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ν_τ Analysis in the DUNE ND

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Introduction

Objectives

- Main objective : study of eventual tau neutrinos that we may have in the DUNE Near detector coming from short baseline oscillations in a sterile neutrino scheme.
  Evaluate the ν_τ appearance sensitivity of DUNE ND in both leptonic and hadronic tau decay channels.

- Event classification : signal and background separation based on kinematic differences. (Same kinematic variables as used in NOMAD)

- Simulation : Events were simulated using GENIE and propagated through the Near Detector using EDEP-SIM .

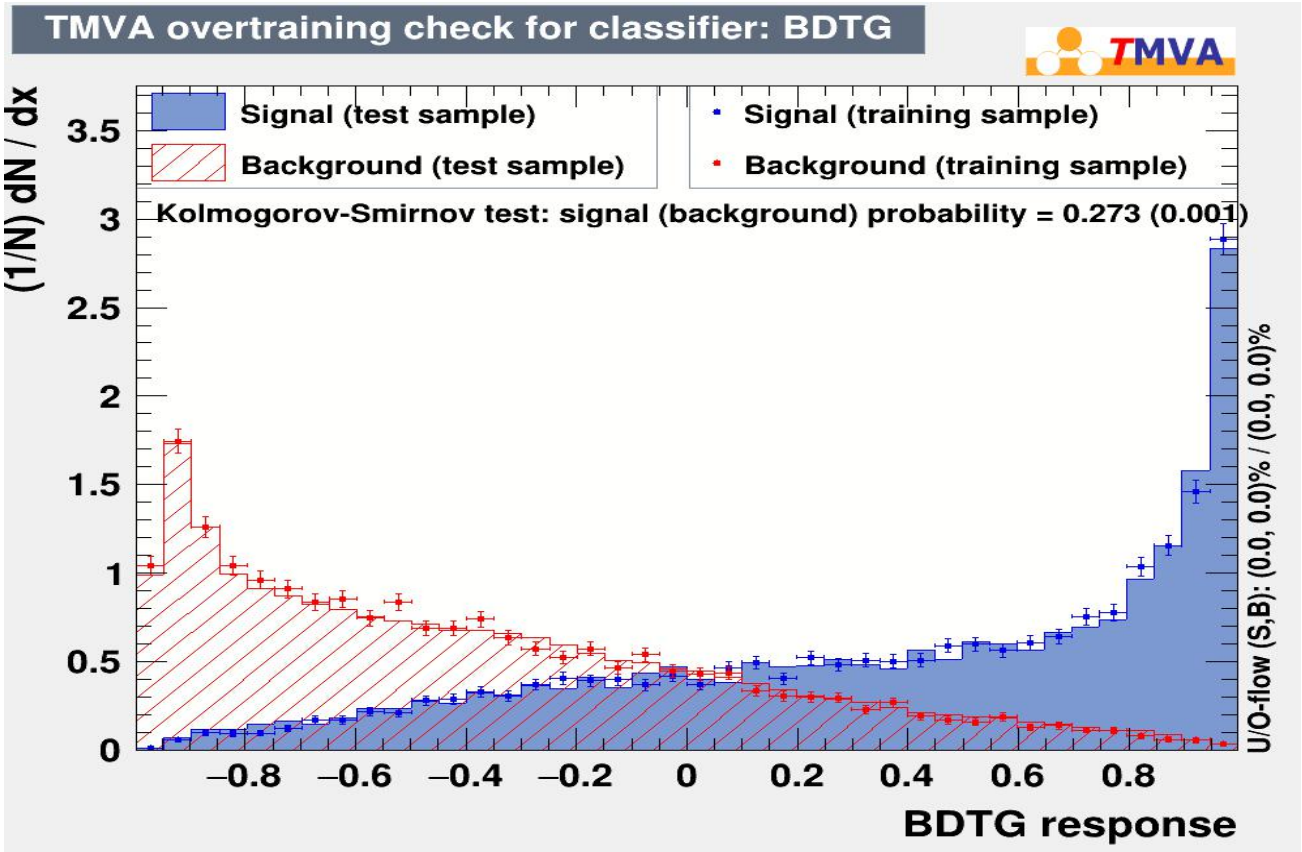
- Beam used : Optimized beam for ν_τ appearance in the DUNE FD.

Outline for section 1

Muon channel

$\tau \rightarrow \mu^-$ channel

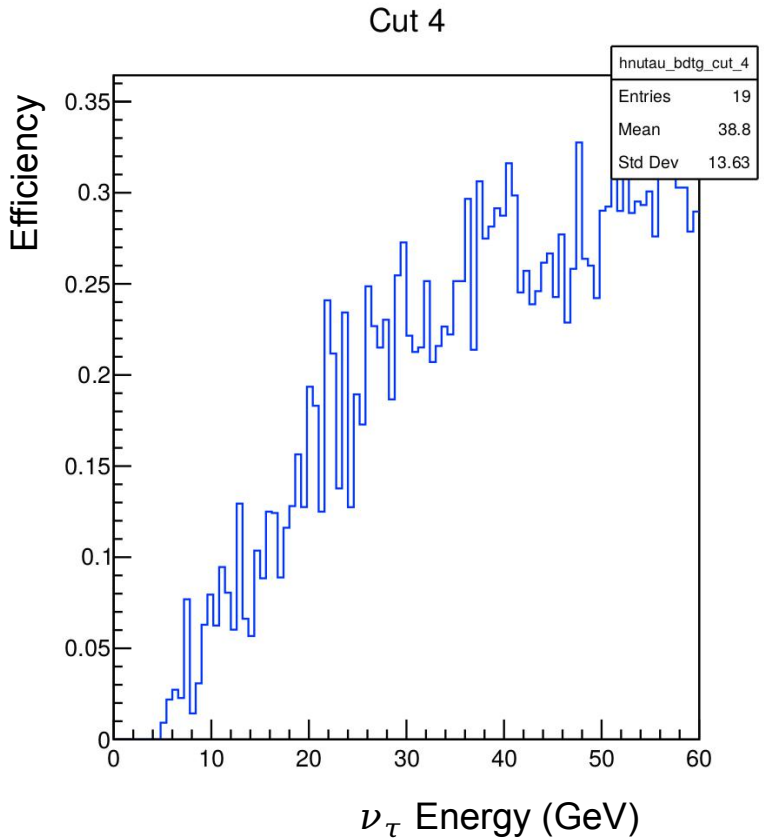
- TMVA Event Classification based on TRUE GENIE kinematic variables

