Measurement of the Gluon Polarization of the Nucleon at COMPASS

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On behalf of the COMPASS Collaboration

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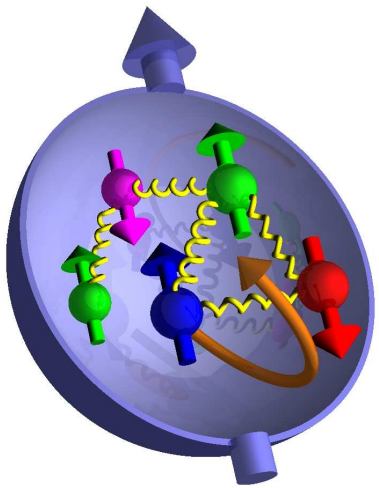
Outline

Spin Structure of the Nucleon



$$S_z^N = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_z^{q,G}$$

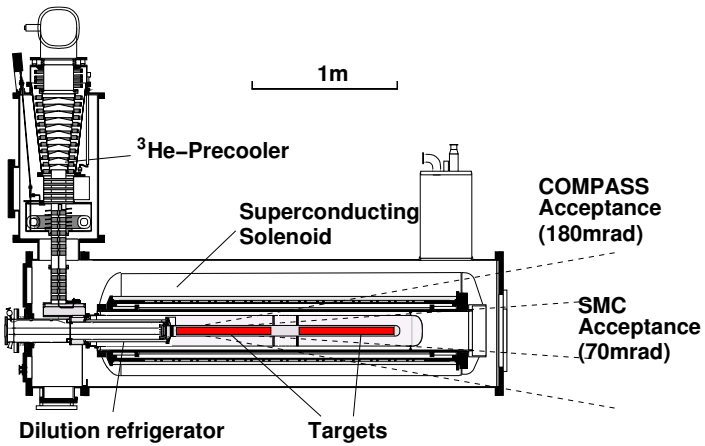
- $\Delta\Sigma \approx 0.3$ (smaller than predicted)
- ΔG under investigation
- L_z: the future

