Precision Measurement of Charmed Meson Masses

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We are searching for a solution to the observed discrepancy in the measured K_s mass as a function of its leg momentum in the decay of $K_s \to \pi^+\pi^-$. Our guess is that the path length of the track, which is dependent on p_t and $\cos\theta$, is the source for the resulting error of measured momentum verse the true momentum. We plan to plot the K_s mass verse both p_t and $\cos\theta$ and analyze the results produced. We find that $\cos\theta$ plays a very small part in the error, and that the measured momentum itself needs to be corrected in order to accurately calculate the correct invariant mass.

I. INTRODUCTION

The goal is to measure masses of charm mesons with an accuracy of ±0.001 GeV. When looking at the $K_s \to \pi^+\pi^-$ decay, we find that as a function of the measured momentum of the legs there is a shift in the reconstruction of the K_s mass. While the resulting shift is small, we feel that it can be improved by studying it as a function of path length.

II. $\cos\theta$

In starting the experiment we decided to look at $K_s \to \pi^+\pi^-$ decay from CLEO II.V data. With approximately 13 million events to look at we felt this would be sufficient in trying to solve our problem.

First we looked at the mean of the observed mass minus the known K_s mass as a function of $\cos\theta$ in all data sets 4sh through 4st. We fit this to a double Gaussian with a second order polynomial to model the background. The data is fit into 10 bins ranging from -1.0 to 1.0. An example, typical to all data sets, is shown in Figure 1. We see that the mean minus the known K_s mass is not dependent on $\cos\theta$ and it appears to be roughly flat right around 0.0005 Gev.

Since we find that at all ranges of $\cos\theta$, the mass is roughly the same, we then decided to look at p_t as a possible source of the error in the observed mass.

III. p_t

We then plotted the mean of the observed mass minus the known K_s mass as a function of p_t. Again this was done to all data sets. We fit the data to a bifurcated Gaussian and a second order polynomial to model the background. The data was fit into 10 bins ranging from 0.0 through 1.25 Gev with all data over 1.25 GeV put into one overflow bin. An example of a single data set fit can be seen in Figure 2 and all data sets can be seen in Figure 3.

You can see that although different data sets appear a little higher or lower on the mean axis, they all take roughly the same shape. So, looking at Figure 3, we decided to compute

p_t dependent corrections to the legs to achieve an accurate measurement of K_s.

IV. CORRECTION TO MOMENTUM

As similarly done in CBX 01-23, we began to work on calculating corrections. We calculate the correction to either leg assuming that the opening angle is measured correctly. The momentum, p_{c1}, that gives the exact K_s mass for the opening angle, θ, and the momentum of the other leg, p_2, is obtained by solving the quadratic equation

$$0 = 4(m_\pi^2 + p_2^2 - p_2^2\cos^2\theta)p_{c1}^2 + 4p_2\cos\theta(2m_\pi^2 - m_{K_s}^2)p_{c1} + 4m_\pi^2(p_2^2 + m_{K_s}^2) - m_{K_s}^4 \,, \quad (1)$$

which is derived from the invariant mass formula for the K_s to two charged pion decay. Next is to compute a correction, c1, to the measured momentum, p_1, so that $p_{c1} = p_1(1 + c1)$. This is done for both legs, resulting in two correction, c_1 and c_2. To solve for the momentum dependent correction we say

$$p_{c1}p_{c2} = p_1(1 + c1)p_2(1 + c2) \quad (2)$$

$$= p_1p_2(1 + c)^2 \quad (3)$$

giving us

$$(1 + c)^2 = (1 + c1)(1 + c2) \quad (4)$$

We then took those calculated corrections and applied them to the observed momentum of all the data sets. Examples of the p_t corrections themselves along with the momentum after the corrections have been applied can be seen in Figures 4 and 5.

V. RESULTS

Looking at Figure 5 one can see the improved accuracy in the calculation of K_s mass. What we have achieved by applying the corrections is to have determined the calculated mass of K_s to within 0.2 MeV of the real value. Before correcting the momentum, we had a difference of up to 1.0 MeV or greater at various energies. Thus, through this experiment we have been able to increase the precision of measuring the mass of the K_s by up to a factor of five. Further iteration on the correction procedure are expected to improve things even more. A similar procedure can be applied to $\phi \to KK$ decays to obtain corrections for K tracks and see if they differ from π tracks.

