Muon Spectra from Data

Momenta Fit Using SFT & DC

This memo gives the muon spectra from μ CC interactions in the emulsion targets using the "conventional" method of determining the momenta of the muons. To find the momentum of the muon, the track must be fit (at least in the *x*-view) in the drift chambers (DC) and the SFT (at least *u*-view and *v*-view). For these results, the VDC was always excluded from the fit. Only events whose primary vertices lie in the range -10cm < *z* < +90cm were used, so that upstream interactions in the lead were excluded, but interactions in the CS or SFT were allowed. The data includes all of Period 3, and events from Period 4 from runs < 3300. This set should be updated soon to include all of Period 4.

These results will be weak for momenta greater than approximately 100 GeV/c, as the uncertainty in the slopes of the fitted lines becomes comparable to the bend in the track due to the magnet. A more accurate statement is that for tracks with small values of $1/p$, the value of $\delta(1/p)$ becomes comparable. The spectrometer response function is assumed to be gaussian for this study, with a width, $\sigma = 0.005$ $(\mathrm{GeV/c})^{-1}$. Therefore, a track with a true momentum value of 200 GeV/c has significance in the sign of the track of only 1σ and so has a ~20% probability of having the wrong sign. In fact, there are other systematic effects which may also adversely affect the momentum measurement. The most important effect is changing the hits on the track in the SFT system: either adding or deleting hits can significantly affect momentum value. Although it is not a gaussian random process, the net effect is approximately to increase the width in $1/p$ from $\sigma = 0.005$ to 0.008. Therefore, in this analysis, the tracks with abs(p) > 150 GeV/c should be considered unreliable in value and sign, and are considered only as the "high-momentum" component of the spectrum.

Discussion of Results

The results for 169 muon events are shown in the Figures 4 through 6. The anticipated spectrum from prompt events is shown in Figures 1 through 3. The non-prompt muon spectrum, *i.e.* ν's not from charm decay, is shown in Figure 7.

• *Ratio -/+* The ratio of the total neutrino cross section to the total anti-neutrino cross section is approximately 2. The MC sample has a ratio of 1.9 after trigger and muon wall acceptance are included. The data has a ratio of 1.52±0.23. This would be the expected ratio for the muons at the highest momentum, as can be seen in the differential ratio of N_-/N_+ in Fig. 2. The ratio exceeds 2.0 for momenta less than 40 GeV/c. This is expected, since the differential anti-ν cross section is proportional to $(1-y)^2$, where $y = (E_\nu - E_\mu)/E_\nu$. The μ^+ sample, from anti-ν's, is depleted for values of p_μ less than the median value, increasing the ratio. The data in Fig. 5, do not show this behavior, since the average ratio, as already mentioned, is about 1.5 .

• *Momentum Spectrum* The momentum distribution of the muons expected from charm decays from the dump is shown in Fig 1. These MC data include the geometric and trigger acceptance. Generally, the acceptance limitations deplete the lowest momentum bins, for $p_\mu < 20$ GeV/c. The MC data was generated with $(1-|x_f|)^{7.7}$ longitudinal weight. This exponent (a.k.a. n) impacts the steepness of the high-momentum fall-off. There is only a small difference between the positive and negative data, but the positive sample is expected to have a slightly higher mean due to the y dependence. The data follows the expected spectrum qualitatively, but is "softer" with a lower average value, and falls off at large values of p_μ more quickly. Contrary to the MC, the positive mean momentum is lower than the negative data. Both MC and data samples are cutoff at 150 GeV/c for the computation of the average momentum. This cut is applied for reasons already stated: the momentum estimate is unreliable at large values.

