pi0 cross section with PARTONS

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Goloskokov-Kroll Model

- Factorization for electroproduction of mesons has been proven only for longitudinally polarized photons [Collins-Frankfurt-Strikman '97]
- For transversely polarized photons, cross section is power suppressed by $1/Q$ [Collins-Frankfurt-Strikman '97]
- But in some kinematics, it is apparent that transversely polarized photons contribute substantially [HERMES Collaboration, arXiv:0907.2596[hep-ex]]

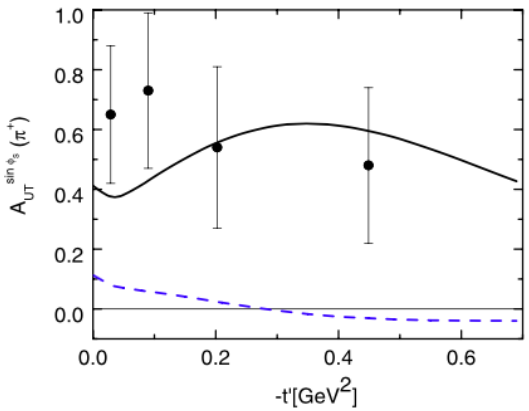


Fig. 2 (Color online) The $\sin\phi_s$ moment for a transversely polarized target at $Q^2 \simeq 2.45$ GeV^2 and $W = 3.99$ GeV. The prediction from our handbag approach is shown as a *solid line*. The *dashed line* is obtained disregarding the twist-3 contribution. Data are taken from [10]

Figure: [Goloskokov-Kroll '10]

Goloskokov-Kroll Model

- Contributions from transversely polarized photons can be computed as a twist-3 effect in the handbag mechanism [Goloskokov-Kroll '10]
- In pseudoscalar meson production, the following amplitudes are relevant in GK model

$$\mathcal{M}_{0+,0+} = \sqrt{1-\xi^2}\frac{e}{Q}[\langle\tilde{H}\rangle - \frac{\xi^2}{1-\xi^2}\langle\tilde{E}\rangle]$$

$$\mathcal{M}_{0-,0+} = \frac{e}{Q}\frac{-t'}{2m}[\xi\langle\tilde{E}\rangle]]$$

$$\mathcal{M}_{0-,++} = \sqrt{1-\xi^2}e\,\langle H_T\rangle$$

$$\mathcal{M}_{0+,\mu+} = -\frac{e}{4m}\sqrt{-t'}\langle\bar{E}_T\rangle$$

Goloskokov-Kroll Model

- Generically, $\langle F \rangle$ represents a convolution of a GPD F with an appropriate subprocess amplitude

$$\langle F \rangle = \sum_{\lambda} \int_{-1}^{1} dx \, \mathcal{H}_{\mu'\lambda,\mu\lambda}(x, \xi, Q^2) \, F(x, \xi, t)$$

  where λ denotes unobserved helicities of the partons.
- Subprocesses are calculated in the so-called modified perturbative approach: Transverse momenta of the quark and the anti-quark in the meson are kept and gluon radiations are taken into account through Sudakov factor

Goloskokov-Kroll Model

- In impact space

$$\mathcal{H}_\pi = \int d\tau d^2\vec{b}\, \hat{\Psi}_\pi(\tau, -\vec{b}) \hat{\mathcal{F}}^i_\pi(\bar{x}, \xi, \tau, Q^2, \vec{b}) \alpha_s(\mu_R)\, exp\big(-S(\tau, \vec{b}, Q^2)\big)$$

where $\hat{\Psi}_\pi(\tau, -\vec{b})$ is the meson wave function, and $\hat{\mathcal{F}}^i_\pi(\bar{x}, \xi, \tau, Q^2, \vec{b})$ is the hard scattering kernel

- GPDs are constructed from double distribution ansatz

$$F^a_i(\bar{x}, \xi, t) = \int_{-1}^{1} d\rho \int_{-1+|\rho|}^{1-|\rho|} d\eta\, \delta(\rho + \xi\eta - \bar{x}) f^a_i(\rho, \eta, t)$$

where for valence-quark GPDs;

$$f_i(\rho, \eta, t) = exp[(b_i - \alpha'_i\, ln\, \rho)t]\, F^a_i(\rho, \xi = t = 0)\, \frac{3}{4} \frac{(1-\rho)^2 - \eta^2}{(1-\rho)^3} \Theta(\rho)$$

