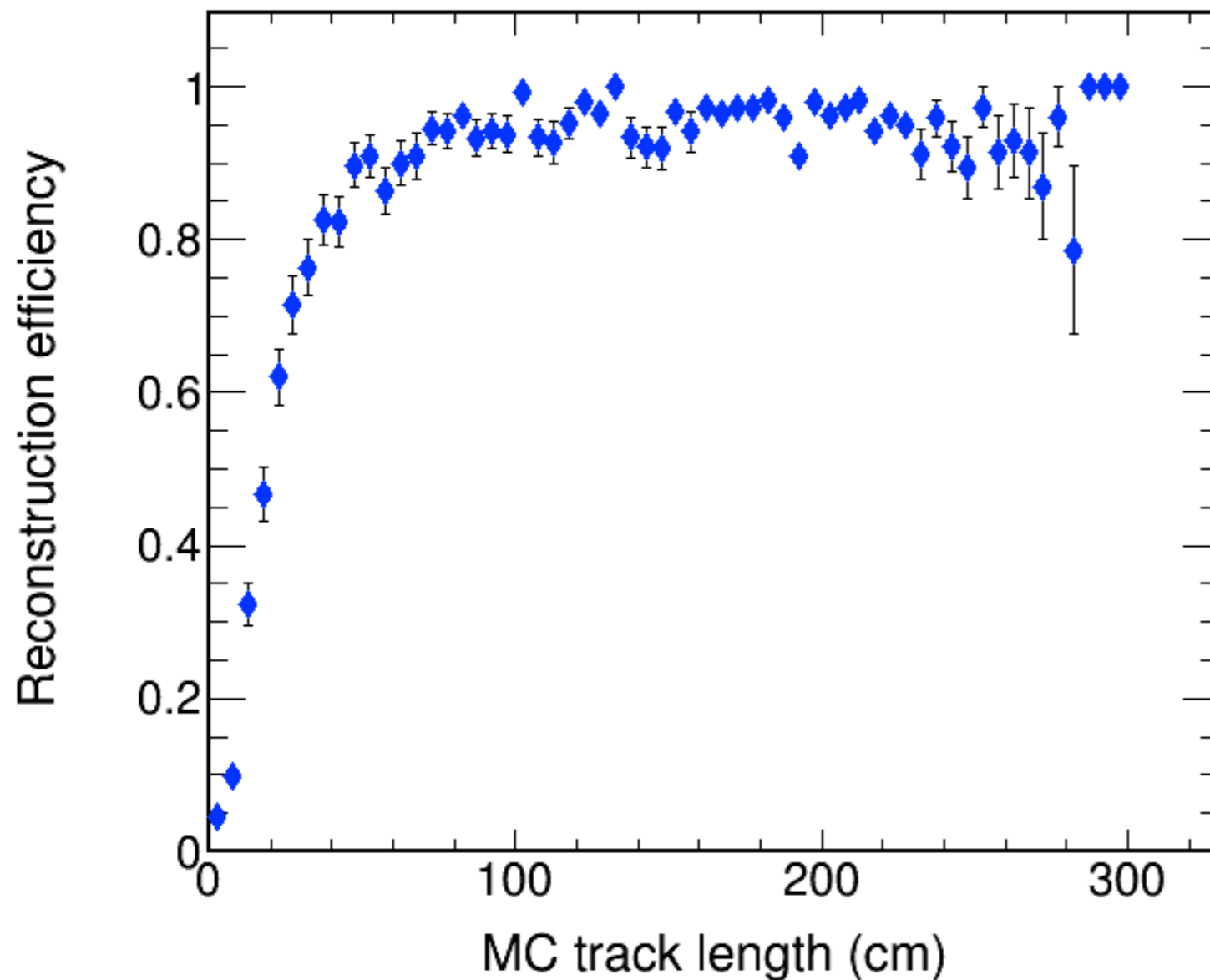# Validation studies of Pandora

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(University of Sheffield)

Pandora is working extremely well for reconstruction in liquid argon.

The plot shows reconstruction efficiency as a function of true track length for single 6 GeV muons with true track length >= 1 cm, where true track length is length within the detector.

Efficiency is 90-100% for tracks with true lengths between ~50 and ~250 cm.

Why are 5-10% of tracks with lengths between 50 and 250 cm not reconstructed by Pandora ? And why are many short tracks not reconstructed ?

Looked at events made by particle gun firing 6 GeV muons at the top of the 35 ton detector. These muons start at different points at the top of the detector and travel in different directions.

Using a home-made event display with 3 histograms: each histogram represents one wire plane (2 induction planes and 1 collection plane), and shows all the reconstructed hits in that plane.

Horizontal axis: hit wire
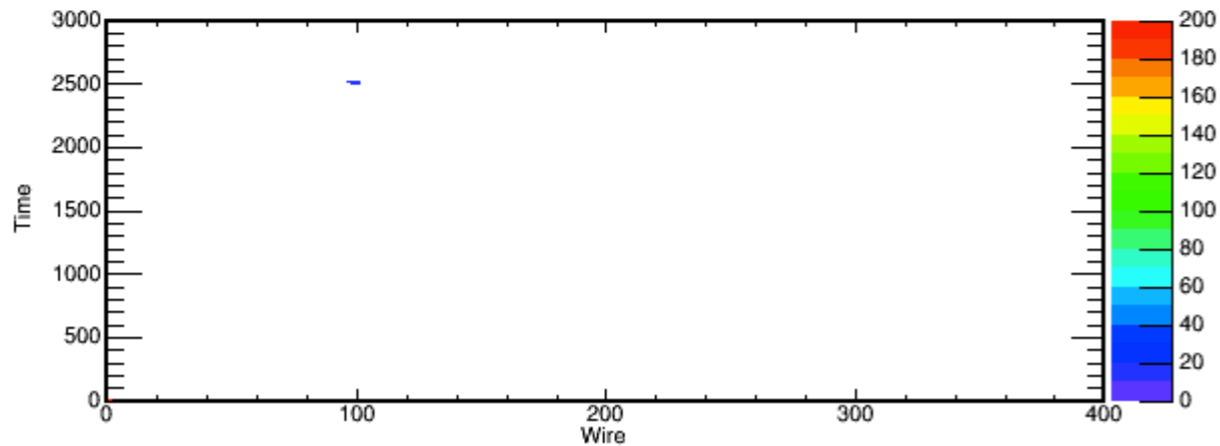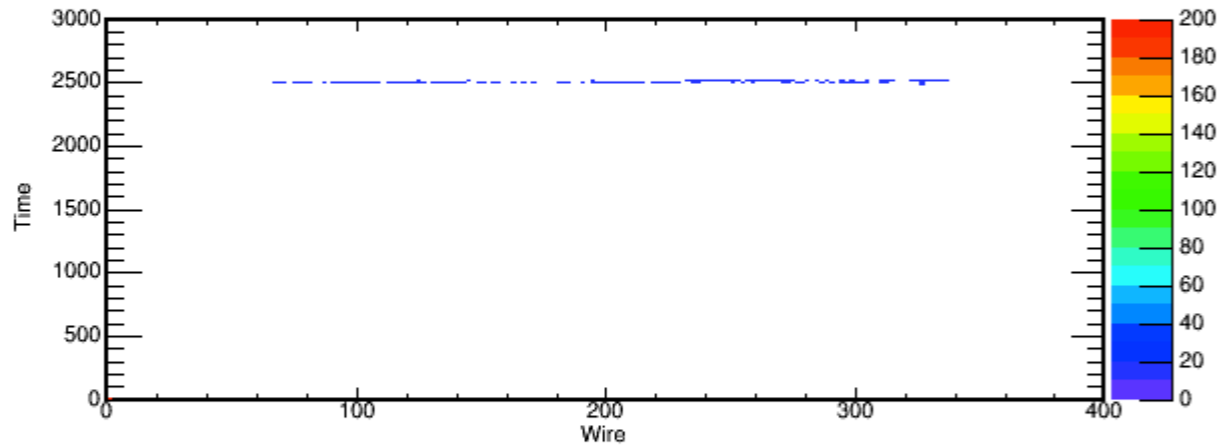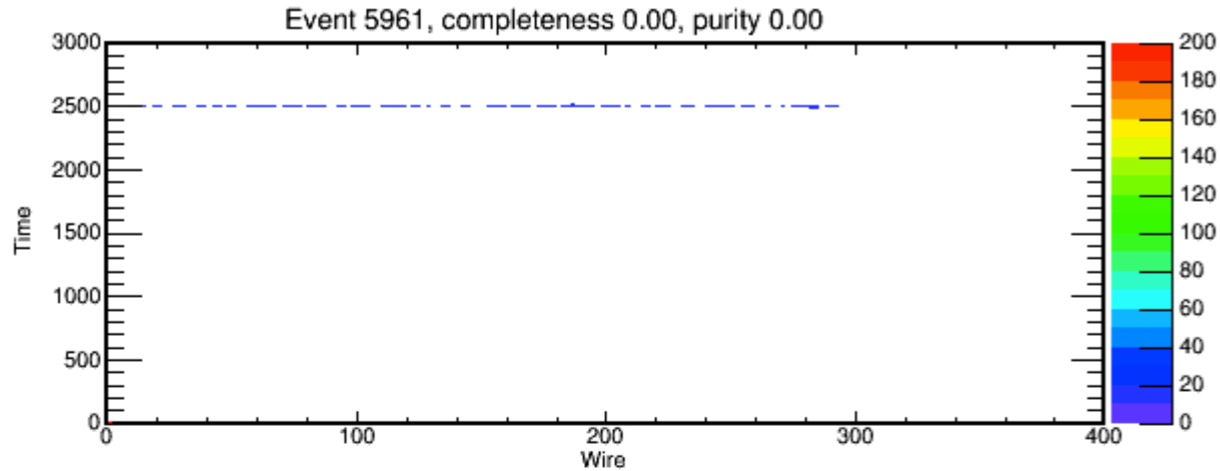Vertical axis: hit time

