MINERvA-TPC Track Matching (for a General Event Selection)

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Introduction

- Purity is not very good out-of-the-box with only ~10-20% of interactions inside the detector from true neutrino-argon interactions.
    - These secondary scatters originating from the rock or MINERvA typically have the same direction and multiplicities as various signal regions. Half come from MINERvA and half come from rock.
    - For example, many events have one track in the final state, which is exactly what a numubar CCQE study would want to include.
- MINERvA experts were adamant about including MINERvA in the event selection at the last Analysis Workshop.

Therefore, I have spent the past two weeks putting MINERvA from the CAFs into a generic event selection.

Definitions
Good match: The G4 particle ID of the reconstructed TPC particle matches the G4 particle ID of the MINERvA track.
    Note: There is a bug in MLReco that may make this metric unreliable regarding G4 ID event-by-event between MLReco and MINERvA. From my understanding, they have been patched and will be in beta3.

Good interaction: The reconstructed interaction comes from a true GENIE interaction on argon using the target PDG variable.
   Note: There is a bug where the vertices in beta2 are nans. I have in the past placed a vertex requirement of <5 cm in all Cartesian directions (so cubic not spherical), so purities may be a little worse due to secondaries from the argon.

Concept of MINERvA-TPC Matching

- Inspired by previous work from ProtoDUNE-SP.
- Assumptions: These are muons or pions that travel straight through.
- Two types of matching coded up right now.

DS Matching
- TPC track must be greater than 5 cm, MINERvA track must be greater than 10 cm and be only in DS panels.
- Select the track that has the best dot product agreement between the track directions **and** the TPC track extrapolated agreement within10 cm in Y (height). Can do X too but we need the timing information in case the TPC track is out-of-time.
- Only include matches with a dot product agreement greater than 0.9975. (Can be further optimized)
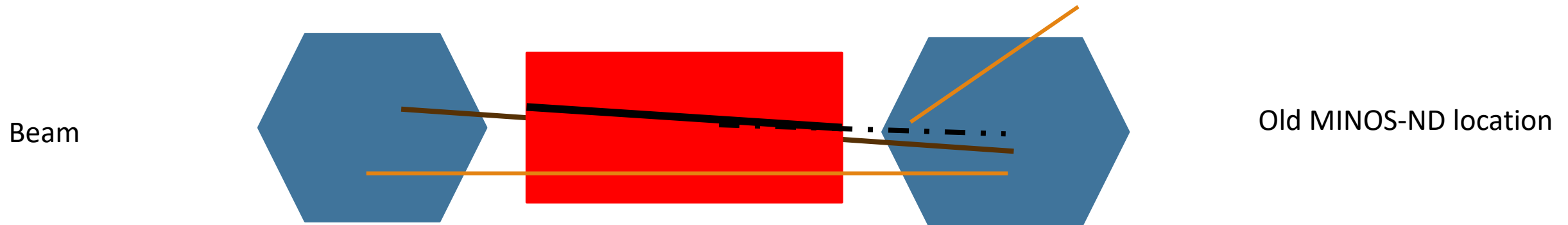
Beam

Old MINOS-ND location
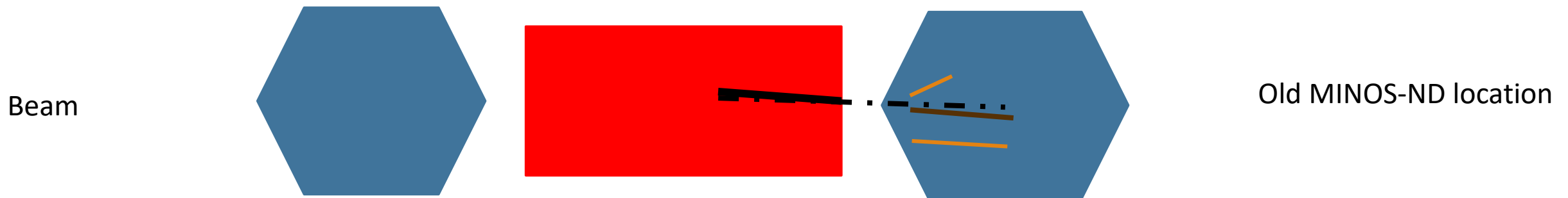
In this example, the TPC track matches to the burgundy MINERvA track as it has the best directional agreement and matches the extrapolated distance in Y.