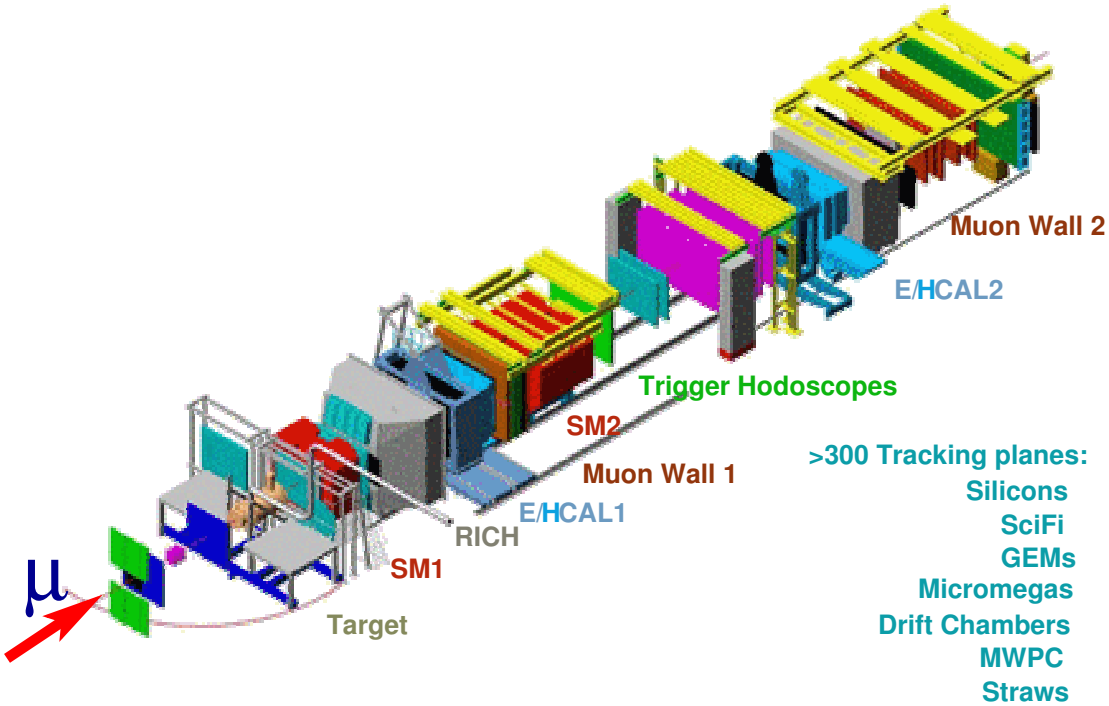
The COMPASS Experiment

COMPASS Collaboration; *Nucl. Instrum. and Meth. A*, **577 (2007)**, 455

Target

- ^{6}LiD
- 2 Cells (60 cm)
- $\approx$ 50 % Polarization

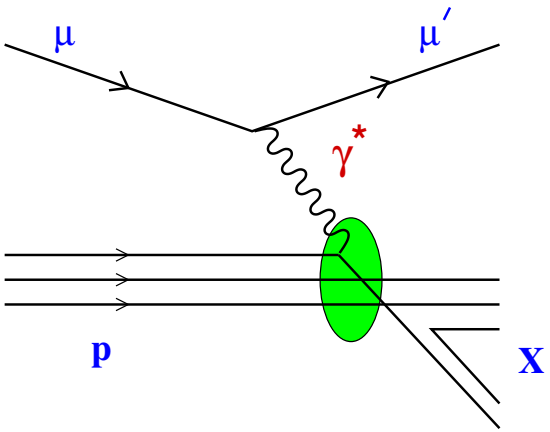


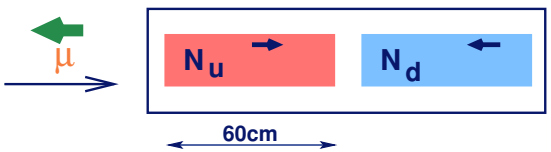


Beam

- $2 \cdot 10^8$ muons/spill (16.8 sec)
- 80(76) % polarization
- 160 GeV/c

Measuring Asymmetries in DIS





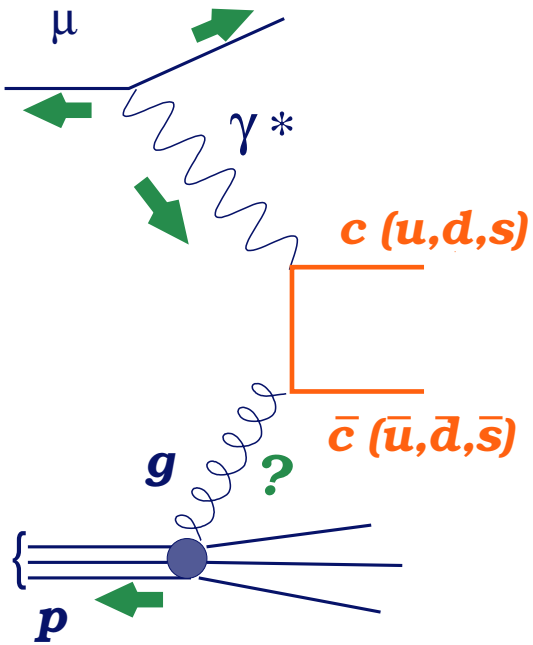
- Scattering Process: Polarized DIS
- Goal: measure longitudinal $A_{\parallel} = \frac{\sigma^{\rightleftarrows} - \sigma^{\rightrightarrows}}{\sigma^{\rightleftarrows} + \sigma^{\rightrightarrows}}$
- Use Counting Rates N_u and N_d
- Experimental Asymmetry

$$A_{exp} = \frac{1}{2}\left(\frac{N_u - N_d}{N_u + N_d} + \frac{N_{u'} - N_{d'}}{N_{u'} + N_{d'}}\right) = P_\mu \, P_t \, f \, A_{\parallel}$$

($N_{u'}$ and $N_{d'}$ with reversed target polarization)

Probing Gluons in DIS

Photon-Gluon-Fusion



$$A_{\parallel}^{PGF} \sim \langle a_{LL} \rangle \frac{\Delta G}{G}$$

Two Channels

- Open Charm

$$\gamma^* g \to c\bar{c} \to D X \xrightarrow{3.8\,\%} (K\pi) X$$

  - hard scale: $\hat{s} \approx 4m_c^2$
  - no physical background
  - low statistics

