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Description of the Daya Bay fit used for NuFit 2.0

based on data given in the Daya Bay talk at Neutrino 2014

The number of events (including oscillations) in the energy bin i in the detector d can be written

$$N_i^d = \sum_r \frac{C^d}{L_{rd}^2} \int dE R_i(E) \phi(E) \sigma(E) P_{rd}(E) \,, \tag{1}$$

where the sum over r is over all reactors, L_{rd} is the distance of reactor r to detector d, and $R_i(E)$ is the response function for the bin i. We assume a Gaussian energy resolution, hence $R_i(E)$ can be written in terms of the error function, and we assume that it is the same for all detectors, and identical binning is used for all detectors. $\phi(E)$ is the reactor flux (assumed to be the same for all reactors), $\sigma(E)$ is the detection cross section, P is the oscillation probability. The factor C^d contains the efficiencies and the DAQ time for each detector, and includes the contributions from the "DayaBay 6" and "DayaBay 8" periods. Those data are given in the Neutrino2014 talk.

The 8 detectors are (somewhat artificially) divided into near and far detectors. Let us write the total number of events in a given energy bin for all the near detectors as

$$N_i^{ND} \equiv \sum_{d=ND} N_i^d = w_{ND} \, M_i \, \langle P \rangle_{i,ND} \,, \tag{2}$$

where

$$w_{ND} = \sum_{d=ND} \sum_r \frac{C^d}{L_{rd}^2} \,, \tag{3}$$

$$M_i = \int dE R_i(E) \phi(E) \sigma(E) \,, \tag{4}$$

and

$$\langle P \rangle_{i,ND} \equiv \frac{1}{w_{ND} M_i} \sum_{d=ND} \sum_r \frac{C^d}{L_{rd}^2} \int dE R_i(E) \phi(E) \sigma(E) P_{rd}(E) \,. \tag{5}$$

The important obeservation is that within our assumptions M_i is independent of r and d.

In an obvious way, we can also write the events in a given bin i in all far detectors:

$$N_i^{FD} = w_{FD} \, M_i \, \langle P \rangle_{i,FD} \,, \tag{6}$$

with the same definitions, but the sum over d runs now over all far detectors. Note that M_i is the same as in eq. (2).

Assumption: It is not clear how exactly the Daya Bay collaboration uses the ND data to predict the FD data in each bin. My assumption is that they use the ND data to determine M_i:

$$M_i = \frac{O_i^{ND}}{w_{ND}\langle P\rangle_{i,ND}}\,, \tag{7}$$

where O_i^{ND} is the total number of observed events in bin i summed over all near detectors, and then use this to predict the FD data:

$$N_i^{FD} = \frac{w_{FD}}{w_{ND}}\,\frac{\langle P\rangle_{i,FD}}{\langle P\rangle_{i,ND}} O_i^{ND}\,. \tag{8}$$

This equation is the basis for my fit. Now I use the following imput:

1. In the talk the FD spectrum expected in case of no oscillations is given, predicted from the ND data. This information is used to obtain O_i^{ND} by setting the probabilities in eq. (8) to one:

$$O_i^{ND} = \frac{w_{ND}}{w_{FD}}\left(N_i^{FD}\right)_{\text{no-osc}}\,. \tag{9}$$

2. Having determined O_i^{ND} we can now use eq. (8) in case of oscillations to predict N_i^{FD} and compare it to the data given in the Neutrino2014 talk. To calculate the average probabilities in eq. (5) we take standard assumptions on $\phi(E)$ (including isotope composition of the cores) and the cross section.

3. Since the data is already background subtracted, the background is taken into account only in the uncertainty in each bin. We include all the background components in the statistical error per bin. Furthermore the (correlated) uncertainty on the accidental background spectrum in included as a pull parameter.

4. Then there are two more pulls:

   - Relative detector normalization: each detector 0.2%. For 4 NDs and 4 FDs: $0.2\%/\sqrt{4}$. Summing the contribution of ND + FD gives a factor $\sqrt{2}$. Hence we obtain an error of $\sqrt{2}\times 0.002/2$.
   - We include also an energy scale uncertainty of 0.35%.

Remark: In order to reproduce exactly the best fit point for θ_{13} we re-scale O_i^{ND} by a fudge factor of 0.999.