Muon Tracking Absorber Study
and
Arm Two Tracking Performance

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1 Introduction

A brief study of the effect of polyethelene and lead absorbers on the mass resolution(s) obtained from the muon arm and on the number of tracks reaching the muon arm has been done. In addition, a comparison of the mass resolutions obtained in muon arms one and two has been done, using a 12 degree piston magnet in arm two and the baseline magnet and geometry in arm one. The tracking stations in this study were assumed to be drift chambers.

2 Baseline Geometry

The baseline muon arm geometry that was used for these studies can be seen in figure 1. Arm one has the following absorbers prior to the tracking stations: 1) a 28 cm copper nosecone in front of the central magnet yoke, 2) approximately 59 cm of steel from the central magnet yoke, 3) 45 cm of borated polyethelene (neutron absorber), 4) 7 cm of lead shielding following the polyethelene and 5) a copper piston plug which sits next to the beamline, inside the polyethelene and lead shielding. Arm two has the same shielding except that the copper nosecone is approximately 12 cm thick. The three arm one tracking stations are located at the approximate z values of 180, 348 and 600 cm and arm two tracking stations are located at 180, 288 and 450 cm, making it 1.5 meters shorter than arm one.

Each tracking station in both arms one and two was divided into octants, and each of these octants was comprised of three chambers each containing x, x', u, u', v, and v' measuring planes. The u and v planes were at stereo angles of +/- 22.5 degrees relative to the x planes. The primed planes contained wires that were offset one-half cell from the unprimed planes, allowing left-right ambiguities to be solved.

3 Mass Resolution Reconstruction

GEANT has been used to swim paricles through the baseline geometry described in the previous section. Hits at each of the muon tracking stations were recorded, and detector responses, track and mass reconstruction were performed in an offline analysis code called PISORP.

The detector response for these studies consisted of turning the (x,y) GEANT hit into a wire hit and drift distance and smearing the drift distance with a gaussian error with 100 micron sigma. The options of adding noise hits, turning on chamber inefficiencies, or turning on a double hit resolution were not used since we were interested just in the affects of different absorbers and different b-fields (when looking at arm two) for these studies.

The mass resolutions were determined by using GEANE to fit the particle track and extract a momentum vector at the vertex (assuming a 1 mm vertex resolution from the inner detectors) for each of the muons produced by the decay of the vector mesons, and then reconstructing the mass given the mass of the muons and the reconstructed momentum vectors. An input guess of the momentum (for GEANE) was obtained by taking the known momentum at the outermost station and smearing it by 10% (this is approximately 7 times the final resolution obtained by GEANE). GEANE then iteratively swam the particle from the outermost tracking plane all the way to the vertex, knowing the field map, the amount of absorber material in the path, and the measured hit points at each tracking plane and at the vertex. The fit to the measured points, with the proper weighting given the material between measurement points, was minimized to get a final momentum vector fit.