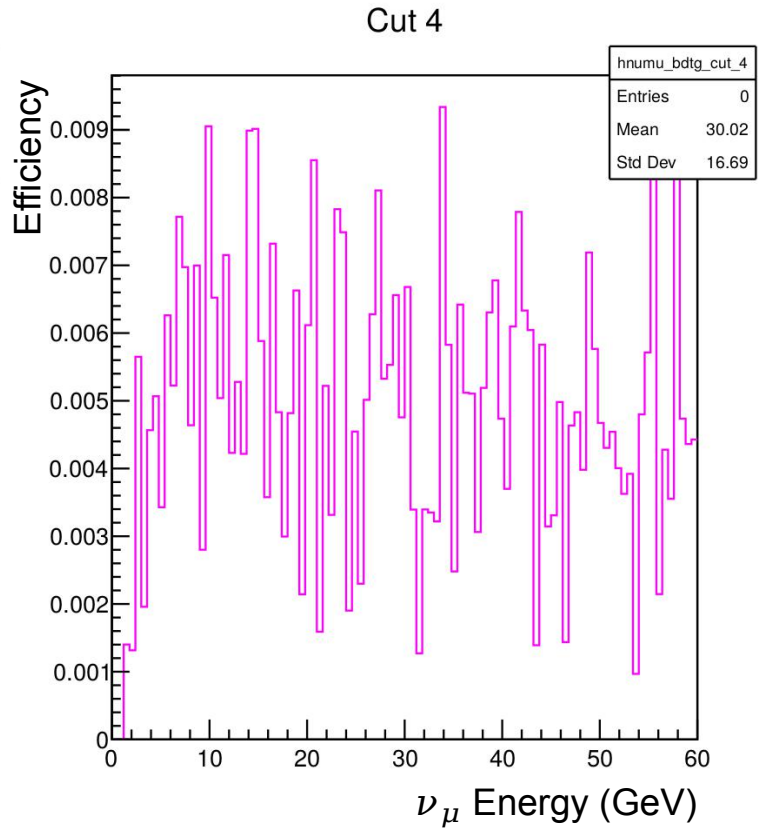


Muon channel

$\tau \rightarrow \mu^-$ channel

- Selection efficiencies for cut : BDTG score > 0.95





Muon channel

$\tau \rightarrow \mu^-$ channel

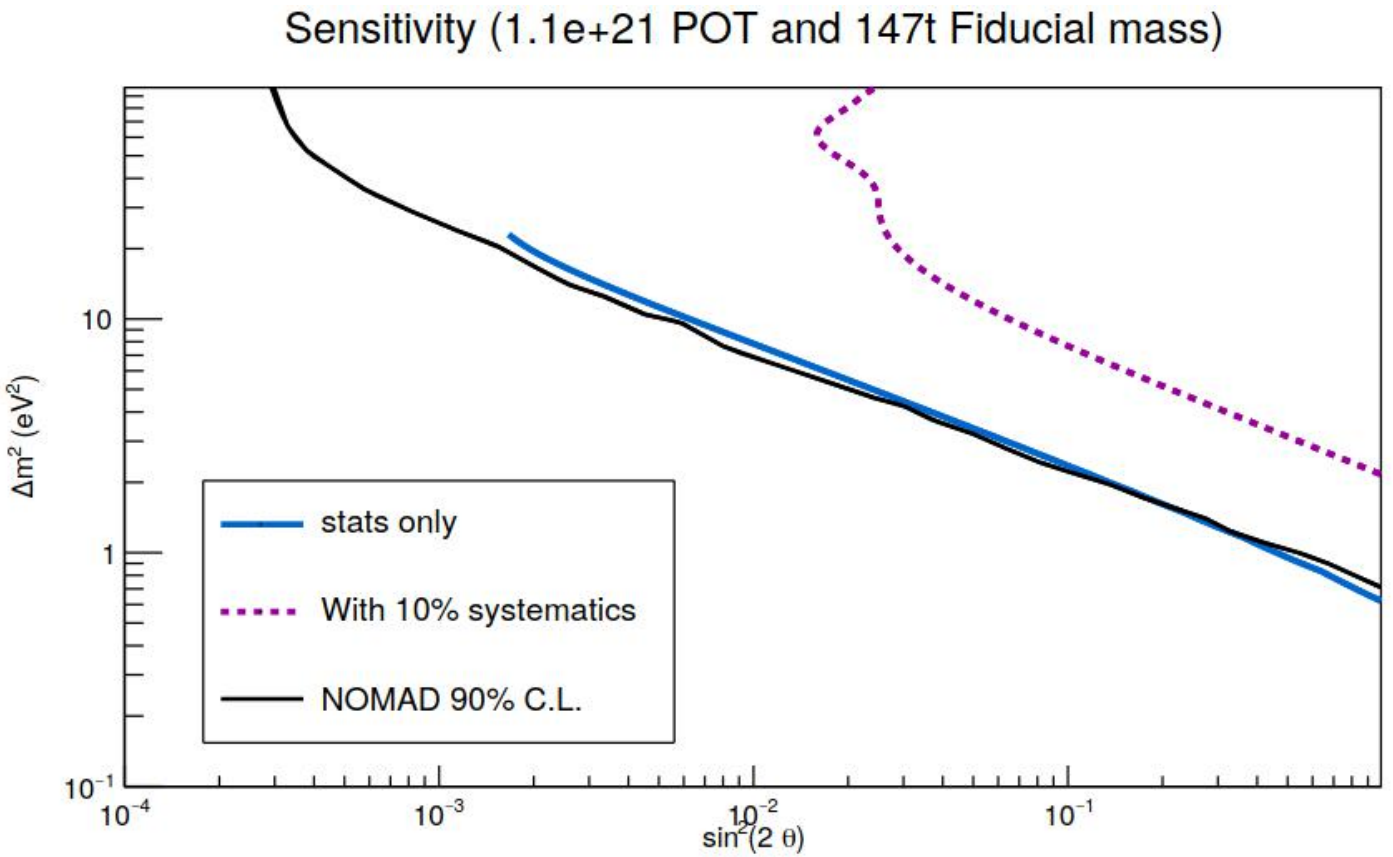
- Sensitivity : based on event counting. All events were normalized such that they would correspond to **1.1e21 P.O.T.** and **147t** fiducial mass.

- Figure of Merit : $\frac{signal}{\sqrt{signal + background}}$; select those with FOM ≥ 1.7 (stats only).

- FOM with 10% systematics : $\frac{signal}{\sqrt{signal + background} + \mathbf{0.1} * (signal+background)}$; select those with FOM ≥ 1.7.

