Electron-like Background in MicroBooNE

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The GENIE Monte Carlo Events

- GENIE events were generated in LArSoft using BNB flux at 470m, for 10.3 x 10^{20} POT in μboone active volume (86.7 metric tons)
  - All tables are normalized to 60 ton fiducial volume, 6.6 x 10^{20} POT (expected POT for MicroBooNE)
  - Total Number of GENIE MC Events (scaled): 181,885
- All of these studies are done with Monte Carlo events, using true particle information

Looking at electron-like background

- For the electron-like background we are interested in the following:
  1. Events with a single e (and no μ) in the final state
  2. Events with a single γ (and no e or μ) in the final state
- Will compare to background estimates from other studies, including scaling of MiniBooNE data

Final states & additional backgrounds

1. Primary Particles (primary)
   - Consider final state particles to be those that exit the Argon nucleus after a neutrino interaction (designated “primary” particles in GENIE)
   - In all tables, rates for these events are listed the column labeled “Event Rate (Primary)”
2. Additional Background (other)
   - Some events that don’t fall into the 1 μ, 1 e, 1γ, or 2 γ final state samples have signatures that *resemble* one of these final states after the “primary” particles have propagated through the LArTPC
   - Such events could potentially be misidentified and placed in one of these samples
   - In all tables, rates for these events are listed in the column labeled "Event Rate (other)”

Event rates for 1 e final states (no energy cuts)

Experimental Signature	Event Rate (Primary)	Event Rate (Other)
1 e + 0 p + 0 π	29	678
1 e + 1 p + 0 π	276	1,346
1 e + ≥2 p + 0 π	198	142
1 e + 0 p + 1 π	56	1
1 e + 1 p + 1 π	144	3
1 e + ≥2 p + 1 π	110	10
1 e + 0 p + ≥2 π	11	1
1 e + 1 p + ≥2 π	35	1
other	38	4
Total 1 e events	897	2,186

- Events with 1 electron and 0 muons in the final state
- Normalized to 6.6 x 10^{20} POT and scaled to 60t fiducial volume
- Again, may include any number of neutrons or de-excitation photons

Slightly higher than found in docdb #1765

Event rates for 1 e final states (with and without 50MeV cut on proton KE)

Experimental Signature	Event Rate (Primary)		Event Rate (Additional)	
	No E Cut	With E Cut	No E Cut	With E Cut
1 e + 0 p + 0 π	29	189	678	1,492
1 e + 1 p + 0 π	276	233	1,346	608
1 e + ≥2 p + 0 π	198	81	142	66
1 e + 0 p + 1 π	56	106	1	3
1 e + 1 p + 1 π	144	156	3	5
1 e + ≥2 p + 1 π	110	48	10	6
1 e + 0 p + ≥2 π	11	23	1	2
1 e + 1 p + ≥2 π	35	42	1	1
other	38	19	4	3
Total 1 e events	897	897	2,186	2,186

Comparison to Doc db #1765

My study	
1 e + 0 or 1 p + 0 π	305
1 e + 0 or 1 or 2p + 0 π	370
1 e + any # of p + 0 π	503
Total 1 e evts	897
1 μ + 0 or 1 p + 0 π	52,838
1 μ + 0 or 1 or 2p + 0 π	64,501
1 μ + any # of p + 0 π	84,750
Total 1 μ evts	131,118
Total MC events	181,885

Doc db 1765 (old event generation)	
$\nu_e/\bar{\nu}_e$ CCQE	385
"	385
"	385
Total CC $\nu_e/\bar{\nu}_e$ evts	813
$\nu_\mu/\bar{\nu}_\mu$ CCQE	68,441
"	68,441
"	68,441
Total CC $\nu_\mu/\bar{\nu}_\mu$ evts	121,862
Total MC events	169,124