The distributions of Fig. 3 are the combined data from Period 3 and Period 4. This was done to increase the statistics, especially to see the high-*p* fall-off. But it must be noted that the two samples may have slightly different systematics, mainly because the data from Period 4 uses trigger types 1 and 2, while for Period 3, the trigger type 2 was not yet installed. Recall that trigger type 2 required only one adjacent hit in each of the counters downstream of the interaction, meaning that it was possible that only one track triggered the event. Thus, the efficiency for triggering on m CC interactions was larger in Period 4 than in Period 3, 98% and 92% respectively. Figure 6 shows the muon spectra from Period 3 only. The ratio of negatives to positives is 1.44±0.31, consistent with the combined sample. The spectra are qualitatively similar, although the mean values from Period 3 alone are slightly lower.

• *Non-prompt Component* It is expected that some fraction of the muon data will not be from charm decays, but come from π decays (mostly) in the dump. Since the ν's have a lower average energy (50 GeV and in the target), the muons from the interaction will be peaked at lower values of p_μ and approximately 40% of the muons from non-prompt interactions will be less than 20 GeV/c, after trigger and acceptance are included. The MC events from charm decay yield about 20% of all interactions which have a muon less than 20 GeV/c. At the other extreme, 4% of the nonprompt muons have momenta exceeding 100 GeV/c, while the MC prompt sample yields 21%. There are effects not included in this study that will reduce the data from μ CC at low energies. There are visual scan biases which undoubtedly reduce the efficiency at low p_μ, but this has not yet been studied quantitatively. More calculations are needed to determine an estimate for the non-prompt μ CC and NC background.

	Data	MC
N_{tot}	169	300
N_-	102	162
N_+	67	138
N_-/N_+	1.52±0.23	1.92±-0.20*
$<p_\mu>_{tot}$	45.2	57.9
$<p_{\mu-}>$	48.3	55.8
$<p_{\mu+}>$	40.5	61.9
N(p_μ>100 GeV/*c*)	13 (7.7%)	(21%)
N(p_μ<20 GeV/*c*)	43 (25%)	(16%)

Table 1. Summary of muon sample
The data and MC events are compared for the Period 3 and the Period 4 muon events for run numbers < 3300. Note * that the ratio for the MC evetns must be computed using the weights that are attached to each event.

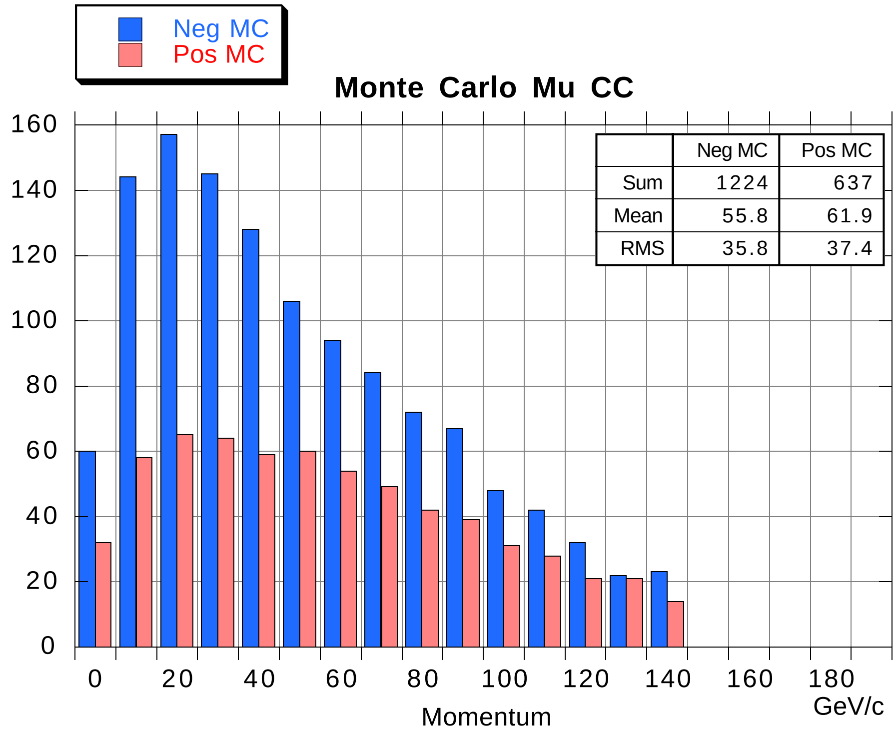

Figure 1. Monte Carlo muon spectrum.
The spectrum from m CC events in the Monte Carlo with the negative muons (from ν interactions) and the positive muons (anti-ν) separated.

