Update on TDA measurements with $p\bar{p} \to \pi^0 e^+ e^-$ reaction based on EPJA referees' comments: Test of factorisation

María Carmen Mora Espí

Helmholz Institut - Mainz

moraespi@kph.uni-mainz.de

PANDA meeting - Jülich
Electromagnetic Processes Session
December 9th, 2014

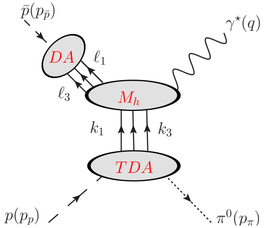
Outline

1. Introduction
2. Motivation for the New Analysis
3. Summary of Previous Analysis
4. Results of the New Analysis
5. Summary and Conclusions

TDA:

- New non-perturbative objects
  - Hard scale: high momentum transfer
  - Low transversal momentum for the π^0
- Transition between a Baryon and a Meson
- Information about the Meson-cloud inside the proton
  - Fourier transform of a Matrix Element of a three-quark light-cone local operator
  - Generalization of GPDs

In CM of $\overline{\text{P}}$ANDA
π^0 backward $\rightarrow$ emmited by p
π^0 forward $\rightarrow$ emmited by $\bar{p}$



$\bar{p}p \rightarrow e^+e^-\pi^0$

Experimentlly accessible through $\bar{p}p \rightarrow \gamma^\star\pi^0 \rightarrow e^+e^+\pi^0$ which admits QCD collinear factorisation in terms of Distribution Amplitudes and Transition Distribution Amplitudes

Validity of QCD factorization and access to TDAs

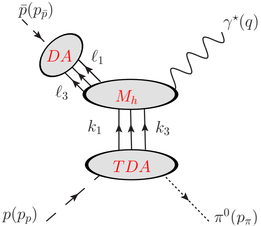
$\rightarrow$ kinematics accesible by $\overline{\text{P}}$ANDA

Studies based on: J. P. Lansberg et al., Phys Rev D 76, 111502(R) (2007)

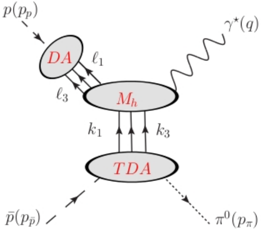
TDAs factorisation

Two subprocesses, $p\bar{p} \to \gamma^\star$ and $\gamma^\star \to e^+e^-$, accept factorized description when:

- $q^2 \sim s$
- $t << q^2$ or $u << q^2$ $\Rightarrow$ π^0 emmitted in $\bar{p}$ direction(fw) or in the p direction (bw)



π^0 forward (t-channel)



π^0 forward (u-channel)

$$\mathcal{M}(\bar{p}p \to \gamma^\star\pi^0) = \mathcal{M}_{\text{parton, parton}} \otimes (\text{DA, TDA})$$

$$\Rightarrow \left.\frac{d\sigma}{dt\,dq^2\,d\cos\theta^\star_\ell}\right|_{\Delta_T=0} = \frac{K}{s-4M^2}\,\frac{1}{(q^2)^5}\left(1+\cos^2\theta^\star_\ell\right) \qquad \text{with} \qquad K = \frac{(4\pi\alpha_{em})^2(4\pi\alpha_s)^4 f_N^4 |\mathcal{I}|^2}{64\cdot 54^2(2\pi)^3 f_\pi^2}$$

DA, TDA MODEL

SCALING

LEPTON PHASE-SPACE IN $\gamma^\star$ REST FRAME

Motivation for the new Analysis

Sent to EPJA:

- Analysis of Signal Reconstruction Efficiency
- Analysis of Background Suppression
- Study of the Precission of Measuremet of the Signal Cross Section

Comments of the EPJA Referees:

- The analysis would be more complete if we include the test of factorisation
  - q^2 factorisation:

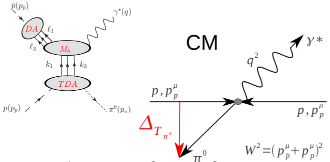
    $$\frac{d\sigma}{dq^2} \sim \frac{1}{(q^2)^5}$$

  - $\cos\theta^\star$ factorisation:

    $$\frac{d\sigma}{d\cos\theta^\star} \sim (1 + 1 \cdot \cos^2\theta^\star)$$

Signal: $\bar{p}p \to e^+e^-\pi^0$

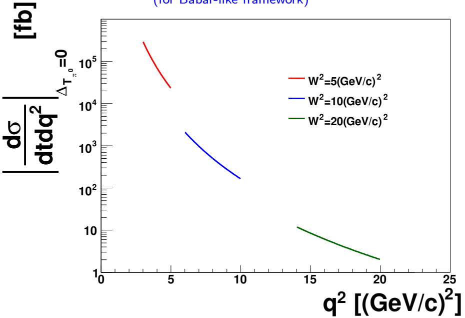
- W^2=5 GeV^2 and 10 GeV^2 (W^2=s)
- π^0 Forward and Backward
  $\to$ 4 simulations
- $\frac{d\sigma}{dq^2}$ calculated for π-transverse momentum $\Delta_{T_{\pi^0}} = 0$,
- extrapolated over a $\Delta_{T_{\pi^0}} < 0.5$ GeV and $[q^2_{min}, q^2_{max}]$[1]



