Momentum evaluation with nuclear emulsion spectrometers: preliminary results on Monte Carlo

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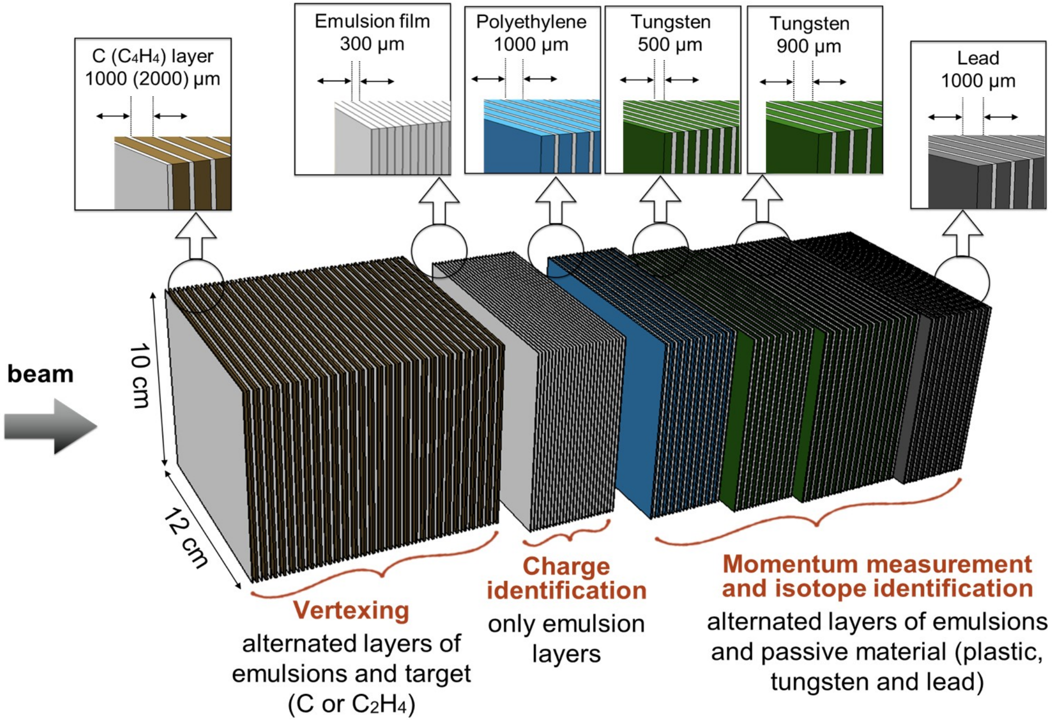
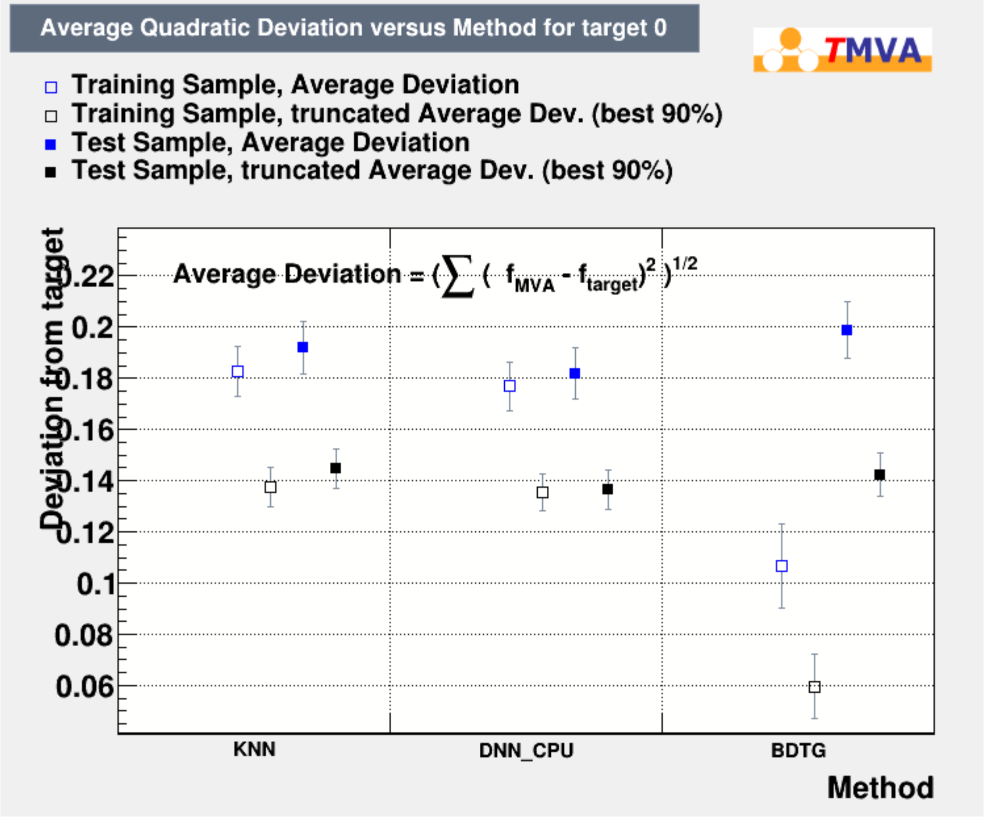
GSI configurations



TARGET \ BEAM	2019	
	Oxygen 200 MeV/n	Oxygen 400 MeV/n
Carbon	GSI1	GSI3
Polyethylene	GSI2	GSI4

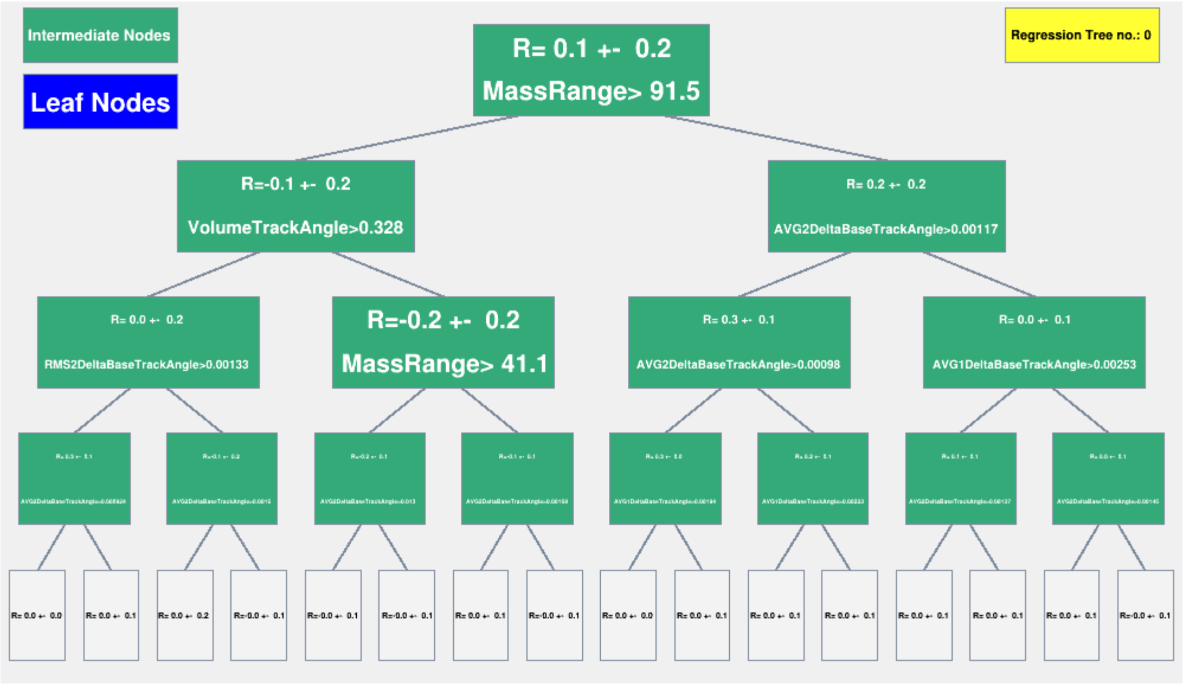
I will show, as an example, the results for the GSI3 configuration.

Multi-Variate analysis



A multivariate classifier is a class of "supervised learning" algorithms which makes use of training events, for which the desired output is known, to determine an approximation of the underlying functional behaviour defining the target value.
After many trials we choose to use the Boosted Decision Tree (BDT) algorithm.

Boosted Decision Tree (BDT)



BDT is a MVA machine learning method based on trees of binary choices taken on one single variable at a time until a stop criterion is fullfilled.

