A Request for Further MiniBooNE Antineutrino Running

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The MiniBooNE Collaboration

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1 Executive Summary

MiniBooNE recently updated its antineutrino oscillation analysis with 70% more data relative to [1], corresponding to a total of 5.66×10^{20} protons on target (POT). Fits to a two neutrino oscillation model above 475 MeV of reconstructed neutrino energy yield a 2.7σ result consistent with the LSND effect [2]. The precision of this result is limited by statistics, therefore tripling the data to a total of 15×10^{20} POT would improve the significance of the fit to 3.7σ if the current best fit signal continues to grow with increasing POT.

MiniBooNE is currently running, and has the capability for continued stable running for many more years. The collaboration is committed to running the experiment and analyzing the data in a timely manner. With extended running at current POT rates, and assuming no long shutdown in 2012, MiniBooNE can attain the 15×10^{20} POT run goal by the end of 2014. If proton rates to the Booster neutrino beamline (BNB) can be doubled, then the POT goal would be reached by the end of 2012. With more realistic assumptions and three months of beam priority, then MiniBooNE can reach its run goals by the end of 2013.

Confirming the antineutrino oscillation result with higher statistics in the short term will prompt new experiments to further study this effect and could be the first confirmed glimpse of physics beyond the Standard Model.

> *MiniBooNE requests additional antineutrino running to collect a total of* 15.0×10^{20} *POT in antineutrino mode. This will allow a powerful statistical check of the current MiniBooNE antineutrino oscillation result that is consistent with LSND. The experiment further requests that these POT be delivered in FY2011 and 2012 if possible.*

2 Introduction

The MiniBooNE experiment was designed to test the neutrino oscillation interpretation of the LSND signal in both neutrino and antineutrino modes. MiniBooNE has approximately the same L/E_ν as LSND but with an order of magnitude higher baseline and energy. Due to the higher energy and dissimilar event signature, the systematic errors affecting the MiniBooNE measurement are different from those in LSND. MiniBooNE's updated oscillation results in neutrino mode [3] show no significant excess of events at higher energies; however, a 3.0σ excess of events is observed at lower energies. Although the excess energy shape does not fit a simple two-neutrino oscillation hypothesis, the number of excess events agrees approximately with the LSND expectation. With the original antineutrino oscillation result with 3.4×10^{20} POT in antineutrino mode, MiniBooNE observes no significant excess at lower energies, while at higher energies the data are inconclusive with respect to antineutrino oscillations suggested by the LSND data [2]. However, the updated result with 5.66×10^{20} POT, discussed next, sheds new light on the LSND puzzle and motivates continued running.

3 Updated Antineutrino Oscillation Results

3.1 Oscillation Event Selection

MiniBooNE searches for $\nu_\mu \rightarrow \nu_e$ oscillations by measuring the rate of $\nu_e C \rightarrow e^- X$ CCQE events in a ν_μ-dominated beam and testing whether the measured rate is consistent with the estimated background rate. A detailed description of the experiment can be found elsewhere [4].

The detector (a mineral oil Cherenkov detector) cannot distinguish between neutrino and antineutrino interactions on an event-by-event basis. Therefore, the antineutrino event reconstruction, PID selection, and fitting are identical to that of the neutrino oscillation analysis [5]. However, the antineutrino mode flux has a sizable contamination of neutrinos, which was not the case in neutrino mode [6]. This contamination is accounted for in the prediction for antineutrino (as opposed to neutrino) oscillations. To help constrain the $\bar{\nu}_e$ (ν_e) candidate events, a $\bar{\nu}_\mu$ (ν_μ) sample is formed. A sample of 24,771 data events pass the $\bar{\nu}_\mu$ CCQE selection requirements. The neutrino content of the sample is 22%. The separation of ν_μ from $\bar{\nu}_\mu$ in this large CCQE sample is accomplished by fitting the observed angular distribution of the outgoing muons to a linear combination of the differing CCQE angular distributions for final state μ^- and μ^+, respectively. Relative to the Monte Carlo prediction, the μ^+ yield required an change of 1.20 to the rate of π^- decays in the Booster neutrino beamline (yielding $\bar{\nu}_\mu$), while the μ^- yield required a decrease of 0.99 relative to its predicted rate. Overall, the normalization required a 13% increase, which is compatible with the combined neutrino flux and cross section uncertainties [7].

3.2 Backgrounds and Systematic Uncertainties

Process	$200-475$ MeV	$475-1250$ MeV
ν_μ & $\bar{\nu}_\mu$ CCQE	4.3	2.0
NC π^0	41.6	12.6
NC $\Delta \to N\gamma$	12.4	3.4
External Events	6.2	2.6
Other ν_μ & $\bar{\nu}_\mu$	7.1	4.2
ν_e & $\bar{\nu}_e$ from $\mu^\pm$ Decay	13.5	31.4
ν_e & $\bar{\nu}_e$ from $K^\pm$ Decay	8.2	18.6
ν_e & $\bar{\nu}_e$ from K_L^0 Decay	5.1	21.2
Other ν_e & $\bar{\nu}_e$	1.3	2.1
Total Background	99.5	98.1
0.26% $\bar{\nu}_\mu \to \bar{\nu}_e$	9.1	29.1

Table 1: *The expected number of events for two different E_ν^{QE} ranges from all of the backgrounds in the $\bar{\nu}_e$ appearance analysis and for the LSND expectation (0.26% oscillation probability averaged over neutrino energy) of $\bar{\nu}_\mu \to \bar{\nu}_e$ oscillations, for 5.66×10^{20} POT.*

The number of predicted $\bar{\nu}_e$ CCQE background events for different ranges of reconstructed neutrino energy (E_ν^{QE}) is shown in Table 1. These estimates include both antineutrino and neutrino events, the latter representing 44% of the total background. The backgrounds in Table 1 are further constained by measurements at MiniBooNE of the rates of neutral current (NC) π^0 events [8], $\Delta \to N\gamma$ radiative decays, and external events from neutrino interactions outside the detector. Other backgrounds from mis-identified ν_μ or $\bar{\nu}_\mu$ [9, 10] and from intrinsic ν_e and $\bar{\nu}_e$ events from the $\pi \to \mu$ decay chain in the beam receive the $\bar{\nu}_\mu$ CCQE normalization correction according to their parentage at production (π^+ or π^-).

