

Exclusive processes at NICA and GPDs.

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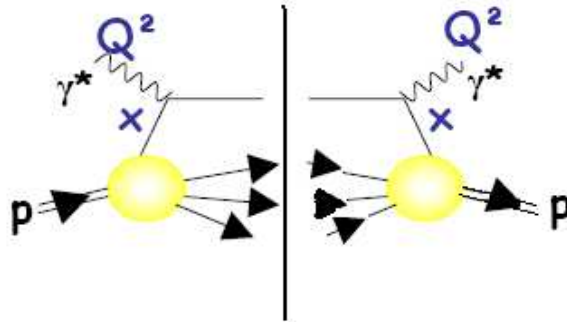
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- GPDs properties and phenomenology- D. Muller talk. Here-only few words on GPDs.
- Some examples of GPDs contribution
- $\gamma p \rightarrow Vp$ amplitudes in terms GPDs .
- Light VM leptonproduction cross section.
- Possibility to study GPDs at NICA in exclusive processes .
- Vector meson production- effects of GPDs H .
- Vector meson production with polarized beams. A_{UT} asymmetries- GPDs E effects.
- Exclusive Drell-Yan with double GPDs contribution. First estimations .

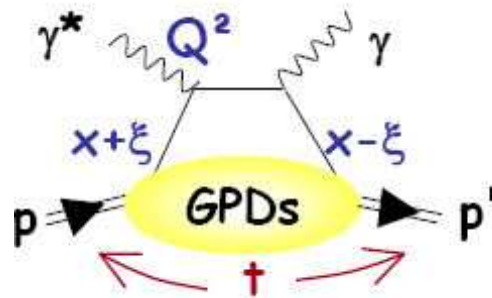
DIS and DVCD

- Deep Inelastic scattering



Cross section - expressed in terms of ordinary parton distributions $q(x)$

- Deeply Virtual Compton Scattering (VM production)



Amplitude - proportional to Generalized Parton Distributions GPDs $H(x, \xi, t)$

Information about GPDs and hadron structure.

★ GPDs – extensive information about hadron structure.

- Ordinary parton distribution connected with GPDs

$$H(x, 0, 0) = xg(x)$$

- Hadron Form factors –are the GPDs moment

$$\int dx H^q(x, \xi, t) = F_1^q(t); \quad \int dx E^q(x, \xi, t) = F_2^q(t); \quad F_1, F_2\text{-flavor } q \text{ components of Dirac and Pauli FF}$$

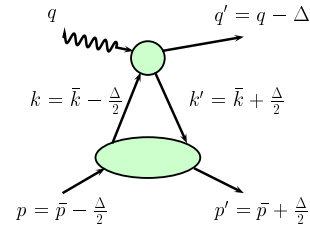
$$\int dx \tilde{H}^q(x, \xi, t) = G_A^q(t); \quad \int dx \tilde{E}^q(x, \xi, t) = G_P^q(t); \quad G_A^q, G_P^q\text{-flavor } q \text{ components of Axial and Pseudoscalar FF}$$

- Information on the parton angular momenta from Ji sum rules

$$\int x dx (H^q(x, \xi, 0) + E^q(x, \xi, 0)) = 2J^q$$

- GPDs H^q and E^q can be tested from VM production cross section and asymmetries.
- GPDs \tilde{H}^q and \tilde{E}^q can be tested from pseudoscalar mesons production & UP effects in VM.

★ $\gamma p \rightarrow V p$ amplitudes in terms of GPDs.



The proton non-flip amplitude is a convolution of H GPDs and hard scattering part.

$$\mathcal{M}_{\mu'+, \mu+} \propto \int_{-1}^1 d\bar{x} H^a(\bar{x}, \xi, t) F_{\mu', \mu}^a(\bar{x}, \xi).$$

The proton spin-flip amplitude is connected with E GPDs

$$\mathcal{M}_{\mu'-, \mu+} \propto \frac{\sqrt{-t}}{2m} \int_{-1}^1 d\bar{x} E^a(\bar{x}, \xi, t) F_{\mu', \mu}^{\prime a}(\bar{x}, \xi).$$

The hard scattering parts F, F' are calculated perturbatively.

They contain as ingredient the nonperturbative meson wave function.

