

Acceptance Study for SciBooNE Charged-Current Coherent Pion Production Technical Note Rough Draft

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Abstract

Should there be an abstract?

1 Introduction

The goal of this document is to provide a reference for the acceptance study performed for the SciBooNE charged current coherent pion re-analysis as well as provide documentation to the code used in this study (in the event anything needs to be revisited in the future).

The code currently lives in this github repository labeled [SciBooNE-MC](#) and the corresponding ROOT files used in the simulation can be downloaded from here (insert dropbox/Google Drive Link here)

The paper is structured such that Section 2 outlines samples used in this study, Section 3 describes the SciBooNE detector as it was simulated in this study, Section 5 gives a high level summary of the results including the event-reduction table as well as the CC-Coh- π acceptance results.

Sections ?? - ?? provide supporting plots which are used to generate the acceptance tables found in Section ??.

The appendix is left to explain how the code is run and the details of the scripts within.

1.1 Goal

The goal of the reanalysis is to examine the acceptance modeling for the SciBooNE results in the presence of modern neutrino generators and updated models in order to understand why SciBooNE did not observe Charged-Current Coherent Pion Production at low neutrino energy. The purpose of this acceptance study is to blah blah blah... (coming back to this later...)

2 Samples

Five different samples were used in this study, three samples for ν -mode and two samples in $\bar{\nu}$ -mode. ¹ Table 1 summarizes these samples. Details on these samples can be found in Appendix

¹All of these samples were generated by Callum Wilkinson (many thanks)

Summary of samples

Mode	NEUT version	Pion-Model	Number of simulated events
ν	5.3.6	Rein-Sehgal	1,000,000
ν	5.3.6	Berger-Sehgal	1,000,000
ν	x.x.x	Rein-Sehgal	100,000
$\bar{\nu}$	5.3.6	Rein-Sehgal	1,000,000
$\bar{\nu}$	5.3.6	Berger-Sehgal	1,000,000

Table 1: Summary of the samples used to build the acceptance model for this study.

3 Simulation

This section is intended to detail the nuances of this acceptance model, and to detail what assumptions are made in the acceptance modeling to result in accurate classifications of events as Charged-Current Coherent Pion Production.

3.1 The Detector

For the purposes of this acceptance study, the SciBooNE experiment as being composed of two sub-detectors. The first (and the more upstream) of the sub-detectors, is the Scintillator Bar Tracker (SciBar) which was originally conceived and constructed to function as the near detector for the K2K experiment [reference]. The second (and more downstream) of the sub-detectors, is the Muon Range Detector (MRD), which is the detector designed and constructed specifically for SciBooNE for measuring the momentum of muons produced from charged-current neutrino interactions up to $1.2 \text{ GeV}/c$ by using the observed range of the trajectory of the muon. These detectors and the corresponding coordinate system we will use throughout this note are shown in Figure 3.1

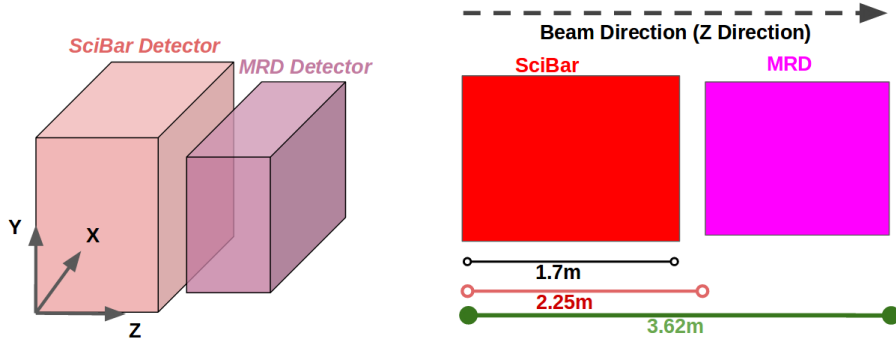


Figure 1: Representation of the SciBooNE detector and the coordinate frame we use in this study

3.1.1 The Scintillator Bar Tracker (SciBar)

The Scintillator Bar Tracker (SciBar) sub-detector is a scintillator detector (go into more detail?). In this acceptance study, the z-direction starts at 0 at the front face of the SciBar sub-detector. The direction of the beam is in the z-direction, which means the xy-plane is perpendicular to the beam. The dimensions of the sub-detector have the x and y dimensions of the same length of 3.0 m . The

z dimension is 1.7 *m*. This simulation models the scintillator materials as having a constant energy deposition (dE/dx) value of 2.04 *MeV/cm*.

3.1.2 The Muon Range Detector (MRD)

The Muon Range Detector (MRD), depicted in Figure 3.1.2 is located 0.55 *m* downstream of SciBar in the z-direction, and is a composition of 2 sets of 13 alternating slabs of steel-scintillator layers, where the scintillator layers alternate between being horizontally oriented or vertically oriented, in the xy-plane. The steel layers have a z-direction thickness of 5.08 *cm* and the scintillator layers have a z-direction thickness of 0.6 *cm*. Combining all the layers of the different alternating materials results in 26 scintillator layers that "sandwich" 25 steel layers inbetween and gives a total z-direction dimension of being 1.37*m*. The xy-plane is modeled as a square again (as was the case with SciBar, too) with dimensions in the x-direction and the y-direction of 2.6 *m*. The energy deposition (dE/dx) of the muon for the scintillator layers is again a constant of 2.04 *MeV/cm* and the energy deposition for the steel layers are a constant with value 11.43 *MeV/cm*.

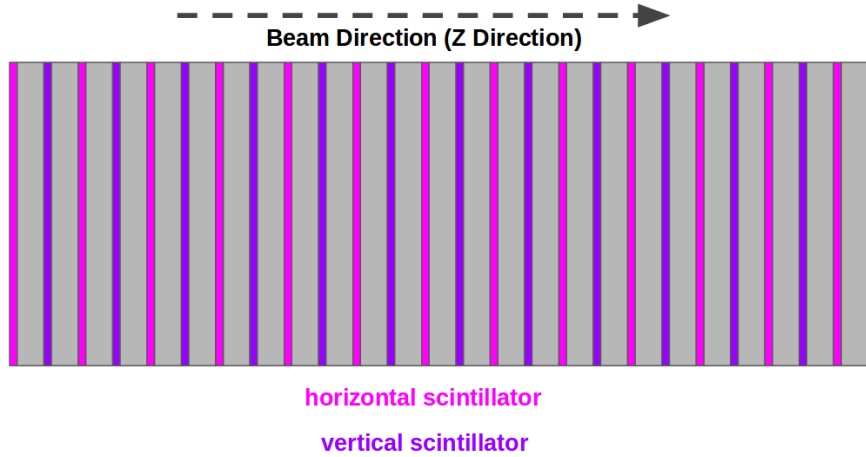


Figure 2: Depiction of the Muon Range Detector (MRB) which consists of alternating layers of horizontal scintillator (shown in pink) steel slabs (shown in grey) and vertical scintillator (shown in purple)

4 Event Selection

4.1 Event Classifications

There were three different classifications for events that qualified as CC-Coh Pion Production events, that the muon made it to the MRD, and the muon penetrated at least three layers of steel. These categories will be referenced multiple times throughout the remainder of this paper, which makes pertinent that the reader has an understanding of what each of the three specifically mean for any event that falls under any of these classifications.

4.1.1 Stopped

An event is classified as "Stopped," if the event qualified as being a CC-Coh Pion Production event, the muon of the event reached the MRD, penetrated three layers of steel, and stopped (or embedded) in the MRD without exiting the sides or the back face. Events that are classified as "Stopped" are included in the combined samples of this acceptance study and are called "Good" events. Maybe put in the dimensions of the xy-plane and z-direction that meet this classification for the MRD? This is shown in the figure below.

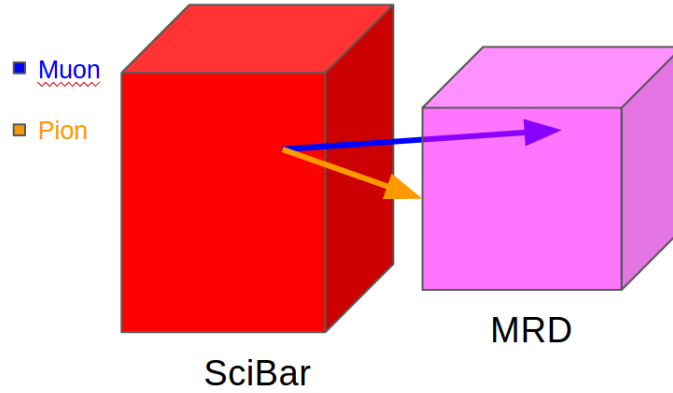


Figure 3: Depiction of an event that was classified as "Stopped."

4.1.2 Not-Stopped

An event is classified as "Not-Stopped," if the event qualified as being a CC-Coh Pion Production event, the muon of the event reached the MRD, and the muon passed out the back face of the MRD without stopping. Events that are classified as "Not-Stopped" are included in the combined samples of this acceptance study and are also called "Good" events. Maybe put in the dimensions of the xy-plane and z-direction that meet this classification for the MRD? This is shown in the figure below.

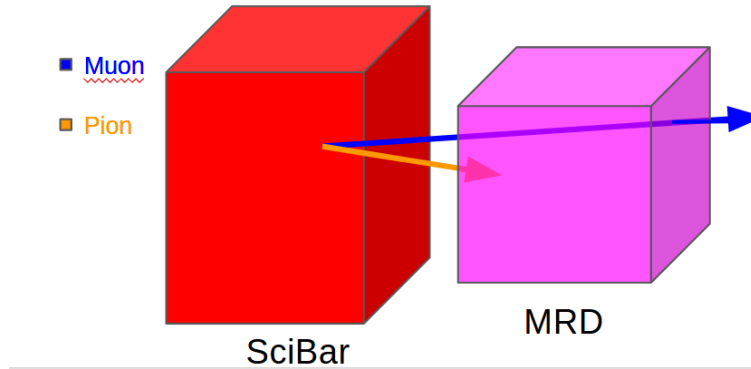


Figure 4: Depiction of an event that was classified as "Not-Stopped."

4.1.3 Out-Side

An event is classified as "Out-Side," if the event qualified as being a CC-Coh Pion Production event, the muon of the event reached the MRD, penetrated three layers of steel, and then passed through one of the sides of the MRD (not including the back face) without stopping. Events that are classified as "Out-Side" are not included in the combined samples because there was not enough material traversal for an accurate reconstruction of the particles momentum and energy to be made. Maybe put in the dimensions of the xy-plane and z-direction that meet this classification for the MRD? This is shown in the figure below.

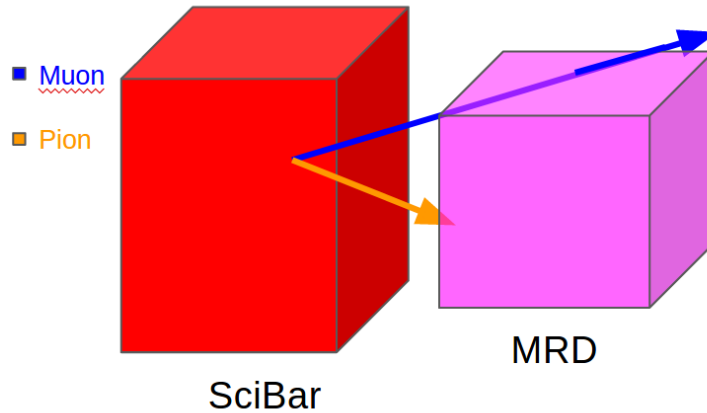


Figure 5: Depiction of an event that was classified as "Out-Side."

4.2 Stepping Through the Detectors Along an Event

I do not know if I am really going to include this here or not...

5 Results

A Appendix: Sample Details

Appendix on samples

A.1 ν -Mode Rein-Sehgal NEUTv5.3.6

A sample of 1,000,000 ν interactions were simulated using the NEUT generator (v5.3.6) and the Rein-Sehgal model for coherent pion production. This sample correspond to the file labeled

`SciBooNE_numu_coh_RooTrack.root`

found at the following link (put link to sample here).

A.2 ν -Mode Berger-Sehgal NEUTv5.3.6

A sample of 1,000,000 ν interactions were simulated using the NEUT generator (v5.3.6) and the Berger-Sehgal model for coherent pion production. This sample correspond to the file labeled

`SciBooNE_numu_coh_RooTrack_NEW.root`

found at the following link (put link to sample here).

A.3 ν -Mode Rein-Sehgal NEUTvx.x.x

A sample of 100,000 ν interactions were simulated using the NEUT generator (vx.x.x, believed to be the version used by the SciBooNE collaboration in the original publication) and the corresponding older Rein-Sehgal model for coherent pion production. This sample correspond to the file labeled

`SciBooNE_numu_coh_OLDNEUT_RooTrack.root`

found at the following link (put link to sample here).

A.4 $\bar{\nu}$ -Mode Rein-Sehgal NEUTv5.3.6

A sample of 1,000,000 $\bar{\nu}$ interactions were simulated using the NEUT generator (v5.3.6) and the Rein-Sehgal model for coherent pion production. This sample correspond to the file labeled

`SciBooNE_numubar_coh_RooTrack.root`

found at the following link (put link to sample here).

A.5 $\bar{\nu}$ -Mode Berger-Sehgal NEUTv5.3.6

A sample of 1,000,000 $\bar{\nu}$ interactions were simulated using the NEUT generator (v5.3.6) and the Berger-Sehgal model for coherent pion production. This sample correspond to the file labeled

`SciBooNE_numubar_coh_RooTrack_NEW.root`

found at the following link (put link to sample here).

A.6 Vertex Distributions

The events were all given a random initial point that was generated with the goal that the vertex distributions of this simulation would closely match the vertex distributions that Hiraide (need to put a reference) showed in his thesis. This was done by... etc.

Put in the code **for** how we made the vertex distributions of the interactions.

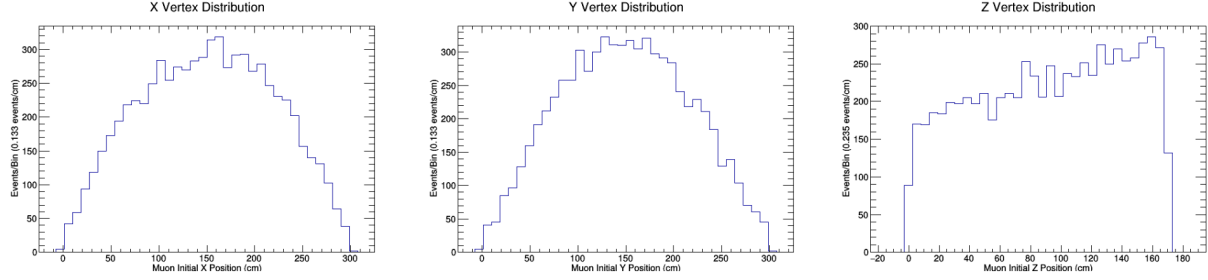


Figure 6: Vertex distributions of the events in the new Rein-Sehgal sample.

A.7 NewNMReinSehgal.C

This file is the macro that corresponds to the "NewNMReinSehgal.h" file, which connects with this file: "SciBooNE_numu_coh_RooTrack.root". This file performs the main analysis for this generated sample, and then organizes the information into many different histograms. The histograms are then written to a file titled "totalmuoninfoRS.root" inside the "ROOTFILES" directory. The "ROOTFILES" directory is included in the SciBooNE-MC repository (it is absolutely pertinent that this directory be located where the macro files are located due to how the calls of the combined data macros reference the now saved histograms). When this macro is run (which can take a while), it also plots a few different histograms. The histograms that are plotted are the ones shown in the figures below with descriptions included with the corresponding figures. The order that the histograms appear in this paper is the same order they will be shown when this macro is run in root.

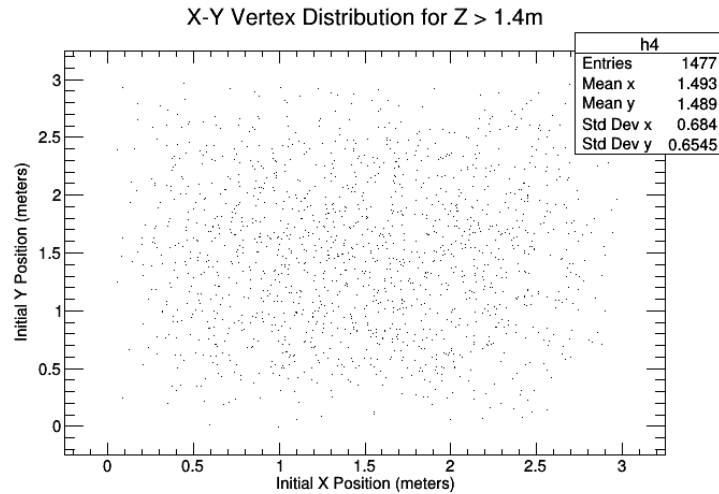


Figure 7: New Rein-Sehgal X-Y vertex distributions for muons that made it to the MRD.

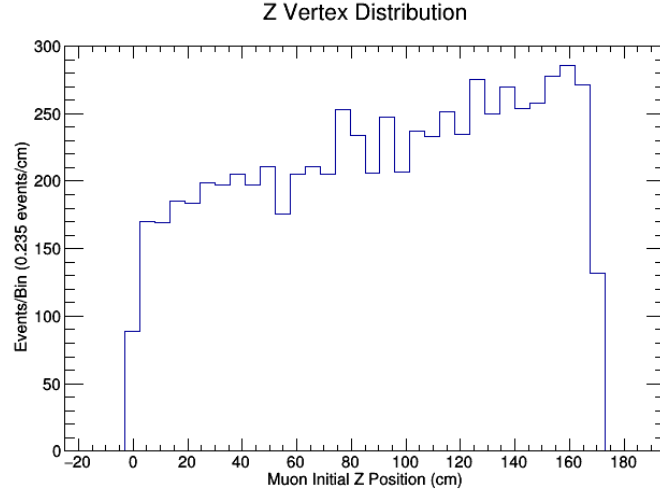


Figure 8: New Rein-Sehgal Z vertex distributions for the interactions.

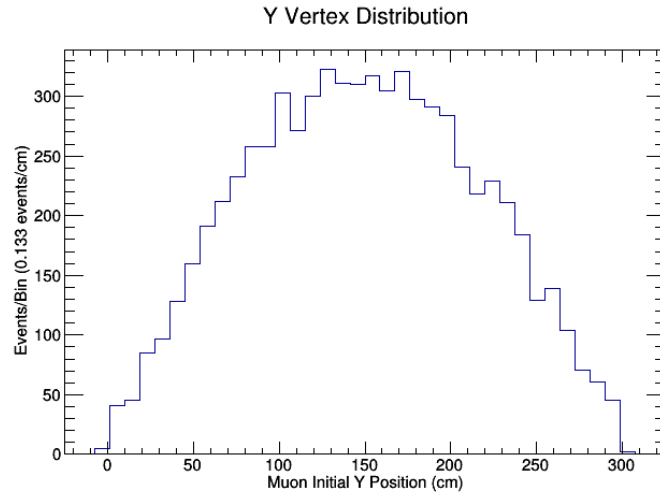


Figure 9: New Rein-Sehgal Y vertex distributions for the interactions.

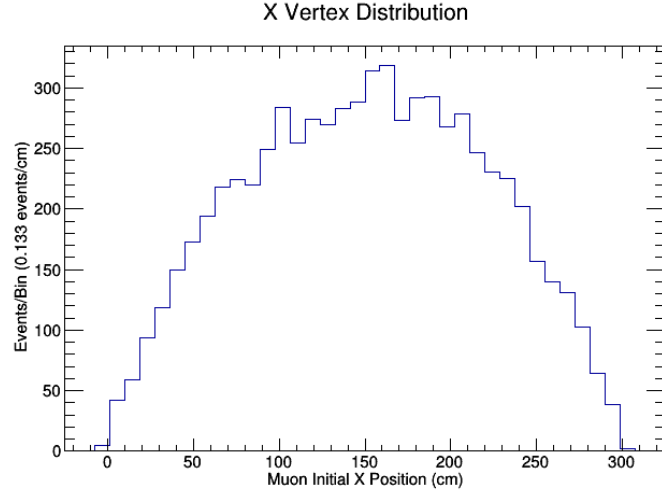


Figure 10: New Rein-Sehgal X vertex distributions for the interactions.

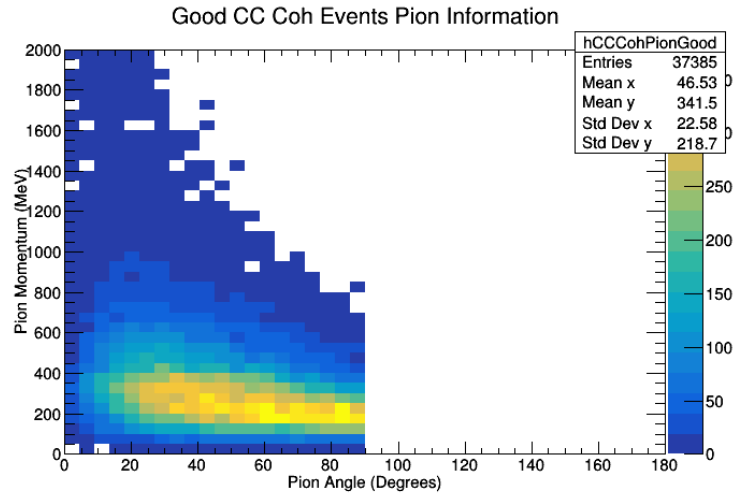


Figure 11: This is a 2D histogram for the momentum and angle of the pion in the CC Coh Pion events that met the qualification of being "good".

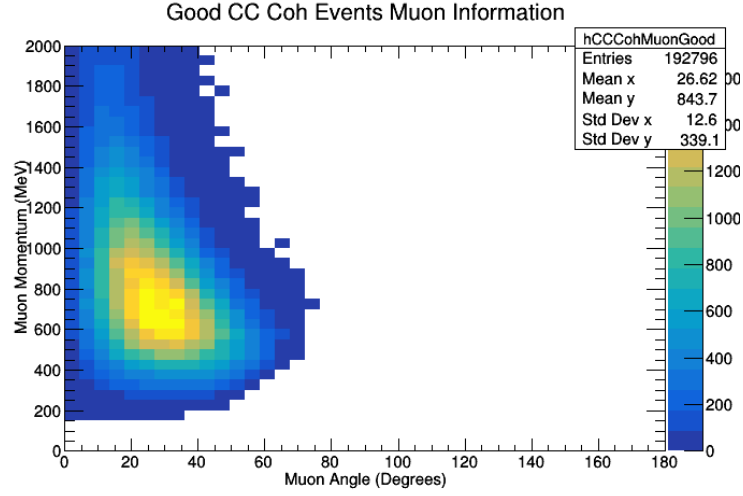


Figure 12: This is a 2D histogram for the momentum and angle of the muon in the CC Coh Pion events that met the qualification of being "good".

