Project Journal

Contents

24 November 2024

Meeting summary:

Enrique gave me a file with results of a simulation of neutrinos interacting with the $\textbf{Faser}\boldsymbol{\nu}$ *detector.*

using a jet algorithm called anti-kT, we find a large number of jets from the neutrino interactions. We expect to see a small number of jets, so we might want to edit the radius parameter of the jet algorithm.

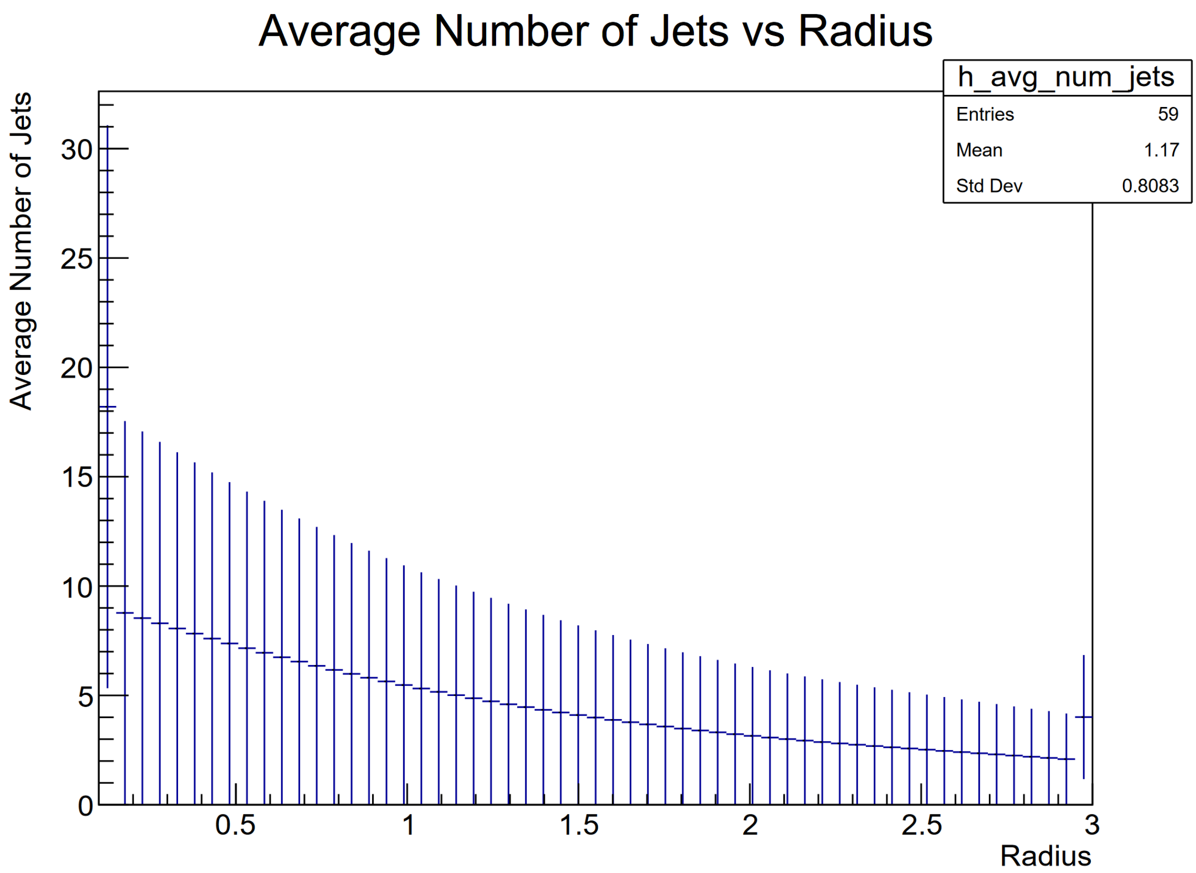
We also expect all of the hadrons to be included in the jets, so if we miss some of them, it's a sign that the radius might be too small.

