# Charged 3 $\pi$ Analysis

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## 1 Signal

The signal MC plots of the $3\pi$ mass and momentum are shown in Fig. 1 and 2. The plots look clean apart from a few events whose MC mass turns out to be zero. This means that there are no tracks whose momentum are within some minimum value from the MC momentum. Events must have at least three tracks and have a total charge of +1. I later put a cut on the number of tracks being equal to 3.

The missing mass for these events is plotted in Fig. 3. The mass of the neutron is clear at around 0.94 GeV. I placed a cut on this variable to be less than 1.5 and greater than 0.5.

Figure 4 shows the total photon energy for photons in the FCAL or BCAL, while figure 5 shows the total photon energy for photons from charged tracks. These values are initialized to zero, so events with no photons coming from charged tracks have a value of zero for this variable. These events are not included in figures 4 and 5.

The transverse momentum for the three charged tracks is shown in figure 6.

By placing a cut on the pion tranverse momentum greater than 0.2, we lose about 7% signal efficiency while reducing the amount of background from $\gamma p \to \pi^+\pi^- p$ (Fig. 7).

## 2 Background

From the one million events that were generated by Ryan, I plot in Fig. 8 and 9 the mass of the three pions as well as their momentum. The missing mass from a kinematic fit are plotted in Fig. 10 along with the MC PID for the background. In this case, "right" means that there is one neutron, two $\pi^+$ and one $\pi^-$ and no other particles. The bottom plot in Fig. 10 shows the composition of the background events. It is apparent that many events have a proton rather than a neutron and events that do not have the correct number of pions.

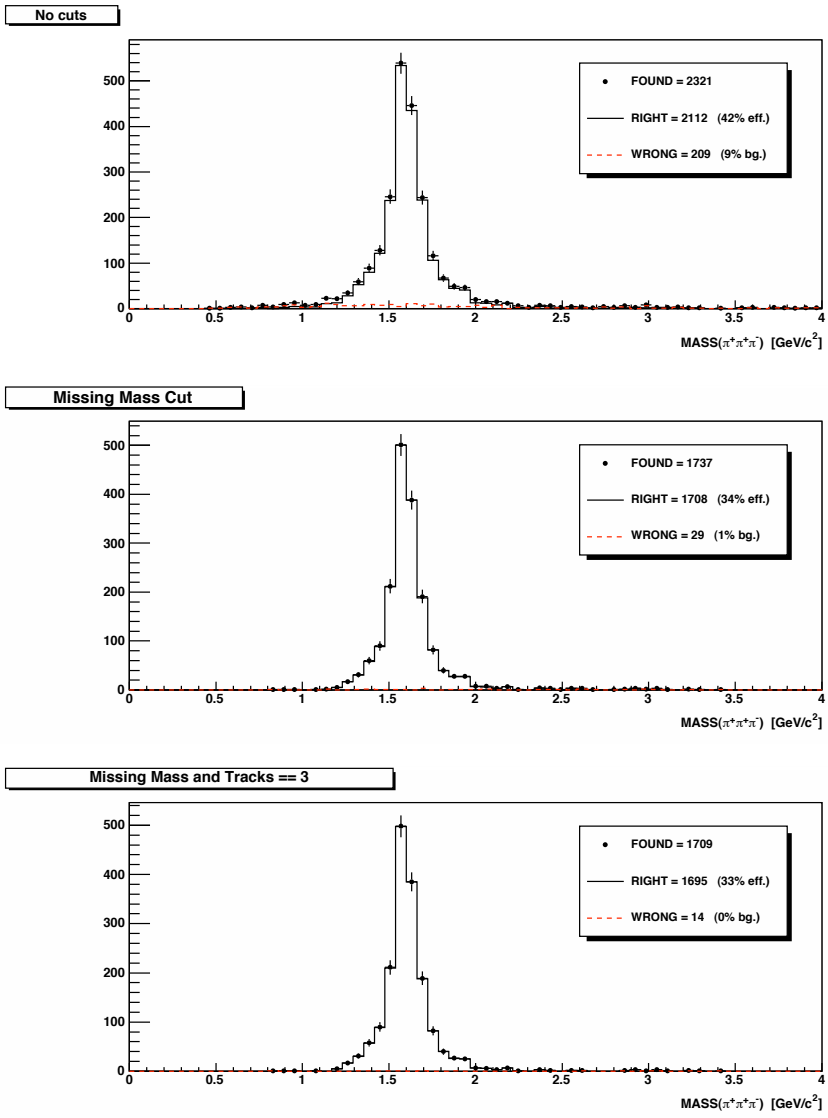

No cuts
FOUND = 2321
RIGHT = 2112 (42% eff.)
WRONG = 209 (9% bg.)
MASS(π⁺π⁺π⁻) [GeV/c²]
Missing Mass Cut
FOUND = 1737
RIGHT = 1708 (34% eff.)
WRONG = 29 (1% bg.)
MASS(π⁺π⁺π⁻) [GeV/c²]
Missing Mass and Tracks == 3
FOUND = 1709
RIGHT = 1695 (33% eff.)
WRONG = 14 (0% bg.)
MASS(π⁺π⁺π⁻) [GeV/c²]

Figure 1:

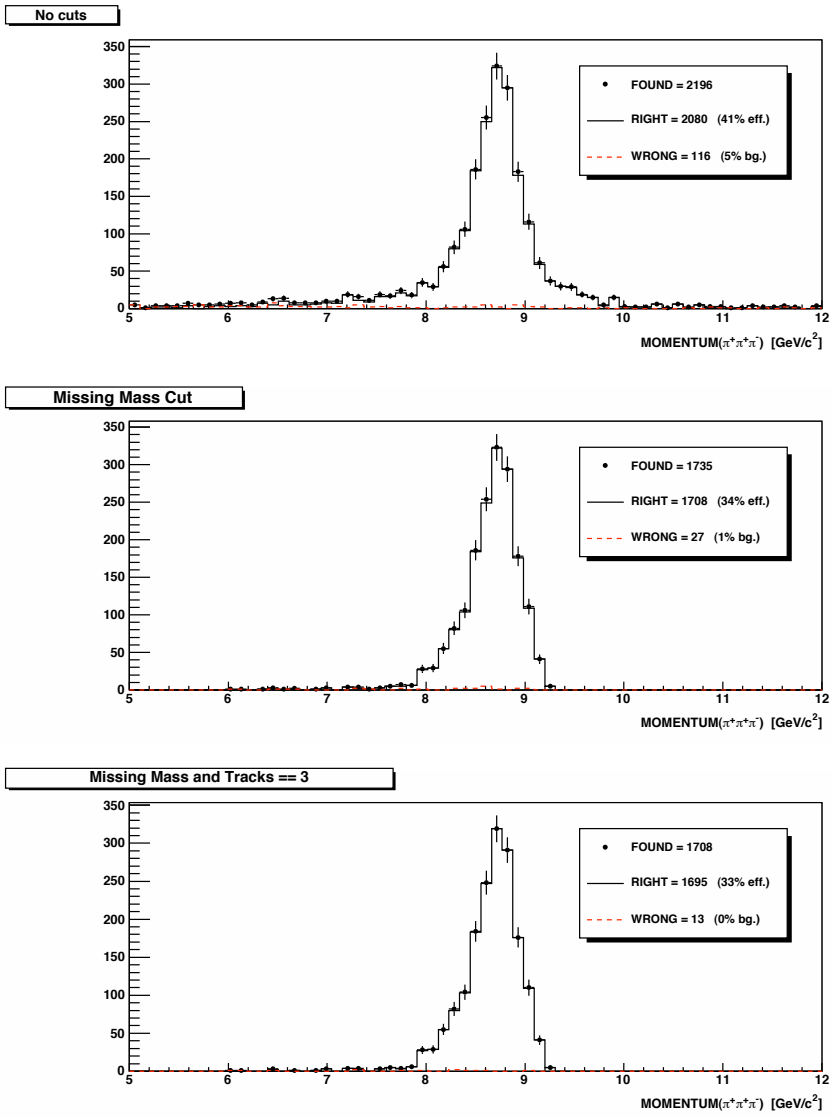

No cuts
FOUND = 2196
RIGHT = 2080 (41% eff.)
WRONG = 116 (5% bg.)
MOMENTUM($\pi^+\pi^+\pi^-$) [GeV/c$^2$]
Missing Mass Cut
FOUND = 1735
RIGHT = 1708 (34% eff.)
WRONG = 27 (1% bg.)
MOMENTUM($\pi^+\pi^+\pi^-$) [GeV/c$^2$]
Missing Mass and Tracks == 3
FOUND = 1708
RIGHT = 1695 (33% eff.)
WRONG = 13 (0% bg.)
MOMENTUM($\pi^+\pi^+\pi^-$) [GeV/c$^2$]