In hard scattering amplitudes F, F' we consider quark transverse momenta in quark propagators

which determined by k_{\perp}^2/Q^2 corrections $\frac{1}{(x-\xi)+k_{\perp}^2/Q^2+i\epsilon}$

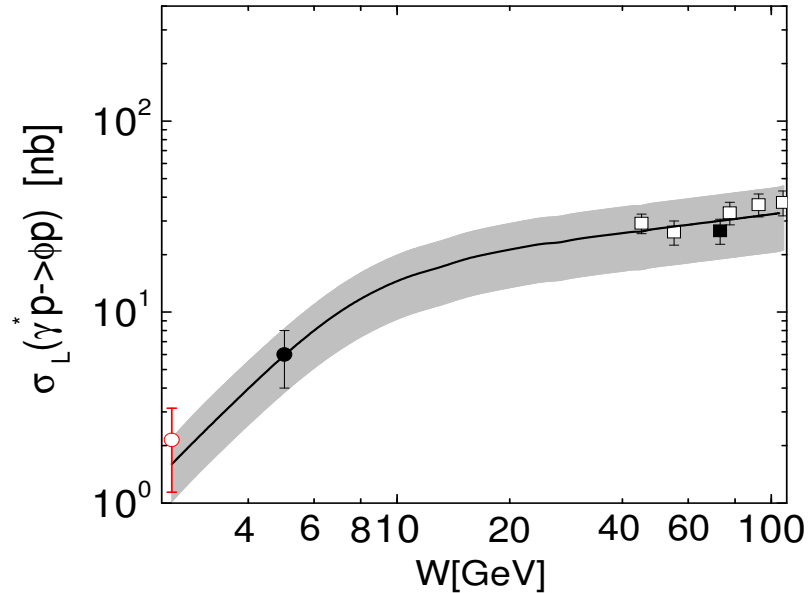
-effective consideration of the non-leading contribution.

GPDs are modeling using double distribution (Radyushkin) +CTEQ PDFs.

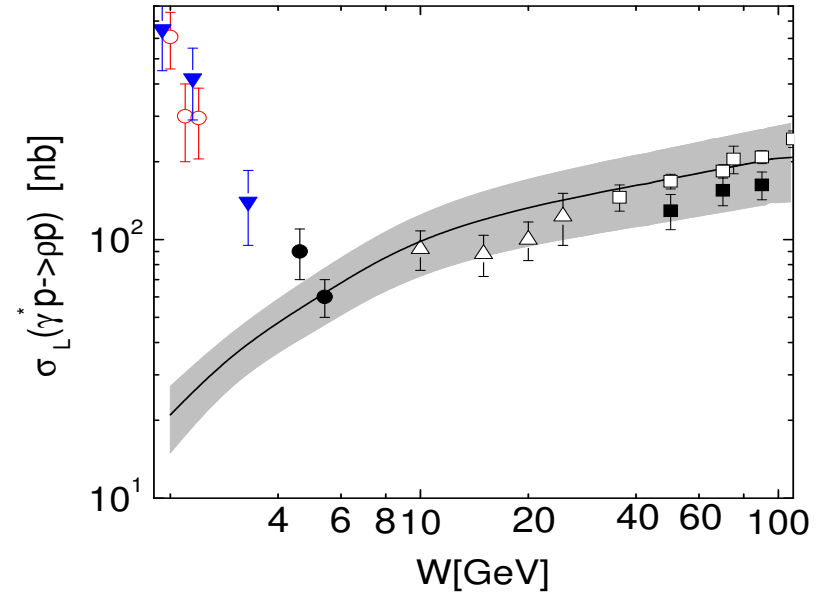
Model for amplitudes and GPDs can be tested by analyses of cross sections and spin observables.

Cross section of ρ and ϕ production - GPDs H effects

SG & P.Kroll



The longitudinal cross section for ϕ at $Q^2 = 3.8 \text{ GeV}^2$.
Data: HERMES (solid circle), ZEUS (open square), H1 (solid square), open circle- CLAS data point

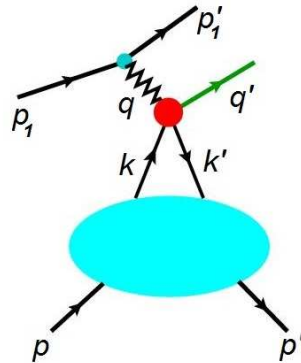


The longitudinal cross section for ρ at $Q^2 = 4.0 \text{ GeV}^2$.
Data: HERMES (solid circle), ZEUS (open square), H1 (solid square), E665 (open triangle), open circles- CLAS, CORNELL -solid triangle

Conclusion: Our knowledge about gluon, sea, quarks GPDs is OK. Problem appears at low $W < 5 \text{ GeV}^2$ in all the cases when valence quark distributions are essential : ρ^0

Meson production at NICA

The proposed process is similar to the corresponding process in lepton-proton reaction.