VI. ACKNOWLEDGMENTS

I would like to thank Prof. David Cinabro of Wayne State University for generously giving large amounts of his time to help answer my questions and guide me along during the course of this research project. Prof. Cinabro has helped me throughout the greater part of the year in working on this experiment and his help has proved invaluable in completing this REU project. I would also like to thank Professors Mikhail Dubrovin and Giovanni Bonvicini of Wayne State University for answering my questions and helping me along the way while studying at Cornell this summer.

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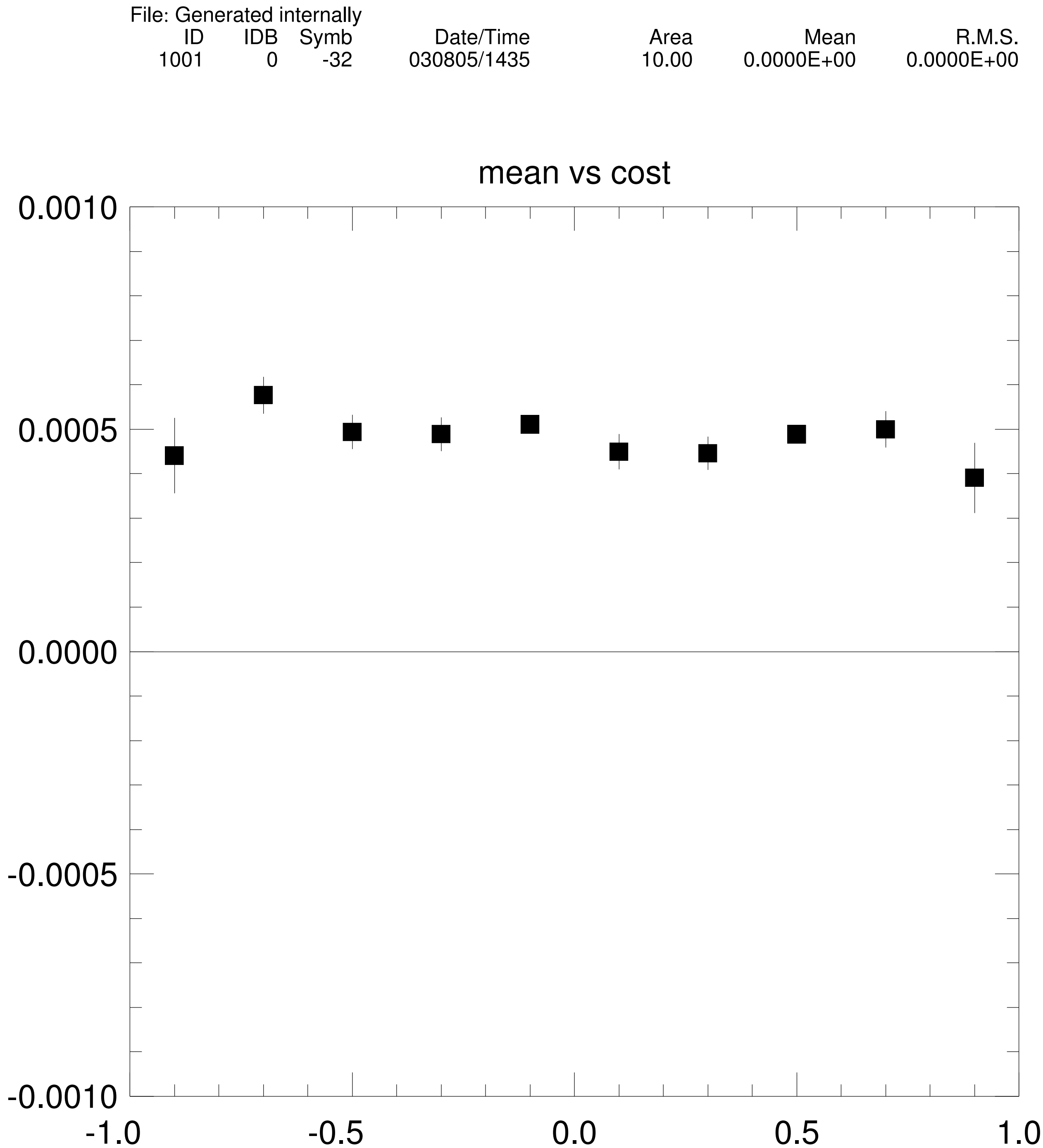

FIG. 1: Plotted mean minus known K_s mass as a function of $\cos\theta$ This figure shows that $\cos\theta$ has very little bearing on the mean. We see the mass values stay very flat for all values of $\cos\theta$.