Long tracks

Looked at reasons for reconstruction failure for events with at least 200 MC hits.

It seems that these are not reconstructed because the muon travels parallel to one of the wire planes.

In some of these events, the muon travels vertically downwards, which is parallel to the collection plane.

Some example event displays are shown in the following slides.

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Event 5961, completeness 0.00, purity 0.00

395 MC hits

Start position

x: 200.0 (outside detector ?)
y: 113
z: 148.9

Initial momentum

x: -0.003
y: -6.00
z: 0.015

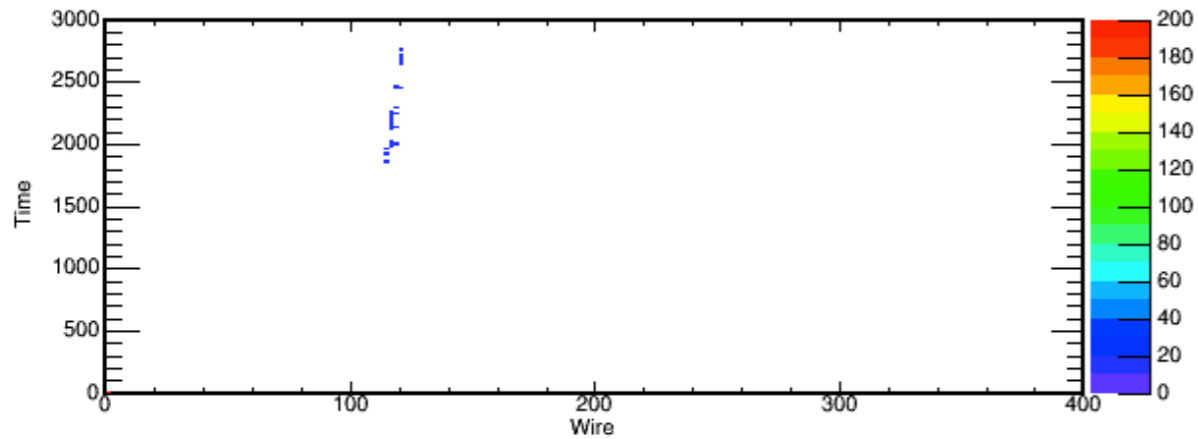Muon travels straight down, i.e. parallel to collection plane wires.

5

Unreconstructed event

Event 9385, completeness 0.00, purity 0.00
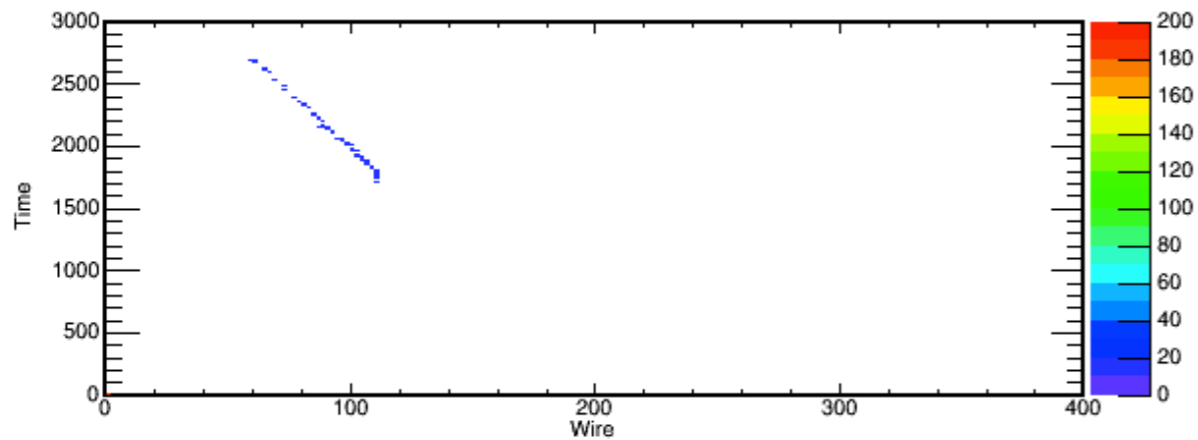
215 MC hits