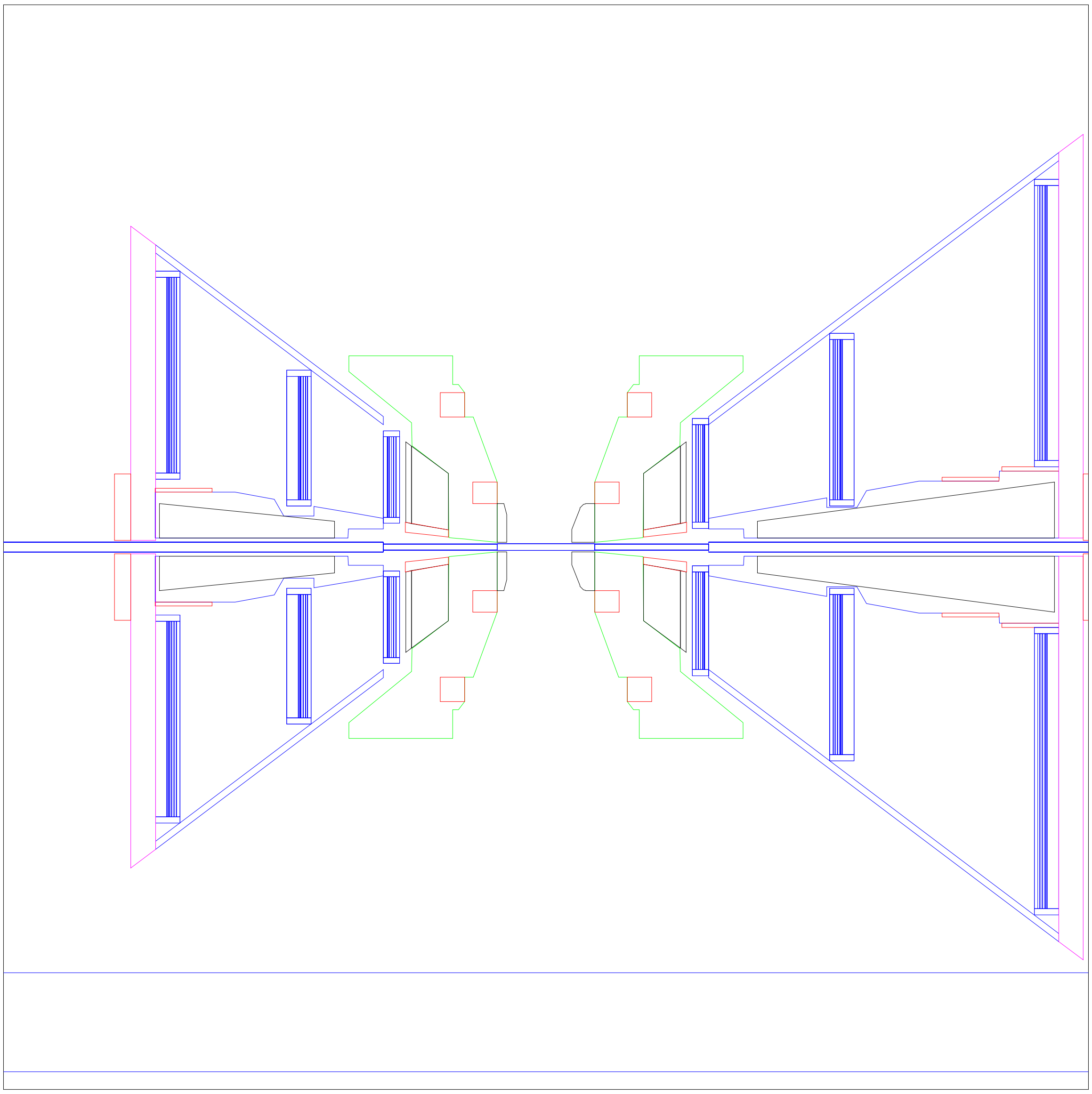

Figure 1: The geometry of the two muon arms in the GEANT simulation code.

4 Mass Resolutions in Arm 1 With and Without Absorbers

Figure 2 shows the mass resolutions obtained for phi, j/psi, and upsilon vector mesons in arm one when all baseline absorber materials were present and the detector resolutions were 100 microns per plane. The results are 118 MeV for phis, 147 MeV for j/psis and 220 MeV for upsilons. Previous studies, which did not include all of the absorber materials and parameterized the momentum resolution of tracks within the muon tracking stations produced mass resolutions of 60, 93, and 175 MeV. The increased resolutions of the phis and j/psis from the previous results is thought to be unacceptable performance for the muon arm since the neighboring mass peaks of the psi-prime and rho (next to the phi) are difficult to separate event at the lower mass resolutions. Since the mass resolutions of the phi and j/psi are dominated by the straggling in the absorbers, it is possible for the mass resolution to be significantly improved if the tracking station geometry is left the same, but the absorber material prior to the tracking stations is decreased. The purpose of this study, therefore, is to see if the mass resolution can be improved significantly by removing some of the absorber, without causing the occupancies in the tracking chambers to increase to unacceptable levels. The mass resolution of the upsilon is not expected to improve significantly since the momentum resolution in the tracking stations is contributing as much to the mass resolution as is the straggling in the absorbers.

The 45 cm of borated polyethelene and the 7 cm of lead were removed from the GEANT simulation and the mass resolutions of the phi and j/psi were recalculated. The results are shown in figure 3. The phi resolution decreased from 118 MeV to 87 MeV. The j/psi resolution decreased from 147 MeV to 117 MeV. Both of these are substantial improvements which bring the resolutions much closer to the hoped for resolutions of 60 and 93 MeV. The concern, then, is that the particle flux at the tracking stations might increase enough to prohibit removing these absorbers. An initial study of this has been done by running hijet events through GEANT with and without the poly-lead absorbers and looking at the flux of charged particles at the first tracking station, where the fluxes are expected to be the highest. Figure 4 shows the radial distribution of tracks at the first plane in station one, arm one with and without the absorbers present. The overall charged particle

