Study of ν_e samples in ND280 with GUNDAM

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Hyper Kamiokande Collaboration Meeting

1 Introduction

2 The ν_e selection in highland

3 The ν_e samples implementation in GUNDAM

4 Results obtained

The context of my work

- ND280 ν_μ ($\overline{\nu}_\mu$) samples used to constrain Φ and x-section of ν ($\overline{\nu}$)
- Correlation matrix propagated to the fit performed at the Far Detector
- No ν_e samples selected at ND280 :
  - The same model of x-sec for ν_e ($\overline{\nu}_e$) and ν_μ ($\overline{\nu}_\mu$) is put in the Far Detector fit
  - $\sigma(\nu_e)/\sigma(\nu_\mu)$ ($\sigma(\overline{\nu}_e)/\sigma(\overline{\nu}_\mu)$) and their correlations only constrained with the theory
- Couldn't we put experimental constraints, especially thanks to the upgrade of ND280 ?

The ν_e production

Particle	Decay Products	Branching Fraction (%)
π^+	$\rightarrow \mu^+\nu_\mu$	99.9877
	$\rightarrow e^+\nu_e$	1.23×10^{-4}
K^+	$\rightarrow \mu^+\nu_\mu$	63.55
	$\rightarrow \pi^0\mu^+\nu_\mu$	3.353
	$\rightarrow \pi^0 e^+\nu_e$	5.07
K_L^0	$\rightarrow \pi^-\mu^+\nu_\mu$	27.04
	$\rightarrow \pi^- e^+\nu_e$	40.55
μ^+	$\rightarrow e^+\overline{\nu}_\mu\nu_e$	100

- ν_e represent $\approx 1\%$ of the total ν flux at ND280

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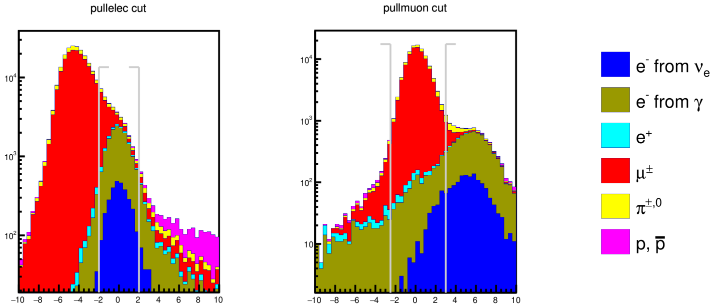
The ν_e selection procedure in the current ND280

- The selection is available in *highland*
- Consists in 17 different cuts that are applied with 2 main ideas :
  - Select electrons among the other charged particles (protons, muons, pions) thanks to the energy deposit information as a function of momentum
  - Distinguish the electrons originating from ν_e from the ones that are coming from $\gamma \to e^+e^-$ conversions thanks to pair tracking, invariant mass measurement and cut on low energy events



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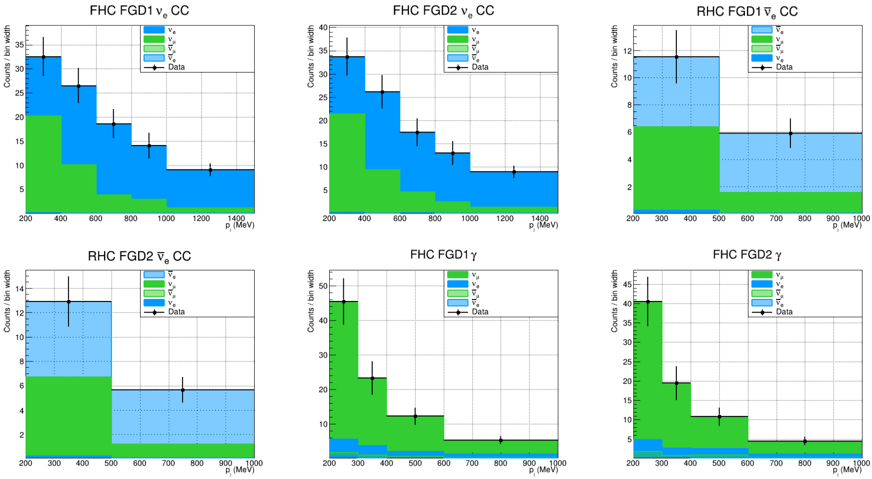
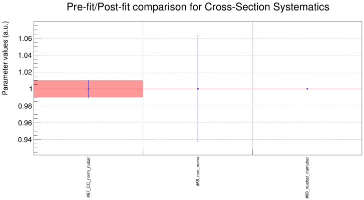
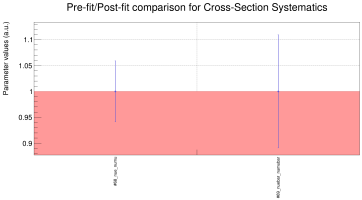
The samples


