MaCh3 Oscillation Analysis Update

Oscillation Analysis Meeting -12/09/2013

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On behalf of the MaCh3 Group



Status

- Updated event rate comparisons
 - BANFF + NIWG tunings
- Toy fits running
 - Some preliminary toy studies
- Density fitter
 - How to determine best fit point in 4 dimensions
- Plans
 - Fake data fits
 - Data fit proposal





Super-K ν_{μ} BANFF v4 Tuned

Oscillations

SKMC 13a @ 6.3933E20 POT

	ν_{μ}	ν_e	$\bar{\nu_{\mu}}$	$\bar{\nu_e}$	ν_e signal			
CCQE	67.2	0.0328	4.35	0.00188	0.186			
$CC1\pi$	27.4	0.0208	1.97	0.00117	0.0681			
CC coherent	0.878	0.00105	0.241	0.000126	0.00509	N _{SK}	N_{SK}	N_{SK}
$CCn\pi$	6.27	0.00376	0.377	0.000235	0.00101	(nominal MC)	(NA61-tuned MC)	(BANFF tuned MC)
CC other	2.04	0.00251	0.093	0.000159	0.000533	113.170201	127.802057	117.776282
$NC\pi^0$	0.635	0.0199	0.0318	0.00203	0		A	
$NC\pi^{+/-}$	2.84	0.0723	0.139	0.00787	0		–	
NC coherent	0.016	0.000382	0.000729	7.48e-05	0			
NC other	2.4	0.0929	0.132	0.00905	0			
Sample Totals	110	0.247	7.33	0.0226	0.26		TNI 155	
Total Rate		_	118				1 IN-1 33	
No Osc	illat	tions	$\bar{\nu_{\mu}}$	$\bar{\nu_e}$	ν_e signal		I	
No Osc	334	0.0354	$\frac{\bar{\nu_{\mu}}}{8.98}$	$\frac{\bar{\nu_e}}{0.00197}$	$\nu_e \text{ signal}$ 0			
No Osc CCQE CC1 <i>π</i>	334 57.2	0.0354 0.0219	$ \frac{\bar{\nu_{\mu}}}{8.98} $ 2.82	$ \frac{\bar{\nu_e}}{0.00197} $ 0.00121	$ \frac{\nu_e \text{ signal}}{0} $			
No Osc CCQE $CC1\pi$ CC coherent	334 57.2 2.04	0.0354 0.0219 0.00112	$ \frac{\bar{\nu_{\mu}}}{8.98} $ 2.82 0.451	$\begin{array}{c} \bar{\nu_e} \\ 0.00197 \\ 0.00121 \\ 0.000131 \end{array}$	$ \begin{array}{c} \nu_e \text{ signal} \\ 0 \\ 0 \\ 0 \end{array} $		₩	
$\frac{NOOSC}{CCQE}$ $\frac{CC1\pi}{CC \text{ coherent}}$ $\frac{CCn\pi}{CCn\pi}$	334 57.2 2.04 7.14	0.0354 0.0219 0.00112 0.00384		$\begin{array}{c} \bar{\nu_e} \\ 0.00197 \\ 0.00121 \\ 0.000131 \\ 0.000238 \end{array}$	$ \begin{array}{c} \nu_e \text{ signal} \\ 0 \\ 0 \\ 0 \\ 0 \end{array} $		V	
No Osc CCQE $CC1\pi$ CC coherent $CC n\pi$ CC other	334 57.2 2.04 7.14 2.17	0.0354 0.0219 0.00112 0.00384 0.00253		$\begin{array}{c} \bar{\nu_e} \\ 0.00197 \\ 0.00121 \\ 0.000131 \\ 0.000238 \\ 0.00016 \end{array}$	$ \begin{array}{c} \nu_e \text{ signal} \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{array} $			N_{SK}
$\begin{array}{c} \textbf{No Osc} \\ CCQE \\ CC1\pi \\ CC \text{ coherent} \\ CCn\pi \\ CC \text{ other} \\ NC\pi^0 \end{array}$	334 57.2 2.04 7.14 2.17 0.635	0.0354 0.0219 0.00112 0.00384 0.00253 0.0199	$\begin{array}{r} \bar{\nu_{\mu}} \\ 8.98 \\ 2.82 \\ 0.451 \\ 0.431 \\ 0.0994 \\ 0.0318 \end{array}$	$\begin{array}{c} \bar{\nu_e} \\ 0.00197 \\ 0.00121 \\ 0.000131 \\ 0.000238 \\ 0.00016 \\ 0.00203 \end{array}$	$ $	N _{SK} (nominal MC) 406.885590	N _{SK} (NA61-tuned MC) 451.896983	N_{SK} (BANEE tuned MC) 421.76 456