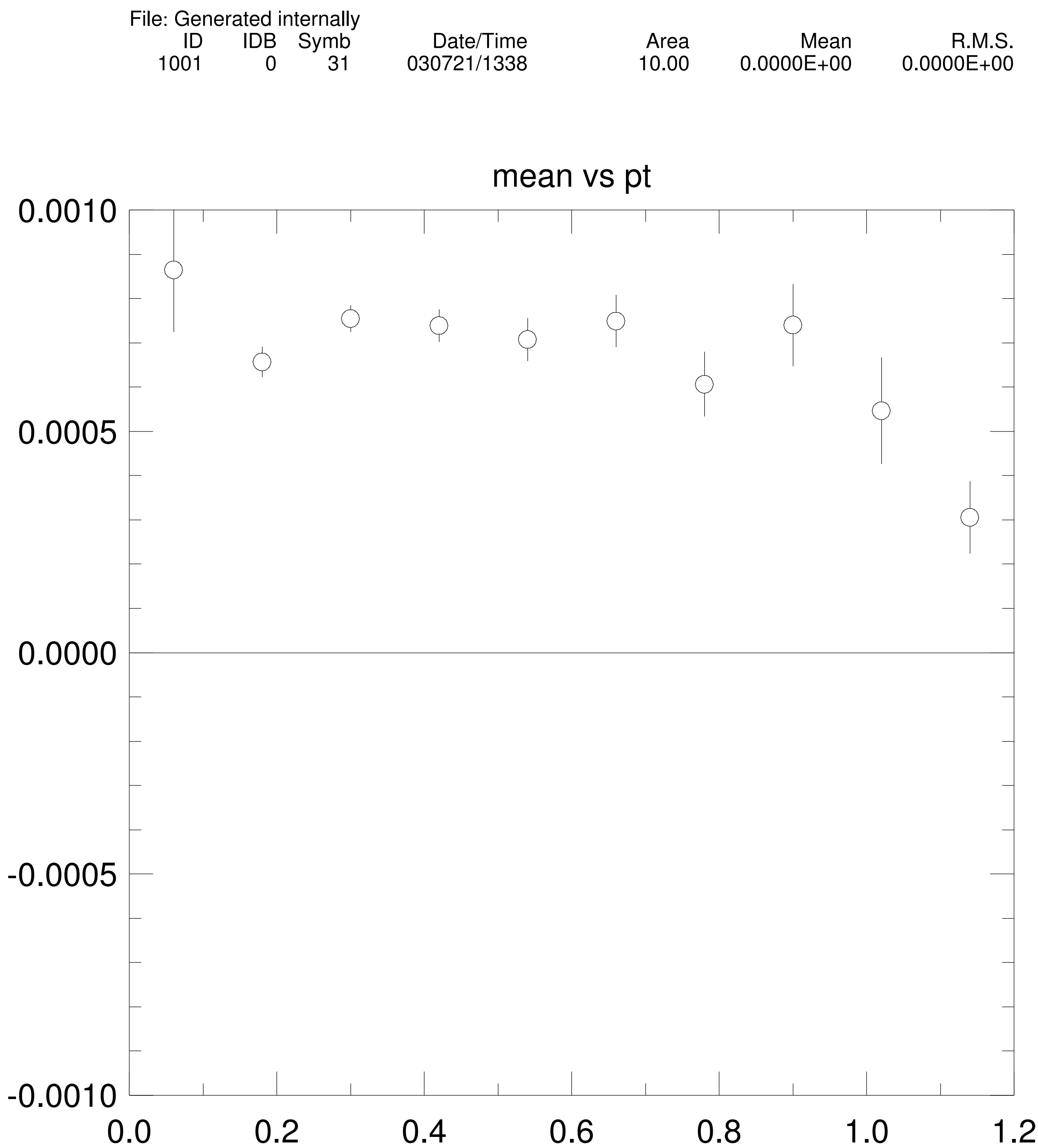

FIG. 2: Plotted mean minus known K_s mass as a function of p_t. All energies over 1.25 are put in the highest bin

