Ongoing Activities Report
Mid-June 2020

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LPNHE - (Paris)

The 17th of June - 2020

Hitachi Seaside Park

ND280-Upgrade Fitter

What's Next ? (last meeting)

- **X-section splines generation**
  - Generate antineutrino splines: for the moment genWeights does not run on RHC runs (debug stage in discutions with devs…) **- Done**

- **Detector-related Systematics**
  - Highland has been ran on all MC files **- Done**
  - Need to generate the covariance matrix with "xsllhDetVariations" **- Done**

- **ND280Up Fit**
  - Fix non-Zero Asimov chi^2 **- Done**
  - Fix convergence problem **- Done**
  - Add detector covariance matrix **- Done**
  - Adding a branch to the official repository dedicated to T2KUpgrade **- Done**

A Branch Dedicated to ND280Upgrade

- **The code is now available on gitlab : *https://gitlab.com/cuddandr/xsLLhFitter/-/tree/ND280UpFit***

Andrew › xsLLhFitter › **Repository**

You pushed to **ND280UpFit** just now — Create merge request

ND280UpFit | xsLLhFitter / + | History | Find file | Web IDE | Clone

- AnaFitParameters.cc : Inverting the covariance matrix with SVD (PCA) ...
Adrien Blanchet authored just now — fbec955b

Name	Last commit	Last update
anaevents/src	- Initializing new branch dedicated to the ND280 Upgrade Fit: "ND280U...	2 weeks ago
cmake	Updates to calc_chisq, change to build setup script.	8 months ago
docs	- [xsllhDetVariations.cxx] Adding FGD indices for accum_level cuts	4 days ago
errprop/src	Added more histograms to errprop output.	10 months ago
fitparam/src	- AnaFitParameters.cc : Inverting the covariance matrix with SVD (PCA)	just now

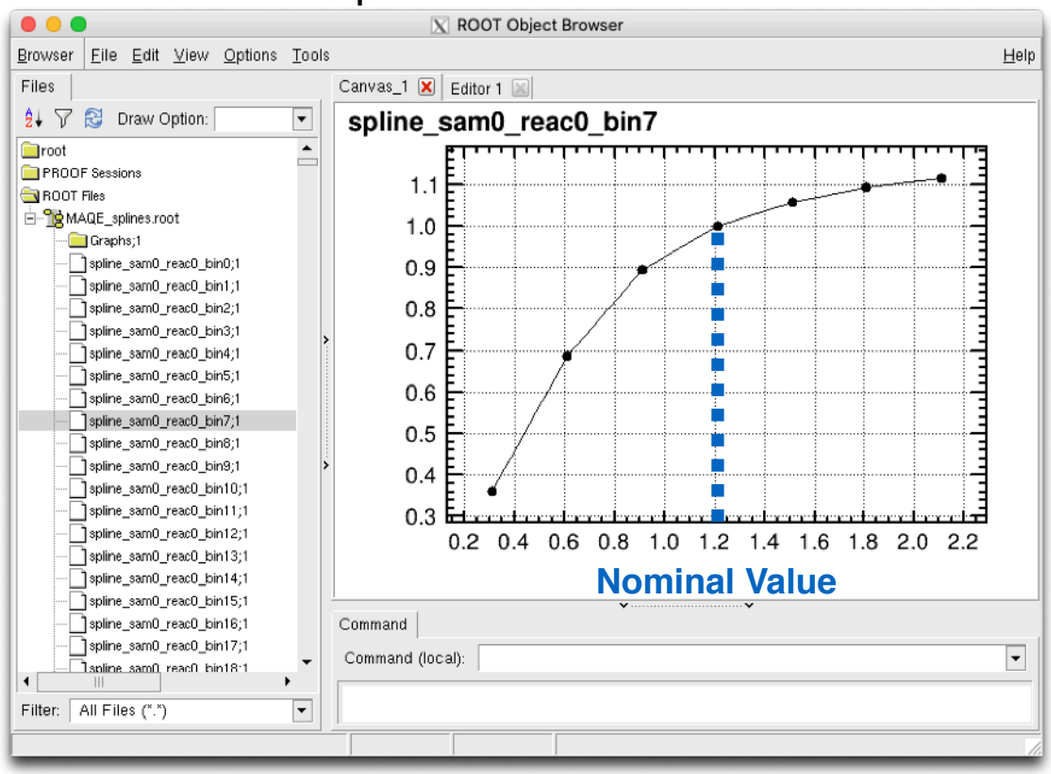
Fixing X-Axis Scale on Splines

- In **xsllhFitter** the X-axis of the spline (representing the variation of the nuisance parameter) **is actually an absolue scale**

- But **BANFF** X-axis are expressed in term of relative deviation right ?
  - All splines are centred at 0
  - The X=0 point represents the nominal value
  - Do non-zero values are scaled by the error (sigma), or in relative deviation ? -> **Well… It depends !**

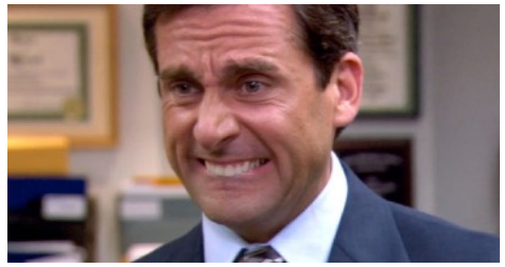
```
// CCQE:
rw.Systematics().SetAbsTwk(t2krew::kNXSec_MaCCQE);

// CC and NC single pion resonance:
rw.Systematics().SetAbsTwk(t2krew::kNXSec_CA5RES);
rw.Systematics().SetAbsTwk(t2krew::kNXSec_MaRES);

// Use the separate iso half background dials
rw.Systematics().SetAbsTwk(t2krew::kNXSec_BgSclRES);
rw.Systematics().SetAbsTwk(t2krew::kNXSec_BgSclLMCPiBarRES);

// All other CC and NC
// Ed's CC DIS dials for 2020 Analysis
rw.Systematics().SetAbsTwk(t2krew::kNIWG_DIS_BY_corr); //Bodek-Yang (BY) corrections on,
rw.Systematics().SetAbsTwk(t2krew::kNIWG_MultiPi_BY_corr); //Bodek-Yang (BY) corrections on/off for Mu
rw.Systematics().SetAbsTwk(t2krew::kNIWG_MultiPi_Xsec_AGKY);

rw.Systematics().SetAbsTwk(t2krew::kNIWG_rpaCCQE_norm);
rw.Systematics().SetAbsTwk(t2krew::kNIWG_rpaCCQE_shape);

// FSI dials
rw.Systematics().SetAbsTwk(t2krew::kNCasc_FrAbs_pi);
rw.Systematics().SetAbsTwk(t2krew::kNCasc_FrCExLow_pi);
rw.Systematics().SetAbsTwk(t2krew::kNCasc_FrInelLow_pi);
```

- xsllhFitter spline file:



Wait… Does this means these specific systematics are expressed in absolute, not relative ?

In fact no ! **“Absolute” means the fractional uncertainty (what I called “relative”)**, instead of “in units of sigma”



- By default, components are scaled in unit of sigmas
- But some are set on a relative scale

Fixing X-Axis Scale on Splines

- Alright ! Lets plug this new changes into the fitter
- However, some systematic parameters which are label as “relative” have a nominal value of 0

```
rw.Systematics().SetAbsTwk(t2krew::kNIWG_DIS_BY_corr); //Bodek-Yang (BY) corrections on/off for DIS events i.e. for W > 2 GeV
  rw.Systematics().SetAbsTwk(t2krew::kNIWG_MultiPi_BY_corr); //Bodek-Yang (BY) corrections on/off for MultiPi events i.e. for W < 2 GeV
  rw.Systematics().SetAbsTwk(t2krew::kNIWG_MultiPi_Xsec_AGKY);
```

Parameter Name	Type	Nominal	Prior	Bounds	Type	Reference
CC DIS BY	Spline, T2KRW, DIS events (W < 4.0)	0.0	0.0±1.0	-9999 to +9999	Gaussian	Ed's talk
CC Multi-pi BY	Spline, T2KRW, MPi events (1.6 < W < 2.0)	0.0	0.0±1.0	-9999 to +9999	Gaussian	
CC AGKY Mult.	Spline, T2KRW, MPi events (1.6 < W < 2.0)	0.0	0.0±1.0	-9999 to +9999	Gaussian	

Ed Atkin 7:23 PM

so basically because the DIS/MultiPi BY and the MultiPi Xsec AGKY are meant to cover some binary uncertainty between models, how I parameterised it was the 1 sigma error is the envelope which covers the difference between the two models. So for the BY dials that's the difference between us applying Bodek-Yang corrections (which is what we use in the production) and not using the Bodek-Yang corrections to the DIS/MPi PDFs. Then for the MultiPi Xsec AGKY it's us changing the MPi cross-section from when we use the NEUT multiplicity model to the AGKY multiplicity model (the GENIE default pion-multiplicity model).

