Updates on ν_τCC selection analysis based on kinematic analysis, combined with current CVN performance.

LBL weekly meeting

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24th February 2020

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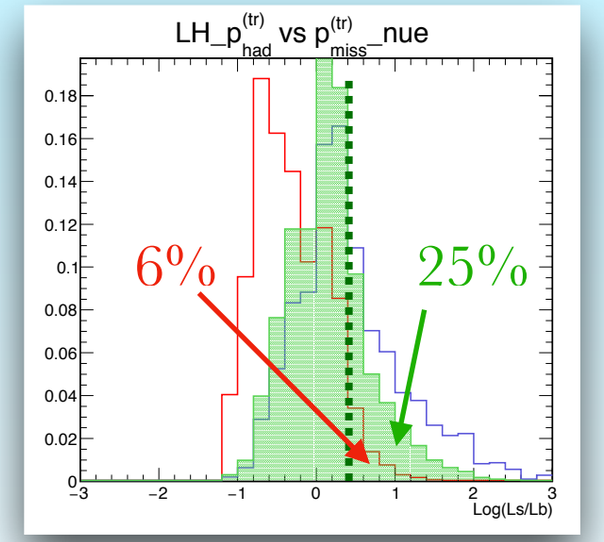
DEEP UNDERGROUND NEUTRINO EXPERIMENT

Abstract

- Following previous presentation at DUNE collab meeting of Jan. 2020 at CERN. Developing a ν_τ CC kinematic analysis and assess the selection efficiencies.

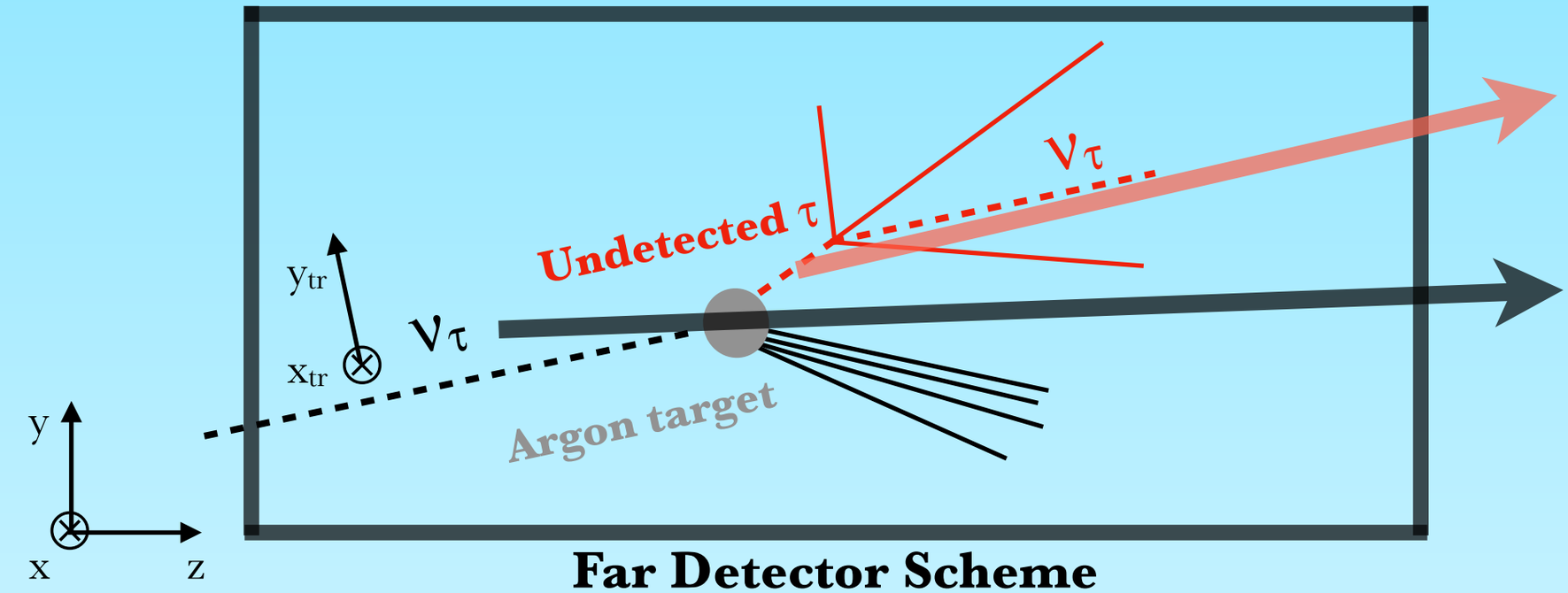
- Likelihood approach, using impinging beam neutrino transverse plan kinematic. **Preliminary results shown, suffering an oversight of neutrino oscillation probabilities (my bad !)**.



Dune Collab meeting plot

- Objective: give the collaboration an updated and more correct oversight of the analysis being developed. Oscillation probabilities are computed with GLoBES v3.2.17 (still struggling with CAFANA framework, I wanted to be able to show quick updates so I'll struggle later…)

For the Recall - Kinematic Method



Far Detector Scheme

τ length track ~100 μm at DUNE

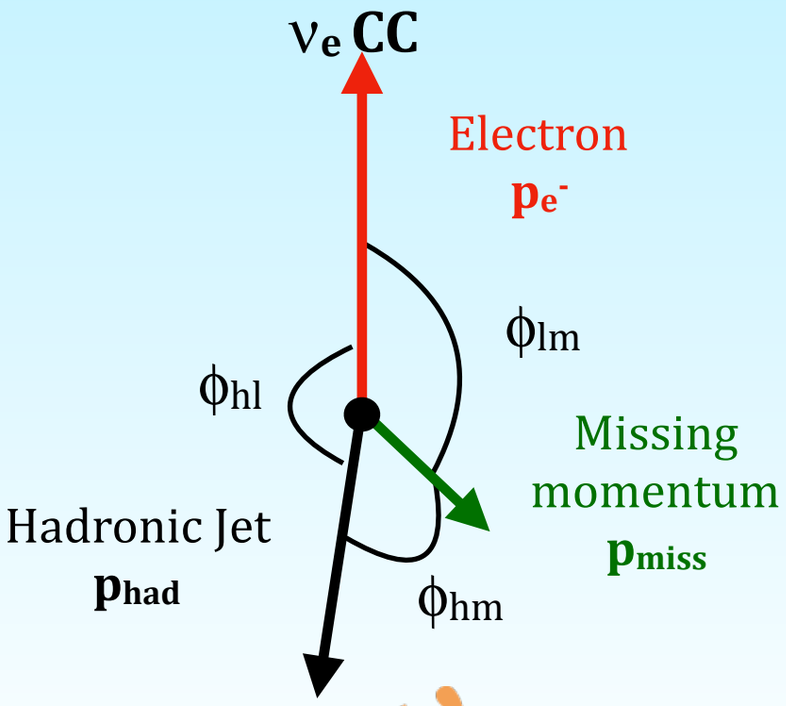
Using mean beam neutrino angle to define the tranverse plan, used for the treatment of all beam events.

