Asymmetry error bar calculation interpretation

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Intro

This talk is initiated by a conversation with Jon U.

Here is a super brief description of Acp calculation and its error bars.

CP asymmetry calculation through oscillation probability measurements:

- oscillation probability = (data - predicted bkg at best fit) / (signal prediction with P = 1);
- wrong sign component is treated as bkg;
- ”Signal prediction with P = 1” is collapsed 2D trueE-recoE histogram from PredictionExtrap (FD extrapolated MC prediction) that is used for the actual predictions for the analysis;
- do this for FHC and RHC data and calculate for each data bin:

$$\frac{P(\nu_\mu \rightarrow \nu_e) - P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e)}{P(\nu_\mu \rightarrow \nu_e) + P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e)}$$

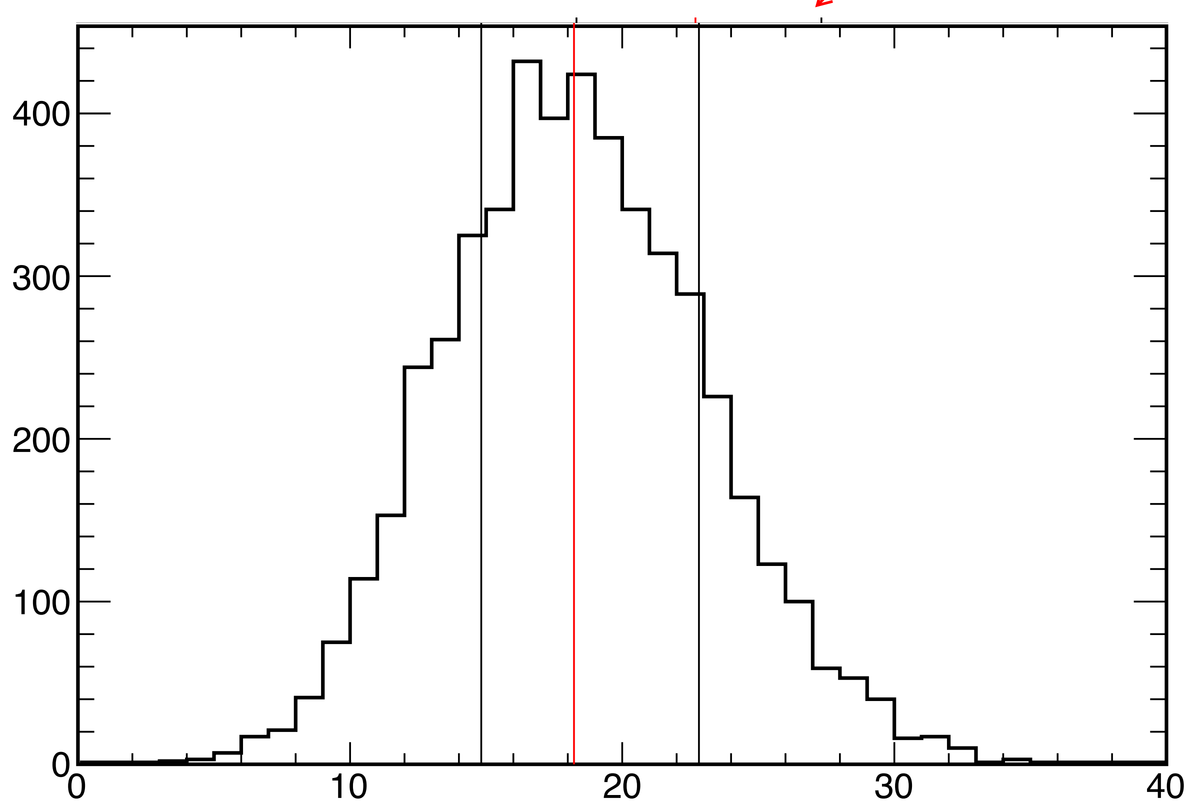
Error bar calculations

* It was decided to use Poisson fluctuations applied to the real FD data and assign the region with 68% of experiments to the error bar.
* Each pseudo-experiment goes through the same chain as it was described on the previous slide . For bkg. calculation each experiment is fitted.
* In total there are 5'000 pseudo-experiments.