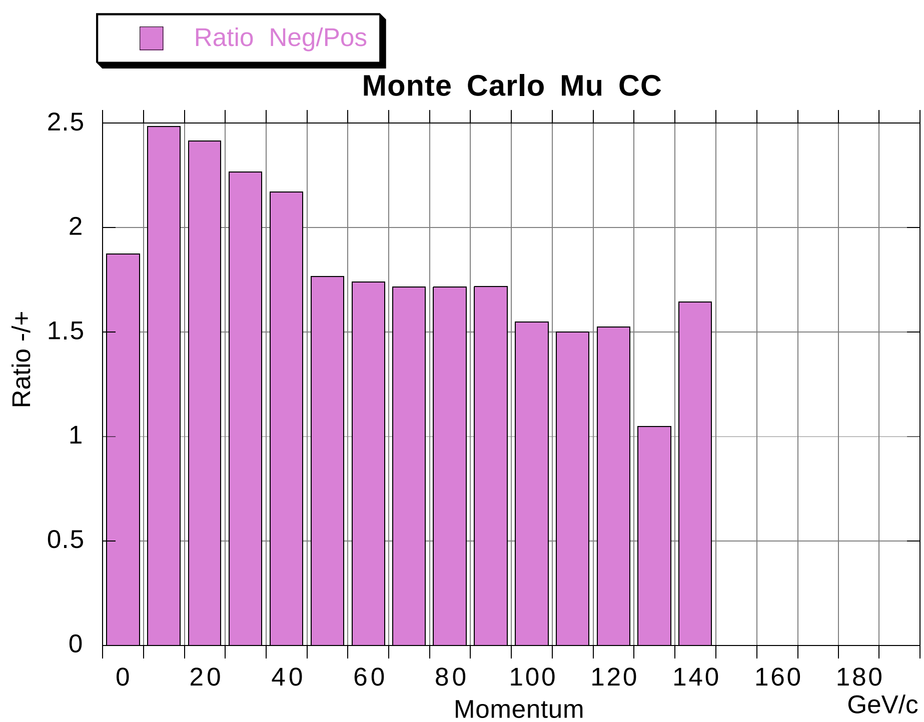

Figure 2. Monte Carlo spectrum ratio.
The ratio of the μ^- spectrum to the μ^+ spectrum. Note the trend from high values at low mometum to a ratio of 1.5 at high momentum, due mainly to the *y* dependence of the differential cross section.