If the low-energy excess observed during neutrino-mode running [5] were scaled by the wrong-sign neutrino component of the predominantly anti-neutrino beam, the expected excess for antineutrino mode running would be 12 events in the region $200 < E_\nu^{QE} < 475$ MeV. These events are not included in Tables 1 and 2 and in Fig. 1 because the origin of these events is unexplained.

Systematic uncertainties are determined by considering the effects of the predicted $\bar{\nu}_\mu$ and $\bar{\nu}_e$ CCQE event rates from variations in the underlying parameters. These include uncertainties in neutrino/antineutrino flux and cross-sections, most of which are constrained by *in situ* rate measurements in MiniBooNE, and uncertainties in detector modeling and reconstruction. By considering the variation from each source of systematic uncertainty on the $\bar{\nu}_e$ CCQE signal, background, and $\bar{\nu}_\mu$ CCQE prediction as a function of E_ν^{QE}, a covariance matrix in bins of E_ν^{QE} is constructed. This matrix includes correlations between $\bar{\nu}_e$ CCQE (signal and background) and $\bar{\nu}_\mu$ CCQE and is used in the χ^2 calculation of the oscillation fit, effectively constraining allowed

variations in the $\bar{\nu}_e$ background and signal predictions.

E_ν^{QE} Range	Data	Background	Excess
$200 - 475$ MeV	119	$100.5 \pm 10.0 \pm 10.2$	18.5 ± 14.3
$475 - 675$ MeV	64	$38.3 \pm 6.2 \pm 3.7$	25.7 ± 7.2
$475 - 1250$ MeV	120	$99.1 \pm 10.0 \pm 9.8$	20.9 ± 14.0
$475 - 3000$ MeV	158	$133.3 \pm 11.5 \pm 13.8$	24.7 ± 18.0
$200 - 3000$ MeV	277	$233.8 \pm 15.3 \pm 16.5$	43.2 ± 22.5

Table 2: *The number of data, fitted (constrained) background, and corresponding excess events in the $\bar{\nu}_e$ appearance analysis for different E_ν^{QE} ranges. The uncertainties include both statistical and constrained systematic errors. All known systematic errors are included in the systematic error estimate.*

3.3 Reconstructed Energy Distributions

Fig. 1 (top) shows the E_ν^{QE} distribution for $\bar{\nu}_e$ CCQE observed data and background. A total of 277 events pass the $\bar{\nu}_e$ event selection requirements with $200 < E_\nu^{QE} < 3000$ MeV, compared to an expectation of $233.8 \pm 15.3 \pm 16.5$ events, where the uncertainty corresponds to statistical and systematic errors, respectively. This corresponds to an excess of 43.2 ± 22.5 events. In the previous neutrino run analysis, event totals were considered in two energy regions: 200 - 475 MeV and 475 - 3000 MeV, where the latter region was the energy range for the neutrino oscillation search. For the antineutrino data, the excess for $475 < E_\nu^{QE} < 3000$ MeV is 24.7 ± 18.0 events. The range with the highest sensitivity to two-neutrino oscillations is that of $475 < E_\nu^{QE} < 1250$ MeV. In that energy range, the observed $\bar{\nu}_e$ events, when the expected background is constrained by the $\bar{\nu}_\mu$ data events, have a $\chi^2/DF = 18.5/6$ and a probability of 0.5% for a background-only hypothesis, where DF is the effective number of degrees of freedom determined from frequentist studies.

The number of data, fitted background, and excess events for different E_ν^{QE} ranges are summarized in Table 2. The excess significance is 1.5σ in the oscillation region of $475 - 1250$ MeV, and 3.6σ in the narrower $475 - 675$ MeV region. The latter region is where the systematic errors are smallest, and where the flux and LSND oscillation probability are maximum. This "sweet spot" is important in the oscillation fits that will be discussed later.

3.4 Data Checks

Checks have been performed on the data to ensure that the backgrounds are estimated correctly. Beam and detector stability checks show that the neutrino event rate is stable to $< 2\%$ and that the detector energy response is stable to $< 1\%$. In addition, the fractions of neutrino and antineutrino events are stable over time, and