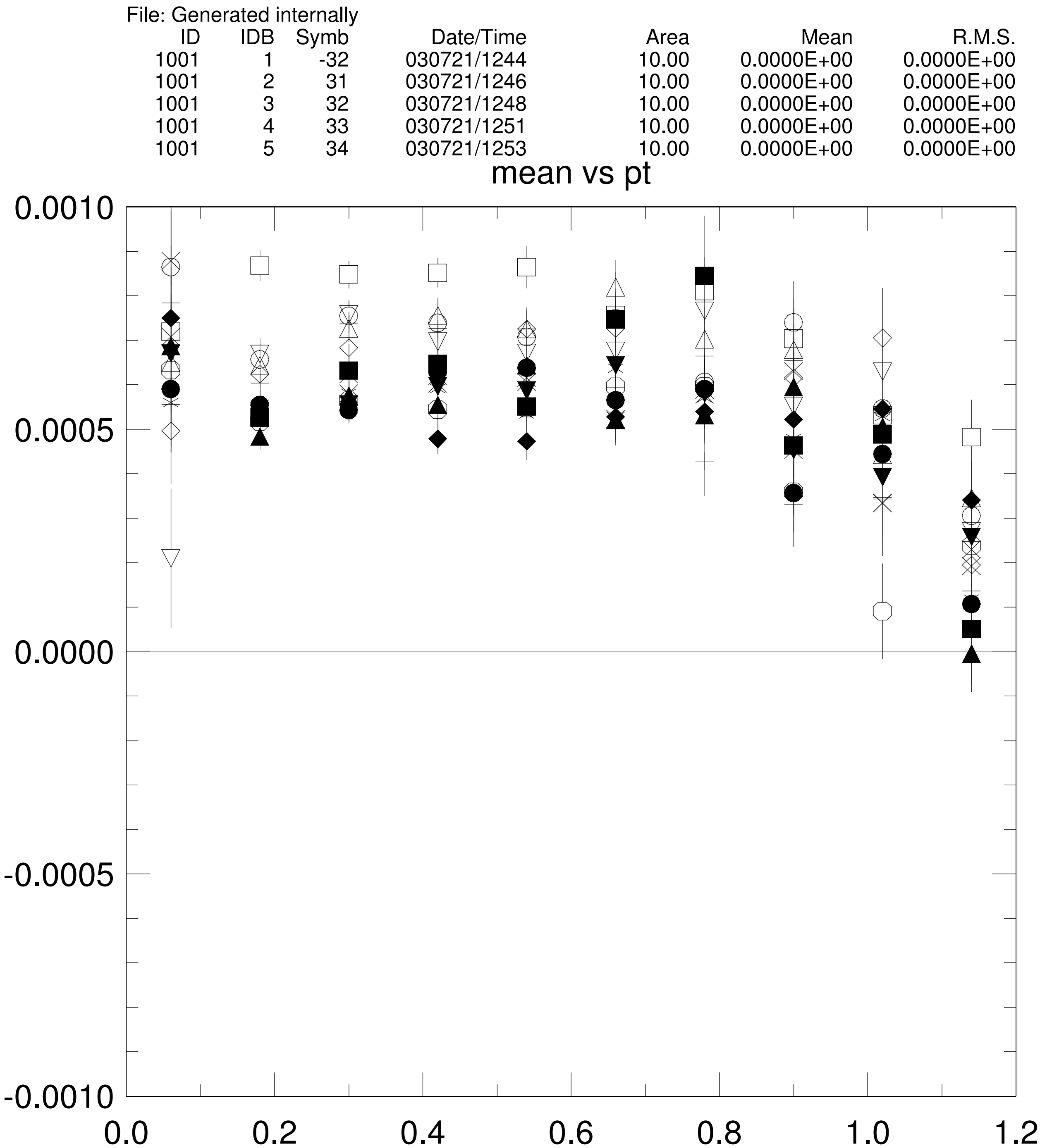

FIG. 3: Plotted mean minus known K_s mass as a function of p_t. All energies over 1.25 are put in the highest bin Although varying on the y-axis, all data sets form the same shape on the plot.