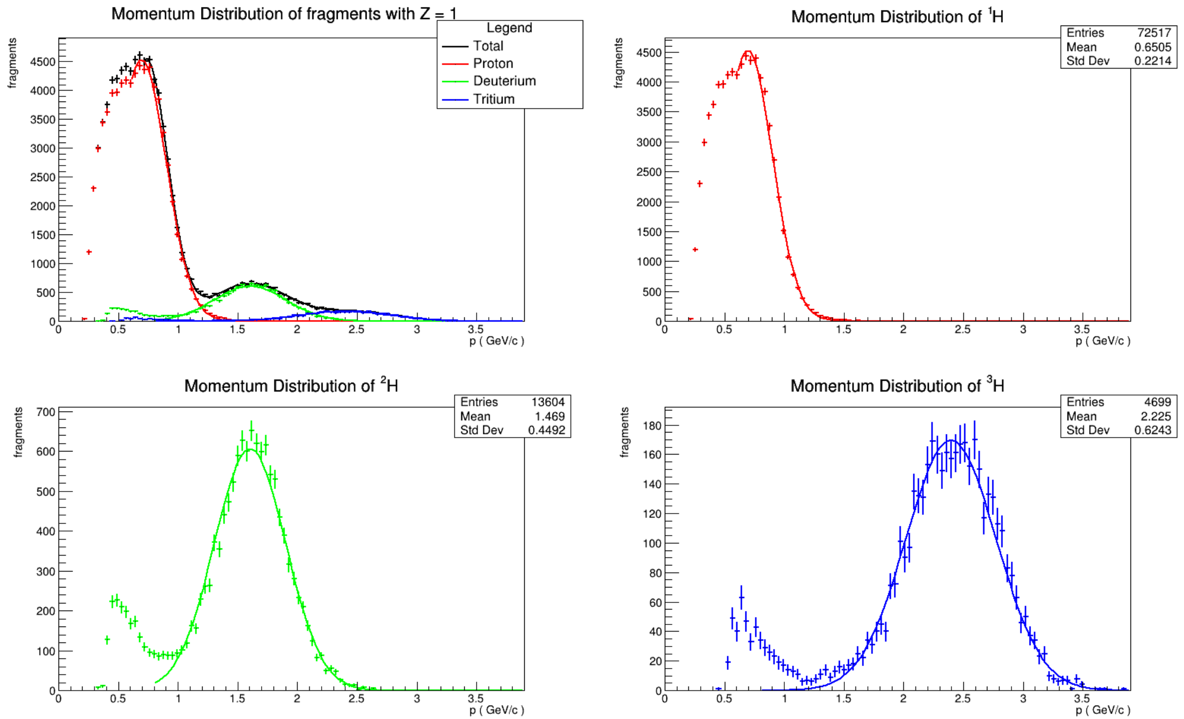
MC True and MC Reconstructed differences

I use the MC true data set to train the BDT algorithm, then I applied it to the data set of the MC reconstructed.

Reconstructed Monte Carlo differs from the true one cause of:

- 5mrad angular smearing;
- Background due to cosmic ray and random base tracks;
- Reconstruction efficiency ~90%;
- Misalignment between films (see Giuliana's talk).

MC true momentum distributions of H isotopes

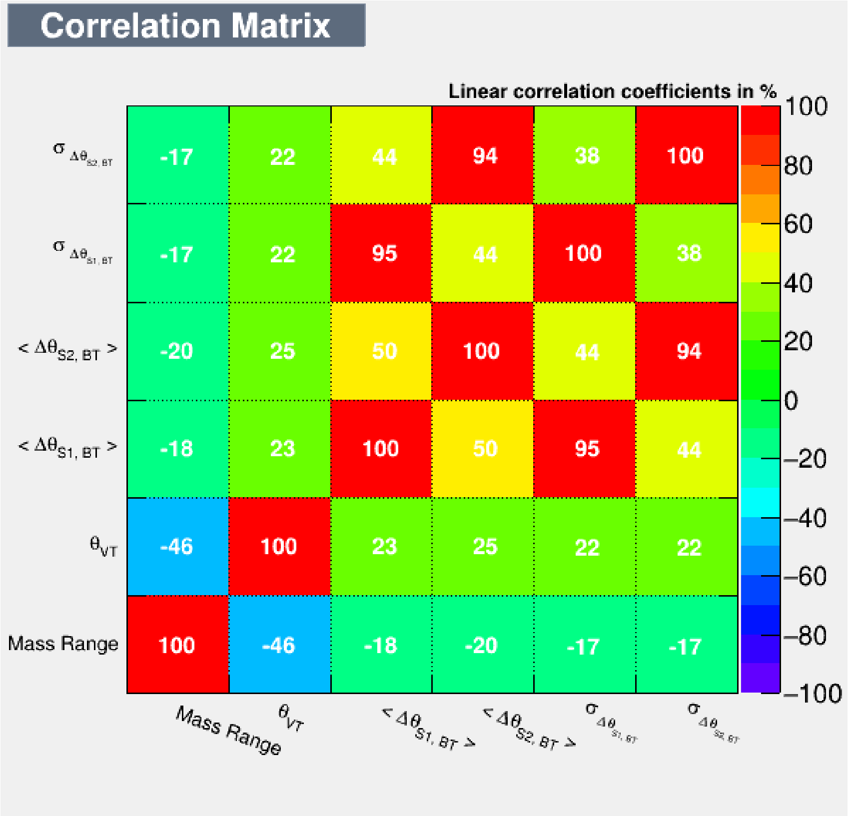


The momentum distribution has different shape for different isotopes.

The peaks of the distributions are at:

- 0.745 ± 0.001 GeV/c for ^{1}H;
- 1.606 ± 0.003 GeV/c for ^{2}H;
- 2.411 ± 0.007 GeV/c for ^{3}H.

Input features for BDT algorithm

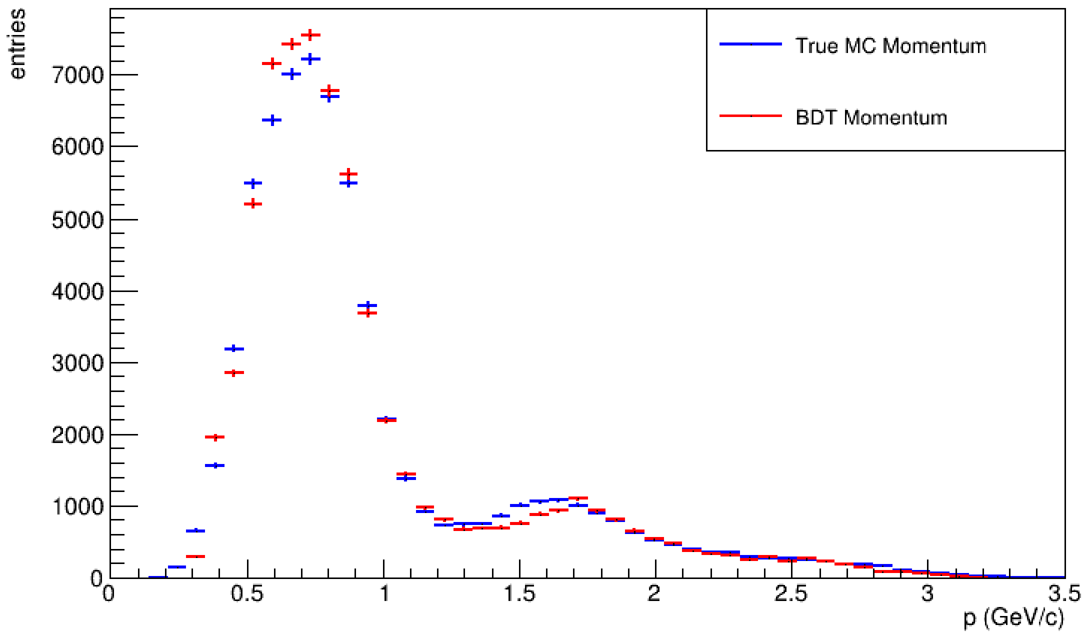


I trained a different algorithm for each charge value.

The input features of the BDT alghoritms are:

- Mass range;
- Emission angle of the volume tracks;
- Average differences between two different base tracks angles in the first and the second stack;
- The RMS of the angular differences between consecutive basetracks in the first and the second stack.

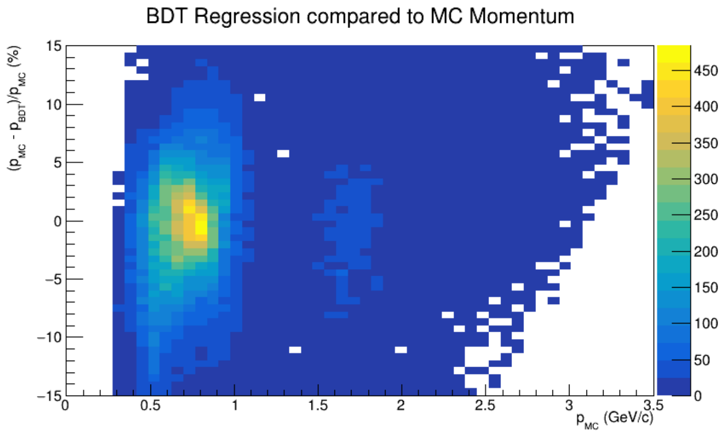
Accurancy of BDT algorithm for H isotopes



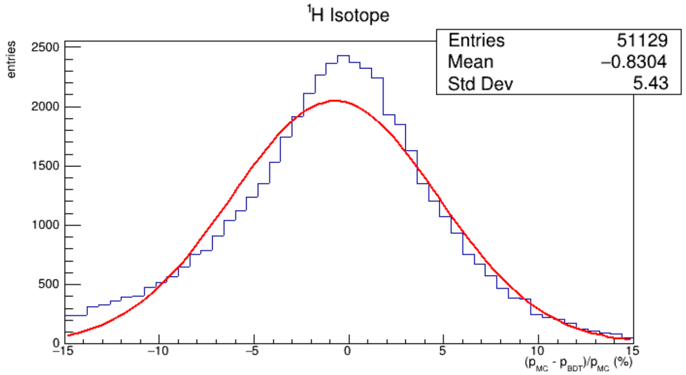
Number of events used: 65834.

