The Spin Dependent Structure Function of Nucleon in the Meson Cloud Model

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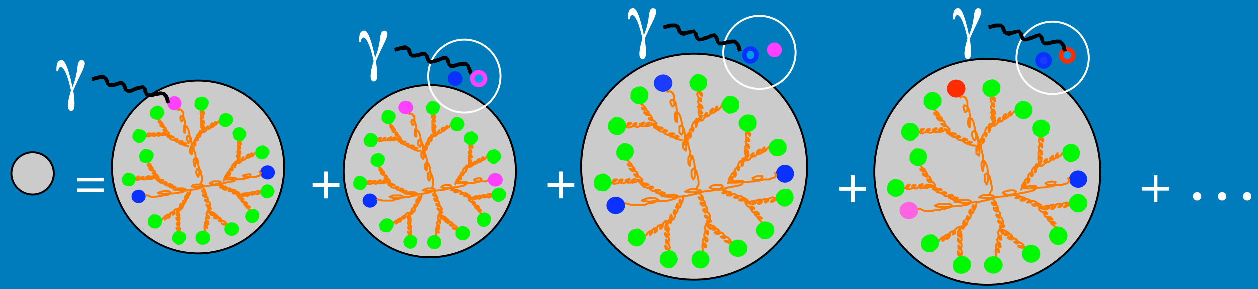
Overview

- Meson cloud model
- Meson cloud contributions to spin structure functions
- Conclusion

Meson Cloud Model

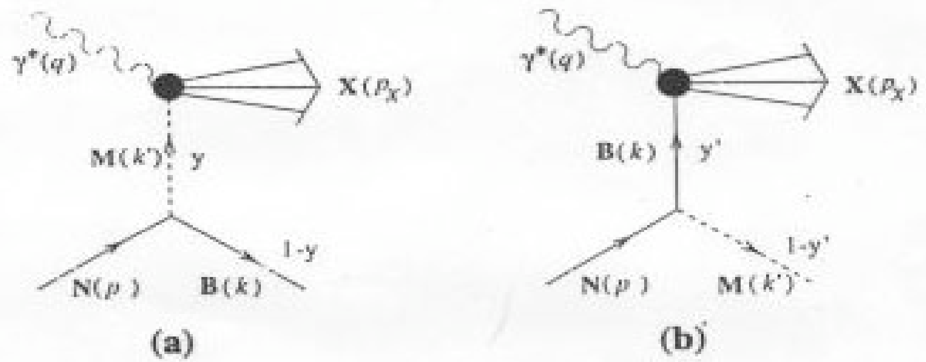


- Fock expansion of proton wavefunction.

$$|p\rangle_{\text{phys}} = \sqrt{Z}|p\rangle_{\text{bare}} + \sum_{BM} \int dy\, dk_{\perp}^2\, \phi_{BM}(y, k_{\perp}^2)|B; M\rangle$$

  - Bare states are SU(6) symmetric
  - *p* → *BM* vertices described by L_{int} plus form factor
  - FF constrained by elastic cross-sec
  - Quick convergence ⇔ Small prob. of high mass states
- Model incorporates structure + interactions
- Can investigate high-energy ⇔ low-energy pictures, symmetry breaking etc.

Meson Cloud Model



DIS from the virtual (a) meson, and (b) baryon components of a physical nucleon.

Crucial observation (Sullivan 72) -

Pion cloud contribution to DIS scales

Implies quark dists of proton modified

Convolution

$$\delta q^p(x) = \int_x^1 \frac{dy}{y} f_{p\pi}(y) q^\pi(\frac{x}{y})$$

- Observed PDF: $q_{phys} = q_{bare} + \delta\, q^{B(M)}$

Flavour asymmetry in the unpolarized nucleon sea

- Gottfried sum rule

$$S_G = \int_0^1 \left(F_2^p - F_2^n\right)\Big/x\,dx$$
$$= \frac{1}{3}\int_0^1 [u_v(x) - d_v(x)]\,dx + \frac{2}{3}\int_0^1 [\bar{u}(x) - \bar{d}(x)]\,dx$$

- Experimental studies

→ NMC (DIS, CERN, 1991) $S_G = 0.235 \pm 0.026\ (Q^2 = 4GeV^2)$

→ NA51 (DY, CERN, 1994) $\bar{d}/\bar{u} = 1.96 \pm 0.15 \pm 0.19\ at\ \langle x \rangle = 0.18$

→ HERMES (SIDIS,DESY,1998)

$$(\bar{d} - \bar{u})\Big/(u - d), 0.02 < x < 0.3, \langle Q^2 \rangle = 2.3GeV^2$$

→ E866 (DY, Fermilab, 1998&2001)