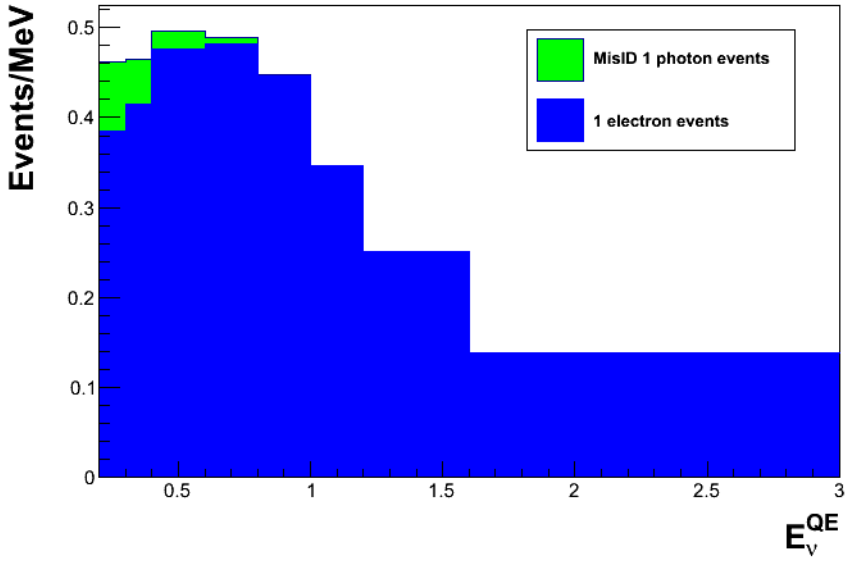
- All event rates are scaled to 6.6 x 10^{20} POT and 60t fiducial vol
- my study was generated for a total of 10.3 x 10^{20} POT
- doc db 1765 was generated for a total of 6.0 x 10^{20} POT

1 photon & 2 photon samples

Experimental Signature	Event Rate (Primary)	Event Rate (Other)
Total # of photon events (0μ, 0e, >0γ)	14,501	10,305
1 γ sample before vertex cuts	152	1,237
1 γ sample after vertex cuts	954	1,134
2 γ sample before vertex cuts	13,677	2,886
2 γ sample after vertex cuts	7,867	1,780

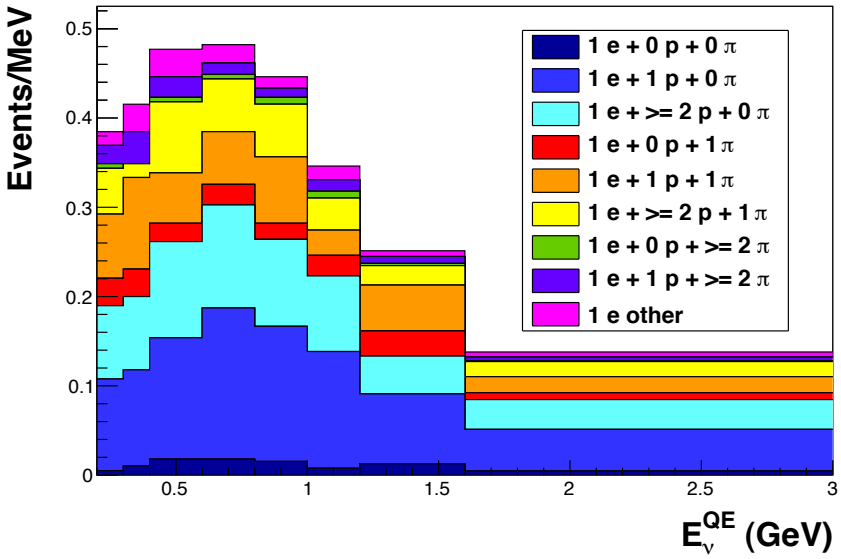
- Vertex cuts on 2 γ sample
  - 1 photons convert to e^+e^- in the fid. volume
  - No other photons convert in the active volume
- Vertex cuts on 1 γ sample
  - 1 photon converts to e^+e^- in the fid. volume
  - No other photon converts in the active volume

What we saw last week …



🡸 Last week's histogram: all 1 electron events (blue)

