Study of Attenuation Length with TMS MC Production

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Introduction

The experimental setup with scintillator bars similar to TMS is taking data in LSU. The motivation of this study is to compare the attenuation length obtained from MC to the expt. data

Light yield refers to the amount of light (photons) produced by a scintillator when it interacts with ionizing radiation.

Attenuation length is the distance over which light intensity is reduced to *1/e* of its original value due to absorption or scattering within a material.

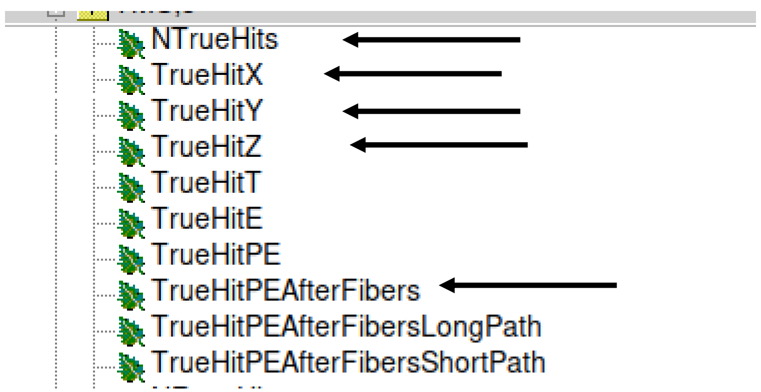
To estimate the attenuation length, we need number of photo electron detected by the readout as a function of distance from the readout.

For this study, the MC files in the directory /pnfs/dune/persistent/users/kleykamp/nd_production/2024-05-13_lar_only_rhc/tmsreadout have been used.

The simulation set up: antineutrino flux hit on ND LAr to produce muons, along with other hadrons. The muons travel to TMS (along with hadrons). These muons should be used for atten. length study.

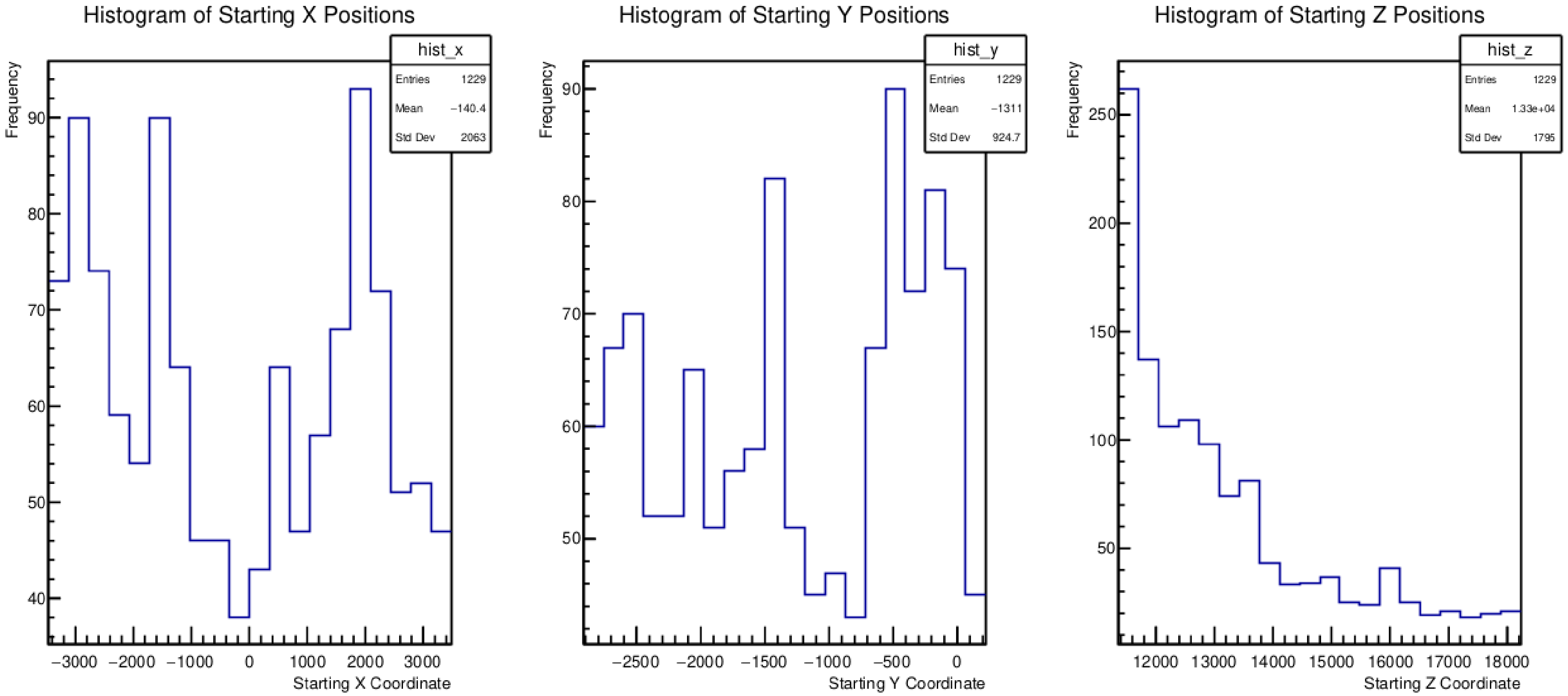
Plan of the Study

- In the MC data, for a non-zero NTrueHits, there can be a muon track and hadronic interactions. It is important to identify the clear muon track.
- To identify the muon track, few cuts and conditions on TrueHitX and TrueHitZ necessary to implement; Z-being the beam direction.
- Once the muon track is identified, obtain the TrueHitPEAfterFibers and TrueHitY for hits corresponding to the muon track, Y being the readout axis.
- Fit the TrueHitPEAfterFibers vs TrueHitY with an exponential function to obtain the atten. length of the fibers.
- Compare with experimental data obtained with cosmics and TMS candidate scintillators.