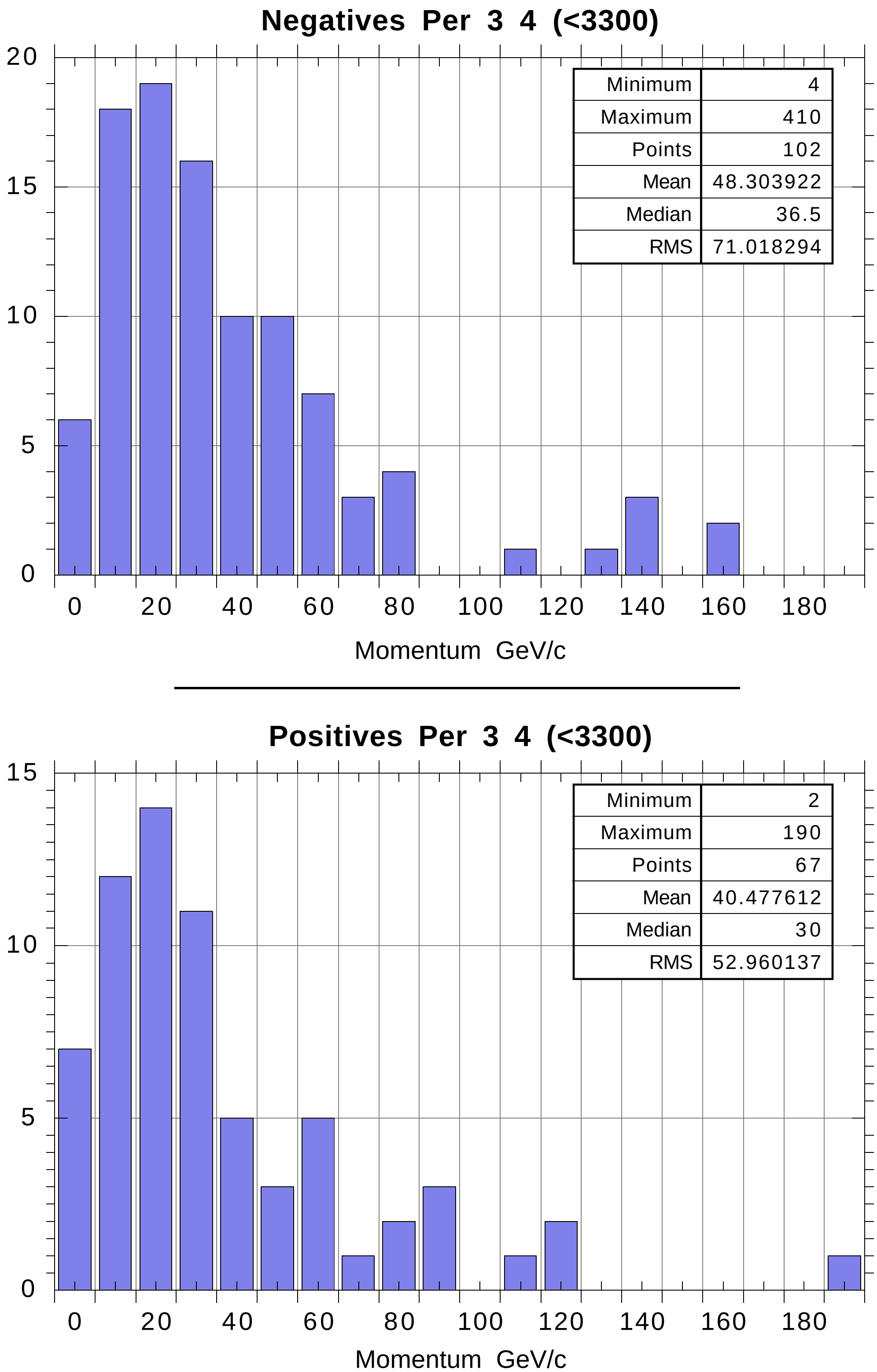

Figure 3. Muon spectra from data: Period 3 and 4.
The data from Periods 3 and 4 is combined. The momentum fit is the standard analysis of track fitting without explicit vertex contraints.

