

COMPASS における高横方向運動量ハドロンを用いたグルーオン偏極度解析

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COMPASS

Recent published results @ COMPASS

Data taking @ COMPASS

Theory

Theoretical estimations

Results

Asymmetry calculation

Kinematic distributions

Deuteron

Proton

Summary



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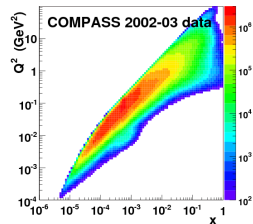
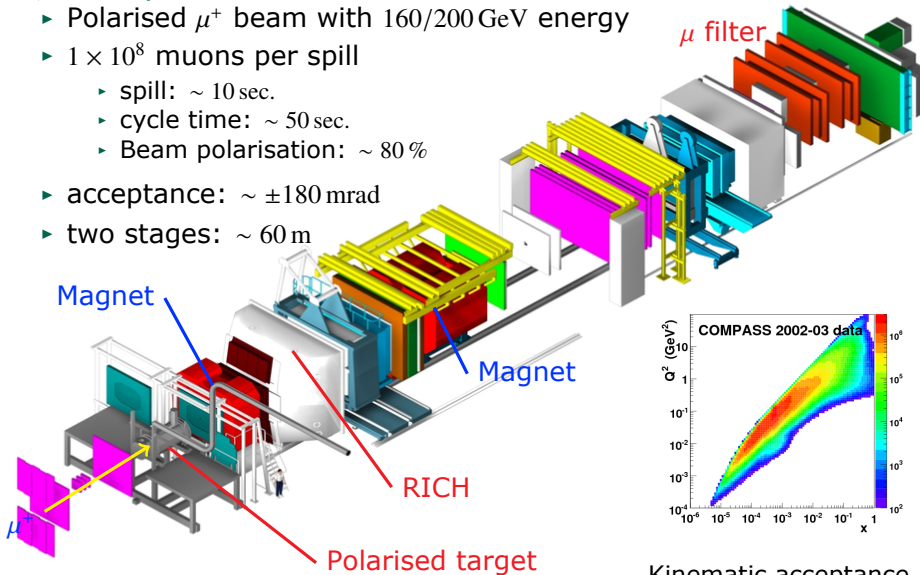


COMPASS @ CERN



Setup

- ▶ Polarised μ^+ beam with 160/200 GeV energy
- ▶ 1×10^8 muons per spill
 - ▶ spill: ~ 10 sec.
 - ▶ cycle time: ~ 50 sec.
 - ▶ Beam polarisation: $\sim 80\%$
- ▶ acceptance: $\sim \pm 180$ mrad
- ▶ two stages: ~ 60 m



Kinematic acceptance

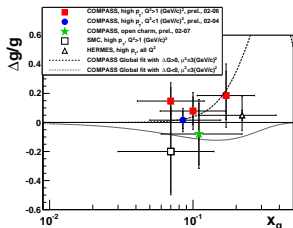


$\Delta g/g$ results @ COMPASS

Recent published results

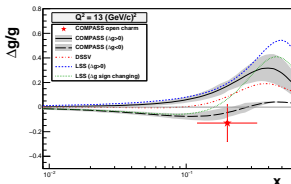


LO @ high- p_T hadron pair



PLB 718 (2013) 922

NLO @ open charm



PRD 87 (2013) 052018

$\Delta g/g$ @ COMPASS

- ▶ $+0.02 \pm 0.09 \pm 0.06$ @ $x_g = \langle 0.01 \rangle$ LO, high- p_T pair, $Q^2 < 1$, PLB 633 (2006) 25
- ▶ $+0.13 \pm 0.06 \pm 0.06$ @ $x_g = \langle 0.09 \rangle$ LO, high- p_T pair, $Q^2 > 1$, PLB 718 (2013) 922
- ▶ $-0.47 \pm 0.44 \pm 0.15$ @ $x_g = \langle 0.11 \rangle$ LO, open charm, arXiv:0802.3023
- ▶ $-0.49 \pm 0.27 \pm 0.11$ @ $x_g = \langle 0.11 \rangle$ LO, open charm, PLB 676 (2009) 31
- ▶ $-0.06 \pm 0.21 \pm 0.08$ @ $x_g = \langle 0.20 \rangle$ LO, open charm, PRD 87 (2013) 052018
- ▶ $-0.13 \pm 0.15 \pm 0.15$ @ $x_g = \langle 0.11 \rangle$ NLO, open charm, PRD 87 (2013) 052018