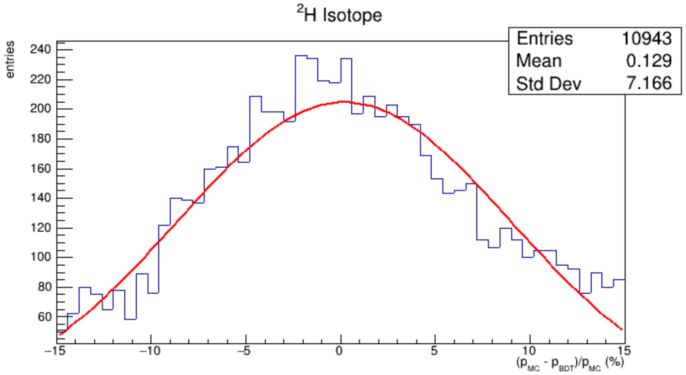
Momentum reconstructed with:

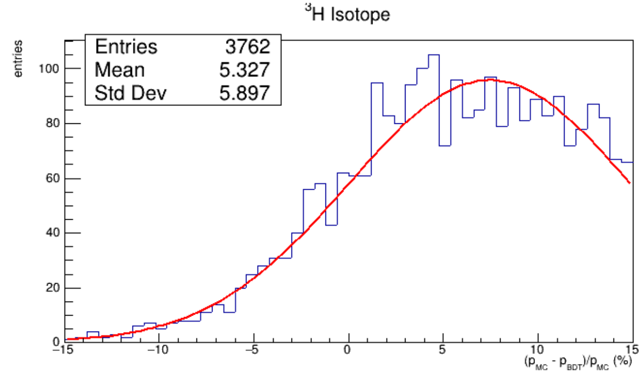
- 5% of error: 54%;
- 10% of error: 77%;
- 15% of error: 87%.



Accuracy for the H isotopes

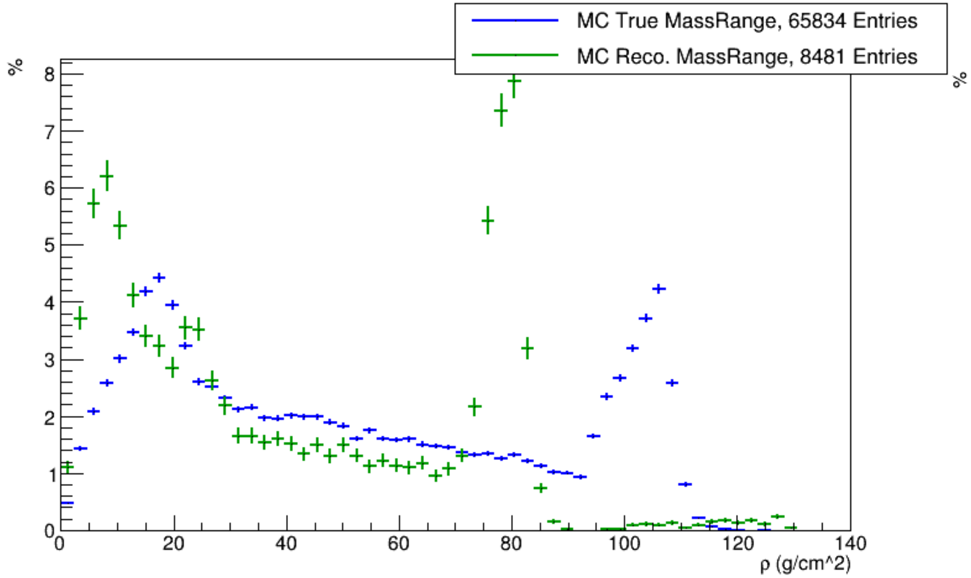


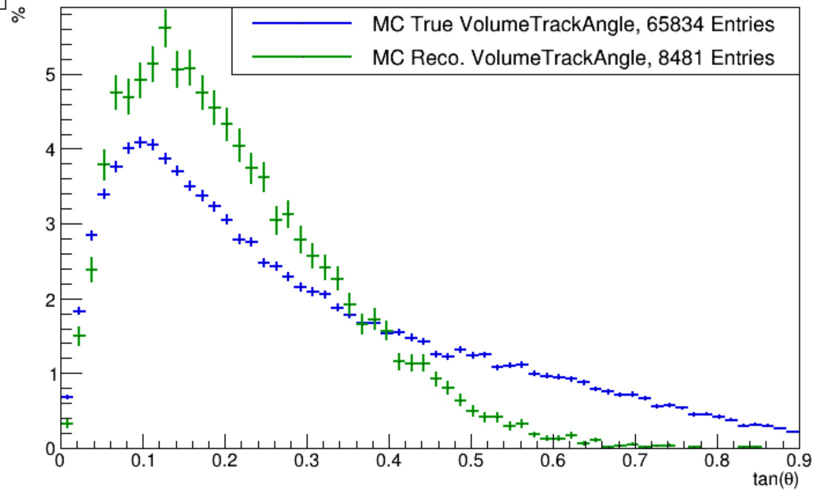




From the distributions of the deviation from the target value we notice that lighter fragments have an overestimated momentum while the heavier ones are underestimated.

MC true and MC reco: features of H isotopes

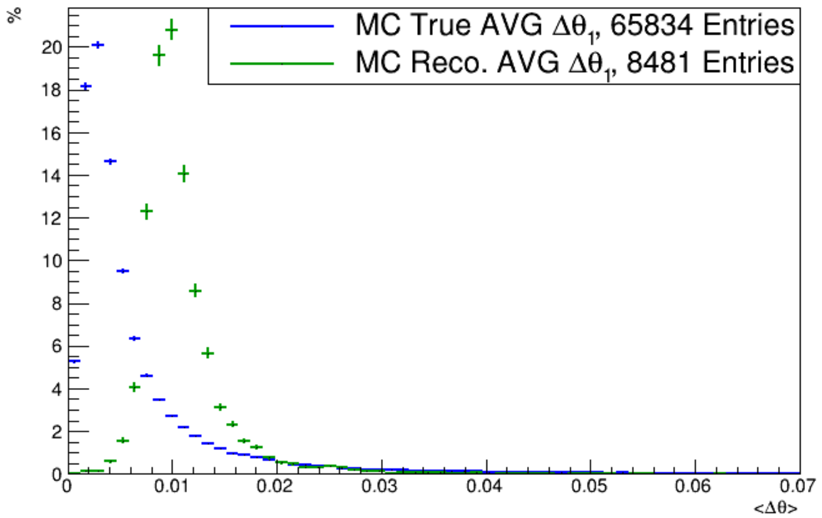


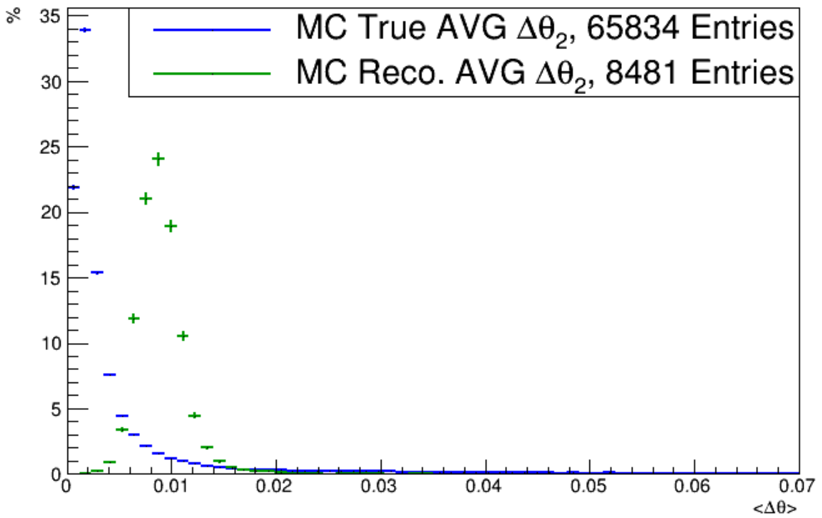


Plots are normalised.

In MC reco tracks are generally shorter than in MC true, as can be seen from the mass range comparison (plot on the left).
We hardly reconstruct tracks with tan(θ) > 0.5 (plot on the right).