[1] Values for q^2_{min} and q^2_{max} are shown later in slide 7

Input for the Event Generator

(for Babar-like framework)



Background: $\bar{p}p \to \pi^+\pi^-\pi^0$

- No data
- The same angular distribution as the signal
- Cosidered to be 10^6 times higher

Event selection: Combinations of $\pi^0 + e^+ + e^-$ candidates per event

- Particle identification cuts (PID):
  - Two charged tracks
  - One positive very tight electron and one negative very tight electron
  - Two photons reconstructing a π^0
- Kinematical fit:
  - Used only to improve the quality of the data, but no cuts on CL or χ^2 are applied.

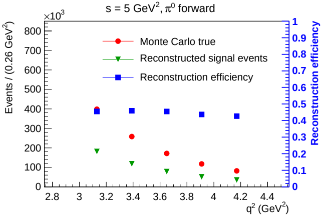
Kinematic region selection (Factorization validity)

- q^2 cuts in the region in which the cross section is integrated

	$W^2 = 5\,\text{GeV}^2$	$W^2 = 10\,\text{GeV}^2$
Analysis limits	$3.8 < q^2 < 4.2$	$7.00 < q^2 < 8.00$
Expected Statistics ($\mathcal{L} = 2fb^{-1}$)	~ 3350	~ 465

- $|cos\theta_{\pi^0}| > 0.5 \Rightarrow \Delta_{T_{\pi^0}} < 0.5\,\text{GeV}$ (QCD factorisation)

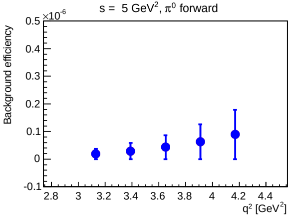
1.- Signal Reconstruction Efficiency



$\sim$ 45%@$W^2 = 5\,\text{GeV}^2$ fw; 33%-43%@$W^2 = 5\,\text{GeV}^2$ bw;

$\sim$ 45%@$W^2 = 10\,\text{GeV}^2$ fw; 25%-40%@$W^2 = 10\,\text{GeV}^2$ bw

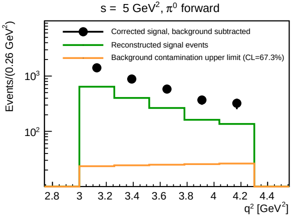
2.- Background Efficiency



Background suppression: $5 \cdot 10^7$-10^7@$W^2 = 5\,\text{GeV}^2$;

10^8-$6 \cdot 10^6$@$W^2 = 10\,\text{GeV}^2$

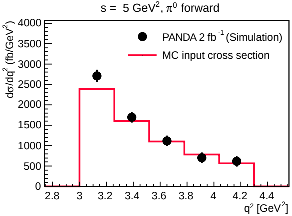
3.- Substraction of Background



Background polution: Few %@ low q^2;

$<$ 20%@ higher q^2

4.- Measured Cross Secction



Precision: 6%-21%@$W^2 = 5\,\text{GeV}^2$;

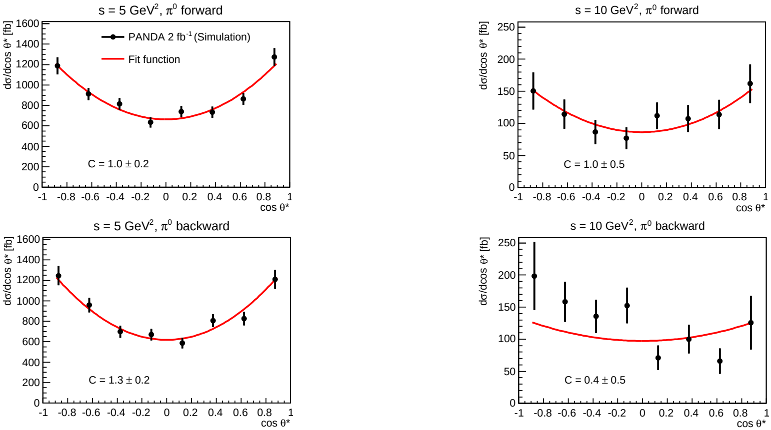
11%-90%@$W^2 = 10\,\text{GeV}^2$; 10%-60%@$W^2 = 10\,\text{GeV}^2$

New analysis: Test of factorisation, term on $(1+\cos^2\theta^\star)$

$$\left.\frac{d\sigma}{dt\,dq^2\,d\cos\theta^\star}\right|_{\Delta_T=0} = \frac{K}{s-4M^2}\,\frac{1}{(q^2)^5}\,(1+\cos^2\theta^\star) \Rightarrow \frac{d\sigma}{d\cos^2\theta^\star} \sim (1+1\cdot\cos^2\theta^\star)$$

