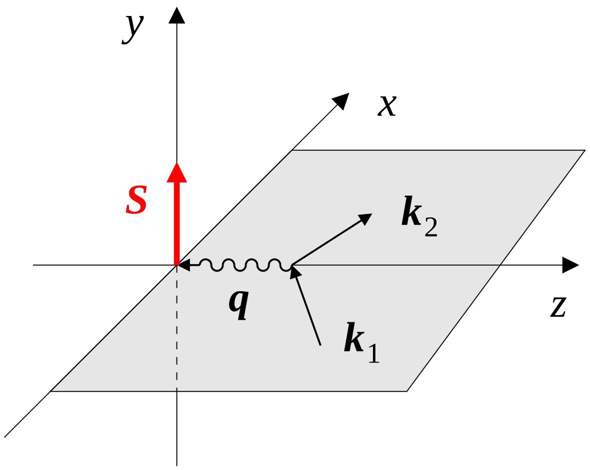
Transversity and spin–orbit correlations in two–photon DIS

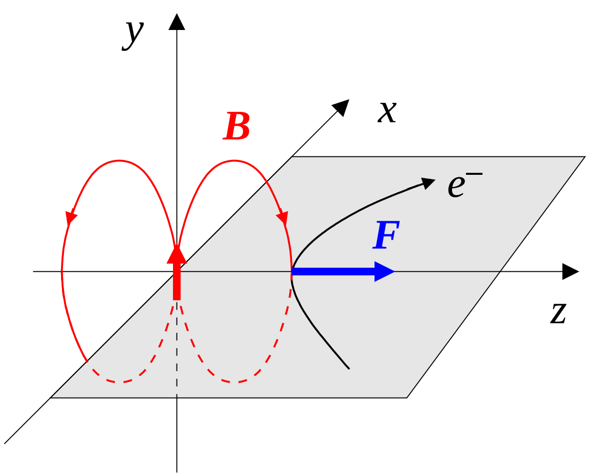
A. Afanasev, M. Strikman, Ch. Weiss
Exclusive Reactions, JLab, May 21–24, 2007

Transverse target single–spin asymmetry in inclusive $e\,N(\uparrow) \longrightarrow e'X$

- "Pure" two–photon exchange effect!
- Probes helicity–flip amplitudes at quark level (h, g_T)
- Approved JLab Hall A experiment PR-07-013 [X. Jiang et al.]
  Sensitivity $\sim 10^{-4}$ cf. SLAC 1970 $\sim 10^{-2}$

Transverse target spin dependence in $eN \to e'X$





- Target spin dependence of cross section

  $\sim \boldsymbol{S} \cdot (\boldsymbol{k}_1 \times \boldsymbol{k}_2)$ "normal spin"

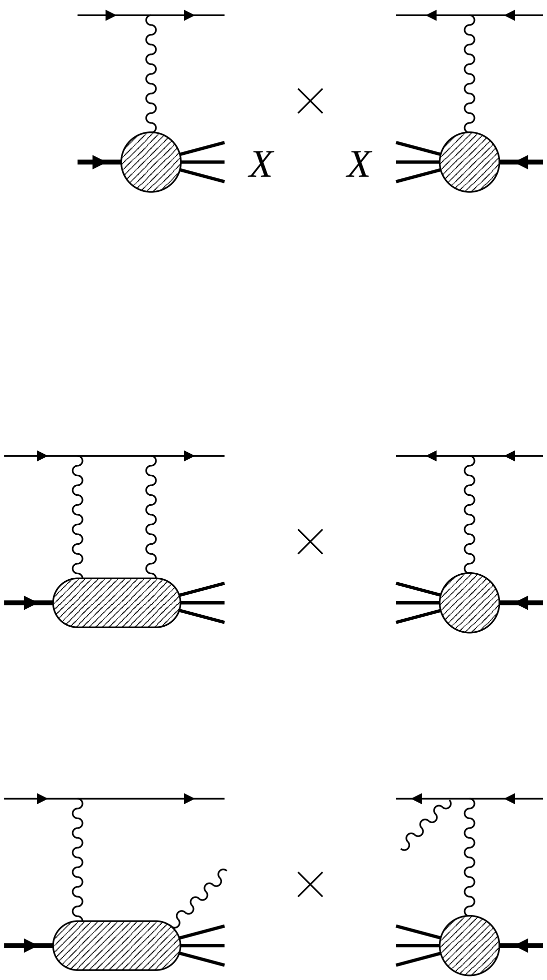
- Relative asymmetry

$$A_y = \frac{\sigma\uparrow - \sigma\downarrow}{\sigma\uparrow + \sigma\downarrow}$$