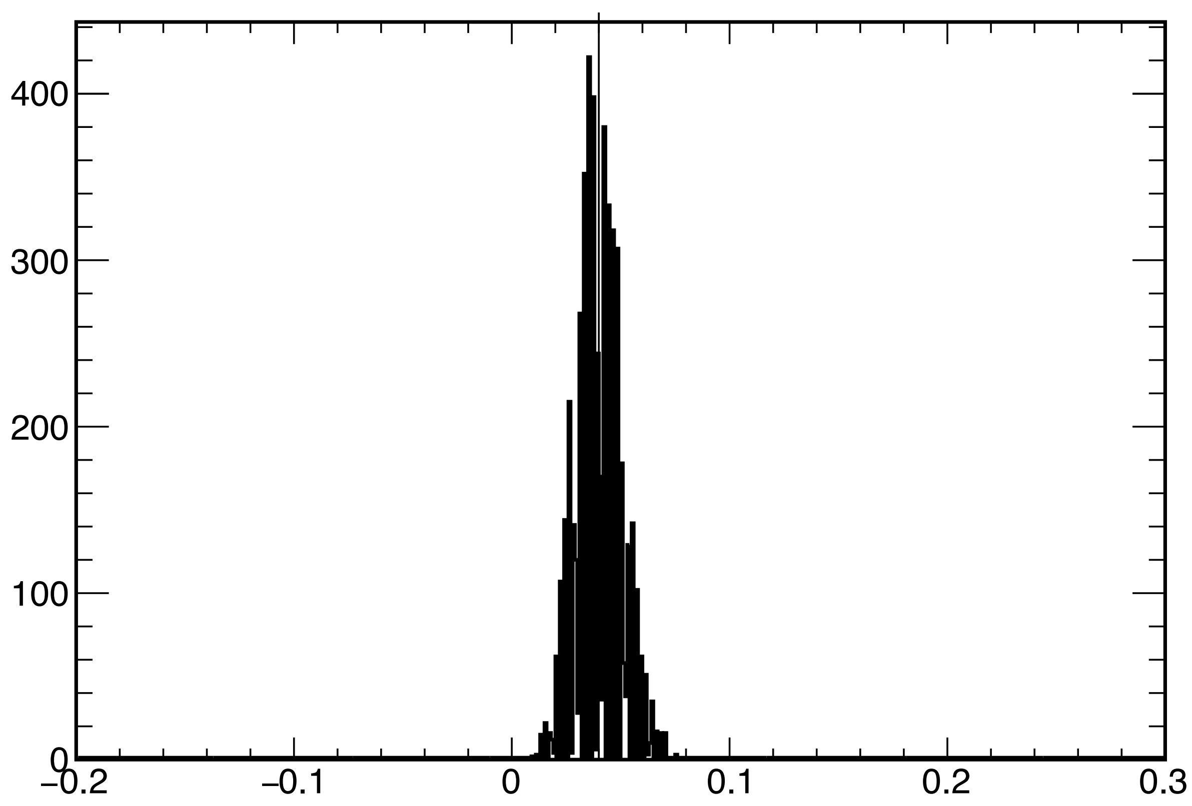
What is the related variable to the x axis?
Is it the observed nu number? So the error bar of the nu number is the region of 68%???
Yeah!!!