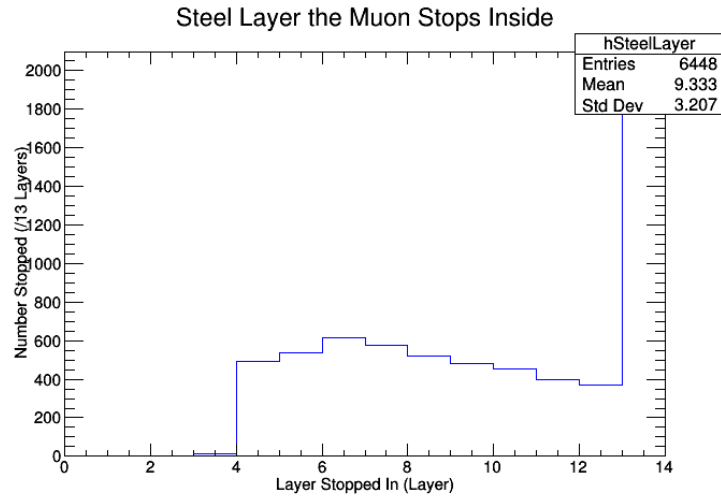


Figure 13: This histogram depicts the amount of muons that embedded in what layer of steel.

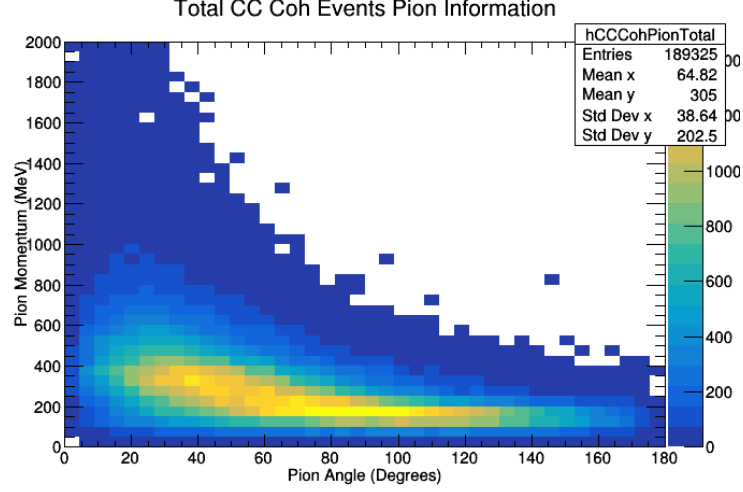


Figure 14: This is a plot right here. Nice of you to notice!

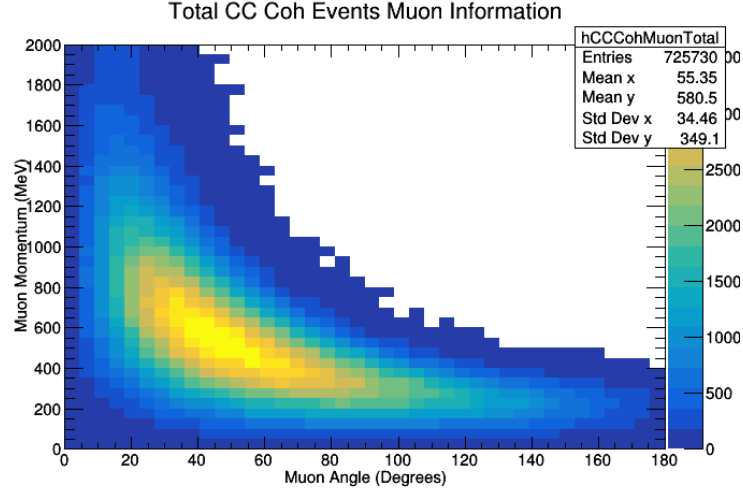


Figure 15: This is a plot right here. Nice of you to notice!

The NewNMReinSehgal.C macro also calculates many different quantities for the generated simulation of the events and saves the information in histograms that are later called upon through the plotting macros (which are after all of the analysis macros). The first quantity that is calculated for the different vertexes is the momentum of both the muon and the pion, which are both calculated using the equations:

$$|\vec{p}_\mu| = \sqrt{P_{\mu_x}^2 + P_{\mu_y}^2 + P_{\mu_z}^2} \quad (1)$$

$$|\vec{p}_\pi| = \sqrt{P_{\pi_x}^2 + P_{\pi_y}^2 + P_{\pi_z}^2} \quad (2)$$

The momentum is reported in units of MeV/c .

The next quantity that is calculated in the macro is the angle from the beam-direction for both the muon and the pion, which are labeled as either θ_μ , or θ_π , respectively. The angle from the beam-direction is the same as the angle from the z-direction, and this angle is known as the azimuthal

angle. The calculation of the azimuthal angle is slightly more involved than the simple calculation used for finding the magnitude of the momentum of the two particles, and is calculated using the equations:

$$\theta_\mu = \tan^{-1}(\sqrt{P_{\mu_x}^2 + P_{\mu_y}^2}/P_{\mu_z}) \quad (3)$$

$$\theta_\pi = \tan^{-1}(\sqrt{P_{\pi_x}^2 + P_{\pi_y}^2}/P_{\pi_z}) \quad (4)$$

The angles are reported in units of $^\circ$, and should run from 0° to 180° . In the case of Charged-Current Coherent Pion Production, the angle should never be larger than 90° .

The last two quantities that this analysis macro calculates are the two different types of four-momentum transfers specific to this interaction, which are Q^2 and $|t|$. The Q^2 corresponds to the four-momentum transfer from the neutrino and muon to the nucleus and pion, and is calculated using the equation:

$$Q^2 = |(P_{\nu_\mu} - P_\mu)^2| \quad (5)$$

This equation is the four-momentum notational form. The code follows the equation below in order to compute Q^2 :

$$Q^2 = |(P_{\nu_{\mu,x}} - P_{\mu_x})^2 + (P_{\nu_{\mu,y}} - P_{\mu_y})^2 + (P_{\nu_{\mu,z}} - P_{\mu_z})^2 + (P_{\nu_{\mu,E}} - P_{\mu_E})^2| \quad (6)$$

Q^2 is reported in units of $(MeV/c)^2$.

The $|t|$ corresponds to the four-momentum transfer from the neutrino, muon, and pion to the nucleus, and is calculated using the equation:

$$|t| = |(Q - P_\pi)^2| = |(P_{\nu_\mu} - P_\mu - P_\pi)^2| \quad (7)$$

This equation is the four-momentum notational form. The code follows the equation below in order to compute $|t|$:

$$|t| = |(P_{\nu_{\mu,x}} - P_{\mu_x} - P_{\pi_x})^2 + (P_{\nu_{\mu,y}} - P_{\mu_y} - P_{\pi_y})^2 + (P_{\nu_{\mu,z}} - P_{\mu_z} - P_{\pi_z})^2 + (P_{\nu_{\mu,E}} - P_{\mu_E} - P_{\pi_E})^2| \quad (8)$$

$|t|$ is reported in units of $(MeV/c)^2$.

A.8 NewNM BergerSehgal.C

This file is the macro that corresponds to the "NewNM BergerSehgal.h" file, which connects with this file: "SciBooNE_numu_coh_RooTrack_NEW.root". This file performs the main analysis for this generated sample, and then organizes the information into many different histograms. The histograms are then written to a file titled "totalmuoninfoBS.root" inside the "ROOTFILES" directory. The "ROOTFILES" directory is included in the SciBooNE-MC repository (it is absolutely pertinent that this directory be located where the macro files are located due to how the calls of the combined data macros reference the now saved histograms).

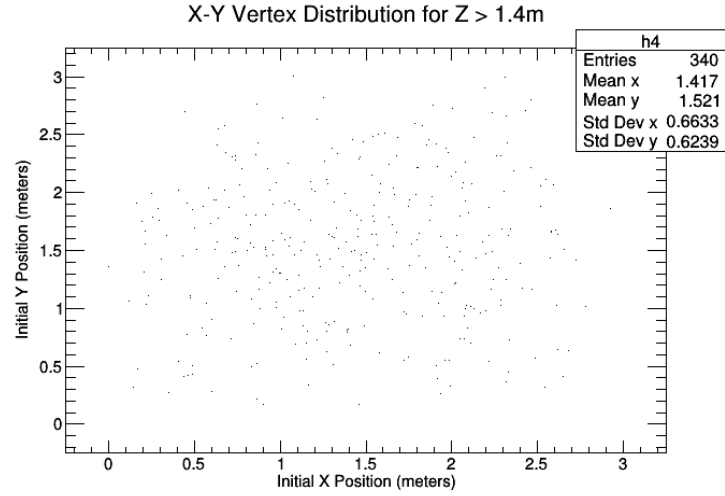


Figure 16: This is a plot right here. Nice of you to notice!

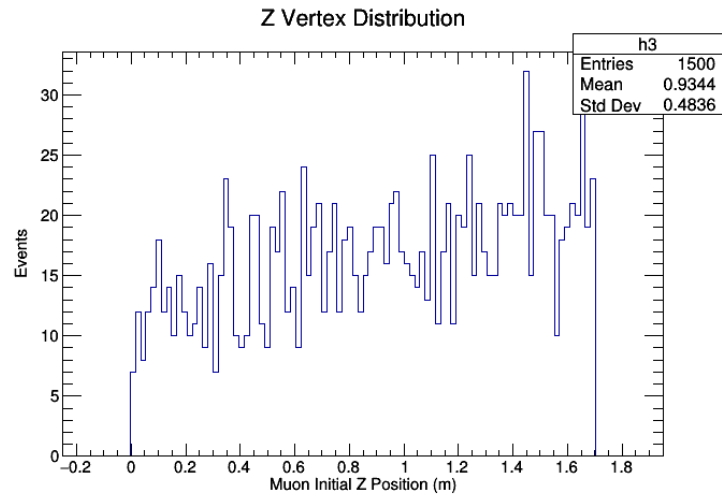


Figure 17: This is a plot right here. Nice of you to notice!

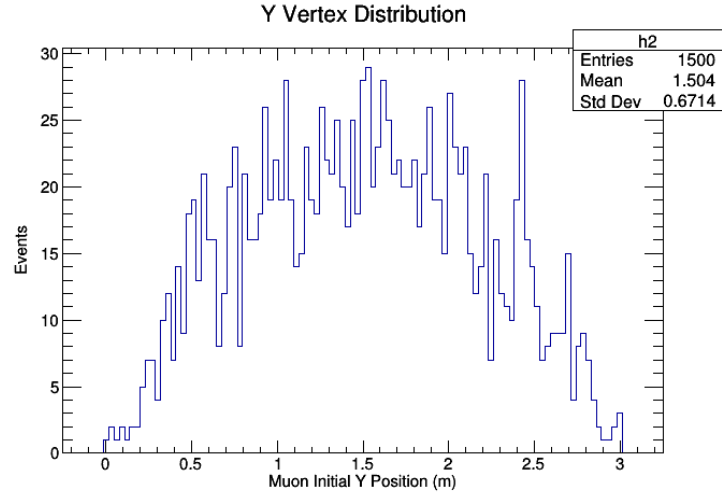


Figure 18: This is a plot right here. Nice of you to notice!

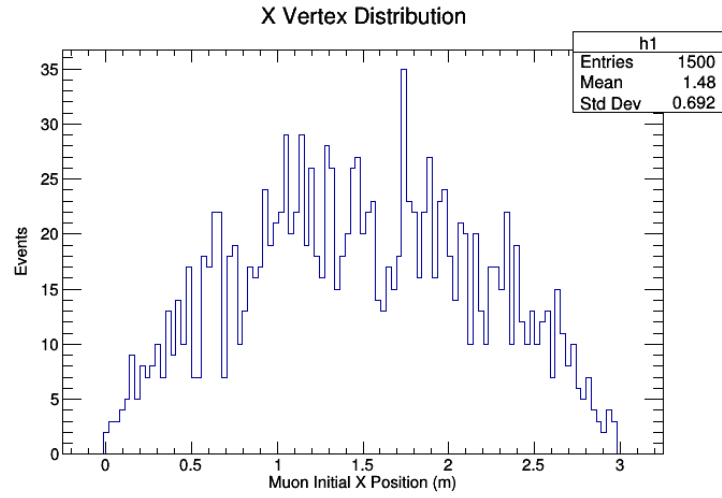


Figure 19: This is a plot right here. Nice of you to notice!

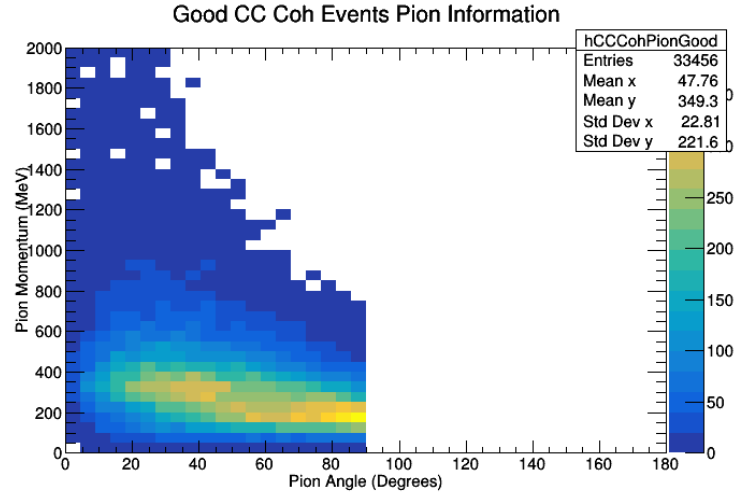


Figure 20: This is a plot right here. Nice of you to notice!

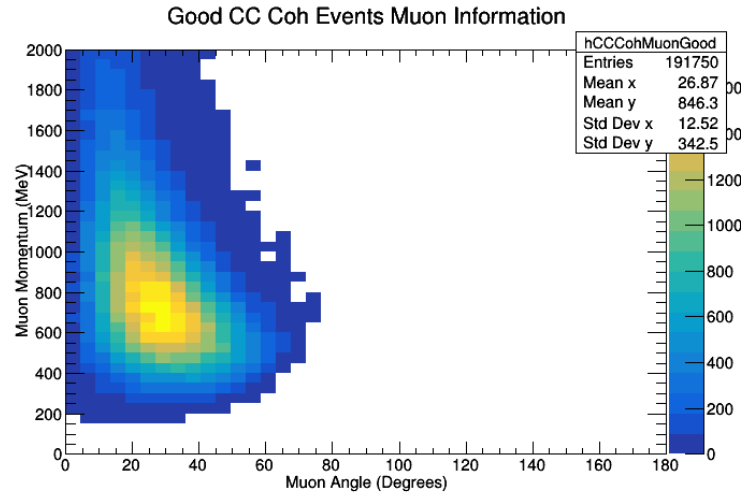


Figure 21: This is a plot right here. Nice of you to notice!

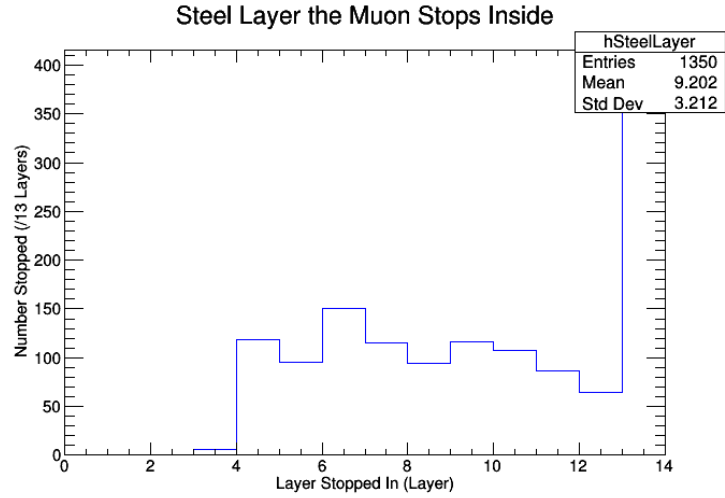


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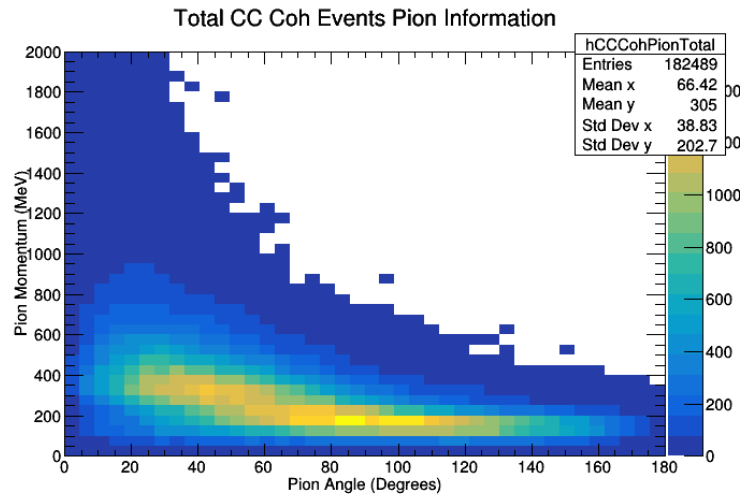


Figure 23: This is a plot right here. Nice of you to notice!

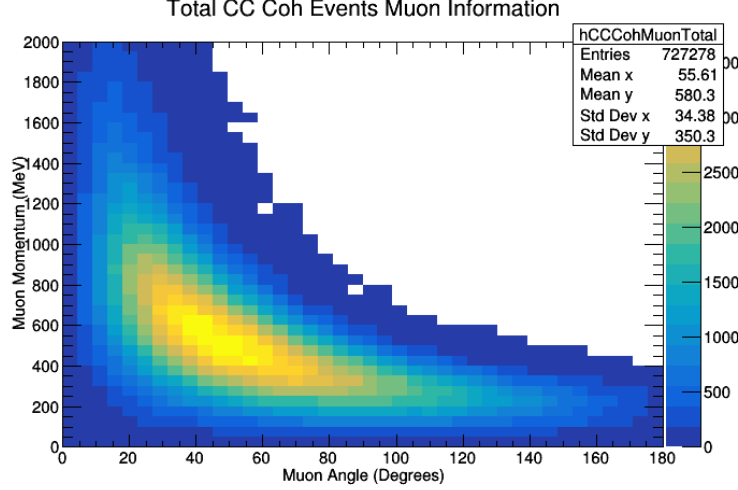


Figure 24: This is a plot right here. Nice of you to notice!

The NewNM BergerSehgal.C macro also calculates many different quantities for the generated simulation of the events and saves the information in histograms that are later called upon through the plotting macros (which are after all of the analysis macros). The first quantity that is calculated for the different vertexes is the momentum of both the muon and the pion, which are both calculated using the equations:

$$|\vec{p}_\mu| = \sqrt{P_{\mu_x}^2 + P_{\mu_y}^2 + P_{\mu_z}^2} \quad (9)$$

$$|\vec{p}_\pi| = \sqrt{P_{\pi_x}^2 + P_{\pi_y}^2 + P_{\pi_z}^2} \quad (10)$$

The momentum is reported in units of MeV/c .

The next quantity that is calculated in the macro is the angle from the beam-direction for both the muon and the pion, which are labeled as either θ_μ , or θ_π , respectively. The angle from the beam-direction is the same as the angle from the z-direction, and this angle is known as the azimuthal angle. The calculation of the azimuthal angle is slightly more involved than the simple calculation used for finding the magnitude of the momentum of the two particles, and is calculated using the equations:

$$\theta_\mu = \tan^{-1}(\sqrt{P_{\mu_x}^2 + P_{\mu_y}^2}/P_{\mu_z}) \quad (11)$$

$$\theta_\pi = \tan^{-1}(\sqrt{P_{\pi_x}^2 + P_{\pi_y}^2}/P_{\pi_z}) \quad (12)$$

The angles are reported in units of $^\circ$, and should run from 0° to 180° . In the case of Charged-Current Coherent Pion Production, the angle should never be larger than 90° .

The last two quantities that this analysis macro calculates are the two different types of four-momentum transfers specific to this interaction, which are Q^2 and $|t|$. The Q^2 corresponds to the four-momentum transfer from the neutrino and muon to the nucleus and pion, and is calculated using the equation:

$$Q^2 = |(P_{\nu_\mu} - P_\mu)^2| \quad (13)$$

This equation is the four-momentum notational form. The code follows the equation below in order to compute Q^2 :

$$Q^2 = |(P_{\nu_{\mu,x}} - P_{\mu_x})^2 + (P_{\nu_{\mu,y}} - P_{\mu_y})^2 + (P_{\nu_{\mu,z}} - P_{\mu_z})^2 + (P_{\nu_{\mu,E}} - P_{\mu_E})^2| \quad (14)$$

Q^2 is reported in units of $(MeV/c)^2$.

The $|t|$ corresponds to the four-momentum transfer from the neutrino, muon, and pion to the nucleus, and is calculated using the equation:

$$|t| = |(Q - P_{\pi})^2| = |(P_{\nu_{\mu}} - P_{\mu} - P_{\pi})^2| \quad (15)$$

This equation is the four-momentum notational form. The code follows the equation below in order to compute $|t|$:

$$|t| = |(P_{\nu_{\mu,x}} - P_{\mu_x} - P_{\pi_x})^2 + (P_{\nu_{\mu,y}} - P_{\mu_y} - P_{\pi_y})^2 + (P_{\nu_{\mu,z}} - P_{\mu_z} - P_{\pi_z})^2 + (P_{\nu_{\mu,E}} - P_{\mu_E} - P_{\pi_E})^2| \quad (16)$$

$|t|$ is reported in units of $(MeV/c)^2$.

A.9 OldNMReinSehgal.C

This file is the macro that corresponds to the "OldNMReinSehgal.h" file, which connects with this file: "SciBooNE_numu_coh_OLDNEUT_RooTrack.root". This file performs the main analysis for this generated sample, and then organizes the information into many different histograms. The histograms are then written to a file titled "totalmuoninfoOBS.root" inside the "ROOTFILES" directory. The "ROOTFILES" directory is included in the SciBooNE-MC repository (it is absolutely pertinent that this directory be located where the macro files are located due to how the calls of the combined data macros reference the now saved histograms).

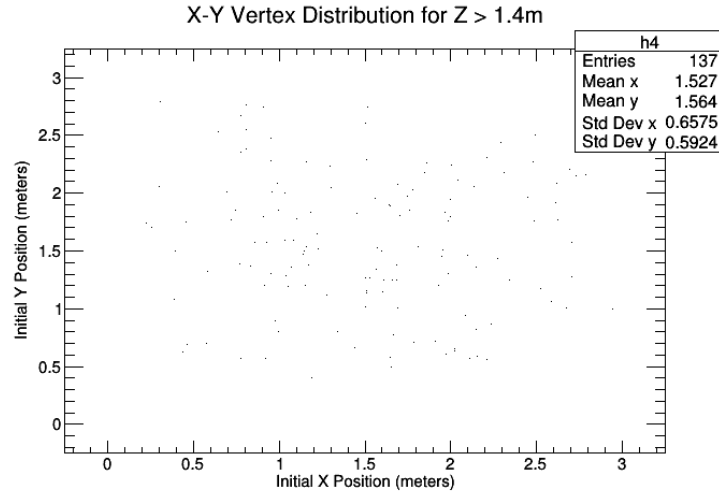


Figure 25: This is a plot right here. Nice of you to notice!

