Transition-Distribution-Amplitudes studies in hard-exclusive processes with PANDA
(+ a few words on COMPASS and JLab)

J.P. Lansberg

Paris Sud XI - IPNO

The Structure and Dynamics of Hadrons
International Workshop XXXIX on Gross Properties of Nuclei and Nuclear Excitations
Hirschegg, Kleinwalsertal, Austria, January 16th-22rd, 2011

Collaborative work with B. Pire and L. Szymanowski

Two extreme limits of hard exclusive processes

- Forward region

  (small momentum transfer squared t between the baryons)

  Based on

  a factorised description of *forward* Deeply Virtual Exclusive Reactions

  in terms of Generalised Parton Distributions

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- Backward region
  (small momentum transfer squared u between 1 baryon & the particle produced)
  Based on
  a factorised description of *backward* Deeply Virtual Exclusive Reactions

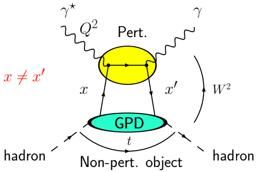
  in terms of Transition Distribution Amplitudes

The forward region

Hard limit for forward exclusive processes

➟ Study of 3D structure of the proton

via Deeply Virtual Compton Scattering (DVCS):



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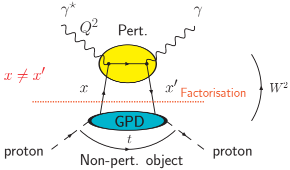

For $Q^2 \gg t$, described in terms of 4 generalised parton distribution: GPDs

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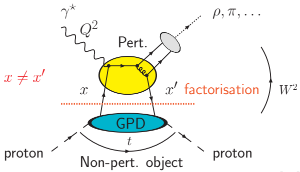

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idem for **meson electroproduction**

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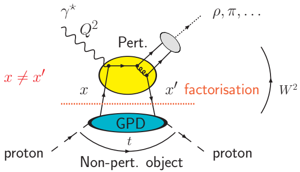

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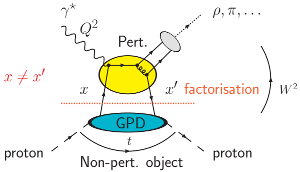

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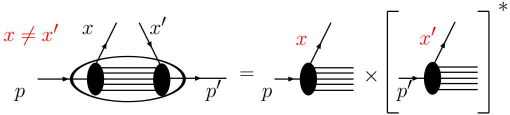

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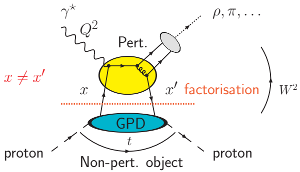

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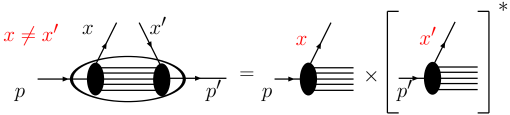

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- Interpretation only at the amplitude level

Amplitude of probability
for a proton to emit a quark with x & to absorb another with x'

Forward exclusive processes with hadron beams

E. Berger, M. Diehl, B. Pire, PLB 523 (2001) 265

➡ $\pi^- p \to \gamma^\star n \to \ell^+ \ell^- n$ at small t can also help study the GPDs.

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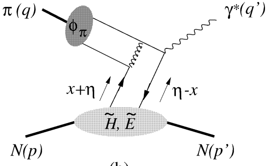

Bjorken variable $\tau = \frac{q'^2}{s - M^2}$

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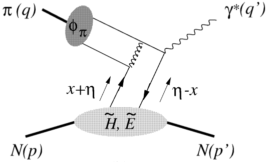

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$\to$ Check the factorization procedure and the universality of GPDs.