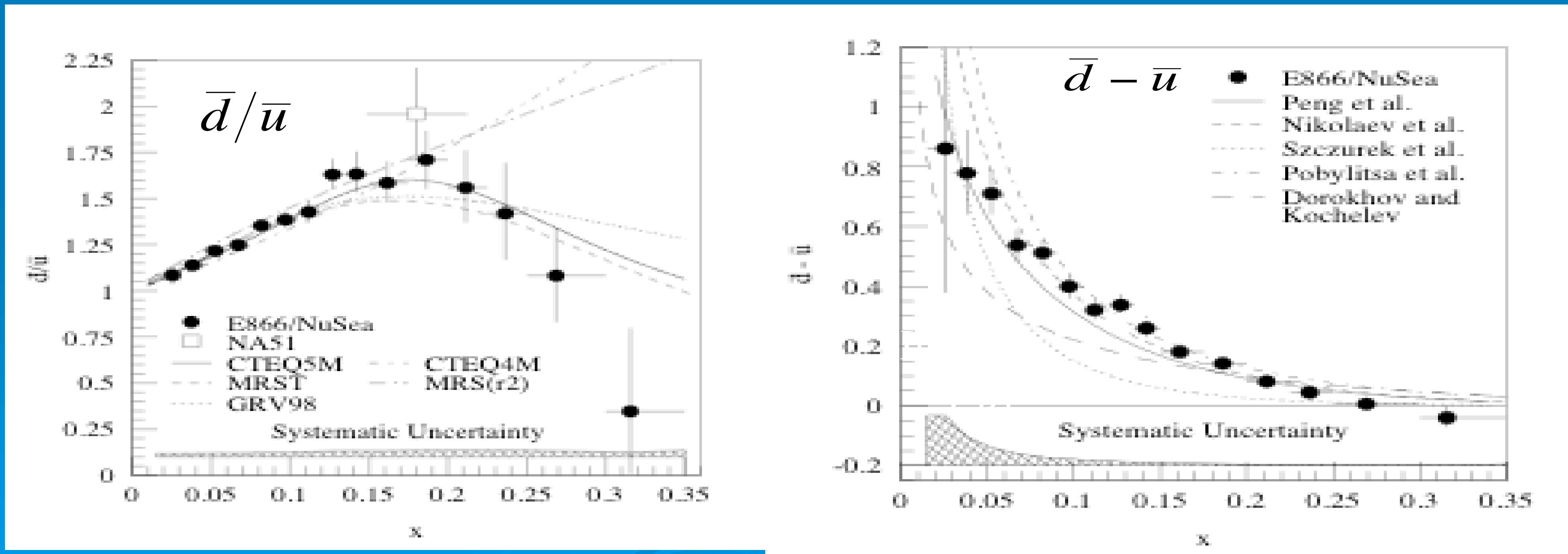
$$\bar{d}/\bar{u}, 0.015 < x < 0.35, \langle Q^2 \rangle = 54GeV^2$$

Flavour asymmetry in the unpolarized nucleon sea

- Isospin broken in sea

$$p \rightarrow n(udd) + \pi^{+}(u\bar{d})$$
$$p \rightarrow \Delta^{++}(uuu) + \pi^{-}(d\bar{u})$$

- MCM gives good fit to $\bar{d}(x) - \bar{u}(x)$



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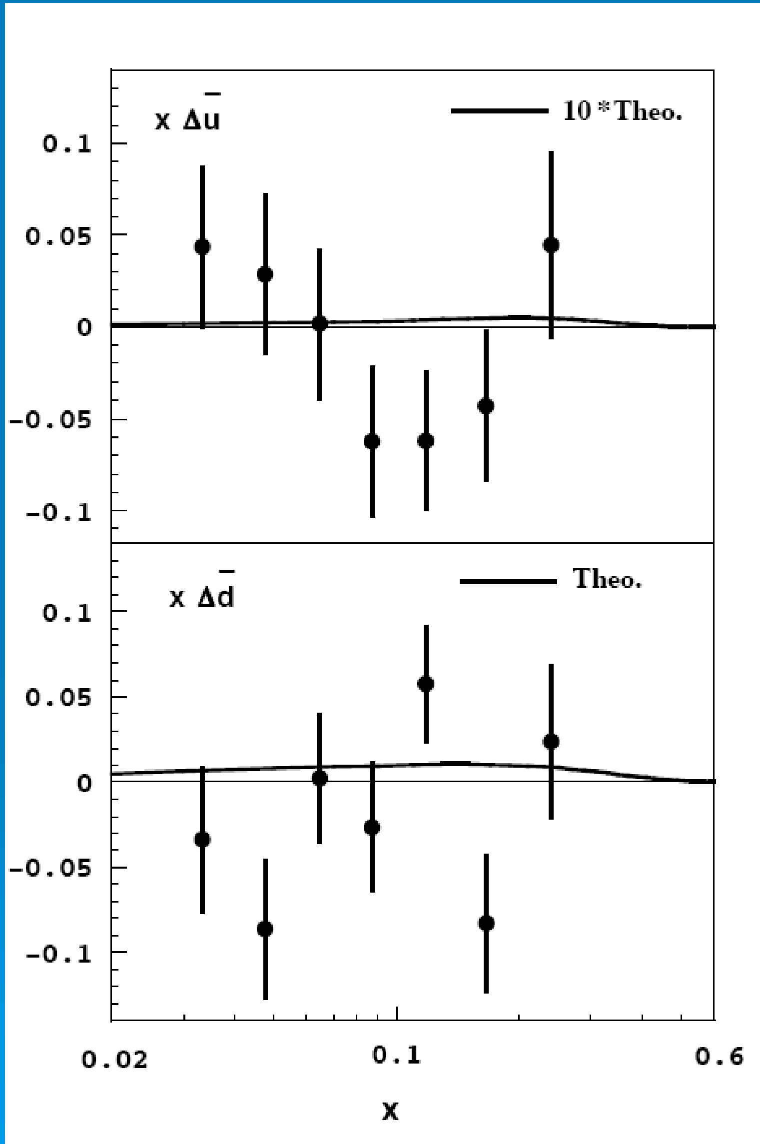
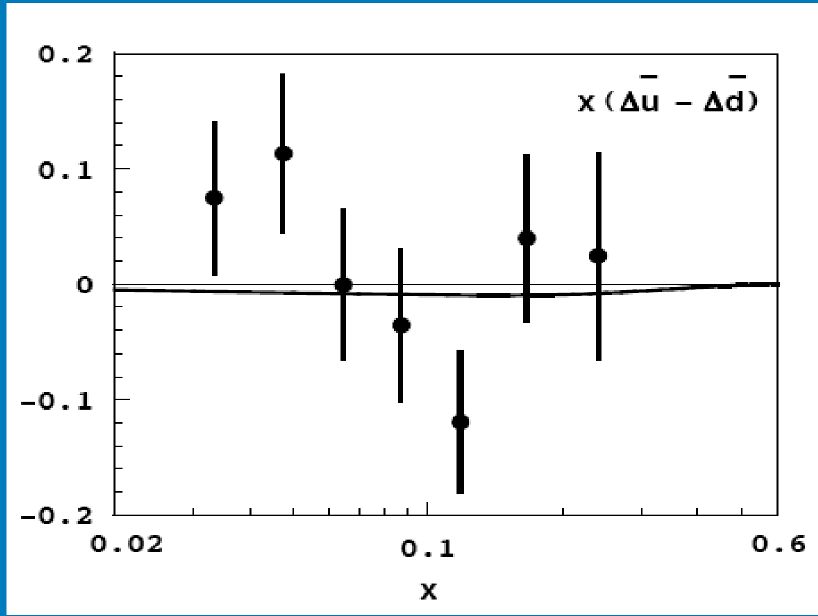
Spin dependent Quark Dists.

