Selection of muon-antineutrino charged-current 1-pion interactions in the ND280 detector

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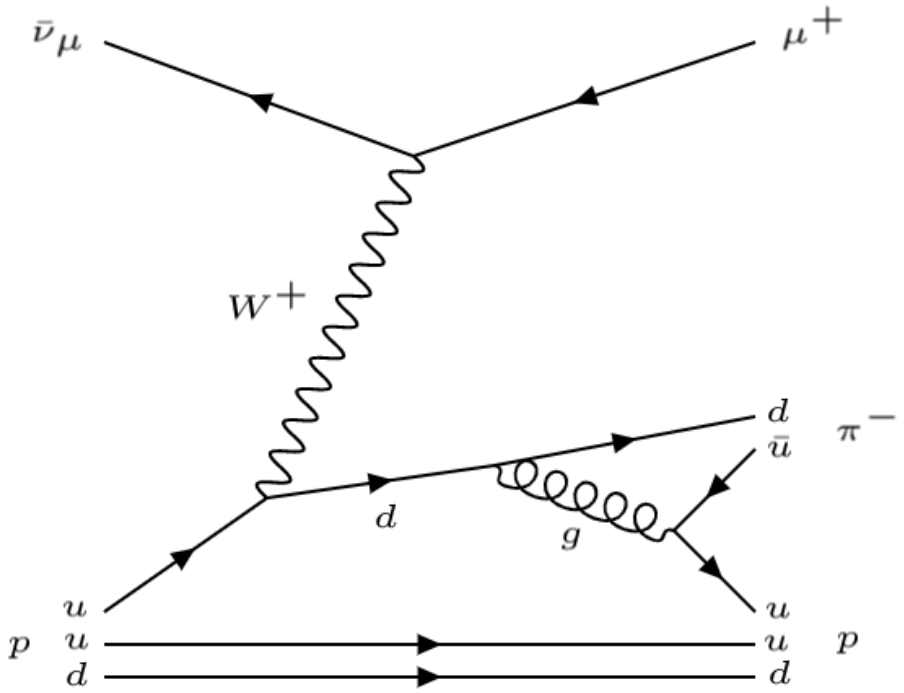
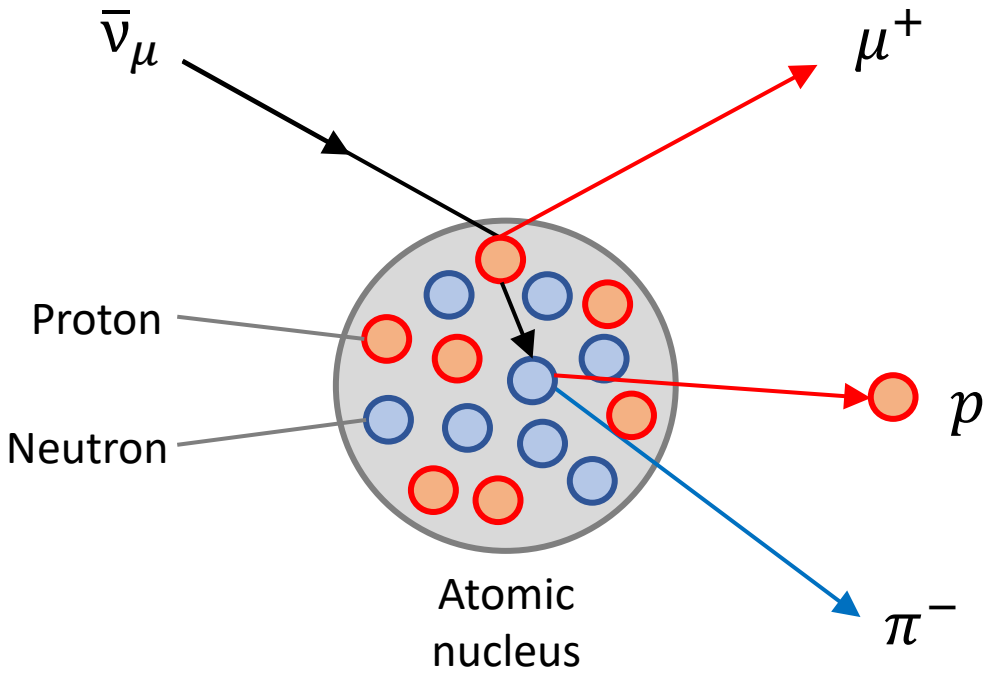
28/04/21

T2K

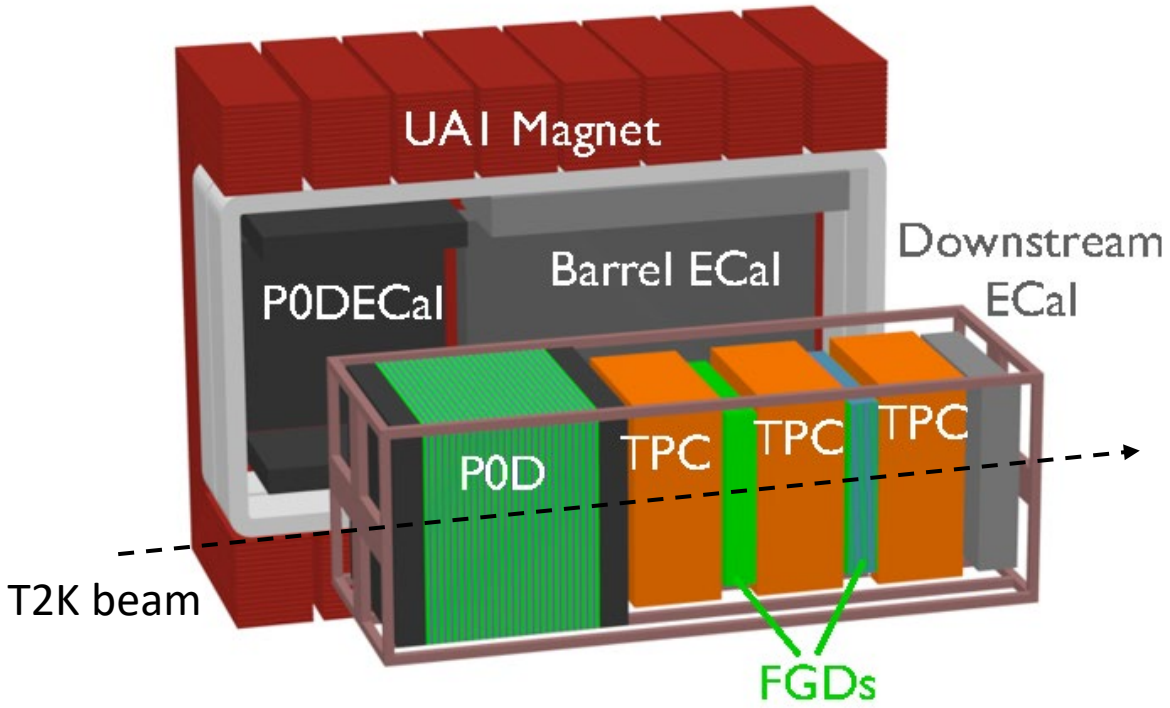
Muon-antineutrino charged-current 1-pion interactions

