PANDA collaboration meeting

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Measuring Color Transparency Observables with PANDA to Probe QCD Factorisation

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Introduction

- The topic of **C**olor **T**ransparency has recently gained interest with relation to TDAs for electron scattering at JLAB:

u-Channel Color Transparency Observables

G.M. Huber,[1,*] W.B. Li,[2,3] W. Cosyn,[4,5] and B. Pire[6]

https://arxiv.org/abs/2202.04470

➔ Study of the onset of color transparency in hard exclusive reactions in the backward regime

➔ Test the appearance of nuclear color transparency for a fast moving nucleon

physics MDPI

Article

The Status and Future of Color Transparency and Nuclear Filtering

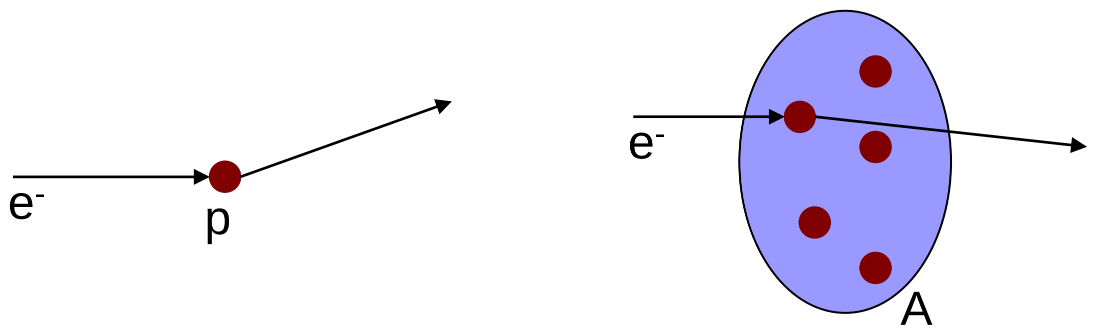
Pankaj Jain [1,*], Bernard Pire [2] and John P. Ralston [3] https://www.mdpi.com/2624-8174/4/2/38

What is Color Transparency (CT)

$$T = \frac{\sigma_N}{A\sigma_0}$$

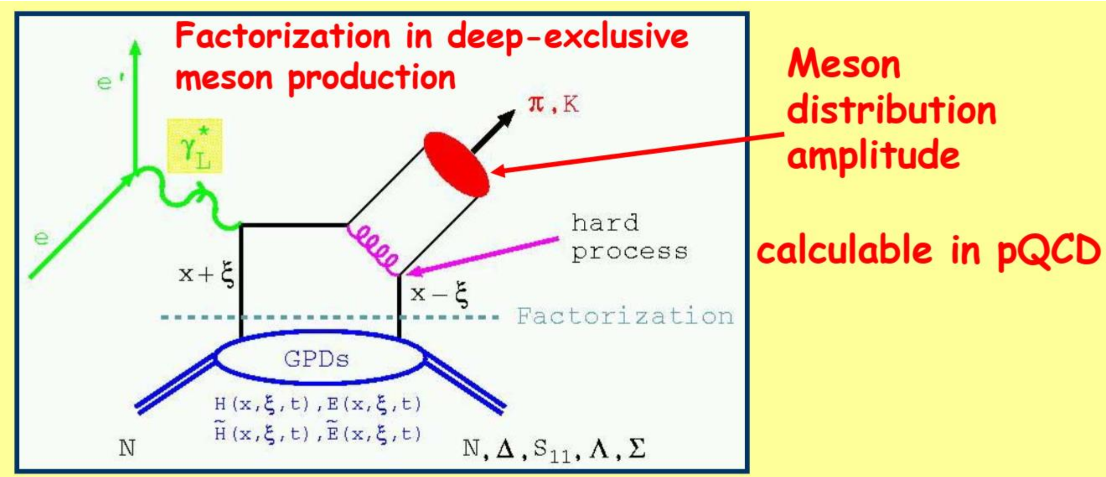
σ_0 = free (nucleon) cross-section

σ_N parameterized as = $\sigma_0 A^{\alpha}$



- At low Q^2 (large transverse size) we have a high chance that the scattering products are stuck in the nucleus (CT is small)
- At higher Q^2 (small transverse size) the nucleus gets more and more transparent (CT increases)

Why is CT of Interest for our Studies?