Example for the bin 2.0-2.5 GeV

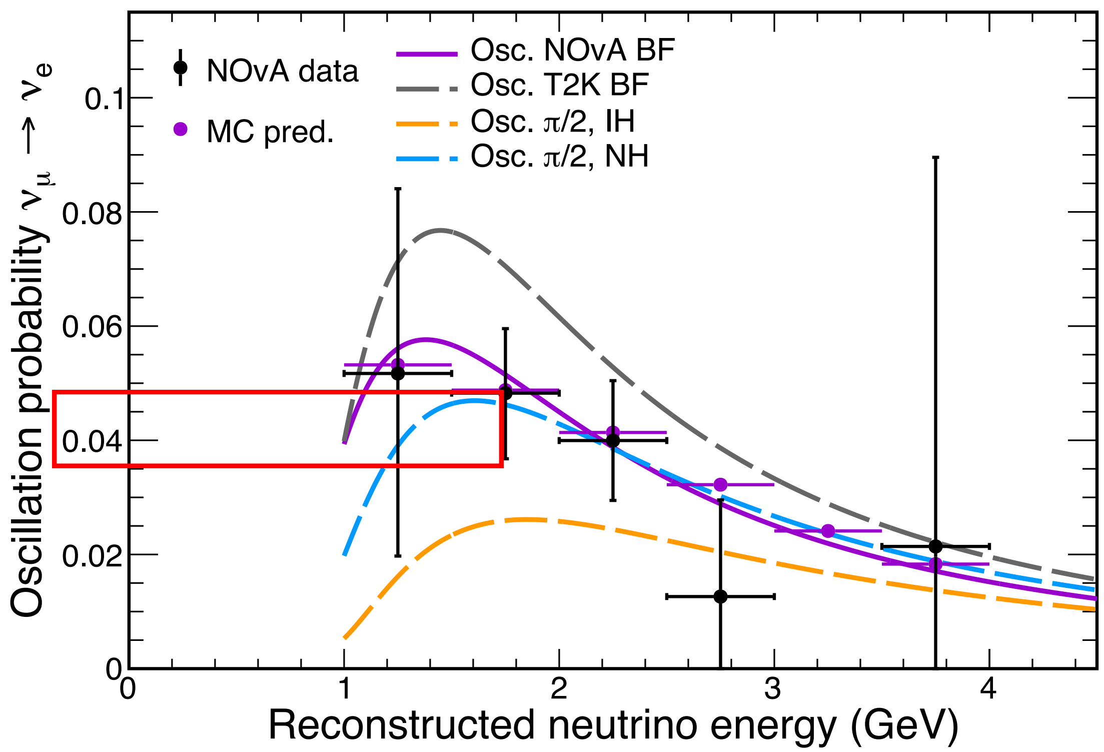
Extracted signal

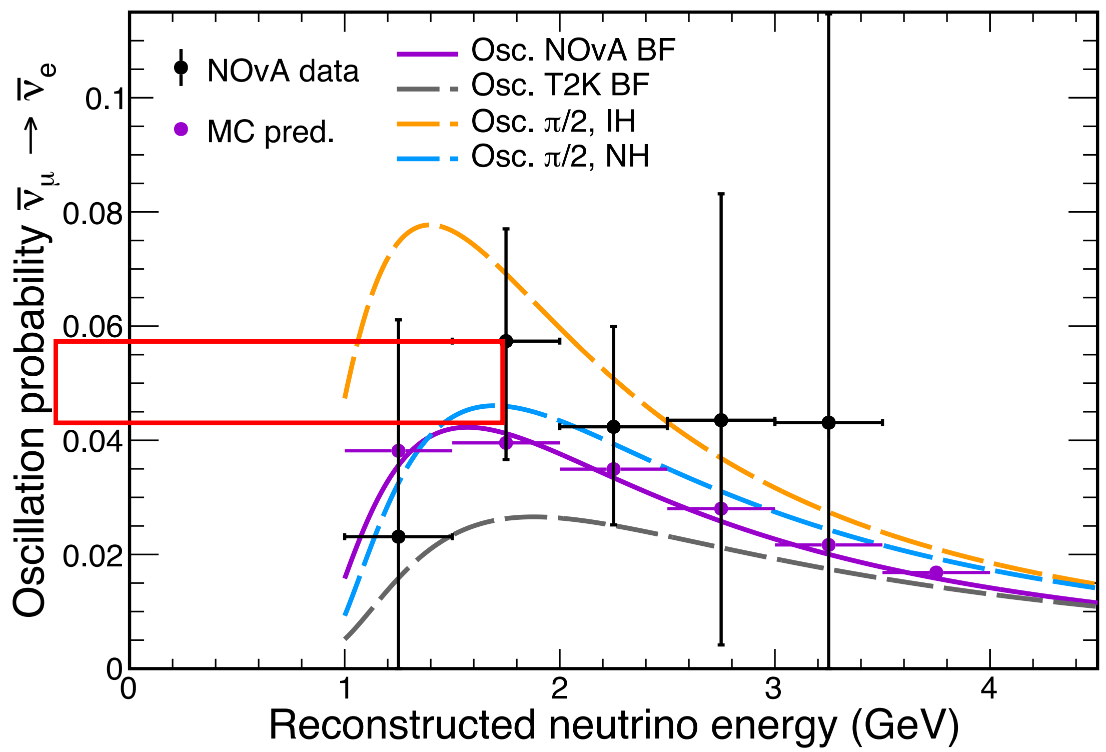


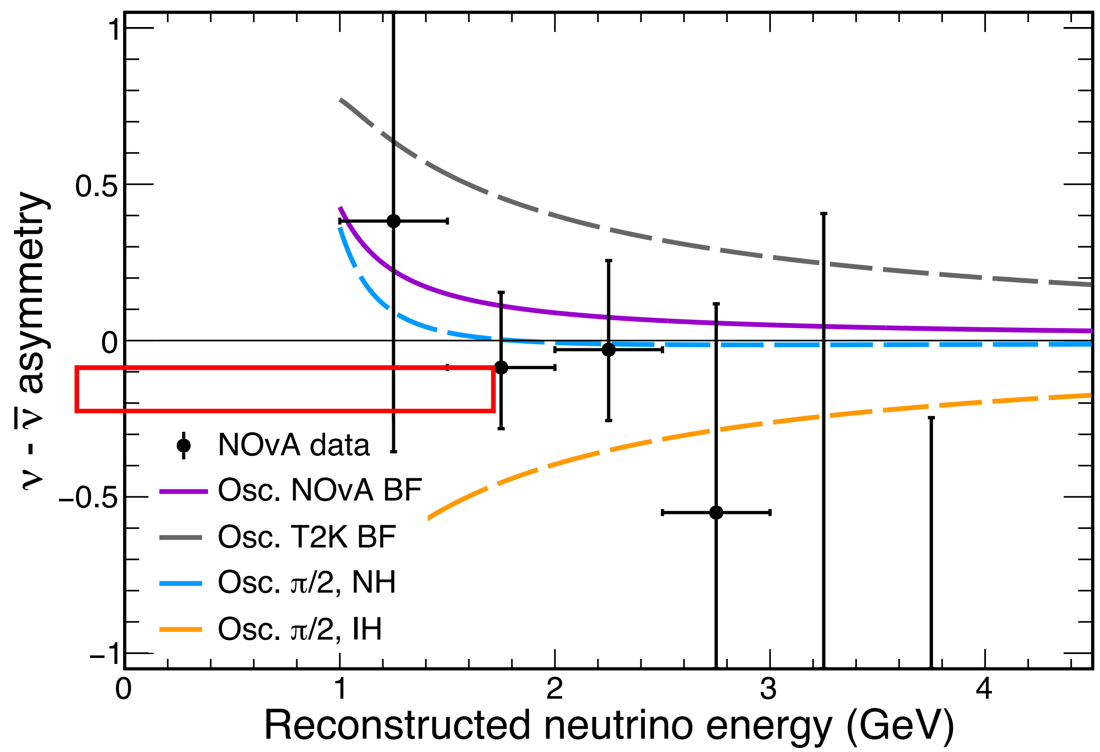
Oscillation probabilities



Final plots


NOvA data
MC pred.
Osc. NOvA BF
Osc. T2K BF
Osc. π/2, IH
Osc. π/2, NH
Oscillation probability $\nu_\mu \rightarrow \nu_e$
Reconstructed neutrino energy (GeV)


NOvA data
MC pred.
Osc. NOvA BF
Osc. T2K BF
Osc. π/2, IH
Osc. π/2, NH
Oscillation probability $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$
Reconstructed neutrino energy (GeV)


NOvA data
Osc. NOvA BF
Osc. T2K BF
Osc. π/2, NH
Osc. π/2, IH
ν - $\bar{\nu}$ asymmetry
Reconstructed neutrino energy (GeV)

$$\frac{P(\nu_\mu \to \nu_e) - P(\bar{\nu}_\mu \to \bar{\nu}_e)}{P(\nu_\mu \to \nu_e) + P(\bar{\nu}_\mu \to \bar{\nu}_e)}$$

Main theme for today's discussion

As Jon U. fairly noted, the described procedure is actually a Bayesian way since it is the conditional probability that is defined based on observed data.
True frequentist way would be in generating pseudo experiments for all Asymmetry values in [-1, 1] and then find confidence interval.

According to above def of Asy, different values of nu and nu-bar can generate the same Asy.