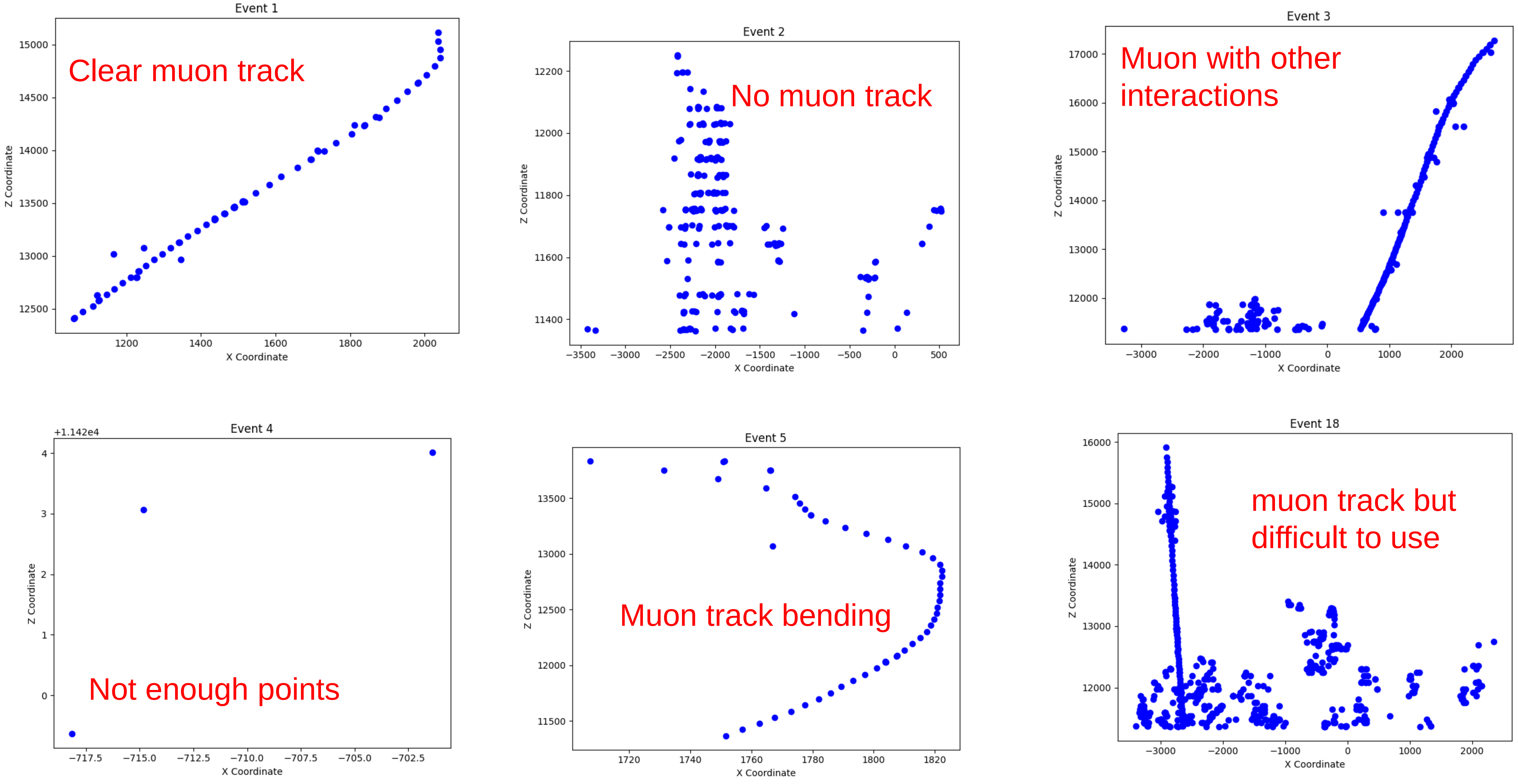
Relevant branches in the MC file for the study, shown by arrow

Selecting the Muon Tracks



Starting position at Z-axis is mostly before 14m; the dimension of TMS ≈12-18 m, can apply additional dZ cut ≈14m

X-axis: left/right, Y-axis: up/down (readout axis), Z-axis: beam direction.


Event 1
Clear muon track
Z Coordinate
X Coordinate
Event 2
No muon track
Z Coordinate
X Coordinate
Event 3
Muon with other interactions
Z Coordinate
X Coordinate
Event 4
+1.142e4
Not enough points
Z Coordinate
X Coordinate
Event 5
Muon track bending
Z Coordinate
X Coordinate
Event 18
muon track but difficult to use
Z Coordinate
X Coordinate

Selecting the Muon Tracks

Following cuts, conditions, and clean up algorithms are implemented to get a clear muon track:

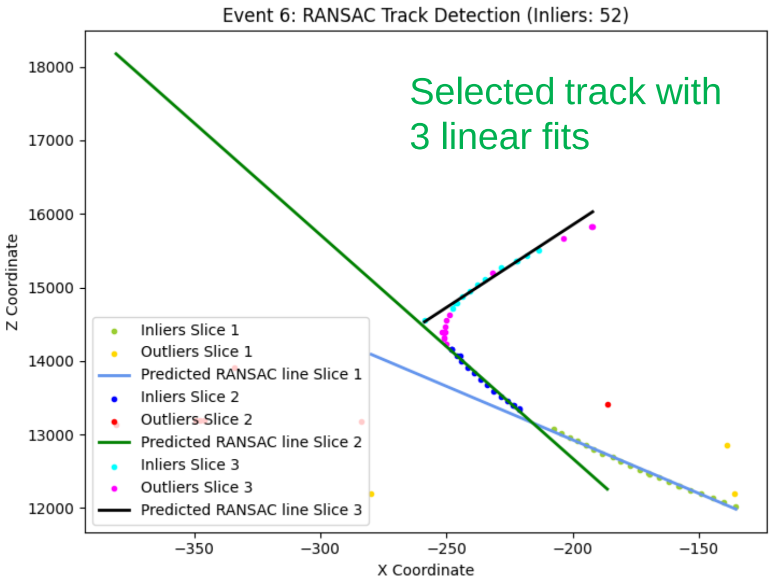
- Z>12000, dZ > 2000 , dX < dZ
  Logic: TMS starts from 12m, track length for muon should be more than 2m, muon should travel more along the beam-direction

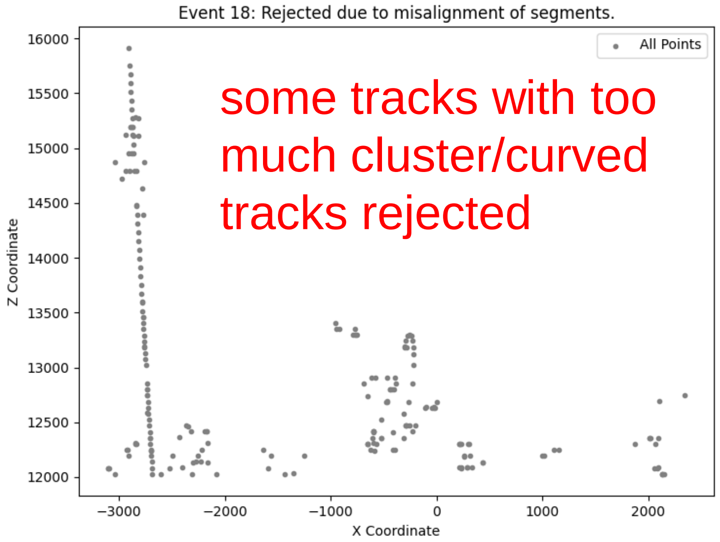
- Identify and clean up the extra clusters corresponding to hadronic interaction for better fitting

- Slice data into three segments

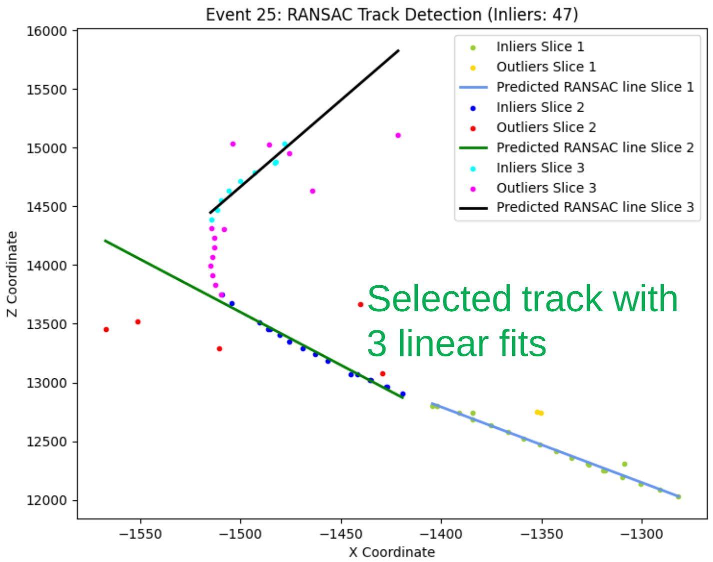
- Employ a three segment linear fit. A more dynamic fitting with unconstrained number of segments might be possible.

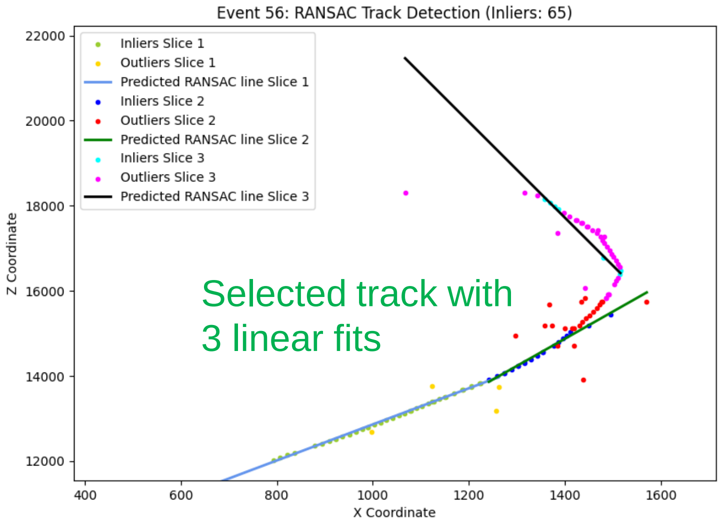
- Check the alignment of the slopes of linear segments. Reject an event if any two adjacent slopes differ by more than 20 or have a ratio greater than 3. This condition can be more dynamic.