- Extend MCM to include vector mesons
  - π cloud dilutes proton spin
  - ρ, ω, K^* able to carry spin
- Interference terms ?
- Get reasonably good agreement with HERMES semi-inclusive data for sea distributions

Spin Dependent Sea Dists.





- Data from Hermes
- Small symmetry breaking

Spin Dependent Structure Functions

- Dominated by valence distributions
  - $N \rightarrow N\pi$, $N \rightarrow \Delta\pi$ most important fluctuations

$$\mathcal{L}_{int} = i g_{NN\pi} \bar{\psi} \gamma_5 \pi \psi, \quad f_{N\Delta\pi} \bar{\psi} \pi \partial_\mu \chi^\mu + \text{h.c.}$$

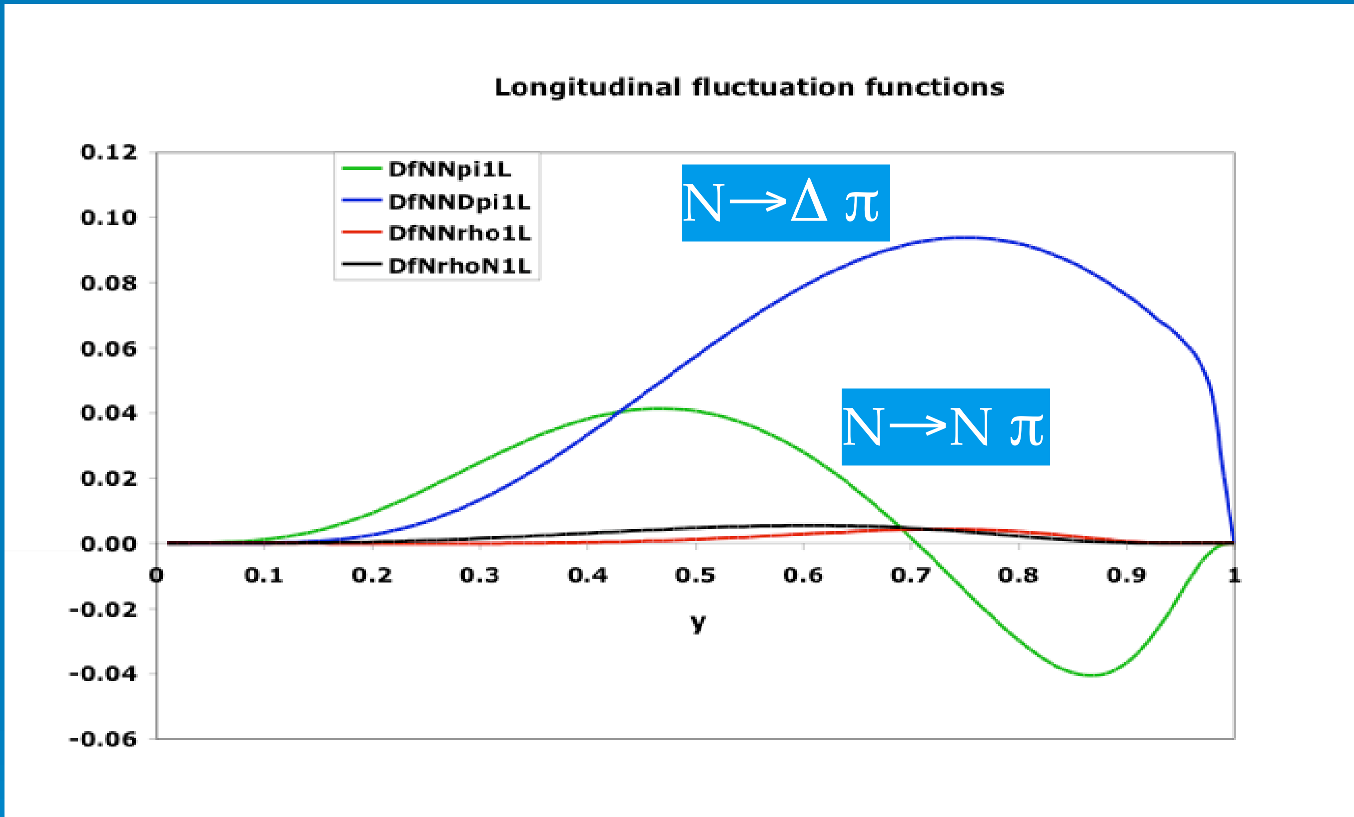
- At finite Q^2 spin of cloud hadrons are not parallel with initial nucleon spin
- Both longitudinal and transverse spin components of cloud contribute to observed structure functions