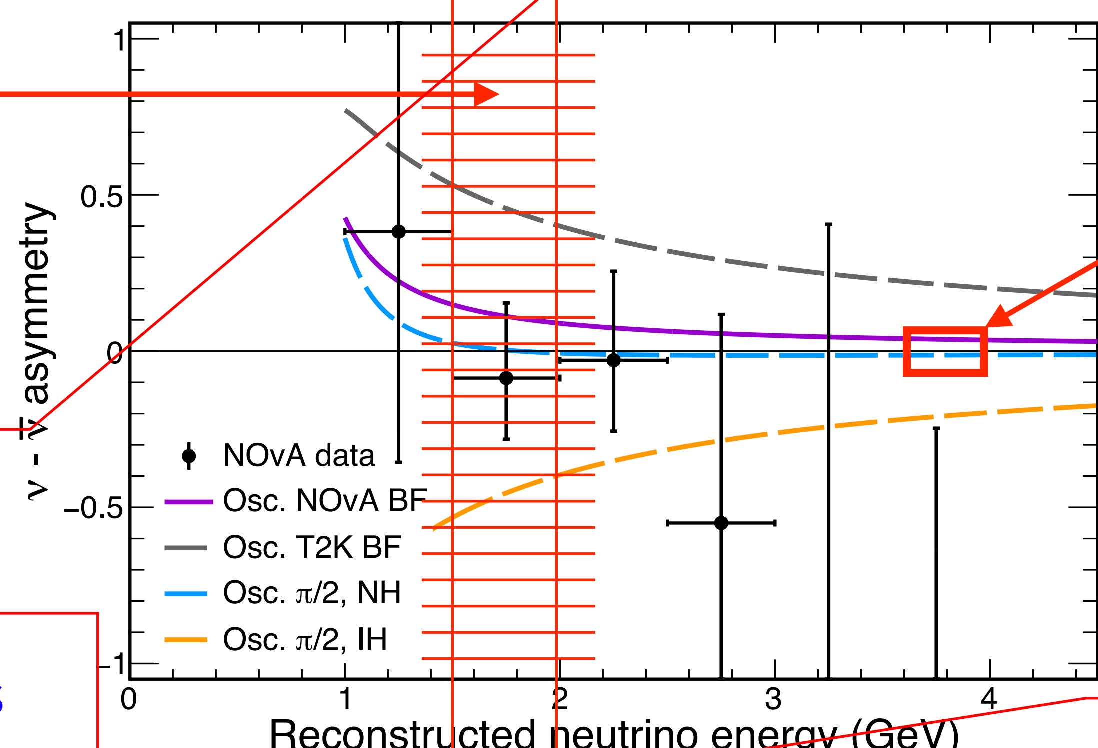
Notes on this procedure:

- ✳ There are a lot of degeneracies in osc. parameters that will represent the same Asymmetry.
- ✳ Will need to make thousands of experiments in each bin of Acp - RecoE surface. And only then find the error bar based on Acp true values which distributions are cut off by data point corresponding to 68% CL. That is similar to FC we're doing for different slices and contours.

Need to generate experiments in each bin, define significance for each bin and then find confidence interval

What is this? Feldmann-Cousin, a complicated method. It is the frequentist approach

How to understand this? Do we take the real value as the mean position then determine the 68% region in the simulated histo?



Like here, NOvA's $\delta_{CP} = 0.82\pi$ and 0.5π are super close

Just imagine how many parameters combinations will give a similar result for Acp

Will need to find all osc. the parameter's combinations and produce experiments in equal proportion for all of them

We take the values of edges of the error bars as the true value and do the simulated work

Jon suggested a quick study …

… on the previous week that is supposed to check whether Bayesian and Frequentist procedures give the same answer *(that would be the best solution to this situation)*.

Hard to understand...

