Measurement of Longitudinal Single-Spin Asymmetry for W Boson Production at STAR

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for the STAR Collaboration

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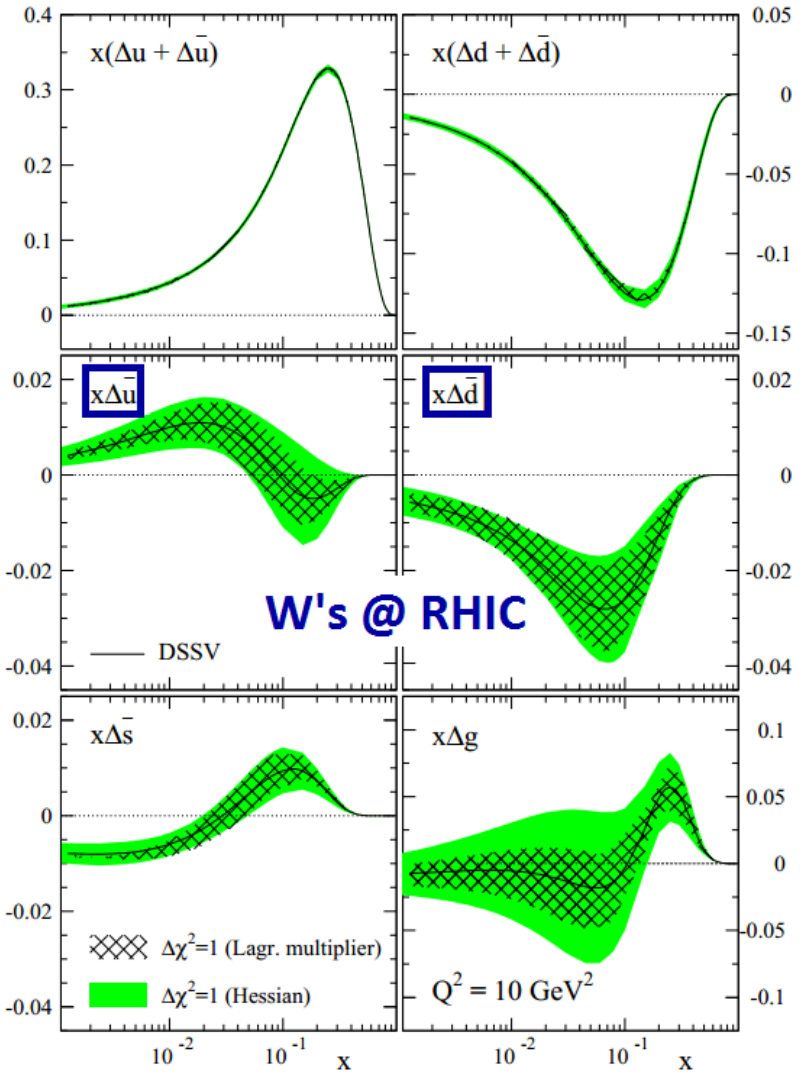
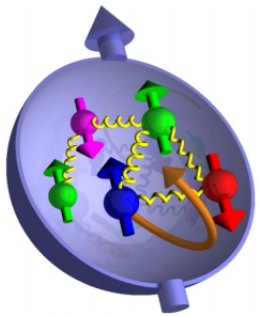
Flavor Separation of Proton Spin

DSSV Global Analysis

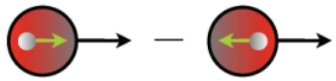


DSSV: PRD 80, 034030(2009)



Polarized PDFs:

$$\Delta f(x) =$$



$$f^{+}(x) - f^{-}(x)$$

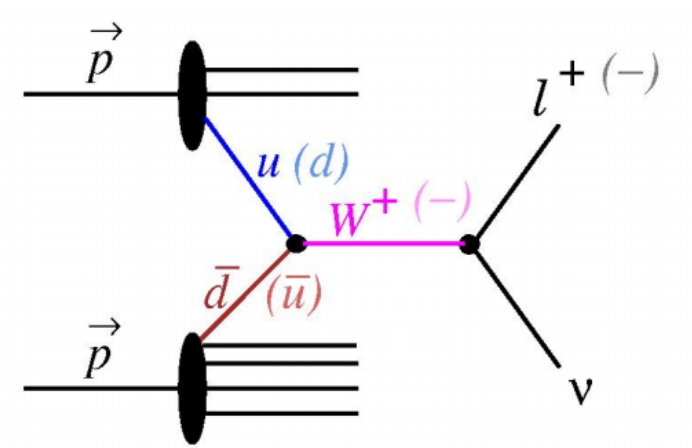
$$< S_p >= \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L$$

(Jaffe-Manohar, 1990)

$$\Delta\Sigma = \int (\Delta u + \Delta d + \Delta s + \Delta\bar{u} + \Delta\bar{d} + \Delta\bar{s})\, dx$$