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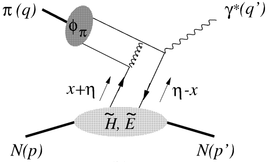

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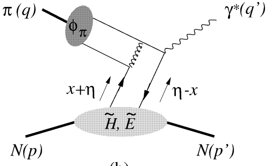

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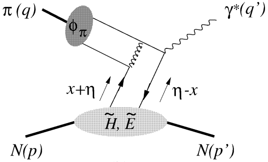

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- Target Transverse Spin Asymmetry: proportional to $\Im m(\tilde{\mathcal{H}}\tilde{\mathcal{E}}^*)$

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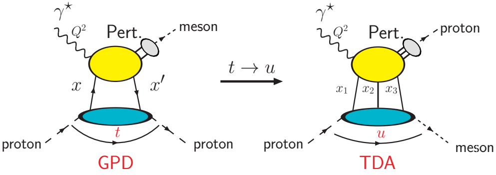

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$\updownarrow$

meson nearly at rest in the target rest frame

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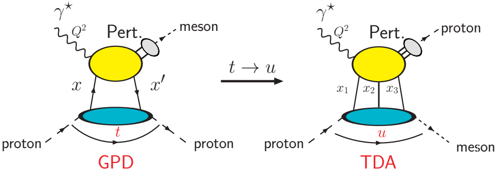

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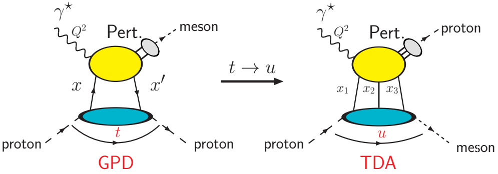

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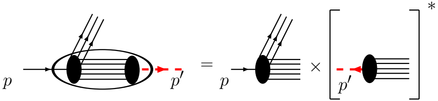

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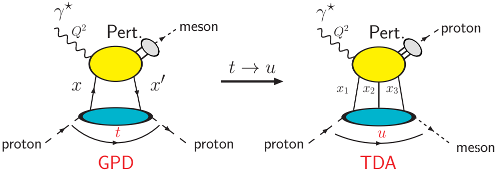

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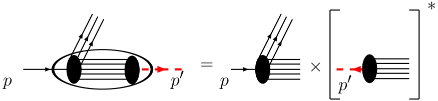
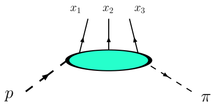


➠ Interpretation at the amplitude level in the ERBL region (for $x_i > 0$)

Amplitude of probability to find a meson within the proton !

$p \to \pi$ parametrisation: similarities with the proton DA



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

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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DA (Chernyak-Zhitnitsky)

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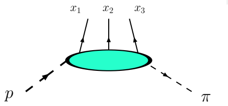

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B. Pasquini *et al.*, PRD 80:014017,2009.

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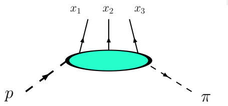

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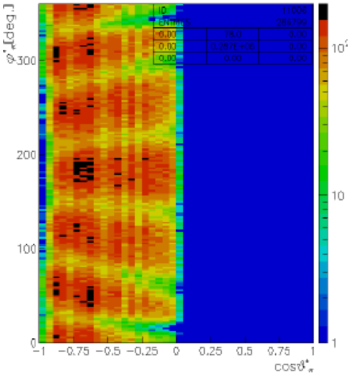
When $\Delta_T \neq 0$, $D^{\uparrow}_{\downarrow\uparrow,\downarrow} \neq 0$,..., $D^{\uparrow}_{\downarrow\downarrow,\downarrow} \neq 0 \to$ 8 TDAs

(Δ_T is source of angular momentum)

Where to look for that ?



➟ Kinematical coverage for π^+ of the CLAS experiment (for $W > 2$ GeV) (E1-6 sample)

K.J. Park, talk at the 4th plenary meeting of the nucleon GDR, Saclay, Nov. 25-26 2011

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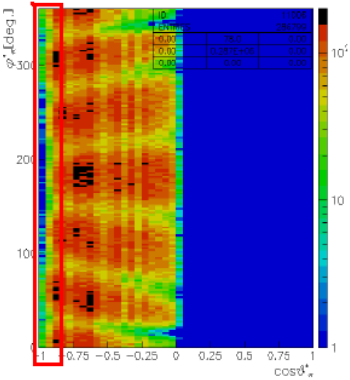

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➟ We are interested in the region where $\cos\theta^\star_\pi$ is close to -1, *i.e.* $u \simeq 0$