Concept of MINERvA-TPC Matching

- Inspired by previous work from [ProtoDUNE-SP](#).
- Assumptions: These are muons or pions that travel straight through.
- Two types of matching coded up.

US Matching
- TPC track must be greater than 5 cm, MINERvA track must be greater than 10 cm and be in both panels.
- Select the track that has the best dot product agreement between the track directions **and** the TPC track extrapolated agrees within 10 cm in Y (height). Can do X too but we need the timing information in case the TPC track is out-of-time.
- Only include matches with a dot product agreement greater than 0.9975. (Can be further optimized)

Beam

Old MINOS-ND location

In this example, the TPC track matches to the burgundy MINERvA track as it has the best directional agreement and matches the extrapolated distance in Y.

We will ignore this one to stick to the time constraints. It has a purity of around 85% for good matches.
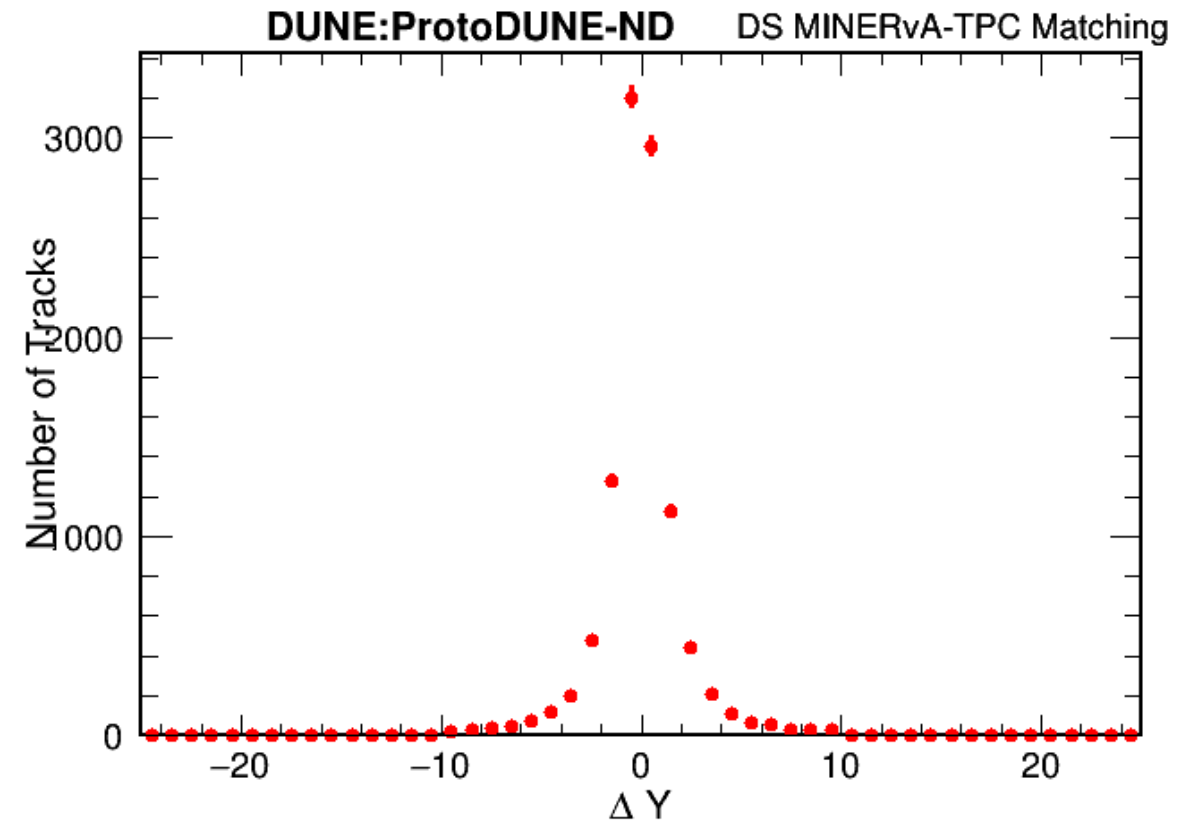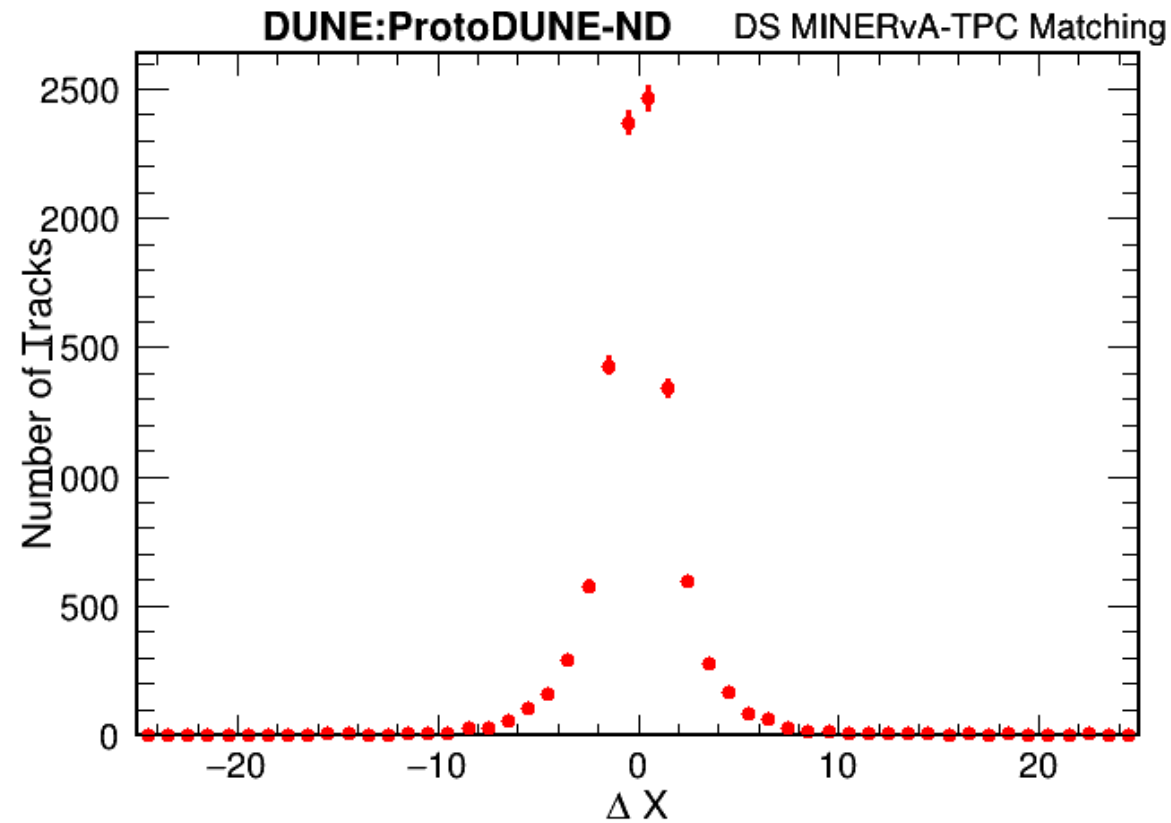
Distributions of DS Matching

