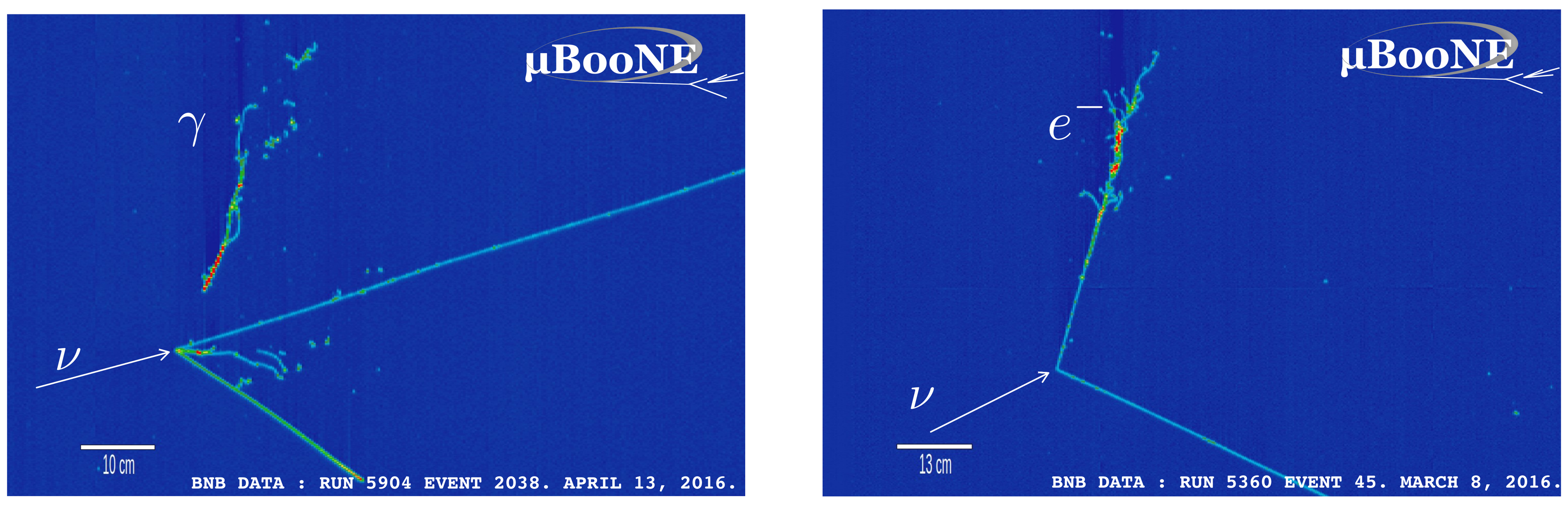



Figure 4: The design of the MicroBooNE LArTPC. Ionization electrons drift to the anode under the electric field $\overleftarrow{E}_{drift}$ [5].




(a) (b)

Figure 5: (a) is an event display with a photon shower and (b) is an event display with an electron shower [6]. Both events happened in the MicroBooNE detector.

- MicroBooNE will also act as a test bed for Deep Underground Neutrino Experiment (DUNE), which employs the similar technology [7].