➔ Meson electroproduction is mainly interpreted in terms of collinear QCD factorized amplitudes

- → GPDs in the forward regime ($-t/Q^2 << 1$)
- → TDAs in the backward regime ($-u/Q^2 << 1$)

Signals for the onset of collinear QCD factorization:
(hadrons transverse sizes shrinks proportionally to 1/Q)

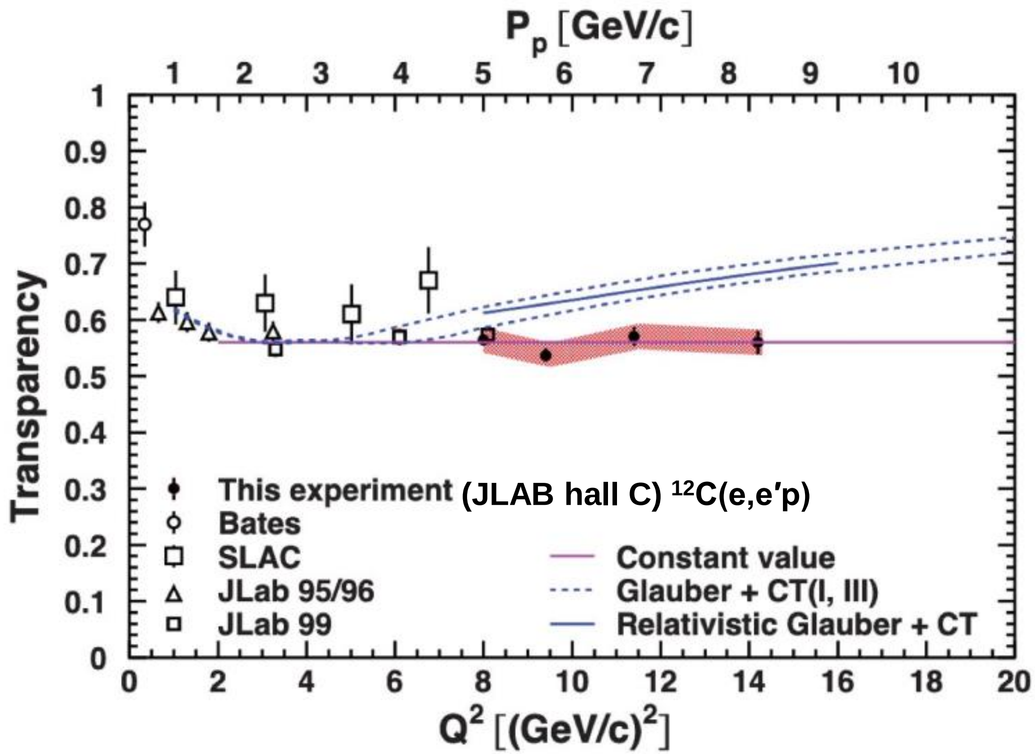
- → Validity of scaling laws
- → Polarisation test
- → Increase of the nuclear transparency ratio with the relevant hard scale (Q^2)

Factorization is not rigorously possible without the onset of CT. *- Strikman, Frankfurt, Miller and Sargsian*

CT is a necessary but not sufficient condition for factorization

Previous Measurements

- Color Transparency in A(p,2p) BNL
- Color Transparency in A(e,e' p) SLAC, JLab
- Color Transparency in A(l,l' ρ) FNAL, HERMES, JLab
- Color Transparency in di-jet production FNAL
- Color Transparency in A(γ,p π), A(e,e' π) JLab



SLAC data (90s):

- Growth of T starts at low Q^2

JLAB hall C (2021):

- T is constant up to Q^2 = 14 GeV^2

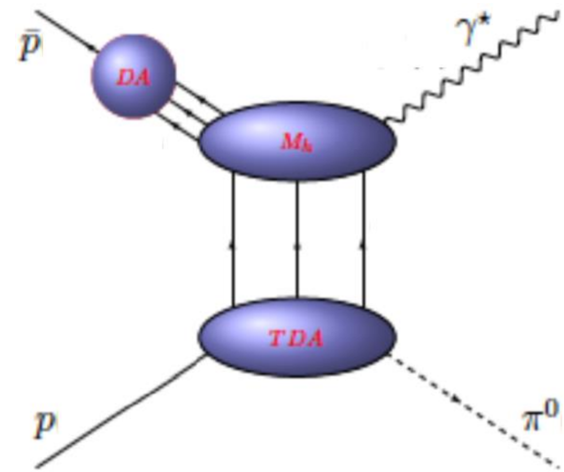
➔ Controvercy also to present theory models!