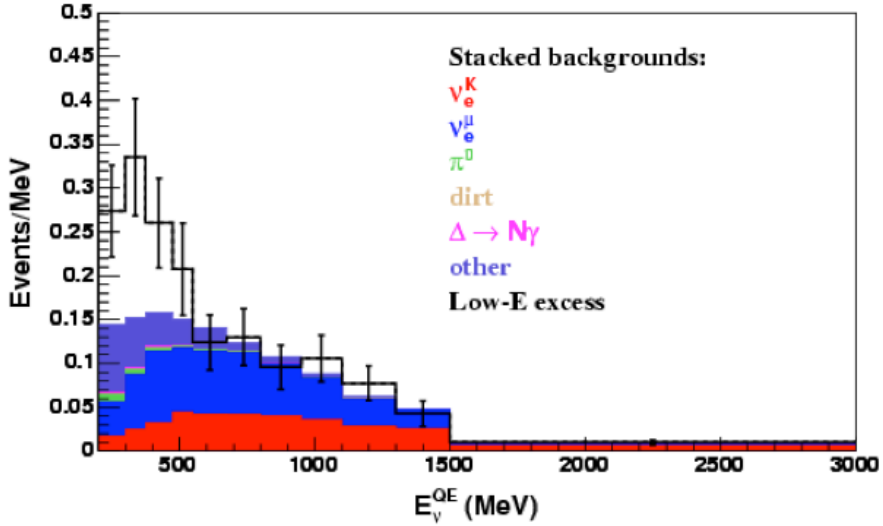
- primary samples only
- scaled to 6.6 x 10^{20} POT, 60t fiducial volume, and 80% efficiency
- way too many events!?!



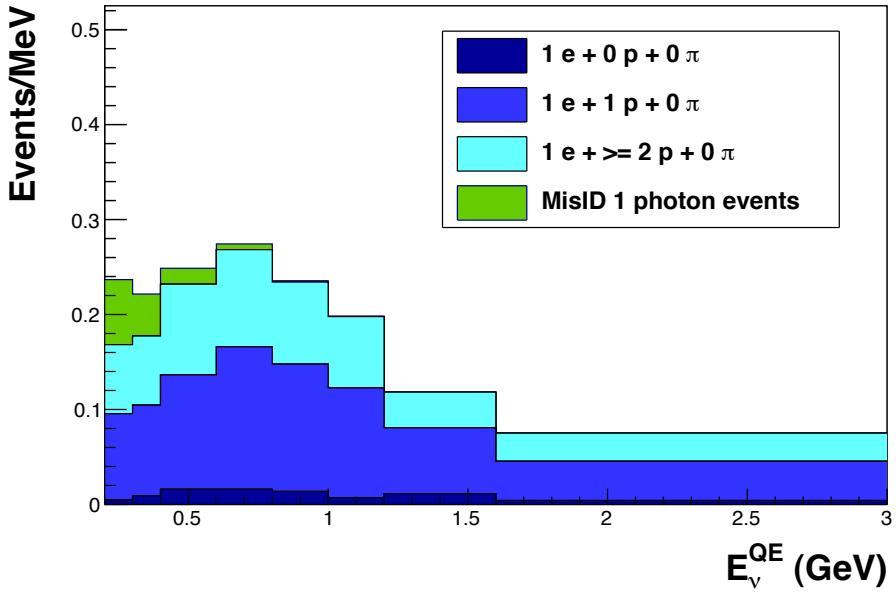
🡸 Same histogram (blue above) divided up by final state

- primary samples only
- includes same scaling for POT, volume, and efficiency

MicroBooNE Backgrounds:



← Background predictions made using MiniBooNE event rates. Scaled to 6.6 x 10^{20} POT, 70t fiducial volume, and 2 x MiniBooNE's assumed efficiency (2 x 40% = 80%)

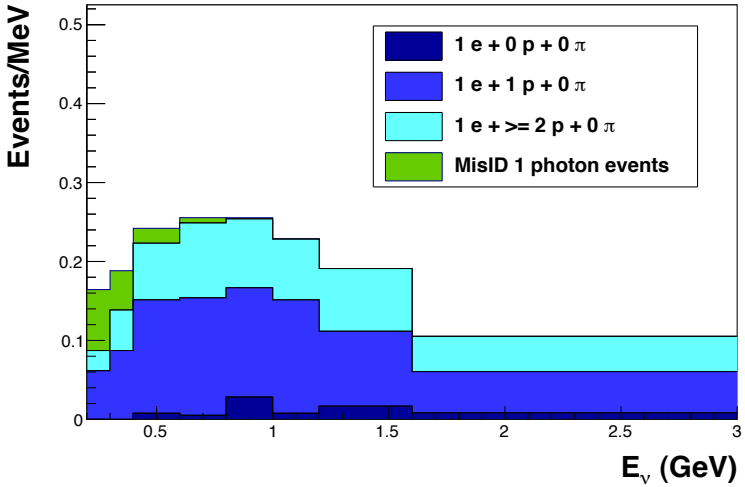


← E_ν^{QE} for ***CCQE-like events only*** (final states with 1 e, 0 π) and 6% of 1 photon events (mis-ID). Scaled to 6.6 x 10^{20} POT, 70t fiducial volume, and 80% efficiency. Also scaled by ($470^2/540^2$) to reflect the difference in flux.

