MicroBooNE Detector Stability

MICROBOONE-NOTE-1013-PUB

The MicroBooNE Collaboration

June 30, 2016

Abstract

The Micro Booster Neutrino Experiment (MicroBooNE) is designed to explore the low-energy excess in the ν_e event spectrum reported by the MiniBooNE experiment [1] and to measure ν-Ar cross sections in the 1 GeV energy range. The detector is a liquid argon time projection chamber with wire readout, supplemented with a light detection system based on photo-multiplier tubes (PMTs). The apparatus is located in the Booster Neutrino Beamline (BNB) at Fermilab and started collecting neutrino data in October 2015. This note presents a study of the stability of the MicroBooNE detector by measuring the average number of reconstructed tracks per event, the average number of reconstructed vertices per event, and the average number of multi-PMT coincidences (flashes) per event. These quantities are chosen since these are the most relevant to the ν_μ charged-current inclusive analysis [2].

1 Introduction

The MicroBooNE experiment has been collecting data since October 2015. Data quality monitoring plays a crucial role in detector and analysis reliability because it ensures that the detector performance is optimal to maximize the precision of the physics results. Reconstruction stability is an important requirement for the ν_μ charged-current inclusive analysis in MicroBooNE. Stable run selection criterion is used in conjunction with other requirements, including good operating conditions for the detector and, in the case of data collected during BNB operation, beam-quality requirements, to ensure data of sufficient quality for MicroBooNE's ν_μ charged-current inclusive analysis. This note presents detector stability plots of selected MicroBooNE reconstruction variables used by ν_μ charged-current inclusive analysis.

2 Detector Reconstruction Algorithms and Objects

We have chosen to use three products of the reconstruction to monitor the detector performance: 3D charged-particle tracks, "flashes" (described below), and interaction vertices. These quantities are chosen since these are the most relevant to the event selection of the ν_μ charged-current (CC) inclusive analysis [2].

A "reconstructed track" is a result of a pattern recognition and tracking algorithm, where a 3D charged-particle trajectory is formed by matching the TPC 'hits' (pulses, after passing through a noise filter [3], deconvolution and calibration) and clusters (formed by grouping hits that are connected in space and time within a wire plane) across the three wire planes of the TPC. We present here the number of reconstructed tracks from the output of one of tracking algorithms—the "KalmanHit" tracking algorithm—where all tracks are treated independently without the use of any neutrino-interaction vertex association. The KalmanHit algorithm is one of the primary tracking algorithms used to reconstruct muon tracks in the CC inclusive analysis.

A “PandoraNu vertex” is the reconstructed vertex created using the Pandora pattern-recognition algorithm suite [4]. It is created by searching for pairs of 2D clusters from different wire-plane views to create plausible candidate 3D vertex positions, and then it selects the best candidate from each match by examining the distribution of 2D hits around projections of the candidates into each view. By only requiring two planes for the reconstruction it reduces the impact of non-responsive or noisy wires.

An “optical flash” is reconstructed by grouping ‘optical hits’ (characterized by their amplitude, width, time relative to the trigger, and the photo multiplier tube (PMT) on which they occurred) that occur coincident within a window of roughly 1 μs in time across the detector. Therefore, an optical flash is a reconstructed detection of prompt scintillation light produced by charged particles in the detector volume. The ν_μ CC inclusive analysis requires a flash with amplitude greater than 50 photo-electrons (PE) over all PMTs to reduce noise and other background events, and so we check the average number of reconstructed flashes above this threshold per event to help ensure a stable selection.

3 Reconstruction Stability over Time

Detector stability plots provide a high level check of data and simulation by monitoring any change in detector hardware and reconstruction software run by run, highlighting the impact of such changes on various reconstructed parameters. The following is a list of key variables for the ν_μ CC inclusive analysis that were monitored for each run.

- Average number of tracks (from the KalmanHit algorithm) per event and its spread.
- Average number of vertices (from the PandoraNu algorithm) per event and its spread
- Average number of > 50 PE flashes per event

These quantities are a reflection of the overall stability and quality of the collected data, and are used as a component selecting good data-taking periods. In addition to above listed quantities, y and z center of flashes distributions were also used for selecting good data-taking periods but are not presented in this note.

