Details of the ND and FD Fiducial Volume for CC and NuMuBar Analyses

Overview

This document gives details of the exact ND and FD fiducial volume cuts used in the analyses as well as the reconstruction variables to be used. Several problems and pitfalls are described together with their solution.

The FD fiducial volume cuts remain almost identical to the summer 2007 versions, with the introduction of a coil cut being the only change. There is however a change in implementation from using plane based cuts to now using z position based cuts.

The ND fiducial volume has been reduced in size significantly: both in terms of the radius of the cylinder and the extent in z.

History and Motivation for Smaller ND Fiducial Volume

Past analyses have used a large ND fiducial volume (1m radius cylinder with 1m<z<5m) for various reasons. However, this volume comes as close as 10cm to the edge of the detector and ends <40 planes away from the spectrometer. By using a smaller fiducial volume the detector performance can be improved in multiple ways, including:

1.) less shower leakage out of the sides
2.) improved muon momentum resolution and less events in the tails of reco-true/true
3.) better vertex resolution
4.) better charge sign separation
5.) less reconstruction failures

In addition, the edges of the detector are not well calibrated and hence not so well modelled in the MC.

The details of the multiple improvements are given minos-doc-3721.

Steel vs. Scintillator

The reconstructed track vertex (trk.vtx.z) in the Cedar/R1.24 standard ntuples (sntp files or .bntp files) falls at a point in the **scintillator** of a plane. In contrast, the reconstructed event vertex (evt.vtx.z) usually falls at a point in the **steel** of a plane. Clearly, the neutrino interactions occur dominantly (~95%) in the steel of a plane. Thus, due to the air-scintillator-steel structure of the detectors, the track vertex is most often reconstructed in the scintillator downstream of the true interaction vertex.

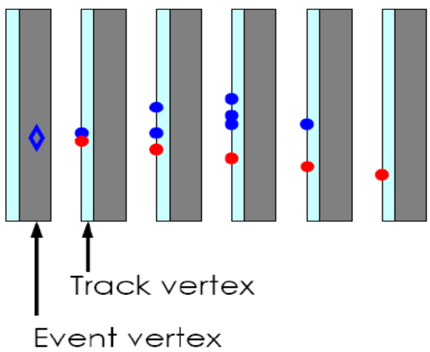

Illustration 1: Figure demonstrating the different positions of track and event vertices. Taken from minos-doc-2409.

The MC truth information gives the actual z-position of the interactions, which are **spatially distributed** throughout the steel and scintillator rather than occurring at a **point** as the reconstructed quantities do. This truth information is used to calculate an efficiency that is used in some extrapolation methods. The cuts have been carefully chosen to sit in the middle of the large ~2.4cm wide air gap between planes. Doing this prevents the possibility of slicing steel-scintillator planes when using the z-position to cut.

In the past the trk.vtx.z variable has been used directly thus, at the front and back of the fiducial volume, there has been a mismatch between the neutrino interactions selected using reconstructed quantities compared to the truth quantities. To avoid this problem 3.92cm is subtracted from trk.vtx.z before it is used (this approach is originally described in minos-doc-2409).

FD Data vs. MC Plane Positions

The plane positions in the FD data and MC do not exactly agree (in the ND there is a perfect match). The planes in the FD data are between 0.7-1.4cm further downstream than in the FD MC. To further ensure that events from the same planes are included in both data and MC it is necessary to adjust the cuts slightly by up to 1.4cm.

Implementation

To standardise the cuts and prevent mistakes analyses must use the functions that have been provided in the DataUtil package in minoscvs. There are 3 classes of interest:
DataUtil/infid.h/cxx
DataUtil/infid_sr_interface.h/cxx
DataUtil/infid_sets.C

infid.h reads in the cuts from infid_sets.C, which effectively acts as a kind of database table. The set of cuts to use is selected once at the start of a job with:

```
choose_infid_set("cc2008");
```

When using standard ntuples there is an interface that uses the NtpStRecord and NtpSRTrack objects directly:

```
infid(myntpstrecord, myntpsrtrk);
```

The advantage of using this interface is that it takes care of subtracting the 3.92cm from the trk.vtx.z variable before using it. Behind the scenes this function calls another function, e.g.:

```
infid(detector, simflag, trk.vtx.x, trk.vtx.y, trk.vtx.z-FidVol::gTrkVtxZOffset);
```

If the NtpStRecord and NtpSRTrack objects are not available then this function can be used directly but great care must be taken to ensure the offset is subtracted from the trk z-position. The offset can be obtained using the FidVol namespace, e.g. FidVol::gTrkVtxZOffset.

The exact z-cuts were obtained by using this function:

```
FidVol::find_z_cuts(13,68,3,239,252,464,FidVol::kDownstreamOfSteel,FidVol::kMiddle,Munits::
micrometer);
```

This function as shown gives the z-positions in the middle of the large (~2.4cm) air gap just downstream of the planes specified for both data and MC.

The cuts specified for the “cc2008” set are given in infid_sets.C and are:

```
void infid_set_cc2008()
{
  gName = "cc2008";
 gNearFollowBeam = false;
```

```
  gNearR          = 0.8;
  gNearZData[0]   = 0.81009;  gNearZData[1]   = 4.07710;
  gNearZMC[0]     = 0.81009;  gNearZMC[1]     = 4.07710;
  gBeamAngleRad   = 3.34321 * TMath::DegToRad();
  gNearDyDz       = TMath::Tan(-gBeamAngleRad);
  gNearX0Beam     = 1.4828;   gNearY0Beam     = 0.2384;
  gNearX0Z        = 1.4828;   gNearY0Z        = 0.2384;
  gFarOctagon     = false;    gFarCoilCut     = true;
  gFarRinner      = 0.4;      gFarRouter      = TMath::Sqrt(14.0);
  gFarZData[0]    =  0.23070;   gFarZData[1]  = 14.27050;
  gFarZData[2]    = 16.12975;   gFarZData[3]  = 28.73315;
  gFarZMC[0]      =  0.21642;   gFarZMC[1]    = 14.25605;
  gFarZMC[2]      = 16.12330;   gFarZMC[3]    = 28.72250;
  gEvtVtxZOffset  = 0.0;
  gTrkVtxZOffset  = 0.0392;
  gShwVtxZOffset  = 0.0;
}
```

It can be seen that the FD z-cuts are slightly different between data and MC (due to the planes not being in the same positions in data and MC).

The gFarRinner variable gives the size of FD coil cut.

Size of Fiducial Volume

The ND fiducial volume includes neutrino interactions from 55 planes (steel planes 14 to 68 inclusive).

The FD fiducial volume includes neutrino interactions from 448 planes (steel planes 4 to 239 and 253 to 464 inclusive).