# CAFAna: Hack Days Activity and Status of DUNE Sensitivity Fits

Elizabeth Worcester

Long-Baseline Physics Working Group

April 9, 2018

# Tutorials and Info

- Thanks to Chris B for the helpful tutorials!
- Installation instructions: https://cdcvs.fnal.gov/redmine/projects/dunelbl/wiki/How_to_use_CAFAna
  - Easy on dunegpvm machines, should work locally with SL6 and CVMFS
- Working tutorial examples:
  - https://github.com/DUNE/lblpwgtools/tree/master/code/CAFAna/CAFAna/tute
- Video presentations:
  - These go through the tutorial demos
  - Intro: https://www.youtube.com/watch?v=odecD0pCvLg
  - Systematics: https://youtu.be/QfvCkzbzrEQ
- New DUNE Slack channel: #cafana

# Hack Days Activities

- Goals:
  - Develop working knowledge of CAFAna
  - Reproduce GLoBES-style sensitivity calculations
- Add CVN PID variables
- Draw oscillated spectra
- $\sin^2\theta_{23}$ fit
- MH and CPV fits
- Write penalty function for oscillation parameter uncertainties that exactly matches GLoBES fit

# Oscillated Spectra

Nominal exposure (300 kt-MW-years) with nominal MCC10.1 CVN selection
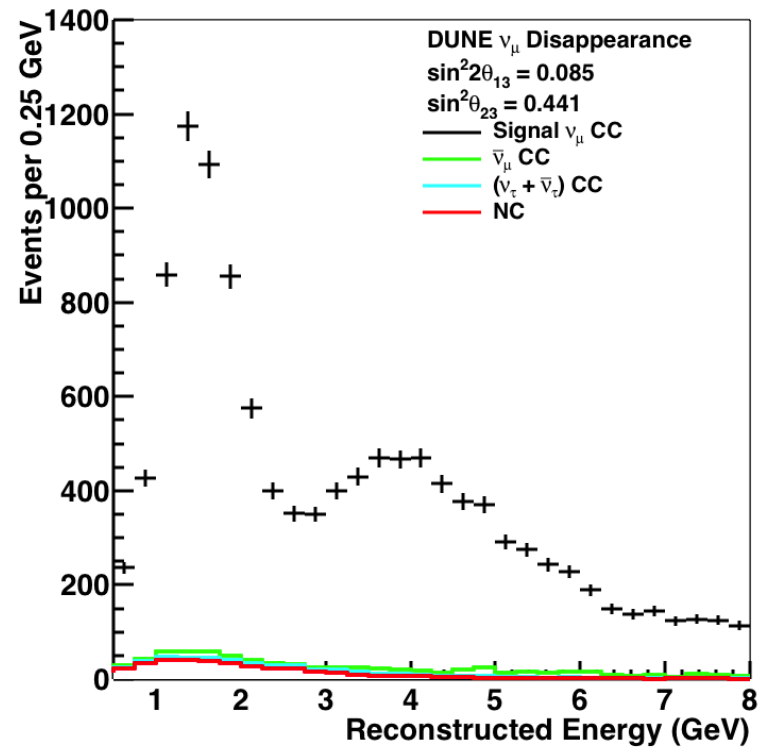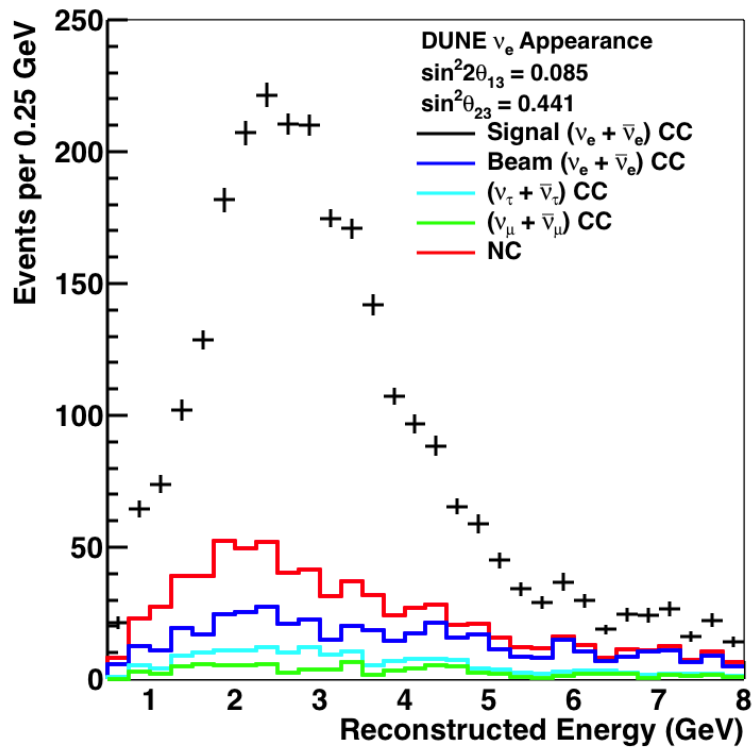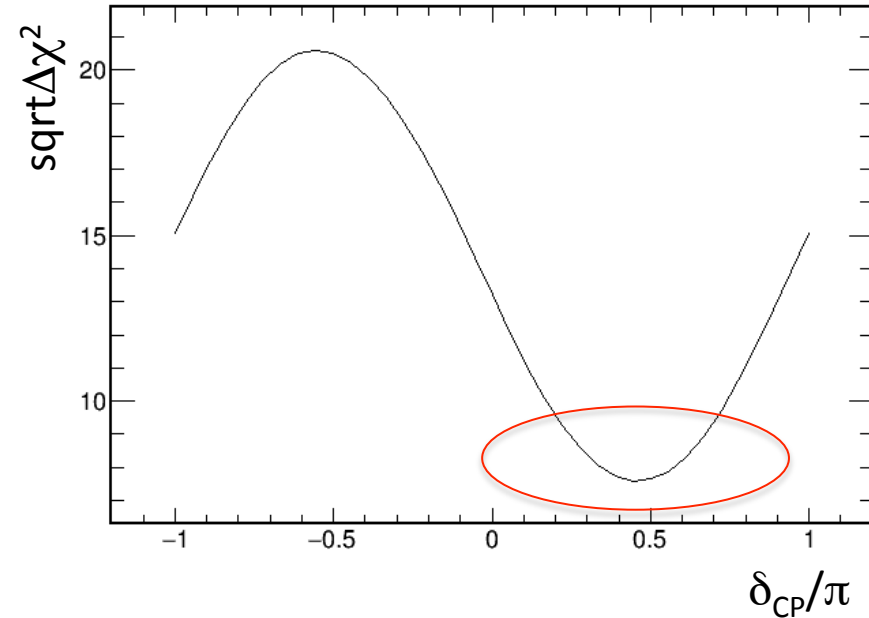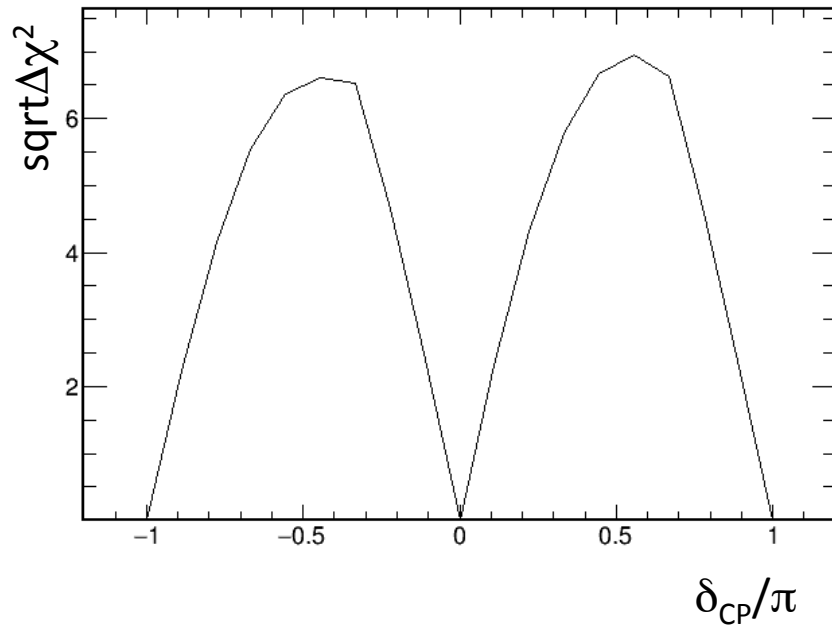
# $\sin^2\theta_{23}$ Fit
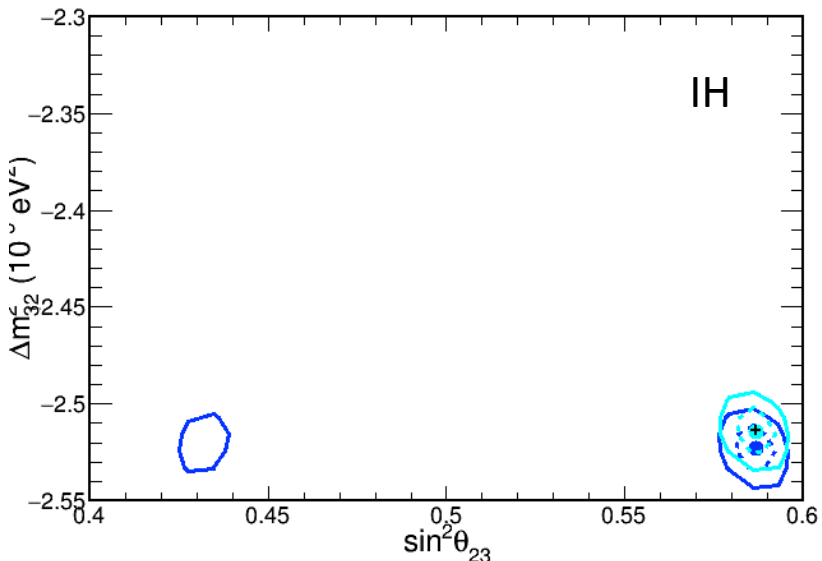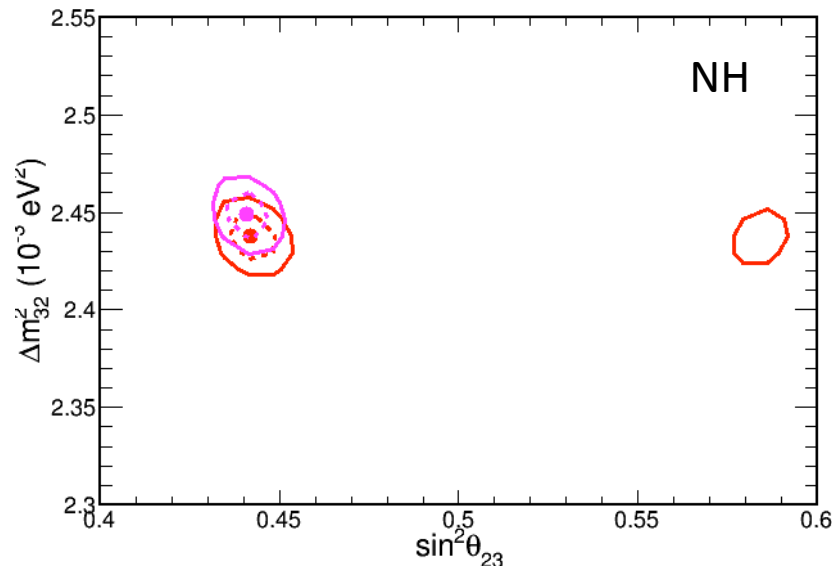