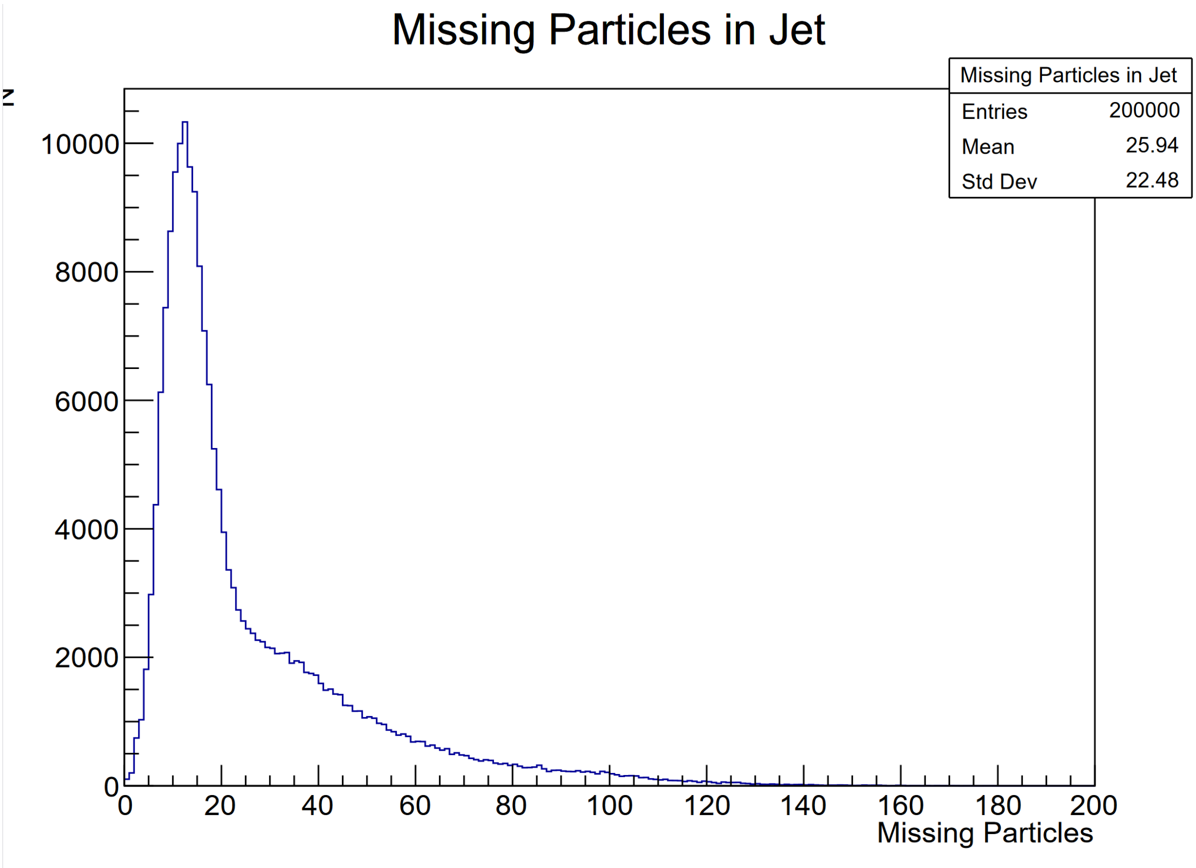
Next Steps:
- *Run the analysis with a varying radius parameter to see how the number of jets and the number of included hadrons change.*
- *Create a plot similar to the one in this link (page 33)*

25 November 2024

Summary of Today's Work:

- *Setup and Initial Runs: Successfully set up the environment and ran initial tests using the jet algorithm.*
- *Data Visualization: Plotted data showing the behavior of jet numbers across different radii, finding a decrease with increasing radii. No optimal cutoff radius identified yet (See Figure 1).*
- *Custom Jet Algorithm: Implemented a custom algorithm (See Figure 2):*
  - *Assumes jets' energy and momentum align with CC event characteristics (e.g., negative momentum relative to leptons, energy summing to neutrino energy).*
  - *Issues Identified:*
    - *Multiple neutrinos and leptons in a single event are problematic, disrupting algorithm reliability.*





Next Steps:

- *Debug code to resolve multiple neutrino/lepton event handling.*
- *Determine an optimal jet radius for the custom algorithm:*
  - *Evaluate physical significance.*
  - *Plot relevant metrics to assess jet completeness and structure.*
  - *Find radius which saturates the number of included hadrons (or understand why one does not exist).*

28 November 2024

Work done today:

Setup new mac.