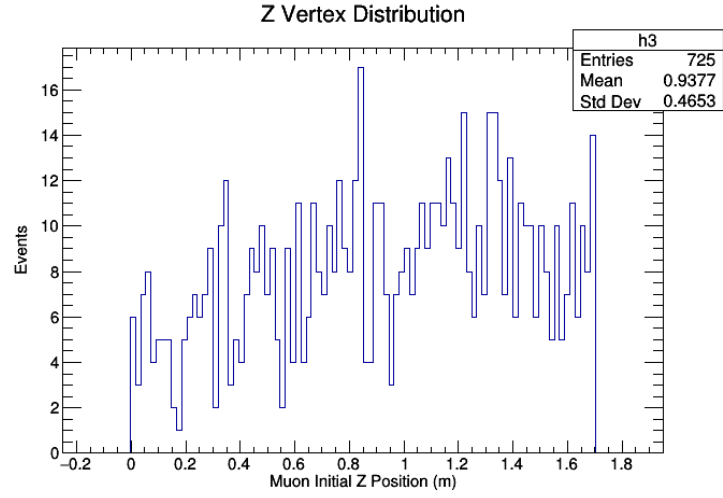


Figure 26: This is a plot right here. Nice of you to notice!

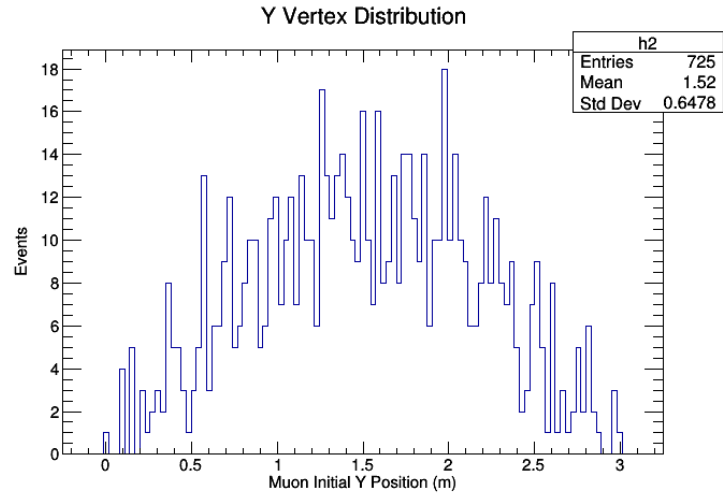


Figure 27: This is a plot right here. Nice of you to notice!

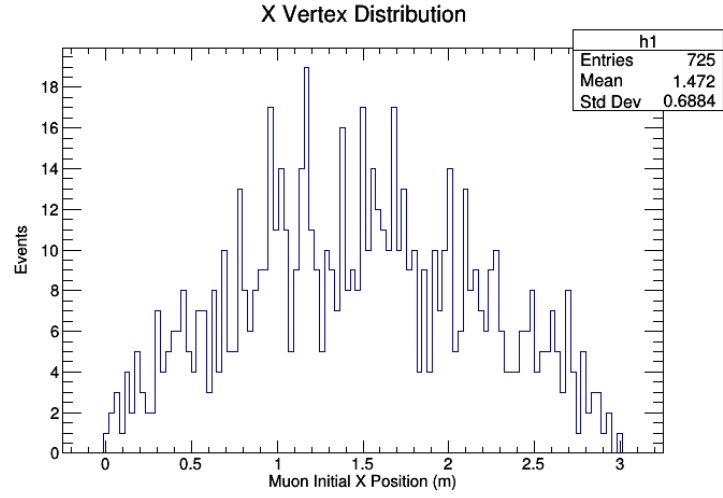


Figure 28: This is a plot right here. Nice of you to notice!

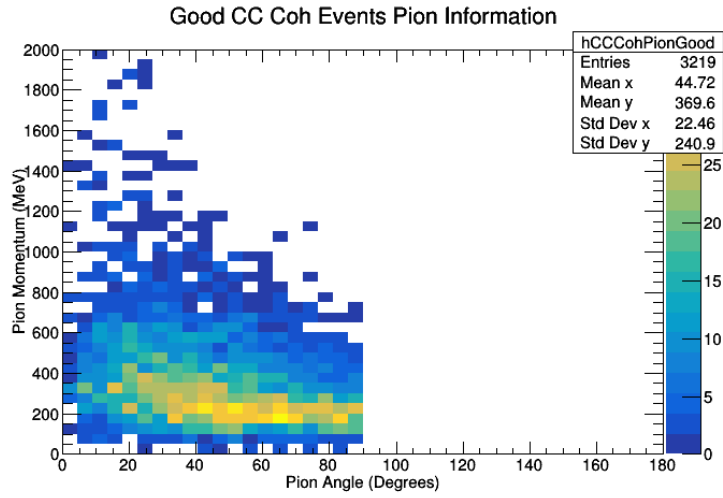


Figure 29: This is a plot right here. Nice of you to notice!

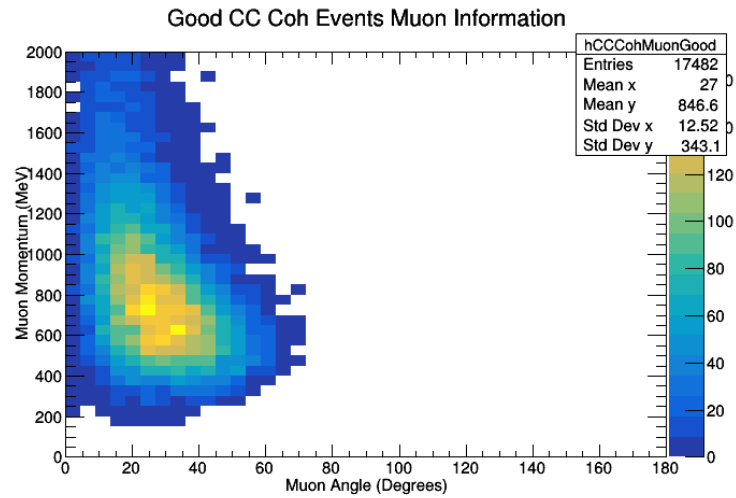


Figure 30: This is a plot right here. Nice of you to notice!

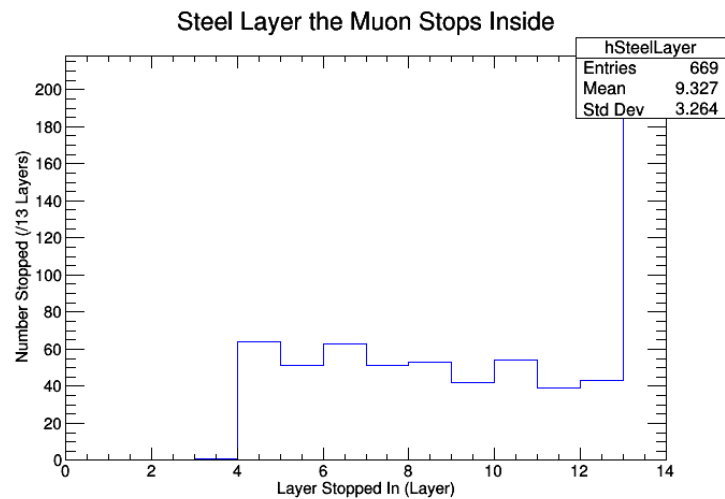


Figure 31: This is a plot right here. Nice of you to notice!

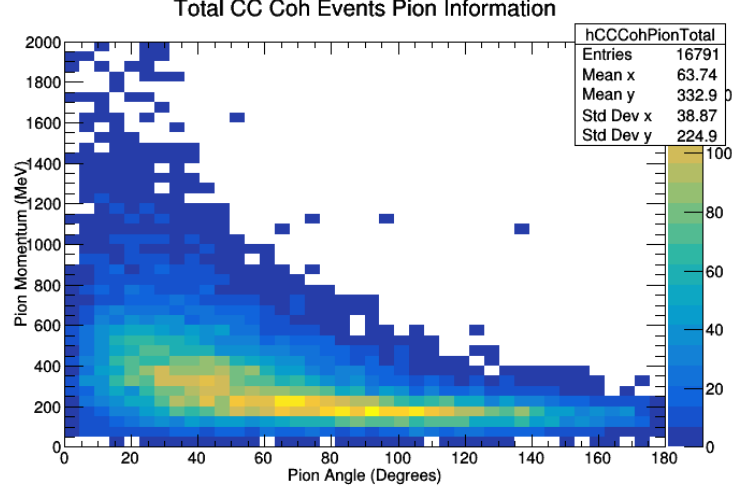


Figure 32: This is a plot right here. Nice of you to notice!

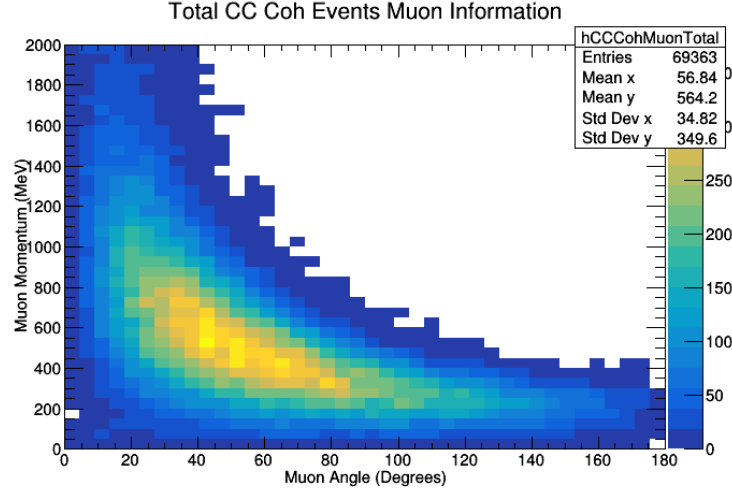


Figure 33: This is a plot right here. Nice of you to notice!

The OldNMReinSehgal.C macro also calculates many different quantities for the generated simulation of the events and saves the information in histograms that are later called upon through the plotting macros (which are after all of the analysis macros). The first quantity that is calculated for the different vertexes is the momentum of both the muon and the pion, which are both calculated using the equations:

$$|\vec{p}_\mu| = \sqrt{P_{\mu_x}^2 + P_{\mu_y}^2 + P_{\mu_z}^2} \quad (17)$$

$$|\vec{p}_\pi| = \sqrt{P_{\pi_x}^2 + P_{\pi_y}^2 + P_{\pi_z}^2} \quad (18)$$

The momentum is reported in units of MeV/c .

The next quantity that is calculated in the macro is the angle from the beam-direction for both the muon and the pion, which are labeled as either θ_μ , or θ_π , respectively. The angle from the beam-direction is the same as the angle from the z-direction, and this angle is known as the azimuthal

angle. The calculation of the azimuthal angle is slightly more involved than the simple calculation used for finding the magnitude of the momentum of the two particles, and is calculated using the equations:

$$\theta_\mu = \tan^{-1}(\sqrt{P_{\mu_x}^2 + P_{\mu_y}^2}/P_{\mu_z}) \quad (19)$$

$$\theta_\pi = \tan^{-1}(\sqrt{P_{\pi_x}^2 + P_{\pi_y}^2}/P_{\pi_z}) \quad (20)$$

The angles are reported in units of $^\circ$, and should run from 0° to 180° . In the case of Charged-Current Coherent Pion Production, the angle should never be larger than 90° .

The last two quantities that this analysis macro calculates are the two different types of four-momentum transfers specific to this interaction, which are Q^2 and $|t|$. The Q^2 corresponds to the four-momentum transfer from the neutrino and muon to the nucleus and pion, and is calculated using the equation:

$$Q^2 = |(P_{\nu_\mu} - P_\mu)^2| \quad (21)$$

This equation is the four-momentum notational form. The code follows the equation below in order to compute Q^2 :

$$Q^2 = |(P_{\nu_{\mu,x}} - P_{\mu_x})^2 + (P_{\nu_{\mu,y}} - P_{\mu_y})^2 + (P_{\nu_{\mu,z}} - P_{\mu_z})^2 + (P_{\nu_{\mu,E}} - P_{\mu_E})^2| \quad (22)$$

Q^2 is reported in units of $(MeV/c)^2$.

The $|t|$ corresponds to the four-momentum transfer from the neutrino, muon, and pion to the nucleus, and is calculated using the equation:

$$|t| = |(Q - P_\pi)^2| = |(P_{\nu_\mu} - P_\mu - P_\pi)^2| \quad (23)$$

This equation is the four-momentum notational form. The code follows the equation below in order to compute $|t|$:

$$|t| = |(P_{\nu_{\mu,x}} - P_{\mu_x} - P_{\pi_x})^2 + (P_{\nu_{\mu,y}} - P_{\mu_y} - P_{\pi_y})^2 + (P_{\nu_{\mu,z}} - P_{\mu_z} - P_{\pi_z})^2 + (P_{\nu_{\mu,E}} - P_{\mu_E} - P_{\pi_E})^2| \quad (24)$$

$|t|$ is reported in units of $(MeV/c)^2$.

A.10 NewANMReinSehgal.C

This file is the macro that corresponds to the "NewANMReinSehgal.h" file, which connects with this file: "SciBooNE_numubar_coh_RooTrack.root". This file performs the main analysis for this generated sample, and then organizes the information into many different histograms. The histograms are then written to a file titled "totalmuoninfoRSBar.root" inside the "ROOTFILES" directory. The "ROOTFILES" directory is included in the SciBooNE-MC repository (it is absolutely pertinent that this directory be located where the macro files are located due to how the calls of the combined data macros reference the now saved histograms).

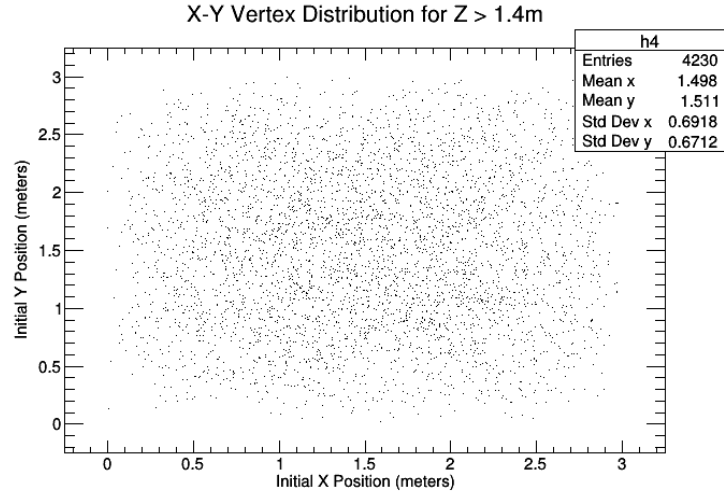


Figure 34: This is a plot right here. Nice of you to notice!

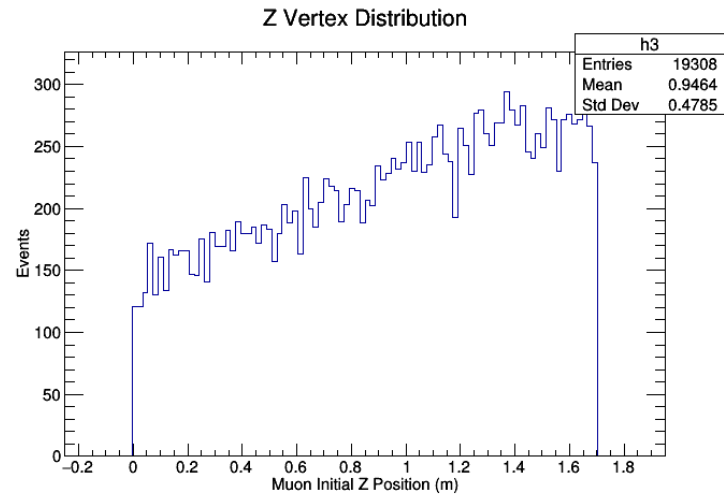


Figure 35: This is a plot right here. Nice of you to notice!

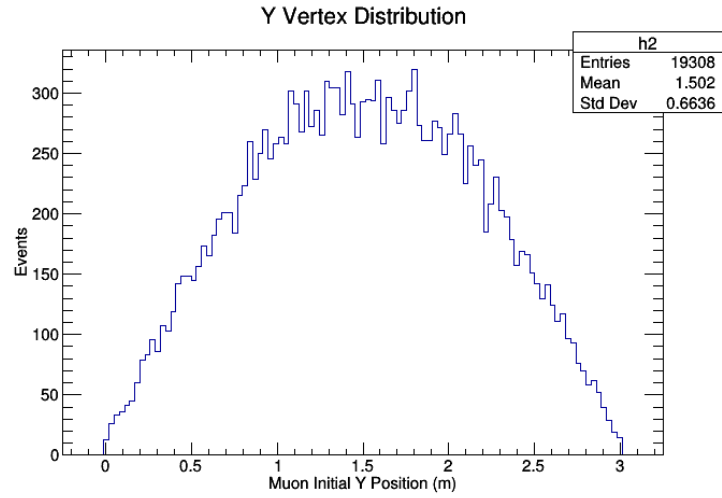


Figure 36: This is a plot right here. Nice of you to notice!

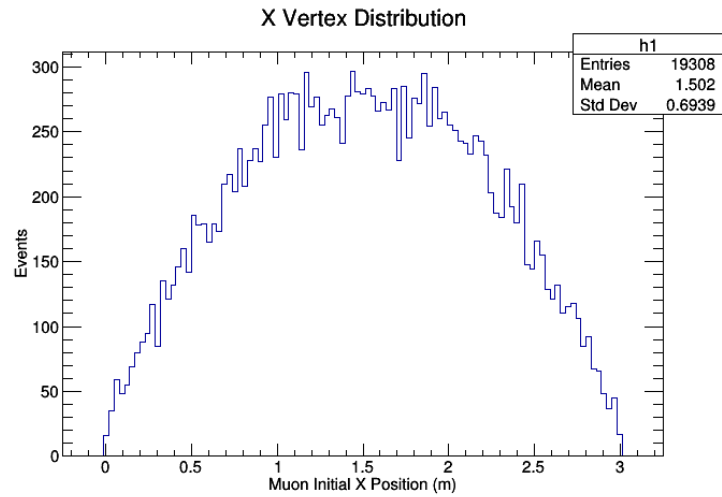


Figure 37: This is a plot right here. Nice of you to notice!

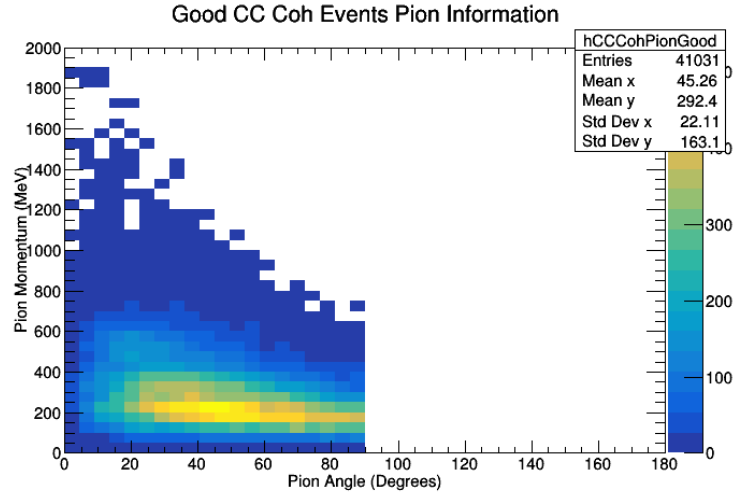


Figure 38: This is a plot right here. Nice of you to notice!

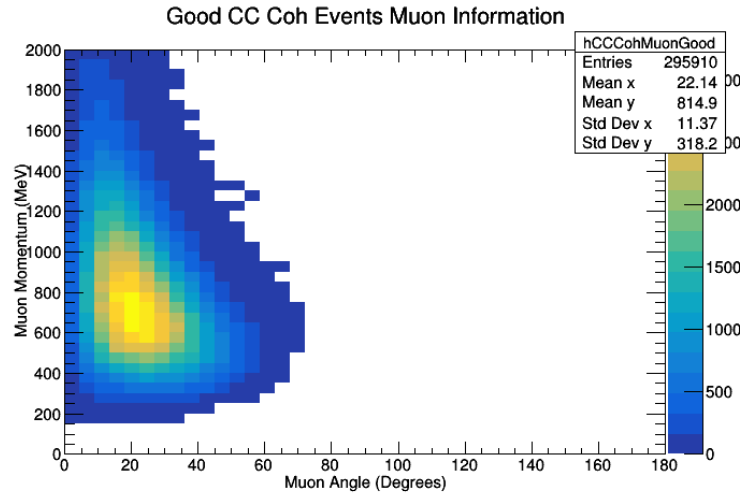


Figure 39: This is a plot right here. Nice of you to notice!

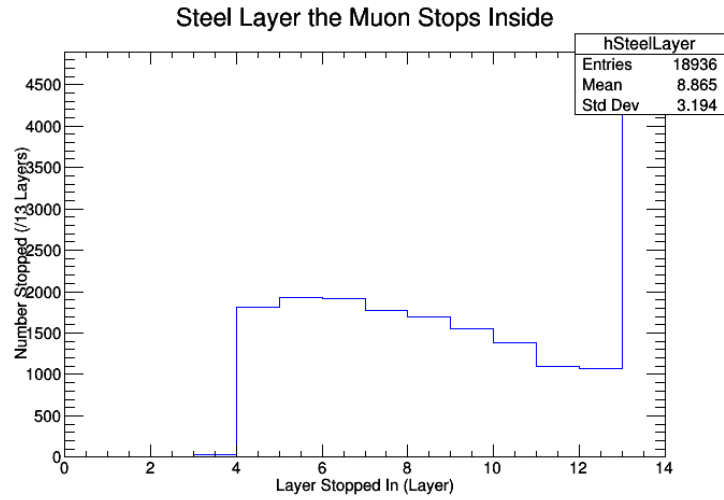


Figure 40: This is a plot right here. Nice of you to notice!

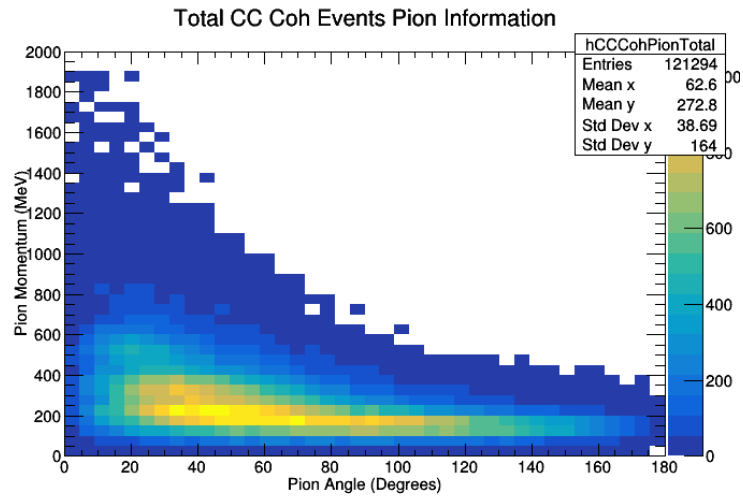


Figure 41: This is a plot right here. Nice of you to notice!

