Interaction Physics at a Near Detector

most slides coming from VIET NUS 2012:

Some Calculations on the NuSTORM ND rates

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on behalf of Steve Boyd & Ken Long & Ian Taylor

work done during workshop

Overview

- Goals
- The Setup
- The Reconstruction
- Analysis:
  - ✦Rates for ν_μ CCQE
  - ✦Systematics - discussion

Goals

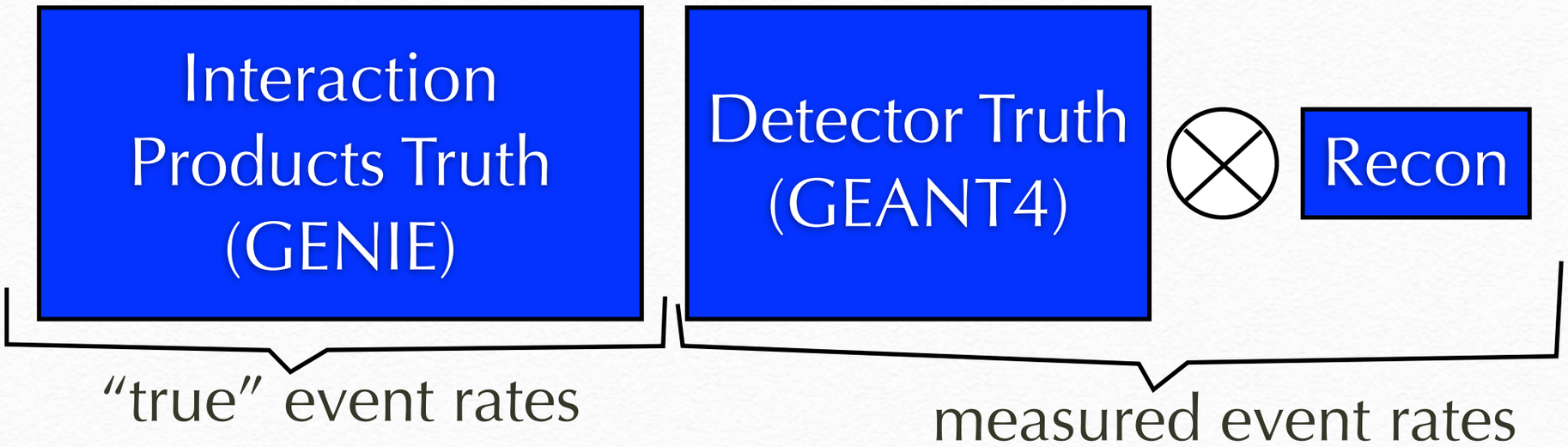
To provide a flexible toolkit that delivers the cross-section measurements that can be done at a nuSTORM near detector.

- GENIE - the neutrino generator

  ➡ can vary neutrino flux

- GEANT4 - propagates the particles that come out of the interaction in the detector(s)