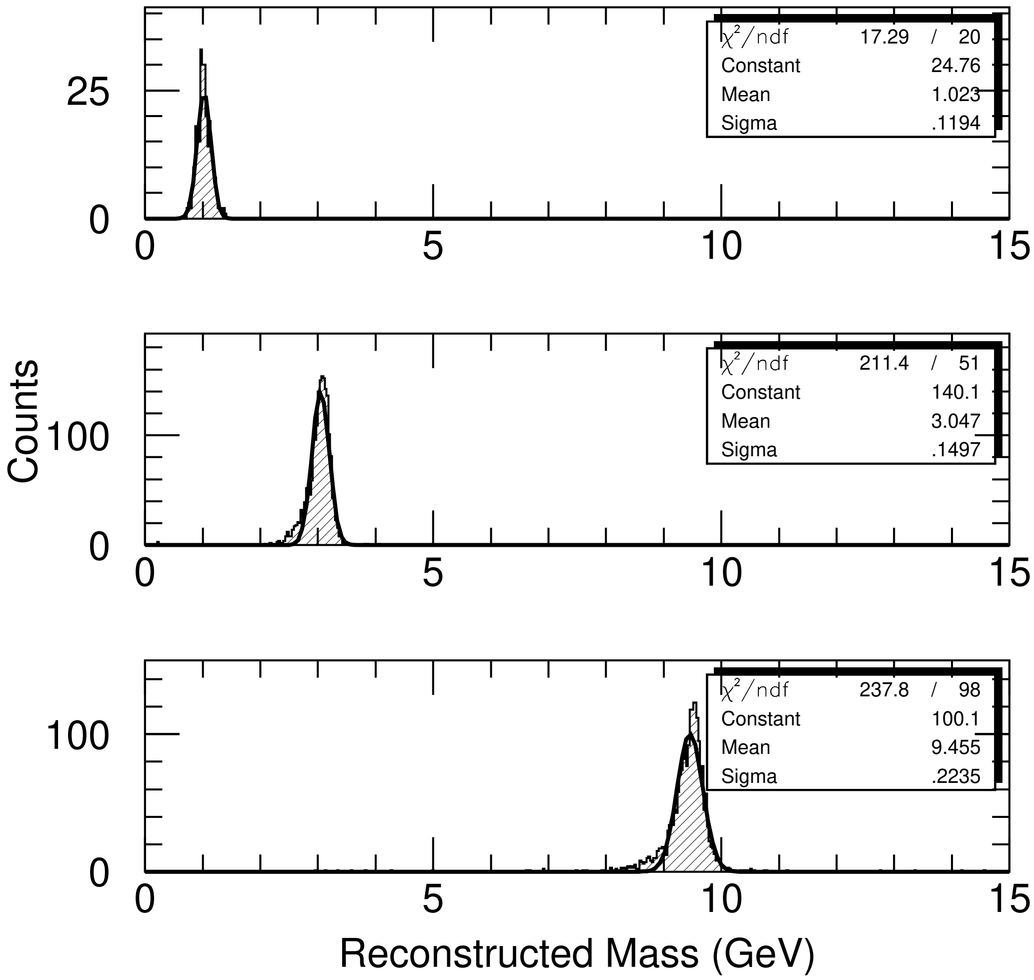

Figure 2: The reconstructed mass of phi, j/psi, and upsilon vector mesons in arm one as produced by the simulation code when all of the baseline absorbers are present. The fit statistics are the results of gaussian fits to the reconstructed mass peaks.

