ALTERNATIVE SHOWER DIRECTION RECONSTRUCTION FOR ELECTRON SHOWERS

Bruno Zamorano - University of Granada

30 November 2022

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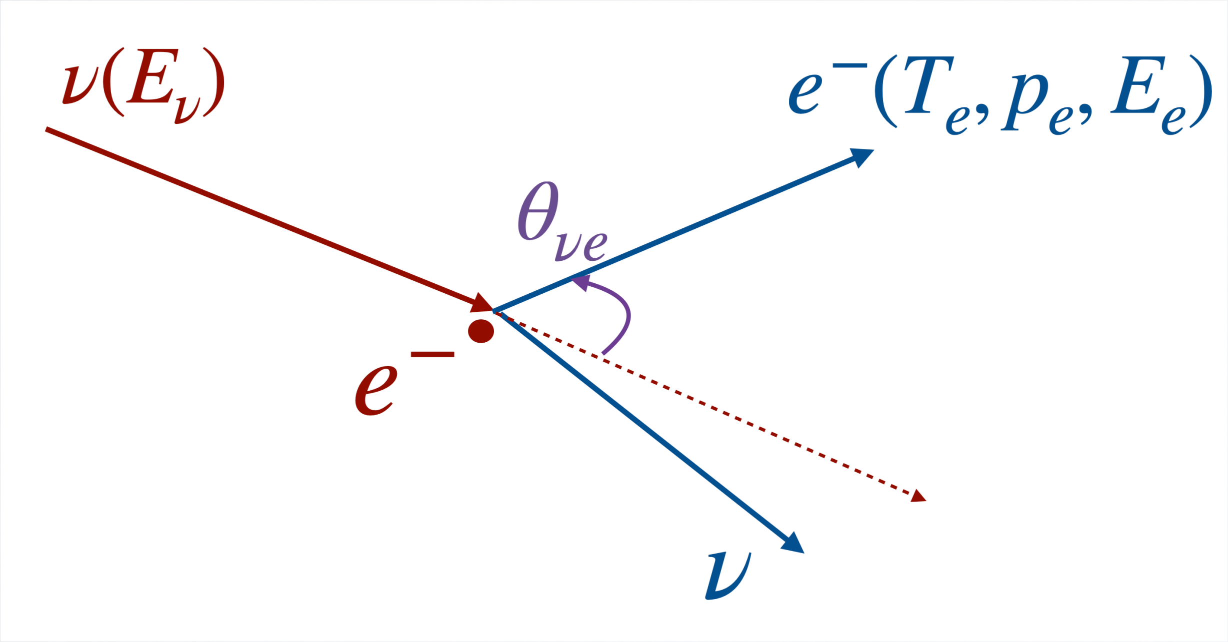
INTRODUCTION

- This works takes up the effort carried out by Marina Bravo a few months ago (see docDB 26620 and 26725 for more details)
- The work was (and somehow still is) developed under the scope of neutrino-electron elastic scattering reconstruction
  - A good direction reconstruction is critical in this type of analyses: very forward events, kinematics heavily dependent on the angular distribution of particles in the final state
  - But an improved direction reconstruction is beneficial in many other areas (e.g., reconstructing invariant masses, cosmic rejection…)

INTRODUCTION



$$E_\nu = \frac{\overset{O(10^{-4})}{m_e}\,\overset{O(1)}{T_e}}{\underset{O(1)}{p_e}\,\underset{\sim 1}{\cos\theta_{\nu e}} - T_e}$$

Caveat:

Measuring the incoming neutrino energy requires an **excellent** precision measuring both the energy and direction of the electron shower

About the kinematic cut

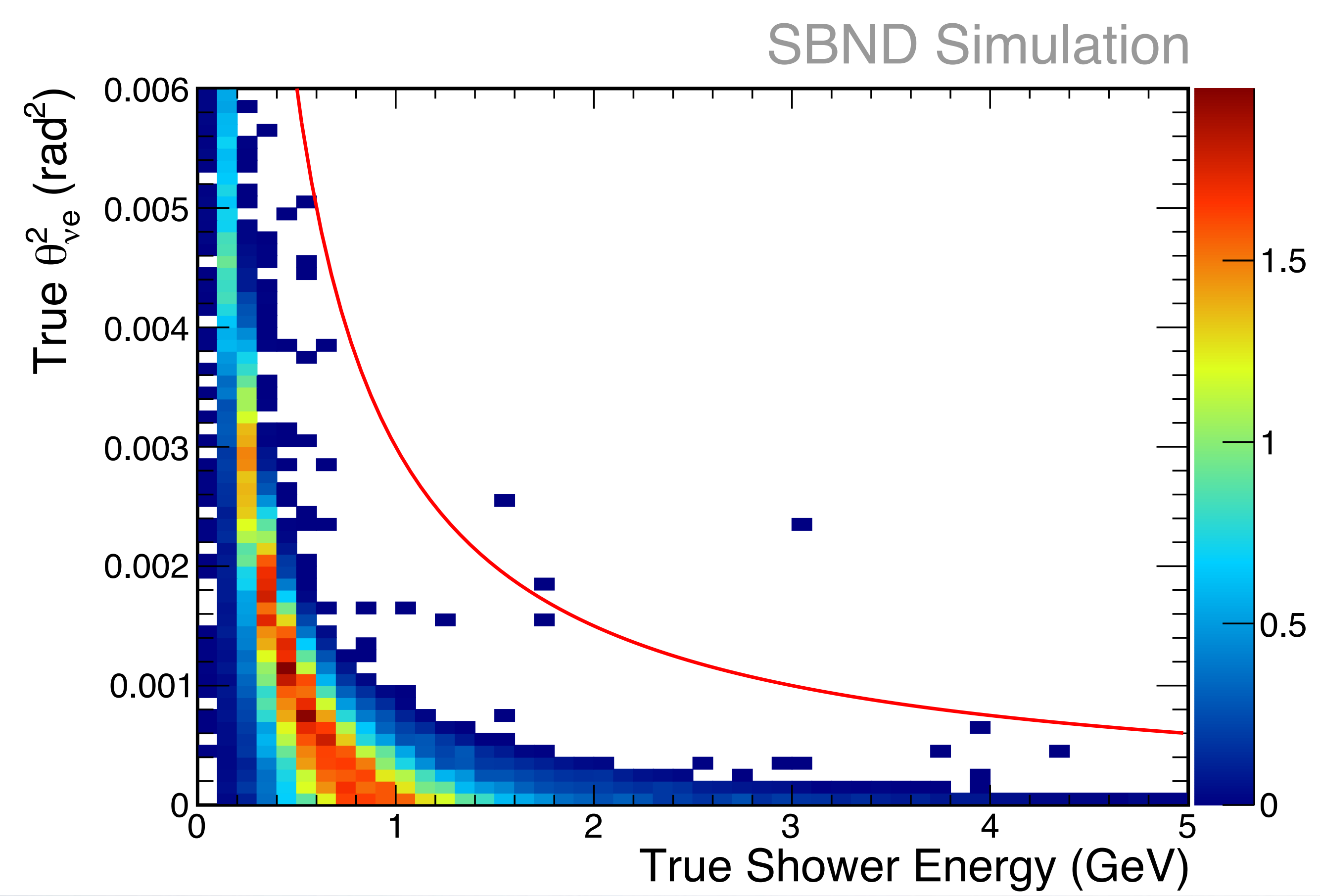
But we also use the shower direction for selecting these events! (Cut in $E\theta^2$)

In the relativistic limit:

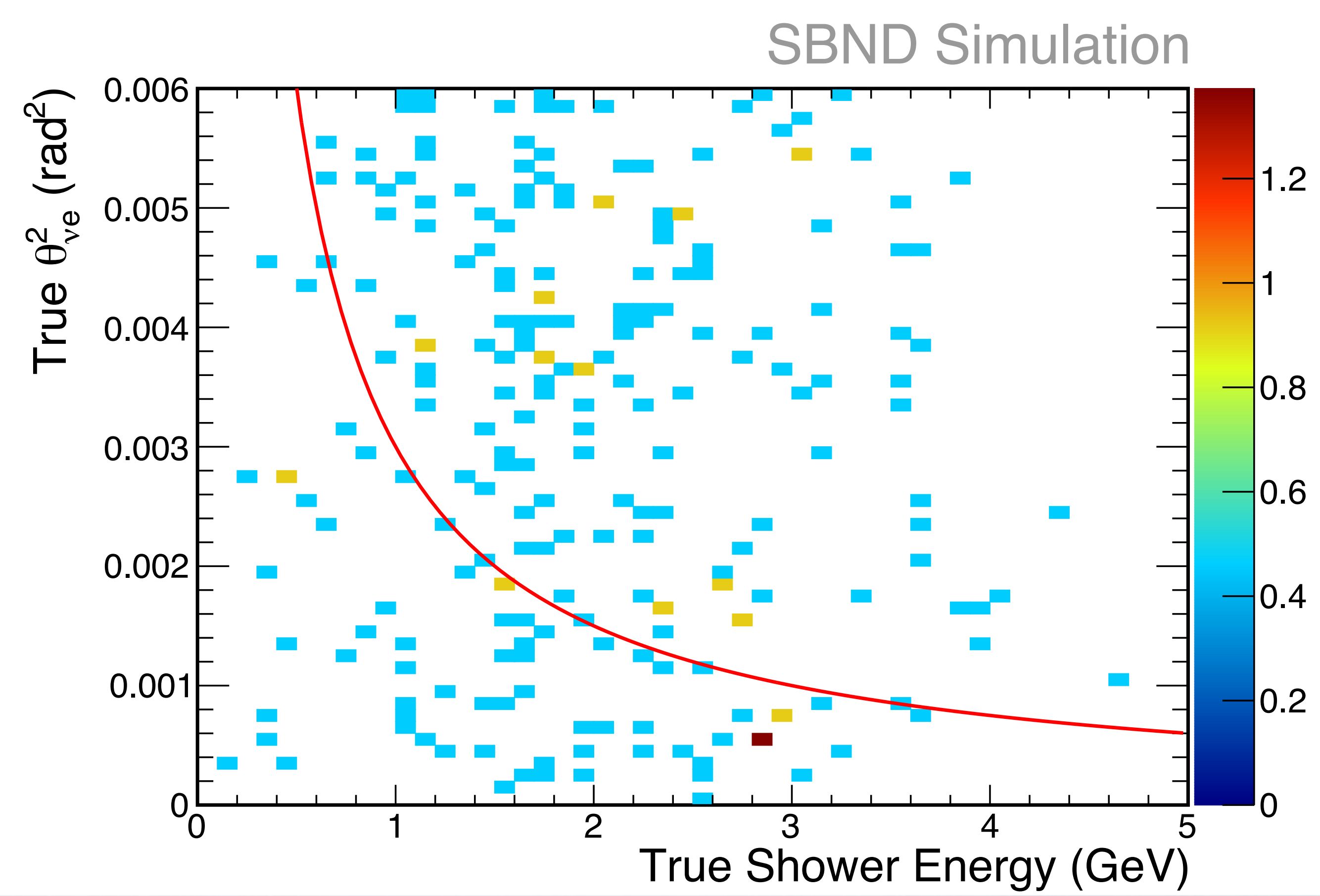
$$1 - \cos\theta = \frac{m_e\left(1-y\right)}{E_e}, \text{ where } y = \frac{T_e}{E_\nu}$$

$$E_e\theta^2 \simeq 2m_e\left(1-y\right) \leq 2m_e = 0.001 \text{ GeV}$$

SELECTION (TRUE VARIABLES)