  ➡ can vary target material, detector assumptions

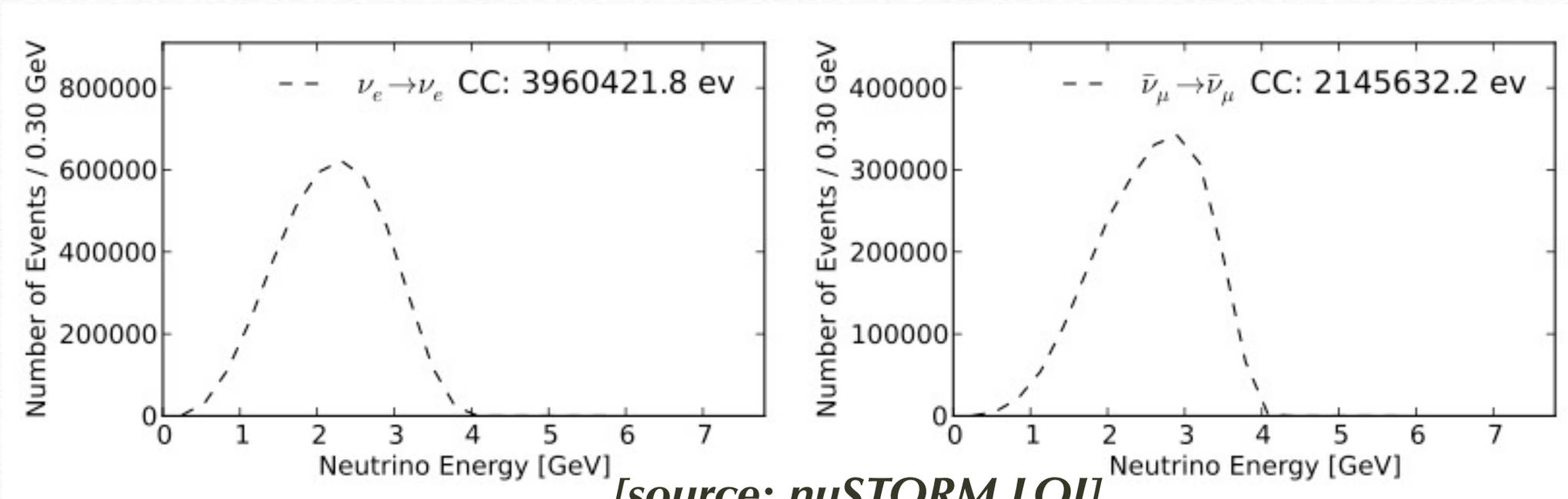

Interaction Products Truth (GENIE)
Detector Truth (GEANT4)
Recon
"true" event rates
measured event rates

The Setup

- Beam assumption: stored μ^+

$$\mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$$

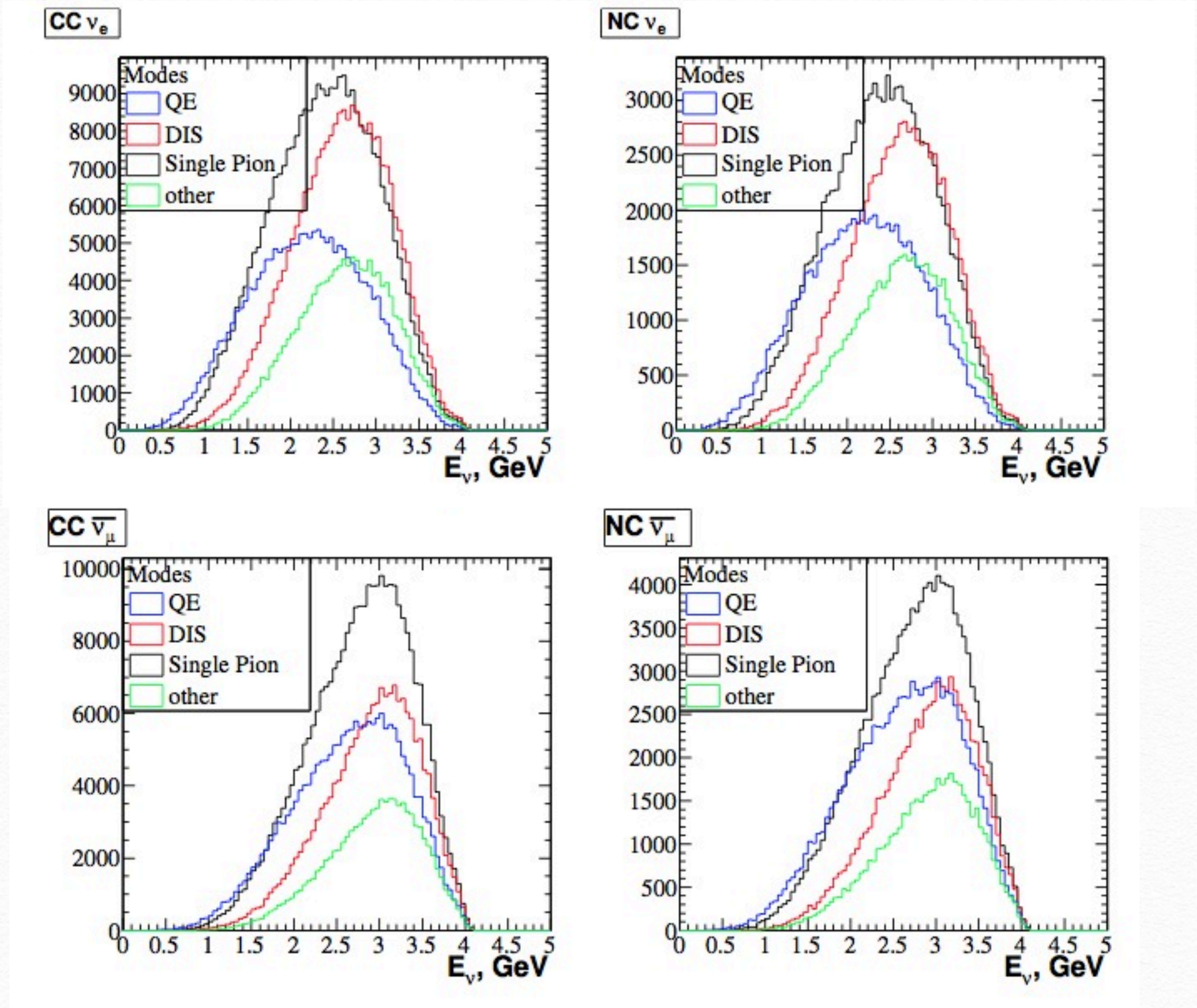
- Flux at near detector: [50 m away from the end of the straight section, 100T fidutial mass, 10^{21} POT]