So basically then the dials work is parameter = 0 + dial_value*(1 sigma uncertainty) where 0 is the NEUT nominal

- **Then these 3 components shouldn’t be labeled as relative variation**
- Should it be corrected for the BANFF ?

Asimov Fit Attempt

- Fix non-Zero Asimov chi^2 - **Solved**

```
[XsecFitter]: Func Calls: 1
[XsecFitter]: Chi2 total: 4220.86
[XsecFitter]: Chi2 stat : 4220.86
[XsecFitter]: Chi2 syst : 0
```

Old

```
[XsecFitter]: Calling Minimize, running Migrad
Minuit2Minimizer: Minimize with max-calls 1000000000 convergence for edm < 0.0001 strategy 1
[XsecFitter]: Chi2 contribution from par_flux is 0
[XsecFitter]: Chi2 contribution from par_xsec is 0
[XsecFitter]: Chi2 for sample CC0pi is 8.95294e-15
[XsecFitter]: Chi2 for sample CC1pi is 5.3819e-16
[XsecFitter]: Chi2 for sample CCOther is 2.10329e-16
[XsecFitter]: Func Calls: 1
[XsecFitter]: Chi2 total: 9.70146e-15
[XsecFitter]: Chi2 stat : 9.70146e-15
[XsecFitter]: Chi2 syst : 0
[XsecFitter]: Chi2 reg  : 0
```

New

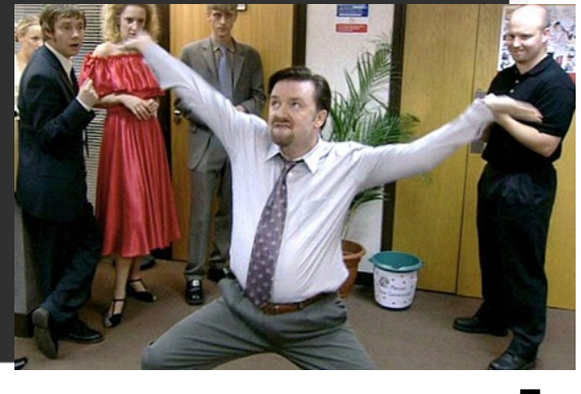
- Still non-zero, but very close tho
  - This is because when TGraphs are converted to splines, the weight at the nominal value is not exactly 1

- Fix convergence problem - **Solved**

```
[XsecFitter]: Chi2 for sample CCOther is 1.98444e-05
[XsecFitter]: Func Calls: 8000
[XsecFitter]: Chi2 total: 0.00882119
[XsecFitter]: Chi2 stat : 0.00853697
[XsecFitter]: Chi2 syst : 0.000284222
[XsecFitter]: Chi2 reg  : 0
[XsecFitter]: Chi2 contribution from par_flux is 2.25628e-28
[XsecFitter]: Chi2 contribution from par_xsec is 0.000284217
[XsecFitter]: Chi2 for sample CC0pi is 0.00874508
[XsecFitter]: Chi2 for sample CC1pi is 4.05344e-05
[XsecFitter]: Chi2 for sample CCOther is 2.04701e-05
[XsecFitter]: Func Calls: 9000
[XsecFitter]: Chi2 total: 0.0090903
[XsecFitter]: Chi2 stat : 0.00880609
[XsecFitter]: Chi2 syst : 0.000284217
[XsecFitter]: Chi2 reg  : 0
Info in matrix forced pos-def by adding to diagonal : padd = 0.0235792
Info: MnHesse: matrix was forced pos. def.
Info in Minuit2Minimizer::Hesse : Hesse is valid - matrix is full but made positive defined
[XsecFitter]: Hesse converged.
[XsecFitter]: Status code: 1
[XsecFitter]: Fit routine finished. Results saved.
[xsFit]: Fit has converged.
[XsecFitter]: Writing Covariance Matrices...
[xsFit]: ありがとうございました！
(END)
```

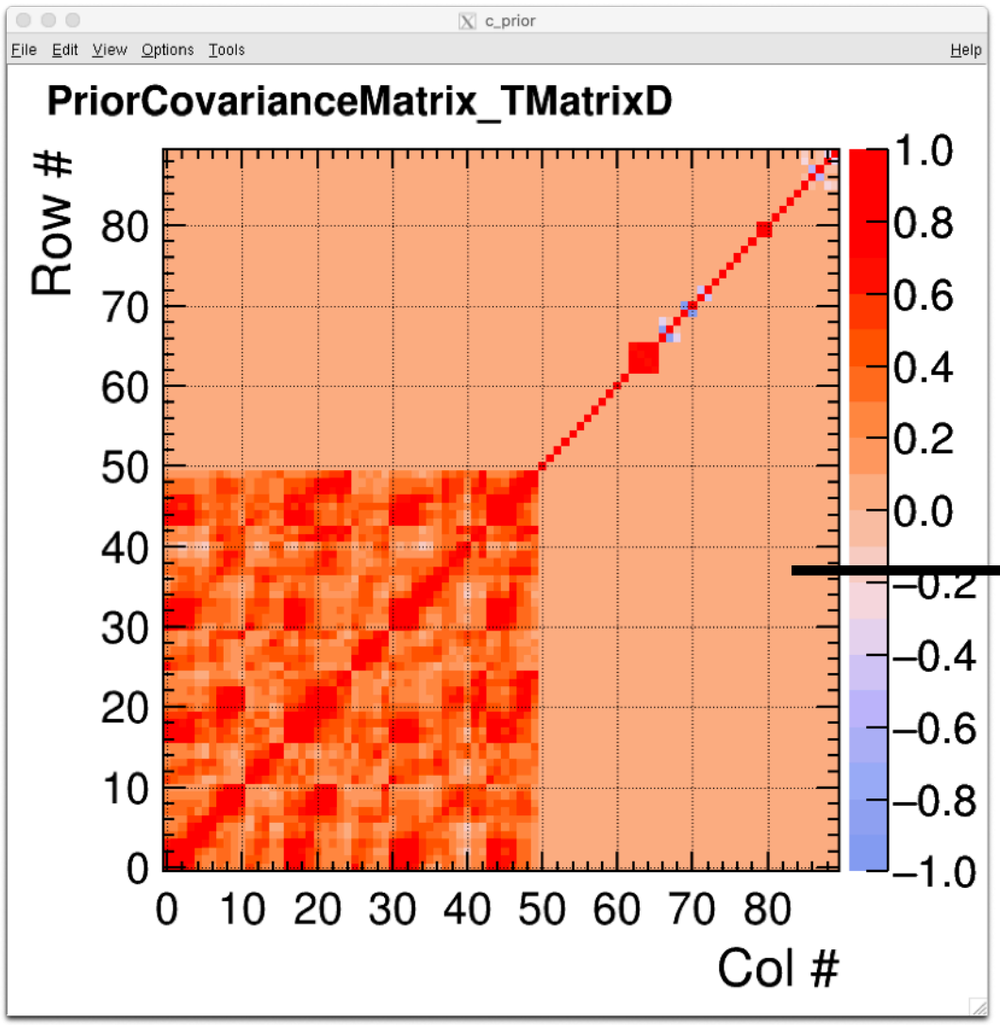
The best fit has been found at the nominal value for each systematic

```
par_flux_ND280_46         = 1    +/-  0.0209633
par_flux_ND280_47         = 1    +/-  0.028161
par_flux_ND280_48         = 1    +/-  0.0303292
par_flux_ND280_49         = 1    +/-  0.0662324
ND280_MAQE        = 1.21          +/-  0.0236027
ND280_2p2h_norm_nu        = 1    +/-  0.0539864
ND280_2p2h_norm_nubar     = 1    +/-  0.0539864
ND280_2p2h_normCtoO       = 1    +/-  0.00216418
ND280_2p2h_Edep_lowEnu    = 1    +/-  0.973508
ND280_2p2h_Edep_highEnu   = 1    +/-  0.819112
ND280_2p2h_Edep_highEnubar        = 1    +/-  0.959664
ND280_Q2_norm_0   = 1    +/-  0.00147355
ND280_Q2_norm_1   = 1    +/-  0.00113836
ND280_Q2_norm_2   = 1    +/-  0.000915348
ND280_Q2_norm_3   = 1    +/-  0.0012181
ND280_Q2_norm_4   = 1    +/-  0.0013857
ND280_EB_dial_C_nu        = 0    +/-  1.68528
ND280_EB_dial_C_nubar     = 0    +/-  1.68528
ND280_EB_dial_O_nu        = 0    +/-  1.68528
ND280_EB_dial_O_nubar     = 0    +/-  1.68528
ND280_CA5         = 1.01          +/-  0.0254507
ND280_MARES       = 0.95          +/-  0.0216022
ND280_ISO_BKG     = 1.3  +/-  0.0514064
ND280_CC_norm_nu          = 1    +/-  1.96012e-05
ND280_CC_norm_nubar       = 1    +/-  8.38565e-06
:
```