- Here are some validations using the cuts outlined on a track-by-track basis:
    - Minerva Match Purity DS: 10128/10522 (96%)
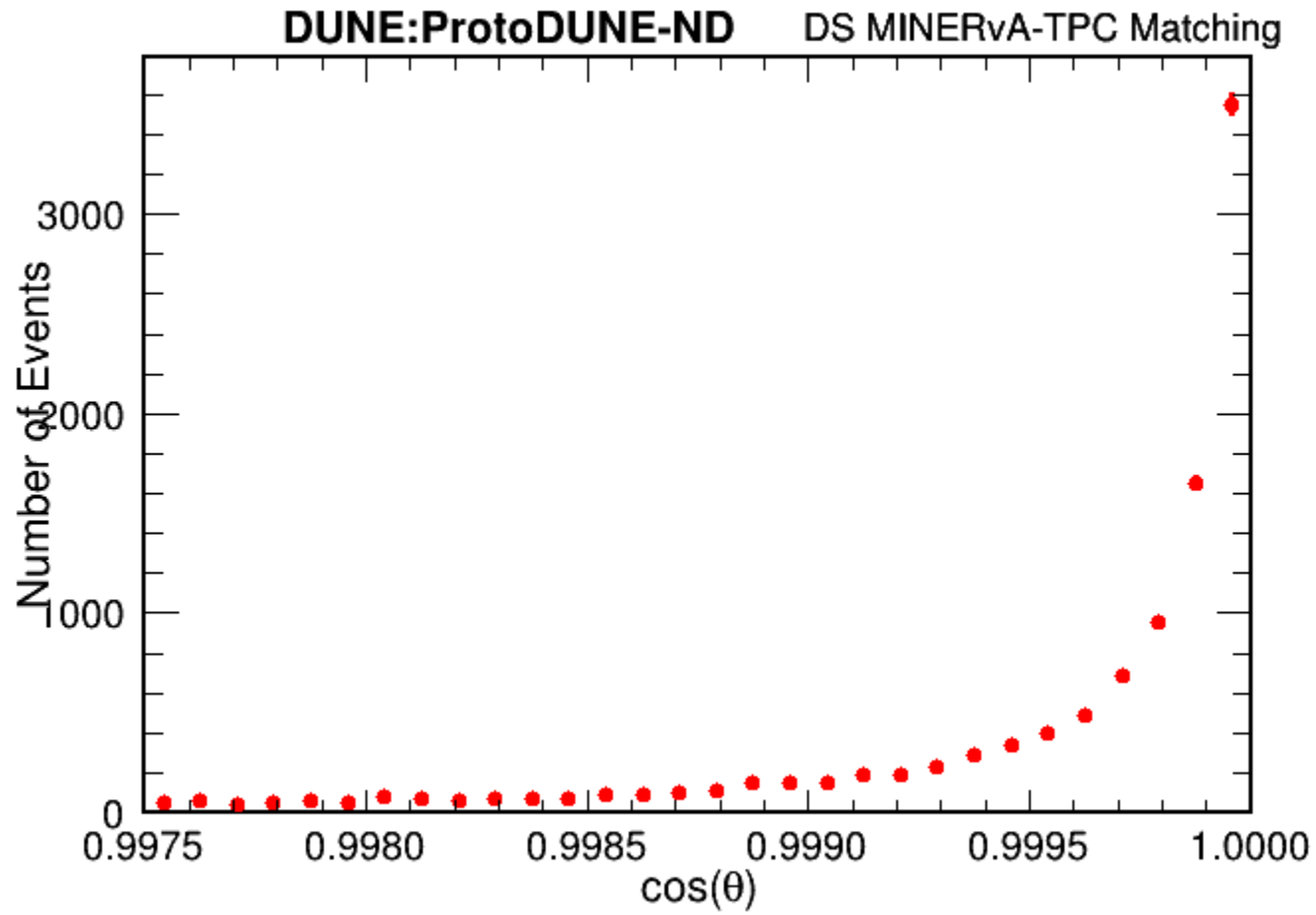
Distributions of DS Matching

