Charge Symmetry Violation Quark Distribution via Precise Measurement of $\pi+/\pi-$ Ratios in SIDIS

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Motivation

What is Charge symmetry?

Charge symmetry (CS) is one special kind of isospin symmetry. It requires invariance with respect to rotation of T2 axis.

$$[H, P_{CS}] = 0, P_{CS} = exp(i\pi T2)$$

For nuclei

CS operator interchanges neutrons and protons

pp, nn interaction

$$\sigma(n, {}^3He) = \sigma(p, {}^3H)$$

$$m({}^3He) = m({}^3H)$$

Quark level

$$P_{CS} |d = P_{CS} |u$$

$$P_{CS} |d = -|u$$

$$u^p(x, Q^2) = d^n(x, Q^2) \; d^p(x, Q^2) = u^n(x, Q^2)$$

In QCD, the sources of CSV are the electromagnetic interaction and the mass difference. At the quark level, one would expect CSV to be of the order of the up-down quark mass difference divided by some average mass expectation value of the QCD Hamiltonian

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- CSV is important for understanding the basic symmetries and the inner structure of the nucleon. It has been universally assumed in extracting PDFs but has never been tested experimentally
- CSV could be part of the explanation for anomalous results of Drell-Yan experiments and the NuTeV anomaly (PRL 102 (2009) 252301, PLB 753 (2016)595)

Experimental Limits

CSV(x) contains d u, where

$$d(x) = d^p(x) \quad u^n(x); \; u(x) = u^p(x) \quad d^n(x):$$

Theoretical limits

Model by Sather:

$$d(x) \quad 2 \quad 3\%$$

$$u(x) \quad 1\%$$

E. Sather, Phys. Lett. B274, 433 (1992)

Model by Rodionov, Thomas and Londergan

d(x) could reach up to 10% at high x

E. N. Rodionov, A. W. Thomas and J. T. Londergan, Mod. Phys. Lett. A 9, 1799 (1994)

Phenomenological limits

MRST Group studied uncertainties in PDFs arising from CSV.

$$u_v = \quad d_v = \quad (1 \quad x)^4 x^{0:5}(x \quad 0:0909); \int dx\, u_v(x) = \int dx\, d_v(x) = 0$$

Good agreement with high energy data, valence CSV e ects could be larger than the

Eur. Phys. J.35(2004)325

Formalism

Londergan, Pang and Thomas PRD54(1996)3154

$$R^{D}_{meas}(x;z) = \frac{4N^{D}\quad(x;z) \quad N^{D\quad +}(x;z)}{N^{D\quad +}(x;z) \quad N^{D}\quad(x;z)} \qquad (1)$$

where $N^{D}\quad(x;z)$ is the yield of electroproduction on a deuterium target

Factorization:

$$N^{Nh}(x;z) \quad \sum_i e_i^2 q_i^N(x) D_i^h(z)$$

Impulse Approximation:

$$N^{D}\quad(x;z) = N^{p}\quad(x;z) + N^{n}\quad(x;z)$$

The charge-symmetry violating quark distributions can be extracted using the above quanti
via the following formula:

$$D(z)\ R(x;z) + CSV(x) = B(x;z)$$

$$D(z) = \frac{1\quad(\quad z)}{1+(\quad z)},\ R(x;z) = \frac{5}{2} + R^{D}_{meas},\ CSV(x) = \frac{4(\ d\quad u\ )}{3(u_V + d_V)},$$

Formalism

$$B(x;z) = \frac{5}{2} + R^{D}_{sea\_S}(x;z) + R^{D}_{sea\_NS}(x):$$

CTEQ6 parameterization:

Sea term:

In this experiment

We measured $R(x;z)$ for 16 bins in x and z for 3 distinct Q^2, we can extract D(z) and CSV(x) term

Experiment Overview

Semi-Inclusive Deep Inelastic Scattering (SIDIS)in Hall C at Je erson Lab

The electron was detected in the HMS and the pion in the SHMS

The experiment ran in Fall 2018 and Spring 2019

10.6 GeV beam, LD_2(10 cm), LH_2(10 cm), Al-dummy

HMS angle 13-21 , 4.4-6.4 GeV, electrons

SHMS angle 11-21 , 1.7-4.5 GeV, + =

$$R_Y = \frac{Yield_D}{Yield_D^{+}}; R^D_{meas}(x;z) = \frac{4R_Y \quad 1}{1 \quad R_Y}$$

Data analysis

Pion selection

Pion selection is perfomed using the beam reference time at the target . The central length in the SHMS from the target to the hodoscope 1st plane is 20.1 m . We can calculate the time di erence between di erent particles.

The time of ight of positively charged hadrons and positrons is di erent in the SHMS spectrometer.

The beam electrons come in every 4ns, di erent hadrons have di erent travel times, pions are aligned at 1.

Pion selection

Apply kaon cut and get the parameter of the kaon tting.

Fit with xed mean and sigma to estimate pion purity for both polarity

$$_{\text{purity}} = 1 \quad \frac{N_{kaons}}{N_{pions} + N_{kaons}}$$

E ciencies

Tracking e ciency

$$TE = \frac{N_{did;track}}{N_{should;notrack}}$$

Live time calculation

$$TLT = \frac{N_{edtm;acc}}{N_{edtm;scl}}$$

Backgrounds estimate by Monte Carlo Simulation

$x = 0:5;\ Q^2 = 5\,\mathrm{GeV}^2;\ z = 0:5$

Data yield

$$Yield = \frac{pions \quad {}_{purity}}{charge \quad TE \quad TLT \quad PID_{eff}}$$

$$Yield = \frac{Norad}{Rad}(data \quad exc \quad delta)$$

Backgrounds

- Exclusive radiative contribution $D(e; e^0 \quad)n(p)$
- Delta radiative contribution $D(e; e^0 p)$
- Di ractive $D\,(e; e^0 \ ! \quad {}^{+} \quad)$ (not included in sum)

Factorization

Preliminary results

Assumed high energy parameterization of the fragmentation function,

$$\frac{{}_p^{+} + {}_p}{{}_d^{+} + {}_d} = \frac{4u(x) + 4\bar{u}(x) + d(x) + \bar{d}(x)}{5[u(x) + d(x) + \bar{u}(x) + \bar{d}(x)]}$$

Using the deuterium data only, the ratio of unfavored to favored fragmentation functions can be extracted, to a good approximation, at LO simply giving by

$$D \;\; = D^{+} = \frac{4 \quad \frac{{}_d(\;\;^{+})}{{}_d(\;\;\;)}}{4\frac{{}_d(\;\;^{+})}{{}_d(\;\;\;)} \quad 1} = \frac{4R_Y \quad 1}{4 \quad R_Y}$$

In the high-energy limit, this ratio should solely depend on z (and Q^2), but not on x

Preliminary result up to now

$x = 0:5$, $Q^2 = 5.5\ GeV^2$, one of the kinematic settings

$Q^2 = 5:5 GeV^2$, $z = 0:45$

CSV(x) and D(z)

We measured $R(x;z)$ for each di erent kinematics. We can extract D(z) and CSV(x) term from our equation
$D(z)\ R(x;z) + CSV(x) = B(x;z)$

Summary

Current work

- Particle Identi cation
- Backgrounds subtraction
- E ciency correction
- Radiative correction

Future work

- Target boiling study
- H_2 check
- Global t to get CSV term

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Thank you!

More Preliminary Yield ratio results