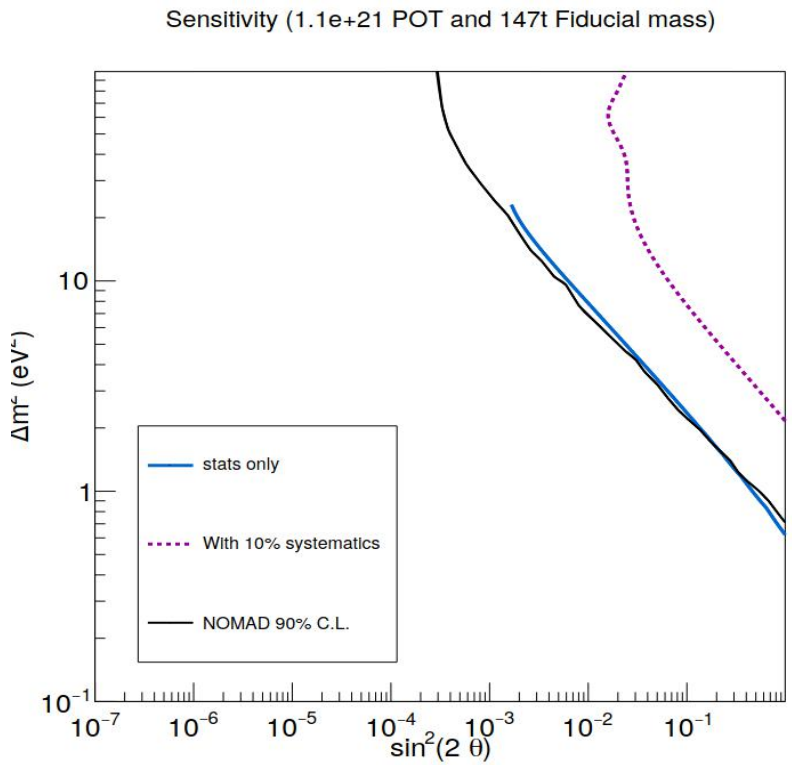
Muon channel

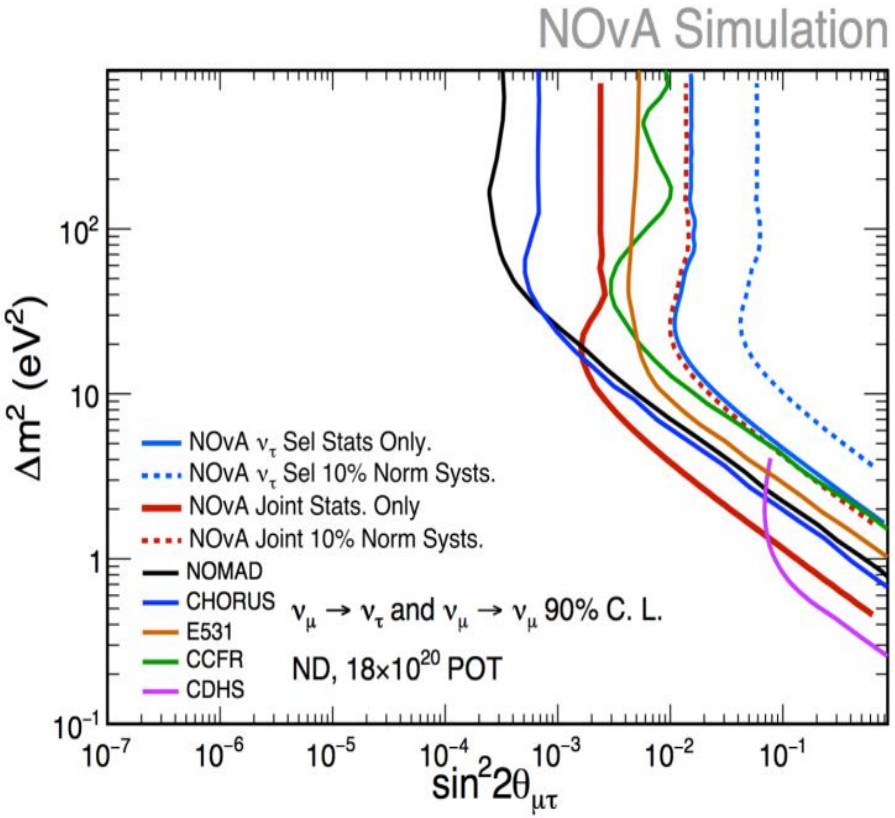
$\tau \rightarrow \mu^-$ channel



Muon channel

$\tau \rightarrow \mu^-$ channel





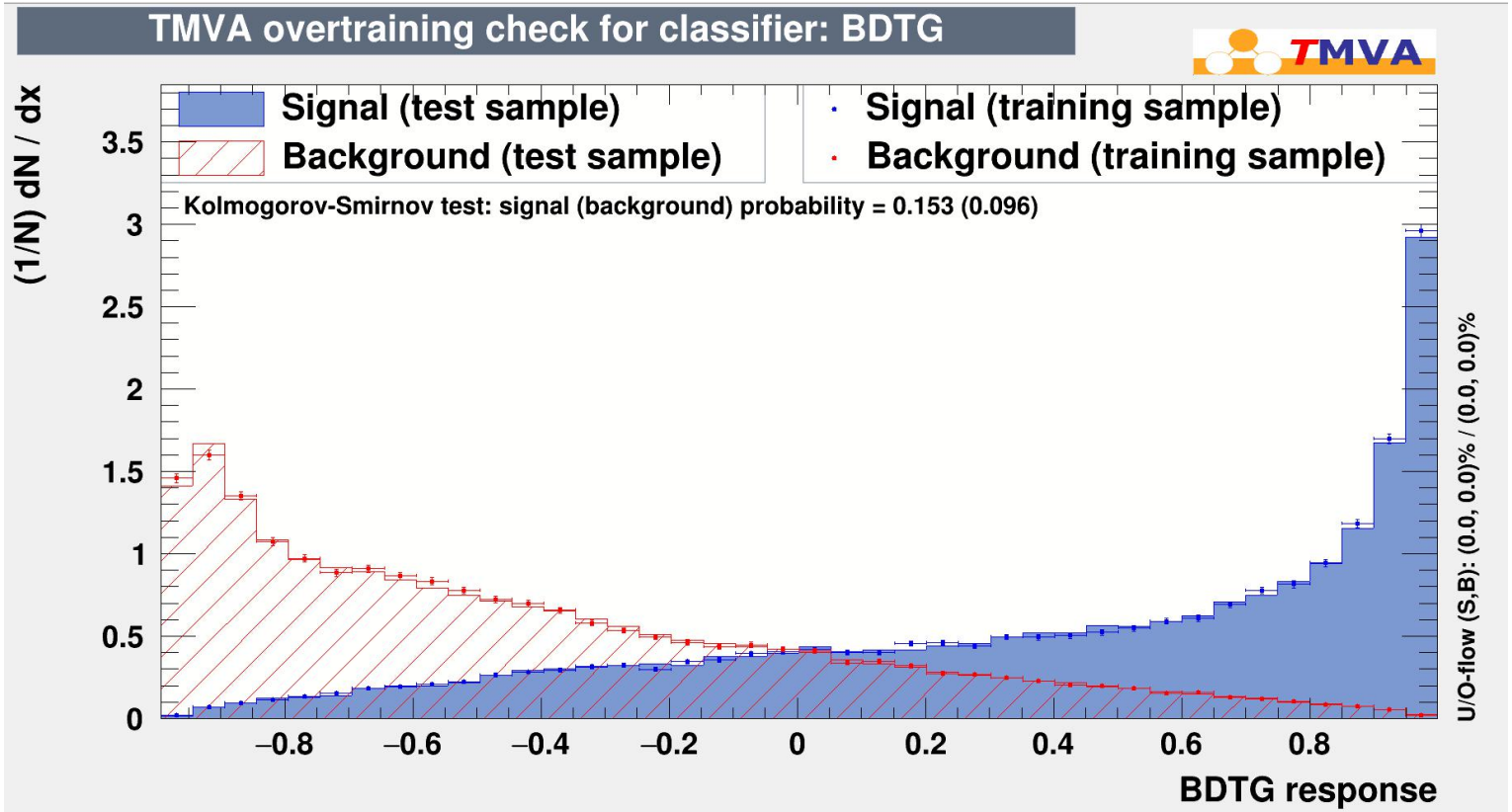
R. Keloth et Al. (arXiv:1710.00295v)

Outline for section 2

Electron channel

$\tau \rightarrow e^-$ channel

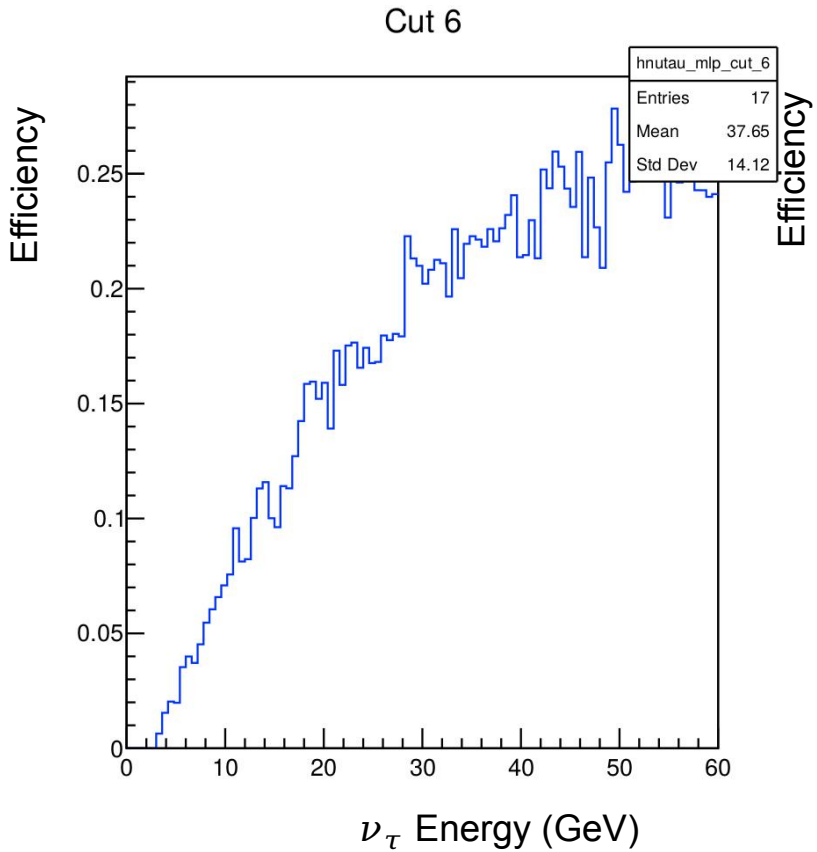
- **TMVA Classification based on TRUE GENIE kinematic variables**