Asimov Fit Attempt

Prior

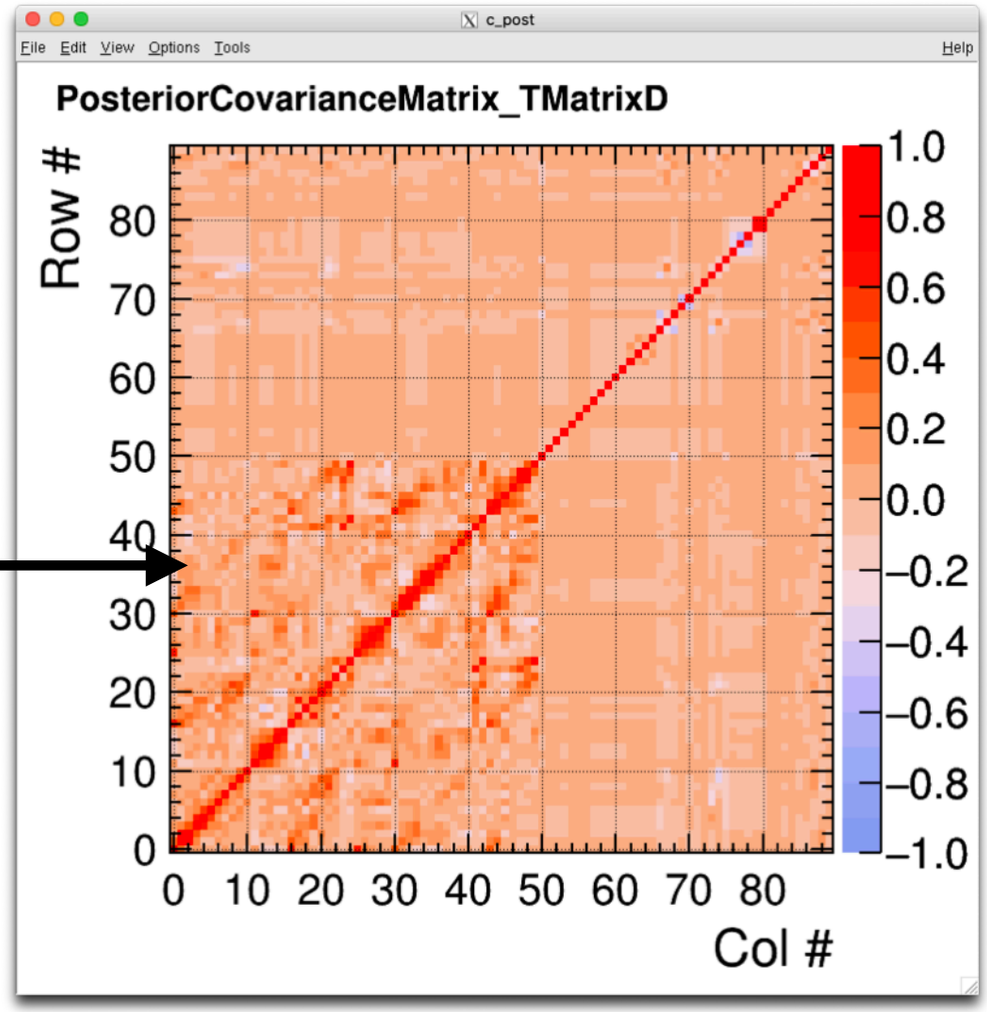


ND280 flux param.

X-sec params.

