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College of Science and Technology
TEMPLE UNIVERSITY

Measurement Of Longitudinal Single-Spin Asymmetry For W Boson Production In Polarized Proton-Proton Collisions At STAR

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Motivation

How is the proton built up from its quark and gluon constituents?

Jaffe and Manohar showed in 1990 that the proton spin can be written as a sum of contributions from quark and gluon spin and orbital angular momentum.

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

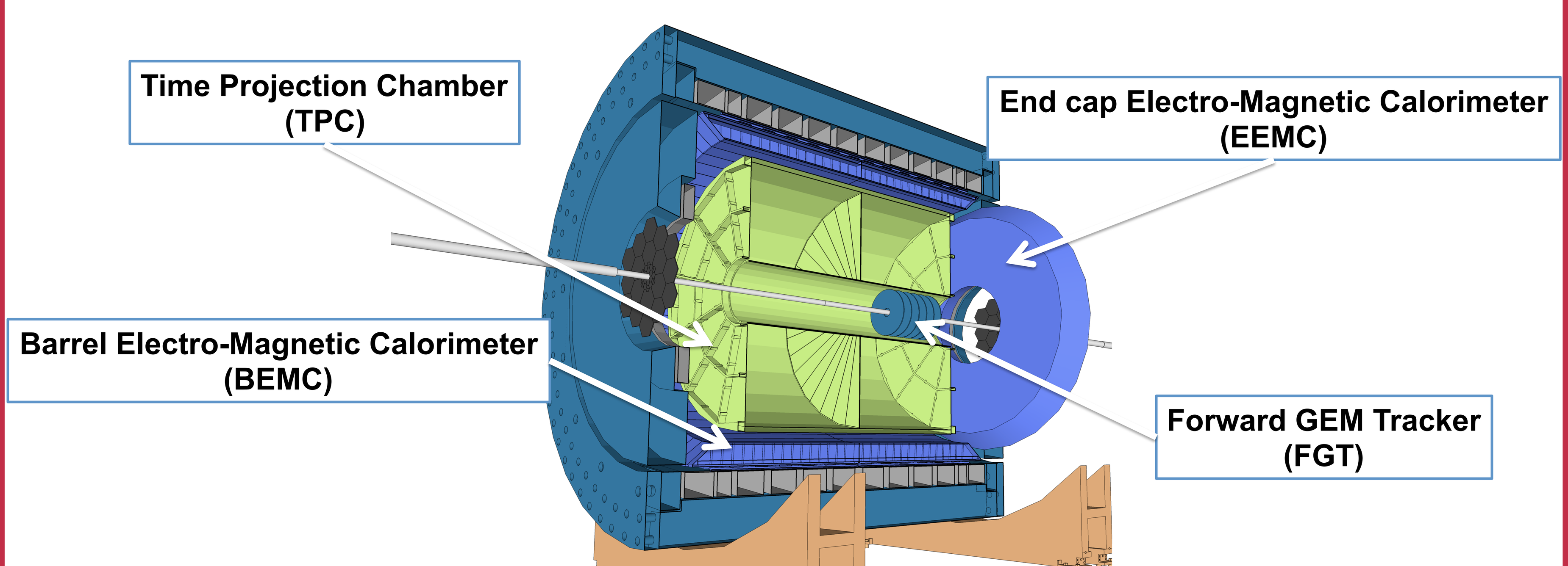
quark and anti-quark contributions

R. L. Jaffe and A. Manohar, Nucl. Phys. B337 (1990) 509.

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

The polarized parton distribution functions (PDFs) of sea quarks are still not well constrained compared to valence quarks.

The STAR Experiment



Sub Detectors

- The TPC is used for particle tracking
- Particle energy was measured using the BEMC and EEMC

$\sqrt{s} = 510\ GeV$
$Integrated\ Luminosity = 245\ pb^{-1}$
$Beam\ Polarization = 56\%$

