Exclusive processes in lepton(hadron)-hadron reactions and GPDs.

S.V. Goloskokov

Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research,

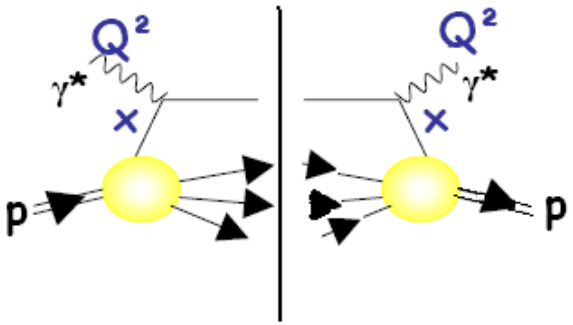
Dubna 141980, Moscow region, Russia

- GPDs properties and some examples of GPDs contribution
- $\gamma p \to V p$ amplitudes in terms GPDs .
- Light VM and PS leptoproduction cross section.
- Transversity effects
- Possibility to study GPDs at NICA in exclusive processes .
- Vector meson production- effects of GPDs H, E.
- Exclusine Drell-Yan with double GPDs contribution in pp process. First estimations .

Session-Conference: Sect. Nucl. Phys., Dep.Phys.Sci. RAN, 10-12 March 2020, Novosibirsk

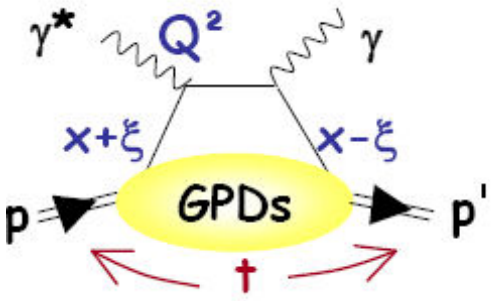
DIS and DVCD

- Deep Inelastic scattering



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

- Deeply Virtual Compton Scattering



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

Information about GPDs and hadron structure.

$\star$ 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

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

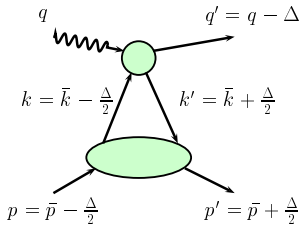
$$\int dx \tilde{H}^q(x,\xi,t) = G_A^q(t); \quad \int dx \tilde{E}^q(x,\xi,t) = G_P^q(t); \quad G_A^q, G_P^q\text{-flavor } q \text{ components of Axial and Pseudoscalar FF}$$

- 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.

$\star\ \gamma p \to V p$ amplitudes in terms of GPDs.



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

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

The proton spin-flip amplitude is connected with E GPDs

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

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

They contain as ingredient the nonperturbative meson wave function.

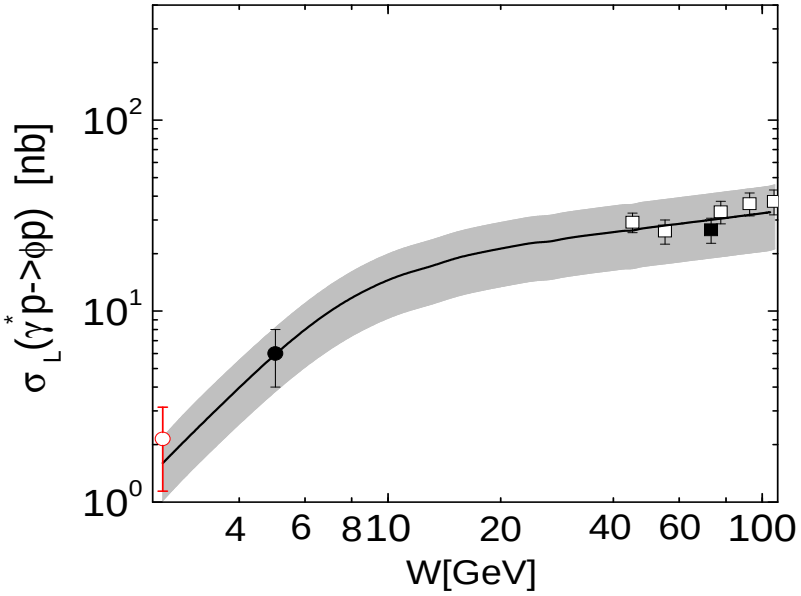
The hard scattering amplitudes F, F' is calculated perturbatively by taking into account the quark transverse momenta in quark propagators

