’Transverse’ SDMEs in exclusive electroproduction of ρ^0

DIS 2009, Madrid

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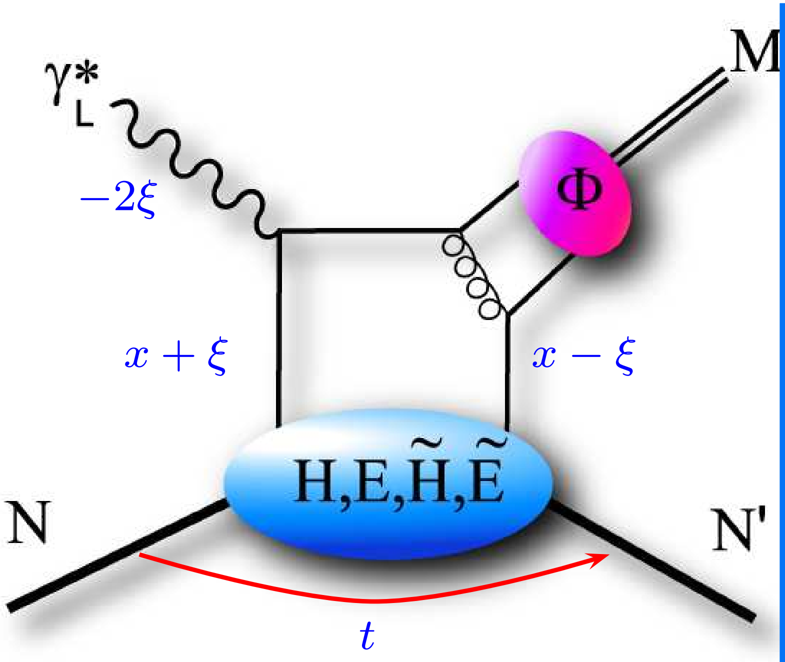
(on behalf of the hermes collaboration)

exclusive meson production

factorization in collnear approximation *-Collins, Frankfurt, Strikman (1997)-*

$$\mathcal{A} \propto F(x,\xi,t;\mu^2) \otimes K(x,\xi,z;\log(Q^2/\mu^2) \otimes \Phi(z;\mu^2)$$



at leading-twist: H, E, $\widetilde{H}$, $\widetilde{E}$

- H and $\widetilde{H}$ conserve the nucleon helicity
- E and $\widetilde{E}$ describe the nucleon helicity flip

quantum numbers of final state selects different GPDs

- vector mesons ($\gamma^*_L \to \rho_L, \omega_L, \phi_L$): H, E
- pseudoscalar mesons ($\gamma^*_L \to \pi, \eta$): $\widetilde{H}$, $\widetilde{E}$

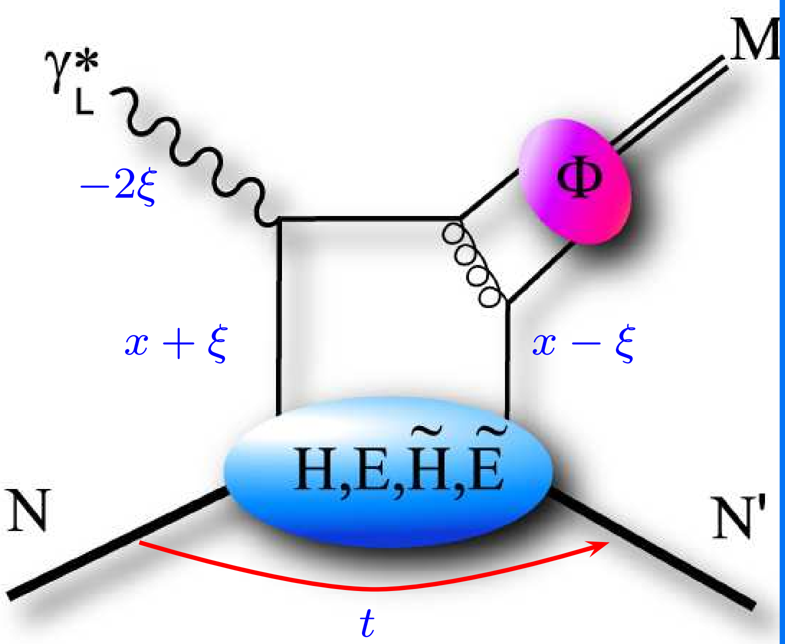
factorization for σ_L (and ρ_L, ω_L, ϕ_L) only

- $\sigma_L - \sigma_T$ suppressed by $1/Q$
- σ_T suppressed by $1/Q^2$

exclusive meson production

modified perturbative approach *-Goloskokov, Kroll (2006)-*

$$\mathcal{A} \propto F(x,\xi,t;\mu^2) \otimes K(x,\xi,z;\log(Q^2/\mu^2) \otimes \Phi(z,k_\perp;\mu^2)$$



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- $\sigma_L - \sigma_T$ suppressed by $1/Q$
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power corrections: $k_\perp$ is not neglected