Average angular difference between base tracks of H isotopes

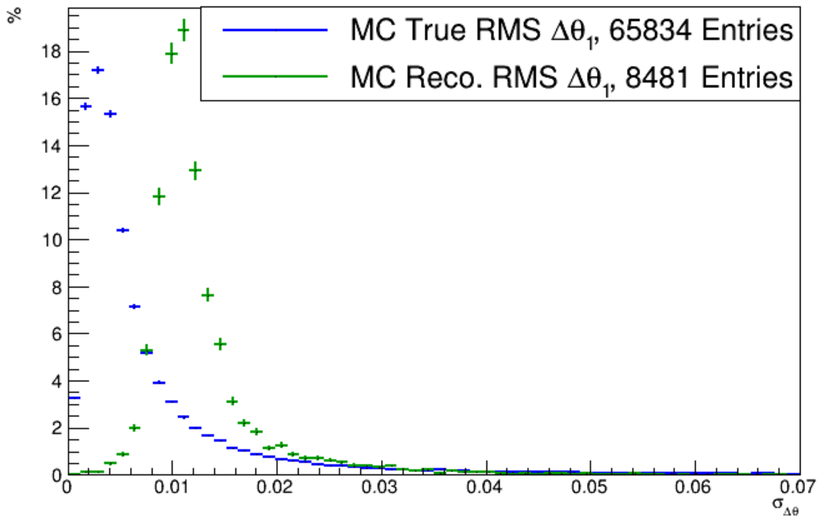


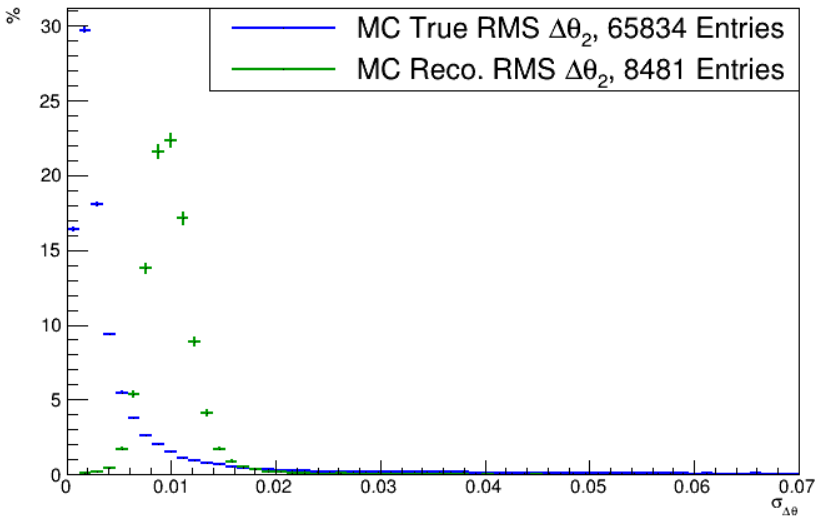


Plots are normalised.

The plot in the left represents the difference between the angles of two consecutive base tracks in the first stack that has emulsions spaced with 1 mm of C, while the plot in the right represents the same quantity in the second stack which is made only by emulsions. The shift seems to be related with the angular smearing applied, but it is still present if we don’t apply any smearing.

RMS of angular difference between base tracks of H isotopes



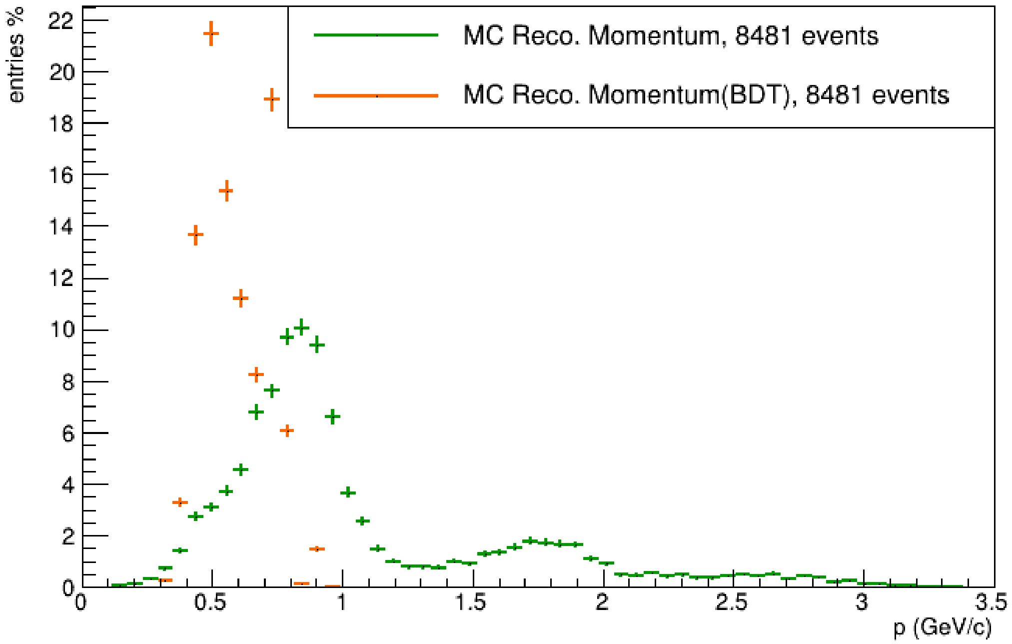


Plots are normalised.

The first plot represents the RMS of differences between the angles of two consecutive base tracks in the first stack that has emulsions spaced with 1 mm of C, while the second plot represents the same quantity in the second stack which is made only by emulsions. Same considerations as before applied.

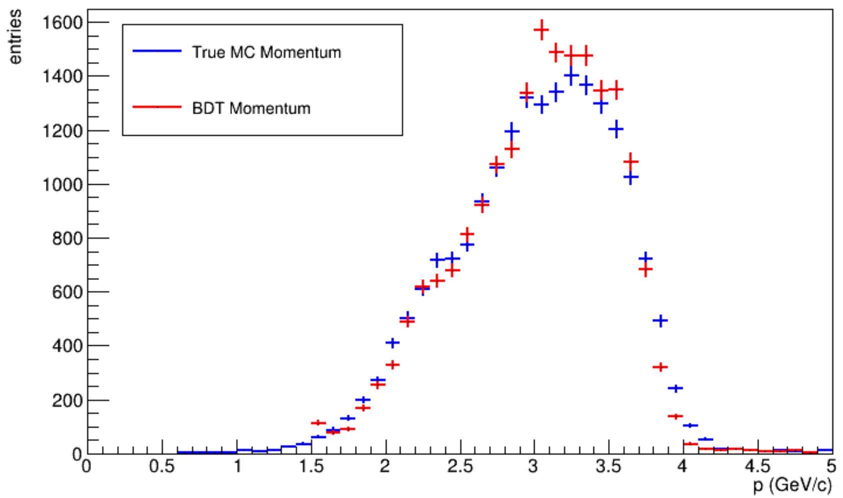
Application of trained BDT to MC reco

The momentum reconstructed by the BDT for MC reco is underestimated and the shape of the true distribution is not reproduced.



Plots are normalised.

Training BDT for fragments of He isotopes

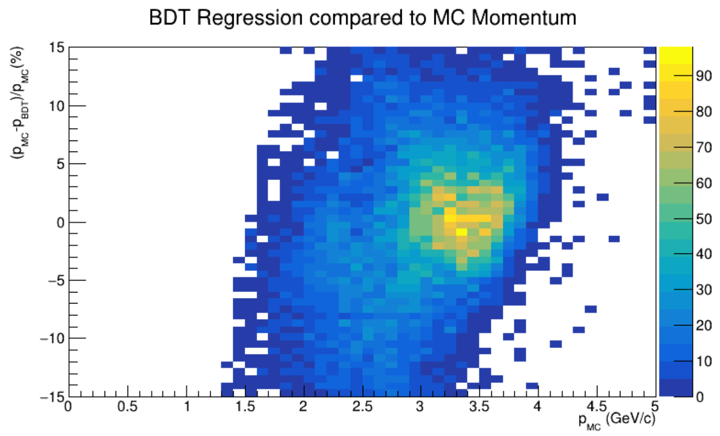


The procedure to evaluate the momentum of the fragments with Z = 2 follows the same steps that are shown previously.

Number of events used: 19775

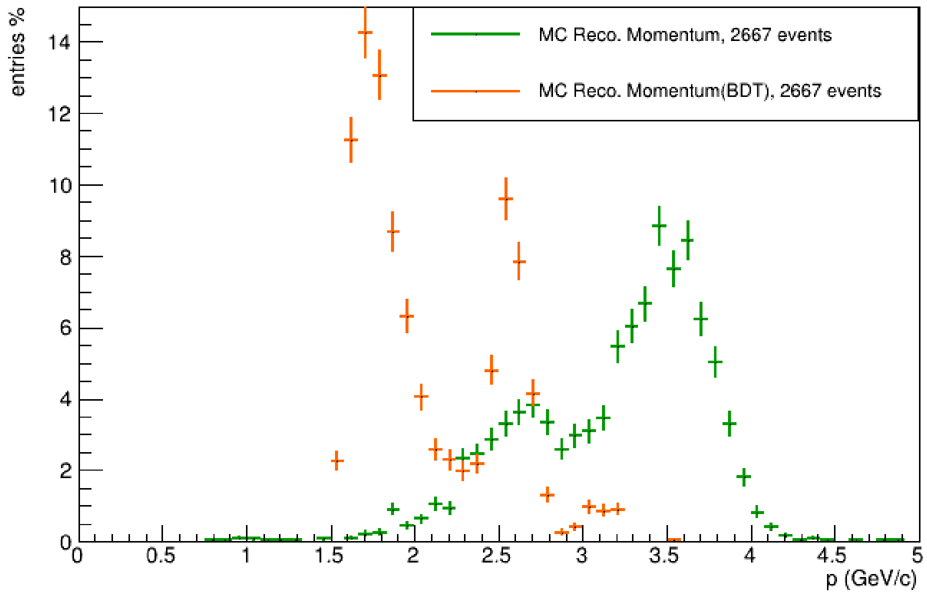
Momentum reconstructed with:

- 5% of error: 57%;
- 10% of error: 82%;
- 15% of error: 93%.



