

Recent STAR Results on the Measurement of the Unpolarized and Polarized Light Quark Flavor Structure of W-Boson Production at RHIC at BNL





XXVI International Workshop on DIS and Related Subjects - DIS2018 Kobe, Japan, April 16-20, 2018



DOE NP contract: DE-SC0013405

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Outline





How do we probe the structure and dynamics of matter in ep vs. pp scattering?



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- Proton spin structure using high-energy polarized p+p collisions W production
 - Observable: Quark/Anti-quark polarization (W production)
 - Longitudinal single-spin
 asymmetry AL

 $A_L = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$

- Parity violation for W production!
- Features of W boson production probing parton distributions:
 - Direct sensitivity to quark (u/d) / antiquark (ubar/dbar) distributions
 - □ Large scale defined by W mass (~80GeV)
 - Simple final state of charged leptons: No

dependency on fragmentation functions

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 Polarized and unpolarized partonic cross-sections known at NLO / Resummation framework - W A_L asymmetry results powerful input for global analyses such as DSSV and NNPDF at NLO level!



Theoretical foundation

Probing the quark flavor structure: W boson production (1)



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Theoretical foundation

Probing the quark flavor structure: W boson production (1)



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Probing the quark flavor structure: W boson production (2)





The world's first polarized proton+proton collider





Polarized p-p collisions

 Production runs at \$\subset s=500/510GeV (long. polarization) in 2009, 2011, 2012 and 2013: W production (Quark polarization) / Jet and Hadron production (Gluon polarization)

Run	L (pb ⁻¹)	P (%)	FOM (P ² L) (pb ⁻¹)
Run 9	12	0.38	1.7
Run 11	9.4	0.49	2.3
Run 12	72	0.56	24
Run 13	250	0.54	73



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Experimental aspects - STAR

Overview

- Calorimetry system with
 2π coverage: BEMC
 (-1<η<1) and EEMC (1<η<2)
- TPC: Tracking and particle ID

- ZDC: Relative luminosity and local polarimetry (500GeV)
- BBC: Relative
 luminosity and
 Minimum bias trigger



$$\eta = -\ln\left(\tan\left(\frac{\theta}{2}\right)\right)$$

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W boson reconstruction at STAR vs. pseudo-rapidity n



W boson reconstruction at STAR vs. pseudo-rapidity n





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Mid-rapidity W⁺ / W⁻ signal distributions / Background determination



Run 13

STAR E_T distributions for W-/W⁺ candidate events well described by $W \rightarrow e + v$ (W-e decay) signal events and datadriven QCD background estimation plus electroweak background events in four mid-rapidity n bins

• QCD background:

- Data-driven QCD background estimate: Background which satisfy et candidate isolation cuts
- Second EEMC QCD background estimate: Background ("Jet") at non-existing calorimetric coverage for -2 < η < 1.1 based on instrumented calorimetric coverage with STAR EEMC for 1.1 < η < 2</p>
- Electro-Weak background: $Z \rightarrow e^+ + e^-$ (Z decay) and $W \rightarrow \tau + v$ (W-Tau decay) / PYTHIA-MC estimation!



W/Z cross-section measurements at collider experiments



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STAR: Probing dbar / ubar ratio: QCD sea



- STAR coverage at mid-rapidity: 0.1 < x < 0.3 for -1 < n < 1
- Constraints on global fitting for dbar/ubar through W production at higher Q² compared E906
- Independent cross-check of Drell-Yan data



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Results / Status: Cross-section ratio W⁺/W⁻

STAR: W cross-section ratio measurements (Run 11 / 500GeV) (Run 12 / 510GeV)



- O Run 11 + Run 12 preliminary result: ~100pb⁻¹
- Run 13 data sample with ~250pb⁻¹ will provide important improvement on precision
- Large Run 17 data sample of ~350pb⁻¹

M. Posik et al. (STAR Collaboration), DIS 2015.

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STAR: W cross-section ratio measurements at (Run 11 / 500GeV) (Run 12 / 510GeV)



- W boson kinematics can be determined by reconstructing the W kinematics via its recoil
- Combination of data/MC simulations allows W boson rapidity reconstruction
- Critical for transverse single-spin asymmetry result of W production probing Sivers sign change



STAR: Run 11 / 12 uncertainties in comparison to projections for Run 13



Charged W Cross Section Ratio Projected Uncertainty

- Improved precision with Run 13 compared to Run 11+12 preliminary results
- Further improvement from Run 17 p+p data sample expected at 510GeV with 350pb-1



RHIC Probing the quark flavor structure using W boson production



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STAR: Published W A_L measurements (Run 11 / 500GeV) (Run 12 / 510GeV)

L. Adamczyk et al. (STAR Collaboration), Phys. Rev. Lett. 113, (2014) 072301.





Impact of STAR 2012 W AL measurements (DSSV)



- Significant constraint for ubar and dbar.
- Significant shift of ubar central value from STAR 2012 W A_L prelim. data.

□ Impact of STAR 2012 W A_L measurements (NNPDF) (1)



• Significant constraint for ubar and dbar.

R. Ball et al. (NNPDF Collaboration), Nucl. Phys. B887, (2014) 276.

- Significant shift of ubar central value from STAR 2012 W A_L prelim. data.
- E. Nocera. PoS DIS2014 (2014) 204, arXiv: 1406:7122.

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Impact of STAR 2012 W A₁ measurements (NNPDF) (2)



• Flavor asymmetry of ubar and dbar is positive

R. Ball et al. (NNPDF Collaboration), Nucl. Phys. B887, (2014) 276.

 Flavor asymmetry of ubar and dbar of similar magnitude as respective unpolarized difference!

E. Nocera. PoS DIS2014 (2014) 204, arXiv: 1406:7122.



STAR: W A_L measurements (Run 13 / 510GeV)





STAR: W A_L measurements (Run 11 / 500GeV) (Run 12 / 510GeV) and Run 13 (510GeV)

- STAR 2013 W A_L preliminary results is the most precise measurement of W A_L up to date.
- STAR 2013 preliminary W A_L results
 consistent with published 2011+2012 results.
- Statistical uncertainties (Dominant uncertainties) were reduced by 40% / Similar systematic uncertainties.





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mid-rapidity measurements.



D. Gunarathne et al. (STAR Collaboration), SPIN2016.



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Summary / Outlook

Summary

- Mid-rapidity (Run 11/12): Published W asymmetry results suggest large anti-u quark polarization along with broken QCD sea.
- New prelim. result of STAR 2013 W AL is the most precise measurement to date: Further constrain anti-quark helicity distributions / Publication in preparation!
- New STAR 2013 W A_L prelim. results consistent with published STAR 2011+2012 results and published PHENIX midrapidity results.
- Preliminary cross-section ratio measurement (Run 11/12): Strong physics case of unpolarized dbar/ubar ratio using W production complementary to SeaQuest at FNAL / New Run 13 result in preparation!
- Outlook
 - Long 510GeV run in 2017 (Run 17) at transverse spin polarization of about 350pb⁻¹: W A_N / Unpol. QCD sea
 - Unpolarized program for Run 17: Cross-section ratio measurements of W⁺/W⁻ Unpolarized dbar / ubar probe
 - Exciting long-term polarized pp/pA program beyond 2020 requiring forward detector upgrade (Cold QCD plan)

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