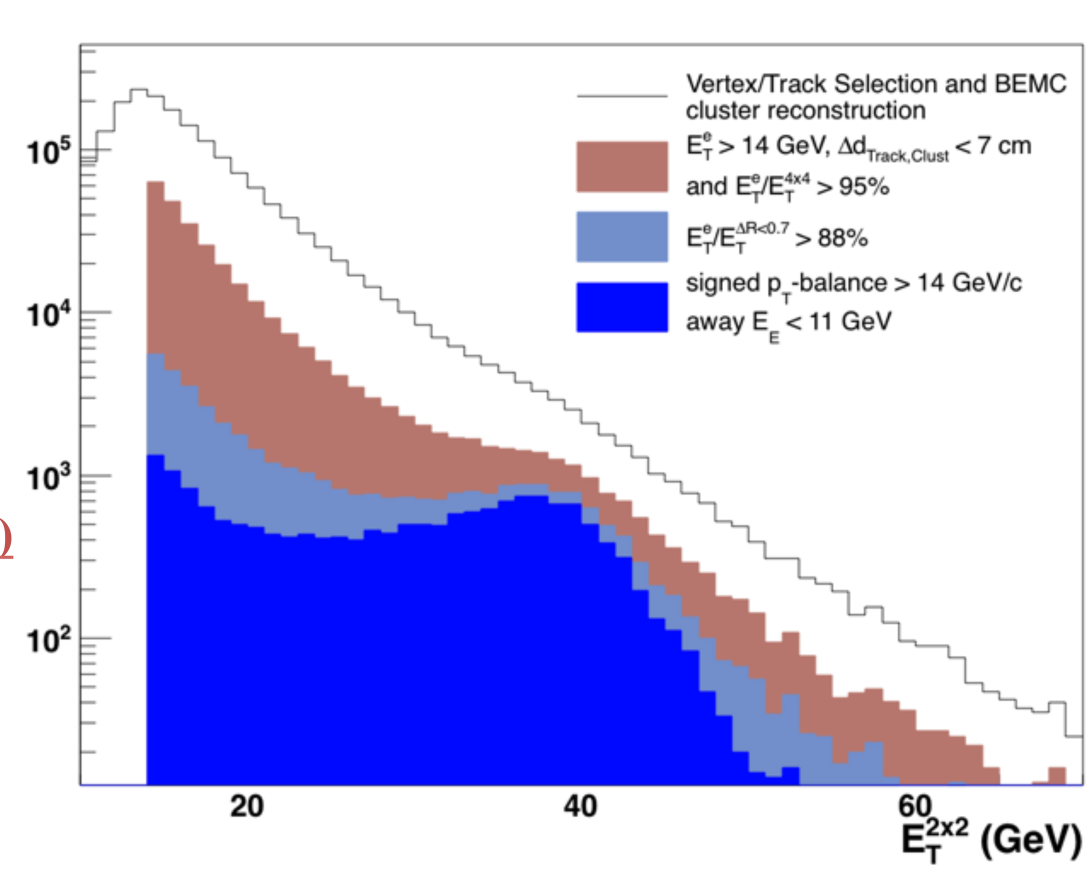
Event Selection

Isolation Barrel (Endcap)

- $E_T^{2x2}/E_T^{4x4} > 0.95\ (0.96)$
- $E_T^{2x2}/E_T^{\Delta R<0.7} > 0.88$
- ESMD > 0.7 (only for forward)

Final W Selection Barrel (Endcap)

- Signed-p_T balance > 16 (20) GeV
- $0.4 < |Q\ E_T/P_T| < 1.8$
- $25\ GeV < E_T^{2x2} < 50\ GeV$



