ORCA4 Oscillation fit

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GOOD NEWS, EVERYONE!

Data and cuts

- 133 days of ORCA4 data [selected runs]

- Reco energy cut: $1.25 < E < 100$

- Cuts: all 15 cuts from previous analyses [see backup for definitions]

Fit configuration

Parameter	Treatment	Fit range	Prior	Start value	Fitted value	Best fit [nu-fit]
θ12 [deg]	Fixed	33.0	-	33.0		
θ13 [deg]	Fitted w/ prior	(7.89, 8.87)	8.43 +-0.15	8.43		
θ23 [deg]	Free	(0, 90)	-	40.7		
Dm21sq [10^-5 eV^2]	Fixed	7.37	-	7.37		
Dm31sq [10^-3eV^2]	Free	(2, 3)	-	2.56		
Dcp [π]	Free	(0, 2)	-	1.38		
Energy tilt	Free	(0.5,0.5)	-	0		
cosθ tilt	Free	(0.5,0.5)	-	0		
e/ae ratio	Fitted w/ prior	(0.5,0.5)	0 +-0.1	0		
mu/amu ratio	Fitted w/ prior	(0.5,0.5)	0 +-0.1	0		
e/mu ratio	Fitted w/ prior	(0.5,0.5)	0 +-0.05	0		
NC norm.	Fitted w/ prior	(0,2)	1+-0.1	1		
tau norm.	Free	(0,2)	-	1		
Energy scale	Fixed	0	-	0		
Overall norm.	Free	...	-	...		

Oscillations

Flux

Xsec

Detector

Fit result

	Parameter	Treatment	Fit range	Prior	Start value	Fitted value	Best fit [nu-fit]
Oscillations	θ12 [deg]	Fixed	33.0	-	33.0	-	
	θ13 [deg]	Fitted w/ prior	(7.89, 8.87)	8.43 +-0.15	8.43	8.40 +-0.15	8.57 +-0.13
	θ23 [deg]	Free	(0, 90)	-	40.7	52.3 +-52.3	49.0 +- 1.4
	Dm21sq [10^-5 eV^2]	Fixed	7.37	-	7.37	-	
	Dm31sq [10^-3eV^2]	Free	(2, 3)	-	2.56	2.84 +-0.89	2.51 +- -0.028
	Dcp [π]	Free	(0, 2)	-	1.38	0.1 +-2.4	0.92 +- 0.27
Flux	Energy tilt	Free	(0.5,0.5)	-	0	-0.028 +-0.071	
	cosθ tilt	Free	(0.5,0.5)	-	0	-0.34 +-0.74	
	e/ae ratio	Fitted w/ prior	(0.5,0.5)	0 +-0.1	0	9.2E-4 +-9.9E-2	
	mu/amu ratio	Fitted w/ prior	(0.5,0.5)	0 +-0.1	0	-1.7E-3 +-9.9E-2	
	e/mu ratio	Fitted w/ prior	(0.5,0.5)	0 +-0.05	0	-4.0E-4 +-4.9E-2	
Xsec	NC norm.	Fitted w/ prior	(0,2)	1+-0.1	1	1.000 +- 0.099	
	tau norm.	Free	(0,2)	-	1	7.9E-6 +-1.6	
Detector	Energy scale	Fixed	0	-	0	-	
	Overall norm.	Free	...	-	...	282.8	Data: 283