- regulate the singularity in the transverse amplitude
- $\gamma^*_T \to \rho^0_T$ transitions can be calculated (model dependent)
- ρ^0: contributions from $\widetilde{H}$ and $\widetilde{E}$

advantage of exclusive ρ^0 production

- Ji relation

$$J_q = \frac{1}{2} \lim_{t \to 0} \int_{-1}^{1} dx\, x \left[H_q(x,\xi,t) + E_q(x,\xi,t) \right]$$

$$J_g = \frac{1}{2} \lim_{t \to 0} \int_{0}^{1} dx \left[H_g(x,\xi,t) + E_g(x,\xi,t) \right]$$

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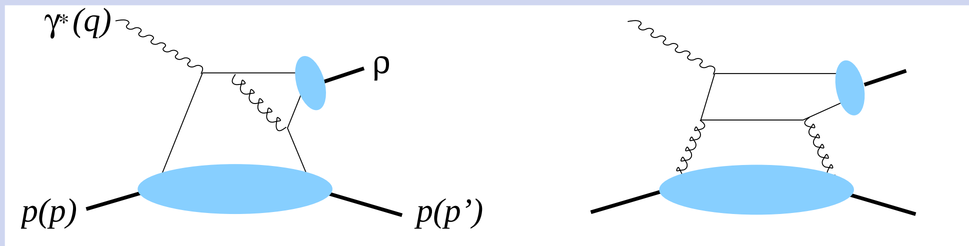
- exclusive ρ^0 sensitive to $H^{q,g}$ and $E^{q,g}$ at the same order in α_s



- process where the gluon contribution enters in LO
- E_g is completely unknown

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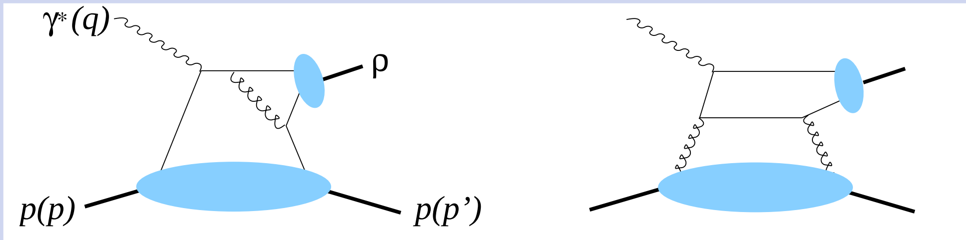


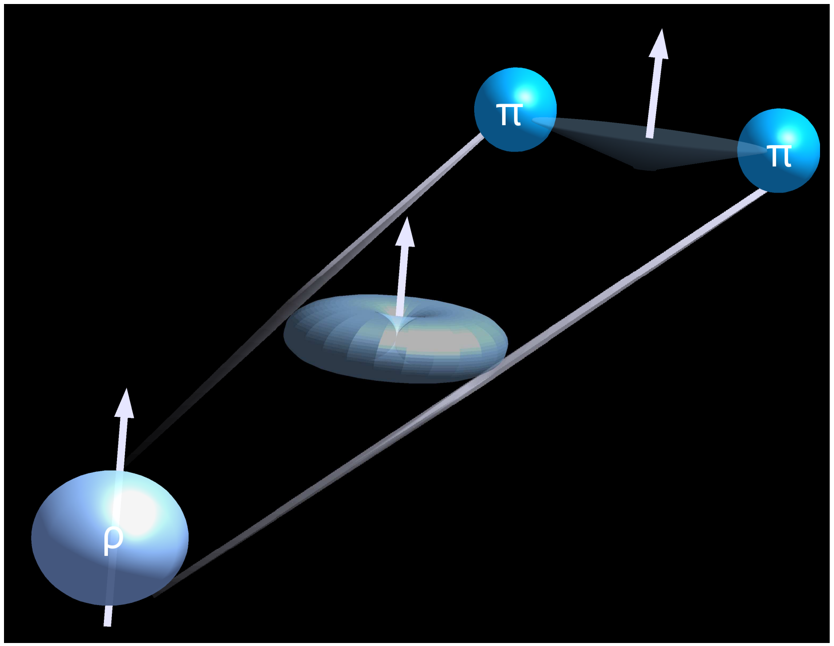
- process where the gluon contribution enters in LO
- E_g is completely unknown
- a cross section asymmetry with respect to the transverse target polarization

$$A_{UT}^{\gamma_L^*}(\phi,\phi_s) \propto \frac{\mathrm{Im}(\mathcal{E}_\rho^*\mathcal{H}_\rho)}{|\mathcal{H}_\rho|^2} \propto \left|\frac{\mathcal{E}_\rho}{\mathcal{H}_\rho}\right|$$

  - depends linearly on the helicity-flip GPDs $E^{q,g}$
  - no kinematic suppression $E^{q,g}$ with respect to $H^{q,g}$

vector meson polarization

- γ^* and ρ^0 have the same quantum numbers
  - helicity transfer $\gamma^* \longrightarrow \rho^0$
    - signature: ρ^0 production angular distribution
- the spin-state of the ρ^0 is reflected in the orbital angular momentum of the decay particles
  - ρ^0 (in the rest frame): $J = L + S = 1$
  - $\pi : S = 0,\ L = 1$
    - signature: decay angular distribution



the angular distribution

- correlations are reflected in the ρ^0 production and decay angular distributions W

$$\frac{d\sigma}{dx_B\,dQ^2\,dt\,d\phi_s\,d\phi\,d\cos\vartheta\,d\varphi} \sim \frac{d\sigma}{dx_B\,dQ^2\,dt} W(x_B, Q^2, t, \phi_s, \phi, \cos\vartheta, \varphi)$$