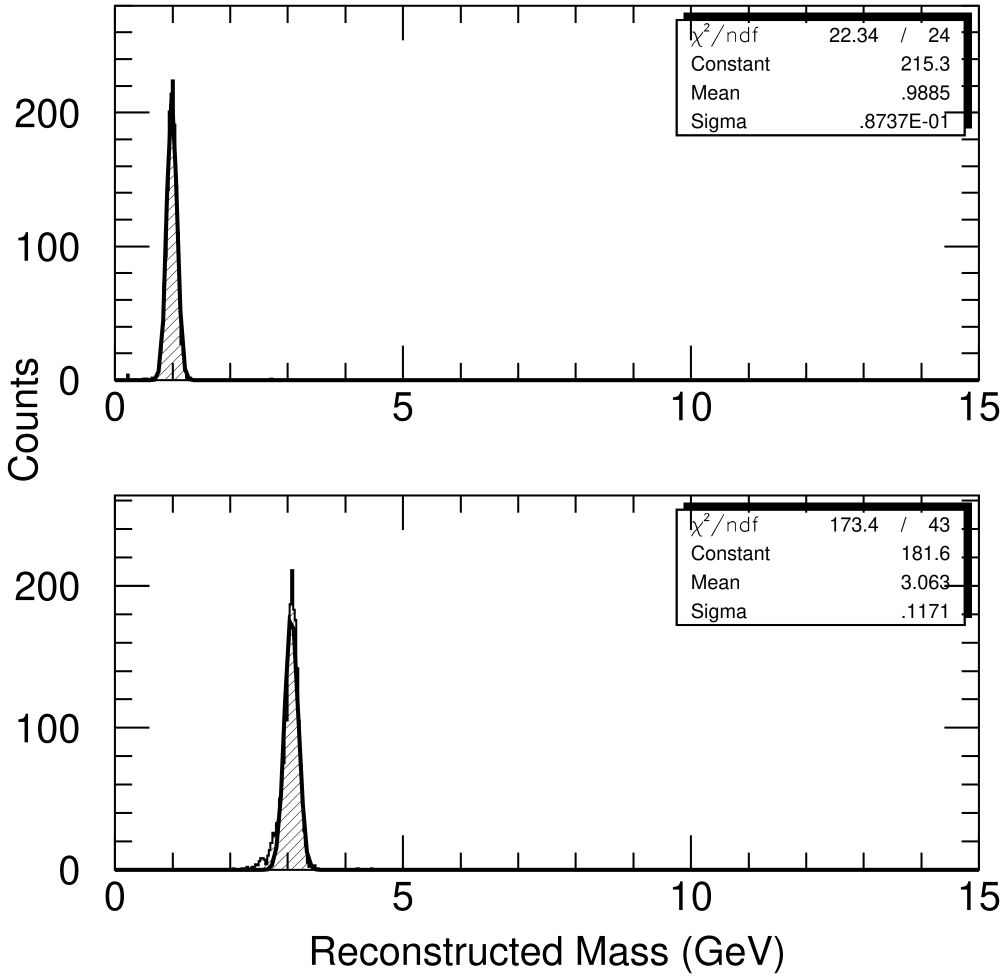

Figure 3: The reconstructed mass of phi and j/psi vector mesons in arm one as produced by the simulation code when the polyethelene and lead absorbers are removed. The fit statistics are the results of gaussian fits to the reconstructed mass peaks.

flux increases by a little less than a factor of two. However, the peak flux, which is found at the inner-most radii of the chambers increases only slightly when the absorbers are removed. Therefore, although the overall average occupancy does increase by a factor of two, the peak occupancies, where there would be the most difficulty in pattern recognition, do not increase significantly. Figure 5 shows the same results for arm two, with similar conclusions. In fact, both the average and peak occupancies in arm two are less than in arm one because of the increased piston angle (10 degrees in arm one and 12 degrees in arm 2).

5 Mass Resolution in Arm Two

The mass resolution in arm two can be expected to be different that in arm one for two separate reasons. The amount of absorber material is slightly less (because the copper nosecone is 16 cm shorter) so the straggling contribution can be expected to be slightly less, but the arm is 1.5 meters shorter so the momentum resolution suffers because of a shorter lever arm to measure the track curvatures. The magnetic field has been tailored to produce the most bend possible in the shorter distance, but the momentum resolution of high-momentum tracks is still poorer in arm two than in arm one.

The mass resolutions produced by this baseline muon arm two are shown in figure 6. As can be seen, the resolution for the phi and the j/psi are as good as or better than the resolutions produced by arm one (arm two has 114 MeV resolution for phis and 130 MeV resolution for j/psis), but the upsilon resolution is degraded somewhat. Arm one produces a resolution of approximately 220 MeV while arm two produces a resolution of 245 MeV. The reason for this can be seen in figure 7 where the momentum resolutions inside the spectrometers are shown for arms one and two. The arm two resolution is a factor of 1.4 worse than arm one, causing the degradation in mass resolution.

Because the upsilon mass resolution in arm two is dominated by the momentum resolution in the spectrometer, there is a much stronger dependence of the mass resolution on the chamber resolution than in arm one. (In arm one the mass resolution is determined by the straggling in the absorbers as well as the resolution in the tracking stations.) This dependence on chamber resolution is shown in figure 8 where the mass resolution of the upsilon is