Pankaj Jain, Bernard Pire and John P. Ralston Physics **2022**, 4, 578–589.
https://doi.org/10.3390/physics4020038

How can we Measure it at PANDA?

PANDA: Similar studies possible to test the QCD factorisation for TDAs

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



➔ Detailed fesability studies in

Eur.Phys.J. A51 (2015) 8, 107

➔ An extension of the PANDA TDA program to nuclear targets will enable the measurement of color transparency ratios

$$\bar{p}A \rightarrow \gamma^{*}\pi^{0}\ (A-1)$$

Existing Feasability Studies for a Proton Target

$$\bar{p}p \rightarrow \gamma^{*}\pi^{0}$$

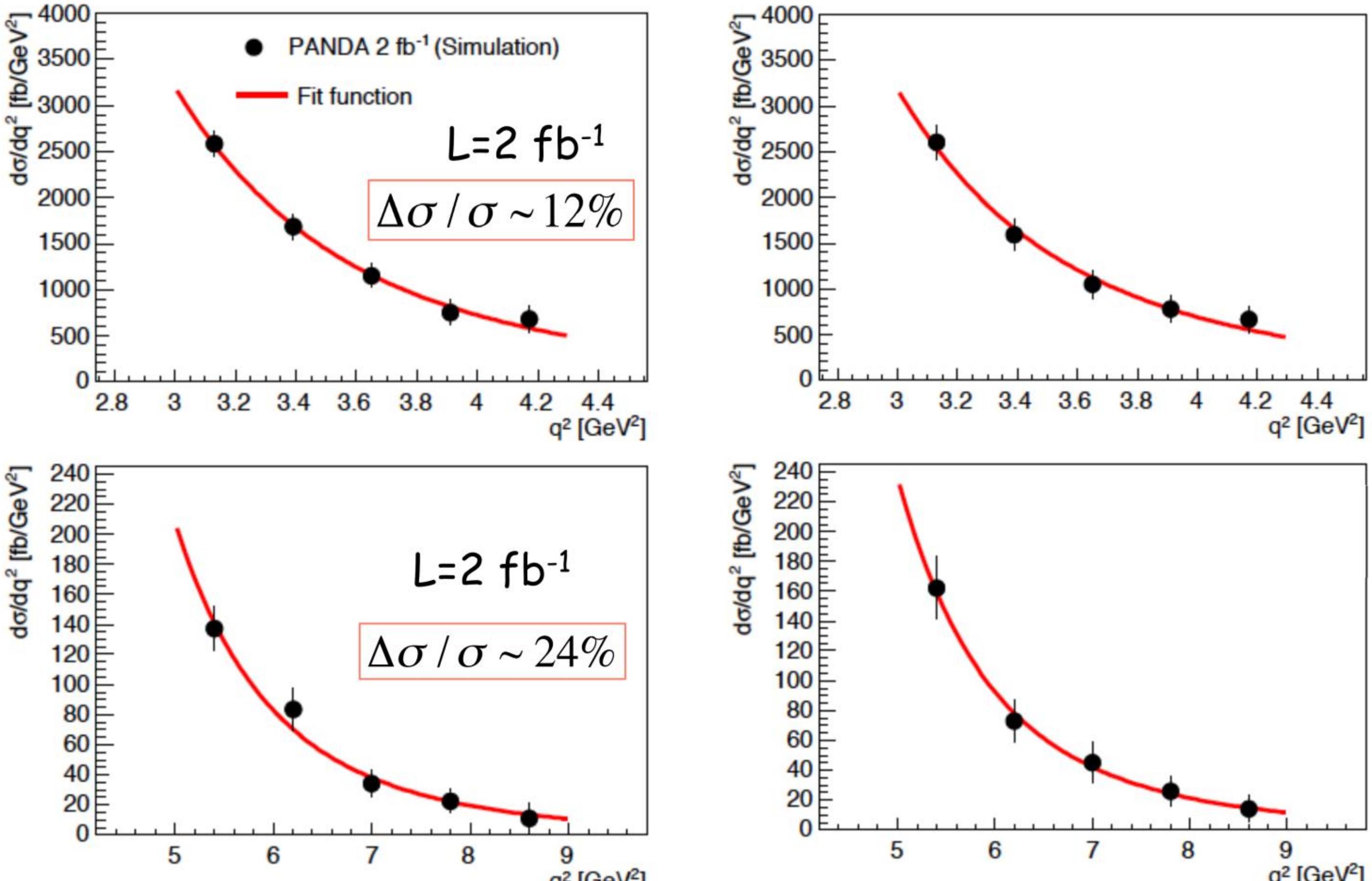
$$\frac{d\sigma}{dq^{2}} \sim \frac{1}{(q^{2})^{5}}$$