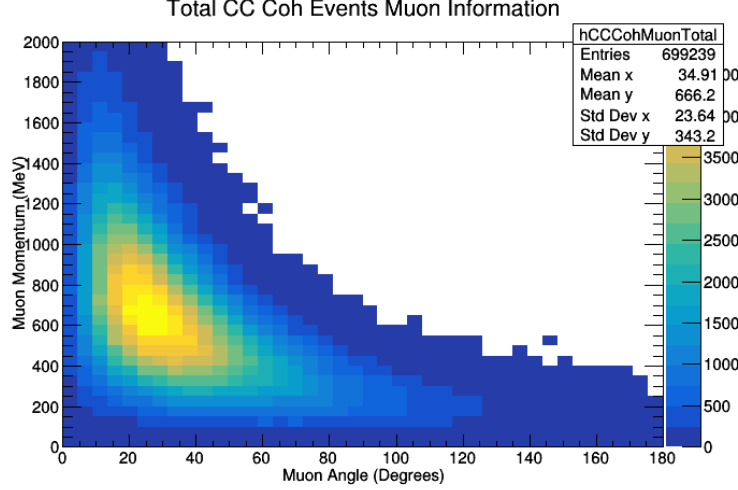


Figure 42: This is a plot right here. Nice of you to notice!

The NewANMReinSehgal.C macro also calculates many different quantities for the generated simulation of the events and saves the information in histograms that are later called upon through the plotting macros (which are after all of the analysis macros). The first quantity that is calculated for the different vertexes is the momentum of both the muon and the pion, which are both calculated using the equations:

$$|\vec{p}_\mu| = \sqrt{P_{\mu_x}^2 + P_{\mu_y}^2 + P_{\mu_z}^2} \quad (25)$$

$$|\vec{p}_\pi| = \sqrt{P_{\pi_x}^2 + P_{\pi_y}^2 + P_{\pi_z}^2} \quad (26)$$

The momentum is reported in units of MeV/c .

The next quantity that is calculated in the macro is the angle from the beam-direction for both the muon and the pion, which are labeled as either θ_μ , or θ_π , respectively. The angle from the beam-direction is the same as the angle from the z-direction, and this angle is known as the azimuthal angle. The calculation of the azimuthal angle is slightly more involved than the simple calculation used for finding the magnitude of the momentum of the two particles, and is calculated using the equations:

$$\theta_\mu = \tan^{-1}(\sqrt{P_{\mu_x}^2 + P_{\mu_y}^2}/P_{\mu_z}) \quad (27)$$

$$\theta_\pi = \tan^{-1}(\sqrt{P_{\pi_x}^2 + P_{\pi_y}^2}/P_{\pi_z}) \quad (28)$$

The angles are reported in units of $^\circ$, and should run from 0° to 180° . In the case of Charged-Current Coherent Pion Production, the angle should never be larger than 90° .

The last two quantities that this analysis macro calculates are the two different types of four-momentum transfers specific to this interaction, which are Q^2 and $|t|$. The Q^2 corresponds to the four-momentum transfer from the neutrino and muon to the nucleus and pion, and is calculated using the equation:

$$Q^2 = |(P_{\nu_\mu} - P_\mu)^2| \quad (29)$$

This equation is the four-momentum notational form. The code follows the equation below in order to compute Q^2 :

$$Q^2 = |(P_{\nu_{\mu,x}} - P_{\mu_x})^2 + (P_{\nu_{\mu,y}} - P_{\mu_y})^2 + (P_{\nu_{\mu,z}} - P_{\mu_z})^2 + (P_{\nu_{\mu,E}} - P_{\mu_E})^2| \quad (30)$$

Q^2 is reported in units of $(MeV/c)^2$.

The $|t|$ corresponds to the four-momentum transfer from the neutrino, muon, and pion to the nucleus, and is calculated using the equation:

$$|t| = |(Q - P_{\pi})^2| = |(P_{\nu_{\mu}} - P_{\mu} - P_{\pi})^2| \quad (31)$$

This equation is the four-momentum notational form. The code follows the equation below in order to compute $|t|$:

$$|t| = |(P_{\nu_{\mu,x}} - P_{\mu_x} - P_{\pi_x})^2 + (P_{\nu_{\mu,y}} - P_{\mu_y} - P_{\pi_y})^2 + (P_{\nu_{\mu,z}} - P_{\mu_z} - P_{\pi_z})^2 + (P_{\nu_{\mu,E}} - P_{\mu_E} - P_{\pi_E})^2| \quad (32)$$

$|t|$ is reported in units of $(MeV/c)^2$.

A.11 NewANMBergerSehgal.C

This file is the macro that corresponds to the "NewANMBergerSehgal.h" file, which connects with this file: "SciBooNE_numubar_coh_RooTrack_NEW.root". This file performs the main analysis for this generated sample, and then organizes the information into many different histograms. The histograms are then written to a file titled "totalmuoninfoBSBar.root" inside the "ROOTFILES" directory. The "ROOTFILES" directory is included in the SciBooNE-MC repository (it is absolutely pertinent that this directory be located where the macro files are located due to how the calls of the combined data macros reference the now saved histograms).

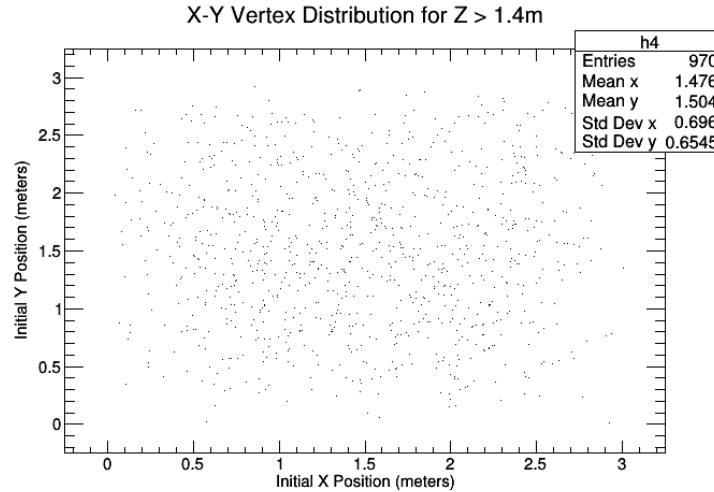


Figure 43: This is a plot right here. Nice of you to notice!

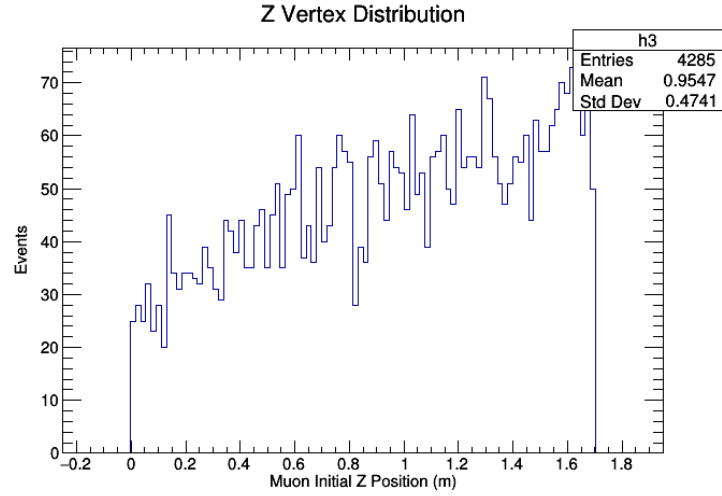


Figure 44: This is a plot right here. Nice of you to notice!

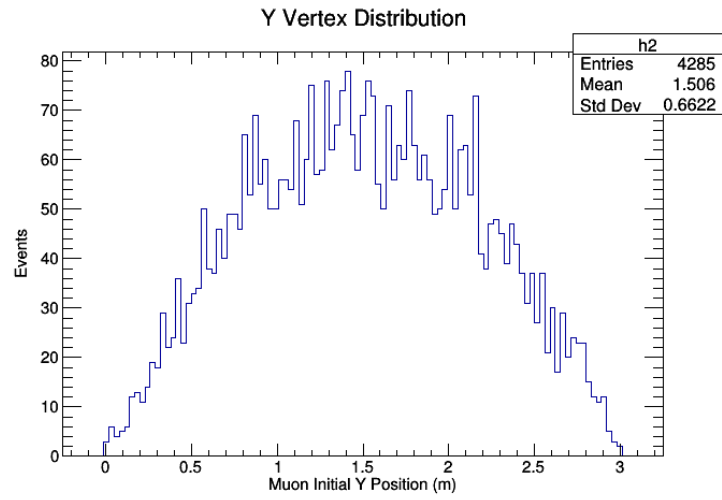


Figure 45: This is a plot right here. Nice of you to notice!

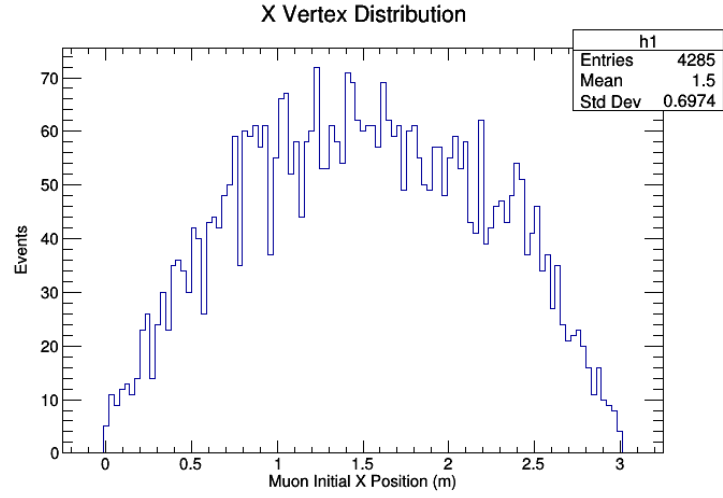


Figure 46: This is a plot right here. Nice of you to notice!

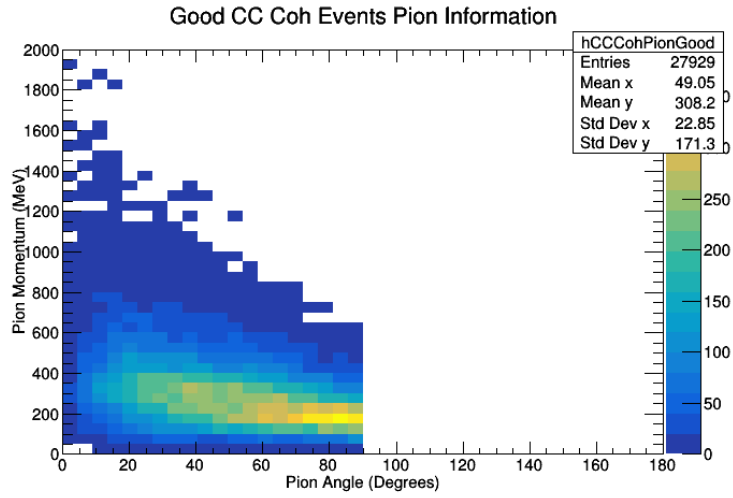


Figure 47: This is a plot right here. Nice of you to notice!

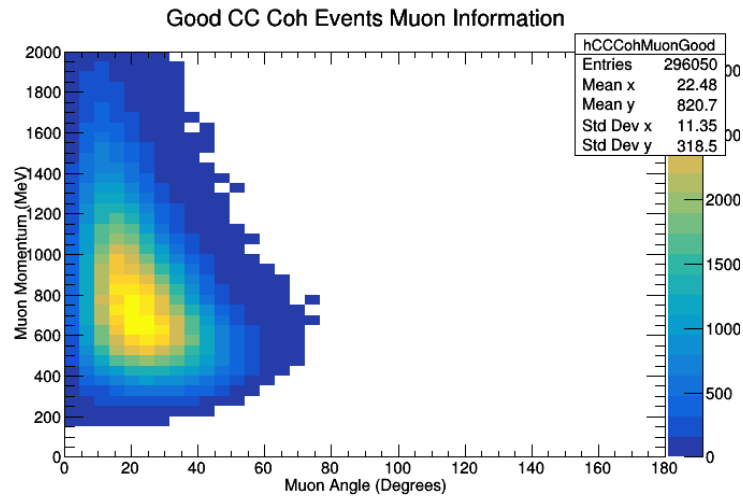


Figure 48: This is a plot right here. Nice of you to notice!

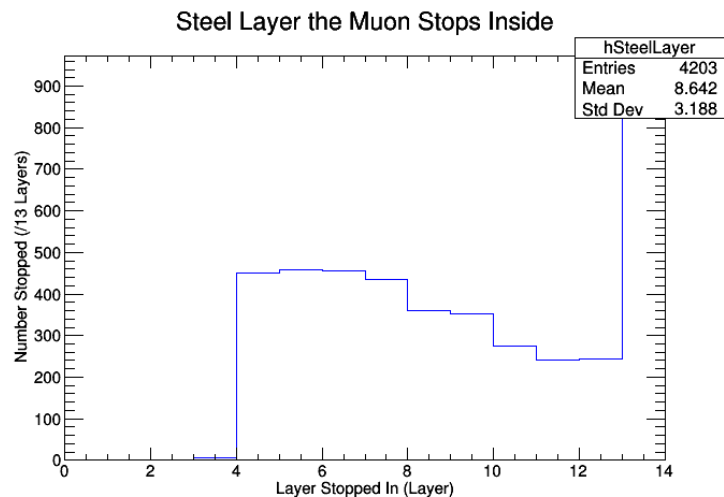


Figure 49: This is a plot right here. Nice of you to notice!

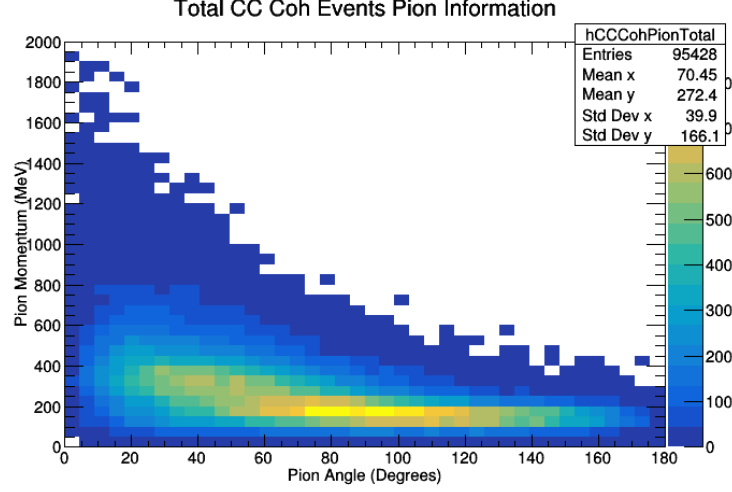


Figure 50: This is a plot right here. Nice of you to notice!

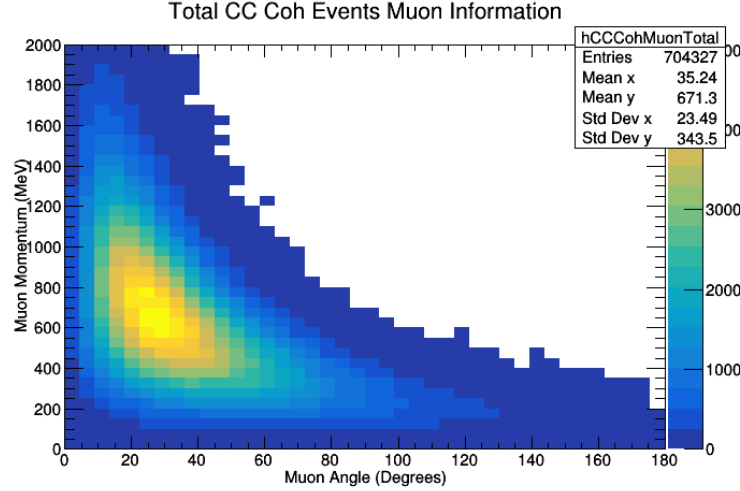


Figure 51: This is a plot right here. Nice of you to notice!

The NewANMBergerSehgal.C macro also calculates many different quantities for the generated simulation of the events and saves the information in histograms that are later called upon through the plotting macros (which are after all of the analysis macros). The first quantity that is calculated for the different vertexes is the momentum of both the muon and the pion, which are both calculated using the equations:

$$|\vec{p}_\mu| = \sqrt{P_{\mu_x}^2 + P_{\mu_y}^2 + P_{\mu_z}^2} \quad (33)$$

$$|\vec{p}_\pi| = \sqrt{P_{\pi_x}^2 + P_{\pi_y}^2 + P_{\pi_z}^2} \quad (34)$$

The momentum is reported in units of MeV/c .

The next quantity that is calculated in the macro is the angle from the beam-direction for both the muon and the pion, which are labeled as either θ_μ , or θ_π , respectively. The angle from the beam-direction is the same as the angle from the z-direction, and this angle is known as the azimuthal

angle. The calculation of the azimuthal angle is slightly more involved than the simple calculation used for finding the magnitude of the momentum of the two particles, and is calculated using the equations:

$$\theta_\mu = \tan^{-1}(\sqrt{P_{\mu_x}^2 + P_{\mu_y}^2}/P_{\mu_z}) \quad (35)$$

$$\theta_\pi = \tan^{-1}(\sqrt{P_{\pi_x}^2 + P_{\pi_y}^2}/P_{\pi_z}) \quad (36)$$

The angles are reported in units of $^\circ$, and should run from 0° to 180° . In the case of Charged-Current Coherent Pion Production, the angle should never be larger than 90° .

The last two quantities that this analysis macro calculates are the two different types of four-momentum transfers specific to this interaction, which are Q^2 and $|t|$. The Q^2 corresponds to the four-momentum transfer from the neutrino and muon to the nucleus and pion, and is calculated using the equation:

$$Q^2 = |(P_{\nu_\mu} - P_\mu)^2| \quad (37)$$

This equation is the four-momentum notational form. The code follows the equation below in order to compute Q^2 :

$$Q^2 = |(P_{\nu_{\mu,x}} - P_{\mu_x})^2 + (P_{\nu_{\mu,y}} - P_{\mu_y})^2 + (P_{\nu_{\mu,z}} - P_{\mu_z})^2 + (P_{\nu_{\mu,E}} - P_{\mu_E})^2| \quad (38)$$

Q^2 is reported in units of $(MeV/c)^2$.

The $|t|$ corresponds to the four-momentum transfer from the neutrino, muon, and pion to the nucleus, and is calculated using the equation:

$$|t| = |(Q - P_\pi)^2| = |(P_{\nu_\mu} - P_\mu - P_\pi)^2| \quad (39)$$

This equation is the four-momentum notational form. The code follows the equation below in order to compute $|t|$:

$$|t| = |(P_{\nu_{\mu,x}} - P_{\mu_x} - P_{\pi_x})^2 + (P_{\nu_{\mu,y}} - P_{\mu_y} - P_{\pi_y})^2 + (P_{\nu_{\mu,z}} - P_{\mu_z} - P_{\pi_z})^2 + (P_{\nu_{\mu,E}} - P_{\mu_E} - P_{\pi_E})^2| \quad (40)$$

$|t|$ is reported in units of $(MeV/c)^2$.

A.12 NMCombinedPlots.C

I need to come back and insert all of my images here.

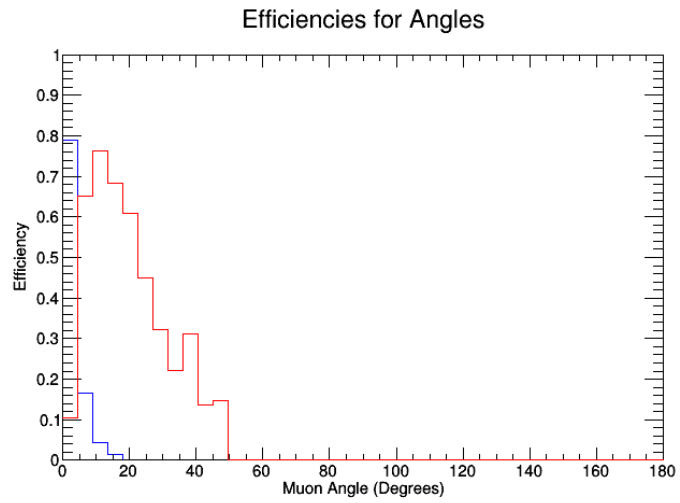


Figure 52: This is a plot right here. Nice of you to notice!

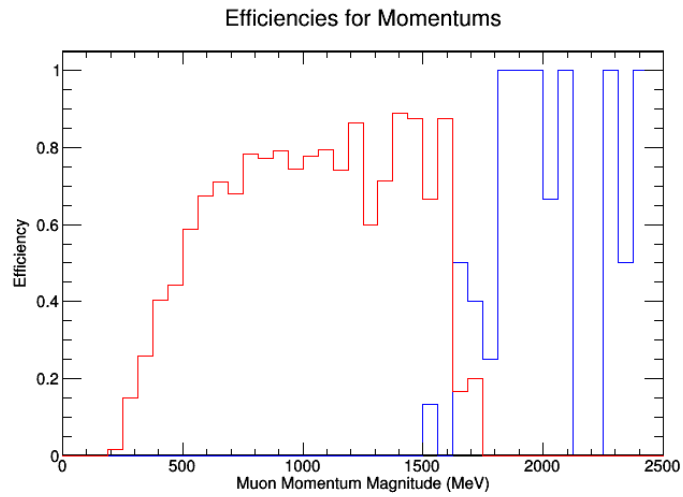


Figure 53: This is a plot right here. Nice of you to notice!

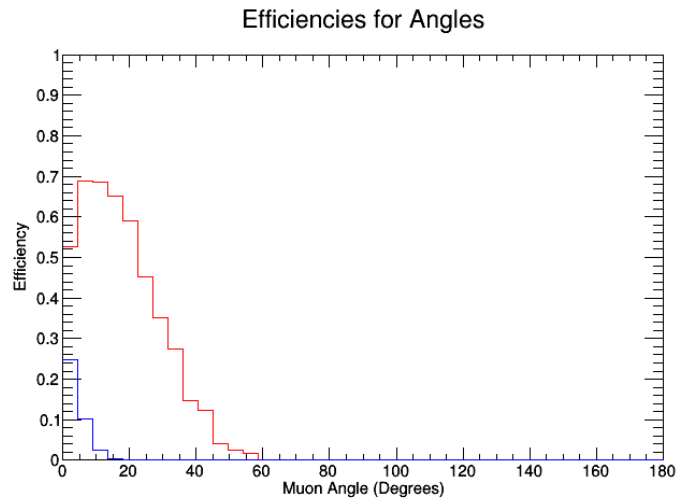


Figure 54: This is a plot right here. Nice of you to notice!

