Hard exclusive processes in the backward region

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Collaborative work with B. Pasquini, B. Pire and L. Szymanowski

Hard limit for backward exclusive processes

➠ Let us analyse Hard Electroproduction of a meson

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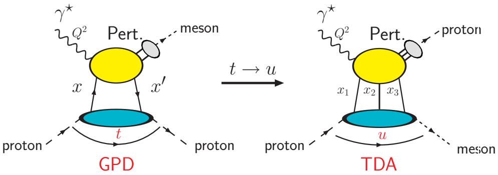

but **backward !**

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meson nearly at rest in the target rest frame

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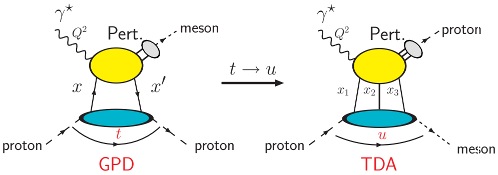

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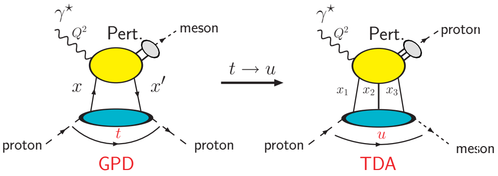

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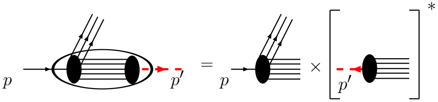

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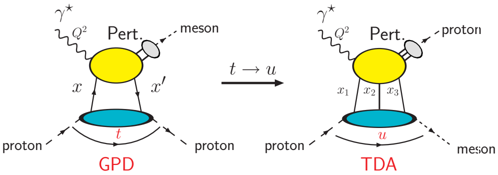

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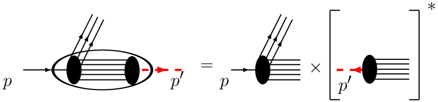
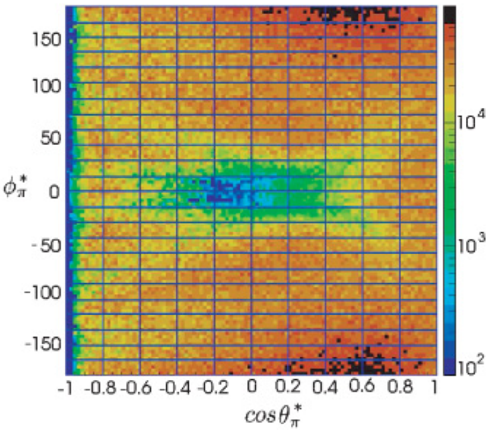


➟ Interpretation at the amplitude level in the ERBL region (for $x_i > 0$)

Amplitude of probability to find a meson within the proton !

Where to look for that ?



- Kinematical coverage for π^+ of the CLAS experiment (for $W \in [1, 2]$ GeV)

  K.J. Park ***et al.*****, PRC77:015208,2008.**

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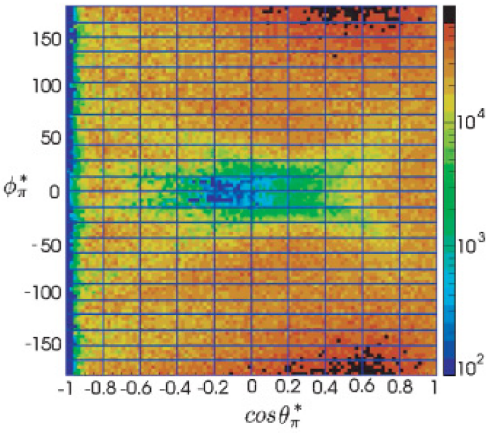

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- The yield should increase when u gets closer to 0.

$p \longrightarrow \pi$: parametrisation – similarities with the proton DAs

- $p \longrightarrow \pi$ (at Leading twist)
  - $\Delta_T = 0$: 3 TDAs ($3 \times p(\uparrow) \rightarrow uud(\uparrow\uparrow\downarrow) + \pi$)

TDA

$$4\langle \pi^0 |\, \epsilon^{ijk} u^i_\alpha(z_1 n) u^j_\beta(z_2 n) d^k_\gamma(z_3 n)\, |p, s_p\rangle \propto$$
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When $\Delta_T \neq 0$, $D^{\uparrow}_{\downarrow\uparrow,\downarrow} \neq 0, \ldots, D^{\uparrow}_{\downarrow\downarrow,\downarrow} \neq 0 \rightarrow$ 8 TDAs

(Δ_T is source of angular momentum)

More quantitatively: the pionic content of the proton

JPL, B. Pire, L. Szymanowski,PRD 75:074004,2007

➟ Let us start with a limiting case: soft pion

$$\langle \pi^a(k)|\mathcal{O}|p(p,s)\rangle = -\frac{i}{f_\pi}\langle 0|[Q_5^a,\mathcal{O}]|p(p,s)\rangle + \frac{ig_A}{4f_\pi p\cdot k}\sum_{s'}\langle 0|\mathcal{O}|p(p,s')\rangle \bar{u}(p,s')\not{k}\gamma_5\tau^a u(p,s)$$