FHC FGD1 νe CC
FHC FGD2 νe CC
RHC FGD1 ν̄e CC
RHC FGD2 ν̄e CC
FHC FGD1 γ
FHC FGD2 γ
Counts / bin width
p_l (MeV)
νe
νμ
ν̄μ
ν̄e
Data

Preliminary results obtained with current ND280





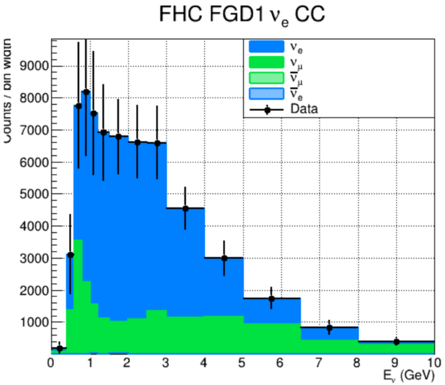
Results of the fit

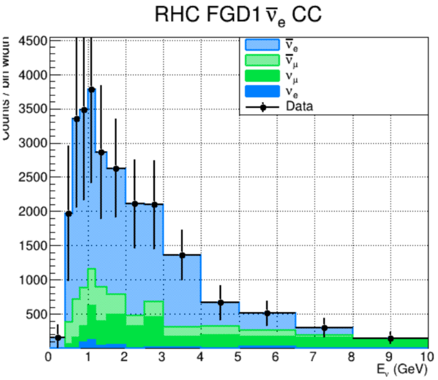
- First, All FHC data ν_e were added to the fit and nue_numu parameter was enabled
- Only flux and xsec parameters were enabled for this fit
- A $\approx 6\%$ constraint on nue_numu parameter was obtained

Adding γ, $\overline{\nu}_e$ and All RHC data

- Next idea was to add also γ and $\overline{\nu}_e$ samples in order to enable nuebar_numubar parameter ($\approx 11\%$ constraint)

ν_e and $\overline{\nu}_e$ samples as a function of true energy

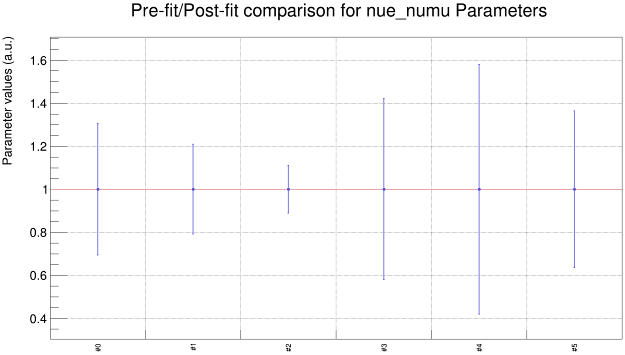


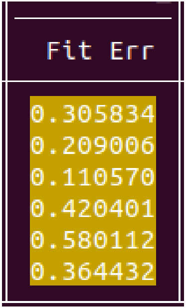


- Next idea is to separate each of nue_numu and nuebar_numubar fit parameters in three different ranges of energy :
  - $[0, 1.2]$ GeV, which corresponds to the range of energy used for the oscillation analysis at SK
  - $[1.2, 2.5]$ GeV, which ends the main peak of initial ν_e energy spectrum
  - $[2.5, 16]$ GeV, for rarer high energy events

Constraints obtained in the different bins

Energy [GeV]	[0, 1.2]	[1.2, 2.5]	[2.5, 16]
nue_numu	#0	#1	#2
nuebar_numubar	#3	#4	#5





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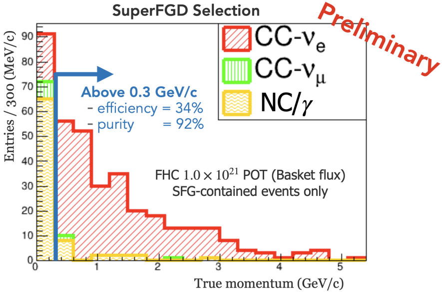
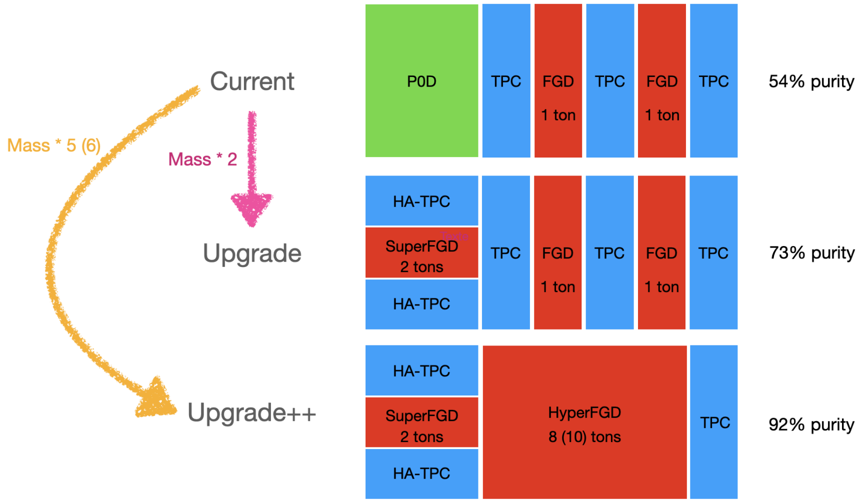
Study as a function of POT weight

- The statistic will increase in the future thanks to the more powerful proton beam, more massive and effitcient near and far detectors
- The idea is to study the impact of this increasing statistic by multiplying the 1.15×10^{21} current POT with different weights
- In addition to these higher statistics the SuperFGD ν_e samples will have 92% purity (for more details see A.Eguchi's slides), as opposed to the 54% we have with current FGD1 and FGD2

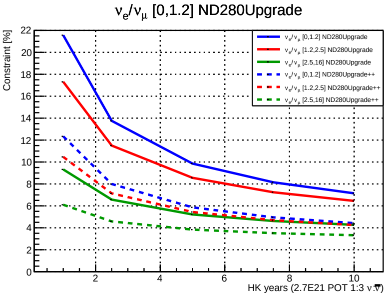


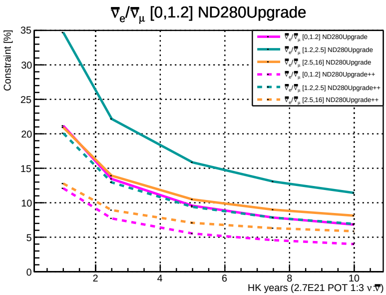
Different upgrade scenarios considered



Evolution as a function of years of HK

- The constraints are improving as current POT is manually increased)

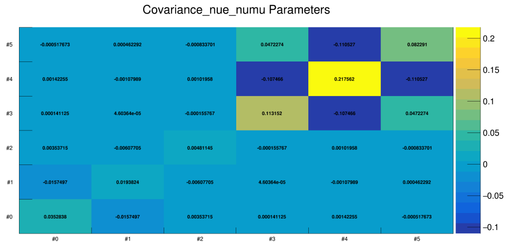


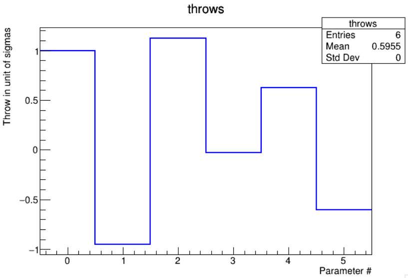


- To do this I consider a purity of 73% for ND280Upgrade and 92% for the so called ND280Upgrade++
- But the impact of these parameters on the sensitivity of HK depends a lot on the fraction of (anti-)correlation between ν_e and $\overline{\nu}_e$, that's why next idea is to evaluate this !

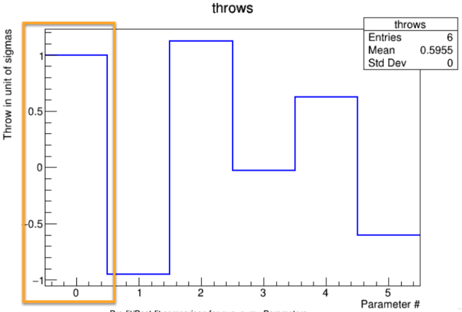
Fraction of (anti-)correlation between ν_e and $\overline{\nu}_e$

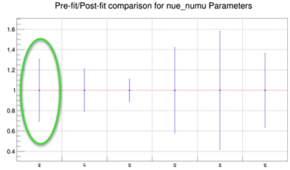
- We take the covariance matrices of ν_e/ν_μ and $\overline{\nu}_e/\overline{\nu}_\mu$ parameters
- And use them to generate 1000 toys per POT value





The procedure to exploit the toys

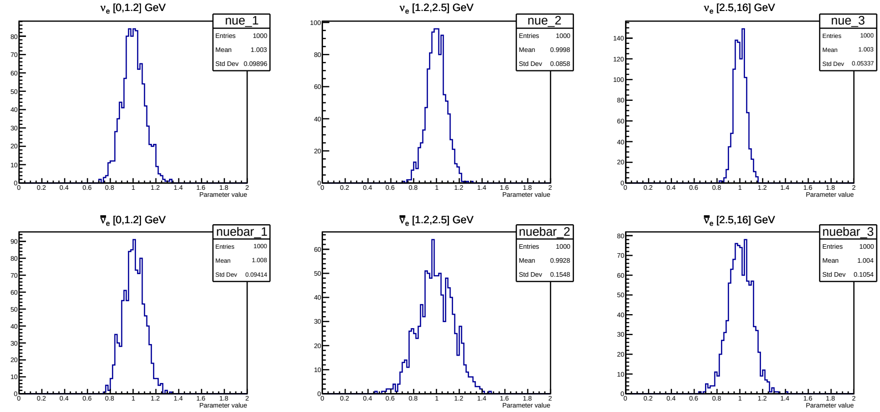




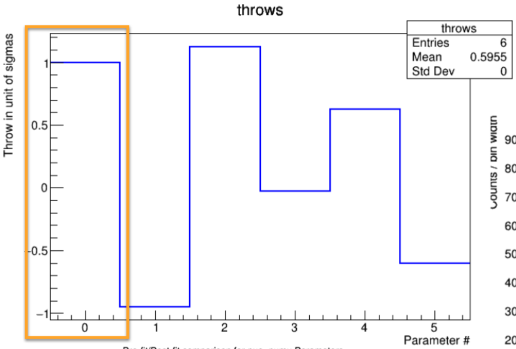
Param. value (toy) * Param. constraint

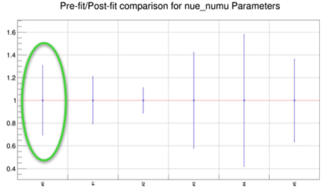
- We take : $1 + Param.value(toy) \times Param.constraint$ in order to get normal distribution centered at 1

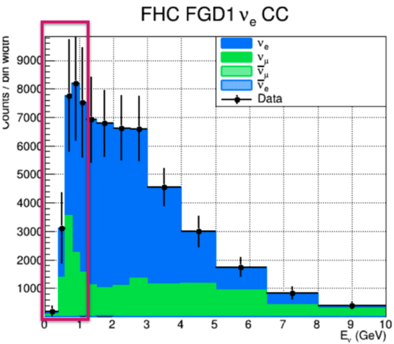
Distributions obtained for each parameter



The $\frac{\nu_e/\nu_\mu}{\overline{\nu}_e/\overline{\nu}_\mu}$ ratio





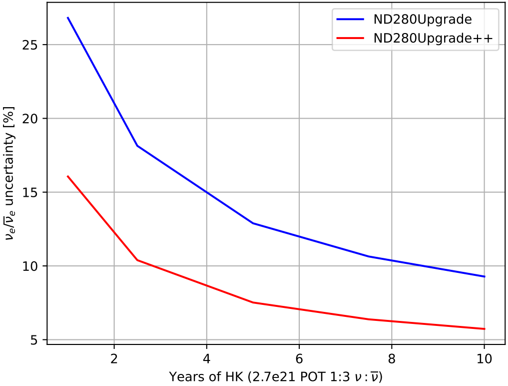


Param. value (toy) * Param. constraint * Stat.

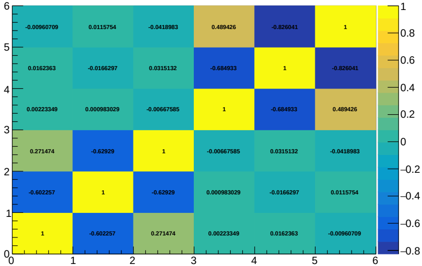
The $\frac{\nu_e/\nu_\mu}{\overline{\nu}_e/\overline{\nu}_\mu}$ ratio in the $[0, 1.2]\,\mathrm{GeV}$ range

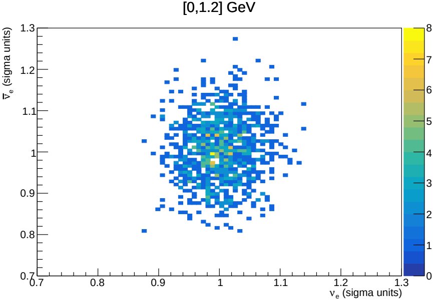
- In order to get the $\frac{\nu_e/\nu_\mu}{\overline{\nu}_e/\overline{\nu}_\mu}$ ratio, I've taken :

$$\frac{(1 + Param.value(toy)_{\nu_e} \times Param.constraint_{\nu_e}) \times Stat._{\nu_e}}{(1 + Param.value(toy)_{\overline{\nu}_e} \times Param.constraint_{\overline{\nu}_e}) \times Stat._{\overline{\nu}_e}}$$



$\nu_e/\overline{\nu}_e$ correlation





- The very good news is that there's no anti-correlation between ν_e and $\overline{\nu}_e$!

Next steps

- Use these constraints in P-Theta (see previous talk of D.Carabadjac)
- I considered the new purities of the samples but I didn't change the efficiency of sample selection
- Therefore even better results should be obtained after having taken that into account !

– Thank you –

– Backup –

Exclusion of *CP* symmetry conservation