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Recent STAR Results on *W* Production and Asymmetry in Polarized $\vec{p} + \vec{p}$ Collisions at $\sqrt{s} = 500$ GeV[1]

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Abstract—The production of $W\pm$ bosons in longitudinally polarized proton + proton collisions at RHIC is a unique way to study the flavor-dependent spin structure of the proton, since at leading order it couples directly and exclusively to specific quark flavor pairings: $u + \bar{d} \to W^+$ and $\bar{u} + d \to W^-$. Measurement of the longitudinal single-spin asymmetry of the electron decay daughters in *W* production is sensitive to the polarizations of the quarks involved. Results from the first proton-proton collisions at $\sqrt{s} = 500$ GeV in 2009 are presented, along with a discussion of the forward-rapidity tracking upgrade.

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There is long-standing interest in understanding the spin-structure of the proton. Polarized Deep Inelastic Scattering (DIS) measurements have shown that the net quark polarization within the proton is too small to account for the total proton spin [1], but inclusive measurements cannot separate out the quark flavors. By opening the *W* production channel that is energetically prohibited in fixed-target experiments, the $\sqrt{s} = 500$ GeV $\vec{p} + \vec{p}$ program at RHIC can provide new, flavor-dependent constraints on antiquark polarizations within the proton.

W production is a very clean probe. At leading order, it occurs only through $u + \bar{d} \to W^+$ and $\bar{u} + d \to W^-$, and the decay of these bosons to leptonic final products ($e^{\pm} + \nu(\bar{\nu})$) provides readily-distinguished event topologies. The parity-violating nature of these decays can give rise to large longitudinal single-spin asymmetries (A_L), directly related to the polarized parton distribution functions (pPDFs) of interest. Theoretical frameworks have been developed to describe these decays in polarized proton collisions [2, 3].

The results discussed in this paper come from 13.2 pb^{-1} of $\vec{p} + \vec{p}$ collisions with an average polarization of 40%, taken in 2009 during the first $\sqrt{s} = 500$ GeV $\vec{p} + \vec{p}$ physics run at RHIC.

The STAR [4] components involved in this work are the large Time Projection Chamber (TPC) and the Barrel and Endcap Electromagnetic Calorimeters (BEMC and EEMC). The TPC provides tracking in pseudorapidities $|\eta| < 1.3$, with transverse momentum (p_T) and charge sign determined by the curvature of the tracks in the solenoidal field. The calorimeters provide EM energy measurements in $-1 < \eta < 1$ (BEMC) and $1.09 < \eta < 2$ (EEMC), divided into 4800 and 720 towers to provide spatial resolution. All of these components cover the full range in azimuth (ϕ).

A two-stage trigger was used online to tag potential *W*-decay candidates, exploiting the structure of these events, where the decay leptons are expected to have transverse energy (E_T) peaked at $M_W/2$. A single BEMC tower was required to have at least 7.3 GeV of E_T, after which an additional software trigger required a 2×2 cluster of towers with at least one tower >5 GeV and the sum of the cluster >13 GeV.

Further cuts were imposed on the data offline to exploit the differences between di-jet events, with two jets back-to-back, and *W*-like events, with an isolated electron back-to-back with an unseen neutrino.

Candidate electrons were defined to be TPC tracks with $p_T > 10$ GeV which originated from a vertex within 100 cm of the nominal interaction point. These were required to point to a 2×2 tower clusters in the BEMC with sum $E_T > 15$ GeV and weighted center within 7 cm of the extrapolated track. To differentiate between isolated electrons and electron-like members of a jet, this cluster was required to contain >95% of the E_T in the 4×4 cluster centered on it, and >88% of the total E_T (in BEMC, EEMC, and TPC) within a cone of radius 0.7 in $\eta - \phi$ space. To be consistent with a missing neutrino, the vector sum of all BEMC, EEMC, and TPC p_T in the away-side (defined as the solid angle $[\phi_e + \pi + 0.7, \phi_e + \pi - 0.7]$, covering all η) must be greater than 15 GeV in the direction of the electron (the resulting scalar is referred to as p_T^{balanse}). Finally, only $E_T > 25$ GeV candidates were used. For A_L, new requirements were imposed on the quality of

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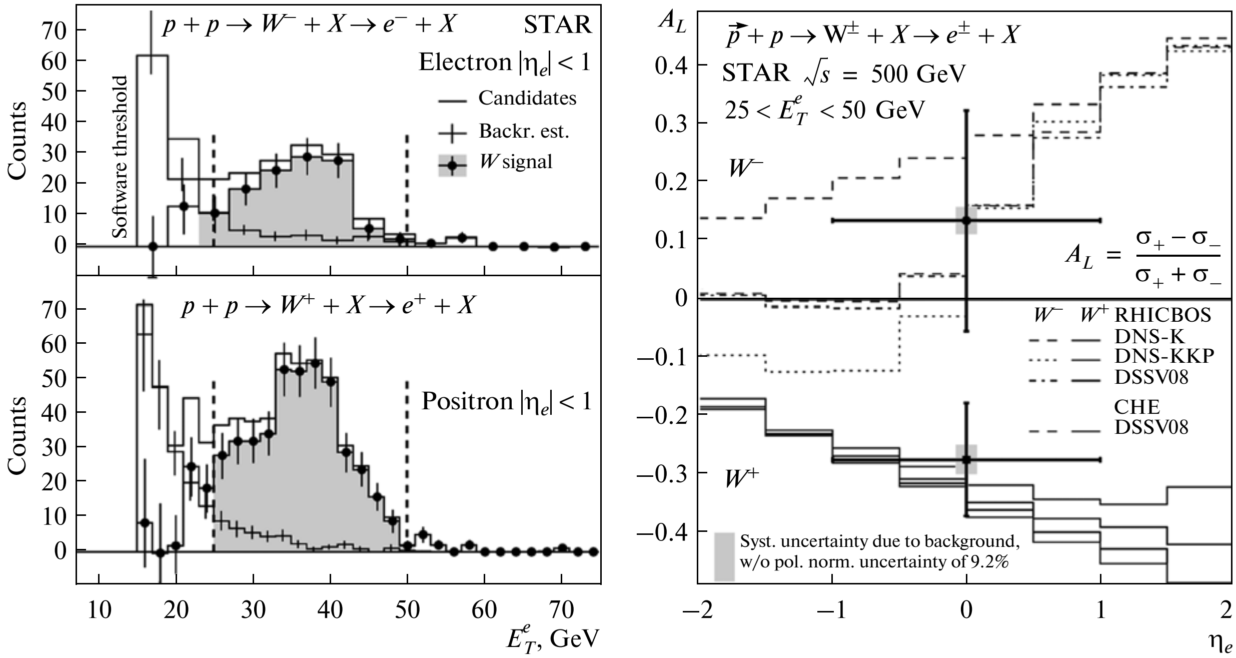