$\begin{array}{c} \textbf{NoOsc} \\ CCQE \\ CC1\pi \\ CC \text{ coherent} \\ CCn\pi \\ CC \text{ other} \\ NC\pi^0 \\ NC\pi^{+/-} \end{array}$	334 57.2 2.04 7.14 2.17 0.635 2.84	0.0354 0.0219 0.00112 0.00384 0.00253 0.0199 0.0723	$\begin{array}{r} \bar{\nu_{\mu}} \\ 8.98 \\ 2.82 \\ 0.451 \\ 0.431 \\ 0.0994 \\ 0.0318 \\ 0.139 \end{array}$	$\begin{array}{c} \bar{\nu_e} \\ 0.00197 \\ 0.00121 \\ 0.000131 \\ 0.000238 \\ 0.00016 \\ 0.00203 \\ 0.00787 \end{array}$	$ $	$\begin{array}{c c} & N_{SK} \\ & (\text{nominal MC}) \\ & 406.885590 \end{array}$	N _{SK} (NA61-tuned MC) 451.896983	$\begin{array}{c} N_{SK} \\ (\text{BANEE tuped MC}) \\ \hline 421.76 \\ \hline 456 \end{array}$
No Osc CCQE $CC1\pi$ CC coherent $CCn\pi$ CC other $NC\pi^0$ $NC\pi^{+/-}$ NC coherent	334 57.2 2.04 7.14 2.17 0.635 2.84 0.016	0.0354 0.0219 0.00112 0.00384 0.00253 0.0199 0.0723 0.000382	$\begin{array}{r} \bar{\nu_{\mu}} \\ 8.98 \\ 2.82 \\ 0.451 \\ 0.431 \\ 0.0994 \\ 0.0318 \\ 0.139 \\ 0.000729 \end{array}$	$\begin{array}{c} \bar{\nu_e} \\ 0.00197 \\ 0.00121 \\ 0.000131 \\ 0.000238 \\ 0.00016 \\ 0.00203 \\ 0.00787 \\ 7.48e\text{-}05 \end{array}$	$ $	$\begin{array}{c c} & N_{SK} \\ (nominal MC) \\ \hline & 406.885590 \end{array}$	N _{SK} (NA61-tuned MC) 451.896983	$\begin{array}{c} N_{SK} \\ (\text{BANEE tuned MC}) \\ \hline 421.761 \\ 456 \end{array}$
No Osc CCQE $CC1\pi$ CC coherent $CCn\pi$ CC other $NC\pi^0$ $NC\pi^{+/-}$ NC coherent NC other	334 57.2 2.04 7.14 2.17 0.635 2.84 0.016 2.4	0.0354 0.0219 0.00112 0.00384 0.00253 0.0199 0.0723 0.000382 0.0929	$\begin{array}{r} \bar{\nu_{\mu}} \\ 8.98 \\ 2.82 \\ 0.451 \\ 0.431 \\ 0.0994 \\ 0.0318 \\ 0.139 \\ 0.000729 \\ 0.132 \end{array}$	$\begin{array}{c} \bar{\nu_e} \\ 0.00197 \\ 0.00121 \\ 0.000131 \\ 0.000238 \\ 0.00016 \\ 0.00203 \\ 0.00787 \\ 7.48e\text{-}05 \\ 0.00905 \end{array}$	$ $	$\begin{array}{c c} & N_{SK} \\ (nominal MC) \\ \hline & 406.885590 \end{array}$	N _{SK} (NA61-tuned MC) 451.896983	$\begin{array}{c} N_{SK} \\ (\mathrm{BANFE tuned MC}) \\ 421.76 \\ 456 \end{array}$
No Osc CCQE $CC1\pi$ CC coherent CC other $NC\pi^0$ $NC\pi^{+/-}$ NC coherent NC other Sample Totals	334 57.2 2.04 7.14 2.17 0.635 2.84 0.016 2.4 408	0.0354 0.0219 0.00112 0.00384 0.00253 0.0199 0.0723 0.000382 0.0929 0.25	$\begin{array}{r} \bar{\nu_{\mu}} \\ 8.98 \\ 2.82 \\ 0.451 \\ 0.431 \\ 0.0994 \\ 0.0318 \\ 0.139 \\ 0.000729 \\ 0.132 \\ 13.1 \end{array}$	$\begin{array}{c} \bar{\nu_e} \\ 0.00197 \\ 0.00121 \\ 0.000131 \\ 0.000238 \\ 0.00016 \\ 0.00203 \\ 0.00787 \\ 7.48e\text{-}05 \\ 0.00905 \\ 0.00227 \end{array}$	$ $	N _{SK} (nominal MC) 406.885590	N _{SK} (NA61-tuned MC) 451.896983	$\begin{array}{c} N_{SK} \\ (\text{BANFF tuned MC}) \\ \hline 421.761456 \end{array}$