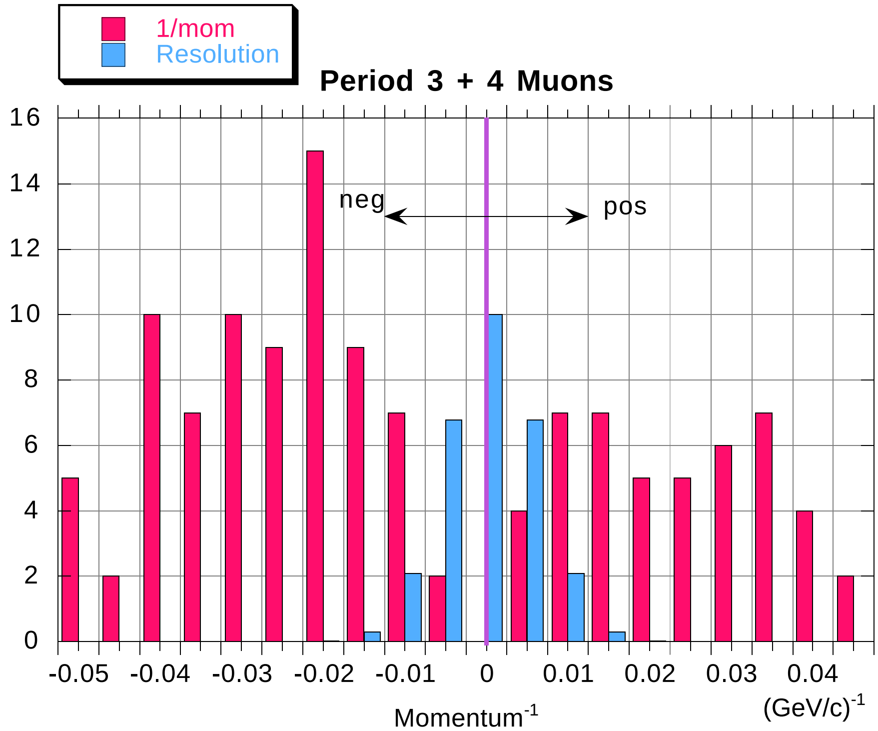

Figure 4. Inverse momentum for the data.
Data from Period 3 and 4 are shown as a 1/*p* distribution, which shows symmetric errors about the origin. Superposed is the expected error function due to uncertainties in the track measurements. For the data within 2σ of the center, the data is considered a poor measurement.

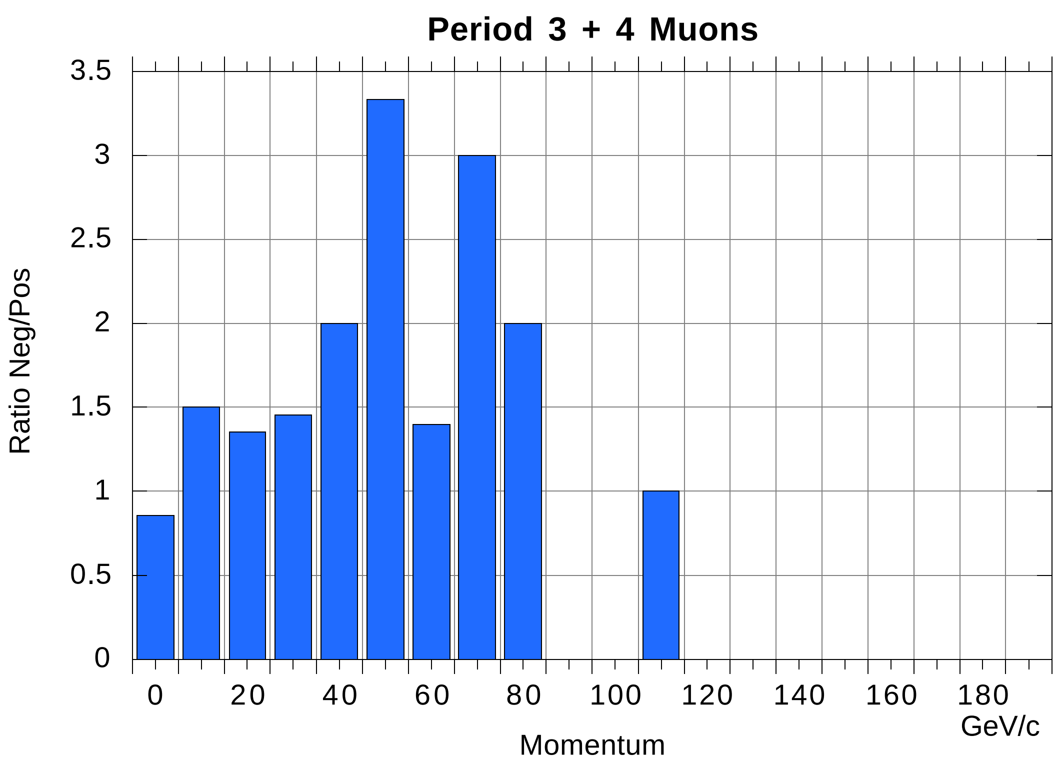

Figure 5. The spectrum ratio for data.
The ratio of the μ^- spectrum to the μ^+ spectrum, although the trend appears to be opposite that of Fig. 2, only the bins with $p_\mu < 50$ GeV/*c* are statistically significant.