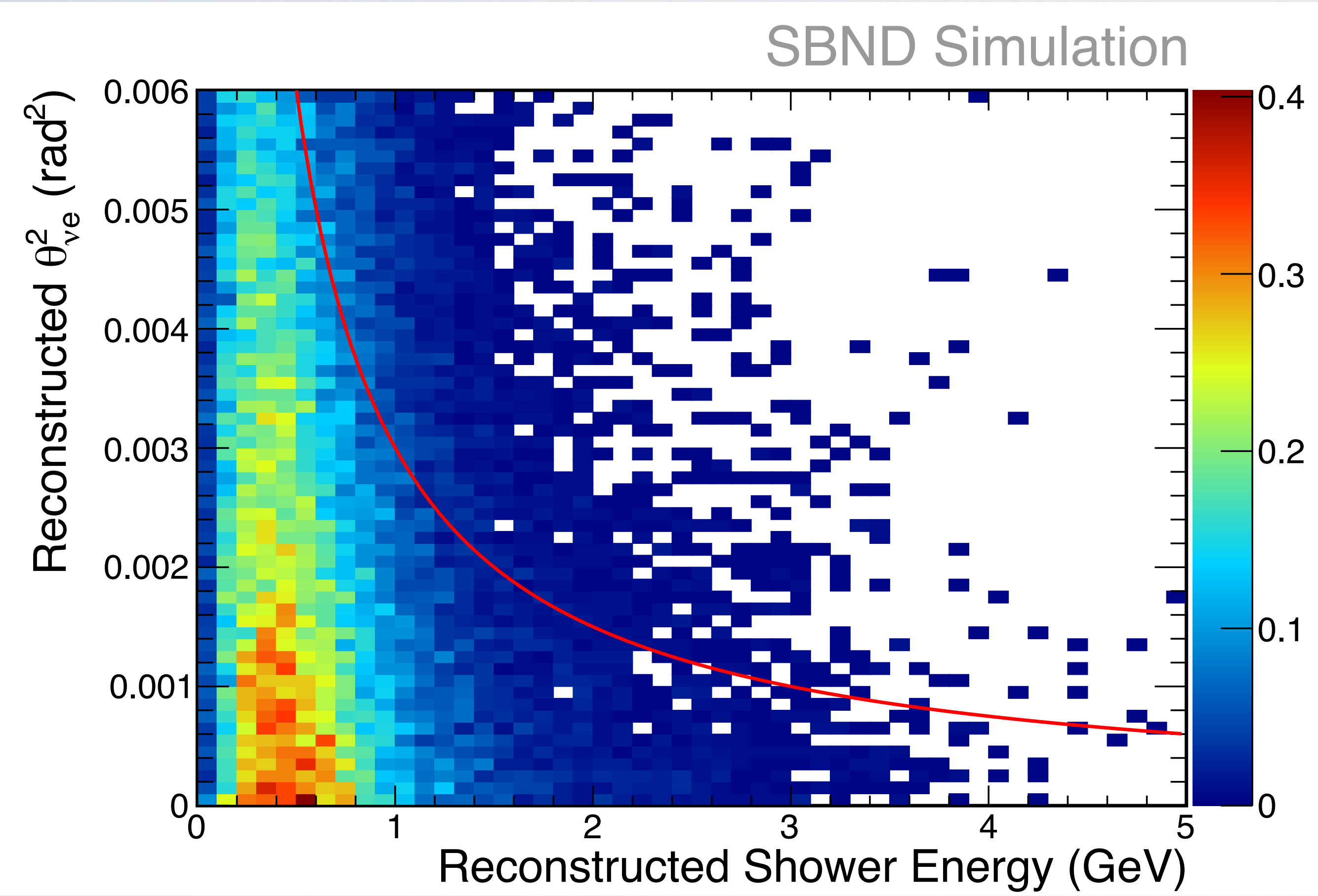
Signal

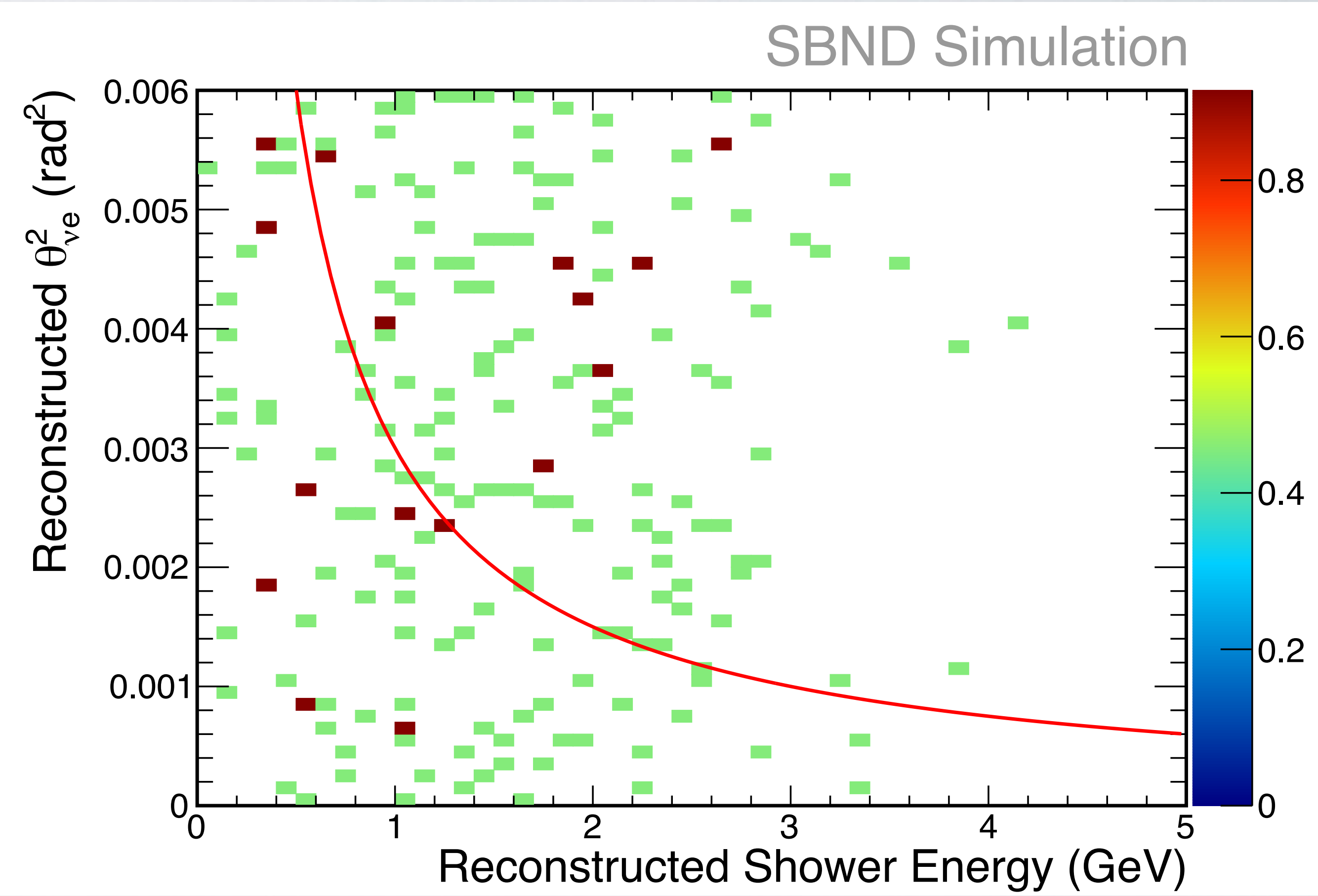


Background

Optimum is at $E\theta^2 < 0.0011$ GeV x rad^2, very close to the theoretical boundary

SELECTION (RECO VARIABLES)



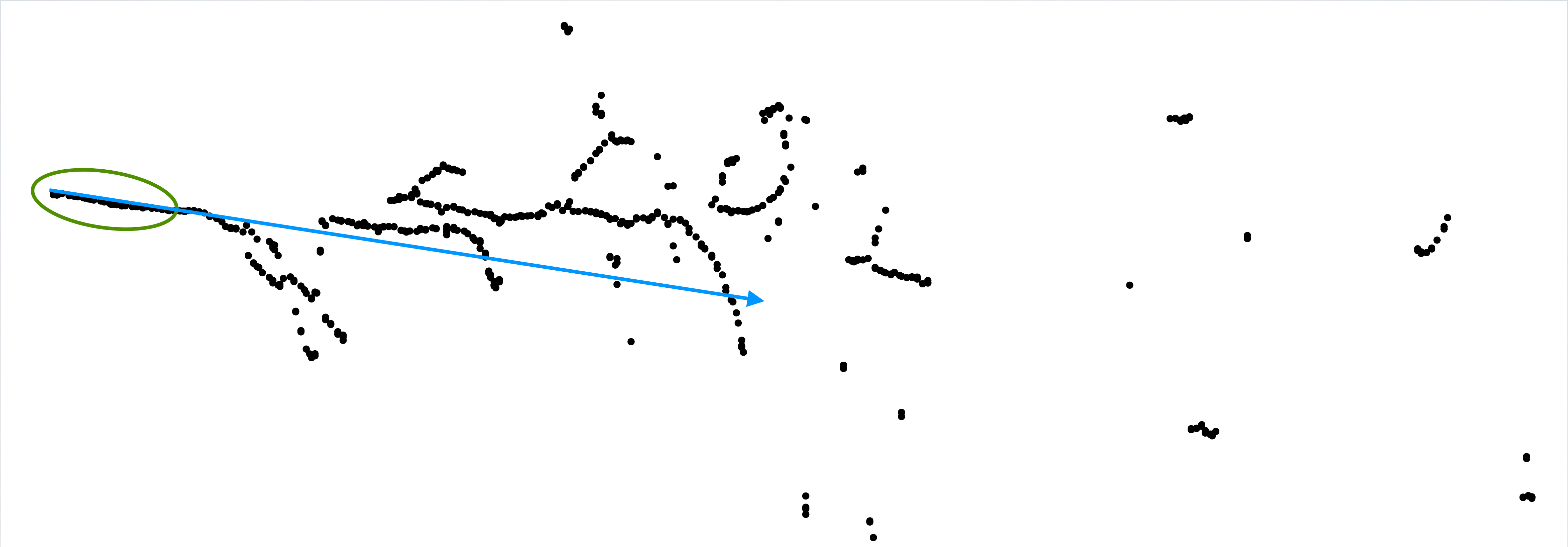


Signal

Background

Optimum is at $E\theta^2 < 0.0029$ GeV x rad^2

STRATEGY

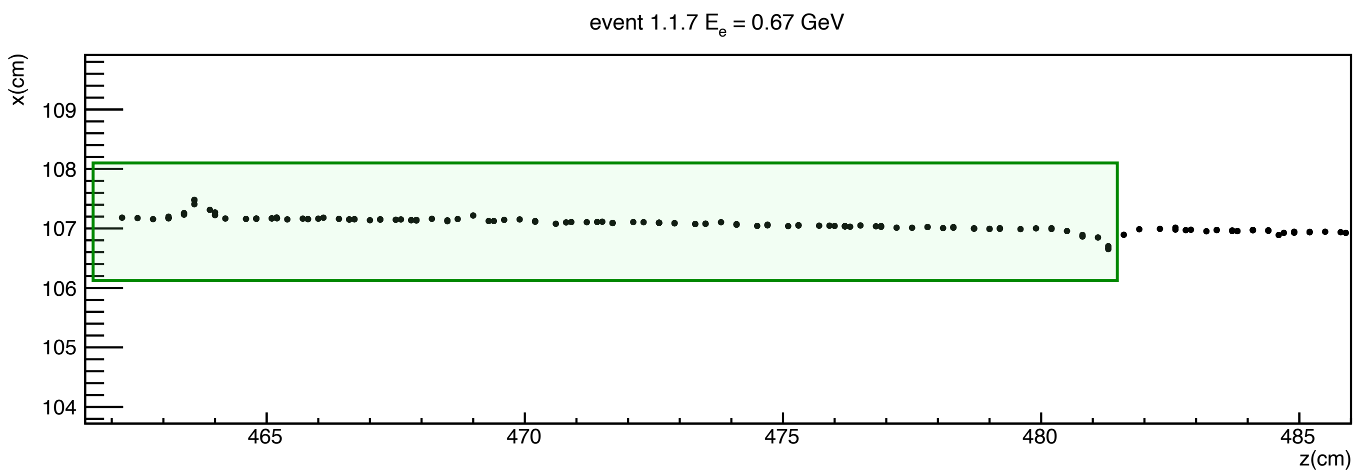


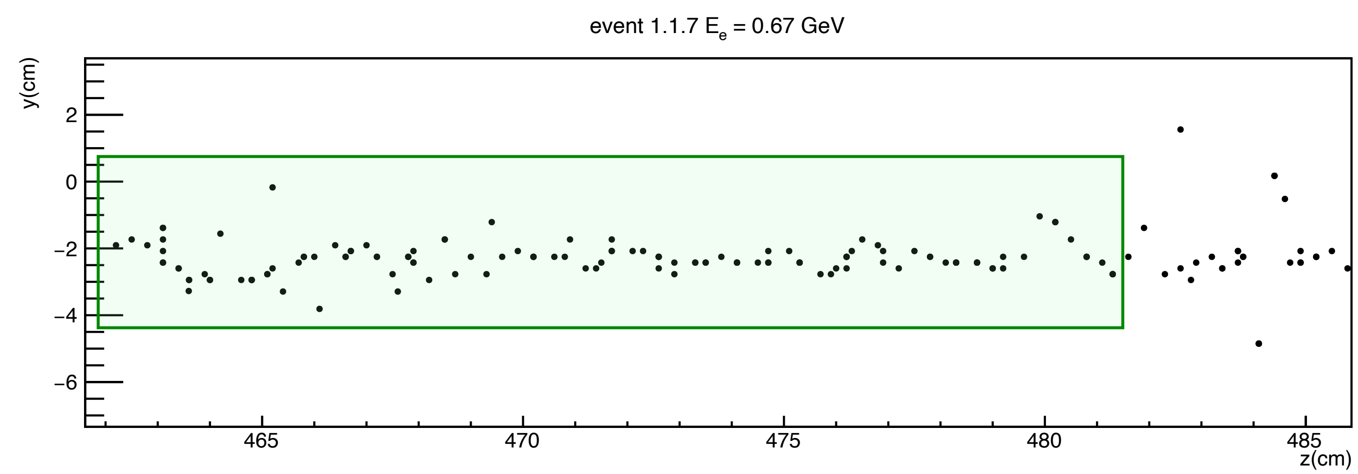
Basic idea:

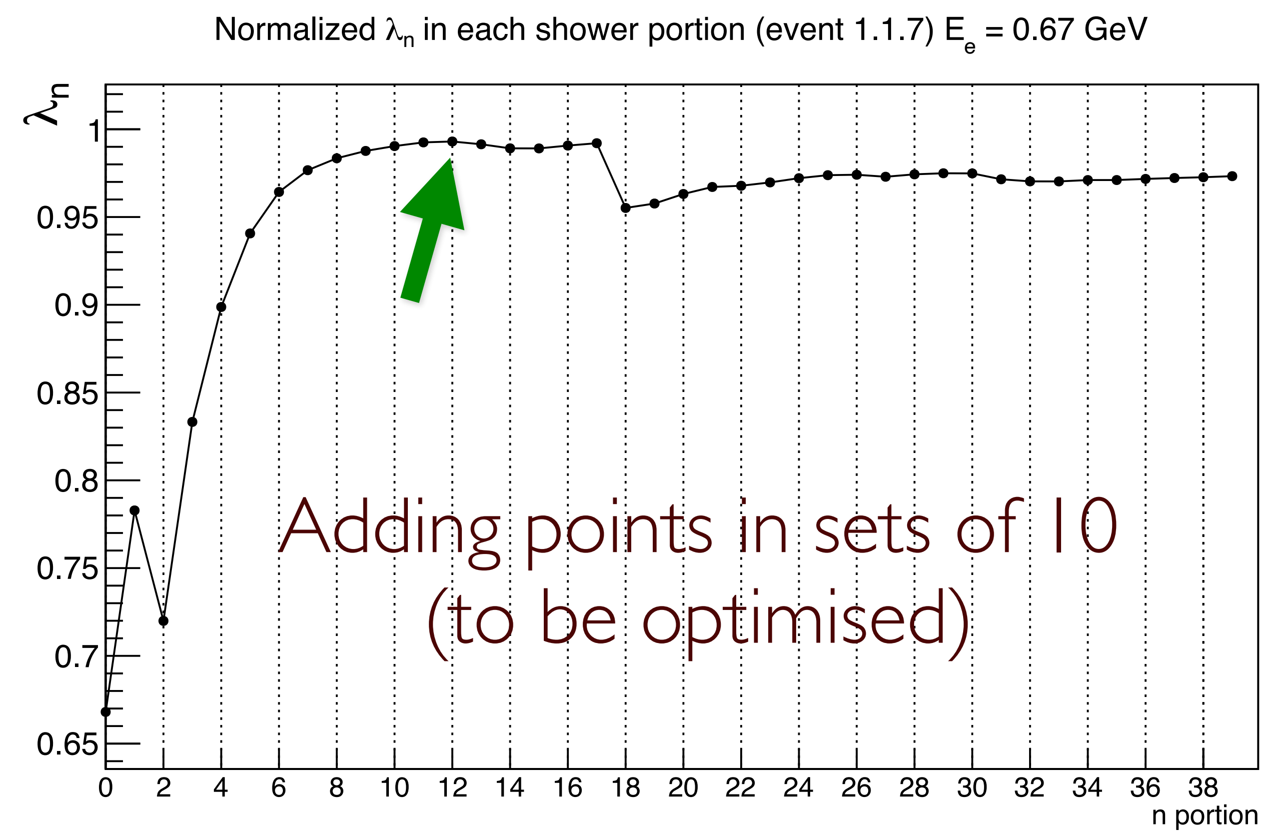
In the **early stage** of an electron-initiated EM shower, there is a **short track-like** produced by the electron, which aligns much more with the initial momentum