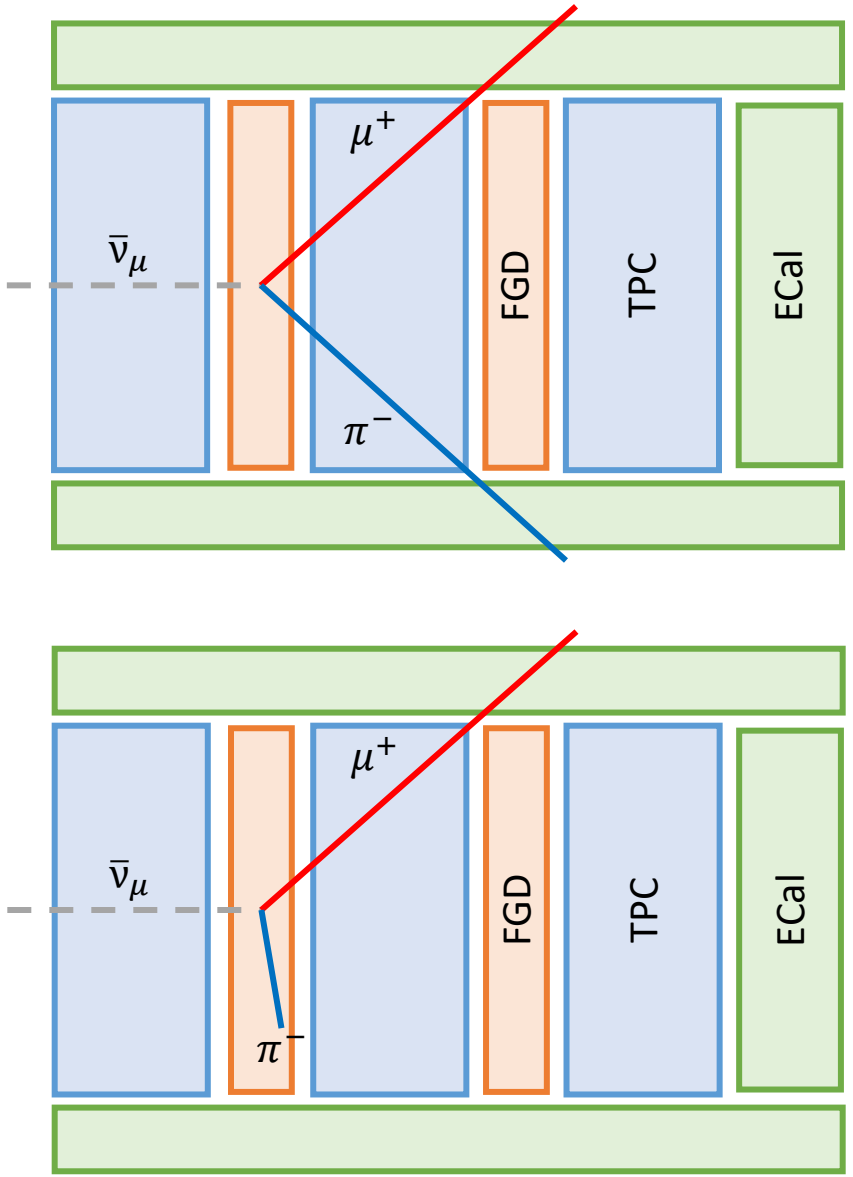




$\bar{\nu}_\mu$ CC1pi topology: $A + \bar{\nu}_\mu \rightarrow A' + \mu^+ + \pi^- \ (+\mathrm{Np})$