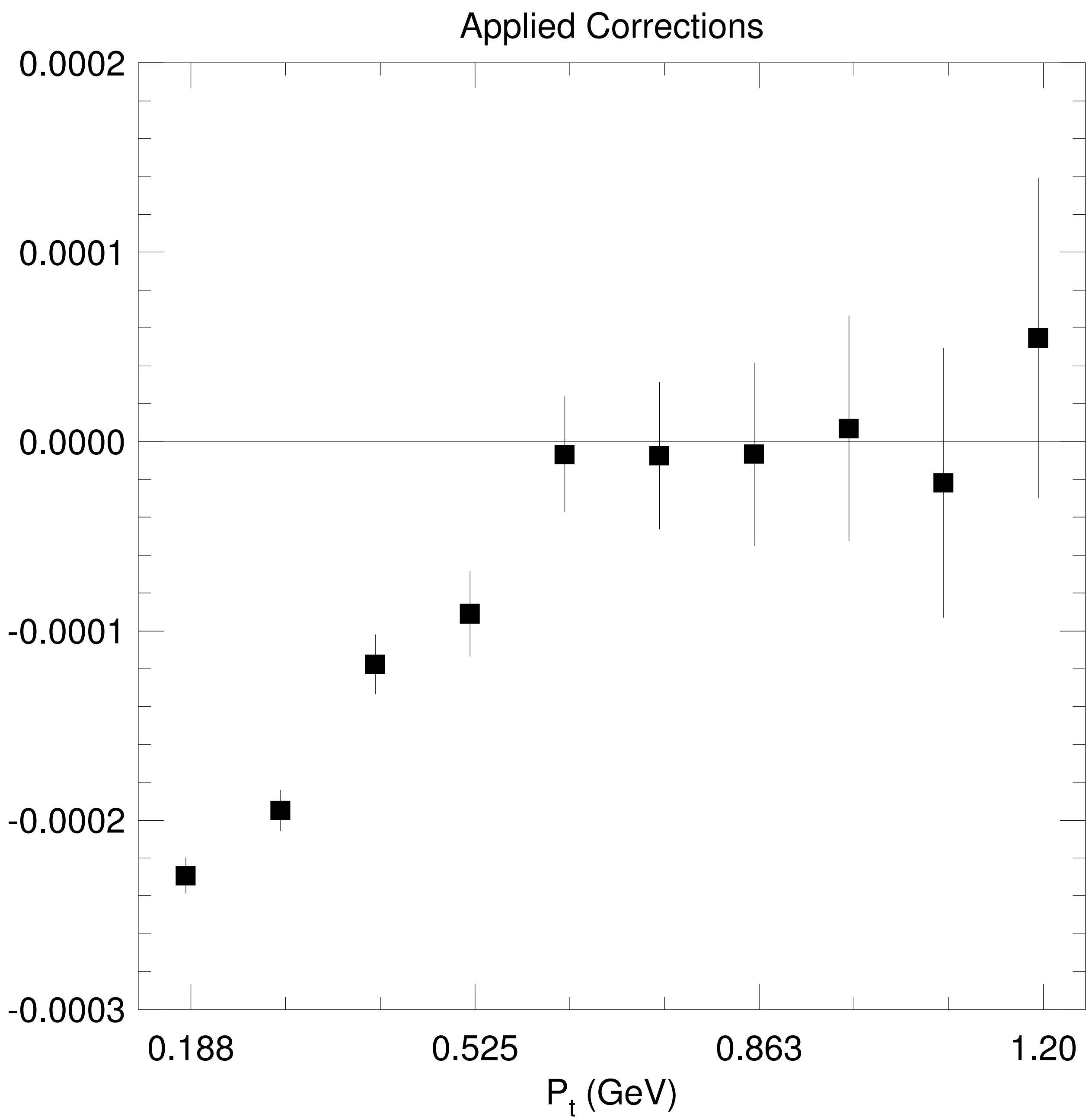

FIG. 4: Correction to measured momentum