Data taking

2002-2011 muon program



Year	Target	Beam Energy(GeV/c)	Acceptance(mrad)
2002	↑ LiD ↓	↑ 160 ↓	↑ 75 ↓
2003			
2004			
2006	↑ NH ₃ ↓	↑ 200 ↓	↑ 180 ↓
2007			
2011			

high- p_T Hadron yield in this analysis (cut: $p_T > 1$, $Q^2 < 1$)

Year	2002	2003	2004	2006	2007	2011
Hadron yield($\times 10^6$)	16.3	30.9	53.3	34.2	65.7	39.8



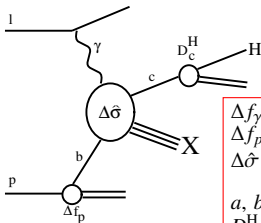
Purpose

- ▶ $\Delta g/g$ evaluation from double longitudinal spin asymmetry $A_{LL}(p_T)$
 - ▶ High- p_T ($> 1.0 \text{ GeV}/c$) and low- Q^2 ($< 1 \text{ (GeV}/c)^2$)
 - ▶ All COMPASS data (2002 - 2011)

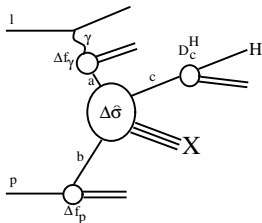
Theoretical framework

- ▶ photoproduction of single inclusive hadrons: $l + N \rightarrow l' + H + X$
- ▶ based on JSV framework (Eur.Phys.J. C44, 533 (2005), hep-ph/0505157)

Direct γ -contribution



Resolved γ -contribution



Δf_γ : Photon's parton density
 Δf_p : Nucleon p 's parton density
 $\Delta \hat{\sigma}$: spin-dependent partonic
 hard scattering cross section
 $a, b, c = q, \bar{q}, g$
 D_c^H : fragmentation function

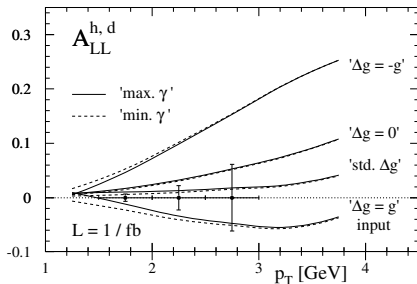


Theoretical estimations of A_{LL}



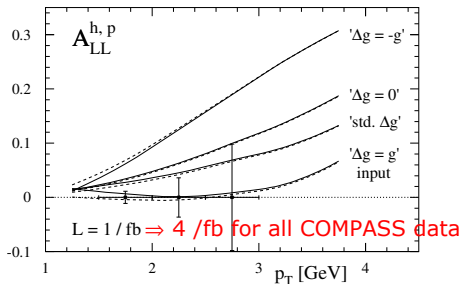
$$\blacktriangleright A_{LL} \equiv \frac{\Delta\sigma}{\sigma} = \frac{\sum_{a,b,c} \Delta f_a^l \otimes \Delta f_b^N \otimes \Delta \hat{\sigma}_{ab \rightarrow cX} \otimes D_c^h}{\sum_{a,b,c} f_a^l \otimes f_b^N \otimes \hat{\sigma}_{ab \rightarrow cX} \otimes D_c^h}$$

$\blacktriangleright A_{LL}$ @ COMPASS Kinematic range



Deuteron

ref: Eur.Phys.J. C44, 533 (2005), hep-ph/0505157



Proton

\blacktriangleright Different curves with different Δg scenarios



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Double longitudinal asymmetry

$$A_{LL} \equiv \frac{\Delta\sigma}{\sigma} \approx \frac{1}{fP_bP_t} \left(\frac{\sigma^{\rightarrow\rightarrow} - \sigma^{\leftarrow\leftarrow}}{\sigma^{\rightarrow\rightarrow} + \sigma^{\leftarrow\leftarrow}} \right) = \frac{1}{fP_bP_t} \left(\frac{N^{\rightarrow\rightarrow} - N^{\leftarrow\leftarrow}}{N^{\rightarrow\rightarrow} + N^{\leftarrow\leftarrow}} \right)$$

- ▶ f : Dilution factor: 0.4(${}^6\text{LiD}$), 0.16(NH_3)
- ▶ P_b : Beam polarisation: $\sim 80\%$
- ▶ P_t : Target polarisation: $\sim 50\%$ (${}^6\text{LiD}$), $\sim 85\%$ (NH_3)
- ▶ N : Hadron yield