The first inliers (points that can be fitted to a line) were used for atten. length estimation (a conservative approach)





Some events with muon tracks were rejected because of the conditions implemented and too many surrounding clusters

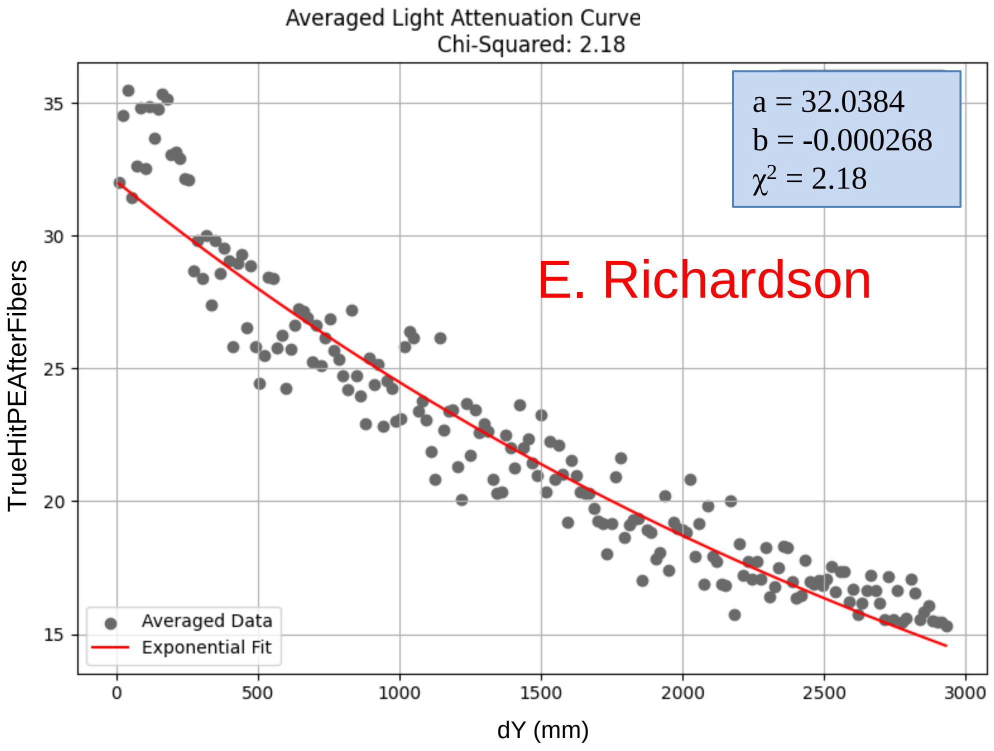
But the quantity of track hits was good enough even after conservative approach to conduct the study (≈5000 points)

Fitting for Attenuation Length

TrueHitPEAfterFibers and TrueHitY corresponding to the first inliers points for each selected muon track has been obtained.

The curve for average TrueHitPEAfterFibers as a function of distance between hit and readout (dY) has been fitted with: $f(y) = A * \exp(by)$

For this study, five MC files have been used. More data may reduce the scattering and uncertainty of fit



Attenuation length $\lambda = 1/b = 3.72 \pm 0.83$ m (uncertainty due to fitting taken into account)

TMS MC config file value:

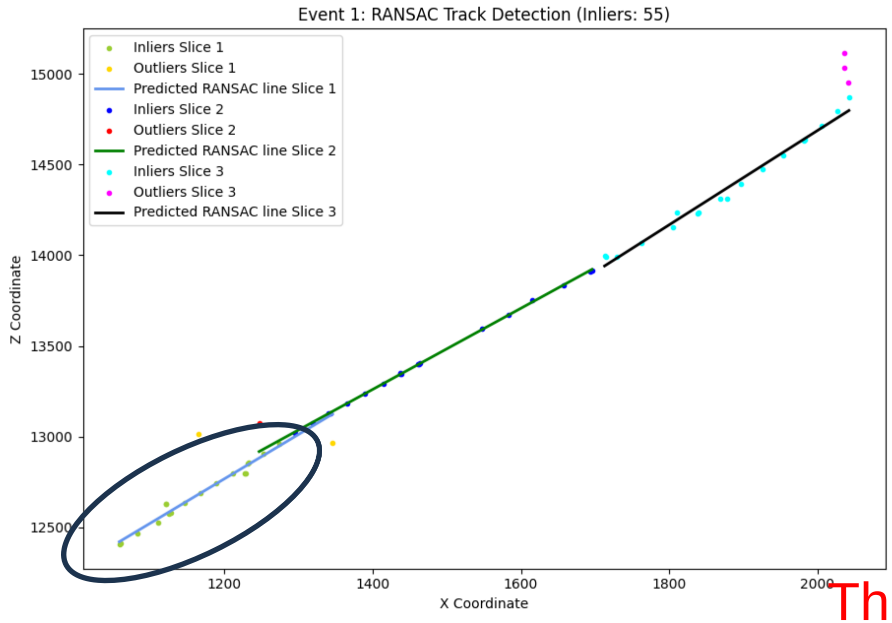
dune-tms / config / TMS_Readout_Default_Config.toml