- Classical analog: Scattering from magnetic dipole (Lorentz force)

  $\to$ Sign, p/n ratio

Spin dependence with two–photon exchange



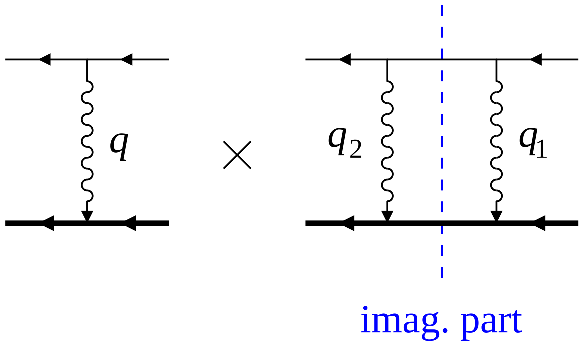
- Transverse spin dependence zero in one–photon exchange [Christ, Lee 66]

$L_{\mu\nu} = L_{\nu\mu}$	leptonic tensor symmetric (unpol. beam)
$W_{\mu\nu}(\boldsymbol{S}) = -W_{\mu\nu}(-\boldsymbol{S})$	hadronic tensor antisymmetric (P, T inv.)

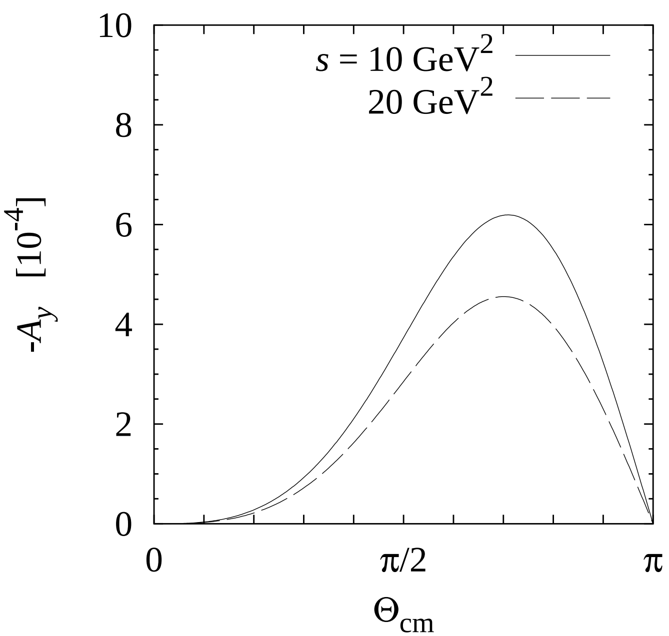
- Nonzero at $O(\alpha^3)$: Two–photon exchange and real emission

- Contributions individually IR-finite
  $\rightarrow$ No cancellations (cf. elastic FF)
  $\rightarrow$ Clean two-photon exchange effect

Example: Pointlike target [Barut, Fronsdal 60; . . .]

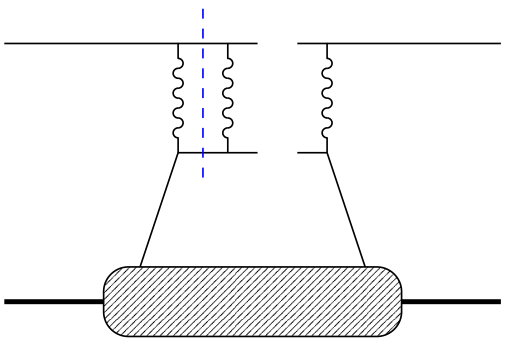


$$A_y = \frac{\alpha M}{\sqrt{s}} f(\Theta_{\rm cm}) \qquad (\Theta_{\rm cm} \leftrightarrow Q^2/s)$$



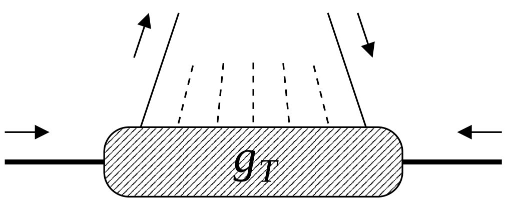
- Only imaginary part of two–photon exchange enters; no IR divergences
- Photon virtualities $-q_1^2, q_2^2 \sim Q^2$
- Include strong interactions: No QED collinear divergences thanks to gauge invariance [Afanasev, Strikman, CW 07]