➔ q^2 scaling of the cross section is a test for the QCD factorisation

π^0 in forward direction | **π^0 in backward direction**

s = 5 GeV²

s = 10 GeV²



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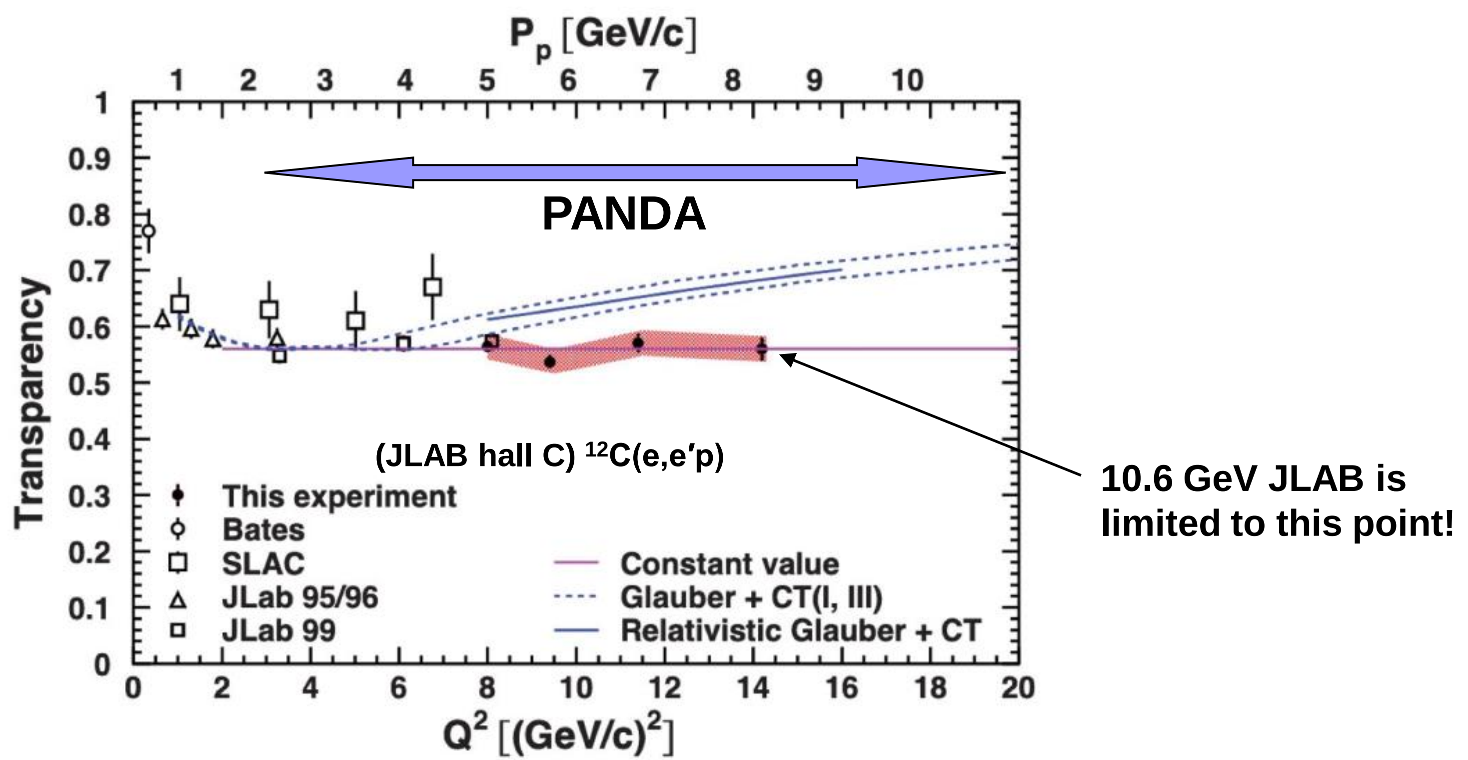
Accessible Q^2 Range of the TDA Studies