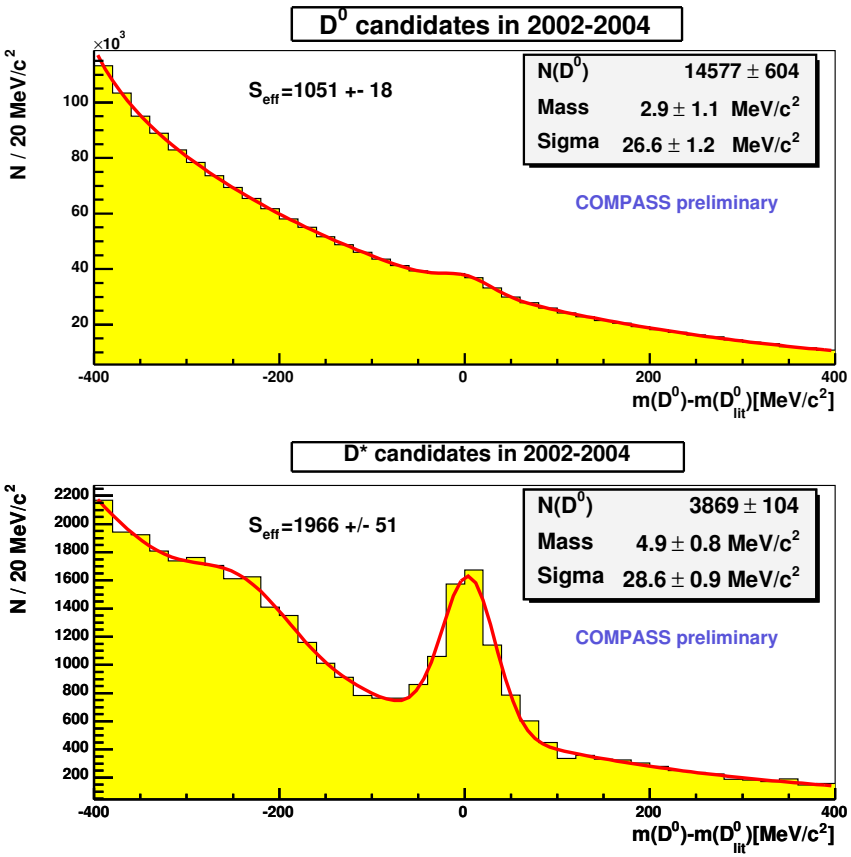
- High p_T Hadron Pairs

$$\gamma^* g \to q\bar{q} \to h^+ h^- \quad (q = u, d, s)$$

  - large statistics
  - competing processes

Open Charm Reconstruction

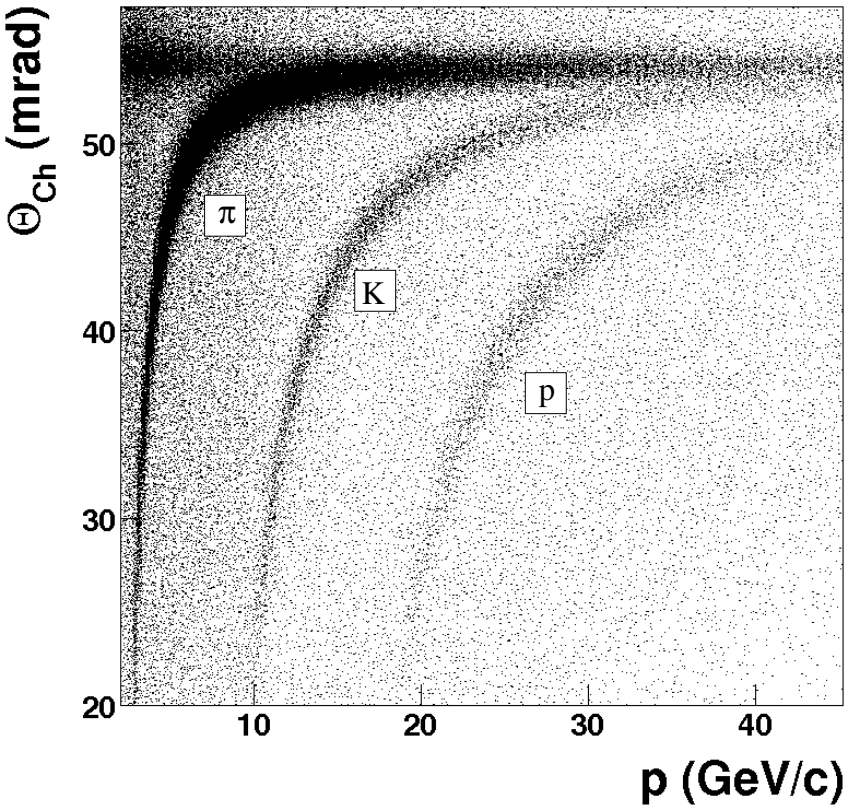
Track based reconstruction (no decay vertex)