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

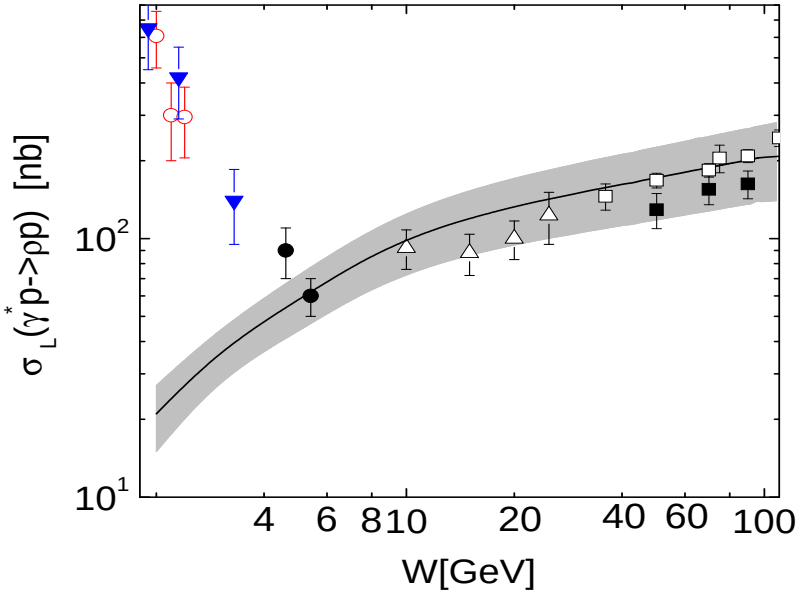
Model for amplitudes and GPDs can be tested by analyses of cross sections and spin observables.

Cross section of ρ and ϕ production - GPDs H effects

SG & P.Kroll



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



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

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

$M_{0\pm,++}$ – twist-3 amplitudes. Transversity GPDs.

$M_{0-,++} \propto \sqrt{-t'}^{\,0} \propto const$ but handbag amplitude $\propto t'$

$M_{0\pm,++}$ -is determined by twist 3 contribution .

Transversity GPDs $(H_T, E_T, ...)$ contribute

$$\mathcal{M}^{twist-3}_{0-,\mu+} \propto \int_{-1}^{1} d\overline{x} \mathcal{H}_{0-,\mu+}(\overline{x}, ...)[H_T + ...O(\xi^2\, E_T)].$$

$$\mathcal{M}^{twist-3}_{0+,\mu+} \propto \frac{\sqrt{-t'}}{4m} \int_{-1}^{1} d\overline{x} \mathcal{H}_{0-,\mu+}(\overline{x}, ...)\ \bar{E}_T.$$

We calculate twist-3 amplitude and use twist-3 meson wave function.