Note: these studies use different ν xsec (on Carbon vs. Argon)

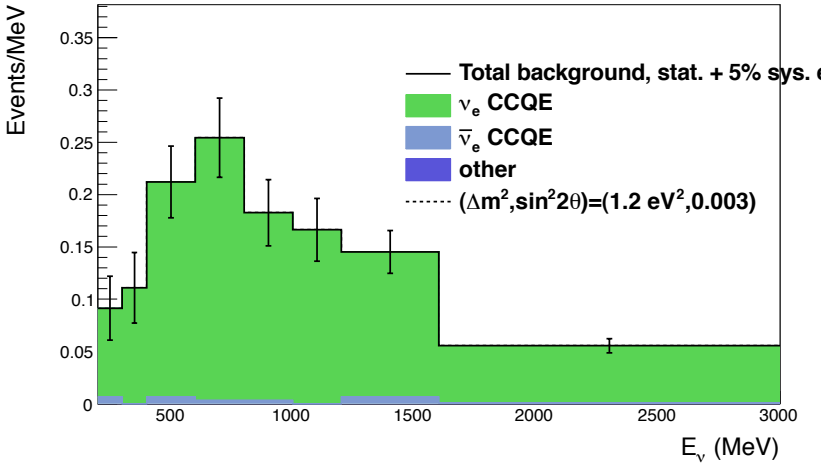
Background Predictions

True ν Energy (1 e + 0 π events)



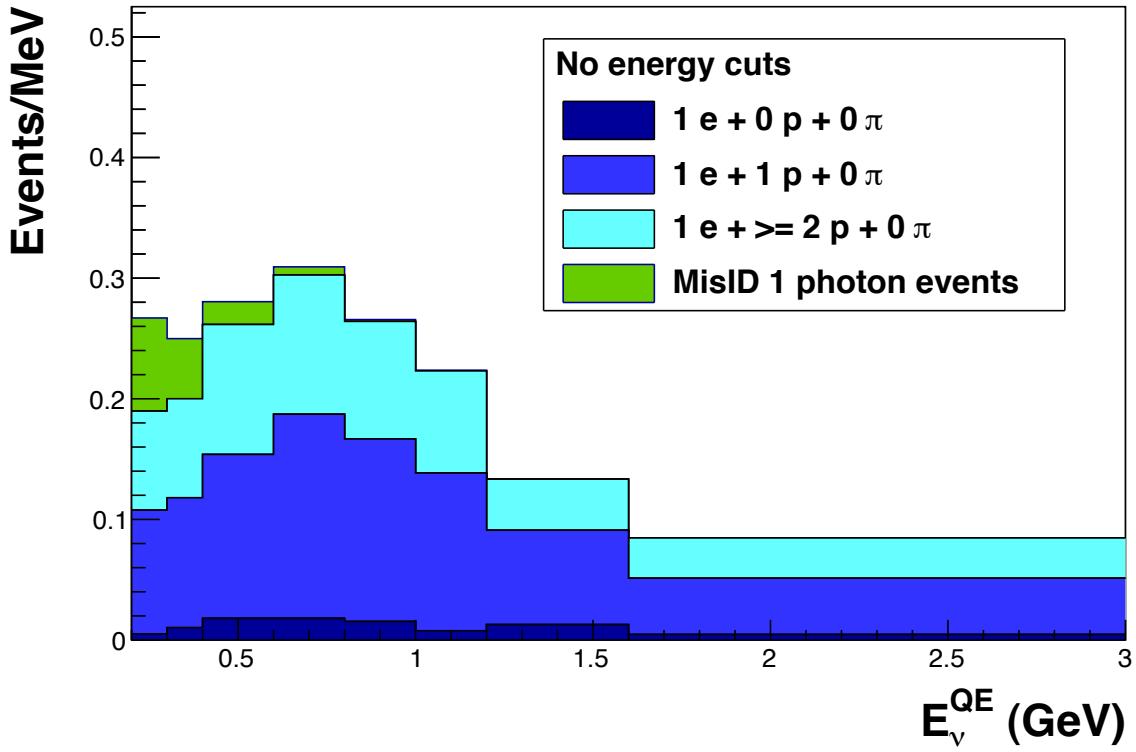
← E_ν for events with 1 electron, 0 pions, and any number of protons in the final state. Scaled to 6.6 x 10^{20} POT, 60t fiducial volume, 80% efficiency