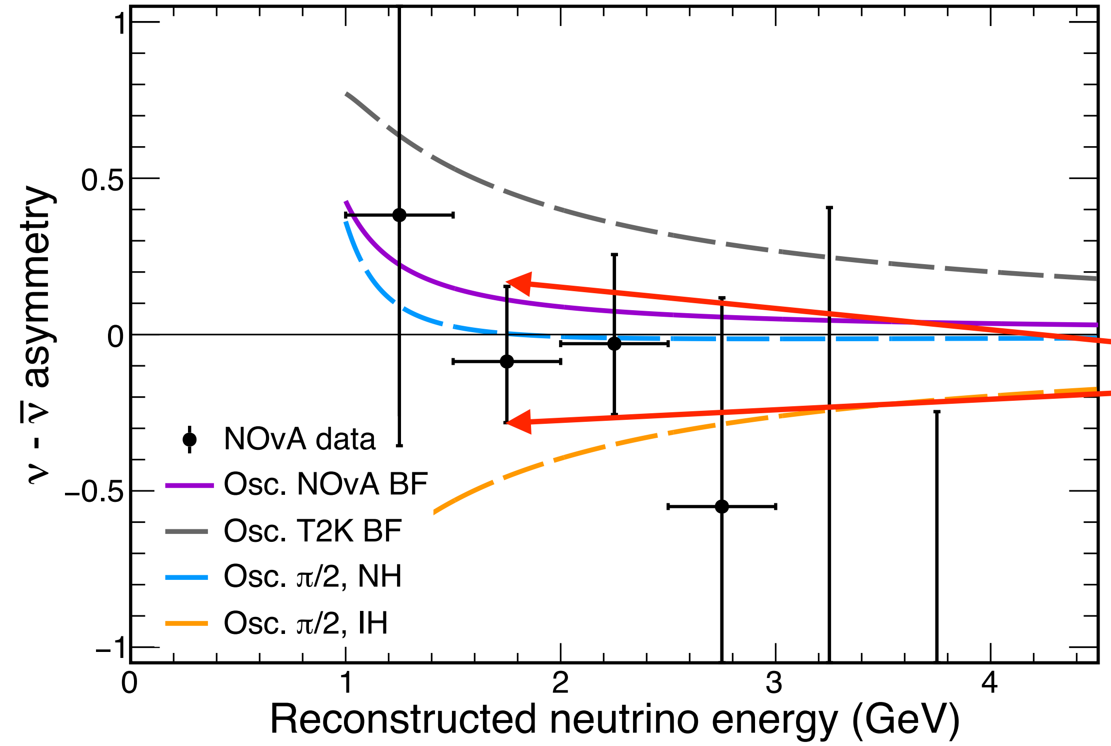
What is the Asimov data???

Idea:

- ✳ I found in a collection of mock experiments the one that resulted in the Acp value closest to the error bar edges. Took its BF osc. parameters as input for Asimov data that were used to play mock experiments.
- ✳ As a result, there is a distribution of mock experiments around one of the error bar edges.
- ✳ The actual NOvA Acp measurement will cut a “p-value” analog. If it’s at the 84%/16% mark of this distribution then everything is fine, both Bayesian and Frequentist ways give the same interval.

If we fix the Acp value like these two, what will we get???

Refer to General_notes.md



Take these points of Acp

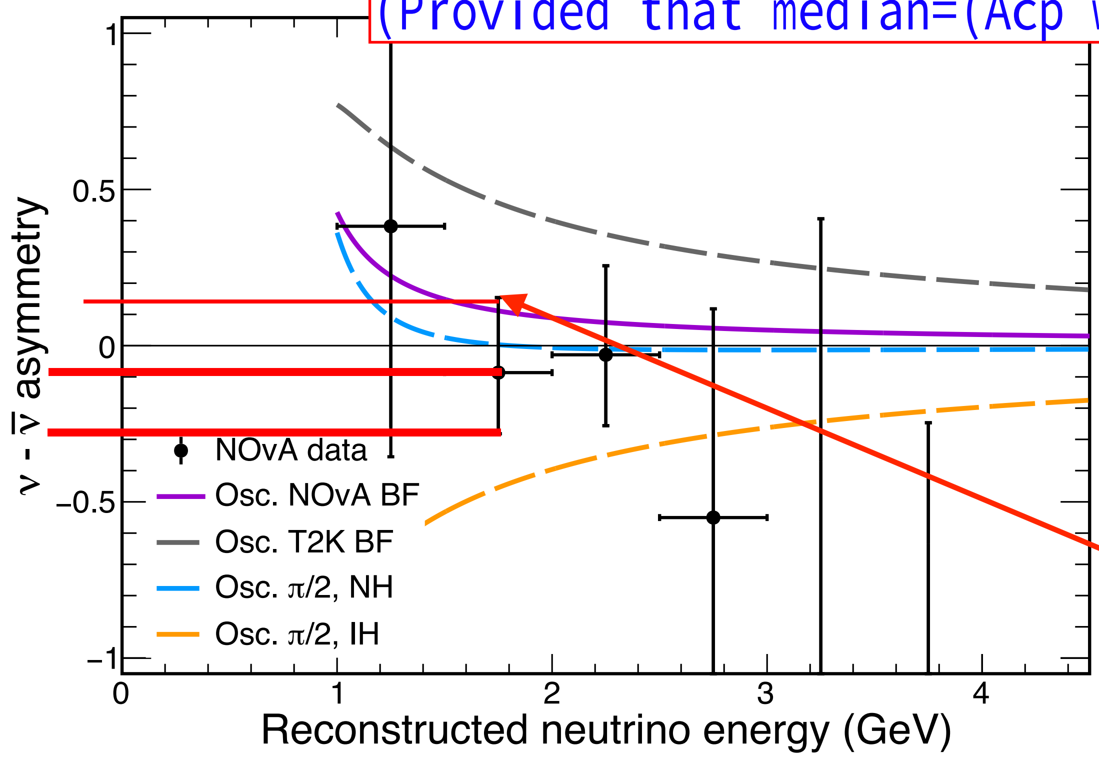
Result of quick study

It is located in the [16%, 84%] range.