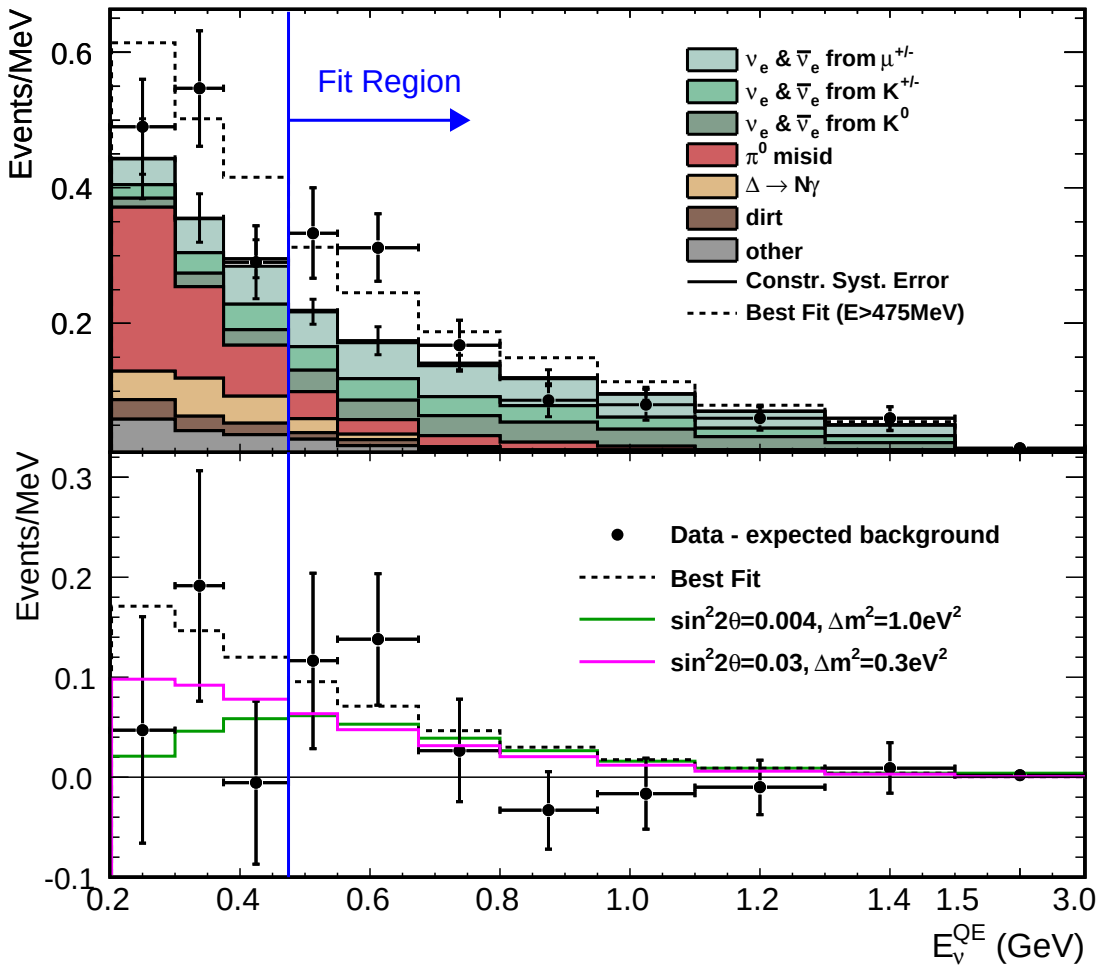

Figure 1: Top: The E_ν^{QE} distribution for $\bar{\nu}_e$ CCQE data (points with statistical errors) and background (histogram with constrained systematic errors). Bottom: The event excess as a function of E_ν^{QE}. Also shown are the expectations from the best oscillation fit with $E_\nu^{QE} > 475$ MeV, corresponding to $(\Delta m^2, \sin^2 2\theta) = (0.064\ \text{eV}^2, 0.96)$, where the fit is extrapolated below 475 MeV, and from two other oscillation parameter sets in the 1σ allowed region. No correction has been made accounting for the low-energy excess of events seen in neutrino mode below 475 MeV. All known systematic errors are included in the systematic error estimate.

the inferred external event rates are similar in both neutrino and antineutrino modes. Furthermore, any single background would have to be increased by more than 3σ to explain the observed excess of events. An additional check comes from the data in neutrino mode, which have a similar background to antineutrino mode and where good agreement is obtained between the data and Monte Carlo simulation for $E_\nu^{QE} > 475$ MeV. Recently SciBooNE has made a measurement of the K^+ background rates and has found a normalization difference in observed data relative to the MiniBooNE prediction of $0.75 \pm 0.05(stat) \pm 0.30(sys)$. This and the $\bar{\nu}_\mu$ rate measurement implies that about 2/3 of the ν_e and $\bar{\nu}_e$ intrinsic backgrounds are checked or constrained by measurements. As a final check, the event rate of candidate $\bar{\nu}_e$ events in the latest 2.27×10^{20} POT is found to be 1.9σ higher than the candidate event rate in the first 3.39×10^{20} POT [1]; however, the $\bar{\nu}_\mu$ event rates are found to be similar for the two running periods.

3.5 Oscillation Fits

Fig. 1 (bottom) shows the event excess as a function of E_ν^{QE}. Using a likelihood-ratio technique, the best MiniBooNE oscillation fit for $475 < E_\nu^{QE} < 3000$ MeV occurs at $(\Delta m^2, \sin^2 2\theta) = (0.064\ \text{eV}^2, 0.96)$. The $E_\nu^{QE} > 475$ MeV energy range avoids the region of the unexplained low-energy excess in neutrino mode [3]. The χ^2 for the best-fit point in the energy range of $475 < E_\nu^{QE} < 1250$ MeV is 8.0 for 4 DF, corresponding to a χ^2-probability of 8.7%. The probability of the ratio of the likelihood of the background-only fit to the likelihood of the best oscillation fit is 0.6%, or 2.7σ. Fig. 2 shows the MiniBooNE 68%, 90%, and 99% C.L. closed contours for $\bar{\nu}_\mu \to \bar{\nu}_e$ oscillations in the $475 < E_\nu^{QE} < 3000$ MeV energy range, where frequentist studies were performed to determine the shown C.L. regions. The allowed regions are in agreement with the LSND allowed region.

As shown in Fig. 2, the best fit point is ruled out by the BUGEY and KARMEN limit. However, this is not significant as the best fit point χ^2 minimum is very shallow, i.e. this best-fit point has only a slightly lower χ^2 than other points in the allowed band. This is demonstrated by the 68% CL which extends throughout a large portion of the LSND allowed region outside of the BUGEY and KARMEN limits.

The MiniBooNE closed contours for $\bar{\nu}_\mu \to \bar{\nu}_e$ oscillations in the $200 < E_\nu^{QE} < 3000$ MeV energy range are similar, as shown in Fig. 3. The solid (dashed) curves are without (with) the subtraction of 12 events from the observed excess in the $200 < E_\nu^{QE} < 475$ MeV region which would be expected assuming the low-energy excess scales with the neutrino component of the beam in either running mode. The best oscillation fits without and with this subtraction occur at $(\Delta m^2, \sin^2 2\theta) = (4.42\ \text{eV}^2, 0.0066)$ and $(4.42\ \text{eV}^2, 0.0061)$, respectively, while the corresponding χ^2-probabilities in the $200 < E_\nu^{QE} < 1250$ MeV energy range are 10.9% and 7.5%.