How do we select this region? We use the same strategy that Pandora uses to estimate the shower direction (main Principal Component of the space points) but adding the points incrementally until we obtain the **largest eigenvalue**

An example of how it works in 3D reco space-points:







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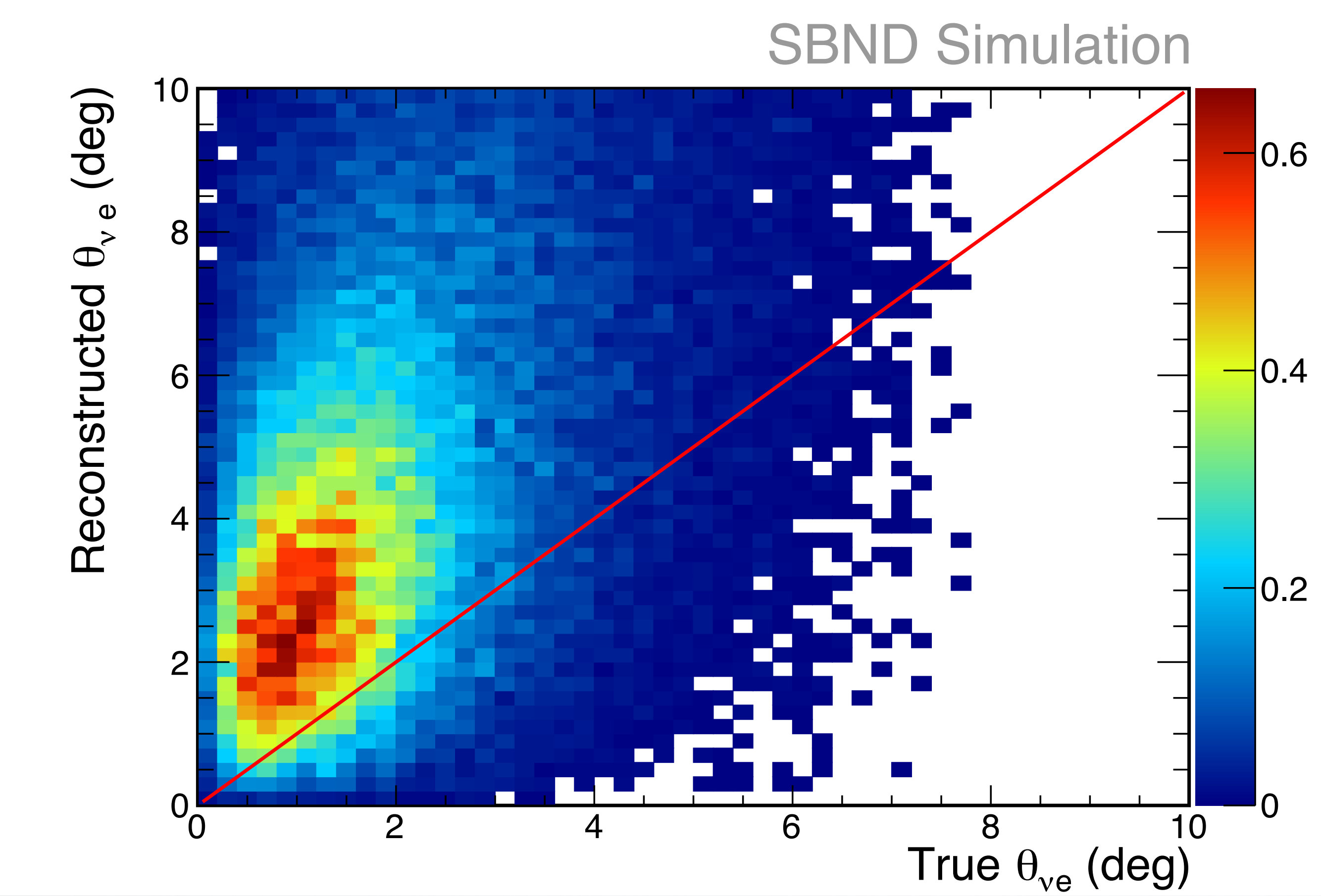
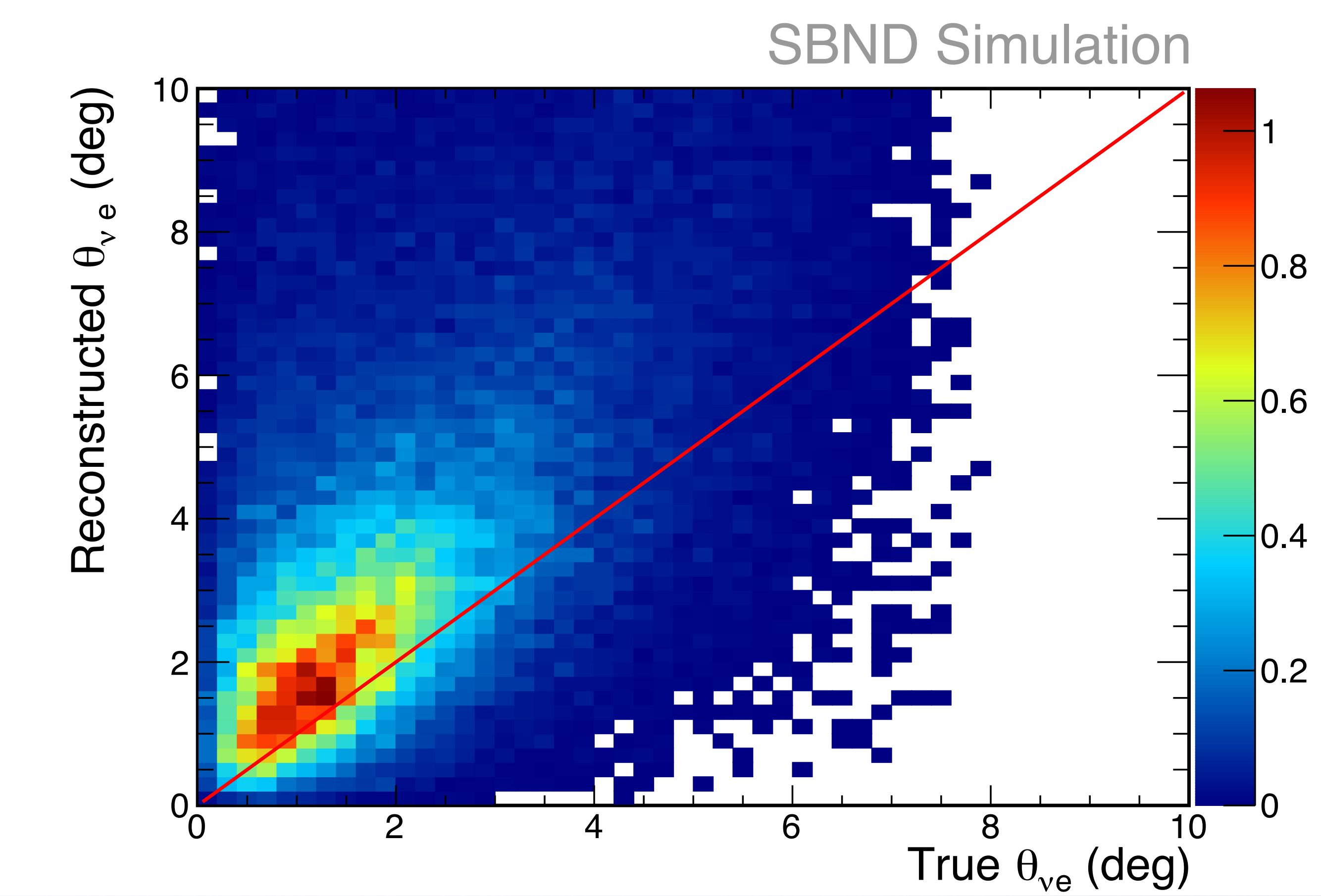
SHOWER DIRECTION (NU-E ELASTIC, ZOOM)



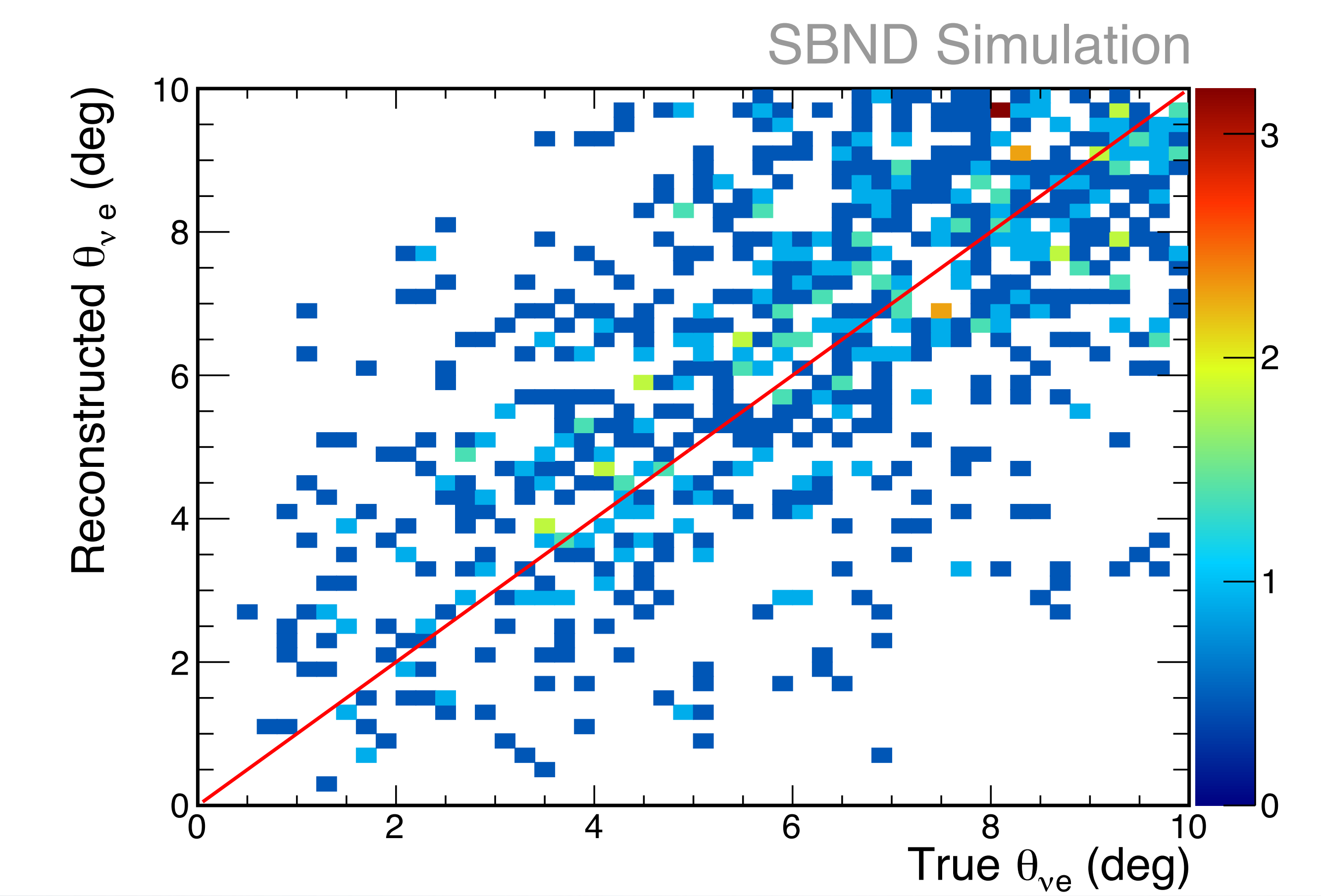


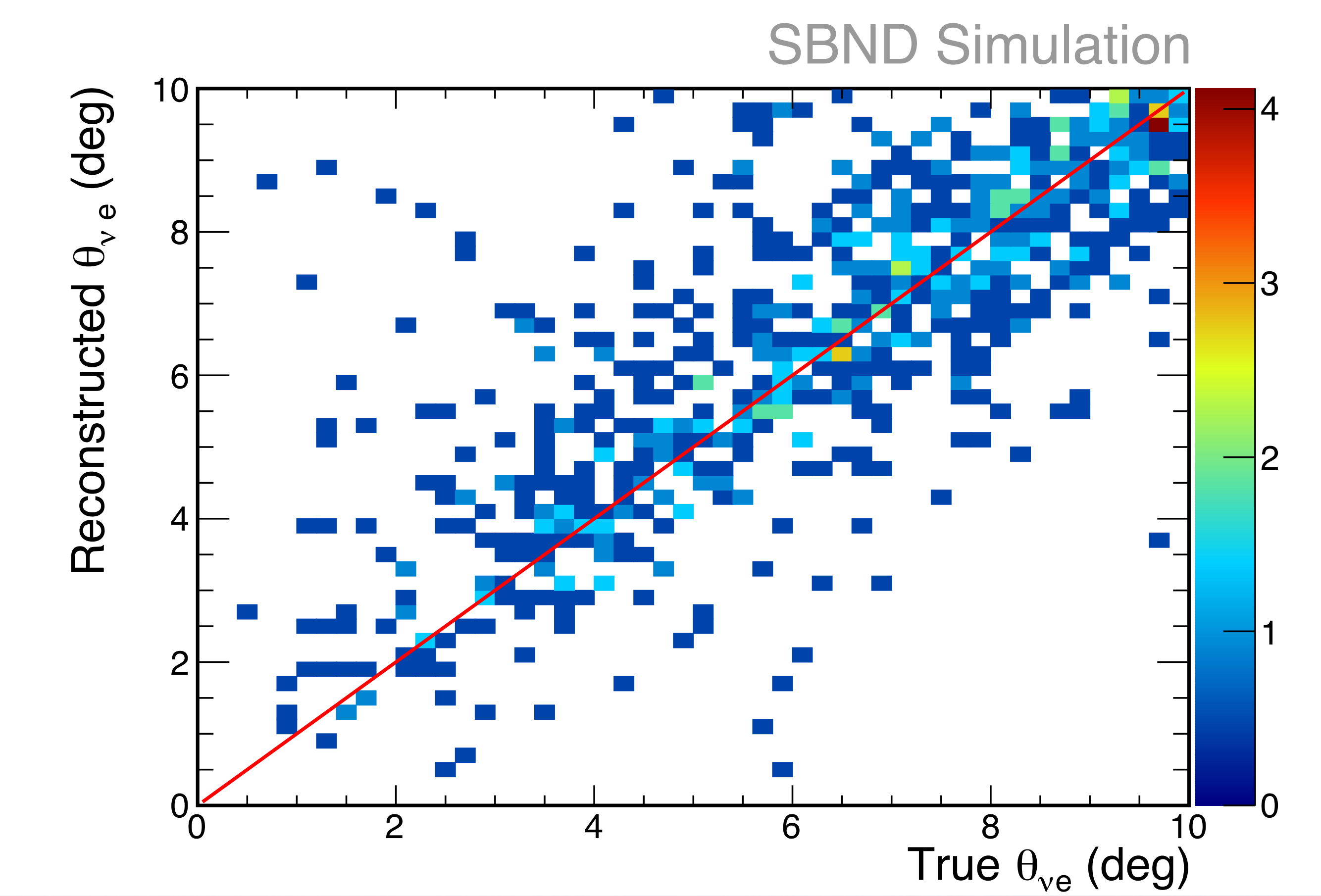
Before

After

For simplicity, in what follows only events with one shower and no tracks will be considered