Spin Dependent Structure Functions

$$\begin{aligned}\delta g_1(x,Q^2) &= \frac{1}{1+\gamma^2}\int_x^1 \frac{dy}{y}\Big([\Delta f_{1L}(y)+\Delta f_{1T}(y)]g_1^B(\frac{x}{y},Q^2)\\ &\quad +[\Delta f_{2L}(y)+\Delta f_{2T}(y)]g_2^B(\frac{x}{y},Q^2)\Big)\\ \delta g_2(x,Q^2) &= -\frac{1}{1+\gamma^2}\int_x^1 \frac{dy}{y}\Big([\Delta f_{1L}(y)-\Delta f_{1T}(y)/\gamma^2]g_1^B(\frac{x}{y},Q^2)\\ &\quad -[\Delta f_{2L}(y)-\Delta f_{2T}(y)/\gamma^2]g_2^B(\frac{x}{y},Q^2)\Big)\end{aligned}$$

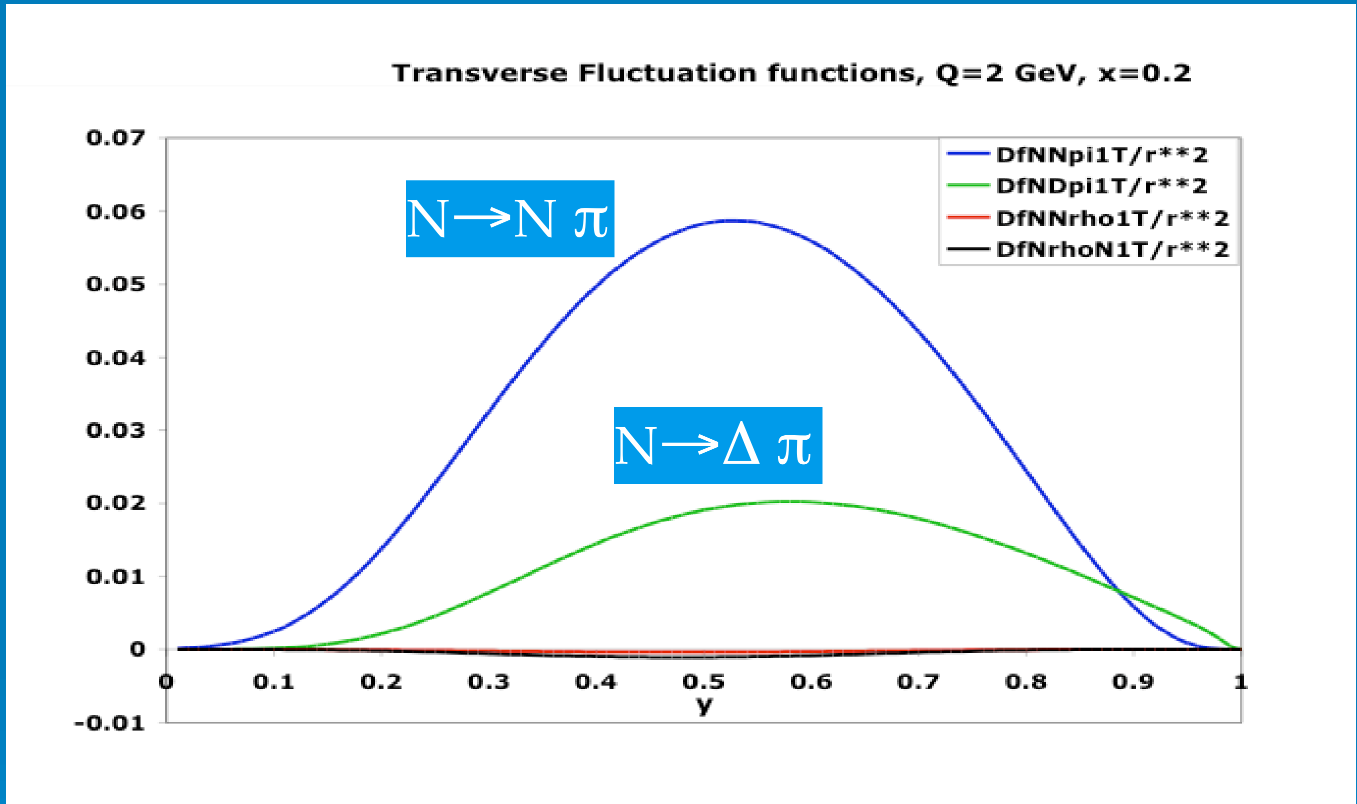
