

# Measurement of the Gluon Polarization of the Nucleon at COMPASS

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On behalf of the COMPASS Collaboration

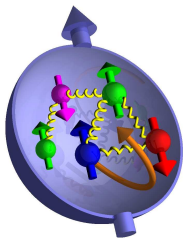
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# Outline

- 1 Introduction
- 2  $\Delta G$  at COMPASS
- 3 Open Charm
- 4 High- $p_T$  Hadron Pairs
- 5 Summary

# Spin Structure of the Nucleon



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

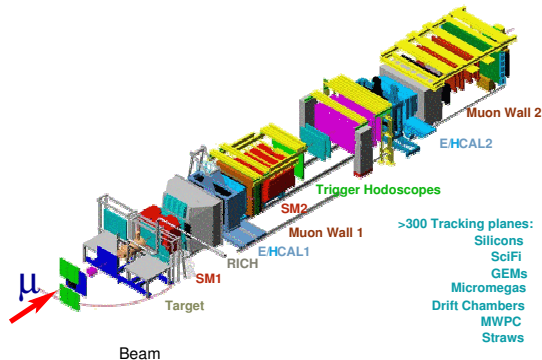
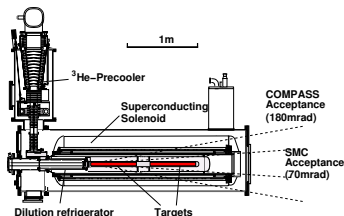
- $\Delta\Sigma \approx 0.3$  (smaller than predicted)
- $\Delta G$  under investigation
- $L_z$ : the future

# The COMPASS Experiment

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

Target

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



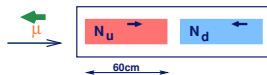
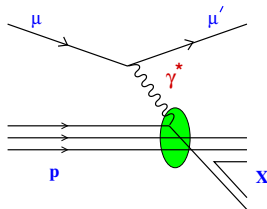
>300 Tracking planes:  
 Silicons  
 SciFi  
 GEMs  
 Micromegas  
 Drift Chambers  
 MWPC  
 Straws

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  $A_{||} = \frac{\sigma_{\uparrow\uparrow} - \sigma_{\uparrow\downarrow}}{\sigma_{\uparrow\uparrow} + \sigma_{\uparrow\downarrow}}$

- Use Counting Rates  $N_u$  and  $N_d$

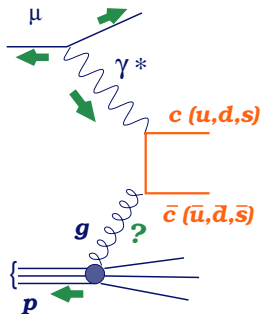
- Experimental Asymmetry

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

( $N_{u'}$  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

$$\gamma^* g \rightarrow c \bar{c} \rightarrow DX \rightarrow (K\pi) X \quad 3.8\%$$

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

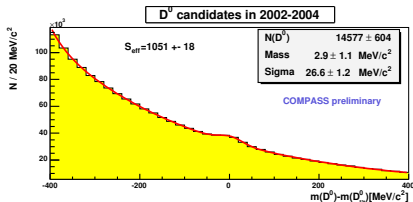
### ■ High $p_T$ Hadron Pairs

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

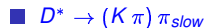
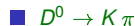
- large statistics
- competing processes

# Open Charm Reconstruction

## Track based reconstruction (no decay vertex)



- Two channels



- Selection

- $D^0$  kinematics:

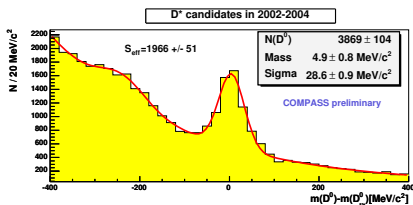
mom. fraction  $z_{D^0} > 0.25$  (0.2)

decay angle  $|\cos\theta^*| < 0.5$  (0.85)

- $D^*$  tag: mass difference  $\delta m$

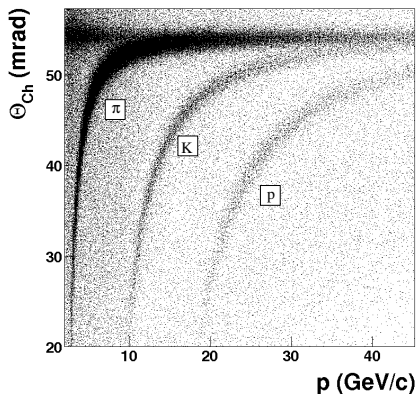
$3.1 \text{ MeV}/c^2 < \delta m - m_\pi < 9.1 \text{ MeV}/c^2$

- Particle Identification



# Particle Identification with RICH

RICH:  $K/\pi$  separation up to  $\approx 50$  GeV/c



- $D$ -mesons

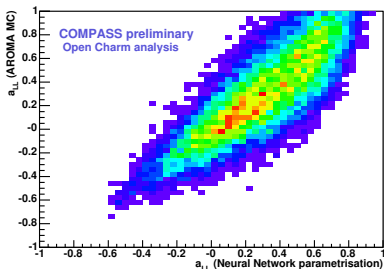
- kaon identification  
( $\approx 80\%$  of K)

- pion: kaon exclusion



# Analyzing Power $a_{LL}$ and Results

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



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

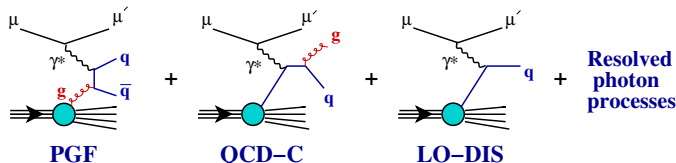
$$\frac{\Delta G}{G} = -0.57 \pm 0.41(\text{stat}) \pm 0.17(\text{syst})$$