- Two channels
  - $D^0 \to K\,\pi$
  - $D^* \to (K\,\pi)\,\pi_{slow}$
- Selection
  - D^0 kinematics:
    mom. fraction $z_{D^0} > 0.25\,(0.2)$
    decay angle $|cos\theta^*| < 0.5\,(0.85)$
  - D^* tag: mass difference δm
    $3.1\ MeV/c^2 < \delta m - m_\pi < 9.1\ MeV/c^2$
  - Particle Identification

Particle Identification with RICH

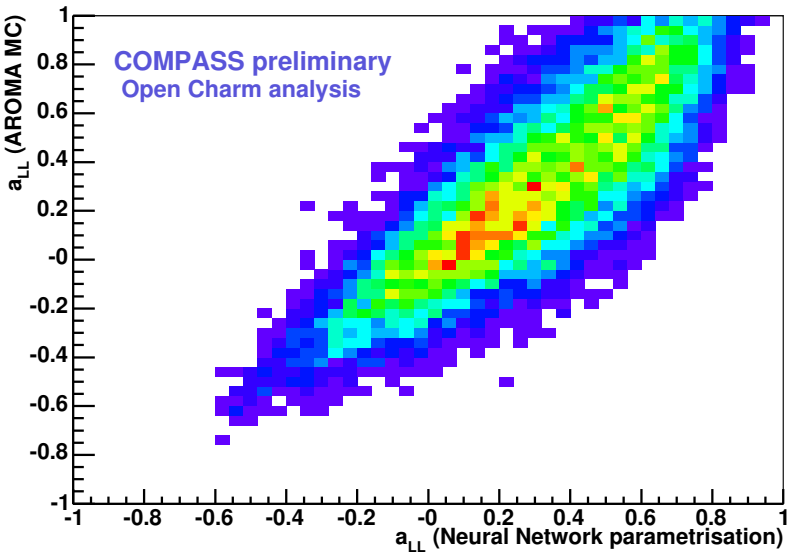
RICH: K/π separation up to ≈ 50 GeV/c



- $D-$mesons
  - kaon identification (≈ 80 % of K)
  - pion: kaon exclusion

Analyzing Power a_{LL} and Results

Events Asymmetry: $A_{exp} = P_\mu P_T f \frac{S}{S+B} A_{||}^{PGF} \sim \langle a_{LL} \rangle \frac{\Delta G}{G}$



- $a_{LL} = \frac{\Delta\sigma_{\mu g \to c\bar{c}}}{\sigma_{\mu g \to c\bar{c}}}$ depends on hard scattering kinematics
- Only one charmed meson reconstructed $\Rightarrow$ MC needed: AROMA
- Parametrization by neural network
- a_{LL} from observables $y, Q^2, z_{D_0}, p_{T\,D_0}^{\gamma}$

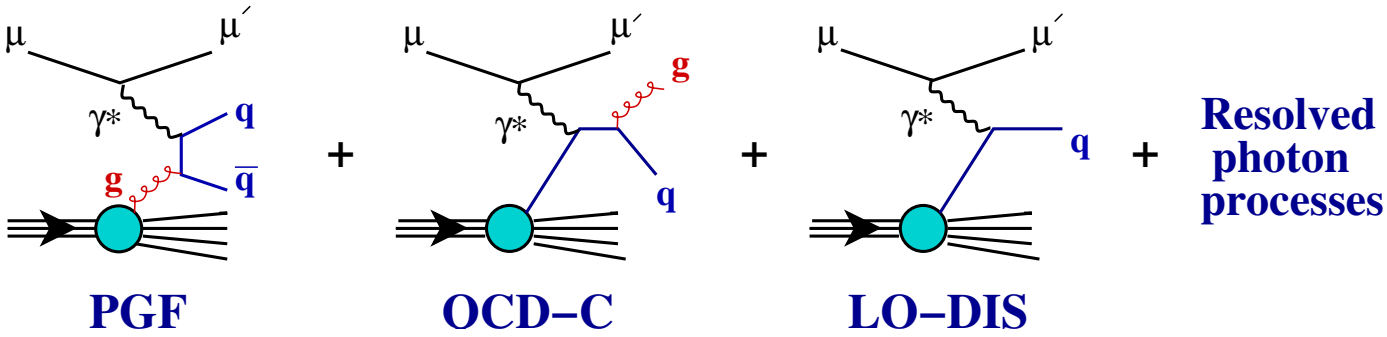
$$\frac{\Delta G}{G} = -0.57 \pm 0.41(\text{stat}) \pm 0.17(\text{syst})$$