Goloskokov-Kroll Model

- To compute the longitudinal cross section, we need:
  Twist-2 meson wave function, kernel, running coupling, Sudakov factor and the GPDs $\tilde{H}$ & $\tilde{E}$.
- To compute the transverse cross section, we need:
  Twist-3 meson wave function, kernel, running coupling, Sudakov factor and the GPDs H_T & $\bar{E}_T$.
- 3 dimensional integrals, over $\bar{x}, \tau$ and b, are performed in impact space
- π^+ electroproduction also receives a pion pole contribution, besides the handbag contribution

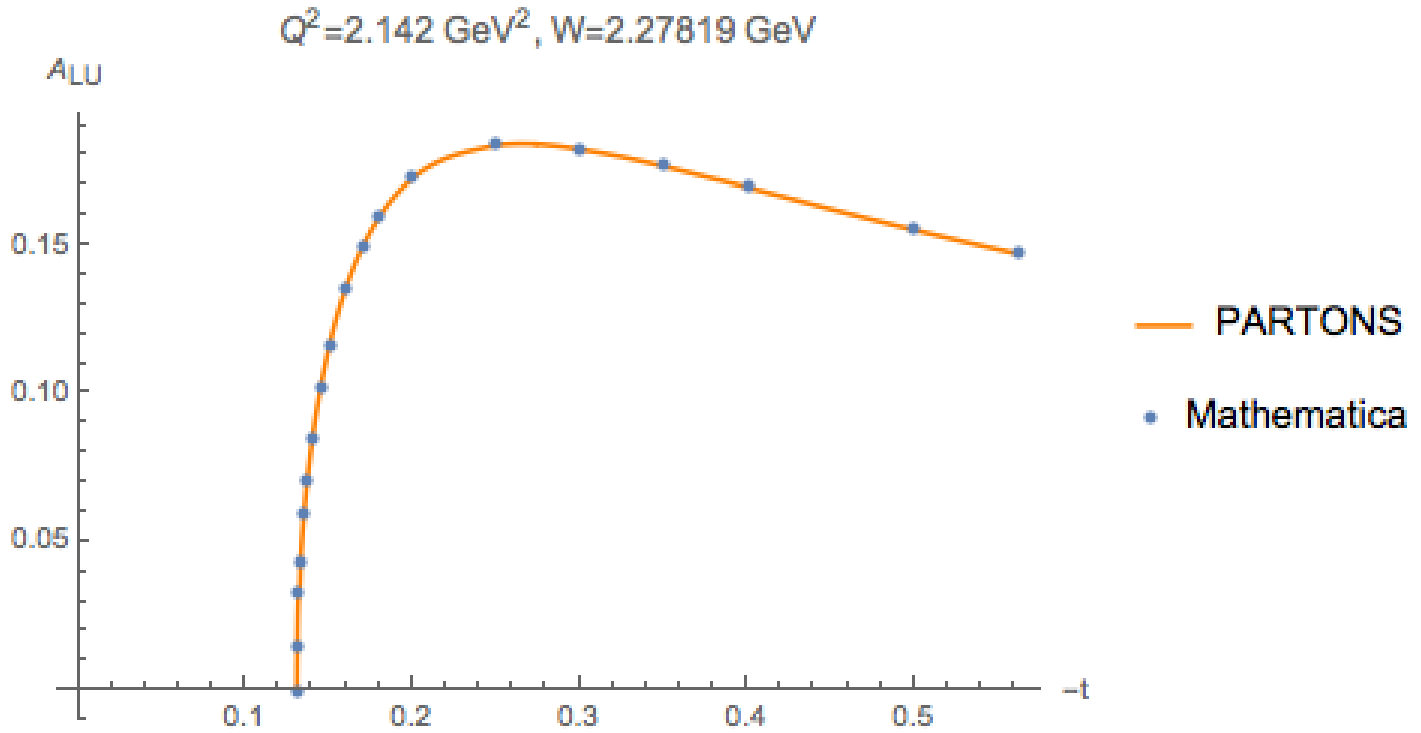
Goloskokov-Kroll Model

- $3D$ integrals are time consuming
- Standard integration routines take hours to compute an observable at a single point
- To speed up, we use VEGAS Monte Carlo integration implemented in gsl library
  - can choose number of evaluations
  - can choose χ^2 range
- As a result, an observable can be computed at a single point within minutes with a good accuracy