W Boson Production

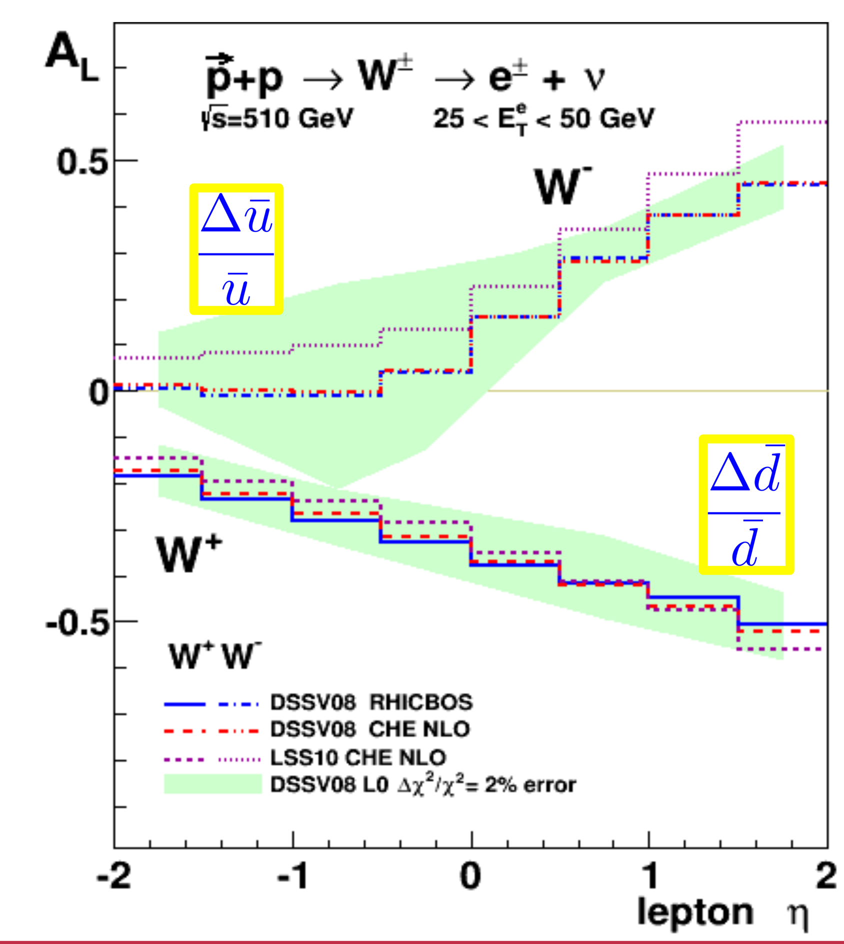
Measurement of A_L of W boson production in polarized proton-proton collision provides unique probe to flavor-separated sea quark polarization

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

$$A_L^{e^-} \approx \frac{\int_{\otimes(x_1,x_2)}[\Delta\bar{u}(x_1)d(x_2)(1-cos\theta)^2 - \Delta d(x_1)\bar{u}(x_2)(1+cos\theta)^2]}{\int_{\otimes(x_1,x_2)}[\bar{u}(x_1)d(x_2)(1-cos\theta)^2 + d(x_1)\bar{u}(x_2)(1+cos\theta)^2]}$$

$$A_L^{e^-} \approx \frac{\int_{\otimes(x_1,x_2)}[\Delta\bar{d}(x_1)u(x_2)(1+cos\theta)^2 - \Delta u(x_1)\bar{d}(x_2)(1-cos\theta)^2]}{\int_{\otimes(x_1,x_2)}[\bar{d}(x_1)u(x_2)(1+cos\theta)^2 + u(x_1)\bar{d}(x_2)(1-cos\theta)^2]}$$

- W production provide direct sensitivity to the u and d quark and anti-quark helicity distributions.
- Large scale defined by W mass (~80 GeV).
- Simple final state of charged leptons: No dependency on fragmentation functions.