In this section we present the stability of these quantities in data collected from the MicroBooNE detector since late February, 2016. We analyze data both with and without exposure to the BNB neutrino beam, called "on-beam" and "off-beam" data, respectively. Due to the long readout time of the detector (4.8 ms), all events (where by 'event' we mean data acquired during the 4.8-ms readout time) are dominated by the presence of cosmic ray interactions.

The spread of these variables was calculated for all events over a run by taking the square root of the variance of the distribution. The distribution of each of these quantities over all runs was fit to a Gaussian and runs lying within 3-σ bounds of the fitted Gaussian distribution in both data streams were selected. In addition 3-σ bound cuts were also applied to y and z center of flashes plots for stable run selection. Table 1 and 2 present average and spread (RMS) values from the Gaussian fits of the selected quantities for on-beam and off-beam data respectively. The average values match rather well, and the spreads are reasonably close, but slightly larger in off-beam data due to less statistics in off-beam data stream. A fraction of 91.7% of the delivered protons on target (POT) from the BNB pass this criterion. As both on-beam and off-beam data streams pass through the same event-triggering algorithms, and, as previously mentioned, the events are dominated by cosmic rays, the properties of reconstructed objects are largely comparable in the two data streams. Figure 1, 2, and 3 present detector stability plots for Kalmanhit tracks, PandoraNu vertices, and > 50 PE flashes per event respectively. Figure 4, 5, and 6 present corresponding normalized y-projections of detector stability plots for both off-beam and on-beam data streams.

Variables & Algorithms	On-beam data	
	mean	spread (σ)
Avg. number of KalmanHit tracks (per event)	15.85 ± 0.01	0.24 ± 0.01
Spread of number of KalmanHit tracks	4.62 ± 0.01	0.13 ± 0.01
Avg. number of PandoraNu vertices (per event)	10.54 ± 0.01	0.21 ± 0.01
Spread of number of PandoraNu vertices	5.04 ± 0.01	0.17 ± 0.01
Avg. number of > 50 PE flashes (per event)	31.23 ± 0.03	0.78 ± 0.03

Table 1: Avergae and spread (RMS) values with errors obtained from Gaussian fits of selected quantities for on-beam data.

Variables & Algorithms	Off-beam data	
	mean	spread (σ)
Avg. number of KalmanHit tracks (per event)	15.81 ± 0.01	0.30 ± 0.01
Spread of number of KalmanHit tracks	4.61 ± 0.01	0.20 ± 0.01
Avg. number of PandoraNu vertices (per event)	10.46 ± 0.01	0.30 ± 0.01
Spread of number of PandoraNu vertices	5.01 ± 0.01	0.23 ± 0.01
Avg. number of > 50 PE flashes (per event)	31.30 ± 0.04	0.83 ± 0.03

Table 2: Average and spread (RMS) values with errors obtained from Gaussian fits of selected quantities for off-beam data..