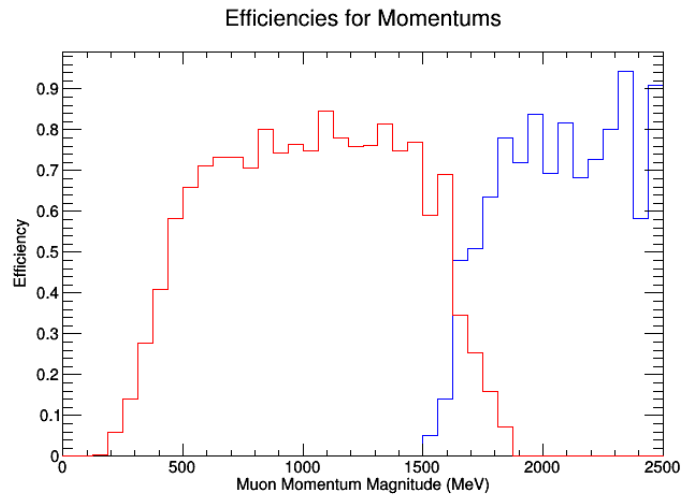


Figure 55: This is a plot right here. Nice of you to notice!

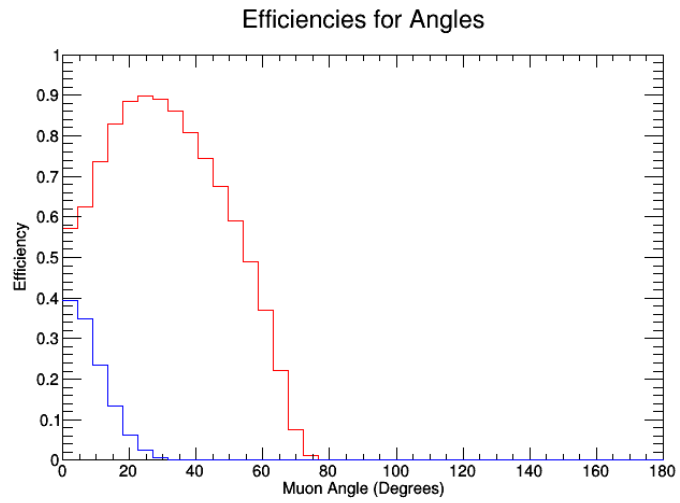


Figure 56: This is a plot right here. Nice of you to notice!

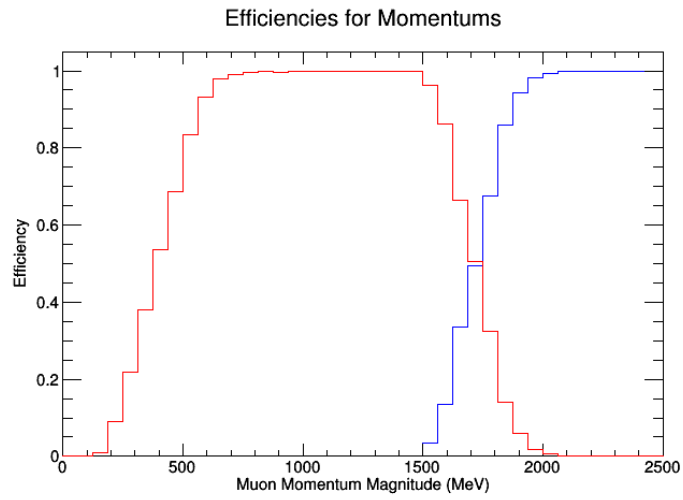


Figure 57: This is a plot right here. Nice of you to notice!

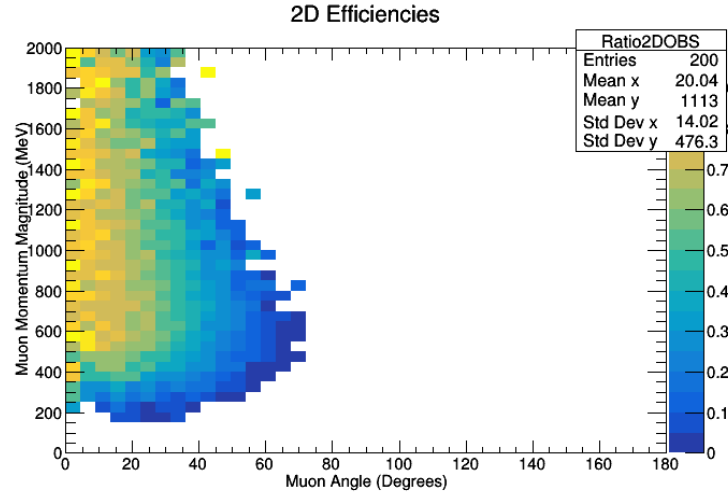


Figure 58: This is a plot right here. Nice of you to notice!

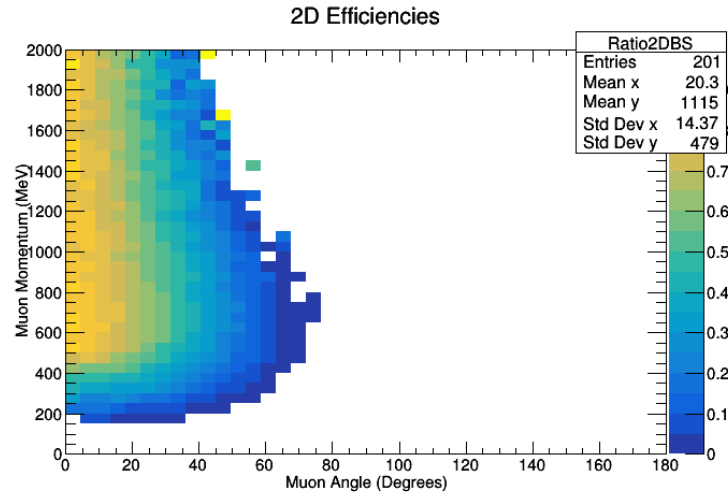


Figure 59: This is a plot right here. Nice of you to notice!

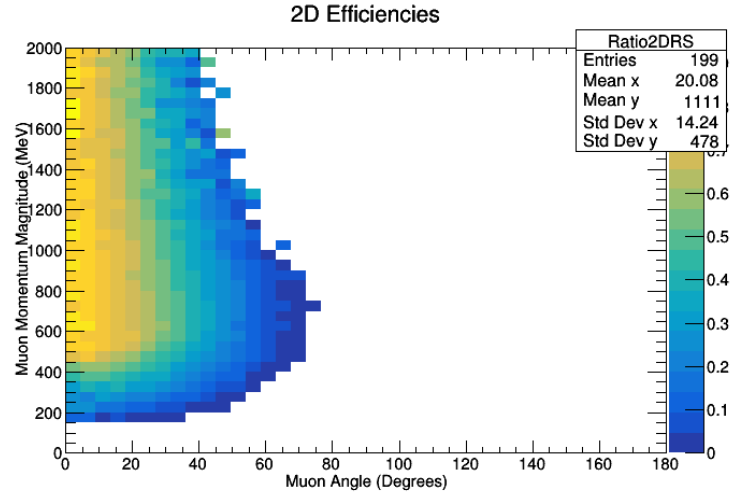


Figure 60: This is a plot right here. Nice of you to notice!

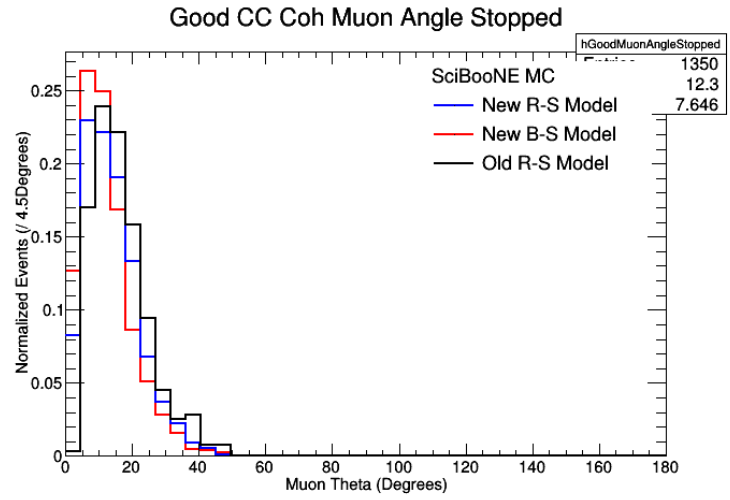


Figure 61: This is a plot right here. Nice of you to notice!

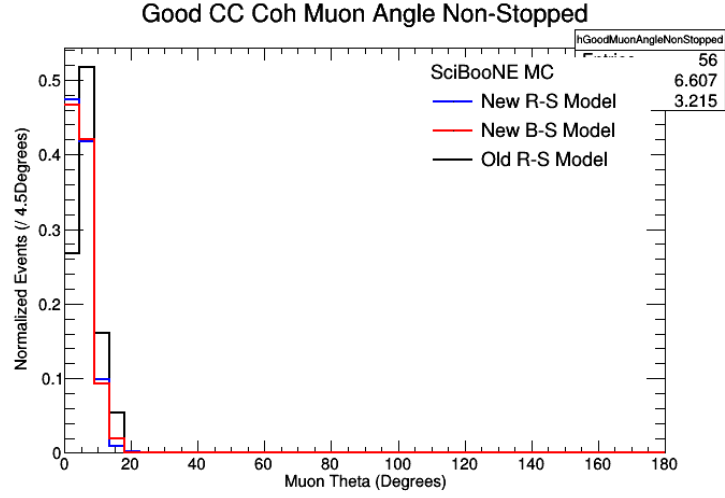


Figure 62: This is a plot right here. Nice of you to notice!

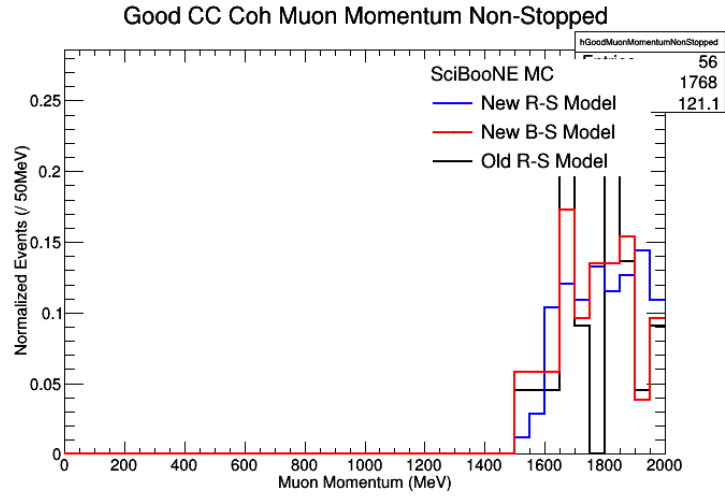


Figure 63: This is a plot right here. Nice of you to notice!

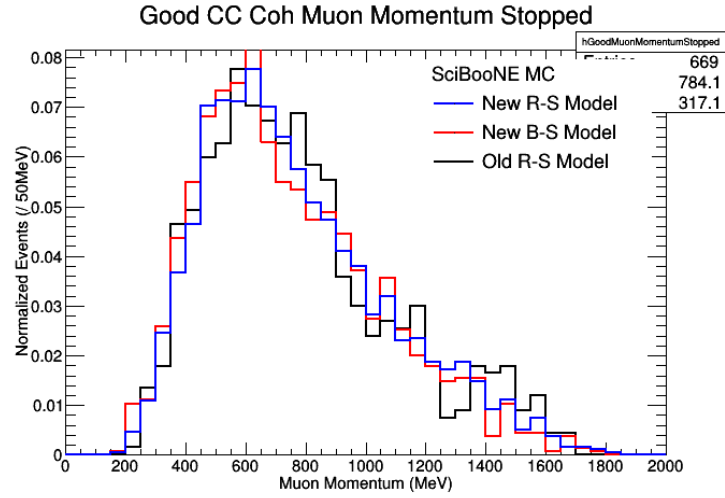


Figure 64: This is a plot right here. Nice of you to notice!

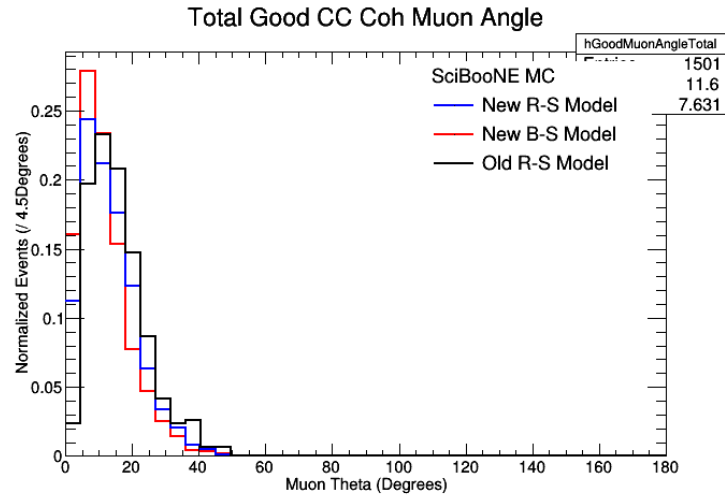


Figure 65: This is a plot right here. Nice of you to notice!

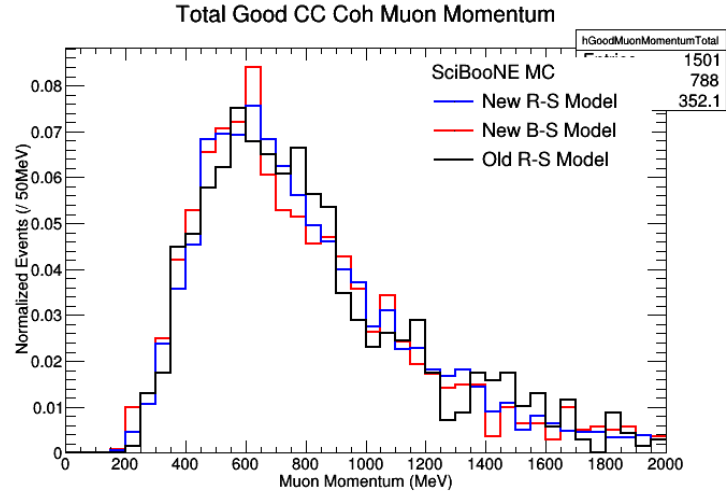


Figure 66: This is a plot right here. Nice of you to notice!

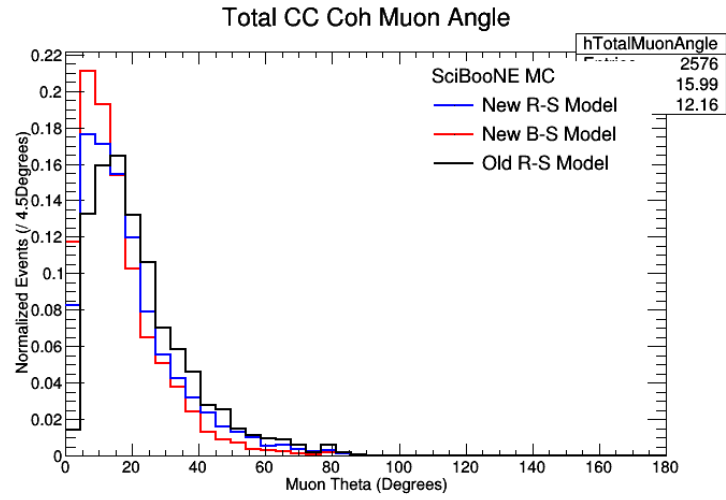


Figure 67: This is a plot right here. Nice of you to notice!

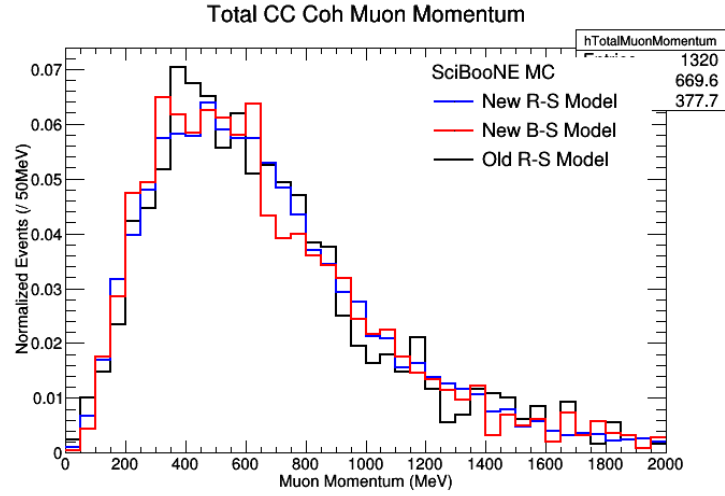


Figure 68: This is a plot right here. Nice of you to notice!

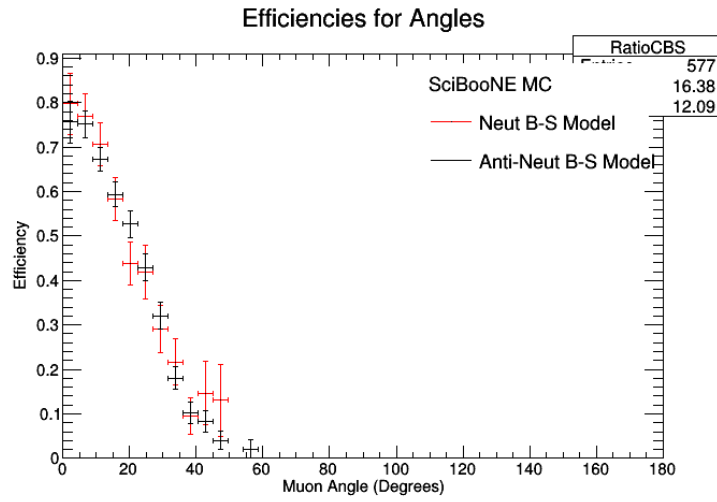


Figure 69: This is a plot right here. Nice of you to notice!

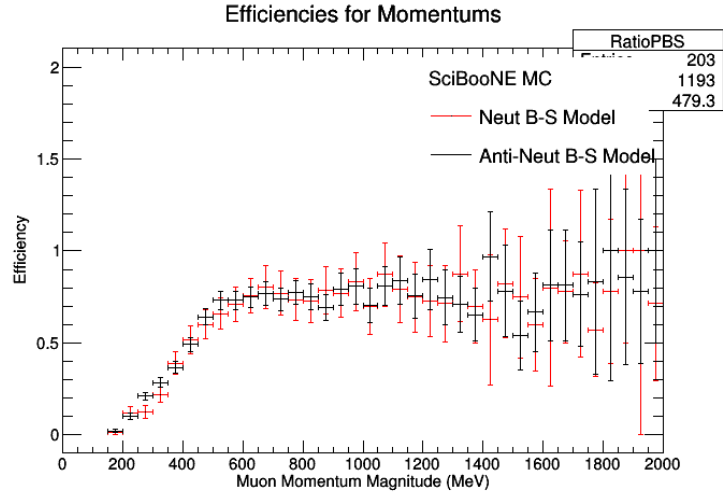


Figure 70: This is a plot right here. Nice of you to notice!

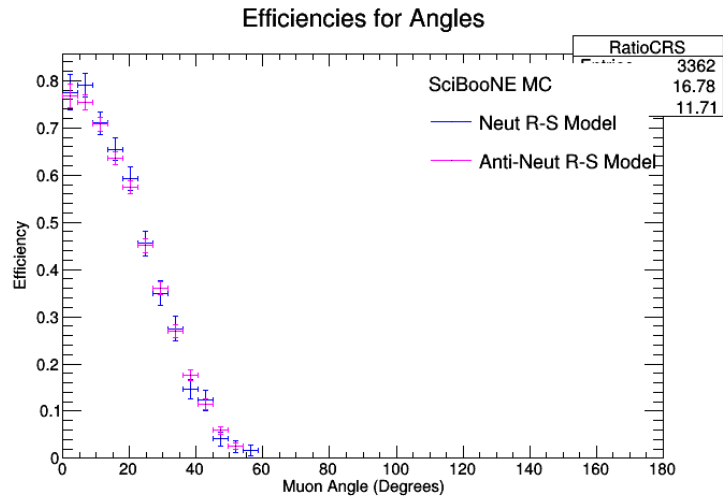


Figure 71: This is a plot right here. Nice of you to notice!

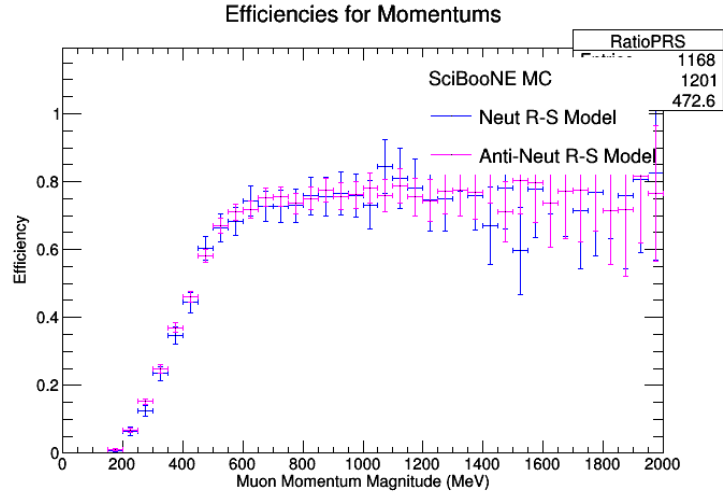


Figure 72: This is a plot right here. Nice of you to notice!

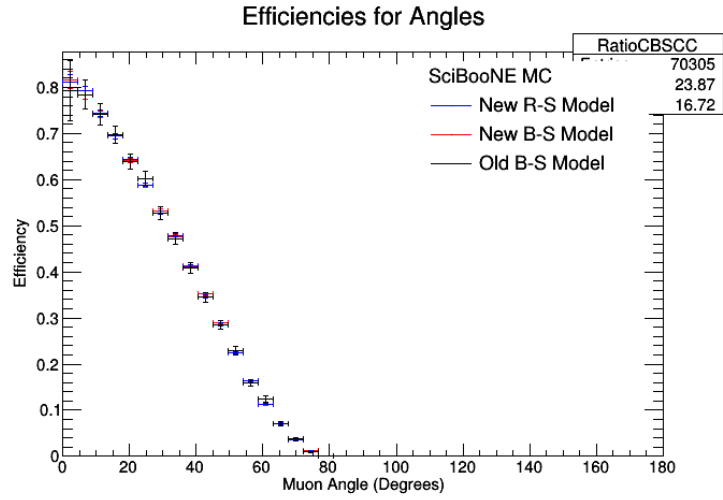


Figure 73: This is a plot right here. Nice of you to notice!

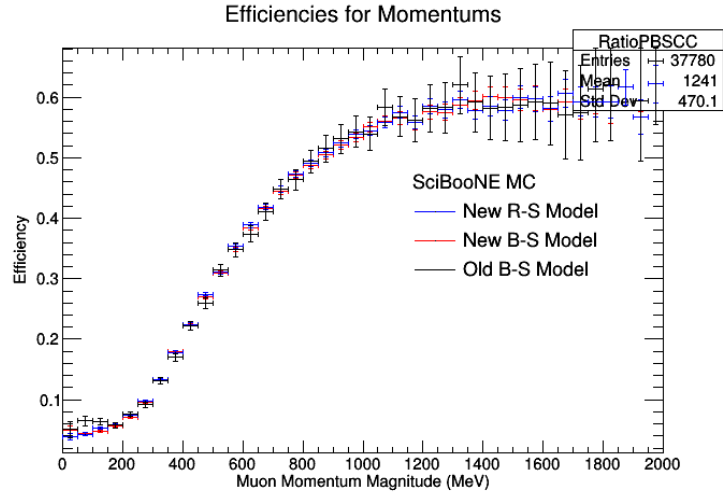


Figure 74: This is a plot right here. Nice of you to notice!

