Spin-Orbit Dynamics from the Gluon Asymmetry

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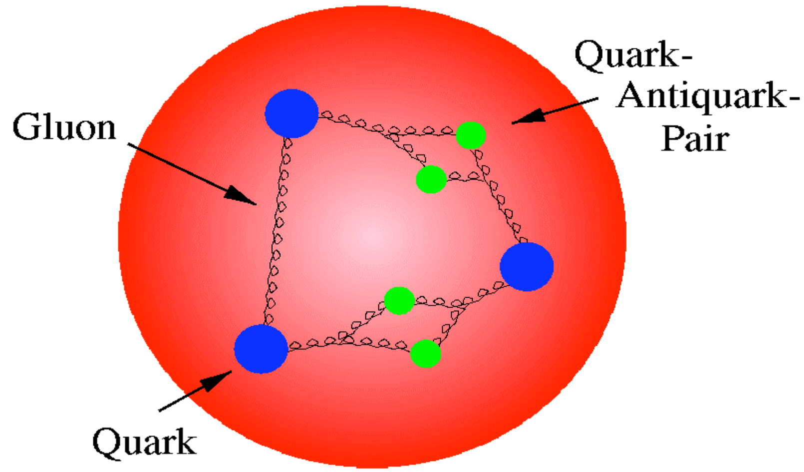
Outline

1. Proton structure status
2. Modeling the gluon asymmetry

   Physical constraints

   DGLAP evolution
3. LO results
4. NLO results
5. Implications for orbital dynamics

Proton Structure



- Quark spin (helicity) $\Delta\Sigma \approx 0.30 \pm 0.03$
- Transverse components $\Delta_T\Sigma$
- Gluon spin ΔG
- Orbital motion L_z (quark and gluon)
- J_z sum rule: $1/2 = \Sigma/2 + \Delta G + L_z$

Definitions

Gluon asymmetry: $A(x,t) \equiv \Delta G/G$

$t \equiv \ln[\alpha_s^{LO}(Q_0^2)]/\ln[\alpha_s^{LO}(Q^2)]$

Split A into t-dependent and t-independent parts:

$$A(x,t) = A_0(x) + \varepsilon(x,t)$$

where $A_0(x) \equiv [\partial \Delta G/\partial t]/[\partial G/\partial t]$ is calculable via DGLAP. Thus,

$\Delta G(x,t) = A_0(x) \bullet G + \Delta G_\varepsilon$

Calculating the asymmetry

Choose a suitable model for ΔG_ε and use the definition of $A_0(x)$ to determine the asymmetry.

$$A_0 = [\Delta P_{Gq} \otimes \Delta q + \Delta P_{GG} \otimes (A_0(x) \bullet G + \Delta G_\varepsilon)] / [P_{Gq} \otimes q + P_{GG} \otimes G]$$

Due to zeros in the denominator, the equation is transformed into.

$$A_0[P_{Gq} \otimes q + P_{GG} \otimes G] - \Delta P_{GG} \otimes [A_0(x) \bullet G] = [\Delta P_{Gq} \otimes \Delta q + \Delta P_{GG} \otimes (\Delta G_\varepsilon)]$$

Modeling the gluon asymmetry

Generate Ansätze for ΔG_ε:

$$-0.25 \leq \int_0^1 \Delta G_\varepsilon dx \leq 0.25$$

Physical constraints on A_0

- Endpoints: $A_0(0) = 0$, $A_0(1) = 1$
- Positivity: $A_0(x) \leq 1$ (all x)
- Monotonicity

To satisfy these assume A_0 has the form

$$A_0 \equiv Ax^\alpha - (B - 1)x^\beta + (B - A)x^{\beta+1}$$

Distributions used to calculate A_0

- Unpolarized q(x) and G(x) are CTEQ5 and CTEQ6
- Polarized $\Delta q(x)$ modified GGR distributions
- $Q_0^2 = 1.0\ GeV^2$ - approximately the scale of chiral symmetry breaking
- ΔG_ε models are polynomials in x that integrate to less than unity.