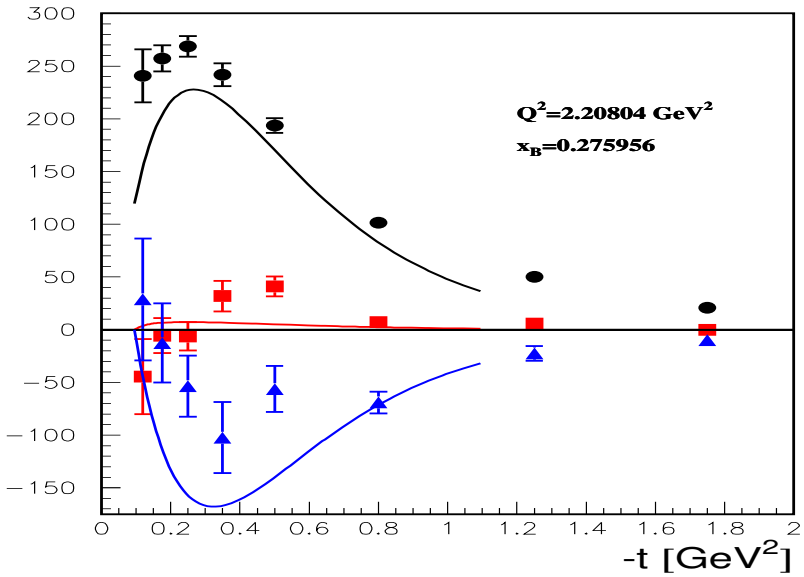
Double distribution model

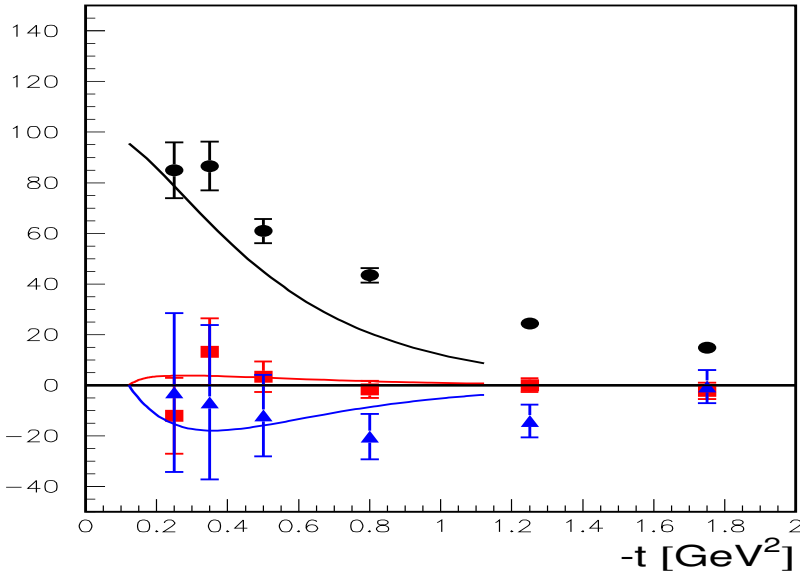
$H^a_T(x,0,0) = \delta^a(x)$, transversity δ –Anselmino model

$$\bar{E}^a_T(x,0,0) = e_T, \quad e_T(\beta,t) = N\, e^{b_0 t} \beta^{-\alpha(t)}\, (1-\beta)^n \tag{1}$$

Parameters are taken from the lattice results for the moments of E_T

π^0 and η production at CLAS energy.





π^0 production

η production

Model results for PS cross section in nb/GeV^2 together with CLAS data.

Black line- $\sigma_T + \epsilon\sigma_L$, red line-$\sigma_{LT}$, blue line- σ_{TT}

E_T contribution is large and we have at CLAS quite large transverse cross section . May be this will be possible in future experiment .

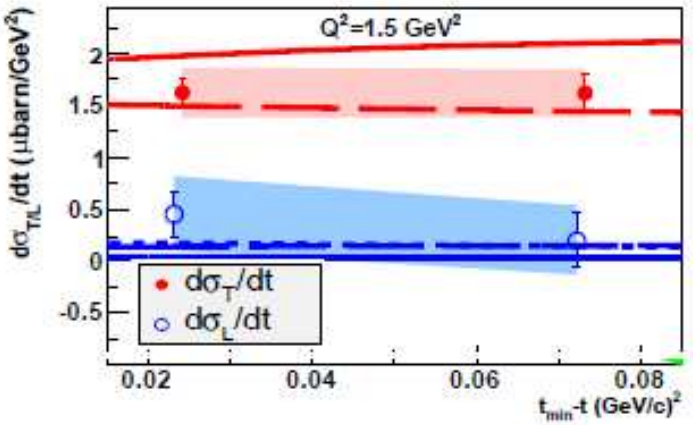
$$F_i^{\pi_0} \sim (e_u F_i^u - e_d F_i^d) \qquad F_i^{\eta} \sim (e_u F_i^u + e_d F_i^d)$$

Some flavor separation is possible from data.