CC1pi events in the ND280 detector



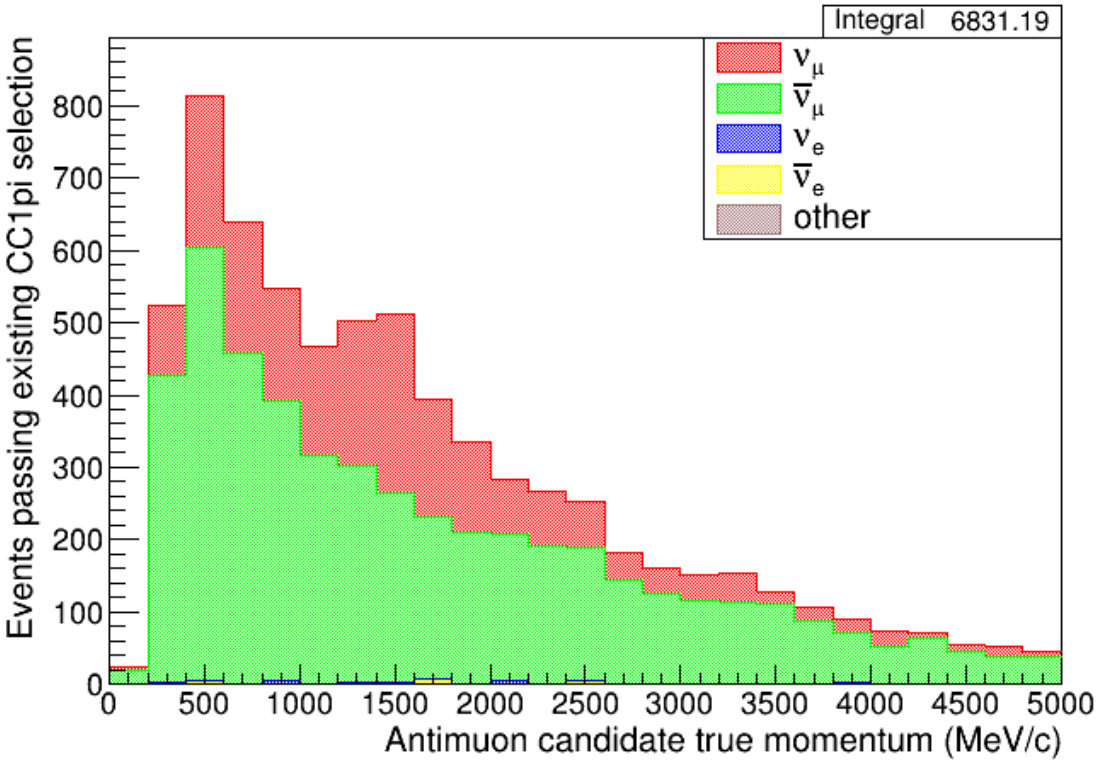


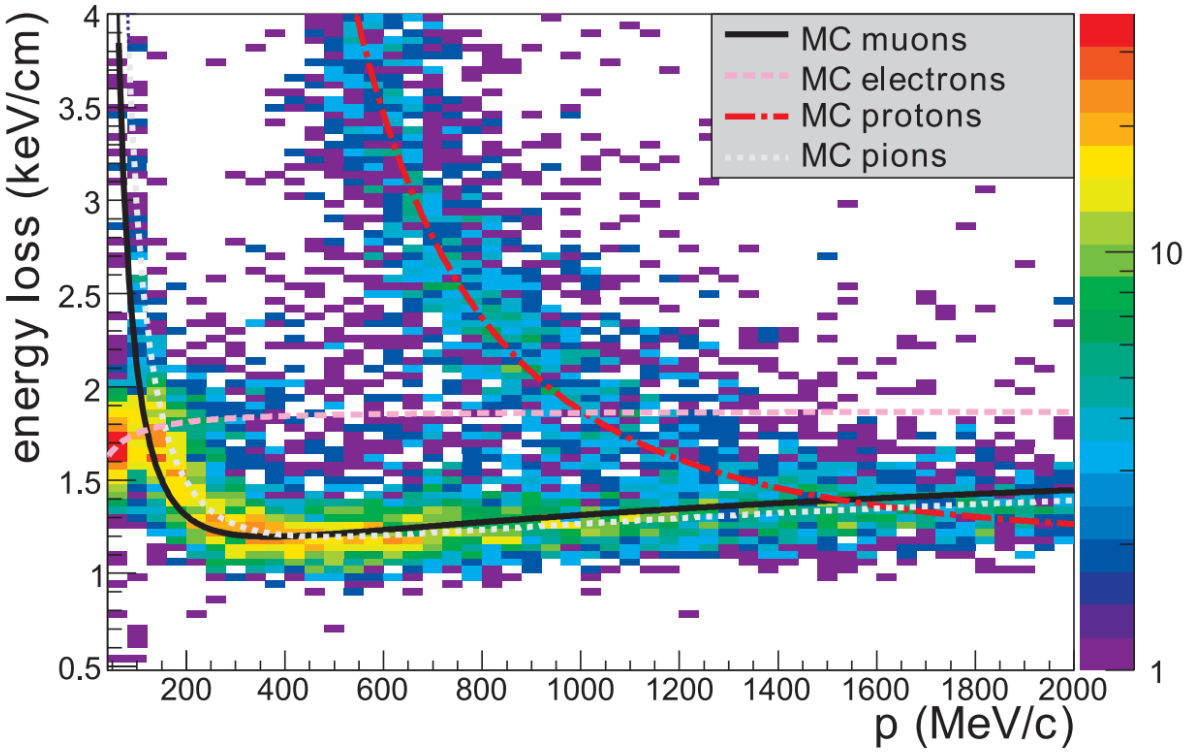
Fine-grained detectors (FGDs): active targets, vertexing

Time projection chambers (TPCs): tracking, momentum

Electromagnetic calorimeters (Ecals): energy measurement

Muon-neutrino CC1pi background





Wrong-sign CC1pi is the main background for the existing selection: $A + \nu_\mu \rightarrow A' + \mu^- + \pi^+ \ (+\mathrm{Np})$

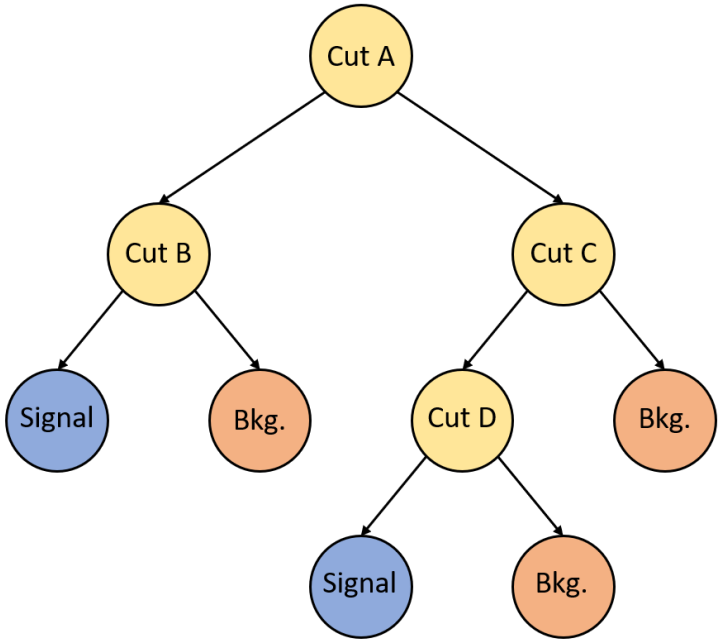
dE/dx particle ID cannot distinguish between muons and pions, so cannot remove this background