  Example: $d\sigma_T/dt$ computation in Mathematica vs. PARTONS at a single kinematic point
  - Mathematica: 2 hours and 14 minutes
  - PARTONS: 5 min and 13 seconds

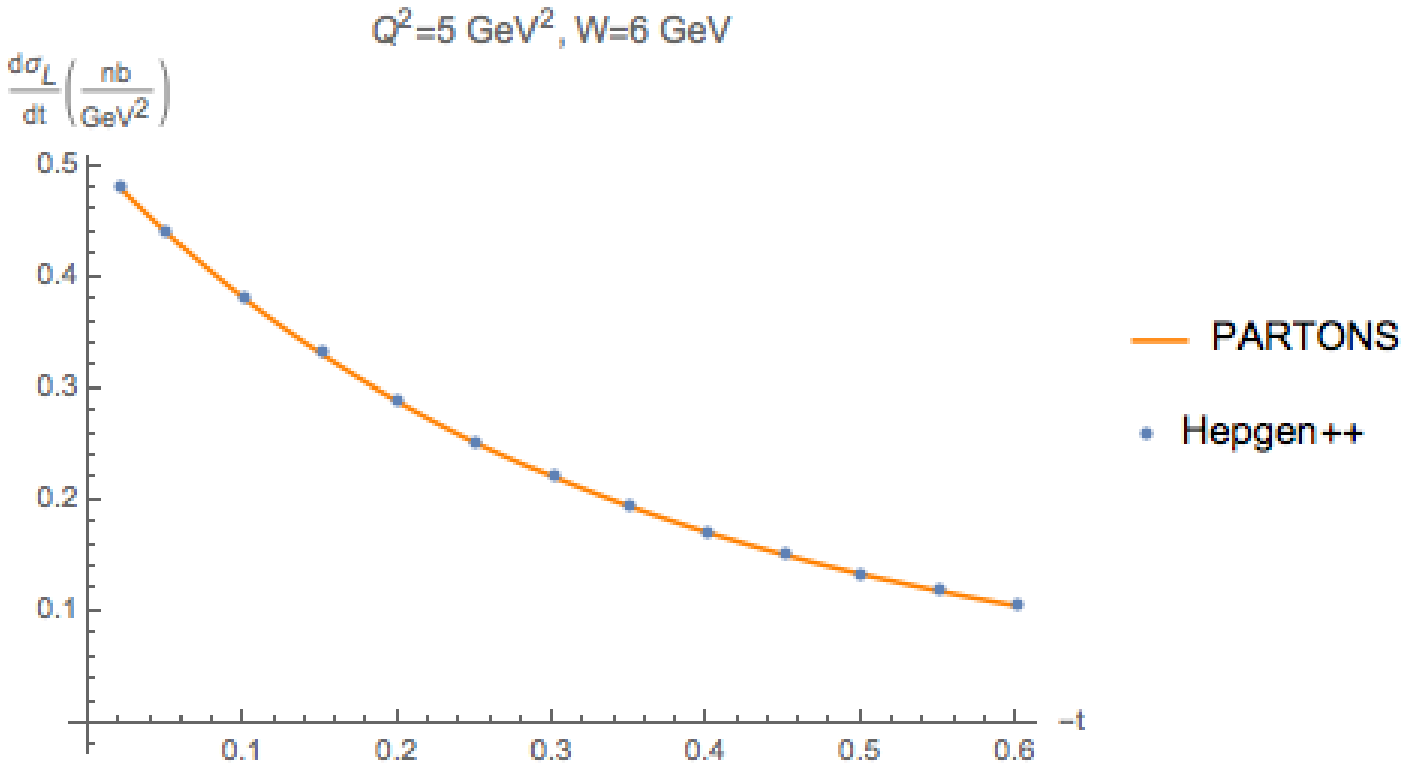
PARTONS vs. Mathmematica