Figure 2:

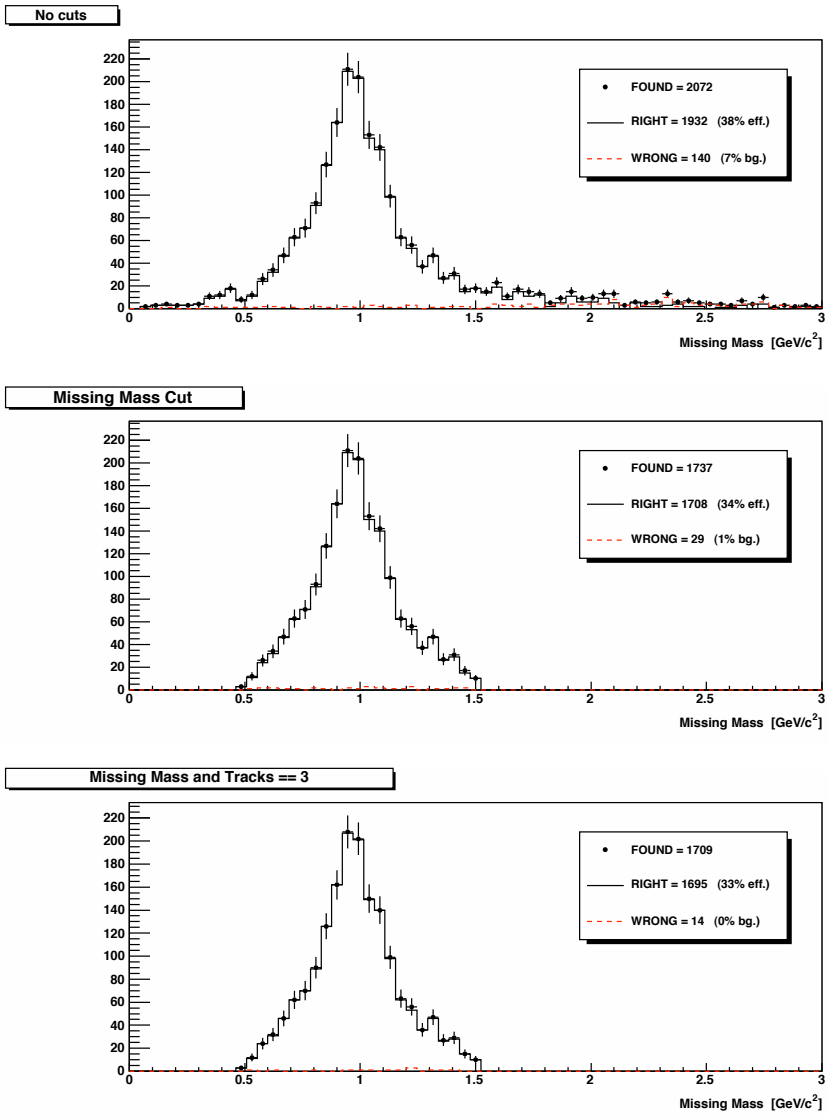

No cuts
FOUND = 2072
RIGHT = 1932 (38% eff.)
WRONG = 140 (7% bg.)
Missing Mass [GeV/c$^2$]
Missing Mass Cut
FOUND = 1737
RIGHT = 1708 (34% eff.)
WRONG = 29 (1% bg.)
Missing Mass [GeV/c$^2$]
Missing Mass and Tracks == 3
FOUND = 1709
RIGHT = 1695 (33% eff.)
WRONG = 14 (0% bg.)
Missing Mass [GeV/c$^2$]

Figure 3:

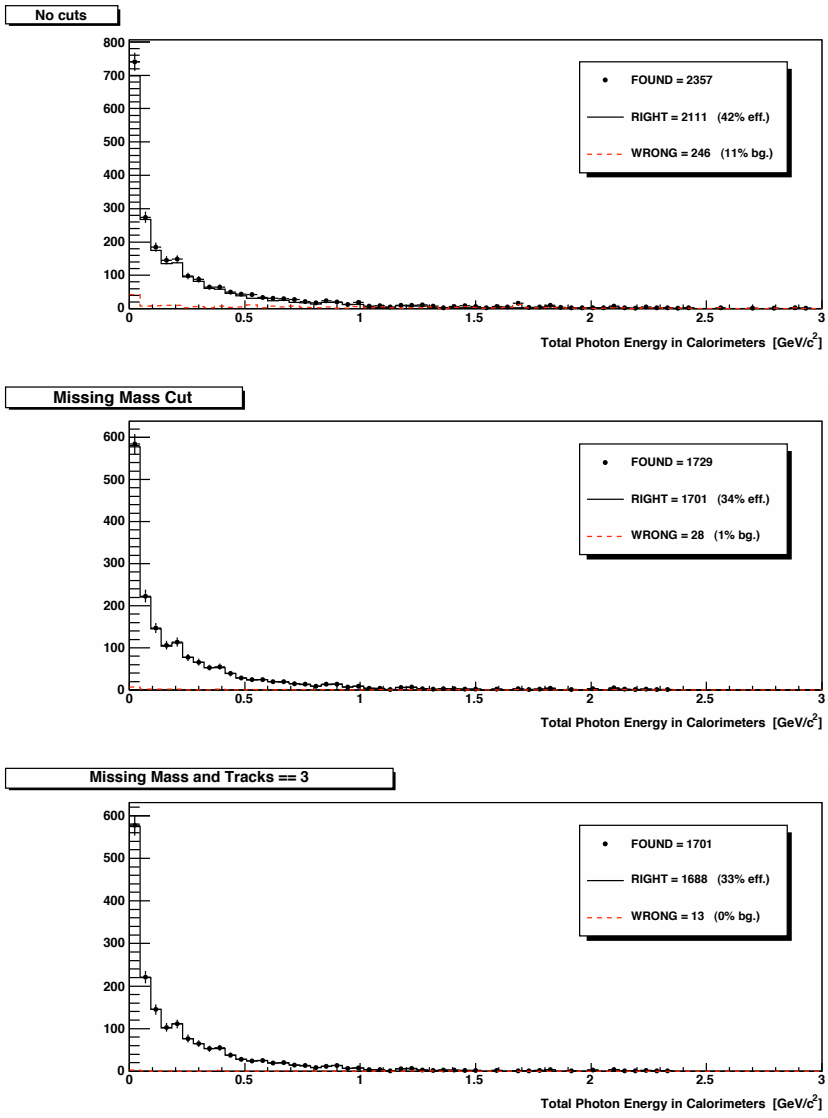

No cuts
FOUND = 2357
RIGHT = 2111 (42% eff.)
WRONG = 246 (11% bg.)
Total Photon Energy in Calorimeters [GeV/c$^2$]
Missing Mass Cut
FOUND = 1729
RIGHT = 1701 (34% eff.)
WRONG = 28 (1% bg.)
Total Photon Energy in Calorimeters [GeV/c$^2$]
Missing Mass and Tracks == 3
FOUND = 1701
RIGHT = 1688 (33% eff.)
WRONG = 13 (0% bg.)
Total Photon Energy in Calorimeters [GeV/c$^2$]