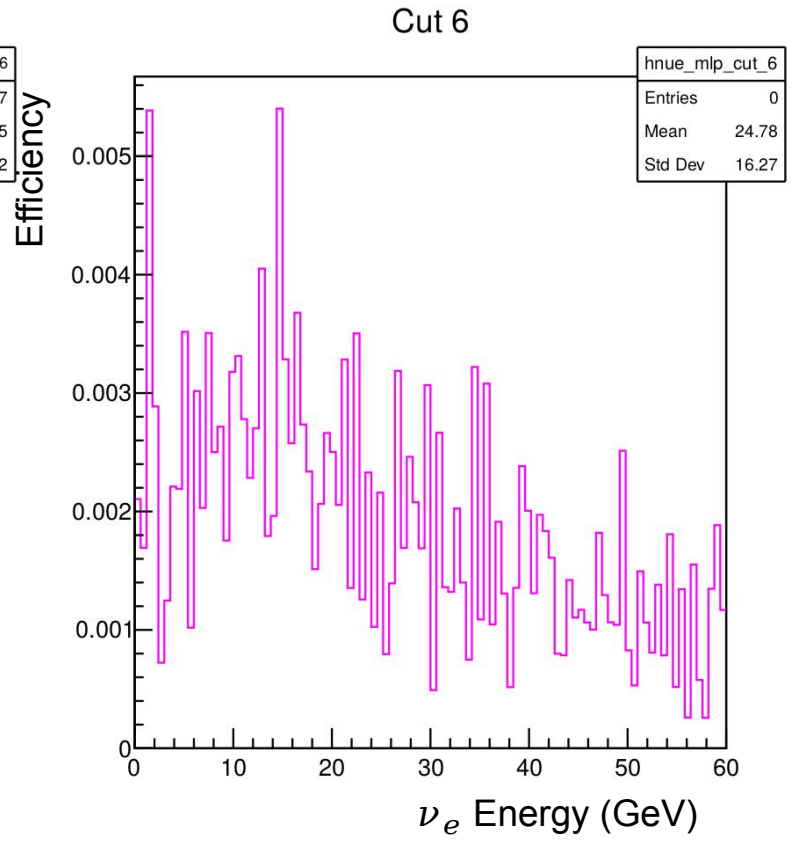


Electron channeln

$\tau \rightarrow e^-$ channel

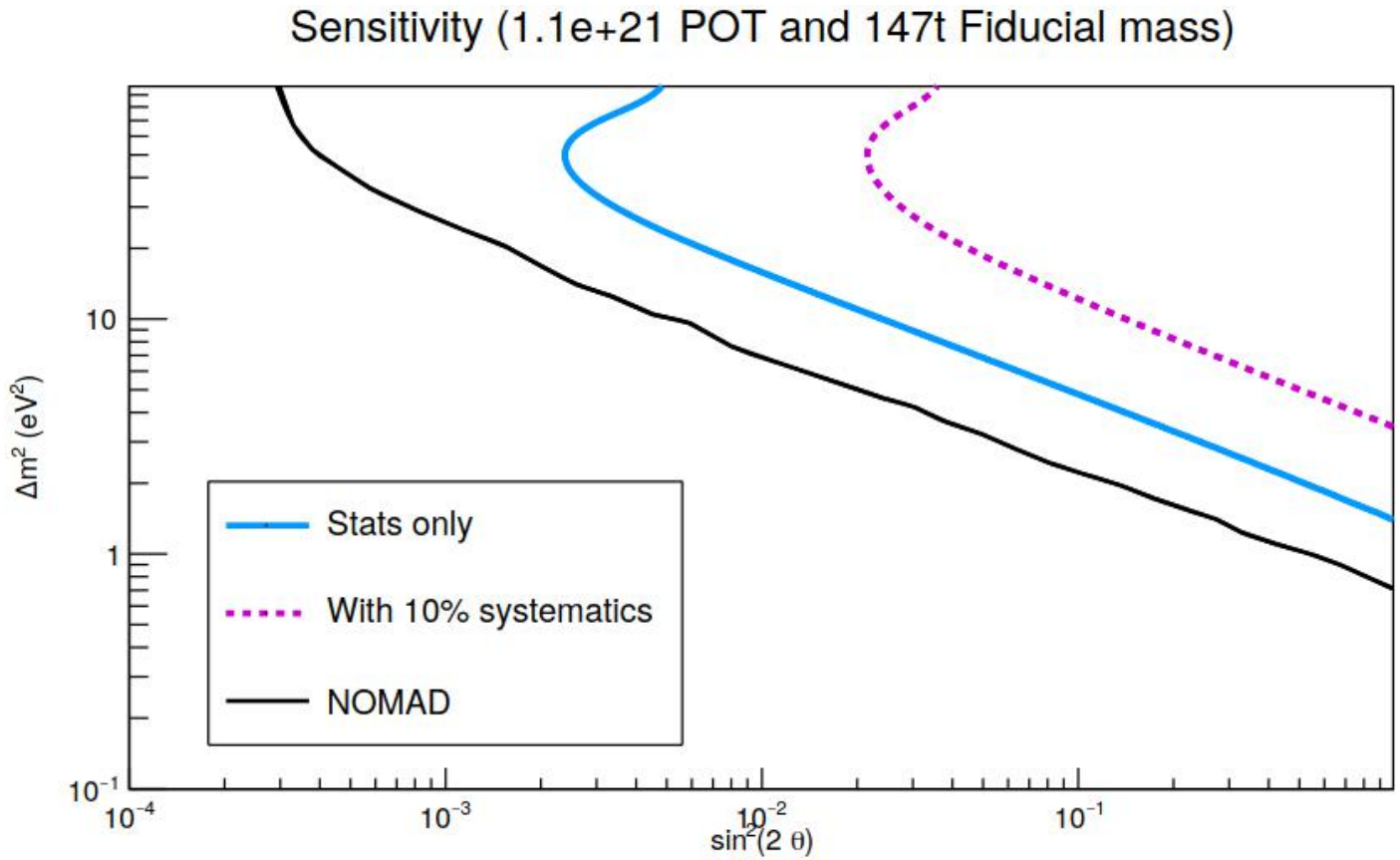
- Selection efficiencies for cut : BDTG score > 0.97