Hall A FNAL experiment confirmation that $\sigma_T >> \sigma_L$.

At experiment σ_T σ_L separations done.

Rosenbluth separation of the π^0 electroproduction cross section Hall A, JLab

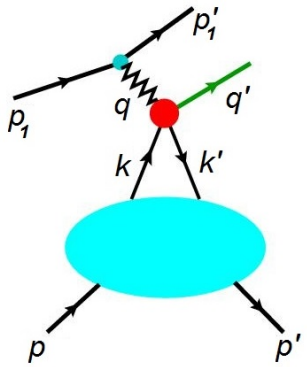


The full lines are predictions from the Goloskokov-Kroll model the long-dashed lines from the Luth-Goldstein model

The fact that $\frac{d\sigma_T}{dt} \gg \frac{d\sigma_L}{dt}$ shows that this kinematic regime is far from the asymptotic prediction of perturbative QCD

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.

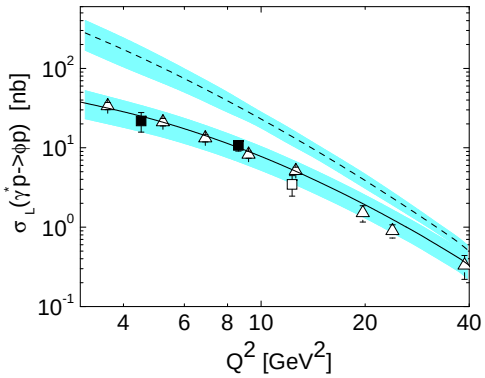
- The proton p_1 radiate a photon with virtuality Q^2 or strong interaction appear which produce the final meson.
- The energy $(p_1' + q')^2 > 100\text{GeV}^2$. At these energies gluon contribution predominate.
- Minimum 3-gluon state contribute= Odderon contribution -rather small.
- Photon contribution 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 $pp \to Vpp$ cross section into photon flux factor and $\gamma p \to Vp$ cross section -the same as in leptoproduction reaction.

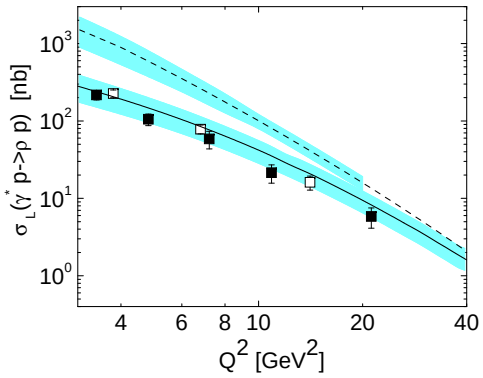
$$\sigma(pp \to Vpp) = \int_{Q_{min}}^{Q_{max}} dQ\Gamma(Q^2)\sigma(\gamma p \to Vp), \quad \Gamma(Q^2) - \text{known photon flux factor for the proton}$$

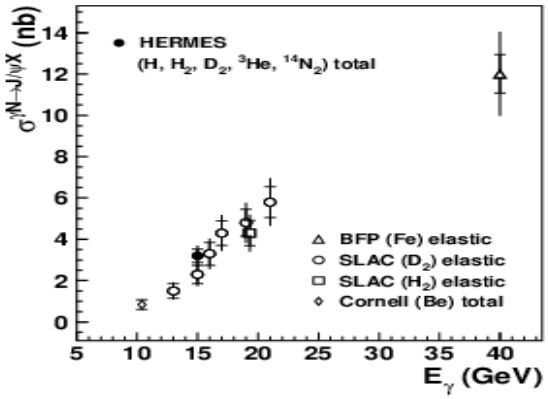
ϕ, ρ meson production can be studied. J/Ψ near threshold.

Meson production at NICA

SG, P.Kroll- from light meson leptoproduction.



