STUDIES OF THE LOW-ν METHOD WITH THE SAND NEAR DETECTOR OF THE DUNE EXPERIMENT

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Erasmus Mundus JMD on Nuclear Physics

Introduction to the Low-ν method

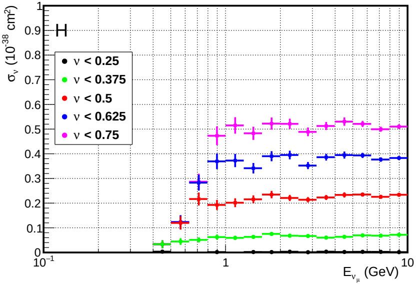
- The aim of the method [1]: Precisely determine the $\nu(\bar{\nu})$ flux at the ND in order to measure the oscillation at the FD.
- The idea of the method, based on the fact that inclusive CC neutrino cross section in the limit of low neutrino energy transfer ($\nu \to 0$) does not depend on the neutrino initial energy.

- Neutrino CC event spectrum for $\nu < \nu_0$ cut can be used to determine the neutrino flux as a function of E_ν:

$$\Phi = \frac{U_\nu(D_\nu - B_\nu)}{C_\nu \cdot \Delta E \cdot NPOTs}$$

$\longrightarrow$ Cross-section:

$$\sigma = k \frac{U(D-B)}{\Phi \cdot \Delta E \cdot T \cdot NPOTs}$$



[1] A. Bodek et al. "Methods to determine neutrino flux at low energies".

Neutrino events spectrum

Selection: CC interactions on CH2

Two ν event samples:

- Flat spectrum: to tune the low-ν method
- The beam sample: to perform the analysis (50% MC/Data)

⟶ Beam flux: 120 GeV proton, 1.1×10^{21} POT/year

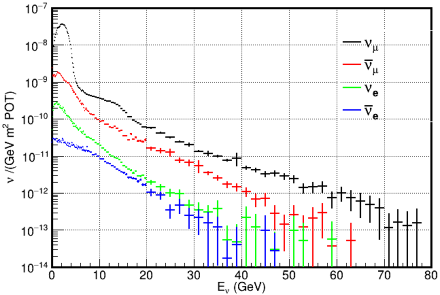
⟶ Geometry: internal STT tracker (nd_hall_kloe_sstonly.gdml provided by Matteo)

⟶ Beam mode: FHC

⟶ Detector: KLOE inner tracker

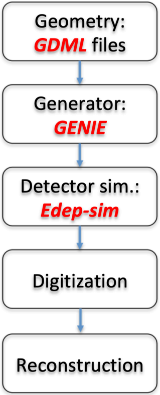
⟶ Generator:GENIE 3.00.06 (G18_02a_00_000)

⟶ Exposure: 5 years (5.5×10^{21} POT)

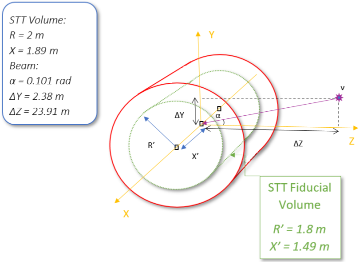


Simulation and reconstruction for SAND

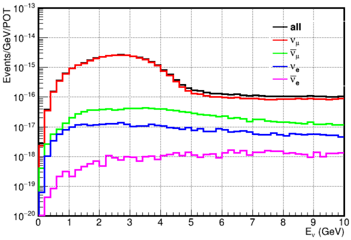
Simulation and reconstraction:



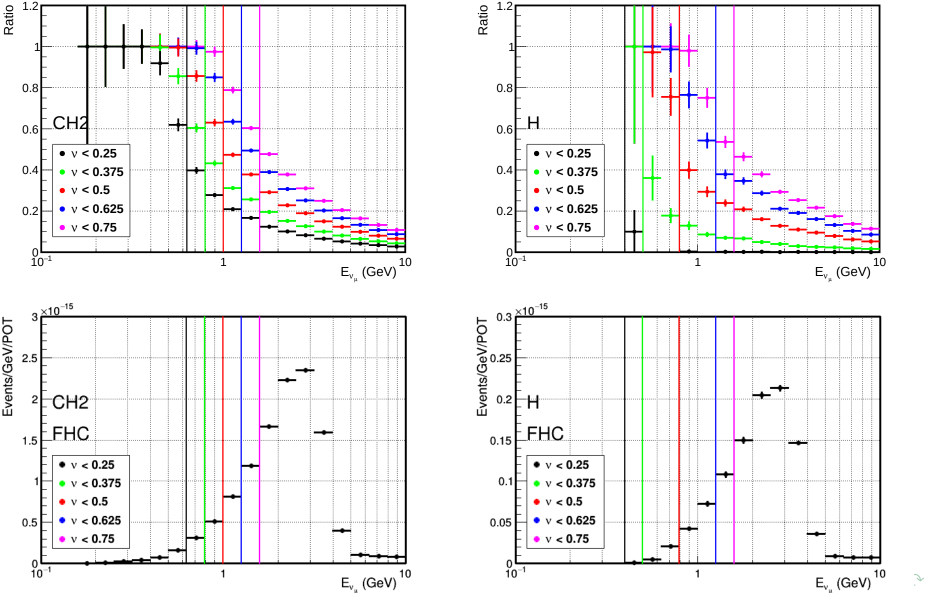
Detector geometry:



Spectra of interacting neutrinos:



Fraction of Low-ν events using a flat energy distribution

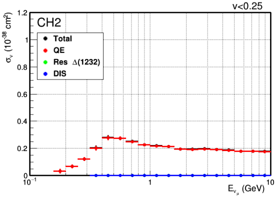


The expected number of interacting neutrinos for 5 years of DUNE exposure in the FHC mode

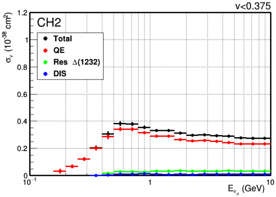
CH2			
ν_0	E_{min}	Evt (5 years)	N^{ν}/N
0.250	0.631	$4.11 \cdot 10^6$	0.09
0.375	0.794	$7.04 \cdot 10^6$	0.15
0.500	1.000	$1.02 \cdot 10^7$	0.22
0.625	1.259	$1.21 \cdot 10^7$	0.26
0.750	1.585	$1.28 \cdot 10^7$	0.28

H			
ν_0	E_{min}	Evt (5 years)	N^{ν}/N
0.250	0.398	$4.91 \cdot 10^3$	0.00
0.375	0.501	$1.94 \cdot 10^5$	0.05
0.500	0.794	$6.16 \cdot 10^5$	0.15
0.625	1.259	$8.94 \cdot 10^5$	0.22
0.750	1.585	$1.06 \cdot 10^6$	0.26

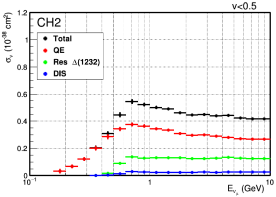
$\nu < 0.25$



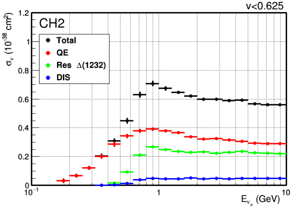
$\nu < 0.375$



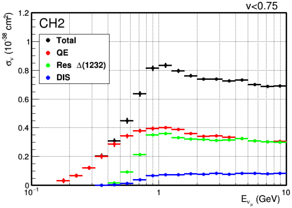
$\nu < 0.5$



$\nu < 0.625$

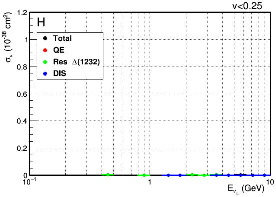


$\nu < 0.750$

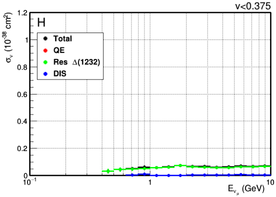


Neutrino reactions: H target

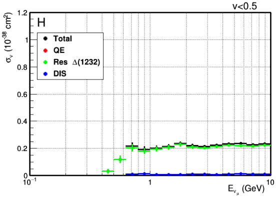
$\nu < 0.25$



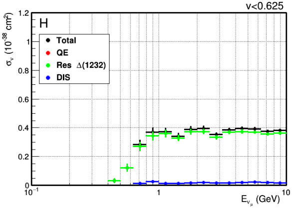
$\nu < 0.375$



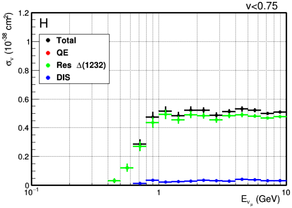
$\nu < 0.5$



$\nu < 0.625$

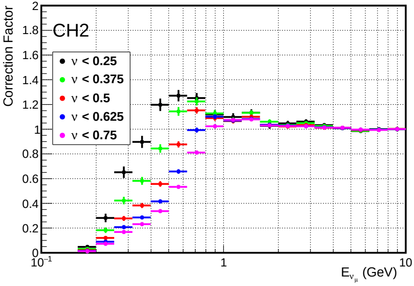


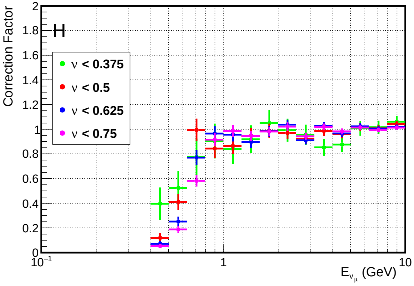
$\nu < 0.750$



Correction Factor

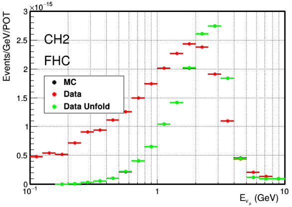
$$C_\nu = \frac{N(E_\nu, \nu < \nu_0)}{N(E \simeq 10 GeV, \nu < \nu_0)}$$

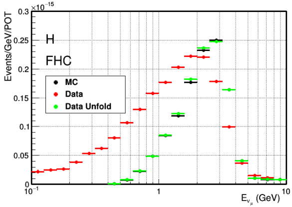


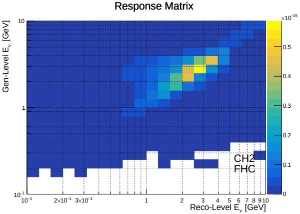


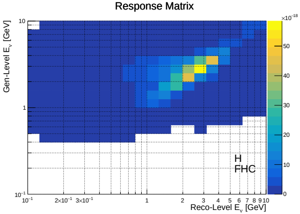
Test of Unfolding: Generated and Reconstructed total events spectra

- The RooUnfold package: iterative Bayesian method was used with number of iterations = 4
- The same events spectra used for data and MC



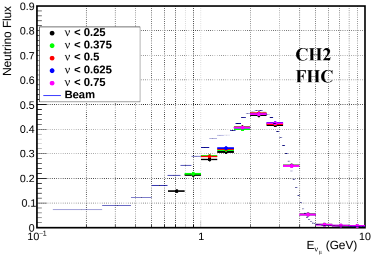


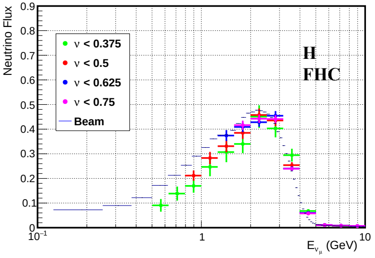




Measured Relative Flux

$$\Phi \propto \frac{U_\nu (D_\nu - B_\nu)}{C_\nu \cdot \Delta E \cdot NPOTs}$$

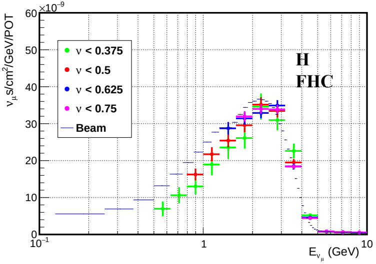


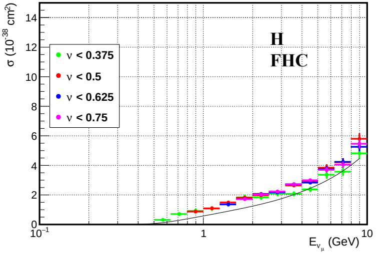


Measured absolute flux and cross section for H target

$$\sigma = k\frac{U(D-B)}{\Phi \cdot \Delta E \cdot T \cdot NPOTs}$$

- H target: $T = 3 \cdot 10^{29}$ nucleons in the STT fiducial volume
- Normalization: GENIE inclusive cross at 15 GeV $(7.2 \cdot 10^{-38}\ cm^2)$





Conclusions:

- The obtained partial muon neutrino cross-sections are almost independent on the neutrino energy, supporting the theoretical grounds of the low-ν method.
- The muon neutrino flux and the cross section were evaluated, applying the Low-ν method.
- The extracted neutrino flux reproduces well the beam flux around the peak and at higher energies. A deviation with respect the beam spectrum is found for energies below the peak. Consequently, further studies are required.

Future studies:

- Background estimation (from muon charge mis-reconstruction etc.)
- Analysis optimization (low-ν cut, energy thresholds etc.)
- Studies on unfolding method (systematics, number of iterations)
- Increase the statistics
- Apply the low-ν method for the antineutrino flux.