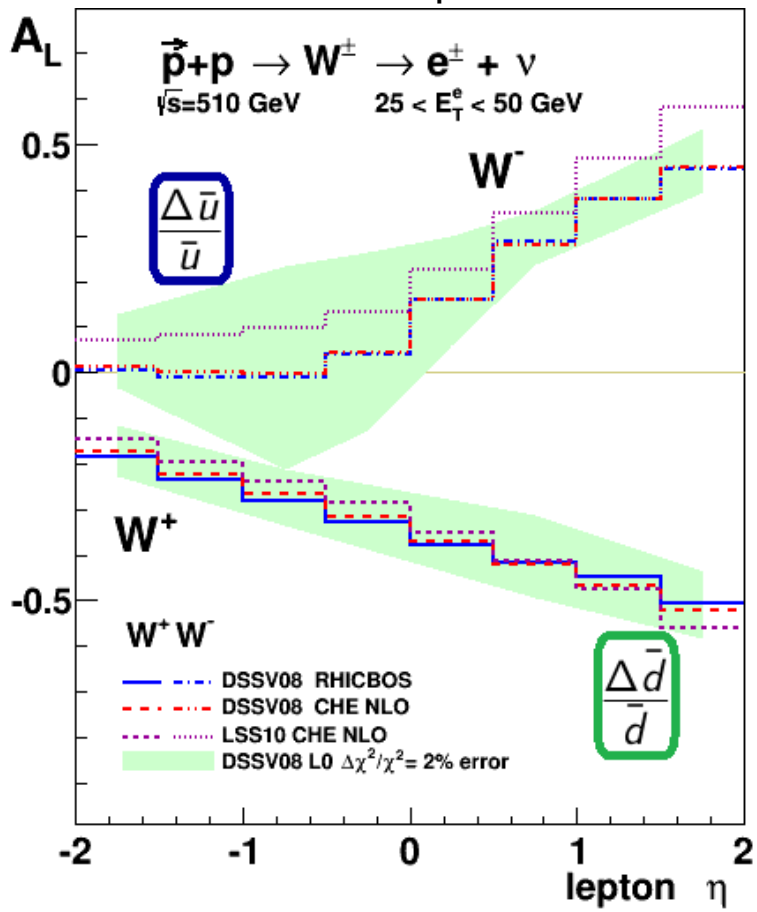
- $\Delta\Sigma^{1}_{0.001} \sim 30\%$ from DIS data
- **Flavor separated contributions** are not well constrained yet

Why W ? — Unique Probe to Sea Quark Polarization



- V-A structure of the weak interaction leads to perfect spin separation
- Complementary to SIDIS, free of fragmentation uncertainties
- Rapidity dependence separates sea quarks from valence quarks

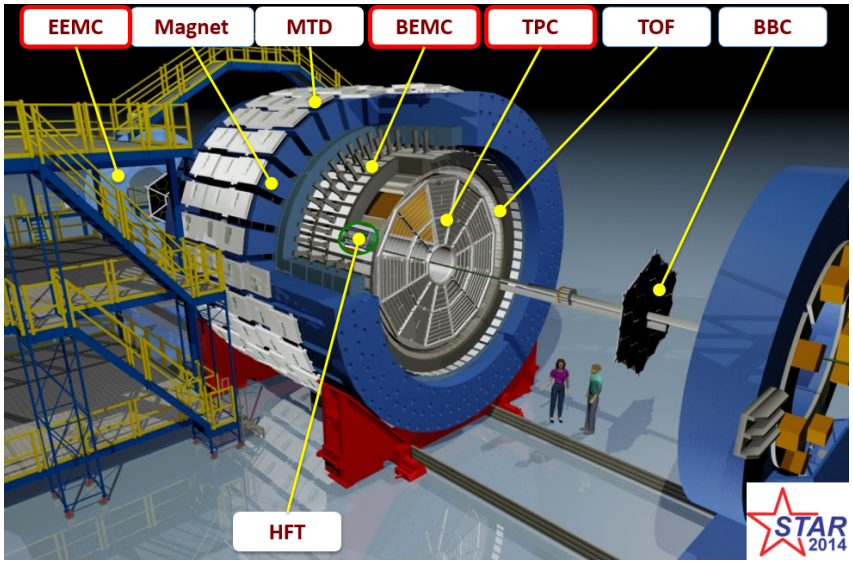
Theoretical expectations



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

$$A_L^{W^+} \propto \frac{-\Delta u(x_1)\bar{d}(x_2) + \Delta\bar{d}(x_1)u(x_2)}{u(x_1)\bar{d}(x_2) + \bar{d}(x_1)u(x_2)}$$

STAR Detector and Data Sample



STAR Longitudinal pp500			
Run	$L\ (pb^{-1})$	P	$P^2 L\ (pb^{-1})$
2009	12	0.38	1.7
2011	9.4	0.49	2.3
2012	77	0.56	24
2013	**246.2**	**0.56**	**77.2**

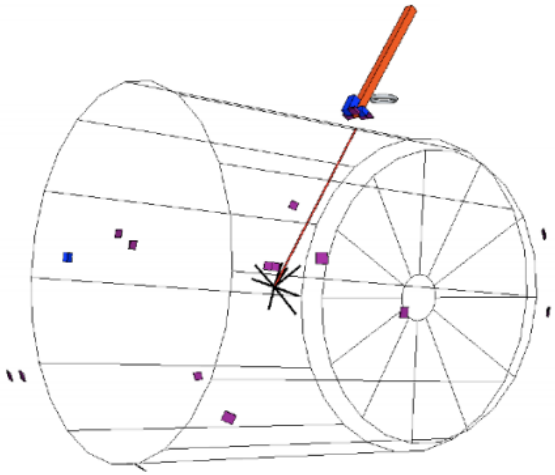
STAR: PRL 106, 062002(2011)
STAR: PRL 113, 072301(2014)