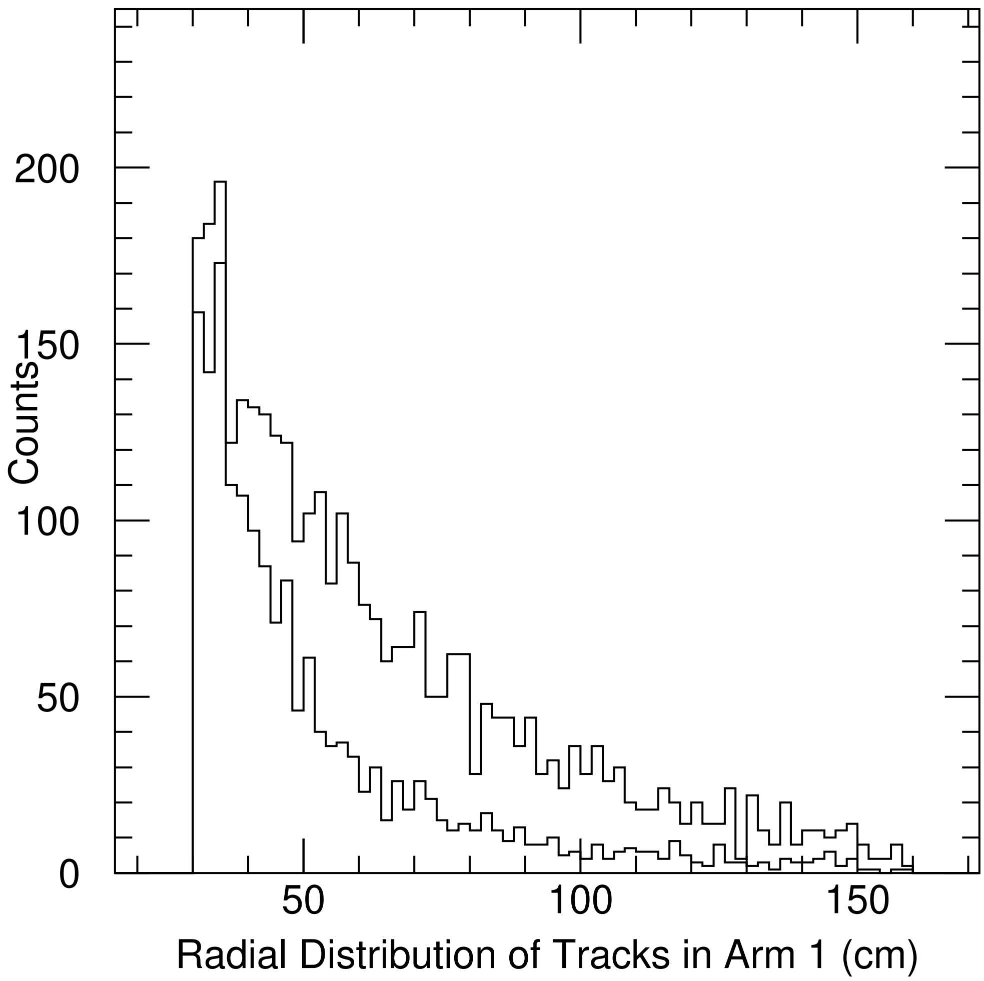

Figure 4: The radial distribution of tracks from hijet events in the first plane in arm one. The distribution of tracks is shown for events with the polyethelene and lead absorbers (bottom curve) and without these absorbers (upper curve).

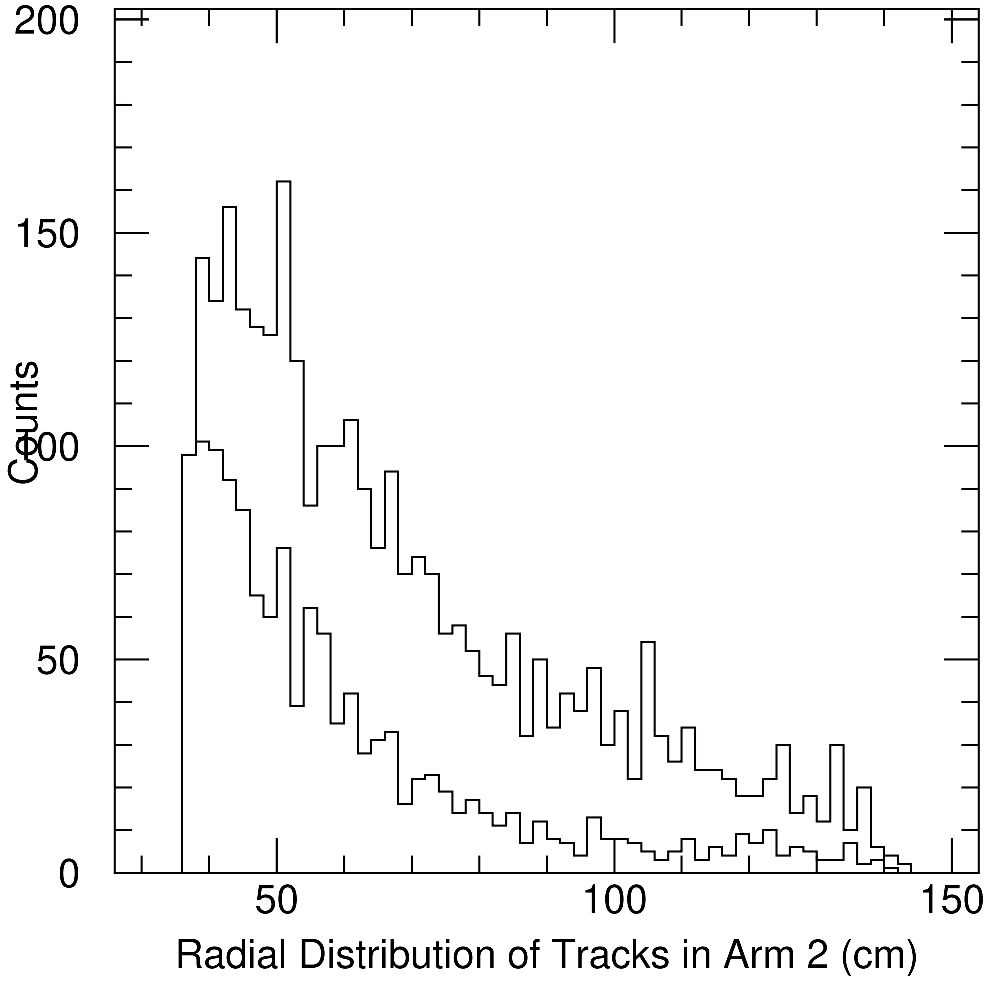

Figure 5: The radial distribution of tracks from hijet events in the first plane in arm two. The distribution of tracks is shown for events with the polyethelene and lead absorbers (bottom curve) and without these absorbers (upper curve).