$$\gamma^2 = \frac{4x^2 m_N^2}{Q^2}$$

Spin Dependent Fluctuations



- Long. fluctuations require both N and Δ
  - s = 3/2 state important

Spin Dependent Fluctuations



- N is more important for transverse fluct.
  - n.b $\gamma \approx 0.19$

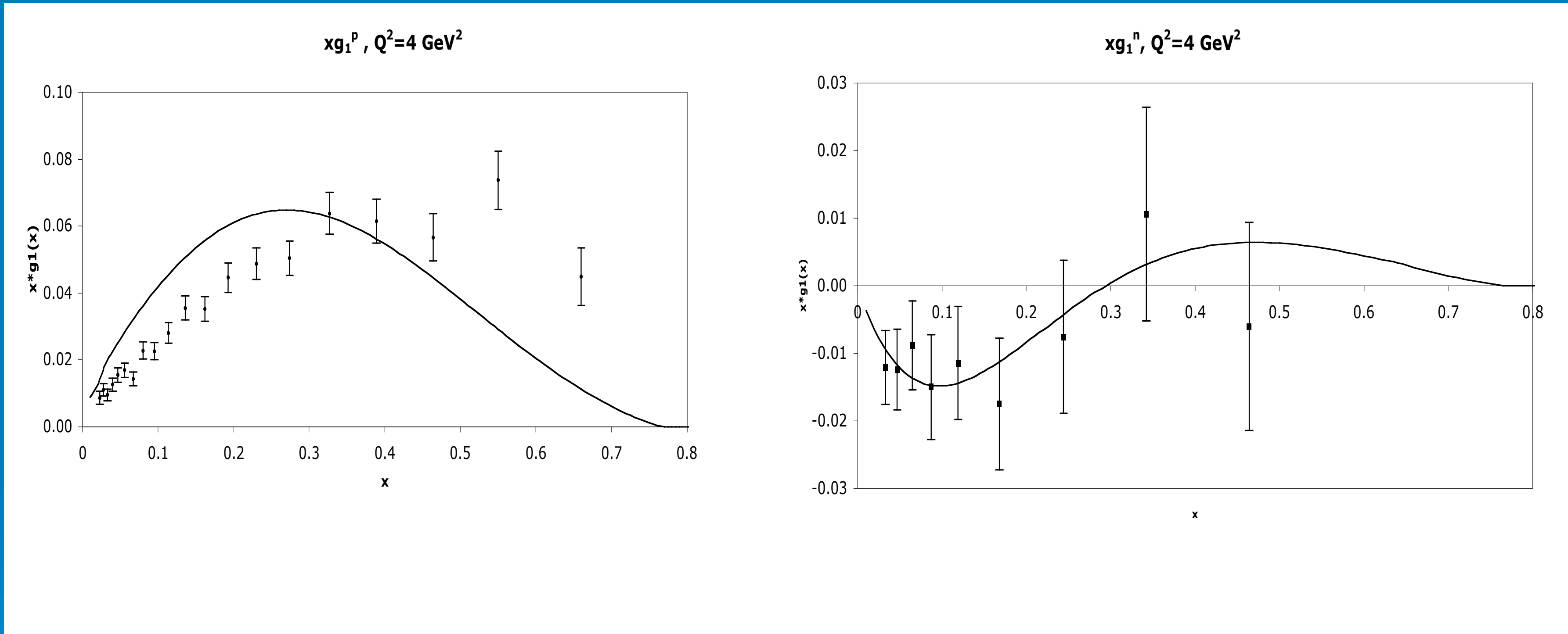
'Bare' Hadron SFs

- Use bag model for N, Δ parton dists
  - Add Δg(x) 'by hand'
  - Hyperfine splitting between N and Δ
  - Use NLO evolution
  - Unpol. dists agree with DIS data
- $g_2(x)$ from Wandzura-Wilczek