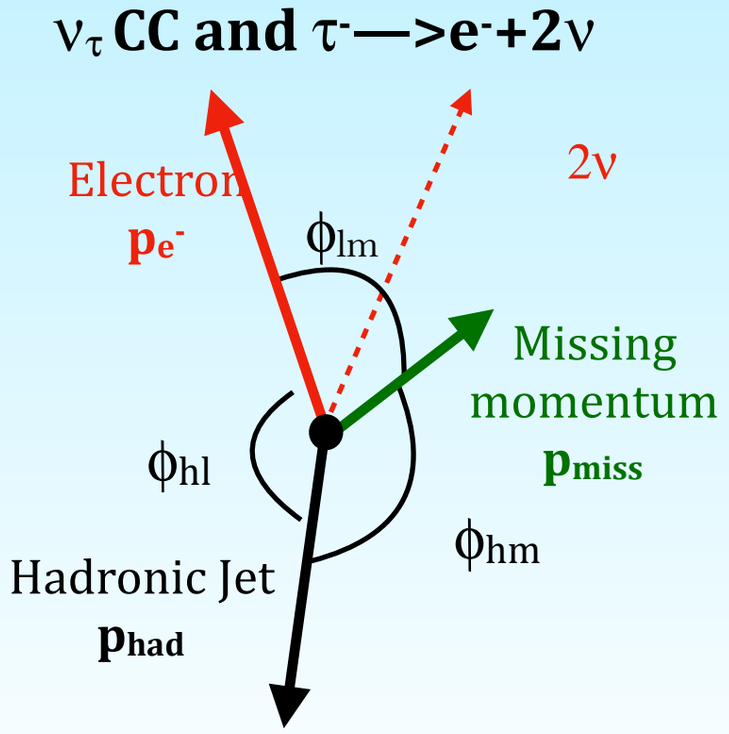
In the transverse plan

$$p_{lep}^{(tr)} \quad p_{had}^{(tr)} \quad p_{miss}^{(tr)}$$

$$\phi_{hl} \quad \phi_{hm} \quad \phi_{lm}$$

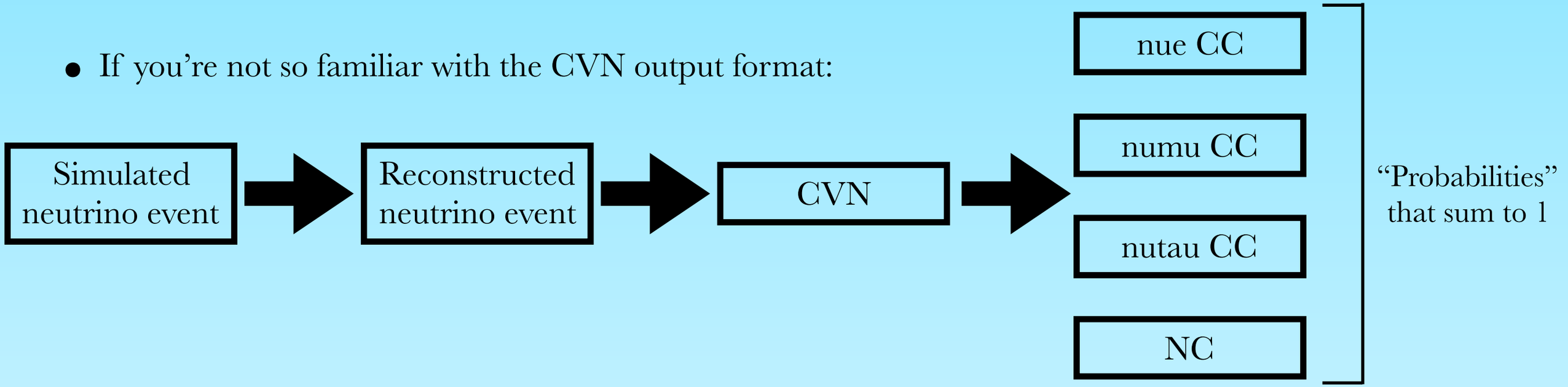
$$+K_{lep}^{\text{(Not Transverse)}}$$



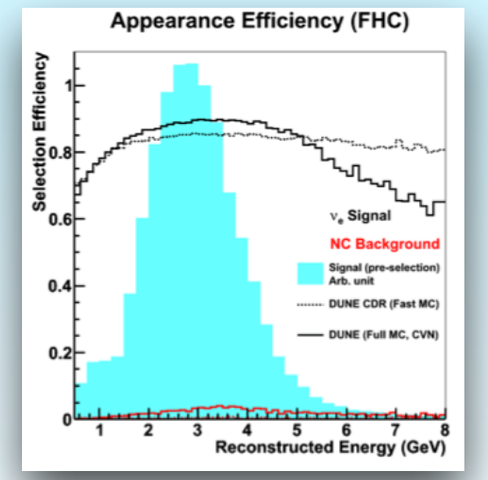


Main CVN outputs

- If you're not so familiar with the CVN output format:



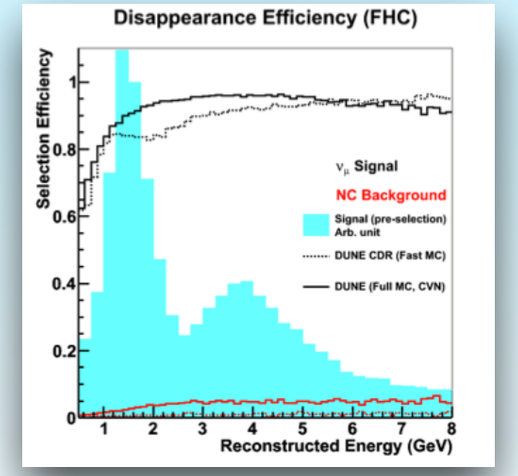
- CVN four main event classification categories —> each associated with a **"likeness" output** (between 0 and 1) ~ probabilities (as they sum to 1).



DUNE TDR ν_e selection efficiency

TDR: $p(\nu_e)>0.85$ and $p(\nu_\mu)>0.5$ for appearance and disappearance candidates.

Efficiencies in each channel reached **~90%** at flux peaks.



DUNE TDR ν_μ selection efficiency

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CVN results #1 : ν_τ CC distribution in CVN output

In the file: oscillated ν_μ—>ν_τ (main flux), contamination of $\bar{\nu}_\mu/\nu_\mu$ (from $\bar{\nu}_e/\nu_e$ osc.), $\bar{\nu}_\tau$ (from $\bar{\nu}_e$ osc.)

My sample study

Thresholds: TDR-like for ν_e and ν_μ, arbitrary for ν_τ

CVN output \ MC truth	ν_e CC	ν_μ CC	ν_τ CC	NC
p(ν_e CC)>0.85	/	< 0,001 %	0,479 %	0,648 %
p(ν_μ CC)>0.5	/	0,157 %	0,771 %	0,771 %
p(ν_τ CC)>0.5	/	0,002 %	0,746 %	0,707 %
p(ν NC)>0.5	/	0,022 %	1,983 %	72,362
Others (none of the condition filled)	/	0,013 %	0,853 %	19,321 %
Sum	0	0,194 %	4,832 %	94,974 %

nutauswap.root (929059 events)

3°/ Current CVN selection efficiency (~15% of nutauCC) using a threshold selection of 0.5 (30%, Adam Aurisano, DUNE Collab).