NLO asymmetry calculation

Similar to the LO asymmetry,

$A_0 = [P_{Gq}^{NLO} \otimes q + P_{GG}^{NLO} \otimes G] - \Delta P_{GG}^{NLO} \otimes [A_0(x) \bullet G]$

$= [\Delta P_{Gq}^{NLO} \otimes \Delta q + \Delta P_{GG}^{NLO} \otimes (\Delta G_\varepsilon)]$

Use NLO DGLAP to develop A_0^{NLO}

Then: $\Delta G(x,t) = A_0(x) \bullet G + \Delta G_\varepsilon$

for each model of ΔG_ε

Use $J_z = 1/2$ sum rule to determine nature of orbital components

Nature of L_z^{Total}

Start with J_z sum rule:

$$1/2 = \Sigma/2 + \Delta G + L_z$$

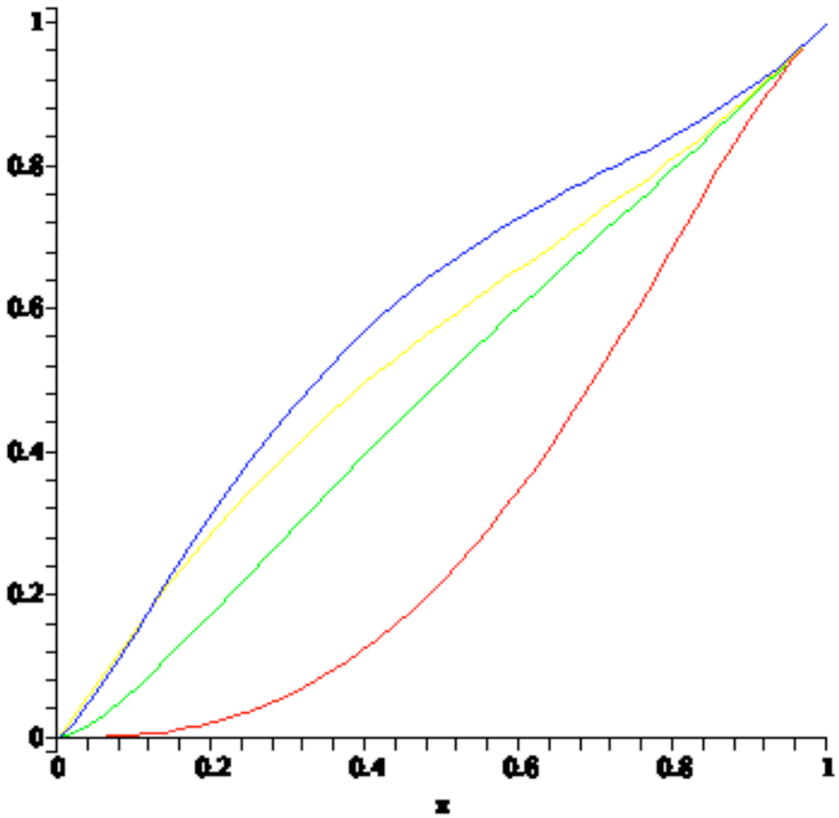
$$\approx 0.15 + (A_0(x)\bullet G + \Delta G_\varepsilon) + L_z$$

$$\Rightarrow L_z \approx 0.35 - <(A_0(x)\bullet G + \Delta G_\varepsilon)>$$

Evolution:

$$\partial L_z/\partial t \approx - A_0(x)\ [\partial G/\partial t] \text{ at LO \& NLO}$$