Start position

x: 65.3
y: 113
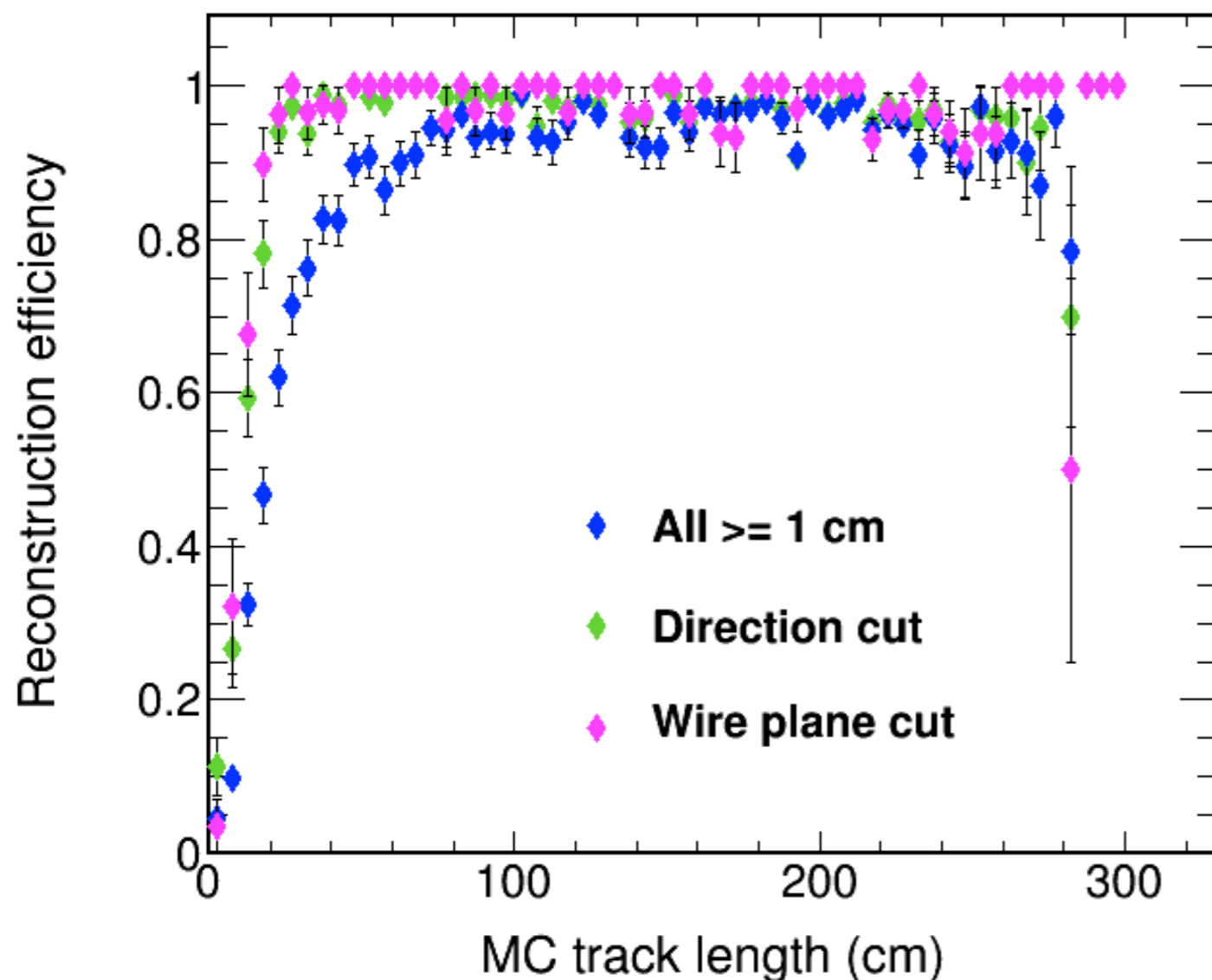z: 179.2 (outside TPCs)

Initial momentum

x: 5.34
y: -2.13
z: 1.95

Reconstruction efficiency as function of MC track length for 1-track events.

All denominators require MC track >= 1 cm

All numerators require MC track >= 1 cm and exactly 1 reconstructed track.

Blue: all
Green: start direction downwards and < 60^0 with vertical
Purple: start direction downwards, < 60^0 with vertical and not parallel to any wire plane (> 10^0 with vertical and not between 35^0 and 55^0 with vertical)
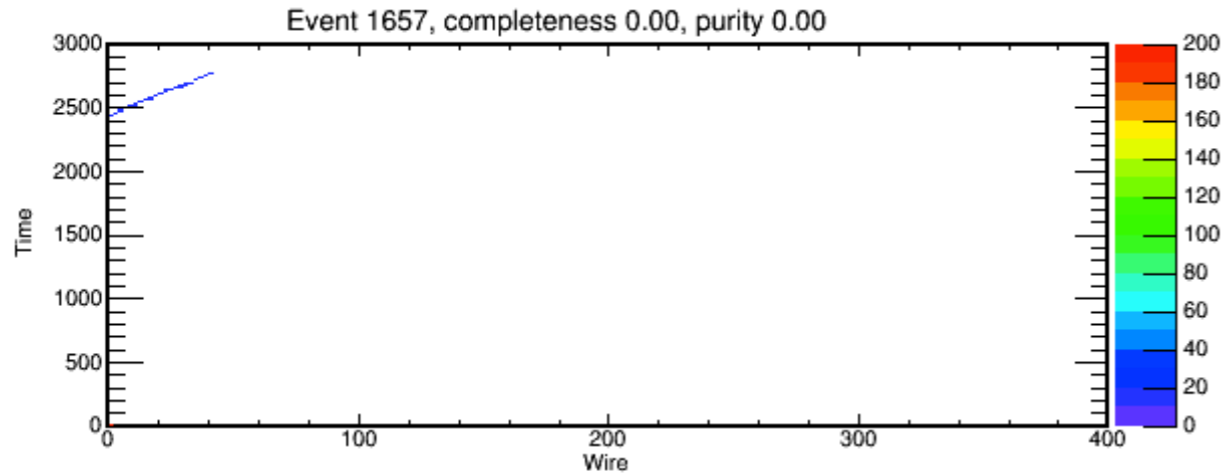
Medium-length tracks

Why are some relatively long tracks that are not parallel to one of the wire planes not reconstructed ?

These tracks have very few reconstructed hits in 1 or 2 planes or the hits in one plane are discontinuous, i.e. have gaps between them.

Some of these events have muons that start outside the TPCs or at the edge of them.

Event 1657, completeness 0.00, purity 0.00

68 MC hits

Start position

x: 32.7
y: 113
z: 195.6 (41 cm outside TPCs !!!)