Note: MaCh3 calculates oscillation weights for each MC event, as opposed to each bin center.

Super-K v_e Fitqun π^0 BANFF v3 Tuned

Oscillations

	ν_{μ}	ν_e	$\bar{\nu_{\mu}}$	$\bar{\nu_e}$	ν_e signal
CCQE	0.0461	2.14	0.000803	0.0911	13.9
$CC1\pi$	0.0185	0.714	0.000278	0.0383	2.45
CC coherent	1.4e-05	0.00885	4.54e-06	0.00632	0.0421
$CCn\pi$	0.000781	0.0483	0.000121	0.00315	0.0296
CC other	0.000161	0.00788	0	0.000342	0.00221
$NC\pi^0$	0.382	0.0102	0.0265	0.00109	0
$NC\pi^{+/-}$	0.107	0.00298	0.0073	0.00031	0
NC coherent	0.121	0.00327	0.0151	0.000581	0
NC other	0.218	0.00693	0.0126	0.000632	0
Sample Totals	0.893	2.94	0.0627	0.142	16.5
Total Rate			20.5		
NO OSC	illati	ons	$\bar{\nu_{\mu}}$	$\bar{\nu_e}$	ν_e signal
NO OSC CCQE	0.0456	<u>0 </u>	$\frac{\bar{\nu_{\mu}}}{0.000807}$	$\frac{\bar{\nu_e}}{0.0976}$	ν_e signal 0.354
NO OSC CCQE CC1π	0.0456 0.0187	0 AS 2.32 0.76	$ \frac{\bar{\nu_{\mu}}}{0.000807} \\ 0.000279 $	$ \frac{\bar{\nu_e}}{0.0976} $ 0.0401	$\frac{\nu_e \text{ signal}}{0.354}$ 0.0347
$\frac{NOOSC}{CCQE}$ $\frac{CC1\pi}{CC \text{ coherent}}$	0.0456 0.0187 1.12e-05	0 AS 2.32 0.76 0.00953			
$\frac{\text{NOOSC}}{\text{CCQE}}$ $\frac{\text{CC1}\pi}{\text{CC coherent}}$ $\frac{\text{CCn}\pi}{\text{CCn}\pi}$	0.0456 0.0187 1.12e-05 0.000786	OAS 2.32 0.76 0.00953 0.0499		$\begin{array}{r} \bar{\nu_e} \\ 0.0976 \\ 0.0401 \\ 0.00675 \\ 0.00325 \end{array}$	
$\begin{array}{c} \textbf{NOOSC}\\ CCQE\\ CC1\pi\\ CC \text{ coherent}\\ CCn\pi\\ CC \text{ other} \end{array}$	0.0456 0.0187 1.12e-05 0.000786 0.000166	OAS 2.32 0.76 0.00953 0.0499 0.00808		$\begin{array}{c} \bar{\nu_e} \\ 0.0976 \\ 0.0401 \\ 0.00675 \\ 0.00325 \\ 0.000349 \end{array}$	$\begin{array}{c} \nu_e \text{ signal} \\ 0.354 \\ 0.0347 \\ 0.000737 \\ 0.000267 \\ 1.8e\text{-}05 \end{array}$
$\begin{array}{c} \textbf{NOOSO}\\ CCQE\\ CC1\pi\\ CC \text{ coherent}\\ CC \text{ other}\\ CC \text{ other}\\ NC\pi^0 \end{array}$	0.0456 0.0187 1.12e-05 0.000786 0.000166 0.382	OAS 2.32 0.76 0.00953 0.0499 0.00808 0.0102	$\begin{array}{c} \bar{\nu_{\mu}} \\ 0.000807 \\ 0.000279 \\ 4.75e-06 \\ 0.000121 \\ 0 \\ 0.0265 \end{array}$	$\begin{array}{c} \bar{\nu_e} \\ 0.0976 \\ 0.0401 \\ 0.00675 \\ 0.00325 \\ 0.000349 \\ 0.00109 \end{array}$	$\begin{array}{c} \nu_e \text{ signal} \\ 0.354 \\ 0.0347 \\ 0.000737 \\ 0.000267 \\ 1.8e\text{-}05 \\ 0 \end{array}$