Towards a multivariate analysis approach

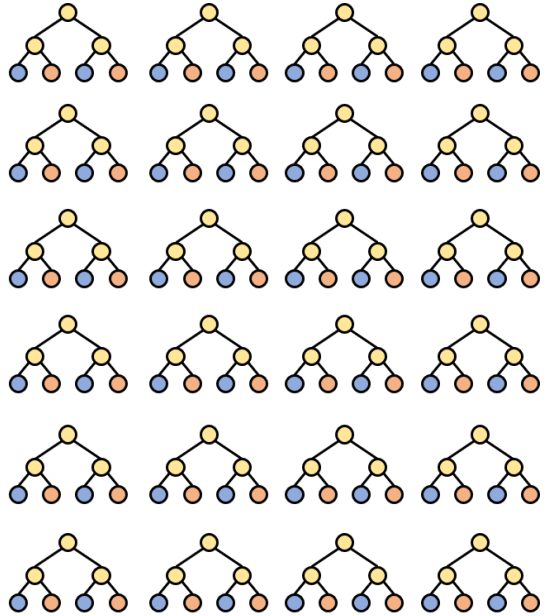
- Aim to mitigate wrong-sign background issue and develop high-performing CC1pi event selection
- Should make full use of all the available PID variables from ND280 subdetectors
- Addition of further rectangular cuts only results in marginal performance gains
- Now developing a boosted decision tree classifier
- Aim to provide a powerful CC1pi selection tool for cross-section analyses and T2K near detector fits

Boosted decision trees

- **Ensemble ('forest')** of simple decision trees optimised for different weightings of training sample
- **Boosting:** training sample is reweighted after each iteration to emphasise events misclassified by previous trees
- Combines many input variables into a single classifier



Simple decision tree



Decision tree forest

BDT for $\bar{\nu}_\mu$ CC1pi event selection: input

Aim to replace all CC1pi PID with a single BDT classifier.

Starting with simple case: 1 positive & 1 negative TPC track

Input variables (already used, new):

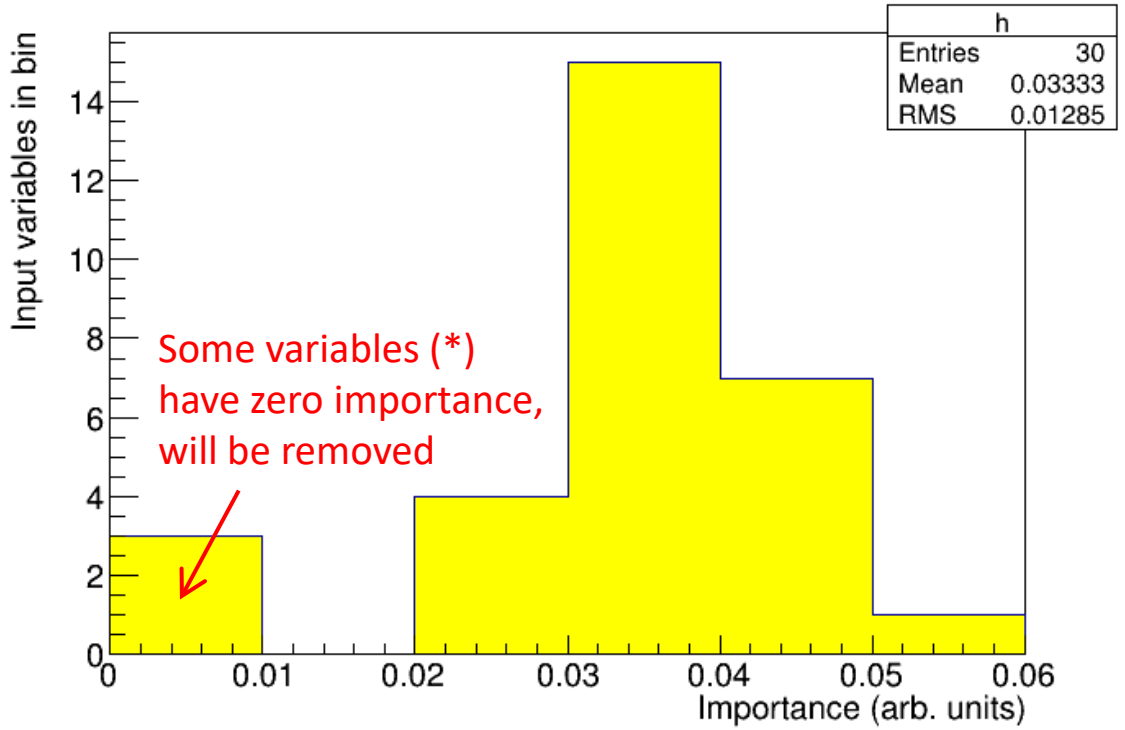
Event-level:

- Number of FGD-contained pions*
- Number of FGD Michel electrons

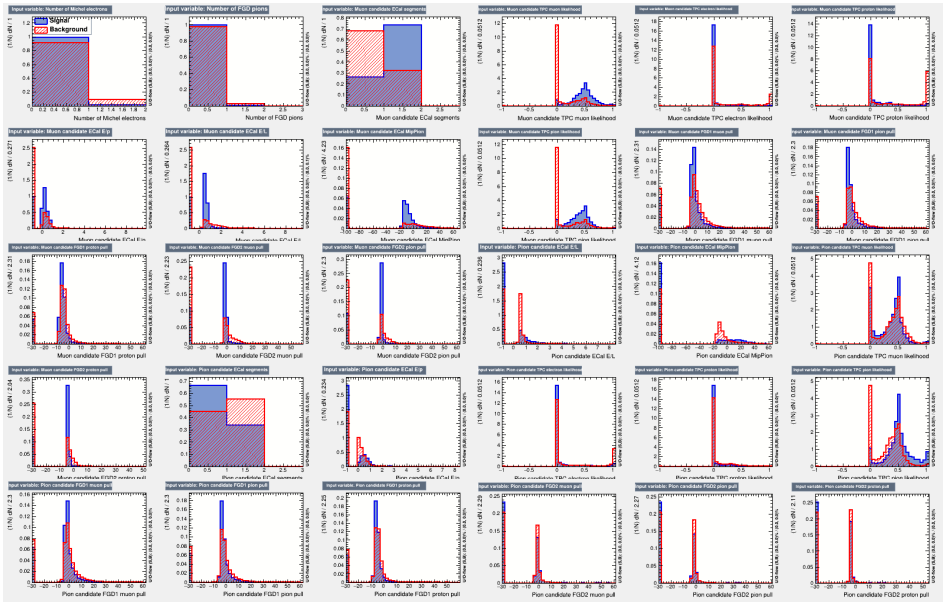
Track-level:

- FGD PID variables: μ, p, π hypotheses
- TPC PID variables: μ, e, p, π hypotheses
- ECal PID variables: E/L, E/p, μ/π hypothesis
- Number of ECal segments*

Importance: how often variables are used to split tree nodes, weighted by separation gain square and number of events in node