Fit

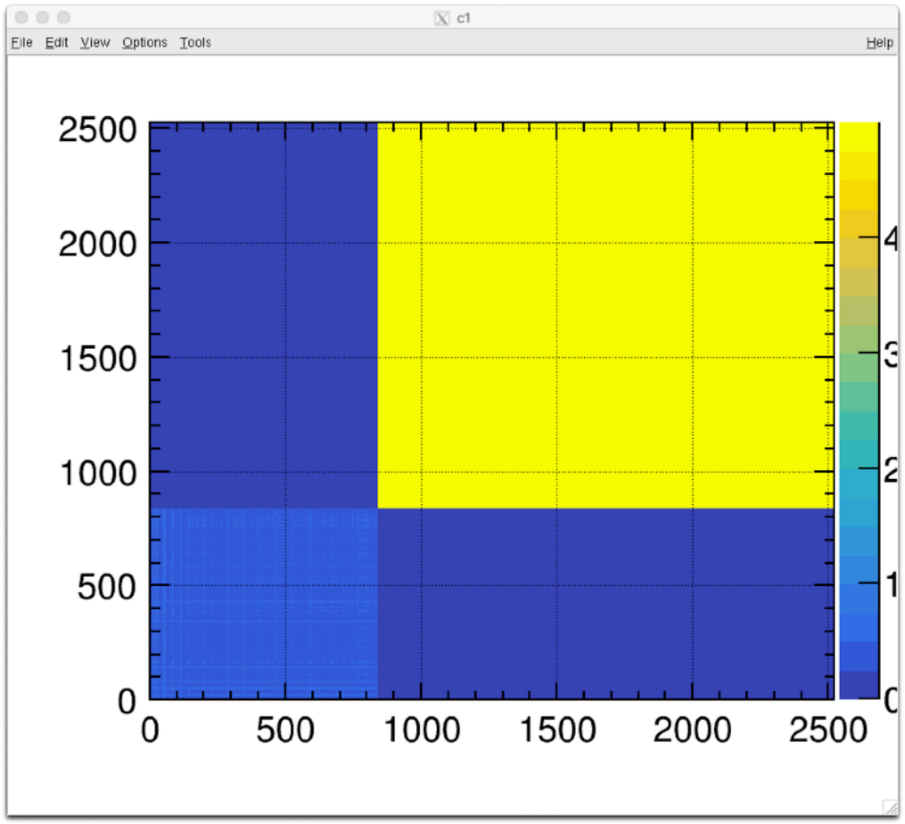
Posterior



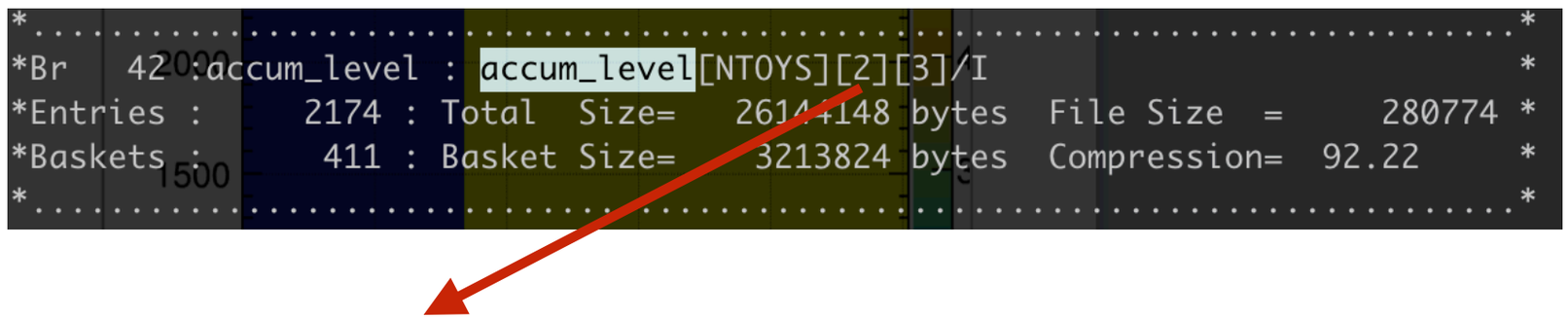
Building the Detector Covariance Matrix

- **ND280Up Fit**
  - **Add detector covariance matrix**
    - Highland has been ran on all MC files
    - Need to generate the covariance matrix with “xsllhDetVariations”
      - Strange segfault happens -> some c++ objects are getting lost along the way **- Fixed**
      - May be due to a lack of copy constructor in the struct handling all the inputs **- Done**

- **The generated matrix has a strange shape**
  - The yellow brick correspond to CC1Pi/CCOther samples
  - The covariance matrix should be expressed is relative variation of each p_mu/cos_theta_mu bin
  - A lot of values are above 1

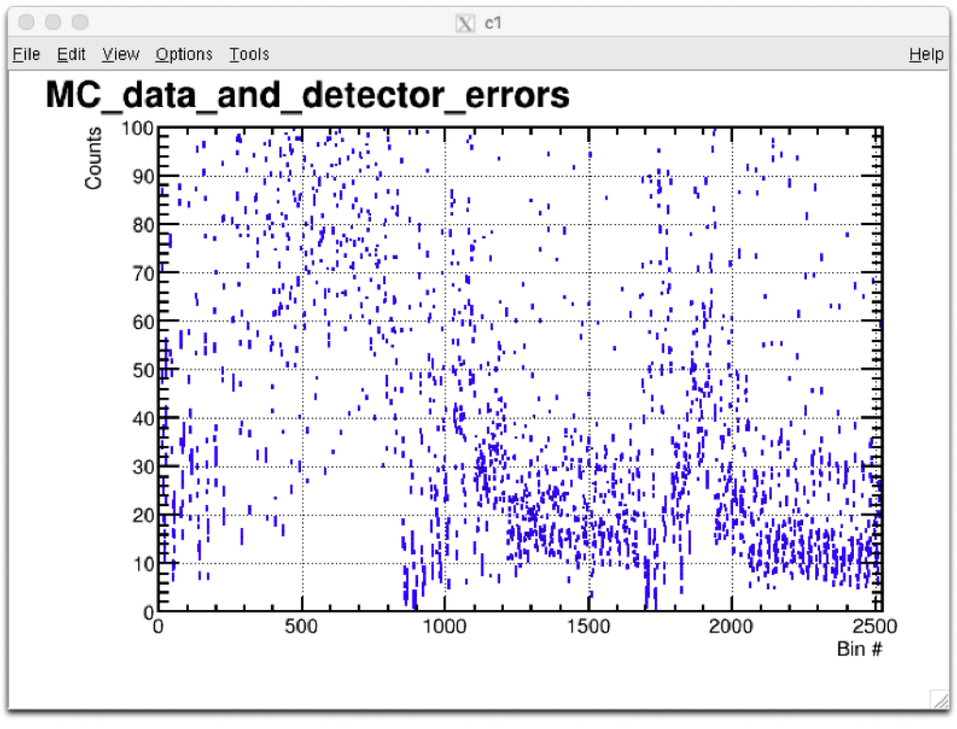


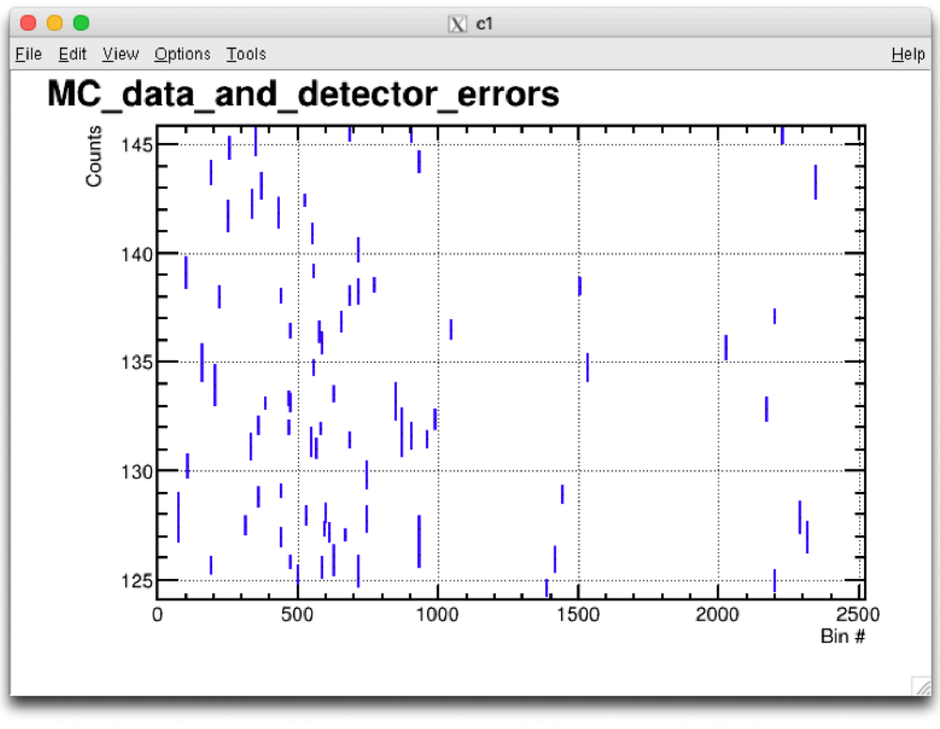
Building the Detector Covariance Matrix



- **This index refers to FGD1 and FGD2**
  - It was not implemented xsllhDetVariation
  - Now the program is looping over the 2 FGDs to compute the covariance

- **Checking the values**
  - In xsllhDetVar, implemented histograms to monitor the uncorrelated uncertainty in each bin on an absolute scale
  - The order of magnitude for each diagonal term varies from few % to ~40 %