[source: nuSTORM LOI]

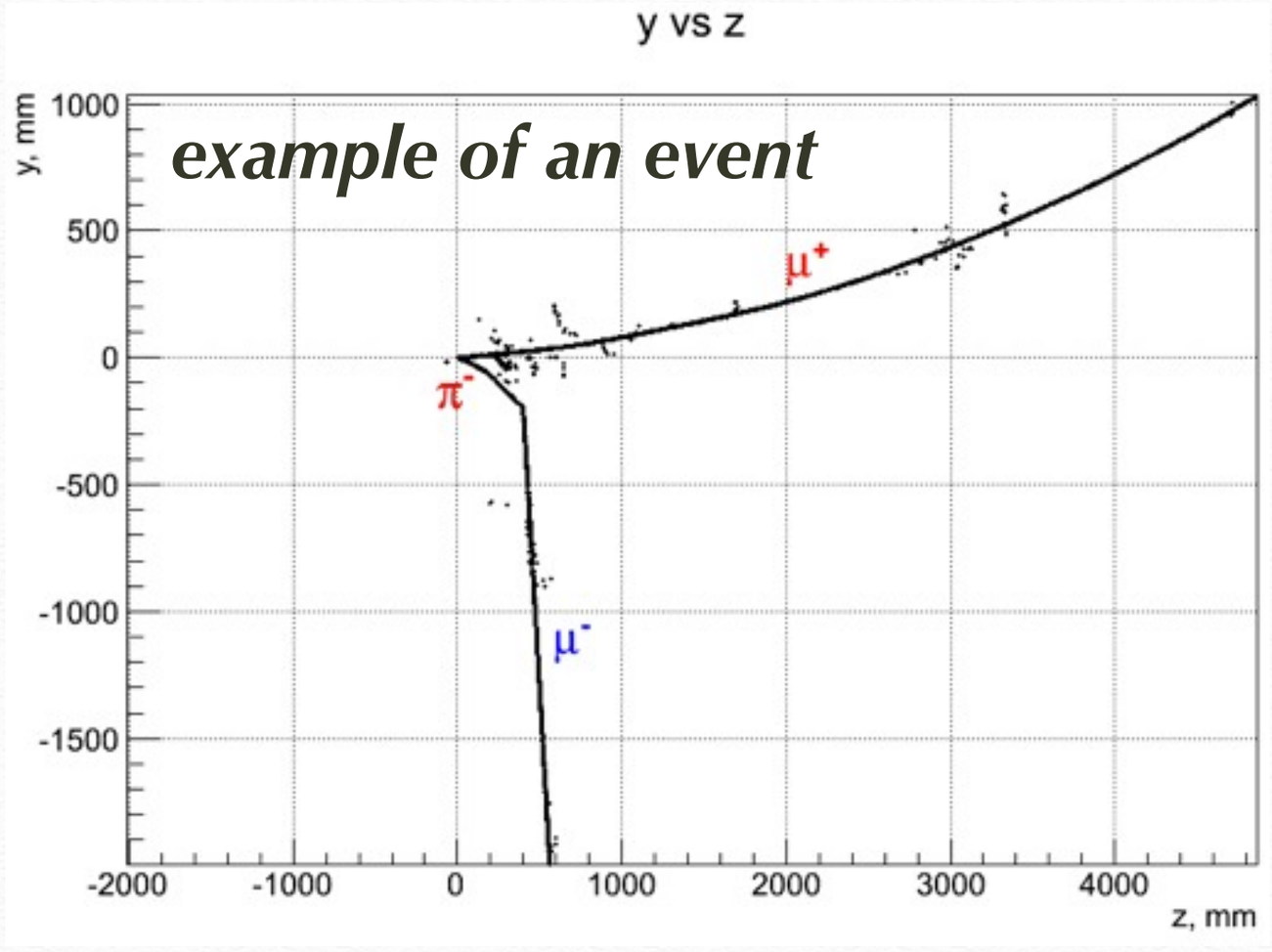
Events modes expected at near detector

Prior-to-reconstruction analysis is already informative.



The Setup

- For the work shown in this talk:
  - Detector is volume of totally active LAr in uniform 0.5 T magnetic field.
  - Detector target geometry: cube 5m side.



Reconstruction

"truth based estimate of what is possible with a good reconstruction"
- Ian Taylor

- The stages of reconstruction are:
  - ✳ digitization of the MC events
    - ✳ smears spacial resolution. Assumed a grid with 2mm pitch.
  - ✳ track selection
    - ✳ 3 usable digits (isolated)
  - ✳ reconstruction of charge, **momentum**, PID