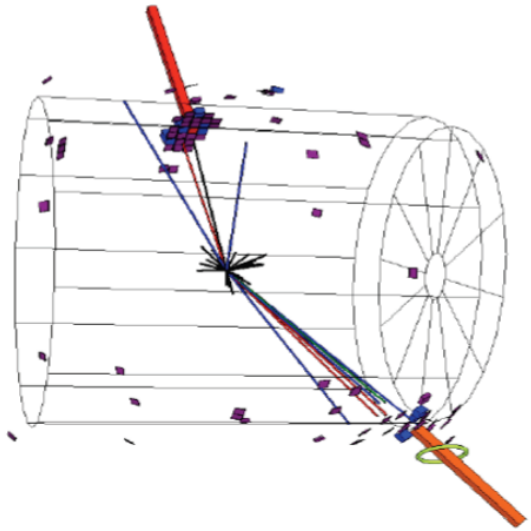
Main subsystems used in this analysis

- TPC, Time Projection Chamber, $|\eta| < 1.3$
- BEMC, Barrel Electromagnetic Calorimeter, $|\eta| < 1.0$
- EEMC, Endcap Electromagnetic Calorimeter, $1.1 < |\eta| < 2$

- After 2009, STAR collected large datasets in 2011 and 2012 with improved beam polarization
- The 2013 data by far surpass the total of previous years

$W \to e\nu$ Candidates





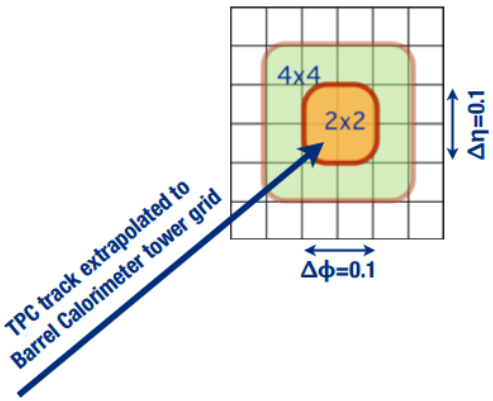
$W \to e + \nu$ Candidate Event:

- Isolated high p_T track pointing to isolated cluster in calorimeter
- p_T imbalance due to the undetected neutrino

QCD Background Event:

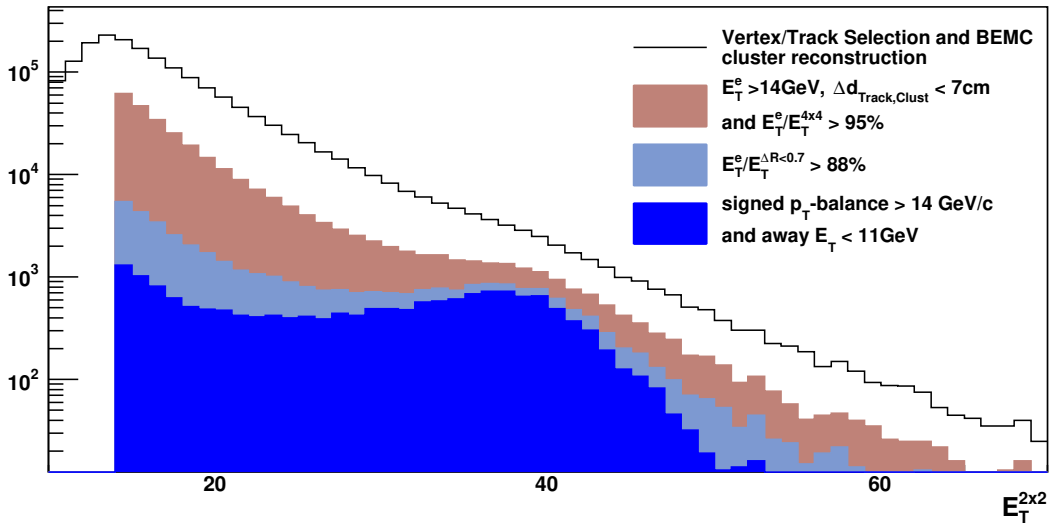
- Several tracks pointing to energy deposit in several towers
- p_T sum is balanced by di-jet, no large ''missing energy''