SHOWER DIRECTION (INTRINSIC NUE, ZOOM)

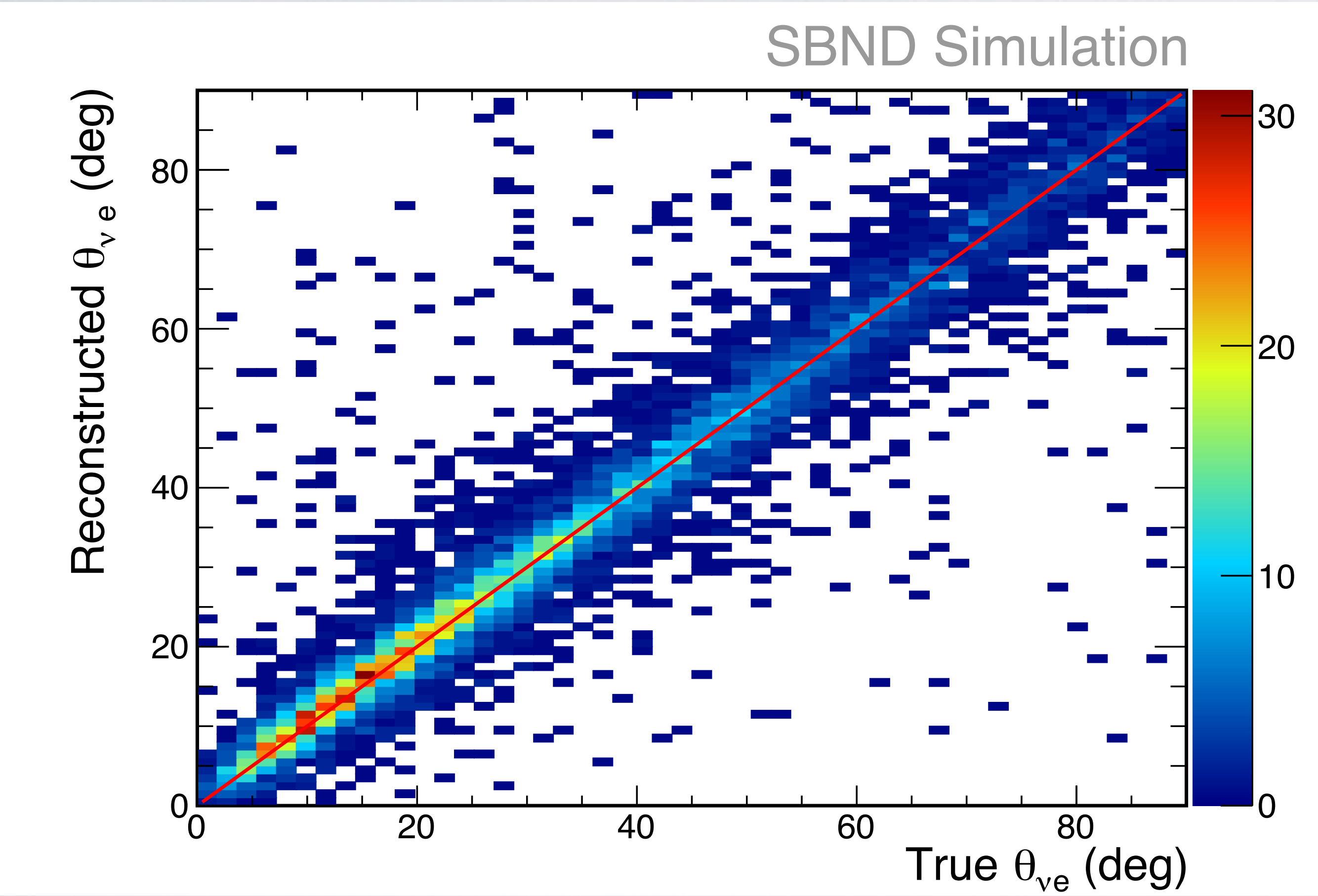


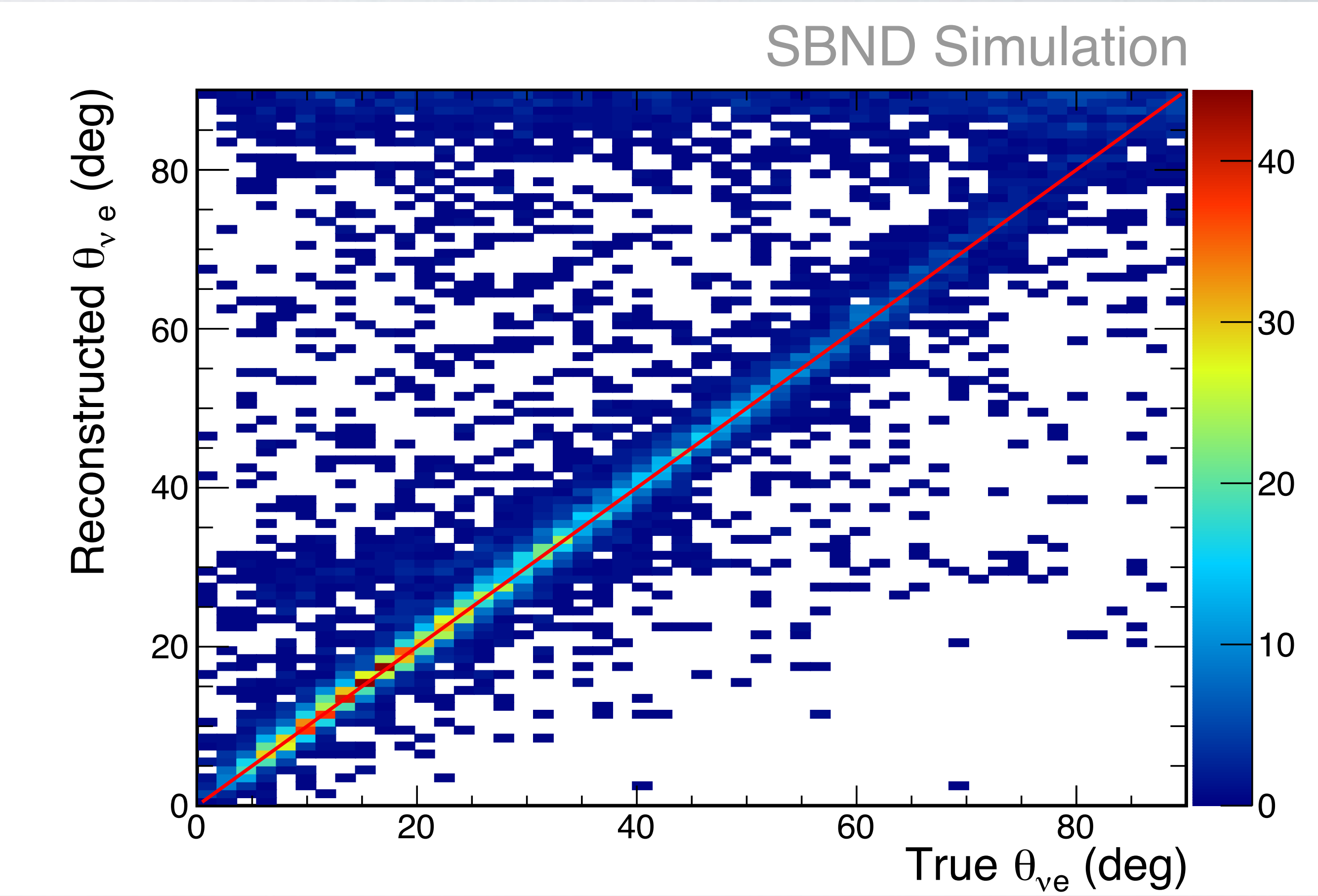


Before

After

SHOWER DIRECTION (INTRINSIC NUE, UNZOOMED)

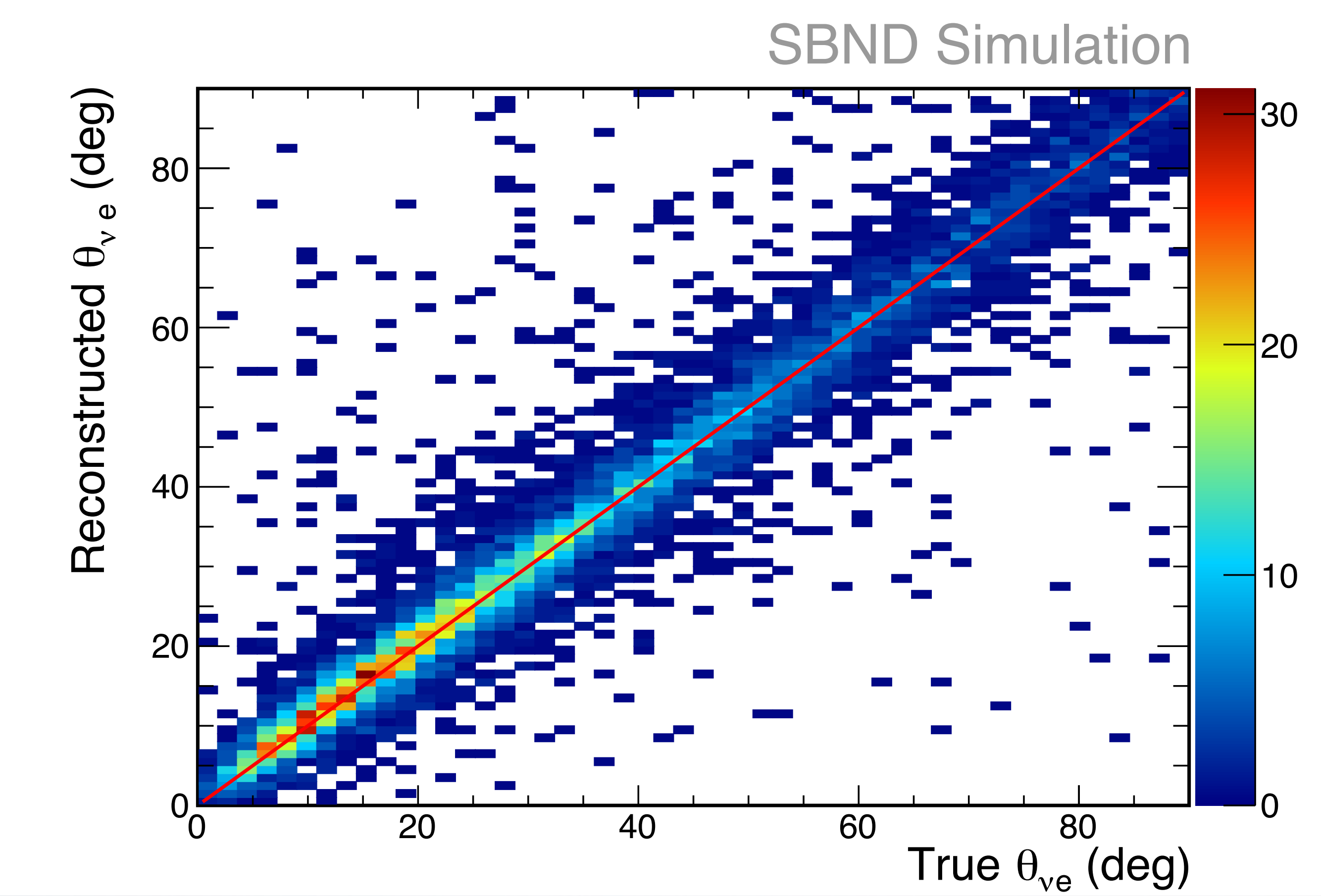


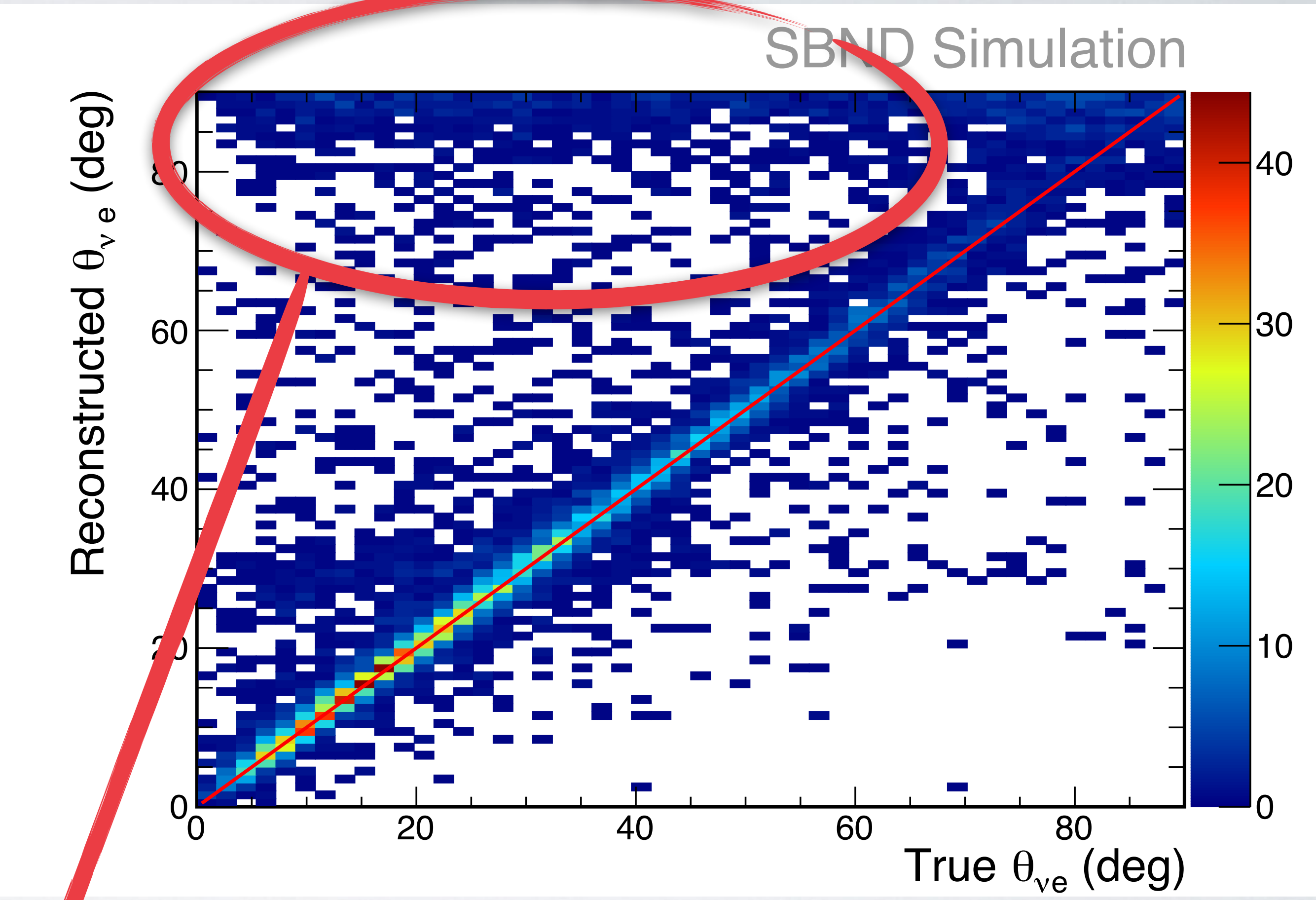


Before

After

SHOWER DIRECTION (INTRINSIC NUE, UNZOOMED)



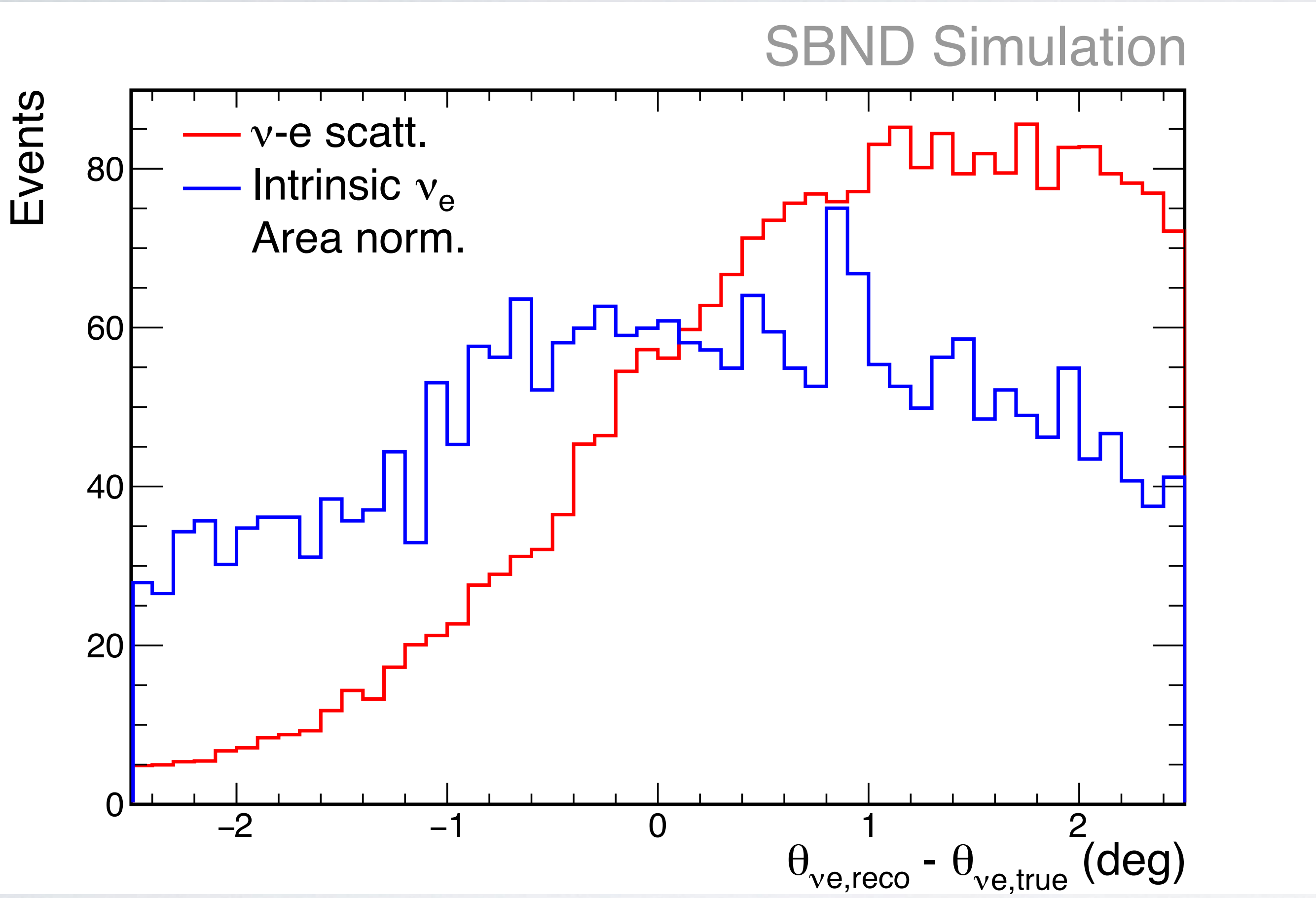


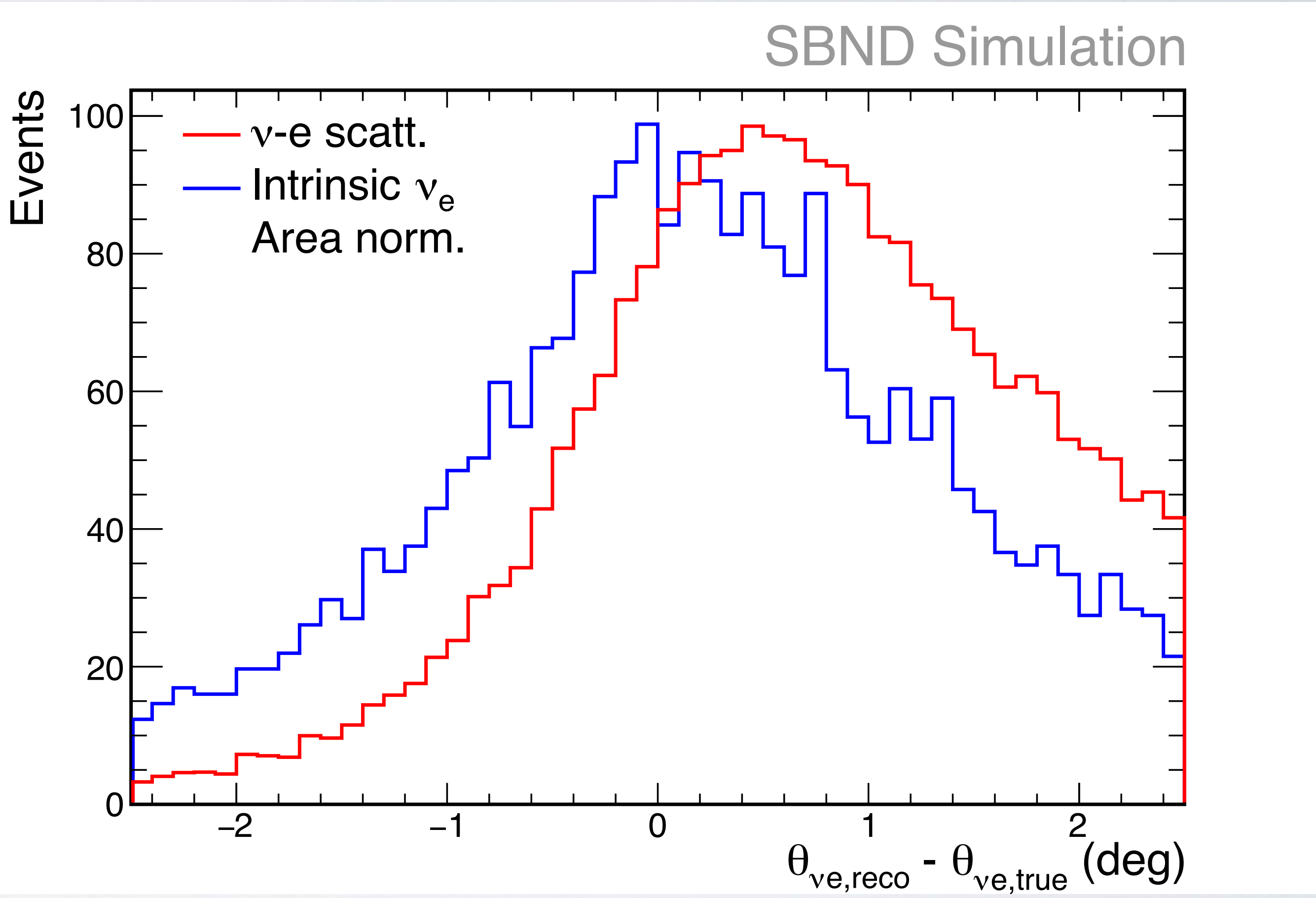
Before

After

Wrong sign (minor fix)

SHOWER DIRECTION (INTRINSIC NUE, UNZOOMED)

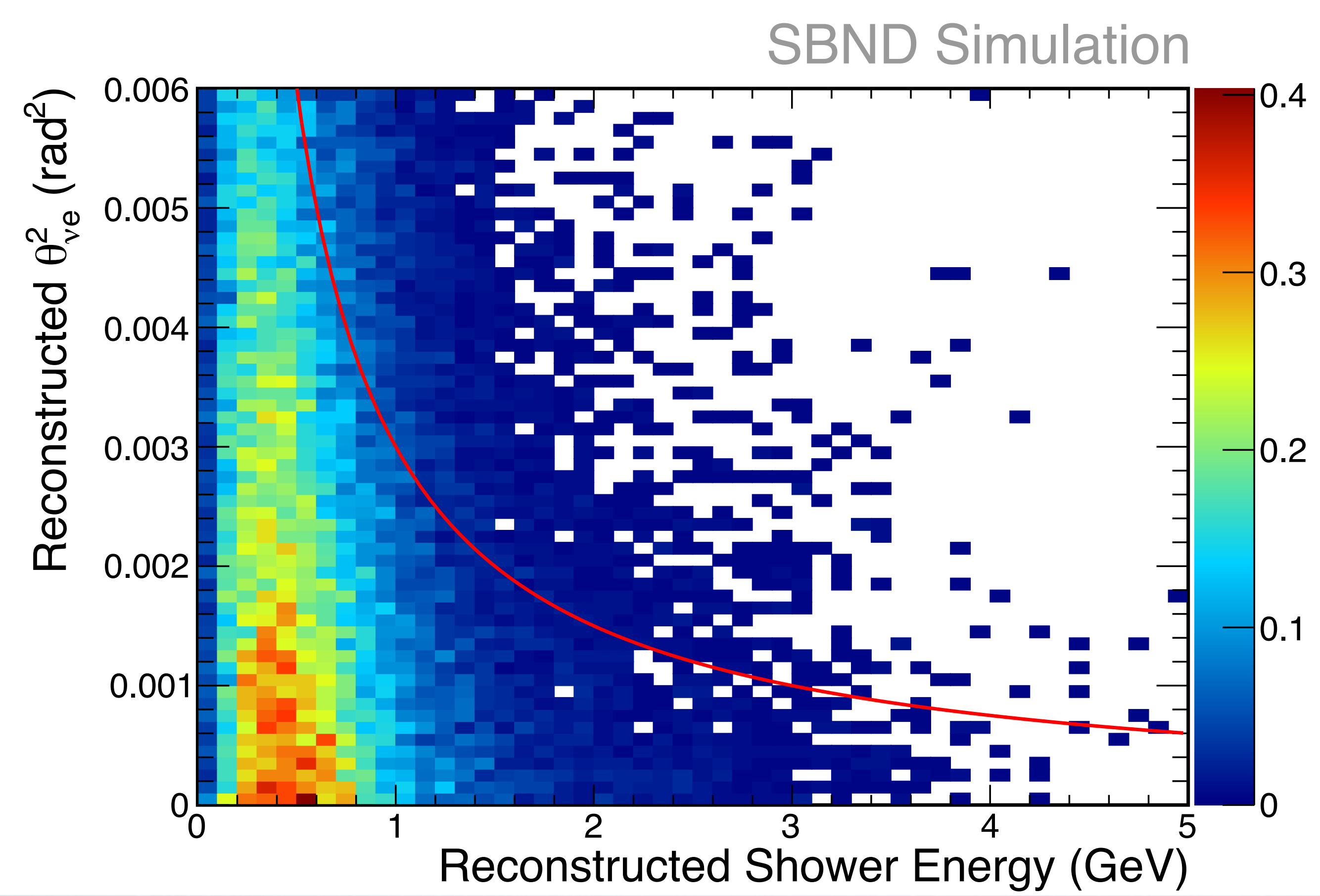


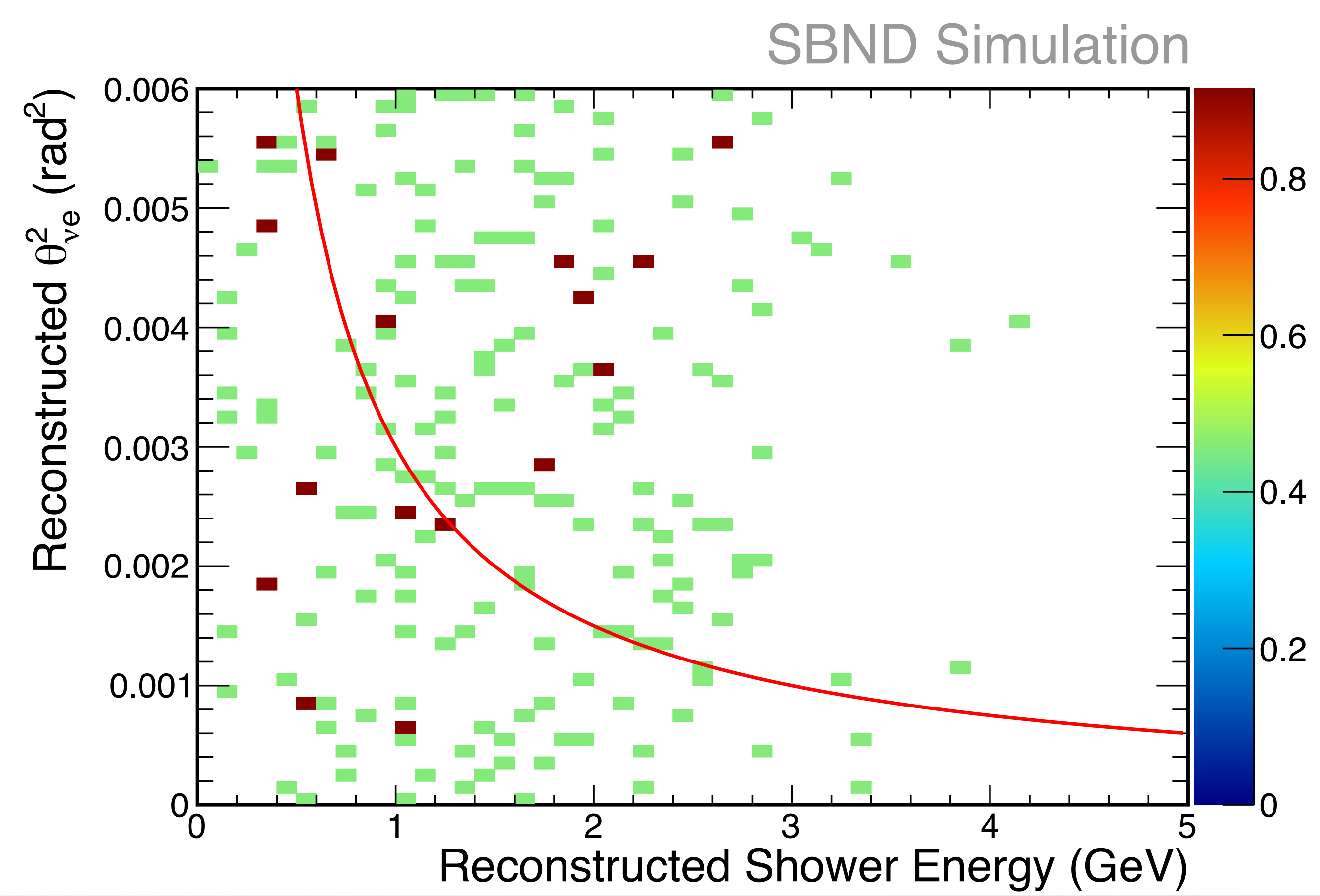


Before

After

SELECTION (BEFORE)