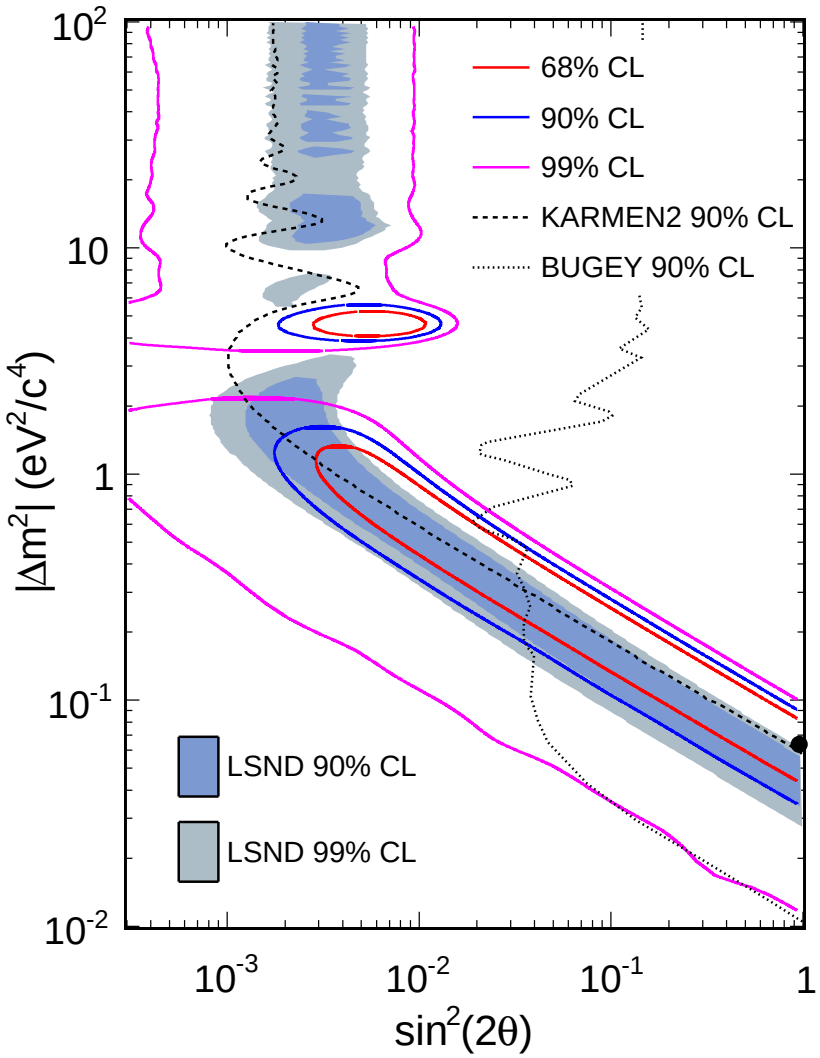

Figure 2: MiniBooNE 68%, 90%, and 99% C.L. allowed regions for events with $E_\nu^{QE} >$ 475 MeV within a two neutrino $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ oscillation model. Also shown are limits from KARMEN [11] and Bugey [12]. The Bugey curve is a 1-sided limit for $\sin^2 2\theta$ corresponding to $\Delta\chi^2 = 1.64$, while the KARMEN curve is a "unified approach" 2D contour. The shaded areas show the 90% and 99% C.L. LSND allowed regions. The black dot shows the best fit point.

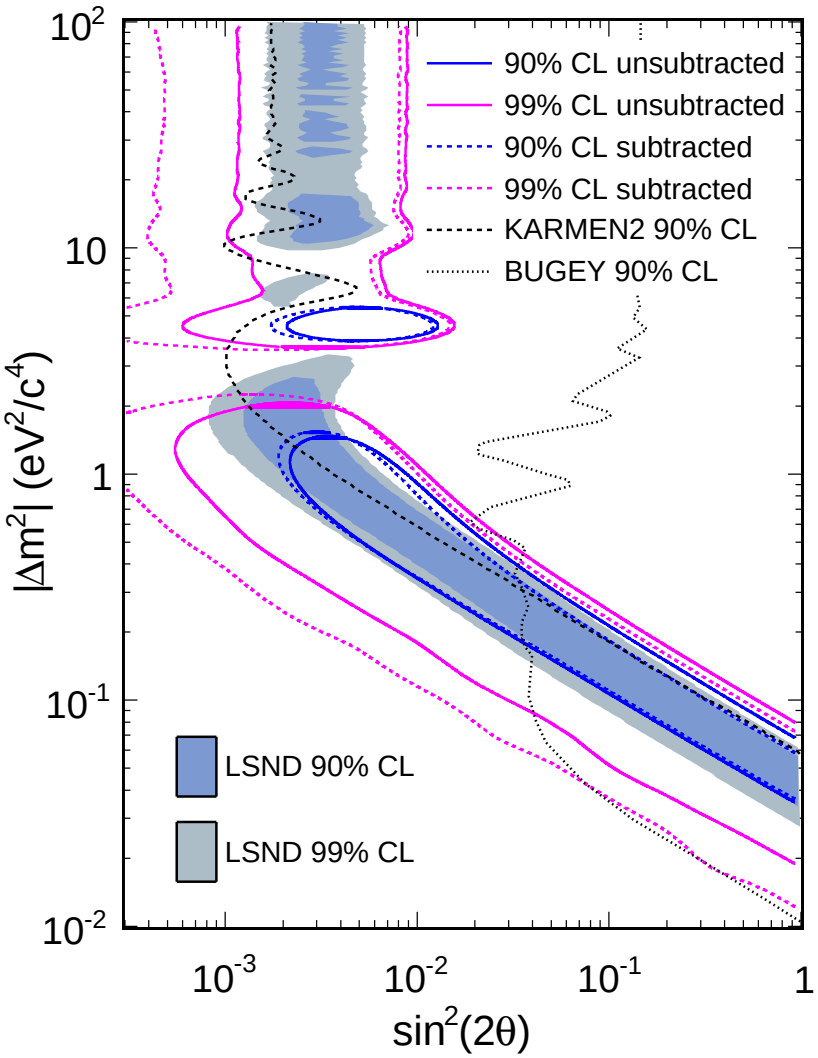

Figure 3: MiniBooNE 90% and 99% C.L. allowed regions for events with $E_\nu^{QE} > 200$ MeV within a two neutrino $\bar{\nu}_\mu \to \bar{\nu}_e$ oscillation model. The solid (dashed) curves are without (with) the subtraction of the expected 12 event excess in the $200 < E_\nu^{QE} < 475$ MeV low-energy region from the neutrino component of the beam. Also shown are limits from KARMEN [11] and Bugey [12]. The shaded areas show the 90% and 99% C.L. LSND allowed regions.