Comparison of A_{LU} between PARTONS and Mathmematica in π^+ electroproduction



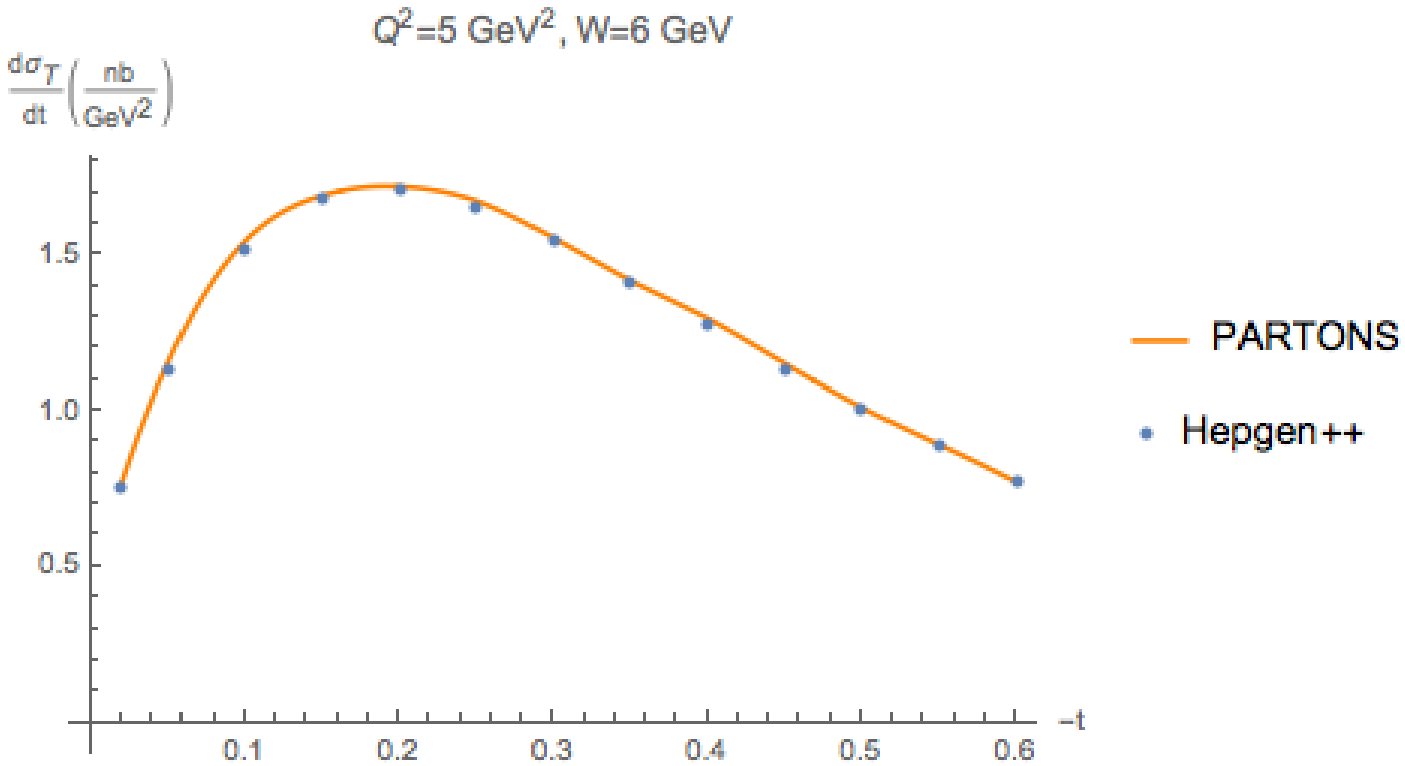
PARTONS vs. Hepgen++

Comparison of $d\sigma_L/dt$ between PARTONS and Hepgen++ in π^0 electroproduction