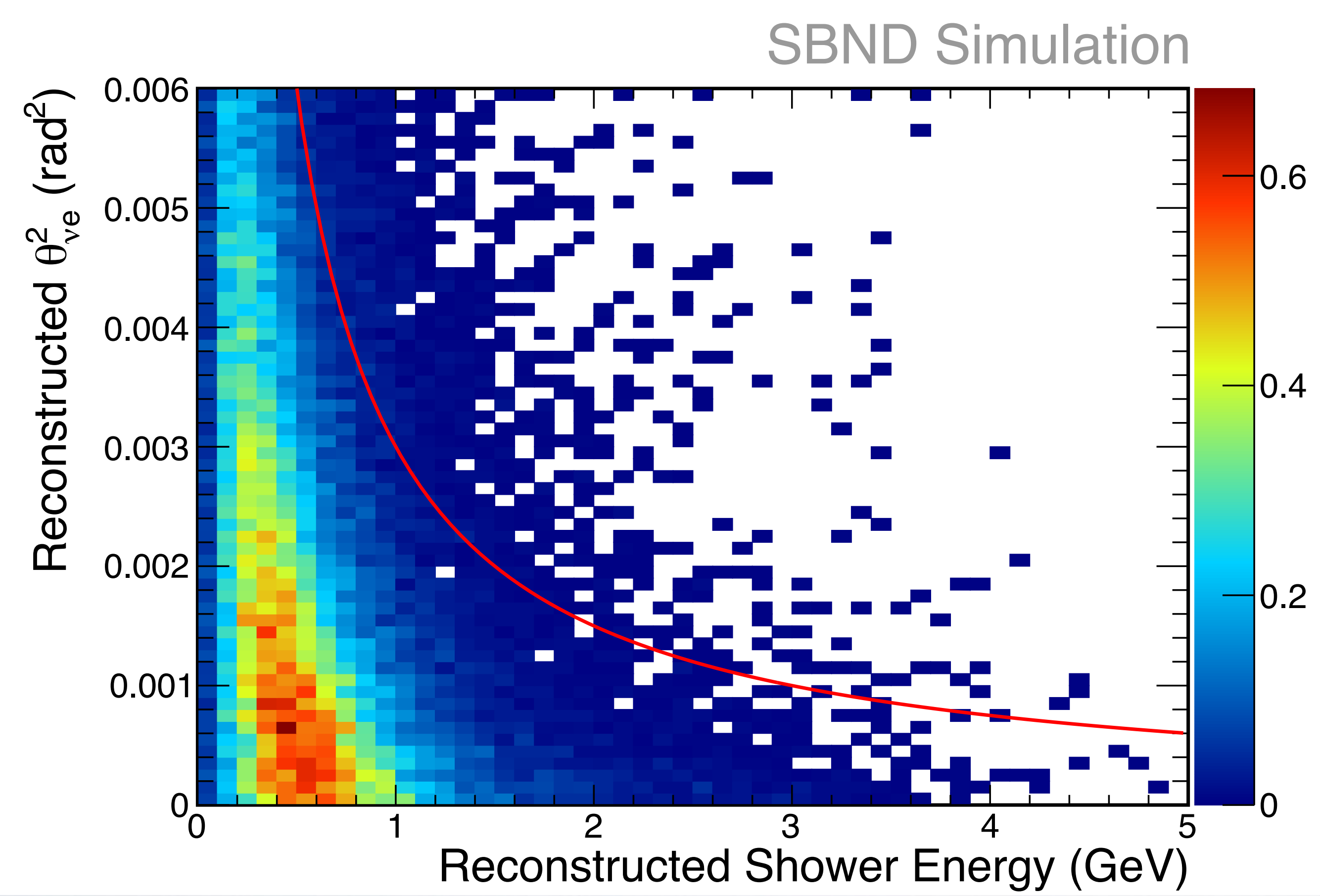


Signal

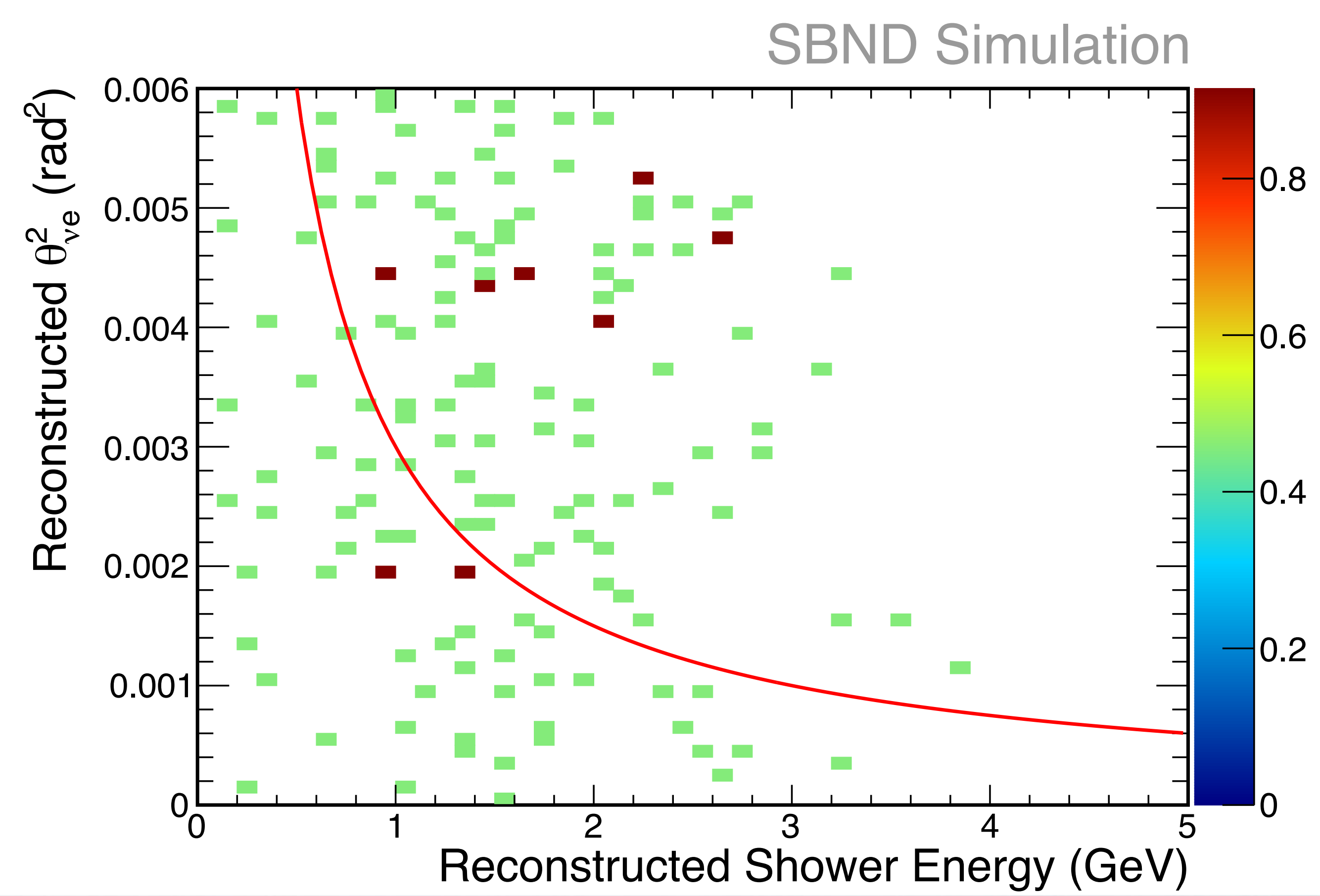
Background

Effect on the selection of nu-e elastic events

SELECTION (AFTER)