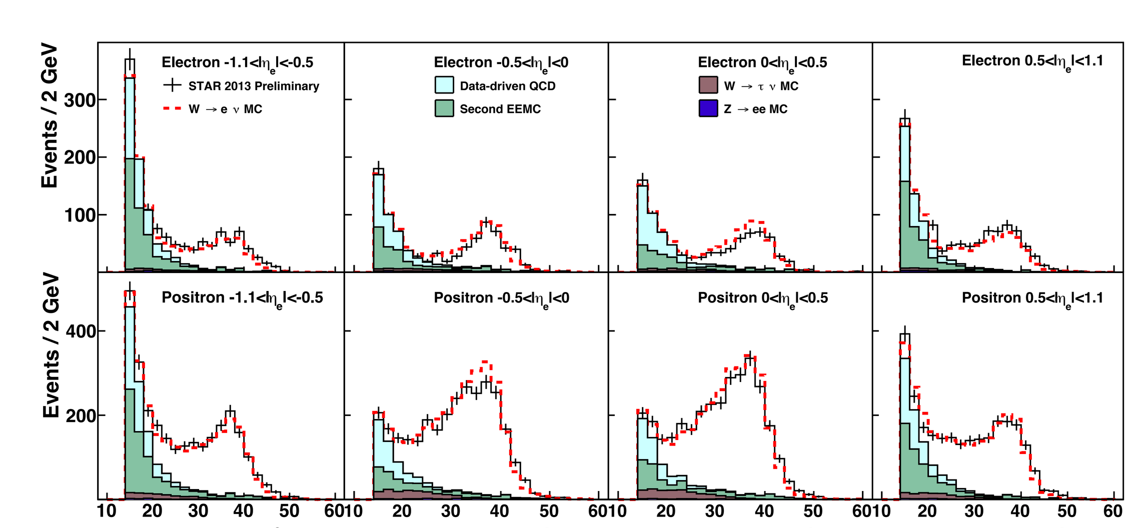


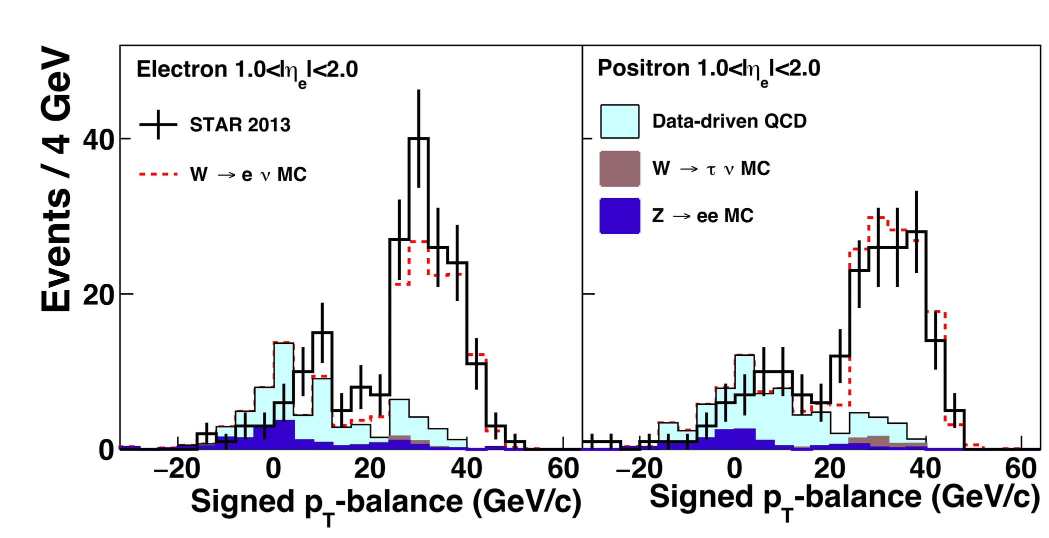
Background Estimation

There are still some residual background events, that passed all the W selection cuts

- **Electroweak Background:**
  This background arise from well-understood electroweak processes:
  - Z→ e⁻+e⁺
  - W→ τ+ν

  Estimated using MC simulations.
- **QCD Background:**
  - Second EEMC:
    Background (di-jets) which counts as a W events by escaping detection through non-existing calorimeter coverage ($-2 < \eta < -1$).
    Estimated using endcap calorimeter at $1 < \eta < 2$.
  - Data–driven QCD:
    Background which passes $e^\pm$ isolation cuts.
    Estimated using a data-driven method.