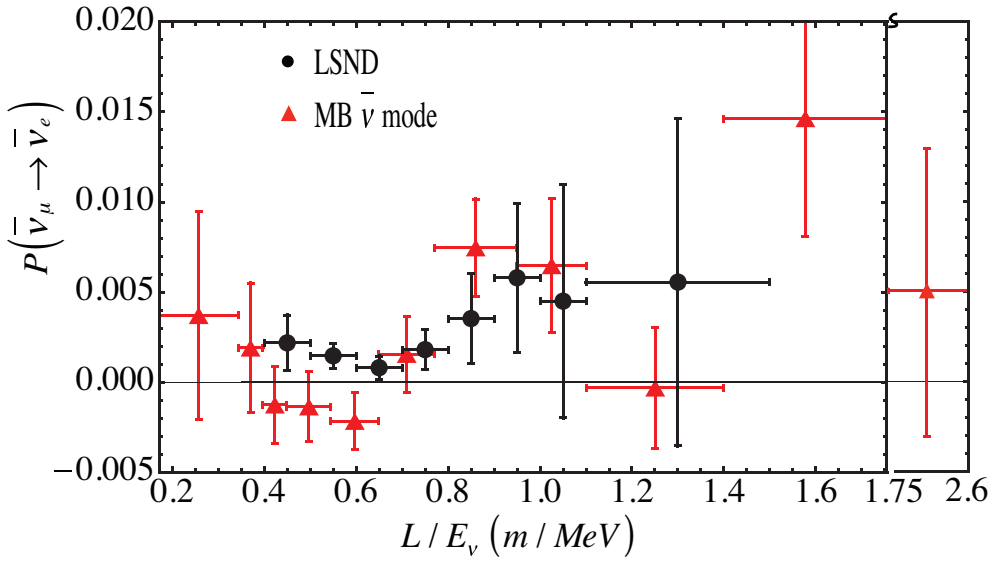

Figure 4: The oscillation probability as a function of L/E_ν^{QE} for $\bar{\nu}_\mu \to \bar{\nu}_e$ candidate events from MiniBooNE and LSND. The data points include both statistical and systematic errors. The MiniBooNE oscillation fit region corresponds to $L/E < 1.1$.

3.6 Comparison to the LSND Data

A further comparison, without fits, between the MiniBooNE and LSND antineutrino data sets is given in Fig. 4. This shows the oscillation probability as a function of L/E_ν for $\bar{\nu}_\mu \to \bar{\nu}_e$ candidate events in the L/E_ν range where MiniBooNE and LSND overlap. The data used for LSND and MiniBooNE correspond to $20 < E_\nu < 60$ MeV and $200 < E_\nu^{QE} < 3000$ MeV, respectively. The oscillation probability is defined as the event excess divided by the number of events expected for 100% $\bar{\nu}_\mu \to \bar{\nu}_e$ transmutation, while L is the reconstructed distance traveled by the antineutrino from the mean neutrino production point to the interaction vertex and E_ν is the reconstructed antineutrino energy. The L/E_ν distributions for the two data sets are consistent.

3.7 Antineutrino Oscillation Summary

In summary, the MiniBooNE experiment observes an excess of $\bar{\nu}_e$ events in the energy region above E_ν^{QE} of 475 MeV for a data sample corresponding to 5.66×10^{20} POT. A model-independent hypothesis test gives a probability of 0.5% for the data to be consistent with the expected backgrounds in the energy range of $475 < E_\nu^{QE} < 1250$

MeV, and a likelihood ratio prefers an LSND-like signal at 99.4% CL (2.7σ) relative to the background only hypothesis

The allowed regions from the fit, shown in Fig. 2, are consistent with $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ oscillations in the 0.1 to 1 eV^2 Δm^2 range and consistent with the allowed region reported by the LSND experiment [2].

4 Oscillation Signal Significance with More Antineutrino Data

The fitted oscillation signal significance is currently dominated by statistical errors. An increase in data could have a dramatic effect on the significance as shown in Figure 5. For example, if the best fit signal continues to increase with POT, then the blue circles show how the significance of the two-neutrino fit will increase. The improvement is noticeable up to 15×10^{20} POT, after which, the systematic errors start to dominate and the significance plateaus. At 15×10^{20} POT, the significance is 3.7σ. On the other hand, if the current excess is simply a statistical fluctuation from the expected backgrounds, then the blue triangles show how its significance would drop to below 95% for 15×10^{20} POT. More data would also better determine the best fit point and reduce the area of the allowed regions.

For the various energy ranges in Table 2, the statistical and systematic errors are approximately equal, so that a reduction in the statistical errors will have an effect on oscillation fits. Specifically, in the "sweet spot" energy range $475 - 675$ MeV, the statistical errors are over twice the systematic errors. Hence, a reduction of statistical errors will have the biggest effect on the most sensitive part of the oscillation region.

Clearly, more data up to 15×10^{20} POT can have a dramatic impact on the signal significance.

5 How to Achieve POT Goals

Various POT projection scenarios are shown in Figures 6, 7 and 8. Three POT rate curves are shown in Figure 6 that correspond to a range of rates that have historically been achieved. Also shown is the actual integrated rate. The integrated POT curves all start at 5×10^{20} POT, which was the POT collected up to the 2009 summer shutdown. At the beginning of the run, MiniBooNE was receiving about 2×10^{16} p/hr, but after some recent Booster improvements, MiniBooNE has been running closer to 2.5×10^{16} p/hr. Assuming we can hold this rate, and projecting to the long shutdown in the spring of 2012, we will only achieve about 9.5×10^{20} POT, which is short of our goal of 15×10^{20} POT.