Feasibility studies of measuring $\bar{p}p \rightarrow \gamma^* \pi^0 \rightarrow e^+ e^- \pi^0$ at PANDA

i) $s = 5\ GeV^2 \rightarrow 3.0 < q^2 < 4.3\ GeV^2, \quad |\cos\theta_{\pi^0}| > 0.5$

ii) $s = 10\ GeV^2 \rightarrow 5 < q^2 < 9\ GeV^2, \quad |\cos\theta_{\pi^0}| > 0.5$

➔ Extension to higher beam energies (s up to 30 GeV^2) → Q^2 up to 25 GeV^2 ???



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Additional Aspects

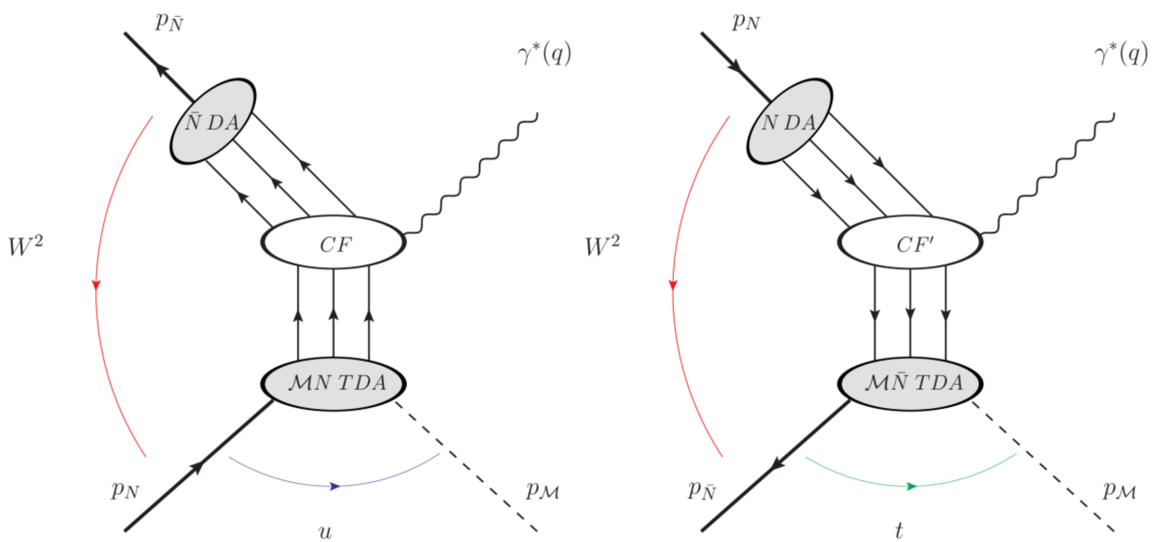

Figure 4. The annihilation process $\overline{N}N \to \gamma^* M$ at $\overline{\text{P}}$ANDA detector is sensitive to the TDA factorization dynamics in both near-backward (**left**) and near-forward (**right**) kinematics. See text for details. Here, "CF" stands for the perturbatively calculated coefficient function and $W^2 = (p_N + p_{\bar{N}})^2$.

- In both cases, the (anti)nucleon is attached to the hard part through its distribution amplitude
  → Transverse extension is restricted to small $O(1/Q)$ sizes.

But: Considerable difference in the relative velocity of this state with respect to the nucleus

➔ A much stronger nuclear transparency effect is expected in the near-backward kinematics than in the near forward kinematics

➔ Unique capability to disentangle small-size configuration production effects from transverse expansion consequences.

Discussion Feasability with PANDA

$$\bar{p}A \rightarrow \gamma^* \pi^0 \ (A-1)$$

➔ Reaction is very similar to the standard TDA reaction (proven to be feasible)

➔ Are there any reasons why the study was not extended to s = 30 GeV^2 ?

To be checked: ➔ Detection of the (A-1) nucleus in the final state!

➔ Change of kinematics by the recoil nucleus

➔ Additional backgrounds from nuclear targets?

➔ Theory predictions for PANDA are not available yet.