Initial momentum

x: 4.79
y: -3.13
z: -1.80

Event 3105, completeness 0.00, purity 0.00
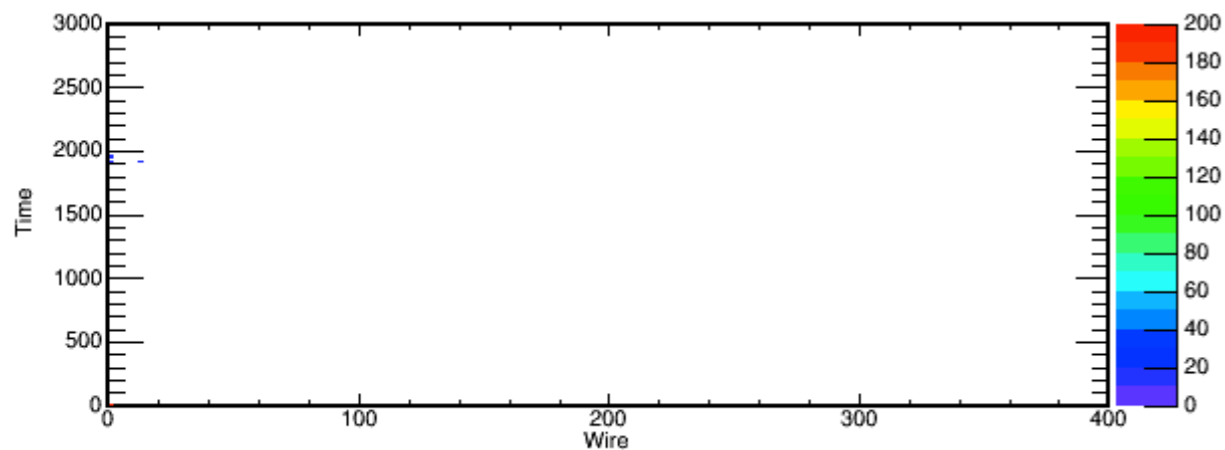
40 MC hits
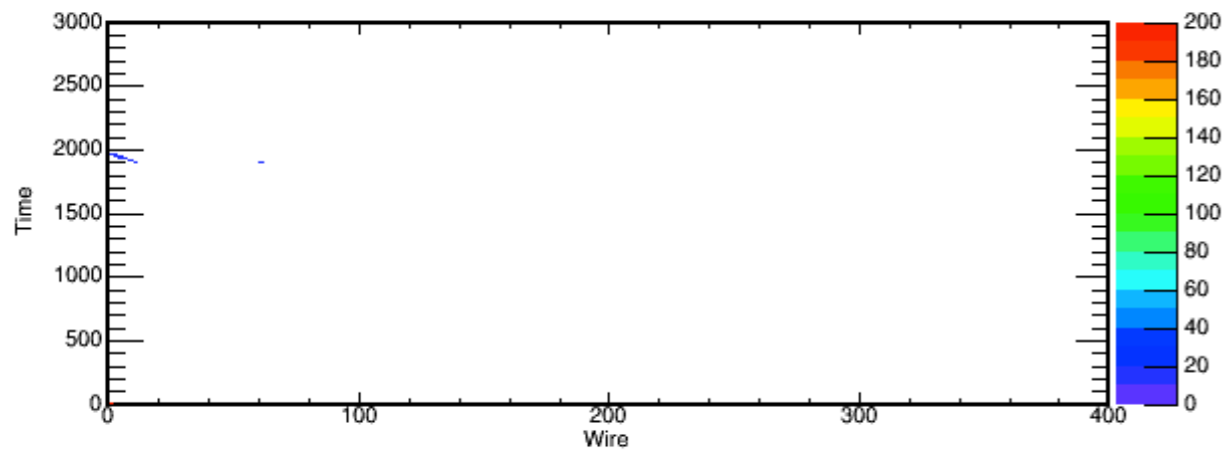
Start position

x: 156.7
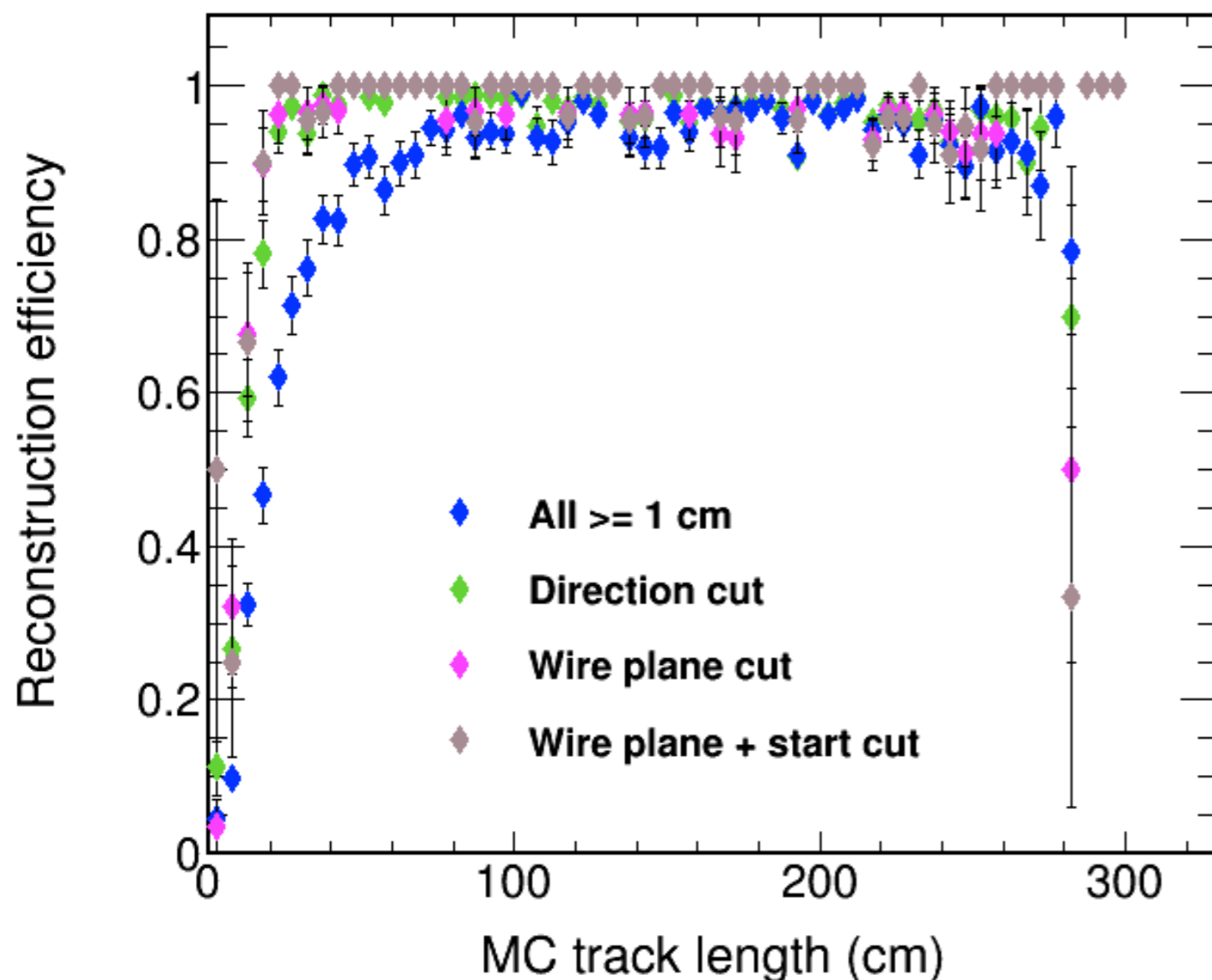y: 113
z: 1.43 (edge of TPCs)

Initial momentum

x: -2.44
y: -5.23
z: -1.62

Reconstruction efficiency as function of MC track length for 1-track events.

All denominators require MC track >= 1 cm

All numerators require MC track >= 1 cm and exactly 1 reconstructed track.

Blue: all
Green: start direction downwards and < 60^0 with vertical
Purple: start direction downwards, < 60^0 with vertical and not parallel to any wire plane (> 10^0 with vertical and not between 35^0 and 55^0 with vertical)
Brown: wire plane cut and -30 < start x < 200 cm and 0 < start z < 154 cm

Short tracks

Looked at reasons for reconstruction failure for events where the MC length of the track is <= 30 cm.