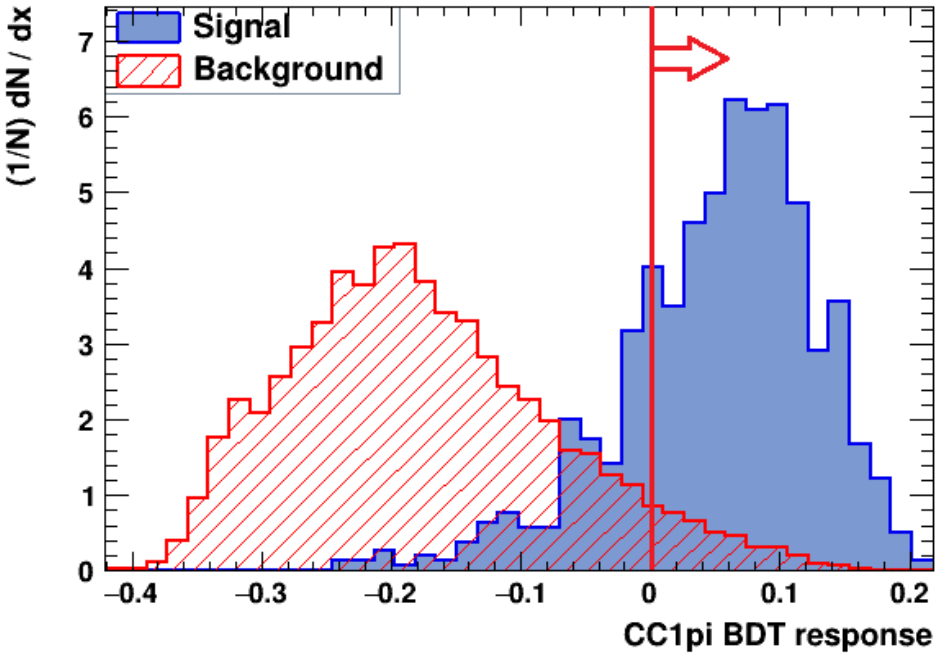


BDT for $\bar{\nu}_\mu$ CC1pi event selection: output



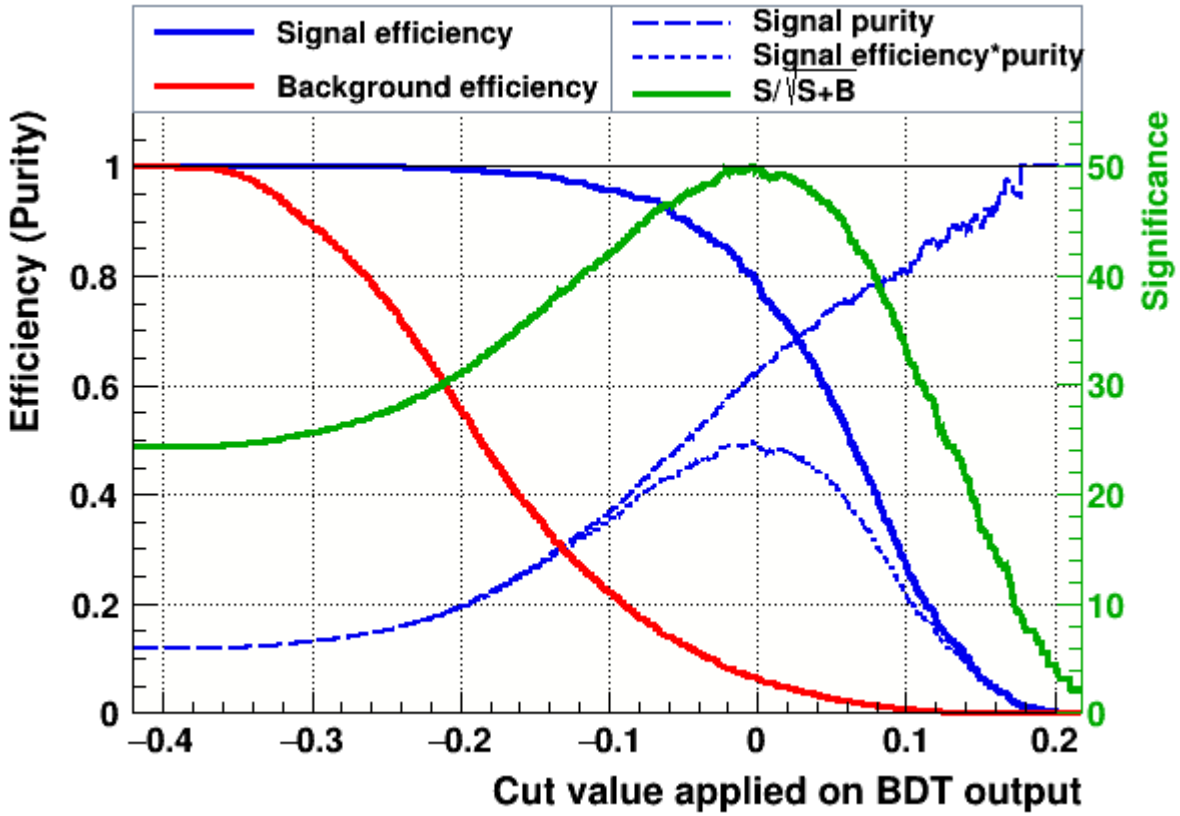
30 input variables

BDT



Output classifier

BDT for $\bar{\nu}_\mu$ CC1pi event selection: performance, outlook



- Significance maximum supports expected zero cut (majority vote of trees)
- Already outperforms rectangular cut-based selections

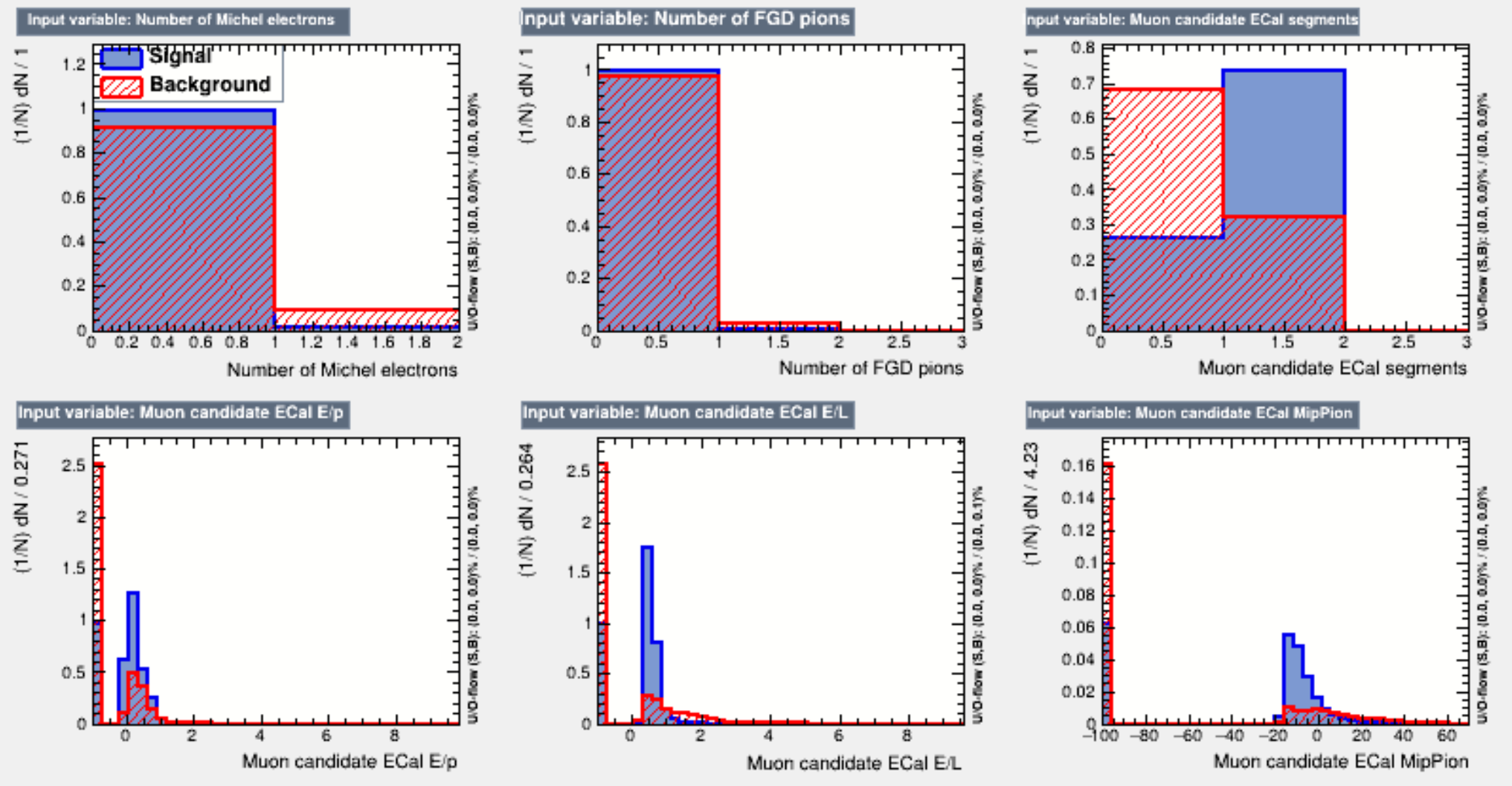
Further work:

- Increase size of Monte Carlo sample
- Add more input variables
- Tune BDT
- Apply tuned BDT to data to select events, make comparisons to MC

Summary

- $\bar{\nu}_\mu$ CC1pi event selections are needed for cross-section measurements, T2K fits
- Existing ND280 $\bar{\nu}_\mu$ CC1pi event selection suffers from large background due to limited particle ID
- Aim to mitigate wrong-sign background issue and develop high-performing CC1pi event selection
- Developing BDT using numerous particle ID variables from multiple ND280 subdetectors
- Current version of BDT already outperforms existing ND280 CC1pi event selection
- Further development should result in powerful selection tool