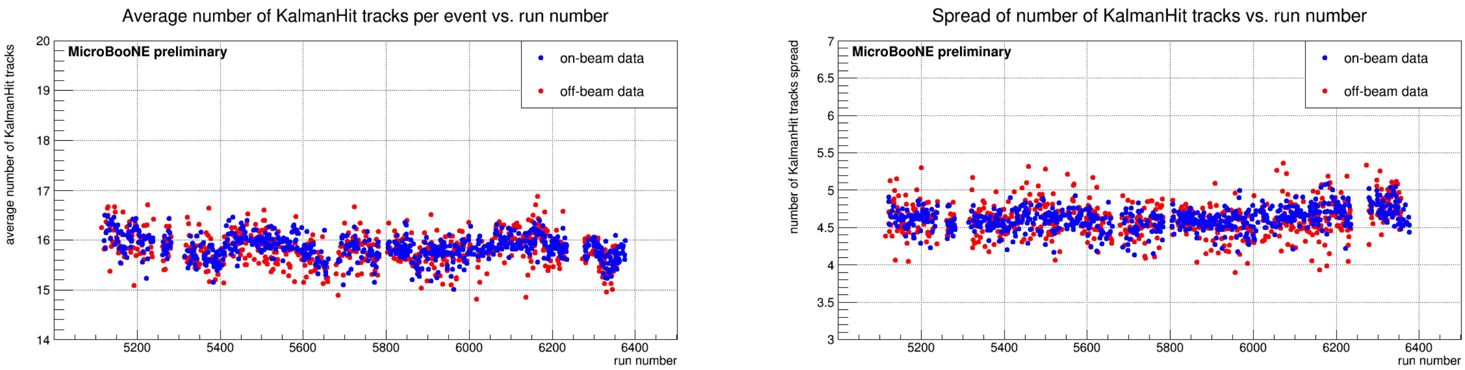

Figure 1: Average number of KalmanHit tracks per event vs. run number with selected stable runs (left) and spread of number of KalmanHit tracks vs. run number with selected stable runs (right).

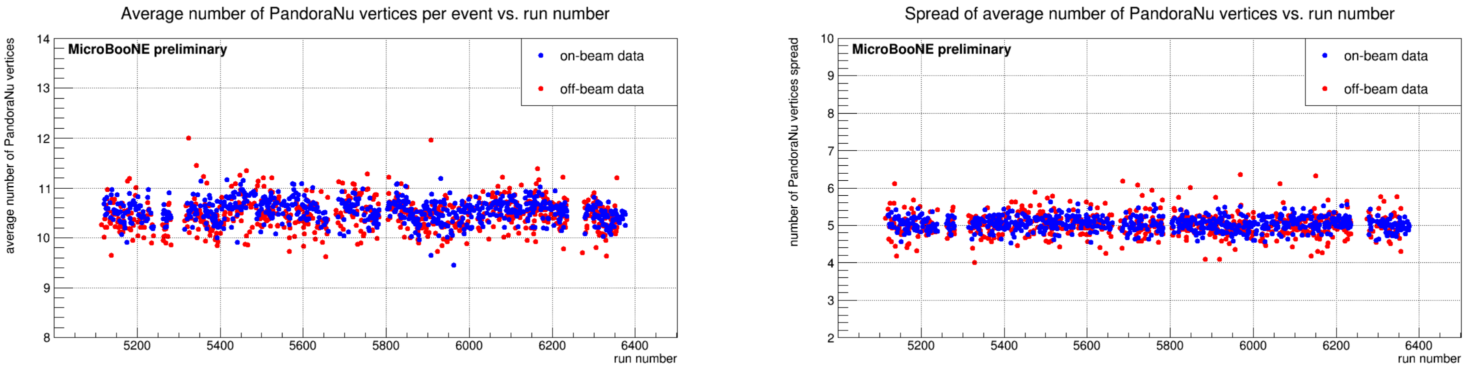

Figure 2: Average number of PandoraNu vertices per event vs. run number with selected stable runs (left) and spread of number of PandoraNu vertices vs. run number with selected stable runs (right).

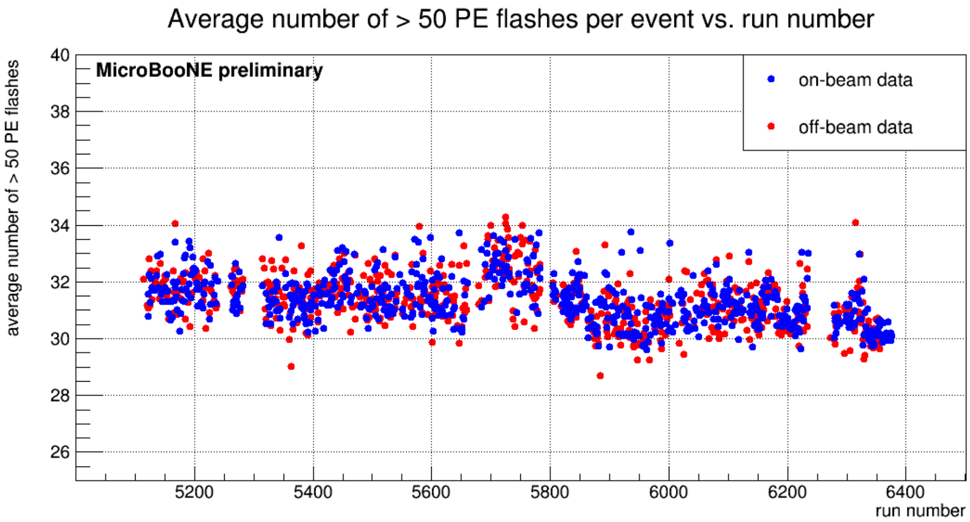

Figure 3: Average number of >50 PE flashes per event vs. run number with selected stable runs