$$x_G \approx 0.15 \qquad \mu^2 \approx 13\,(\text{GeV/c})^2$$

PGF in High p_T Hadron Pairs

Measured asymmetry from many contributions

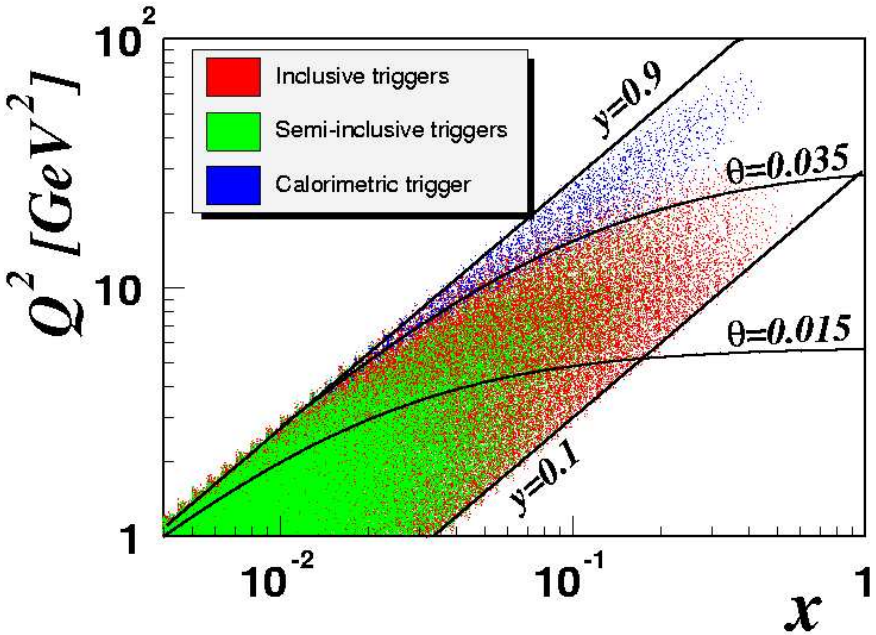
$$A_{\parallel} = R_{PGF}\langle a_{LL}^{PGF}\rangle \frac{\Delta G}{G} + R_{QCD-C}\langle a_{LL}^{QCD-C}\rangle \frac{\Delta q}{q} + R_{LO}\langle a_{LL}^{LO}\rangle \frac{\Delta q}{q} \; (+\text{Resolved Photon})_{Q^2<1}$$



MC needed to determine R_i and a_{LL}^i:

- LEPTO, $Q^2 > 1\,\text{GeV}^2 \rightarrow 10\,\%$ of data
- PYTHIA, $Q^2 < 1\,\text{GeV}^2 \rightarrow 90\,\%$ of data

High p_T Event Selection



Kinematical cuts:

- $Q^2 \lesssim 1$
- $0.1 < y < 0.9$
- $x < 0.05$ $(A_1^d \approx 0)$

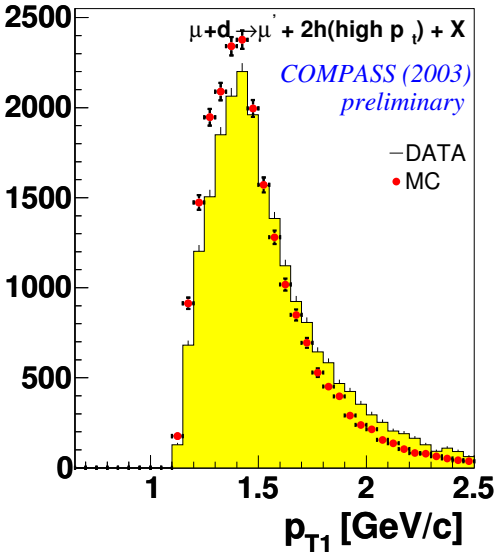
High-p_T:

- $p_{T,1}$,$p_{T,2} > 0.7$ GeV/c
- $p_{T,1}^2 + p_{T,2}^2 > 2.5\,(\text{GeV/c})^2$
- $z > 0.1$
- $x_F > 0.1$ (exclude target fragmentation)

$\frac{\Delta G}{G}$ from High-p_T, $Q^2 > 1$

2002 and 2003 Data (28k Events)

Measured Asymmetry: $\langle \frac{A_\parallel}{D} \rangle = -0.015 \pm 0.080(\text{stat}) \pm 0.013(\text{syst})$



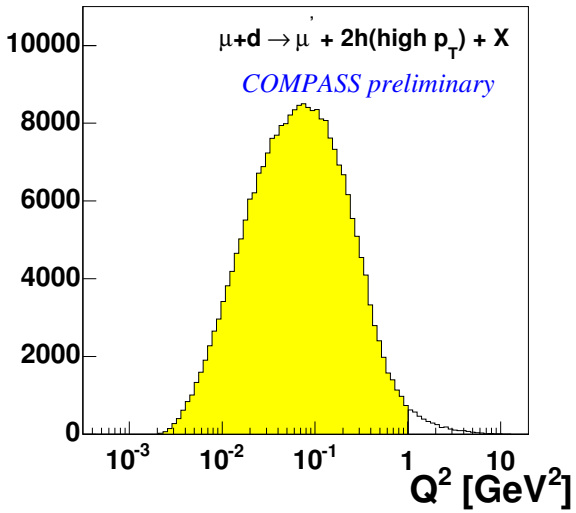
MC vs DATA: good agreement

- $\langle a_{LL}/D \rangle = -0.75 \pm 0.05$
- $R_{PGF} = 0.34 \pm 0.07$

Hard scale ensured by $Q^2 > 1$

$\frac{\Delta G}{G} = 0.06 \pm 0.31(\text{stat}) \pm 0.06(\text{syst})$ $(< x_G >= 0.13, \ < \mu^2 >= 2.4\,(GeV/c)^2)$

Asymmetry from High-p_T, $Q^2 < 1$



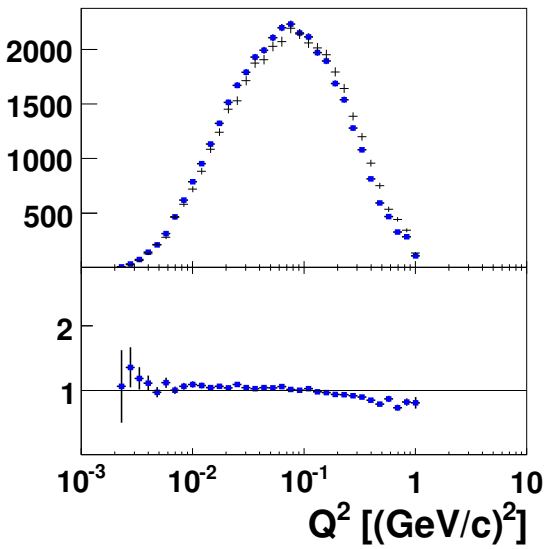
- 2002, 2003 and 2004 data
- High statistics (500k events)
- Hard scale fixed by p_T cut
- $\langle \frac{A_\parallel}{D} \rangle = +0.004 \pm 0.013(\text{stat}) \pm 0.003(\text{syst})$

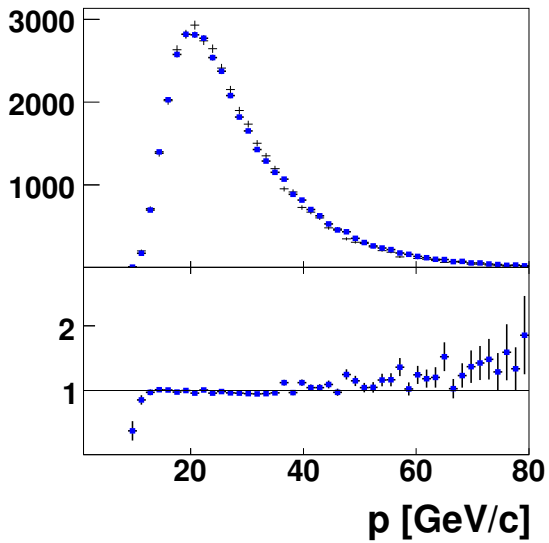
$Q^2 < 1 \Longrightarrow$ Resolved Photon Processes

