## Nu mu CC cross-section measurement

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## Introduction

- Summer project
- Measure nu mu CC x-sec
- Efficiency \& Purity
- Unfolding
- NEUT \& NUANCE independent
- MSc in Physics at Imperial College London
- Started June 2012
- Ends September 2012
- Start PhD at Liverpool University in October 2012.


## Cuts



SciBar stopped: track upstream end within fiducial volume \& track contained in SciBar.
MRD stopped: track upstream end within fiducial volume \& track matched to MRD hit.
Fiducial volume: " $|\mathrm{x}|<130 \mathrm{~cm} \&|\mathrm{y}|<130 \mathrm{~cm} \& 2.62 \mathrm{~cm}<\mathrm{z}<157.2 \mathrm{~cm} "$.
Not looking at MRD penetrated events because no pmu value.

## Data

- Using processed root trees from Nakajima-san
- Using two Monte Carlo files, one treated as fake data.
- Two Monte Carlo files for blind analysis before applying method to real data.


## SciBar stopped events

Hist. of SciBar stopped pmu reconstructed (MC)


Hist. of SciBar stopped $\cos \theta$ reconstructed (MC)

$N_{S B-T O T}^{M C}=$ Number of SciBar stopped events in MC

## MRD stopped events

Hist. of MRD stopped pmu reconstructed (MC)


Hist. of MRD stopped $\cos \theta$ reconstructed (MC)

$N_{\text {MRD-TOT }}^{M C}=$ Number of MRD stopped events in MC

## SciBar stopped CC events

Hist. of SciBar stopped cc pmu reconstructed (MC)


Hist. of SciBar stopped cc $\cos \theta$ reconstructed (MC)

$N_{S B-C C}^{M C}=$ Number of CC SciBar stopped events in MC

## MRD stopped CC events

Hist. of MRD stopped cc pmu reconstructed (MC)


Hist. of MRD stopped cc $\cos \theta$ reconstructed (MC)

$N_{M R D-C C}^{M C}=$ Number of CC MRD stopped events in MC

## Fiducial volume interactions

Hist. of fiducial volume pmu reconstructed (MC)


Hist. of fiducial volume $\cos \theta$ reconstructed (MC)

$N_{F V-T O T}^{M C}=$ number of events for which true vertex occurs within
fiducial volume for MC . fiducial volume for MC.

## Efficiency plots

Hist. of SciBar stopped pmu reconstructed efficiency (MC)


Hist. of SciBar stopped $\cos \theta$ reconstructed efficiency (MC)

$E_{S B} \quad=$ efficiency for SB cuts in MC
$N_{S B-\text { TOT }}^{M C}=$ number of events that pass SB cuts in MC
$N_{F V-T O T}^{M C}=$ number of events for which true vertex occurs within

$$
E_{S B}=\frac{N_{S B-T O T}^{M C}}{N_{F V-T O T}^{M C}}
$$

Hist. of MRD stopped pmu reconstructed efficiency (MC)


Hist. of MRD stopped cos $\theta$ reconstructed efficiency (MC)

$E_{\text {MRD }} \quad=$ efficiency for MRD cuts in MC
$N_{M R D-\text { тот }}^{M C}=$ number of events that pass MRD cuts in MC
$N_{F V-T O T}^{M C}=$ number of events for which true vertex occurs within fiducial volume.

$$
E_{M R D}=\frac{N_{M R D-T O T}^{M C}}{N_{F V-T O T}^{M C}}
$$

## Purity plots

Hist. of SciBar stopped pmu reconstructed cc purity (MC)


Hist. of SciBar stopped $\cos \theta$ reconstructed cc purity (MC)

$P_{S B-C C}=$ CC purity for SB cuts in MC
$N_{S B-C C}^{M C}=$ number of true CC events that pass SB cuts in MC
$N_{S B-T O T}^{M C}=$ number of events that pass SB cuts in MC

$$
P_{S B-C C}=\frac{N_{S B-C C}^{M C}}{N_{S B-T O T}^{M C}}
$$

Hist. of MRD stopped pmu reconstructed cc purity (MC)


Hist. of MRD stopped cos $\theta$ reconstructed cc purity (MC)

$P_{\text {MRD }-C C}=$ CC purity for MRD cuts in MC
$N_{M R D-C C}^{M C}=$ number of true CC events that pass MRD cuts in MC
$N_{M R D-T O T}^{M C D}=$ number of events that pass MRD cuts in MC

$$
P_{M R D-C C}=\frac{N_{M R D-C C}^{M C}}{N_{M R D-T O T}^{M C}}
$$

## Data file events

Hist. of SciBar stopped pmu reconstructed (data)


Hist. of SciBar stopped $\cos \theta$ reconstructed (data)

$N_{S B-T O T}^{\text {DATA }}=$ number of events that pass SB cuts in data

Hist. of MRD stopped pmu reconstructed (data)


Hist. of MRD stopped $\cos \theta$ reconstructed (data)

$N_{\text {MRD-TOT }}^{\text {DATA }}=$ number of events that pass MRD cuts in data

## Unfolding matrices (MC)



Unfolding(i, j$)=\mathrm{P}($ true pmu in bin $\mathrm{i} \mid$ reconstructed pmu in bin j$)$
pmu unfolding matrix for MRD stopped events (MC)