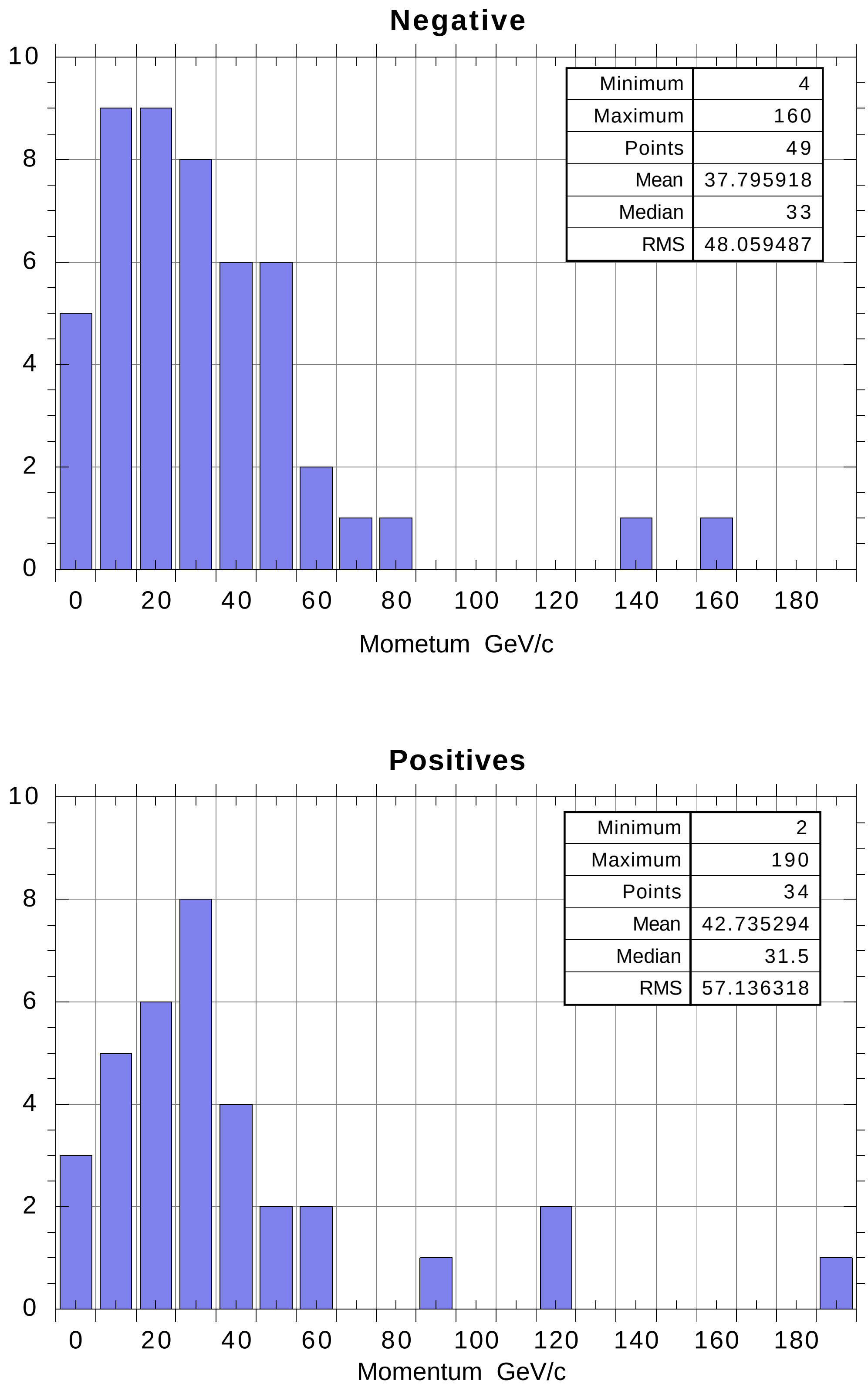

Figure 6. The data for Period 3 only.