- No uncertainties here
- Red and blue: disappearance only
- Magenta and cyan: disappearance + appearance
- Appearance data rules out opposite octant solution allowed by disappearance data

# CPV & MH Fits



- At first glance seems pretty reasonable given that there are no norm. systematics, but the worst point for MH is very hard to move (generally unaffected by systematics) and it's too good compared to comparable GLoBES fits
- Note that CPV and MH plots have different systematics treatment as I've focused on development for MH to understand the $+\pi/2$ point and haven't circled back to update CPV plot

# Treatment of Oscillation Parameter Uncertainties

- Existing CAFAna class applies penalty terms based on NuFit uncertainties, but it's not identical to what is done in GLoBES
- Developed new class Penalizer_GlbLike to attempt exact match to GLoBES fits
  - Sets uncertainty on oscillation parameters using fractional uncertainty with different $\theta_{23}$ uncertainties for different true hierarchy
  - Resets central values to allow opposite octant check
- Turns out not to move the MH curve much, but will be useful for validation against GLoBES fits – will commit soon
- Neither is ideal – seems reasonably easy to implement better external constraints in CAFAna using NuFit PDFs
  - Not immediately critical, but would allow removal of awkward opposite octant minimization
  - On my to-do list

# Sensitivity Mismatch

- Now (I think) closely matching GLoBES treatment of:
  - Fit definitions
  - Oscillation parameter uncertainty (profile over all except solar parameters – GLoBES also profiles over solar parameters)
  - Matter density uncertainty
  - Minimizing over opposite hierarchy and octant
  - No normalization systematics
- What else could it be?
  - Bug somewhere
  - Binning difference (same in range 0.5-8.0 GeV)
  - Difference in oscillation engine or fitter behavior
  - Difference in flux
- Plan step-by-step comparison starting with oscillated event rates to isolate source of difference

# Summary

- CAFAna is pretty awesome!
- Basic CAFAna scripts for plotting spectra and performing standard DUNE fits have been developed
- Code to exactly match CDR-style treatment of oscillation parameter uncertainty has been written
- Plan to commit these to github after a little cleanup
- Next: step-by-step comparison to MVAtoGLoBES results to track down sensitivity mismatch and validate everything
- After that: Add normalization systematics (some code already exists), reweight systematics (Matt B developing code), energy systematics (Seb J developing code)