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CVN results #2 :
CVN distribution of τ decay modes

nutauswap.root (173 309 nutau CC)

MC tau decay / CVN output	τ—>e	τ—>μ	τ—>had	Sum
p(ν_e CC)>0.85	**8.154 %** (~46 %)	0.02 %	1.73 %	9.90 %
p(ν_μ CC)>0.5	0.124 % (<1 %)	**11.55 %**	4.28 %	15.95 %
p(ν_τ CC)>0.5	1.851 % (~10 %)	0.96 %	**12.63 %** (~27 %)	**15.44 %**
p(ν NC)>0.5	2,982 % (~17 %)	3.06 %	35.00 %	41.04 %
Others (none of the condition filled)	4.716 % (~26%)	1.86 %	11.08 %	17.66 %
Sum	17.83 %	17.46 %	64.71 %	100 %

Normalized to electron decay sample (higher than without osc. prob. weight)

1°/ Most of CVN identified ν_τ CC have a τ decaying hadronically

2°/ ~2/3 of ν_τ CC with τ—>e are classified as ν_e CC or "not classified".

3°/ Current CVN selection efficiency using a threshold selection of 0.5.

Expected Branching Ratios (see PDG)

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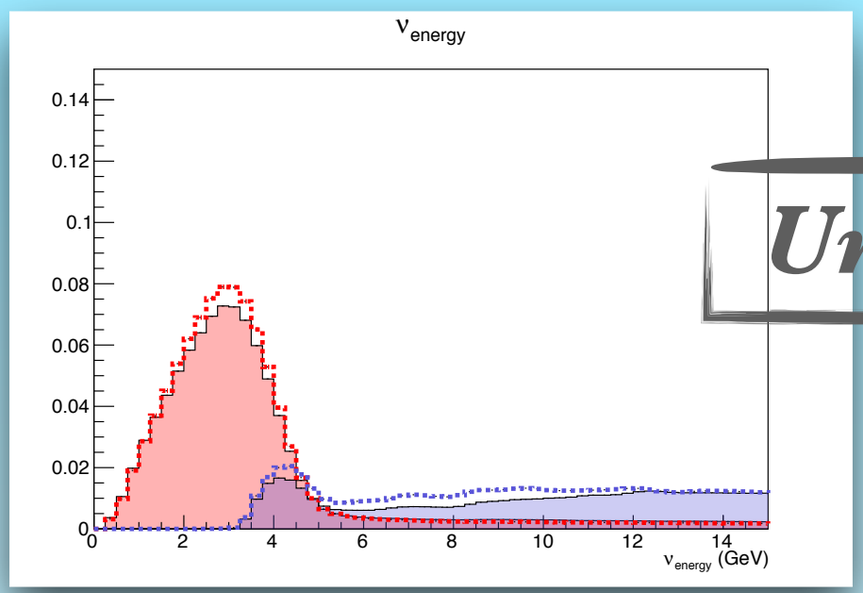
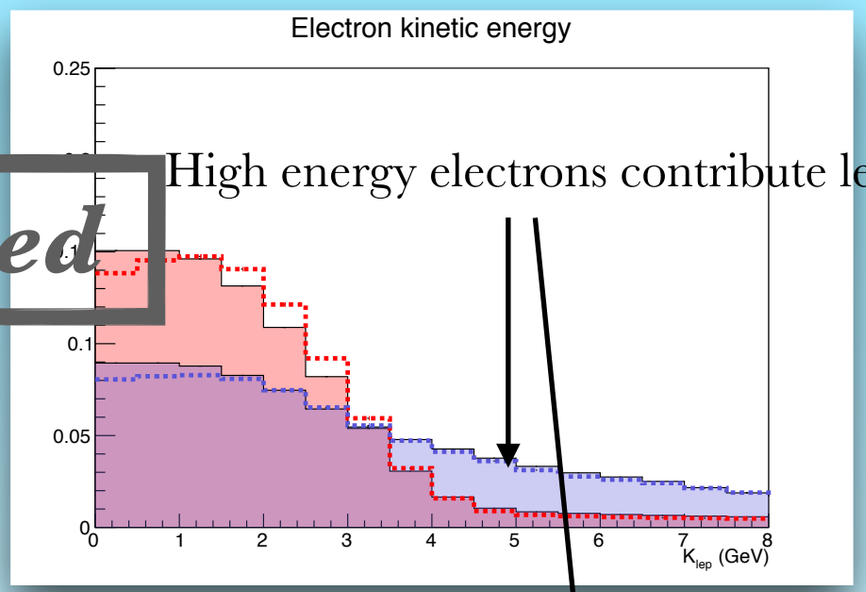
Oscillation weight & CVN selection effect on kinematic distributions #1