Figure 4:

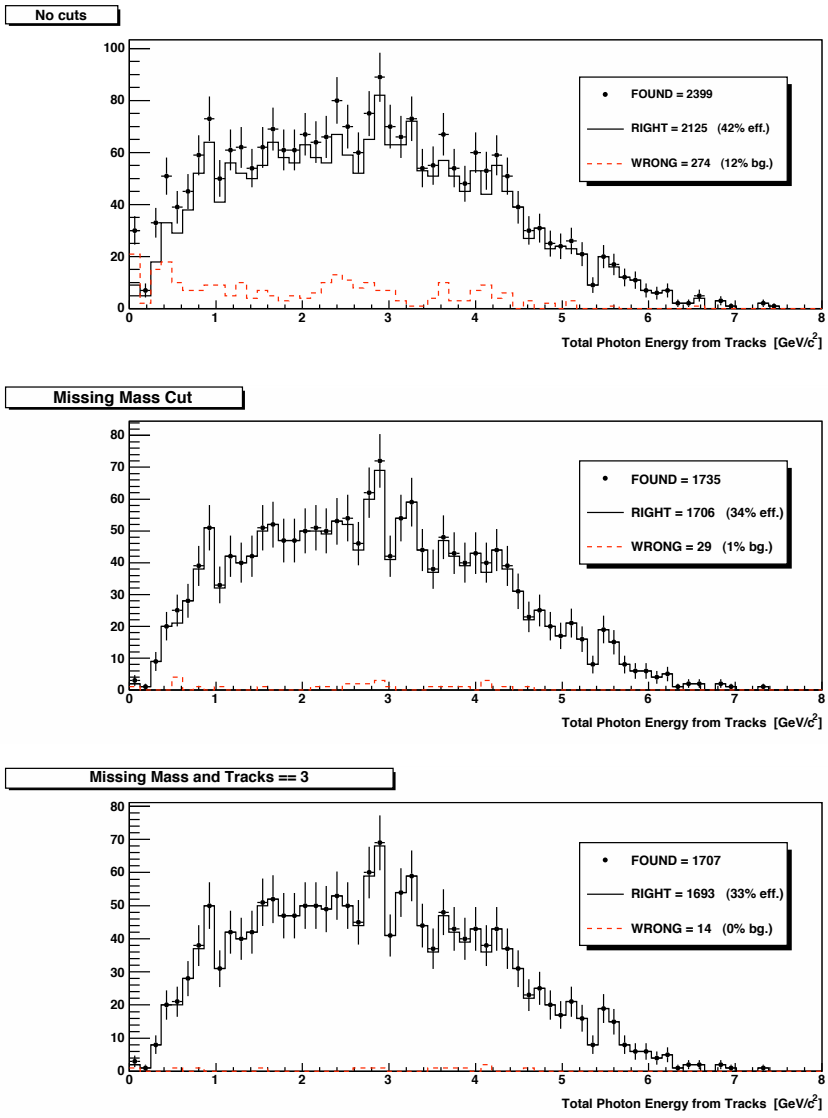

No cuts
FOUND = 2399
RIGHT = 2125 (42% eff.)
WRONG = 274 (12% bg.)
Total Photon Energy from Tracks [GeV/c²]
Missing Mass Cut
FOUND = 1735
RIGHT = 1706 (34% eff.)
WRONG = 29 (1% bg.)
Total Photon Energy from Tracks [GeV/c²]
Missing Mass and Tracks == 3
FOUND = 1707
RIGHT = 1693 (33% eff.)
WRONG = 14 (0% bg.)
Total Photon Energy from Tracks [GeV/c²]

Figure 5:

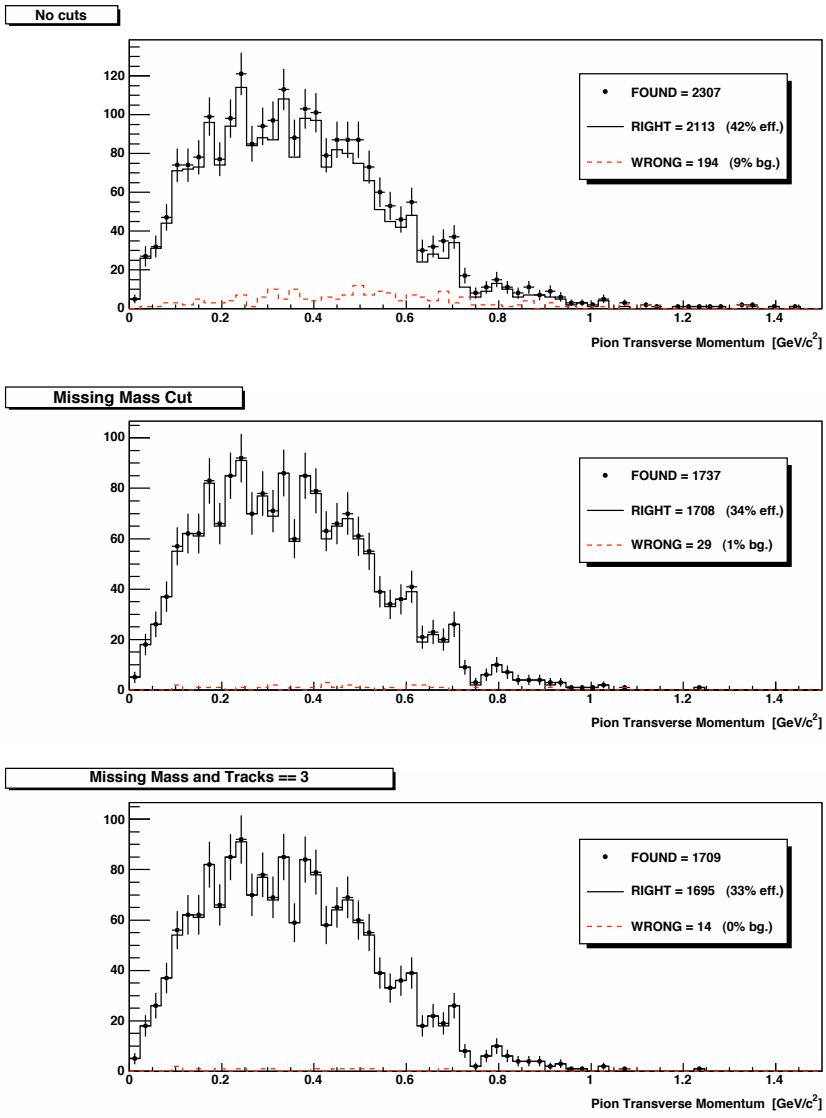

No cuts
FOUND = 2307
RIGHT = 2113 (42% eff.)
WRONG = 194 (9% bg.)
Pion Transverse Momentum [GeV/c$^2$]
Missing Mass Cut
FOUND = 1737
RIGHT = 1708 (34% eff.)
WRONG = 29 (1% bg.)
Pion Transverse Momentum [GeV/c$^2$]
Missing Mass and Tracks == 3
FOUND = 1709
RIGHT = 1695 (33% eff.)
WRONG = 14 (0% bg.)
Pion Transverse Momentum [GeV/c$^2$]