Fit function: $f(\cos^2\theta) = D\cdot(1+C\cdot\cos^2\theta) \xrightarrow{\text{bin average}} g(x) = \frac{1}{a}\int_{x-a/2}^{x+a/2} D\cdot(1+C\cdot x^2)dx$

with $x=\cos\theta$

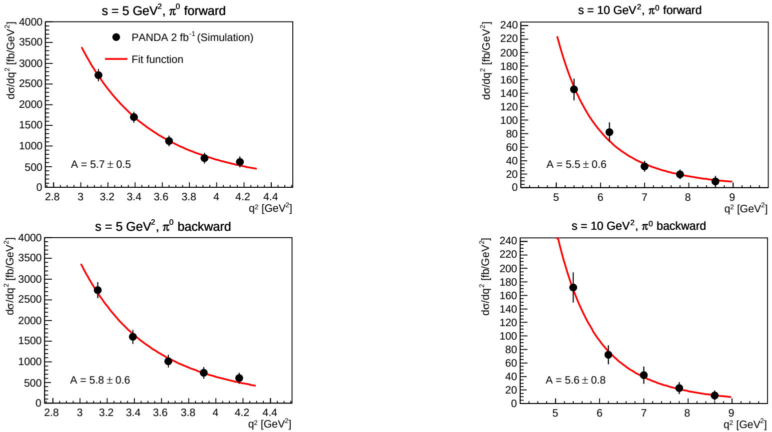


$\rightarrow <C> \pm\sigma_{n-1} = 0.925 \pm 0.377$

Leaving out the fit for $W^2 = 10\,\text{GeV}^2$ π^0-bw: $<C> \pm\sigma_{n-1} = 1.1 \pm 0.17$

$$\left.\frac{d\sigma}{dtdq^2\,dcos\theta^\star_\ell}\right|_{p_T=0} = \frac{K}{s-4M^2}\frac{1}{(q^2)^5}\left(1+cos^2\theta^\star\right) \Rightarrow \frac{d\sigma}{dq^2} \sim \frac{1}{(q^2)^5}$$

Fit function: $f(q^2) = B\frac{1}{(q^2)^A} \xrightarrow{\text{bin average}} g(x) = \frac{1}{a}\int_{x-a/2}^{x+a/2} B\frac{1}{x^A}dx$ with $x = q^2$



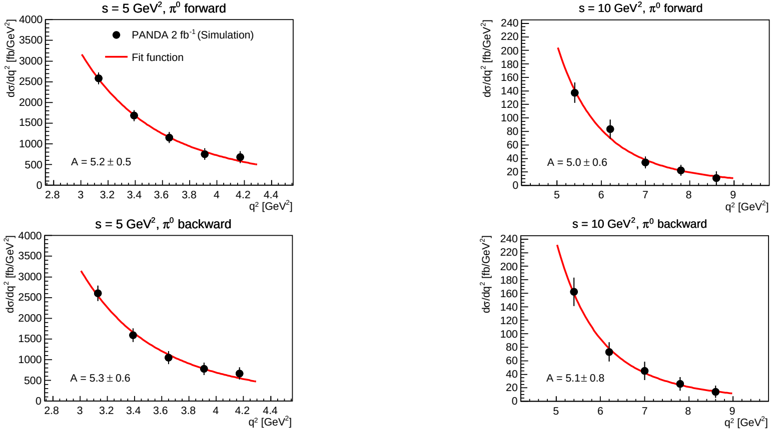
$\rightarrow < A > \pm\sigma_{n-1} = 5.65 \pm 0.13 \Rightarrow$ Scaling factor systematically higher!!

$\rightarrow$ Data have been reweighted keeping the same total measured cross section to correct the error in the event generator and refitted.

$$\left.\frac{d\sigma}{dtdq^2 dcos\theta^\star}\right|_{p_T=0} = \frac{K}{s-4M^2}\,\frac{1}{(q^2)^5}\left(1+cos^2\theta^\star\right) \Rightarrow \frac{d\sigma}{dq^2} \sim \frac{1}{(q^2)^5}$$

Fit function: $f(q^2) = B\frac{1}{(q^2)^A} \xrightarrow{\text{bin average}} g(x) = \frac{1}{a}\int_{x-a/2}^{x+a/2} B\frac{1}{x^A}dx$ with $x = q^2$

Reweighted



$\rightarrow < A > \pm\sigma_{n-1} = 5.15 \pm 0.13$

Summary and Conclusions

Summary

- The Analysis have been extended following the comments of the referees.
- Thanks to that a mistake in the cuts for $\cos\theta_{lab} < -0.83$ was found and corrected.
- A problem with the dependence of q^2 in the event generator was also found.
- The dependence of q^2 has been corrected reweighting the data and fitting again

Conclusions:

- We can measure the factorization with an accuracy:
  - $< A > \pm\sigma_{n-1} = 5.15 \pm 0.13$ for the scaling factor of $\frac{1}{(q^2)^A}$,
  - and $< C > \pm\sigma_{n-1} = 0.925 \pm 0.377$ for the $(1 + C \cdot \cos\theta^{\star})$ dependence.
- After correcting the small errors in the Analysis no changes in the conclusions of the paper have been found.

THANKS FOR LISTENING