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Constraining the Sea Quark Distributions Through $W^{+/-}$ Cross Section Ratios Measured at STAR

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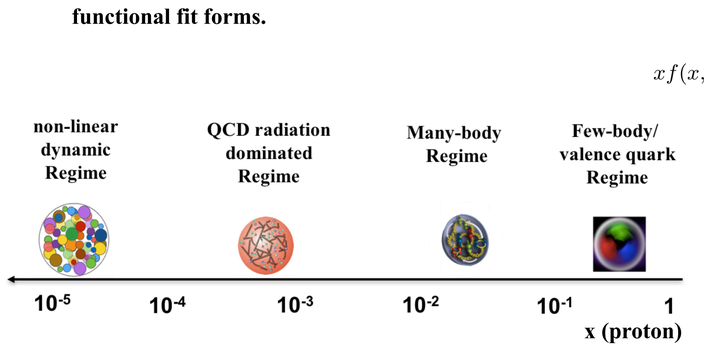
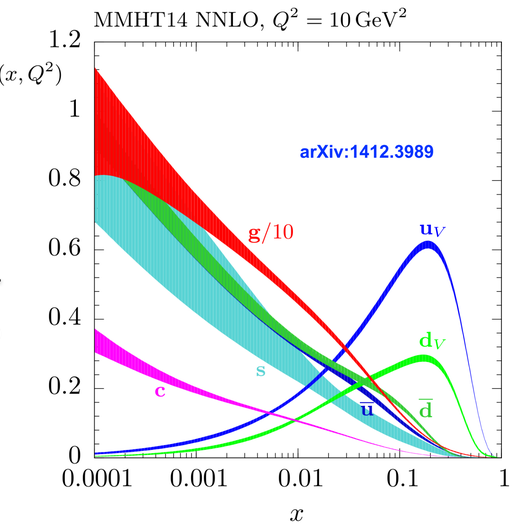
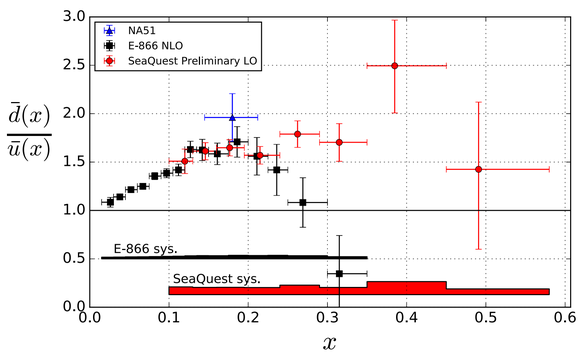
Motivation

- Parton distribution functions (PDFs) probe the internal structure of the proton. The x-dependence of these PDFs allows one to map the intrinsic and dynamic properties of the proton.
- Various global analyses (CT14, MMHT14, BS15, etc.) extract PDFs from data using various data sets and functional fit forms.





B. Kerns et al. (SeaQuest Collaboration), APS April Meeting 2016.

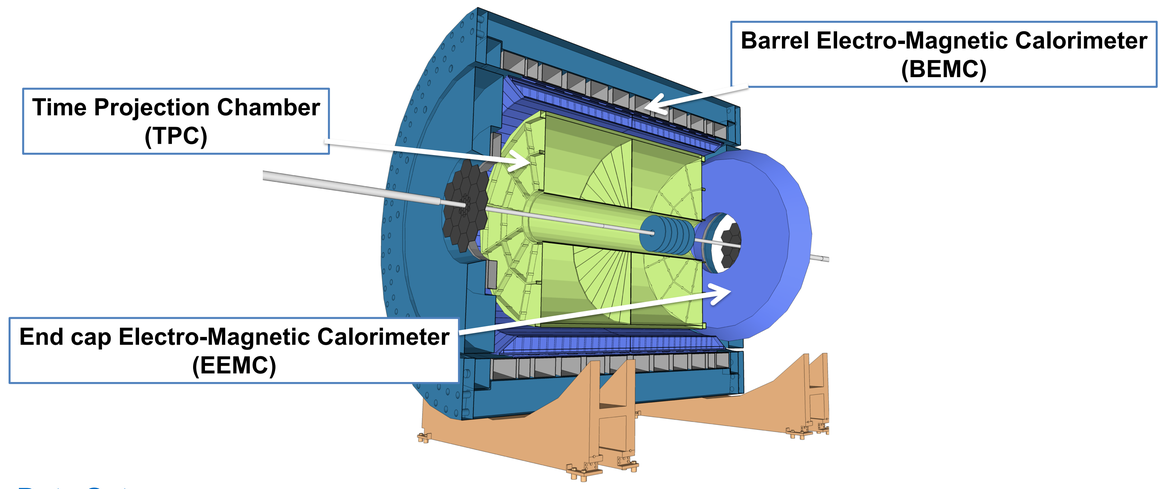


- The $\bar{d}/\bar{u}$ distribution has been measured by several experiments.
- More data are needed at higher x to help constrain the sea quark distributions.
- New measurements from different experiments can provide more data at different Q^2 values and scattering processes.