Asymmetry models at LO



Key to plots

Blue

$\Delta G_{\varepsilon} = -90x^2(1-x)^7$

$<\Delta G> = 0.05$

Yellow

$\Delta G_{\varepsilon} = -4.5x(1-x)^7$

$<\Delta G> = 0.23$

Green

$\Delta G_{\varepsilon} = 2(1-x)^7$

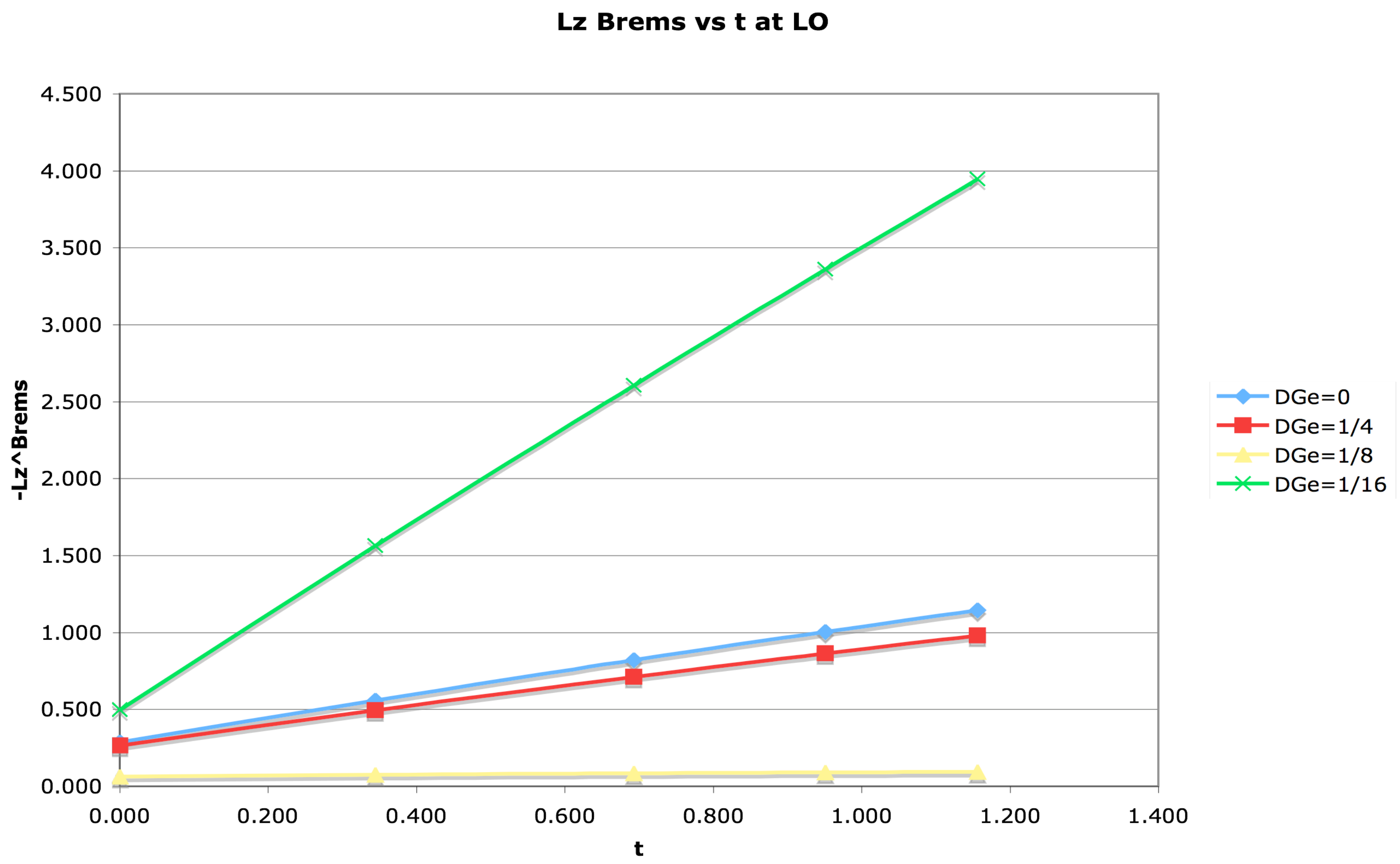
$<\Delta G> = 0.42$

Red

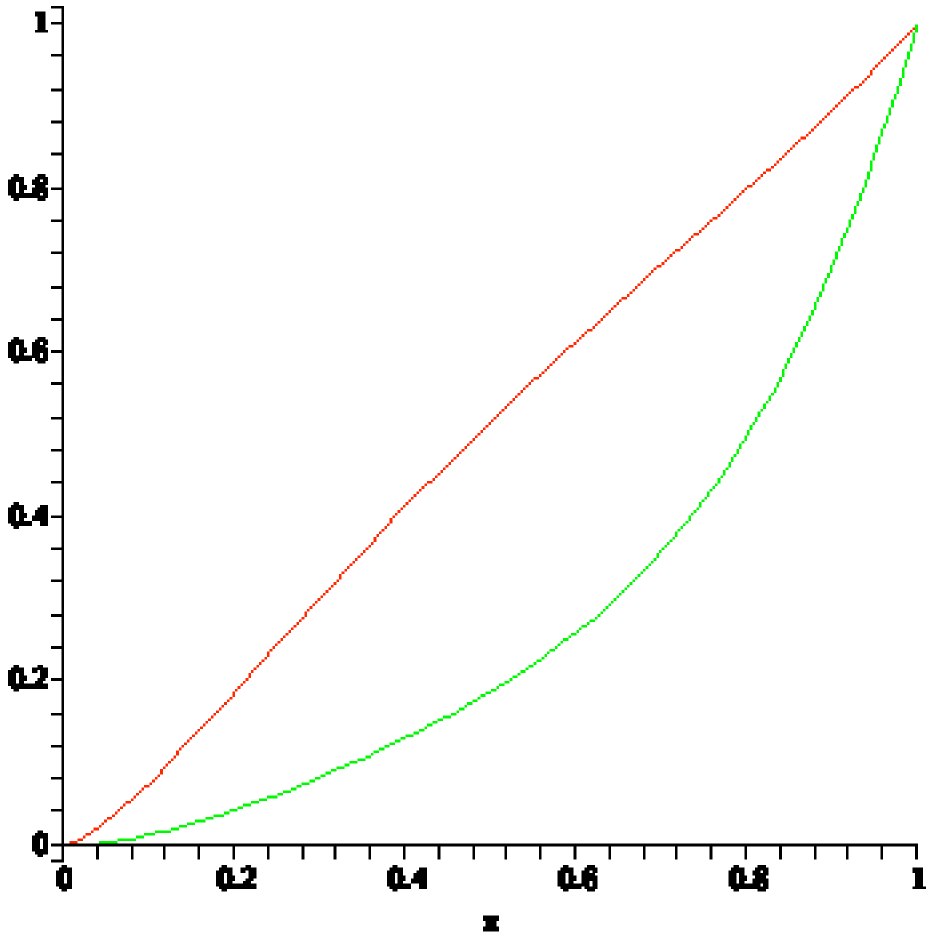
$\Delta G_{\varepsilon} = 0$

$<\Delta G> = 0.03$

Evolution of L_z with t at LO



