

CLAS collaboration meeting, JLAB

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A Multidimensional Study of Hard Exclusive π⁺ BSA in the GPD Regime

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN



Stefan Diehl

Justus Liebig University Giessen University of Connecticut

Motivation

$$ep \rightarrow en\pi^+$$

t / Q² << 1: GPD based description



 $\pi^{\scriptscriptstyle +}$ in forward region

Goldstein, Hernandez, Liuti Phys. Rev. D 84, 034007 (2011)

Goloskokov, Kroll Eur. Phys. J. A. 47: 112 (2011)



4 chiral even GPDs 4 chiral odd GPDs

GPDs:

- Constructed by double distributions
- Costrained by the latest results from lattice QCD and transversity parton dsitribution functions

Hard Exclusive π^+ Electroproduction and BSA

<u>Cross section</u> (longitudinally pol. beam and unpol. target):

$$2\pi \frac{d^2\sigma}{dtd\phi} = \frac{d\sigma_T}{dt} + \epsilon \frac{d\sigma_L}{dt} + \epsilon \cdot \cos(2\phi) \frac{d\sigma_{TT}}{dt} + \sqrt{2\epsilon(1+\epsilon)} \cdot \cos(\phi) \frac{d\sigma_{LT}}{dt} + h \cdot \sqrt{2\epsilon(1-\epsilon)} \cdot \sin(\phi) \frac{d\sigma_{LT'}}{dt} ep \rightarrow en\pi^+$$

$$\sigma = \sigma_0 (1 + A_{UU}^{\cos(2\phi)} \cos(2\phi) + A_{UU}^{\cos(\phi)} \cos(\phi) + h A_{LU}^{\sin(\phi)} \sin(\phi))$$

$$BSA(t,\phi,x_B,Q^2) = \frac{d\sigma^+ - d\sigma^-}{d\sigma^+ + d\sigma^-} = \frac{A_{LU}^{\sin\phi}\sin\phi}{1 + A_{UU}^{\cos\phi}\cos\phi + A_{UU}^{\cos 2\phi}\cos 2\phi}$$
$$A_{LU}^{\sin\phi} = \frac{\sqrt{2\epsilon(1-\epsilon)}\sigma_{LT'}}{\sigma_T + \epsilon\sigma_L}$$

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e'.

Theoretical Interpretation

$$A_{LU}^{\sin\phi} = \frac{\sqrt{2\epsilon(1-\epsilon)} \sigma_{LT'}}{\sigma_T + \epsilon \sigma_L}$$

$$\begin{aligned} \boldsymbol{\sigma}_{\text{LT}'} &: \text{ convolution of GPDs with subprocess amplitudes} \\ &: \text{ product of chiral-odd and chiral-even GPDs} \\ \sigma_{LT'} &\sim Im \left[< \overline{E}_T >^* < \widetilde{H} > + < H_T >^* < \widetilde{E} > \right] \quad \begin{array}{l} \widetilde{E} &= \ \widetilde{E}_{generic} + \ pole \ term \\ &\quad \widetilde{H} &= \ \widetilde{H}_{generic} + \ pole \ term \end{array} \end{aligned}$$

- ➔ Imaginary part of small chiral odd GPDs is significantly amplified by the pion pole term
- → Polarized π^+ observables show an increased sensitivity to chiral-odd GPDs

 $\sigma_{LT'} \sim Im[<H_T>^*<\widetilde{E}>]$ \widetilde{E} is dominated by the pion pole

→ Complementary information to π^0 studies

Previous Studies



CLAS12 Experimental Setup in Hall B



→ Data recorded with CLAS12 during fall of 2018

→ 10.6 GeV electron beam → 87 % average polarization → liquid H₂ target

→ Analysed data ~ 20 % of the approved RG-A beam time

Particle ID and Kinematic Cuts



Kinematic Coverage and Torus Field Settings



Topologies

$$ep \rightarrow en\pi^+$$

- All particles detected
- → low statistics
- Limitted phi acceptance if pion and neutron are detected in the FD only

$$ep \rightarrow e\pi^+ X$$

- Neutron reconstructed via missing mass
- ➔ Good statistics
- ➔ Full phi coverage in the GPD regime (-t < 1 GeV²)



Missing Neutron Mass

First study: Integrate over $Q^2 > 1.5$ GeV² and x_B



Beam Spin Asymmetry

$$BSA_{i} = \frac{1}{P_{e}} \cdot \frac{N_{i}^{+} - N_{i}^{-}}{N_{i}^{+} + N_{i}^{-}}$$



Raw Result for $\sigma_{LT'}$ / σ_0



Background Treatment

- S/B ratio is decreasing from 4 5 at low -t to ~ 2 for 0.3 GeV² < -t < 1.0 GeV²
- Background has to be subtracted / considered
- Where is the background coming from?
- 2 MC versions: a) exclsuive MC: Based on aaonorad b) SIDIS MC: Used for SIDIS publications





Background Treatment

- MC shows that SIDIS background stops at ~ 1.05 GeV²
- → Since real resolution is ~ 2-3 times higher, a small fraction may still leak below our cut at M_{miss} < 1.01 GeV²
- →The main thing which we interpret as "background" is coming from the signal itself and from other effects!
 - ➔ A sideband subtraction will over- /under- estimate the background!

→ A bin by bin background subtraction has to be performed!

• Plot the missing neutron peak in each phi and -t bin for each helicity state

Two methods:

- a) Get background distribution from root BG estimator
 - Subtract the BG distribution
 - Integrate the signal distribution within the limits
- b) Fit the comlete shape with a gaussian and a third order polynomial
 - Only allow one scaling factor for the gaussian and one for the background when the second helicity state is fitted to stabilize the result

Bin by Bin Background Subtraction



root BG estimator

fitted polynonmial BG

Resulting Signal BSA



Final Result For the Q², x_B Integrated Case



A Multidimensional Binning



Bin by Bin Background Subtraction

• A bin by bin fit of the signal shape has been performed for each Q^2 , x_B , -t and Φ bin in each helicity state



Resulting Signal BSA

Example: bin 8 (high Q², high x_B)





Systematic Studies: Data MC Comparison



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Systematic Studies: Data MC Comparison



- → Good data / MC agreement in the GPD regime
- → ~ 250 Million generated events are needed to match the data

Sources of Systematic Uncertainties

- Uncertainty of the beam polarization
- Effect of fiducial cuts
- Signal extraction / background treatment
 - \rightarrow Different methods have been compared
- Acceptance effects
 - \rightarrow Study based on MC
- Extraction method and higher order moments
 - \rightarrow Study based on data and MC
- Binning / resolution effects
 - \rightarrow Study based on MC
- Radiative effects

Next step: Produce a large scale MC (> 250 M events)

Conclusion and Outlook

- Hard exclusive π⁺ BSA in the GPD regime (-t < 1 GeV²) can be well extracted from CLAS12 RG-A data using only the FD.
- Theory calculations based on the GK modell are available and show a good agreement of the observed variation of the shape for the different Q²-x_B bins.
- The background shape is understood and based on a bin by bin fit, the background subtraction is well under controll.
- A dedicated eventgenerator (aaonorad) is available and shows a good agreement with data in the GPD regime.
- A large scale MC production (250 500 Million events) will be requested.
- All methods for systematic studies are ready based on the SIDIS $\pi^{\scriptscriptstyle +}$ study.
- Analysis note can be ready early next year