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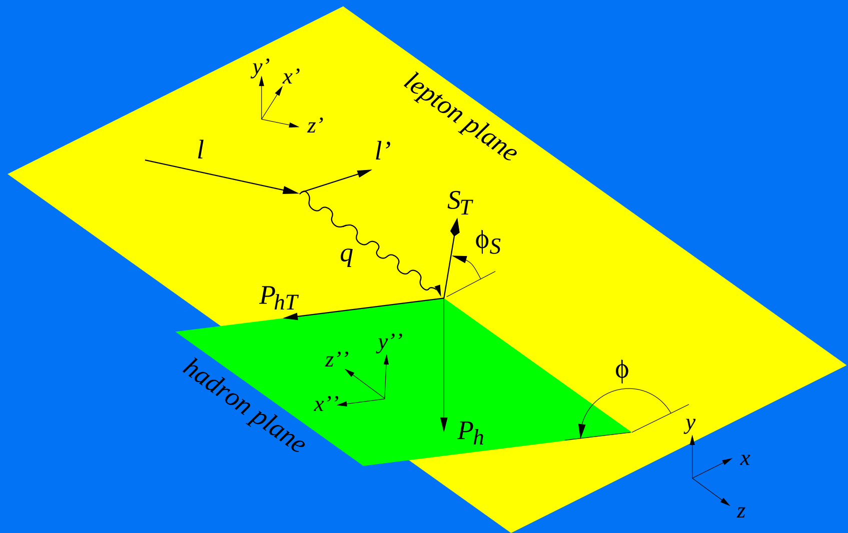

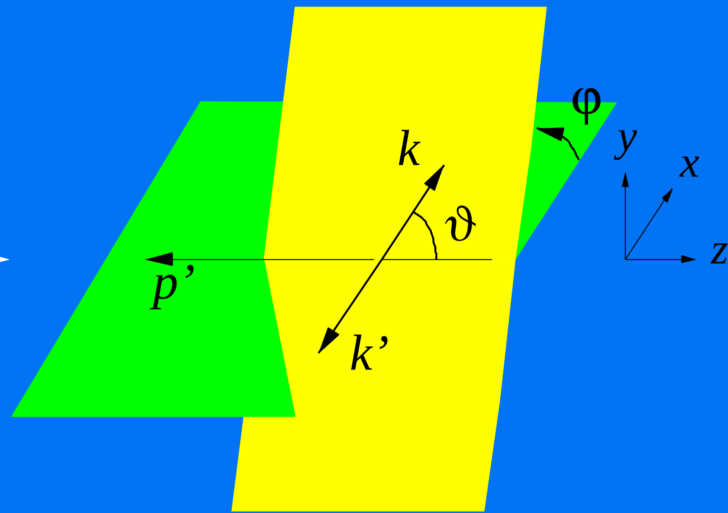

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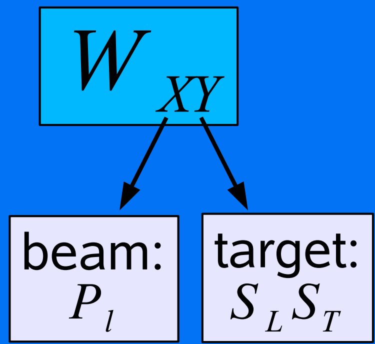
- decomposed:

$$W = W_{UU} + P_l W_{LU} + S_L W_{UL} + P_l S_L W_{LL} + S_T W_{UT} + P_l S_T W_{LT}$$



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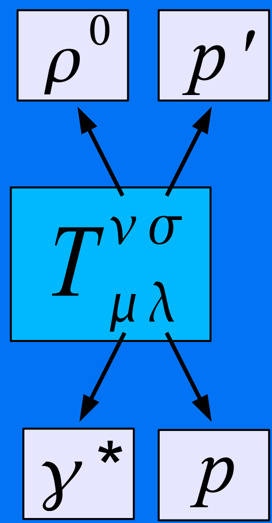
- parameterized by helicity amplitudes $T^{\nu\sigma}_{\mu\lambda}$:

-Diehl notation (2007)-



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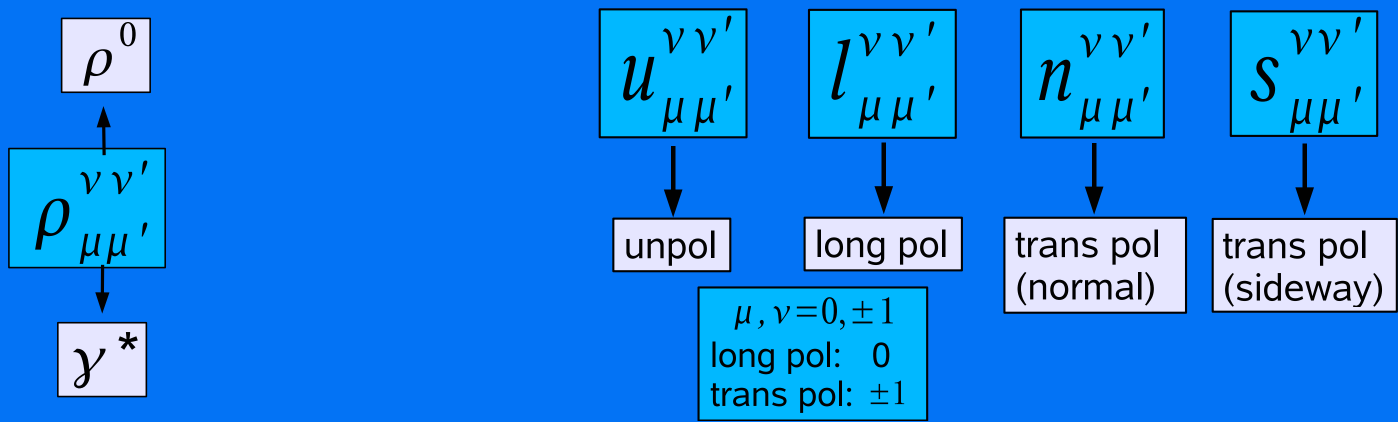
- parameterized by helicity amplitudes $T^{\nu\sigma}_{\mu\lambda}$: *-Diehl notation (2007)-*
- spin-density matrix elements (SDMEs):

$$\rho^{\nu\nu'}_{\mu\mu',\lambda\lambda'} \propto \sum_\sigma T^{\nu\sigma}_{\mu\lambda} \left(T^{\nu'\sigma}_{\mu'\lambda'}\right)^*$$



the definition of the asymmetry

$$\mathcal{A}_{UT}^{\gamma^*}(\phi,\phi_s) = \frac{\sigma_{UT}(\phi,\phi_s)}{\widehat{\sigma}_{UU}}$$

- $\widehat{\sigma}_{UU}$ - no ϕ-dependence
- the cross section can be separated into angle-independent and angular dependent parts

$$\mathcal{A}_{UT}^{\gamma^*}(\phi,\phi_s) = \frac{W_{UT}(\phi,\phi_s)}{\widehat{W}_{UU}}$$

- theoretically at leading order in $1/Q$ ($\gamma_L^* \to \rho_L^0$):

$$A_{UT}^{\gamma^*}(\phi,\phi_s) = \frac{\mathrm{Im}\, n_{00}^{00}}{u_{00}^{00}}$$

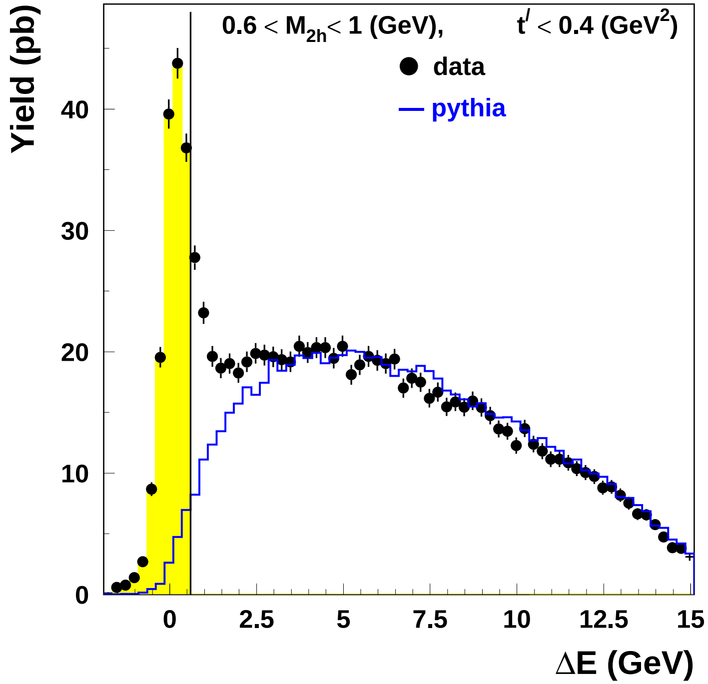
- experimentally:

$$A_{UT}^{\gamma^*}(\phi,\phi_s) = \frac{\mathrm{Im}\left(n_{++}^{00} + \epsilon n_{00}^{00}\right)}{u_{++}^{00} + \epsilon u_{00}^{00}}$$

- u_{++}^{00} and n_{++}^{00} are expected to be negligible

exclusive ρ^0 sample

- $\rho^0 \xrightarrow{100\%} \pi^+ + \pi^-$
- the invariant mass distribution: $M_{2\pi} = \sqrt{(p_{\pi^+} + p_{\pi^-})^2}$
- no recoil proton detection
- for exclusive elastic scattering: $\Delta E = (M_x^2 - M^2)/(2M) = 0$
- only little energy transferred to the target $t = (\mathbf{q} - \mathbf{v})^2$
- transverse four-momentum transfer is often used $t' = t - t_0$
- main contribution at small values of ΔE and t' $\Delta E < 0.6$ GeV and $t' < 0.4$ GeV^2