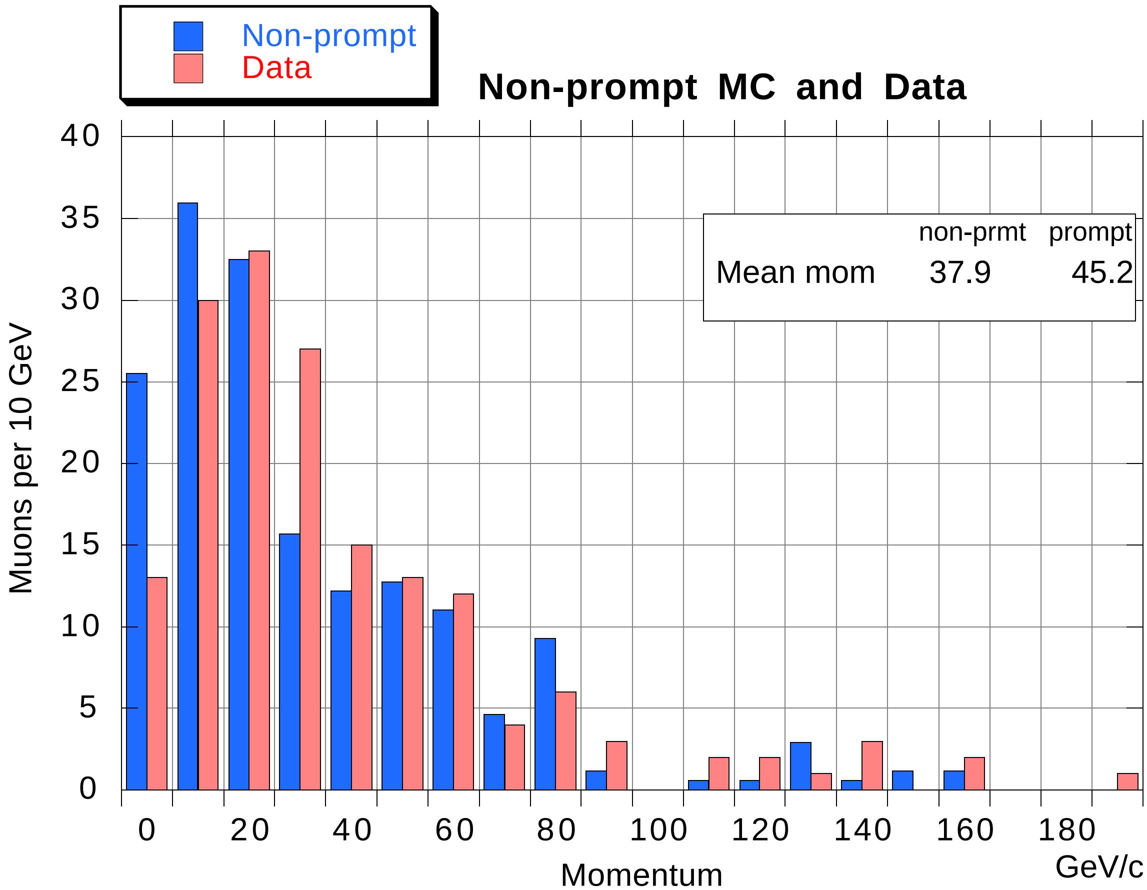

Figure 7. Non-prompt spectrum.
The expected spectrum from non-prompt muons is shown together with the combined data: both signs, and Period 3 and 4. Both data sets have the same number of events.