Analysis

Goal is to find measured event rates for the interaction channels (not the event modes).

Just out of curiosity, here's the list of the 7 most frequent interaction channels we found:

mode ID	particles	parent	frequency (%)
0	$\mu^+ + n + p$	$\bar{\nu}_\mu$	14.5
1	$e^- + n + p$	ν_e	13.75
2	$e^- + p$	ν_e	13.73
3	$\mu^+ + n$	$\bar{\nu}_\mu$	12.1
4	$\mu^+ + \pi^- n$	$\bar{\nu}_\mu$	9.2
5	$e^- + \pi^+ + n + p$	ν_e	7.76
6	$\mu^+ + \pi^+ + n + p$	$\bar{\nu}_\mu$	7.3
7	$\mu^+ + \pi^+ + p$	$\bar{\nu}_\mu$	7.12

Analysis

However, for the workshop we did something simpler...

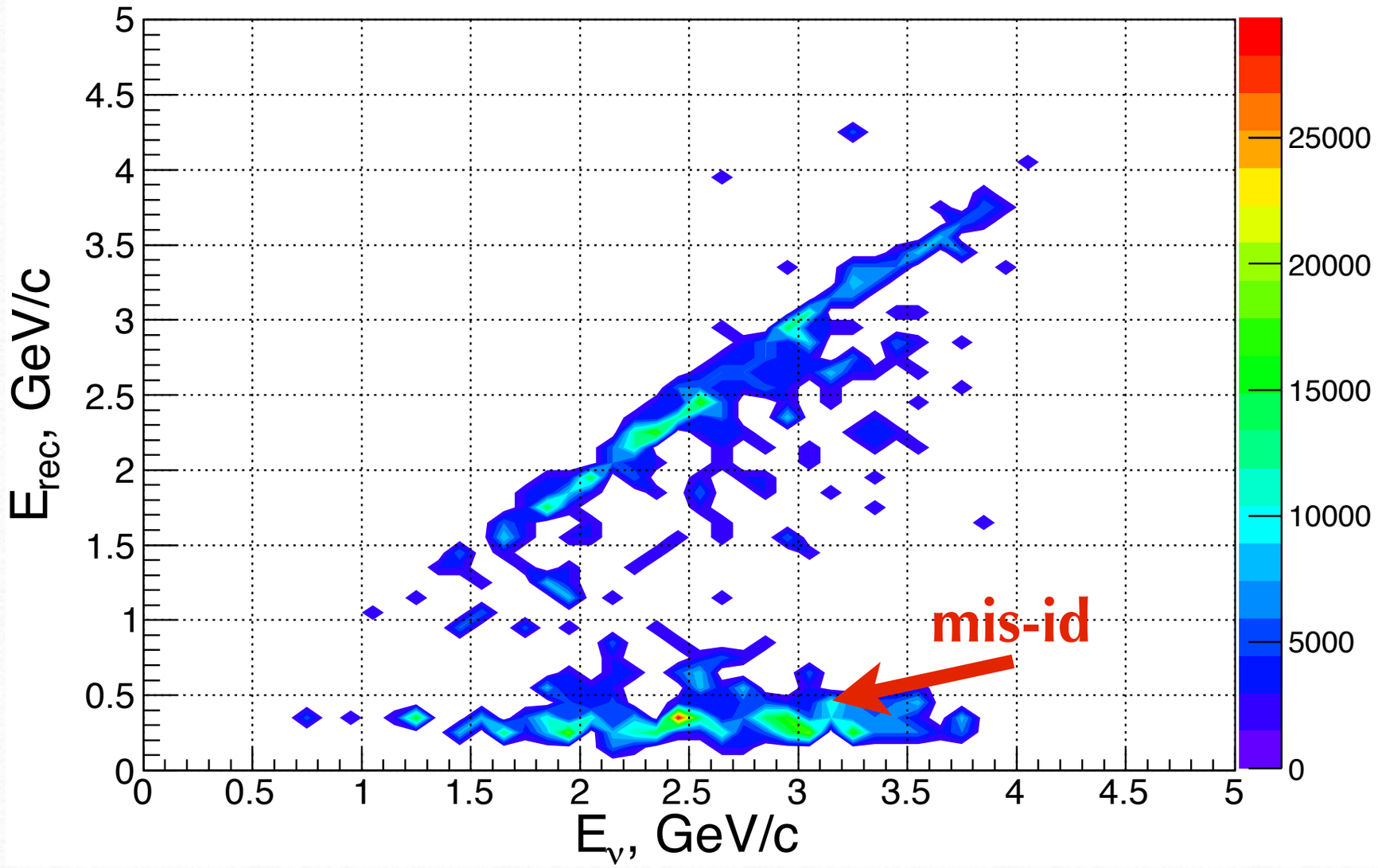
First attempt of analysis: ν_μ CCQE events:

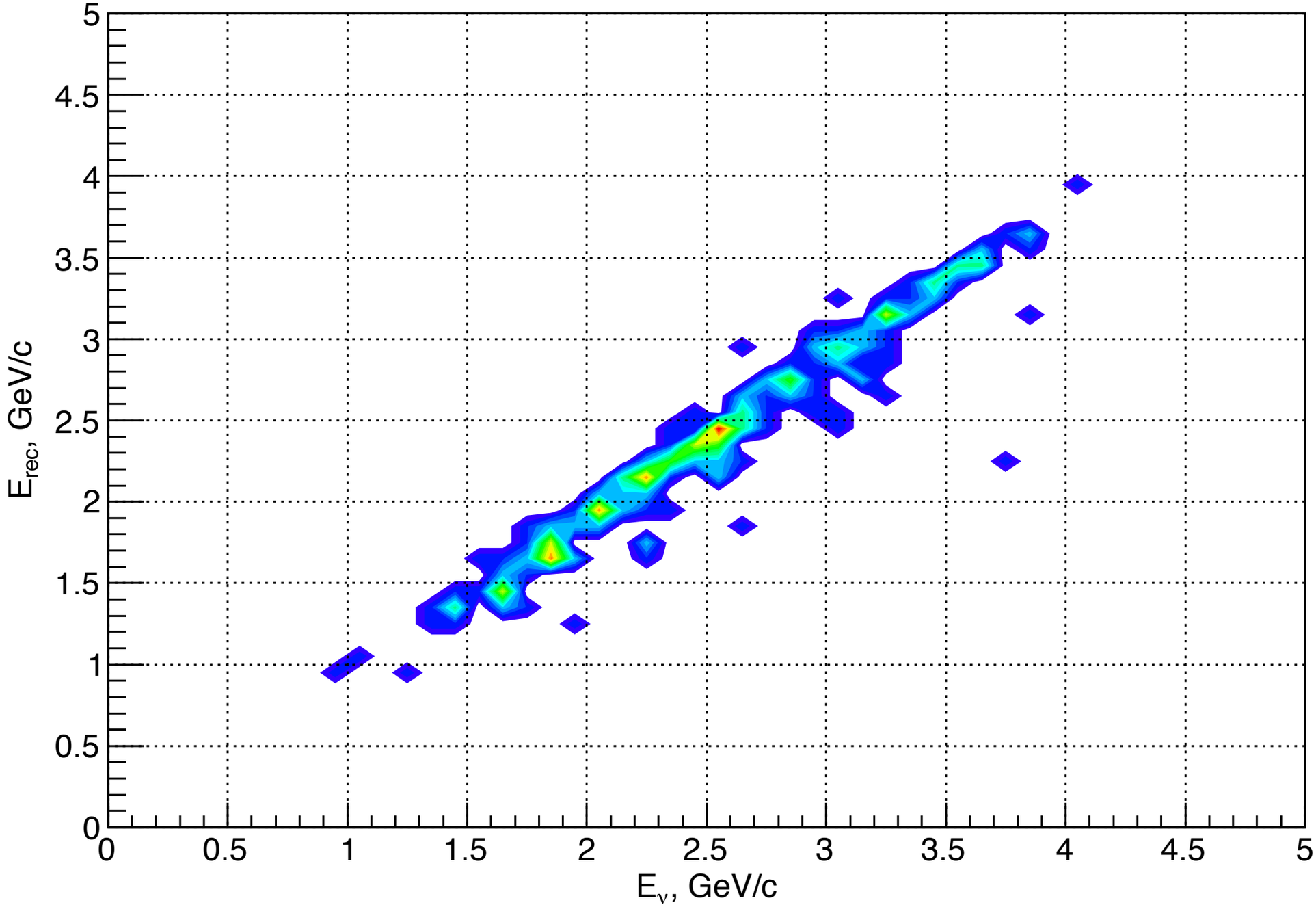
- ➡ Efficiency of finding full CCQE events;
- ➡ Purity;
- ➡ What's the ν_e background?