Transverse spin dependence in QCD

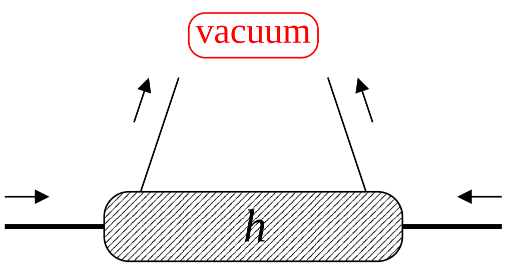


- Dominance of scattering from same quark (no “anomalous” IR/collinear enhancement)

- Two contributions



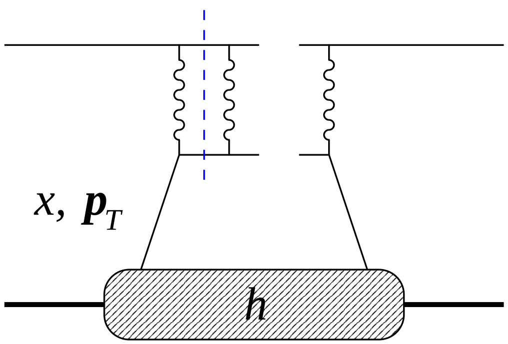
I) Quark helicity non-flip and interactions w. spectators
[Goeke, Metz, Schlegel 06 . . . gauge invariance!]



II) Quark helicity flip by interaction with vacuum fields: Chiral symmetry breaking

No Sudakov suppression if
IR cutoff $\sim \mu^2$(chiral) $\gg \Lambda^2_{\mathrm{QCD}}$

Composite nucleon approximation [ASW 06/07]

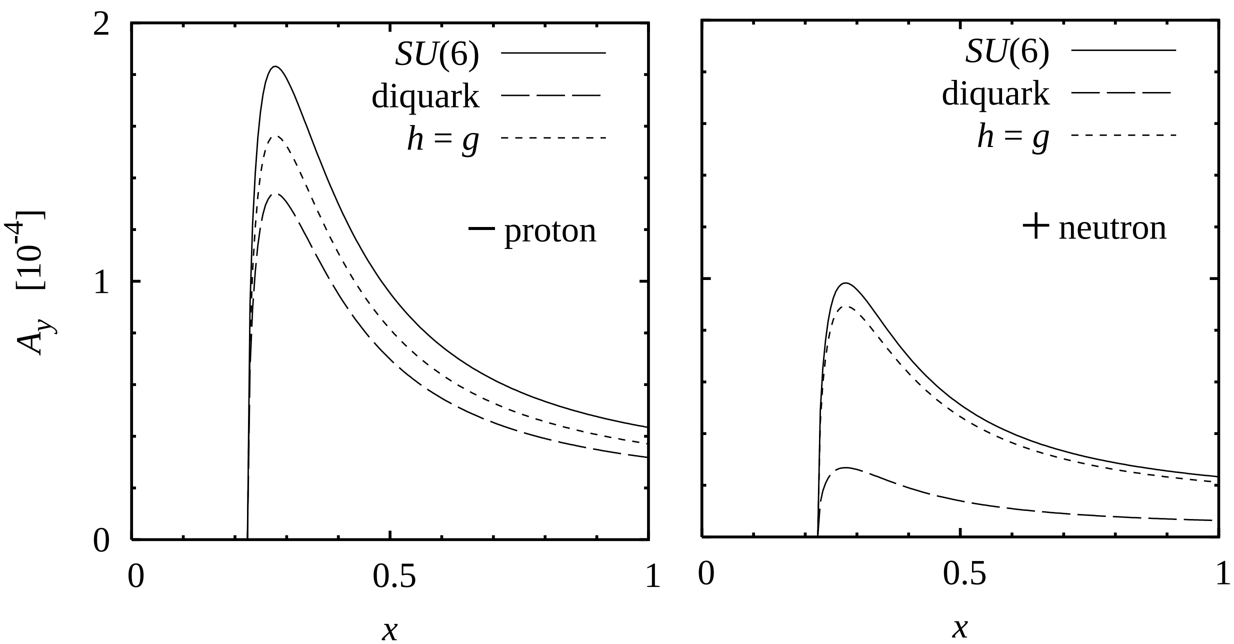


- Assume "composite" nucleon

$$R_N^{-2} \sim \langle p_T^2 \rangle \ll M_q^2$$

$\rightarrow$ Quark helicity flip dominates!