Unweighted



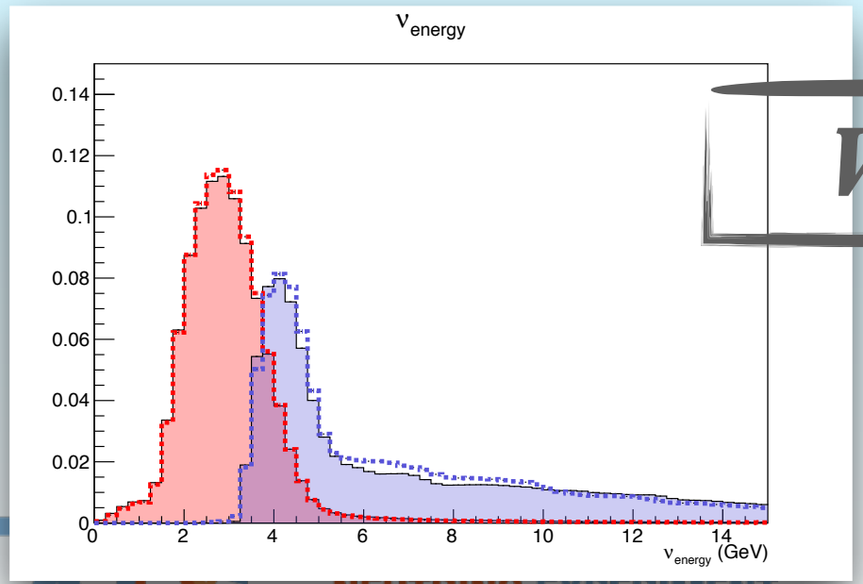
High energy electrons contribute less

All sample

subsample CVN tagged as ν_eCC

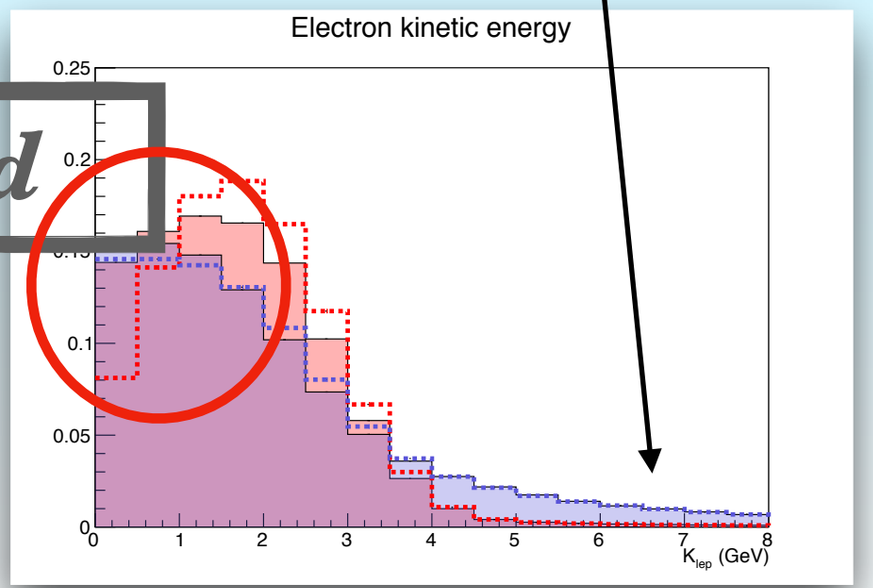
ν_eCC from file nuewap.root

ν_τCC from file nutauwap.root

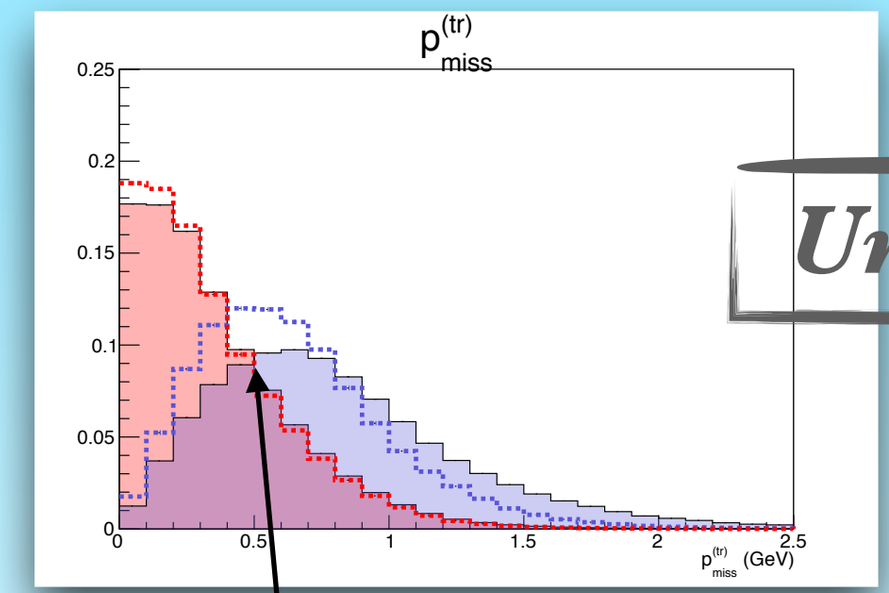


Weighted

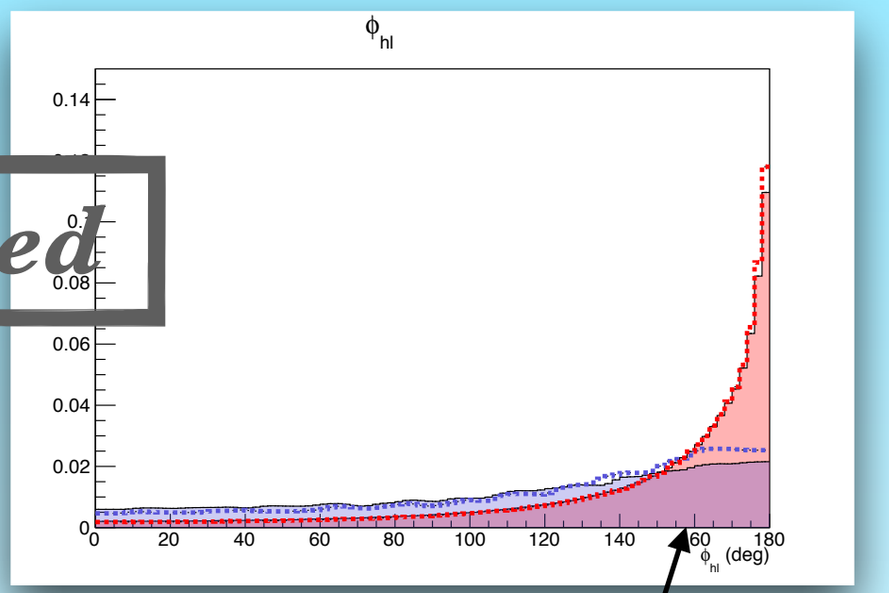
CVN ν_eCC selection less efficient for small electron energy