Figure 6:

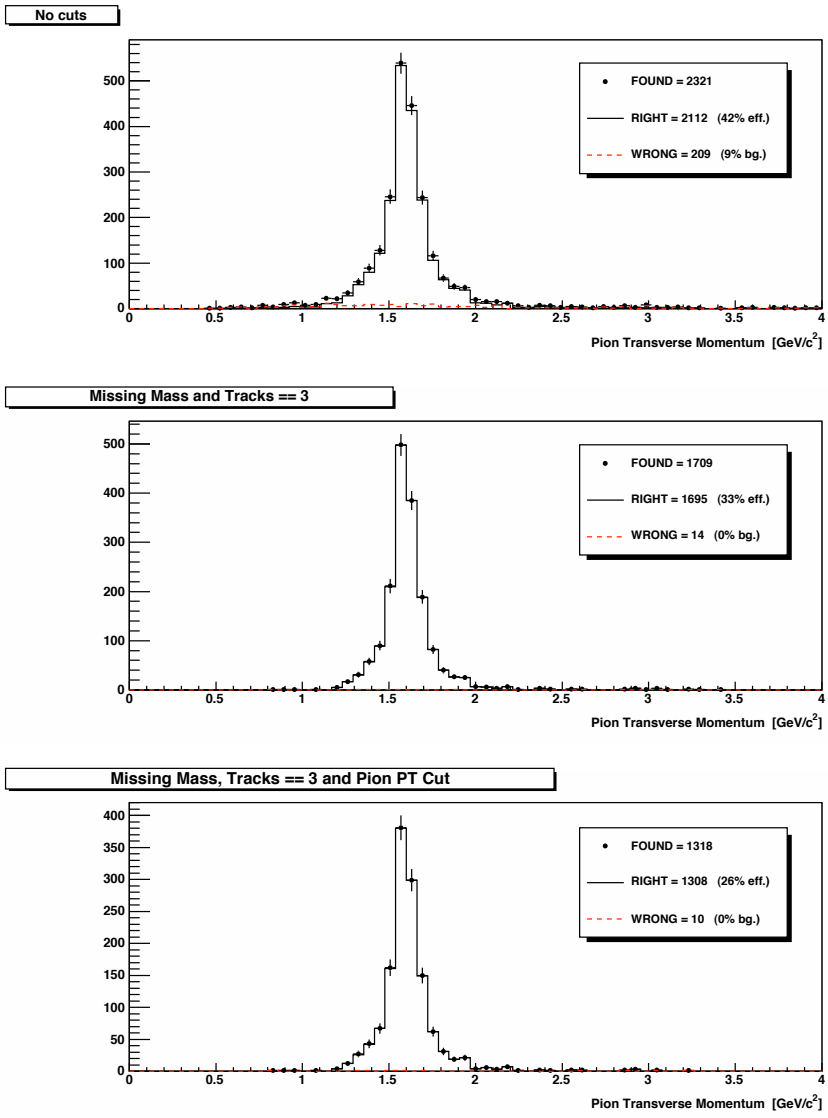

No cuts
FOUND = 2321
RIGHT = 2112 (42% eff.)
WRONG = 209 (9% bg.)
Pion Transverse Momentum [GeV/c$^2$]
Missing Mass and Tracks == 3
FOUND = 1709
RIGHT = 1695 (33% eff.)
WRONG = 14 (0% bg.)
Pion Transverse Momentum [GeV/c$^2$]
Missing Mass, Tracks == 3 and Pion PT Cut
FOUND = 1318
RIGHT = 1308 (26% eff.)
WRONG = 10 (0% bg.)
Pion Transverse Momentum [GeV/c$^2$]

Figure 7:

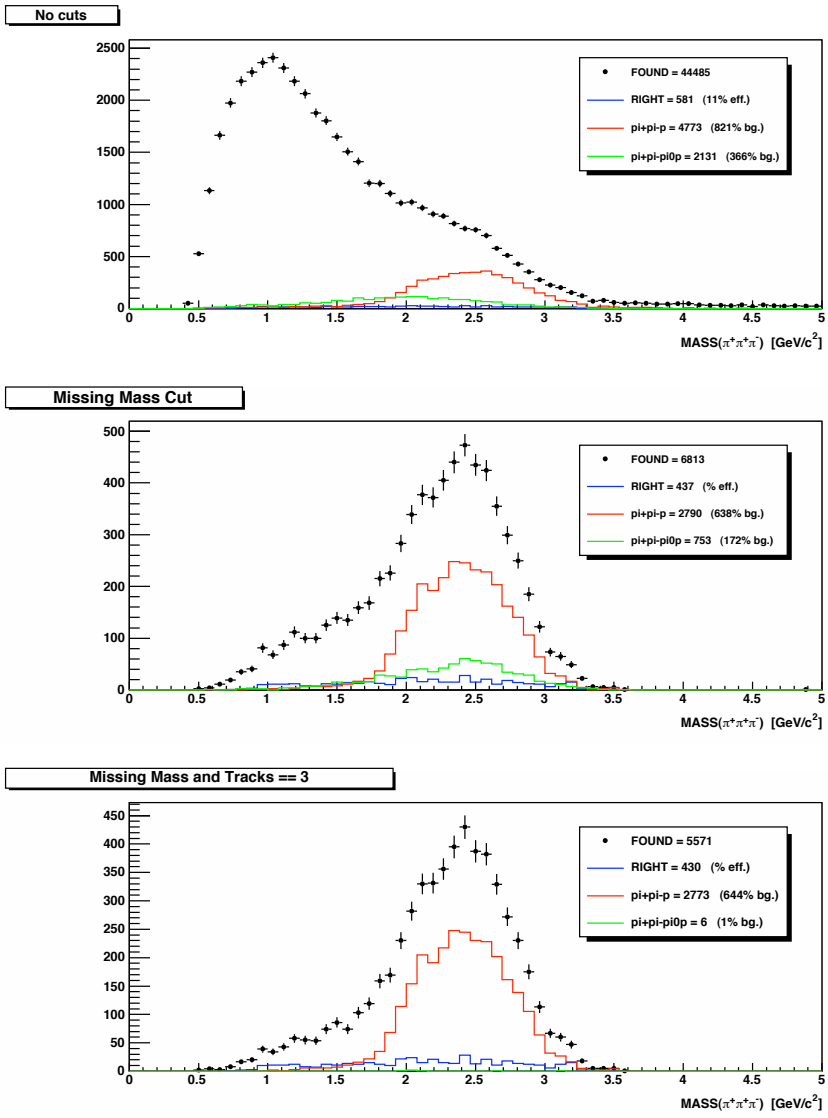

No cuts
FOUND = 44485
RIGHT = 581 (11% eff.)
pi+pi-p = 4773 (821% bg.)
pi+pi-pi0p = 2131 (366% bg.)
MASS($\pi^+\pi^+\pi^-$) [GeV/c$^2$]
Missing Mass Cut
FOUND = 6813
RIGHT = 437 (% eff.)
pi+pi-p = 2790 (638% bg.)
pi+pi-pi0p = 753 (172% bg.)
MASS($\pi^+\pi^+\pi^-$) [GeV/c$^2$]
Missing Mass and Tracks == 3
FOUND = 5571
RIGHT = 430 (% eff.)
pi+pi-p = 2773 (644% bg.)
pi+pi-pi0p = 6 (1% bg.)
MASS($\pi^+\pi^+\pi^-$) [GeV/c$^2$]

Figure 8:

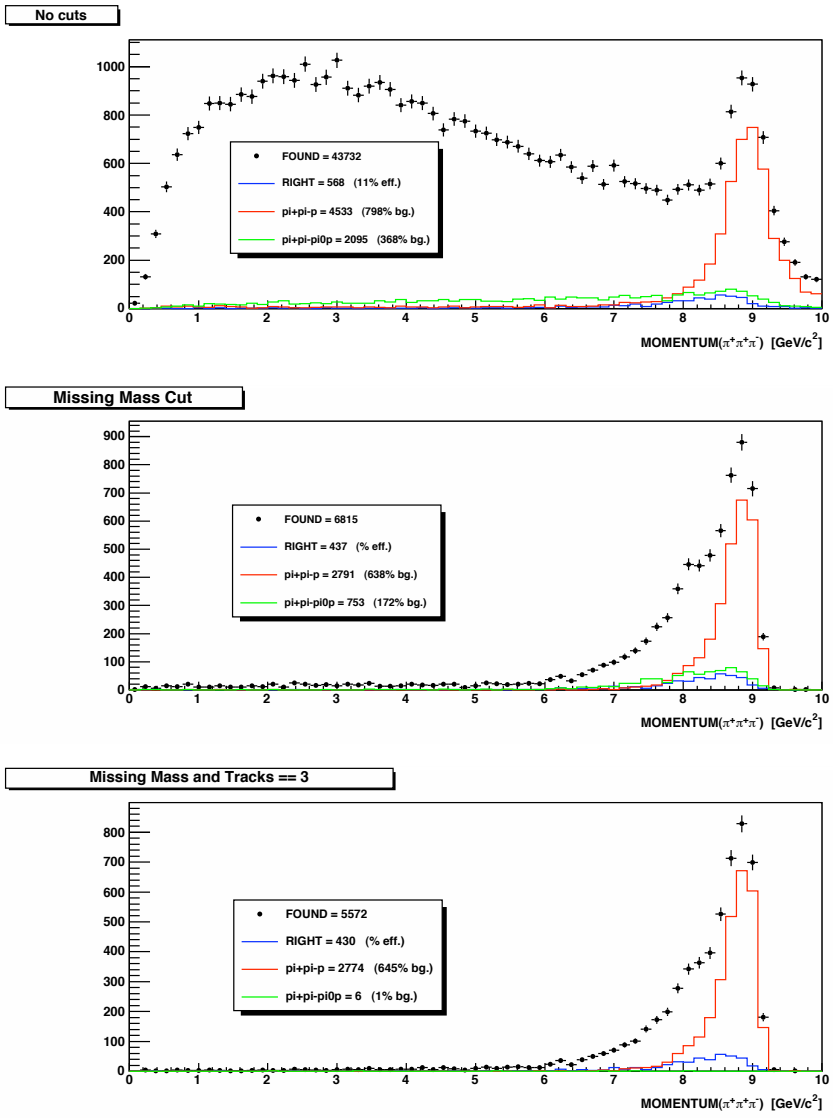

No cuts
FOUND = 43732
RIGHT = 568 (11% eff.)
pi+pi-p = 4533 (798% bg.)
pi+pi-pi0p = 2095 (368% bg.)
MOMENTUM($\pi^+\pi^+\pi^-$) [GeV/c$^2$]
Missing Mass Cut
FOUND = 6815
RIGHT = 437 (% eff.)
pi+pi-p = 2791 (638% bg.)
pi+pi-pi0p = 753 (172% bg.)
MOMENTUM($\pi^+\pi^+\pi^-$) [GeV/c$^2$]
Missing Mass and Tracks == 3
FOUND = 5572
RIGHT = 430 (% eff.)
pi+pi-p = 2774 (645% bg.)
pi+pi-pi0p = 6 (1% bg.)
MOMENTUM($\pi^+\pi^+\pi^-$) [GeV/c$^2$]

Figure 9:

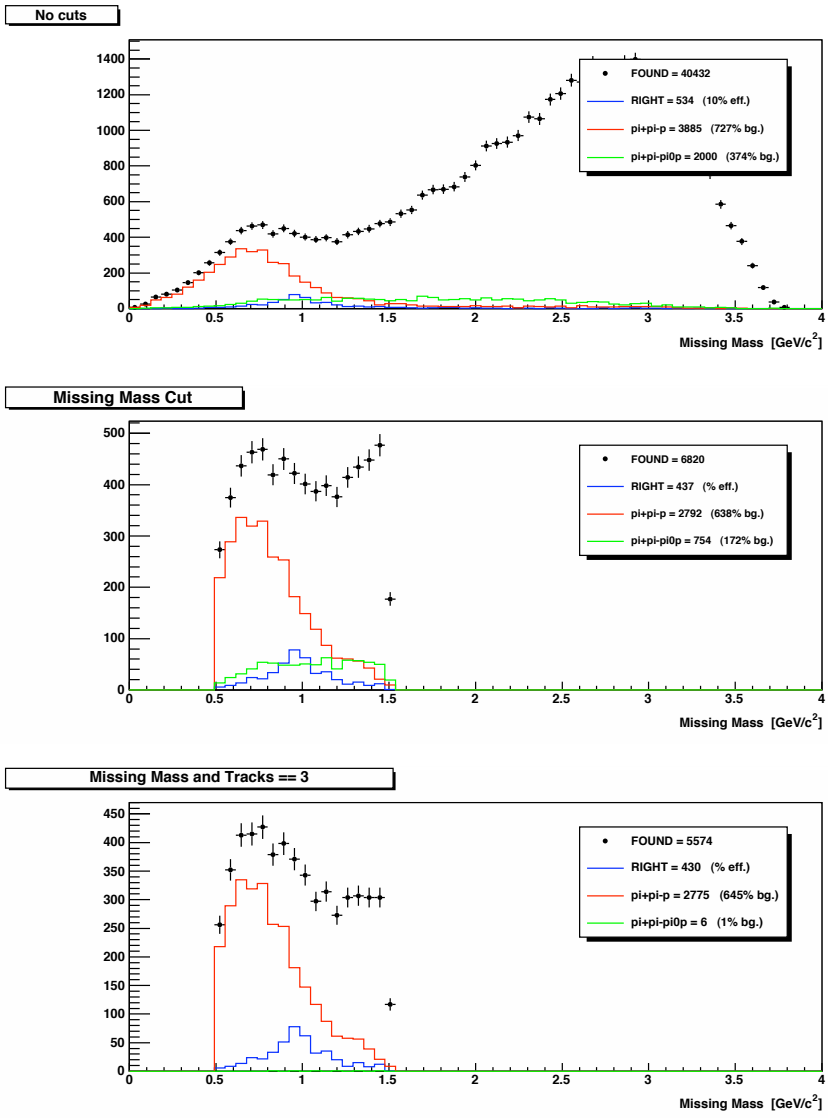

No cuts
FOUND = 40432
RIGHT = 534 (10% eff.)
pi+pi-p = 3885 (727% bg.)
pi+pi-pi0p = 2000 (374% bg.)
Missing Mass [GeV/c$^2$]
Missing Mass Cut
FOUND = 6820
RIGHT = 437 (% eff.)
pi+pi-p = 2792 (638% bg.)
pi+pi-pi0p = 754 (172% bg.)
Missing Mass [GeV/c$^2$]
Missing Mass and Tracks == 3
FOUND = 5574
RIGHT = 430 (% eff.)
pi+pi-p = 2775 (645% bg.)
pi+pi-pi0p = 6 (1% bg.)
Missing Mass [GeV/c$^2$]

Figure 10:

Figure 11 shows the total photon energy for photons in the FCAL or BCAL, while figure 12 shows the total photon energy for photons from charged tracks. These values are initialized to zero, so events with no photons coming from charged tracks have a value of zero for this variable. These events are not included in figures 11 and 12.