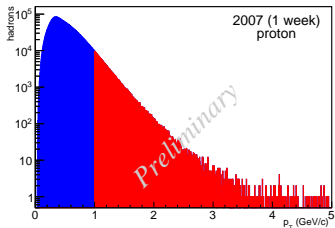
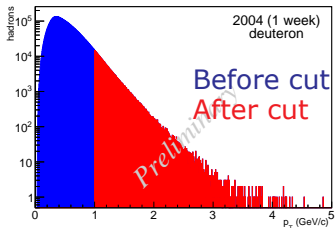


Kinematic distributions

p_T , Q^2 in 2004 and 2007

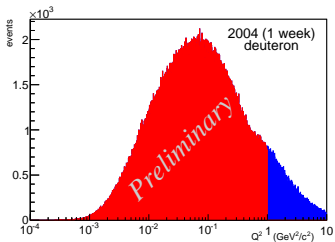


p_T

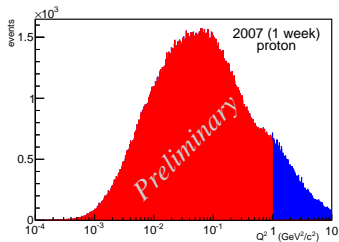


Q^2

Deuteron



Proton



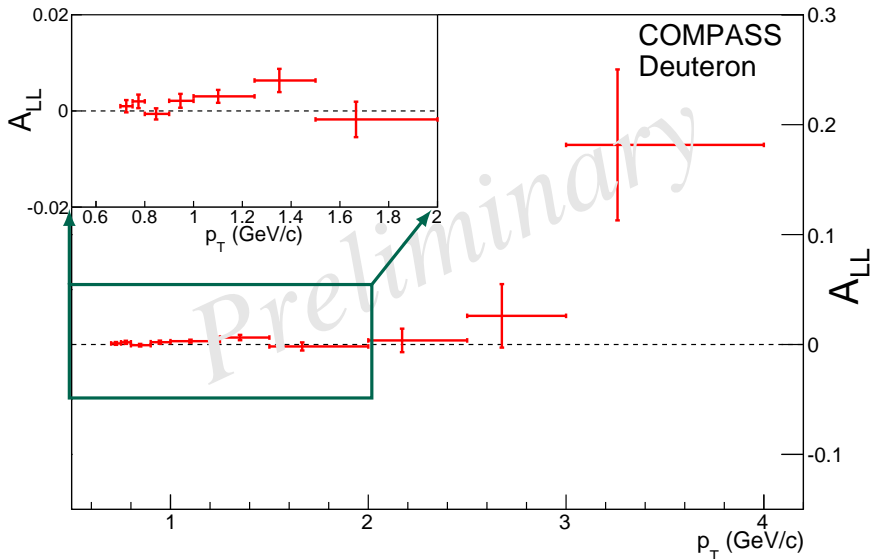
Deuteron

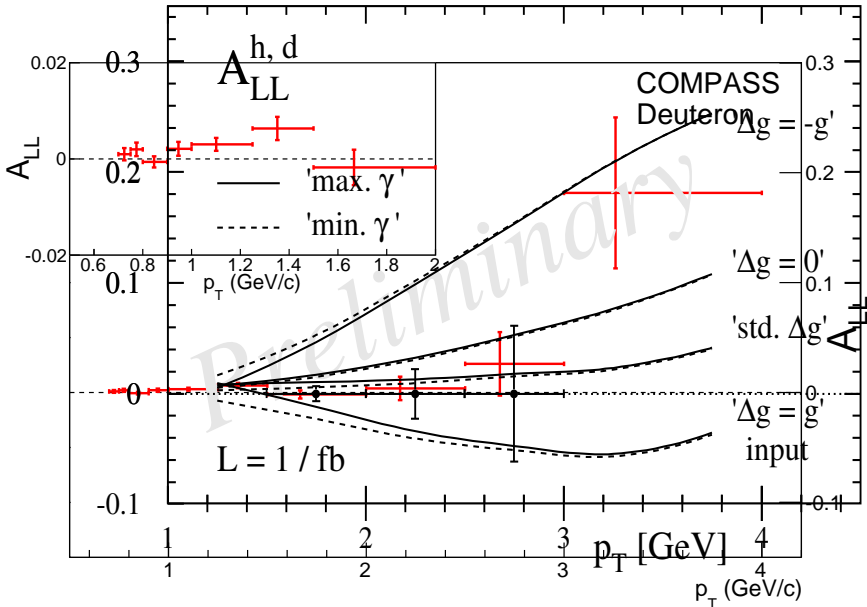
Proton



Asymmetry: deuteron

2002-2006

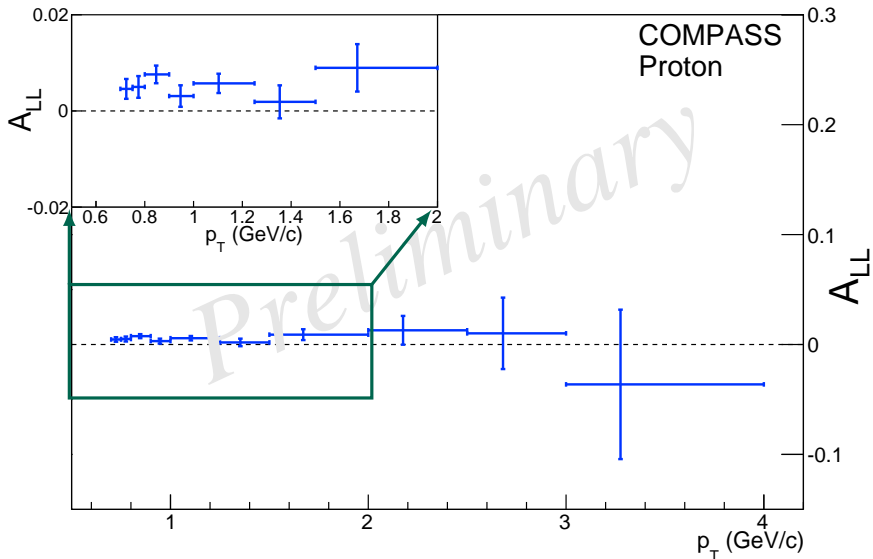


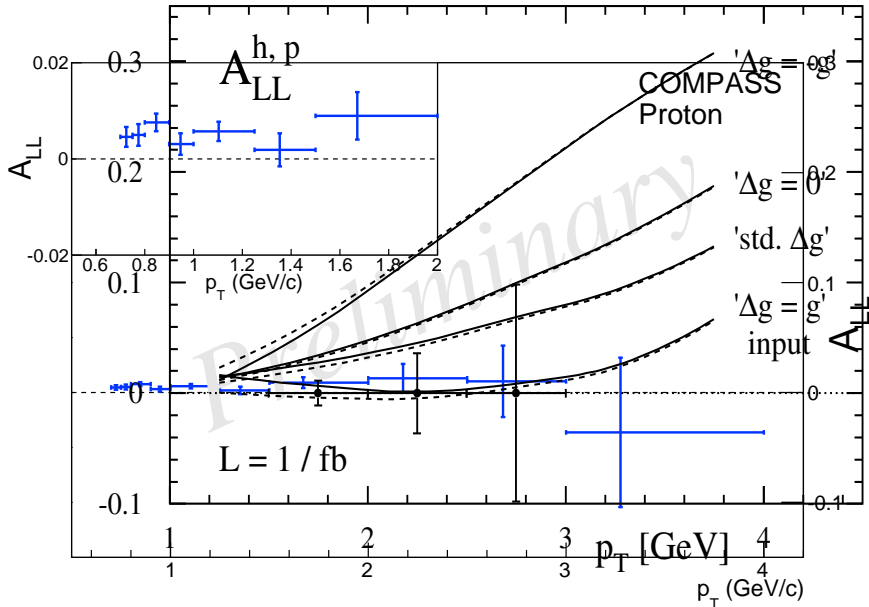




Asymmetry: proton

2007-2011







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Summary

- ▶ $\Delta g/g$ evaluation from double longitudinal asymmetry A_{LL} from high- p_T hadrons with low- Q^2
- ▶ All COMPASS data with longitudinal beam/target used
- ▶ Asymmetries: compatible with zero except high- p_T bin
- ▶ Systematic error: of the order of statistical error

Outlook

- ▶ further quantification of systematic errors
- ▶ comparisons between data and theoretical calculation
- ▶ evaluation of $\Delta g/g$