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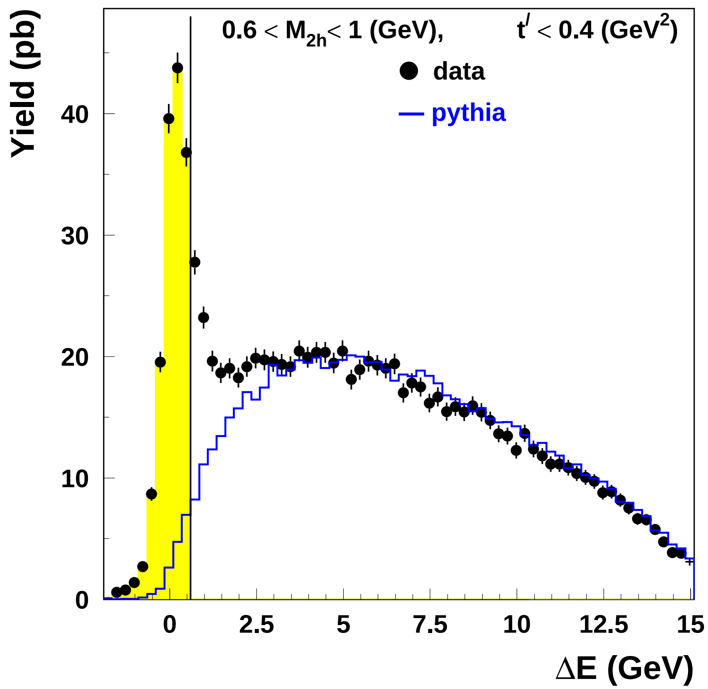


- non-exclusive events: $\Delta E > 0$
- contribute due to the experimental resolution and restricted acceptance
- estimate the semi-inclusive background contamination with PYTHIA
- events produced in non-exclusive processes as an estimate of the background contamination: 11%

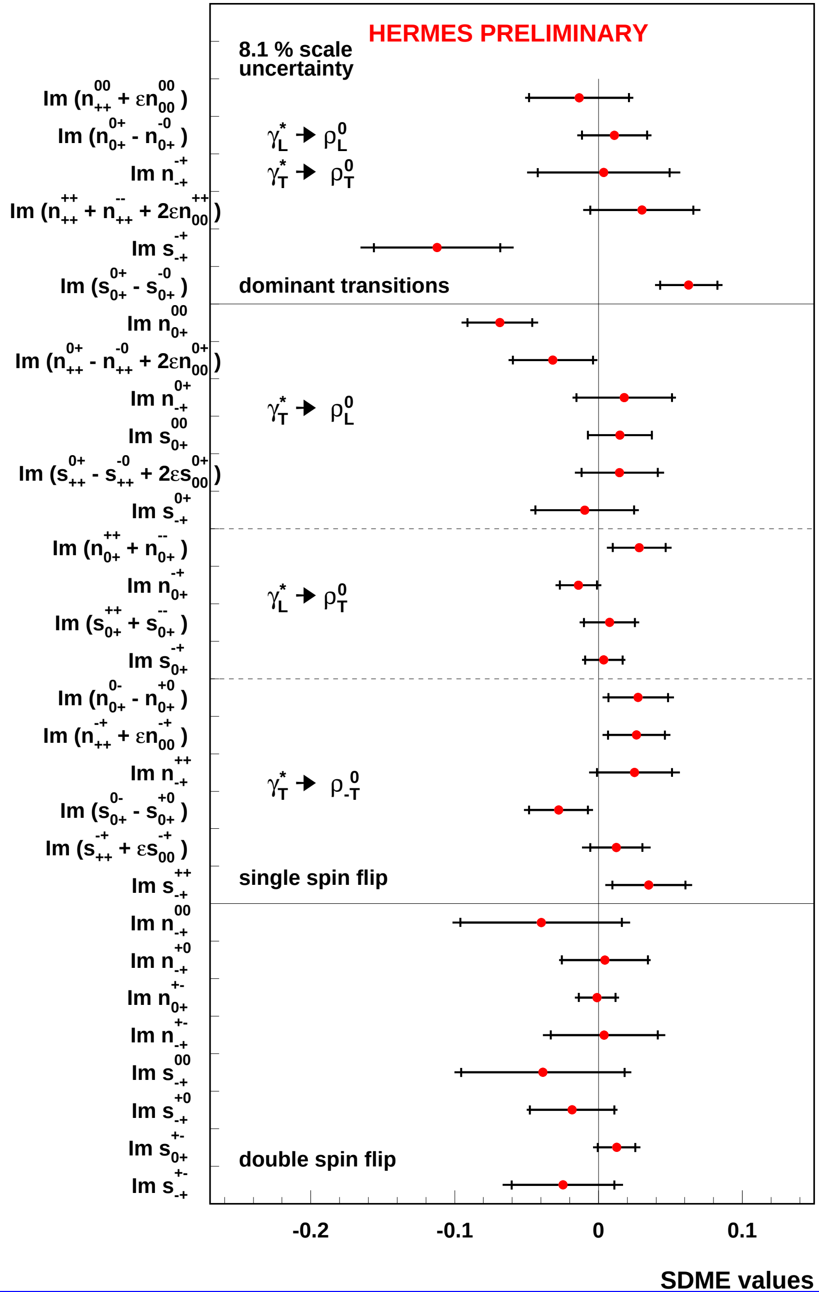
’transverse’ SDMEs

unpolarized SDMEs $u^{\nu\nu'}_{\mu\mu'}$:

- already measured by various experiments
- from HERMES:
  see talk by Wolf-Dieter Nowak

transverse SDMEs $n^{\nu\nu'}_{\mu\mu'}$ and $s^{\nu\nu'}_{\mu\mu'}$:

- measured for the first time
  - average kinematics:
    $\langle -t' \rangle = 0.13$ GeV^2
    $\langle x_B \rangle = 0.09$
    $\langle Q^2 \rangle = 2.0$ GeV^2
- related to the proton helicity-flip amplitude
- suppressed by a factor $\sqrt{-t}/2M_p$



'transverse' SDMEs

$$\rho^{\nu\nu'}_{\mu\mu',\lambda\lambda'} \propto \sum_{\sigma} T^{\nu\sigma}_{\mu\lambda} \left(T^{\nu'\sigma}_{\mu'\lambda'}\right)^*$$

- class I: s-channel helicity conservation

  $$\nu = \mu, \quad \nu' = \mu'$$

  - large unpolarized equivalents $(0.4 - 0.5)$
  - $\mathrm{Im}\left(n^{00}_{++} + \epsilon n^{00}_{00}\right)$: consistent with zero
  - $\mathrm{Im}\, s^{-+}_{-+}$ and $\mathrm{Im}\left(s^{0+}_{0+} - s^{-0}_{0+}\right)$: deviate from 0 by 2.5σ

- class II: single helicity flip

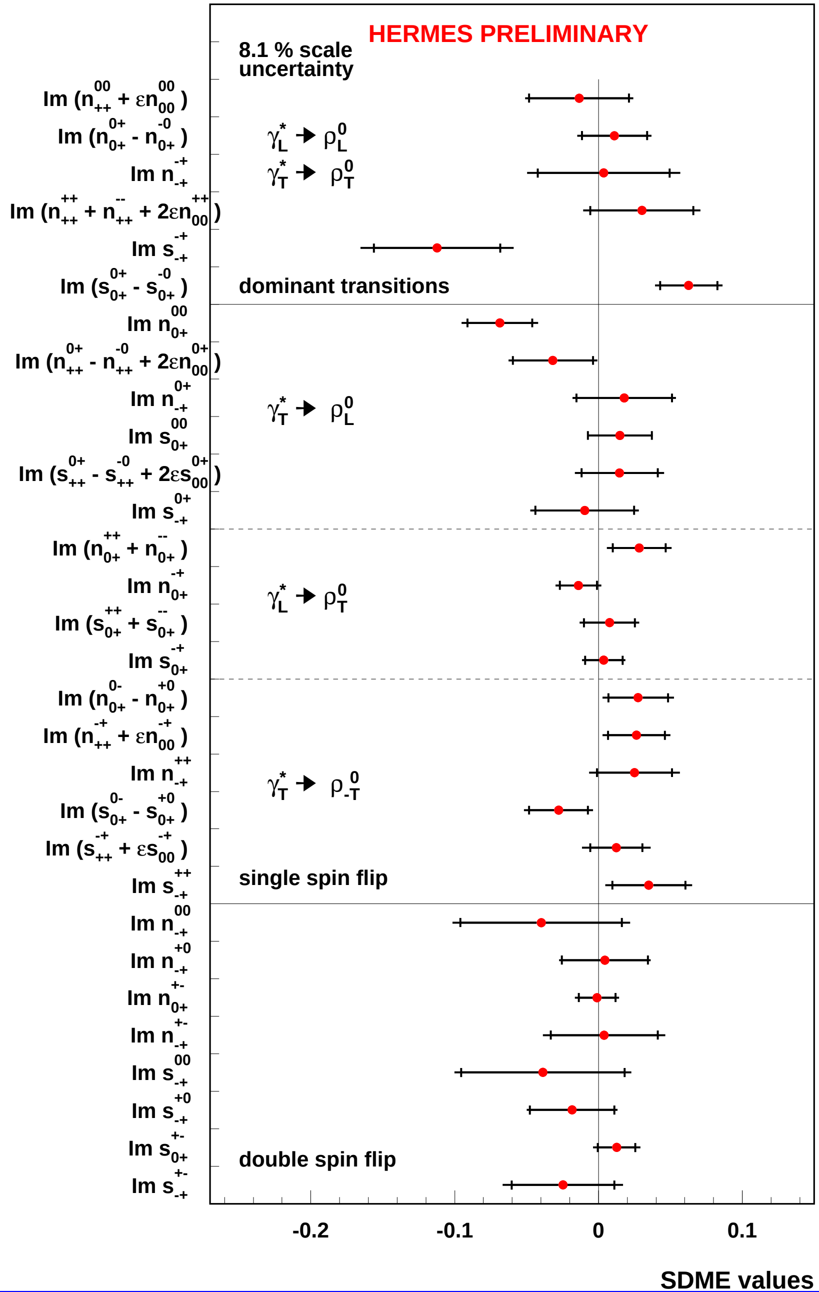
  $$\nu \neq \mu \quad \mathrm{OR} \quad \nu' \neq \mu'$$