The transverse momentum for the three charged tracks is shown in figure 13. The relative amount of background events from $\pi^+\pi^i p$ and $\pi^+\pi^i\pi^0 p$ are visible as well as the signal events.

With all cuts thus far, we obtain plots 15 and 16 for signal and background. Cuts included are, number of tracks equals 3, total charge is 1, pion transverse momentum is greater than 0.2 GeV and the total energy from photons in the calorimeter is less than 0.5 GeV. I am still trying to identify the remaining background. I think I have a decent handle on it, I just need to sit down and write it all out. I'll try to get this done this weekend.

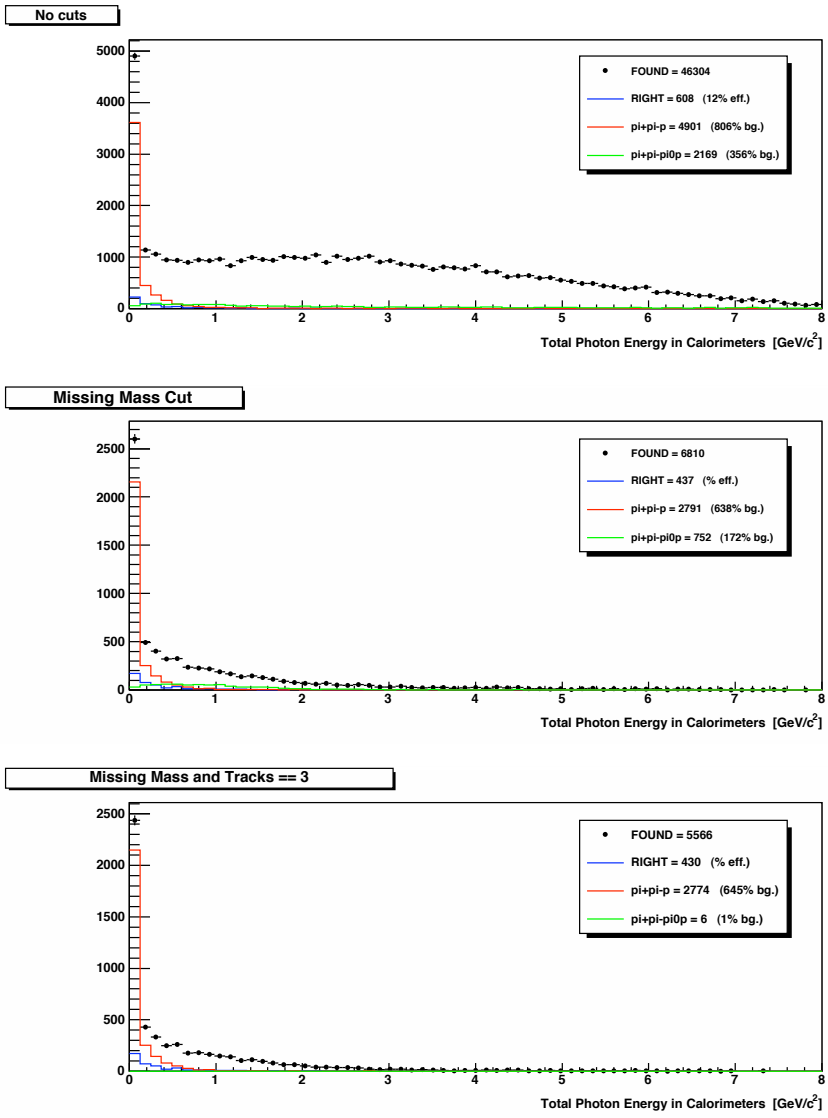

No cuts
FOUND = 46304
RIGHT = 608 (12% eff.)
pi+pi-p = 4901 (806% bg.)
pi+pi-pi0p = 2169 (356% bg.)
Total Photon Energy in Calorimeters [GeV/c$^2$]
Missing Mass Cut
FOUND = 6810
RIGHT = 437 (% eff.)
pi+pi-p = 2791 (638% bg.)
pi+pi-pi0p = 752 (172% bg.)
Total Photon Energy in Calorimeters [GeV/c$^2$]
Missing Mass and Tracks == 3
FOUND = 5566
RIGHT = 430 (% eff.)
pi+pi-p = 2774 (645% bg.)
pi+pi-pi0p = 6 (1% bg.)
Total Photon Energy in Calorimeters [GeV/c$^2$]

Figure 11:

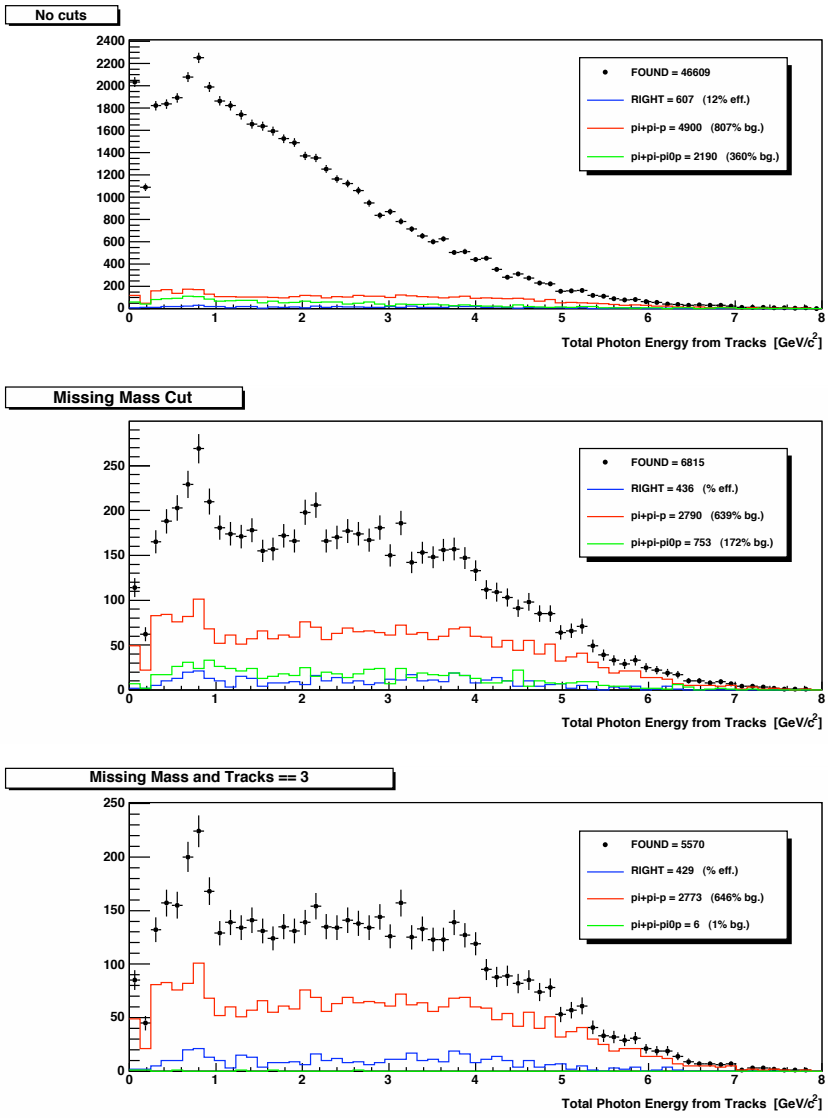
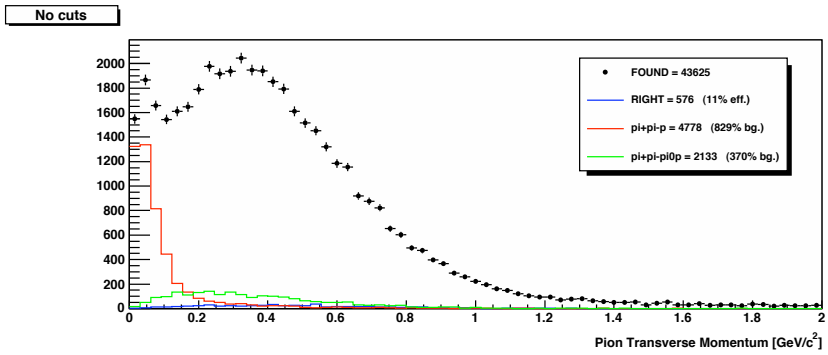
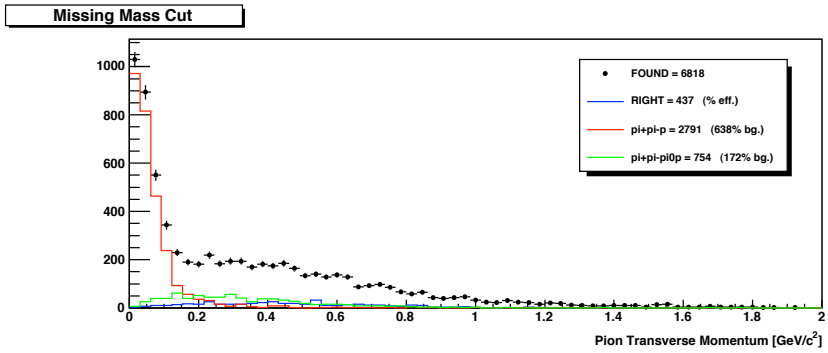