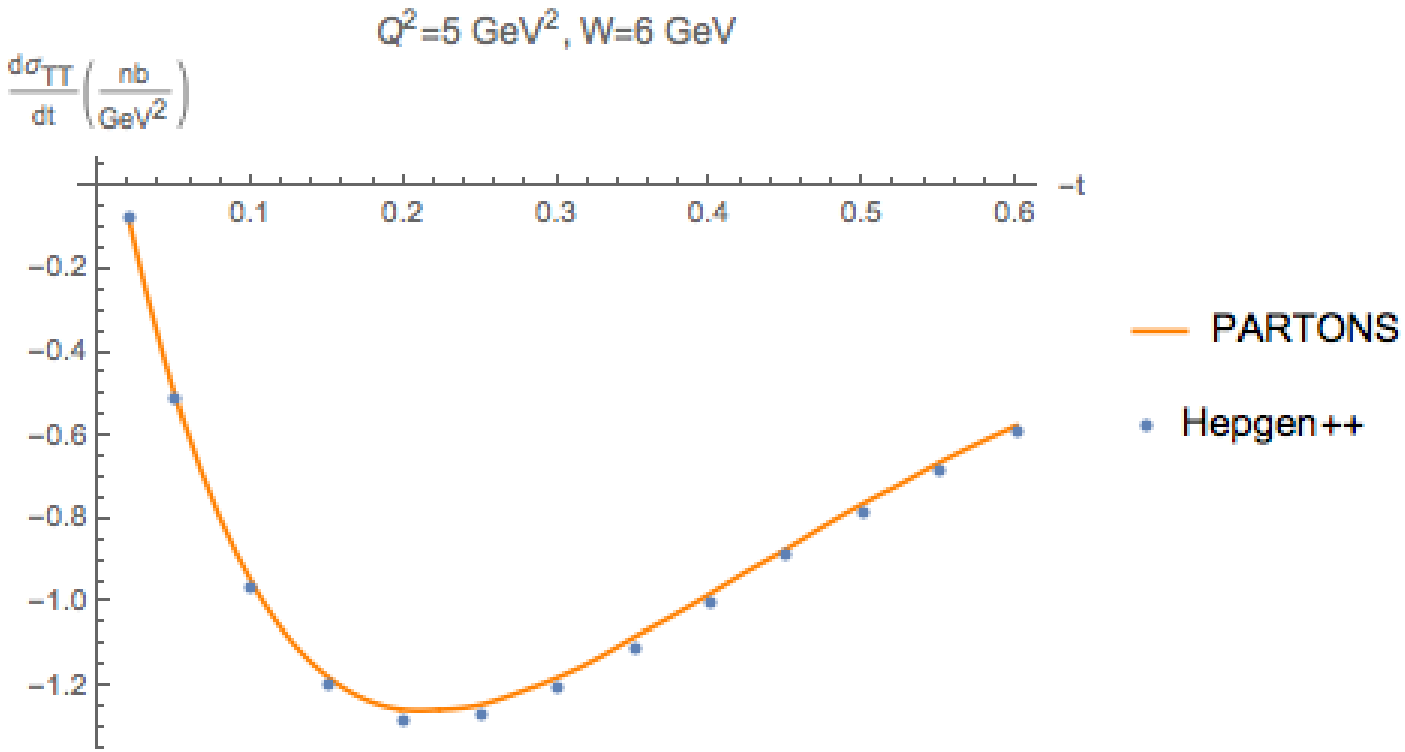
PARTONS vs. Hepgen++

Comparison of $d\sigma_T/dt$ between PARTONS and Hepgen++ in π^0 electroproduction



PARTONS vs. Hepgen++

Comparison of $d\sigma_{TT}/dt$ between the *PARTONS* and *Hepgen* $++$ in π^0 electroproduction



Monte Carlo studies

At $x = 0.1$, $Q^2 = 5\ GeV^2$ and $t = -0.2\ GeV^2$

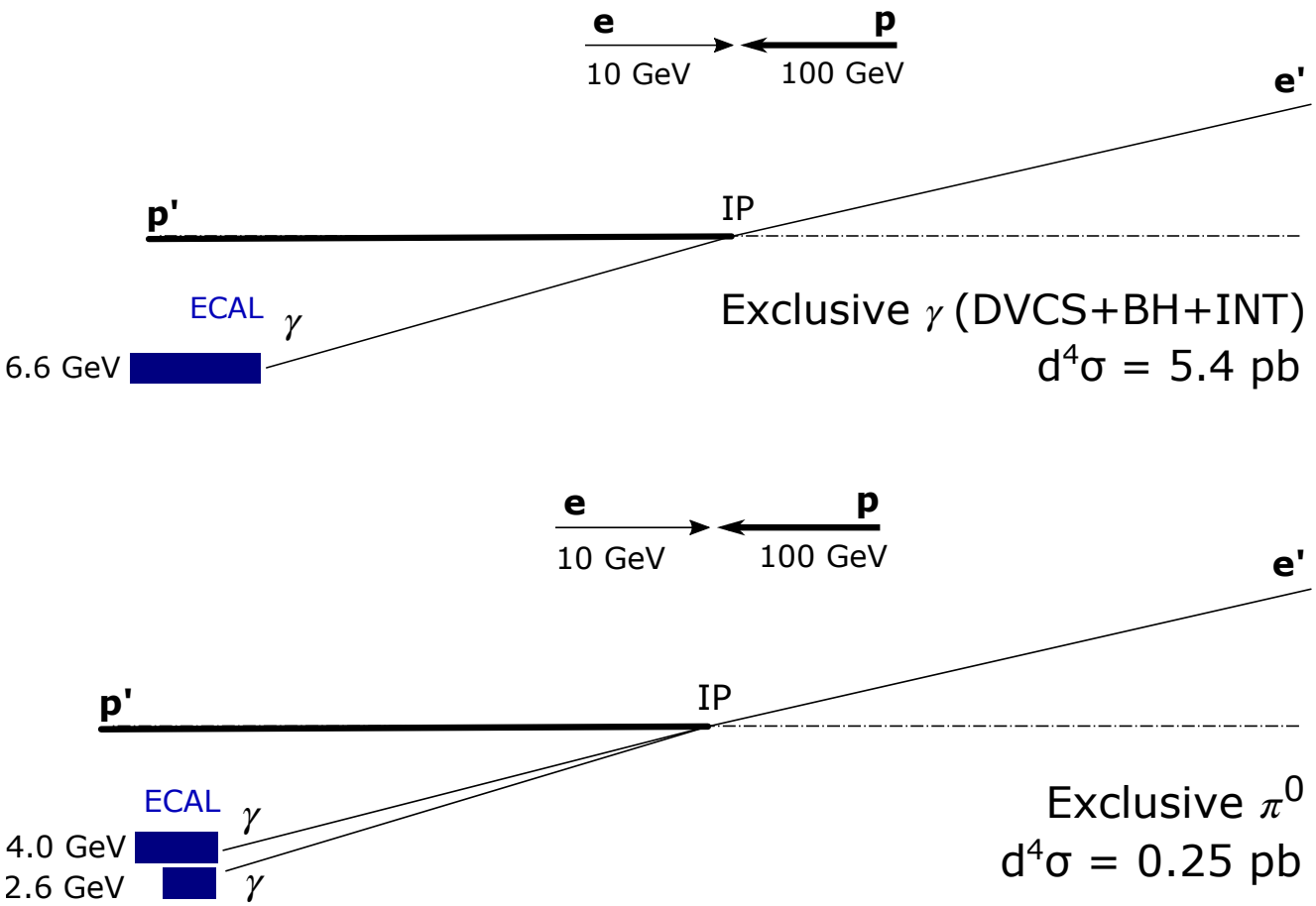


Image credit: Pawel Sznajder

Concluding remarks

- Implementation of GK model π^0 leptoproduction in PARTONS is complete
- Updated parameters from P. Kroll
- PARTONS team is ready to provide input for Monte Carlo studies
- PARTONS is flexible to accommodate other models and channels