$\boldsymbol{\operatorname { c o s }} \theta$ unfolding matrix for MRD stopped events (MC)


Unfolding(i, j$)=\mathrm{P}($ true pmu in bin $\mathrm{i} \mid$ reconstructed pmu in bin j$)$

## Unfolding matrices (data)

pmu unfolding matrix for SB stopped events (data)

$\cos \theta$ unfolding matrix for SB stopped events (data)


Unfolding(i, j$)=\mathrm{P}($ true pmu in bin $\mathrm{i} \mid$ reconstructed pmu in bin j$)$
pmu unfolding matrix for MRD stopped events (data)

$\cos \theta$ unfolding matrix for MRD stopped events (data)


Unfolding(i, j$)=\mathrm{P}($ true pmu in bin $\mathrm{i} \mid$ reconstructed pmu in bin j$)$

# Corrected events: unfolded MC vs true MC 

Unfolded MC vs true MC for SciBar stopped events


Unfolded MC vs true MC for SciBar stopped events


All SciBar-stopped events in the MC file, corrected for purity and efficiency calculated from MC events. Unfolded MC events are plotted vs true MC events.

$$
\begin{aligned}
& N_{S B-\text { Corrected }}^{M C-U N F}=\frac{N_{S B-T O T}^{M C-U N F} \cdot P_{S B-C C}}{E_{S B}} \\
& N_{S B-\text { Corrected }}^{M C-T R U E}=\frac{N_{S B-T R T}^{M C-T R U E} \cdot P_{S B-C C}}{E_{S B}}
\end{aligned}
$$

Unfolded MC vs true MC for MRD stopped events


Unfolded MC vs true MC for MRD stopped events


All MRD-stopped events in the MC file, corrected for purity and efficiency calculated from MC events. Unfolded MC events are plotted vs true MC events.

$$
\begin{aligned}
& N_{M R D-C o r r e c t e d}^{D A T A}=\frac{N_{M R D-T O T}^{D A T A-U N F} \cdot P_{M R D-C C}}{E_{M R D}} \\
& N_{M R D-\text { Corrected }}^{M C}=\frac{N_{M R D-T O T}^{M C-T R U E} \cdot P_{M R D-C C}}{E_{M R D}}
\end{aligned}
$$

## Corrected events: unfolded data vs unfolded MC

Unfolded data vs unfolded MC for SciBar stopped events


Unfolded data vs unfolded MC for SciBar stopped events


All SciBar-stopped events in the data and MC files, corrected for purity and efficiency calculated from MC events. Data and MC are unfolded.

$$
\begin{aligned}
N_{S B-\text { Corrected }}^{D A T A} & =\frac{N_{S B-T O T}^{D A T A-U N F} \cdot P_{S B-C C}}{E_{S B}} \\
N_{S B-\text { Corrected }}^{M C} & =\frac{N_{S B-T O T}^{M C-U N F} \cdot P_{S B-C C}}{E_{S B}}
\end{aligned}
$$

Unfolded data vs unfolded MC for MRD stopped events


Unfolded data vs unfolded MC for MRD stopped events


All MRD-stopped events in the data and MC files, corrected for purity and efficiency calculated from MC events. Data and MC are unfolded.

$$
\begin{aligned}
& N_{M R D-C o r r e c t e d}^{D A T A}= \\
& N_{M R D-C o r r e c t e d}^{M C}=\frac{N_{M R D-T O T}^{D A T A-U N F} \cdot P_{M R D-C C}}{E_{M R D}} \\
& N_{M R D-T O T} \cdot P_{M R D-C C} \\
& E_{M R D}
\end{aligned}
$$

## Corrected events: unfolded data vs true MC

Unfolded data vs true MC for SciBar stopped events


Unfolded data vs true MC for SciBar stopped events


All SciBar-stopped events in the data and MC files, corrected for purity and efficiency calculated from MC events. Data is unfolded, MC uses true data.

$$
\begin{aligned}
N_{S B-C o r r e c t e d}^{D A T A} & =\frac{N_{S B-T O T}^{D A T A-U N F} \cdot P_{S B-C C}}{E_{S B}} \\
N_{S B-\text { Corrected }}^{M C} & =\frac{N_{S B-T O T}^{M C-T R U E} \cdot P_{S B-C C}}{E_{S B}}
\end{aligned}
$$

Unfolded data vs true MC for MRD stopped events


Unfolded data vs true MC for MRD stopped events


All MRD-stopped events in the data and MC files, corrected for purity and efficiency calculated from MC events. Data is unfolded, MC uses true.

$$
\begin{aligned}
& N_{M R D-C o r r e c t e d}^{D A T A}=\frac{N_{M R D-T O T}^{D A T A-U N F} \cdot P_{M R D-C C}}{E_{M R D}} \\
& N_{M R D-\text { Corrected }}^{M C}=\frac{N_{M R D-T O T}^{M C-T R U E} \cdot P_{M R D-C C}}{E_{M R D}}
\end{aligned}
$$

## Future analysis

- Make sure method is correct.
- Deal with errors properly.
- Weight adjusted
- Divide by flux to calculate cross section
- Apply method to real data