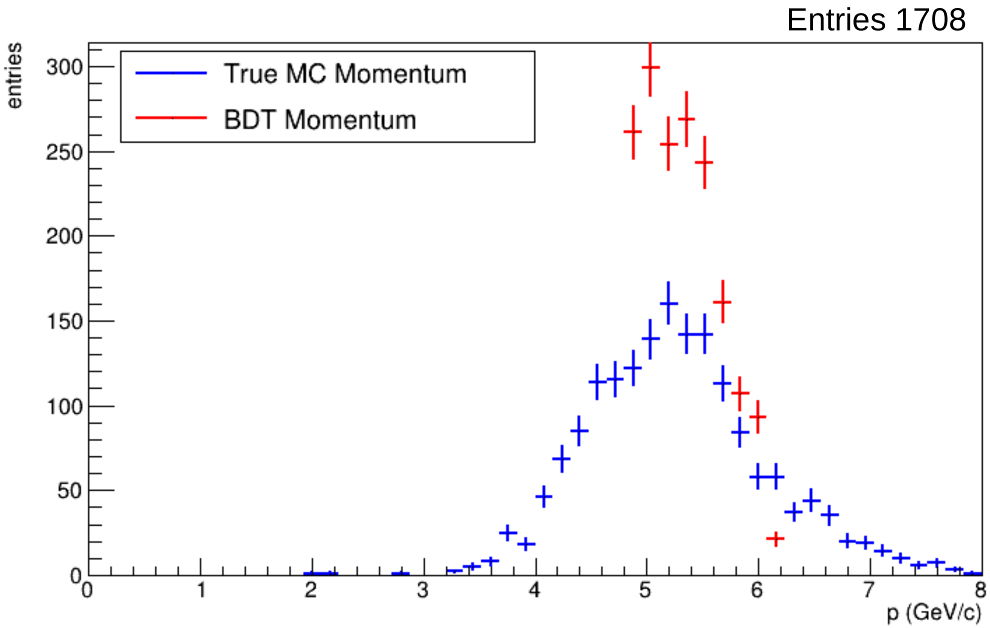
Application fo BDT to the MC reconstructed

Also with the He isotopes there is an underestimation of the momentum due to the different distributions of the input features from the Monte Carlo true.



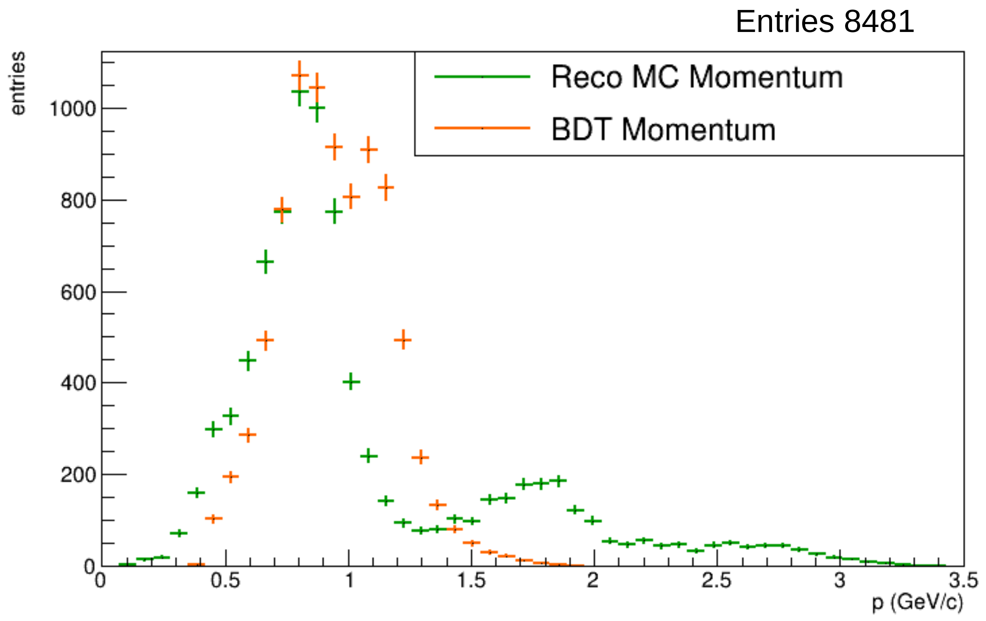
Plots are normalised.

Training BDT with MC true Li isotopes



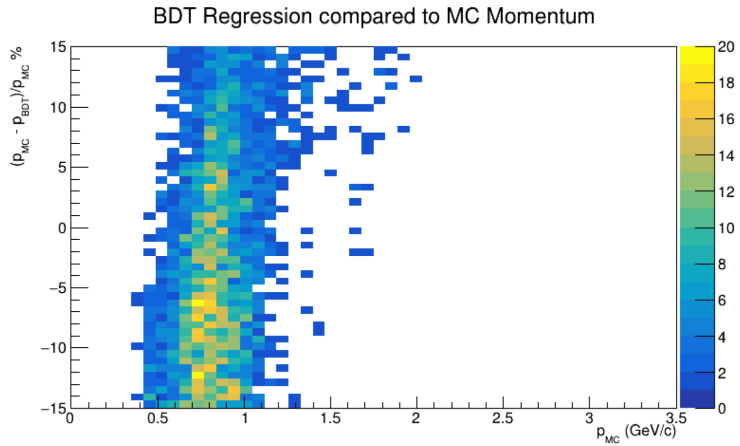
In this case even the MC true has a poor number of entries and the reconstruction of the fragments' momentum is not accurate as it need to be, so more statistic is needed.

Training BDT with MC reco H isotopes

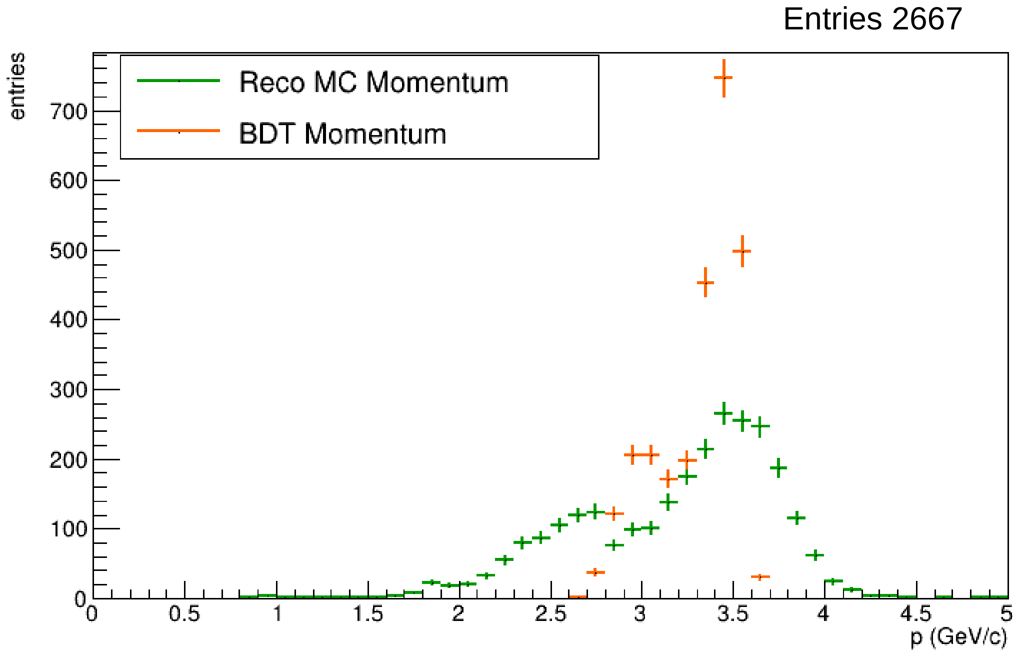


The reason why the momentum is not well reconstructed lies in the different shape of input variables.

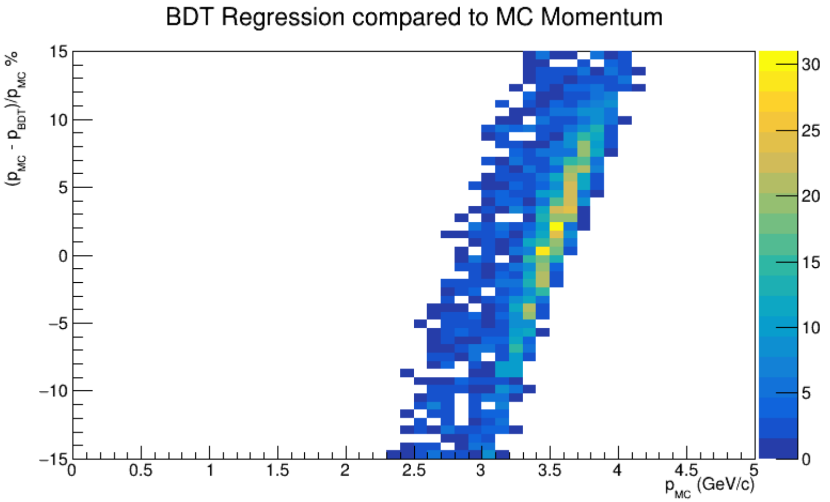
For this reason I tried to use MC reco to train a new BDT algorithm for the H isotopes.