Selection Cuts



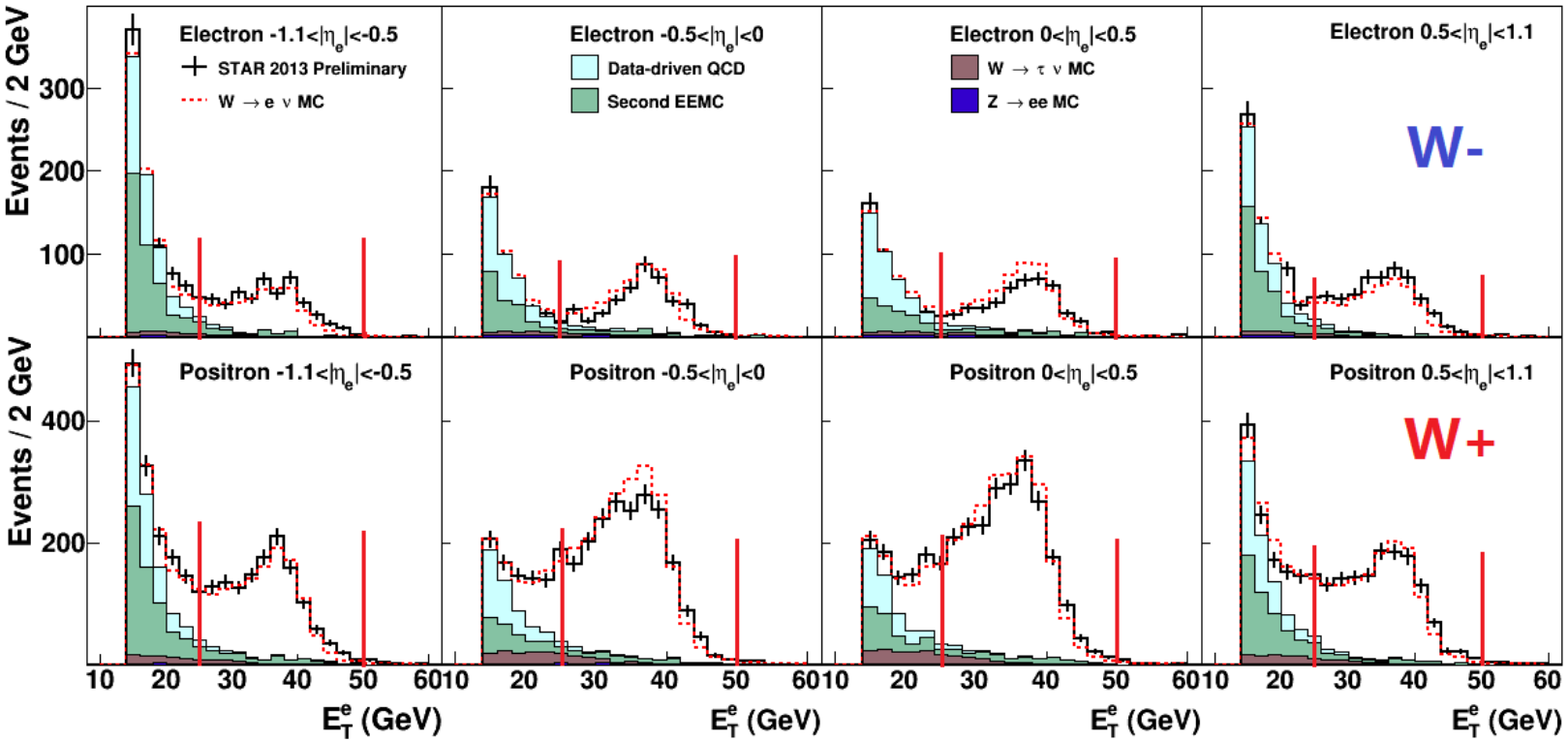
$$\vec{p_T}^{bal} = \vec{p_T}^{e} + \sum_{\Delta R>0.7} \vec{p_T}^{jets}$$

- Isolation ratio $E_{2\times2}/E_{4\times4} > 95\%$
- Isolation ratio $E_T^e/E_T^{\Delta R<0.7} > 88\%$
- Signed P_T-balance $= \frac{\vec{p_T}^{e}\cdot\vec{p_T}^{bal}}{|\vec{p_T}^{e}|} > 14$GeV
- away $E_T < 11$GeV



- Candidate electron E_T distribution
- Jacobian Peak Pronounce as cut applied

Background Estimation



W signal

- **"Jacobian Peak"**

Electroweak Background:

Determined from Monte-Carlo simulation.

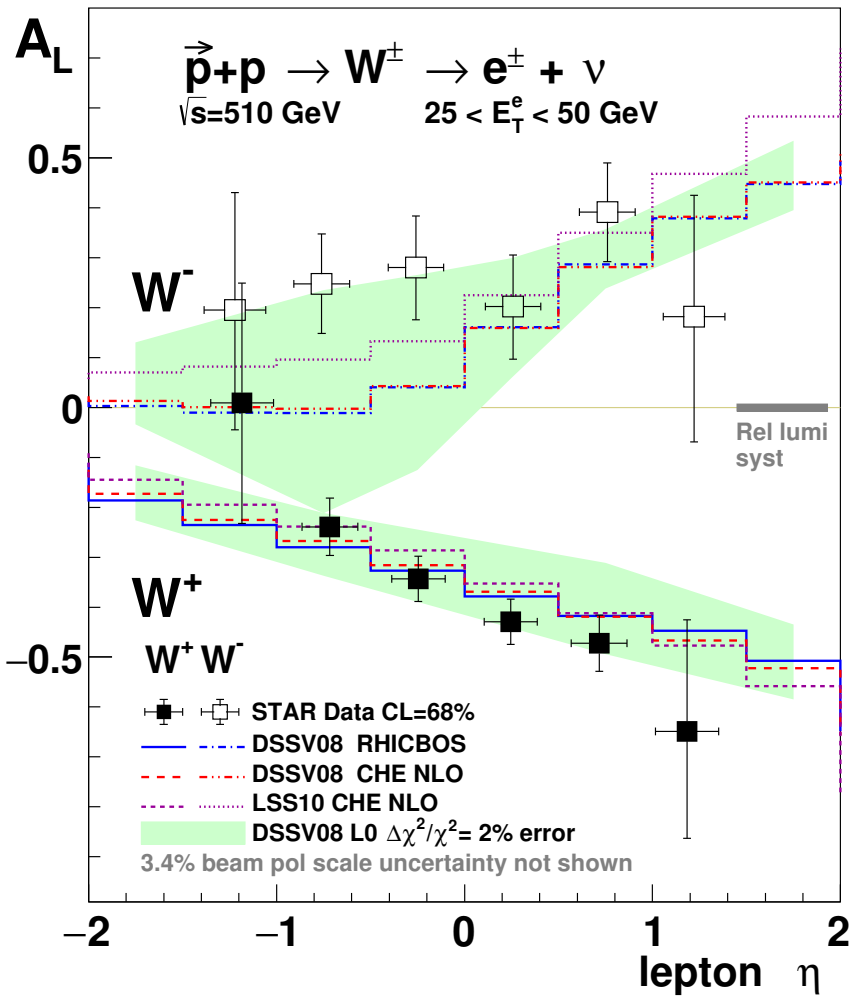
- $Z \rightarrow ee$ MC
- $W \rightarrow \tau\nu$ MC

Primary Background:

Satisfy W selection cuts but contain jets escaping detection at $\eta < -1$ and $\eta > 2$.