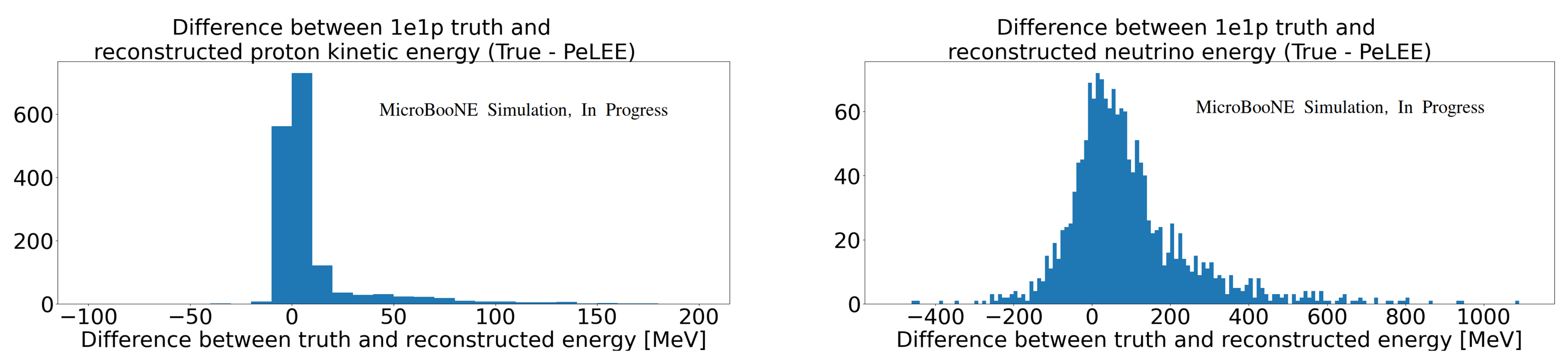
## 3. MicroBooNE analyses comparison

- MicroBooNE investigates the LEE using four individual methodologies. Two electron-like methodologies are compared here:
  - "Pion-less" searches for "1eNp" events using the Pandora reconstruction [3].
  - "CCQE" searches for "1e1p" quasi-elastic events using Deep-Learning based methods [4].
- Geometric reconstruction comparison — True and reconstructed values agree well for Pion-less and CCQE:

| Variable | Difference between true and reconstruction |
|---|---|
| Vertex position | 1 cm |
| Shower angle | 7 deg |
| Proton angle | 10 deg |

Table 1: Ranges that include over 90% of events in truth and reconstruction comparison. A smaller range suggests a better agreement between the truth and the reconstruction.

- Energy reconstruction comparison:

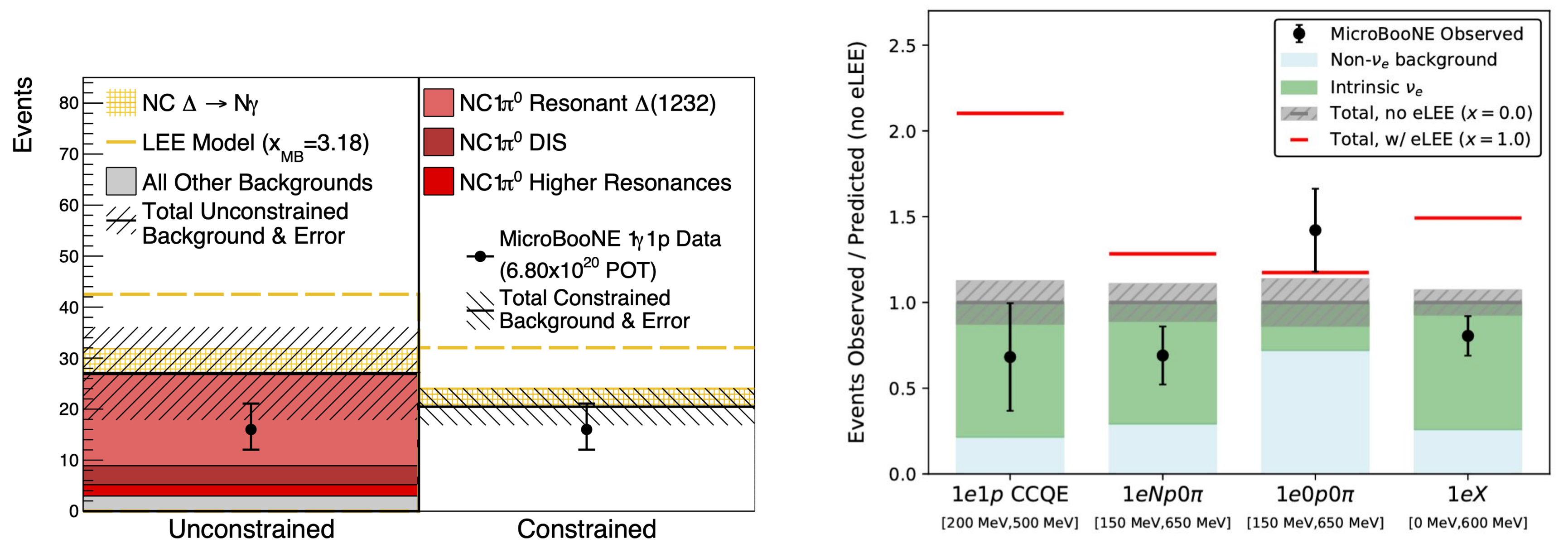



(a) (b)

Figure 3: (a) Differences between the true proton kinetic energy and the Pion-less reconstruction for 1e1p events. (b) Differences between the true neutrino energy and the Pion-less reconstruction for 1e1p events.

- **These comparisons add confidence to our results.**

## 4. MicroBooNE results




(a) (b)

Figure 6: (a) is the rate of 1$\gamma$1p events, suggesting the excess is not incurred by photons [8]. (b) is the ratio of data compared with predictions in each channel, indicating no excess is observed [9].

- The rate of photon events agrees with predictions as shown in Figure 6(a).
- No excess in the channels we have searched, as shown in Figure 6(b).

## 5. References

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