Signal



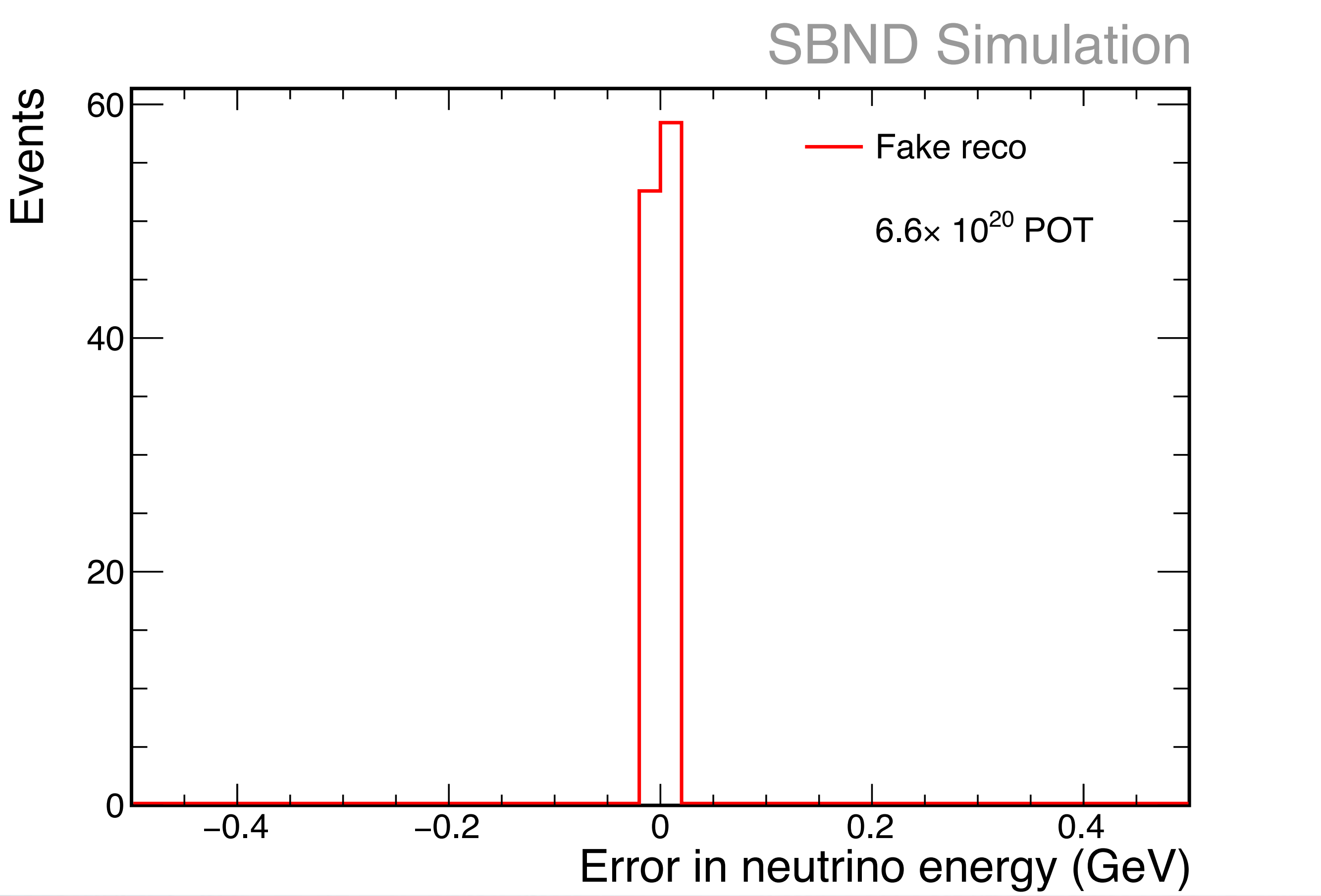
Background

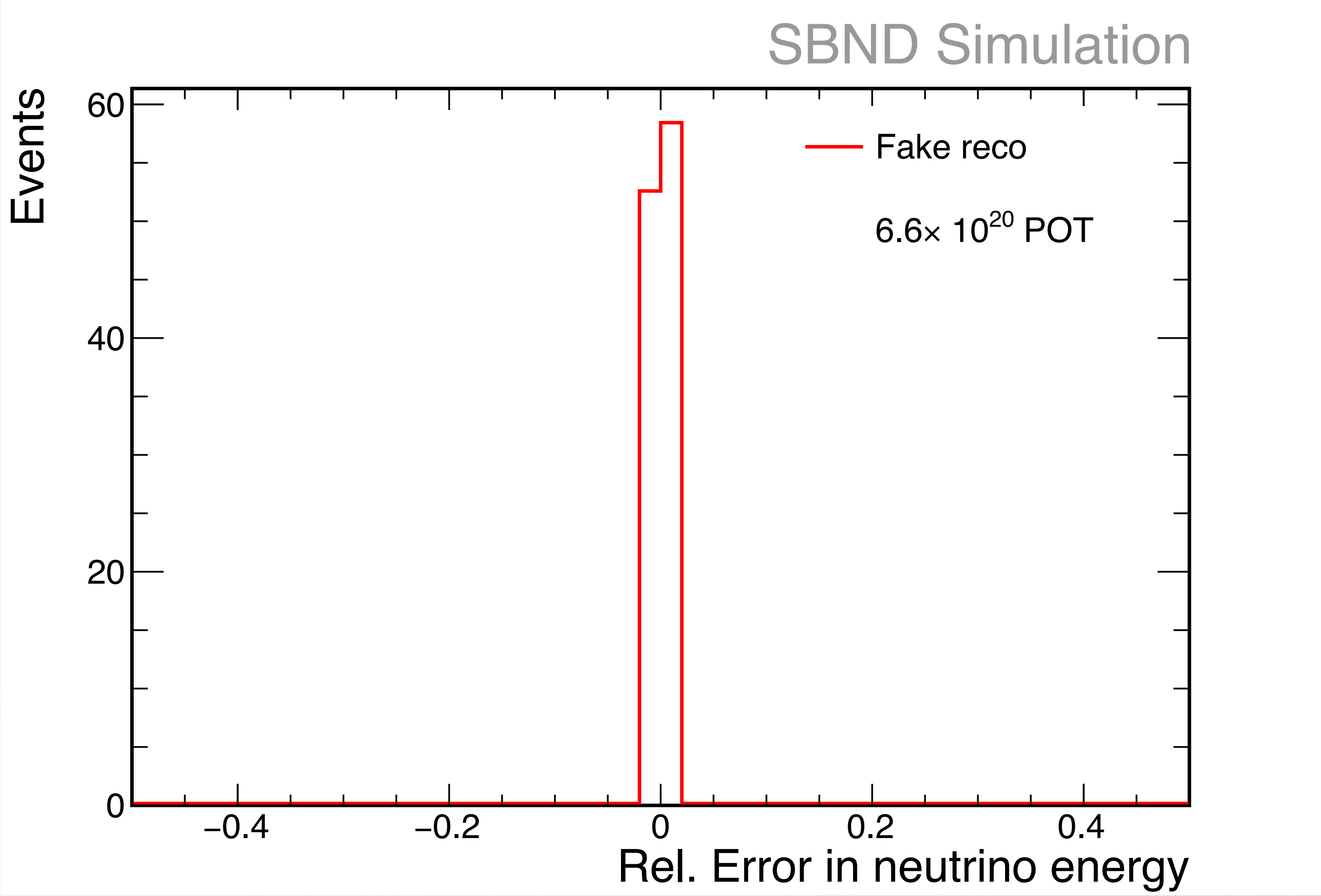
CONCLUSIONS

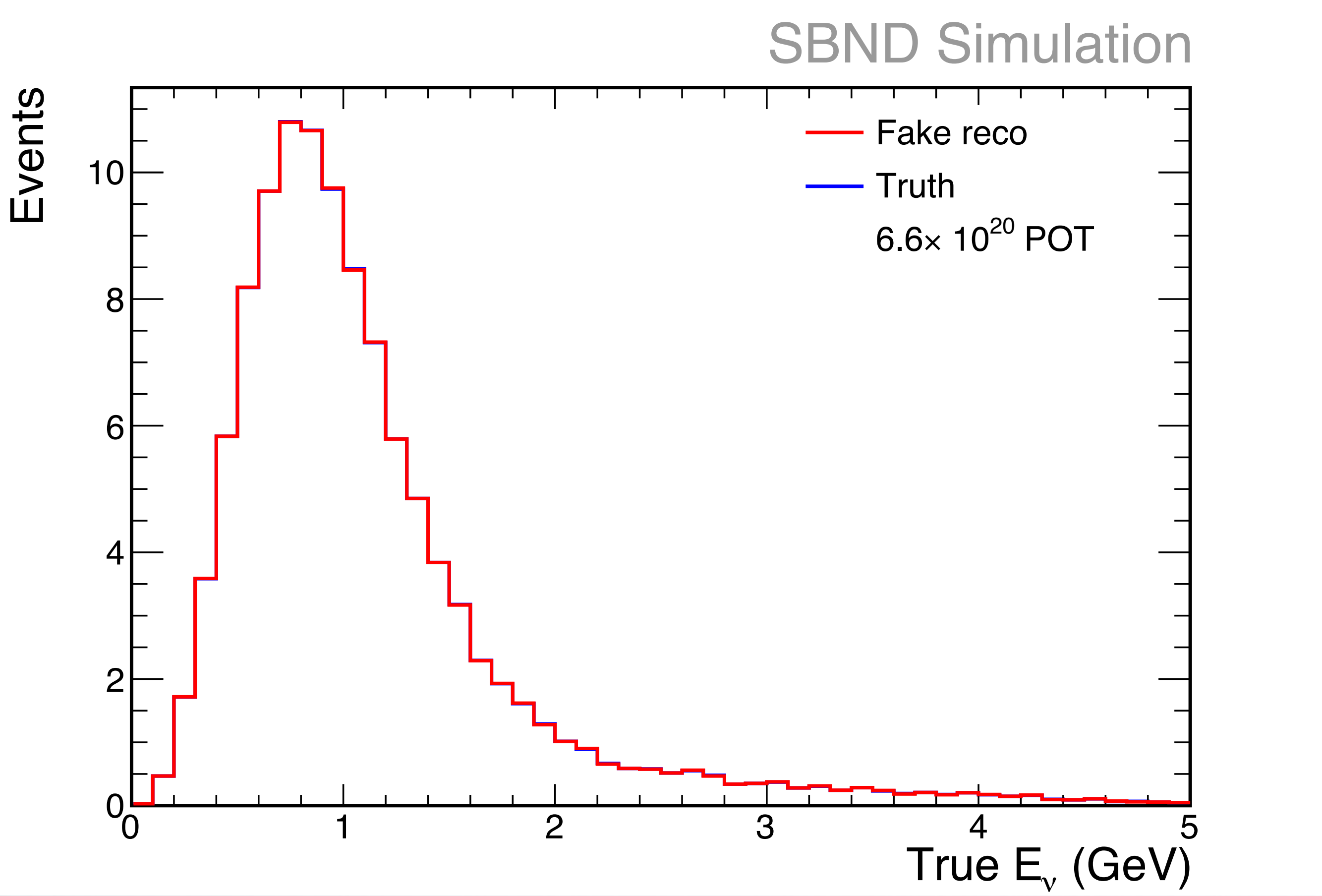
- Promising out-of-the-box performance (some room for tuning)
- Significant improvement for nu-e elastic events, with impact both on the energy estimate and the signal selection
- For intrinsic neutrinos, there are some issues having to do with the ordering of the hits (currently using time), sign, vertex, etc.
    - Some, but possibly not all, workable

BACKUP:

HOW GOOD DO WE *NEED* THE RECONSTRUCTION TO BE?