$$g_2^{WW}(x) = -g_1(x) + \int_x^1 \frac{dy}{y} g_1(y)$$

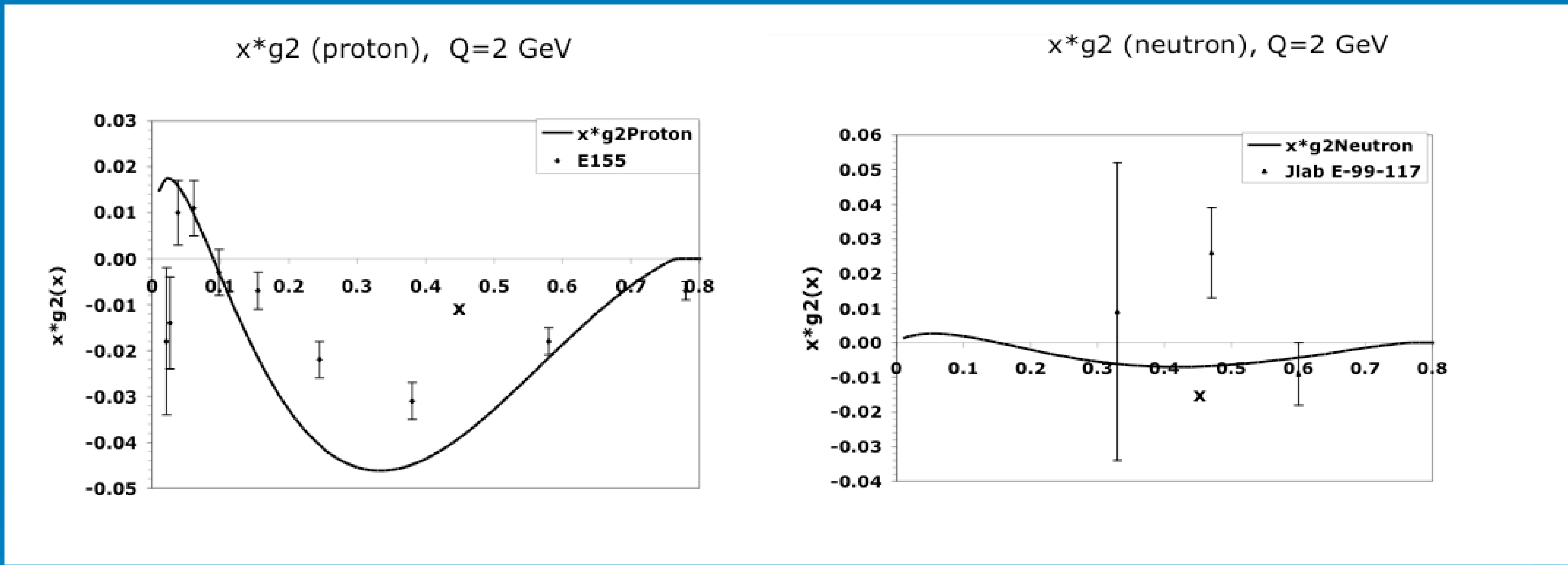
  - No higher twist component

‘Bare’ Nucleon $g_1(x)$



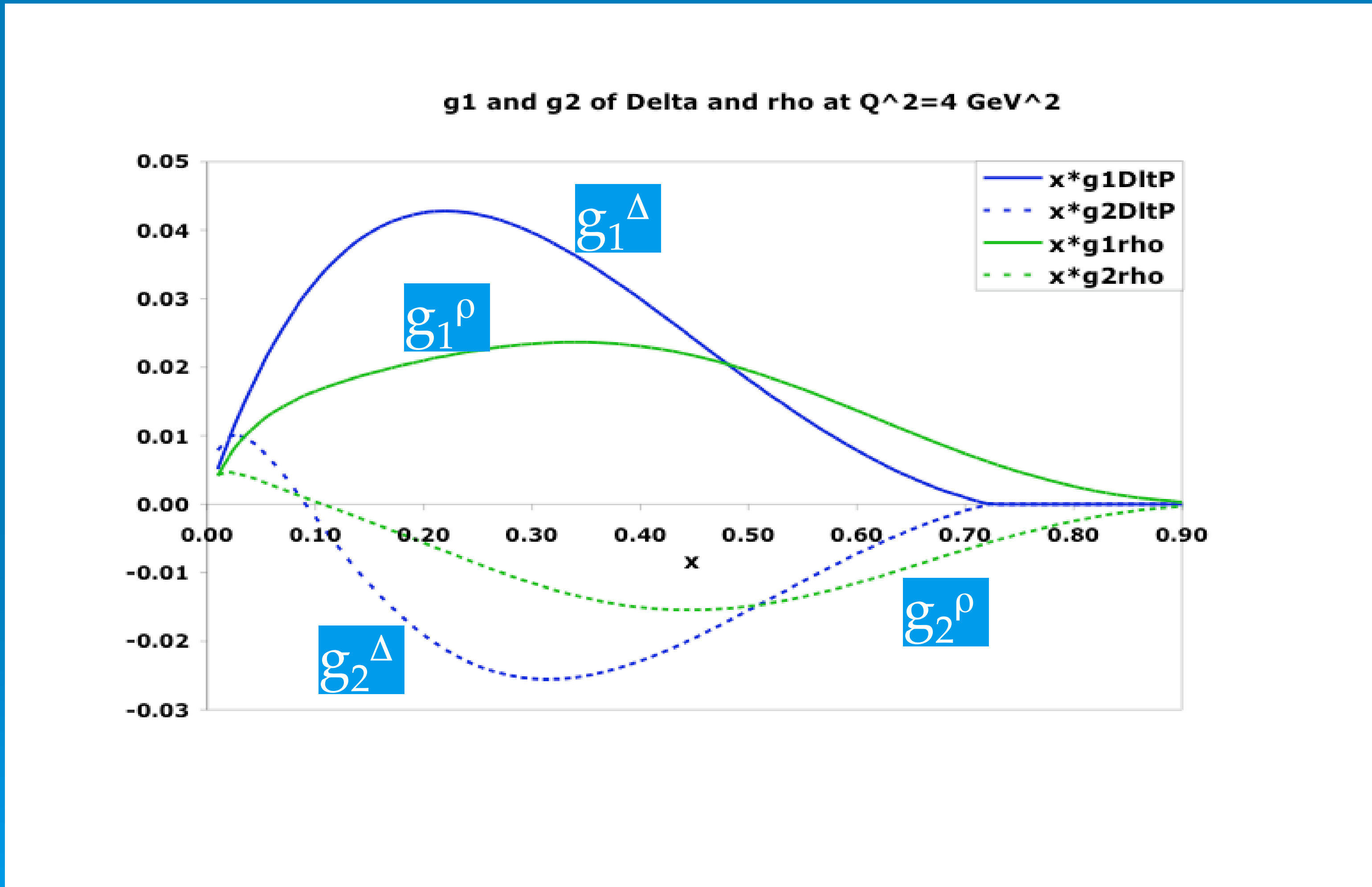
- Data from Hermes

‘Bare’ Nucleon $g_2(x)$

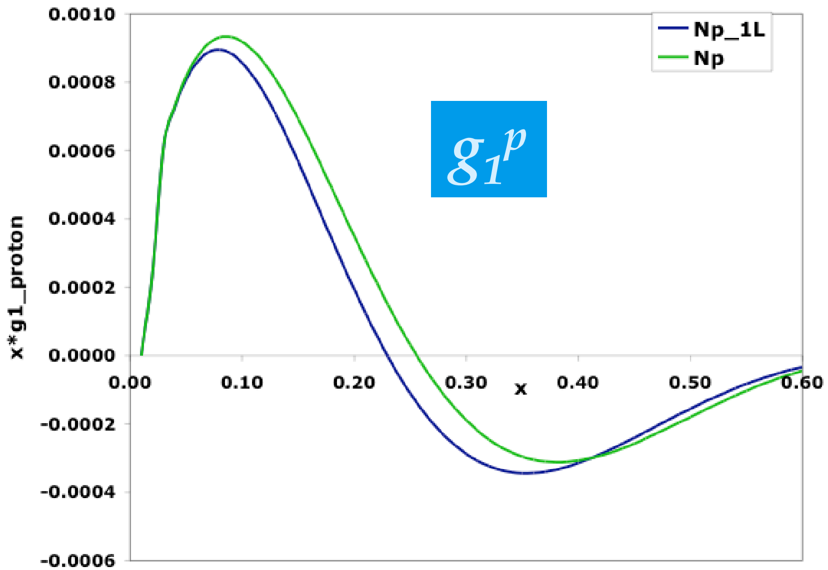


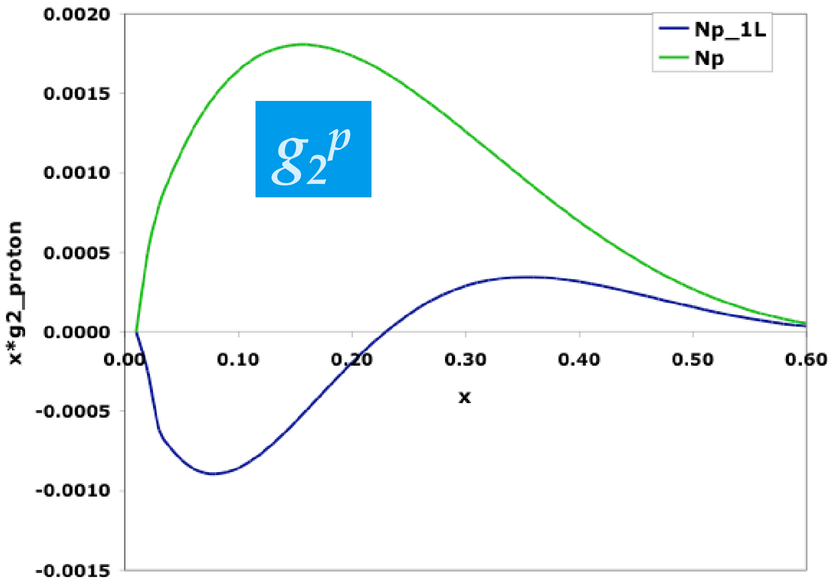
