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

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Outline

- Motivation
- Formalism
- Experiment Overview
- Data Analysis
- Preliminary Results

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.

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

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For nuclei

CS operator interchanges neutrons and protons

- pp, nn interaction
- $\sigma(n, {}^3He) = \sigma(p, {}^3H)$
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Quark level

- $P_{CS}\,|d = P_{CS}\,|u$
  $P_{CS}\,|d = -\,|u$
- $u^p(x, Q^2) = d^n(x, Q^2)\ d^p(x, Q^2) = u^n(x, Q^2)$

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In QCD, the source of CSV are electromagnetic interaction and the mass difference. At quark level, we would expect CSV to be of the order of the up-down current quark mass difference divided by some average mass expectation value of the strong Hamiltonian, i.e., $(m_d - m_u)/\langle M \rangle$, where $\langle M \rangle$ has a value roughly 0.5-1.0GeV.

Motivation

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

Formalism

Londergan, Pang and Thomas PRD54(1996)3154

$$R^D_{meas}(x,z) = \frac{4N^{D\pi^-}(x,z) - N^{D\pi^+}(x,z)}{N^{D\pi^+}(x,z) - N^{D\pi^-}(x,z)}$$

$$R^D_{Meas}(x,z) = \frac{4R_Y(x,z) - 1}{1 - R_Y(x,z)}$$

$$R_Y = Y^{D\pi^-}(x,z)/Y^{D\pi^+}(x,z)$$

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

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

Formalism

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

$$D(z) = \frac{1-\Delta(z)}{1+\Delta(z)},\ R(x,z) = \frac{5}{2} + R^{D}_{meas},\ CSV(x) = \frac{-4(\delta d - \delta u)}{3(u_v + d_v)},$$

In D(z), $\Delta(z)$ is the ratio of unfavored to favored fragmentation functions, $D_u^{\pi^-}(z)/D_u^{\pi^+}(z)$.
B(x,z), can be calculated from PDF parametrizations.
CSV(x) contains the difference of charge symmetry violating quark distributions, $\delta d - \delta u$

For experiment

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

Experimental Limits

$CSV(x)$ contains $\delta d - \delta u$, where

$$\delta d(x) = d^p(x) - u^n(x),$$
$$\delta u(x) = u^p(x) - d^n(x).$$

Theoretical limits

Model by Sather:

$$\delta d(x) \sim 2 - 3\%$$

$$\delta u(x) \sim 1\%$$

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

Model by Rodionov, Thomas and Londergan
$\delta d(x)$ could reach up to 10% at high x E. N.

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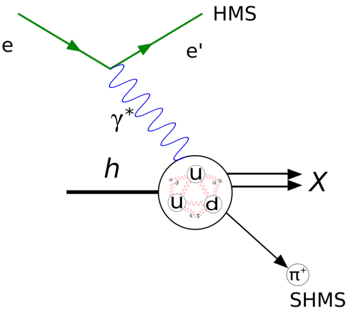
Phenomenological limits

Using the uncertainties in PDFs studied by MRST Group, CSV is constrained to less than 9%

Eur. Phys. J.35(2004)325

Experiment Overview



SIDIS in Je□erson Lab Hall C

- 10.6GeV beam, 10 cm LD_2, 10 cm LH_2, Dummy
- 4 z measurements (0.4,0.5,0.6,0.7) for each x, Q^2 setting.

$$Q^2 = 3.9 - 4.0GeV \dashrightarrow x = 0.35, 0.4, 0.45, 0.5$$

$$Q^2 = 4.7 - 5.0GeV \dashrightarrow x = 0.45, 0.5, 0.55, 0.60$$

$$Q^2 = 5.5GeV \dashrightarrow x = 0.5, 0.55, 0.6, 0.65$$

- HMS angle 13-21degree, 4.4-6.4GeV, electrons
- SHMS angle 11-21degree, 1.7-4.5GeV, pions
- Fall 2018 and spring 2019

We used isoscalar target (LD2) to extrac CSV distribution, LH2 target for cross-section check and factorization test and dummy target to subtract the contribution from the target wall.

Data analysis:Calibrations

SHMS calorimeter calibration

Data analysis:Calibrations

SHMS calorimeter calibration

Time of flight calibration

Data analysis

Coincidence time for Fall and Spring runs.

Fall 2018

Spring 2019

Red is for pions, blue is for protons

Data analysis: Heavy Gas Cherenkov

- HGC has a hole in the middle
- Large momentum range, below threshold

$$N_p = L \frac{{}^2 z^2}{r_e m_e c^2} \; R \; (E) \sin^2 {}_c(E) dE$$

$$N_p \quad LN_0 < \sin^2 \; > = p_0 (1 \quad p_1 \frac{p^2 + m^2}{n^2 p^2})$$

Data analysis

Pion selection by target reference time. Central length is 20.1m from target to hodoscope 1st plane. We can calculate time di erence between the reference time at target and hodoscope.

time of ight is di erent for hadrons and electrons(positrons) in SHMS spectrometer.