Backup: BDT input variable distributions



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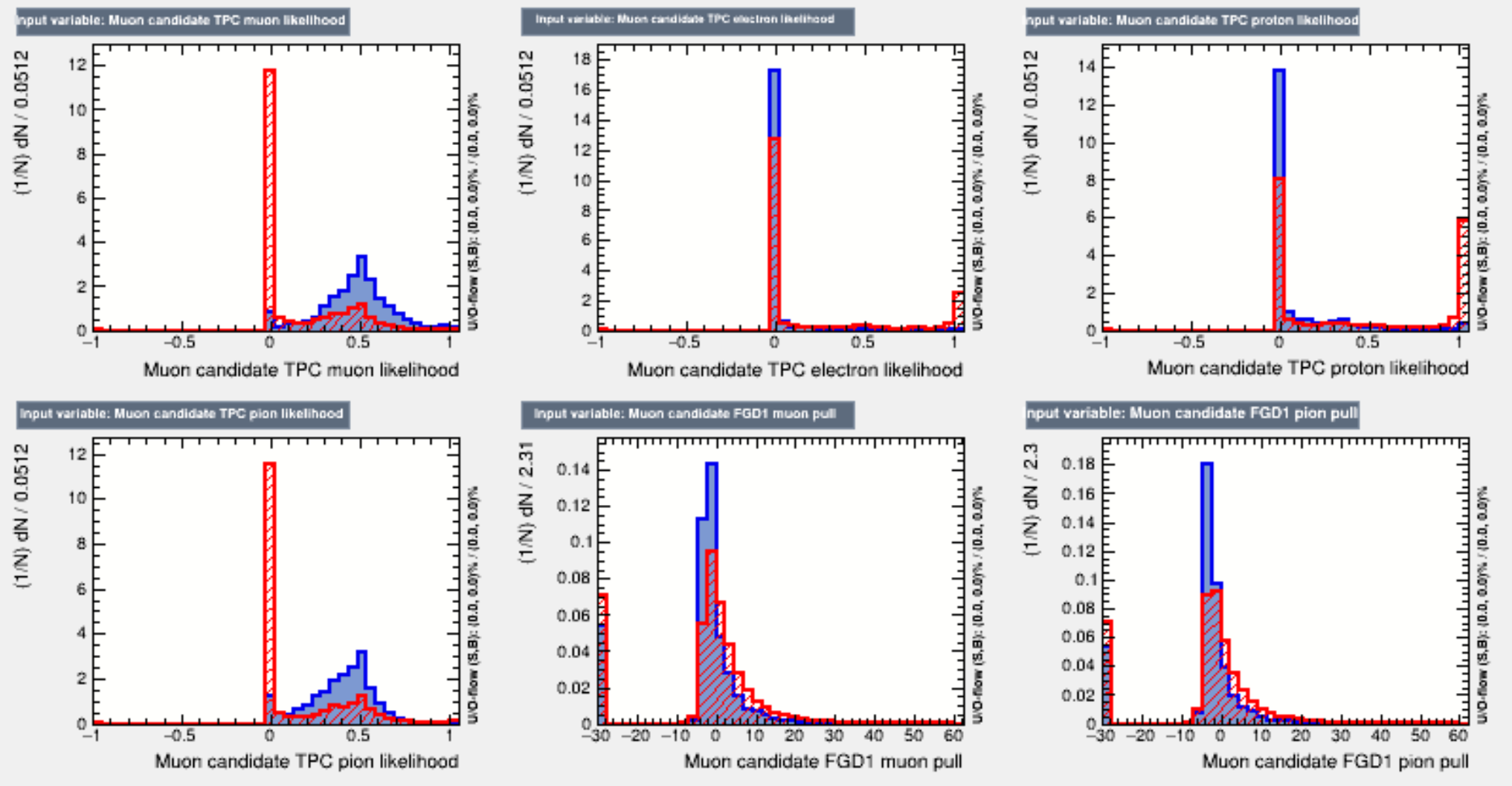