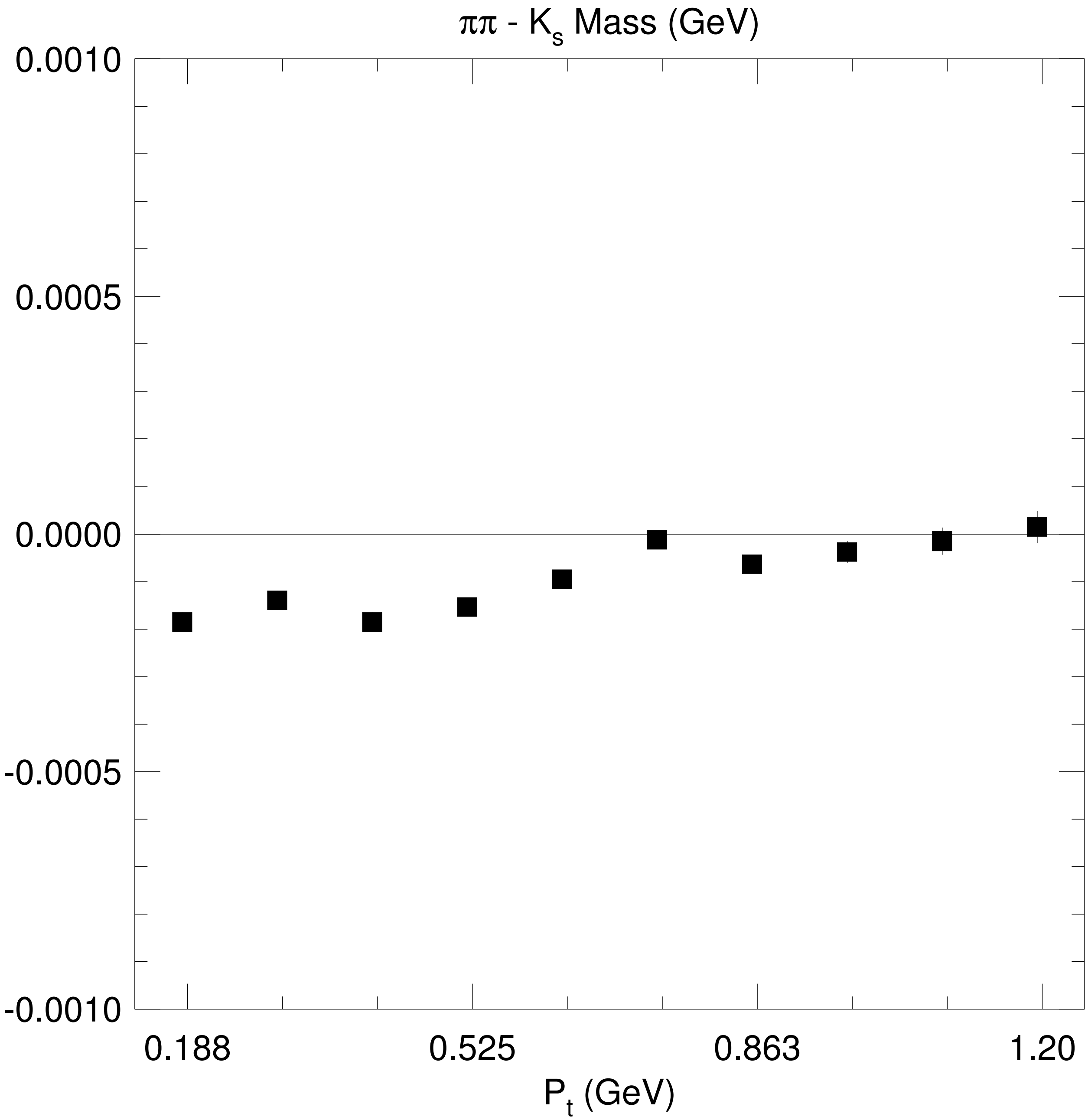

FIG. 5: Here we see the corrections applied