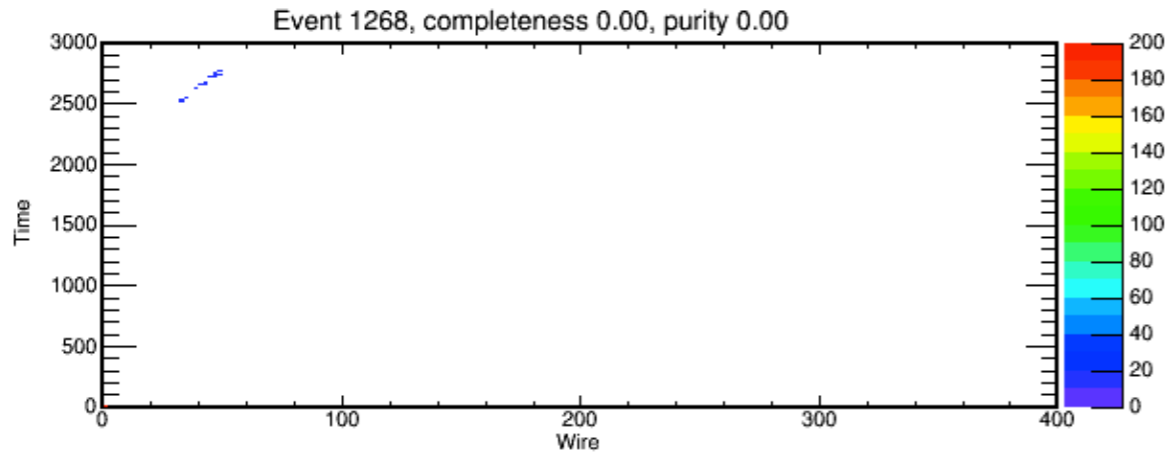Some example event displays are shown in the following slides.

Again some of these are not reconstructed because the muon travels parallel to one of the wire planes.

Or there can be very few hits in 1 or 2 planes.

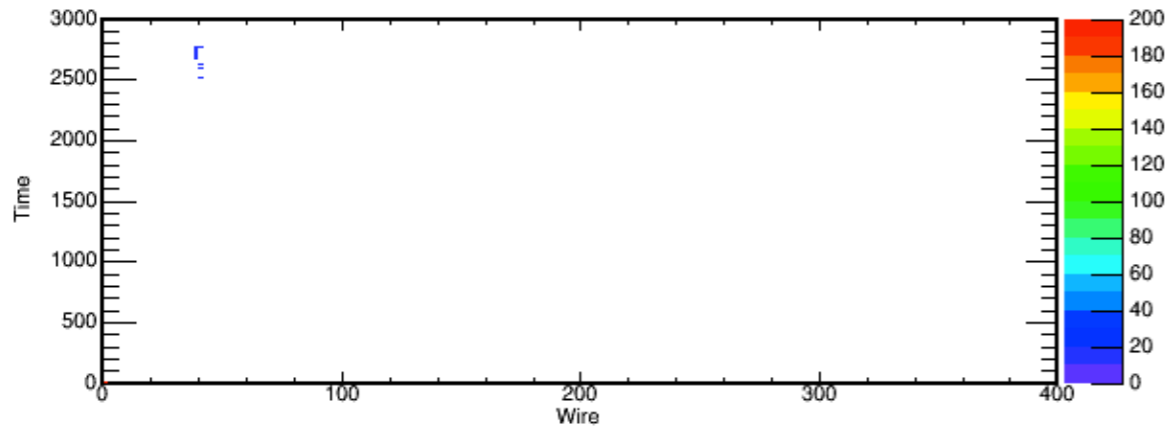Or the hits can be split into several groups, even within one wire plane.
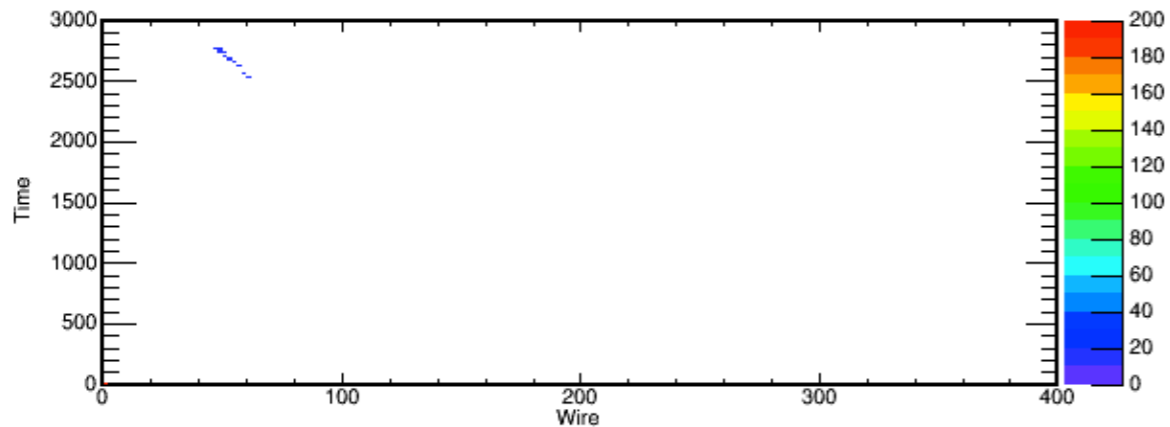
Unreconstructed event