Oscillation weight & CVN selection effect on kinematic distributions #2



Unweighted

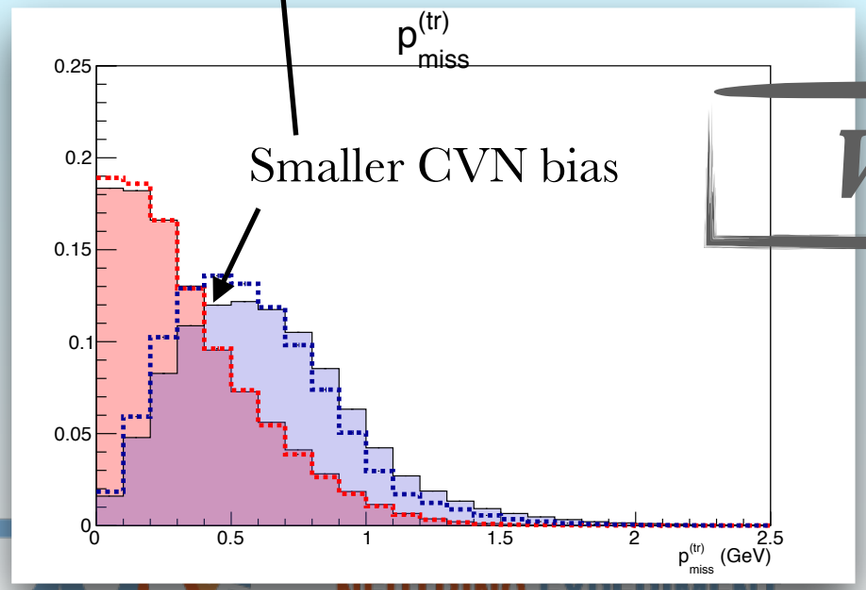


All sample

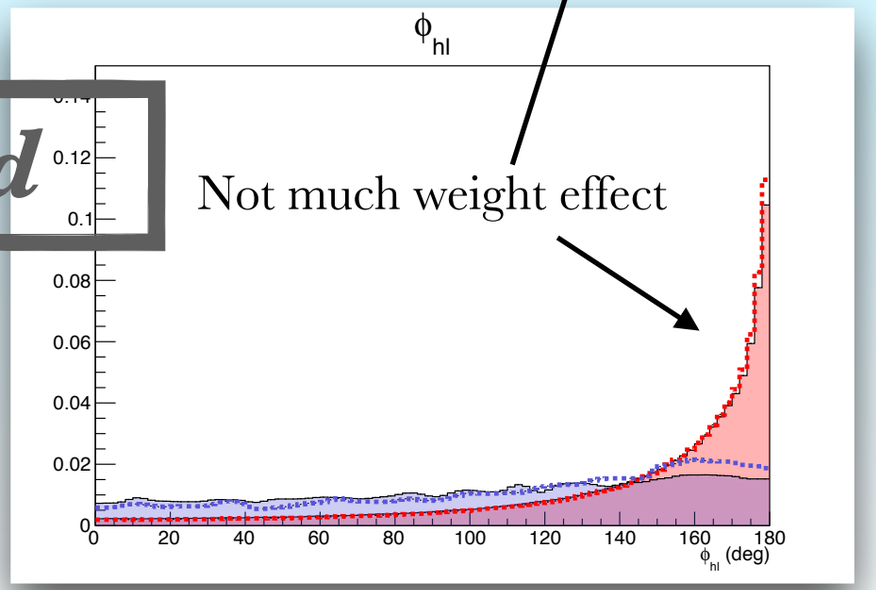
subsample CVN tagged as ν_eCC

ν_eCC from file nuewap.root

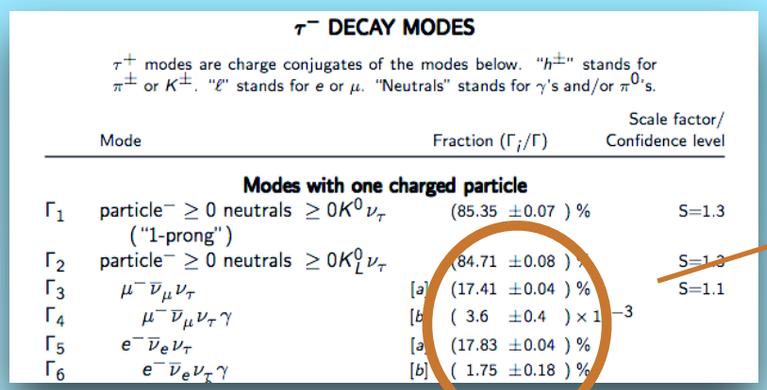
ν_τCC from file nutauwap.root



Weighted



Likelihood analysis for $\tau^{\pm}$—>$e^{\pm}$ decay mode #1



τ^- DECAY MODES

τ^+ modes are charge conjugates of the modes below. "$h^{\pm}$" stands for $\pi^{\pm}$ or $K^{\pm}$. "ℓ" stands for e or μ. "Neutrals" stands for γ's and/or π^0's.

	Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
	Modes with one charged particle		
Γ_1	particle$^-$ ≥ 0 neutrals $\geq 0 K^0 \nu_\tau$ ("1-prong")	(85.35 $\pm$0.07) %	S=1.3
Γ_2	particle$^-$ ≥ 0 neutrals $\geq 0 K^0_L \nu_\tau$	(84.71 $\pm$0.08) %	S=1.3
Γ_3	$\mu^- \overline{\nu}_\mu \nu_\tau$	[a] (17.41 $\pm$0.04) %	S=1.1
Γ_4	$\mu^- \overline{\nu}_\mu \nu_\tau \gamma$	[b] (3.6 $\pm$0.4) $\times 10^{-3}$	
Γ_5	$e^- \overline{\nu}_e \nu_\tau$	[a] (17.83 $\pm$0.04) %	
Γ_6	$e^- \overline{\nu}_e \nu_\tau \gamma$	[b] (1.75 $\pm$0.18) %	

Particle Data Group

17.41% : μ decay

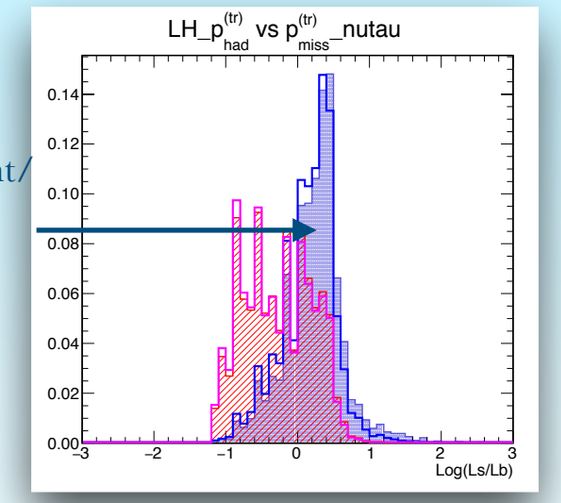
17.83% : e± decay

64.76% : hadronic decay

As many analyses as decay mode…

likelihood distributions (normalized to 1) for two examples of correlations of kinematic variables.

/pnfs/dune/persistent/LBL_TDR/CAFs/nutauwap.root



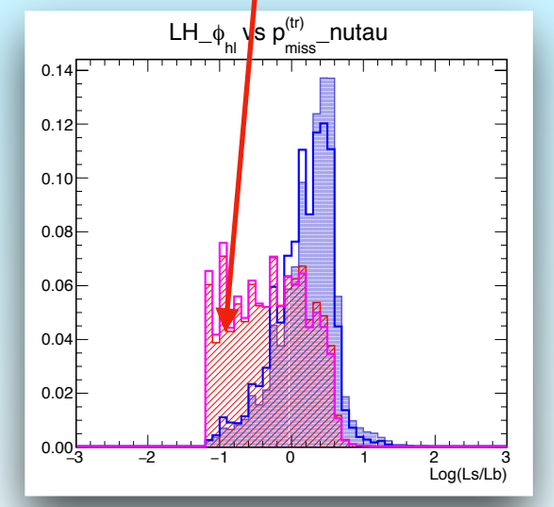
$$L\left(\left[\, p^{(tr)}_{had}, p^{(tr)}_{miss} \,\right]\right)$$

All sample

Subsample CVN tagged as ν_eCC

No obvious correlation between CVN selection and kinematic likelihood value

/pnfs/dune/persistent/LBL_TDR/CAFs/nuewap.root



$$L\left(\left[\, \phi_{hl}, p^{(tr)}_{miss} \,\right]\right)$$

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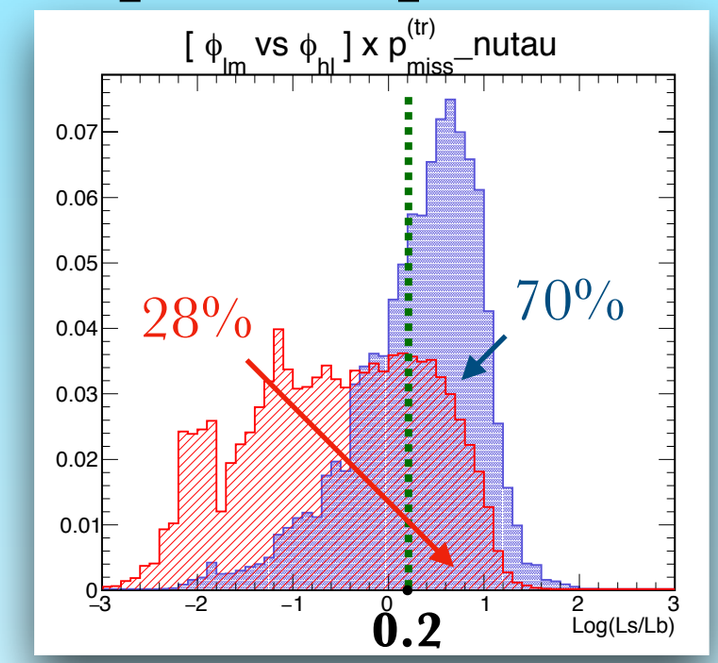
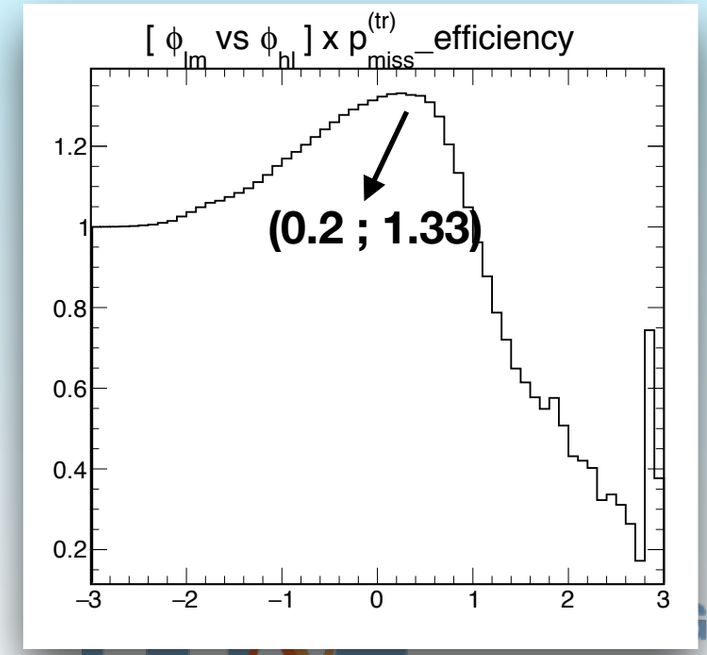
Evaluate S/sqrt(B) #2

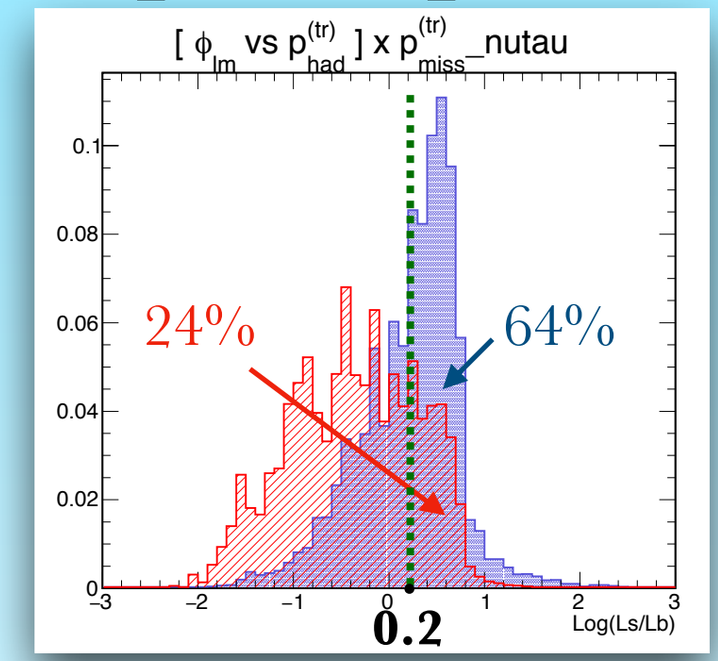
$$\left[\phi_{lm}, \phi_{hl}\right] \times p_{miss}^{(tr)}$$



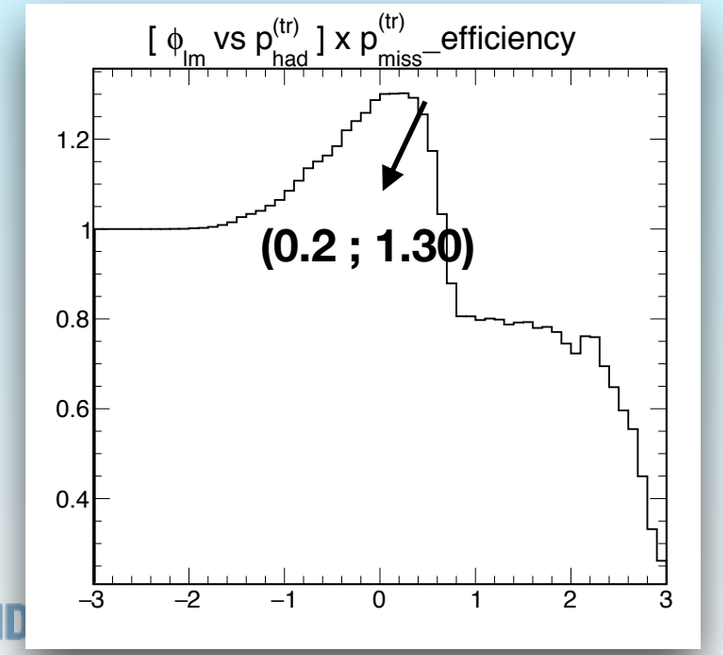
Signal/sqrt(Background)



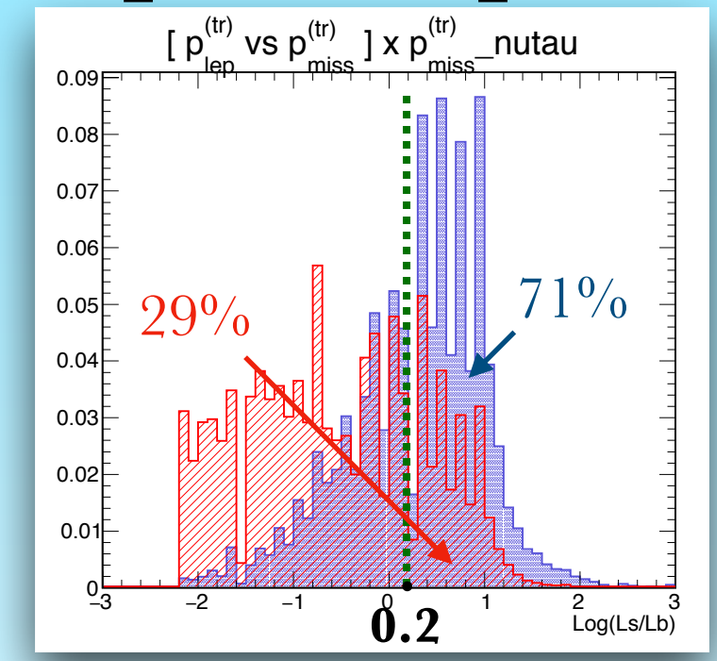
$$\left[\phi_{lm}, p_{had}^{(tr)}\right] \times p_{miss}^{(tr)}$$



