Theia LBL status at BNL

Feb 26 2024

Ratpac simulation: 14 big sensitive pads with R7081 QE

Ratpac information extraction: Extract the ratpac output information and get rid of the ratpac library dependence

Fast reconstruction: Only reconstruct the energy. The PID and more detailed information are with assumptions.

CAF file generation: Match the format required by fitter -> versioning can be complicated

Mach3 fitting

CAF samples

A full set of CAF samples are ready for the 5% WbLS.

6 samples in total, with each 10,000 events.

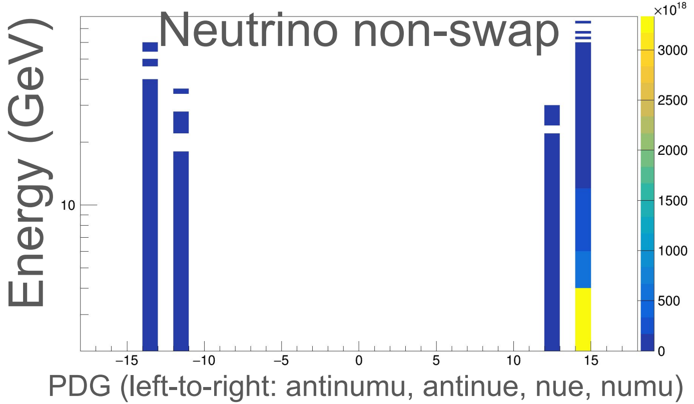
Two caveats: 1. Nutau is completely simplified in this process, 2. PID is perfect, 3. Reconstruction was estimated with samples generated around the center of the detector

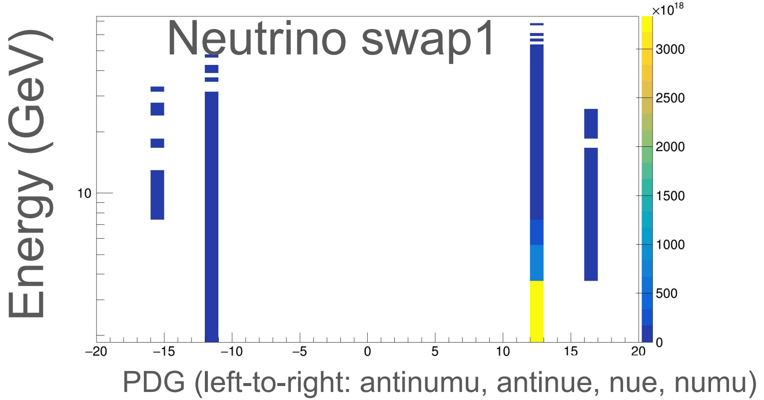
Steps to get the sample:

- Flux generation
- Ratpac simulation
- Fast reconstruction
- Energy smearing mapping
- Genie event generation and applying smearing to genie events
- Convert to CAF format

Flux generation and ratpac simulation

- for all 6 samples (nominal numu+nue, numu-> nue+ nue->nutau, numu->nutau+nue->numu and antineutrino counterpart)

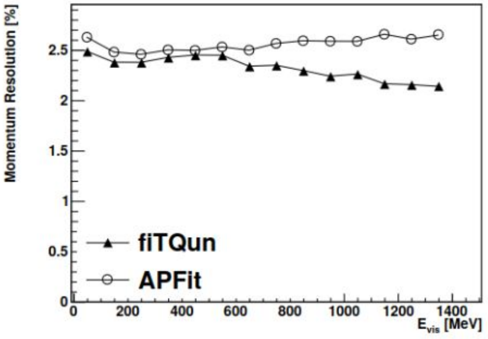


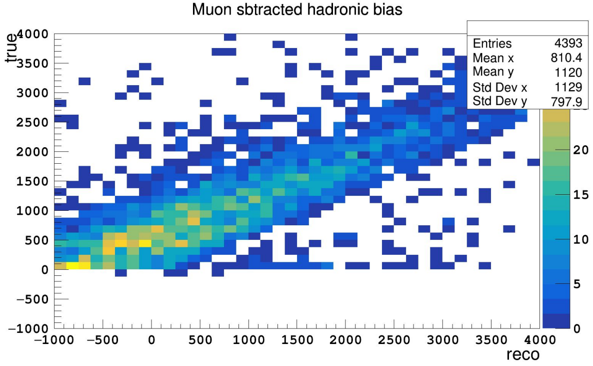


- For every ~30,000 events, it takes only one day at Fermilab to run ratpac simulation. It may not be a problem since now we are only using ratpac to get the response map, i.e. 100,000 events could be enough.