Backup



Comparison unpolarised cross section

COMPASS data v.s. theoretical calculation



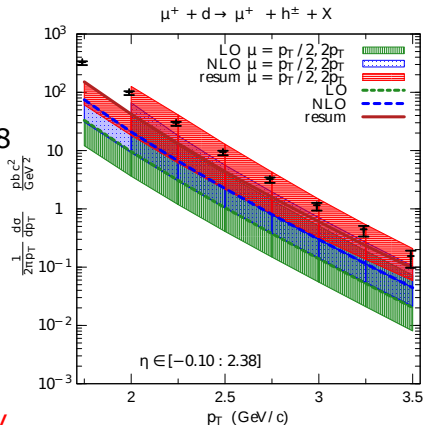
COMPASS data in 2004

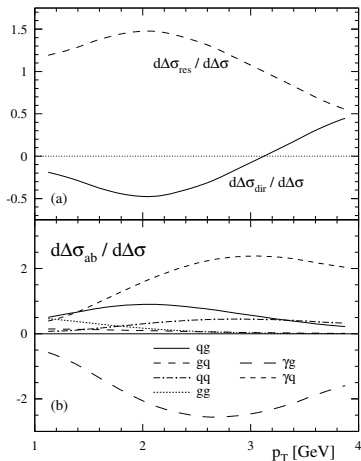
- ▶ C. Adolph, *et. al.*, PRD 88 (2013) 091101
- ▶ $\mu + d \rightarrow \mu' + h^\pm + X$ cross section at $Q^2 < 0.1$ (GeV/c)²

Theoretical calculations

- ▶ D. Florian, *et. al.*, arXiv:1305.6468
- ▶ Higher-order QCD corrections to the cross section
- ▶ Large logarithmic "threshold" corrections
→ improved the agreement between data and theory

⇒ Valid within theoretical uncertainty





- ▶ Resolved photon contribution dominates over the direct contribution
- ▶ Large cancellation between γg and γq → Numerically smaller resolved subprocesses become important

Fig. 5. (a) Direct and resolved NLO($\overline{\text{MS}}$) contributions and (b) NLO($\overline{\text{MS}}$) contributions of different partonic channels $a + b \rightarrow c + X$ to the full NLO polarized photoproduction cross section shown in Fig. 2.



Difference between previous analyses



Fit method(This analysis)

- ▶ pQCD collinear NLO
- ▶ All hadrons with high- p_T
- ▶ Compare data with theoretical curve
- ▶ quark distributions: from global fit

Direct methods(COMPASS's main stream method)

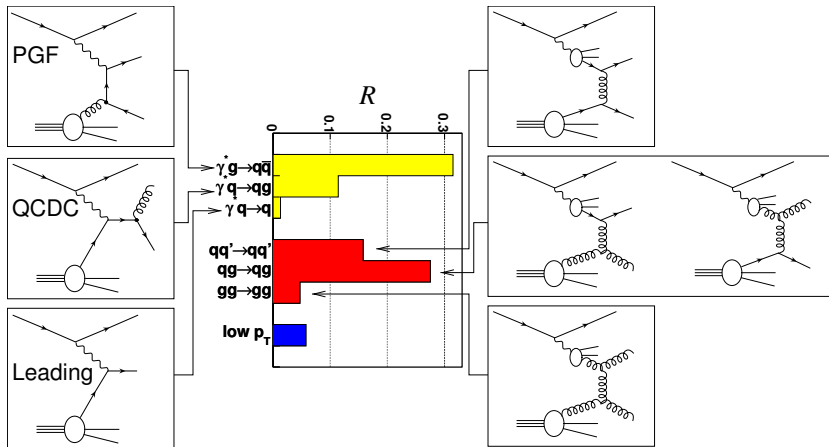
high- p_T hadron pair

- ▶ LO
- ▶ 2 hadrons pair with high- p_T
- ▶ (Neural Network tuned)
Mote Carlo simulation
- ▶ High statistics
- ▶ Large background

open charm

- ▶ LO or NLO
- ▶ D meson from PGF
- ▶ (Neural Network tuned)
Mote Carlo simulation
- ▶ Low statistics
- ▶ Small background

Contributions from each process @ $Q^2 < 1$



Ref: PLB 633 (2006) 25–32



COMPASS data taking



Year	Target	E_{beam}	Detail	
2002	Deuteron	160	Longitudinal mode (~20 % transverse mode)	
2003	Deuteron	160	Longitudinal mode (~20 % transverse mode)	
2004	Deuteron	160	Longitudinal mode (~20 % transverse mode)	
2005			Shutdown & upgrade	
2006	Deuteron	160	New setup, longitudinal mode	
2007	Proton	160	1/2 longitudinal, 1/2 transverse	
2008			Hadron physics	
2009			Hadron physics	
2010	Proton	160	Transverse	
2011	Proton	200	Longitudinal	
2012	Hydrogen		Hadron physics (Primakoff) + DVCS test run and SIDIS	
2013			Shutdown & upgrade	
<hr/>				
2014	Proton		Drell-Yan	
2015	Proton		Drell-Yan	
2016	Hydrogen		DVCS	
2017	Hydrogen		DVCS	



Asymmetry: year by year

2002-2011