Assuming that the Tevatron run is extended another three years, and there is no long shutdown in 2012, then running through to the end of 2014 would achieve our

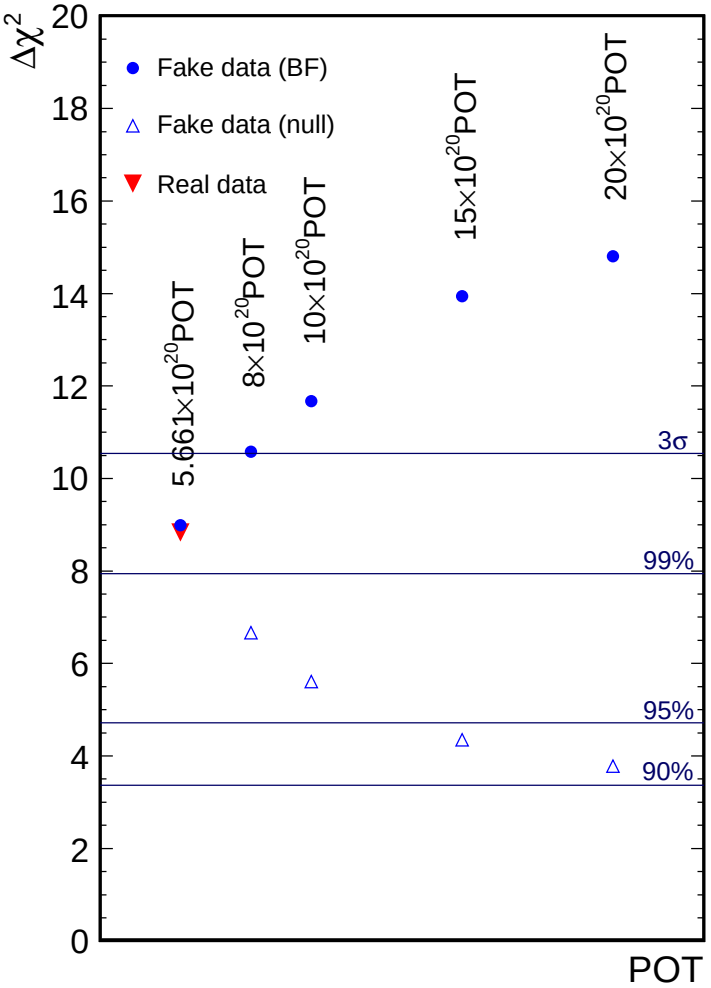

Figure 5: Signal significance as a function of POT. The blue circles show the two neutrino fit significance assuming the best fit signal continues to grow at current rates. The open triangles show the two neutrino fit significance assuming the excess stops growing (null signal).

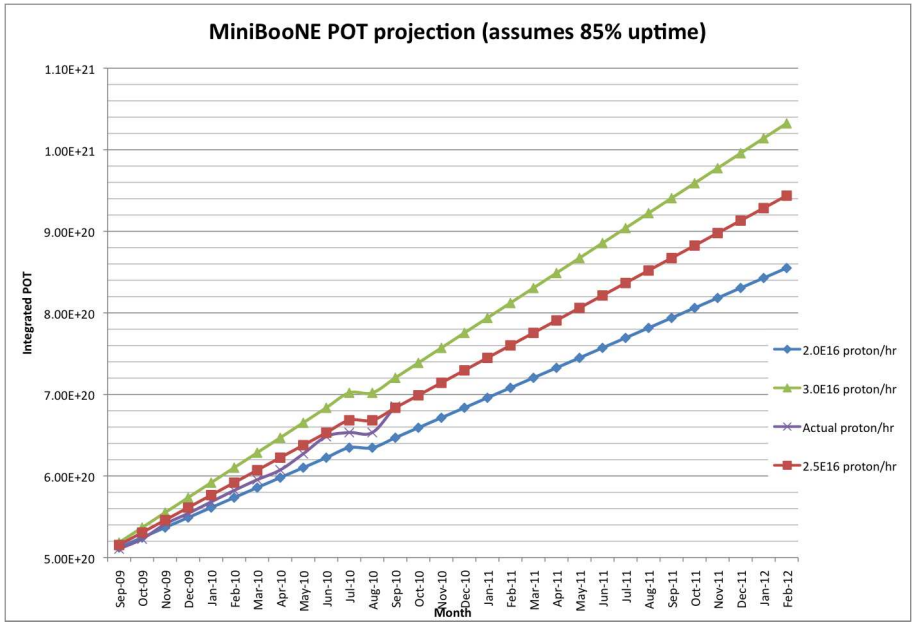

Figure 6: POT projection to the start of the long shutdown in spring 2012. Shown are various possible proton/hour rates, as well as the actual data rate (purple line). The y-axis starts at 5×10^{20} POT, which is what was collected at the start of the current antineutrino run. In antineutrino mode we have collected a total of 6.85×10^{20} POT (purple line).

POT goals at current rates. This is shown in Figure 7, where the end date of the run is extended out to the end of 2014.

Given future Booster improvements and/or proton plan rearrangements, a third possibility is increasing MiniBooNE POT rates as shown in Figure 8. If we could double our POT rates to 5×10^{16} p/hr by the end of this year, and there is no long shutdown, then our POT goal of 15×10^{20} POT would be reached by the end of 2012, that is in just a two year run. This is the quickest way of accumulating a significant amount of data that would test the statistical robustness of the current antineutrino oscillation signal.

The POT projections shown so far are simplifications of the two possible run extremes, i.e. running at current rates or a doubling of rates. A more detailed and realistic calculation of POT rates and projections are shown in Table 3. The assumptions that went into making Table 3 are:

- The current NuMI downtime to repair horn will end on 7 Nov 2010.
- Starting in Jan 2012 the revised Booster assessment and corrector system will allow a 10% increase in the turns delivered to MiniBooNE.
- Between now and March 2012 there will be one standard 8 week shutdown.