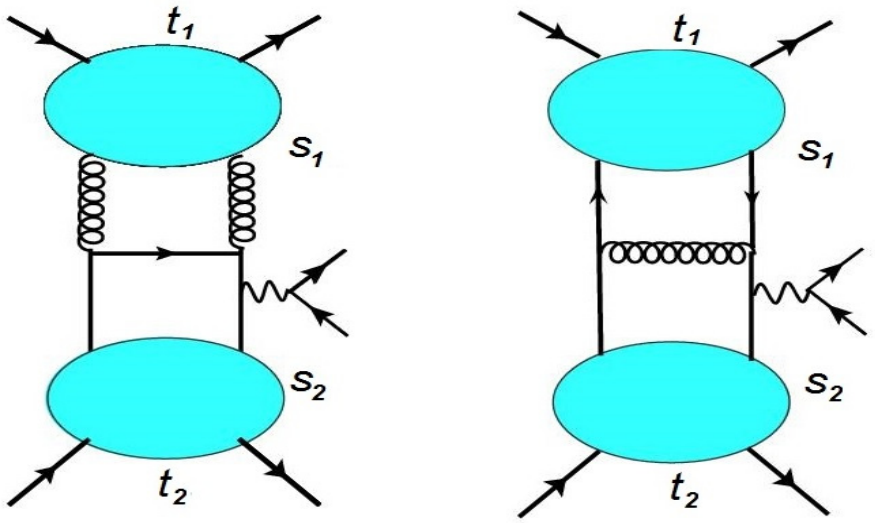




- Photoproduction mechanism of exclusive VM production as a function of Q^2 at NICA energies. Full line $W = 5$GeV, dashed line $W = 10$GeV
- γp energy $W = \sqrt{2mE_\gamma}$. At NICA J/Ψ production is not far from the threshold.
- Access to GPDs H: ρ Valence, sea, Gluon GPDs; ϕ Sea, Gluon GPDs; J/Ψ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

Exclusive Drell-Yan process with two GPDs

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



We consider quark-gluon and quark-quark effects

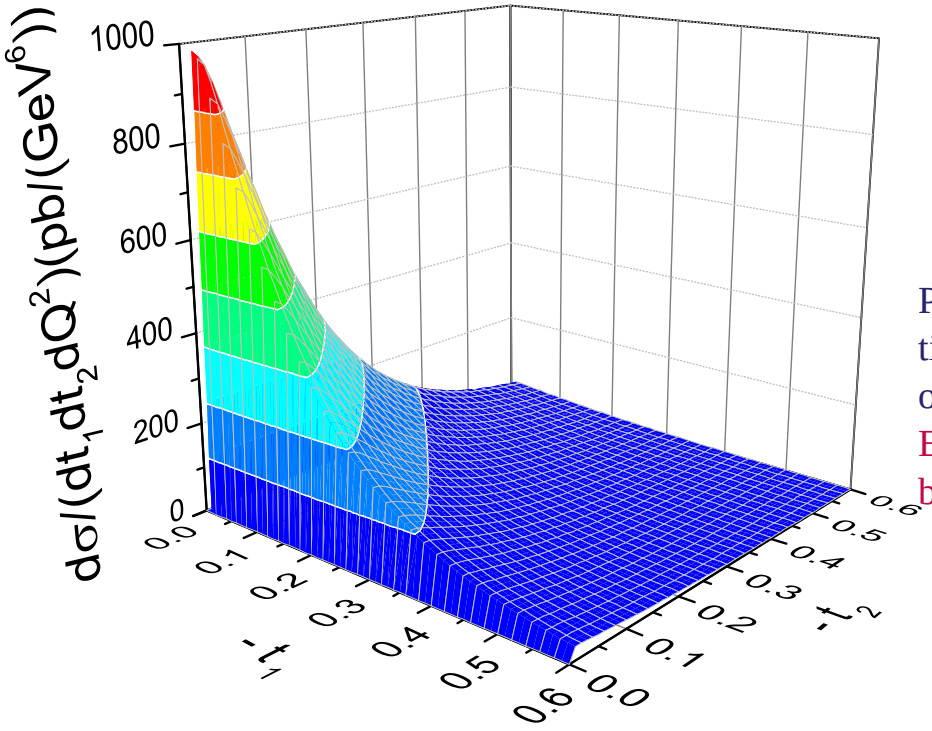
Problem- some divergencies like double pole appear in the amplitudes