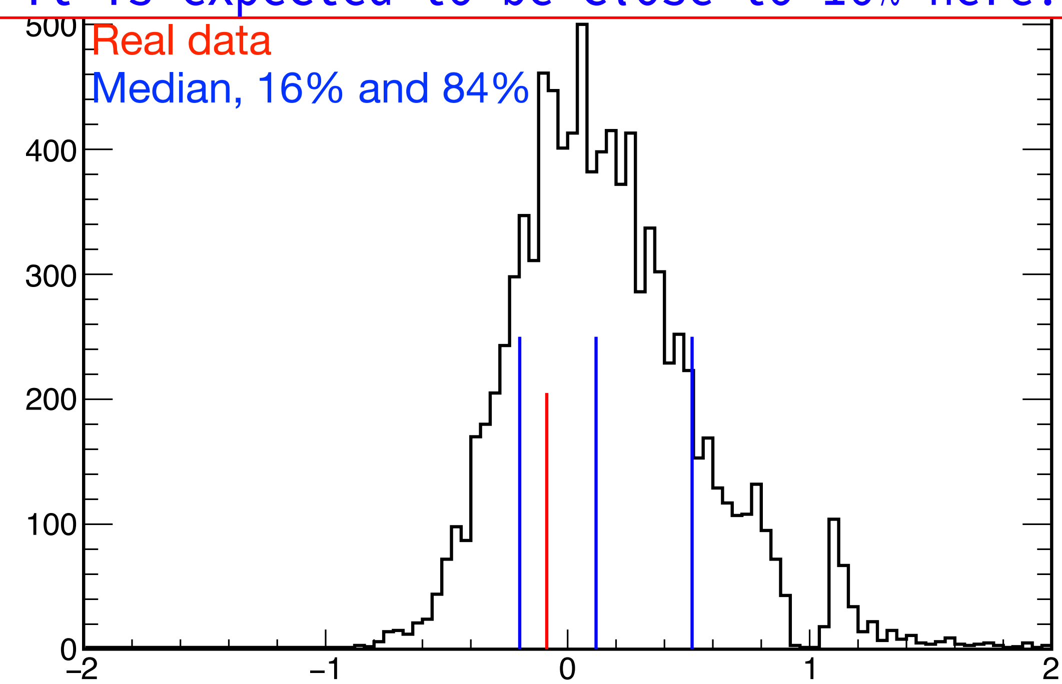
Test 1.5 - 2.0 GeV bin, its details:

- ✳ The real data Acp is -0.0809091, just the statistical range for 68% I got from mock experiments in Bayesian way is [-0.28212110; 0.15234090].
- ✳ Check here the right boundary.
- ✳ The distribution below is mock experiments played around Asimov data (>5k of them).
- ✳ If Bayesian = Frequentist we'll get red (real data) = blue (16%). That didn't happen.
- ✳ One more specific thing here is that Asimov data Acp is 0.1523 while the median of the distribution is 0.117382 . So, median != Asimov for low statistics.

This is because in real experiment |Data-upper edge|=1 sigma. Here we choose the upper limit as the real data, we certainly hope here |median- Data|=1 sigma again (Provided that median=(Acp we use)). So it is expected to be close to 16% here.



This point test



Questions to think on

* Bayesian way of calculating error bars for Acp and osc.prob plots while the rest of analysis is Frequentist. Confidence interval or creditable intervals, what should be chosen?
* The Bayesian way is pretty easy. A Frequentist will require some work on finding osc. parameters that represent all Acp values and generate experiments with them.
* Technically, in order to get a correct Bayesian approach, we'd have to use Bayes' rule to get the posterior probability for the Acp and osc. probability. That wasn't done.
* Possible inconsistency with other our plots. Does it matter if this is just an illustrative thing to present data?
* Should this procedure be coordinated with T2K in order to to get consistent results for the same kind of plots?