In the final state one detect two protons p_1, p and meson state.

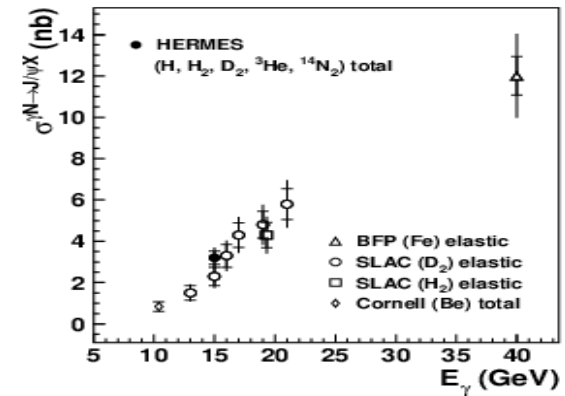
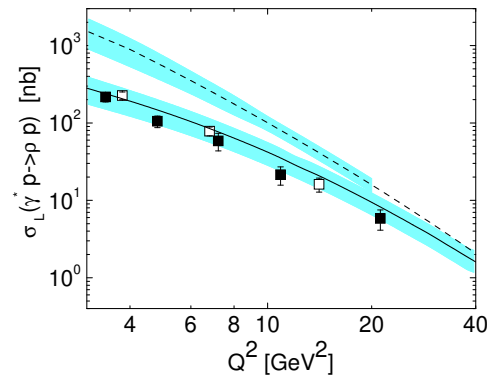
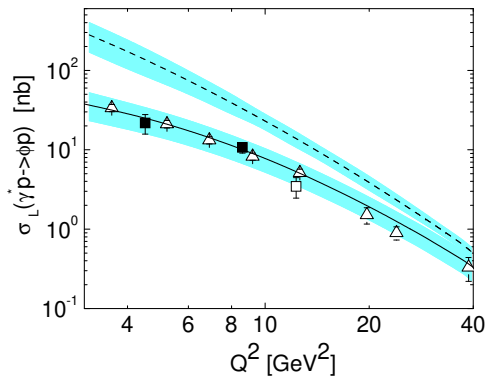
- The proton p_1 radiate a photon with virtuality Q^2 or strong interaction appear which produce the final meson.
- The energy $(p'_1 + q')^2 > 100\text{GeV}^2$. At these energies gluon contribution predominate.
- Minimum 3-gluon state contribute= Odderon contribution -rather small.
- Photon contribution predominate at not high Q^2 . At NICA we shall have the hard photon-proton interaction with energy $W \sim 5 - 12\text{GeV}$ in the γp system.
- Usual way- decomposition of $pp \rightarrow Vpp$ cross section into photon flux factor and $\gamma p \rightarrow Vp$ cross section -the same as in leptoproduction reaction.

$$\sigma(pp \rightarrow Vpp) = \int_{Q_{min}}^{Q_{max}} dQ \Gamma(Q^2) \sigma(\gamma p \rightarrow Vp), \quad \Gamma(Q^2) - \text{known photon flux factor for the proton}$$

ϕ, ρ meson production can be studied. J/Ψ near threshold.

Meson production at NICA

SG, P.Kroll- from light meson leptonproduction.



- Photoproduction mechanism of exclusive VM production as a function of Q^2 at NICA energies. Full line $W = 5\text{GeV}$, dashed line $W = 10\text{GeV}$
- γp energy $W = \sqrt{2mE_\gamma}$. At NICA J/Ψ production is not far from the threshold.
- Access to GPDs H : ρ Valence, sea, Gluon GPDs; ϕ Sea, Gluon GPDs; J/Ψ Gluon GPDs .