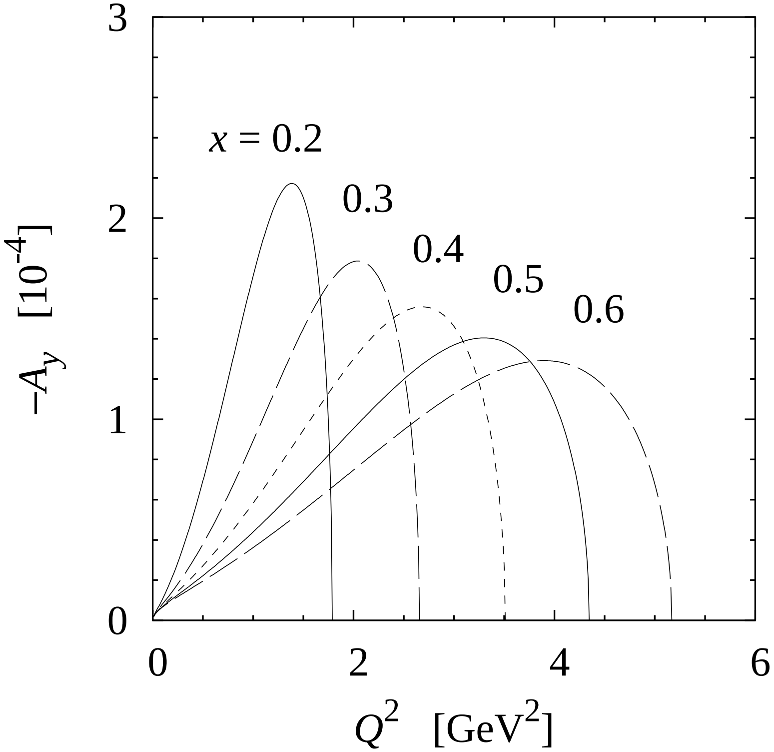
$\rightarrow$ Light–front constituent quark model [cf. Miller 02]

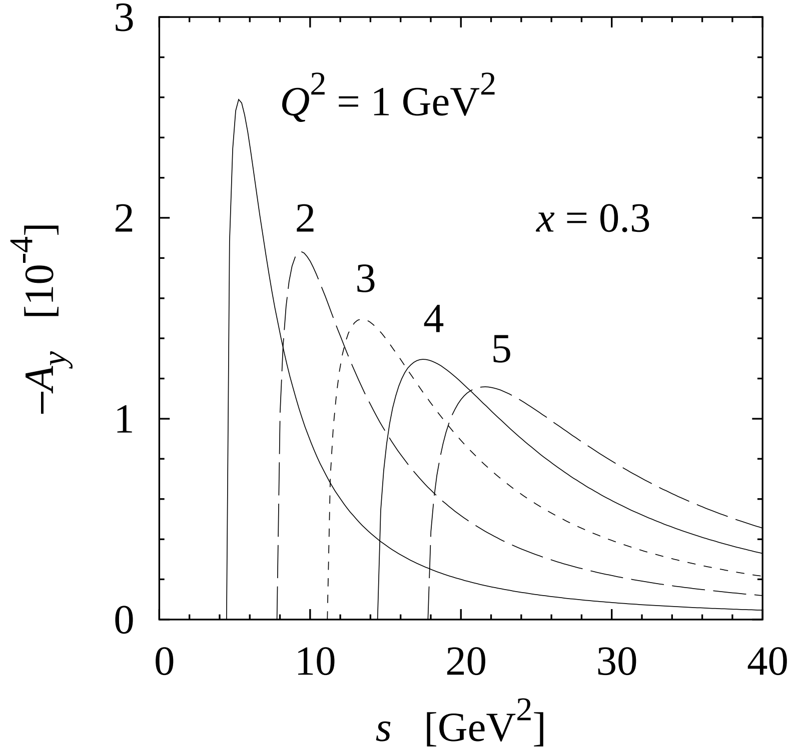


$$A_y = \frac{\sum e_q^3 \, h_q(x)}{\sum e_q^2 \, f_q(x)} \times A_y(\text{quark})$$

[$\propto M_q \approx 300\,\text{MeV}$]

Predictions for kinematic dependences





$s = 10\,\mathrm{GeV}^2$ [JLab 6 GeV]

- Asymmetry vanishes in high–energy limit $A_y \sim s^{-2} \quad (s \gg Q^2)$
  cf. photon polarizations in 2γ box [Gribov, Lipatov, Frolov 70]

Summary

- Very interesting/challenging problem!
  - Higher–order QED corrections
  - QCD factorization
  - Vacuum structure

- “Cleanest” two–photon exchange observable
  - IR finite — no IR cancellations with real emission
  - How large are finite contributions from real emission?

- Probes helicity–flip amplitudes at quark level
  - Composite Nucleon Approximation $\rightarrow h(x)$ transversity
  - How large are helicity–conserving contributions?