Event 1268, completeness 0.00, purity 0.00

57 MC hits

Start position

x: 199.8
y: 113
z: 132.8

Initial momentum

x: 5.58
y: -1.39
z: -1.72

Event 4851, completeness 0.00, purity 0.00

56 MC hits
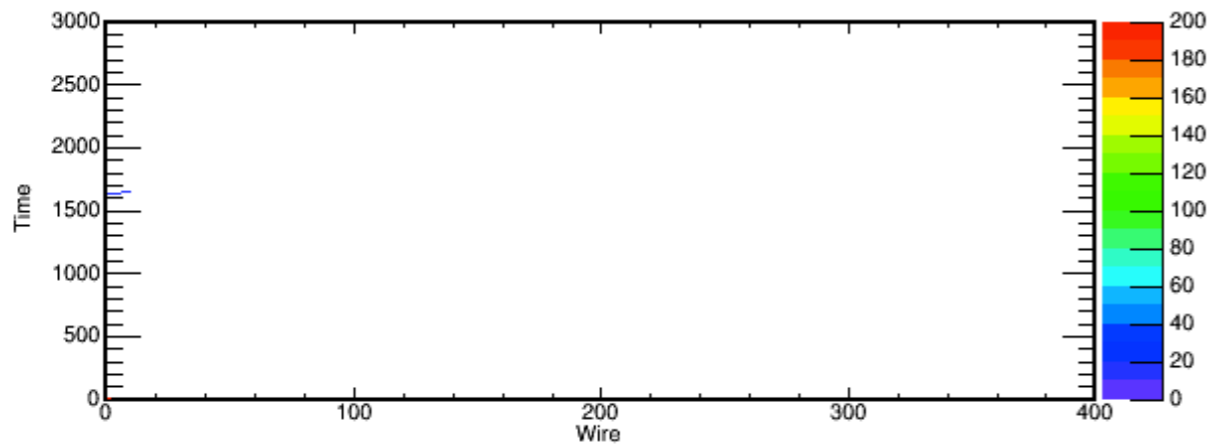
Start position

x: 130.8
y: 113
z: 4.5

Initial momentum

x: -0.54
y: -5.54
z: -2.24

Unreconstructed event

Event 7942, completeness 0.00, purity 0.00
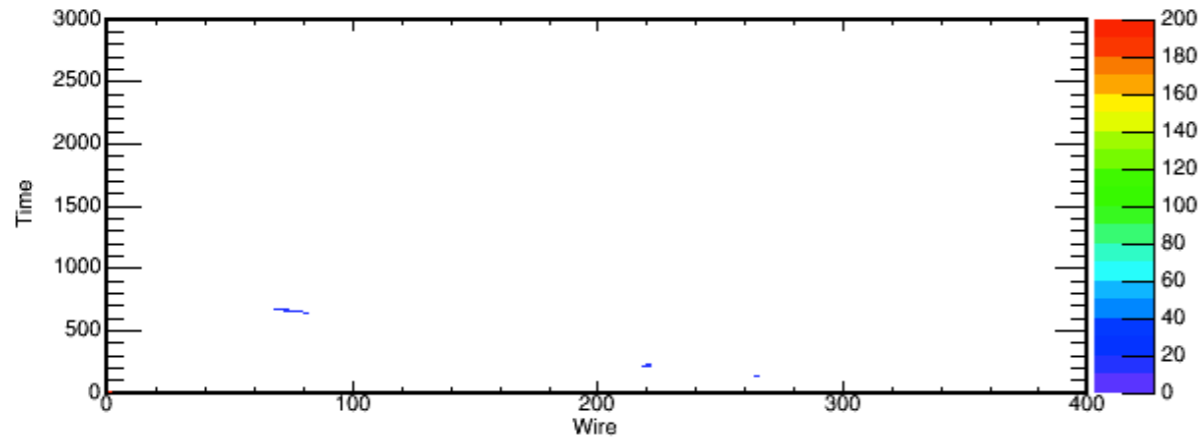
39 MC hits

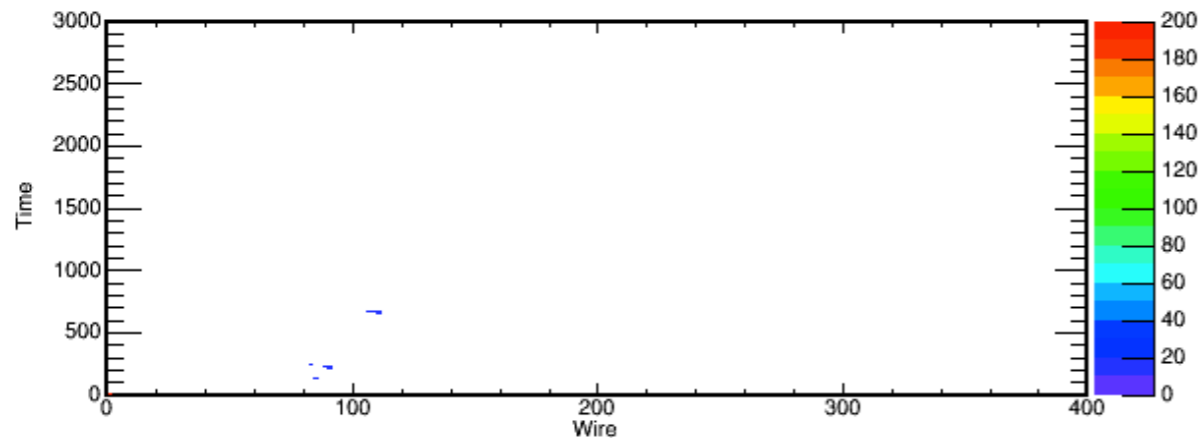Start position

x: 53.1
y: 113
z: 152.5 (edge of TPCs)

Initial momentum

x: -1.93
y: -4.15
z: 3.87

These checks have shown that Pandora is working very well.

It fails to reconstruct a track only when the reconstructed hits in one plane (or sometimes two planes) are compromised in some way:
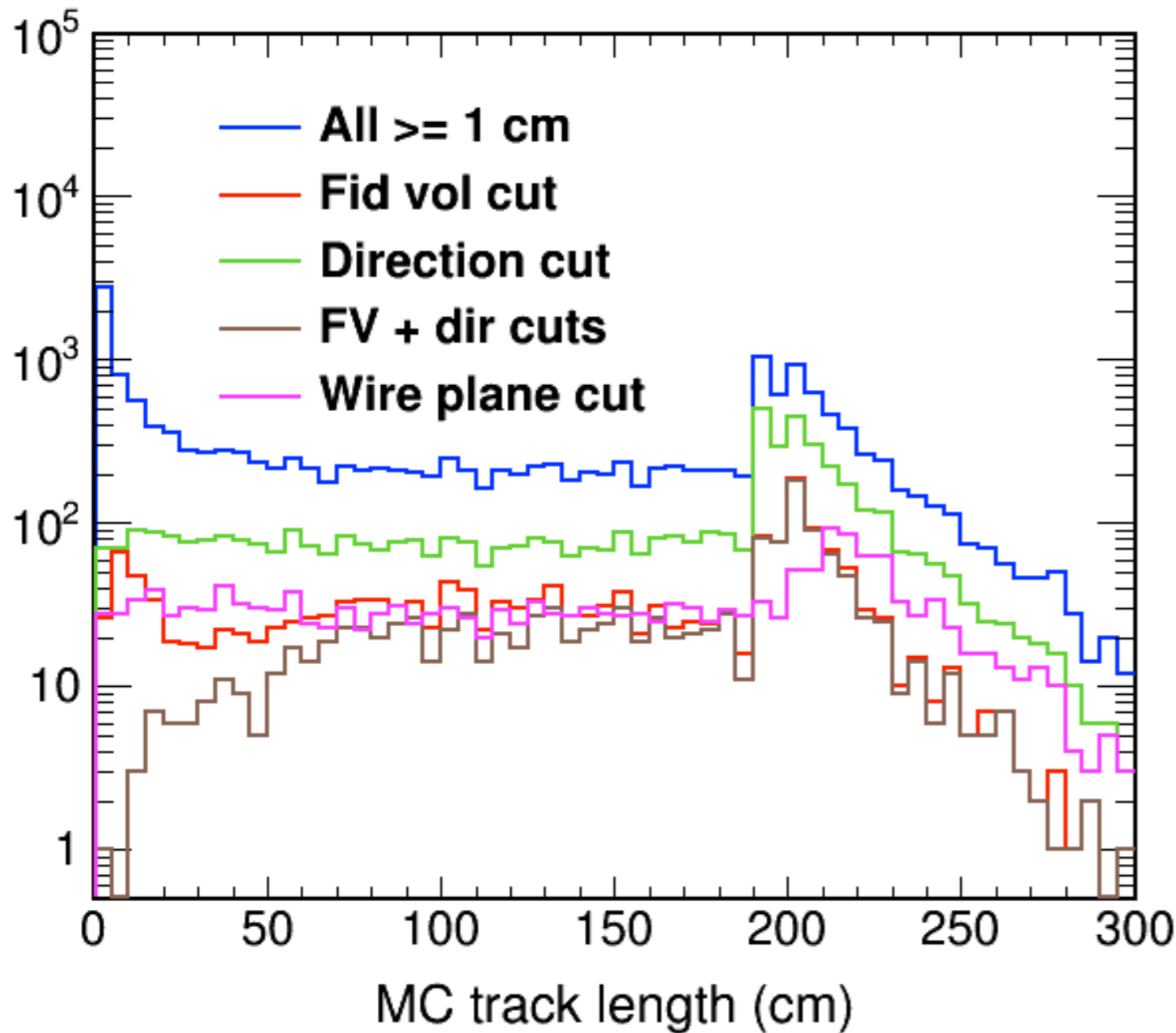
1. Track is parallel to wire plane.