Electrons come in every 4ns, so I mod time of ight by the period and move the pion peak at 1.

Data analysis

pion selection

time di erence vs. SHMS momentum. Flat band at 1 is pion band. Kaons and protons are slower than pions

Aerogel Cerenkov detector Npe vs time di erence

Data analysis

accidental background

We need to consider both statistical error and systematic errors.

Vary the background subtraction selection

Minimal systematic uncertainty between di erent samples.

Data analysis

Tracking e ciency

Tracking e ciency is pions detected (with tracks in DC) over pion expected (detected only b
hodoscope).

Preliminary result up to now

$x = 0.5, Q^2 = 5.0$, 1/16 kinematic settings

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To do list

Compare with SIMC simulation for acceptance study

radiative correction

correction from exclusive particle decay into pions

Acknowledgement

I would like to acknowledge my advisor Dr. Zein-Eddine Meziani. And thanks to Dr. Dipangkar Dutta, Dr. Dave Gaskell and Dr. Whitney Armstrong for their help. Also thanks to collaborator Hem Bhatt.

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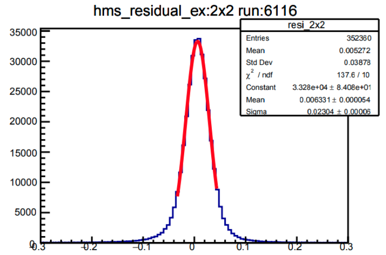
Thank you!

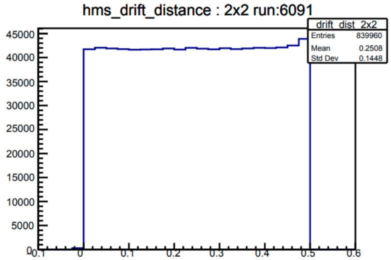
Back up

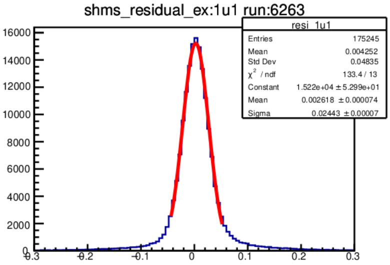
cuts

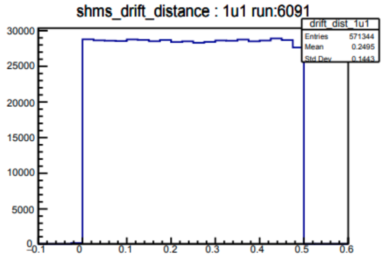
- HMS calorimeter
- HMS Cerenkov
- HMS dp
- SHMS calorimeter
- SHMS dp
- SHMS aero
- coin type
- cintime cut
- rftime cut for SHMS momentum less than 3.2GeV
- HGC cut for SHMS momentum greater than 3.2GeV
- tracking efficiency correction
- background accidental

DC calibration

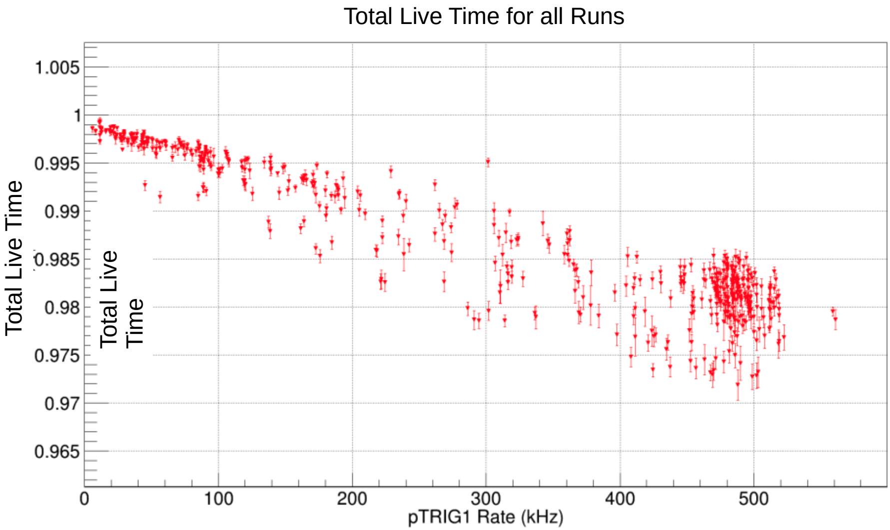








livetime



Total Live Time for all Runs
Total Live Time
Total Live Time
1.005
1
0.995
0.99
0.985
0.98
0.975
0.97
0.965
0
100
200
300
400
500
pTRIG1 Rate (kHz)