True ν Energy ($\nu_e/\bar{\nu}_e$ CCQE only)



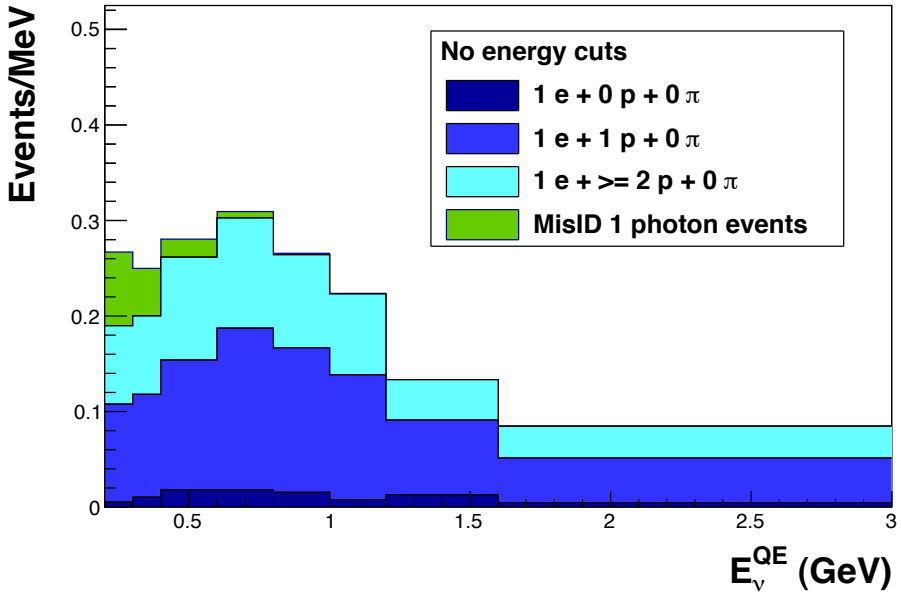
←Background predictions for μBooNE made using LArSoft (older generated samples) event rates, 6.6 x 10^{20} POT, and 60t fiducial volume, 80% efficiency