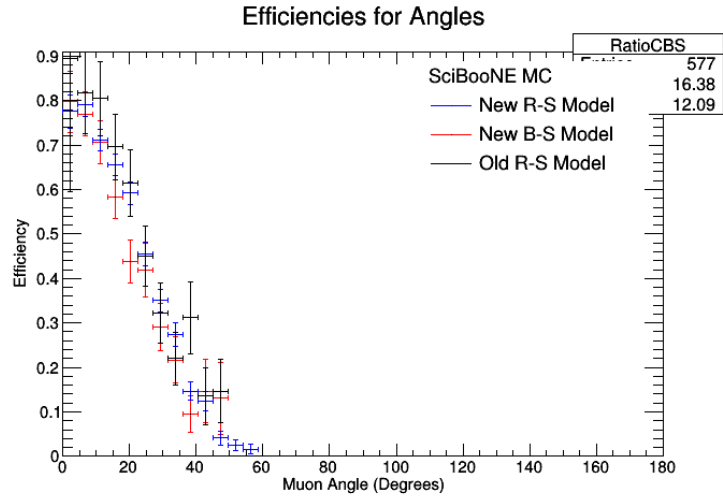


Figure 75: This is a plot right here. Nice of you to notice!

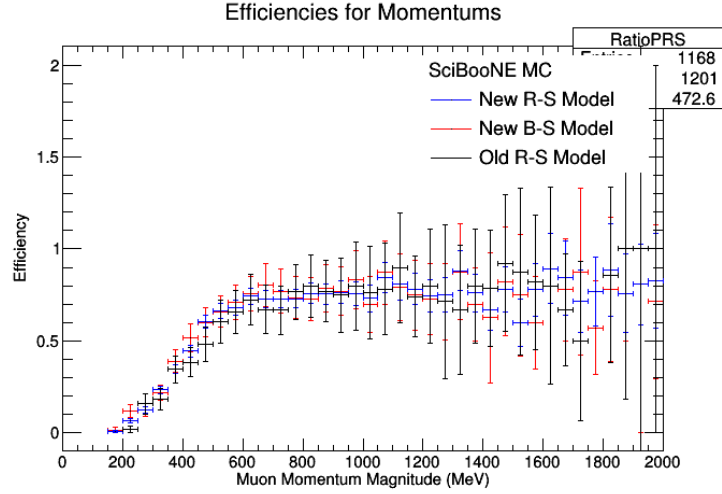


Figure 76: This is a plot right here. Nice of you to notice!

A.13 NMPionPlotting.C

I need to come back and insert all of my images here.

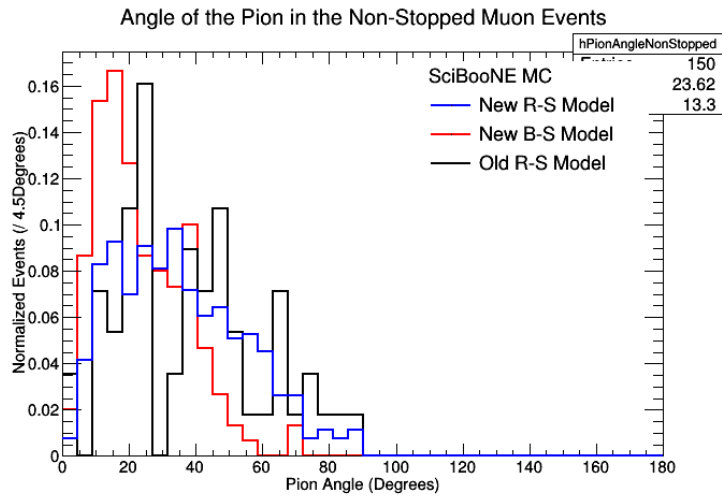


Figure 77: This is a plot right here. Nice of you to notice!

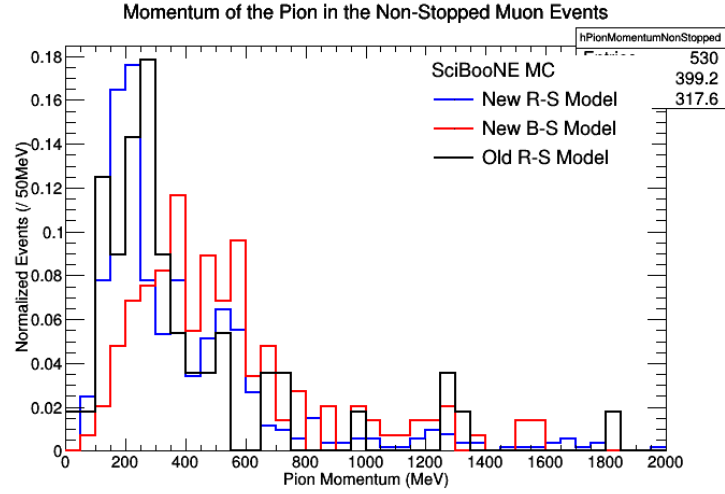


Figure 78: This is a plot right here. Nice of you to notice!

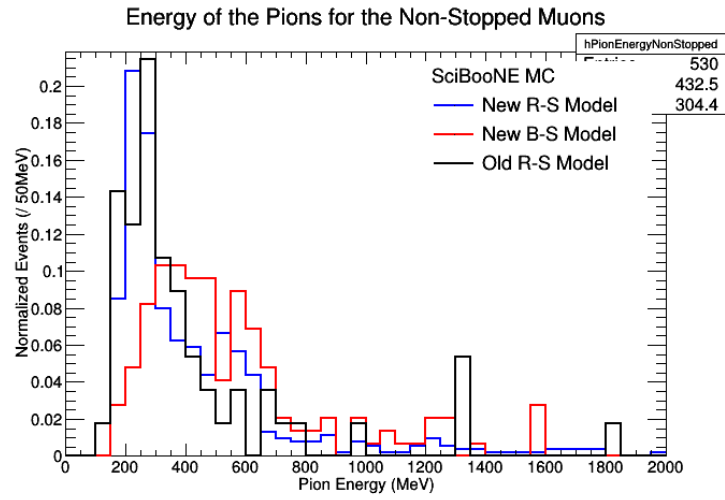


Figure 79: This is a plot right here. Nice of you to notice!

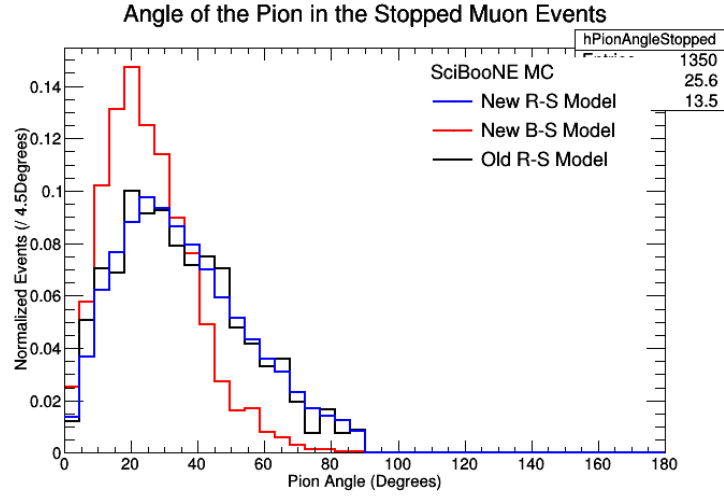


Figure 80: This is a plot right here. Nice of you to notice!

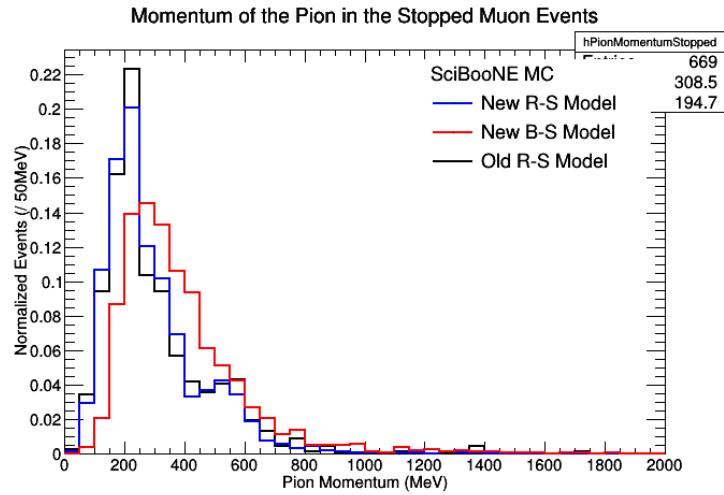


Figure 81: This is a plot right here. Nice of you to notice!

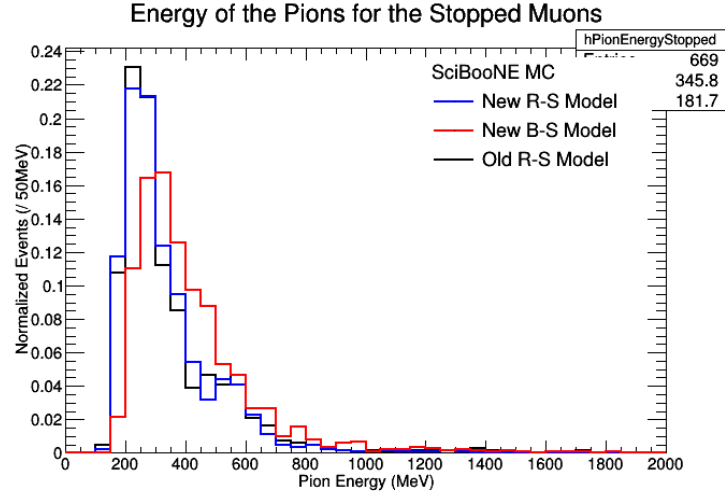


Figure 82: This is a plot right here. Nice of you to notice!

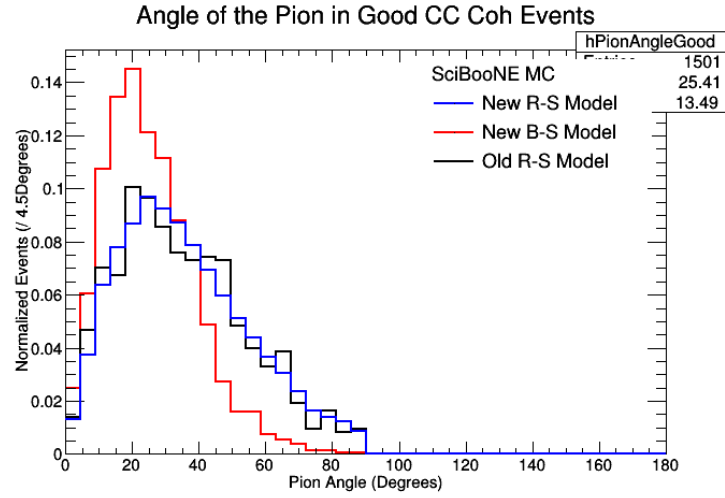


Figure 83: This is a plot right here. Nice of you to notice!

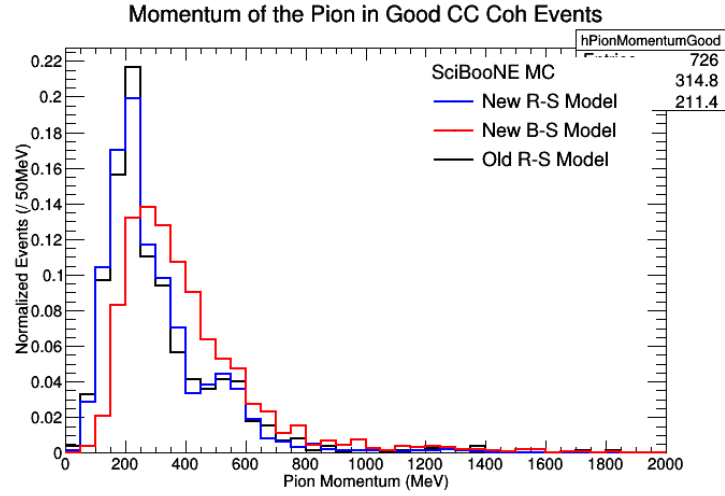


Figure 84: This is a plot right here. Nice of you to notice!

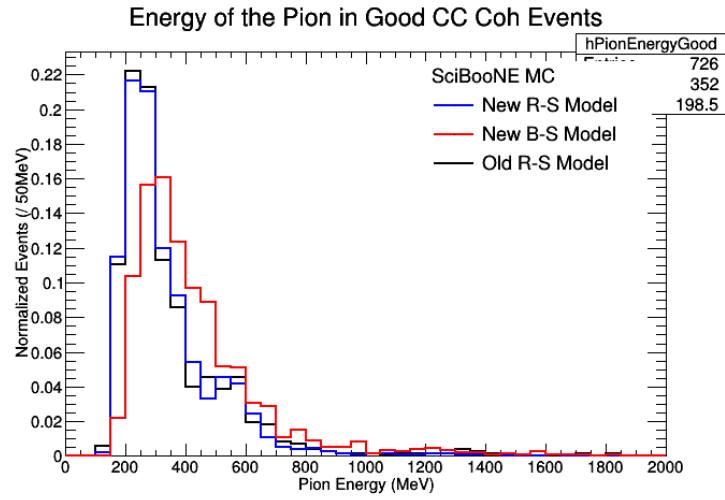


Figure 85: This is a plot right here. Nice of you to notice!

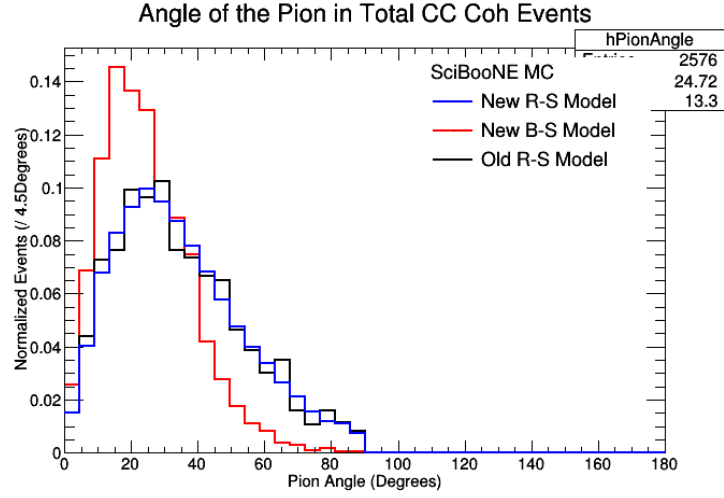


Figure 86: This is a plot right here. Nice of you to notice!

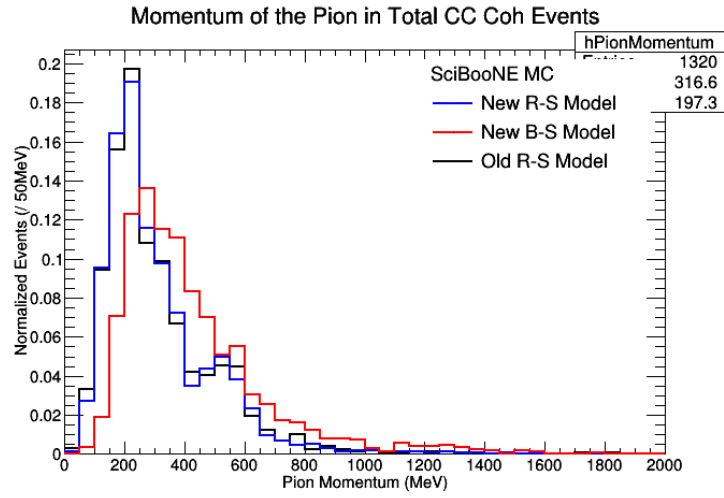


Figure 87: This is a plot right here. Nice of you to notice!

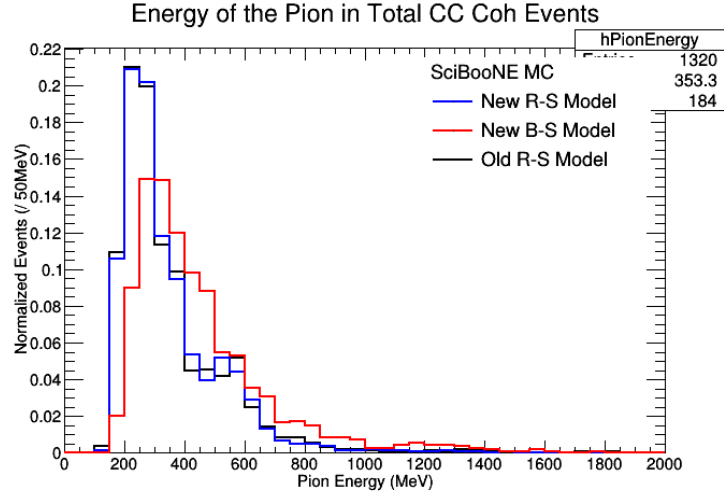


Figure 88: This is a plot right here. Nice of you to notice!

A.14 NMFourSquaredPlotting.C

I need to come back and insert all of my images here.

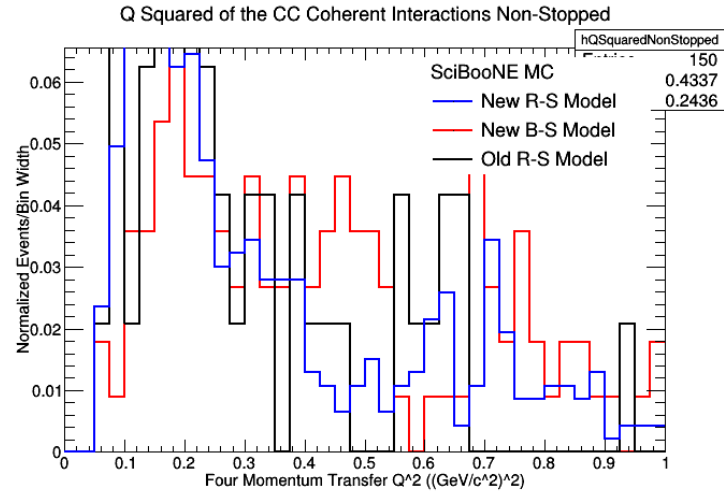


Figure 89: This is a plot right here. Nice of you to notice!

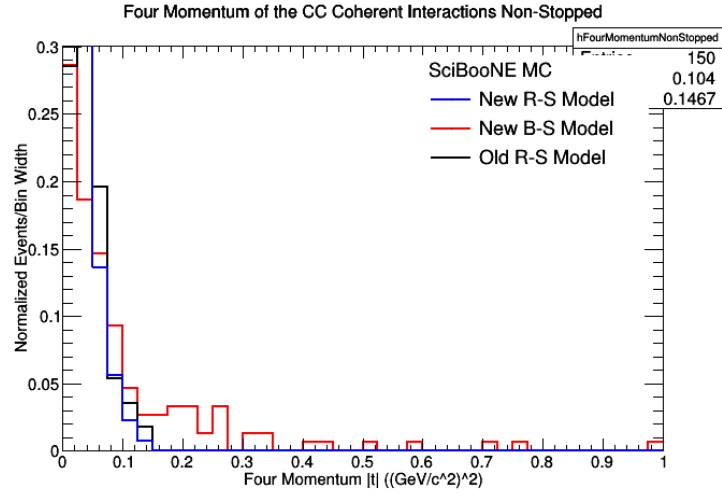


Figure 90: This is a plot right here. Nice of you to notice!

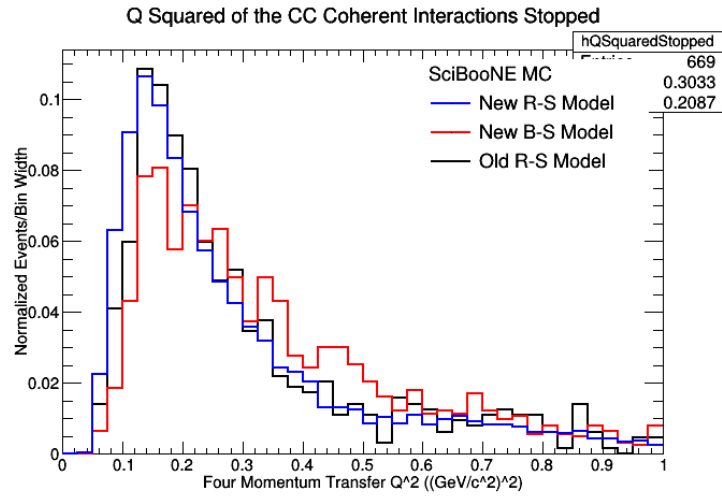


Figure 91: This is a plot right here. Nice of you to notice!

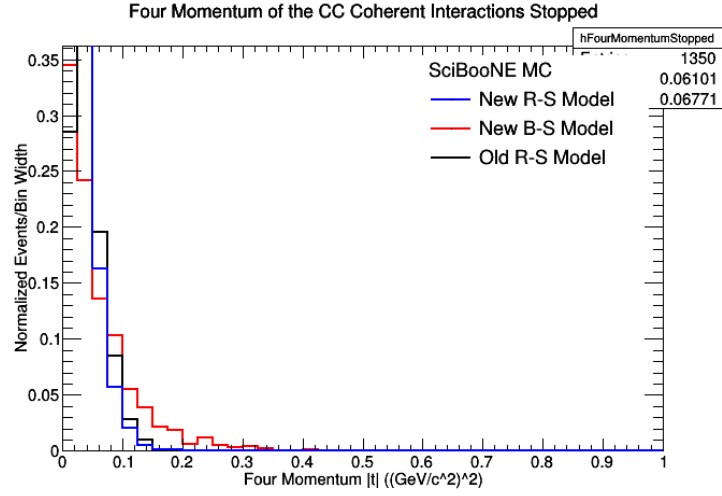


Figure 92: This is a plot right here. Nice of you to notice!

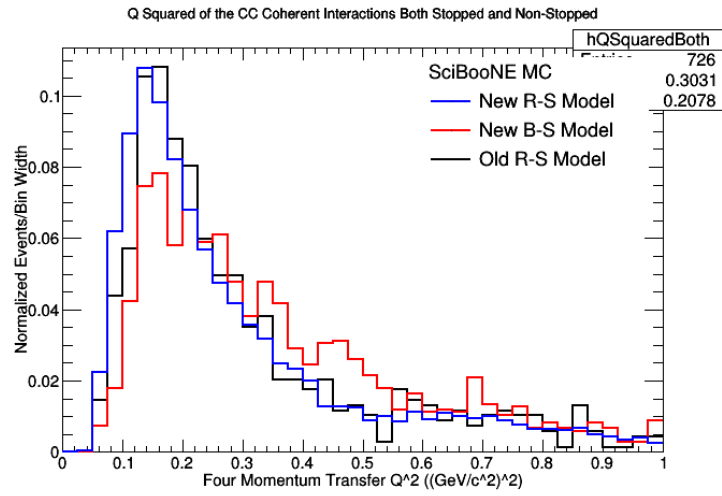


Figure 93: This is a plot right here. Nice of you to notice!