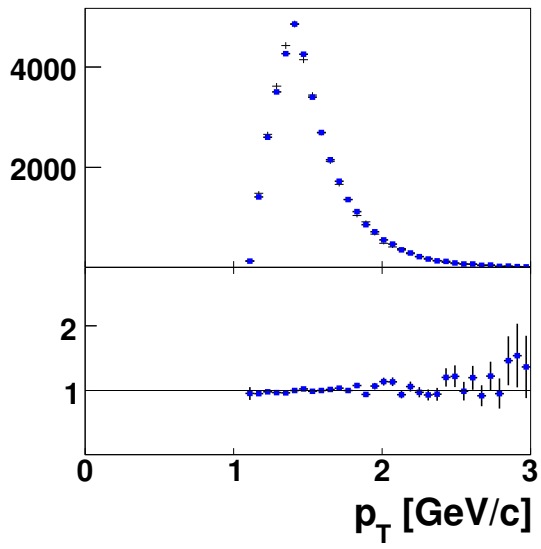
Background Contribution from MC $\Rightarrow$ model dependence

MC vs Data ($Q^2 < 1$)

Leading Hadron kinematics



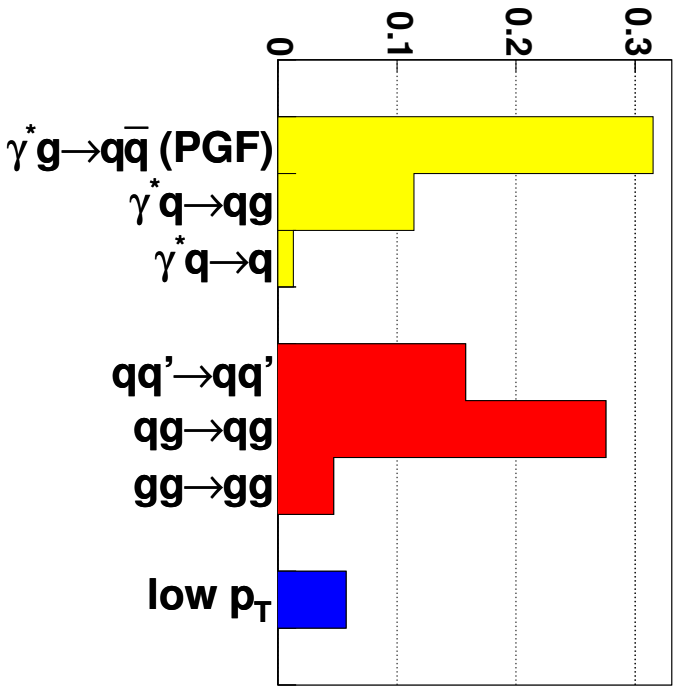




PHYTHIA describes COMPASS data very well!

Subprocesses from PYTHIA ($Q^2 < 1$)

$$\frac{A_\parallel}{D} \approx R_{PGF} \left\langle \frac{a_{LL}^{PGF}}{D} \right\rangle \frac{\Delta G}{G} + R_{QCD-C} \left\langle \frac{a_{LL}^{QCD-C}}{D} \right\rangle A_1 + \sum_{f,f^\gamma} R_{ff^\gamma} \left\langle a_{LL}^{ff^\gamma} \frac{\Delta f}{f} \frac{\Delta f^\gamma}{f^\gamma} \right\rangle$$



- R_i, a_{LL}^i, $\langle x_G \rangle$ and $\langle \mu^2 \rangle$ provided by MC
- LO-DIS and Low-p_T scattering processes can be neglected
- Δf^γ are unknown, but $-f^\gamma < \Delta f^\gamma < f^\gamma \leftarrow$ measured! $\Rightarrow$ two scenarios (min and max)