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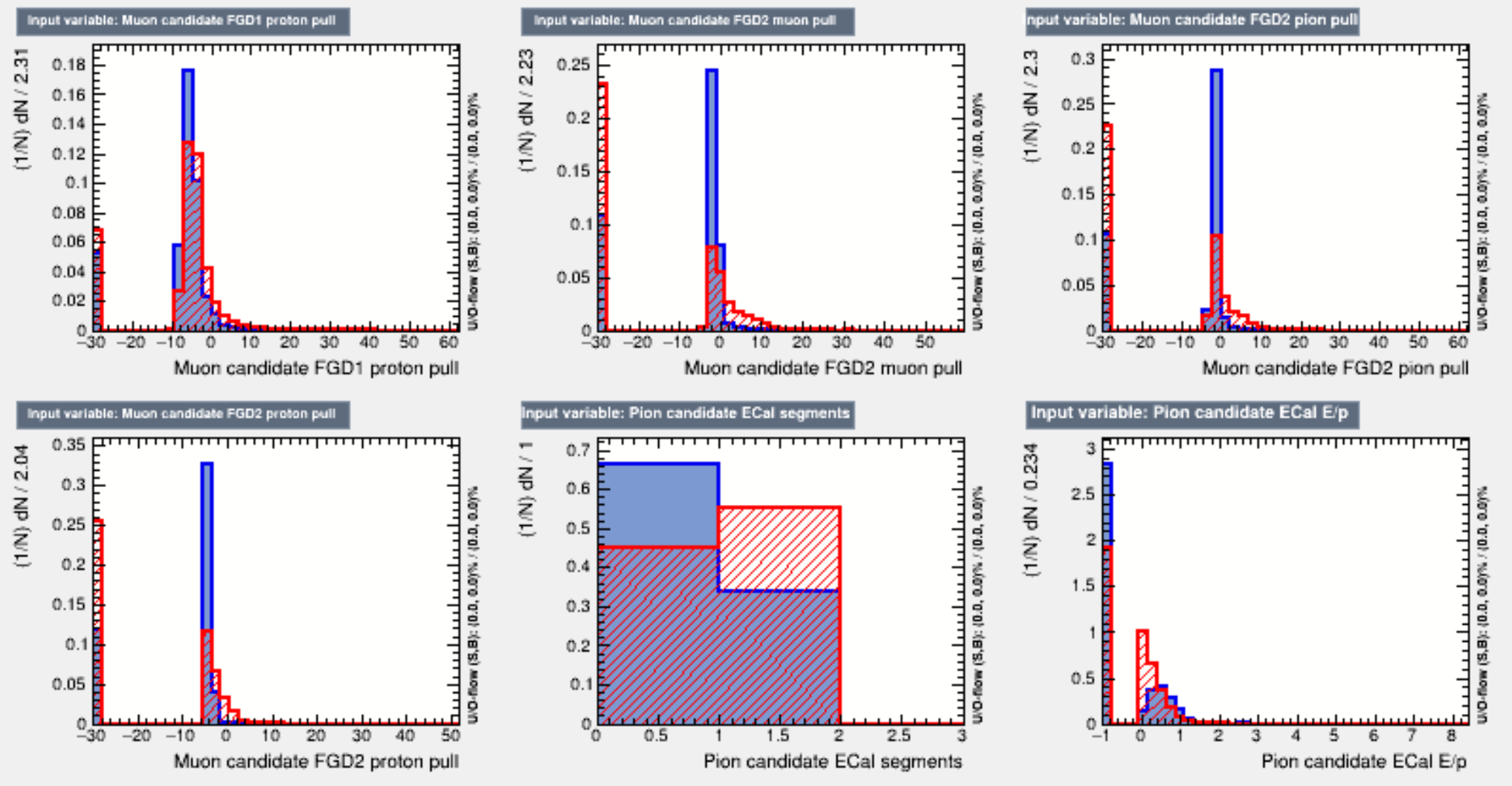

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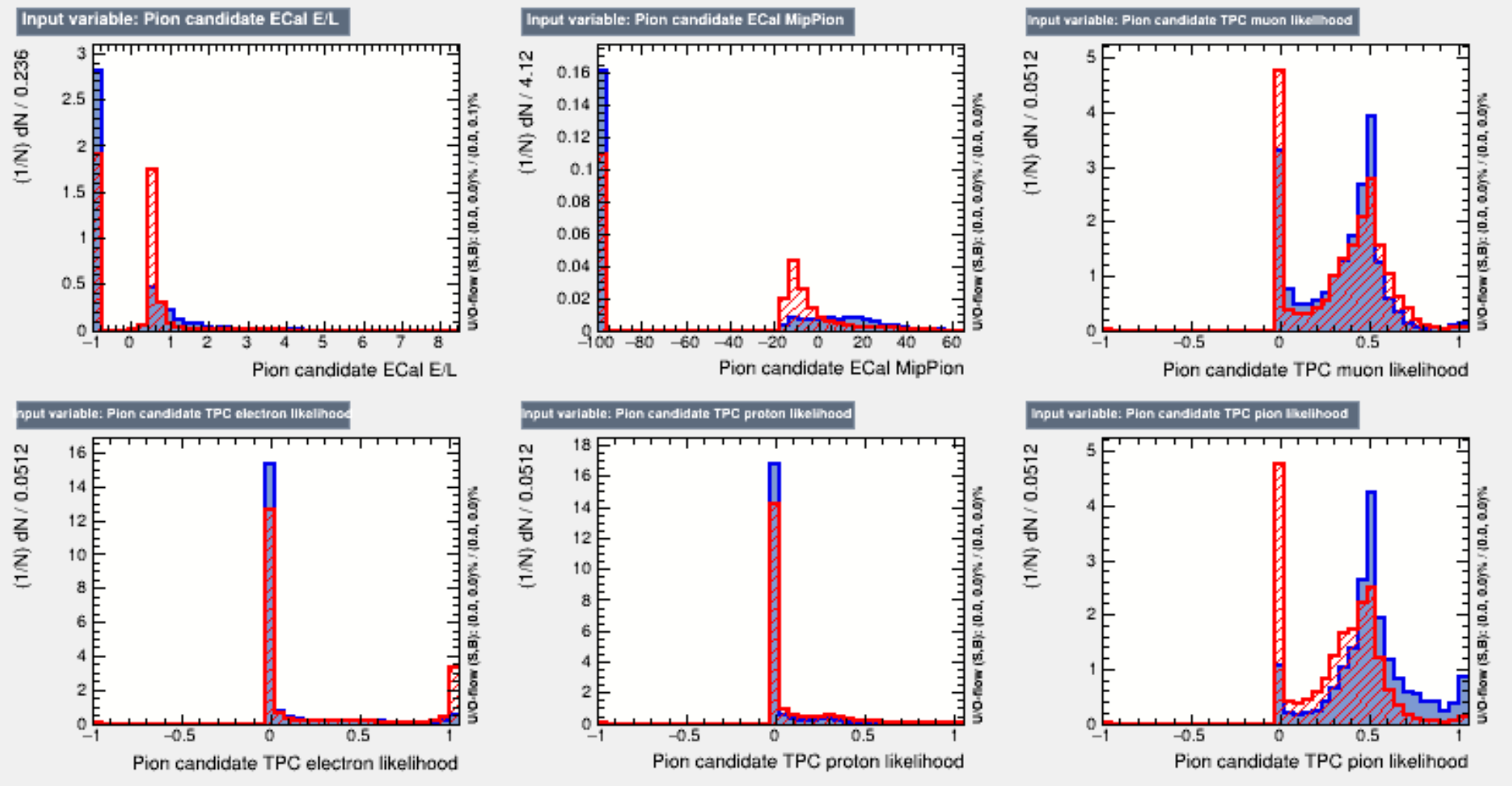

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