2. There are very few reconstructed hits in one plane (or sometimes two planes).

3. Reconstructed hits in one (or sometimes two) planes are disjointed with gaps between them; this sometimes happens when the track starts outside the TPCs or at the edge of them.

In the future, a focus of Pandora development will be to recover events in which the reconstructed hits are compromised in one plane.

BACKUP SLIDES

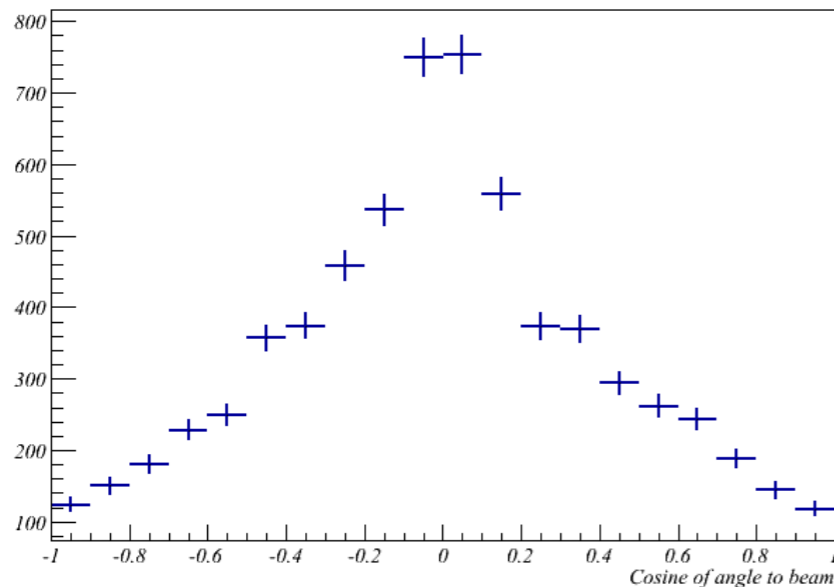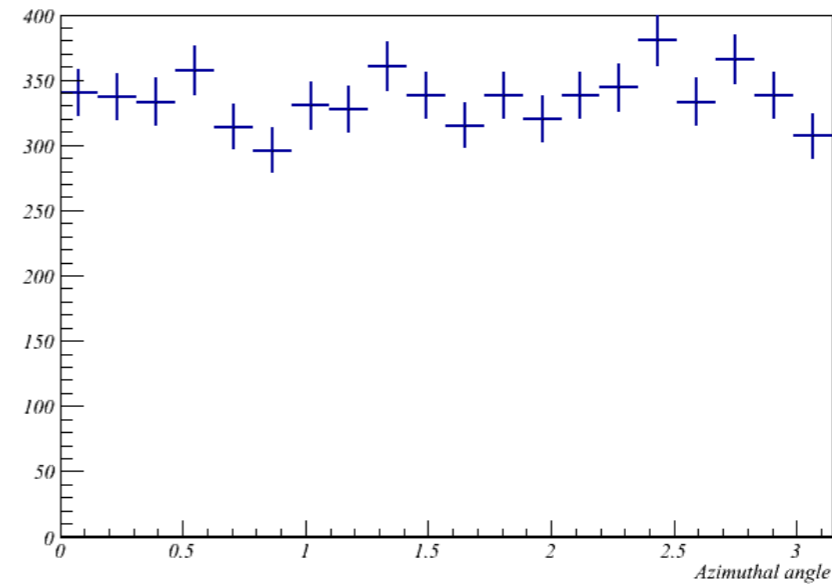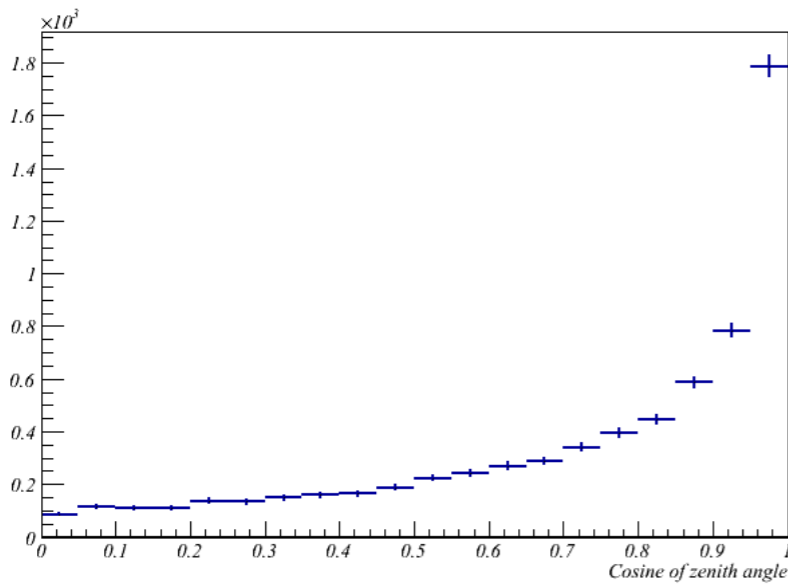Lengths of MC tracks for various selections

Blue: all
Red: -25 < start x <120 cm, 38 < start z < 116 cm (start y is always +113 cm).
Green: start direction downwards and < 60^0 with vertical
Brown: start position and direction cuts
Purple: start direction downwards, < 60^0 with vertical and not parallel to any wire plane (> 10^0 with vertical and not between 35^0 and 55^0 with vertical)

Angles of MC tracks

MC distributions

- Zenith angle is 3D angle of muon to y axis.
- Azimuthal angle is 2D angle from x axis in xz plane.
- Beam angle is 3D angle of muon to beam axis.
- Cosine of zenith angle probably not right because of our basic simulation. Should be ok for our purposes though.

Reference: slide 3 in talk by Martin Haigh at
https://dune-uk.physics.ox.ac.uk/images/c/c1/Validation_070515.pdf

Reconstruction efficiency as function of MC track length for 1-track events.

All denominators require MC track >= 1 cm

All numerators require MC track >= 1 cm and exactly 1 reconstructed track.