Reconstruction of the Neutrino Energy

- Based on energy of outgoing muon:

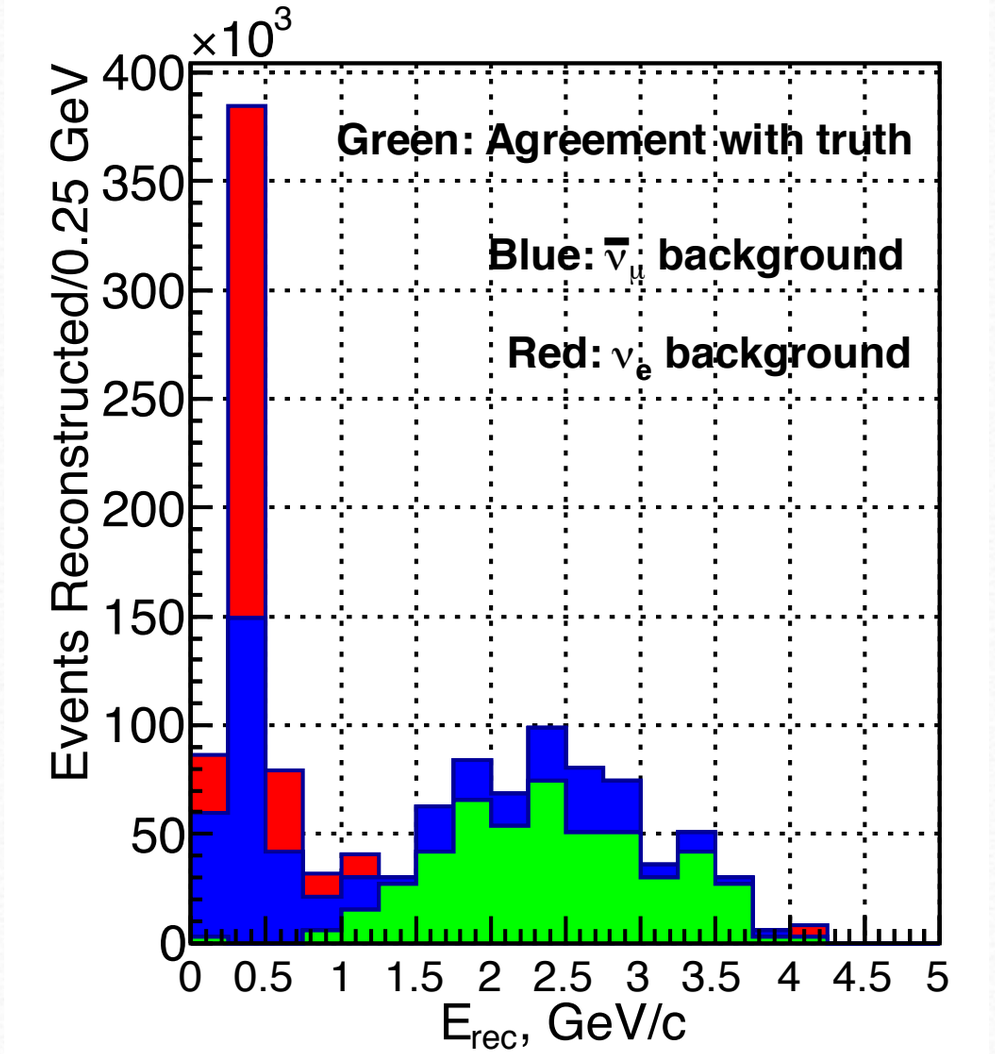
$$E_{rec} = \frac{ME_\mu - m_\mu^2/2}{M - E_\mu + p_\mu \cos(\theta_\mu)}$$