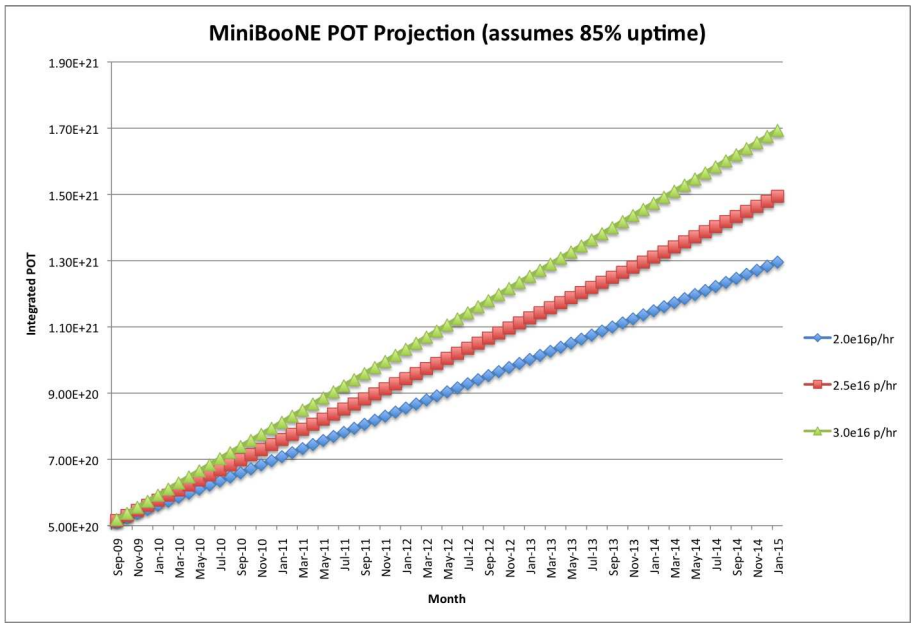

Figure 7: POT projection to early 2015 and no long shutdown in 2012. Shown are various possible proton/hour rates. The y-axis starts at 5×10^{20} POT, which is what was collected at the start of the current antineutrino run.

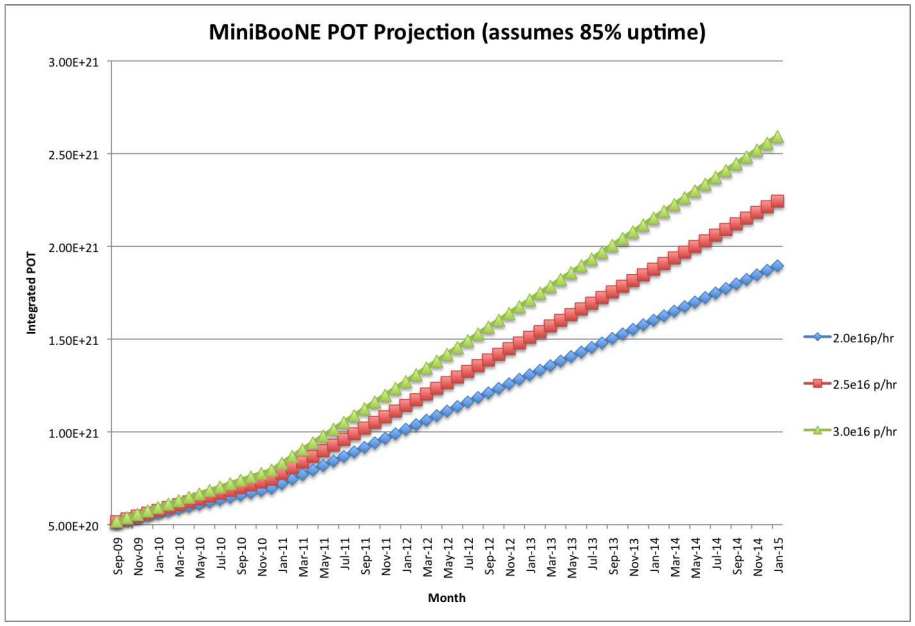

Figure 8: POT projection to early 2015 and no long shutdown in 2012. Shown are various proton/hour rates which are doubled starting January 2011. The y-axis starts at 5×10^{20} POT, which is what was collected at the start of the current antineutrino run.

POT Collection Period	N Weeks	Rate [10^{19} POT/wk]	POT$\times 10^{20}$
Published through 3/14/10			5.7
Nominal running 3/15/10-9/19/10	27	0.4	1.1
NuMI down 9/19/10-11/7/10	7	1.0	0.7
Nominal running 11/8/10-3/1/12	59	0.4	2.4
+10% Shielding Assess. 1/1/11-3/1/12	52	0.04	0.2
Total Through March 2012			**10.1**
Running 3/1/12-10/1/13 (Run IIe/No Run IIe)	72/36	0.44	3.2/1.6
Total Through Oct 2013			**13.3/11.7**
Other possibilities:			
3 Month dedicated run (no NuMI)	12	1.0	1.2
Adding 1 Hz·year to Booster	44		1.1

Table 3: Projections for beam delivery to MiniBooNE in the upcoming years. The period from March 2012-Oct 2013 has been projected with/without an extension of Tevatron Run II.

- Beyond March 2012, an anti-neutrino beam will be delivered until the MicroBooNE experiment is ready to take physics data in Oct 2013 (current projections).
- From March 2012 through Oct 2013 there will be one 12 week shutdown if Run II is extended.
- If there is no Run II extension, then the currently planned 11 month shutdown will commence in March 2012.
- A three month dedicated run to MiniBooNE might be possible under certain circumstances, i.e. program planning, a problem with the NuMI beam delivery, or a window in the 11 month shutdown where the Booster can still be operated.
- In order to run MicroBooNE and NOvA in Oct 2013 an increase in the Booster rep rate from 7.5 Hz to 12 Hz is required (minimally). If the rep rate can be increased somewhat earlier than even 1 extra Hz increases the beam to MiniBooNE by 40%.

In the scenario where the Tevatron continues running, and MiniBooNE runs to Oct 2013, then a total of 13.3×10^{20} POT can be collected. By adding an extra three months of running with NuMI off, then we reach 14.5×10^{20} POT by the end of 2013. This is close to our run goals, and requires only a three year extension of our run.