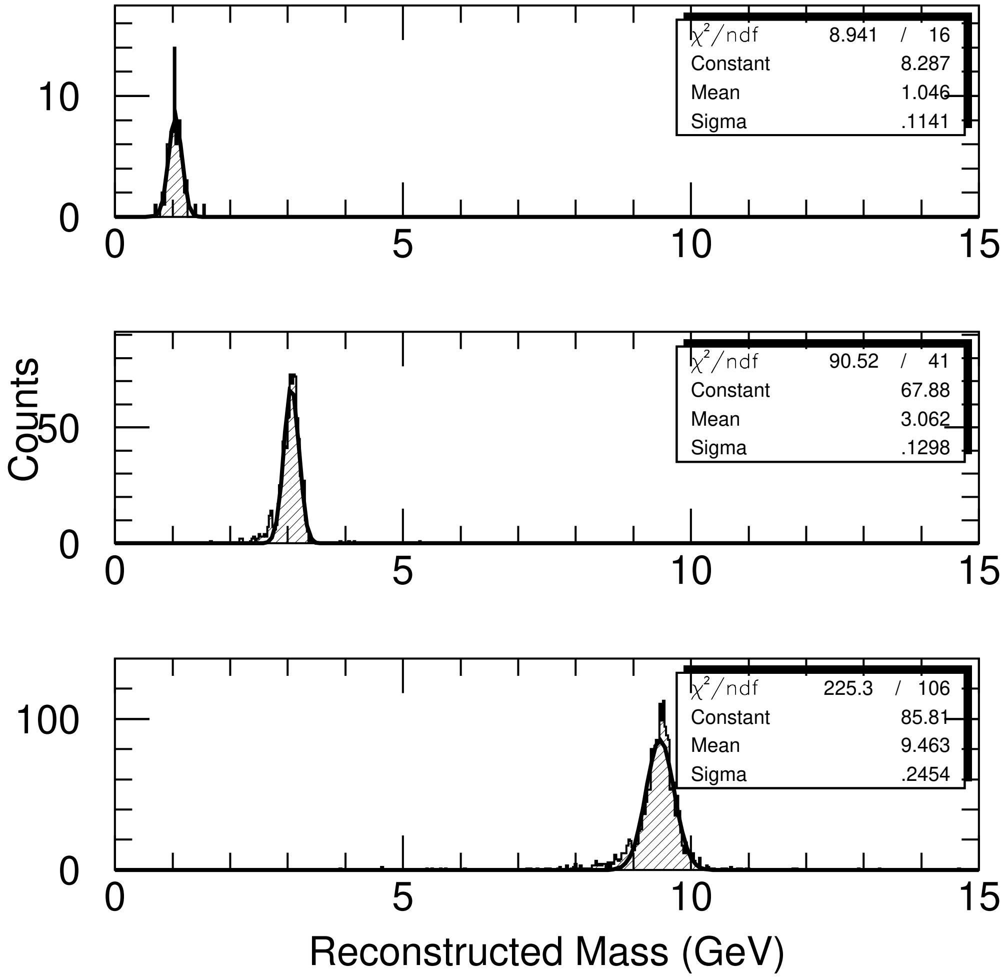

Figure 6: The mass resolution of phi, j/psi, and upsilon vector mesons as reconstructed in arm two by the simulation program. The fit statistics are the results of gaussian fits to the mass peaks.