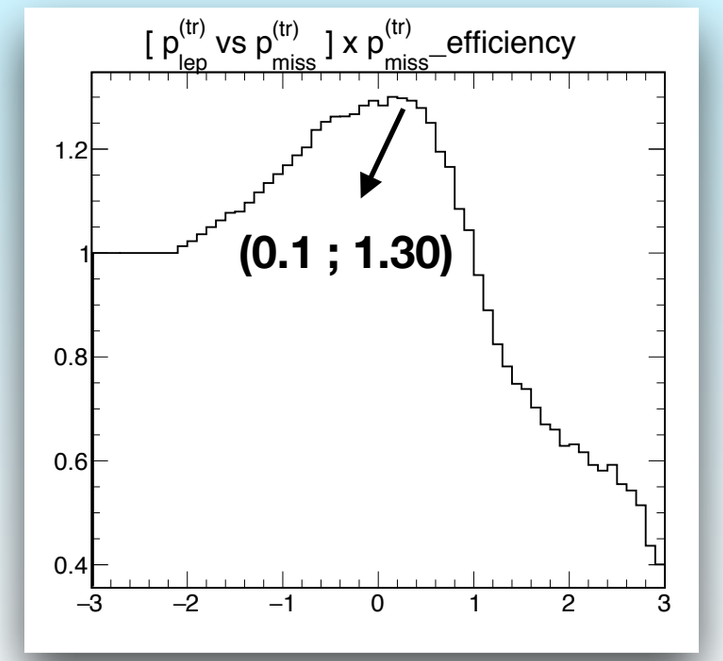
Signal/sqrt(Background)



$$\left[p_{lep}^{(tr)}, p_{miss}^{(tr)}\right] \times p_{miss}^{(tr)}$$

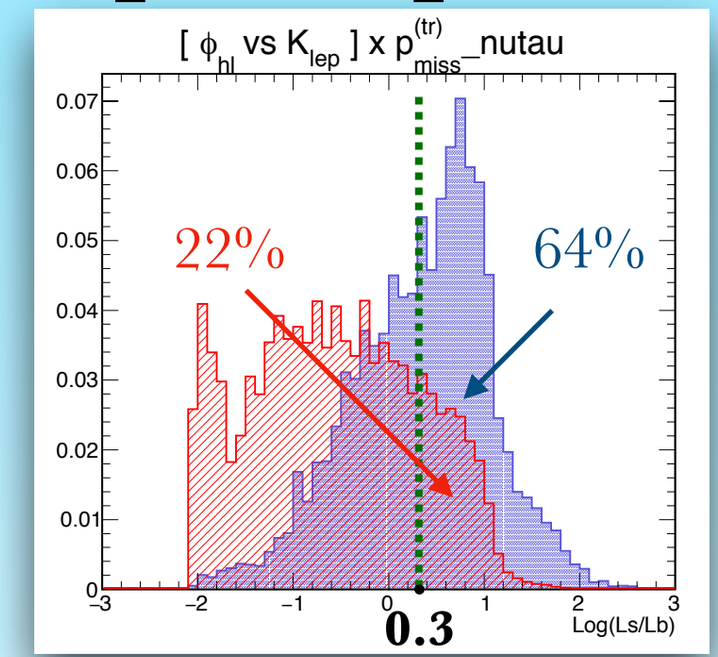


Signal/sqrt(Background)

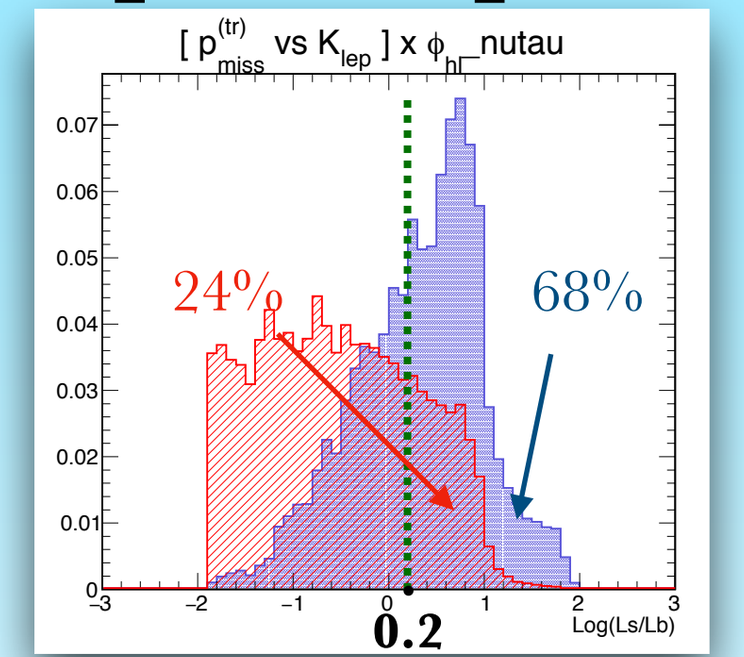


Evaluate S/sqrt(B) #2

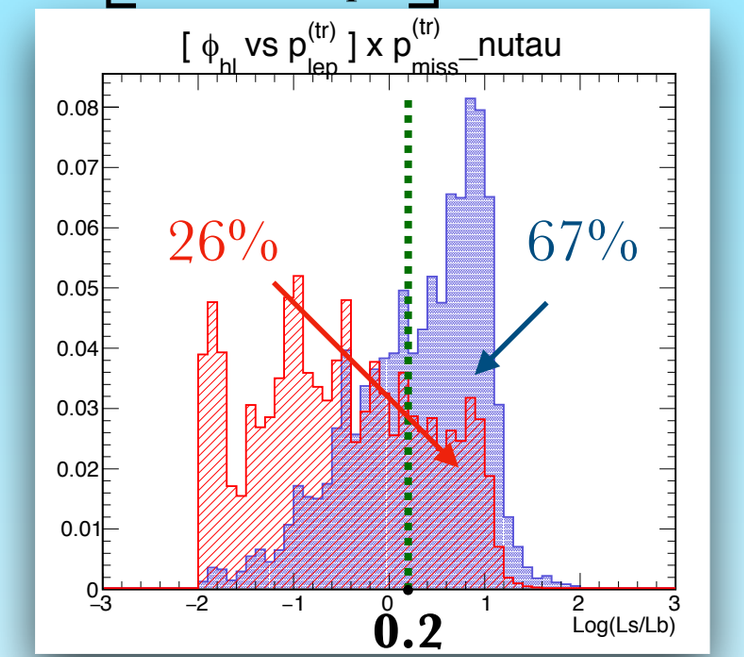
$$\left[\phi_{hl}, K_{lep}\right] \times p_{miss}^{(tr)}$$