- Data from E155, Jlab E-99-117

‘Bare’ Hadrons Δ and ρ, $g_1(x)$ and $g_2(x)$



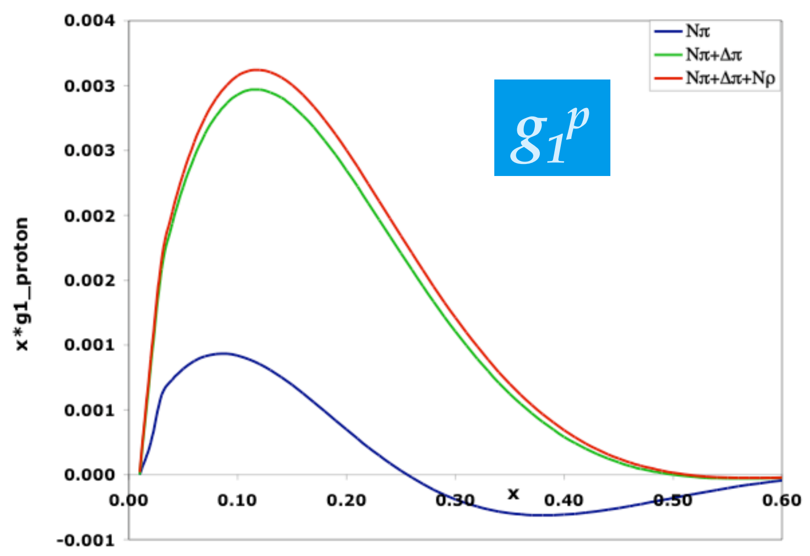
MC Contributions to g_1^p and g_2^p

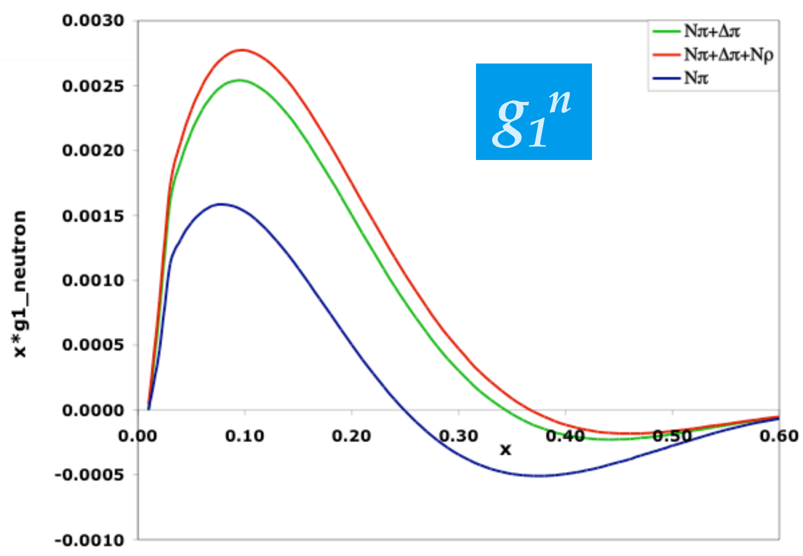




- The results for the neutron are very similar
- Δf_{1T}, Δf_{2L}, Δf_{2T} are important to g_2^p and g_2^n