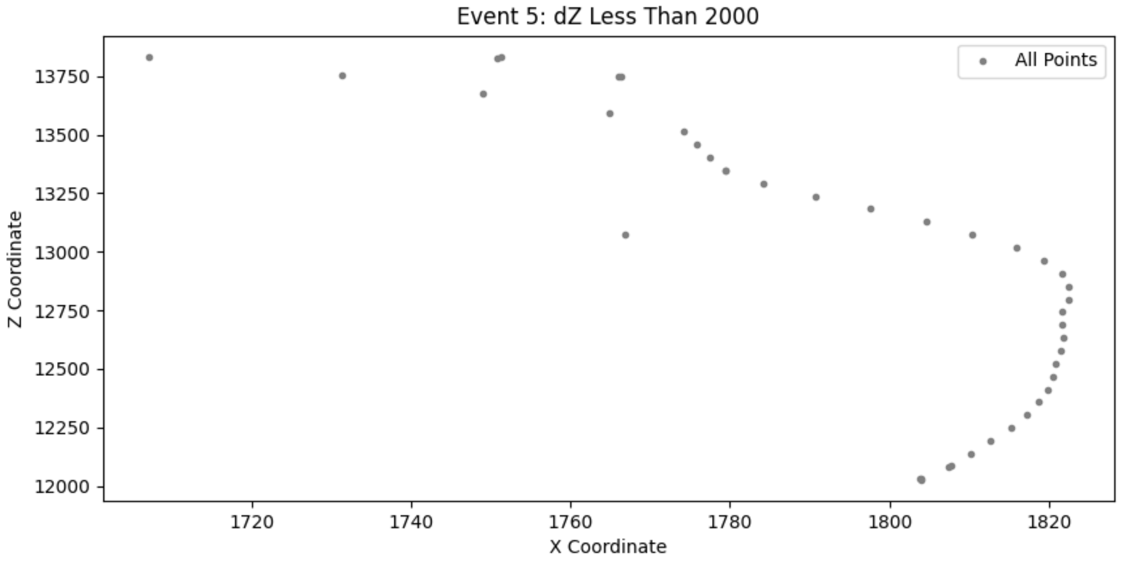
```
ShouldSimulateFiberLengths = true
WSFAttenuationLength = 4.160 # m
WSFLengthMultiplier = 1.8 # Light doesn't travel straight through the fiber
WSFEndReflectionEff = 0.95
```

Summary

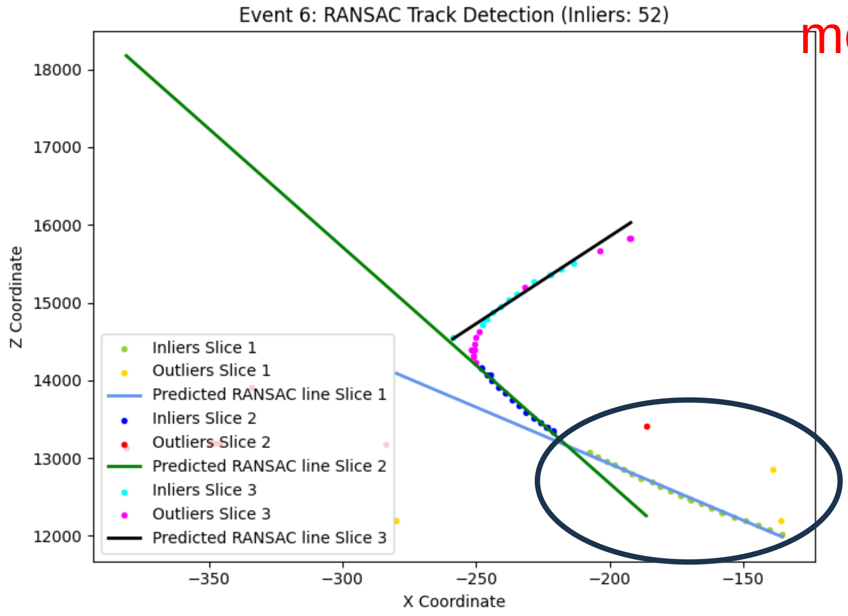
- The truth TMS MC data has been used to extract the attenuation length of the fibers.
- As the MC consist of muon track with hadronic interactions, it was necessary to distinguish the muon tracks that can be used for further analysis.
- Different cuts have been applied to obtain the muon tracks. The muon tracks have been used to get the atten. length 3.72 ± 0.83 m.
- Experimental setup at LSU has been taking data and preliminary results have been obtained. Improvements to setup are being implemented before data taking resumes. The MC atten. length needs to be compared with expt. data with cosmics.