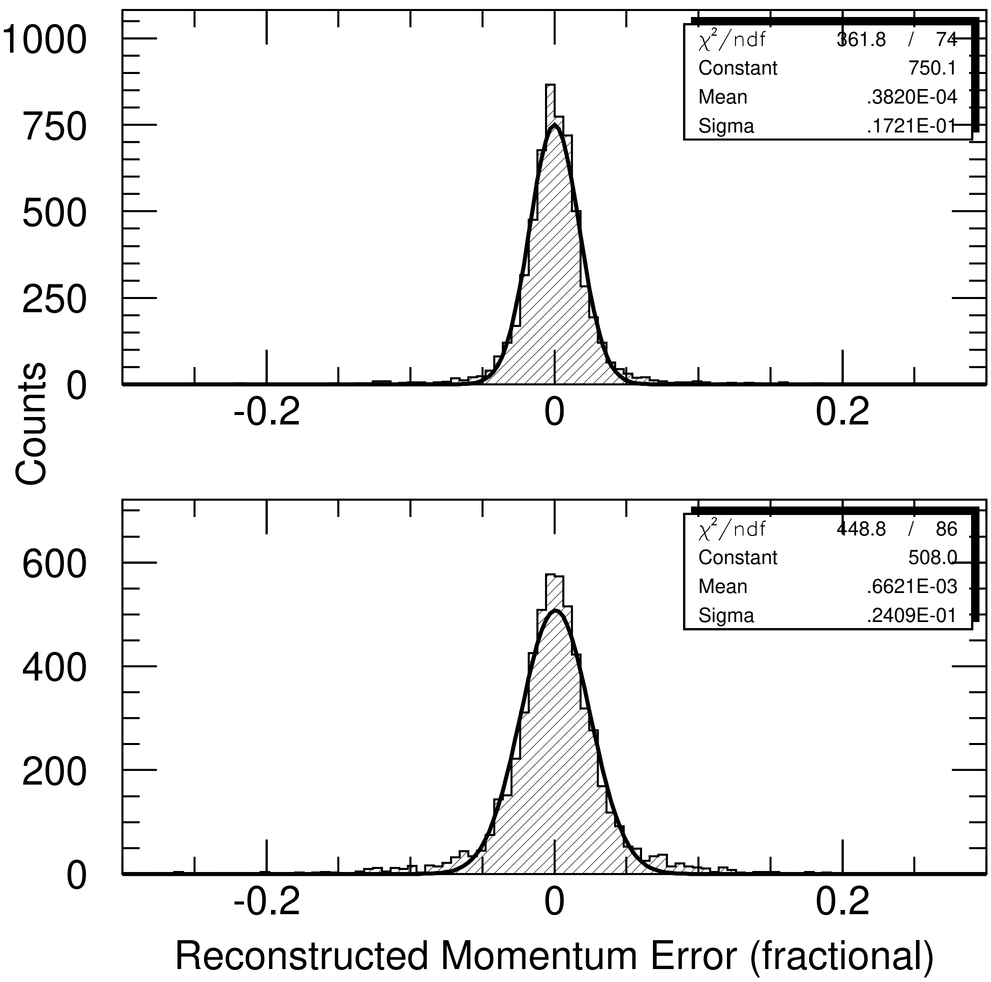

Figure 7: The momentum resolution of reconstructed muons from upsilons in arm one (top figure) and arm two (bottom figure). The fit statistics are the results of gaussian fits to the momentum peaks.

shown versus the chamber resolution.

The mass resolution in arm two can also be improved more dramatically if the b-field is increased than it would in arm two. If the b-field could be increased by 20%, the mass resolution of 225 MeV which is shown in figure 9 would result.

6 Conclusions

Both muon arms can produce significantly improved mass resolutions at the phi and j/psi mass if the polyethelene and lead absorbers are removed. The result on the charged particle flux is an increase in average occupancy of about a factor of two, but little increase in the peak occupancy which occurs at the inner radii of the chambers. The neutron and other fluxes should also be looked at to see if removal of these absorbers causes other detrimental effects.

The mass resolution performance in arm two, with a baseline magnet that has a 12 degree piston is comparable to arm one at the phi and j/psi. The resolution at the upsilon is noticeably degraded by about 20 percent from arm one and depends much more strongly on the chamber resolution that can be obtained. However, if the b-field can be increased the mass resolution will improve by approximately the same factor.