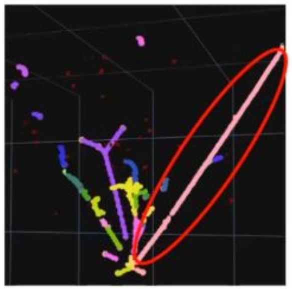
Fast reconstruction

Numu sample shown, same thing done for nue and the antineutrino counterparts



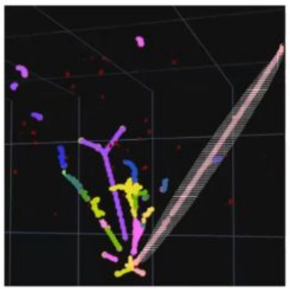


$$E_\nu(\nu_\mu) =$$



Cherenkov ring

$+$



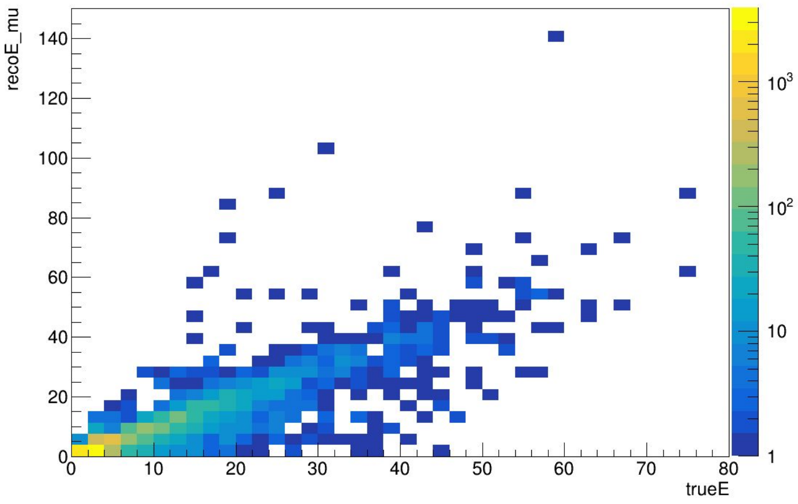
Scintillation light

Detail:
https://docs.google.com/presentation/d/17jvdAT0AeHH5JFy9H05CWBCNnmaxE3-hgMBGZdrbPdo/edit#slide=id.p3

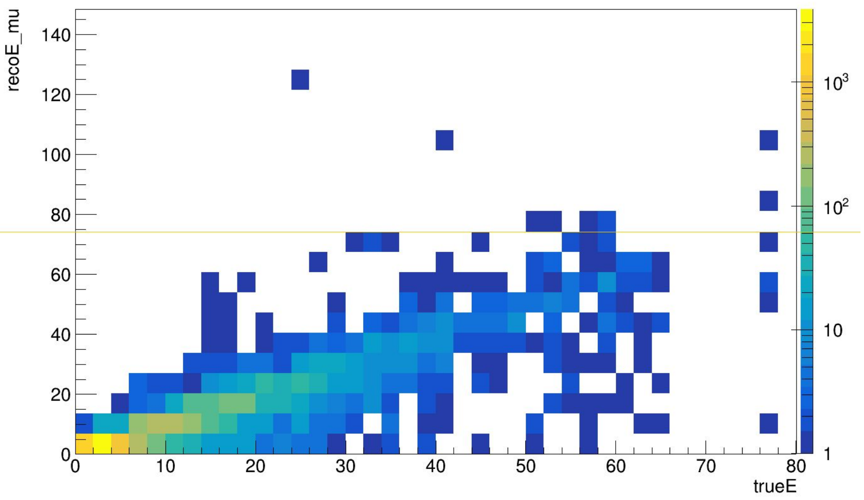
Generating GENIE events and applying the energy smearing

Any number of GENIE events can be generated fastly. It can easily satisfy the requirement for precision estimate of the oscillation parameter sensitivity.

Nu non-swap



antinu swap1



CAF format files ready

All 6 samples ready to be fed into Mach3.

We might start to put these samples in Mach3.

Already had some first-hand knowledge of the speed of Mach3 with fermilab cluster.

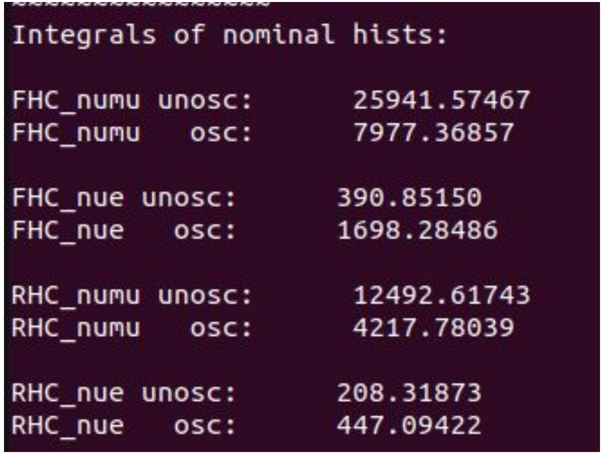
```
TFile**         caf_wbls_neutrino_swap0.root
 TFile*         caf_wbls_neutrino_swap0.root
  KEY: TTree    globalTree;1    globalTree
  KEY: TTree    cafTree;1       cafTree
  KEY: TTree    meta;1  meta
```