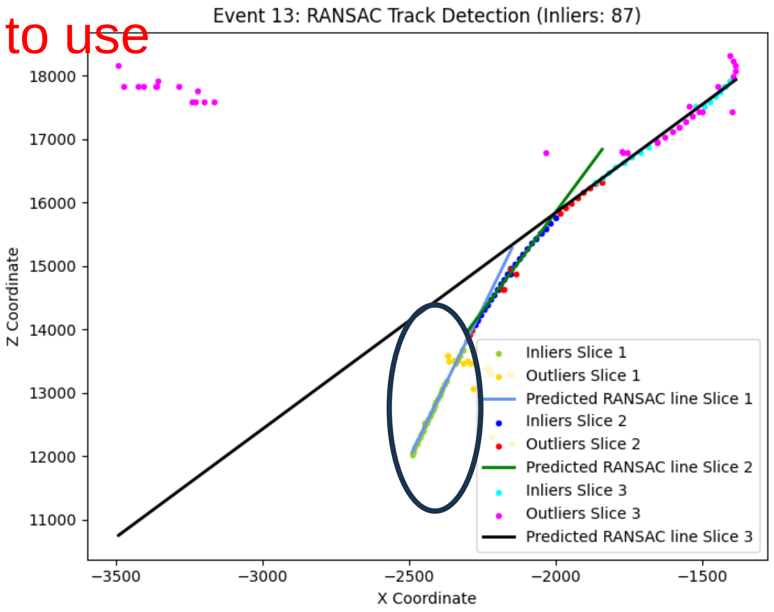
BACKUP SLIDES

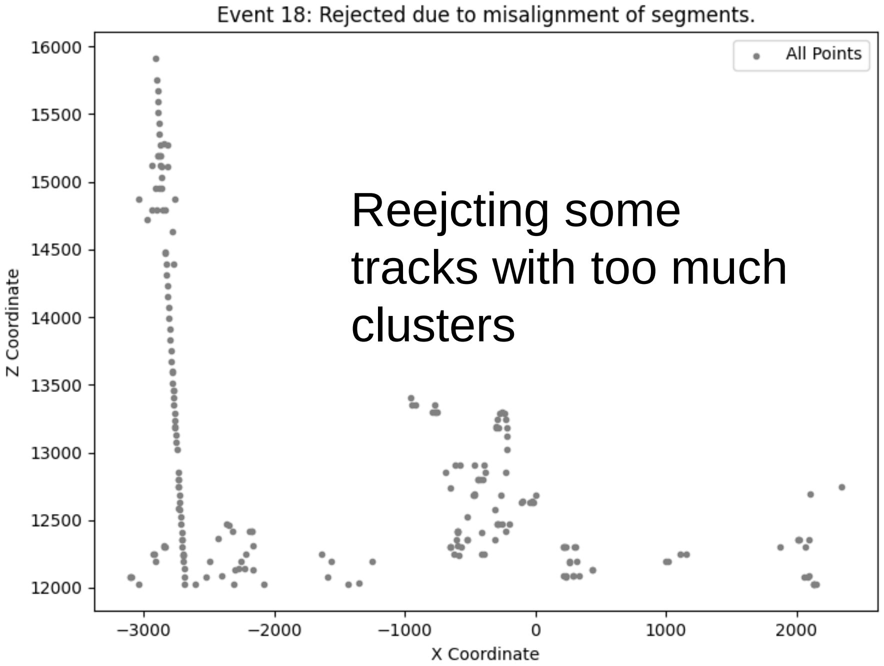




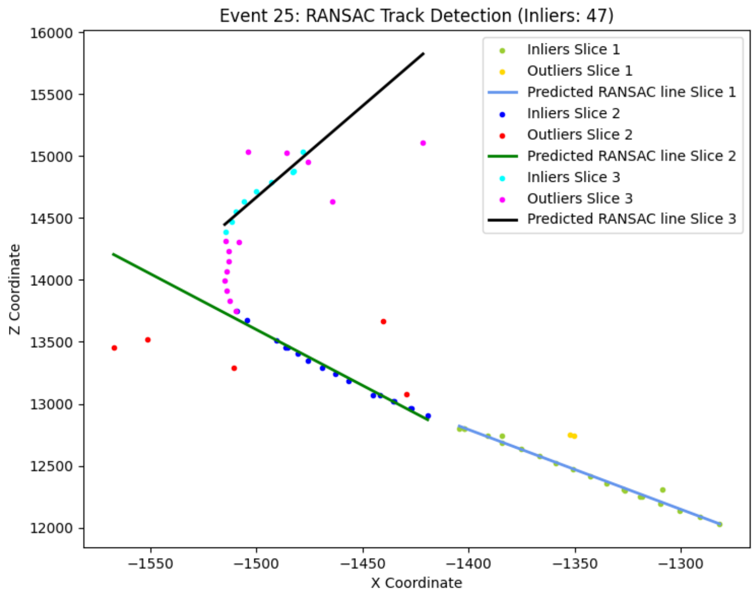
The first inliers are most accurate to use