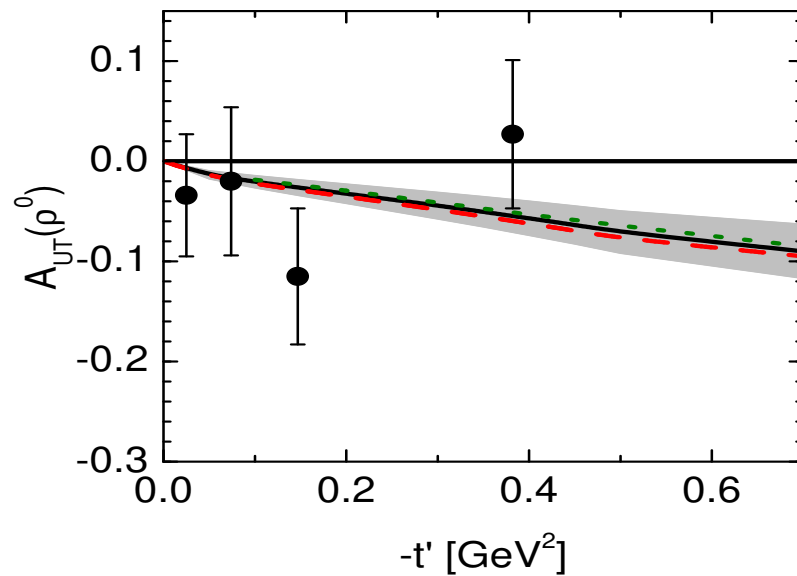
SPD- Polarized effects at NICA.

SG & P.Kroll- from light meson leptonproduction.

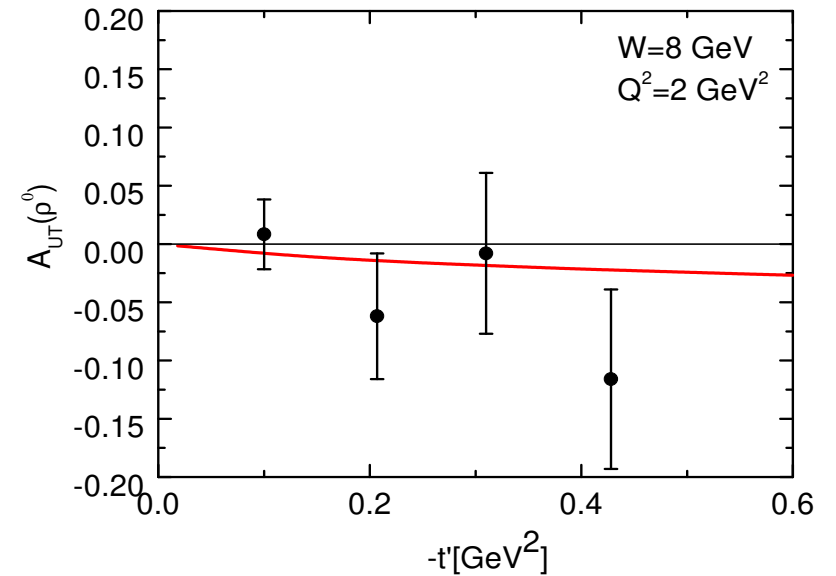
A_{UT} asymmetry of VM production-access to GPDs E .

$$A_{UT} \propto \frac{\text{Im} \langle E \rangle^* \langle H \rangle}{|\langle H \rangle|^2}$$

Example of A_{UT} asymmetry in ρ production at NICA energies.



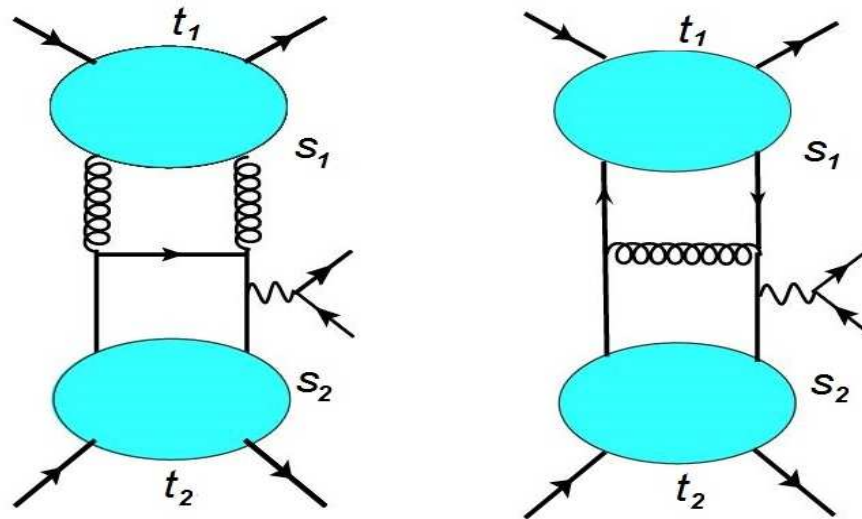
Model results for HERMES energy $W = 5\text{GeV}$, $Q^2 = 3\text{GeV}^2$. HERMES data are shown.