Fit result [plot]
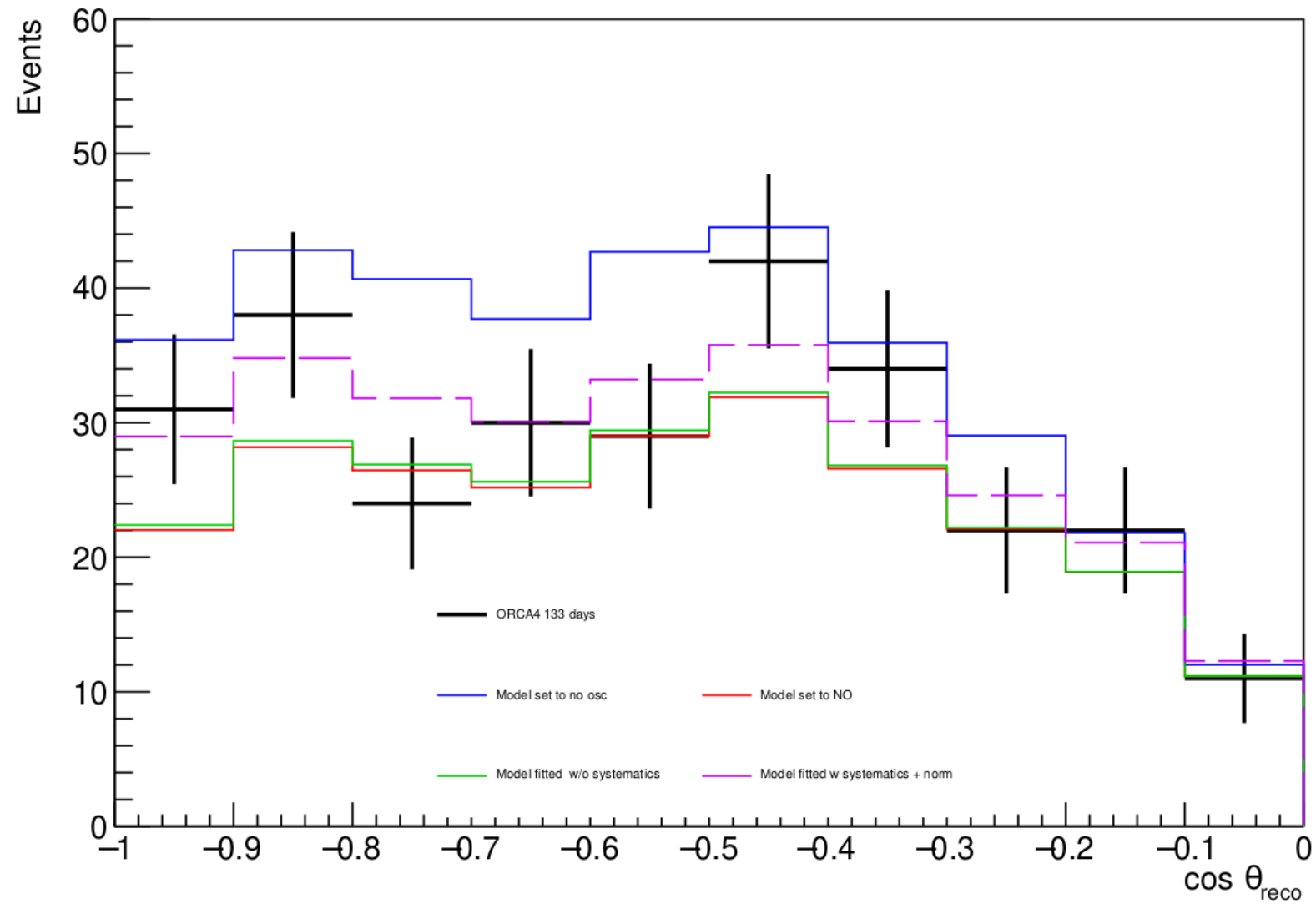
Fit results in different scenarios

	No osc.	NO [no fit]	Fit w/o syst.	Fit w/ syst. + norm	data
Chi2(data|model)	7.62	6.27	6.06	5.42	
Θ23 [deg]	0	37.9	27.6	52.3	
Dm31sq [10^-3eV^2]	0	2.56	2.86	2.84	
N events	343.4	241.5	244.3	282.8 [fitted]	283

Conclusion

- Fit converges well given limited statistics and absent shower channel
  - θ23 is inside best fit 3σ range: 2.3σ away
  - Dm31sq is in the same ballpark as best fit value, but quite far from it
  - This makes sense because E/L is important to determine Dm31sq, while the overall amplitude (appearance/disappearance) is used for θ23

$$\sin^2(2\theta) \sin^2\left(\frac{\Delta m^2 L}{4E}\right)$$ Don't take E into acct.

- Errors are quite large

- Need shower channel to add some tensions to fit and improve convergence, also it may help with tau-norm

Cut definitions

- Containment cuts:
  gandalf_pos_r < 35
  Distance from mean DU position is l.t. 35m

- Physics cuts:
  gandalf_dir_z < 0
  Events are reconstructed as upward going
  1 < gandalf_energy < 100
  Reconstructed energy in range 1-100 GeV

- Cherenkov conditions (CC):
  Hit time <= 15ns from expected hit time
  Hit distance closest approach < 100m

  chercond_n_doms >= 5
  Number of DOMs in CC
  chercond_n_doms_trig >= 3
  Number of triggerd DOMs in CC
  chercond_n_hits_dnf >= 5
  Number of hits on downward facing PMTs on all??
  DOMs in CC
  chercond_n_hits_dnMup >= 10
  Number of hits on downward facing PMT – upward
  facing PMT on all?? DOMs in CC
  chercond_n_hits_trig_dnMup >= 0
  Number of triggered hits on downward facing PMT –
  upward facing PMT on DOMs in CC

- BG Suppression cuts:
  maxToT < 240
  Largest ToT in set of hits that triggered is l.t. 240

  L_up/nHits > 2
  Quality of best upgoing / number of hits used in
  reconstruction

  L_up / L_down > 40
  Quality of best up / quality of best downgoing
  reconstruction

  d_closest < 20
  Distance of closest hit to reco track is l.t. 20m

  "cut1": L_up * (1./nHits + 0.045) > 5
  Adjusted reco quality cut...

  "cut2": ((((meanZhitTrig - lowest_dom_z) > 25) ||
  ((gandalf_pos_r < 20.) && (meanZhitTrig -
  lowest_dom_z > 15.))) > 1
  Mean z position of triggered hits is 25m higher than
  lowest hit DOM   OR   distance from mean DU position
  is l.t 20m AND mean z position of triggered hits is 15m
  higher than lowest hit DOM