The STAR Detector and Data

Sub Detectors

- The charged W cross section ratios were measured in the mid-rapidity region making use of three major sub detectors:
  - The TPC and solenoid magnet were used for particle tracking
  - Particle energy was measured using the BEMC
  - QCD background estimates and corrections made use of the EEMC

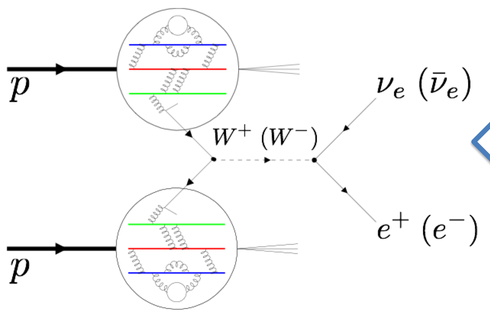


Data Sets

- Charged W cross sections were measured during the run period of 2011, 2012, and 2013
- Protons were collided at center of mass energies of 500 and 510 GeV
- Data totaling about 345 pb^{-1} from years 2011, 2012, and 2013 have now been analyzed and a new preliminary result has been released
- Proton-proton data at 510 GeV was also taken in 2017. This data set is in the early analysis stages, but when combined with years 2011, 2012, and 2013, the total data sampled will be approximately 700 pb^{-1}

W Boson Production

- W bosons are directly sensitive to quark/anti-quark distributions. They can be measured through the W lepton decay channels in proton + proton collisions
- W production probes high Q^2 ($Q^2 = M^2_W$)



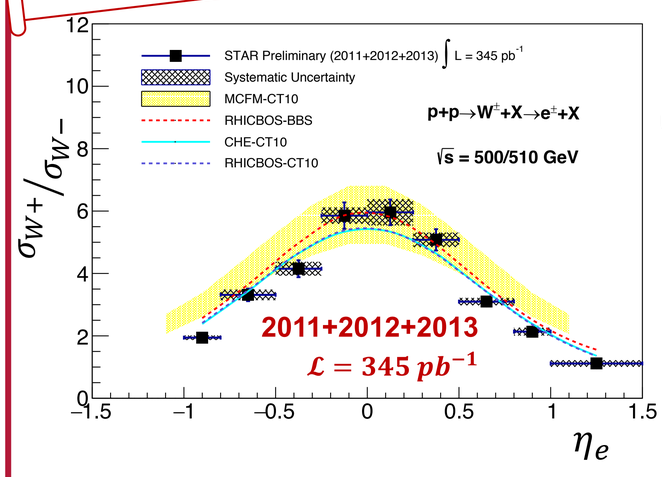
$$\mathbf{u} + \bar{\mathbf{d}} \rightarrow \mathbf{W}^+ \rightarrow \mathbf{e}^+ + \nu$$

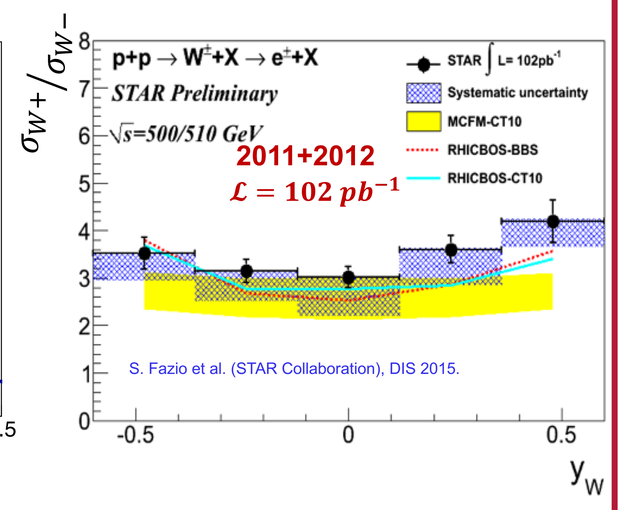
$$\mathbf{d} + \bar{\mathbf{u}} \rightarrow \mathbf{W}^- \rightarrow \mathbf{e}^- + \bar{\nu}$$

- The W cross section ratio at leading order takes the form: $\frac{\sigma_{W+}}{\sigma_{W-}} \approx \frac{u(x_1)\bar{d}(x_2) + \bar{d}(x_1)u(x_2)}{\bar{u}(x_1)d(x_2) + d(x_1)\bar{u}(x_2)}$
- Experimentally this takes the form: $\frac{\sigma_{W+}}{\sigma_{W-}} = \left(\frac{N_O^+ - N_B^+}{N_O^- - N_B^-}\right)\left(\frac{\epsilon^-}{\epsilon^+}\right)$
  - +/- is positron/electron from W leptonic decay
  - N_O is number of observed W events
  - N_B is number of background events
  - ε is the measured W efficiency