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

# PGF in High $p_T$ Hadron Pairs

Measured asymmetry from many contributions

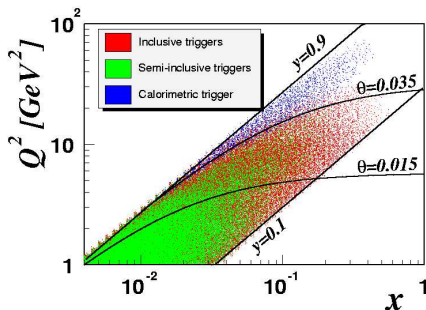
$$A_{||} = R_{PGF} \langle a_{LL}^{PGF} \rangle \frac{\Delta G}{G} + R_{QCD-C} \langle a_{LL}^{QCD-C} \rangle \frac{\Delta q}{q} + R_{LO} \langle a_{LL}^{LO} \rangle \frac{\Delta q}{q} \quad (+\text{Resolved Photon})_{Q^2 < 1}$$



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:

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

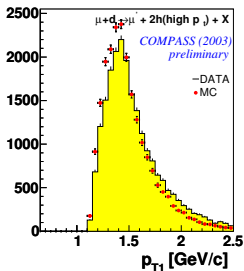
High- $p_T$ :

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

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

2002 and 2003 Data (28k Events)

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



MC vs DATA: good agreement

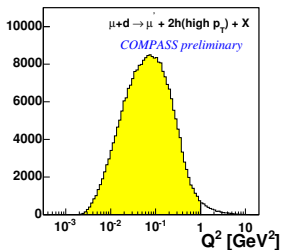
$$\langle a_{LL}/D \rangle = -0.75 \pm 0.05$$

$$R_{PGF} = 0.34 \pm 0.07$$

Hard scale ensured by  $Q^2 > 1$

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

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



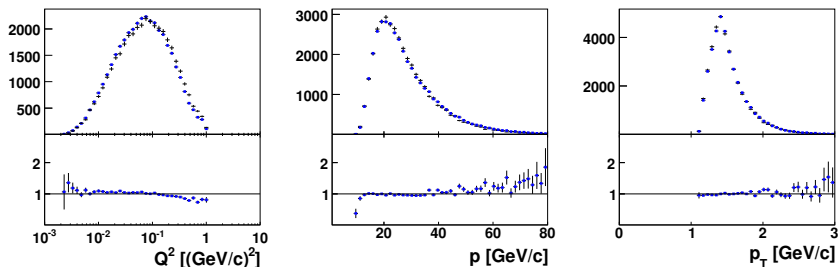
- 2002, 2003 and 2004 data
- High statistics (500k events)
- Hard scale fixed by  $p_T$  cut
- $\langle \frac{A_{\parallel}}{D} \rangle = +0.004 \pm 0.013(\text{stat}) \pm 0.003(\text{syst})$

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

Background Contribution from MC  $\implies$  model dependence

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

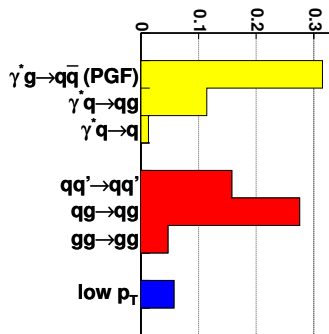
## Leading Hadron kinematics



PHYTHIA describes COMPASS data very well!

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

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



- $R_i$ ,  $a_{LL}^i$ ,  $\langle x_G \rangle$  and  $\langle \mu^2 \rangle$  provided by MC
- LO-DIS and Low- $p_T$  scattering processes can be neglected
- $\Delta f^\gamma$  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- $p_T$ , $Q^2 < 1$

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

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

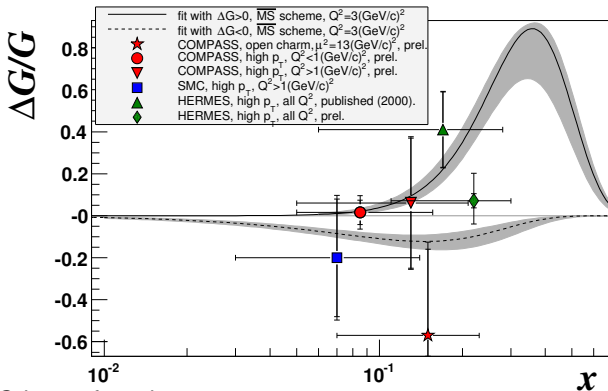
$$\frac{\Delta G}{G} = 0.016$$

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

$$\langle x_G \rangle = 0.085, \quad \langle \mu^2 \rangle = 3 (\text{GeV}/c)^2$$

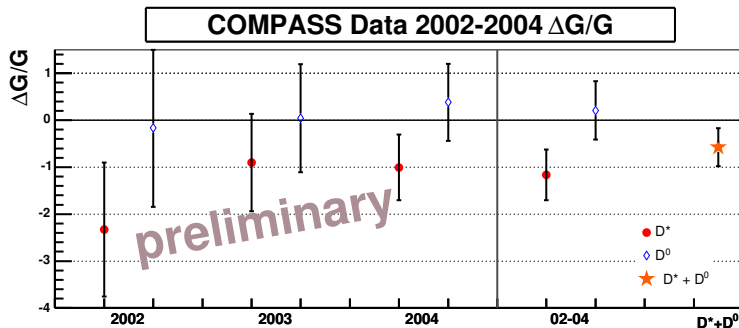


# Conclusion



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

# $\frac{\Delta G}{G}$ from Open Charm



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

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