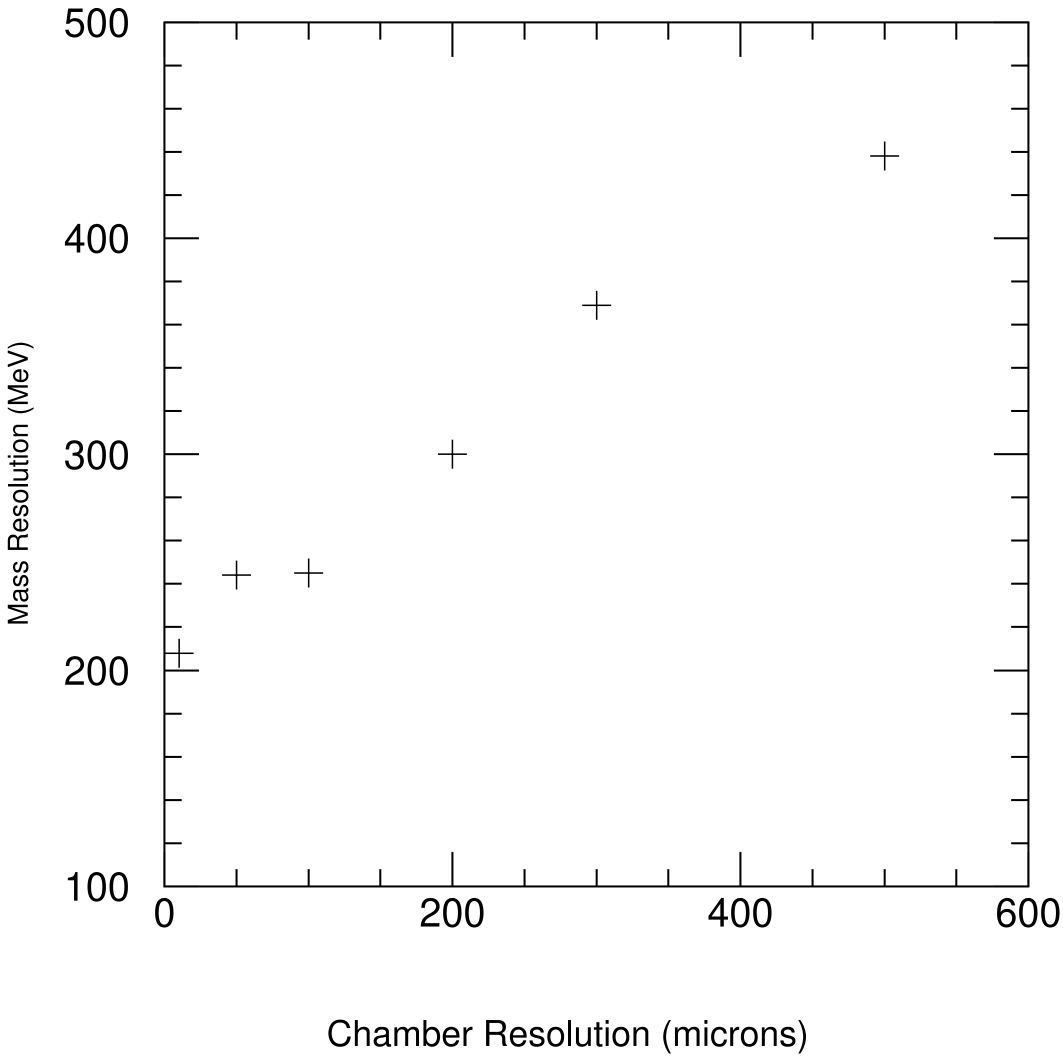

Figure 8: The momentum resolution of reconstructed muons from upsilons in arm two versus the chamber resolution.

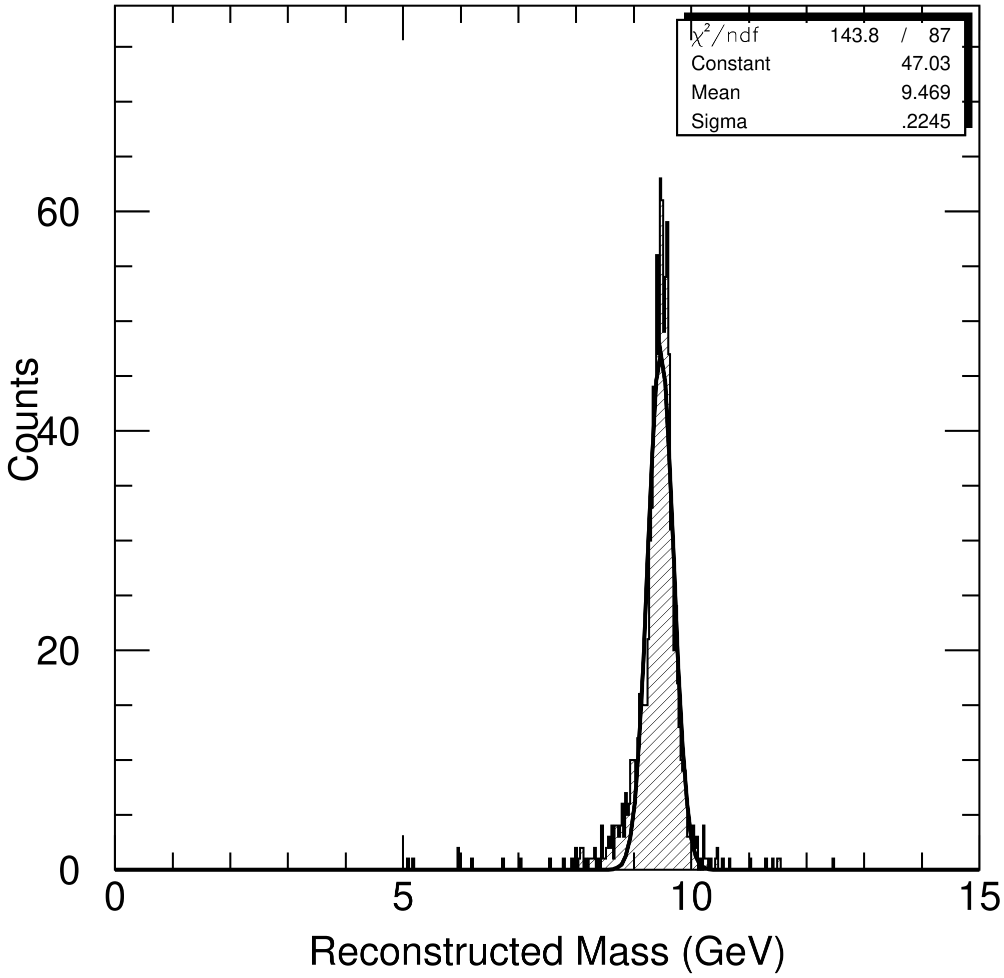

Figure 9: The reconstructed mass of upsilons in arm two when the magnetic field is increased by a factor of 1.2 from the baseline field.