Training BDT with MC reco He isotopes



BDT algorithms trained with MC reco need more statistics in order to reach a better performance.

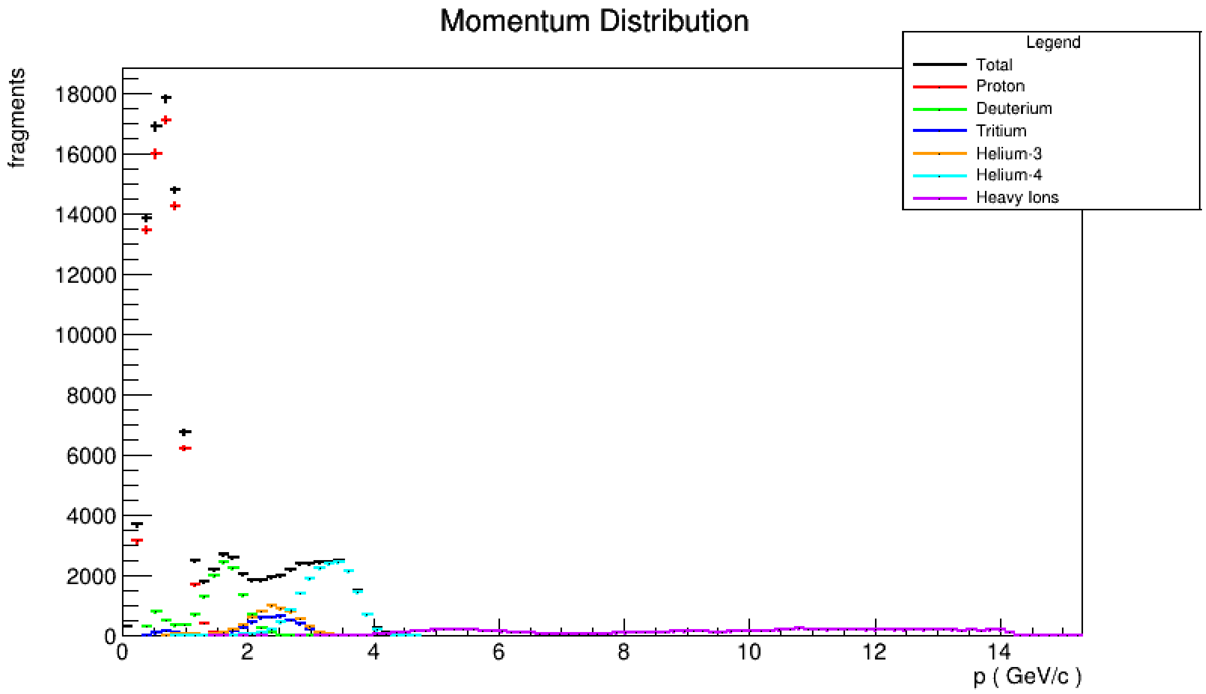


Conclusions

- Fragments' momentum can be evaluated through multivariate analysis
- Several algorithms have been tried: the one giving the best results is the Boosted Decision Tree (BDT)
- The algorithm is based on input variables regarding mass range, emission angle, average difference and its RMS of consecutive basetracks
- When trained and applied on MC true the algorithm gives good results (less than 5% of error in 54% of cases)
- Problems when the algorithm is applied on MC reco because of different shape of input variables: studies on-going to understand which strategy can be applied -> First trial training BDT on MC Reco: to be checked with more statistics...

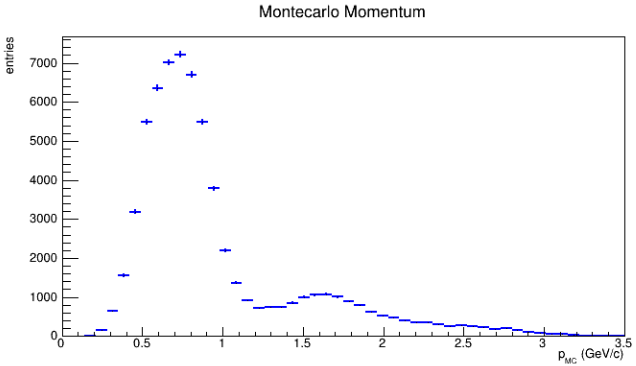
Back-up Slides

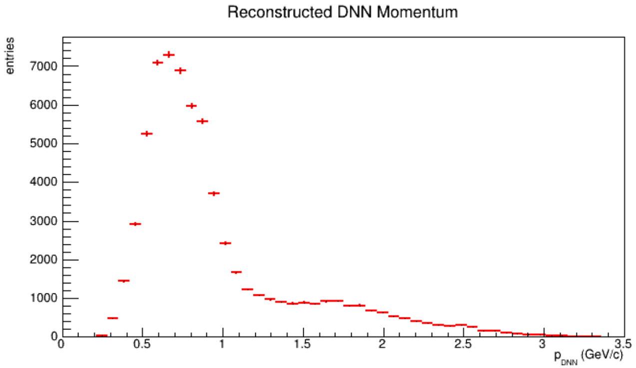
Features distributions of GSI3

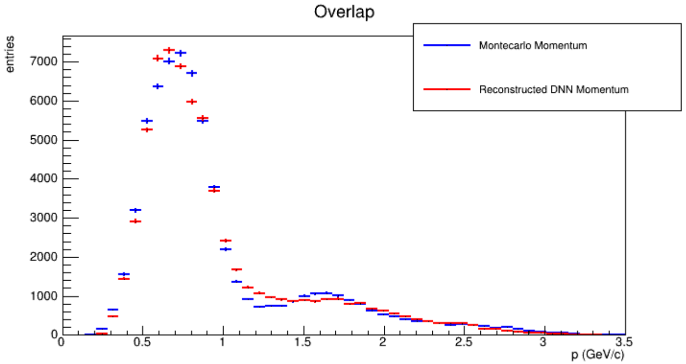


The distributions of the main features used by the TMVA algorithms were studied for fragments of Z equals to 1, 2 and 3.

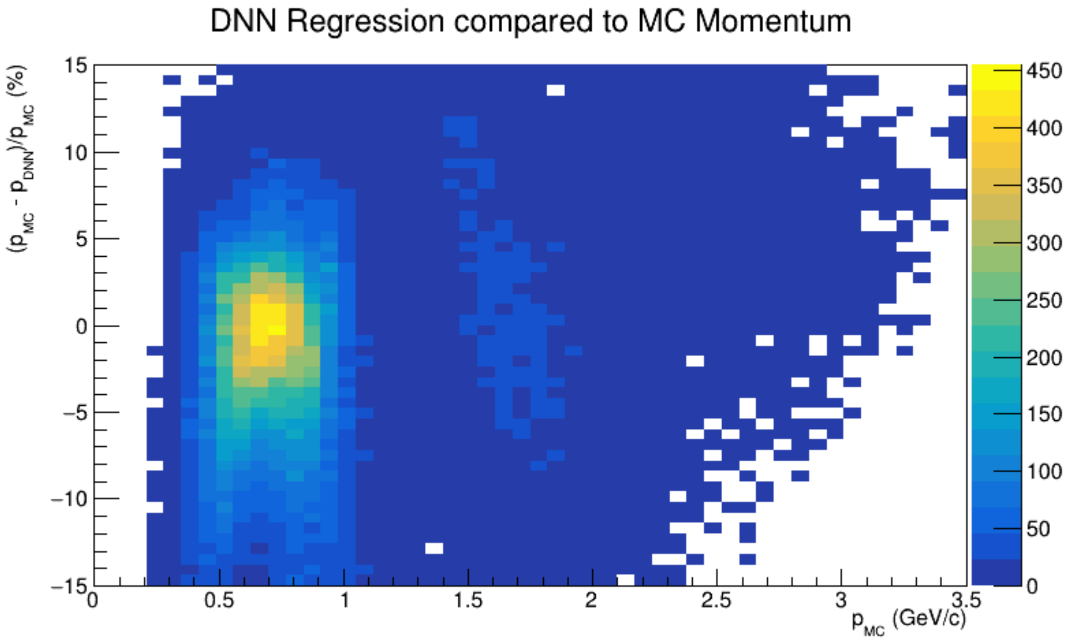
Momentum distribution comparison of DNN algorhitm







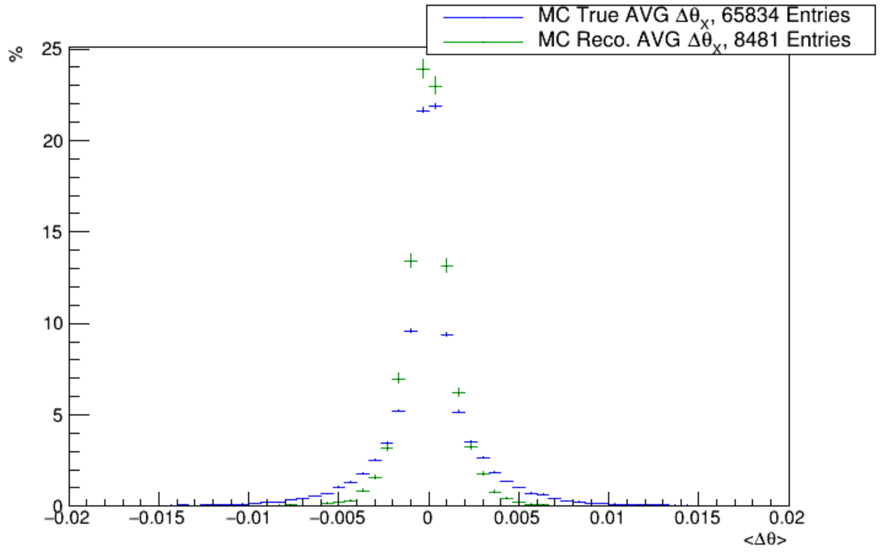
Accurancy of the DNN algorhitm

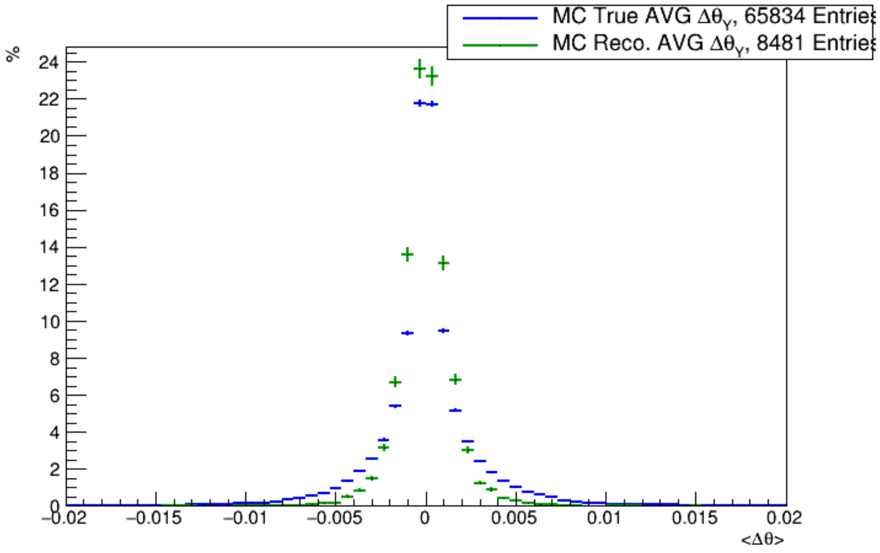


Analizing 65834 events:

- Entries which are correctly defined whitin the 5% of error: 53.530%;
- Entries which are correctly defined whitin the 10% of error: 76.293 %;
- Entries which are correctly defined whitin the 15% of error: 86.922 %.

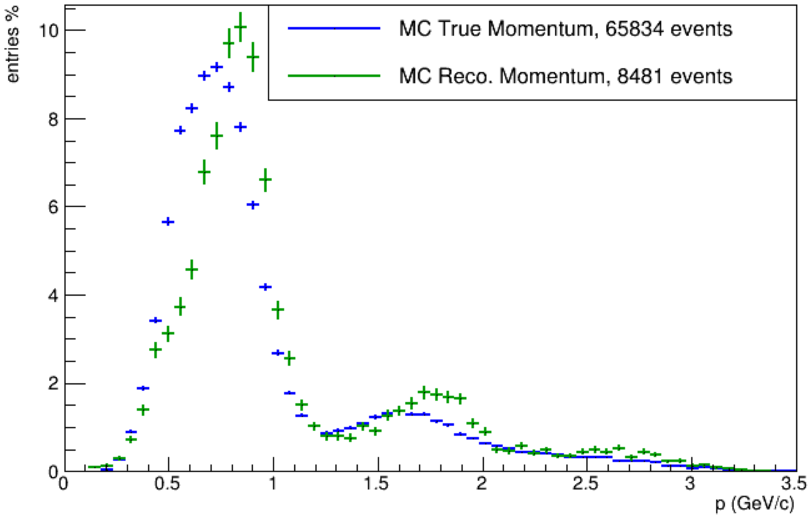
Projected difference in angles for H isotopes

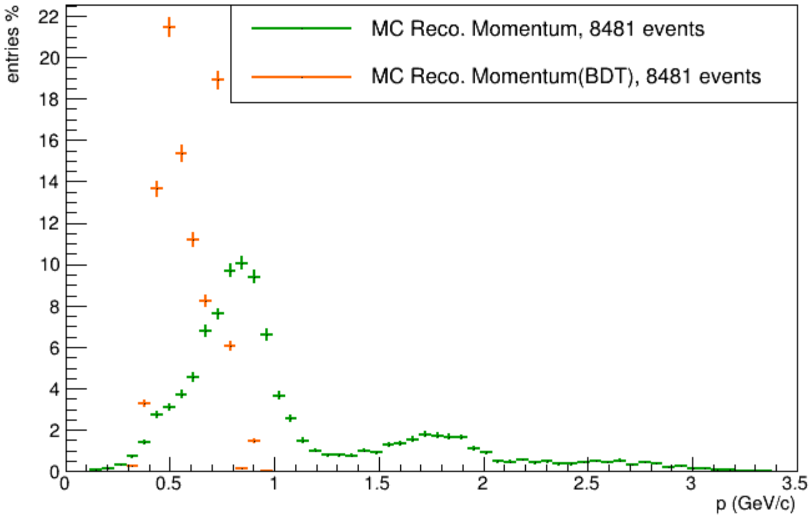




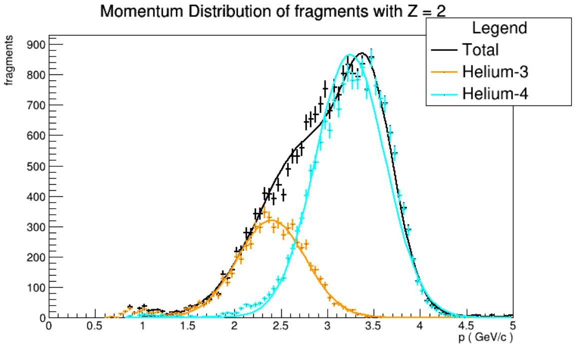
These plots represent the difference in the average difference in the angles of two consecutive base tracks along all the volume track

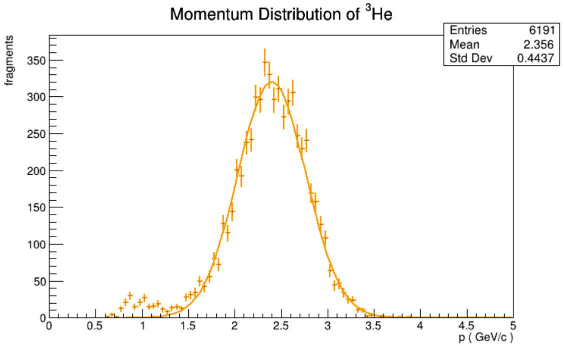
MC true and MC reco momentum

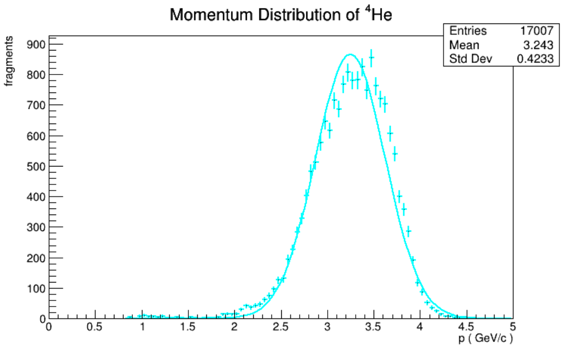




MC true momentum distributions of He isotopes





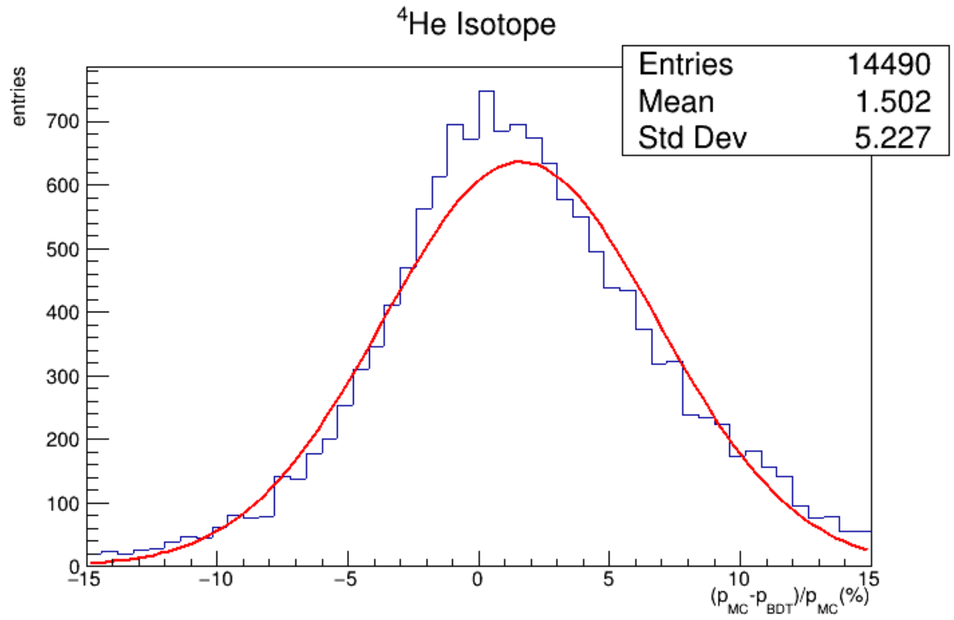


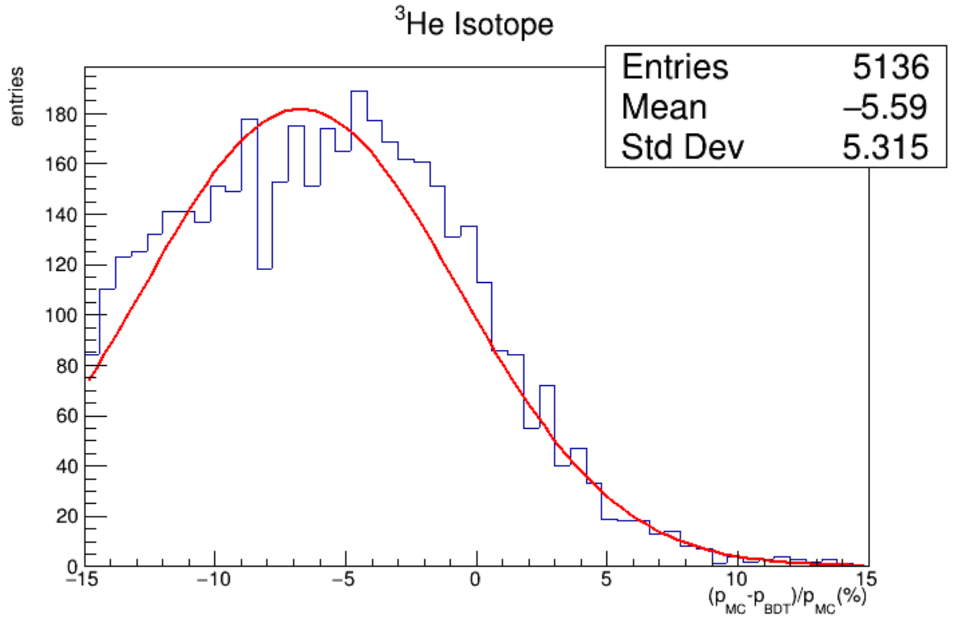
The momentum distribution has different shape for different isotopes.

The peaks of the distributions are at:

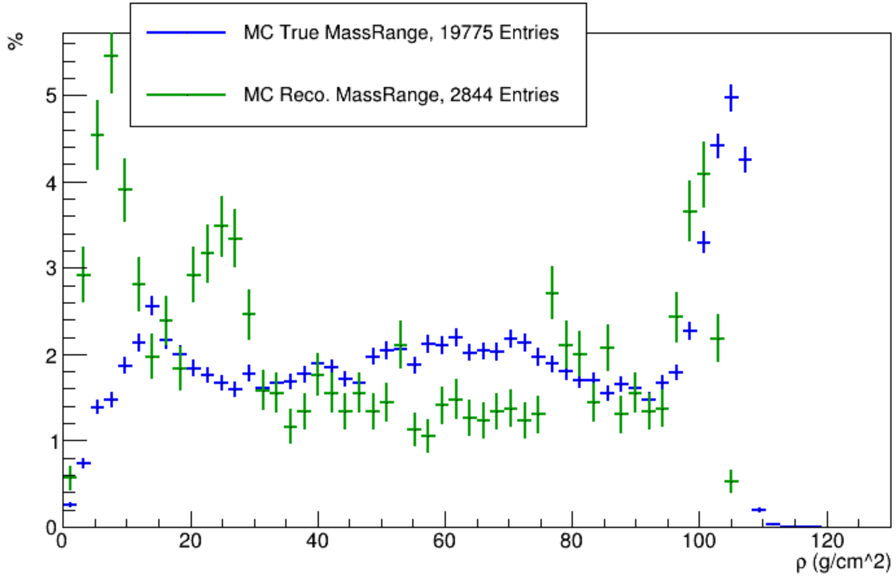
- 2.401 ± 0.005 GeV/c for ^{3}He;
- 3.250 ± 0.003 GeV/c for ^{4}He.

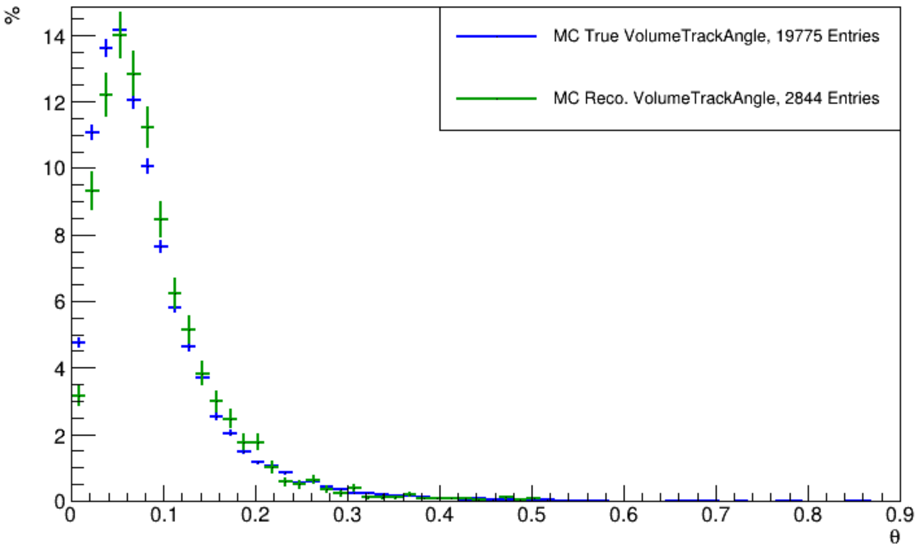
Projection of BDT accurancy for He



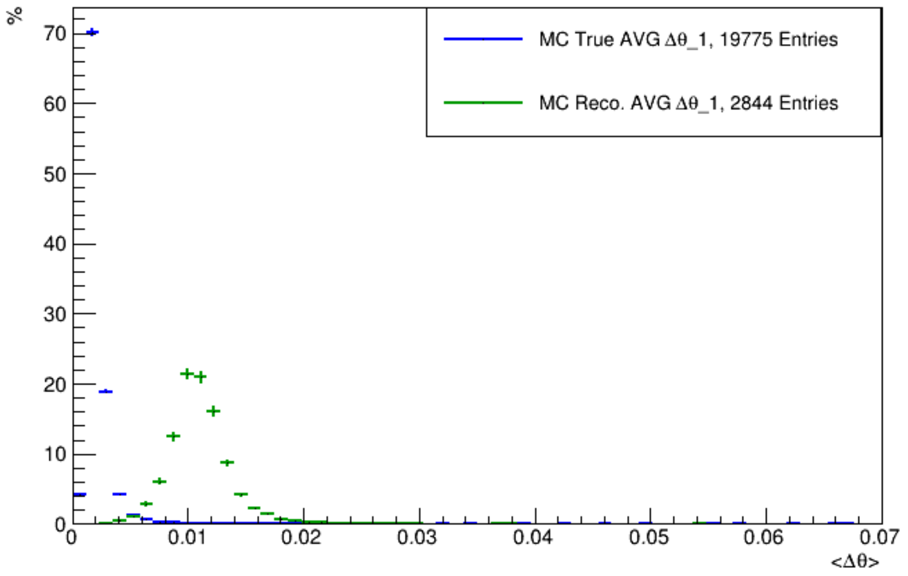


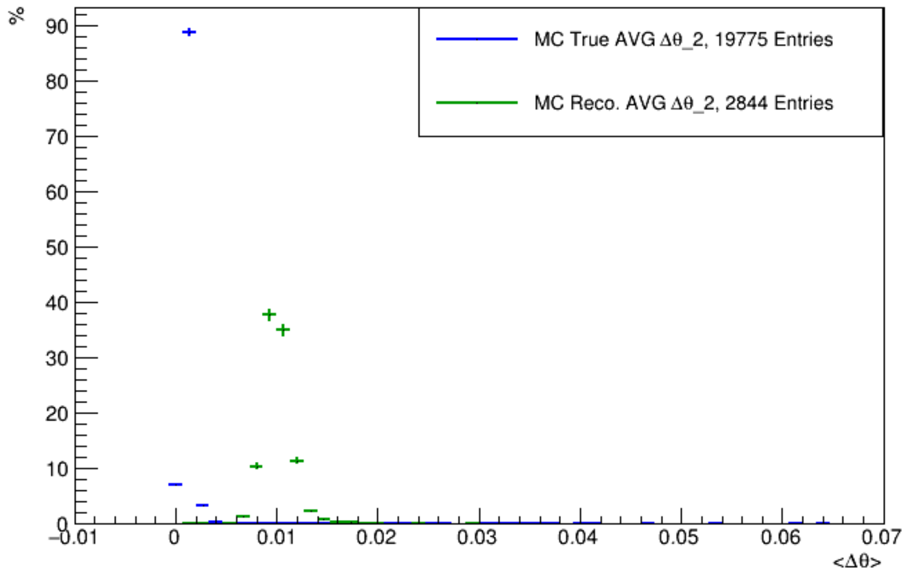
Comparing MC true and MC reco features of He isotopes





Average angular difference between base tracks of He





RMS of angular difference between base tracks of He