  - most of elements consistent with 0
  - $\mathrm{Im}\, n^{00}_{0+}$: 2.5σ deviation from 0
    - polarized equivalent of $\mathrm{Im}\, u^{00}_{0+}$

- class III: double helicity flip

  $$\nu \neq \mu, \quad \nu' \neq \mu'$$

  - no s-channel helicity violation



(un)natural-parity exchange

- natural parity
  - related to GPDs H and E
- unnatural parity
  - related to GPDs $\widetilde{H}$ and $\widetilde{E}$
- UPE amplitudes are expected to be smaller than the NPE amplitudes
- expected $s^{\nu\nu'}_{\mu\mu'} < n^{\nu\nu'}_{\mu\mu'}$ (if identical indices)
- exceptions are not excluded

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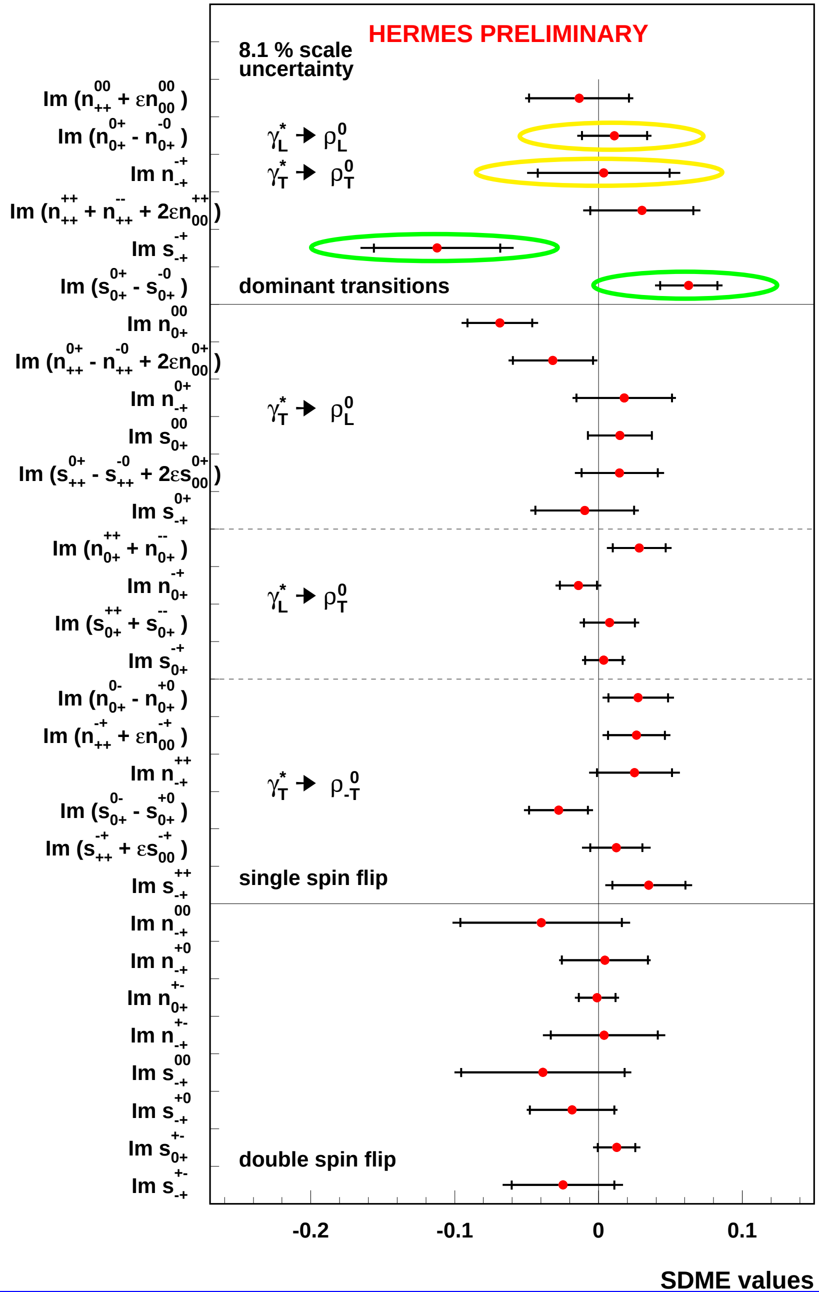
- expected $s^{\nu\nu'}_{\mu\mu'} < n^{\nu\nu'}_{\mu\mu'}$ (if identical indices)
- exceptions are not excluded
- s^{-+}_{-+} and $\mathrm{Im}\, s^{0+}_{0+}$ involve