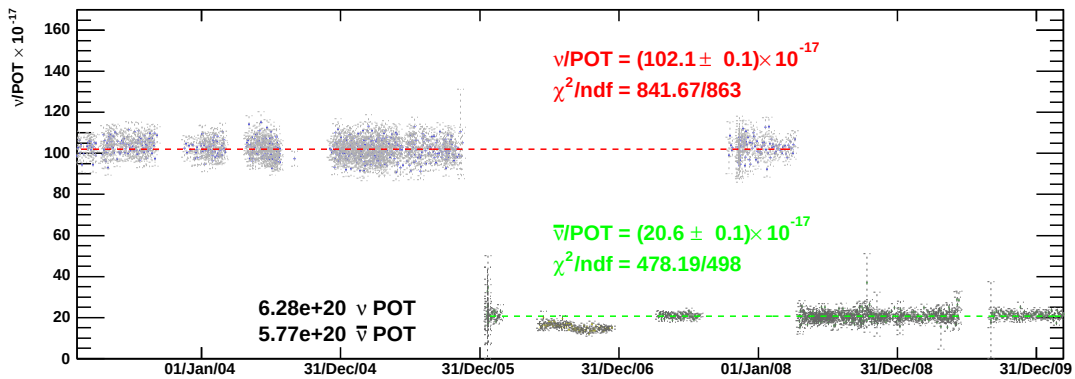

Figure 9: The neutrino per POT for the entire MiniBooNE run. The antineutrino/POT rate is down by a factor of five due to the reduced flux and cross sections. The antineutrino χ^2/DF does not include the period of fallen absorbers (May 06 to October 06), but that data is included in the oscillation analysis.

6 Logistics of the Extended Run

MiniBooNE has been running well over the last eight years. Figure 9 shows the neutrino/POT for most of the run period. As can be seen, the overall beam stability is very good. Besides changing out the Horn in 2004 and the period of the fallen absorber in early 2006, running has been very smooth. Figure 10 shows the Michel energy over the duration of MiniBooNE run, which demonstrates the detector response and energy scale stability. This is critical for good reconstruction and particle identification, and again shows overall excellent performance and stability of the oil, PMT's, and electronics. The overall stability of the experiment is crucial for continued running. This has been achieved in the past, and should continue into the future. The above distributions are just some of the monitoring inputs that are reviewed on a regular basis.

The success of the run requires a large number of personnel to staff shifts on a continual basis. A two year projection (2011 and 2012) of personnel available for running shifts, based on replies of collaboration members, is shown in Table 4. With a MIT/LANL hire of a full time owl shifter, and the number of remaining collaborators, there are sufficient personnel available to staff shifts and experts on-site to handle run problems. As well, remote shifting was enabled two years ago that allows shifters to take shifts from remote institutions. This has been instrumental in allowing off-site personnel to continue shift duties and participation in the experiment.

The collaboration is open to allowing new institutions to join. With a commitment to more running, this would become an easier task to undertake.

With the analysis in place from both the ν_e and the $\bar{\nu}_e$ appearance results, the addition of the extra data is straight forward. There are sufficient computer resources and man power to perform the analysis successfully. With the recent addition of three

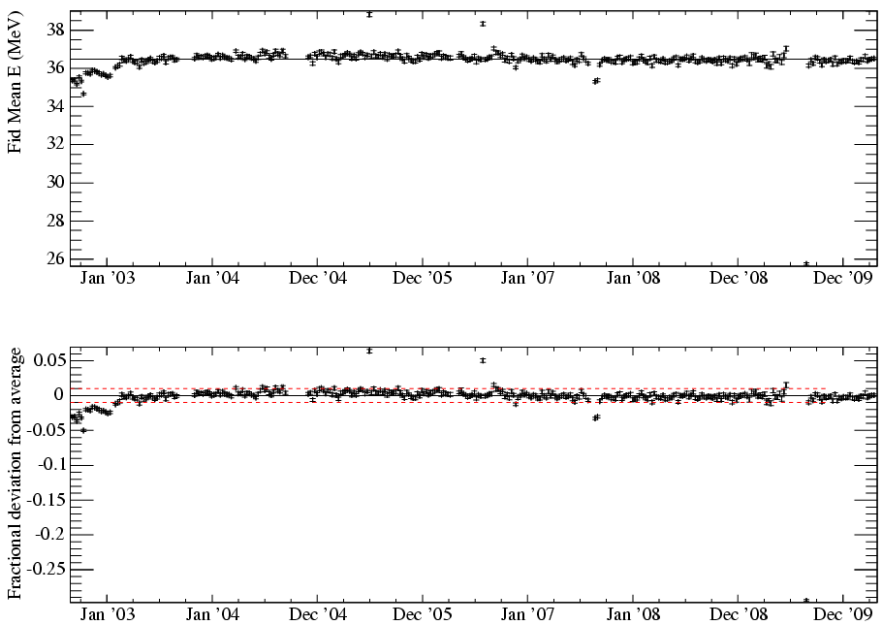

Figure 10: Detector Energy scale calibrated with Michel electrons over the duration of the run. The top plot shows the Michel mean energy (MeV), and the bottom the percent deviation. The red lines show $\pm 1\%$ deviation lines. There are no corrections except for the PMT calibrations, which are done every four days. The energy scale deviation at the beginning is during commissioning, and is data that is not used for analysis.

Year	Number of Collaborators	New postdocs and students	Hired Full Tme Shifter
2007	54	0	0
2008	54	1	0
2009	54	1	1
2010	42	2	1
2011	40	Unkown	1
2012	40	Unkown	1

Table 4: *Projected MiniBooNE shift personnel. 2011 and 2012 is projected based on collaborators willingness to continue on MiniBooNE. We began remote shifting in 2009, which has been instrumental in reducing the constant shift burden. The FTE equivalent is about 50% and the full time shifter staffs 25% of all shifts.*

new students and a postdoc, a fresh look at the analysis is ongoing with optimizing of cuts, new algorithms, and tuning of simulations. As well, work is continuing on the combined SciBooNE/MiniBooNE neutrino and antineutrino disappearance analysis and the neutrino and antineutrino appearance ratio analysis. This last analysis could especially benefit from more antineutrino data, since many systematic errors cancel and statistical errors become even more important.

The data we are taking will be reprocessed and analyzed on a roughly six month time scale. This allows detailed checks of the data and the monitoring of the signal.

The beamline, horn system, and detector have been operating well for the duration of the experiment since 2002. One horn replacement has been needed, and a repair of the 25 m absorber, but no major detector repairs or downtimes have occurred. A third horn and target are ready, as are spare accelerator parts, and spare detector electronics sufficient to run the experiment for many more years.

7 The Request

MiniBooNE requests additional antineutrino running to collect a total of 15.0×10^{20} *POT in antineutrino mode. This will allow a powerful statistical check of the current MiniBooNE antineutrino oscillation result that is consistent with LSND. The experiment further requests that these POT be delivered in FY2011 and 2012 if possible.*

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