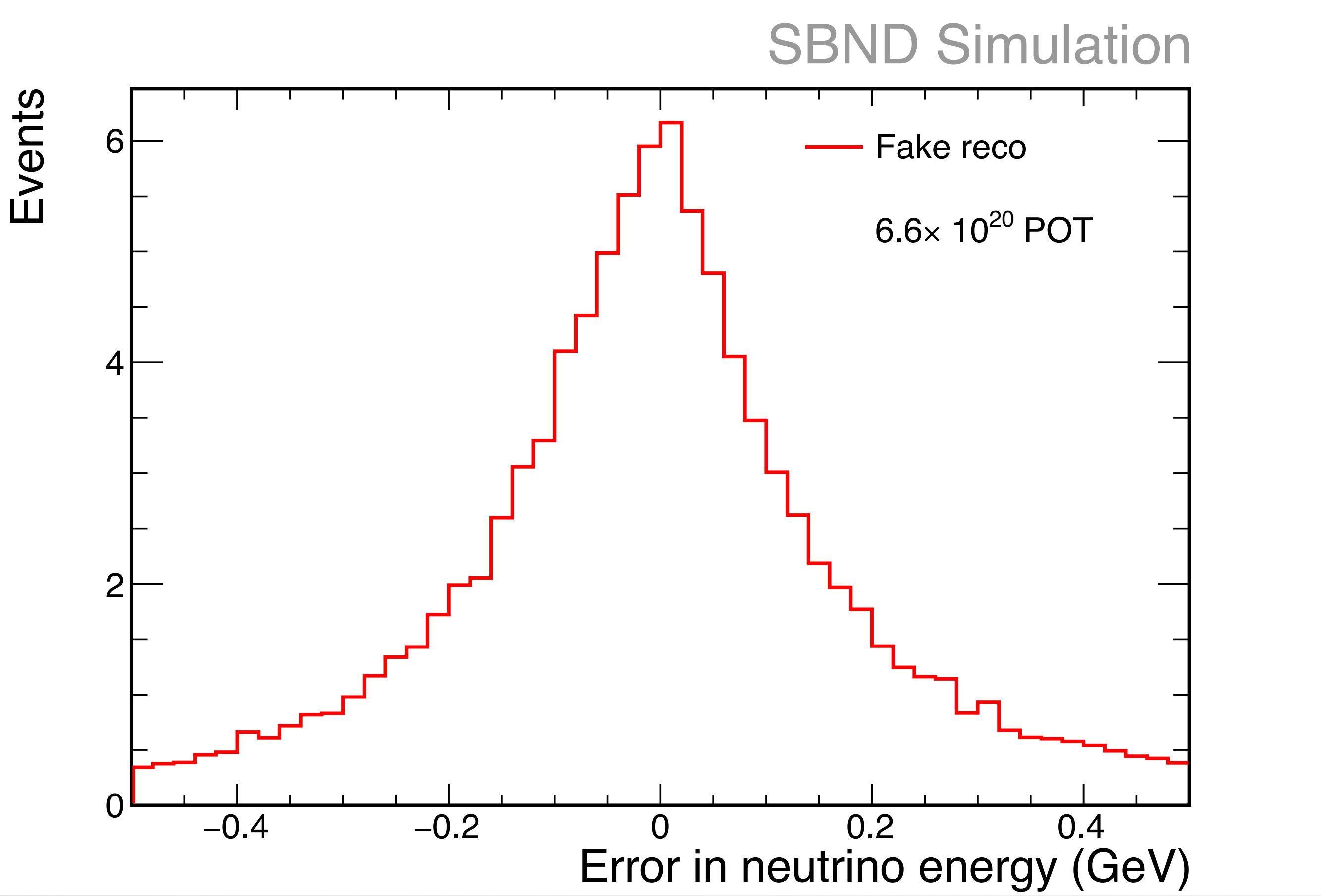


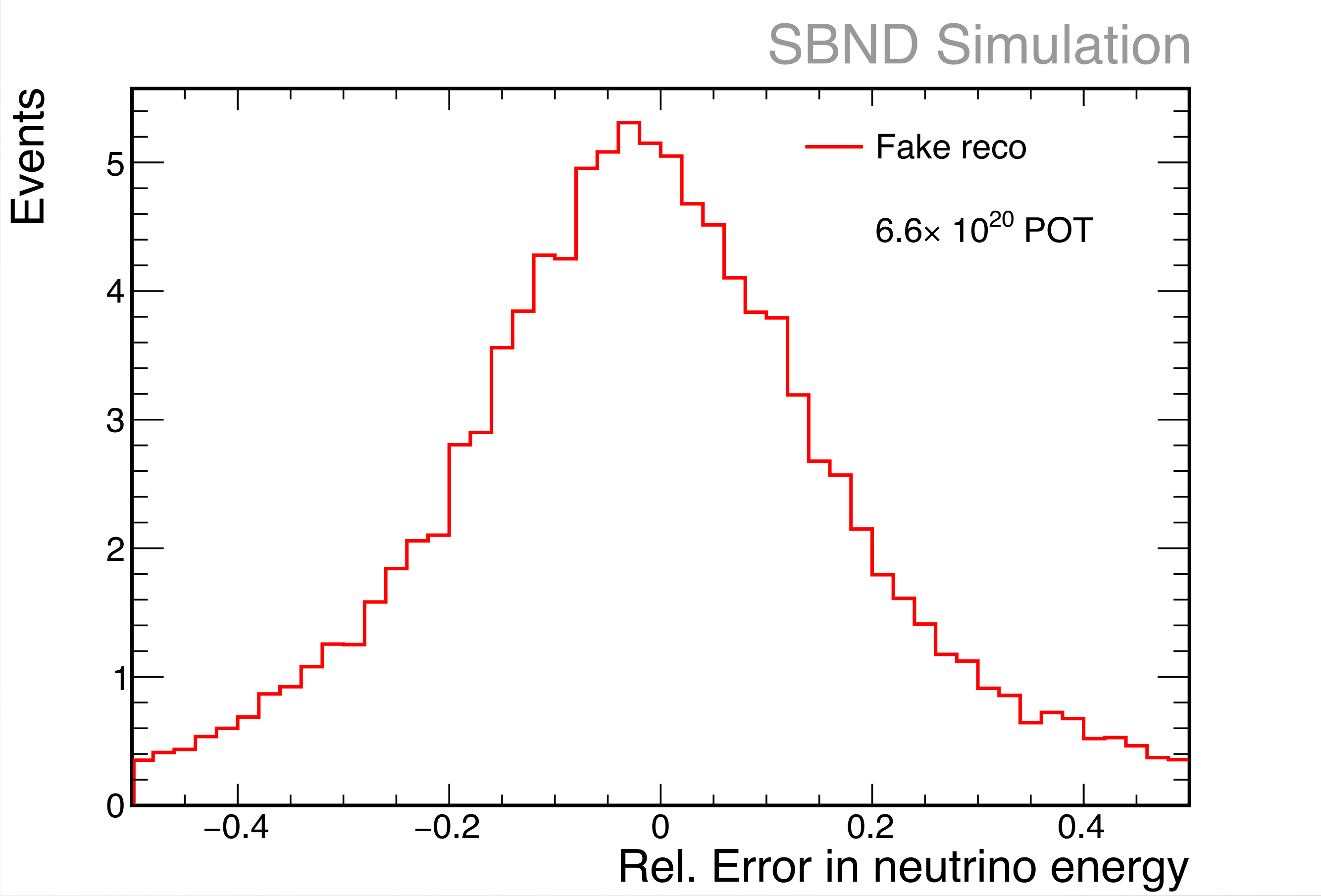


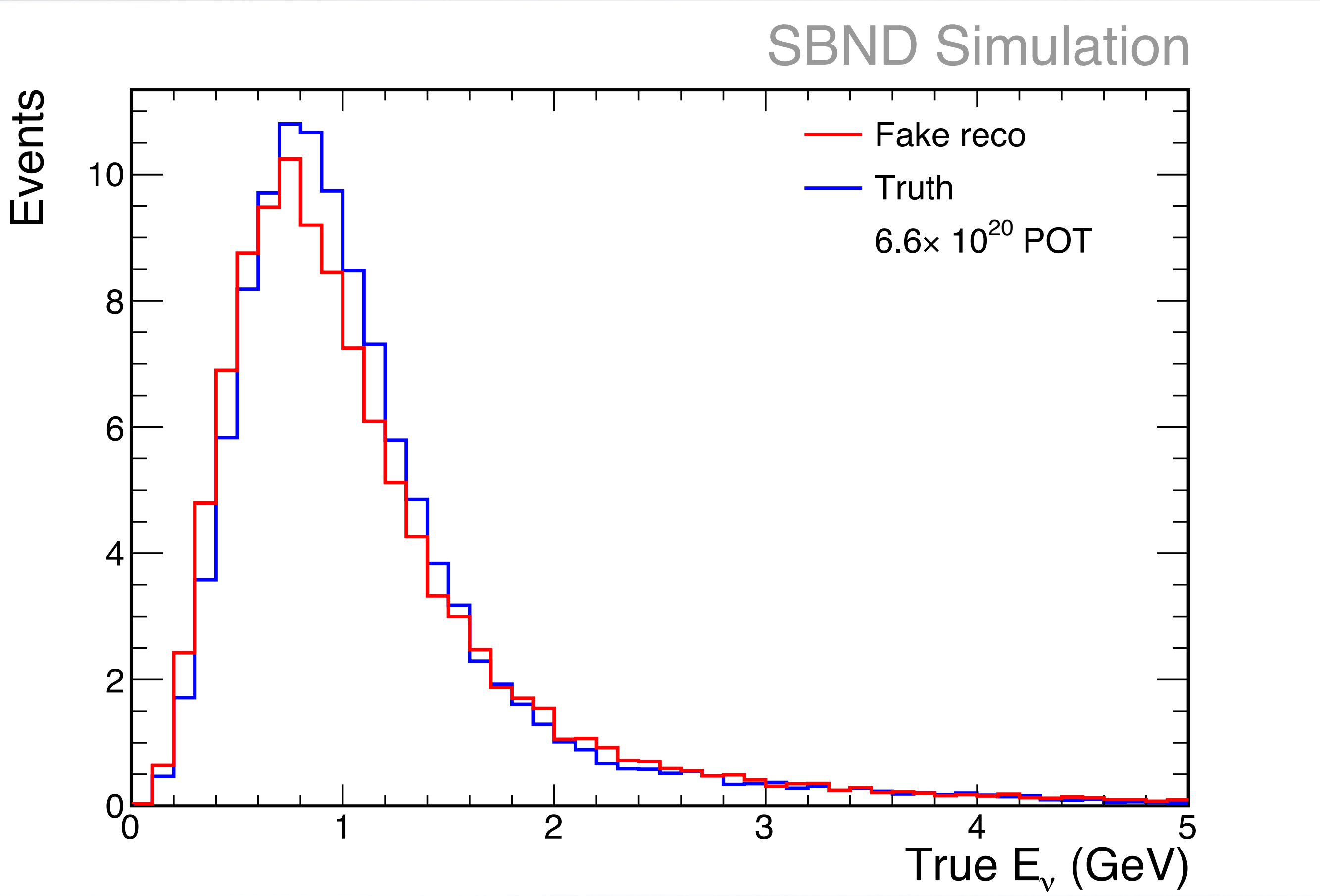


Using all the true information in

$$E_\nu = \frac{m_e T_e}{p_e \cos\theta_{\nu e} - T_e}$$

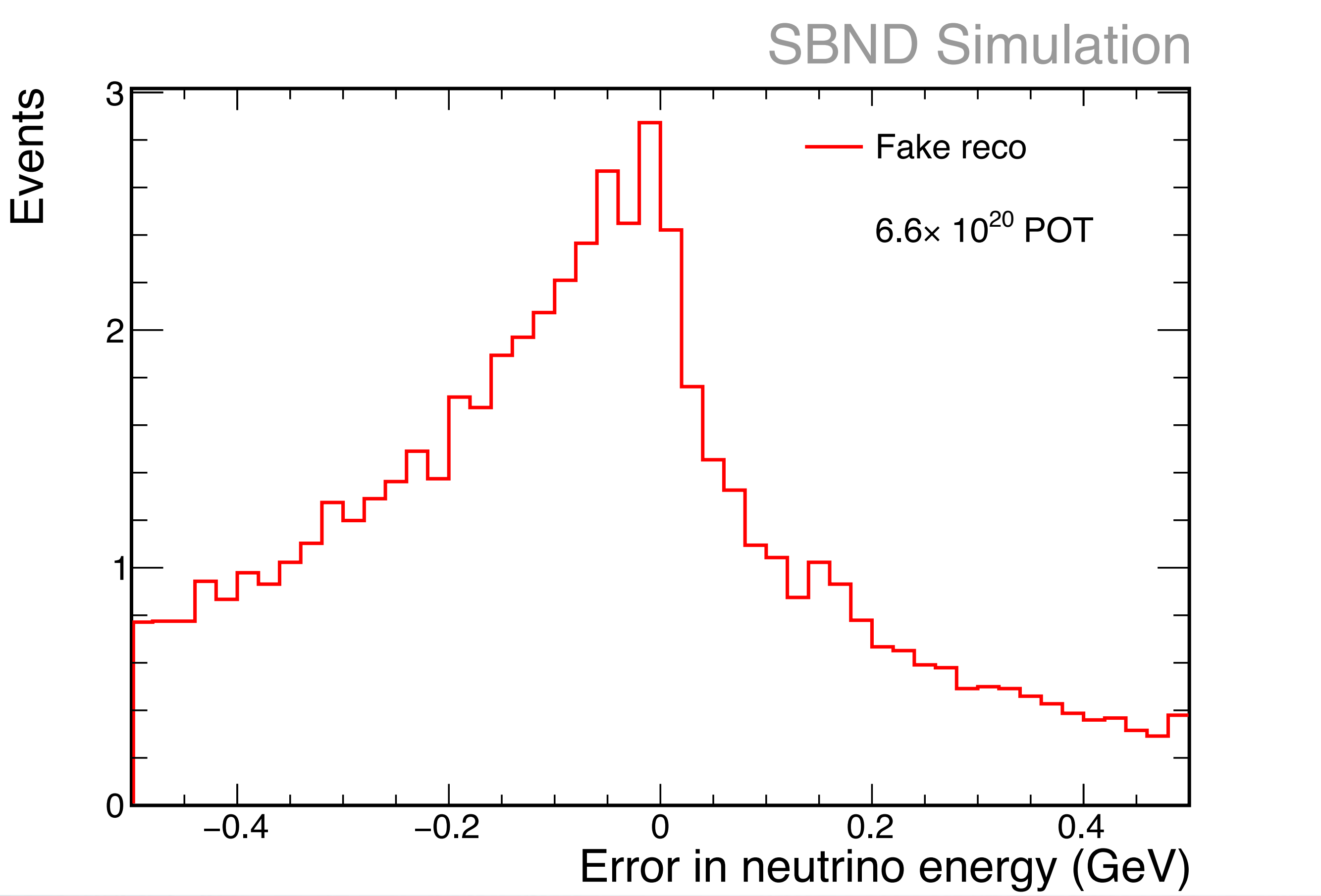


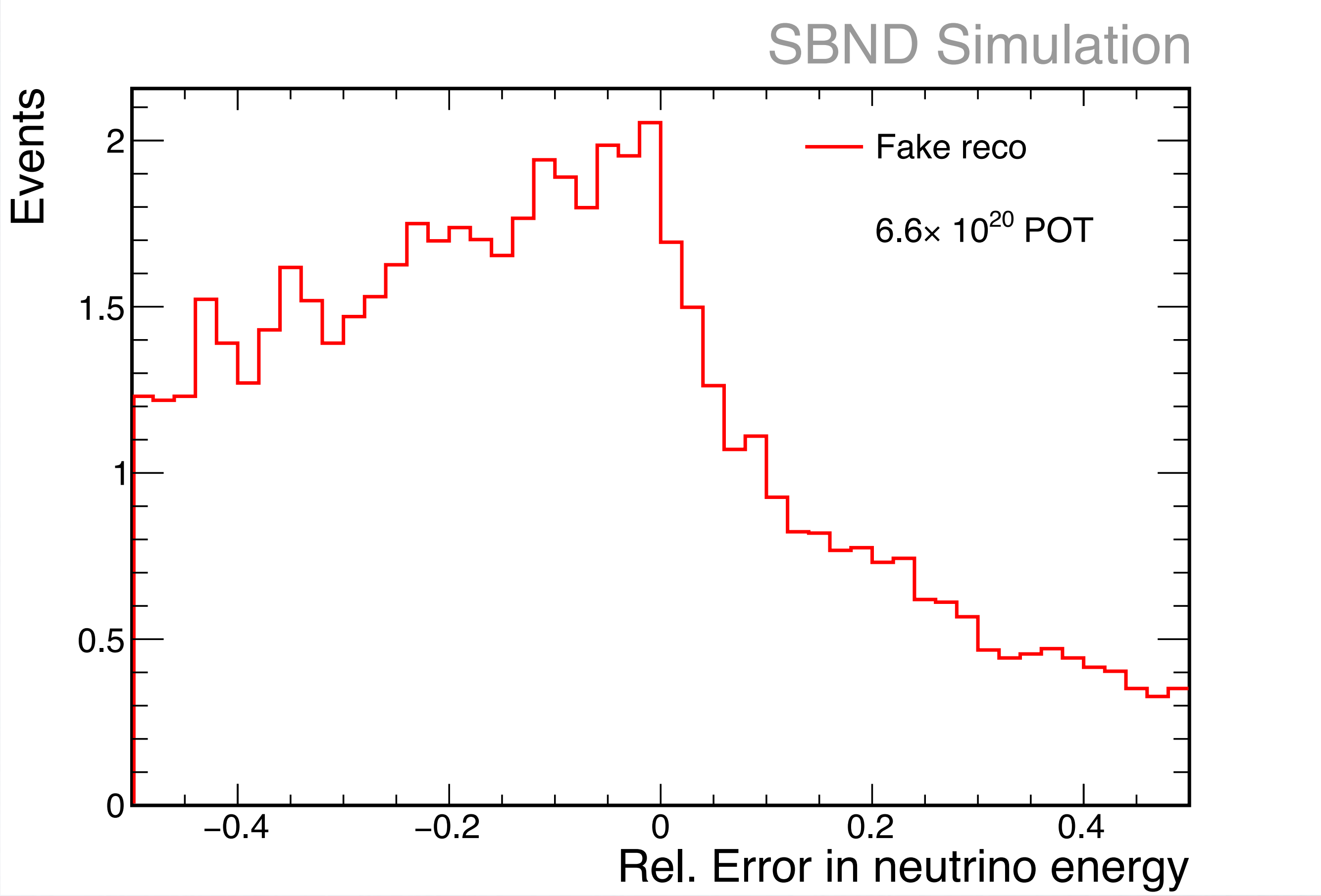


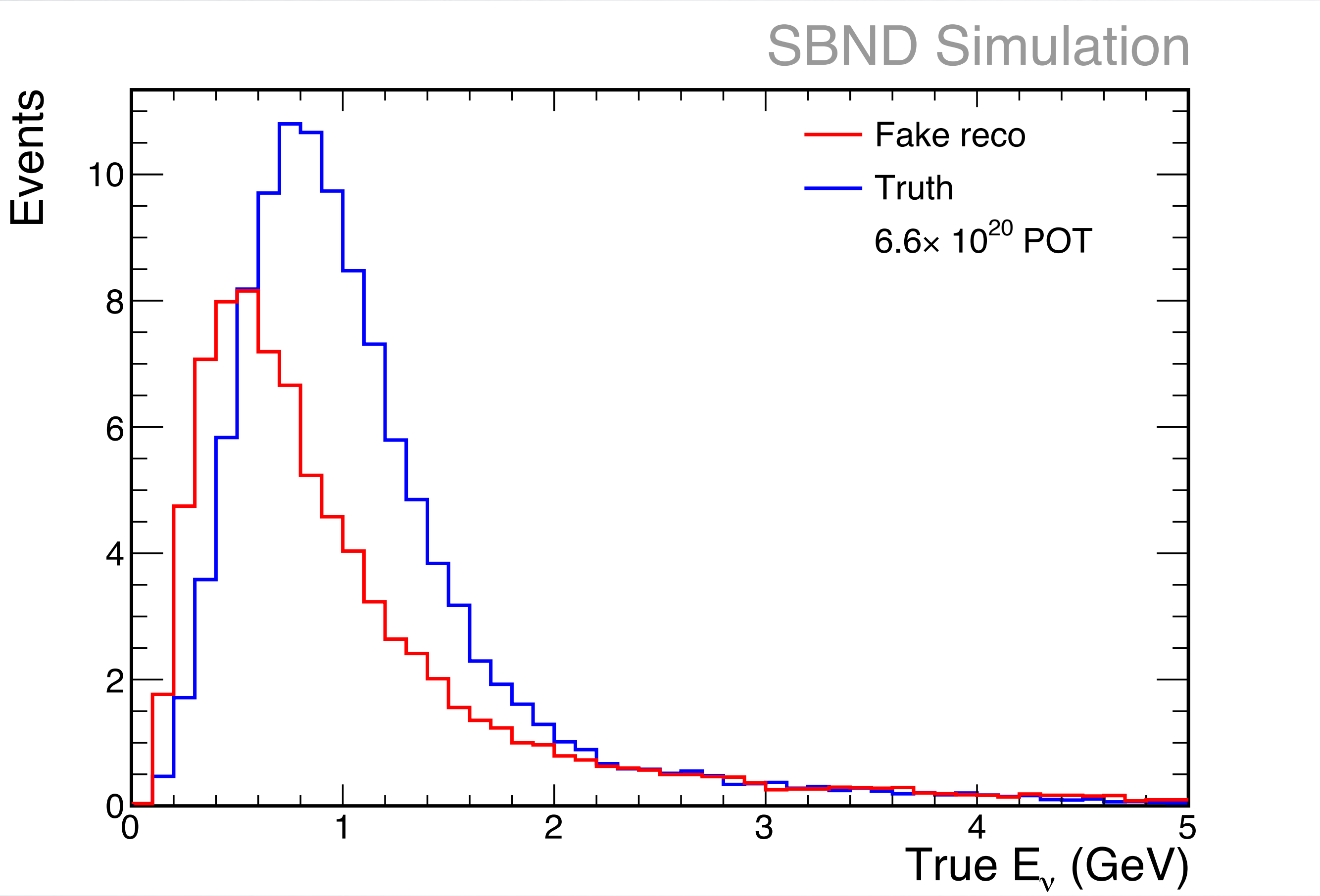


Smearing energy reconstruction by a gaussian 10% (unbiased)

We can absorb this with unfolding (reco-to-true matrix)







Smearing the angle by 1° (unbiased)

Improving the direction reconstruction is the priority

CUTFLOW

Cut	Efficiency	Purity
No cut	100%	0.8%
One shower	68.5%	1.4%
No tracks	59.0%	4.3%
$E\theta^2 < 0.003$	32.7%	68.9%