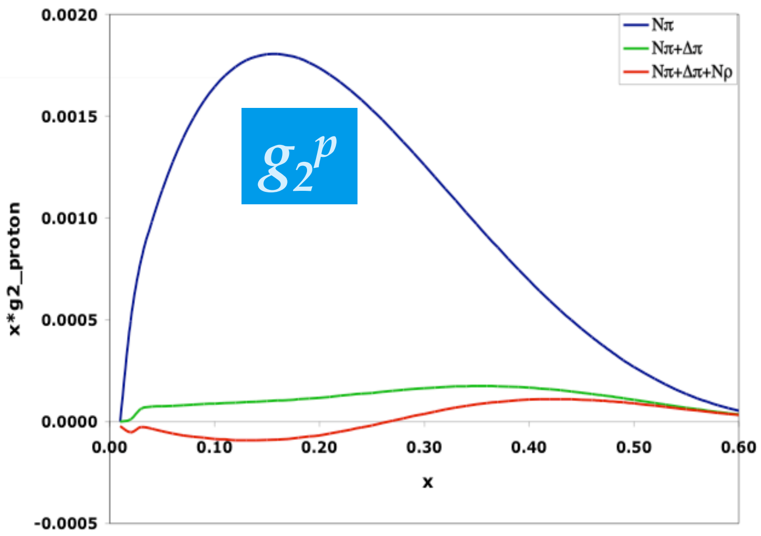
MC Contributions to g_1^p and g_1^n

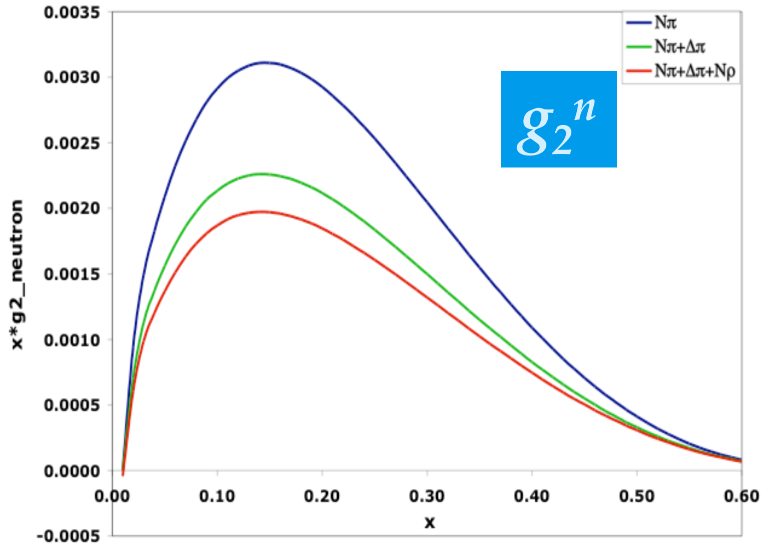




- Δπ is important while Nρ is not
- Δπ increases g_1^p more than that for g_1^n

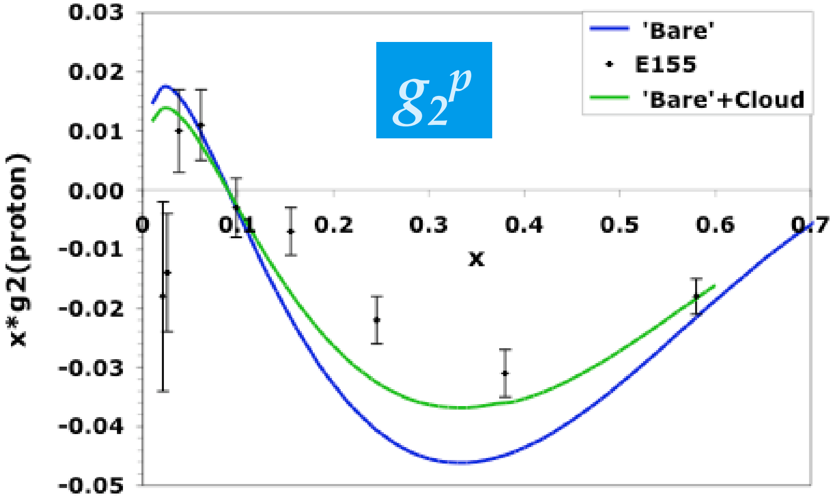
MC Contributions to g_2^p and g_2^n

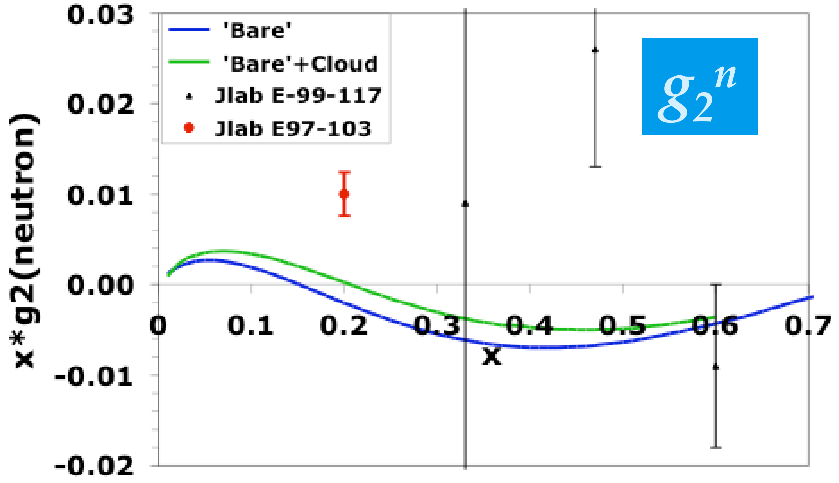




- Δπ is important
- Δπ affects g_2^p more than that for g_2^n

Comparison with data: g_2^p and g_2^n





- 20~30% corrections from MC
- Improve the agreement with the experiment

Summary

- Longitudinal (g_1) structure ftns of cloud hadrons affect observed transverse (g_2) structure ftns
- MC contributions to g_1 are small
- MC contributions to g_2 are 20%
  - Similar size to higher twist in g_2^n
  - Theorists have to be careful!

Thanks

- Tony Signal (Massey)
- François Bissey (Massey)