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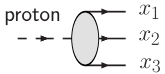

➡ Direct relation between the TDAs, $\langle \pi^a(k)|\mathcal{O}|p(p,s)\rangle$, and the proton wavefunction (DAs), $\langle 0|\mathcal{O}|p(p,s)\rangle$

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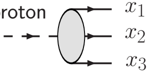

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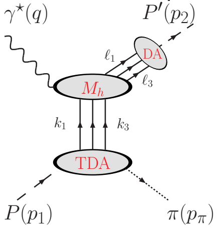
$$T_1^{\pi^0}(x_1,x_2,x_3,\xi,\Delta^2) \overset{p_\pi^z\to 0}{\longrightarrow} \frac{3}{4\xi} T\left(\frac{x_1}{2\xi},\frac{x_2}{2\xi},\frac{x_3}{2\xi}\right)$$

➟ Similar relations obtained for the proton-pion DAs $\langle 0|\mathcal{O}|\pi(k)p(p,s)\rangle$

V.M Braun *et al.* **PRD75:014021,2007**

Backward Electroproduction of a pion: II

- Sufficient to evaluate the backward electroproduction of a pion for $p_\pi^z \to 0$



- The amplitude at the Leading-twist accuracy:

$$\mathcal{M}^{\lambda}_{s_1 s_2} = -i\frac{(4\pi\alpha_s)^2\sqrt{4\pi\alpha_{em}}f_N^2}{54 f_\pi Q^4}\bar{u}(p_2,s_2)\not\epsilon(\lambda)\gamma^5 u(p_1,s_1)$$

$$\times \int_{-1+\xi}^{1+\xi} d^3x \int_0^1 d^3y \left(2\sum_{\alpha=1}^{7} T_\alpha + \sum_{\alpha=8}^{14} T_\alpha\right)$$

Example:

$$T_7 = \frac{Q_d(2\xi)^2[(V_1^{p\pi^0}-A_1^{p\pi^0})(V^p-A^p)]}{(x_1-i\epsilon)(2\xi-x_1-i\epsilon)(x_2-i\epsilon)y_1y_2(1-y_3)}$$

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JPL, B. Pire, L. Szymanowski,PRD 75:074004,2007

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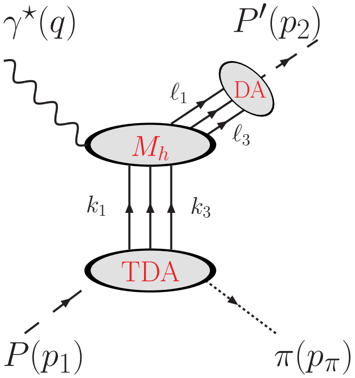

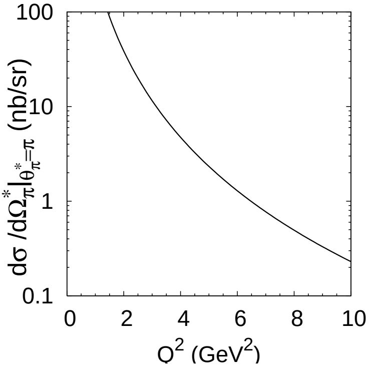

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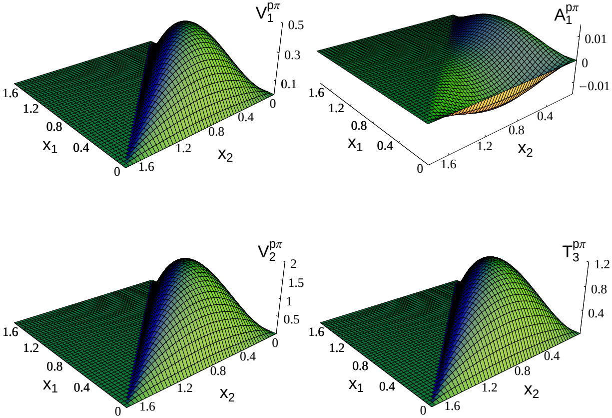

Backward Electroproduction of a pion: IV

JPL, B. Pire, L. Szymanowski,PRD 75:074004,2007

→ Model-independent predictions

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$$\frac{\mathcal{M}(\gamma^\star p \to p\pi)}{\mathcal{M}(\gamma^\star p \to p\gamma)}, \frac{\mathcal{M}(\gamma^\star p \to p\pi)}{\mathcal{M}(\gamma^\star p \to p\rho)} \text{ and } \frac{\frac{d\sigma(p\bar{p}\to\ell^+\ell^-\pi^0)}{dQ^2}}{\frac{d\sigma(p\bar{p}\to\ell^+\ell^-)}{dQ^2}} \text{(see later)}$$

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  - Dominance of $\gamma_T^\star p \to p\pi, \ldots$

Single Spin Asymmetry and the DGLAP contribution

JPL, *et al.*, **work in progress**

- Single Transverse Spin Asymmetry:

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- Non vanishing SSA: signal of a non zero DGLAP contribution
- One expects a vanishing SSA for (simple) baryon-exchange approaches (including the soft pion limit)