References

[1] The MiniBooNE Collaboration. Unexplained Excess of Electron-Like Events From a 1-GeV Neutrino Beam. *arXiv:0812.2243, 2008.*

[2] The MicroBooNE Collaboration. Selection and kinematic properties of a first charged-current ν_μ inclusive event sample in MicroBooNE. *MicroBooNE Public*

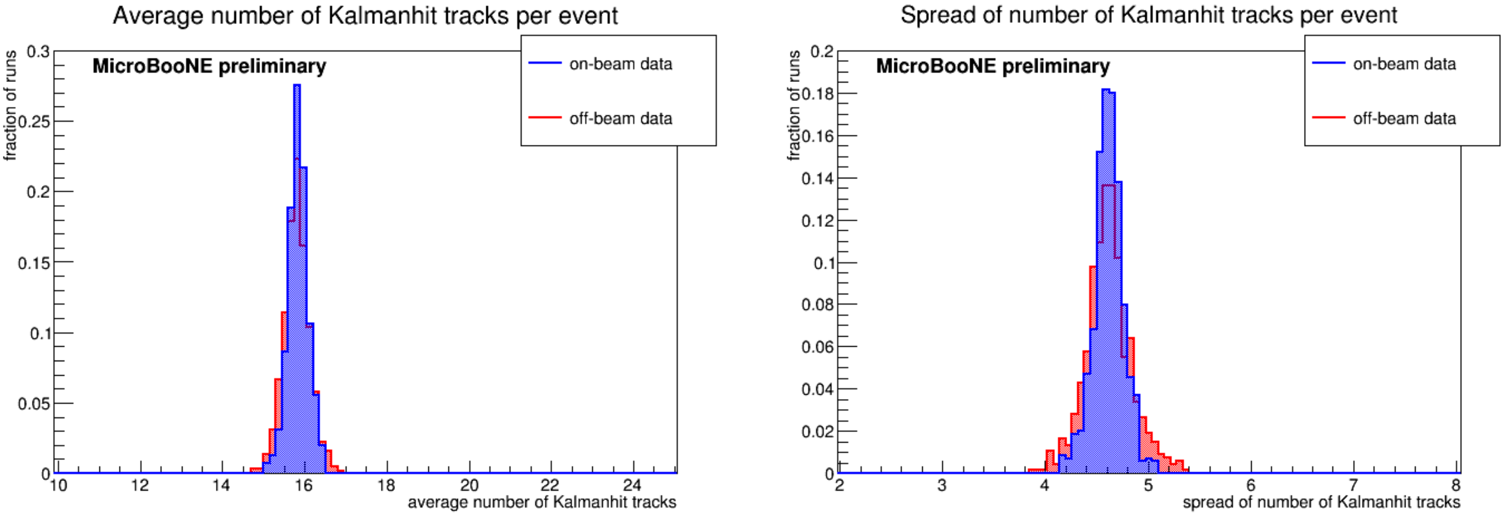

Figure 4: Average number of KalmanHit tracks per event with selected stable runs (left) and spread of number of KalmanHit tracks with selected stable runs (right).