- Here are some validations using the cuts outlined on a track-by-track basis:
  - Minerva Match Purity DS: 10128/10522 (96%)

- In the X distribution, 5% of events are outside the 10 cm window.
- In the Y distribution, the extrapolated displacement cannot be greater than 10.

Distributions of DS Matching for Good Matches

- Here are some validations using the cuts outlined on a track-by-track basis:
 - Minerva Match Purity DS: 10128/10522 (96%)
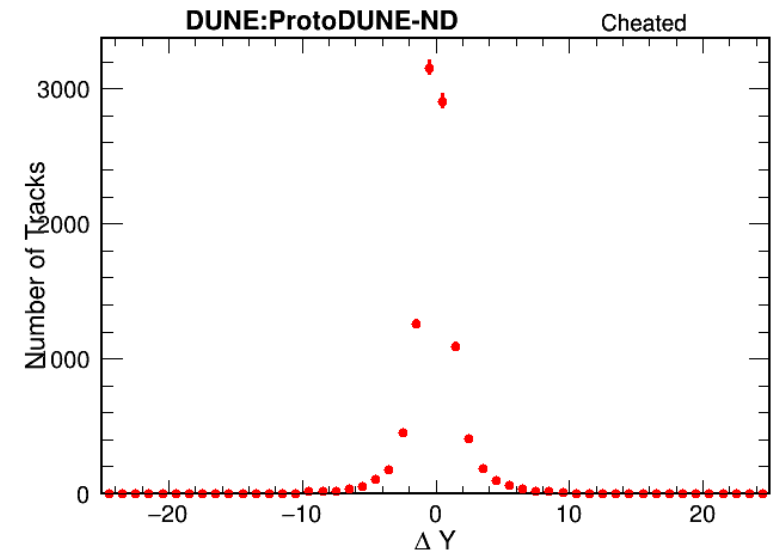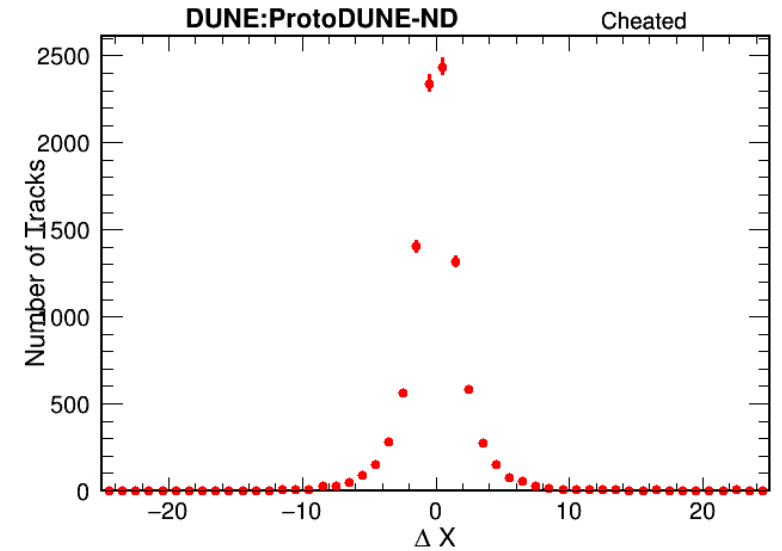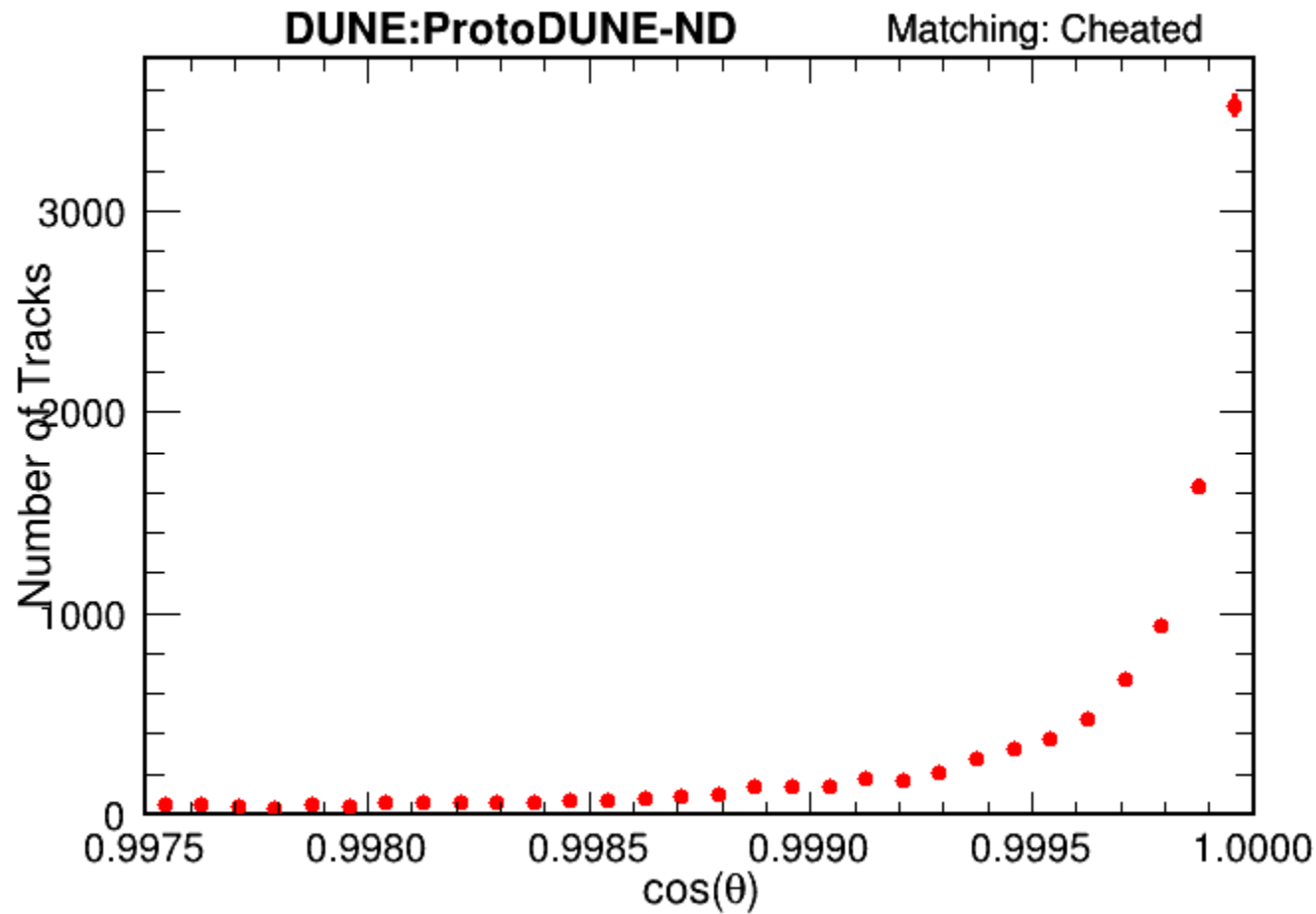
Interaction Selection

