New Measurement of $\frac{\Delta G}{G}$ at COMPASS
From Open Charm Events

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on behalf of the COMPASS collaboration
The nucleon spin can be decomposed on its constituents: quarks and gluons

\[
\frac{1}{2} = \frac{1}{2} \Delta \Sigma + \Delta G + L_{qg}
\]

$\Delta \Sigma$ measurements show that the quark spin has a small contribution to the nucleon spin

\(COMPASS, HERMES, SMC, EMC, SLAC\)

⇒ Gluons?

$\Delta G$: 2 motivations for its measurement

• How much does it contribute to the nucleon spin?
• If it is large (~2-3) it could explain why $\Delta \Sigma$ was found small (axial anomaly)
Polarized Photon-Gluon Fusion Process (PGF) $\Rightarrow$ Spin Asymmetries

**How to tag PGF?**

- **Production of high-$p_T$ hadrons**
  - $(u, d, s, c$ quarks$)$; hard scale: $p_T$
  - high statistics
  - background processes

- **Production of charm mesons**
  - $(c$ quarks only$)$; hard scale: $m_{charm}$
  - no physical background
  - low statistics
Probing the Gluons through Open Charm

Photons-Gluon Fusion Process (PGF)

\[ D^0 \rightarrow K\pi \quad \text{(D}^0\text{ channel)} \]
\[ D^* \rightarrow D^0 \pi_{\text{soft}} \rightarrow K\pi \pi_{\text{soft}} \quad \text{(D}^*\text{ channel)} \]
Probing the Gluons through Open Charm

Photon-Gluon Fusion Process (PGF)

\[ \text{polarized muon} \]
\[ l \rightarrow l' \]
\[ q \rightarrow D^0 \Rightarrow K\pi \]
\[ D^0 \Rightarrow D^0 \pi_{\text{soft}} \Rightarrow K\pi\pi_{\text{soft}} \]
\[ (D^0 \text{ channel}) \]

\[ \text{polarized proton} \]
\[ p \]
\[ ar{q} \rightarrow D^* \Rightarrow D^0 \pi_{\text{soft}} \Rightarrow K\pi\pi_{\text{soft}} \]
\[ (D^* \text{ channel}) \]

$\Rightarrow K\pi$ invariant mass : Signal centered on the $D^0$ mass

Selection to reduce the combinatorial background:

- Kinematical cuts ($z_D$, $D^0$ decay angle, $\pi$ momentum)
- **RICH PID**
  - $K$ and $\pi$ are identified
  - electrons are rejected from the $\pi_{\text{soft}}$ sample

For $D^*$, cut on the 3-body mass
Muon Beam:
160 GeV
polar = 80%
$2 \times 10^8 \mu$/spill (4.8/16.8 s)

LiD Target (2002-2006):
polar = 50%
dilution factor = 40%
The COMPASS Experiment

Muon Beam:
- 160 GeV
- polar = 80%
- $2.10^8$ μ/beam
- LiD Target (2002-2006)
  - polar = 50%
  - dilution factor = 40%

Spin directions are rotated every 8 hours

- $u$ cell
- $d$ cell

2 Stage Spectrometer
- SCI-FI
- MicroMegas
- DC
- MWPC
- Si
- GEM
- Straw

NIMA 577 (2007) 455
335 tracking planes:
The 2006 Upgrades

• **RICH Upgrades**: MAPMT + faster electronics
  - Faster (less pile-up)
  - More photons
  ⇒ **More D⁰/μ, S/B improved**

• **Larger Acceptance**: 70 mrad ⇒ 180 mrad

• **3-cells target** ⇒ reduced false asymmetries
  - *u* and *d cell* have the “same” acceptance

---

*target magnet*

* u cell  d cell  u cell
All data with a deuterium target have been analyzed.

2002 $D^0$-tagged events
2003 $D^0$-tagged events
2004 $D^0$-tagged events
2006 $D^0$-tagged events

2002 $D^0$ untagged events
2003 $D^0$ untagged events
2004 $D^0$ untagged events
2006 $D^0$ untagged events

TOTAL: $8675 \text{ D}^*$

$37398 \text{ D}^0$
Gluon Polarization

$$\frac{\Delta G}{G} = \frac{1}{P_T P_\mu f a_{LL}} \frac{S}{S + B} \times \frac{N_d - N_u}{N_d + N_u}$$

- $$\Delta G / G$$: the change in gluon polarization
- $$P_T$$: target polarization
- $$P_\mu$$: beam polarization
- $$f$$: dilution factor
- $$a_{LL}$$: analyzing power
Gluon Polarization

Target

\[ \frac{\Delta G}{G} = \frac{1}{P_T P_\mu f a_{LL}} \times \frac{N_d - N_u}{N_d + N_u} \]

\[ \Delta G = \frac{1}{P_T} \times \frac{\sum w_d - \sum w_u}{\sum w_d^2 + \sum w_u^2} \]

Statistical gain: \[ \frac{\langle w^2 \rangle}{\langle w \rangle^2} \]

\( P_T \): target polarization
\( P_\mu \): beam polarization
\( f \): dilution factor
\( a_{LL} \): analyzing power

Event weight \( w \)
To compute $a_{LL}$, one needs to know the full partonic kinematics.