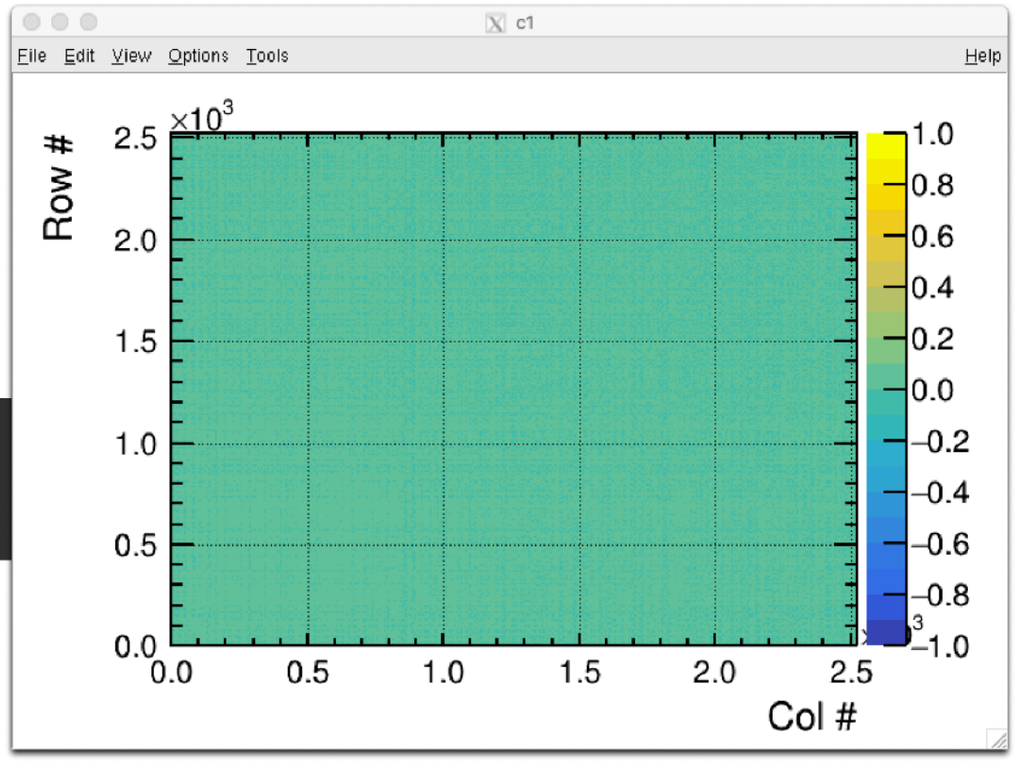




Inverting Detector Covariance Matrix

- **The matrix isn't invertible**
  - This was expected since the matrix is binned on the p_mu, cos_theta_mu
  - Since the number of detector parameters is lower than the number of bins, some Eigen values must be vanishing

```
root [5] covariance_matrix->Invert()
Error in <TDecompLU::DecomposeLUCrout>: matrix is singular
Error in <TDecompLU::InvertLU>: matrix is singular, 1 diag elements < tolerance of 2.2204e-16
(TMatrixTSym<double> &) Name: TMatrixTSym<double> Title:
root [6]
```

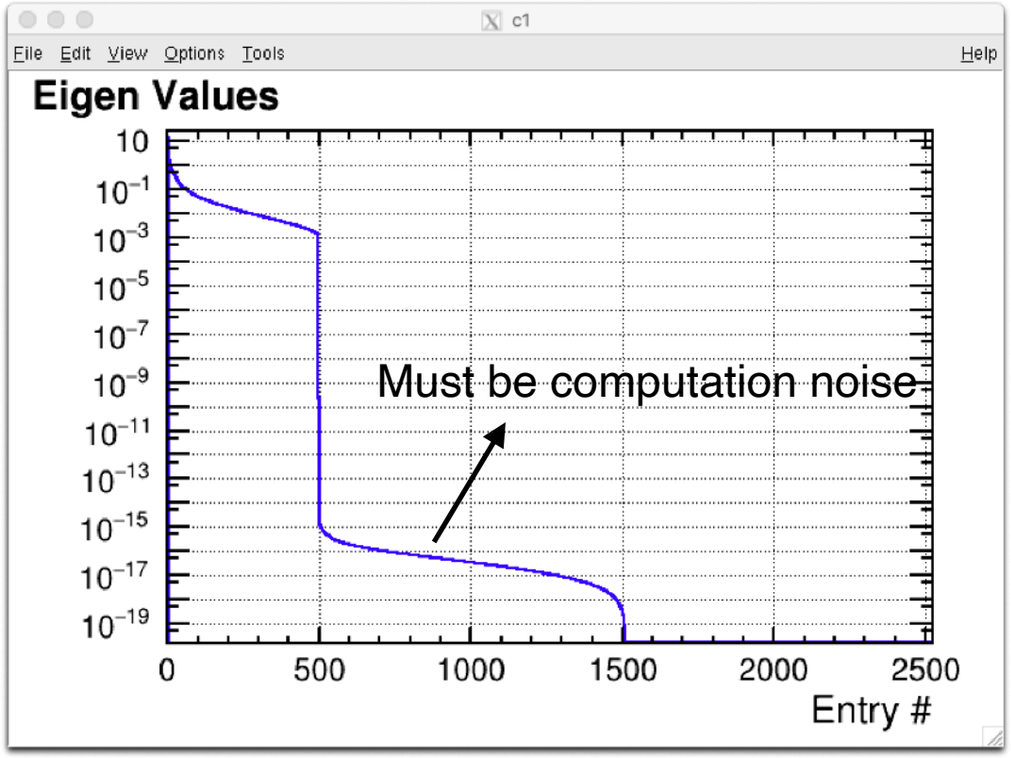


- **Needs to get rid of the extra dof**
  - Implementing SVD matrix inversion

$$V = \sum_i^{N_b} \lambda_i \left|u_i\right\rangle \left\langle u_i\right| \longrightarrow V^{-1} = \sum_i^{N_b} \frac{1}{\lambda_i} \left|u_i\right\rangle \left\langle u_i\right|$$

Eigen values — Eigen vectors

- We can ignore the pathological degree of freedom by removing them from the sum
- Applying a cut-off when the Eigen value is lower than 10^-5 times the highest value
- *Projecting the data on the remaining dof might be necessary (ignored at the moment)*



Fitting with All the Systematics

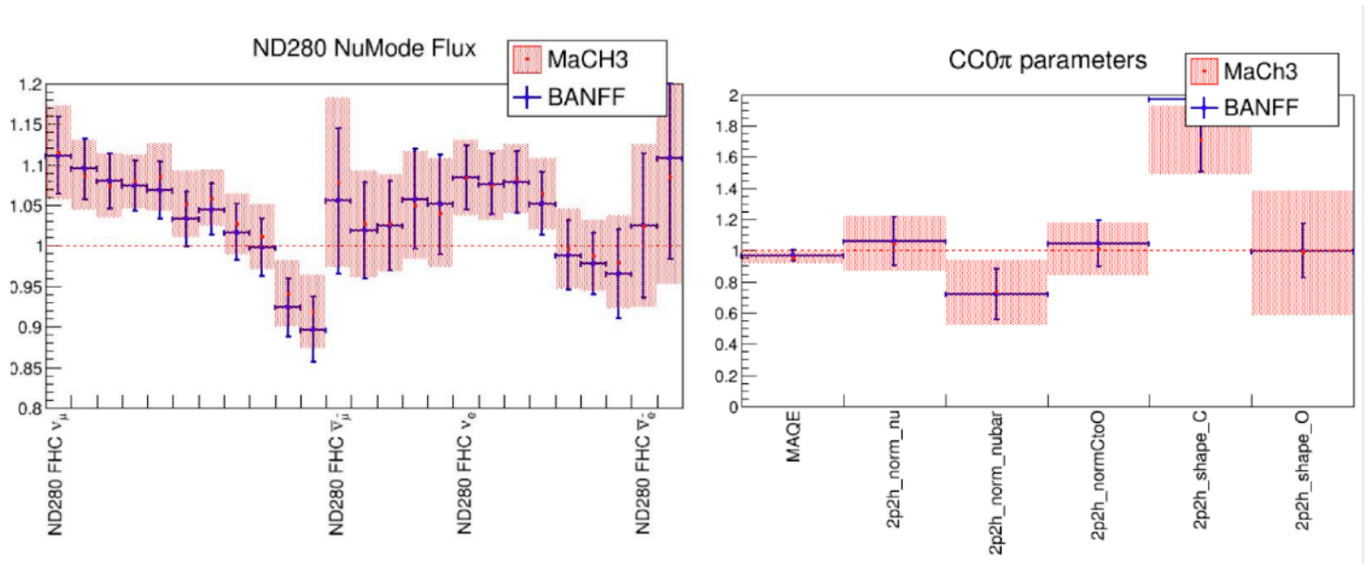
- **Works, but the fitter takes too much time**
  - CPU time limit has been reached on the CC Lyon
  - Even the “long” queue is not enough due to the parallelisation
  - The fitter reached 37000+ steps