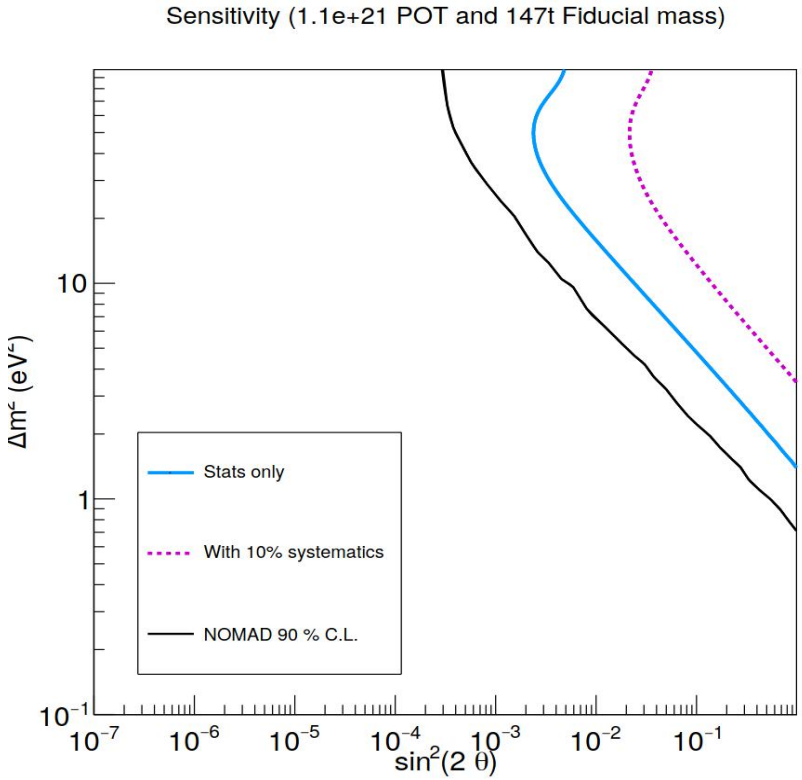
Electron channel

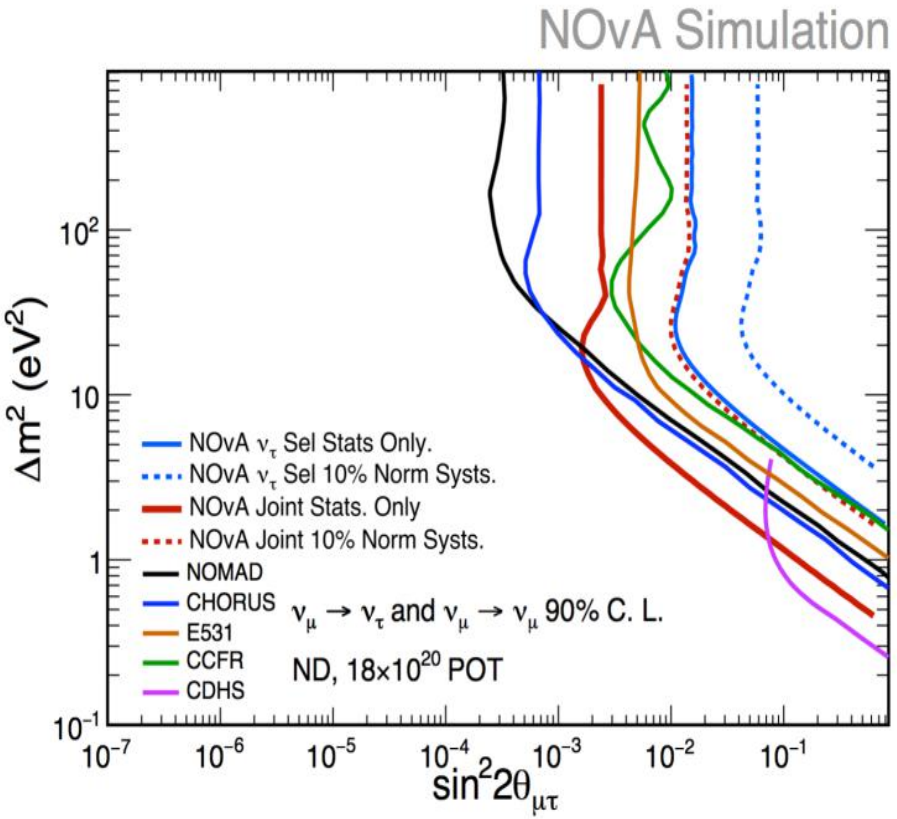
$\tau \rightarrow e^-$ channel



Electron channel

$\tau \rightarrow e^-$ channel





R. Keloth et Al. (arXiv:1710.00295v)

Outline for section 3

Muon channel

Electron channel

$\tau \longrightarrow \rho$ channel

Conclusion

$\tau \longrightarrow \rho$ channel

$\tau \rightarrow \rho^-$ channel

- **Steps :** develop a ρ selector then develop a classifier that separates NC events from $\nu_\tau(\tau \rightarrow \rho^-)$.

- ***ρ* classification :** TMVA Classification based on kinematic infomations.

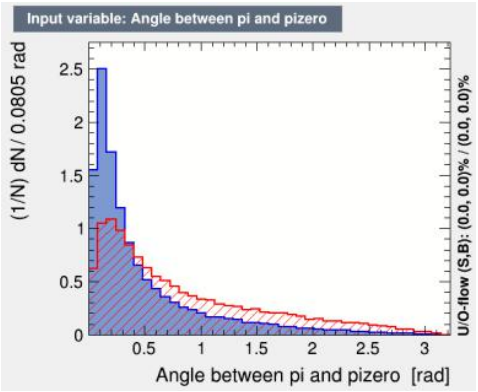
  - Signal (true ρ) : - from ν_τ CC events : $\tau \rightarrow \rho^- + \nu_\tau$; $\rho^- \rightarrow \pi^- + \pi^0$; $\pi^0 \rightarrow 2\gamma$
    - from NC events : $\rho^- \rightarrow \pi^- + \pi^0$ (the ρ is recorded)

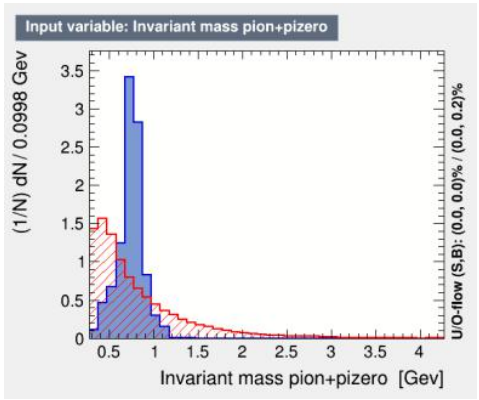
  - Background (false ρ) : any $\pi^\pm + \pi^0$ couple that doesn't come from a true ρ^- from the hadronic system or τ decay.

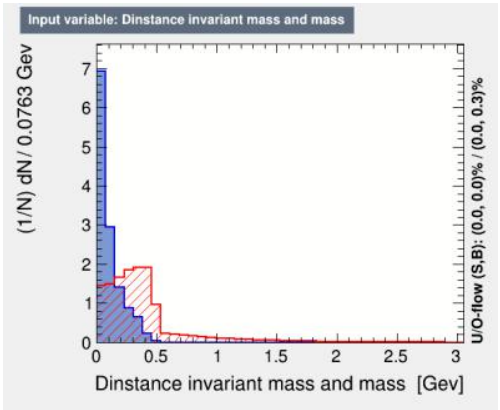
$\tau \longrightarrow \rho$ channel

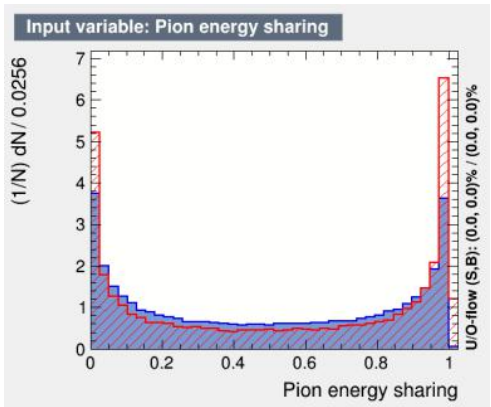
$\tau \rightarrow \rho^{-}$ channel

- Kinematic variables including :









$$d = \sqrt{(M_{\pi^0}^{(in\nu)} - m_{\pi^0})^2 + (M_{\rho}^{(in\nu)} - m_{\rho})^2}$$