First data in the backward region

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

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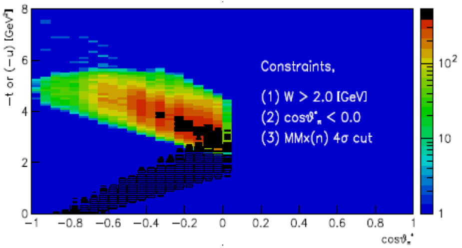
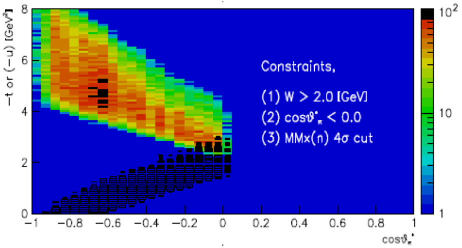
Simulation: t-dependence $\propto e^{-at}$



Data



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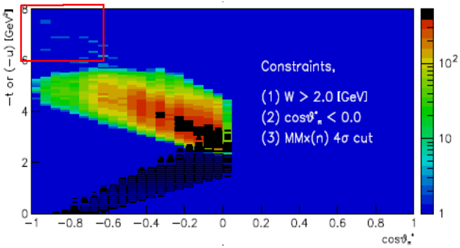

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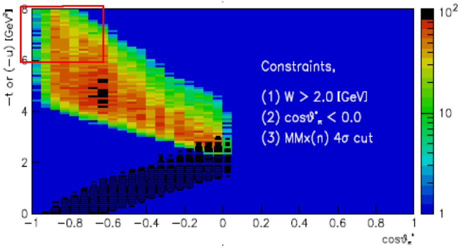
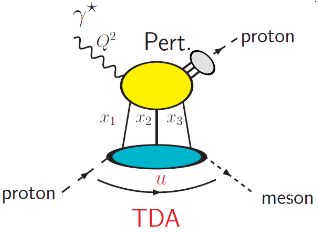


➟ Obvious –and very encouraging– excess !

Backward Electroproduction of a meson: existing data



➟ Data from JLab for the π^+

Analysis nearly done (K. Park)

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

(G. Huber, Sept. 09)

➟ Electrodruction of η and π^0 at small *u*

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

TDA studies at GSI/FAIR

TDAs in exclusive processes at GSI/FAIR

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

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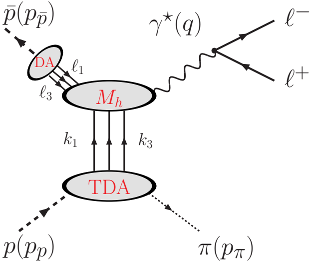

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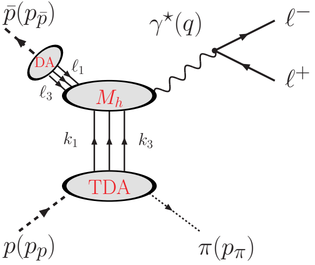

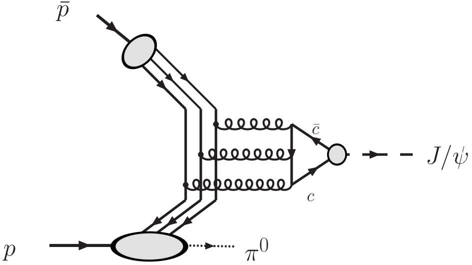

- The same TDAs appear also in $p\bar{p} \to J/\psi + \pi^0$

Same channel as for h_c studies

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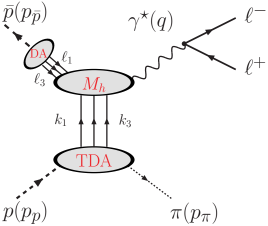
➟ Factorised picture



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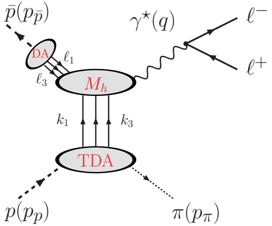

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$$\mathcal{M}^{\lambda}_{s_1 s_2} = -i \frac{(4\pi\alpha_s)^2 \sqrt{4\pi\alpha_{em}} f_N^2}{54 f_\pi Q^4} \bar{v}(p_{\bar{p}}, s_{\bar{p}}) \not{\epsilon}(\lambda) \gamma^5 u(p_p, s_p)$$

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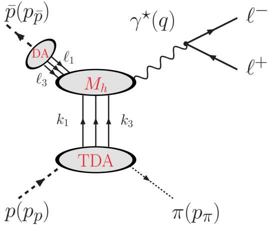

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Physics Performance Report for PANDA, 0903.3905 [hep-ex]

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- Other channels are also of much interest, such as $\bar{p}p \to \ell^+\ell^-\eta$ or $\bar{p}p \to \ell^+\ell^-\rho^0$

Not only a baryon exchange ?