Direct **Resolved photon** **Low-p_T scattering**

$\frac{\Delta G}{G}$ from High-p_T, $Q^2 < 1$

$$\left(\frac{\Delta G}{G}\right)_{min} = 0.010 \pm 0.045(\text{stat}) \pm 0.011(\text{exp.syst}) \pm 0.018(\text{MC.syst})$$

$$\left(\frac{\Delta G}{G}\right)_{max} = 0.023 \pm 0.058(\text{stat}) \pm 0.014(\text{exp.syst}) \pm 0.052(\text{MC.syst})$$

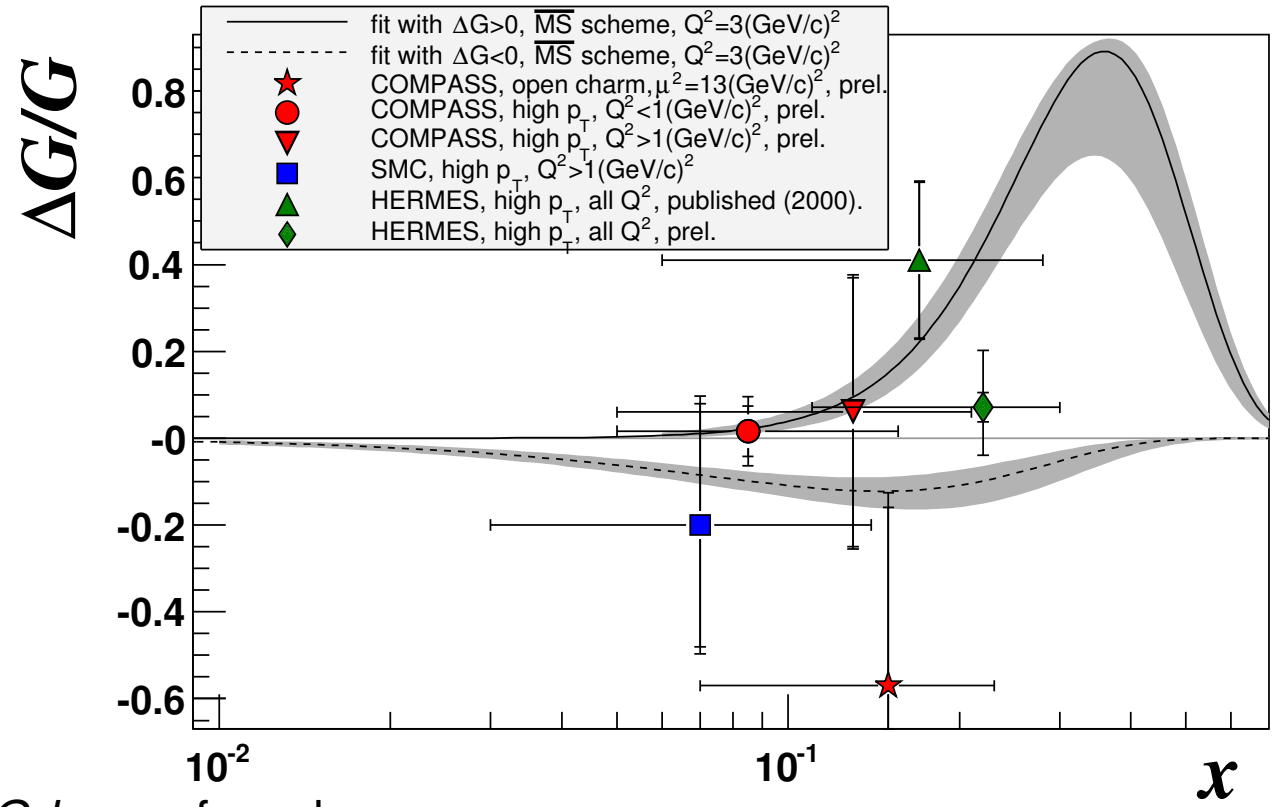
$$\frac{\Delta G}{G} = 0.016$$

$$\pm 0.058(\text{stat}) \pm 0.014(\text{exp.syst}) \pm 0.052(\text{MC.syst}) \pm 0.013(\text{photon})$$

$$(< x_G >= 0.085, \quad < \mu^2 >= 3\,(GeV/c)^2)$$

COMPASS Collaboration; *Phys. Lett. B*, **633 (2006)**, 25

Conclusion



- Small $\int \Delta G dx_G$ preferred
- Spin Puzzle far from being solved!
- 2006 data being analyzed, 2007 data taking started!