$$r_{\pi}^{K} = \frac{E_{\pi}^{K}}{E_{\pi}^{K} + E_{\pi^0}^{K}}$$

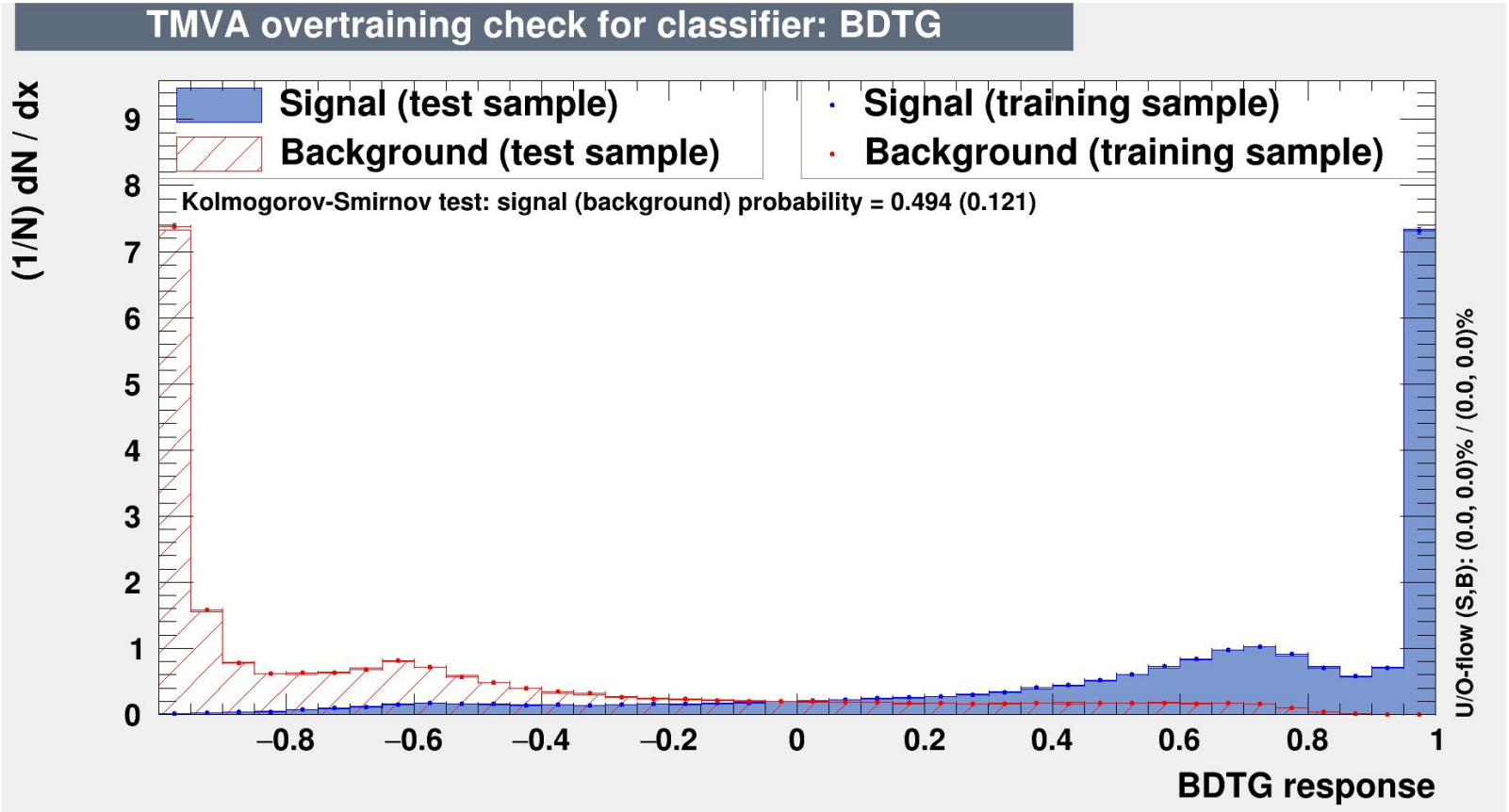
Thomas Kosc

(DUNE ν_τ meeting 11/05/2020)