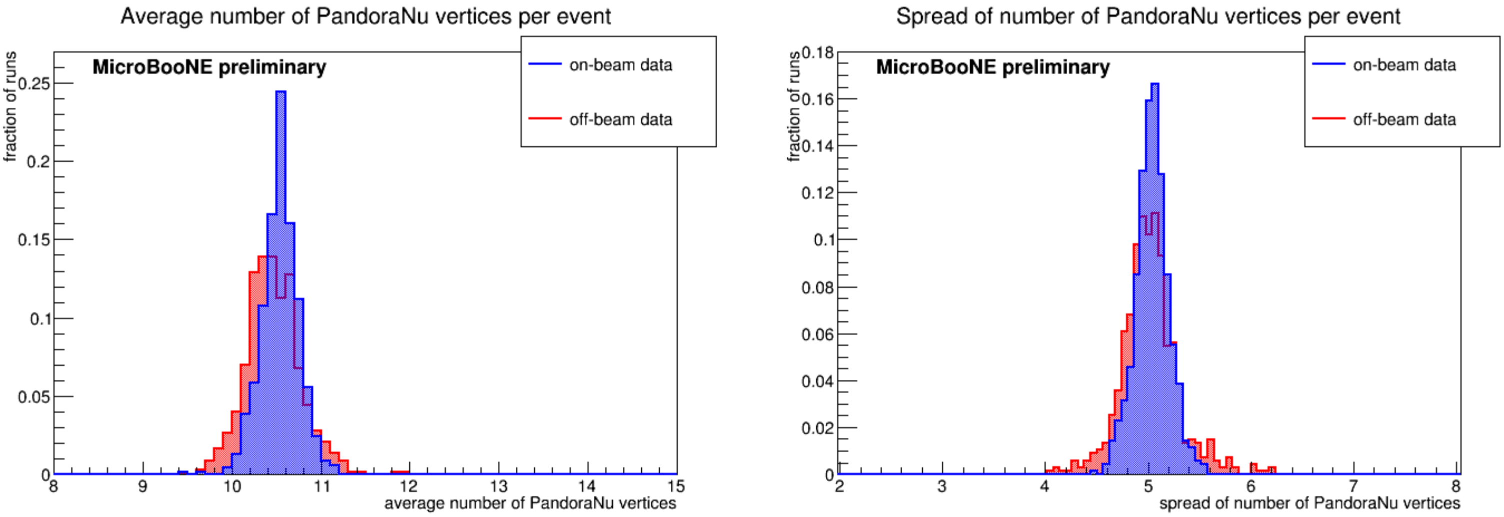

Figure 5: Average number of PandoraNu vertices per event with selected stable runs (left) and spread of number of PandoraNu vertices with selected stable runs (right).

Note, MICROBOONE-NOTE-1010-PUB, 2016. URL `http://www-microboone.fnal.gov/publications/publicnotes/`.

[3] The MicroBooNE Collaboration. First neutrino interactions observed with the MicroBooNE Liquid-Argon TPC detector. *MicroBooNE Public Note*, MICROBOONE-NOTE-1005-PUB,

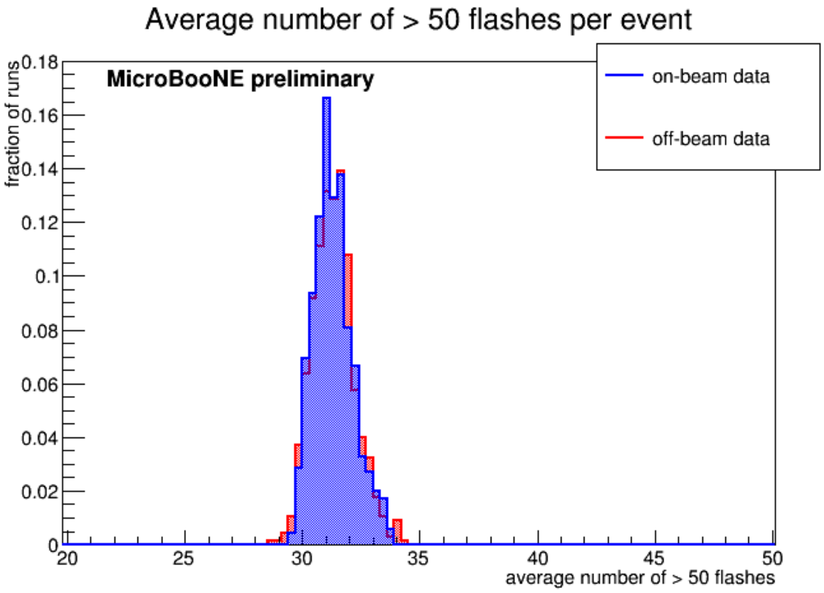

Figure 6: Average number of > 50 PE flashes per event with selected stable runs

2015. URL `http://www-microboone.fnal.gov/publications/publicnotes/`.

[4] The MicroBooNE Collaboration. The Pandora multi-algorithm approach to automated pattern recognition in LAr TPC detectors. *MicroBooNE Public Note*, MICROBOONE-NOTE-1015-PUB, 2016. URL `http://www-microboone.fnal.gov/publications/publicnotes/`.