Asymmetry models at NLO

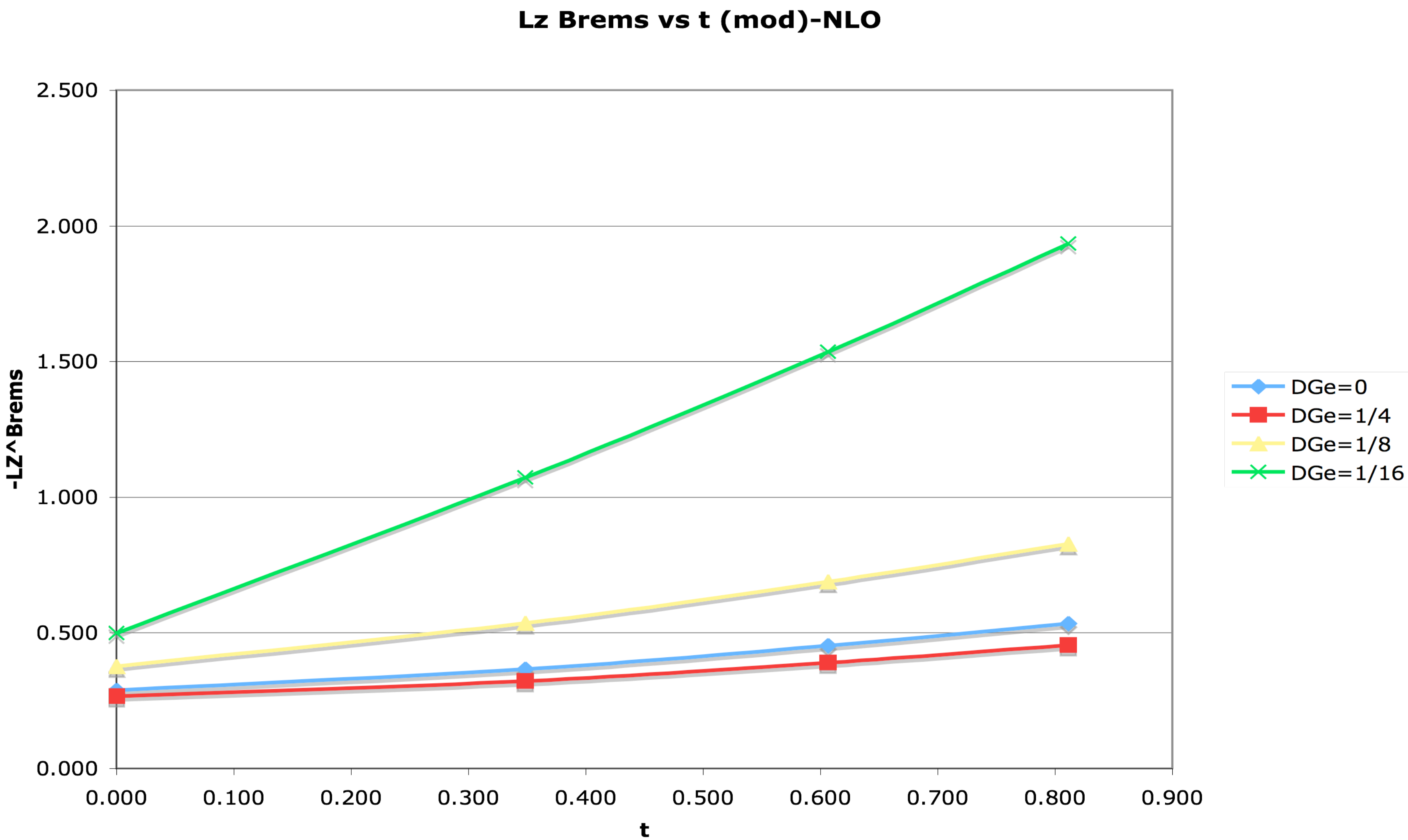


Red - LO
$\Delta G_{\varepsilon} = 0$

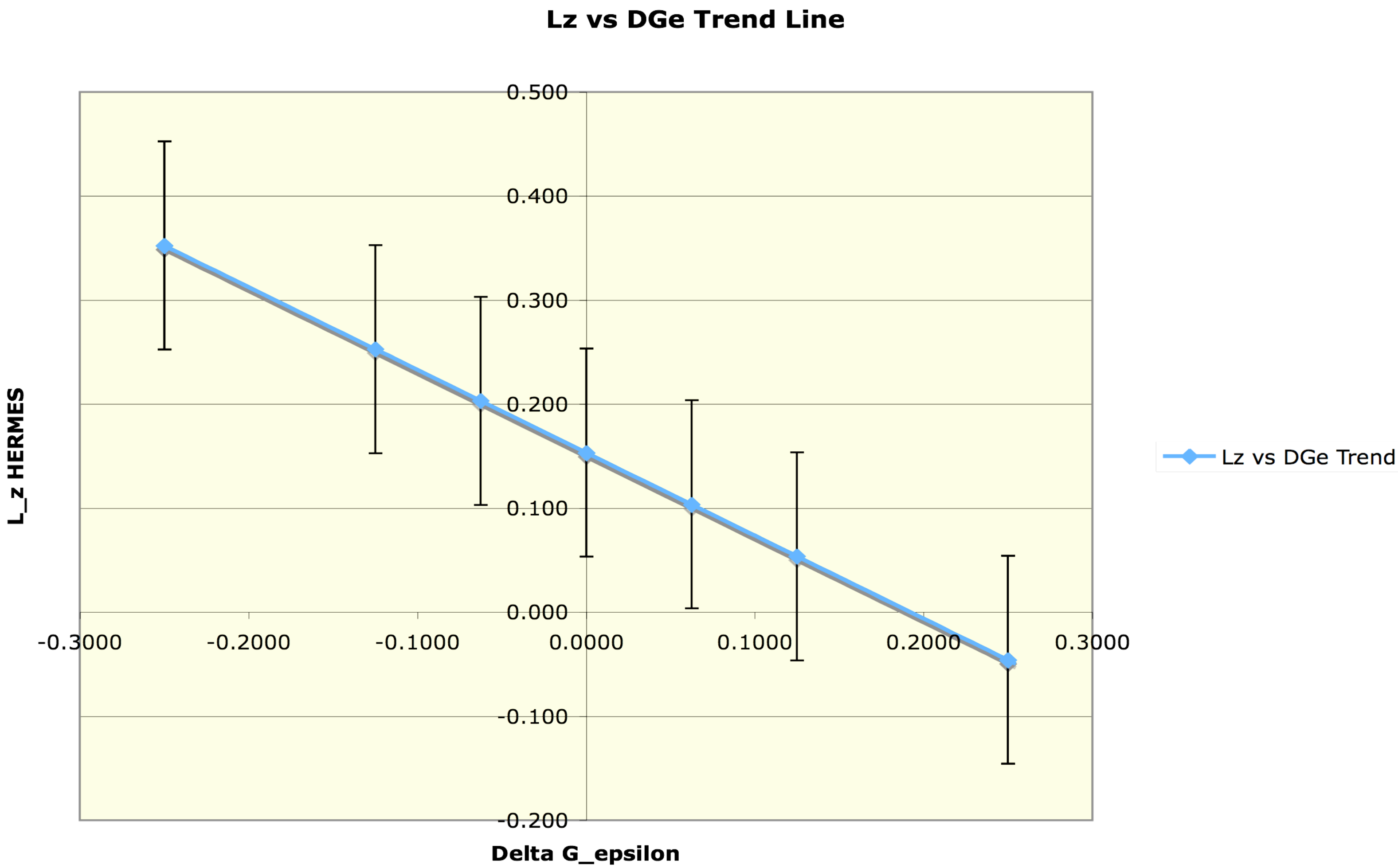
Green - NLO
$\Delta G_{\varepsilon} = 0$