Backward Electroproduction of a meson: existing data

- Data from JLab exist for the π^+

  Analysis on-going (K. Park)

- "Visible signal in the yield of ω at 180°"

  (G. Huber, Sept. 09)

- Electroduction of η and π^0

  (CLAS DVMP: V. Kubarovsky, P. Stoler)

  η to be modelled

TDAs in exclusive processes at GSI/FAIR

JPL, B. Pire, L. Szymanowski PRD76 :111502(R),2007

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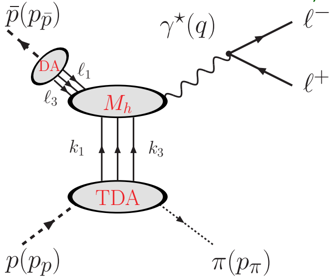
- Involves the same TDAs as for backward electroproduction

In the GPD case, after crossing, we have to deal with GDAs



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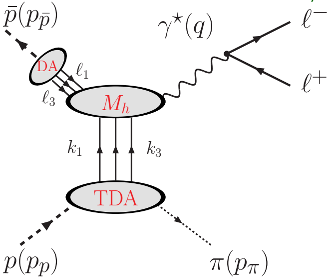

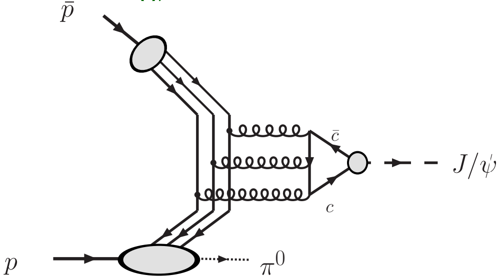

- The same TDAs appear also in $p\bar{p} \longrightarrow J/\psi + \pi^0$

Same channel as for h_c studies

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JPL, B. Pire, L. Szymanowski PRD76 :111502(R),2007

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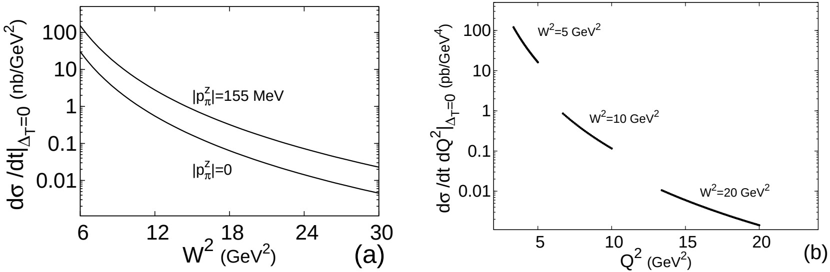

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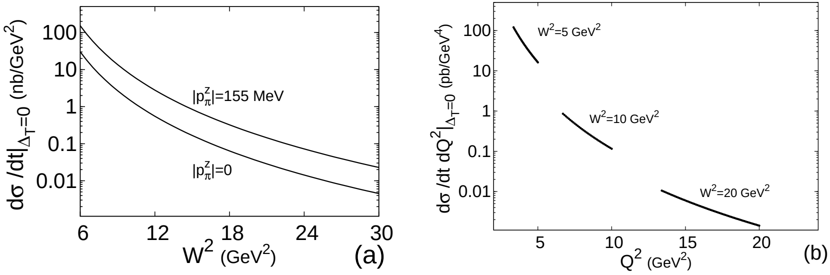


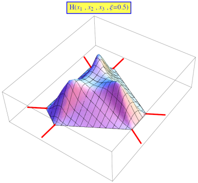
- $\sigma^{\ell^+\ell^-\pi^0}(7 < Q^2 < 8\text{GeV}^2, W^2 = 10\text{GeV}^2, \Delta_T < 0.5\text{GeV}) \sim 100\text{fb}.$
- Expected $\int dt\mathcal{L}$ of about 2 fb^{-1} for a 100-day experiment
- Other channels are also of much interest, such as

$\bar{p}p \to \ell^+\ell^-\eta$ or $\bar{p}p \to \ell^+\ell^-\rho^0$

Summary

→ Further quantitative predictions require models

- ➟ Soft pion limit: OK
- ➟ Pion Cloud Model: on-going
- ➟ 4-ple distribution (spectral representation: double distr. for GPD):



K. Semenov *et al.*, **to appear.**

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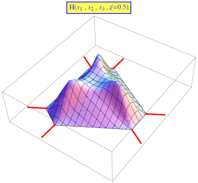

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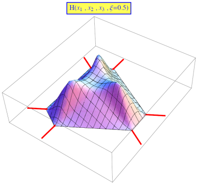

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- ...expected from
  - JLab-6 GeV: Backward electroproduction of π, η, ω. Backward DVCS ?
  - GSI: $p\bar{p} \to \gamma^\star \pi^0$, $p\bar{p} \to J/\psi \pi^0$, $p\bar{p} \to \gamma^\star \gamma$, ...
  - Of course JLab-12 GeV
  - COMPASS: $\gamma^\star p \to pJ/\psi$