Preliminary Results

New Preliminary



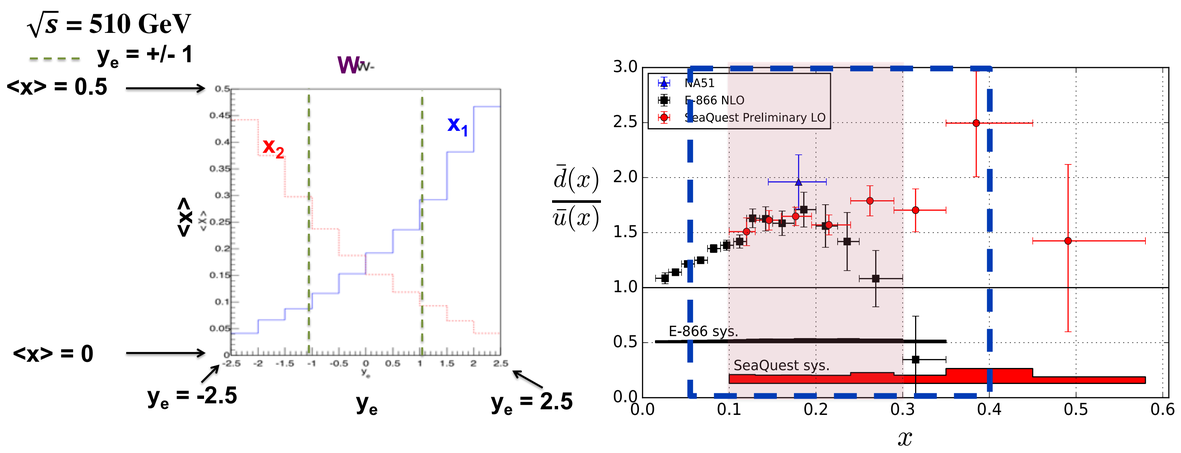


S. Fazio et al. (STAR Collaboration), DIS 2015.

- Analysis of the W cross section ratio follows closely the W A_L analysis, which is described in the poster by Amani Kraishan.
- The W boson rapidity can be determined by reconstructing the W kinematics via its recoil through the use of Monte-Carlo simulations (critical for transvers single spin asymmetry Phys. Rev. Lett. 116, 13, 132301 (2016)). This was applied to the 2011 and 2012 combined data sets.

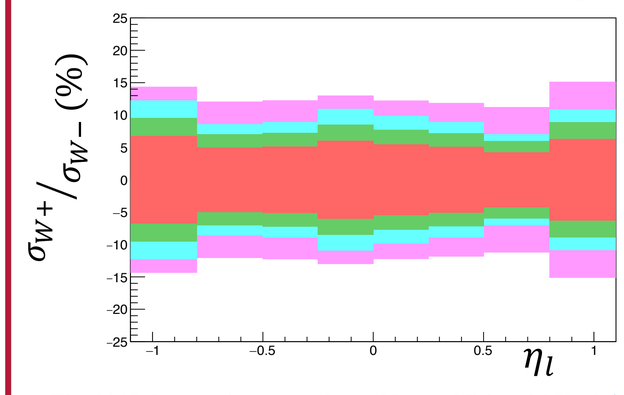
Kinematic Reach at STAR

- The STAR experiment is an excellent place to measure the W cross section ratio and help provide constraints to the sea quark distributions in the x-range where E866 and SeaQuest data appear to not overlap and have larger uncertainties.



- For collisions in STAR at center of mass energy $\sqrt{s} = 500\ GeV$ and $\eta = 0, < x > = \frac{M_W}{\sqrt{s}} \approx 0.16$
- Approximate kinematic range at STAR mid-rapidity (TPC + BEMC):
  - $0.1 \leq x \leq 0.3$ for $-1 \leq \eta \leq 1$ (red shaded box).
- The use of the STAR EEMC could push the data more forward ($1.1 \leq \eta \leq 2$), which extends the x reach
  - $0.06 \leq x \leq 0.4$ for $-2 \leq \eta \leq 2$ (blue dashed box).

Projections



Projected Statistical Uncertainties

- 2011 + 2012 (~100 pb^{-1})
- 2013 (~250 pb^{-1})
- 2017 (~350 pb^{-1})
- Combined Sets (~700 pb^{-1})

- The 2017 data set is expected to add an additional 350 pb^{-1}, totaling ~700 pb^{-1} of integrated luminosity for the cross section ratio measurement.

Summary

- The STAR charged W cross section ratio measurements lay in an interesting kinematic range where existing measurements hint at an interesting behavior in the sea quark distributions. Fits to the STAR data will help to constrain the sea quark PDFs and could help better understand the sea quark distributions.
- New Preliminary charged W cross section ratios using combined 2011, 2012, and 2013 data sets have been measured as a function of electron pseudo-rapidity. This accounts for about 345 pb^{-1}.
- Preliminary charged W cross section ratios using combined 2011 and 2012 data sets have been measured as a function of W boson rapidity. This accounts for ~100 pb^{-1}.
- The 2017 data have delivered ~350 pb^{-1} and will further improve the charged W cross section ratio measurement.