- Second EEMC
  Estimate non-existent "east" EEMC background based on real west EEMC
- Data-driven QCD

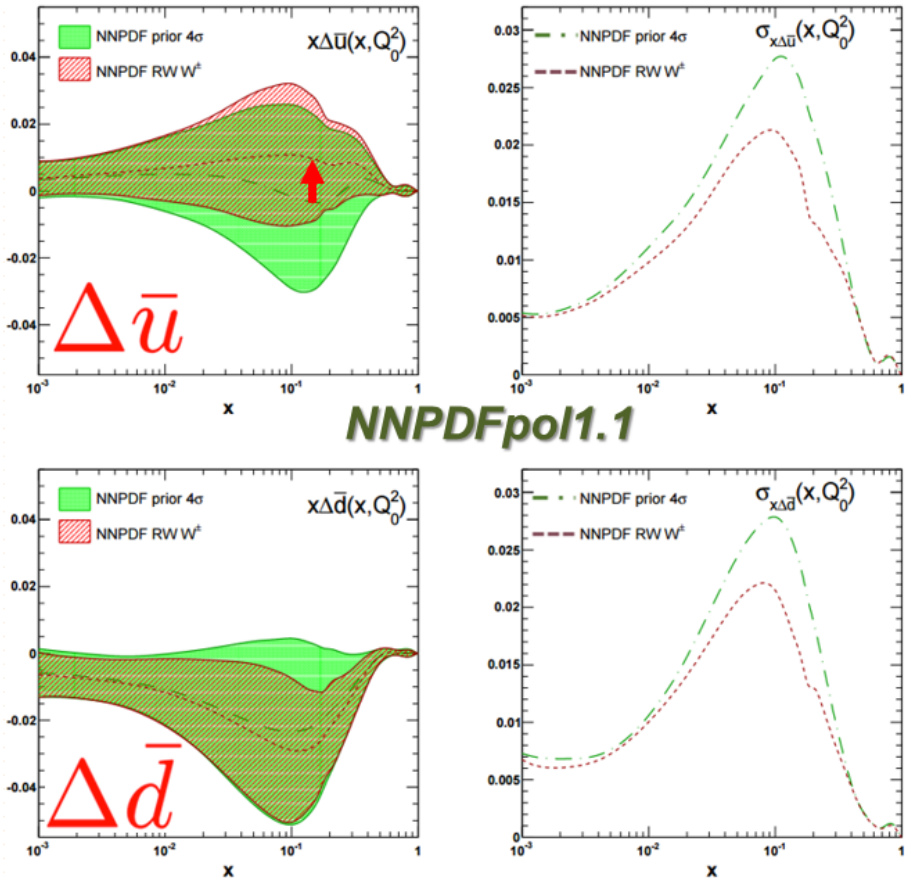
STAR 2011+2012 $W^{\pm}$ A_L Results



STAR, PRL113,072301(2014)

- First Measurement of lepton pseudorapidity dependent $W^{\pm}$ longitudinal single-spin asymmetry
- W^{+} A_L consistent with theoretical predictions, indicating consistent results with SIDIS for $\Delta\bar{d}$
- W^{-} A_L larger than the predictions for $\eta_e < 0$, prefer a more positive $\Delta\bar{u}$ than measured in SIDIS