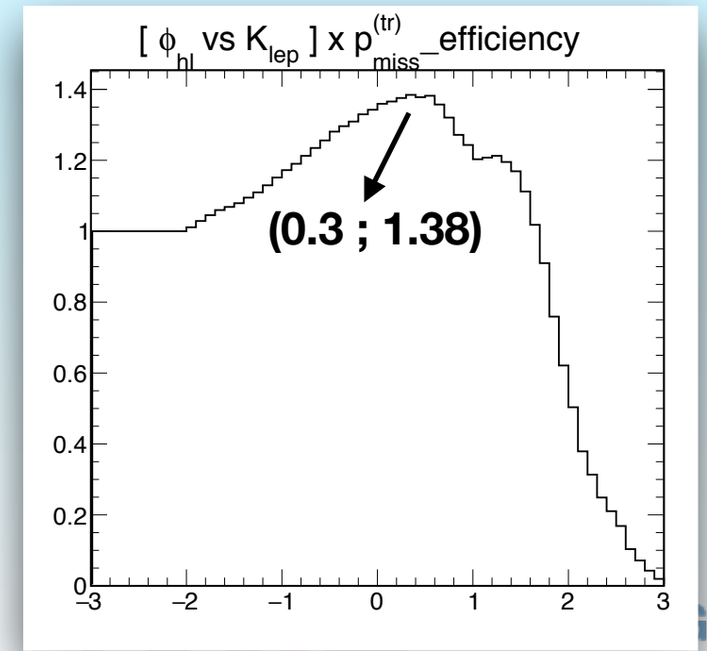
$$\left[p_{miss}^{(tr)}, K_{lep}\right] \times \phi_{hl}$$



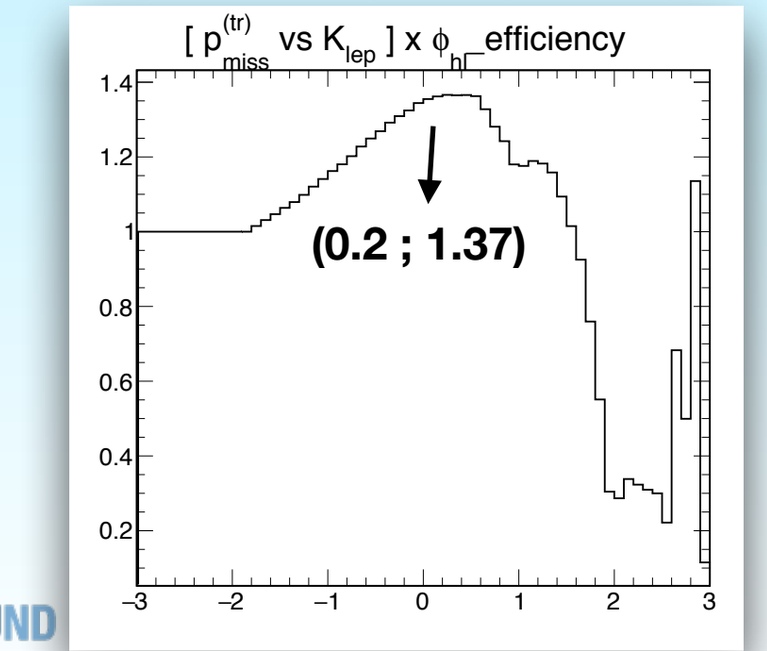
$$\left[\phi_{hl}, p_{lep}^{(tr)}\right] \times p_{miss}^{(tr)}$$



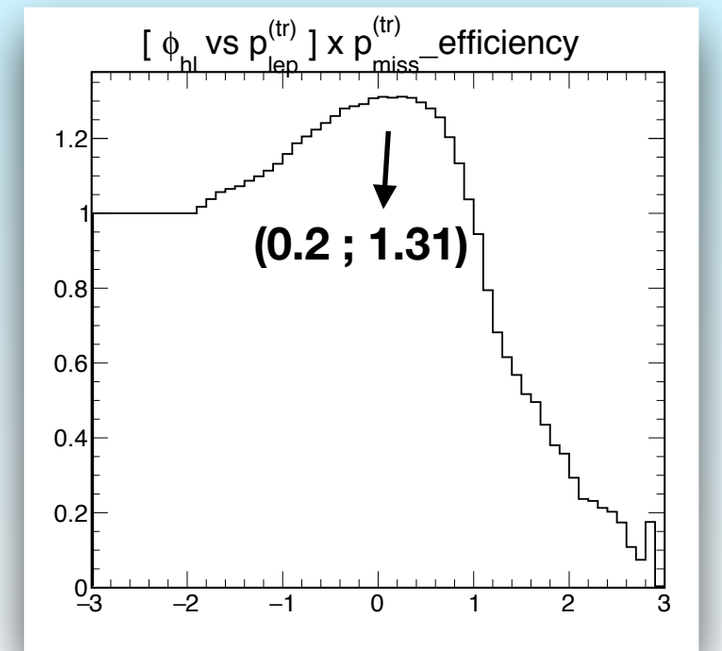
Signal/sqrt(Background)



Signal/sqrt(Background)



Signal/sqrt(Background)



CVN results #1 :
ν_e CC distribution in CVN output

CVN output MC tau decay	p(ν_e CC)>0.85	p(ν_μ CC)>0.5	p(ν_τ CC)>0.5	p(ν NC)>0.5	Others (none of the conditions filled)
ν_e CC	72.4 %	0.9 %	0.8 %	13.4 %	12.6 %

nueswap.root : true ν_eCC repartition by the CVN

CVN output MC tau decay	p(ν_e CC)>0.85	p(ν_μ CC)>0.5	p(ν_τ CC)>0.5	p(ν NC)>0.5	Others (none of the conditions
τ—>e	45.7 %	0.7 %	10.4 %	16.7 %	26.4 %

nutauswap.root : true ν_τCC (τ—>e) repartition by the CVN

CVN output MC tau decay	3.5 years staged #events	CVN efficiency —> ν_e CC	LH efficiency (illusttration)	Other ?	Events remaining
ν_e CC	1167	72.4 %	25 %	/	211 (out of 845)
ν_τ CC	173	46 %	66 %	17.8 % (τ—>e BR)	9 (out of 14)

Normalisation idea to 3.5 years staged number of events

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Outlook/Discussion

- Developing a combined CVN/kinematics analysis, applied to ν_τ beam selection (à la NOMAD). Updates following the lack of oscillation weigthing, now done ! Not much impact.

- The track of the tau lepton won't be visible at DUNE: look at its decay modes ! 1 decay mode = 1 dedicated kinematical analysis. Efforts currently deployed for τ—>e+2ν. Need to extend to other decay modes.

- Additional reconstruction effects to be implemented in computing the likelihoods (already done last year on personnal sample, not re-implemented yet).

- Current CVN ν_τ CC selection efficiency ~ 16% (mainly hadronic decays). Number likely to evolve.

- Work in progress in developing and optimizing the likelihoods for all decay channels and in computing related backgrounds.

- Nutau optimized flux and interaction type (QEL, RES and DIS) analysis.