Similarly for other models

Evolution of L_z with t at NLO



L_z as a function of $<\Delta G_\varepsilon>$



Constraints as a function of ΔG_ε

The range of A_0 is near linear in x and satisfies all physical constraints.

The models of ΔG_ε giving these asymmetries leads to constraints on ΔG and L_z

Values of ΔG_ε satisfying physical constraints:

$$-0.25 \leq \Delta G_\varepsilon \leq 0.25$$

Constraint on ΔG:

$$-0.15 \leq \int_0^1 \Delta G \, dx \leq 0.42$$

Constraint on L_z:

$$-0.10 \leq L_z \leq 0.50$$

Phenomemology

- Lattice results on L_z – hep-lat/0509100 - L_q consistent with zero.
- Measurements of $\Delta G/G$ over a wider kinematic range of x and Q^2 [find $\varepsilon(x,t)$]
- Determine $\Delta G(x,t)$ - large kinematic range
- Role of transversity measurements – flavor dependence of L_z & B-M functions

Conclusions

1. The asymmetry models hover around a certain range around the line $A_0 = x$ with more positive $<\Delta G_\varepsilon>$ being less than or approximately equal to $A_0 = x$ and negative $<\Delta G_\varepsilon>$ being greater than $A_0 = x$ L_z^{Brems} LO evolution increases almost linearly in absolute value
2. A_0 linear gives larger values of $<\Delta G>$