Total number of neutrino-argon interactions in MiniRun 4.5 beta2: 39,846
- There needs to be a reconstructed vertex.
  - 25,502 good from 135,529 interactions for a purity of 18% with an efficiency of around 64%
- The reconstructed vertex needs to be x<55 cm, y<55 cm , z<55 cm, x>10 cm, z>10 cm, and abs(x-33)>1.5
  - 7141 good from 24396 interactions for a purity of 29% with an efficiency of 17%.
- There needs to be at least one primary track that is within 5 cm of the vertex and 1 cm long.
  - 5175 good from 11693 for a purity of 44% with an efficiency of 13%.
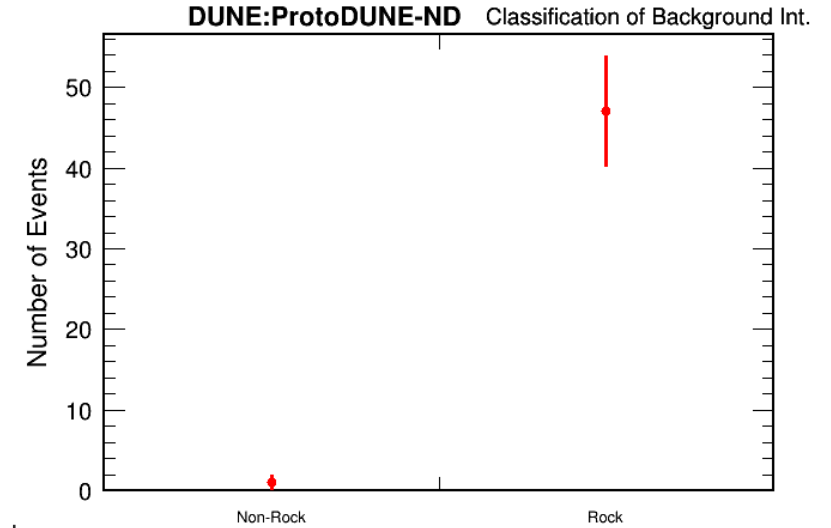
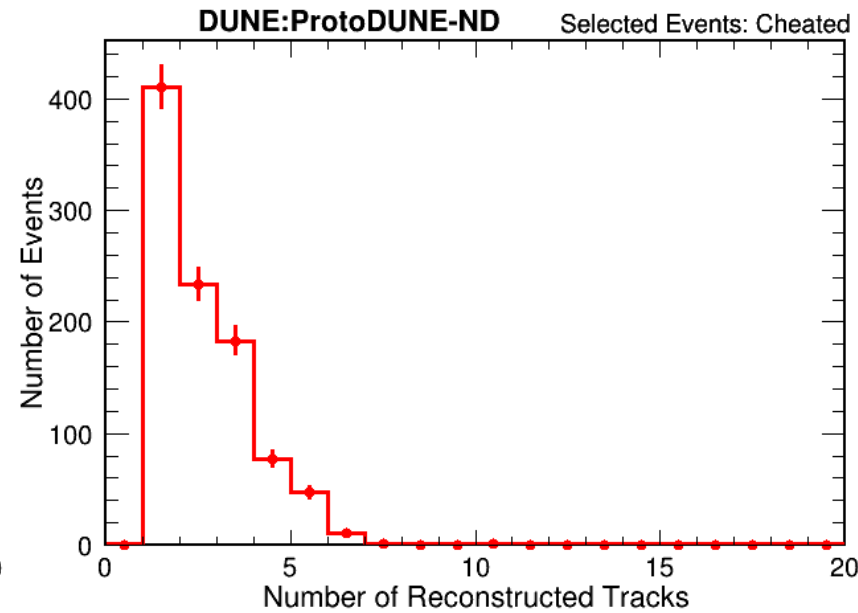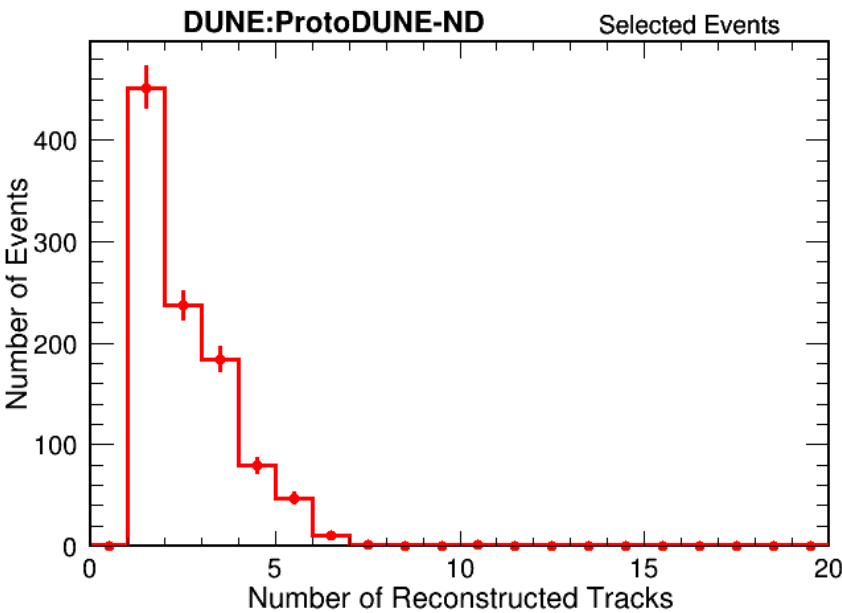Here are the results without MINERvA:
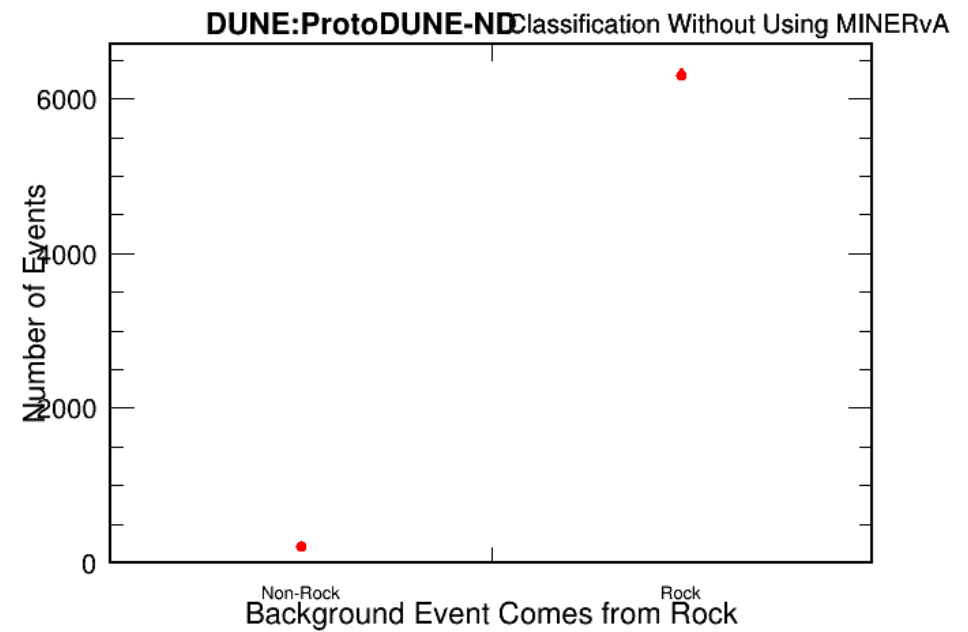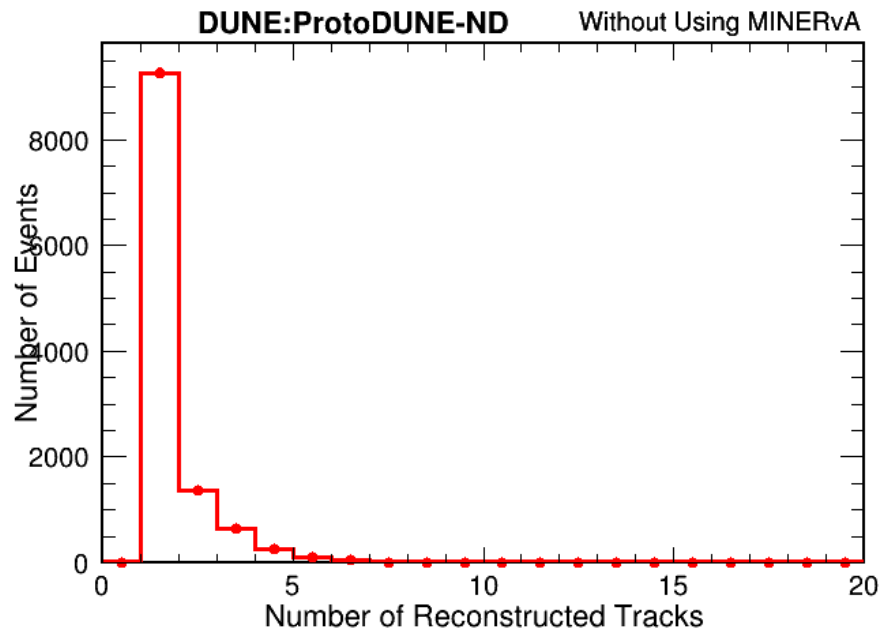
Track Multiplicity with MINERvA Matching

Total number of neutrino-argon interactions in MiniRun 4.5 beta2: 39,846

- At least one track must be matched to the DS MINERvA panels.
  - 964 good interactions out of 1012 for a purity of 95% and an efficiency of 2.4%.
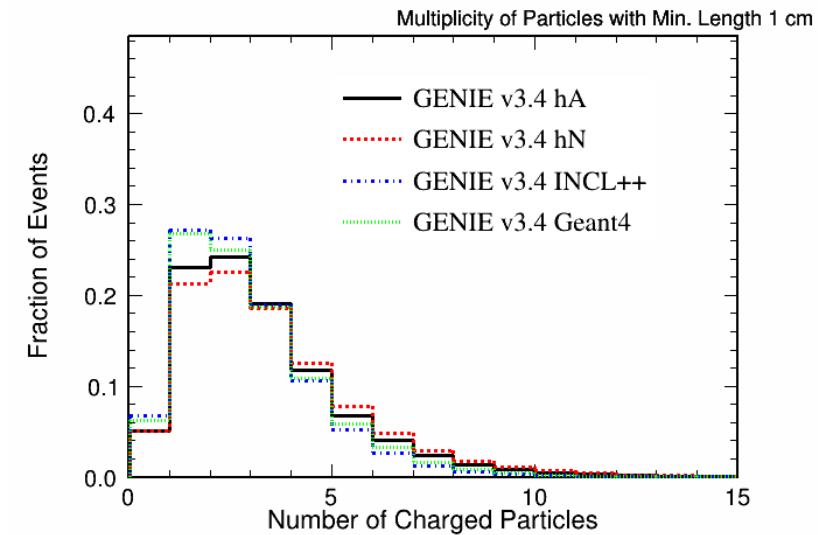
Here are the results with MINERvA:

Moving Forward

- A matching algorithm for downstream MINERvA panels to the TPC is introduced with preliminary results.
  - Purity, according to beta2 files and their related adjustments, is greater than 90%.
- Matching involves optimizing the directional agreement between tracks within an extrapolated displ. window.
  - Consider adding relevant timing information to CAFs to T0-correct.
- The code is available here /dune/app/users/rdiurba/minervaMatcher, will push to github after beta3 tests.

Future Studies (in order of complexity):
- Adapting code for flat CAFs.
- Sorting punch-through tracks from tracks that stop in MINERvA.
- Efficiency studies on dot product cuts.
- Developing an energy "look-up table" to translate TPC length+MINERvA length into energy measurements.

And many more if you ask me.

Please contact me if you have questions or concerns.

Multiplicity of Particles with Min. Length 1 cm
- GENIE v3.4 hA
- GENIE v3.4 hN
- GENIE v3.4 INCL++
- GENIE v3.4 Geant4

Next step is to see if the disagreement between GENIE and MLReco is also seen at CAF G4-level and can be attributed to secondary interactions.

And to apply signal definitions since the MINERvA cut eliminates most NC events.