BUT, knowing the kinematics of one charm meson ($D^0$) is sufficient to have a rather good determination of the true $a_{LL}$.

$a_{LL}$ is given by a Neural Network parameterization (LO) MC studies: the reconstructed $a_{LL}$ is strongly correlated with the real one.

$$a_{LL} = \frac{\Delta \sigma^{PGF}}{\sigma^{PGF}} \left( y, Q^2, x_g, z_c, \phi \right)$$
The signal purity gives the probability for an event to be a open charm

**Old** analysis: $S/(S+B)$ was obtained from a fit on the mass spectra in $a_{LL}$ bins:

$$\frac{S}{S+B} = f(M(K\pi))$$

**New**: $S/(S+B)$ is parameterized ($\Sigma$) as a function of kinematical variables and the RICH response and is given event-by-event

- $\Rightarrow$ events with $\Sigma$ close to 0: high probability for being background
- $\Rightarrow$ events with $\Sigma$ close to 1: high probability for being open charm

Event weight: $w = P_\mu f a_{LL} \Sigma$

$\Sigma$ is built on the data only
Events with a small $\Sigma$ (mostly background events) $\Rightarrow$ small weight

Events with a large $\Sigma$ (mostly signal events) $\Rightarrow$ large weight
Signal Purity: $\Sigma$ - parameterization

Events with a small $\Sigma$ (mostly background events) $\Rightarrow$ small weight

With $\Sigma$ in the weight, the cuts can be less strict:

- Background events are added
- Signal events are “saved”

Events with a large $\Sigma$ (mostly signal events) $\Rightarrow$ large weight
COMPASS

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DIS2008

London, April 2008

Σ - Weighted Mass Spectra

COMPASS 2002 - 2006 D⁰-untagged Mass Spectrum

Preliminary

37398 D⁰

RAW HISTOGRAMS

COMPASS 2002 - 2006 D⁰-tagged Mass Spectrum

Preliminary

8675 D*

Σ-WEIGHTED HISTOGRAMS

COMPASS 2002 - 2006 D⁰-untagged Weighted Mass Spectrum

Preliminary

COMPASS 2002 - 2006 D⁰-tagged Weighted Mass Spectrum

Preliminary
\[ \Delta G/G = -0.49 \pm 0.27 \text{ (stat)} \pm 0.11 \text{ (syst)} \]

<table>
<thead>
<tr>
<th>Source</th>
<th>D⁰</th>
<th>D*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam polar</td>
<td>0.025</td>
<td>0.025</td>
</tr>
<tr>
<td>Target polar</td>
<td>0.025</td>
<td>0.025</td>
</tr>
<tr>
<td>Dil. Fact.</td>
<td>0.025</td>
<td>0.025</td>
</tr>
<tr>
<td>False asymmetry</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Signal extraction ((\Sigma))</td>
<td>0.07</td>
<td>0.01</td>
</tr>
<tr>
<td>(a_{11}) (charm mass)</td>
<td>0.05</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>0.11</strong></td>
<td><strong>0.07</strong></td>
</tr>
</tbody>
</table>

\[ \langle x_g \rangle = 0.11^{+0.11}_{-0.05} \]
\[ \langle \mu^2 \rangle = 13 \text{ GeV}^2 \]
Conclusion

The new result of the $\Delta G/G$ measurement has been presented and reveals a significant statistical improvement in comparison to our previous release:

2002-2004 old analysis: $\Delta G/G = -0.47 \pm 0.44$ (stat) $\pm 0.15$ (syst)


2002-2006 new analysis: $\Delta G/G = -0.49 \pm 0.27$ (stat) $\pm 0.11$ (syst)

The reasons of this improvement are:

- the new 2006 data
- new data production (improved tracking)
- the $\Sigma$-parameterization in the event weighting
- a new cut for the $D^*$ channel: electron rejected from the soft pion sample
Conclusion

- Small $\Delta G$ values are preferred
- The new charm point is negative but compatible with zero.

Improvements are expected:
- 2007 data
- Improvements of the analysis
2006 D⁰ events in Σ bins

D⁰-untagged events with Σ < 0.055

COMPASS Preliminary

D⁰-untagged events with 0.055 < Σ < 0.085

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D⁰-untagged events with 0.085 < Σ < 0.12

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D⁰-untagged events with 0.12 < Σ < 0.2

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D⁰-untagged events with 0.2 < Σ

COMPASS Preliminary