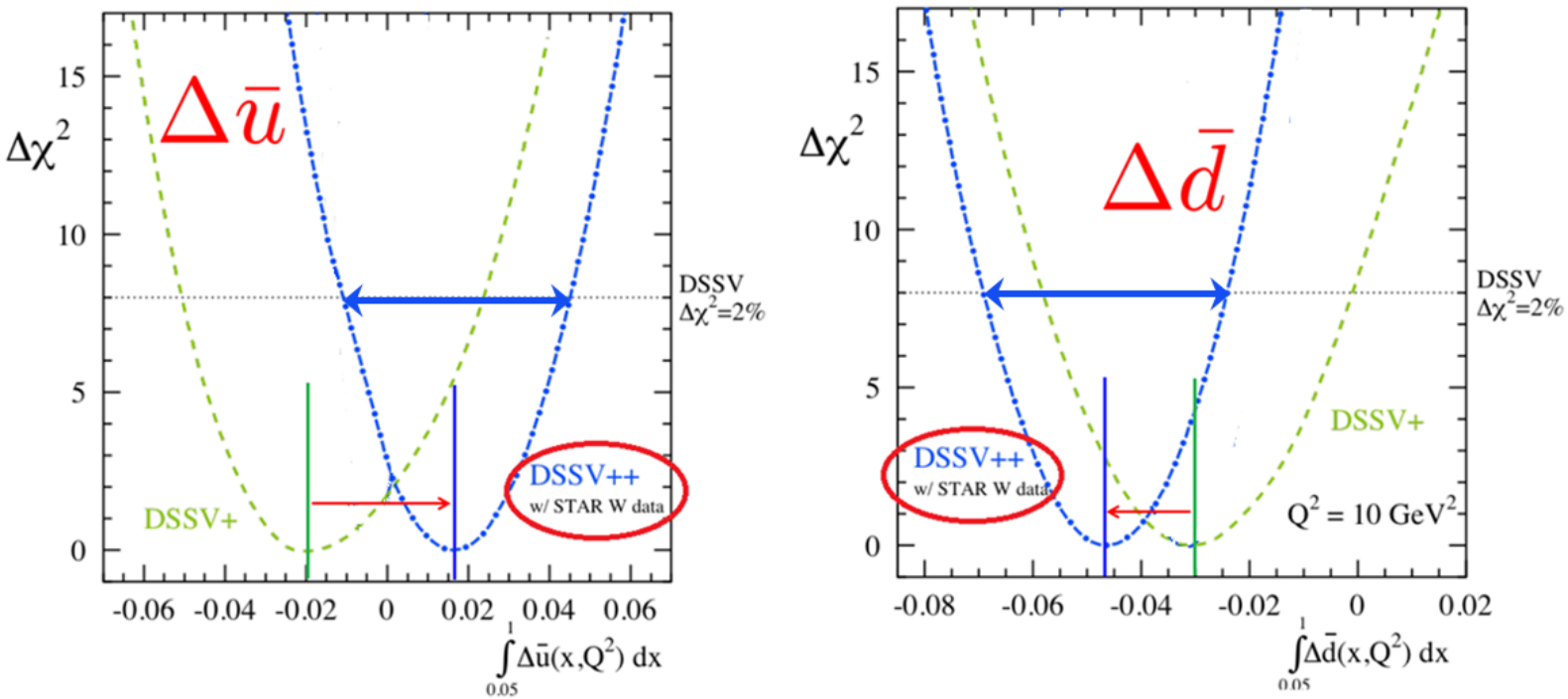
Impact on $\Delta\bar{u}(x)$ and $\Delta\bar{d}(x)$ from NNPDF



NNPDF, Nucl.Phys.B887,276-238(2014)

- STAR 2011+2012 results provide constraints on $\Delta\bar{u}$, $\Delta\bar{d}$
- $\Delta\bar{u}$ central value in $0.05 < x < 0.2$ shift to **positive**

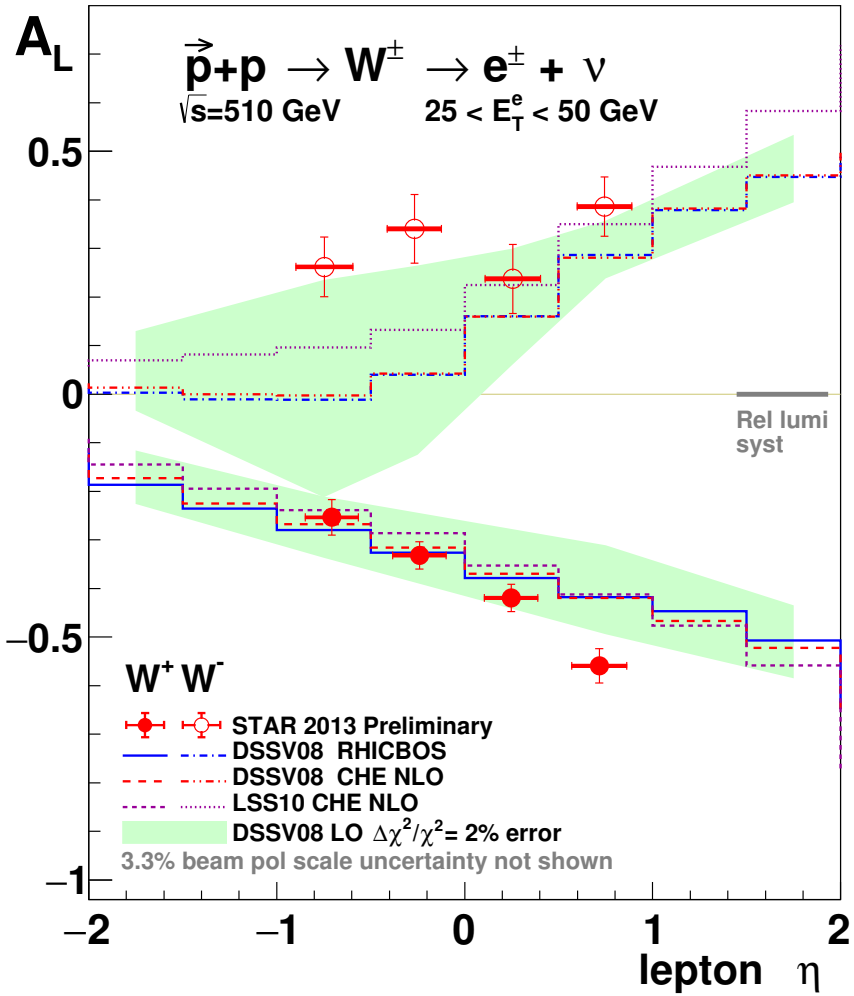
Impact on $\Delta\bar{u}$ and $\Delta\bar{d}$ from DSSV



E.Aschenauer, et.al. arXiv:1304.0079

- STAR 2012 results provide significant constraints on $\Delta\bar{u}$, $\Delta\bar{d}$
- $\int_{0.05}^{1}\Delta\bar{u}dx$ shift to **positive**

STAR 2013 $W^{\pm}$ A_L Preliminary Results



- Most precise measurement of W A_L
- Expect to further constrain $\Delta\bar{u}$, $\Delta\bar{d}$ distributions