- **Needs to be cleaver on how the detector parameters are propagated**
  - Need to make the fitter play with only the non-vanishing parameters (like the BANFF does with PCA ?) **- Now Done**

```
xslllhFit -j config_Fit.json
/var/spool/sge/ccwsge0872/job_scripts/12742120: line 10:  3490 CPU time limit exceeded xslllhFit -j config_Fit.json &
>/sps/t2k/ablanche/work/jobs/logs/xslllhFit//log_20200611_094433_xslllhFit_config_Fit.log
**********************************************************************
COMPUTATION FINISHED
**********************************************************************

**********************************************************************
* Submitted on:                  Thu Jun 11 11:44:34 CEST 2020      *
* Started on:                    Thu Jun 11 11:44:45 CEST 2020      *
* Ended on:                      Thu Jun 11 21:52:28 CEST 2020      *
* Exit status:                   0                                  *
**********************************************************************
* Requested                                                         *
*   CPU cores:                   1 core(s)                          *
*   CPU time:                    23:59:59 (86399 seconds) (1)       *
**********************************************************************
* Consumed                                                          *
*   wallclock:                   10:07:43 (36463 seconds)           *
*   CPU time:                    23:57:19 (86239 seconds)           *
*   CPU scaling factor:          10.87                              *
*   normalized CPU time:         260:23:45 (937425 HS06 seconds)    *
*   CPU efficiency:              236 % (2)                          *
*   vmem:                        1.289 GB (3)                       *
*   maxvmem:                     1.399 GB (3)                       *
*   maxrss:                      932.270 MB (3)                     *
**********************************************************************
Notes:
(1) Formula: requested CPU time * requested CPU cores
(2) Formula: CPU time / ( wallclock * requested CPU cores )
(3) See man sge_accounting
```

What's Next ?

- **ND280Up Fit**
  - Implement proper PCA **- Done**
  - Validation with BANFF data



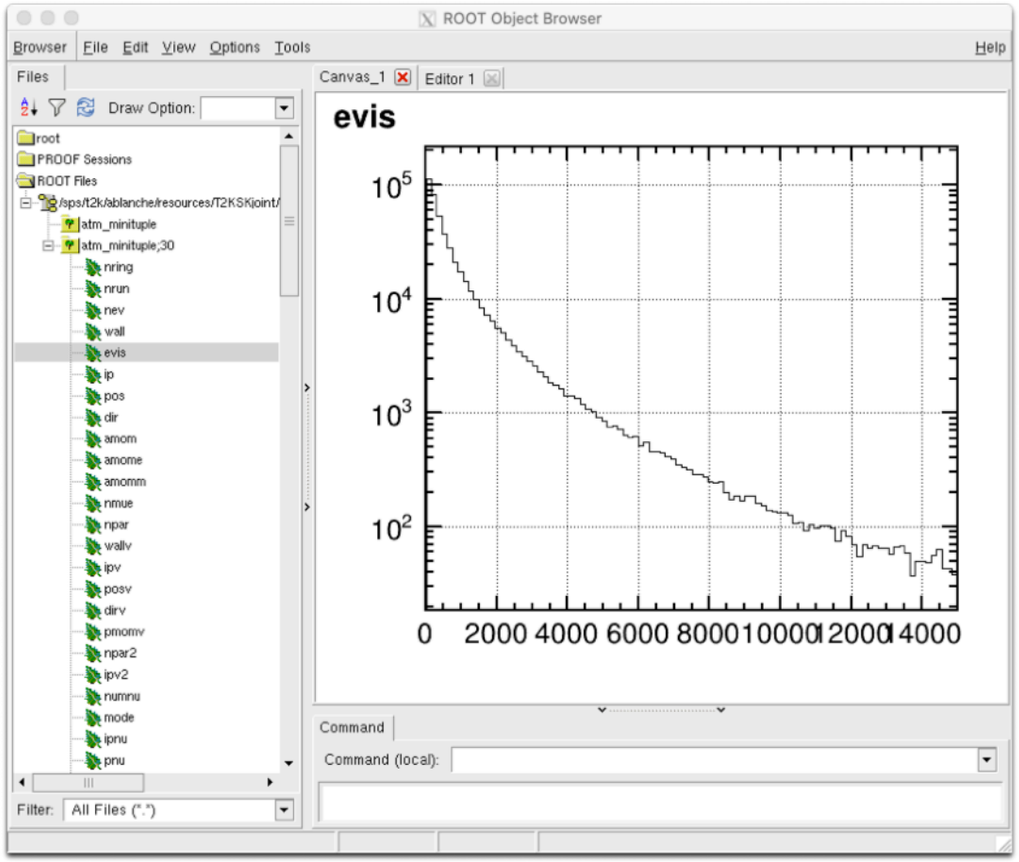
  - Perform a fit with the upgrade MC
    - Keep all systematics
    - Change the phase space to dpT/dalphaT

- **Postponed tasks**
  - ND280Up Fit : Include antineutrino to the Fit
  - ND280Up Fit : Implement better indexing of splines
  - X-section splines generation : Generate Validation Plots

T2K-SK Joint Fit

SK MC Files

- **Roger provided us the ntuple containing the atmospheric MC neutrino data**
  - ~500,000 entries
  - The format is similar with the beam data
  - For the new branches, Roger provided a README file describing how we a supposed to use them
  - The events selection is described in:
    - [M. Jiang et al. PTEP 053F01 (2019)]



README.txt — Open with TextEdit

```
##
#  20200503
#  Questions can be made to roger:
#  raw@scphys.kyoto-u.ac.jp
#

This file contains a ROOT tree ("atm_minituple") summarizing the atmospheric neutrino MC from SK-4.
The variables in the tree closely follow the T2K "minituple" structure, but have
several new variables used to describe the atmospheric neutrino event selection.

The event selection itself corresponds to that in:
M. Jiang et al. PTEP 053F01 (2019):

ATMPDEventType is a variable that encodes the selected type for each event:

            SubGeV_elike_0dcy = 1,
            SubGeV_elike_1dcy,
            SubGeV_SingleRing_pi0like,
            SubGeV_mulike_0dcy,
            SubGeV_mulike_1dcy,
            SubGeV_mulike_2dcy,
            SubGeV_pi0like,
            MultiGeV_elike_nue,
            MultiGeV_elike_nuebar,
            MultiGeV_mulike,
            MultiRing_elike_nue,
            MultiRing_elike_nuebar,
            MultiRing_mulike,
            MultiRingOther_1,
            PCStop,
            PCThru,
            UpStop_mu,
```

First Step : Reproducing the Spectra from SK-IV Paper

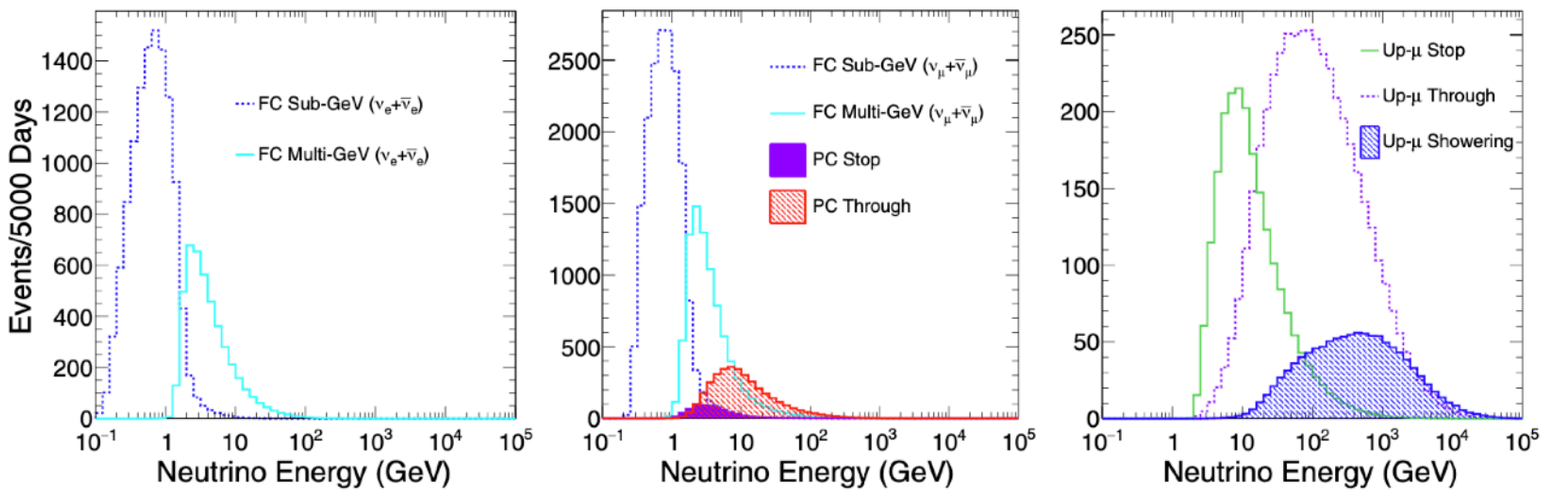


FIG. 6. True Super-K atmospheric neutrino energy spectra from simulation without oscillations.

- **Reproducing FC Sub-GeV nue/nue_bar spectrum**
- **Cuts :**
  - AnaEventType : *SubGeV_elike_0dcy* or *SubGeV_elike_1dcy*
  - Number of reconstructed rings : *1*
  - PID : *electron*
  - Vertex distance to the wall : *> 50cm* (expanded FV)
- **Normalisation :**

$$\textbf{osc weight 3 flavors} \times \textbf{solar activity weight} \times 3244.4/365.25 \times 1/100.0$$

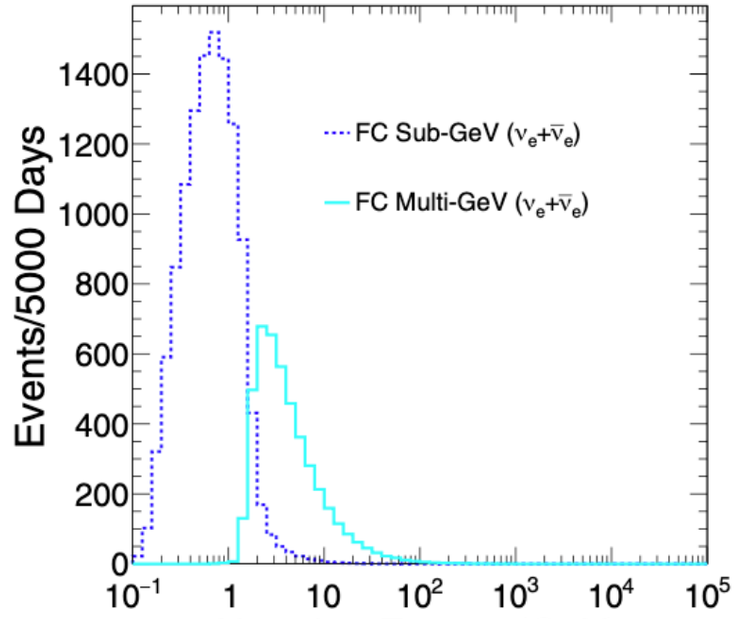
SK livetime

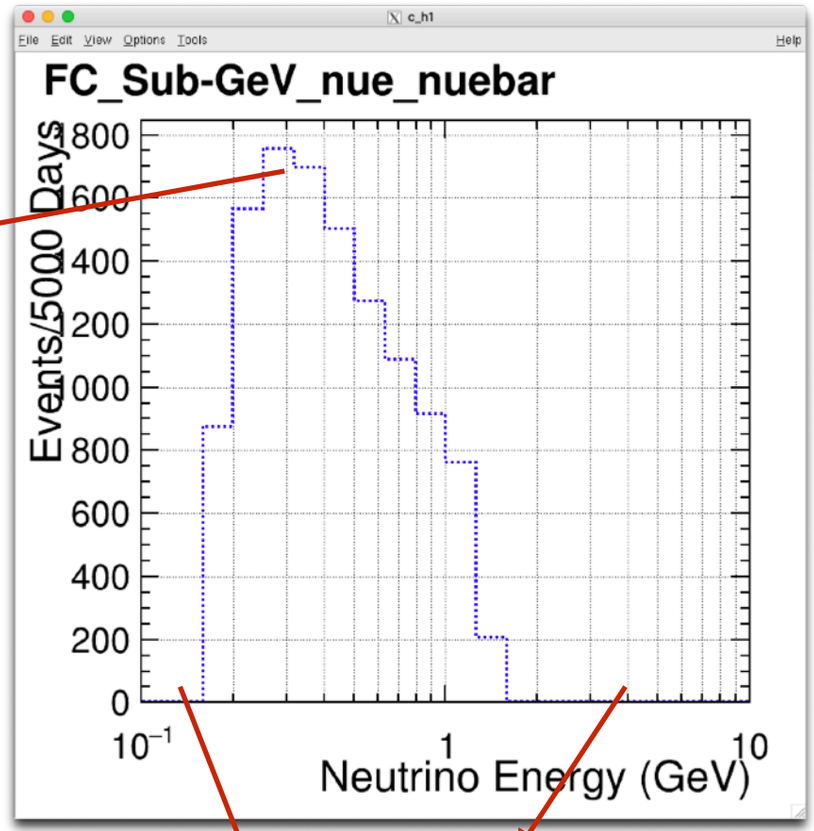
MC has been produced with x100 stat

- **Observable :**
  - Neutrino energy isn't available : use of the CCQE formulae to get it from the momentum

First Step : Reproducing the Spectra from SK-IV Paper

- **Distributions are different:**





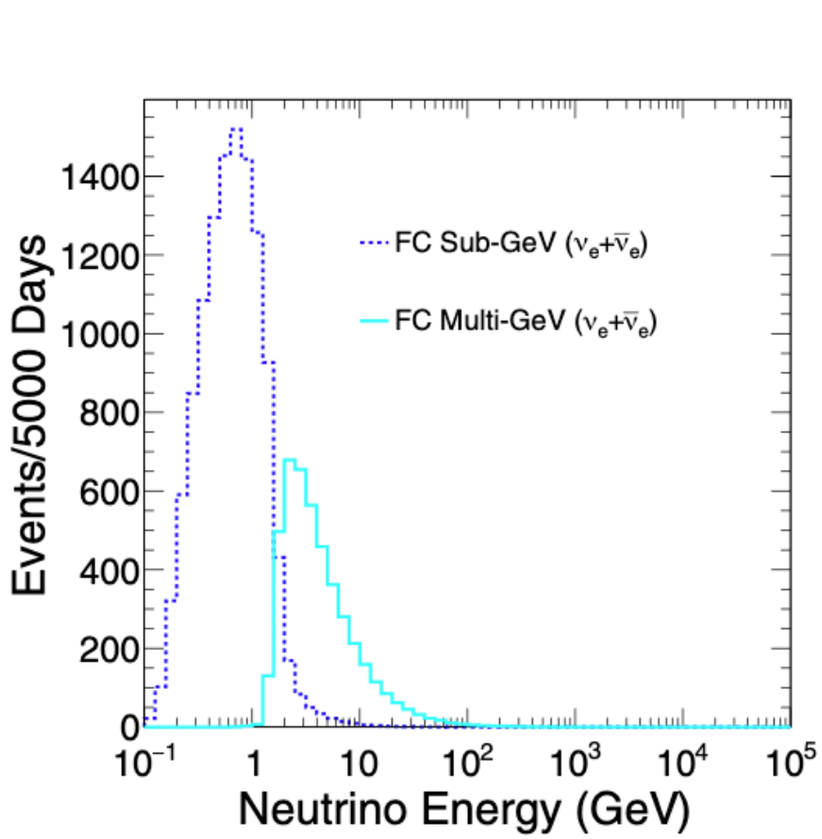
Misplaced peak
Need to weight with the detection efficiency ?