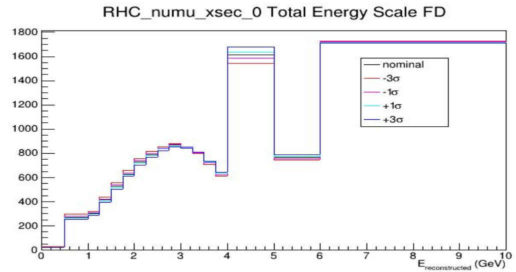
```
******************************************************************************
*Tree    :cafTree   : cafTree                                                *
*Entries :     9033 : Total =        14081444 bytes  File  Size =     489177 *
*        :          : Tree compression factor =  30.07                       *
******************************************************************************
*Branch  :rec                                                                *
*Entries :     9033 : BranchElement (see below)                              *
*............................................................................*
*Br    0 :meta_run  : Int_t                                                  *
*Entries :     9033 : Total  Size=      36789 bytes  File Size  =        379 *
*Baskets :        2 : Basket Size=      32000 bytes  Compression=  95.75     *
*............................................................................*
*Br    1 :meta_subrun : Int_t                                                *
*Entries :     9033 : Total  Size=      36807 bytes  File Size  =        385 *
*Baskets :        2 : Basket Size=      32000 bytes  Compression=  94.27     *
*............................................................................*
*Br    2 :pot       : Double_t                                               *
*Entries :     9033 : Total  Size=      72964 bytes  File Size  =        632 *
*Baskets :        3 : Basket Size=      32000 bytes  Compression= 114.69     *
*............................................................................*
*Br    3 :eRec_FromDep : Float_t                                             *
*Entries :     9033 : Total  Size=      36813 bytes  File Size  =        416 *
*Baskets :        2 : Basket Size=      32000 bytes  Compression=  87.25     *
*............................................................................*
*Br    4 :Ev_reco   : Float_t                                                *
*Entries :     9033 : Total  Size=      36783 bytes  File Size  =        406 *
*Baskets :        2 : Basket Size=      32000 bytes  Compression=  89.37     *
*............................................................................*
*Br    5 :Ev_reco_nue : Float_t                                              *
*Entries :     9033 : Total  Size=      36807 bytes  File Size  =        414 *
*Baskets :        2 : Basket Size=      32000 bytes  Compression=  87.67     *
*............................................................................*
*Br    6 :Ev_reco_numu : Float_t                                             *
*Entries :     9033 : Total  Size=      36813 bytes  File Size  =      32955 *
*Baskets :        2 : Basket Size=      32000 bytes  Compression=   1.10     *
*............................................................................*
*Br    7 :mvaresult : Float_t                                                *
*Entries :     9033 : Total  Size=      36795 bytes  File Size  =        410 *
*Baskets :        2 : Basket Size=      32000 bytes  Compression=  88.51     *
*............................................................................*
```

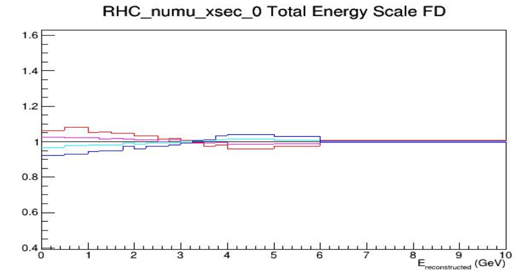
MaCh3 fitting

- Joined regular MaCh3 DUNE meeting for many weeks already
- Compiled and run MaCh3 successfully to obtain event rate and systematic variations
- Compiled MaCh3 with our version of CAF files -> took a lot of effort
- Obtain reasonable event rate with our samples
- Had a basic idea of fitting framework functionality

Trying to understand deeper on the source code and figure out the resource requirement





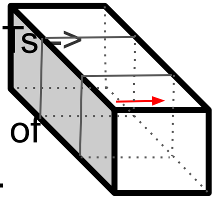


Backups

Simulation with ratpac

Geometry

- Considering a 25-kt Theia, 40% coverage results in >46,000 20-inch PMTs -> too heavy for simulation.
- Instead, having 14 big sensitive regions and look at the detailed location of each hit, with quantum efficiency from Hamamatsu R14688 without TTS.



Physics model

- Various GENIE versions (2_12 for today) are ready for the neutrino interaction.
- Various G4 models are ready for the particle propagation, default QGSP_BERT.

WbLS Optical model

- Scintillation code in RAT is based on GLG4Sim with model parameter inputs.
- Light yield from measurement: here.
- Rayleigh scattering from BNL measurement.
- *Absorption length from combination of BNL LABPPO measurement and Pope+Smith for water.*
- Refractive index, scintillation rise time and spectrum are from measurements.

Output information

- Ratpac output root with true PE location and time.
- PMT Transit time spread, charge can be added, but not at the moment.

Fast energy reconstruction - Methodology

Muon can be measured with Cherenkov ring.

- **Energy excluding muon ~ Total scintillation light - muon energy equivalent scintillation light**

In addition, pions may be measured with Cherenkov ring if above Ch. threshold.

- **Energy excluding muon and pions ~ Total scintillation - muon energy scintillation - pion energy scintillation**

All remaining energy may be measured calorimetrically.

Neutrino and antineutrino interaction with DUNE spectra with 5% WbLS target
-> focus on FHC for today