Blue: all
Red: -25 < start x <120 cm, 38 < start z < 116 cm (start y is always +113 cm).
Green: start direction downwards and < 60^0 with vertical
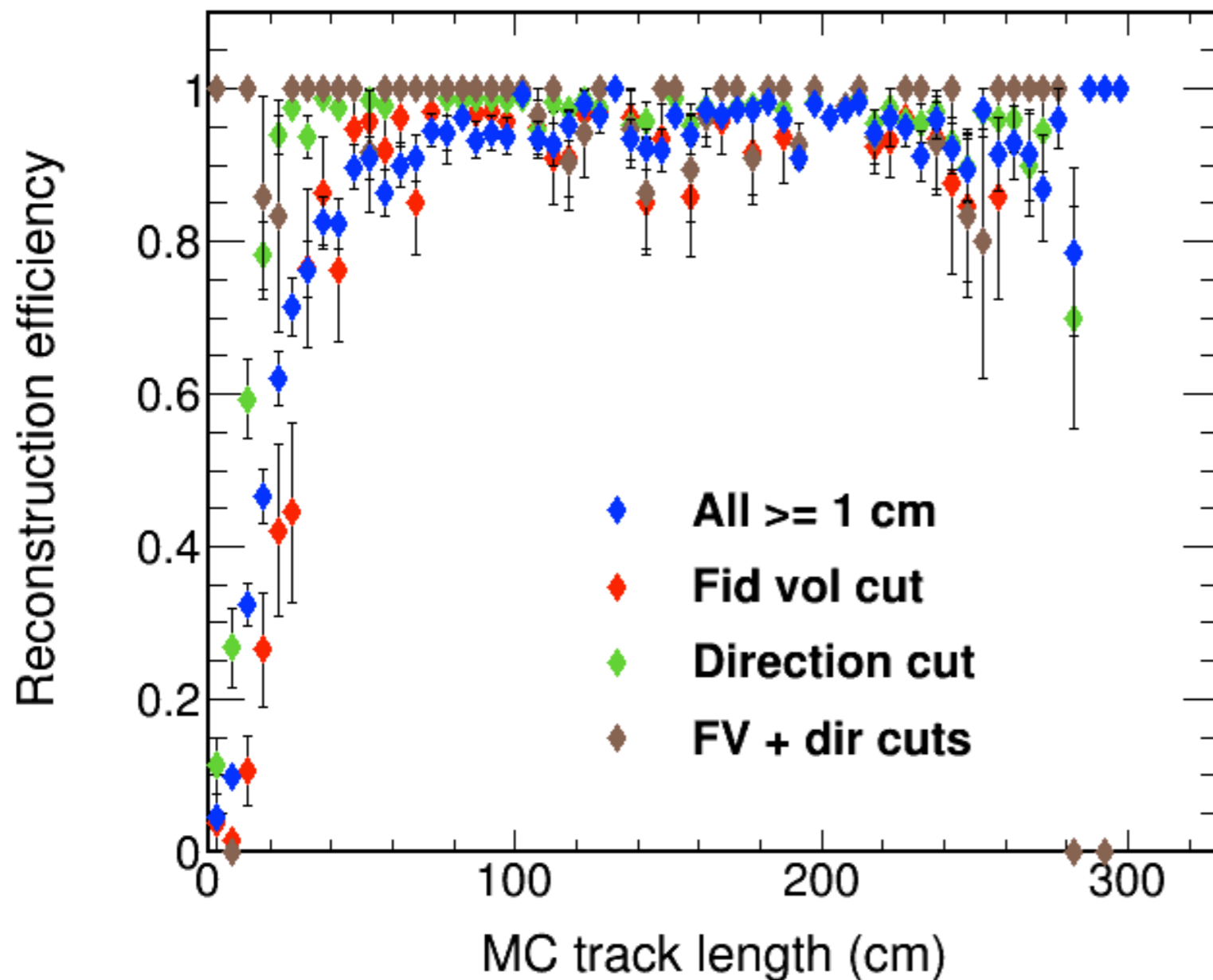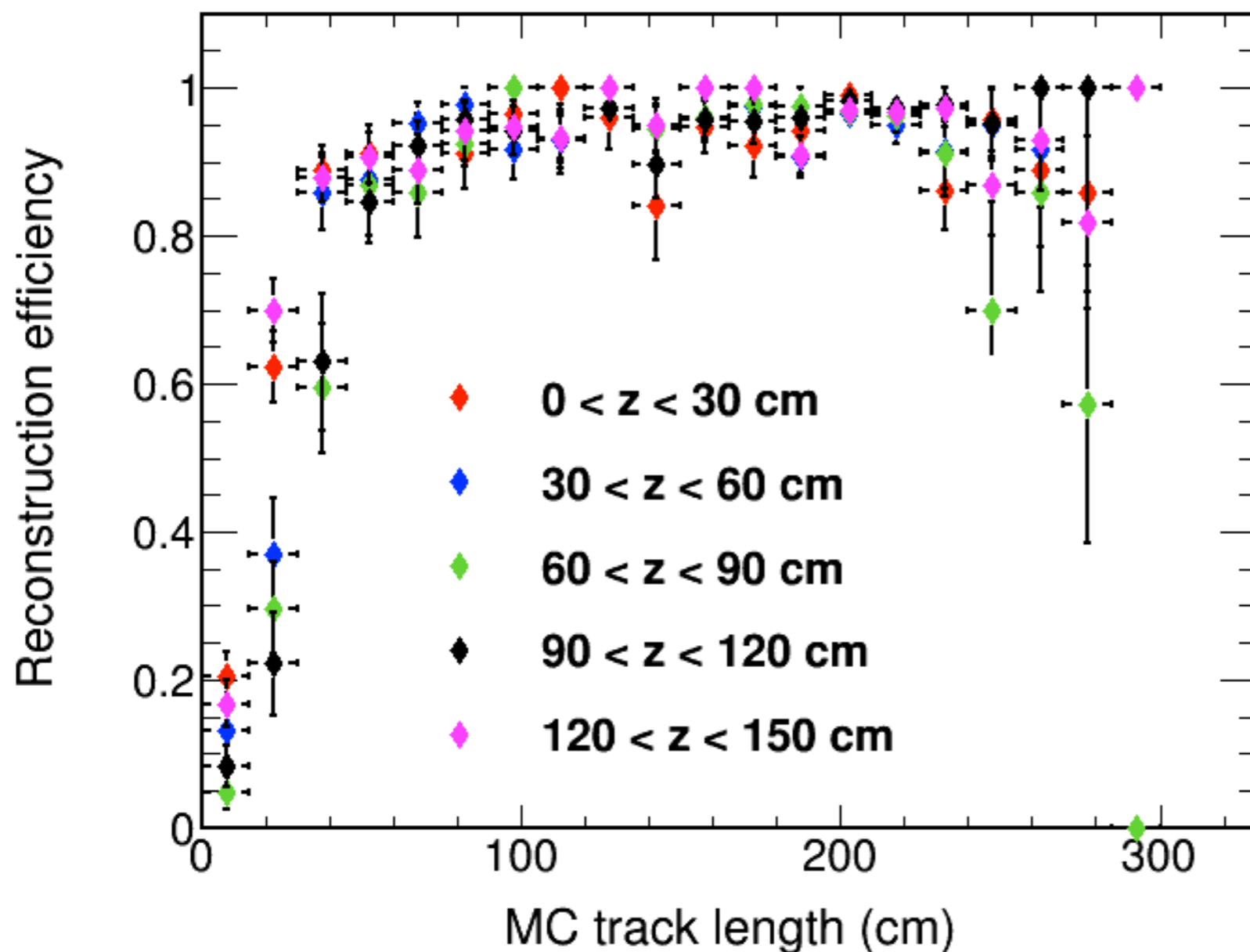Brown: start position and direction cuts

Reconstruction efficiencies

Reconstruction efficiency as function of MC track length for 1-track events.

All denominators require MC track >= 1 cm

All numerators require MC track >= 1 cm and exactly 1 reconstructed track.

This plot shows reconstruction efficiencies for different ranges of start z. For short tracks, the efficiency is much worse in the middle of the detector (in z) than at the edges.