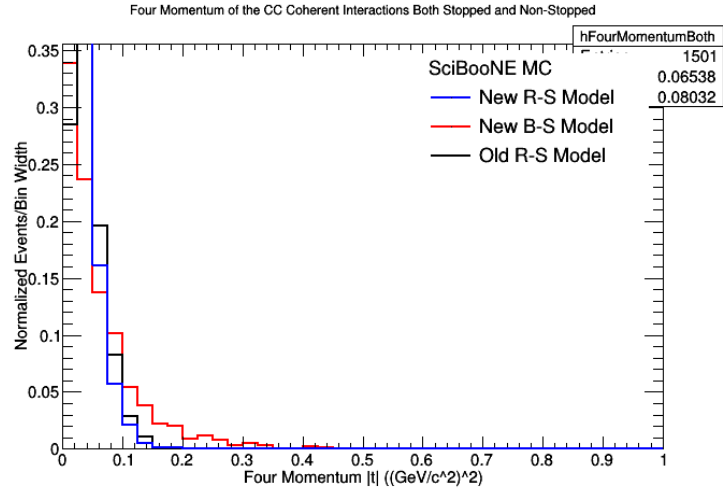


Figure 94: This is a plot right here. Nice of you to notice!

A.15 ANMCombinedPlots.C

I need to come back and insert all of my images here.

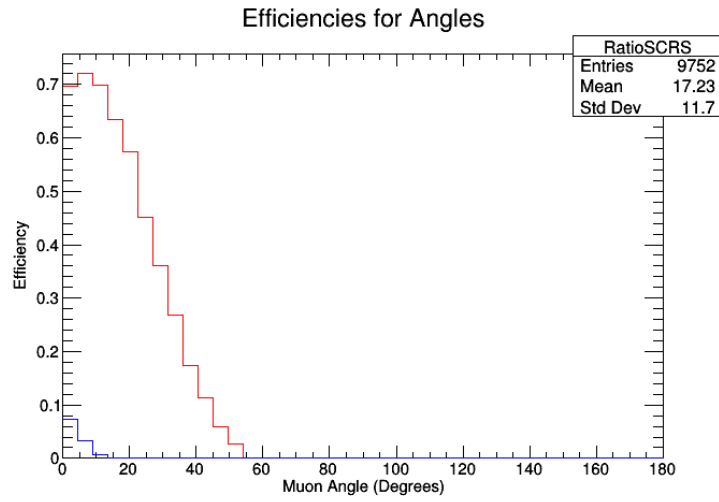


Figure 95: This is a plot right here. Nice of you to notice!

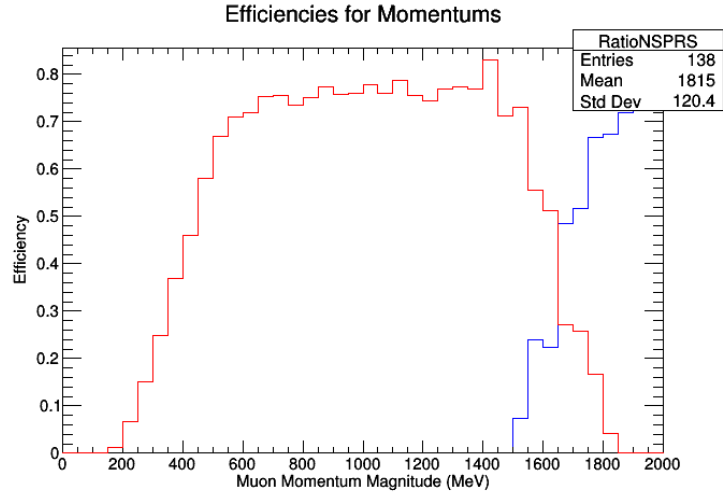


Figure 96: This is a plot right here. Nice of you to notice!

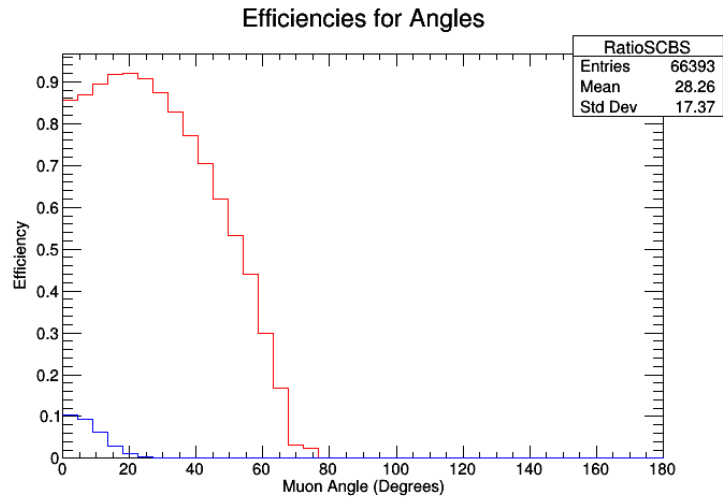


Figure 97: This is a plot right here. Nice of you to notice!

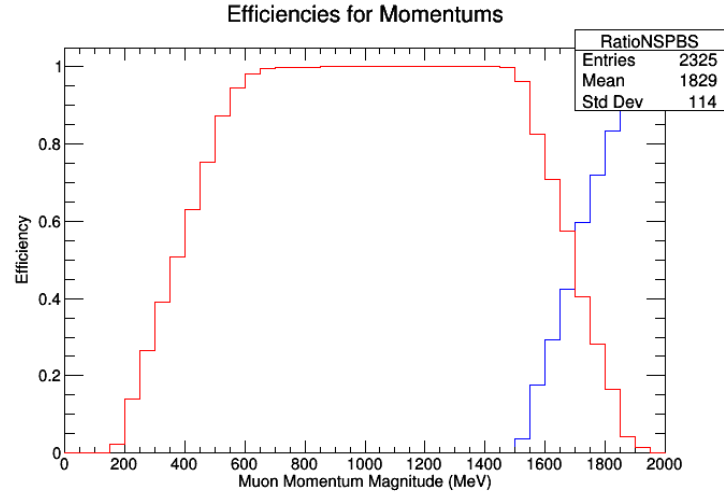


Figure 98: This is a plot right here. Nice of you to notice!

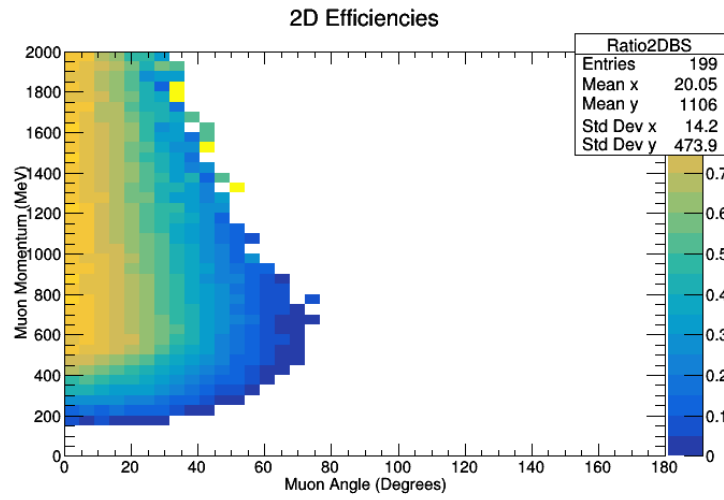


Figure 99: This is a plot right here. Nice of you to notice!

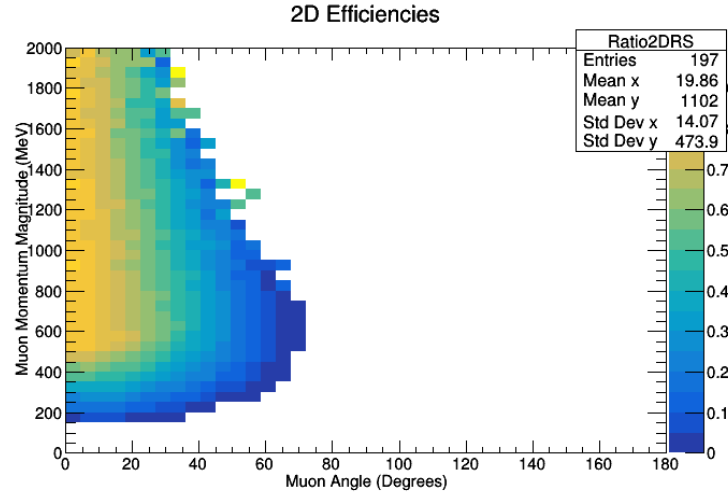


Figure 100: This is a plot right here. Nice of you to notice!

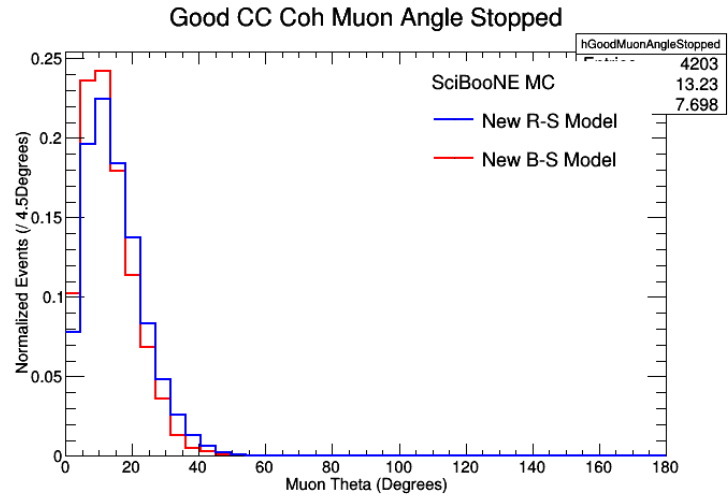


Figure 101: This is a plot right here. Nice of you to notice!

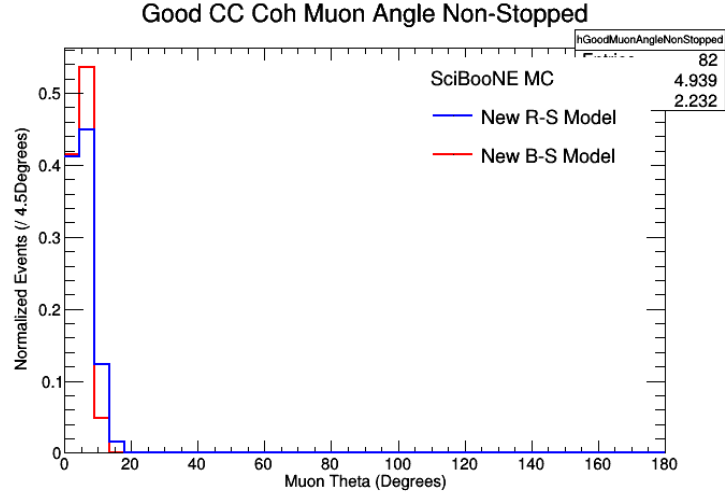


Figure 102: This is a plot right here. Nice of you to notice!

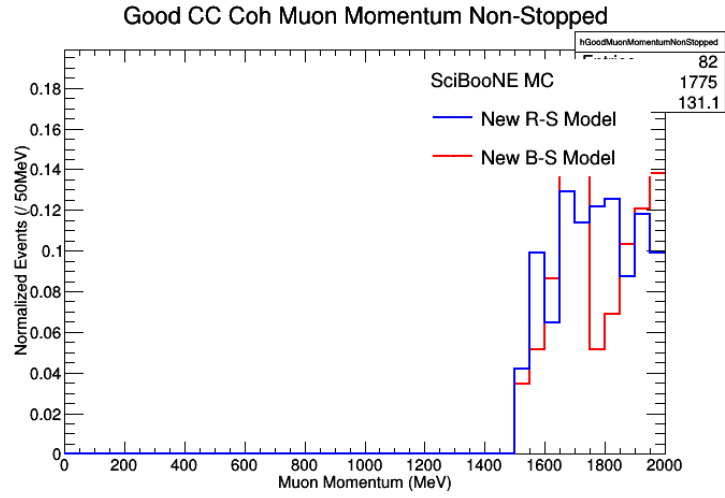


Figure 103: This is a plot right here. Nice of you to notice!

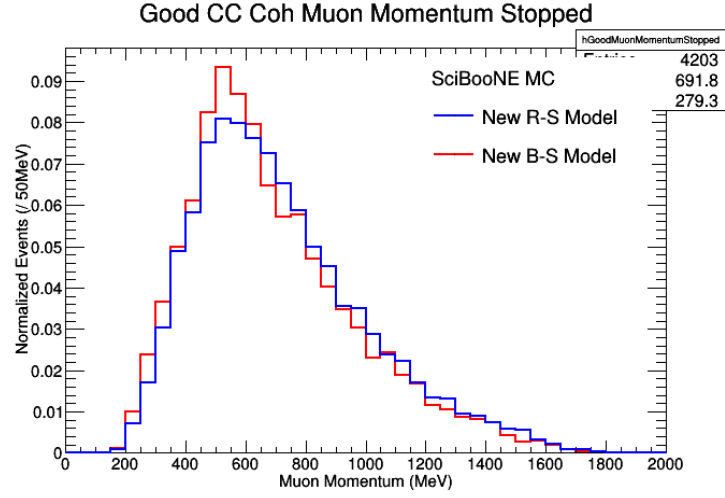


Figure 104: This is a plot right here. Nice of you to notice!

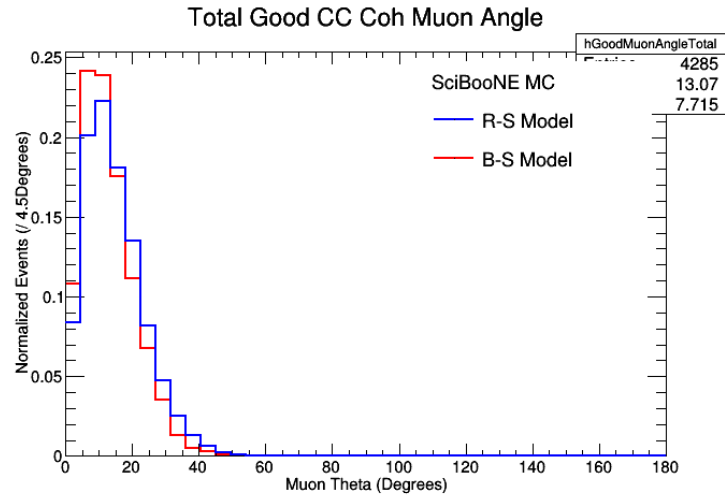


Figure 105: This is a plot right here. Nice of you to notice!

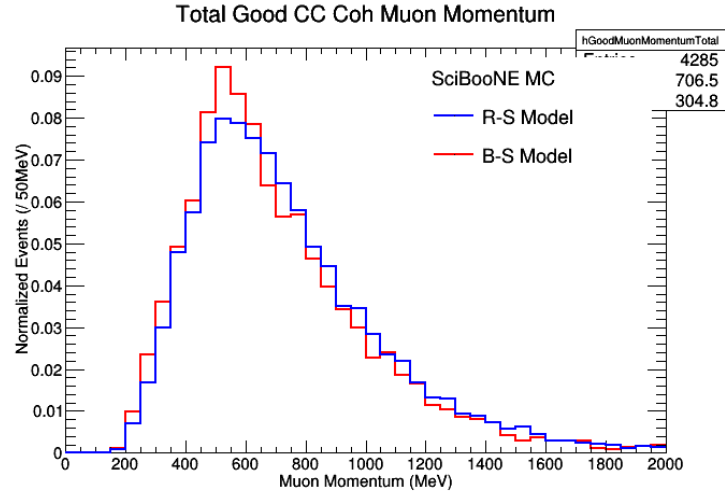


Figure 106: This is a plot right here. Nice of you to notice!

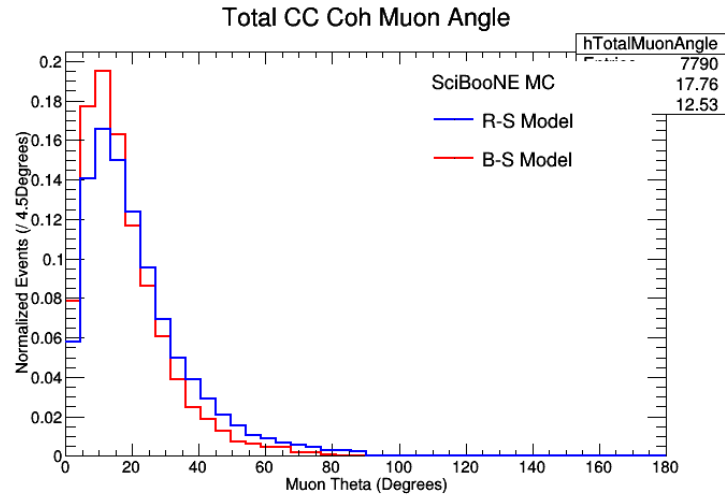


Figure 107: This is a plot right here. Nice of you to notice!

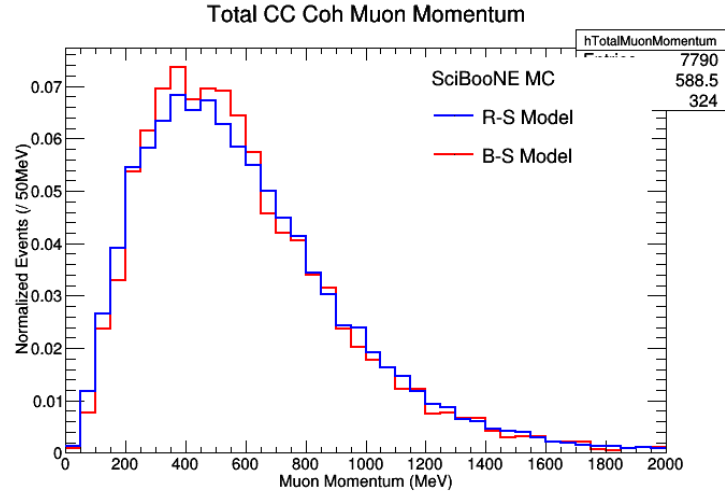


Figure 108: This is a plot right here. Nice of you to notice!

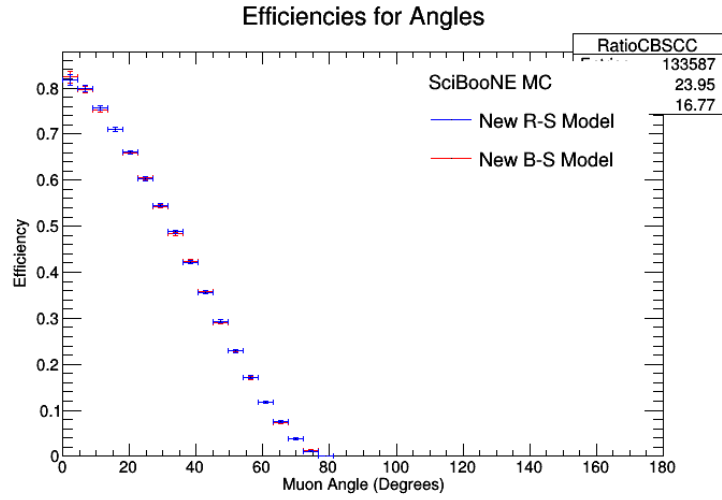


Figure 109: This is a plot right here. Nice of you to notice!

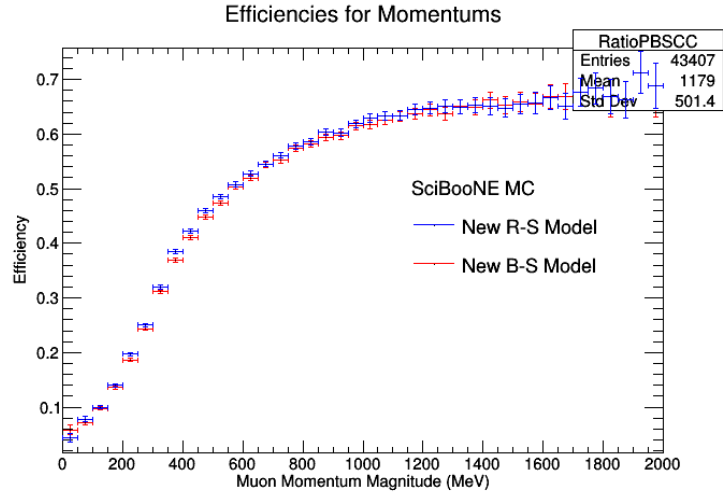


Figure 110: This is a plot right here. Nice of you to notice!

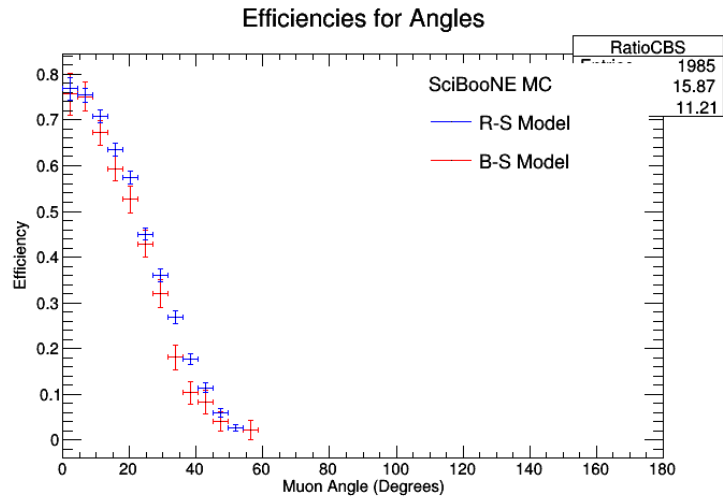


Figure 111: This is a plot right here. Nice of you to notice!

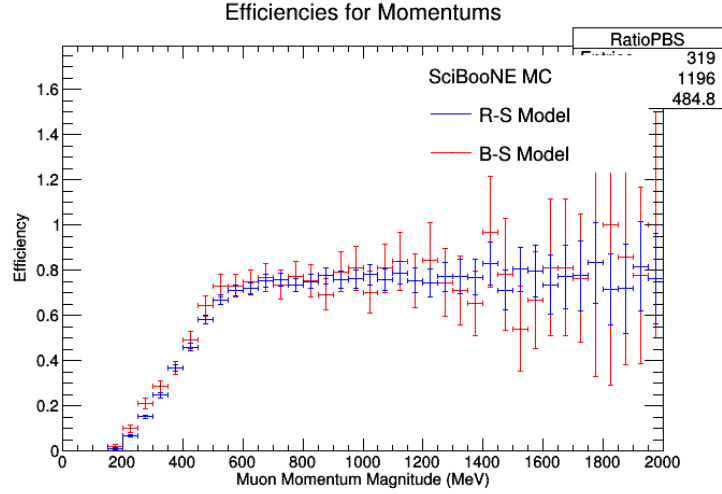


Figure 112: This is a plot right here. Nice of you to notice!