Regularization procedure

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

Cross section is integrated over s_1 and s_2 was calculated at NICA energies

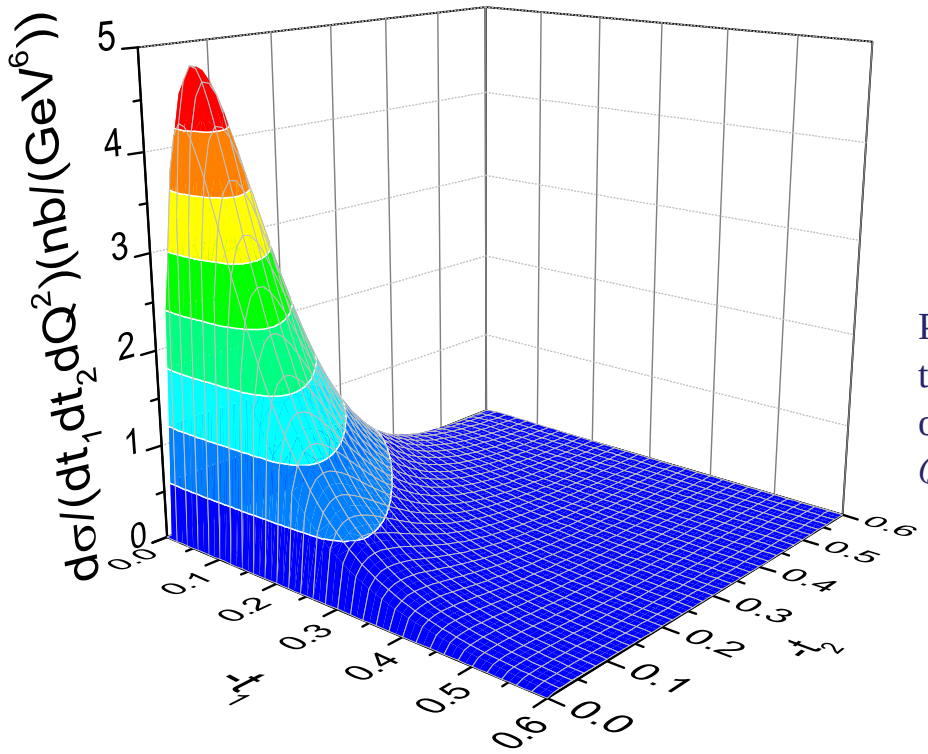
Preliminary result for cross section of $p\,p \to p\,p\,l^+\,l^-$ process at NICA energies,$Q^2 = 3\text{GeV}^2$



Preliminary results for cross section of exclusive Drell-Yan process over t_1 and t_2 at NICA energies. Estimations show that such contribution might be visible.

Integrated over t_1 and t_2 cross section $d\sigma/dQ^2 \sim 50$ pb/GeV^2 at $Q^2 = 3\text{GeV}^2$ (NICA energies)

Cross section is integrated over s_1 and s_2 was calculated at LHC energy $\sqrt{s} = 13$TeV
Preliminary result for cross section of $p\,p \to p\,p\,l^+\,l^-$ process at LHC energies



Preliminary results for cross section of exclusive Drell-Yan process over t_1 and t_2 at LHC energies, $Q^2 = 5\text{GeV}^2$.

Integrated over t_1 and t_2 cross section $d\sigma/dQ^2 \sim 230$ pb/GeV^2 at $Q^2 = 5\text{GeV}^2$ (is larger by factor 43 with respect to NICA energies)

Conclusion

- We analyse GPDs model for exclusive meson production.
  – Discuss GPDs properties, amplitudes structure in terms of GPDs.
- Model results for vector and pseudoscalar 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 future polarized experiments at COMPASS, CLAS12, NICA.

Thank You