Milano Antineutrino Spectral FITter (MASFit) guide

Elisa Percalli[1], Barbara Caccianiga[1], Davide Basilico[1], Alessandra Re[1]

[1] University of Milan and INFN Milan, Italy

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MASFit aims to perform basic sensitivity studies for the NMO analysis in JUNO χ^2 test [1]. The code will produce a simulated spectrum and fit it with both normal and inverted models, computing a Chi2 difference: $\Delta\chi^2 = \chi^2_{IO} - \chi^2_{NO}$.

You can run the code `MASFit_0.py` with Python3 giving as input the file `input_MASFit_0.txt` and `inputFlux.txt`.
Command line example: *python3 MASFit_0.py input_MASFit_0.txt inputFlux.txt*
The file `inputFlux.txt` contains the un-oscillated flux of anti-neutrinos from reactor. It has to have the same number of elements of the Nbin in the main code (you can set it from the input file).
The file `MASFit_func.py` is called in the main code and contains some of the functions used.
The code will produce two different outputs:

- if you use an Asimov data-set (Fluctuations=0) the output will be a plot of the simulated data with the two fits (called `MASFit_plot.png`) and a file with all the free parameters of the fit and their reconstructed values (called `MASFit_parameters.txt`)
- if the option Fluctuations is True (1) it will produce an histogram with the distribution of the Delta Chi Squared, by executing M fits

This is an explanation of the input file, in which you can control everything of the simulation (names and values as to be separated form "tab"):

- **Fluctuations?** if the answer is 0 it will produce an Asimov data-set, if the answer is 1 it will introduce statistical fluctuation (Poisson) on the Asimov data-set.
- **M** is the number of fits you want to do with statistical fluctuations (1000 fits takes nearly 1 hour)
- **Nbin** is the number of bin in which you divide the histogram (suggested 200)
- **Emin(MeV)** is the lower energy for the simulation (don't go below 1.806)
- **Emax(MeV)** is the maximum energy for the simulation
- **Ncont** is the number of events you want to simulate (6y=100000, 20y=330000 etc..)
- **Dist(km)** is the mean distance between the reactors and JUNO

The following entries are the physical parameters for neutrino oscillation:

- **Sin2Theta12**
- **Sin2Theta13_NO**
- **Sin2Theta13_IO**
- **DeltaM21**
- **DeltaM31_NO**
- **DeltaM32_IO**

The following lines are parameters for the energy resolution and the systematic uncertainties:

- **a**(%) First term of the energy resolution ($a/\sqrt{E}$)
- **b**(%) Second term of the energy resolution (b, the constant one)
- **c**(%) Third therm in the energy resolution (c/E)
- **sigma_a**(%) Uncertainties on the terms of the energy resolution
- **sigma_b**(%) ””
- **sigma_c**(%) ””
- **sigma_alphaC**(%) Correlated reactor uncertainty
- **sigma_alphaD**(%) Detector uncertainty
- **sigma_b2b**(%) Bin to bin uncorrelated uncertainty
- **sigma_alphaR**(%) Reactor uncorrelated uncertainty
- **Systematics?** if the answer is 0 it will do a fit with the standard χ^2 and some pull terms on a,b,c. If the answer is 1 it will also include systematic uncertainties in the χ^2 (see below).
- **Scan?** If the answer is 1 it will produce a plot with the χ^2 scan in function of Δm^2_{3l}, otherwise nothing will be produced.

Here you have the possibility to chose which parameter of the fit are free and which are fixed. If you put 0 the parameter will be free, if you put 1 it will be fixed

- **Fix_M21**
- **Fix_Theta13**
- **Fix_Theta12**
- **Fix_N**
- **Fix_a**
- **Fix_b**
- **Fix_c**

The last option is if you want the plot to pop-up, or just be separately saved:

- **Plot?** if the answer is 1 it will pop up and block the terminal until you have closed it, if it is 0 it won't appear, but will be saved anyways.

Systematic χ^2

The minimizer used if systematics are activated is [1]:

$$\chi^2 = \sum_i^{n_{bin}} \left(\frac{(M_i - T_i \cdot (1 + \alpha_C + \sum_r w_r \cdot \alpha_r \ + \alpha_D))^2}{M_i + (T_i \cdot \sigma_{b2b})^2} \right) + \left(\frac{\alpha_C}{\sigma_C} \right)^2 + \left(\frac{\alpha_D}{\sigma_D} \right)^2 + \sum_r \left(\frac{\alpha_r}{\sigma_r} \right)^2$$

- α_C represents a rate uncertainty related to reactors, with $\sigma_C = 2\%$, and it's correlated among all bins.

- α_r models another rate uncertainty related to reactors that is different from core to core. In my code r=1, because I simulate only one core and $\sigma_C = 0.8\%$.

- α_D represents a rate uncertainty related to detector, with $\sigma_D = 1\%$, and it's correlated among all bins.

- $\sigma_{b2b} = 1\%$ models a shape uncertainty that affects each bin separately

Starting from this χ^2 I've then added three pull terms for the parameters of the energy resolution (a,b,c). The pull terms are in the form $\left(\frac{a - a_0}{\sigma_a} \right)^2$.

References

[1] Fengpeng et al. An. Neutrino physics with juno. *Journal of Physics G: Nuclear and Particle Physics*, 43(3):030401, Feb 2016.