A.16 ANMPionPlotting.C

I need to come back and insert all of my images here.

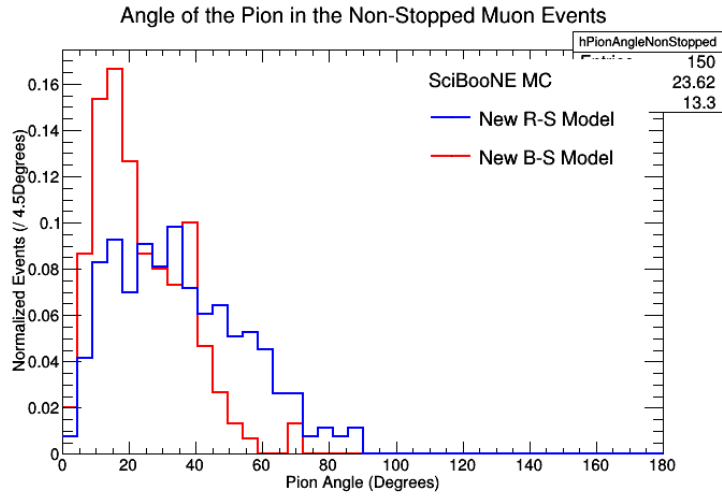


Figure 113: This is a plot right here. Nice of you to notice!

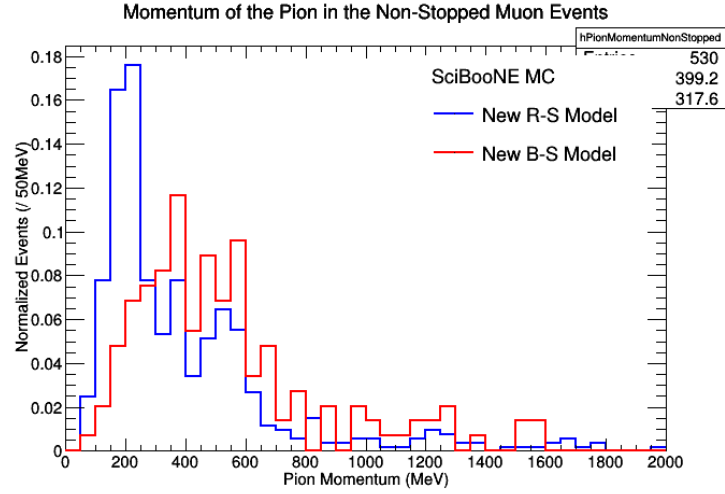


Figure 114: This is a plot right here. Nice of you to notice!

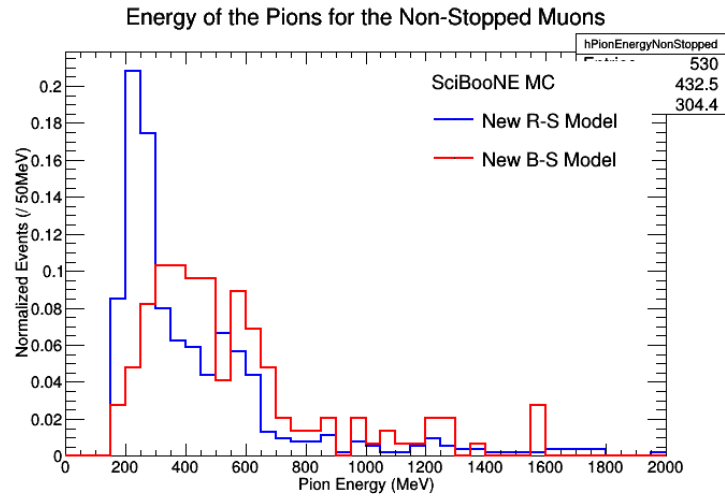


Figure 115: This is a plot right here. Nice of you to notice!

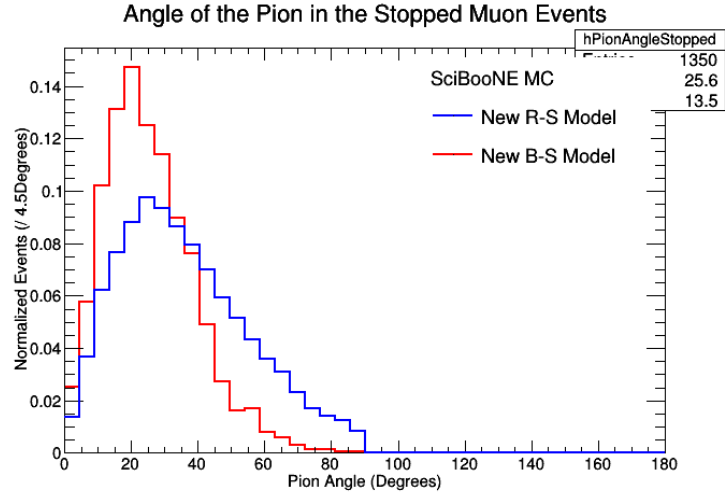


Figure 116: This is a plot right here. Nice of you to notice!

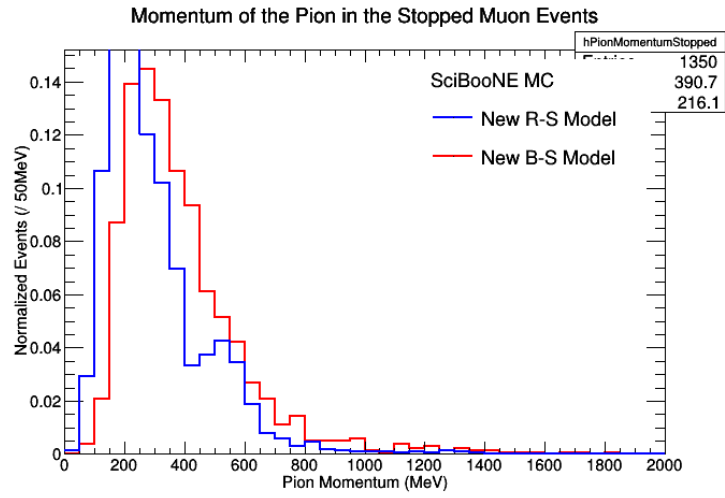


Figure 117: This is a plot right here. Nice of you to notice!

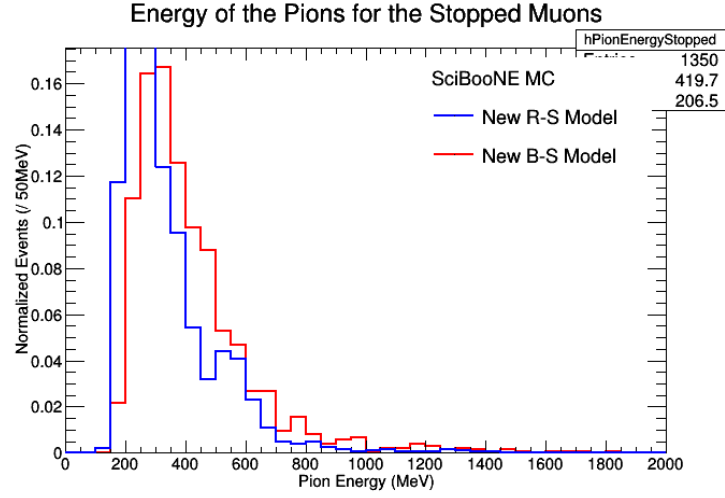


Figure 118: This is a plot right here. Nice of you to notice!

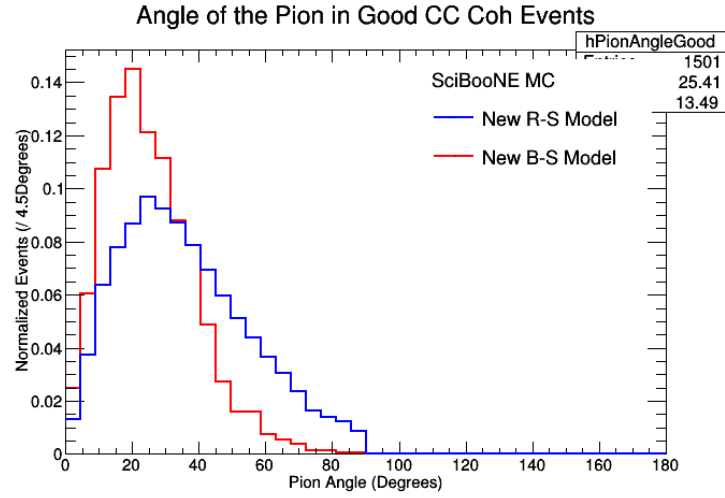


Figure 119: This is a plot right here. Nice of you to notice!

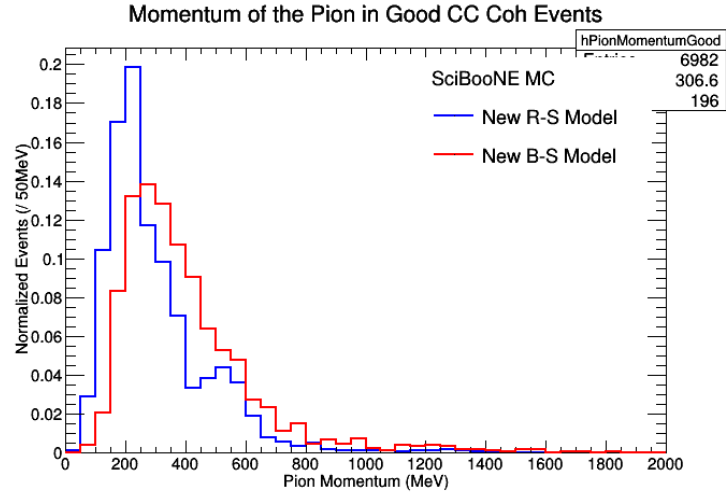


Figure 120: This is a plot right here. Nice of you to notice!

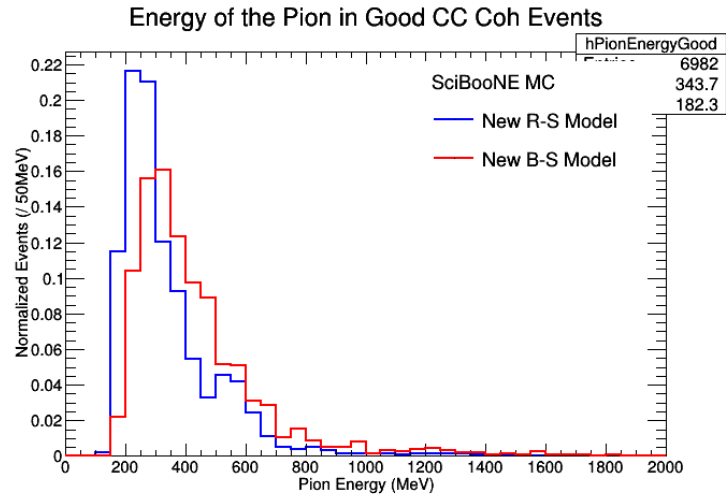


Figure 121: This is a plot right here. Nice of you to notice!

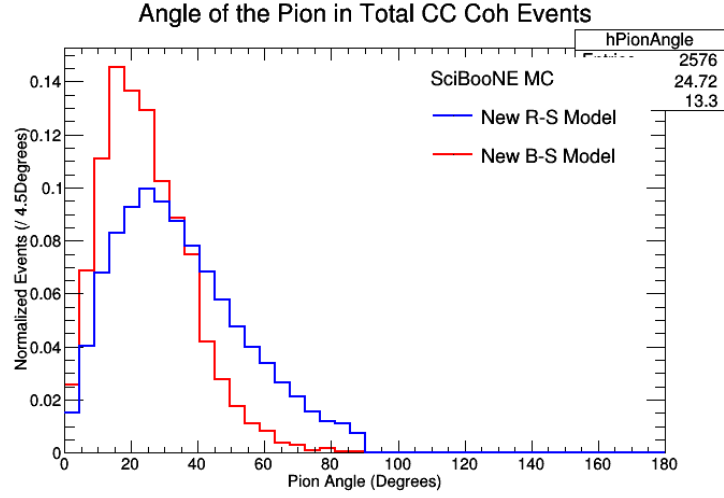


Figure 122: This is a plot right here. Nice of you to notice!

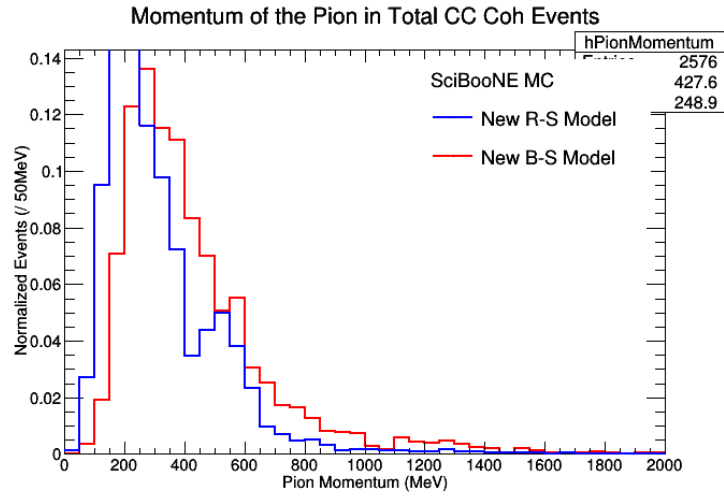


Figure 123: This is a plot right here. Nice of you to notice!

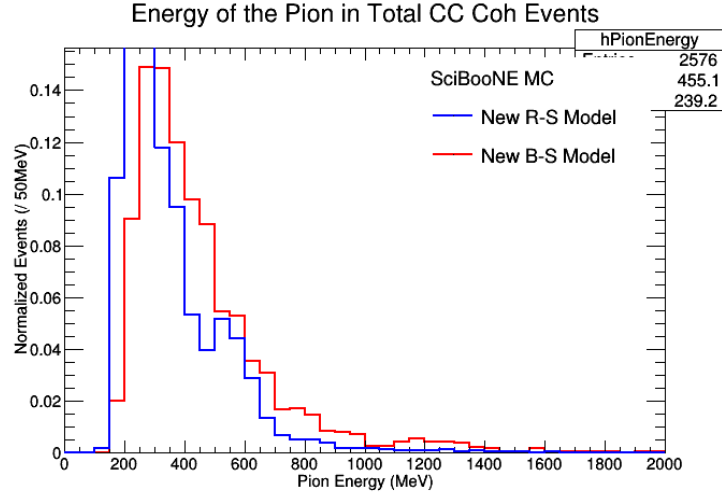


Figure 124: This is a plot right here. Nice of you to notice!

A.17 ANMFourSquaredPlotting.C

I need to come back and insert all of my images here.

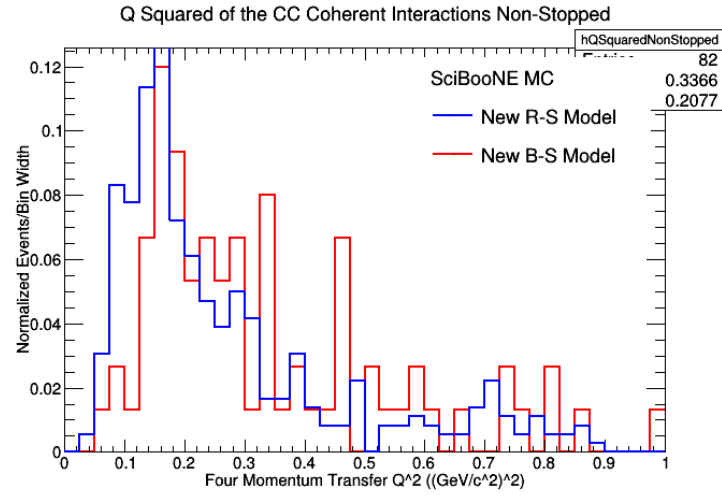


Figure 125: This is a plot right here. Nice of you to notice!

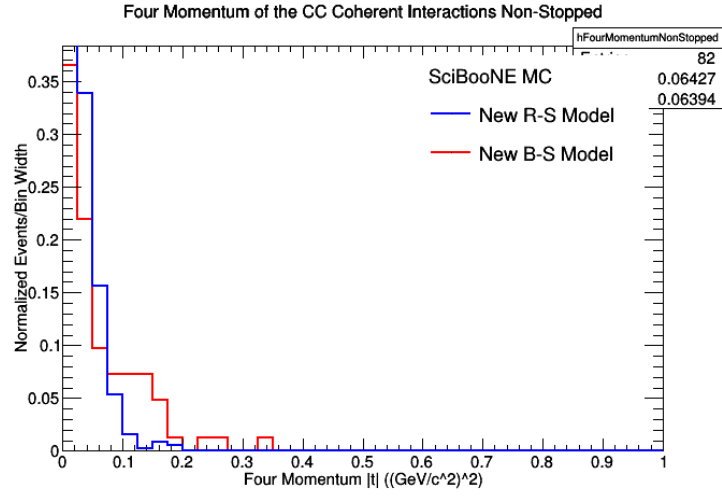


Figure 126: This is a plot right here. Nice of you to notice!

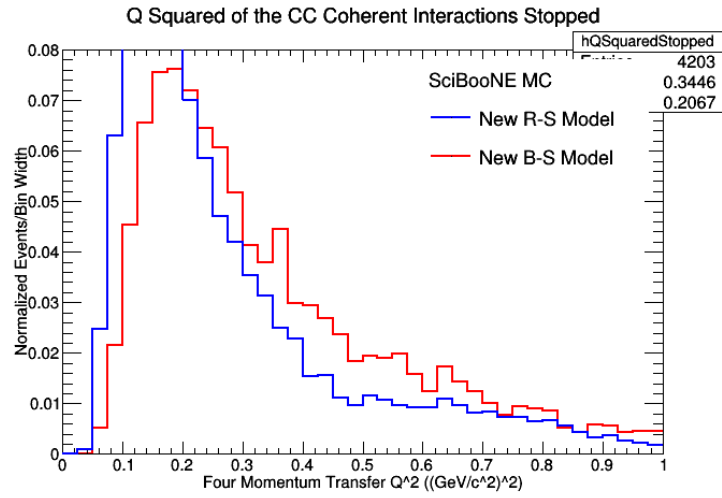


Figure 127: This is a plot right here. Nice of you to notice!

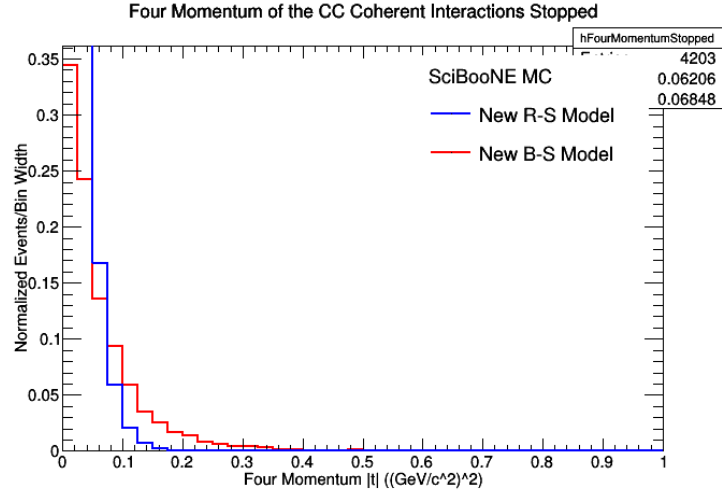


Figure 128: This is a plot right here. Nice of you to notice!

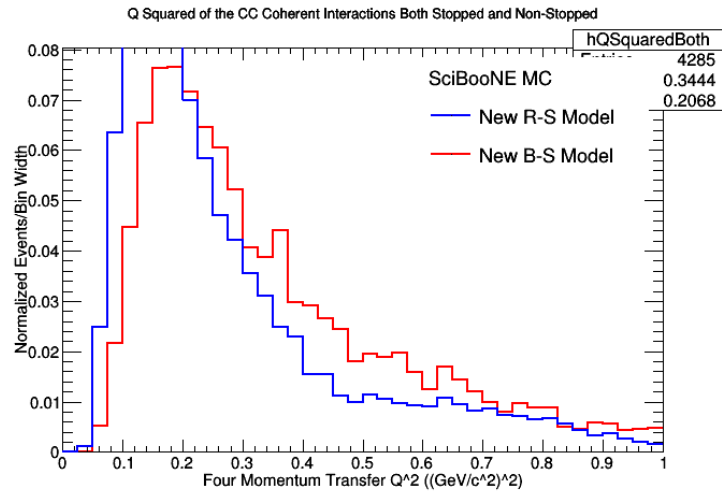


Figure 129: This is a plot right here. Nice of you to notice!

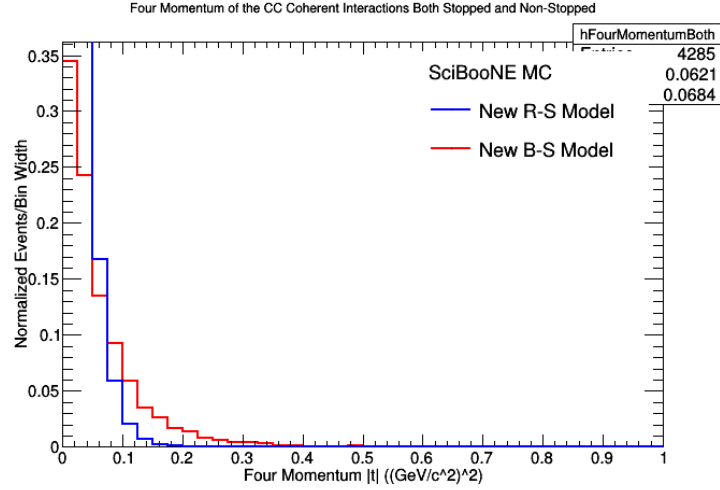


Figure 130: This is a plot right here. Nice of you to notice!

B Steps for Running the Code

The instructions on how to run the code and the order the files need to run in so that there are no resulting error messages, or other issues while running the code, are detailed in this section.

- Step 1: This is the first step. (Run the NewNM macros and the NewANM macros and the OldNM macro.)
- Step 2: This is the second step. (Run the combined plotting macros.)
- Step 3: This is the third step. (Run the Pion Plotting macros.)
- Step 4: Etc. (Run the FourSquaredMomentum macros.)

C Closing Remarks and Cautions

These are just a few cautionary suggestions for potential issues that might be encountered while trying to use this code. This will also be where and further closing remarks can be made.

D Acknowledgements

Thank everyone who helped, and thank everyone who gave their inputs into your acceptance study. YOU NEED TO GIVE A HUGE AND SPECIAL THANKS TO DR. ASAADI RIGHT HERE! (He has been suuuuuuper patient...)

E Appendix

E.1 List of Figures

There will eventually be a huge list of figures here.

E.2 List of Tables

There will eventually be the event reduction tables and 2D histogram tables here.

Table 2: Table for 2D Histogram for New NM-Rein-Sehgal

Year	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
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Table 3: Table for 2D Histogram for New NM-Berger-Sehgal

[illegible]

Table 4: Table for 2D Histogram for Old NM-Rein-Sehgal

Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64																																				

Table 5: Table for 2D Histogram for New ANM-Rein-Sehgal

[illegible]

