Cross section and longitudinal single-spin asymmetry A_L for forward $W^{\pm} \rightarrow \mu^{\pm}\nu$ production in polarized $p+p$ collisions at $\sqrt{s} = 510$ GeV[†]

R. Seidl[*1] for the PHENIX collaboration

Understanding the spin of the proton and its decomposition is essential to explaining how the strong interaction, described by quantum chromodynamics QCD, creates the basic building blocks of the visible matter in our universe, protons and neutrons. Sea quarks are found to be asymmetric at small to intermediate Bjorken $x < 0.2$, where x is the parton momentum fraction. While several models can describe the measured unpolarized light sea, these models differ significantly in their predictions for the polarized case. Valence quark helicity contributions to the total spin of the nucleon are already relatively well known, but sea quark helicities are still poorly understood. An elegant way to access sea quark helicities is via the weak interaction as possible at the Relativistic Heavy Ion Collider (RHIC).[1)] In $p+p$ collisions, real W's can be produced in the annihilation of predominantly up(down) and anti-down(up) quark pairs for $W^{+(-)}$ production. Furthermore, the helicity of participating quarks and anti-quarks is fixed to be left-handed and right-handed, respectively, due to the parity violating nature of the weak interaction. If one of the two proton beams is longitudinally polarized, the helicity of the proton beam therefore selects quarks that are polarized parallel or anti-parallel with it and vice versa for anti-quarks.

In this analysis, we rely on the reconstruction of forward-going muons impinging the muon-spectrometer of the PHENIX detector. The data sets used in this analysis were recorded at RHIC during the 2012 and 2013 polarized proton running periods at a center-of-mass energy $\sqrt{s} = 510$ GeV with a luminosity of approximately 53 and 285 pb $^{-1}$. The average beam polarizations were between 54% and 58% for the two beams and running periods. For each event a combined probability distribution, $W_{\rm ness}$ is formed from all variables. Tracks with high $W_{\rm ness}$ (> 0.92) are used for further analysis. An unbinned maximum likelihood fit approach is used to determine the final number of Ws and remaining backgrounds. Figure 1 shows the extracted total cross sections for inclusive $W^{\pm} \rightarrow \mu^{\pm}$ production in $p+p$ collisions at a center-of-mass energy of 510 GeV. The cross sections are consistent within uncertainties with previous measurements at this energy from central $W \rightarrow e$ decay channels and with the expected NLO predictions. The longitudinal single-spin asymmetries, A_L are shown in Fig. 2 for positive and negative $W+Z$ decay muon candidates. They show the first muon single spin asymmetry results from $W+Z$ decays at pseudorapidities $|\eta| > 1$ of the decay lepton. They help determine the valence and sea quark helicities at different momentum fractions than at central rapidities. The behavior of the asymmetries is generally consistent with the parameterizations.

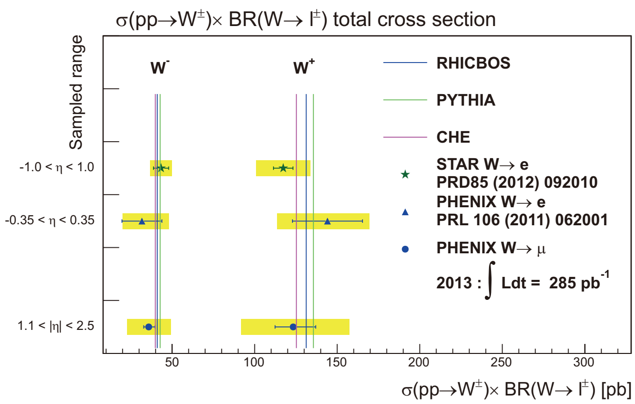

Fig. 1. The $W^{\pm} \rightarrow \mu^{\pm}\nu$ cross section measured at forward and backward rapidity $1.1 < |\eta| < 2.5$ (closed [blue] circles) and previously published results at central rapidity.

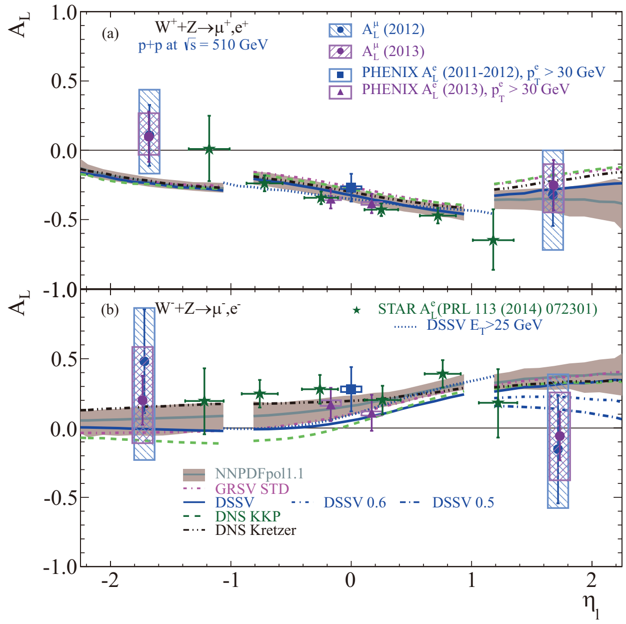

Fig. 2. Longitudinal single spin asymmetry, A_L for (a) $W^{+}+Z \rightarrow \mu^{+}$, e^{+} and (b) $W^{-}+Z \rightarrow \mu^{-}$, e^{-} for PHENIX for 2012 (closed [blue] circles) and 2013 (closed [purple] circles) and previously published data and parameterizations.

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*1 RIKEN Nishina Center

Reference

1) C. Bourrely and J. Soffer, Phys. Lett. B **314**, 132 (1993).