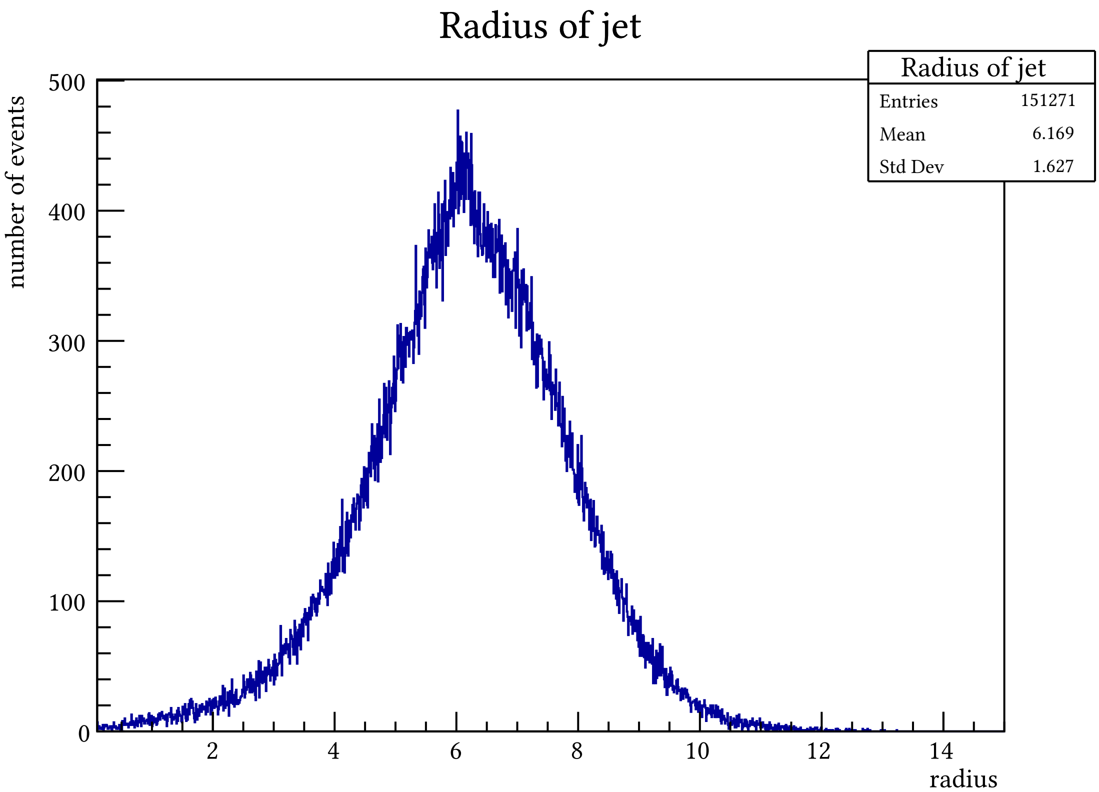
Discussion with Enrique about project:

- *Containment of p_T reaches 100% only around radius ≈ 3 and there is a very large radius distribution of the jets.*
- *Want to find a variable with high correlation with the radius of the jet, so that we can improve the algorithm.*

01 December 2024

Work done today:

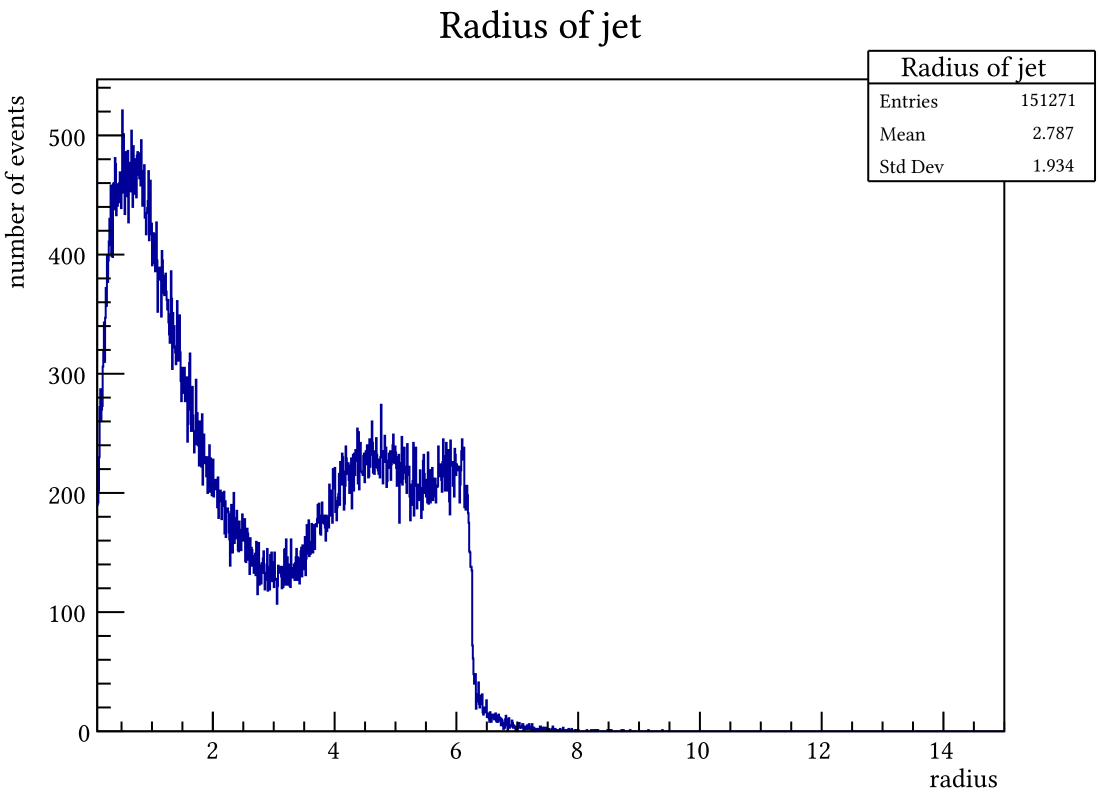
- *Most of the work today was to familiarize myself with the data and setting up a good workflow. I fixed some bugs and started to look at what would be a good way to find a variable which is correlated with the radius.*
- *Most of the "double" neutrino events were just bugs in the program, but there are still some events which have this. I am filtering out these events for now as there's not many of them.*
- *For every event, I am searching for the farthest particle from the location where the jet should be. This can be seen in Figure 3.*
- *We can see that the average "radius" (if we want to include all particles in the jet) is 6, and to "capture" all of the cases, we would want to have a radius of about 12.*
- *Now that I have the "radius" of the jet for each event I can start to search for correlated variables.*
- *Need to understand from Enrique what data we will actually have access to in order to determine the possible variables to look at (since we won't have the jet vector for the real data).*



02 December 2024

Work done today:

- *Changed the way we calculate the radius of the jet. Now we are looking at the radius which contains X% of the energy of the jet (See Figure 4 for a 90% containment)*
- *Since we found this interesting pattern which suggests 2 regimes, we decided to look at them separately and plot some variables. Interestingly, we found that the number of baryons in the jet is different in each regime (See Figure 5). This suggests that the "large radius" events are events in which the neutrino is breaking the nucleus, which causes the jet to have more baryons. This is interesting because it suggests that we can use the number of baryons to classify the events.*
- *We graphed the mesons and baryons' average distance, and bizarrely found that the baryons are closer to the jet axis than the mesons (See Figure 6 and Figure 7).*



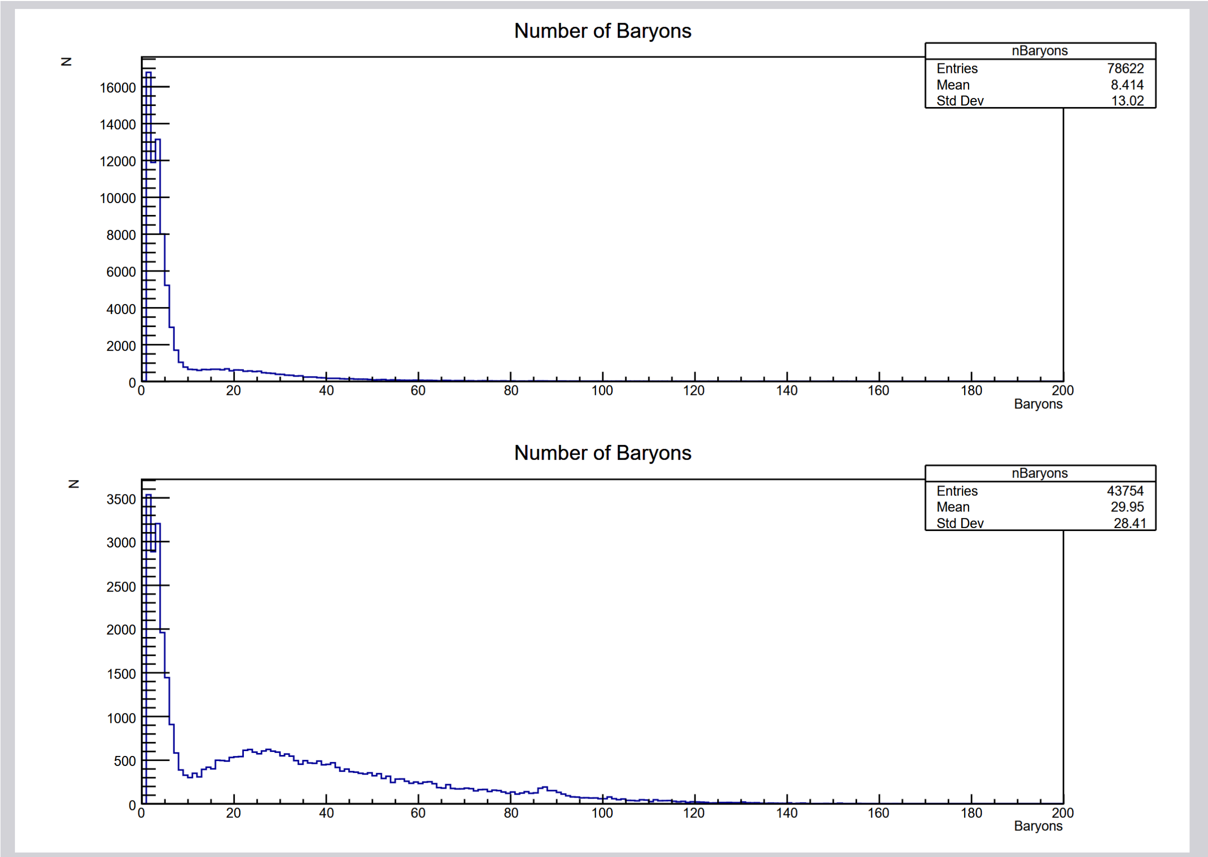


Figure 5: Top: small radius regime, Bottom: large radius regime

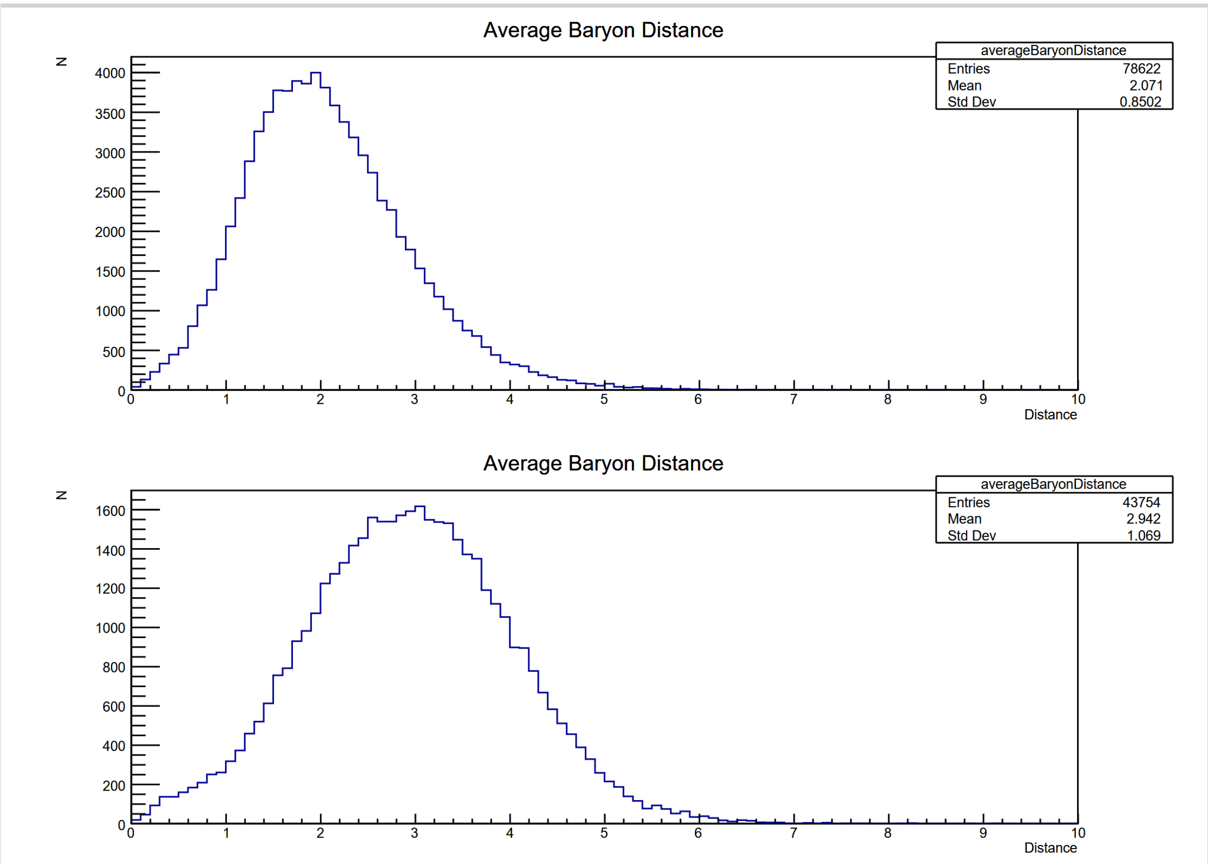


Figure 6: The average baryon distances

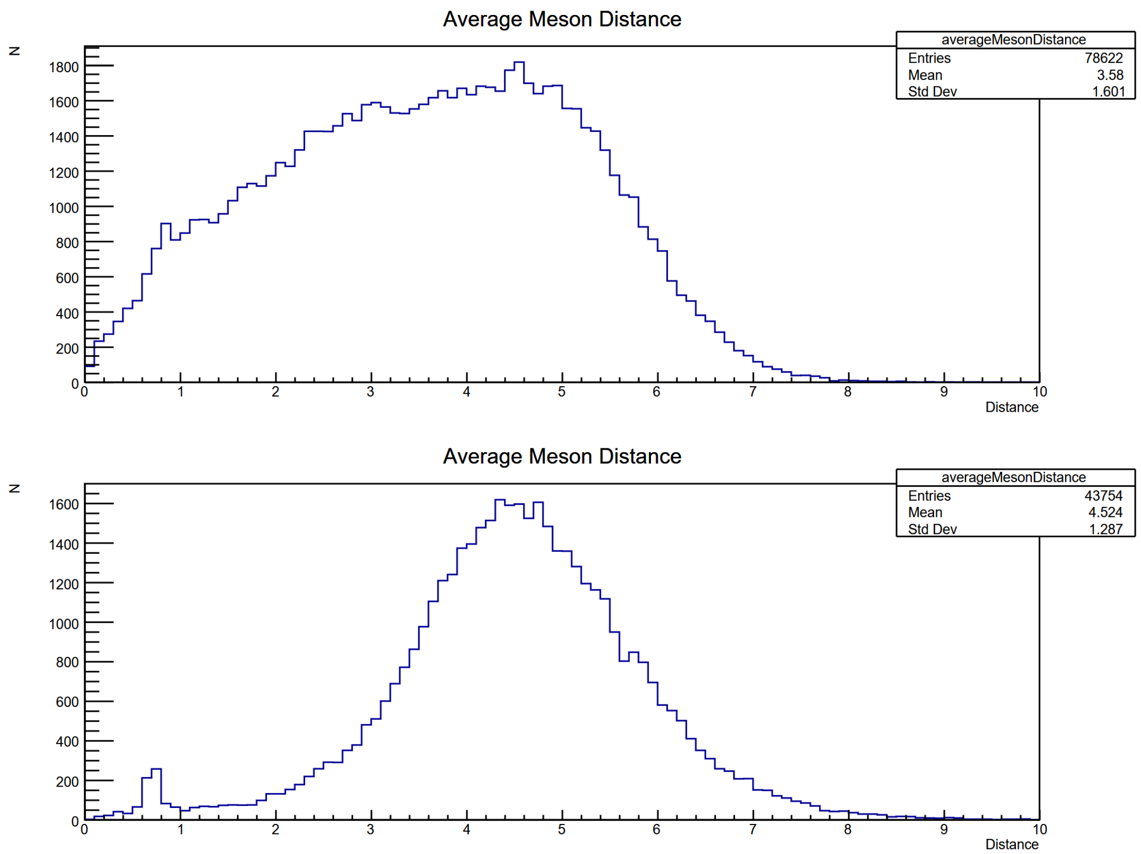


Figure 7: The average meson distances

05 December 2024

Meeting summary:

- *Some Muons reach* $\mathbf{Faser}\boldsymbol{\nu}$ *from the LHC as well. We can use the data about these muons and their interaction (through* γ*) with the nucleus to calibrate our algorithm for the neutrino interactions, as it should be largely the same (we still expect to see wide jets).*
- *Discussed the paper "Measurement of nuclear effects in neutrino interactions with minimal dependence on neutrino energy" [PHYSICAL REVIEW C 94, 015503]. We will try to use* $\delta(p_T), \delta\alpha_T, \delta\phi_T$ *and see if they are indeed independent of the neutrino energy.*

Work done today:

- *Plotted the variables in our simulation, and found that it's consistent with the paper (to some point) (See Figure 8, Figure 9, Figure 10).*

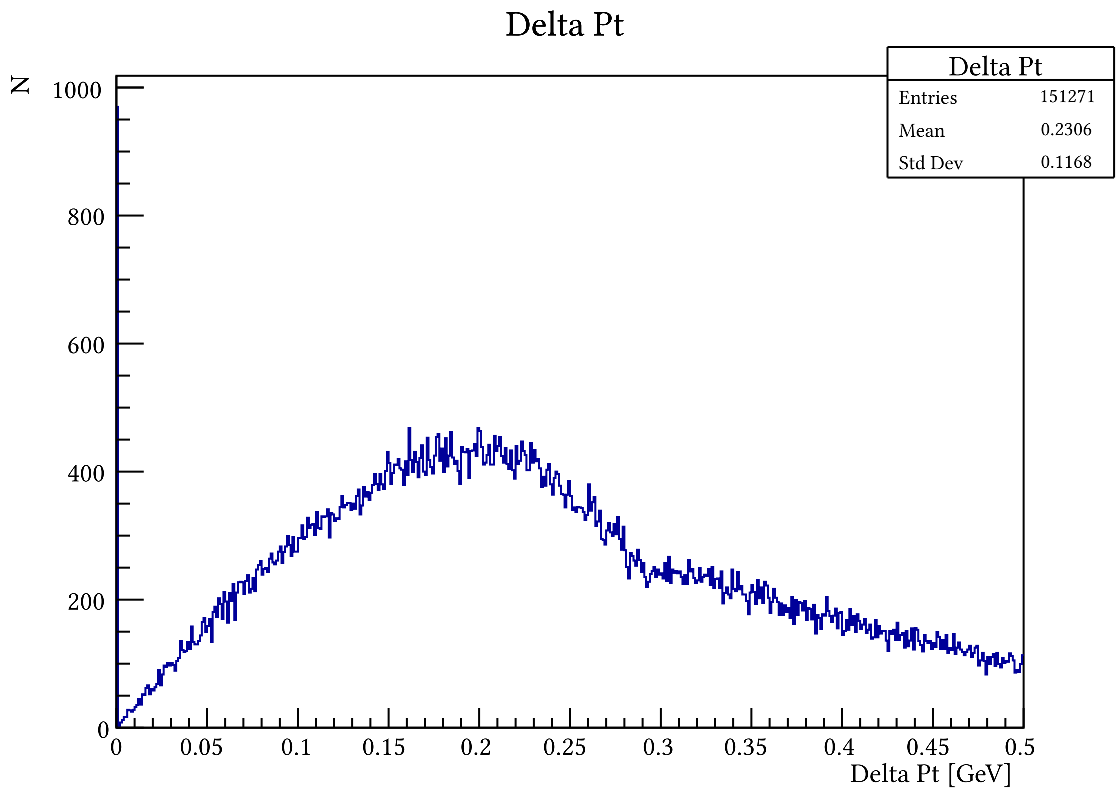


Figure 8: δp_T

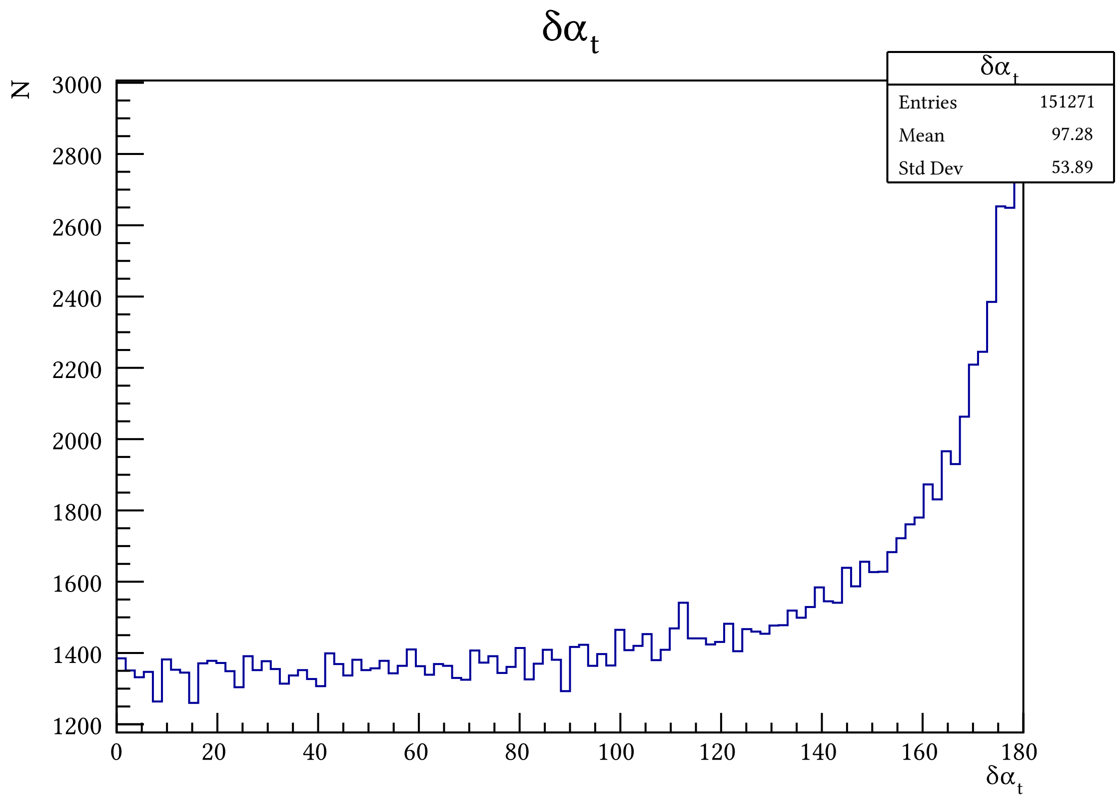


Figure 9: $\delta\alpha_T$

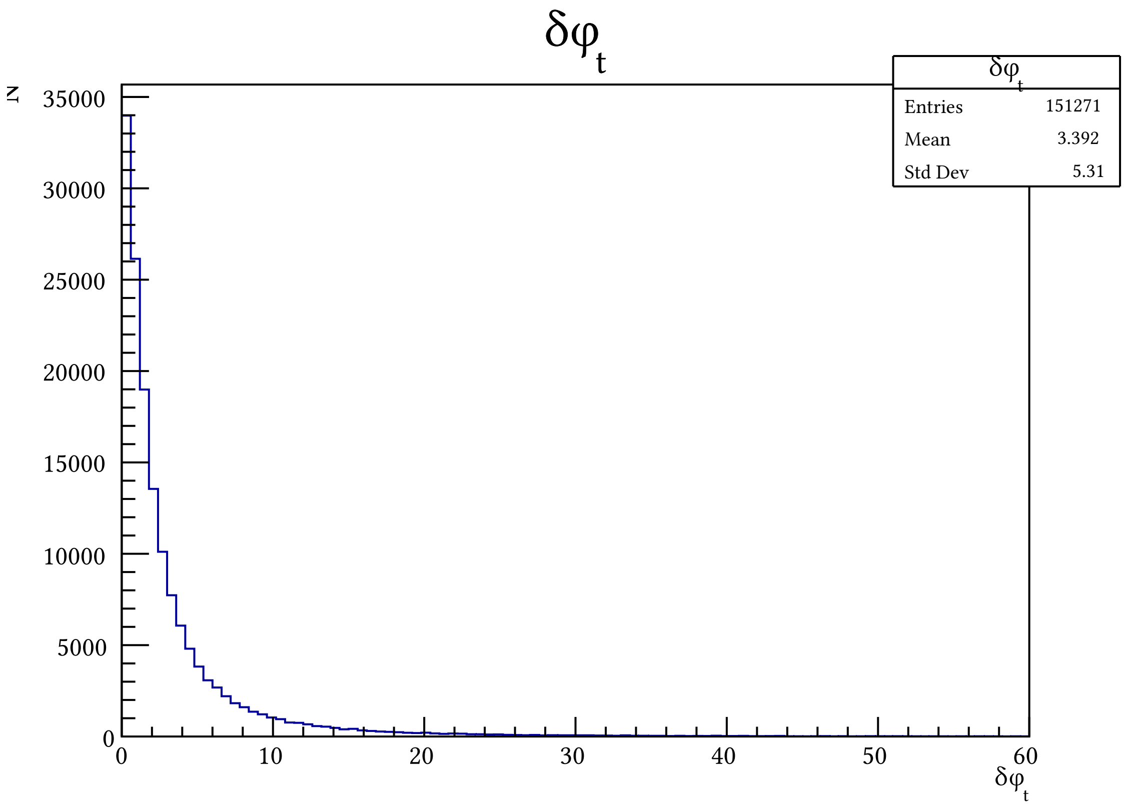


Figure 10: $\delta\phi_T$

08 December 2024

Meeting summary:

- *We decided that the best way forward is to find some observable that will let us distinguish between the 2 cases that we found.*
- *Possible observables include the energy correlation functions, which might be able to tell us about the jet substructure (there could possibly be a difference in the jet substructure between the 2 cases).*
- *Another observable we could look at is something similar to N-subjettiness, but we expect that we are in a different case (we don't expect 2 vs 1 prong, but rather a different radius of the jet).*

Relevant sources:

- *"Energy Correlation Functions for Jet Substructure [arXiv:1305.0007]"*

09 December 2024

15 January 2025

We started to work on locating vertices from the data of the tracks.

The current implementation of the algorithm uses Delaunay triangulation to find the closest points, and iterates over all faces from smallest to largest. If the neighbourhood of a face passes certain criteria, we assume that there is a vertex and calculate its position using a weighted average of the neighbourhood points.

This works well on simulated data, and the next step is to run it on the real data.

To do this, we triangulate over tracks which begin on the same film, so the triangulation is done on a smaller subset of the data.

10 February 2025

We ended up changing to algorithm to use a density based algorithm called DBSCAN. This algorithm is more robust to noise and outliers, and is able to find clusters of points in the data. It is also $n \log(n)$.

It looks like the algorithm works well, and setting $\mathrm{minPts} = 10$, $\varepsilon = 20$ *we get* ≈ 1000 *clusters for the data.*

We then select only the clusters which have at least 1 long track (for the muon). After this we get ≈ 350 *clusters.*

The next step is to try and run a Kalman Filter algorithm on each cluster that we found, and to see if we can estimate the location of the vertex and the originating tracks.

Since it is complicated to run implement the Kalman Filter algorithm, we want to use the "ACTS" framework in order to do it.

I am currently trying to understand how to parse the data into the relevant format for the ACTS framework.

13 February 2025

I parsed everything other than the covariance matrices. Until I figure out how to parse them, I will try to set them to a default value.