[Excluding Mis-ID's]

ν_μ CCQE events found by Reconstruction



(stacked histogram)

cross-section (E) = event rate (E) / flux (E)

Estimation of systematics affecting rate isn't trivial.

Systematic Uncertainties on the Event Rate

*No estimations, just an overview of **what** to look at.*

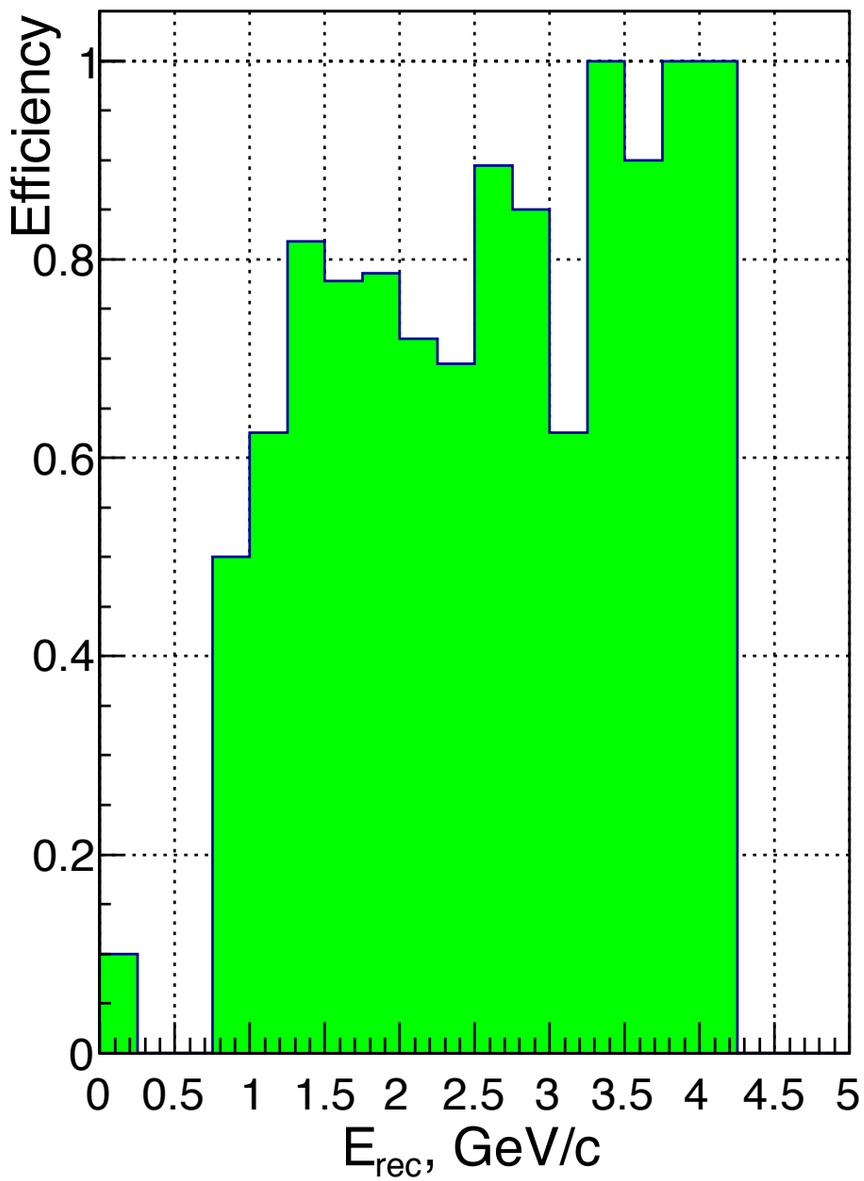
Contributions:

- detector & reconstruction:
  - charge mis-id, event contamination. Example: how much does the rate change if we move the threshold for nu_e exclusion? (previous slide)

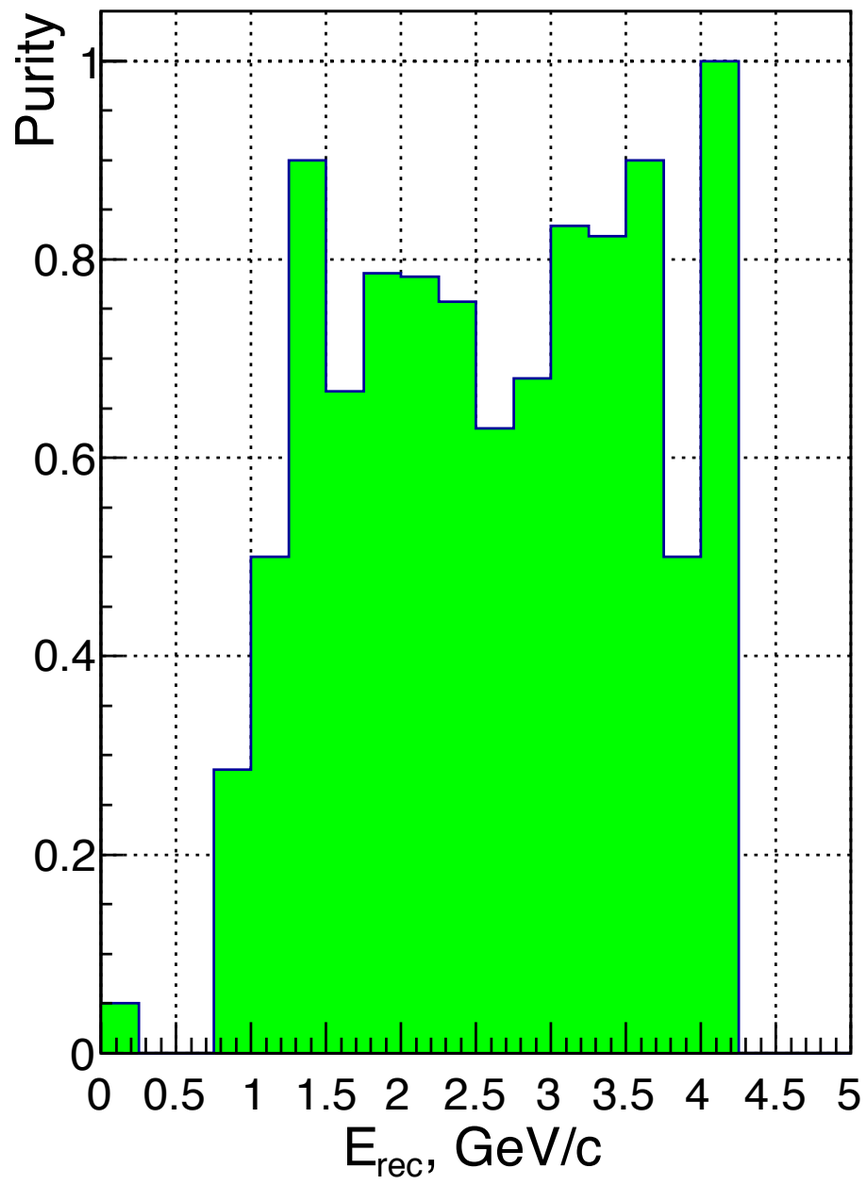
- others:
  - effect of final state interactions on the measured energy.

Purity and Efficiency for the ν_μ CCQE analysis

Efficiency = $\frac{\text{\#correctly recon ev}}{\text{\# ev generated}}$



Purity = $\frac{\text{\#correctly recon ev}}{\text{\# ev reconstructed}}$



Summary

- Work is reliable up to the detector digitization.
- Reconstruction still needs some planning and efficiencies must be collected from literature.
- Some crude ideas about the systematics.
- More analysis to follow.