$\begin{array}{c} \textbf{NOOSC}\\ CCQE\\ CC1\pi\\ CC \text{ coherent}\\ CC n\pi\\ CC \text{ other}\\ NC\pi^0\\ NC\pi^{+/-} \end{array}$	0.0456 0.0187 1.12e-05 0.000786 0.000166 0.382 0.107	OAS 2.32 0.76 0.00953 0.0499 0.00808 0.0102 0.00298	$\begin{array}{c} \bar{\nu_{\mu}} \\ 0.000807 \\ 0.000279 \\ 4.75e-06 \\ 0.000121 \\ 0 \\ 0.0265 \\ 0.0073 \end{array}$	$\begin{array}{c} \bar{\nu_e} \\ 0.0976 \\ 0.0401 \\ 0.00675 \\ 0.00325 \\ 0.000349 \\ 0.00109 \\ 0.00031 \end{array}$	
$\frac{\text{NOOSO}}{\text{CCQE}}$ $\frac{\text{CC1}\pi}{\text{CC oherent}}$ $\frac{\text{CC oher}}{\text{NC}\pi^{0}}$ $\frac{\text{NC}\pi^{+/-}}{\text{NC coherent}}$	0.0456 0.0187 1.12e-05 0.000786 0.000166 0.382 0.107 0.121	OAS 2.32 0.76 0.00953 0.0499 0.00808 0.0102 0.00298 0.00327	$\begin{array}{c} \bar{\nu_{\mu}} \\ 0.000807 \\ 0.000279 \\ 4.75e-06 \\ 0.000121 \\ 0 \\ 0.0265 \\ 0.0073 \\ 0.0151 \end{array}$	$\begin{array}{c} \bar{\nu_e} \\ 0.0976 \\ 0.0401 \\ 0.00675 \\ 0.00325 \\ 0.000349 \\ 0.00109 \\ 0.00031 \\ 0.000581 \end{array}$	$\begin{array}{c} \nu_e \text{ signal} \\ 0.354 \\ 0.0347 \\ 0.000737 \\ 0.000267 \\ 1.8e\text{-}05 \\ 0 \\ 0 \\ 0 \\ 0 \\ \end{array}$
NOOSCCQE $CC1\pi$ CC coherent $CCn\pi$ $CC other$ $NC\pi^0$ $NC\pi^{+/-}$ $NC other$ $NC other$	0.0456 0.0187 1.12e-05 0.000786 0.000166 0.382 0.107 0.121 0.218	 DAS 2.32 0.76 0.00953 0.0499 0.00808 0.0102 0.00298 0.00327 0.00693 	$\begin{array}{c} \bar{\nu_{\mu}} \\ 0.000807 \\ 0.000279 \\ 4.75e-06 \\ 0.000121 \\ 0 \\ 0.0265 \\ 0.0073 \\ 0.0151 \\ 0.0126 \end{array}$	$\begin{array}{c} \bar{\nu_e} \\ 0.0976 \\ 0.0401 \\ 0.00675 \\ 0.00325 \\ 0.000349 \\ 0.00109 \\ 0.00031 \\ 0.000581 \\ 0.000632 \end{array}$	
NOOSCCQE $CC1\pi$ CC coherent $CCn\pi$ $CC other$ $NC\pi^0$ $NC\pi^{+/-}$ NC coherentNC otherSample Totals	0.0456 0.0187 1.12e-05 0.000786 0.000166 0.382 0.107 0.121 0.218 0.893	 DAS 2.32 0.76 0.00953 0.0499 0.0499 0.00808 0.0102 0.00298 0.00298 0.00327 0.00693 3.17 	$\begin{array}{r} \bar{\nu_{\mu}} \\ 0.000807 \\ 0.000279 \\ 4.75e-06 \\ 0.000121 \\ 0 \\ 0.0265 \\ 0.0073 \\ 0.0151 \\ 0.0126 \\ 0.0627 \end{array}$	$\begin{array}{r} \bar{\nu_e} \\ 0.0976 \\ 0.0401 \\ 0.00675 \\ 0.00325 \\ 0.000349 \\ 0.00109 \\ 0.00031 \\ 0.000581 \\ 0.000632 \\ 0.151 \end{array}$	