$\tau \longrightarrow \rho$ channel

$\tau \rightarrow \rho^-$ channel

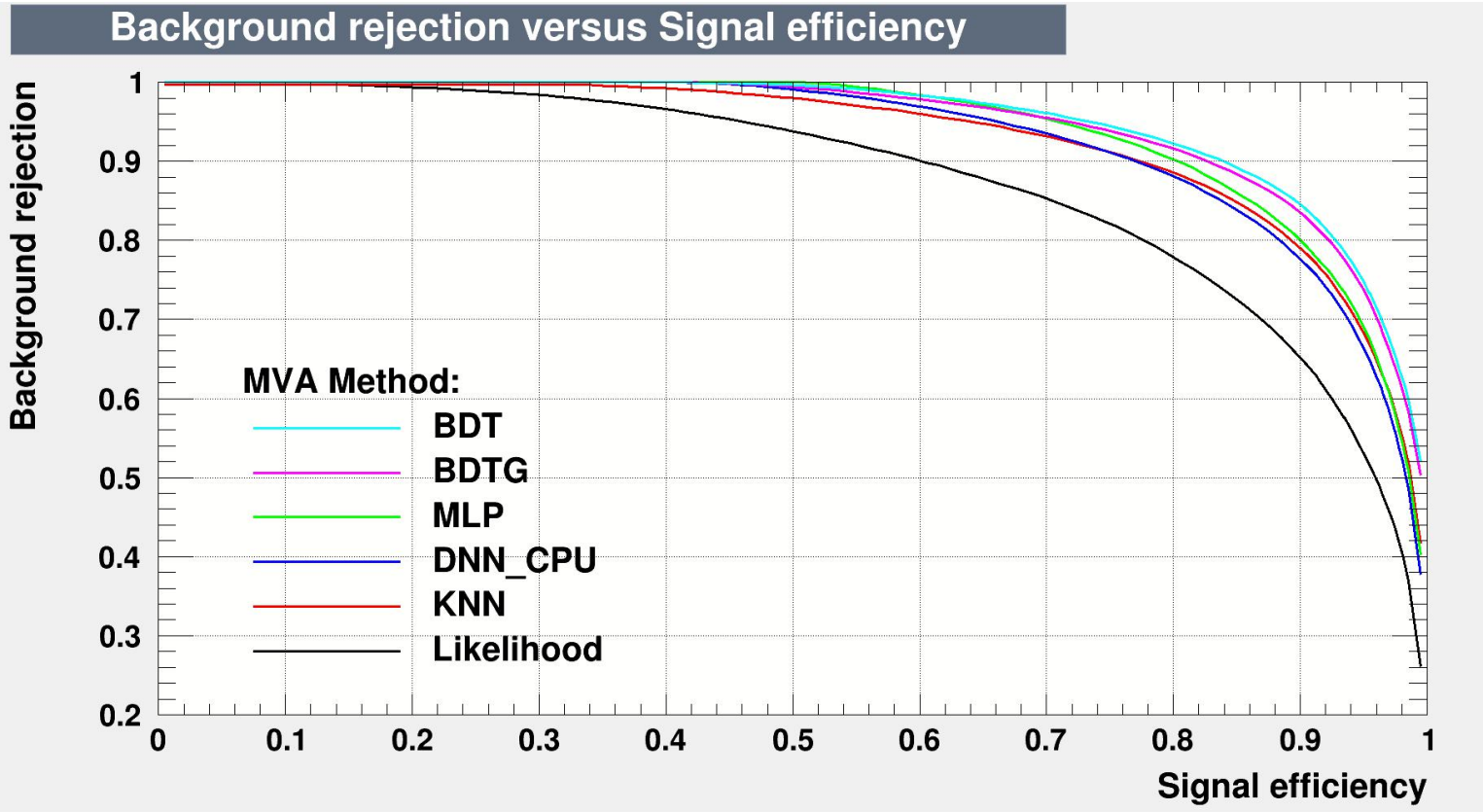
- BDTG response



$\tau \longrightarrow \rho$ channel

$\tau \rightarrow \rho^-$ channel

- ROC Curve



$\tau \longrightarrow \rho$ channel

ν_τ CC vs NC

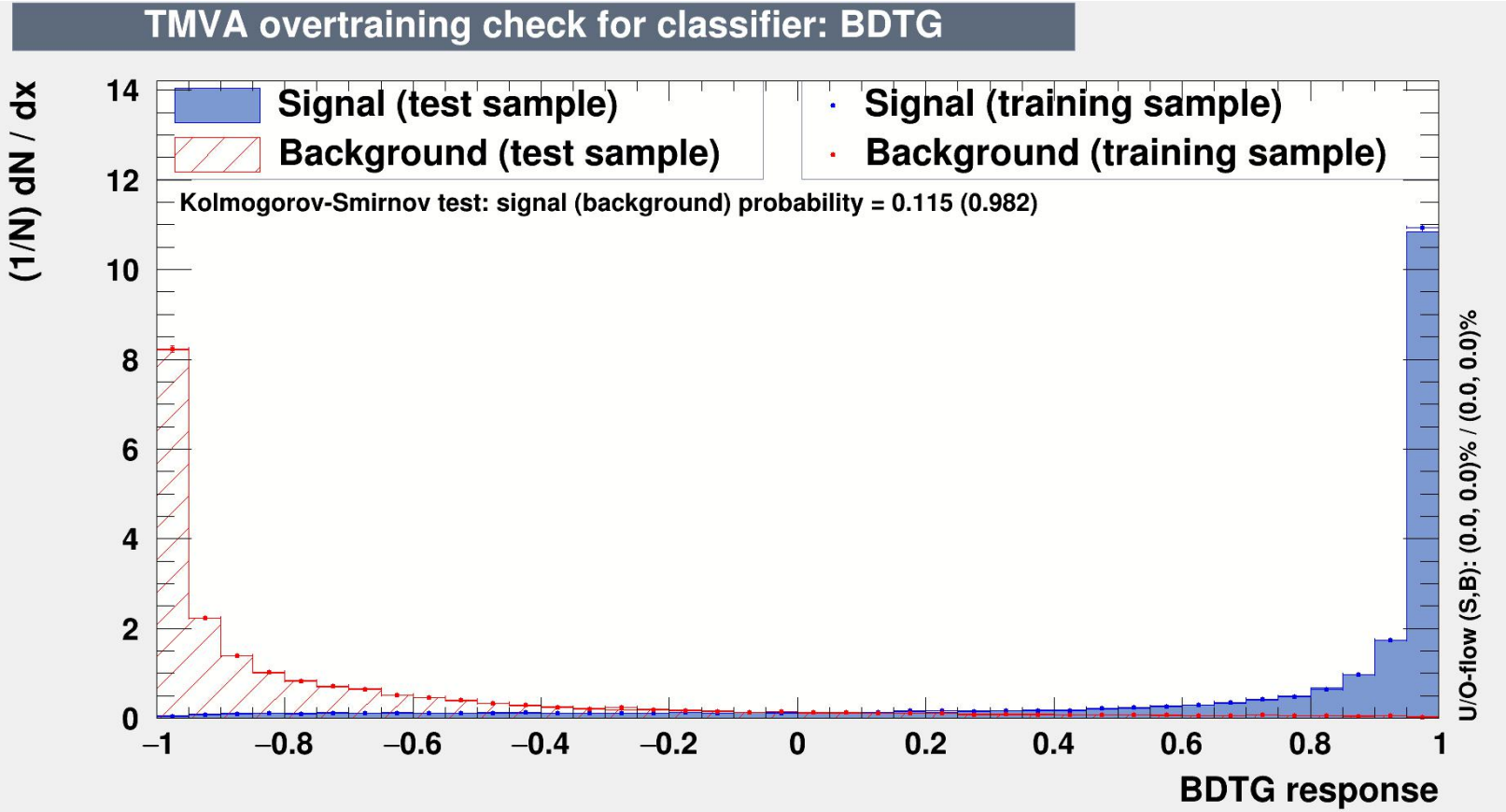
- ν_τ CC vs NC classification :TMVA Classification based on kinematic infomations.

- Signal (for training purposes) ν_τ CC: $\tau \rightarrow \rho^- + \nu_\tau$; $\rho^- \rightarrow \pi^- + \pi^0$; $\pi^0 \rightarrow 2\gamma$ (assuming they would score high on rho score).

- Background : NC events with $\pi^\pm + \pi^0$ systems that come from a true ρ (assuming those would have a high rho score).

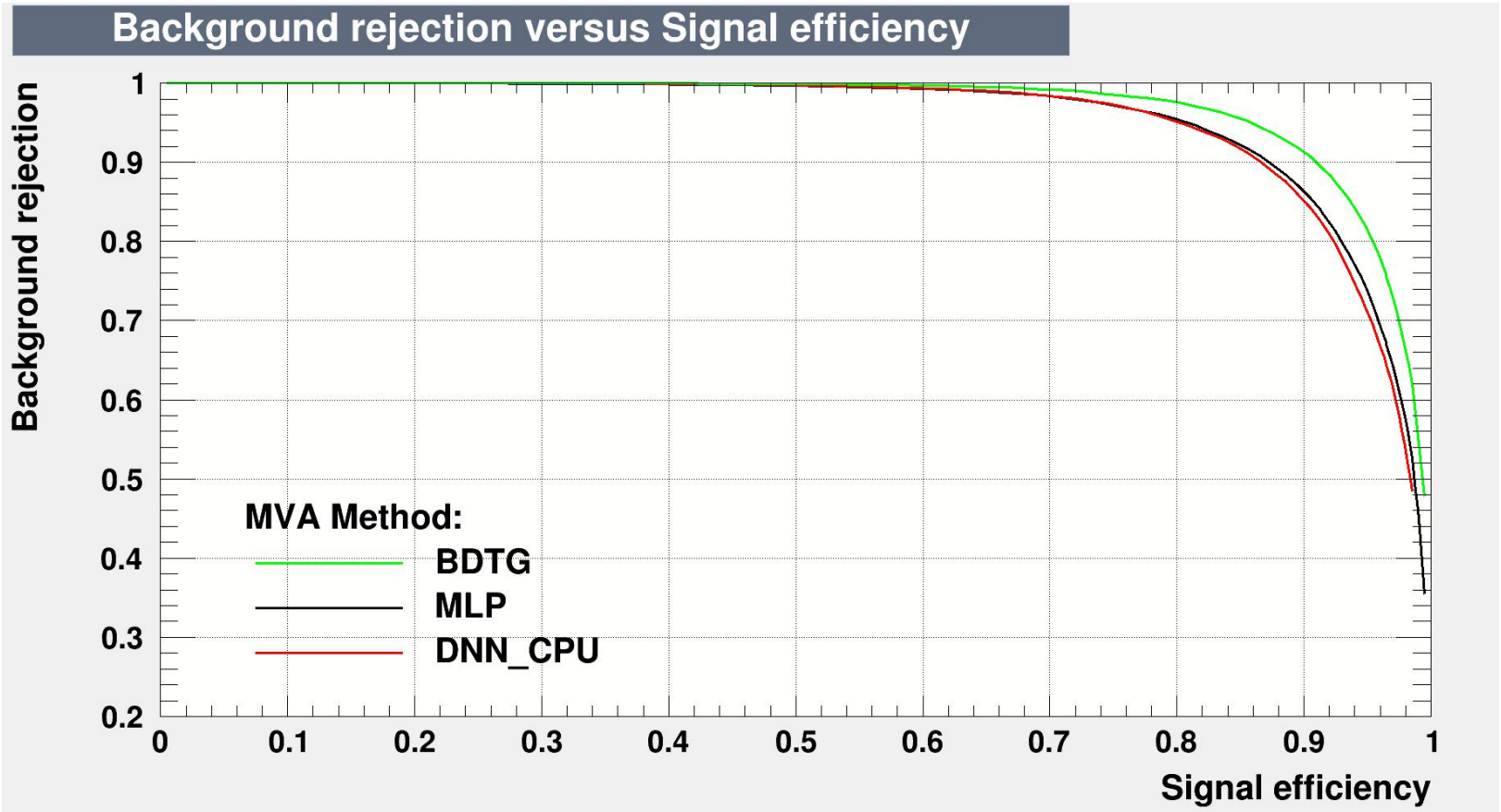
$\tau \longrightarrow \rho$ channel

ν_τ CC vs NC



$\tau \longrightarrow \rho$ channel

ν_τ CC vs NC



$\tau \longrightarrow \rho$ channel

ν_τ CC vs NC

- Step 1 : get all the events with potential ρ candidates for ν_τCC events and NC events. (Anything that has $\pi^\pm + \pi^0$ or $\pi^\pm + 2\gamma$). Look at all possible ρ system combination.