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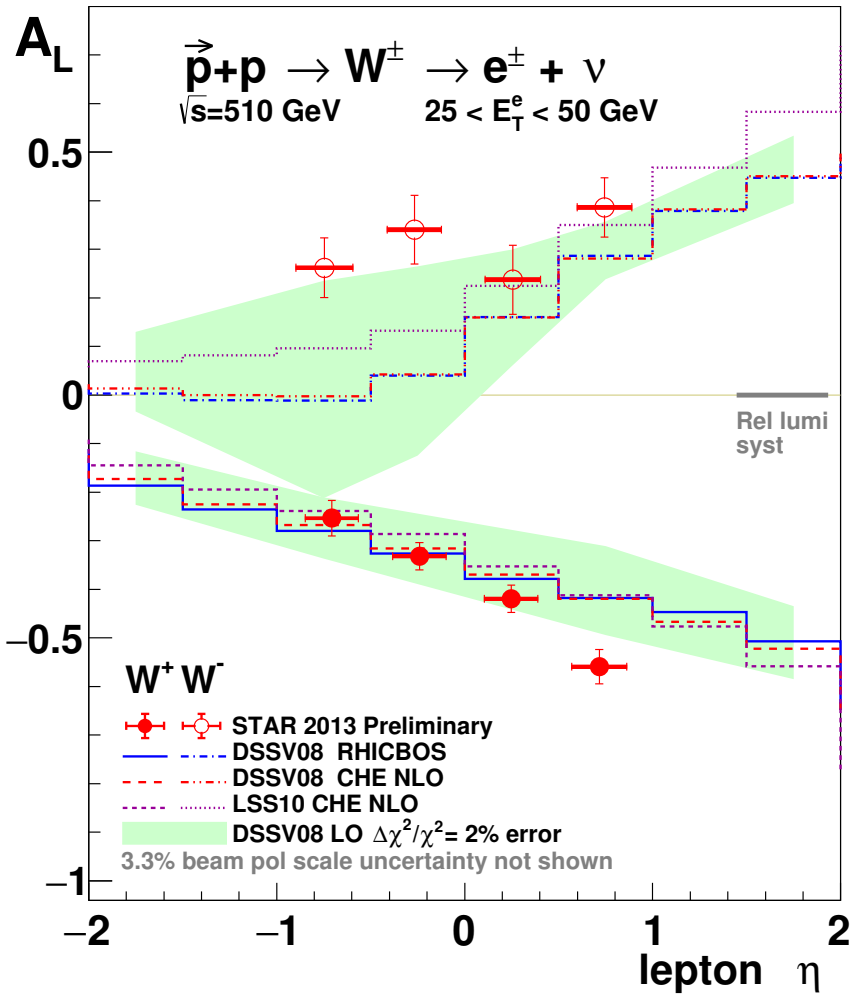

