# 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	Quark level
CS operator interchanges neutrons and protons • pp, nn interaction • $\sigma(n, {}^{3}He) = \sigma(p, {}^{3}H)$ • $m({}^{3}He) = m({}^{3}H)$	• $P_{CS}  d\rangle = P_{CS}  u\rangle$ $P_{CS}  d\rangle = -  u\rangle$ • $u^p(x, Q^2) = d^n(x, Q^2) d^p(x, Q^2) = u^n(x, Q^2)$

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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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

- 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)

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# **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:	Model by Rodionov, Thomas and Londergan
$\delta d(x) \sim 2 - 3\%$	$\delta d(x)$ could reach up to $10\%$ at high $x$
	E. N. Rodionov, A. W. Thomas and J. T. Londergan, Mod.
$\delta u(x) \sim 1\%$	Phys. Lett. A 9, 1799 (1994)
E. Sather, Phys. Lett. B274, 433 (1992)	

#### Phenomenological limits

MRST Group studied uncertainties in PDFs arising from CSV.

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$$\delta u_v = -\delta d_v = \kappa (1-x)^4 x^{-0.5} (x-0.0909), \int dx \delta u_v(x) = \int dx \delta d_v(x) = 0$$

 $\bullet\,$  Good agreement with high energy data, valence CSV effects could be larger than theory Eur. Phys. J.35(2004)325

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#### Formalism

Londergan, Pang and Thomas PRD54(1996)3154

$$R_{meas}^{D}(x,z) = \frac{4N^{D\pi^{-}}(x,z) - N^{D\pi^{+}}(x,z)}{N^{D\pi^{+}}(x,z) - N^{D\pi^{-}}(x,z)}$$
(1)

where  $N^{D\pi^{\pm}}(x, z)$  is the yield of  $\pi^{\pm}$  electroproduction on a deuterium target Factorization: Impulse Approximation:

 $N^{Nh}(x,z) \equiv \sum_{i} e_i^2 q_i^N(x) D_i^h(z) \qquad N^{D\pi^{\pm}}(x,z) = N^{p\pi^{\pm}}(x,z) + N^{n\pi^{\pm}}(x,z)$ The charge-symmetry violating quark distributions can be extracted using the above quantity via the following formula:

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

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

Formalism

$$B(x,z) = \frac{5}{2} + R^{D}_{sea_{-}S}(x,z) + R^{D}_{sea_{-}NS}(x).$$

CTEQ6 parameterization:





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

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# **Experiment Overview**



Semi-Inclusive Deep Inelastic Scattering (SIDIS)in Hall C at Jefferson 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<sub>2</sub>(10 cm), LH<sub>2</sub>(10 cm), Al-dummy
- HMS angle  $13^{\circ}$ - $21^{\circ}$ , 4.4-6.4 GeV, electrons
- SHMS angle  $11^{\circ}$ - $21^{\circ}$ , 1.7-4.5 GeV,  $\pi + /\pi -$

$$R_{Y} = \frac{Yield_{D}^{\pi-}}{Yield_{D}^{\pi+}}, R_{meas}^{D}(x,z) = \frac{4R_{Y}-1}{1-R_{Y}}$$

# 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 difference between different particles.



The time of flight of positively charged hadrons and positrons is different in the SHMS spectrometer.

The beam electrons come in every 4ns, different hadrons have different travel times pions are aligned at  $1\!$ 

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## Pion selection



$$\pi_{purity} = 1 - \frac{N_{kaons}}{N_{pions} + N_{kaons}}$$

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# **Efficiencies**



# Backgrounds estimate by Monte Carlo Simulation



$$Yield = \frac{pions * \pi_{purity}}{charge * TE * TLT * PID_{eff}}$$

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

#### Backgrounds

- Exclusive radiative contribution  $D(e,e'\pi^{\pm})n(p)\gamma$
- $\bullet$  Delta radiative contribution  $D(e,e^\prime p)\pi$
- Diffractive  $\rho \ D(e, e'\rho \to \pi^+\pi^-)$  (not included in sum)

#### Factorization

Preliminary results

Assumed high energy parameterization of the fragmentation function,

$$\frac{\sigma_p^{\pi+} + \sigma_p^{\pi-}}{\sigma_d^{\pi+} + \sigma_d^{\pi-}} = \frac{4u(x) + 4\overline{u}(x) + d(x) + \overline{d}(x)}{5[u(x) + d(x) + \overline{u}(x) + \overline{d}(x)]}$$

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

$$D^{-}/D^{+} = \frac{4 - \frac{\sigma_{d}(\pi^{+})}{\sigma_{d}(\pi^{-})}}{4\frac{\sigma_{d}(\pi^{+})}{\sigma_{d}(\pi^{-})} - 1} = \frac{4R_{Y} - 1}{4 - R_{Y}}$$

In the high-energy limit, this ratio should solely depend on z ( and  $Q^2),\,{\rm but}$  not on  $\times$ 



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# Preliminary result up to now



#### CSV(x) and D(z)

We measured R(x, z) for each different kinematics. We can extract D(z) and CSV(x) term from our equation D(z) R(x, z) + CSV(x) = B(x, z)

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# Summary

#### Current work

- Particle Identification
- Backgrounds subtraction
- Efficiency correction
- Radiative correction

#### Future work

- Target boiling study
- $H_2$  check
- Global fit to get CSV term

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Thank you!

# More Preliminary Yield ratio results





0.65 07 0.75 0.8

0.7 0.75 0







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