Model results for COMPASS energy $W = 8\text{GeV}$. COMPASS data are shown.

Exclusive Drell-Yan process with two GPDs

SG, P.Kroll and O.Teryaev in progress.



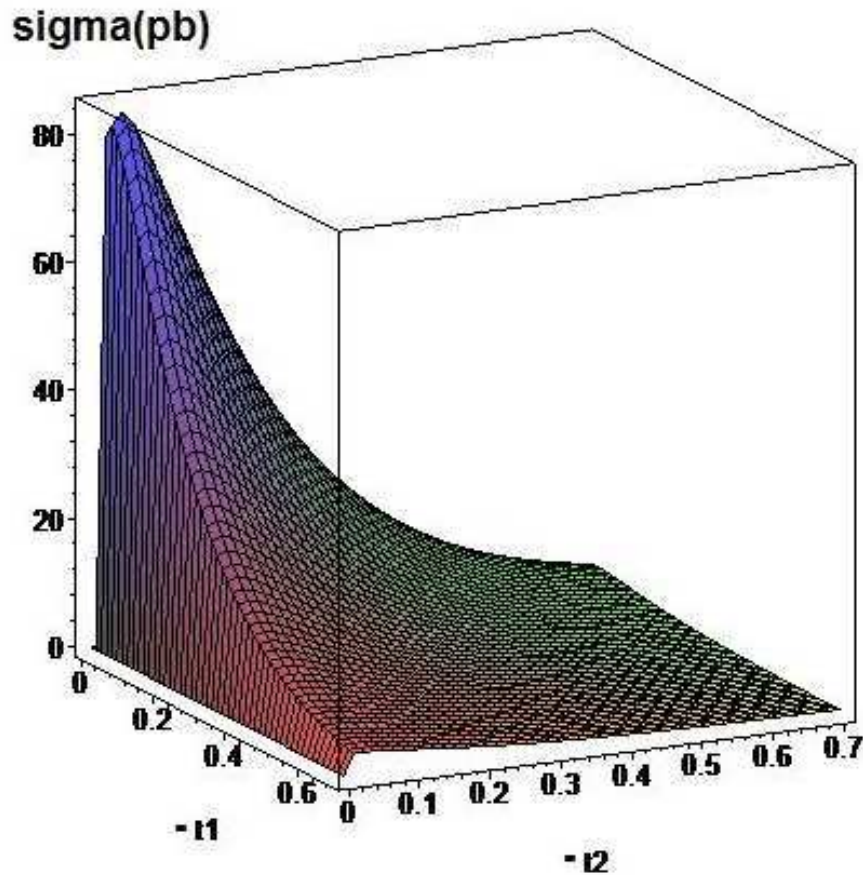
We consider quark-gluon and quark-quark effects

Problem- some divergencies like double pole appear in the amplitudes

Regularization procedure

$$\frac{1}{(x_1 - \xi_1)(x_2 - \xi_2) + i\epsilon} \rightarrow \frac{1}{[(x_1 - \xi_1) + i\epsilon][(x_2 - \xi_2) + i\epsilon]}$$

Cross section is integrated over s_1 and s_2 was calculated at NICA energies
Preliminary result for cross section of $pp \rightarrow pp l^+ l^-$ process at NICA energies



Preliminary results for cross section of exclusive Drell-Yan process over t_1 and t_2 at NICA energies. $\frac{d\sigma}{dQ^2 dt_1 dt_2}$ -in pb/GeV^6 . **Estimations show that such contribution might be visible.** Both final protons should be detected

Integrated over t_1 and t_2 cross section $d\sigma/dQ^2 \sim 5.5 pb/GeV^2$ at $Q^2 = 5GeV^2$ (NICA energies)

Conclusion

- We analyse GPDs model for exclusive meson production.
 - Discuss GPDs properties, amplitudes structure in terms of GPDs.
- **Model results for vector meson production: example of cross section**
- Discussion of possibility to study exclusive processes at NICA to get information on GPDs. Photon mechanism of VM production predominate.
- ϕ, ρ production-test H, E GPDs contributions.
- J/Ψ production-gluon GPDs effects- not far from threshold.
- Exclusive Drell-Yan with double GPDs contribution - important test of GPD model. Cross section is rather small. But hopefully might analysed.
- Important information on GPDs structure can be obtained at NICA with polarized beams.

Thank You