Predicted background for electron CCQE-like events

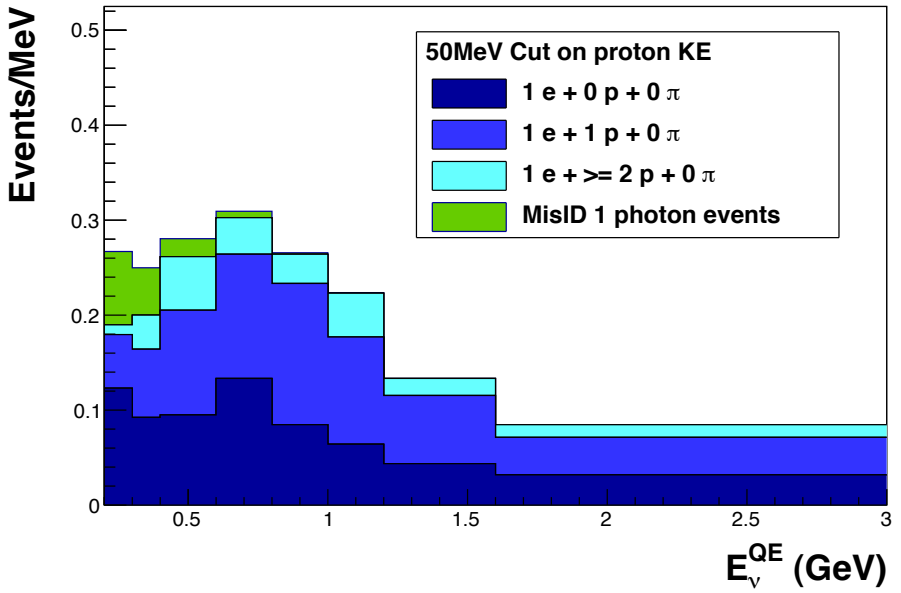


- Distribution of E_ν^{QE} for 1 electron events with 1 e and 0 π in the final state, plus mis-ID 1 photon events (E_ν^{QE} calculated using photon energy)
- 6% of 1γ events will be misidentified as electron events
- Scaled to 6.6 x 10^{20} POT, 60t fiducial volume, and 80% efficiency
- No energy cut on proton KE

With KE cut on proton energy



🡐Without cut on proton energy (from previous slide)



🡐 With cut on proton energy. Requires proton kinetic energy to be at least 50 MeV

- Currently revising a tech note I have written describing this study in detail
- Should be finished next week
- Let me know if you have suggestions for other things I ought to include

Backup Slides

Event rates for ν_e/ν_e-bar From doc db# 1765

MicroBooNE at 470m ν mode $(\nu_e/\bar{\nu}_e)$

Table 10: Rates for MicroBooNE (61.4t F.V.) for ν_e and $\bar{\nu}_e$ at 470m, for $6 \times 10^{20} POT$ in neutrino mode.

Nuance Channel		Reaction	Number of Interactions	Percentage of Interactions
ν_e				
CCQE	1 (CC)	$\nu_e n \rightarrow e^- p$	350	35.24
NC Elastic	2 (NC)	$\nu_e N \rightarrow \nu_e N$	120	12.08
Single pion resonant	3 (CC)	$\nu_e p \rightarrow e^- p \pi^+$	148	14.90
	4 (CC)	$\nu_e n \rightarrow e^- p \pi^0$	48	4.83
	5 (CC)	$\nu_e n \rightarrow e^- n \pi^+$	50	5.04
	6 (NC)	$\nu_e p \rightarrow \nu_e p \pi^0$	26	2.62
	7 (NC)	$\nu_e p \rightarrow \nu_e n \pi^+$	13	1.31
	8 (NC)	$\nu_e n \rightarrow \nu_e n \pi^0$	28	2.82
	9 (NC)	$\nu_e n \rightarrow \nu_e p \pi^-$	21	2.11
DIS	91 (CC)	$\nu_e N \rightarrow e^- X$	139	14.00
	92 (NC)	$\nu_e N \rightarrow \nu_e X$	43	4.33
Coherent/Diffractive	96 (NC)	$\nu_e A \rightarrow \nu_e A \pi^0$	1	0.10
	97 (CC)	$\nu_e A \rightarrow e^- A \pi^+$	6	0.60
		Total CC	741	74.62
		Total NC	252	25.38
		Total	993	100.0
$\bar{\nu}_e$				
CCQE	1 (CC)	$\bar{\nu}_e p \rightarrow e^+ n$	8	29.63
NC Elastic	2 (NC)	$\bar{\nu}_e N \rightarrow \bar{\nu}_e N$	6	22.22
Single pion resonant	10 (CC)	$\bar{\nu}_e n \rightarrow e^+ n \pi^-$	0	0.0
	11 (CC)	$\bar{\nu}_e p \rightarrow e^+ n \pi^0$	0	0.0
	12 (CC)	$\bar{\nu}_e p \rightarrow e^+ p \pi^-$	0	0.0
	13 (NC)	$\bar{\nu}_e p \rightarrow \bar{\nu}_e p \pi^0$	1	3.70
	14 (NC)	$\bar{\nu}_e p \rightarrow \bar{\nu}_e n \pi^+$	1	3.70
	15 (NC)	$\bar{\nu}_e n \rightarrow \bar{\nu}_e n \pi^0$	3	11.11
	16 (NC)	$\bar{\nu}_e n \rightarrow \bar{\nu}_e p \pi^-$	1	3.70
DIS	91 (CC)	$\bar{\nu}_e N \rightarrow e^+ X$	5	18.52
	92 (NC)	$\bar{\nu}_e N \rightarrow \bar{\nu}_e X$	1	3.70
Coherent/Diffractive	96 (NC)	$\bar{\nu}_e A \rightarrow \bar{\nu}_e A \pi^0$	0	0.0
	97 (CC)	$\bar{\nu}_e A \rightarrow e^+ A \pi^-$	1	3.70
		Total CC	14	51.85
		Total NC	13	48.15
		Total	27	100.0