Fig. 1. Yields (left) and resulting A_L (right) for W^+ and W^- production.

the TPC track to ensure the charge sign was correct. The implementations of the cuts in these two analyses are not identical. See [5] and [6] for details in each case.

The charge-separated yields after applying these conditions are shown in figure. The efficiency of the cuts was determined to be 56%, using PYTHIA Monte-Carlo events with leptons in $-1 < \eta < 1$ and $E_T > 25$ GeV, run through a GEANT simulation of the STAR detector.

Limited resolution and η-coverage allow various types of backgrounds to pass these cuts. The first method used to reduce this contamination was a "second endcap". By comparing the yields with and without considering the EEMC, the number of events rejected due to jet energy deposited in the existing endcap was measured. Since $\vec{p} + \vec{p}$ collisions are symmetric on average, the same number would have been rejected due to a fictional endcap spanning the opposite η range, $-1 < \eta < -2$.

Remaining background was divided into two groups: For electroweak backgrounds, Monte-Carlo simulations provided an estimate of the number of events in the given luminosity. For dijets, the estimate was taken from the data by repeating the analysis with away-side cuts inverted ($E_T^{\text{away}} > 30$ GeV, $p_T^{\text{balance}} <$ 15 GeV). The resulting dijet spectrum was taken to be independent of the η of the away-side component, differing from the dijets where the away-side jet is not seen by an overall normalization. This normalization was set in $E_T < 20$ GeV, with the normalization window and positions of the inverted cuts varied to estimate the uncertainty stemming from this contribution. The total from these three components is shown in blue in Fig. 1 (left), with the remaining *W* signal in heavy black.

For this leptonic decay, after correcting for acceptance, the measured cross sections are $\sigma_{W^+}^{\text{tot}} = 117.3 \pm 5.9(\text{stat.}) \pm 6.2(\text{syst.}) \pm 15.2(\text{lumi.})$ pb and $\sigma_{W^-}^{\text{tot}} = 43.3 \pm 4.6(\text{stat.}) \pm 3.4(\text{syst.}) \pm 5.6(\text{lumi.})$ pb, in agreement with expectations.

For A_L, the yields are sorted by the spin configuration of the collision, with $A_L = (\sigma^+ - \sigma^-)/(\sigma^+ + \sigma^-)$, where $\sigma^{+(-)}$ refers to the cross section when the helicity of the polarized proton beam is positive (negative), resulting in $A_L^{W^+} = -0.27 \pm 0.10(\text{stat.}) \pm 0.02(\text{syst.}) \pm 0.03(\text{norm.})$ and $A_L^{W^-} = 0.14 \pm 0.19(\text{stat.}) \pm 0.02(\text{syst.}) \pm 0.01(\text{norm.})$ (Fig. 1, right) for decays where the electrons fall into $|\eta| < 1$, again grossly consistent with predictions.

The A_L theory curves show significant dependence on η of the decay lepton, a consequence of the correlation between the *W* and its daughters imposed by parity violation. This strongly motivated the construction of the Forward GEM Tracker (FGT) [7] at STAR to extend tracking into the $|\eta| > 1$ range where the predictions diverge. The upgrade is based on Gas Electron Multiplication (GEM) technology, with six triple-GEM disks located between the beam pipe and the inner edge of TPC. The FGT was partially installed and commissioned during the 2012 run, with the remainder completed during the shut down following that run.

In summary, W production in polarized proton collisions is a unique probe to explore the flavor-dependent spin structure of the proton. The results from the 2009 dataset presented here are consistent with current theoretical expectations, and motivate the need for larger datasets and enhanced acceptance to fully test the different n dependences predicted. A much larger dataset (~80 pb^{-1}) with improved polarization and partial installation of the FGT is currently being analyzed. These data and even larger upcoming datasets are expected to provide significant constraints on the polarized QCD sea.

REFERENCES

1. S. D. Bass and A. W. Thomas, J. Phys. G: Nucl. Part. Phys. **19**, 925 (1993).
2. P. M. Nadolsky and C.-P. Yuan, Nucl. Phys. B **666**, 31 (2003).
3. D. de Florian and W. Vogelsang, Phys. Rev. D **81**, 094020 (2010).
4. K. H. Ackermann et al., Nucl. Instr. Meth. **499**, 624 (2003).
5. L. Adamczyk et al., Phys. Rev. D **85**, 092010 (2012).
6. M. M. Aggarwal et al., Phys. Rev. Lett. **106**, 062002 (2011).
7. Simon F. et al., arXiv:0811.2432.