SKMC 13a @ 6.3933E20 POT

TN-162

 $\sin^2 2\theta_{13} = 0.1$

	Nominal	Pre ND280 fit	Post ND280 fit
ν_e CC signal	17.4	17.9	16.0
ν_{μ} background	1.1	1.2	0.9
$\overline{\nu}_{\mu}$ background	0.1	0.1	0.1
ν_e background	3.0	3.3	2.9
$\overline{\nu}_e$ background	0.2	0.2	0.1
Total	21.6	22.6	20.4

$\sin^2 2\theta_{13} = 0.0$

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	Nominal	Pre ND280 fit	Post ND280 fit
ν_e CC signal	0.4	0.4	0.4
ν_{μ} background	1.1	1.2	0.9
$\overline{\nu}_{\mu}$ background	0.1	0.1	0.1
ν_e background	3.3	3.5	3.2
$\overline{\nu}_e$ background	0.2	0.2	0.2
Total	4.9	5.3	4.6



Best Fit Point

- Constrained systematics are determined from the mean of gaussian fit to the posterior
- For oscillation parameters of interest, the point of highest density in 4-dimensional space must be found



- We use a *kernel density estimation method (KDE)* to find the most dense point of the posterior distribution
 - Turn discrete steps into a continuous distribution
 - Use minuit to find the highest density

Cranmer KS, Kernel Estimation in High-Energy Physics. Computer Physics Communications 136:198-207,2001 - e-Print Archive: hep ex/0011057



KDE – Toy Fit Results (In progress)





Plots generated with ~10% of full posterior (preliminary testing), results still look promising.

Toy Fit Studies

- Toy experiments are running on the emerald GPU cluster
 - Bugs found (and fixed), but had to restart toys
 - Currently have 20-30 complete toys, aiming for 50-100
- Not enough statistics yet, but so-far nothing alarming
- Expect toy studies to be complete in 1-2 weeks



Error Reduction



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- For each toy experiment, calculate error on each parameter posterior
- Compare to prior error and BANFF postfit error (v4)
- Error reduction from simultaneous fit matches error reduction from BANFF fit
- Spectral function parameters are unconstrained in the fit (xsec par 3 & 7)

Scatter plot – MaCh3 Toy Posterior Error Blue – Prior Error Red – BANFF v4 (joint matrix)

Conclusion

- PDFs are producing valid event rates
- Toy fits are halfway finished
- We have determined a best fit method for oscillation parameters
- Preparing to perform fake data fits
- Hope to start performing run1-4 data fits in the next couple of weeks
 - **4 fits:** both hierarchies & with/without reactor constraint
- What would OA group like to see before beginning to fit data?