Event rates for $\nu_\mu/\bar{\nu}_\mu$-bar From doc db# 1765

MicroBooNE at 470m ν mode $(\nu_\mu/\bar{\nu}_\mu)$

Table 9: Rates for MicroBooNE (61.4t F.V.) for ν_μ and $\bar{\nu_\mu}$ at 470m, for $6 \times 10^{20} POT$ in neutrino mode.

Nuance Channel		Reaction	Number of Interactions	Percentage of Interactions
ν_μ				
CCQE	1 (CC)	$\nu_\mu n \rightarrow \mu^- p$	63107	40.70
NC Elastic	2 (NC)	$\nu_\mu N \rightarrow \nu_\mu N$	23689	15.28
Single pion resonant	3 (CC)	$\nu_\mu p \rightarrow \mu^- p \pi^+$	22127	14.27
	4 (CC)	$\nu_\mu n \rightarrow \mu^- p \pi^0$	7316	4.72
	5 (CC)	$\nu_\mu n \rightarrow \mu^- n \pi^+$	6005	3.87
	6 (NC)	$\nu_\mu p \rightarrow \nu_\mu p \pi^0$	3944	2.54
	7 (NC)	$\nu_\mu p \rightarrow \nu_\mu n \pi^+$	2247	1.45
	8 (NC)	$\nu_\mu n \rightarrow \nu_\mu n \pi^0$	4692	3.03
	9 (NC)	$\nu_\mu n \rightarrow \nu_\mu p \pi^-$	2879	1.86
DIS	91 (CC)	$\nu_\mu N \rightarrow \mu^- X$	13689	8.83
	92 (NC)	$\nu_\mu N \rightarrow \nu_\mu X$	4585	2.96
Coherent/Diffractive	96 (NC)	$\nu_\mu A \rightarrow \nu_\mu A \pi^0$	320	0.21
	97 (CC)	$\nu_\mu A \rightarrow \mu^- A \pi^+$	457	0.29
		Total CC	112701	72.68
		Total NC	42356	27.32
		Total	155057	100.0
$\bar{\nu_\mu}$				
CCQE	1 (CC)	$\bar{\nu}_\mu p \rightarrow \mu^+ n$	564	44.76
NC Elastic	2 (NC)	$\bar{\nu}_\mu N \rightarrow \bar{\nu}_\mu N$	384	30.48
Single pion resonant	10 (CC)	$\bar{\nu}_\mu n \rightarrow \mu^+ n \pi^-$	0	0.0
	11 (CC)	$\bar{\nu}_\mu p \rightarrow \mu^+ n \pi^0$	0	0.0
	12 (CC)	$\bar{\nu}_\mu p \rightarrow \mu^+ p \pi^-$	0	0.0
	13 (NC)	$\bar{\nu}_\mu p \rightarrow \bar{\nu}_\mu p \pi^0$	36	2.86
	14 (NC)	$\bar{\nu}_\mu p \rightarrow \bar{\nu}_\mu n \pi^+$	36	2.86
	15 (NC)	$\bar{\nu}_\mu n \rightarrow \bar{\nu}_\mu n \pi^0$	59	4.68
	16 (NC)	$\bar{\nu}_\mu n \rightarrow \bar{\nu}_\mu p \pi^-$	24	1.90
DIS	91 (CC)	$\bar{\nu}_\mu N \rightarrow \mu^+ X$	88	6.98
	92 (NC)	$\bar{\nu}_\mu N \rightarrow \bar{\nu}_\mu X$	45	3.57
Coherent/Diffractive	96 (NC)	$\bar{\nu}_\mu A \rightarrow \bar{\nu}_\mu A \pi^0$	8	0.63
	97 (CC)	$\bar{\nu}_\mu A \rightarrow \mu^+ A \pi^-$	16	1.27
		Total CC	668	53.02
		Total NC	592	46.98
		Total	1260	100.0