Conclusions continued

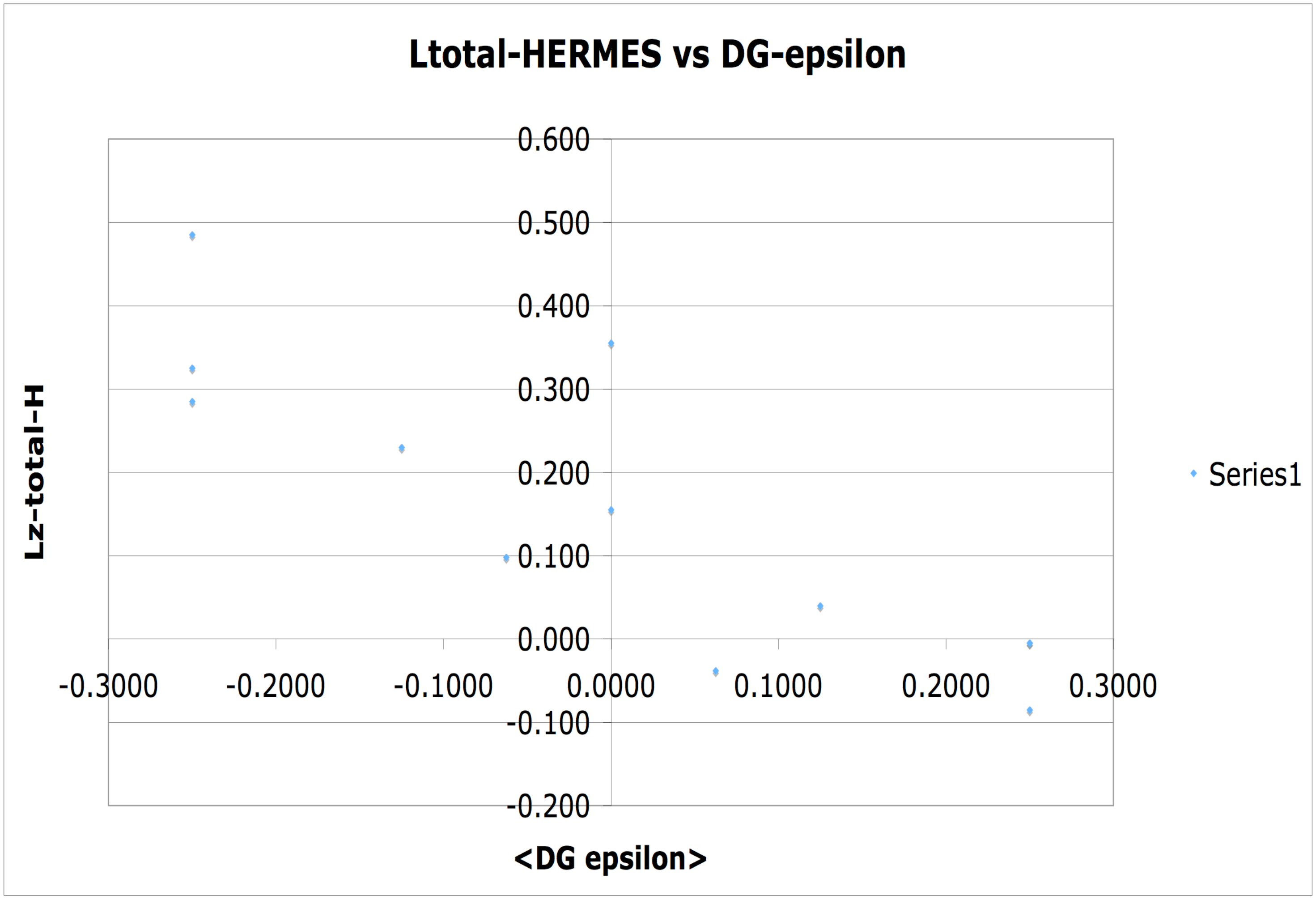
3. <ΔG> roughly increases with ΔG_ε the trend being linear, including sign L_z^{Brems} NLO evolution increases less, but still linear in t
4. There is a trend that L_z is more negative with negative ΔG_ε
5. $L^{total}_{HERMES} \approx -0.80 \langle \Delta G_\varepsilon \rangle +0.15$ and $L^{total}_{COMPASS} \approx -0.80 \langle \Delta G_\varepsilon \rangle +0.18$
6. The angular momentum L_z tends to be more positive and less than 0.5 in absolute value, as does ΔG

Final conclusion

7. Measurements of ΔG/G (extrension of present experiments) and ΔG alone (jet production and prompt photon production) over a wide kinematic range is important
8. Determining transversity properties of the proton can add additional valuable information on the orbital angular momentum of its constituents.

End of talk

Extra slide follows



Ltotal-HERMES vs DG-epsilon
Lz-total-H
<DG epsilon>
0.600
0.500
0.400
0.300
0.200
0.100
0.000
-0.100
-0.200
-0.3000
-0.2000
-0.1000
0.0000
0.1000
0.2000
0.3000
Series1