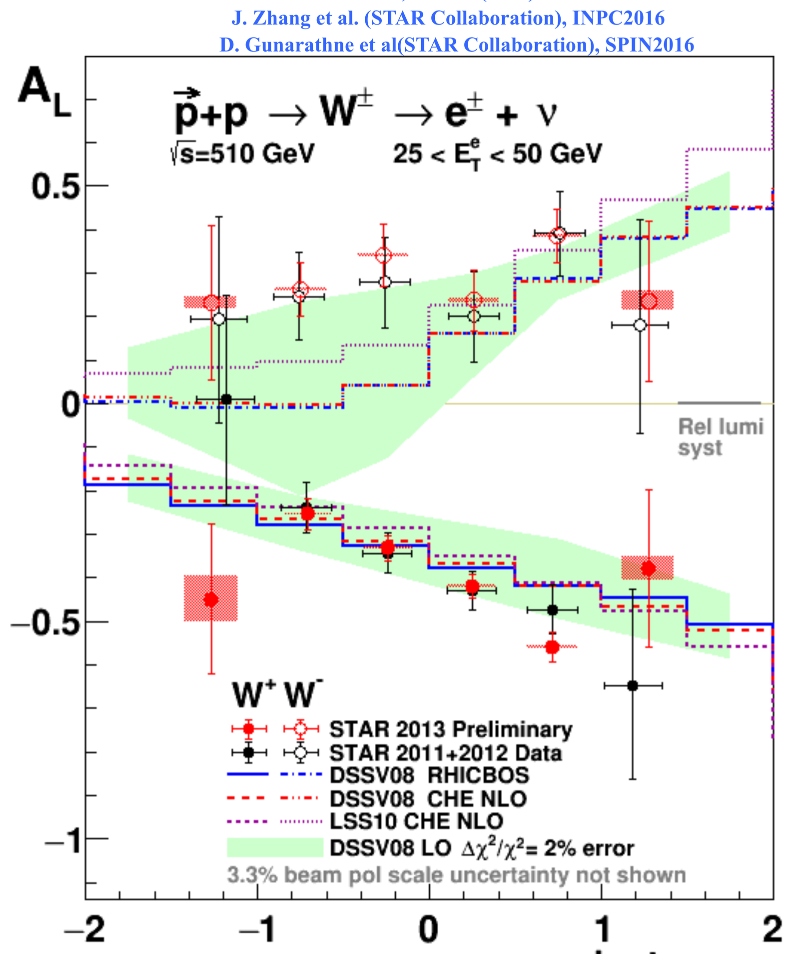




Results

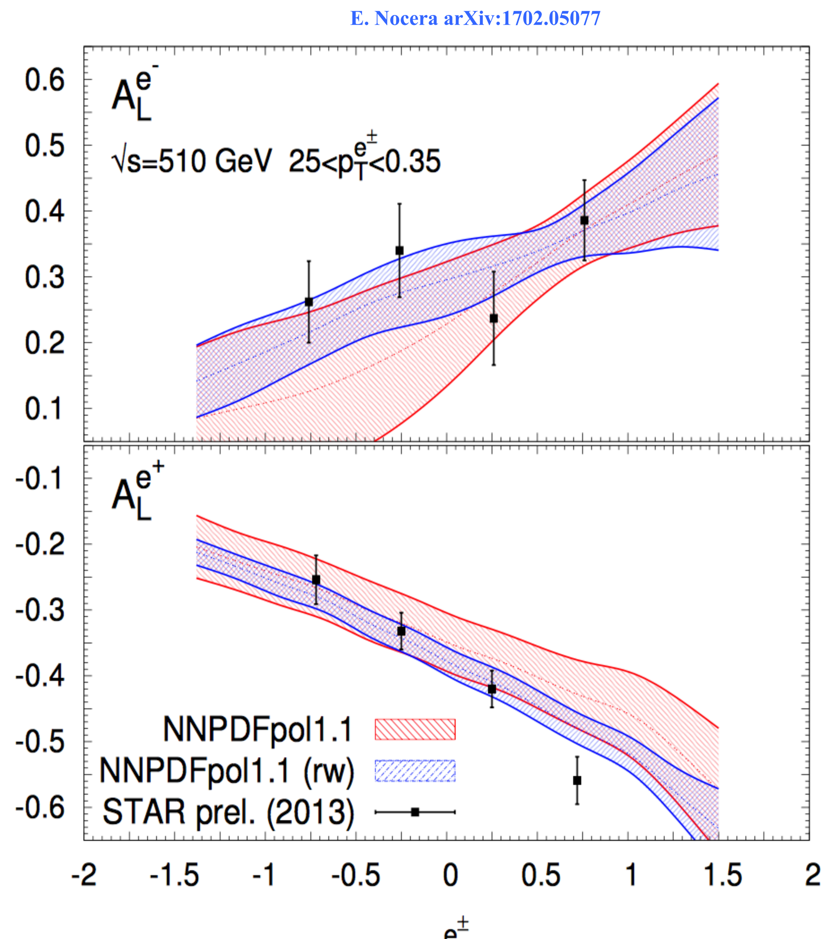
$$A_L = \frac{1}{\beta}\frac{1}{P}\frac{N_+/l_+ - N_-/l_-}{N_+/l_+ + N_-/l_-}$$

PRL 113, 072301 (2014)
J. Zhang et al. (STAR Collaboration), INPC2016
D. Gunarathne et al(STAR Collaboration), SPIN2016