Single Spin Asymmetry and the DGLAP contribution

JPL, B. Pire, L. Szymanowski, arXiv:1008.3119

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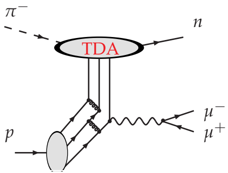
- Non vanishing and Q^2-independent SSA :
  signal of a non-zero DGLAP contribution → antiquark exchanges !

Further TDA studies with hadron beams

Ideas for TDA Studies with COMPASS

→ Reminder: $\pi^- p \to \gamma^\star n \to \ell^+ \ell^- n$ at small t: study of GPDs

→ Its backward limit (small $u = (t_\pi - t_n)^2$) would provide info on TDAs



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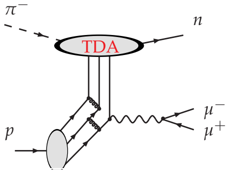

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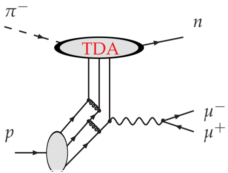

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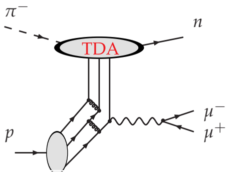

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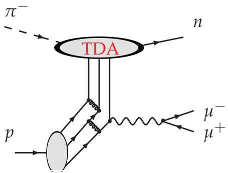

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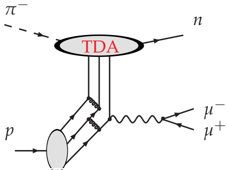

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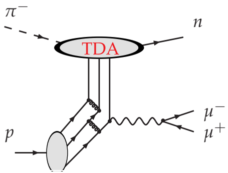

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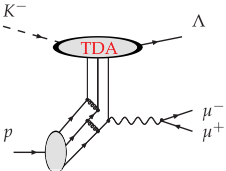

Going further with COMPASS

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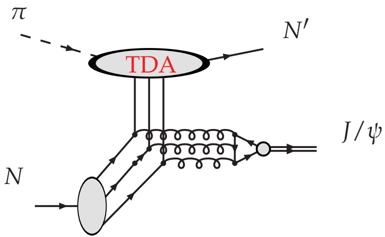

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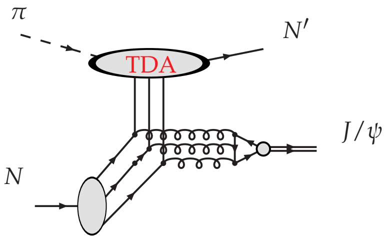

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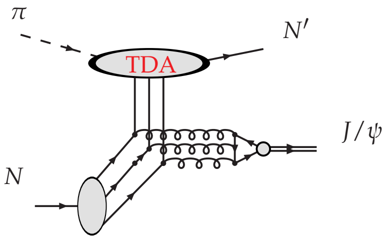

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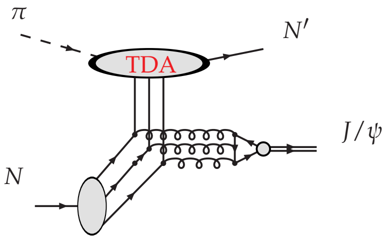

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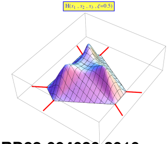
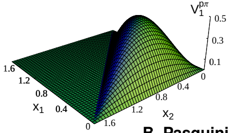


B. Pire, K. Semenov, L. Szymanowski, PRD82:094030,2010.



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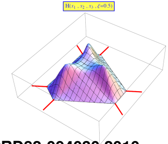

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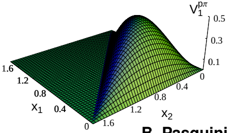

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  - ➟ Simulations to come for PANDA
  - ➟ Hopefully discussions as well with COMPASS members