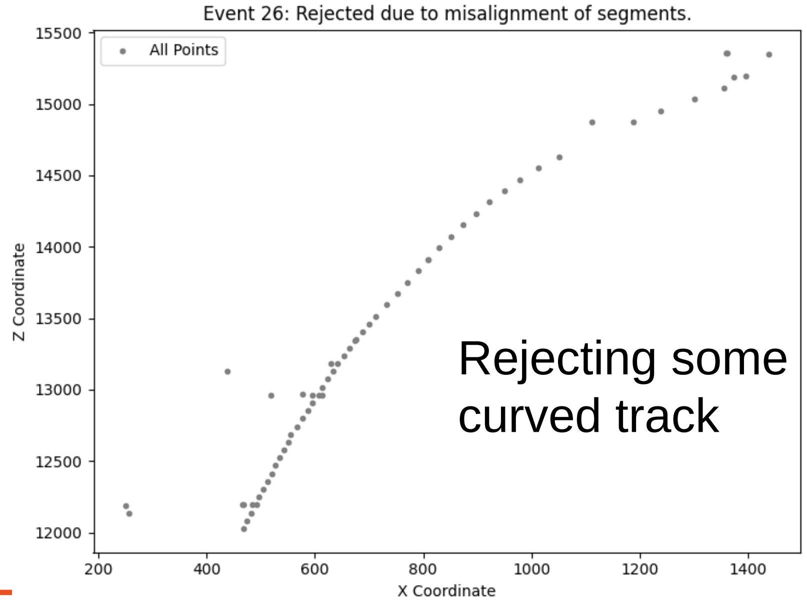




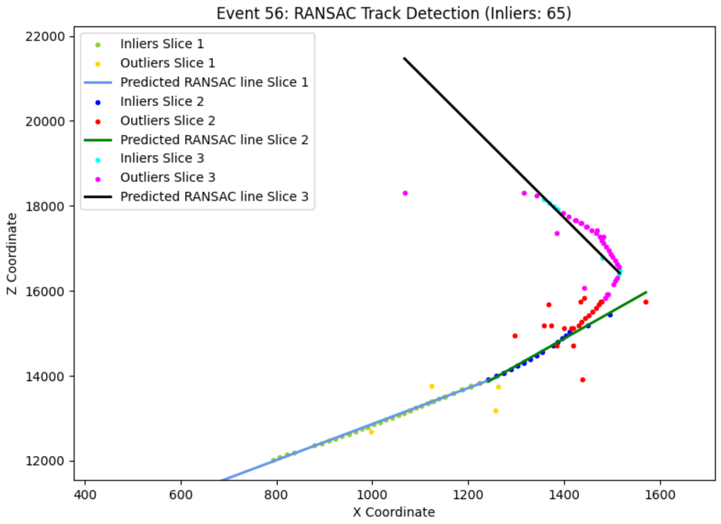


Reejcting some tracks with too much clusters

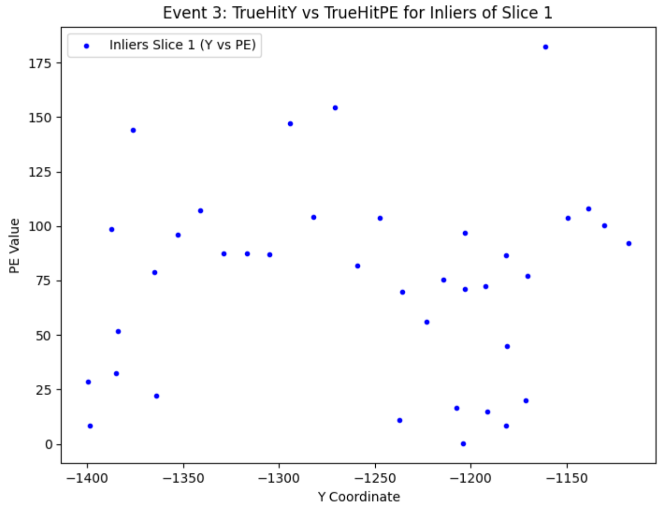


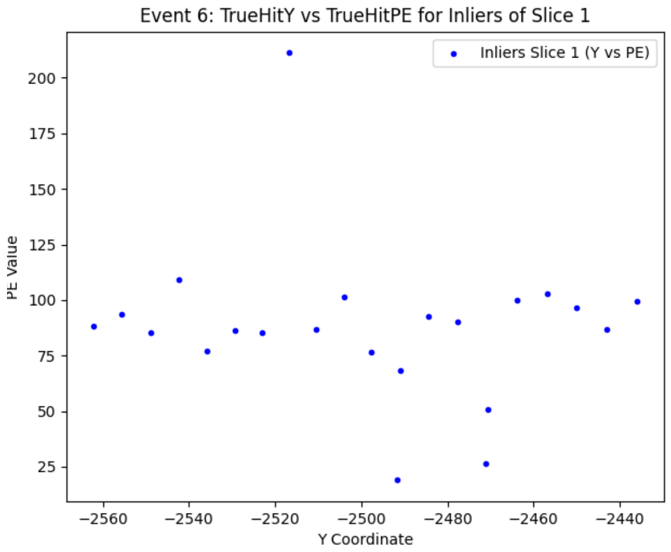


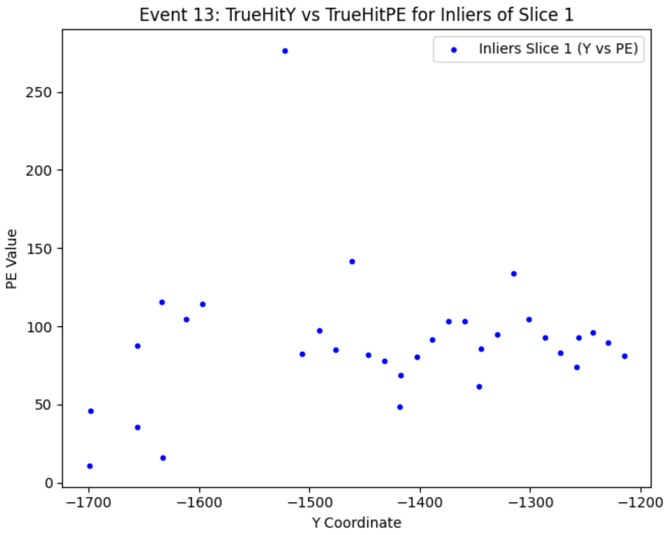
Rejecting some curved track



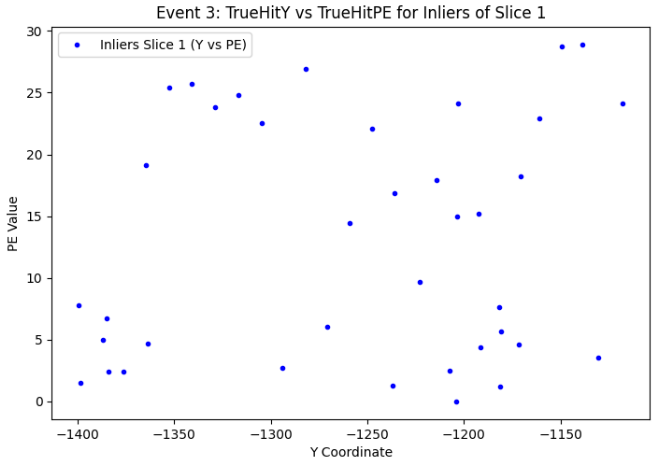
TrueHitPE (not after fibers) vs Y plots for selected tracks first inliers