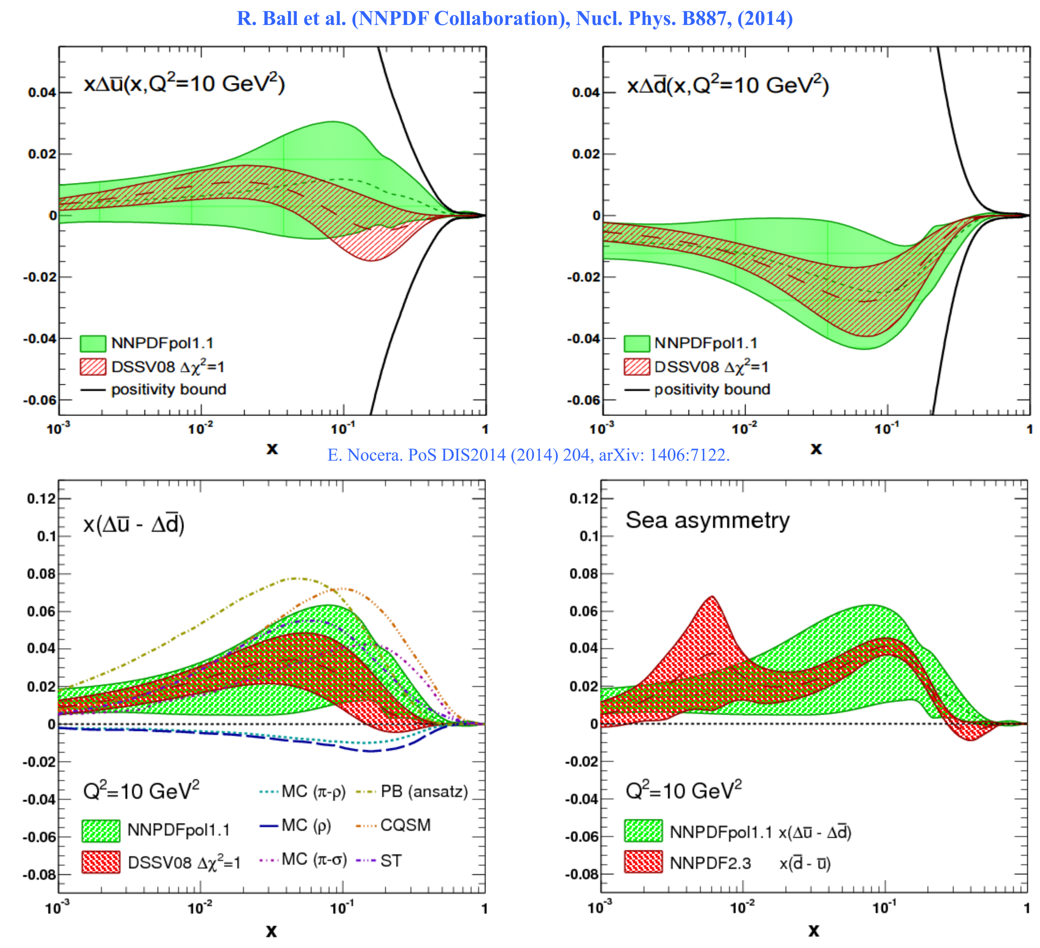
Impact of STAR 2013 W A_L Measurements (NNPDF)

E. Nocera arXiv:1702.05077



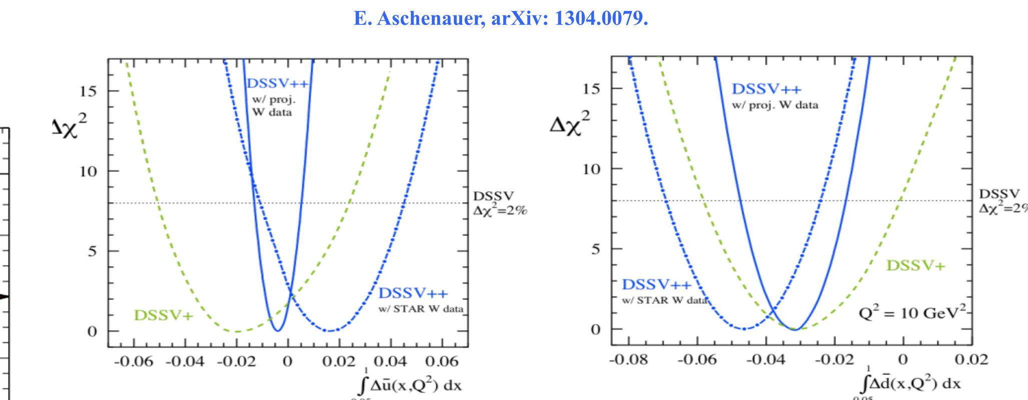
Impact of STAR 2012 W A_L Measurements (NNPDF)

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



Impact of STAR 2012 W A_L Measurements (DSSV)

E. Aschenauer, arXiv: 1304.0079.



- Most precise measurement of W A_L up to date.
- Significantly constrain $\Delta\bar{u}$, $\Delta\bar{d}$ distributions.
- The asymmetry in the polarized sea is OPPOSITE to that in the unpolarized sea (where $\bar{d} > \bar{u}$).