-Manaenkov (2008)-

  - the biggest NPE amplitudes N^{-+}_{-+} or N^{0+}_{0+}
  - the biggest UPE amplitude U^{++}_{+-}
    - correspond to the pion-exchange in the Regge theory



transverse target-spin asymmetry

- leading transition: $\gamma_L^* \rightarrow \rho_L^0$:

$$A_{UT}^{\gamma^*}(\phi, \phi_s) = \frac{\mathrm{Im}\left(n_{++}^{00} + \epsilon n_{00}^{00}\right)}{u_{++}^{00} + \epsilon u_{00}^{00}}$$

- GPD parameterizations are needed

$$A_{UT} \propto \frac{E}{H} \propto \frac{E^q + E^g}{H^q + H^g}$$

- Goeke, Polyakov, Vanderhaeghen (1999)-

- Ellinghaus, Nowak, Vinnikov, Ye (2004)-

-Goloskokov, Kroll (2007)-

-Diehl, Kugler (2008)-

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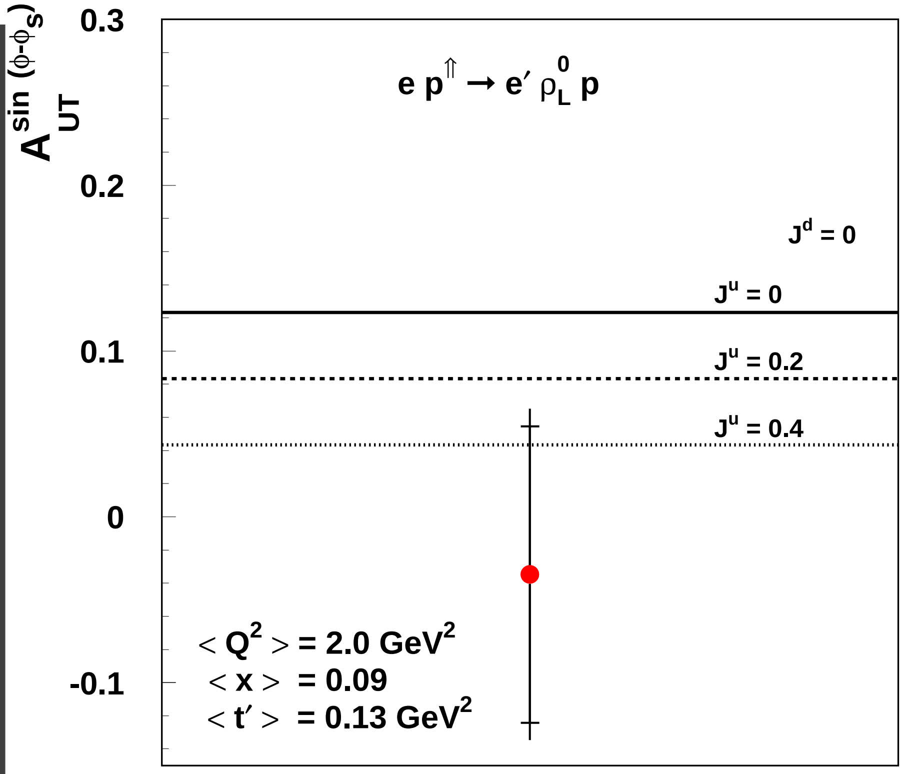
- parameterizations for H^q, $H^{\bar{q}}$, H^g
- E^q is related to the total angular momenta J^u and J^d
  - predictions for $J^d = 0$
- $E^{\bar{q}}$ and E^g are neglected
- data favors positive J^u
  - statistics too low to reliably determine the value of J^u and its uncertainty
- within the statistical uncertainty in agreement with theoretical calculations
  - indication of small E^g and $E^{\bar{q}}$?



overall

transverse target-spin asymmetry

- leading transition: $\gamma^*_L \to \rho^0_L$:

$$A^{\gamma^*}_{UT}(\phi,\phi_s) = \frac{\mathrm{Im}(n^{00}_{++} + \epsilon n^{00}_{00})}{u^{00}_{++} + \epsilon u^{00}_{00}}$$

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$$A_{UT} \propto \frac{E}{H} \propto \frac{E^q + E^g}{H^q + H^g}$$

predictions for mean kinematics larger than the average HERMES kinematics

-Goloskokov, Kroll (2007)-

- power corrections
- $\gamma^*_L \to \rho^0_L$ and $\gamma^*_T \to \rho^0_T$ are considered
- predictions for transverse SDMEs and asymmetries
- can be compared to the HERMES at larger values of Q^2
  - data binned in Q^2, x_B and t' will be published soon

transverse target-spin asymmetry

- leading transition: $\gamma^*_L \to \rho^0_L$:

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-Diehl, Kugler (2008)-

- parameterizations for $H^{q,\bar{q},g}$ and $E^{q,\bar{q},g}$
- asymmetry predictions
- NLO corrections are computed
- large size of the NLO corrections

-Ivanov (2008)-

- another attempt to resume the NLO correction
- small corrections to the LO

summary

waiting for data with higher statistics and theoretical models