No cuts
FOUND = 46609
RIGHT = 607 (12% eff.)
pi+pi-p = 4900 (807% bg.)
pi+pi-pi0p = 2190 (360% bg.)
Total Photon Energy from Tracks [GeV/c²]
Missing Mass Cut
FOUND = 6815
RIGHT = 436 (% eff.)
pi+pi-p = 2790 (639% bg.)
pi+pi-pi0p = 753 (172% bg.)
Total Photon Energy from Tracks [GeV/c²]
Missing Mass and Tracks == 3
FOUND = 5570
RIGHT = 429 (% eff.)
pi+pi-p = 2773 (646% bg.)
pi+pi-pi0p = 6 (1% bg.)
Total Photon Energy from Tracks [GeV/c²]

Figure 12:


No cuts
FOUND = 43625
RIGHT = 576 (11% eff.)
pi+pi-p = 4778 (829% bg.)
pi+pi-pi0p = 2133 (370% bg.)
Pion Transverse Momentum [GeV/c$^2$]


Missing Mass Cut
FOUND = 6818
RIGHT = 437 (% eff.)
pi+pi-p = 2791 (638% bg.)
pi+pi-pi0p = 754 (172% bg.)
Pion Transverse Momentum [GeV/c$^2$]

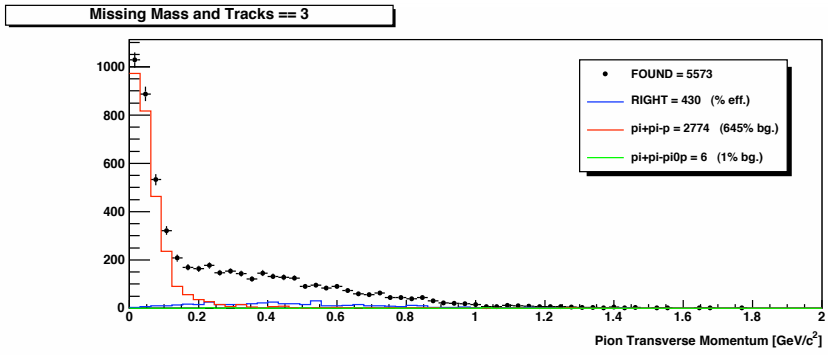

Missing Mass and Tracks == 3
FOUND = 5573
RIGHT = 430 (% eff.)
pi+pi-p = 2774 (645% bg.)
pi+pi-pi0p = 6 (1% bg.)
Pion Transverse Momentum [GeV/c$^2$]

Figure 13:

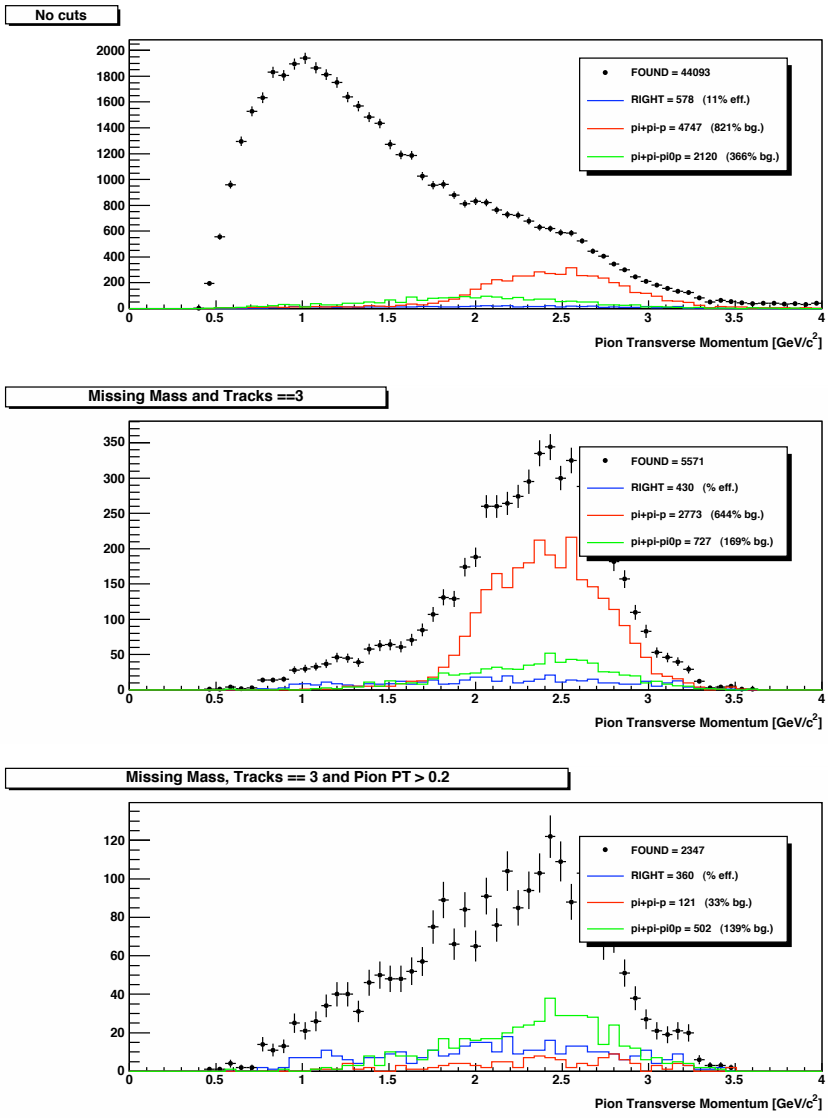

No cuts
FOUND = 44093
RIGHT = 578 (11% eff.)
pi+pi-p = 4747 (821% bg.)
pi+pi-pi0p = 2120 (366% bg.)
Pion Transverse Momentum [GeV/c$^2$]
Missing Mass and Tracks ==3
FOUND = 5571
RIGHT = 430 (% eff.)
pi+pi-p = 2773 (644% bg.)
pi+pi-pi0p = 727 (169% bg.)
Pion Transverse Momentum [GeV/c$^2$]
Missing Mass, Tracks == 3 and Pion PT > 0.2
FOUND = 2347
RIGHT = 360 (% eff.)
pi+pi-p = 121 (33% bg.)
pi+pi-pi0p = 502 (139% bg.)
Pion Transverse Momentum [GeV/c$^2$]