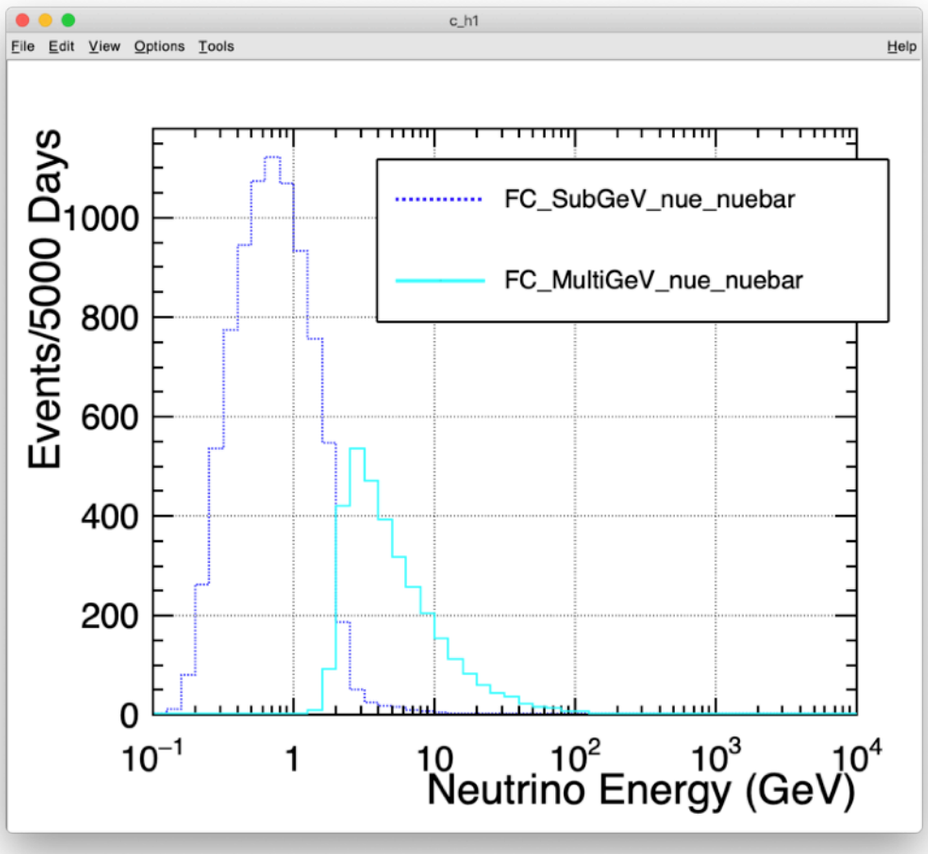
Lack of events : wrong cuts applied

First Step : Reproducing the Spectra from SK-IV Paper

- **After Monday's meeting, Roger updated the ntuples and the README with more details**
  - Now we have access to the truth informations
  - Proper re-weighting variables for the oscillation

- **What's left we need ?**
  - PC events are not included at the moment
  - Production altitude will be included





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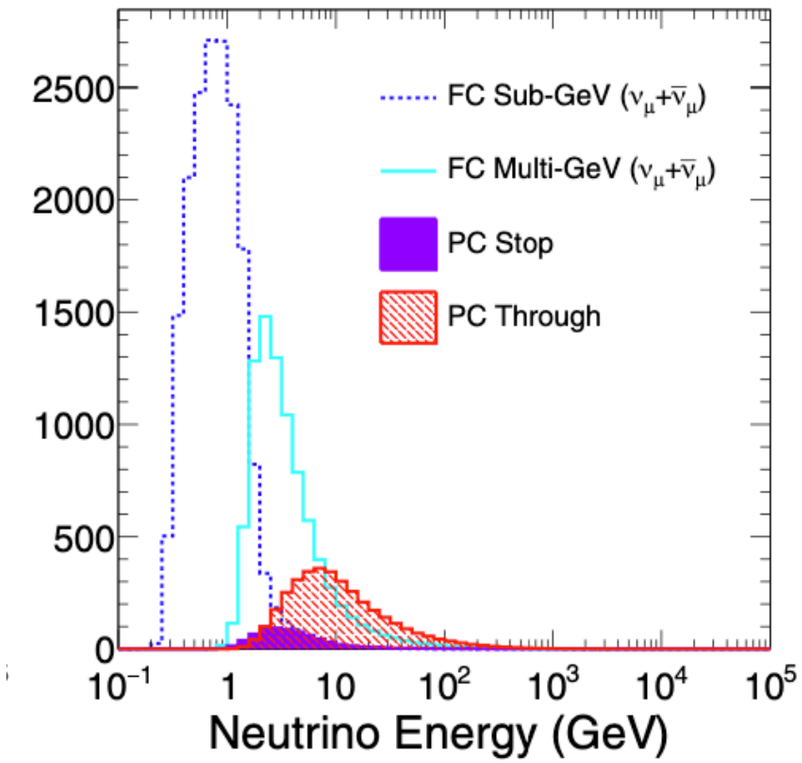

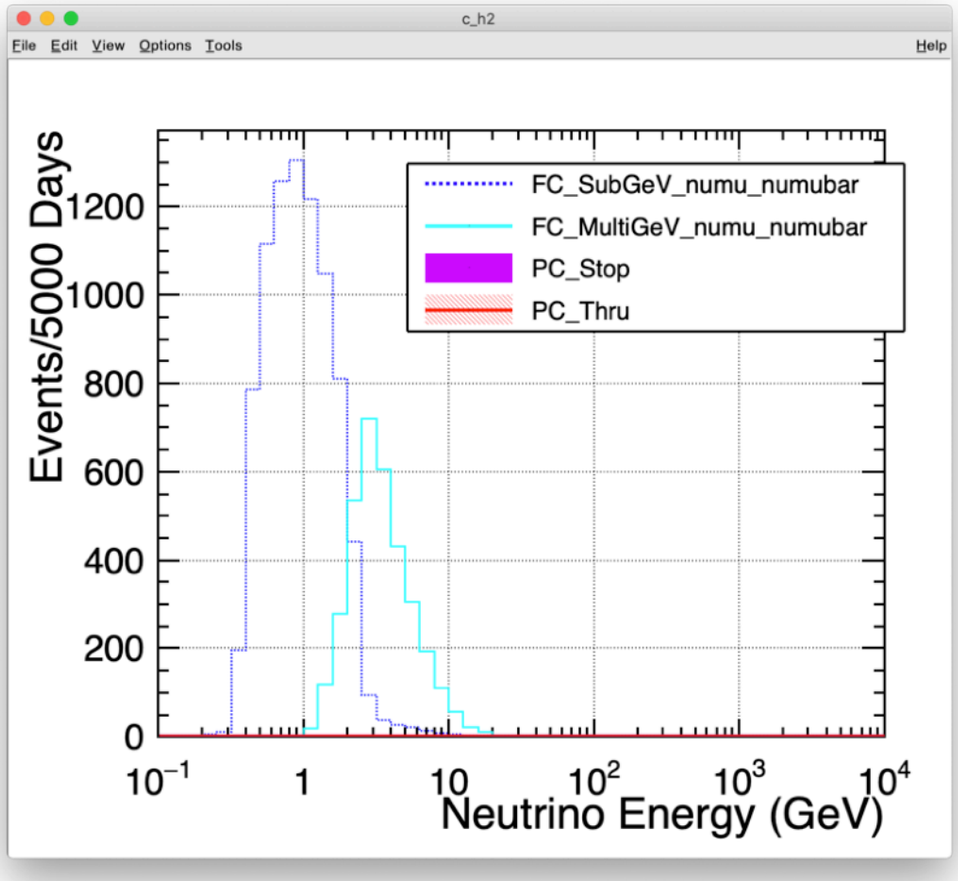

Thanks for Listening