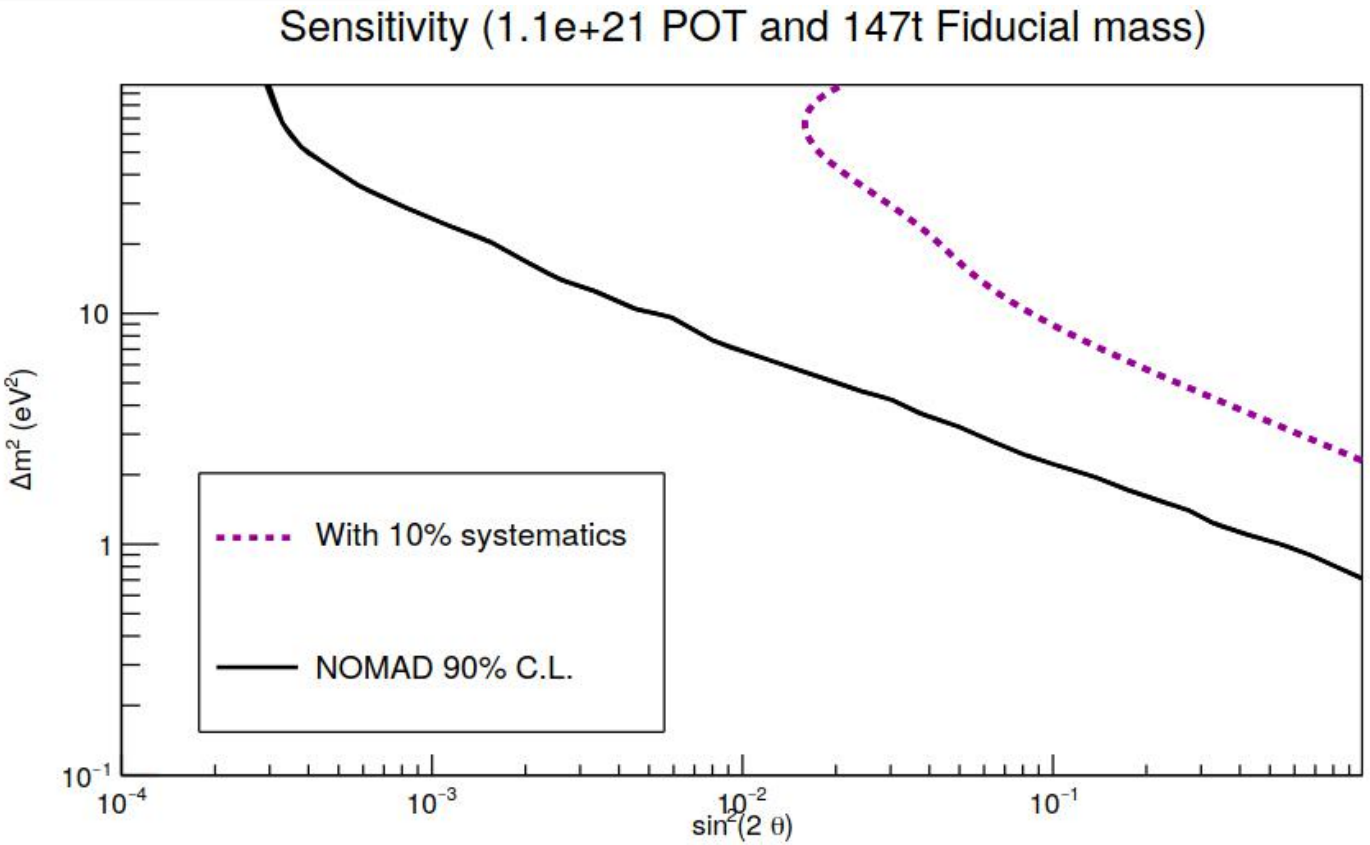
  1^{st} cut : select those with ρ BDTG score > 0.9

- Step 2 : pass through the ν_τCC vs NC selector to get a ν_τ BDTG score.

  2^{nd} cut : select those with ν_τ BDTG score > 0.9

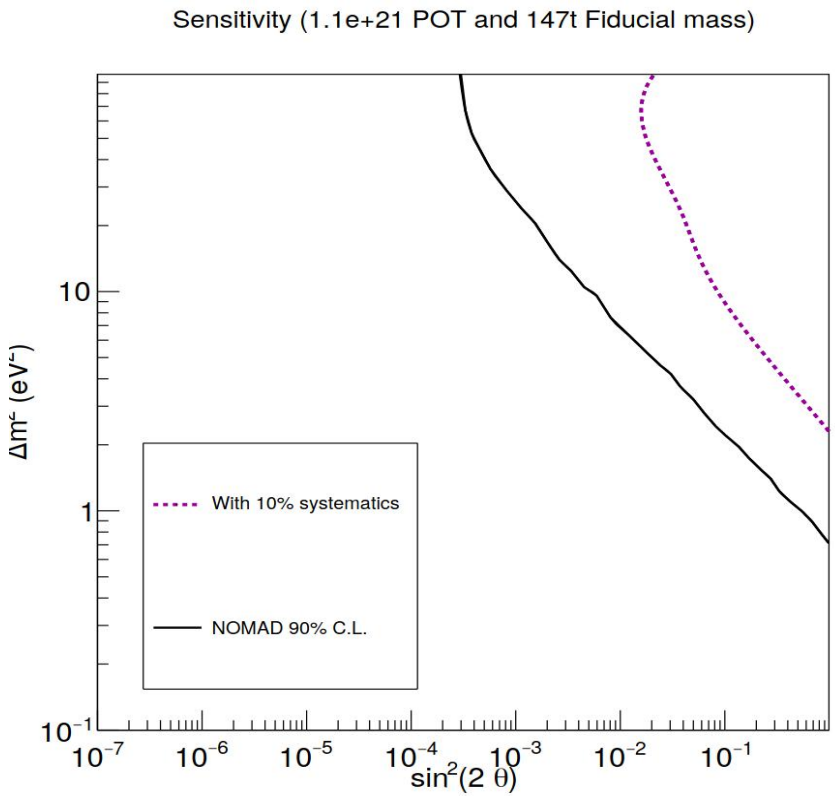
$\tau \longrightarrow \rho$ channel

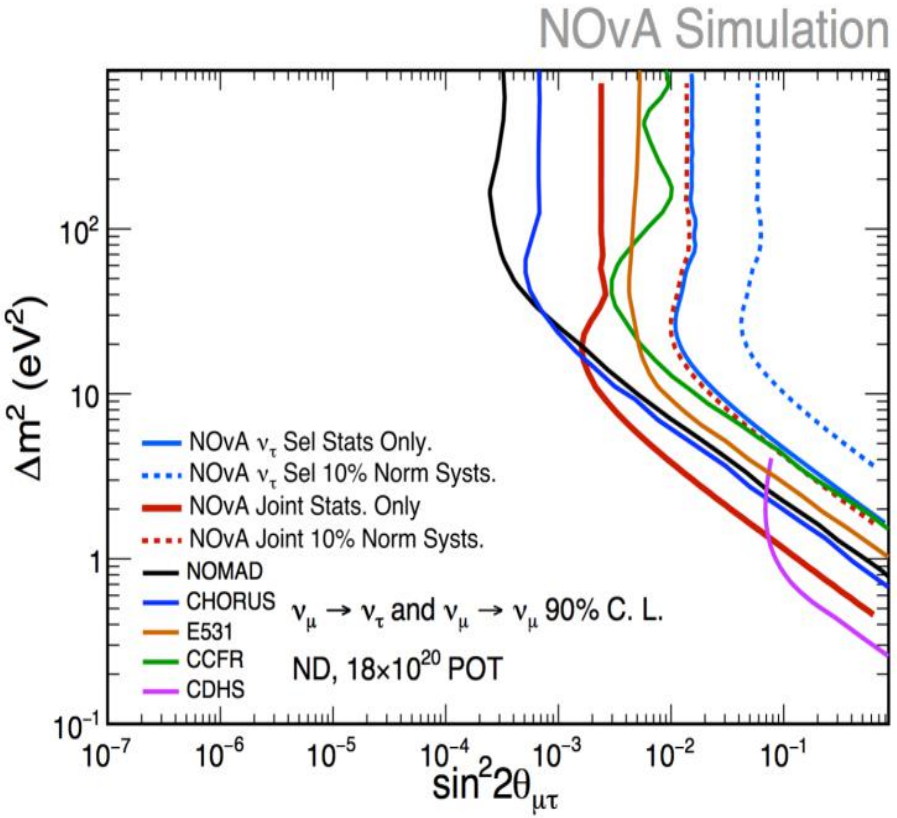
Sensitivity



$\tau \longrightarrow \rho$ channel

$\tau \rightarrow \rho^-$ channel





R. Keloth et Al. (arXiv:1710.00295v)

Outline for section 4

Conclusion

- Classification based on kinematic variables gives a reasonnable output for tau leptonic decay channels.
- For the hadronic channel, $\tau \rightarrow \rho^{-}$, supposing that we can select the ρ appropriately, kinematic-based classification gives a good separation for ν_{τ} and NC.
- For $\tau \rightarrow \rho^{-}$ channels, due to the double cuts, other cuts combinations may improve the sensitivity. Same if the ρ selection is improved.
- Sensitivities : stats only contours are reasonnable, but with our high statistics, the sensitivity is highly affected.
- Sensitivities : currently using just the single bin FOM with event counting. It is possible to do a multi-bin shape analysis eventually.

Thank you very much!