Figure 14:

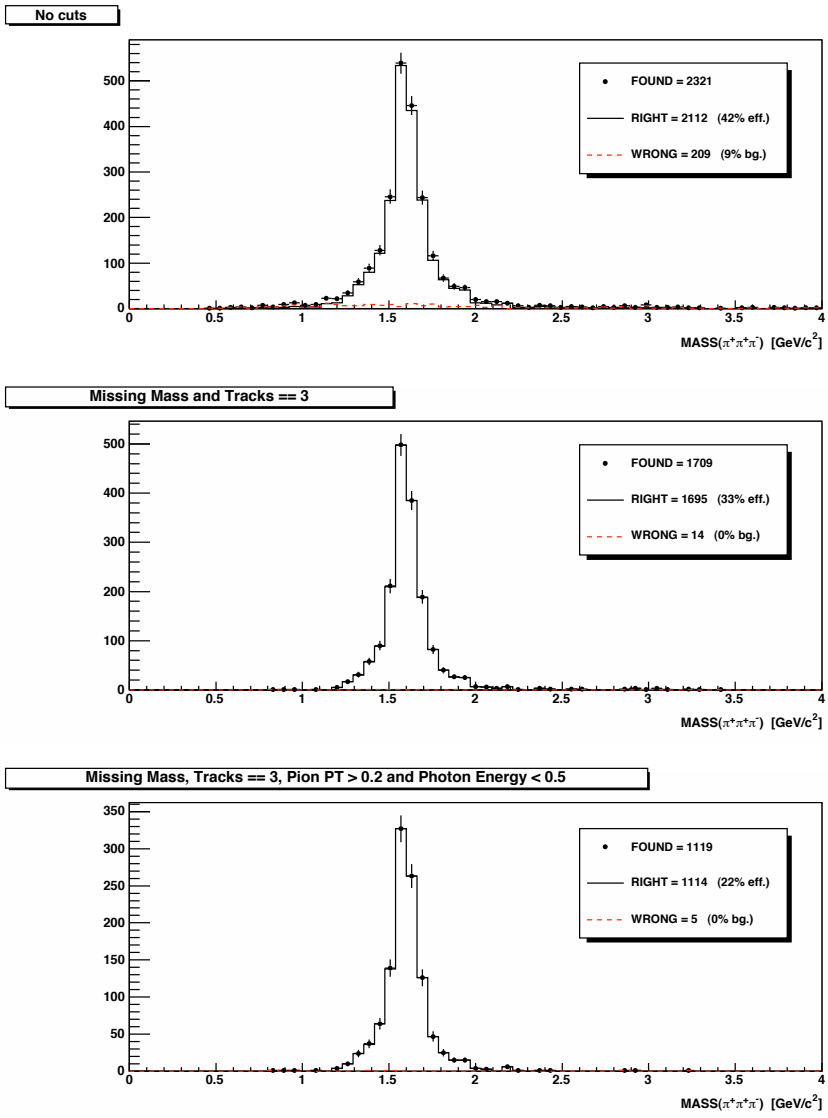

No cuts
FOUND = 2321
RIGHT = 2112 (42% eff.)
WRONG = 209 (9% bg.)
MASS(π⁺π⁺π⁻) [GeV/c²]
Missing Mass and Tracks == 3
FOUND = 1709
RIGHT = 1695 (33% eff.)
WRONG = 14 (0% bg.)
MASS(π⁺π⁺π⁻) [GeV/c²]
Missing Mass, Tracks == 3, Pion PT > 0.2 and Photon Energy < 0.5
FOUND = 1119
RIGHT = 1114 (22% eff.)
WRONG = 5 (0% bg.)
MASS(π⁺π⁺π⁻) [GeV/c²]

Figure 15:

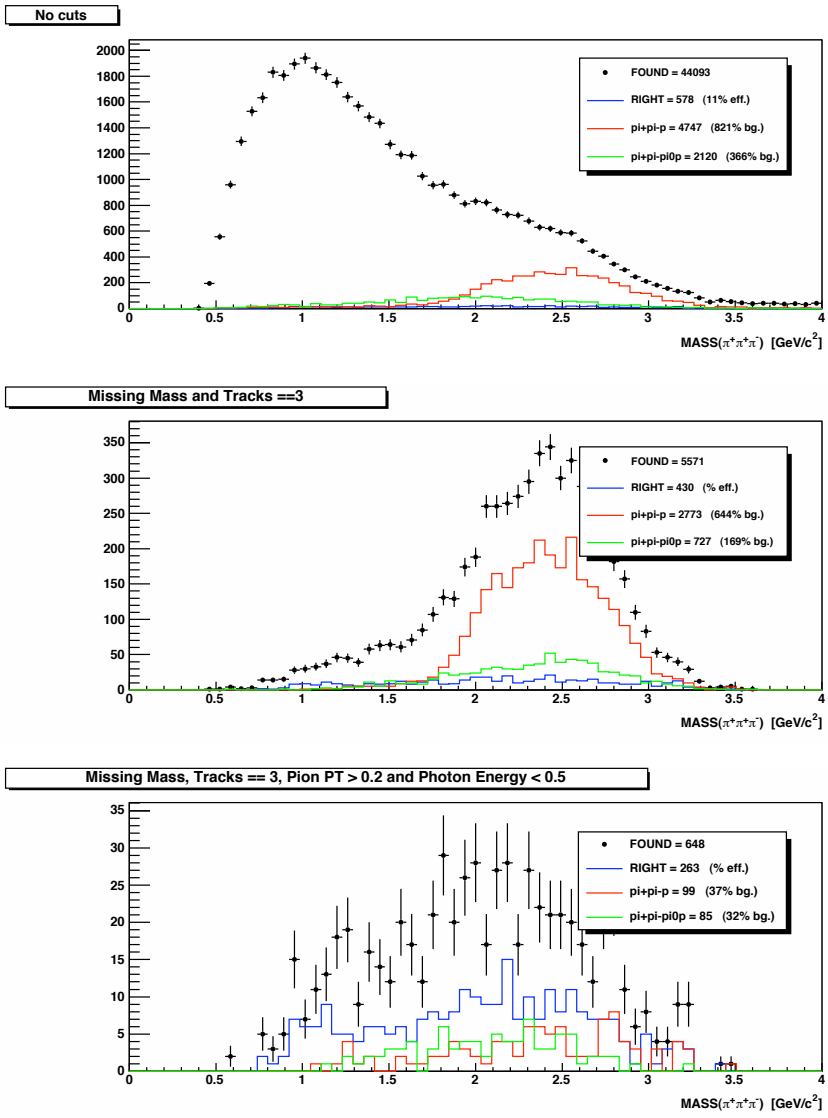

No cuts
FOUND = 44093
RIGHT = 578 (11% eff.)
pi+pi-p = 4747 (821% bg.)
pi+pi-pi0p = 2120 (366% bg.)
MASS(π⁺π⁺π⁻) [GeV/c²]
Missing Mass and Tracks ==3
FOUND = 5571
RIGHT = 430 (% eff.)
pi+pi-p = 2773 (644% bg.)
pi+pi-pi0p = 727 (169% bg.)
MASS(π⁺π⁺π⁻) [GeV/c²]
Missing Mass, Tracks == 3, Pion PT > 0.2 and Photon Energy < 0.5
FOUND = 648
RIGHT = 263 (% eff.)
pi+pi-p = 99 (37% bg.)
pi+pi-pi0p = 85 (32% bg.)
MASS(π⁺π⁺π⁻) [GeV/c²]

Figure 16: