Single Spin Asymmetries In Inclusive K_Short Data

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1 Abstract

At the HERMES experiment at DESY a polarized lepton beam collides with a fixed target. In this report we look at single-spin asymmetries of inclusive K_Short data. To obtain these asymmetries a transversally polarized target is required and it is most important to make a good selection of events with K_Shorts. By analyzing this info we can learn more about the spin-structure of the proton.

2 The Phenomenological Framework

Through deep-inelastic scattering processes of leptons off protons, it is possible to learn more about the spin-structure of the proton. The differential cross section for the scattered lepton contains leptonic and hadronic tensors which both can be split up in symmetric and antisymmetric parts under parity transformation. The antisymmetric part is spin-dependent. The leptonic part can be calculated in QED while the hadronic part is too complex to calculate exact. Only a parametrization in function of the structure functions is possible. The polarized cross section depends on the spin of the incoming lepton and the proton. For longitudinally polarized leptons and transversally polarized protons the cross section is ϕ-dependent.

The differential cross section can be split up into unpolarized and polarized terms. We are interested in the $d\sigma_{UT}^{6}$ where the first index shows an unpolarized leptonbeam and the T stands for transversally polarized target. In this cross section there are several azimuthal modulations. For inlusive reactions only one modulation as function of $sin(\phi_S)$ remains. To obtain this modulation it is easier to measure asymmetries than to measure absolute cross sections. A lot of uncertainties or systematic errors in detector acceptances cancel with asymmetry measurements.

3 The Extraction of the Analysing Power A_{UT}

3.1 The Extraction Method

In inclusive reactions, as mentioned, only a modulation in $sin(\phi_S)$ remains. The experimental measurement of the amplitude of this modulation can provide data to support or improve theoretical studies. The asymmetry can be calculated as follows

$$A_{UT}(P_T, \frac{p_z}{E_{Beam}}, \phi_S) = \frac{\frac{N^{\uparrow}}{L_p^{\uparrow}} - \frac{N^{\downarrow}}{L_p^{\downarrow}}}{\frac{N^{\uparrow}}{L^{\uparrow}} + \frac{N^{\downarrow}}{L^{\downarrow}}}$$

with N being the yield of a given particle, in our case the K_Short. L_p stands for the polarization weighted luminosity and L is the integrated luminosity. The asymmetry is a function of the transverse momentum, the z-component of the momentum over the beam energy and the ϕ_S angle. This ϕ_S is equeal to ϕ plus $\pi/2$ where ϕ is the angle between the hadron production plane and the spindirection of the target. The yield of a given particle is given by

$$\begin{aligned} N^{\uparrow(\downarrow)}(P_T, \frac{p_z}{E_{Beam}}, \phi) =& \sigma_0(P_T, \frac{p_z}{E_{Beam}})* \\ & [L^{\uparrow(\downarrow)} + (-)L^{\uparrow(\downarrow)} * A_{UT}^{\sin\phi_S}(P_T, \frac{p_z}{E_{Beam}}) * \sin\phi_S]* \\ & \Omega(P_T, \frac{p_z}{E_{Beam}}, \phi_S) \end{aligned}$$

It is impossible to calculate an asymmetry for every value of the kinematical variables, so the data is binned. In ϕ the data is put in intervals of $\frac{\pi}{9}$ wide. For P_T the bin limits were (0, 0.2, 0.4, 0.6, 1, 3) and for $\frac{p_z}{E_{Beam}}$ (0, 0.15, 0.25, 0.35, 0.5, 1). For every momentum bin we extract an asymmetry amplitude.

3.2 Data Selection

For this analysis the 2004d1 and 2005d1 productions have been used.

3.2.1 Burst Level Data Selection

There are different Burst Selection Criteria called bits which can be set. For this analysis all but two bits, bit #01 and bit #28, were set. The two excluded bits deal with the polarization of the lepton beam which we do not require.

3.2.2 Track Level Data Selection

First we apply the standard fiducial volume cuts and geometry cuts as described in [1]. We require at least one positive and one negative pion. These are the candidates to come from the decaying K_Short since the K_Short is neutral and cannot be detected directly. First we distinguish between leptons and hadrons which we do with the PID ("Particle Identification"). The hadron range for the PID is between -100 and zero. To select the pions from the hadrons, RICH is a very powerfull tool. RICH gives back the probability that a track comes from a charged pion, kaon or proton. We use a momentum range of 1-15 GeV, because in this region RICH gives the best results for pion identification. We have a high pion efficiency which means that a pion in the detector will mostly be recognised as a pion. But even more important is that it has very low background contamination. This means that the probability of a kaon or a proton being mistakenly identified as a pion will be very low. This ensures our clean sample. For example the Λ^0 background of our K_Short sample is negligible, because the Λ^0 will decay in a proton and a π^-. A Λ^0 will then only contribute to our sample if the proton is mistakenly seen as a π^+, which with the good results RICH gives is very unlikely.

3.2.3 Reconstruction of K_Short with HTC

Once we selected the pions, we can take a look at their kinematic variables in fig. 1. The momentumdistribution is shown, the θ angle and the ϕ-distribution. In the ϕ-distribution you can clearly see the gap in the detector acceptance, caused by the beam pipe and the peaks by the bending of lowmomentum pions.

For every π^+ π^- pair we then calculate the invariant mass. In this spectrum we see the K_Short peak at about 497 MeV. For these K_Short's we want to reconstruct the track. HTC is HERMES' newest track reconstructor. It not only offers better resolution, but unlike HRC, the previous version, it provides the possibility to calculate the vertex of two tracks with each other instead of just a single track with the beam. Because of this we can combine the piontracks and see if they actually form a vertex. This vertex is then the decay vertex of the K_Short particle. Furthermore if we assume a straight propagation of the K_Short, we can calculate its production vertex. HTC not only calculates the vertices, it also gives back the probability of this vertex and the covariance matrix. From the production vertex we can calculate the distance of closest approach to the beam line. From the production and decay vertex we can then determine the decay length of the K_Short, the distance it travels before it decays. This is an important cut parameter. The larger you require the decay length to be, the purer your K_Short sample will be. We can now study the optimal value for this parameter. The distribution of these variables are seen in fig. 2

In fig. 3 then we can see the kinematical variables of the K_Shorts. The momentumdistribution and its components are shown. In the transverse

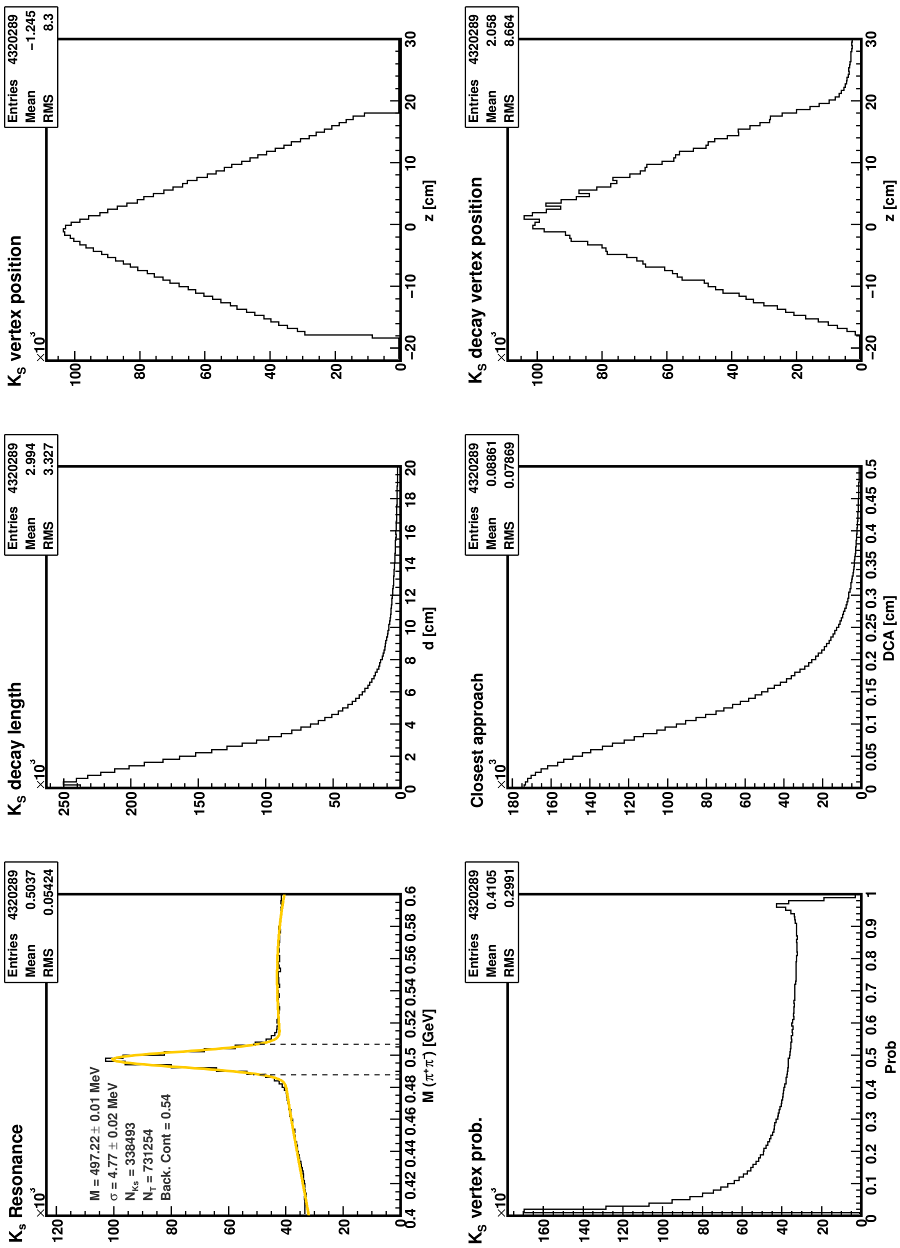

Figure 1: Kinematical variables of the pions

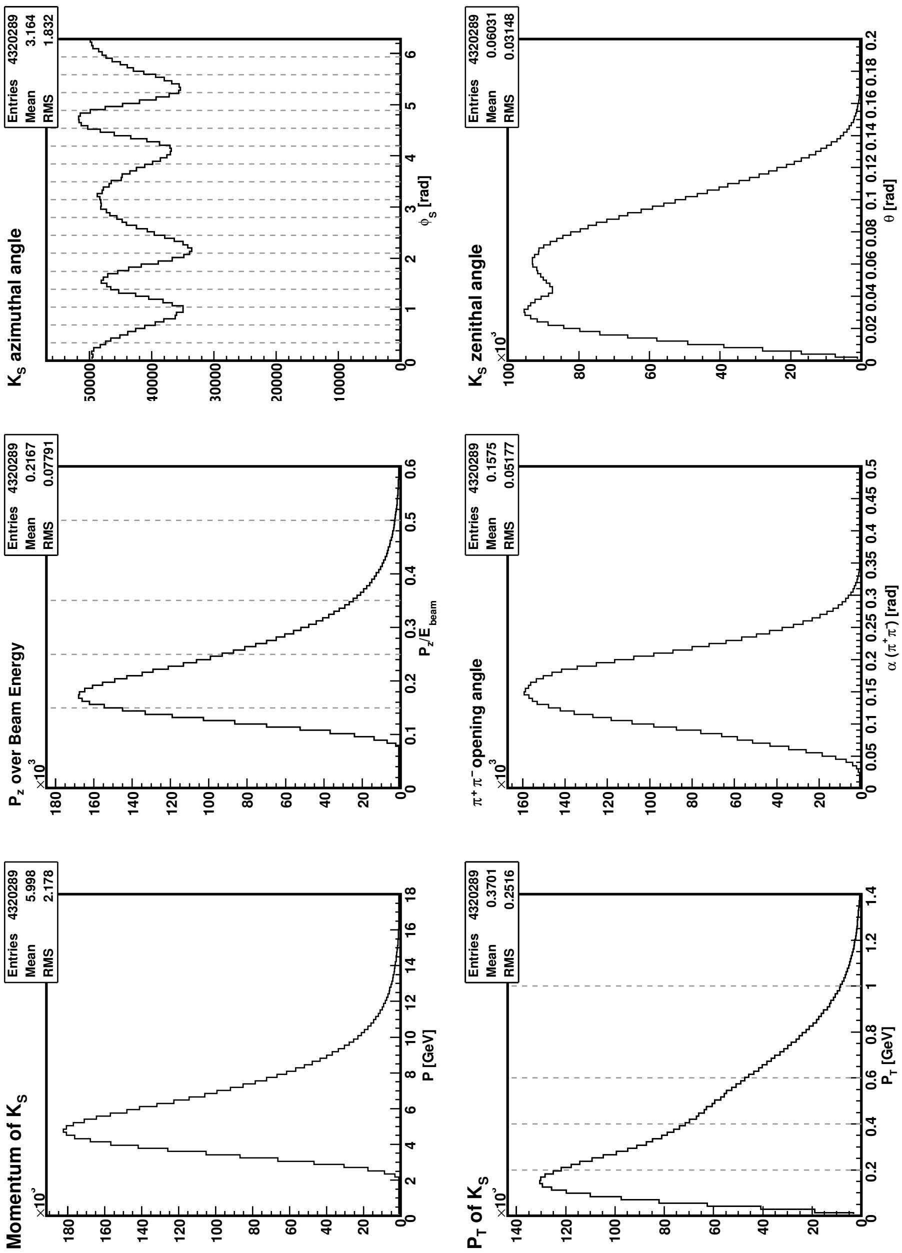

Figure 2: K_Short variables

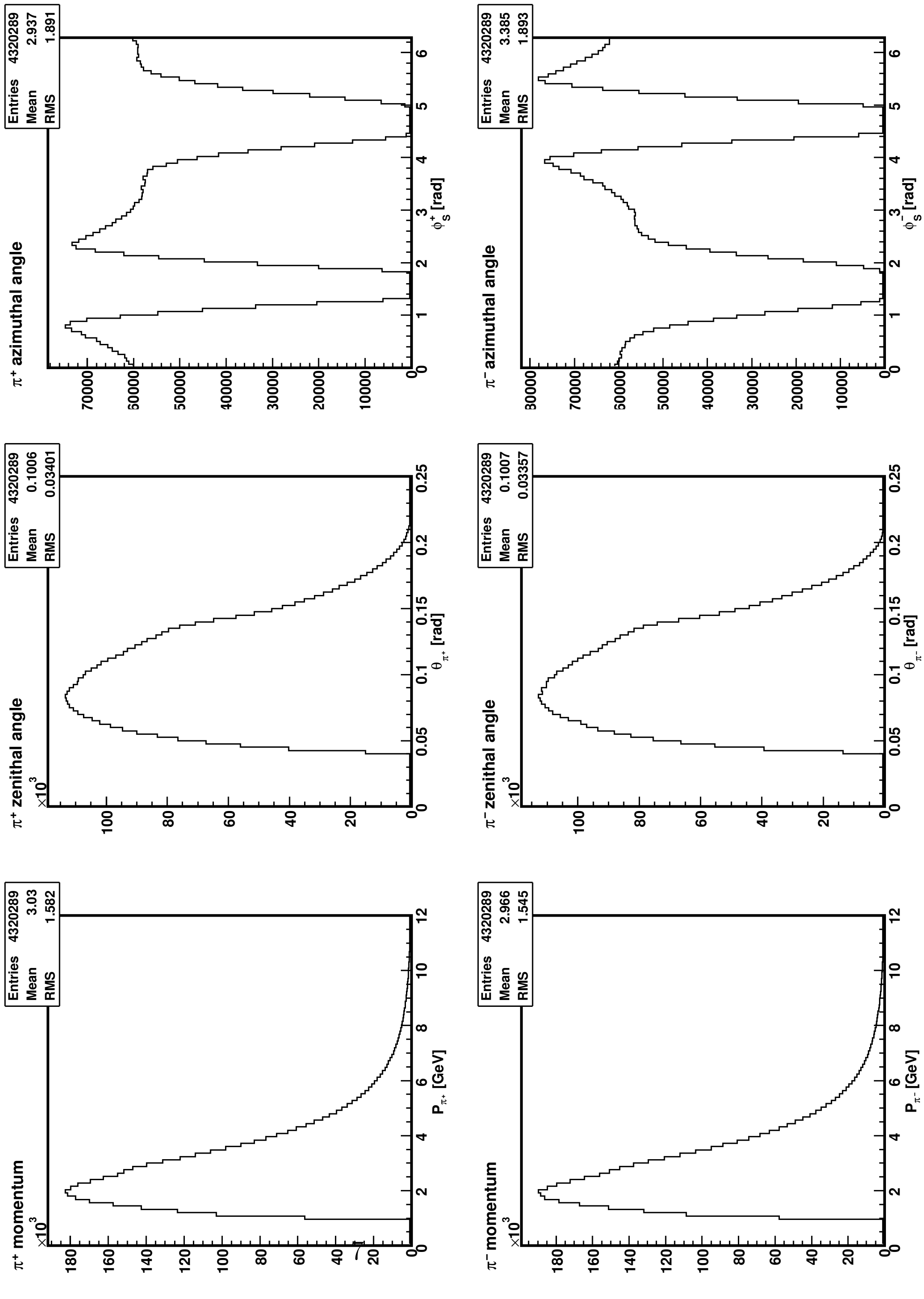

Figure 3: Kinematical variables of the K_Shorts

momentumplot the vertical lines indicate the binlimits applied to calculate the asymmetry. Though these plots are without the cuts applied yet, it should give an idea about how many entries there will be in each bin. The most interesting is of course the ϕ-distribution. We see that we no longer have gaps because of the acceptance because we do not detect the K_Short directly also the bump in the θ-distribution is caused by this.

When we look at the invariant mass spectrum we see that the peak is a gaussian on top of a polynomial background. When we fit these functions to our data in fig. 4, we can calculate the integral under the peak and under the polynomial below the peak. From this we can calculate the amount of background and actual signal contained in the peak. Notice that the height of the peak itself does not vary this much. This gives us an estimate of how pure our sample is. When we then look at this backgroundcontamination in function of the cut on the dacay length, we see that the background goes down very fast at first but from a decay length from 8 cm onwards we do not gain so much purity. When we then take a look at our signal, we see that we lose a lot of statistics. The amount of K_Short candidates before the cut and after drops even faster. So we are looking for a compromise between a pure sample and having enough statistics. We decided to fix the cutparameter value at 7 cm because at that point we reach a backgroundcontamination of about ten percent, which is acceptable, and this is also traditionally the value used to select K_Shorts.

Once we have made this cut, we fit the gaussian to the K_Short peak and make a cut obtaining all entries within a 2σ deviation of the mean value. Thanks to HTC the σ value is much better. For our data it was a little below 5 MeV while before it was around 7 MeV. Now the K_Short sample is selected, the calculation of the asymmetry is possible.

4 Results for the Analysing Power A_{UT}

In fig. 5 the final results are shown. Our K_Short sample has a contamination of 12 percent. From this we extract the asymmetry A_{UT} in function of ϕ_S. When we fit a sinusoidal to the datapoints, we obtain a value for the amplitude that is compatible with zero. As a second step, we plot the asymmetry amplitude for every momentum bin. We can conclude that the azimuthal asymmetry for K_Shorts is zero. Though we can suspect a non-zero and positive value in the higher momentum region.