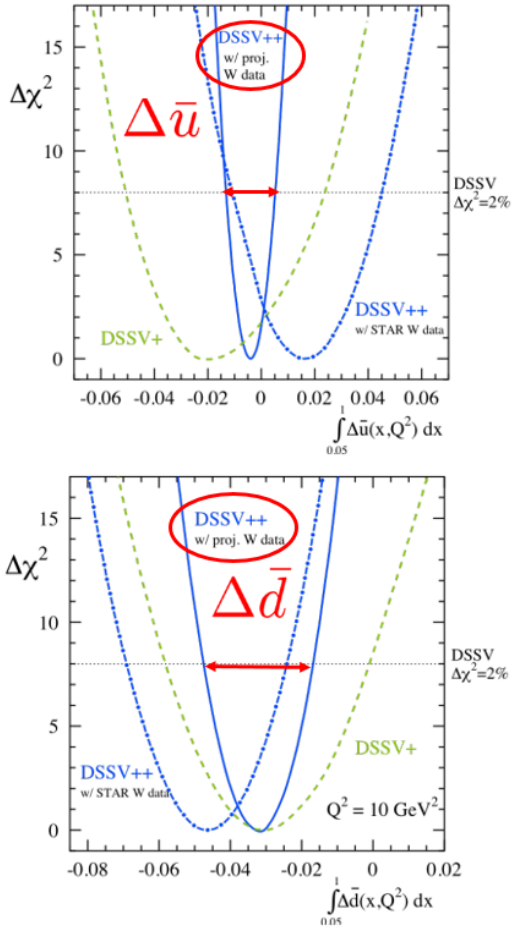

DSSV: uncertainty projection from STAR 2013 W A_L data arXiv:1304.0079

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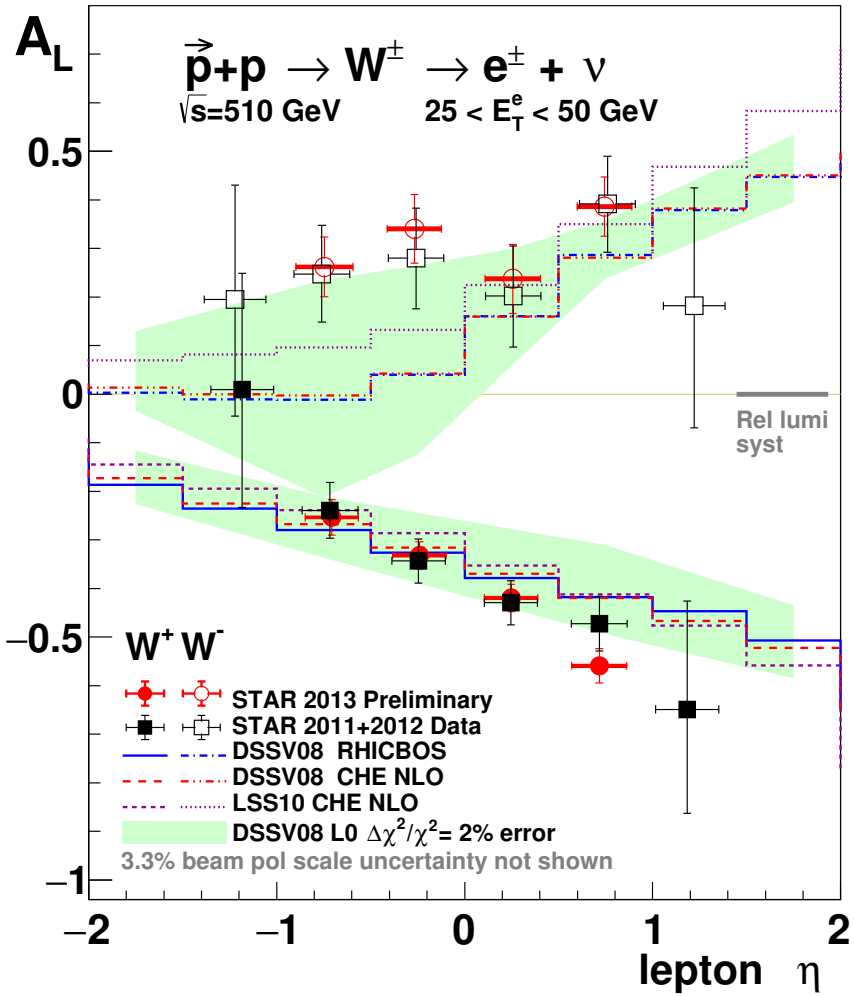

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- Consistent with STAR 2011+2012 results with 40% smaller uncertainty

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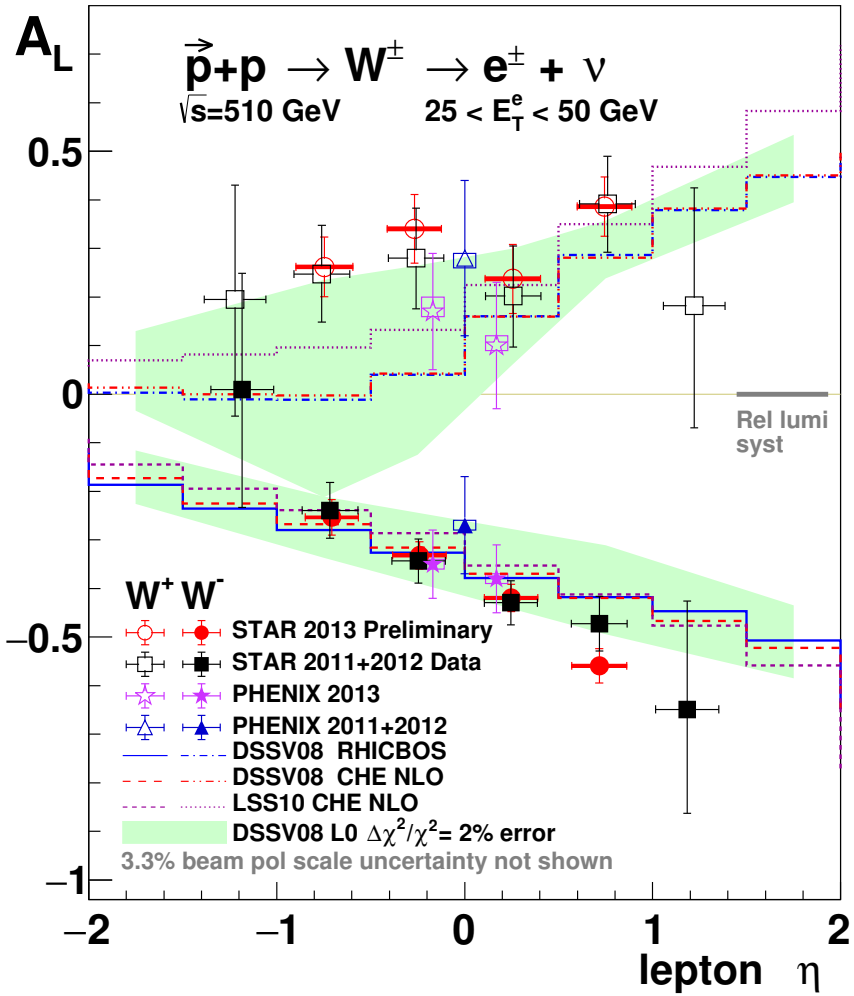

- Most precise measurement of W A_L
- Expect to further constrain $\Delta\bar{u}$, $\Delta\bar{d}$ distributions
- Consistent with STAR 2011+2012 results with 40% smaller uncertainty
- Consistent with PHENIX W/Z A_L measurements

PHENIX, PRD93,051103(2016)

Summary

- Measurement of A_L of W boson production in polarized pp collision provides unique probe to flavor-separated sea quark polarization
- Most precise measurement of $W^{\pm}$ A_L from preliminary STAR 2013 data released here
- Significantly constrain $\Delta\bar{u}$, $\Delta\bar{d}$ distributions
- Data prefer $\Delta\bar{u} > \Delta\bar{d}$, opposite to the difference between unpolarized sea quark distributions