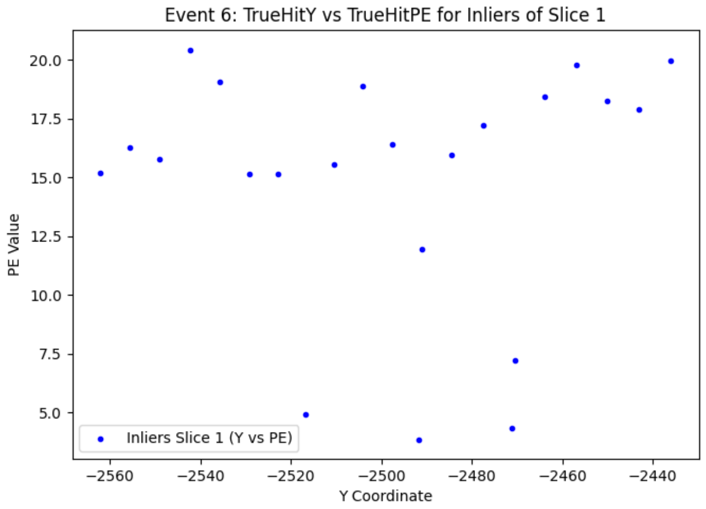


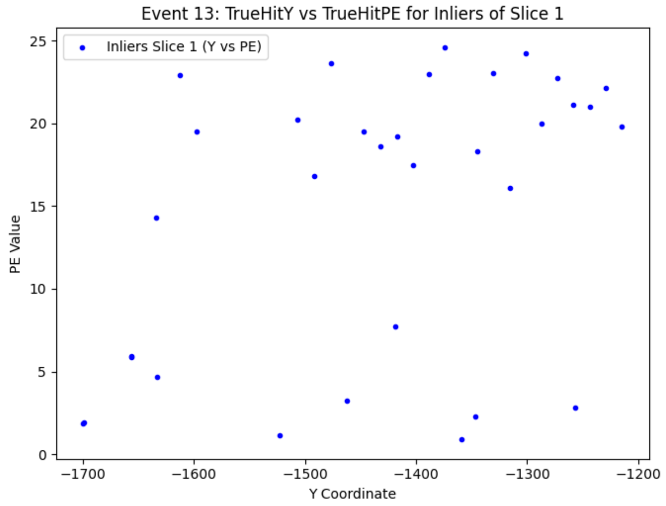




AfterFibers







Study conducted by Uni. Tokyo: Prog. Theor. Exp. Phys. **2024 (5)** 053H01

Function used for fit: $L = L_0 \cdot \left[\alpha \cdot \exp\left(-\frac{x}{A_L}\right) + (1-\alpha) \cdot \exp\left(-\frac{x}{A_S}\right)\right]$

L and L_0 are the attenuated and unattenuated light yields, x is the distance between the light injection position and the MPPC, A_L and A_S are the long and short attenuation lengths, respectively, and α is the fraction of the long attenuation component.

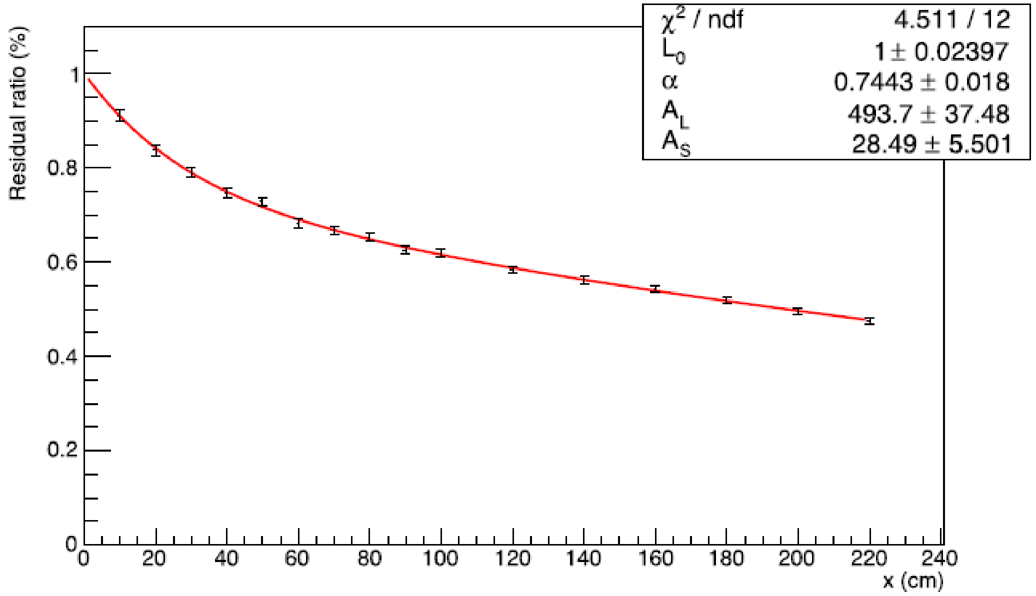


Table 3. Attenuation lengths measured using the laser. The uncertainties are from fitting.

Type	α	A_L (cm)	A_S (cm)
Y-11	0.74 ± 0.02	494 ± 37	28 ± 6
YS-2	0.75 ± 0.02	437 ± 19	34 ± 5
YS-4	0.84 ± 0.02	558 ± 27	26 ± 8
YS-6	0.73 ± 0.02	527 ± 22	29 ± 4