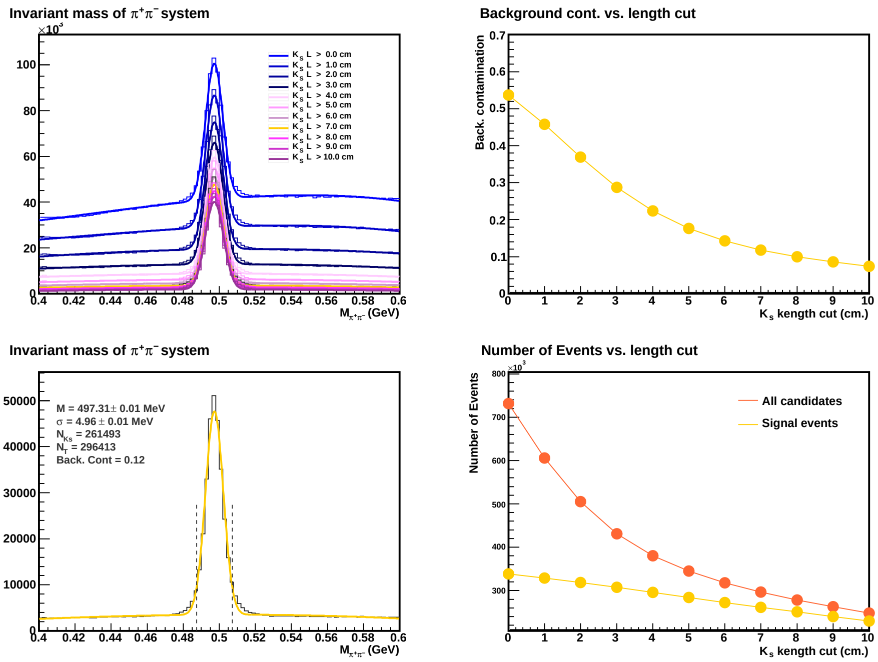

Figure 4: Influence of the cut on the decay length

Now we can compare our experimental results with the theoretical predictions made by Anselmino et al. [3]. These predictions are for semi-inclusive reactions but the asymmetry amplitude for semi-inlusive and inclusive reactions are proportional. In this paper we clearly see (fig. 6)that the value should be zero.

5 Future studies

There are more cuts that could be implemented to obtain a cleaner K_Short sample. For example cuts on the distance of closest approach to the beam line or on the vertex probability would be usefull. And studies should be made to obtain the optimal parameter values. Monte Carlo simulations can be run. We could include more data to obtain higher statistics. Different techniques for background extraction should be considered and most important a cross check of our results is essential.

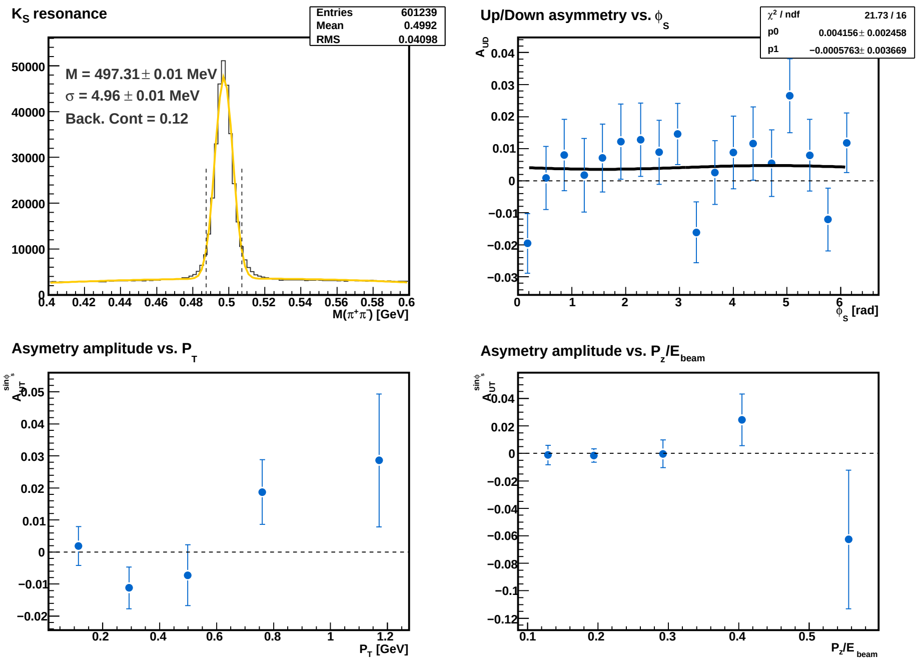

Figure 5: Azimuthal asymmetry for the K_Short

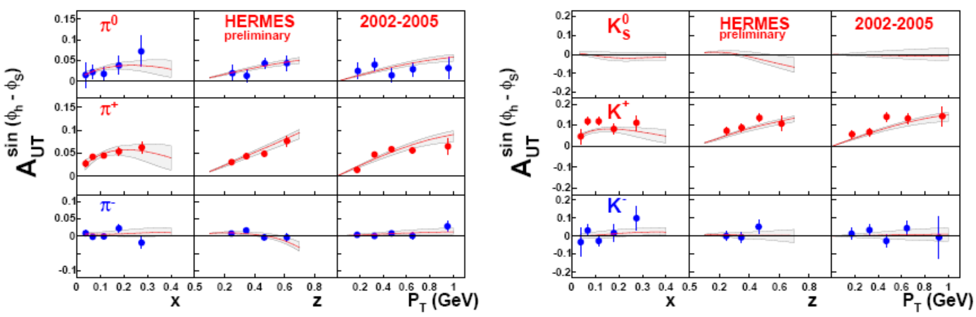

Figure 6: Theoretical prediction for the asymmetry [3]

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7 Bibliography

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